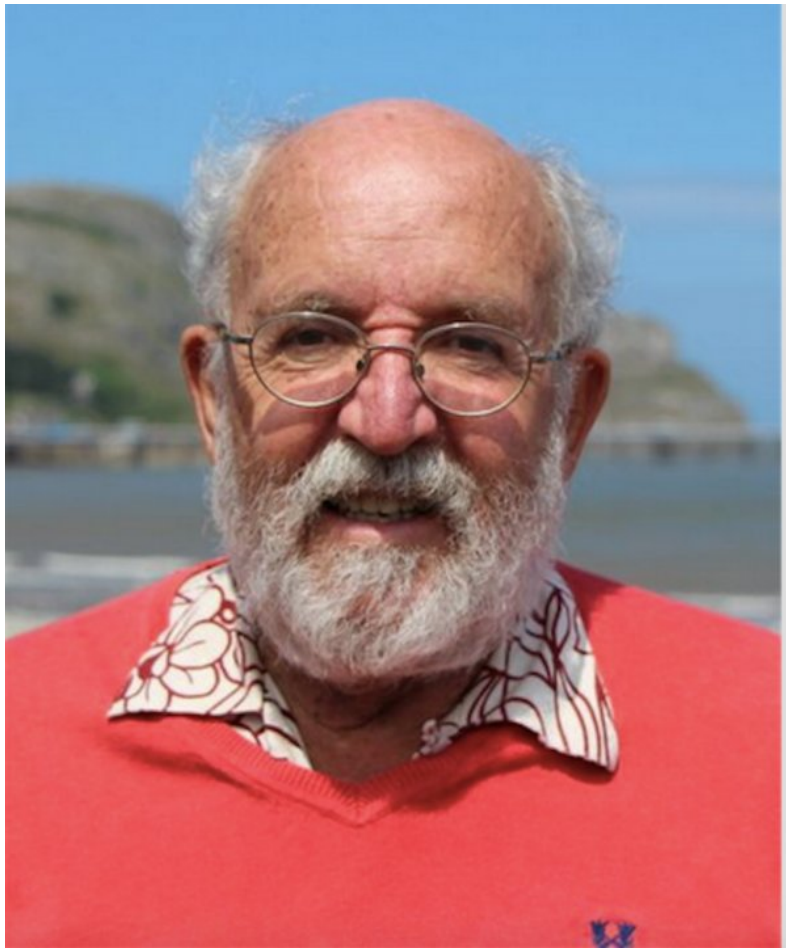
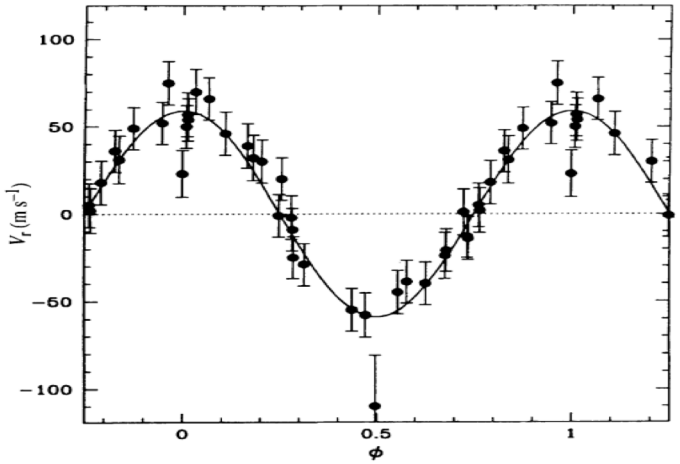
Voyage 2050: Exoplanets

A. Quirrenbach
on behalf of a very large community

Congratulations to our Swiss Colleagues!



