Exoplanets

Fall/Winter 2023/2024
Lecture 4
20.10.2023

Outline

- Space mission detecting exoplanets
- Planetary candidates turning into planets
- Data archives
- Tools
- Virtual tour of Ondrejov observatory

Exoplanet detection process

- Detection by a space mission (or by RVs)
- Spectroscopic characterization of the system
- High resolution imaging
- Precise Radial Velocities (RVs)
- Confirmed planet

Need for ground based follow-up
Case of the CoRoT space mission

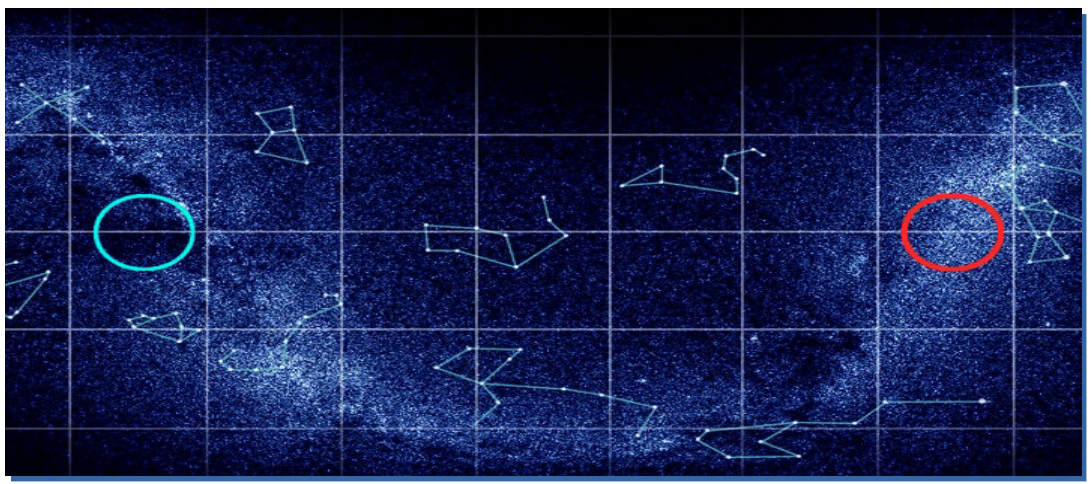
- Ground based support of CoRoT
- Contribution to the follow-up observations
- Observations of the CoRoT target fields
  about 1 year ahead of CoRoT
- Contribution to additional science programme

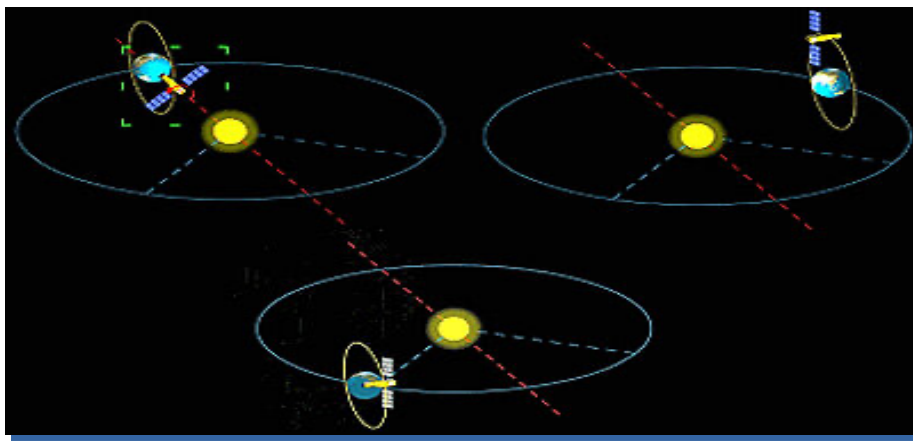
CoRoT space mission

- Small aperture -27cm
- Exoplanets, Asteroseismology
- Launched 2006
- Mission end 2014
- More than 30 confirmed and fully characterized exoplanets
- Several hundreds of candidates

Corot Observing Strategy

- Long run fields up-to 150 days
- Several shorter fields

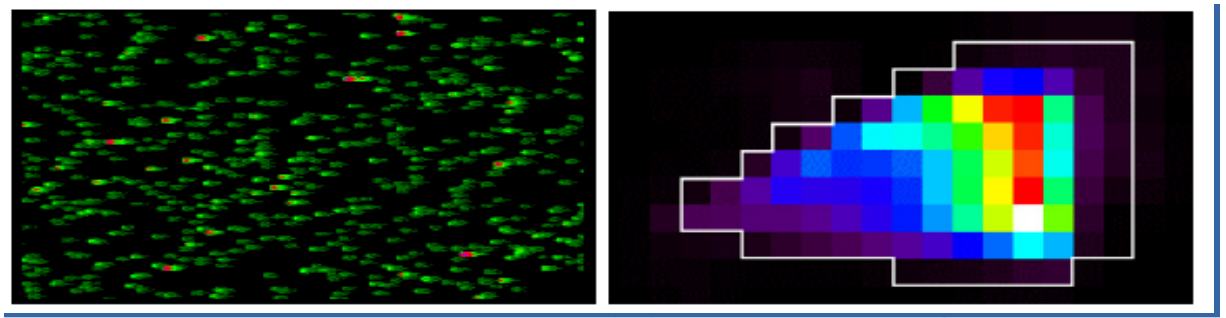




https://www.esa.int/Science_Exploration/Space_Science/COROT/COROT_mission_strategy

Need for ground based follow-up

Up to 12000 masks for objects



Angular resolution of CoRoT: 2.3 “/pixel

↓

Broadening of stellar PSF due to prisms

↓

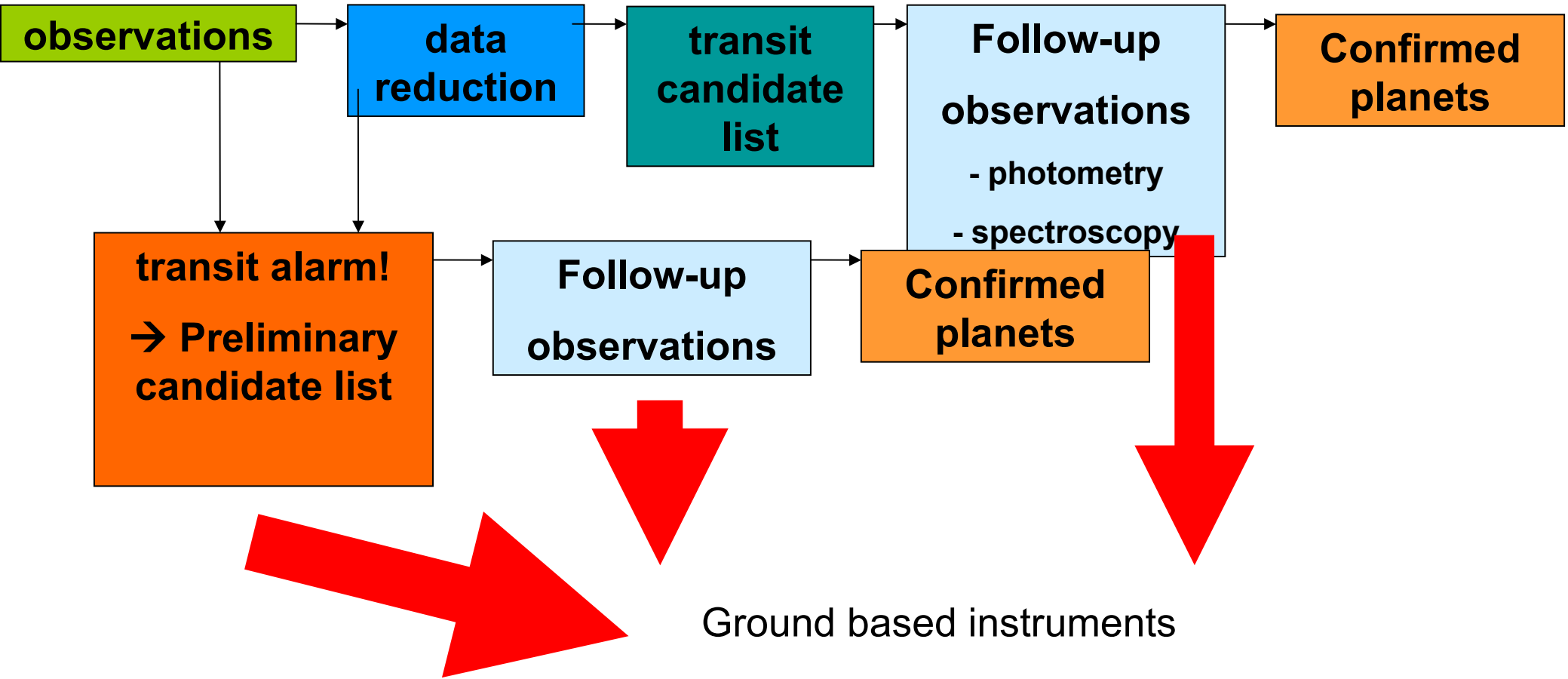
FLASE POSITIVE ALARMS

↓

GROUND BASED FOLOW-UP

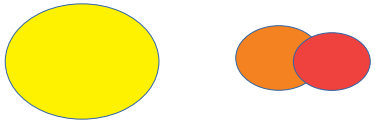
Follow-up for CoRoT - BEST II

Confirmtation of candidates (Case of CoRoT)

