

Exoplanets

Lecture 4
Fall 2020/2021
27.10.2020

Outline


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

Lecture materials

- <http://erasmus.asu.cas.cz/events.html>
- Videos and audio files will be uploaded here
- Lecture slides will be here too

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

A decorative header image showing a satellite or spacecraft in space, with a planet and stars visible in the background.

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

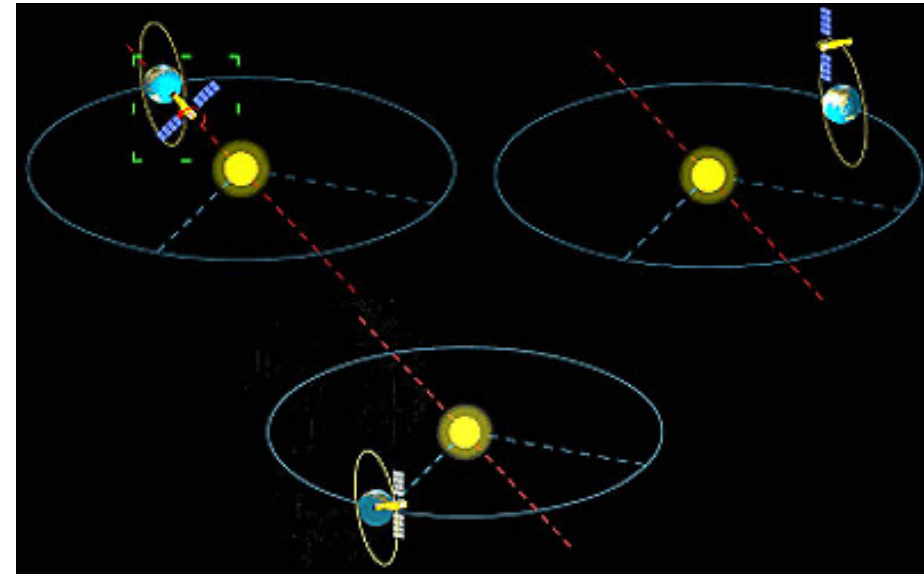
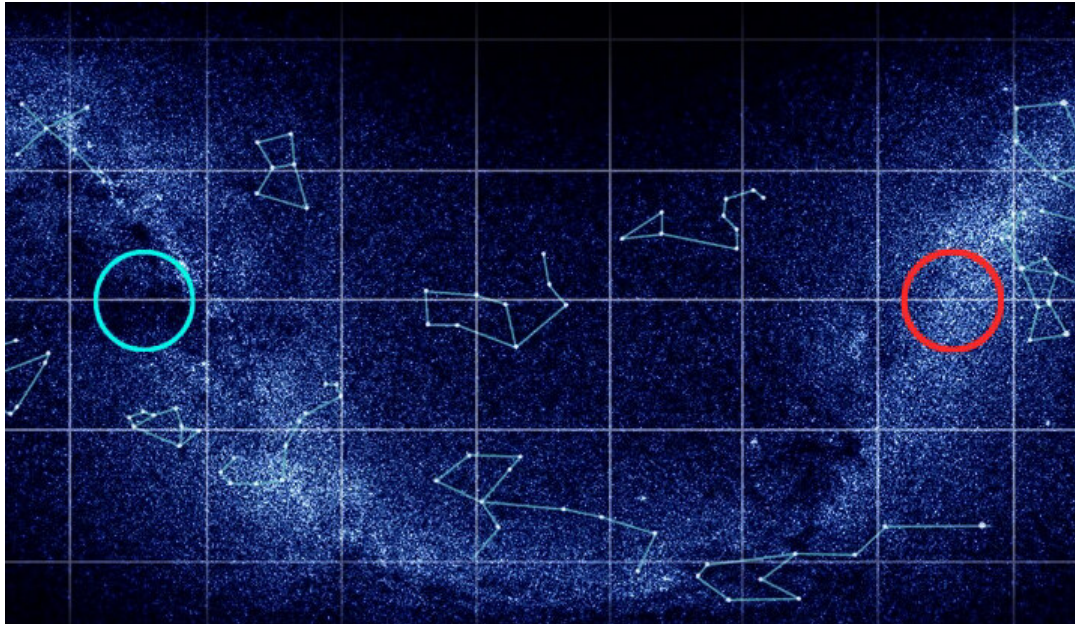
CoRoT space mission

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



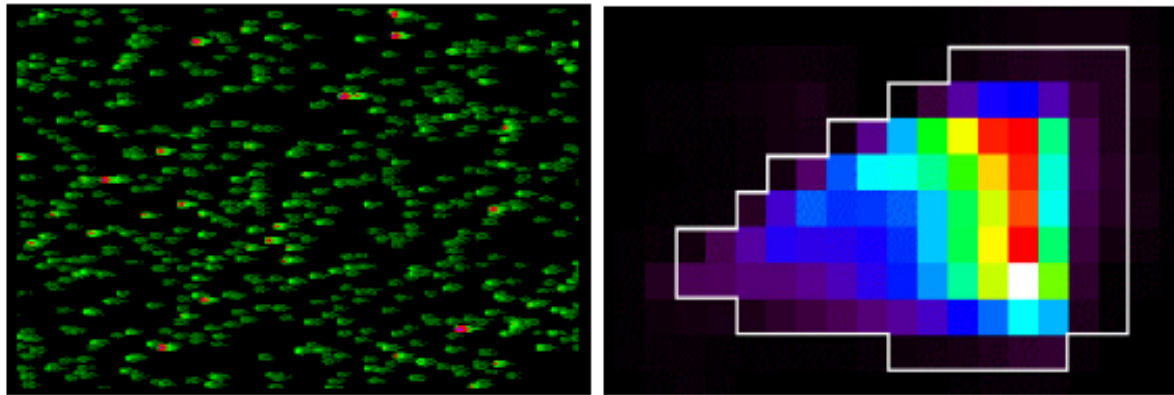
Corot Observing Strategy

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



Need for ground based follow-up

Up to 12000 masks for objects



Angular resolution of CoRoT: $2.3''/\text{pixel}$



Broadening of stellar PSF due to prisms



FLASE POSITIVE ALARMS

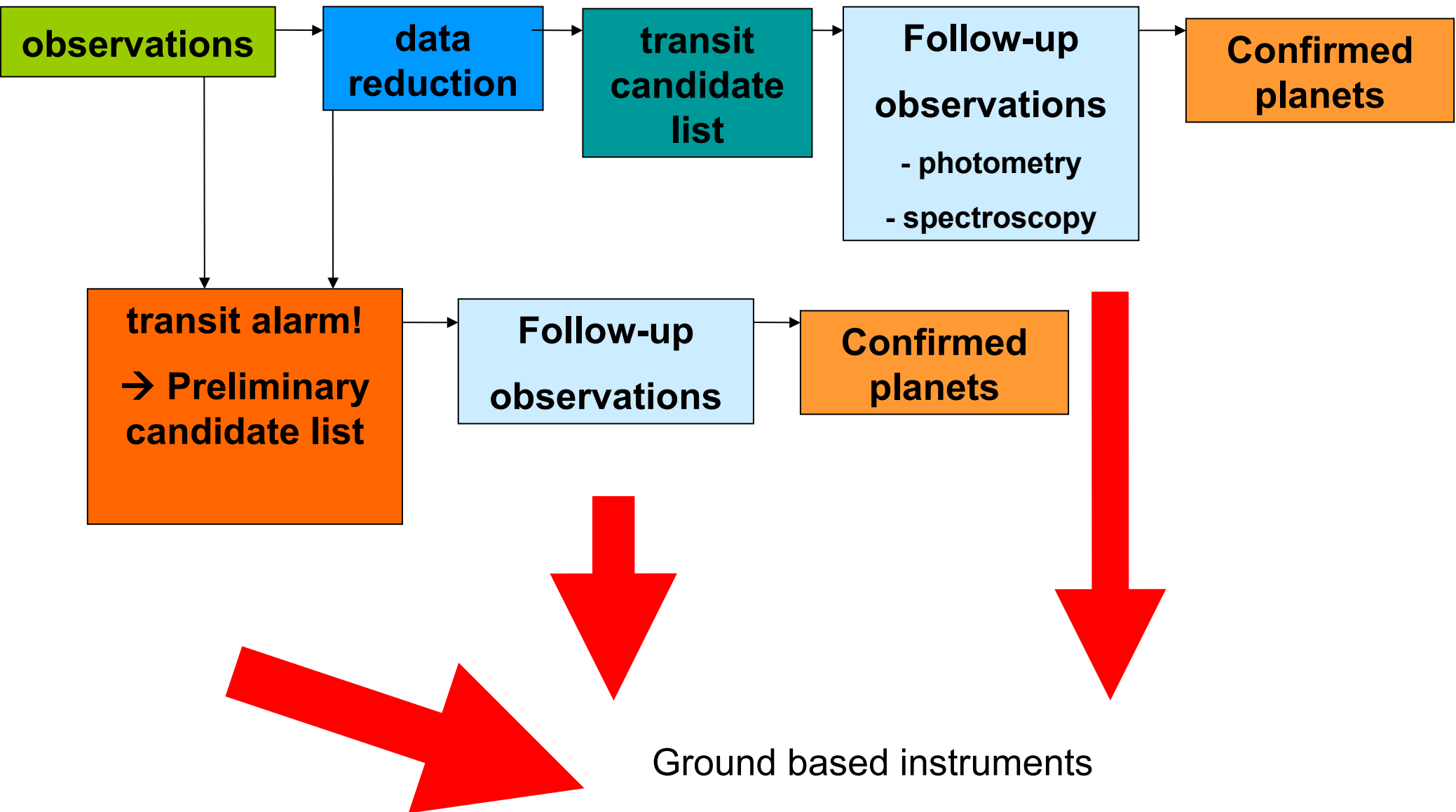


GROUND BASED FOLOW-UP

Follow-up for CoRoT - BEST II

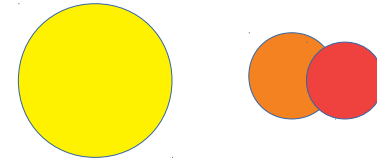


Confirmation of candidates (Case of CoRoT)

