TOI-836: Two planets transiting a nearby K-dwarf

Faith Hawthorn

(she/her)

WARWICK
THE UNIVERSITY OF WARWICK

TOI-836

‘TOI-836: A super-Earth and mini-Neptune transiting a nearby K-dwarf’

- Observed with TESS in April 2019
- Bright (T = **8.5** mag, V = **9.92** mag)
- Nearby (**27.5** pc, **89.7** ly)
- High proper motion (**201.4** mas/yr)
- Significant TTVs (**5-45** mins)
- `exoplanet` package (Dan Foreman-Mackey)[1]
- Target Pixel File (`tpfplotter`)[2] and **Keck2** imaging

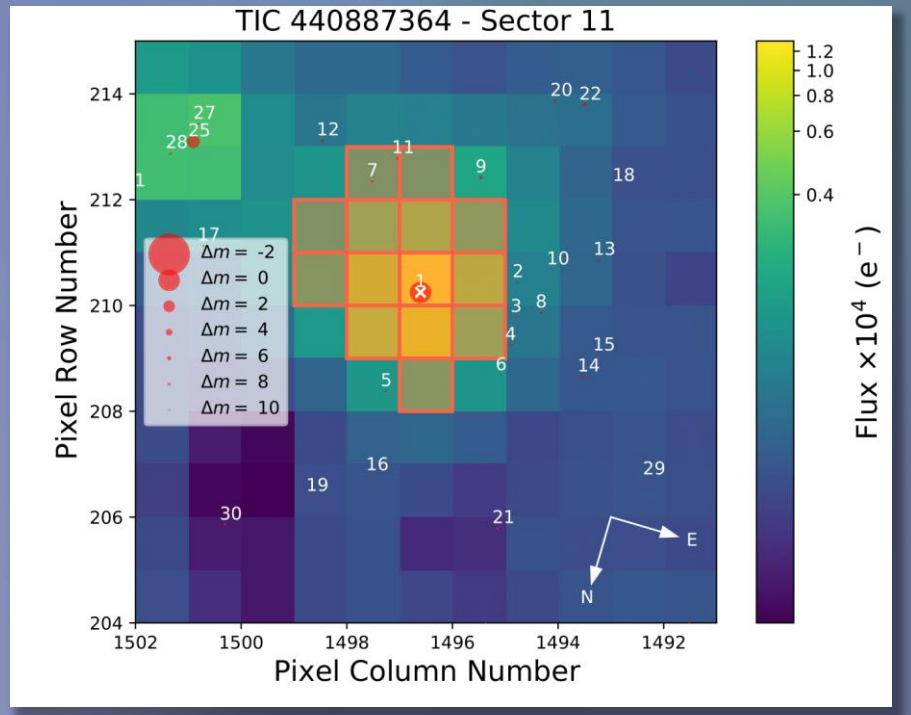


Image credit: `tpfplotter` (Aller et al., 2020)

[1] `exoplanet`: Gradient-based probabilistic inference for exoplanet data & other astronomical time series – Foreman-Mackey et al., 2021
[2] Planetary nebulae seen with TESS: Discovery of new binary central star candidates from Cycle 1 – Aller et al., 2020

WARWICK
THE UNIVERSITY OF WARWICK

TOI-836

‘TOI-836: A super-Earth and mini-Neptune transiting a nearby K-dwarf’

- Observed with TESS in April 2019
- Bright (T = **8.5** mag, V = **9.92** mag)
- Nearby (**27.5** pc, **89.7** ly)
- High proper motion (**201.4** mas/yr)
- Significant TTVs (**5-45** mins)
- `exoplanet` package (Dan Foreman-Mackey)[1]
- Target Pixel File (`tpfplotter`)[2] and **Keck2** imaging

