PLATO

the ESA M3 mission

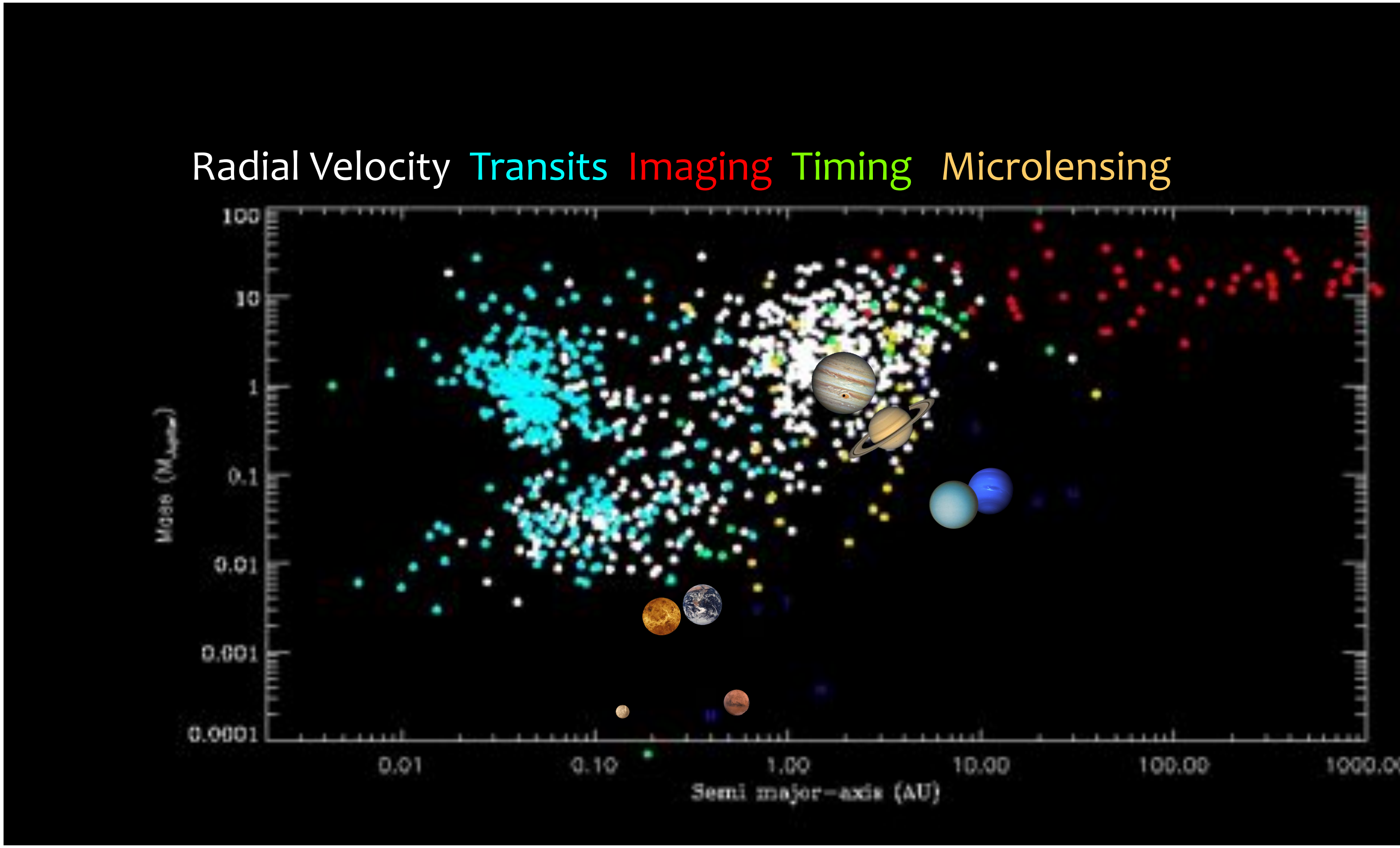
in the Cosmic Vision 2015-25

Isabella Pagano
INAF - Osservatorio Astrofisico di Catania

and the PLATO Mission Consortium

esa

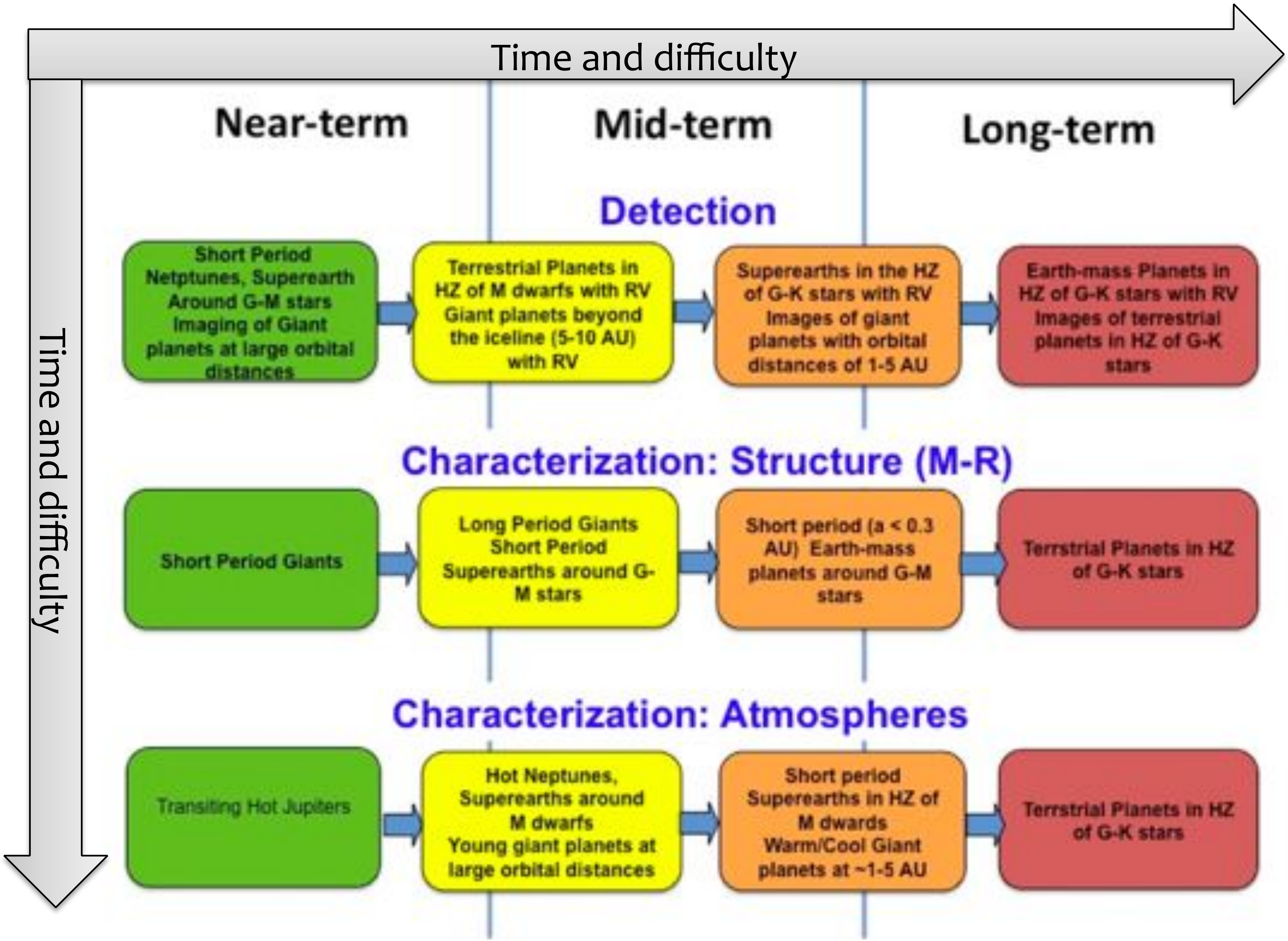
Detections



Planets data from http://exoplanet.eu/ up to May 2015

The EP-RAT Roadmap

ESA EXOPLANET ROADMAP ADVISORY TEAM – Oct 2010

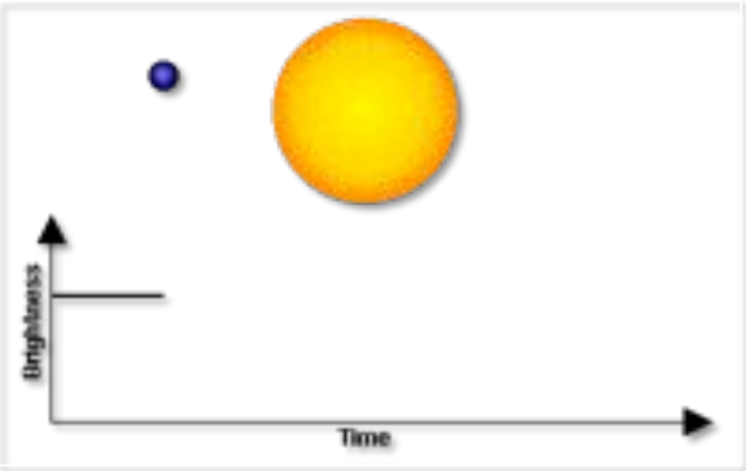


Full characterization

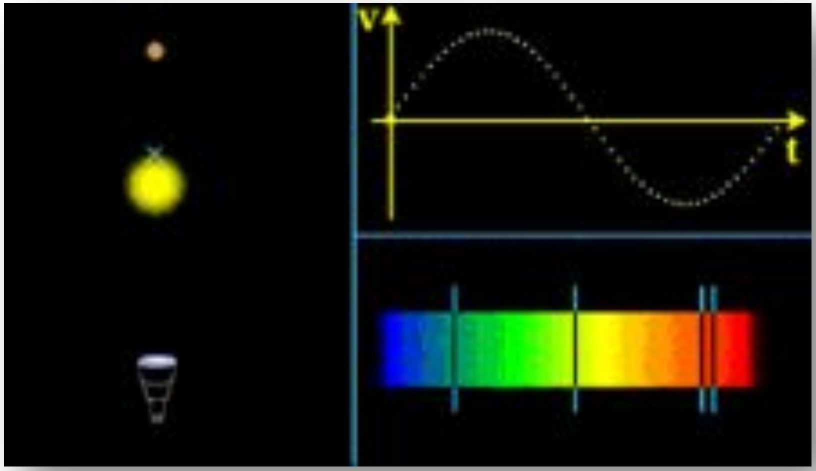
RADIAL VELOCITY AND TRANSITS

RV & Transits: the power of complementarity

Transit Method



Radial velocity method



$$K = \left(\frac{2\pi G}{P}\right)^{1/3} \frac{M_P \sin i}{(M_\star + M_P)^{2/3}} \frac{1}{\sqrt{1-e^2}}$$

- Orbit parameters
- Orbital inclination, ***i***
- Planet radius, R_p

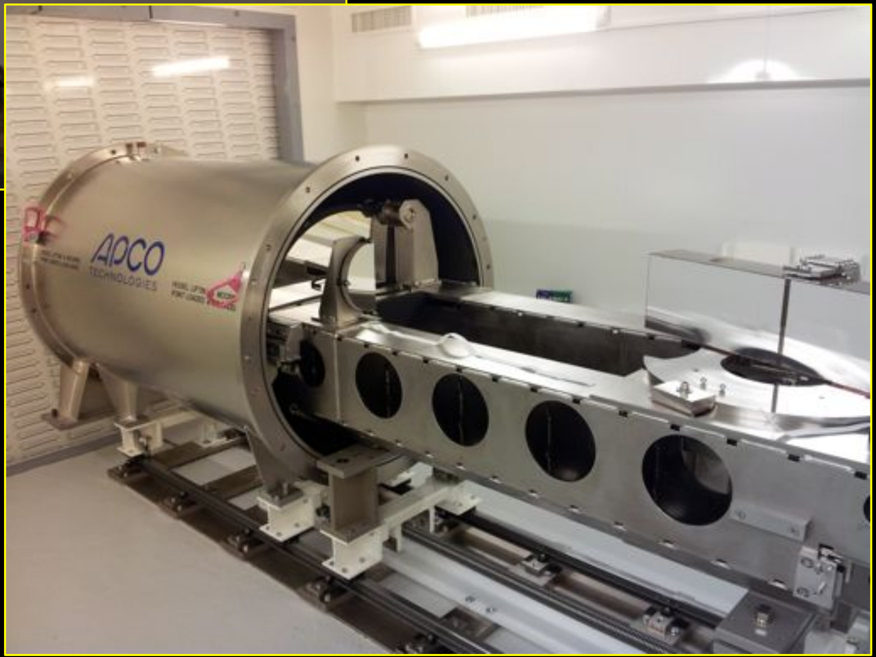
$$\frac{\Delta F}{F} = \left(\frac{R_p}{R_*}\right)^2$$

- Orbital parameters
- Minimum planet mass, $M_p \sin i$

$$K \propto M_p / M_*^{2/3}$$

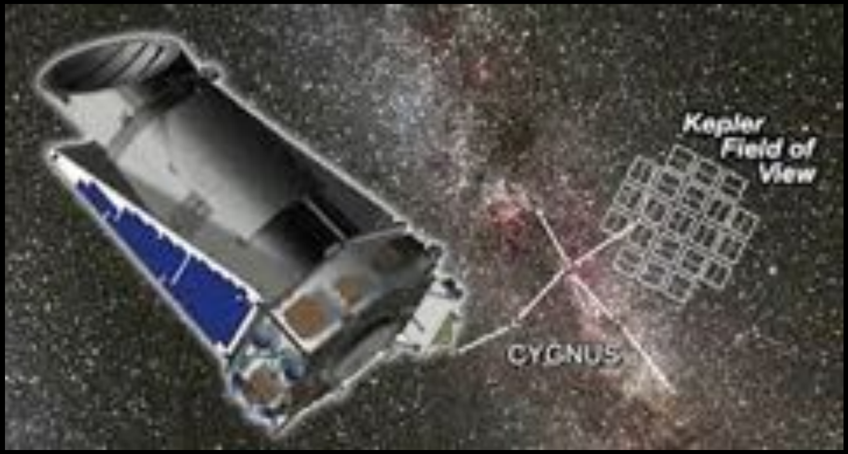
True planet mass and mean density

Telescopio
Nazionale
Galileo



HARPS- N

The Kepler revolution



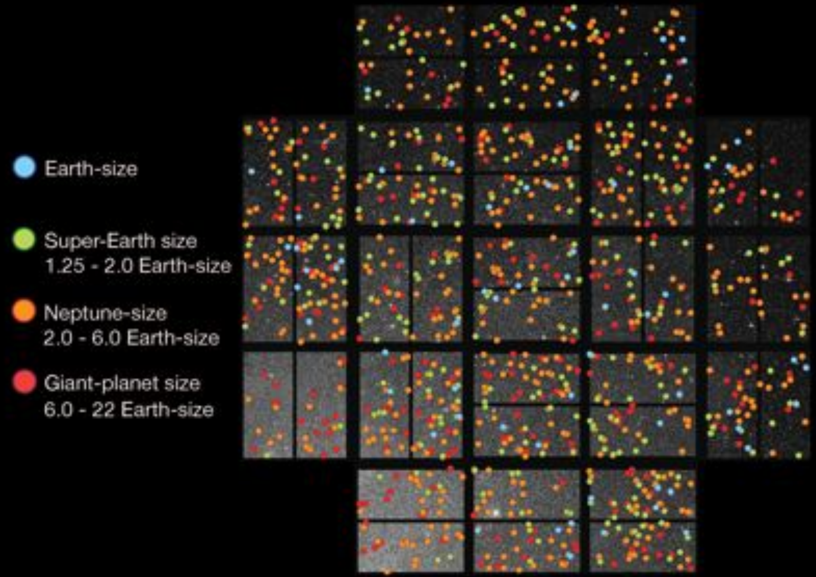
- Launched in 2009
- Still working as K2

