Transiting giants planets in multi-planetary systems

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Collaborators:
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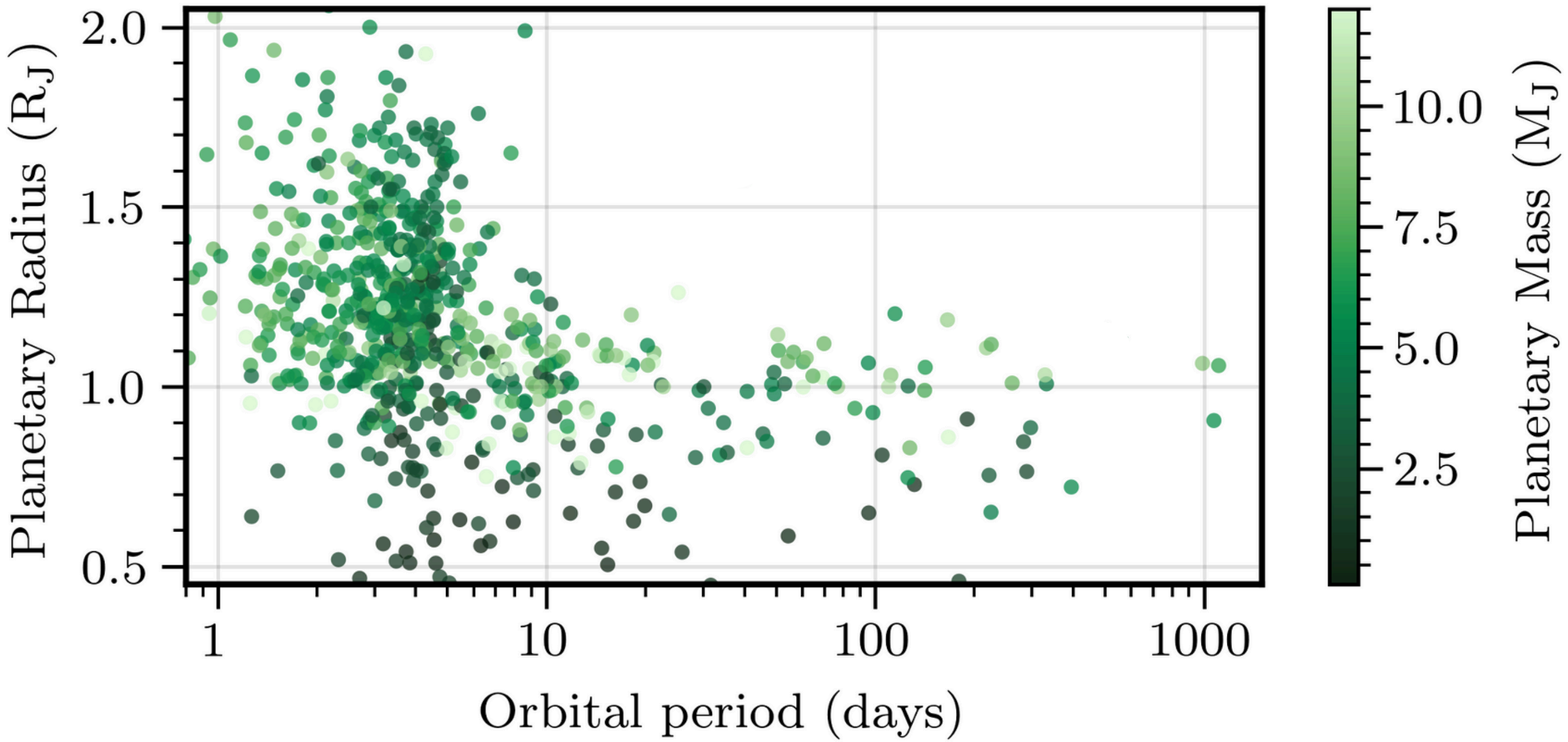
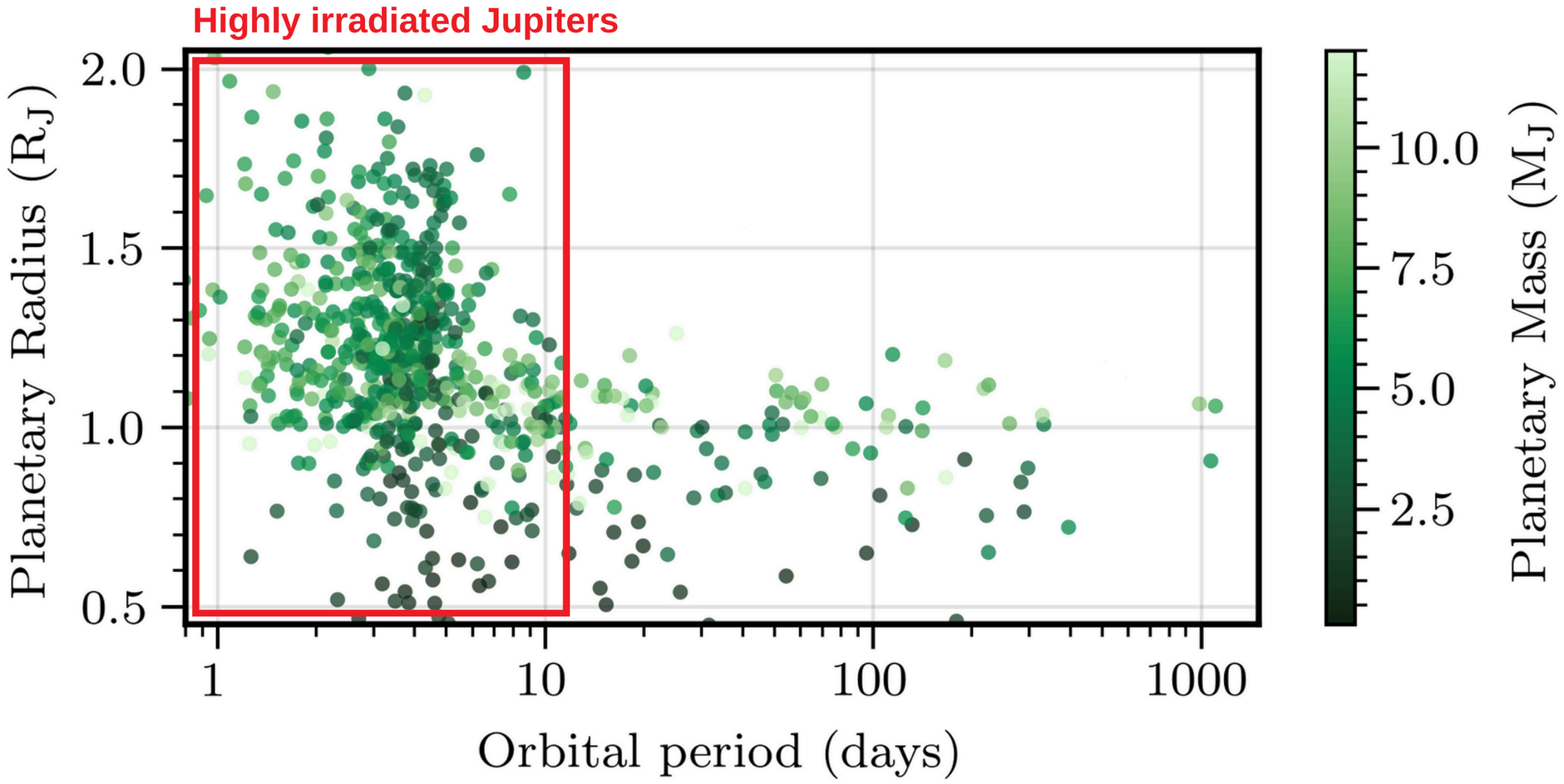
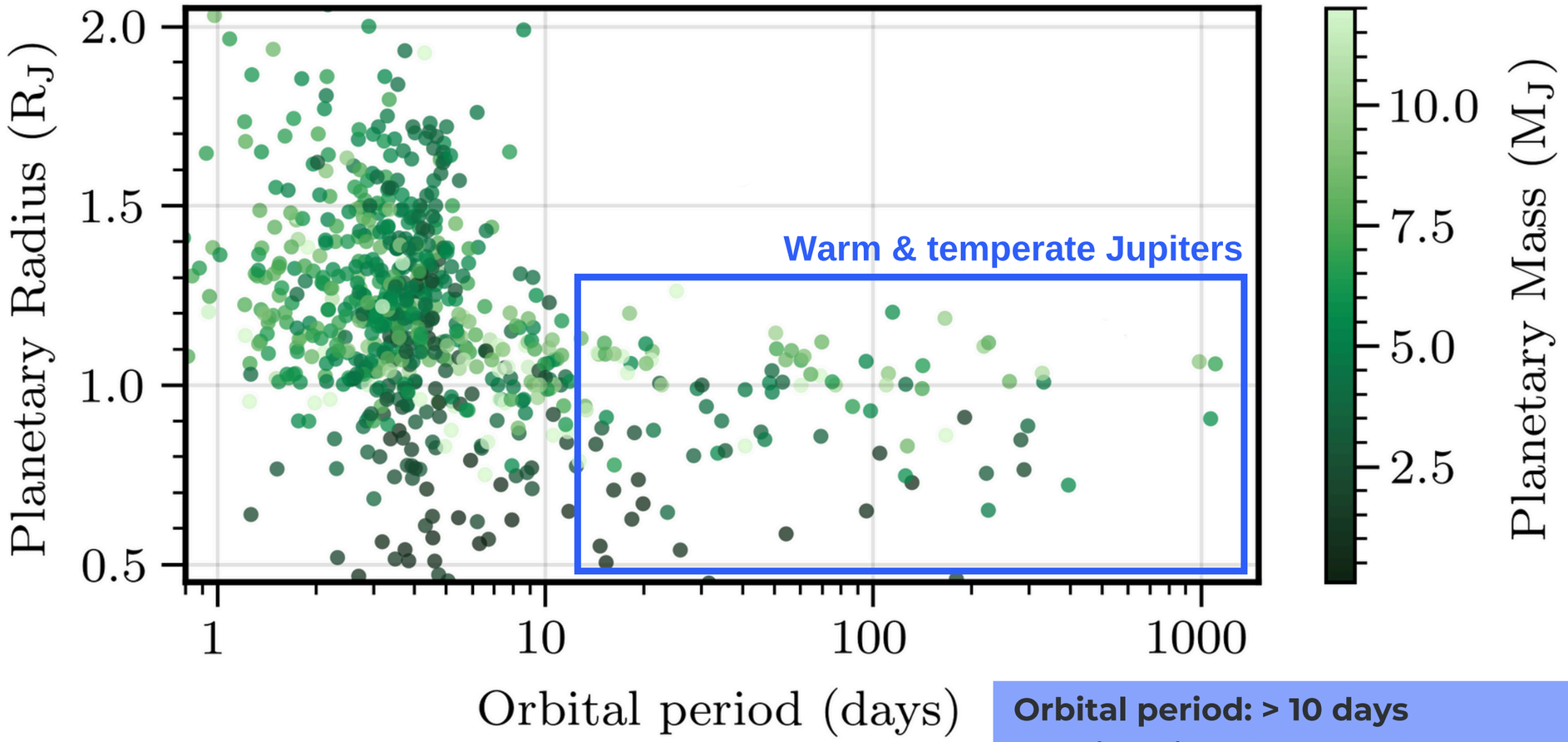
Leiden Observatory