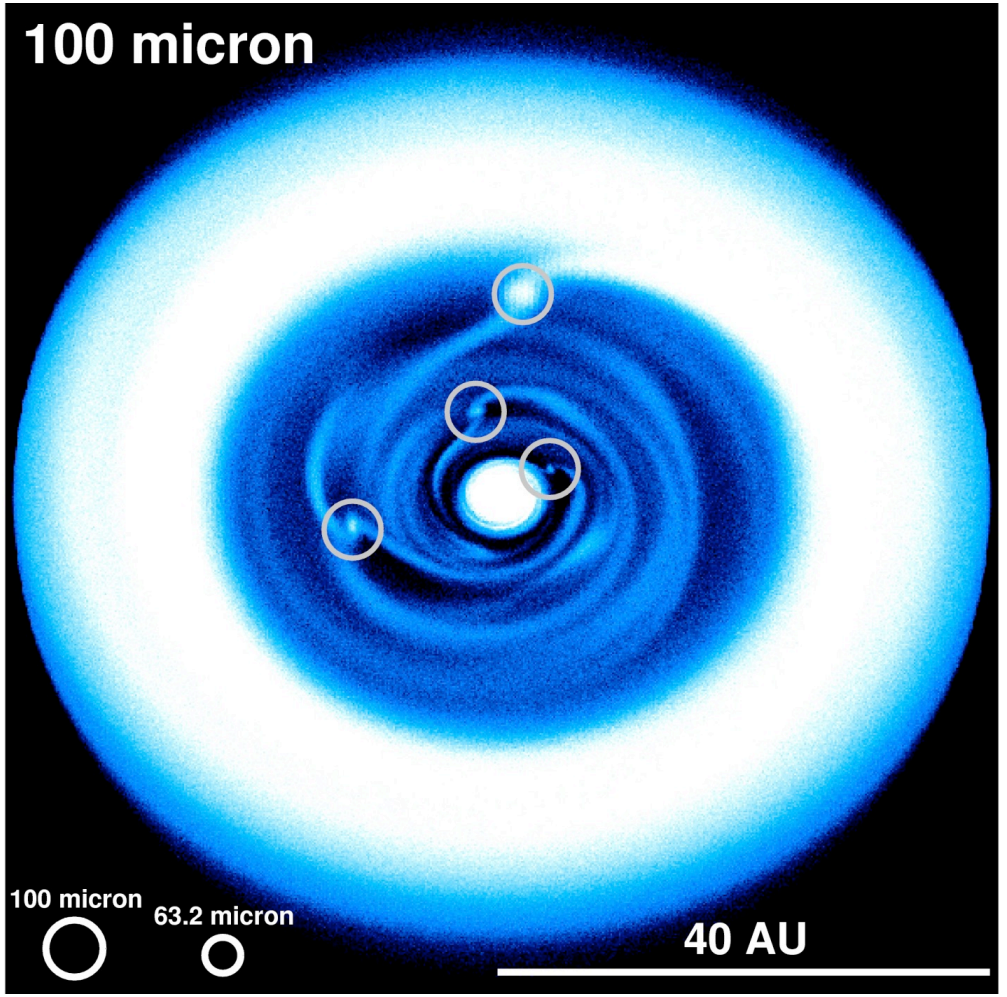


Exoplanets: A Rapidly Evolving Field

- 1995: First planet around Sun-like star confirmed
- < 2000: Surprise, surprise (hot Jupiters, high e, …)
- < 2010: Orbits, systems, transits
- < 2020: Statistics, atmospheres, Earth twins (almost)
- < 2030: Details, taxa, Earth twins (real!)
- Voyage 2050: Habitability and Life

Great Exoplanet Missions are Usually General-Purpose Observatories

- Spitzer , Hubble, JWST
- CoRoT, Kepler, TESS, Plato
- Gaia, future astrometry
- WFIRST
- Large UV-optical telescope (e.g. HabEx, LUVOIR)
- Mid-IR / far-IR interferometer



Relevant White Papers Submitted

M. Barstow / C. Evans	**The search for living worlds and the connection to our cosmic origins**
J.-L. Bertaux	**Exploring the nearest habitable exoplanets**
A. I. Gómez de Castro	**EUVO – The UV window into the universe**
P. Horzempa	**Precise astrometry: earth analogs and beyond**
K. Jahnke	**The need for a multi-purpose, optical-NIR space facility after HST and JWST**
M. Janson	**Prospects for studying earth-like planets with the E-ELT and a space-based occulter**
H. Linz	**Bringing high spatial resolution to the far-infrared**
F. Malbet	**Faint objects in motion: the new frontier of high precision astrometry**
P. Plavchan	**EarthFinder**
S. Quanz	**Atmospheric characterization of terrestrial exoplanets in the mid-infrared:**
L. Rossi	**Spectropolarimetry as a tool for understanding the diversity of planetary atmospheres**
J. Schneider	**Very high resolution spectro-polarimetric interferometry and imaging from the moon**
I. Snellen	**Detecting life outside our solar system with a large high-contrast-imaging mission**
M. Wiedner	**Origins Space Telescope: from first light to life**

J.-L. Bertaux

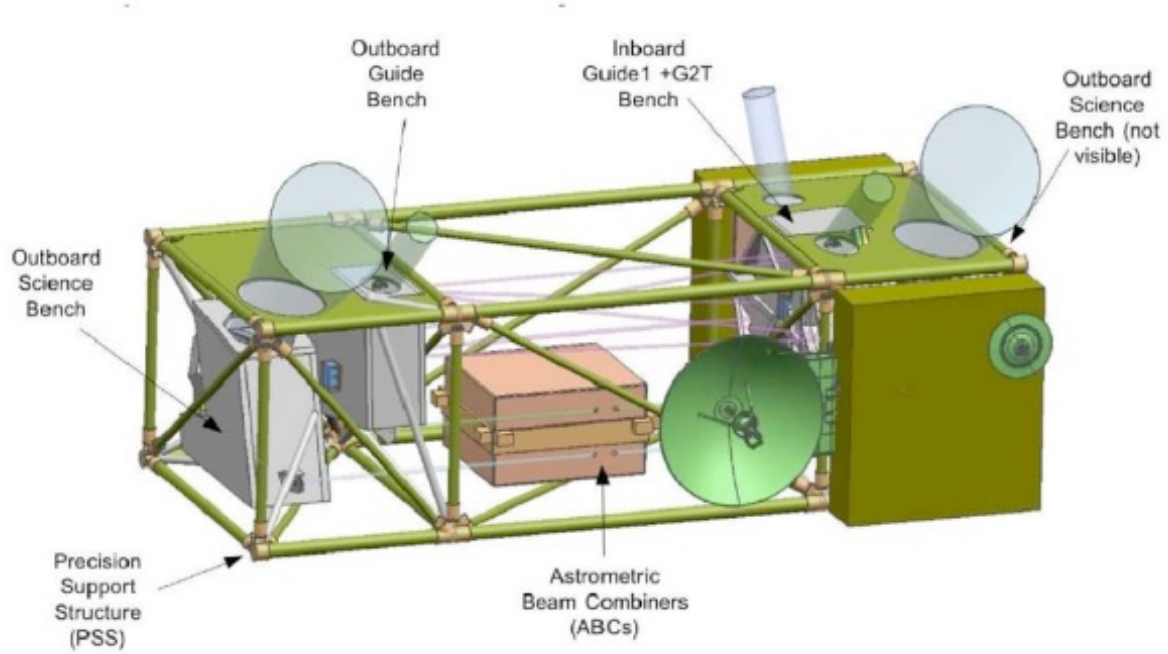
Exploring the nearest habitable exoplanets