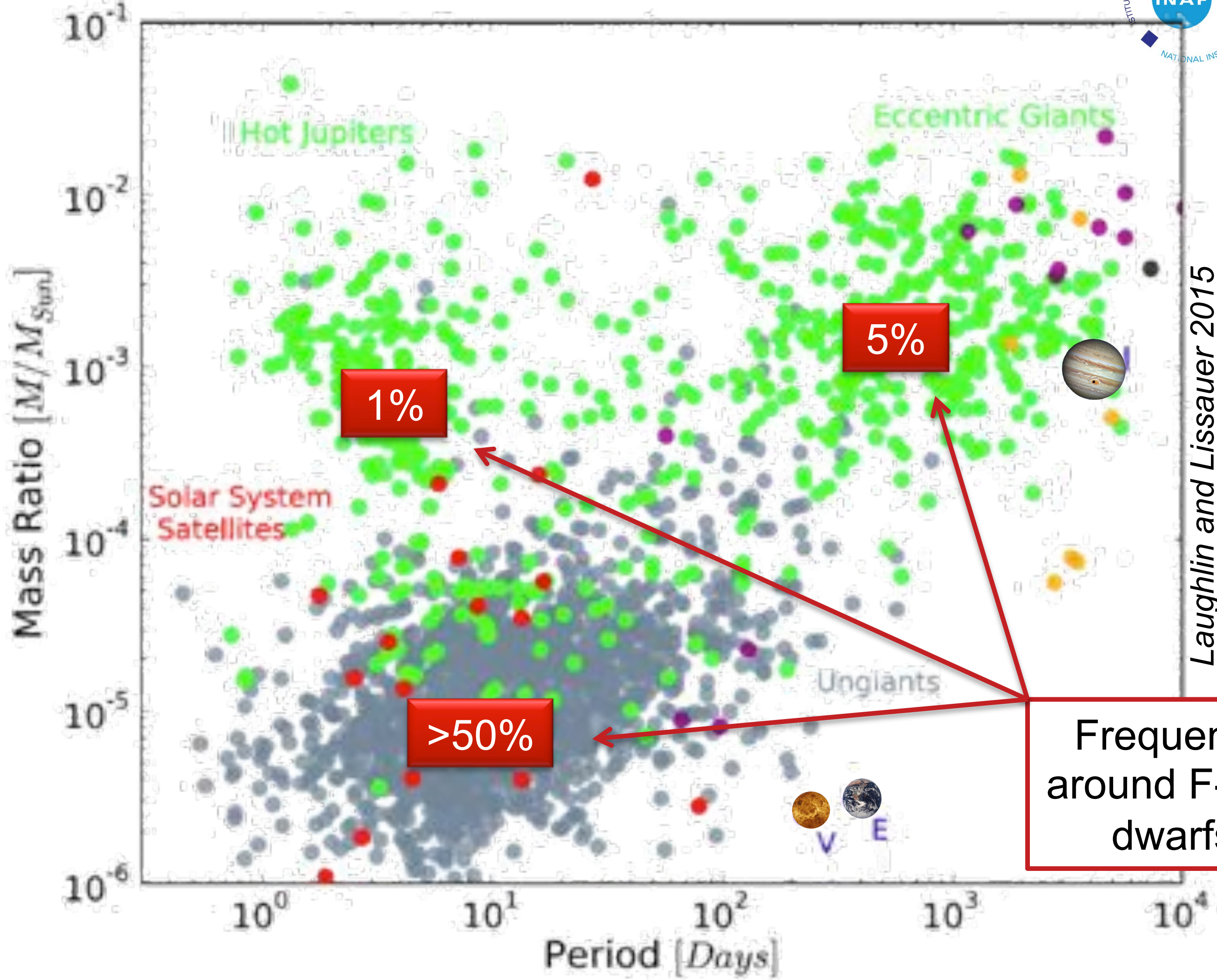
- FoV ~100 sqdeg
- (0.25 % of the sky)

- ~ 145 000 stelle

➡ 4706 planet candidates
➡ 2327 confirmed planets

http://kepler.nasa.gov

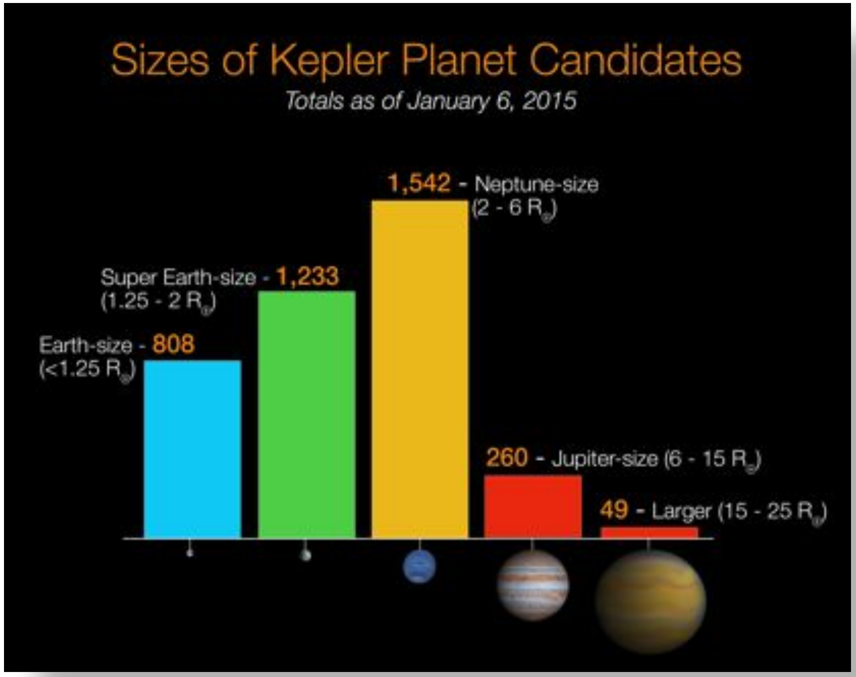




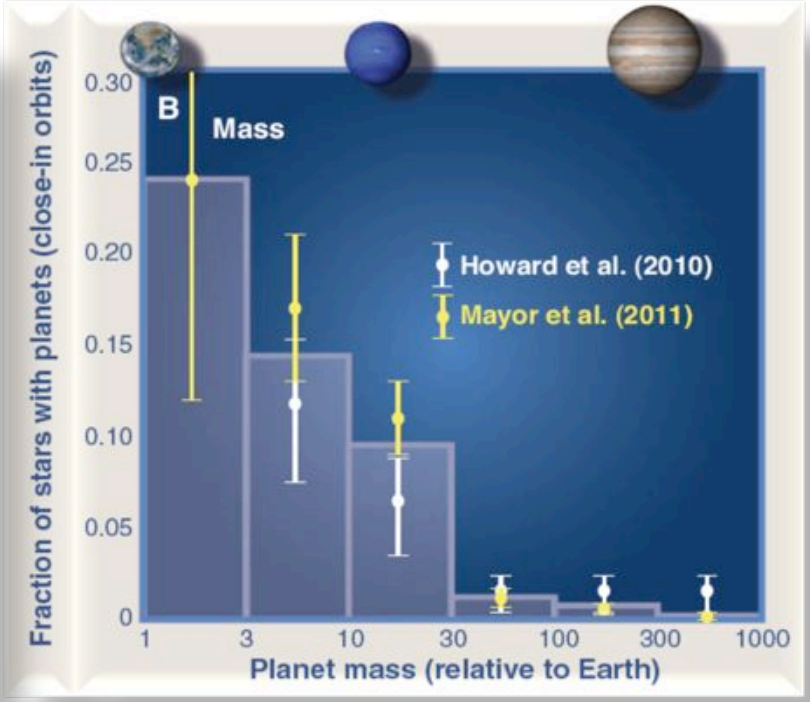
Frequency around F-G K dwarfs

Small planets are common

Size from Kepler



Mass from Radial Velocity Survey



BUT mass and radius mostly come from different techniques: few objects with both measurements

Small planets are common

Size from Kepler

Mass from Radial Velocity Survey

Half of the Sun-like stars in the solar neighborhood are accompanied by systems of one or more planets with

periods ranging from days to months

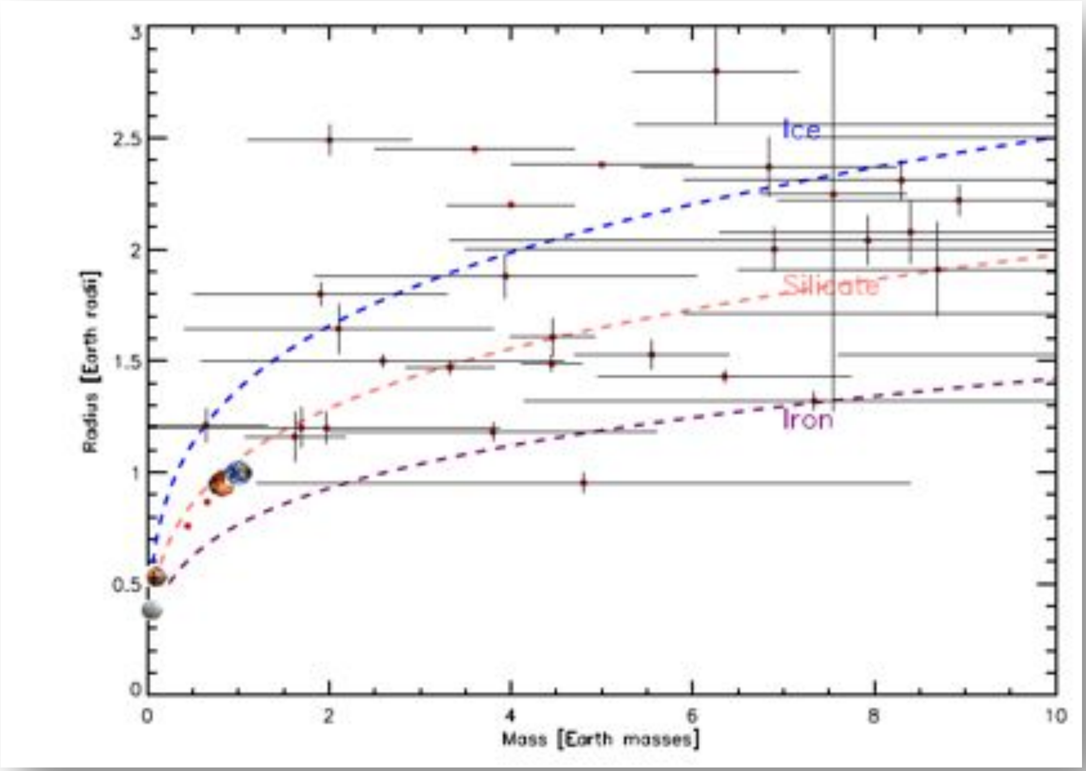
&

masses in the $1\ M_E < M_P < 50\ M_E$ range

(Mayor et al. 2009, 2011)

BUT mass and radius mostly come from different techniques: few objects with both measurements

From CoRoT, Kepler and Most → Diversity of super-Earths



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

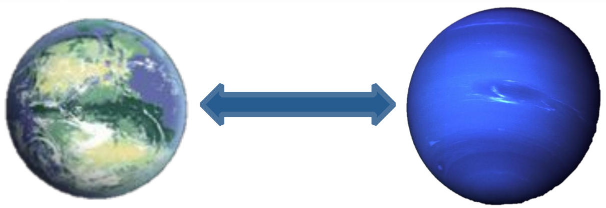
→ **Accurate masses & radii are required to separate terrestrial from mini-gas planets**

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



Searching for Habitability requires:

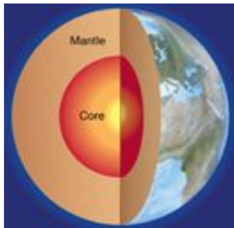
➢ accurate mean densities to identify terrestrial planets

➢ bulk characterize targets for atmosphere spectroscopy follow-up

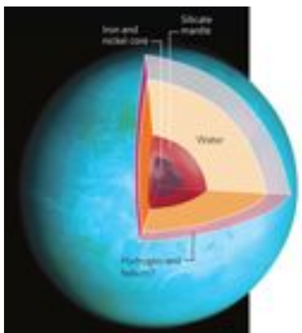
Planet diversity

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

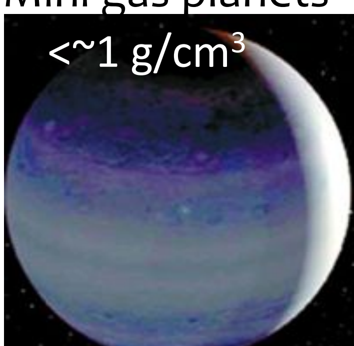
Earth 5.5 g/cm³

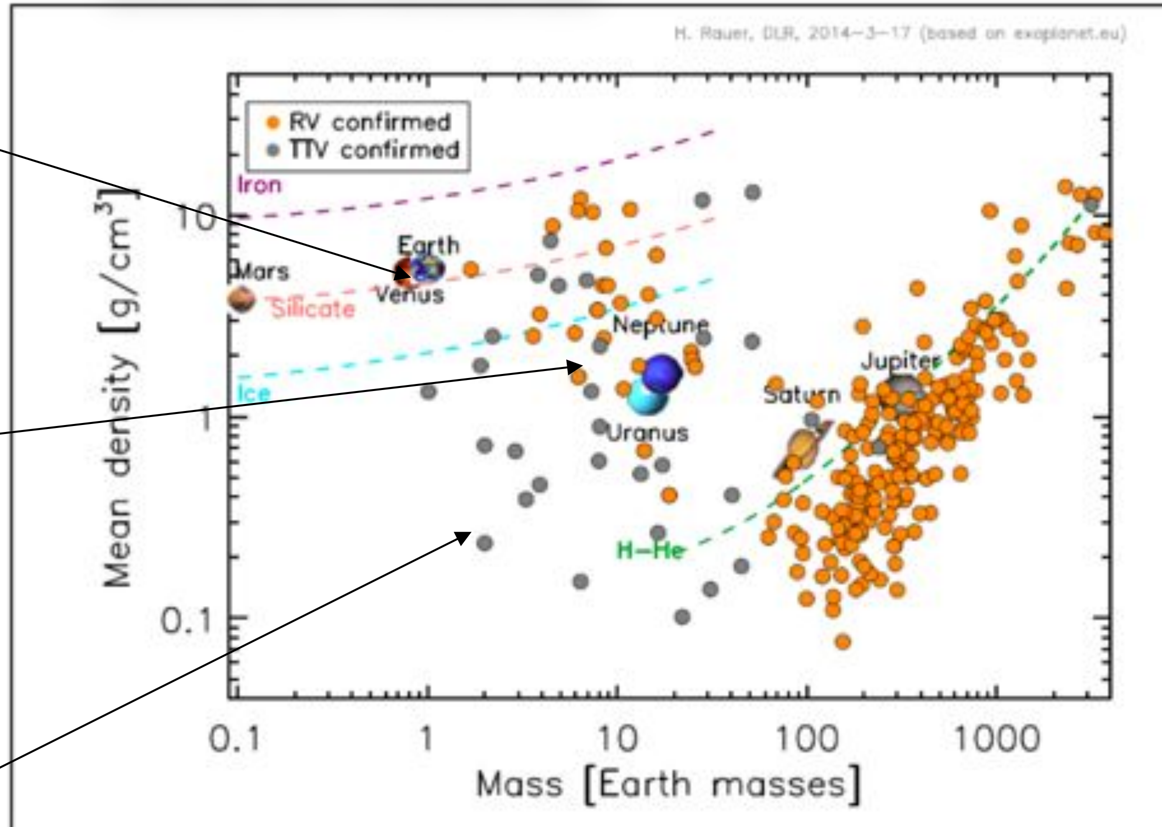


GJ1214b 1.6 g/cm³



Mini gas planets



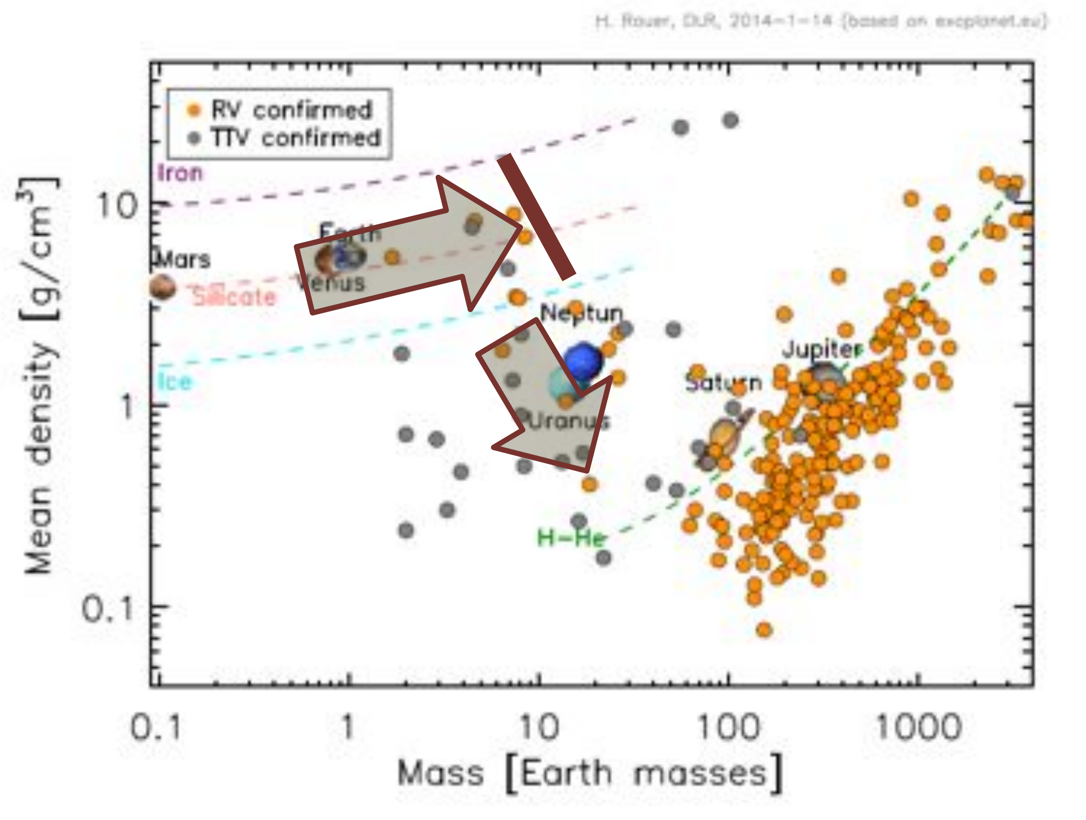


- ➔ Need mean densities to separate terrestrial planets from mini-gas planets

Planet diversity and planet formation

Test planet formation models:

- What is the observed critical core mass? How massive can a solid **core** grow before accreting **volatiles**?
- Can super-massive rocky planets exist? How are they formed?



