PLATO Mission Performance

ESP2024 Planetary Systems

14-16 May 2024

PLATO Mission Performance

ESP2024 Planetary Systems
14-16 May 2024

Juan Cabrera, Sami-Matias Niemi, Reza Samadi, Claas Ziemke, Ulrike Witteck, Dave Walton, Peter Verhoeve, Bart Vandenbussche, Alan Smith, Gabriel Schwarzkopf, Francesco Santoli, Pierre Royer, Sara Regibo, Roberto Ragazzoni, Giampaolo Piotto, Martin Pertenais, Carsten Paproth, Gianalfredo Nicolini, Valerio Nascimbeni, Marco Montalto, Francesca Molendini, Paola Marrese, Silvia Marinoni, Demetrio Magrin, Alexander Koncz, Peter Klagyivik, Nicholas Jannsen, Sascha Grziwa, Valentina Granata, Marijo Goupil, Nicolas Gorius, Denis Grießbach, Yoshi Eschen, Giacomo Dinuzzi, Joris De Ridder, Cilia Damiani, Anders Erikson, Philipp Eigmüller, Szilárd Csizmadia, Francesco Borsa, Anko Börner, Aaron Birch, Claudio Arena, Thierry Appourchaux, Jose Lorenzo Alvarez, Heike Rauer, Isabella Pagano, J. Miguel Mas-Hesse.

PLATO Mission

- **Prime mission goals**:
  - detect and characterize a large number of extrasolar transiting planets including **Earth-sized planets up to the habitable zone of solar-like stars**
  - investigate seismic activity in stars, enabling the precise characterisation of the planet host star, including its **age**

- **Payload design drivers:**
  - **Planet detection**

    → large number of target stars
  - **Planet and star characterization**

    → bright target stars → wide field-of-view

→ **multi-camera approach:**
- 24 normal cameras (photometry)
- 2 fast cameras (fine-guidance, photometry in red and blue)

PLATO Spacecraft

Image credit: ESA//ATG Medialab

Payload design drivers

planet detection
(up to HZ solar-like stars)

- 80 ppm 1h — (planet yield)
- long baseline (>2yr)
- 600s sampling

stellar characterization
(up to 10% age for Sun-like star)

- 25s sampling
- noise requirements in the Fourier domain — requirements on the residuals of systematic noise
- 34 ppm in 1h (3% Rp; 10% age)

planet characterization
(down to 3% uncertainty in radius for Earth-Sun analogs)

- 34 ppm in 1h (3% Rp; 10% age)
- 50 ppm in 1h (5% Rp; 20% age)
- V<11 (radial velocity)

600s sampling, 25s sampling → telemetry and data processing requirements

34 ppm in 1h, 50 ppm in 1h → random noise requirements

V<11 (radial velocity) → P1 sample requirements → FOV requirements

requirements on the residuals of systematic noise, random noise requirements, P1 sample requirements → pointing requirements

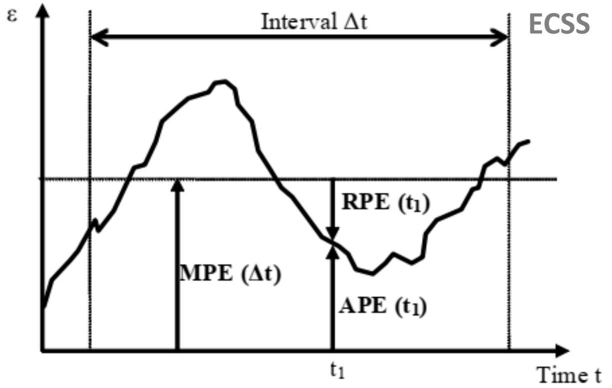


Figure A-1: Example showing the APE, MPE and RPE error indices

APE: Absolute Performance Error of the pointing.
PDE: Performance Drift Error of the pointing.
MPE: Mean Performance Error of the pointing.
PRE: Performance Repeatability Error of the pointing.
RPE: Relative Performance Error of the pointing

PLATO today

The total estimated field of view is estimated to be approximately 2132 deg^2, with 294 deg^2 observed by 24 cameras, 171 deg^2 observed by 18 cameras, 796 deg^2 observed by 12 cameras, and 871 deg^2 observed by 6 cameras.

