

# Mass measurement with *ESPRESSO* of rocky worlds detected by TESS

F. Bouchy, F. Pepe, C. Lovis on behalf of the ESPRESSO consortium and science team



With the contribution of M.R. Zapatero, D. Ségransan, A. Sozzetti, O. Demangeon, M. Damasso, A. Malescot



# ESPRESSO in a nutshell

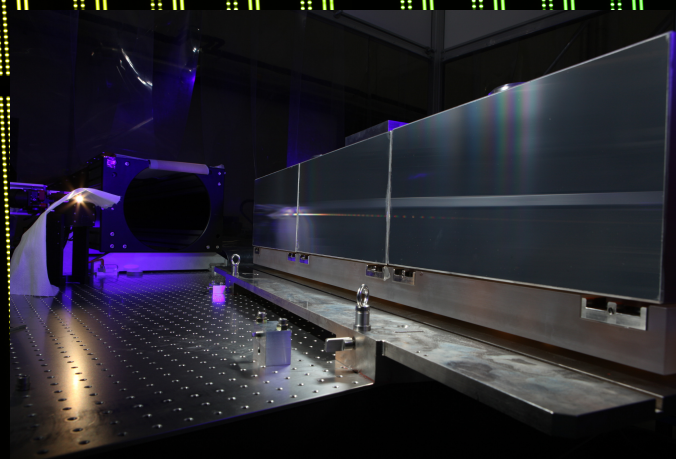
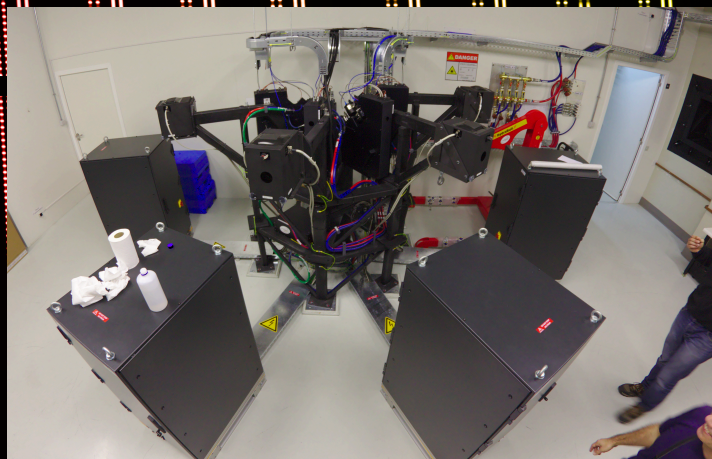
Echelle Spectrograph for Rocky Exoplanets and Stable Spectroscopic Observation

collect the light of any UT  
independently or together

Unit  
Telescope  
VLT

- 2007 STC and ESO identified need for a "HARPS" on the VLT
- Jan 2011 : Project Kick-Off
- May 2013 : Final Design Review
- Jan – Aug 2017 : Integration in Geneva
- 27<sup>th</sup> Nov 2017 : First light at Paranal
- 2<sup>nd</sup> Sept 2018 : Start of scientific operations
- 5<sup>th</sup> Sept 2018 : First TOIs release
- 6<sup>th</sup> Sep 2018 : DDT submitted (F. Pepe) & accepted for Pi Men c

Parameter	singleUHR	singleHR	multiMR
Wavelengths	Blue arm: 380 – 520 nm Red arm: 520 – 780 nm		
Resolving power	225'000	134'000	59'000
Aperture on sky	0.5 arcsec	1.0 arcsec	4x1.0 arcsec
Spectral sampling	2.5 pixels	4.5 pixels	10 pixels





