The PLATO Mission

Science

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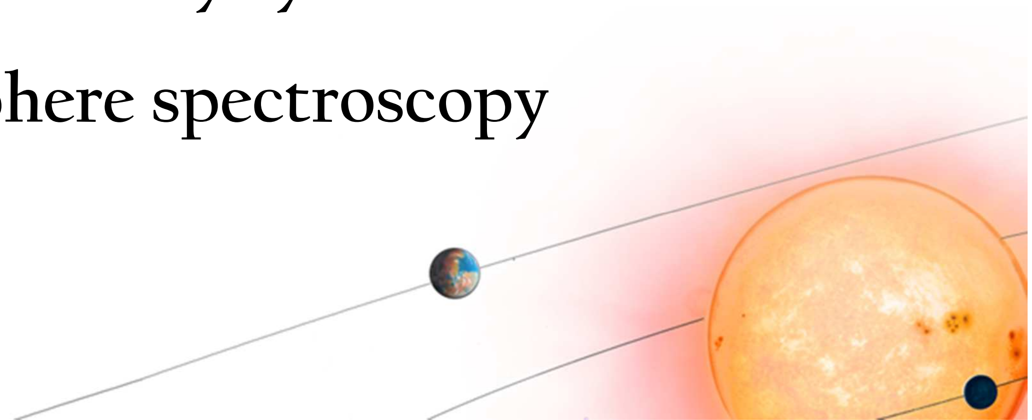
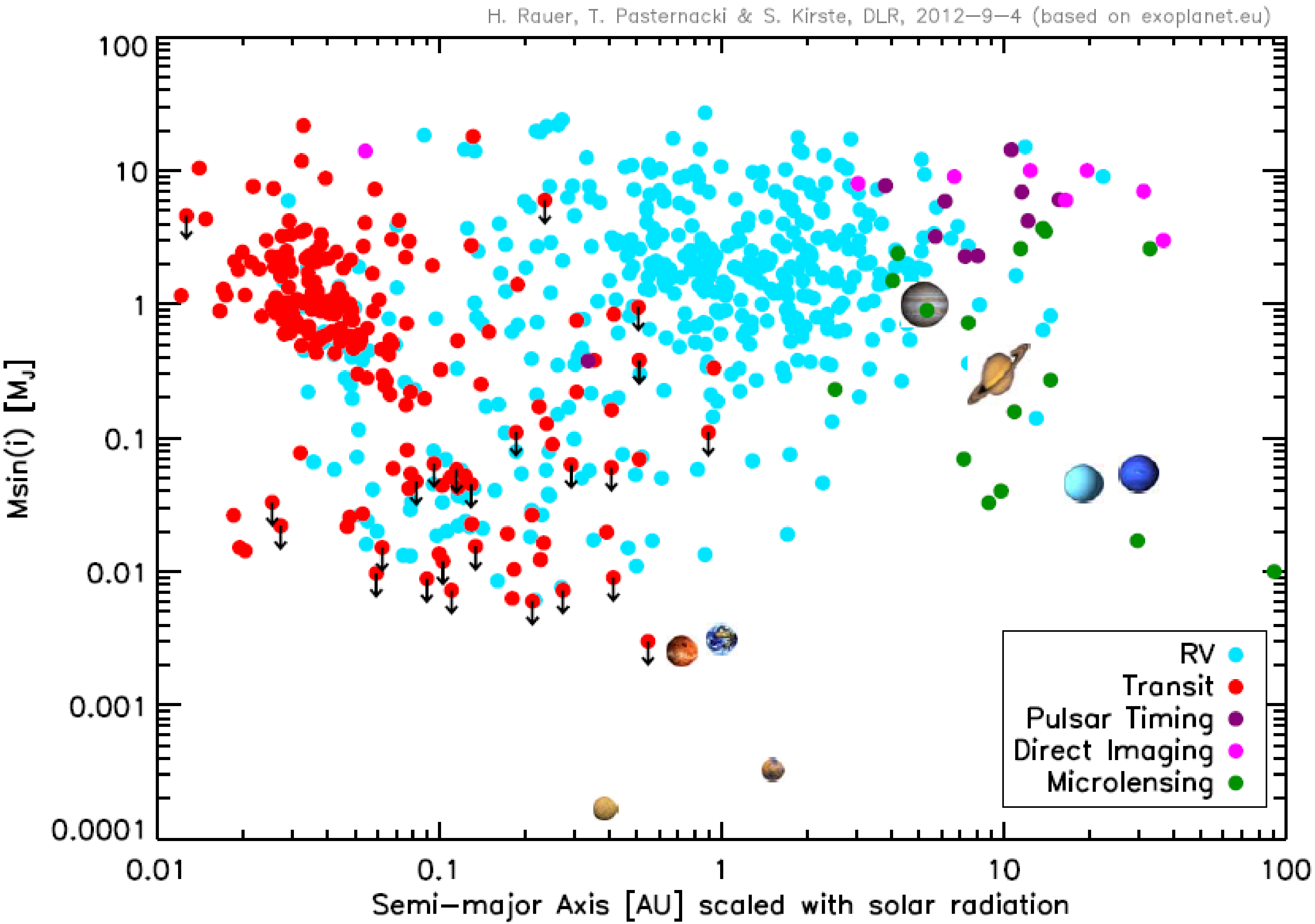
Science