Planetary Radius (R_J)
2.0
1.5
1.0
0.5
1
10
100
1000
Orbital period (days)
10.0
7.5
5.0
2.5
Planetary Mass (M_J)

Orbital period < 10 days
Highly irradiated and strong tidal interactions
Equilibrium temperature: 1000 - 3000 K
Overall low eccentricity distribution





Orbital period: > 10 days
Less irradiated, atmospheres are not inflated
Equilibrium temperature: ~200 - 900 K
Wide range of eccentricity distribution

Characterize new temperate planets with photometry and spectroscopy

What are the orbital periods, masses, and radii of these warm planets?

Measure the interior composition of temperate planets.

What is their fraction of heavy elements?

Determine the atmospheric composition of gas giants.

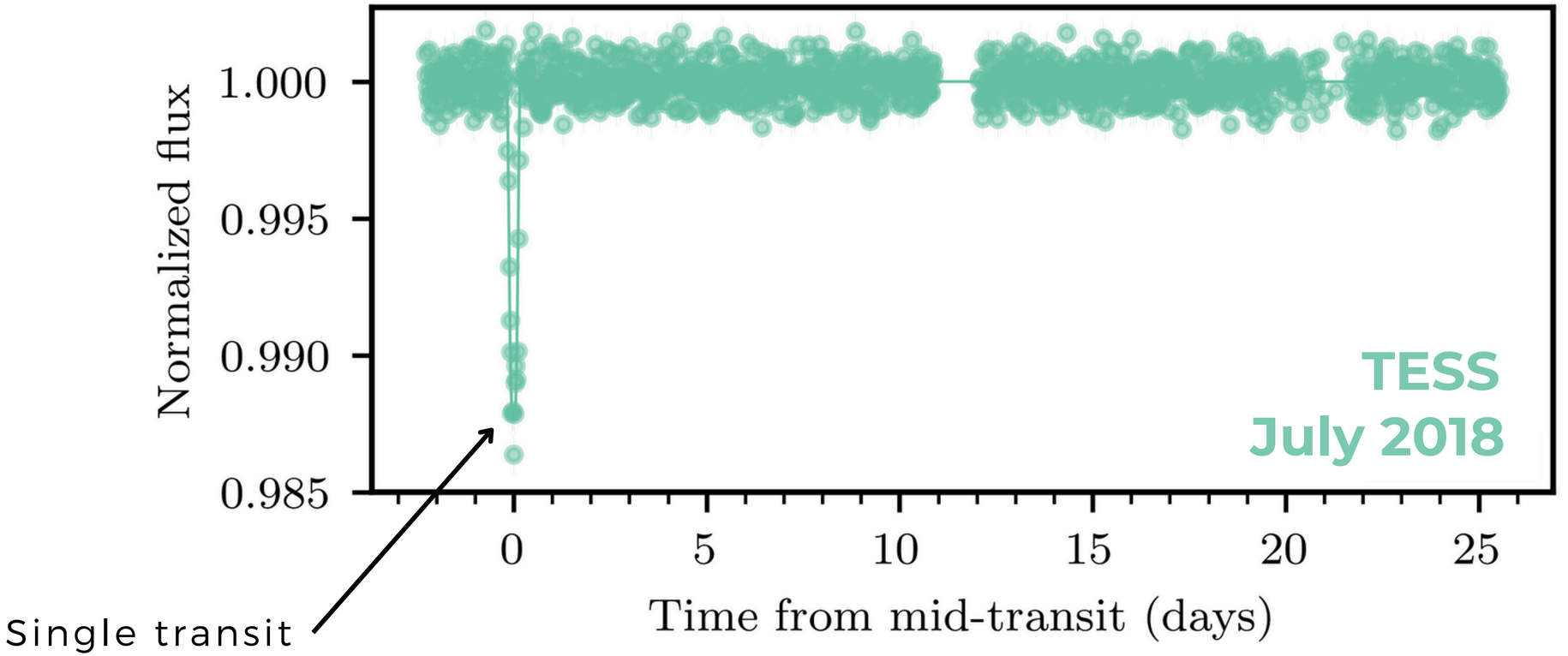
What are their atmospheric metallicities?

Study the dynamics of eccentric temperate Jupiters.

Are they misaligned with their host star?

let’s look at two new planetary systems

Identify transiting planet candidate

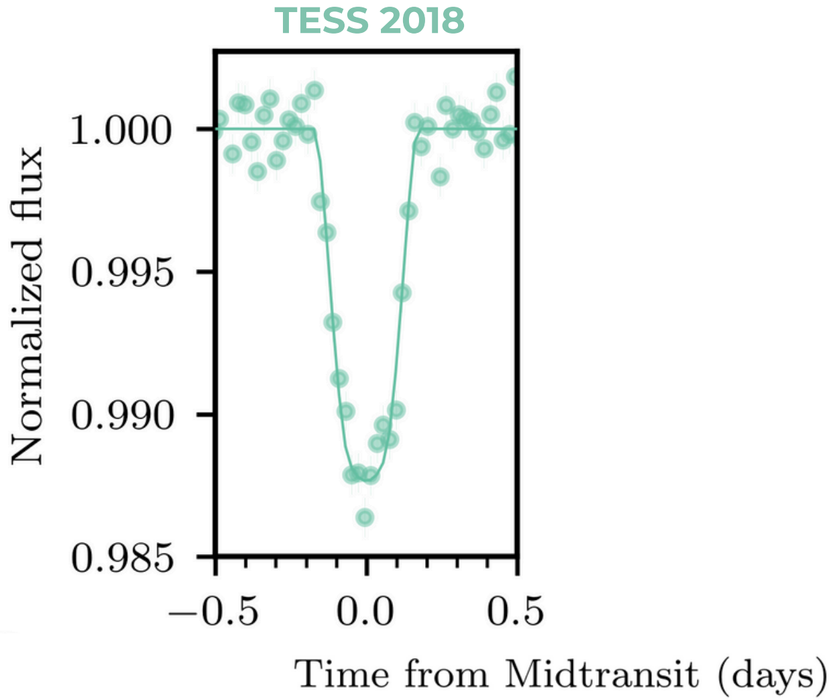


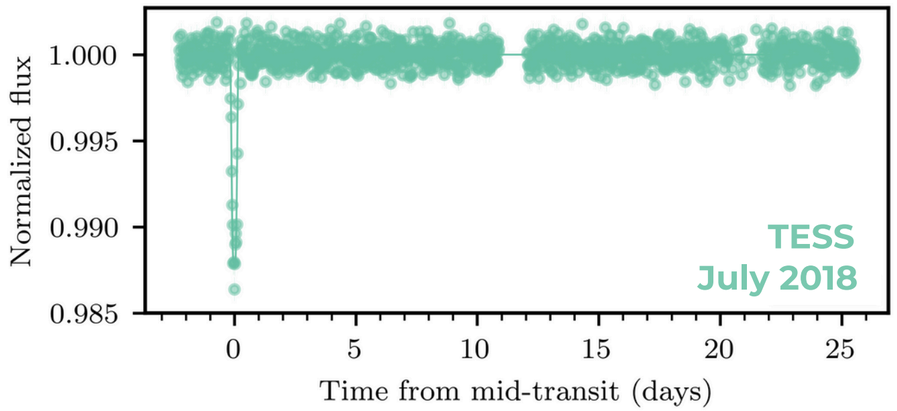
TESS observes a patch of the sky for 27 days in a row.
Planets with an orbital period longer than this appear as a single transit

Confirm transiting planet candidates

Transit photometry

- Measure transit parameters :
  - planetary radius, duration, impact parameter
  - period aliases for duo-transits
- Perform photometric vetting
- Schedule follow-up observations :
  - ESA-CHEOPS
  - NGTS : 12 telescopes, Paranal





