19 May 2021

PLATO

PLAnetary Transits and Oscillations of stars

Isabella Pagano

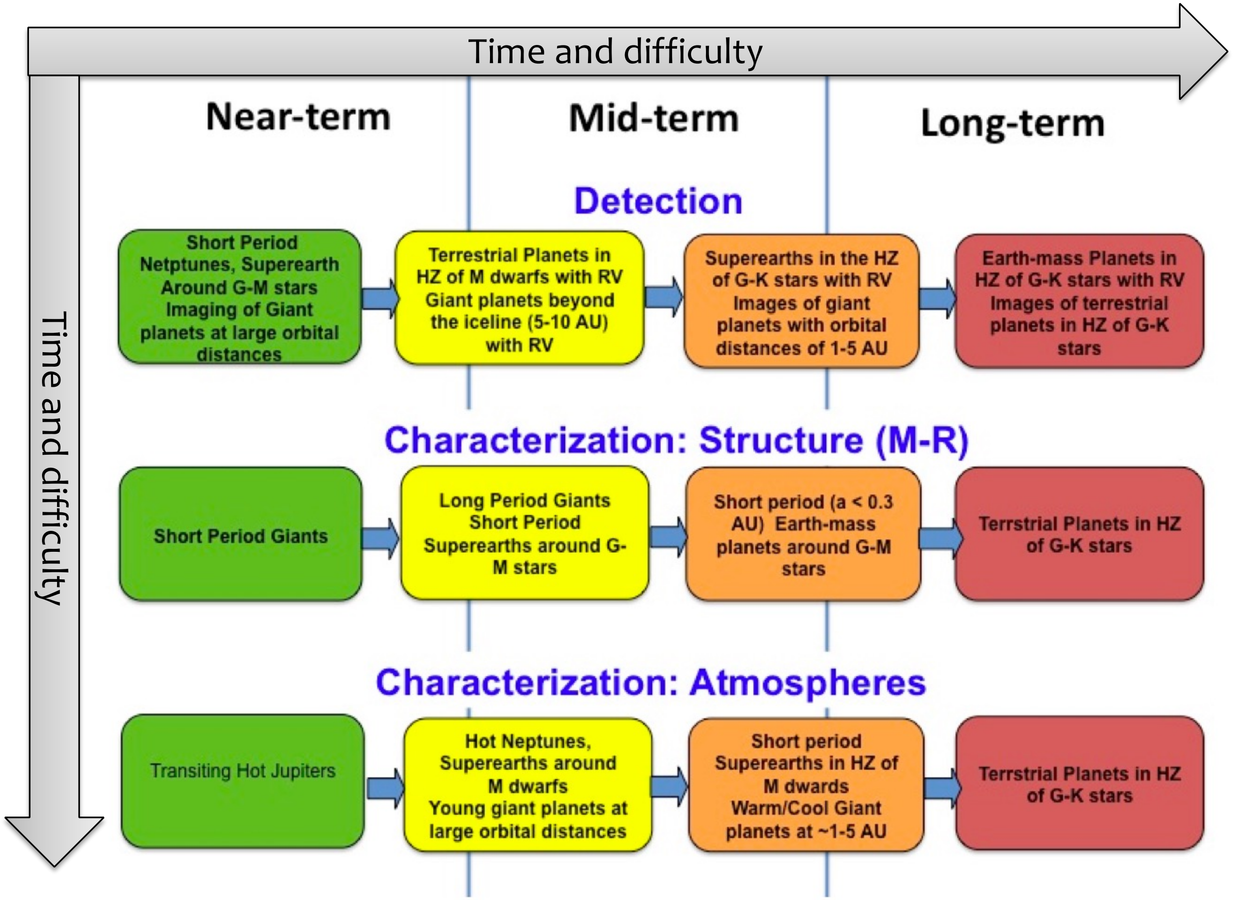
Resp. Scientifica partecipazione Italiana a PLATO

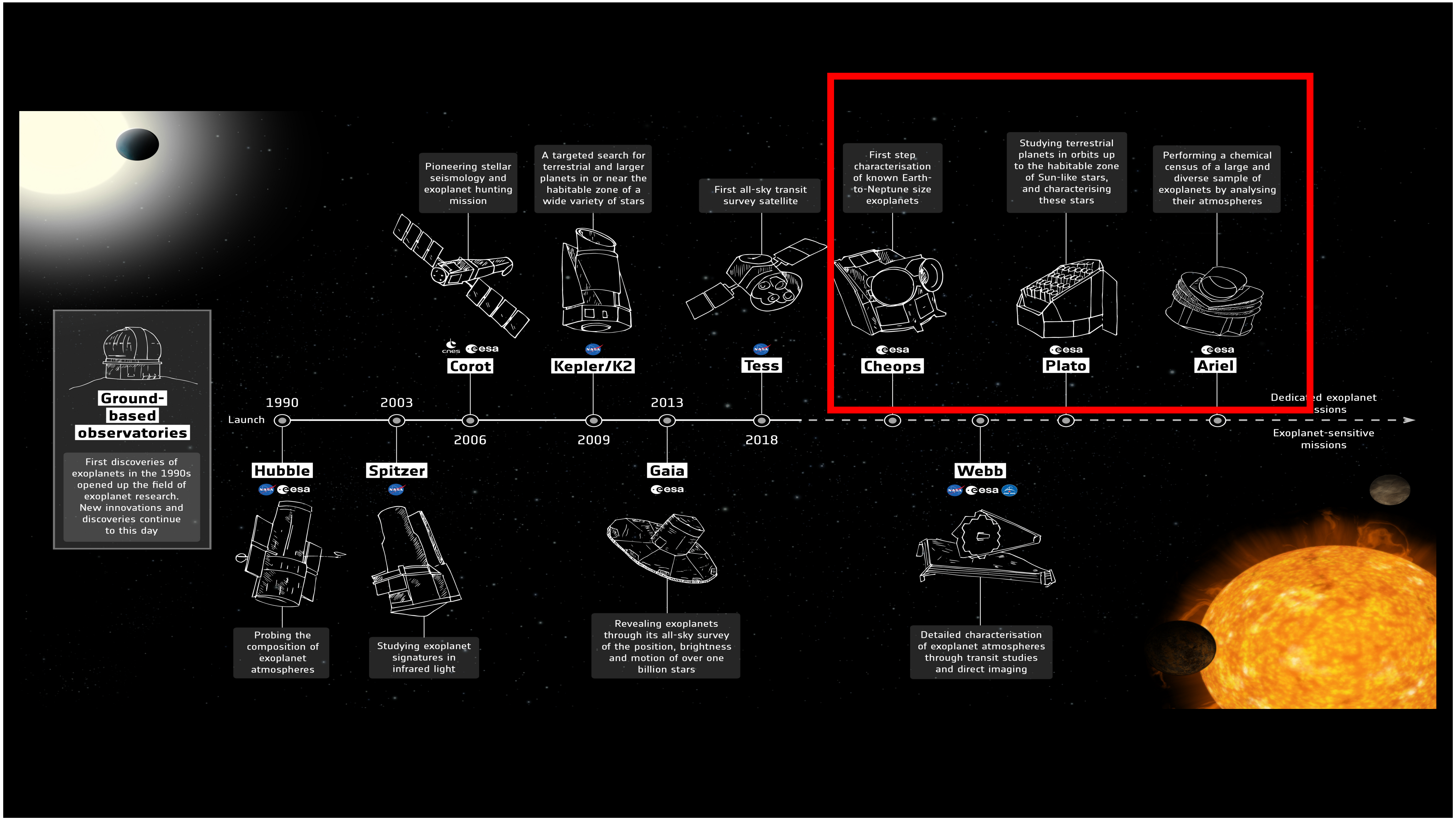
PLATO Co-PI

AUDIZIONI SCHEDE INAF
17-31 MAY 2021

The EP-RAT Roadmap

ESA EXOPLANET ROADMAP ADVISORY TEAM – Oct 2010




Ground-based observatories
First discoveries of exoplanets in the 1990s opened up the field of exoplanet research. New innovations and discoveries continue to this day
Launch
1990
2003
2006
2009
2013
2018
Pioneering stellar seismology and exoplanet hunting mission
cnes esa
Corot
A targeted search for terrestrial and larger planets in or near the habitable zone of a wide variety of stars
NASA
Kepler/K2
First all-sky transit survey satellite
NASA
Tess
First step characterisation of known Earth-to-Neptune size exoplanets
esa
Cheops
Studying terrestrial planets in orbits up to the habitable zone of Sun-like stars, and characterising these stars
esa
Plato
Performing a chemical census of a large and diverse sample of exoplanets by analysing their atmospheres
esa
Ariel
Dedica ed exoplanet
ssions
Exoplanet-sensitive missions
Hubble
NASA esa
Probing the composition of exoplanet atmospheres
Spitzer
NASA
Studying exoplanet signatures in infrared light
Gaia
esa
Revealing exoplanets through its all-sky survey of the position, brightness and motion of over one billion stars
Webb
NASA esa
Detailed characterisation of exoplanet atmospheres through transit studies and direct imaging

PLATO

PLAnetary Transits & Oscillations of Stars

- 3° M class mission in ESA's Cosmic Vision 2015-2025 Programme
- Launch: end 2026 – Ariane 6 from Kourou
- Operation: 4.25 yr (+2) yrs

  [*satellite built with consumable for 8 yr*]

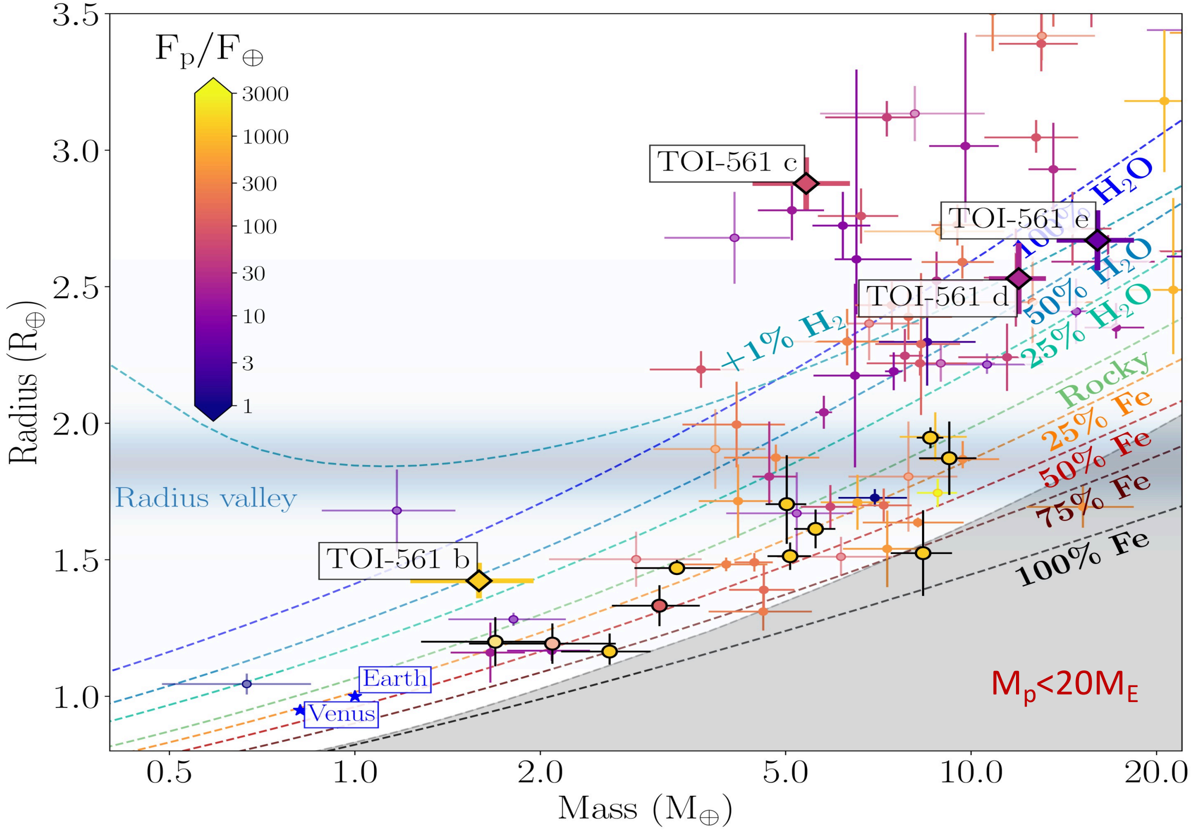
Key Science Goals:

✓ 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.