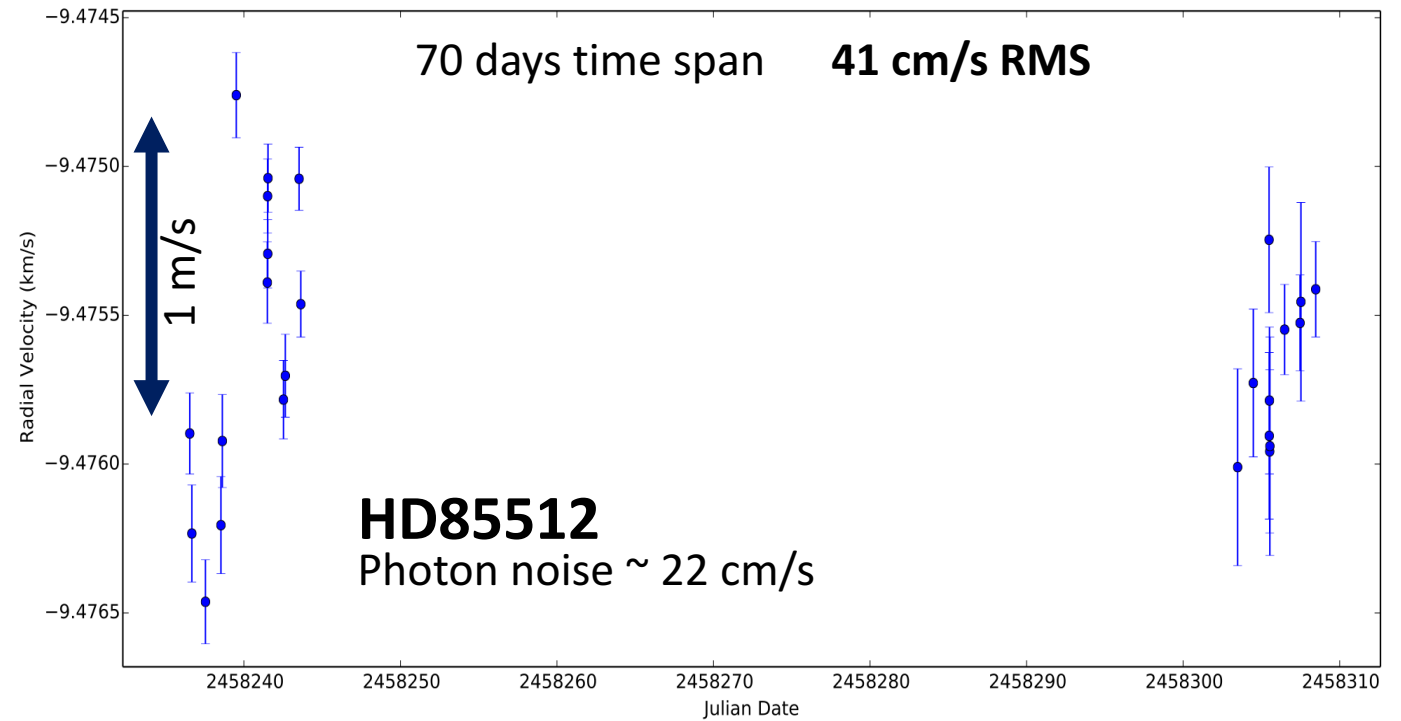
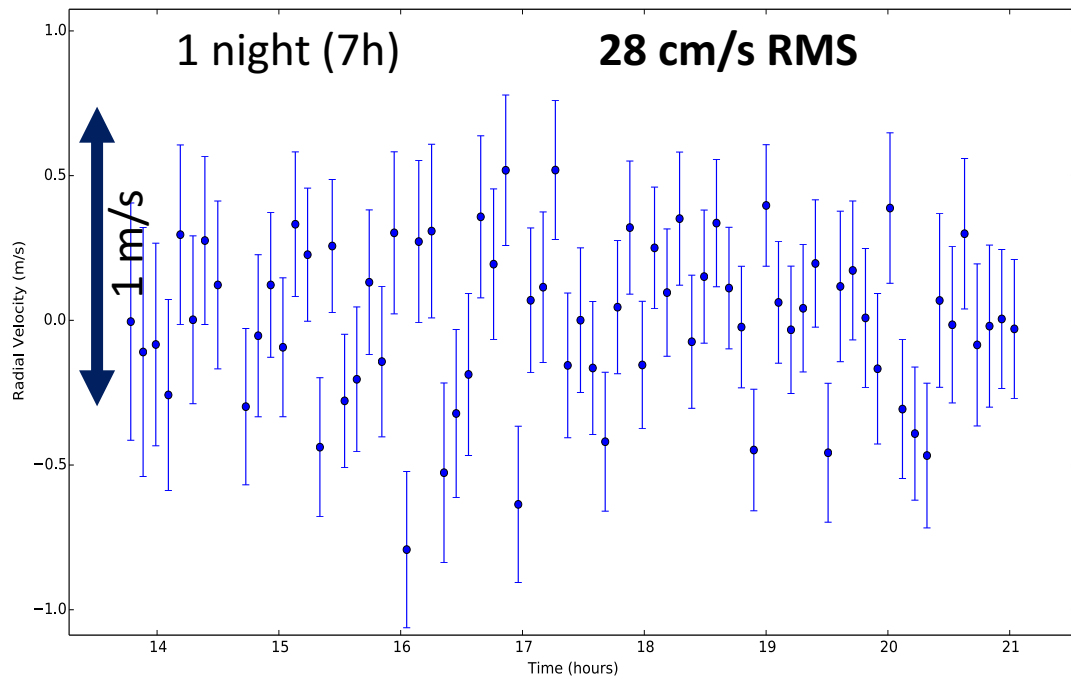
# ESPRESSO performances

- ❓ Instrumental effects -> better scrambling, better calibration sources, better detectors, improved software
- ❓ Photon noise -> Better efficiency, high spectral resolution, larger telescope(s), efficient observations
- ❓ Stellar noise -> Better understanding, pre-selection, observation strategy, activity indicators, modelling

## Benchmarks:

Mv=10    Texp = 2.5 min     $\sigma_{\text{phot}} = 100 \text{ cm/s}$   
Mv=7.7    Texp = 5 min     $\sigma_{\text{phot}} = 25 \text{ cm/s}$   
Mv= 4    Texp = 1 min     $\sigma_{\text{phot}} = 10 \text{ cm/s}$

