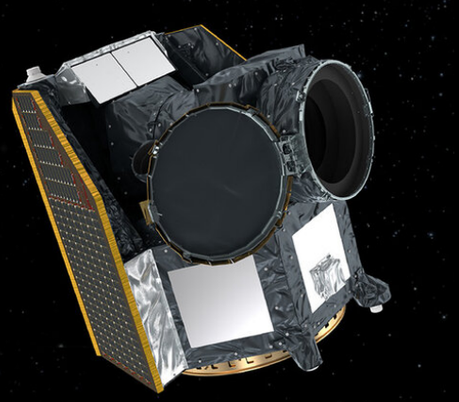
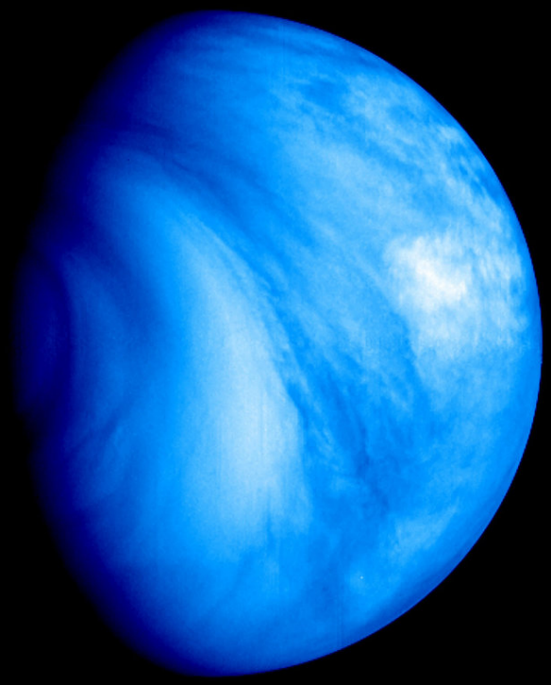
Exoplanet science in the age of CHEOPS



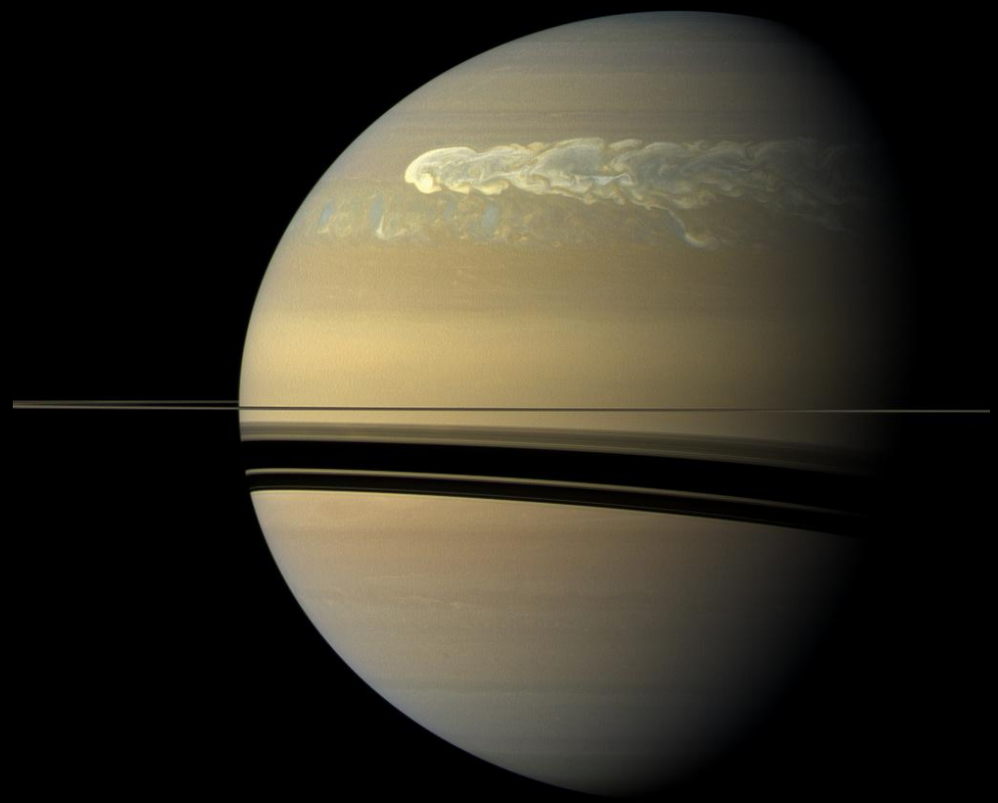
Monika Lendl
Université de Genève

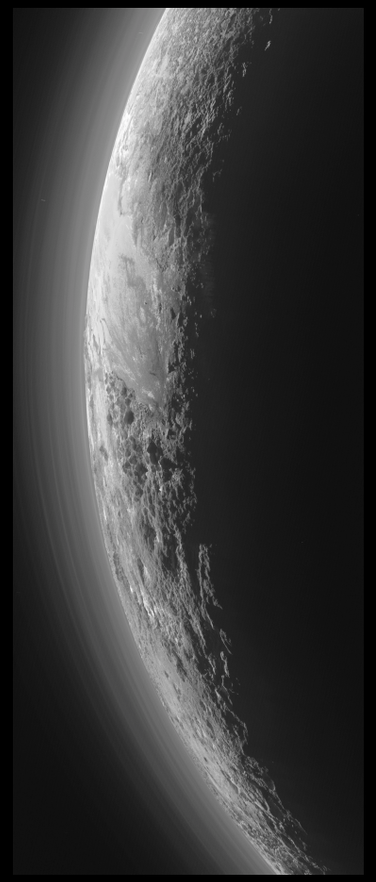
SEA - Reunión Cientifica 2020

Venus (VEX)



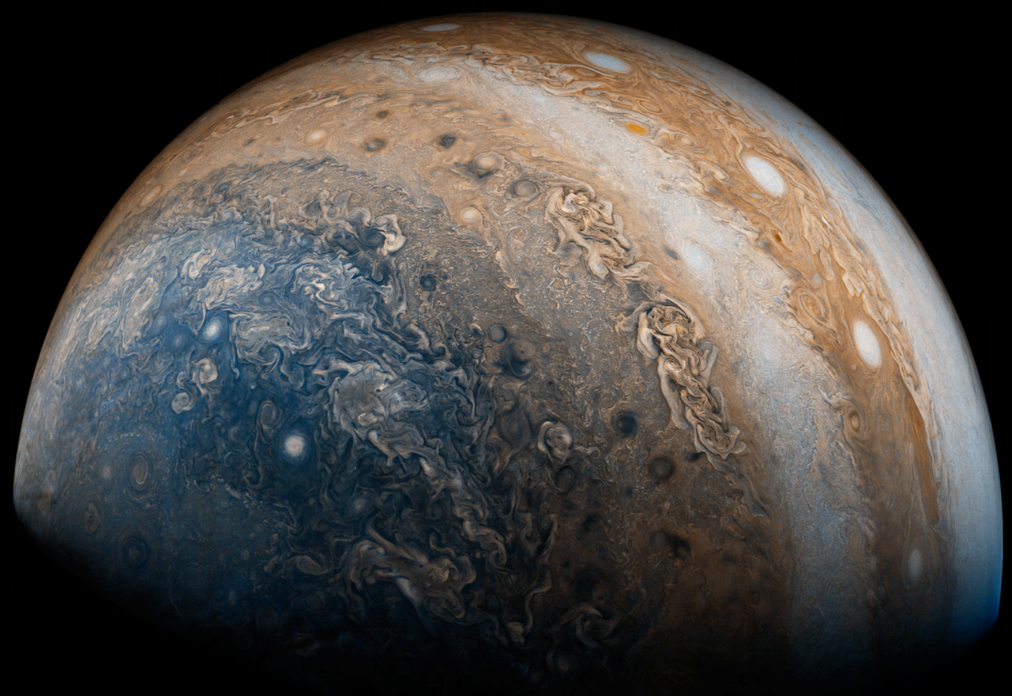
Saturn (Cassini)





Pluto (New Horizons)

Mars (MEX)



Jupiter (Juno)

Venus (VEX)

Saturn (Cassini)

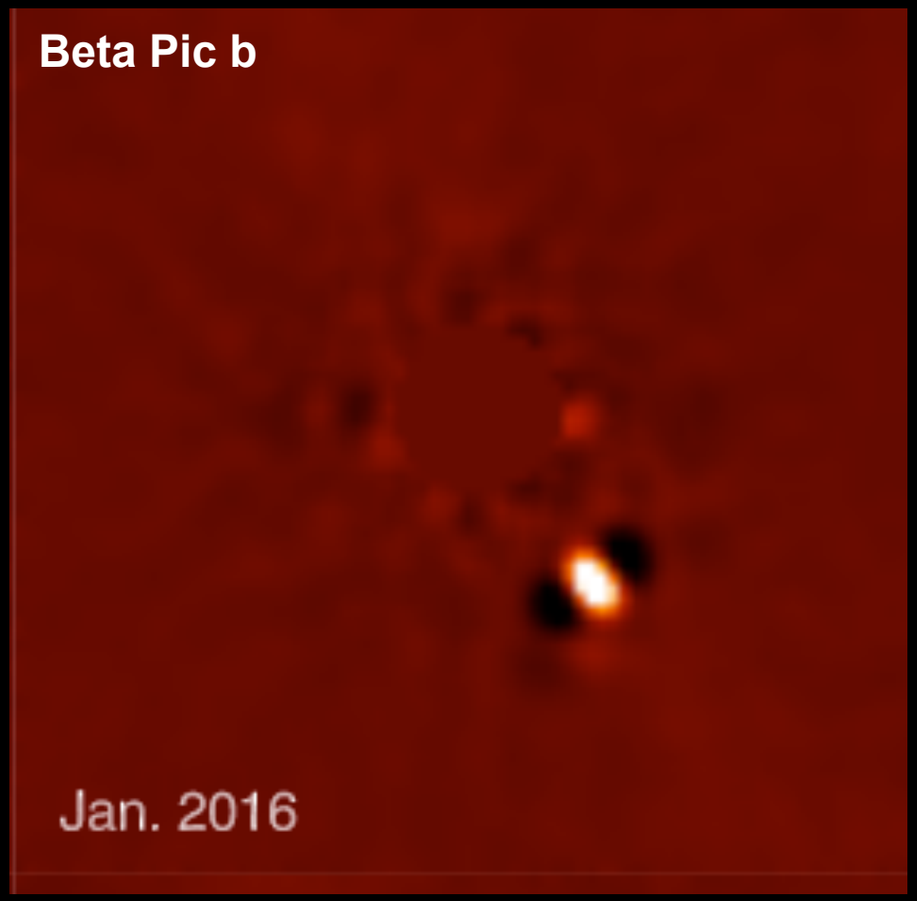
What about exoplanets?

Pluto (N Hor)

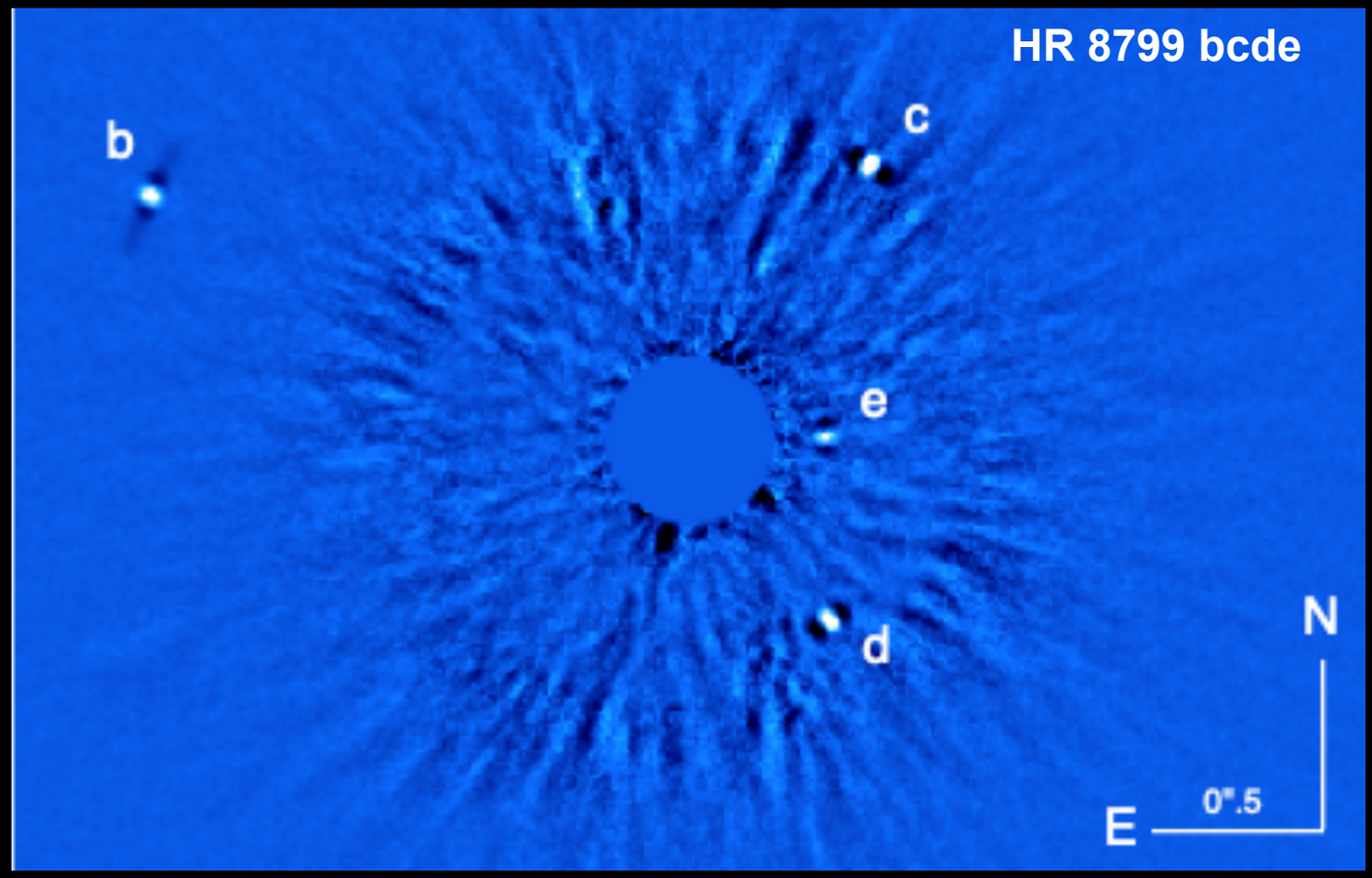
Mars (MEX)

Jupiter (Juno)

What about exoplanets?



