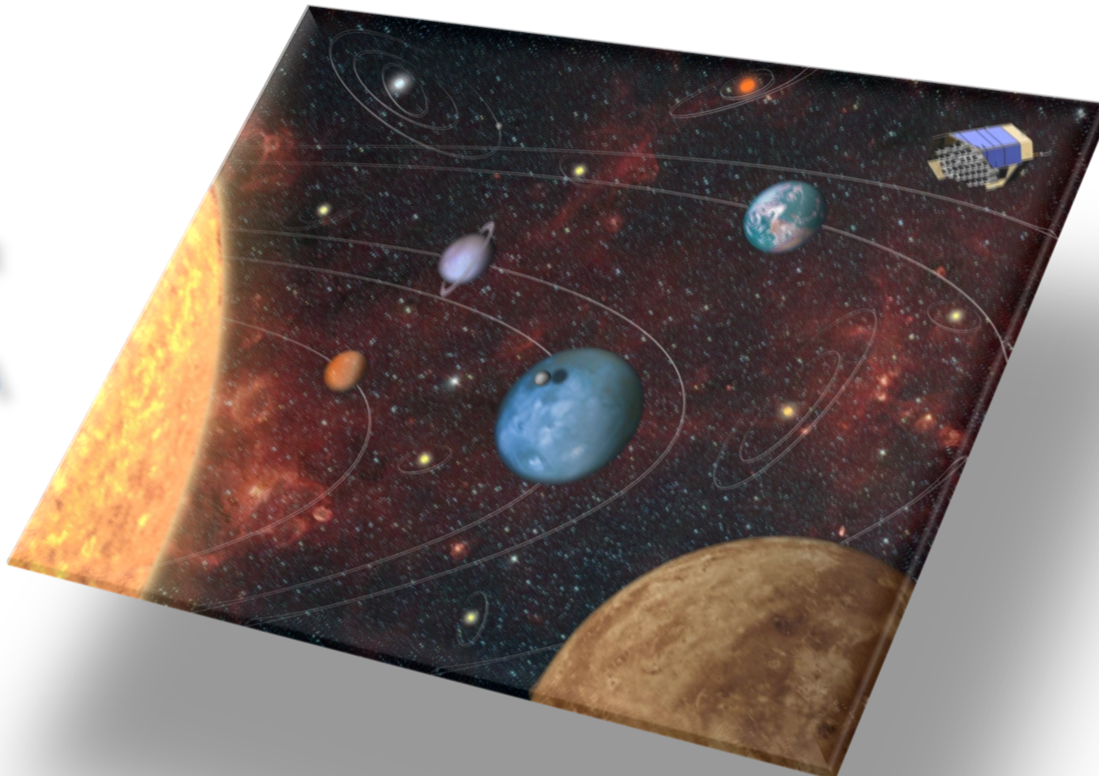
CHEOPS & PLATO 2.0



Partecipazione Italiana alle missioni esoplanetarie dell'ESA

SAIt 2014

INAF - Milano

Isabella Pagano, INAF – OACT
on behalf the CHEOPS and PLATO 2.0 Teams

CHEOPS

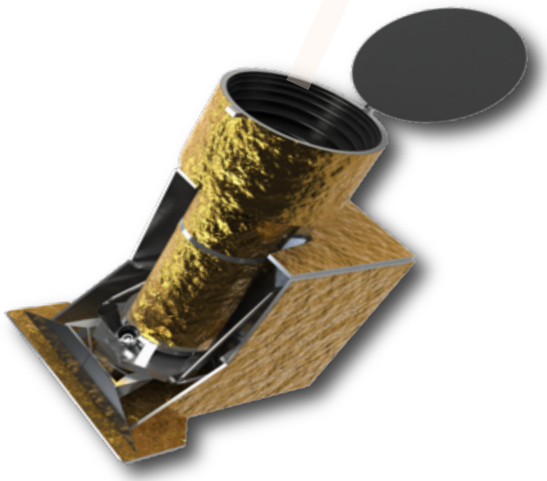
CHaracterizing ExOPlanet Satellite

- S class mission (S1)
- Budget envelope < 150 M€ (≤ 50 M€ from ESA)
- Launch: end of 2017 => fast development (TRL 5 when selected)
- Operation: 3.5 (+1.5) yrs - shared launch
- Follow up mission: measure radius of known planets

Key Science Goals:

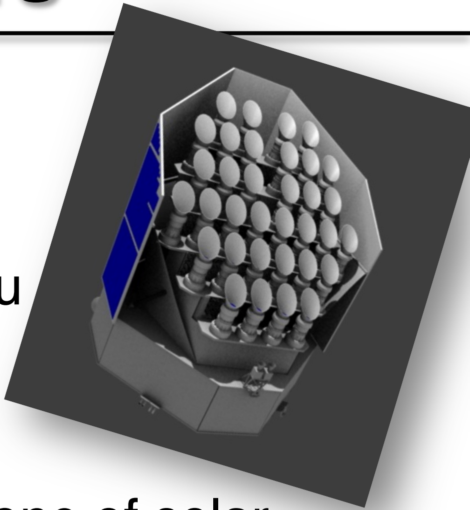
- ✓ Mass-radius relation for super-Earths & Neptunes
- ✓ Identification of planets with atmospheres
- ✓ Constraints on planet migration paths
- ✓ Cloud coverage in hot-Jupiter atmospheres
- ✓ Targets for future spectroscopic facilities

20% open time (selection through ESA)



esa

PLATO 2.0: PLAnetary Transits & Oscillations of Stars



- M class mission (M3)
- Budget envelope ~ 650 M€ (≤ 500 M€ from ESA)
- Launch: 2024 – Launcher Soyuz Fregat from Kourou
- Operation: 6.25 (+2) yrs

Key Science Goals:

✓ Detection of terrestrial exoplanets in the habitable zone of solar-type stars and characterization of their bulk properties needed to determine their habitability.

✓ Understanding of the formation, the architecture, and the evolution (ages) of planetary systems by means of a full inventory of the physical properties of thousands of rocky, icy, and gaseous giant planets.

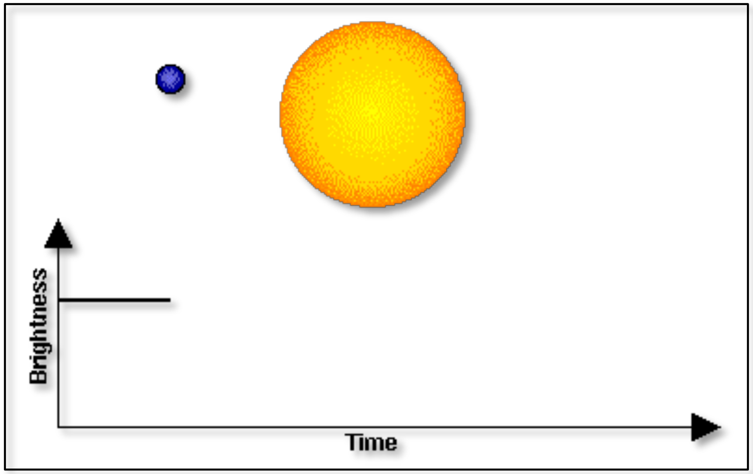
The Cosmic Vision Themes

- **How do planets and planetary systems form and evolve?**
- **Is our Solar System special? Are there other systems like ours?**
- **What makes planets habitable?**
- **Is the Earth unique or can life also developed elsewhere?**

CHEOPS & PLATO 2.0 addresses the ESA Cosmic Vision science questions and follows the recommendations of ESA's Exoplanet Roadmap Advisory Team (EPRAT).