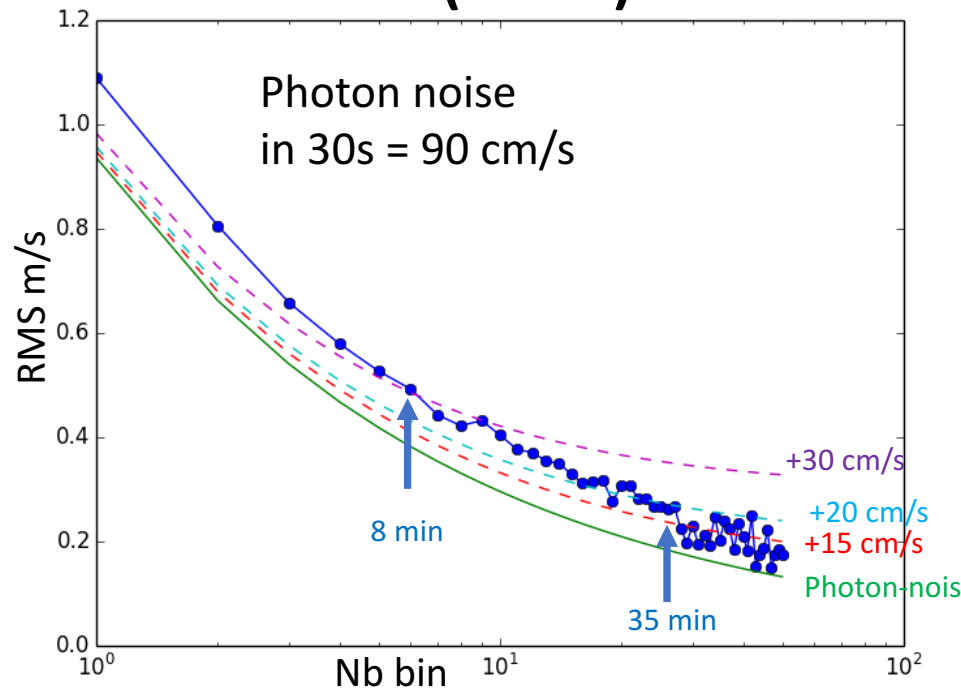
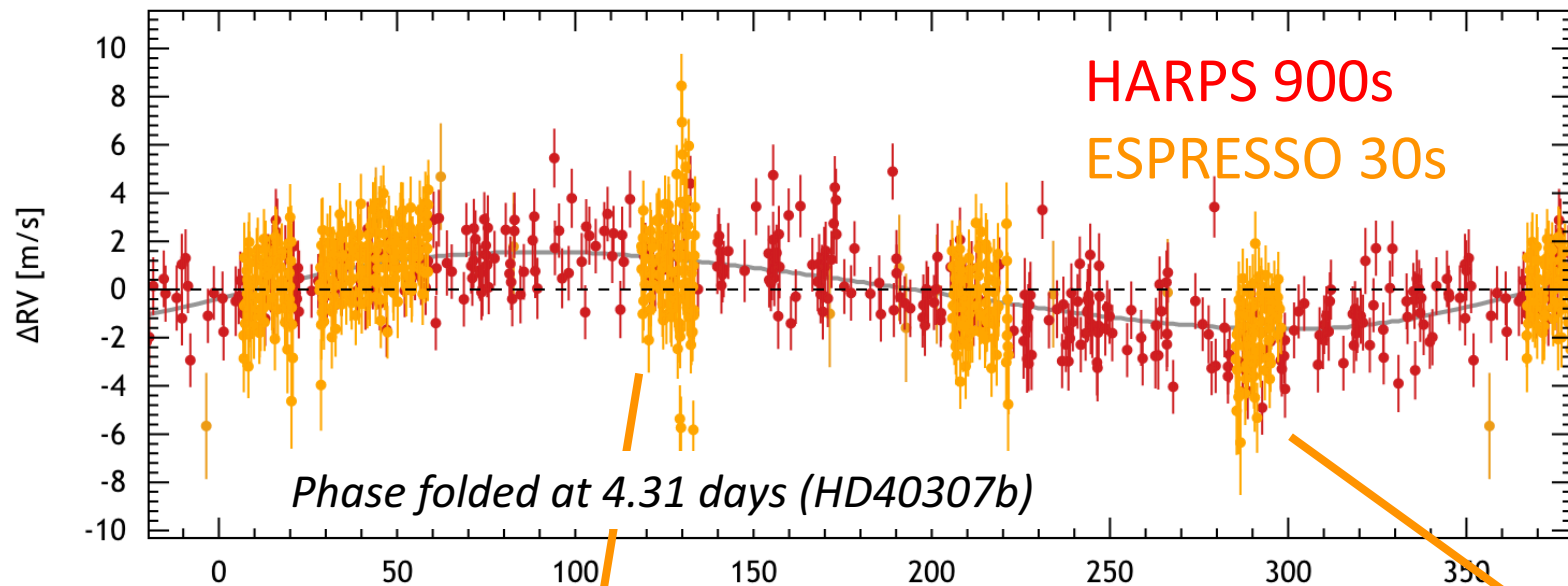
Wavelength calibration precision  
(combining ThAr + FP) at the level of 5 cm/s



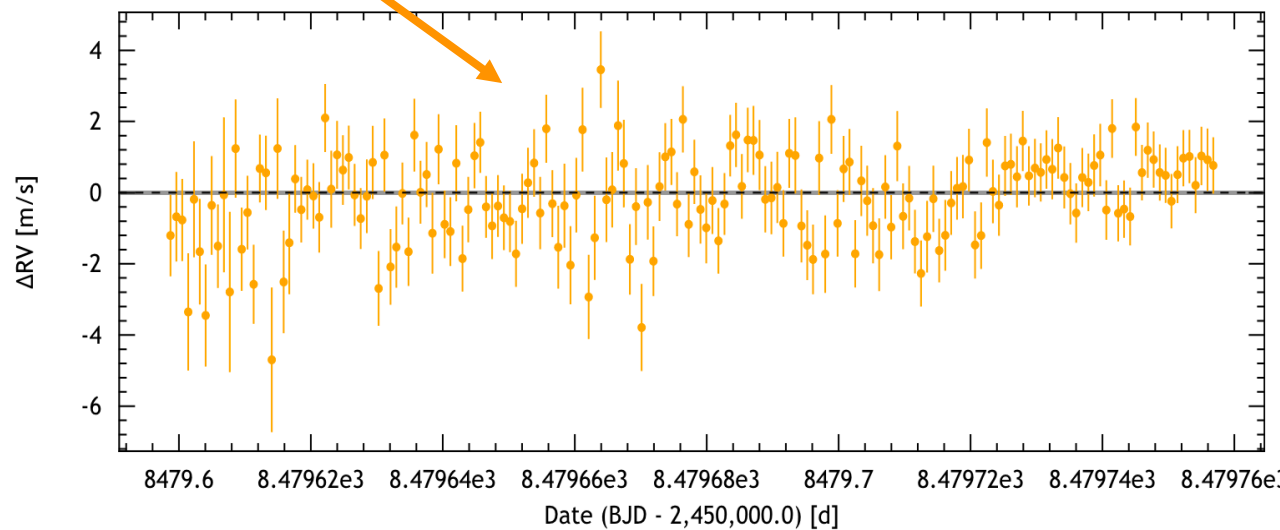
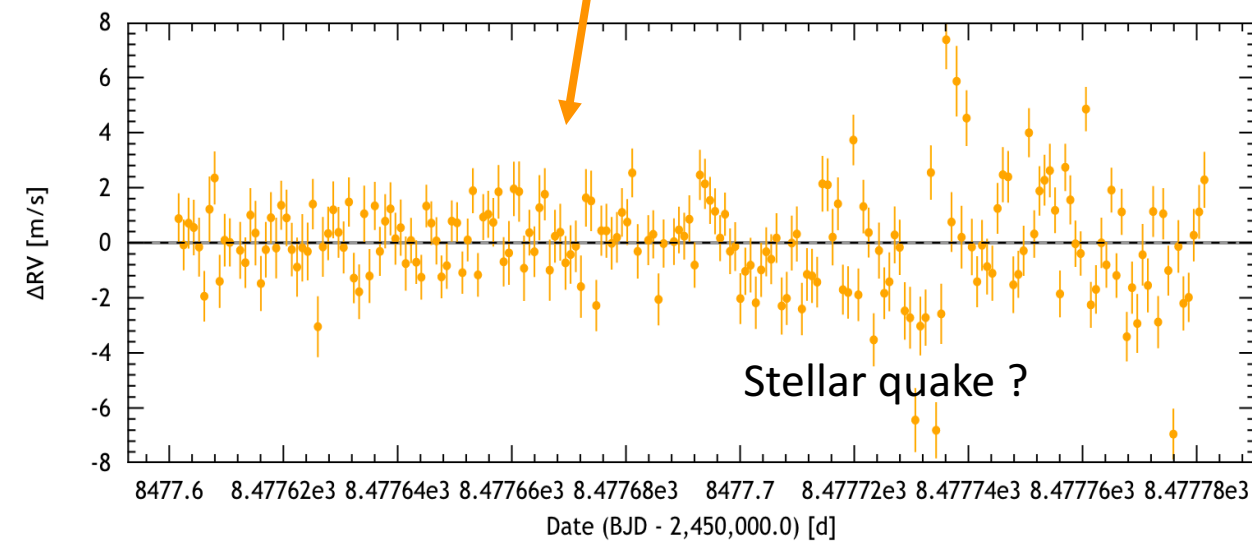