Lagrange+ 2018

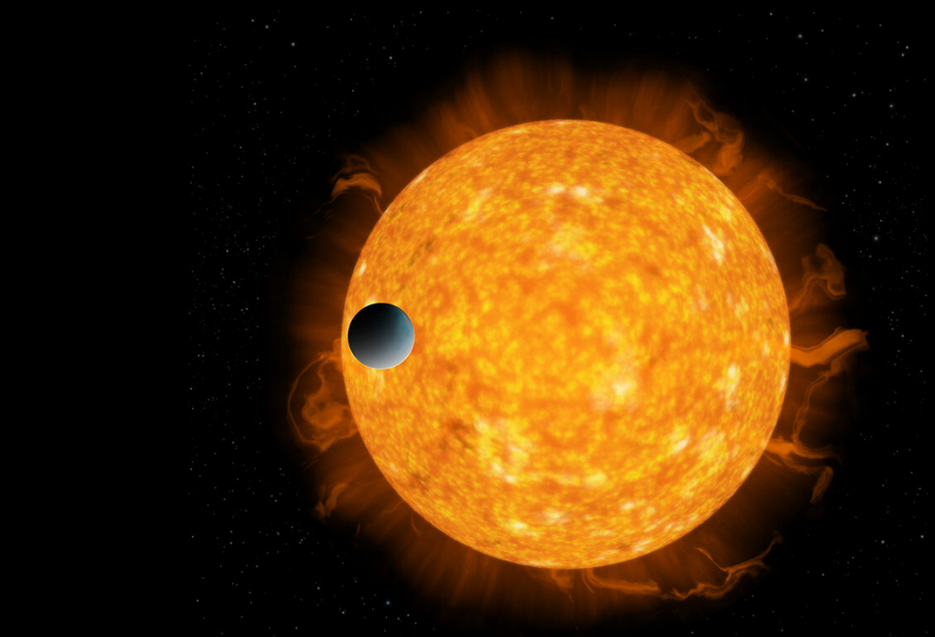


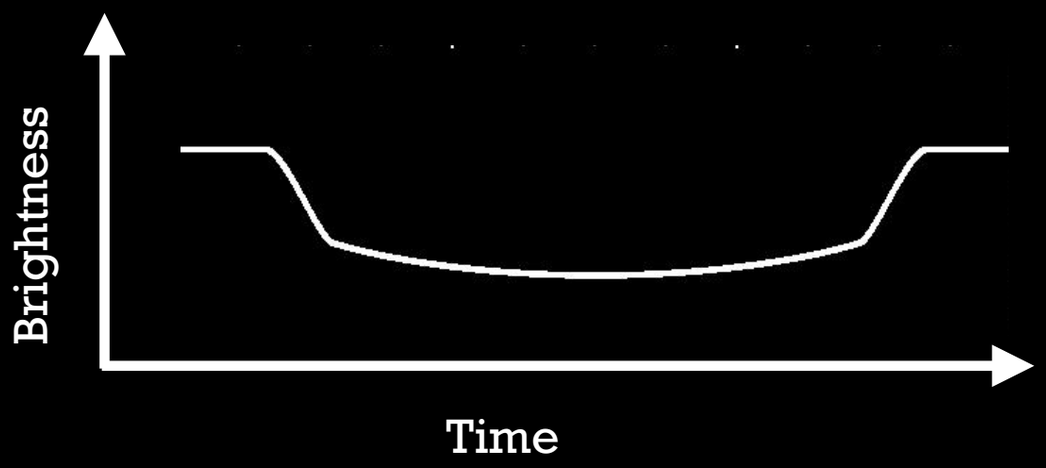
Wertz+ 2016

- Precious directly imaged systems are few and far between
- Young systems, massive planets

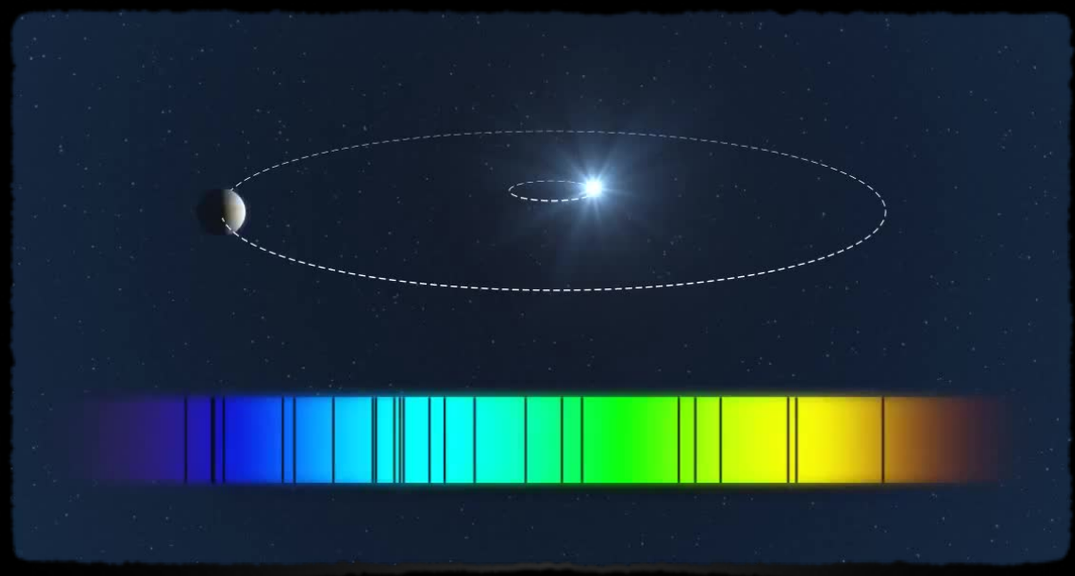
Indirectly detected exoplanets

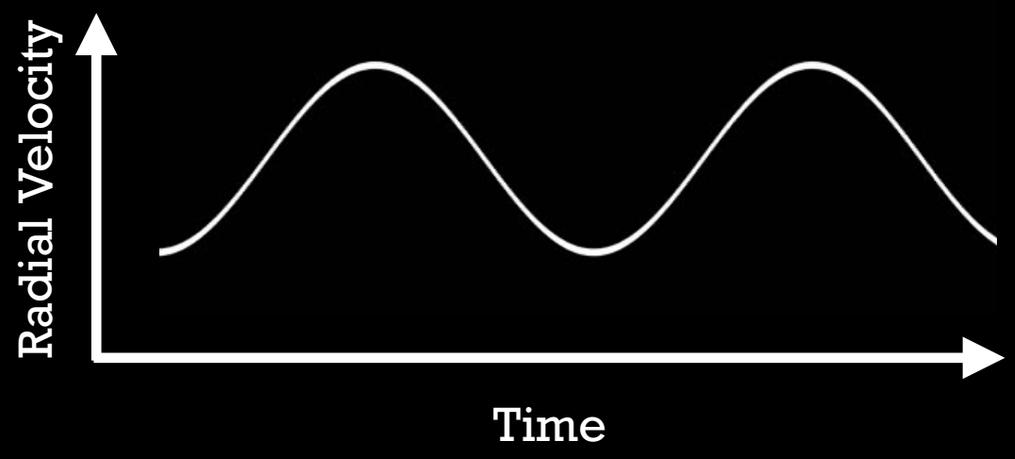
Transits





Radial Velocity

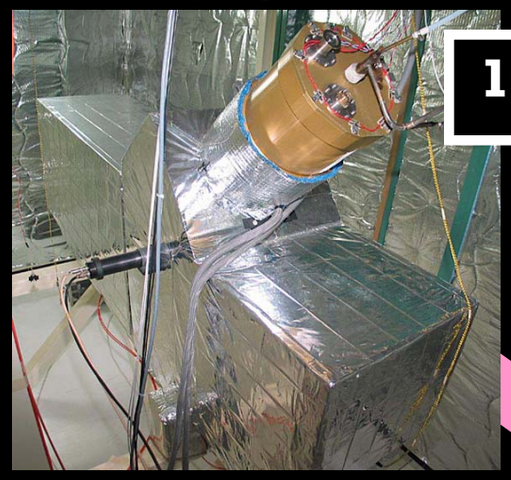




The Exoplanet Boom

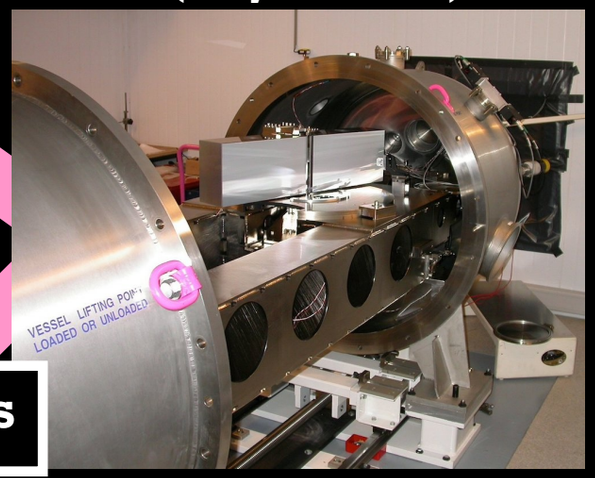
… since 1995

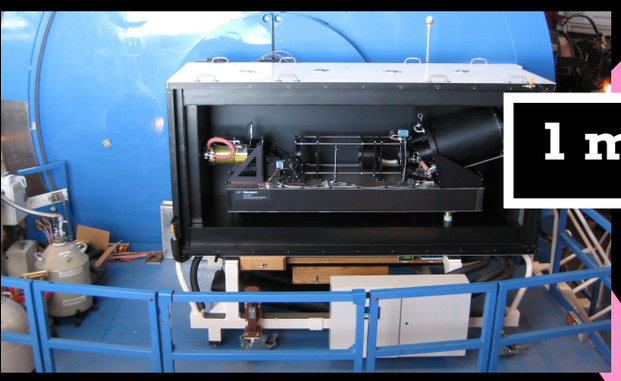
ELODIE (Mayor & Queloz 1995)



10 m/s

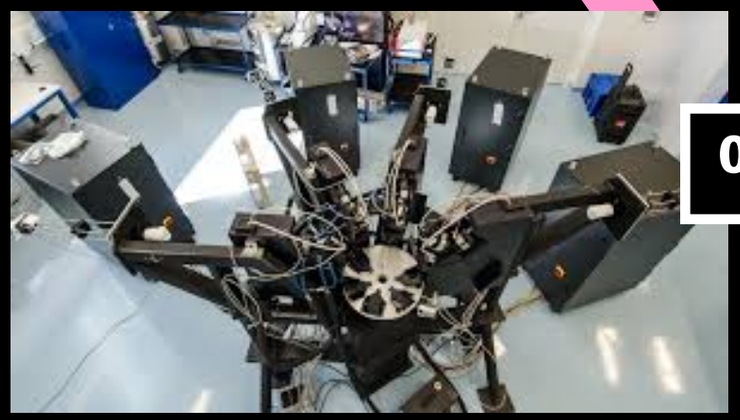
HARPS (Mayor+ 2003)





1 m/s

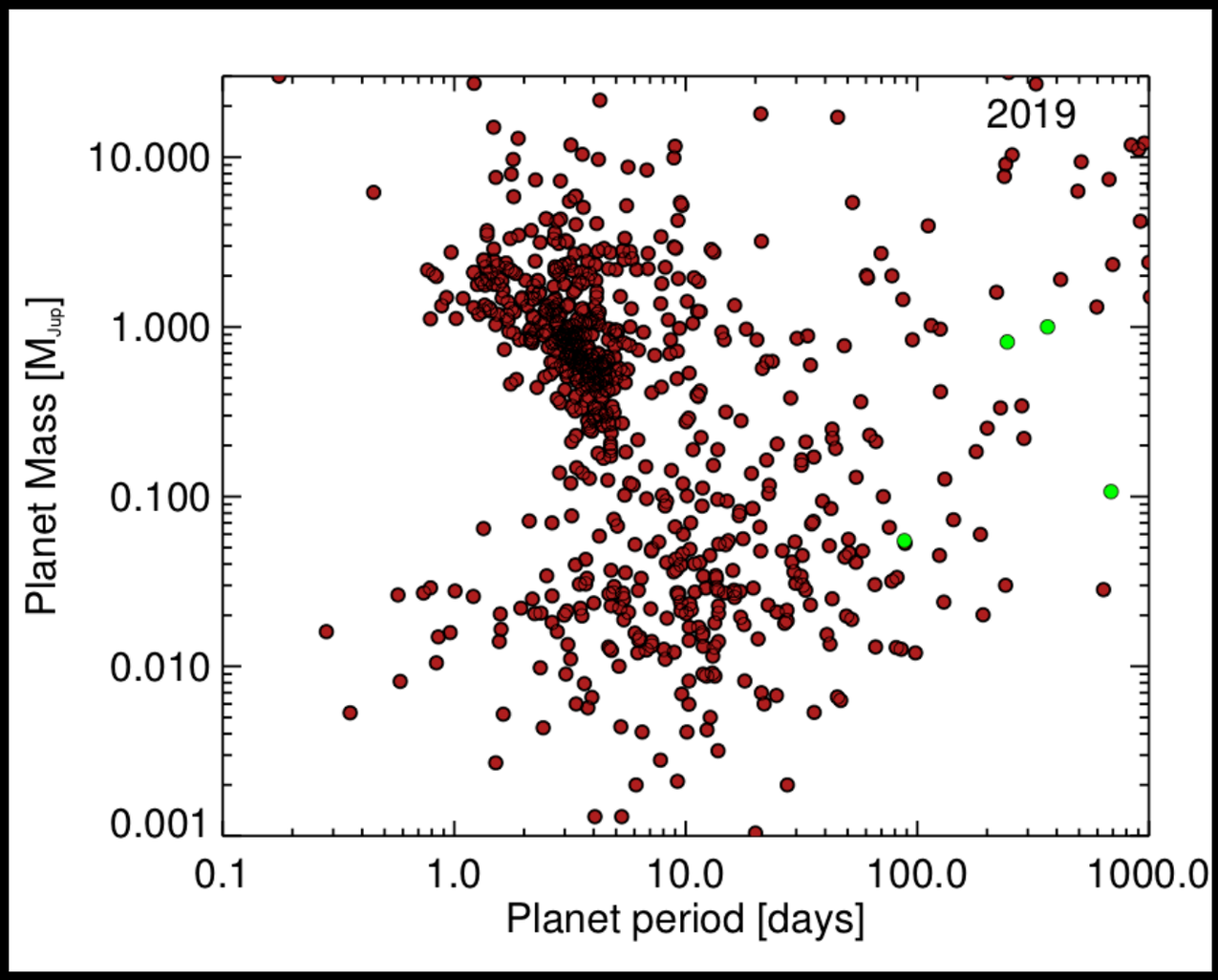
PFS (Crane + 2010)



0.1 m/s

ESPRESSO (Pepe+ 2010)

RV planets

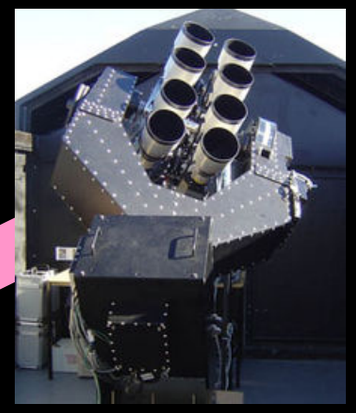


The Exoplanet Boom

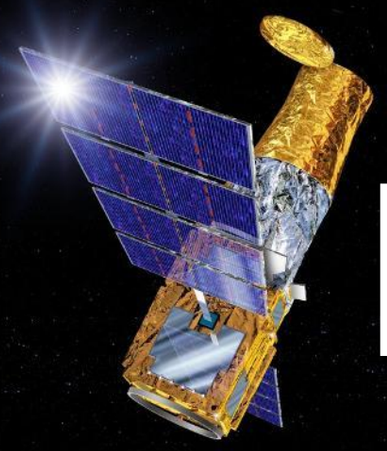
… in transit since 2000

Ground-based surveys

WASP (Pollacco+ 2006), HAT (Bakos+ 2004)



