# TRANSITING WARM JUPITERS

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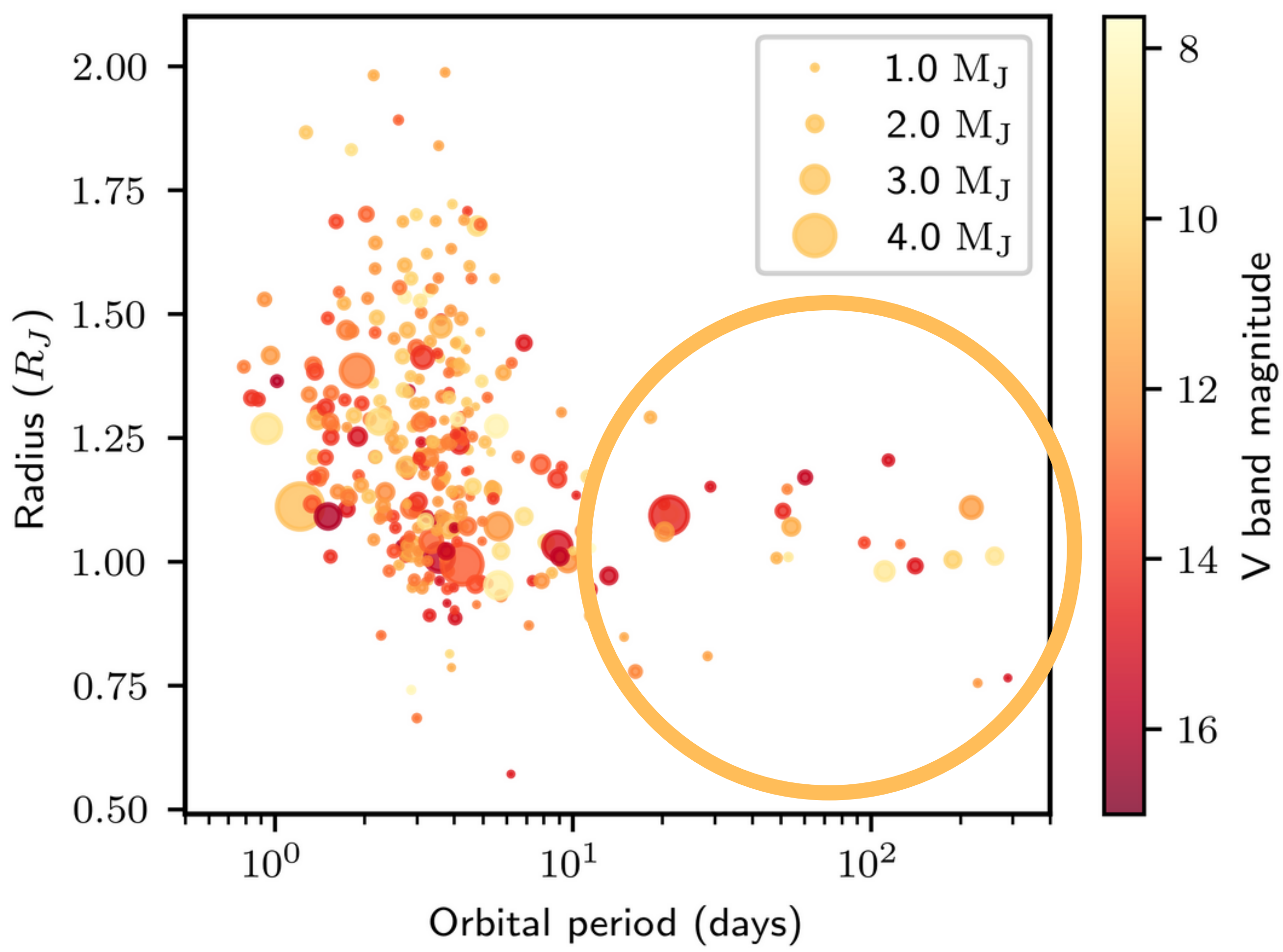
# Few transiting WJs detected

Increase the sample of longer period transiting giant exoplanets to understand their migrational history through occurence rate and eccentricity distribution and resonnances with planetary companions.

**Population of transiting warm Jupiters**:

Period > 20 days
Mp > 0.2 Mjup

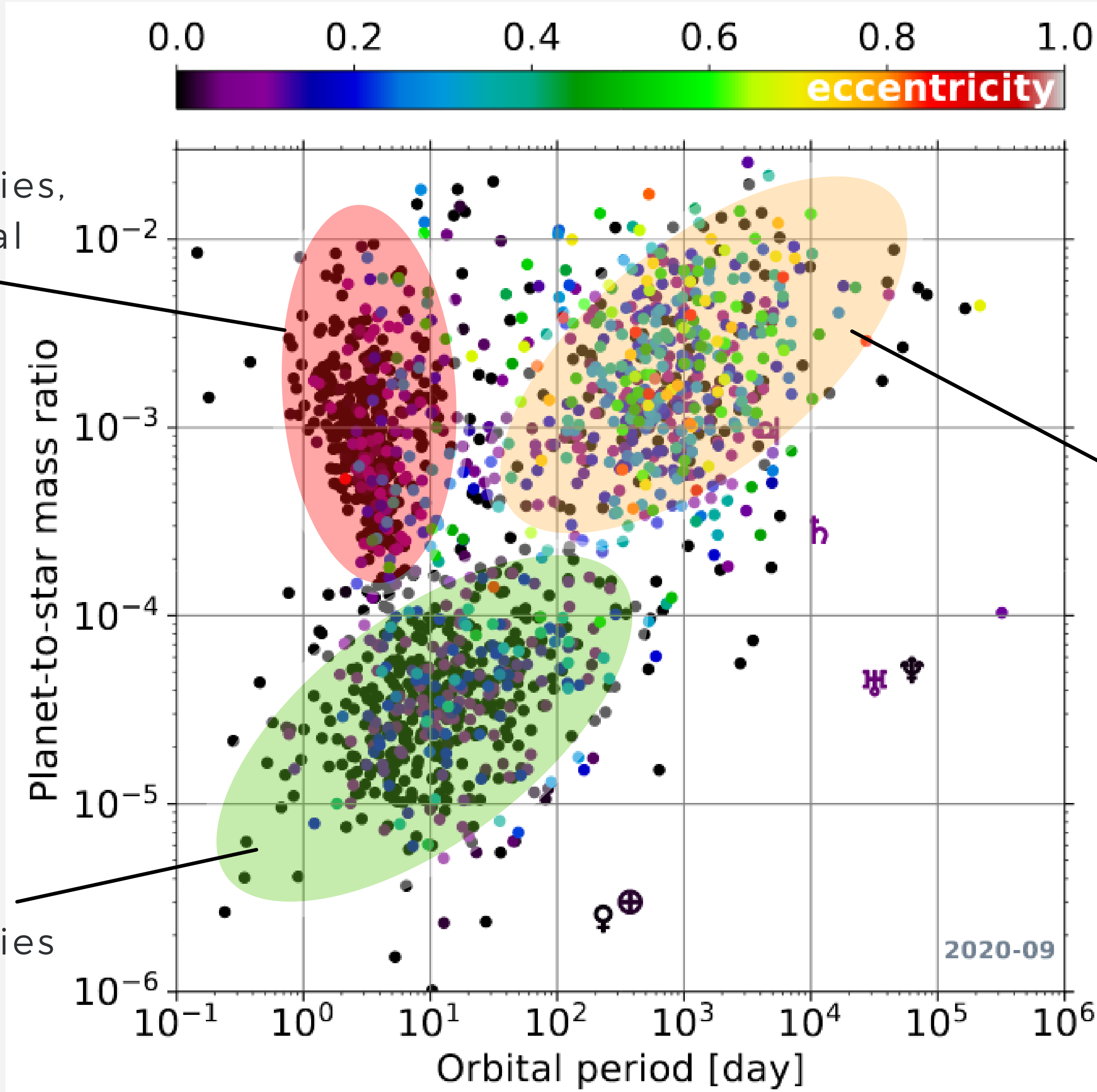
Precise mass and radius measurements
(< 25% mass, < 8% radius)




PlanetS DACE catalog

# WJs have a wide range of eccentricities

**Hot Jupiters**
low eccentricities,
star-planet tidal
interactions



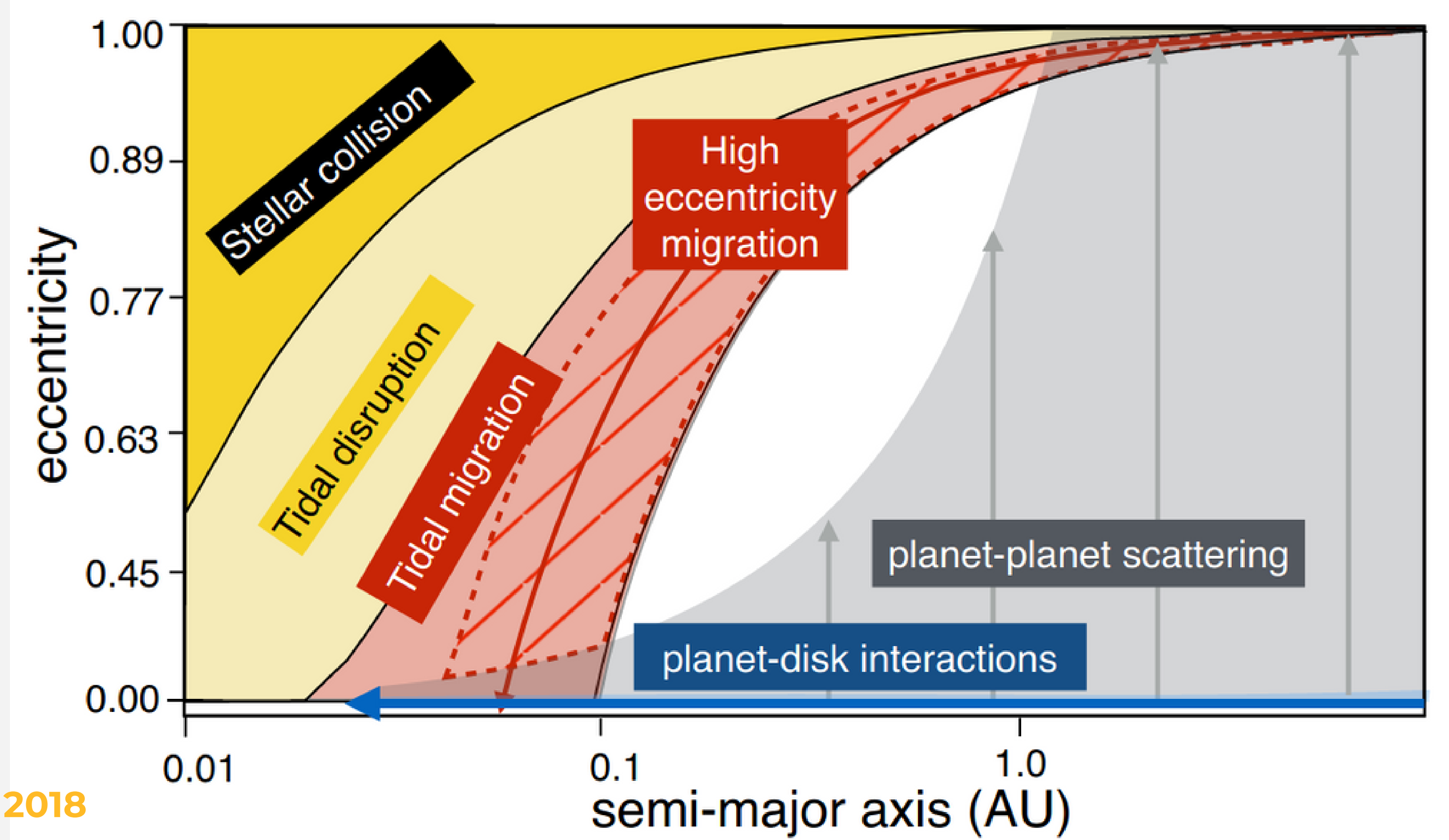

**Warm Jupiters**
wide range of
eccentricities with
two components

**Super Earths**
low eccentricities
planet-planet
interactions

Debras et al. 2021

# Unclear formation pathways

Formation pathways for warm giant planets
- disk migration
- high eccentricity tidal migration
- in situ formation
- migration in a disk cavity