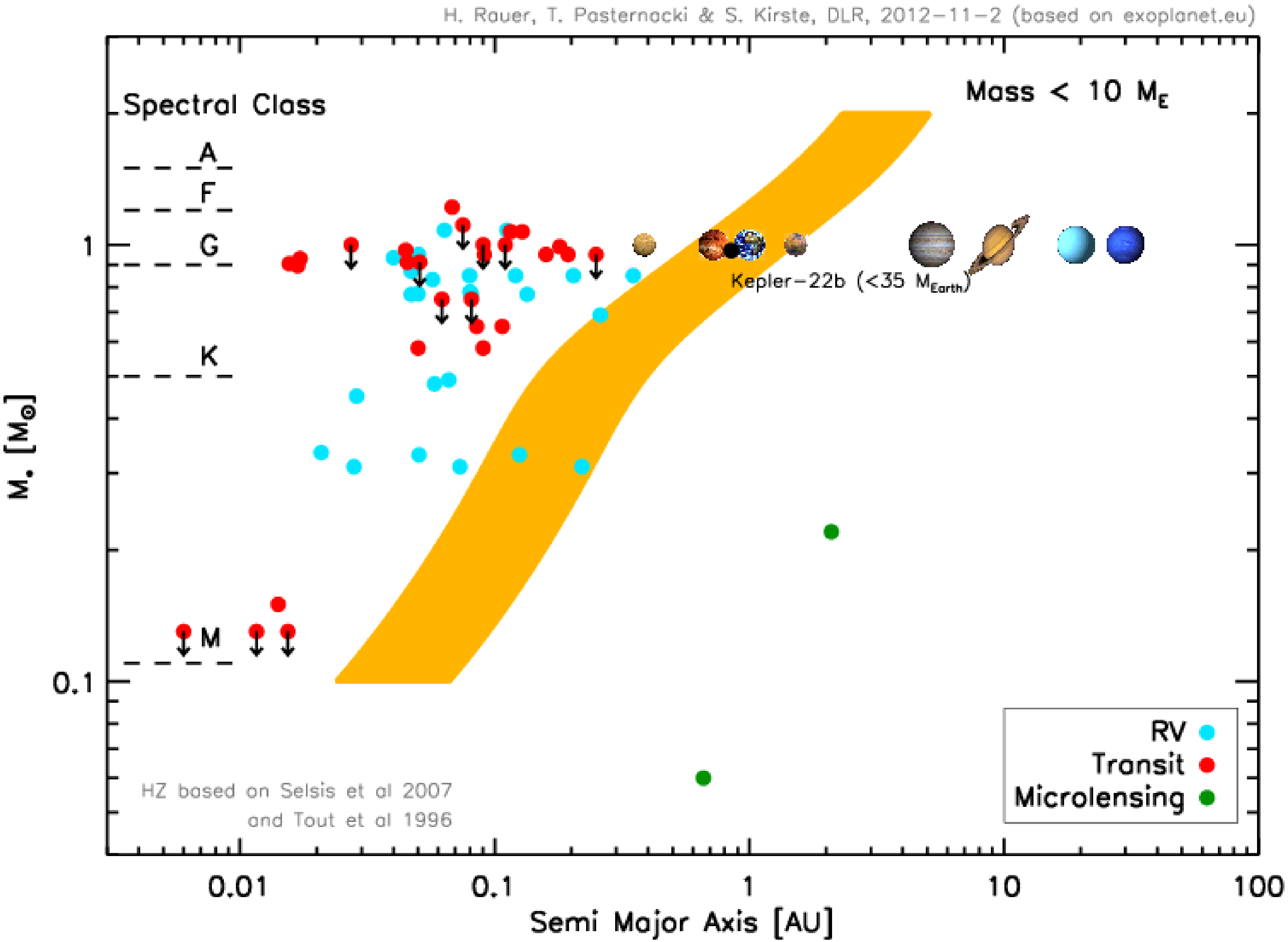
- reveal the interior of planets and stars
- characterize planets over the whole sky, including terrestrial planets in the habitable zone
- constrain planet formation and evolution
- provide accurate ages of planetary systems
- provide targets for atmosphere spectroscopy