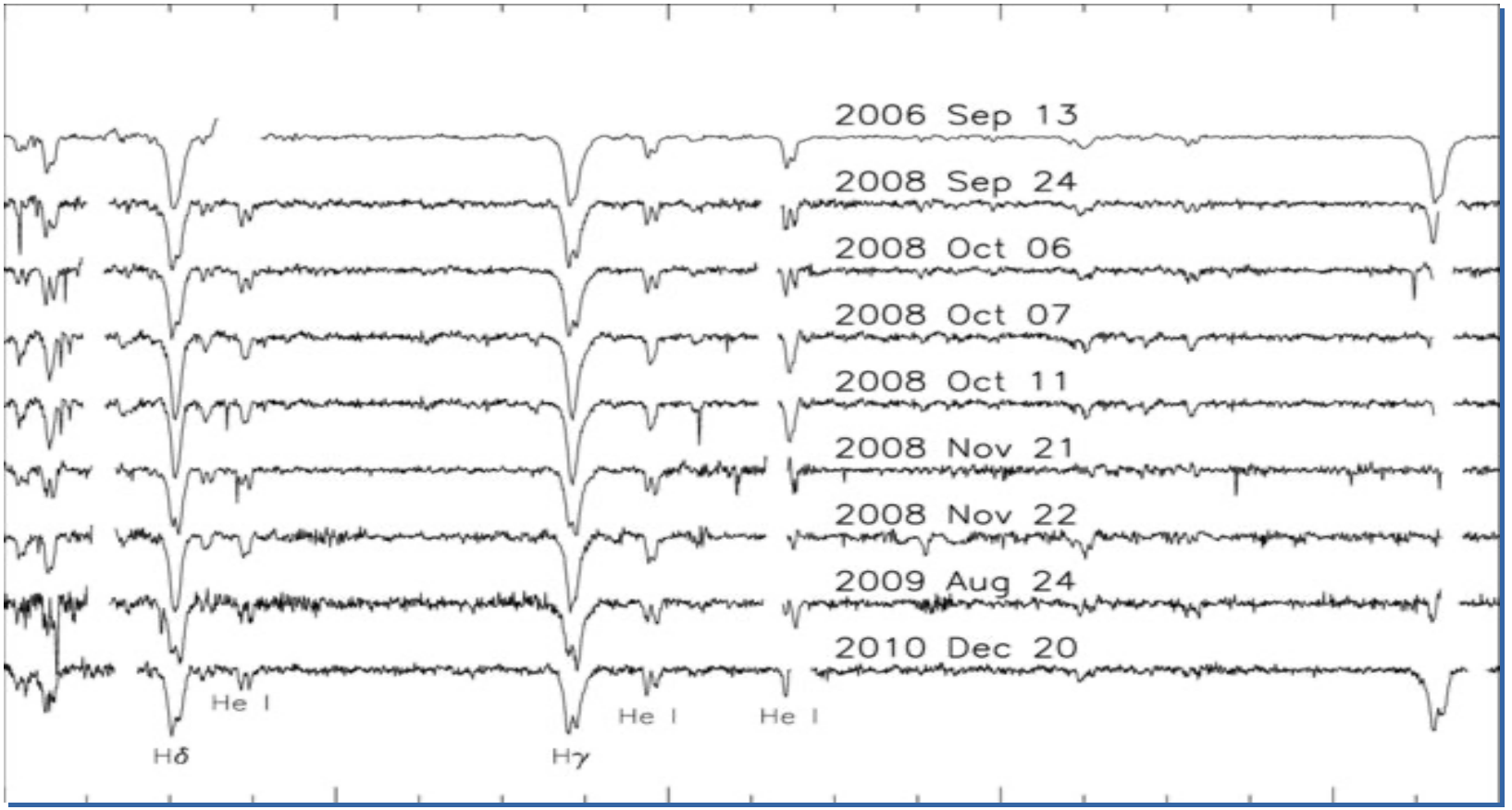


False positives

- Eclipsing binaries
- Triple systems
- Background eclipsing binaries
- Background eclipsing BD/WD
- Star is not at main sequence
- False positives estimates Santerne et al. 2012 – around 40% for close-in giant planets Kepler candidates (from observing)
- Santerne et al. 2013 evaluates global false positive probability to about 11% for Kepler candidates



Example of a binary from spectra



Joel B. Lamb et al., 2015, The Astrophysical Journal 817(2)

Characterization of exoplanets combination of methods

- Transits

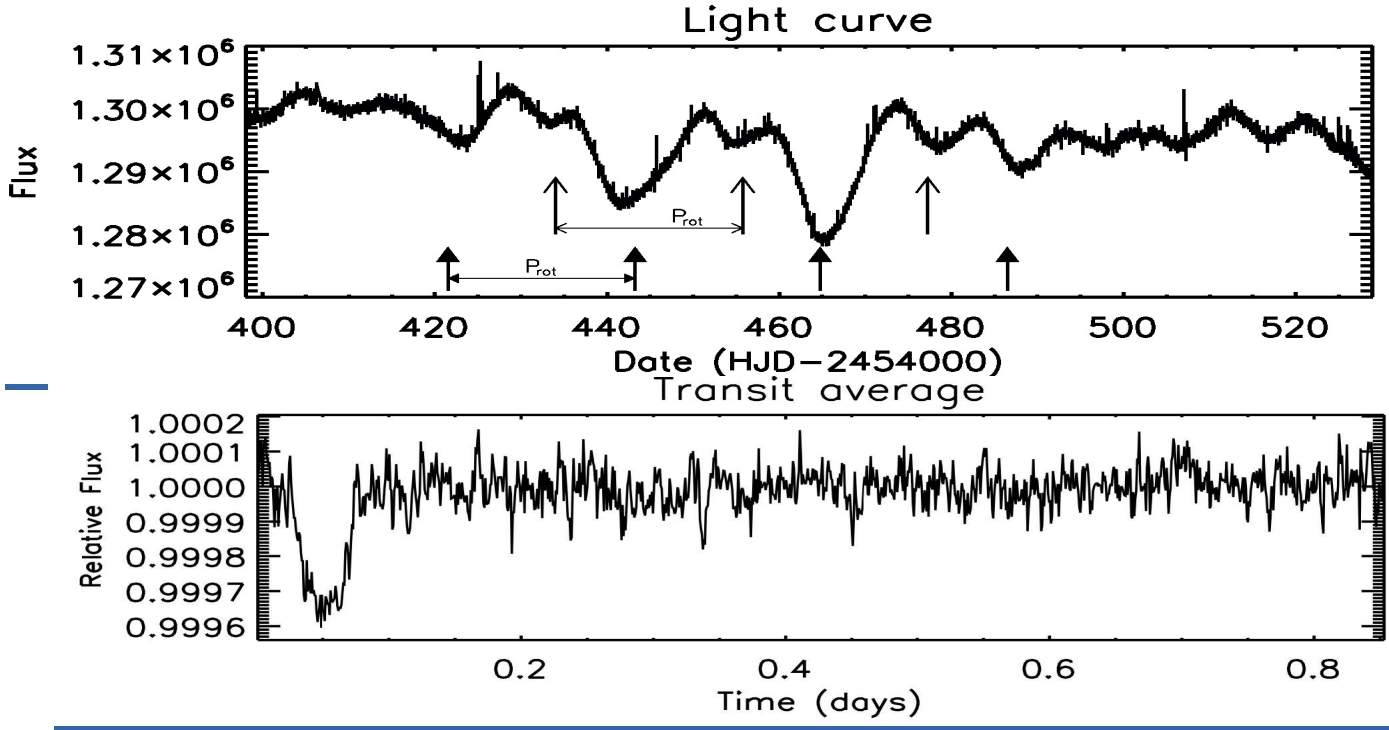
  Radius of the planet (if stellar params known), inclination

- Spectroscopy

  Mass limit, stellar parameters

- STELLAR PARAMETERS NEEDED (spectroscopy)