Dawson & Johnson 2018

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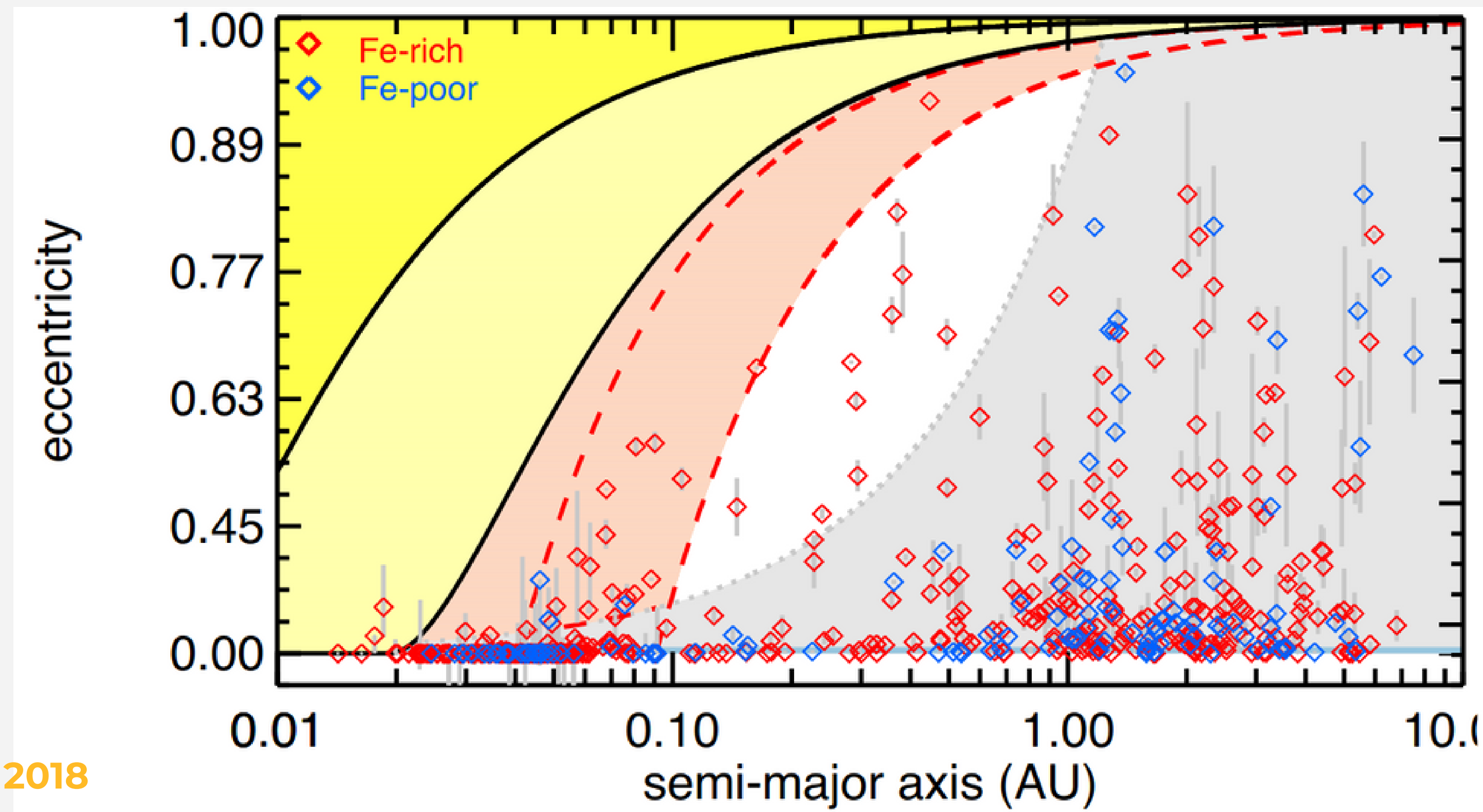
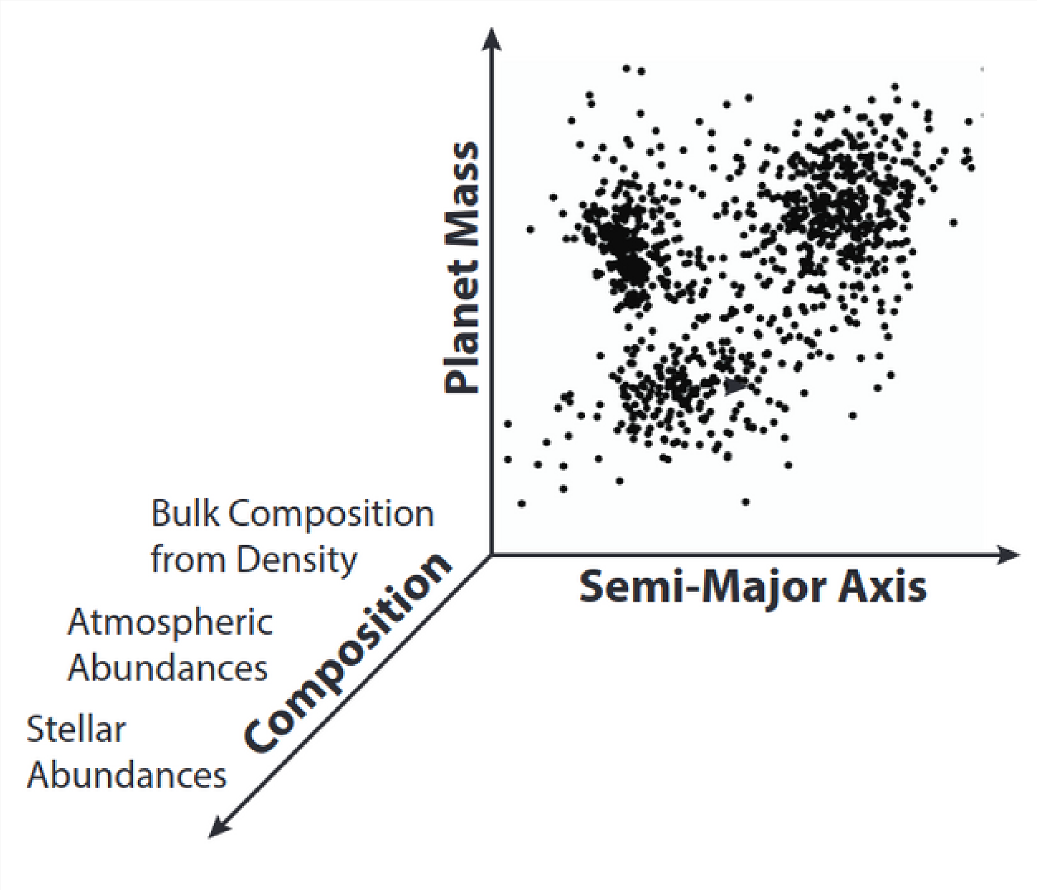



Dawson & Johnson 2018

# Bulk composition are available for transiting WJs

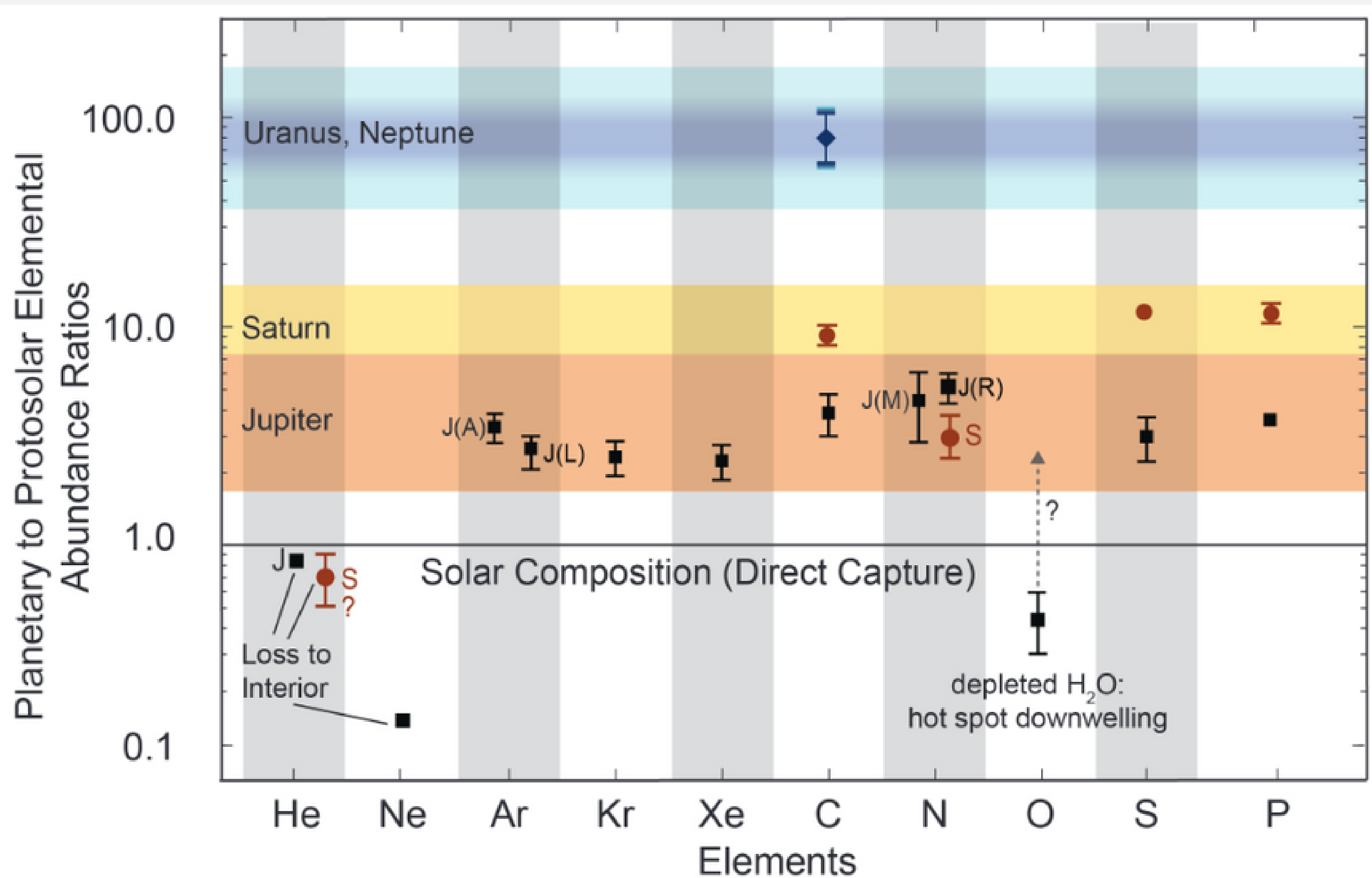
Using transiting WJs to measure their mass and radius gives us insight on their bulk and atmosphere composition. WJs present the advantage that their radii is not inflated compared to HJs.




