Circumbinary planets with PLATO

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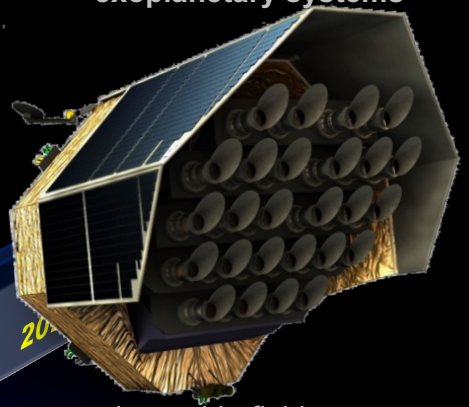
and
PLATO WP 112 510
(Circumbinary Planet Detection)

plato

PLATO builds on legacy of
(transiting) Exoplanet Science Missions

PLATO
fine characterization of exoplanetary systems



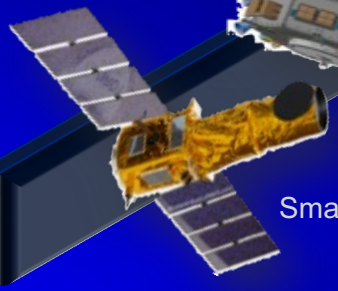
deep wide-field survey
on stars ≲ 13mag
(Prime sample ≲ 11 mag)

TESS

All-sky survey ≤12mag

Kepler
K2

CoRoT



Small-field survey ≲ 13mag

2015

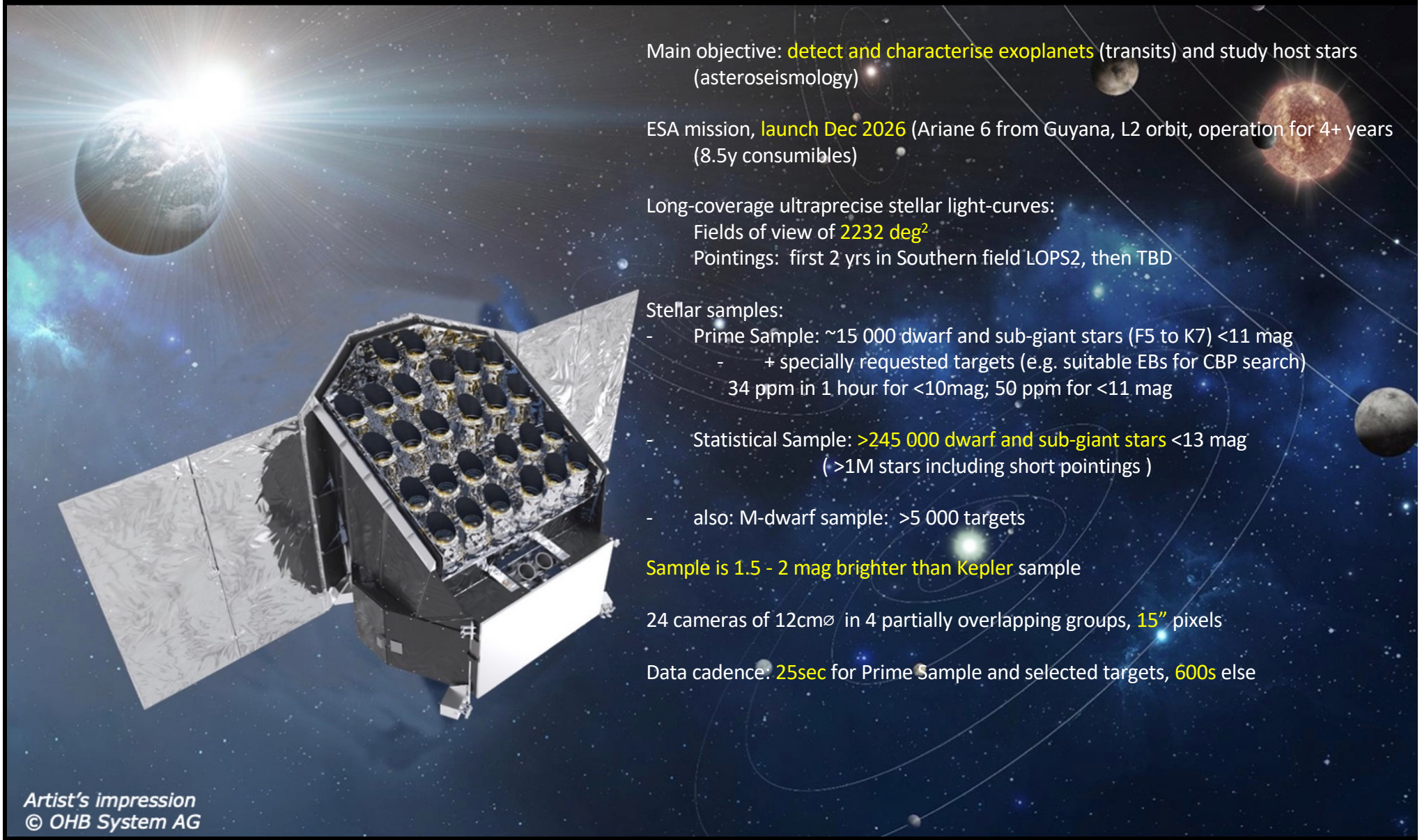
Deep survey
≲ 14mag

2020

CHEOPS

30cm telesc
for charact. of bright
transiting systems

PLATO in brief



Main objective: detect and characterise exoplanets (transits) and study host stars (asteroseismology)