Large diversity of planetary structure

Lacedelli et al. (2020, MNRAS 501, 4148)

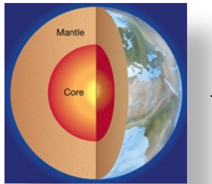


- ✓ Masses vary by a factor of ~4 (with large errors)
- ✓ Radii vary by a factor of ~3

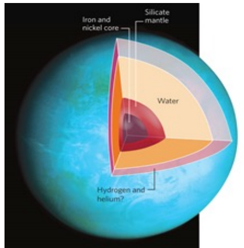
Accurate M & R are required to separate terrestrial from mini-gas planets

Planet diversity

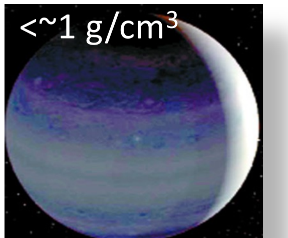
Earth 5.5 g/cm^3



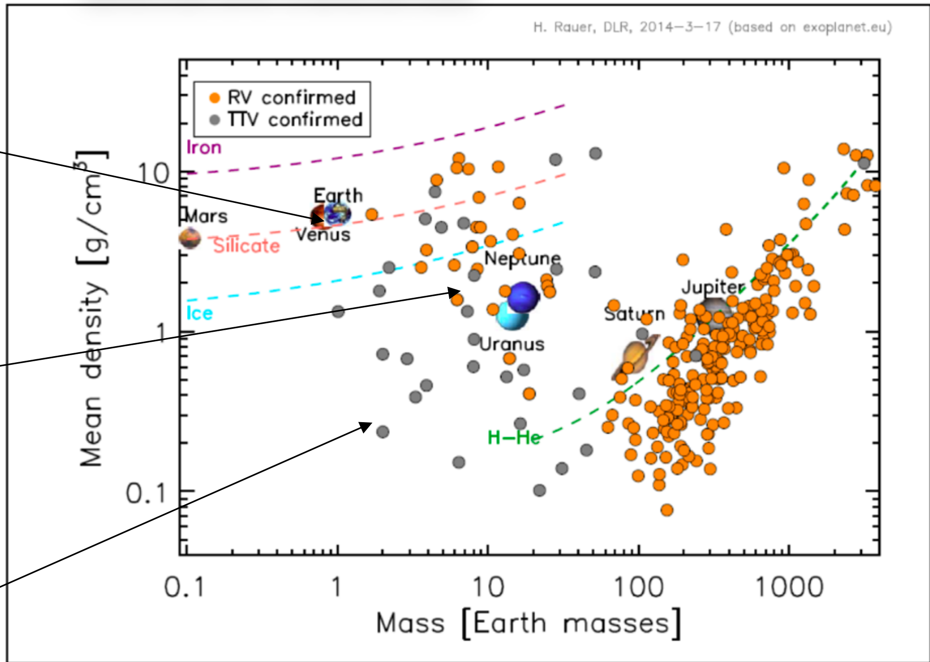
GJ1214b 1.6 g/cm^3



Mini gas planets

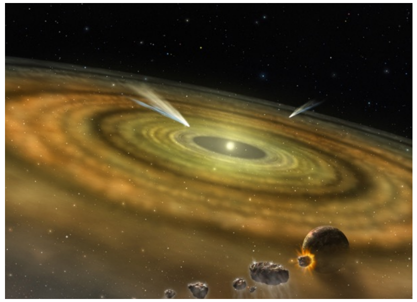


- Planets of Earth mass and below remain to be detected and characterized



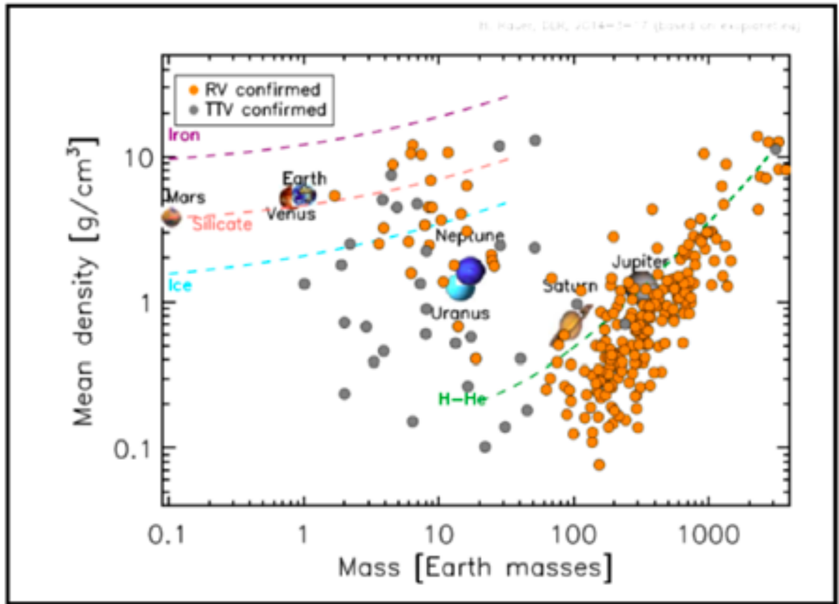
➔ Mean densities required to separate terrestrial planets from mini-gas planets

A biased view

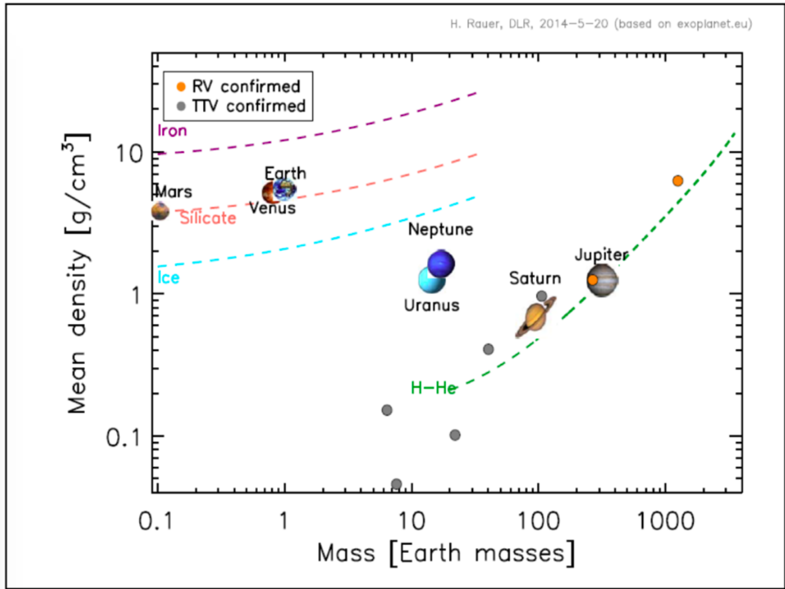


Our knowledge on planet nature is limited to close-in planets so far.

All planets



Planets with P>80 days



Small planets with both Radius and Mass measured

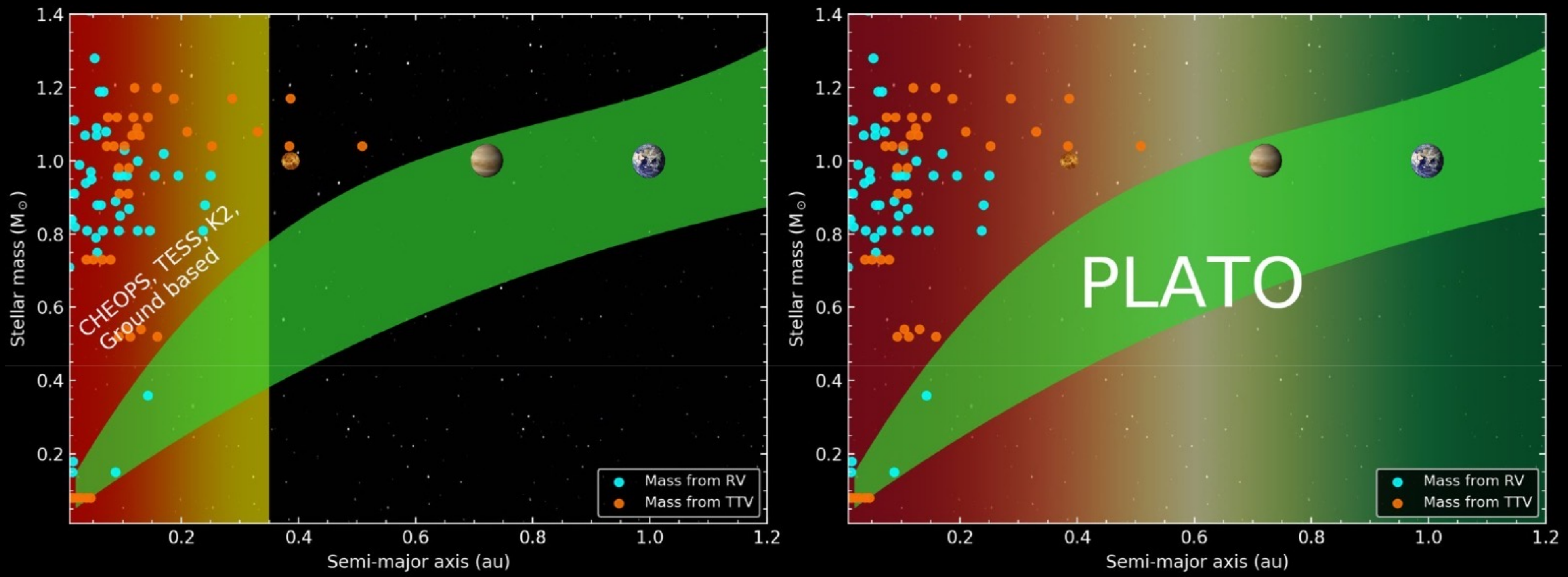
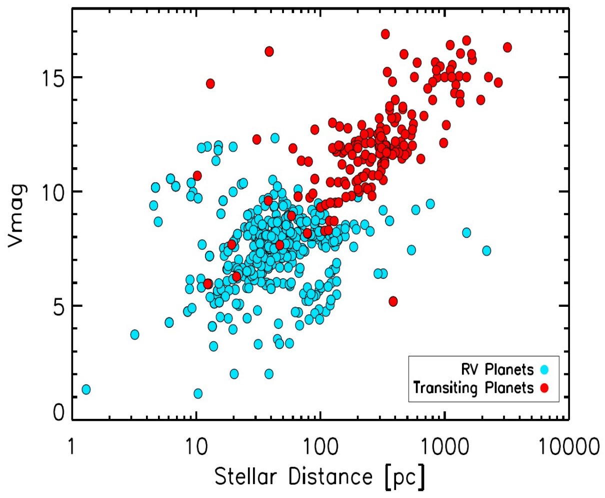


Illustration of PLATO science exoplanet target range in comparison to other missions (Rauer et al. in preparation)

The need for bright stars

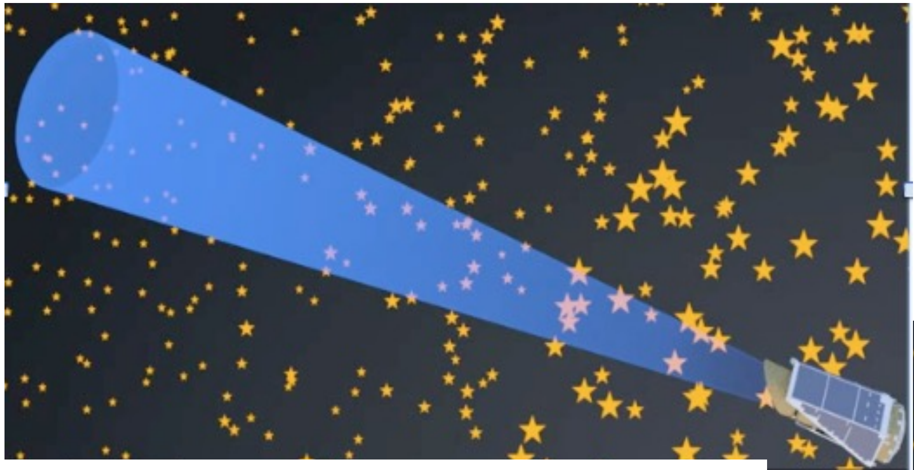
Known planets from radial velocity and transit surveys



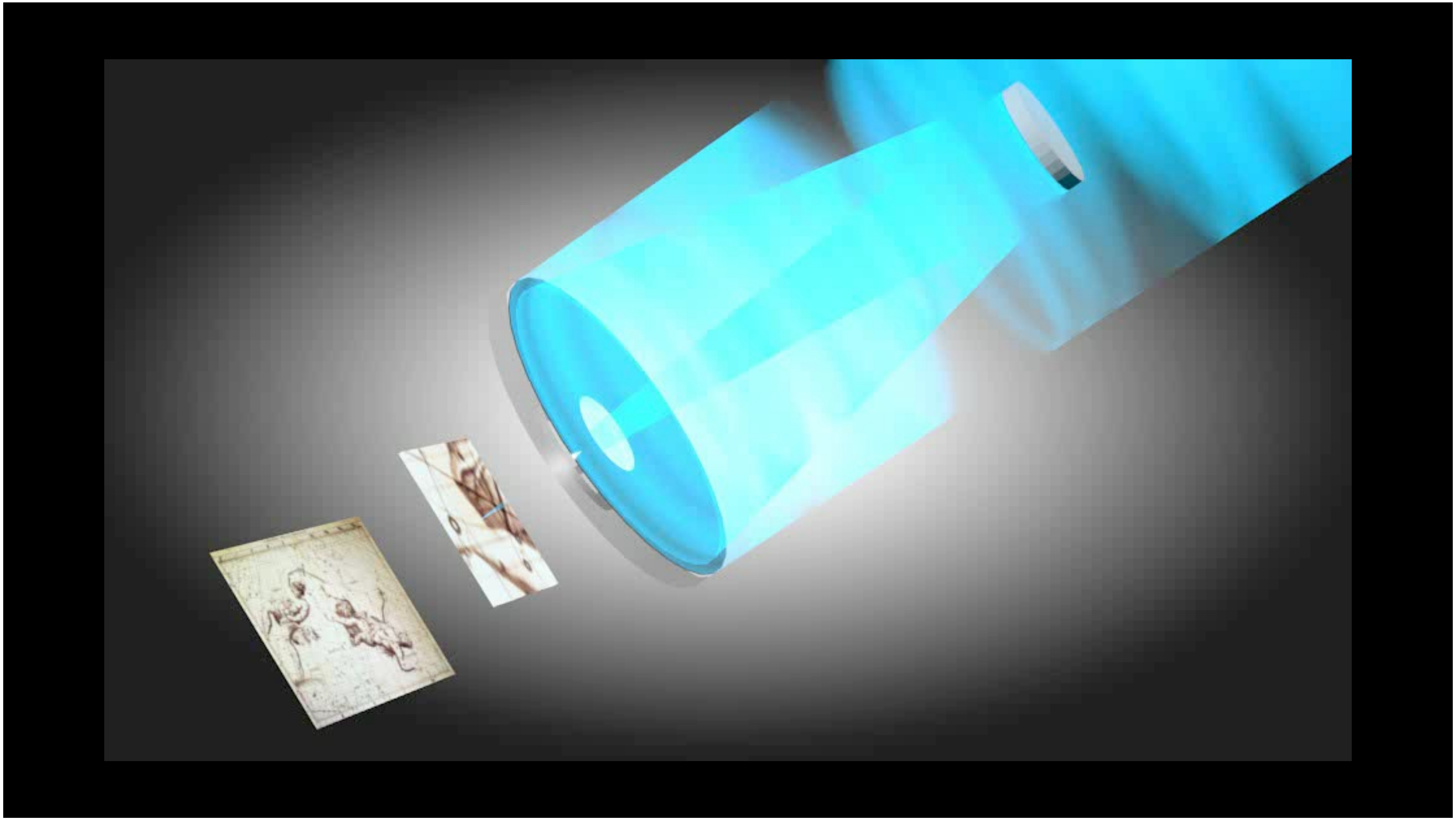
- ✓ Why have so few targets been characterized?
- ✓ Transit surveys targeted faint and distant stars to maximize detection performance.
- ✓ Radial velocity surveys need bright stars (≤11 mag) to keep telescope resources limited.

