Synergies with TESS

M. Montalto
INAF - Osservatorio Astrofisico di Catania

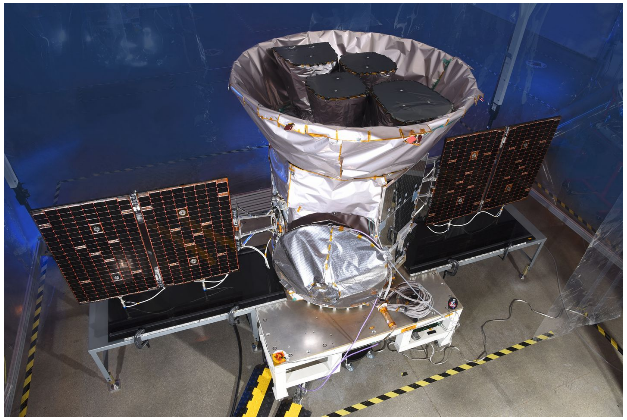
PLATO Science in Italy: ready to data exploitation? - Catania 25-27 September 2023

Synergies PLATO - TESS

- Main characteristics of the two missions, observing strategies, field of views, targets acquisition strategies
- Coverage of PLATO targets by TESS
- Systems response curves
- Photometric precisions
- Predicted exoplanets detections: TESS
- TESS candidate planets
- TESS candidate planets in PLATO/LOPS2
- Astrophysical contamination of PLATO targets: eclipsing binaries in the field of view of PLATO detected by TESS
- The identification of fgPIC and cPIC stars: constraints on variability

TESS - Transiting Exoplanet Survey Satellite

- Lauched: April 18, 2018 (Cape Canaveral)
- Duration: 2 years (nominal mission). First extended mission ended in September 2022. The second extended mission will last till 2025 (Year 5 - Year 7)



(Ricker et al. 2015, JATIS, 1, 40003)

Key scientific objective:

- The Transiting Exoplanet Survey Satellite (TESS) is designed to discover thousands of exoplanets in orbit around the brightest dwarf stars across the whole sky

PLATO - PLAnetary Transits & Oscillations of Stars

- The third M class mission in the ESA Cosmic Vision Program
- Launch: end 2026, Ariane 6 (Kourou)
- Duration: 4 years (up to 8 years)

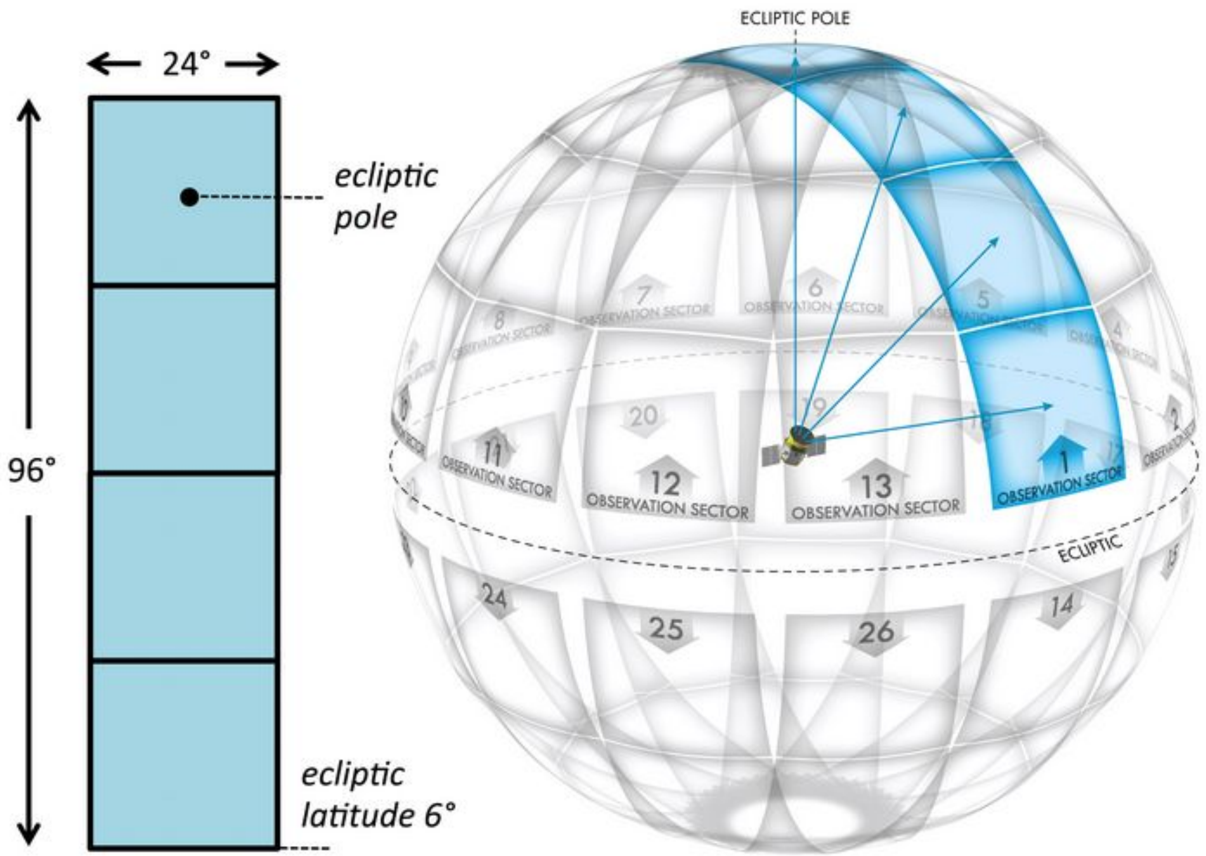
(Rauer et al. 2014, ExA, 38, 249)

Key scientific objectives:

- Detection and characterisation of terrestrial exoplanets around bright solar-type stars, with emphasis on planets orbiting in the habitable zone.
- Understand the formation, evolution, architecture of planetary systems through the analysis of a vast sample of thousands of planets of any kind

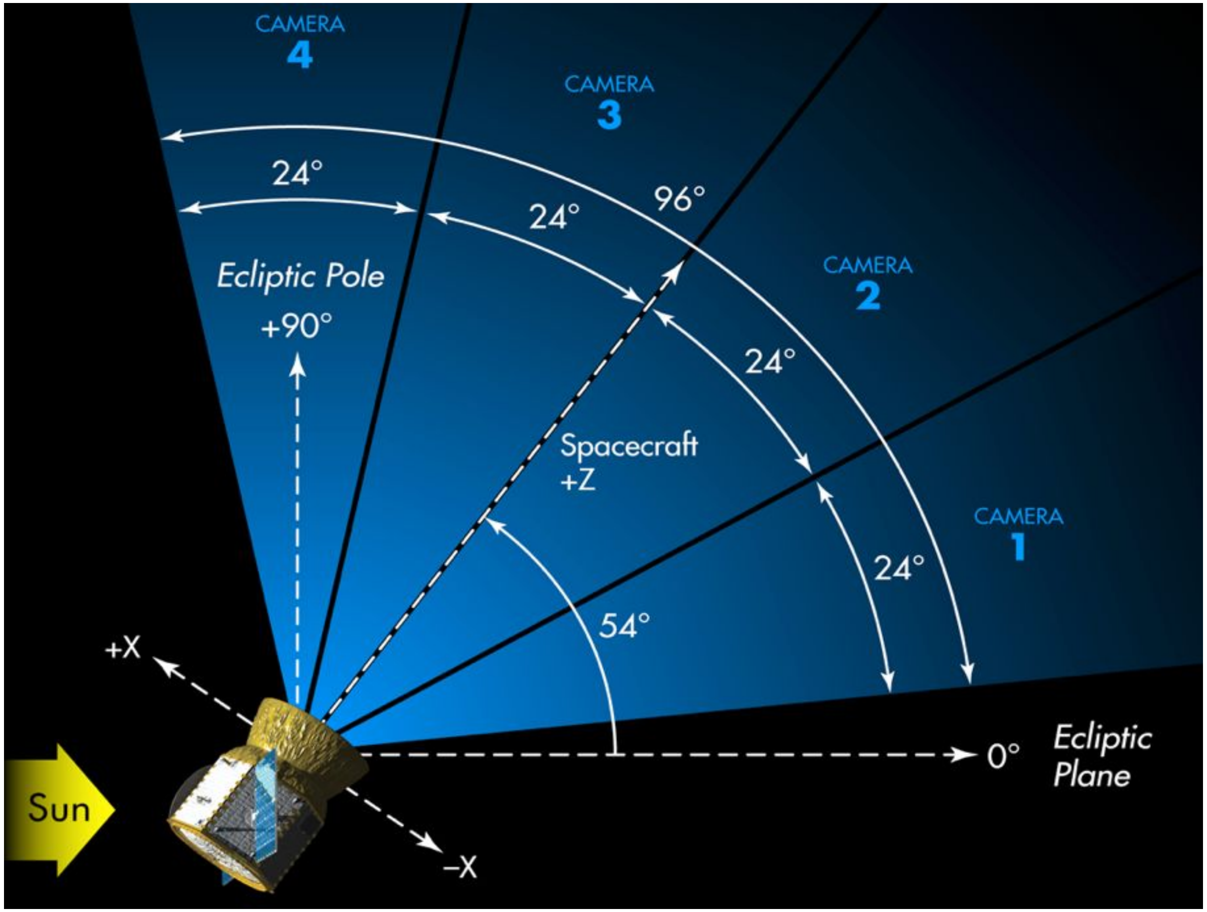
	PLATO	TESS
Orbit	Large amplitude libration orbit around Sun-Earth Lagrangian point, L2	High Earth Orbit (HEO, period 13.7 days)
Lifetime	4 years of nominal science operations; satellite built and verified for an in-orbit lifetime of 6.5 years, accommodating consumables for 8.5 years	2 years nominal Ist extension : +2 years IInd extension : + 3 years
Cameras	26 cameras (2 fast + 24 normal)	4 cameras
Diameter	12 cm	10 cm
Bandpass	500 nm - 1000 nm (NC) 500 nm - 675 nm (BFC) 675 nm - 1000 nm (RFC)	600 nm - 1000 nm
Total Field of view (FOV)	2100 sq. deg.	3200 sq. deg.

Observing strategy: TESS



TESS observes one sector of $24^{\circ} \times 96^{\circ} = 2304$ sq.deg. for about 27 days then moves to the next sector

Field of view: TESS



The four TESS cameras observe four non overlapping field of views

Observing strategy: PLATO

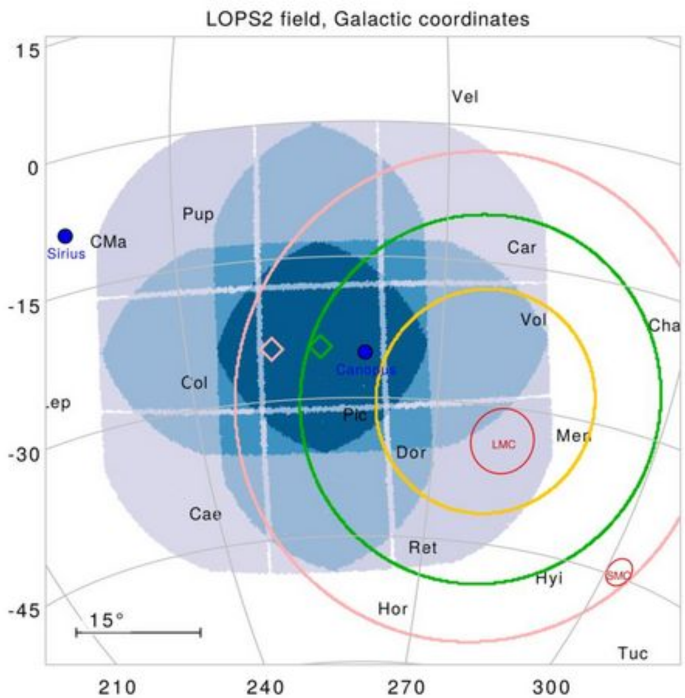
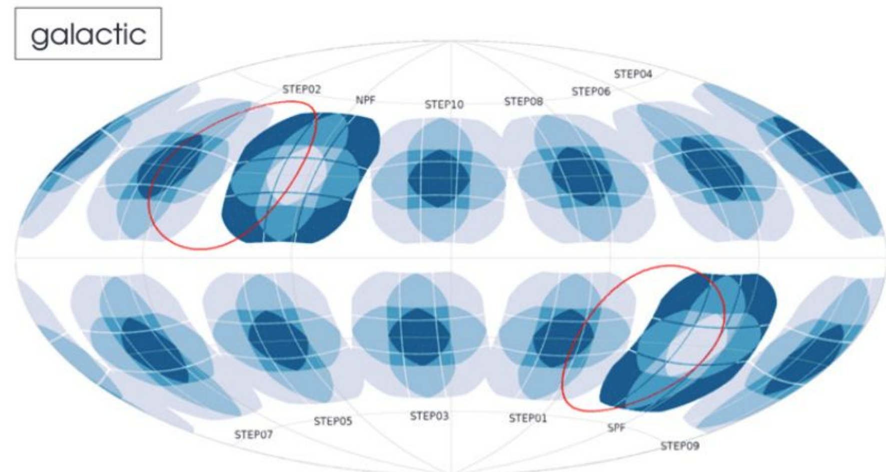


Figure 1: PLATO Field of View of LOPS2 (credit: PLATO SWT)



Step-and-stare fields (credit: PLATO red book)

During the LOPs, PLATO will continue to monitor the same field for 2 years. During the Step-and-Stare phase PLATO will cover a much larger fraction of the sky. Each field in the Step-and-Stare phase will be observed for 2.5 months.

