Exoplanets

Lecture 11
MFF UK
18 December 2023

Outline

- Future missions and instruments
- Discussion wrap-up
- Assignments for exams

https://stelweb.asu.cas.cz/plato/index.html

PLATO Space mission

- Monitoring of 1 million bright stars
- Need for extensive RV follow-up
- ***Minimum*** 50 nights/year on 1-2 m facilities
- **Ground based follow-up for PLATO is recognized by ESA as a part of the mission!**
- **Literally every spectrograph on a 1-2 m class telescope will be needed! There are no projects like PLATOSPec!**
- **Contribution to TESS space mission is foreseen too!**

PlatoSpec

PLATOSPec specs

- Stellar parameters
- Initial screening of candidates
- Rejection of false positives
- Characterization of hot Jupiters
- Exoatmospheres
- Asteroseismology
- Additional science

- RV measurements
  - accuracy 5-10 m/s
  - for stars 4-11 mag
  - SNR 30-40 in max. 1 hrs (est.)

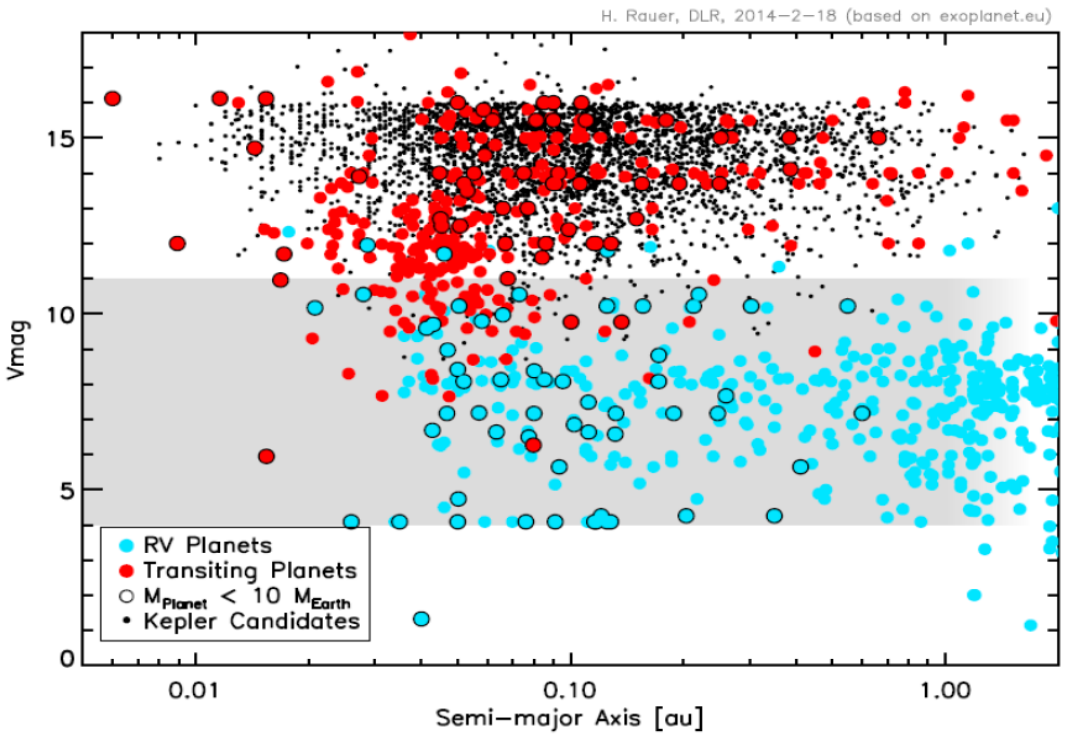
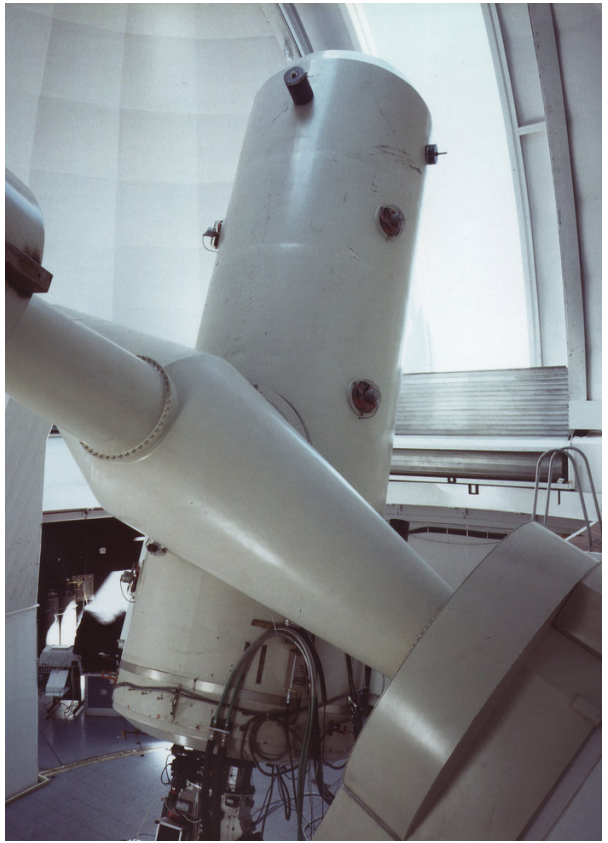


Fig. 2: *PLATO space mission will provide photometric measurements for about 1 million Stars in the grey area of the Figure. From Rauer et al. 2012*

