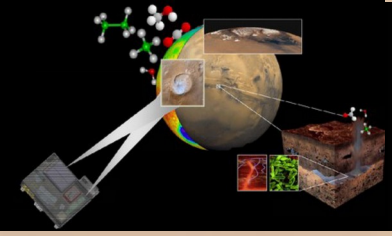


V Encuentro Nacional Ciencias Planetarias y Exploración del Sistema Solar

ESAC , Madrid 8-10 Junio 2017

The instrument NOMAD on board Exomars Trace Gas Orbiter : Scientific possibilities beyond the nominal goals

Miguel Angel Lopez-Valverde, Francisco González-Galindo, Sergio Jimenez-Monferrer, Bernd Funke, Maya García-Comas, Jose Juan López-Moreno (co-IP), Manuel López-Puertas, A. Molina-Cuevas

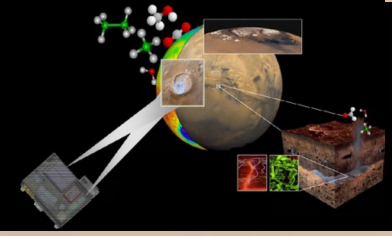
Instituto de Astrofísica de Andalucía/CSIC, Granada, Spain

J.-C. Gerard *Universidad de Lieja, Bélgica*

A. Vandaele (IP), I. Thomas *IASB, Bruselas, Bélgica*

A. Cardesin *ESAC, Madrid*

and the NOMAD Team



The instrument NOMAD on board Exomars Trace Gas Orbiter : Scientific possibilities beyond the nominal goals

ÍNDICE :

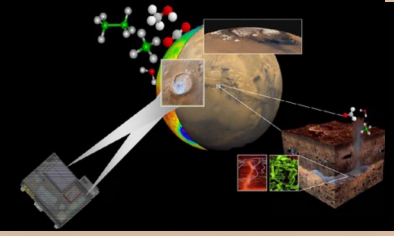
Status of Exomars TGO and NOMAD

Revision of NOMAD & TGO nominal operations

Proposal of limb observations & additional science

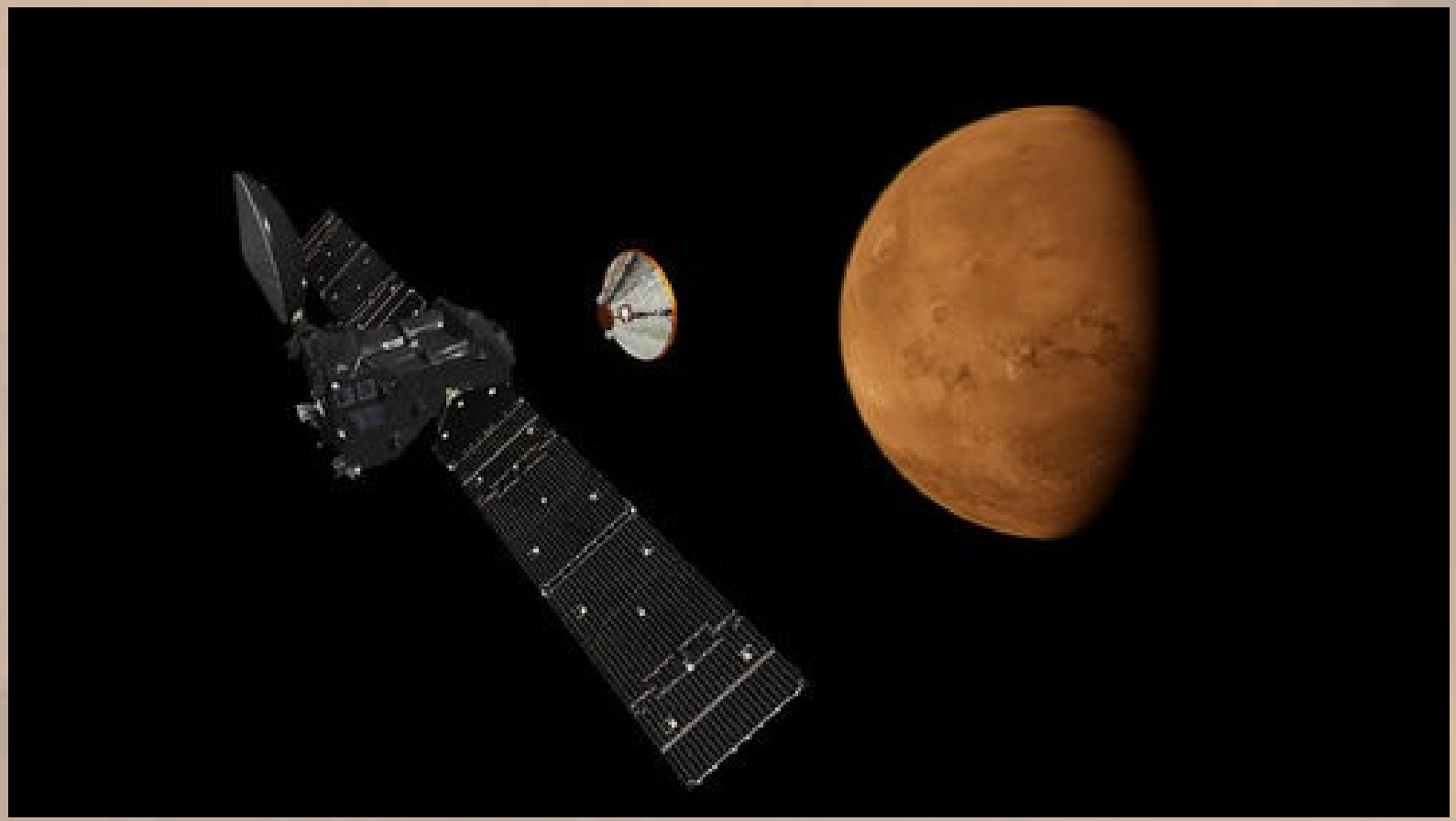
López-Valverde et al., Space Sci. Rev., 2017 submittted

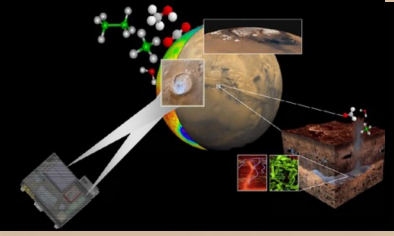
Summary



NOMAD / TGO : Expanding its science possibilities

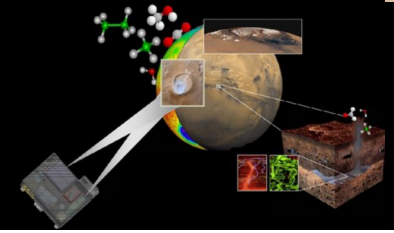
NOMAD ⊂ Trace Gas Orbiter ⊂ Exomars 2016 ⊂ Exomars Program (2016-2020)





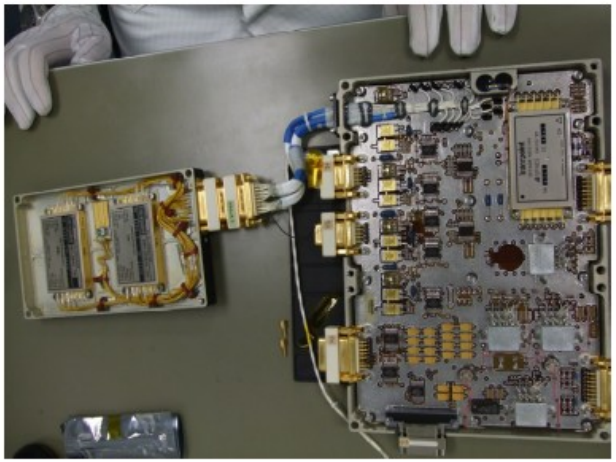
NOMAD / TGO : Expanding its science possibilities

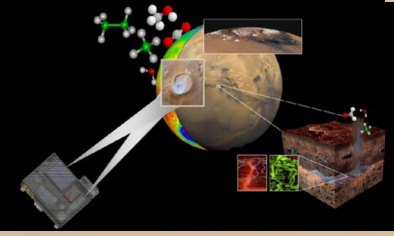
6 years ago, in Bilbao, during the II Spanish Meeting CEPSS