Field of view: PLATO

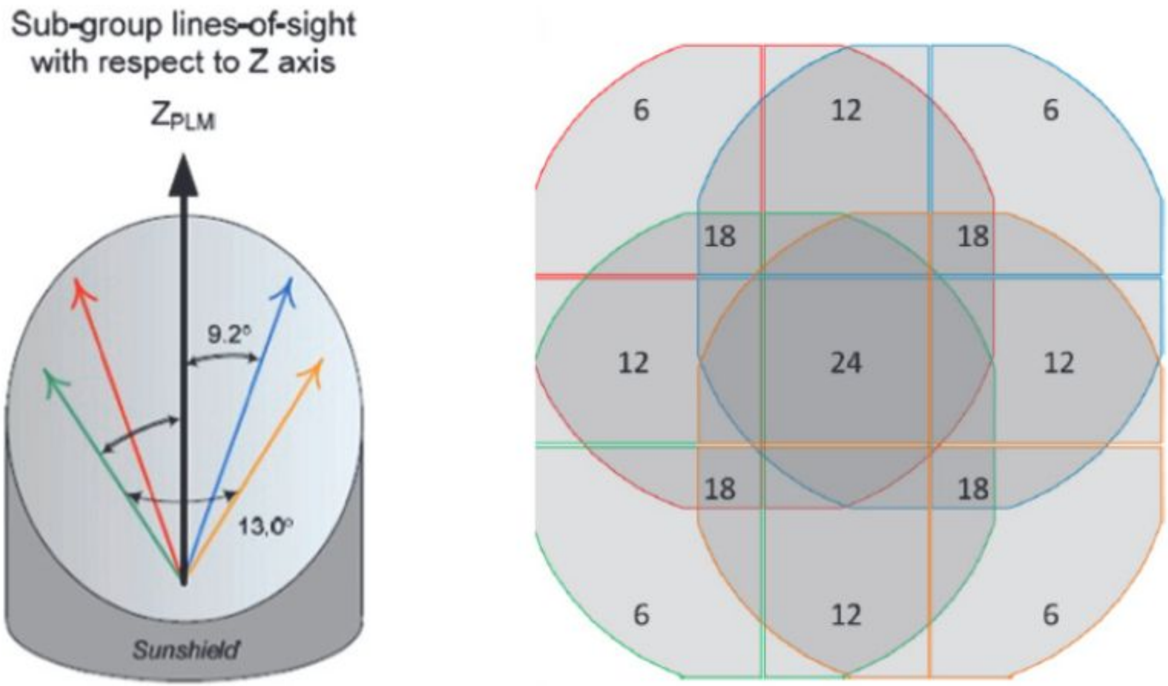


Figure 4.1: The overlapping line-of-sight concept (left) and the resulting field-of-view configuration (right).

(credits: PLATO red book)

PLATO cameras observe overlapping field of views

Target acquisition strategy: TESS

- The CCDs (Charge Coupled Devices) produce a continuous stream of images with an exposure time of 2 seconds.

- For a subset of 200 000 (20 000 per sector) pre-selected targets a subarray (10 pix by 10 pix) is stored every 2 minutes and then downloaded to the ground

- Full Frame Images (FFIs) are also stored and downloaded:
  - ❖ During the primary mission (Year 1 - Year 2) : 30 minutes
  - ❖ During the first extended mission (Year 3 - Year 4) : 10 minutes
  - ❖ During the second extended mission (Year 5 - Year 6 - Year 7) : 5 minutes

Target acquisition strategy: PLATO

From the PLATO Science Requirement document (SciRD):

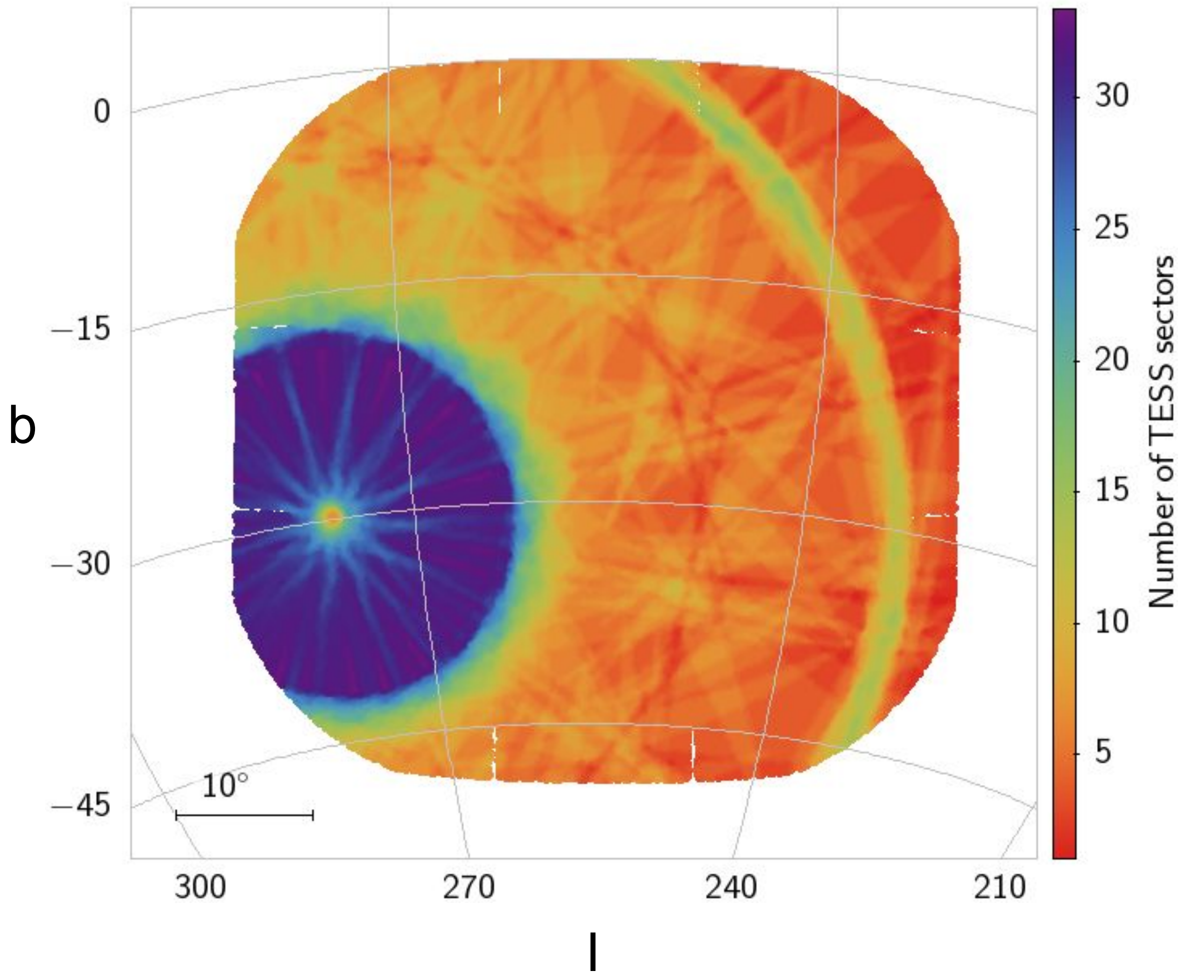
- Imagettes of all targets in stellar sample 1 (15 000) shall be obtained, with a sampling time of 25 seconds

- Imagettes of all targets in stellar sample 2 (1000) shall be obtained with a sampling time equal to 25 seconds. For a sub-sample, the sampling time shall be equal to 2.5 seconds

- Imagettes of all targets in stellar sample 4 (5000) shall be obtained, with a sampling time equal to 25 seconds.

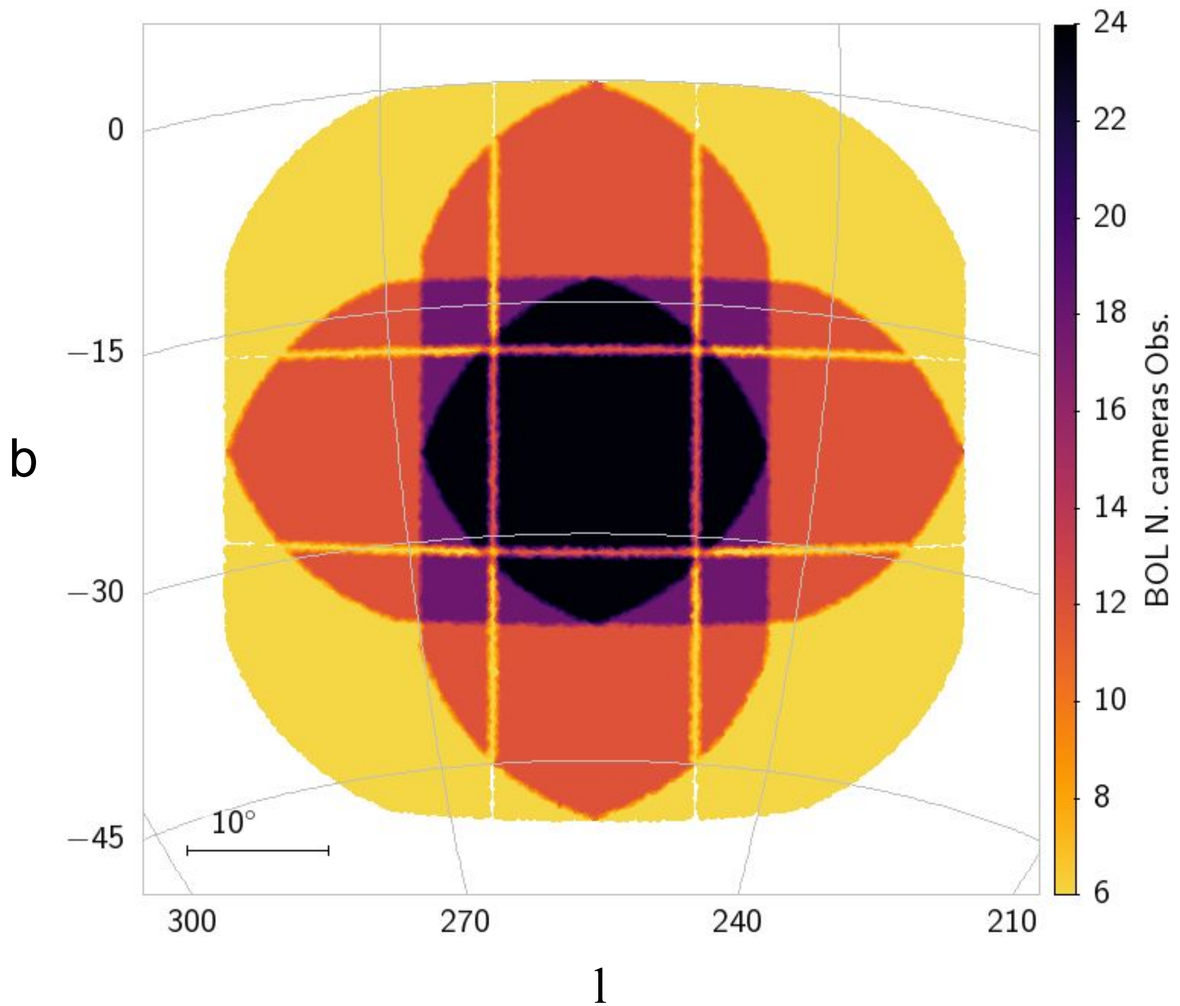
- The sampling time of stellar sample 5 shall be equal to or shorter than:
  - 600 seconds for initial intensity measurements
  - 50 seconds for at least 10% of the targets, for which potential transit events have been identified
  - 50 seconds for centroid measurements for at least 5% of the targets, which are of special astrophysical interest or for which potential transit events have been identified.
  - Imagettes of more than 9 000 targets in stellar sample 5 shall be obtained, with a sampling time equal to 25 seconds.