PlatoSpec

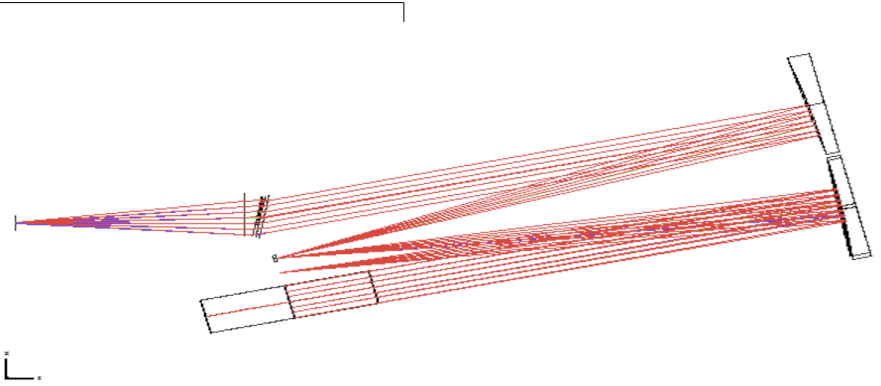
The Telescope

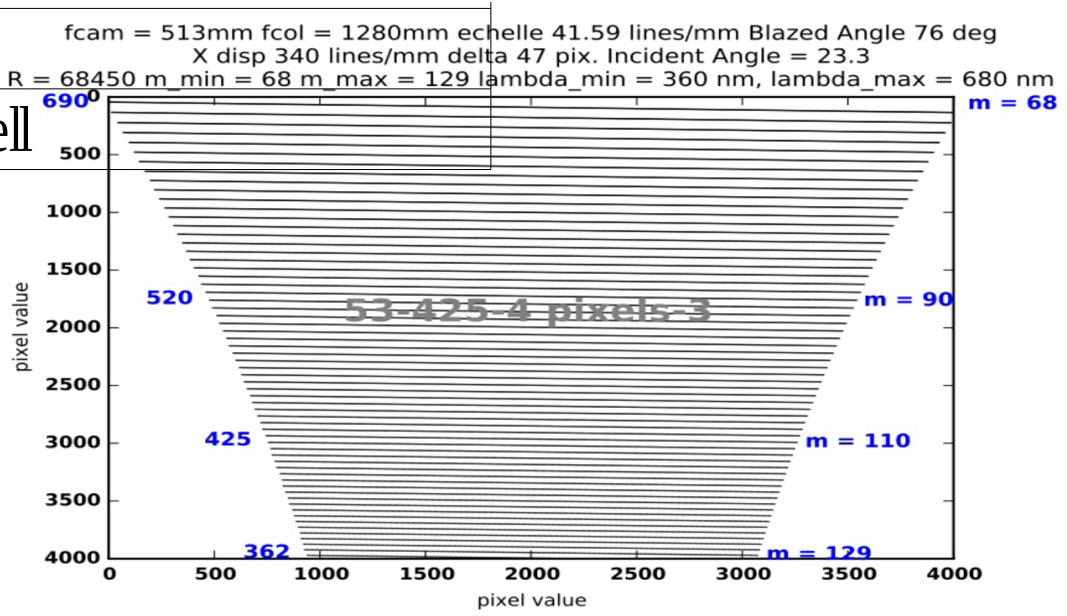


1.52-m former ESO telescope at La Silla

The instrument

Table 1: Main paramateres of the spectrograph	
Echelle spectrograph	Parameter value
Wavelength coverage	360-680 nm
Spectral resolution	70k
Thermal stability	0.1deg
RV accuracy	3m/s
Calibration	ThAr+Iodine cell



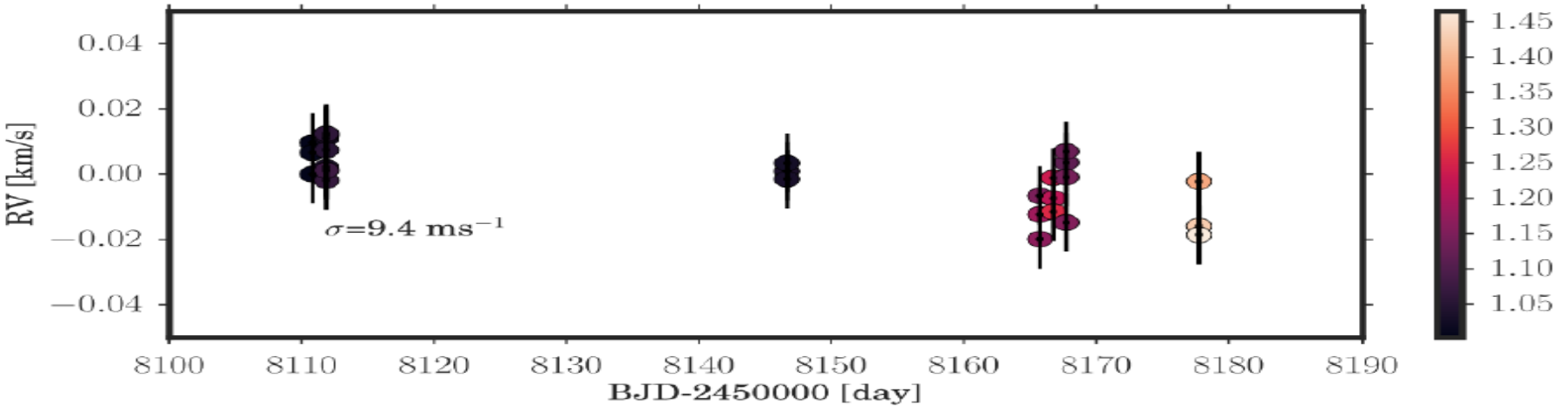


Figures and Table from:

PLATO science justification report - ESO STC

Expected performance

- PLATOSpec RV performance down to 3 m/s (1 m/s)
- FIDEOS (see below) – long term over 3 months about 9 m/s
- OES over 3 months – about 300 m/s
- OES during one night – down to 12 m/s (IC bright) or typically about 80 m/s (see Kabath et al. 2020)



RV of HD72673(standard RV) measured with FIDEOS during 80 nights (Vanzi, L. et al. 2018).

Figure from: Vanzi et al 2018

September 2022: PUCHEROS+ An interim spectrograph

- Gap year spectrograph PUCHEROS+
- PUCHEROS is a fiber fed spectrograph with R approx. 20000

See Vanzi et al.

https://doi.org/10.1111/j.1365-2966.2012.21382.x

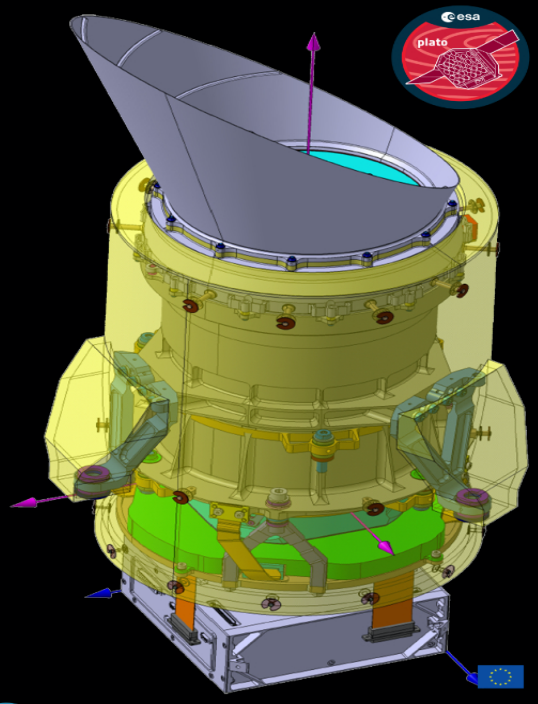
PUCHEROS+ modes offered

- **Spectroscopy (E152)**
  - echelle spectroscopy, fiber fed, ThAr non-simultaneous
  - R= approx 18000
  - wavelength range 400-700 nm
  - FOV of the autguider 1.6x1.6 arcmin approx

- **Photometry (old guider 15 cm x 2) – simultaneous w. spectroscopy**
  - coaxial with E152, FOV about 1.2 deg
  - GrazCam: ugriz, prism filter (low res), focusser and rotator, GUIs under development
  - OnCam: ugriz, Halpha, clear, focussing unit, C4 (moravian instruments) CMOS, rapid readout, 4k by 4k, OPERATIONAL

Planet Hunters

PlatoSpec



Space observatory
PLATO telescope
(2026)

E152 telescope
ESO, La Silla observatory
Chile (2021)