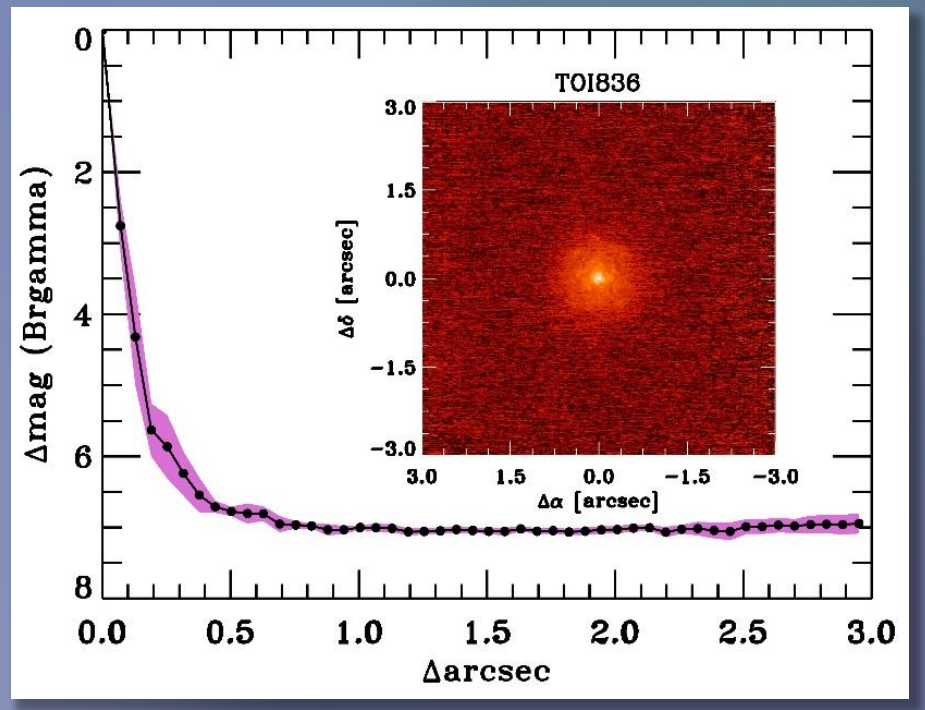


Image credit: Keck2-10m (Beichman, Ciardi)

[1] `exoplanet`: Gradient-based probabilistic inference for exoplanet data & other astronomical time series – Foreman-Mackey et al., 2021
[2] Planetary nebulae seen with TESS: Discovery of new binary central star candidates from Cycle 1 – Aller et al., 2020

WARWICK
THE UNIVERSITY OF WARWICK

Observations

Photometry (Transit)

- TESS - sector 11, sector 38
- CHEOPS x5
- NGTS x2
- MEarth-South
- LCO x14
- ASTEP-South

Spectroscopy (RV)