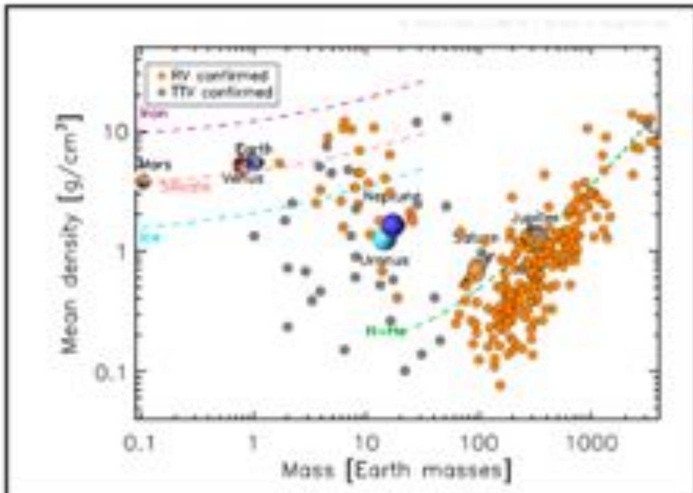
- Are light planets with H_2-dominated atmospheres common?

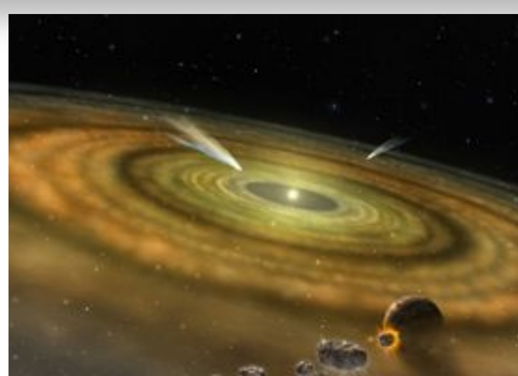
A biased view

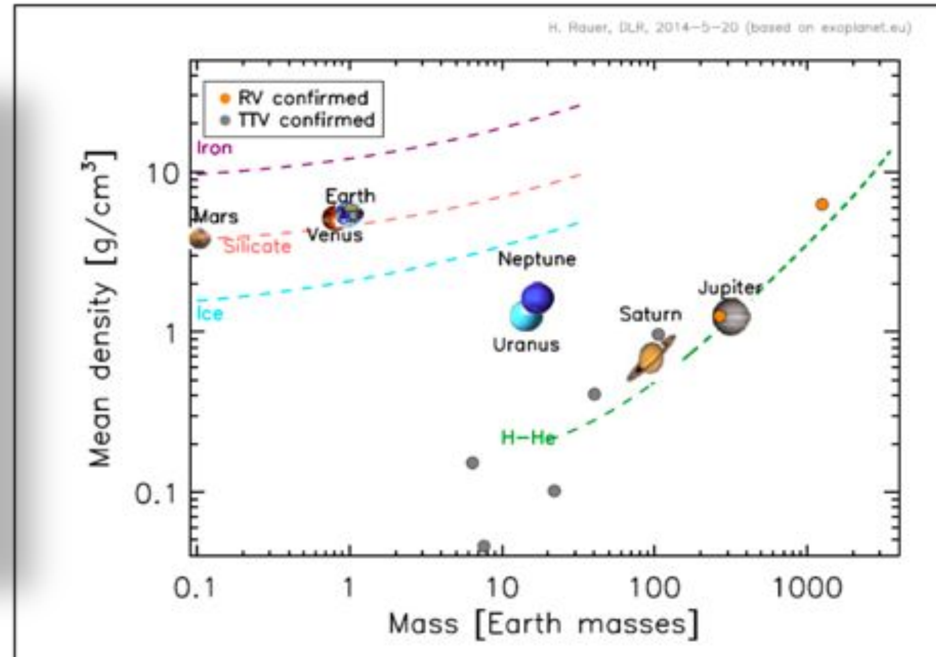
Our knowledge on planet nature is limited to close-in planets so far.

Planets with P>80 days

All planets

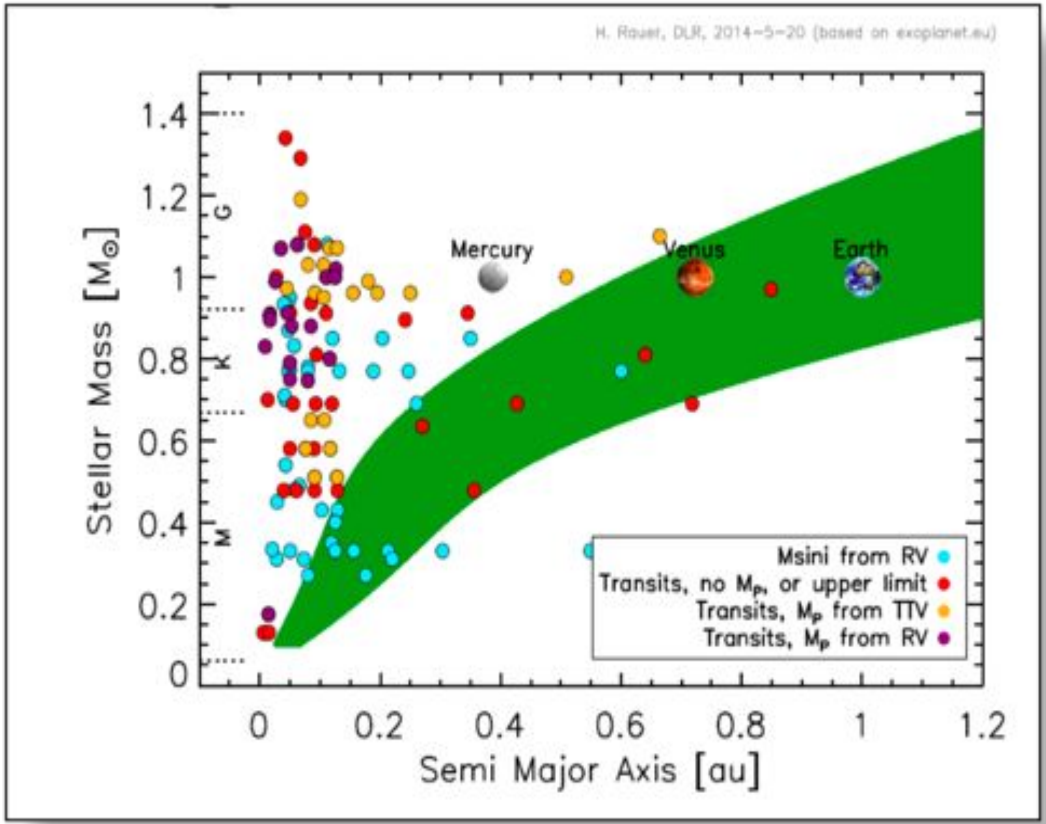






Super-Earths in the habitable zone

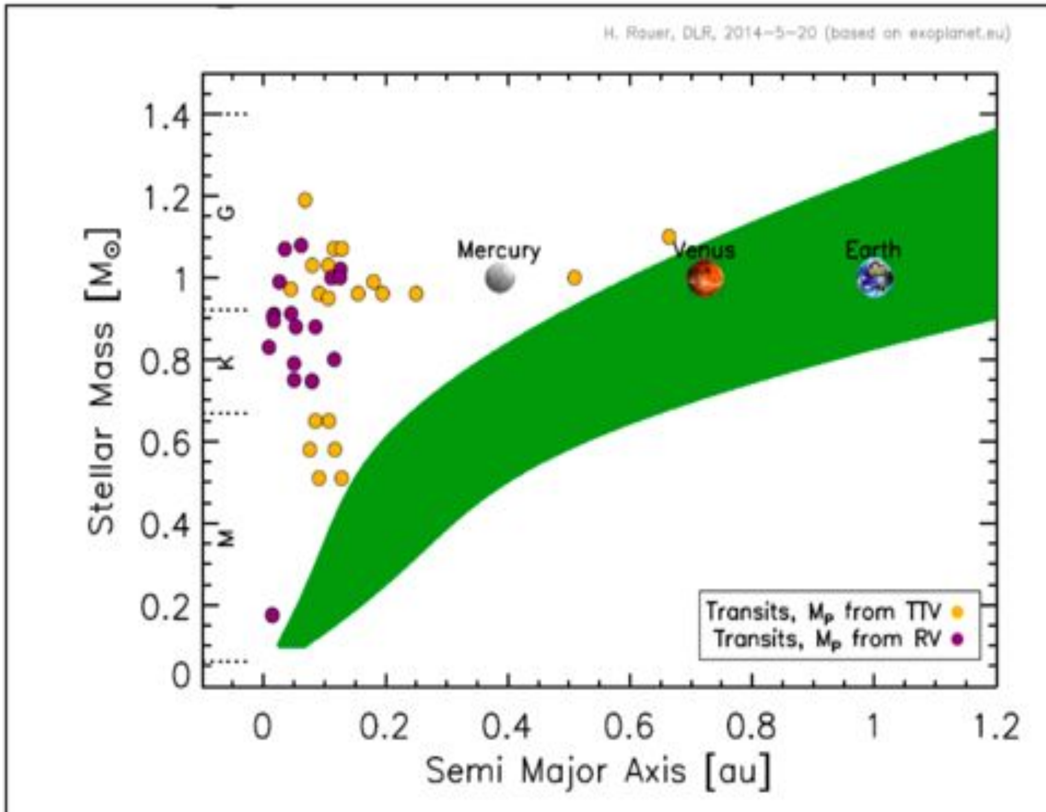
Detected super-Earths



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

Super-Earths in the habitable zone

Super-Earths with measured radius and mass

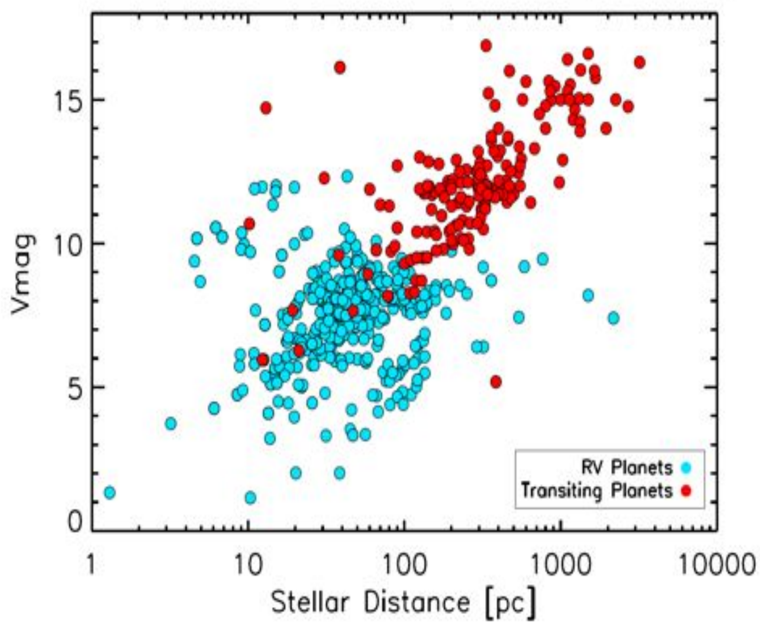


- Goal: Detect and characterize super-Earths in habitable zones
- Status: very few small/ light planets in habitable zones detected

No „super-Earths“ with known mean density in the habitable zone !

The need for bright stars

Known planets from radial velocity and transit surveys



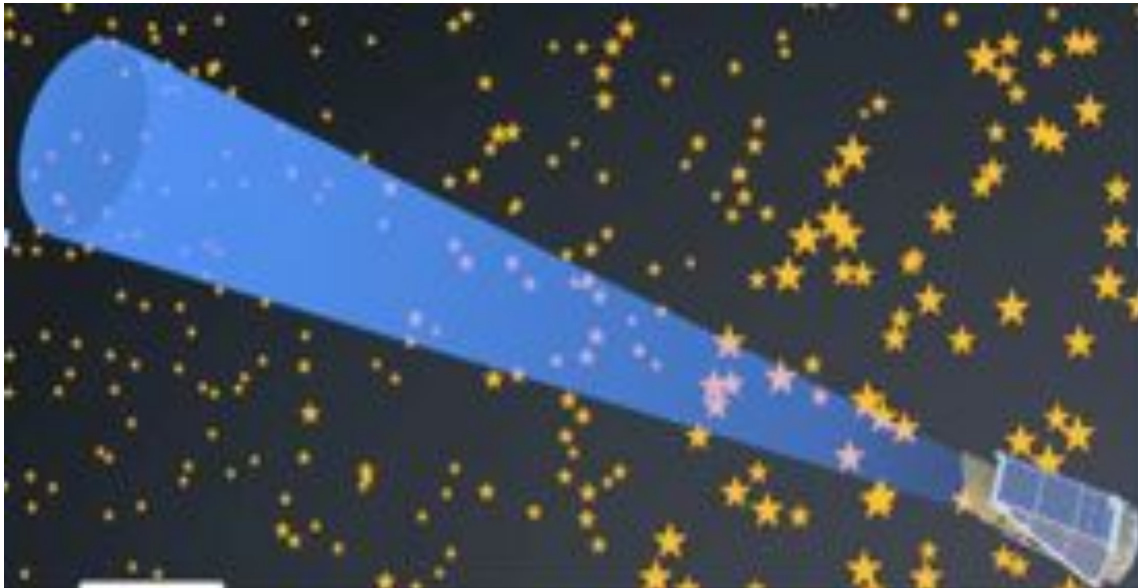
Why have so few targets been characterized?

- 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!

Large FoV concept

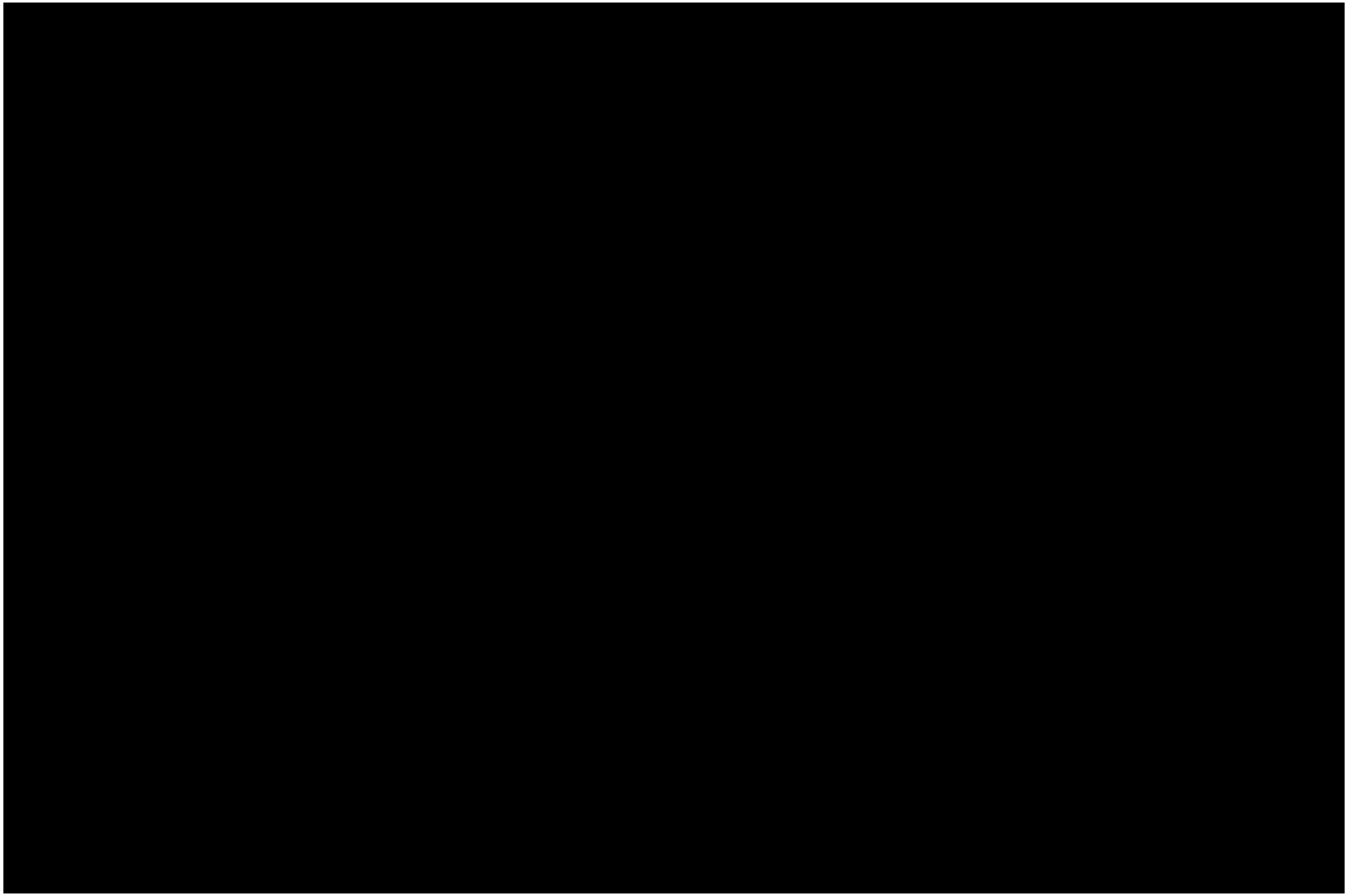


Searching for transits of Bright Stars ➔

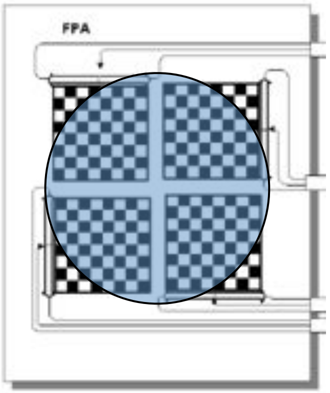
➔ large FoV!