Coverage of PLATO targets by TESS



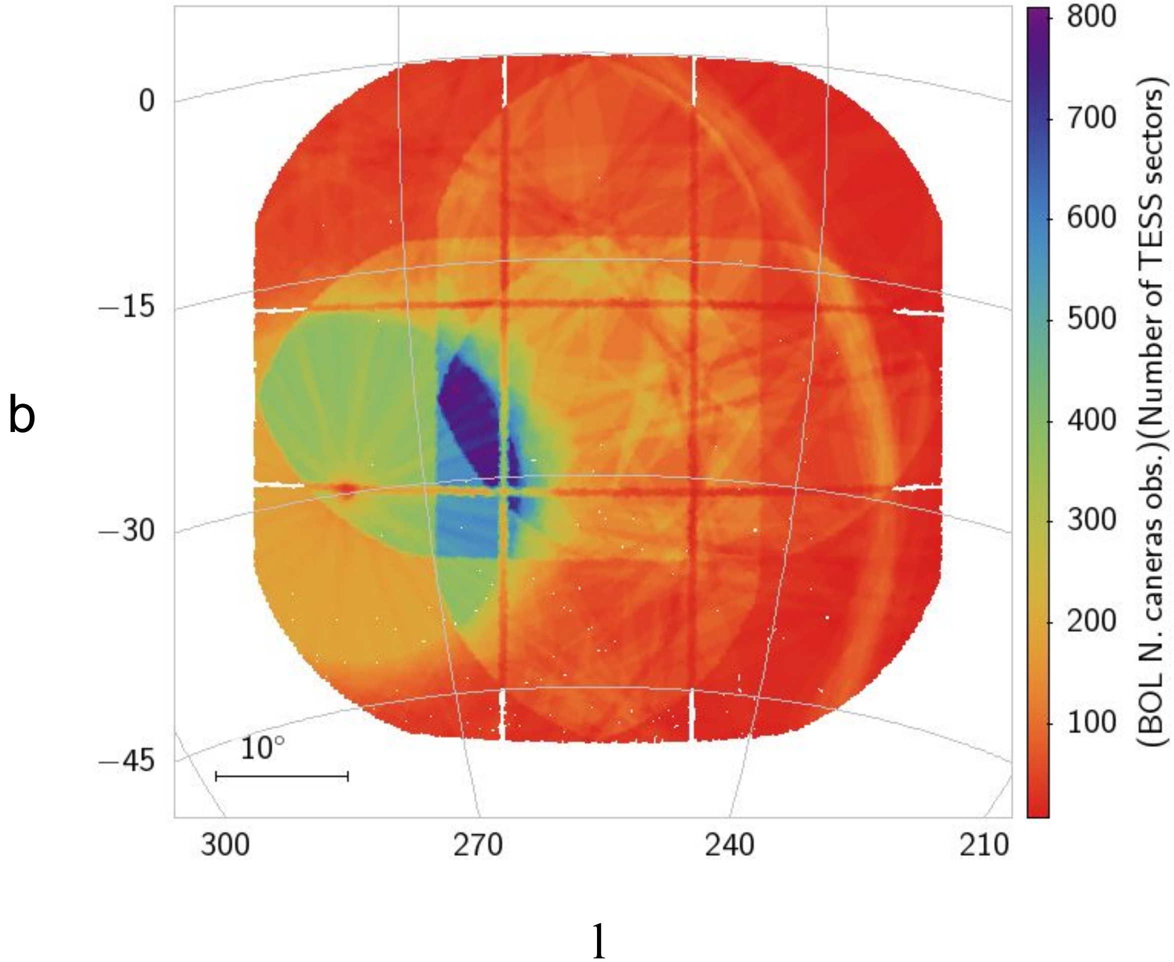
PIC2.0.0.1-t, LOPS2 - TESS sectors: 1 - 67

Number of PLATO cameras



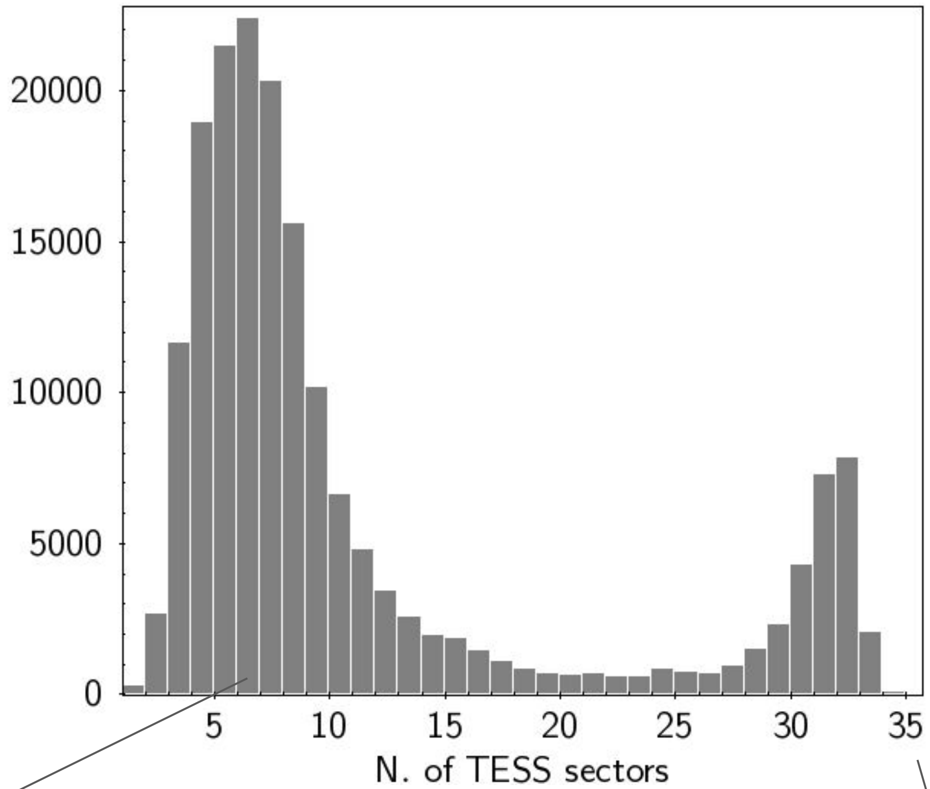
PIC2.0.0.1-t - LOPS2

Coverage of PLATO targets by TESS (best observed by PLATO)