ESA mission, launch Dec 2026 (Ariane 6 from Guyana, L2 orbit, operation for 4+ years (8.5y consumibles)

Long-coverage ultraprecise stellar light-curves:
Fields of view of 2232 deg^2
Pointings: first 2 yrs in Southern field LOPS2, then TBD

Stellar samples:
- Prime Sample: ~15 000 dwarf and sub-giant stars (F5 to K7) <11 mag
  - + specially requested targets (e.g. suitable EBs for CBP search)

  34 ppm in 1 hour for <10mag; 50 ppm for <11 mag

- Statistical Sample: >245 000 dwarf and sub-giant stars <13 mag
  (>1M stars including short pointings)

- also: M-dwarf sample: >5 000 targets

Sample is 1.5 - 2 mag brighter than Kepler sample

24 cameras of 12cm⌀ in 4 partially overlapping groups, 15" pixels

Data cadence: 25sec for Prime Sample and selected targets, 600s else

Payload (provided by PLATO mission consortium)

Instrument concept

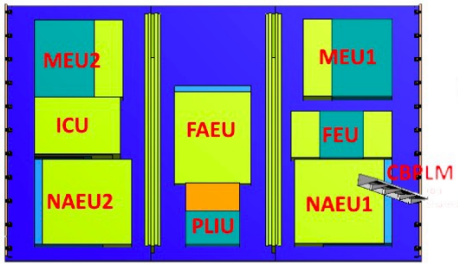
- Wide Field-of-View and large photometric dynamic range to maximise the number of observable stars
- Multi-telescope configuration with CCD-based focal planes in the visible wavelength

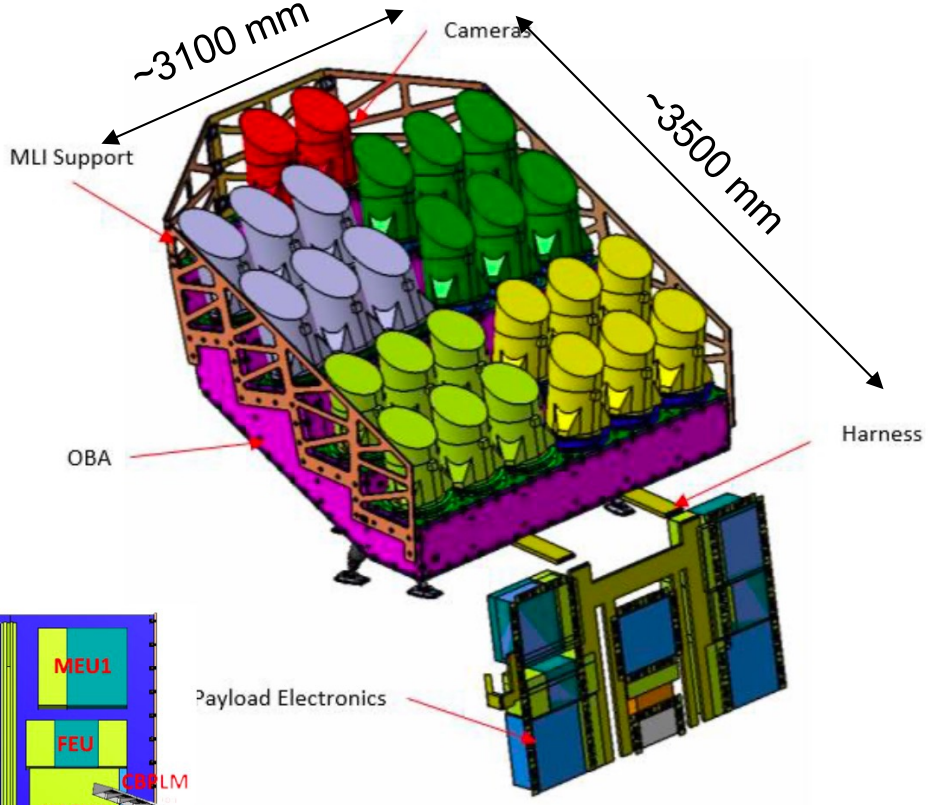
CAMERA Subsystem

- 24 almost identical “normal” cameras (N-CAM)
- 2 “fast” cameras (F-CAM) for observation of brighter stars and Fine Guidance Sensor capabilities (AOCS)
- Ancillary Electronic Units (2x N-AEU & 1x F-AEU)
- Payload Interface Unit (PLIU) for thermal control

Data Processing Subsystem

- Main Electronic Units (2x MEU) for N-CAMs
- Fast Electronic Unit (FEU) for F-CAMs
- Instrument Control Unit (ICU)