Astronomický ústav AV ČR

2-meter Perek Telescope
Astronomical Institute ASCR
Czech Republic

2-meter Alfred Jensch Telescope
The Karl Schwarzschild Observatory
Germany

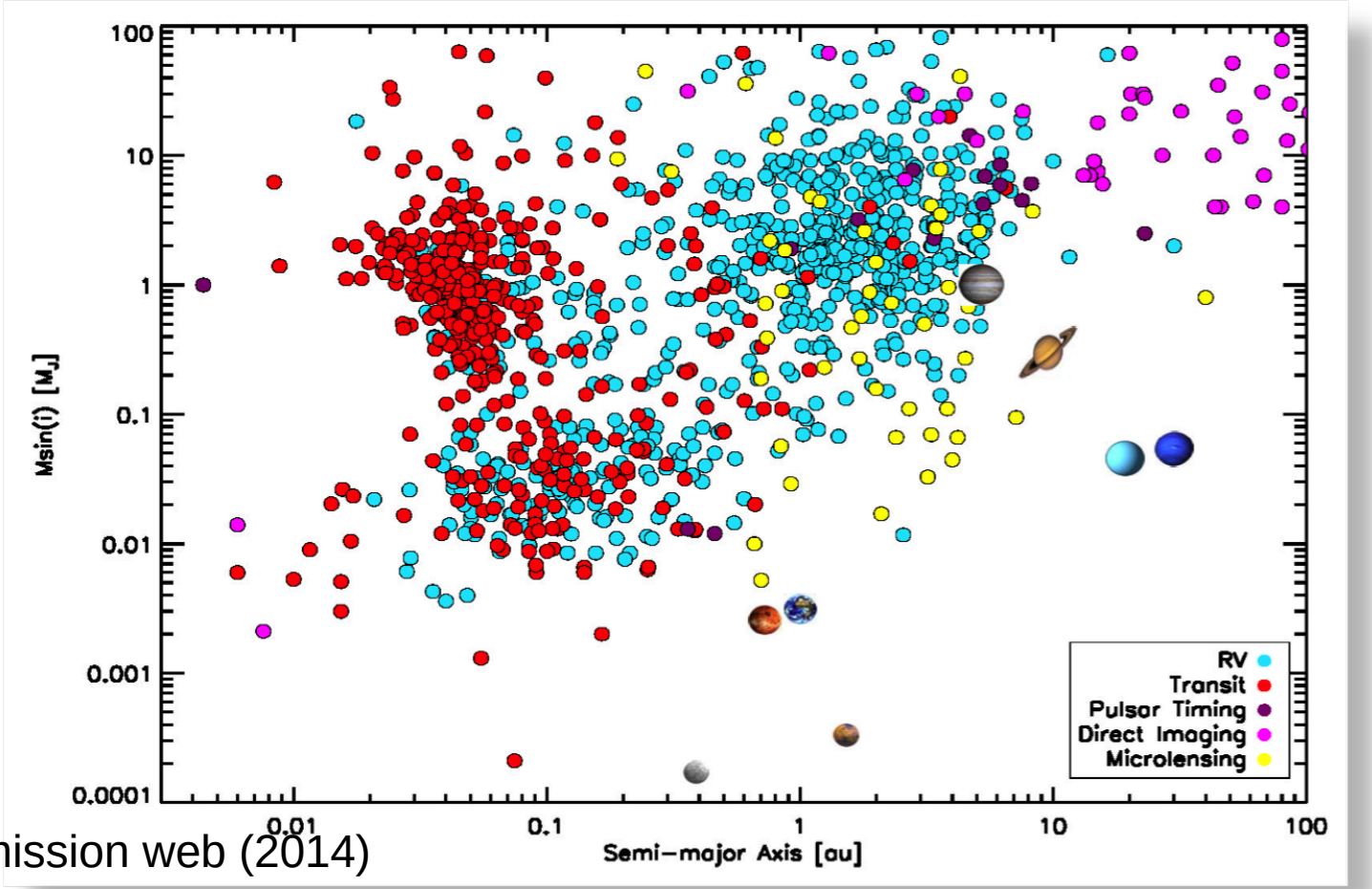
Images credit: Zdenek Bardon/ESO

Astronomický ústav AV ČR

E152

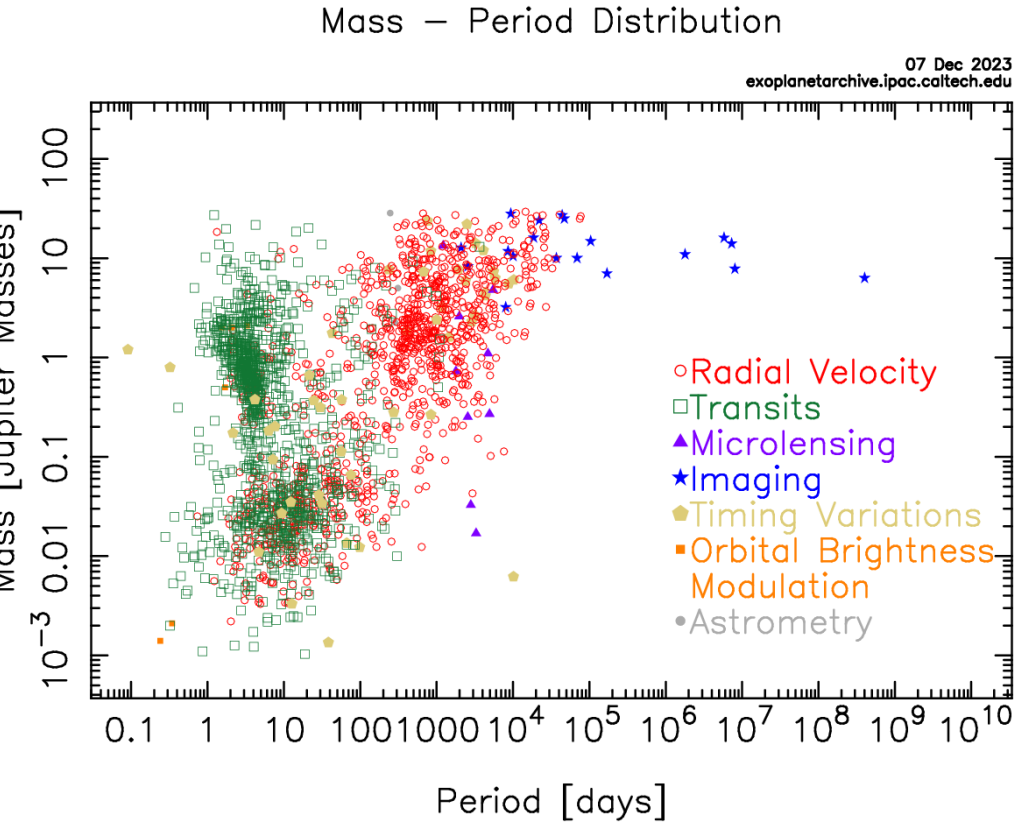
Foto Z. Bardon

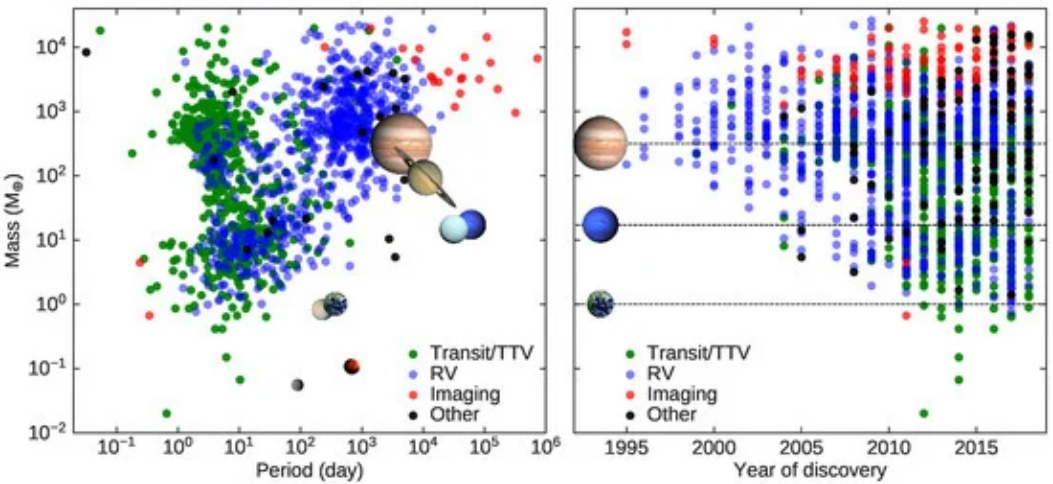
What is the status?