Thorngren et al. 2017

# Jupiter and Saturn are metal-enriched

Warm Jupiters are the link between hot Jupiters and the cold giants of our solar systems. Abundance ratios were measured for various elements for the well studied giants Jupiter and Saturn



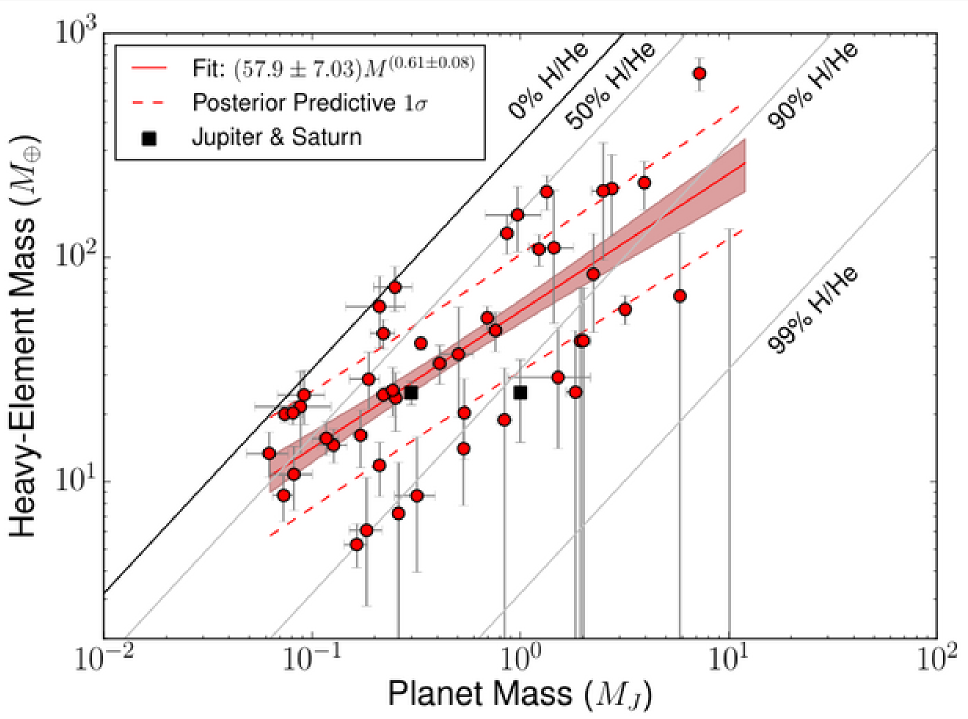

The solar system giants are enhanced above solar composition in metals, both in their visible atmospheres and bulk compositions.

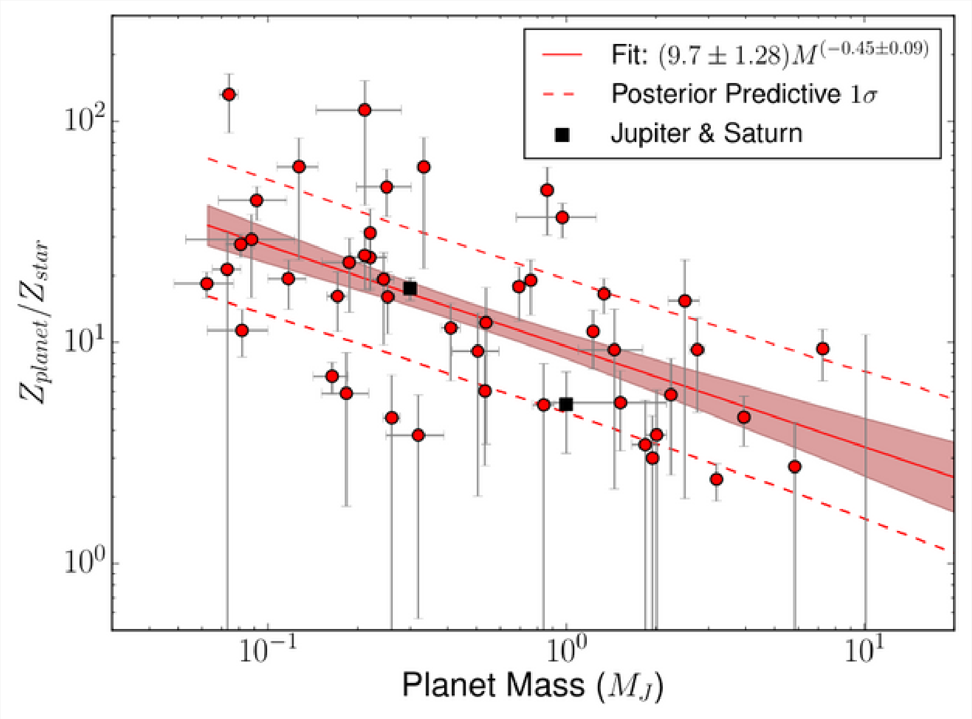
Is the metal enrichment of gas giants correlated with that of their host stars ?

Atreya et al. 2016

# Heavy element mass correlates with planet's mass

Studying 47 transiting WJs, Thorngren et al. showed that:
- heavy element mass correlates with planetary mass
- planet metal enrichment (Zplanet/Zstar) anti-correlates with planetary mass




Thorngren et al. 2017

# PlanetS Monotransit initiative

## collaboration UGE & UBE

Detecting cool giant transiting planets orbiting bright stars, and interpreting their nature using planet formation and evolution models.

Combine the core expertises of UGE and UBE,

- planet detection and characterisation
- numerical modelling, fundamental processes governing planet formation

How can we explain the wide range of eccentricities of warm giants?
How do warm giants form and migrate?
How do giant planets accrete their heavy elements?
Are the trends in planetary metal enrichement linked with stellar or orbital parameters?

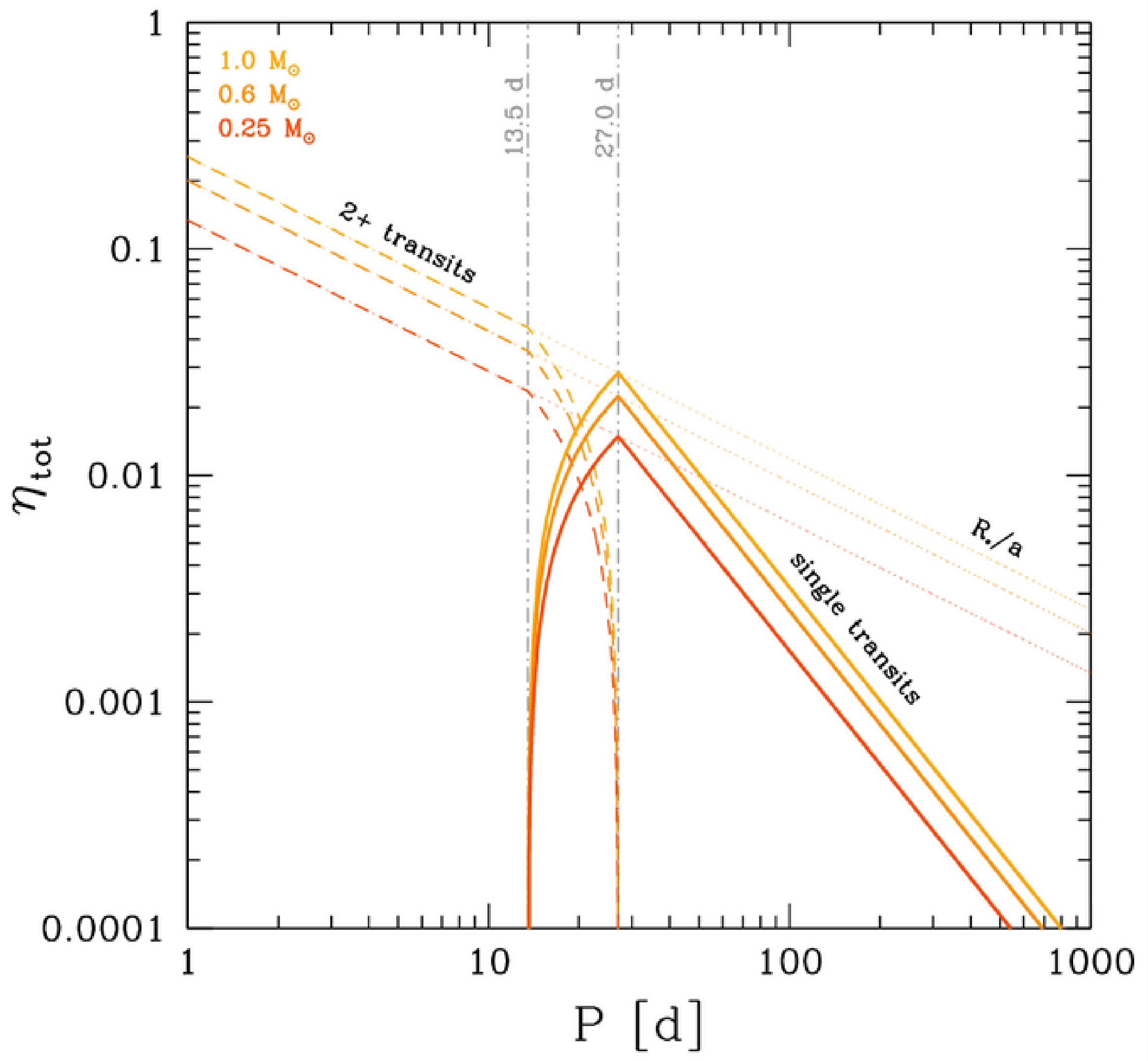
**>> TESS opportunity**

# WJs appear as TESS monotransits

TESS is covering the majority of sky by observing sectors during 27 days and we expect to find more than 1000 monotransits in the first two years of TESS data. Single transits in TESS data allow us to discover longer period transiting planets

probability of observing a single transit (solid) for the 27.4 day baseline

as compared to the geometric transit probability (dotted).