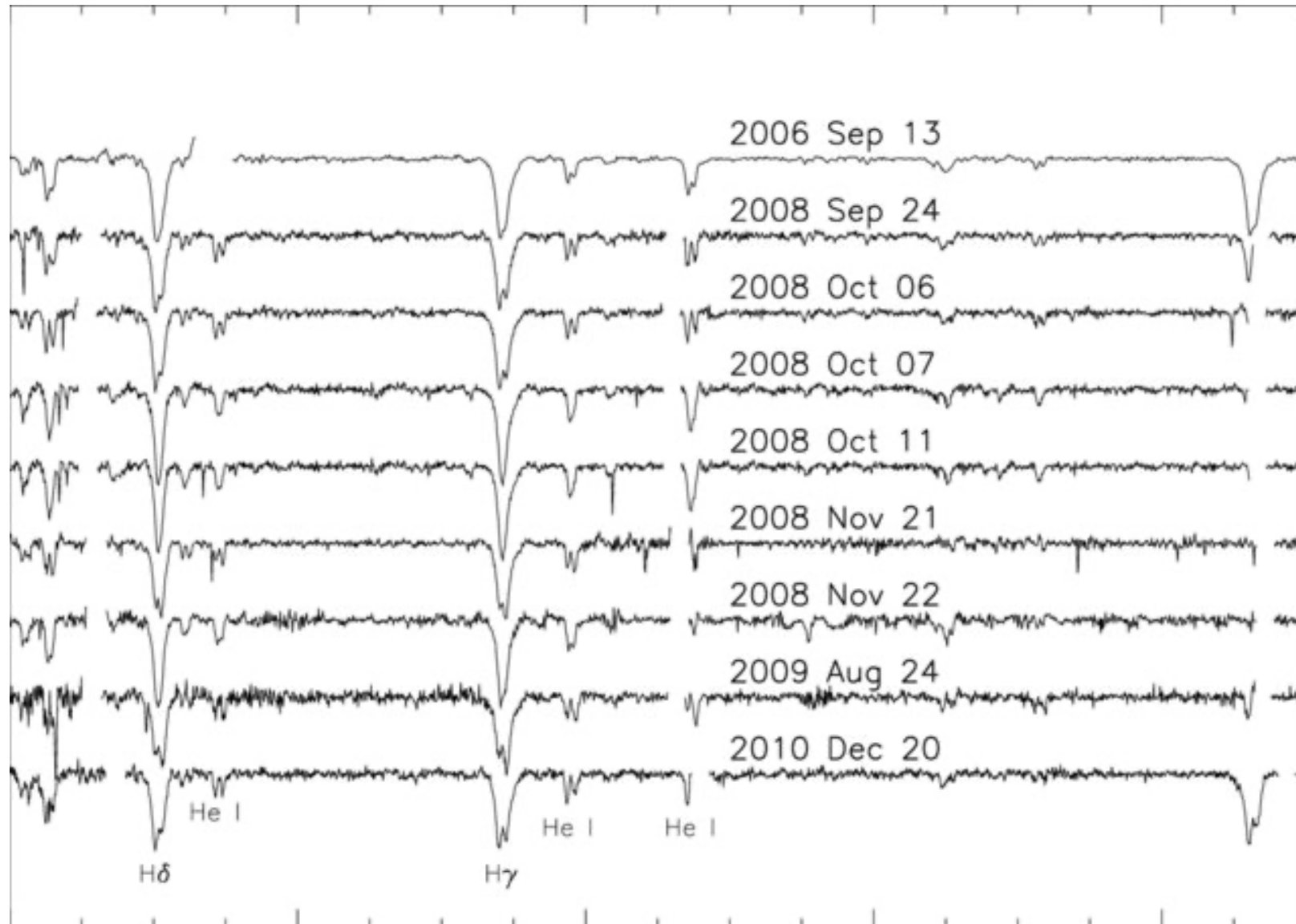


False positives

- 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



Characterization of exoplanets combination of methods

- Transits

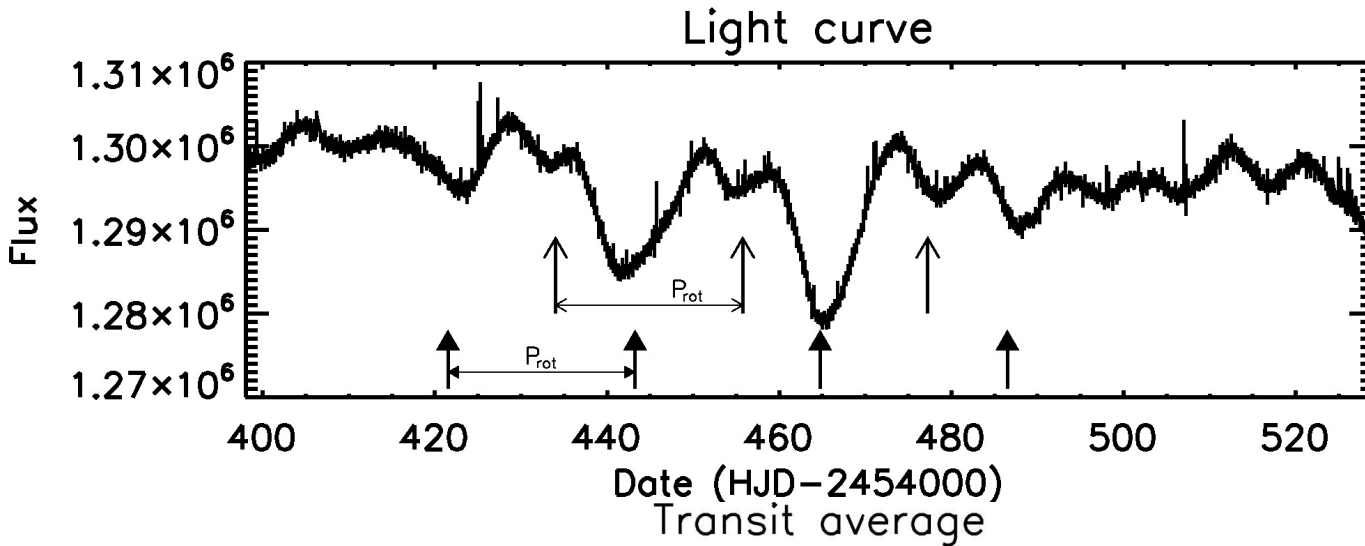
Radius of the planet (if stellar params known),
inclination

- Spectroscopy

Mass limit, stellar parameters

- STELLAR PARAMETERS NEEDED (spectroscopy)