24 N-CAMs	**294 deg^2**
18 N-CAMs	171 deg^2
12 N-CAMs	796 deg^2
6 N-CAMs	871 deg^2

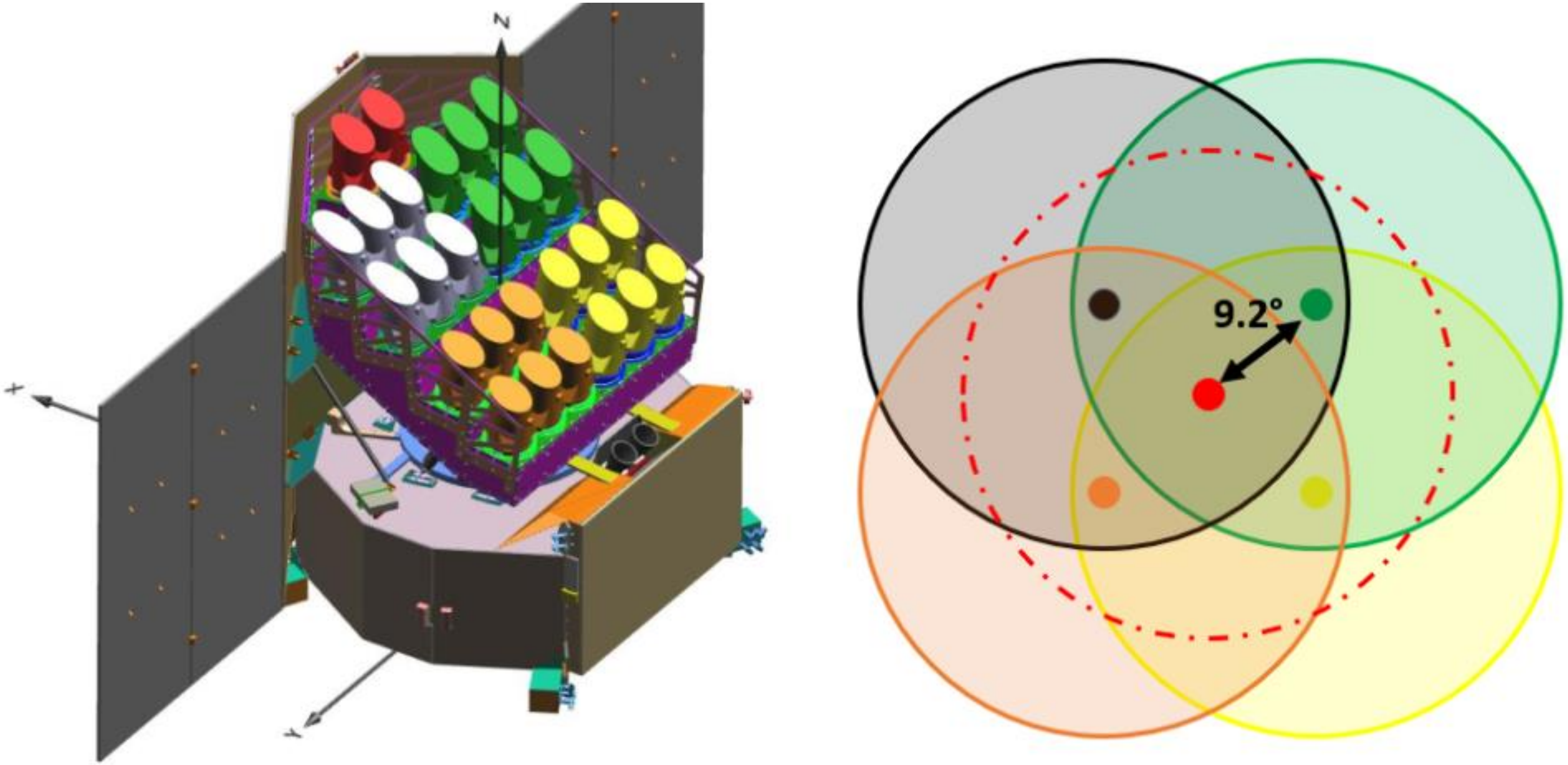


Figure 1. Left: Group arrangement of the cameras on the spacecraft. Credits: OHB System AG. Right: Tilt Angle of 9.2° for each of the 4 N-CAM groups.

Pertenais et al. 2021

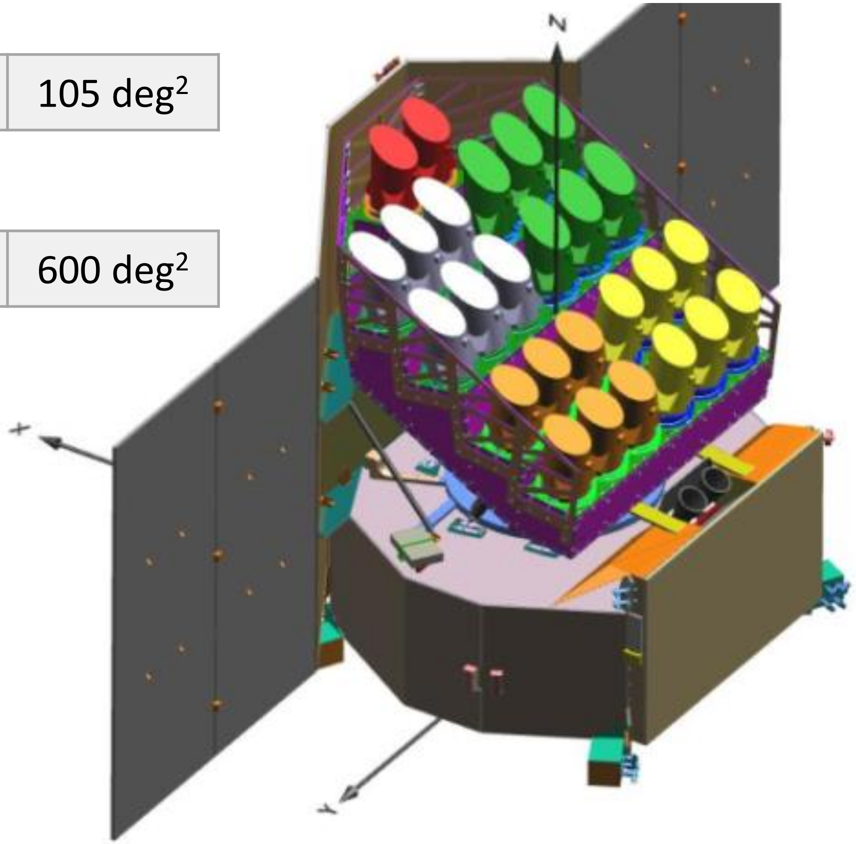
PLATO today

The total estimated field of view is estimated to be approximately 2132 deg², with 294 deg² observed by 24 cameras, 171 deg² observed by 18 cameras, 796 deg² observed by 12 cameras, and 871 deg² observed by 6 cameras.