NOMAD / TGO : Expanding its science possibilities

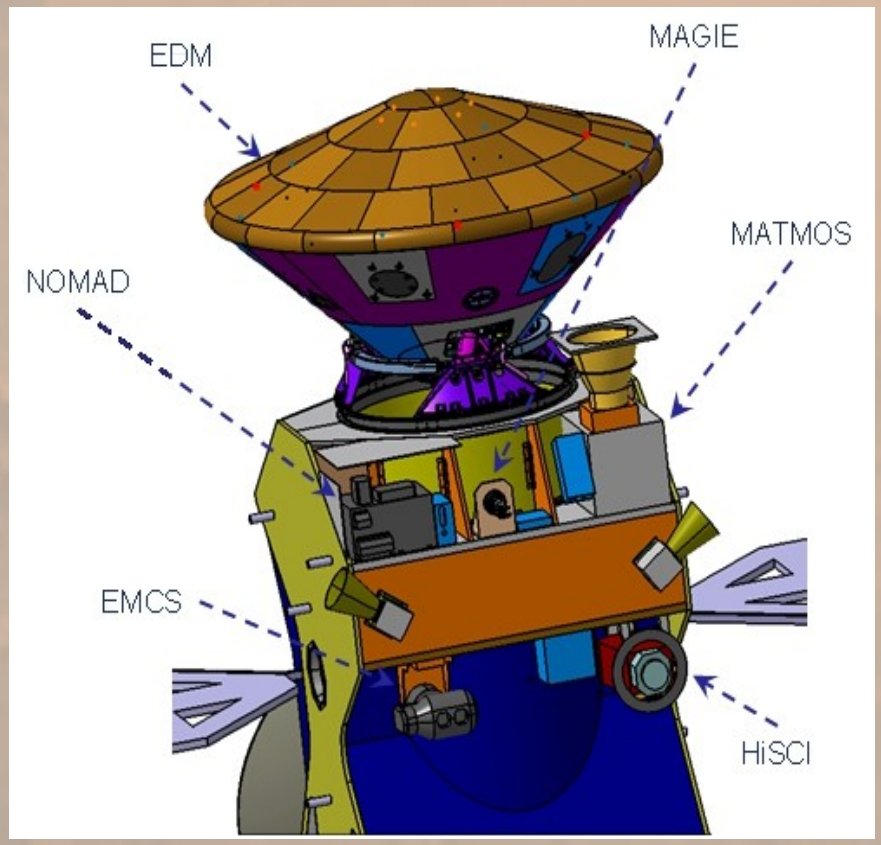
SINBAD PFM.



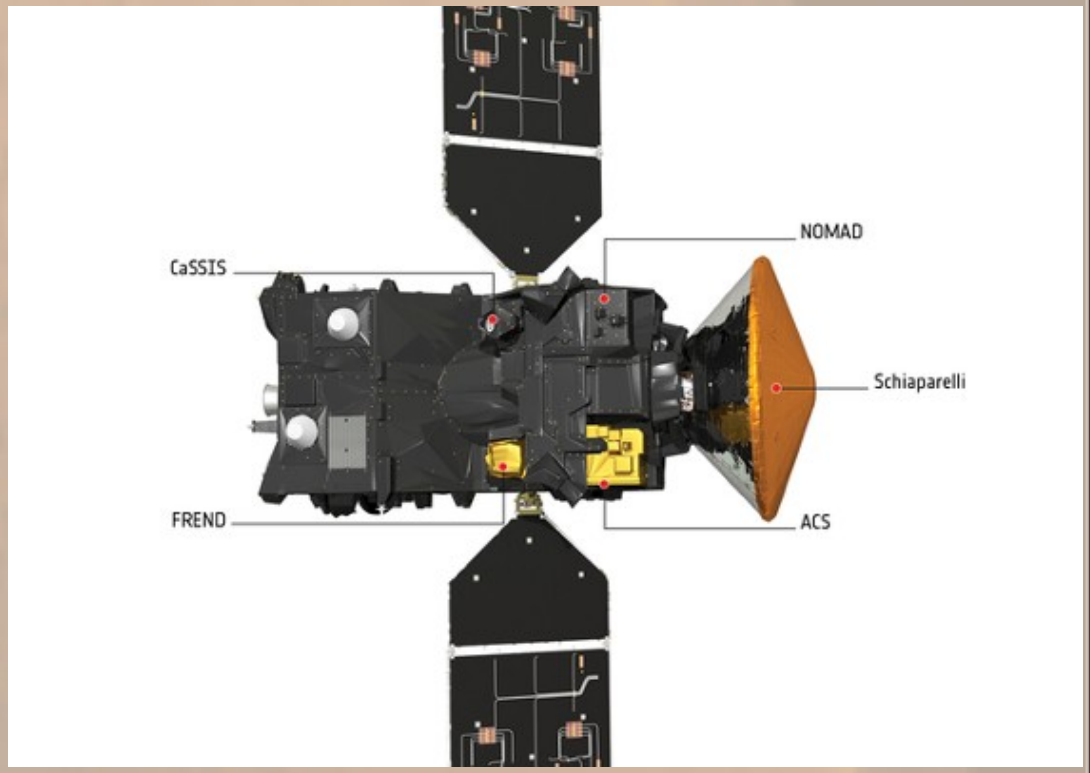


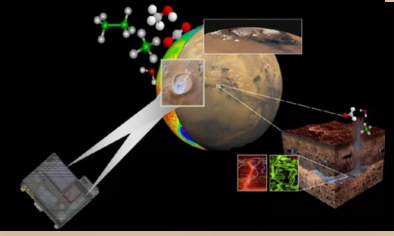
NOMAD / TGO : Expanding its science possibilities

Novedad 1 : ESA + NASA ➔ ESA + ROSCOSMOS



➔





NOMAD / TGO : Expanding its science possibilities

NOMAD
High resolution occultation and nadir spectrometers

Atmospheric composition (CH_4, O_3, trace species, isotopes) dust, clouds, P&T profiles

UVIS (0.20 – 0.65 μm) λ/Δλ ~ 250	SO	Limb	Nadir
IR (2.3 – 3.8 μm) λ/Δλ ~ 10,000	SO	Limb	Nadi r
IR (2.3 – 4.3 μm) λ/Δλ ~ 20,000	SO		

CaSSIS
High-resolution camera

Mapping of sources; landing site selection

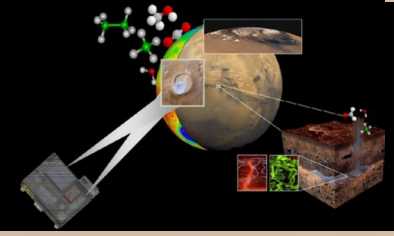
ACS
Suite of 3 high-resolution spectrometers

Atmospheric chemistry, aerosols, surface T, structure

Near IR (0.7 – 1.7 μm) λ/Δλ ~ 20,000	SO	Limb	Nadir
IR (Fourier, 2 – 25 μm) λ/Δλ ~ 4000 (so)/500 (N	SO		Nadir
Mid IR (2.2 – 4.5 μm) λ/Δλ ~ 50,000	SO		

FREND
Collimated neutron detector

Mapping of subsurface water



NOMAD / TGO : Expanding its science possibilities

NOMAD — High resolution occultation and nadir spectrometers — *Atmospheric composition (CH_4, O_3, trace species, isotopes) dust, clouds, P&T profiles*

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CaSSIS — High-resolution camera — *Mapping of sources; landing site selection*

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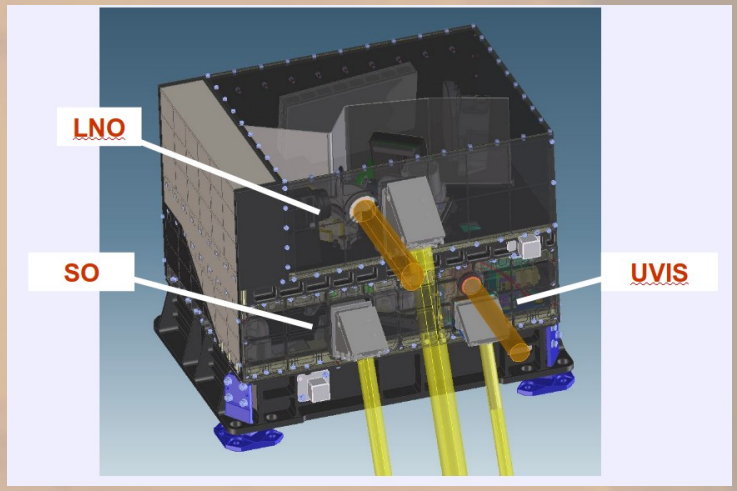
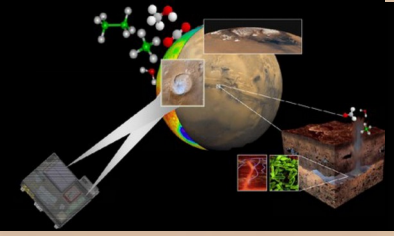
FREND — Collimated neutron detector — *Mapping of subsurface water*



"Nadir & Occultation for Mars Discovery"

OBJECTIVES:

1. Detect a broad suite of Trace Gases & Isotopes
2. Map their Spatial & Temporal Variability
3. Localization of Sources



NOMAD / TGO : Expanding its science possibilities

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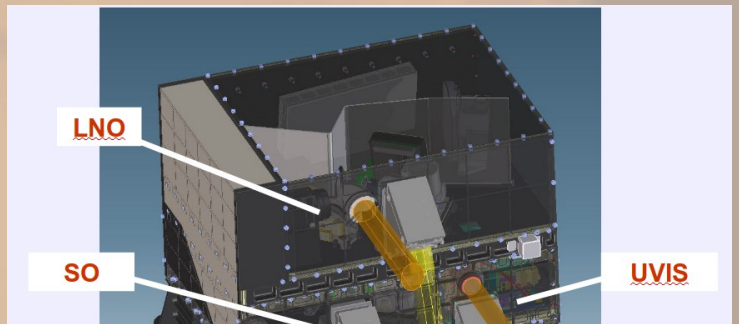


