Programme & Abstract Book

→ 51ST ESLAB SYMPOSIUM

Extreme habitable worlds

04-08 december 2017, ESA ESTEC, The Netherlands

- *Venus, Earth, and Mars —the first 500 million years*
- *Planetary habitability processes: accretion, evolution, impacts, ingredients*
- *Evolution of habitability and settings for origins of life at Earth*
- *Earth extreme habitats: natural (surface and subsurface), artificial and sustainable*
- *Life support systems in Earth extreme places and in orbit, human spaceflight*
- *Making the Moon habitable*
- *Mars past, current, and future habitability*
- *Asteroid and small body habitats*
- *Outer solar system: Sub-surface Habitability at icy moons of Jupiter and Saturn*
- *Effects of space weather and Astrophysical hazards*
- *Planetary protection and measuring extreme biomarkers*
- *Stellar, interstellar and interplanetary ingredients for extreme habitability*
- *Engineering of travel to and exploration of Extreme Habitable Worlds*
- *Finding and Characterising Habitable Exoplanets: Proxima Centauri, Trappist1 and beyond*
- *Galactic and Extragalactic Habitability*
- *Education, outreach, societal, philosophical & artistic views on "Extreme Habitable Worlds"*

Sponsors: ESA, ESTEC, ESA Science Support Office, COSPAR, ILEWG

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European Space Agency

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Programme 51st ESLAB Symposium

Monday 04 December 2017

Opening Session
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12:00 Welcome & Logistics from SOC + LOC

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12:20 B. Foing et al., 'Understanding Extreme Habitability with ESA Missions'

12:35 J.-P. Bibring [Keynote], 'Rosetta, Mars, and the emergence of life: genericity and contingencies'

13:00 Lunch

14:00 Welcome from Director ESTEC and TEC Directorate, Franco Ongaro

14:05 Welcome from ESA Director of Science, Alvaro Giménez-Cañete

2: Planetary habitability processes: accretion, evolution, impacts, ingredients
Session Chairs: K. Harriss, E. Sefton-Nash

14:20 O. Mousis [Invited], 'Formation of ices in the protosolar nebula and implications for the composition of outer planets'

14:40 A. Johansen [Invited], 'Forming volatile-rich planetesimals'

15:00 S. Berger, 'Quantifying the Effects of Temperature on Short Period Rocky Planets'

15:15 C. Avdellidou [Invited], 'Hypervelocity impacts and Habitability'

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15:50 D. Wilson, 'Measuring planetary chemistry via observations of remnant planetary systems at white dwarfs'

1: Habitability of Young Venus
Session Chair: B. Foing

16:05 J. Schirmack, 'Venus: from a Terrestrial Ocean to a Possible Habitat in the Lower Atmosphere'

16:20 S. Limaye, 'Could microorganisms cause the absorption of solar radiation in the Venus clouds?'

16:35 Posters Up

17:00 Welcome Drink

Tuesday 05 December 2017

3: Evolution of habitability and settings for origins of life at Earth
Session Chairs: K. Moelling, F. Westall

09:00 F. Westall [Invited], 'Habitability from a Microbial Point of View'

09:20 K. Moelling, 'The origin of life based on RNA and viruses'

09:35 H. Moors, 'Habitable planet Earth: We owe everything to microbes!'

4: Earth extreme habitats: natural (surface and subsurface), artificial and sustainable

Session Chairs: K. Moelling, F. Westall

09:50 F. Hasan, 'Astrobiological Studies on Halophilic Psychrophiles Isolated from High Altitude cold region of North of Pakistan'

10:05 S. Evetts, 'Blue Abyss Planetary Exploration Simulation Service'

10:20 J-L. Bertaux [Keynote], 'Spectroscopy markers of habitability variables on Earth, Mars, Venus and planetary atmospheres'

10:45 M. Drinkwater, [Invited], Overview of ESA Earth Observation Programme and exemple of monitoring processes in extreme cryosphere'

11:05 Coffee Break

7A: Mars past, present, and future habitability

Session Chairs: J. Vago, O. Korablev

11:35 D. Titov [Invited], 'Mars Express Highlights on Mars extreme habitability'

11:55 S. Adeli, 'Investigating the chloride-rich deposits in the highlands of Terra Sirenum: implication on bio-signature preservation'

12:10 J. Campbell, 'Compositional Mapping of the Martian South Polar Residual Cap using hyperspectral data from CRISM'

12:25 J. L. Vago [Invited], 'Searching for Signs of Life with the ExoMars 2020 Rover'

12:45 O. Witasse/H. Svedhem, 'ExoMars 2016 Trace Gas Orbiter'

13:00 Lunch

7B: Mars past, present, and future habitability

Session Chairs: D. Titov, J.-L. Bertaux

14:00 O. Korablev [Keynote], 'Mars atmospheric and surface spectroscopic diagnostics: Mars Express results and ExoMars update'

14:25 A. Riedo (poster flash talk), 'A miniature LIMS instrument for in situ chemical analysis of solids with high spatial resolution on planetary surfaces'

14:30 F. Da Pieve (poster flash talk), 'Response of potential new solar cells on the surface of Mars for assessing future habitability: a space weather and materials modelling study'

6: Making the Moon/Mars habitable

Session Chairs: A. Kolodziedjczyk, E. Sefton-Nash

14:35 B. H. Foing [Invited], 'Making the Moon Habitable: Science, Research, Technology & Innovation'

14:55 E. Sefton-Nash, 'PROSPECT: ESA’s Package for Resource Observation and In-Situ Prospecting for Exploration, Commercial Exploitation and Transportation'

15:10 A. M. Kolodziejczyk [Invited], 'Space biology and space medicine in the Lunares habitat in Poland'

15:30 Coffee Break

16:00 T. Volkova [Invited], 'Safety and comfort for Moon and Mars habitats: key design considerations.'

16:20 J.L. Moro, 'Lunar Base 1 – Conceptual architectural design studies for a base on the Moon'

16:35 H. Ghassabian Gilan, 'Study of Isokinetic Structures and Applications for Expandable and Adaptive Habitats using in-situ Lunar Resources for Future Moon Surface Missions'

16:50 D. Cooper, 'Lunar Mission One: Paving the Way for Human Habitability on the Moon'

17:05 M. M. Mukadam, 'Moon Gait Pilot Experiment'

16: Special Outreach Presentation

Session Chairs: B. Foing, E. Sefton-Nash

17:20 C. Carreau [Invited], 'Our Solar System and planets formation, the appearance of life: A slideshow for the general public.'

17:40 **Poster Session**

Wednesday 06 December 2017

5: Life support systems in Earth extreme places and in orbit, human spaceflight

Session Chairs: J.-P. de Vera, C. Heinicke

09:00 J.-P. De Vera [Invited], 'Space as a Tool for Astrobiological Exploration of the Solar System'

09:20 C. Heinicke [Invited], 'How to live on Mars'

09:40 C. Lasseur [Invited], 'MELiSSA: the European project of closed Life support system'

10:00 G. Detrell, 'Photobioreactor Technology for Microalgae Cultivation To Support Humans in Space with Oxygen and Edible Biomass'

10:15 M. Knie, 'Zooplankton for the production of biomass in bioregenerative life support systems in space'

10:30 T. Etheridge, 'Deep Space Petri-Pod, a new platform for astrobiology experiments beyond the van Allen belts'

10:45 K. Schlosser, 'Addressing Key Psychological, Social and Physiological Factors in Preparation for Long Duration Manned Missions – Suggested Adaptations of the Current Astronaut Selelction and Training'

11:00 P. Clauwaert, 'Nitrogen recovery from urine in Space: a case for nitrification'

11:15 R. M. Giurgiu (poster flash talk), 'From Waste to Taste; Closing the MELiSSA Loops for escaping and sustaining the Earth habitat'

11:20 ***Coffee Break***

8: Asteroids and small bodies habitats

Session Chairs: C. Avdellidou, D. Koschny

11:45 M. Delbo [Invited], 'Sources of primordial matter in the asteroid belt'

12:05 M. C. De Sanctis [Invited], 'Latest results on Ceres from DAWN: ingredients for life?'

12:25 D. Koschny [Invited], 'Hazards from asteroid impacts and the Space Situational Awareness programme'

12:45 C. Sathiyavel, 'A New concept of Asteroid Mitigation using Expulsion Payload in Spacecraft system.'

13:00 ***Lunch***

14:00 M. A. Barucci [Invited], 'Probing asteroids with remote sensing and sample return'

9: Outer solar system: Sub-surface Habitability at icy moons of Jupiter and Saturn

Session Chairs: O. Witasse, B. Sherwood

14:20 A. Coustenis [Invited], 'Habitability potential of icy moons around giant planets and the JUICE mission'

14:40 F. Klenner, 'Mass spectrometry of astrobiologically relevant organic material - Implications on future space missions to ocean worlds in the outer Solar System'

14:55 N. A. Khawaja, 'Organic compounds in ice grains from the subsurface ocean of Enceladus'

15:10 O. Witasse [Invited], 'JUICE: A European Mission to Jupiter and its Icy Moons'

15:30 B. Sherwood, 'Program Options to Explore Ocean Worlds'

15:45 M. Gomes Rachid (poster flash talk), 'Processing of Cometary surface by swift ions'

15:50 Coffee Break

10: Effects of space weather and Astrophysical hazards

Session Chairs: P. Ubertini, D. Mueller

16:20 H. Lammer [Invited], 'Evolution of Atmospheres, Outgassing History, and Water Inventories of terrestrial planets'

16:40 D. Müller [Invited], 'Understanding our star and its influence on Earth with SOHO'

17:00 V. Nwankwo, 'Effects of Space weather on the ionosphere and LEO satellites' orbital trajectory in equatorial, low and middle latitude'

17:15 S. Piling, 'Effect of ionizing radiation (X-rays and Cosmic rays) on frozen worlds'

17:30 P. Ubertini [Invited], 'High energy astrophysical hazards for habitability'

11: Planetary protection and measuring extreme biomarkers

Session Chairs: G. Kminek, J. Rummel

17:50 G. Kminek [Invited], 'Protecting solar system bodies from us'

18:10 J. Rummel [Invited], 'Protecting our Planet from Extraterrestrial Life: Safe Solar System Exploration'

Special JWST Presentation

Session Chair: B. Foing

18:30 P. Ferruit [Invited], 'JWST Status and prospects for habitability studies'

19:00 Buses: ESTEC to Restaurant La France, Oegstgeest

Symposium Dinner

19:15 Arrival/aperitif

19:30 Dinner

21:30 Bus La France to Noordwijk 21:30

22:30 Bus La France to Noordwijk 22:30

Thursday 07 December 2017

14A: Finding and Characterising Habitable Exoplanets: Proxima Centauri, Trappist-1 and beyond

Session Chairs: A. Heras, I. Ribas

09:00 M. Turbet [Keynote], 'Global climate models and extreme habitability'

09:25 J-P. Beaulieu [Invited], 'Microlensing survey and exoplanets'

09:45 I. Ribas [Invited], 'The habitability of Proxima Centauri b'

10:05 M. Davies [Invited], 'Exoplanetary systems dynamics and habitability'

10:25 E. Bolmont [Invited], 'Habitability in the Trappist-1 and other exoplanetary systems around red dwarfs'

10:45 J. Gale, 'Potential for Life on Trappist-1 and other Red Dwarf Planets'

11:00 Coffee Break

11:20 M. Popp [Invited], 'Climate variations on water-rich circumbinary planets and their impact on habitability'

11:40 A. Struminsky, 'Radiation Environment near Exoplanets'

11:55 A. Wandel, 'Discovering biosignatures of Red Dwarf habitable planets with future telescopes and estimating the probability of biotic planets.'

14B: Finding and Characterising Habitable Exoplanets: Proxima Centauri, Trappist-1 and beyond
Session Chairs: I. Snellen, G. Tinetti

12:10 K. Isaak [Invited], 'CHEOPS: Characterising exoplanet Satellite - ESA's first S-class mission'

12:25 A. Heras [Invited], 'The PLATO space mission and the quest for habitable worlds'

12:40 G. Tinetti [Invited], 'Discriminating habitable worlds from their atmospheric composition'

13:00 Lunch

14:00 A. Quirrenbach [Invited], 'Characterizing Habitable Exoplanets with Interferometry'

14:20 I. Snellen, 'Atmospheric characterization of extrasolar planets: from hot Jupiters to Earth-like planets'

14:35 M. K. Jagadeesh (poster flash talk), 'Indexing of exoplanets in search for potential habitability: application to Mars-like worlds'

13: Engineering of travel to and exploration of Extreme Habitable Worlds
Session Chairs: G. Ortega Hernando, B. Foing

14:40 G. Ortega Hernando [Invited], 'Technology Roadmaps for Moon and Mars Exploration'

15:00 V. Hipkin [Invited], 'Moon & Mars Sample Return Analogue Deployment Validation'

15:20 J. Manca, 'Next generation solar cells for powering extreme habitable worlds : light-weight, flexible and printable-on-demand'

15:35 Coffee Break

16:05 S. P. Worden [Keynote], 'Breakthrough Starshot Initiative'

16A: Education, outreach, societal, philosophical & artistic views on "Extreme Habitable Worlds"
Session Chairs: J. de Dalmau, M. Waltemathe

16:30 E. Chatzichchristou [Invited], 'Europlanet 2020 RI Education and Outreach projects focusing on Extreme Habitable Worlds'

16:50 P. Evellin, 'EuroMoonMars workshop and simulation at ESTEC'

17:05 S. Aloserij, 'What our future heritage can be: the purpose of an archive and library on the moon'

17:20 A. Ricchiuti, 'The role of communication in science and astrobiology'

17:35 M. Waltemathe, E. Hemminger, 'Teaching With Astrobiology. Enhancing Science And Technology Awareness In Humanities And Social Science Students.'

18:00 Introduction to Performance Session: Extremely Habitable Art

18:05 M. Prokofieva (Piano) ESTEC Space Strings, A. Arkhanskaya "Visual Art performance"

19:00 Social & Music event in Newton Foyer

Friday 08 December 2017

12: Stellar, interstellar and interplanetary ingredients for extreme habitability
Session Chairs: R. Rudawska, L. d'Hendecourt

09:00 L-S. D'Hendecourt [Invited], 'From Astrochemistry to Astrobiology: the importance of cosmic ices for astrochemical and prebiotic evolution'

09:20 M. Guedel [Invited], 'Stellar and interplanetary ingredients for extreme habitability'

09:40 J. Dworkin [Invited], 'Synthesis of Extreme Organics in Meteorites'

10:00 J. Sanz-Forcada [Invited], 'The role of X-rays in exoplanet evolution and habitability'

10:20 J. Zender [Invited], 'Monitoring space weather: from SOHO, PROBA2 to the future'

10:40 J. Jackman, 'Stellar Flares Detected By NGTS'

10:55 P. Estrela (poster flash talk), 'Exploring habitability under an environment of strong superflares at a time when the ozone layer first formed on Earth'

11:00 Coffee Break

16B: Education, outreach, societal, philosophical & artistic views on "Extreme Habitable Worlds"
Session Chairs:T. Alvarez, B. Foing

11:30 T. Alvarez [Invited], 'Cave Dwellers, Eskimos, Tuaregs: Anthropological Lessons for Human Adaptation to Space Environments'

11:50 S. Guinard, 'Philosophical aspects of space exploration and human spaceflight: the ecopolitics of sharing place with non-human others in outer space'

12:05 M.S. Khan, 'Educational Outreach towards Manned Exploration of Mars and beyond'

Wrap Up & Closing
Session Chair: B. Foing

12:25 [Selected Session Chairs] Panel Wrap-Up: 'ESLAB 51 Highlights'

Posters

Posters with author in attendance

A. Nikolaou, 'Duration of magma ocean in the early Earth with a grey and a H2O steam atmosphere'

N. Feshangsaz, 'Survival of halophilic archaeon Halovarius luteus gen. nov., sp. nov., to desiccation, simulated Martian UV radiation and vacuum in comparison to Bacillus atrophaeus'

S. Romanchuk, 'Species of plant Brassicaceae as a component of an autotrophic element of bioregenerating life support systems of a spacecraft'

T. Sassen, 'Investigating phage-related threats to the MELiSSA loop'

A. Oren, 'R-evolution of architecture'

C. Martin, 'Architectural Distancing from the Exit Strategy: the Habitability of Extreme Worlds Versus the Extreme Habitability of Worlds'

M. Walthemathe, E. Hemminger, 'A Historic Choice of Number: The Planetary Protection Requirement for Ocean World Exploration'

E. Palle, 'Biosignatures across time'

L. Ksanfomaliti, 'Signs of Hypothetical Flora and Fauna of the Planet Venus: Returning to Archive of the Old Tv-Experiments'

A. Wandel, 'Potential for Life on Trappist-1 and other Red Dwarf Star Planets'

J.-P. P. De Vera 'Is Recent Mars A Habitable Planet? - Microorganisms From New Terrestrial Mars Analog Habitat Sites In The Permafrost Of Continental Antarctica Survive Mars Simulation Experiments In The Lab And In Space'

B.H. Foing, A. Lillo, et al, '' EuroMoonMars Extreme Field Analogue Campaigns

B. Foing, A. Lillo, P. Evellin et al, 'ILEWG EuroMoonMars research technology and simulation'

P. Evellin, B. Foing, A. Lillo et al, '2017 EuroMoonMars Analog Habitat Preparation and Simulation at ESTEC'

A. Lillo, B. Foing, P. Evellin et al, 'Remote operations of ExoGeoLab lander at ESTEC and LunAres base'

V. Guinet, M. Monnerie, B.Jehannin, A. Cowley, C. Jonglez, B. Foing, 'Preparation of human telerobotics operations using EAC and ESTEC facilities'

C. Stoker, J. Clarke, B. Foing, K. Martin, 'Mineralogical and organic properties of samples from MDRS Mars Desert Research Station; analog study for MSL Curiosity'

M. Offringa, B. Foing, C. Jonglez, 'UV-VIS NIR and FTIR spectroscopy of MoonMars analogues'

D.Wills, B. Foing. 'Gamma-Ray bursts spectral structure and implications For life'

N. Verschoor, B. Foing & WDKA Applied Art students, 'King of Mars: Exploring and Creating Space'

N. Verschoor, B. Foing & WDKA Applied Art students, 'King on The MoonVillage'

Kate Isaak on behalf of the ESA CHEOPS Project Team and the CHEOPS Consortium CHEOPS: 'Characterising ExOPlanet Satellite'

Kate Isaak: ''Observing with CHEOPS'

D.Winterhalter, 'A Systematic Search of the Nearest Stars for Exoplanetary Radio Emission: Strong Radio Bursts from ROSS 614 AB'

M. Turšic, 'Becoming an Oikos'

P. B. Rimmer, 'Universal Life'

Posters with Oral Flash Talks

M. Gomes Rachid, 'Processing of Cometary surface by swift ions'

P. Estrela, 'Exploring habitability under an environment of strong superflares at a time when the ozone layer first formed on Earth'

F. Da Pieve, 'Response of potential new solar cells on the surface of Mars for assessing future habitability: a space weather and materials modelling study'

M. K. Jagadeesh, 'Indexing of exoplanets in search for potential habitability: application to Mars-like worlds'

R. M. Giurgiu, 'From Waste to Taste; Closing the MELiSSA Loops for escaping and sustaining the Earth habitat'

A. Riedo, 'A miniature LIMS instrument for in situ chemical analysis of solids with high spatial resolution on planetary surfaces'

General Information

Organised Bus transfers

Date	Time	From	To
4 December	19:15	ESTEC Main building	Noordwijk Hotels
5 December	08:00	Noordwijk Hotels	ESTEC Main building
	20:00	ESTEC Main building	Noordwijk Hotels
6 December	08:00	Noordwijk Hotels	ESTEC Main building
	19:00	ESTEC Main building	Oegstgeest (Dinner venue)
	21:30	Oegstgeest (Dinner venue)	ESTEC & Noordwijk hotels
	22:30	Oegstgeest (Dinner venue)	ESTEC & Noordwijk hotels
7 December	08:00	Noordwijk Hotels	ESTEC Main building
	18:15	ESTEC Main building	Noordwijk Hotels
	20:00	ESTEC Main building	Noordwijk Hotels
8 December	08:00	Noordwijk Hotels	ESTEC Main building

Pick up points for Specific Hotels, please check below:

Hotel	Pick up point
Hotel Admiraal Heeren van Noortwijck	Quarles van Uffordstraat 103
Hotels van Oranje Beach Hotel	Kon. Wilhelminaboulevard 20-31
Golden Tulip Beach Hotel	Kon. Wilhelmnaboulevard 8
Huis ter Duin Radisson Blu Palace Hotel Astoria Alexander Hotel	in front of the Alexander hotel, Oude Zeeweg 63

Regular hotel shuttle

There is also a regular shuttle bus service between ESTEC and the Noordwijk hotels. For more information and timetables, please contact the Conference Bureau at the Newton Desk, or the ESTEC Reception.

Taxi / Getting to the airport

In order to reserve a taxi, please consult the ESTEC Reception or send your request by email: Estec.Reception@esa.int

If you wish to reserve the Airport Shuttle, please bear in mind to reserve a seat one day in advance. Purchase a ticket at the ESTEC reception located in the A building (cash payment only). The costs for a one-way voucher are €15.00

Schedule ESTEC - Schiphol, Monday to Friday

- 14:30 hrs
- 15:00 hrs
- 15:30 hrs
- 16:00 hrs
- 16:30 hrs
- 17:00 hrs
- 17:30 hrs
- 18:00 hrs
- 18:30 hrs

Local Bus to Leiden

The local bus line 30 to Leiden has a bus stop just outside the gate, approximately 100 m from the gate house. Travel time to Leiden Central Station is approximately 20-25 min.

Further information can be found on www.arriva.nl or www.9292.nl/en

Wireless Internet

All pre-registered participants have received their log-in details by email, sent by the ESA ServDesk. A copy of your login details is also available in the back of your badge.

Abstracts

Monday 04 December 2017

Understanding Extreme Habitability with ESA Missions

B. H. Foing[1,2,3, 4]

[1] *ESA/ESTEC, * Bernard.Foing @esa.int*
[2] *ILEWG/COSPAR International Lunar Exploration Working Group (sci.esa.int/ilewg)*
[3] *VU Amsterdam*
[3] *Chair Science Organising Committee, Co-Chair Local Organising Committee (ESLAB51)*

ESLAB 51 rationale

The 51st ESLAB Symposium: “Extreme Habitable Worlds”, at ESTEC 04-08 December 2017 [1] covers contributions on a variety of interdisciplinary themes regarding extreme habitability on Earth, in orbit, at Moon, Mars, in the solar system and throughout the universe. The symposium programme includes keynote talks, invited talks, oral and Flash contributions, poster presentations, interactive demo presentations and performances, debates, social habitability and artistic events [2]. ESLAB51 audience ranges from scientists, engineers, experts from various disciplines and age. 15 Young Researcher Awards have been funded by the ESLAB 51 Symposium, COSPAR & ILEWG.

As introduction to the various specific ESLAB51 sessions, we shall discuss how space missions, in particular from ESA (across all ESA programmes: Science, Earth, Exploration, Human Spaceflight, Technology & Application) address the overall ESLAB51 themes of Extreme Habitability .

ESLAB 51 Themes & Understanding Extreme Habitability with ESA Missions

1. Venus, Earth, and Mars —the first 500 million years
2. Planetary habitability processes: accretion, evolution, impacts, ingredients
3. Evolution of habitability and settings for origins of life at Earth
4. Earth extreme habitats: natural (surface and subsurface), artificial and sustainable
5. Life support systems in Earth extreme places and in orbit, human spaceflight
6. Making the Moon and Mars habitable
7. Mars past, current , and future habitability
8. Asteroid and small body habitats
9. Outer solar system: Sub-surface Habitability at icy moons of Jupiter and Saturn
10. Effects of space weather and Astrophysical hazards
11. Planetary protection and measuring extreme biomarkers
12. Stellar, interstellar and interplanetary ingredients for extreme habitability
13. Engineering of travel to and exploration of Extreme Habitable Worlds
14. Finding and Characterising Habitable Exoplanets: Proxima Centauri, Trappist1 and beyond
15. Galactic and Extragalactic Habitability
16. Education, outreach, societal, philosophical & artistic views on "Extreme Habitable Worlds"

We thank the Science and Local Organising Committees [3], organisers, participants, speakers and posters authors, sponsors (ESA, ESTEC, ESA Science Support Office, COSPAR, ILEWG) and supporters of ESLAB51.

References

[1] http://old.esaconferencebureau.com/2017-events/eslab2017/introduction

[2] http://old.esaconferencebureau.com/2017-events/eslab2017/preliminary-programme

[3] http://old.esaconferencebureau.com/2017-events/eslab2017/committees

Rosetta, Mars, and the emergence of life: genericity and contingencies

J-P. Bibring

IAS, 91405 Orsay Campus, France

1. Introduction

The solar system space exploration is revolutionizing fundamental paradigms, with outcomes far beyond the mere scientific community. The *plurality of worlds*, conceived as a direct consequence of universality of laws, which justifies the search for extraterrestrial life, is getting replaced by that of *diversity of worlds*, both while characterizing the planets within our solar system, and the solar system within the stellar systems. What drives the diversity of evolutionary pathways? How can similar processes account for such distinct evolutions? At what scale, in time and space, is Earth unique, and the life it harbours? Does the extreme ability of terrestrial live to get adapted to a wide variety of environments favour the presence of life beyond Earth? Rosetta and Mars space missions offer key contributions to these new addresses.

2. Generic processes, contingent forms

The extreme and totally unexpected diversity of the solar system planets, in their evolution and present status, is one of the dominant outcomes of the solar system space missions. It contrasts with their originating from the collapse of the same protosolar cloud, which loaded their evolution with a large level of initial commonalities. The planet size and heliocentric distance are by far not sufficient to account for their present diversity: what then are the major drivers? Although the involved processes, as such, are generic, the forms they took are highly contingent, dictated by the specifics of each set of conditions. Two examples can be outlined for illustration. 1. Early planet migration appears to constitute a very general process in stellar system evolution. However, each exoplanet seems to have followed a very specific migration, depending of the specific disk structure and stellar evolution in which it took place. This might in particular be the case of the solar system, as suggested by the Nice model of “grand tack” migration of Jupiter and Saturn [1], which resulted in a very specific space and mass distribution of the inner planets, including that of Earth. In addition, the turbulent input of outer icy-rich bodies during their accretion is required to account for the presence of water, at least in Earth and Mars. 2. Giant impacts, among the inner proto-planets, likely constitute a very general process which was first suggested to account for the formation of the Earth Moon. Actually, this impact has played a critical role on the further highly specific evolution of the Earth, as for the Moon stabilizing Earth obliquity, the building of perennial surface oceans, the hydration of mantle materials driving a specific plate tectonics etc. Noticeably, these effects are very sensitive to the parameters of the giant impact (geometry, mass ratio etc.), emphasizing the role the specific form taken by a generic process, does play.

3. ORGANiCeS, and contingent emergence of (terrestrial) life

Rosetta and Philae have ruled out the comet as a dirty ice ball. Instead, it is likely made predominantly of a carbon-rich matrix, with carbon-rich grains up to a few mm in size, in which both silicates and ices are embedded. They would thus more appropriately be quoted “ORGANiCeS”, to translate and emphasize that ice is trapped within complex organics. Although the analysis of the most refractory phase could not be performed on Philae, by lack of energy to initiate the long term science, the coupling of measurements performed on Rosetta and Philae exhibits a large suite of compounds, sufficient to account for most, if not all building blocks of terrestrial living structures. Enantiomeric excesses might even have been produced by a specific UV irradiation of the early Sun in carbon-rich grains within the turbulent accretion disk. Objects similar to the Churyumov-Gerassimenko nucleus, with the presence of a sintered crust similar to that which forced Philae to bounce, operating as a thermal shield against atmospheric disruption, might have favoured the seeding of these “organices” in Earth long standing bodies of liquid water, with specific conditions such as temperature, pH and cations. In such contingent conditions, autocatalytic reactions would have been initiated, leading to “living structures” from the ingredients contingently synthesized through a specific chemistry within the protosolar disk.

4. Mars, as a potential witness

Mars Express, followed by MRO, has driven a major revisiting of Mars history, by indicating that Mars might have hosted, soon after it formed, conditions enabling surface liquid water to remain stable over geologic timescales, before having disappeared following a global climate change. We have identified and located at the surface of Mars a few sites which have preserved, as a unique feature possibly in the entire solar system, the conditions which prevailed at these ancient times: the evolution of Mars early environment can be deciphered in the sequence of aqueously altered minerals, such as the phyllosilicates of distinct Mg/Fe/Al content. Sites with such a preserved stratigraphy do thus constitute ideal targets for the upcoming roving Mars space exploration (EXoMars 2020, NASA Mars 2020, China Mars 2020). Supposedly life ever emerged other than on Earth, these locations are likely the most favourable to have preserved its record. If some form of chemical evolution of the organics is discovered trapped within one of these phases (e.g. smectite or kaolinite), one would be able to identify the environment more favourable to life emergence at Mars, and thus possibly on Earth as well. If, on the other hand, no complex organics are detected, other than those, unprocessed, coupled to extraterrestrial material, it would increase the contingent character of the emergence of life on Earth.

5. Discussion

The sequence of processes which built Earth as a "habitable" planet reveals a key role played by contingency; it forces an in depth revisiting of previous paradigms, in which the occurrence of stable liquid water was the driving condition. Although zones in which liquid water cannot be stable are likely non habitable, quoting habitable zones those in which water might be stable does severely ignore the wealth of progress our understanding of planet evolution has gained recently.

At the same time Earth is recognized unique, in time and space (at a scale still to be determined), life might be as well, a contingent product of a specific evolution: life on Earth emerged only once, and the coming space solar system exploration will try to address the contingent/generic ratio of the processes involved.

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Short Summary

The solar system space exploration is revolutionizing fundamental paradigms, with outcomes far beyond the mere scientific community. The plurality of worlds, conceived as a direct consequence of universality of laws, which justifies the search for extraterrestrial life, is getting replaced by that of diversity of worlds, both while characterizing the planets within our solar system, and the solar system within the stellar systems. What drives the diversity of evolutionary pathways? How can similar processes account for such distinct evolutions? At what scale, in time and space, is Earth unique, and the life it harbours? Does the extreme ability of terrestrial live to get adapted to a wide variety of environments favour the presence of life beyond Earth? Rosetta and Mars space missions offer key contributions to these new addresses.

Formation of ices in the protosolar nebula and implications for the composition of outer planets

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The presence of Jupiter, Saturn, Uranus and Neptune in our solar system raises the question of how they formed in the framework of the standard theories of planetary formation, namely the *core accretion* and the *disk instability* models. The direct or indirect measurements of the volatiles abundances in the atmospheres of these four giants (see Figure 1) are key to decipher their formation conditions in the protosolar nebula. So far, only the composition of Jupiter's atmosphere has been (partly) explored, thanks to the in situ measurements performed by the Galileo probe and the ongoing investigation of the Juno spacecraft. A giant planet formed in the framework of the *disk instability* model implies that oxygen, carbon, nitrogen, sulfur, argon, krypton and xenon elements should (*in principle*) all be enriched by a similar factor relative to their protosolar abundances in its envelope, depending on the extent of photoevaporation in the envelope and settling of dust grains prior to mass loss. A giant planet formed in the framework of the *core accretion* model will present enrichments in volatiles whose characteristics depend on their trapping conditions in the PSN. Because the trapping efficiencies of C, N, S, Ar, Kr, and Xe volatiles are similar at low temperature in amorphous ice, the delivery of such solids to a growing giant planet should be also consistent with the prediction of homogeneous enrichments in volatiles in the envelopes. On the other hand, if the volatiles were incorporated in clathrate structures in the PSN, then their enrichment values in the giants atmospheres should strongly vary from a species to another. An alternative scenario is built upon the ideas that i) Ar, Kr and Xe were homogeneously adsorbed by icy grains in the cold outer part of the PSN midplane and that ii) the disk experienced some chemical evolution. In this scenario, Ar, Kr and Xe would have been supplied in supersolar proportions with the PSN gas to the forming giant planets. Interestingly, recent formation models based on disk's photoevaporation, formation of giants via pebbles and gas accretion suggest that the measured volatiles enrichments can be explained in the four giants. These models deserve to be examined from close to identify the key assumptions that make them consistent (or not) with the other scenarios. In any case, future in situ measurements performed by planetary probes will be mandatory if one wants to disentangle between the different volatiles delivery scenarios to the giants of our solar system.

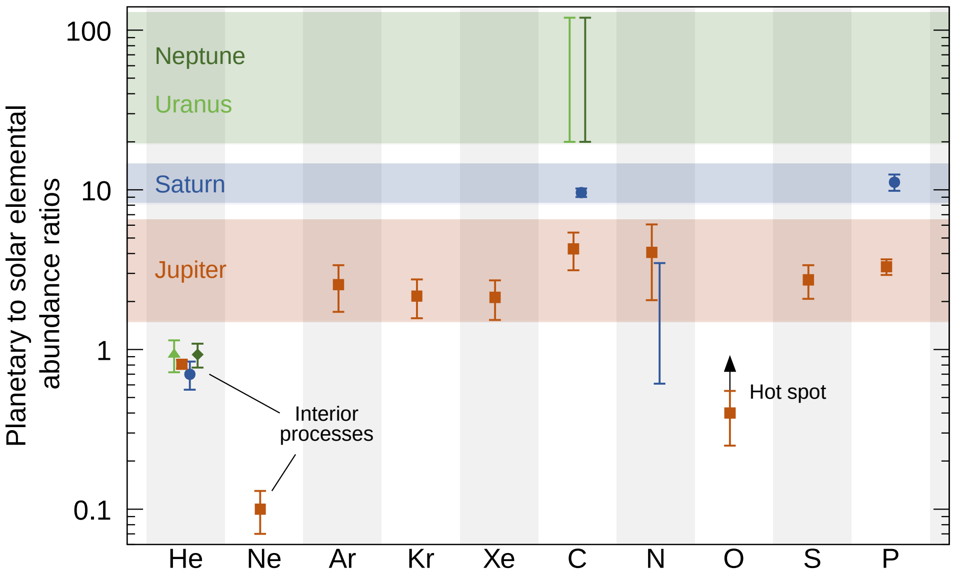

Figure 1: Volatiles enrichments (with respect to their solar abundances) measured in the envelopes of the four giants of the solar system (figure adapted from Mousis et al. 2017).

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Short Summary

The presence of Jupiter, Saturn, Uranus and Neptune in our solar system raises the question of how they formed in the framework of the standard theories of planetary formation, namely the core accretion and the disk instability models. The measurements of volatiles atmospheric abundances are key to decipher their formation conditions in the protosolar nebula.

Forming volatile-rich planetesimals

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1. Introduction

Habitable planets, such as our own Earth, form in the inner region of protoplanetary discs where the temperature is too high for volatile molecules such as water to exist in solid form. Elements and molecules essential for life as we know it - including water, carbon and nitrogen - are likely delivered via collisions with planetesimals that formed under much colder conditions several astronomical units further away from the star. I will present theories for the formation of planetesimals in protoplanetary discs (see [1] for a recent review). I will focus on the formation regions, formation times [2] and initial mass function [3] of planetesimals and make connections between planetesimal formation theories and the habitability of planets. I will show that ice lines of volatile species are favourable sites for the early formation of volatile-rich planetesimals in protoplanetary discs.

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Short Summary

Elements and molecules essential for life - including water, carbon and nitrogen - are likely delivered via collisions with planetesimals that formed under cold conditions several astronomical units away from the star. I will present theories for the formation of such volatile-rich planetesimals in protoplanetary discs.

Quantifying the Effects of Temperature on Short Period Rocky Planets

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1. Introduction

Rocky planets can be very diverse in structure and composition compared to the Earth. Their temperature profiles could also differ greatly from Earth's depending on their mass and distance from their host stars. Interior structure models of rocky exoplanets have not yet studied the full range of possible temperature profiles. We develop a simulation, PyPlanet, for a rocky planet with an arbitrary number of layers and equations of state. We apply this model to explore many possible temperature profiles and quantify the thermal effects on the mass-radius relations of rocky planets. We also couple this model with a simple thermal evolution model of rocky planets to gain intuition as to how the initial thermal conditions of a rocky planet can affect its overall properties. This detailed modeling will be crucial for making robust inferences about rocky planet structure and composition from transit and radial velocity observations.

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Short Summary

Interior structure models of rocky exoplanets have not yet studied the full range of possible temperature profiles. We develop a simulation for rocky planets with an arbitrary number of layers and equations of state. This detailed modeling will be crucial for making robust inferences about rocky planet structure and composition.

Hypervelocity impacts and habitability.

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Impacts is a driving process in the Solar System, which breaks bodies, changes the morphology and alters the materials of their surfaces. However, impacts apart from catastrophic events are of extreme importance as they transfer and implant materials in different places of the Solar System.

Detailed spectroscopic observations on small bodies (asteroids) have shown variability, which could be explained by deposits of exogenous material via impacts. In particular more and more asteroids seem to have in their spectrum the 3-micron band in the near-infrared which is an indication of the presence of hydrations or even water-ice on their surface [1,2,3]. Hydration has been even detected on bodies that seem to be anhydrous [4] and such finding cannot be explained otherwise. Asteroid and cometary impacts are responsible also for the water delivery on Earth.

It has been proposed that the ingredients for the formation of life were generated during hypervelocity collisions where favourable conditions existed, or where even delivered directly with small body collisions. This idea is enhanced by the findings of lunar and martian meteorites and even by the exchange of material between Mars and its satellites [6].

They hypothesis of panspermia, that life exists in Universe and is transported by bodies at different areas, was introduced since ancient years at the 5th century BC from the Greek philosophers. Recent observations from the Dawn mission have reviled organic material on the surface of the dwarf planet Ceres [7] and there is a debate on whether the organics are endogenous or exogenous.

In this work it is going to present an overview of the laboratory experiments that have been done so far and focus mainly on these that involve organics [7] or the survivability of microorganisms [8,9,10]. Laboratory work will be coupled with the aforementioned findings on small body surfaces.

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Short Summary

In this work it is going to present an overview of the laboratory experiments that have been done so far and focus mainly on these that involve organics or the survivability of microorganisms. Laboratory work will be coupled with the aforementioned findings on small body surfaces.

Impact cratering and disruption on Icy bodies and landscapes

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1. Introduction

The icy moons of Saturn and Jupiter are large and many are theorised to have a subsurface ocean beneath the surface layer of ice such as Europa [1] and Enceladus [2]. This makes these bodies prime targets for possible habitability with the ocean providing the medium which support the organic molecule needed for life to form. However, icy bodies are just as likely as other bodies to suffer impacts and though this may bring in the energy required for life to form [3], impacts can also cause major disruption to body, but the results of impacts also provide information about the icy moon structure which can help understand where life could develop due to variation in the size, shape and depth of the crater.

2. Aims of Project

This abstract is a summary of two major projects being undertaken by the Kent Impact Group at the University of Kent in order to discover more about the structure of icy moons and the scenarios under which catastrophic disruption would occur and what occurs on the surface during large scale impacts.

For project one impact experiments were undertaken with targets of ice over a sub-surface material of water, basalt or sand. For each sub-surface material, different thickness of the ice was laid above to recreate a planetary surface with an icy crust [4].

Project two investigated large impacts into whole ice spheres. Three types of ice spheres have been impacted: 1. Solid ice spheres, 2. Hollow ice spheres filled with water, 3. Hollow ice spheres filled with water and a solid core. Similar to the first project impact experiments were undertaking changing the thickness of the ice crust to understand the impact features that form on the surface including the impact crater and resulting fractures and disruption.

3. Methods

3.1 Layered Ice Targets

Each target was prepared so that the required ice thickness would be completely frozen with few blemishes and no cracks to act as weakened areas of the target. The ice formed downwards from the open top surface of a cylindrical flask of water, and the thickness required for each investigation was determined by varying the time interval the target remained within a -23 ^{O}C environment. Once placed in the target chamber a metal ring cooled to -140 ^{O}C was placed on the target to prevent the edge of the target melting and the water inside escaping. Impacts into water ice targets have been extensively researched [5 and 6 etc.] which provided a method for producing clear unblemished ice targets that were then modified for this study.

3.2 Ice Spheres

The ice spheres were formed using a similar method freezing from the outside inwards allowing different thicknesses to form as required. A balloon was used to form the correct shape and a core was placed within the balloon during the freezing process.

3.3 Impact Experiments

The impacts were produced using the two stage light gas gun facility at the University of Kent [7]. Table 1 shows the impact parameters used for each project.

Project	Impactor	Impact velocities used	Ice thickness
Layered Ice Targets	1.5 Al sphere	1 – 5 km s^{-1}	5 – 210 mm
Water filled Sphere	1.5 Glass sphere	1 – 5 km s^{-1}	25 mm
Water filled Sphere with Core	1.5 Glass sphere	1 – 3 km s^{-1}	7 – 40 mm

Table 1: Impact parameters for each Icy Moons project

4. Results and Discussion

4.1 Depth of Ice

There is a positive correlation between the thickness of the ice layer and the size of the crater. However, it was found that once the ice thickness was >15.5 times the diameter of the projectile there are no changes to the size or depth of the crater, meaning that at this thickness the ice layer is semi-infinite. When the ice thickness is less than this value there is a 4% reduction in the crater diameter for every projectile diameter reduction in ice thickness [4]. At an ice thickness of < 7 times the projectile diameter, penetration of the ice layer occurs forming deep shallow craters with an H/D (crater depth/diameter) of around 0.65. Between 7 and 15.5 times projectile diameter, there is a positive correlation between the ice thickness and the crater size meaning that within a limited threshold dependent of the projectile size the thickness of the ice can be determined. The density of the subsurface material also has an effect on the crater produced when the impacts were penetrative with all three target types producing different crater morphologies [4].

4.2 The Production of Fissures

The results of project two are still ongoing but the initial results show that during an impact fractures can from across the breadth of the body and open up. In the laboratory, this results in fragments of the target falling away but on a planetary scale, this would probably result in the opening of fissures allowing the escape of gasses and liquids from the sub -surface ocean which would then refreeze over time.

4.3 Disruption

Disruption of a target is when the target is completely broken up due to a single impact. It was concluded from the initial experiments using a constant thickness of 25 mm and a range of impact speeds, (see table 1) that below energy density of 13 J kg $^{-1}$ a non-penetrative crater is produced, 13 – 15 J kg $^{-1}$ a penetrative impact is produced and 15 -18 J kg $^{-1}$ disruption of the target occurs. In addition to the water filled target impact were also undertaken into solid ice bodies for a comparison between a homogeneous and a heterogeneous target. It was found that for a solid ice sphere at an energy density greater than 18 J kg^{-1} complete disruption of the target occurs.

5. Conclusions and ongoing work

This work is ongoing and is attempting to aid in our understanding of icy moons from remote sensing analyses alone. This work has shown that impact crater morphology can be used to gain an idea of the thickness of the ice layer and so the location where the ice is a suitable thickness to allow life to develop with enough light reaching the ocean. This work will continue to investigate impacts into these whole bodies including the more detailed study into the effects a solid core may have on the products produced by an large impact cratering event.

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Short Summary

Impact craters onto icy bodies can aid in our understanding of the internal mechanics and structures of those bodies. We present the results of a series of impact experiments into icy moon analogues in order to discover more about the possible habitability of these bodies.

Measuring planetary chemistry via observations of remnant planetary systems at white dwarfs

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Summary

Observations of remnant planetary systems at white dwarfs provide the only technique to measure the bulk chemical composition of rocky exoplanets. In this talk I will review the field, present notable results such as the detection of icy planetesimals, and discuss the implications of this research for planetary habitability.

Abstract

Observations of remnant planetary systems at white dwarfs provide important contributions to exoplanet science in general and habitability in particular. Foremost among these is the only method to directly measure the bulk chemical composition of solid extrasolar material. The high density of Earth radii, but ~ Solar mass white dwarfs implies that metals heavier than hydrogen or helium sink out of their atmospheres on short timescales. The metal absorption lines seen in ~30 percent of white dwarfs must all therefore have an external origin. Observations of transiting material and dusty debris discs from tidally disrupted planetesimals, scattered into the white dwarf by planets that survived the main sequence evolution, confirm this scenario. High resolution spectroscopy of an increasing number of white dwarfs has revealed a plethora of atomic species, allowing detailed conclusions about planetesimal compositions to be drawn. As the progenitor stars of white dwarfs are, on average, 2-3 Solar masses, these observations also explore a parameter space of host stars that is hard to be studied in systems with host stars still on the main sequence.

In this talk, I will first review the historical observations that have led to our current understanding of remnant planetary systems at white dwarfs, as well as the state of the field today. I will present Hubble Space Telescope and Very Large Telescope data of metal polluted white dwarfs where multiple metals have been detected, including objects with high levels of core (Fe, Ni) material that may have undergone mantle stripping during the post main sequence, as well as objects with carbon and oxygen measurements that can be used to place limits on the existence of the hypothetical carbon planets. Finally, I will describe how white dwarfs can be used to search for water in extrasolar systems via detection of excess oxygen and hydrogen.

Short Summary

Chemical composition of rocky exoplanets. In this talk I will review the field, present notable results such as the detection of icy planetesimals, and discuss the implications of this research for planetary habitability.

Venus: from a Terrestrial Ocean to a Possible Habitat in the Lower Atmosphere

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[2]*SETI Institute. Mountain View, California, United States of America*

In its first 500 million years Venus started out with environmental conditions very similar to Earth, including the presence of an early ocean on its planetary surface [1]. However, it is unclear how long the ocean remained stable on the Venusian surface. Some estimates indicate that liquid water was present on the Venusian surface for a billion years or longer [2]. If so and taking into account the dynamic endogen-driven activity on Venus, the origin of life on Earth's twin planet or its proliferation through panspermia (e.g. through transport from Earth) seems reasonable. Once life was present on Venus, it would have become established in the ocean or oceans, and spread into environmental niches. Since the ocean on Venus was probably hot for a considerable period of time [1, 3], thermophilic chemotrophs and phototrophs, but possibly also heterotrophic microorganisms could have become established on Venus.

As the Sun increased in brightness and Venus increased in temperature through its thickening greenhouse gas atmosphere [2], life could have coped with these changes through directional selection. There are several examples of microbial life on Earth, which thrive at high temperatures [e.g. 4, 5, 6]. The dramatic shift in climate could have happened fast, in which case the environmental change would have probably been catastrophic to life resulting in the extinction of life on the planet. Or, microbial life could have retreated to one potential habitat still available: the lower cloud layer. The possibility of life in the lower Venusian atmosphere has been discussed by various authors [2, 3, 7, 8, 9, 10]. Several parameters that are favorable to the possible habitability of the cloud layer today can be pointed out:

1. The clouds of Venus are much larger, more continuous, and stable than the clouds on Earth.
- The atmosphere is in chemical disequilibrium, with H_2 and O_2, and H_2S and SO_2 coexisting.
- The lower cloud layer contains non-spherical particles comparable in size to microbes on Earth.
- Conditions in the clouds at 50 km in altitude are relatively benign, with temperatures of 25 to 75°C, pressure of 100 kPa, and a pH of about 0.
- The super-rotation of the atmosphere enhances the potential for photosynthetic reactions.
- COS is present in the atmosphere, which on Earth is a strong indicator of biological activity.
- CO is less abundant than expected under Venusian atmospheric conditions, and could be oxidized as a reactant in plausible metabolic pathways.
- The biologically critical elements of carbon, phosphorus, and nitrogen are present.
- While water is scarce on Venus, water vapor concentrations reach several hundred ppm in the lower cloud layer.

However, any putative organism would have to deal with low pH, desiccation and high UV irradiation. At this time, there is no known microorganism on Earth, which can grow under these combined conditions. Nevertheless, putative Venusian microbes could have evolved the needed adaptations if the climate change occurred slowly [10]. These combined stresses do not often occur on Earth; thus, evolutionary pressure is not as intense to evolve this kind of adaptation. But on Venus it would be and so there is a chance that life could still be present at Venus today.

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Short Summary

Conditions on early Venus were very similar at a time when life first arose on Earth. Thus, life could have evolved on Venus independently or brought in from Earth by asteroids. As temperatures on Venus increased, life might have found a habitable niche in the lower Venusian atmosphere.

Could microorganisms cause the absorption of solar radiation in the Venus clouds?

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1. Introduction

Two key questions remain regarding the Venus global cloud cover which deserve further investigation. The planet's global cloud cover is highly reflective at wavelengths longer than the peak solar radiation (~ 0.9) and decreases to as low as ~ 0.3 at shorter wavelengths (200-400 nm) [1]. Cloud contrasts peaks are also higher in the shorter wavelengths and in reflected sunlight, the planet is nearly featureless at longer wavelengths. What substances in the Venus clouds are responsible for the albedo decrease below 600 nm remains an on-going mystery. It has been suggested that at least two different substances are needed to explain both the decrease in albedo at the shorter wavelengths and the dependence of contrasts [2]. On the nightside contrast features in the cloud cover are seen in the near infrared windows between between1.7 to about 5 µm. The first question pertains to the causes of the observed spectral dependence of the solar energy absorption below 500 nm. The second question investigates the causes of the observed contrasts in the clouds first identified at the ultraviolet (UV) wavelengths. The absorption at UV wavelengths by the Venus clouds represents a dominant deposition of incident solar energy that drives the atmospheric superrotation. The global structure of the superrotation in turn has been mostly discovered from tracking cloud contrasts from UV to NIR wavelengths. It is thus necessary that we learn about the nature of the UV absorption and the generation of the cloud contrasts on Venus to better understand the planet's atmosphere.

2. Identity of the shortwave absorber

Over the decades a several molecular absorbers have been proposed to explain the observed spectrum [3]. Below 330 nm, sulfur dioxide has been identified as one of the two substances likely responsible for the ultraviolet (uv) absorption [4] but the available information regarding its spatial distribution and temporal evolution [5] and contribution to the albedo appear to be somewhat counter-indicative as the clear primary absorber below 330 nm. Most candidates for the second absorber [6] have been discarded after analysis of limited data from in-situ measurements [7]. $FeCl_3$ has also been proposed [4, 8] and remains the most likely candidate [9] however, in the presence of sulfuric acid its lifetime is short and continuous replenishment is problematic. Recently another substance (OSSO) has been proposed as a possible ultraviolet absorber to explain the observed absorption between 320-400 nm [10], however the lifetime of the two isomers of OSSO proposed as sulfur reservoirs is very short (a few seconds) and the estimates of opacity are very uncertain [10] and not compatible with the sulfur abundance [11]. From probe measurements it is known that the uv absorption takes place above 62 km and likely begins at the cloud tops [12]. The uv absorbers may however be present in deeper levels, at least down to 47 km based on VeGa lander measurements [13].

Against this uncertainty regarding the nature of the uv absorber, the possibility for biologic origins of the absorption and contrasts have not received much attention. The detection of hydroxyl ions by Venus Express is consistent with this interpretation. It has been suggested that Venus may have been the first habitable planet as it could have harbored liquid water on the surface for more than a billion years in its past [14]. The possibility of life in the clouds of Venus was suggested by Morowitz and Sagan [15] and also discussed by Cockell [16] and followed up by Shulze-Makuch et al. [17] and Grinspoon and Bullock [18] as *acid and uv resistant* bacteria. Limaye et al. [19, 20] speculate as to whether microorganisms with uv absorptive properties such as those found on Earth could have evolved on Venus when liquid water was present on the surface, and then subsequently migrated to the clouds. The possibility that microorganisms may be extant in the clouds of Venus, perhaps in the lower cloud region where large particles have been detected [21], and where there is more water vapor and suitable temperatures for some terrestrial organisms such as *A. thiobacillus ferroxidans* cannot be easily discarded, given the similarities of its chemical, physical and spectral properties with those of the Venus cloud particles.

Laboratory measurements and new observations of the cloud particles from long lived aerial platforms sampling different altitudes of the Venus clouds during day and night are needed. Desired observations include microscopic images of the cloud particles, with ability to detect live or dead microorganisms [22], ambient atmospherictrace species and meteorological parameters. Laboratory experiments are needed to consider the survival and life cycles of microorganisms that can survive in the chemical and physical conditions found in the clouds of Venus, particularly in the lower atmospheric region. Spectral characteristics of different acid resistant bacteria over the 200 – 4000 nm range are needed, particularly for uv absorptive, sulfuric acid resistant species.

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Short Summary

The nature and identity of the absorbers of incident solar radiation between about 330-600 nm ij the clouds of Venus have been a mystery for decades. We explore the possibility of microorganisms being responsible for the absorption and the observed contrasts and measurements needed.

Tuesday 05 December 2017

Habitability from a Microbial Point of View

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1. Introduction

Microbial life could have been (or still be) present on a number of the worlds in the Solar System, in the past, today, and possibly in the future, as well as innumerable exoworlds. While the conditions for the emergence of life could have been relatively widespread during the early stages of the evolution of the Solar System, as well as on many other planets and satellites in the Universe, in the Solar System at least, the possibility for evolution from the anaerobic, chemotrophic microbial stage seems to have been limited to the Earth alone. What does this mean for the search for life elsewhere? Will we find it in the Solar System, will we detect it on exoplanets?

2. The origin of life and habitability

It all begins with our understanding of the origin of life. And by life, we consider entities composed of carbon molecules and water, formed of the most common elements in the Universe. On Earth, a variety of environments, from submarine hydrothermal vents, hydrothermal marine sediments and pumice rafts, through volcanic-hosted splash pools to continental springs and rivers, have been proposed for the emergence of life, each with respective advantages and certain disadvantages [see reviews in 1,2]. In the Solar System, it is likely that similar environments existed on the local scale on Mars, especially early in its history and probably Venus. Some of the satellites may have had liquid water containing organic molecules and in contact with hot rocky crusts hosting hydrothermal activity in their early stages, such as Enceladus, Titan, Europa, Callisto and possibly others.

The origin of life requires carbon molecules and essential elements such as H, N, O, P and S, liquid water, and energy sources, all of which were available on the above-mentioned planets and satellites. The important prebiotic processes that led to the origin of cellular life [2] included: (1) concentration of the molecular components participating in prebiotic reactions and control of water activity, (2) stabilisation and structural conformation of molecules, and (3) chemical evolution through complexification. These processes were controlled by the physicochemical conditions of the environment, including element availability, water temperature, pH, ionic strength, energy, irradiation, gradients and molecular diffusion. It is the balance of these parameters over time scales conducive to the emergence of life that dictates which of the proposed types of environments was likely to have been relevant or not (although we do not know how long it took for life to emerge on Earth but the process from prebiotic chemistry to protocell must have been rapid, like a snowball effect, in order to prevent reactions from going backward; this translates into tens – hundreds kyears to a few My – but nobody knows).