Lessons learned:
Future transit missions must target bright stars!

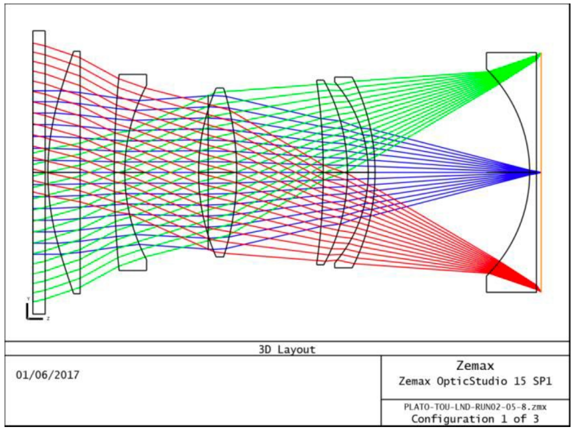
Large FoV concept

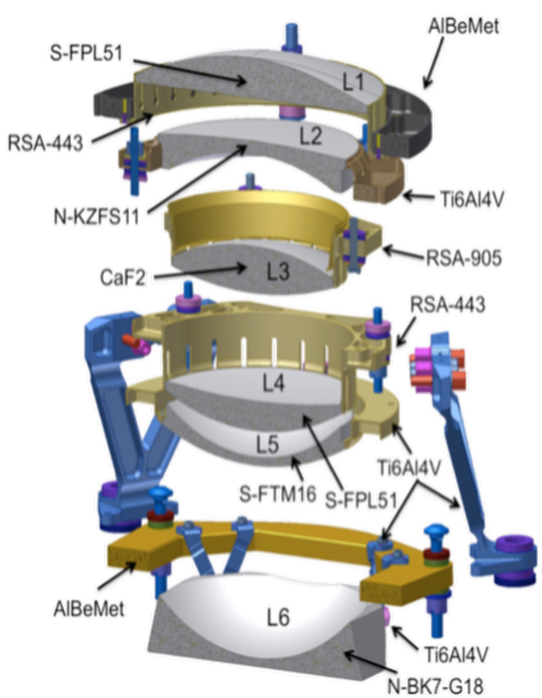


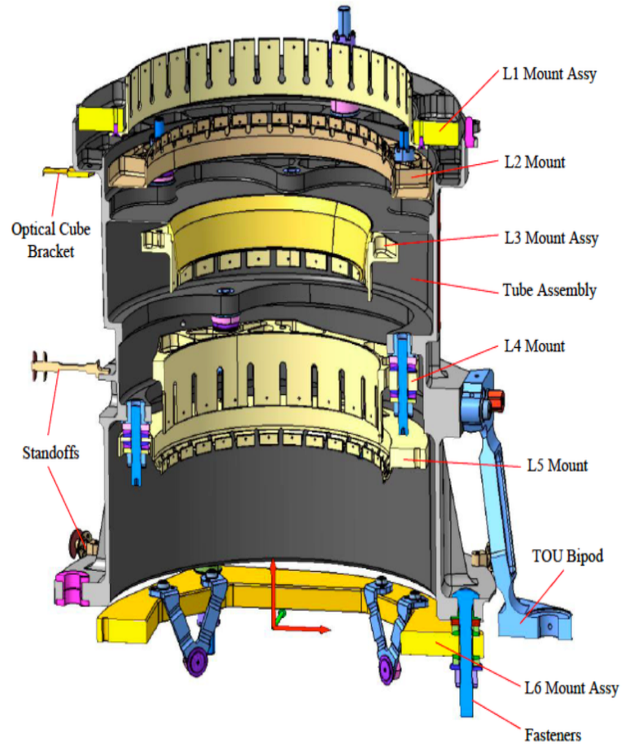
Searching for transits of Bright Stars
➔➔ large FoV!



The Telescope Optical Units design concept







One Camera

Single Telescope FoV ~1200 sqdeg
Equivalent to a circle of ~38.7 deg diameter

Telescopes

CCDs

FPAs & Test House

TOU+FPA integration

Test House

Test House

FSS

OGSE+ MLI

Transport Container

F Filter

Telescope Struct

N-FEE

F-FEE

24 Normal cameras

fully dioptric, 6 lenses

pupil 120 mm

Dynam. range: ~8 ≤ mV ≤ 11 (13)

4 x CCD 4510×4510px per camera

Pixels size: 18 µm square

read-out cadence: 25 sec

Band: 500 – 1050 nm

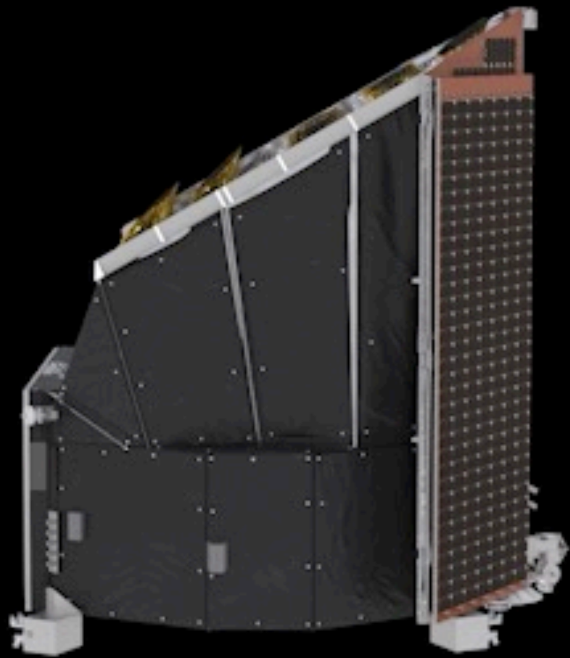
2 Fast cameras

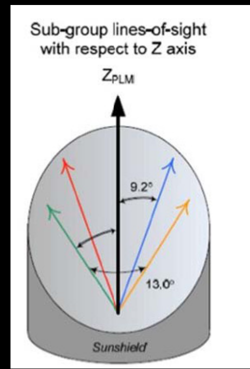
Bright stars (<~8 mag)

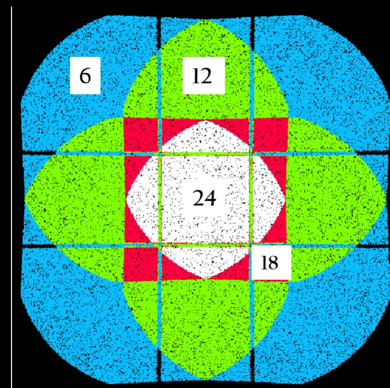
read-out cadence: 2.5 sec

one „red“ & one „blue“ camera

Payload Concept

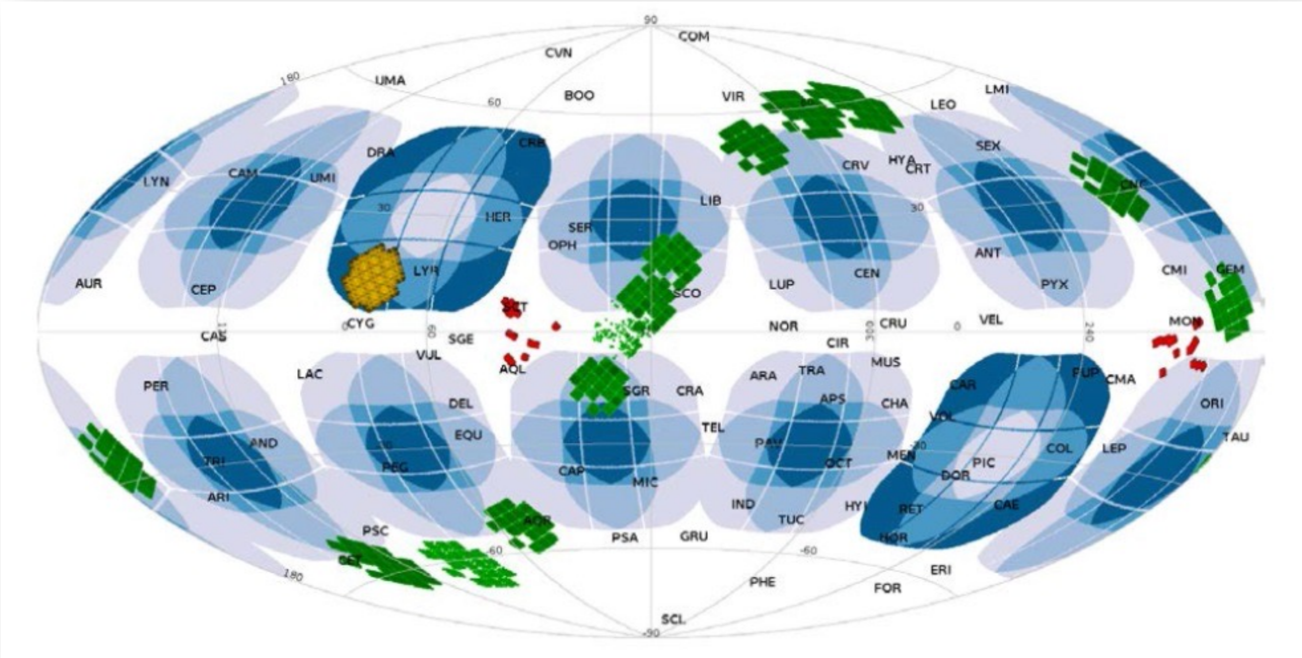


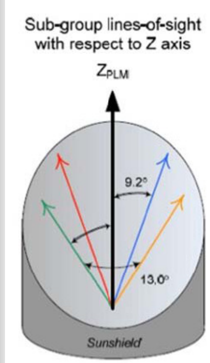


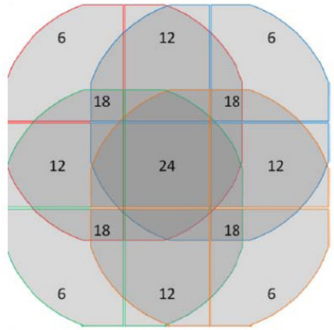


Instrument field of view is 2200 square degrees (vs 105 deg2 Kepler)
~2 billion pixels (2 000 Mpx vs 98 Mpx for Kepler) ~6 600 cm2 of sensitive area (2x Gaia)

The PLATO sky







The final observing strategy will be fixed ~2 yrs before launch and can be adapted during the mission.