Status - Exoplanets

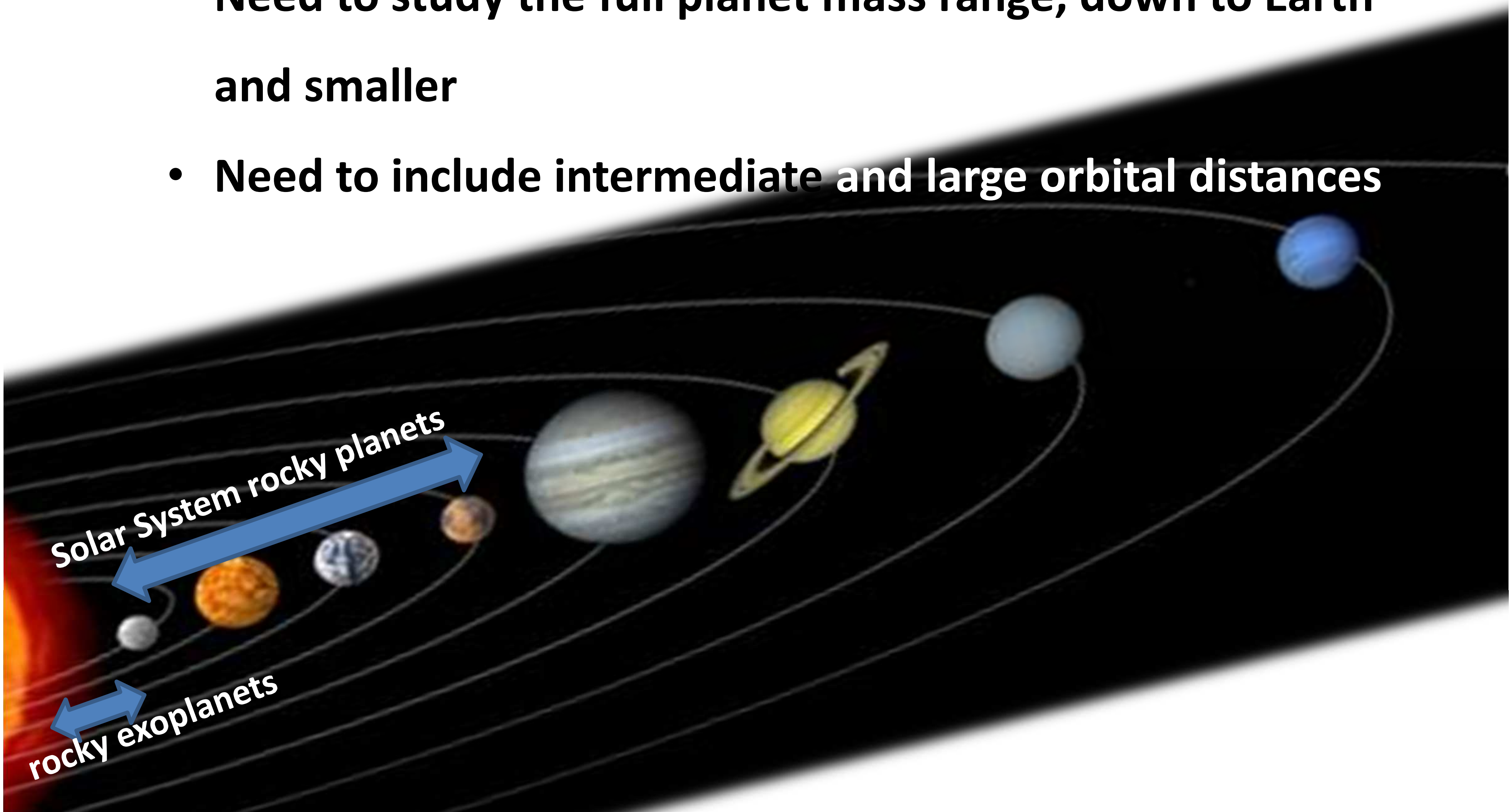


Status - Super-Earth

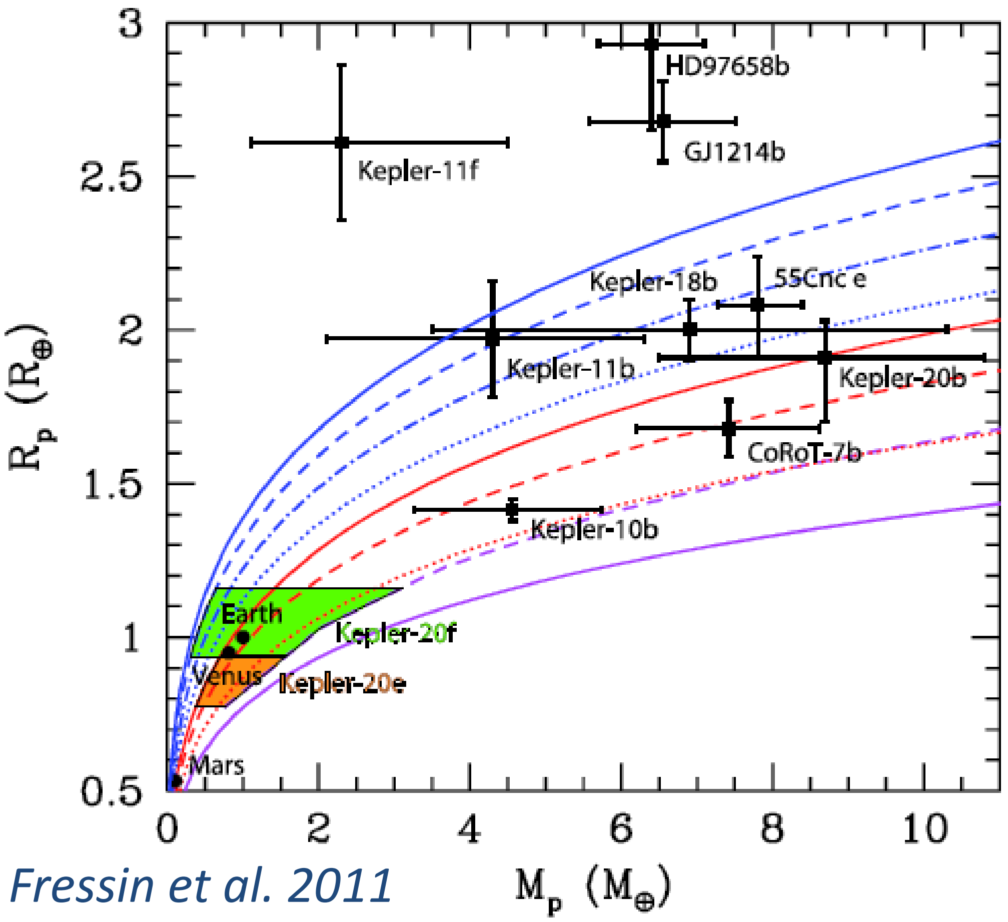


How typical is our Solar System?

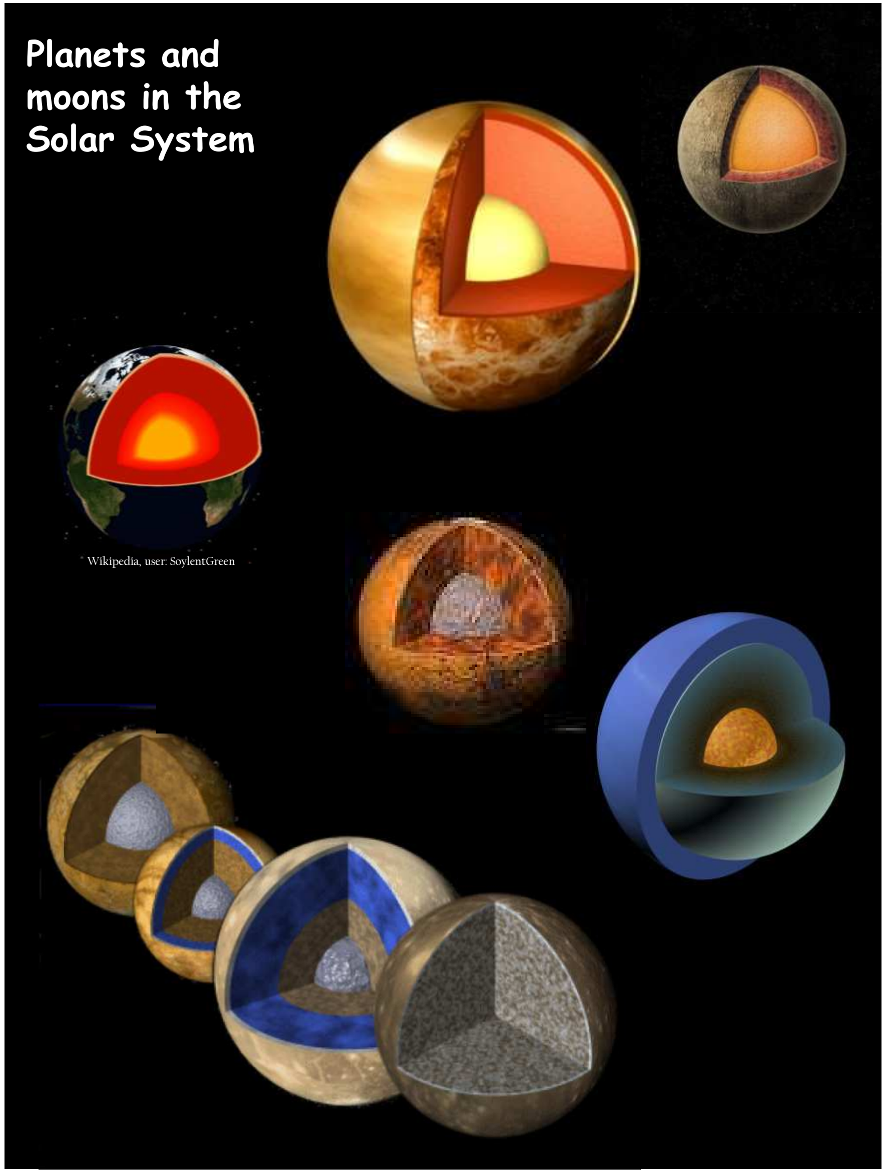
- **Need to study the full planet mass range, down to Earth and smaller**
- **Need to include intermediate and large orbital distances**