PLATO space mission web (2014)

Now





https://www.mdpi.com/2076-3263/9/3/105

https://exoplanetarchive.ipac.caltech.edu/exoplanetplots/

Pushing the limits

Table 1. Current Doppler Planet Search Programs

Spectrograph	slit or fiber	Environmental Control	Spectral Resolution	Wavelength range [nm]	Wavelength calibrator	SMP [m s^{-1}] SNR = 200	Number of stars	Duration of program
HARPS	f	Y	115,000	380 – 690	ThAr	0.8	2000	2003 –
HARPS-N	f	Y	115,000	380 – 690	ThAr	0.8	500	2012 –
PARAS	f	Y	67,000	380 – 690	ThAr	1.0	27	2012 –
CHIRON	f	Y	90,000	440 – 650	Iodine	1.0	35	2011 –
SOPHIE	f	Y	75,000	387 – 694	ThAr	1.1	190	2011 –
PFS	s	Y	76,000	390 – 670	Iodine	1.2	530	2010 –
HIRES	s	Y	55,000	364 – 800	Iodine	1.5	4000	1996 –
Levy (LCPS)	s	Y	110,000	376 – 970	Iodine	1.5	100	2013 –
Levy (CPS)	s	Y	100,000	376 – 940	Iodine	2.0	300	2013 –
SONG	s	N	90,000	440 – 690	Iodine	2.0	12	2014 –
HRS	s	Y	60,000	408 – 784	Iodine	3.0	100	2001 – 2013
Hamilton	s	N	50,000	390 – 800	Iodine	3.0	350	1987 - 2011
UCLES	s	N	45,000	478 – 871	Iodine	3.0	240	1998 –
Tull	s	N	60,000	345 – 980	Iodine	5.0	200	1998 –

https://ui.adsabs.harvard.edu/abs/2016PASP..128f6001F/abstract

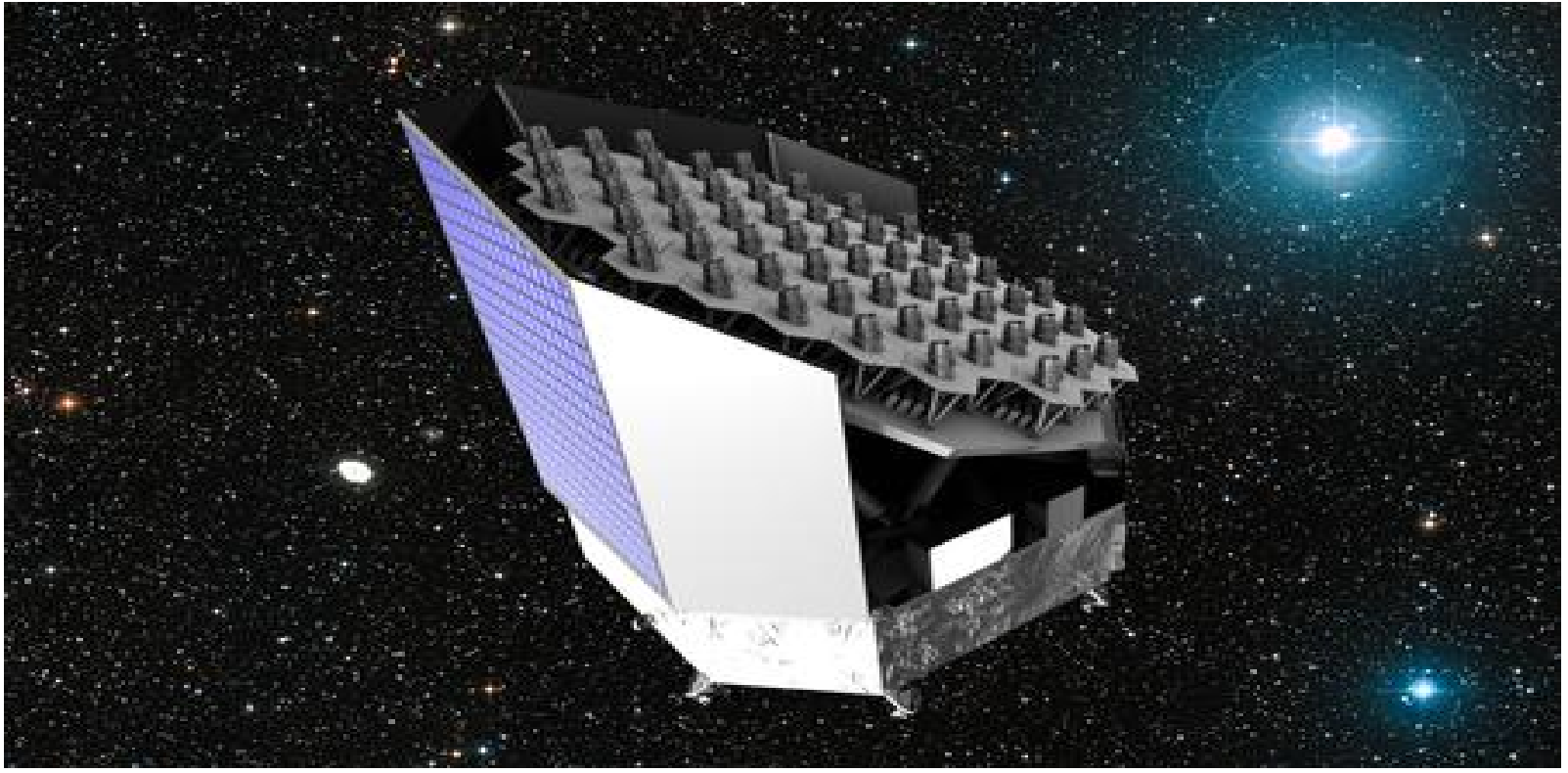
Recent achievements

The Astronomical Journal, 159:187 (14pp), 2020 May

Table 4
Fit Parameters for 51 Peg b

Instr.	$K/\mathrm{m\ s^{-1}}$	e	$\mathrm{RMS}/\mathrm{m\ s^{-1}}$	$\sigma_v/\mathrm{m\ s^{-1}}$
EXPRES CCF	56.24 ± 0.14	0.000 ± 0.002	0.924	0.340
EXPRES FM	56.26 ± 0.13	0.007 ± 0.003	0.875	0.335
HARPS DRS	53.4 ± 1.6	0.062 ± 0.010	0.941	1.023
HIRES	56.7 ± 0.4	0.020 ± 0.007	2.74	1.169