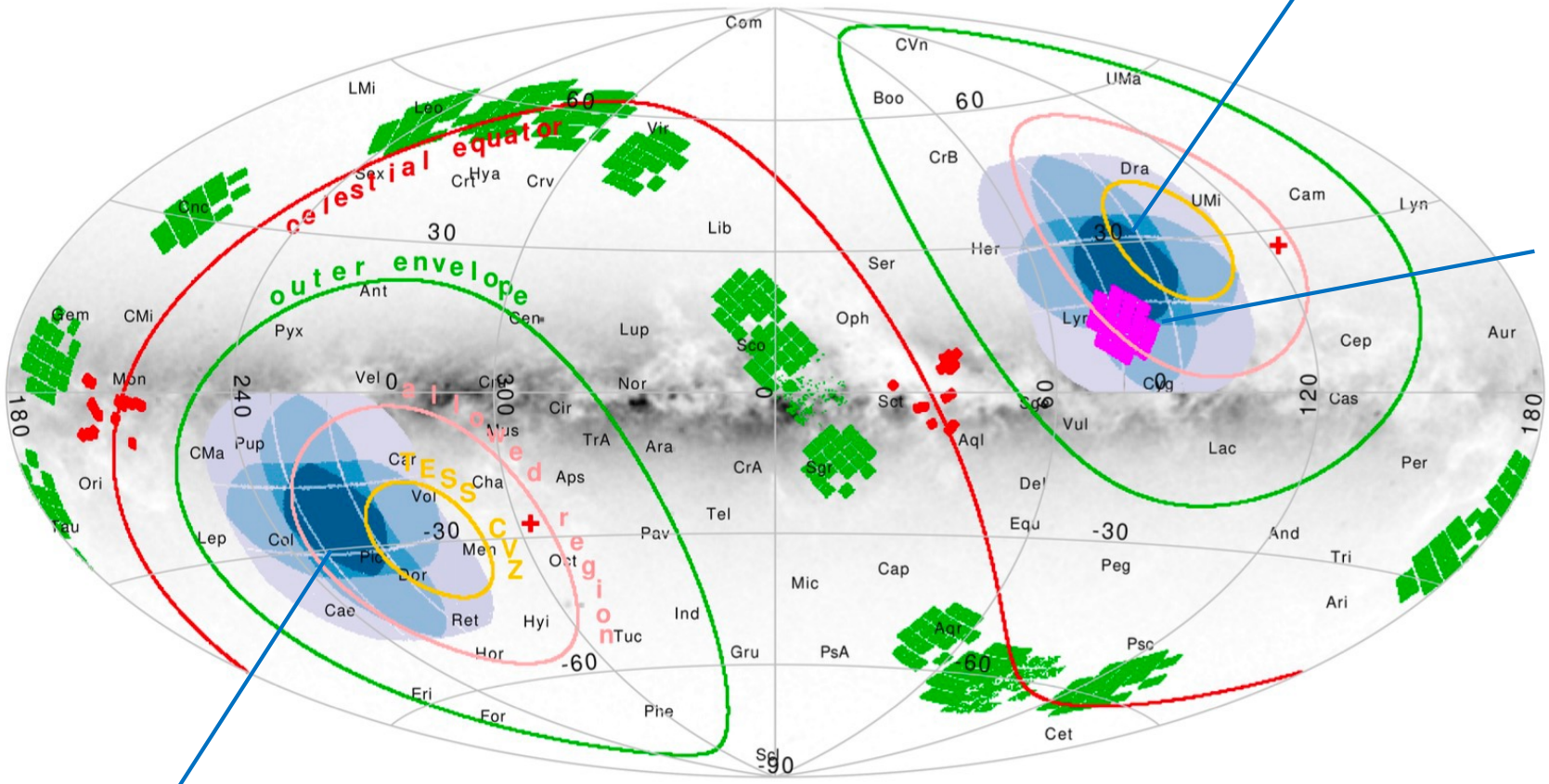


Spacecraft weight : 2280kg

PLM-PFM integration in OHB – ISO5 cleanroom

Oct 2024

The two PLATO Long Observations fields in S and N



TBD: 2nd PLATO pointing
2029 + 2030

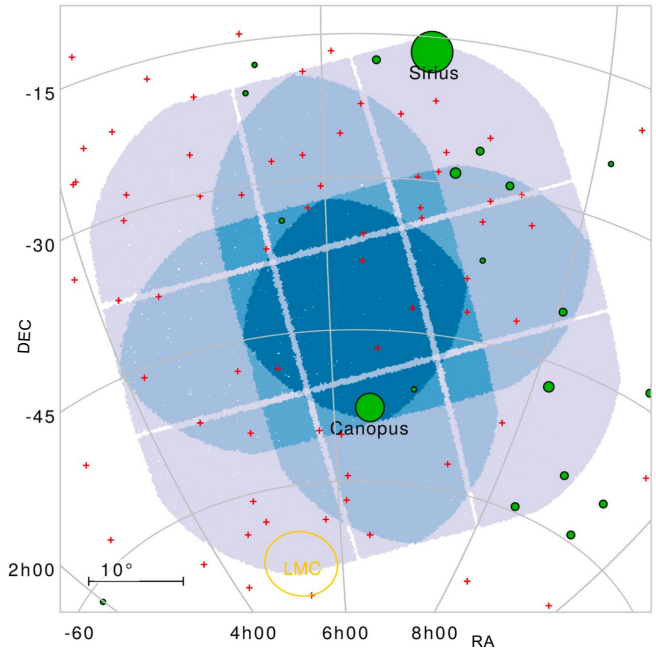
Kepler

LOPS2:
1st PLATO pointing
2027 + 2028

Details to PLATO-fields in
Nascimbeni+ 2022, 2025(subm)