LOPS2 - TESS sectors: 1 - 67

Coverage of PLATO targets by TESS

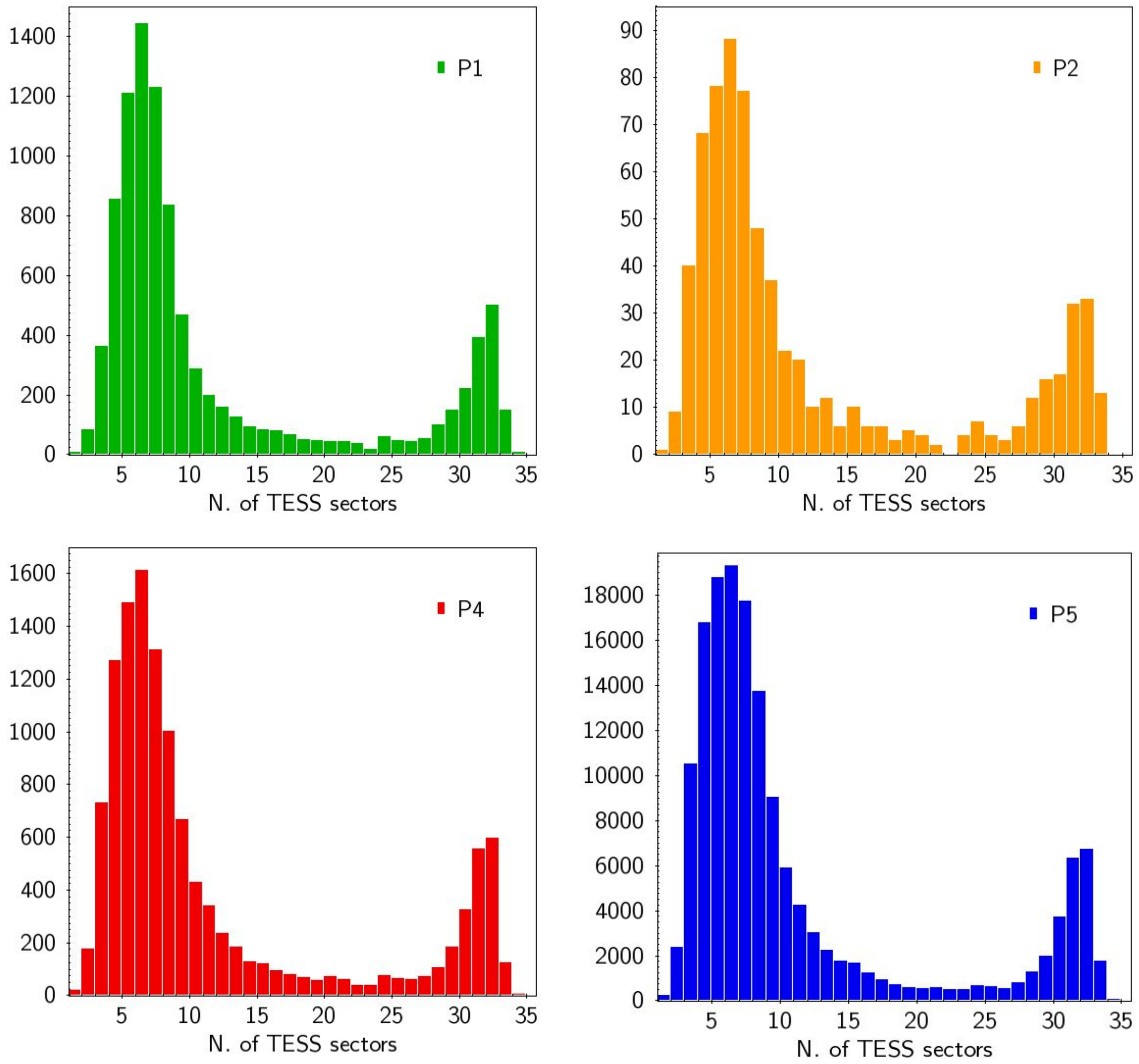


7 sectors = 189 days

35 sectors = 2.6 yr

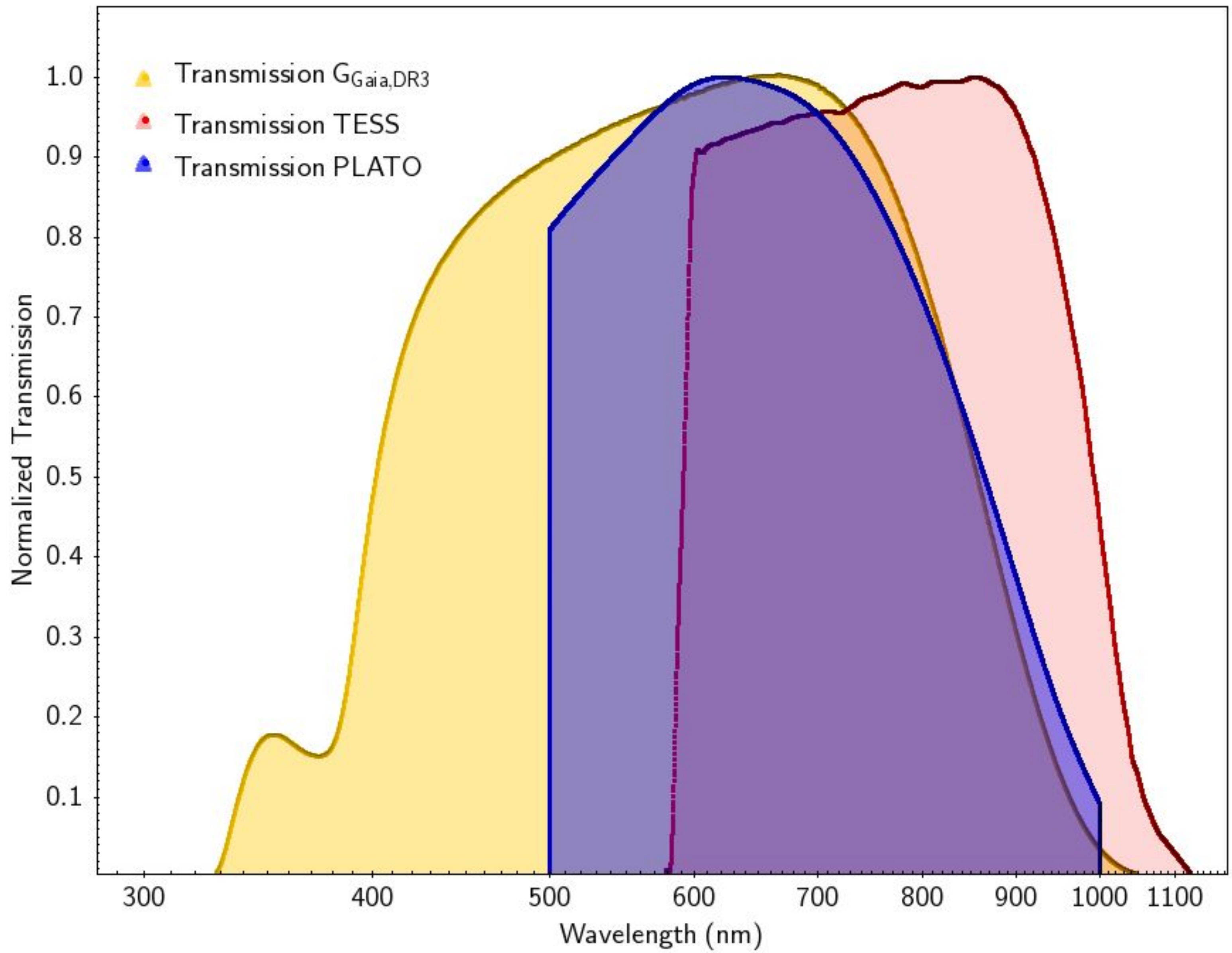
LOPS2 - TESS sectors: 1 - 67

Coverage of PLATO targets by TESS (stellar samples)