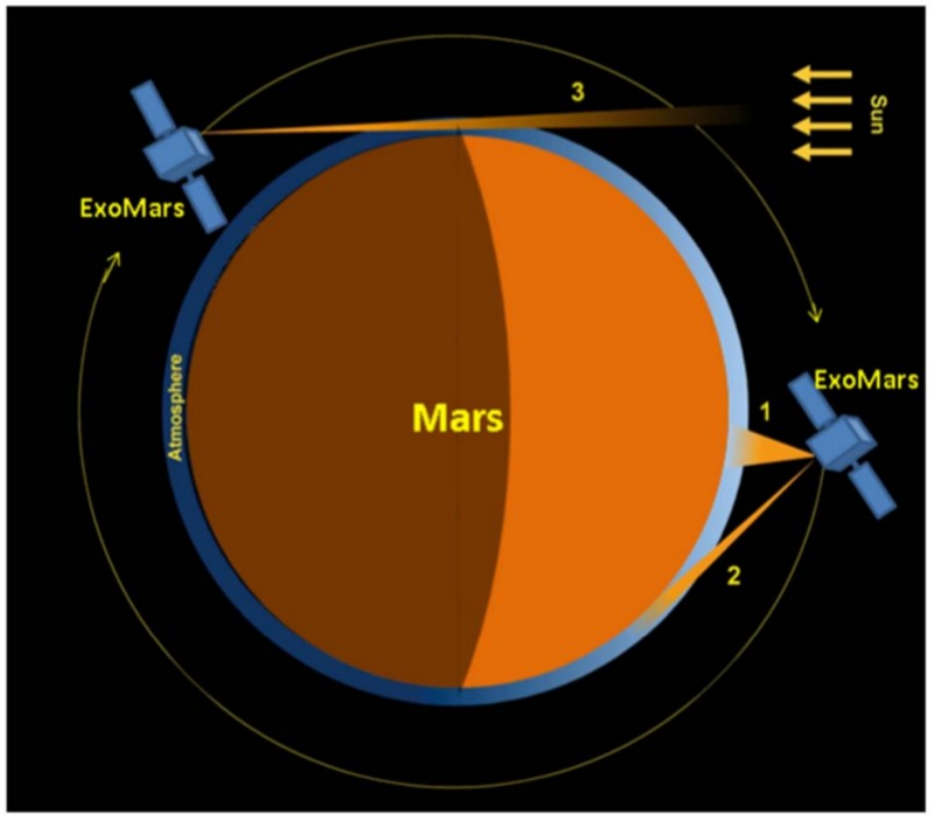
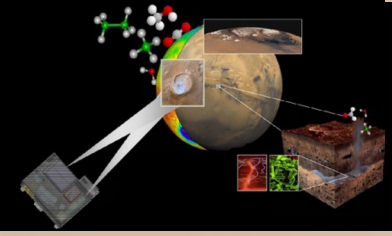
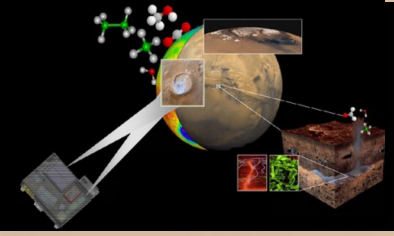


Fig. 1. Different observation modes with NOMAD in orbit around Mars (1 = nadir, 2 = limb, 3 = SO).



NOMAD / TGO : Expanding its science possibilities

Novedad 2 : Atmospheric CH4 confirmed by SAM/Curiosity



NOMAD / TGO : Expanding its science possibilities

Novedad 2 : Atmospheric CH4 confirmed by SAM/Curiosity

Sciencexpress

Mars methane detection and variability at Gale crater

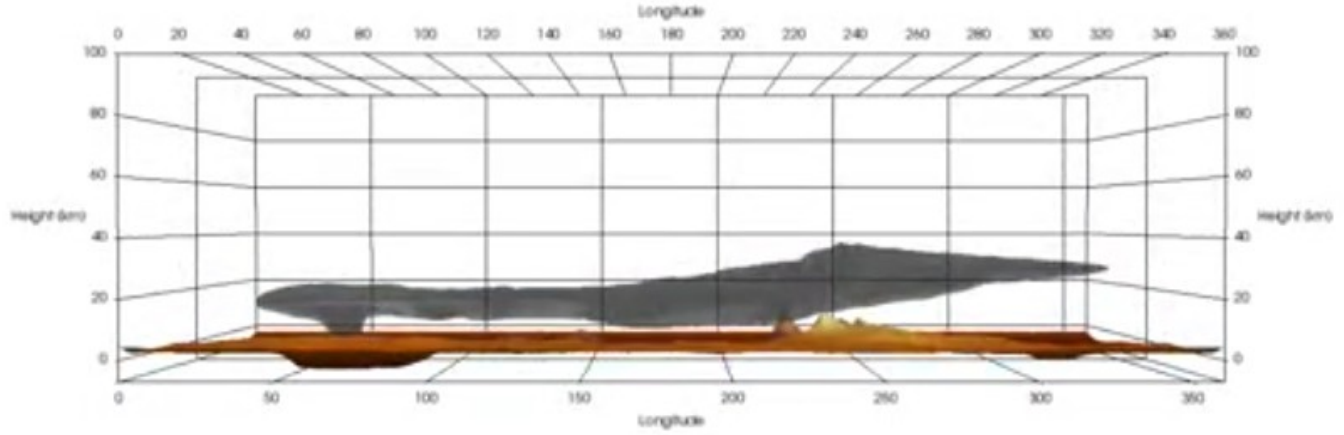
Reports of plumes or patches of methane in the Martian atmosphere that vary over monthly timescales have defied explanation to date. From in situ measurements made over a 20-month period by the Tunable Laser Spectrometer (TLS) of the Sample Analysis at Mars (SAM) instrument suite on Curiosity at Gale Crater, we report detection of background levels of atmospheric methane of mean value 0.69 ± 0.25 ppbv at the 95% confidence interval (CI). This abundance is lower than model estimates of ultraviolet (UV) degradation of accreted interplanetary dust particles (IDP's) or carbonaceous chondrite material. Additionally, in four sequential measurements spanning a 60-sol period, we observed elevated levels of methane of 7.2 ± 2.1 (95% CI) ppbv implying that Mars is episodically producing methane from an additional unknown source.

Webster et al., Science, 2014

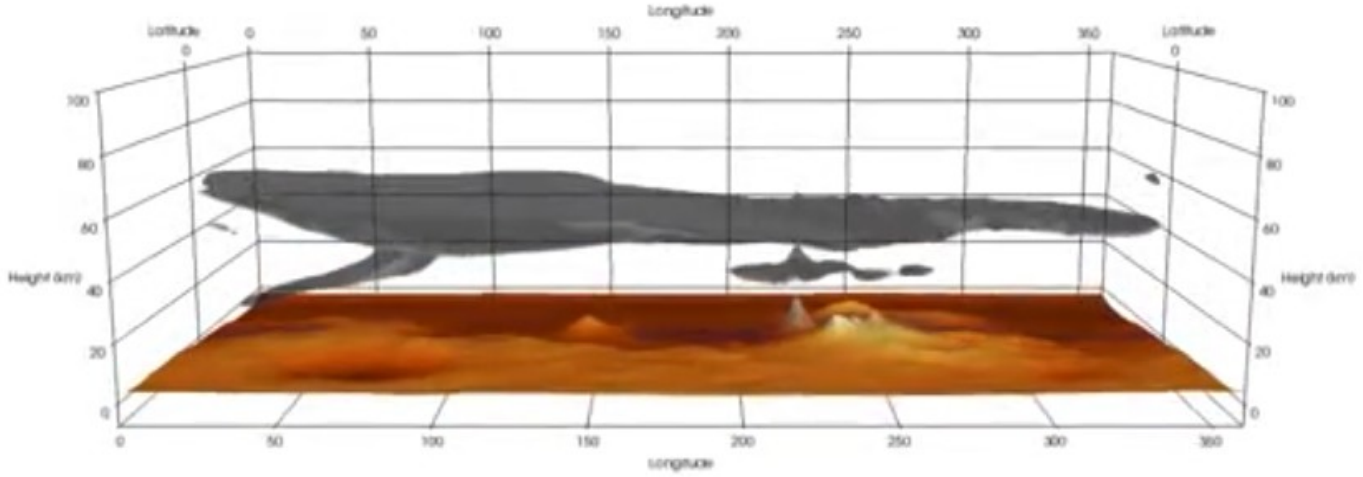
NOMAD / TGO : Expanding its science possibilities