- Look for potentially habitable planets from the ground
- Space is needed for characterization
- Consider biosignatures and technosignatures
- Cooperate with NASA

P. Horzempa

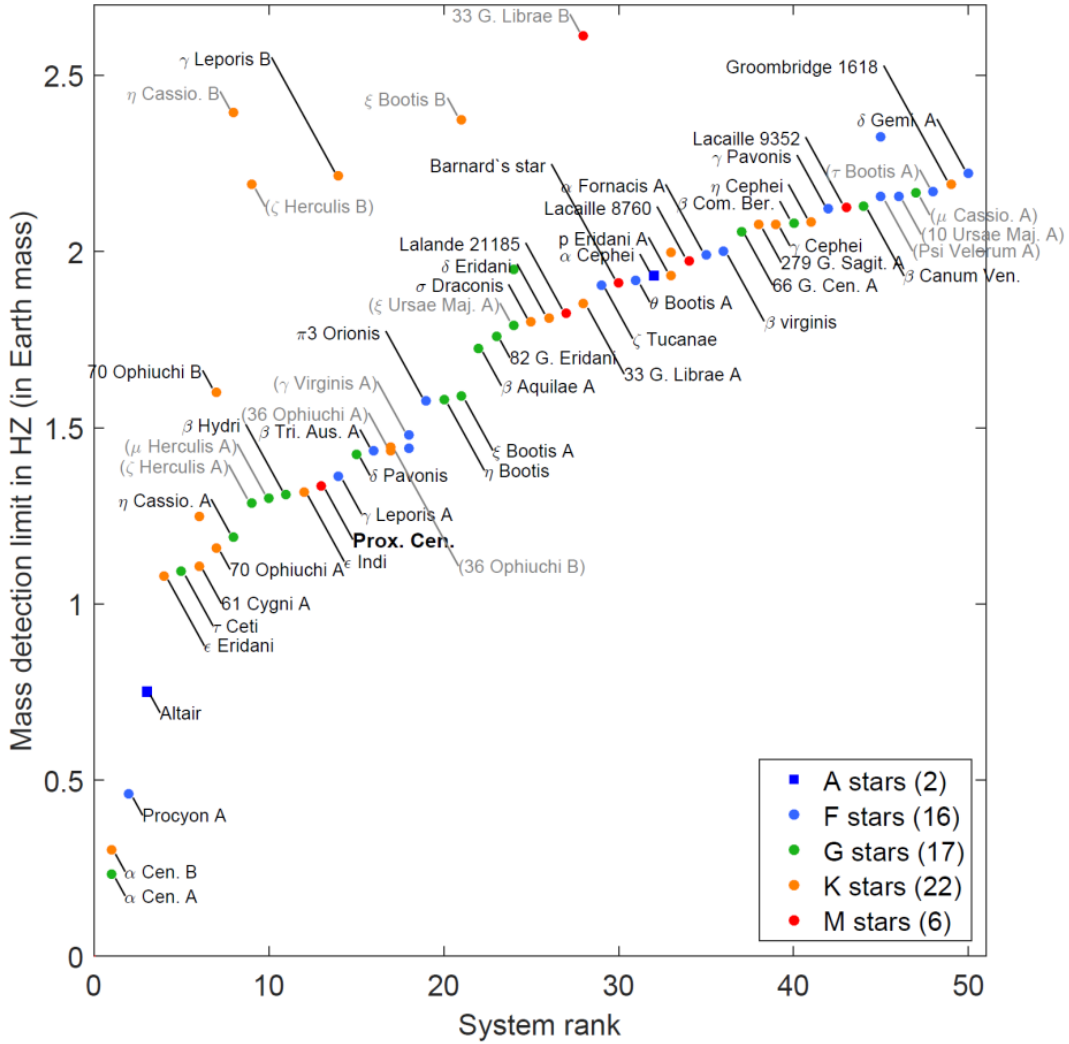
Precise astrometry: earth analogs and beyond