The case of CoRoT-7b

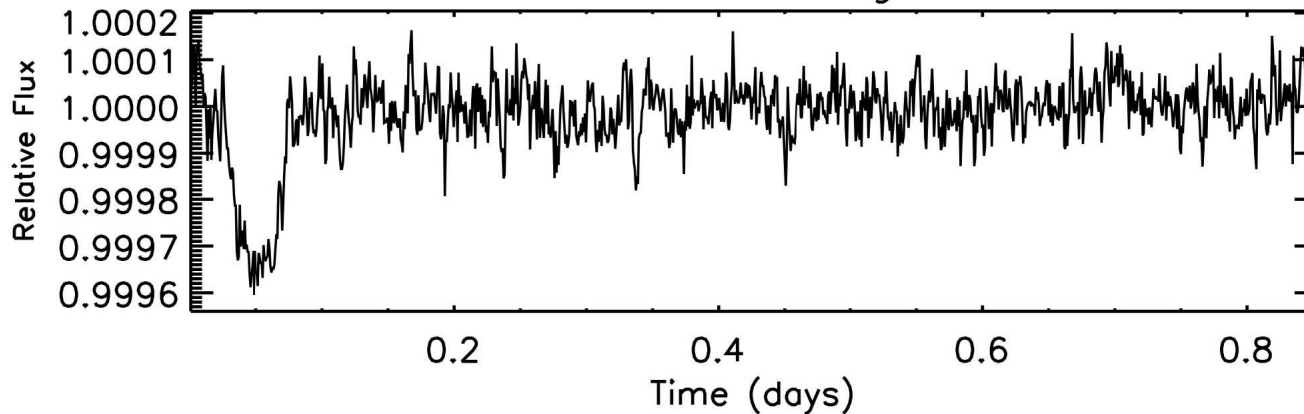


CoRoT-7b

Orbital Period 0.85 days

Mass $< 9M_{\text{Earth}}$

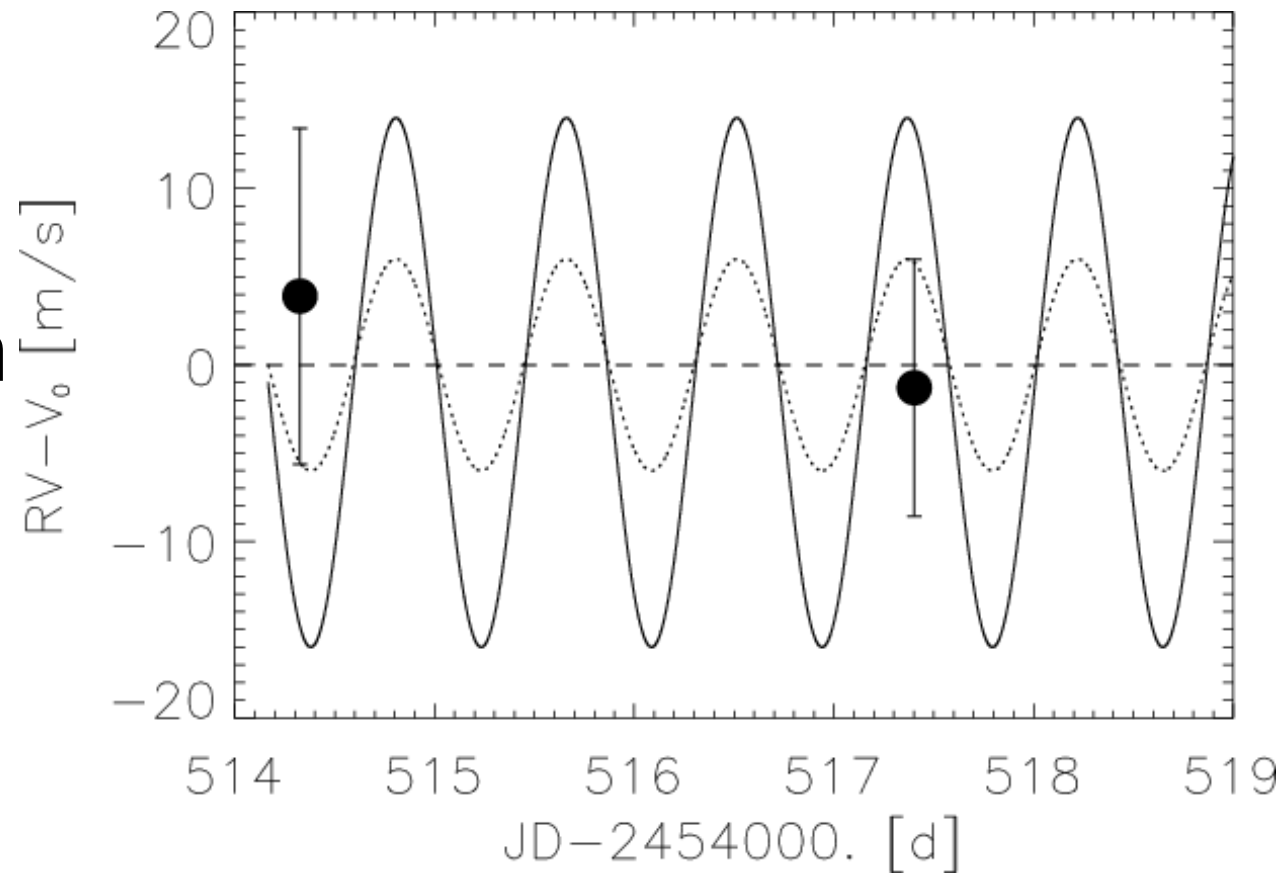
Radius $1.51R_{\text{earth}}$



From Leger et al. 2007, A&A

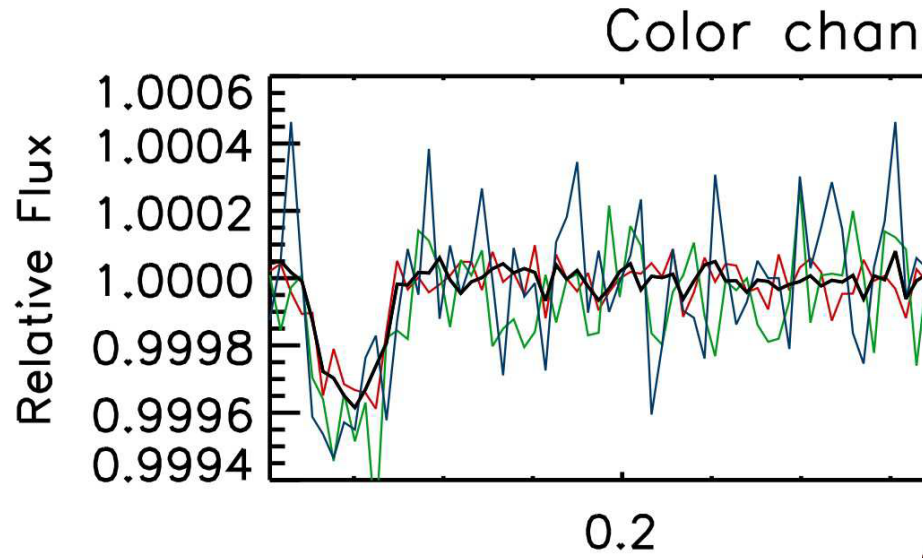
CoRoT-7b

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



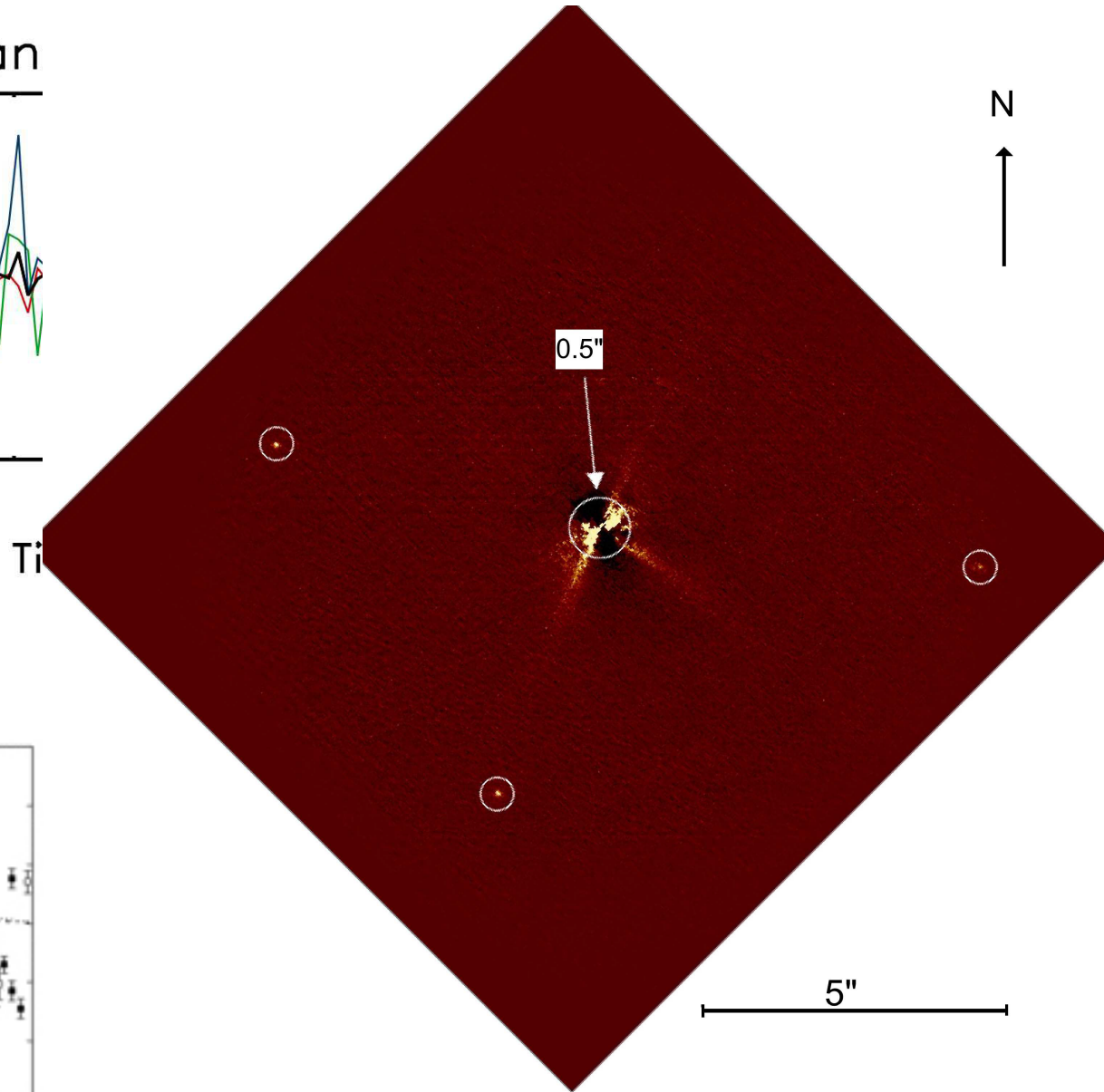
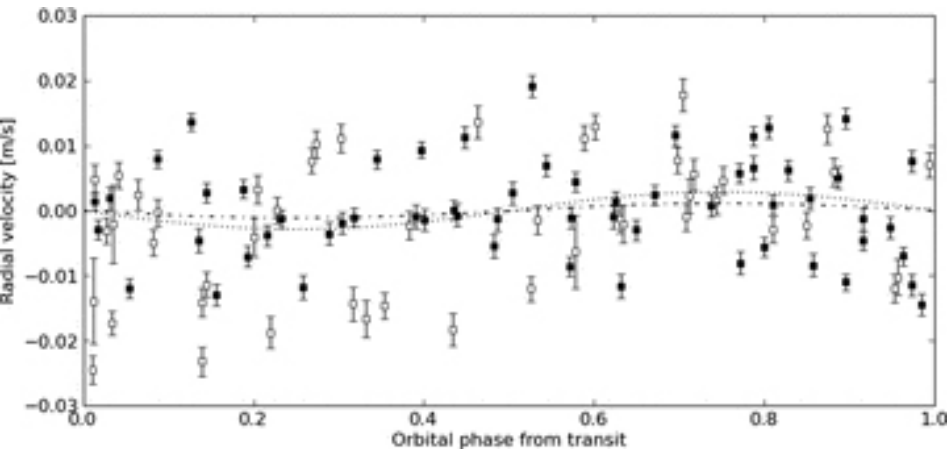
From Leger et al. 2007, A&A