One PLATO telescope

FoV~ ~1200 sqdeg (12 times Kepler) – like a circle of 39 deg diameter



Fast and Normal Telescopes



« normal »

Full frame CCD

4510 × 4510 18 µm sq px

$m_V > 8$

t=25 s

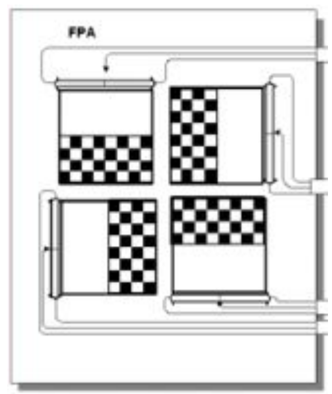
« fast »

Frame transfer CCD

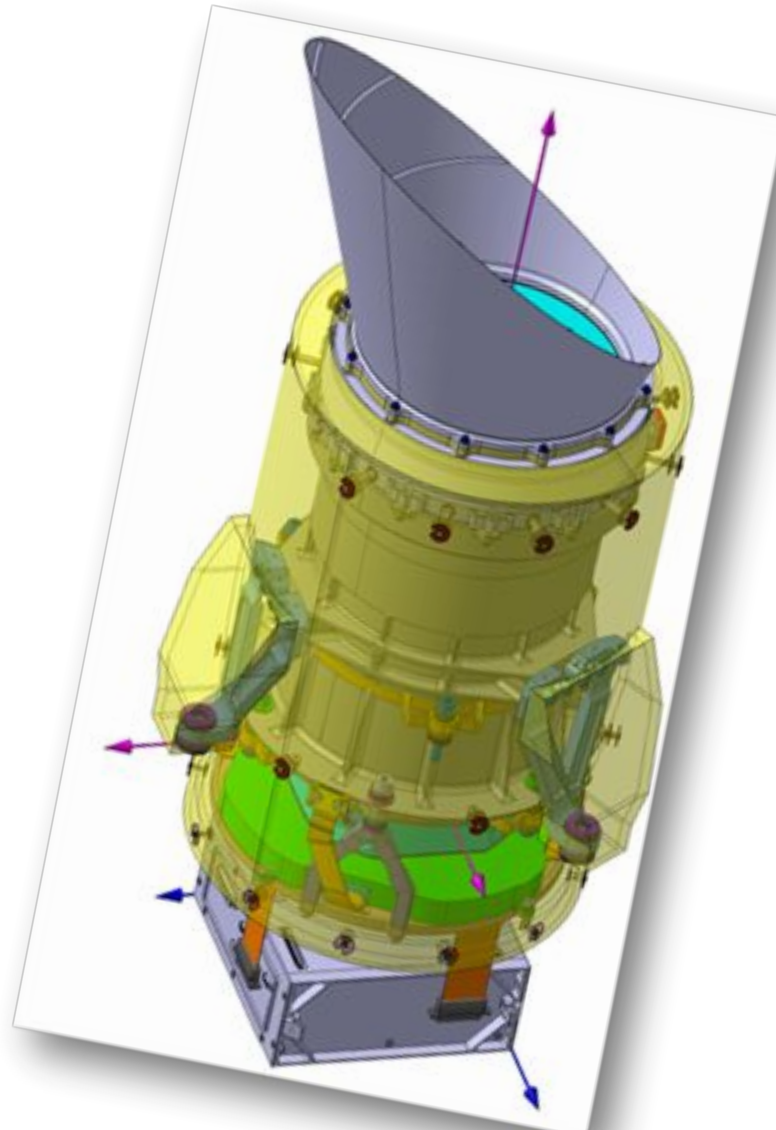
4510 × 2255 18 µm sq px

m_V ~4–8

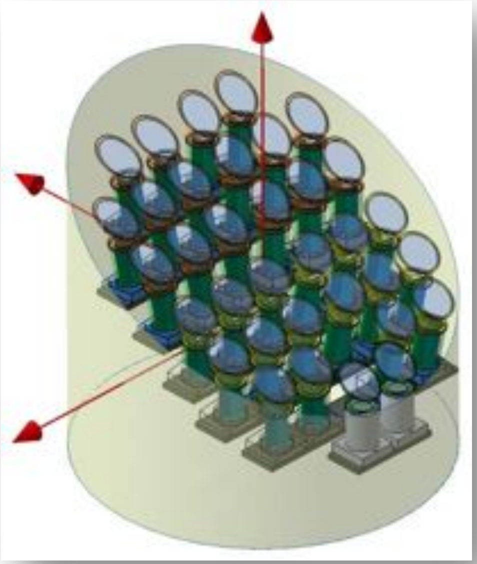
t=2.5 s *AOCS*

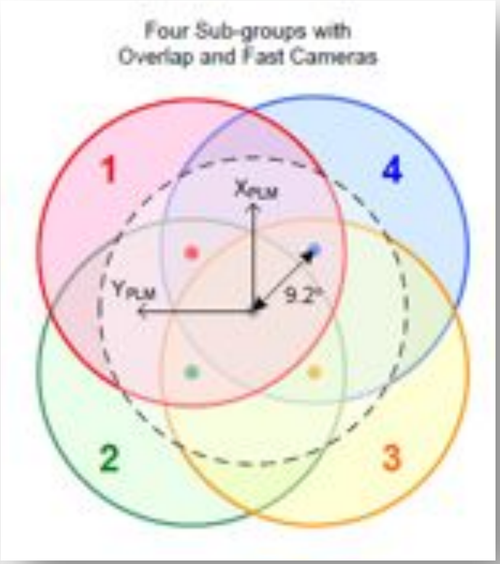


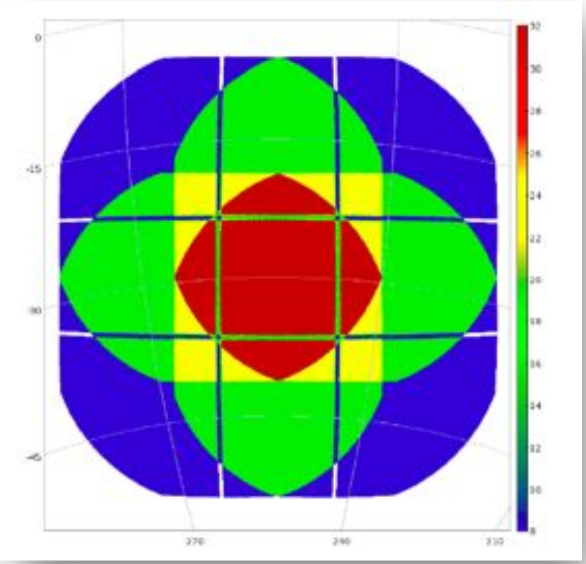
- ✓ 132 CCDs → ~ 0.95 sq meter
- ✓ 1 FEE / camera;
- ✓ 1 DPU / 2 cameras;
- ✓ 2 ICUs in cold redundancy



Telescopes on the satellite







- 32 “Normal” telescopes: 4 sets of 8 telescopes
- 2 “Fast” telescopes

NTEL=8 NTEL=16 NTEL=24 NTEL=32

PLATO – the set of 34 telescopes

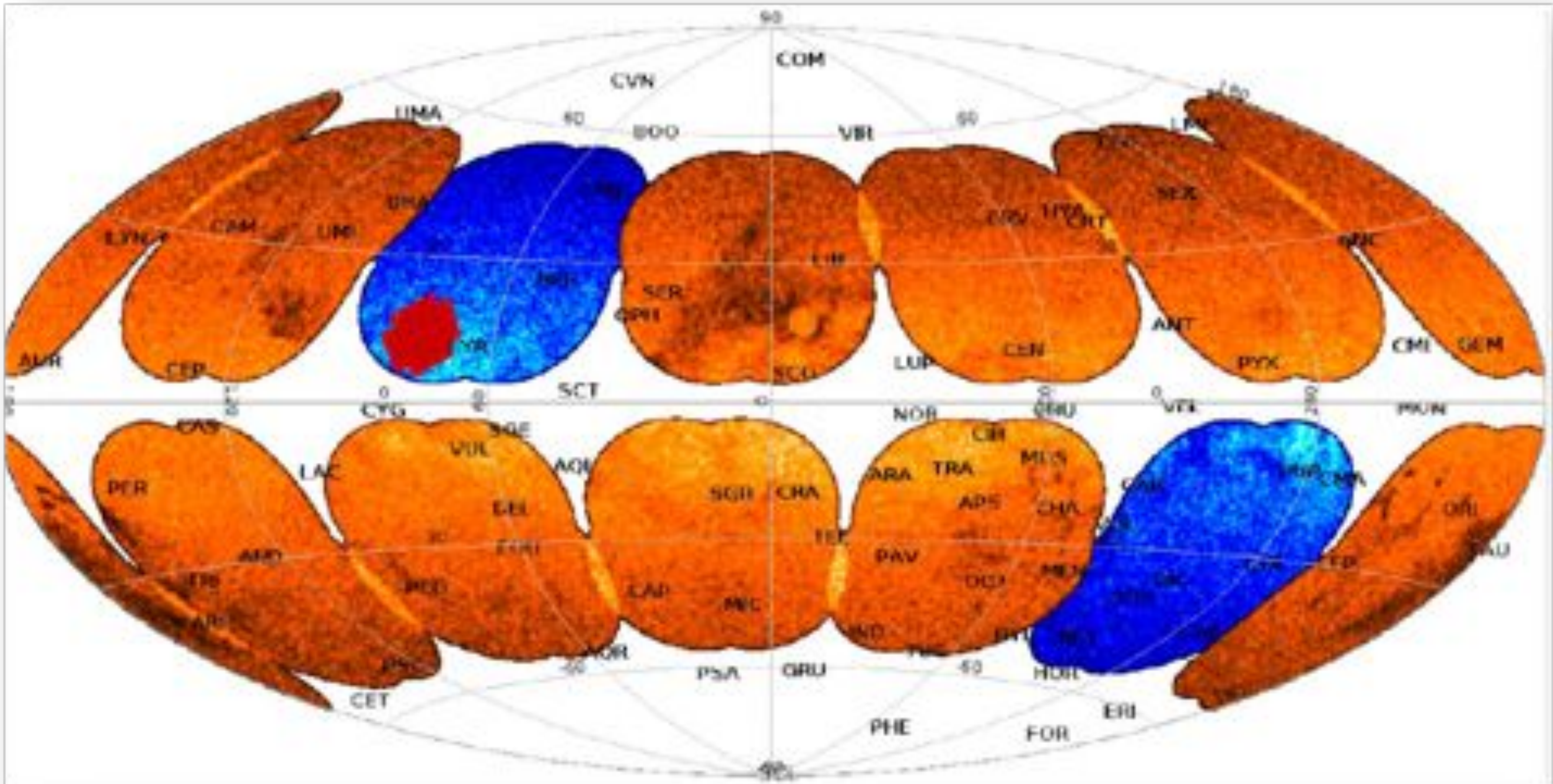
24 times Kepler

Overlapping FoV ~2250 sqdeg, equivalent to a circle of ~53 deg diameter

Observing Strategy

The observing duty cycle will be at least 95%.

The PLATO sky

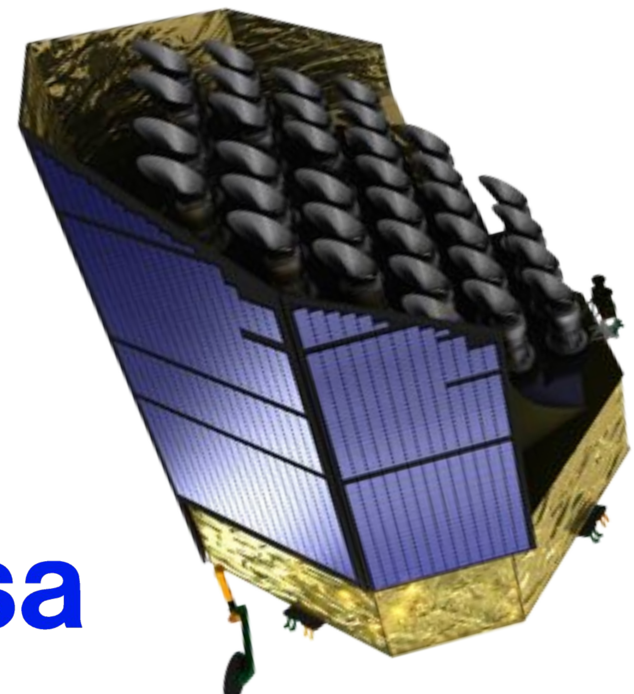


→ ~50% sky coverage

PLATO

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



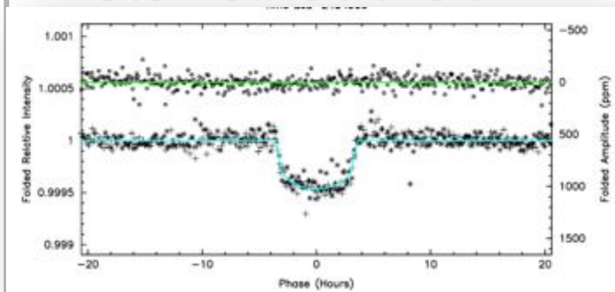
PLATO Science Goals

from the SMP

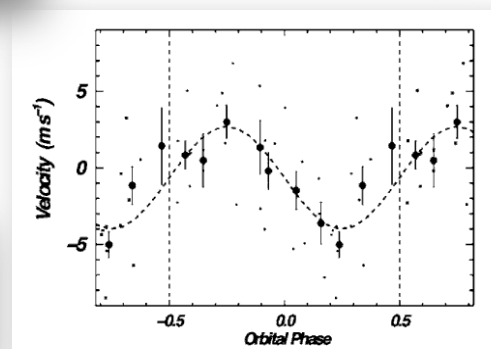
- Determine planet bulk properties (**mass, radius and mean density**)
- Study how planets and planet systems **evolve with age**
- Study the typical **architectures of planetary systems**
- Analyse the correlation of planet properties and their frequencies with stellar parameters (e.g., stellar metallicity, stellar type)
- Analyse correlations with the environment in which they formed
- Identify targets for spectroscopy to investigate planetary atmospheres
- Study the internal structure of stars and how it evolves with age
- + guest observer program (complementary and legacy science topics).

The Method

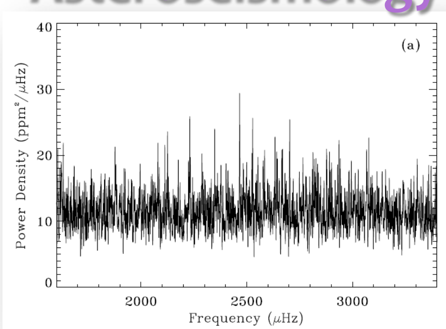
Photometric transit



RV – follow-up



Asteroseismology



Example: Kepler-10 b (V=11.5 mag)