Methods for detection and bulk characterization of planets

Transit Method

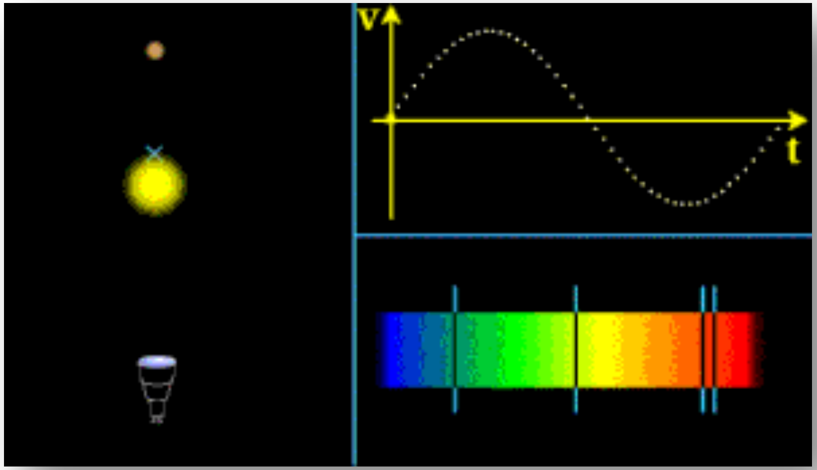


→ Orbit parameters

→ Orbital inclination, ***i***

→ Planet radius

Radial velocity method



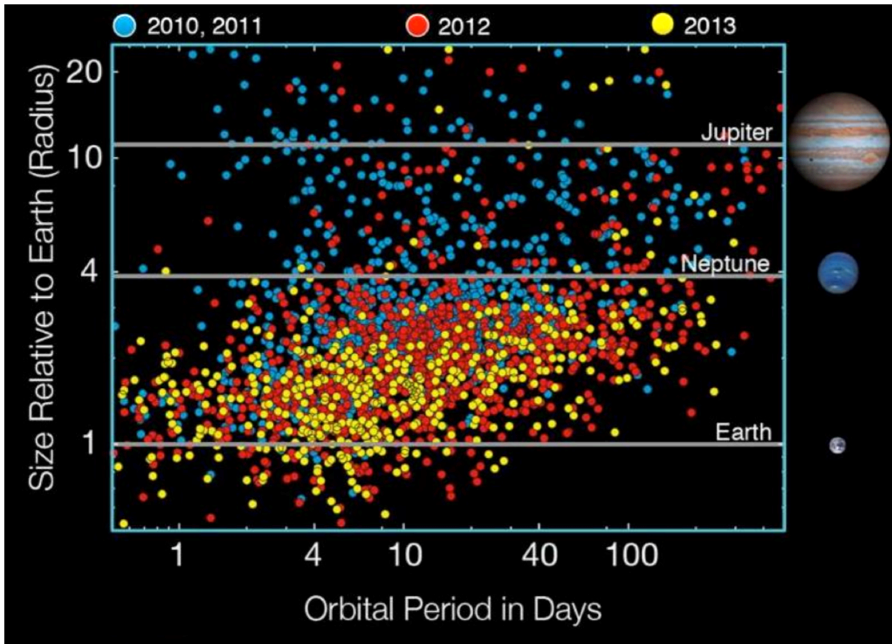
→ Orbital parameters

→ Minimum planet mass, ***m* sin *i***

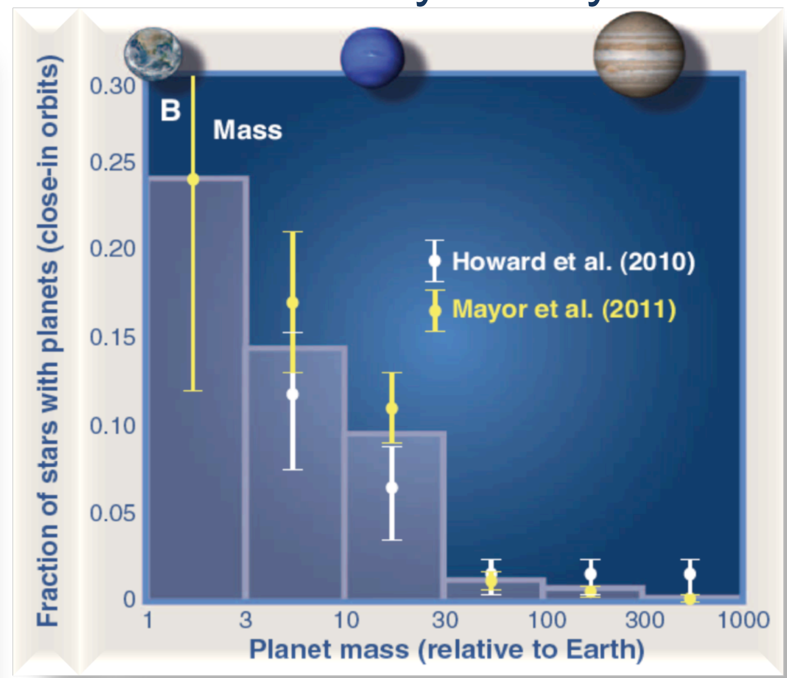
True planet mass and mean density

Planet detection today

Kepler planet candidate statistics



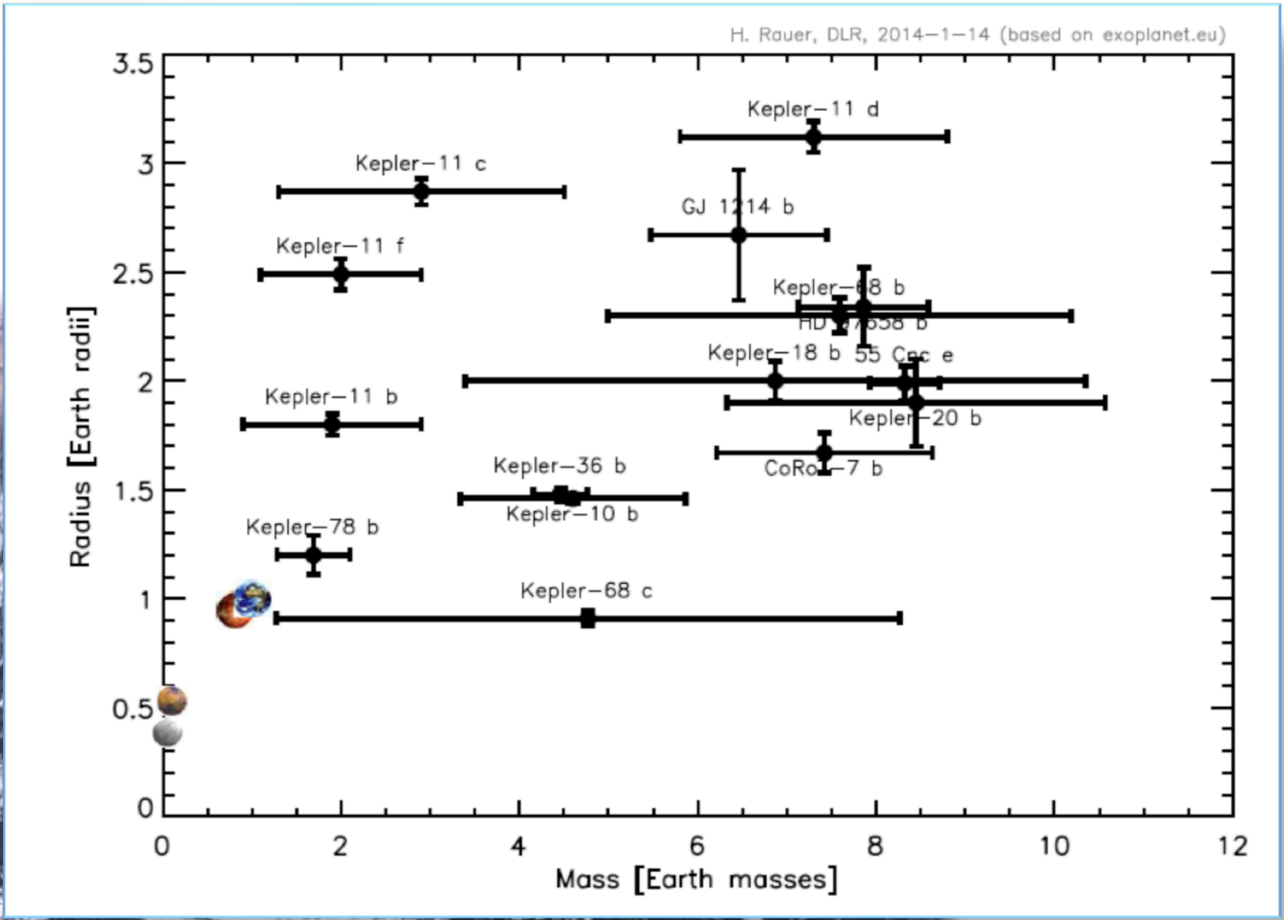
Radial velocity surveys



- Current status: ~3000 planet candidates, ~1000 confirmed exoplanets and ~800 validated
- *Kepler* mission and radial-velocity surveys → small and low-mass planets are numerous

However, only few detections of small planets in the habitable zone, and no characterization.

Diversity of „super-Earths"

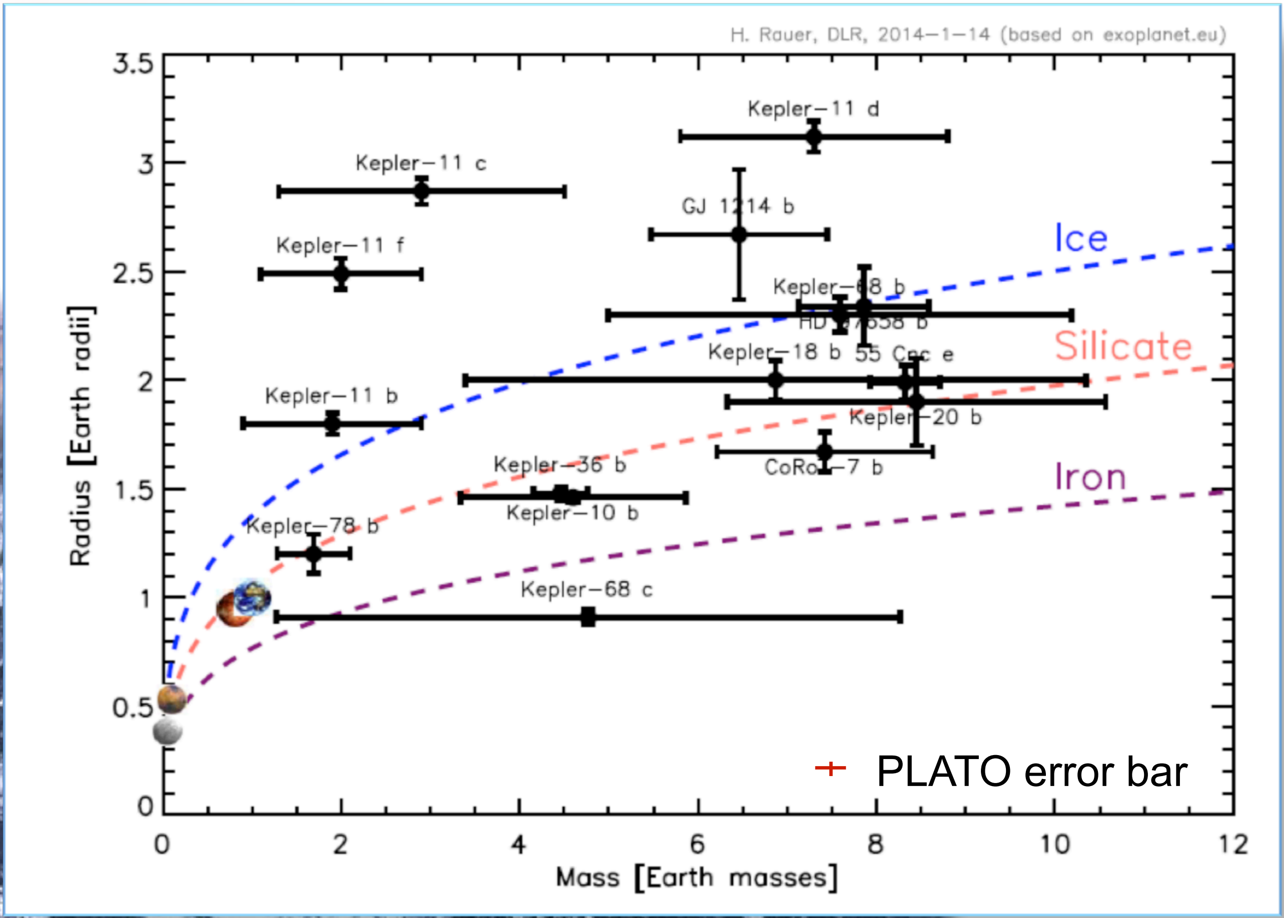


Wagner et al., 2012

2–10 M_E

- Masses vary by a factor of ~4 (with large errors)
- Radii vary by a factor of ~3

Diversity of „super-Earths"



Wagner et al., 2012

2–10 M_E

- Masses vary by a factor of ~4 (with large errors)
- Radii vary by a factor of ~3

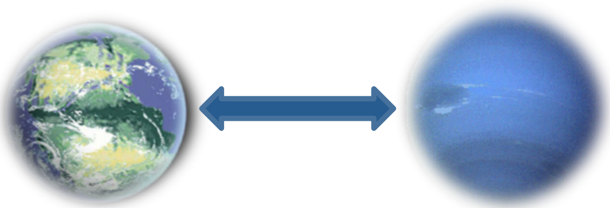
→ **We need both**: Accurate masses & radii to separate terrestrial from mini-gas planets.

„Super-Earths“: diversity and implications on habitability

Solar System planets are NOT the general rule:

small ≠> rocky, large ≠> gaseous

- Small exoplanets are very diverse:
  from Earth-like to mini-gas planets

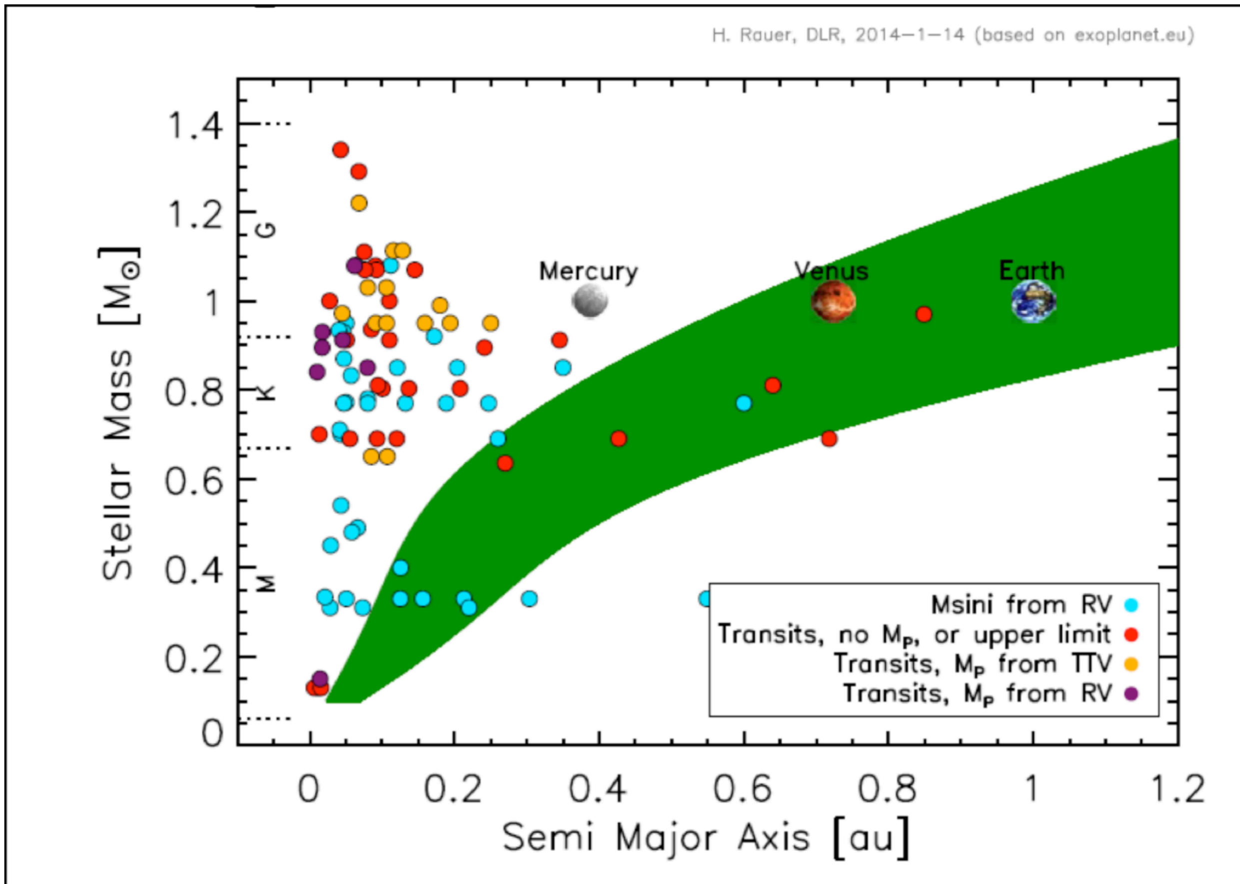


  - Mini-gas planets are likely not habitable
  - Silicate-iron planets are prime targets for atmosphere spectroscopy

Both **CHEOPS** and **PLATO 2.0**:
→ will identify potentially habitable planets (M → FGK dwarfs)
→ and will characterize targets for atmosphere spectroscopy