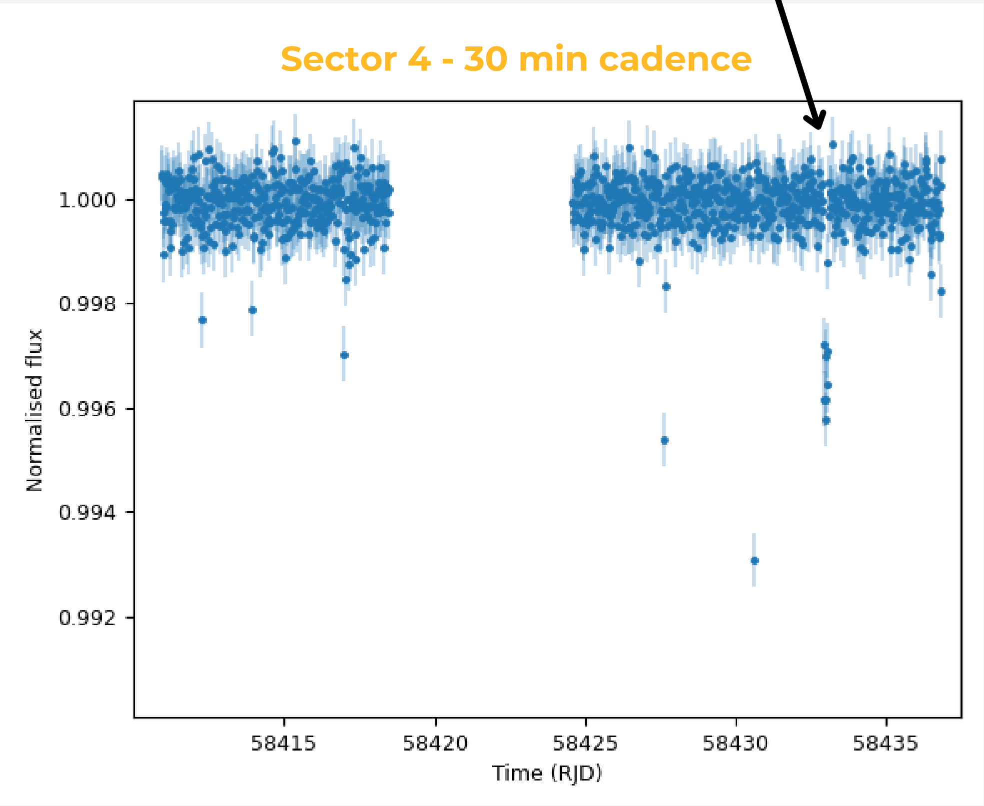


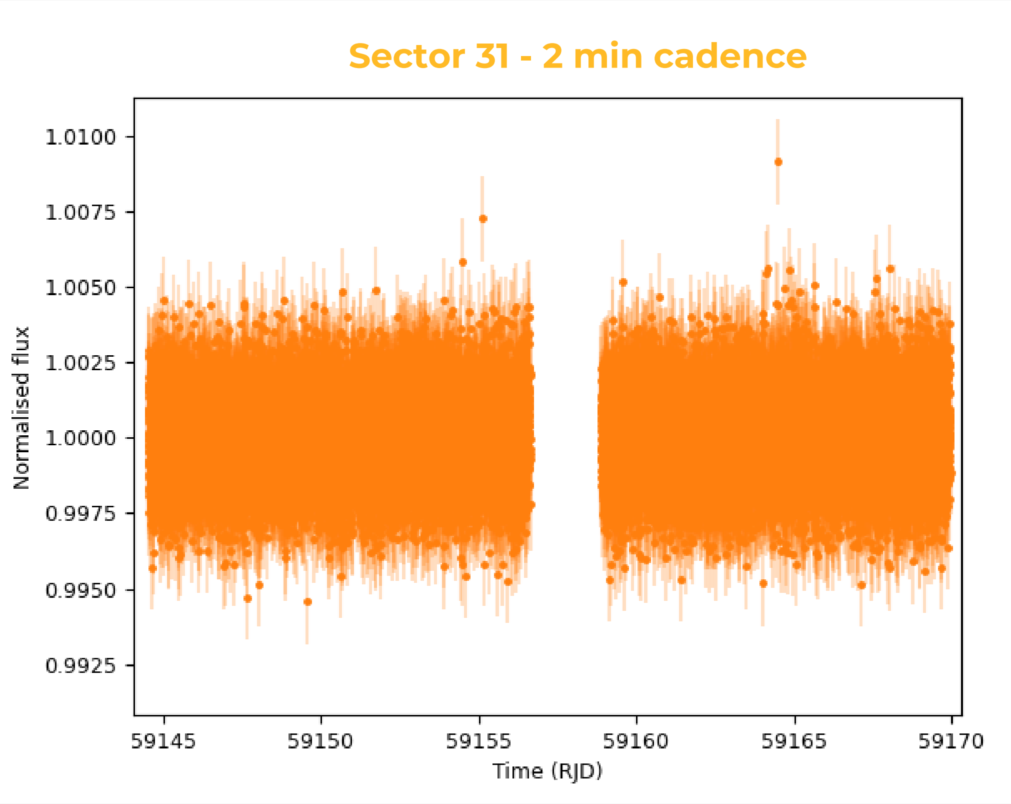

Villanueva et al. 2019

# TESS re-observes the southern sky

TESS observes Sector 4.
One single transit is detected

TESS re-observes the same field two years later but no transit is seen in this second TESS light curve.



# Four sources of candidates

**TSTPC: TESS single transit planetary candidates**

**NGTS Monotransit Working group**

Two pipelines tailored to find single transit events:

- extracting light curves from FFIs / SPOC
- detrending light curves
- BLS
- automatic vetting
  fit sinusoid vs boxcar model
- manual vetting
  asteroid vetting / centroid shifts

**TOIs: TESS object of Interest**

Aimed at periodic signals, but some single transits are reported

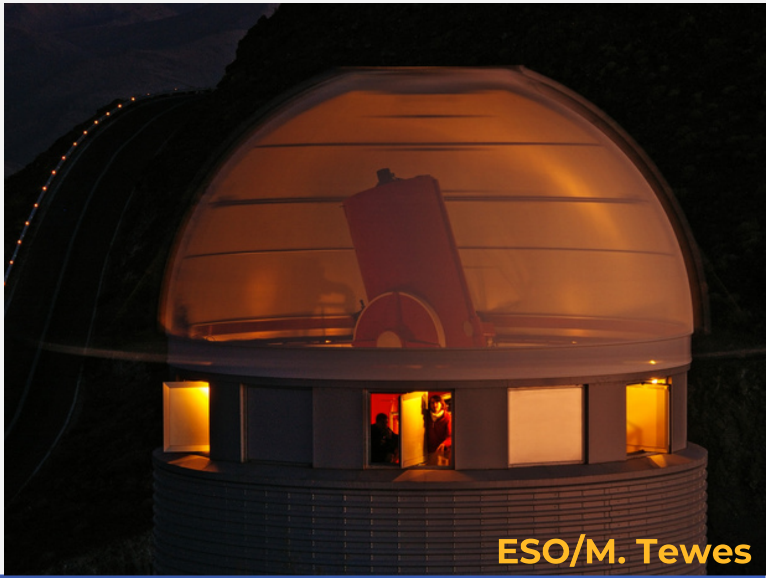
**CTOIs: Community TOIs**

Various independent pipelines, for exemple Planet Hunter candidates
Some are specific to single transits.

# TESS monotransits require vetting and follow up observations

Pipelines to extract light curves from full frame images and algorithm search for single transit event. Vetting of candidates to exclude eclipsing binaries, asteroid crossings, systematic artifacts.

Spectroscopic observations
**CORALIE** is used to exclude spectroscopic binaries and obtain the planetary mass of the companion.
**EULER Camera** to target specific transit events.

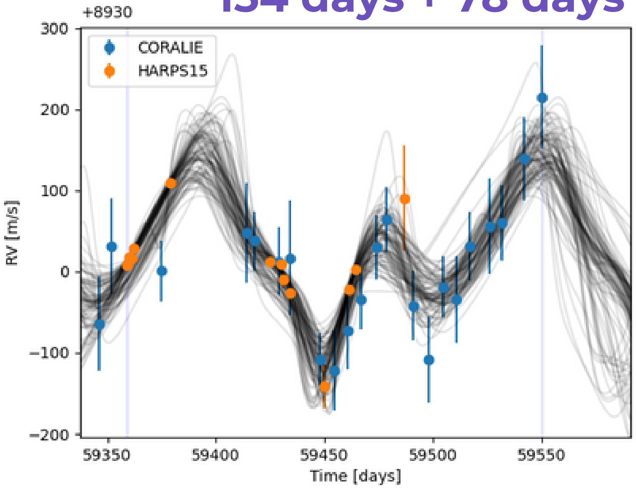



Photometric observations
**NGTS** has the capacity to detect transit event of a depth of 0.1%, thus TESS monotransits are targeted in order to find subsequent transits