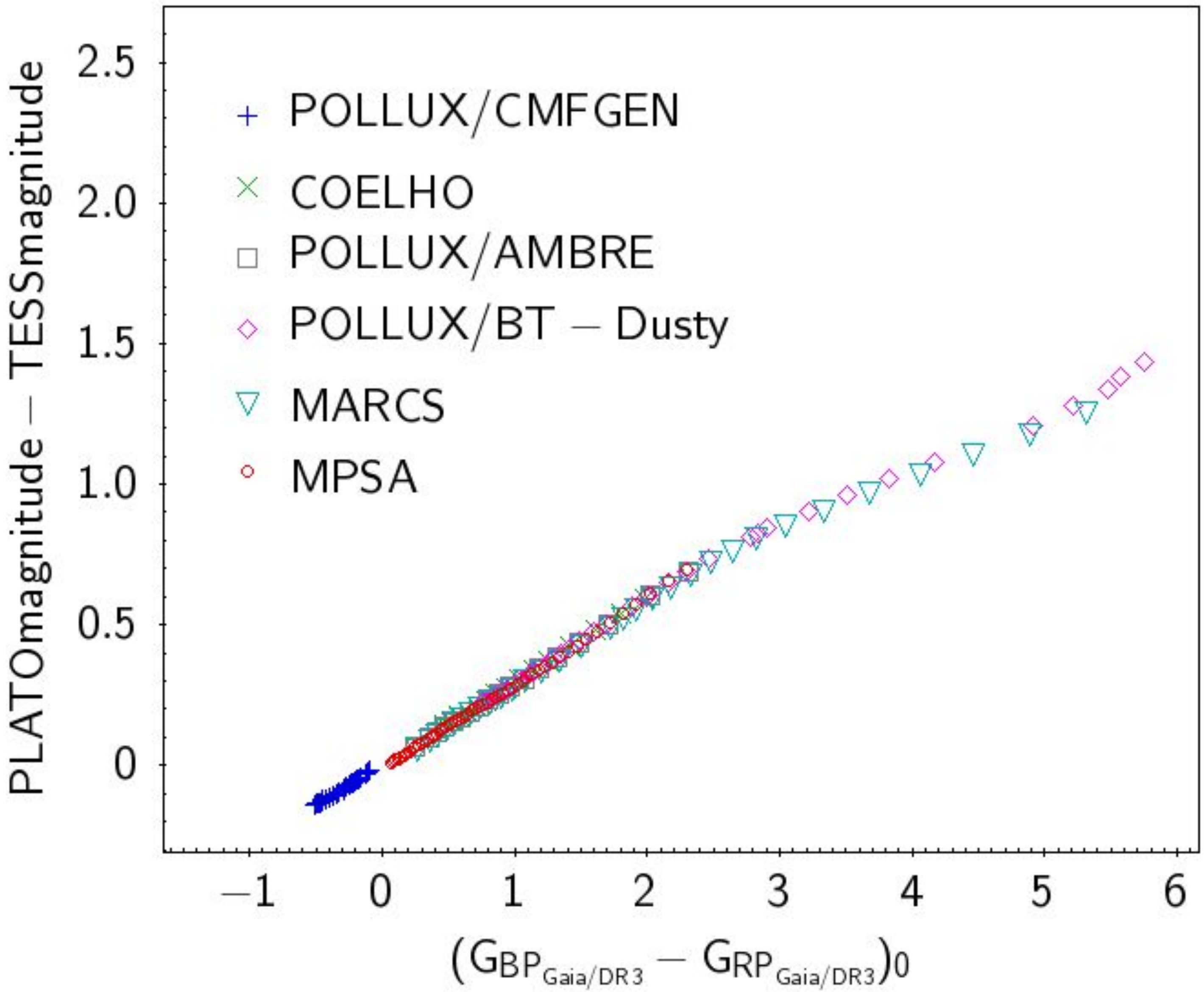


LOPS2 - TESS sectors: 1 - 67

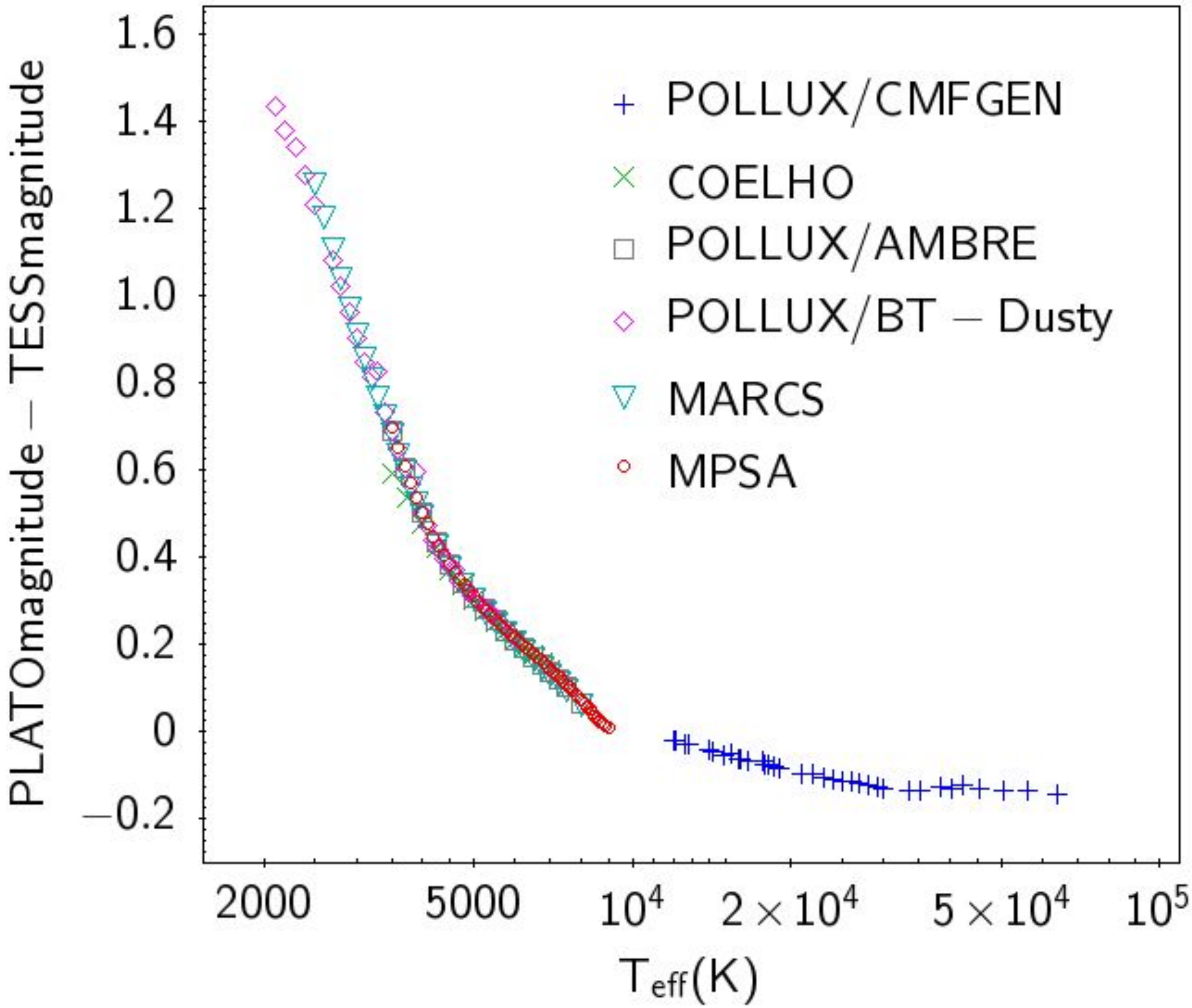
Systems response curves



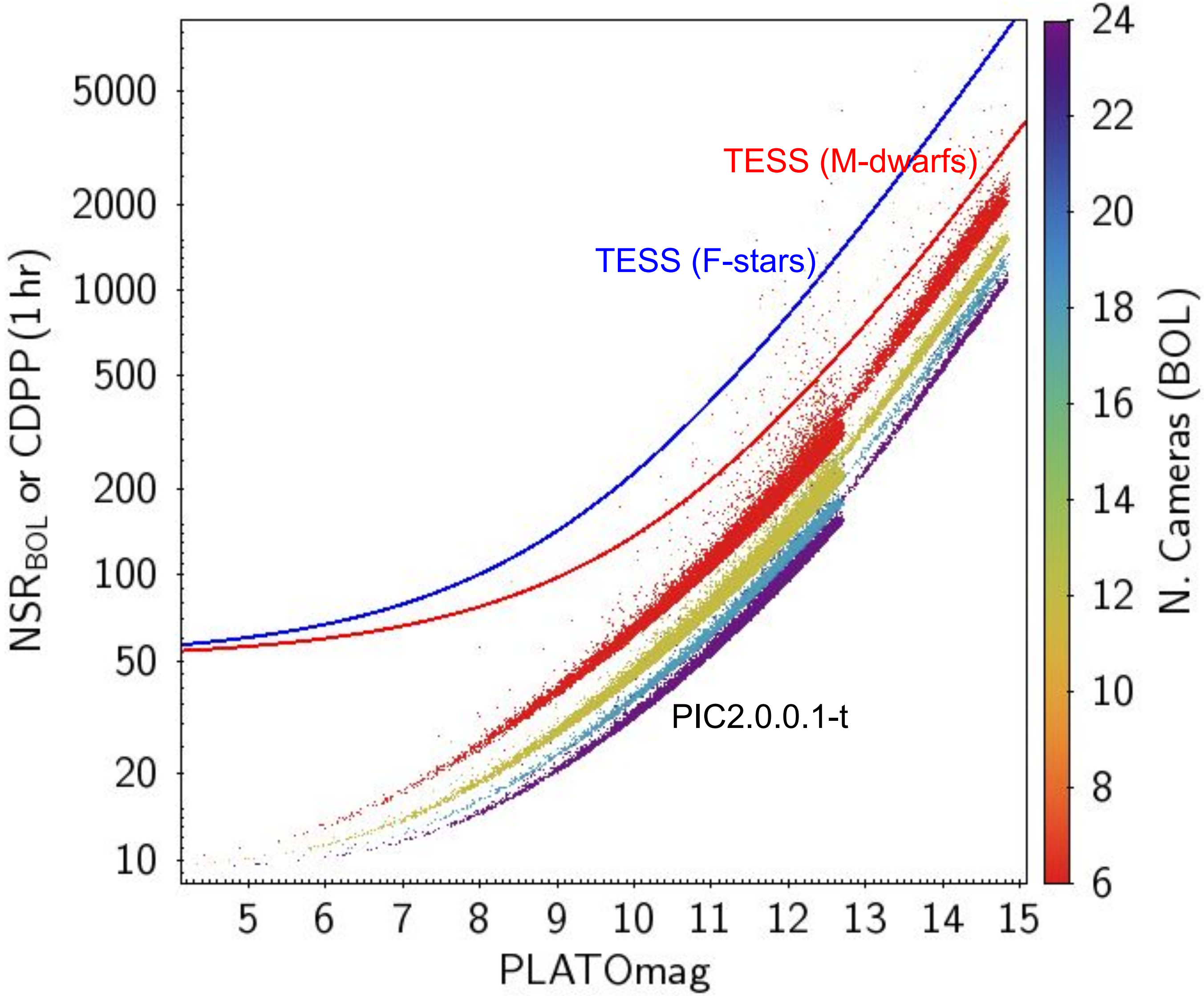
PLATO magnitude vs TESS magnitude



PLATO magnitude vs TESS magnitude

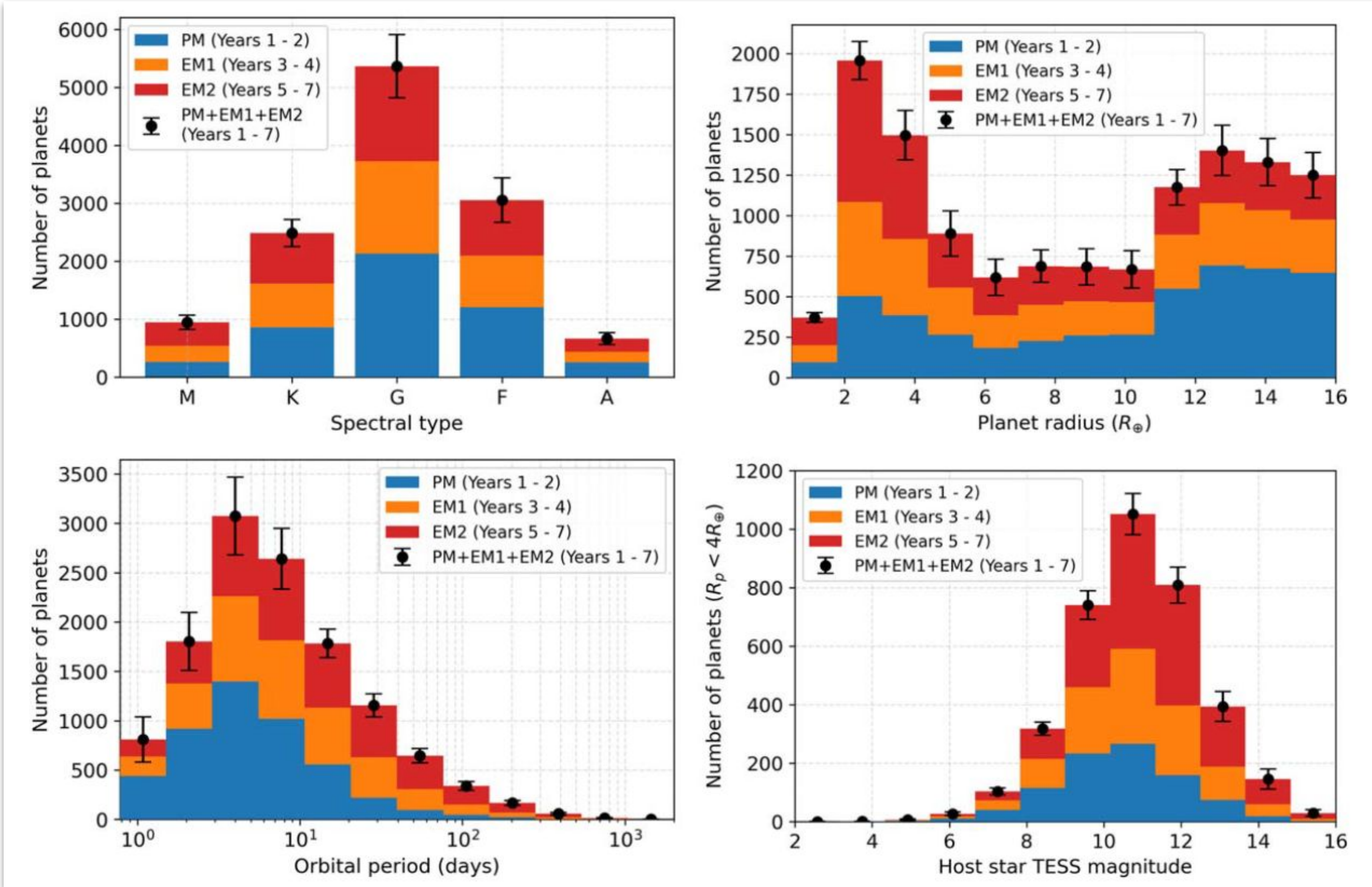


Photometric precision: PLATO vs TESS