Observing strategy

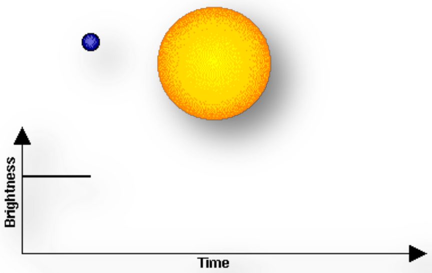
- **Baseline**
  2 long pointings of 2 years
- **Alternative**
  3 years + 1 year step-and-stare phase

Methods and goals

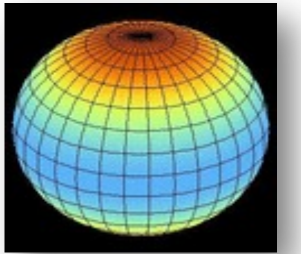
PHOTOMETRY FROM SPACE

SPECTROSCOPY FROM THE GROUND

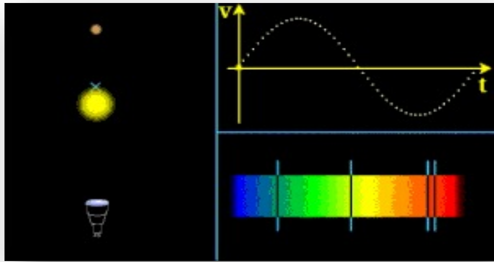
Transit Method



Asteroseismology



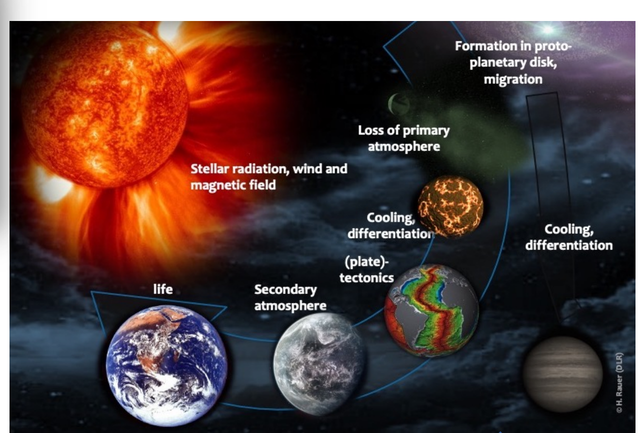
Radial velocity method



- → R_p/R_*
- → Orbital inclination
- → *Orbit parameters*

- → R_*
- → M_*
- → Stellar age

- → $M_p/M_* \sin i$



Mean Densities, Age

Evolution of planets & planetary systems, Habitability

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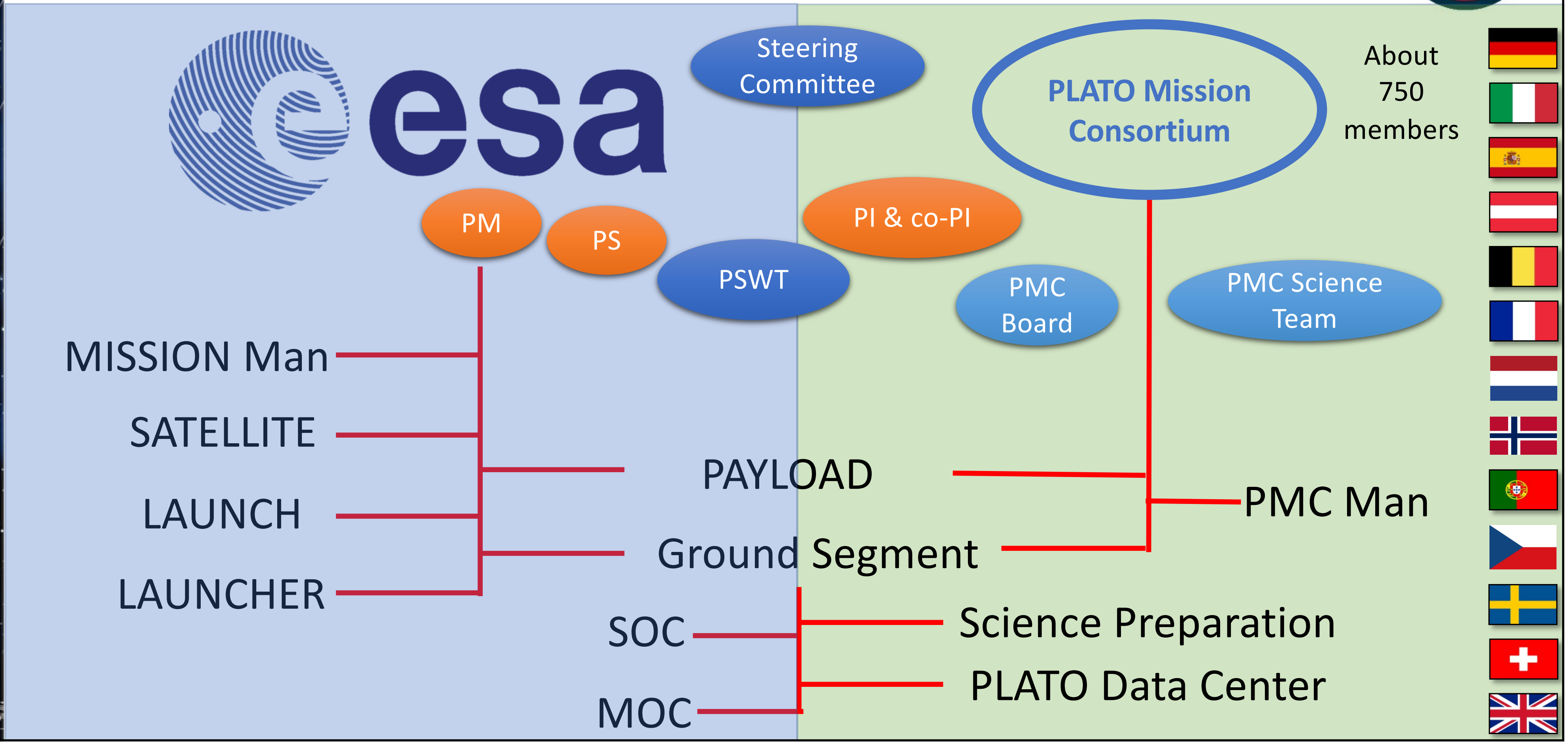
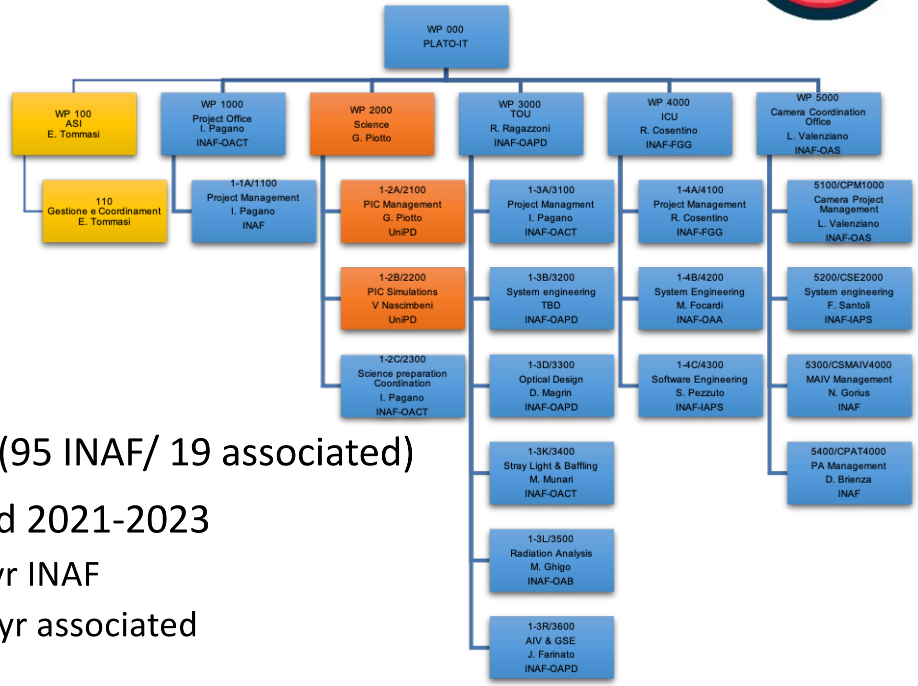
How PLATO is organised



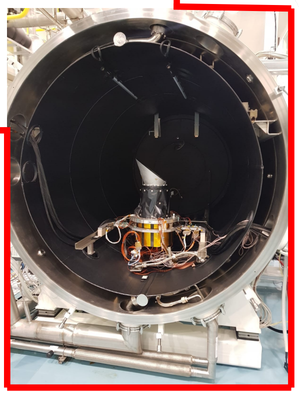
Il Team INAF (and associated)

- ✓ INAF
  - OA Catania Science, Payload
  - OA Padova Science, Payload
  - OA Brera Science, Payload
  - IAPS Roma Science, Payload
  - OAS Payload
  - FGG Payload
  - OA Palermo Science
  - OA Torino Science
  - OA Capodimonte Science
  - OA Roma Science
  - OAAB Science
  - OA Arcetri Science
- ✓ UNIPD, UNIBO, UNIPI Science
- ✓ SSDC PDC



- 114 people (95 INAF/ 19 associated)
- In the period 2021-2023
  - 15 FTE/yr INAF
  - 4.5 FTE/yr associated
- Distribution
  - 40 ➔ Payload
  - 72 ➔ PSM
  - 4 ➔ PDC (SSDC)

What we do for PLATO: PAYLOAD



Cameras System Management

TOUs

ICU

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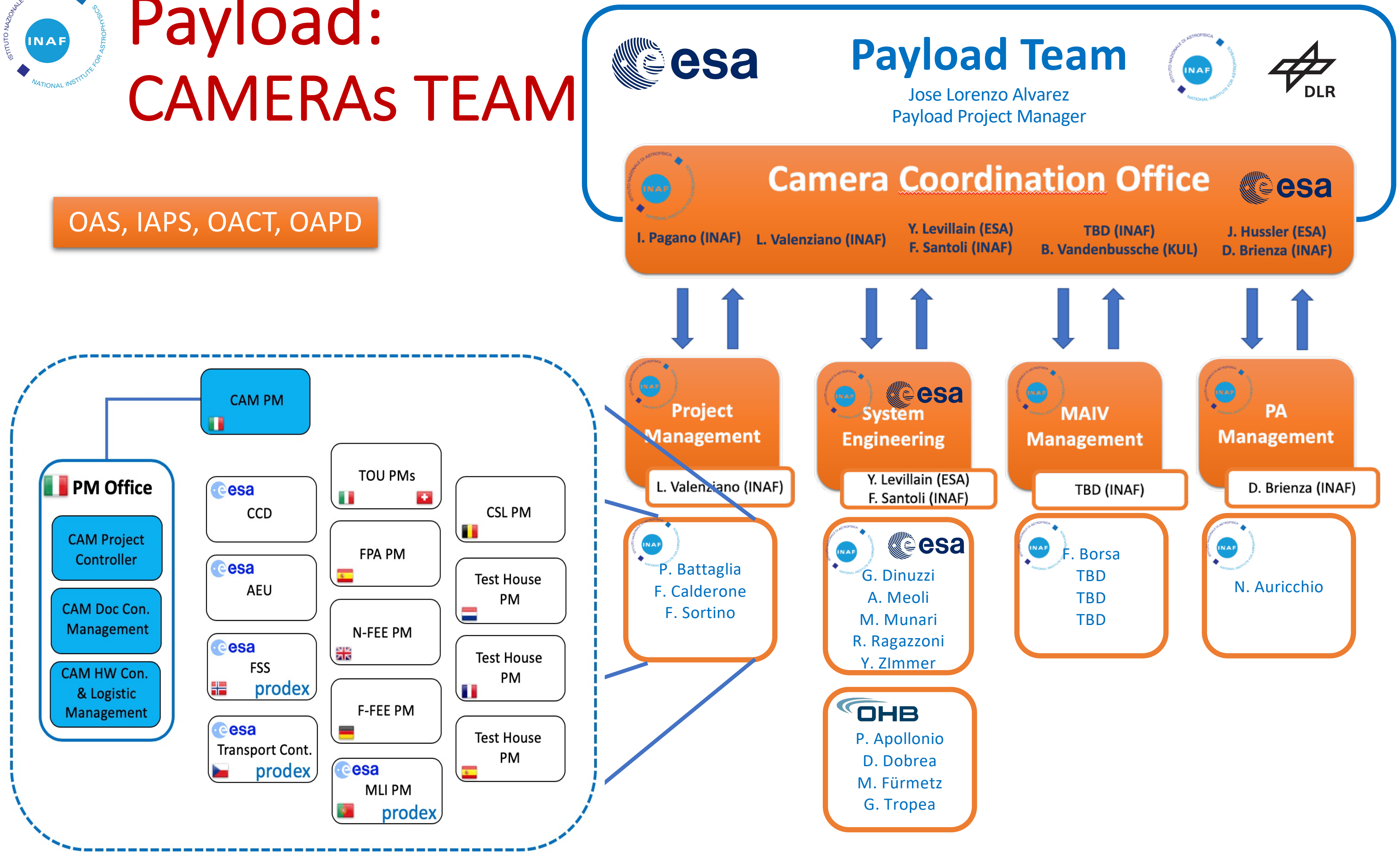
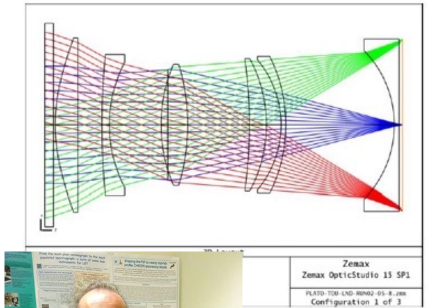
Payload: CAMERAs TEAM