# ESPRESSO performances

## Intensive Doppler Monitoring of the nearby and bright K3 dwarf HD40307 (V=7.1)



P-mode oscillations @ 2.5-3.0 min





# ESPRESSO-GTO science goals

273 nights over 6-8 semesters

WP1 : Intensive RV searches for nearby habitable rocky exoplanets

WP2 : Survey for exoplanet atmospheres through transmission/emission spectroscopy

WP3 : Mass measurement of transiting small-size exoplanets (mainly from K2 and TESS)

WP4 : tests of the invariance of fundamental physical constants

27% = 73 nights



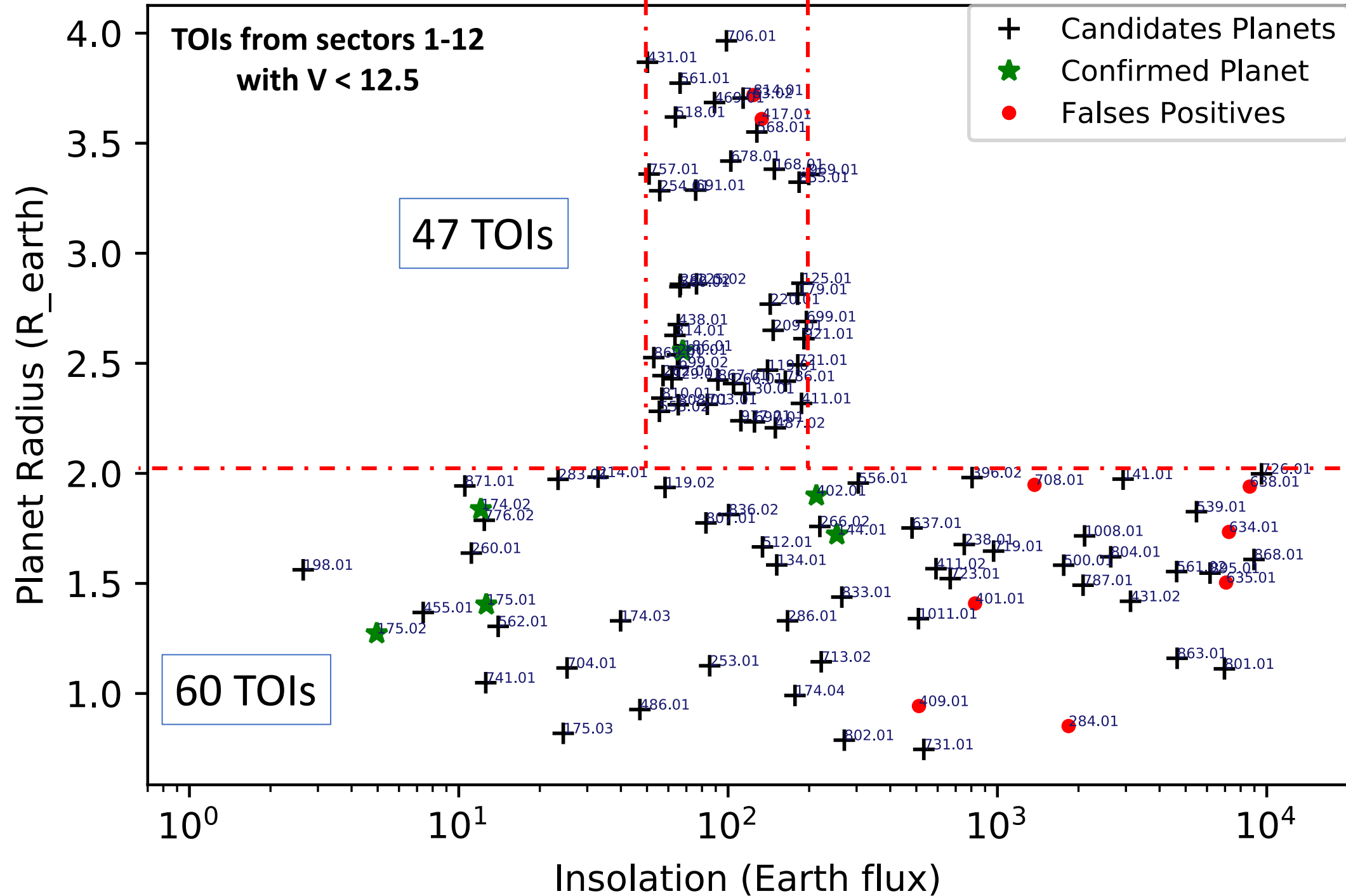
3.1) Characterize the rocky planet population up to the habitable zone

3.2) Explore the rocky/sub-Neptune transition within the 50-200x Earth irradiation range

3.3) Measure the mass of objects to be further characterized by JWST/ESPRESSO

- Precise *and* accurate mass measurements, eccentricity and multiplicity
- Explore low-mass/long-period domain inaccessible to other facilities
- Focus on the small-radius population  $R < 2.0 R_{\text{Earth}}$  with no expected H/He envelope with the possibility to constrain iron/rock/water fraction and their dependence on external parameters