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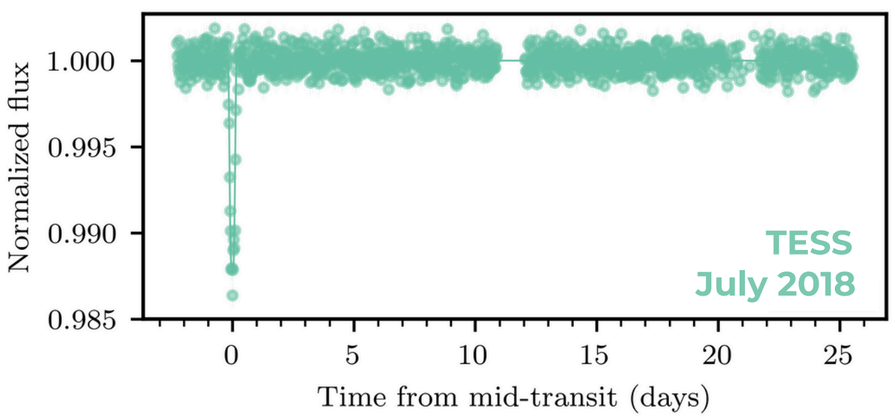
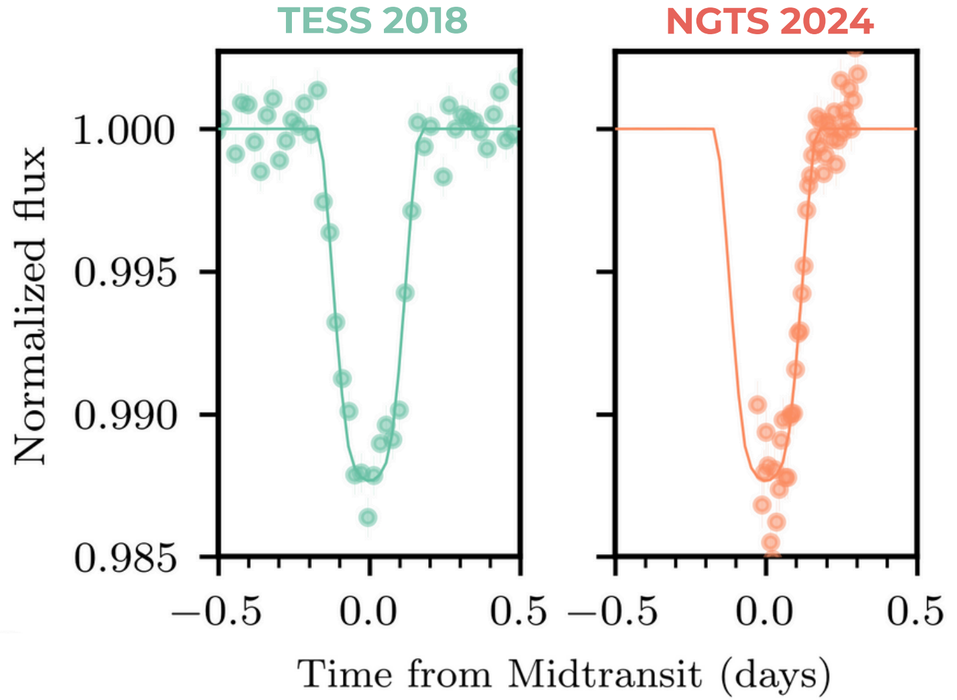




6 years later, NGTS detected a matching transit event !

NGTS
Next-Generation Transit Survey

Confirm transiting planet candidates

Transit photometry

- From single transit event, we measure :
  - planetary radius
  - transit duration
- Perform photometric vetting
- Schedule follow-up observations :
  - ESA-CHEOPS
  - NGTS : 12 telescopes, Paranal

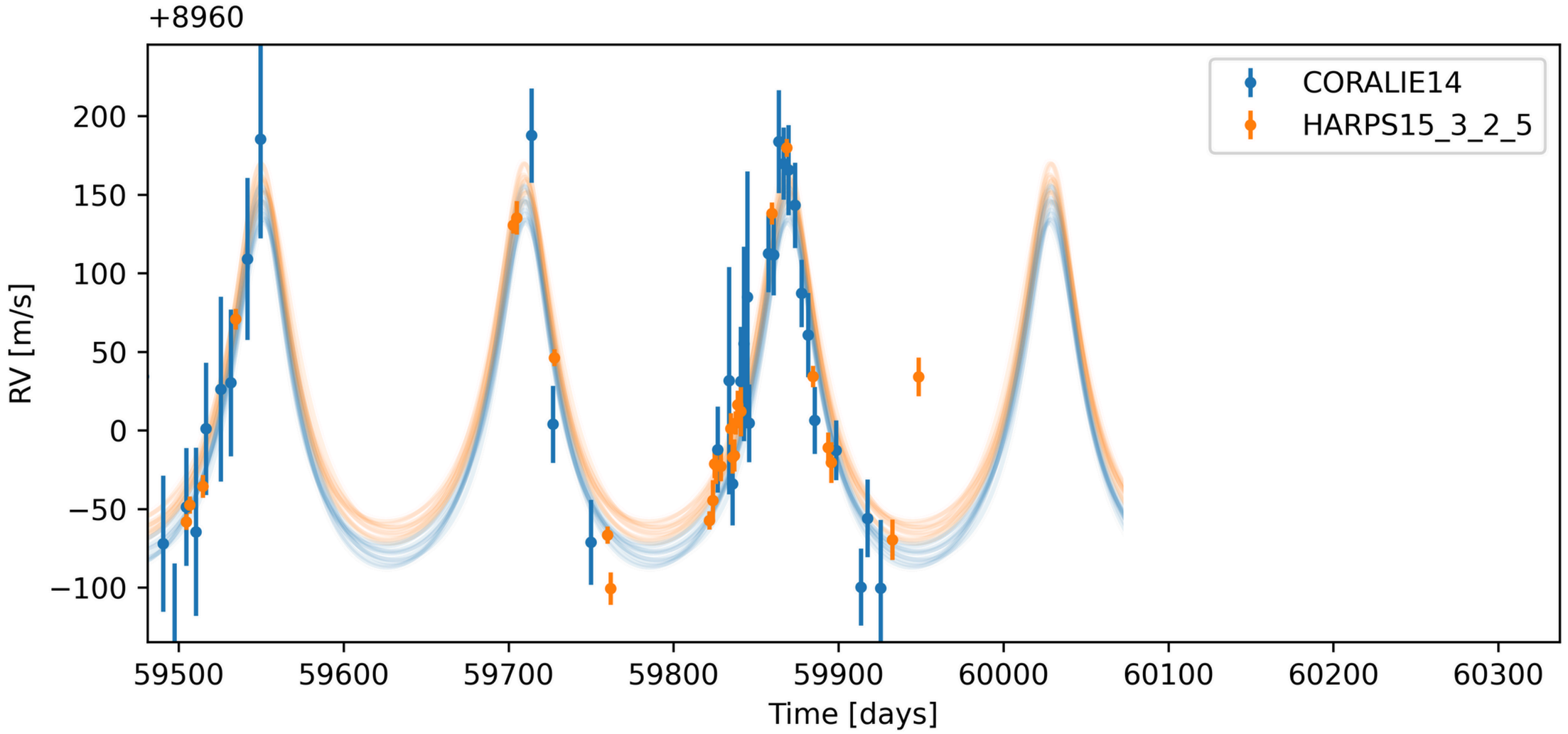
Radial velocity

- Perform spectrocopic vetting :
  - excl. SB1, SB2,
- Measure planetary masses and eccentricities :
  - CORALIE @ Euler telescope
  - HARPS @ 3.6m La Silla

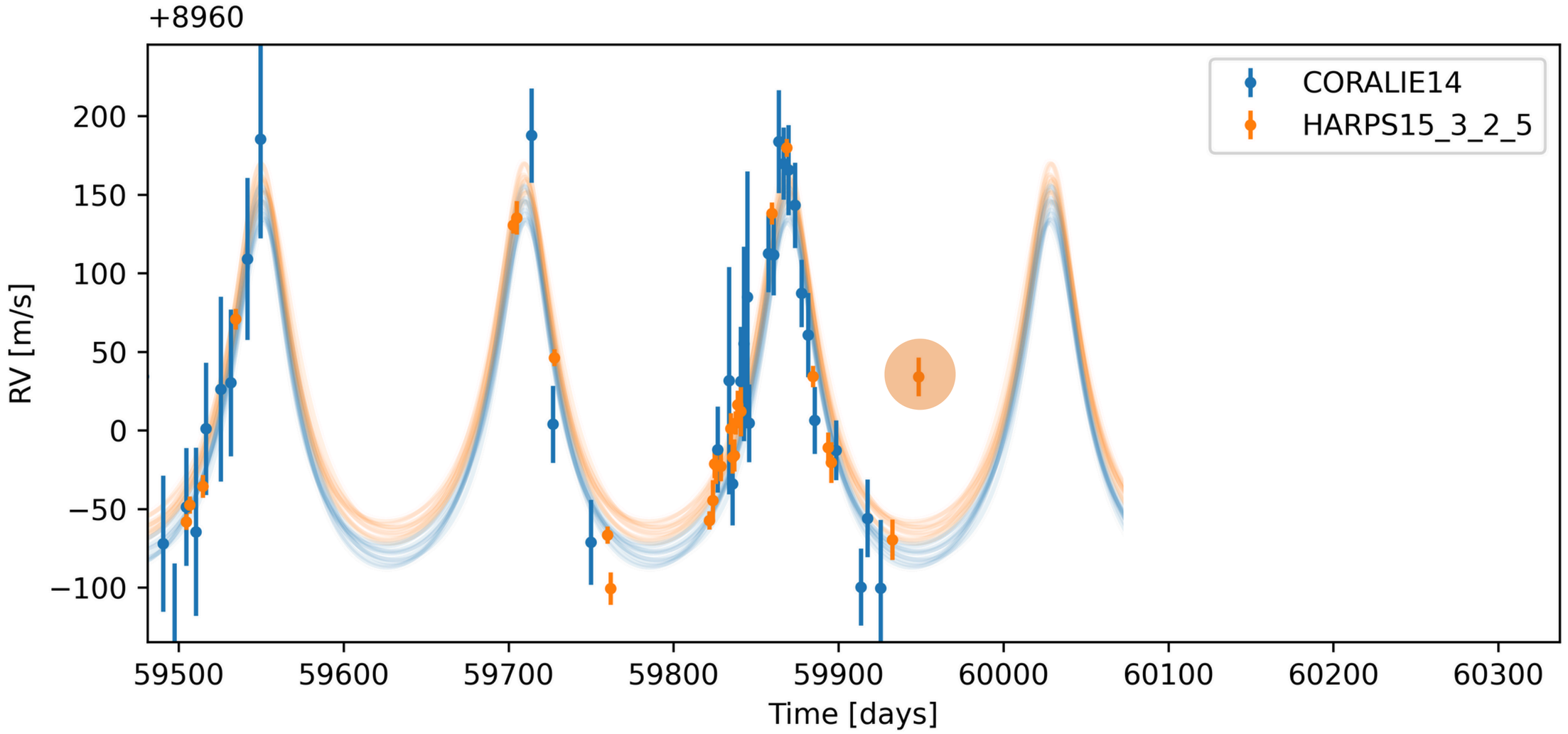
HARPS Large Program
PI : Ulmer-Moll
70 nights (2021 - 2026)