CoRoT-7b



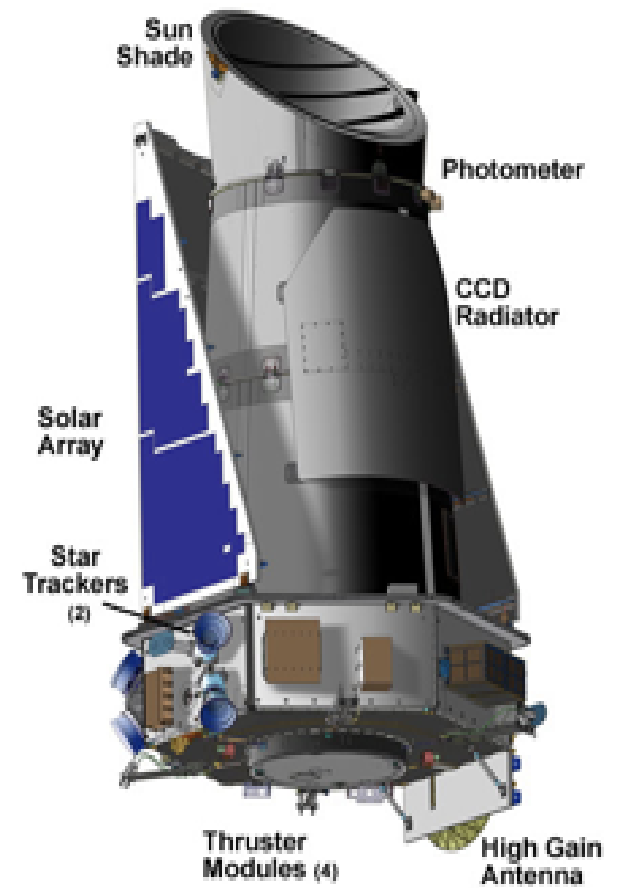
From Leger et al. 2007, A&A

Bottom from F. Pont 2011, MNRAS

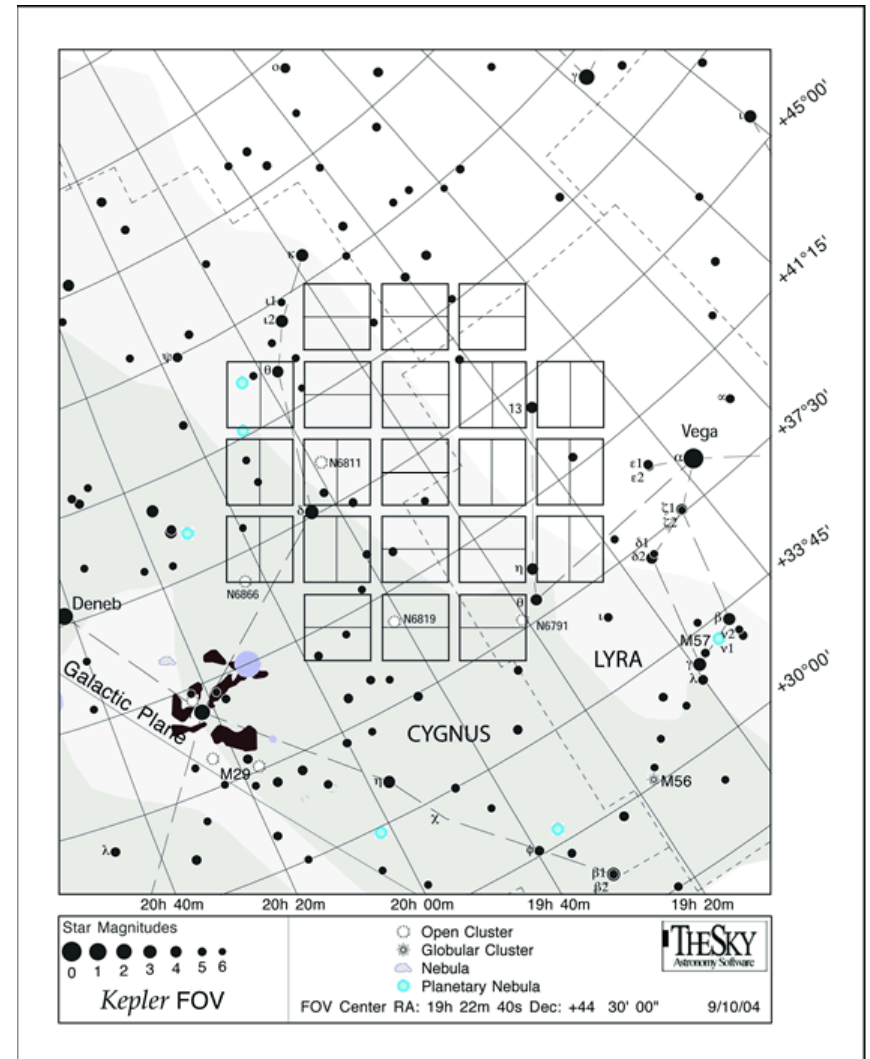
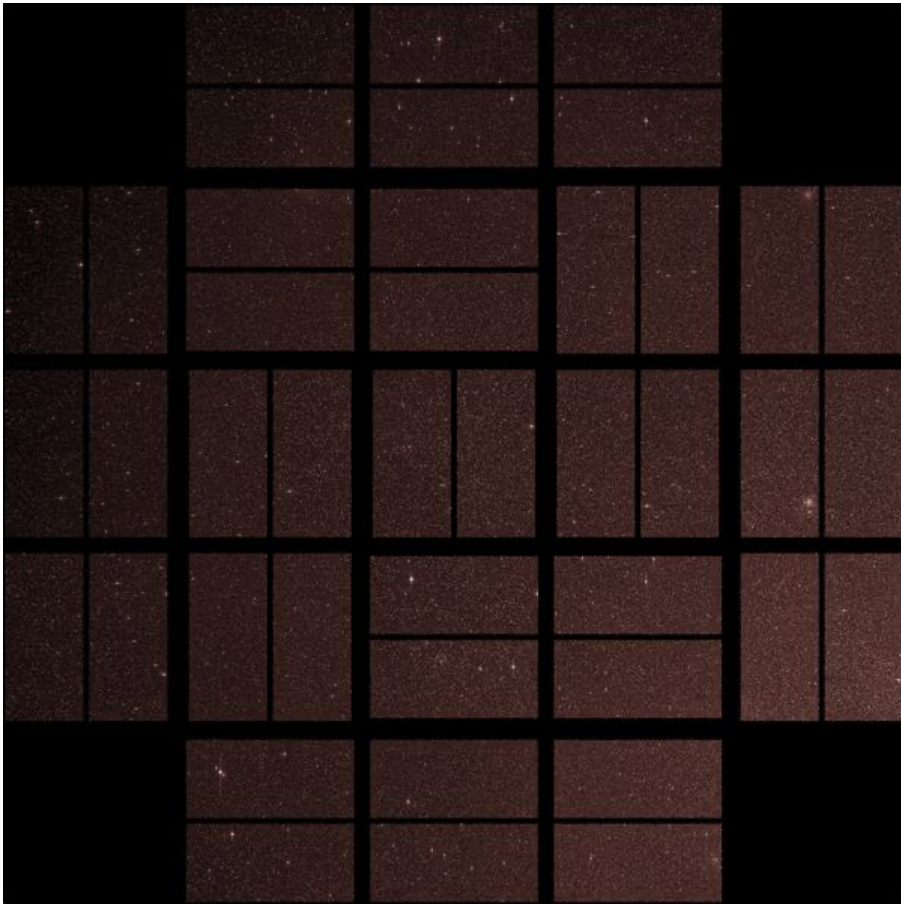


The era of Kepler

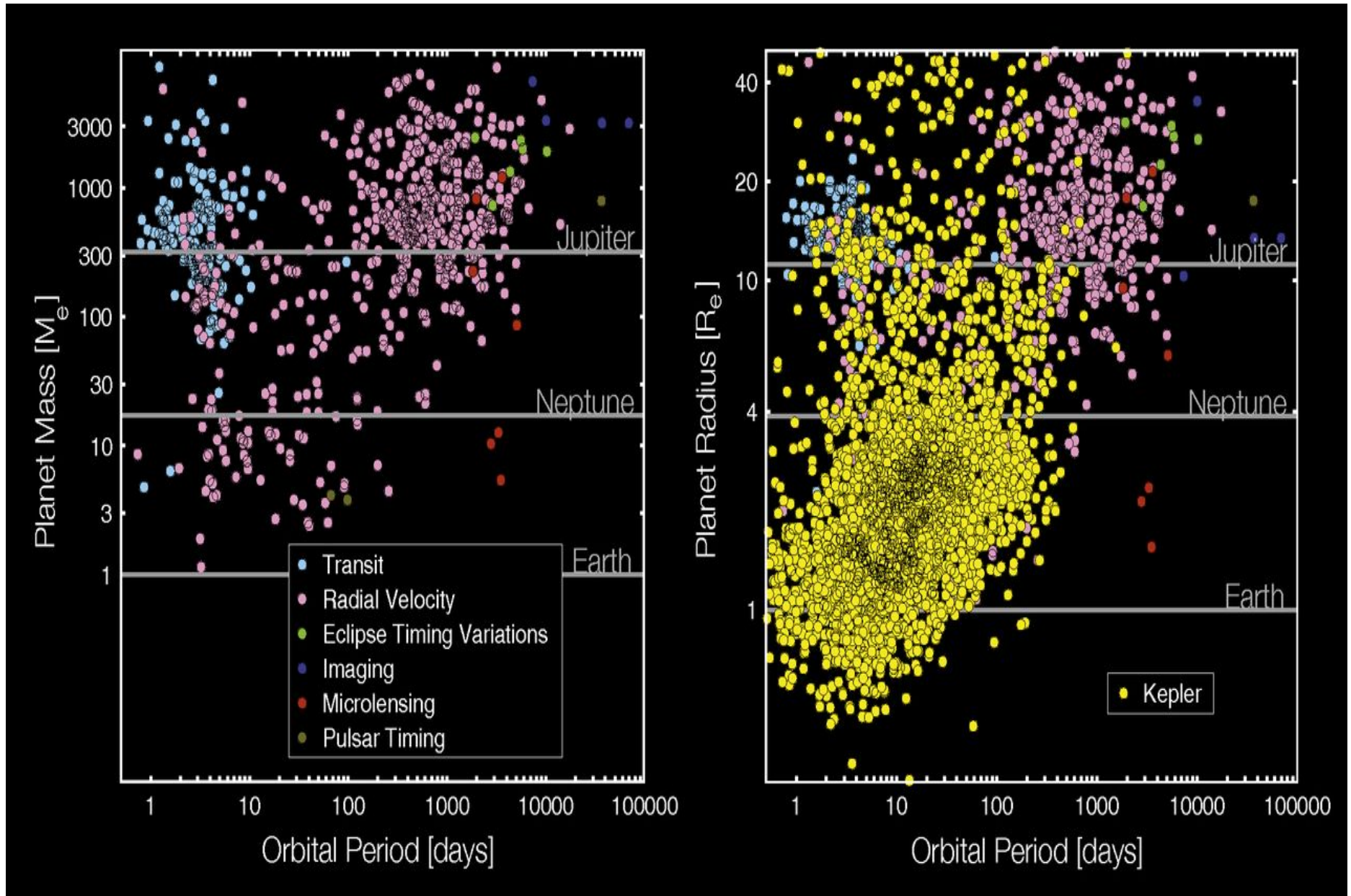
- Detections of exoplanets
- Launched 2009
- 1.4-m primary mirror
- Monitored 100k stars in Cygnus
- Around 2000 planets
- K2 continuation with different observing strategy
- Many stars were faint 13+ mag!