Simulations of CH4 plume dispersion with Mars GEM

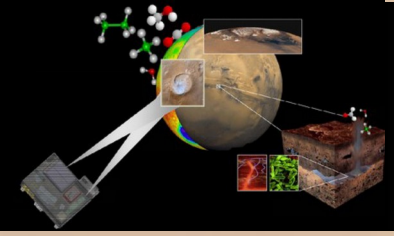
F. Daerden
IASB



Time: 9.6 sols



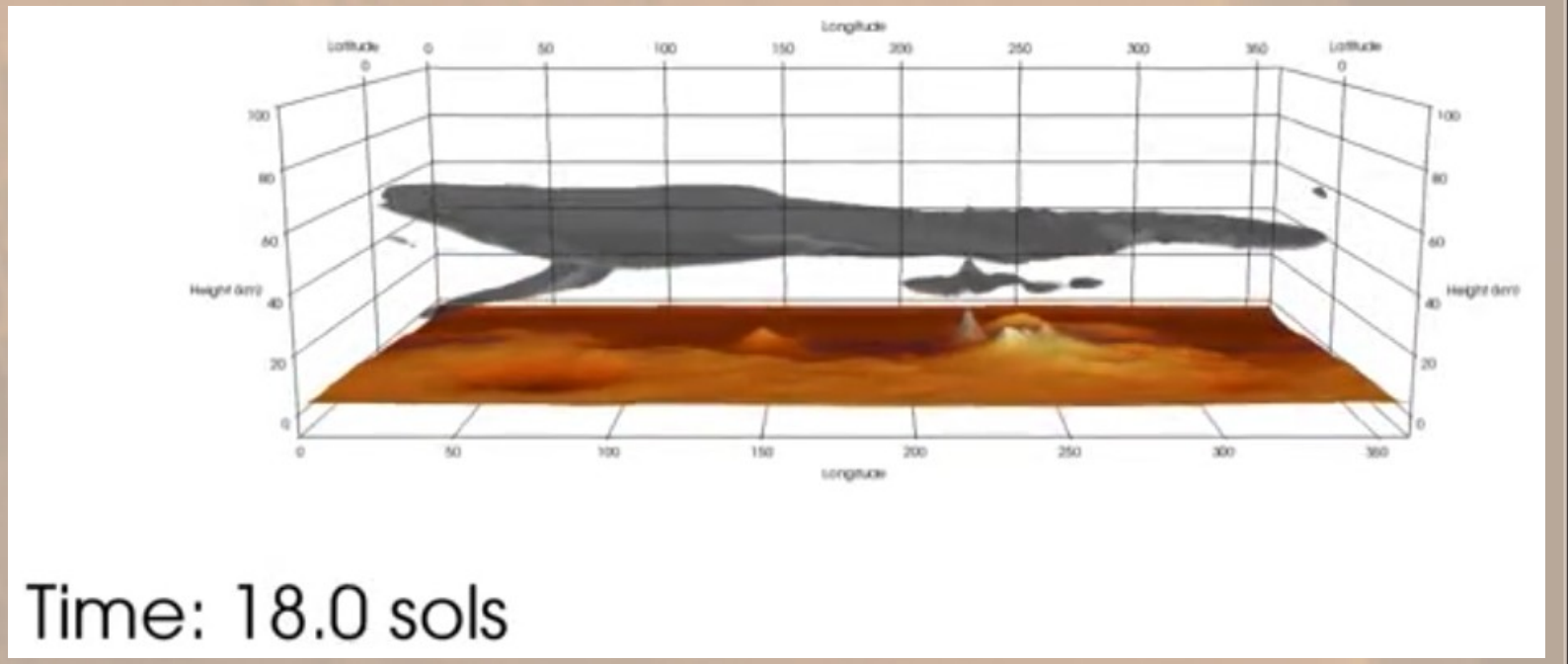
Time: 18.0 sols

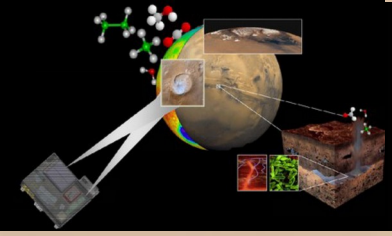


NOMAD / TGO : Expanding its science possibilities

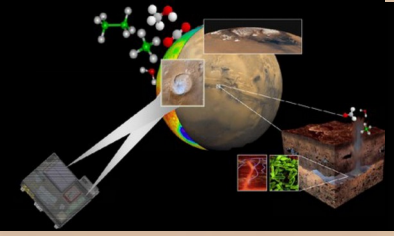
OPEN QUESTIONS :

- Will NOMAD detect these vertical variations ?
- Could the CH4 peak abudance be much larger at 2 km above SAM/Curiosity?
- Are efficient destruction agents at high altitude instead of at the surface?





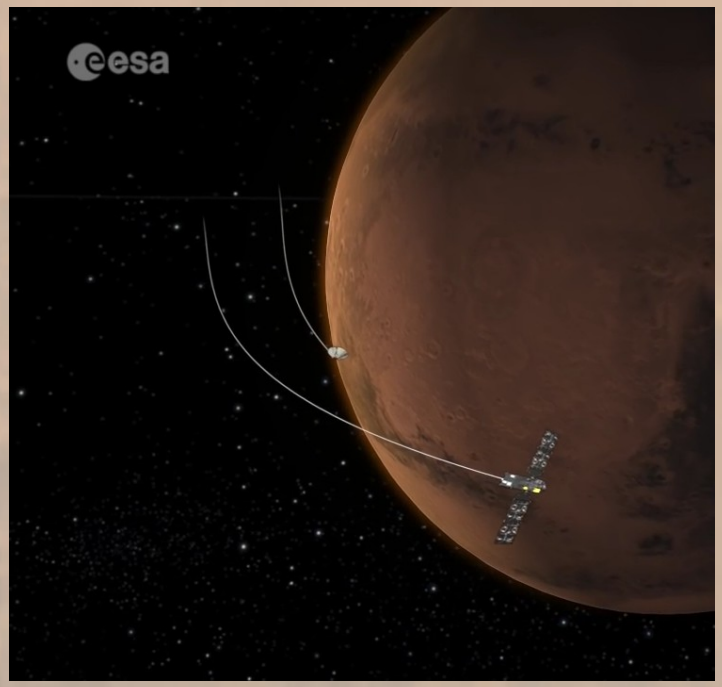
STATUS OF NOMAD / TGO



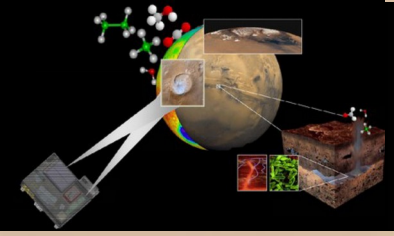
NOMAD / TGO : Expanding its science possibilities

STATUS OF NOMAD / TGO

ORBIT INSERTION



INITIAL MARS CAPTURE ORBITS



NOMAD / TGO : Expanding its science possibilities

STATUS OF NOMAD / TGO

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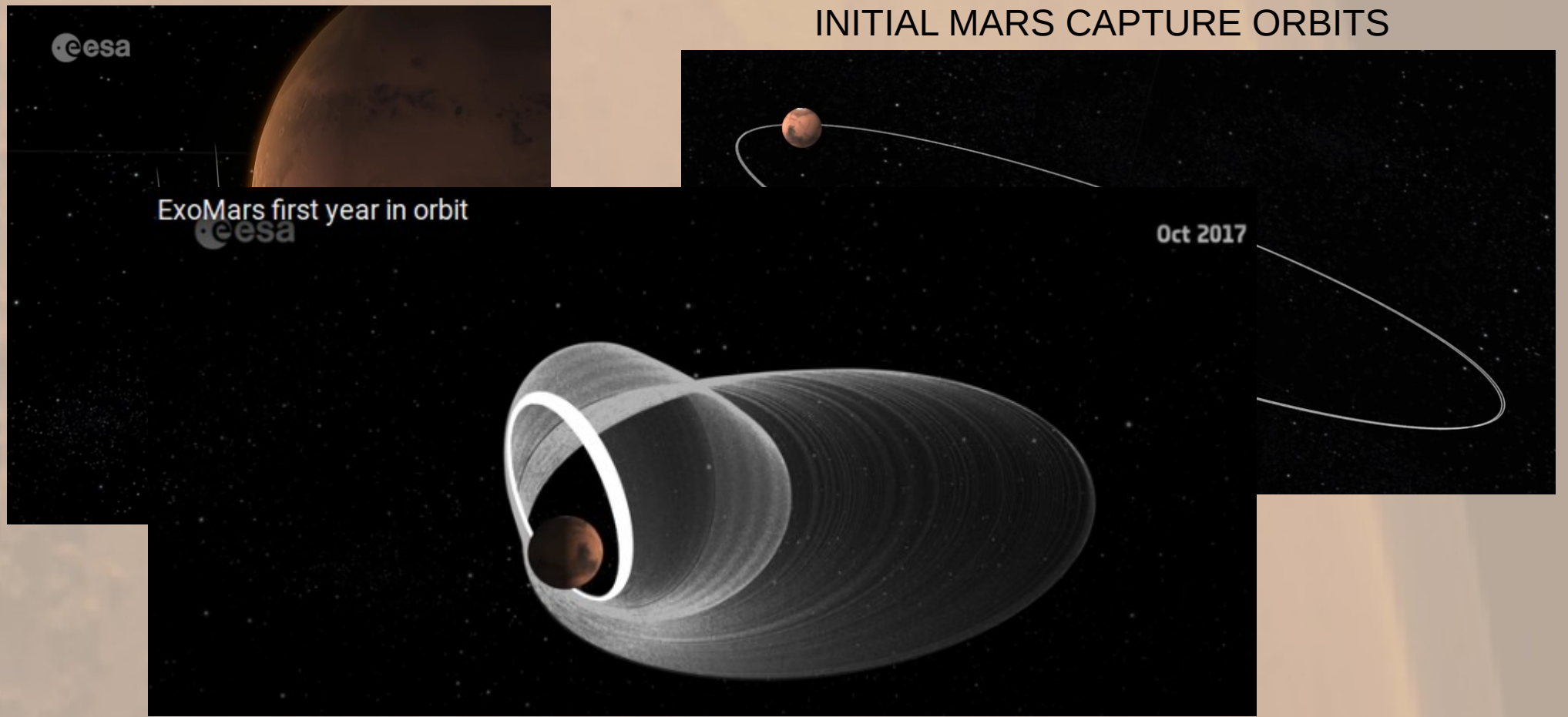
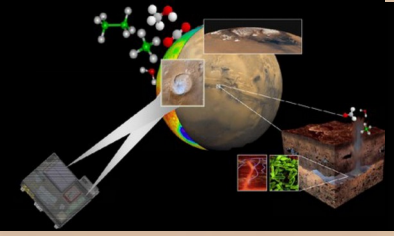