RV follow-up TESS planets
10 nights per semester

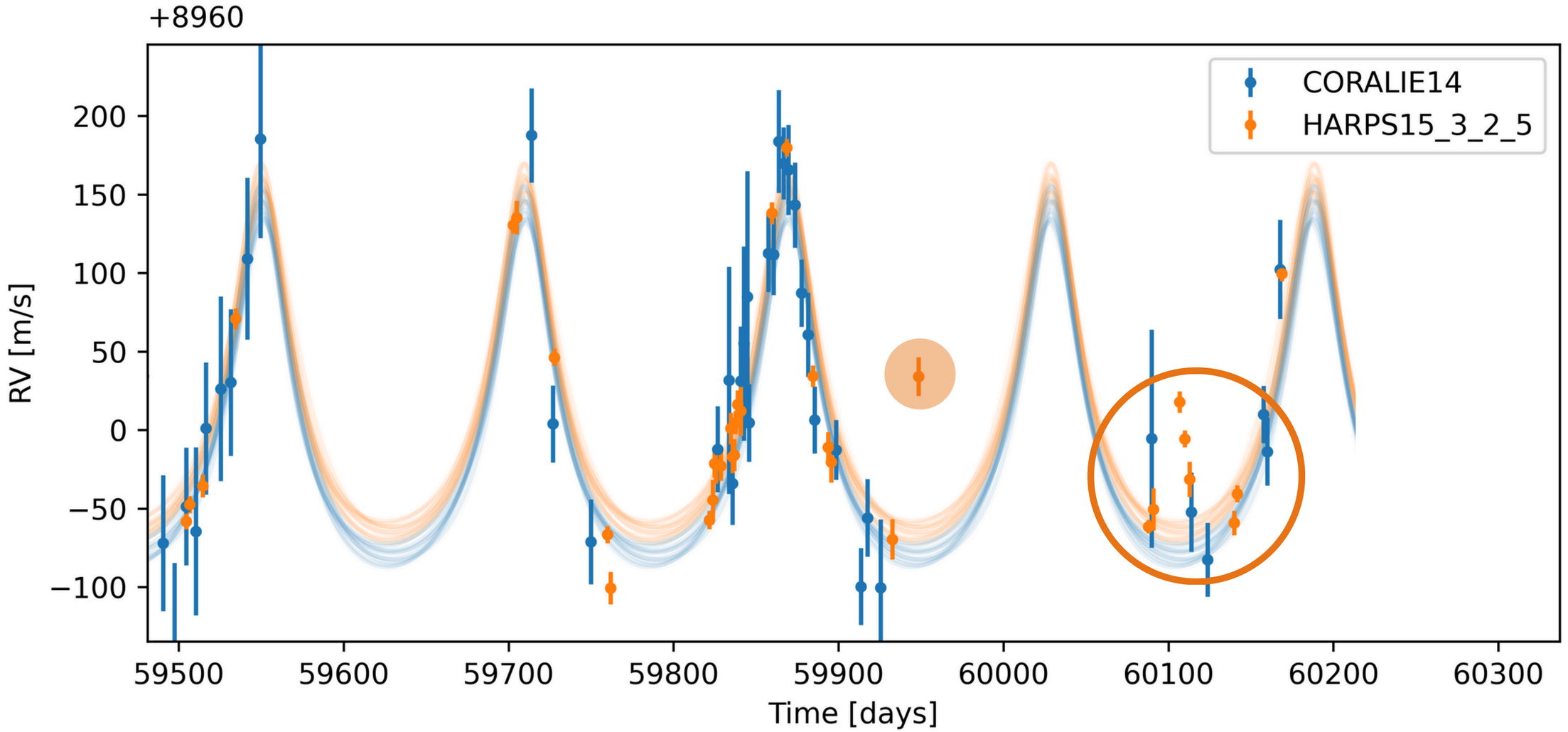
Starting the RV follow-up



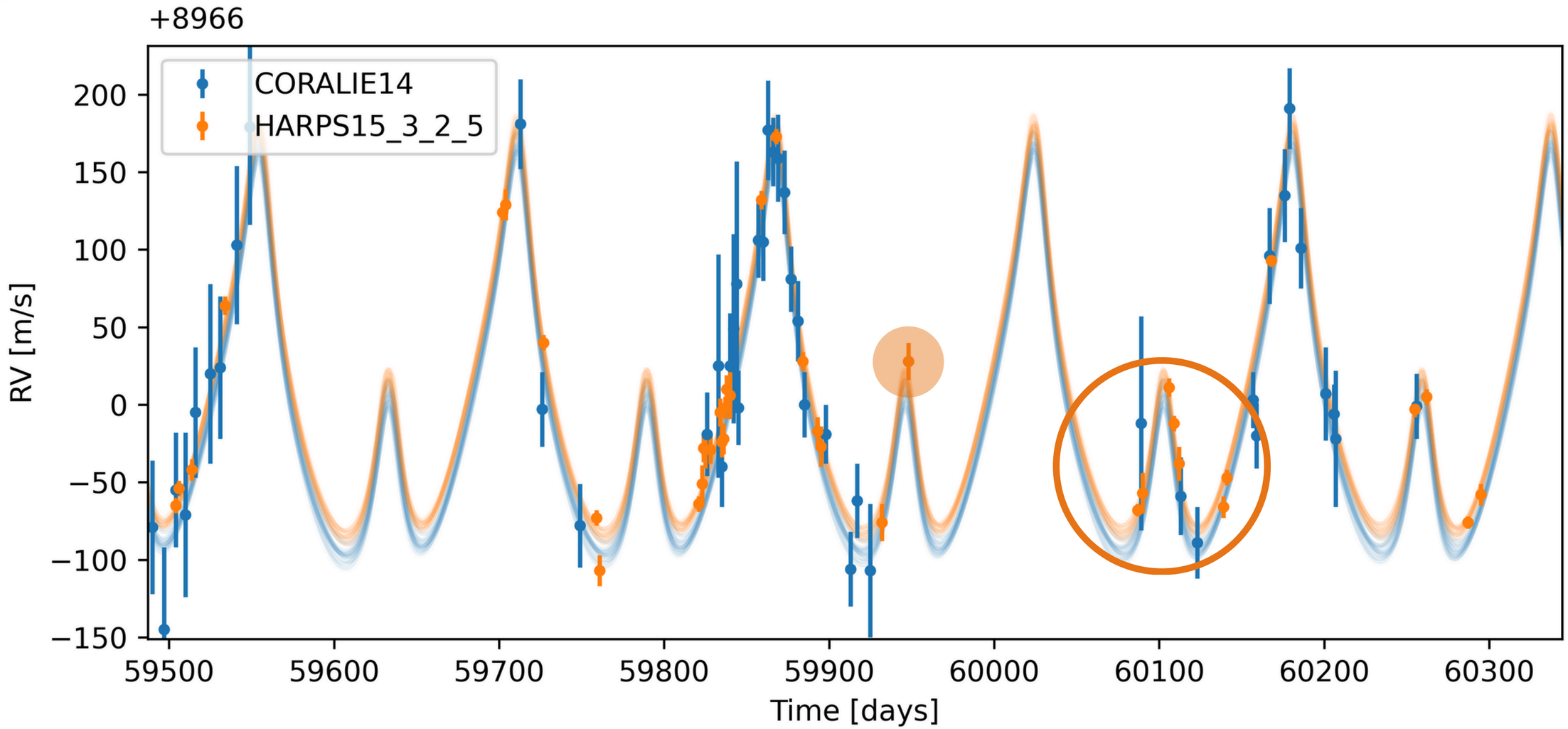
Noticing an outlier



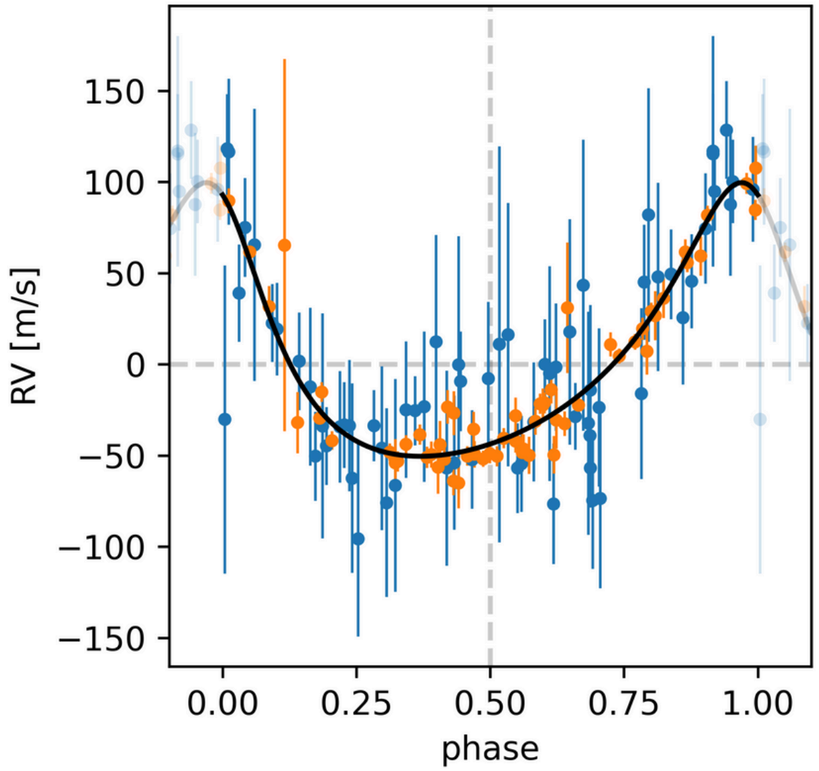
Taking more RVs

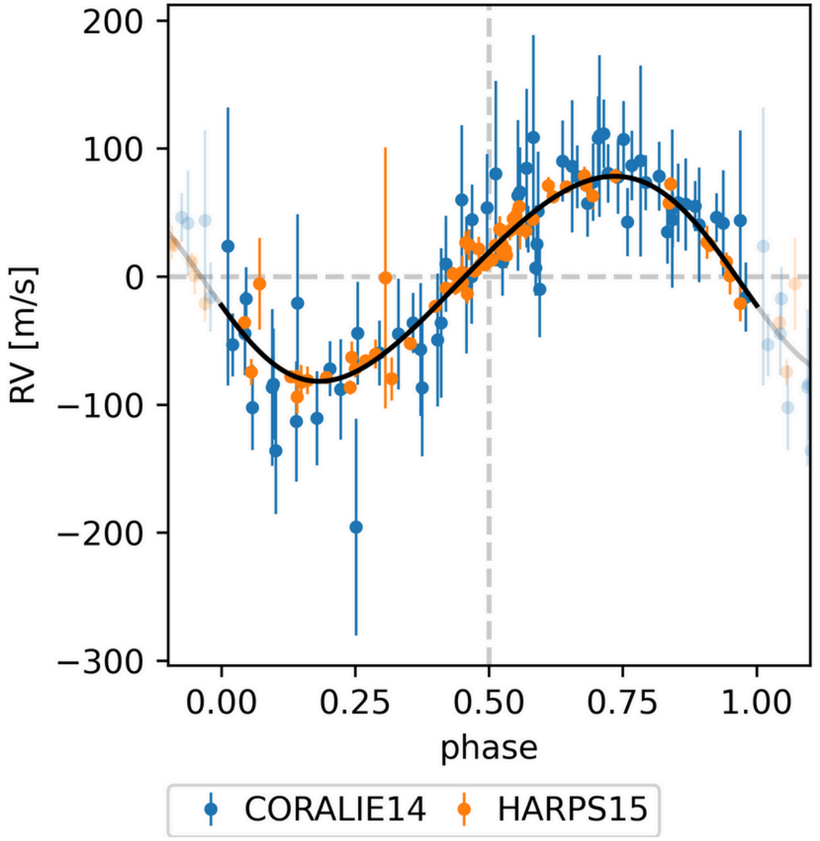


Third RV season reveals another planet



Two long-period Jupiters in 2:1 resonance





Planet b

No transit detection

1.25 Mjup @ 78.5 days

moderate eccentricity: 0.4

Planet c

Duo transiting planet (TESS+NGTS)

2.15 Mjup @ 157 days

smaller eccentricity: 0.1

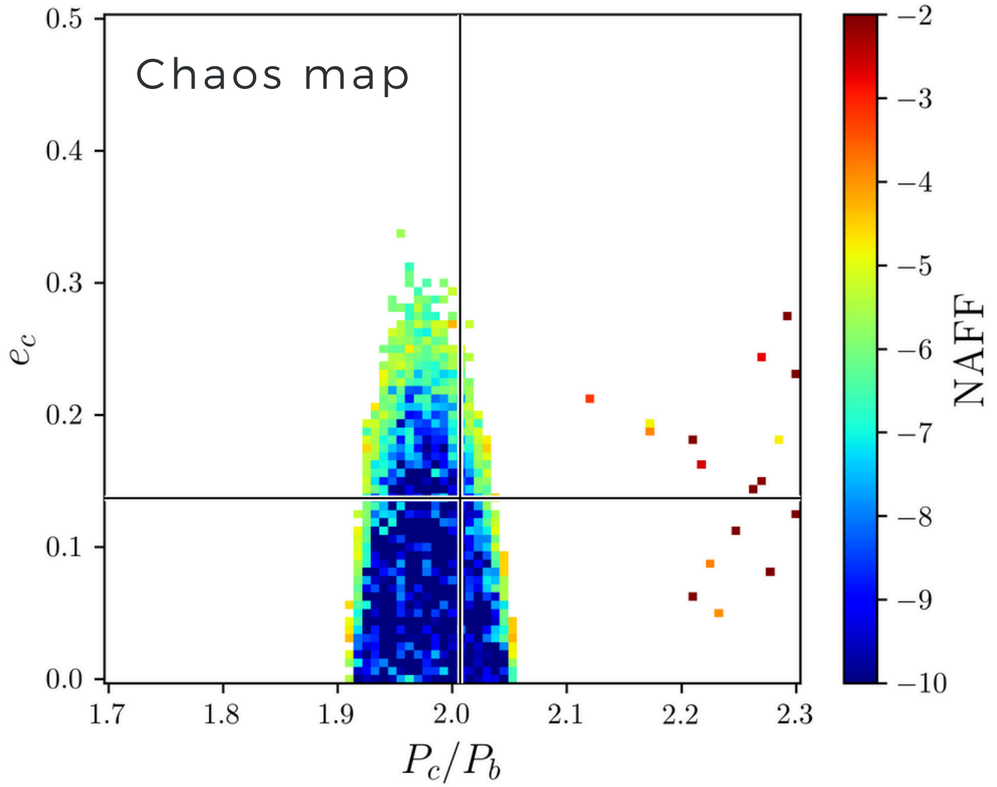
157-day planet was predicted to transit last June


but ...


let’s try again in 1 month !