Kepler observing strategies

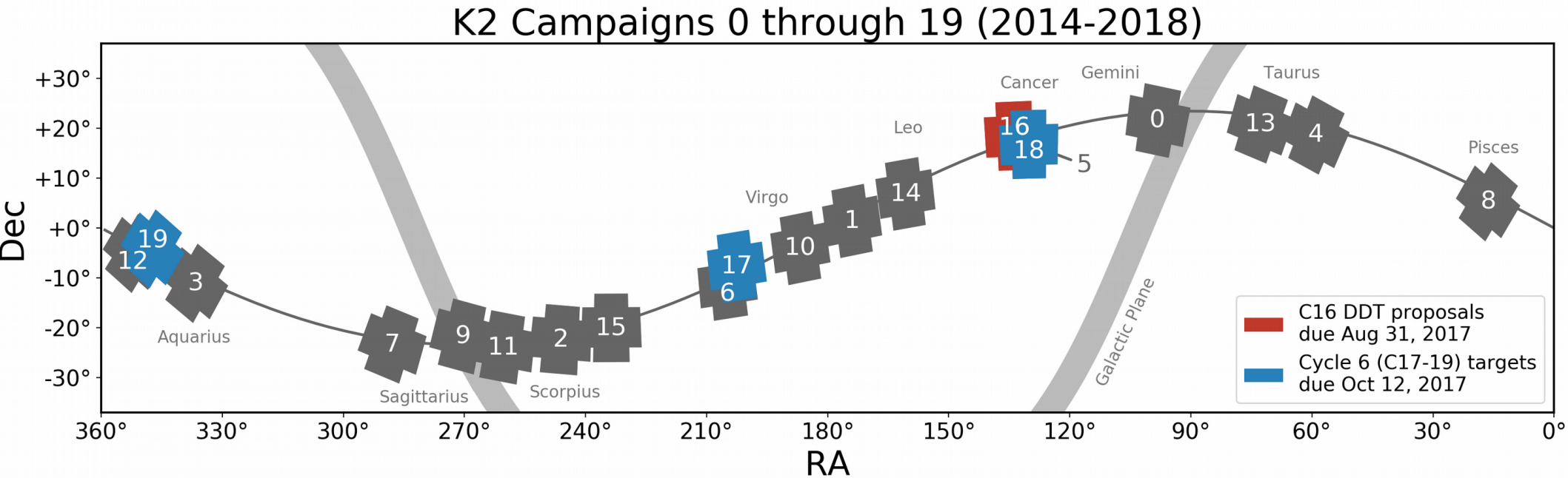


KEPLER planets



Credit: NASA

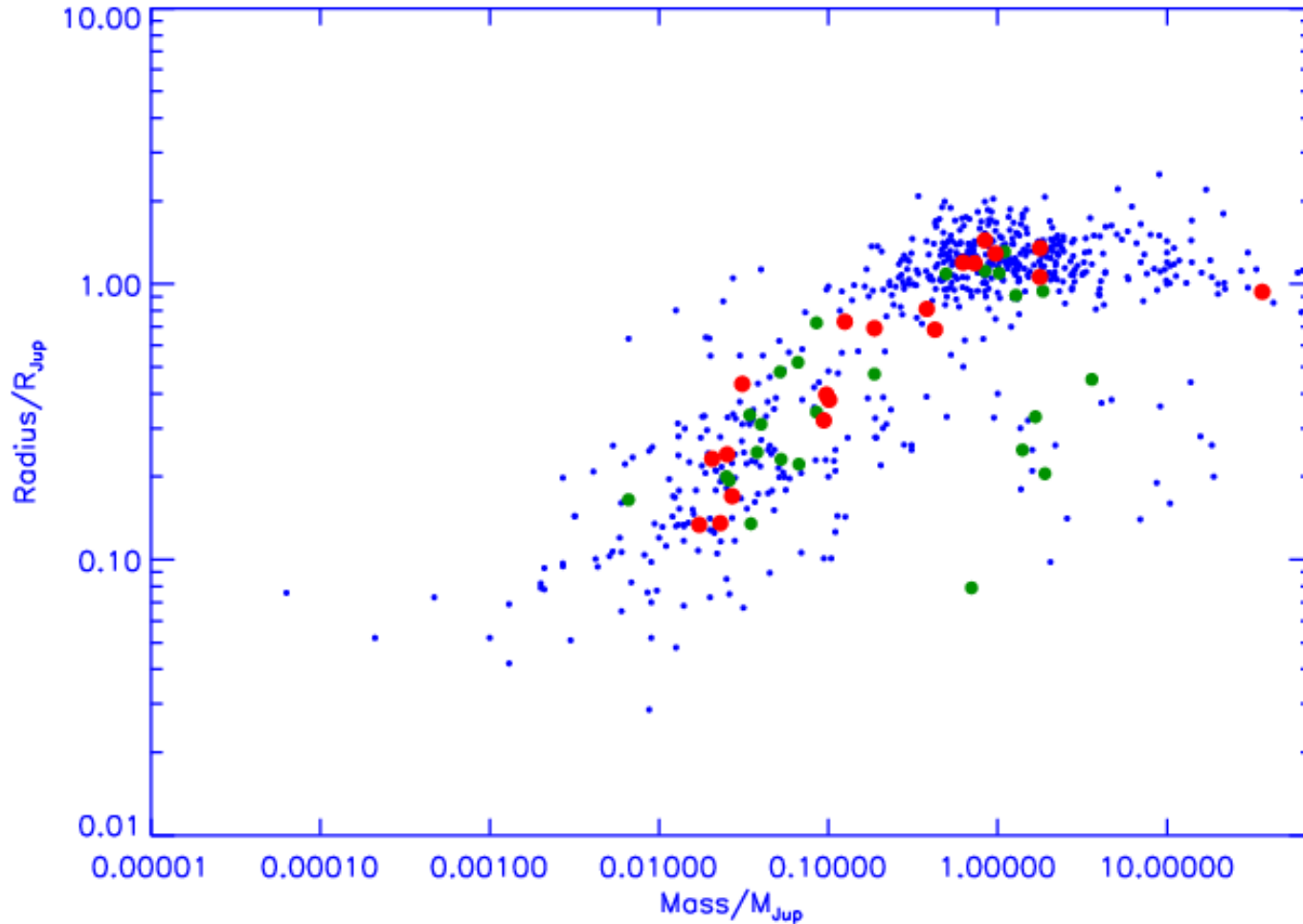
K2 continuation of Kepler



Credit: Nasa

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

Great but.....



In Sep. 2017 – approx.
120 K2 planets

Blue – all planets
around 4000

Green – K2 planets
with masses (40)

Red – KESPRINT
(21)

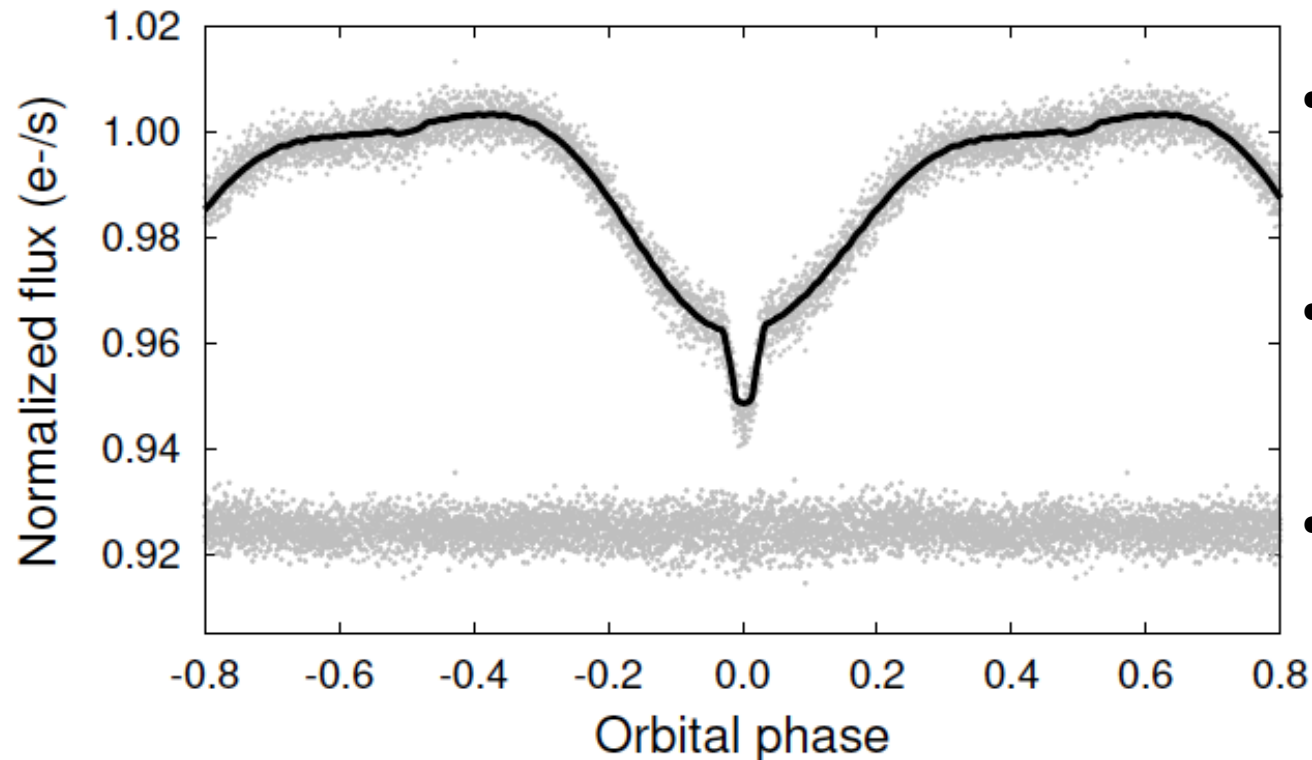
Numbers from
Csizmadia et al. 2017

From Csizmadia et al. Plato mission conference 2017

The case of HD99458

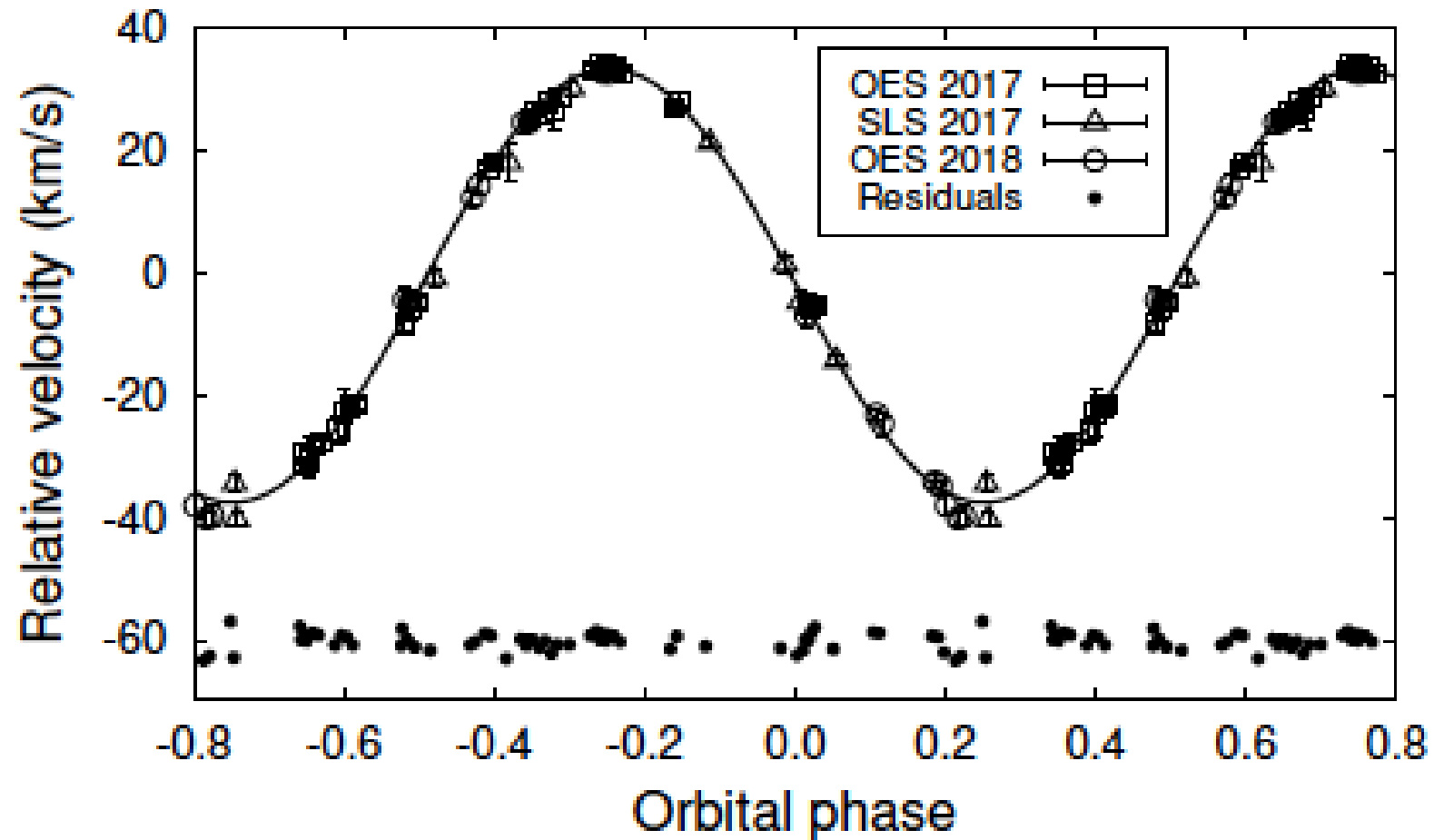
- Planetary candidate with
- Transit depth of a few %
- Suspected hot Jupiter
- Follow-up with OES at Ondrejov

Intriguing system?