Status: Characterized „super-Earths" in their habitable zone

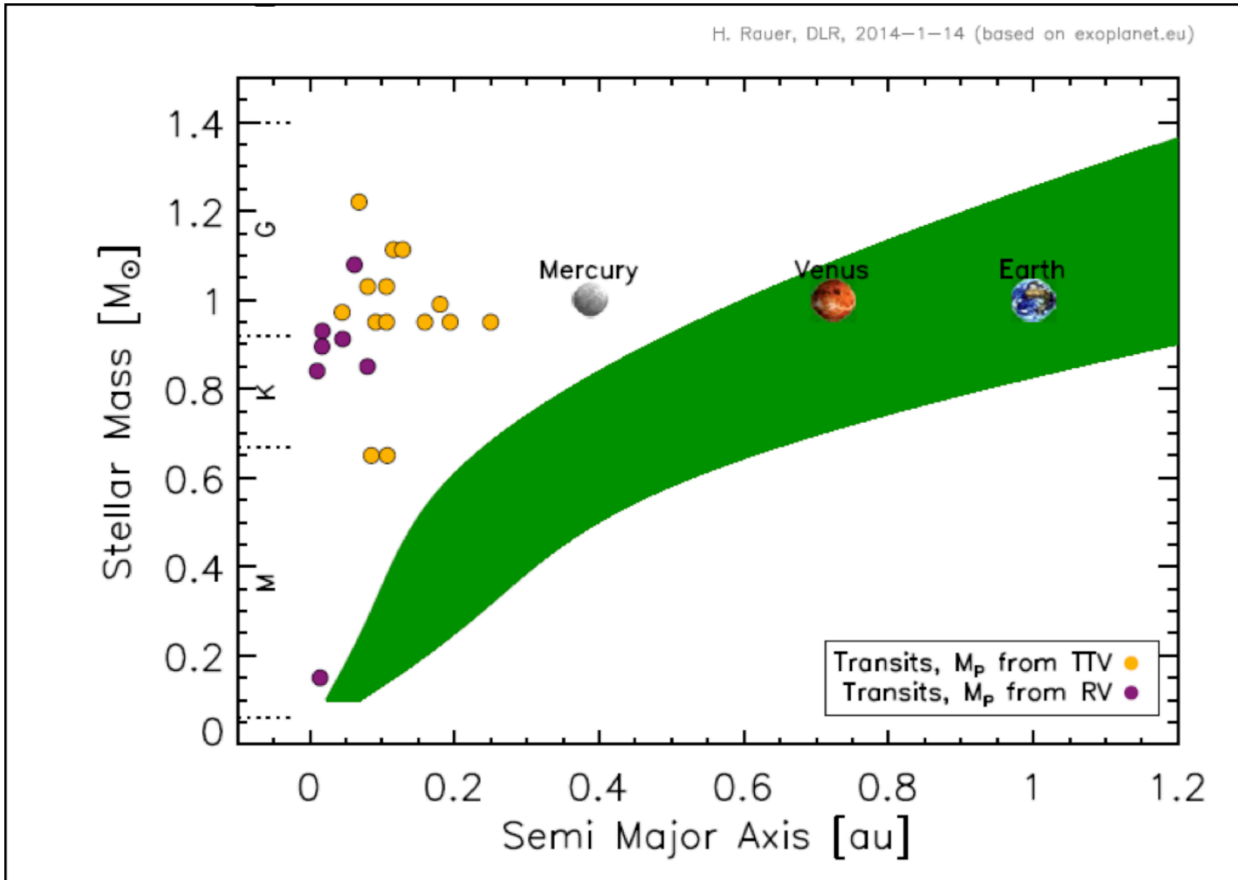
Detected super-Earths



- Goal: Detect and characterize super-Earths in habitable zones
- Status: very few small/light planets in habitable zones detected

Status: Characterized „super-Earths" in their habitable zone

„Super-Earths" with characterized radius and mass

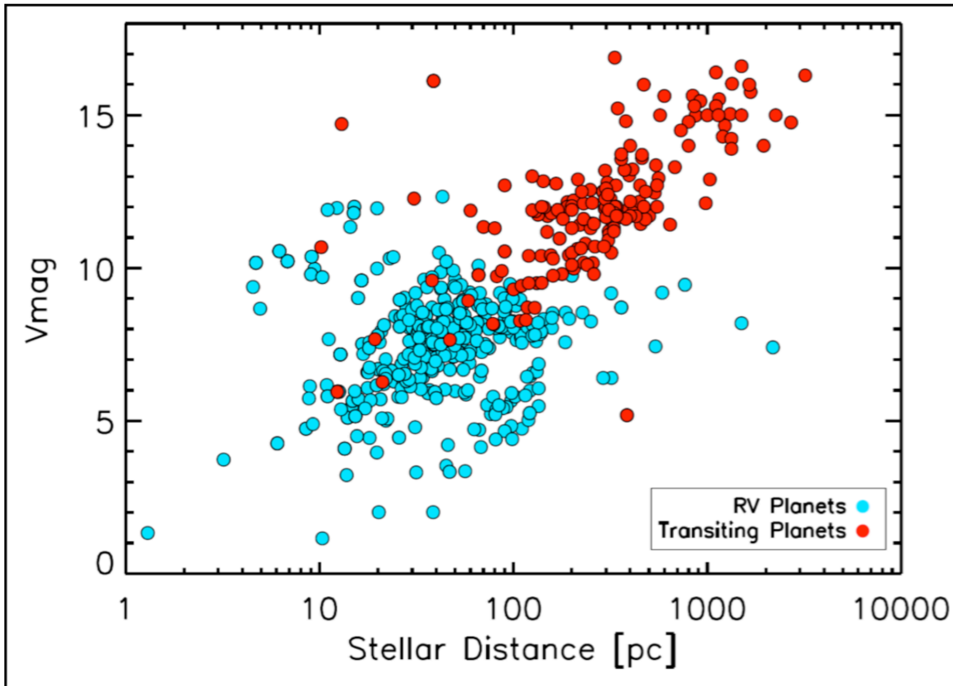


- Goal: Detect and characterize super-Earths in habitable zones
- Status: very few small/light planets in habitable zones detected

→ No characterized „super-Earths" in its habitable zone

The need for bright stars

Known planets from radial velocity and transit surveys



Why have so few targets been characterized?

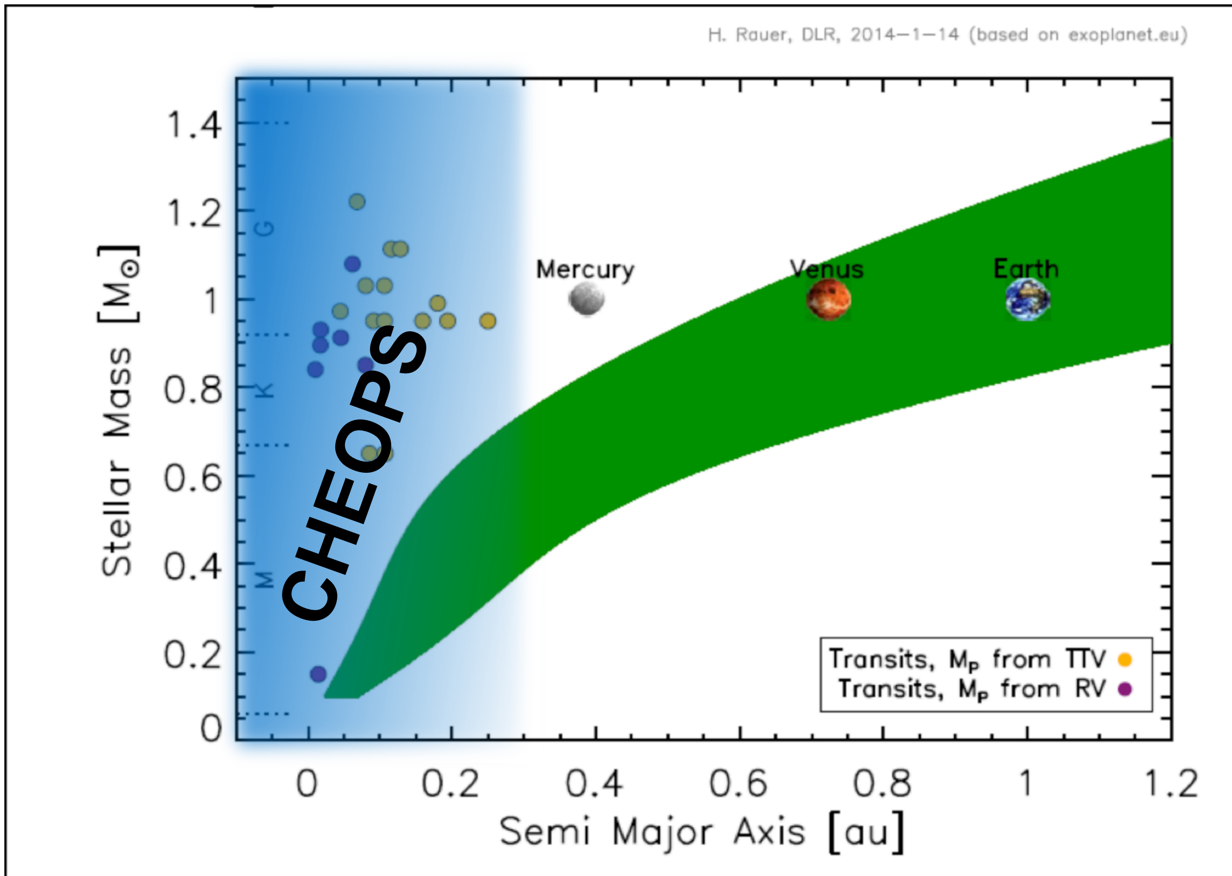
→ Transit surveys targeted faint and distant stars to maximize detection performance.

→ Radial velocity surveys need bright stars (≤11 mag) to keep telescope resources limited.

Lessons learned:
→ Future transit missions must target bright stars

Prospects: Characterized „super-Earths" in their habitable zone

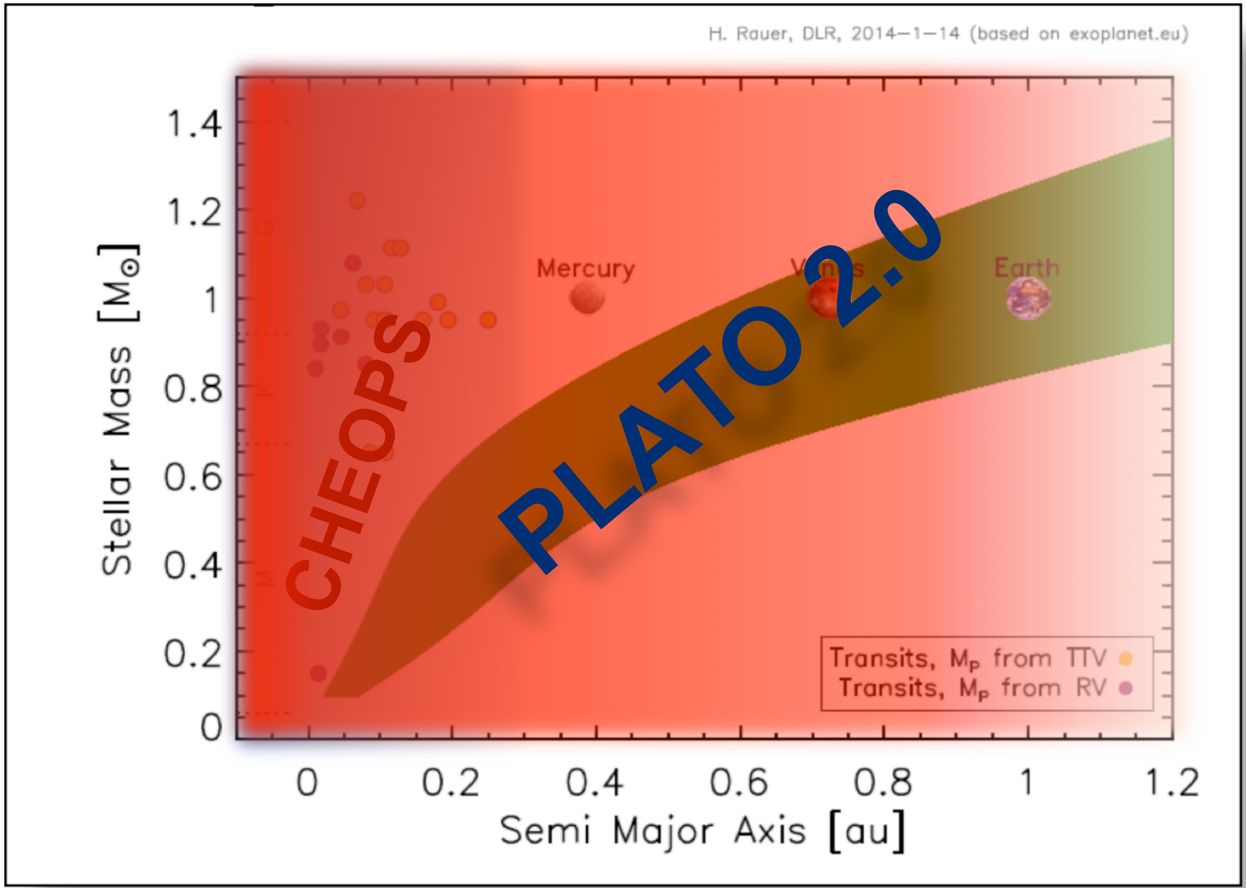
„Super-Earths" with characterized radius and mass



- No rocky planets in the habitable zone known with certainty
- CHEOPS will cover orbital periods up to ~50 days
- PLATO 2.0 will characterize planets outside the Mercury's orbit!