Two long-period Jupiters in 2:1 resonance

Test the hypothesis of MMR by exploring the dynamics around the best fit solution.
Period ratio of 2.005 (Pc / Pb)



→ Best fit coplanar solution is trapped in a 2:1 mean motion resonance

→ Two resonant angles are librating around 0 (5k years integrating)

→ Next step : explore the global stability of the posterior

Work by Manu Stalport

We detected another system with two giant planets

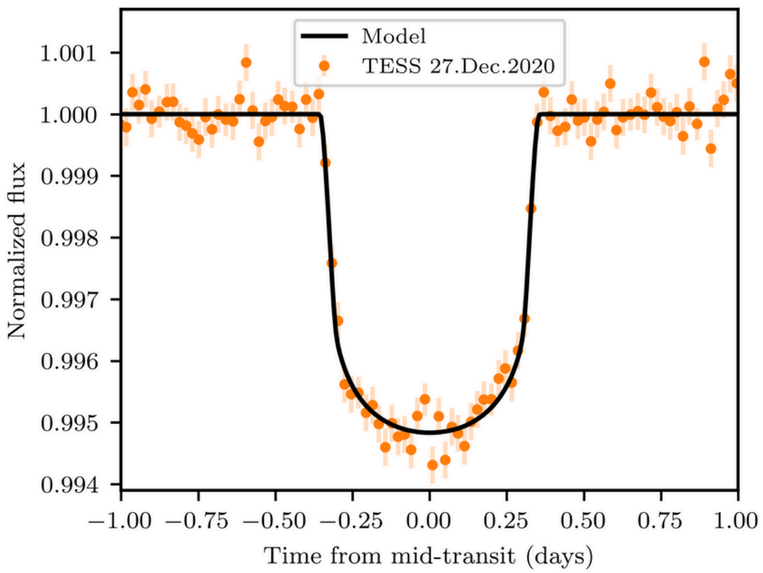
Two massive giant planets around an evolved Solar-like star

Transit photometry

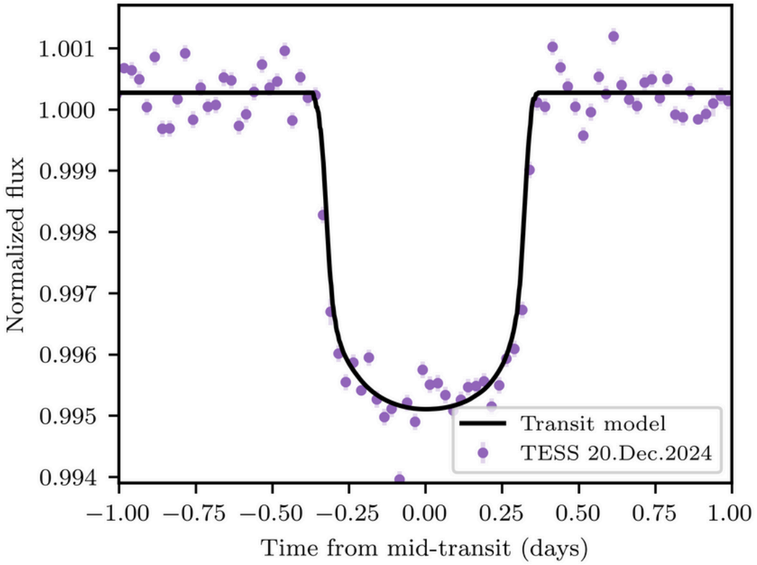
We detect two matching transit events in the TESS photometry.