Hot Jupiters

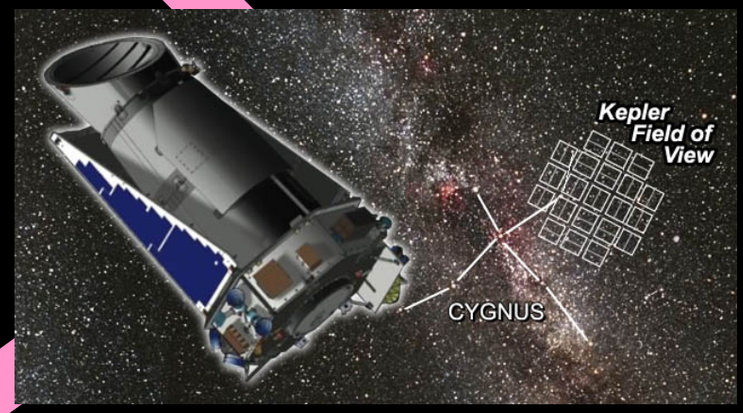


CoRoT (Baglin+ 2006)

First rocky planet

(Leger+ 2009)

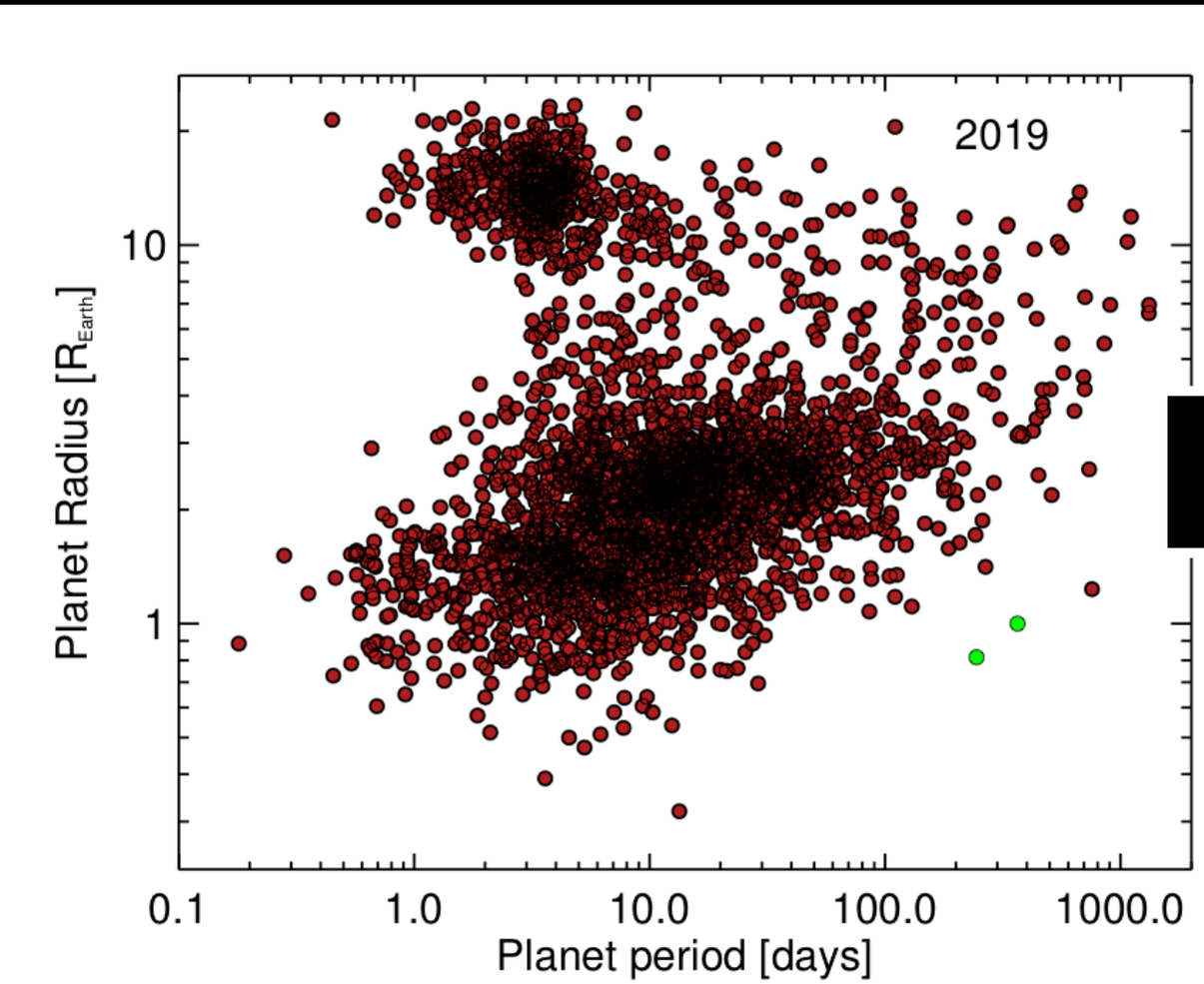
Kepler (Borucki+ 2010)

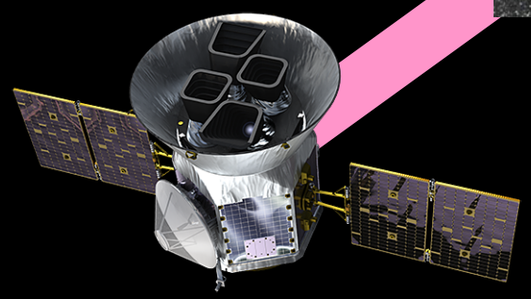


Ubiquity of small planets

(Howard+ 2012)

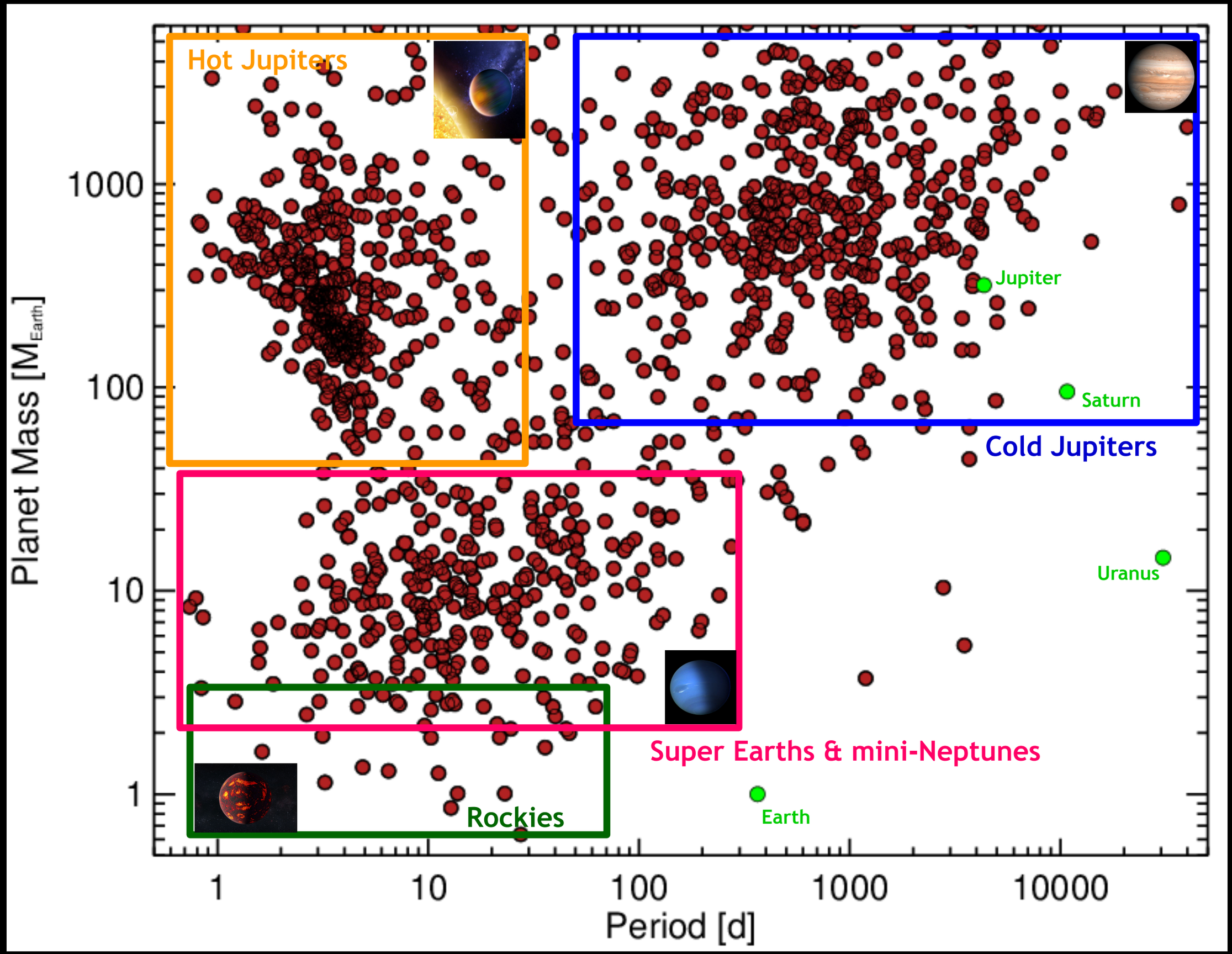
Transiting planets

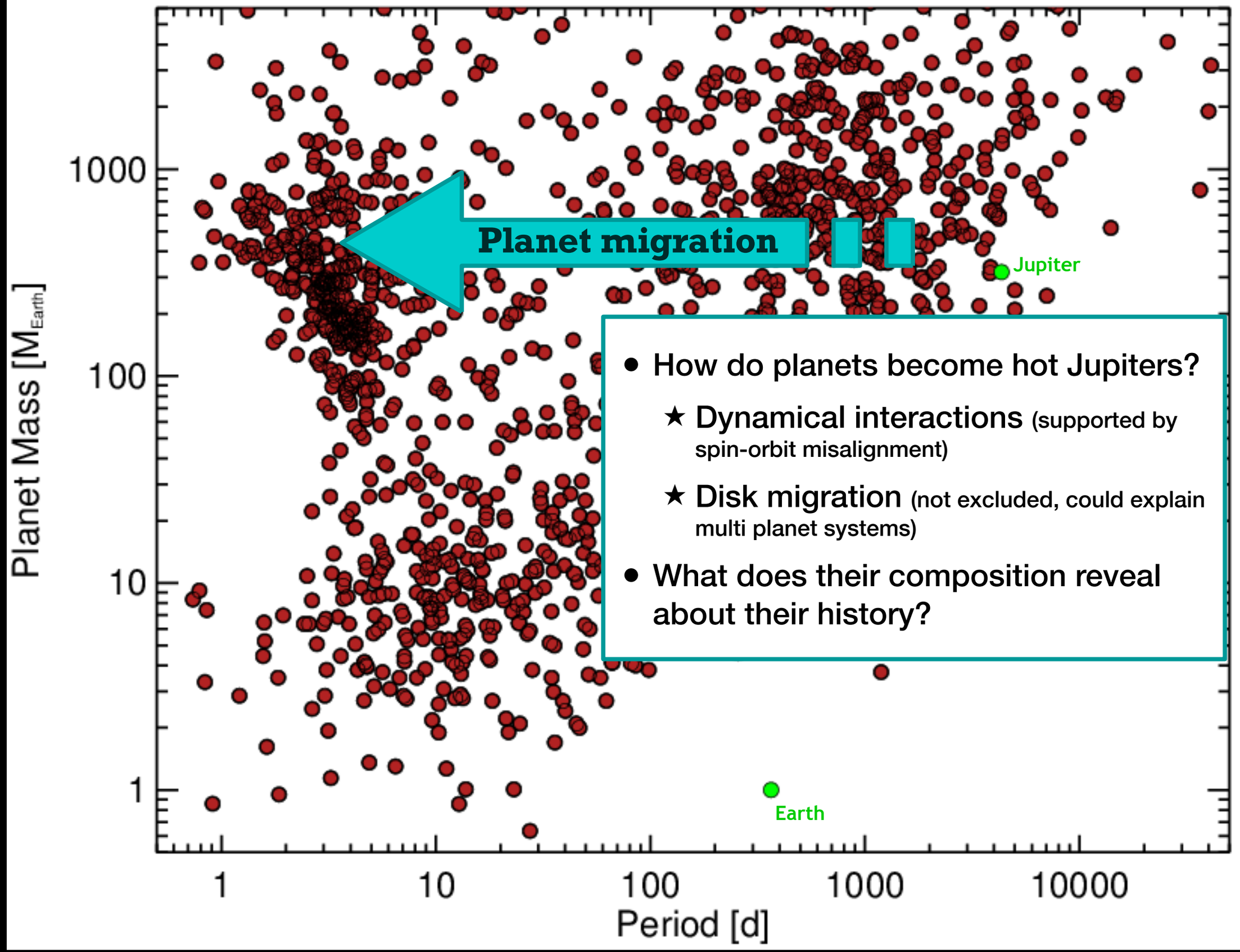




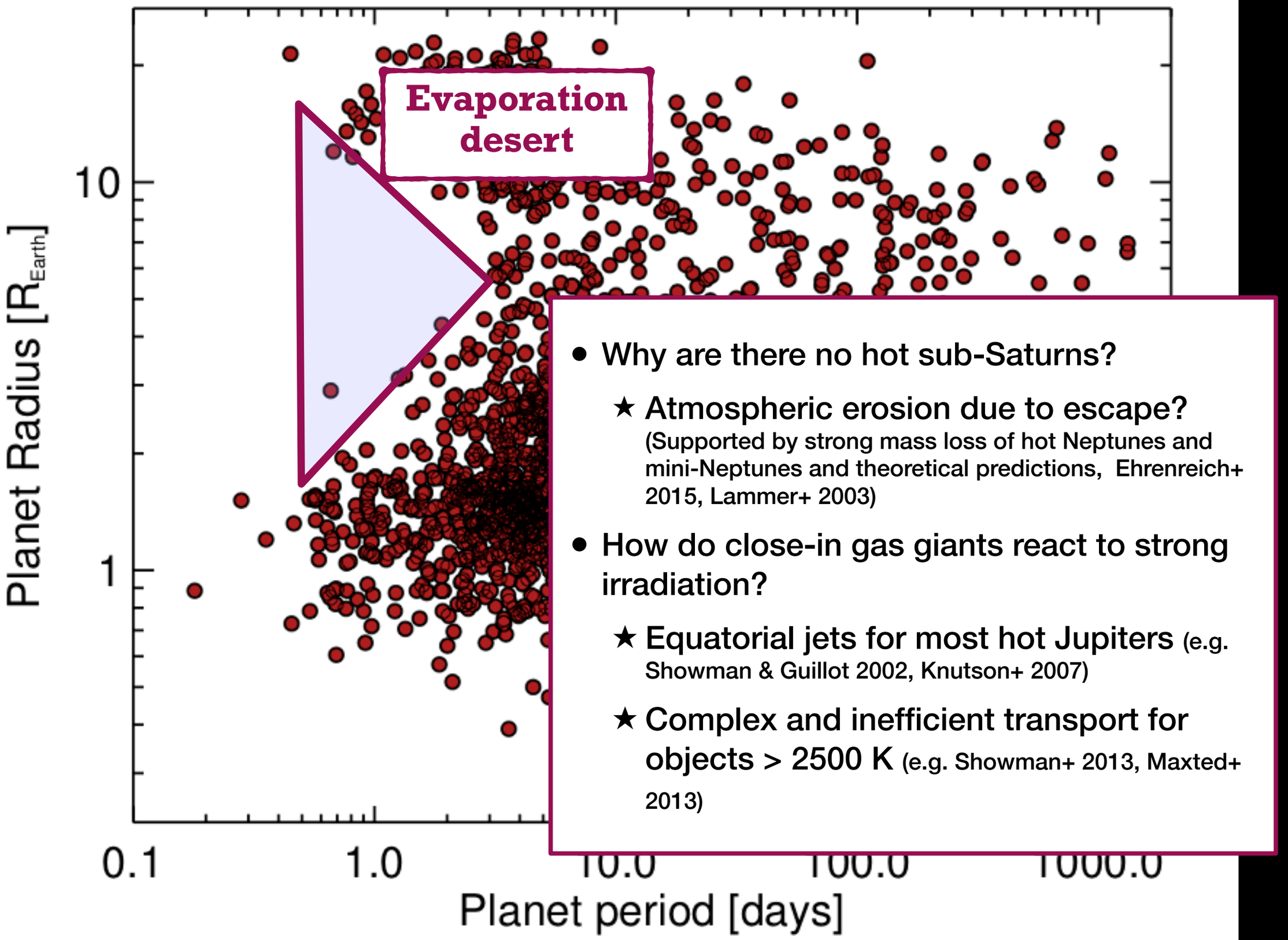
TESS (Ricker+ 2015)