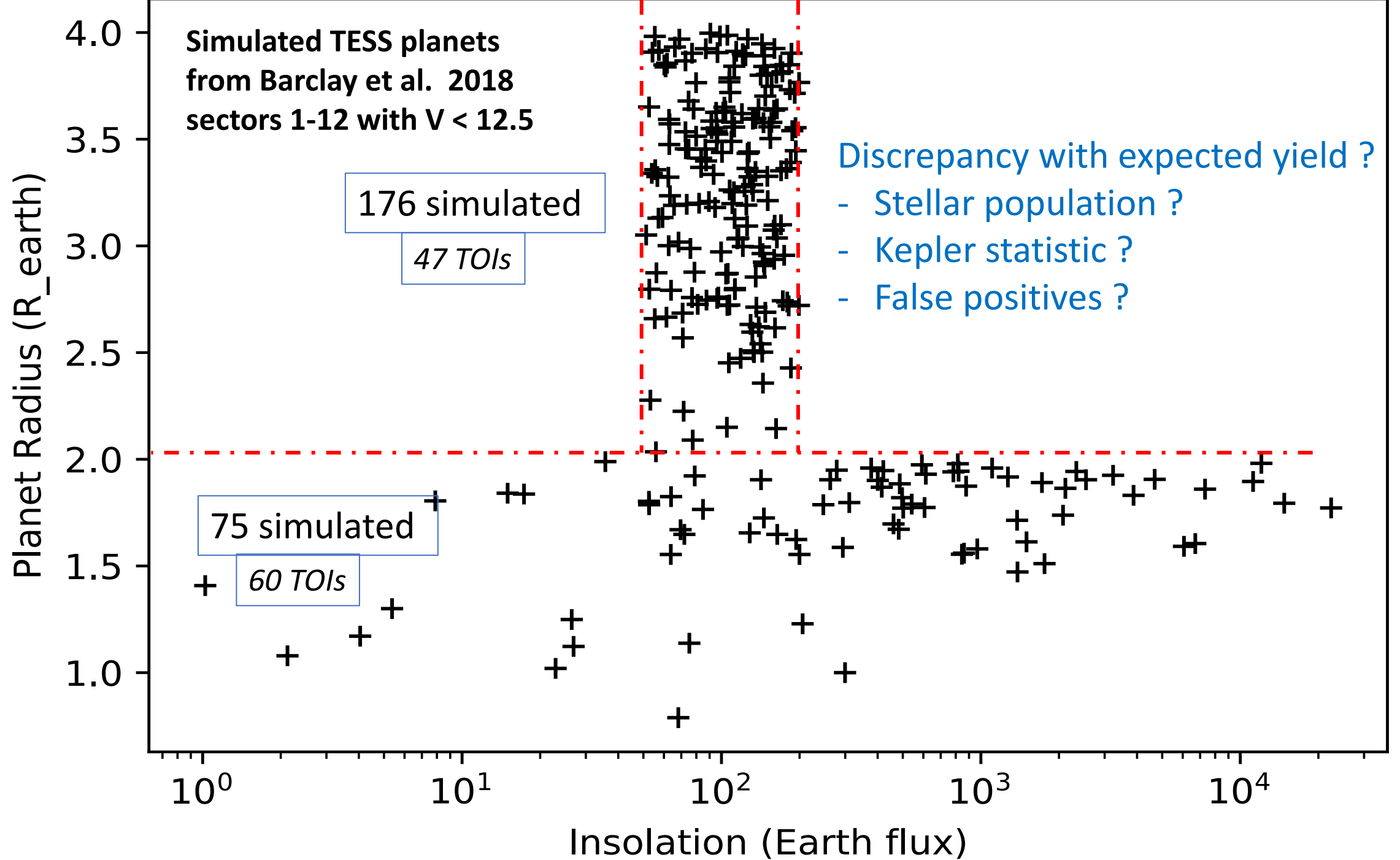


















# TOI-144 = Pi Men c

2.04  $R_{\oplus}$  @ 6.27 days

$V=5.7$

Huang et al. 2018

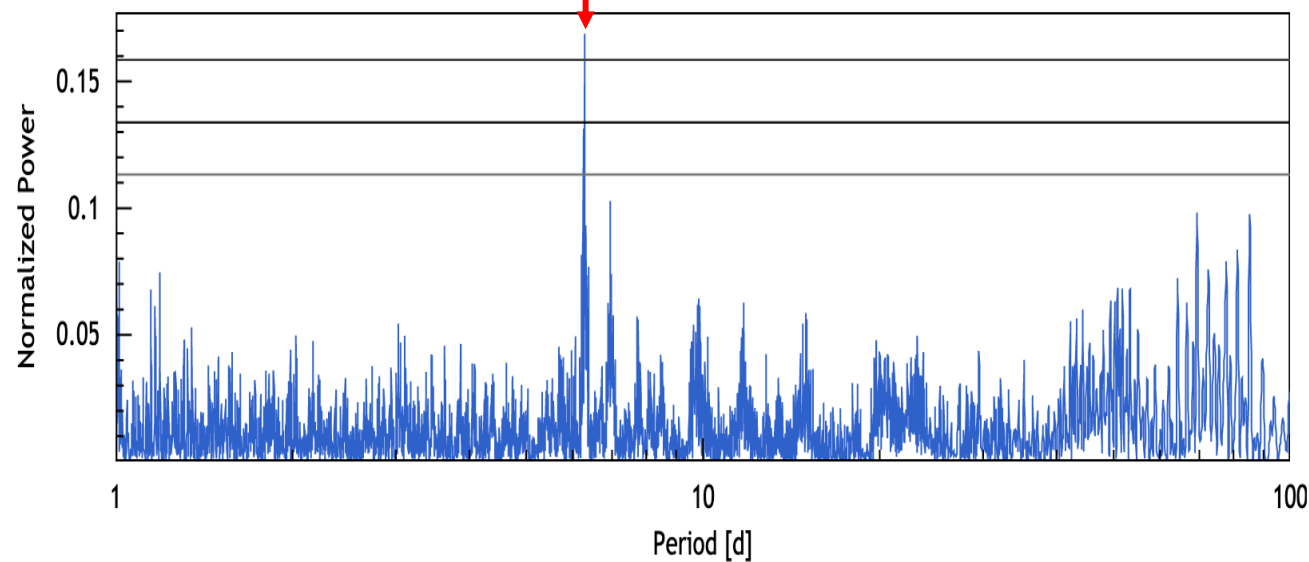