Host star : 6200K, 1.9Rs, 1.2Ms

TESS 2020



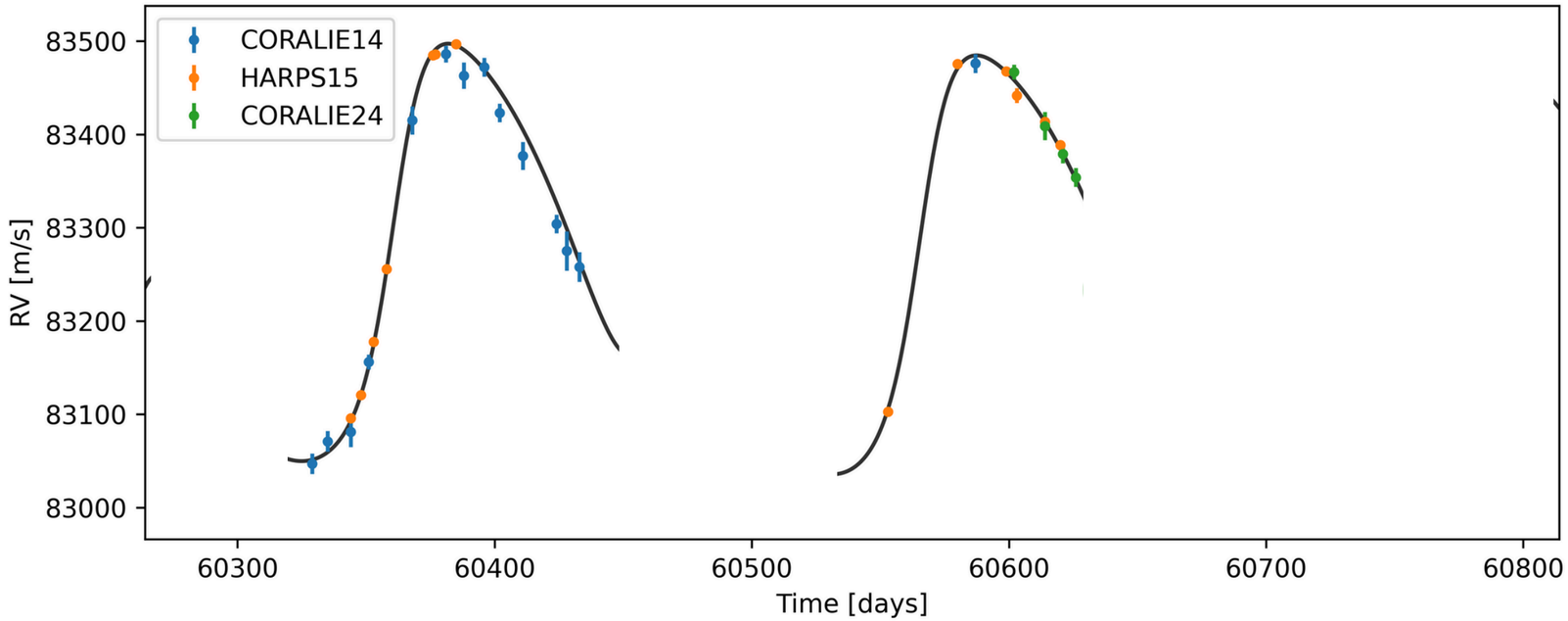
TESS 2024



Two massive giant planets around an evolved Solar-like star

Radial velocity

Clear detection of a giant planet

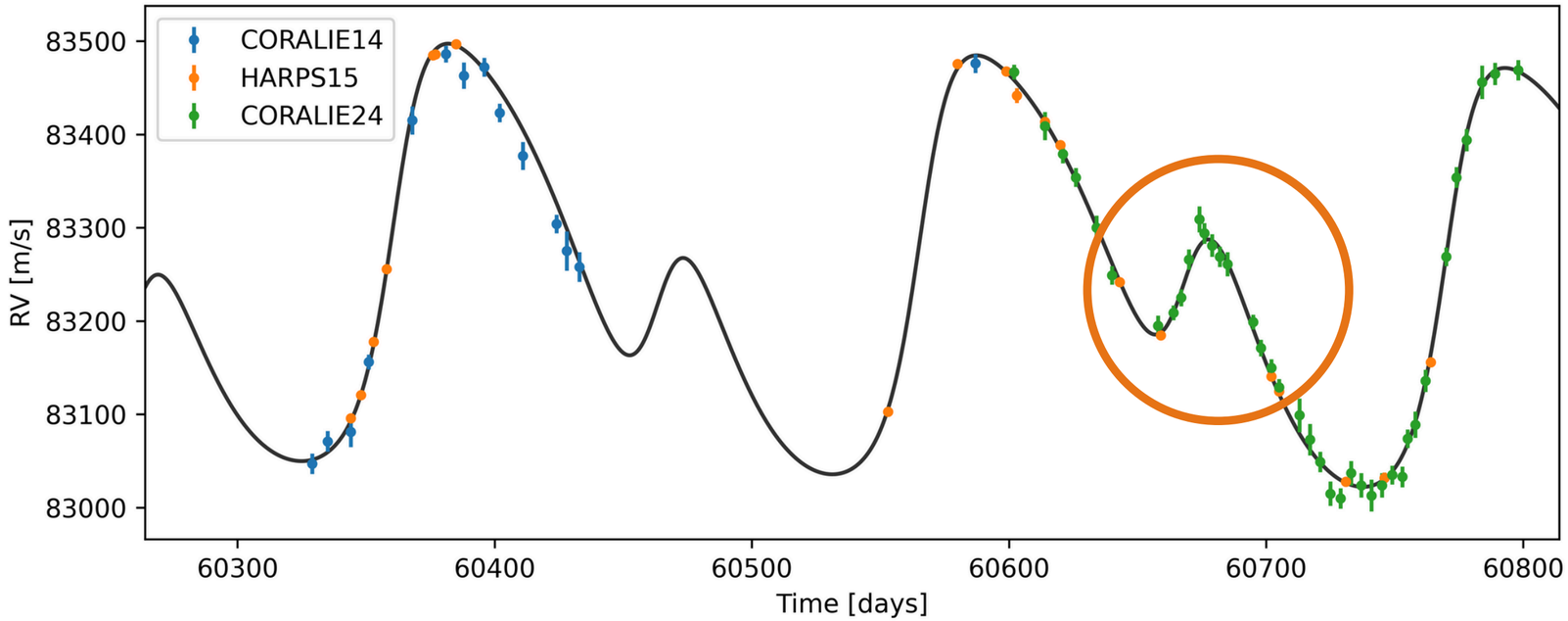


Two massive giant planets around an evolved Solar-like star

Radial velocity

Clear detection of a giant planet

Second season of RV follow-up reveals a 2nd planet



Planet b

No transit detection
2.5 Mjup @ 102.2 days
moderate eccentricity: 0.3

Planet c

Duo transiting planet (TESS)
5 Mjup @ 207.6 days
circular orbit

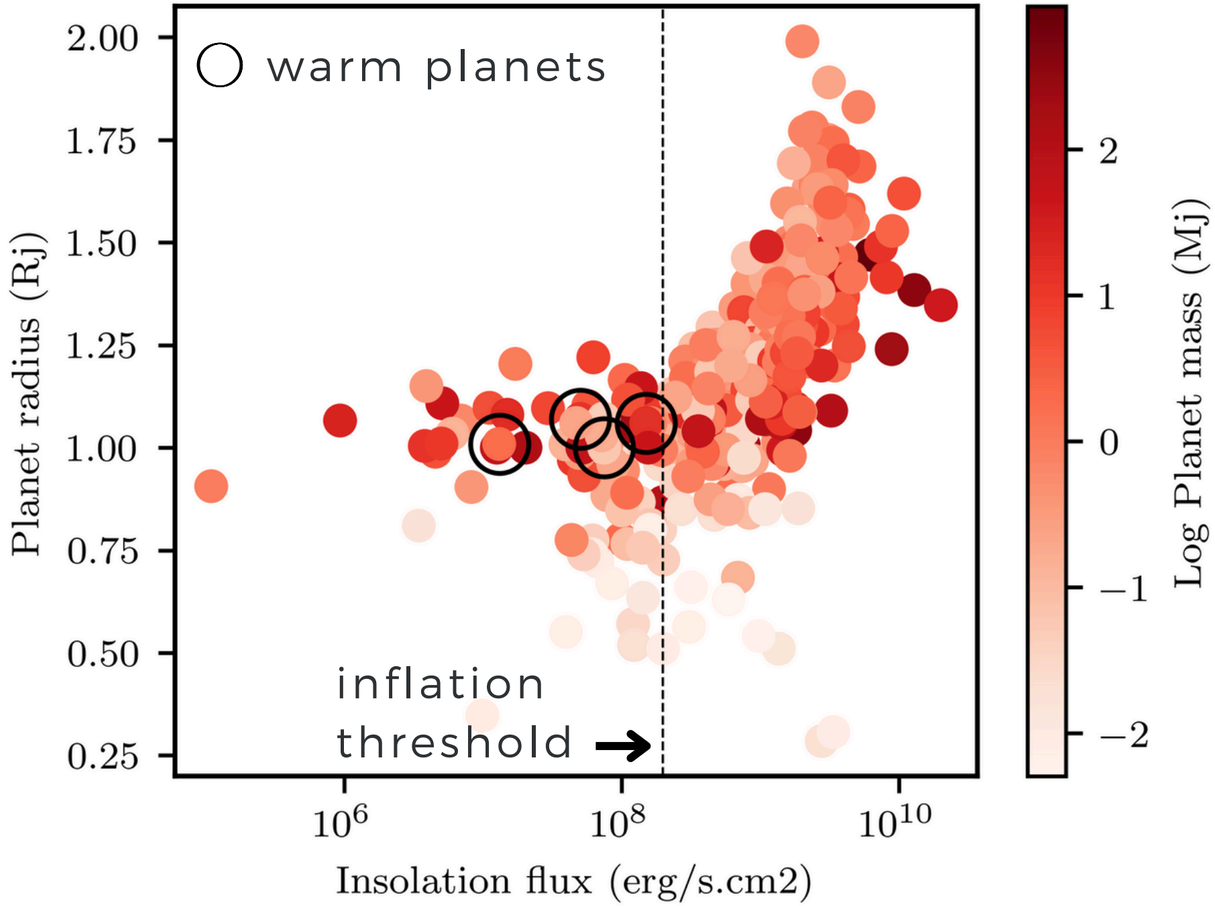
Long-period transiting Jupiters are ideal to study their interior

Warm Jupiters are usually not inflated

We have precise mass and radius measurements for these warm giant planets.