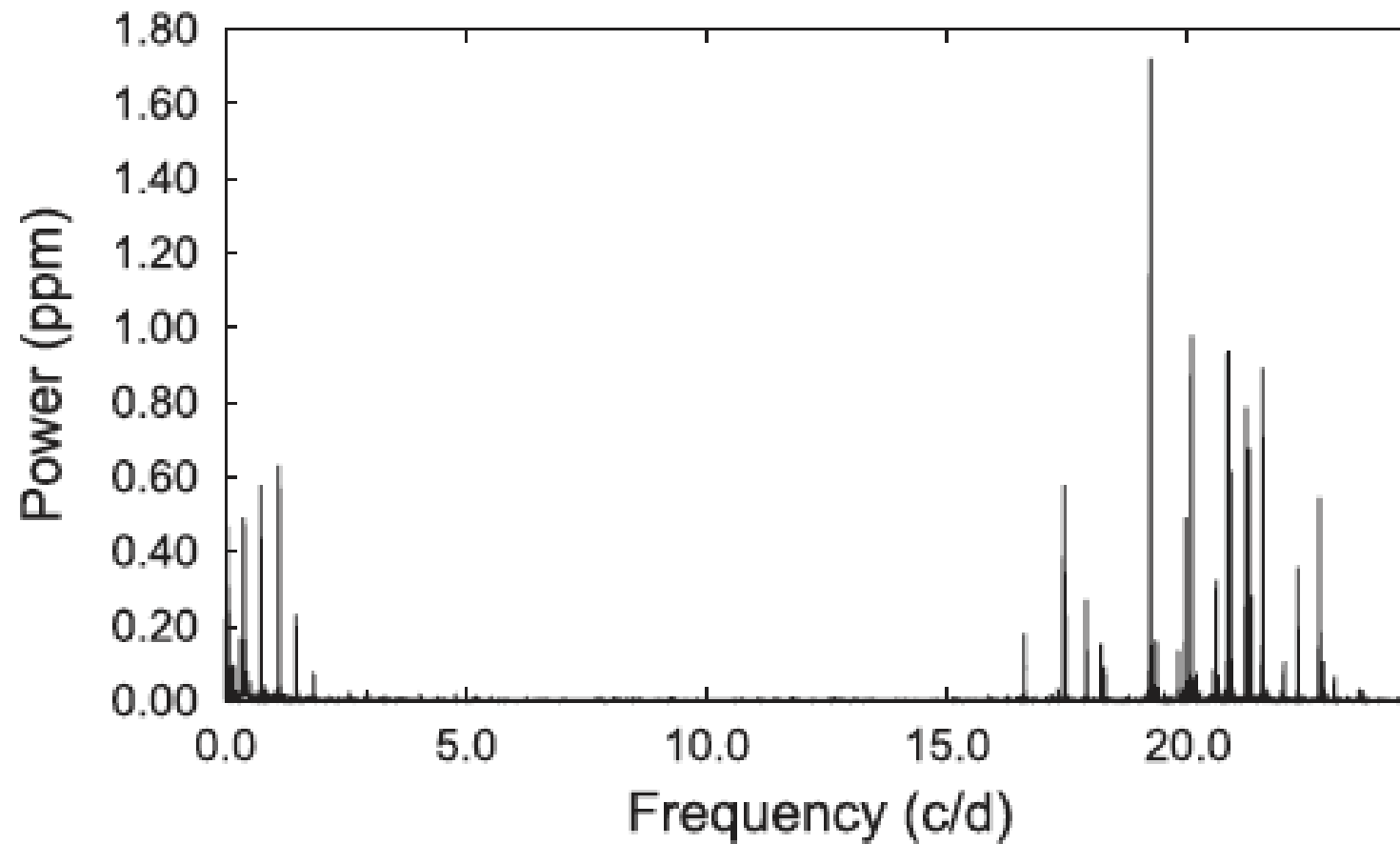


- Kepler candidate for Jupiter-sized planet
- Observing with OES and at Stará Lesná, SK
- Short period binary, magnetic star with DSCT pulsations and spots
- NO EXOPLANET

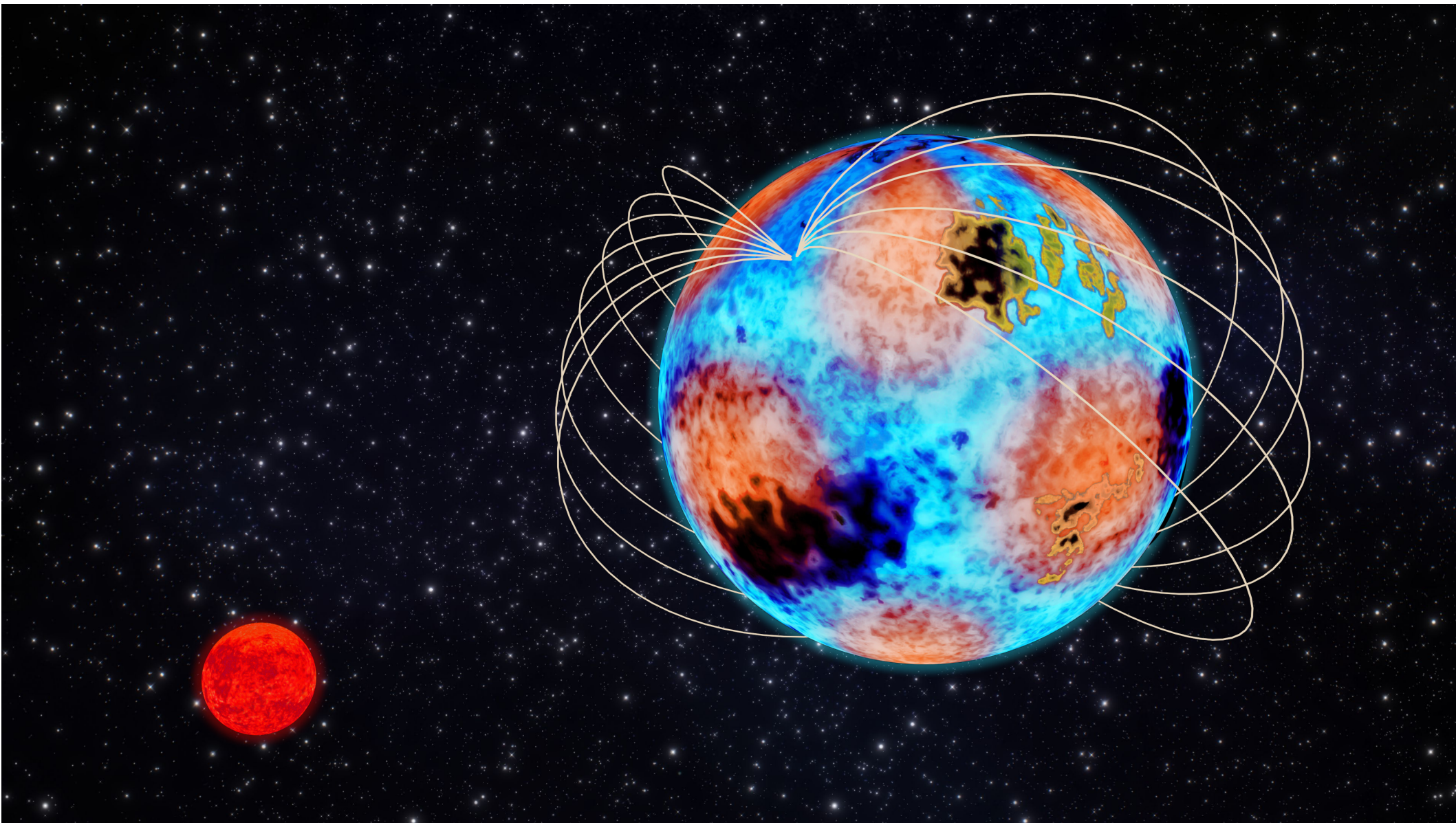
A false positive



Pulsations



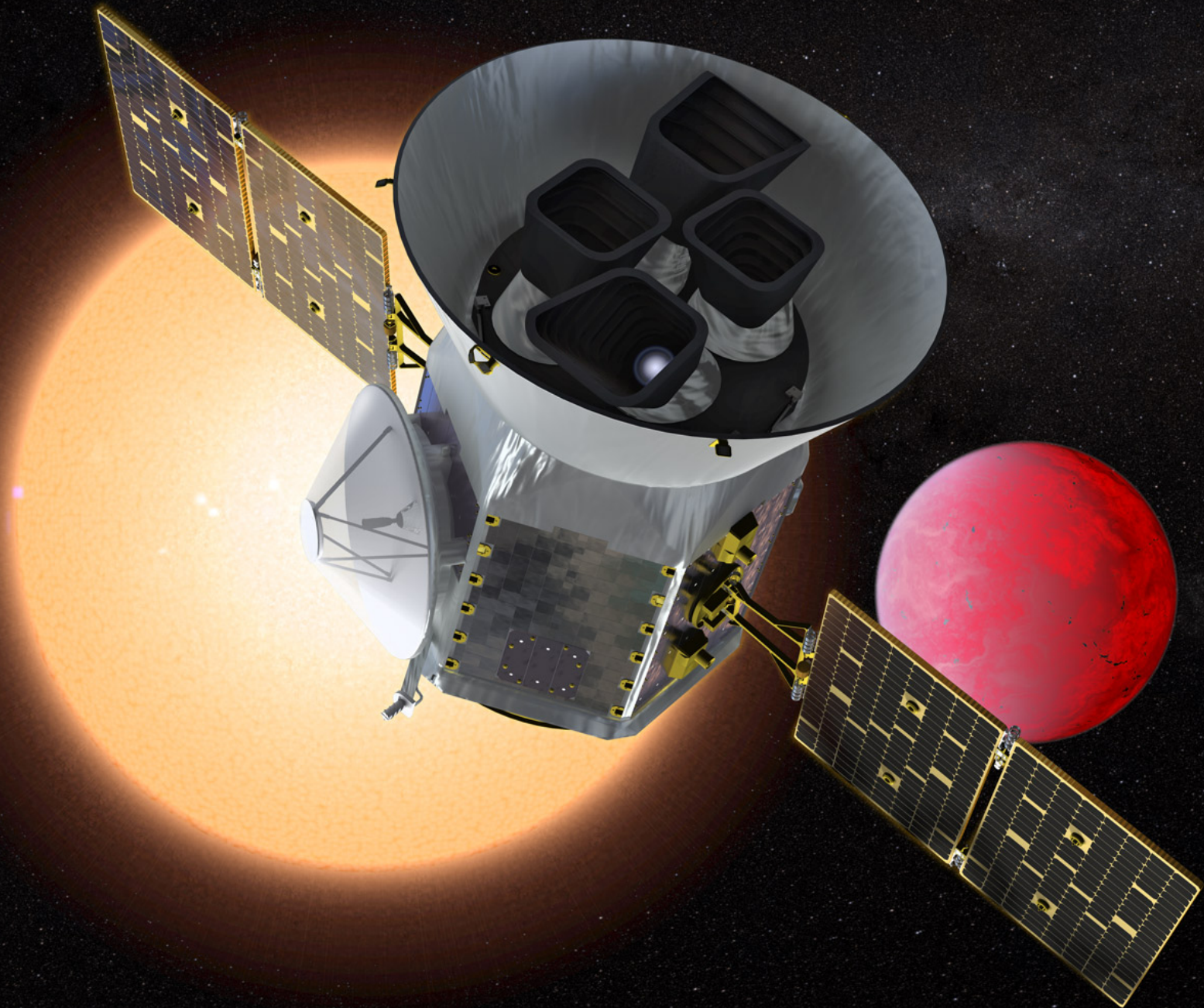
Artists impression



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)