Prospects: Characterized „super-Earths" in their habitable zone

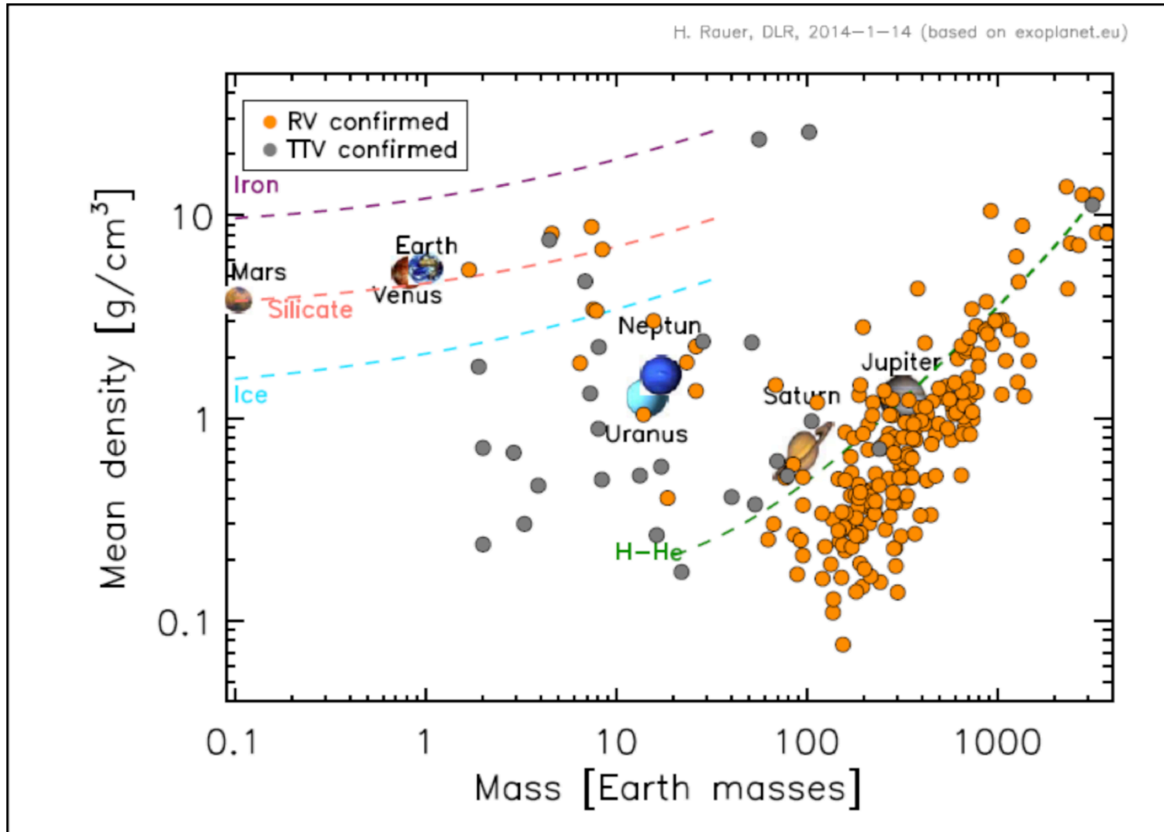
„Super-Earths" with characterized radius and mass



PLATO 2.0 will detect and bulk characterize small planets up to the habitable zone of solar-like stars.

Planet diversity and planet formation

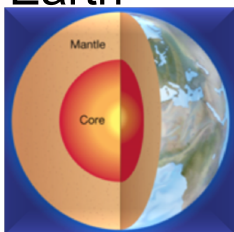
- Mean density varies by two orders of magnitude for a given mass
- Planets of Earth mass and below remain to be detected and characterized