AEROBRAKING PHASE FROM MARCH 2017



NOMAD / TGO : Expanding its science possibilities

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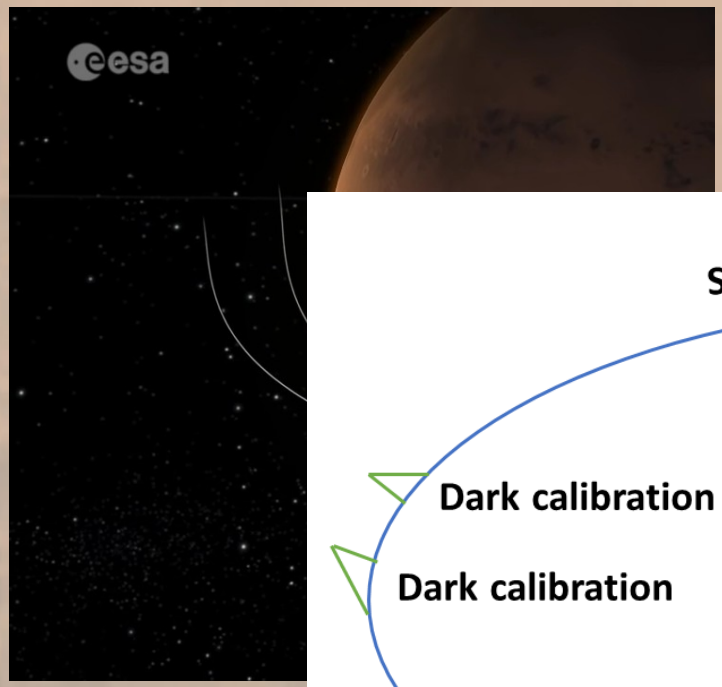

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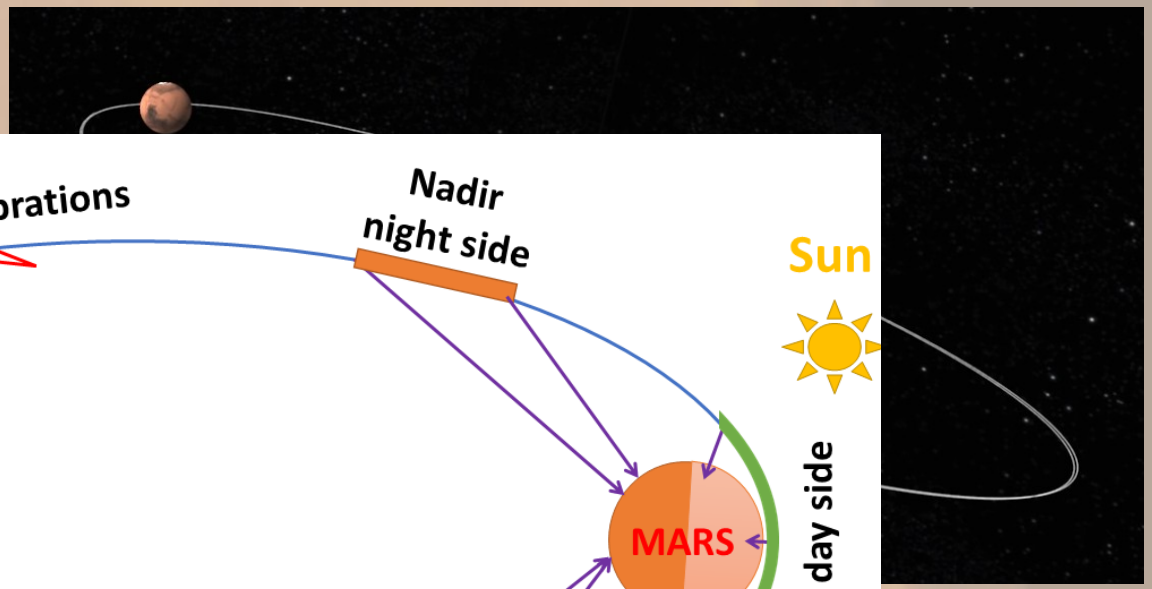
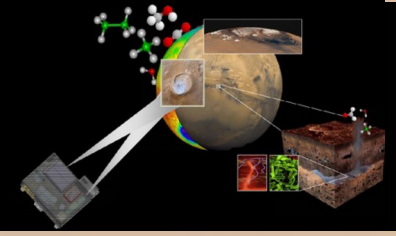
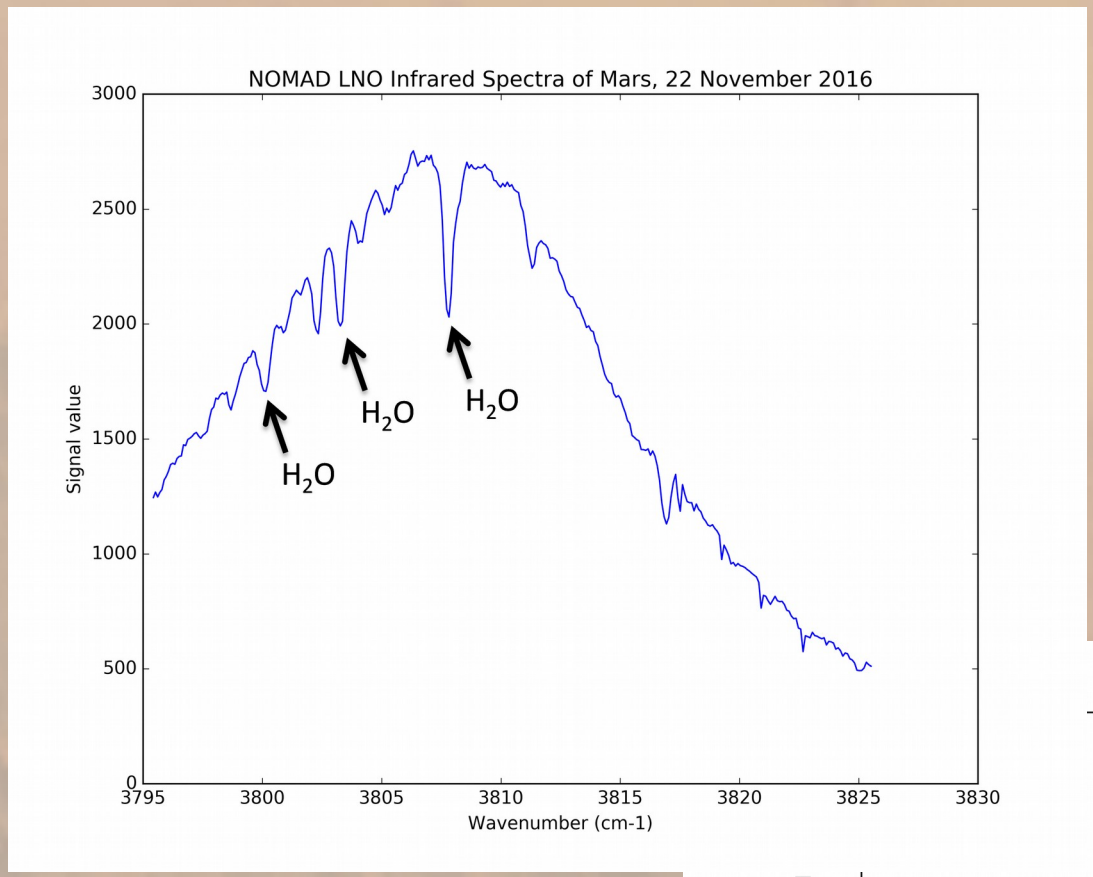
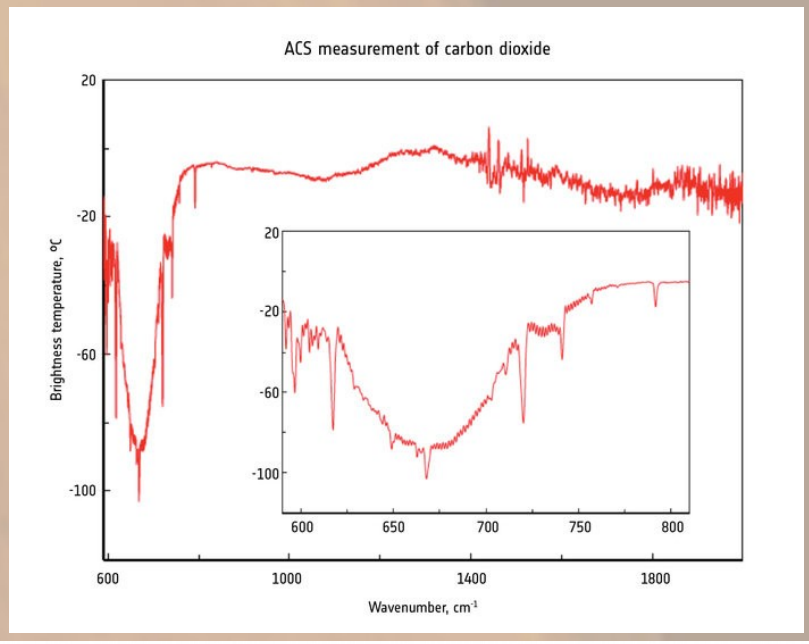
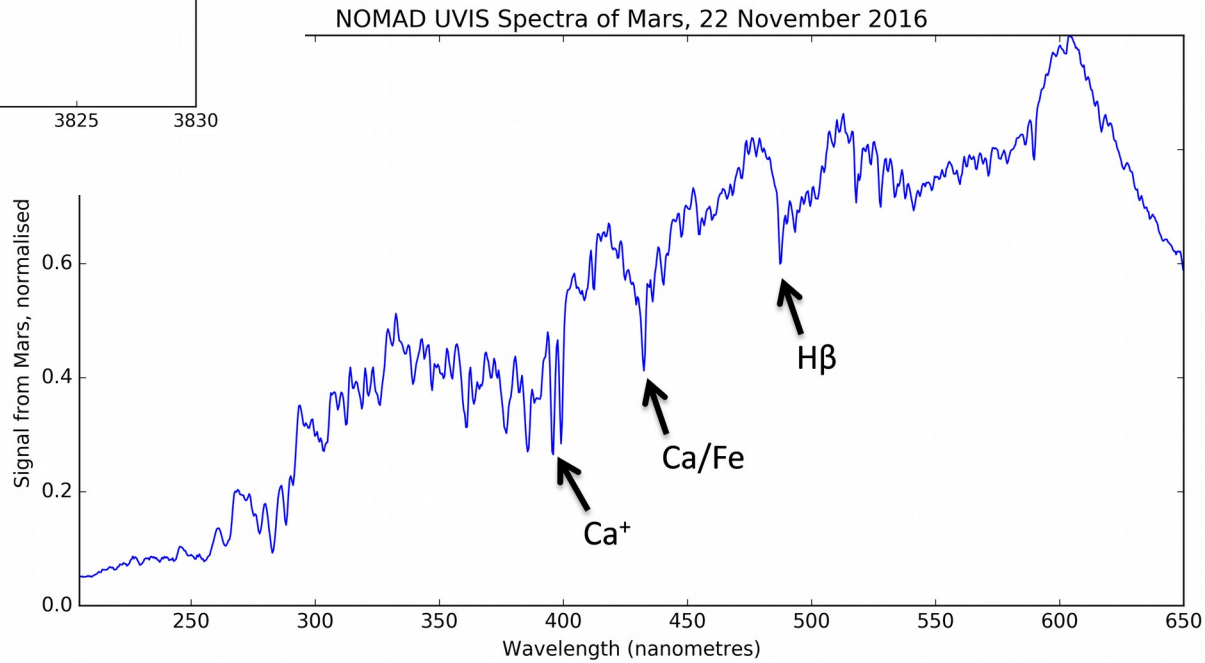