- radius ~2%
- Mass ~10%
- Age ~10%

Exoplanets and Stars

Characterization of exoplanets … needs characterization of stars

- **Mass + radius → mean density**

  gaseous vs. rocky, composition, structure
- **Orbital distance, atmosphere**

  habitability
- **Age**

  planet and planetary system evolution

- **Stellar mass, radius**

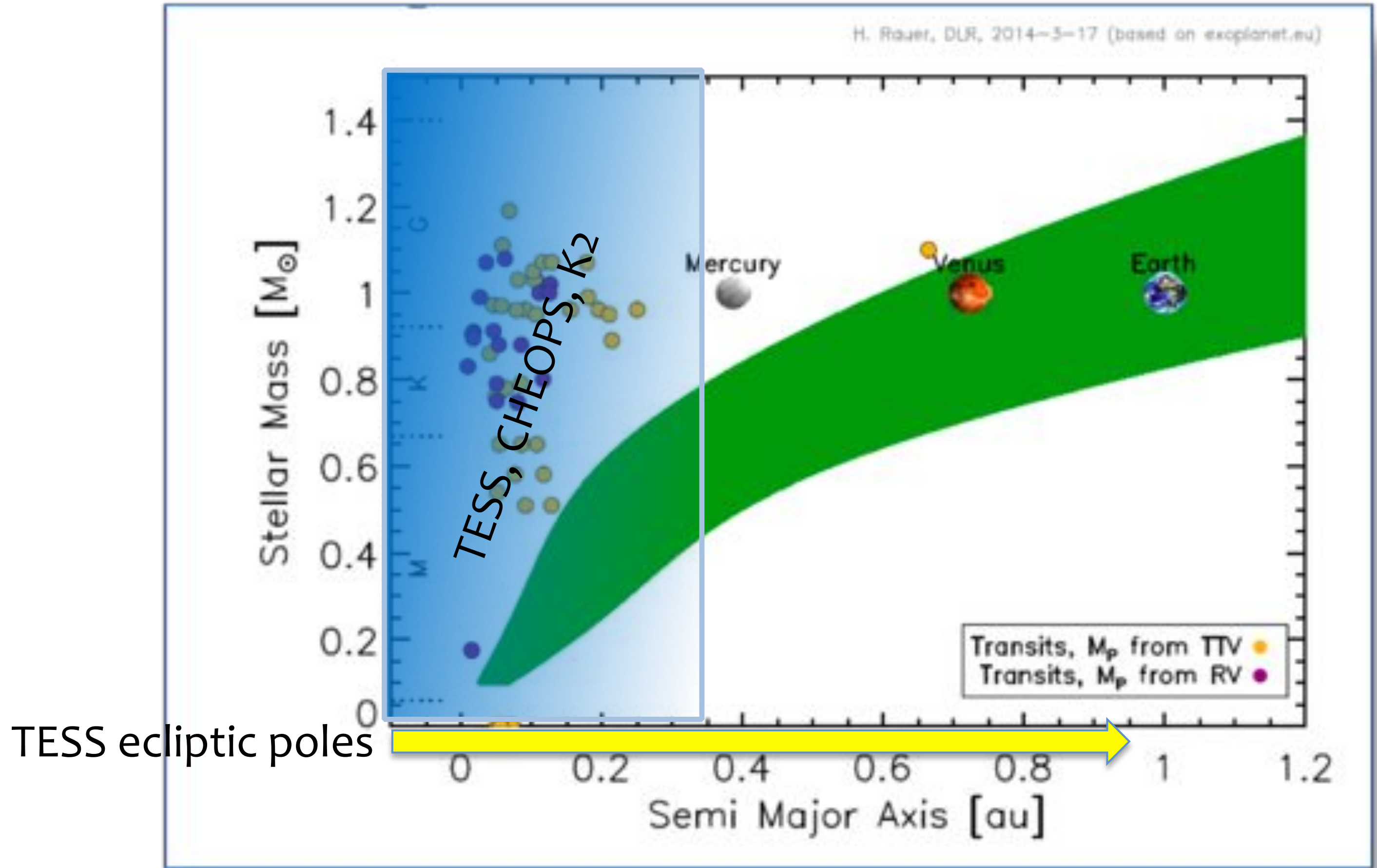
  derive planet mass, radius
- **Stellar type, luminosity, activity**

  planet insolation
- **Stellar age**

  defines planet age

Prospects for characterized super-Earths in the habitable zone

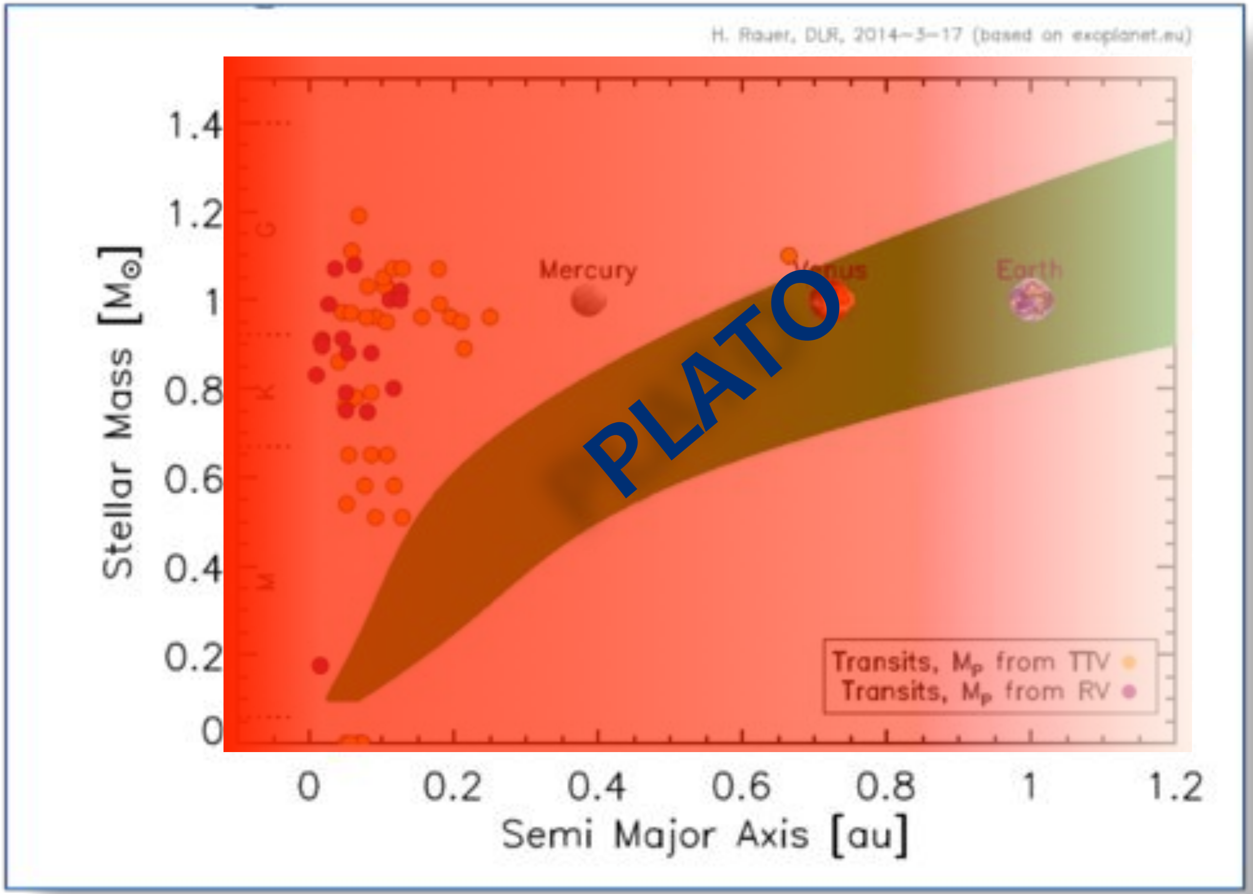
„Super-Earths" with measured radius and mass



TESS, CHEOPS, K2 will mainly cover orbital periods up to ~80 days

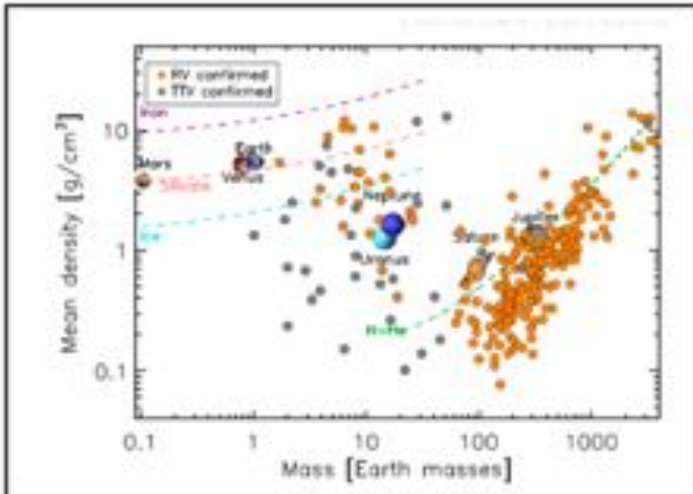
PLATO misurerà la densità dei pianeti piccoli con P> 80 g

„Super-Earths“ with measured radius and mass

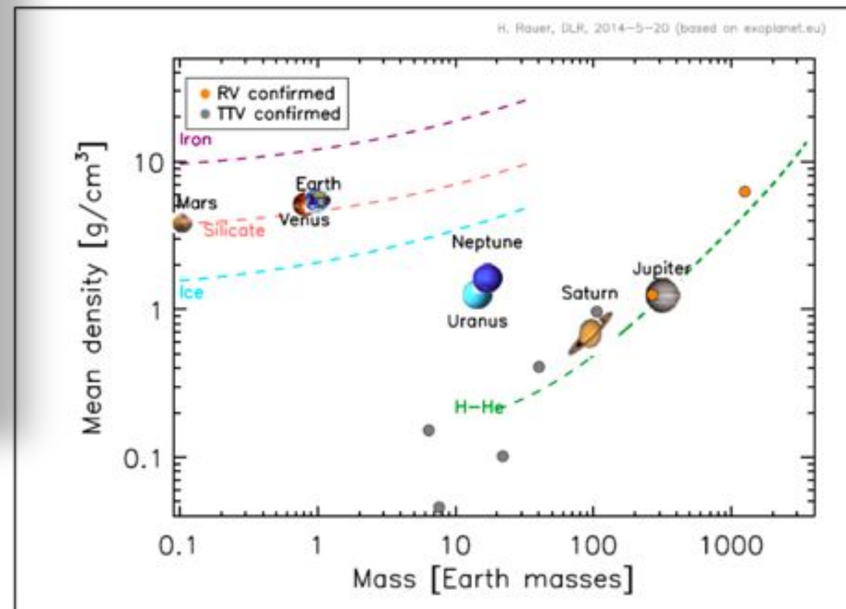


PLATO uniqueness

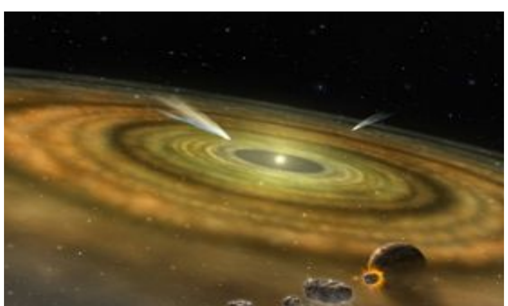
All planets



Planets with P>80 days

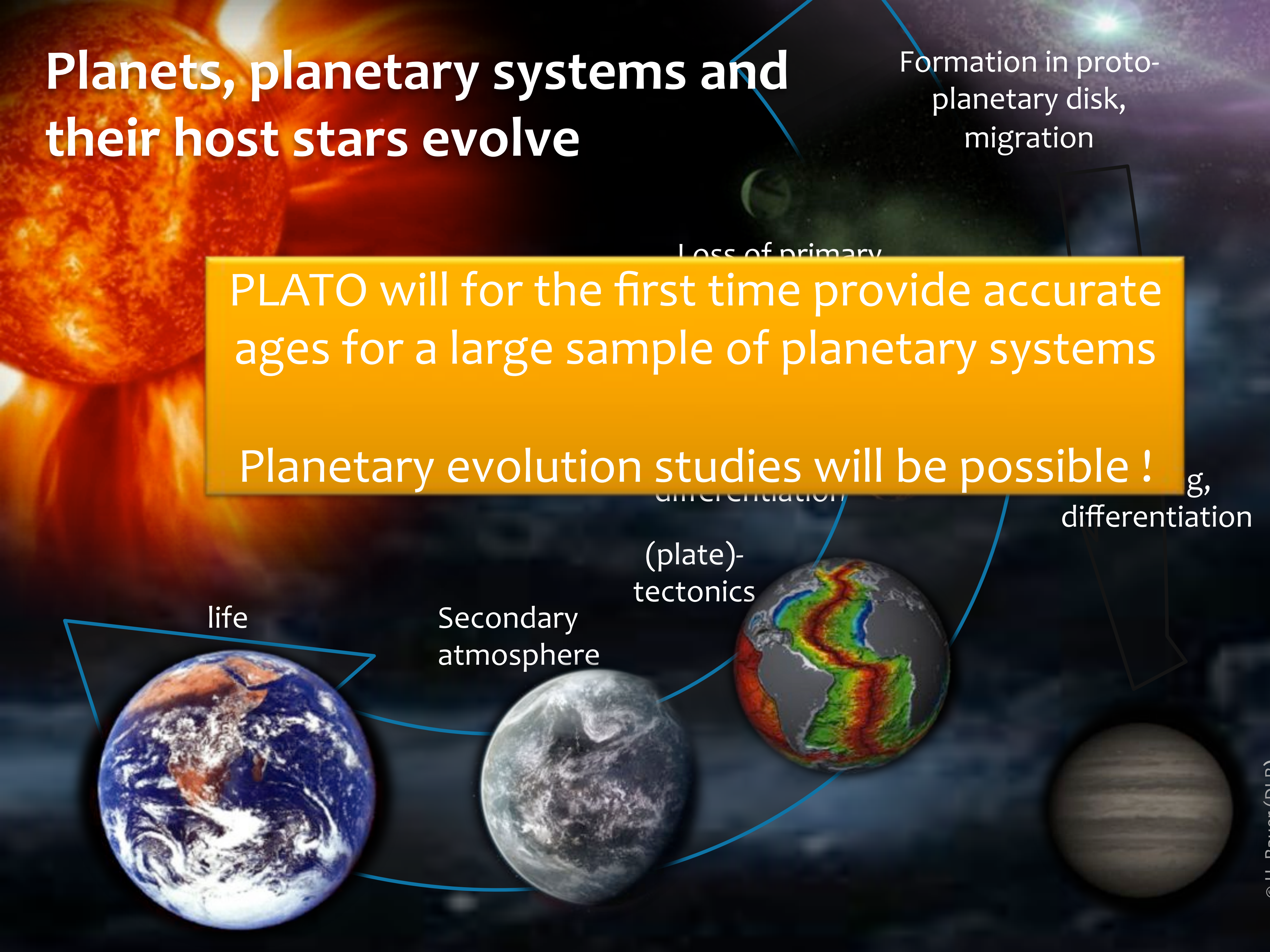


Our knowledge on planet nature is limited to close-in planets so far.

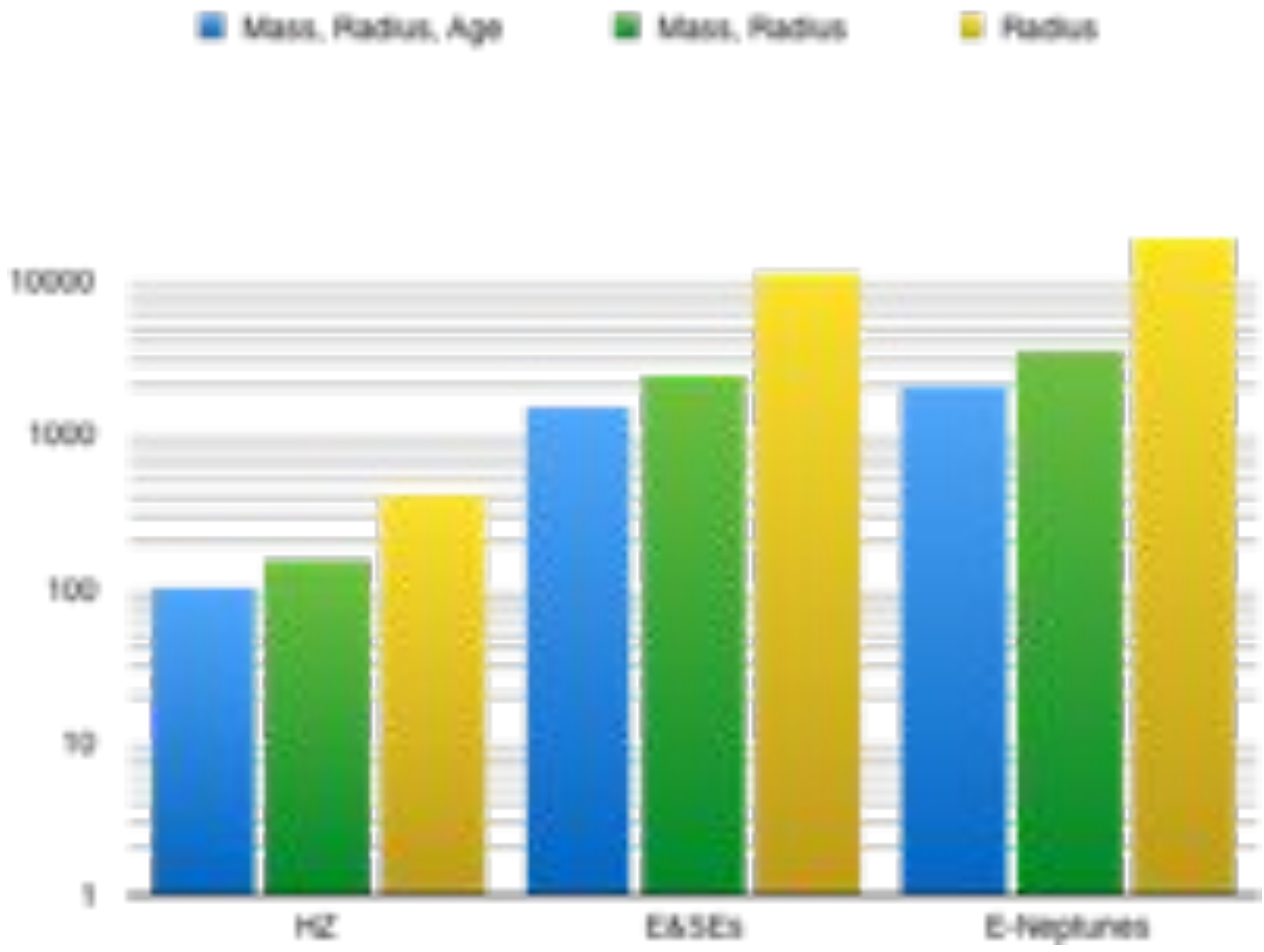


PLATO will fill the parameter range for long orbital periods

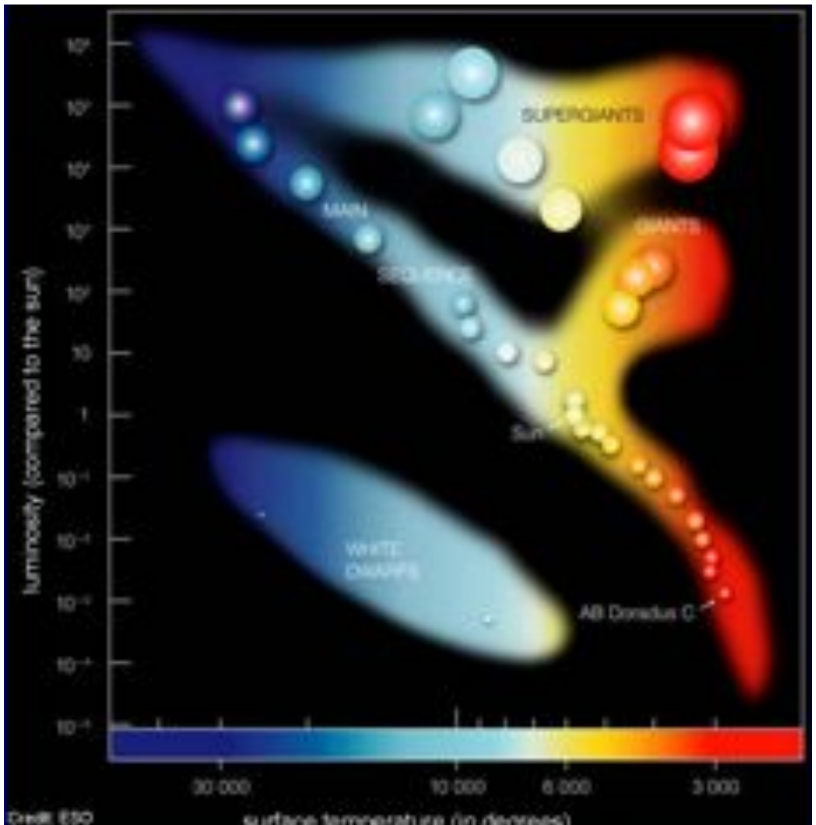
Study planets where they form!