Planet diversity and planet formation

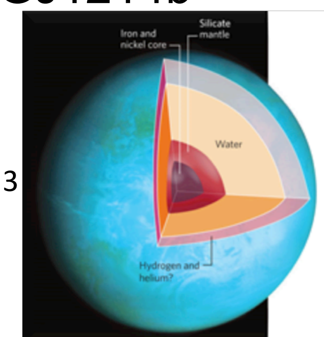
Earth

5.5 g/cm^3



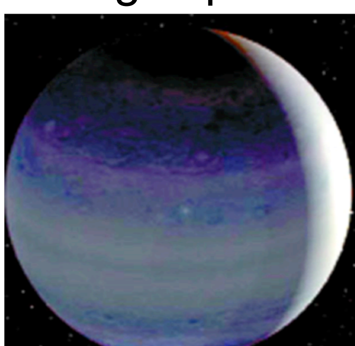
GJ1214b

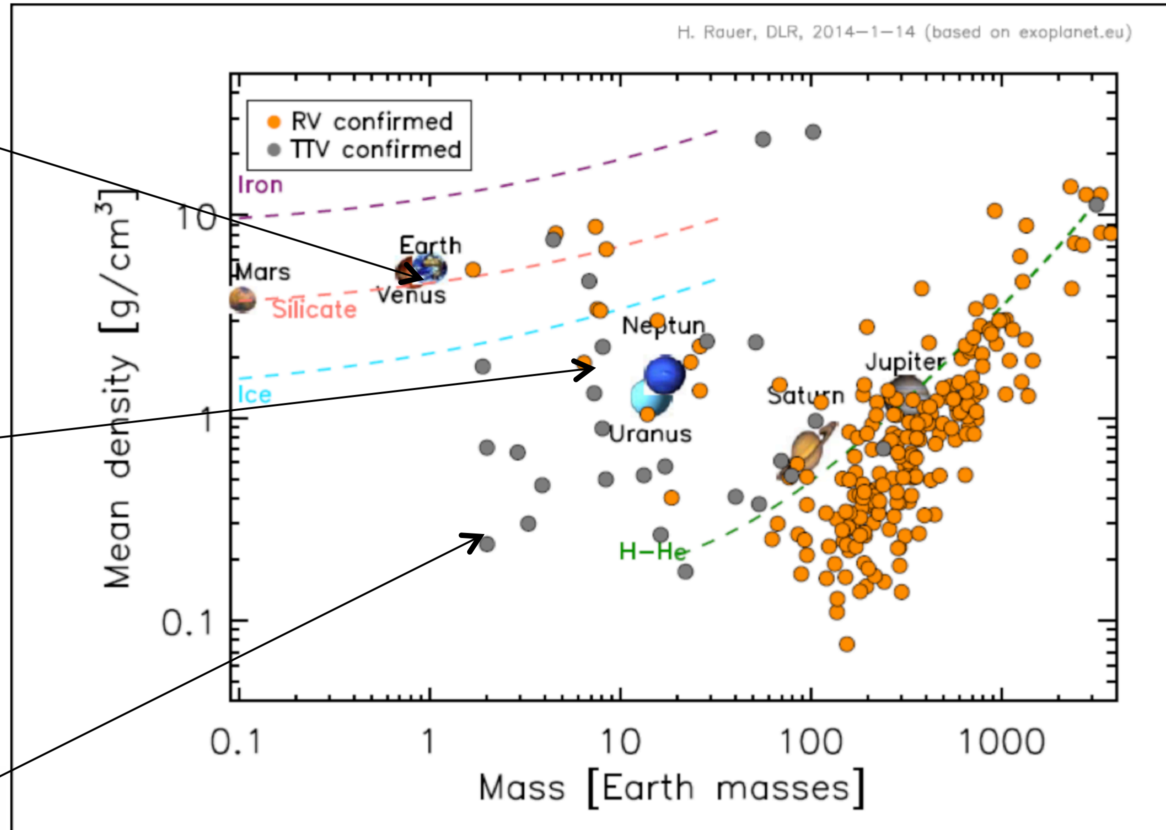
1.6 g/cm^3



Mini gas planets

<~1 g/cm^3



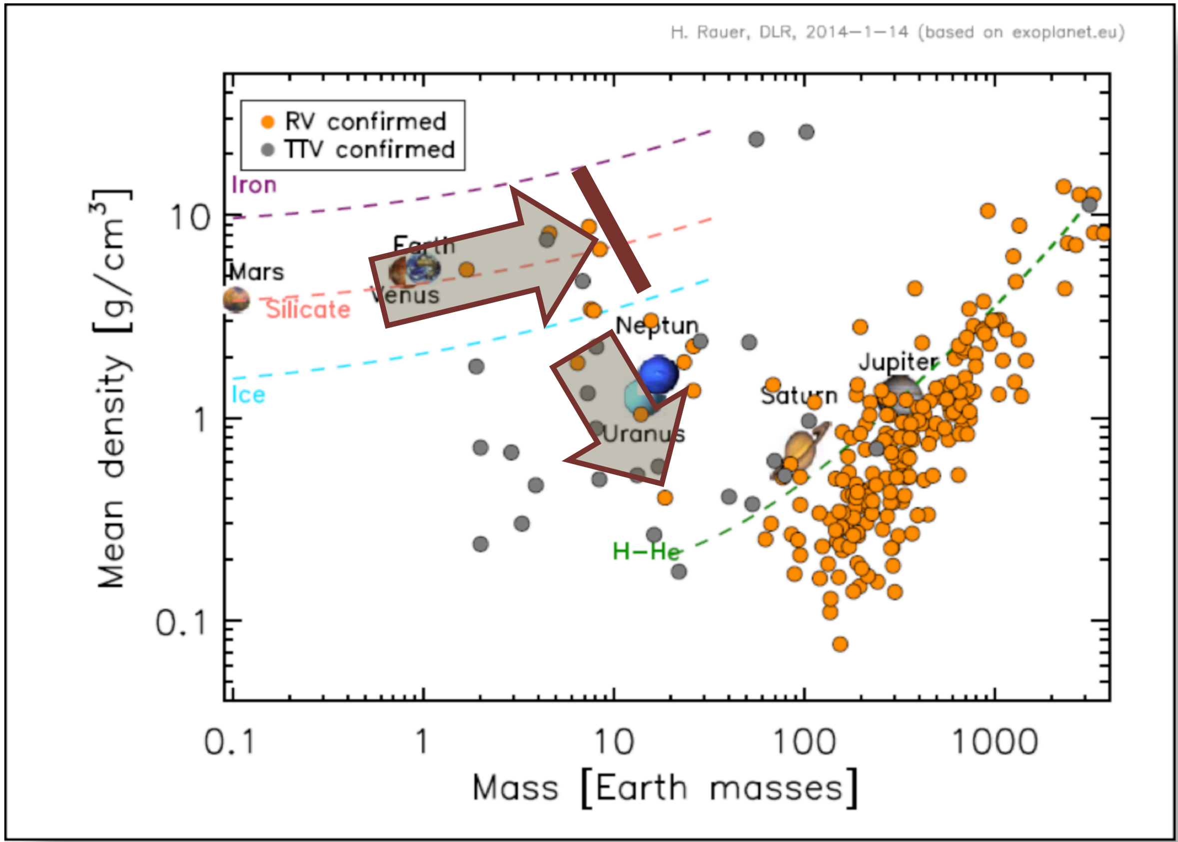


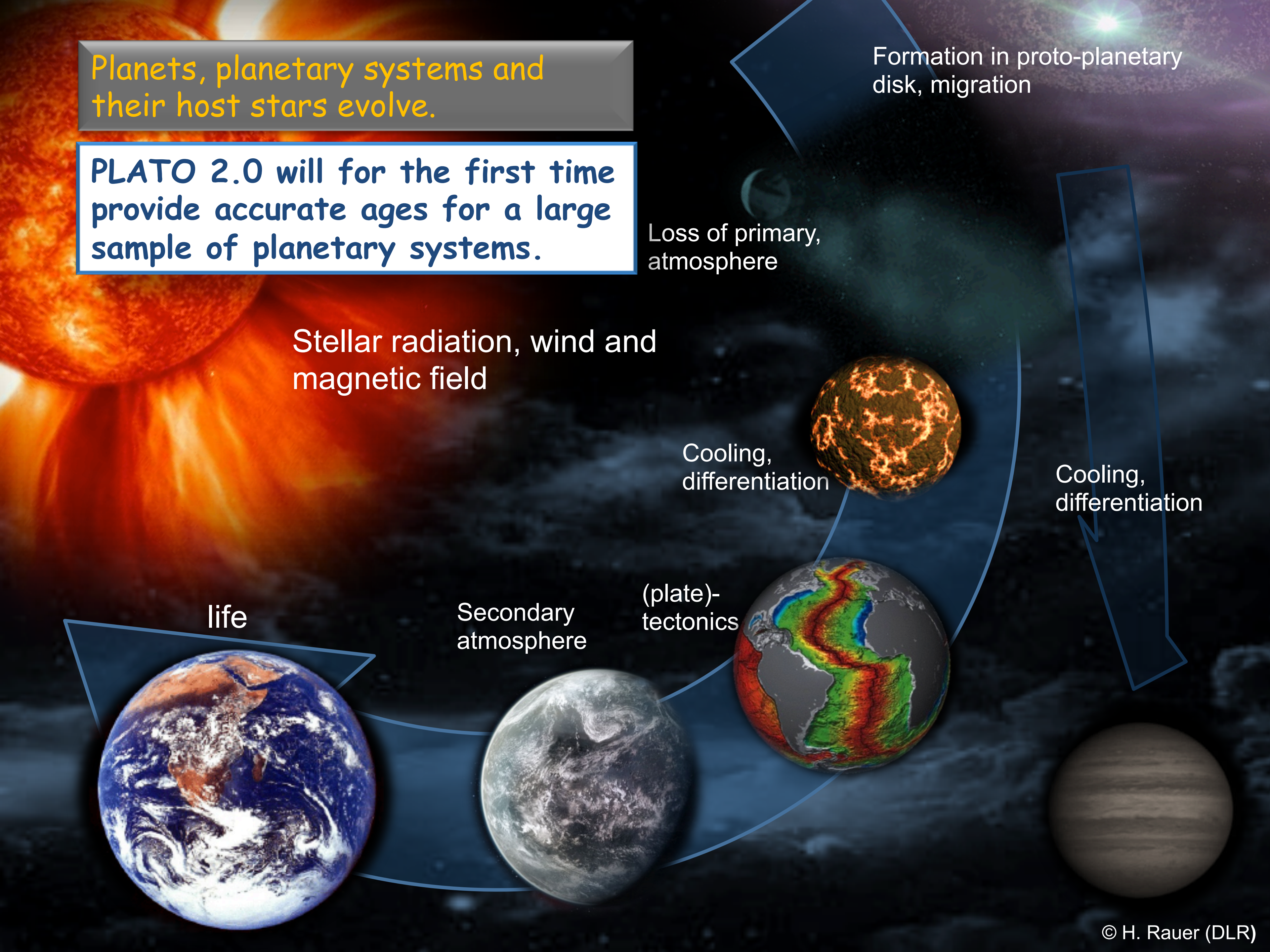
Low-mass planets have a range of compositions and interior structures for similar masses.

Planet diversity and planet formation

Test planet formation models:

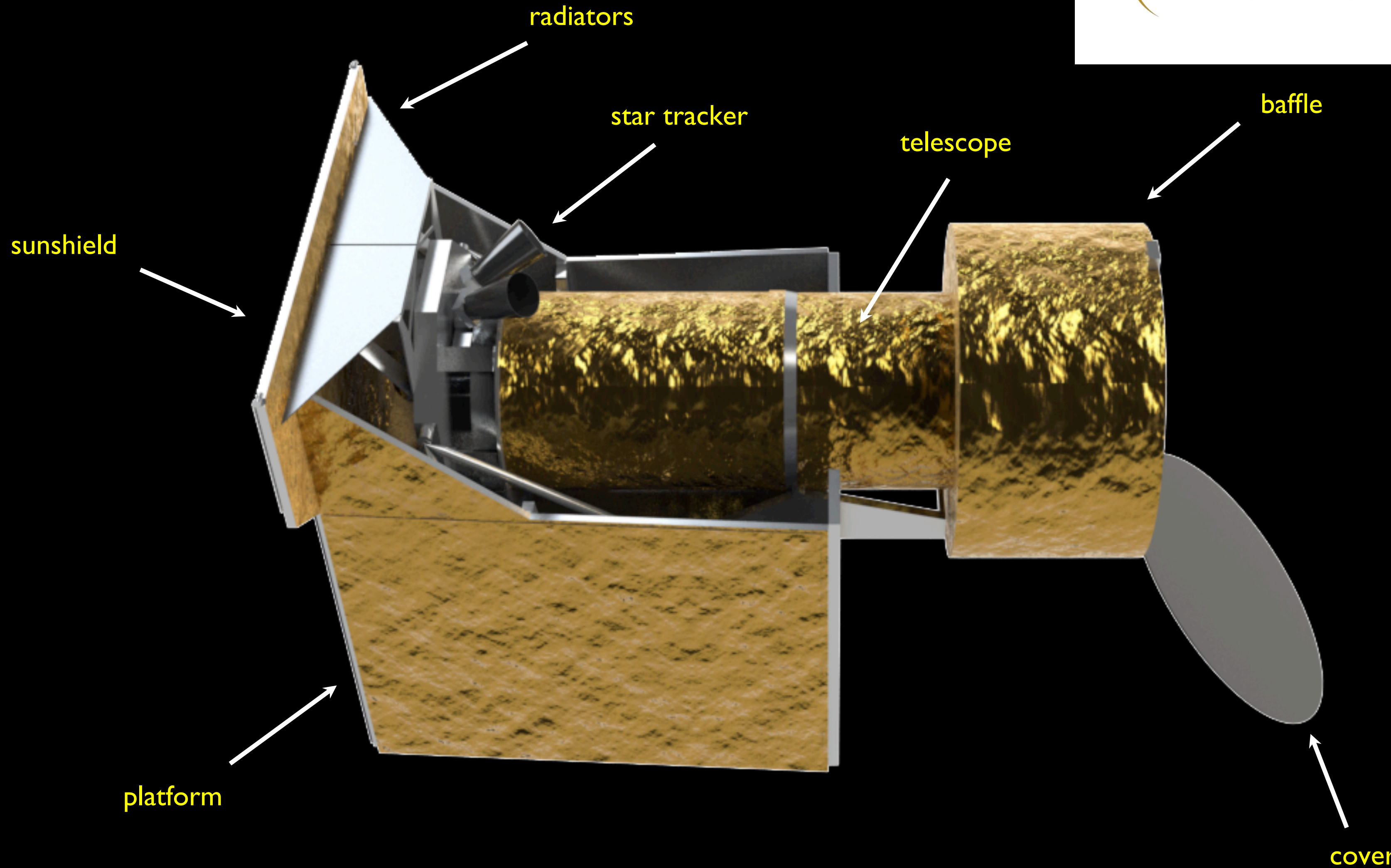
- What is the observed critical core mass?
- Can super-massive rocky planets exist? How are they formed?
- Are light planets with H_2-dominated atmospheres common?




Planets, planetary systems and their host stars evolve.
PLATO 2.0 will for the first time provide accurate ages for a large sample of planetary systems.
Formation in proto-planetary disk, migration
Loss of primary, atmosphere
Stellar radiation, wind and magnetic field
Cooling, differentiation
Cooling, differentiation
(plate)-tectonics
Secondary atmosphere
life
© H. Rauer (DLR)

CHEOPS & PLATO 2.0 missions: How we do them

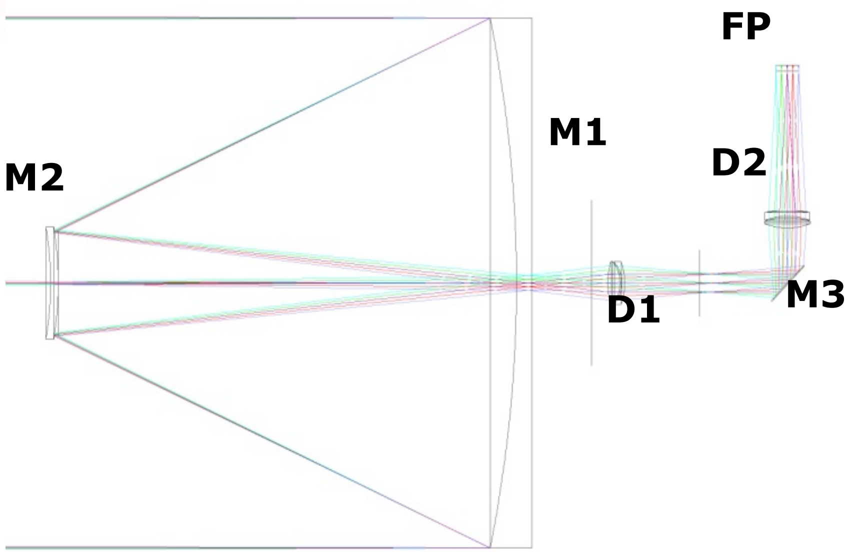
Image Copyright: Mark A. Garlick. Science Credit: Carole Haswell & Andrew Norton (The Open University)



Total weight: 250 kg
Total length: 1.3m

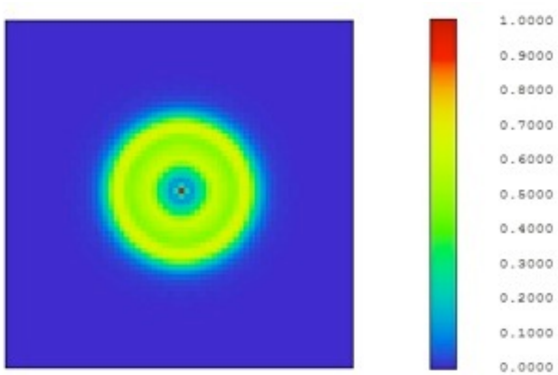
CHEOPS Optical design

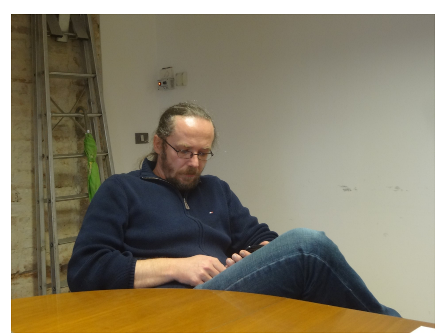
Temperature = 20°C, Pressure = 1 atm



Entrance Pupil Diameter	320 mm
Central Obstruction Diameter	68 mm
(+8.6% collecting area with respect to 300 mm)	
Distance M1-M2	300 mm
Effective Focal Length Tel	1600
Effective Focal Length Sys	2681.4 mm
F/# Tel	5
F/# Sys	8.4
Wavelength range	400-1100 nm
Detector format	1024×1024
Pixel size	13 µm
Plate scale	1 arcsec/pixel
FoV (FP diagonal)	0.40 degrees
FoV BEO Opt.	0.32 degrees
FoV box (diagonal)	0.08 degrees

Polychromatic defocused PSF with 30 pixel diameter





Optical Engineer:
D. Magrin - OAPD

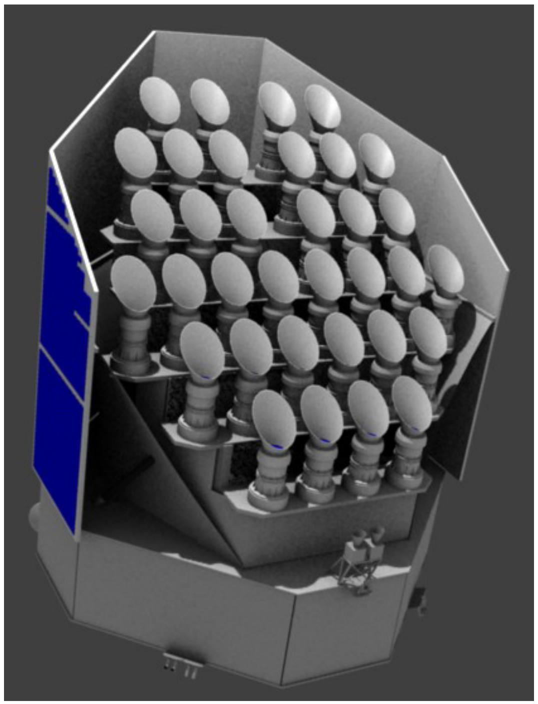
CHEOPS in Italy

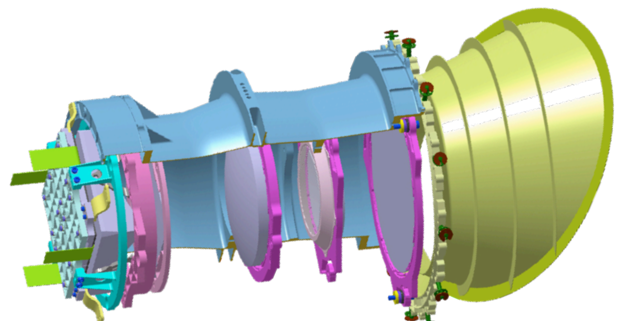
- ❑ 5 INAF structures
  - ❑ OACT (S, P)
  - ❑ OAPD (S, P)
  - ❑ OAPA (S)
  - ❑ OAT (S)
  - ❑ FGG (S)
- ❑ Dip. Fis. e Astron. UNIPD (S)
- ❑ ASI
  - ❑ ASDC (GS)