C, H, N, O and P are elements with minor endogenic and major exogenic origins on Earth, and probably similarly on Mars [1,3]. While the early Earth was a more or less ocean planet with relatively few, mostly short-lived exposed land masses (could the young Venus have been similar?), the opposite was the case for Mars, while the icy satellites remained totally ocean worlds. On Earth, the subaerial environments, especially, suffer from lack of longevity and exposure to combined high doses of radiation, desiccation etc. While radiation and

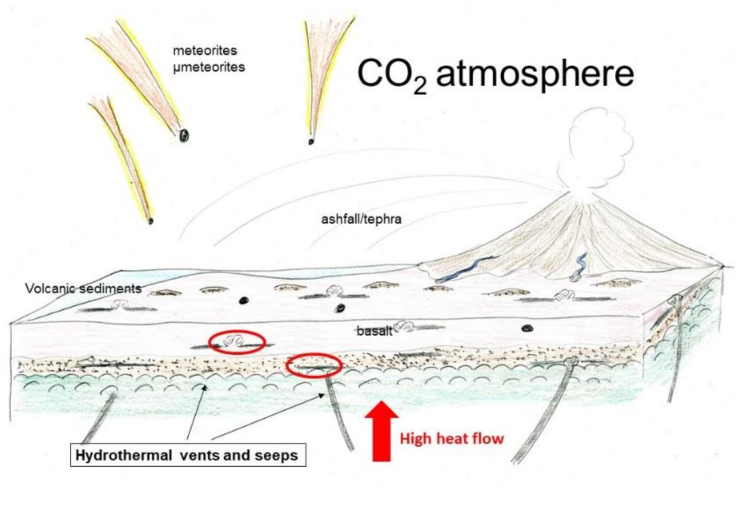

Figure 1*. Hydrothermal environments in which life could have emerged and which would have favoured biomass development of chemotrophic organisms.*

desiccation have been advocated as potentially useful in terms of an energy source and means of condensation [e.g. 4], respectively, together they are a hazard to the survival of organic molecules. As we understand the origin of life today, these parameters seem to rule out life appearing in streams, rivers or geysers at the exposed surface of any of the planets (Earth, Mars, or Venus), but not such environments as potential habitats for already existing life forms.

This leaves, as possible environments where life could have emerged on Earth, the submarine locations, hydrothermal vents or hydrothermally-charged volcanic sediments, possibly with additions of useful prebiotic molecules formed in other kinds of environments [2] (Fig. 1). On Mars, for instance, early seas and crater lakes on a geothermally hotter planet, subject to volcanism and impacts, could have seen the emergence of life, at different places at different times, despite the lack of total ocean cover [2]. Life forms on all the early planets were likely to have been chemotrophs, possibly initially litho-autotrophs (obtaining their nutrients and energy from inorganic sources) given the importance of mineral surfaces in the origin of life [e.g. 5], accompanied or closely followed by organotrophs (nutrients and energy from organic sources). However, further evolution of life on Earth was spurred by continuous habitability on the scale of hundreds of millions of years, as well as access to sunlight. In the case of Mars, the lack of continuous habitability is likely to have been a hindrance to further evolution towards martian life forms producing more biomass and more easily detectable biosignatures, such as phototrophs that use sunlight as an energy source. Could phototrophs have developed on Venus? We will probably never know. Could it have developed on the icy satellites of the Solar System? They are all far from the Sun, whose luminescence was low at the early stages when liquid water could have been in contact with hot crust on the satellites. Moreover, if any incipient microbes existed, they would be concentrated close to the lithic sources of heat, nutrients and energy, not free-floating in the upper realms of the water column where limited sunlight could reach.

3. Implications for the search for life on extreme habitable worlds?

From our understanding of the early terrestrial environment, when the Earth was anaerobic, hot and colonised by chemotrophs (as well as phototrophs), it is clear that the chemotrophs were most at home and "comfortable" in and around hydrothermal vents, *i.e.* small and localised phenomena [6]. They occurred also on volcanic surfaces at distance from hydrothermal effluents but their biomass development in these cases was limited - and biomass development is important in the search for and detection of traces of life on the planet. The anaerobic phototrophs had the advantage of not being dependent on the nutrient-rich hydrothermal sources, they could invade what we consider to be oligotrophic environments, *i.e.* environments poor in nutrients, because they got their energy from the sun and whatever nutrients there were in the seawater [7]. However, they had to live at shallow water depths, or even on land in the vadose zone [8] or hot springs [9].

Microbes are the archetypal opportunists. This means that, from the microbial point of view, many places on Mars, for instance, could potentially have been inhabited since microbes can colonise even briefly habitable environments. Whether occurring in subtle expression or in "well-stocked" biofilms, traces of chemotrophic microbial life can be preserved in the form of physical fossils or entrapped organic molecules encased a mineral matrix. The biological organic material can also be detrital, *i.e.* transported from its site of formation and deposited elsewhere – over short distances and presuming the minimum of environmental degradation. The important point is rapid encapsulation followed by cementation and preservation of the rock host. Hydrothermal environments, especially, favour microbe and organic preservation, as do other fine-grained materials, such as clays.

Detection of traces of microbial life in the Solar System may be possible on Mars, especially if we can land in the sweet spot where there has been hydrothermal activity to stimulate chemotrophic growth [10]. Detection of traces of life on the icy crusts of the satellites is more challenging. Even if there is life on them and cells are extruded in the plumes from the underlying oceans, the extremely hostile radiation environments bathing the icy crusts make detection of organic molecules challenging. So, Mars is still the best choice in the Solar System. And exoplanets inhabited by phototrophs, of course.

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Short Summary

Life could have been/still be present on a number of Solar System worlds, and on innumerable exoworlds, all of them extreme, in the form of mostly simple microorganisms. But Mars is the only planet where we have a likely chance of finding traces of life.

Origin of Life on earth by RNA and viruses

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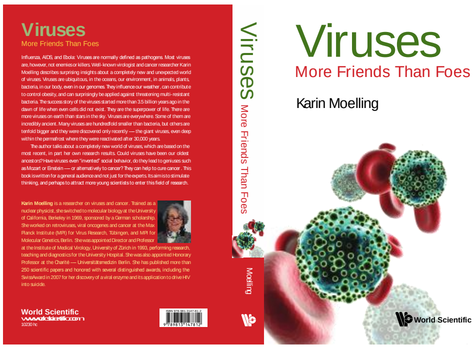
1. Introduction

The origin of life started under extreme conditions presumably at the hydrothermal vents in the oceans 3.8 bio years ago. Can one extrapolate from that to other extreme conditions and habitable zones outside of our planet?

2. An additional section

The first biomolecle on the earth are replicating RNA molecules. They are biologically active, able to cleave and join, mutate and evolve under extreme conditions at hydrothermal vents. They are designated today as catalytic RNA, riboszymes. They arose before cells existed and metabolized on chemical energy supplied by the environment, without sun or cellular background. Only later viruses depended on cells. Ribozymes lack genetic code information and rely on structural information such as hairpin-loops. The ribozymes evolved to the catalytic centres of the ribosomes, the protein synthsis machinery today. "Ribosomes are ribozymes", consisting today of about 100 proteins as scaffolds for protein sysnthesis. Ribozymes exist still today and are closely related to small naked viruses, the viroids. A major contribution to protein synthesis is based on tRNAs, also highly structured non-coding RNAs. The majority of the genomes of even the most complex forms of life, the humans, consist of 98% of non-coding sequnces. Thus our genomes evolved from non-coding to coding RNA sequences, which is reflected today in rapidly evolving RNA viruses, such as Influenza. A major driver of evolution are the viruses, most specifically the retroviruses (such as HIV today), which also contributed to generate the more stable DNA from the versatile mutagenic RNA. More than 50% of the human genome consists of retrovirus-related sequences. One retrovirus candidate form the human genome was revitalized under laboratory conditions, Phoenix, which existed 35Mio years ago. These propertis are still reflected in the virus world today. Most recently giant viruses have been discovered which are bigger than many bacteria and may be a transition form of earlier life to bacteria and archaea. Archaea can be considered as the most innovative organisms, named the extremphils- however the evolution of novel metabolic pathways takes time. I will discuss, what we can possibly learn and extrapolate from our world, starting from replicating molecules to LUCA, microorganisms and life on our planet today. Tardigrades are certainly far too advanced a species for survial of life. As reference I will give my recent book on "Viruses, more friends than foes" (World Scientific Press), which describes and explains all of what is mentioned here for non-spcialists and contains recent literature for further reading [1].

3. Figures



4. References

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Short Summary

The origin of life based on RNA and viruses.

Habitable planet Earth: We owe everything to microbes!

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1. Introduction

"Life would not long remain possible in the absence of microbes" a quote of the famous scientist Louis Pasteur [16]. I even want to go further and claim that "A habitable planet can only exists, or become habitable, with the help of microbes". To strengthen this claim, let us just take a look at planet Earth.

2. The formation of planet Earth and a possible start of life

Four and half billion years ago a lifeless planet, Earth, was formed by a series of hostile astrophysical forces and events [10, 12, 20]. A sizeable quantity of water was most probably already present in the primary materials that formed Earth [7]. As a consequence chemical forces helped shaping our planet right from the start [4]. Rocks weathered and eroded, minerals repeatedly dissolved and precipitated. Below the surface of the water of the first oceans, hundreds of thousands of different types of hydrothermal vents generated a multitude of extreme physico-chemical conditions. Immense pressure fluctuations and temperature gradients, cycled water from a super critical liquid in the proximity of molten magma, to a very cold solution, only a few meters away from the chimney of the hydrothermal vent. These extreme conditions lasted for millions of years and may have turned substantial amounts of simple inorganic molecules, like H_2, H_2O, CO_2, N_2, NH_3, CN, H_2S, PO_4^{2-} and CO, ubiquitous present in the Universe and on the early Earth, into life essential–, biochemical– and organo–minerals. Less than a billion years after the formation of the Earth, the variety and concentration of the chemical building blocks of life were divers and high enough, to possibly allow the abiotic formation of the very first living cellular structures, protocells. The thermal cycling conditions in the vicinity of hydrothermal vents, resembling conditions generated in modern PCR-machines, probably stimulated the biochemical polymerase reactions of biochemical molecules like peptides and RNA. Clays may very well have been the key to the formation of the first protocells, as vesicle formation and RNA polymerization can be catalysed by montmorillonite [5]. The membranes of protocells were most likely very simple structures, possibly entirely composed out of fatty acids that are, in contrast with the complex phospholipids and phospholipid acids of current cell membranes, highly permeable and could very easily split up or fuse with one and another [2] [21]. This property is probably one of the reasons why first life was dominated by processes like, endosymbiosis and lateral gene transfer, horizontal evolution, thereby adding and mixing the information carried by internal present polynucleotides. The protocells evolved first into prokaryotic Bacteria and almost simultaneously into Archaea. Later on, endosymbiosis probably generated the first Eukaryotic cells.

3. Historical geological impact of microbes

The first major impact of life on Earth was a microbial induced climate change. A massive production and release of methane most probably forced hydrogen away from Earth's surface into open space. This process might have preceded the first great oxygenation event that happened about 2.33 billion years ago, caused by oxygen producing photosynthetic cyanobacteria [11]. An event that irreversible changed Earth's geochemistry [13]. A second global microbial impact that happened about 600 millions years ago, was the oxygenation of Earth's atmosphere. The ice cap that was formed during the biggest ice age ever encountered by our planet, "Snowball Earth", melted and caused nutrient rich water to flood into the oceans, that triggered a second more massive outburst of oxygen producing photosynthetic cyanobacteria. The result was an exponential increase of the oxygen concentration of Earth's atmosphere. The impact of microbes could also be devastating. Earth's greatest mass extinction event, the End-Permian Extinction event, colloquially known as the Great Dying event, is linked to an outburst of methanogens [17]. This End-Permian Extinction event occurred about 252 million years ago, and the bio-methane release lead to the extinction of 96% of all marine species [1] and 70% of the terrestrial vertebrate species [18]. Today, on the current Earth, microbes are very often integrally involved in numerous geo(chemical) cycling of elements. Not only natural processes but also world wide anthropogenic activities, like mining, often require and obtain the help of microbes to avoid life threatening element accumulation.

4. Endosymbiosis: How Eukaryotes were formed

Since the work of Lynn Margulis, we know that we owe our very existence to microbes [14]. Endosymbiosis is the process that created the first eukaryotic cells, which ultimately evolved to all known multicellular species, including us humans. Two of the most important endosymbiotic evidences we know of today, are the mitochondria and chloroplasts. The proto-mitochondrion was probably very closely related to bacteria belonging to the class of the alpha-proteobacteria, the genus *Rickettsia* [8]. Genetics of the chloroplasts revealed that they belong to the phylum of the cyanobacteria [15].

5. Relationship of microbes and Eukaryotes

Almost all eukaryotic species, plants and animals, need microbes for survival. For instance, the origin of 90% of the nitrogen present in plants, could only have been assimilated with the help of microbes. Also, higher animals and even humans harbour a huge amount of microbes. A revised and recent estimate suggests that the human body contains approximately the same number of bacterial – and human cells [19]. This symbiosis with microbes is necessary for the host as microbes digest food components into essential and bioavailable nutrients and educate our immune system for a better protection against pathogens. More and more evidence is becoming available proving that the impact of these symbiotic bacteria extends much further then digestion or teaching the immune system alone. There is strong indication that brain development and diseases, like autism and obesity, are linked to the function and diversity of the human microbiome [3], [6]. A recent new discipline of biology, the gnotobiology, aims to study eukaryotic life without microbes. Although, gnotobiology succeeded in generating germ-free animals, the consequences of eukaryotic live without microbes are not yet fully understood [9].

6. Conclusion

This paper illustrates the tremendous impact microbes have on the formation of habitable planet. It also shows the historical and unbreakable relationship between Eukaryotes and symbiotic microbes.

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Short Summary

We owe everything to microbes: our oxygenated world, a sequence of beneficial climate changes for oxygen breathing mammalians, a habitable Earth, our own eukaryotic existence by well organized endosymbiosis processes, our daily live and our health. Maintaining this chronology and relationship with microbes might be essential when envisaging exoplanet colonisation.

Astrobiological Studies on Halophilic Psychrophiles Isolated from High Altitude cold region of North of Pakistan

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1. Introduction

As halophiles tolerate so many forms of environmental stress, they are 'exophiles'- organisms that might survive on Mars or other planets. They might also be capable of surviving journey between planetary or celestial bodies - embedded in salt crystals that protect them from damaging radiations. The Shergotty and Nakhla meteorites from Mars, contain halite salt crystals, which could carry halophilic organisms and transport to other planets. The indications of presence of a brine ocean beneath the ice of Europa suggests that it constitutes of hydrated minerals [1] but it is not clear yet, if these are sulphate salts, acid or alkaline. The infrared spectroscopy by the Galileo spacecraft has indicated the possible presence of hydrated salts, with mixtures of epsomite ($MgSO_4.7H_2O$), bloedite ($MgSO_4.Na_2SO_4.4H_2O$), mirabilite ($Na_2SO_4.10H_2O$) and natron ($Na_2CO_3.10H_2O$) [4]. The ocean of Europa may also be salty, and could contain NaCl [2].

2. Aim of the study

In order to assess the possible ability to survive in space ecosystem, bacterial and archaeal isolates from glaciers and high altitude cold lake, were exposed to extreme conditions of temperature, UV radiation, high concentration of NaCl and other salts.

3. Methodology & Findings

The bacterial and archaeal isolates DBA1 (*Halorubrum chaoviator*), BSA (*Halostagnicola* spp.), KK4 (*Chomohalobacter salexigens*), HTP-9 (*Pseudoalteromonas haloplanktis*), HTP-11(*Psychrobacter cryohalolentis*), HTS-4(*Janthinobacterium lividium*) and HTS-27 (*Arthrobacter citreus*) were from from hypersaline regions and Borith Lake, Passu, Siachen glaciers in HKKH region (Hindukush, Karakoram Himalaya). Strains HTP-9, HTP-11, HTS-4, HTS-27 showed growth at 5-20°C. The strains HTP-9, HTS-4, and HTS-27 were able to survive at NaCl concentration up to 26%, and HTP-11 was able to tolerate up to 36% NaCl. Only DBA1, HTP-9, and HTP-11 were able to survive at different concentrations of $MgSO_4$, $CaCl_2$, Na_2HPO_4, and KNO_3. However, BSA, HTP-9, HTP-11 and HTS-4 were able to survive at increased concentration of $KClO_4$. The growth of strains DBA1, KK4 and BSA was observed up to 45°C. Strain DBA1 demonstrated higher percentage survival at 700 Jm^{-2} while HTP-11 showed least percentage survival at 700 Jm^{-2}

4. Conclusion & Future Prospects

This study highlights the characteristics of microbes that can adapt to extreme conditions of space or planetary bodies with high salt concentrations and resist UV. Behavior of these microbes shows promising astrobiological implications in future.

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Short Summary

Bacteria and archaea from glaciers and cold brine lake in Pakistan were exposed to extreme temperature, UV radiation, high concentration of NaCl and other salts. They showed growth at 5-20°C, survived 26% and 36% of NaCl, 37 different concentrations of $MgSO_4$, $CaCl_2$, Na_2HPO_4, and KNO_3, and increased concentrations of $KClO_4$ also demonstrated higher percentage survival at 700 Jm^{-2}.

Blue Abyss Planetary Exploration Simulation Service

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ABSTRACT

The commercial human spaceflight sector is developing at a rapid rate and will grow in size and capacity at an exponential rate once a certain tipping point has been reached. Low Earth orbit will become increasingly a realm of commercial activity with government space endeavours focusing more and more on exploration of the Solar System. To optimise operations and minimise risk, appropriate pre exploration mission training and preparation will be required.

Blue Abyss will be the world's most versatile commercial extreme environment test, training and research facility. The centre will be based upon four main elements: (1) A multi-use dive pool with platforms at 10 and 20 m and a 50 m deep shaft, making it the deepest diving pool in the world; (2) A centrifuge for high-G training and to refine the study of hypergravity physiological effects; (3) A parabolic flight capability to offer zero, reduced and hyper gravity and (4) A pedagogical and outreach programme to promote a dynamic STEM approach towards the general public and youth, tomorrow's scientists and astronauts.

Using the apparatus, facilities and capabilities provided at Blue Abyss, high-fidelity planetary exploration analogue training/familiarisation programmes will be available to the space industry. Short term simulations of launch and return 'altered-G' profiles will be possible as will micro- and hypo-G exposure, by means of the long arm centrifuge and parabolic flight services. Longer term exploration environment simulations will be provided through the neutral buoyancy capabilities in the pool, coupled with appropriate simulated landscapes and pressurised habitation modules. Virtual and augmented reality technology will ensure the highest degree of fidelity possible within a training environment, thus offering a comprehensive planetary exploration training service.

The breadth of human spaceflight related experiences and training facilities required to prepare humans to travel to and spend time in space will be offered to the international space community by Blue Abyss in the UK from 2019. The services will span hyper G, hypo and zeroG, hyper and hypobaric, R&D and neutral buoyancy capabilities. The inclusion of certified marine and space operations experienced staff and partnerships with leading international commercial and government extreme environment organisations, provides a capability both appropriate and timely as the world prepares for routine excursions to low earth orbit and for extra-terrestrial planetary exploration in the years ahead. Looking forward, Blue Abyss's vision is that the next generation of extreme environment test, training and research capabilities will be established to underpin humanities expansion to the depths of our oceans and space.

Short Summary

Blue Abyss will be the world's most comprehensive extreme environment test, research and training centre aimed at enabling innovation and technology and procedural advancement in environments ranging from the ocean through to space.

Spectroscopy markers of habitability variables on Earth, Mars, Venus and planetary atmospheres

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1. Introduction

Even before any exoplanet had been detected, the problem of bio-signatures was addressed by visionary scientists. Here what is called a bio-signature is a spectroscopic feature that could be related to the presence of life in the spectrum of an observed exo-planet. In 1991, the first Earth fly-by of Galileo spacecraft was an opportunity to examine the planet Earth from outside, and a number of measurements were conducted (figure 1). They were interpreted in Sagan et al., (1993). We quote: "…the Galileo spacecraft found abundant gaseous O_2, a widely distributed surface pigment with a sharp absorption edge in the red [chlorophyll], and atmospheric methane in extreme thermodynamic disequilibrium; together, they are strongly suggestive of life on Earth."

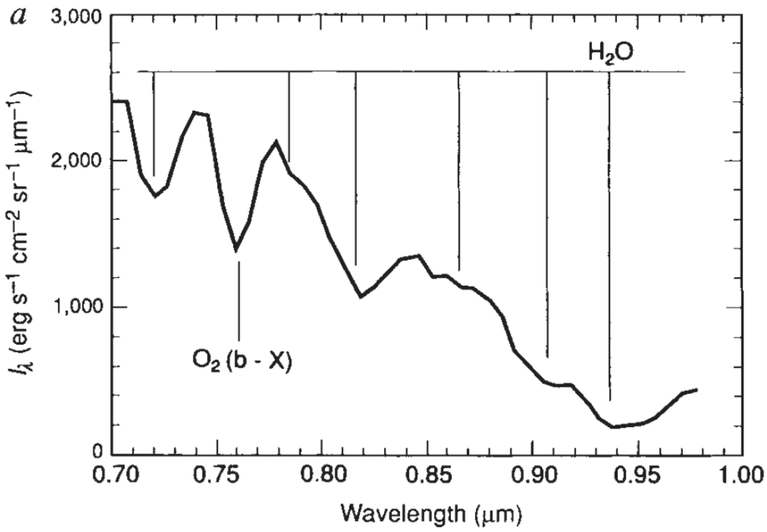

Figure 1. Spectrum of Earth reflected solar radiation collected by Galileo during its Earth fly-by over ocean. Within this small spectrum range, H_2O has several bands, and O_2 shows the conspicuous A band (also noted (b-X). From Sagan et al., 1993 [4].

Today, with a new knowledge of Earth, Venus, and Mars atmospheres and outgoing spectra, we will examine the spectra of these three terrestrial planets to understand what they can tell us about their potential habitability, and the possible presence of life on these planets.

2. The case of water, gas, liquid or solid.

Liquid water is a pre-requisite for life as we know it. This is because it is a fantastic solvent in which many chemical reactions may take place easily. Given the phase diagram of water, liquid water requires that the surface temperature T_s must be >273 K. Then, the relative humidity must be measured, by comparing the observed column of H_2O (vapour) to the one of saturation at temperature T_s. A relative humidity of 20% or less is considered as very dry on Earth. Liquid water has no specific spectral signature (except its very low albedo), while water ice may be recognized from its reflectance spectrum.

3. The case of other gases.

Molecular oxygen O_2 is produced by photosynthesis on Earth and was suggested by Owen [2] as a main life indicator target to be searched for. The main O2 absorptions are at 0.76 µm and 1.27 µm. A by-product of O_2 is O_3, which UV absorption protects life on ground from DNA damaging solar UV. Ozone was abundant enough only 500 million years ago, and before life was only in water. It means that the fact that there is life on Earth is known in the whole Galaxy, and many other galaxies too. The case of other gases like Methane, N_2O, and chloromethane (CH_3Cl) potentially biogenic, and other freons, potentially produced by high technology, will be discussed also.

4. Mars.

The day side spectum of Mars is a combination of atmospheric absorption features and surface reflectances (H_2O ice, CO_2 ice, hydrated minerals…) which can be disentangled with sufficient spectral resolution. The thermal IR spectrum of Mars reveals a mean surface temperature well below 0°C (-63° C). Therefore, there is no liquid water, a very dry atmosphere, no measurable O_2, and the ozone columns, though detectable (in the UV), is not enough to protect life on the ground. The CH_4 observations are sporadic and reveals very small quantities. Mars would fail our criteria for habitablity.

5. Venus

The day side spectrum of Venus is fully dominated by the solar spectrum scattered by cloud droplets, a moderate temperature (below 0° C), with a small column of CO_2 and very small H_2O. It could be interpreted as a solid surface and a cool and dry atmosphere. Ozone is present but in a very small amount, insufficient to protect life as we know it. If it is possible to observe the night side emission (difficult), then the observed spectrum (figure 2) reveals an extremely hot surface, an enormous quantity of atmospheric CO_2 (which greenhouse effect may be calculated for consistency), and only a small amount of water vapour. With the absence of liquid water, Venus fails the criteria for habitability as we know it.

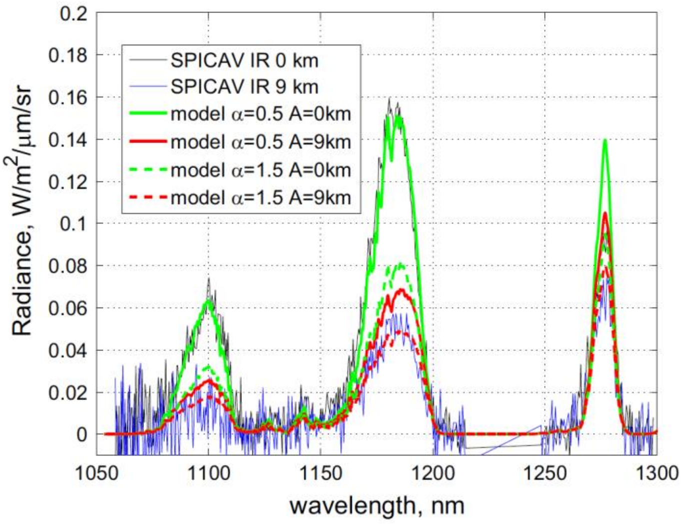

Figure 2: Spectrum of the night side emission recorded by SPICAM-IR instrument on board Venus-Express, in three spectral windows (not fully absorbed by CO_2 or H_2O), compared to various models. The black and blue curves are the measurements obtained respectively over a terrain at 0 and 9 km altitude (from Fedorova et al., 2015).

6. Changes with time: a sign of extra-terrestrial stupidity and poor overall political management

When monitoring Earth from outside, an extra-terrestrial astronomer would notice a very rapid increase of the quantity of CO_2 in the atmosphere: + 50% in 80 years, correlated with a decrease of O_2, one major constituent. With a little thinking (facilitated perhaps by the presence of radio-electric “noisy” signals), he could conclude that there is a massive burning of fossils hydrocarbons, uncontrolled. He would interpret this CO_2 rapid change as a sign of stupidity and poor overall political management by the inhabitants of this planet (Bertaux, 2017).

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Short Summary

We review a number of bio-signatures which have been proposed in the past, like molecular oxygen, methane, water vapour, temperature, chlorophyll, N2O and Chloromethane. We examine he case of Earth, Mars and Venus. Only the Earth is showing positive signs of life, but CO2 changes indicates poor managment from inhabitants.

Mars Express highlights on Mars habitability

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Mars Express is ESA’s multi-disciplinary mission to unveil the current conditions, evolution and history of the Red Planet. The geophysical data collected by the mission over the period of almost 15 years are directly relevant to habitability of the planet. Mineralogical mapping allowed one to reconstruct global Mars history indicating periods of water and sulphur rich environment. Characterization of the geological processes on a local-to-regional scale allowed constraining land-forming processes in space and time. Recent results suggest episodic geological activity as well as the presence of large bodies of liquid water in several provinces (e.g. Eridania Planum, Terra Chimeria) in the early and middle Amazonian epoch and formation of vast sedimentary plains north of the Hellas basin. Mars Express observations and experimental teams provided essential contribution to characterization and selection of exobiologically and geologically interesting landing sites for future missions.

More than a decade-long record of the atmospheric parameters such as temperature, dust loading, water vapor and ozone abundance, water ice and CO2 clouds distribution as well as subsequent climate modeling provided key contributions to our understanding of the Mars climate now and in the past. ASPERA-3 observations of the ion escape covering complete solar cycle revealed important dependencies of the atmospheric erosion rate on parameters of the solar wind and EUV flux.

Mars Express has fully accomplished its objectives set for 2015-2016. The mission provides unique observation capabilities amongst the flotilla of spacecraft investigating Mars. The mission has been confirmed till the end of 2018. The science case for the mission extension until the end of 2020 has been submitted to the ESA Science Program Committee. The observation program proposed for 2019-2020 includes both augmenting the coverage and extending long-time series, as well as new elements and potentially new opportunities for discoveries. It will be boosted by collaboration and synergies with NASA’s MAVEN, ESA-Roscosmos Trace Gas Orbiter (TGO) and other missions. The talk will highlight Mars Express findings related to the planet habitability.

Short Summary

The talk overviews almost 15 years of Mars Express observations relevant to the planet history, current and past climate, evolution and habitability

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Investigating the chloride-rich deposits in the highlands of Terra Sirenum: implication on bio-signature preservation

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Introduction

Chloride-bearing deposits have been widely identified on the southern highlands of Mars, mostly within Noachian-aged terrains [1]. These deposits were mainly detected by using multispectral thermal infrared imagery from the Thermal Emission Imagery System (THEMIS) instrument [1, 2], and locally by using the hyperspectral data of Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [1- 4]. The chloride-salts may have formed as evaporates in local ponds fed by runoff or groundwater [2, 5]. On Earth, chloride-salts form in alkaline and hypersaline conditions, and they can preserve traces of life, e.g., salt crystals which can preserve amino acids for 4-40 Ma [6]. The salt deposits on Mars are paleo-environmental indicators, thus their capacity of preserving surface and/or near-surface life evidence turns them into a highly interesting target of remote sensing as well as *in situ* investigations by future missions.

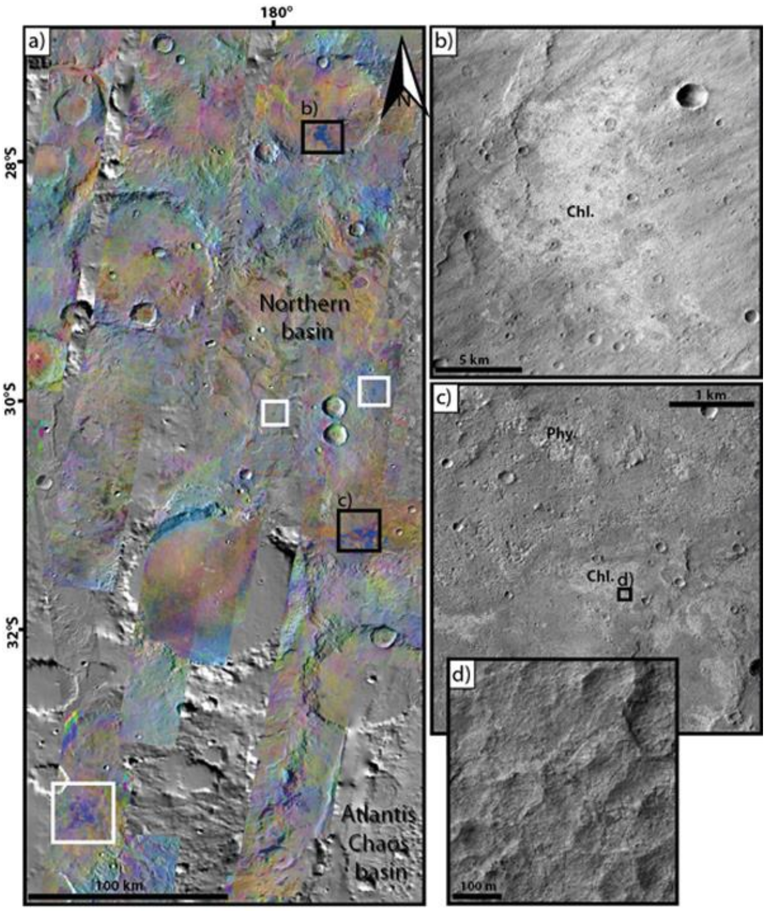

Figure 1: (a) Mosaic of false-color THEMIS TIR radiance data that are displayed in 8/7/5 DCS bands as red/green/blue overlying a MOLA hillshade map. Chloride salts appear in blue (white and black boxes), located in the northern Atlantis basin. (b) Chloride-rich materials deposited on the floor of a crater. (c) Chloride-bearing deposits in the northern basin. (d) Example of the texture of the chloride-bearing materials.

Terra Sirenum-regional setting

Terra Sirenum is located in the southern mid-latitudes and shows wide-spread chloride-rich material [3, 7]. This region has a rich aqueous and geologic history, including the large Eridania paleolake [7, 8], the E-W-trending Sirenum Fossae grabens, possible evidence of volcanism, such as wide lava flows, and local, small volcanos [9]. Terra Sirenum is mineralogically diverse, providing unique insights into Mars' aqueous processes. Analyses of remote sensing data over the region indicate the presence of both Fe- or Mg-rich phyllosilicates and chloride salts. Moreover, there have been also indications of local Amazonian fluvial activities in this area, as reported by [10].

Chloride-bearing deposits

Here, we present the preliminary results of our study focused on chloride-rich material in Terra Sirenum. Most of these deposits have been previously mapped as chloride-rich by [2]. Here we used imagery (HRSC, CTX, HiRISE), topographic (HRSC, HiRISE), and spectroscopic (THEMIS, CRISM) data to investigate the origin, formation mechanism, and chronology of these deposits at two sites in more detail. The first site has been previously studied by [7] and is located in a basin north of Atlantis basin (Figure 1). The second site is located in a basin east of Gorgonum Chaos. The reported chloride-bearing materials are found in local depressions and appear within light-toned deposits ranging in width from a few tens of meters to a few kilometres (Figure 1-b) with polygonal fractures that are a few tens of meters wide with an irregular plan-view shape that does not follow a regular geometrical pattern (Figure 1-d). The deposits rich in chloride are found in proximity to phyllosilicate-bearing deposits. The stratigraphic relationships indicate that the phyllosilicates are part of the ancient highland crust and that the salts were deposited at a later time. Thus, the formation of chloride-bearing deposits is likely caused by a later water activity. This relation between chloride-bearing and phyllosilicate-rich deposits has also been observed in other areas in Terra Sirenum [e.g., 2, 3, 7, 11] and been interpreted as result of water accumulation in ponds, brine concentration by water evaporation, and precipitation [2].

At both sites, the light-toned material is exposed due to erosion and degradation of a wide-spread low-albedo upper layer. Inverted channels are clearly observable within the area where the dark upper layer has been removed and the light-toned material is present. Where higher resolution images (CTX or HiRISE) are available, we can observe that several of these inverted channels are linked to a valley or channel in the dark upper layer, indicating their pre-erosion formation. On the floor of a few of these inverted channels, there are locally exposed thin layers of light-toned material, with similar texture and polygonal features to the previously reported chloride-bearing deposits. If these deposits are chloride-rich, this would rise the question whether chlorides precipitated in these areas contemporaneous to the pre-erosion and wide-spread light-toned material deposition, or later due to local aqueous processes in Terra Sirenum, most likely the same activity which formed the channels. Understanding the morphological and chronologic constraints of chloride-salt formation would improve our knowledge about the ancient and perhaps recent chemical environments on Mars, which would be of high importance for the search for possible ancient, yet preserved bio signatures as well as for identifying potential currently habitable sites on the surface or near sub-surface of Mars.

Future work

We aim to address the above question by providing a geological map of the area, analyzing spectroscopic data, identifying the stratigraphic relation of the various light-toned materials in this area, and the dark upper layer, assessing the digital terrain models, investigating the source of water for the inverted channels, analyzing the model age of the dark upper layer to constrain the inverted channels and light-toned material formation time.

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Compositional Mapping of the Martian South Polar Residual Cap using hyperspectral data from CRISM

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1. Introduction

We present our research on compositional characterization of the Martian South Polar Residual Cap (SPRC), with a focus on the detection of organic signatures within the dust content of the ice. The SPRC exhibits unique CO_2 ice sublimation features known colloquially as ‘Swiss Cheese Terrain’ (SCT). These circular depressions are dynamic, exhibiting seasonal scarp wall retreat, which may expose dust particles previously trapped within the ice. Here, we identify suitable regions for potential dust exposure on the SPRC, and use data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on board NASA’s Mars Reconnaissance Orbiter (MRO) satellite to examine infrared spectra of scarp walls to establish the mineral composition of exposed dust, to eliminate the spectral contamination effects of ices on sub-pixel features, and to assess whether there might be signatures indicative of Polycyclic Aromatic Hydrocarbons (PAHs). Spectral mapping has established pure CO_2 and H_2O local ice signatures, identified compositional differences between depression rims and the majority of the SPRC, and CRISM spectra have been corrected to minimise the influence of CO_2 and H_2O ices. Whilst no conclusive evidence for PAHs has been found, depression rims are shown to have higher water content than regions of featureless ice, and there are indications of magnesium carbonate within the dark, dusty regions

2. Background

While Mars was not initially thought to have been a planet with a dynamic surface, repeat observations starting with the Mariner missions of the 1960s [1] have indicated otherwise. In particular, the polar caps exhibit significant change over time, both seasonal and long term. On board MRO, is an imaging spectrometer, CRISM [2] attaining spatial resolutions of ~20m and spectral resolutions of 6nm, which can analyse compositional properties of the Martian surface. Mars’ south polar cap consists of a permanent 400km diameter layer of solid CO_2, 8m thick, overlaying water ice layered deposits [3].

So-called “Swiss Cheese Terrain” (SCT) is an unique surface feature found only in the SPRC on Mars. Its characteristic appearance (shown in Figure 1) is thought to be caused by seasonal differences in the sublimation rates of water and CO_2 ice [4]; scarp retreat through sublimation exposes material, including dust, previously trapped in the SPRC which can then be analysed using CRISM.

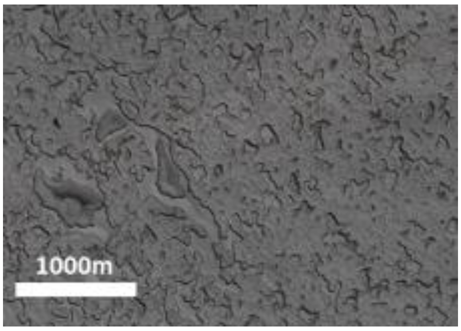

Figure 1: Example of SCT sublimation features (CTX: B08_012572_0943_XI)

a. Polycyclic Aromatic Hydrocarbons

PAHs are a group of chemical compounds consisting of benzene rings of hydrogen and carbon [5] and are considered to be important in theories of abiogenesis; the search for organic molecules on Mars is important in ascertaining Mars’ past conditions, and current habitability [6].

PAHs are abundant throughout the universe, coalescing in space within dust clouds, [7] and they have been detected on two of Saturn’s icy moons, Iapetus and Phoebe [8]. The delivery of complex organic compounds to planetary surfaces via bolide impact is a very important concept in astrobiology. The ability to identify PAHs could prove a critical tool in the search for putative locations for extra-terrestrial organisms.

To date, the hypothesised connection of Martian SCT and the presence of PAHs has not been systematically examined.

3. Methods

Initially, only Full Targeted Resolution (FRT) CRISM products have been considered for study to try to maximise spatial resolution (~20m/pixel) of small-scale SCT features. Analysis of the SPRC has been carried out using HiRISE, CTX, MOC-NA and HRSC imagery to better constrain regions of interest, and select CRISM scenes for spectral analysis. Five (5) candidate scenes were chosen for further analysis.

The CRISM Analysis Tool (CAT) plugin for ENVI software was used to process the CRISM scenes with corrections for photometry, atmosphere, image artefacts, 'despiking' and 'destriping', and to generate summary products. Forty-four (44) spectral summary products based on multispectral parameters are derived from reflectances for each CRISM observation that can be used as a targeting tool to identify areas of mineralogical interest for further analysis [9]. Those of particular interest to this investigation are those which highlight carbonate overtones, along with CO_2 and water ice, in order to differentiate materials of astrobiological interest from the bulk of the SPRC.

Region of Interest (ROI) band thresholds were used to identify the strongest 10% of CO_2 and H_2O ice signatures from each scene (Figure 2, left), and then ROIs of a minimum of 25 pixels chosen from the same across-track region of the scene as the dark-rim features to provide local 'pure' ice spectra. These samples were then used to carry out correction to remove the overwhelming effects of ice spectral signals on dust rim spectra.

Pelkey's summary products [9] were utilized to create RGB composite images of regions of interest to identify regions of spectral difference around dust rims (figure 2, right). Spectra for specific rim features with strong carbonate overtone responses, corrected for ices, were then analysed and compared to laboratory spectra for Martian mineralogy and PAH signatures.

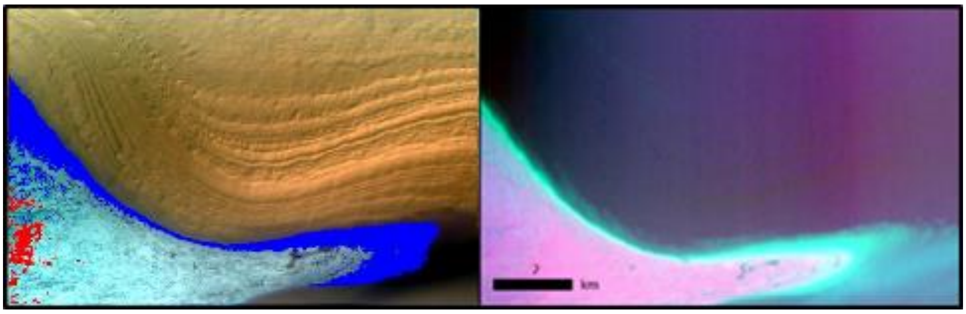

Figure 2: Left: 'True colour' visualisation of Site 1 from CRISM bands R = 230 G = 75 B = 10. Strongest 10% spectral responses for ices shown in red (CO_2) and blue (H_2O). Right: False colour visualisation of Site 1 using Pelkey (2007) summary products R = 1435 (CO_2 ice) G = 1500 (H_2O ice) B = BDCARB (carbonate overtones)

4. Conclusions

There are clear spectral differences between dust rims and non-rim regions, with indications of carbonate components within SCT dust rims. CO_2 ice signatures are a limiting factor in identifying PAHs as the removal of CO_2 ice spectrum may also remove subtle features in the 3.3μm PAH region of CRISM spectra. Work is currently being carried out to look for compositional changes over time in dust-rich regions, and how spectral changes relate to dust content and morphological processes. Further spectral data is also being collected on CO_2 and water ice mixtures to better determine their spectral contamination.

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Short Summary

We present our research on compositional characterization of the Martian South Polar Residual Cap (SPRC), with a focus on the detection of organic signatures within the dust content of the ice.

Searching for Signs of Life with the ExoMars Rover

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Based on what we knew about planetary evolution in the 1970's, many scientists regarded as plausible the presence of simple microorganisms on other planets. The 1976 Viking landers can be considered the first missions with a serious chance of discovering signs of life on Mars. That the landers did not provide conclusive evidence was not due to a lack of careful preparation. In fact, these missions were remarkable in many ways, particularly taking into account the technologies available at the time. The Viking results were a consequence of the manner in which the life question was posed. The apparent failure to detect organic molecules on Mars had an effect on all subsequent landed Mars missions, which focused initially on geology and later on habitability.

The second ExoMars mission is scheduled to launch on 24 July 2020. It will deliver to the martian surface a 310-kg mass rover and an instrumented landed platform having nominal mission durations of 218 sols and one Earth year, respectively.

The rover will explore the landing site's geological environment searching for signs of life. A drill—having a maximum reach of 2 m—will allow to collect samples from outcrops and from the subsurface. Such depth range has never been probed on Mars before. ExoMars' sampling capability will provide the best chance yet to access and analyse well-preserved sedimentary deposits, possibly containing molecular biosignatures, that may have been spared the ravages of ionising radiation.

The rover's Pasteur payload includes: panoramic instruments (wide-angle and high-resolution cameras, an infrared spectrometer, a ground-penetrating radar, and a neutron detector); a subsurface drill to acquire samples; contact instruments for studying rocks and collected material (a close-up imager and an infrared spectrometer in the drill head); a Sample Preparation and Distribution System (SPDS); and the analytical laboratory, the latter including a visual and infrared imaging spectrometer, a Raman spectrometer, and a Laser-Desorption, Thermal-Volatilisation, Derivatisation, Gas Chromatograph Mass Spectrometer (LD + Der-TV GCMS). The very powerful combination of mobility with the ability to access subsurface locations is unique to this mission.

After the Rover will have egressed, the Surface Platform will carry out environmental measurements at the landing site.

This presentation will discuss the ExoMars rover and the strategy to search for biosignatures.

Short Summary

This presentation will describe the mission and strategy to be used by the ExoMars rover to search for possible traces of past life on the red planet

Mars atmospheric and surface spectroscopic diagnostics: Mars Express results and ExoMars update

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1. **Introduction**

Optical spectroscopy is one of the main, if not the primary, source of information about both the atmosphere and surface of Mars obtained remotely. Measurements are mostly performed in the optical spectral range of electromagnetic radiation, from the UV range 1000-2000 Å to the `thermal' infrared (IR) range 25-50 µm, from ground or space observatories, but mainly from spacecraft in orbits around Mars.

Spectral measurements started from the very beginning of spacecraft exploration of Mars. Earlier results we mostly related to the atmosphere: Mariner 6 and 7, Mars 2, 3, and 5 gave first data on the surface temperature, on the structure and composition of the atmosphere. Mariner 9 studied the seasonal cycle of ozone and water vapour. Viking orbiters monitored water vapour, thermal structure of the atmosphere, and surface temperature.

After a long gap in the spacecraft exploration of Mars, a brief Phobos 2 mission (1988-1989) gave some pioneering results, and implemented first the method of spectral surface mapping. Such studies are favored by the tenuous atmosphere of Mars. The surface best sensed in the range of reflected solar radiation (near- and mid-IR, 1-5 µm), which includes absorption bands of rock-forming minerals, clays, sedimentary rocks. Interpretation of the near-IR spectra is easier than in the thermal IR. As a spacecraft moves along the orbit, a surface image is constructed, each point corresponding to a spectrum.

Highly successful MGS with thermal emission spectrometer (TES) gave important hints about the surface composition, and monitored key atmospheric parameters during three Martian years. THEMIS, high-spatial-resolution radiometer on board Mars Odyssey performed global mapping of thermal inertia and led to several important conclusions about Martian geology. No trace of geothermal or volcanic activity (hot spots) has been found. The ESA Mars Express spacecraft launched in 2003 was equipped with three spectral instruments OMEGA, PFS and SPICAM, previously planned for unsuccessful Russian Mars 96 mission. Mars Reconnaissance Orbiter (MRO) carries CRISM mapping spectrometer and MCS limb radiometer. Spectral investigations of Mars after the Viking mission, with some selected references are listed in Table 1.

Mission	Instrument	Spectral range, µm	Spectral resolution	Spatial resolution	Main results
Phobos-2 1989	ISM-KRFM	0.315-0.6 0.8-3.1	30 nm 50 nm	20x30 km	Mineralogical mapping of a limited region; rock-forming minerals [1]
	Termoskan	0.6-0.95 8.5-12	- -	2 km	First mapping of thermal inertia [2]
	Auguste	0.22-0.43 0.76, 0.94 1.9, 3.7	10-30 nm - 2-3 nm	3-10 km limb	Vertical profiles of aerosol and water vapor [3, 4]
MGS 1997-2004	TES	5.8-50	6, 12 cm^{-1}	3 km	Global mapping; volcanic rocks, hematite locally found; no carbonates, clays, or sulfates found [5]. Monitoring of climate [6]
Mars Odyssey 2001-	THEMIS	0.45-0.85 6.5-15	5 bands 9 bands	100 m	Global mapping of thermal inertia [7]
Mars Express 2003-	OMEGA	0.35-1 1-2.5 2.5-5.1	7 nm 14 nm 20 nm	0.3-5 km	Global mineralogical mapping; hydrated minerals, clays, sulfides locally found [8]
	PFS	2-40	1.5 cm^{-1}	≥9 km	Discovery of methane in the atmosphere [9]
	SPICAM	0.118-0.32 0.9-1.7	1 nm 3.5 cm^{-1}	1x50 km 4 km	A number of atmospheric results [10]
MRO 2005-	CRISM	0.362-3.92	6.6 nm/pix	18 m	Detailed mapping, carbonates and serpentine locally found [11, 12]
	MCS	16.5-42.1	9 bands	5 km limb 1x1.7 km	Vertical structure of atmosphere and aerosols [13, 14]

Table 1: Spectral orbital spacecraft studies of Mars after Vikings.

2. **Spectral mapping and the history of Mars's climate**

The first global mineralogical mapping of Mars was performed by TES/MGS [5]. It revealed main rock-forming minerals: basalts typical for southern ancient highlands and andesites found in younger northern flatlands. The `wet' past of the planet was confirmed by local detections of hematite, a mineral formed in presence of water. No sedimentary rocks, carbonates, or the results of chemical erosion (clays) were detected, suggesting the cold dry climate dominated in the history of Mars. Also, no sulfates, indicative of volcanic activity, were found.

OMEGA at Mars Express revealed far more diversified surface and allowed making key conclusions about the history of Mars's climate. OMEGA data suggest that two widespread groups of hydrated minerals, phyllosilicates and sulfates, were formed during considerably different periods: clays at the early Noachian period, whereas sulfates, formed in an acidic and most likely dry environment, appeared later, 4-3.5 billion years ago [15]. Therefore, the ‘early warm’ period of Mars could have ended earlier than the ‘classical’ chronology based on geological estimates assumes. Later, Mars remained dry and its surface activity was very restricted, allowing slow oxidation and erosion to form the present-day appearance of the planet [8].

The enigma of carbonates on Mars was solved by CRISM/MRO thanks to its better spatial resolution [11]. Ancient carbonates, potentially burying the early atmosphere of Mars, are observed in very restricted regions, on valley slopes and meteorite craters.

3. Atmosphere and evidences of current activity

Spectral studies of the atmosphere are the main source of data for climate monitoring, and provide detection of minor atmospheric components, notably, those of possible volcanic or biological origin. The near and mid-IR regions are good for measuring many minor constituents, which are detected at high spectral resolution. Upper atmosphere, excited molecular states, and some gases, are studied in the UV, water vapour in the near-IR, and, a 15 µm CO_2 band can be inverted to estimate temperature profile from the surface up to 40-60 km. PFS and SPICAM, two versatile spectrometers on board Mars Express are mainly used to investigate the atmosphere and climate of the planet. Among their multiple results [Giuranna, Montmessin] the discovery of methane revived hopes of Mars still being an active planet from a geological or biological perspective. In fact the detection of methane was first reported in three nearly simultaneous pioneering works [9, 16, 17], but astronomical observations and their analysis were undoubtedly stimulated by the PFS measurements.

The putative presence of methane promoted detailed studies of the Martian atmosphere and climate, identified as the primary scientific goal of the ExoMars Trace Gas Orbiter (TGO) [18]. TGO, now in aerobraking phase carries a powerful set of atmospheric instruments, ACS and NOMAD, to establish a detailed inventory of the trace gases existing in the Martian atmosphere [19, 20].

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Short Summary

Spectroscopic diagnostics and mapping is a primary source of information about the atmosphere and surface of Mars obtained remotely. The spacecraft spectral investigation will be reviewed with an emphasis on Mars Express results and ExoMars expected capabilities.

A miniature LIMS instrument for in situ chemical analysis of solids with high spatial resolution on planetary surfaces (Poster Flash Talk)

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1. Introduction

The detection of extinct or extant life and the assessment of the habitability on Mars are currently two of the most thriving interests in Astrobiology and Space Research, which drive significantly the development of dedicated instrumentation for in situ exploration on planetary surfaces. To improve the current understanding of processes (chemical and physical) that might have altered the Martian surface accurate and sensitive information of solids with high spatial resolution at micrometre level are required, complementing the chemical information at larger scale (bulk analysis). Instrumentation based on laser ablation/ionisation mass spectrometry is a promising alternative measurement technique for future space exploration missions. In our contribution we demonstrate the measurement performance and capabilities of our miniature LIMS system for sensitive chemical analysis of solids with high spatial resolution (micrometre and nanometre level), on the basis of measurement campaigns conducted on basaltic and mineral samples with some of which containing micrometre sized fossil structures.

2. Instrument Description

The system used for the analysis of the chemical (elements and isotopes) composition of solids is a miniature reflectron-type time-of-flight (R-TOF) mass spectrometer (dimension mass analyser: 160 mm x Ø 60mm) coupled with a femtosecond laser ablation ionisation source (τ ~190 fs, λ = 775 nm, 1 kHz pulse repetition rate, max. 1 mJ/pulse) [2,4,5,7]. A lens system placed on top of the instrument is used to focus laser pulses through the mass analyser towards the sample surface to spot sizes in the range of about 10 – 20 µm in diameter. Only positively charged species can enter the instrument where they are accelerated, focussed and confined into the interior by the ion optical system. After passing the drift path the ions are reflected at the ion mirror towards the multi-channel plate (MCP) detector system passing a second time the drift path. The positively charged species arrive in time sequences at the detector system (TOF principle), according to their mass over charge ratio. TOF spectra are converted subsequently to mass spectra [4].

3. Materials

To demonstrate the measurement capabilities of the miniature LIMS system, *tomographical* measure-ments of two different sample materials will be presented and discussed in detail. The two samples are i) a basalt sample including mineral filamentous structures (Fig. 1, top row, approximate age of 360–320 Ma), that were collected at Kinghorn, Fife, Scotland [1], and ii) an aragonite host with embedded micrometre-sized fossil veins (Fig 1, bottom row), collected from slow-spreading Mid-Atlantic Ridge at 26.9 m depth below the seafloor [6].

4. Results and Discussion

The spot-wise chemical analysis and the sequenced storage of mass spectra allow for a detailed 3D chemical analysis of the investigated samples. In this way the monitoring of bio-relevant elements allows the identification and localisation of fossil structures embedded within the aragonite host (see Fig. 2) where conventional optical microscope imaging techniques find its limitation. Furthermore, this measurement procedure allows to improve the quantitative nature of the chemical analysis of these micrometre structures as only mass spectra containing chemical information attributed to the fossil can be selected and accumulated to increase the signal-to-noise ratio (SRN) [6]. A similar analysis procedure was applied for the chemical analysis of the basaltic sample material, however, this time by monitoring mineral specific elements, including e.g. the elements of millerite (NiS) or quartz (SiO_2). This analysis procedure allows us to monitor changes of mineral phases within the sample material and hence to chemically “zoom-in” into locations of interest [1]. Both measurement campaigns will be discussed in more detail during the contribution to demonstrate the versatility of our miniature LIMS system.

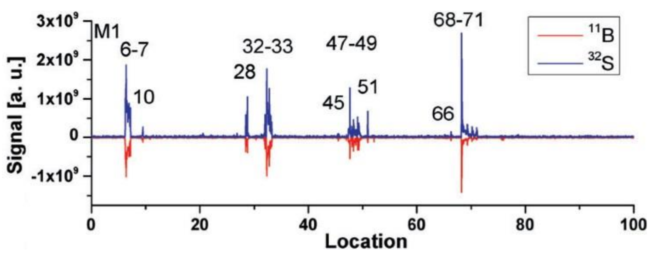

Fig. 1: By monitoring bio-relevant elements during the mass spectrometric acquisition filament structures within the sample material can be identified. Image adopted from [6].