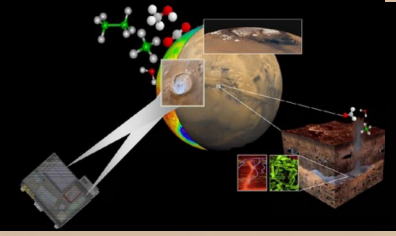


NOMAD / TGO : Expanding its science possibilities









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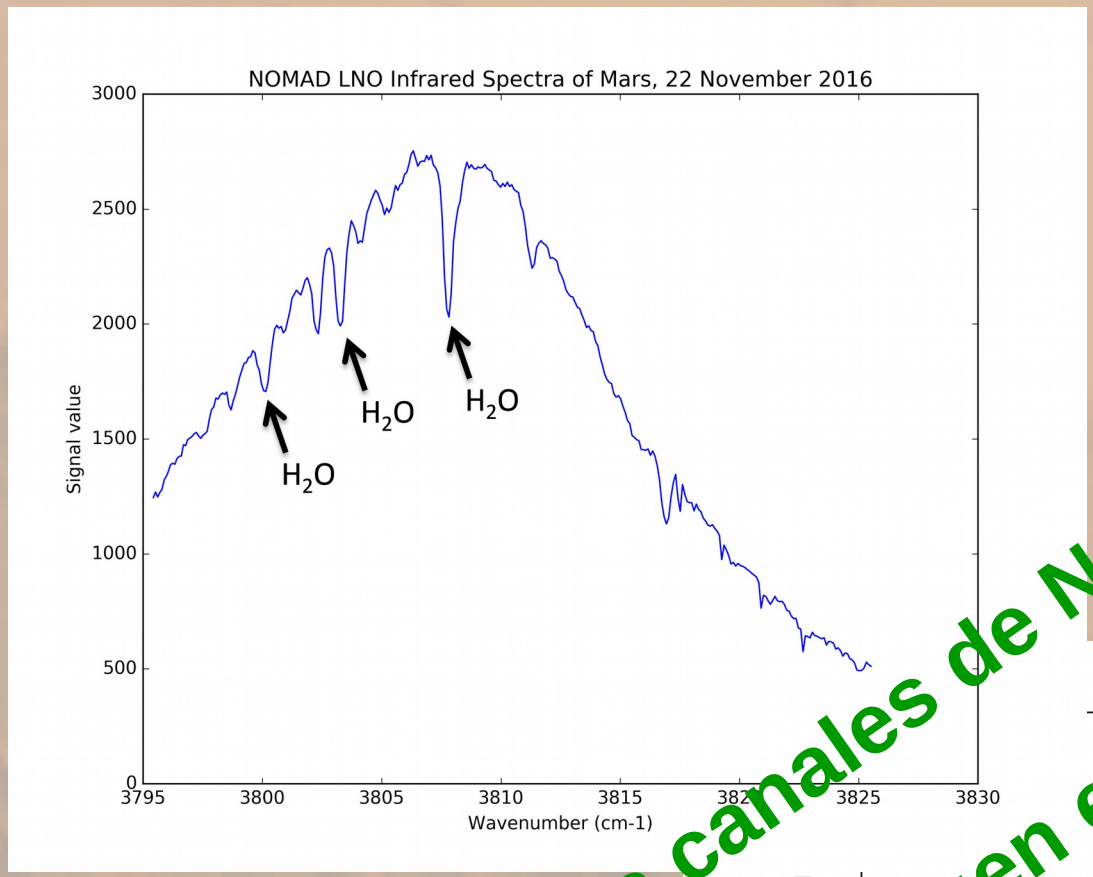
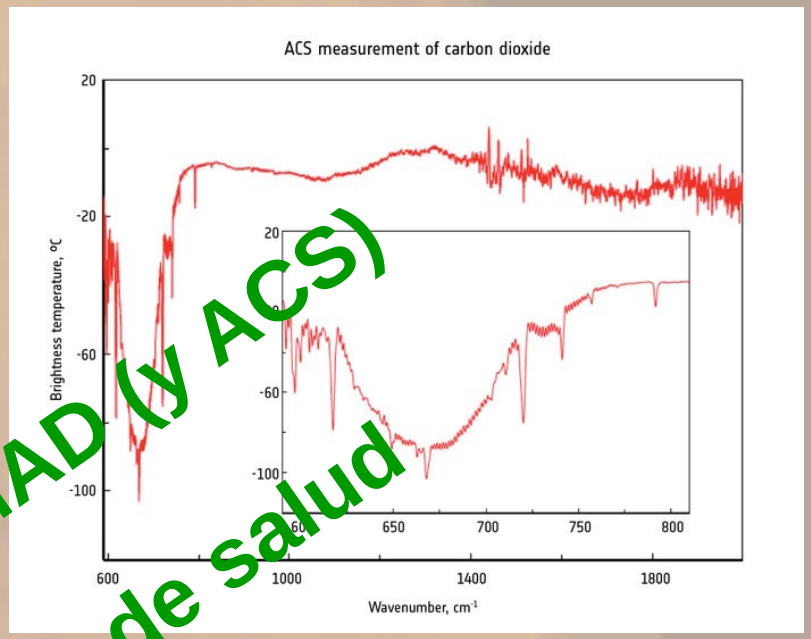
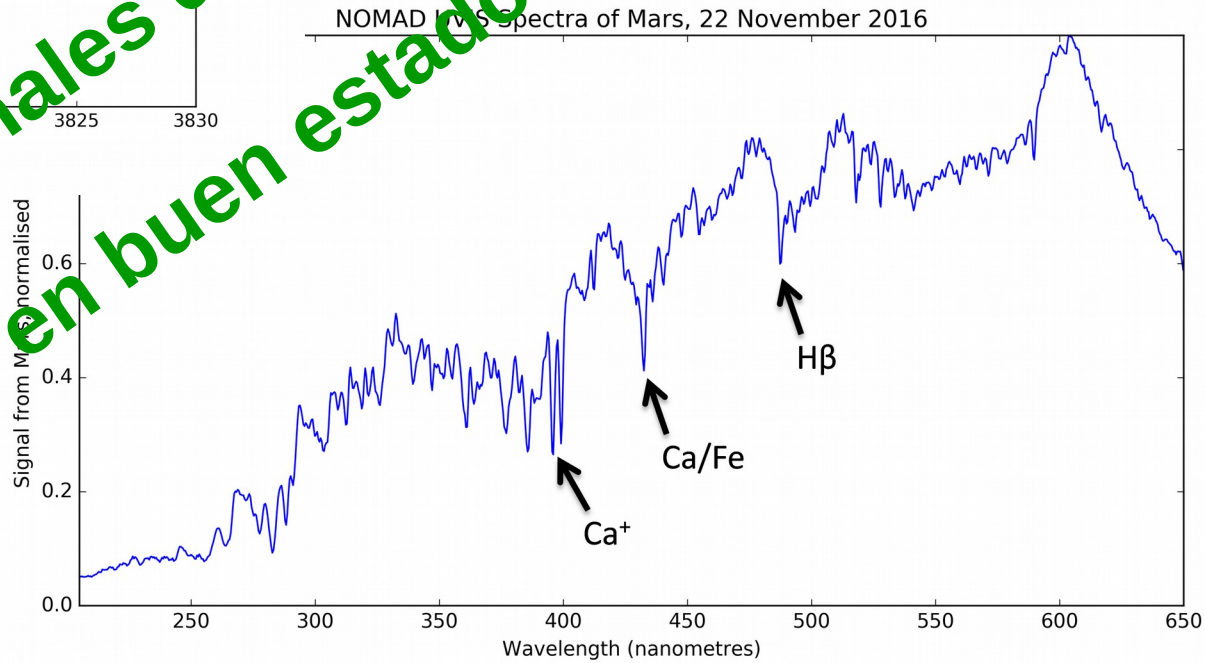
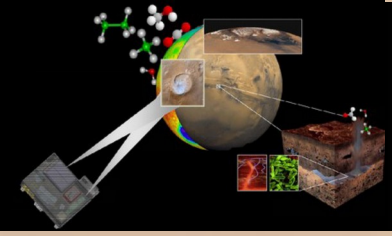