Nascimbeni et al. 2022

24 N-CAMs	**294 deg^2**
18 N-CAMs	171 deg^2
12 N-CAMs	796 deg^2
6 N-CAMs	871 deg^2

Kepler	105 deg^2
TESS	600 deg^2



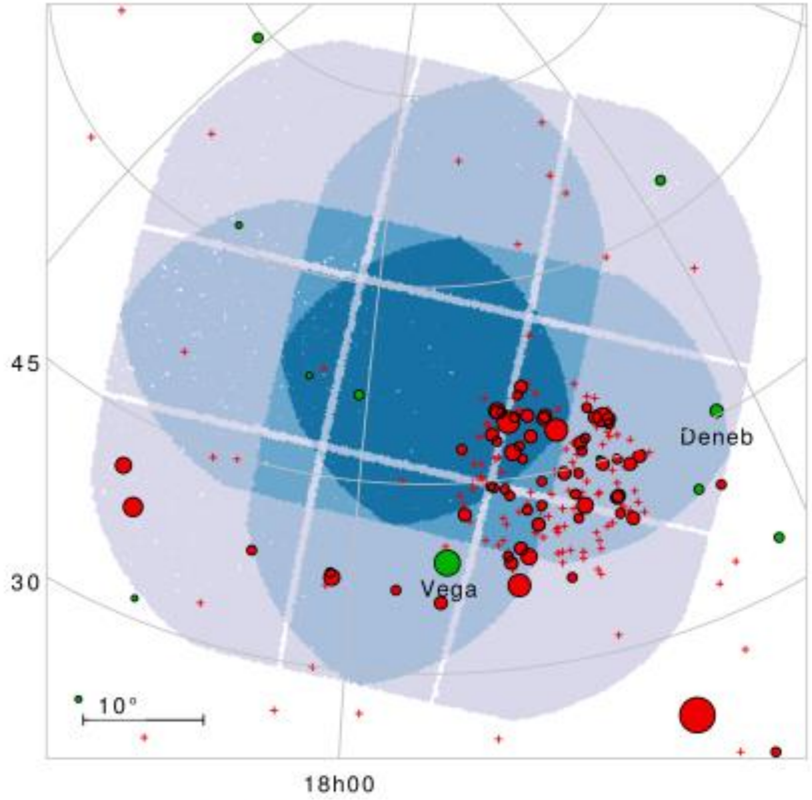
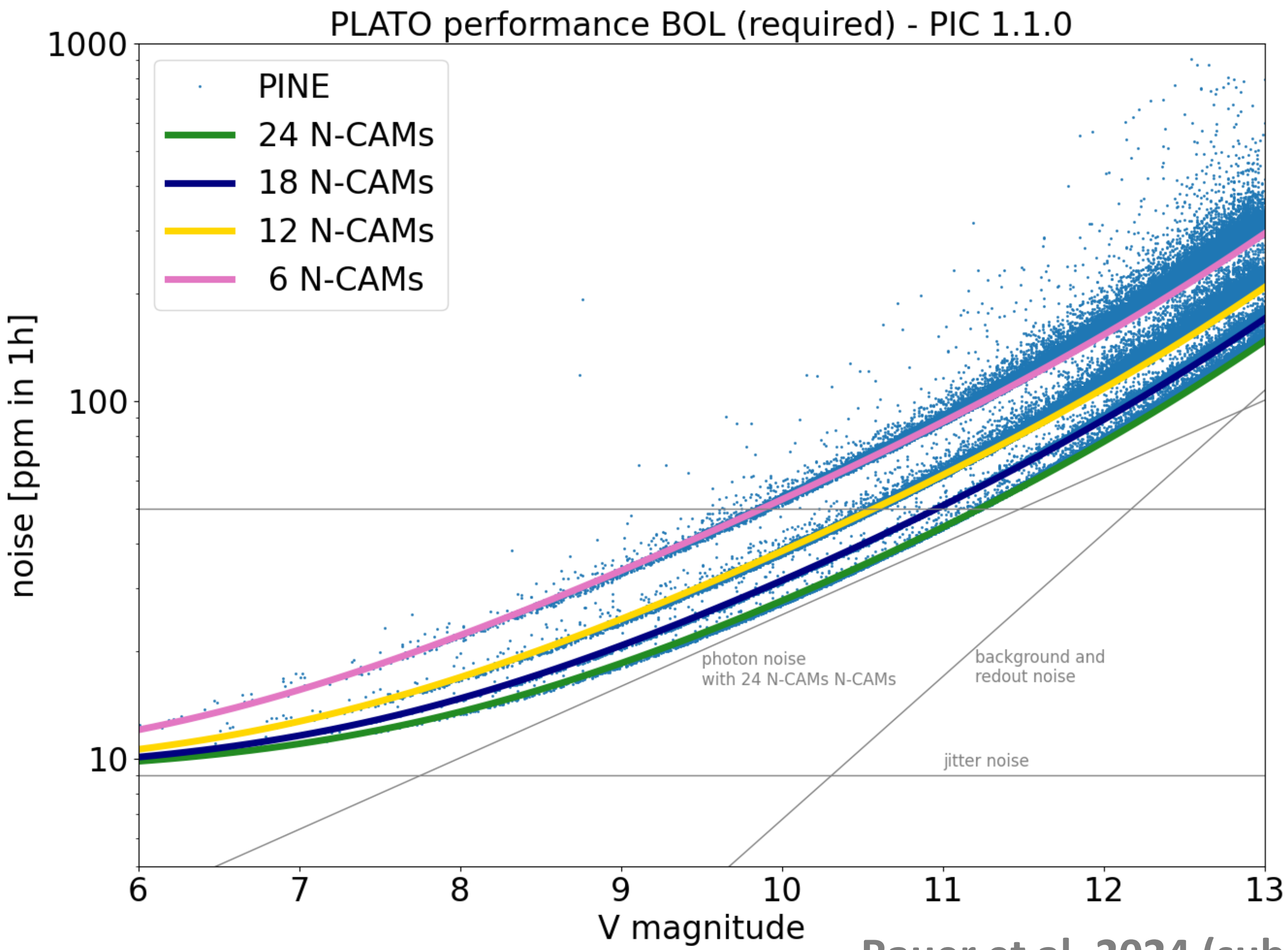


Figure 1. Left: Group arrangement of the cameras on the spacecraft. Credits: OHB System AG. Right: Tilt Angle of 9.2° for each of the 4 N-CAM groups.

Pertenais et al. 2021

signal and noise budget



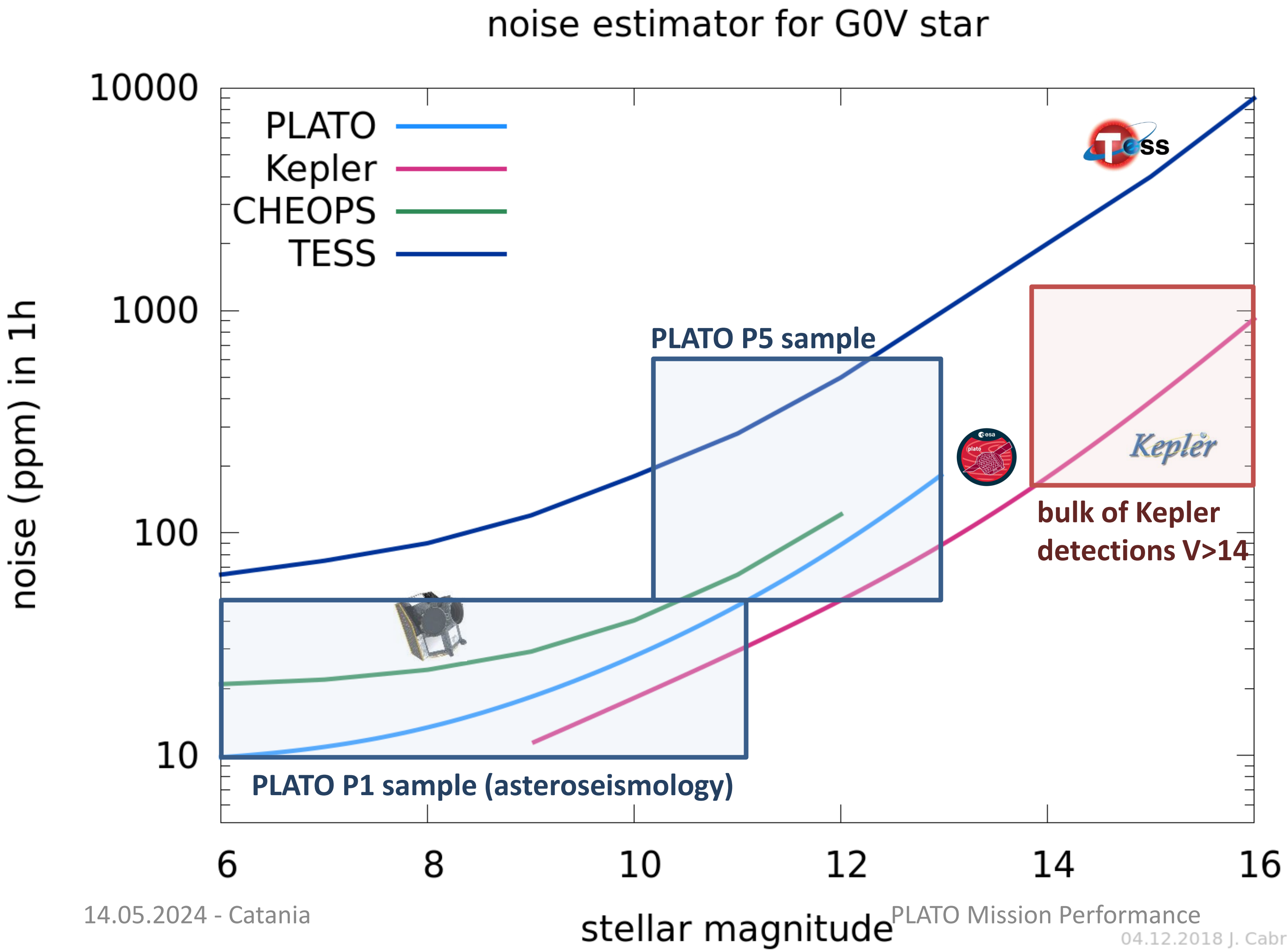
Rauer et al. 2024 (submitted)