5. Summary

To date, the miniature LIMS system shows various measurement capabilities for the chemical analysis of highly heterogeneous sample materials, ranging from sensitive (10 ppb, atomic fraction) and quantitative element analysis [2,4], high accurate isotope analysis that allows for in situ dating [3], high lateral (at micrometre level) and vertical (at nanometre level) resolution providing 2D and 3D chemical investigations of solids [1,6,7], to the determination of sample mineralogy [1]. Therefore, the miniature LIMS system is a promising alternative measurement technique for future space exploration missions where high detection sensitivity and versatility are requested.

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Short Summary

The measurement performance and capabilities of our miniature LIMS system for in situ chemical analysis of solids with high spatial resolution will be demonstrated, on the basis of measurement campaigns conducted on basaltic and mineral samples with some of which containing micrometer sized fossil structures.

Response of potential new solar cells on the surface of Mars for assessing future habitability: a space weather and materials modelling study (Poster Flash Talk)

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1. Introduction

Planning manned missions to planets such as Mars require not only efficient shielding of astronauts to harmful radiation such as energetic particles from solar and galactic sources, but also a future vision of how to sustain life on the planet itself. Arrays of solar cells, possibly different from those used on spacecraft, should be conceived and studied in order to explore possibilities for power generation, in particular for generating electricity and possibly creating hydrogen.

Traditional methods to study radiation damage of solar cells rely on Monte Carlo tools, well accurate to study the primary damage. Such tools give an overall loss of efficiency and are often used to study the damage of the commonly used solar cells on spacecraft (based on GaAs or Si) [1,2].

Dye-sensitized solar cells, although under intense study by the whole international community working on solar cells since several years, have been considered only by very few studies for space applications [2]. This is mainly because of their efficiencies (still to be improved considerably), the use of liquid electrolytes and long-term degradation mechanisms, which have prevented them from much consideration for applications as spacecraft components.

However, their potentiality to create energy and sustain humans on the very surface of Mars must still be investigated. Recent advances in nanocrystalline dye-sensitized solar cells lead encouraging results and stimulate the investigation of their potential for power generation. Indeed, they could provide light-weight, low-cost arrays for power generation.

Designing new solar cells is a challenge. Investigating possible solutions involves a combination of particle transport tools and detailed results of the changes in the electronic/optical properties via first principles tools which go beyond the description of the primary, averaged damage obtained by Monte Carlo tool. Such first-principles tools allow to study the details of the structural and electronic changes in the microscopic description of the response of the materials.

1.1. Radiation damage of TiO2 as main component of future solar cells on Mars

We report a first space environment characterization of TiO2, the main component of dye-sensitized solar cells. TiO2 is considered as exposed to different simulated space environment conditions at the surface of Mars, assuming different solar activity scenarios.

The space radiation environment analysis is the first step to determine the particle spectra that emerge after having passed through the atmosphere of Mars and are thus directly impinging on the solar cell. Different types of solar activity scenarios might lead to effects of different magnitudes in target materials [3].

The Space radiation environment and the particle transport through the Mars atmosphere are calculated via SPENVIS (SPace ENVironment Information System [4,5]), which is a web application used worldwide to model the Space environment (galactic cosmic rays, trapped particles, solar energetic particles, plasmas, debris and meteoroids) around Earth, Mercury, Mars and Jupiter, in the interplanetary medium and to plan space missions.

The radiation passing through the atmosphere and impinging on the material is calculated using PLANETOCOSMICS [6], a Monte Carlo Geant4 tool included in SPENVIS. The performance of the material is evaluated by looking at the energy deposited and the effects of structural damage induced by the impinging particles, the latter being analyzed via first principles tools from the materials science community [7].

2. Results

The results show how the induced change in the electronic levels influences the possibility of generating hydrogen and the trapping of charge carriers which might limit the output current. The effects of induced vacancies, the introduction of deep/shallow electronic levels [8,9] in the material, the change in the electronic and optical band gap and the potential to absorb photons of different energies and to generate hydrogen are presented.

The study is a first exploration of the combination of traditional methods used in space environment modelling and particle transport with microscopic first-principles description of the induced changes in the target. It encourages further studies for assessing the future potential of new solar cells for power generation and for sustaining human life on Mars.

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Short Summary

Assessing the future habitability of Mars also implies the study of how humain life can be sustained. Here we present a study of the radiation damage and potential power generation by future TiO2-solar cells under different space weather scenarios, via a combination of Space environment modelling and first-principles materials modelling.

Making the Moon Habitable: Science, Research, Technology & Innovation

B.H. Foing[1*] *and ILEWG/MoonVillage working groups*

[1] *ESA/ESTEC*
[2] *ILEWG International Lunar Exploration Working Group*
[3] *VU Amsterdam*

1. Introduction

We shall discuss the science goals, innovation, status of upcoming missions in the context of Making the Moon Habitable and elaborating the concept of a Moon Village with the goal of a sustainable human presence and activity on the lunar surface [1-3] as an ensemble where multiple users can carry out multiple activities.

Multiple goals of the Moon Village include planetary science, life sciences, astronomy, fundamental re-search, resources utilisation, human spaceflight, peace-ful cooperation, economical development, inspiration, training and capacity building.

2. Previous projects

The Moon represents a prime choice for political, programmatic, technical, scientific, operational, economical and inspirational reasons. COSPAR and its ILEWG International Lunar Exploration Working Group (created 20 years ago) have been supporting opportunities of collaboration between lunar missions and exchange on future projects [4-8]. A flotilla of lunar orbiters has been deployed for science and reconnaissance in the last international lunar decade (SMART-1, Kaguya, Chang'E1&2, Chandrayaan-1, LCROSS, LRO, GRAIL, LADEE).

De facto, collaborative opportunities and elements of a Robotic Village on the Moon exist, as China landed in 2013 the Chang'E3 and its Yutu rover, and from 2017 other landers are planned (GLXP, Chang'E 4&5, SLIM, Luna 25-27, LRP, etc..). A number of human missions with Orion & ESA service module to lunar orbit, as well as private missions for humans and cargo are also planned.

3. Current missions for MoonVillage

We shall discuss roadmaps and technical studies held in international groups [4- 15] such as COSPAR, ILEWG, ISECG, IAF, IAA or national and regional groups (eg LEAG). We shall discuss the upcoming international and private lunar robotic and human missions and how they can address science, research, technology, innovation and infrastructures to enable the vision and implementation of a Moon Village.

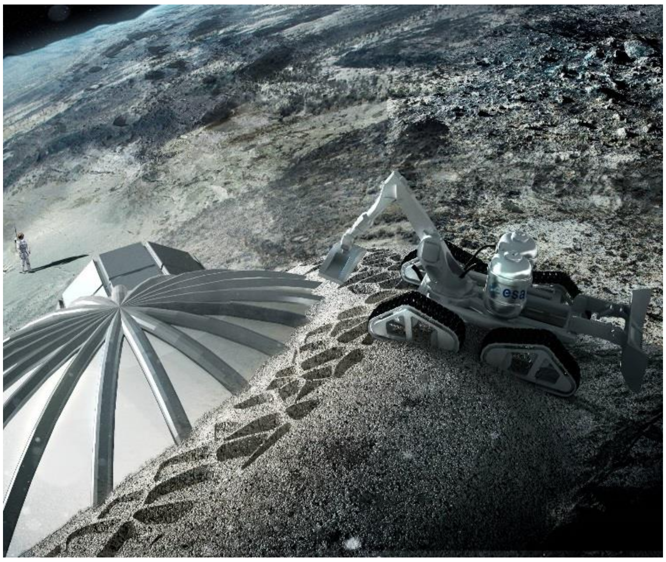

Figure 1: possible step towards the MoonVillage using robotic with 3D printing to consolidate inflatable domes against radiation and meteorites before the arrival of astronauts.

4. Acknowledgements

We thank Prof J. Woerner (ESA DG) for energizing the concept of MoonVillage. We thank co-conveners of MoonVillage Workshops and ILEWG EuroMoonMars field campaigns in 2016 &2017 (including A. Lillo, P.

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Figure 2: enthusiastic public endorsing the MoonVillage concept after a talk given during ESTEC open day, and being asked who wants to become MoonVillagers.

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Short Summary

How to make the Moon Habitable and design a Moon Village with sustainable human activity on the lunar surface where multiple users can carry out multiple activities including planetary science, life sciences, astronomy, fundamental research, technology, resources utilisation, human spaceflight, peaceful cooperation, economical development, inspiration, training and capacity building.

PROSPECT: ESA's Package for Resource Observation and In-Situ Prospecting for Exploration, Commercial Exploitation and Transportation

J. D. Carpenter[1], *E. Sefton-Nash[1*], R. Fisackerly[1], the ESA Lunar Exploration Team, the PROSPECT User Group and the PROSPECT Industrial Team.*

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1. Introduction

The Package for Resource Observation and in-Situ Prospecting for Exploration, Commercial exploitation and Transportation (PROSPECT) is in development by ESA for application at the lunar surface as part of international lunar exploration missions in the coming decade, including the Russian Luna-27 mission planned for 2021. Establishing the utilization potential of resources found in-situ on the Moon may be key to enabling sustainable exploration and lunar habitability in the future. The purpose of PROSPECT is to support the identification of potential resources, to assess the utilization potential of those resources at a given location and to provide information to help establish the broader distribution. PROSPECT will also perform investigations into resource extraction methodologies that maybe applied at larger scales in the future and provide data with important implications for fundamental scientific investigations on the Moon.

2. Objectives

PROSPECT aims to assess the in-situ resource potential of lunar regolith at any given location on the Moon. In order to achieve this PROSPECT is required to:

- Extract samples from depths of at least 1m.
- Extract water, oxygen and other chemicals of interest in the context of resources.
- Identify the chemical species extracted.
- Quantify the abundances of these species.
- Characterize isotopes such that the origins and emplacement processes can be established.

In the lunar polar regions PROSPECT is able to target water ice. At all locations on the Moon PROSPECT is able to extract solar wind implanted volatiles from the regolith through heating and aims to extract oxygen and other chemicals of interest as resources from minerals by a variety of techniques.

3. System functions

Drilling and sampling: PROSPECT includes a drill that is required to access the subsurface to depths of at least 1m. Once at the required depth a sampling tool removes small samples, whilst preserving sample temperature. Samples must then be extracted and handled whilst minimizing alteration of the samples. The drill is derived from that being developed for the ExoMars Rover [1] and the Rosetta drill [2]. Modifications are considered to account for unique lunar mission requirements and material properties.

Sample heating and chemical extraction: Samples are sealed in ovens, derived with heritage from those developed for ExoMars [3], Rosetta and activities performed through the German LUISE programme. Samples can then be heated to temperatures as high at 1000°C. Heating in vacuum extracts ices and solar wind implanted volatiles, and pyrolyses some volatiles from minerals. Reacting gasses may also be introduced to the ovens to extract additional chemistry of interest. A number of techniques are under investigation, based on a combination of flight heritage and laboratory investigations. These include combustion with oxygen [4] and reduction using hydrogen and methane [5].

Gas compositional analysis: Evolved gasses can be analyzed using an ion trap mass spectrometer [4] for masses up to around 200AMU. This gives a qualitative measure of the composition.

Gas chemical processing: Target gasses are prepared for isotopic analysis through refinement or conversion to other chemicals [4]. Such conversion can prepare chemicals, which are better suited than the original compounds to analysis using a mass spectrometer and can remove isobaric interferences.

Gas isotopic analysis: Isotopes of the elements of interest are measured using a magnetic sector mass spectrometer, along with measurements of reference standards [4]. Using this technique accurate analysis is achieved, allowing comparison with laboratory measurements on Earth.

4. Conclusion

PROSPECT is a package for the investigation of lunar volatiles and other potential resources with potential applications for both exploration and fundamental science. The package builds on extensive flight heritage and a unique set of capabilities, developed over decades by a number of groups across Europe. PROSPECT is in development for flight on the Russian led Luna-27 mission as part of the first phase of lunar resource characterisation [6] and could be available as part of international missions in this timeframe.

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6. Acknowledgement

The PROSPECT Industrial Team is led by Leonardo (Italy). Development of the chemical laboratory is led by the Open University UK.

Short Summary

The Package for Resource Observation and in-Situ Prospecting for Exploration, Commercial exploitation and Transportation (PROSPECT) is in development by ESA for application at the lunar surface as part of international lunar exploration missions in the coming decade, including the Russian Luna-27 mission, planned for 2021.

Space Biology and space medicine in the Lunares habitat in Poland

Short Summary

Space biology and space medicine are crucial for advanced human spaceflight beyond the Earth's orbit. A newly built habitat in Poland opened this year, brings new opportunities to investigate life support systems and extreme medicine issues in preparation for future colonization of harsh extraterrestrial environments.

Safety and comfort for Moon and Mars habitats: key design considerations.

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1. Introduction

Safety requirements are critical in designing for extreme environments. However, safety alone is not enough when designing for long-term missions in extreme environments on Earth and in space. Comfortable and functional design that accommodates crew's physical and psychological needs can help to improve their everyday life and work performance. Currently, a common habitat design approach is based on a linear process satisfying technical requirements of the mission and provid Barucci ing necessary life support for the crew [3]. Nevertheless, to ensure crew members' wellbeing and productivity, aesthetics and other architectural design aspects have to be given equal attention throughout the whole design process. In addition, it is important to examine habitat safety and comfort requirements according to selected construction and technical options.

Habitats in extreme conditions need to satisfy exceptional requirements for construction, environmental protection, and maintenance; they have to ensure life safety, crew's physical and psychological health, productivity, and emergency response protocols [1].

Key design aspects of planning a Moon/Mars base or settlement emerge from answering the following questions:

- Where is better to locate Moon or Mars bases and why?
- What can be learned from comparing permafrost conditions in Antarctica and Mars Polar Regions?
- How to integrate life support systems into the base design?
- How to provide safety in emergency situations?

2. Examples of effective architectures and technologies in extreme environments

Advancing crew working performance while reducing base maintenance costs is the major concern that determines habitat design requirements and design overall efficiency [14]. In particular, architecture of the whole structure or facility has to provide systems and inhabitants security, sustainability and good living standards. Such strategy fundamentally changes the approach to designing habitats and equipment for extreme conditions on Earth and in space.

Pleasing, yet comfortable and easy-to-use interior design combined with the latest technology allows multiple options for efficient use of habitat's compartments [14]. That increases functional and operational flexibility of habitats and other modules interior spaces. Elegant design with unobtrusive design elements can help the crew to relax mentally and to rest. Consequently, comfortable conditions for life and work contribute to improvement of crew's health and well-being stimulating better psychological and physical conditions of every crewmember who works under extreme conditions. With the new approach to habitat design habitat structures become more efficient due to their compactness, modularity and flexibility.

These assumptions are based on our research of the best practices and recommendations derived from experience on the medium-duration orbiting facilities including Skylab, Spacelab, Salyut 7, Mir, and the International Space Station; orbital spacecraft system Shuttle; polar research stations in the Antarctica and Arctic; and Earth-based human space mission simulators [5]. The Earth-based recent, present, and planned simulators were ranged, analysed and categorized. Virtual and parabolic flights were also considered as simulating environments (Annex 1).

In addition, selected key results from international studies on innovative technologies and structures for habitats, radiation protection, and regenerative life support systems are summarized and reviewed.

The paper summarizes with definition of current major problems in the habitat design and discusses a new architectural strategy to creating innovative and effective habitation systems for Moon and Mars applications.

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http://www.pavilionlake.com/blog/
Flashline Mars Arctic Research Station (FMARS): http://fmars.marssociety.org/
Mars Desert Research Station (MDRS): http://mdrs.marssociety.org/
European Mars Analogue Research Station Project (Euro-MARS): http://euromars.net/
Haughton-Mars Project (HMP): http://www.marsonearth.org/
NASA Desert Research and Technology Studies (D-RATS):
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NASA Extreme Environment Mission Operations (NEEMO):
http://www.nasa.gov/mission_pages/NEEMO/index.html
Pavilion Lake Research Project (PLRP): http://www.pavilionlake.com/
Pacific International Space Center for Exploration Systems (PISCES): http://pisces.uhh.hawaii.edu/
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Short Summary

This paper discusses a new architectural strategy for creating innovative and effective habitation systems for Moon and Mars applications that based on identification of current major problems in design and planning of medium-duration orbiting facilities, polar research stations in the Antarctica and Arctic, and other human-space-mission analogs and simulators.

”Lunar Base 1 – Conceptual architectural design studies for a base on the Moon”

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Abstract
Building a base on the Moon will be a complex endeavour based on an international collaboration of spacefaring nations involving different public and private actors. The design and configuration of the base will strongly depend on the contributing parties as well as aims and objectives associated with the mission. For long-term missions, such as a settlement on the Moon, inhabitants will be confronted with harsh environmental, social and psycho-physiological conditions. Far from Earth, the living spaces of a Moon base will be isolated and confined. Living for a long time in such environment puts extra emphasis on the habitability and human factors as critical determinants for the design. The architectural design of a base will have a strong influence on the success of the mission and therefore requires not only a technical expertise of space and civil engineers, but also considerable contributions from architects and other humanities experts in creating liveable spaces. In addition, a permanent base on the Moon will need to become self-sustaining over time. Manufacturing structures in-situ from local resources will decrease the mission costs and will limit the dependability from Earth. Therefore, developing in-situ resource (ISRU) derived manufacturing techniques of habitats become a key element for the establishment of a base.
This paper describes the results of a first conceptual design study done by students of architecture and civil engineering in the framework of a MSc semester project at the University of Stuttgart, Institute of Design and Construction (IEK), with support from the European Space Agency and the Institute of Space Systems (IRS) and the involvement of multidisciplinary and international field experts. The aim of the project was to investigate architectural design solutions for an ISRU derived sustainable lunar base at three different candidate locations, such as Shackleton crater, Schroedinger basin and lava tubes near the equator. In addition, an expansion strategy and incorporation of the possibility for commercial projects and partners had to be part of the design. During the project six different design solutions for a base on the Moon were developed.

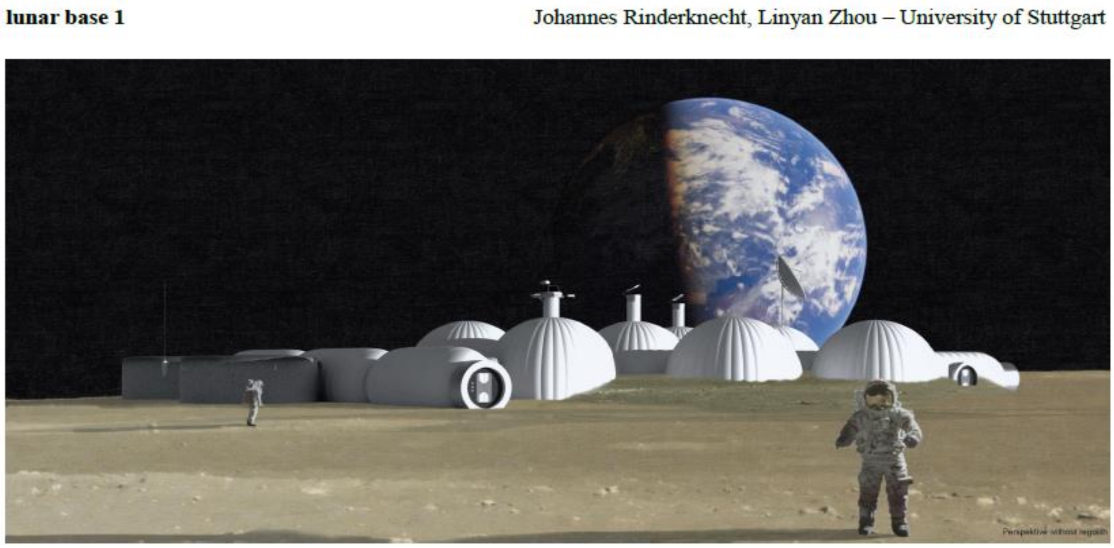

Figure 3 - regolith free view of design solution group B

Short Summary

A conceptual design study was performed as a semester project at the University of Stuttgart, Institute of Design and Construction (IEK). The aim was to investigate architectural designs for an ISRU derived sustainable lunar base. An expansion strategy and incorporation of the possibility for commercial projects and partners had to be part of the design.

Study of Isokinetic Structures and Applications for Expandable and Adaptive Habitats using in-situ Lunar Resources for Future Moon Surface Missions

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1. Introduction

Numerous concepts for permanent lunar base structures have been proposed. Among these designs, some of them highlight expandability anticipating future growth at the expense of a detailed study of the lunar surface environment and the effects it may have on the structure and materials. Others concepts have the advantage of being structurally sound however, they do not consider the availability of lunar construction materials.

In this paper, we present a modular architecture for a lunar habitat taking into account the properties of isokinetic structures and the possibility of in-situ resources utilization. The overall concept would allow a mission crew of four to live and work on the Moon's surface, in collaboration with robots. The proposed solution presents the idea of an isokinetic expandable geodesic dome as the main and internal structure. It will contain a particular layer design to be covered by regolith and/or lunarcrete at the same time that allows future growth. This layer would provide a protection shield against outer environment. The layer is made from a pattern of empty triangular-based pyramids to be filled with regolith. At this stage of the work, the dimensions of the maximum expansion of the dome are 6 m diameter with 3 m height. However, we contemplate the possibility to have a bigger dome with an expansion up to 10 m diameter. Further expansions are yet to be studied.

A future mission scenario has also been studied for finding the best outpost for placing the habitat.
We have taken into consideration the lunar environment, construction methods and materials, structural systems and design loads among other parameters in the designing of the habitat. We also understand the role of human and robots, their performances and their interactions during the development and completion of the mission. Other aspects such as life-support systems, interior design, regolith processing and transportation will be studied within the next steps of the work.

This habitat requires achieved and available technology therefore, the lunar base idea may become a reality within the next decade, expanding our frontiers and open new opportunities for research.

Keywords: Lunar habitat, Space exploration, Manned missions, Geodesic dome, Adaptive habitat, Regolith, Human-Robot Interaction, Isokinetic structure

2. Overview

The Moon has been considered of special interest for exploration both because of its intrinsic scientific characteristics but also as a stepping stone to broader endeavours. The surface of the Moon provides with excellent opportunities for other scientific research such as astronomy, physics, astrobiology, human physiology and medicine [1]. According to the Global Exploration Roadmap (GER) humans will get to the Moon once again to achieve milestones in space exploration [2]

2.1. Habitat mechanism

Mechanism of isokinetic expandable geodesic dome (Figure 1.), the base will be placed in selected locations by means of a tele-operated rover (Figure 2.)

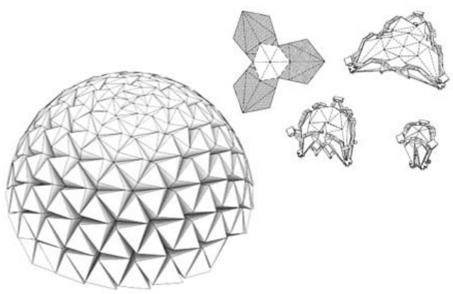


Figure 1. Dome concept based on origami pattern and hoberman sphere mechanism

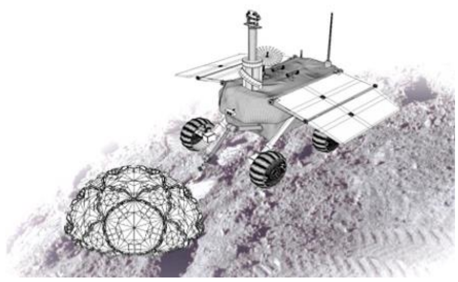
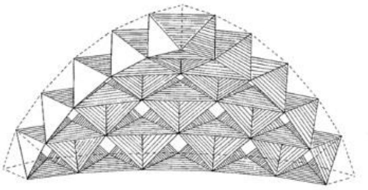


Figure 2. Illustration of the rover placing the 'un-expanded' dome



Once placed the dome will expand and the empty spaces of the triangular shaped patter (Figure 3.) will be filled by lunarcrete (Figure 4.) increasing the safety and efficiency of the structure.

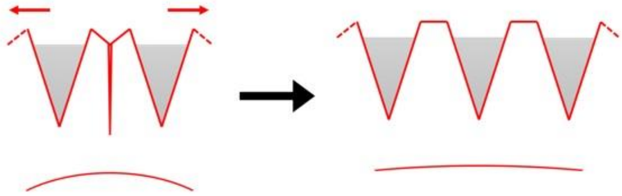


Figure 3. Detail of a triangular shaped pattern

Figure 4. Sketch of filling the empty spaces with lunarcrete

Mission Architecture

As a possible mission scenario we selected the Amundsen-Ganswindt basin (Figure 5.) as the landing site mainly for the presence of permanently shadowed regions, its position within the South Pole and its proximity to the Schrödinger basin making it a potential place to find cold traps and volatiles[2][3][4].

Four Traverses have been proposed for in this case study by analysing the slope (Figure 6.)

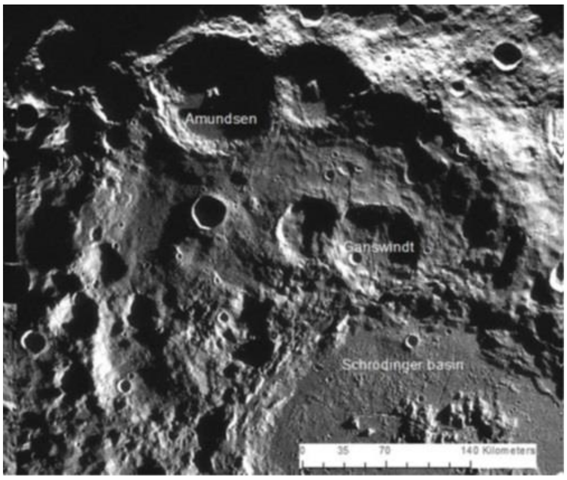


Figure 5. Amundsen-Ganswindt basin. LROC WAC image 100m/pixel of resolution

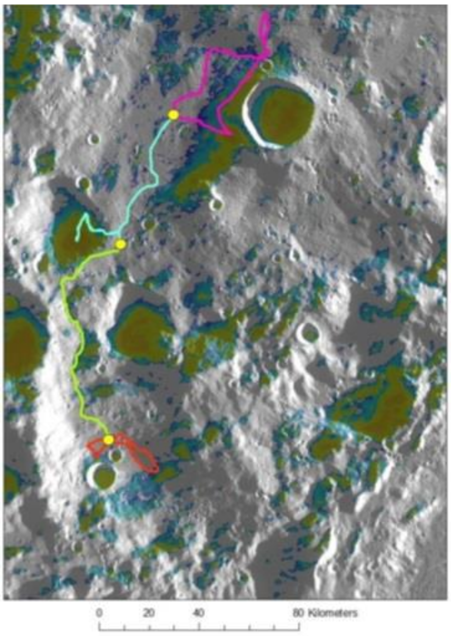


Figure 6. The orange areas on this image represent the locations where water ice may be cold trapped on the surface and the yellow and blue areas define the upper surface of the lunar ice permafrost boundary according to Paige et al, 2010. The pink, blue, green [3]

3. References

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Short Summary

A modular lunar habitat architecture, taking into account the properties of isokinetic structures and the possibility of in-situ resources utilization. The proposed solution is an isokinetic expandable geodesic dome with a particular layer design made from a pattern of empty triangular-based pyramids to be filled and covered by regolith and/or lunarcrete, allowing future expansions.

Lunar Mission One: Paving the Way for Human Habitability on the Moon

D. Cooper

Lunar Mission One: UK Chapter, United Kingdom

Summary
A human base on the Lunar South Pole would offer unique opportunities for scientific research that are not available on the Earth or in Low-Earth orbit. Difficulties faced by potential human inhabitants include the loss of H_2O (water ice) as H_2 is created due to the regoliths exposure to cosmic rays. Lunar Mission One proposes to send a robotic lunar lander to obtain essential knowledge required for the preparation of human habitation on the Moon.

1. Introduction

Lunar Mission One (LM1) is a proposed robotic lander mission to the Moon, funded by public subscriptions to a buried archive of Life on Earth with an anticipated launch date within the next ten years. Stage 1 was successfully funded by international public backers through a capital funding campaign using the crowdfunding platform 'Kickstarter'.
LM1's proposed mission objectives are aligned to the Global Exploration Roadmap [1] and can provide scientific data essential for implementation of a 'Moon Village', as envisioned by the European Space Agency (ESA) [2].
The ESA Director General has stated that 'The Moon Village is open to any and all interested parties and nations' [3] and LM1 reflects this open inclusivity as a truly international project, welcoming contributions from scientific engineers, scientists of different fields and volunteers of all backgrounds.

2. Mission objectives to provide essential knowledge for human habitability

The Lunar South Pole is a primary candidate as the site for a human lunar base [4, 5] due to the power harnessing advantage of virtually constant exposure to solar radiation. This would also power the LM1 lander throughout its surface mission timeline and would provide useful data on the reliability of using solar power as a focal energy source.

The lander will carry equipment to enable analysis of the geochemistry of the lunar crust. This will include a wire-line drilling system (Figure 1), which will be accompanied by a jointed robotic arm for handling core samples, as well as a number of instruments to analyse the samples and determine the volatile content of the lunar regolith.

The lander will retrieve lunar samples from a borehole of >20m deep at the landing site. This is to be accomplished by lowering the complete drill assembly into the borehole by an attached cable. The drill assembly will repeat a drilling cycle of increasing depths of around 15cm. At each 15cm interval, the attached cable will retrieve the regolith core sample to the surface for analysis by the on-board instruments in situ.

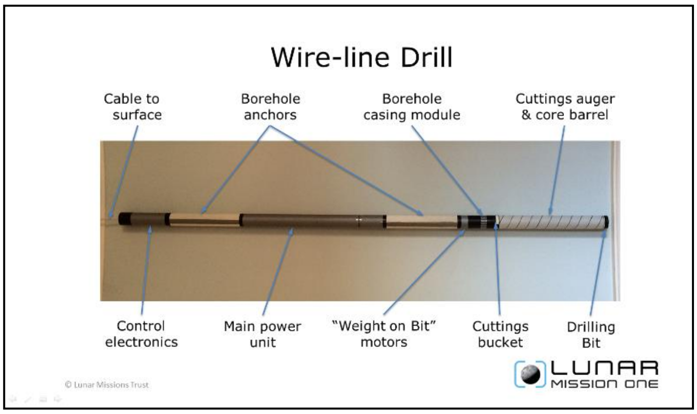

Figure 1: Example of a Wire-line Drill. (*Lunar Mission One: A new way to explore outer space* [2016])

An area of research that would be further enhanced by the prospect of a lunar base would be the study of the flux and composition of cosmic rays. One important difficulty faced by potential human inhabitants is the erosion of lunar regolith and chemical alterations, including the loss of H_2O (water ice) as molecular hydrogen is created due to the regoliths exposure to cosmic rays [6]. Levels of H_2 per original H_2O (%) against cosmic ray penetration depth of lunar regolith is shown in Figure 2.

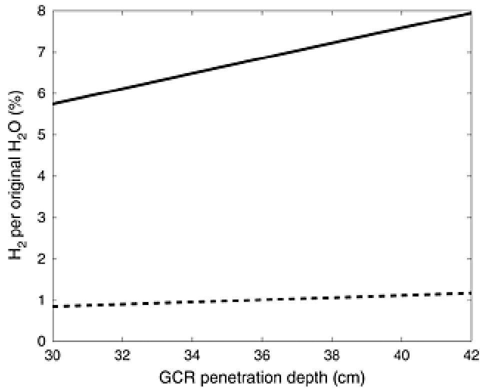

Figure 2: Levels of H_2 per original H_2O (%) against cosmic ray penetration depth of lunar regolith. (*The formation of molecular hydrogen from water ice in the lunar regolith by energetic charged particles, J. Geophys. Res. Planets, 118, 1257–126, 2013*)

LM1 could provide essential data using an on-board Neutron spectrometer to determine hydrogen concentrations in the local geology to be compared with orbital measurements, such as those observed by the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) on the Lunar Reconnaissance Orbiter (LRO).

LM1 also proposes to analyse materials using a Raman-LIBS (Laser Induced Breakdown Spectrometer) to determine elemental composition, local mineralogy and volatiles as well as measuring the surface environment for the suitability of the South Pole as a location for a lunar base.

The lander will have the potential to conduct proof-of-concept studies for experiments that would bring long term benefits to various scientific fields that would be enriched by a lunar base [7]. These include low-frequency radio astronomy from the Moon, terrestrial emission, the lunar exosphere, and the effects of the lunar surface on radio propagation and communication. Proposed on-board instruments are shown in Table 1.

Instruments / Science Goals	Goal 1: Geochemistry & Mineralogy	Goal 2: Impact chronology (including SPA Basin Age)*	Goal 3: Volatiles	Goal 4: Internal Thermal	Goal 5: Environment (Dust, radiation, seismic surface conditions)	Goal 6: Resources	Goal 7: Radio-Astronomy/ Magnetosphere Studies	Goal 8: Science Education
Landing Site Imager					X	X		X
IR Spectrometer	X				X	X		
X-ray/Gamma-ray Spectrometer	X	X (v. approx age only*)	X (if low energy response)			X		
Raman-LIBS	X		X			X		
Mass Spectrometer	X	X (v. approx age only*)	X		X	X		
Neutron spectrometer	X		X					
Seismometer				X	X	X		
Heat Flow				X				
Dust, Radiation Charging Package					X	X		
Sample Imager	X		X			X		X
Radio-astronomy demo package							X	X
Magnetospheric Imager							X	X

Table 1: Example Instruments and Science Goals (*Preliminary Lunar Science Drivers for Lunar Mission One [2014]*)

3. Conclusion

A human base on the Lunar South Pole would provide a valuable resource for carrying out scientific research that cannot be conducted on Earth, as well as to pave the way for future possible human habitation of the Solar System. However, data will be required on the local suitability of every aspect of a lunar base (materials, sustainability, location, etc.) from the surface before any planning and construction can begin. A robotic lander, with the mission objectives and payload that Lunar Mission One provides [7], can obtain the essential knowledge required for a lunar base in a cost-effective way and gather significant scientific data *in situ*.

Acknowledgements

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1) Department of Earth and Planetary Sciences, Birkbeck College, University of London, UK

2) Lunar Mission One

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Short Summary

A human base on the Lunar South Pole would offer unique opportunities for scientific research that are not available on the Earth or in Low-Earth orbit. Lunar Mission One proposes to send a robotic lunar lander to obtain essential knowledge required for the preparation of human habitation on the Moon.

MOON GAIT PILOT EXPERIMENT

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In the context of Moon and Mars missions, the difference in gravity strongly affects human posture and gait, the Ohr-Augen-Ebene (OAE), movement, and physical interaction. In light of current plans for Moon and Mars missions, human interaction needs to be integrated starting from the earliest phases of mission design. Many studies have been done in simulated conditions, starting from the Lunar Gravity Simulation performed at NASA in 1966 by the famous Prof. Moon (Prof. Dr. Walter Kuehnegger), or the Gantry experiment in 1964, also at NASA. Today we still lack detailed biomechanical data in order to completely understand the interactive behavior on the Moon and Mars terrain and gravity. Indeed, altered gravity conditions also affect locomotor-related tasks, such as the negotiation of stationary and moving obstructions during walking or gait initiation/termination [1].

To investigate human behavior in hypogravity, a new pilot experiment called Moon Gait has been performed at the German Aerospace Center (DLR) under the guidance of Prof. Jörn Rittweger (Head of `Space Physiology' division at the DLR), Dr. Irene Lia Schlacht and different international field specialists.

This paper presents the first pilot experiment result and formulated hypothesis after measuring the differences in gait's posture under the influence of hypogravity, starting from the video realized by DLR on a normal horizontal treadmill and a vertical treadmill. The vertical treadmill is an instrument where the participant is able to walk vertically. In this position, gravity no longer has any influence and hypogravity can be simulated using a special type of software that calculates the tightness of the string where the subject is belted.

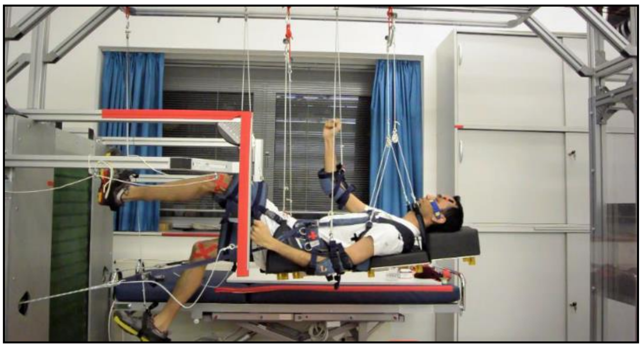

Figure 4: Student Mukadam self experimenting Vertical Treadmill at DLR in Köln, © Mukadam 2017

In the frame of the first author's thesis "Moon Gait: Investigating a methodology for analysis of hypogravity gait posture for architecture design in space." [2] in cooperation with Karlsruhe Institute of Technology and DLR, a detailed optimization of the Moon Gait experiment design, setup and statistical analysis procedure has been identified and tested. The statistical analysis has been done with 5 tests on 36 videos with a sample size of 6 participants of different age, gender and mass. The video analysis has been performed using a software called Tracker, through this software the gait vertical oscillation has been measured (the variation in the height given by the oscillation of the top of the head) and the variation of OAE angle again during the gait. The steps applied are:

1. Record a participant's video with defined markers on the vertical treadmill at slow and fast speeds (4km/h & 11.5km/h) and different weight loads (0.3*g*, 0.6*g* & 1*g*).
    1. Extract position data with the Tracker software to compare:
        a. Different speeds and same weight load.
        b. Different weight loads and same speed.
    2. Statistical significant difference analysis using Kruskal-Wallis H test with an alpha level of 0.05.

The results of Kruskal-Wallis H Test showed that there was statistically significant difference of participants, in vertical oscillation running at 4km/h & 11.5km/h at the same weight load of 1*g* (simulated Earth gravity) on the vertical treadmill, while there was no statistical significant difference in vertical oscillation running at 4km/h and 11.5km/h at the same weight load of 0.6*g* and 0.3*g* (simulated Martian gravity).

Variable	Mean	Std. Deviation	Chi-square	Asymp. Sig.	Statistical Sig.
Amplitude at Earth Gravity	9.255	5.677	7.410	.006	Yes
Amplitude at Martian Gravity	8.791	6.372	2.564	0.109	No
Amplitude at 0.6*g* Simulated Gravity	19.38	8.495	1.844	.175	No

Table 1: Result of statistical significant difference analysis with alpha level 0.05

This significant result of the Moon Gait pilot experiment brought about an enticing hypothesis that, on Earth vertical oscillation variates relative to speed of running, as well known to field experts [3], while on Mars or any other hypogravity region like the Moon this behavior is completely different, the vertical oscillation during the gait has no major change at both slow and fast speed. This hypothesis should be investigated with the following setup:

1. Number of subjects 30.
2. Data analysis made step by step, (left step separate from the right one).
3. Application of “Linear Mixed Effects Model” statistical test.
4. Bed rest performed by participant before vertical run on treadmill.

The observations of the effects of hypogravity will help to reveal the intrinsic properties of locomotor pattern generators facilitating greater understanding of Earth, Mars and Moon gait. Further development of this study including effects of vestibular system on gait balance in relation with difference in gravity is planned to be performed both on parabolic flight and also on the Motigravity tool developed by Mars Planet [4]. This tool uses virtual reality and a biomechanical system to simulate the interaction in low gravity environment including walking behavior.

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Thanks

All the people and entities involved. In particular:

Klaus Müller and Wolfram Sies from DLR for the great support during the visit at DLR. Walter Kuehnegger (Prof. Moon) to be a blissful resource of encouragement and inspiration, Raùl Feuillard for the cooperation in data analysis, the research group www.extreme-design.eu coordinated by Irene Schlacht and Martin Daumer the scientific director of the Human Motion Institute.

Short Summary

The pilot experiment in simulated hypogravity on the DLR’s vertical treadmill brought about the hypothesis that comparing slow and fast gait (4-11.5 km/h), the vertical oscillation on Earth confirms a significant change, while on Mars or Moon it is completely different, it has a similar oscillation at both the speeds.

Our Solar System and planets formation, the appearance of life: A slideshow for the general public.

C. Carreau[1]*; *J. Vago[2], J. Benkhoff [2], O. Witasse [2], D.i Titov [2] , P. Ferruit [2], G. de Marchi [2]*

[1]*ESA/ESTEC Noordwijk, The Netherlands*
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Space the general public, and an efficient mean to raise awareness. The general public and college students, which are our primary targets here, are captivated by scientific themes and adventures, that:

1. they the overall pictureas opposed to a specialised and detailed field of research

- they are around a "plot", a story exhaustive list of events, data or dates
- they are image oriented, typically slideshows, scientific formulas.

and work of a scientist doesallow for such an overview and generic knowledge to be maintained. Each scientist s deeply own field of research and the overall picture binding the various fields together quickly lost. Presentations therefore been developed for when the Agency needs to address and engage the general public, during events like "Le Bourget Air Show" at the ESA booth, for instance.

P themes "Rosetta chasing a comet" or "Astronomy, the birth of the Universe and the life of the stars",a new presentation about our "Solar System formation and the appearance of life". This represents a yearlong effort involving scientists who have kindly dedicated some of their time to build up and validate th

The themes relevant to the 51st ESLAB Symposium: "Extreme Habitable Worlds" that are being tackled by this presentation, to a greater or lesser exten, are:

- Venus, Earth, and Mars —the first 500 million years
- Planetary habitability processes: accretion, evolution, impacts, ingredients
- Evolution of habitability and settings for origins of life at Earth
- Earth extreme habitats: natural (surface and subsurface)
- Mars past habitability

Short Summary

Space science attracts a lot of attention from the general public, and is an efficient means to raise awareness about ESA. We here for the first time reveal a new presentation, in the form of a slide show, about our "Solar System formation and the appearance of life".

Posters

Duration of magma ocean in the early Earth with a grey and a H2O steam atmosphere.

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1. Introduction

The early period of terrestrial planetary evolution likely included a phase where the mantle was molten to a large degree, known as magma ocean [7]. The energy needed for melting was made available to the system through delivery of impactors, release of potential energy in the interior during its differentiation and the decay of early radiogenic elements [2]. The system is estimated to have a low viscosity compared to water and convect vigorously. Our Moon is argued to have experienced such a phase, due to the buoyant plagioclase found close to its surface. However, we do not have constraints on the duration of this phase, neither on our planet nor its satellite.

A molten silicate mantle is expected to contribute to the building of a secondary atmosphere, due to extensive outgassing of volatiles from the interior. In this study we examine the cooling rate of the mantle that starts in magma ocean state, mediated by the presence of an atmosphere composed of greenhouse gases. We follow the system until the temperature of the mantle drops below the rheology front transition temperature, a value that depends on the composition of the mantle. We are studying the role of two volatiles in the atmosphere and we focus especially on the role of water. We find that a planet could even be trapped in a long-term magma ocean stage with the suitable combination of albedo and orbital distance.

The interior-atmospheric coupling helps us better constrain the Hadean period on our planet and the Moon, and gain insight for rocky exoplanets that could be found in similar stages, in the future.

2. Methods

We build a model based on [5], with differences in the interior and the atmospheric treatment, in order to calculate solidification times for indicative initial concentration of volatiles.

For the case of the steam only atmosphere we use a line by line model [6].

In order for the system to be in steady state, a balance between the convective flux at the top of the magma ocean and the net flux at the top of the atmosphere (hereafter mentioned as TOA) is demanded:

(1)

A solution to the suggested energy flux balance is found through iteration, with varying inputs: the viscosity of the melt, potential temperature of the mantle, and outgassed atmospheric gases. The surface temperature and the cooling flux are found at each iteration. With these, the energy equation is resolved and yields the thermal evolution of the system. Solubility curves are used to calculate the volatiles that are exsolved, assuming saturation conditions. The mantle starts from a global molten state at 4000 K, well above its phase change temperature and solidifies from the bottom to the top, due to the characteristic steeper slope of its adiabat compared to the melting curves. When the last layer reaches the rheology front temperature at the surface, the magma ocean phase ends.

3. Results

The configuration in equation (1) ensures cooling if both fluxes are positive. The convective cooling flux is always positive for a surface temperature that is lower than the temperature of the interior. The grey atmosphere of [1,2,5] is able to represent both and .It yields positive values for the range of volatiles assumed and ensures that the magma ocean phase has finite duration. In the colourmap of Fig.1 (left) we thus calculate the solidification times for various volatile contents. An Earth sized planet that contains an ocean of initial H_2O (300 bar) and CO_2 equivalent to the content in the crustal carbonates (100 bar) is marked as "reference". The solidification time barely exceeds 5 Myr, even by assuming a very rich chondritic abundance of water (CC1%wt). However, in our results that employ the steam atmosphere, we find that the atmosphere can reach an outgoing radiation limit that allows the net flux to be either positive or negative at the TOA, according to the incoming energy from the Sun [4]. In Fig.1 (right) we see a set of limiting curves, each of which defines the distance for which a planet with given albedo can be trapped in the magma ocean stage, as it stops cooling. The shaded region corresponds to estimated values for a steam albedo without clouds taken from the literature [3]. Any albedo higher than the curve at a given distance ensures that the magma ocean phase will be transient for the system. Note, that this limit is different for an atmosphere that has a different mass of water steam, ranging from 4 bar to 300 bar. The highest the mass of the atmosphere, the more efficient is the absorption and the lowest the limit of radiation at the TOA that should be equilibrated by the solar irradiation. This effect pushes the transition limit of long-term to transient magma ocean, further away from the Sun, the more massive the outgassed steam atmosphere is. Future work is planned in order to include the effect of additional gas species on this mechanism.

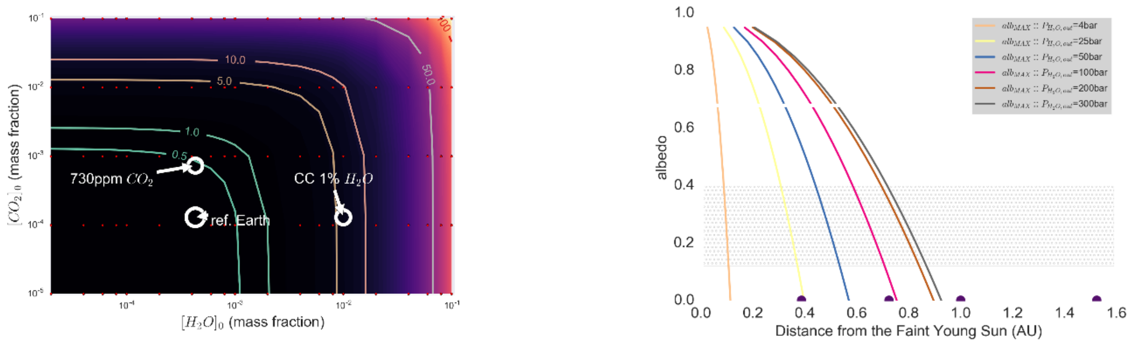

Figure 1: Left: The solidification time for a planet of Earth size (colormap) is plotted for different combinations of initial H_2O and CO_2 abundances in the mantle, as calculated with the use of grey approximation for the atmosphere, described in [1]. Right: The maximum albedo/ distance combinations for a planet of Earth size, with H_2O steam atmospheres that vary from 4 to 300 bar.

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Short Summary

The early evolution of terrestrial planets likely included a phase of extensive molten mantle accompanied by outgassing of a secondary atmosphere, referred to as magma ocean. We use a model to resolve its thermal evolution and put constraints on the role of steam water in thermal blanketing.

Survival of halophilic archaeon Halovarius luteus gen. nov., sp. nov., to desiccation, simulated Martian UV radiation and vacuum in comparison to Bacillus atrophaeus

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Introduction
Some of the most ancient inhabitants on Earth are microorganisms with the capability of coping with high levels of salinity, even ten-fold that of sea water, also able to withstand high temperatures, extreme desiccation and ionizing radiation. Extraterrestrial environments have lethal effects on organisms and imply devastating tensions on their biochemistry due to high levels of radiation, extreme vacuum, temperatures, lack of water and nutrients. Haloarchaea are considered interesting species for astrobiological studies due to their high capabilities of tolerating desiccation, radiation and hypersaline environments.

Materials and Methods
In this study a novel haloarchaea, isolated from Urmia Salt Lake, Iran, *Halovarius luteus* strain DA50^T, was exposed to varying levels of simulated space conditions, UV-radiation, high and low vacuum and desiccation, and compared with *Bacillus atrophaeus*. Thin films were produced with different concentrations from both strains and their viability studied without any protective effect of thick cell multi-layers. *Hvr. luteus* and *B. atrophaeus* were desiccated in salt crystals and PBS, respectively. Resistance to Mars UV light intensity was measured at 54.78 W/m^2. Samples were exposed to desiccation, low and high vacuum conditions and their viabilities were studied by Most Probable Number methods for both strains. The proteome was analyzed by electrophoresis (SDS-PAGE).

Results
Changes in viability of the spore-forming bacteria *B. atrophaeus* were only minor. On the other hand, the halophile strain under the extreme conditions demonstrated a range of different viabilities. The highest intensity radiation flux was 100000 J/m^2 with nitrogen gas and two weeks of desiccation shows the highest decrease in viability. This study further expands our understanding of the boundary conditions of astrobiologically relevant cells to survive the harsh space environment.

Key words
Halovarius luteus, *Bacillus atrophaeus*, desiccation, simulated Martian UV radiation, vacuum, Most Probable Number

Short Summary

Very novel haloarchaea, Halovarius luteus, was exposed to UV-radiation, high and low vacuum, desiccation and compared with Bacillus atrophaeus. These two strains were desiccated in salt crystals and PBS, respectively. The highest intensity radiation flux was 100000 J/m2 with nitrogen and two weeks of desiccation shows the highest decrease in viability.

Species of plant Brassicaceae as a component of an autotrophic element of bioregenerating life support systems of a spacecraft

S. Romanchuk

State Scientific Research Forensic Centre of Ministry of Internal Affairs of Ukraine

Introduction

Mankind's space exploration ambitions boosted the study of an impact of microgravity and ionizing radiation on plants as autotrophic elements of spacecraft bioregenerating life support systems. Results of the study of adaptation of plants toward these factors lay the theoretical foundation of the development of technology for plant cultivation in space.

Years-long study has established a number of regular patterns in microgravity influence over morphogenesis, spatial orientation and polarity of organogenesis, physiology of basic functions, cellular metabolism biochemistry, gene expression, cell reproduction and differentiation, i.e. processes fundamental for the growth and evolution of organisms [1, 2]. But the problem of an impact of ionizing radiation on individual cell organs is still scantily explored. It is known that radioresistance of plants depends on their specie and individual characteristics. Brassicaceae family of plants is considered to be particularly radioresistant. Their cells have endoplasmic bodies (ER-bodies) that constitute cisternae of rough endoplasmic reticulum and contain β-glucosidase ferment. This ferment protects cells of the plants [5, 7]. Study of the role of β-glucosidase in securing radioresistance of Brassicaceae family of plants is a key to understanding the mechanism of their adaptation towards space-vehicle conditions.

Methods and subjects of analysis

In course of the experiment 3- and 13-day-old sprouts of *Arsbidopsis thaliana* (L.) Heynh of Columbia (Col−0) ecotype were X-rayed with Roentgen apparatus *РУМ-17* (dose rate 0.43 cGy/s) in Petri dishes in doses of 0.5, 1, 2, 4, 6, 8, 10 and 12 Gy (separate dish for each dose). Every dish contained 200 sprouts. Treated sprouts were examined 2 hours and 10 days after the irradiation. Untreated sprouts of the same age were used as control samples.

β-glucosidase activity was determined by the amount of 4-nitrophenyl formed in the reaction [6]. Measurement results were denominated as nM 4-nitrophenyl/h/mg of protein (hereinafter referred to as ‘‘activity units’’). Optical density was measured with *СФ2000* Ukrainian spectrophotometer at a wavelength of 420 nm. Protein concentration was determined by the Bradford assay.

Experiment results and their interpretation

In control samples 3-day-old sprouts had dark green oval cotyledonary leaves with solid lamina. Primary roots had bases of lateral roots. 13-day-old control sprouts had regular-shaped rosettes (four leaves of more than 1 mm). Leaves of rosettes were oval in shape, deep green in color and had serrate edges. Roots comprised main roots and branched lateral roots. Leaves of rosettes and roots of both 3-day-old and 13-day-old sprouts were in turgor.

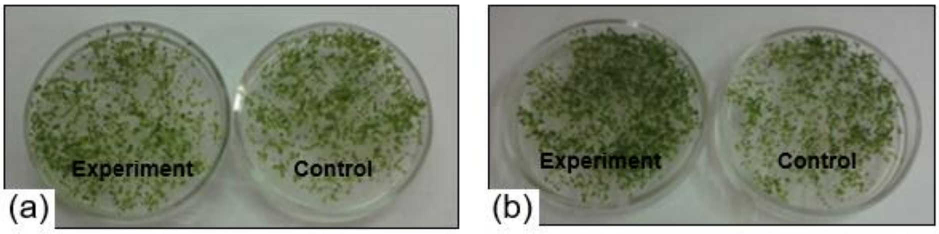

Figure 1. Control samples of 13-day-old sprouts of *A. thaliana* and experiment samples after irradiation in doses of 0.5 Gy (a) and 8 Gy (b).

The morphology of irradiated 3-day-old and 13-day-old sprouts, including dimensions, color and turgidity of leaves of rosettes and primary roots, was similar to that of control samples (see Figure 1).

β-glucosidase activity in control 3-day-old sprouts was 0.42 activity units. β-glucosidase activity fluctuated 2 hours after irradiation with various doses (see Figure 2). An increase in dose caused a non-linear increase in ferment activity.

β-glucosidase activity was especially high under 0.5, 8 and 12 Gy, more than doubled that of control samples (see Figure 2). Such an increase in β-glucosidase activity 2 hours after irradiation can be indicative of the role of this ferment in cell reaction to ionizing radiation and other exciters.

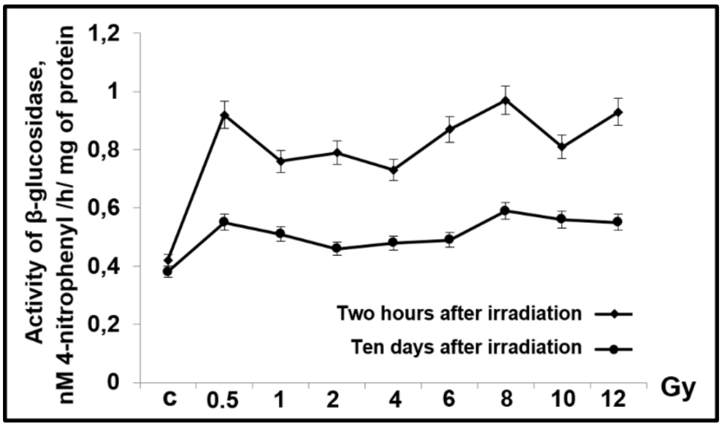

Figure 2. Activity of β-glucosidase in *A. thaliana* sprouts in control (c)
and irradiated samples (Gy – Gray).