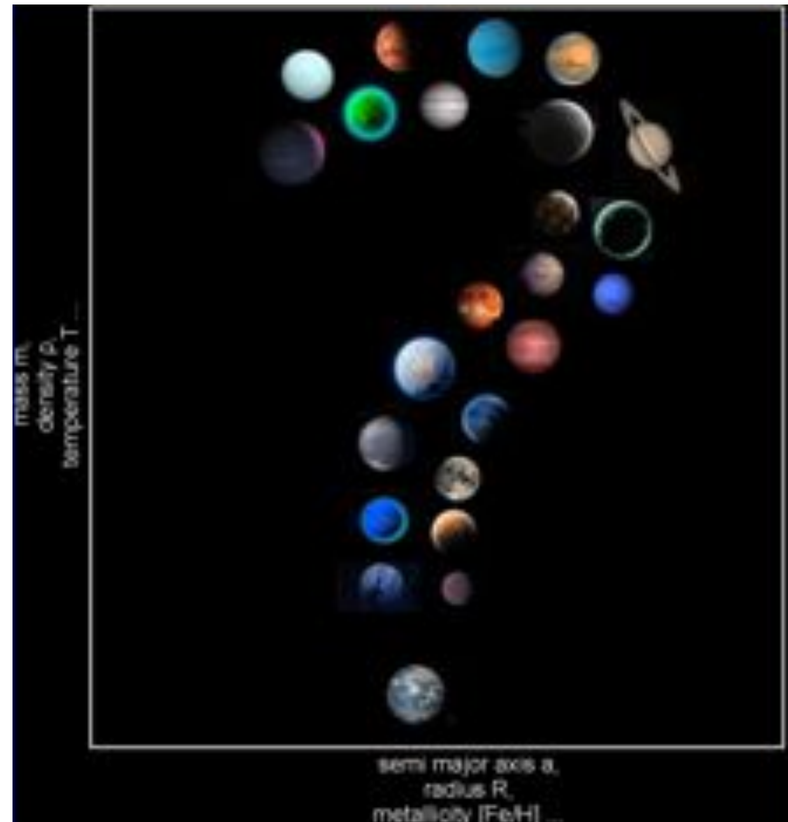

Planets, planetary systems and their host stars evolve
Formation in proto-planetary disk, migration
PLATO will for the first time provide accurate ages for a large sample of planetary systems
Planetary evolution studies will be possible !
differentiation
(plate)-tectonics
life
Secondary atmosphere

Planet yields

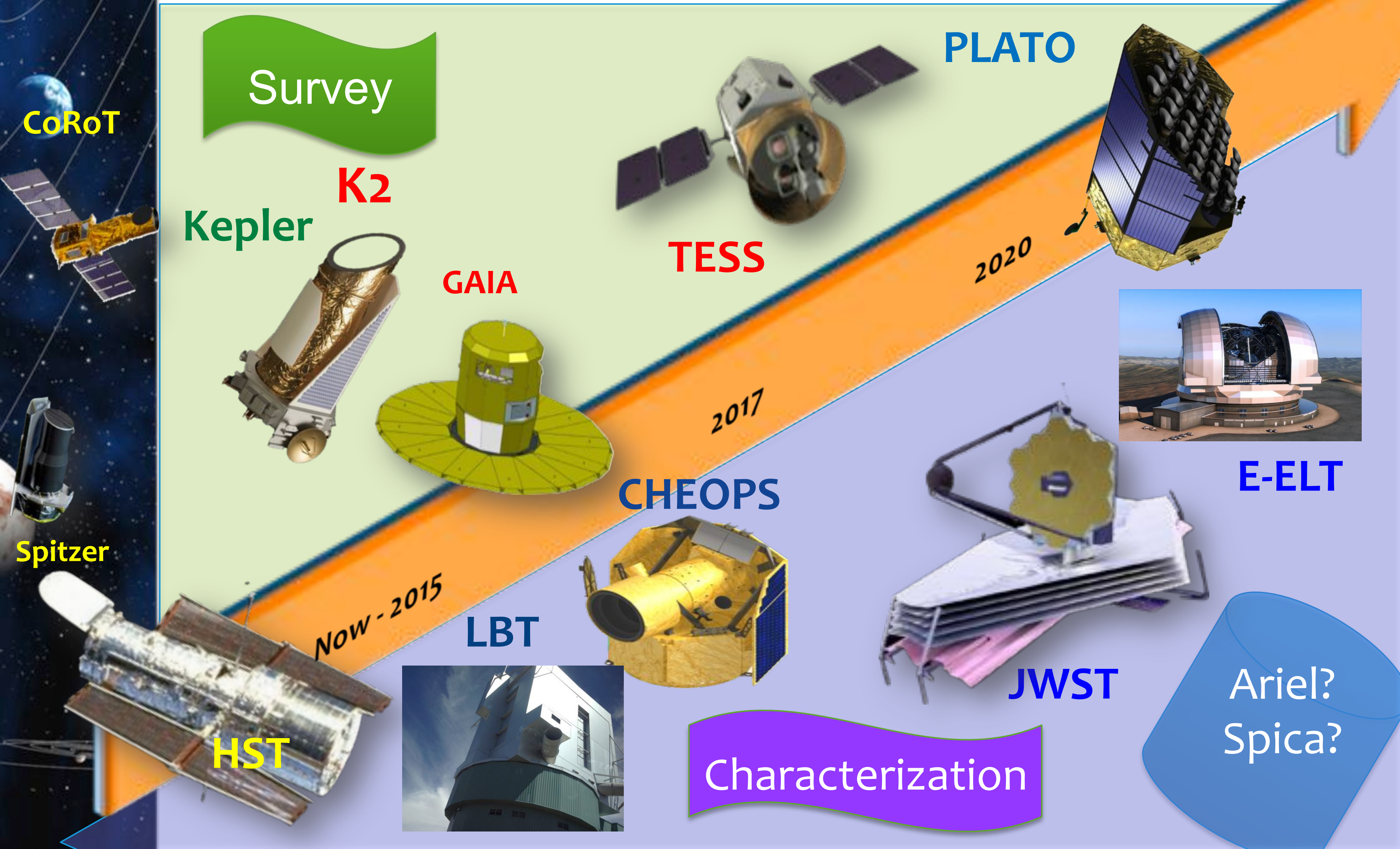


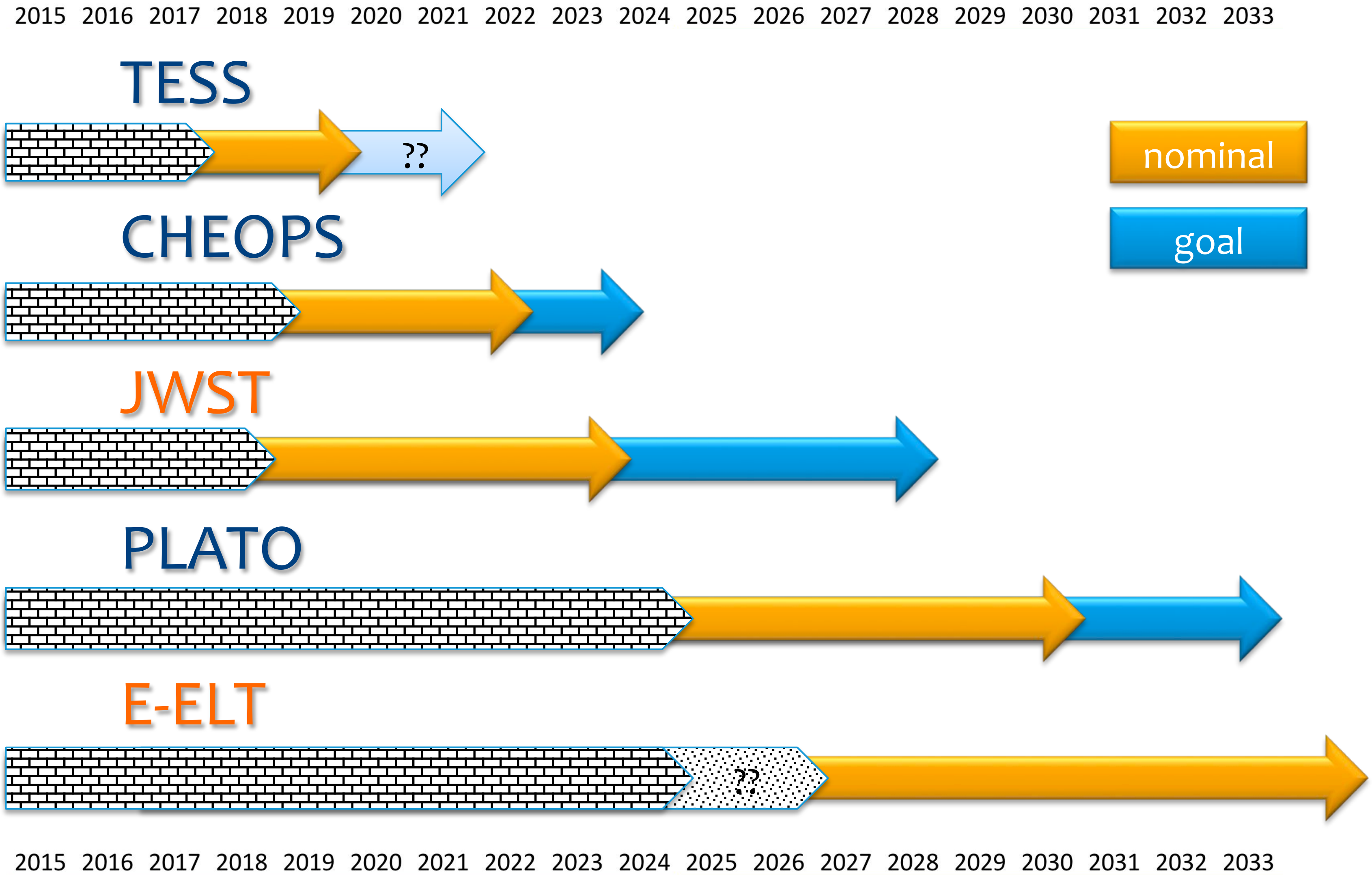
A possible HR-like diagram for planets?





Missions and Observatories for Exoplanets




2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033
TESS
??
nominal
goal
CHEOPS
JWST
PLATO
E-ELT
??
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033

Who does what

ESA

- Satellite
- Mission Operation Center (MOC)
- Science Operation Center (SOC)
- Launcher and launch facilities

PLATO Mission Consortium:

- Payload
- Data Center (PDC)
- Plato Science Management (PSM)

Organization

The PLATO Community

PLATO in Italia

Accordo ASI-INAF "PLATO Fasi B2/C" - n.2015-019-R0 del 29 luglio 2015

- ✓ **INAF**
  - OA Catania (Science, Payload)
  - OA Padova (Science, Payload)
  - OA Brera (Science, Payload)
  - IAPS-Roma (Science, Payload)
  - FGG (Payload)
  - OA Palermo (Science)
  - OA Torino (Science)
  - OA Capodimonte (Science)
  - OA Roma (+Teramo) (Science)
  - OA Arcetri (Science)

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

About 120 scientists interested to exoplanets field in Italy!

- ✓ **Padua University, Physics & Astronomy Dep.** (Science)
- ✓ **ASI-ASDC** (PDC, Science)

- **Italian Scientific Responsible:** I. Pagano
- **Members of the Advisory Science Team:** G. Piotto, R. Ragazzoni
- **Members of the PMC Board:** I. Pagano, G. Piotto

www.plato-mission.eu

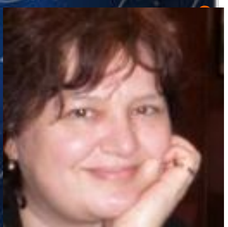
www.oact.inaf.it/plato/Plato-Italia/

PLATO Italian Team

Laura Affer OAPA, Elio Antonello OAB, **Stefano Basso** OAB, Luigi Bedin OAPD, Andrea Bellini UNIPD, **Serena Benatti** OAPD, Milena Benedettini IAPS, **Maria Bergomi** OAPD, Katia Biazzo OACT, David Biondi IAPS, Alfio Bonanno OACT, Andrea Bonfanti UNIPD, Rosaria Bonito , Giuseppe Bono OARO, **Aldo Bonomo** OATO, Francesco Borsa OAB, **Luca Borsato** UNIPD, Alessandro Bressan OAPD, Enzo Brocato OARM, Roberto Buonanno ASDC, **Santi Cassisi** OATE, Marco Castellani OARM, **Simonetta Chinellato** OAPD, **Riccardo Claudi** OAPD, **Rosario Cosentino** FGG, Giuseppe Cutispoto OACT, Valentina D'Orazi OAPD, Mario Damasso UNPD, Domitilla De Martino OACN, **Silvano Desidera** OAPD, Salvatore Di Franco OAA, **Anna Di Giorgio** IFSI, Maria Pia Di Mauro IAFS**, Marco Dima** OAPD, **Jacopo Farinato** OAPD, Ettore Flaccomio OAPA, **Mauro Focardi** OAA, Antonio Frasca OACT, **Mauro Ghigo** OAB, Paolo Giommi ASI, Leo Girardi OAPD, **Giuliano Giuffrida** ASDC, Giovanni Giusi IAPS, **Valentina Granata** UNIPD, **Davide Greggio** OAPD, Marco Gullieuszik OAPD, **Nuccio Lanza** OACT, Alessandro Lanzafame OACT, **Mario Gilberto Lattanzi** OATO, Giuseppe Leto OACT, Gianluca Li Causi IAPS, Mattia Libralato UNIPD, John Scige Liu IAPS, Carla Maceroni OARM, **Demetrio Magrin** OAPD, **Luca Malavolta** UNIPD, **Luca Marafatto** OAPD, Marcella Marconi OAC, Paola Marigo UNIPD, **Paola Maria Marrese** ASDC, **Francesco Marzari** UNIPD, **Dino Mesa** OAPD, **Sergio Messina** OACT, Giusi Micela OAPA, **Josepha Montalban** UNIPD, **Matteo Munari** OACT, **Ulisse Munari** OAPD, Ilaria Musella OAC, Domenico Nardiello UNIPD, **Valerio Nascimbeni** UNIPD, Renato Orfei IFSI, **Sergio Ortolani** UNIPD, Emanuele Pace OAAR, **Isabella Pagano** OACT, Maurizio Pancrazi OAAR, **Stefano Pezzuto** IFSI, Giovanni Picogna INFNPD, Adriano Pietrinferni OATE, **Giampaolo Piotto** UNIPD, Ennio Porretti OAB, **Loredana Prisinzano** UNIPA, **Roberto Ragazzoni** OAPD, Gabriella Raimondo OATE, Monica Rainer OAB, Vincenzo Ripepi OAC, Thaise Rodrigez UNIPD, Gaetano Scandariato OACT, Daniela Sicilia OACT, Roberto Silvotti OATO, Richard Smart OATO, **Alessandro Sozzetti** OATO, **Daniele Spiga** OAB, Michele Trabucchi UNIPD, **Paolo Ventura** OARO, Rita Ventura OACT, **Valentina Viotto** OAPD, Ricardo Zanmar Sanchez OACT,

Italian TOU Team

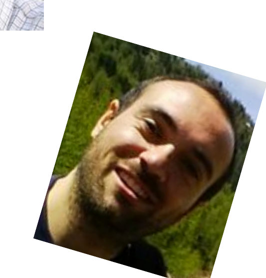
e-mail: PLATO-TOU-IT@oact.inaf.it



INAF-OAB: Stefano Basso, Francesco Borsa, Mauro Ghigo, Daniele Spiga;

INAF-OACT: Matteo Munari, Isabella Pagano, Gaetano Scandariato, Daniela Sicilia;

INAF-OAPD: Maria Bergomi, Simonetta Chinmellato, Mario Dima, Davide Greggio, Jacopo Farinato, Demetrio Magrin, Luca Marafatto, Roberto Ragazzoni, Valentina Viotto.