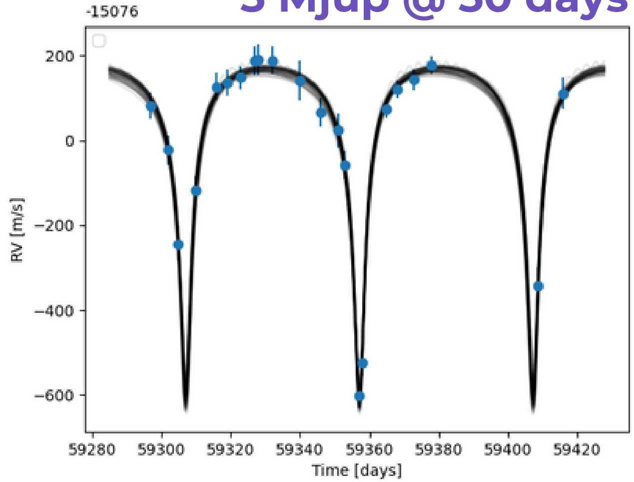
**CHEOPS** duo and deep duo program

# A subset of the detected planets

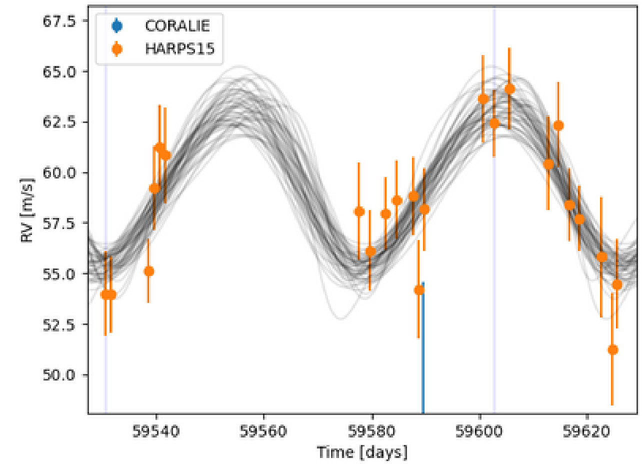
154 days + 78 days

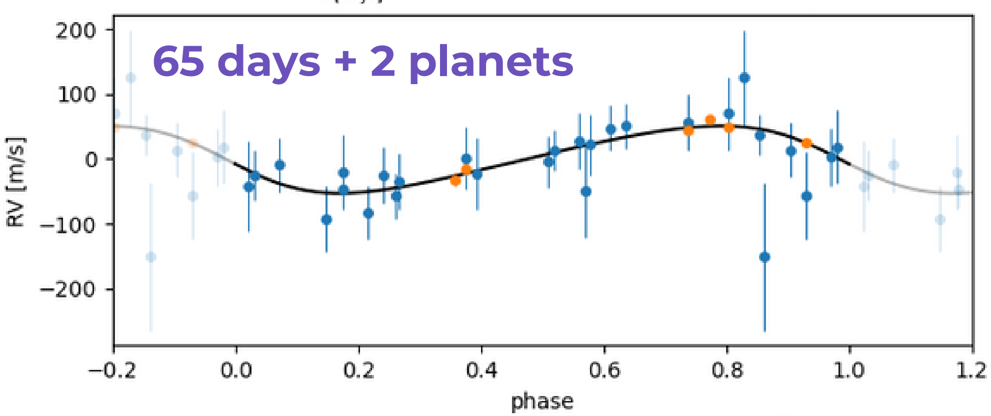


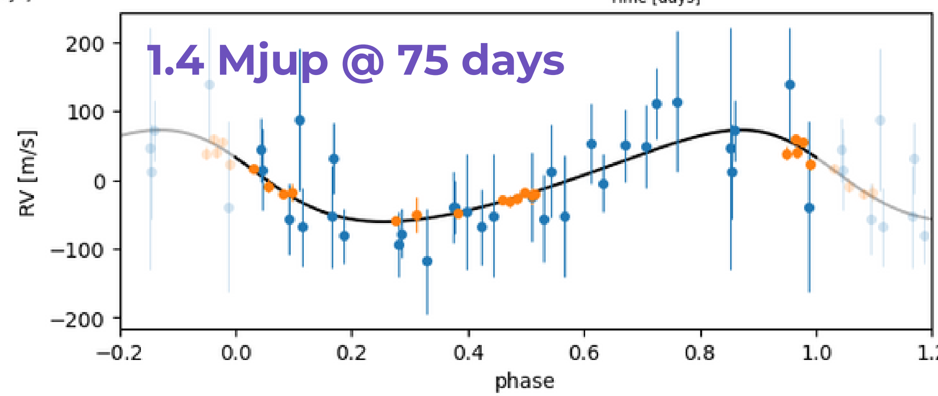

5 Mjup @ 50 days

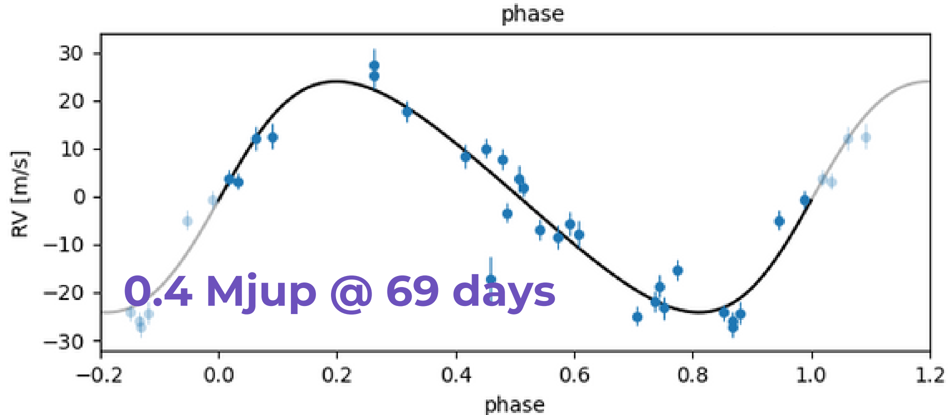


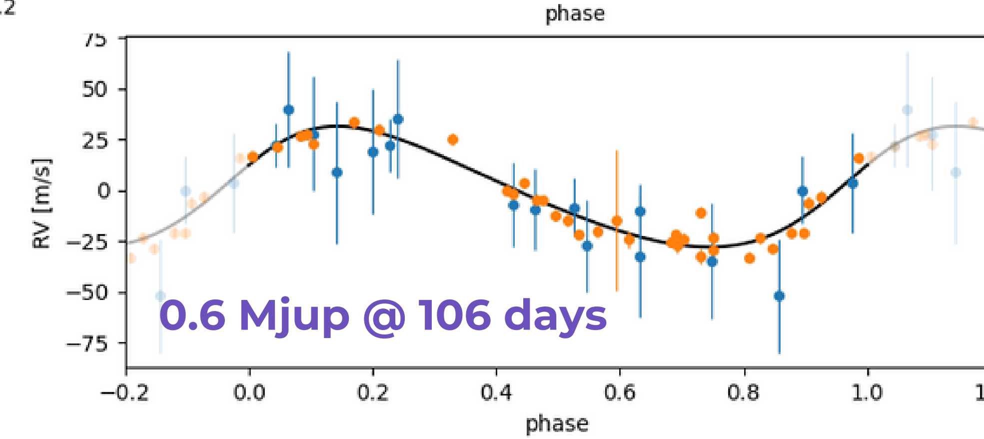

20 Me @ 47 days



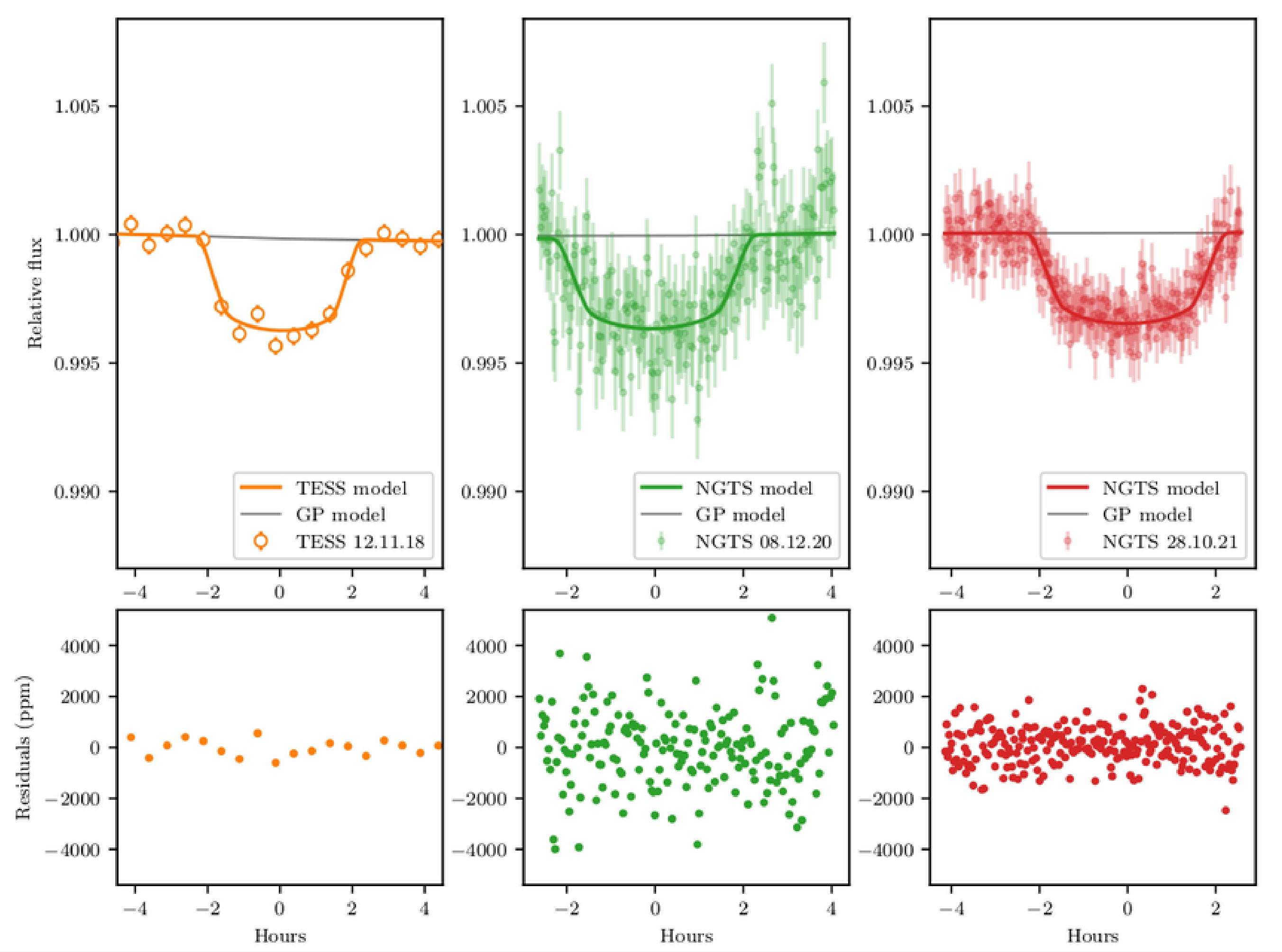



# NGTS-20 b: transiting warm Jupiter on an eccentric orbit

Single transit in TESS Sector 4, no second transit observed by TESS
**Blind survey** mode with NGTS: observe every possible night
Second transit detected with NGTS