Thus mechanical injury, eating by herbivorous insects and, exposure to pathogens and chemicals also cause an increase in β-glucosidase activity of *A. thaliana* [3-5, 7].

β-glucosidase activity of 13-day-old control sprouts constituted 0.38 activity units. Figure 2 presents the results of a study of β-glucosidase activity 10 days after irradiation with various doses of x-rays.

The most active was the dose of 8 Gy. Its effect lasted 10 days after irradiation. β-glucosidase activity of 13-day-old sprouts irradiated at this dose was 1.5 times higher than that of the control samples. We can infer that β-glucosidase as hydrolyzing ferment catalyzes hydrolytic processes of cell regeneration after being irradiated with X-rays.

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Short Summary

Study show that morphology of irradiated 3-day-old and 13-day-old A. thaliana sprouts, including dimensions, color and turgidity of leaves of rosettes and primary roots, was similar to that of control samples. The obtained data show an increased β-glucosidase level in A. thaliana seedlings after X-radiation.

Investigating phage-related threats to the MELiSSA loop

T. Sassen[1,2], *J.r Mahony[2], R. van Houdt[1], N. Leys[1],F. Mastroleo[1], D. van Sinderen[2,3]*
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The MELiSSA (Micro-Ecological Life Support Alternative) loop is an artificial ecosystem intended as a regenerative life support system for long-term space missions. It is important to know whether the bacteria that are used in such a system are susceptible to external threats such as infection by bacteriophages or internal ones like induction of prophages present in their genome. DNA stress, such as caused by cosmic radiation, is known to induce prophages in various bacterial species, and factors like the high biodiversity in waste streams and the mixed culture fermentation in the first compartment increase the odds of a bacteriophage being present with a host range that includes *Rhodospirillum rubrum* S1H (the bacterium used in the consecutive compartment).

To investigate those phage related threats, a three pronged approach was taken: 1) the genome of *R. rubrum* was analysed to find regions similar to known prophages, 2) *R. rubrum* was exposed to DNA damage caused by mitomycin C and the cell lysate was analysed for the presence or absence of induced prophages, 3) samples of dissimilar sources of waste (A sample from a pilot of MELiSSA compartment I, two sewage samples, two grease trap samples and a compost sample) were used to investigate the presence of bacteriophages with lytic activity against *R. rubrum*.

The initial investigation *in silico* indicated that the presence of prophages was unlikely, which was confirmed by the absence of induced prophages in the cell lysates. No bacteriophages with lytic activity against *R. rubrum* were found, only against the *E. coli* BL21 strain used to demonstrate the validity of the lytic bacteriophage detection method.

Short Summary

Investigating internal and external phage-related threats to compartment II of the MELiSSA loop, an artificial ecosystem intended as a regenerative life support system for long-term space missions.

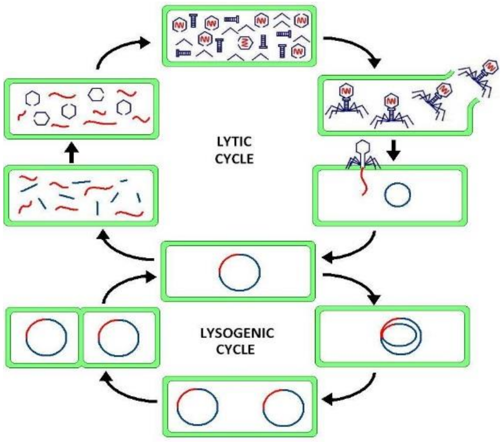

Figure 6: Prophage life cycles.

[Online Image retrieved from https://commons.wikimedia.org/wiki/File:Phage2.JPG, used under the Creative Commons license]

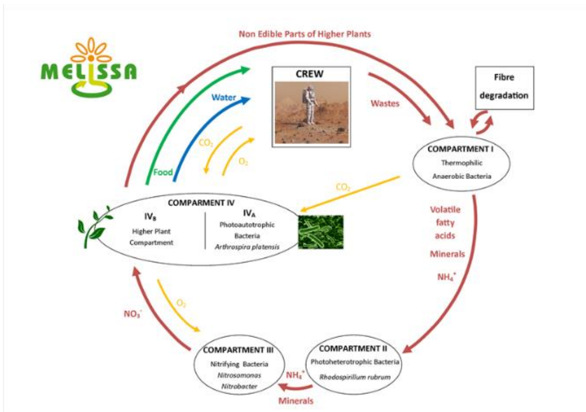

Figure 5: The MELiSSA loop

R-evolution of Architecture

A. Oren

DesignArt, Istanbul, Turkey

1. Introduction

As we embark on a journey for new homes in the new worlds to lay solid foundations, we should consider not only the survival of frontiers but also well-being of those to live in zero gravity.

As a versatile science, architecture encompasses abstract human needs as well.

On our new different direction in the course of the Homo sapiens evolution, we can do this with designs addressing both our needs and senses. Well-being of humans can be achieved by creating environments supporting the cognitive and social stages in the evolution process.

Space stations are going through their own evolution process. Any step taken can serve as a reference for further attempts.
When studying the history of architecture, window designing is discussed in a later phase, which is the case for building a spaceship as well.

We lean on the places we live both physically and metaphorically.
The feeling of belonging is essential here, entailing trans-humanism, which is significant since the environment therein is like a dress comfortable enough to fit in, meeting needs without any burden.

Utilizing the advent of technology, we can create moods and atmospheres to regulate night and day cycles, thus we can turn claustrophobic places into cosy or dream-like places.

Senses provoke a psychological sensation going beyond cultural codes as they are rooted within consciousness, which allows designers to create a mood within a space that tells a story and evokes an emotional impact.

Colour, amount of light, sound and odour are not superficial. As much as intangible, they are real and powerful tools with a physical presence.

Tapping into induction, we can solve a whole system based on a part thereof. Therefore, fractal designs may not yield good results unless used correctly in terms of design although they are functional, which makes geometric arrangement critical.

If we start to examine space stations – we need to understand how we get there.
When we took vertical section of history we see architecture, because architecture is what remains from humans.

After the industrial era, the use of metal and technical advantages of it reflected to architecture.
Joseph Paxton who is a gardener and an entrepreneur, built Lily's house (green house) in Queen Victoria' era, he developed the space cage inspiring from the pattern of a Lily. The pattern of a leaf is fractal design. And it can solve modularity problem because by understanding the design principle of the system you can solve the entire system.

Flexible and changeable means; thinking about the recycling process of mechanical parts from the very beginning of design. Development of production processes is such arrangement that the product will turn into another product after use.
The open plan is also an option where reshaping can be necessary.

The combination detail of these metals adds structural flexibility to the structure that enables modularity.

By contemporary means, the nodes and connection detail are the ornament in architecture.

If we think more thoroughly about the change of space, the module land on the surface of planet can win another function after landing.

You most probably start to compare,

One is stone other is white painted, the other is metal
Let's start from the first one –Göbeklitepe
How it meets the ground.
It almost seems to be emerging from the earth or the metaphor of mountain.

When we came, Mies Van der Rohe's Farnsworth House,
It is lifted off the earth. It is kind of perches on the earth and still conscious of the landscape.

When we came to space stations architecture, they free from the earth surface, elevated from the ground and conceptualized.

SPACE STATIONS
Due to the technical importance of the subject, Architectural part is still very primitive. But it is going to arise from its restrictions.
The important thing is to understand what you can do and what you can't do and be creative in this restricted zone.
When we compare Skylab, Mir, and ISS
They are going through their own evolution process.

Anything that is done is a reference for the subsequent ones.

Short Summary

When we took vertical section of history we see architecture. Architecture appears in history as a representation of culture that moves and changes through time from temple to spacecraft

Architectural Distancing from the Exit strategy: the Habitability of Extreme Worlds Versus the Extreme Habitability of Worlds

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Aiming to secure the survival of humankind, several contemporary architects and scholars in the humanities have a shared interest in multiplying perspectives, defining separately and as a whole terms pertaining to a life and death complex. These expand the understanding of world, habitability and extreme, shifting the Earth-Moon relation from Exit to Distance.

• Abstract

> "If space-junk is the human debris that litters the universe, Junk-space is the residue mankind leaves on the planet."
>
> *Rem Koolhaas, Junkspace* [1]

Architecture protects the human, enabling his inhabitation of worlds. Yet it has throughout the 20th century sought to propose extreme environments of habitability. Thus humankind would not always need protection from extreme worlds. These life-threats are furthermore sought out as surroundings for architecture. *Extreme habitable worlds* refers to countless hazardous behaviours, or life threatening realms in which humans develop new habits, learn to inhabit, dwell, and create new worlds.

Contemplating the Moon as an extension of, part of a world built by humankind, the Earth and Moon separation is not in effect. One reflects the other and reversely: the two worlds influence each other. What is known of the Earth will leak onto the Moon and the latter's extremities will enable a reconsideration of life on our planet. Worlds begin and end with humankind.

Environments have transformed the human and it can be anticipated that it will alter him further. Extreme and technological environments of the anthropocene have already mutated our species. While the *Exit strategy* has been used to qualify incentives of growth and land appropriation [1], it is used by feminist theory and ecology to blame its modus operandi [2], disqualifying the merit of outer space exploration.

The notion of *Exit* is intrinsic to the idea of separation, a process of splitting and fragmenting. A contrary perspective of co-emergence of the world, of matter and of individuals [3], parallel to the notions of ecology and landscape, anchors humankind within worlds that can never be escaped. Immersion within worlds is a prerequisite to architecture and the emergence of life. It names a move inside and between ubiquitous, overlapping and neighbouring worlds as *Distance*.

Distancing calls for extension, variation, and mutation rather than break and split. A number of architects have developed practices in accord with these beliefs, among which Rem Koolhaas [1] in his description of *Junkspace* as the production of inescapable yet dematerializing human environments, Greg Lynn's fictitious non-horizon, non-gravitational, non-grounded *New City* movie set [4], Lebbeus Woods's post-war strategies [5], Arakawa & Gins *Architectural Body* [6] or Lars Spuybroek's description of Frei Otto's co-emergent agencies of matter [7].

In this perspective, can be re-examined separately and in combination the notions of world, habitability and extremism.

1. Inescapable world(s).

Philosophy considers the inescapable predicament of worlds existing in co-emergence, as parallel systems of correlations that define modes of survival or destruction, in tension and evolving flux of causality [8]. Architecture is a link between occurring worlds [9], alive when it's purpose evolves, never rigid, univocal, or univalent [10], in bumptious inter-intra action with other species [11]. Habitable worlds are extensions of man, which amass, interlock, precede and follow his presence on Earth or the Moon.

- Habitability reliability.

Architects have defined various manners of inhabitation or human-environment connections: a co-emergence of body and world, a *Landscape for One* [6] or a capacity to engage in the unforeseen [7]. What sticks, resists, is reproduced or extended into the explored territory, on Earth or the Moon, creating new parallel and converging worlds. It is in the inhabitation of the gap between dimensions unknown, in the connections, that new environments for life appear.

- Extreme condition for survival.

Extreme occurs when forces surrounding the human are at a breaking point in flow and rhythm. The punctual disturbance within a rich ethnographic context [12] can contribute to the emergence, liveliness and complexity of the habitable world. Humans are under pressure of relentless unvaried conditions of environments [13]. Active vagueness, the coalescence of opposing agencies releases this pressure [7]. The tension between a hostile lunar environment and the human is a fertile ground to enact an attraction of opposites, as principle of life [10].

Figure 1: Greg Lynn, New City, 2008

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Short Summary

Aiming to secure the survival of humankind, several contemporary architects and scholars in the humanities have a shared interest in multiplying perspectives, defining separately and as a whole terms pertaining to a life and death complex.These expand the understanding of world, habitability and extreme, shifting the Earth-Moon relation from Exit to Distance.

A HISTORIC CHOICE OF NUMBER: THE PLANETARY-PROTECTION REQUIREMENT FOR OCEAN WORLD EXPLORATION

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1. Introduction

Despite existing international requirements, planetary protection is a new field. Robotic exploration of our solar system's ocean worlds – especially certain icy moons of Jupiter and Saturn that contain vast interior oceans – is imminent in the coming decades. Around Earth's seafloor hydrothermal vents and in the thick ice of its cryosphere (our best analogues for these ocean worlds) life abounds. Our space flight instruments may encounter alien microbial life within two decades. Being on the cusp of breaching faraway habitable environments makes the risk of "forward contamination" real. How ready are we for this unique event? What are humanity's obligations?

2. The requirement

Today's governing requirement for avoiding the contamination of an alien habitable environment with terrestrial organisms rests on a single value: limiting to one in ten thousand the probability that a single viable Earth organism enters an alien liquid water reservoir. Enforceable under international treaty, this 10^{-4} forward-contamination requirement constrains NASA, JAXA, ESA, and private companies alike. It strongly drives mission concepts, implementation procedures, technologies, and costs. But where did this value come from, and what makes it correct?

The 10^{-4} requirement originated in the US at the time of Viking mission planning, and ultimately reflects 1940s capability for sterilizing hospital equipment rather than a de novo consideration of appropriate avoidance of contaminating other worlds. Furthermore, the requirement originally pertained to a series of missions but is now applied on a per-mission basis. The 10^{-4} value may still be appropriate for the missions we now contemplate for the coming decades. But it is also possible that the requirement is technically or socio-culturally outdated, or both. Without validation by an explicit conversation among a broad, international cross-section of stakeholders, mission plans could be expensively derailed once in development. If the requirement should be modified, starting the renovation of international consensus now would be timely.

3. Technological and conceptual developments

Many changes in the half-century since Viking justify revisiting the requirement's rationale: 1) vastly improved technology for assaying biomolecules and organisms; 2) expansion of the definition of self-replicating organisms; 3) recognition of a wide range of environments now known to be habitable; 4) deeper understanding of how multi-cellular communities behave differently from single organisms; 5) expansion of the astrobiology target list from just Mars to a plethora of ocean worlds; and 6) a sociological and international context for setting technology policy quite different from the mid-20th century. In this analysis, we describe how the current requirement arose: its source; how it was deemed appropriate for humanity's first contact with Mars; and its verifiability. We then summarize the current state of fields affecting our understanding of how life might take hold in ocean-world environments: biology of extremophiles; specific scenarios for the origin of life; self-replication of non-life macromolecules; rapid evolution in changing environments; and how microbial communities sustain habitability. All these factors affect how we might quantify the probability of survival and replication in a given alien environment.

4. Risk-assessment and ethical decision making

We then summarize contemporary methodology for developing technology policy surrounding low-probability, high-consequence risks, including ways to compensate limitations in human cognition about improbable events; and how perceptions of risk are normalized and acculturated. We consider the applicability of these methods to the risk of contaminating another world: an irreversible event that would affect every person and subsequent generations, albeit without personal physical hazard. We assess how decision responsibility might be distributed across diverse stakeholders. This leads directly to consideration of the ethical basis for developing workable guidelines and requirements for forward contamination. As with other techno-ethical decisions facing humanity today, we must weigh consequences, compare ethical values, and accept uncertainty based on the comparison. We contrast a meta-ethical discussion about absolute values with reliance on an arbitrary number for governing the necessity of preserving opportunities for scientific discovery or of avoiding interference with alien life. The ethical decision-making process in this special case is not comparable to other ethical discourses, and needs a different ethical model. Models based on utility, suffering or other features of sentience can not be applied. Value-based models face us with the problem of ascribing value to contamination of other worlds, something that is highly hypothetical and very hard to communicate. Risk-based models leave us with the same problem of assessing the value of non-contamination while at the same time complicating the communication process. As these problems can not be solved by an objective ethical decision making process, as we show in the discussion of ethical models, we propose a stakeholder discussion that should try and establish a meta-consensus including a broad range of societal agents. We describe how an enlightened understanding and evolving consensus could flow into governing policy. If the 10^{-4} requirement does not deserve automatic perpetuation, how could a reasoned conversation advance to achieve consensus?

Short Summary

Today's governing requirement is a single value: limiting to 10-4 the probability of a viable Earth organism entering a liquid water reservoir.The paper gives a history of the requirement, it's source and describes scientific progress since then. It argues decision responsibility and the ethical basis for developing forward-contamination requirements.

Biosignatures across time

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Introduction

Over the past two decades, enormous advances in the detection of exoplanets have taken place. Currently, we have discovered hundreds of earth-sized planets, several of them within the habitable zone of their star. In the coming years, the efforts will concentrate in the characterization of these planets and their atmospheres to try to detect the presence of biomarkers. However, even if we discovered a second Earth, it is very unlikely that it would present a stage of evolution similar to the present-day Earth. Our planet has been far from static since its formation about 4.5 Ga ago; on the contrary, during this time, it has undergone multiple changes in it's atmospheric composition, it's temperature structure, it's continental distribution, and even changes in the forms of life that inhabit it. All these changes have affected the global properties of Earth as seen from an astronomical distance. Thus, it is of interest not only to characterize the observables of the Earth as it is today, but also at different epochs.

Contents

Here we review the detectability of the Earth's globally-averaged properties over time. This includes atmospheric composition and biomarkers, surface properties that can be interpreted as sings of habitability or biomarkers, and the overall photometric, spectroscopic and polarimetric features detectable on the Earth's reflected/emitted light. We particularly focus on the detection of possible signs of life, and how these different biomarkers have appeared or disappeared in time.

Short Summary

Our planet has been far from static since its formation about 4.5 Ga ago; on the contrary, during this time, it has undergone multiple changes in it's global properties. Here we review the detectability of the Earth's globally-averaged properties, focussing on biomarkers detection, over time.

SIGNS OF HYPOTHETICAL FLORA AND FAUNA OF THE PLANET VENUS: RETURNING TO ARCHIVE OF THE OLD TV-EXPERIMENTS

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Habitability of planets is a fundamental question of planetary astrophysics. Some of exoplanets possess physical settings close to those of Venus. Therefore, the planet Venus, with its dense and hot (735 K) oxygen-free atmosphere of CO_2, having a high pressure of 9.2 MPa at the surface, can be a natural laboratory for this kind of studies. The only existing direct data on the planet's surface are still the results obtained by the Soviet VENERA landers. The TV experiments of Venera-9 and 10 (October, 1975) and Venera-13 and 14 (March, 1982) delivered 41 panoramas of Venus surface or their fragments [1]. The experiments were of extreme technical complexity. There have not been any similar missions to Venus in the subsequent 42 and 35 years. The results of these missions are studied anew. The Venera images ("panoramas") were re-examined using modern processing techniques. As a result of these studies, rather specific objects were observed. In their morphology, some of them recalled Earth living forms. Their striking similarity to terrestrial forms was called terramorphism. The number of detected objects of the hypothetical forms of the flora and fauna of Venus reaches 15.

Fig. 1. Amisada

A dozen of relatively large objects, from a decimeter to a meter in size, with an unusual morphology have been found which are static, moved very slowly or changed slightly their shape. Objects of hypothetical flora and fauna have been found at different areas of the planet. Due to the availability of up to eight duplicates of the images obtained and their low level of masking noise, the VENERA archive panoramas permit identifying and exploring details of hypothetical living forms of Venus. Among them is a 10 cm 'amisada' that stands out with its lizard-like form. On photo (Fig. 1) the amisada is climbing up a stone plates surrounding it.

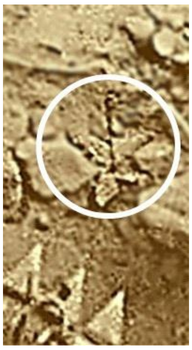
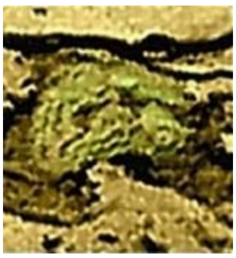


Fig. 2. Stem

The first found "stem" [2] is a thin vertically arranged knotty trunk that has a height of approximately 40 cm and a thickening ("burgeon") on the top (Fig. 2). At its base, on the surface, there is a group of details that resembles leaves in a quatrefoil. The "stem" was located at a distance of approximately 40 cm from the landing buffer of the *VENERA*-14 lander. There are other stems with flowers. Their position varies slightly with respect to the adjacent stones. As was shown by the animation, changes arise from the swinging of flowers by the wind.



The greenish coiled "snake" about 40 cm long is shown in Fig. 3. Color of the snake is exaggerated. The object actually resembles a convolved snake [3]. The surface of the object is covered by regularly located spotted cells and is decorated by the crest on its neck. The object is positioned in a small (5 to 10 cm) depression. The snake demonstrares small displacements of the body and changes in its positions with respect to stone plates. E.g., the displacement of the crest on the snake's neck in sequential frames attained 3 to 4 cm for 30 min.

Fig. 3. Snake

The scanning cameras of the *VENERA* landers (1975 and 1982) were intended to produce a general notion about the planet's surface and did not anticipate finding any possible inhabitants of Venus. Nevertheless, certain unusual findings that have a structure similar to the Earth' fauna and flora were found in different areas of the planet. The planet's Venus surface needs for new investigations with better resolution and longer observation. The special mission, if it ever takes place, should be significantly more complex than the *VENERA* probes.

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Short Summary

In 1975 and 1982, TV experiments on the surface of the planet Venus with Soviet landers of the VENERA series were performed. The images were re-examined using modern processing techniques resulting in hypothetical discovery of living forms on Venus.Architectural Distancing from the Exit Strateg.

Potential for Life on Trappist-1 and other Red Dwarf Star Planets

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1. The Trappist-1 system

The To date seven planets have been detected orbiting the “nearby” Red Dwarf star Trappist-1 [1], but the number may be significantly greater. The star is relatively small (0.12 Rsun) and cool (2,550K) compared to our Sun (5,780K). Consequently its radiation flux is low (0.05% that of the Sun), mainly in the infrared, with a spectral peak at ~1μm, well above the Photosynthetically Active Radiation (PAR) waveband of 400 – 700nm, used by Earth vegetation.

2. Habitability and Oxygenic Photosynthesis

At least three of the planets are in the Habitable Zone (defined as regions where surface temperatures may support liquid water), but all six inner planets could have such temperatures, depending on their atmospheres. The six inner, closely orbiting planets (at 0.1-0.35AU), receive a radiation flux 0.3-4 that of Earth, but only ~10% of this is PAR, compared with ~40% on Earth. However, the star-facing hemisphere of tidally locked Trappist-1 planets would receive continuous PAR. Earth at high northerly or southerly latitudes, provides an analogy for the possible outcome. During only 3-4 months per Earth year, the almost continuous low-level radiation, above 80^o north or south, produces lush vegetation (Figure 1).

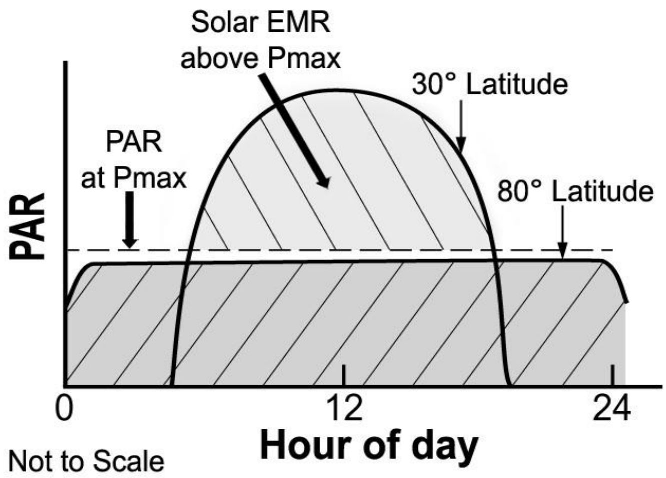

Figure 1: Diagram of the summer radiation regimes in mid and high latitudes on Earth.

The radiation intensity on such a tidally locked planet would be maximum immediately facing the star, falling off to zero, towards the terminator, at 90^o (Figure 2). This would allow plants to “select” the most appropriate radiation regime optimizing their growth.

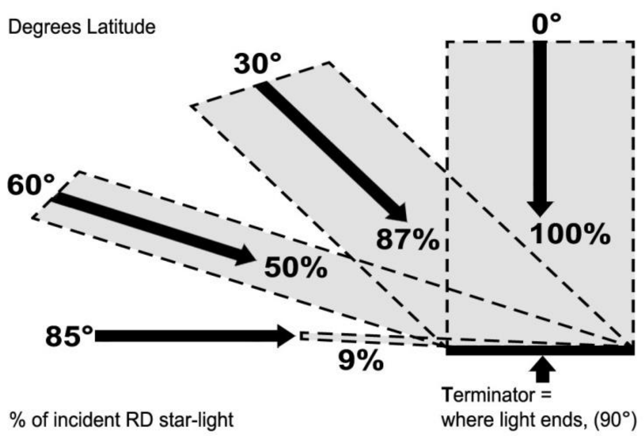

Figure 2. Percentage incident radiation on Tidally Locked Planets as a function of Geographic Latitude.

3. The potential for life

The XUV radiation from Trappist -1 is much higher that of the Sun. This radiation could (possibly, but not necessarily) erode the primary atmosphere and oceans, and directly endanger life, unless life evolves in water or under a dense atmosphere. Dry land plants on Trappist-1 and other RDS planets could possibly evolve to utilize the infrared radiation between 700 and 1,000nm, which is energetically sufficient to drive water splitting oxygenic photosynthesis, an important precursor of complex life. These considerations and the abundance of RD stars, enhance the chance of finding other life clement abodes in the Milky Way [3].

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Short Summary

Planets of Red Dwarf stars have an incident radiation and climate pattern very different from Earth. However, their climate modeling and the high abundance of Earth-sized planets in the habitable zone of Red Dwarfs suggest that many such planets may support life clement conditions, oxygenic photosynthesis and eventually complex life.

Is Recent Mars A Habitable Planet? - Microorganisms From New Terrestrial Mars Analog Habitat Sites In The Permafrost Of Continental Antarctica Survive Mars Simulation Experiments In The Lab And In Space

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1. Introduction

Astrobiological investigations were performed in the Transantarctic Mountains within the study sites located in the Northern Helliwell Hills, Sothern Helliwell Hills (Boggs Valley) and in the Morozumi Range in North Victoria Land (~71.73°S/161.38°E) and were visited in the framework of the 10th and 11th German Antarctic North Victoria Land Expedition (GANOVEX X and XI) during the austral summer of 2009/2010 and 2015/2016. The local bedrock consists mostly of sedimentary rocks (sandstones) of the Beacon Supergroup and mafic igneous intrusions (Ferrar Dolerites). Within these rocks a variety of micro-niches such as fissures, cracks and some structural micro-cavities within the fine-grained sedimentary rocks are colonized by a diversity of microorganisms. These micro-niches are protecting the organisms against extreme desiccation and UV-irradiation. Collected microorganisms of these Mars-analogue field sites are checked if they are able to survive or to be metabolically active under simulated Mars-like conditions in the lab and in space.

2. Mars analogues and Mars simulation experiments

Through comparison to structures on the surface of Mars the geologically and geomorphologically well-defined macro- and micro-habitats can be classified as Mars-analogs. The Mars-analogy can also be confirmed particularly due to the presence of liquid water at an air temperature below zero and the presence of perchlorates. A test series on collected and isolated microorganisms from these potential Mars analog field sites started for checks on the ability to survive or even to live under simulated Mars-like conditions both in the laboratories and in space [1], [2]. Metabolic activity and vitality tests were performed (e.g. CFU, CLSM, protein synthesis and photosynthetic activity tests). Some of the samples which were tested for 1.5 years on the International Space Station (ISS) in the frame of the ESA/DLR-space experiment BIOMEX (BIOlogy and Mars EXperiment, 2014-2016, [3]) show the high resistance of polar microorganisms to Mars-like environmental conditions simulated by Mars-like space exposure on the ISS. They mainly survive the conditions of simulated Mars environment either in the lab or in space.

3. Conclusions

The simulation experiments in the laboratory and the space tests performed by ESA, NASA and DLR additionally highlight how important the collaboration between Polar Research and Space Research is as a prerequisite to investigate the habitability of Mars in a very extreme environment. The cooperation of these disciplines is also mandatory to find out if new investigated field sites are from a biological point of view real Mars-analogues and if microorganisms in these areas might have relevance to survival or to be metabolic active on Mars.

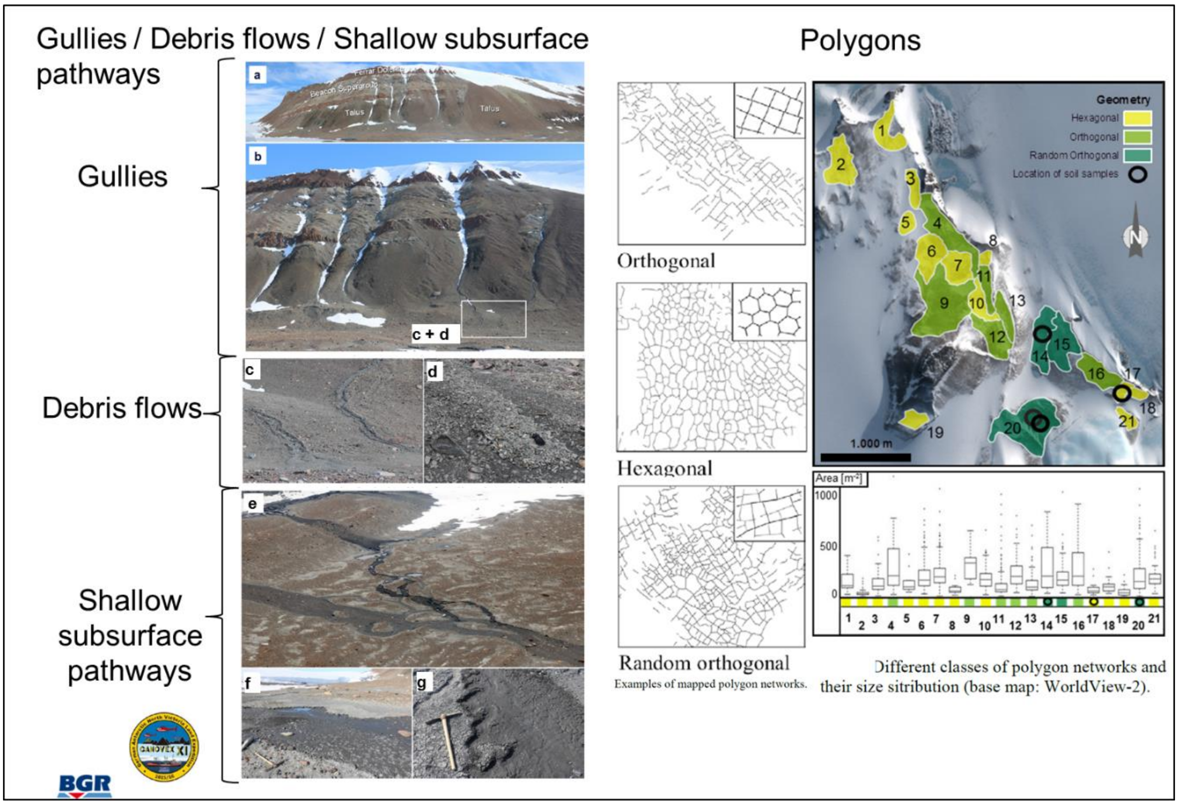

Figure 1: Geomorphological structures with Mars-analogy. (a) overview on slopes with gullies, (b) zoom into a section of (a). (c) water tracks and (d) debris flows, (e), (f), (g) shallow subsurface pathways at different locations.

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Short Summary

Microorganisms from polar Mars-analog field sites are able to be active and survive simulated Mars-like conditions in the lab and in space. Recent Mars could be still a habitable planet, at least in some niches.

EuroMoonMars Extreme Field Analogue Campaigns

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[8] *SGAC Space Generation Advisory Council*

EuroMoonMars campaigns

We have organised field campaigns (EuroMoonMars) in specific locations of technical, scientific and exploration interest. Field tests have been conducted in ESTEC, EAC, at Utah MDRS station , Eifel, Rio Tinto, Iceland, La Reunion, Hawaii, and LunAres base at Pila Poland in summer 2017. These were organised by ILEWG in partnership with ESTEC, VU Amsterdam, NASA Ames, GWU in Utah MDRS (EuroGeoMars 2009, and then yearly for EuroMoonMars 2010-2013).

Other EuroMoonMars analogue field campaigns using selected instruments from ExoGeoLab suite were conducted in other MoonMars extreme analogues such as Eifel volcano, Rio Tinto, Iceland, La Reunion, Hawaii.

The ExoGeoLab research incubator project, has started in the frame of a collaboration between ILEWG [3] (International Lunar Exploration working Group http://sci.esa.int/ilewg), ESTEC and partners, supported by a design and control desk in the European Space Incubator (ESI), as well as infrastructure.

We brought the ExoGeoLab lander and suite of instruments for a test campaign at Eifel volcano park in

Germany in 2009 (EuroMoonMars 2009), and more recently in 2015 & 2016. We tested various phases of a robotic lander mission (rover deployment, lander inspection , instruments remote operations, lander + 2 rovers cooperative operations, sample collection and analysis) as well as possible operations during Extravehicular activity astronaut simulations .

EuroMoonMars 2017 & campaigns at LunAres base at Pila, Poland.

In Summer 2017, the ILEWG ExoGeoLab lander was brought to be part of a series of MoonMars simulation campaigns in LunAres base just completed in Pila airport , Poland. We present various posters illustrating these EuroMoonMars results:

B. Foing, A. Lillo, P. Evellin et al: ILEWG EuroMoonMars research technology and simulation

P. Evellin, B. Foing, A. Lillo et al: 2017 EuroMoonMars Analog Habitat Preparation and Simulation at ESTEC

A. Lillo, B. Foing, P. Evellin et al: Remote operations of ExoGeoLab lander at ESTEC and LunAres base

V. Guinet, M. Monnerie, B.Jehannin, A. Cowley, C. Jonglez, B. Foing: Preparation of human telerobotics operations using EAC & ESTEC facilities

C. Stoker, J. Clarke, B. Foing, K. Martin Mineralogical and organic properties of samples from MDRS Mars Desert Research Station; analog study for MSL Curiosity

M. Offringa, B. Foing, C. Jonglez: UV-VIS NIR and FTIR spectroscopy of MoonMars analogues

D.Wills, B. Foing: Gamma-Ray bursts spectral structure and implications for life

Acknowledgements "*We thank the participants and collaborators for the ILEWG EuroMoonMars 2009-2019 campaigns at ESTEC,Utah MDRS, Eifel Volcano & at LunAres base, Poland.

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[10] Foing B. H. et al. (2016) LPSC 47, Abstract 2719

[11] Batenburg P. et al. (2016) LPSC 47, Abstract 2798

[12] Offringa M. S. et al (2016) LPSC 47, 2522

[13] Kamps O. M. et al (2016) LPSC 47, Abstract 2508

Short Summary

We organised field campaigns (EuroMoonMars) in specific locations of technical, scientific and exploration interest. Field tests have been conducted at ESTEC, EAC, Utah MDRS station , Eifel, RioTinto, Iceland, La Reunion, Hawaii, and LunAres base at Pila Poland in summer 2017. These were organised by ILEWG in partnership with ESTEC, VU Amsterdam, NASA Ames, GWU.

Testing Facilities for Extreme Analogue Simulations: ExoGeoLab, ExoHab, ExoLab

B.H. Foing, A. Lillo, C. Jonglez, M. Offringa, O. Kamps, V. Guinet, M. Monnerie, B.Jehannin, A. Cowley, A. Kolodziejczyk, M . Harasymczuk, L. Authier, A. Blanc, C. Chahla, P. Evellin, A. Neklesa, J. Preusterink, A. Tomic, M. Mirino, S. Hettrich, J.L. Lousada, M. Fonseka, B. Martinez, A. Decadi
(ILEWG/ESTEC ExoGeoLab/ExoHab/ExoLab Teams & EuroMoonMars Team[1,2,3,4,5,6,7])
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[3] *VU Amsterdam*
[4] *ISAE Supaero Toulouse*
[5] *EAC European Astronaut Centre/ DLR Cologne*
[6] *ISU International Space University*
7 *SGAC Space Generation Advisory Council*

Introduction

We have developed with ILEWG since 2008 an evolving pilot research programme "EuroMoonMars" with a Robotic Test Bench (ExoGeoLab) [1,2] and a Mobile Laboratory Habitat (ExoHab) at ESTEC . They can be used to validate concepts and external instruments from partner institutes. Field campaigns have been conducted in ESTEC, EAC, at Utah MDRS station , Eifel, Rio Tinto, Iceland, La Reunion, Hawaii, and LunAres base at Pila Poland in summer 2017.

Goals and methods of EuroMoonMars & ESTEC ExoGeoLab, ExoHab, ExoLab

We integrated instruments integrated in an ExoGeoLab test bench, crossing various techniques. The methodic steps for this hands-on research are:

1) We have procured and adapted instruments to equip a small surface ExoGeoLab demo lander. Some instruments can also be used on a small or mid-size Rover. some instruments can be brought for field site campaigns.

2) This terrestrial payload (instruments, sensors, data handling) has been deployed, operated and used as collaborative research pilot facility (ExoGeoLab), first tested and operated at ESTEC , and later transportable

4) We have implemented the possibility of remote control of instruments from an adjacent mobile laboratory, and a remote science desk.

5) The suite of measurements includes a comprehensive set with telescopic imaging reconnaissance and monitoring, geophysical studies, general geology and morphology context,geochemistry (minerals, volatiles, organics), subsurface probe, sample extraction and retrieval, sample spectroscopy analysis.

6) We have reproduced some simulation of diverse soil and rocks conditions (mixture of minerals, organics, ice, penetrations of water, oxydant, organics, living organisms & plants) and diagnostics

7) We used these instrument packages to characterise geological context, soil and rock properties

8) Science investigations include geology, geochemistry, mineral, oxydant, organics, and volatiles diagnostics.

9) After first validations we started to exploit the facility for collaboration with partners that have provided some additional guest instruments, and perform specific investigations,

10) We can make use of the mobile lab habitat ExoHab for logistics support and local operations.

11) An additional ExoBiology Laboratory module (ExoLab) has been equipped to support related technical research. A new version ExoLab 2.0 was developed over summer 2017

12) From this test bench and kit of ExoGeoLab instruments, we plan to operate comprehensive instruments packages that could help in the technical research and science preparation of future lander/rover missions.

This research can benefit the frame of Science, Exploration or Application programmes, or in support of International Tasks Groups such as ILEWG, IMEWG, ISECG, space agencies, and research partners.

Field tests of ExoGeoLab Lander Demonstrator:

We have built a demonstration model for a generic small planetary lander. This ExoGeoLab lander was developed in partnership with ILEWG, ESTEC in synergy with the requirements from the Google Lunar-X Prize GLXP competition. The platform allows to accommodate a flexible suite of instruments for different missions configurations (e.g. GLXP, lunar science, lunar polar exploration, Mars exobiology, Mars environment, outer Moons). The ExoGeoLab lander was upgraded to allow remote operations of cameras, a fiber -fed spectrometer, a telescope and various lander subsystems. It was tested at ESTEC outdoor field area (Fig. 2).

Fig 1 (left) : we thank ILEWG EuroMoonMars 2017 campaign crew at ESTEC (here with ExoGeoLab lander & Puli Rover) & at simulation campaigns (PMAS, LUNEX1, IcAres) at LunAres base, Poland. Fig. 2 (right), ILEWG ExoGeoLab lander with remotely controlled USB4000 spectrometer and rover

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[3] Groemer G, Stumptner W, Foing BH and ILEWG Eifel campaign team (2010) LPI, 41, 1680

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[7] Offringa M. S. et al (2016) LPSC 47, 2522

[8] Kamps O. M. et al (2016) LPSC 47, 2508

Short Summary

We developed with ILEWG an evolving pilot research programme "EuroMoonMars" with Robotic Test Bench (ExoGeoLab), and a Mobile Laboratory Habitat (ExoHab & ExoLab) at ESTEC . Field campaigns have been conducted in ESTEC, EAC, Utah MDRS station , Eifel, RioTinto, Iceland, La Reunion, and LunAres base at Pila Poland in 2017.

King of Mars & King of the MoonVillage: Exploring and Creating Space

B. Foing[1,2,3], N. Verschoor[4] & WDKA Applied Art students[4]

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[2] *ILEWG International Lunar Exploration Working Group*
[3] *VU Amsterdam*
[4] *WDKA Willem de Kooning Applied Arts Academy, Rotterdam*

It will sure take a while, but it's going to happen one day: the colonization of the Moon and Mars. Space agencies, scientists, international companies and architects; they already make plans to build a new society outside of the Earth. These developments place the notion of 'public space' and the limits thereof in a challenging context. (Im)possibilities seem endless. Main goal of the practice ‘King on the Moon’ and ‘King on Mars’ is the search for new areas to discover and to develop. You examine issues and generate solutions to explore and take possession of new public/private spaces.

Practice: King of MoonVillage & King of Mars

The two practice projects (King of MoonVillage & King of Mars) were initiated between W de Kooning Applied Arts Academy and ESTEC and was followed by 2 classes of about 20 art students. They were challenged with the following questions: “In this practice you will be dealing with different (political) ideas about power, gender, colonization and technological progress. You will have to rethink you position and responsibility as a creative entrepreneur as scientific, philosophical or creative ideas are at stake in a still unexplored area. What if humans can take possession of an unlimited new public space? How much 'freedom' offers that space? Who owns what, who is in charge?

King on the Moon and King on Mars are autonomous practices; therefore, it is essential to define your own individual position within the field of design and art in public space. What role do you choose for yourself and why. This will include your personal artistic vision, intuition and emotions but also social ideals or political liking to be part of a (autonomous) visual statement.”

17. Assignment

The W de Kooning Applied Arts Academy art students visited ESTEC and were also proposed specific tasks: “1) research and develop a plan for taking possession of a new (un)claimed or alien area in the public space, consider the moon as starting point; 2) position yourself in this future developments bases on your own discipline; 3) the outcome can be anything; a 3D model, a performance or protest, a poem or music or... 4) write a research document “

18. Kings of Moon & Mars: Results at ESLAB51 Extreme Habitable Worlds

We present at ESLAB51 a summary selection of posters from King of Moon & Mars individual projects, visual results and products. We thank the students of King of MoonVillage/ King of Mars programmes, ESA ESTEC, WdKA and colleagues that supported the practice. Some snapshots of the posters produced as part of practice are shown in Figure above. More will be shown at ESLAB51 !

King on Moon Village

The Commoondments	**Robin Huisman**
The Think Tank	**Gino Bodt**
Future Mooncity	**Lieuwe Oldersma**
Green evolution	**Mark Verdult**
Mission 69	**Rais van der Kroef & Sterre Richard**

From Luna with Love	**Colin Dassen**
The overview effect	**Laura Mollous**
No brainer: a galactic-fantastisc way away	**Madelief de Kock**
Touch Home: a Spacesuit as a Space to explore	**Beer Boutkam**
Drawing down the Moon	**Merel Jansen**
The buddy system	**Joris de Jong**
Moontopia	**Koen Dekker**
Moon harvesting	**Alexander Zaklynsky (Artscience The Hague)**

King of Mars

Back up	**Lisanne Kremers**
Back on Earth: the story for the kid of the future	**Samantha Groen**
Space garden	**Karlijn den Hoet**

MoonMars

100 years in Space	**Lot van den Bos**
Taking Off	**Celine van Ooijen**
"Sta even stil" take a moment - aresearch about luck	**Gaelle Van den Dool**
Ennui	**Hansje Struijk**
Marsol	**Lot Mars**
The High frontier	**Luuk van de Grif**
New social status: Public/private Autonomous Practice	**Anne Exoo , Dian Padmasari**
CORTEX: your remedy against spatial disorientation	**Naomi Jansen**

19.

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Short Summary

The two practice projects (King of MoonVillage & King of Mars) were initiated between W de Kooning Applied Arts Academy and ESTEC and was followed by 2 classes of about 20 art students: Space agencies, scientists, international companies and architects already make plans to build a new society outside of the Earth. And you?

A Systematic Search of the Nearest Stars for Exoplanetary Radio Emission: Strong Radio Bursts from ROSS 614 AB

Daniel Winterhalter[1], Mary Knapp[2], Tim Bastian[3]

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1. Introduction

Radio observations have been used as a tool to search for exoplanets since before the confirmed discovery of the first extrasolar planet. However, to date there have been no definitive detections of exoplanets in the radio regime. In 2016/17 we have started to conduct a blind (in terms of frequency) radio survey of the nearest star systems for exoplanetary radio emission with the VLA and LOFAR observatories. The goal of the survey is to obtain meaningful upper limits on radio emissions from (or modulated by) sub-stellar companions of the nearest stars.

2. The Nearest Stars

The selection of the “Nearest Stars” targets was guided by two considerations. First, while star systems close and far have been searched for radio emissions, a systematic survey of the nearest ones is lacking. Since any emission will, of course, fall off rapidly with distance, those from the nearest emitters would be strongest. Second, all of the nearest stars are M Dwarfs and Brown Dwarfs, star types known to be very active. Stellar activity is an advantage in observing anticipated magnetospheric emissions, as is shown in our Observing Probability study [1].

We thus are undertaking deep and unbiased ("blind") stares at the 10 nearest star systems observable with LOFAR’s Low Band Array (LBA), and the National Radio Astronomy Observatory’s (NRAO) Very Large Array (VLA). We undertake this survey without preconceptions of what magnetic fields may be present on exoplanets, or are modulated by them. The goal is to obtain, at least, a good upper limit (on the order of 10 mJy) on any radio emission produced by or modulated by the nearest exoplanets, covering a wide frequency range, starting with LOFAR’s 30 – 80 MHz band, and reaching up with the VLA in the P, L, S, and C-bands (230 – 8,000 MHz).

3. Observations

Not all the targets have been observed yet, nor have has all the available data been fully analyzed. Of particular interest, however, are the results obtained from our VLA observations of ROSS 614 AB, a red dwarf UV Ceti flare binary star system with no known planetary companions, 4.13 pc away. The ROSS 614 preliminary results are presented here. The Ross 614 system characteristics are:

- M-dwarf binary system (M4-4.5 V, M4.5-6.5 V)
- Distance: 4.3 pc
- Orbital period of 16.6 years
- Member of the Pleiades Moving Group
- Flare stars (strong radio emission has been detected from the location of the system previously)
- No substellar companions detected to date

We observed the ROSS 614 system 10 times over a 4-month period, for approximately 21 minutes each time. Data was acquired in L and S bands, and the array was in C configuration. No emission was detected in three of the observations. Strong radio emission was detected in each of the first six VLA observations, as well as the eighth.

All six detections were moderately left-hand circularly polarized (~50%). The measured fluxes for the first six observations with detections vary from 1-7 mJy (Stokes I), while the last is ~ 350 μJy. The image noise floors are below 30 μJy for LS-band and 45-90 μJy for L-band, yielding a signal-to-noise ratio greater than 10 on the first six detections. The last detection is weaker, but still significant. The higher frequency, wider bandwidth LS-band observations have lower noise than the L-band observations, as expected.

The recovered position of each detected source was compared to the expected current position of Ross 614 AB, accounting for proper motion. All detected sources were consistent with Ross 614 AB within the synthesized beam width of the observation. The interferometric resolution was not sufficient to spatially separate the binary components, so both stars are within a synthesized beam. There are no known extragalactic sources in close proximity to the current location of Ross 614 AB, so the detected flux is likely from one or both of the stars in the binary.

There is no consistent spectral shape across all observations. The polarization fraction stays roughly constant within the error bars. Stellar radio emission is commonly interpreted on a dynamic spectrum plot (time vs. frequency), but the short duration of the observations in this campaign preclude typical dynamic spectrum analysis. Stellar radio bursts show complex, fine time-frequency structure throughout their evolution, so it is unsurprising that the spectra of the Ross 614 AB flare observations vary relative to one another.

4. References

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Becoming an Oikos

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1. Introduction

Space exploration has shown that the Cartesian human in association with techné lacks the capacity to enliven abiotic environments outside of Earth. Ecological thought understands that only oikos, the interconnection between numerous living agencies and the environment, can meet the challenges of pioneering into extreme habitable worlds. Thus, an exploration of hybrid ecological, technoscientific and anthropological epistemes applied to extraterrestrial environments is necessary to assist functional but earth-bound categories of knowledge in their becoming out-of-the-cradle systems of thought. With Becoming an Oikos, we research different epistemic modes of being human in non-terrestrial conditions.

Although natural sciences and humanities have been considered separate domains for over four centuries, we are beginning to realize it is not possible to understand the human condition as separate from the living environment that shaped it. This insight is clearest when studying the human condition in the abiotic surroundings of outer space, which comes as a novel challenge for humanities. Thus one of the big frontiers in humanities studies is not just the question of relations between humans, technologies and the environment, but the very epistemes within which observations, perceptions and appearances take shape.

2. From techné to Oikos

Outer space is an extreme living environment, but it appears so especially from an anthropocentric perspective that seeks to establish human materiality outside its natural habitable zone. At the moment the capacity of terrestrial life that is most represented in outer space is space technology. Techné (technology in the widest sense) historically emerged as an extension of the human body with which oeconomus (ancient Greek meaning the manager, housekeeper) managed the oikos (ancient Greek meaning the family, the family's property, and the house). With oeconomus reaching into outer space, Earth's oikos extends beyond terrestrial living materiality. Satellites, probes and rovers are not merely human prostheses; they are also extensions of terrestrial life. They are not just human-made, they are the product of "more than human" efforts.

Contemporary economic models, in general, take resources as a given and have a blind spot for material processes that established and continuously replenish the capacities used by humans in the production process. Since humans are not isolated entities but share existence and body with non-human organisms [1], taking credit for all production in a closed (biological) system (i.e. Earth as such) is an ideologically biased perception. However, it is true that the ecology of life [2] has evolved from simple forms into more complex cultural forms that start to compete with natural forms.

Human reach into outer space is thus not just human; it's also non-human. For example, the "less than human non-human" [1], the microbiomes are confronted with outer space conditions in intimacy with the astronauts' bodies dwelling on the space station. Another example is the "extended non-human", where techné is the mode with which we observe and sense outer space materiality. However, if we aim to reach outer space embodiment [3], an emancipated and self-sustainable life system has to be established. Life does not begin here or end there, or connect a point of origin with a final destination, but rather keeps on going, finding a way through the myriad of things that form, persist and break up in its currents [4]. Life is not self-contained form, it's formed together with living environment, or more precisely, the living environment is produced by living entities through their life [2]. Existing techné has proven to lack Spinoza's capacity to act [5] or Morton's essence [1] with which it could form a sustainable living environment. To achieve that, a more complex system is required, one like Earth's ecosystem or experimental closed biological systems. We can understand extreme environments as other-than-human living environments, where humanness can be extended with its non-human extensions and counterparts.

If we seek to establish a living environment outside the Earth, we should consider doing that not with techné but with oikos. And that is another paradigm, where the contemporary dominant technoscientific episteme would have to evolve towards an ecological episteme, as British philosopher Timothy Morton describes the ecological thought is a thought about ecology, but it also thinks ecologically. Thinking the ecological thought is part of an ecological project [1]. German philosopher Erich Hörl goes even further with environmentality as a new contemporary condition, discussing how we must take into account our environmental becoming, not only of technology, but also of power, thinking, and the world itself [6].

We can conclude, that if we aim to establish a sustainable human presence in outer space, emancipated from the Earth, then the oeconomus has to become one with the oikos.

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Universal Life

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1. Introduction

The only known method to form the building blocks of life selectively and at high yields is via photochemistry [1,2]. We concentrate on the formation of sugars and RNA precursors from hydrogen cyanide and solvated electrons. The amount of light is critical to determining whether these reactions succeed, and the amount of light necessary can be connected to the star. If there is not enough light, the hydrogen cyanide is locked into an inert adduct that is not of prebiotic interest. If there is enough light, the reaction of hydrogen cyanide with the photochemically produced solvated electrons will produce simple sugars.

2. Methods

We take hydrogen cyanide and two prebiotically relevant anions which can produce simple sugars that lead to RNA precursors [2]. We perform these measurements with two different numbers of lamps and with different exposure times to estimate the photochemical cross-section for these reactions. We also take the hydrogen cyanide and these anions and leave them in the dark at different temperatures. In the dark, they react to form an inert adduct. We compare the rates in the light and dark to see which wins.

3. Results

Our primary results are that stars below a certain effective temperature with planets greater than a certain period provide insufficient flux for generating the building blocks of life. Life cannot originate photochemically on these worlds [3]. Planets for which the ultraviolet irradiation is sufficient to generate these building blocks of life are within what we term the 'abiogenesis zone' [3], which is distinct from the 'liquid water habitable zone' [4]. For more active M-dwarfs, flares of sufficient energy, at sufficient frequency, can drive the chemistry forward.

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Wednesday 06 December 2017

Space as a Tool for Astrobiological Exploration of the Solar System

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1. Introduction

For the existence of life in the Solar System liquid water is required. Promising targets include Mars and the icy moons, Europa and Enceladus. Finding evidence of life within these potentially habitable environments is dependent on finding unique biosignatures that can be used as irrefutable evidence of life. The main aim of the two ESA space experiments BIOMEX [1] and BioSigN is to support future exploration missions to Mars, Enceladus and Europa using a set of exposure experiments to identify feasible organic biosignatures. There are three specific objectives relevant to this aim: 1) analyse the extent to which selected organisms can survive conditions of space and simulated planetary conditions; 2) analyse the stability and degradation of biosignatures in Low Earth Orbit (LEO) and simulated planetary conditions and 3) to evaluate if some of the resistant microorganisms could be used in future life supporting systems or could be applied for medical treatments to support the human immune system during manned space missions.

2. BIOMEX and BioSigN

The space experiments BIOMEX (BIOlogy and Mars EXperiment) and BioSigN (BioSignatures and habitable Niches) are concepts of investigations to be performed on space exposure platforms on the ISS. Whereas BIOMEX was realized on the space exposure platform EXOPOSE-R2 and results from this experiment are available and will be presented, BioSigN is in the initial phase and is to be performed on a new ESA space exposure device. Both of the projects are using organisms that have previously been isolated from Mars- and sub-surface icy moon analogue sites like Antarctica and the deep sea. The major output of these experiments is on one hand a database of spectra, obtained by mainly Raman spectroscopy of organic biosignatures that are detectable after exposure to LEO and simulated planetary conditions. This database will give insights into the stability of biomolecules under different environmental conditions and the value and pitfalls of using the specified instrumentation for life detection missions. On the other hand both of the experiments are also providing results which are relevant for maintenance of human health and for the use of the tested organisms in life supporting systems. Here the rationale behind BIOMEX as well as BioSigN to support future space exploration missions like ExoMars and Mars 2020 or missions to the icy moons or even manned space missions will be presented.