- Uninterrupted observations for ≥**2 years**
- Duty cycle >93% in-flight
  (Kepler ~88%, see Burke et al. 2015)
- Noise budget dominated by:
  - **jitter** in the bright end
  - **background** and **readout** noise in the faint end
  - **photon shot noise** everywhere else

But note the particular architecture of the FOV.

in this presentation, ppm in 1h should be understood as ppm/sqrt(1h) in the Fourier domain

signal and noise budget



- Uninterrupted observations for ≥**2 years**
- Duty cycle >93% in-flight
  (Kepler ~88%, see Burke et al. 2015)
- Noise budget dominated by:
  - **jitter** in the bright end
  - **background** and **readout** noise in the faint end
  - **photon shot noise** everywhere else

But note the particular architecture of the FOV.

Rauer et al. 2024 (submitted)

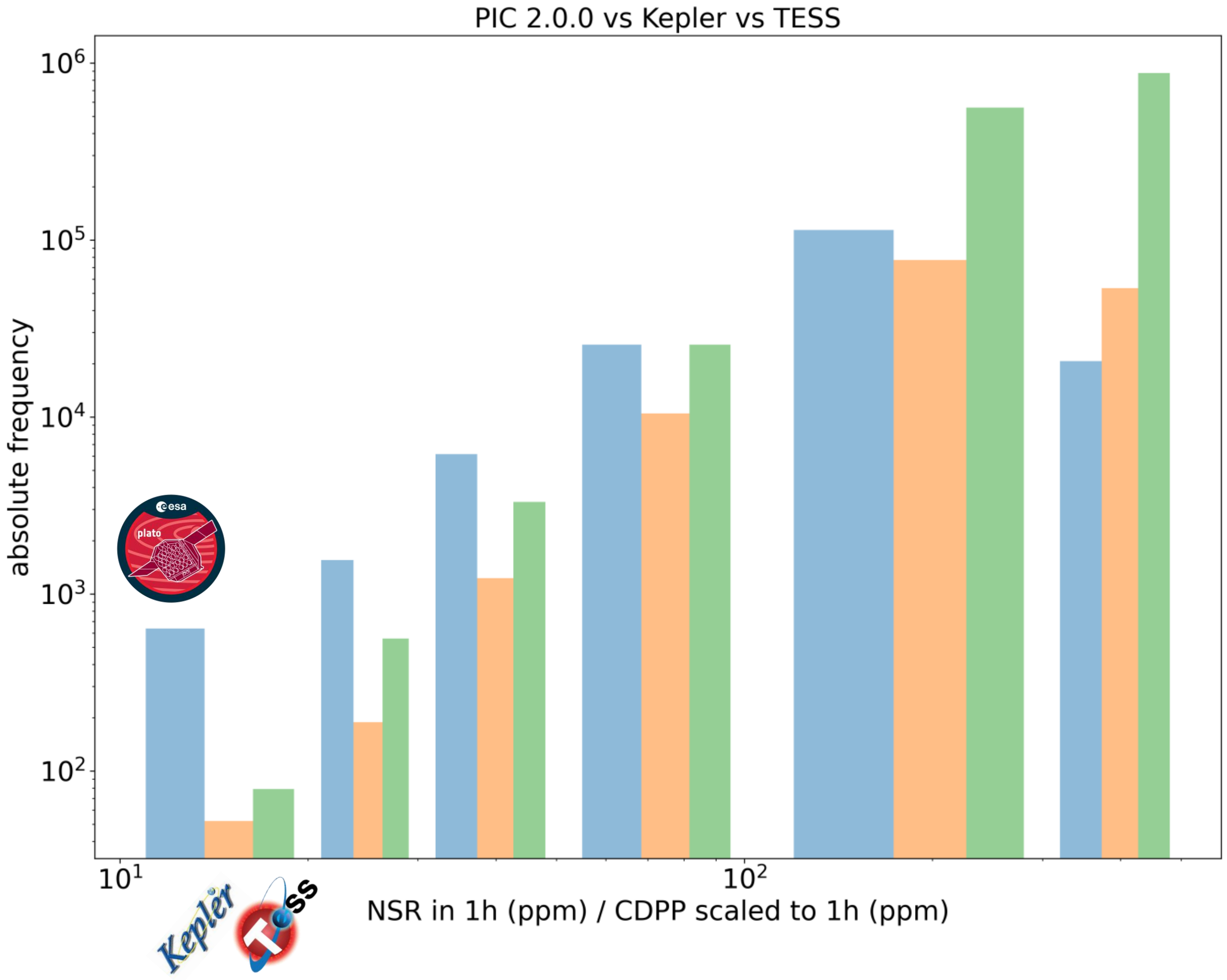
in this presentation, ppm in 1h should be understood as ppm/sqrt(1h) in the Fourier domain

signal and noise budget

tPIC 2.0.0

CDPP from Q3
(Christiansen et al. 2012)