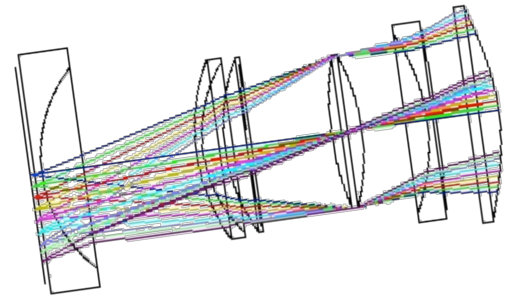
- I-PDR 30 Jun 2014
- I-CDR Jan 2015
- Delivery of TEL for further integration in Nov 2015

PLATO 2.0 Instrumental Concept

To observe a significant high number of Bright Stars
➔ Very wide field + large collecting area: multi-instrument concept







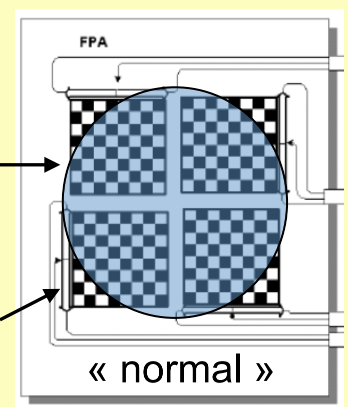
Camera FoV
~1100 deg^2

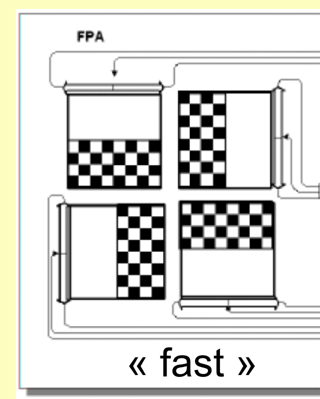
- ✓ fully dioptric, 6 lenses
- ✓ pupil 120 mm
- ✓ dynamical range: $4 \leq m_V \leq 16$

focal planes

optical field
Ø 38.5°

4 CCDs:
4510^2 18µm





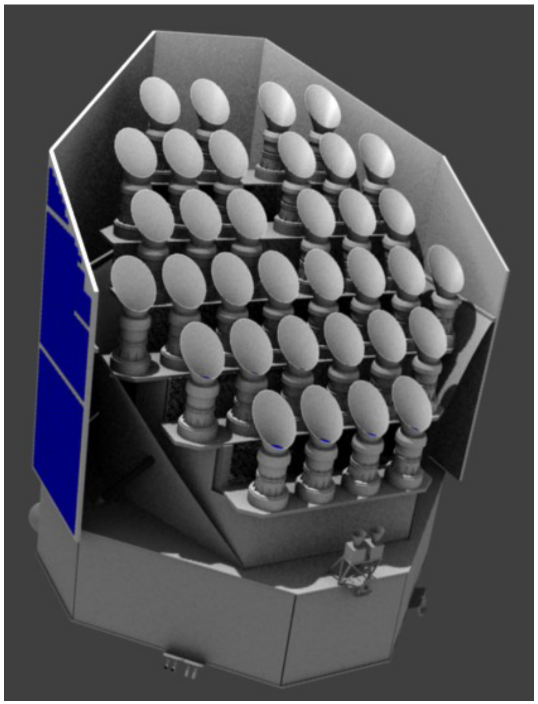
- Sp. range = 500 – 1050 nm
- 32 « normal » cameras : cadence 25 sec
- 2 « fast » cameras : cadence 2.5 sec
- 132 CCDs

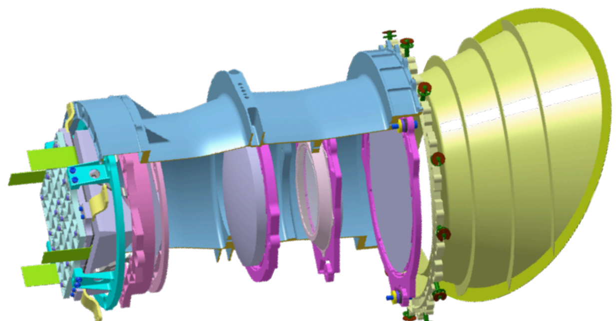
On board data treatment: **1 DPU per camera**
1 ICU

PLATO 2.0 Instrumental Concept

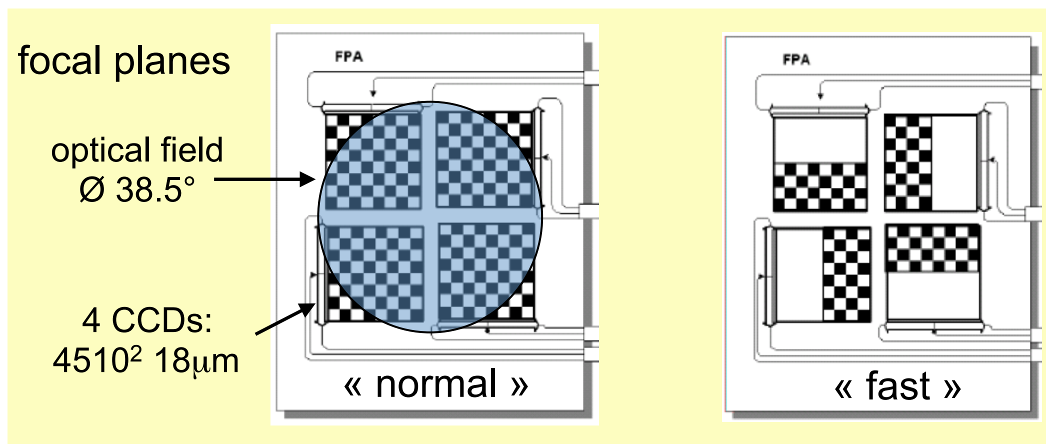
To observe a significant high number of Bright Stars

➔ Very wide field + large collecting area: multi-instrument concept





✓ fully dioptric, 6 lenses
✓ pupil 120 mm
✓ dynamical range: $4 \leq m_V \leq 16$



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- 32 « normal » cameras : cadence 25 sec
- 2 « fast » cameras : cadence 2.5 sec
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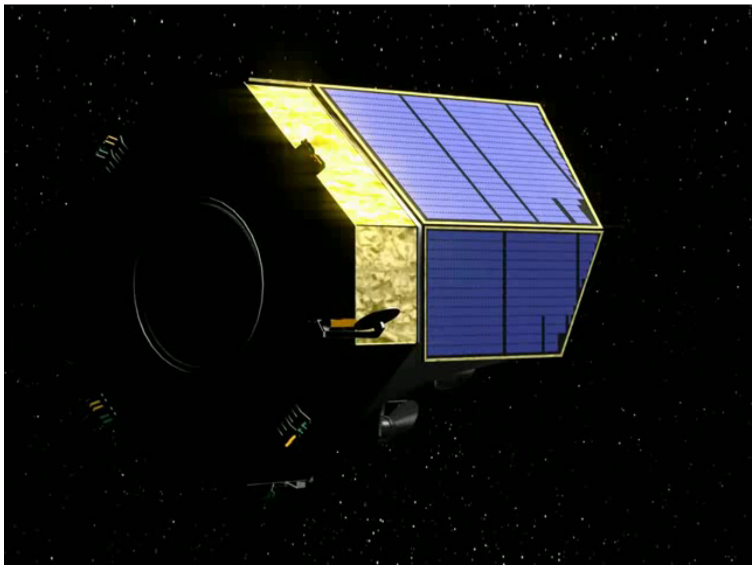
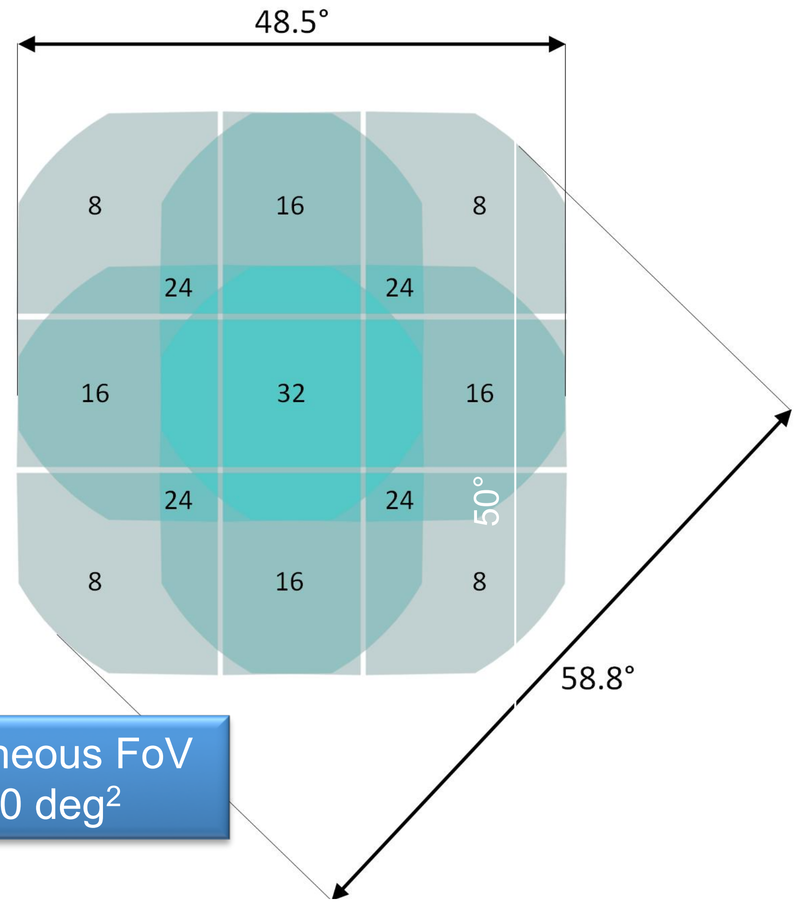
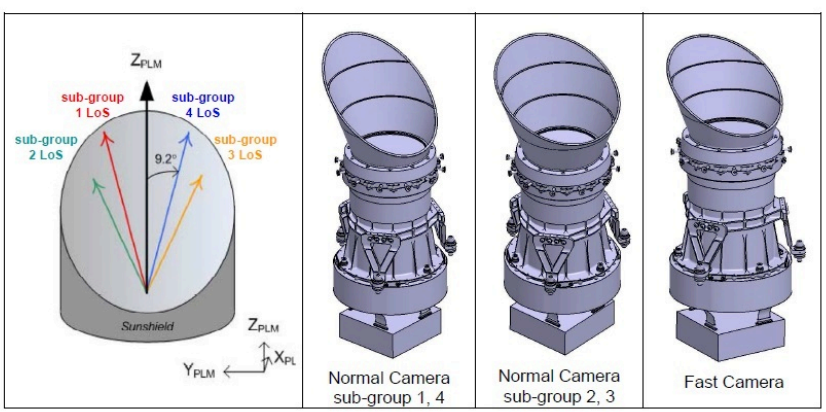
1 ICU