- HARPS x41
- PFS x30
- MINERVA-Australis x27
- HIRES x11
- iSHELL x10

WARWICK
THE UNIVERSITY OF WARWICK

Hints of TTVs

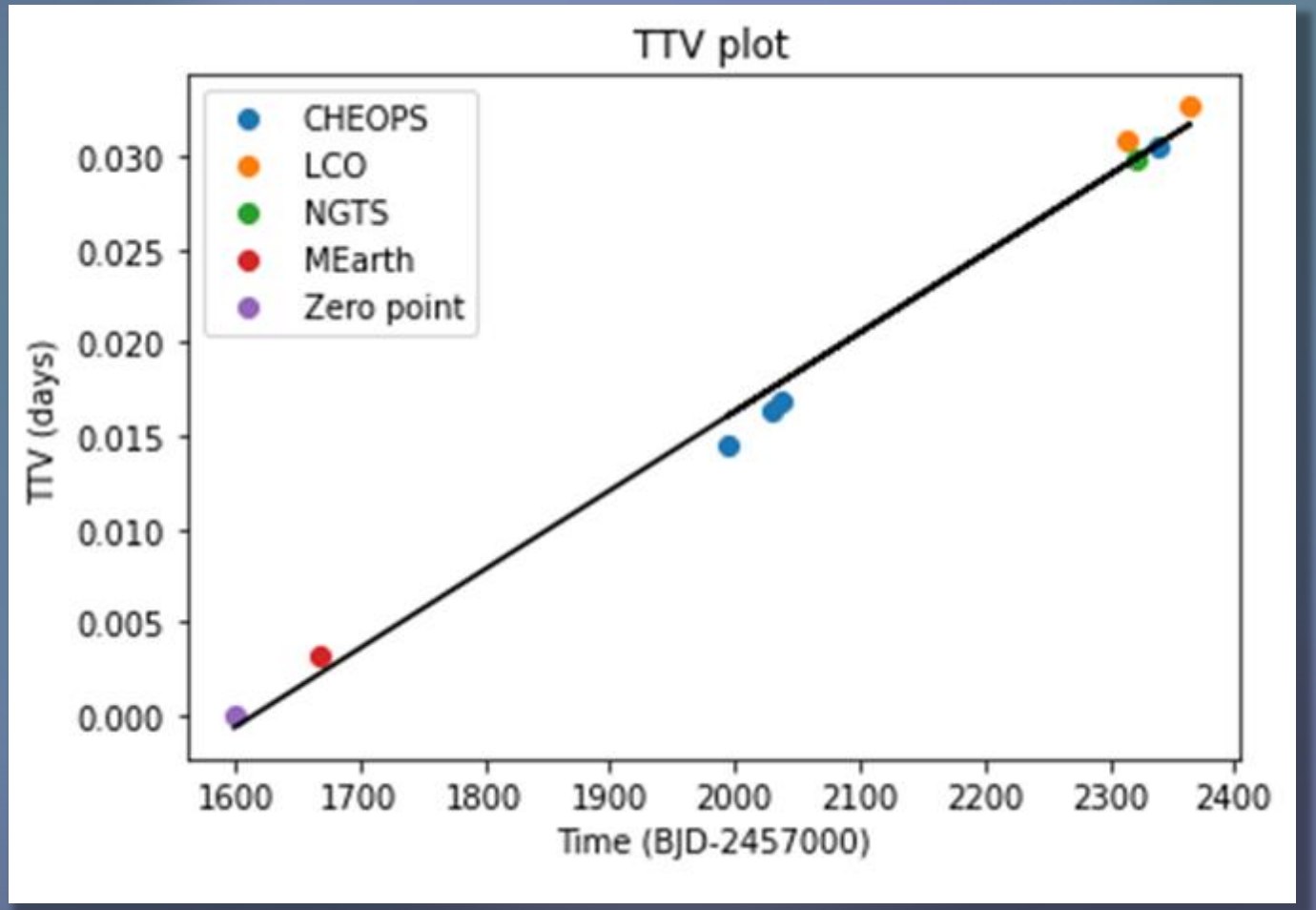


Image and work credit: Harvey Gillard, Tamzin Masters – University of Warwick

WARWICK
THE UNIVERSITY OF WARWICK

Why CHEOPS?

- Sufficient brightness in CHEOPS band (V = **9.92** mag)
- Transit durations are short enough – continuous monitoring unnecessary
- TTVs on suitable and measurable order
- Planet b transit is too shallow for many ground-based observations
- Planet radius refinement