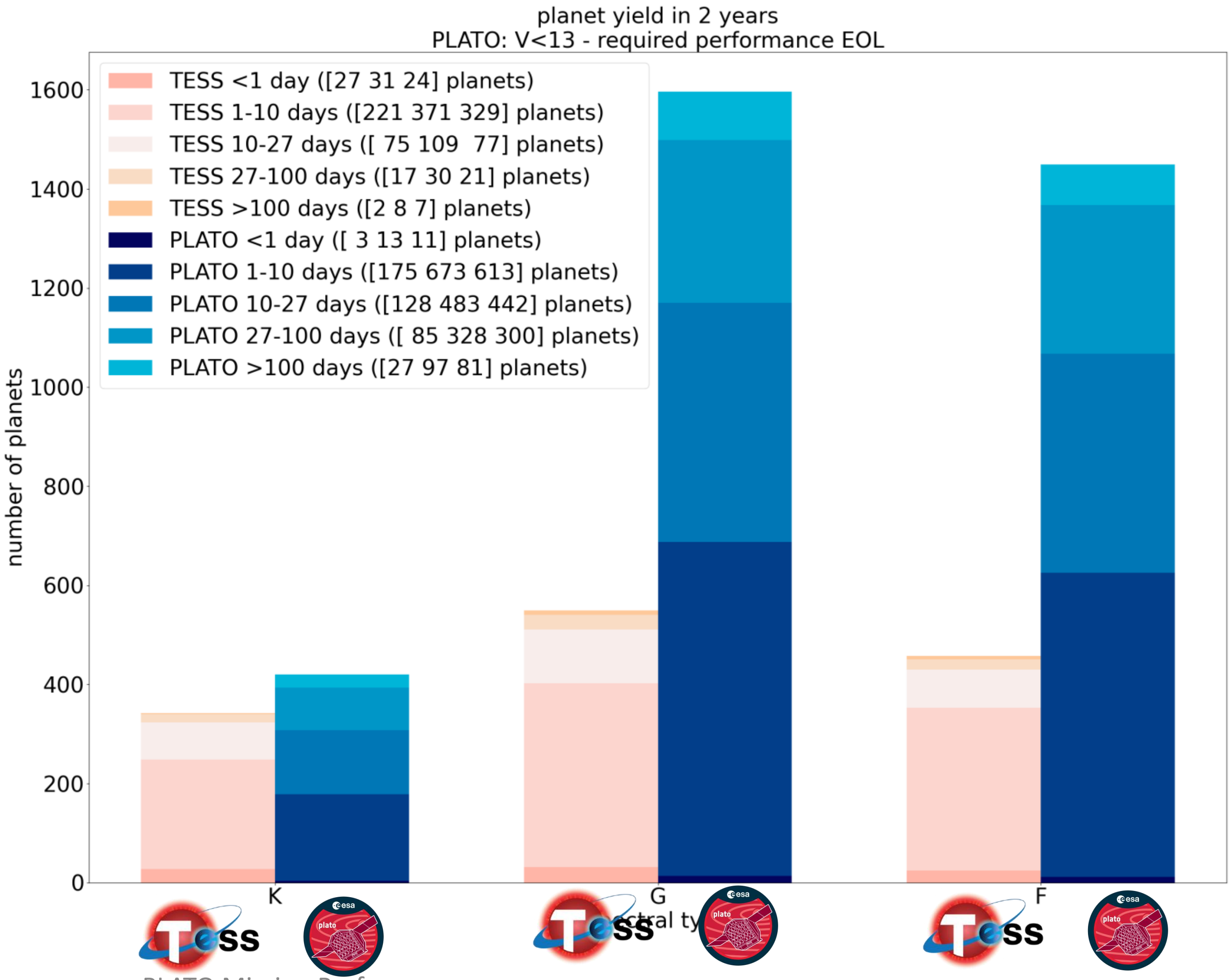
SPOC CDPP
Sectors 1 to 28



in this presentation, ppm in 1h should be understood as ppm/sqrt(1h) in the Fourier domain

planet yield

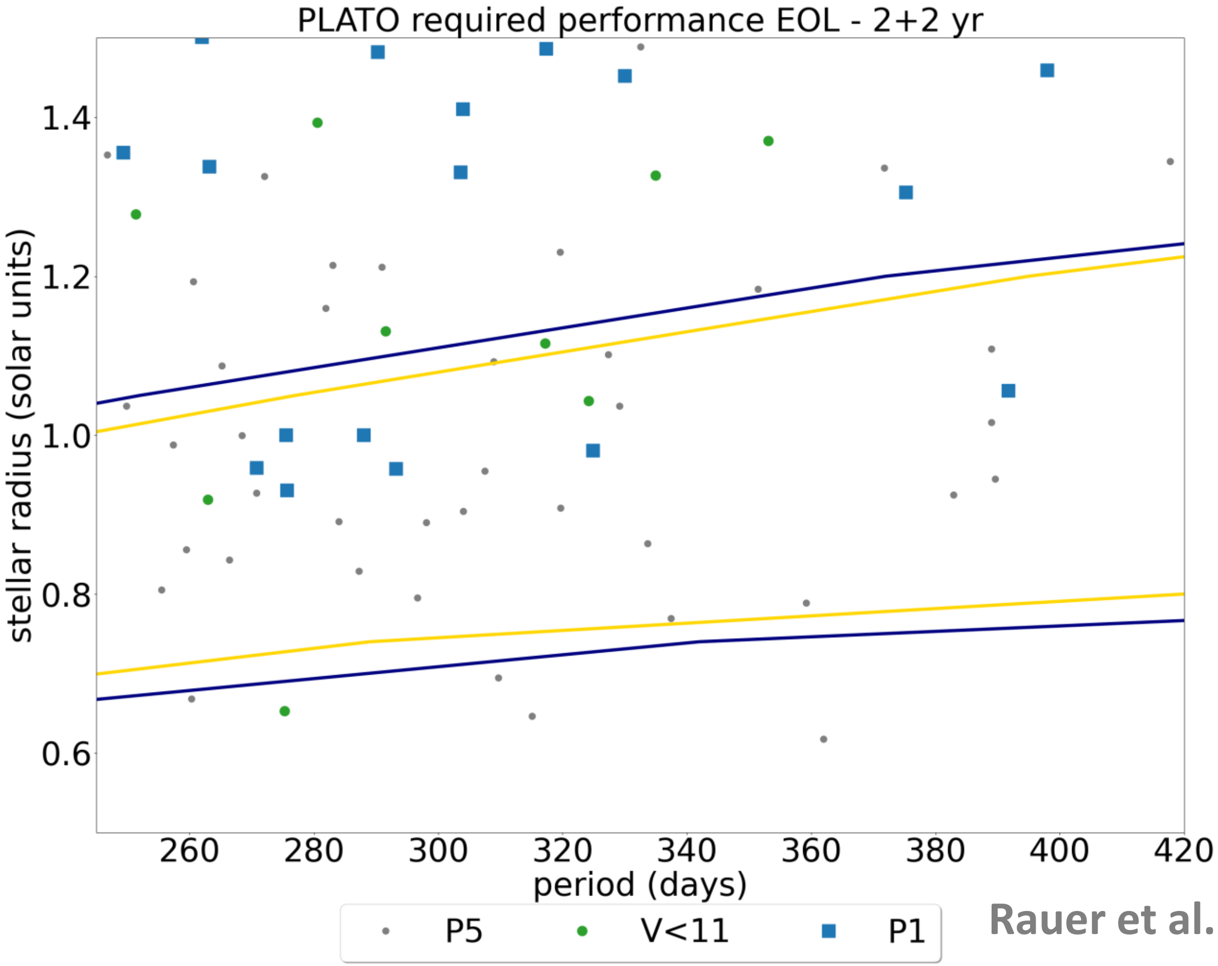
Spectral type distribution for TESS Object of Interest (TOI) host stars compared with our expectations for PLATO. The number of planet detections for each spectral type (K, G, and F) is plotted as histogram. The values for TESS are taken from Guerrero et al (2021, their Fig. 7) and correspond to all magnitudes. False-positive TOIs have been removed. For PLATO we have taken the stellar population from the PIC (Montalto et al, 2021), which in its current version does not include M or A stars (hence we do not show any counts for these spectral types). We have considered the end-of-life (EOL) performance as per requirements, which is a conservative approach. We compare the nominal mission of TESS (2 years) with half of the nominal mission for PLATO (2 years).