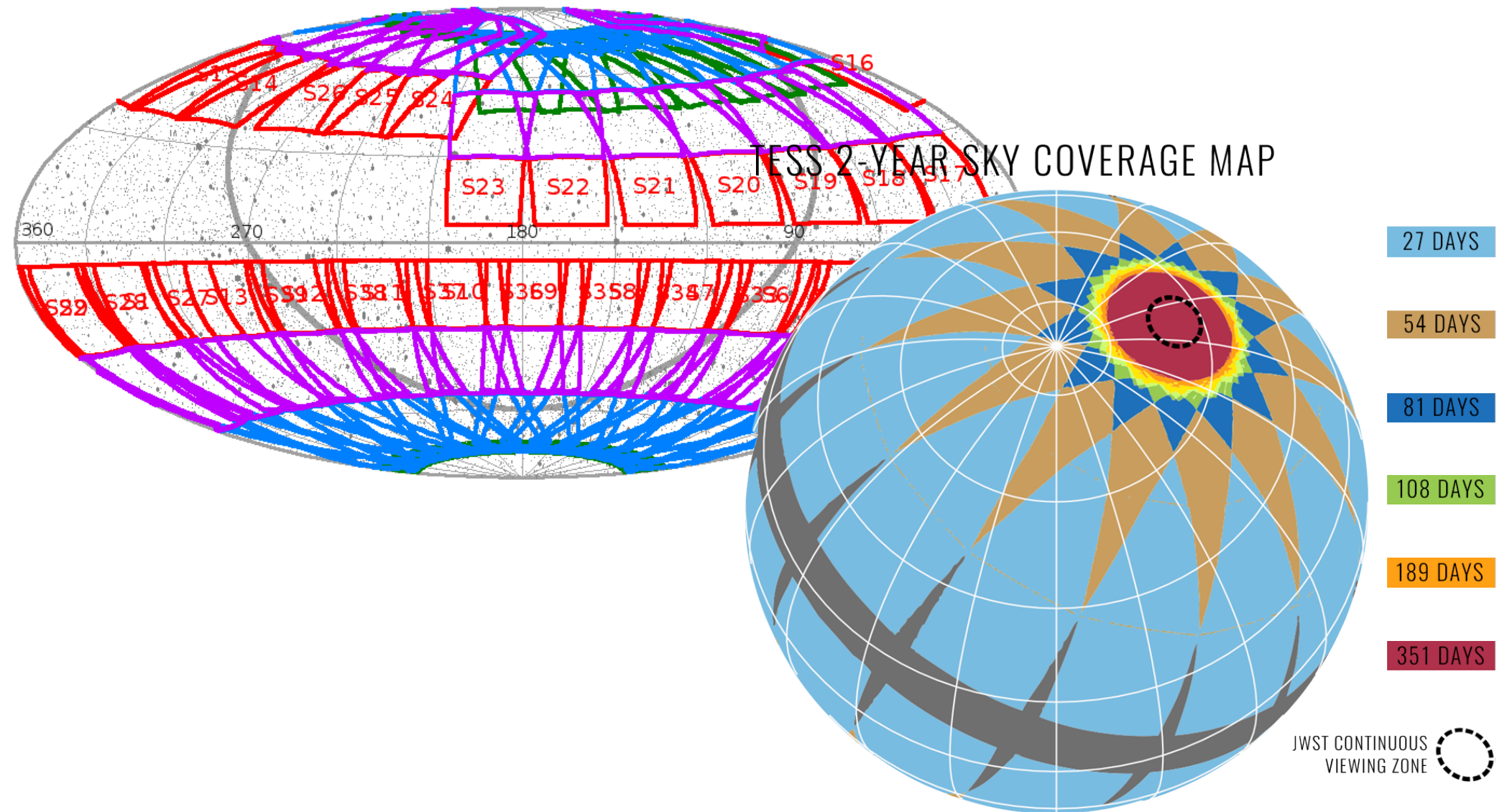
TESS



TESS

- Almost all sky coverage
- 4 x 100mm lenses
- Monitoring of more than 200k bright stars
- Targets will be 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

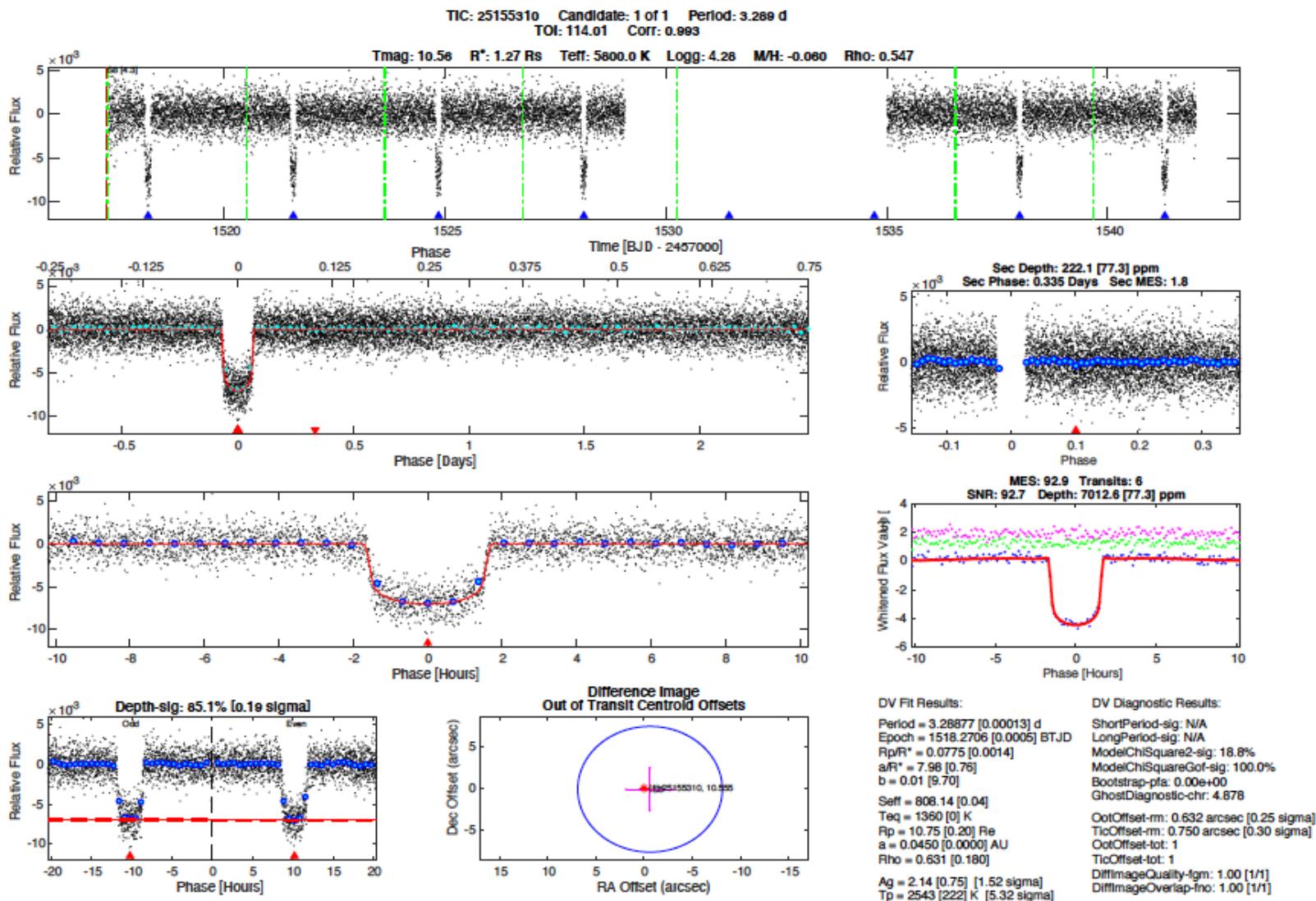


Example of a validation report

Summary Reports

Sectors 8 - 8

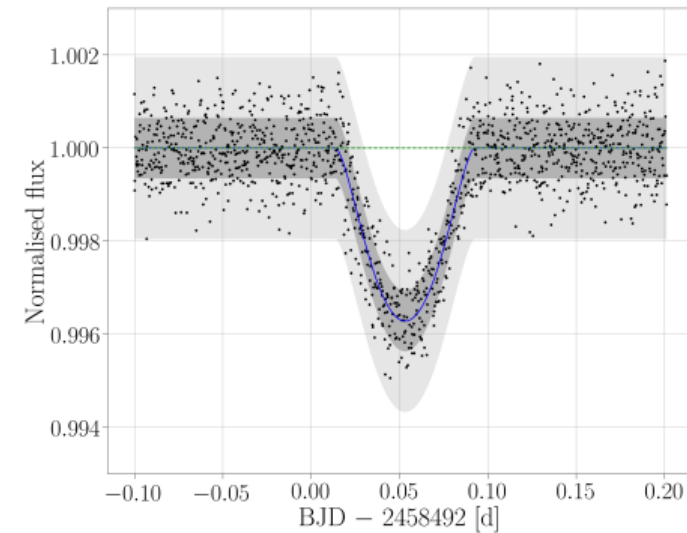
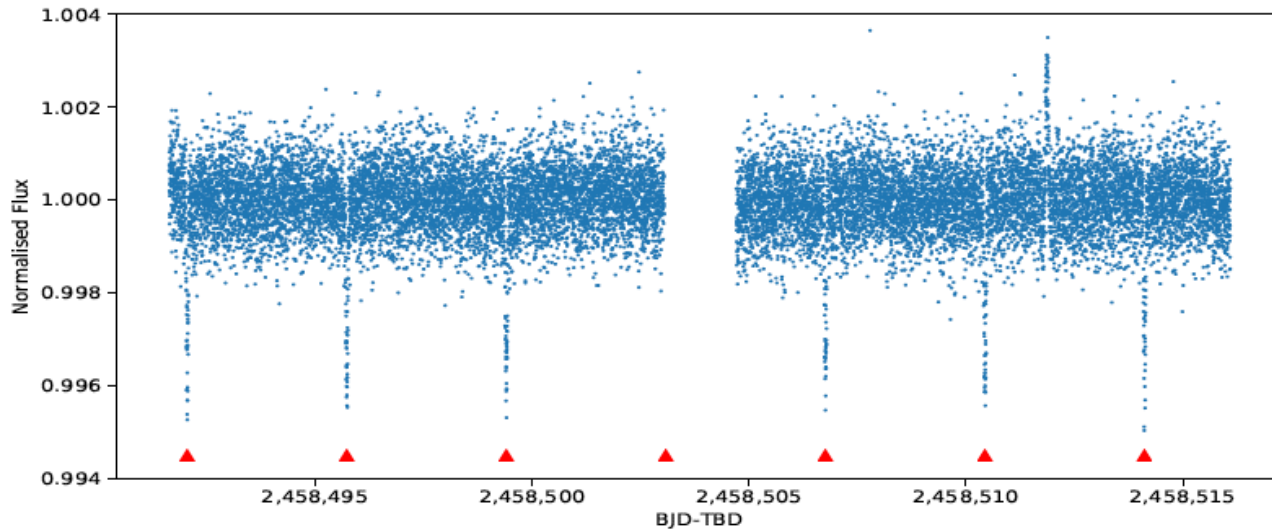
Target 25155310 / Planet Candidate 1