- Astrometric detection and mass measurement of exoplantes
- Precision ≈ 0.3 μas
- Compelling general astrophysics
- Build on expertise and hardware developed by NASA (SIM)



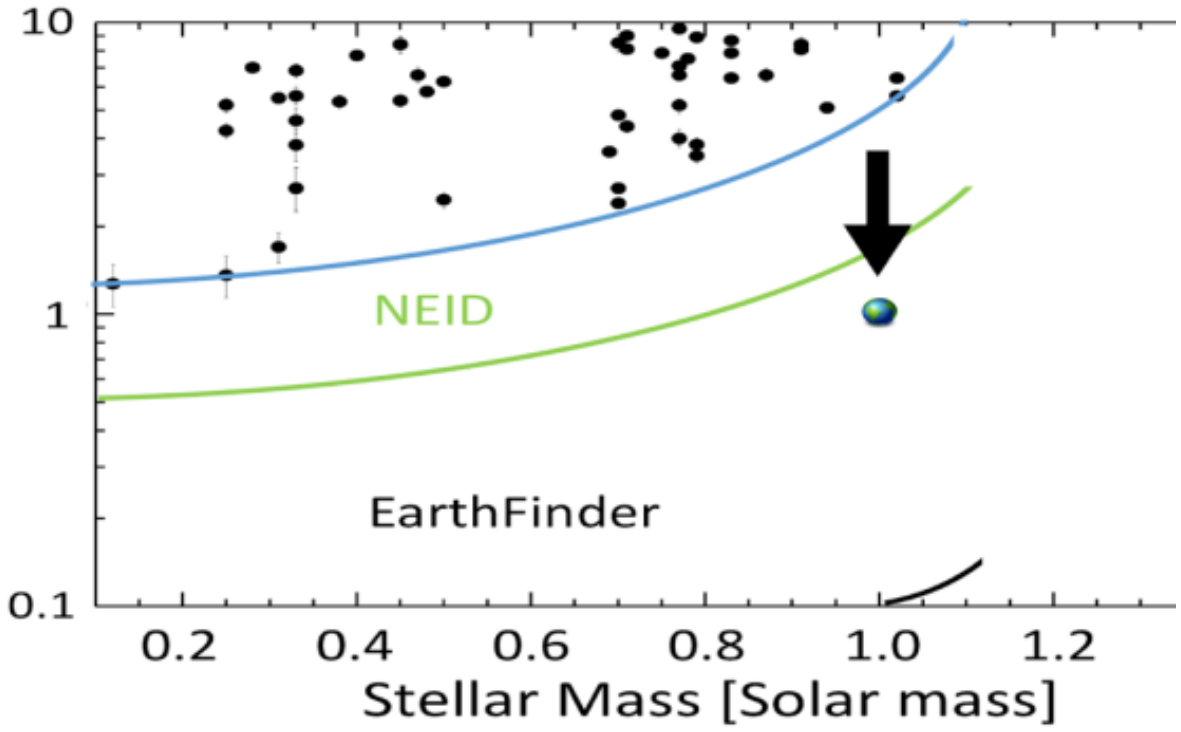
F. Malbet Faint objects in motion: the new frontier of high precision astrometry

- M-class targeted astrometry mission
- ≈ 0.15 μas precision at $V = 5$
- Broad science case
- Discovery, masses and orbits of Earth analogs



P. Plavchan
EarthFinder

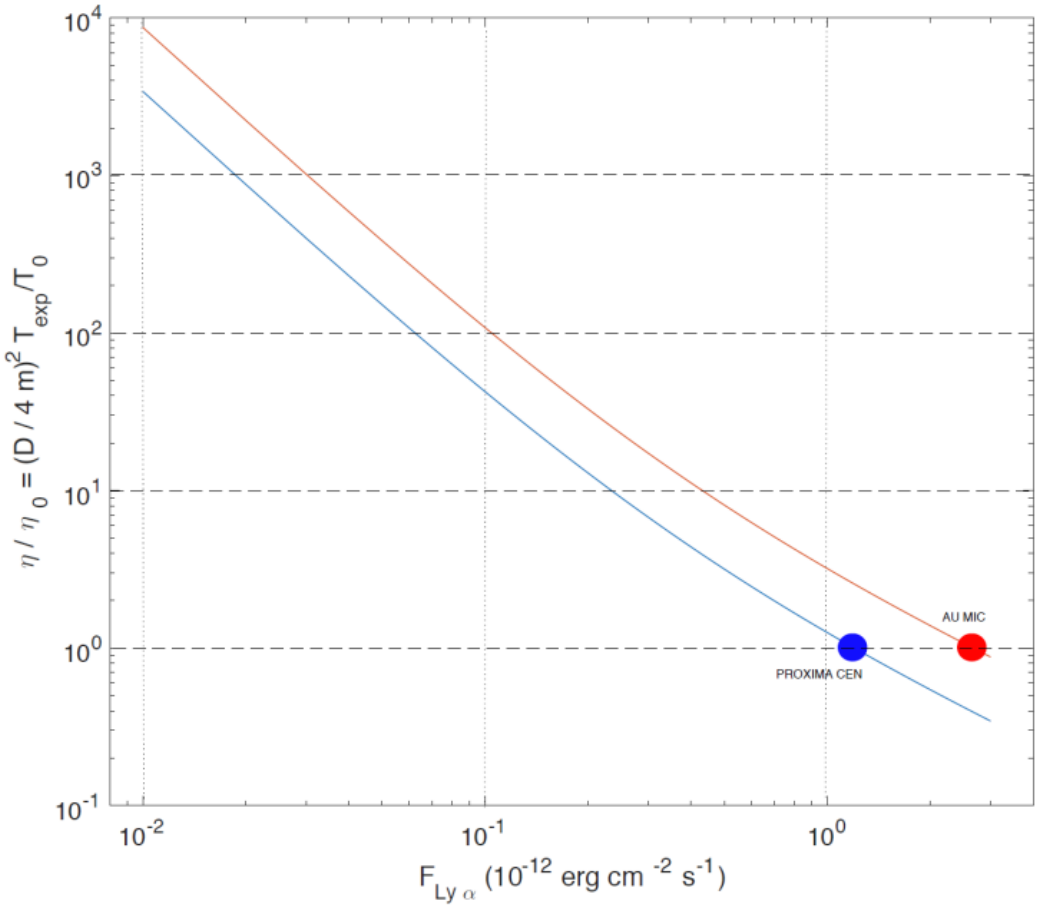
- Radial velocities from space
- No telluric contamination
- Access to visible / NIR to mitigate stellar activity
- ≈ 1 cm/s precision
- Study for NASA Probe class mission