The case of CoRoT-7b



From Leger et al. 2007, A&A

CoRoT-7b

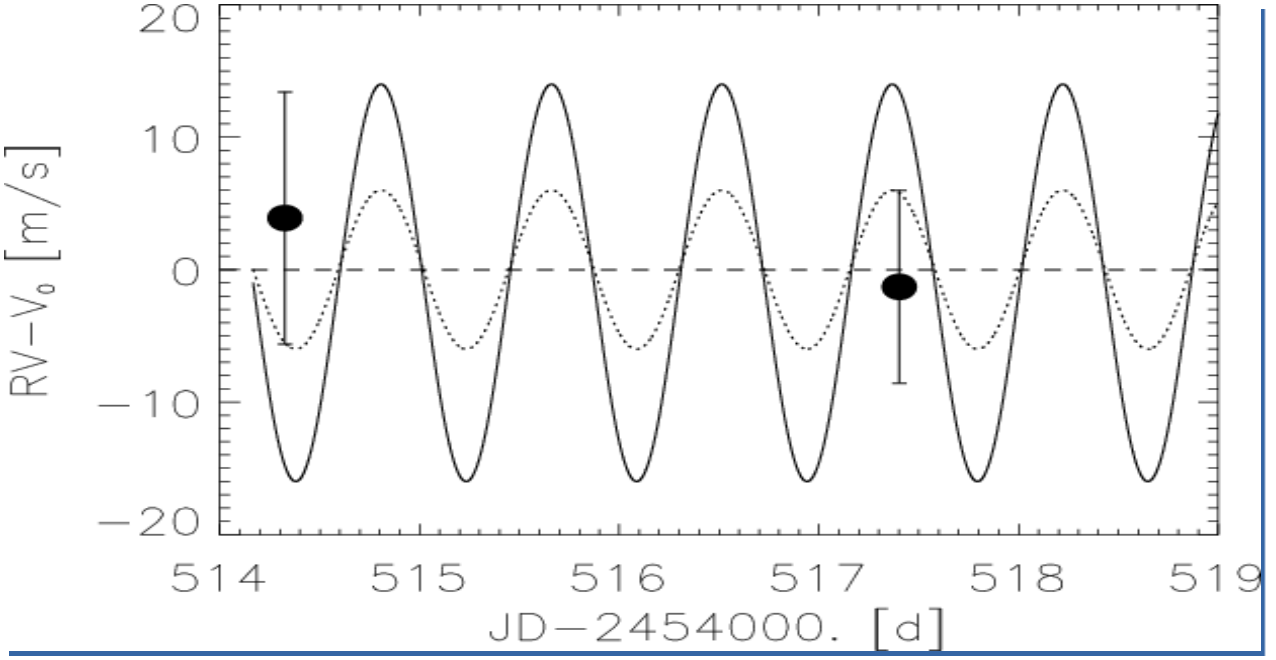
Orbital Period 0.85 days

Mass $<9M_{Earth}$

Radius $1.51R_{earth}$

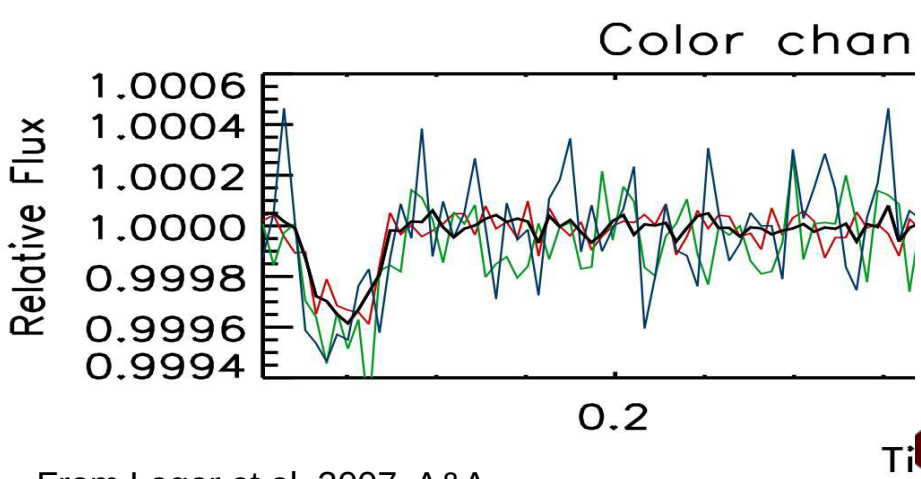
CoRoT-7b

- SOPHIE at OHP
- Excluded large companion
- Case for small telescope

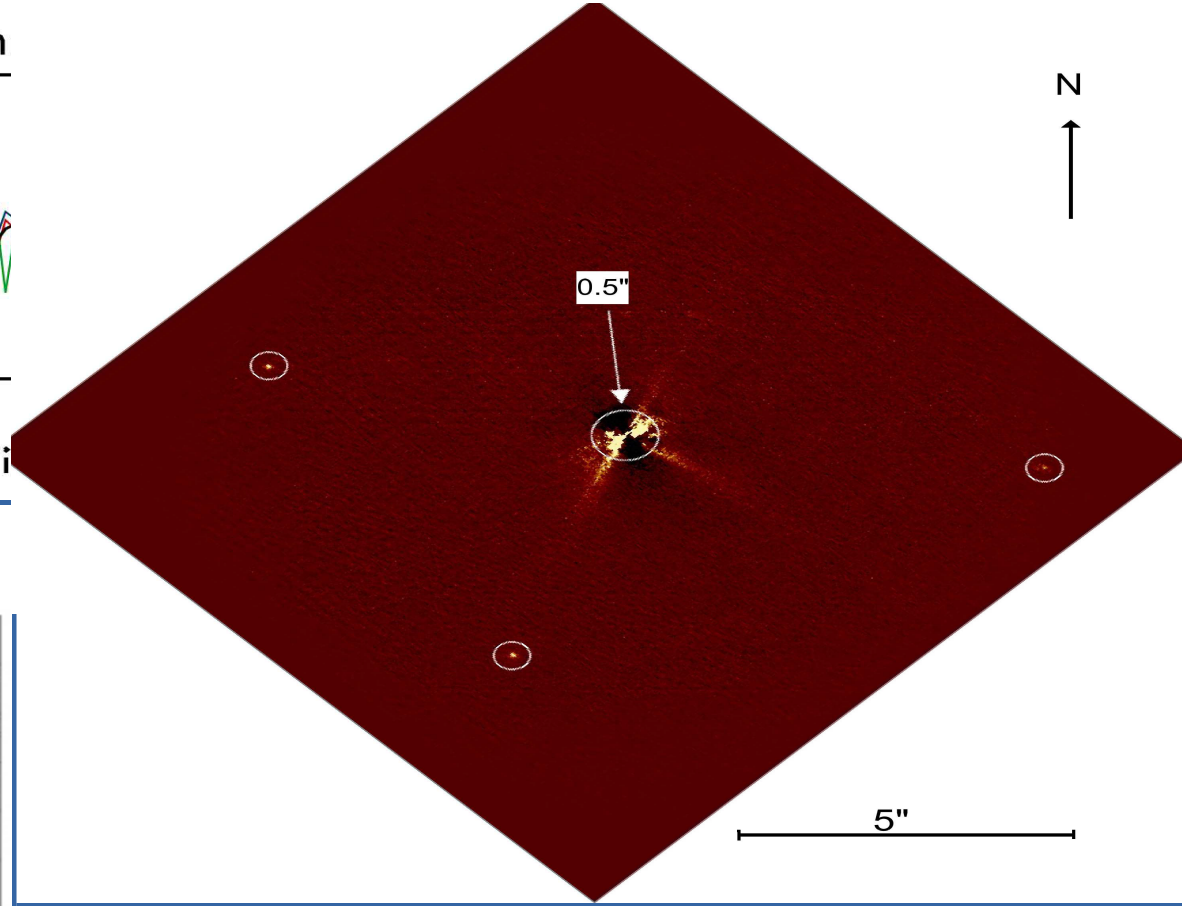


From Leger et al. 2007, A&A

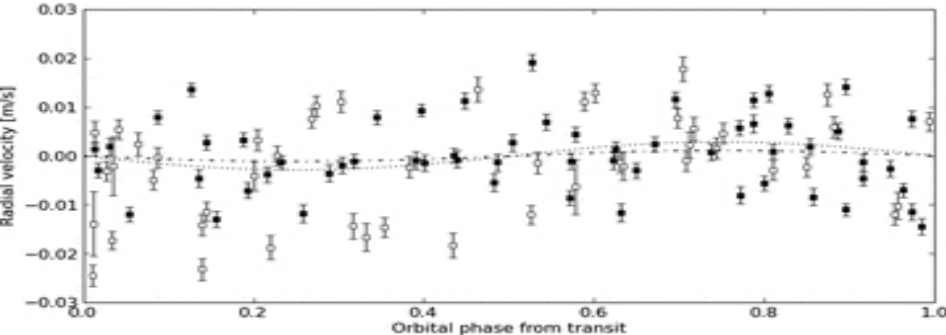
CoRoT-7b



From Leger et al. 2007, A&A

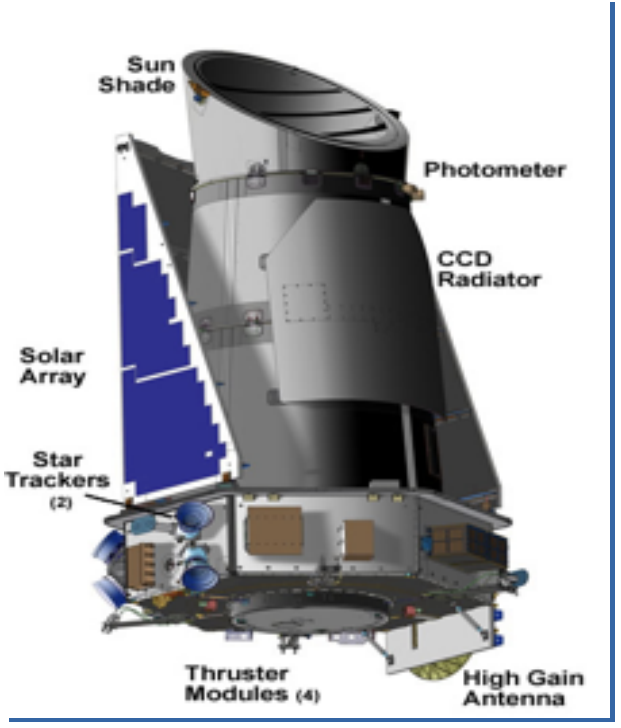


Bottom from F. Pont 2011, MNRAS

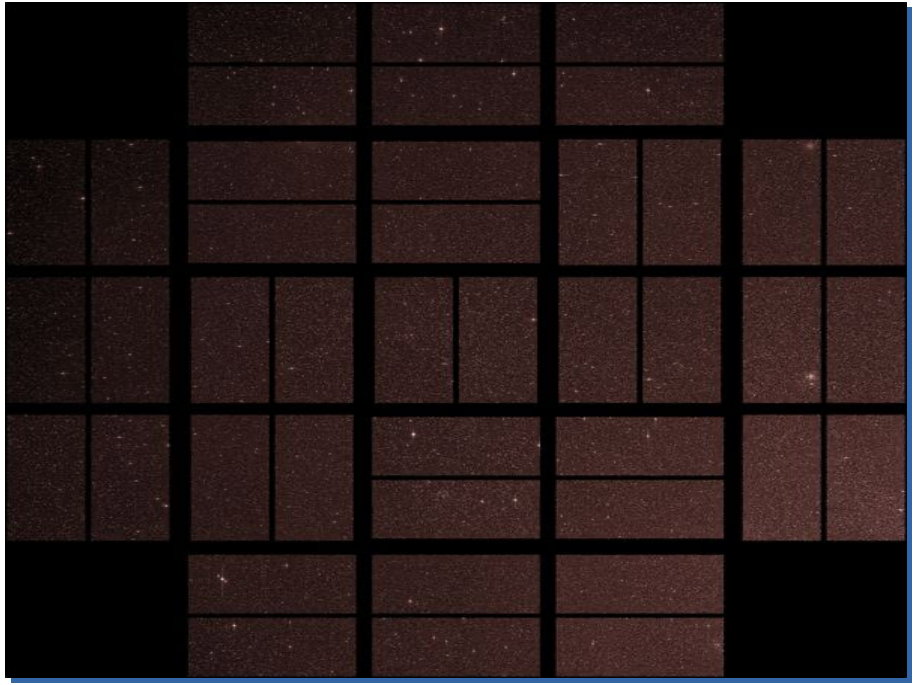


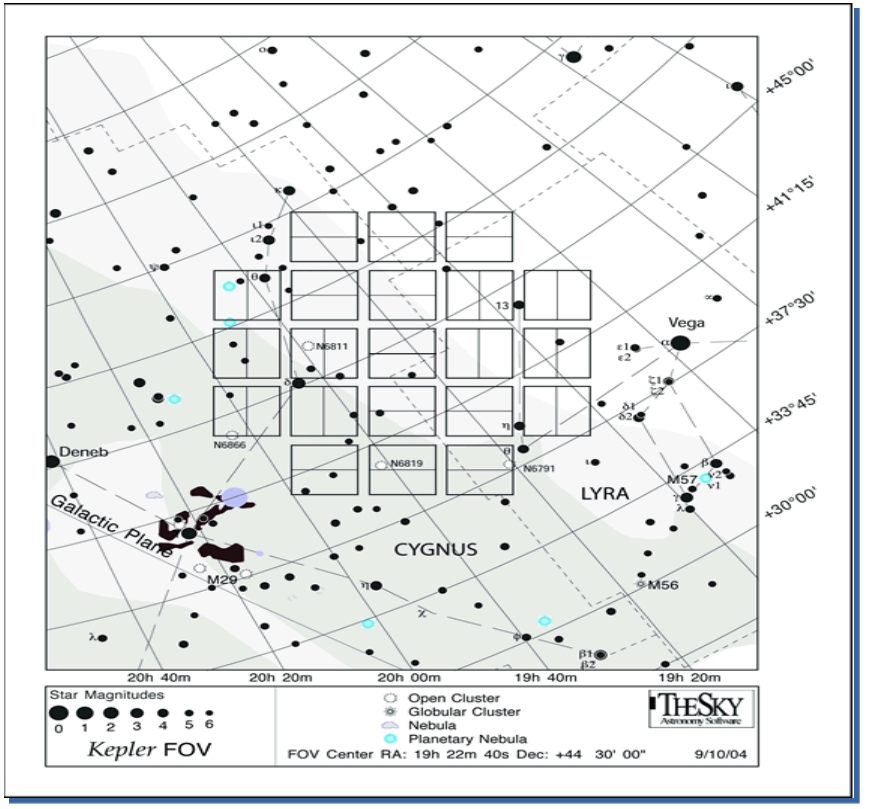
The era of Kepler

- Detections of exoplanets
- Launched 2009
- 1.4-m primary mirror
- Monitored 100k stars in Cygnus
- Around 2000 planets
- K2 continuation with different observing strategy
- Many stars were faint 13+ mag!