They receive lower levels of stellar irradiation than HJs and usually do not have inflated atmospheres.

No degeneracy between radius inflation mechanisms and composition study.



How to estimate the planet's composition?

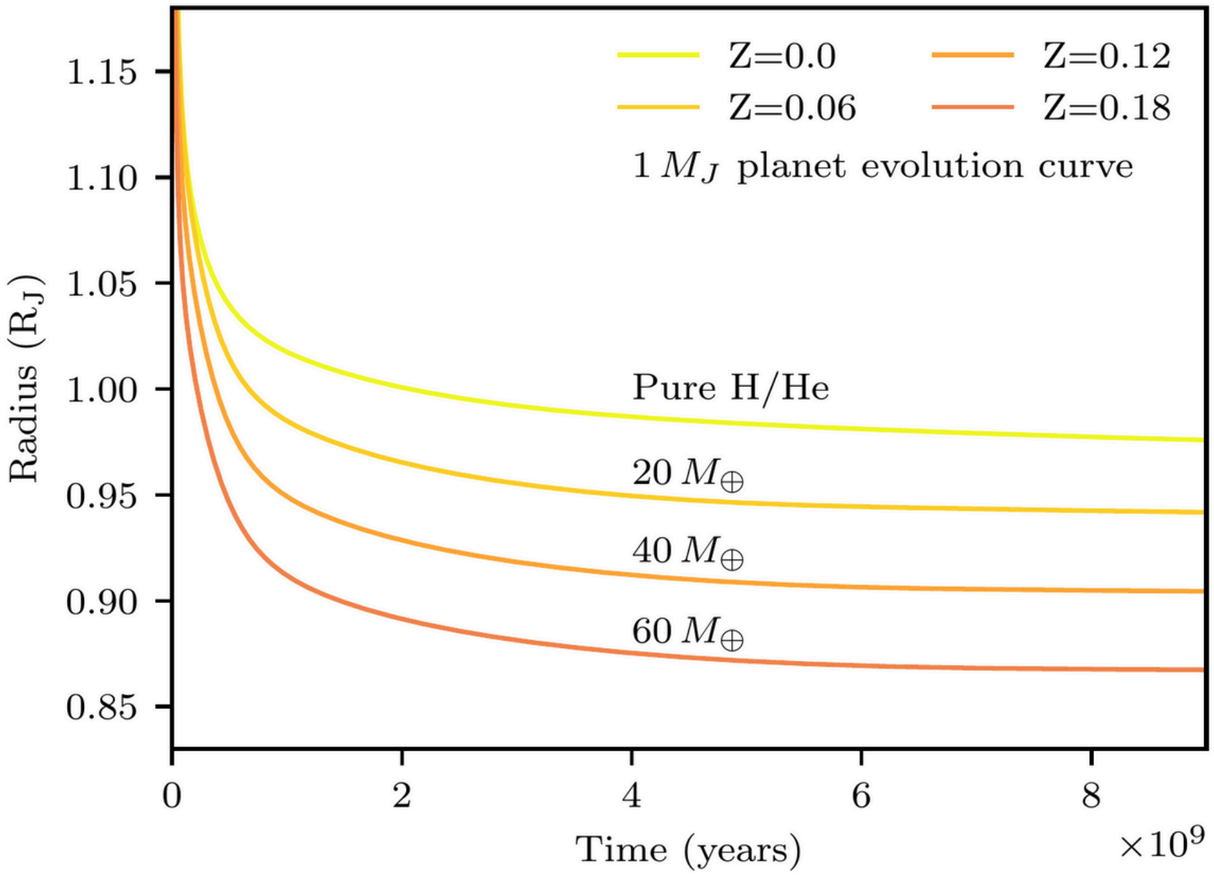
We combine **observations and modeling**
to measure the amount of heavy elements and metal enrichment.

We model the evolution of the planet with time

Radius decreases with age and heavy element enrichment

We can explore the impact of varying the heavy elements (Z) in the envelope

Completo code
Mordasini et al. (2012)

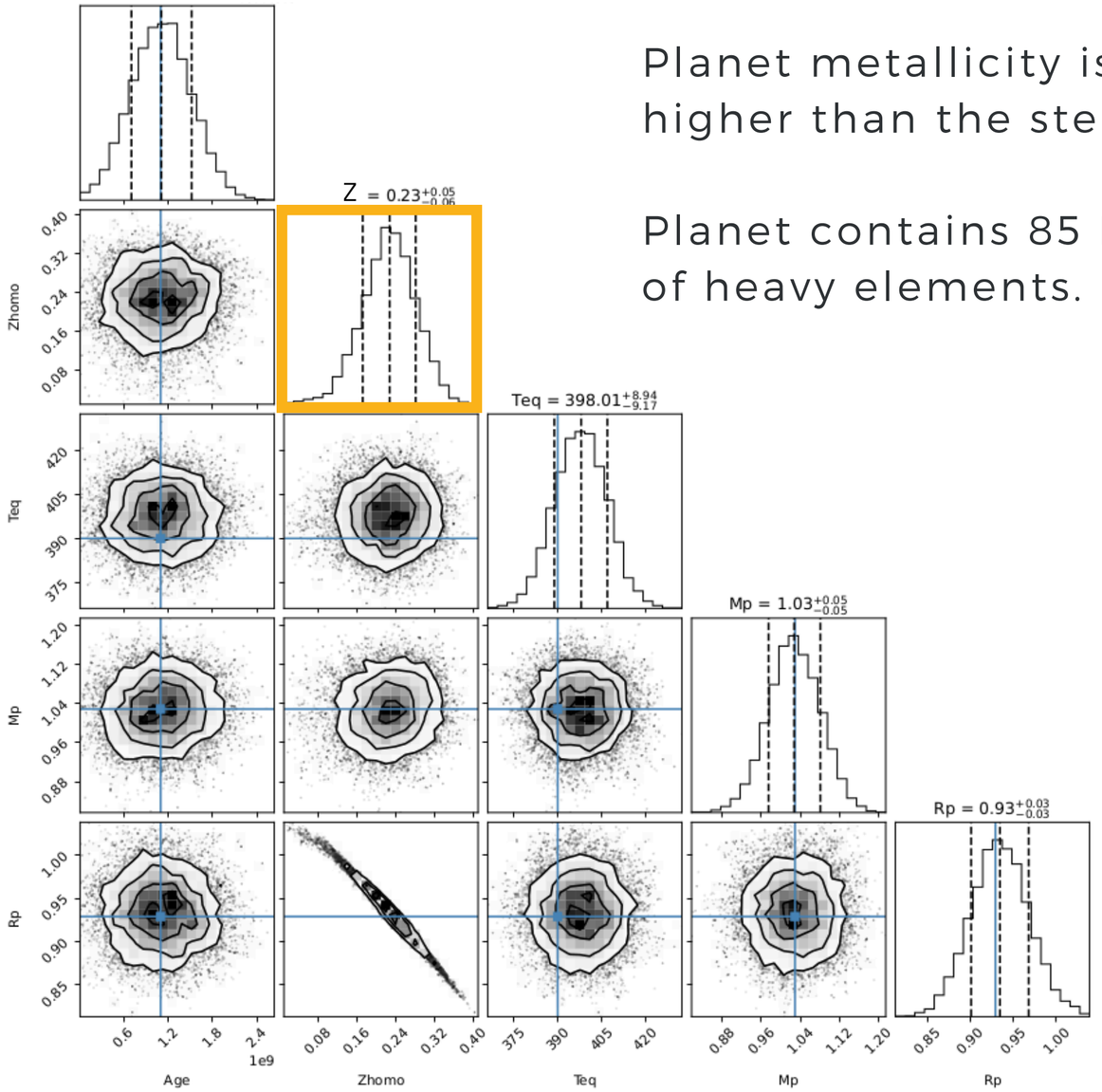


Warm Jupiters are metal-enriched

TOI-4862 b
1 Mjup @ 98 days
Teq: 400K
Age: 1.1 (+-0.4) Gyr

Battley+(2024)

- *late-stage accretion of planetesimals (Mousis+2009, Shibata+2020)*
- *multiple mergers during gas accretion phase (Ginzburg & Chiang 2020)*