A. I. Gómez de Castro

EUVO – The UV window into the universe

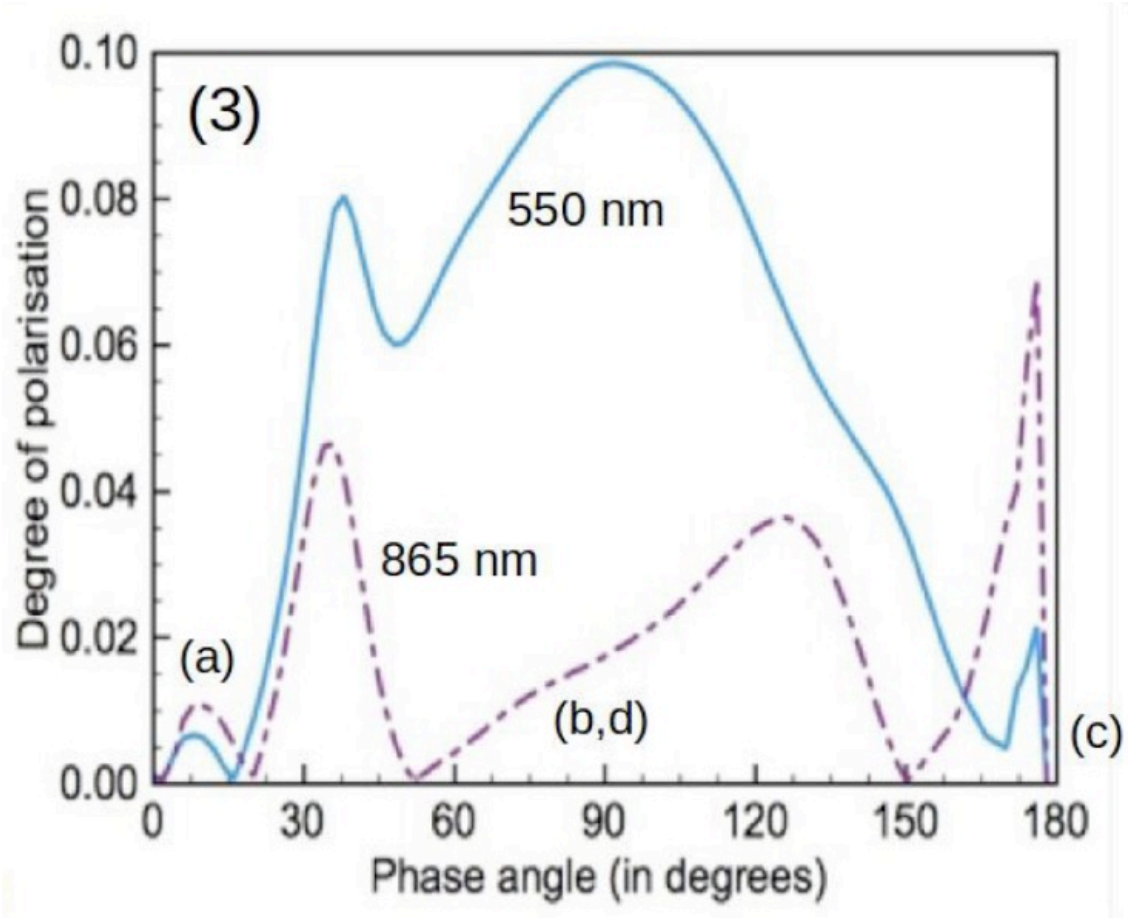
- UV diagnostics of exoplanet atmospheres
- Evaporating planets
- Implications for habitability of Earth-like planets