3. Figures

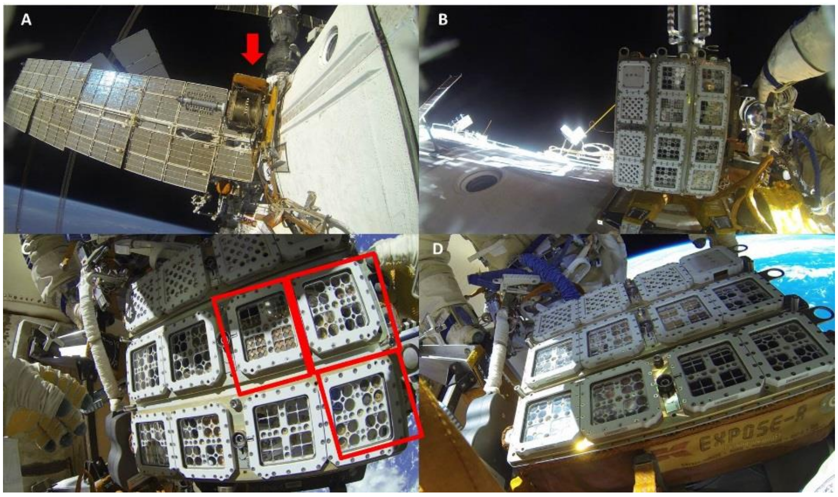

Figure 1: Pictures from the EVA during the EXPOSE-R2 mission in Low Earth Orbit on the ISS. A) Position on the Zvezda module; red arrow: EXPOSE-R2; B) Cosmonauts are approaching the facility. C) The compartments of the BIOMEX experiment are indicated by red squares; C) EXPOSE-R2 - view from the side with in the back our blue planet Earth.

4. References

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Short Summary

The two space experiments BIOMEX and BioSigN in Low Earth Orbit on the ISS serve as a tool for future manned and unmanned space exploration missions to Mars and the icy moons in the outer solar system. The main task is to investigate the habitability and the search for life.

How to live on Mars

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1. Introduction

Human space flight to another planetary body has gained new momentum over the past few years: ESA hopes to reach the Moon within 15 years, and NASA currently aims for Mars in about 20 years. Private companies occasionally announce more ambitious timelines. Nevertheless, important technologies still have to be developed and improved before humans can face the risks and difficulties of interplanetary travel. However, astronauts on long-duration space flights will have to overcome additional challenges, such as the psychological effects of isolated, confined, and extreme (ICE) environments [2-4].

In order to understand and prepare for these psychological challenges, a number of analog habitats have been built in the recent past, including habitats such as HI-SEAS [1] or LUNARES. These have been the locations of record-breaking and innovative concept studies, of which two will be presented in this paper: some lessons learned from the one-year simulation of life on Mars HI-SEAS 4 (section 2), as well as lessons from the first ever mission with a physically handicapped (analog) astronaut, ICAres-1 (section 3).

Both mentioned stations, however, are designed for human factors studies. They share some fundamental design flaws that result in their being inherently limited to terrestrial use. That is, they are true analog habitats, rather than technologically functional prototypes of habitats for extraterrestrial use. However, it is obvious that a mission to another planetary body does not only require rockets and boosters, but also a shelter for the astronauts at their destination. Thus, the final section of this paper will present MaMBA, the proposal for a functioning habitat prototype.

HI-SEAS: 1 year on simulated Mars

In August 2016, the longest simulation of life on Mars on American soil has ended. Six volunteer scientists and engineers had been living inside the HI-SEAS habitat for one year under Mars-like conditions: confined to the 110 sqm habitat, only allowed to leave in mock space suits, and with communications that were delayed by 20 minutes in each direction to simulate the large distance between Earth and Mars.

HI-SEAS stands for Hawaii Space Exploration Analog and Simulation; and the simulation study has been conducted by the University of Hawaii in collaboration with NASA as part of a series of long-duration missions. The HI-SEAS facility is located on the barren slopes of the Mauna Loa volcano in Hawaii.

The constraints of life on Mars are numerous, and some are less obvious than others. For example, resources were limited, including water and research equipment. Despite these limitations, the HI-SEAS 4 crew worked on a number of projects in the fields of geology and biology, both conducting field work and lab analyses, as well as studying EVAs and Human Factors.

Figure 1: The HI-SEAS habitat (left) and a HI-SEAS 4 crew member (right).

ICAres-1: Mars with handicap

The first mission to date that included a physically disabled analog astronaut was conducted at the LUNARES habitat in Poland in October 2017. Unlike other analog habitats (such as MDRS or HI-SEAS), the design of LUNARES allows the simulation of accidents that could result in damage to both the habitat and/or astronauts.

The crew of ICAres-1, which stands for Innovative Concepts for Mars, was composed similarly to the HI-SEAS 4; both crews were international and consisted of 3 males and 3 females. However, due to the special circumstances, the average age of ICAres-1 was higher than at HI-SEAS 4 and 3 crew members instead of just 1 had a medical background.

Living conditions at LUNARES were similarly Mars-like, most notably, the crew could only communicate with mission support via time-delayed emails.

MaMBA: A shelter for Mars (and the Moon)

Today's habitats are (1) located at the surface, even though space radiation is a known threat to crew health, (2) built with a single (central) module, even though one single catastrophic event may then render the entire habitat uninhabitable, and are (3) designed around the crew's living space, with limited attention to the realistic instrumentation of the laboratory which arguably is the most important module for a scientific mission.

MaMBA, the Moon and Mars Base Analog proposed here, will learn from these design flaws: It will consist of separate, connected modules which can be shut off independently from each other, and will adress the possibility of astronauts (temporary) incapacitation. The central piece of the habitat will be the laboratory module; and scientists will play an integral part in the design process for the laboratory. Moreover, as MaMBA aims to be a functioning habitat prototype, it will have closed loops for water and air and a self-sufficient power supply at its final stage. Functionality will be verified during short and medium-duration simulations with analog astronauts.

Summary

Analog habitats are important for studying human factors influencing the success of interplanetary missions. Some existing habitats have recently been used to extend our knowledge about extended life under extreme conditions. However, although these habitats are invaluable for understanding and predicting human factors, they fail to realistically represent the technological challenges remaining today. Therefore, an analog base is suggested that may serve as a prototype for a non-analog base.

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Short Summary

Analog simulations are vital in understanding the influence of human factors on the success of an manned interplanetary mission. We will discuss two analog missions that have broken records (HI-SEAS 4) and been innovative (ICAres-1), and present the lessons learned from them, particularly with respect to future habitat design (MaMBA).

MELiSSA: the European project of closed Life support system

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The MELiSSA (Micro-Ecological Life Support System Alternative) project was initiated in 1989. It is intended as a tool to gain understanding of closed life support, as well as the development of the technology for a future life support system for long term manned space missions, e.g. a lunar base, a CIS lunar orbiter, or a mission to Mars.

The collaboration was established through a Memorandum of Understanding (i.e MOU) and is managed by ESA. It involves roughly 40 organisations, 14 of these organisations have signed the MOU. It is co-funded by ESA, the MELiSSA partners, local, regional and national authorities. The driving element of MELiSSA is the production of food, water and oxygen from organic waste (e.g. inedible biomass, CO_2, faeces, urea). Inspired by the principle of an “aquatic” ecosystem, MELiSSA process comprises several processes, called compartments, from the anoxygenic fermenter up to the photosynthetic one (i.e. algae and higher plants). The choice of this compartmentalised structure is required by the very high level of safety requirements and justified by the need of an engineering approach and to build deterministic control strategy.
During the past 28 years of research and development, a very progressive approach has been developed to understand and control the MELiSSA loop. This approach starts from the selection of processes, their characterisation and mathematical modelling, the validation of the control strategy, up to the demonstration on Earth, at pilot scale. It includes as well the stress detection issues and the potential evolution of the metabolic pathways, mainly via the use of biomolecular techniques. Recently several flight experiments have been performed.

The project is organised in 5 phases: Basic R&D, Preliminary flight experiment, Ground & space demonstration, Terrestrial transfer, Education & communication.
This presentation recalls the main features of the project and summarises the recent achievements.

Short Summary

MELiSSA project is aiming to reach the highest degree of closure of crew metabolic resources, via recovery of these resources from the organic wastes of the mission.

Photobioreactor Technology for Microalgae Cultivation To Support Humans in Space with Oxygen and Edible Biomass

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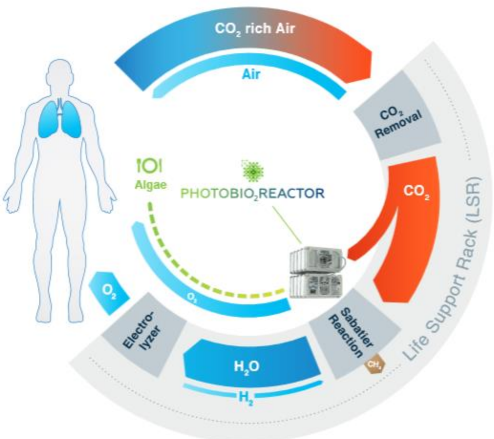
1. Microalgae cultivation

Microalgae cultivation in space enables an essential step to close the carbon loop in future advanced life support systems (LSS), which is important for future and far-distant exploration missions. Utilization of photosynthesis and the combination with existent physicochemical technologies offer a wide potential of benefit for LSS. *Chlorella vulgaris* as a promising microalgae species allows for cultivation in pumped loops to produce oxygen and edible biomass from carbon dioxide and water. Further nutrients such as ammonium and phosphate are needed. Microalgae offer various advantages compared to higher plants for first integrating steps of biological components into the LSS. Microalgae have a higher harvest index (> 90%), higher light exploitation (9% of microalgae, higher plants 4-6%, 19% upper biological limit), more rapid growth (five to ten times), lower water demand, mostly higher photosynthetic quotient (PQ), and a well controllable metabolism [4], [5]. Long-term cultivation and stability of the algae culture are one of the most critical development steps.

2. Photobioreactor technology for space

Encouraged by the positive results of several pre-studies on long-term cultivation of microalgae and synergetic integration in LSS at the Institute of Space Systems (IRS), University of Stuttgart/Germany in collaboration with the German Aerospace Center (DLR), the spaceflight experiment Photobioreactor at the Life Support Rack (PBR@LSR) was initiated in 2014 and kicked off in 2015 [1], [2], [3]. DLR, Airbus DS and IRS are aiming to establish a PBR system as a biological component to be connected with the physicochemical LSR to increase system closure and to demonstrate operational feasibility, see Fig. 1 (left). Technological demonstration of the ability to control microalgae cultivation under space conditions in a photobioreactor is the main focus of the spaceflight experiment PBR@LSR on the International Space Station (ISS), especially to prove the functionality and feasibility of a hybrid system in a real environment (CO_2 from astronauts), the short- and long-term performance of photosynthetic conversion of concentrated CO_2 into biomass and O_2, and the stability of the algae system under microgravity and radiation impact.

The cultivation in a 650 ml loop shall last half a year, and the CO_2 for the algae is extracted from cabin air by the CO_2 concentration unit of the LSR. The photobioreactors and LED panels, the algae liquid loop with the pump and tubing, and the required sensors (CO_2, O_2, pH value, temperature, humidity and pressure) are housed in a middeck locker, see Fig. 1 (right).



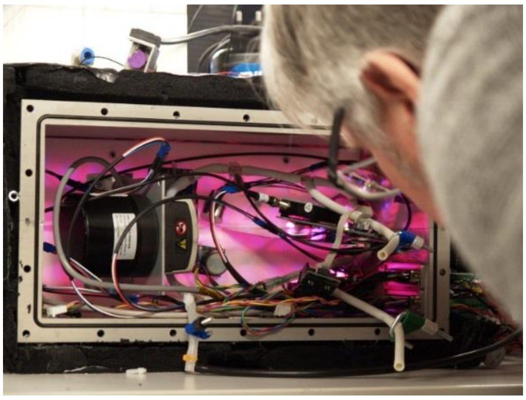


Figure 1: The integration of the photobioreactor in the LSR (left). Breadboard model for testing the long-term cultivation on-ground (right).

3. Long-term cultivation in space and on-ground

During the breadboard experiments, the settings of cultivation parameters (e.g. upper and lower CO_2 and O_2 concentration inside the ‘well balanced’ experiment compartment, temperature limits), operational techniques (inoculation, feeding and harvesting, termination and storage) and the development of tools for the astronaut for regular liquid exchange were investigated and developed. Besides station accommodation and safety requirements these results are shaping the design. The breadboard activities are on a very good way to finalize the proto flight model by end of 2017. A successful long-term cultivation over 186 days was performed from September 2016 until March 2017, see Figure 2 (left). Regular CO_2 consumption and O_2 production could be achieved. Further long-term cultivation in ground-based flat plate airlift reactors proved the feasibility of long-term cultivation of *C. vulgaris* in batch and continuous modes, see Figure 2 (right). The PQ during the high-performance phases are quite equal at 0.5-0.6.

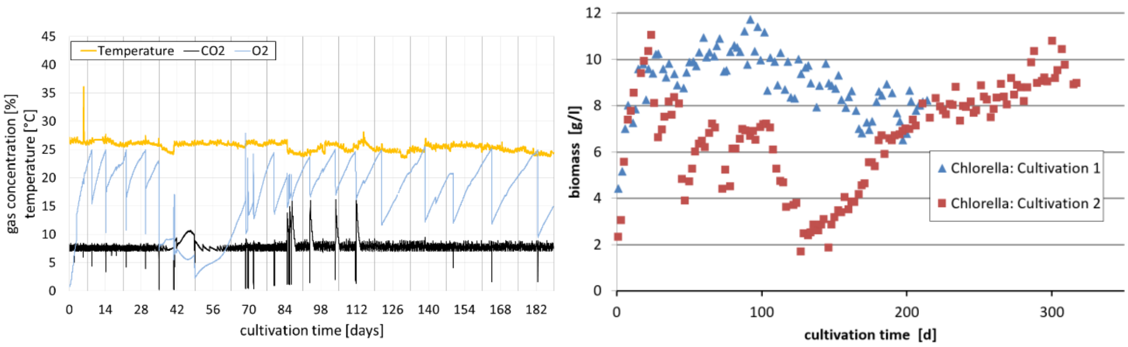


Figure 2: CO_2 consumption and O_2 production during the long-term cultivation of 186 days in the breadboard at IRS (left). Growth development during two long-term cultivation cycles in a flat plate airlift PBR at IRS (right).

4. Conclusion

The long-term cultivation on-board of the ISS offers the great opportunity to investigate the growth behaviour and metabolic performance of *C. vulgaris* under realistic operating conditions in space. A return of selected algae suspension samples and sequencing of isolated genetic material and possible changes in the genome of *C. vulgaris* enhanced or caused by µg and radiation could be investigated by effects on photosynthesis associated genes. Regarding its genetic stability *C. vulgaris* could be finally evaluated for its permanent application as a biological component in a hybrid life support system.

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Short Summary

Utilizing photosynthesis, microalgae are easier to control and more efficient than higher plants. Cultivation of microalgae (Chlorella vulgaris) in photobioreactors enable a first step to close the carbon loop in future life support systems. The spaceflight experiment PBR@LSR is in preparation and shall prove technological readiness for future exploration missions.

Zooplankton for the production of biomass in bioregenerative life support systems in space

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Zooplankton, like the water flea *Daphnia magna*, plays an essential role in the aquatic food web as a link between oxygen-producing microalgae and higher trophic levels such as fish. The major part of zooplankton consist of tiny crustaceans. These animals form an enormous amount of biomass and are therefore of great ecological importance. That makes them good candidates for the production of protein in aquatic bioregenerative life support systems (BLSS) aboard space stations or in extreme habitats. Little is known about the effect of gravity, respectively weightlessness, on the behaviour and physiology of zooplankton organisms so far. Therefore, it is necessary to test its impact on possible candidates for future life support systems in space.

The first step to this objective is to analyse the behaviour of different zooplankton species in diminished gravity conditions with the help of parabolic flights and sounding rockets, and to test whether they are able to adapt to the altered environmental conditions. As the examination of gravi perceptive organs in zooplankton did attract little attention in the past, the identification of these structures is part of our research project. We were able to show that the perception of gravity in *Daphnia* is accomplished in an indirect manner by a mechanoreceptor which is associated with the postabdominal setae of the animal. This represents a novel mechanism of graviperception and may be true for other zooplankton organisms as well. Therefore, we analyse the development of graviperception in zooplankton in an evolutionary context. A further component of our research project deals with the reproduction of zooplankton in altered gravity conditions. Here, experiments with the 2D-clinostat have provided insights in the eclosion of different zooplankton species from dormant stages, and the embryonic development respectively, under simulated microgravity. Another important prerequisite for an operative BLSS is the consistency of interactions between different trophic levels, like predator-prey interaction, in microgravity, which was addressed with an experiment on the sounding rocket TEXUS 52. A further key aspect of our research project deals with the impact of altered gravity on the cellular and molecular level in the model organism *D. magna*.

The combination of behavioural, ecologic and molecular research will enable the identification of zooplankton organisms, which are suitable for the long-term utilisation in BLSS in prospective manned space missions. The findings gained with this project also offers potential for transferring them into the sector of green economy.

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Short Summary

Zooplankton organisms are promising candidates for the production of protein in aquatic bioregenerative life support systems (BLSS). A combination of behavioural, ecological and molecular research is used to analyse the suitability of zooplankton for the long-term utilisation in BLSS in prospective manned space missions.

Deep Space Petri-Pod, a new platform for astrobiology experiments beyond the van Allen belts

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Abstract:

Survival of humanity is likely dependent on our ability to leave Earth and colonise other planetary bodies. To promote this, a common goal of the World's Space Agencies is manned exploration of deep space and of planets such as Mars. However, the deep space environment presents several environmental stressors that prove deleterious to human health, for example high cosmic radiation doses and prolonged microgravity. The consequences of human exposure to such stressors in Low Earth Orbit is well documented and do not appear to subside with up to ~180 d spaceflight examined to date. As such, a major obstacle preventing long duration missions into deep space is exponential decline in multiple physiological systems that would ultimately pose a serious risk to astronaut health. There is therefore a need to understand how life responds to the challenges associated with life in space and, importantly, develop effective countermeasures. Due to the inherent risk associated with human space exploration, utilising model organisms to understand the biological effects of deep space represents an essential first step towards manned missions. However, hardware and associated life support systems for life science experiments in deep space currently do not exist.

We have therefore developed the 'Deep Space Petri-Pod' (figure 1): a small (~100 x 75 mm) multi-user platform designed to accommodate a variety of biological samples, including microorganisms and *C. elegans* as an established *in vivo* model organism of human health and disease. A flex-rigid polyimide printed circuit board is used as a substrate to the 'Pods' and top flange, enabling the integration of embedded heaters (individual Pod temp control) and micro sensors inside the Petri-Pod (a paraylene coating protects the sensors from wet chemistry). Photodiodes with LEDs also enable optical density measurements. Future models could include sensor technologies such as RadFET for radiation monitoring and integration with NanoPore technology for real-time RNA sequencing. Additionally, created with common interface capabilities, DSPP can be incorporated into future missions beyond the van Allen belts, for example Phobos Sample Return, CubeSat and mission to the Moon and asteroids. DSPP therefore represents a novel opportunity for establishing how life responds to the unique deep space environment for promoting targeted therapeutic development prior to sending humans on such high-risk missions. Additionally, DSPP provides a new future platform for conducting astrobiology experiments beyond the van Allen belts fully in keeping with the European Science Foundations' recommendations following the most recent review of ESA science activities.

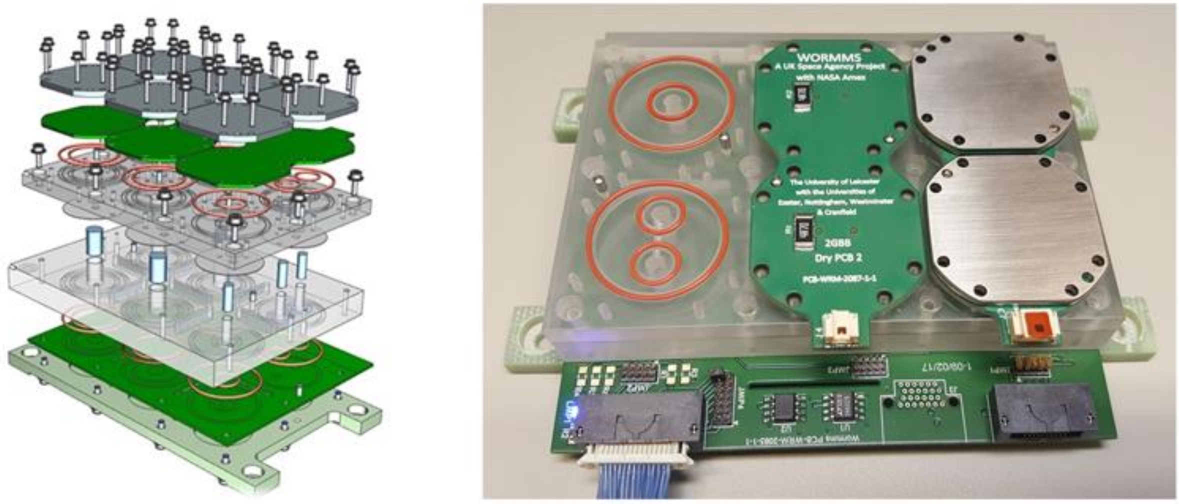

Figure 1. (A) Expanded computer-aided design illustration of the 'Deep Space Petri-Pod' (DSPP) design layers. (B) Photgraph of the DSPP breadboard prototype, including electronic circuit board control system.

Short Summary

The deep space environment poses several health risks that must be understood and countered prior to sending humans on missions to other planets. We have therefore developed the 'Deep Space Petri-Pod' as a multi-user platform for conducting astrobiology experiments beyond the van Allen belts.

Addressing Key Psychological, Social and Physiological Factors in Preparation for Long Duration Manned Missions – Suggested Adaptations of the Current Astronaut Selection and Training

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*Space Generation Advisory Council (SGAC)

1. Abstract

Long-duration human space missions (6 months or more) raise new issues in space exploration. Maintaining crew well-being and performance is critical for the success of these missions. In addition to physiological effects (e.g. due to microgravity or radiation), experiments have demonstrated that in adjusting to the extreme change of environment, long-term spaceflight can have adverse psychological and sociological effects on crew.

The Space Exploration Working Group of the 2nd European - Space Generation Workshop (E-SGW organised by the SGAC at ESA Headquarters in Paris, France in March of 2017 addressed the following issues: 1) Identify physiological and psychosocial risks for long-duration manned missions 2) Propose mitigation measures against these negative effects and impacts 3) Adapt the astronaut selection process and training to the needs of future missions.

Physiological risks are dominated by the effects of radiation and microgravity causing a myriad of potential health issues for astronauts on both short and long-term. It is clear that not only do physiological issues associated with spaceflight need to be addressed technically via mitigation methods but also that team composition and training will be crucial to overcome the medical challenges supported by a suite of medical equipment.

Potential psychological disorders involve a wide range of mental health problems (for example chronic stress, sleep disorders, anxiety, psychosis, psychosomatic illness, mood disorders) that leads to reduce productivity. Interpersonal challenges involve the tendency to avoid social contact, tension and conflicts within the team, which increases with the duration of the mission and as distance from Earth grows and crew feels more isolated. These issues and their interactions present serious threats to crew psychosocial health and performance. The breadth of psychological problems also identified a number of parallel actions needed to address the stress-inducing environment. We believe that Acceptance and Commitment Therapy (ACT) and mindfulness meditation, underpinned by over two decades of empirical research, is well placed to improve the psychological and behavioural skills needed for such demanding missions (1).

Further, a range of potential changes to current selection and training techniques for long-term missions are discussed focusing on selection for a good interpersonal mix within teams and training to support both physical and psychological endurance for long-term space travel. Linking these fields is a clear need to identify a practical and pragmatic approach to enabling spaceflight, balancing risk acceptance vs. risk mitigation.

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Short Summary

Discussing and addressing key human factors affecting long-duration manned missions. Further, a range of potential changes to current selection and training techniques for long-term missions are discussed focusing psychological factors.

Nitrogen recovery from urine in Space: a case for nitrification

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1. Introduction

Human life in space flights is currently enabled by a regular resupply of food and water. However, in order to explore deep space with long-term missions and space habitation, transport of food from earth becomes difficult and extremely expensive, if not impossible on the long run. In order to allow for deep space manned missions or permanent habitation, in situ food production in a life support system will most likely be necessary. Such systems are called Bioregenerative Life Support Systems (BLSS) [1]. The 'Micro-Ecological Life Support System Alternative' (MELiSSA) of the European Space Agency (ESA) is an example of a BLSS. In BLSS research, the development of an engineered bio-based system for food production has been investigated by major governmental space research agencies for the past half century [2-5]. The shared focus of these BLSSs has been the integration of different biological and physicochemical technologies for the breakdown and conversion of waste products into useful building blocks for plant food production in a closed material recycle. Nitrogen is a critical nutrient for this cycle, and ~80% of the nitrogen in the food consumed is excreted and concentrated in the urine. This makes urine an attractive waste stream for nitrogen recovery and purification for subsequent proteinaceous food production.

2. Urine nitrification

Urea accounts for more than 90% of the nitrogen in fresh urine and can be ammonified to ammonia by the widespread enzyme urease or by urea amidolyase. Although in some cases urea and ammonia can be taken up directly by plants and microorganisms grown for food production, it can be preferable to convert urea and ammonia, at least partially, to nitrate in a BLSS. In confined spaces, the occurrence of liquid streams with high ammonia concentrations is considered a hazard as ammonia volatilization increases with an increasing pH and temperature, and can accumulate to toxic levels in the atmospheric compartment. Moreover, high ammonia concentrations resulting from failing or inadequate dosage can become toxic as well to the plants and microorganisms, even when the pH is controlled and high levels of ammonium can inhibit the uptake of key minerals in hydroponic solutions. Nitrate, on the other hand, is not volatile and is not considered to be toxic in the concentrations that are expected.

The biological process in which ammonia is aerobically oxidized to nitrite or nitrate is called nitrification. The first step (nitritation) consists of the oxidation of ammonia over hydroxylamine (NH_2OH) to nitrite (NO_2^-) and is catalyzed by sequential action of ammonium mono-oxygenase (AMO) and hydroxylamine oxidoreductase (HAO). Nitritation is typically performed by chemolithoautotrophic ammonia oxidizing bacteria (AOB) and archaea (AOA). The second step (nitratation) is the oxidation of nitrite to nitrate (NO_3^-) by nitrite oxidizing bacteria (NOB), catalyzed by nitrite oxidoreductase (NXR).

For BLSS, nitrification systems with an open, mixed microbial community have been proposed. On one hand, these self-organizing microbial communities can evolve and adapt to changing conditions and microbial invasions, which increases the robustness of the system. On the other hand, such complex microbial communities and interactions are currently difficult to capture in a mechanistic mathematical model, which might be required for space application where a high level of predictability is desired. Also, the use of a microbial community with unknown species, which might be pathogenic, is highly undesired in confined spaces as it presents health hazard to the crew members of a BLSS.

For this reason, in the MELiSSA loop, nitrification of inorganic streams is envisaged to be carried out by an 'axenic' synthetic co-culture of the AOB *Nitrosomonas europaea* ATCC 19718 and of the NOB *Nitrobacter winogradskyi* ATCC 25391 [6]. The complexity of the reactor construction and operation increases when such synthetic co-cultures are used, but the specific conversion rates obtained (1.7-1.9 g N m^{-2} d^{-1} or 0.55-

0.59 g N L^{-1} d^{-1}[6]) are in the range of terrestrial biofilm-based wastewater nitrification systems using an open, mixed microbial community. Besides nitrogen (~5-8 g N L^{-1}), urine also contains organic compounds (~9 g COD L^{-1}) and elevated levels of salts. It has recently been shown that complete nitrification can occur in a nitrification reactor fed with undiluted urine at this level of electrical conductivity [7]. In case a synthetic co-culture is used for urine nitrification, specific heterotrophic strains will have to be introduced as well to oxidize the organic compounds. Recently, such synthetic co-culture has been developed in the context of MELiSSA's UNICUM project to allow urine nitrification (Ilgrande *et al*. in preparation, Christiaens *et al*. in preparation).

3. Preliminary Space experiments

One of the challenges of applying nitrification in BLSS in space, is the survival and storage of the strains during launch and space flight. Two recent experiments (NITRIMEL and BISTRO) performed by the authors of this abstract demonstrated that nitrifying pure strains, synthetic co-cultures as well as mixed nitrifying microbial communities could successfully be reactivated after spaceflight in low earth orbit (Ilgrande *et al*. in preparation). Reactivation of denitrification and anaerobic ammonium oxidation activity could also be demonstrated after a space flight in orbit.

The next challenge is the application of urine nitrification in microgravity conditions, which significantly affects fluid dynamics, is the reduced convection and strong cohesion forces in space which make efficient gas-liquid interactions no longer possible with major consequences for aeration. Due to the lower diffusion rate of oxygen in water, the oxygen transfer rate might become problematic. Therefore in MELiSSA's URINIS project, activity tests of the relevant urine nitrification strains are foreseen in dedicated set-ups that allow diffusive aeration for both batch tests as well as a continuous tests in a bioreactor. Preliminary ground experiments are being performed to prepare for a demonstration in the ISS in the coming years.

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Short Summary

Nitrogen recovery from urine will become necessary to produce fertilizer for food production in Space (deep space missions and space habitation). An essential process to make convert the waste (urine) into a fertilizer is nitrification. The current developments and space experiments from MELiSSA are presented.

From Waste to Taste; Closing the MELiSSA Loops for escaping and sustaining the Earth habitat (Poster Flash Talk)

R. Giurgiu[1*]; R. Suters[2], C. Lasseur[3], P. Scheer[2], D. Vodnar[1]

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1. Introduction

MELiSSA (Micro-Ecological Life Support Alternative) has been initiated by ESA with the ambitious goal of developing "autonomous habitats in deep space, supplying astronauts with fresh air, water and food through continuous microbial recycling of human wastes" [1]. The now popular MELiSSA Diagram (Figure 1) that showed little change since it was first outlined by Mergeay et al [2] is the foundation for the consortium's research objectives. It describes the flows and interaction of the crew with 4 different compartments colonized from anoxygenic thermophilic up to photo-autrophic organisms (plants) [3].

This paper discusses the outcomes of the latest MELiSSA endeavors and their potential for Earth applications. The SEMiLLA Sanitation Hubs project is described by analyzing the feasibility of scaling the MELiSSA loop to a 40 feet container and closing the gaps by recovering water and nutrients and producing food for extreme Earth habitats.

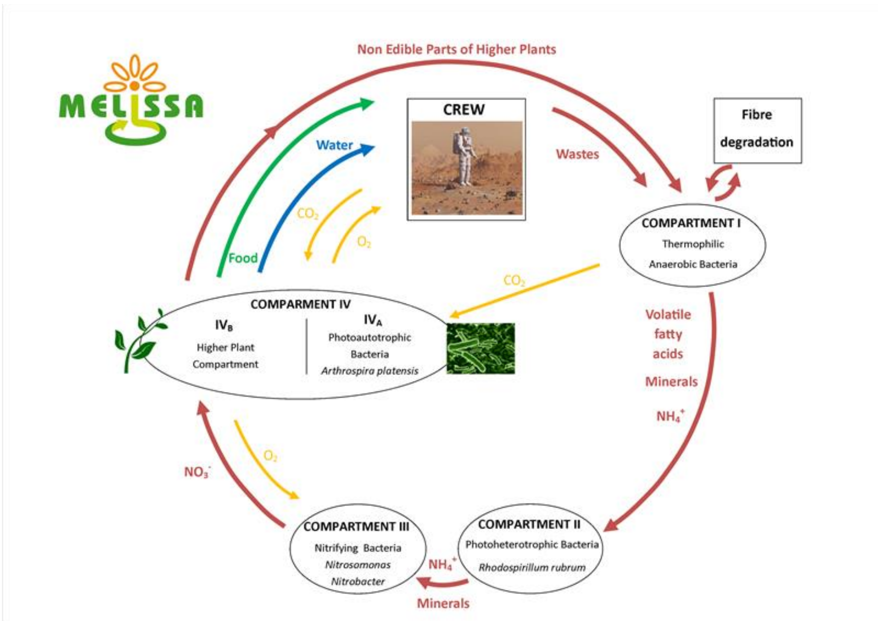

Figure 1: MELiSSA Diagram

2. MELiSSA Application for Space and Earth

The scientific knowledge unfolding in the framework of MELiSSA is paving the way to achieving the artificial environment that can assure the crew with food, oxygen, and water in the confined habitats designed for space exploration. Equally important, this know-how can be applied on Earth to improving the life of the people in terrestrial closed ecosystems (eg desert), smart cities of the future and even remote or disaster areas.

2.1 SEMiLLA Sanitation Hubs

The project is a cooperation between IP Star, University Ghent and HAS University and aims to establish the feasibility of using advanced space technology from MELiSSA program for urine, gray and black water treatment. The compartments described before are scaled down to a **40 feet container** which is modular and can be rapidly transported by air, land or water to the targeted area. The goal is to have deployable containers that have the hardware that allows the recovery of nutrients and water.

3. From waste to taste

3.1 Waste Water Treatment Unit (WWTU)

The objective of this work is to manage the flows and stock of the MELiSSA loop through mathematical models. The existing ones will be adapted to the unit scale (40 feet container) which will enclose the first three compartments from the loop. Next, the input-output balance will be addressed with case studies and further experiments on the prototype. For the case studies, it is considered that a “dietary protein intake of 0.8-1.5 g protein kg^{-1} body weight for a crew member with a body weight between 65 and 85 kg is expected to result in a urinary excretion of between 7 and 16 g N d^{-1}. Fecal nitrogen excretion is typically in the order of 1-2 g N d^{-1}” [4] (Figure2). The project aims to assess the feasibility of the unit through mathematical modeling with a high degree of prediction regarding the water and nutrient flows. By the end of 2017, the sanitation container will be ready to be deployed in remote areas.

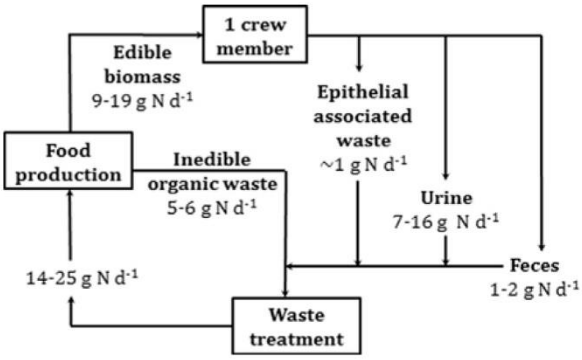

Figure 2: Theoretically calculated Nitrogen balances [4]

3.2 Food Production Unit (FPU)

Based on the results obtained from the mathematical model and the experiments regarding the WWTU, a second container will be designed that will use the water and fertilizers recovered, for producing food in the controlled environment. The container allows vertical stacked growing beds that can assure a surface of approximately 150 sqm for the plants which suffice for an intake of 3040 kcal $person^{-1}$ day^{-1} for about 3 crew members. These models aim to match the complexity of the compartments interaction and then be validated by experiments on the prototypes. Using the technology developed for compartment C4 (Figure1) the linkage of the two units will correspond with closing the MELiSSA loop at unit scale for terrestrial extreme habitats.

4. Life support systems outer and inner Earth feedback loop

The results of the various, multiple, ongoing research projects conducted by the partners from the MELiSSA consortium are pushing the scientific knowledge and help to reach the goal of developing reliable life support systems for long term space missions. The know-how can be transferred and adapted to the extreme habitats on Earth. Nonetheless, the application tested and validated on Earth is a certification of the efforts directed to interplanetary objectives. This creates a feedback loop that is accelerating the progress in the energy, waste, water, air and food nexus.

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Short Summary

This paper discusses the outcomes of the latest MELiSSA endeavors and their potential for Earth applications. The SEMiLLA Sanitation Hubs project is described by analyzing the feasibility of scaling the MELiSSA loop to a 40 feet container and closing the gaps by recovering water and nutrients and producing food for extreme Earth habitats.

Sources of primordial matter in the asteroid belt

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Abstract
Asteroids are numerous small bodies orbiting the sun with heliocentric distances mainly between that of Mars and Jupiter. They have diverse compositions, ranging from metallic [27], to rocky, to carbonaceous [13], to water- [7, 25] and organic-rich [4]. These last categories include objects that compositionally may form a continuum with comets [10], which also contain important amount of water ice [9, 5, 23], organics [3] and other volatile compounds [20, 17]. The volatile-rich composition indicates that these bodies formed in the cold regions of the protoplanetary disk [19], probably much farther away than one astronomical unit from the Sun. Some of these bodies might also contain matter that formed before our Sun was born, in the interstellar medium

Asteroids and comets have impacted [11] our planet (and many other bodies including the sun [8]) all along the history of our solar system. Therefore, they are carriers of water and other volatile and organic compounds, which are the basic ingredients for life on Earth. In particular, impacts between asteroids within the main belt create families [21] of smaller fragments, which can become Earth-crossers [18] and impact our planet [11]. This process has been going on at least during the last 4 Gyr [6]. This time corresponds to the age of the oldest known family of asteroid fragments [6].

But earlier than that epoch the structure of our solar system was different than the one we know today [28, 29, 1]. Large asteroids were more numerous than they are at present, and Earth was struck very frequently [22]: indeed, our planet formed in one of the most fiery environment of the young solar system. It is during these stages of Earth formation that small bodies brought most of their volatile materials [24].

I will review current information about the physical properties of asteroids and comets that highlight the importance of these bodies as carriers of organics and volatiles materials across the solar system. Spectroscopy, by which we analyse the surface composition, indeed revealed water [25, 26, 2, 13] and organics on asteroids (and of course on comets). Another important piece of information about the composition of minor bodies come from meteorites [16]. Although these objects constitute a very limited sample of asteroid, and to less extend, cometary materials, they reveal the presence of water [12] and complex organic molecules. Further information will be obtained by NASA's OSIRIS-REx [15, 14] and JAXA's Hayabusa2 space missions, which will return to Earth samples of fresh materials from low-albedo and likely organic-rich asteroids.

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Short Summary

There will be a review of the current information about the physical properties of asteroids and comets that highlight the importance of these bodies as carriers of organics and volatiles materials across the solar system.

Latest results on Ceres from DAWN: ingredients for life ?

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1. Introduction

Ceres, the largest body in the main belt, has been the subject of extensive telescopic observation since its discovery on January 1, 1801. The arrival of Dawn mission at Ceres allowed to understand better this intriguing body. The Dawn mission has spent over two years orbiting Ceres, assessing the characteristics of its surface and interior [1]. Here we report about the main results of the mission, with particular care of the astro-biological implications.

2. Dawn discoveries

The Dawn data show that the crust is composed of an intimate mixture of rock and ice. Below ~50 km depth, the material weakens. The surface is cratered but very large craters are absent, indicating relaxa-tion. Ceres also has mountains, like very well preserved Ahuna Mons, that are likely cryovolcanic construct(s) [2].

Clearly, Ceres experienced extensive water-related processes and chemical differentiation. The surface is mainly composed of a dark and spectrally neutral component (carbon, magnetite), Mg-phyllosilicates, ammoniated clays, carbonates and salts. The observed species suggest endogenous, global-scale aqueous alteration [3,4,5]. The surface is uniform in composition at large scale with subtle but important variations in the abundance of the chemical species [5,6].

Water ice has been detected in localized small areas especially at high latitudes [7] in the North hemisphere but also in the southern hemisphere, in a crater not far from the equator [8], indicating ice on the surface and immediate subsurface. Global distribution of water ice shows strong latitudinal dependence [9]. Carbonates are ubiquitous in small abundance but very high concentrations of carbonates have been identified in several areas on the surface, notably in Occator bright faculae (fig.1) [3]. Many of the bright areas [10] that punctuate the surface of Ceres are compatible with the presence of sodium carbonates [5].

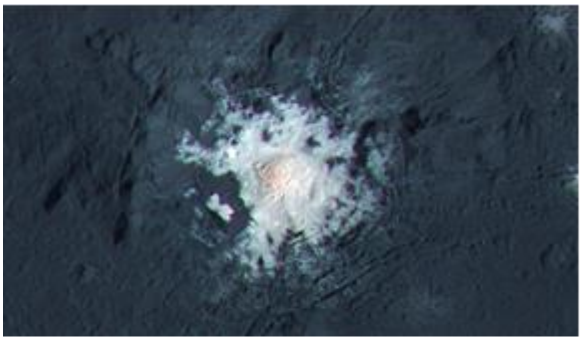

Figure 1. Cerealia facula on the dome of Occator crater. The dome is fractured as if it were pushed up from below. The bright material is mainly sodium carbonate.

The distribution of the material on the Occator crater suggests that this material was produced inside Ceres in brine-fed hydrothermal systems that brought this material to the surface [3]. Moreover, sodium and ammomium salts have been also identified [3]. Many if the compounds observed on Ceres are also identified in the Enceladus' plume suggesting some similarities between these bodies.

Some regions on Ceres show the presence of organics, identified by a strong absorption at 3.4 µm in the spectra [11]. The signature is extremely strong and clear indicating a high quantity of organics (fig.2). The main candidates for the 3.4 µm absorption are materials containing C-H bonds, including a variety of organic materials. The Ceres band at 3.3-3.5 µm shows marked similarities with the organic bands of terrestrial hydrocarbons, like asphaltite and kerite, considered to be analogues for asteroidal and cometary organics. It is also very similar to the organic 3.4 µm observed in Insoluble Organic Matter (IOM) extracted from the carbonaceous chondrites. The overall characteristics of the 3.3-3.5 µm band (shape, position, intensity) discovered on Ceres indicate unambiguously the presence of organic material on this dwarf planet.

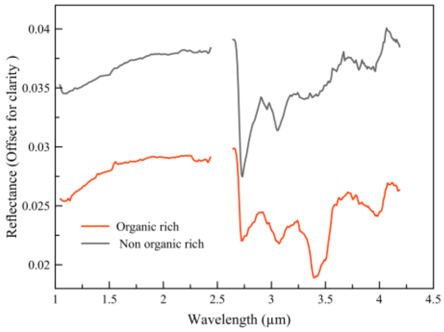

Figure 3. Red-line: Ceres organic-rich spectrum; gray-line: Ceres generic spectrum.

Liquid water is the first potential indicator of habitability on the Solar System bodies (planets and satellites). Ceres is very appealing in terms of habiltability. It has clear signs of fluids circulation in the recent past or even now, presence of acqueous alteration products, water ice and organic material. Moreover, Ceres experiences mild temperatures on the surface and resides in the habitable solar system region

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Short Summary

Ceres, is the largest body in the main belt, and the Dawn mission allowed to understand better this intriguing body. The mission has spent over two years orbiting Ceres, assessing the characteristics of its surface and interior. Here we report about the main results of the mission, with particular care of the astro-biological implications.

Hazards from asteroid impacts and the Space Situational Awareness programme

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1. Introduction

Asteroids are considered as potential sources for the building blocks of life on Earth. Impacts onto our planet and also other solar system objects may have affected the capabilities of bearing living organisms. A good understanding of the asteroid environment will therefore contribute to understanding habitable worlds.

2. The SSA-NEO programme

Since 2009, ESA has been building up the so-called Space Situational Awareness programme. It consists of three so-called segments: Space Weather, Space Surveillance and Tracking (of artificial space objects) and near-Earth objects. The last one - henceforth called SSA-NEO - deals with asteroids that may come close to the Earth and pose a potential impact threat. While currently focusing on understanding the impact threat onto our planet, one of the requirements stated in the Customer Requirements Document says 'The European SSA-NEO segment shall provide impact assessments (probability, location, brightness of fireball, time) for the Moon and other planets (Mercury, Venus, Mars, Jupiter, Saturn) over a time scale of 100 years'.

This presentation will give an overview of the current state of the SSA-NEO segment. The focus is on being able to collect NEO observations, compute precise orbits from the observations, propagate them 100 years into the future, and predict possible Earth impacts. The segment is building up capabilities to observe and discover new solar system objects by developing a 'NEO Survey Telescope'. It is also extending its capabilities to determine and archive they physical properties of asteroids.

These activities make the SSA-NEO segment an interesting data source for studying habitability issues in our solar system and beyond.

Short Summary

This presentation describes how the SSA-NEO segment can contribute to better understanding asteroids and other solar system bodies as habitable worlds.

A New concept of Asteroid Mitigation using Expulsion Payload in Spacecraft system

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1. Introduction

The recent studies by international space university identify Thermo-Nuclear Devices, Directed energy system as gives better a set of recommendations for better preparation to mitigation of asteroid. These studies are highly drawback to developing experimental work in future. This paper presents a suitable of experimental work in real time model to mitigation of Asteroid and compares the performance with simulation work through different liquid propellants. In principle this can be achieved by a spacecraft that carries a Expulsive payload which is including liquid propellants [liquid Hydrogen, Liquid Oxygen], laser beam, Arduino Controller. The trajectory path is dispense to Spacecraft , placed at a distance of a few asteroid diameter would need the controller is ON ,the continuously the liquid propellant onto the Asteroid surface ,the same time as ignite the liquid propellant throughout laser beam in order to vaporize surface material, hence transferring a continuous force to the Asteroid. We model evaporation progression and vapour highly growth to demonstrate that the functionality exists. Therefore a multi spacecraft system might only be applicable to Asteroid with size > 200m.

2. Tables

S.NO	Methods	Advantageous
1	Combustion process in Surface of Asteroid (g/m^2/s)	Evaporation rate is Increased compared to Surface Ablation & Laser Ablation.

3.Reference :

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Short Summary

Liquid propellants[Liquid hydrogen,Liquid Oxygen],Arduino Microcontroller,Laser Beam.

Probing asteroids with remote sensing and sample return

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1. Asteroid relevance

The origin of the solar system is one of the fundamental questions that we seek to understand, and tells us not only about the birth of our own Sun and the planet that is our home, but also informs us of some of the key processes at the heart of the very development of Life on Earth itself. Two of the key ingredients for Life may have been delivered to Earth after the main formation event, with the delivery of water and complex organic molecules by asteroids and/or comets. However, questions remain unanswered as to how the Earth acquired so much water, having formed from a hot, dry part of the disk of gas and dust from which the solar system formed.

Small bodies, as primitive leftover building blocks of the solar system formation process, offer clues to the chemical mixture from which the planets formed some 4.6 billion years ago. In addition, they retain material that predates the solar system and contains evidence for interstellar processes and its original formation in late-type stars. Current exobiological scenarios for the origin of Life on Earth invoke an exogenous delivery of organic matter: primitive bodies could have brought these complex organic molecules capable of triggering the pre-biotic synthesis of biochemical compounds on the early Earth. It has been proposed that carbonaceous chondrite matter (in the form of planetesimals down to cosmic dust) could have imported vast amounts of complex organic molecules capable of triggering the prebiotic synthesis of biochemical compounds [1].

For these reasons, asteroids and comets have been targets of interest for missions for over three decades.

2. Presence of water

Small bodies may have been the principal contributors of the water and organic material on Earth. Pioneer works [2, 3, 4] found that about 60 % of the C-class asteroids, at heliocentric distances between 2.5 and 3.5 AU, have undergone some kind of aqueous alteration process. Aqueous alteration is a low-temperature chemical alteration of compounds by liquid water which acts as a solvent and produces secondary minerals such as phyllosilicates, sulphates, oxides, carbonates, and hydroxides. It also plays a major role in the modification and synthesis of organics. Several transitions are only possible in the presence of liquid water on the surface of the object. Related spectral features, found on several meteorites and asteroids, indicate that liquid water was present on their surface during some previous epoch. Moreover, water ice and organics were recently observed on the surface of three asteroids of the C-complex, (24) Themis, (65) Cybele [5, 6] and (1) Ceres by DAWN mission [7].

It remains unclear from where the water for the Earth's oceans came. Models of the early solar system indicate that accretion at 1 AU and the energy released during this process would have led to a body poor in water. Comets are a major available source of water in the solar system, but the D/H ratio of water measured in a number of comets is in general much higher (by a factor of 2-3) than that of the Earth's oceans [8]. The mean D/H ratio of carbonaceous chondrites appears to be much closer to that of the oceans – and therefore primitive asteroids originally from the main belt may be considered as the potential delivery mechanism for the abundance of water now present on the Earth that is so essential for all life.

3. Present and future small body exploration

The outstanding success of the Rosetta mission highlights the importance of studying primitive minor bodies. The Rosetta mission provided unique new insight into the nature of comet 67P/ Churyumov-Gerasimenko, but the instruments aboard Rosetta and Philae were not able to define the organic material present on its surface. In fact, the type and quality of information that can be obtained from a rendezvous and remote landing mission is always heavily compromised by the resource limitation of instruments carried by spacecraft.

Fly-bys provided the first close-up views of these objects and led to major advances in our knowledge of their physical properties and evolution. However, remote sensing gives only limited information on their composition, and even in-situ measurements that could be made by a lander are limited by the resources available. Only a mission returning a sample of primitive material will be able to answer the fundamental questions and in fact all the major space agencies are planning sample return missions with the two missions recently launched by JAXA, Hayabusa2 to the C-type asteroid Ryugu and by NASA, OSIRIS-REx to the B-type asteroid Bennu. Space missions of sample return from primitive near Earth asteroids (as

OSIRIS-Rex and Hayabusa-2) will provide insight to the abundance and isotopic signatures of water on asteroids.

Only in the laboratory can instruments with the necessary precision and sensitivity be applied to individual components of the complex mixture of materials that forms an asteroid regolith, to determine their precise chemical and isotopic composition. Such measurements are vital for revealing the evidence of stellar, interstellar medium, pre-solar nebula and parent body processes that are retained in primitive asteroidal material, unaltered by atmospheric entry or terrestrial contamination. It is no surprise therefore that sample return missions are considered a priority by a number of the leading space agencies.

Asteroids could even one day be a vast new source of scarce and precious material if the financial and technological obstacles can be overcome and discussions start to learn how to mine them. Asteroids are lumps of metals, rock and water. The numerous number of asteroids start to be considered by space industries as possible source of water as it is a critical life-support item for a spacefaring civilization. Moreover water can provide with its constituent hydrogen and oxygen in-situ sources for rocket fuel.

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Short Summary

The relevance of asteroid for the origin of the solar system and the condition of Life apparition on Earth, as well as the state of the art of asteroid exploration are presented.

Habitability potential of icy moons around giant planets and the JUICE mission

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1. Introduction

When looking for habitable conditions in the solar system, recent studies focus on the natural satellites of gas giants, rather than the terrestrial planets only. Indeed, the habitable zone may be larger than defined by the traditional concept where liquid water exists on the surface of a planet or a natural satellite. The strong gravitational pull caused by the giant planets may produce enough energy to sufficiently heat the interiors of orbiting icy moons. And several satellites show evidence for harboring organic chemistry in their atmospheres or exospheres. The outer solar system satellites then provide a conceptual basis within which new theories for understanding habitability can be constructed. Measurements from the ground but also by the Voyager, Galileo and the Cassini spacecraft revealed the potential of these satellites in this context, and our understanding of habitability in the solar system and beyond can be greatly enhanced by investigating several of these bodies together [1].

2. Habitats in the jovian system

Indeed, several of the moons show promising conditions for habitability and the development and/or maintenance of life. Europa, Callisto and Ganymede may be hiding, under their icy crust, putative undersurface liquid water oceans [2] which, in the case of Europa [3], may be in direct contact with a silicate mantle floor and kept warm by tidally generated heat [4].

Such potential habitats can only be investigated with appropriate designed space missions, like ESA's L1 JUICE (JUpiter ICy moon Explorer) for Ganymede and Europa [5] and NASA's Europa Clipper mission.

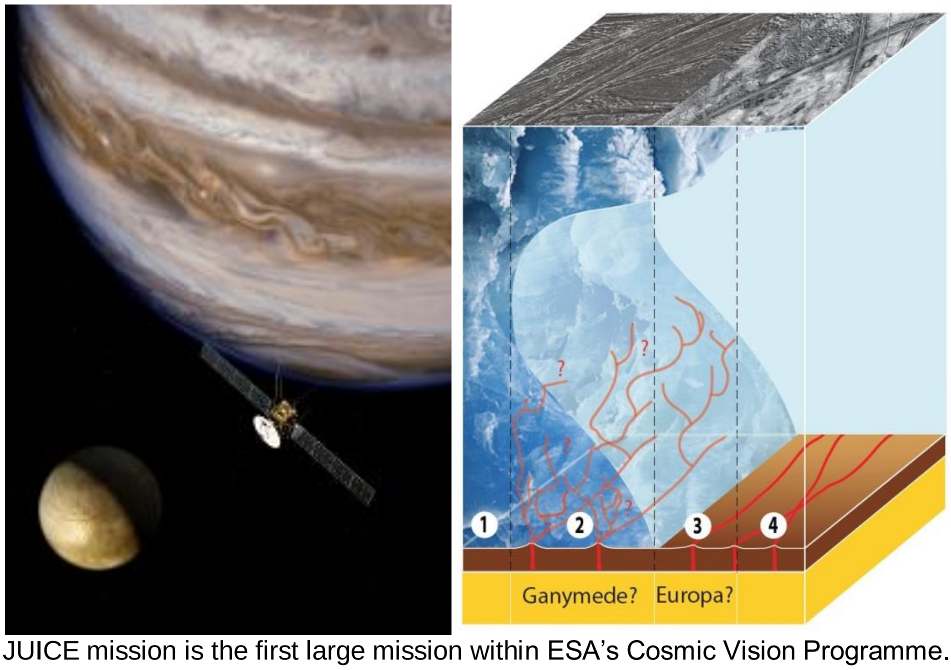

Figure 1: The JUICE mission is the first large mission within ESA's Cosmic Vision Programme. It will launch in 2022 aiming to study the emergence of habitable moons around Jupiter, with emphasis on Ganymede, but also Europa and Callisto, and the Jovian system [5].

3. Habitats in the kronian system

Titan and Enceladus, Saturn's satellites, were found by the Cassini-Huygens mission to possess active organic chemistries with seasonal variations [6], unique geological features and possibly internal liquid water oceans. Titan's rigid crust and the probable existence of a subsurface ocean create an analogy with terrestrial-type plate tectonics, at least surficial [7], while Enceladus' plumes find an analogue in geysers. As revealed by Cassini the liquid hydrocarbon lakes [8] distributed mainly at polar latitudes on Titan are ideal isolated environments to look for biomarkers.

Titan has been suggested to be a possible cryovolcanic world due to the presence of local complex volcanic-like geomorphology and the indications of surface albedo changes with time [9,10]. Such dynamic activity that would most probably include tidal heating, possible internal convection, and ice tectonics, is believed to be a pre-requisite of a habitable planetary body as it allows the recycling of minerals and potential nutrients and provides localized energy sources. In a recent study by [4], we have shown that tidal forces are a constant and significant source of internal deformation on Titan and the interior liquid water ocean can be relatively warm for reasonable amounts of ammonia concentrations, thus completing the set of parameters needed for a truly habitable planetary body.