Plato Space mission



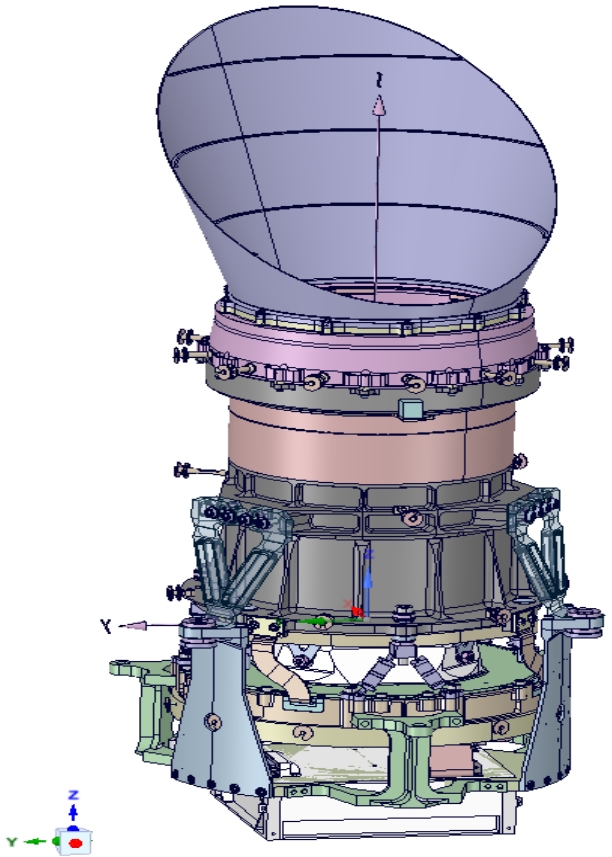
Credit: Thales Alenia Space

PLATO Space mission

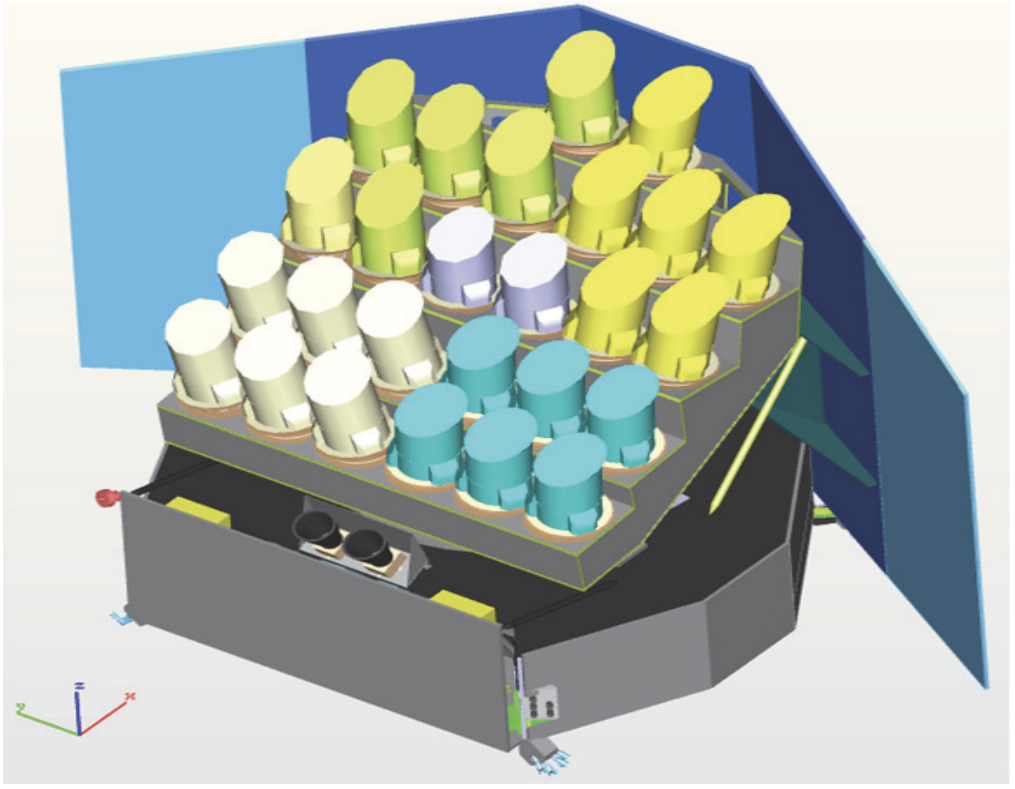
- PLAnetary Transits and Oscillations of stars
- Theme: What are the conditions for planet formation and the emergence of life?
- Primary Goal Detection and characterisation of terrestrial exoplanets around bright solar-type stars, with emphasis on planets orbiting in the habitable zone.
- Photometric monitoring of a large number of bright stars for the detection of planetary transits and the determination of the planetary radii (around 2% accuracy)
- Ground-based radial velocity follow-up observations for the determination of the planetary masses (around 10% accuracy)
- Asteroseismology for the determination of stellar masses, radii, and ages (up to 10% of the main sequence lifetime)
- Identification of bright targets fr spectroscopic follow-up observations of planetary atmospheres with other ground and space facilities