Median CDPP in 1hr for all 230 000, 2-minute targets processed by the TESS Science Processing Operations Center (SPOC) pipeline across the Primary Mission taken from Kunimoto et al. 2022, AJ, 163, 290

Predicted exoplanets detections: TESS



Kunimoto et al. 2022, AJ, 163, 290

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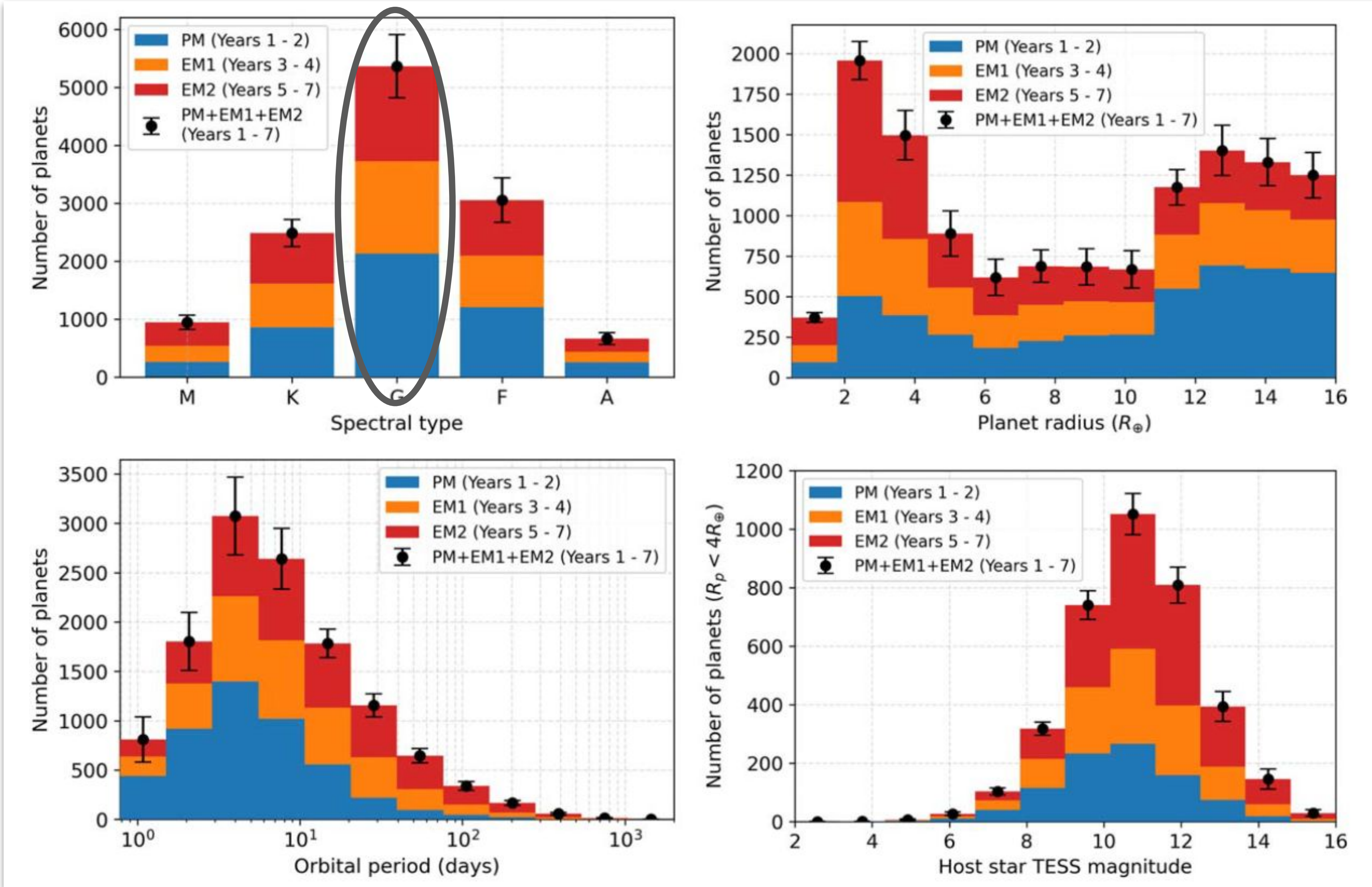
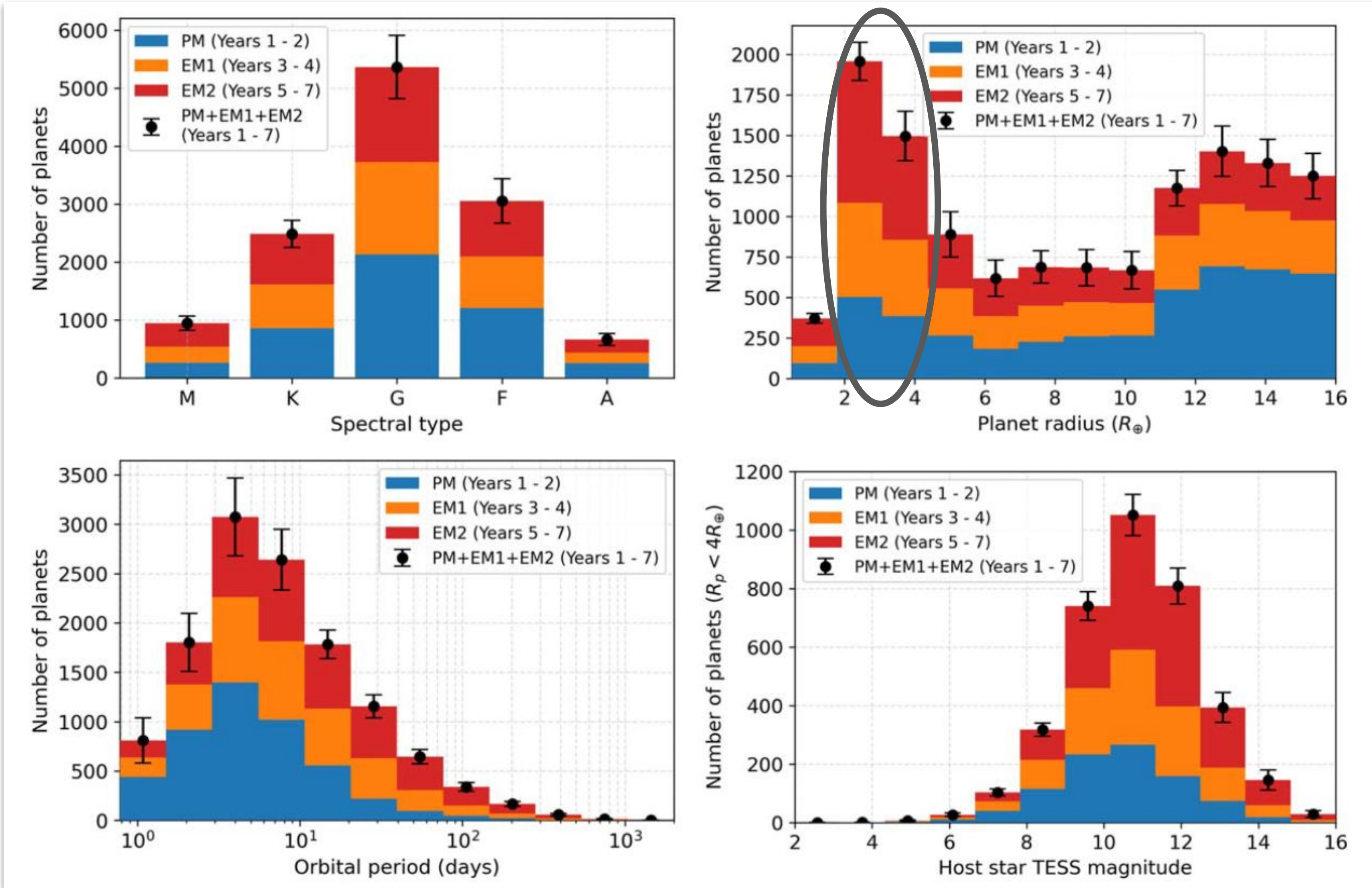