Small planets transiting bright stars


Hot Jupiters
Cold Jupiters
Super Earths & mini-Neptunes
Rockies
Jupiter
Saturn
Uranus
Earth
1000
100
10
1
Planet Mass [M_Earth]
1
10
100
1000
10000
Period [d]

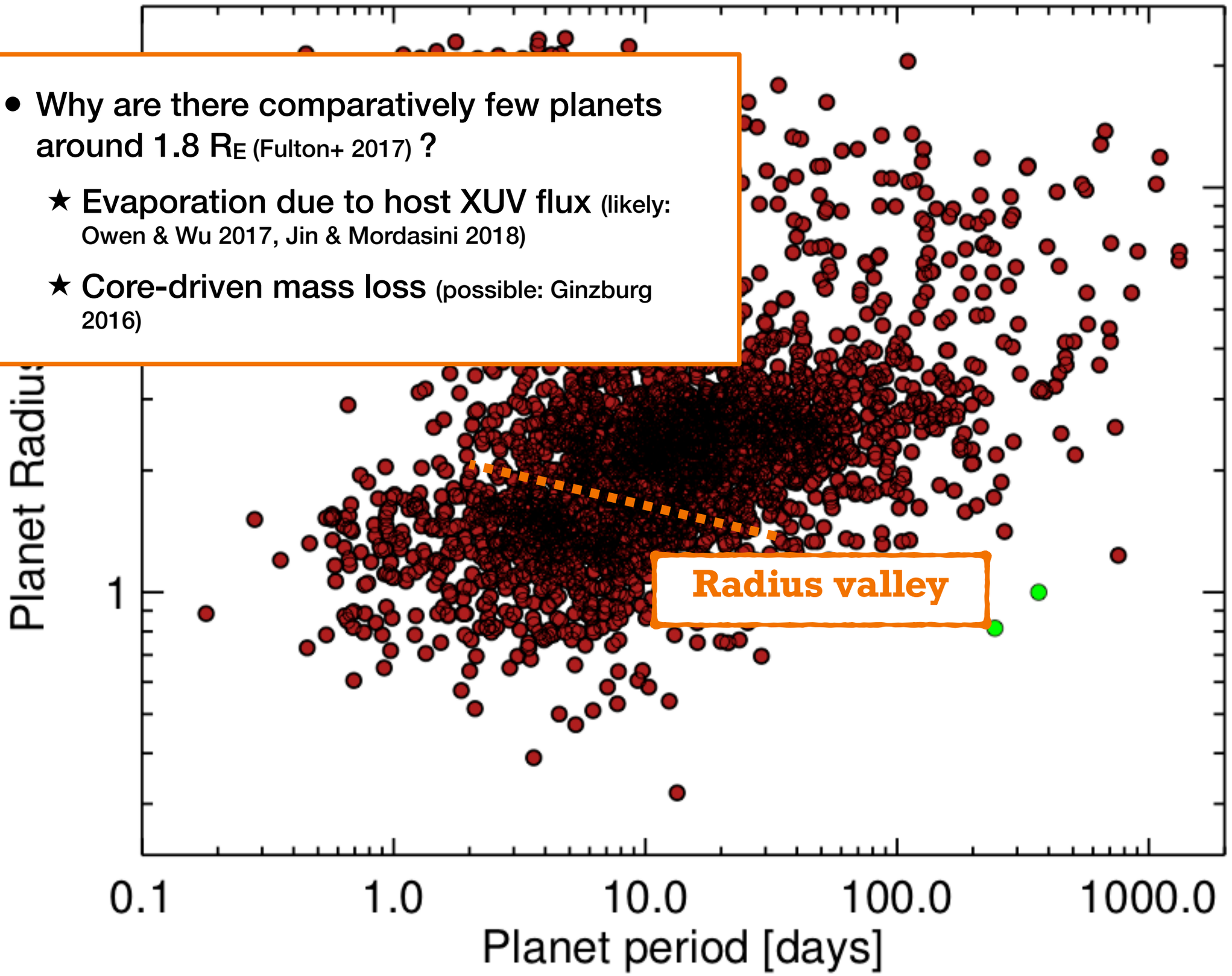


- How do planets become hot Jupiters?
  - ★ Dynamical interactions (supported by spin-orbit misalignment)
  - ★ Disk migration (not excluded, could explain multi planet systems)
- What does their composition reveal about their history?



- Why are there no hot sub-Saturns?
  - ★ Atmospheric erosion due to escape? (Supported by strong mass loss of hot Neptunes and mini-Neptunes and theoretical predictions, Ehrenreich+ 2015, Lammer+ 2003)
- How do close-in gas giants react to strong irradiation?
  - ★ Equatorial jets for most hot Jupiters (e.g. Showman & Guillot 2002, Knutson+ 2007)
  - ★ Complex and inefficient transport for objects > 2500 K (e.g. Showman+ 2013, Maxted+ 2013)

- Why are there comparatively few planets around 1.8 R_E (Fulton+ 2017) ?
  - ★ Evaporation due to host XUV flux (likely: Owen & Wu 2017, Jin & Mordasini 2018)
  - ★ Core-driven mass loss (possible: Ginzburg 2016)

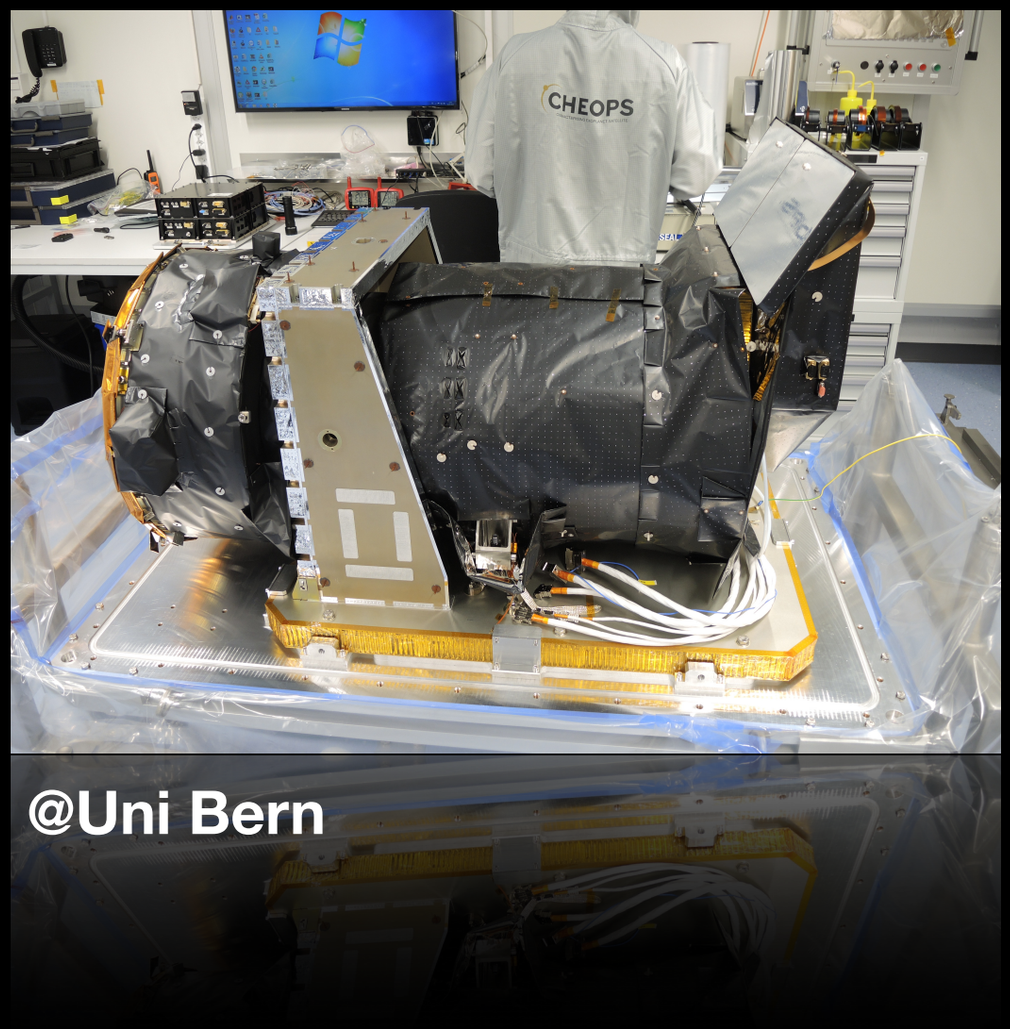


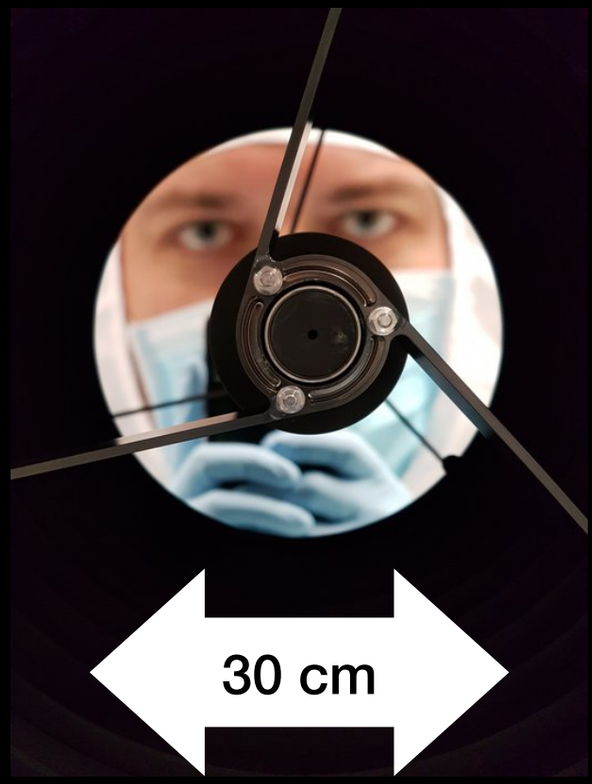
CHEOPS

The Characterising Exoplanets Satellite

What is CHEOPS?

The first ESA S-class mission, dedicated to study known exoplanets

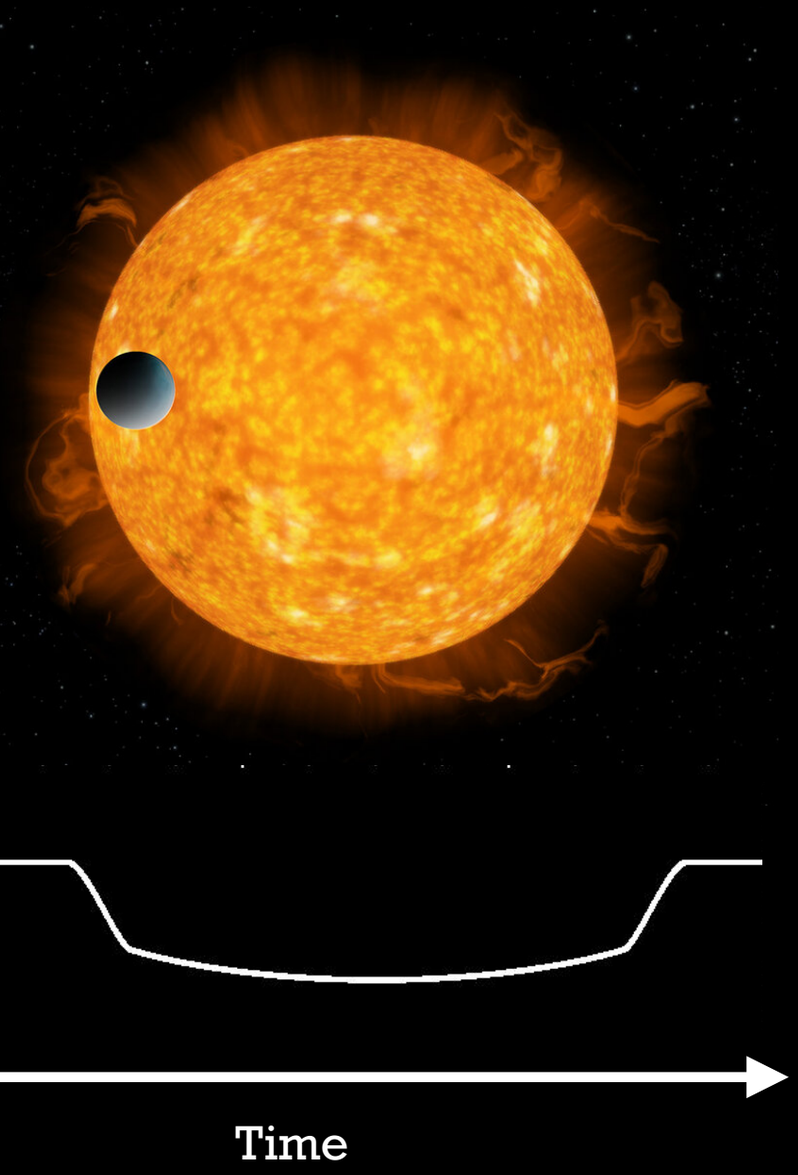




A 30-cm space telescope capable of ultra high-precision photometry

What does CHEOPS do?