L. Rossi

Spectropolarimetry as a tool for understanding the diversity of planetary atmospheres

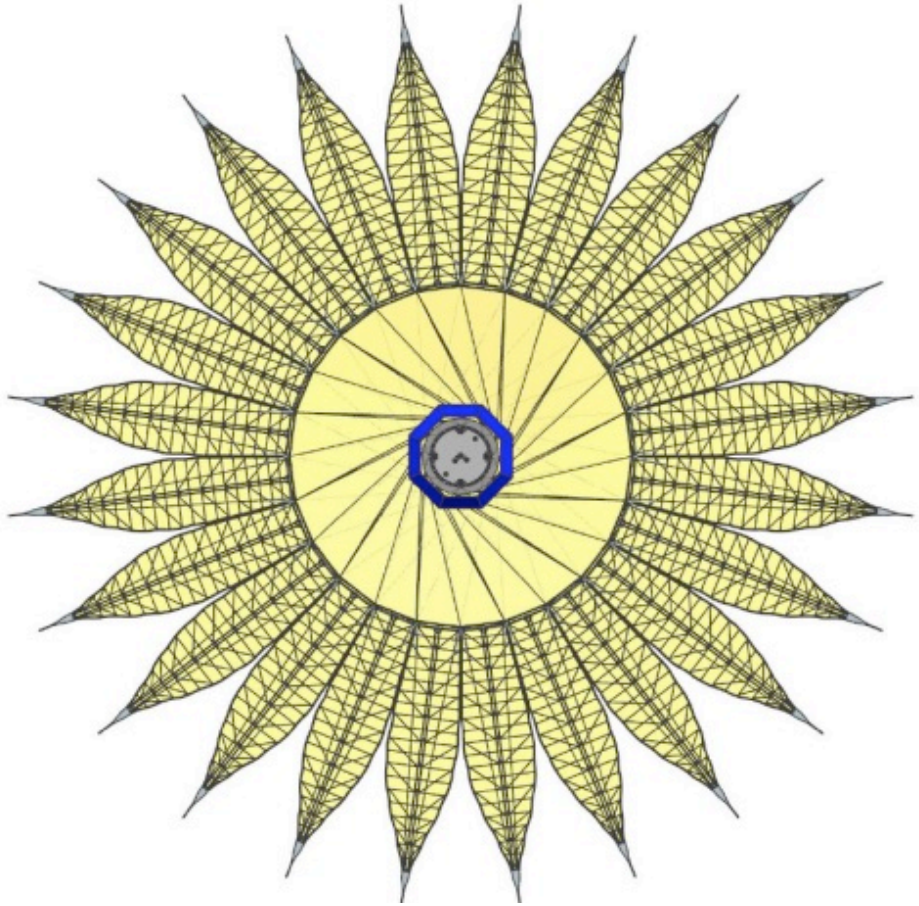
- Light reflected by planets is highly polarized
- Detailed studies of atmospheric composition
- L class mission
- Coronograph or external occulter



M. Janson

Prospects for studying earth-like planets with the E-ELT and a space-based occulter

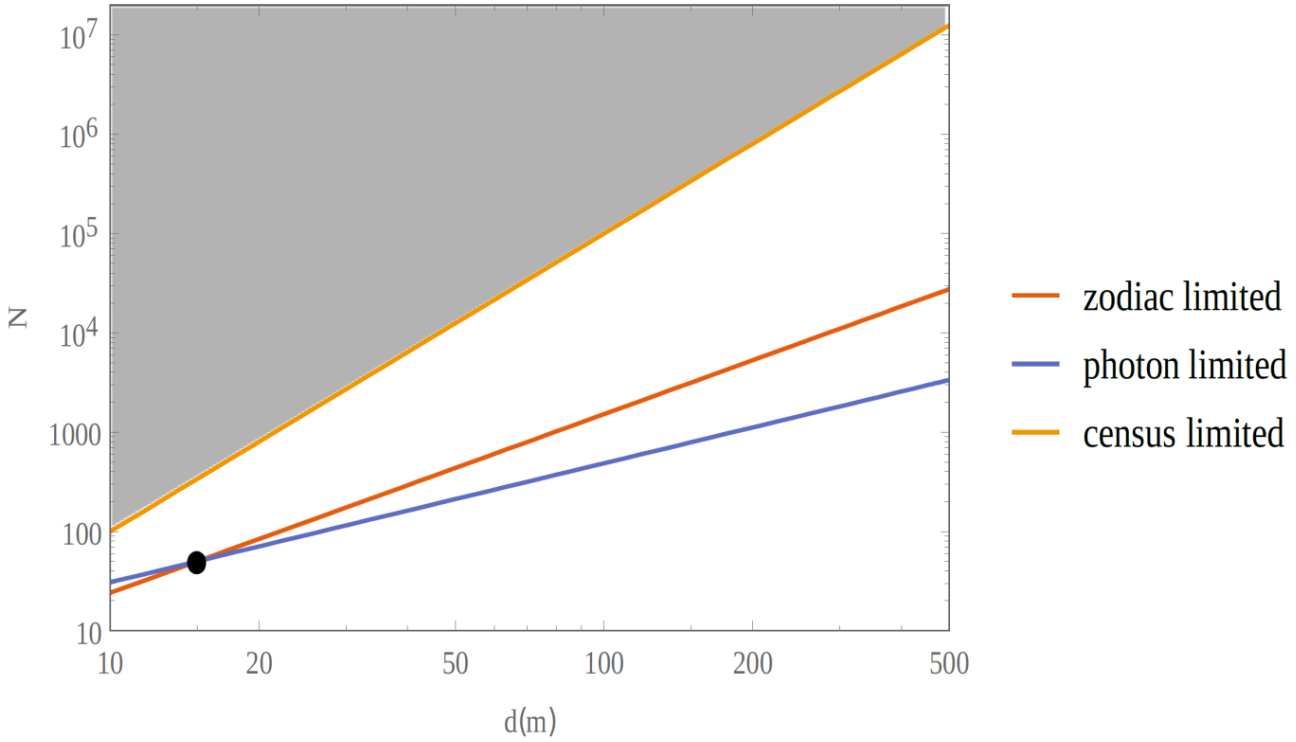
- ≈ 100 m Occulter for high-contrast imaging and spectroscopy
- Use with E-ELT
- Special orbits to achieve long integration times