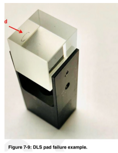
OAS, IAPS, OACT, OAPD



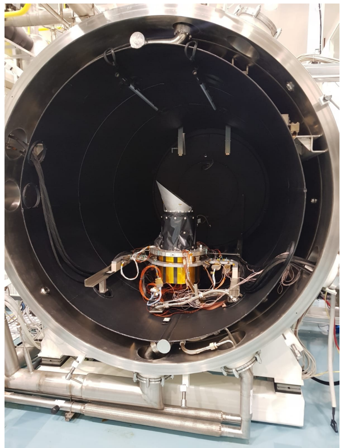
Telescope Optical Units Team

OACT, OAPD, OAB





STM →



← EM

PROJECT OFFICE

- TOU Project Manager — Isabella Pagano — INAF-OACT
- TOU Mechanical Structure Project Manager — Virginie Cessa — UBE
- F-TOU Filter Project Manager — Alexis Brandeker — UST
- TOU Document Configuration Man — Flavia Calderone — INAF-OACT
- TOU Mechanical Structure Product Assurance Manager
  - Configuration Control and Quality Control — Virginie Cessa — UBE
  - Material Parts & Process — Timothy Bandy — UBE
- TOU Instrument Scientist — Roberto Ragazzoni — INAF-OAPD
- TOU Mechanical Structure Scientist — Willy Benz — UBE
- TOU Product Assurance Manager — Simonetta Chinellato — INAF-OAPD
- TOU Project Office Assistant — Flavia Calderone — INAF-OACT
- F-TOU Filters Product Assurance Manager — TBD — UST

SYSTEM ENGINEERING

- TOU System Engineer — Valentina Viotto — INAF-OAPD
- Mechanical Structure System Engineer — Timothy Bandy — UBE
- TOU Interface Engineer — Maria Bergomi — INAF-OAPD
- Visualization and Rendering — Marco Dima — INAF-OAPD

DESIGN

- Chief Optical Engineer — Demetrio Magrin — INAF-OAPD
- Chief Mechanical Engineer — Daniele Piazza — UBE
- Mechanical Engineer — Timothy Bandy — UBE

ANALYSIS & PERFORMANCE

- Optical Engineer, Straylight Analysis — §Matteo Munari — INAF-OACT
- Optical Engineer, Radiation analysis — Mauro Ghigo — INAF-OAB
- Optical Engineer, Radiation analysis — Francesco Borsa — INAF-OAB
- Mechanical Engineer, Thermal Analysis — Stefano Basso — INAF-OAB
- Thermal Engineer, Thermal Analysis — Sebastian Wolf — UBE
- Mechanical Engineer, Structural Analysis — Martin Rieder — UBE
- Optical Engineer, Optical Performance — Demetrio Magrin — INAF-OAPD
- Optical Engineer, F-TOU Filter Performance — Göran Olofsson — UST

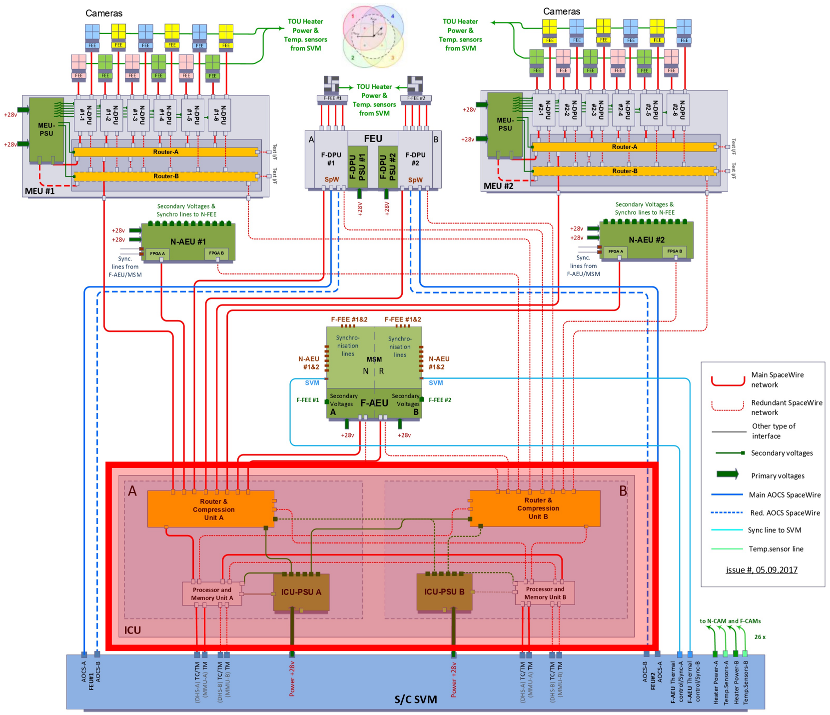
AIV & GSE

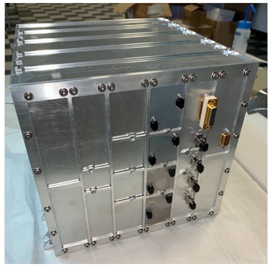
- Chief AIV Engineer — Jacopo Farinato — INAF-OAPD
- AIV Engineer — Maria Bergomi — INAF-OAPD
- AIV Engineer — Gabriele Umbriaco — INAF-OAPD
- AIV Engineer — Daniela Vassallo — INAF-OAPD
- Structural Tests Engineer — Daniel Schaedeli — UBE
- Chief GSE Engineer — Luca Marafatto — INAF-OAPD
- AIV support — Florian Hosttettler — UBE

Serial Production already started
1 PFM 25 FM, 5 FS

LEONARDO AIRBORNE & SPACE SYSTEMS · ThalesAlenia Space · Media Lario · Universität Bern · Stockholms Universitet · HST · TRIOPTICS · ASI Agenzia Spaziale Italiana

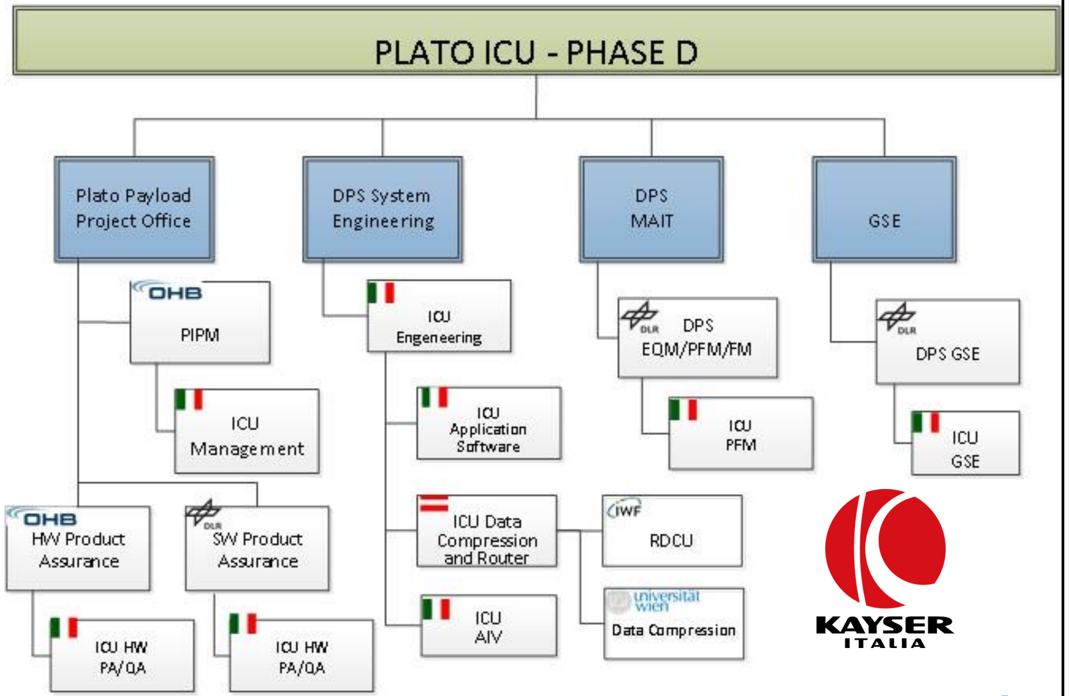
Payload: ICU Team





OAA, IAPS, TNG

← *ICU EM#1*



KAYSER ITALIA

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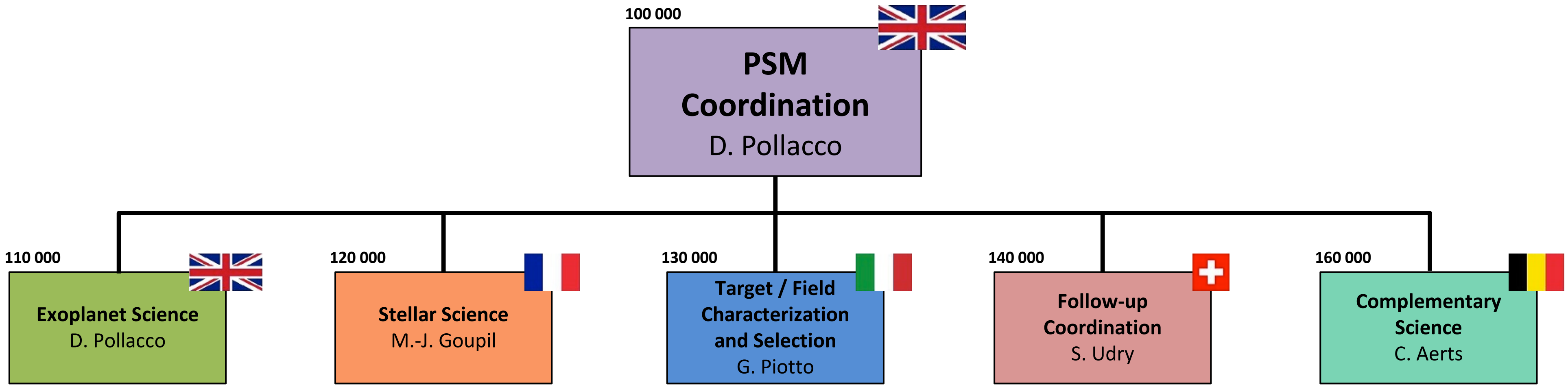
Science Preparation