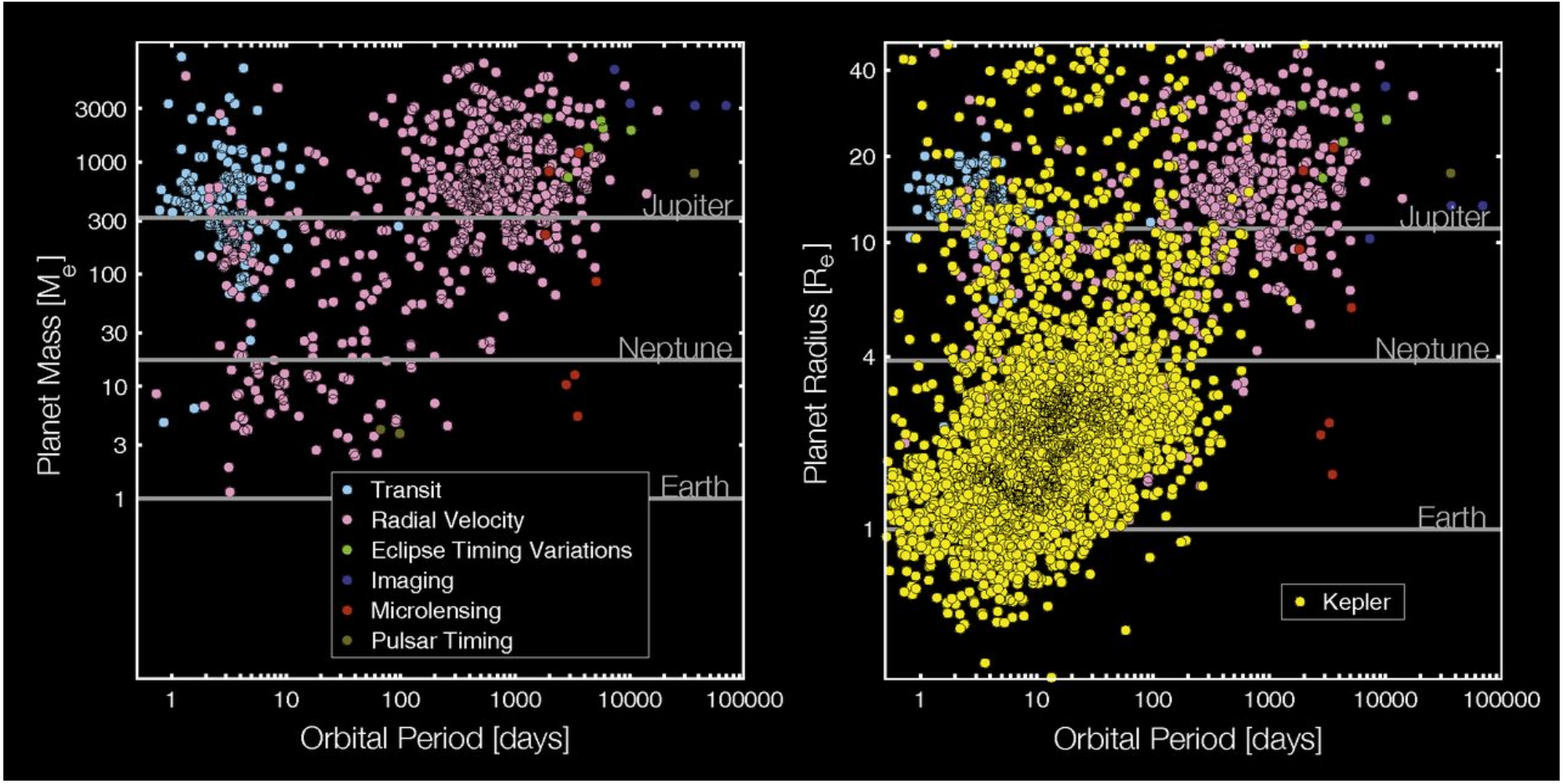
Kepler observing strategies





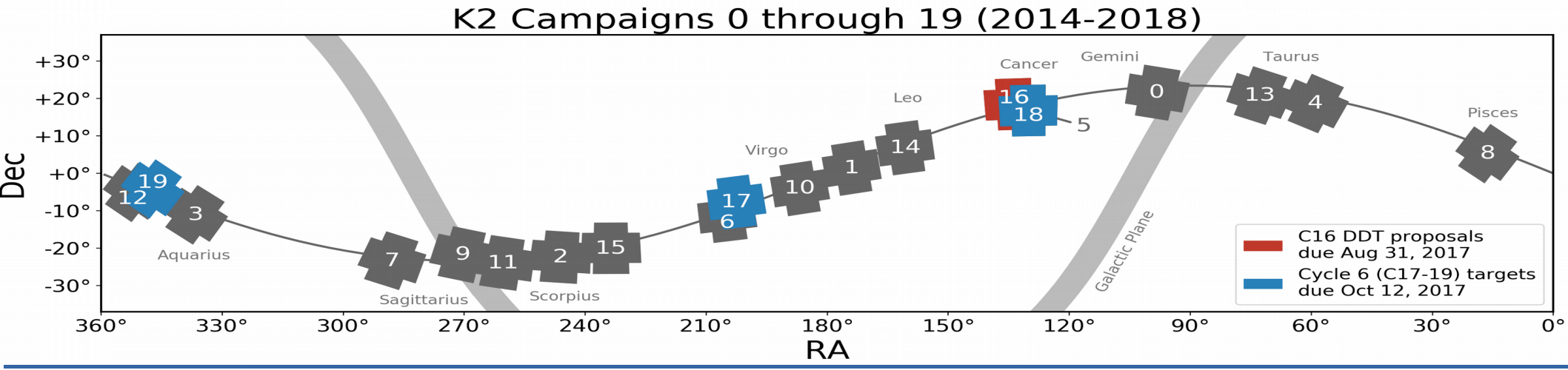
https://keplerscience.arc.nasa.gov/the-kepler-space-telescope.html

KEPLER planets



Credit: NASA

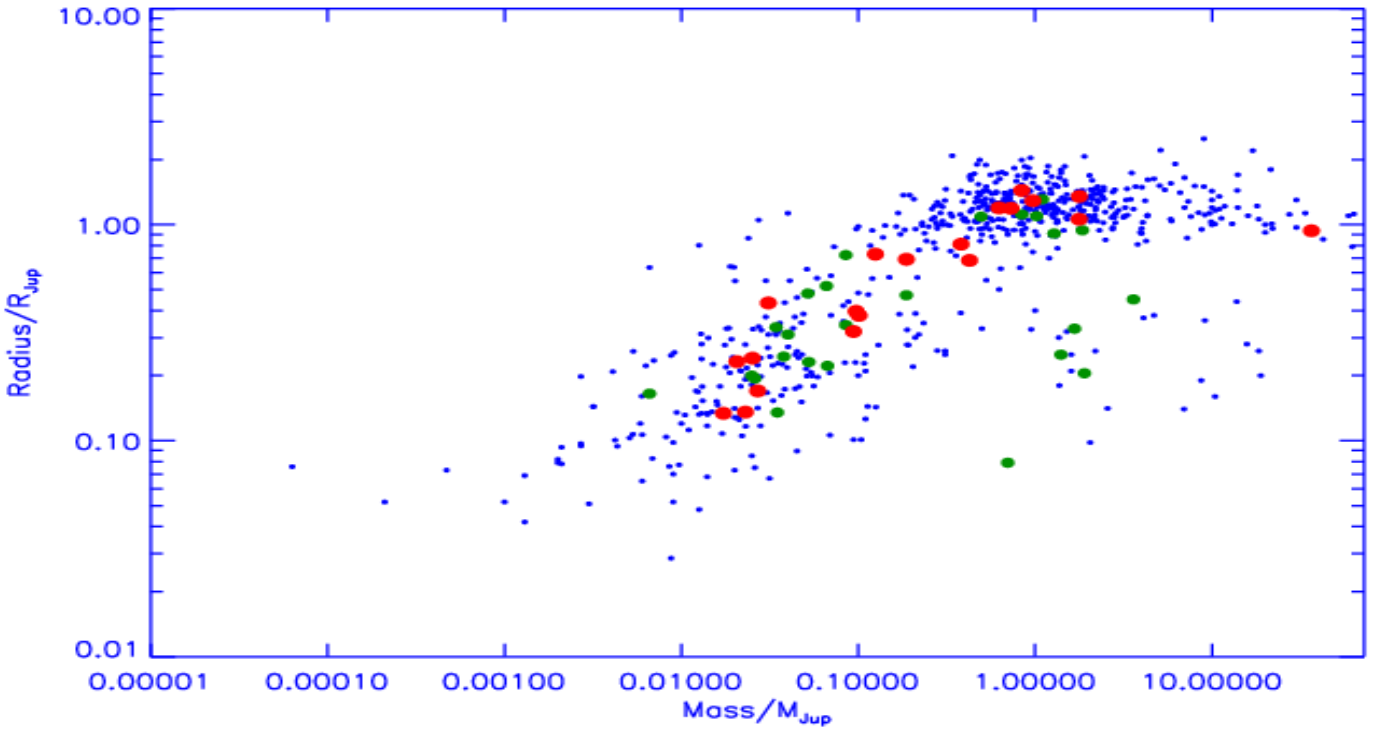
K2 continuation of Kepler



Credit: Nasa

- Nowadays 325 planets from K2 (Sep 2018)
- About 400 candidate (Sep 2018)
- Need for ground-based RV

Great but…..



From Csizmadia et al. Plato mission conference 2017

In Sep. 2017 – approx. 120 K2 planets

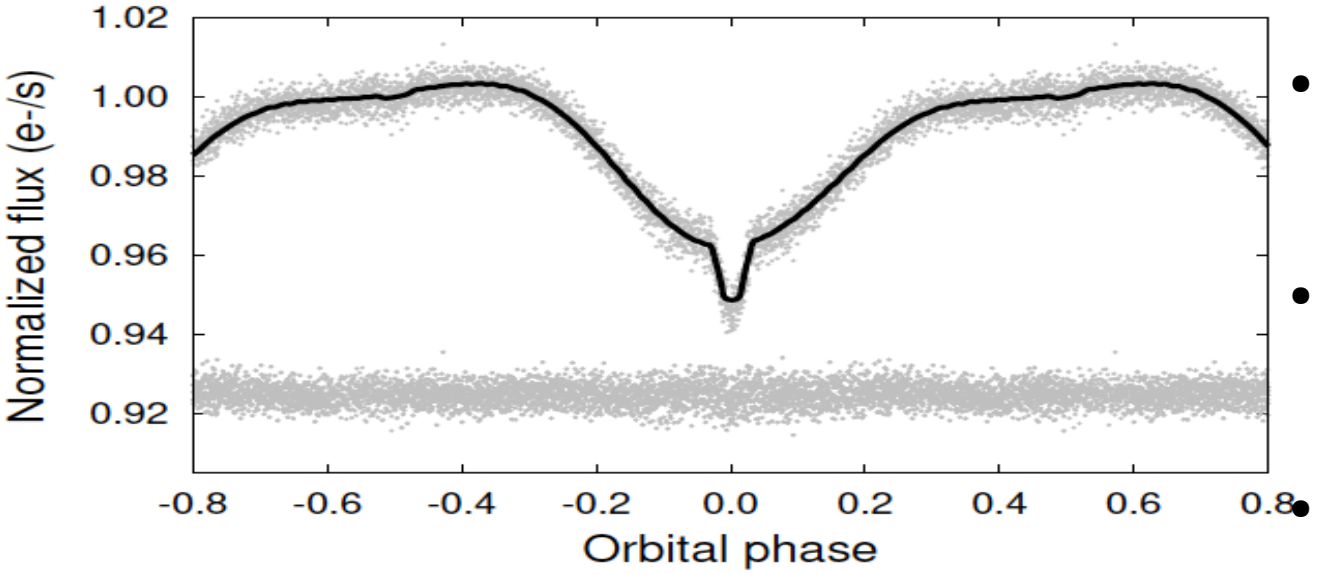
Blue – all planets around 4000
Green – K2 planets with masses (40)
Red – KESPRINT (21)

Numbers from Csizmadia et al. 2017

The case of HD99458

- Planetary candidate with
- Transit depth of a few %
- Suspected hot Jupiter
- Follow-up with OES at Ondrejov