J. Schneider

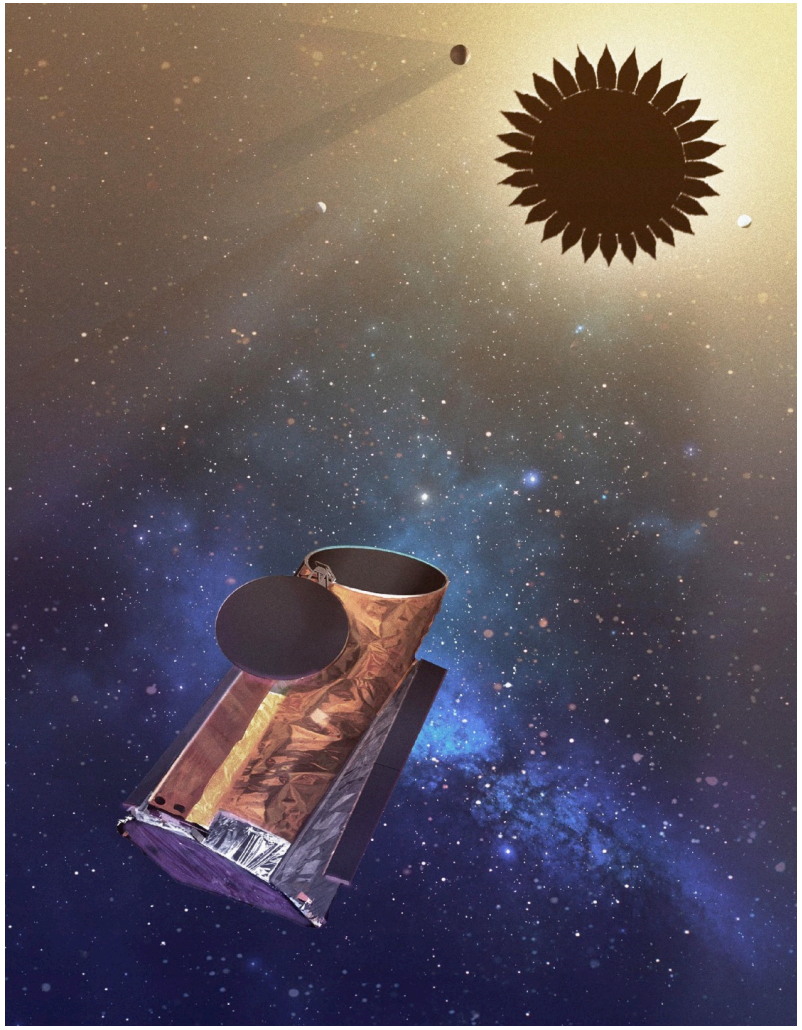
Very high resolution spectro-polarimetric interferometry and imaging from the moon

- Frequency of life, photosynthesis, multicellularity, technology
- OWL-like telescope on the Moon
- Also intensity interferometry between Earth and Moon



HabEx and LUVOIR

- Two of four studies funded by NASA for 2020 decadal survey
- Coronograph and/or occulter
- Not two competing missions
- Largely overlapping science addressed from two angles
- “Realistic” vs. “very ambitious”
- 2.4 m to 15 m telescopes studied



Europe and HabEx / LUVOIR

- Large UV-optical telescope in space
- Broad appeal including strong exoplanet science
- European members of study teams appointed by several national agencies
- Opportunities for ESA to join (M-level commitment?)
- Contributions to mission and instruments
- Follow successful HST / JWST approach