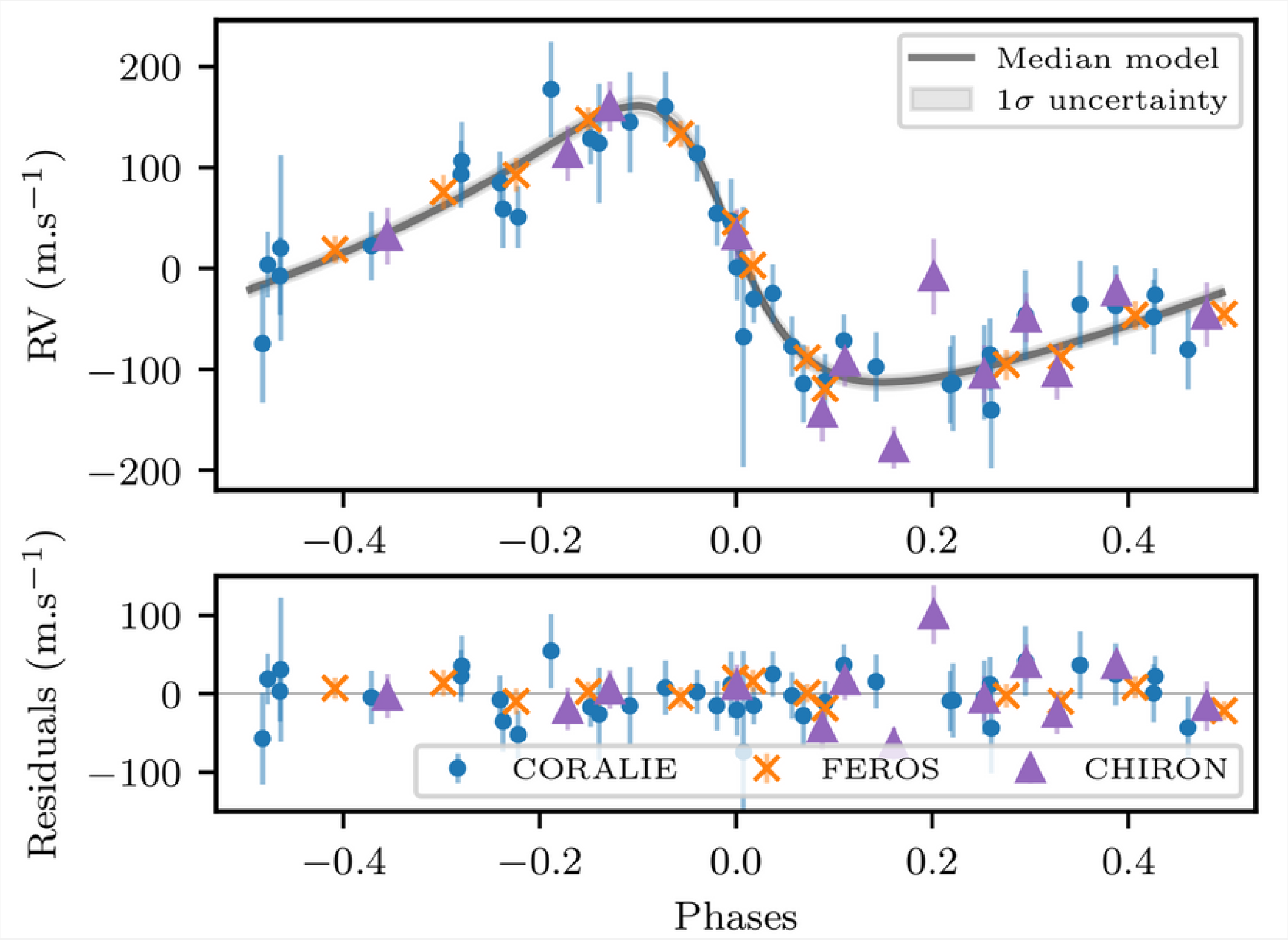



**Alias chasing** mode: observation when a period alias is observable

NGTS obtains a third transit which confirms the period

# NGTS-20 b: transiting warm Jupiter on an eccentric orbit

CORALIE radial velocity detects a 54 day periodic signal
2.98 Mj planet with a radius of 1.07 Rj on an eccentric 0.432 (+-0.024) orbit with an orbital period of 54.19 days




Ulmer-Moll et al. (under review)

# Vet and characterize with CORALIE

After one year of observations, we can sumarize the follow up of TESS planetary candidates in the different categories.

CORALIE time ~ 1.0 night / week

**50 candidates spectroscopically vetted**

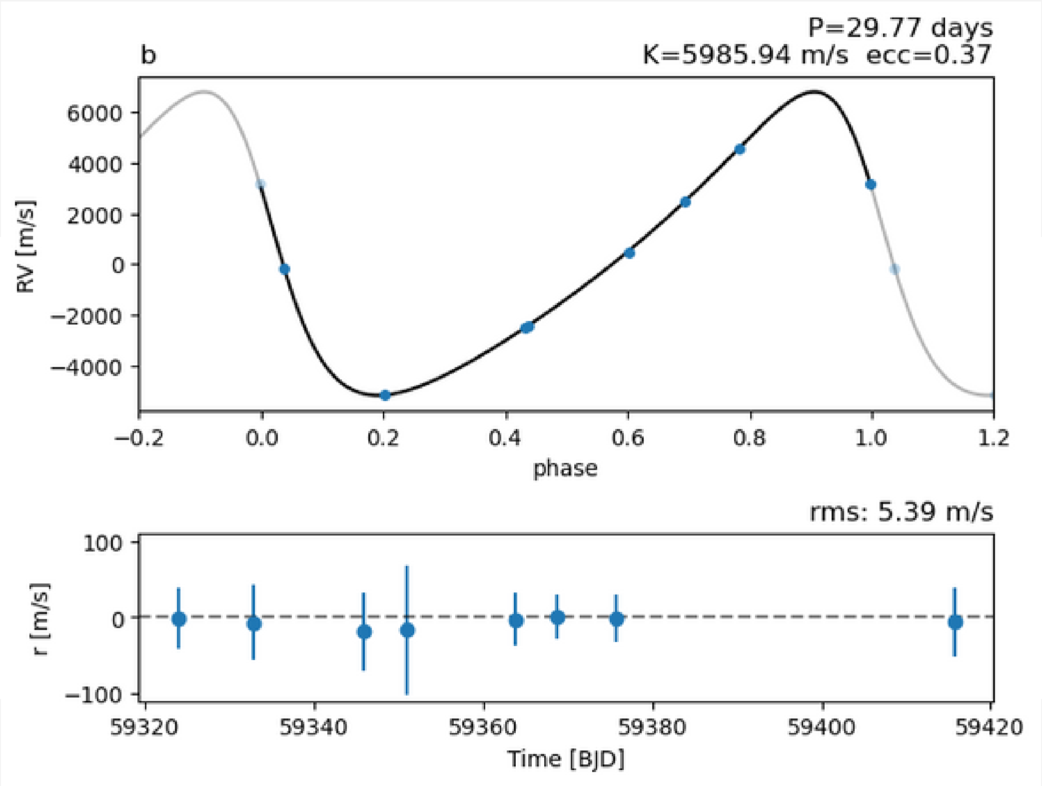
**Detection: 9 targets (18 %)**
Planets: 7 targets
Brown dwarfs: 2 targets

**Promising: 13 targets (26 %)**
Planetary candidates: 12 targets
RV long term drift: 1 target

**Stopped: 3 targets (6 %)**
RV precision > 100 m/s
fast rotating host star

**Unclear: 5 targets (10 % )**

**False positive: 20 targets (40 %)**
7 Low mass eclipsing binaries
Eclipsing binaries: 13 targets




**Upper limit on false positive rate: 50 %**

**Gill et al. 2022**
**TIC320687387 B: EBLM close to the hydrogen burning limit**

# HARPS time to detect lighter and longer period planets

**25 candidates observed with HARPS**

**Detection: 10 targets (40 %)**
TIC 124029677 / TOI-5153: 3Mjup @ 20days
TIC 257527578 / NGTS-20: 3Mjup @ 54 days
TIC 466206508 : 1.4 Mjup @ 75 days
TOI-2447: 0.4 Mjup @ 69 days
...

**Promising: 9 targets (36 %)**
TIC 139: 2.6Mjup @ 154 day + 78 day signal
TIC 237: < 0.15 Mjup @ 25 days
...

P107: 7.2 nights (Bouchy)
P108: 7.9 nights (Ulmer-Moll)

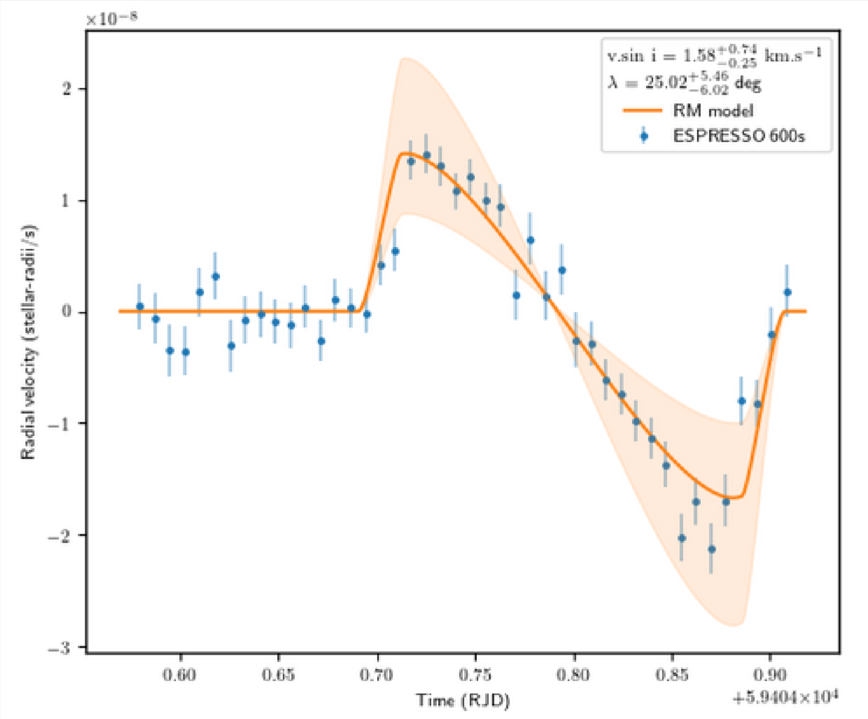
**Unclear: 5 targets (20 % )**

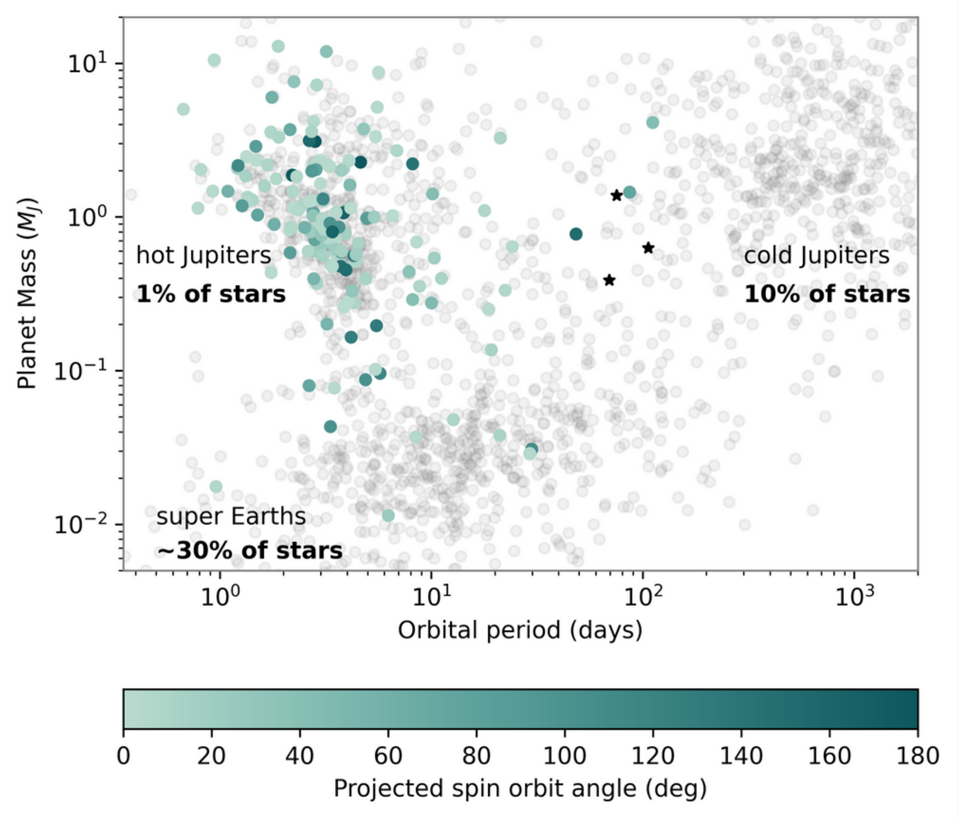
**False positive: 1 target (4 %)**
AO imaging revealed a nearby companion

**Upper limit on false positive rate: 24 %**
**but totaling only 13 % of the observing time**

# Shedding light on the dynamical architecture of warm Jupiters

**TIC 61024636: test case**
Massive warm Jupiter-sized planet on a highly eccentric orbit.
Projected spin-orbit angle is equal to 25 (+- 6) degrees




**Submitted ESPRESSO proposal** to measure the spin-orbit angle of three transiting warm Jupiters discovered with the mono-transit working group.
Monitoring program over 3 semesters.