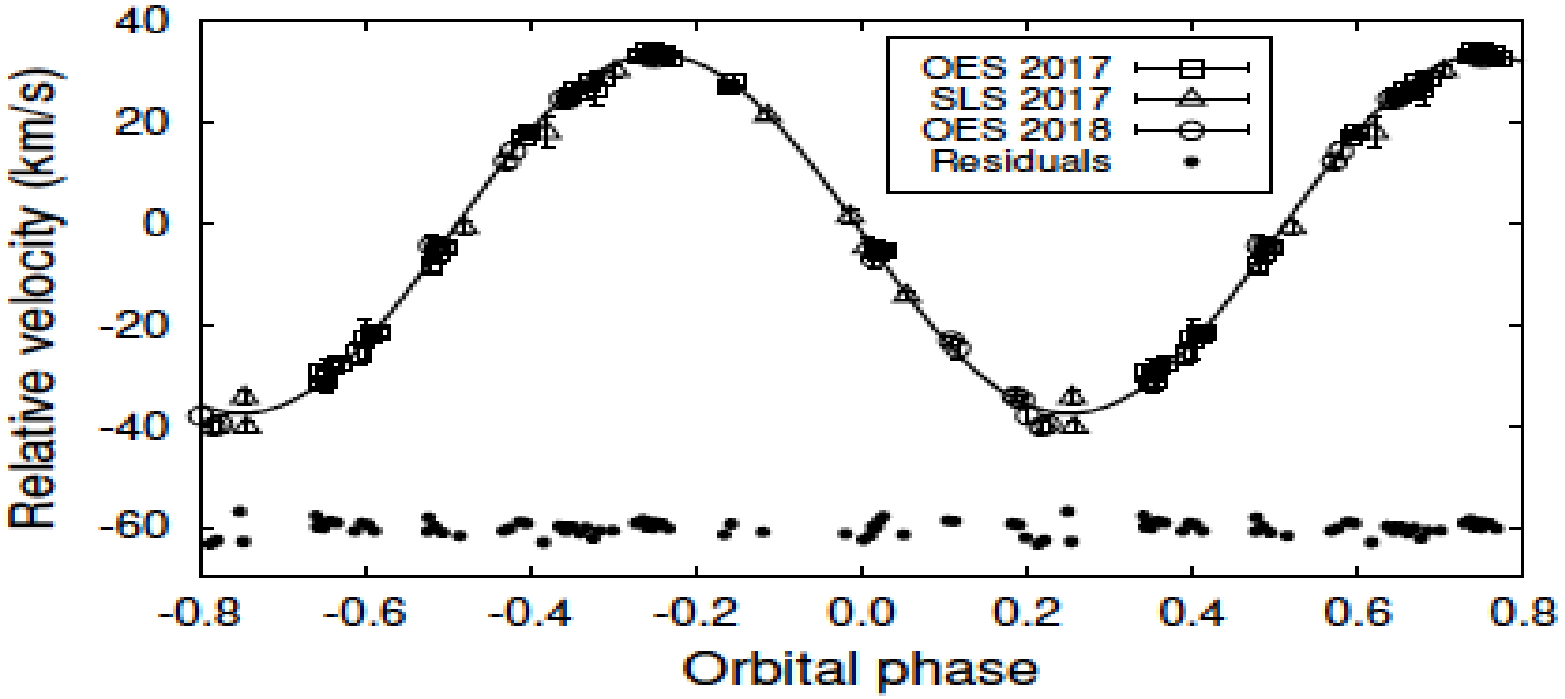
Intriguing system?



- Kepler candidate for Jupiter-sized planet
- Obsevring with OES and at Stará Lesná, SK
- Short period binary, magnetic star with DSCT pulsations and spots
- NO EXOPLANET