Image credit: ESA/ATG medialab

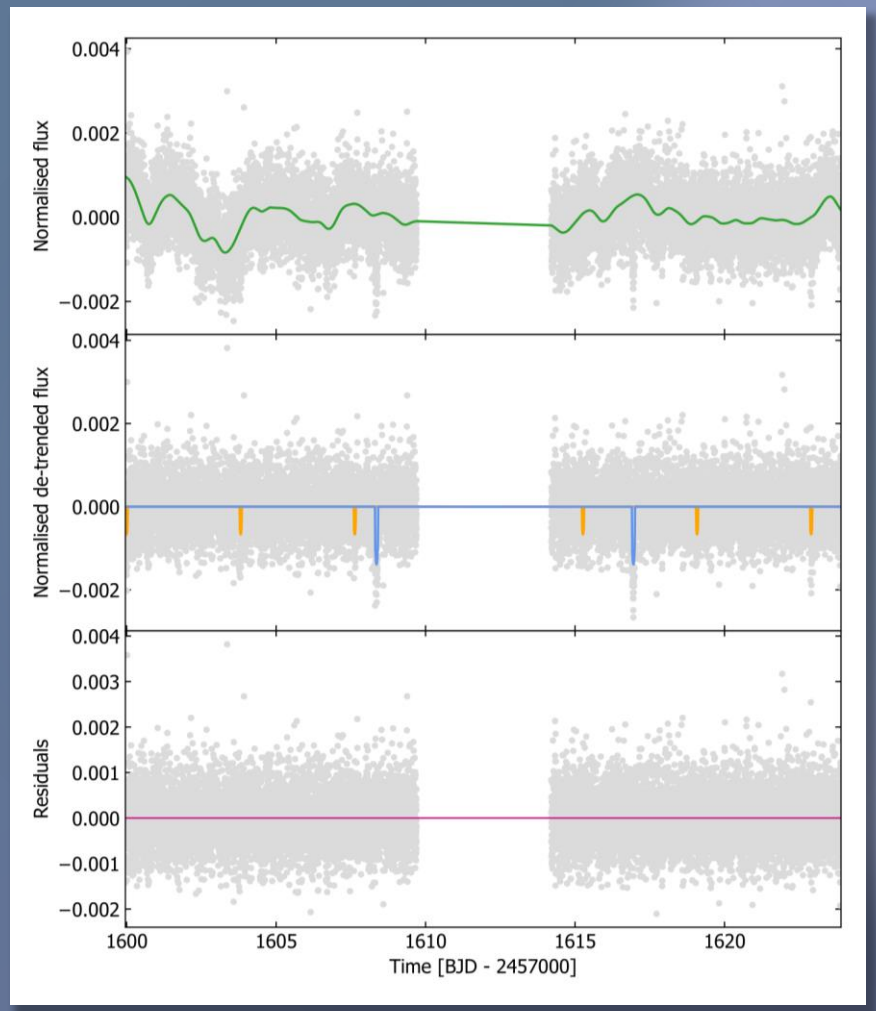
WARWICK
THE UNIVERSITY OF WARWICK

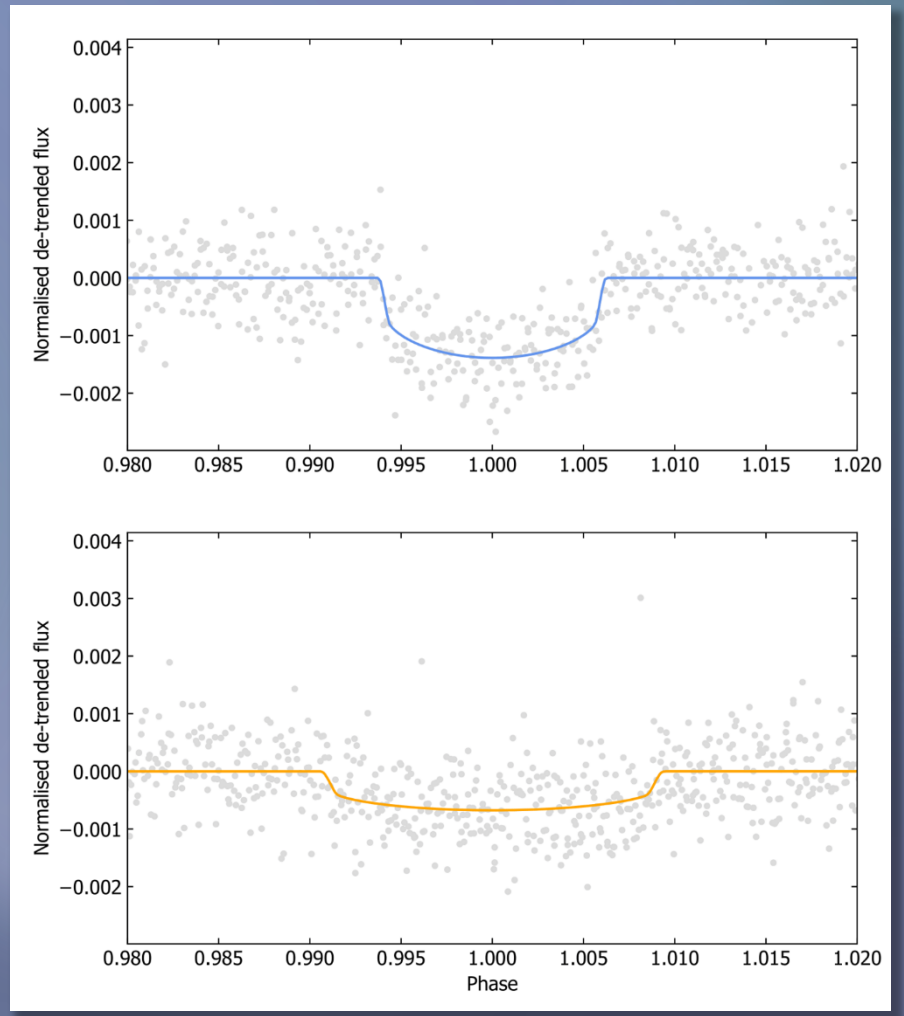
CHEOPS observations

- CHEOPS bridges the gap between TESS sectors 11 and 38
- **4 transits** of TOI-836 c
- **1 transit** of TOI-836 b