- LAUNCH 2026

PLATO camera

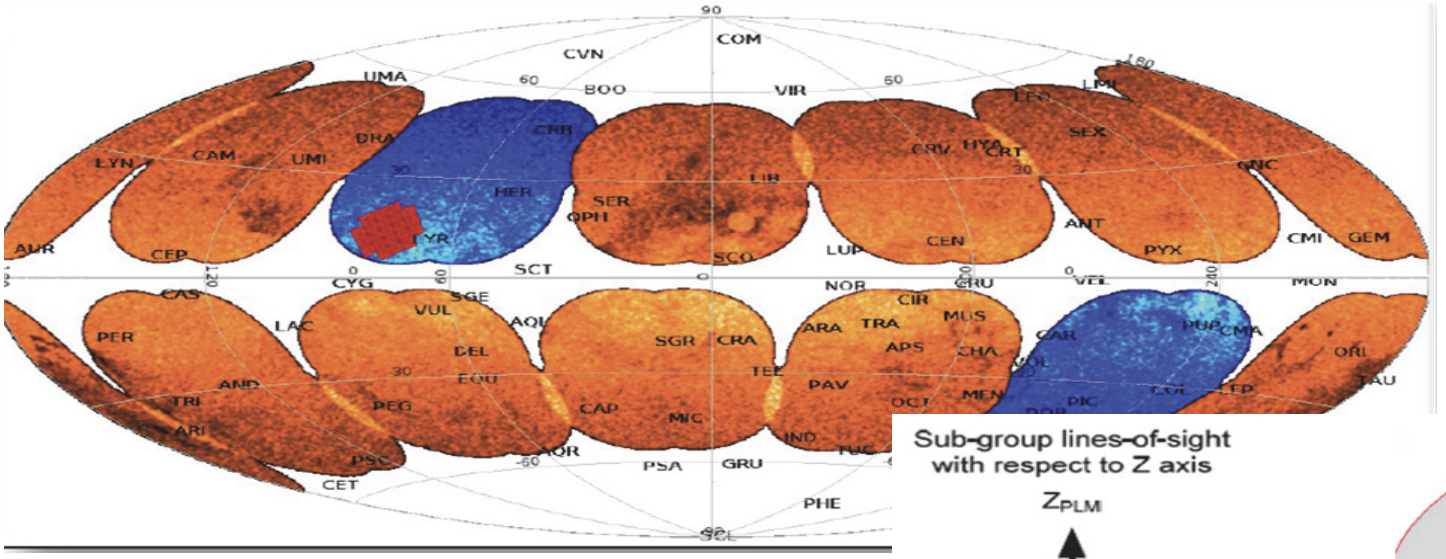


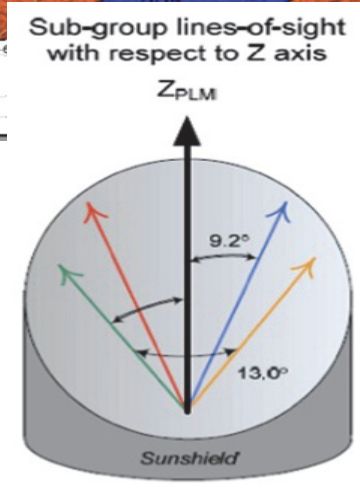
Credit: PLATO consortium

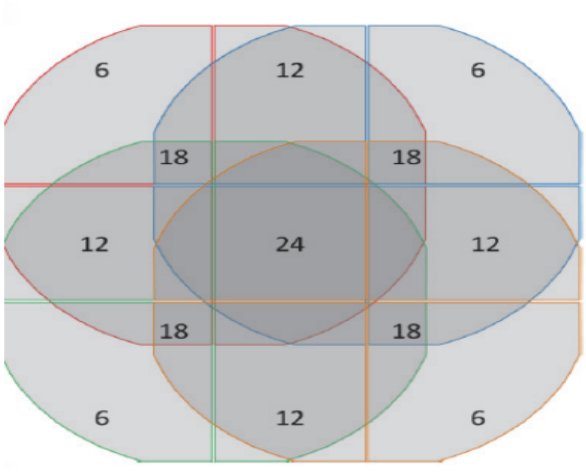


Credit: PLATO consortium

PLATO observing strategy







Approx 40% sky coverage

Credit: PLATO consortium

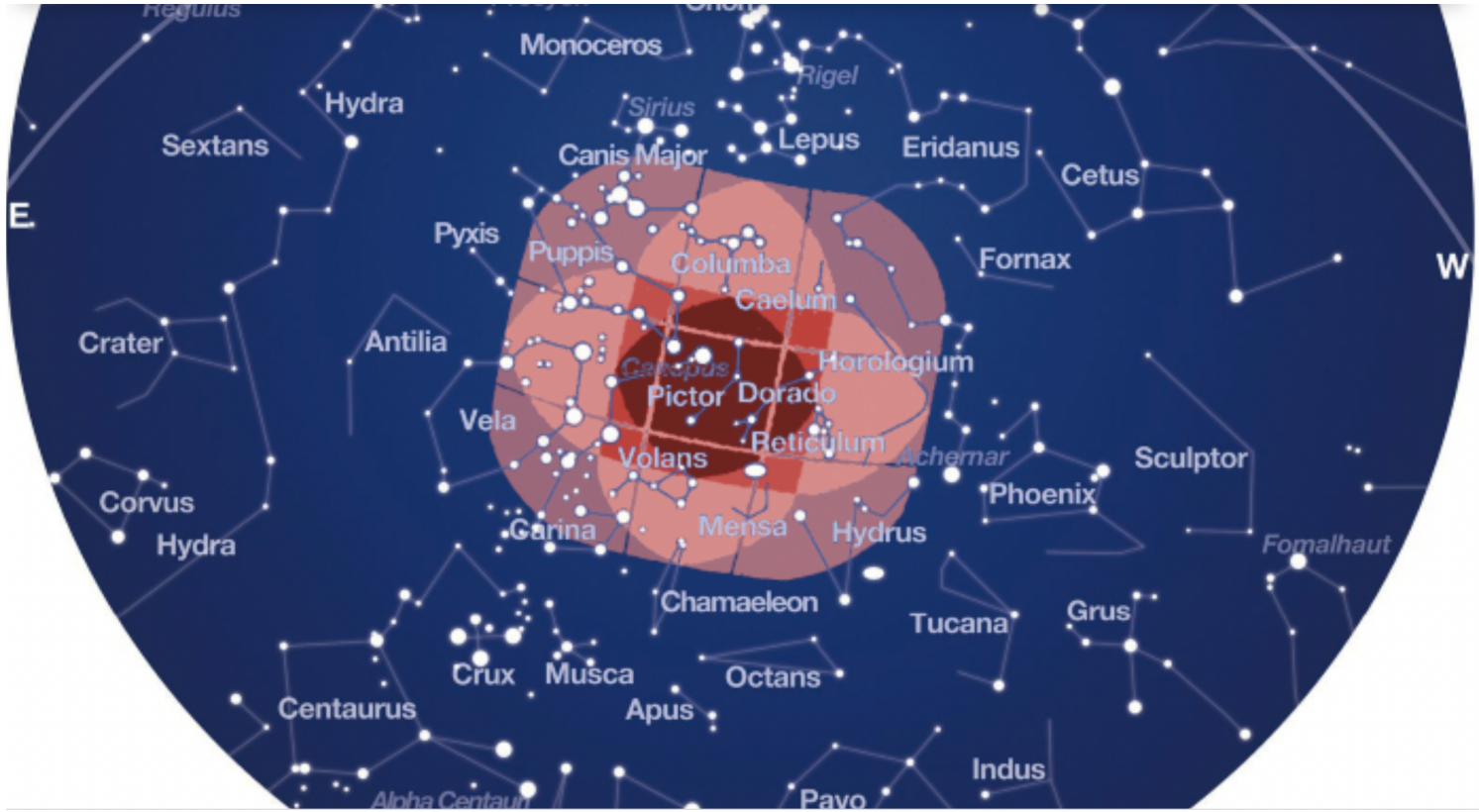
PLATO Spec

Astronomický ústav AV ČR

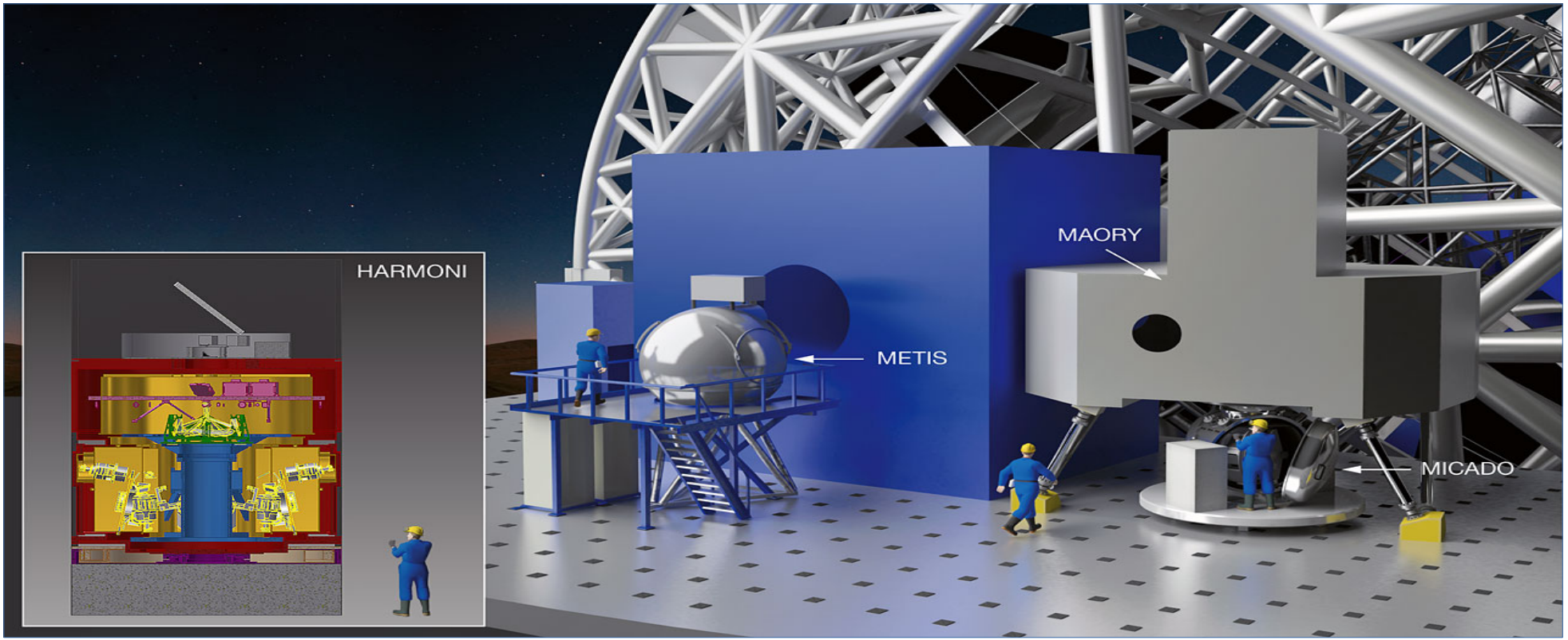
PLATO field SELECTED (FINALLY)