High-precision photometry of bright exoplanet systems



<u>Goals:</u>

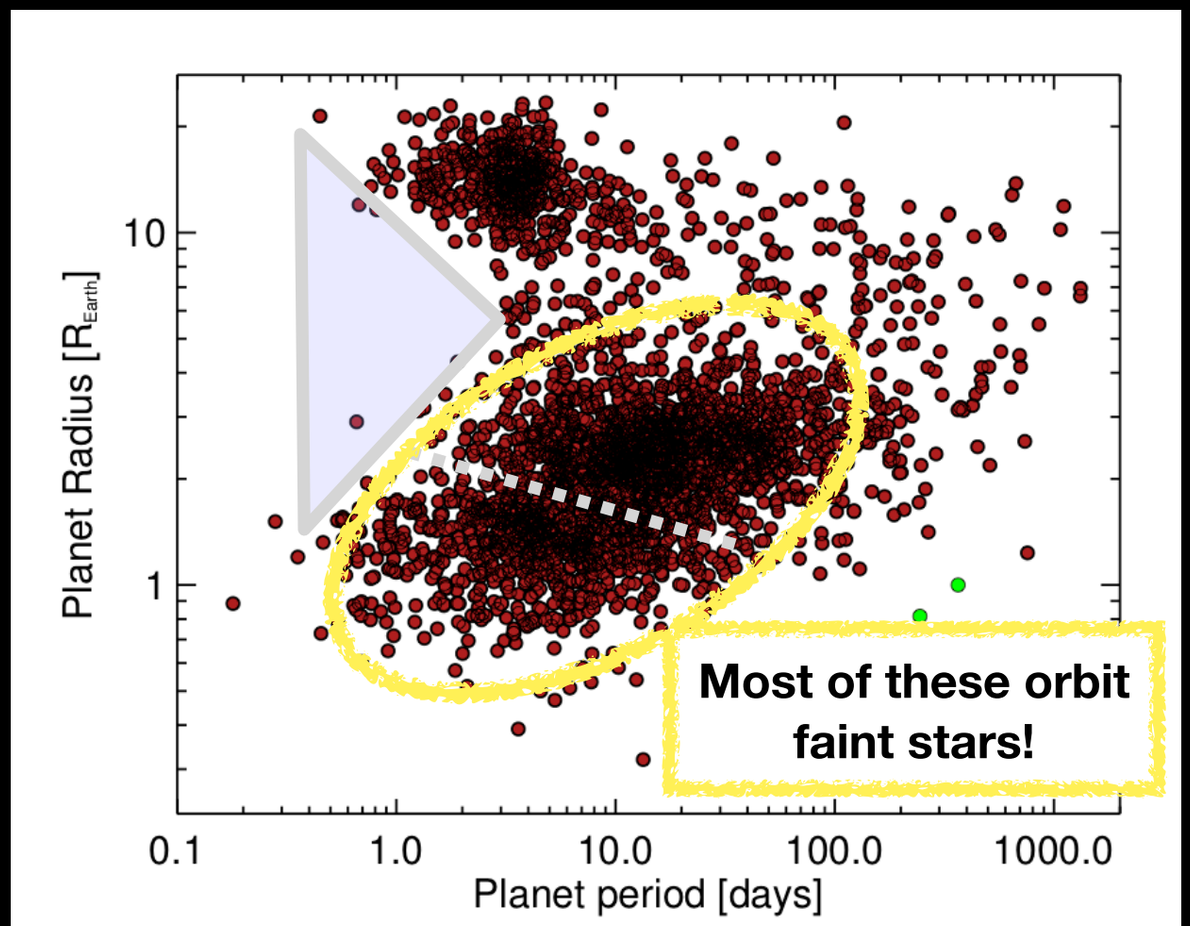
★ **20 ppm per 6 hours for V = 6-9 stars**

Detect transits of <u>Earth-size</u> planets around <u>Solar-type</u> stars

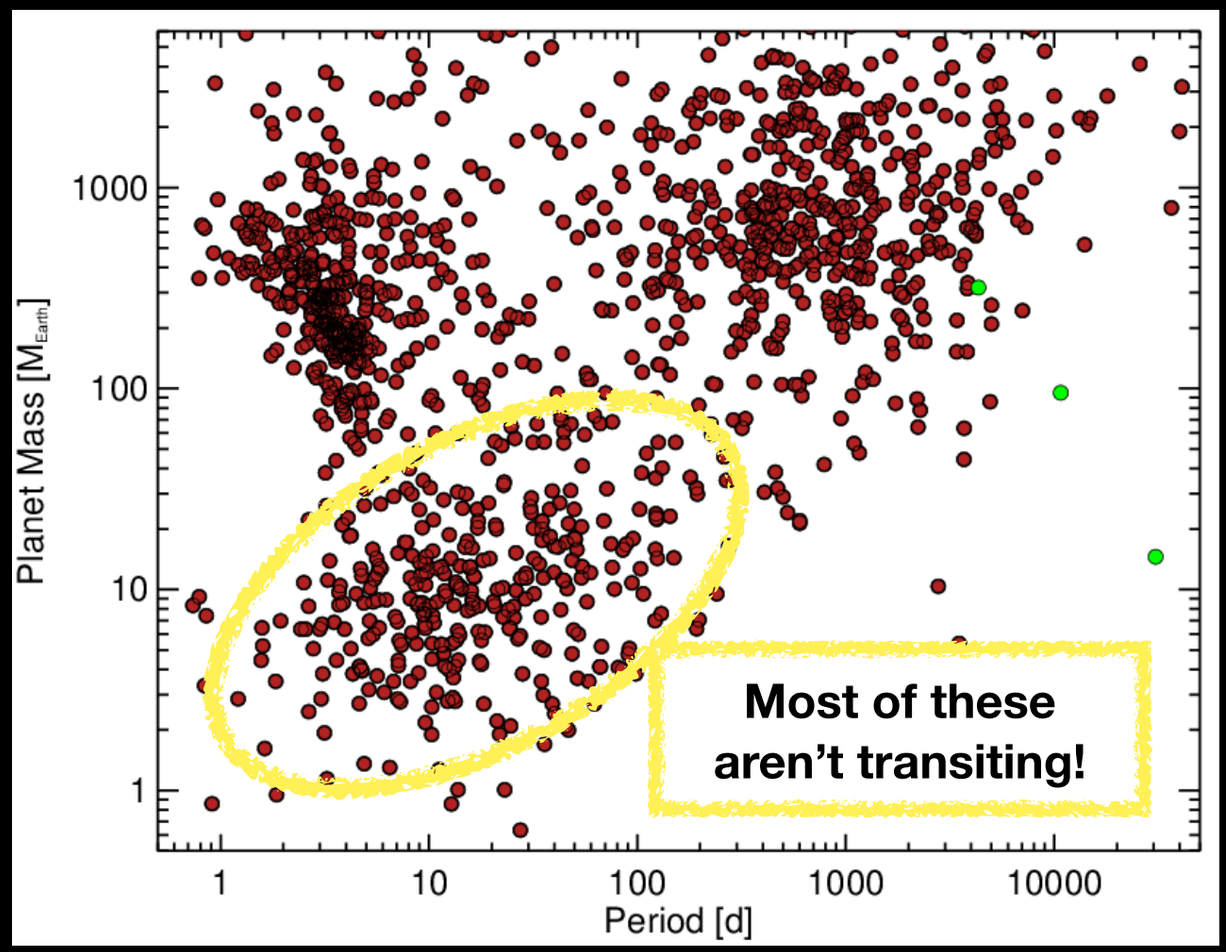
★ ***85* ppm per 6 hours for V = 9-12 stars**

Measure precise radii for super-Earths and mini-Neptunes

Transiting planets

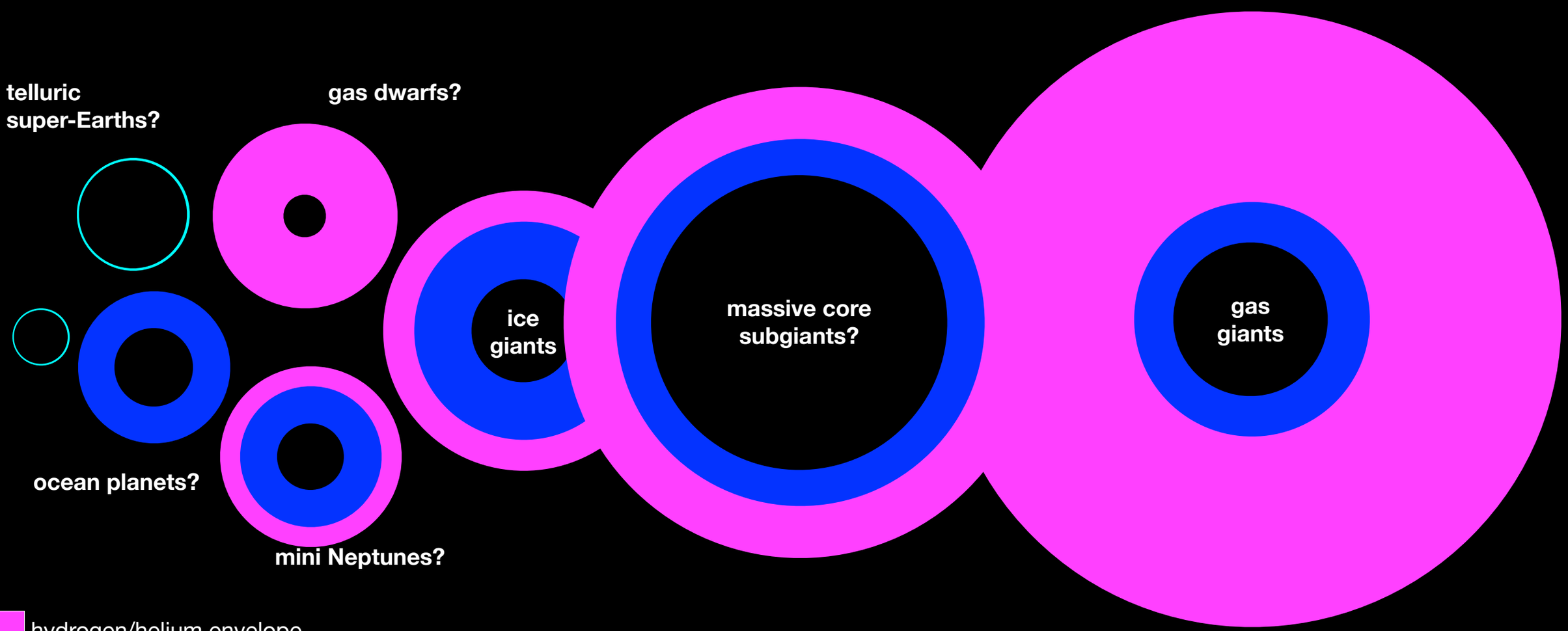


RV planets



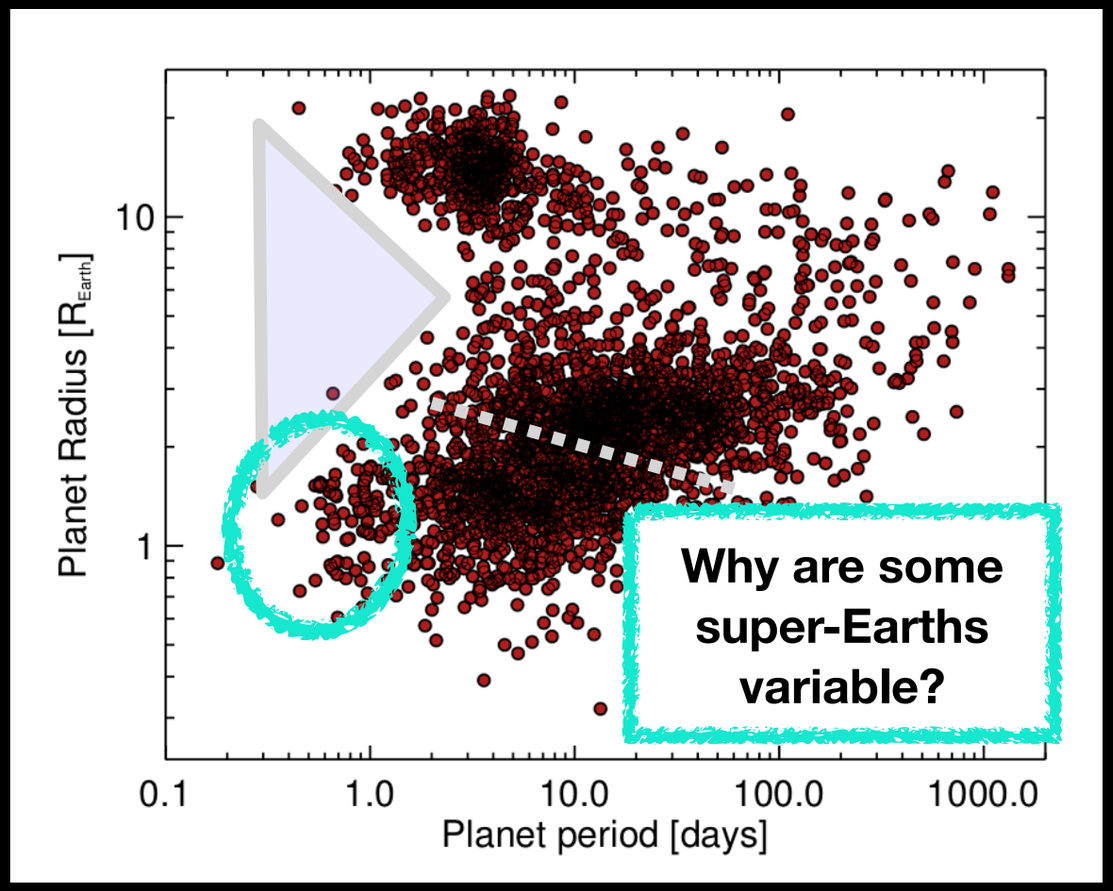
Measure precise radii for planets orbiting bright stars that have <u>masses measured with RVs</u>

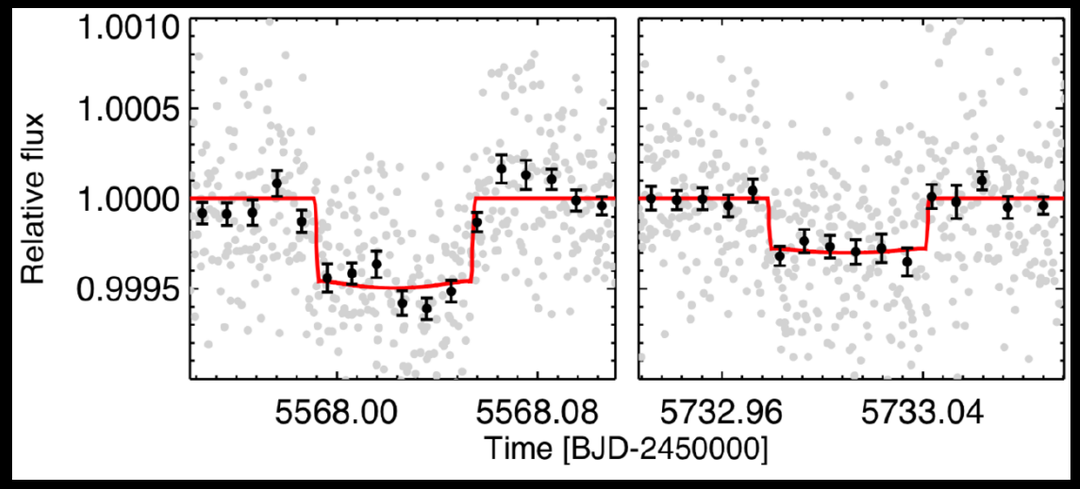
Determine bulk composition



- hydrogen/helium envelope
- thin atmosphere
- ice mantle/volatile envelope
- solid core (rocks+metals)

Are super-Earths variable?