WARWICK
THE UNIVERSITY OF WARWICK

TESS Sector 11





GP model

TESS PDCSAP

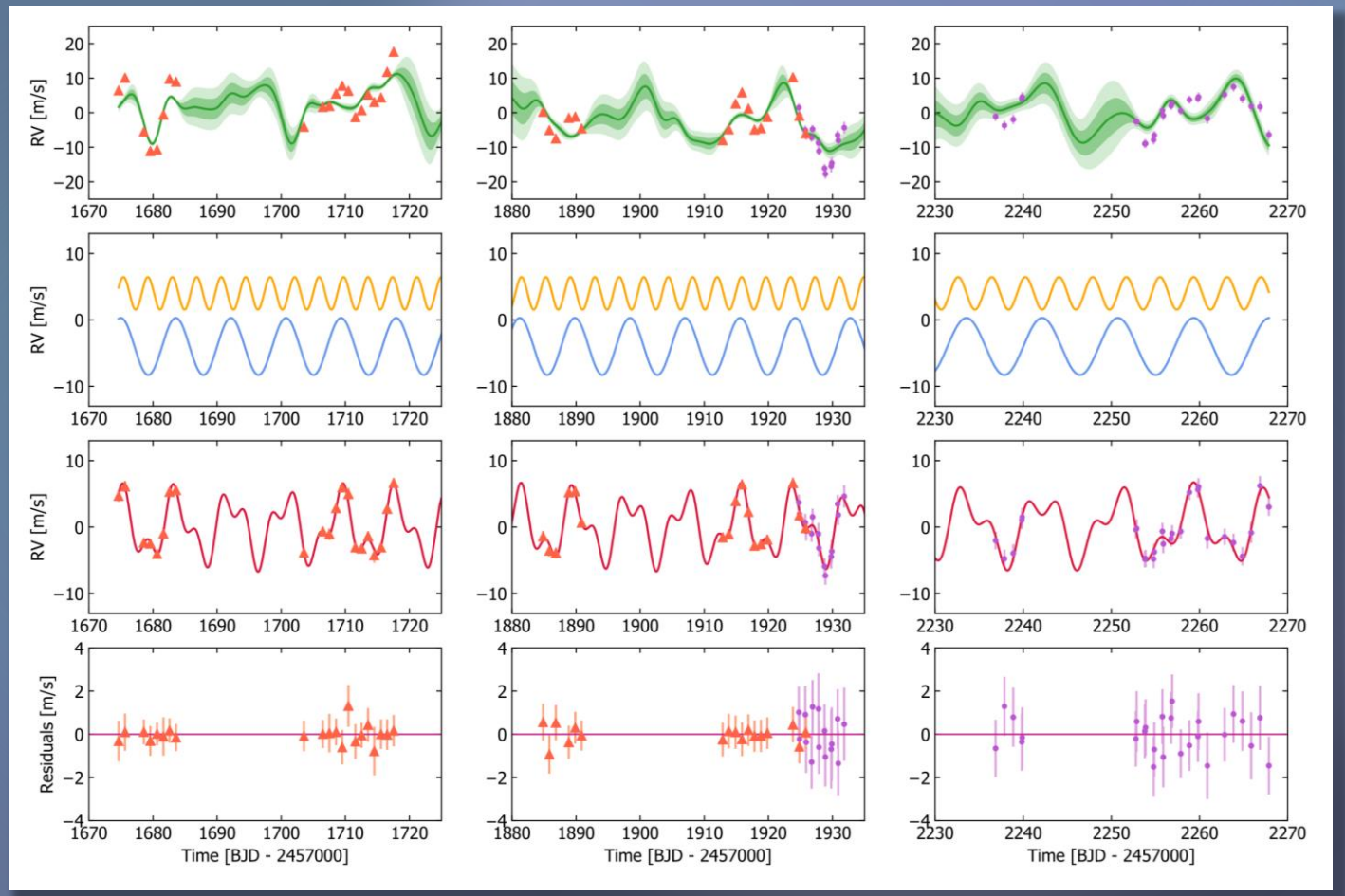
TOI-836 b model

TOI-836 c model

Baseline

WARWICK