PLATO observing field 'LOPS2' for the first 2 years (2027,2028)

Equatorial coords

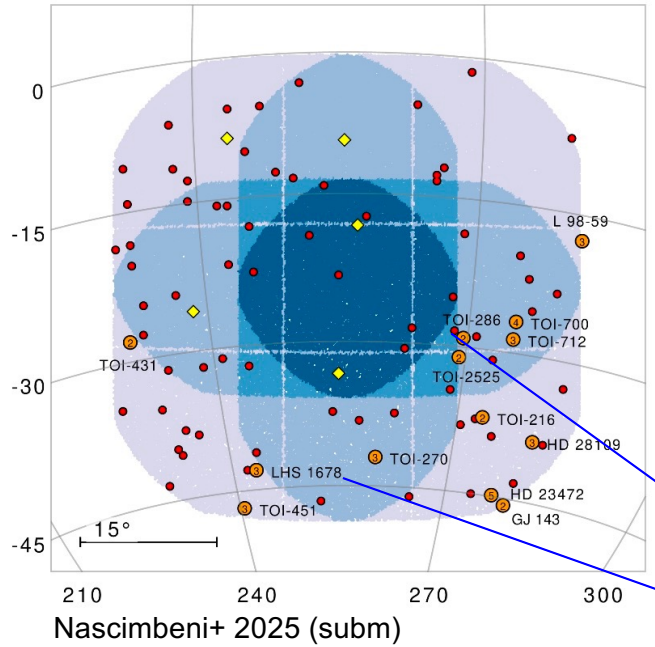


LOPS2 field:

Field center: -06:h21m -47.9°
Northern tip: -17° dec
Southern tip: -80° dec

➔ Only observers at latitudes south of 20° S
may cover the entire field at good airmasses (altitudes ≳ 30 °).

Galactic coords



Nascimbeni+ 2025 (subm)

Transiting planets in LOPS2

(red circles: known single planet, yellow: multi-planet system)

Nascimbeni+25:
108 known transiting planets in 84 systems
612 vetted (disposition PC or CP) TESS- candidates

CBPs: TOI-1338 / BEBOP-1
RR Cae (dM+WD PCEB w. 1 or 2 candidates from ETV)

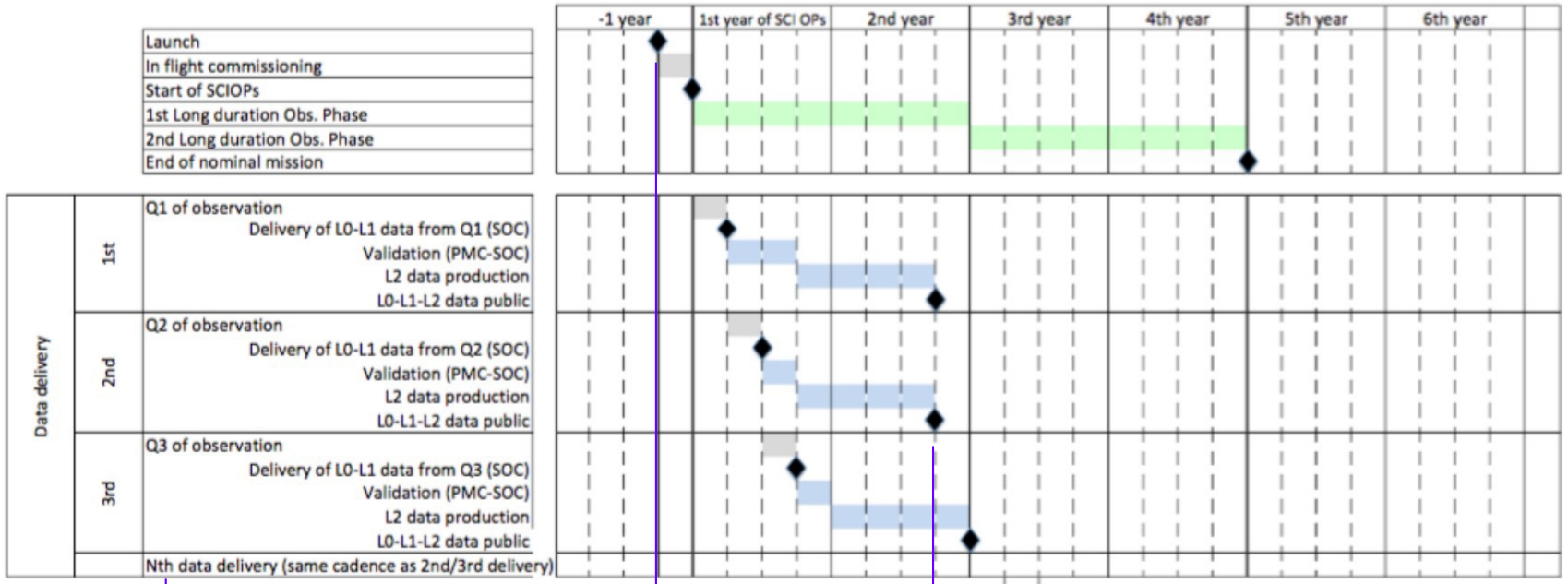
7787 EB of V<15 (including 3017 detached)