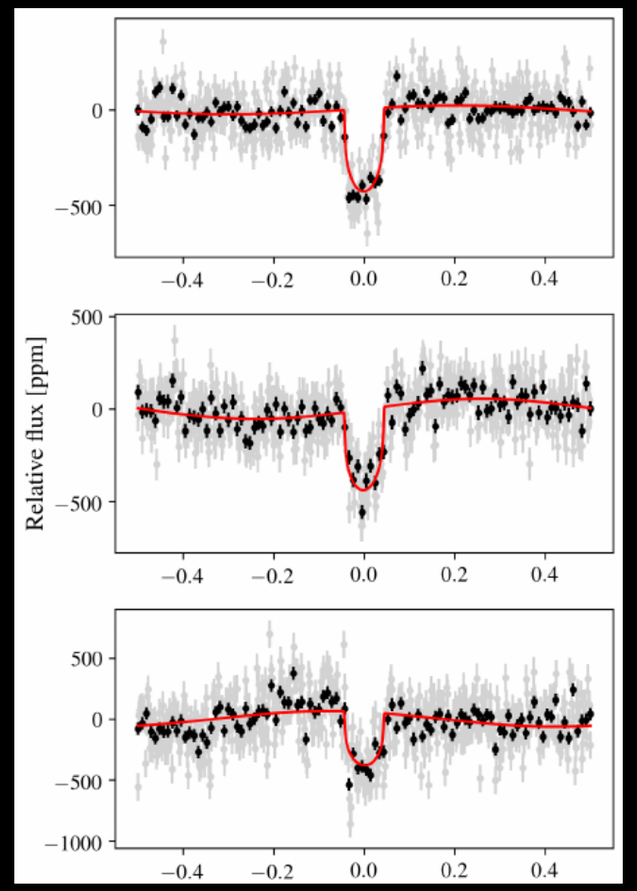
Demory+ 2015

<u>55 Cnc e:</u>

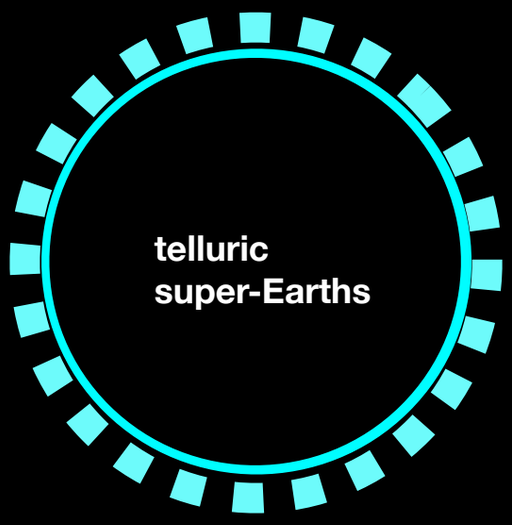
a 0.7-day super-Earth

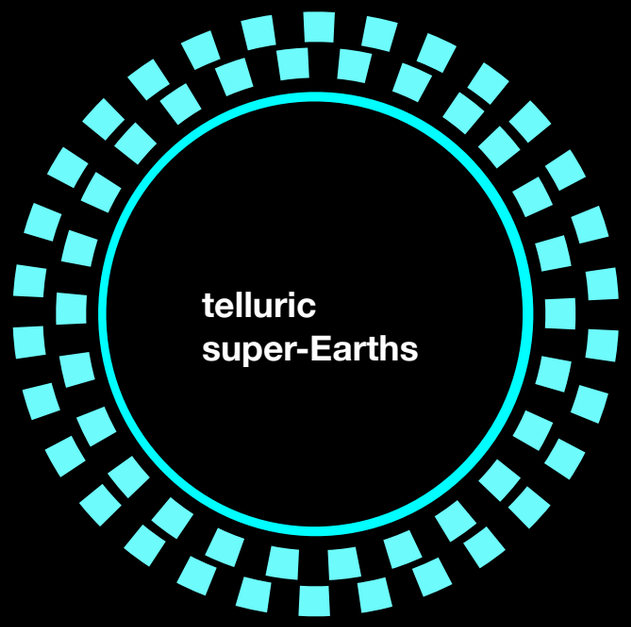
➡ Variable occultation

➡ Variable phase curve

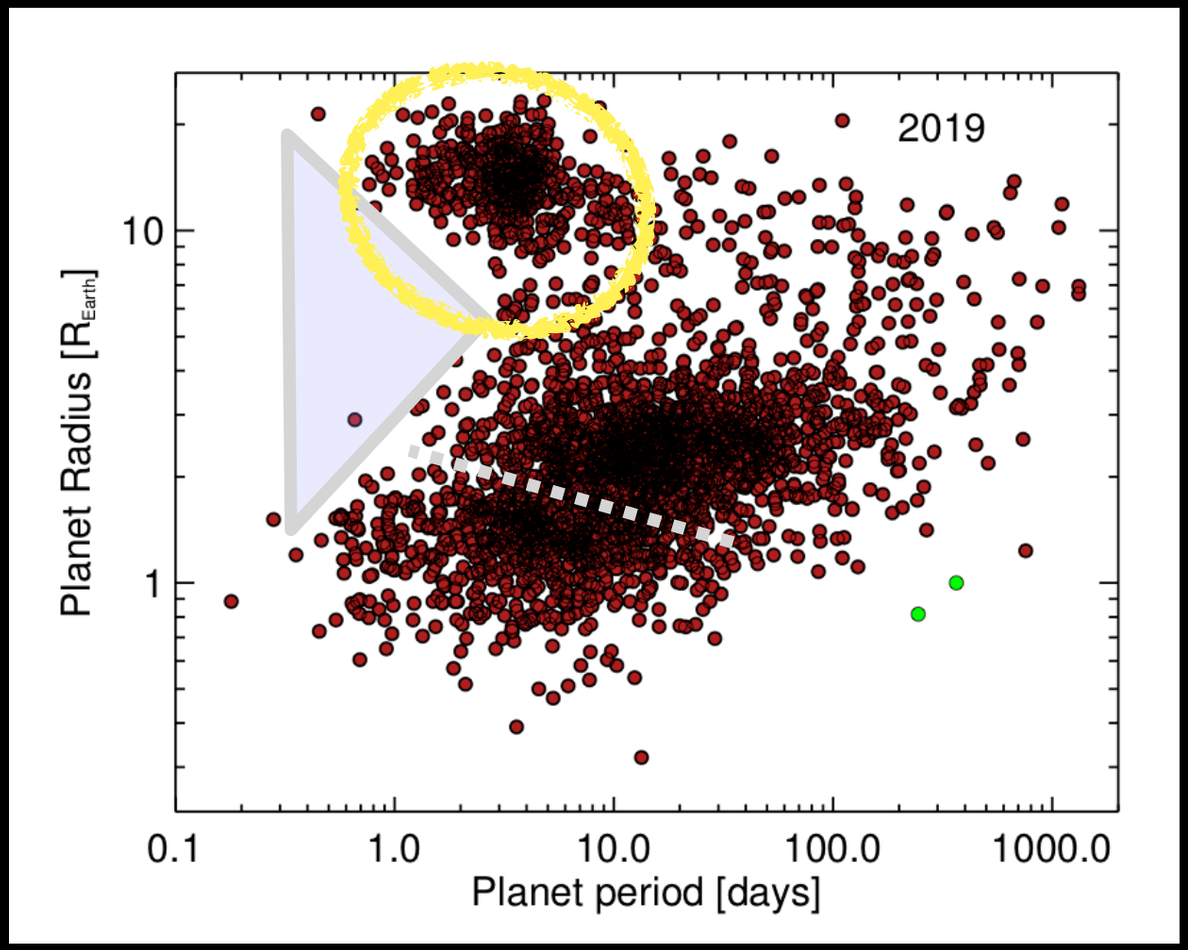


Sulis+ 2019

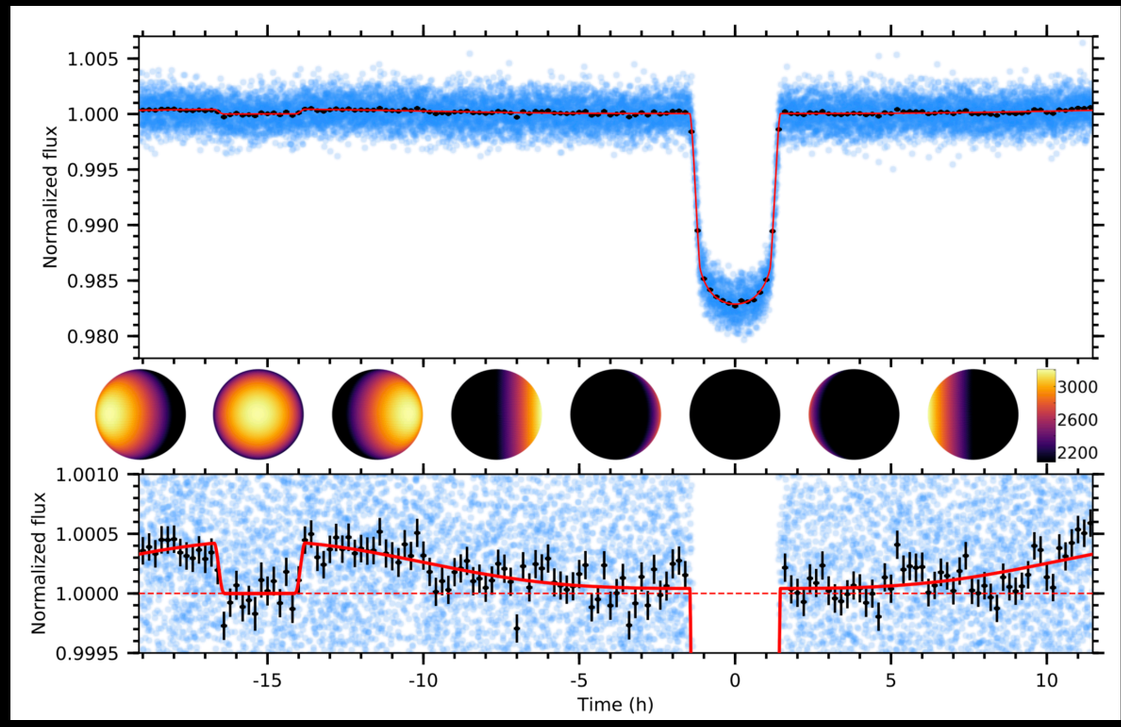




Hot Jupiter climates



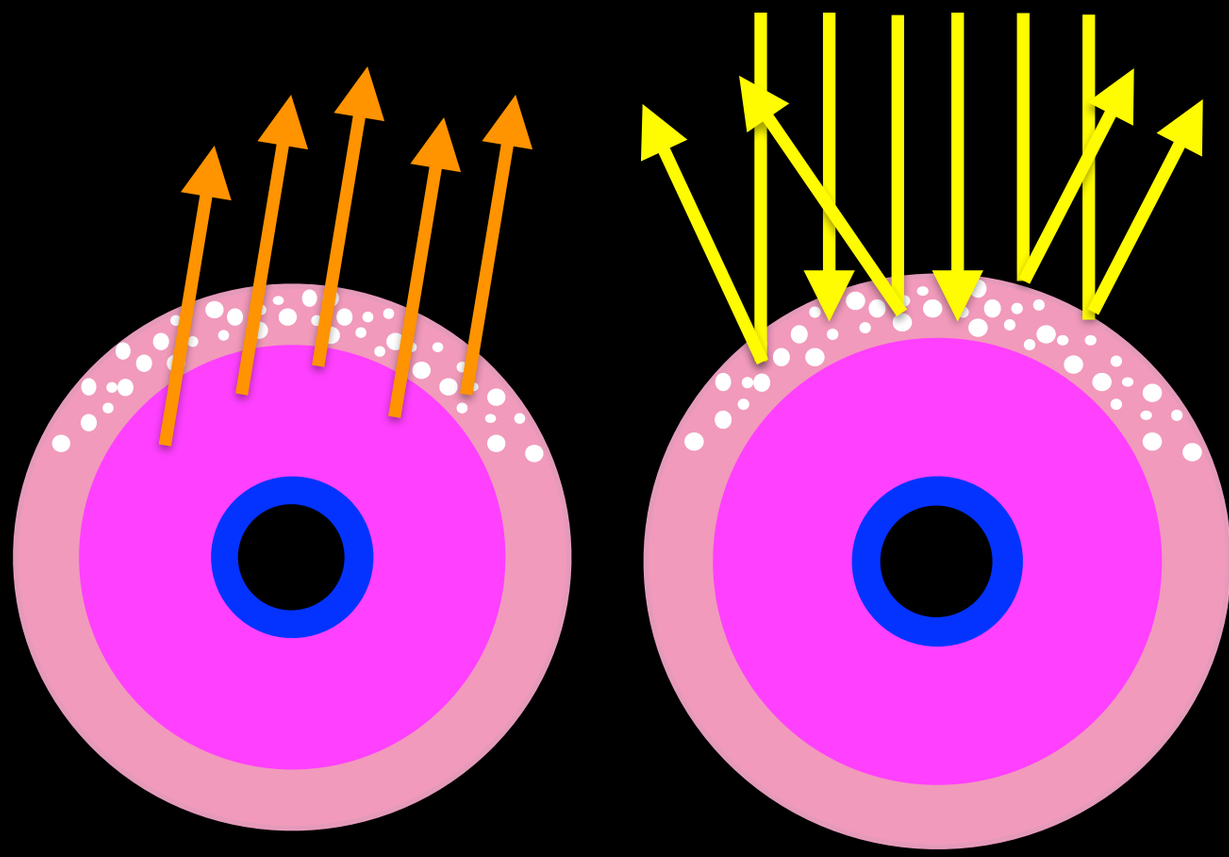
Bourrier+ (2020)



How do these gas giants process the heat?

On which planets do clouds form?