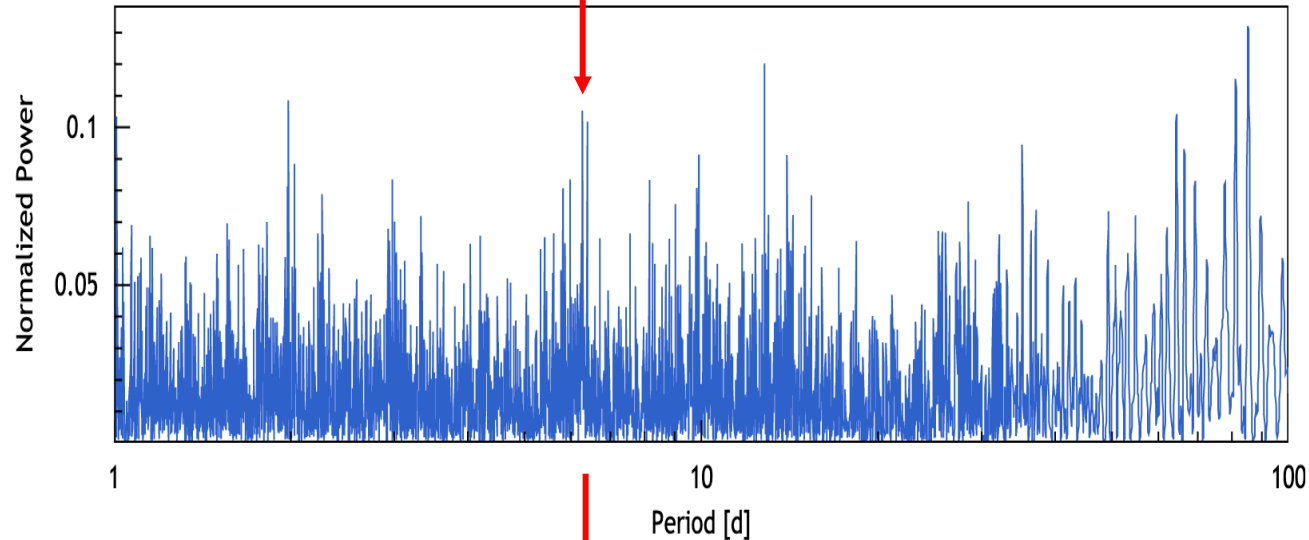
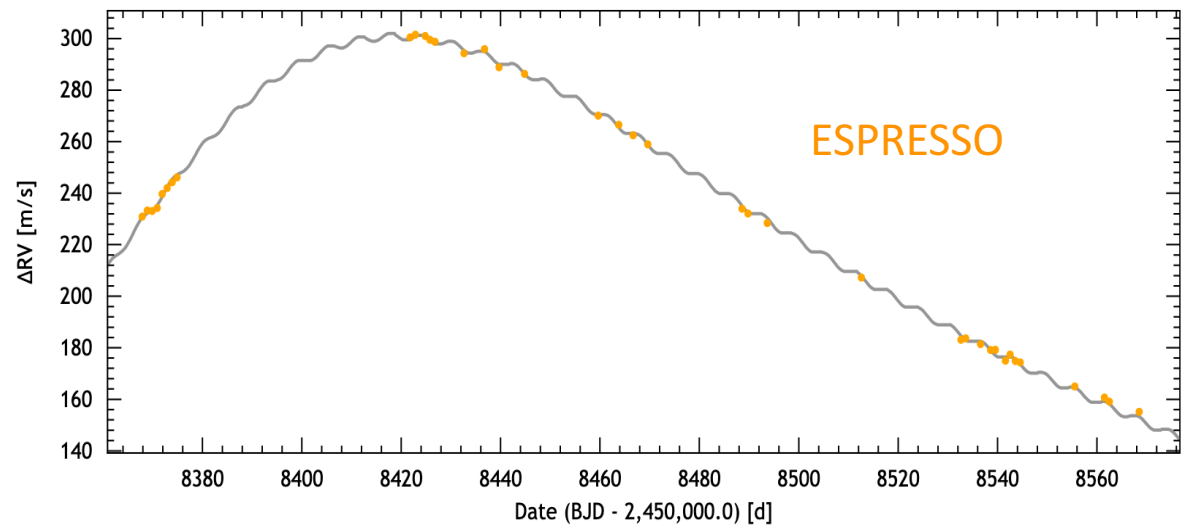
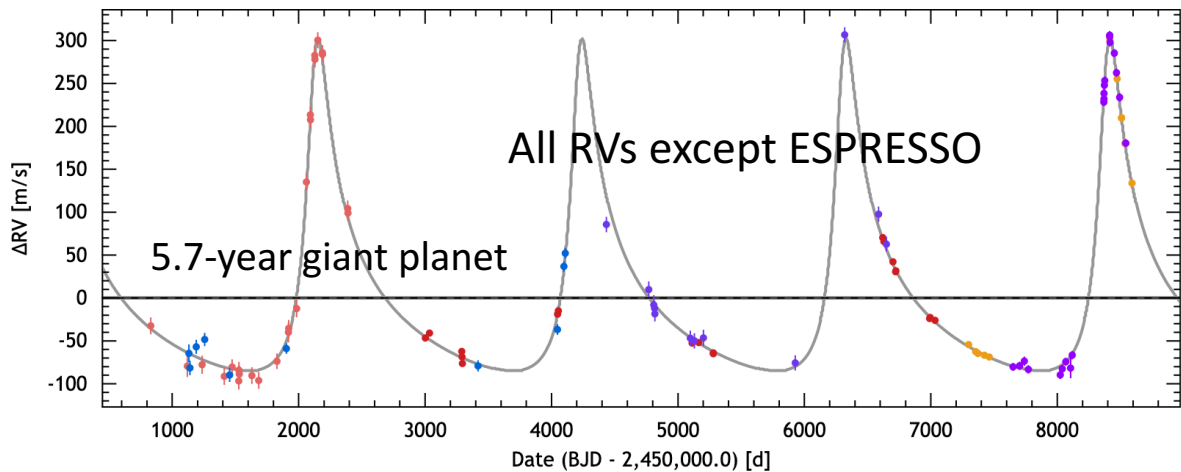
$K_c = 1.58 \pm 0.27$  m/s