Planet diversity

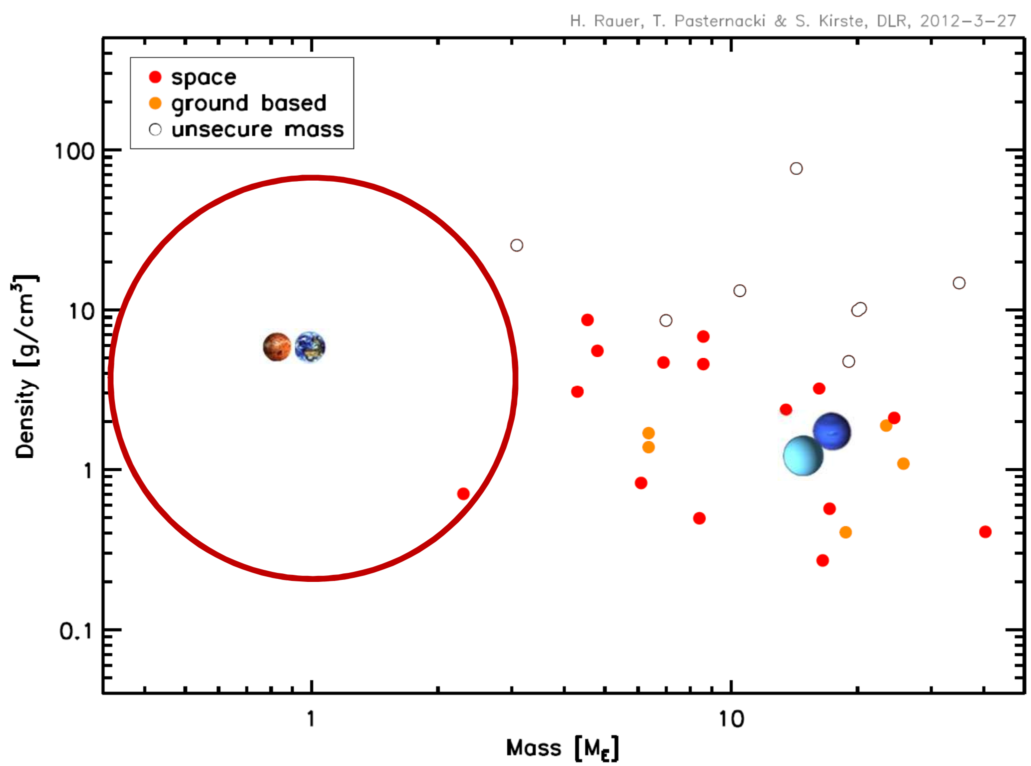


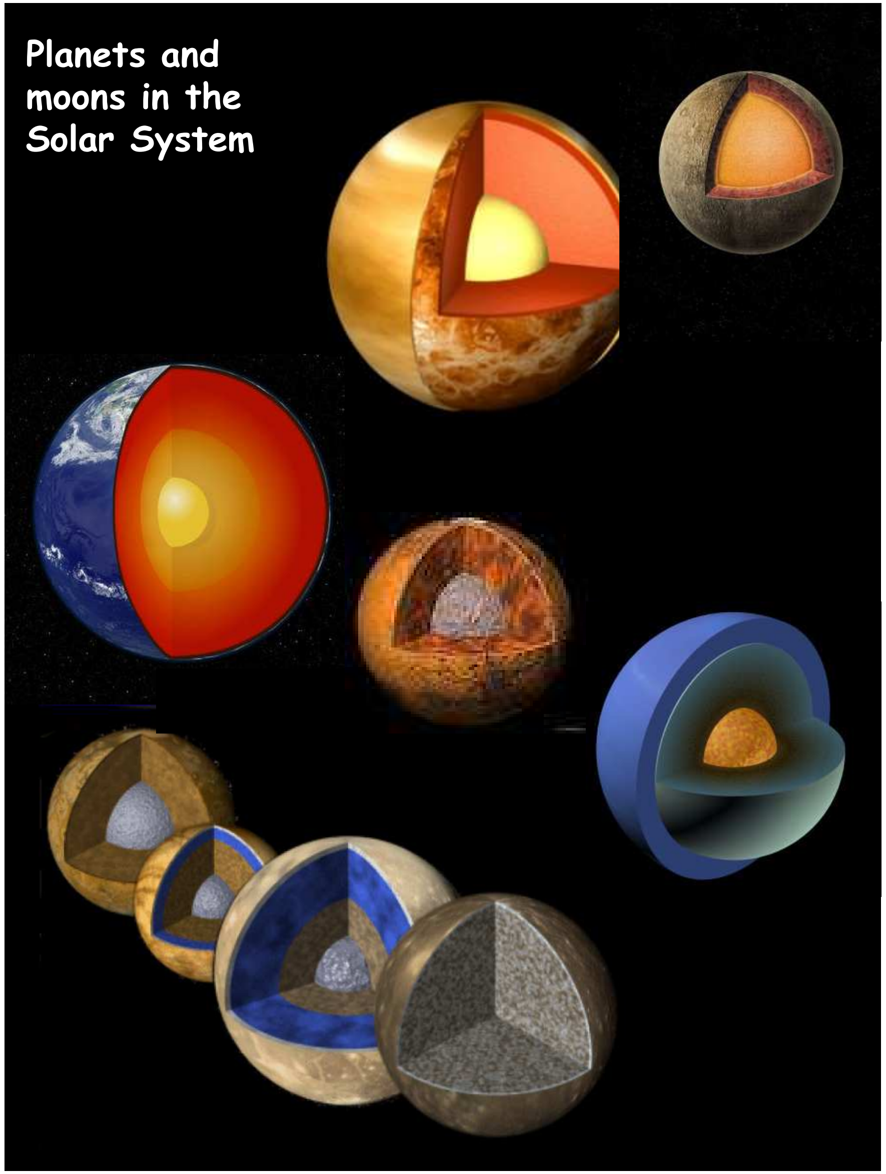
Fressin et al. 2011



Meaningful constraints on planet interior require high accuracy on radius (2%) and mass (10%)

Planet diversity





The parameter range of super-Earths to Earth planets is basically unexplored.

Why a new transit mission?

- Need brighter target stars to:
  - Determine accurate planetary radii and masses through astroseismology
  - rv-follow-up for a large number of terrestrial planets to derive masses
  - and future spectroscopy of a sample of targets!

A large sample of rocky and gassy planets with known densities and interior allows us to

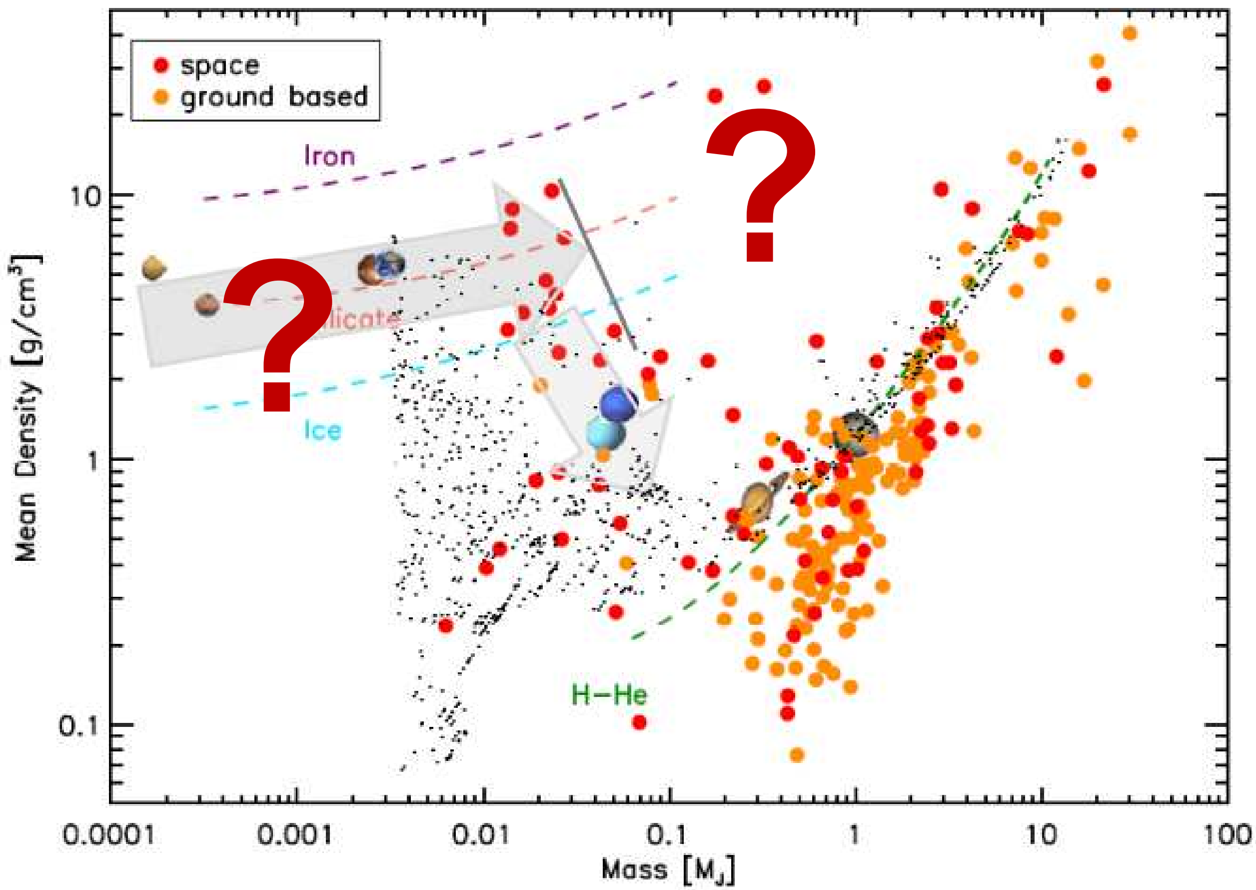
- determine mean density gradients in planetary systems

- study the evolution of planets and planetary systems

- provides constrains on planet formation, depending on:
  stellar type, metallicity, environment, ...