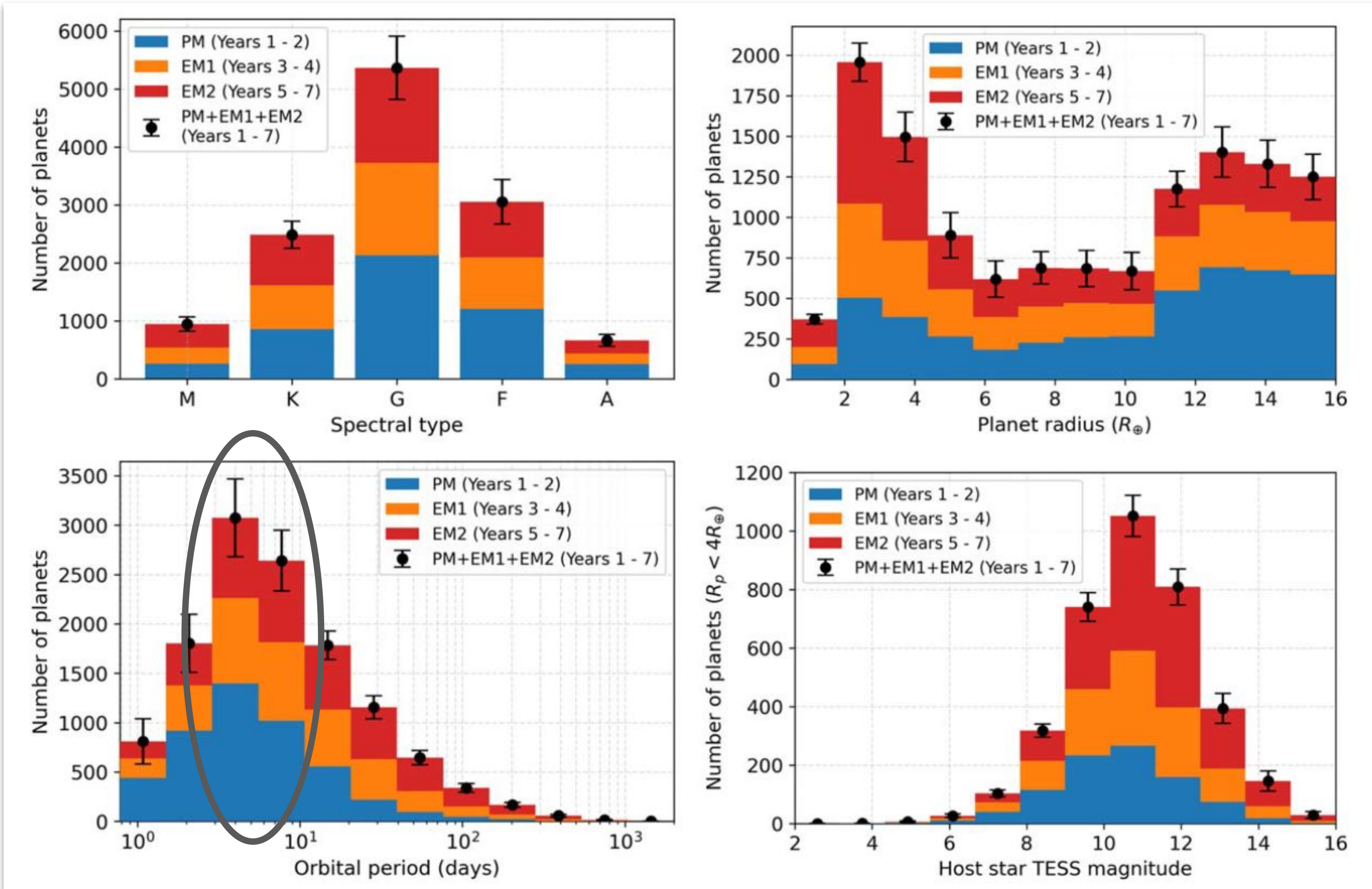
Kunimoto et al. 2022, AJ, 163, 290

Predicted exoplanets detections: TESS



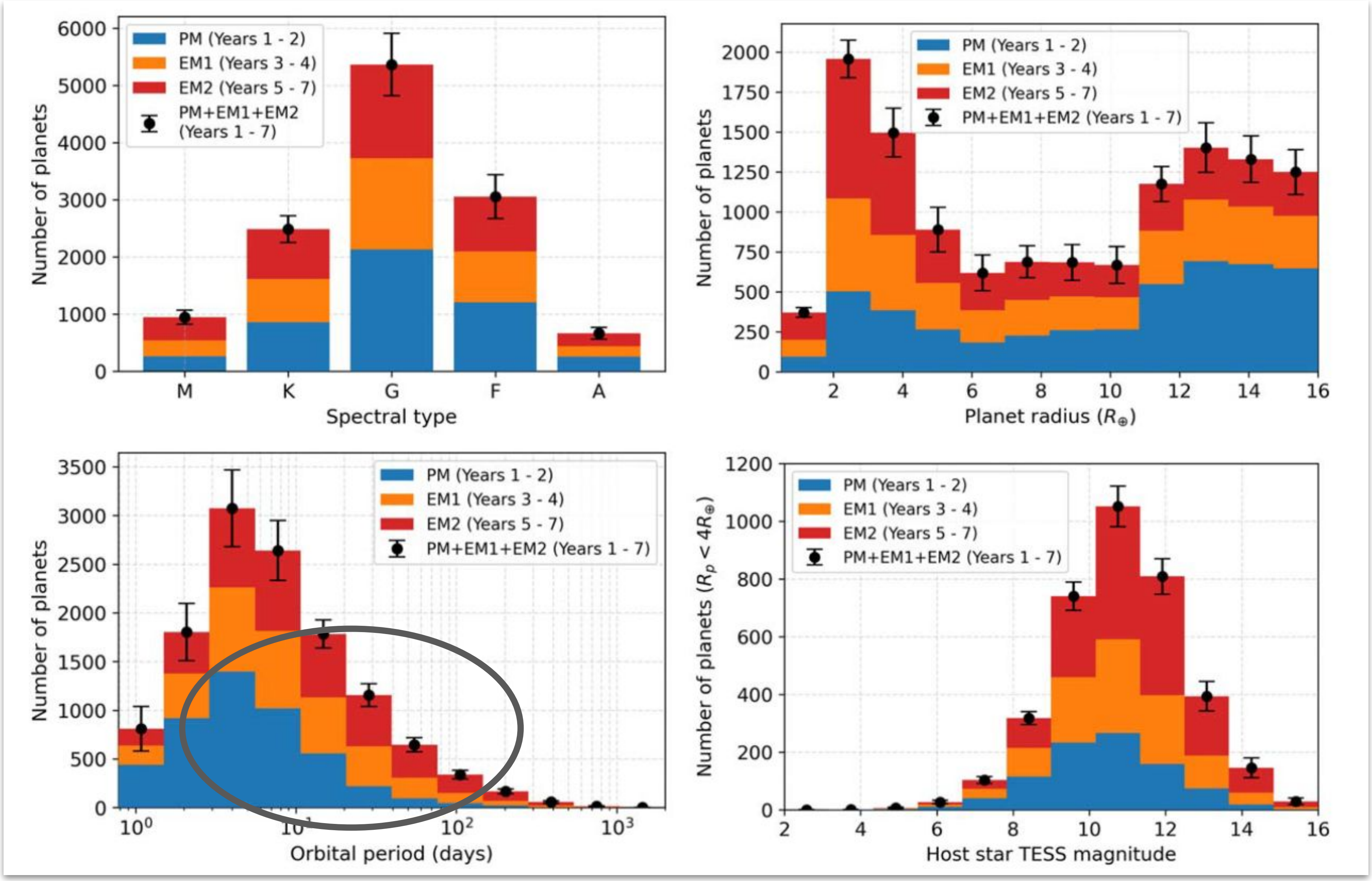
Kunimoto et al. 2022, AJ, 163, 290

Predicted exoplanets detections: TESS



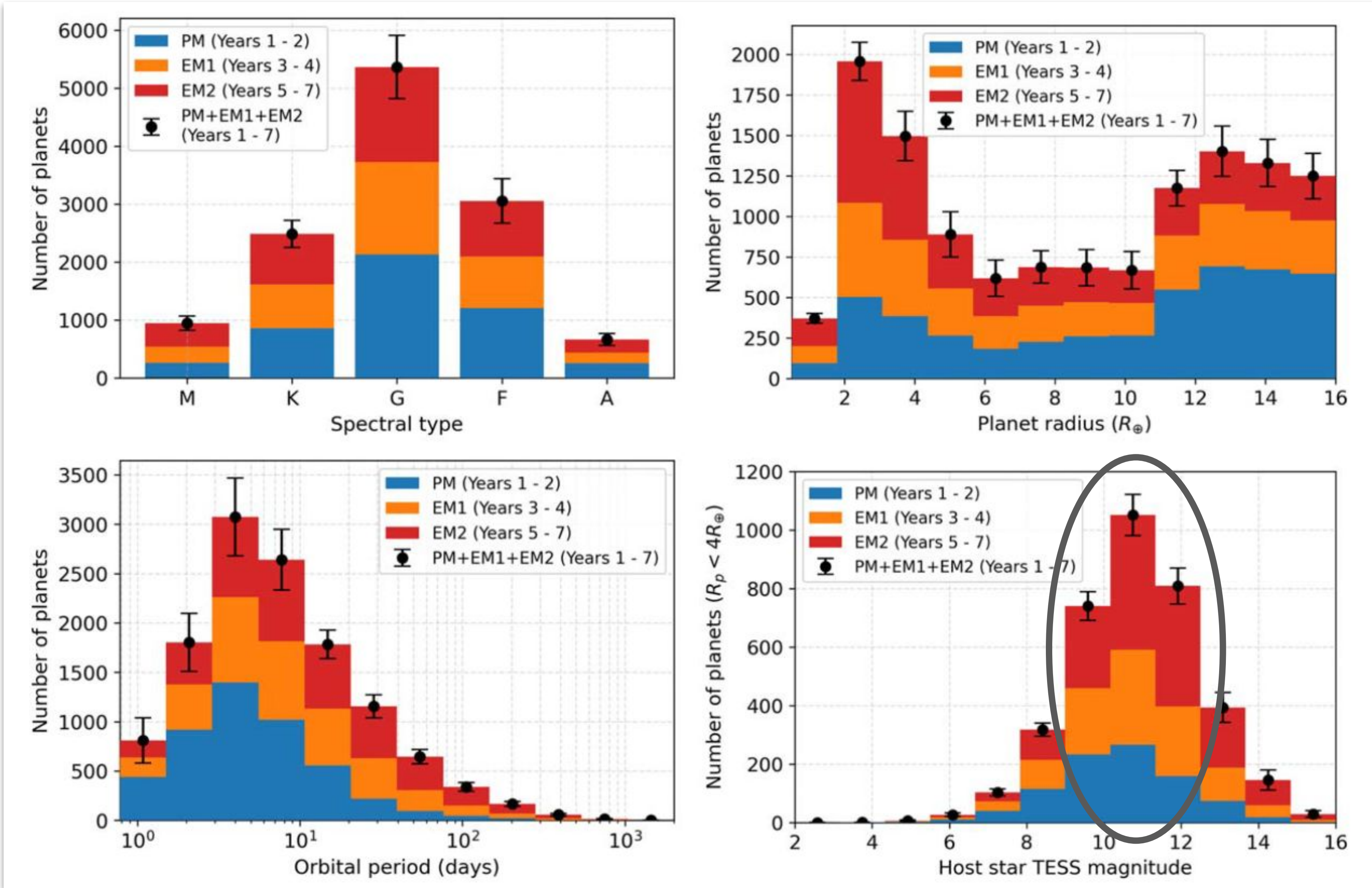
Kunimoto et al. 2022, AJ, 163, 290

Predicted exoplanets detections: TESS



Kunimoto et al. 2022, AJ, 163, 290

Predicted exoplanets detections: TESS



Kunimoto et al. 2022, AJ, 163, 290

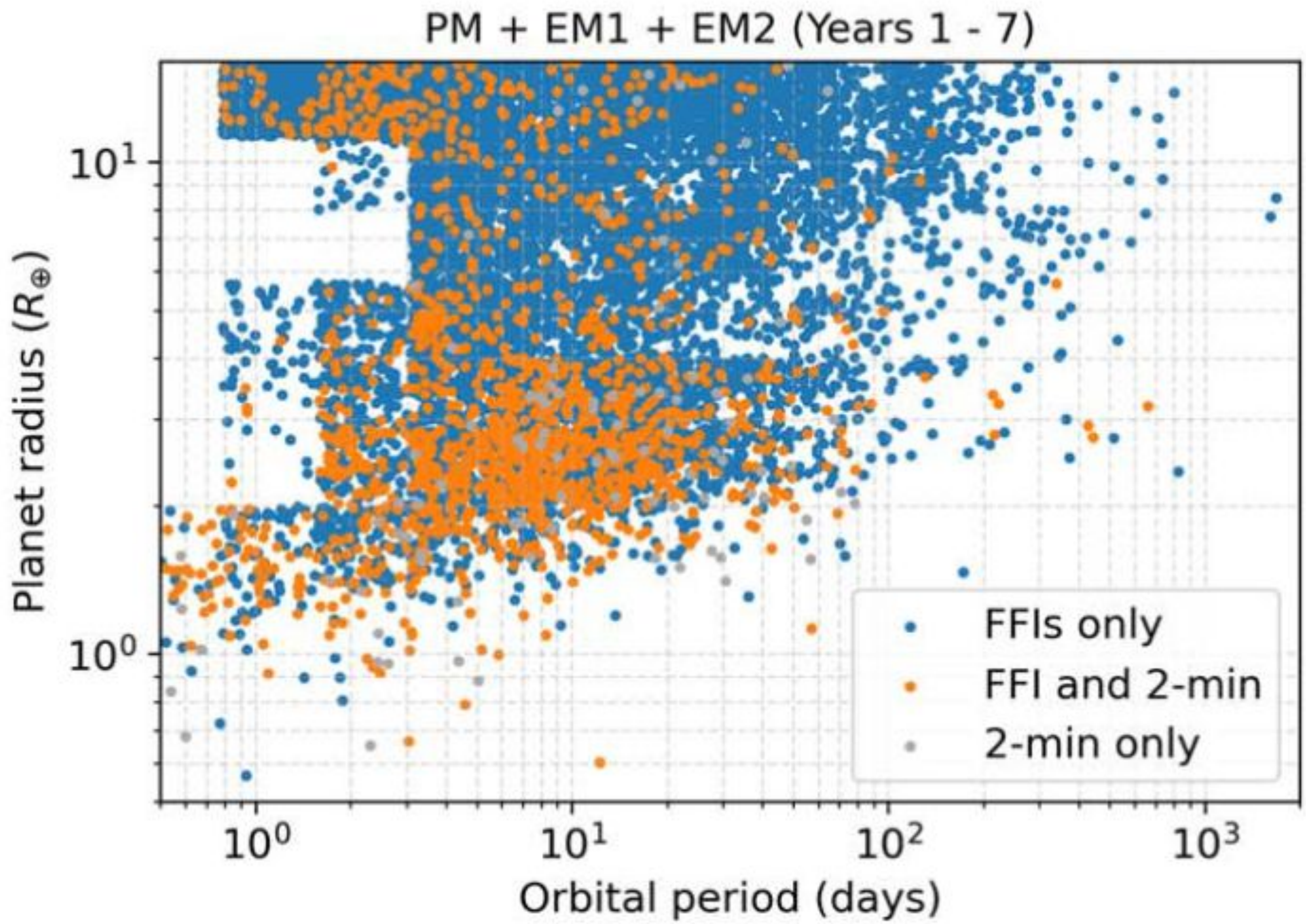
Predicted exoplanets detections: TESS

Mission	Years	FFIs + 2 minutes
PM	1-2	4719 ± 334
PM+EM1	1-4	8426 ± 525
PM+EM1+EM2	1-7	12519 ± 678

By the end of the second Extended Mission, more than 94% of planets found in the 2-minute data can also be found in the FFIs