Rauer et al. 2024 (submitted)

planet yield

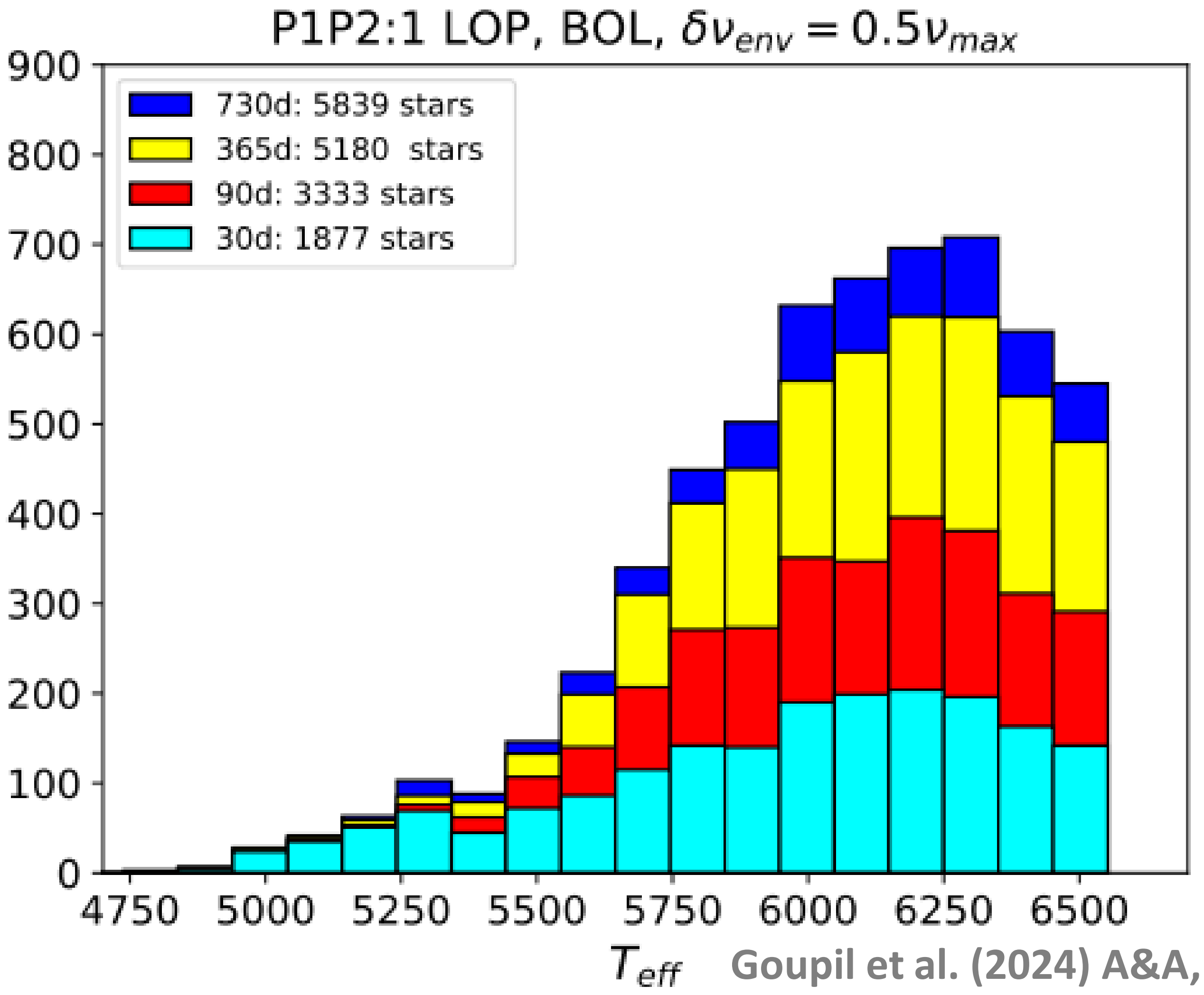
Yield of planets with <2 R_{Earth} in the HZ for the 2+2 scenario assuming 40% occurrence rate. We include two definitions for the HZ (the continuous lines): the optimistic (Kasting and Harman, 2013, blue) and the more conservative (Kopparapu et al, 2013, yellow). Symbols indicate the magnitude of host or target samples (P1 and P5) as indicated in the label.



Rauer et al. 2024 (submitted)

stellar physics

The **PLATO** mission is expected to produce a catalog sample of **extremely well seismically characterized stars** of a quality that is equivalent to the ***Kepler* Legacy sample**, but containing a number that is about **80 times greater**, when observing **two PLATO fields for two years** apiece. These stars are a gold mine that will make it possible to make significant advances in stellar modelling.