NASA/JPL-Caltech

Planet formation



Not all density-mass combinations are realized.
How about small terrestrial planets?

One order-of-magnitude diversity in mean density for a given mass.
What is their internal structure?

Current planet formation and evolution models do not reproduce the distribution of terrestrial and icy planets.

Do large silicate planets without significant envelope exist?

Black dots: results of planet formation models (Mordasini et al. 2012)

Rauer et al. 2012 submitted

Planet formation: constains from exoplanets

- What is the critical core size for giant plant growth?
- Can super-dense rocky planets exist, and how are they formed?
- Do the predicted rocky planets with large gas envelopes exist?
- How large are planetary cores and how do they compare to model predictions?
- What are the bulk parameters of Earth- to Mars-sized planets?
- How do the planet bulk parameters in general correlate with e.g. stellar metallicity, stellar type, orbital distance, disk properties, age?

- RoPACS main goals:
    - How does planet formation depend on the host star?
    - How does our solar system relate to the full diversity of planetary systems?

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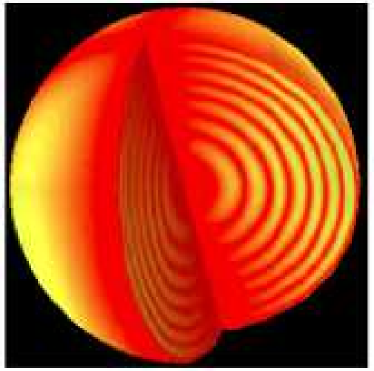
→ Answering these questions requires planets with **accurately** known mass, radius, and mean density in **numbers sufficiently large** to correlate them with planet formation relevant factors.

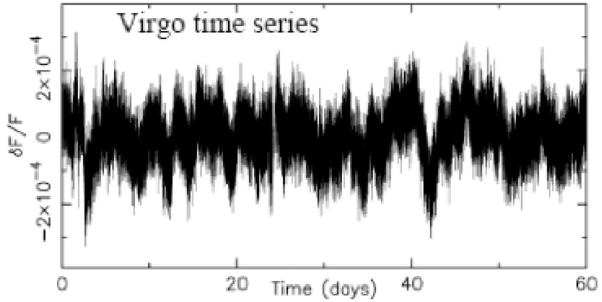
Characterisation of host stars with Asteroseismology

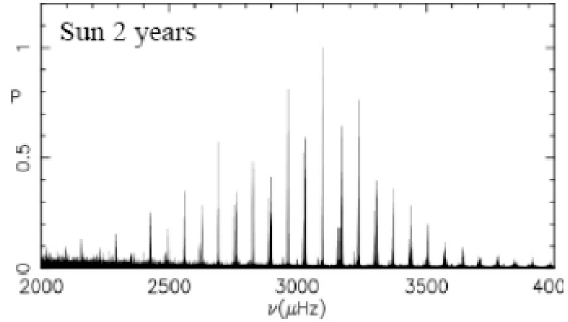


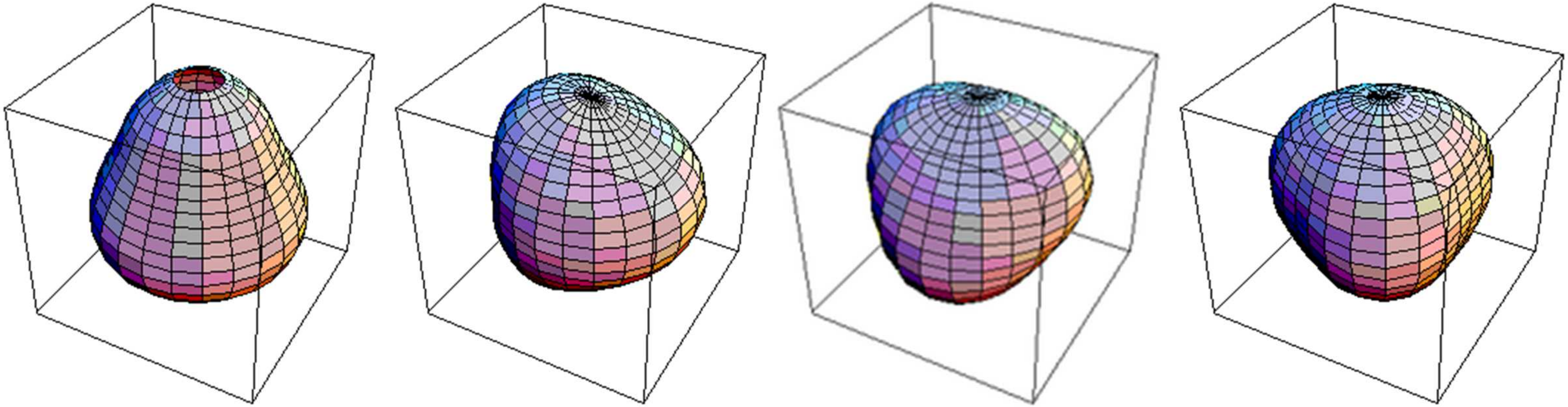
Planet parameters ← stellar parameters (asteroseismology)

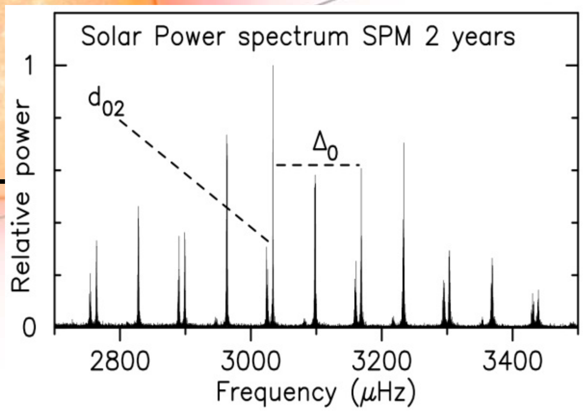
Solar-like stars oscillate in many modes, excited by convection. Sound waves trapped in interior

Resonant frequencies determined by structure:
→ frequencies probe structure
→ gives mass, angular momentum, age