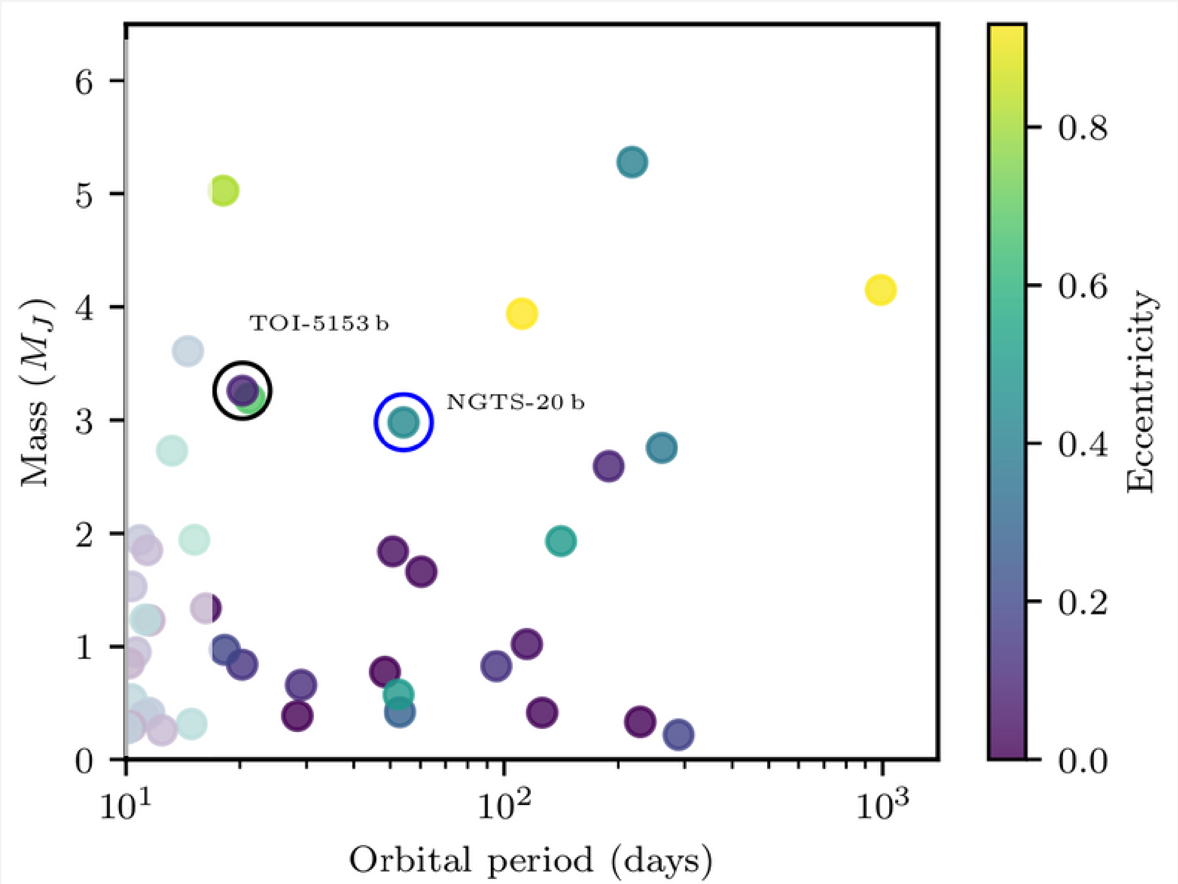
Periods: 69, 75, and 106 days
Eccentricity ranging from 0 to 0.4

# Conclusions

**In one year of observations:**

**10 new warm giants detected**
**50% increase of the transiting warm Jupiters population**

Parameter space:
Period > 20 days
Radius > 6 Re
V mag < 12.5




**Semester April to October 2022 (P109)**
HARPS follow up continues with 5 nights allocated (PI: Ulmer-Moll)
ESPRESSO observations of one multi-transiting planetary system (PI: Gill)

**Study the bulk and atmospheric composition of these newly detected warm Jupiters.** These objects will be key to understand how exoplanet atmospheres vary with equilibrium temperature, but also to look for rings and moons with further observations.

# Extra slides

# Heavy element mass correlates with planet's mass

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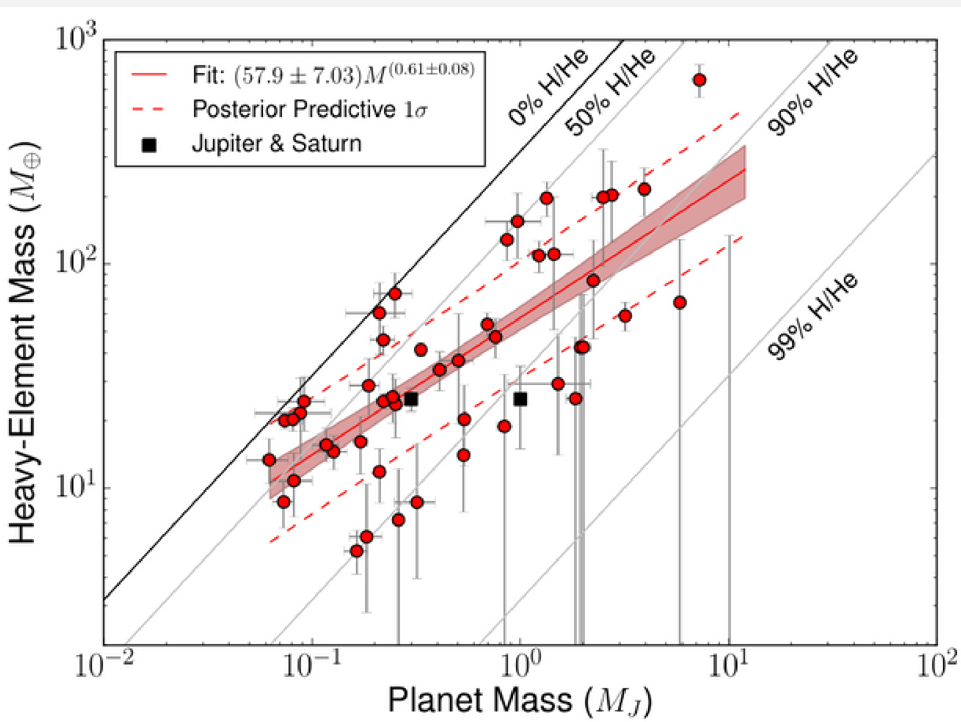
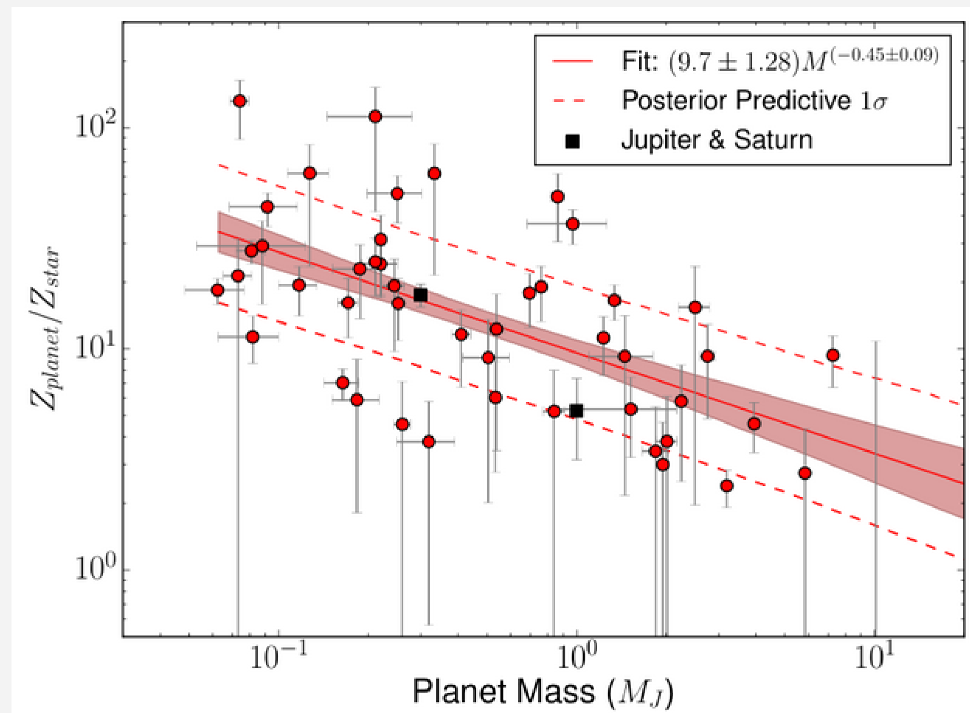
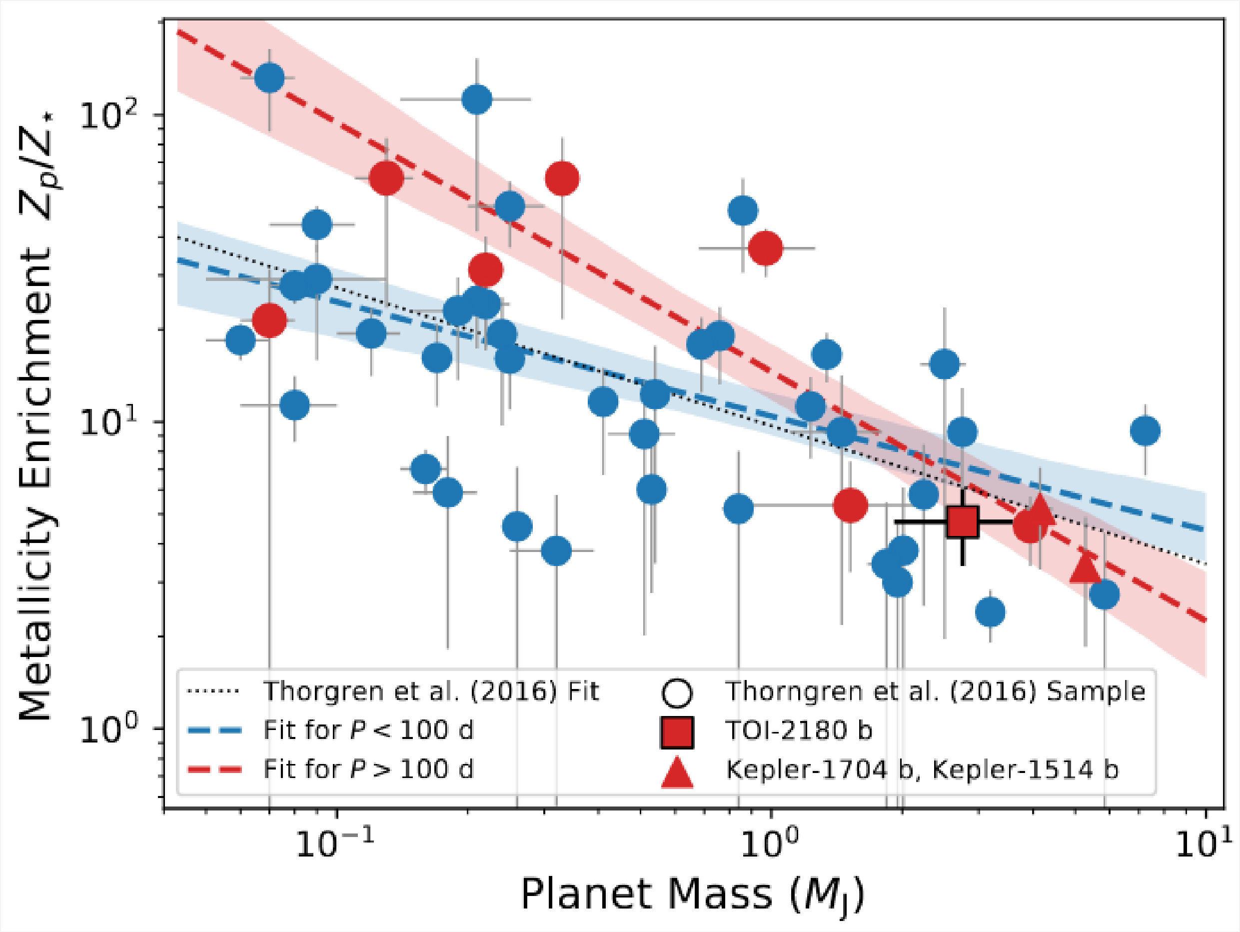