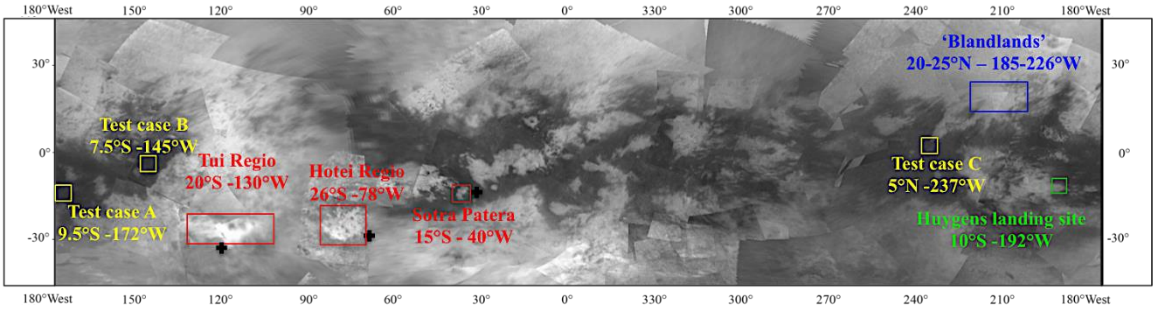

Figure 2: Map of Titan's surface showing possible active regions [10].

4. Conclusions

If the silicate mantles of Europa and Ganymede and the liquid sources of Titan and Enceladus are geologically active as on Earth, giving rise to the equivalent of hydrothermal systems, the simultaneous presence of water, geodynamic interactions, chemical energy sources and a diversity of key chemical elements may fulfil the basic conditions for habitability.

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Short Summary

Several of the icy moons in the outer solar solar present conditions which may be favorable for habitability, like the presence of liquid water underneath the surfaces, organic chemistry and energy sources. Future space missions will investigate that potential.

Mass spectrometry of astrobiologically relevant organic material - Implications on future space missions to ocean worlds in the outer Solar System

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1. Introduction

Most astrobiologists agree that it is fundamental to characterize the abundance of various amino acids and fatty acids in the search for extraterrestrial life. For future space missions these investigations are possible with impact ionization detectors [1,2] that assess the abundance of these key species in ice grains that might emerge from ocean bearing moons like Enceladus and Europa. Since amino acids exist also in comets and other primitive bodies it is crucial that biotic and abiotic fingerprints of these organic substances can be distinguished.

2. Analog experiment

With our worldwide unique setup in Heidelberg we are able to generate analog mass spectra of amino acids, peptides and fatty acids in ice grains. It simulates the impact ionization mechanism in space instruments by an IR Laser intersecting an ultra-thin water beam. The resulting spectra have been demonstrated to be highly comparable to those of icy particles detected by impact ionization space detectors like the Cosmic Dust Analyzer (CDA) on board the Cassini spacecraft [2] or the Surface Dust Analyser (SUDA) on board the future Europa Clipper mission [1]. The experimental setup (FL-MALDI-ToF-MS) consists of a vacuum chamber (5×10^{-5} mbar) in which a water beam (radius of 7.5 µm) is inserted. Chemical substances like amino acids and fatty acids are dissolved in water. A pulsed infrared laser hits the beam of the aqueous solution. In this way ions, electrons and neutral molecules of the dissolved substances and water are created. The generated cations as well as the anions can be detected in a commercial ToF mass spectrometer.

3. Results

Our laboratory results show a high sensitivity on the tested substances. The detection limits are in the ppm or even ppb range. Different amounts of the organic substances lead to different intensities of the related peaks in the mass spectra. We are able to easily differentiate between biotic and abiotic signatures of amino acids and fatty acids in the analog spectra. Peptides can also be reliably characterized. By comparing the laboratory results with spacecraft data we have the ability to recognize and distinguish such signatures in ice grains from icy moons with a subsurface ocean. In the future we aim to create a comprehensive mass spectral reference library for in situ mass spectrometers in space from a wide variety of organic analog materials in icy grains.

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Short Summary

With our experimental setup mass spectra of impact ionization space detectors can be accurately reproduced. Biotic and abiotic signatures of organic key compounds important for the origin of life like amino acids can be distinguished in the laboratory and compared to mass spectra of ice grains of ocean bearing moons.

Organic compounds in ice grains from the subsurface ocean of Enceladus

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Cassini's on board mass spectrometers – the Ion and Neutral Mass Spectrometer (INMS) [1] and the Cosmic Dust Analyzer (CDA) [2] – have measured the plume of gas and ice grains ejected from Enceladus' south pole [3] that are linked directly to the moon's subsurface global ocean [4]. CDA provided evidences that the ocean is in contact with the rocky-core [5] and there is an on-going hydrothermal activity [6]. The detection of molecular hydrogen by INMS [7] not only confirmed water-mineral interaction but also indicates the geochemical process serpentinization to occur, similar to some of Earth's hydrothermal systems like Lost City [8]. The INMS has already detected multitudes of organic species in the gas phase [1] and CDA has indicated organic material in the ice grains [9]. In this work, we present a detailed compositional analysis of organic bearing ice grains and infer the composition of refractory organic components. Compared to the volatile organics detected by INMS, CDA detects larger and more complex organic compounds in the ice grains emitted from Enceladus' subsurface.

The Chemical Analyzer (CA) subsystem of CDA produces cationic time-of-flight (tof) mass spectra of hyper velocity grains impinging onto a rhodium metal target. From CDA mass spectra three compositional types of ice grains have already been identified [5,9]: Type 1 - almost pure water ice, Type 2 - organic enriched and Type 3 - salt rich. In contrast to Type 1 and Type 3, Type 2 spectra show a great diversity indicating varying contribution of different organic compounds. To infer the organic compounds we have used our analogue experiment in Heidelberg to reproduce different CDA spectra. A micron-sized water beam with dissolved substances is exposed to an infrared laser. As a result cations, anions and neutral species of water and the dissolved substances are produced that are very similar to those from the impact ionization process of ice grains observed with CDA [5]. Cation spectra are recorded by a commercial tof mass spectrometer and are used as analogue spectra for CDA ice impacts.

Aqueous solutions of a variety of organic compounds were tested to simulate different impact energies of impinging Type 2 grains onto the CDA metal target occurring at varying impact velocities. The simulation of organic compounds in a water matrix allows us to further classify CDA Type 2 spectra and attribute them to certain classes of organic compounds. Our results show that a substantial fraction of Type 2 grains contains at least three kinds of organic compounds: (i) amines (ii) carbonyls and (iii) aromatics. In ice grains spectra amines are identified by significant ammonium cations, carbonyl compounds are specified by characteristic acylium cations and aromatic species are identified by a series of aromatic fragment cations. In addition to the identified features Type 2 spectra often show contributions from other yet un-specified organic species that require more investigation in future. Our results show a strong indication of different organic compounds in ice grains emerging from the subsurface ocean. Like other inorganic products previously identified [6, 7], the observed organic species might be linked to hydrothermal sites [10] and be used to characterize their habitability.

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Short Summary

We are presenting a detailed compositional analysis of organic bearing ice grains emanating from the subsurface ocean of Enceladus. The results show that Cassini's onboard mass spectrometer, the Cosmic Dust Analyzer (CDA), has detected atleast three kinds of organic compounds.

JUICE: A European Mission to Jupiter and its Icy Moons

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1. Introduction

JUICE - JUpiter ICy moons Explorer - is the first large mission in the European Space Agency Cosmic Vision programme. The implementation phase started in July 2015. JUICE will be launched in June 2022 from Kourou, and will arrive at Jupiter in October 2029. It will spend three years characterizing the Jovian system, the planet itself, its giant magnetosphere, and the giant icy moons Ganymede, Callisto and Europa [1,2]. JUICE will then orbit Ganymede for almost a year.

2. The science objectives

The main goal is to explore the habitable zone around Jupiter. Ganymede is a high-priority target because it provides a unique laboratory for analyzing the nature, evolution and habitability of icy worlds, including the characteristics of subsurface oceans, and because it possesses unique magnetic fields and plasma interactions with the environment. On Europa, the focus will be on recently active zones, where the composition, surface and subsurface features (including putative water reservoirs) will be characterized. Callisto will be explored as a witness of the early Solar System. JUICE will also explore the Jupiter system as an archetype of gas giants. The circulation, meteorology, chemistry and structure of the Jovian atmosphere will be studied from the cloud tops to the thermosphere and ionosphere. JUICE will also investigate the 3D properties of the magnetodisc, and will study the coupling processes within the magnetosphere, ionosphere and thermosphere. The mission also focuses on characterizing the processes that influence surface and space environments of the moons.

3. The payload

The payload consists of 10 instruments plus a ground-based experiment (PRIDE) to better constrain the S/C position. A remote sensing package includes imaging (JANUS) and spectral-imaging capabilities from the UV to the sub-mm wavelengths (UVS, MAJIS, SWI). A geophysical package consists of a laser altimeter (GALA) and a radar sounder (RIME) for exploring the moons, and a radio science experiment (3GM) to probe the atmospheres and to determine the gravity fields. The in situ package comprises a suite to study plasma and neutral gas environments (PEP) with remote sensing capabilities via energetic neutrals, a magnetometer (J-MAG) and a radio and plasma wave instrument (RPWI).

4. The trajectory

The mission profile can be divided into two main parts: an interplanetary transfer to Jupiter, and the transfer to a Ganymede bound trajectory during the science phase at Jupiter. The mission is based on a launch from the Centre Spatial de Guyane in Kourou (CSG) with Ariane 5 ECA. The baseline launch is 1st of June 2022, which is in the middle of a 20 days launch window. There are backup launch slots two or three times per year. The interplanetary transfer sequence relies on gravity assist with Venus, the Earth and Mars. The Jupiter orbit insertion will be performed in October 2029. The tour of the Jupiter system starts with a series of four Ganymede swing-bys that reduce the orbit energy, the inclination and the infinite velocity, and which initiate the Europa science phase, one year after the Jupiter insertion. The Europa science phase is composed of two fly-bys, separated by 15 days, with closest approach at 400 km altitude. The next phase is a 200-day period characterised by an excursion to moderate inclinations, in order to investigate regions of the Jupiter environment away from the equatorial plane. A series of resonant transfers with Callisto gravity assists raises the inclination with respect to Jupiter's equator to a maximum value of 29 deg. After decreasing the inclination again, the spacecraft is then using Callisto and Ganymede flybys to prepare the insertion into Ganymede orbit, in September 2032. The science phase around Ganymede is decomposed first into an elliptic subphase, a circular orbit at 5000 km altitude followed by a second elliptic subphase, and then a circular phase at 500 km altitude. The total duration of the Ganymede orbital phase is about nine months, the end of the nominal mission being planned in June 2033. The spacecraft will eventually impact the surface, in line with planetary protection.

5. References

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Short Summary

JUICE will be launched in June 2022 from Kourou, and will arrive at Jupiter in October 2029. It will spend three years characterizing the Jovian system, the planet itself, its giant magnetosphere, and the giant icy moons Ganymede, Callisto and Europa. JUICE will then orbit Ganymede for almost a year.

Program Options to Explore Ocean Worlds

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1. Introduction

Our solar system contains at least a dozen 'ocean worlds' of multiple types [1, 2], where liquid water poses astrobiological potential. Some of these worlds may be habitable, and all of them are extreme: one with ubiquitous life even deep in the crust; relict ocean worlds that had surface water (Mars) and interior mud oceans (Ceres); multiple large and small icy moons of the gas giants Jupiter and Saturn, and even distant Kuiper Belt Objects like Triton, Pluto, and Charon where liquid water clearly drives geology. Since these worlds contain the sum total of all tangible evidence available to humanity in our quest to find life beyond Earth, we must likely explore them all to "learn the limits of life" in the cosmos [2]. Given other priorities, and the daunting space flight technology challenges involved, gradual exploration of these tantalizing places could take centuries.

Alternatively, a structured 'ocean worlds exploration program' (OWEP) conducted over many decades starting now could become a defining scientific pursuit for the 21st century, a grand challenge energized by its existential significance for humankind's view of our place in the universe. Structured programs require strategic planning and organization, which requires in turn a scientific-strategic roadmap that lays out options, multiple paths, and priorities capable of aligning and focusing effort and investments. This presentation summarizes strategy analysis performed in 2016-17 to inform OWEP planning.

2. Analysis

The analysis treats in turn the major elements of a structured program, including how they differ from precedent, how they could be adapted for the OWEP purpose, and implications of implementing them.

2.1. Target priorities

Among the confirmed ocean worlds, three stand out as the primary targets for a combination of scientific and programmatic reasons: Europa (likely the most propitious place for life to have arisen); Enceladus (known to be habitable by today's standards and by far the easiest place to look directly for biosignatures); and Titan (extensive organics synthesis, with possible interaction with a vast interior salt-water ocean). Each world would advance different aspects of the total quest, and all are targets of NASA mission plans and proposals.

2.2. Technical constraints

The three primary ocean worlds are all harder to explore than the surface of Mars. Europa is 2-5 years from Earth and orbits within Jupiter's harsh radiation environment. Enceladus and Titan are more benign, but also have thick, cryogenic ice crusts and are 5-10 years from Earth. Each world introduces unique considerations and challenges, but six key capabilities needed to explore all three are not yet matured for space flight: planetary protection of and from ocean-world material; 'life-detection' measurement techniques and instruments; sample acquisition, handling, and preservation; cryogenic mechanisms and electronics; modular radioisotope power sources; and autonomous exploration that can conduct complex science investigations out of touch with Earth.

2.3. Lessons from MEP

The closest precedent for a structured scientific exploration program is NASA's Mars Exploration Program (MEP), which offers both positive and cautionary lessons. Six points of comparison allow mapping MEP lessons to the unique challenges of an OWEP: 1) almost all OW mission concepts are technically more challenging than Mars missions, which collectively have cost NASA about ~$10B (FY17) over a quarter century; 2) OW missions cannot respond to emergent results on the half-decade timescale Mars missions can, due to celestial mechanics; 3) core technologies and capabilities should be developed outside the framework of individual flight projects, to assure strategic objectives and cadence are met; 4) ongoing operational infrastructure 'lowers the bar' for individual missions, and in the case of distributed OW exploration this primarily means heavy-life launch and in-space propulsion; 5) sheltering individual flight projects within a budget-line-item would give the managing agency planning and replanning flexibility; and 6) a class of medium-size, 'directed purpose' missions can form 'connective tissue' that sustains progress on a strategic roadmap.

2.4. OWEP program options

The analysis describes, compares, and estimates the cost of six potential, progressive scenarios for an OWEP, ranging from the status quo, through the strategic use and adaptation of the New Frontiers program, to creation of a $1B directed-purpose mission class and strategic OW technology program, to establishment of a formal OWEP. The most aggressive of these case studies would cost about 1/40th more than today's NASA budget. The value proposition of this investment can be compared to other types of investments by society.

3. Conclusions

The half-century of planetary exploration done to date has yielded a trove of important places to conduct detailed science investigations that can reveal the limits of life in the cosmos. Given today's state of technology and program opportunities, pursuing this quest among the ocean worlds of our solar system will take a very long time. For example, under today's constraints, a principal investigator active today, born in 1960, would be 75 years old by the time the first biosignature results could be returned from Europa or Enceladus, or both, in about 2035. A structured OWEP would allow the planetary science and astrobiology communities to increase the velocity, scope, and depth of this grand challenge.

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Short Summary

Strategic analysis of options for a structured program to explore the ocean worlds of our solar system. These worlds contain all the tangible evidence humanity can access regarding the existence and nature of life beyond Earth. Only a structured program can yield results in our lifetime.

Processing of Cometary surface by swift ions (Poster Flash Talk)

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1. Introduction

In the last years, a great variety of experimental work have been performed to analyze the chemical transformations of astrophysical ices exposed to cosmic ray analogs and other agents (Moore et al 2003, Palumbo et al. 2006, Pilling et al. 2010, Pilling et al. 2011). These experiments have helped the comprehension of observational data from space telescopes (for example ISO and Spitzer) and spacecrafts like ROSETTA, that provided detailed data about the composition of 67P/Churyumov-Gerasimenko comet (Carpaccioni et al. 2015).

In this work we conducted an experimental study on the effects of medium-mass highly charged and energetic ions with astrophysical ice analogs with composition H_2O,CO_2,CH_4 (10:1:1) and H_2O,CO_2,CH_4:NH_3 (10:1:1:1). The experiment were conducted in physicochemical condition similar to the ones found in comets and other cold surfaces of solar system such as Enceladus and other solar system objects. We investigate the stability and chemical changes of the ices, determine the effective dissociation (destruction) cross section of parent species molecules and the effective formation cross sections of formed species (e.g. CO, CO_3, H_3COH) in the sample from the radiolysis.

2. Methodology

We used the facilities at the heavy ion accelerator GANIL (Grand Accelerateur National d'Ions Lourds) in Caen, France. The analysis of data sets were performed in-situ by employing Fourier transform infrared spectroscopy (FTIR) in a transmission mode. The frozen sample at 72 K was bombarded by 15.7 MeV O^{+5} ions up to the fluence of 3.10^{14} ion cm^{-2} simulating the incoming cosmic rays and/or solar energetic particles in the interplanetary ices. Figure 1 shows a schematic picture of the apparatus.

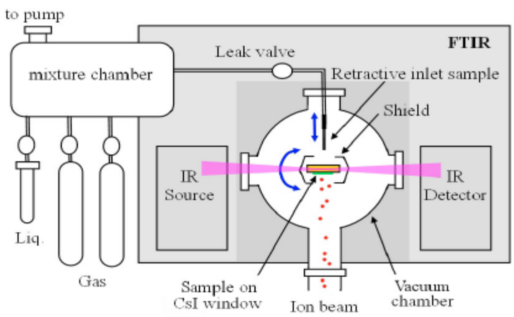

Figure 1: Schematic diagram of the experimental set-up.

3. Results

We measure the area of IR bands of parents and daughter species varying with the fluence. With this measurement we could calculate the effective cross section for destruction/formation of species and consequently other physicochemical parameter, as half-live and EBR. Figure 2 shows the graph of the difference areas of some selected bands of parent and daughter species for H_2O,CO_2,CH_4 (10:1:1) ice , that is related to the effective destruction/formation cross section by:

$$A - A_0 = A_{\infty}(1 - \exp(-\sigma_{d,f} F)) \quad [\,cm^{-1}\,], \qquad (1)$$

where F is the fluence (in ions cm^{-2}), A, A_0 , and A_∞ are the areas of the infrared band area at a given fluence (A), for the unirradiated sample (A_0), and at the highest fluence (A_∞). In this equation, $\sigma_{d,f}$ represents the effective formation cross section (σ_f) of new formed species or the effective destruction cross section (σ_d) of parent species, in cm^2 (see also Pilling & Bergantini, 2015).

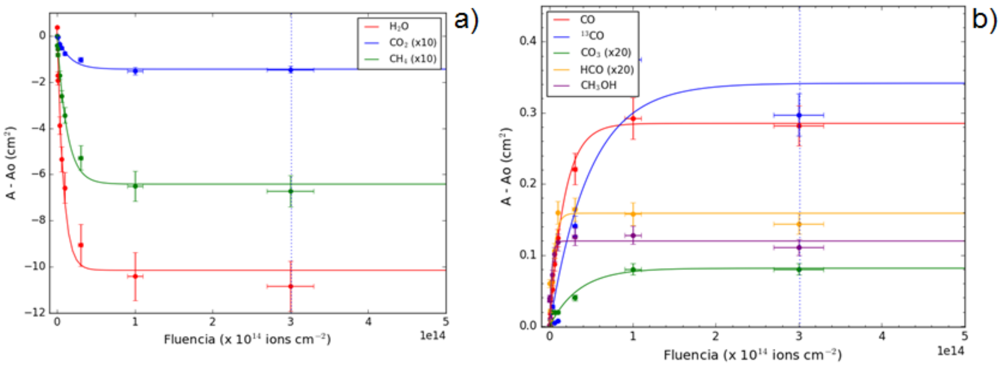

Figure 2: a) Difference area of parent specie bands for H_2O,CO_2,CH_4 (10:1:1) ice; b) Difference area for daughter species bands

Another parameter of interest is the EBR (Equilibrium branching ration). The EBR is the relative abundance of detected new molecules after the system reach chemical equilibrium. Using the column density of daughter species at infinite fluence we calculate the EBR for daughter species, given by:

, (2)

where n_i is the column density of each identified species after the icy sample reaches chemistry equilibrium (higher fluences). The calculated EBR for the detected and assigned species are show in are 75% for CO, 23,1% for CH_3OH, 1% for HCO and 0,12% for CO_3. The CO was the main product of the radiolysis.

4. Summary and perspectives

We studied the chemical transformation of astrophysical ices with composition H_2O,CO_2,CH_4 (10:1:1) and H_2O,CO_2,CH_4:NH_3 (10:1:1:1) under cosmic ray analogs bombardment. We calculated physicochemical parameters of astrochemical interest and studied the composition of such ices in equilibrium. Currently, we are studying the chemical transformation of ices with similar composition when exposed to low energy ions (solar wind and low energy magnetospheric particles). This will give us a more complete scenario of the interaction of cosmic rays with astrophysical ices and chemical changes that are going on in ice bodies of interplanetary medium.

5. Acknowledgement

The authors acknowledge the Brazilian agencies FAPESP (Projects JP 2009/18304-0, IC 2014/08643-0, DR 2012/17248-2 and MS 2016/11334-5) and CNPq (Research fellowship 304130/2012-5 and 306145/2015-4).

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Short Summary

We conducted an experimental study on the effects of medium-mass highly charged and energetic ions with astrophysical ice analogs with composition H2O,CO2,CH4 (10:1:1) and H2O,CO2,CH4:NH3 (10:1:1:1). The frozen sample at 72 K was bombarded by 15.7 MeV O+5 ions to simulate the effect of cosmic ray bombardment in astrophysical ices in the solar system.

Evolution of Atmospheres, Outgassing History, and Water Inventories of terrestrial planets

H. Lammer

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1. Introduction

The origin and evolution of the terrestrial planet atmospheres are discussed since their protoplanets have been released from the protoplanetary disk a few million years after the Sun/star and the planets originated. The early disk-embedded phase of the evolution of protoplanetary cores, that can accumulate nebular gas and form thin planetary hydrogen-envelopes, is discussed. As illustrated in Fig. 1, this formation scenario is compared to cases of late stage planet formation where terrestrial planets accrete from large planetary embryos after the protoplanetary gas disk already disappeared.

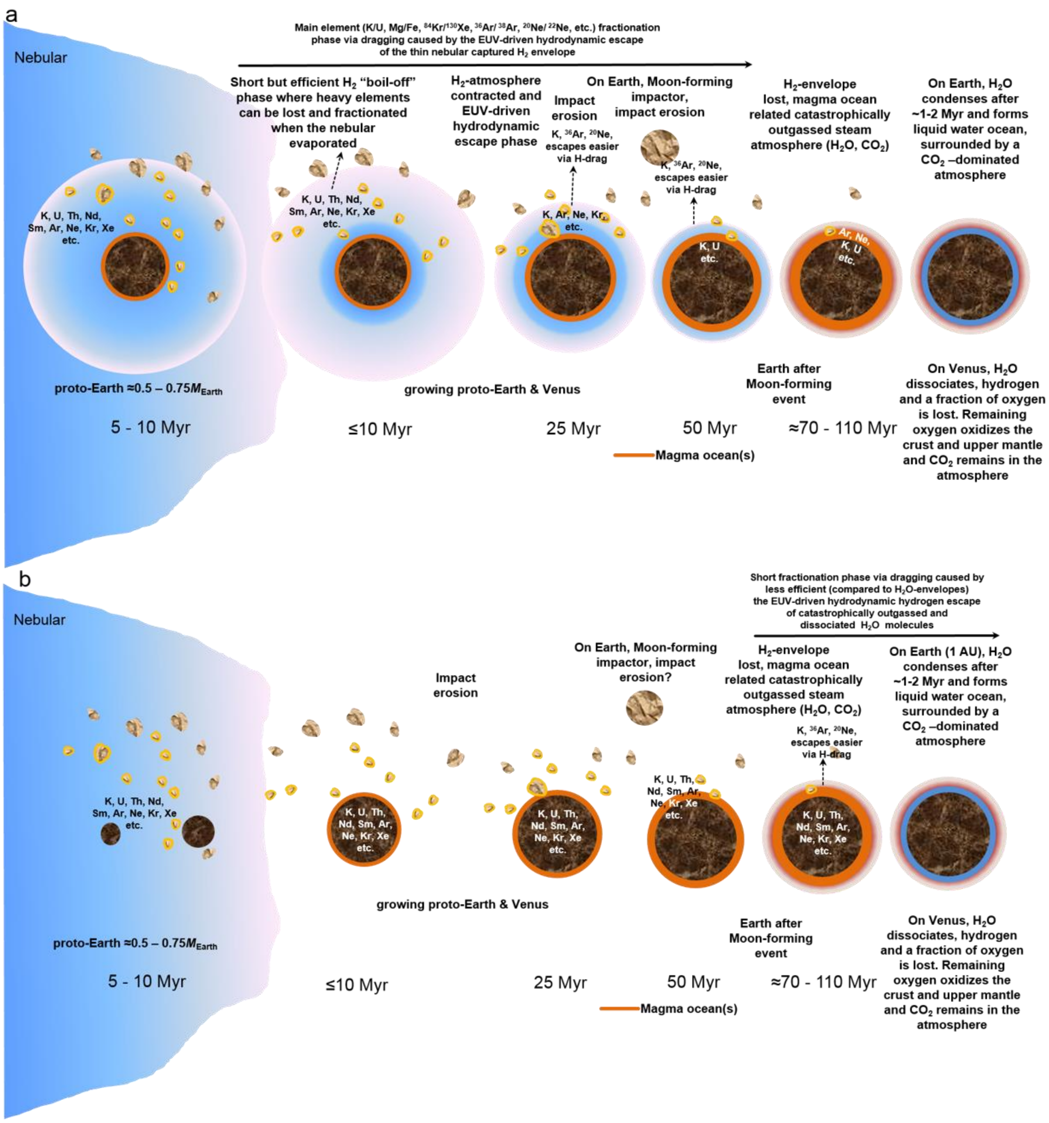

Figure 1: a) Protoplanetary cores accrete fast while they are embedded in the gas disk. A H_2-envelope can be captured and should be lost during a short boil-off phase, the young Sun/stars high EUV radiation and impacts. b) Late-stage accretion means that the planet forms mainly after the gas disk disappeared. Both scenarios are accompanied by the solidification of magma oceans and related catastrophic outgassing, leading to steam atmospheres and later to secondary outgassed atmospheres.

After the loss of the primordial atmospheres caused by the EUV radiation of the active young Sun/star, the catastrophic outgassing of volatiles (i.e., H_2O, CO_2) and the formation and cooling of steam atmospheres after the solidification of magma oceans is addressed together with the geochemical evidence of additional delivery of volatile-rich (i.e., H_2O, NH_3, HCN, CO_2, etc.) chondritic materials to early planets (i.e., Venus, Earth, Mars) during the main stages of their formation. On early Earth and possible similar exoplanets, the complex interplay between the atmosphere-surface-interaction related CO_2 carbonate-silicate cycle and surface weathering of atmospheric constituents is discussed. The differences that occurred on early Earth are then compared with the atmosphere evolution of one-plate planets like Venus or Mars during the first few hundred million years. The diversity between early terrestrial planets related to their geochemical, geodynamical and geophysical conditions, including plate tectonics, crust and mantle oxidation processes and the role of outgassed secondary N_2 atmospheres is also addressed.

2. Summary

A discussion on the implications of understanding Earth's and Venus geophysical and related atmospheric evolution in relation to the discovery of potential habitable terrestrial exoplanets finalizes and concludes the talk.

Short Summary

The origin and evolution of the terrestrial planet atmospheres are discussed since their protoplanets have been released from the protoplanetary disk. A discussion on the implications of understanding Earth's/Venus geophysical and related atmospheric evolution in relation to the discovery of potential habitable terrestrial exoplanets finalizes and concludes the talk.

Understanding our star and its influence on Earth with SOHO

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Originally planned for a two-year mission, the ESA–NASA Solar and Heliospheric Observatory, SOHO, has been operating for more than two decades by now. The satellite enjoys an uninterrupted view of our star from Lagrangian point L1, and its numerous mission extensions have allowed it to cover nearly all of two 11-year solar cycles, making it the longest-lived Sun-watching satellite to date. SOHO has returned a wealth of new information about the Sun, from its core through to the hot and dynamic outer atmosphere, the solar wind and solar energetic particles. Crucially, SOHO is relied upon today to monitor the effect of space weather on our planet, and it plays a vital role in forecasting potentially dangerous solar storms. These storms are typically driven by coronal mass ejections, or CMEs, which propel billions of tonnes of electrified gas from the Sun into space at millions of kilometers per hour. If Earth lies in the path of a CME our planet can be subjected to major geomagnetic storms, which may damage satellites, disrupt telecommunications, endanger astronauts and cause current surges in power lines. SOHO has studied more than 20 000 coronal mass ejections to date, pinpointing their sources on the Earth-facing hemisphere of the Sun, and determining their speed and direction to provide up to three days' warning – sufficient to take action on Earth. In addition to investigating how the Sun works, SOHO is the most prolific discoverer of comets in astronomical history, with the destinies of more than 3000 tracked as these icy worlds endured fiery encounters with the Sun.

Effects of Space weather on the ionosphere and LEO satellites' orbital trajectory in equatorial, low and middle latitude

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1. Introduction

We study the effects of space weather on the ionosphere and LEO satellites' orbital trajectory in equatorial, low- and mid-latitude (EQL, LLT and MLT) regions during (and around) the notable storms of October/November, 2003. We briefly review space weather effects on the thermosphere and ionosphere to demonstrate that such effects are also latitude-dependent, and well established in the literature. Following the review we simulate the trend in variation of satellite's orbital radius *r*, mean height *h* and orbit decay rate *ODR* during 15 October - 14 November 2003 in EQL, LLT and MLT. Nominal atmospheric drag on LEO satellite is usually enhanced by space weather or solar-induced variation in thermospheric temperature and density profile. To separate nominal orbit decay from solar-induced accelerated orbit decay, we compute *r*, *h* and *ODR* in three regimes viz. (i) excluding solar indices (or effect), where $h=h_0$ and $ODR=ODR_0$ (ii) with mean value of solar indices for the interval, where $h=h_m$ and $ODR=ODR_m$ and (iii) with actual daily values of solar parameters for the interval (*h* and *ODR*).

2. Data, scope and method

Data include daily variation in solar wind speed (V_{sw}) and associated particle density (PD), solar radio flux ($F_{10.7}$), geomagnetic (Ap), disturbance storm time (Dst) index and auroral electrojet (AE) during 15 October - 14 November 2003. We complement and/or update the data using NOAA's list of 'proton events that affected the Earth's environment', archival solar data (DSD) and SOHO/LASCO's CME catalog. Variations in V_{sw} and associated PD, $F_{10.7}$, A p , Dst index, AE during 15 October - 14 November 2003 is shown in figure 1. We simulate trend in variation of satellite's *r*, *h* and *ODR* at 450 km as it traverse the middle (around 60°), Low (around 30°) and equatorial (around 0°) latitudes. We also analyse the density (ρ) and temperature (T) of the thermosphere, because atmospheric drag force on LEOSs and consequent orbital decay strongly depends on the condition of the atmosphere (defined by ρ and T) through which they traverse.

1. **Figure**

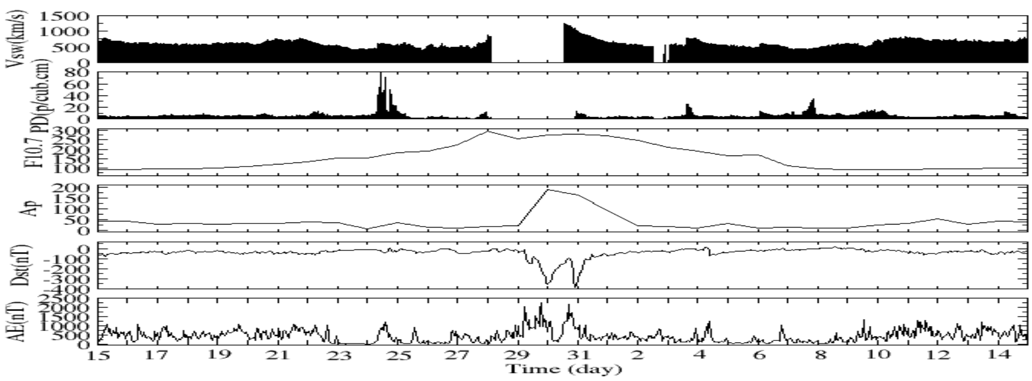

Figure 1: Daily variation of solar wind speed (V_{sw}) and associated particle density (PD), solar radio flux ($F_{10.7}$), geomagnetic Ap , disturbance storm time Dst index and auroral electrojet (AE) during 15 October - 14 November 2003.

3. Equations

We compute r, h and ODR from the following coupled equations [1],[2],[3].

$$\dot{v}_r = -\phi r^2 (A_s C_d / m_s), \qquad (1)$$

$$\dot{r} = v_r,$$

$$\ddot{\phi} = -\frac{1}{2} r \rho \dot{\phi}^2 \frac{A_s C_d}{m_s},$$

$$\dot{\phi} = v_\phi / r,$$

where v_r and v_φ are the radial and tangential velocity components respectively, r (sum of Earth's Radius (R_e) and h) is the radius of the orbit, A_s (1.1 m 2 is used here) is the satellite projected area with respect to the direction of motion, ρ is atmospheric density, m s (1100 kg in this case) is the mass of the satellite and C_d (3.7 in this case) is the dimensionless drag coefficient of the satellite.

4. Summary

For a typical LEO satellite at *h*=450 km, we show that the total decay in *r* with respect to EQL, LLT and MLT during the period is about 4.2 km, 3.9 km and 3.2 km respectively. While the respective nominal decay (r_0) is 0.4 km, 0.34 km and 0.22 km, solar-induced orbital decay (r_m) is about 3.8 km, 3.55 km and 2.95 km. Similarly, the respective nominal ODR_0 is about 13.5 m/day, 11.2 m/day and 7.2 m/day, while mean solar-induced ODR_m is about 124.3 m/day, 116.9 m/day and 97.3 m/day. We also show that severe geomagnetic storms can increase *ODR* (from daily mean value) by about 117%.

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Short Summary

We study the effects of space weather on the ionosphere and simulate the trend in variation of LEO satellite's orbital radius r, mean height h and orbit decay rate ODR in equatorial, low- and mid-latitude (EQL, LLT and MLT) regions during the notable storms of October/November, 2003.

Effect of ionizing radiation (X-rays and Cosmic rays) on frozen worlds

S. Pilling[1,2*]

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[2]*ITA-DCTA, Sao Jose dos Campos, Brazil,*

1. Introduction

The employment of soft X-rays and swift ions has been used in laboratory to simulate the physicochemical processing of astrophysical ice analogs by energetic photons and cosmic rays. This processing includes excitation, ionization and molecular dissociation, desorption, as well as triggers the formation of new compounds. Here we present some results from experiments employing infrared spectroscopy in two different laboratories: LNLS/CNPEM in Campinas/Brazil and GANIL/CIRIL/CIMAP in Caen/France. Among the results are, for example, the formation of alkenes and aromatic compounds during the irradiation of saturated hydrocarbon-containing ices by cosmic ray analogs, the production of the nucleobase adenine during soft X-ray photolysis of N_2:CH_4 ice, as well as the formation of peptide bonds during the bombardment of frozen glycine by cosmic ray analogs. The interaction between cosmic ray analogs and ionizing soft X-rays probed in the laboratory allows us to identify reaction routes that lead to chemistry enhancement of astrophysical ices and help us put constrains in prebiotic chemistry.

2. Experimental methodology

The experiments described here were performed employing two similar high-vacuum chambers at two different laboratories: the Brazilian Synchrotron light source (LNLS/CNPEM) in Campinas/Brazil, and the Grand Accélérateur d'Ion Lourdes (GANIL/CIRIL/CIMAP) in Caen/France. Briefly, the gaseous samples were inserted in the mixed chamber and the gas mixture was prepared in proportions similar to those observed in space environments (e.g. ices at protoplanetary disks PPDs, surface of Jovian moons, comets, etc.). For pure samples, only one type of compound is used. Basically, the pressure inside the mixed chamber is in the order of 10-100 mbars during sample preparation. The gas mixture (or pure sample) is usually inserted slowly into the main chamber trough an inlet needle with its end close to the IR-transparent cold substrate (e.g. ZNSe, KBr or CaF2) resulting in ice film formation (~ 0.02-0.1 micron min-1). The icy sample has thickness usually from 0.1-2 microns. The base pressure of the main chamber is around 1E-9 mbar. After ice production, an infrared spectrum is obtained to characterize the sample and its thickness. The molecular column densities and ice thickness of samples were determined from the relation between the measured IR band area of a given vibrational mode in the IR spectrum and its respective and band strength, B (cm molecule^{-1}) and average number density of ice, both taken from literature (details are given elsewhere [1-6])

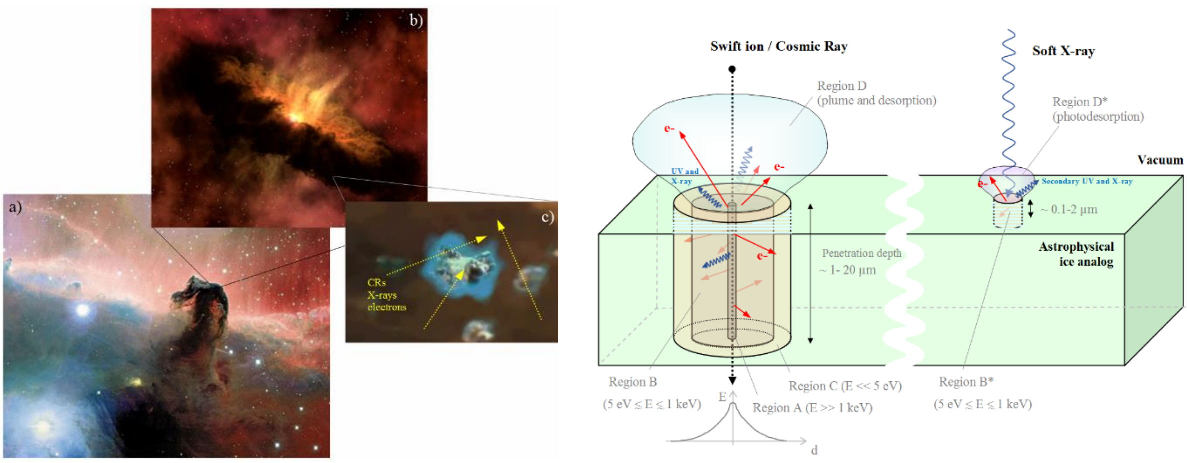

Figure 1: Mosaic with a schematic representation of the interaction between ionizing agents with interstellar grains inside dense clouds (also applicable to frozen worlds in space). Adapted from [12].

The in-situ IR spectra were recorded for ices irradiated at different fluences using FTIR spectrometer (e.g. Agilent Carry 630 or Nicolet Magna 550) from 4000 to 600 cm^{-1} with 1-2 cm^{-1} resolution. A background spectrum allowing the absorbance measurements was collected before gas deposition. From the analysis of the evolution of IR bands as a function of radiation fluence we derive molecular parameters such as effective destruction cross sections (for parent species) and effective formation cross section (for daughter species). Additionally, the desorption yield and molecular branching ratio at chemical equilibrium can be determined [7-11]. Such chemical equilibrium occurs at a large radiation fluence and the chemistry of the sample, kept at a constant temperature, stays constant even if the sample continues to be exposed to radiation. With such parameters, we can estimate the reaction rates and the half-life of parent species, as well as the yield of new compounds produced in the ices in astrophysical environments by knowing the radiation flux in space.

Figure 1 shows a mosaic with a schematic representation of the interaction between ionizing agents with interstellar grains inside dense clouds (also applicable to frozen worlds in space). A) Picture of the Horsehead Nebula b) Artist impression of a protostellar disk around a recently formed or forming star (NASA) c) Illustration of interstellar grains covered with an ice cap being processed by ionizing radiation (Cosmic rays, X-rays and electrons); d) Schematic diagram of the different physicochemical regions surrounding the ion and photon track during processing of the typical astrophysical ice by cosmic rays and soft X-rays). Adapted from [12].

3. Selected Results and Concluding Remarks

The interaction between cosmic ray analogs and ionizing soft X-rays probed in the laboratory and allow us to identify reaction routes that lead to chemistry enhancement of astrophysical ices. For example, cosmic rays can induce the formation of alkenes and aromatic compounds (with eventual H_2 release to the gas phase) during the irradiation of saturated hydrocarbon-containing ices, as well as the formation of peptide bonds in ices containing amino acids. Such organic compound production was also observed during the processing of N_2:CH_4 ices by soft X-rays with the appearance of the nucleobase adenine, among the products of sample irradiation. [13]

The results employing bombardment of astrophysical ice analogs by swift ions indicated that cosmic ray bombardment of saturated alkanes can be an alternative scenario for the production of unsaturated hydrocarbons and possibly aromatic rings (via dehydrogenation processes) in interstellar and protostellar ices. The results also indicate that a comparison between the laboratory spectra and IR observations of protostellar ices suggest that saturated hydrocarbons such as cyclohexane may be a part of the initial chemical inventory of interstellar ices. [14] Additionally, the processing of some Nitrogen-rich surfaces by ionizing radiation indicates the presence of the simplest proteinaceous amino acid, glycine, among the produced new species [2] and the radiolysis of glycine-rich ices by cosmic ray analogs indicates the formation of of peptide bonds [5]

The determination of the effective destruction and formation cross section in solid state allows us to estimate the molecular half-life extrapolated for astrophysical and help us put constrains also in prebiotic chemistry that may have triggered life to arise in the Early Earth [5,12,14].

Acknowledgement

The author acknowledges the Brazilian agencies FAPESP (Projects BPE 2016/ 22018-7; JP 2009/18304-0; IC 2014/08643-0; DR 2012/17248-2 and MS 2016/11334-5) and CNPq (Research fellowship 304130/2012-5 and 306145/2015-4), as well as FVE/ UNIVAP for the financial support. A special thank is given to the staff of UNIVAP and LNLS/CNPEM and GANIL/CIRIL/CIMAP for the technical support and help during the experiments.

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Short Summary

The employment of soft X-rays and swift ions has been used in laboratory to simulate the physicochemical processing of astrophysical ice analogs by energetic photons and cosmic rays. This processing includes excitation, ionization and molecular dissociation, desorption, as well as triggers the formation of new compounds.

High energy astrophysical hazards for habitability

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So far about 600 astronauts have spent substantial time out of the atmosphere. Since the Yuri Gagarin's short flight up to the last missions onboard the ISS, they have experienced very different conditions, thought sheltered by the protective Earth magnetic shield.

Only 24 people have flown in the outer space during the mission to the Moon and, so far,
the Apollo flights crew are still the only human exposed for several days to space environment. In fact, the human adventure out of the magnetosphere started with the Apollo 8 mission, the 21 December 1968, lasting 6 days and 20 revolutions around the Moon.

Among the Apollo program astronauts, only 12 of them experienced a "full" exposure to the external environment walking on the Moon surface for periods from a few to tens of hours.

The major astrophysical hazards to manned space flights are due to several types of radiation, such soft X-rays and gamma rays, and particle radiation from Galactic Cosmic Rays (GCRs) and **Solar Particle Events** (**SEP**), both including high energy protons, electrons and heavy nuclei, and radiation from secondary neutrons.

Although significant progress has been made in the last decades in the field of radiation biology, a major problem is presently to assess and limit the risk of effects due to long term exposure to GCRs and short term exposure to SEPs.

This work will address the main risks at which will be exposed astronaut crews during interplanetary long flights and surface activities, and the evaluation of possible shielding materials to improve their safety minimizing the radiation doses.

Short Summary

This work will address the main risks at which will be exposed astronaut crews during interplanetary long flights and surface activities, and the evaluation of possible shielding materials to improve their safety minimizing the radiation doses

Protecting our Planet from Extraterrestrial Life: Safe Solar System Exploration

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1. Introduction

For several decades the prioritisation for robotic exploration missions has been roughly: 'flyby, orbit, land, rove, and return samples for further study.' This prioritisation has reflected both the state of the technology available to each mission, as well as the state of the knowledge-base that each mission needed to depend on for success. More recent missions that have targeted comets and asteroids for the return of samples have reflected that same tiered approach and knowledge-base, and reflect our current understanding of those bodies in both their science and in the measures thought necessary to conduct them safely. Meanwhile, with the application of new technology and concomitant funding, space agencies are now beginning a serious attempt to return samples from solar system bodies that may have significant water as both ice and subsurface liquid, and one of the compelling themes about such missions is the potential for them to detect extraterrestrial life – either extinct or extant – a factor not seriously considered for sample return missions since the Apollo missions of the 1960s and 70s.

2. Responsibly addressing the possibility of life, elsewhere

In this paper a review of the criteria that are addressed in planetary protection policies (e.g., NASA, ESA, COSPAR [1]) to determine whether such a mission has an "unrestricted" or "restricted" Earth return will be given, and the logical implications for such missions (or suite of missions) gaining a "restricted" categorization will be discussed. In particular, the anticipated role of certain regulatory authorities and their relationship with the space agencies conducted such missions will be examined.

3. Reference

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Short Summary

A review of the criteria addressed in planetary protection policies to determine whether a mission has an "unrestricted" or "restricted" Earth return and the logical implications for missions given a "restricted" categorization. The anticipated role of certain regulatory authorities and their relationship with space agencies will be examined.

JWST Status and prospects for habitability studies

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The James Webb Space Telescope (JWST), developed jointly by NASA, the European Space Agency (ESA) and the Canadian one (CSA), is scheduled for launch in Spring 2019 and will be one of the major space observatories of the next decade. JWST will offer a unique combination of large collecting area, good spatial resolution, wide wavelength coverage (0.6-28.5 microns) and excellent stability. This is going to make it a very powerful tool for studying objects in our solar system as well as exoplanets.

In this talk, after giving a very brief update on the status of the mission, I will present the capabilities of JWST's instrument suite, with a focus on solar system observations, direct imaging of exoplanets and the study of transiting exoplanets.

I will then give an overview of the elements of the guaranteed time and early release science programs targeting our solar system and exoplanets. I will conclude with a short discussion on what prospects JWST will bring for habitability studies.

Short Summary

JWST will be a powerful tool for studying our outer solar system and exoplanets. I will first present the status and capabilities of the mission. I will then talk about the guaranteed time and early release science programs before concluding with a short discussion on what prospects JWST will bring for habitability studies.

Thursday 07 December 2017

Global climate models and extreme habitability

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1. Introduction

As It not easy to define life and what is needed for it, drawing a line between "habitable" and "not-habitable" is difficult. We usually postulate that "habitable = liquid water available" because liquid water seems required for life as we can imagine it, and because life on Earth has proven to thrive as long as some liquid water is available. Within that context, finding habitable environments is a matter of obtaining the right pressure and temperature conditions at the surface or in the interior of planets, in presence of H_2O. Surface habitability is thus primarily a problem of climate.

To first order, a planetary climate primarily depends on 1) The incident stellar flux; 2) The tidal evolution of the planetary spin (which can notably lock a planet with a permanent night side), and, 3) last but not least, the atmospheric composition and the volatile inventory. Assuming that the atmosphere and the other parameters are known, we can try to explore the possible environments using numerical climate model

2. A new generation of 3D climate models

In the past 20 years, on the basis of the Global Climate Models (GCMs) originally developed for the Earth, it has been possible to develop GCMs for the other terrestrial environments in our solar system: Venus, Mars, Titan, Triton, Pluto. This experience has suggested that realistic 3D climate simulators can be developed by combining components like a “dynamical core”, a radiative transfer solver, a parametrisation of subgridscale turbulence and convection, a thermal ground model, and a volatile phase change code. On this basis, our team and others around the world have undertaken to build realistic "generic" climate models able to predict the environment on any terrestrial planets that we can imagine, with any given atmosphere, around any star etc.

3. Extreme surface habitability

Such 3D climate models have been used to explore a wide range of exotic cases, including the surprising configurations that have been revealed when detecting extrasolar planets. These studies have shown that liquid water may be present on a wide range of worlds, sometime very different than the Earth. The possible configurations are countless: planet around stars very different than our Sun ; planet completely covered by an ocean, or, on the opposite, arid planets able to keep liquid water only around their poles ; planet with very thick atmosphere enabling a strong greenhouse effect and possibly hot oceans; tidally locked planet with a permanent nigh side and a permanent day side, etc.

We will describe some of these cases, and show that, whatever the accuracy of the models, predicting the actual climate regime on a specific planet remains challenging because climate systems are affected by strong positive feedbacks. They can drive planets with very similar forcing and volatile inventory to completely different states. For instance the coupling between temperature, volatile phase changes and radiative properties results in instabilities such as runaway glaciations and runaway greenhouse effect. Furthermore, our imagination is probably too limited when we try to predict the possible atmosphere that may be present on exoplanets. The atmospheric composition and mass depends on complex processes, which are even more difficult to model than climate itself: origins of volatiles, atmospheric escape, geochemistry, photochemistry, etc. Our theoretical knowledge is insufficient and our solar system experience is too limited. For this, observations are needed.

Short Summary

The possible climates on exoplanets can be explored using 3D Global Climate Models analogous to the ones developed to simulate the Earth and the other planets in the solar system.Such 3D models have shown that liquid water may be present on a wide range of worlds, sometime very different than the Earth.

The habitability of Proxima Centauri b

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Proxima b is a planet with a minimum mass of 1.3 $M_{\oplus}$ orbiting within the habitable zone (HZ) of Proxima Centauri, a very low-mass, active star and the Sun's closest neighbour. Here we investigate a number of factors related to the potential habitability of Proxima b and its ability to maintain liquid water on its surface [1].

The analysis of data from multiple facilities shows that the top-of- atmosphere average XUV irradiance on Proxima b is 0.293 W m^{-2}, that is, nearly 60 times higher than Earth, and that the total irradiance is 877±44 W m^{-2}, or 64±3% of the solar constant but with a significantly redder spectrum [2]. Interestingly, our spectral energy distribution analysis revealed a ~20% excess in the 3–30 μm flux of the star that is best interpreted as arising from warm dust in the system, possibly as a result of planet formation processes.

We discuss different scenarios regarding the time evolution of the star's spectrum [1,3], which is essential for modeling the flux received over Proxima b's lifetime. We show that Proxima b's obliquity is likely null and its spin is either synchronous or in a 3:2 spin-orbit resonance, depending on the planet's eccentricity and level of triaxiality. The evolution of Proxima b's water inventory follows from the spectral energy distribution and the calculation of the hydrogen loss from the planet using an improved energy-limited escape formalism. Despite the high level of stellar activity, we find that Proxima b is likely to have lost 0.5-2 Earth ocean's worth of hydrogen (EO_H), depending on the assumptions, before it reached the HZ 90–200 Myr after its formation. The largest uncertainty is the initial water budget, which is not constrained by planet formation models. From our work, we conclude that Proxima b is a viable candidate habitable planet. Additional studies on the current habitability of Proxima b will also be discussed [3,4].

If we assume that Proxima b could have retained enough volatiles to sustain surface habitability, one can use a 3D Global Climate Model (GCM) to simulate Proxima b's atmosphere and water cycle for its two likely rotation modes (the 1:1 and 3:2 spin-orbit resonances) [5]. We find that a broad range of atmospheric compositions can allow surface liquid water. On a tidally-locked planet with a surface water inventory larger than 0.6 Earth ocean, liquid water is always present (assuming 1 bar of N_2), at least in the substellar region. For smaller water inventories, water can be trapped on the night side, forming either glaciers or lakes, depending on the amount of greenhouse gases. The GCM also produces reflection/emission spectra and phase curves for the different rotations and surface volatile inventories. We find that atmospheric characterization will be possible by direct imaging with forthcoming large telescopes thanks to an angular separation of 7λ/D at 1 μm (with the E-ELT) and a contrast of ~10^{-7}. The magnitude of the planet will allow for high-resolution spectroscopy and the search for molecular signatures, including H_2O, O_2, and CO_2. Within a decade, it will be possible to image Proxima b and possibly determine whether this exoplanet's surface is habitable.

Finally, we briefly discuss if photosynthesis could function currently on Proxima b, in spite of having only 3% of the photosynthetically active radiation (400–700 nm) of Earth. Because of the very red spectrum, the oxygenic photic zone would be only ~10 m deep in water compared with ~200 m on Earth. Nevertheless, a substantial aerobic or anaerobic ecology could be possible on Proxima b [6].

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Short Summary

Proxima b is a planet with a minimum mass of 1.3 MEarth orbiting within the habitable zone of Proxima Centauri, a very low-mass, active star and the Sun’s closest neighbour. Here we investigate the potential habitability of Proxima b and its ability to maintain liquid water on its surface.

Exoplanetary systems dynamics and habitability

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Many observed giant planets lie on eccentric orbits. Such orbits could be the result of strong scatterings with other giant planets. The same dynamical instability that produces these scatterings may also cause habitable planets in interior orbits to become ejected, destroyed, or be transported out of the habitable zone. I show how by measuring the orbital properties of any surviving gas giants, one may infer the likelyhood that the system contains habitable worlds.

Sciencetown, Sciencecountry, 2001.

Short Summary

Many observed giant planets lie on eccentric orbits. Such orbits could be the result of strong scatterings with other giant planets. The same dynamical instability that produces these scatterings may also cause habitable planets in interior orbits to become ejected, destroyed, or be transported out of the habitable zone.

Habitability in the Trappist-1 and other exoplanetary systems around red dwarfs

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[2]Laboratoire d'astrophysique de Bordeaux, Univ. Bordeaux, CNRS, B18N, France
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1. Introduction

The very recent discovery of planets orbiting very low mass stars such as Proxima-b [1] and the TRAPPIST-1 system [9, 10] sheds light on these exotic objects. Planetary systems around low-mass stars and brown dwarfs (or ultra-cool dwarfs) are very different from our solar system: the planets are expected to be much closer than Mercury, in a layout that could resemble the system of Jupiter and its moons. The recent discoveries point in that direction with, for example, the system of Kepler-42 [13] and especially the system of TRAPPIST-1 [10] which hosts planets in a mean motion resonance configuration comparable to the one of the moons of Jupiter.

Ultra-cool dwarfs are thought 1) to be very common in our neighborhood and 2) to host many planetary systems [6]. As is the case for TRAPPIST-1, we expect that ultra-cool dwarfs can host a suite of small rocky planets. The planets orbiting in the habitable zone of these objects thus represent one of the next challenges of the following decades. Understanding the dynamical evolution of such systems and investigating their possible climates is now necessary. Indeed, planets in the habitable zone of ultra-cool dwarfs are the only planets of the habitable zone whose atmosphere we will be able to probe (e.g., using transit spectroscopy with the JWST, e.g [3], [4]).