Goupil et al. (2024) A&A, 683

Histograms of the number of stars from the P1P2 sample (subgiants of all masses and MS stars with masses $M = M_{\odot} < 1{:}6$) with a probability of >99% of positive detection of solar-like oscillation in the case of (1 LOP, BOL, $\nu_{env} = 0{:}5\nu_{max}$).

tests

analogue chain not finished yet (19/26), N-CAM chain not finished (13/24), F-CAM chain not started

PLATO-DLR-PL-PLN-0001
1, Rev. 6
08.12.2021

4.3. Incompressible Test List

	Unit Level (CCD, FEE, TOU)	Analogue Chain	N-Camera	F-Camera
Offset	No	No	No	No
Pixel-to-Pixel Crosstalk	No	No	No	No
Readout Noise	No	No	No	No
QE and Relative QE	No	No	No	No
BFE	No	No	No	No
Charge Injection Stability	No	No	No	No
PRNU	No	Yes	No	No
Gain	Yes	Yes	No	No
Linearity and saturation	No	Yes	No	No
Radiometric characterisation	No	No	No	No
Boresight-Cube Alignment	Yes	NA	No	No
Camera Geometrical Model	NA	NA	No	Yes
Best Focus Temperature	NA	NA	Yes	Yes

tests

offset is not constant in the full-frame CCDs
- it has a spatial structure (line-start effect)
- it has a temporal variability (odd-even effect)

Brighter Fatter Effect correction parameters are unclear

Gain is computed under certain assumptions that have been challenged

Linearity and **saturation**
- there is a certain degree of non-linearity in the front-end electronics
- the saturation suffers from non-asymmetric blooming

Radiometric characterization
- the FOV extends beyond the 18.8 degree limit that is now considered for the generation of the PIC
- ghosts might induce false positive or additional contamination

First PSM Data Challenge (October 2023)

https://s2e2.cosmos.esa.int/confluence/display/PCOT/Kick-off+telecon+-+October+9th%2C+2023

contact:
simulations-helpdesk@dlr.de

data products

per camera	N-DPU designation	SSS	NDPU-SRS-6910
imagettes		27 500	
	F_IMA	-	27 500
	saturated imagette	-	1 500
light curves @600s		73 500	
	L_FX	-	< 73 500
	L_FX_EFX	>7 000 (*)	< 33 700
centroids @600s		3 700 (*)	
	L_FX_NCOB	-	< 3 700
	L_FX_EFX_NCOB_ECOB	> 400 (*)	< 3 700
light curves @50s		31 350	
	S_FX	-	< 31 350
	S_FX_EFX	>3 000 (*)	< 11 700
centroids @50s		3 700	
	S_FX_NCOB	-	< 3 700
	S_FX_EFX_NCOB_ECOB	> 400 (*)	< 3 700

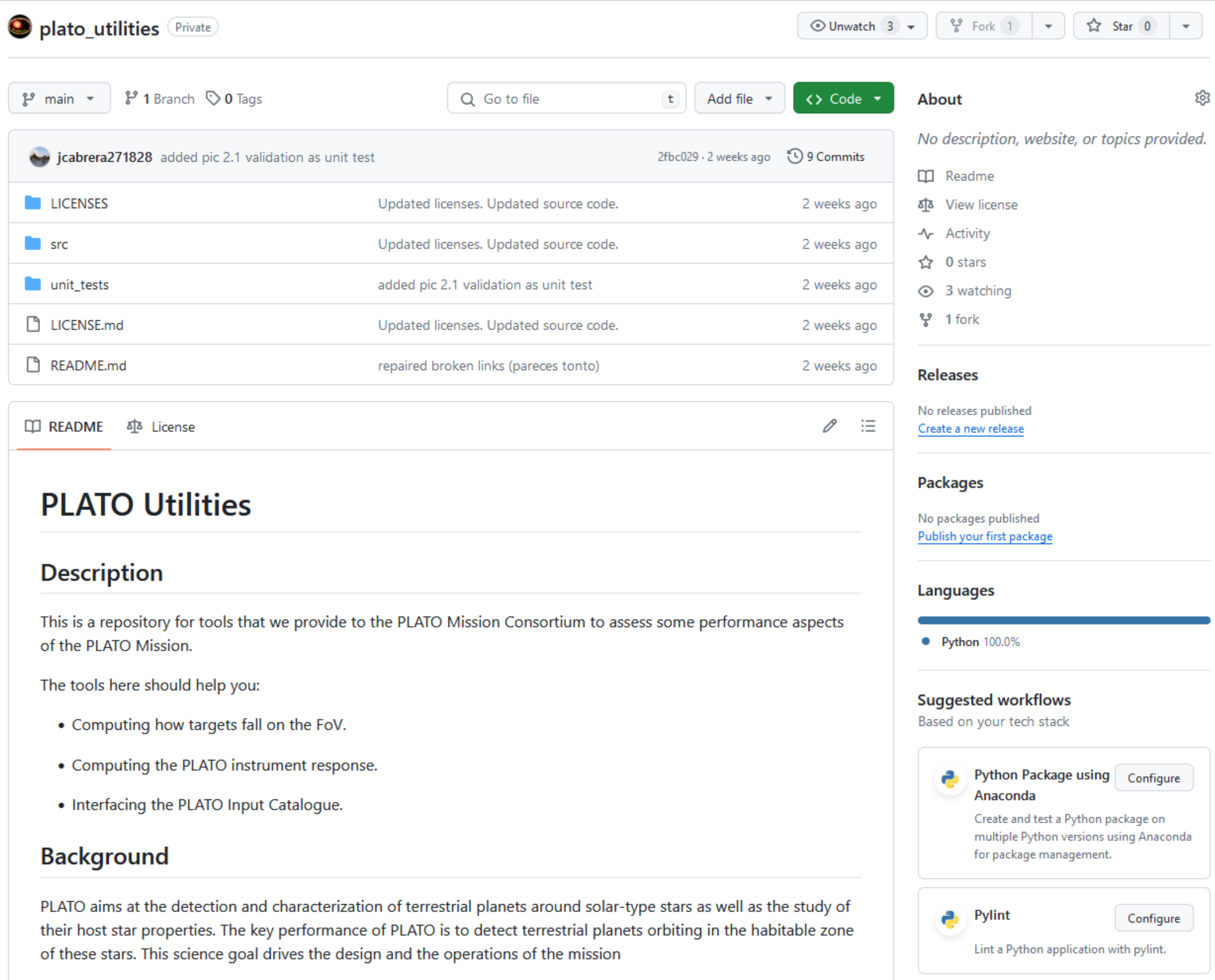
Centroids and **extended masks** to mitigate the impact of **false positives** from stellar contaminants.