Thorngren et al. 2017

# Planet metal-enrichment dependent on orbital properties?

**Correlation between planet metal-enrichment and planetary mass still needs further investigation, in terms of**



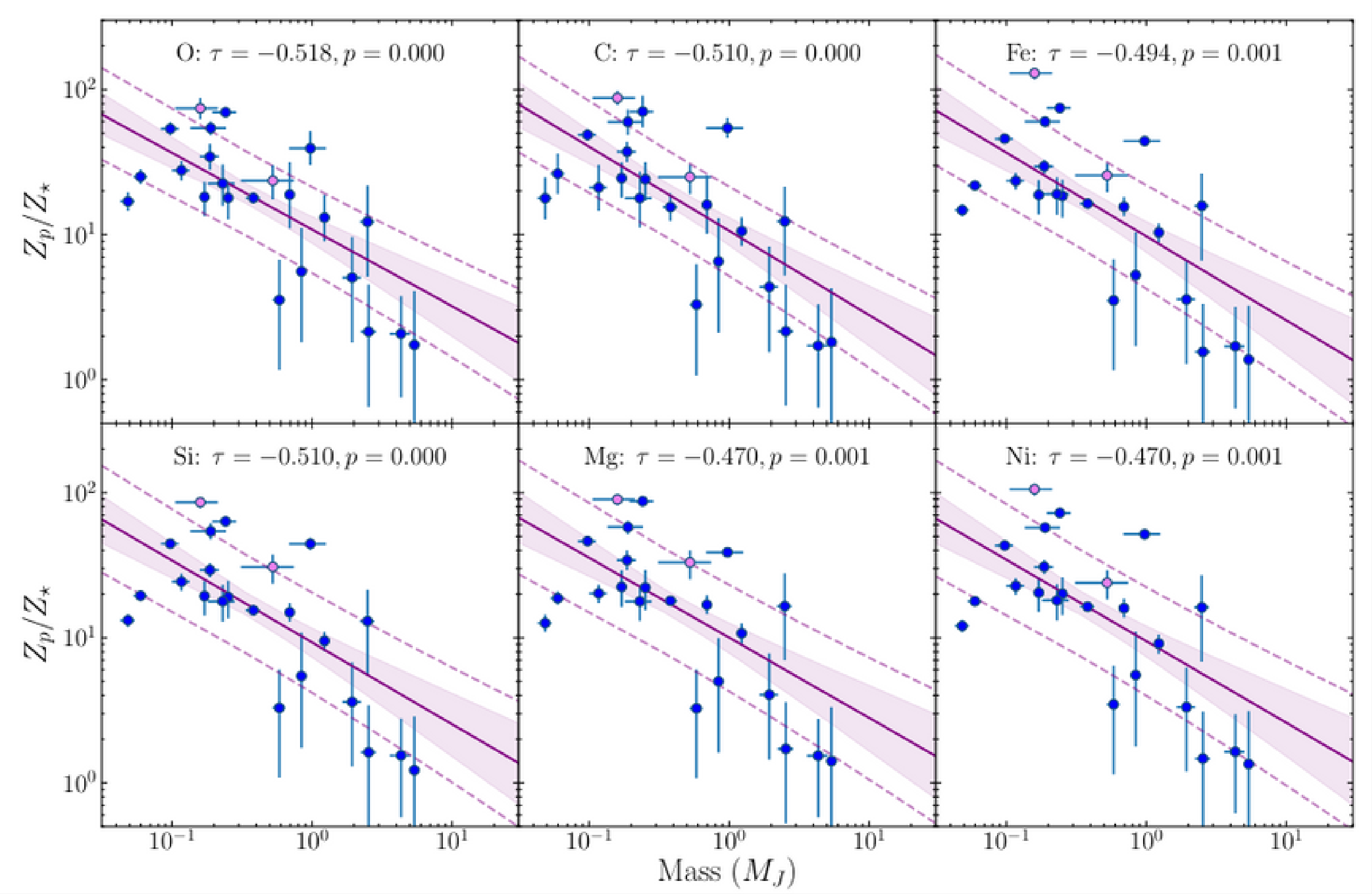

**Its dependence on orbital properties of the planetary systems (Dalba et al. 2022)**

Do giant planets accrete differently their heavy elements based on orbital period?

# Planet metal-enrichment by elements

**its dependence on detailed host star abundances (Teske et al. 2019)**

the mass of a planet vs planet metal-enrichment relative to the parent star using each element considered as a proxy for total the metallicity

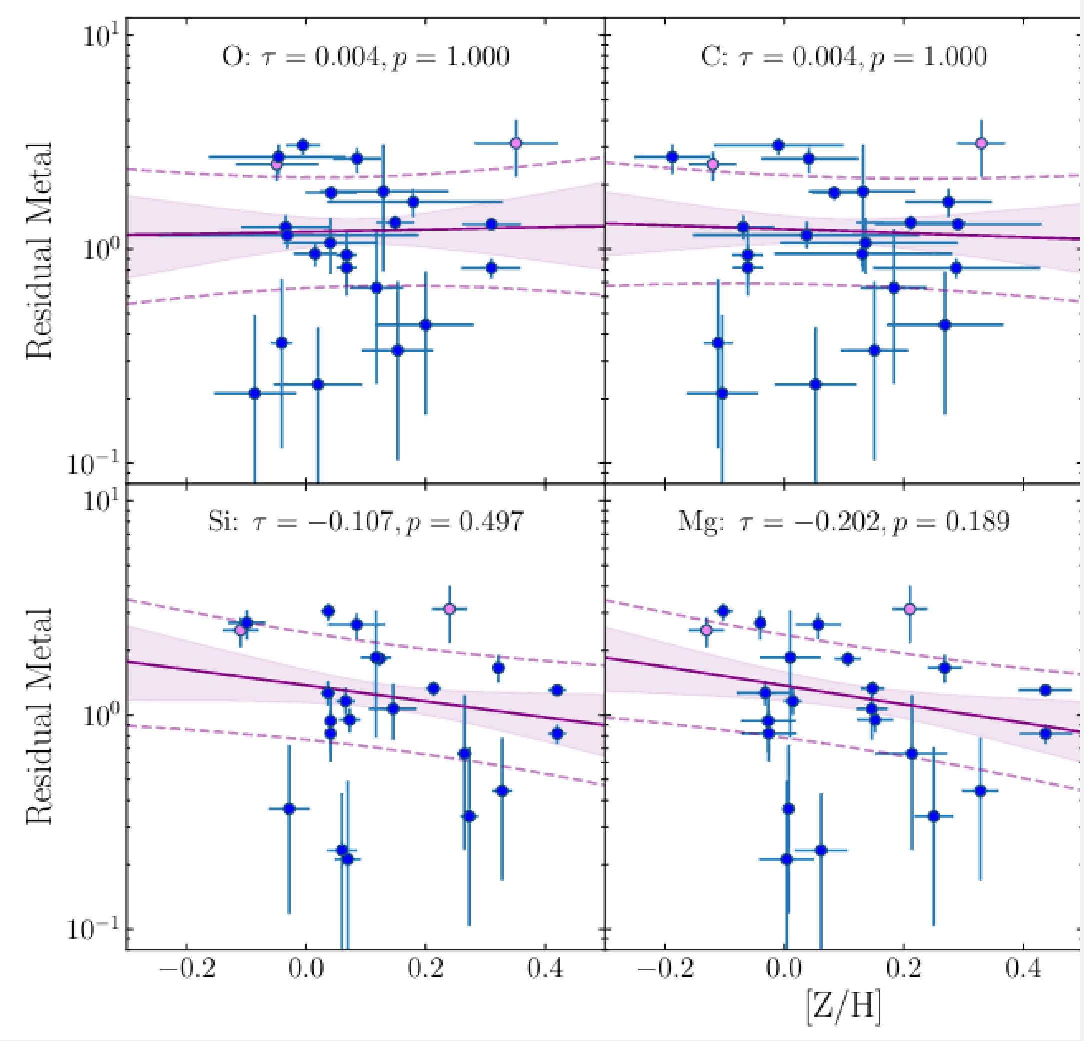



Same strong negative relationship observed in Thorngren+2016,

considering individual element

# Planet metal-enrichment independent of stellar metallicity?

**How the scatter in residual metal mass relates to the stellar metal abundances?**




**Planetary residual metallicity:** the relative amount of metal in a planet beyond (or below) what would be expected for its mass

absence of a clear correlation between stellar and planetary (residual) metallicity