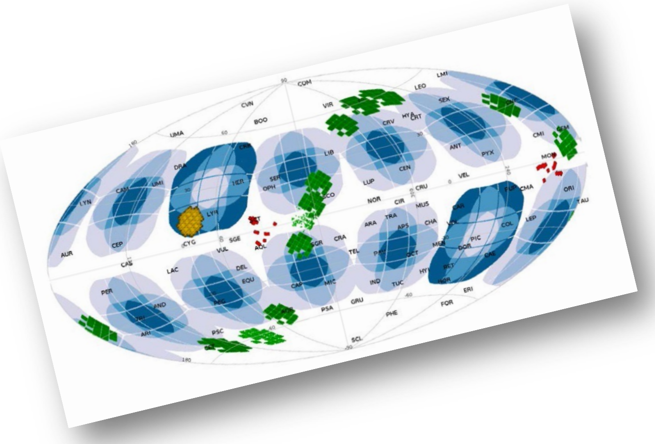


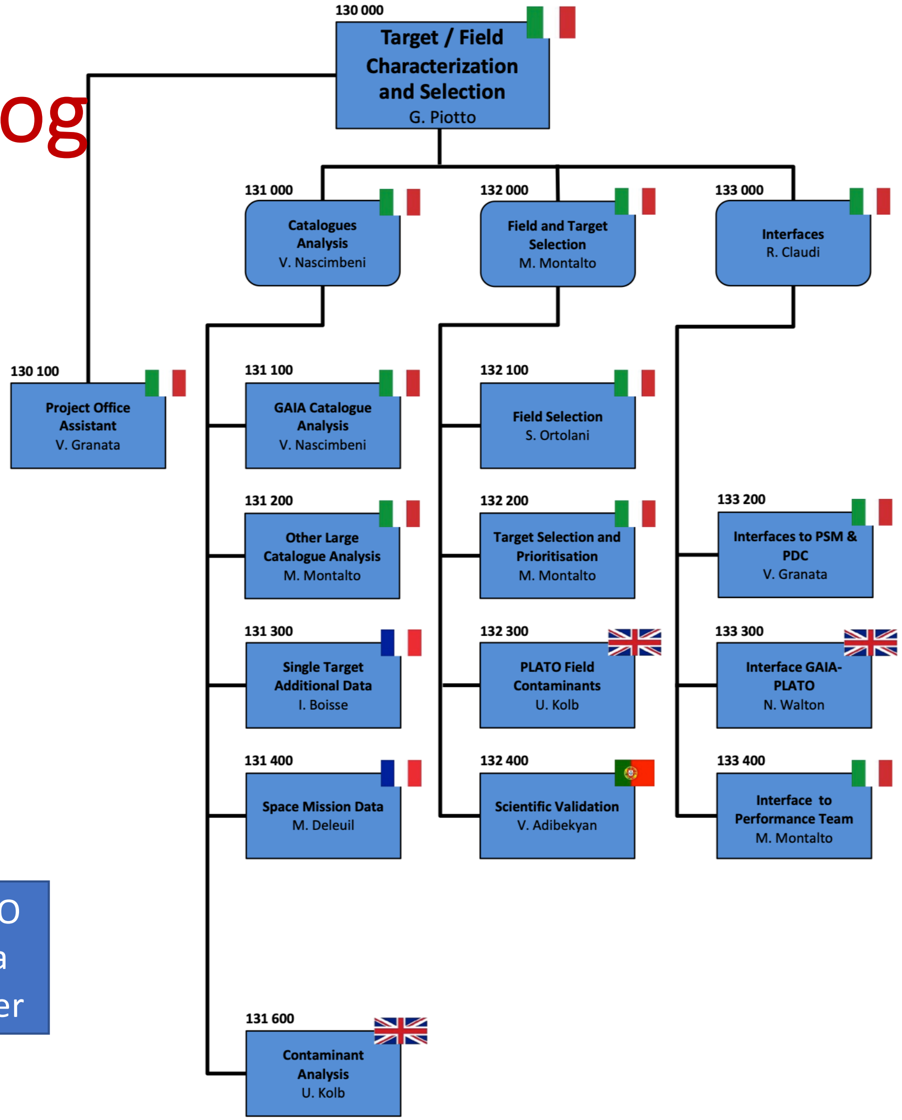
EXO-Arch
EXO-Young
EXO-SPI

EXO-Stars

RSN2
RSN3
RSN4

PLATO Input Catalog





PLATO INPUT CATALOG

UNIPD, OAPD, OAPA, OACT e **SSDC**

PLATO Data Center

The all sky PLATO Input Catalogue
AA/2021/40717

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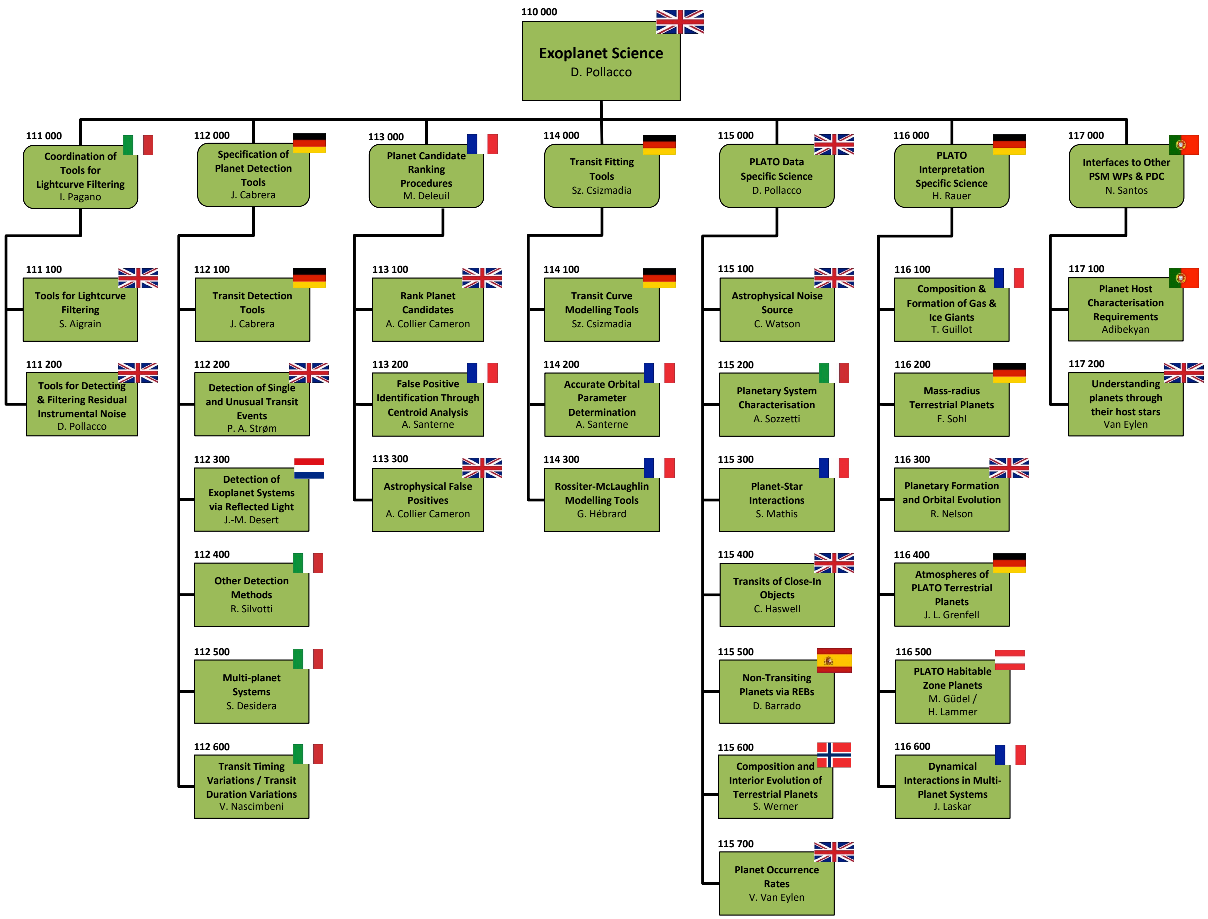
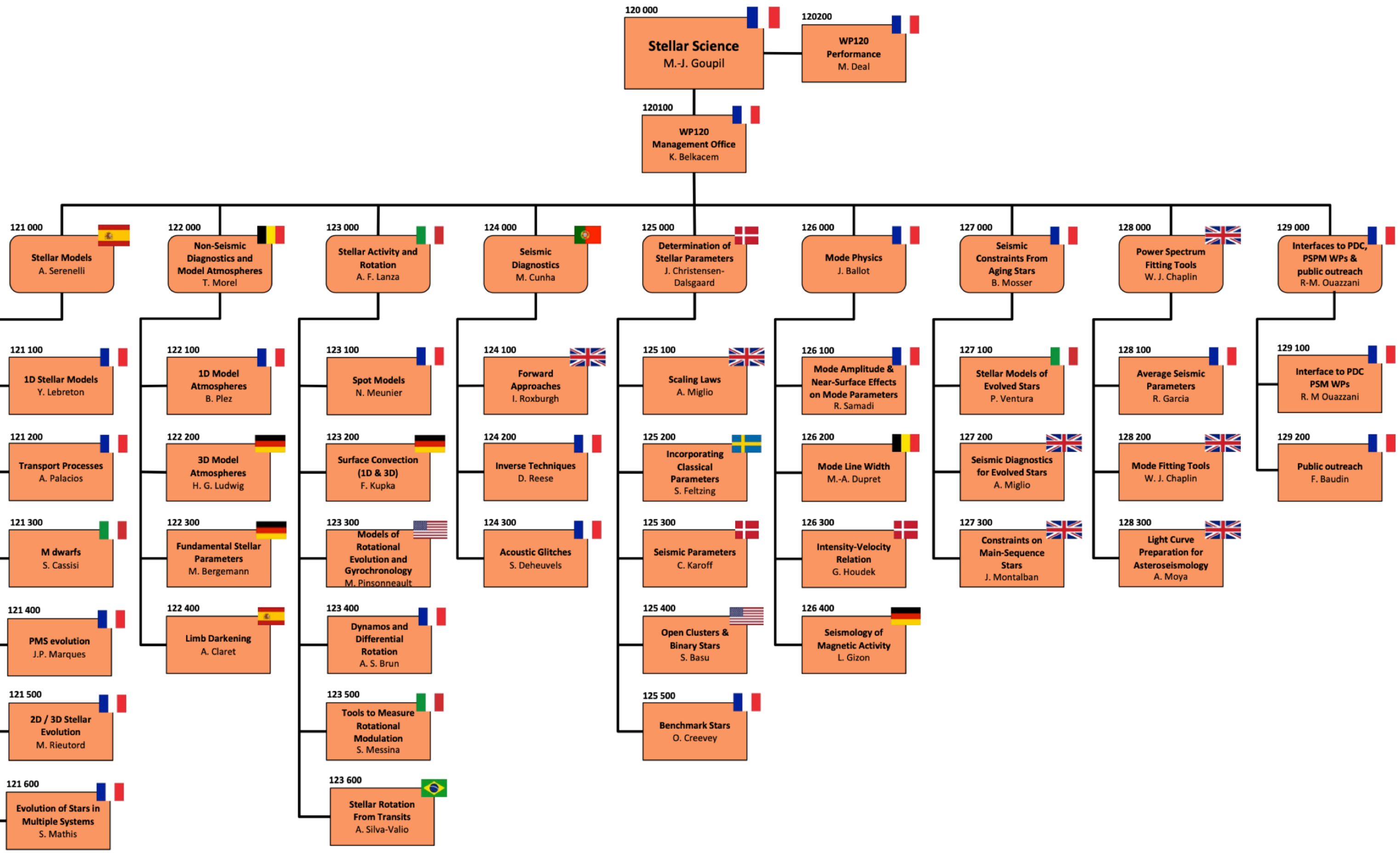
Exoplanets Science preparation



Stellar Science Preparation



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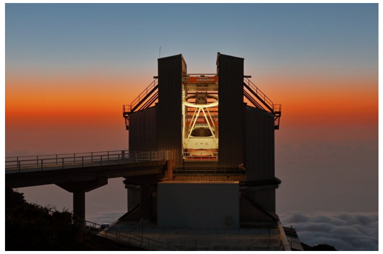
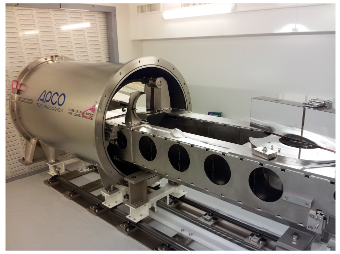
Follow-up Preparation

140 000 Follow-up Coordination — S. Udry

- **141 000 Strategy and Operation Preparation** — D. Pollacco
  - 141 100 Target Distribution Requirements — I. Ribas
  - 141 200 Aids for Optimizing Photometric and Spectroscopic Measurements — J. Colomé
  - 141 300 Information Transfer — F. Villardell
  - 141 400 Planet Yield Determination — Y. Alibert
- **142 000 RV Follow-Up** — F. Bouchy
  - 142 100 Radial Velocity Computation and Global Analysis Tools — D. Segransan
  - 142 200 First Radial Velocity Screening [≥10 m/s] — E. Guenther
  - 142 300 Intermediate Precision Radial Velocity Follow-Up [3-5 m/s] — C. Moutou
  - 142 400 Very High-Precision RV Measurements [≤1 m/s] — F. Pepe
  - 142 500 Infrared Radial Velocity Measurements — T. Forveille
- **143 000 Time Critical Photometry** — R. Alonso
  - 143 100 Photometry Specific Tools — H. Deeg
  - 143 200 Photometric Follow-Up with Small Telescopes — G. Wuchterl
  - 143 300 Standard Photometric Observations — R. Alonso
  - 143 400 Very High Precision Photometric Observations — E. Palle
- **144 000 Higher Angular Resolution Imaging** — S. Desidera
  - 144 100 Imaging Analysis Tools — A. Vigan
  - 144 200 Single-Epoch Seeing-Limited Imaging — V. Nascimbeni
  - 144 300 Reconnaissance High Resolution Imaging — M. Janson
  - 144 400 High Contrast Imaging — D. Mesa
  - 144 500 Candidate Classification — M. Bonavita
- **145 000 Additional Exoplanet Follow-Up** — X. Bonfils
  - 145 100 Transmission Spectroscopy Follow-up — D. Ehrenreich
  - 145 200 Secondary Eclipse and Phase Variation Spectroscopy — R. Alonso
  - 145 300 Developing Techniques for Atmosphere Characteristation — X. Bonfils
  - 145 400 Rossiter-McLaughlin Effect — G. Hébrard
  - 145 500 Additional Long Term Follow-Up (RV and Transit Timing) — F. Bouchy
- **146 000 Spectroscopy** — A. Hatzes
  - 146 100 Activity Indicators and Doppler Information on Active Stars — C. Lovis
  - 146 200 Tools for Spectral Classification — L. Buchhave
  - 146 300 Infrared Spectroscopy — P. Figueira
  - 146 400 Spectropolarimetric Follow-up — P. Petit
- **147 000 Perfomances Assessment and Follow-Up Efficiency** — S. Udry
- **148 000 Interfaces to Other PSM WPs and PDC** — S. Udry