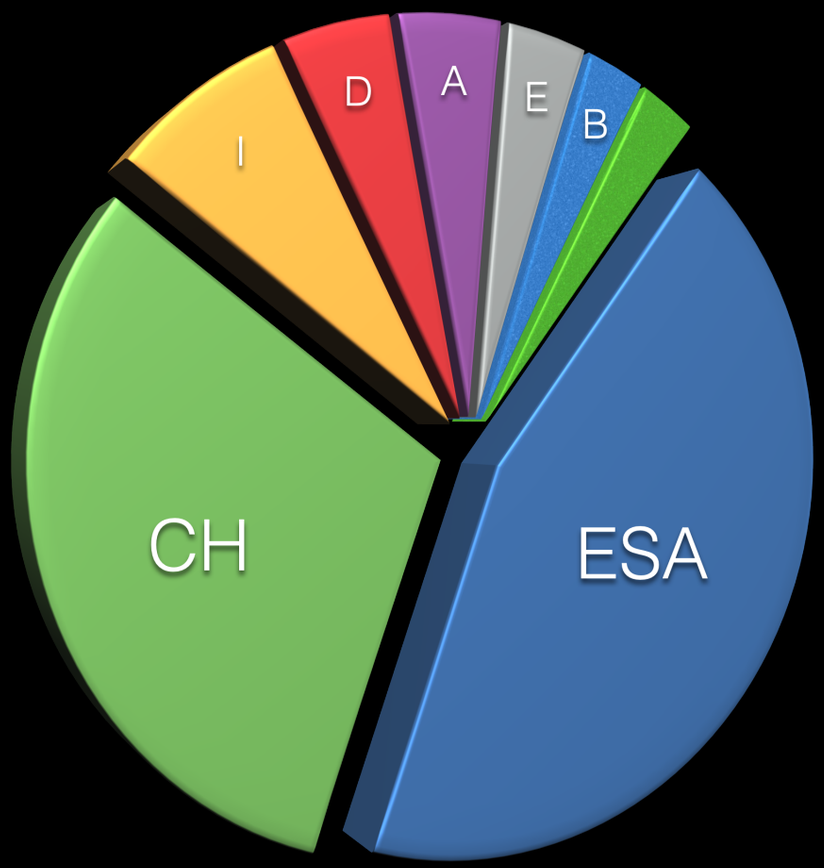
How do they distribute in the atmosphere?



S-class mission:

S is not for "*S*imple"

"**S**mall" Budget



- total budget: ~105 M€
- ESA: 50 M€

Short time

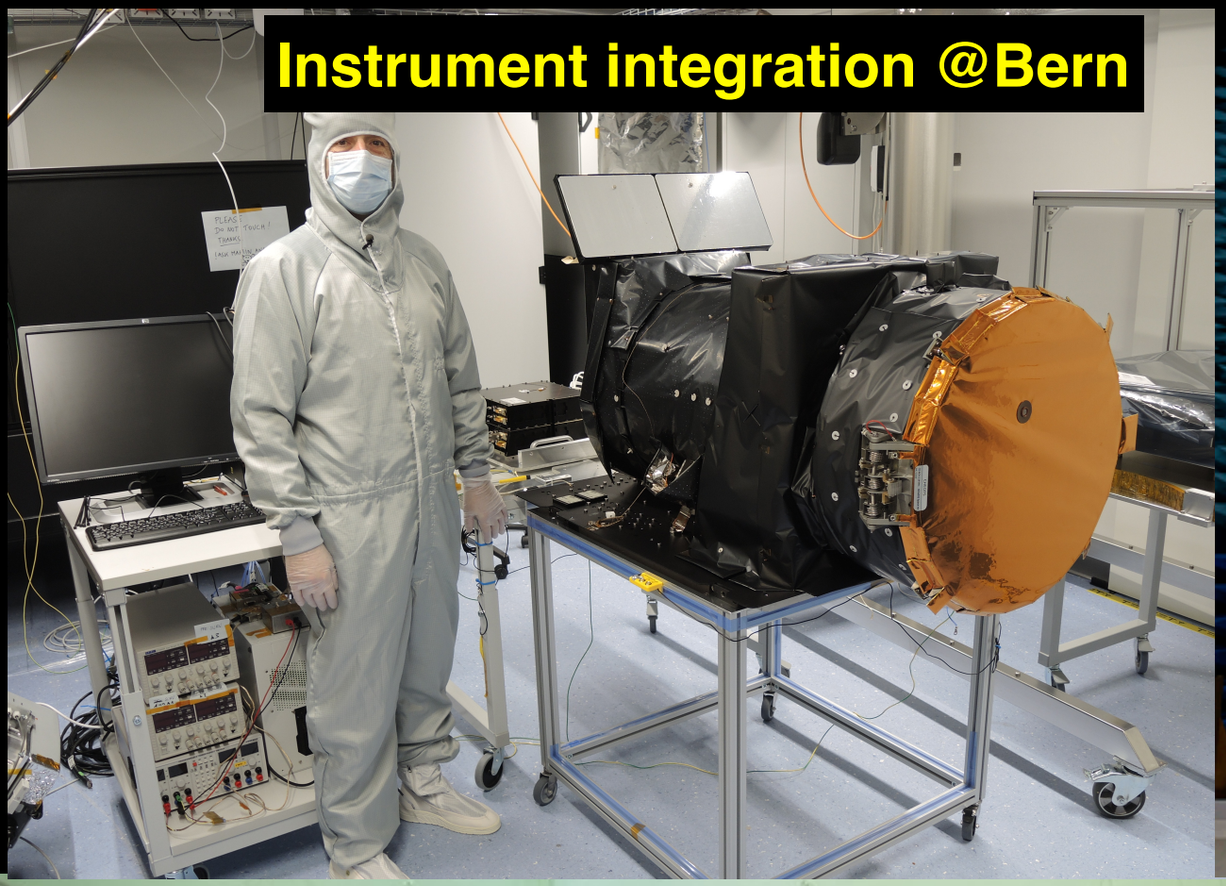
milestone	when
call issued	Mar 2012
call answered	Jun 2012
mission selected	Nov 2012
mission adopted	Feb 2014
instrument delivered	Feb 2019
launch	Dec 2019

- 4–5 years development time

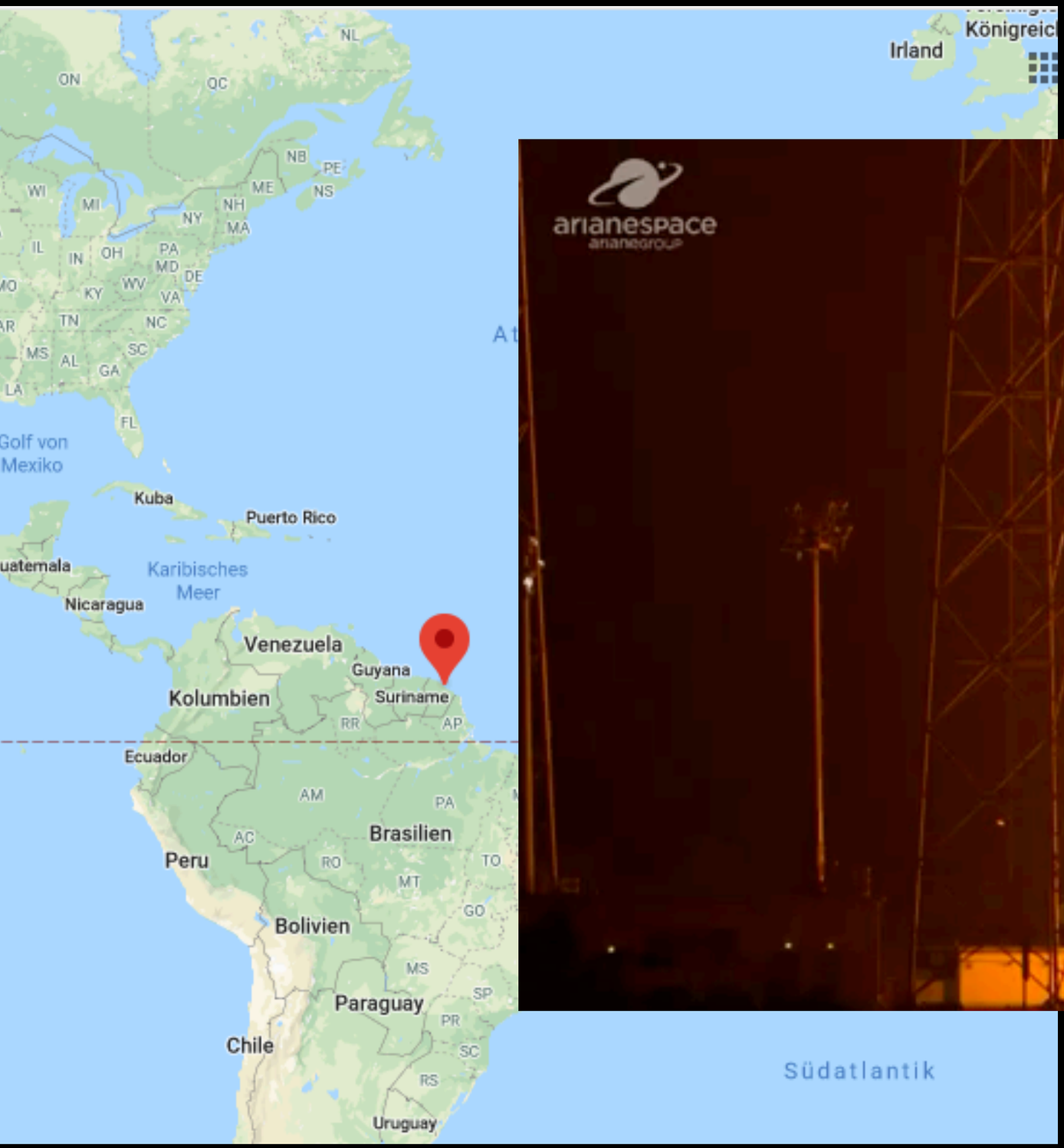
Several countries

- 11 countries & ESA
- ~30 institutions

CHEOPS en route



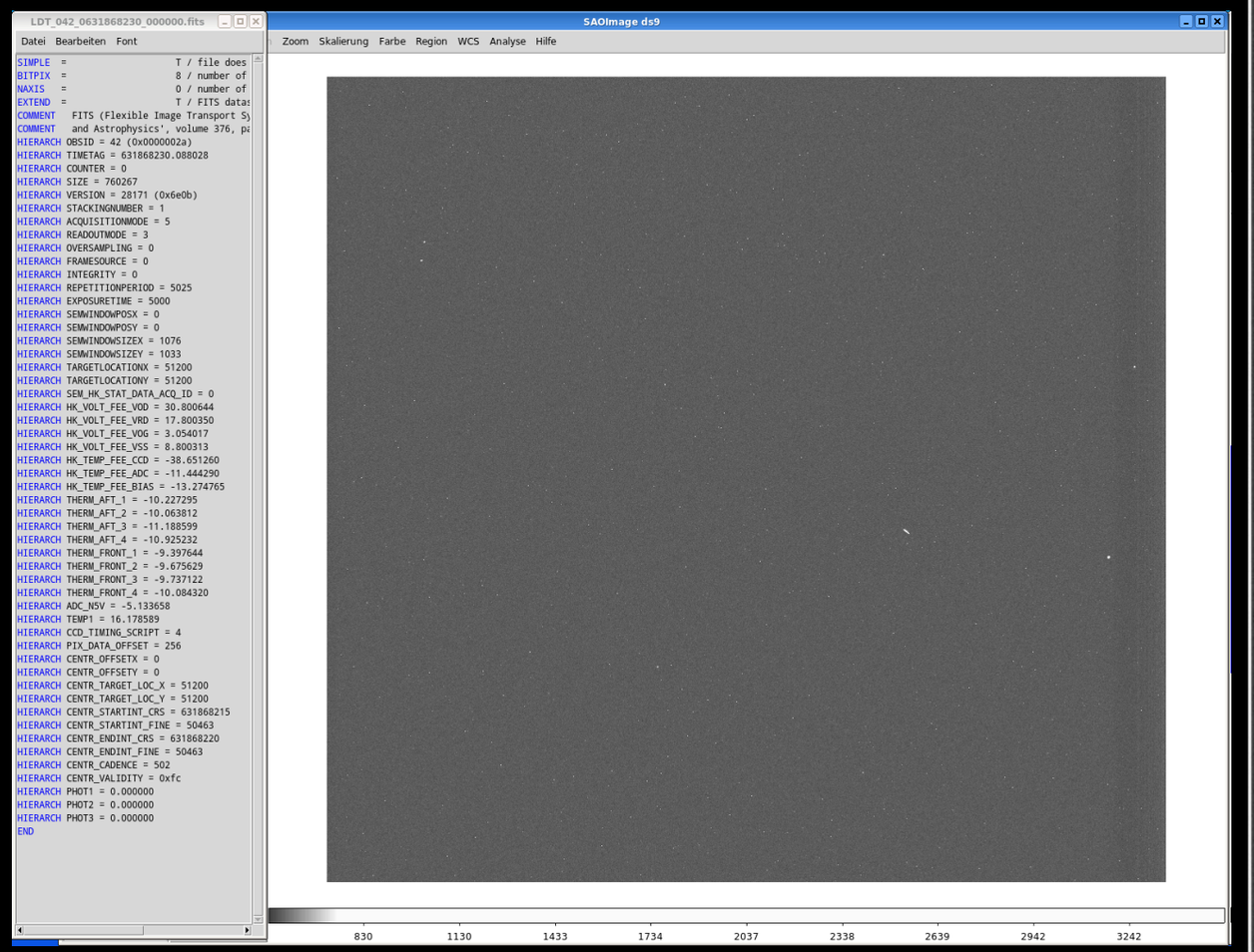
Soyuz launch VS-23 from French Guyana Space Center
18 December 2019

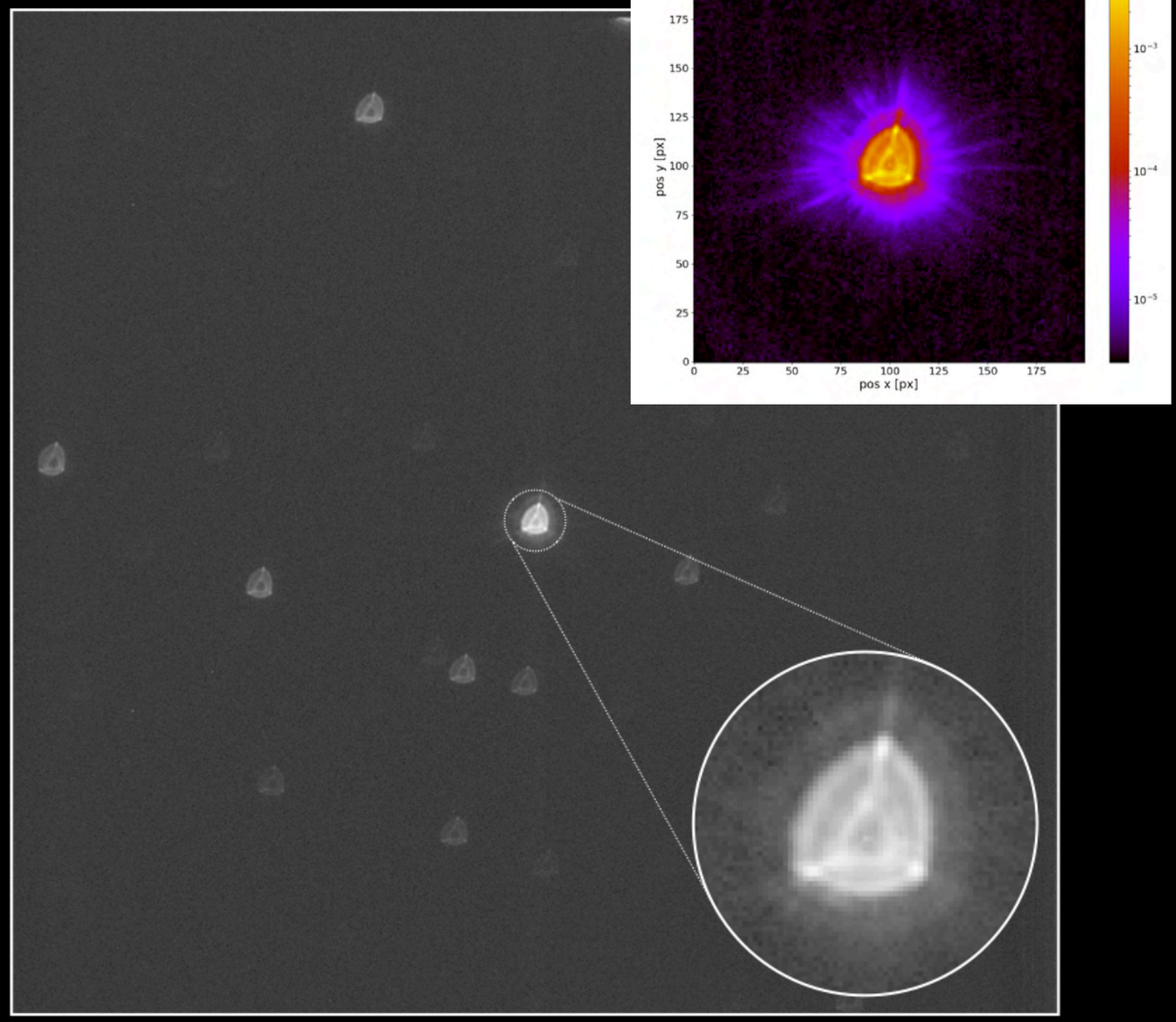


Credits: Arianespace

News since the launch

- 8 Jan 2020: CHEOPS switched on (darks!)
- 29 Jan 2020: Cover opened!
- 25 Mar 2020: In-orbit commissioning completed