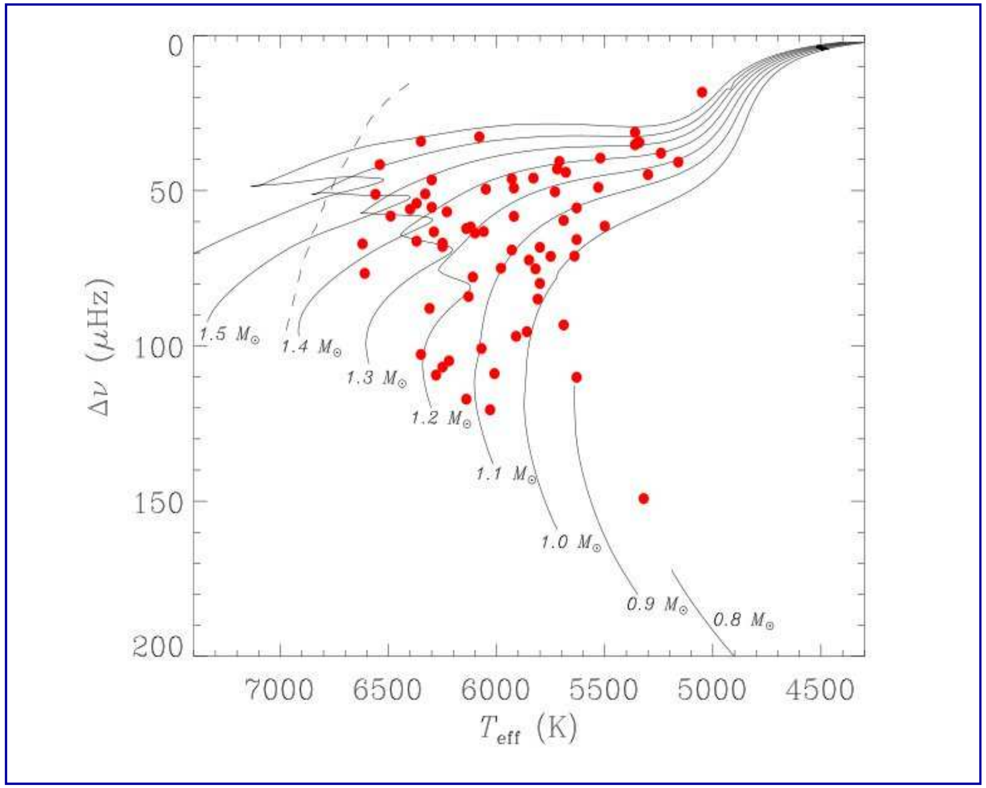


Asteroseismology

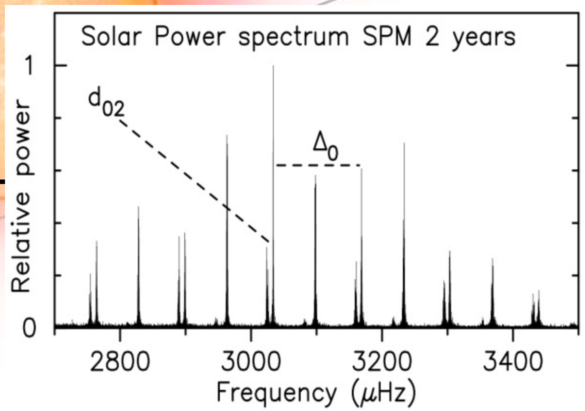
mass and age of host stars

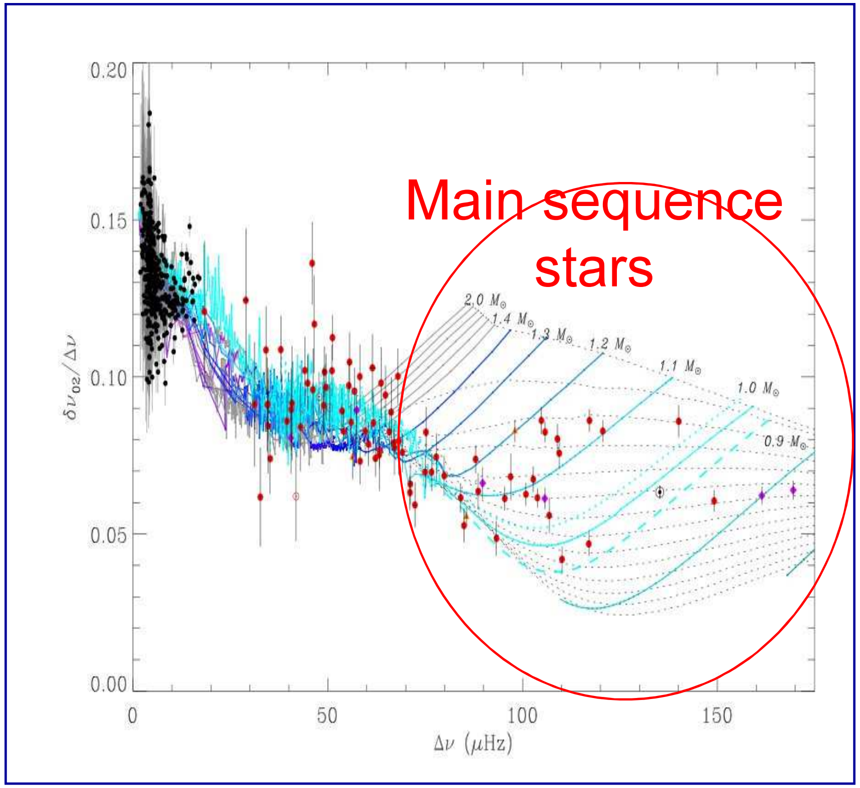
1. Large separations $\Delta_0 \propto \sqrt{M/R3}$
   → mean density
2. Small separations d_{02}
   → probe the core → age
3. Inversions + mode fitting
   → consistent ρ, M, age

Asteroseismology has been successfully applied to bright Kepler stars, showing how powerful this technique is.



Mean large separation as a function of the effective temperature for 78 solar like oscillating stars observed by Kepler over 10 months (White et al. 2011)





Normalized mean small separation as a function of the mean large separation and evolutionary tracks (blue solid lines). Horizontal dotted lines are isochrones in 1 Gyr steps (White et al. 2011)

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PLATO will improve the achieved accuracies to:

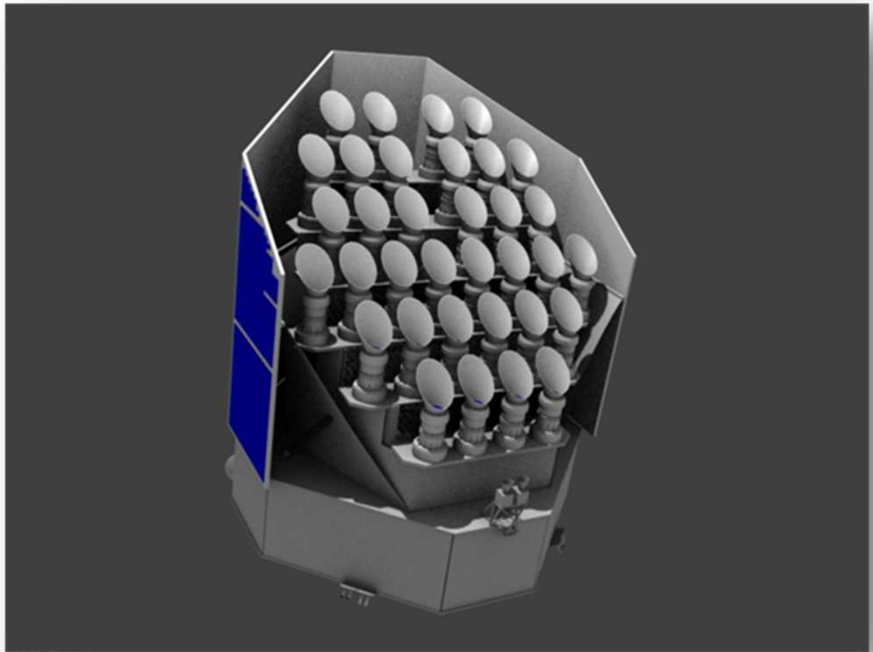
- Uncertainty in Mass ≤ 2%
- Uncertainty in Age ~ 10%