TOI-1338

RR Cae

Data delivery schedule

(excepting proprietary targets: Earth-like planet candidates, GO targets)



Ref: PLATO Science Management Plan (2017)

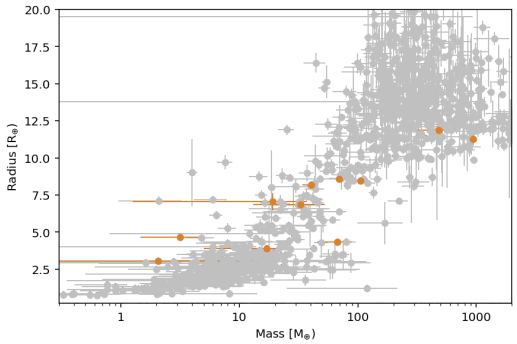
90 deg field rotation every 3 months (Quarters like Kepler, TESS)

Launch Dec 2026

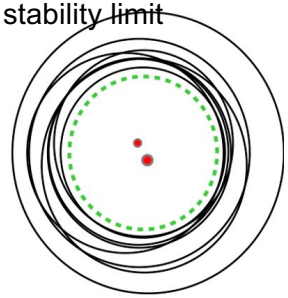
1st public release: Q4 of 2028

Features of CBPs around Main-sequence binaries (transiting ones from from Kepler, TESS)

Mass - radius plot

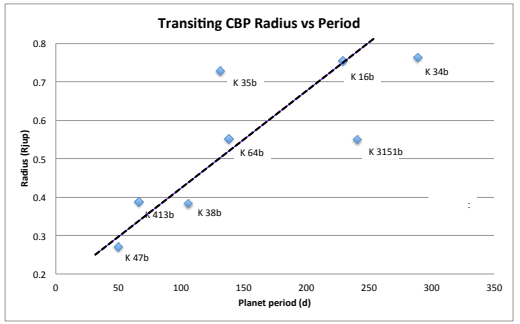


Pile-up near inner stability limit



Marsh 2018

Radius - period relation of the *inner* CBPs



Features from current >small< sample of 14 transiting CBPs:

CBPs are massive terrestrial – Saturn like, a few Jupiter-like ones

Periods of (inner) planets close to stability limit (Jupiter-like ones are further out, Kostov+21, Anna Penzlin's talk).

Central binaries have periods > 7d

Mutual inclinations $\Delta i \lesssim 3.5^{\circ}$ (J. Orosz: likely outer CBP on HD 29037: 15.7deg)

Are these properties universal for CBPs around MS binaries, or outcome from very limited sample?

PLATO CBP detection: expectations for CBP detections

Rauer+ 2014 (PLATO description paper):
PLATO will increase number of transiting CBPs several times over Kepler

PLATO Long Duration observations, 2-3 yrs: ~ 267k stars 80ppm/√h
To first order, multiply Kepler detection rates by 1.66 -> 15-20 'Kepler-like' CBP
(about 3300 known EBs in LOPS2)

TBD: PLATO Step & Stare, 2-5 months: 10^6 stars
Reduced detection capability for longer-periodic (p>0.2yr) CBPs
Assuming 50% CBP detectability (CBPs similar characteristics to Keplers'): -> 20-40 CBP
(Discovery of TESS CBPs is motivating)

CBPs from PLATO: Science Topics

Topics we may address with extended CBP sample from PLATO:

Do the following CBPs exist? :
- small (Earth-like) CBPs
- CBPs with large mutual (e.g. polar) inclinations
- Co-orbiting planets in 1:1 orbital periods (horseshoe orbits)

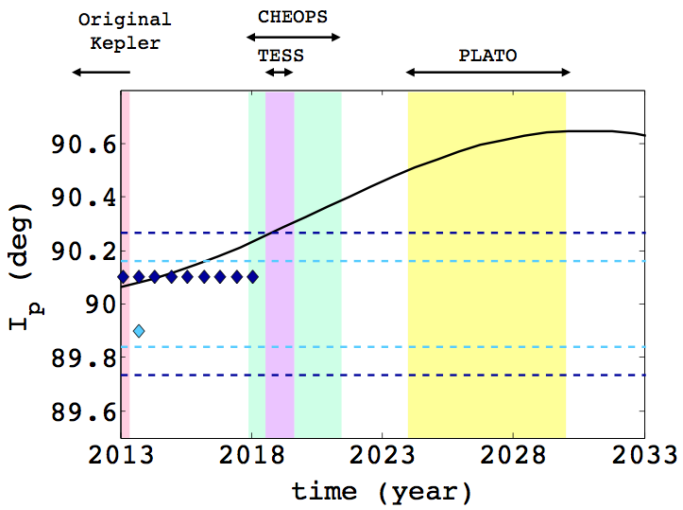
Well characterizable systems:
- transiting CBPs on bright binaries permitting RV FU (planet-masses, Rossiter effect)
- 'puffy' CBPs that permit mass verification from ETV and RVs