RA (J2000): 06:21:14.5

DE (J2000) -47:53:13



ELT



Credit: ESO

ELT - 2024

- EPICS – Exoplanet imaging camera and spectrograph

  https://www.eso.org/sci/libraries/SPIE2010/7735-84.pdf
- METIS - The Mid-infrared E-ELT Im. and Spectr. - 3–20 μm

  Low-resolution (R < 1,000) at L,M,N

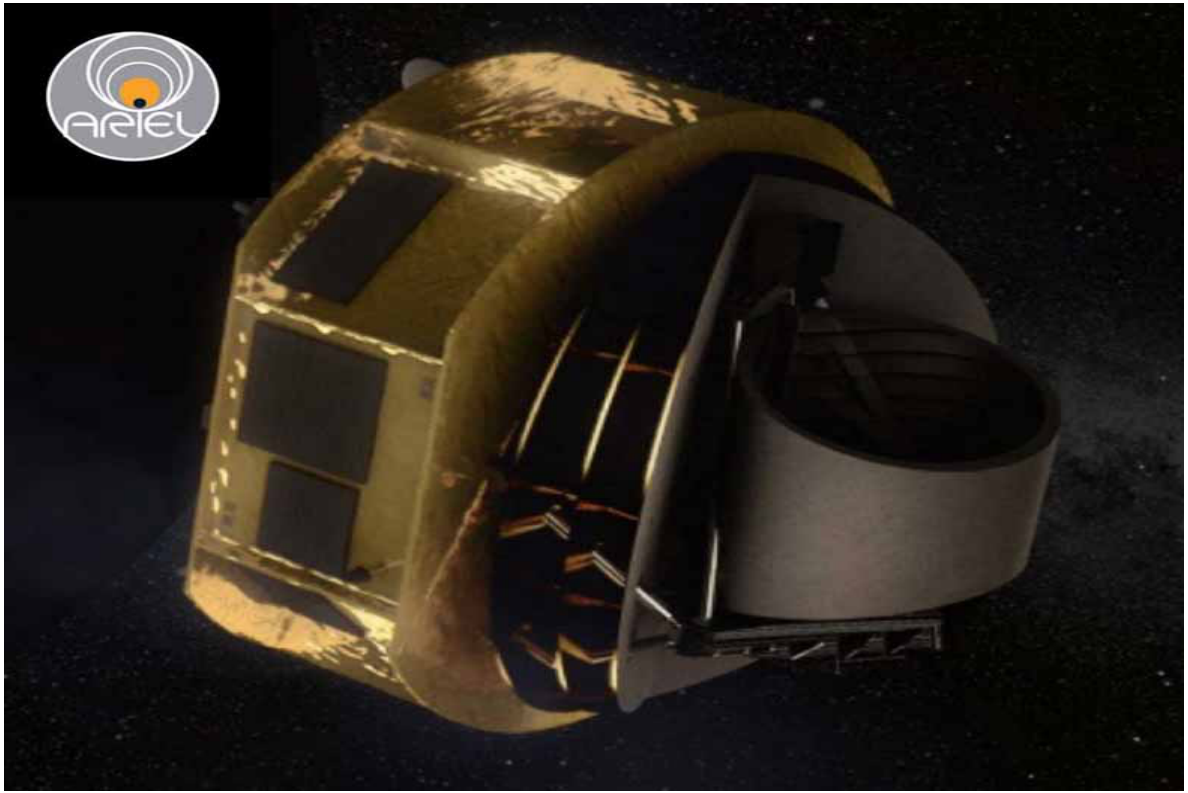
  Medium-resolution (R <10,000) at N

  High-resolution (R~100,000) IFU at L,M
- HARMONI - is a visible and near-infrared (0.47 to 2.45 μm) integral field spectrograph, providing the E-ELT's core spectroscopic capability, over a range of resolving powers from R (≡λ/Δλ) ~500 to R~20000.

https://www.eso.org/public/images/ann15056a/

ARIEL

- NIR spectrograph for characterization of exo-atmospheres
- Launch date 2028
- CZ contribution



Credit: ARIEL consortium

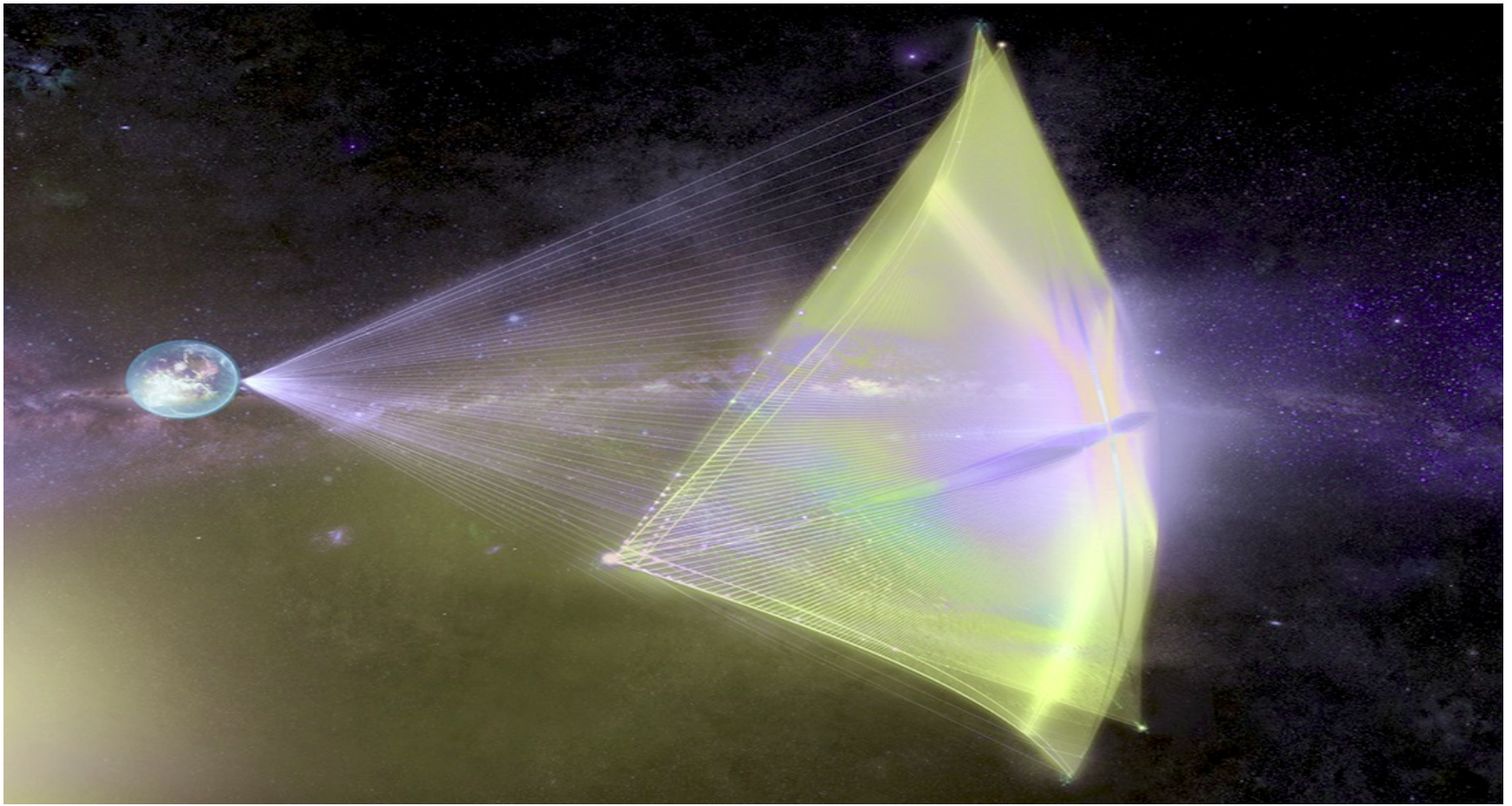
Elliptical primary mirror:Â 1.1 x 0.7 metres