TOU Team

TOU Instrument Scientist
Roberto Ragazzoni

TOU Structure Instrument Scientist
Willy Benz

TOU PM
Isabella Pagano

TOU Structure PM
Daniele Piazza

TOU SE
Valentina Viotto

Intefaces Engineer
Maria Bergomi

TOU Structure SE
Timothy Bandy

Thermal Analysis
Giordano Bruno

PA Manager
Simonetta Chinellato

Optical Design & Performance Engineer
Demetrio Magrin

Mechanical Engineer
Martin Rieder

Optics Procurement
Davide Greggio

Optical Coating
Daniele Spiga

Structure PA
TBD

Thermo-Mechanical Engineer
Mathias Brändli

Radiation Analysis Engineer
Mauro Ghigo

Thermal Performance
Stefano Basso

AIV Engineer
Jacopo Farinato

Structural Tests Engineer
Thierry De Roche

Straylight Analysis
Matteo Munari

F-TOU
Filters PM
Alexis Brandeker

GSE Engineer
Luca Marafatto

Project Office Assistant
Daniela Sicilia

Radiation Analysis Engineer
Francesco Borsa

Visualization & Rendering
Marco Dima

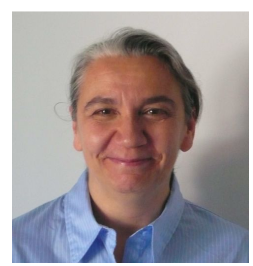
F-TOU Filters Performance
Göran Oloffson

Italian ICU Team

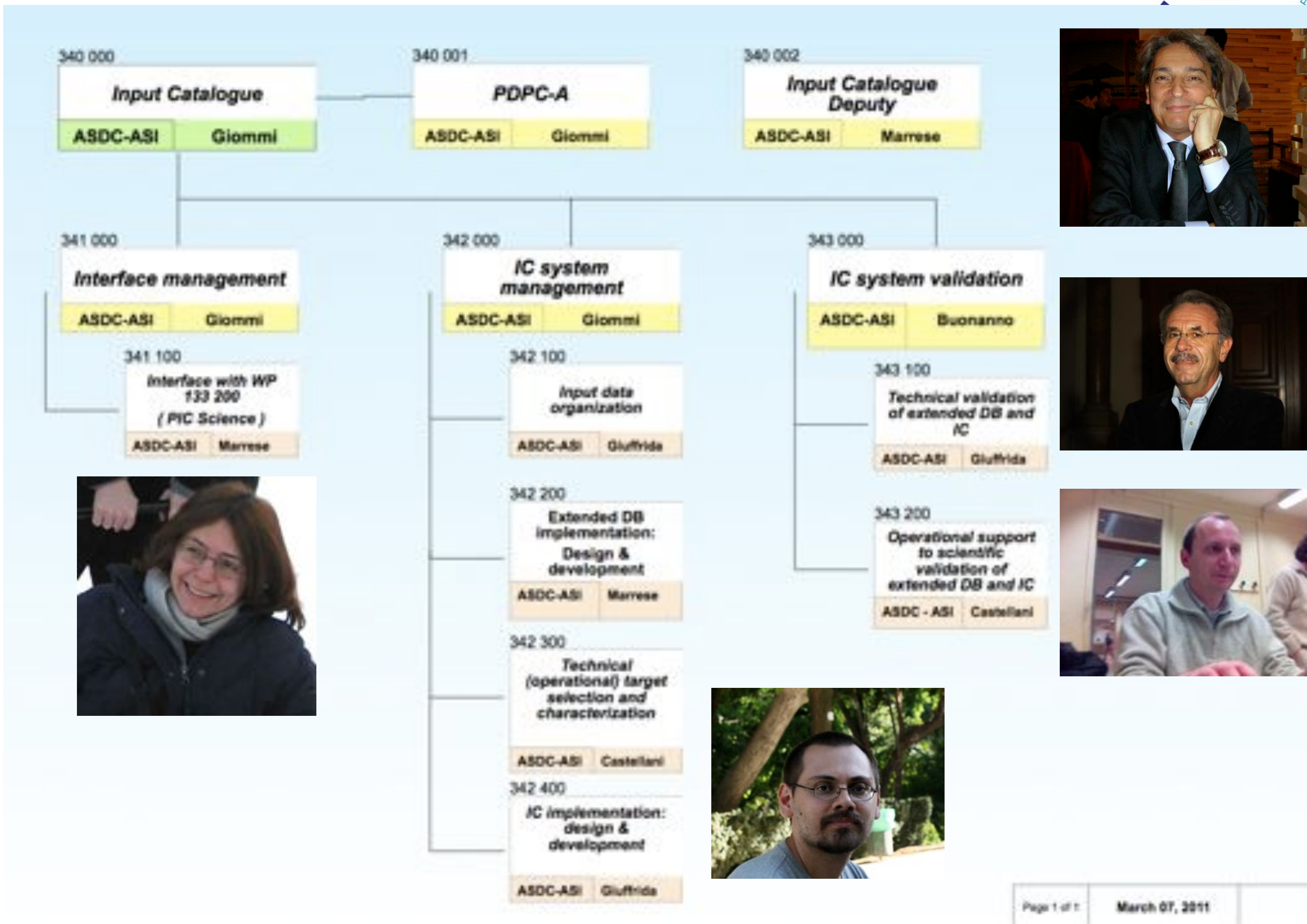
e-mail: PLATO-ICU-IT@oact.inaf.it

- **INAF-FGG**: R. Cosentino;
- **INAF-IFSI**: S. Pezzuto, M. Benedettini, D. Biondi, A. Di Giorgio, G. Giusi, G. Li Causi, J. Liu, R. Orfei ;
- **INAF-OAA:** M. Focardi, M. Pancrazzi, E. Pace, S. Di Franco.

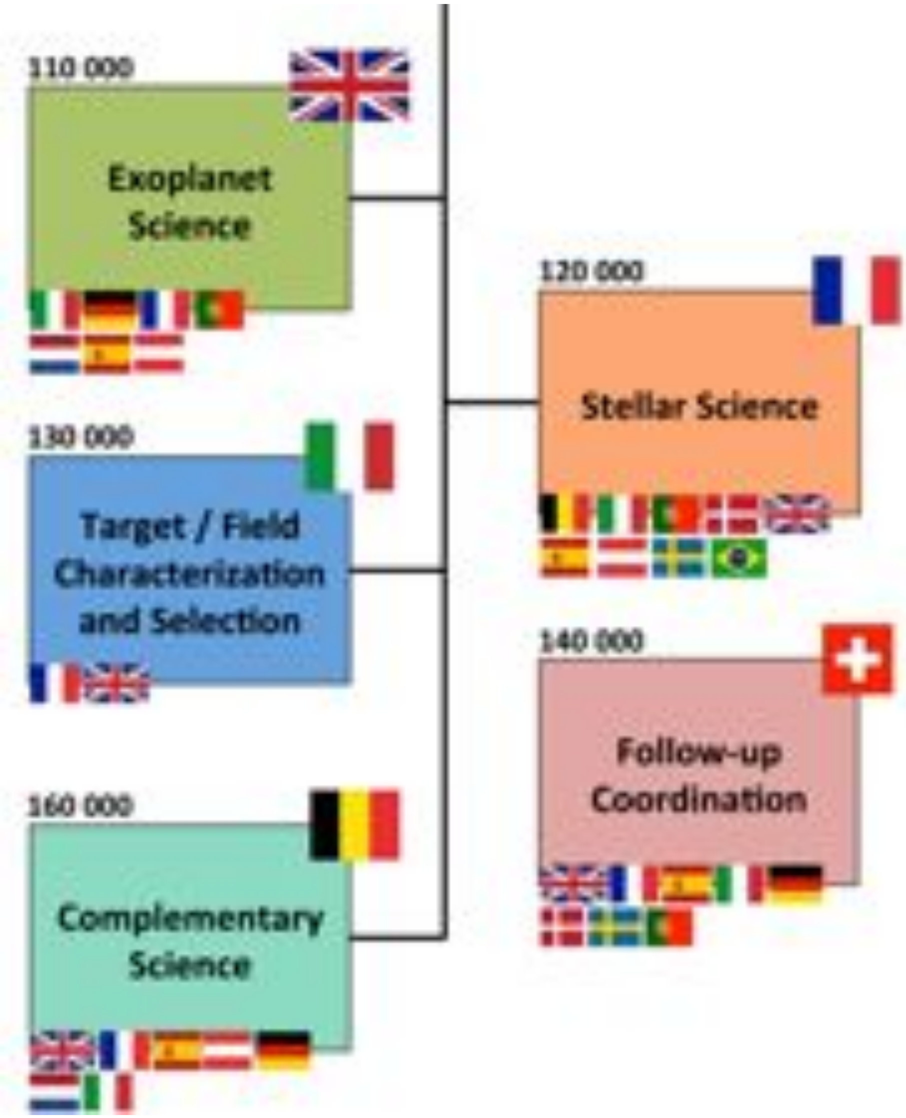


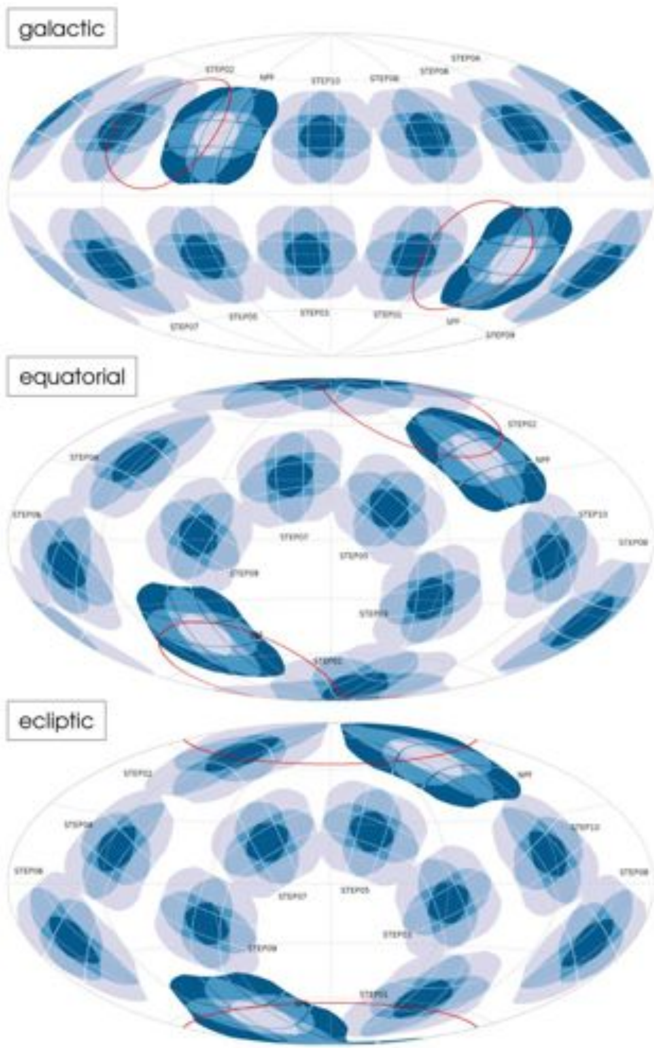

asdc
ASI Science Data Center


340 000
Input Catalogue
ASDC-ASI
Giommi
340 001
PDPC-A
ASDC-ASI
Giommi
340 002
Input Catalogue Deputy
ASDC-ASI
Marrese
341 000
Interface management
ASDC-ASI
Giommi
341 100
Interface with WP 133 200 (PIC Science)
ASDC-ASI
Marrese
342 000
IC system management
ASDC-ASI
Giommi
342 100
Input data organization
ASDC-ASI
Giuffrida
342 200
Extended DB implementation: Design & development
ASDC-ASI
Marrese
342 300
Technical (operational) target selection and characterization
ASDC-ASI
Castellani
342 400
IC implementation: design & development
ASDC-ASI
Giuffrida
343 000
IC system validation
ASDC-ASI
Buonanno
343 100
Technical validation of extended DB and IC
ASDC-ASI
Giuffrida
343 200
Operational support to scientific validation of extended DB and IC
ASDC - ASI
Castellani
Page 1 of 1
March 07, 2011

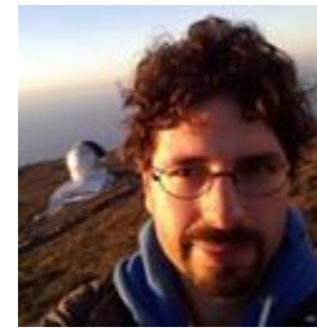
Science Preparation



Field Characterization and Target Selection



- 2 "**long-duration**" (LD) fields + "**step & stare**" (S&S) fields
- Scientific requirements: 5 stellar (dwarfs & giants) samples **(P1 – P5)**
  - **P1** ≥ 20 000 stars in LD fields (spectral type >F5; V < 11)
  - **P2** ≥ 1000 stars in LD fields (V < 8)
  - **P3** ≥ 3000 stars (extension of P2) in LD and/or S&S fields
  - **P4** ≥ 10 000 M stars (5000 in LD + 5000 in S&S)
  - **P5** ≥ 245 000 stars in LD fields (V < 13)



- PLATO will not download the images
  - **P1 – P5 selected in advance**
  - **Spectral-type selection**
- **No suitable all-sky catalogs exist for stellar parameters**

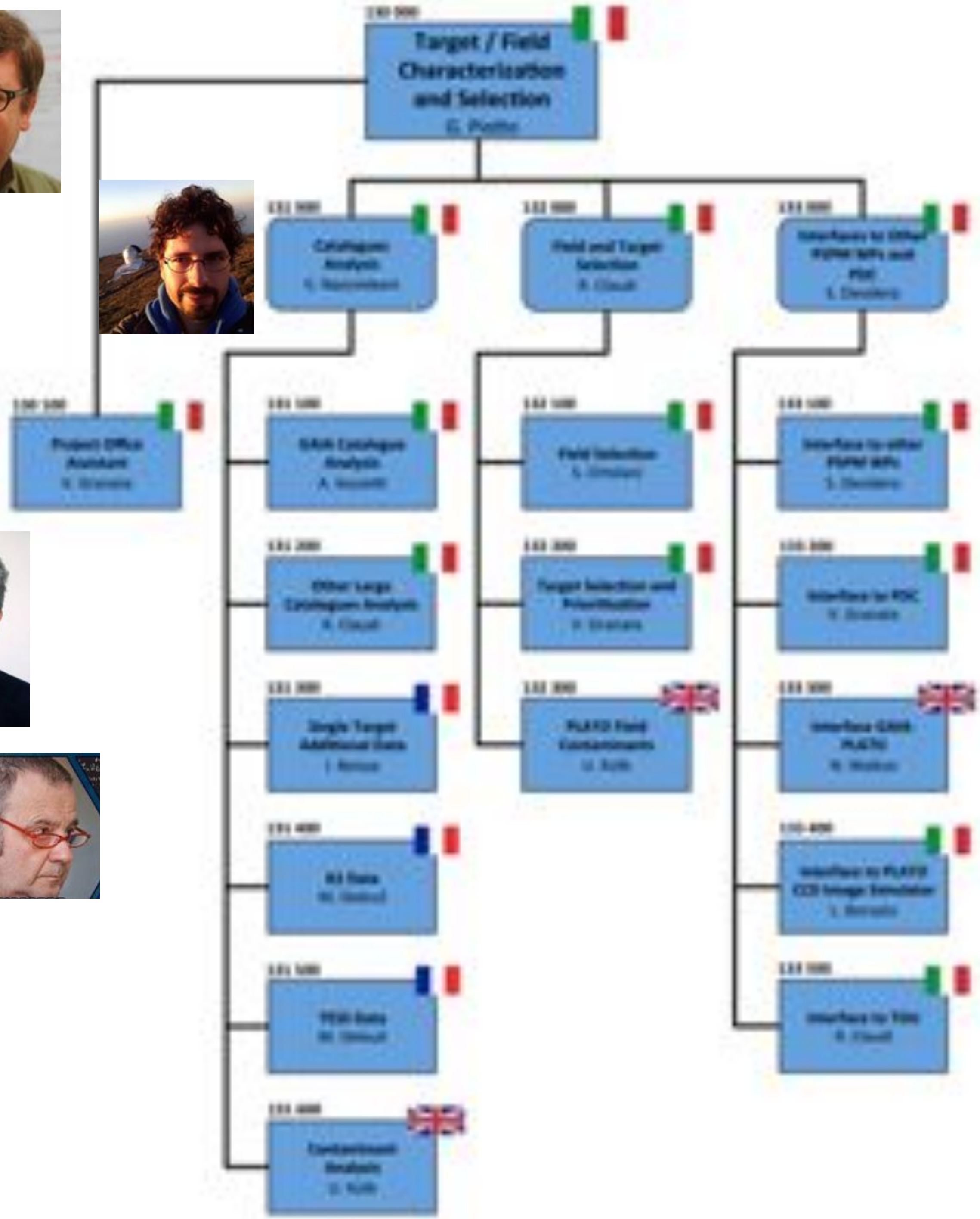
➢ **Gaia:** intermediate catalog release in 2017
1. Single-catalog dependence is a risk
2. Gaia will be affected by crowding at low Galactic latitudes
3. Degeneracy between parameters (temperature and interstellar extinction)
4. Complementary catalogs