2. Importance of stellar history on the potential habitability of planets

One major difference between ultra-cool dwarfs (UCD; T_{eff} <~ 3000 K) and Sun-like stars is that they cool down to settle on the main sequence after about 1 Gyr (see Figure 1 for TRAPPIST-1). Their habitable zones (HZ) thus sweeps inward at least during the first Gyr of their lives. Assuming they possess water, planets found in the HZ of UCDs have experienced a runaway greenhouse phase too hot for liquid water prior to enter the HZ. It has been proposed that such planets are desiccated by this hot early phase and enter the HZ as dry worlds [2,11].

Here, we present results of the modeling of the water loss during this pre-HZ hot phase taking into account recent upper limits on the XUV emission of UCDs and using 1D radiation-hydrodynamic simulations. We applied this model to Proxima-b in [14] and to the planets of TRAPPIST-1 in [5, 7, 8]. We find that there is a possibility that Proxima-b and the outer planets of TRAPPIST-1 to have retained a part of their potential initial water reservoir. However, our model shows that TRAPPIST1-b and c are likely dry.

3. Potential climates of planets around UCDs

Assuming a synchronized rotation, an important water content for the planets, a N_2, CO_2 atmosphere and using a global climate model (LMDz, e.g. [17]), we simulated the potential climate of Proxima-b [15] and the outer TRAPPIST-1 planets [16].

We find that there are configurations for which Proxima-b, TRAPPIST-1 e, f and g can harbour surface liquid water. While TRAPPIST-1 h is too cold to sustain liquid water.

We also investigated the impact of tidal heating on the climate of the TRAPPIST-1 planets. Just as in the Jovian system, the planet-planet interactions excite the eccentricities of the orbits [12]. The resulting eccentricities lead to an important tidal heat flux which can impact broad characteristics of the climates like the condensation of particular species on the night side.

We also looked at the feasibility of potential observations for Proxima-b with the E-ELT.

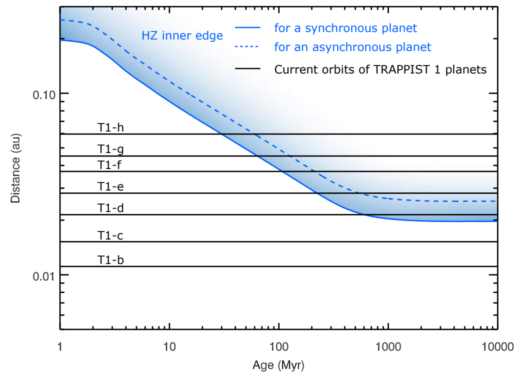

Figure 1: Architecture of the TRAPPIST-1 system and evolution of the inner edge of the habitable zone for two different hypotheses for the rotation rate of the planet: synchronized and asynchronized.

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Short Summary

The recent discoveries of planets around red dwarfs rise several questions regarding the habitability of these extreme worlds. How different is their history is compared to Earth? Could they host surface liquid water? What are the observational prospects?

I will talk about the efforts made to answer these questions.

Potential for Life on Trappist-1 and other Red Dwarf Star Planets

J. Gale[1], *A. Wandel*[1]

[1]*The Hebrew University, Jerusalem, Israel*

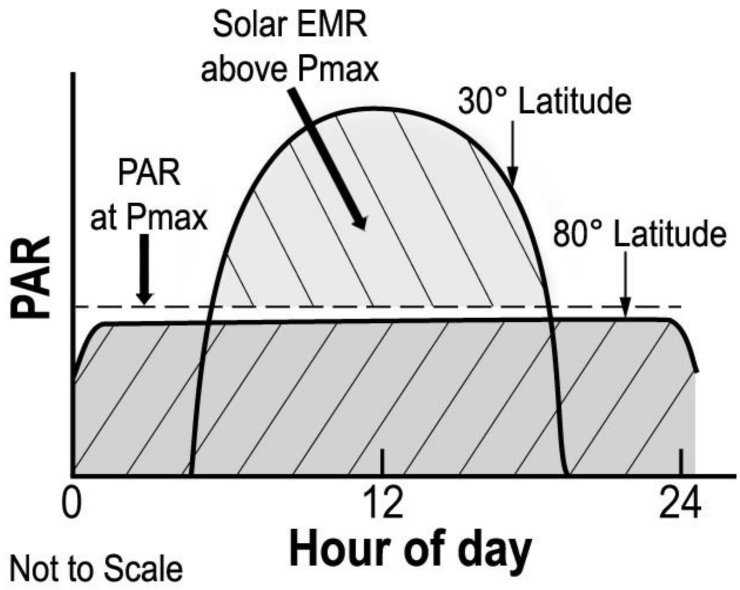
1. The Trappist-1 system

The To date seven planets have been detected orbiting the “nearby” Red Dwarf star Trappist-1 [1], but the number may be significantly greater. The star is relatively small (0.12 Rsun) and cool (2,550K) compared to our Sun (5,780K). Consequently its radiation flux is low (0.05% that of the Sun), mainly in the infrared, with a spectral peak at ~1μm, well above the Photosynthetically Active Radiation (PAR) waveband of 400 – 700nm, used by Earth vegetation.

2. Habitability and Oxygenic Photosynthesis

To date seven planets have been detected orbiting the “nearby” Red Dwarf star Trappist-1, but the number may be significantly greater than that obtained so far, by the transit, occultation method. The star is relatively small (0.12 Rsun) and cool (2,550K) compared to our Sun (5,780K). Consequently its radiation flux is low (0.05% that of the Sun), mainly in the infrared, with a spectral peak at ~1μm, well above the Photosynthetically Active Radiation (PAR) waveband of 400 – 700nm, used by Earth vegetation [2].

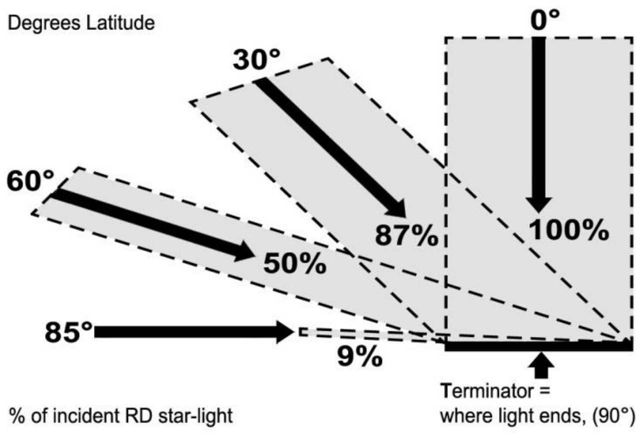
Figure 1: Diagram of the summer radiation regimes in mid and high latitudes on Earth.



3. The potential for life

The XUV radiation from Trappist -1 is much higher that of the Sun. This radiation could (possibly, but not necessarily) erode the primary atmosphere and oceans, and directly endanger life, unless life evolves in water or under a dense atmosphere. Dry land plants on Trappist-1 and other RDS planets could possibly evolve to utilize the infrared radiation between 700 and 1,000nm, which is energetically sufficient to drive water splitting oxygenic photosynthesis, an important precursor of complex life. These considerations and the abundance of RD stars, enhance the chance of finding other life clement abodes in the Milky Way [3].

Figure 2. Fig 2. Percentage incident radiation on Tidally Locked Planets as a function of Geographic Latitude.



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Short Summary

Many Earth Sized planets orbiting Red Dwarf stars have been reported in the last few years. From considerations of the radiation incident on these planets, both continuous and flaring, and by analogy to certain regions of Earth, we conclude that life, oxygenic photosynthesis and hence complex life could be supported.

Climate variations on water-rich circumbinary planets and their impact on habitability

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Planets orbiting close binary-star systems experience strong variations in insolation due to the non-trivial evolution of the distance between the planet and the two stars. Insolation variability on such a scale can have a significant influence on a planet's climate and, thus, on its habitability. Pervious work on the topic was based on one-dimensional climate models that lack important dynamical processes. We performed the first simulations of a hypothetical Earth-like circumbinary planet with a three-dimensional atmospheric general circulation model coupled to an analytic orbit propagator [1]. Choosing a Kepler-35-like setup we substituted the gas giant present in the actual system with an aqua-planet (fully water-covered planet) serving as a proxy for the Earth. We could show that an Earth-like circumbinary world has a similar climate to an identical planet orbiting our sun, if it receives the same amount of sunlight in the annual mean. Moreover, the absolute extent of the region around the binary star is somewhat larger than the habitable zone in single star systems. This makes rocky, circumbinary planets prime targets in the search for habitable worlds. The variations in insolation a terrestrial planet experiences in a binary star system have, however, various other effects on planetary climates. Signatures of periodic variations in important climate indicators such as surface temperature and precipitation appear. Those may make the interpretation of observations of such planets more challenging.

[1] Popp M. and Eggl S.: Climate Variations on Earth-like circumbinary planets, Nature Communications, 8:14957, 2017

Short Summary

We performed the first simulations of a hypothetical Earth-like circumbinary planet with a three-dimensional atmospheric general circulation model coupled to an analytic orbit propagator and show thus that rocky, circumbinary planets can be prime targets in the search for habitable worlds.

Radiation Environment near Exoplanets

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1. Introduction

Stellar winds and cosmic rays are an important factor, which determines the radiation Earth environment. Several candidates of terrestrial planet were discovered last years and it seems to be essential to clarify radiation conditions near them too. We present estimations of stellar wind parameters based on the Parker model, possible fluxes and fluencies of cosmic rays based on the available data of star's activity and magnetic field for Proxima Centauri and Trappist1.
For atmospheric implications it is interesting to know cosmic ray's flux near extrasolar Earth-like planets at the atmospheric boundary, which is determined by effects in the planetary magnetoshere considered in different papers [1, 3]. Authors of [4] supposed that for such planets the GCR rays flux can be regarded as an isotropic and approximately constant as near the Earth at the magnetospheric boundary, i.e. effects of CR modulation were not considered. However stellar wind velocity and magnetic field as well as an activity of other stars (especially red dwarfs) might be much higher in comparison with solar values and the modulation of GCR might be stronger.
Stellar cosmic rays (SCR) were considered in many papers [2, 7-8] as an important factor of space weather in a habitable zone of star. Since the details of SCR spectrum are unknown to model the effect of SCR one may use spectra of well known solar events [2] or average spectrum of solar proton events [8]. Another approach is to base on general physical principles [7] assuming solar-stellar analogies but not on near Earth observations of solar cosmic rays.
Below we use simple equations, which have been proposed in the beginning of space era and may give the necessary answers with accuracy of factor 2--3. The main reason for using this approach is that our knowledge about stellar activities the same as the knowledge of the Sun environments in the beginning of space era in 1950th.

2. Stellar wind and astrospheres

According to model developed by Parker [5] we may estimate a sound speed as a function of the coronal electron temperature, a distance to the critical point and stellar wind velocity . Using the velocity of stellar wind it is possible to estimate its density and derive a coronal temperature for which the critical point of stellar wind is at the coronal boundary , i.e. the maximal temperature for a quite corona.
Knowing the stellar wind parameters and the energy density of local interstellar medium we may estimate the radius of the astrosphere .

3. Galactic and stellar cosmic rays

In paper [6] was suggested that the modulation of GCR by solar wind occurs inside the solar wind shell, which extends uniformly and with spherical symmetry, from a solar distance out to . Stellar wind magnetic field is assumed in a form of the standard Parker spiral. Following [6] we may estimate how the steady state cosmic ray density inside the modulation shell is related to the galactic density outside.
Main modulation parameters are stellar wind magnetic field and velocity. Stellar wind velocities for stars of the same spectral class should not be very different, values of their magnetic fields may differ by one-two orders. As a result effects of GCR modulation might be much stronger and lead to a nearly total absence of GCR fluxes near some exoplanets as shown in Figure 1 for reasonable values near Proxima b. In this case radiation environment near exoplanets would be determined by fluxes of SCR, which should be mainly determined by a level of stellar activity and orbital parameters of the planet.

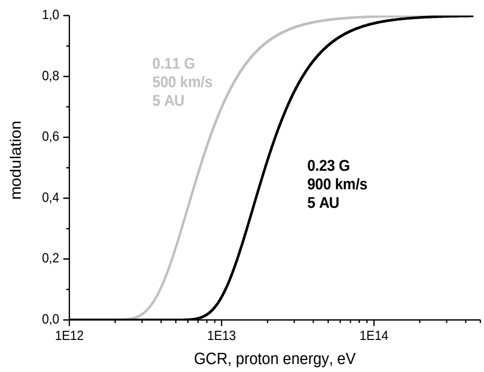

Figure 1: Dependence of modulation coefficient on proton energy near Proxima b

.	n, cm^{-3}		nV/2π, $(cm^2 s\ st)^{-1}$	
	V=484 km/s, 23AU	V=900 km/s 43 AU	V=484km/s 23 AU	V=900km/s 43 AU
30 MeV	1.2E-8	1.8E-9	0.099	0.025
200 MeV	1.7E-9	2.7E-10	0.013	0.0038

.

Table 1: Densities and fluxes of Proxima cosmic rays within the first turn of the Parker spiral

4. Conclusions

In paper we discussed the stellar winds and cosmic rays as an important factor of space weather which determine radiation environment near planets. We used the available parameters and made estimates for stellar winds, possible fluxes and fluencies of galactic and stellar cosmic rays near Proxima b and Trappist1. We obtained that the simple models, which were derived for the Sun in 1950^{th}-1960^{th}, can give the reasonable results for the parameters and conditions on the orbit of exoplanets. Using the available data we showed the level of cosmic rays activity in the habitable zone and influences of the stellar winds on it.
The work was partly supported by the Russian Foundation for Basic Research (grant 16-02-00328) and the Program 1.7 P2 of the Russian Academy of Sciences.

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Short Summary

Stellar winds and cosmic rays are an important factor, which determines the radiation environment of planets and exoplanets. We present estimations of stellar wind parameters using the Parker model, possible fluxes and fluencies of cosmic rays based on the available data of star's activity and magnetic field for Proxima Centauri and Trappist1.

On the bio-habitability of Red Dwarf planets and estimating the abundance of biotic planets with future telescopes

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1. Introduction

The Earth-sized planets detected in the Habitable Zone of Trappist-1, Proxima Centauri and numerous other M-type stars [1], suggests that biotic planets may be found around our nearest neighbor-stars [2,3]. A key condition in such a scenario is the question whether planets orbiting red dwarf stars could support life.

2. The bio-habitable atmospheric range

Using a simple model for the surface temperature distribution [4,5] we express the the habitable zone limits of red dwarf stars and the habitability condition for their planets in terms of the atmospheric pressure, composition and heat convection. We argue that habitable planets of red dwarf stars may have conditions for liquid water for a wide range of atmospheric properties. We apply these results to Proxima b and the Trappist-1 planets (fig. 1), elaborating on the hypothesis that Earthlike oxygenic photosynthesis could evolve on such planets and produce oxygen-rich atmospheres [6,7].

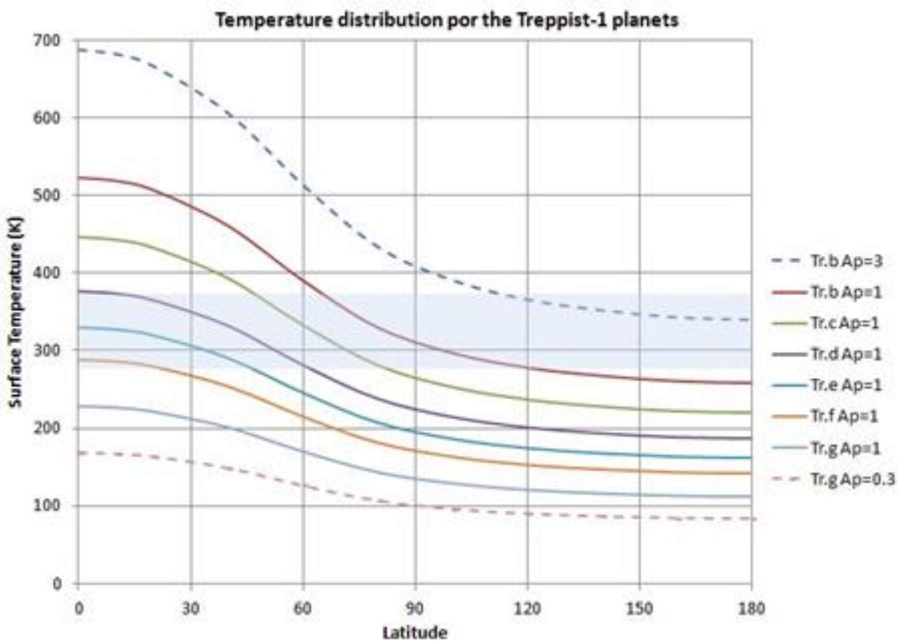

Figure 1: Surface temperature profiles for the Trappist-1 planets with an assumed Earthlike atmosphere (*Ap=1*) and with an an increased and decreased greenhouse effect (dashed). The temperature range of liquid water (at 1 bar) is indicated by the shaded blue area.

3. Estimating the abundance of biotic planets

These results are applied to predict the abundance of biotic planets from the spectral signature of atmospheric Ozone, Oxygen and water in planets of nearby M-stars, which may be obtained with JWST and other telescopes planned to be operational in the near future. We calculate the expected number of such planets as a function of the distance (fig. 2) at which future missions might be able to detect planetary spectral signatures. We discuss the implications to detecting M-dwarf planets that actually have liquid water and oxygen and suggest how it will be possible to estimate the abundance of such planets using TESS and future exoplanet missions. Observing a statistically significant sample of planets for spectral signatures of water and oxygen could yield an estimate of the abundance of biotic planets and of the probability for the evolution of organic life.

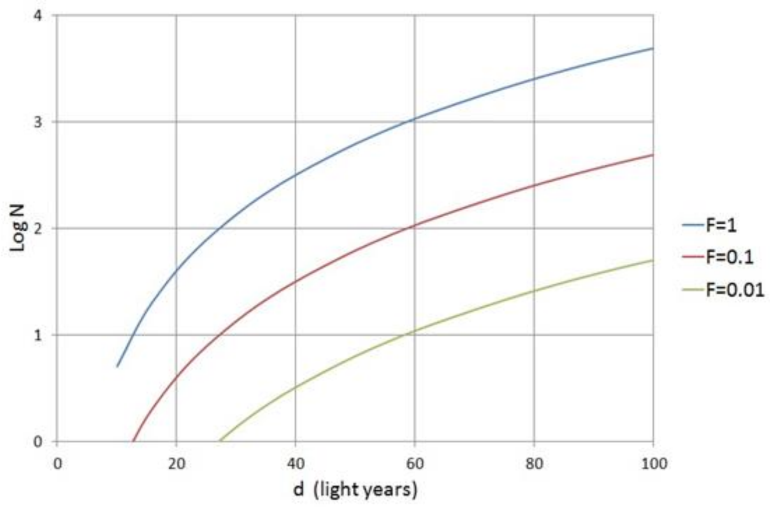

Figure 2. The number of planets with oxygenic bio-signatures expected within a distance d, for several values of the bio-habitability parameter F, the product of the abundance of biotic planets and the probability to find Earth sized planets in the HZ of red dwarfs.

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Short Summary

We estimate the number of M-star planets having biosignatures detectable with JWST and future missions. With a statistically significant sample of such planets it may be possible to estimate of the abundance of biotic planets and of the probability of life.

CHEOPS: Characterising exoplanet Satellite - ESA's first S-class mission

K. Isaak[1] , the CHEOPS Mission Consortium and the ESA CHEOPS Project Team.

[1]*ESA CHEOPS Project Scientist ESA/ESTEC, Noordwijk, The Netherlands*

Abstract

CHEOPS (CHaracterising ExOPlanet Satellite) is the first exoplanet mission dedicated to the search for transits of exoplanets by means of ultrahigh precision photometry of bright stars already known to host planets, with launch readiness foreseen by the end of 2018. It is also the first S-class mission in ESA's Cosmic Vision 2015-2025. The mission is a partnership between Switzerland and ESA's science programme, with important contributions from 10 other member states. It will provide the unique capability of determining accurate radii for a subset of those planets in the super-Earth to Neptune mass range, for which the mass has already been estimated from ground-based spectroscopic surveys. It will also provide precision radii for new planets discovered by the next generation of ground-based transits surveys (Neptune-size and smaller). By unveiling transiting exoplanets with high potential for in-depth characterization, CHEOPS will also provide prime targets for future instruments suited to the spectroscopic characterisation of exoplanetary atmospheres.

The high photometric precision of CHEOPS will be achieved using a photometer covering the 0.35 - 1.1μm waveband, designed around a single frame-transfer CCD which is mounted in the focal plane of a 30 cm equivalent aperture diameter, f/5 on-axis Ritchey-Chretien telescope.

20% of the observing time in the 3.5 year nominal mission will be available to Guest Observers from the Community. Proposals will be requested through open calls from ESA that are foreseen to be every year, with the first 6 months before launch.

In this talk I will give a short overview of the mission, its science objectives and its current status, as well as the observing opportunities that it will present to the Community.

Short Summary

CHEOPS (CHaracterising ExOPlanet Satellite) is the first exoplanet mission dedicated to the search for transits of exoplanets through ultrahigh precision photometry of bright stars already known to host planets. In this talk I will give an overview of the mission (launch ready end 2018), including observing opportunities for the Community.

The PLATO space mission and the quest for habitable worlds

A.M. Heras[1*]

[1]*Science Support Office, Directorate of Science, European Space Agency, Noordwijk, The Netherlands*

Invited talk

The PLATO mission has recently been confirmed as the M3 (Medium-class) mission in ESA's Cosmic Vision programme. PLATO will detect and characterise a large number of extrasolar planetary systems around bright stars, including hundreds of terrestrial exoplanets orbiting in distances up to the habitable zone of solar like stars. PLATO will provide accurate determinations of the planets radii and ages, the stellar irradiation, and the planetary system architecture. Thanks to the brightness of its targets, PLATO will enable us to measure accurate planetary masses and mean densities through the combination of satellite data and ground-based observations. As a result, it will be possible to distinguish between mini-gas planets and terrestrial planets, and therefore to identify worlds where life could exist as targets for spectroscopic atmosphere observations with other facilities. A deep knowledge of the planet host star, essential in the assessment of habitability, will be achieved with the asteroseismic analysis of the PLATO data. The planets detected by PLATO will show a great diversity of compositions and will orbit different types of stars, from solar-type and M-stars to Red Giants and binary systems. PLATO will also have the capability to discover exomoons. This rich variety of planets and environments will be a unique resource to enhance our understanding of habitability under a large range of conditions.

In this contribution, we will give an overview of the mission concept, science objectives, and present the mission design resultant from the recently completed Definition study.

Short Summary

The PLATO mission has recently been confirmed as the M3 (Medium-class) mission in ESA's Cosmic Vision programme. PLATO will detect and characterise a large number of extrasolar planetary systems around bright stars, including hundreds of terrestrial exoplanets orbiting in distances up to the habitable zone of solar like stars.

Discriminating habitable worlds from their atmospheric composition

Prof. G. Tinetti[1]

[1] *University College London, London, United Kingdom*

The acquisition of spectroscopic data of the Earth's atmosphere from artificial satellites has changed our perception of terrestrial life and has provided, for the first time, a rigorous scientific framework to search for life elsewhere in our Galaxy. Seen from the outside, our planet appears to be similar, for some aspects, to other planets, yet it shows distinctive signatures of a life-hosting planet, which cannot be found elsewhere in the Solar System.

Lovelock (1965) suggested to search for the presence of compounds in the planet's atmosphere which are incompatible on a longterm basis, i.e. in chemical disequilibrium – for example, oxygen and hydrocarbons co-exist in the Earth's atmosphere. While being the only recipe of biosignature currently available, is that a robust one?

The discovery of planets around other stars will offer in the next decades the chance to test this hypothesis outside the boundaries of our Solar System. While the number of discovered planets located at the right distance to the star to host some liquid water is increasing by the day, are those objects really habitable or inhabited?

From the little we know about these alien worlds, it appears we need to progress further in the understanding of galactic planetary science before we can commit to a conclusive answer concerning habitability. In this talk I will review the current knowledge about exoplanets and what are, in my view, the necessary steps to be taken in the future to address the question of planetary habitability.

Short Summary

The number of discovered planets located at the right distance to the star to host some liquid water is increasing by the day, are those objects really habitable or inhabited?
It appears we need to progress further in the understanding of non-habitable worlds before we can commit to a conclusive answer concerning habitability.

Characterizing Habitable Exoplanets with Interferometry

A. Quirrenbach[1*]

[1]*Landessternwarte, Zentrum für Astronomie der Universität Heidelberg*

1. Observing Habitable Worlds

The in-depth characterization of the physical and chemical properties of terrestrial exoplanets is an important long-term goal of exoplanet research. This will require spectroscopy with sufficient resolving power and SNR at both thermal and scattered wavelengths. A broad spectral coverage from visible to mid-IR is necessary to assess the radiative budget of the planet, which is the key to understanding its climate. In addition, it also enhances the number of observable spectral molecular signatures, making the identification of molecules more robust and minimizing the uncertainty on their abundances. Observations will also have to be spread over several orbital periods, with different sampling frequencies, in order to characterize the signal variability associated with climate, rotation, seasons, phases and variations in the stellar luminosity. Polarimetry combined with visible spectroscopy would also constitute an additional way to derive the atmospheric gaseous/particle content. Techniques to constrain the mass and radius of the planet will not only contribute to understanding the nature of the planets but will also strongly increase the information content of the spectra whose interpretation depends on both the gravity and the radius. The radius, in particular, allows converting observed fluxes into albedos (scattered light) and brightness temperatures (thermal emission). The radii and masses of non-transiting planets can be constrained from spectra, although at reduced accuracy and with reliance on suitable models.

2. Why Mid-Infrared?

With a low-resolution spectrum of the thermal emission, the mean effective temperature and the radius of the planet can be obtained. Furthermore, the mid-infrared spectral region (~6–20μm) contains a number of important spectral features that can be used to diagnose the presence of H_2O, CO_2, and O_3, which serves as a proxy for O_2 (Angel et al. 1986, Léger et al. 1996). Methane also has a strong absorption band in this spectral region, but it would be extremely difficult to detect in an Earth-like atmosphere. In the past, however, before the rise of oxygen, biogenic CH_4 may have been more abundant in the Earth's atmosphere by a factor 100–1000 (Catling et al. 2001); at this level it would also be detectable and serve as an indicator of bacterial life. One cautionary remark is in order, however: the detection and interpretation of infrared absorption bands could be complicated by the presence of cirrus clouds, which tend to reduce the depth of these features (Smith et al. 1993).

3. Mid-Infrared Means Interferometry

An instrument that aims at spatially resolving the planet from its host stars needs to provide sufficient angular resolution, i.e. of order 0.1" for a habitable-zone planet at a distance of 10pc. At visible wavelengths, this corresponds roughly to the resolution limit of a meter-sized telescope; in the thermal infrared an interferometer is needed to keep the unit telescope size reasonable. Working at very high contrast means that the starlight has to be rejected efficiently, and this in turn requires extremely precise control of the wavefront.

A space-based interferometer with starlight rejection capabilities – i.e. nulling (Bracewell 1978, Angel & Woolf 1997) – offers simultaneously the sensitivity, angular resolution and dynamic range needed to isolate and spectroscopically characterize the light of an exo-Earth in the ~6–20μm mid-infrared spectral domain. This technique is able to spatially resolve and discern the faint planetary photons from the 10^6 times brighter stellar flux, as well as from spurious sources like stellar leaks (due to resolved stellar disk), our own local Zodiacal cloud, the exozodiacal light, and the thermal emission produced by the instrument. Luckily, the mid-IR range is also where the otherwise huge flux contrast of the system is reduced.

A 10-year long activity on both sides of the Atlantic to select the optimal array geometry converged to the so-called Emma X-array configuration (Cockell et al. 2009). The baseline concept is an X-shape configuration of four 2-m collectors flying in formation at L2 over a 5-year duration. The beams are combined within an additional centrally positioned spacecraft, where destructive interference cancels out the light from the central star. The long and short baselines of the rectangular configuration are tunable from tens to hundreds of meters in order to uniquely optimize the transmission map of the interferometer to the size of the habitable zone, which directly depends on a given stellar spectral type. In the X-array arrangement, the respective destructive outputs of the two short-baseline Bracewell interferometers are combined with opposite phase shifts (±90°). This results in an internal “phase chopping” process (Mennesson 2005), which efficiently removes the thermal background and any emission from centro-symmetric sources around the nulled star.

The key enabling technologies (formation flying and starlight suppression by nulling) have been advanced substantially in recent years.

4. Conclusions

During the past few years, most efforts to develop mission concepts and technologies for habitable planet characterization have focused on the visible and near-infrared wavelength range, with coronographs and external occulters considered for the technical realization. However, our knowledge will remain incomplete without access to the thermal infrared, where most of the planetary flux is emitted. Nulling interferometry is the natural mission architecture in this wavelength range, driven by basic resolution requirements. Implementing such a mission appears entirely feasible with technologies whose foundations are well-understood and that could be brought to flight readiness within one decade.

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Short Summary

Invited talk on interferometry

Atmospheric characterization of extrasolar planets: from Earth to Moon

I. Snellen*[1]

[1]*Leiden Observatory, Leiden University, Leiden, The Netherlands*

In this talk I will first discuss the current status of characterization observations of extrasolar planet atmospheres, explaining the different techniques that are utilized. What information can and cannot be extracted from these distant worlds? Subsequently, I will particularly focus on techniques that are being used using ground-based telescopes. The future extremely large telescopes (ELTs) will be particularly geared towards studying the atmospheres of Earth-like planets, like that of Proxima b and those in the TRAPPIST family. Detection of potential biomarker gases like molecular oxygen could result in the first evidence of extraterrestrial life by the end of the next decade.

Short Summary

The future extremely large telescopes will be geared towards studying the atmospheres of Earth-like planets, like that of Proxima b and those in the TRAPPIST family. Detection of potential biomarker gases like molecular oxygen could result in the first evidence of extraterrestrial life by the end of the next decade.

Indexing of exoplanets in search for potential habitability: application to Mars-like worlds (Poster Flash Talk)

Abstract: Earth Similarity Index (ESI) ranges from 1 (Earth) to 0 (dissimilar to Earth). We established the calibration between surface and equilibrium temperatures of exoplanets. New approach called Mars Similarity Index (MSI) similar to ESI, to identify planets that may be habitable to the methane-specific forms of life.

J. M. Kashyap[1*]; *S. B. Gudennava[2], Urmi Doshi[3], M. Safonova[4]*

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Introduction

Study of exoplanets is one of the main goals of present research in planetary sciences and astrobiology. Analysis of huge amount of planetary data from space missions such as CoRoT and Kepler is directed ultimately at finding a planet similar to Earth. The Earth Similarity Index (ESI) is a first step in this quest, where the range from 1 (Earth) to 0 (totally dissimilar to Earth). It was defined for four physical parameters of a planet: radius, density, escape velocity and surface temperature. The ESI is further sub-divided into interior ESI (geometrical mean of radius and density) and surface ESI (geometrical mean of escape velocity and surface temperature)(Schulze-Makuch et al. 2011). The challenge here is to determine which exoplanet parameter(s) is important in finding this similarity; how exactly the individual parameters entering the interior ESI and surface ESI are contributing to the global ESI. Since the surface temperature entering surface ESI is a non-observable quantity, it is difficult to determine its value. Using the known data for the Solar System objects, we established the calibration relation between surface and equilibrium temperatures to devise an effective way to estimate the value of the surface temperature of exoplanets. ESI is a first step in determining potential exo-habitability, which may not be similar to a terrestrial life. Thus, we introduced a new approach, called Mars Similarity Index (MSI), to identify planets that may be habitable to the extreme forms of life. MSI is defined in the range between 1 (present Mars) and 0 (dissimilar to present Mars) and uses the same physical parameters as ESI. We are interested in Mars-like planets to search for planets that may host the extreme life forms, such as the ones living in extreme environments on Earth; for example, methane on Mars may be a product of the methane-specific extremophile life form metabolism(Webster et al).

Figures

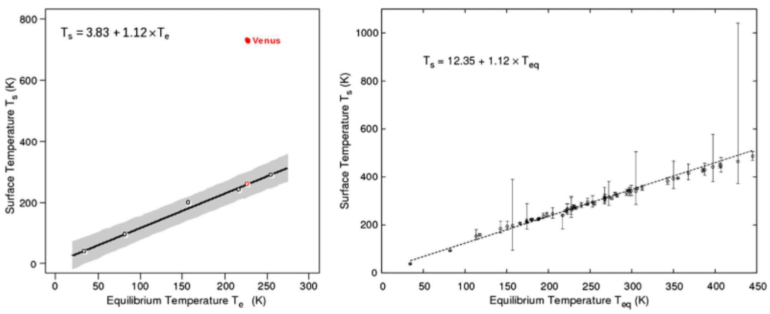

Fig. 1 Calibration of surface temperature: *Left*: Only Solar System objects with a linear fit. Venus was not used the fit due its very high surface temperature. *Grey colour* shows 95% prediction band for the model. The *red dot* on the fitting line is the predicted value for Venus. *Right*: of the exoplanets with temperature ranges.

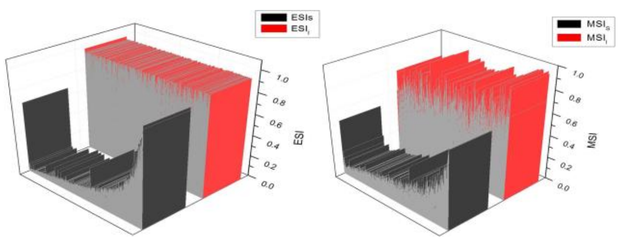

Fig. 2 Left: Interior and Surface ESI, right: Interior and Surface MSI for 1650 rocky planets.

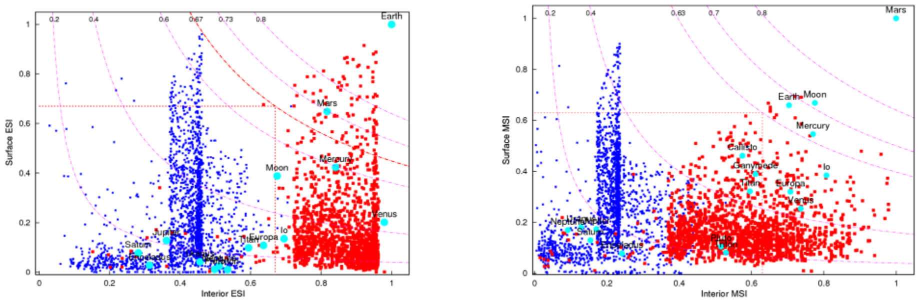

Fig. 3 Left: Plot of interior ESI versus surface ESI. *Blue dots* are the giant planets, *red dots* are the rocky planets, and *cyan circles* are the Solar System objects. The *dashed curves* are the isolines of constant global ESI, with values shown in the plot. However, the optimistic limit is~ 0.67. Right Plot is for MSI with optimistic limit of~ 0.63.

Tables

Table 1:The parameters for ESI and MSI scale

Planetary property	Reference values for ESI	Weight exponents for ESI	Reference values for MSI	Weight exponents for MSI
Mean radius (R)	1 EU	0.57	1 MU	0.86
Bulk density()	1 EU	1.07	1 MU	2.10
Escape velocity (V_e)	1 EU	0.70	1 MU	1.09
Surface temperature (T_s)	288 K	5.58	240 K	3.23

Equations

The ESI and MSI are mathematically expressed as:

$$ESI_x = \left\{1 - \left|\frac{x - x_0}{x + x_0}\right|\right\}^{w_x}$$

$$MSI_x = \left\{1 - \left|\frac{x - x_0}{x + x_0}\right|\right\}^{w_x}$$

Where, x is the physical property of the exoplanet (for example, radius or density), and x_0 is the reference to Earth in ESI, and to Mars in MSI, w_x is the weight exponents as mentioned in Table 1. The full dataset of ESI and MSI is available online (Kashyap et al. 2017).

Summary

In this investigation, we have collectted the data of 3566 exoplanets available online as archives and analyzed it for Earth Similarity Index (ESI) using the work of Schulze-Makuch et al. 2011, Mars Similarity Index (MSI). We have studied how exactly the individual parameters entering the interior ESI (geometrical mean of radius and density) and surface ESI (geometrical mean of surface temperature and escape velocity), are contributing to the global ESI using graphical analysis.The mean surface temperature parameter entering into the surface ESI is non-observable quantity. In the PHL-EC data, maintained by the PHL, this parameter is obtained by adding a correction factor of 30 K based on the Earth's greenhouse effect. The main limitation of this method is that it is not consistent with all the given exoplanet. Hence the calibration of surface temperure is introduced and analyzed. From our study, we found that 20 Earth-like exoplanets with ESI value above 0.8 are potentially habitable planets and 12 Mars-like planets with MSI above 0.63.

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Short Summary

Earth Similarity Index (ESI) ranges from 1 (Earth) to 0 (dissimilar to Earth). We established the calibration between surface and equilibrium temperatures of exoplanets.New approach called Mars Similarity Index (MSI) similar to ESI, to identify planets that may be habitable to the methane-specific forms of life.

Technology Roadmaps for Moon and Mars Exploration

G. Ortega[1]

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1. Introduction

Robotics and human space exploration space missions have brought astonishing accomplishments till date (e.g. 12 humans actually walking on the lunar surface).

A Global Exploration Roadmap GER is being developed by space agencies participating in the International Space Exploration Coordination Group (ISECG). The roadmap builds on the vision for coordinated human and robotic exploration of our solar system that was established in May 2007 and updated in 2011 and in August 2013. It reflects a coordinated international effort to prepare for collaborative space exploration missions beginning with the International Space Station (ISS) and continuing to the Moon, near-Earth asteroids, and Mars

In parallel, the European Space Agency is elaborating the technology exploration roadmaps that will in synchrony with the GER enable the ESA Member States to prepare for the upcoming complex missions yet to arrive.

2. The ESA road

The ESA roadmaps of technology for the exploration of the Solar System have been designed to set the goal of fostering robotics exploration with the final aim to support human exploration. Within those technology roadmaps, a set of key techniques and technologies play a special and remarkable role.

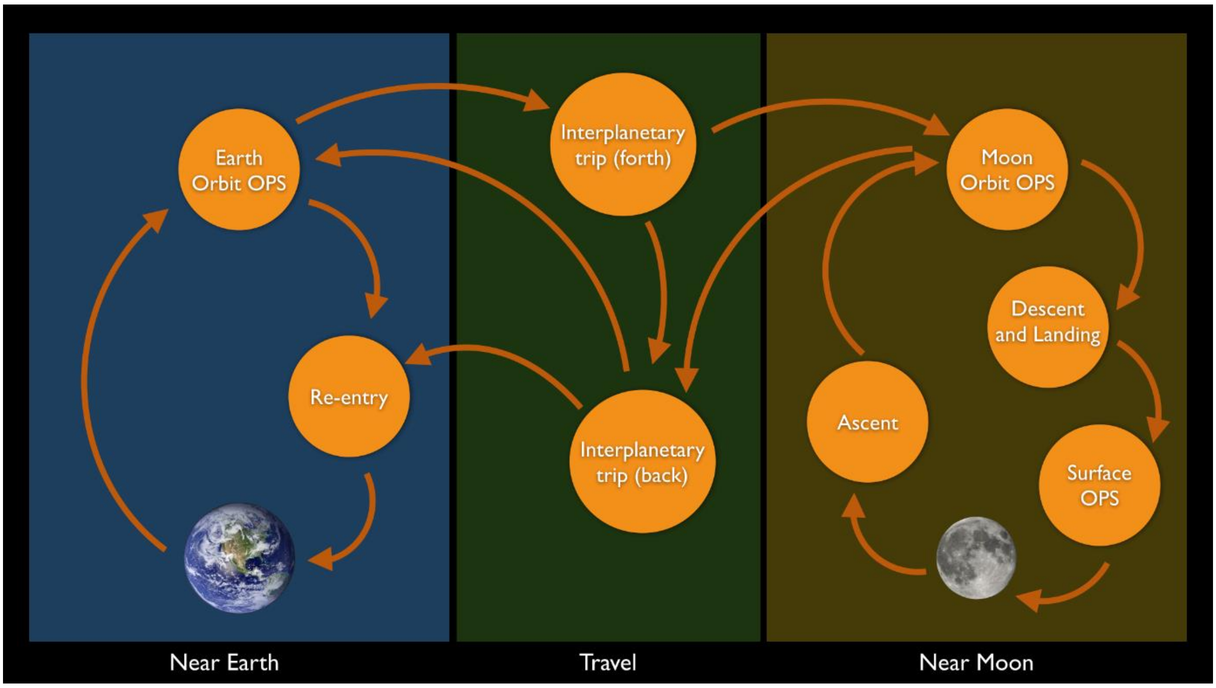

Figure 1: This is an example of a figure.

ESA initiated in 2013, under leadership of the Directorate for Technical and Quality Management, the development of its technology roadmaps for space exploration.

Two iterations of these roadmaps have been developed so far, one in 2013 and an updated version in 2015. A current iteration is on-going right now.

This talk provides a wide overview of the current technology roadmaps, programs, and activities in the area of space engineering, including planned missions for the Moon (South Pole landing), and Mars (sample return and human).

Short Summary

This talk provides a wide overview of the current technology roadmaps, programs, and activities in the area of space engineering, including planned missions for the Moon (South Pole landing), and Mars (sample return and human).

Moon & Mars Sample Return Analogue Deployment Validation

V. Hipkin[1*]

[1]*Canadian Space Agency, St Hubert, Canada,*

1. Introduction

The Canadian Space Agency (CSA) has been investing in science and technology development to position Canadian scientists and industry for a role in Mars Sample Return and human exploration of the Moon. The Canadian Space Agency's prototype Mars Exploration and Science Rover (MESR) was deployed in Utah in 2016 [3] under CSA's leadership with the intent of demonstrating technologies and advancing operational strategies for the international Mars Sample Return campaign [4]. The CSA also plans a future Lunar Exploration Analogue Deployment (nominally in 2019) related to Lunar Sample Return. These deployments are conducted in collaboration with academia and industry, and with other agencies, notably the NASA Mars program and NASA Mars 2020 Project, and ESA's Human-Enhanced Robotic Architecture and Capability for Lunar Exploration and Science *(*HERACLES) project [5].

Figure 1: The Canadian Space Agency's prototype MESR Rover returning samples to a Mars Ascent Vehicle mock up during the 2016 Utah MSR Analogue Deployment.

The focus of this paper is a discussion of the use of analogue deployments to explore and validate rover mission requirements, and particularly the new requirements of the upcoming generation of Mars and Moon sample return missions. The objectives, implementation and results from the 2016 Canadian Mars Sample Return Analogue Deployment will be presented and discussed, as well as current status of the planned 2019 Lunar Exploration Analogue Deployment.

2. Definitions and Needs

Analogues are sites or facilities on Earth that resemble planetary environments: ie. typically extreme environments on Earth with challenging logistics and permit access. Deployments at analogue sites or 'analogue deployments' take many forms, ranging from a focussed technology test to end-to-end mission scenario, and have a mission engineering aspect that goes beyond scientific fieldwork.
Analogue deployments at scientifically relevant analogue field sites are key to developing and validating *science operations* requirements for planetary rover and astronaut missions. The purpose of validation efforts is to ensure that mission requirements will meet the intended mission objectives. Analogue deployments can also provide additional benefits such as demonstrating capabilities to potential partners and decision-makers, training students and mission teams, and engaging the public.

For the upcoming generation of Moon and Mars sample return mission concepts, the scientific community desires targeted samples acquired with geological context, with mobility for regional exploration, rather than the simpler landed mission or grab bag approaches, placing requirements on the scientific payload and mobility and sample handling systems. This generation of sample return missions remains highly constrained by mission duration, such that the new requirements on science operations need new highly efficient science operations approaches. Public engagement in the eventual missions is also expected to be high, with pressure on mission teams for rapid reporting of mission success and new levels of public participation during operations.

3. The 2016 Canadian Mars Sample Return Analogue Deployment (MSRAD)

MSRAD took place near Hanksville, Utah, from October 22nd to November 19th 2016, as a two phase deployment. Requirements for site selection included road access for a truck, reliable fair weather, 500m of unvegetated land for rover navigation testing, and geological features relevant to Mars science operations testing. A review of many potential sites in Canada and US resulted in the selection of a site around 4km NW of Hanksville, Utah, with a distinct inverted ancient fluvial channel feature.

In phase 1, CSA's prototype rover 'MESR', built by MDA [6], was successfully deployed as a Cache rover, testing science operations capabilities and approaches, with a payload simulating NASA's Mars 2020 sample cache mission. In phase 2, MESR was deployed as a Fetch rover technology demonstration after a change in payload, while science operations continued using hand held instruments with humans simulating rover mobility. Science operations were conducted by a largely student team led by Western University [8]. International collaboration was sought to develop and strengthen future partnerships. Collaboration with the NASA Mars Program and Mars 2020 [7] project team helped enhance the validation effort and value of research outcomes. The design of the validation approach was a significant part of mission planning and has resulted in an extensive and comprehensive data set consisting of targeted samples in the context of type samples from all stratigraphic units at the site, instrument data acquired by the mission, documentation of the decision-making process by remote science operations and field geology teams [1], and geological field mapping by two separate university teams. A special journal issue is in preparation.

The MSRAD fetch rover mission technology demonstration will also be described. A new solution was developed and successfully demonstrated to locate, acquire and transfer Mars 2020-like sample tubes. Six tubes were transfered over 6 sols under 47 hours of operations including 613m of autonomous navigation.

4. Lunar Exploration Analogue Deployment (LEAD)

Since 2009, the Canadian Space Agency has funded several studies related to lunar surface exploration, from small rovers designed for scientific exploration to 'moon buggy' systems for human exploration, building Canadian expertise in surface mobility systems, drilling and in analogue mission deployments using prototype systems [2]. Requirements for compact rovers were developed in the context of NASA's Resource Prospector and ESA's HERACLES mission concepts. A major technology development study that has recently completed is the Lunar Rover Platform and Drivetrain Prototype (LRPDP), a TRL-6 prototype derived from the CSA's Artemis Jr platform [9] tested under lunar-representative environmental conditions of 'dirty' T-VAC using CHENOBI regolith simulant. A TRL-4 Small Planetary Rover Prototype (SPRP) was also developed in 2016 to advance low cost solutions to surface exploration. Weighing in at 95kg it uses the same drivetrain as the LRPDP to ensure portability of the TRL-6 solution.
CSA remains an active partner in ESA's HERACLES mission concept development, leading the lunar surface rover component, with interest in using HERACLES to demonstrate technology solutions which could be scaled to a potential lunar surface human pressurized rover chassis contribution. Current CSA studies include twin industry studies that will each develop a detailed Lunar surface mobility concept for two main assets: (1) Precursor to Human And Scientific Rover (PHASR) (2) Lunar Pressurized Rover Core (LPRC).

In parallel with these technology efforts, CSA is funding a Lunar Demonstrator Mission Science Maturation Study to provide input to a science instrument payload for PHASR and a science operations scenario for the 2019 LEAD. HERACLES will present significant opportunities for science. While the primary objective of the HERACLES Lunar Demonstrator Mission is to demonstrate key precursor technologies, its design reference mission includes landing at a site of high scientific interest, nominally Schrödinder crater, and return of lunar samples of high scientific value, before conducting a long distance traverse and providing further opportunities for science and exploration.

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Short Summary

Discussion of use of analogue deployments to explore and validate rover mission requirements, particularly the new requirements of the upcoming generation of Mars and Moon sample return missions. The 2016 Canadian Mars Sample Return Analogue Deployment is presented and discussed, and current status of the planned Lunar Exploration Analogue Deployment.

Next generation solar cells for powering extreme habitable worlds : light-weight, flexible and printable-on-demand

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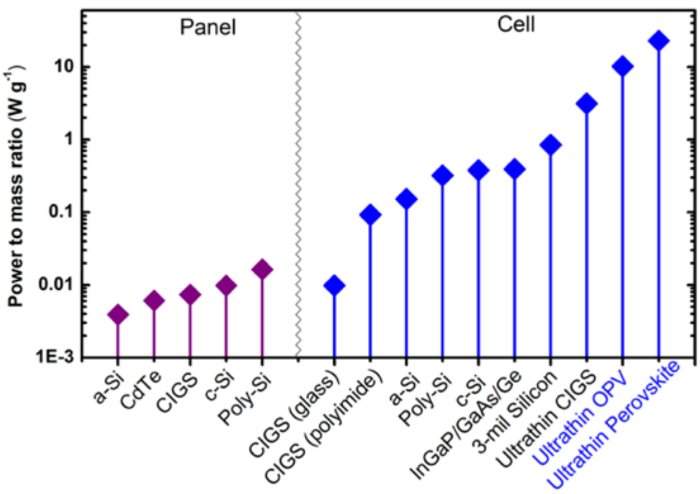
1. 'Print-on-demand' electronics and solar cells

During long missions in space and for specific circumstances or conditions it could be of great interest to manufacture on the spot dedicated electronics and photovoltaics through an in-flight or in-situ 'print-on-demand' procedure (cfr. '*Printable Spacecraft'*-concept of Nasa – 2012).

The functional non-conventional semi-conductor materials (e.g. conjugated polymers, hybrid perovskites, metal oxides,...) that can be used for these electro-optical devices have been improving over the last decade, leading to materials that are more stable and more resistant. Furthermore, printable electronics and solar cells can be printed on various (flexible) substrates ranging from thin plastic foils to paper, resulting in very thin (typically hundreds of nanometers) and light weight (foldable) devices.

In particular the emerging class of organic based photovoltaics – ranging from fully organic solar cells to hybrid organic-inorganic perovskite solar cells - offer a lot of potential for space applications because they are very light weight, resulting in a champion power-to-mass ratio[1], compared to other inorganic solar cell technologies (figure 1).



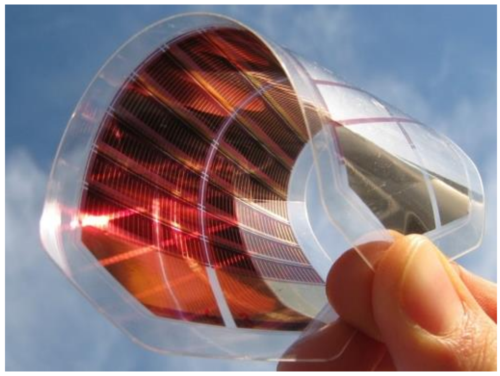


Figure 1 : Left : Power-to-mass-ratio for various types of solar cells[1-2]/ Right : Flexible organic solar cell.

Based on one hand, on arguments related to the unique combination of their intrinsic properties and versatile preparation methodology (e.g. power-to-mass-ratio in the order of 0.1-0.2 W/g for commercial devices), and on the other, on a successful first demonstration of these technologies during a near-space test mission (OSCAR-project – see below), we would like to propose organic based photovoltaics as a disruptive technology for photovoltaic energy generation in space and other extreme environments.

2. The OSCAR-project – first demonstration of organic based solar cells as space solar cells

The very recent OSCAR project (Optical Sensor based on CARbon-materials) aimed to explore the use of novel generation carbon based (i.e. polymer:fullerene, perovskite, diamond) optical sensors/solar cells for (aero)space applications. This has been achieved through the in-situ investigation of devices' performance during a stratospheric balloon flight in October 2016.

The concept of this experiment was to allocate organic based solar cells on modular panels, including the measurement electronics, which are mounted on the four sides of the gondola, and a centralized payload box, containing the data transmission electronics. The photovoltaic devices under test include 4 commercial polymer solar cell modules from infinityPV, 36 vacuum processed small molecule solar cells acquired from IAPP (TU Dresden), 16 polymer solar cells prepared at UHasselt, and 8 perovskite solar cells purchased from IMEC.

The launch campaign (1-10 october 2016) was very successful and the total flight time lasted more than 5 hours, including a floating phase of 2.7 hours at an altitude of 32.2 km.

Next to the in-flight experiments, in-situ climate chamber and thermal analysis experiments are ongoing to investigate the temperature window of operation and the stability for the various types of organic based solar cells.

The importance of the OSCAR-balloon experiment is that it has demonstrated for the first time the use of organic based solar cells in (aero)space conditions and it has opened the route towards future applications in extreme habitable worlds

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Acknowledgements

The OSCAR project was developed in the framework of the REXUS/BEXUS program, supported by the Swedish National Space Board (SNSB), the Deutsches Zentrum für Luft- und Raumfahrt (DLR), the European Space Agency (ESA), and the Swedish Space Corporation.The authors deeply thank M. De Roeve, R. Lempens, J. Soogen, K. Daniëls and Jan Mertens for the technical help, and K. Wauters and M.A. Beynaerts for their support during testing. IMEC vzw is acknowledged for their availability with sample supplies and encapsulation. For the small molecule based devices thanks are due to TU/Dresden.

Short Summary

During long missions in space and for specific extreme conditions it could be of great interest to manufacture on the spot dedicated electronics and photovoltaics through a ‘print-on-demand’ procedure. Organic based electronics/photovoltaics are not only printable, but also flexible, foldable and have a low weight and are therefore a potential disruptive technology for space applicatoins.

Breakthrough Starshot Initiative

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1. Abstract

At the Royal Society in London on July 20, 2015, Yuri Milner, Stephen Hawking and Lord Martin Rees announced a set of initiatives — a scientific programme aimed at finding evidence of technological life beyond Earth entitled 'Breakthrough Listen, and a contest to devise potential messages named 'Breakthrough Message'. In addition, atop the One World Trade Center in New York on April 20, 2016, Breakthrough Starshot was announced, an interstellar programme to Alpha Centauri. These are the first of several privately-funded global initiatives to answer the fundamental science questions surrounding the origin, extent and nature of life in the universe. The Breakthrough Initiatives are managed by the Breakthrough Prize Foundation: breakthroughinitiatives.org.

Europlanet 2020 RI Education and Outreach projects focusing on Extreme Habitable Worlds

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1. Introduction

Since 2005, Europlanet has been providing European's planetary science community with a platform to exchange ideas and personnel, share research tools, data and facilities, define key science goals for the future and engage stakeholders, policy makers and European Citizens with planetary science.

Europlanet 2020 Research Infrastructure (RI) is a €9.95 million project to address key scientific and technological challenges facing modern planetary science by providing open access to state-of-the-art data, models and facilities across the European Research Area. The project was launched on 1st September 2015 and is funded under the European Commission's Horizon 2020 programme. It carries networking, transnational access and joint research activities and services towards more than 33 beneficiaries and many associate partners from 22 countries.

Europlanet 2020 RI provides:

- Free transnational access to world-class laboratory facilities that simulate conditions found on planetary bodies, as well as analogue fields sites for Mars, Europa and Titan
- Virtual access to the diverse datasets and visualisation tools needed for comparing and understanding planetary environments in the Solar System and beyond
- Networking activities, including meetings, workshops and personnel exchanges, to strengthen the community, develop industry-academic collaboration, discuss latest scientific results, and set the strategy and goals for planetary science in Europe for decades to come.