Statistics issues:
- better mass/ radius / period /inclination distributions of CBPs, … in dependence of host-binary properties
- are there dominant multi-planet architectures in CBP systems?
- 'severity' of the 7-d limit of binary periods

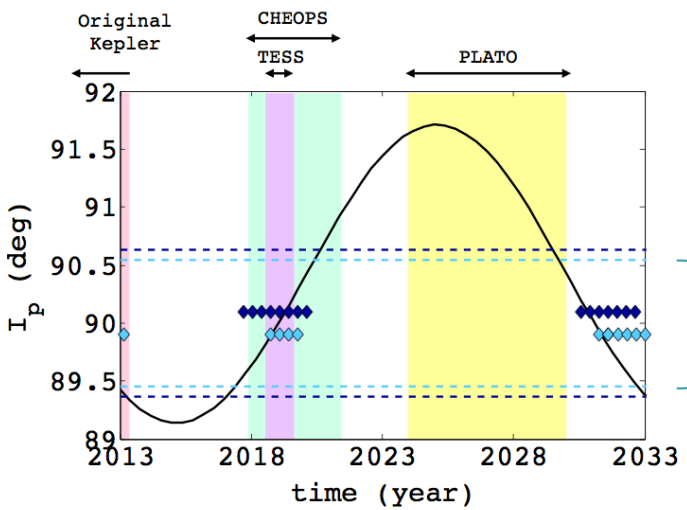
PLATO Northern field LOPN1 (likely observed later in mission)

Revisiting Kepler : Future transit occurences of known CBPs

(a) Kepler-16

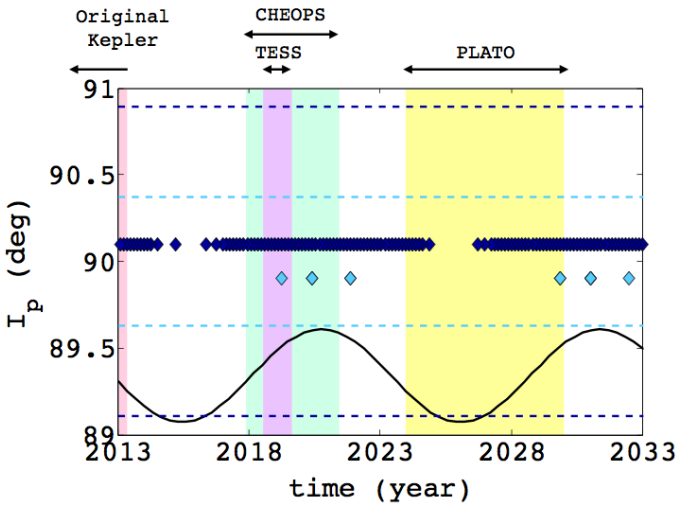


(c) Kepler-35

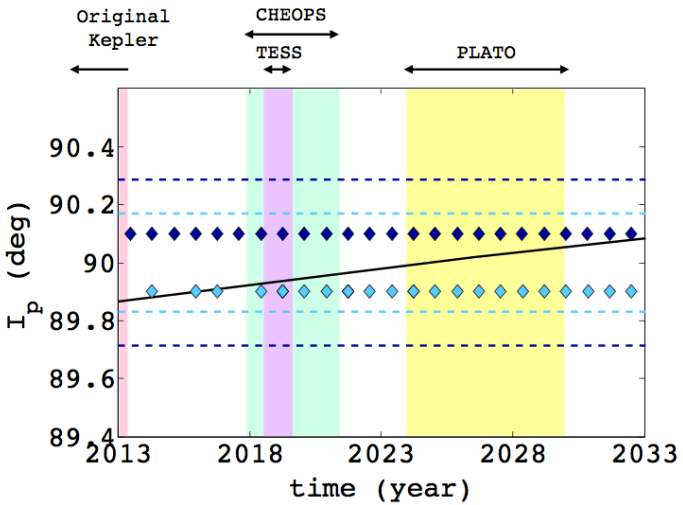


Limits of I_p for transits across primary /secondary star

(e) Kepler-47b



(f) Kepler-47c



Fraction of time when I_p is within limits: few % to 100 %. Typical: 30-50%

-> 2-3 times more CBPs could be at *known* Kepler EBs, that were not discovered due to precession.

Martin & Triaud (2016)

CBP science within PLATO mission

To date:

PLATO WP 112510
Photometric detection of circumbinary planets
Lead: Hans-Jörg Deeg

A formal group charged with preparing the CBP detection in PLATO:
Selection of targets, detection algorithms, feedback to Science Team
-> Propose targets for PLATO prime sample (need to be done)
-> Decided: CBP detection algorithm will not be part of official transit-detection pipeline
(it will find however EBs and mono-transit TCEs)
hence: detection of CBPs will be community effort:
-> Preparation of community challenge to test CBP detection algorithms.