National Aeronautics and Space Administration

HabEx

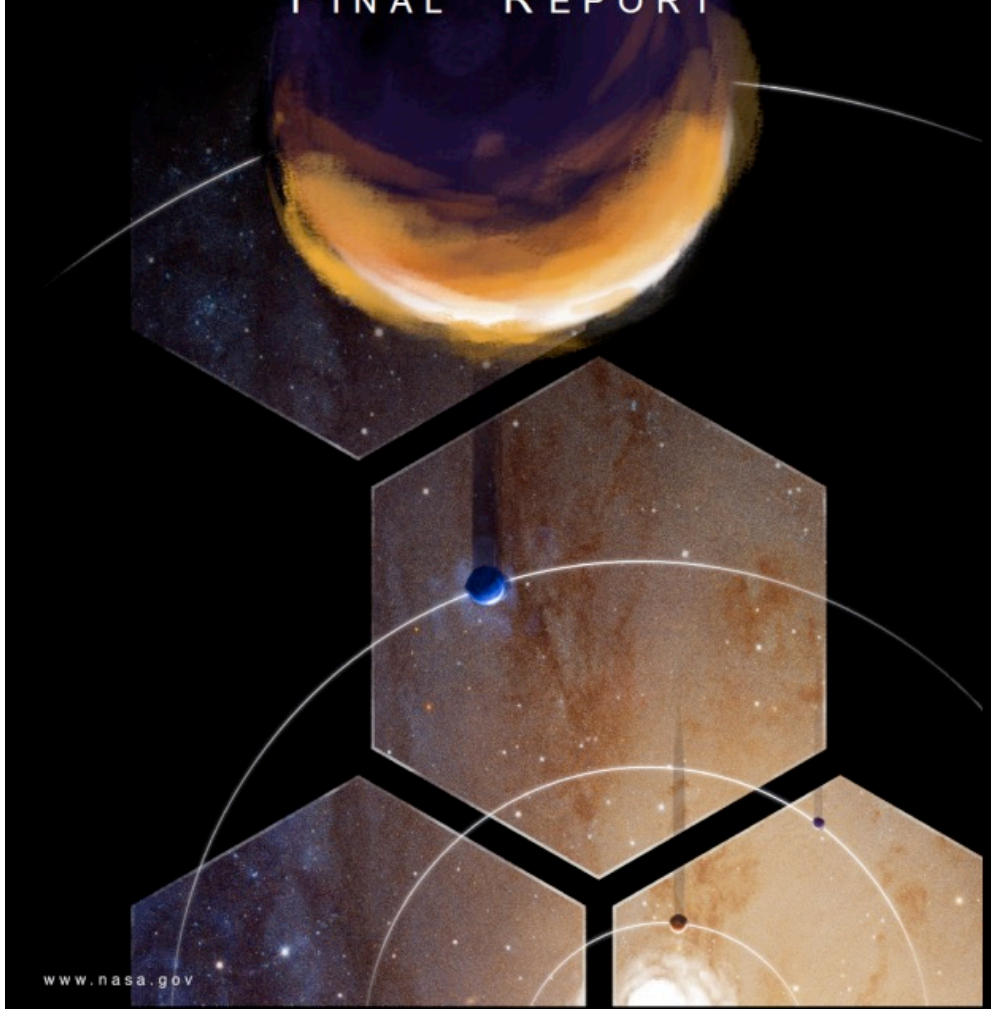
Habitable Exoplanet Observatory

Exploring New Worlds,
Understanding Our Universe

National Aeronautics and Space Administration

L U V O I R

Final Report



www.nasa.gov

The Periodic Table of Exoplanets

Over 3800 Exoplanets

Number of Stellar Systems

2266 | 425 | 140 | 47 | 17 | 7 | 2 | 1

	Terrans Group				Giants Group	
	Miniterrans (Mercury Size) 10^{-5} – 0.1 M_E or 0.03 – 0.4 R_E	**Subterrans** (Mars Size) 0.1 – 0.5 M_E or 0.4 – 0.8 R_E	**Terrans** (Earth Size) 0.5 – 5 M_E or 0.8 – 1.5 R_E	**Superterrans** (Super-Earths & Mini-Neptunes) 5 – 10 M_E or 1.5 – 2.5 R_E	**Neptunians** (Neptune Size) 10 – 50 M_E or 2.5 – 6.0 R_E	**Jovians** (Jupiter Size) > 50 M_E or > 6 R_E
Hot Zone	Hot Miniterrans: 5 (0.1%)	Hot Subterrans: 54 (1.4%)	Hot Terrans: 614 (15.9%)	Hot Superterrans: 971 (25.1%)	Hot Neptunians: 776 (20.0%)	Hot Jovians: 827 (21.4%)
Warm 'Habitable' Zone	Warm Miniterrans: 0 (0%)	Warm Subterrans: 1 (<0.1%)	Warm Terrans: 22 (0.6%)	Warm Superterrans: 32 (0.8%)	Warm Neptunians: 39 (1.0%)	Warm Jovians: 139 (3.6%)
		Potentially Habitable				
Cold Zone	Cold Miniterrans: 0 (0%)	Cold Subterrans: 1 (<0.1%)	Cold Terrans: 8 (0.2%)	Cold Superterrans: 10 (0.3%)	Cold Neptunians: 25 (0.6%)	Cold Jovians: 301 (7.8%)

M_E = Earth Mass, R_E = Earth Radius

CREDIT: PHL @ UPR Arecibo (phl.upr.edu) Jul 2018