➢ Analysis of available catalogs in literature (UCAC4, RAVE, …)

➢ Analysis of theoretical models (GUMS) and available techniques

➢ **UCAC4-RPM**: a new *ad-hoc* all-sky database for FGKM stars, based on already known tools and catalogs

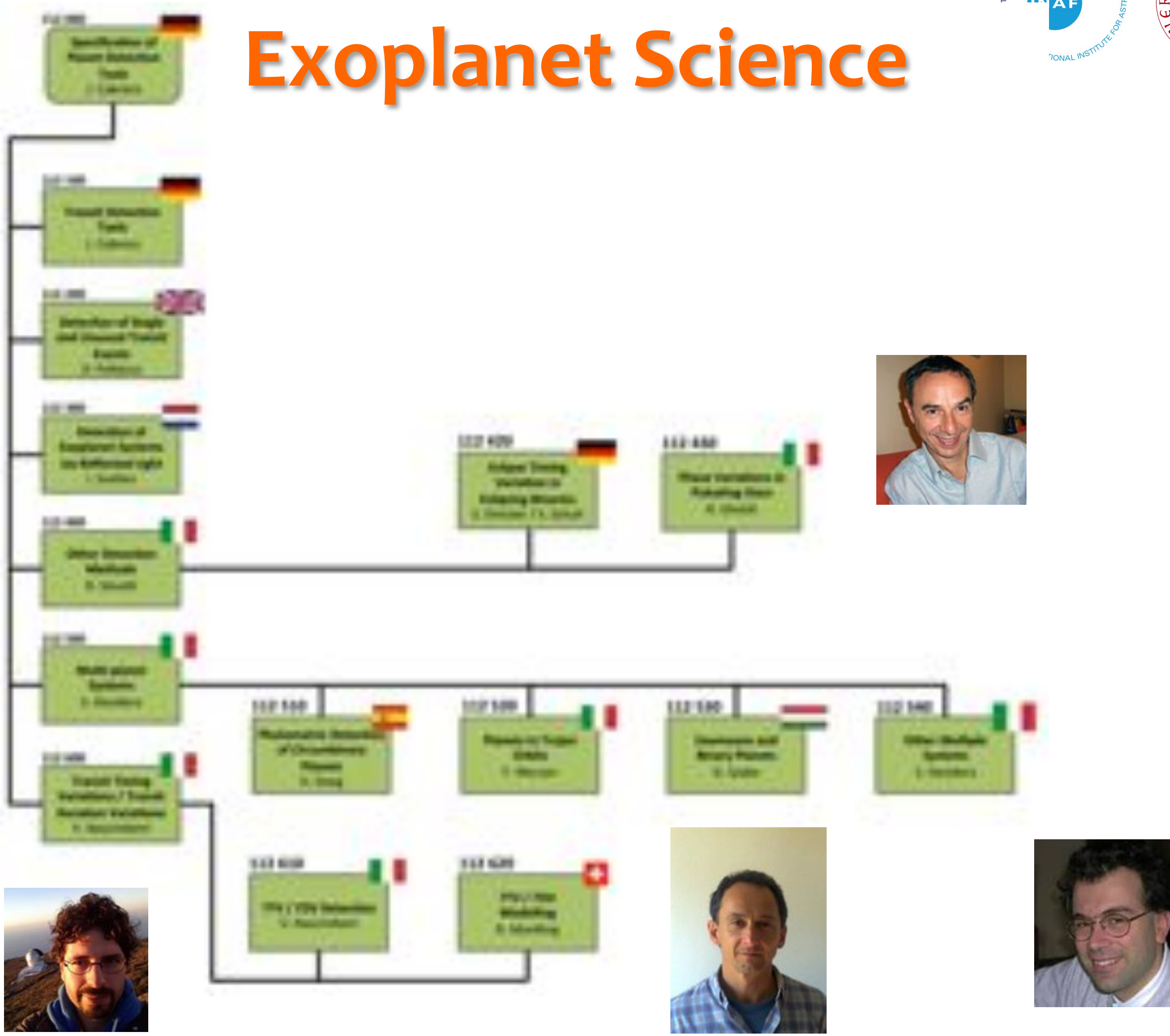
Nascimbeni, Piotto, et al. in preparation


Target / Field Characterization and Selection
Catalogues Analysis
Field and Target Selection
Field Selection
PLATO Field Contaminants
Contaminant Analysis

Target/Field Characterization & Selection

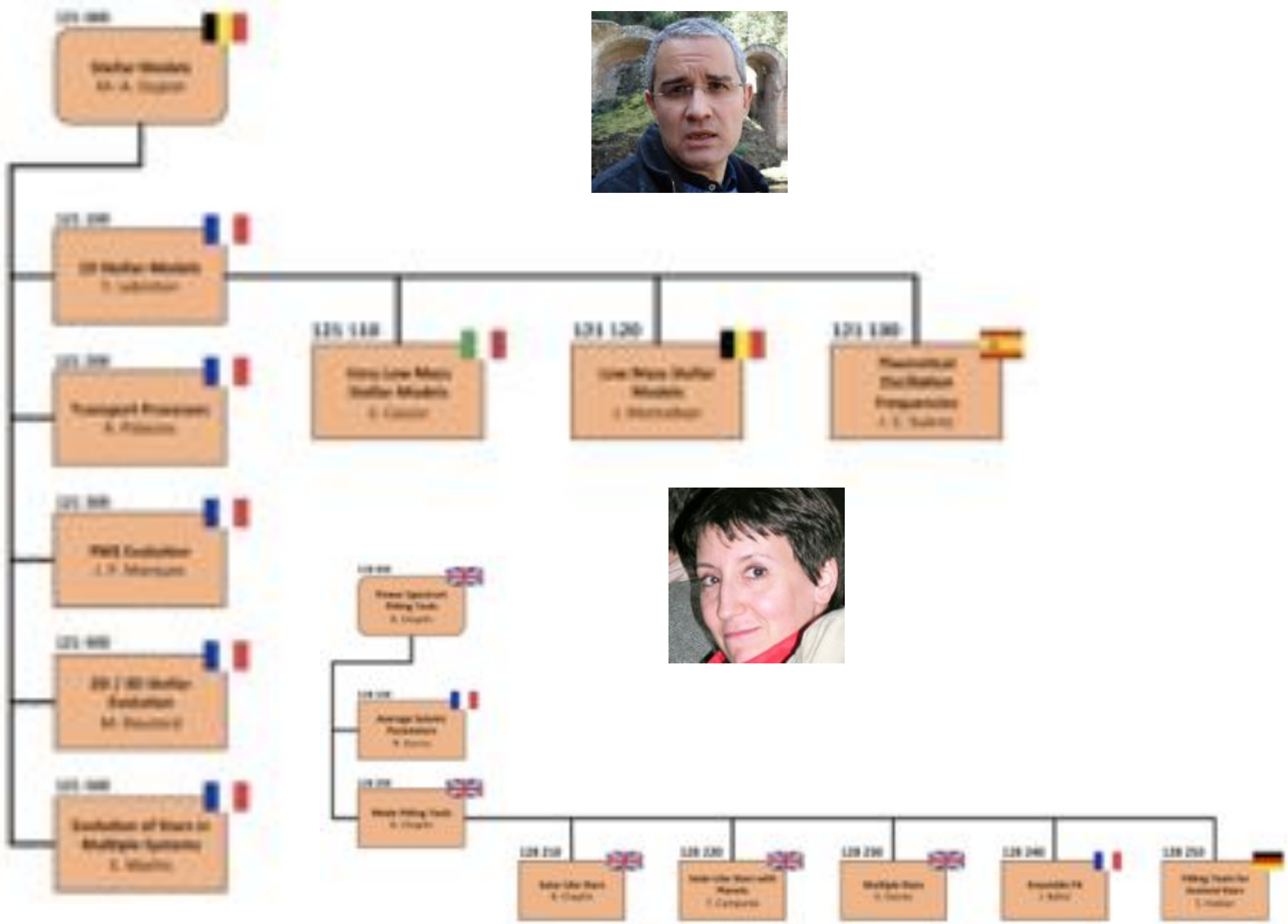
Exoplanet Science

Exoplanet Science



Stellar Science

Stellar Science

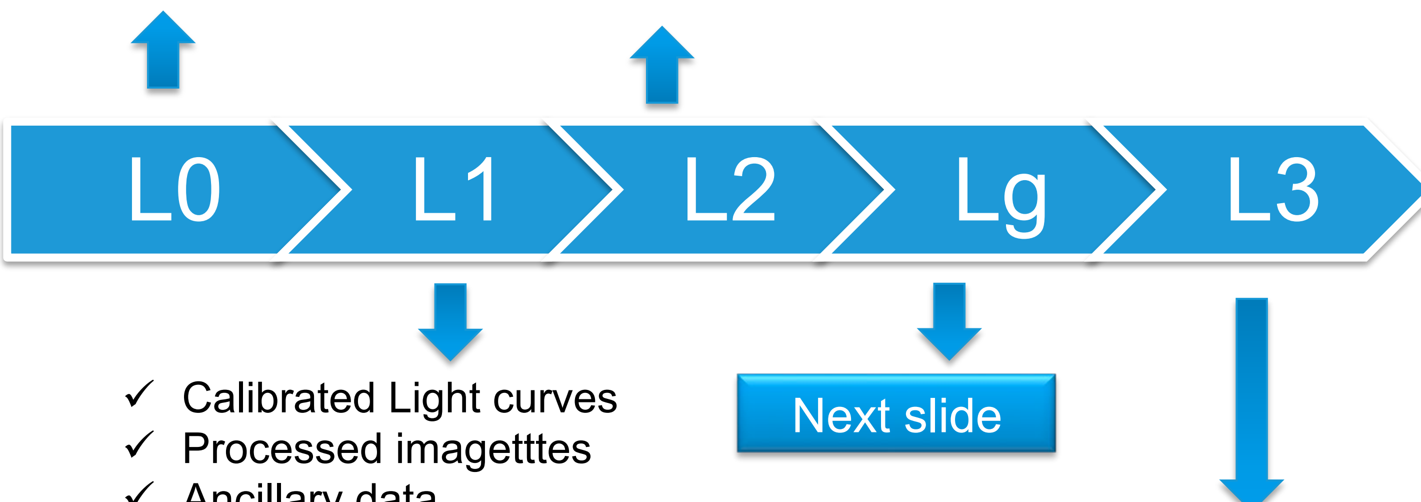


Follow-up coordination

Data products

- ✓ Imagettes
- ✓ Light curves and centroids
- ✓ Housekeeping
- ✓ Quality data

- ✓ Planetary transit candidates and their parameters
- ✓ asteroseismological analysis
- ✓ stellar rotation periods and stellar activity properties
- ✓ seismically-determined stellar masses, radii and ages of stars
- ✓ TTV planetary systems



- ✓ Calibrated Light curves
- ✓ Processed imagetttes
- ✓ Ancillary data
- ✓ Quality data

- ✓ list of confirmed planetary systems, which will be fully characterised by combining information from the planetary transits, the seismology of the planet-hosting stars, and the results of ground-based observations.

Ground-based observations data (Lg)

- Ground-based observations for filtering false planet transits:
  - Low-precision spectroscopy (1-2 m telescopes);
  - High-resolution imaging (2 m telescopes);
  - On and off transit photometry (1-2 m telescopes);
  - High-resolution spectroscopy (4-8 m telescopes);
  - Rossiter-McLaughlin (RM) observations (8 m telescopes).

- Ground-based observations for the characterisation of planets:
  - High-resolution spectroscopy (1-2 m, 4 m and 8 m telescopes);
  - Rossiter-McLaughlin (RM) observations (8 m telescopes).

Ground-based Observation Programme

Made by a GOP Team

Telescope Class	Candidate Confirmation		Radial Velocity Measurements		Total Nights
	(Nights/year)	(Total nights in 7 years)	(Nights/year)	(Total Nights in 9 years)	
1-2 m, low-resolution spectroscopy	~ 35	~ 245	-	-	~245
1-2 m, high-resolution imaging	~ 15	~ 105	-	-	~ 105
1-2 m, on-off photometry	~ 10	~ 70	-	-	~ 70
1-2 m, high-resolution spectroscopy			~ 3	~30	~ 30
4 m, high resolution spectroscopy	~ 20	~ 140	~ 100	~ 900	~ 1040
8 m, high resolution spectroscopy	~ 5	~ 35	~ 80	~ 720	~ 755

Few hardest cases (e.g., faintest hosts with Earths in the habitable zone) will need E-ELT

Ground-based Observation Programme

Made by a GOP Tea

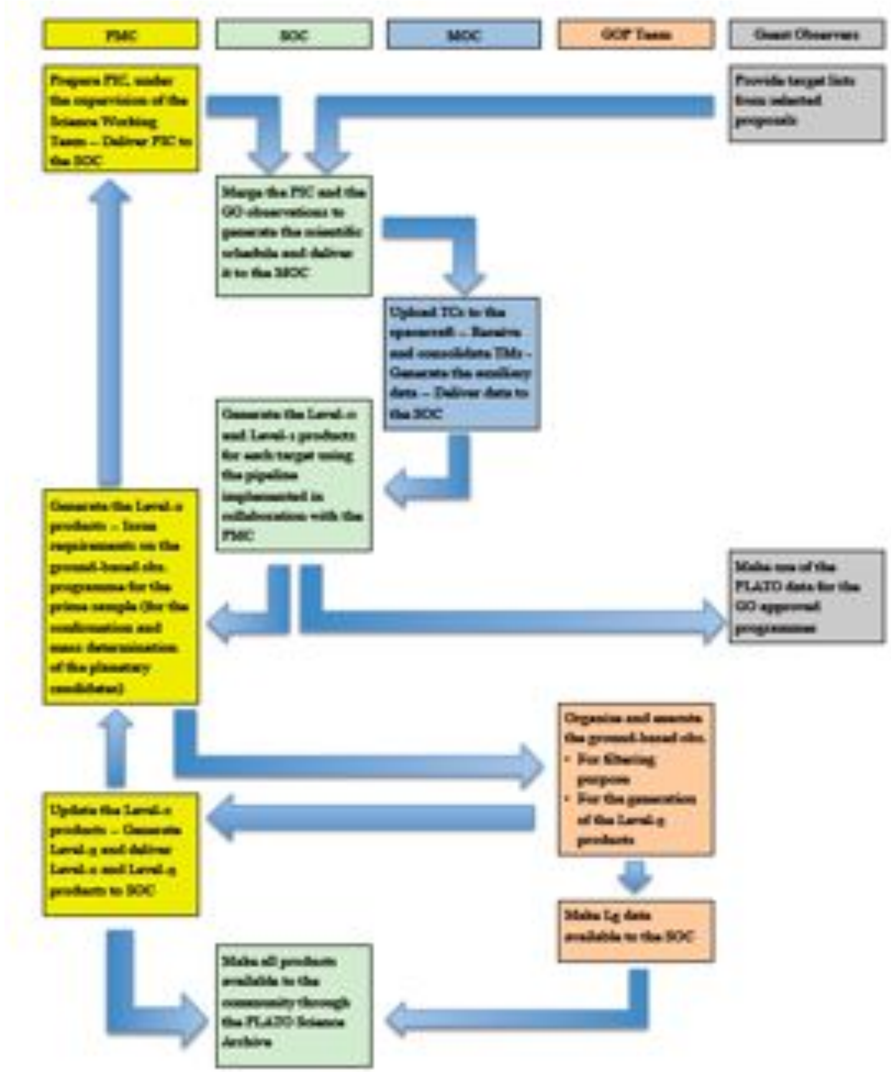
ESA will take the lead in establishing agreements and managing relations with main ground-based facilities such as (but not only) the European Southern Observatory (ESO).

Based on an ESA-ESO agreement, access to ESO ground-based facilities for the observation of the PLATO candidates in the "prime sample" will be through a competitive selection process for likely one or more ESO Large Programmes.

T					tal hts
1-2 spe					
1-2 imag					
1-2 m				-	~ 70
1-2 m spectr			~3	~30	~ 30
4 m, hi spectro		~ 140	~ 100	~ 900	~ 1040
8 m, hig solution spectroscopy	~ 5	~ 35	~ 80	~ 720	~ 755

Few hardest cases (e.g., faintest hosts with Earths in the habitable zone) will need E-ELT

Flow diagram of PLATO operations



PLATO Status

- ✓ PHASE B2 in progress
- ✓ Mission Adoption Review: completed
- ✓ PDR: summer 2017

Adoption in Nov 2016

Launch end of 2024

What we need

- PLATO preparation and data exploitation require competences in
  - **All aspects of exoplanetary science** (e.g., transits analysis, imaging, RV, planetary atmospheres, planetary formation & evolution) ←→ *SS planetology (macroarea 3)*
  - **Many aspects of stellar physics** (e.g., stellar magnetic activity, astroseismology, stellar evolution, atmosphere chemical analysis, oscillations, dynamics of the outer layers, stellar-planet interactions, stellar populations)

What we need

- Being ready to PLATO requires being on the forefront of exoplanetology and stellar physics at large.
- To maintain a lively and productive Macroarea 2, in all its subtopics, is a must if we want our community being protagonist in the use PLATO data.

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