$m_c = 4.82 \pm 0.85 M_{\oplus}$

Gandolfi et al. 2018

$K_c = 1.55 \pm 0.27$  m/s

$m_c = 4.52 \pm 0.81 M_{\oplus}$



■ FAP:10%

■ FAP:1%

■ FAP:0.1%



**TOI-144 = Pi Men c**

2.04 R<sub>⊕</sub> @ 6.27 days

V=5.7

Huang et al. 2018

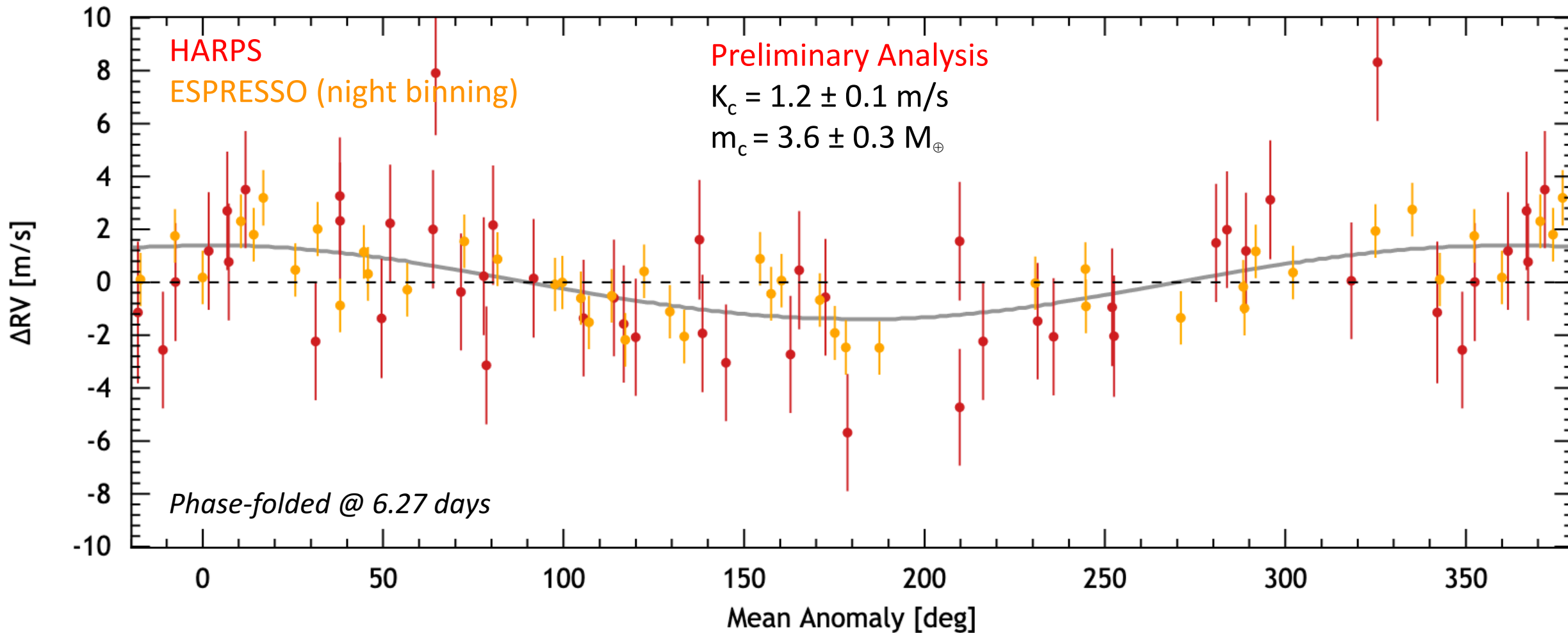
$K_c = 1.58 \pm 0.27$  m/s

$m_c = 4.82 \pm 0.85$  M<sub>⊕</sub>

Gandolfi et al. 2018

$K_c = 1.55 \pm 0.27$  m/s

$m_c = 4.52 \pm 0.81$  M<sub>⊕</sub>

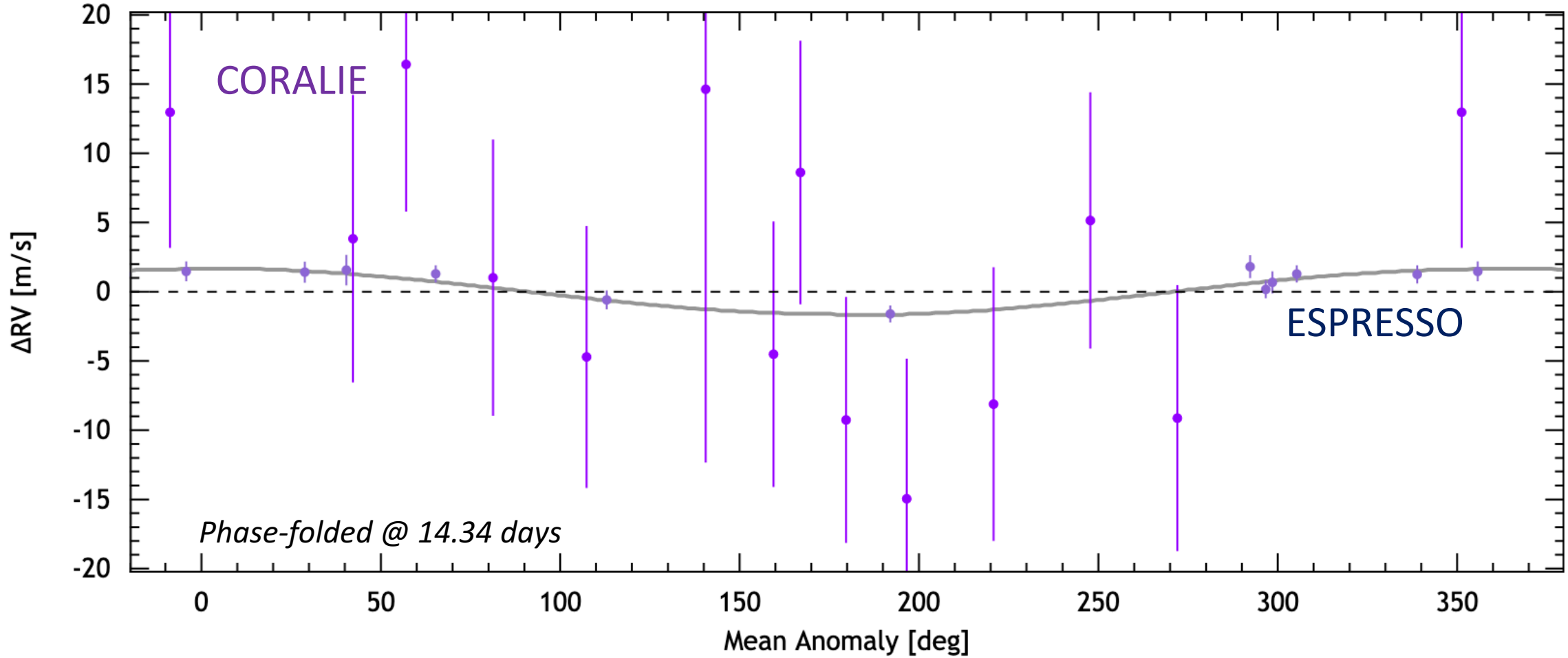


# TOI-130 = HD5278

2.36  $R_{\oplus}$  @ 14.34 days  
 $V = 7.9$

Preliminary Analysis

$K = 1.7 \pm 0.4$  m/s  $\rightarrow \sim 7 M_{\oplus}$   
+ additional long period signal



on-going observations