Planet metallicity is 20x higher than the stellar one

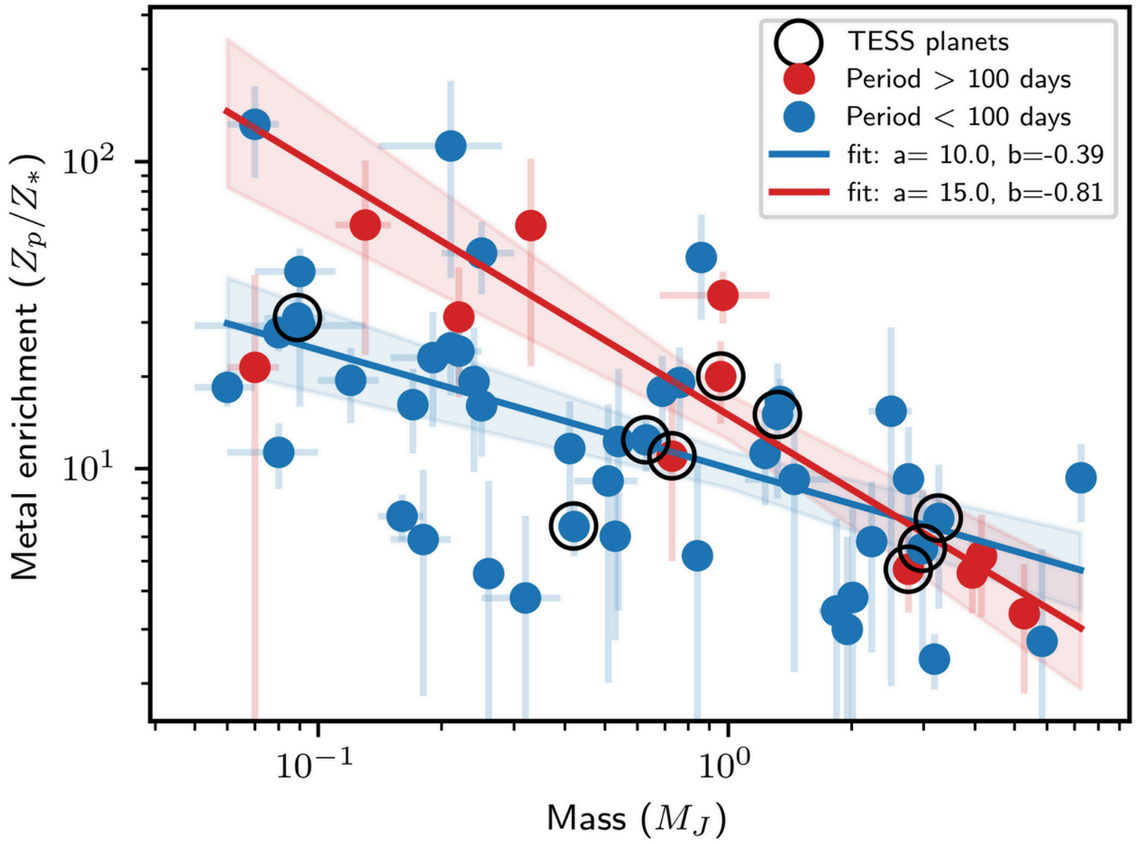
Planet contains 85 Me of heavy elements.

Planet metal-enrichment correlates with planetary mass

This inverse correlation is expected from core-accretion formation models.

The newly detected planets match well with this correlation.

There is a hint of a different mass-metallicity relation for longer period planets.

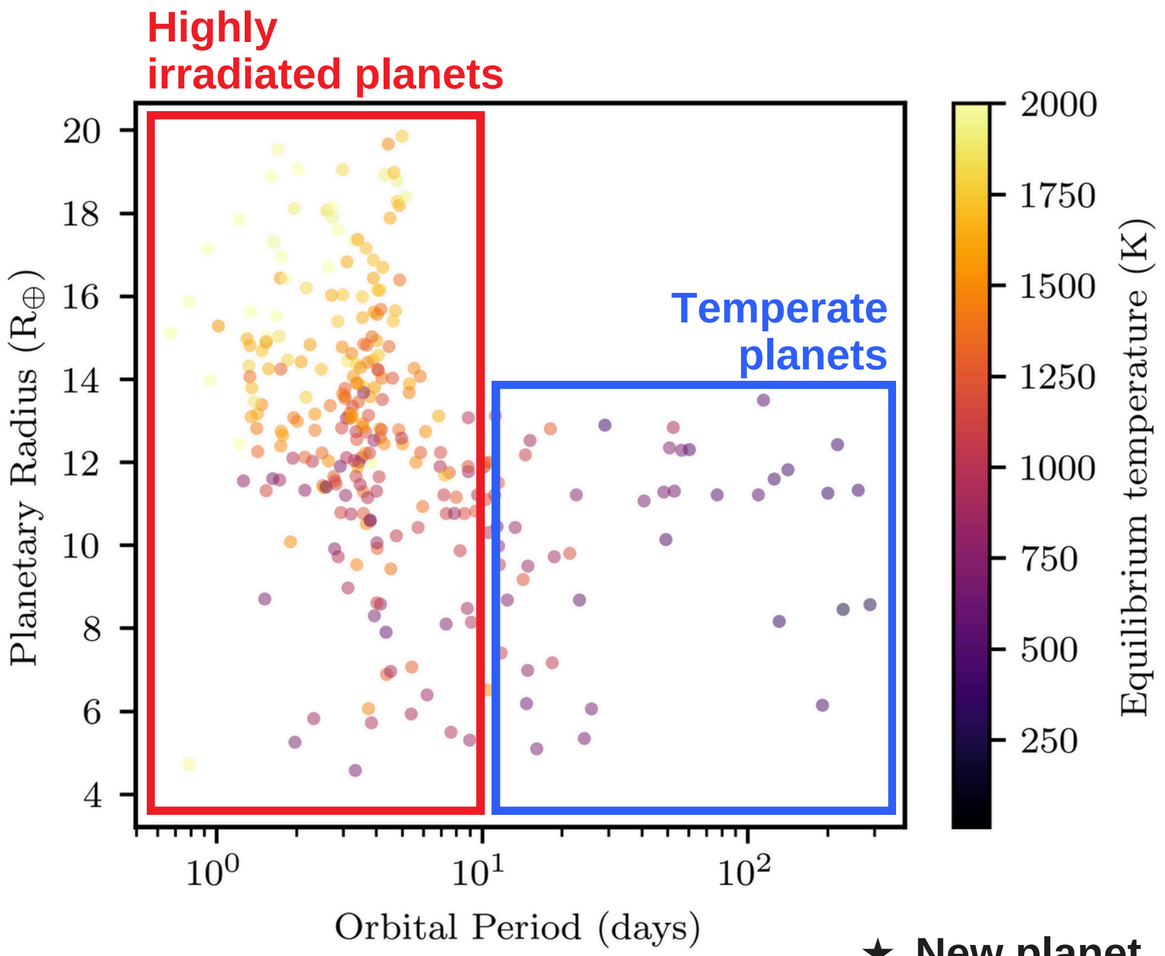


Updated from Dalba+2022

In summary

- 4 year RV and photometric follow-up
- Detection of **30 new exoplanets with precise masses and radii**

We doubled the known population of transiting warm and temperate planets



Transiting planets with precise mass and radius

In summary

- 4 year RV and photometric follow-up
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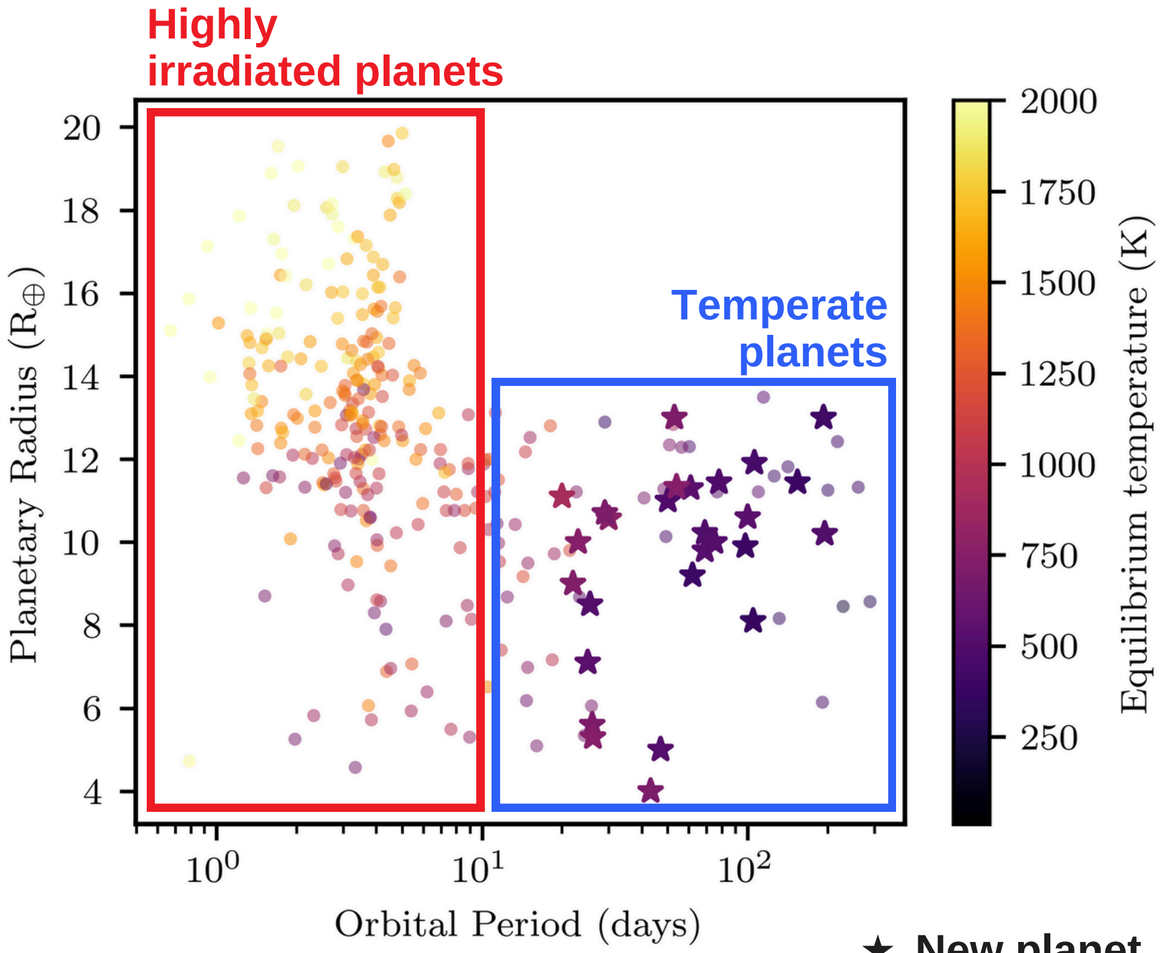
Publications : Ulmer-Moll+2022, 2023, 2025
Grieves+2022, Brahm+2023, Gill+2024,
Battley+2024, Essack+2025, Rodriguez+2025

HARPS program 70 nights (2021 - 2026)



Transiting planets with precise mass and radius