The PLATO Mission

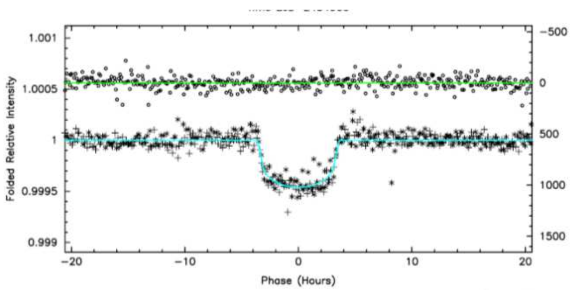
Mission proposal for ESA M3 launch selection

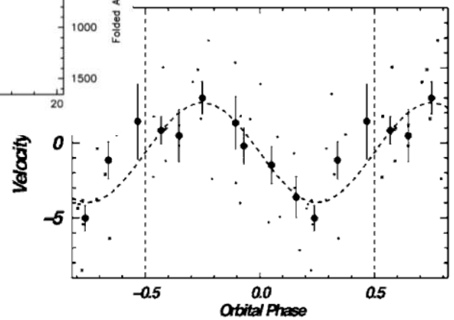
The instrument:

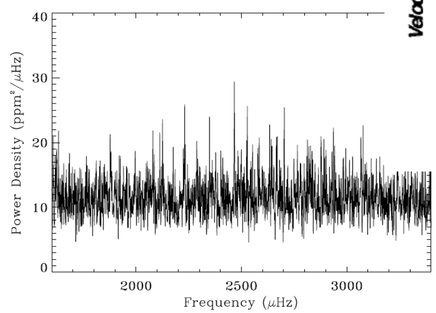
- 32 «normal» cameras :
  cadence 25 sec
- 2 «fast» cameras :
  cadence 2.5 sec,
  2 colours
- pupil: 120 mm
- dynamical range: $4 \leq m_V \leq 16$



The methods







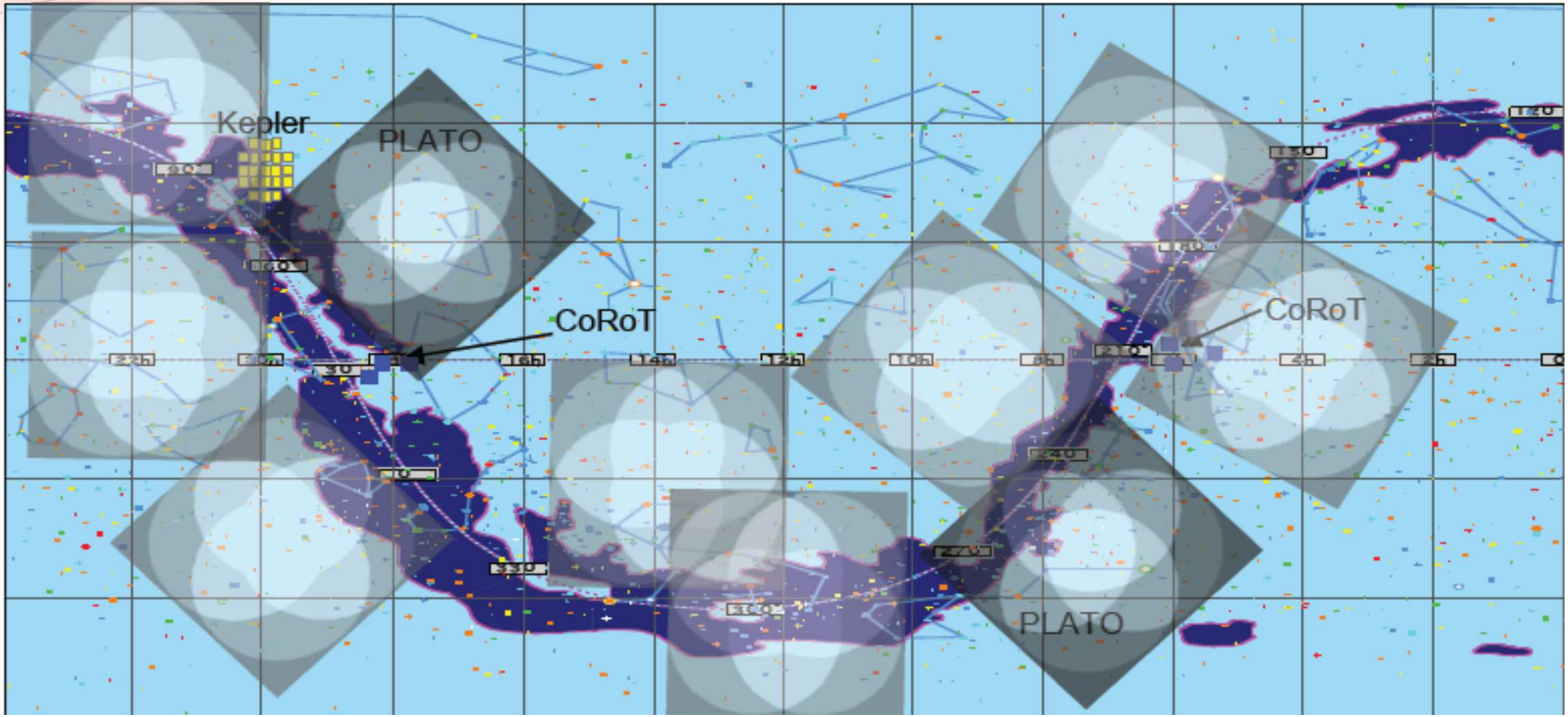
Example: Kepler-10b

Accuracy:

An Earth around a Sun :

- **radius up to 2%**
- **mass up to 10%**
- **age known to 10%**

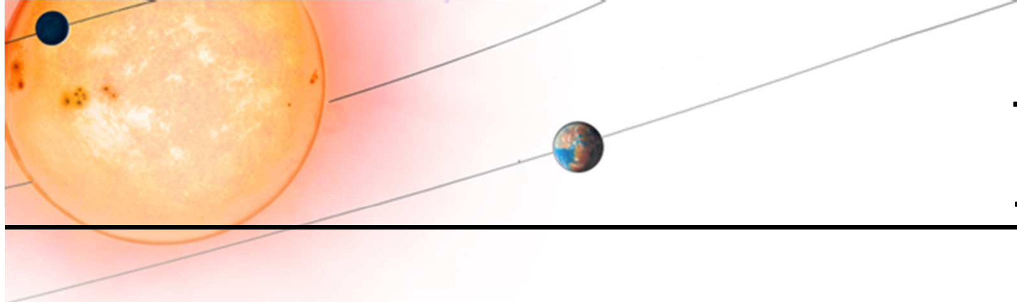
Field of View



The M2 baseline assumed 2 long pointing + step-and-stare phase

For M3: Other observing other strategies are possible, e.g.:

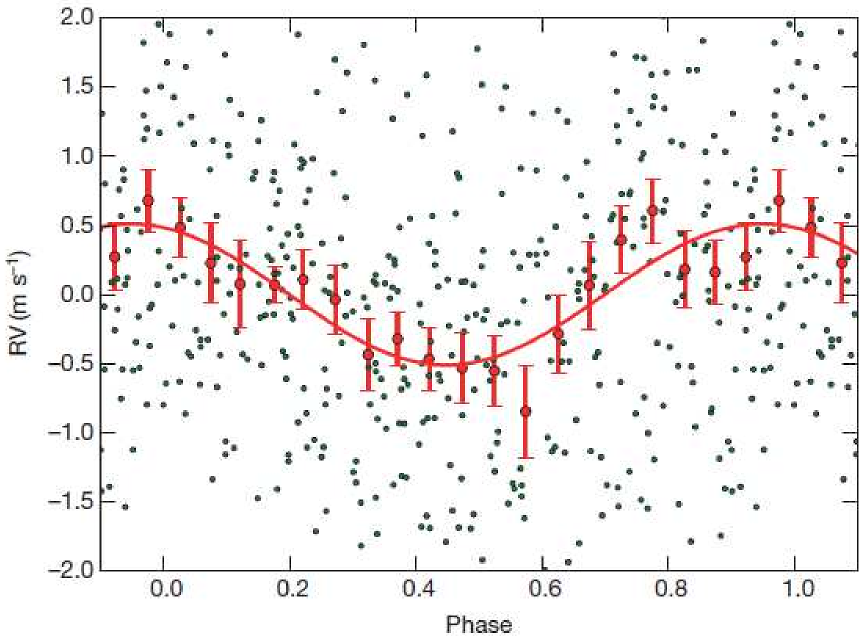
- Start with step-and-stare phase for large coverage in the early phase → >50% sky
- Start at regions with interesting objects



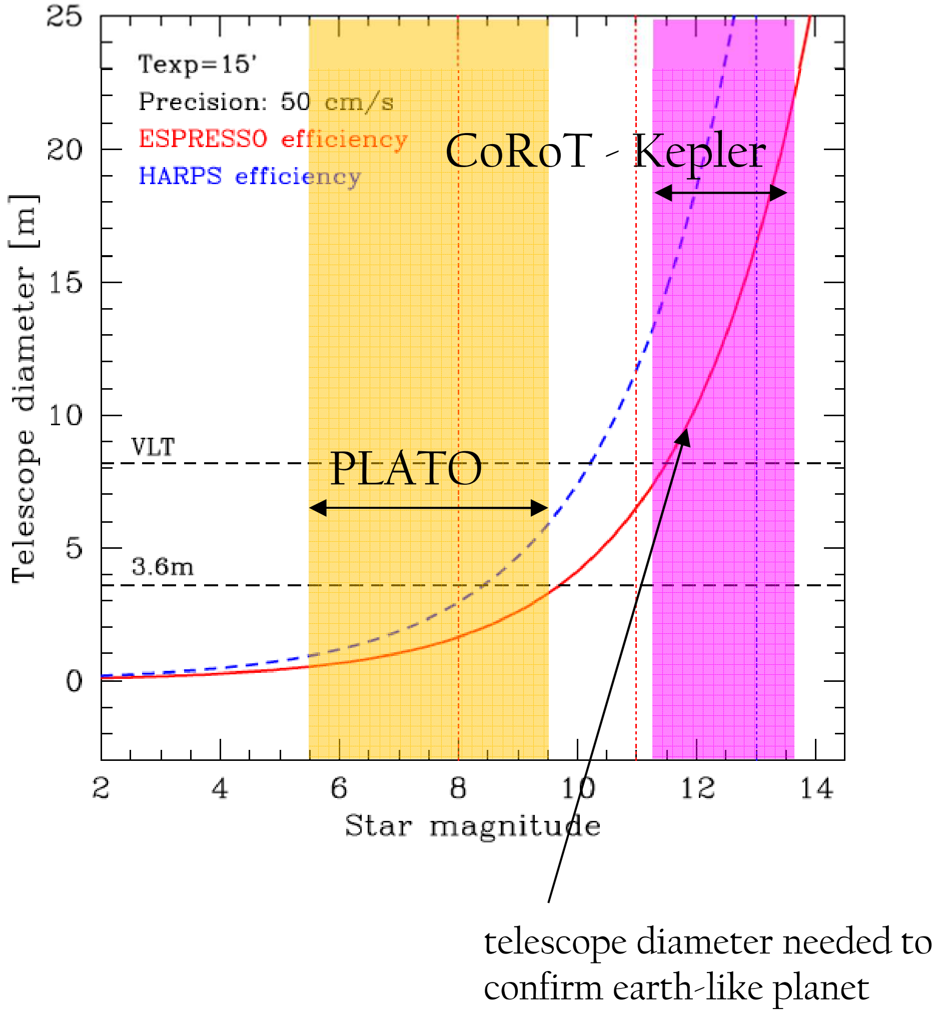
Follow Up

- Vigorous follow-up needed
- Most important aspect = radial velocity monitoring
  ⇒ planet confirmation and mass measurement

- stellar intrinsic « noise »:
  oscillations, granulation, activity
- need to apply proper averaging technique
- time consuming
- in practice limited to bright stars



alpha Cen B b Dumusque et al. 2012



Summary: PLATO Science Case

- Detect Earth-sized planets in the habitable zone with known radii and masses, including planets orbiting solar-like stars.
- Obtain statistical significant numbers of characterized small planets at different orbits, stars, …
- Study planet interior composition and structure including terrestrial objects
- Determine accurate ages of planet systems
- Provide small terrestrial planets around bright stars as targets for atmosphere spectroscopy

Selection of science questions

- What are the bulk properties (mass, radius, mean density) of terrestrial planets in systems of all kinds, including planets in the HZ of solar-like stars?
- How correlate the bulk planet properties with e.g. stellar metallicity, stellar type, orbital distance, disk properties, age?
- What is the critical core mass for giant planet formation?
- Do super-dense rocky planets exist and how are they formed?
- Do very low-mass planets with large envelopes predicted by formation models exist?
- What is the internal structure of terrestrial, Neptune-like and gas giant planets? (interesting question also in our Solar System)

The PLATO legacy

- a huge sample of characterized planets with known mass, radius and age, including terrestrial planets in the HZ of solar-like stars

- planets surrounding stars bright enough for detailed follow-up

→ **pioneers true comparative planetology and taxonomy of planet systems**

A huge complementary science program:

- 1,000,000 of high-precision photometric stellar light-curves

- 85,000 of these stars (V<11 mag) will allow for astroseismic characterization

- in synergy with Gaia: mass, age, rotation, distance, luminosity, radius

→ **a breakthrough in stellar physics** (e.g. stellar structure and evolution, internal mixing processes, stellar rotation, ages of globular clusters, young open clusters)

- Potential for solar-system science: Kuiper-belt objects