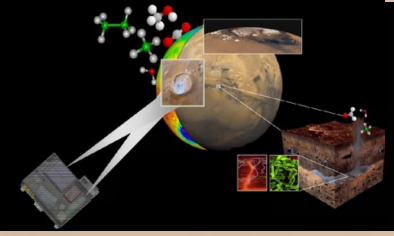
Los tres canales de NOMAD (y ACS)
están en buen estado de salud





NOMAD / TGO : Expanding its science possibilities

The Mars Upper Atmosphere



NOMAD / TGO : Expanding its science possibilities

The Mars Upper Atmosphere

Lack of Data

Energy Balance

Photochemical escape

Day-Night Changes

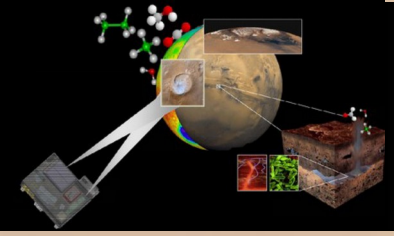
Wave Coupling with lower atmosphere

Homopause altitude

Mesopause variability

H2O ice at high altitudes

Atmospheric modelling challenges



The Mars Upper Atmosphere

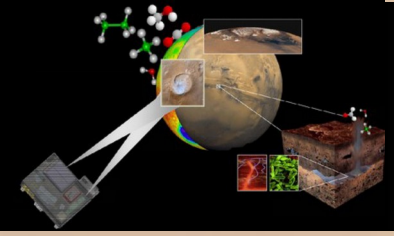
TGO Nominal observations

Solar occultation

3.1.1 IR channels (NOMAD + ACS)	*densities, temperatures, NLTE*
3.1.2 UVIS channel (UVIS)	*ozone, aerosols*

Nadir mapping

3.2.1 Infrared mapping with LNO and TIRVIM	*upper mesosphere temps daytime*
3.2.2 Ultraviolet mapping with UVIS	*NO nightglow*



NOMAD / TGO : Expanding its science possibilities

The Mars Upper Atmosphere

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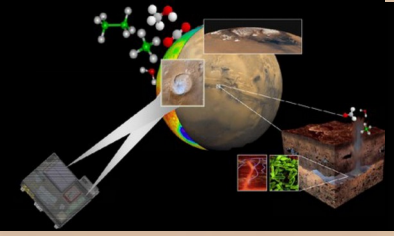
- Solar occultation
  - 3.1.1 IR channels (NOMAD + ACS) — *densities, temperatures, NLTE*
  - 3.1.2 UVIS channel (UVIS) — *ozone, aerosols*
- Nadir mapping
  - 3.2.1 Infrared mapping with LNO and TIRVIM — *upper mesosphere temps daytime*
  - 3.2.2 Ultraviolet mapping with UVIS — *NO nightglow*

Additional capabilities

- TGO Aerobraking Phase — *total density, waves*
- Limb emissions off-the-terminator — *Day & Night coverage*
  - 4.2.1 Nightglow
    - *Mars aurora*
    - *O2 IR atmospheric band 1.27 um & other O2 bands in the UV and visible*
    - *NO UV & near-IR nighttime emission*
    - *Atomic oxygen green line emission*
    - *OH Meinel bands*
  - 4.2.2 Dayglow and fluorescent emissions
    - *UV dayglow (O, CO, N2, CO2+, temps from emission profiles)*
    - *IR NLTE emissions by CO and CO2 (atmospheric variability)*
    - *High altitude plumes in the visible & H2O ice clouds in the near-IR*



NOMAD / TGO : Expanding its science possibilities

LSoffT 1 = Limb pointing using NOMAD flip mirror
LSoffT 2 = Inertial limb scan
LSoffT 3 = Nadir boresight slew
LSoffT 4 = Fixed limb tracking

} Dayside & Nightside coverage !!

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LSoffT 1

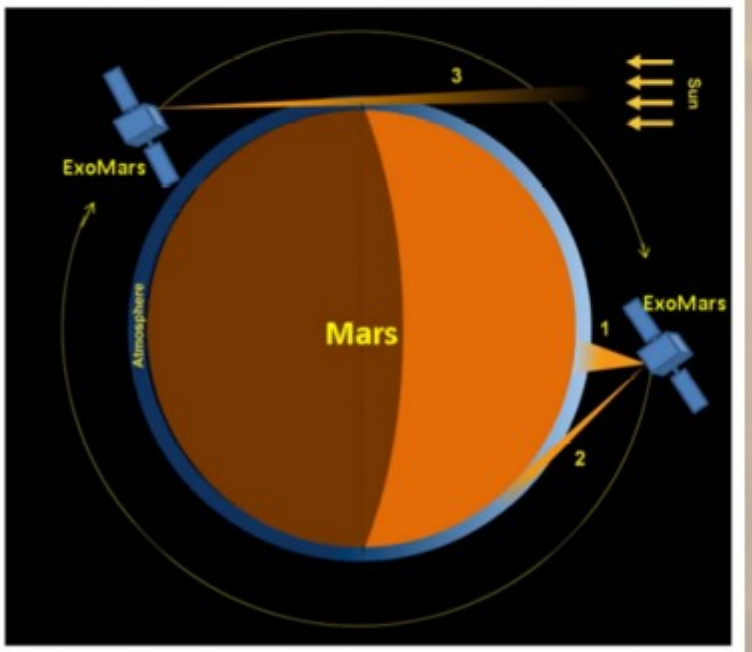
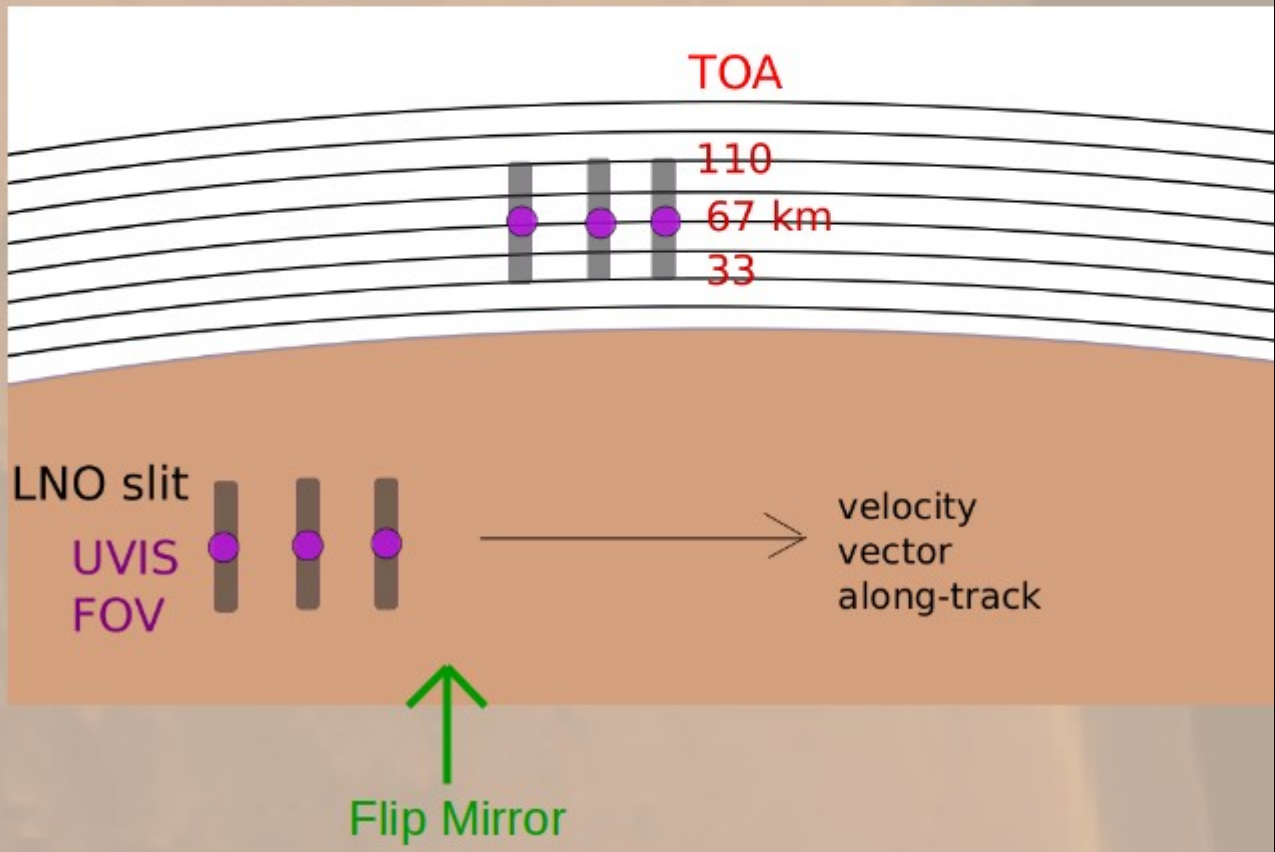