Upcoming:
Circumbinary Planet Working group:
A 'transversal' WG treating all questions related to CBPs and PLATO
(analysis, interpretation, underlying science theory)

Work Packages versus Working Groups

- **Work Packages** (WPs) have been defined throughout the project covering tasks with a delivery for the mission development (with exception of WP115/116).

- **Working Groups** address specific tasks involving severals WPs.

  They have a topical focus, complementing (not duplicating) existing WPs.

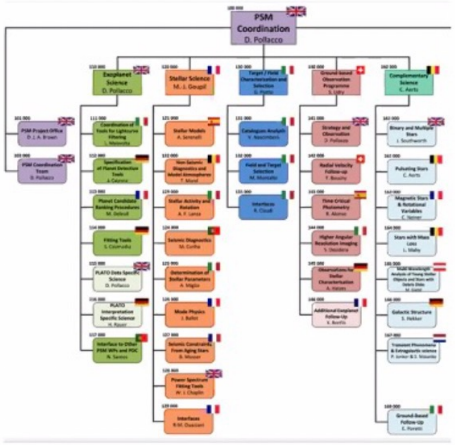
  They can exist for a limited time, until the task is fulfilled.

- Working group members have to be members of the PMC and agree to our NDA and publication policy.

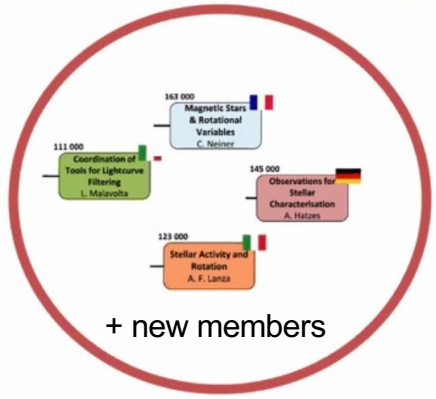
PLATO Mission Consortium

To date

Work Packages



Working Groups



Community challenge for detection of CBPs in simulated PLATO data

Hans Deeg and Peter Klagyivik (DLR, Berlin)

Let interested researchers try their own/their favorite CBP detection algorithm

Sample will contain simulated light-curves with/without CBPs, with PLATO-like noise characteristics.

CBPs will go (to reasonable extend) beyond currently known CBP parameter-space.

"reasonable extend": Extended parameter-spaces w/o 'crazy stuff'
No CBPs around non-eclipsing binaries

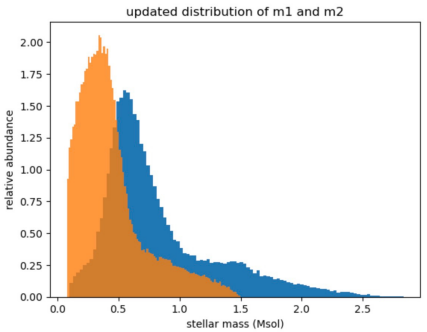
Goal: - Find strengths , application cases of CBP algorithm(s) for PLATO EB sample;
- Preparation of community to deal with PLATO data once they arrive

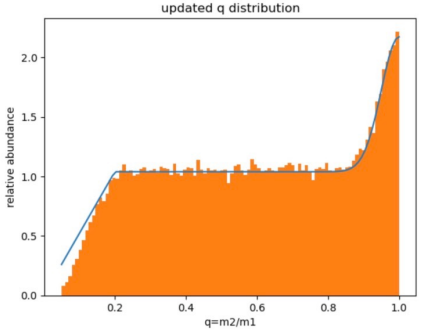
Simulations are in preparation for release in Q2 2025,
with participation open to anyone interested

Community challenge for detection of CBPs in simulated PLATO data

Current status:

- O(1000) light-curves covering 2yrs of PLATO data will be simulated
- Stellar parameters (binary components) are based on real CBP-host population; are ready for simulation of noisy eclipse-less curves by PLATOSIM (official data simulator)



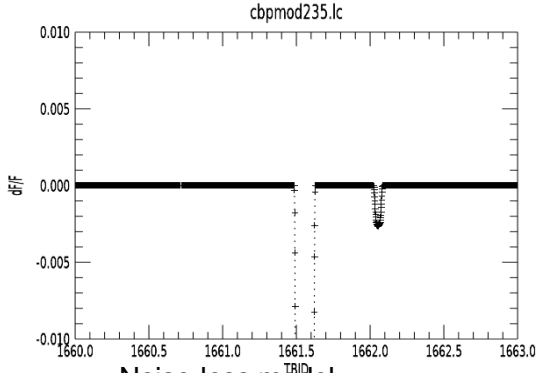


Binary periods: 5 – 50 d
(going slightly below the P ≳ 7d distrib. of known CBP hosts)