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

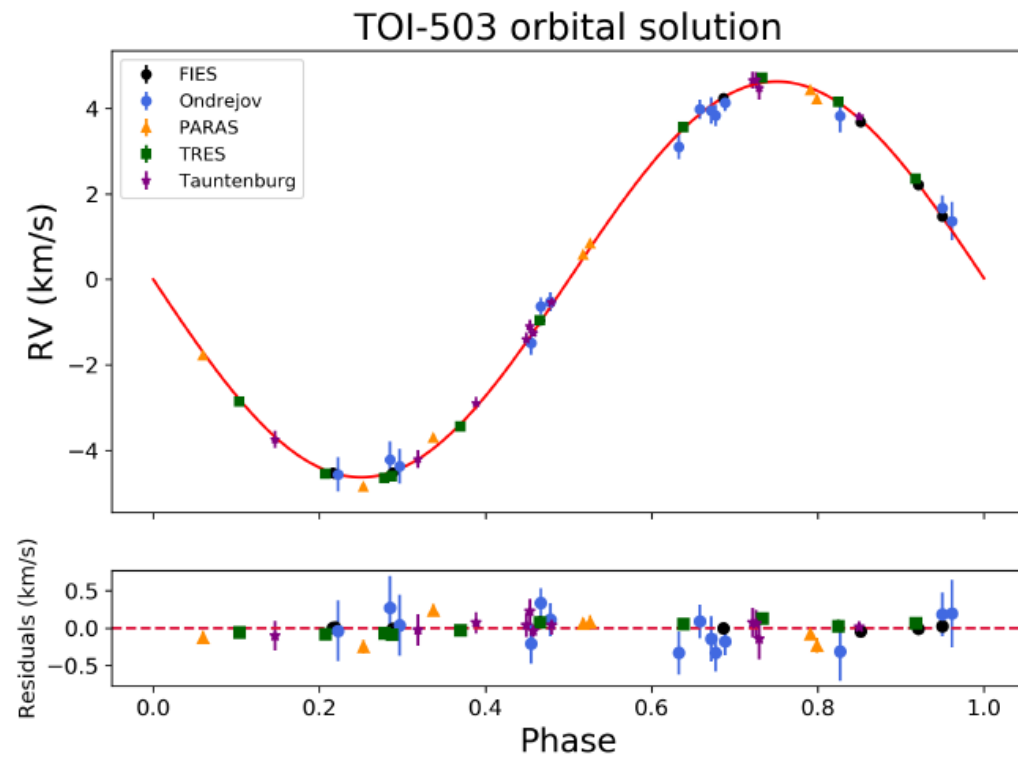
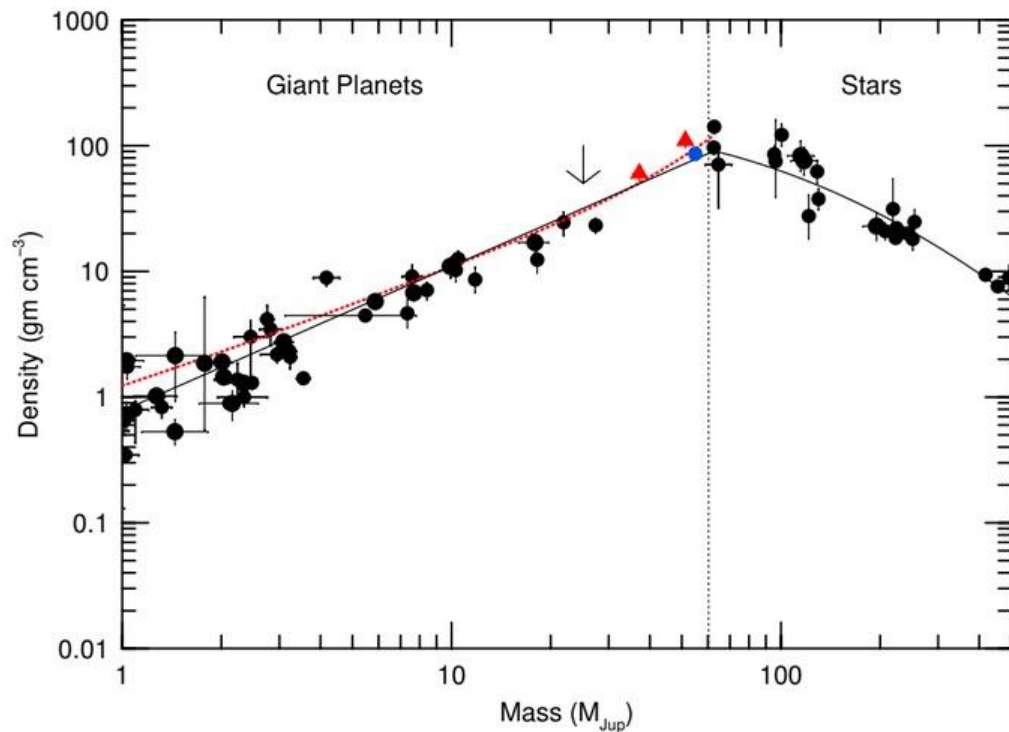
Candidate from TESS TOI-503?



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

First Brown Dwarf from Ondřejov

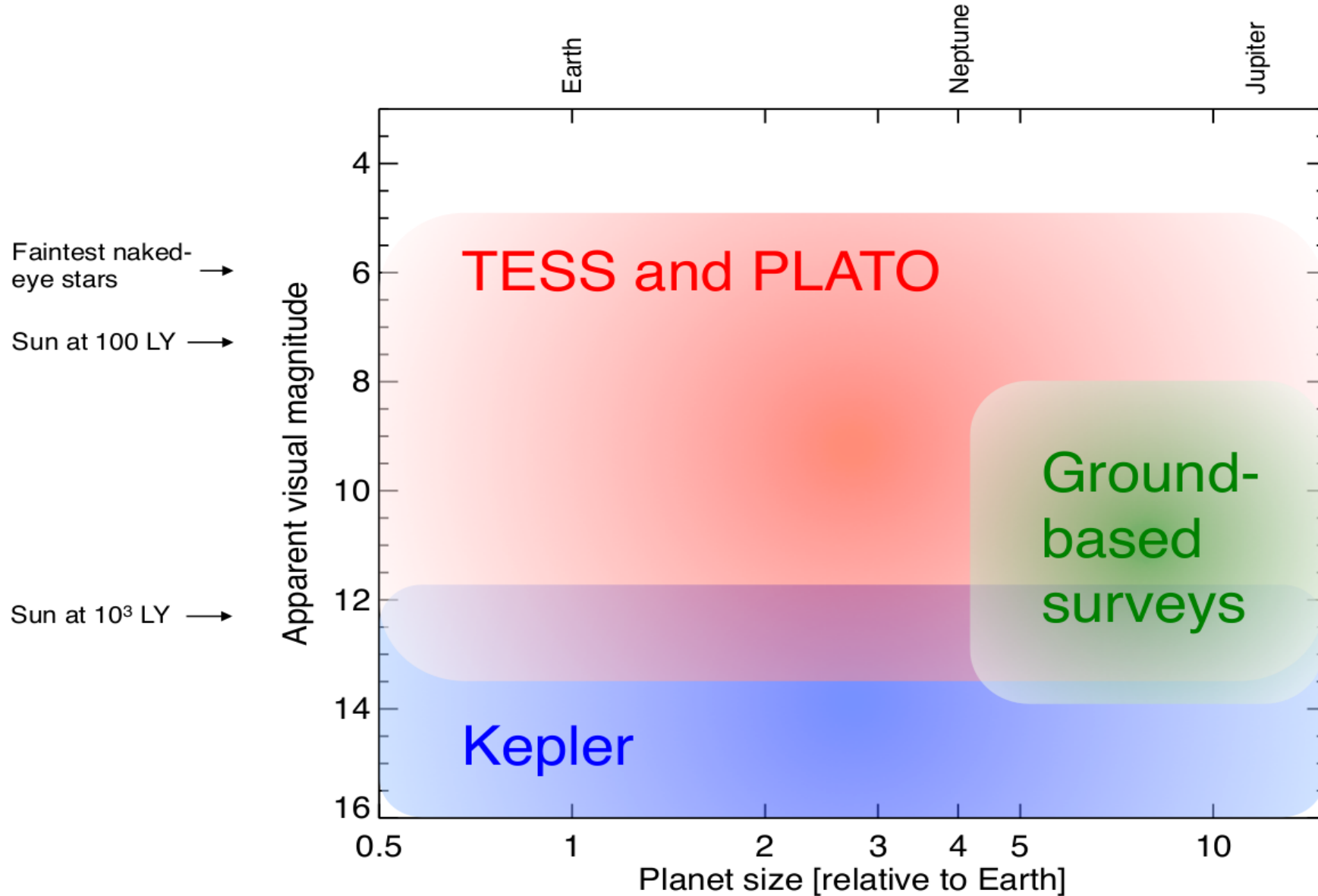
- Mass – 53 Jupiter masses
- Radial velocities between -5 a +5 km/s



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 synchronized
- The follow-up can take more than 6 months

Space missions compared



Credit: PLATO Space mission

Next week (06 November?)

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

- Please try to install

<https://adina.feinste.in/eleanor/>