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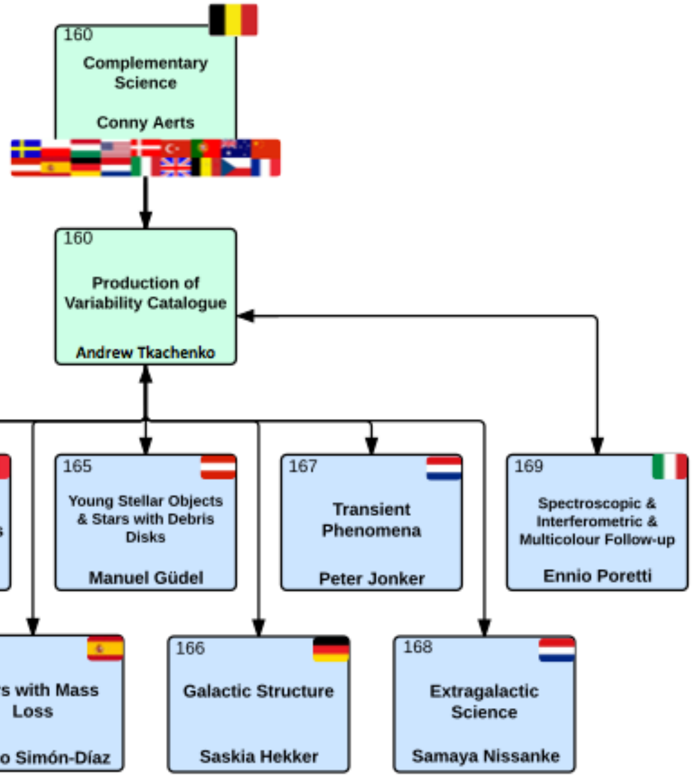
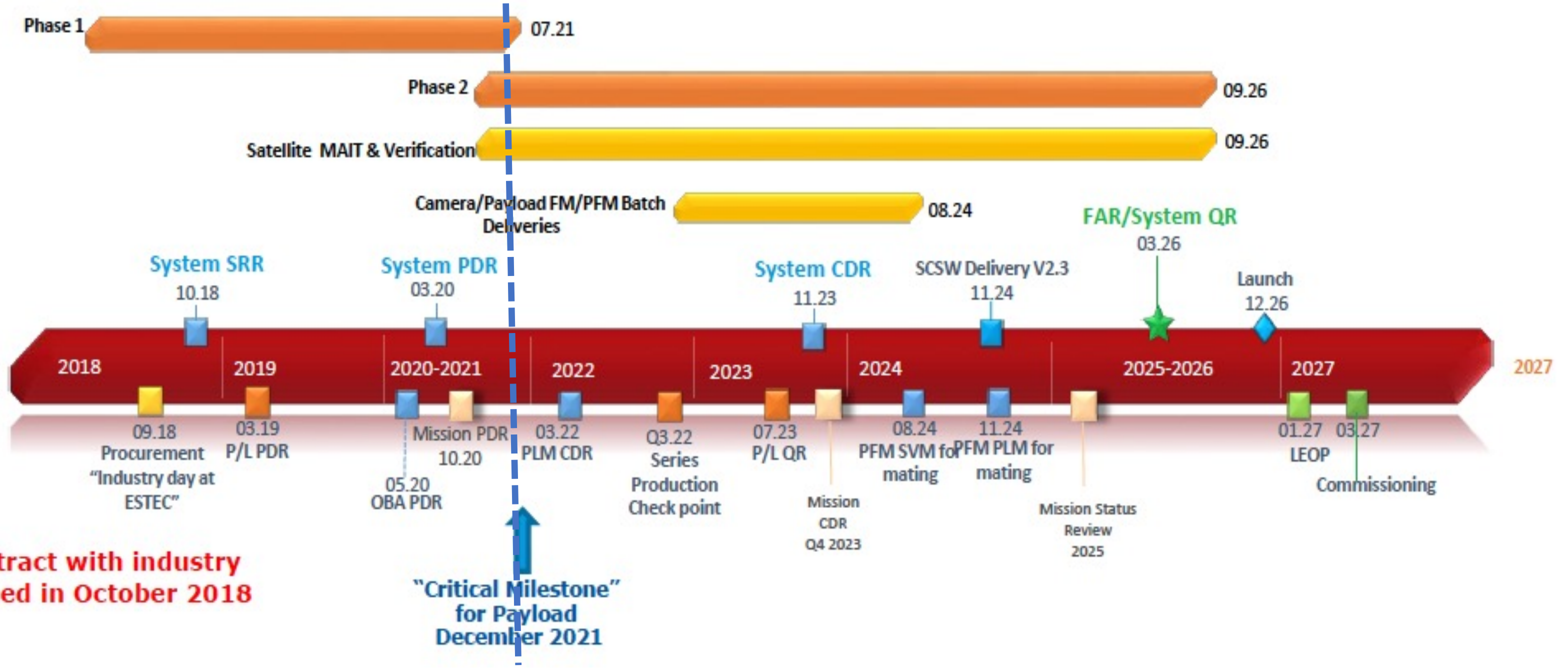
Complementary Science



Programmazione

PLATO Timeline

TOU → CDR going on
ICU → CDR ready to start
Critical Milestone → KOM July 2021



Contract with industry signed in October 2018

Leadership

esa

Steering Committee

PM

PSWT

12 members including:
I. Pagano, INAF
G. Piotto, UNIPD
R. Ragazzoni, INAF

PAYLOAD
Camera Team

L. Valenziano
F. Santoli
N. Gorius
D. Brienza

PLATO Mission Consortium

About 750 members

PI & co-PI

PI: H. Rauer, DLR
Co-PI: I. Pagano, INAF
Co-PI: M. Mass-Hesse, INTA

PMC Board

PMC Science Team

Co-Is (TBD)

20 members including:
I. Pagano, INAF
G. Piotto, UNIPD

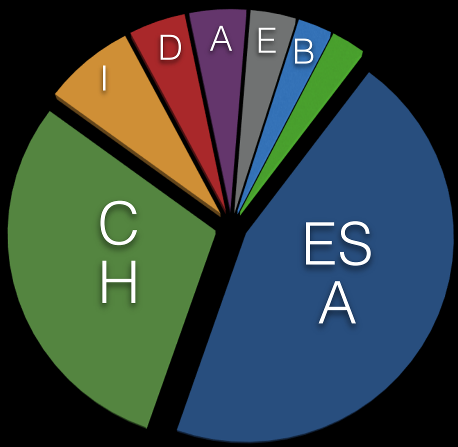
CHEOPS

Isabella Pagano e Valerio Nascimbeni

S-class mission:

S is not for “Simple”

“Small” Budget



- total budget: ~105 M€
- ESA: 50 M€

Short time

milestone	when
call issued	Mar 2012
call answered	Jun 2012
mission selected	Nov 2012
mission adopted	Feb 2014
instrument delivered	Feb 2019
launch	Dec 2019

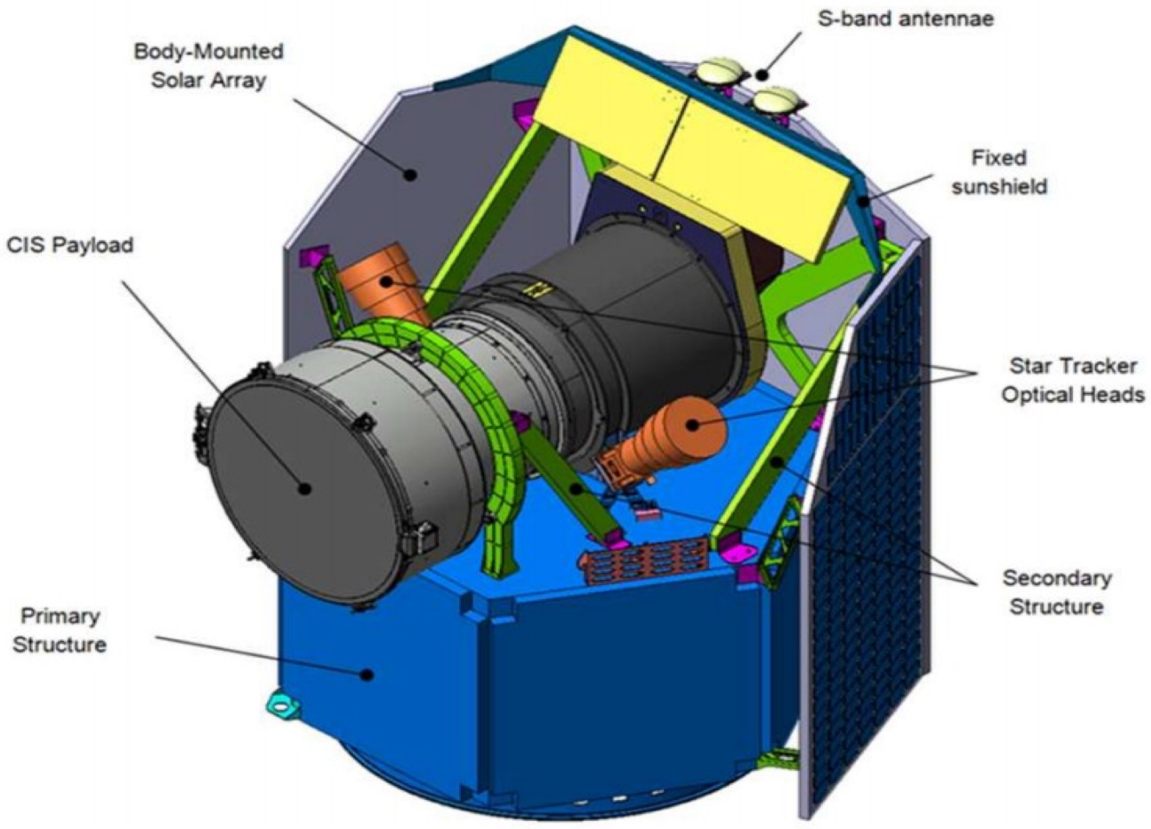
- 4–5 years development time

Several countries

- 11 countries & ESA
- ~30 institutions

Top Science was expected and is actually done!

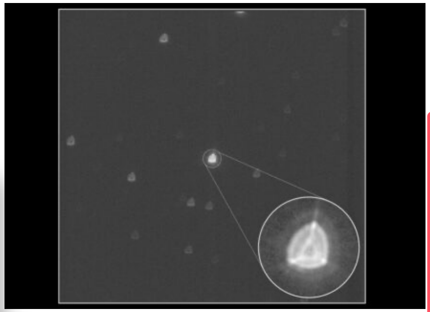
Il Satellite CHEOPS



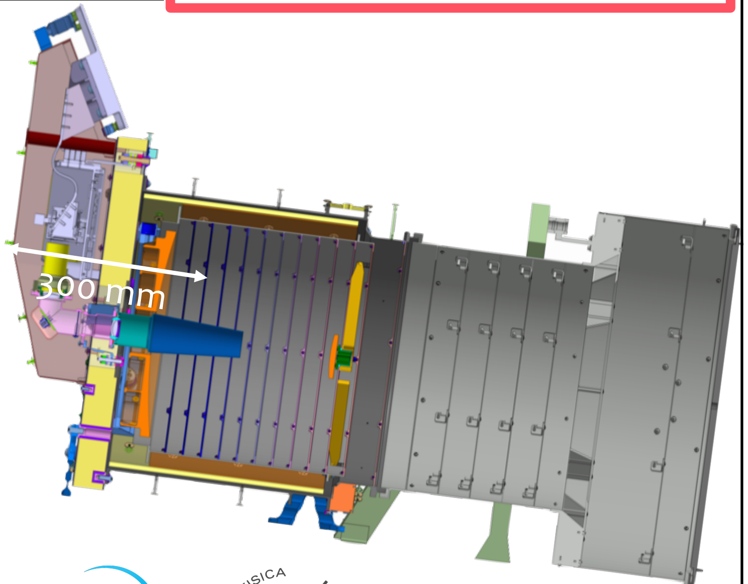
From Europe to Kourou

cheops

Il Telescopio



Progetto ottico
Costruzione delle ottiche
Integrazione dello strumento
Test funzionamento e prestazioni



Diametro dello specchio: 33 cm
Peso strumento: 60 kg

UNIVERSITÄT BERN
Agenzia Spaziale Italiana
ISTITUTO NAZIONALE DI ASTROFISICA
LEONARDO AIRBORNE & SPACE SYSTEMS


Isabella Pagano
INAF Catania
Resp. Nazionale
Project Manager del Telescopio
Membro del Board
Roberto Ragazzoni
INAF Padova
Instrument Scientist del Telescopio
Membro del Board
Giampaolo Piotto
Univ. Padova
Membro dello Science Team
Valerio Nascimbeni
INAF Padova
Membro dello Science Team
Gaetano Scandariato
INAF Catania
Membro dello Science Team
Luca Borsato
INAF Padova
Team Scientifico
Giuseppe Leto
INAF Catania
Team Scientifico
Giovanni Bruno
INAF Catania
Team Scientifico
LEONARDO
THALES
Media Lario
INAF
Vikash Singh
Univ. Catania
INAF Catania
Team Scientifico
Daniela Sicilia
Univ. Padova
INAF Catania
Team Scientifico
Elisabetta Tommasi
ASI
Resp. Accordo Scientifico
Mario Salatti
ASI
Project Manager
Contratto Industriale
Steering Committee
Marco Dima
INAF Padova
Rendering
Davide Greggio
INAF Padova
Progetto Ottico
Luca Marafatto
INAF Padova
Progetto Ottico
Valentina Viotto
INAF Padova
System Engineer del Telescopio
Demetrio Magrin
INAF Padova
Progetto Ottico del Telescopio
Matteo Munari
INAF Catania
Analisi Luce Diffusa
Jacopo Farinato
INAF Padova
Interfacce del Telescopio
Maria Bergomi
INAF Padova
AIV del Telescopio
Federico Biondi
INAF Padova
AIV del Telescopio