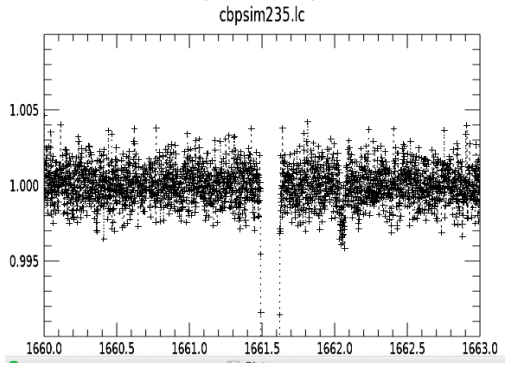
Lots of parameters to be assumed
(D. Martin: 18 pars for 1-planet CBP system)

- Definition of detailed planet parameters still TBD (Pmax ~ 350d)
- Binary and planet eclipses will be injected from Keplerian orbits (no orbital dynamics simulation, potentially with osculating Keplerian orbits)

Simulated EB eclipse and CBP transit (S/N ~10)



Noise-less model



Model with noise (S/N of transit 10)
Participants will only receive this!

- Protocols for book-keeping, reporting by participants and analysis (performance metrics) are TBDefined

IF you are interested:

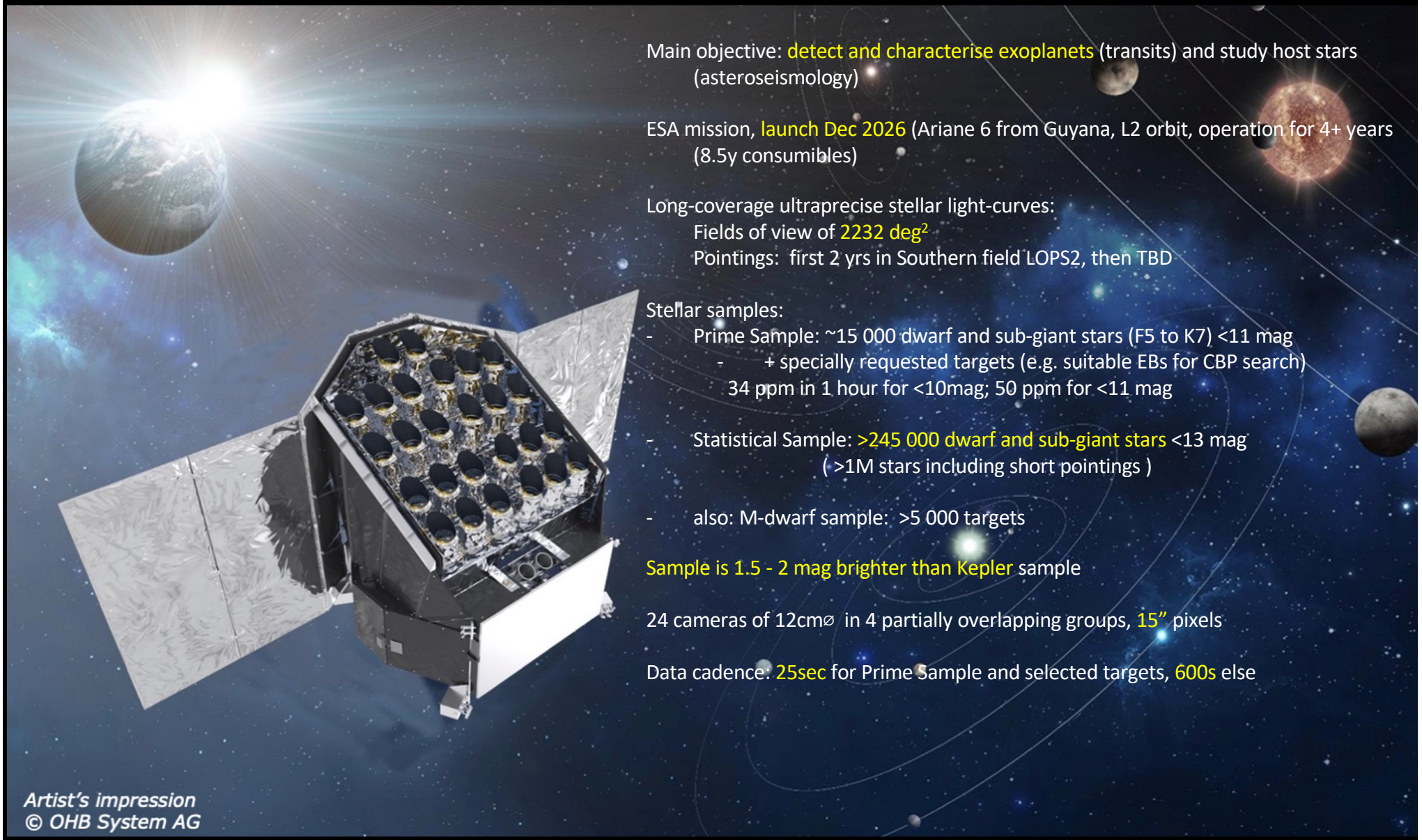
- in the PLATO CBP Working group
  and/or
- the CBP detection challenge:

Send a note to Hans Deeg
at
hdeeg@iac.es

PLATO model at Max Planck Institute for Solar System Research, Göttingen (Germany)
Photo: H. Deeg

Let us be well prepared and
hope that it makes it into
the sky !

PLATO in brief



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