THE UNIVERSITY OF WARWICK

HARPS + PFS

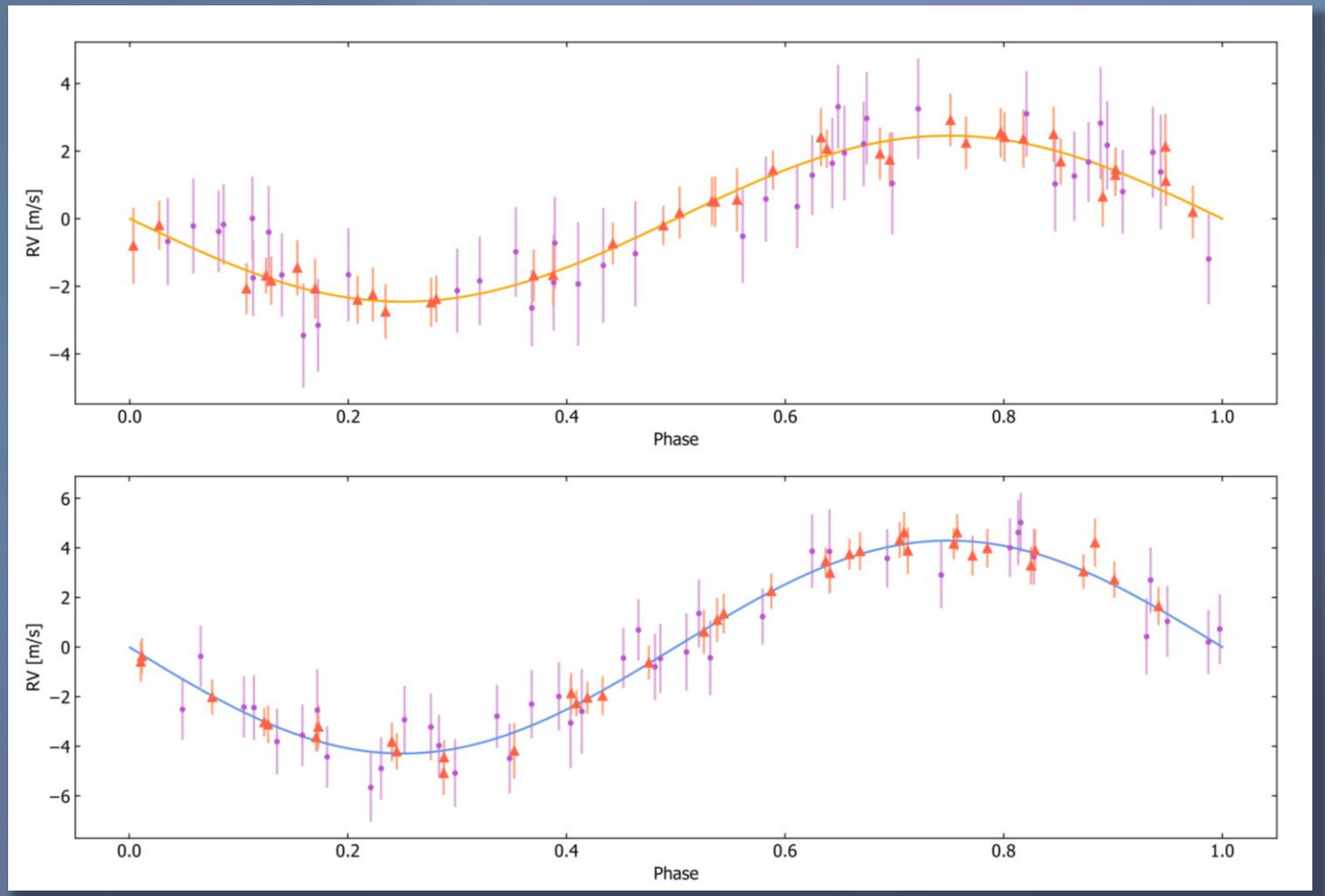


GP model
HARPS data
PFS data
TOI-836 b model
TOI-836 c model
Combined model
Baseline