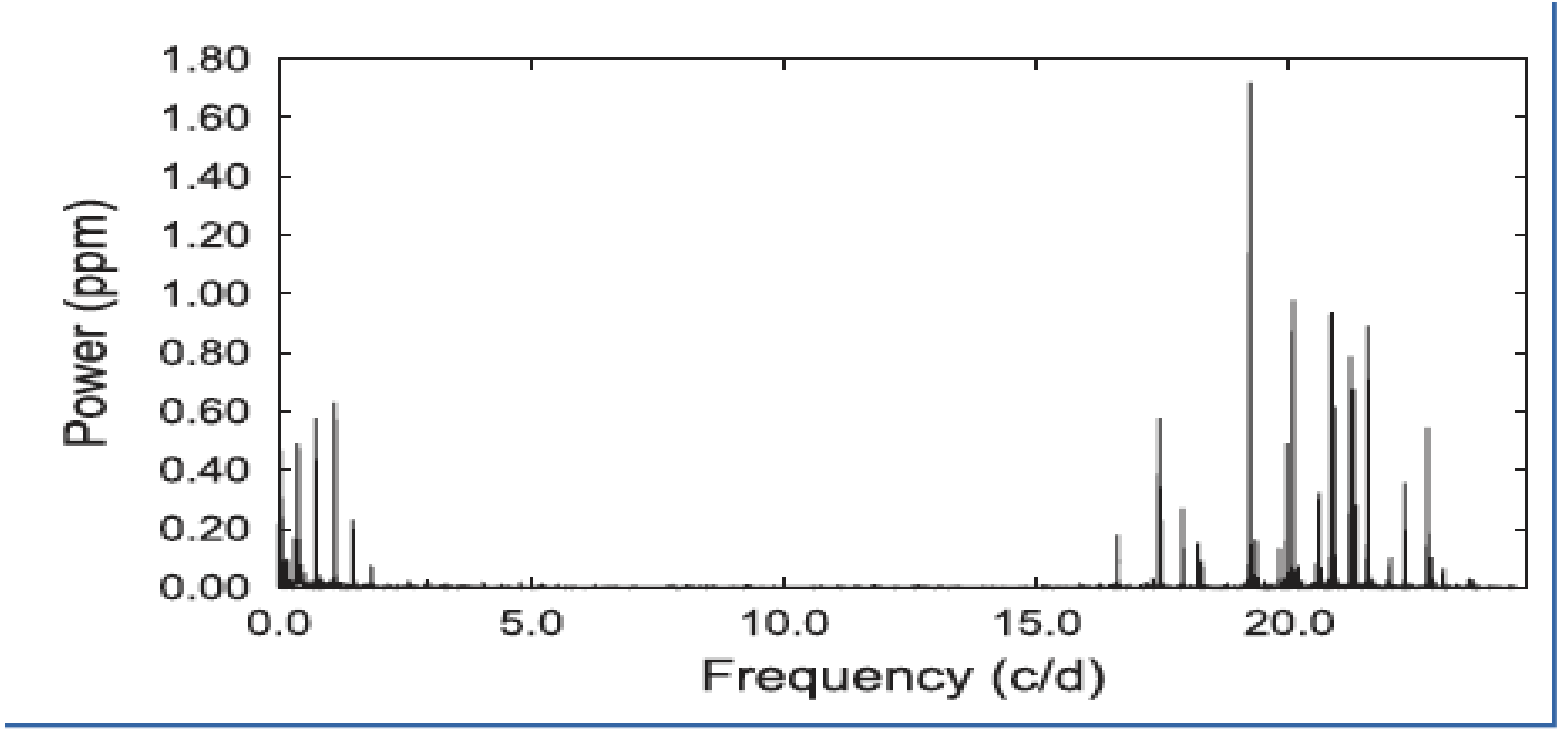
Skarka, Kabath, et al. 2019, MNRAS

A false positive



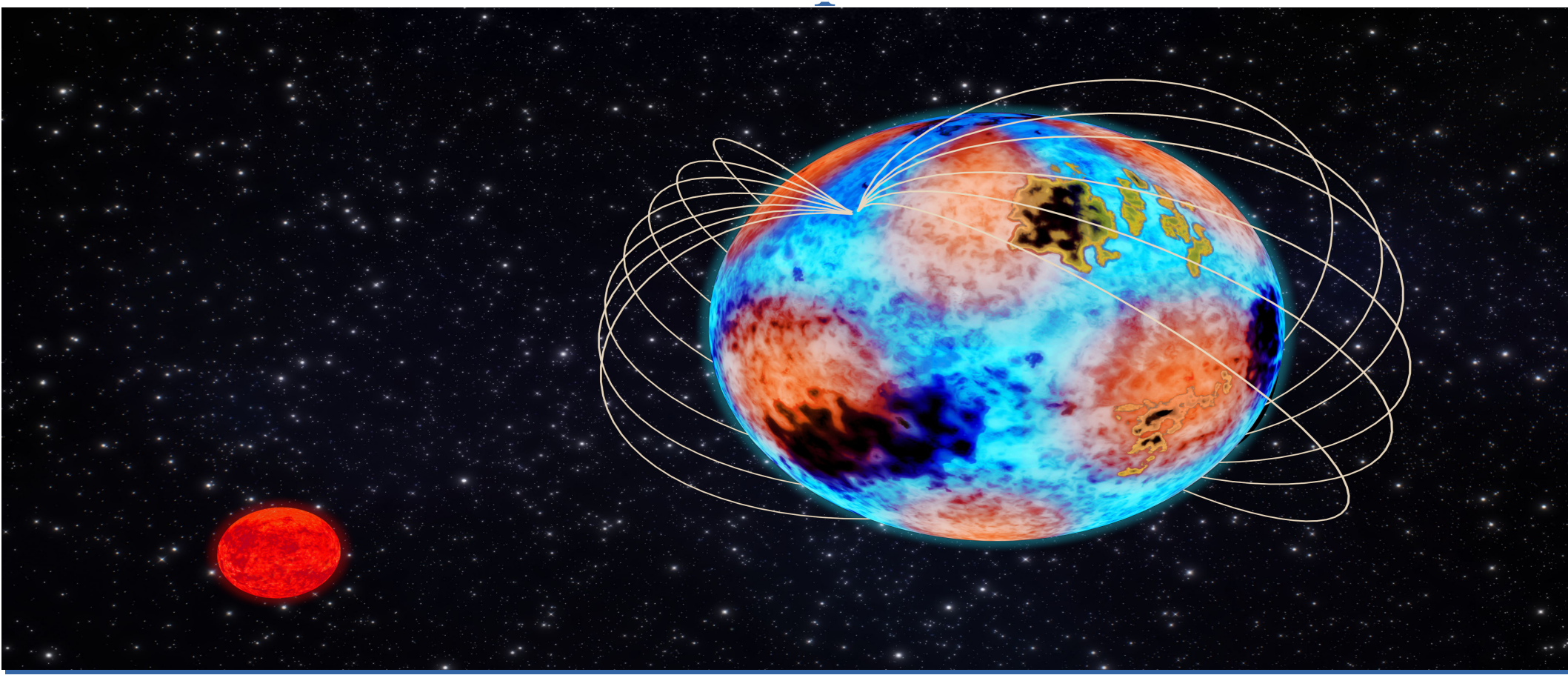
Skarka, Kabath, et al. 2019, MNRAS

Pulsations



Skarka, Kabath, et al. 2019, MNRAS

Artists impression



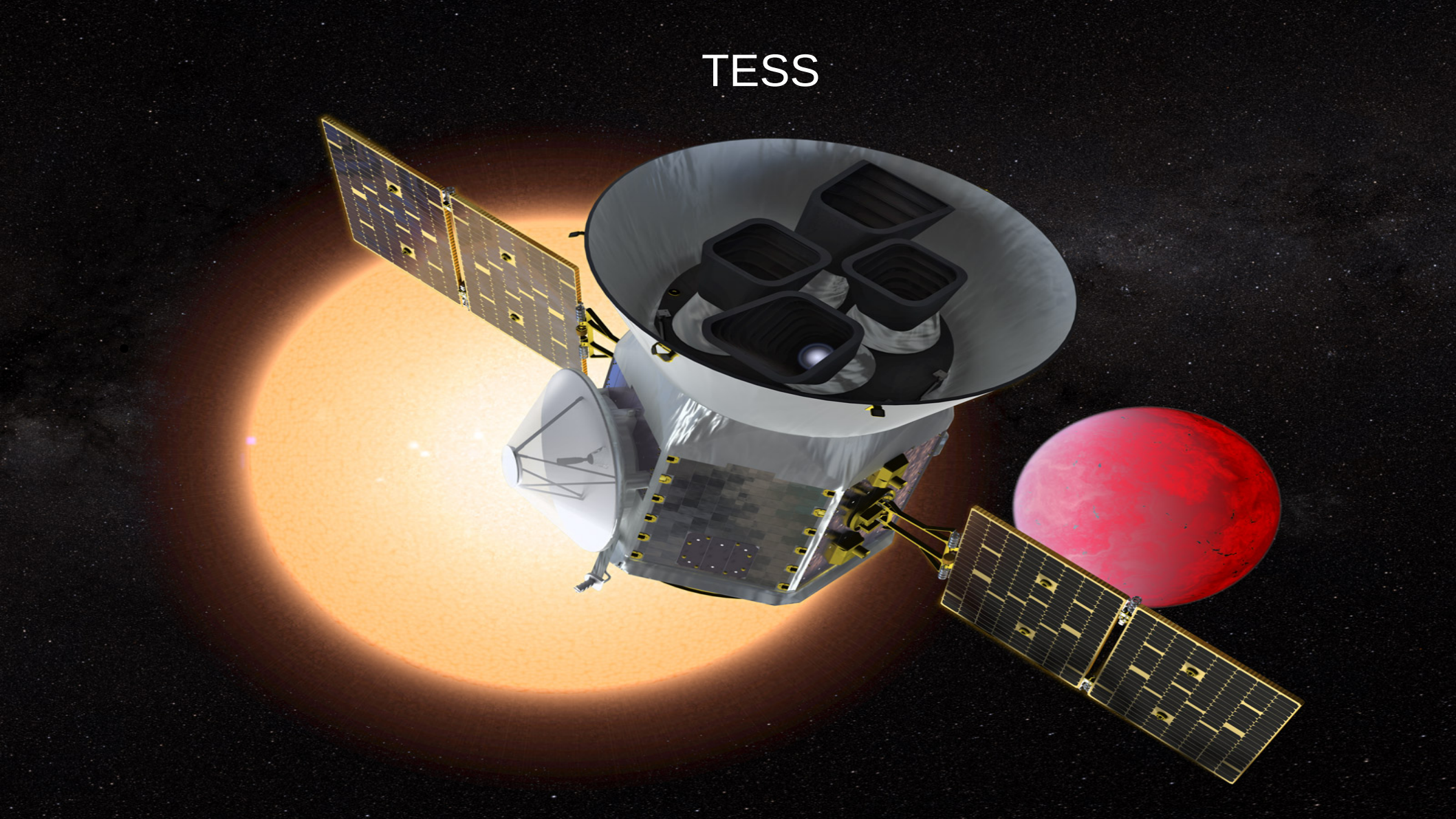
Skarka, Kabath, et al. 2019, MNRAS

Need for coordination

- spectroscopic follow-up
  - spectral typing, stellar parameters (1-2-m class)
  - RV follow-up (1-8+ m class)
  - exo-atmospheres (2-8+ m class)

- Photometric follow-up
  - high spatial resolution imaging (small telescopes)
  - on-off photometry (small telescopes)
  - high-res. (AO) imaging (typicall 8-m)

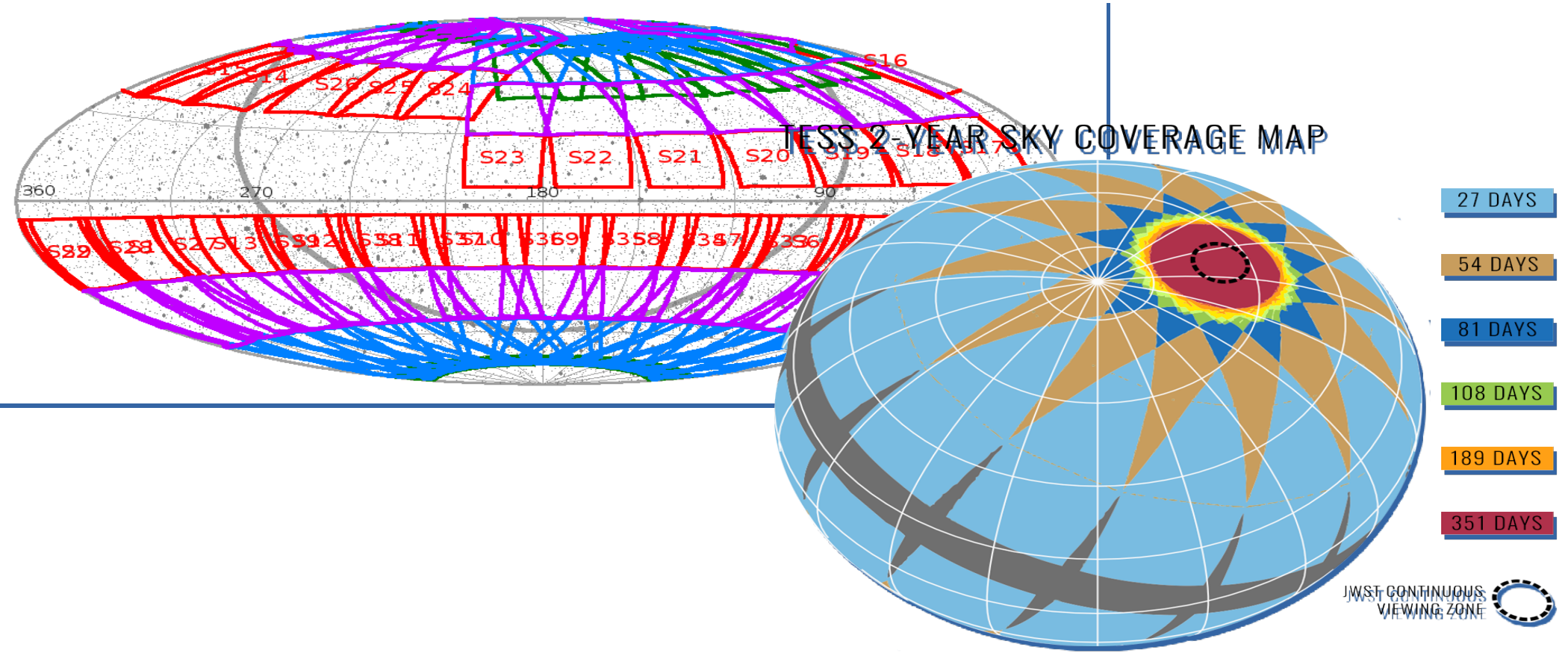
TESS



TESS

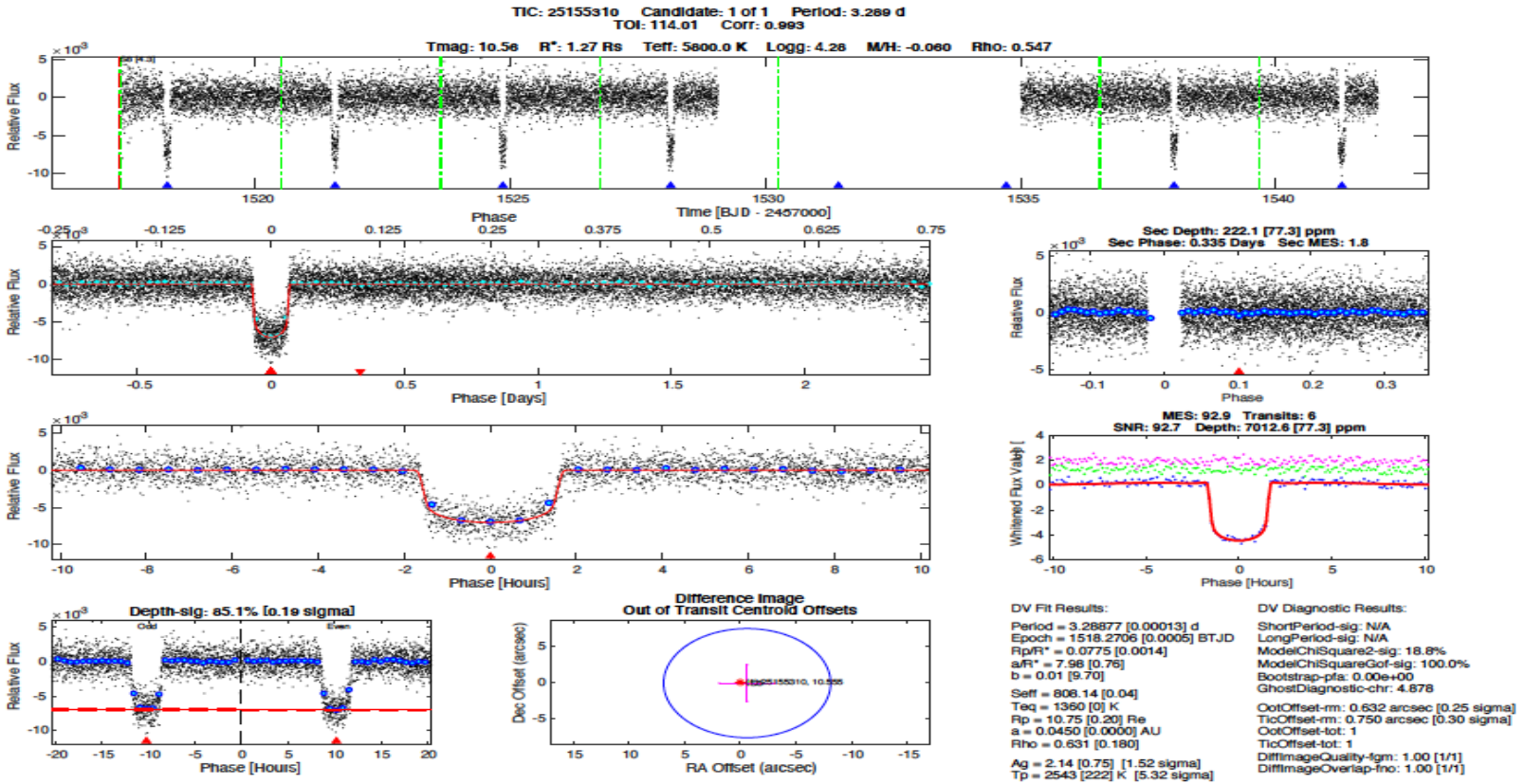
- Almost all sky coverage
- 4 x 100mm lenses
- Monitoring of more than 200k bright stars
- Targets will suitable for ground-based follow-up
- Perfect for small telescopes!!!
- First 73 candidates list delivered
  - Brightest TESS candidate is 5.1 mag
  - Most of targets brighter than 12 mag

TESS observing fields



://archive.stsci.edu/missions-and-data/transiting-exoplanet-survey-satellite-tess

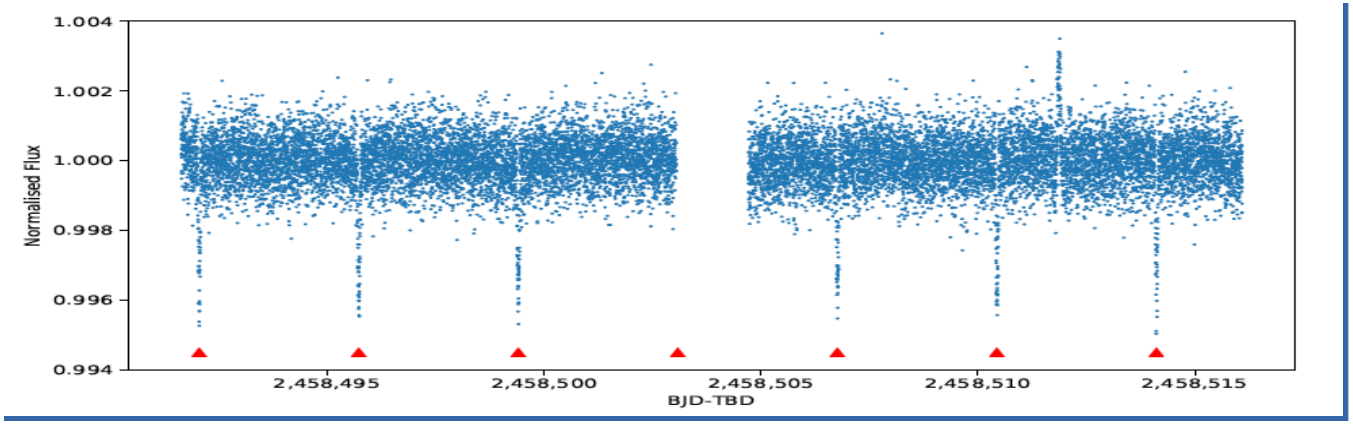
Example of a validation report

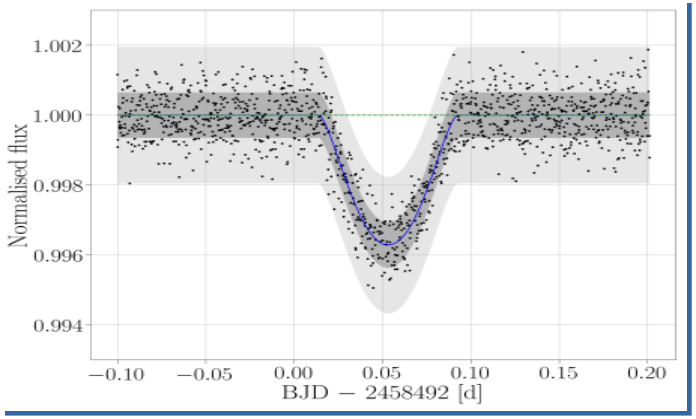


Software Revision: spoc-3.3.61-20190323 -- Date Generated: 27-Mar-2019 01:37:22 Z

This Data Validation Report Summary was produced in the TESS Science Processing Operations Center Pipeline at NASA Ames Research Center

Candidate from TESS
TOI-503?