Fig. 1. Different observation modes with NOMAD in orbit around Mars (1 = nadir, 2 = limb, 3 = SO).



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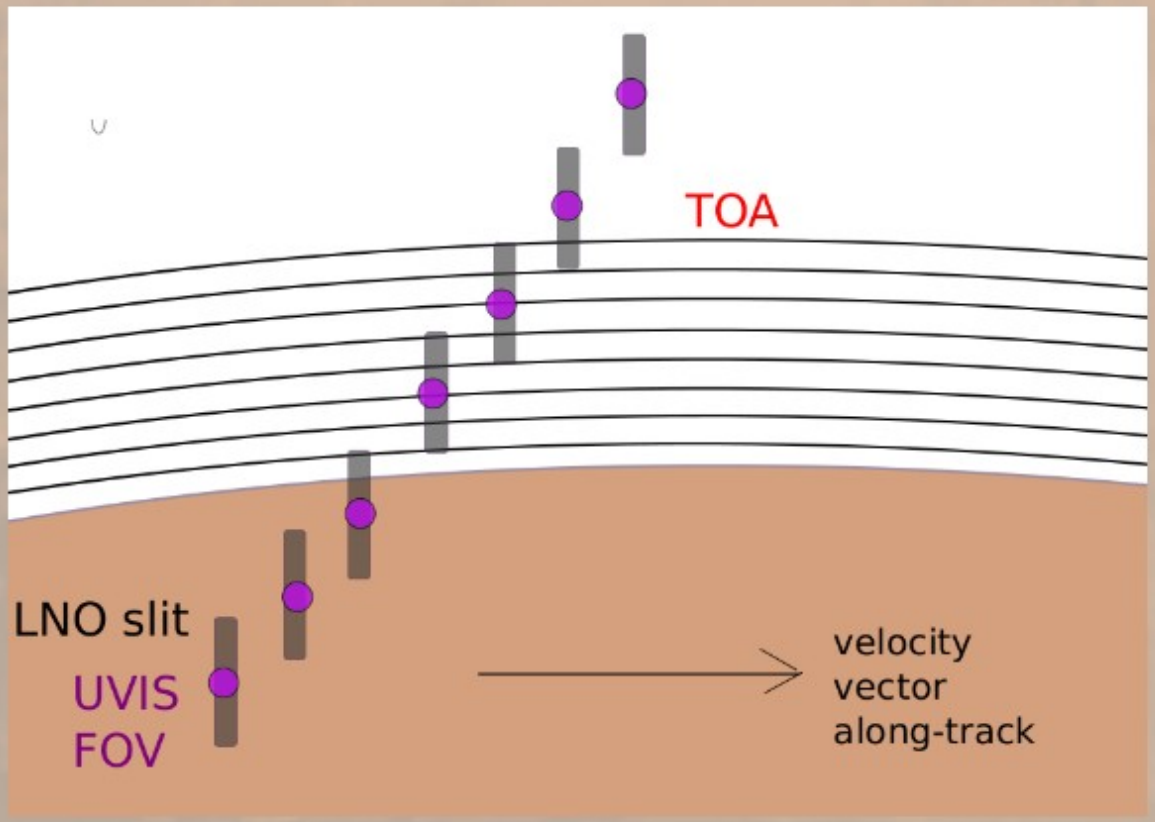
LSoffT 3



Advantages over LSoffT 1 :
- NOMAD + ACS
- Nadir channels
- Full vertical sampling

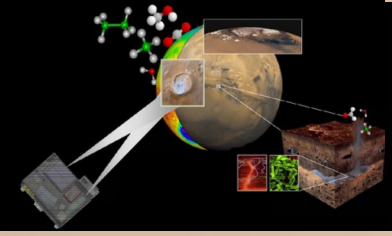
LSoffT 4 = LSoffT 3 @ fixed tgt z

LSoffT2 ~ LSoffT3 but less flexible
(sampling imposed)
but easier to implement ?

Table 2 Summary of TGO Capabilities for Upper Atmosphere Science

Confidence Level	Science Target	Nomad+ACS Channels	Observation Modes$^{\oplus}$
Solid Prediction	Lower-Upper atm couplings	SO+MIR	Nominal S.Occ
	Diffusion & Escape processes	SO+MIR	Nominal S.Occ
	Improve UA† Climatologies (for CO_2, CO, H_2O, Temperature, aerosols and clouds)	SO+MIR+UVIS +NIR	Nominal S.Occ
	CO_2 Hot Bands & NLTE science	SO+MIR	Nominal S.Occ
	Detect & Distinguish between dust & Ice aerosols. Study of bi-modal distributions.	SO+MIR+UVIS +NIR	Nominal S.Occ
	Latitudinal & Seasonal variability in Thermospheric Densities and Atmospheric Wave Propagation		Aerobraking
	CO_2 VMR vs Total density		Aerobraking + Nominal S.Occ
	CO_2 daylight 4.3 um fluorescence	TIRVIM	LSoffT 3, 4
Likely Detection	NO nightglow in NADIR	UVIS	Nominal Nadir mapping
	O_3 at the day-night transition	UVIS	Nominal S.Occ
	Thermospheric temps from NADIR CO_2 fluorescence at 4.3 um	TIRVIM	Nominal Nadir mapping
	NO Nightglow High Lats	UVIS	LSoffT 1, 2
	OH Meinel Bands in the polar night	LNO+NIR	LSoffT 1, 2, 4
	Aurora in solar storms period	UVIS	LSoffT 2
	O_2 1.27 um Nightglow High Lats	NIR	LSoffT 2, 3
	UV dayglow and Thermospheric Temperatures from their limb profiles	UVIS	LSoffT 2, 3, 4
	Very high altitude H_2O ice clouds	NIR+UVIS	LSoffT 2, 3
	Thermospheric Plumes	LNO+NIR+UVIS (+TIRVIM)	LSoffT 1, 2, 3 (4)
Difficult Target	First Detection of the O Green Line emission$^{\nabla}$	UVIS	LSoffT 1, 2
	Nightglow O_2 bands at high latitudes	UVIS	LSoffT 1, 2
	Visible Dayglow by CO_2+ and CO	UVIS	LSoffT 1, 2
	CO_2 2.7 um daylight fluorescence	LNO	LSoffT 1−4
	NO 1.22 μm nightglow	NIR	LSoffT 2, 3, 4

$^{\oplus}$ LSoffT stands for "limb sounding off-the-terminator" (see section 4.2 for details) :



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CONCLUSIONES

NOMAD & TGO están en buen estado, continuando la fase de aerofrenado.

Continuamos preparando herramientas (retrieval methods) y modelos

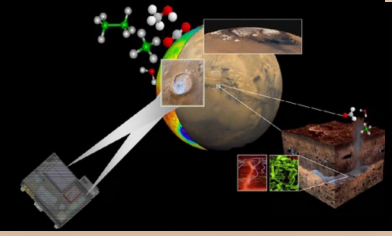
Abril 2018 (?) : Fin aerofrenado

→ Observaciones Regulares desde la órbita final

→ Explotación Científica

Esperamos que con campañas específicas en el limbo

FASE EXCITANTE QUE REQUIERE UN MÍNIMO DE FINANCIACIÓN



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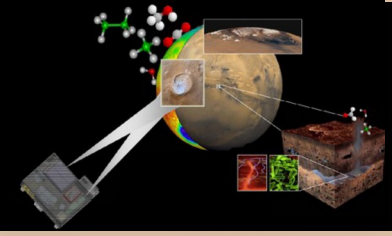
Gracias por la atención



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