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The Team

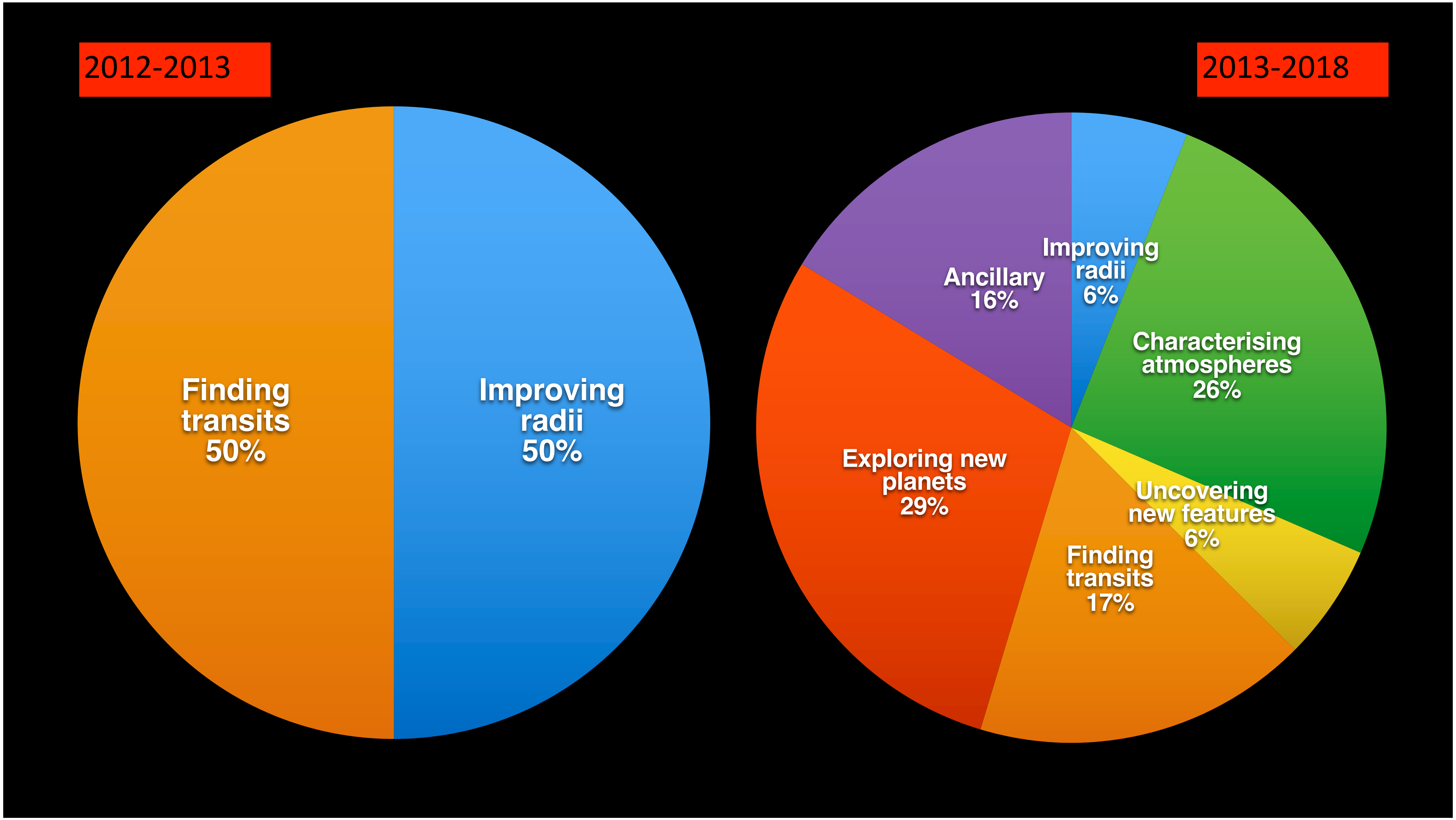
INAF

- OACT
- OAPD
- OAPA
- OATO
- FGG

- 28 people (23 INAF/ 5 associated)
- In the period 2021-2023
  - 5 FTE/yr INAF
  - 1.5 FTE/yr associated

UNIPD

SSDC


2012-2013
Finding transits 50%
Improving radii 50%
2013-2018
Improving radii 6%
Ancillary 16%
Characterising atmospheres 26%
Exploring new planets 29%
Uncovering new features 6%
Finding transits 17%

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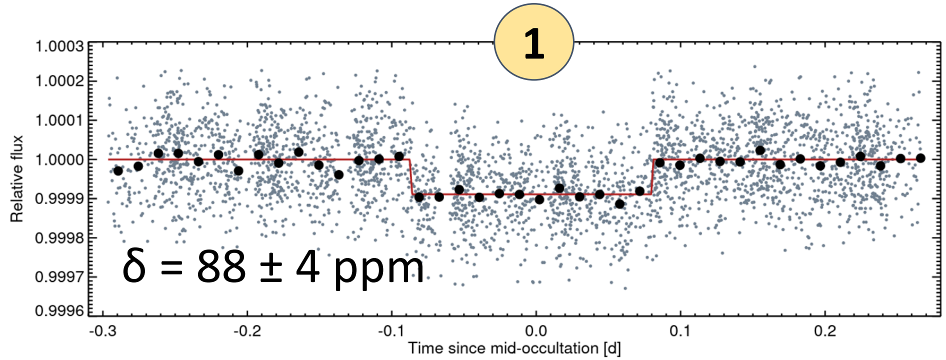
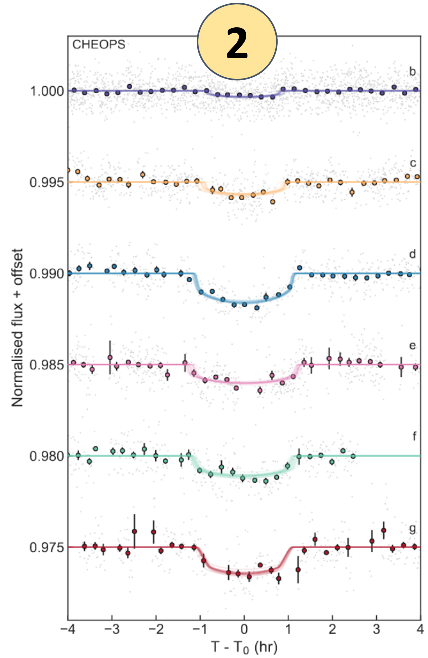
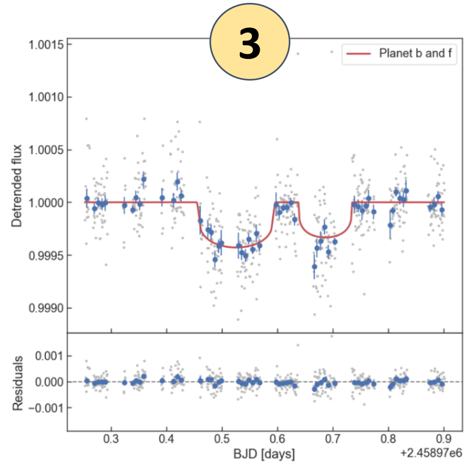
Some early science results

1) Measurement of the dayside temperature (3435±27 K) and true orbital obliquity (Ψ=85°±4°) of the hot-Jupiter WASP-189b (Lendl+ 2020)
2) Full reconstruction of the dynamical architecture of a six-planet system locked in a chain of Laplace resonances (2:4:6:9:12), including mass and density measurements (Leleu+ 2021)
3) Discovery of an additional 2 $R_\oplus$ planet in a multiple system hosted by the bright star HD 108236 (Bonfanti+ 2021)







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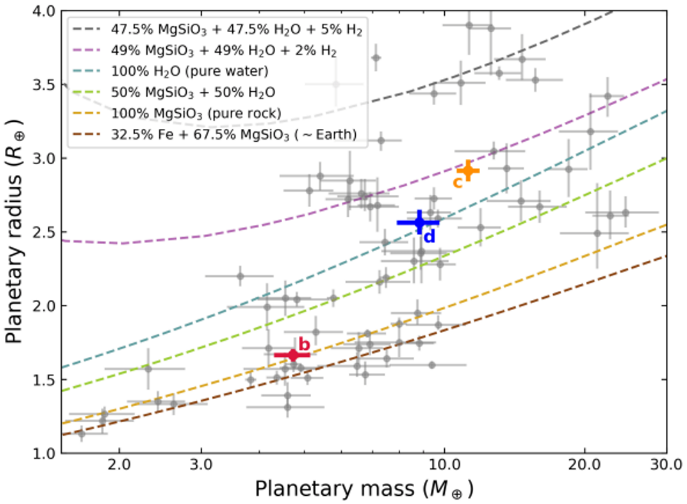
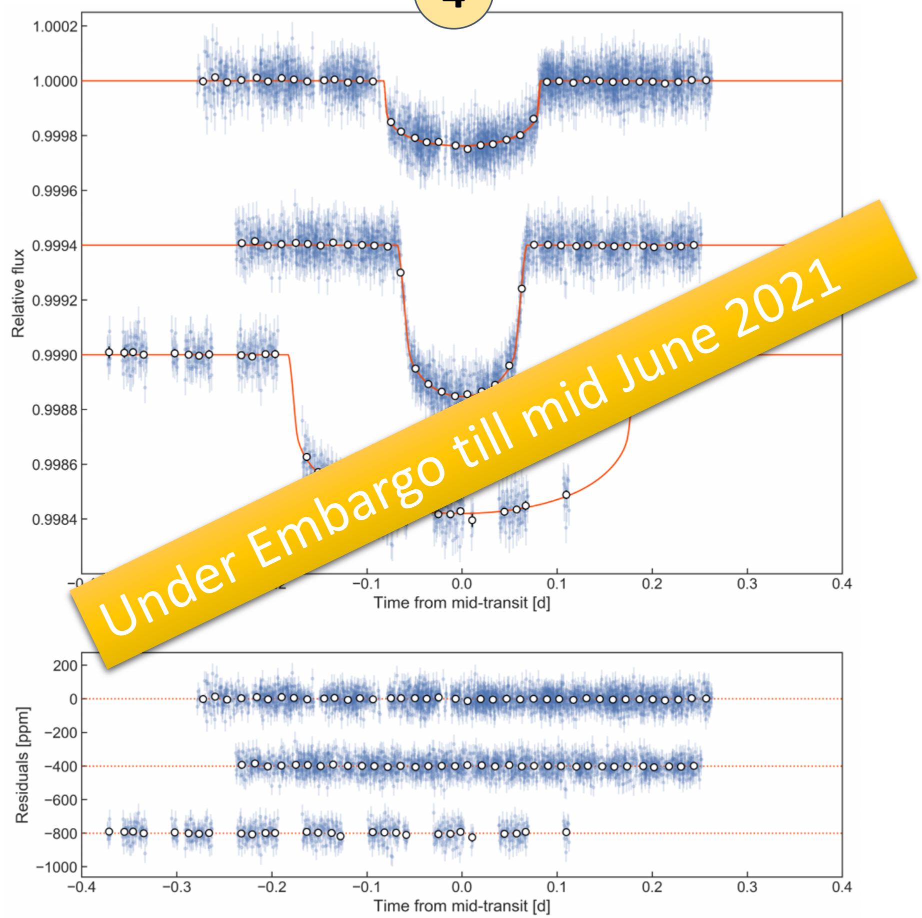
Some early science results

4) Characterization of a planetary system hosted by a naked-eye star (Nu2 Lup), including the discovery of a transiting, mildly-irradiated super-Earth amenable of a detailed atmospheric characterization (Delrez+ 2021, Nature Astronomy, in press).

4



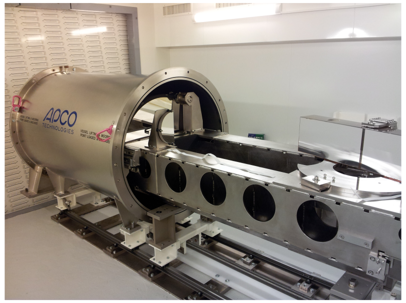
4



Criticità

- Ricercatori e ingegneri di altissimo profilo
  - competenze maturate all'interno e all'esterno dell'ente.
  - E' fondamentale trattenere all'interno queste competenze spesso difficili da reperire.

- Per mettere a frutto un giusto ritorno dell'investimento prodotto dalla nostra nazione nel progetto occorre avere una generazione di ricercatori e ricercatrici pronti all'utilizzo dei dati della missione.
  - Il campo esopianeti è molto attrattivo per i giovani a inizio di carriera.
  - Occorre non farli scappare e essere capaci di attrarne da fuori.



- Per PLATO un aspetto che farà la differenza durante la fase operativa sarà **la capacità di partecipare da leader alla campagna ground based di follow-up**, che è parte intrinseca della missione.
- L'INAF parte in condizione di vantaggio grazie alla presenza di **HARPS-N al TNG**. Occorre che esso sia disponibile a INAF quando PLATO sarà operative.

Punti di forza

- L'Italia è al top sui sistemi ottici per lo spazio: **sinergia da rafforzare tra INAF e aziende**
- La comunità esoplanetologica italiana, che si è aggregata intorno al 2009 proprio grazie alla selezione di **PLATO** da parte di ESA per lo studio di fattibilità, e che ha proseguito insieme a crescere con l'opportunità giunta nel 2012 quanto la dirigenza INAF ha chiesto di valutare la proposta di installare **HARPS-N al TNG**, è oggi numerosa, rilevante a livello internazionale, piena di giovani promettenti, e coinvolta oltre che in PLATO in progetti di punta per lo studio degli esopianeti quali le missioni **Cheops** e **Ariel,** gli strumenti **Espresso**, **SHARK-VIR** e **SHARK-NIR**, spaziando dallo studio delle architetture e proprietà fisiche dei sistemi planetari (**EXO-Arch**), alla formazione ed evoluzione iniziale degli stessi (**EXO-Young**), alle atmosfere dei pianeti (**EXO-Atm**), alle caratteristiche dell'interazione stella-pianeta (**EXO-SPI**), allo studio delle proprietà stellari che servono a vincolare con precisione i parametri planetari (**EXO-Stars**).
- Questa comunità è cresciuta grazie ai finanziamenti ricevuti dai **Progetti Premiali WOW (PI. G. Micela)** e **FRONTIERA (PI I. Pagano)** che sono stati gestiti in modo da includere e rafforzare il tema di ricerca e creare massa critica per incidere nell'ambito delle collaborazioni internazionali.
- Altri finanziamenti sono stati ottenuti grazie **a PRIN INAF, PRIN Universitari e bandi ASI** più specificatamente mirati a focalizzare precisi temi di ricerca.
- Assicurare continuità nei finanziamenti della ricerca di "oggi" per essere sempre più preparati a quella di "domani" è una delle criticità più rilevanti anche per PLATO.