As an Advanced Infrastructure, Europlanet 2020 RI places particular emphasis on widening the participation of previously under-represented research communities and stakeholders, including new EU Member States. Our outreach and education programmes engage Europe's citizens, teachers, students and policy makers with cutting-edge planetary science and exploration.

2. Focusing on Planetary Habitability

One of the most important activities of Europlanet are its involvement with five (5) planetary analogue field sites (PFA):

- Rio Tinto Field Site, Spain
- Ibn Battuta Centre, Morocco
- The glacial and volcanically active areas of Iceland, Iceland
- *Danakil Depression, Ethiopia*
- *Tírez Lake, Spain*

PFA offer access to these well-characterised terrestrial field sites that have been selected so as to provide the most realistic analogues of surfaces of Mars, Europa and Titan, to which planetary missions have either recently been directed or are planned. Access is provided for scientists to perform high quality scientific research and test instrumentation for space missions under realistic planetary conditions and undertake comparative planetology research.

In addition to PFA, Virtual Access activities (VESPA) are making available the diverse datasets and visualisation tools needed for comparing and understanding planetary environments in the Solar System and beyond.

In its early days Europlanet established an Exoplanet Discipline working group on issues related to the characterisation of exoplanets, including long-time habitability. Two main scientific areas were identified related to terrestrial exoplanets and short periodic Jupiter-like exoplanets. requiring the joint expertise of Europlanet scientists for finding solutions which are relevant to the evolution of habitable planets and giant exoplanets. The interest in planetary habitability remains high until today. In January 2018 Europlanet

2020RI supports the Planetary Exploration 2061 workshop (Technologies and Infrastructures Workshop for Planetary Exploration, Horizon 2061)

3. Widening Participation: Focus on Education and Outreach

Europlanet 2020 RI has an active outreach and dissemination programme to engage European citizens with the scientific, social, economic and cultural impact of planetary science. The Europlanet Media Centre and Europlanet's social media channels provide news from the European planetary science community and commentary on planetary events. Europlanet 2020 RI promotes public engagement through science communication training and best practice workshops, the Europlanet Prize for Public Engagement and a funding scheme for innovative outreach projects. In addition, since 2010 Europlanet has been leading other European research infrastructures in engaging policy makers with the cutting-edge science and technological challenges of planetary science and exploration.

Target audiences include outreach providers, educators, informal learning, media, policy makers, industry, general public, teachers and students. Our activities include:

• Outreach services and community support

• Best practice meetings, training workshops

• Collections of planetary-related outreach activities

• Dissemination to stakeholders

• Europlanet Media Centre (Press releases, blogs, interviews)

• Social media (Twitter, Facebook, Instagram, LinkedIn, Webinars)

• Policy engagement (Dinner debates, briefings, conference sessions and

exhibitions)

• Outreach tools

• 5-minute animations on planetary topics

Europlanet is also funding innovation by setting up a scheme aiming to capitalise on the inspirational value of planetary science in order to attract young people in science.

Through a prize for public engagement and regular science communication training workshops, Europlanet hopes to encourage planetary scientists to communicate their research to wider audiences and to discuss issues with non-specialists and to encourage partnerships between scientists and educators, industry and professional communicators.

Europlanet's yearly Best Practice Workshops aim in developing new ways of communicating planetary science subjects or engaging "hard-to-reach" audiences with planetary science.

Europlanet 2020 RI has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208.

Short Summary

Europlanet 2020 RI is providing European's planetary science community with a platform to exchange ideas and personnel, share research tools, data and facilities, define key science goals for the future and engage stakeholders, policy makers and European Citizens with planetary science. Its focus on Extreme Habitable Worlds through a variety of activities will be discussed.

EuroMoonMars workshop and simulation at ESTEC

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[5]ISAE/Supaero
[6]Exrem Design
[7]SGAC
[8]PuliSpace

1. Introduction

The 20th and 21st of July, ESTEC held a EuroMoonMars workshop to gather actors from various backgrounds around the topic of the MoonVillage. The workshop was split into four main activities: Talks related to the MoonVillage, demonstration of existing equipment, brainstorming on specific issues linked to the MoonVillage and a Moon base simulation.

2. Description of EuroMoonMars

The 2017 EuroMoonMars analog habitat was intended to provide a knowledge about what is the minimum and necessary equipment needed when arriving on the Moon using off the shelf and cheap components and where the focus should be put on. Even though the purpose is neither to test new equipment and technologies nor to perform some human and psychological experiments, high technologies experiments are developed and tested to increase the coherence of the data collected [1]. It is composed of three main elements, ExoHab, ExoLab and ExoGeoLab.

ExoHab is designed to assure the primary functions of a geological laboratory, as well as a communication centre and a place for the astronauts to rest [2]. It represents the “first house” of the MoonVillage. As such, it is used to centralize every aspect of the mission (communication, science, life).

ExoLab is a modular laboratory based on standard space container. Thus, the whole layout has been thought to be dismountable and reusable in similar containers. For this purpose, highly modular magnetic walls capable of supporting heavy charges have been developed using off-the-shelf components as well as modular furniture.

ExoGeoLab is a lander developed at ESTEC with the collaboration of ILEWG [3]. It is equipped with multiple equipment such as a spectrometer and a telescope. It is possible to remote control all the instruments of the lander to be able to operate from ExoHab, ExoHab or any control centre. Additional experiments can be implemented on ExoGeoLab thanks to its modularity. Recently, plant growth on lunar soil experiments have been added.

3. Goals of EuroMoonMars

International Tasks Groups such as ILEWG, IMEWG, ISECG, space agencies, and research partners can use the results of the research performed in the frame of EuroMoonMars for the benefits of Science, Exploration and Application programs. It also serves to raise awareness through public demonstrations.

4. EuroMoonMars Workshop

The EuroMoonMars workshop is a unique opportunity to gather space actors with totally different backgrounds (from Arts to Engineering, Sciences, Business and Economics).

The first part of the workshop enables each participant to talk about his/her work. Results from other MoonVillage workshops are presented as well as individual and agency/companies projects.

The second part of the workshop gives an opportunity to demonstrate new systems or technologies. Communication devices were shown as well as different rovers or the ExoGeoLab capabilities.

The third part of the workshop split the participant into three groups to brainstorm about three topics:

- The habitat on the Moon and the analog missions
- The technologies
- The outreach and funding

The fourth part of the workshop was a simulation of the first day on the Moon in ExoHab and ExoLab. The participants were given protocols and schedules with specific tasks to perform. They were split in different groups (ExoHab, ExoLab, Moon Orbiter, Mission Control). The simulation gives precious information for future iterations and enables extend the outreach by giving a realistic overview of a Moon habitat.

5. Conclusion

EuroMoonMars workshop gathers actors in the space industry, as well as space enthusiasts, artists and others, and brings, through all these meetings and knowledge sharing, new opportunities and collaboration to progress further on the way to the MoonVillage.

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Short Summary

EuroMoonMars workshop gathers engineers, artists, scientists, economists, businessmen and, more generally, space enthusiasts to elaborate the future of Moon exploration through talks, demonstrations, brainstormings and actual simulations.

What our future heritage can be: the purpose of an archive and library on the moon

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Introduction

The Lunar Sanctuary: a safe haven, a research facility, a place to discover the past and to improve the future.

This, almost, science fictional idea has not been born out of "I have a dream", but "We have a dream". All over the world people are introducing the concepts of humanities and heritage into the space travel industry. A couple of examples are First Library In Space, Memory of Mankind on the Moon and Footsteps on the Moon [1][2][3]. Also within the fictional area there have been great examples of ideas for an archive and library in space [4][5]. Now it's up to us to finally make it a reality.

Figure 1: logo for The Lunar Sanctuary.

Summary

During this research project we will not only explore this dream further, but also focus on the different kind of viewpoints that come with it as well. That means we'll have to (try to) answer some critical questions, for example:

1. What have archives and libraries meant throughout history and how will Alvarez they transform in the future? [6][7]
    - What do we see as our true heritage?
    - What will show the history of mankind in the most dynamic way? [8]
    - What will actually go to the moon, and who will make that final decision? [9][10]
    - How will it be stored? (Architectural and preservation designs) [11][12]
    - Where on the moon will the archive and library be build?
    - Who will actually benefit from making this dream a reality? [13][14]

This means that next to the historical, archival and educational research, we need to look at our history of colonization, we need to look at our history and today's topics of immigration and emigration, and also important we need to look at (new) ways to collaborate and involve different kinds of areas of expertise. We may be not able to answer all these questions; even maybe more will arise when the research project evolves. It may be the tip of an iceberg, but it will be part of our future, so it's important to start asking these questions and see what it will lead us to.

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Short Summary

Welcome to the future! During this research project we will answer some critical questions concerning a "dream come true" facility that holds the knowledge of mankind, available to all: an archive and library on the moon. But what will it actually take to achieve this dream?

The role of communication in science and astrobiology

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Misinformation is the activity of spreading misleading and non-objective information in order to deceive and modify someone's opinion about a person, a situation or a fact. Misinformation can be particularly dangerous in science. A great effort has been done (and it is still going on) by Italian scientists and communicators in order to suffocate the movement that states vaccines cause autism. A lack of scientific education and false but easy-to-believe stories lead many parents not to vaccinate their children exposing them to terrible diseases. That is why it is necessary to give people correct and reliable information about every field of science.

Science communication plays a key role in order to fight against misinformation but it can have other important roles. First, to point out how useful scientific research can be even when it seems useless (like space exploration). Second, to make science something interesting, friendly and suitable for everyone; third, to make people understand scientists are firstly moved by passion, curiosity and the desire of knowledge. Not every single thing a scientist does is necessarily "useful" to someone or something. As astrobiologists, we want to study the origin and evolution of life in the universe and we want to find extraterrestrial life. That is just because we are passionate, because we feel a connection with the universe.

The language used in science communication is essential and it must vary respect to the type of audience (children, general public, specialists) and event (birthday, conference, entertainment show). A communicator or a researcher should carefully choose the strategies to make his activity charming, so he can plan a power point presentation or take advantage of the full-dome technology of planetariums which allows people to feel involved and carried away by the images. A planetarium can be particularly suitable to talk about astrobiology, for example to represent how the Earth was when the first form of life emerged or to picture molecules and chemical reactions. In order to stay in close contact with people, a science communicator can run amazing experiments or use simple and common objects to represent difficult issues: a stone can become a meteorite or a little ball can become a bacteria. This is very successful especially when we are dealing with kids. On the other side, some specific occasions require professional instruments like telescopes for astronomical observations.

NB: Please note that I tried to match all the possible rules for the abstract template, but my abstract and, hopefully, my presentation, are very particular (e.g. I do not need equations and tables).

Short Summary

If every scientist in the world could communicate his discoveries with passion and clarity, people would be much more aware and enthusiastic about science.
"A good communication is made of 20% of what you know and 80% of what you feel about what you know."

TEACHING WITH ASTROBIOLOGY. ENHANCING SCIENCE AND TECHNOLOGY AWARENESS IN HUMANITIES AND SOCIAL SCIENCE STUDENTS.

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1. Introduction

In a preliminary empirical study of social-science students enrolled in teacher-training programs at two German universities, the authors have found a disparaging view of technology and science among said students. Their material knowledge of technology and science is the result of content they learned in highschool themselves. After having graduated, they chose social sciences or humanities as their subjects. There is little or no overlap between science and engineering subjects and social-science and humanities subjects in teacher training programs. That is not institutionally aimed for, but rather the consequence of the students choices. The consequence for science- and technology awareness among the students is problematic, to say the least. While their knowledge of science and technology -being the product of high-school education - is often not up to date and also lacking in current developments, their moral and ethical judgement about the implications of scientific research and use of technology is strong.

The preliminary study also showed, that the students are interested in new technological and scientific developments, they just lack the ability to include this into their world-view, which is very strongly influenced by their choice of subjects in the humanities and social sciences. Teaching these students has convinced the authors, that their lack of technology and science knowledge combined with their inherent tendency to judge science and technology from the point of view of their respective field impairs their ability to taken an adequate part in science and technology discourse. Their awareness and thus their competence to rationally engage with science and technology is lacking.

That is in part due to the depiction of science in technology in humanities and social-science courses, on the other hand due to a lack in current science and technology education as part of a humanities and social - sciences program. As the authors study has shown, these students are really interested in science and technology, they just lack key competencies to make an analytical connection between their field of choice (humanities and social sciences) and technology and science, without resorting to moral and ethical judgement.

2. Adding Astrobiology

This is where the authors believe that Astrobiology as an interdisciplinary academic field will show its merits.

Astrobiology is the study of the origins, evolution, distribution, and future of life in the universe. This interdisciplinary field requires a comprehensive, integrated understanding of biological, planetary, and cosmic phenomena. It also includes key questions the humanities and social sciences have been asking for centuries. Especially when looking at extreme habitable worlds, worlds that force humanity to try and accept a new understanding of life and its conditions, this field breaks the boundaries of traditional distinctions between disciplines.

3. Changing Worldviews

Approaching the key questions of habitability and the origins and conditions of and for life in an open and scientific way from an interdisciplinary field gives new approaches to the answers the humanities have given for centuries. This approach will show some of them to be worthwhile and others to be wrong. It will - in short - change established world-views. This addresses one of the key problems the authors have identified with their students technology and science awareness.

4. Teaching with Astrobiology

Our approach to teaching Astrobiology is not so much teaching Astrobiology itself, but using key concepts of Astrobiology research and analysing their underlying assumptions and scientific reasoning. Many of the key concepts of Astrobiology are very well suited to show the students how to bridge a perceived conceptual gap between the STEM subjects and their respective fields without having to resort to ethical or even moral evaluation and judgement. This is where a constructivist pedagogical approach in combination with the concept of the thought experiment comes into play.

5. Thought Experiments

The common denominator between STEM and humanities and social sciences while approaching new ground is the thought experiment. The thought experiment has a long history in philosophy, religion and other fields of the humanities as well as in the natural sciences. Thought experiments have been used for example to further the theory of relativity, they have a long history in philosophical schools and they have been widely used in education in the form of ethical dilemmas to enable students to learn to make analytically sound decisions.
This paper will show the basic structure of the thought experiment in either perspective. Building on this, the paper will explain the pedagogical merits of hypothetical thinking and the structural gain in competencies for the students. A short excursion into the didactics of games and play will serve to theoretically ground the didactical considerations in constructivist pedagogy.

6. Extreme habitable worlds as educational thought experiments

The paper will close with some examples that show a deep connection between Astrobiological methodology and current debates in the humanties and social sciences in an exemplary fashion, thus arguing for the specific merit that the use of Astrobiology in the humanities classroom has to bridge the perceived divide between STEM and the humanities and social sciences.
Thus the students approach to science and technology will change from being an ethical or even moral evaluation of these to learning from both sides of the coin and facing the common possibilities of social and scientific growth.

Short Summary

Astrobiology approaches an unknown in a scientific way while at the same time possibly including traditional philosophical, religious and social questions that come with learning about life. This can be used to teach humanities and social-science students how to bridge the gap between science and the humanities.

Friday 08 December 2017

From Astrochemistry to Astrobiology? The importance of cosmic ices for astrochemical and prebiotic evolution

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1. Introduction

Ices made of simple molecules are ubiquitously detected in the infrared spectra of many astrophysical environments such as molecular clouds [1, 2] out of which stars and planetary systems do form, together with many icy debris (asteroids, comets, dust…). Ices may also undergo efficient energetic processing, including ultraviolet irradiation at the turbulent edges of protoplanetary disks [3]. Such icy materials can be straightforwardly simulated in laboratory non-directed experiments in which the photo and thermal evolution of the ices are performed using, in our case, vacuum ultraviolet irradiation, following the classical methods of "matrix isolation techniques" [4]. These laboratory ices may then be used as templates for the astrophysical ones, where an intricate radical chemistry develops, leading to the formation of a complex organic material, soluble (in water and classical organic solvents) and insoluble [5], similar to what is indeed observed in primitive carbonaceous chondritic meteorites and known as SOM for soluble) and IOM (for insoluble). More specific molecules such as amino acids [6], sugars [7, 8] and nucleobases [9] make these materials particularly attractive for the possible onset of a "true" prebiotic evolution at the surface of a telluric planet if adequate conditions are met (mostly liquid water, organic chemistry, free energy…). Global analytical methods using very high resolution mass spectrometry of the soluble organic residues [10,11] reveal the extreme complexity of these materials which parallels the one observed in the Murchison chondrite for example [12] or within the Paris meteorite, as far as specific "biological molecular bricks" are considered [13].

2. Scientific Content

I will replace the importance of extraterrestrial ices evolution toward the making-of the organic matter within the general framework of *Astrochemistry* i.e. the chemical evolution of the Galaxy [14] and show, under which conditions and conceptual considerations, the exogeneous delivery of volatiles and organic matter on telluric planets such as the Earth, as postulated a long time ago [15], should be considered as a serious possibility for the starting-up of a *Prebiotic Chemistry* on telluric planets and thus of importance for *Astrobiology*. A short presentation of an ongoing new non-directed experiment will also be given.

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Short Summary

From Astrochemistry to Astrobiology?

Extraterrestrial ices are abundant in diverse astrophysical environments, from molecular clouds to comets. Laboratory simulation of the photo and thermochemical evolution of ices leads to the formation of complex organic residues that may present some truly prebiotic potential if delivered on telluric planets.

Stellar and interplanetary ingredients for extreme habitability

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1. Short Summary

Planetary habitability crucially depends on the evolution of the host star, in particular its rotational evolution and the consequent long-term changes of its magnetic activity, wind, and high-energy radiation. We present calculations of this non-unique stellar evolution and present simulation results for atmospheric erosion on planets.

2. Evolution of Stellar Rotation, High-Energy Radiation and Winds

Planetary habitability requires conditions that are to a large extent determined by the stellar and planetary environments. A stable atmosphere and conditions allowing for the long-term presence of liquid water are among the most important prerequisites for habitability. Atmospheres are processed by a wide range of stellar radiative and particle output, many of them resulting from stellar magnetic activity which in turn is a result of a rotationally driven internal dynamo. To understand the pathways of a planet toward habitability, a full understanding of the co-evolution of the planetary atmosphere and stellar radiative output is required. In the early times of a planetary system, however, extreme conditions may prevail due to elevated stellar activity. This period coincides with the formation of planetary crusts, water oceans, and outgassed atmospheres, all setting the stage for future habitable conditions. Similar extreme conditions may prevail for long times in the habitable zones of lower-mass stars such as M dwarfs.

We present results from a large project devoted to the study of the long-term evolution of star-planet systems, with a focus on the early phases of planetary and stellar evolution. We first discuss the stellar spin-down behavior and the resulting - non-unique - stellar radiative and wind history in the pre-main sequence and the main-sequence phase; as Fig. 1 shows, different initial stellar rotation rates (after the disk phase) lead to dramatically different spin-down behavior and consequently largely different evolution of the crucial high-energy radiation (X-ray, extreme ultraviolet, ultraviolet; [1]).

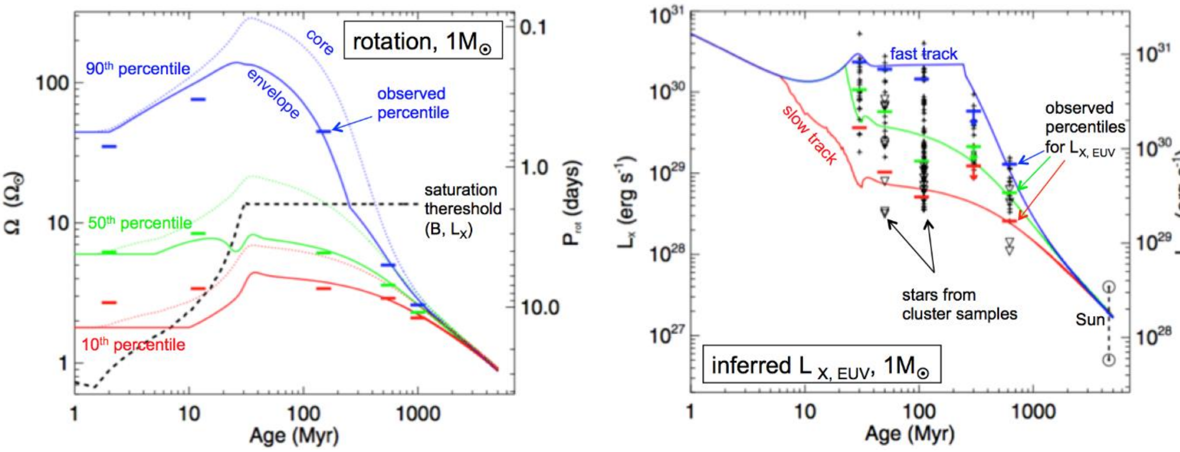

Figure 1: We show the non-unique evolution of the rotation rate Ω and inferred luminosities $L_{X,EUV}$ for a $1M_\odot$ star from the end of the disk phase to the end of the main-sequence life ($10^{th}/50^{th}/90^{th}$ percentiles of Ω), together with observed Ω from clusters. Between ~20 and 500 Myr, the X/EUV output scatters by ~an order of magnitude or more depending on the initial Ω [1].

We will show full reconstructions of the short-wavelength spectral irradiance resulting from this evolution. We then discuss the consequences for atmospheric processing, including thermal evaporation and non-thermal escape processes in young planets; results of hydrodynamic calculations for thermal escape (“evaporation”) from planets around a solar-type star are shown in Fig. 2 below [2].

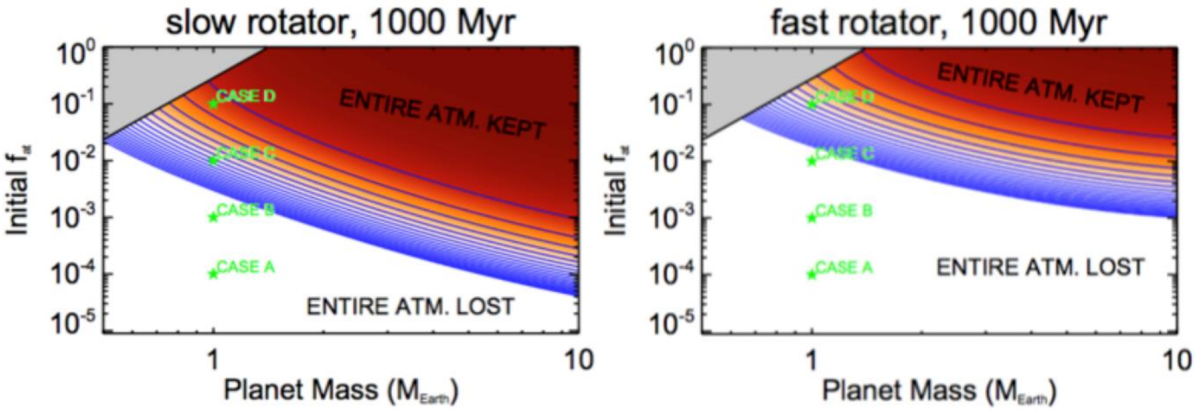

Figure 2: The figure illustrates the loss history of a hydrogen envelope of a planet in the habitable zone of a $1M_{\odot}$ star. It shows the remaining atmosphere (dark red = 100%) after 1Gyr of *thermal escape*, as a function of planetary and initial atmospheric mass (fraction f_{at} of M_{planet}), for a slowly and a rapidly rotating star in Fig. 1. Order-of-magnitude differences are evident [2].

In this context, we will also discuss the role of extreme conditions such as strong magnetic fields or winds in the early phases of evolution, or close to the host stars. We also mention applications to selected exoplanets and the possible early evolution of solar-system planets.

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Short Summary

Planetary habitability crucially depends on the evolution of the host star, in particular its rotational evolution and the consequent long-term changes of its magnetic activity, wind, and high-energy radiation. We present calculations of this non-unique stellar evolution and present simulation results for atmospheric erosion on planets.

Synthesis of Extreme Organics in Meteorites

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1. Introduction

Meteoritic organic compounds trace the history of the solar system; from quiescent to violent. Species or their precursors were formed in the temperature and radiation extremes of the interstellar medium, the collapse of the protosolar nebula into our solar system, and the environment within fragmented planetessimals before they arrive on Earth to be collected and analysed (Figure 1).

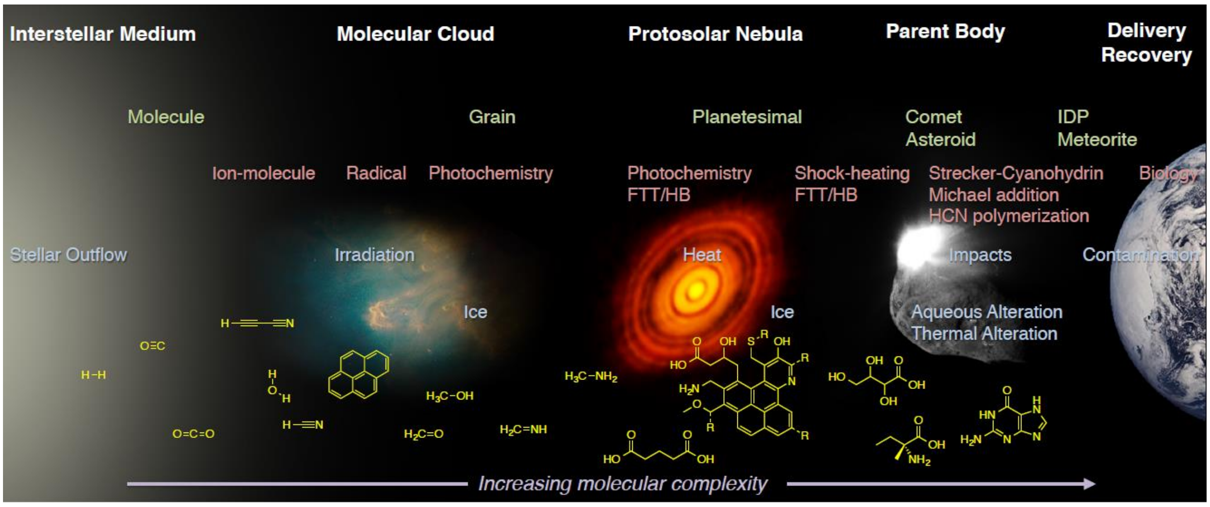

Figure 1: The formation and evolution of simple molecules to more complex organic compounds from the interstellar medium to small bodies and planets in solar systems. Representative reaction mechanism, processes, and example molecules are shown [from 1].

Analyses of primitive carbonaceous chondrites over the last five decades have revealed a major insoluble organic component, as well as a complex and highly diverse suite of soluble organic molecules that includes aliphatic and aromatic hydrocarbons, carboxylic acids, hydroxy acids, N-heterocycles, sugar acids, polyols, amino acids, amines, and many other molecules that have not yet been identified.

Comparing a suite of compounds across meteorite petrology revels correlations with the meteorite parent body, suggesting that thermal and aqueous alteration in primitive asteroids played an important role in the formation and destruction organics, including amplification of L-amino acids that may have contributed to the origin of homochirality in life on Earth. Amino acids are the best studied example (Figure 2) [2].

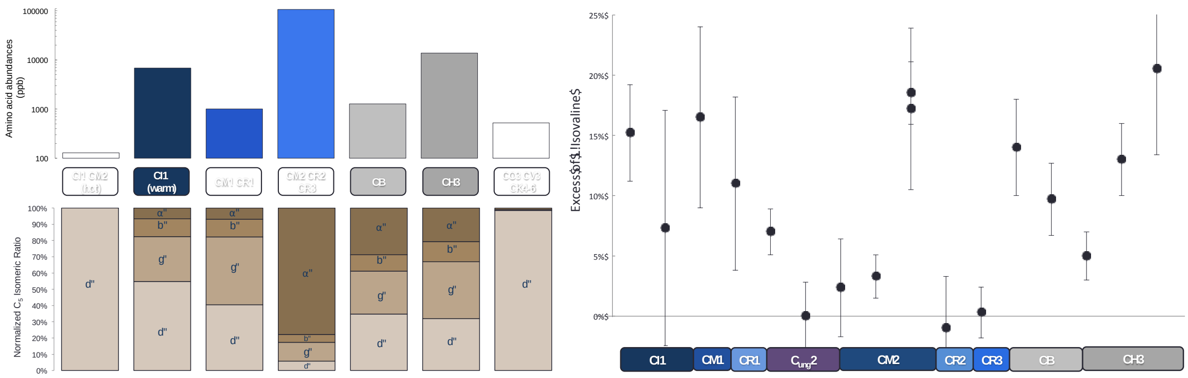

Figure 2: Average total amino acid abundances (top left) and structural distributions of amine position (α, β, ɣ, and δ) in 5-carbon aliphatic amino acids (bottom left) in carbonaceous chondrites vary greatly with class and petrographic type, and extent of aqueous and thermal alteration on the parent body. L-Enantiomeric excesses of the amino acid isovaline (right) [from 2].

Amino acids are useful, not just because of their obvious relevance to the origin of life and habitability, but the can be employed to elucidate the chemical pathways that were active in a particular meteorite's parent body (Figure 3) [3].

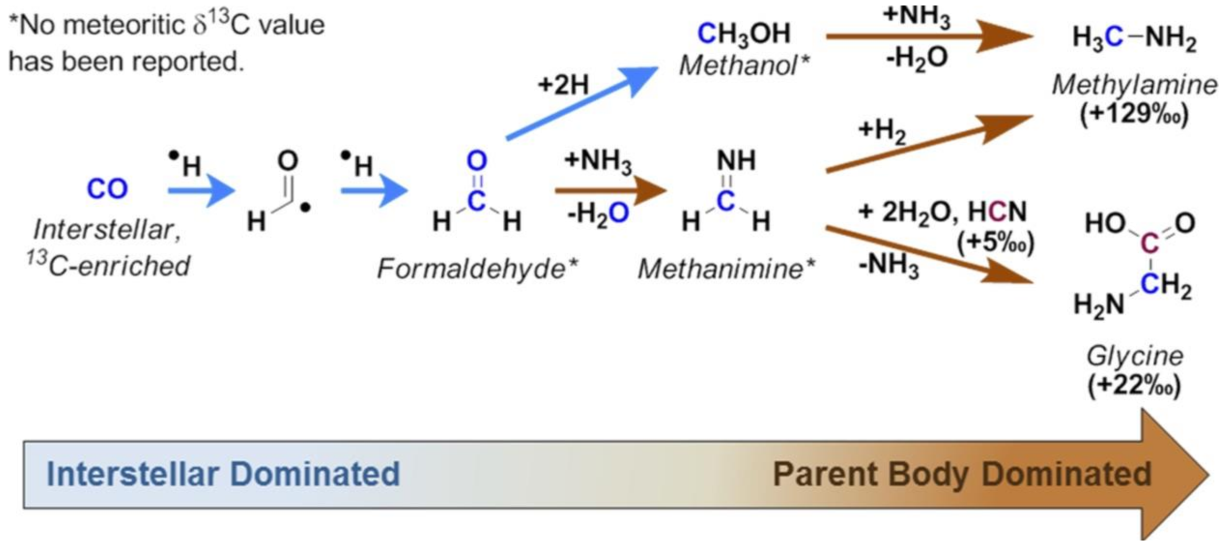

Figure 3: The Strecker-cyanohydrin synthesis and reductive amination of formaldehyde is one of several potential synthetic routes for glycine and methylamine. In the Murchison meteorite ^{13}C-enriched CO from the interstellar medium results in ^{13}C-enriched glycine and methylamine. These reactions may be dominant but not exclusive inside the indicated environments. [from 3]

The presence of chiral excesses in some amino acids [2] also point to an unknown enrichment and amplification process in solar system history. Though amino acids and related compounds are informative and perhaps the best studied, they not the only interesting class of compounds which can be extracted from meteorites [e.g. 1].

The complex mixture organics and the presence of chiral asymmetry in meteorites could have implications for the potential of habitability and complicate the discrimination of meteoritic influx, terrestrial contamination, and extra-terrestrial biomarkers.

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Short Summary

The study of organic compounds, especially amino acids, in a range of meteorites trace the history of the solar system and the material available for habitable worlds.

The role of X-rays in exoplanet evolution and habitability

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Research on exoplanetary atmospheres has developed an increasing interest. Astrobiology has put its eyes on the effects that stellar irradiance may have on the atmosphere of planets, and on the early development of life. The high energy (XUV and UV) part of the spectrum is of special interest for this purpose. This radiation is originated in the outer layers of late type (F, G, K, M) stars. Stellar coronae, transition region and chromosphere are present in these stars as a combined effect of convection and stellar rotation. Younger stars heritage a fast rotation from their parental cloud, resulting on an enhanced stellar activity, that implies a copious XUV emission. As the star ages, its rotation decreases. The XUV emission is sensitive to this lower rotation: the Sun has three orders of magnitude lower X-ray luminosity now than it had at its early stages.

There are three main effects of XUV radiation: i) dissipation of protoplanetary disk during planet formation phase, ii) planet inflation and atmospheric evaporation due to energetic irradiance of the atmosphere, iii) effect of the atmosphere chemistry, and eventually, the life forms on the planet surface. Planet formation takes place in the first ~10 Myr of the star, although other processes, such as dust production and absorption, and collisions with minor bodies are frequent during several tens of Myr. Once the planet is formed, the incoming stellar irradiance is the main external ingredient for its evolution. An example of its effects is the observed distribution of planet radii in the biased sample of transiting planets (due to observational reasons, these planets use to be planets close to their stars). The distribution (see Figure 1) shows a large number of Jovian-mass planets with radii quite larger than 1 Jupiter radii. This can be interpreted as planet inflation due to the incoming high-energy radiation. Atmospheric chemistry is also strongly affected by the radiation. Finally, life forms in the planet evolve partly due to the incoming UV photons, some of them produced as secondary photons after absorption of X-rays in the upper atmosphere.

Along the talk the example of the solar evolution will be displayed, with some comments on activity cycles, and how the effects on planets change with the stellar Spectral Type.

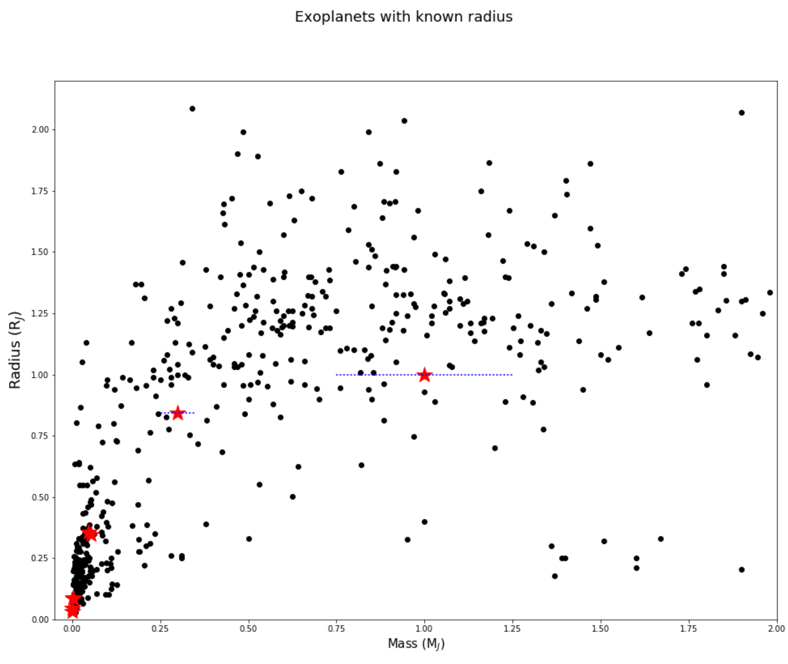

Figure 1: Distribution of planets mass and radius. Solar System planets are indicated with red asterisks.

Short Summary

Stellar coronae and transition region emit high energy (XUV and UV) radiation that has strong influence on exoplanet atmospheres. Early evolution of planet atmospheres, planet inflation and even mass loss due to evaporation are among its effects. The early development and evolution of life can be affected too.

Monitoring space weather: from SOHO, PROBA2 to the future

J.J. Zender

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If we define weather as the atmospheric conditions at a location at Earth over a short period of time, then space weather is the environmental condition at a place in our solar system over a short period of time. The variables that define the 'environmental conditions' are manifold and increase in sync with our increased knowledge about the Sun, the solar wind, and planetary atmospheres. At the same time, the number of 'places' of interest for human kind increases continuously with the technology advances on Earth, in the Earth vicinity, and astronomy in general.

Weather is of interest for all of us. Weather plays however a crucial role – and here especially the art of weather forecasting – to protect economic and safety interest. In previous times, weather forecasting could ensure the success of the yearly harvest or the lives of ship crews. With a better understanding of our Sun and it's related activities in the solar corona and the propagation of the solar wind in our solar system, scientists were able to predict the impact of the solar wind to the upper Earth atmosphere, and in particular the impact on technology either in low Earth orbit or on-ground, e.g. power grid systems.

With astronauts in Earth orbit or rovers on Mars, scientists had to increase their space weather prediction capabilities both in timeliness and scope.

The variables that determine the space weather prediction capabilities are manifold. First to mention the radio wave emissions from the Sun itself, e.g. caused by solar flares. These can disturb communication systems on the surface of planets as well as in their respective orbit. Solar electro-magnetic field interactions with the Earth magnetosphere can cause disturbances on high-frequency devices used by a manifold of equipment. Thirdly, ionizing radiation origination from solar high-energetic particle events, the galactic cosmic ray background, or from Earth trapped radiation belts, has an effect on detectors and electronics in general.

An overview is given following these considerations and their evolution in the past decades, and an outlook dared into the next couple of years.

Stellar Flares Detected By NGTS

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Conference Abstract

Stellar flares are explosive events on the surface of stars, believed to be due to the release of magnetic energy in magnetic reconnection events [1]. These events are marked with a sudden increase of flux emission, followed by a gradual decay. This increase in flux takes place across a wide range of wavelengths, from radio to X-ray [2]. In particular there is a strong increase in UV emission. This UV emission can have damaging effects on nearby exoplanets, in particular on their atmospheres. Studies from [3] and [4] have shown the UV irradiation associated with a single large stellar flare from AD Leo, for an Earth-like planet, could deplete the ozone layer and irreversibly alter atmospheric chemical abundances. Further flares within a short timescale could then allow sudden UV irradiation to reach the planetary surface.

Previous works have found that K and M stars will flare with greater relative amplitudes compared to those of earlier spectral type [5], with flare behaviour also changing within spectral types [6]. It is these spectral types that are of current interest to exoplanet astronomers, particularly with the recent discoveries of LHS 1140b, a super-Earth in the habitable zone of an M4.5V star [7] and of the 7 Earth sized planets in the TRAPPIST-1 system [8]. We now know it is possible for Earth sized planets to exist close in such proximity to their host star, however this proximity can also increase their chance of flare impact. Due to the aforementioned effects of large stellar flares on an Earth-like planet, knowledge of the flare properties is required to aid in determining the habitability of such systems.

The Next Generation Transit Survey (NGTS) is a wide-field survey designed to detect Neptune-sized exoplanets around bright (I≤16) K and M stars [9]. It consists of 12 telescopes located at the ESO Paranal Observatory in Chile which together have a total field of view of 96 square degrees. Each camera has an exposure time of 10 seconds, enabling fast observations of stars across the southern sky for 100s of hours during a full season. Our bandpass of 550-900nm is designed to focus on K and M stars, due to the increased amplitudes of transit signals from these low mass systems. Consequently, NGTS has the capabilities to monitor lightcurves in high cadence for hundreds of thousands of stars, making it ideal for detecting and characterising the morphology of stellar flares.

In this talk I will present results from our search for stellar flares in the NGTS datasets. I will initially present NGTS, discussing its aims, current achievements and why it is well suited for studies of stellar flares. I will then proceed to discuss the methods used to detect and confirm flares on 11 fields of data, along with details of the over 330 flares we have found in the process. These flares are from over 180 stars, ranging from G8V to M5V, including over 30 from K stars. All these flares have been temporally resolved beyond that of the *Kepler* short cadence [10], enabling detection of the flare rise and detailed substructure. For these detected flares, where possible we calculate flare parameters such as bolometric energy, flare duration and fractional amplitude. We can then compare these flare parameters to stellar parameters, to search for relations. Of note is the maximum flare energy against stellar colour, shown in Figure 1. With this knowledge, we can obtain empirical lower limits of the maximum energy expected to be output from a stellar flare for a chosen star. Studies of the flare duration will also allow modellers to know how long an exoplanet could be in the vicinity of such a flare, another thing NGTS is capable of. Along with these results I will present examples from the NGTS dataset of our most active stars and what could happen to hypothetical exoplanets orbiting them – from their magnetosphere to their surface. An example of such a system HD41362C, of which we have detected 23 flares. A mixture of simple and complex events, the largest of which has an lower energy limit of 4×10^{34} erg – over 100x larger than the largest event seen from the Sun, the Carrington Event. This flare is shown in Figure 2 and also shows the capabilities of the high cadence of NGTS in resolving significant substructure, along with potential habitability-affecting flares. For these stars we can also determine how often flares are expected, contributing to results from previous studies. Along with the effects of a stellar flare on an exoplanet I will also discuss whether, for our case study stars, their vulnerability of the exoplanet atmosphere to multiple flare events. Finally I will detail how we intend to make our findings available to the public.

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Short Summary

The Next Generation Transit Survey (NGTS) is a transiting exoplanet survey, searching for Neptune-sized exoplanets around bright K and M stars. In this talk I will present the detection of stellar flares in the NGTS dataset, along with their effects on exoplanet habitability.

Exploring habitability under superflares when the ozone layer formed on Earth (Poster Flash Talk)

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[1]*Center for Radioastronomy and Astrophysics Mackenzie, Sao Paulo, Brazil*

Introduction

Kepler-96 is a solar analogue star harbouring a Super-Earth planet in close orbit. Its age of 2.3 Gyr is the same as the Sun when there was a considerable increase of oxygen in Earth's atmosphere in the end of the Archean era due to micro-organisms living under the sea. This star is still very active and has several superflares on its lightcurve. Some authours (Airapetian et al (2016), Manasvi and Loeb (2017)) discussed about the possibility of such superflares occuring in the young Sun and their impact on the primitive Earth. Thus, Kepler-96 is an interesting target to study the Archean Earth conditions if the Sun have had such superflares at that time.

Goal

The goal of this work is to analyze the biological impact of Kepler-96 superflares (seen on the transit lightcurve of Kepler-96b) on the close by planet and also to an hypothetical Archean Earth-like planet in the habitable zone (HZ) of this star.

Methods

Our analysis is based on the four years of continuous short cadence observation of the star by the Kepler telescope. The model used here simulates a planetary transit and allows the insertion of a flare in the stellar disc with different size, amplitude, and position. By fitting the observational data with this model, it is possible to infer thephysical properties of the flares. The model fitting of the flare peaks seeing during the transit yields the estimate of the duration (few minutes) and energy released by each flare.

Afterwards, we analyse the increase of the MUV surface irradiance flux due to the superflares under different atmospheric scenarios adopted from Cnossen et al (2007): an Archean atmosphere and a Present day atmosphere with ozone. To estimate the UV flux contribution of the Kepler-96 flares, we used the UV flux measured on the most intense solar flares observed. Woods et al (2004) reported one of the largest flares found in the Sun, a X17 GOES class flare with total energy of $E = 4 \times 10^{32}$ ergs, that increased by 12% the solar MUV flux. As the total thermal blackbody flux of Kepler-96 and the Sun are very similar, we considered that the superflares found in Kepler-96 would increase the UV flux proportionally.

Then, we estimated the biological impacts that the MUV flux of the strongest superflare found here could have in Kepler-96b and in a hypothetical Earth in the HZ either for life on the planet surface or under the ocean. In both cases, we analysed the increase in the MUV flux due to the superflares by weighting it with the DNA action spectrum know as biological effectiveness irradiance (E_{eff}):

(1)

where F_{inc} is the total incident MUV flux with the superflare contribution arriving at the planet surface/ocean depth, S is the DNA action spectra and λ is the MUV wavelengths.

For the ocean, the propagation of the UV radiation in the varies considerably with depth, and can be determined by the equation:

(2)

where $I(\lambda, z)$ is the UV spectral irradiance at depth z, $I_0(\lambda)$ is the UV spectral irradiance with the superflare contribution passing through an Archean atmosphere and $K(\lambda)$ is the diffuse attenuation coefficient for water. Then, we verify if the MUV flux received by the biological body present in these planets can be tolerated by microorganisms that define the surviving zone for life such as Deinococcus radiodurans and Escherichia coli.

Results

We estimated the E_{eff} for an Earth-like planet in the HZ of Kepler-96 and for the super-Earth Kepler-96b. The threshold for the E_{eff} was chosen using two microorganisms that define the surviving zone for life: Deinococcus radiodurans and Escherichia coli. The maximum UV flux for 10% survival for D. Radiodurans is $F_{10}^{UV} = 5.53 \times 10^2$ J/m^2 (Ghosal et al, 2005), while for E. Coli is $F_{10}^{UV} = 22.6$ J/m^2 (Gascon et al, 1995).

For the contribution of the strongest superflare found (increase of 5430% in the MUV flux), the biological effective irradiance shows that D. radiodurans would only survive on the surface of Kepler-96b and of a hypothetical Earth at 1AU if there is an ozone layer present on the planet atmosphere (see Table 1).

Biogolical Effective Irradiance (Surface), E_{eff} [J/m^2]		
Planet	Archean atmosphere	Present-day atmosphere
Kepler-96	3.4×10^7	178
Planet at 1AU	1.6×10^4	0.0084

Table 1: Biologically effective irradiance for DNA damage at the surface of Kepler-96 and of a Earth-like planet at 1AU.

Moreover, we also analysed the ocean depths that could harbour extremophile life in Kepler-96 planets without being damaged by the strongest superflare found in Kepler-96 (see Table 2). Although Kepler-96b and a hypothetical Earth-like orbiting Kepler-96 receive an increased UV radiation due to the superflares, life could still survive in depths inside the photic zone (up to 200m) of an Archean ocean present in these planets.

Biogolical Effective Irradiance (Ocean), E_{eff} [J/m^2]		
	Ocean depth	
Planet	E. Coli	D. Radiodurans
Kepler-96	48m	35m
Planet at 1AU	20m	8m

Table 2: Biologically effective irradiance for DNA damage with depth in an Archean ocean present in Kepler-96b and in a Earth-like planet at 1AU. The ocean depths found are those receiving the maximum UV dosage that E. Coli and D. Radiodurans could support.

Conclusions

The conclusion is that life would only survive on the surface of Kepler-96b if there was an ozone layer present on the planet atmosphere. Life could also support the effects of the strongest superflare in this planet if it was at a depth of below 48m the ocean surface. For a hypothetical Archean Earth, life can be sustained only in the presence of ozone, considering the effects of the strongest superflare, or at 8-20m ocean depth.

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Short Summary

Kepler-96 is a solar analogue with the same age as the Sun when a considerable increase of oxygen in Earth's atmosphere happened. Here we analyze the biological impact of Kepler-96 superflares (seen on the transit lightcurves) on a Super-earth and also on a hypothetical Earth-like planet in the habitable zone of this star.

Cave Dwellers, Eskimos, Tuaregs: Anthropological Lessons for Human Adaptation to Space Environments

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Space analogues have become an important method to study human habitation in extreme and isolated environments. Analogues provide standardized conditions and results that help us understand the challenges these environments pose for the human exploration of the Moon or Mars, and thus design more efficient operations protocols. However, *homo sapiens*' experience of the extreme is far from new. For long anthropologists and other experts have been researching the physical and cultural adaptations that have allowed peoples on Earth --Eskimos, Andean and Himalayan natives, Afghan cave dwellers, or Tuaregs, among many others— to live and thrive in inhospitable environments for generations. In partnership with particular technologies (e.g. igloos, coca leaves) and heavily drawing upon in-situ resource utilization, these populations have developed societies and economies in arid deserts, monotonous landscapes of ice, extended periods of darkness, and thin-air mountains where most humans fall prey of altitude sickness. In this presentation we will discuss some examples of these physical and cultural adaptations that might provide inspiration for the design of space analogues, and the re-imagining of the relations between humans, technologies, and off-Earth environments.

Short Summary

Physical and cultural adaptations have allowed peoples on Earth to thrive in inhospitable environments for generations. In this presentation we will discuss some examples of these adaptations that might provide inspiration for the design of space analogues, and the re-imagining of the relations between humans, technologies, and off-Earth environments.

“Philosophical aspects of space exploration and human spaceflight: the ecopolitics of sharing place with non-human others in outer space”

S. Guinard[1*]

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1. Introduction

This presentation originates in a fieldwork-based philosophical approach of multispecies communities in space stations. Envisioning longer stays in outer space - whether on a spacecraft or on another planet - will require programs that create multispecies ecosystems. But this opens existential and ethical questions of how to include and dwell with non-human living systems in contained spaces. There has been at least a fifty years-long history weaving together space and ecology, but philosophers and social scientists have not yet investigated the question of space as a place for multispecies exchanges.

In the midst of the Anthropocene, we find ourselves, as ecofeminist Val Plumwood foresaw it, at the edge of a near-death experience that obliges us to acknowledge our “ecological vulnerability”[6]. Extinction, instability, and uncertain futures now define our ordinary condition. How should we make room for care or trouble, within the epic narratives that have fuelled space exploration for decades? What “ecological vulnerability” draws us into is the need to take a closer look at the multispecies communities we are embedded in. Although space stations might look overwhelmingly abiotic, I will argue that they do not stand for any kind of exception to this sense of vulnerability. What sort of place is a space station or a space habitat then? What kinds of more-than-human or beyond-human beings are to give us meaning and a sense of home up there? In return, are they to be provided with a meaning of their own? What aspects of space exploration can be challenged and used to reflect on our current relationship to the ecosystems supporting our lives on Earth?

2. Methods and purpose

This presentation will briefly introduced previous cultural ties between space exploration and environmental awareness:

- The adoption of the photographs of Earth from Space as an iconography for environmental counter-cultural movements
- The advocacy for Space colonies, in the wake of the publication of *The Limits to Growth*
- Architectural projects emerging in the 70s and reinterpreting closed-loop ecosystems here on Earth.

Our own perspective will advocate for a critical reworking of the “spaceship Earth” metaphor, a configuration in which, too often, only humans are the ultimate pilots.

By an overview of data gathered on two different projects, VEGGIE at NASA KSC, and the European controlled loop MELiSSA, we will argue that world-making practices in space are not only relying on the work of architects and engineers but are also rooted in alliances and intertwined intentionalities of a multispecies multitude [3]. The point here is not to state that space ecologies should be models for earthly ones, but that they might result in producing awareness concerning the necessity of reintroducing care and redistributing agency within our techno-scientific regimes [7].

As Myers [4] underlines it in her response to Battaglia’s “ethics in suspension” [1], we must bear in mind that artificial ecosystem, as modeled and designed in the context of human spaceflight and when simply replicated on Earth – for farming purpose for instance (e.g. Aerofarm), might just as well be called “design for the Anthropocene” - a view on living systems that reinforce control and a managerial approach to the entities in presence, reducing their agency – or ways of world-making - to a set of parameters captured by sensors. On the contrary, we will stress the necessity to use concepts such as care, ecopolitics, parasitism, and difference, in order to characterize the regime of coexistence of human and non-human beings in such artificial manmade environments.

Anthropologists Danowski and Viveiros de Castro reminded us in “L’Arrêt de Monde” that cosmogonic narratives circulating among amazonian animist tribes generally mention that “In the beginning there was nothing, there were only people.” [2] – Multispecies worlds in outer space might also express this view and stress the dynamics of the entanglements between living and non-living agents. Researches on “artificial” ecologies have materialized a world where there is no stable and inert world lying under *us*. The loop is entirely composed of “people”, human and extra-human, whose lightest action can significantly alter the whole stuff this world is made of - each one sharing the responsibility of sustaining the existence of all the others; each one being a gardener for the other. “We are all astronauts” will therefore acquire a different meaning by re-elaborating the content of the terms “we” and “astronauts”.

3. References

[1] BATTAGLIA Debbora, “Aeroponic gardens and their magic: Plants/persons/ethics in suspension”, *History and Anthropology*, 2017.
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[7] PUIG DE LA BELLACASA Maria, “Making time for soil: Technoscientific futurity and the pace of care”, *Social Studies of Science*, Vol. 45(5) 691–716, 2015.

Short Summary

Envisioning longer stays in outer space - whether on a spacecraft or on another planet - will require programs that create multispecies ecosystems. But this opens existential and ethical questions of how to include and dwell with non-human living systems in contained spaces.

Educational Outreach towards Manned Exploration of Mars and beyond

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1. Introduction

The human' beings ongoing quest to explore Planetary bodies like Mars for prospective Manned Missions and future permanent habitation of Human civilization brings lot of questions to the people on Earth about this prospective ambition. Educational Outreach activities are the best way to educate people especially young school kids in order to make them aware about the happenings in the field of space research activities.

2. Planetary Exploration and Simulation Activities

Before the arrival and landing of humans on Moon, the world has questions when the humans will reach Moon and in present times that shift is towards Mars that when and how humans will arrive on Mars. Considering the various challenges and fears involved in carrying out a manned mission to Mars it is almost impossible to predict what will be the outcome of the first manned trip to Mars once the humans embark on the journey to the Red Planet which has attracted the human beings on Earth since old age times. In this direction it is very important to teach and educate the humans on Earth in particular to young school students whose minds are engulfed with hundreds of questions. Educational Outreach events conducted in this direction not only help the students to get acquainted with the basic challenges towards Manned exploration of Mars but also help them to get an understanding about the research activities being carried out in the direction of preparing for future manned mission through various simulation missions being carried by various agencies and organisations around the world. Conducting an Educational Outreach event in parallel with any ongoing Mars Simulation activities like MARS 500, MARS2013 and PMAS2017 helps the students to get live interaction with the crew involved in the simulation activities thus helping them to come to know about the steps being taken to prepare for the future trip to Mars and beyond. Such kind of outreach activities not only helps the students in getting diverse range of information related to space science but it also helps the organisers of the outreach activities to get acquainted with the imagination and approach of students towards space travel through activities like painting and drawing competition organised during the activity.

3. Figures

Figure 1: Educational Outreach Activity at Central Academy, Basti, India

4. Conclusion

Considering the fact that seeing the current happenings there is still a big time gap when the humans actually embark on the trip to Mars, educational outreach activities carried out in this direction will help in inspiring and motivating the current generation of young school kids to prepare themselves to get involved in the future with the various organisations and research centres working towards making the manned trip to Mars successful.

5. References

[1] www.esa.int/OurActivities/Human_Spaceflight/Mars500
[2] http://spacegeneration.org/home/1660-mars-analogue-simulation-news.html
[3] http://oewf.org/en/portfolio/morocco-mars-2013/

Short Summary

Educational Outreach activities towards the ongoing human effort to explore Mars and beyond. Such Educational activities inspires and motivates the young school students about the space travel and the various constraints and challenges towards the future of space travel

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