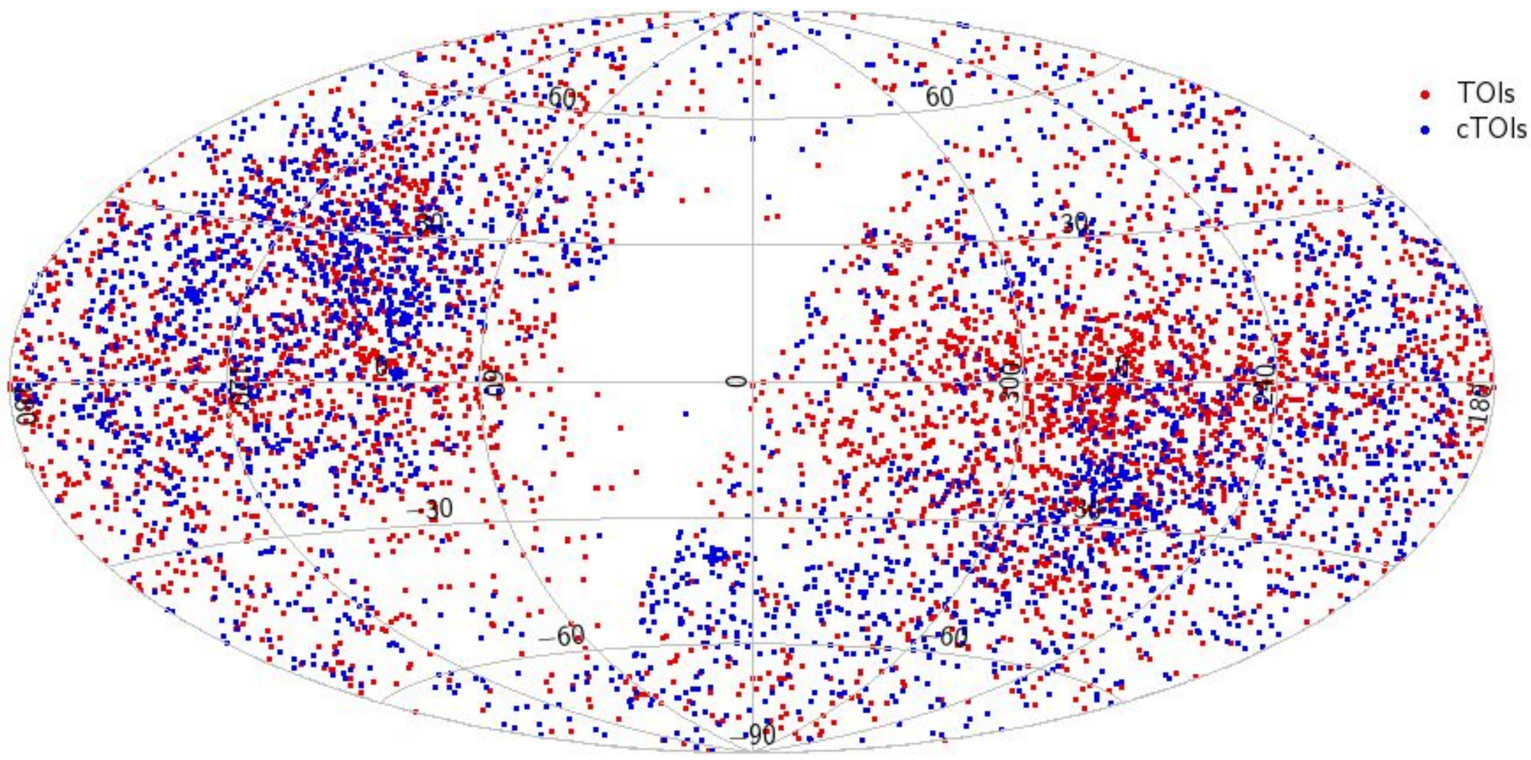
Kunimoto et al. 2022, AJ, 163, 290

Predicted exoplanets detections: TESS



Kunimoto et al. 2022, AJ, 163, 290

TESS candidate planets

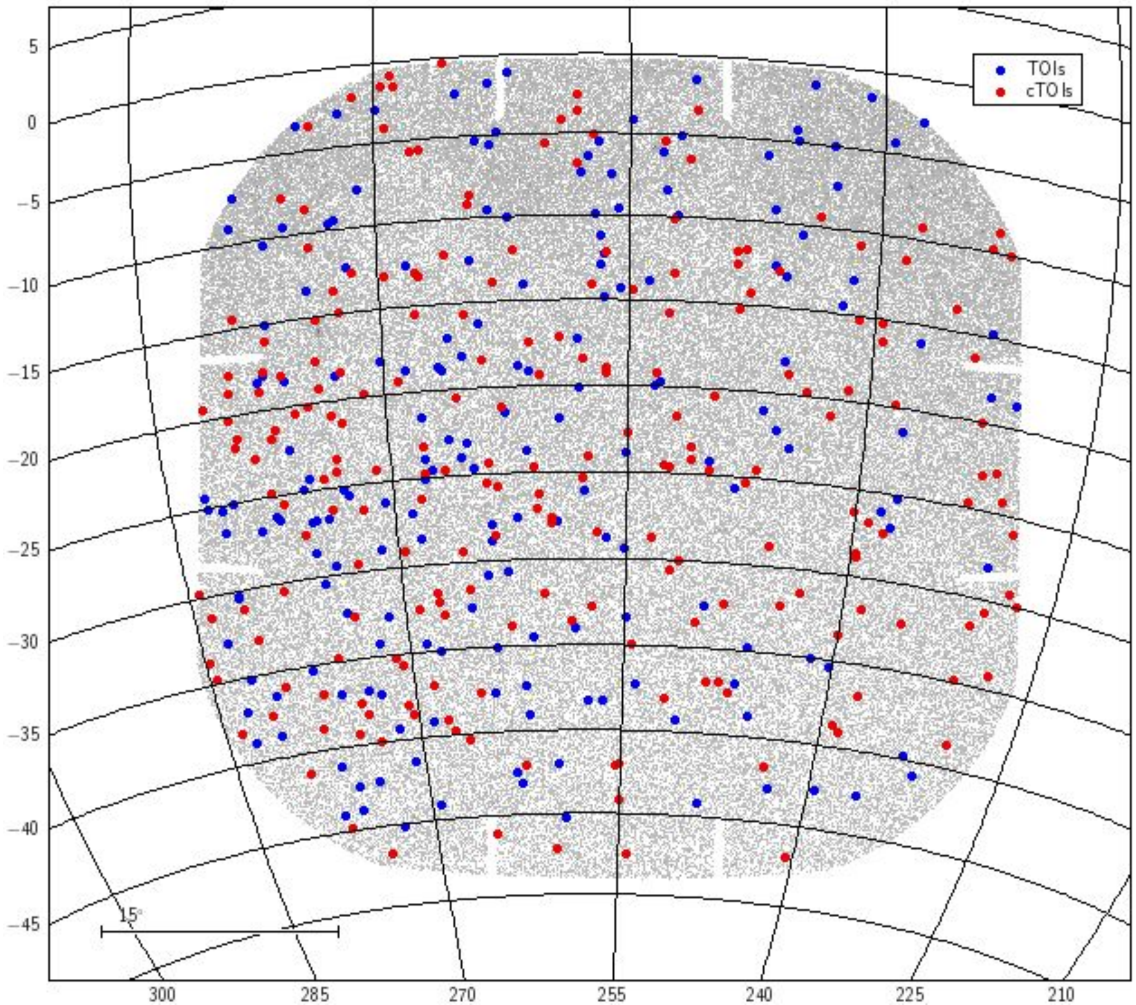


Galactic coordinates

4464 TOIs (disposition TFOPWG Planet Candidate)
3115 cTOIs
(467 in common)

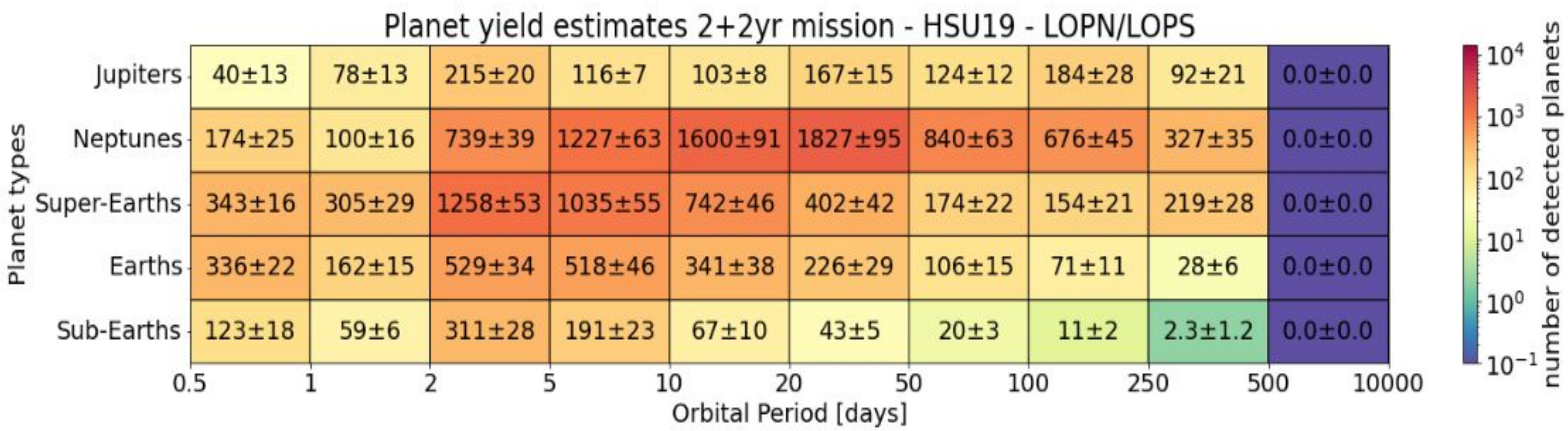
Most of the planets detectable by TESS have still to be discovered

TESS candidate planets in PLATO-LOPS2



237 TOIs (disposition TFOPWG Planet Candidate)
220 cTOIs
(47 in common)

Expected PLATO yield



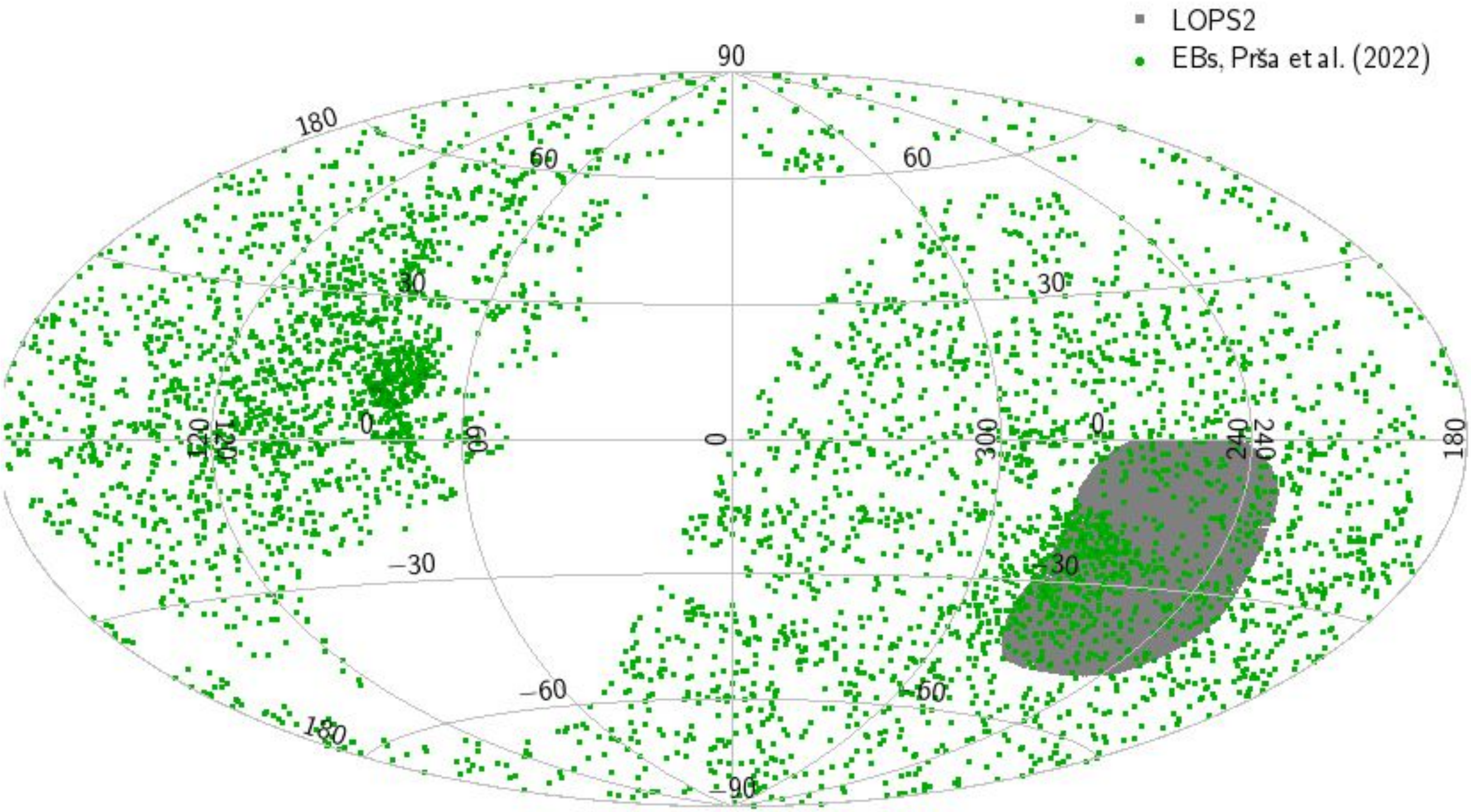
Matuszewski et al. 2023, A&A, 677, 133

TESS candidate planets in PLATO-LOPS2

Planets already discovered by TESS in the PLATO field could benefit in the best case scenario of 2.5 yr of TESS + >2 yr of PLATO observations and will be optimal targets to search for:

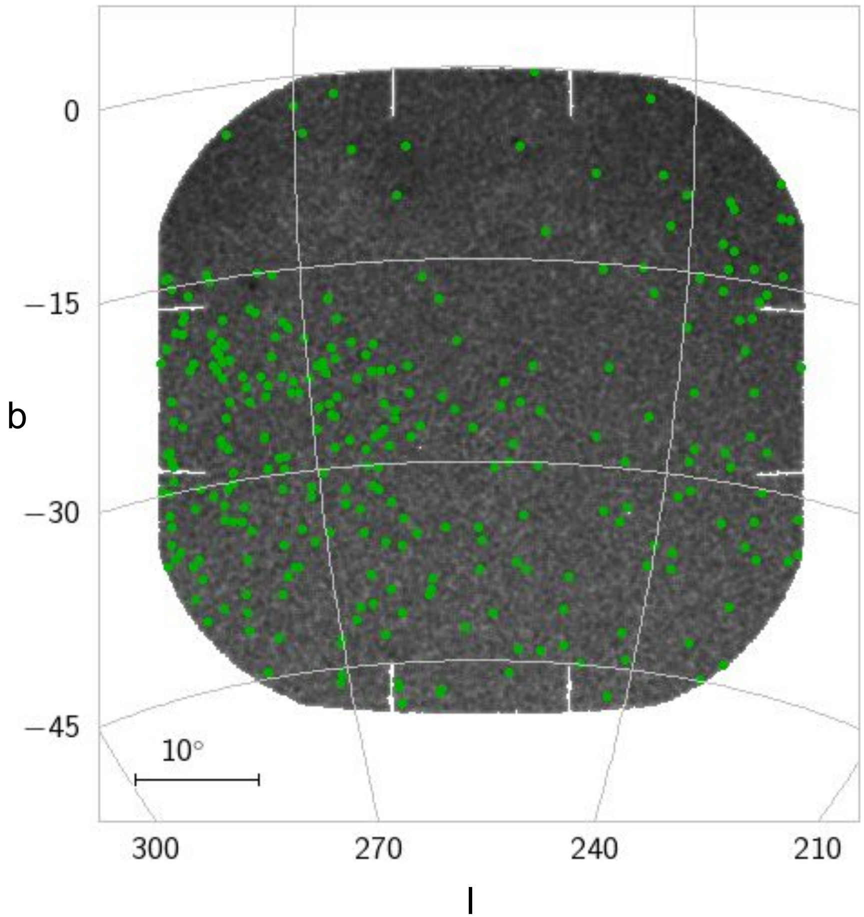
- Multi-planetary systems, thanks to PLATO higher sensitivity
- Planets showing TTVs
- Long period planets joining the full datasets (e.g. follow-up of mono-transits -> C. Magliano's talk in this meeting)

Astrophysical contamination of PLATO targets: eclipsing binaries in the field of view of PLATO detected with TESS



Prša et al. 2022, ApJS, 258, 16: 4584 Eclipsing Binaries in Sectors 1-26 from the 200000, 2 minutes targets.

Astrophysical contamination of PLATO targets: eclipsing binaries in the field of view of PLATO detected with TESS



284 EBs of Prša et al. (2022) are in the PLATO LOPS2

In LOPS2 there are 179 564 targets that can be searched for EBs with FFIs.

Searching all stars (also contaminants) in the field of view of LOPS2 with TESS FFIs should deliver many more EBs even on faint stars.

Gaia DR3 contains a collection of 2 184 477 EBs, 86 918 of which provided with orbital solution (A. Barbieri, Master Thesis, in preparation).

Prša et al. 2022, ApJS, 258, 16: 4584 Eclipsing Binaries in Sectors 1-26 from the 200 000, 2 minutes targets.

The variability of fgPIC and cPIC stars

Selection processes in common for both cPIC and fgPIC

“The catalog shall exclude known eclipsing binaries, known visual binaries, long-period variables, flaring stars, and cepheids. No star is known to be absolutely constant. ***Maximum peak-to-peak amplitude allowed is 1%.***“

Currently there is no way to establish this before the mission starts.

This criterium has been suspended in the definition of the calibration sample.

TESS observations could be useful to exclude variables or stars contaminated by close-by variables from the calibration sample and to establish a variability level of each calibration star.

Conclusions

- The broad coverage of the PLATO LOPS2 field by TESS during the primary and extended missions permits a strong synergy between the two missions

- Planets detected by TESS will be followed-up by PLATO permitting to discover more multi-planet systems, more planets showing TTVs and more long-period planets

- Variability studies of the PLATO field based on TESS data could be particularly important for the preparation of PLATO, both to identify true variable sources in the PLATO fields and sources of astrophysiscal contaminants (e.g. EBs) and to identify the best calibration stars