Concept of overlapping line of sight





Instantaneous FoV
~2250 deg^2

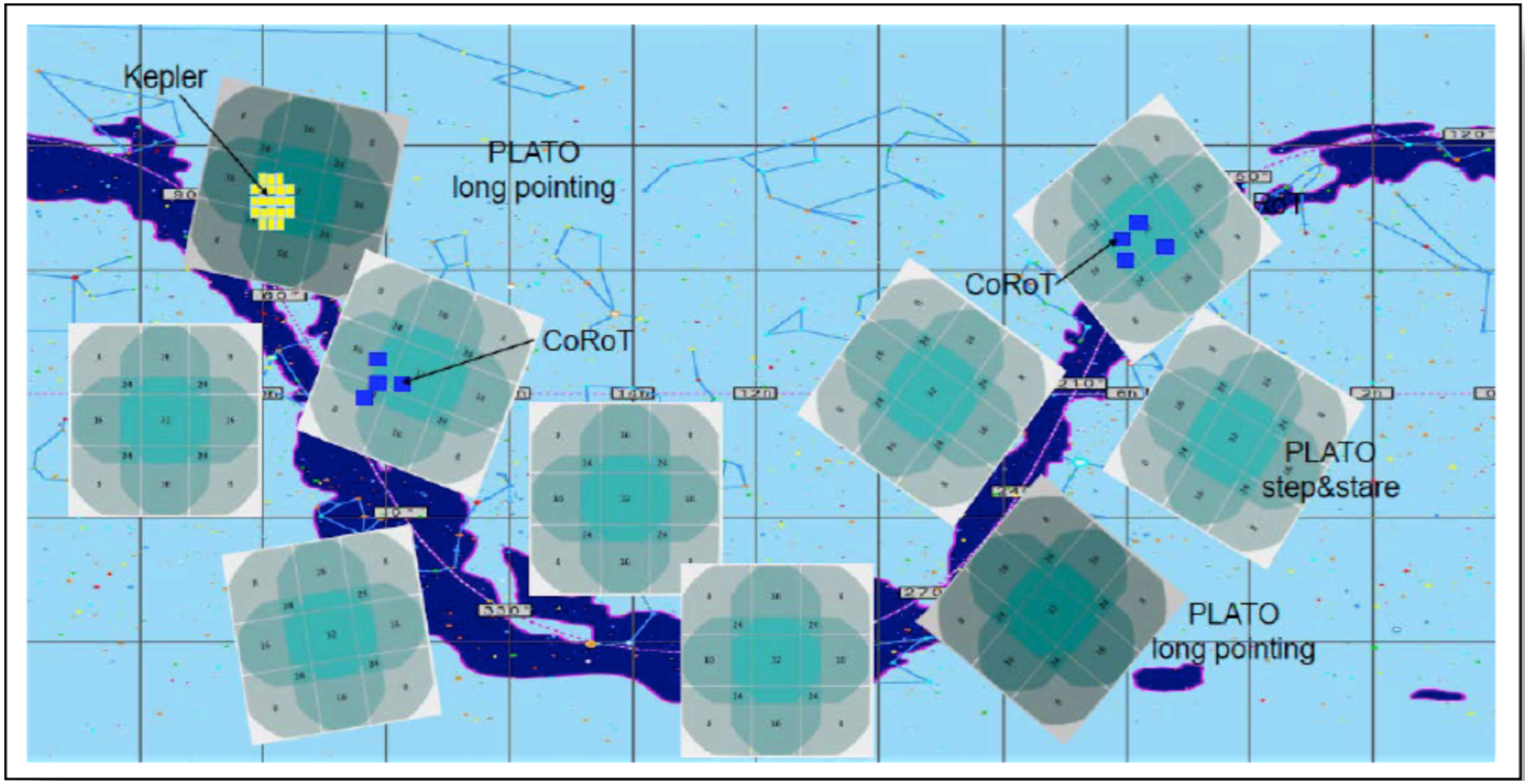


Optimization of number of stars at given noise level *and* of number of stars at given magnitude

Observing strategy

Baseline observing strategy:

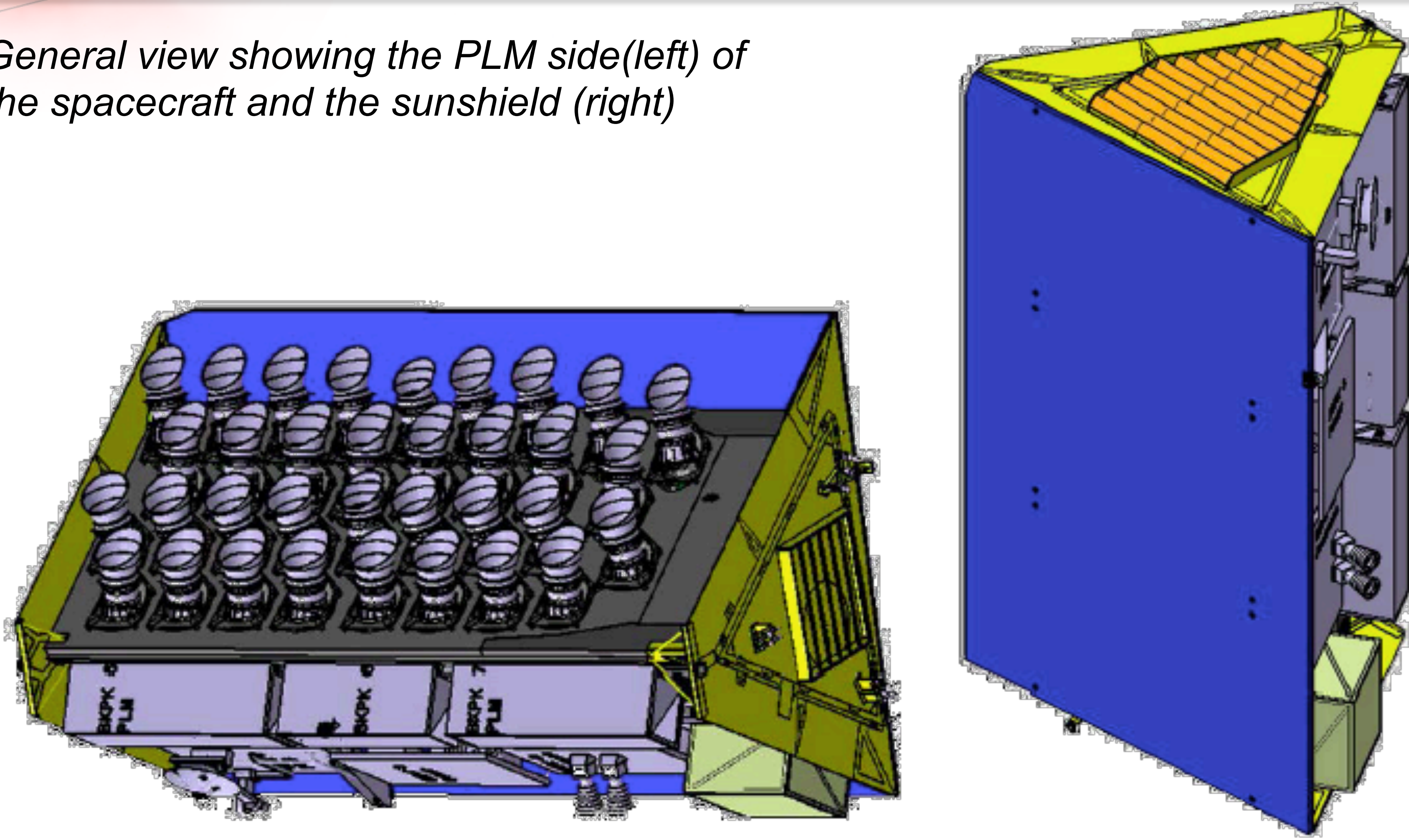
- **6 years nominal science operation**
- **2 long pointings of 2-3 years + step-and-stare phase (2-5 months per pointing)**



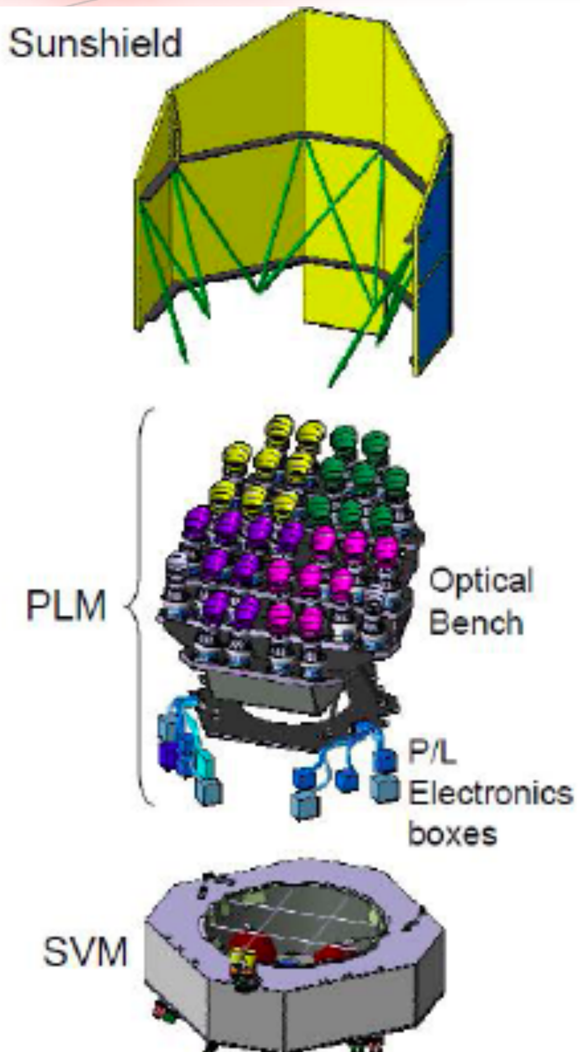
→ covers ~50% of the sky

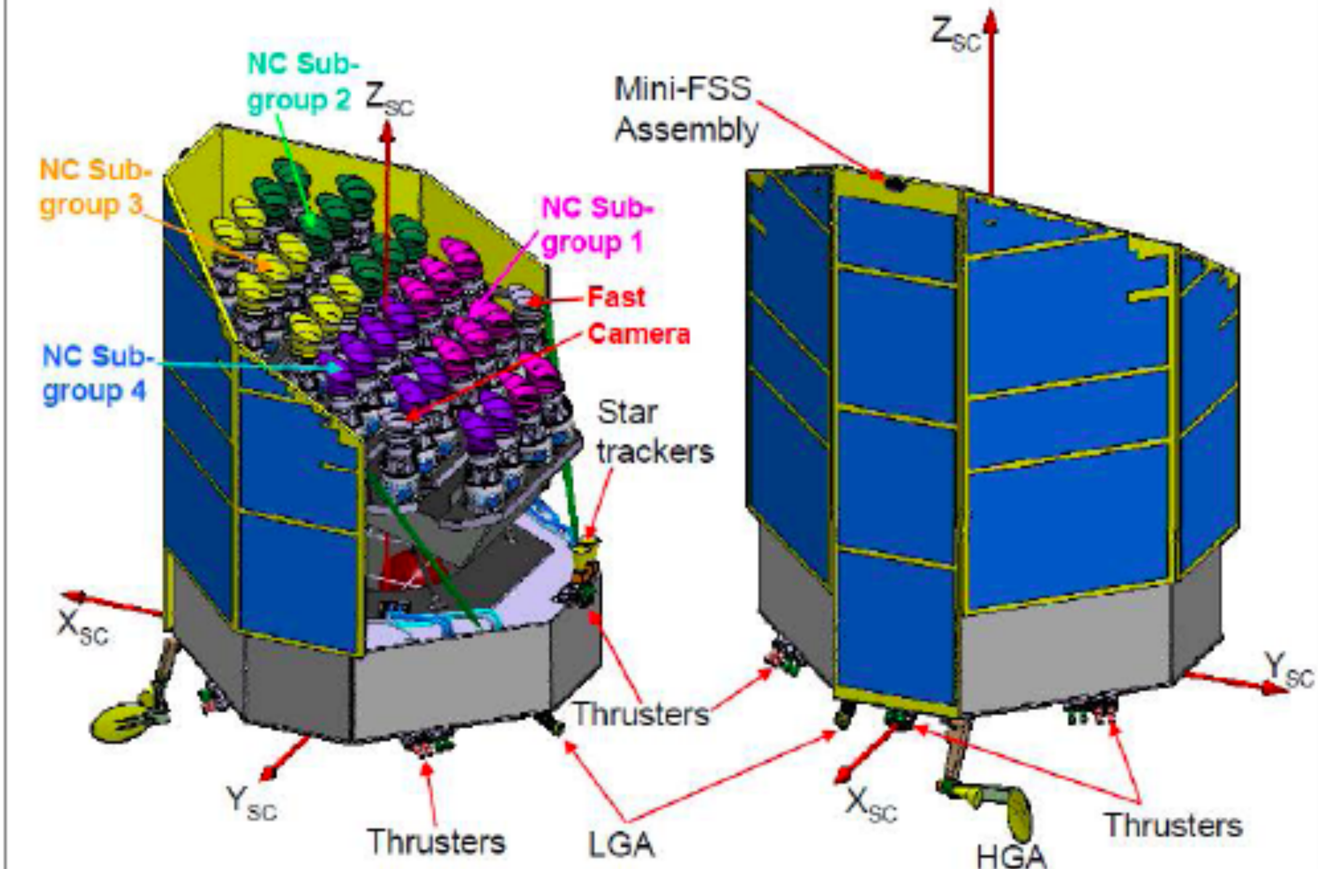
ASTRIUM Concept

General view showing the PLM side(left) of the spacecraft and the sunshield (right)