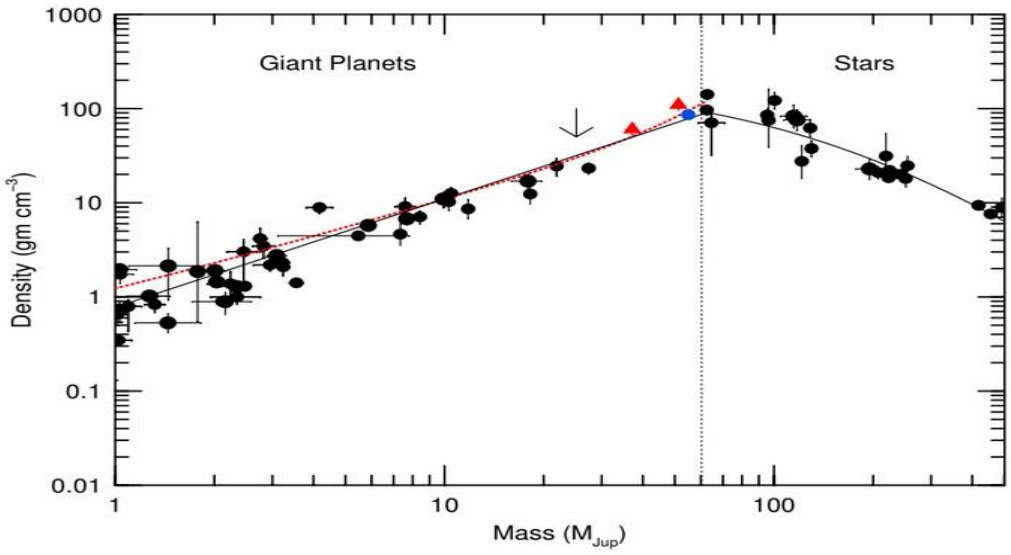


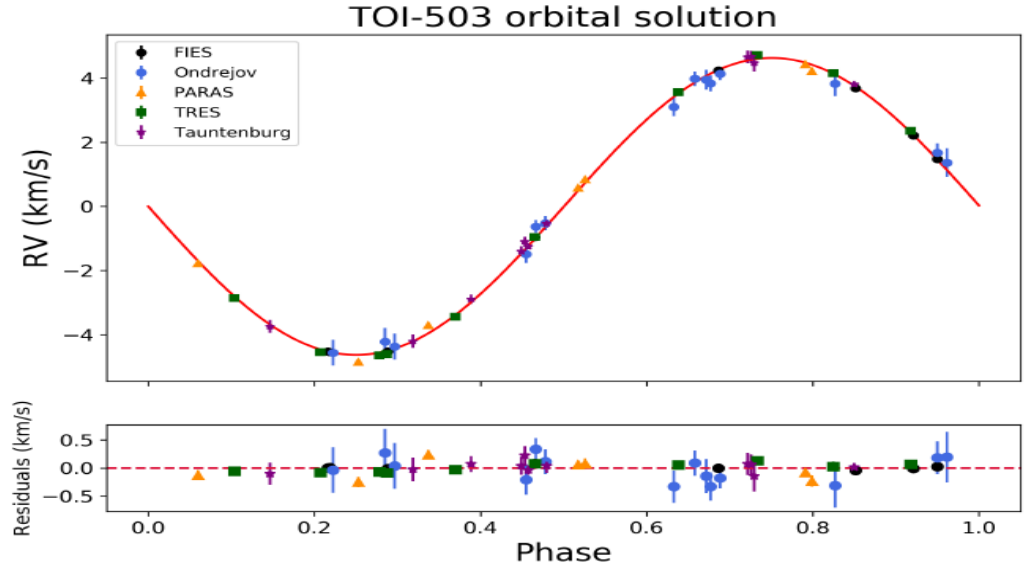
- TESS detected a Period around 3 days for TOI-503 A type star
- 3% depth – border line planet

Subjak et al. 2020AJ....159..151S

First Brown Dwarf from Ondřejov

- Mass – 53 Jupiter masses
- Radial velocities between -5 a +5 km/s

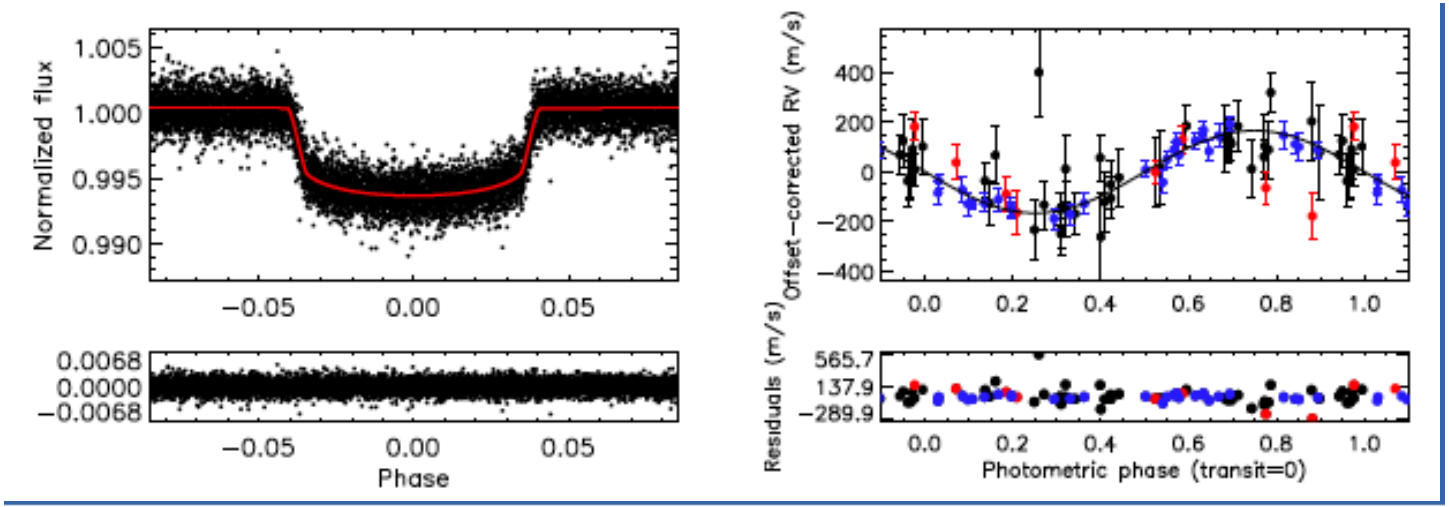




Parsson et al. 2019A&A...628A..64P and Subjak et al. 2020AJ....159..151S

TOI-1181b

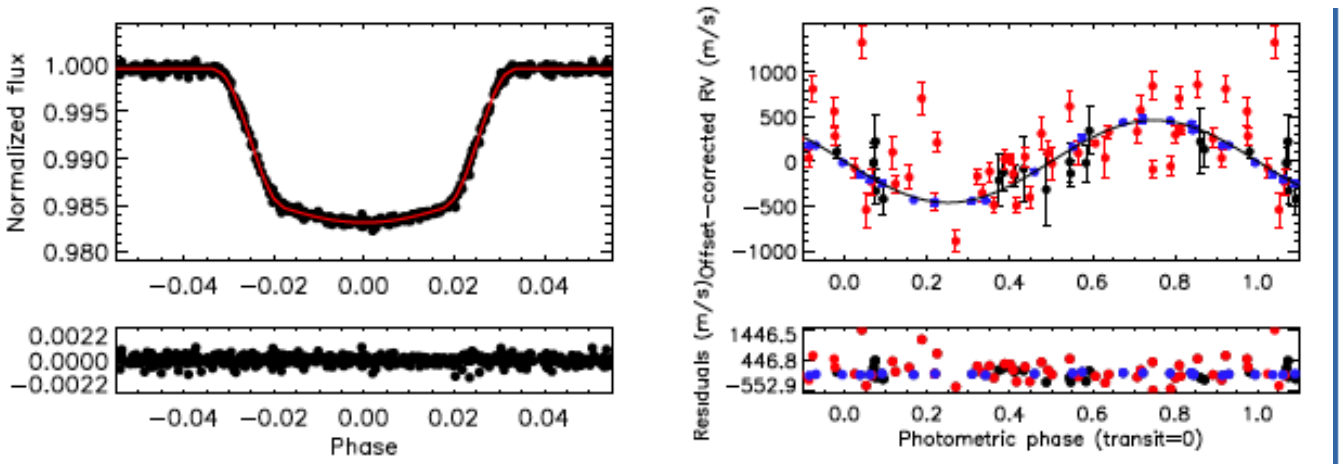
- A hot Jupiter around a G subgiant star
- Period 2.1 days
- Radius 1.3 $R_{Jupiter}$ and Mass 1.18 $M_{Jupiter}$



From Kabath et al. 2021 MNRAS

TOI-1516b

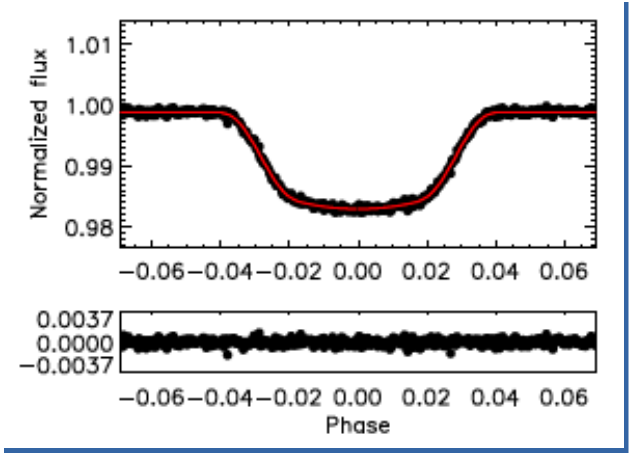
- A regular hot Jupiter
- Period 2.06 days
- Radius 1.36 $R_{Jupiter}$ and Mass 3.16 $M_{Jupiter}$