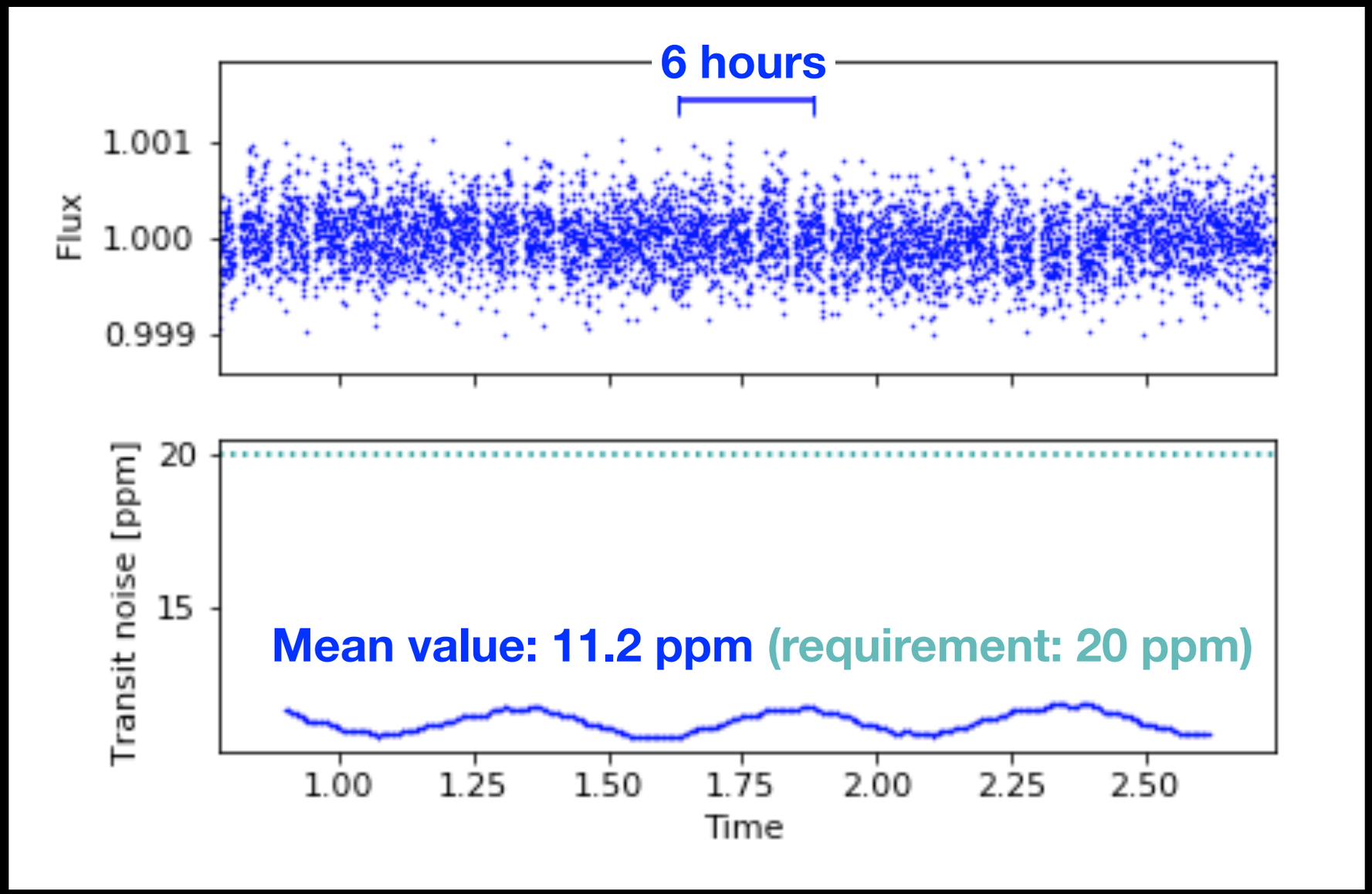




Benz et al. (submitted)

In-flight performances

- 47 hour “flat” sequence on ***V*=9** star



Credits: CHEOPS Project Science Office
Andrea Fortier (Instrument scientist), Christopher Broeg (project manager)

The Sun

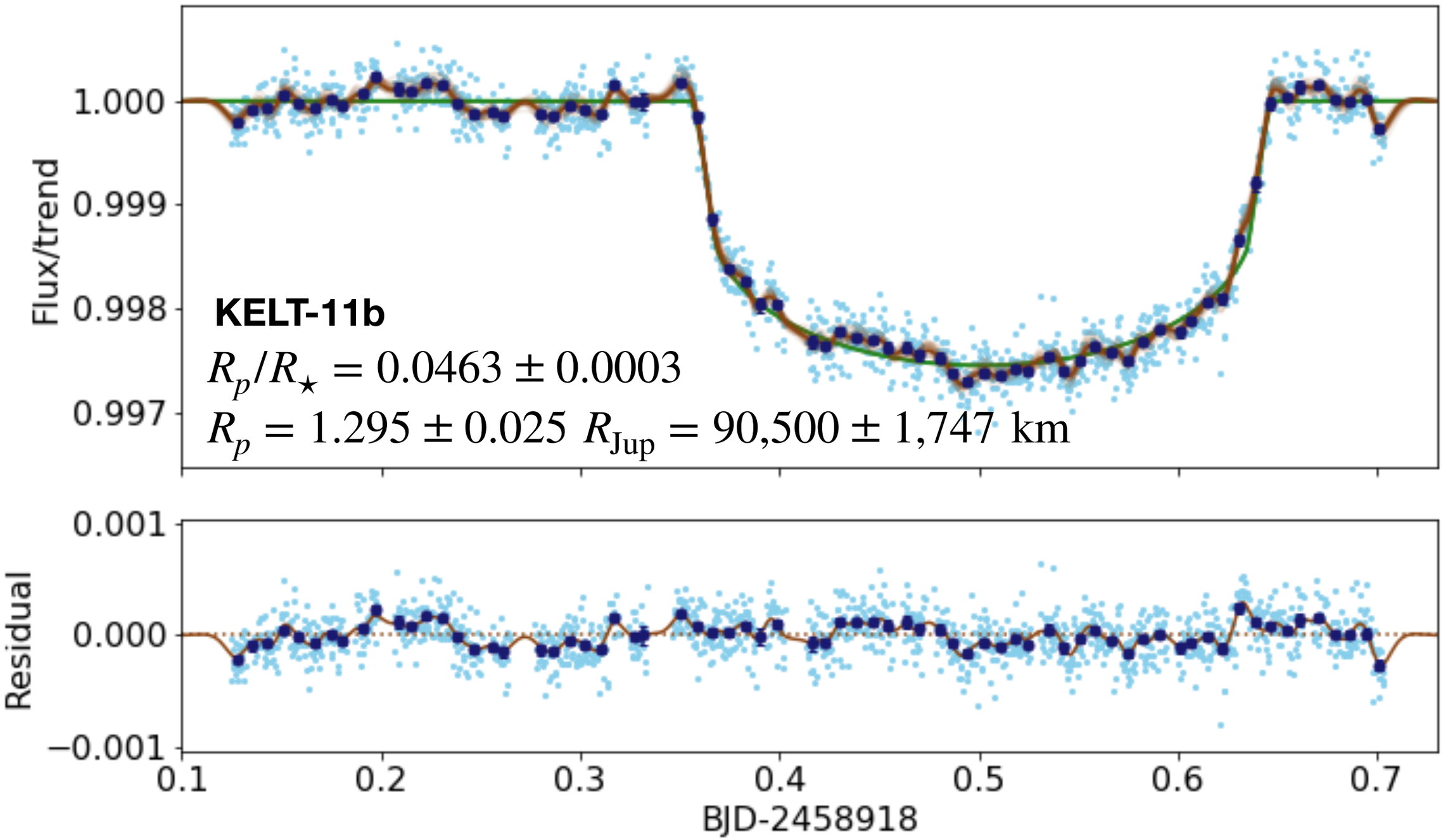
Jupiter

Earth

HD 93396 (*V*=8)

KELT-11b (Pepper et al. 2017)

9 March 2020: CHEOPS' first transit!

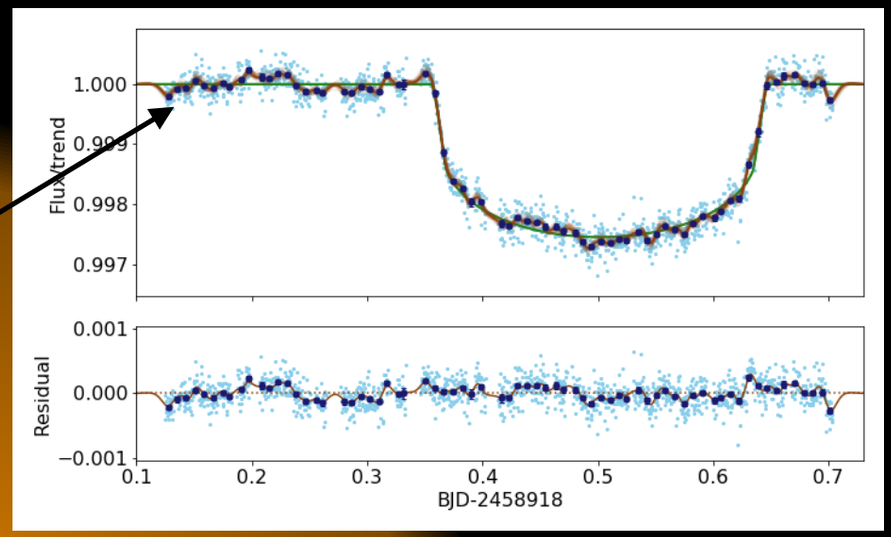


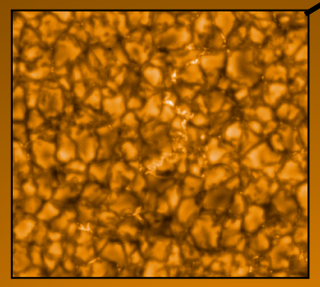
Benz et al. (submitted)

9 March 2020: CHEOPS' first transit!

The Sun

HD 93396



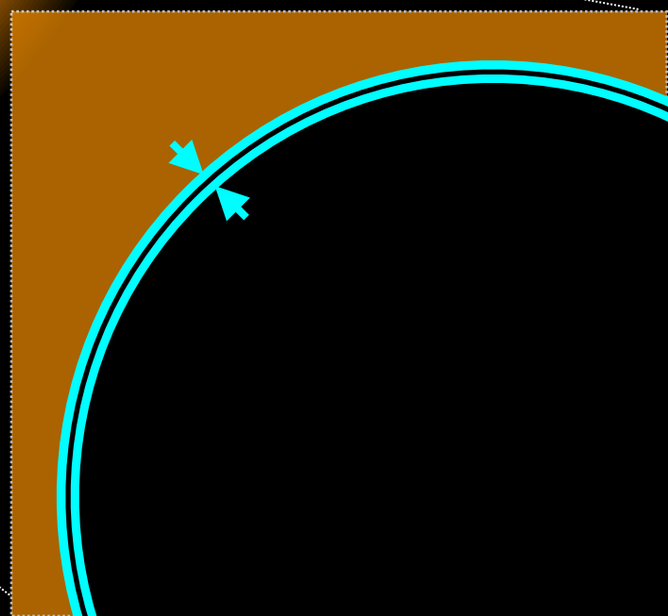


Jupiter

Earth

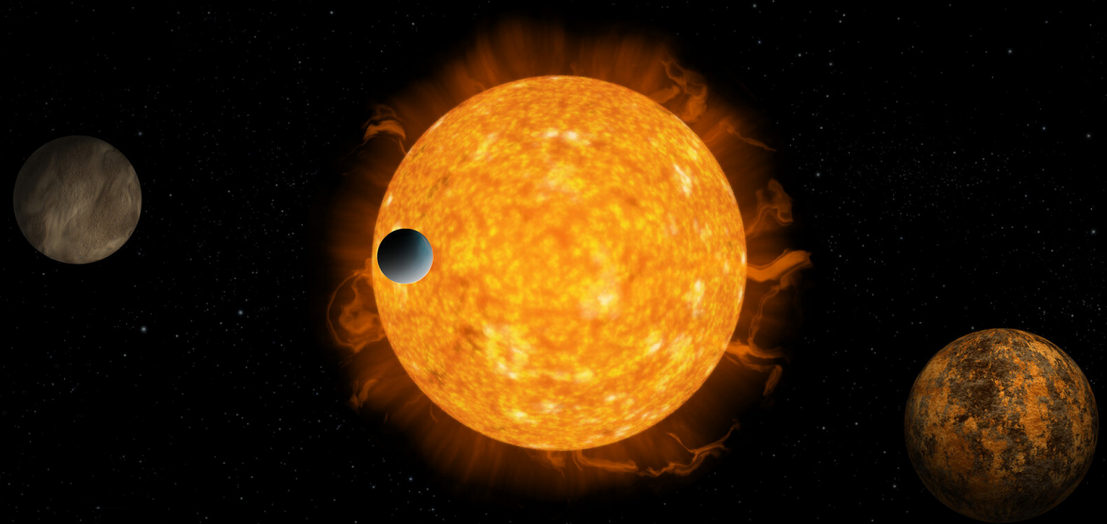
KELT-11b

$R_p = 90{,}500 \pm \mathbf{1{,}747}$ km



ESA Guest Observer's programme

- 20% observing time to Community
- Proposals solicited through Annual Calls, open to ***all***
- Selected on scientific merit, by an ESA-appointed TAC
- Can be on ***any science topic***,
  using existing capabilities of CHEOPS
  * Targets on the Guaranteed Time Target List (Science Team) are ***blocked***
- Second Call/Announcement of Opportunity
  ➡ **Fall 2020** (for observations beginning in April 2021)



Thank You!

Muchas gracias!