Thales-Alenia Space Concept

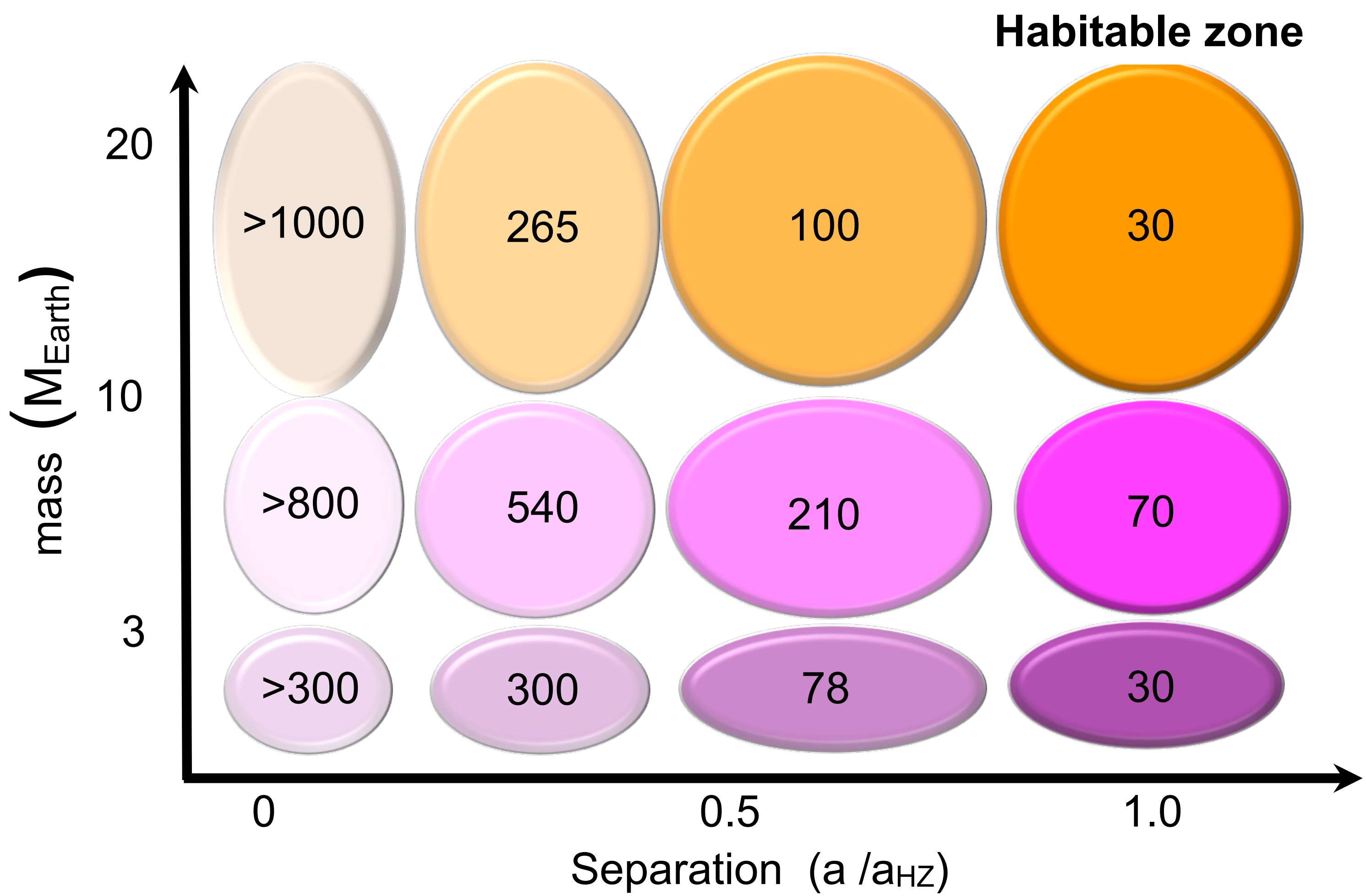




PLATO spacecraft configuration and external equipment layout (XSC, YSC, ZSC = Spacecraft Reference Frame - SRF)

Total numbers of characterized planets in core sample

Number of characterized planets (**Earth to Neptune mass**) after detailed model of radial velocity efforts and the impact of stellar activity:



The PLATO Italian team

ASI Contracts (Assessment and Definition phases)

- G. Piotto – UniPD
  - I. Pagano – INAF
  - E. Pace - UniFI

- ✓ **Università di Padova, Dip. di Astronomia** (Science)
- ✓ **INAF**
  - – **OA Catania** **(Science, Payload)**
  - – **OA Padova** **(Science, Payload)**
  - – **OA Brera** **(Science, Payl**
  - – **IFSI-Roma** **(Science**
  - – **FGG** **(Payload)**
  - – **OA Palermo** **(Science)**
  - – **OA Torino** **(Science)**
  - – **OA Capodimonte** **(Scie**
  - – **OA Roma (+Teramo)** **(S**
  - – **OA Arcetri** **(Science)**
  - – **IASF Roma** **(Science)**
- ✓ **Università di Firenze, Dip. di Fisica e Astronomia** (Payload)
- ✓ **ASI-ASDC** (PDC, Science)

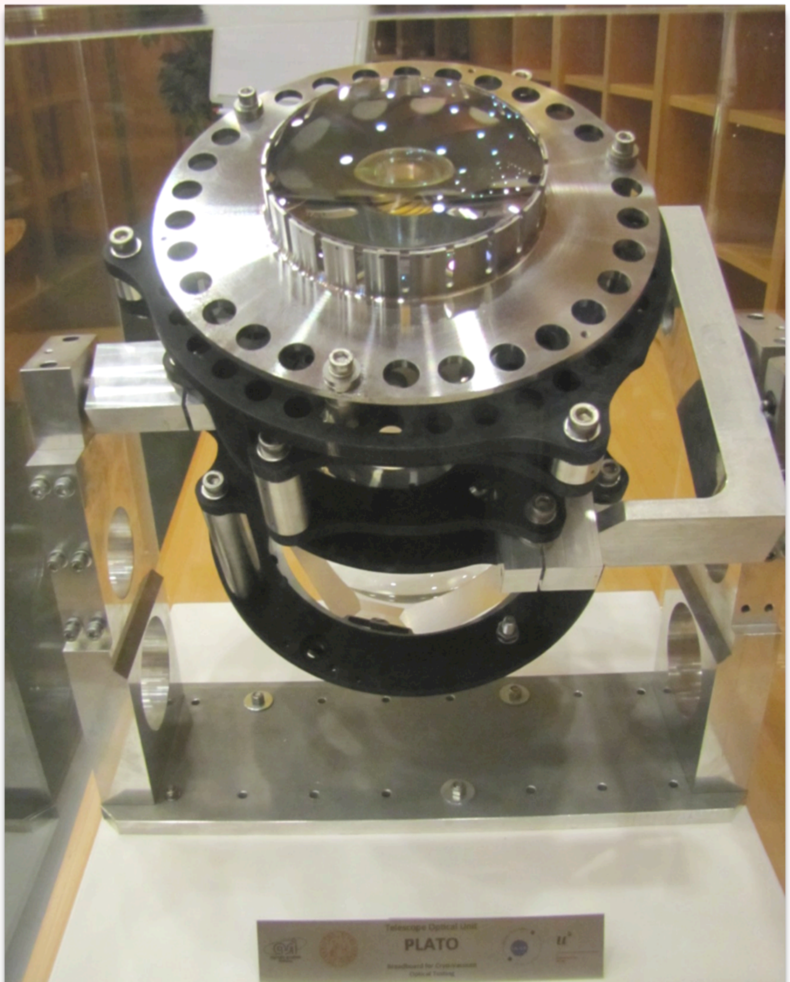
About 70 scientists/ engineers active in PLATO in Italian research institutes!

About 120 scientists interested to exoplanets field in Italy!

Italian Contribution to PLATO 2.0

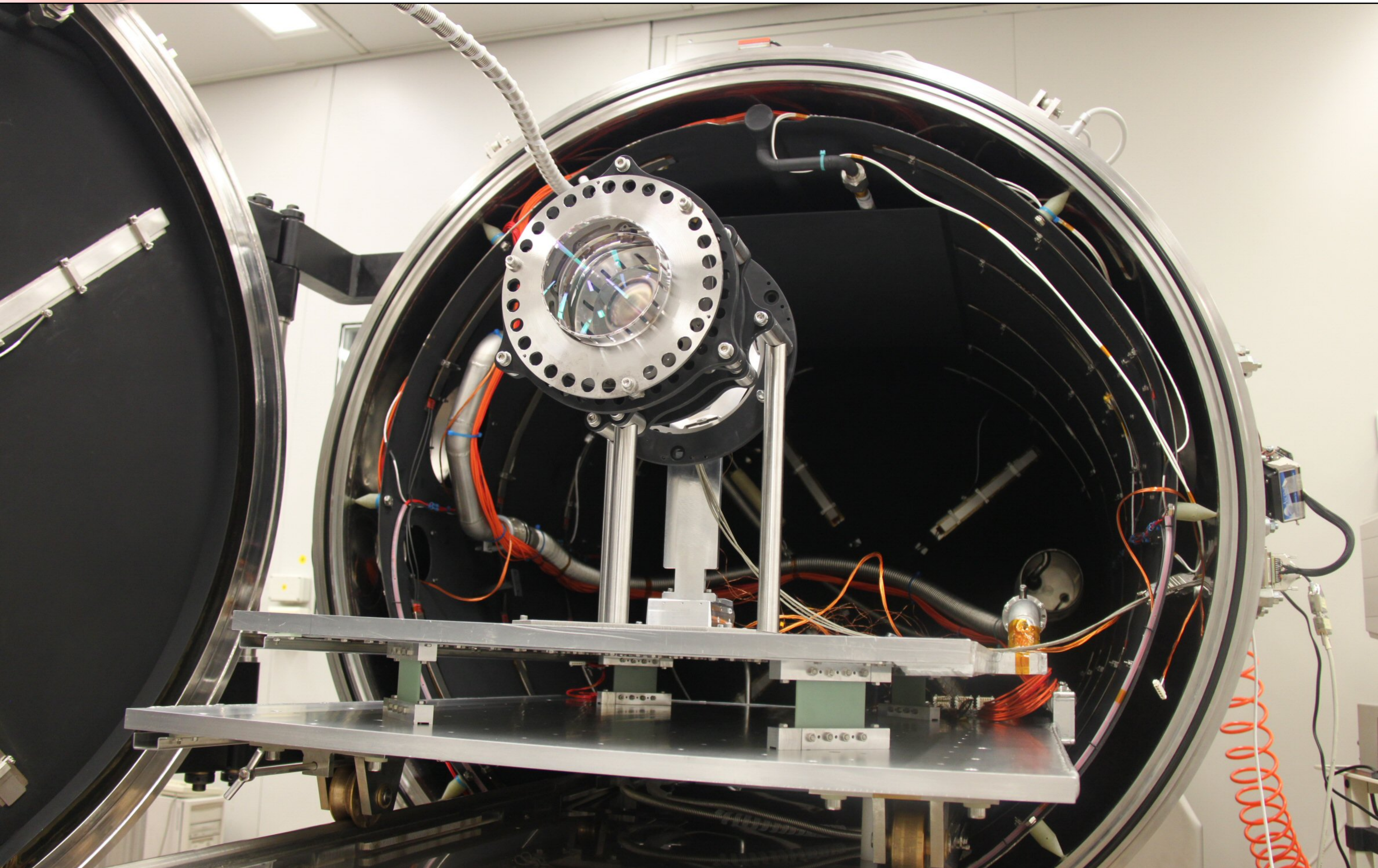
- Science Preparation
  - Field characterization and target selections
  - …..
- Telescope Optical Units
- Instrument Control Unit
- Participation to the PDC (ASDC)

BreadBoard of the PLATO Telescope



- Aspheric feasibility demonstrated.
- CaF lenses demonstrated.
- Alignment in warm demonstrated.

Testing the BB into the space environment…



Comparison with expected figures

Italian Science Working Team

- **Univ. Salerno**, Gabriella Raimondo

Berlino 2011

Next PLATO Conference
iCatania
December 2014

The end