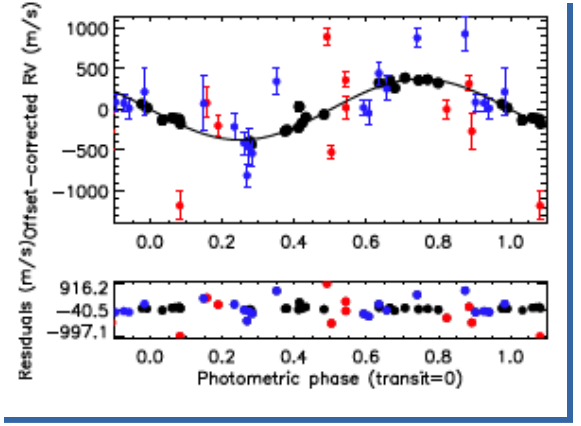


From Kabath et al. 2021 MNRAS

Hot Jupiter around young star, TOI-2046b

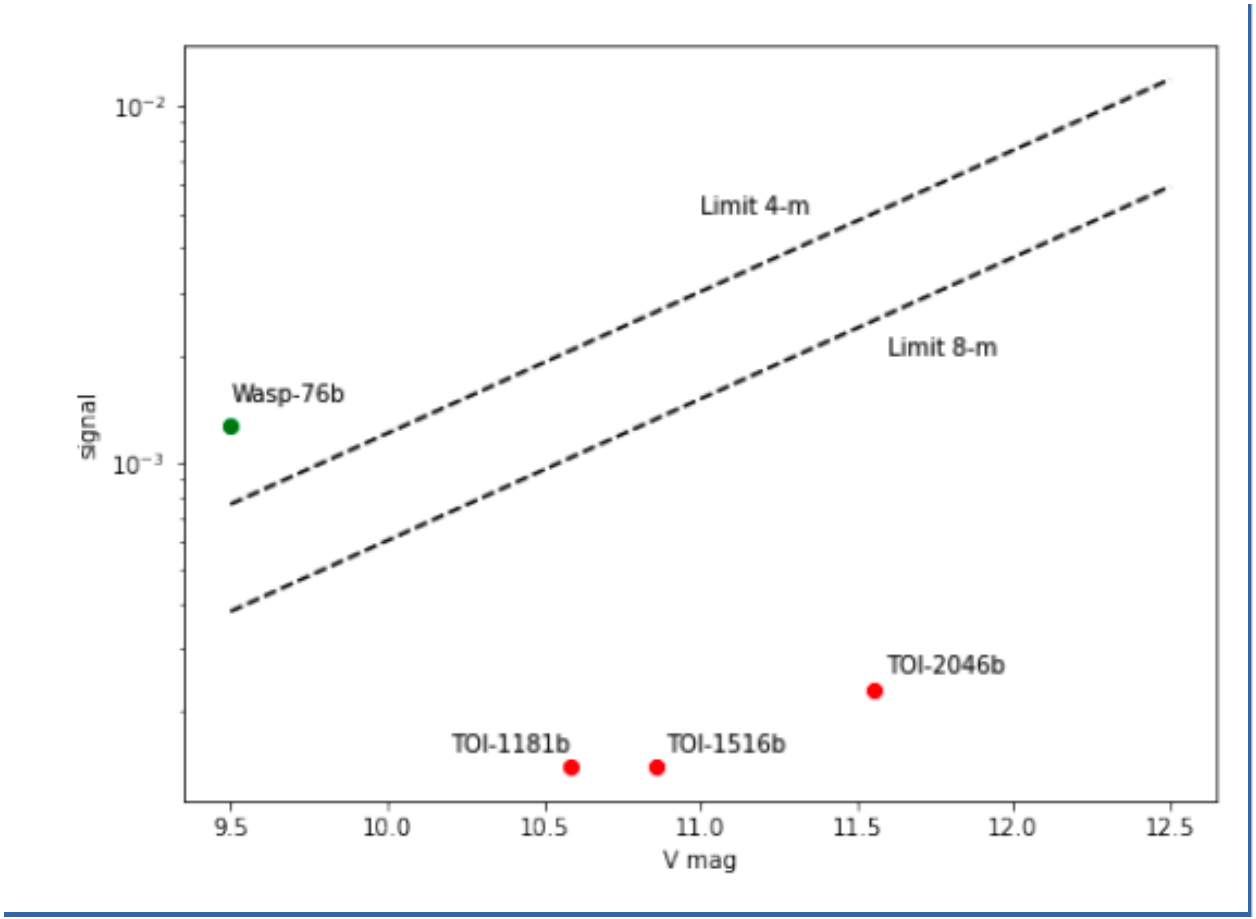
- Young system perhaps 100-400 Myr (Li line)
- Period 1.5 days
- Radius 2.44 $R_{jupiter}$ and Mass 2.3 $M_{Jupiter}$





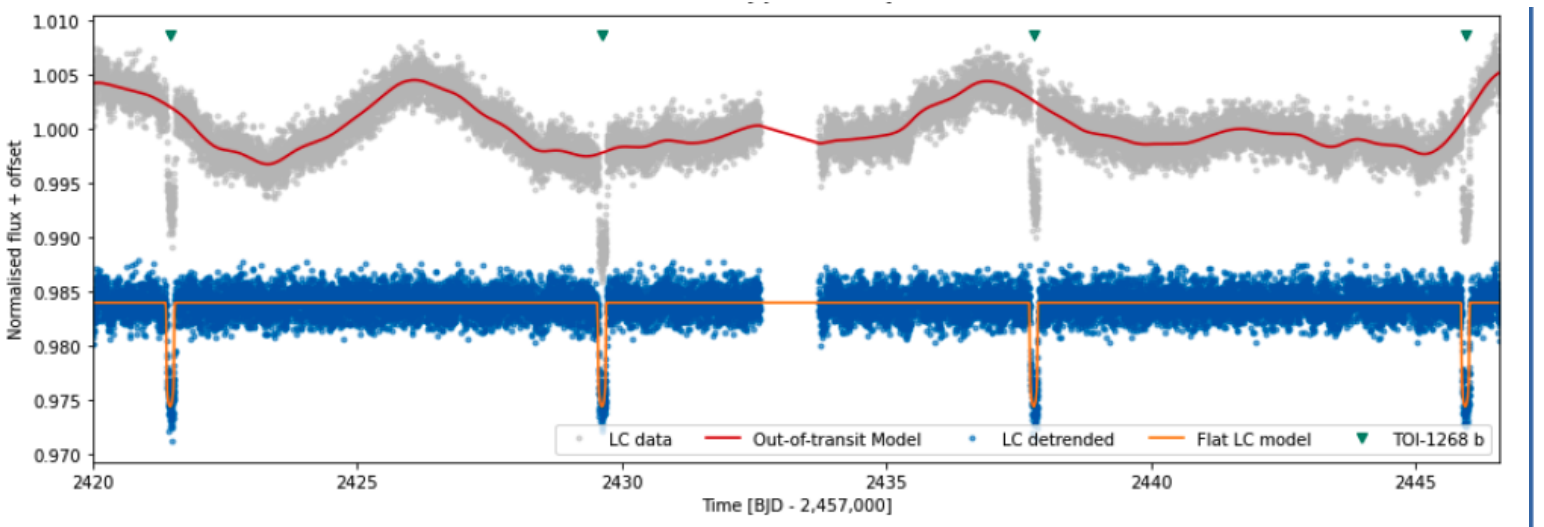
From Kabath et al. 2021 MNRAS

Further characterization?



TOI-1268 warm Saturn around a young K star

- A warm Saturn
- Period 8.1 days
- Paper J. Subjak et al. 2022, A&A

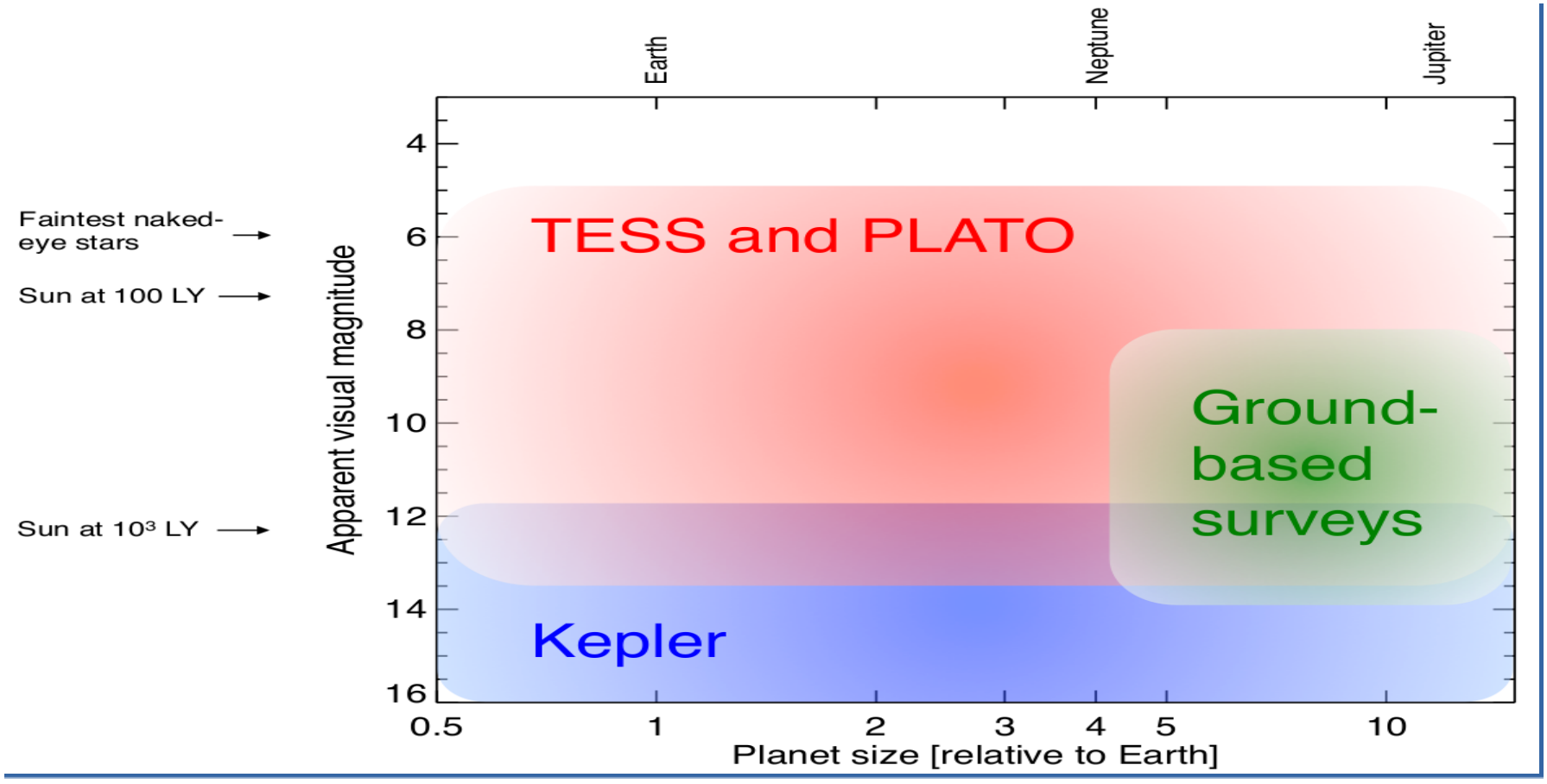


Conclusions

- Detection of a candidate is the very first step
- Ground based follow-up is extremely important
- Confirmation process has several steps

  - stellar parameters, high. Res photometry, high precision RVs
- Only candidates passing all steps above are planets
- The mission strategy and follow-up strategy need to be synchonized
- The follow-up can take more than 6 months

Space missions compared



Credit: PLATO Space mission

Next lecture

- Data archives
- Light curve handling
- Tools to understand the exoplanet data
- Exoplanet types and statistics