- How many targets can we validate with PLATO photometry?
- Which is the optimal mask for a given target?
- Which is the optimal on-board processing?

github repository

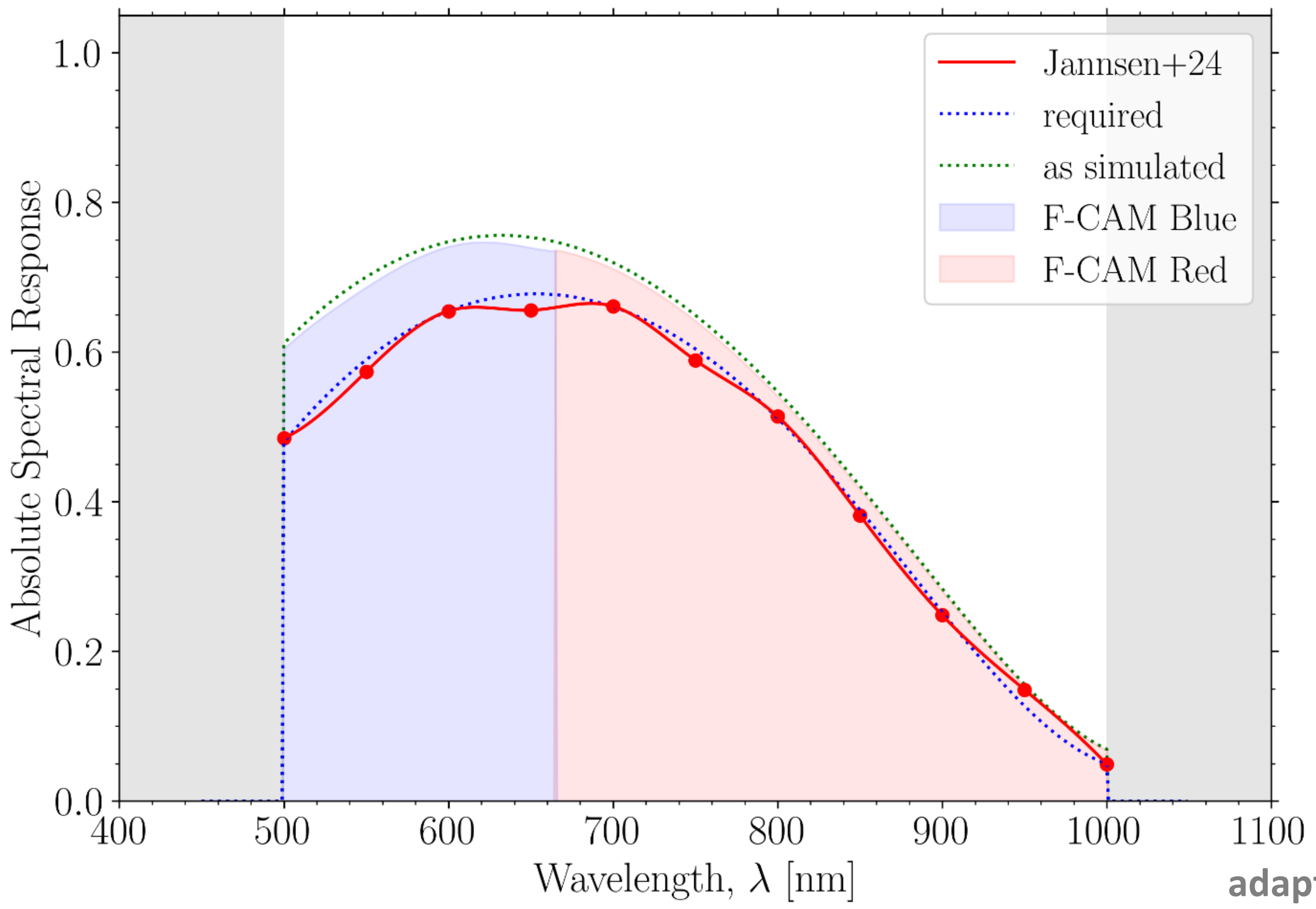
We make available to PLATO Mission Consortium members tools developed by the PLATO Performance Team:

- To compute how targets fall on the FoV.
- To compute instrument response.
- To interface the PIC.
- Etc.



contact:
`simulations-helpdesk@dlr.de`

instrument response



As part of the PMC, you can contribute to the analysis of the instrument performance and use this knowledge to improve the exploitation of the PLATO science.

adapted from Jannsen et al. (2024) A&A, 681

take-home message: 957

There is abundant information available to **the PLATO Mission Co**nsortium on **PLATO Performance**.
We want to **make this information available** to the community in a useful way.
We want to **involve the PLATO community** in the preparation of the exploitation of the PLATO data.

- Goupil et al. (2024) A&A, 683, A78
- Jannsen et al. (2024) A&A, 681, A18 (PlatoSim).
- Betrisey et al. (2024) A&A, 681, A99.
- Magliano et al. (2024) MNRAS, 528, 2851.
- Betrisey et al. (2023) A&A, 676, A10.
- Bray et al. (2023) MNRAS, 518, 3637.
- Canocchi et al. (2023) A&A, 672, A114.
- Matuszewski et al. (2023) A&A, 677, A133.
- Heller et al. (2022) A&A, 665, A11.
- Morello et al. (2022) RNAAS, 6, 248.
- Nascimbeni et al (2022) A&A, 658, A31.
- Cunha et al. (2021) MNRAS, 508, 5864.
- Montalto et al. (2021) A&A, 653, A98.
- Pertenais et al. (2021) SPIE 11852 (and references therein, including Ragazzoni et al. 2016; Magrin et al. 2016a, b; etc.).
- de Almeida et al. (2020) Exp. Ast. 50, 73.
- Grenfell et al. (2020) Exp. Ast. 50, 1.
- Marchiori et al. (2019) A&A, 627, A71.
- Samadi et al. (2019) A&A, 624, A117 (PLATO Solar-like Light-curve Simulator)
- Miglio et al. (2017) AN, 338, 644.
- Verhoeve et al. (2016) SPIE 9915 (see also Prod'homme et al. 2016, 2018).
- Nascimbeni et al. (2016) MNRAS, 463, 4210.
- Rauer et al. (2014) Exp. Ast. 38 (but see also Rauer et al. 2016, AN, 337).

and Rauer et al. (2024) submitted, Börner et al. (2024) submitted, Krenn et al. (2024) submitted...

https://platopub.phys.au.dk/

short announcement

Two postdoc positions are open a the department of Extrasolar Planets and Atmospheres at **DLR**, Berlin.

http://s.dlr.de/exoplanets

Investigating the **interior structure of planets** to determine their composition using observational constraints.

http://s.dlr.de/c48lL

Investigating the **statistical properties of planetary systems** with the aim of understanding the processes of planetary formation and evolution.

http://s.dlr.de/1FvH4