Foto Z. Bardon

2030+


Goddard Space Flight Center
asd.gsfc.nasa.gov/luvoir/
National Aeronautics and Space Administration
NASA
LUVOIR
Large Ultraviolet / Optical / Infrared Surveyor
LUVOIR is a concept for a highly capable, multi-wavelength observatory with ambitious science goals. This mission would enable great leaps forward in a broad range of astrophysics, from the epoch of reionization, through galaxy formation and evolution, to star and planet formation. Powerful remote sensing observations of Solar System bodies will also be possible. LUVOIR will study a wide range of exoplanets in depth, including those that might be habitable – or even inhabited.
Simulated high-contrast image of the Solar System at 10 parsecs
Jupiter
Earth
Venus
Hubble
LUVOIR

The Breakthrough initiative
Starshot



https://breakthroughinitiatives.org/Initiative/3

LIFE space mission

- https://life-space-mission.com/mission/
- An ambitious nulling interferometer mission to characterize the habitable worlds

Projects at AsÚ

- Investigating the extreme precise instrumentation for the future
- PLATOSpec – test bench for pushing of the limits
- LIFE space mission?

Exams

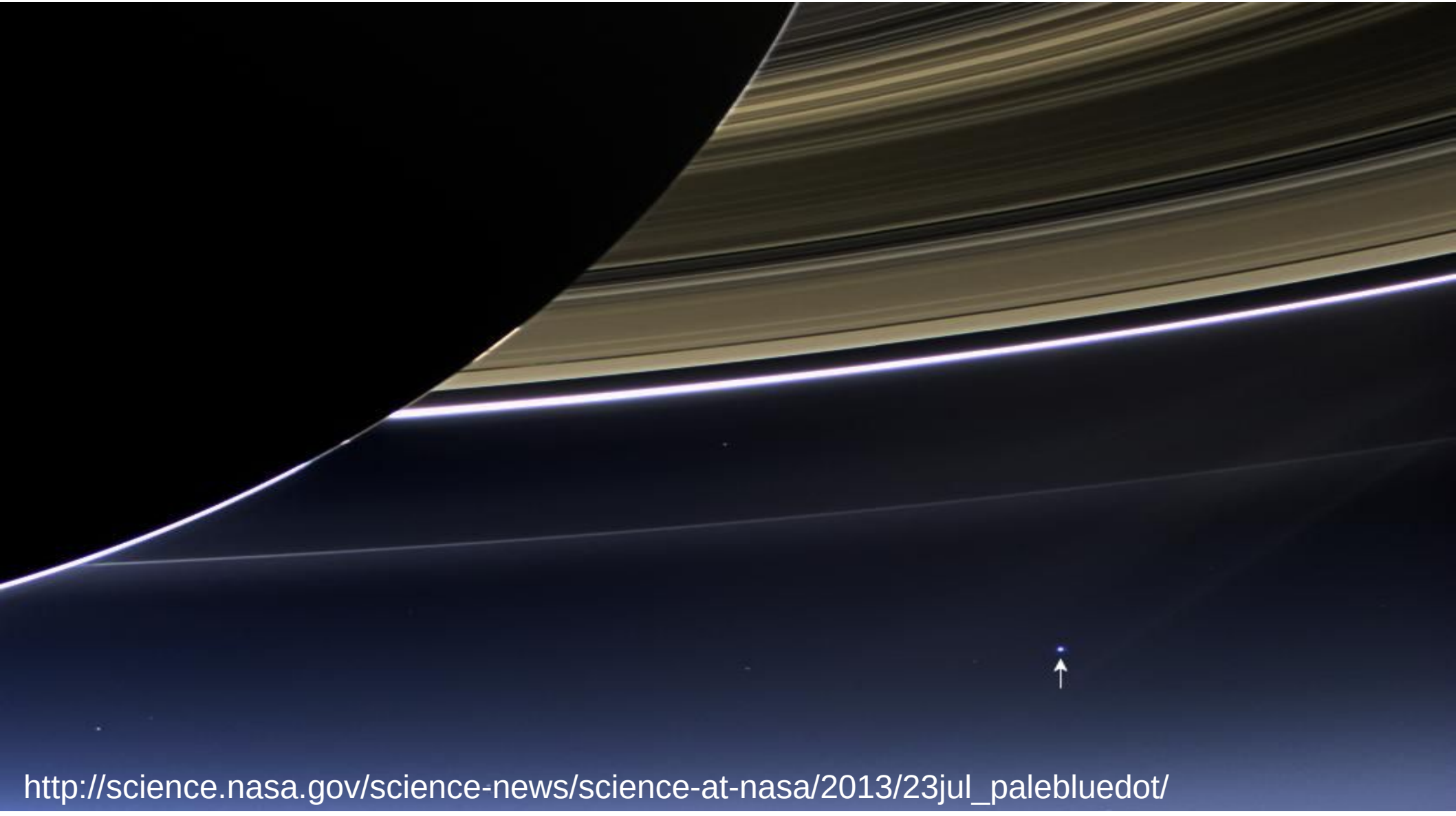
- Please choose 1 from the topics below and prepare a 5 minutes presentation which will be followed by a discussion of about 10-15 minutes

  Format of the presentation is free but the idea is to wrap-up the chosen topic and present to other colleagues
- Please look for an interesting paper from your topic (of your choice) and you will present it as in a journal club

  (10-15 minutes presentation on screen with discussion)

Exam topics

- 1 Spectroscopic characterization of exoplanets
- 2 Photometric characterization of exoplanets
- 3 Exoplanetary atmospheres
- 4 Statistics of exoplanets (occurance rates, etc.)
- 5 Statistics of exoplanets (types of exoplanets, etc.)
- 6 Instrumentation for exoplanetary research
- 7 Evolution of exoplanetary systems
- 8 Life in the Universe
- 9 Architecture of exoplanetary systems (interesting systems)



http://science.nasa.gov/science-news/science-at-nasa/2013/23jul_palebluedot/

Thank you!

Foto Z. Bardon

https://stelweb.asu.cas.cz/plato/ WEB PLATOSpec

http://stelweb.asu.cas.cz/exogroup/ WEB exoplanet group