# TOI-175 = L 98-59

0.77  $R_{\oplus}$  @ 2.25 days

1.37  $R_{\oplus}$  @ 3.69 days

1.48  $R_{\oplus}$  @ 7.45 days

M3V V = 11.7

Cloutier et al. 2019 arXiv:1905.10669

< 1.03 m/s

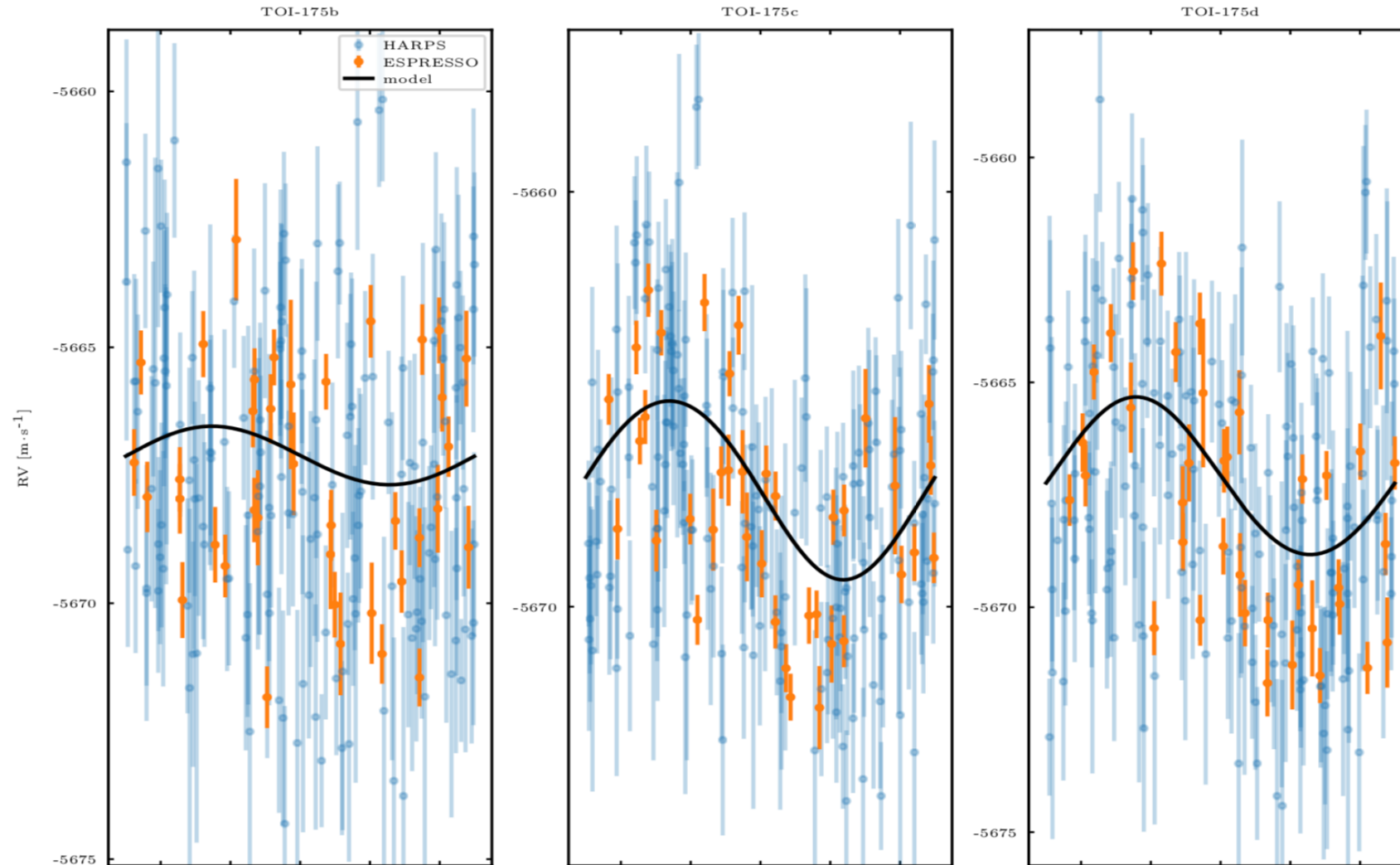
< 0.98  $M_{\oplus}$

$2.21 \pm 0.28$  m/s

$2.46 \pm 0.31$   $M_{\oplus}$

$1.61 \pm 0.36$  m/s

$2.26 \pm 0.50$   $M_{\oplus}$



161 HARPS spectra

39 ESPRESSO spectra

Preliminary Analysis

$m_b = 0.53 \pm 0.20$   $M_{\oplus}$



## ESPRESSO on-going improvements

- Service mode observations (better sampling)
- Stellar activity indexes
- CCF mask optimisation (up to 780 nm)
- Laser Frequency Comb fiabilisation
- Recent fiber link replacement (last June)