~August 2019 ~February 2020 ~February 2021

WARWICK
THE UNIVERSITY OF WARWICK

HARPS + PFS



HARPS data
PFS data
TOI-836 b model
TOI-836 c model

Stellar parameters (HARPS)

- $0.648 \pm 0.031\ M_{\odot}$
- $0.564 \pm 0.018\ R_{\odot}$
- $\log(g) = 4.743 \pm 0.105$
- $T_{eff} \approx 4552$ K
- $[Fe/H] \approx -0.284$

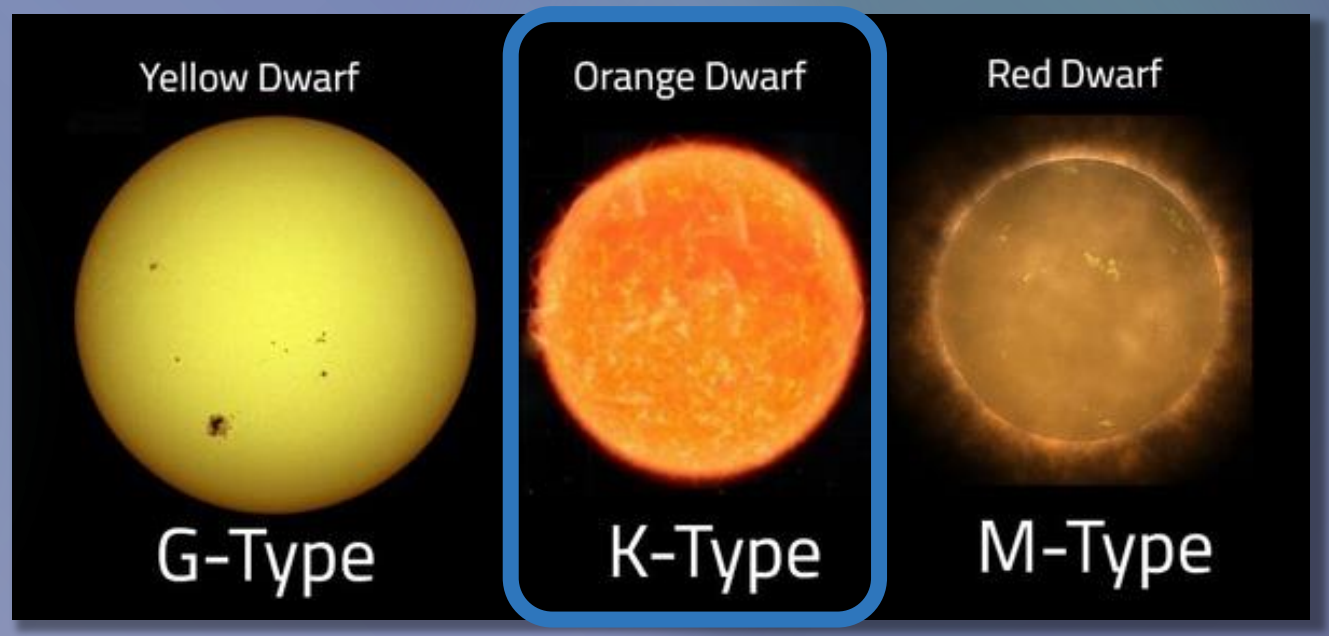


Image credit: Sankalan Baidya / Facts Legend

Vardan Adibekyan, Sérgio Sousa, Nuno Santos, Elisa Delgado-Mena

WARWICK
THE UNIVERSITY OF WARWICK

Stellar rotation

- Predicted **~21 day** period in DACE[1] from HARPS data
- Confirmed with **WASP-South**

Coel Hellier

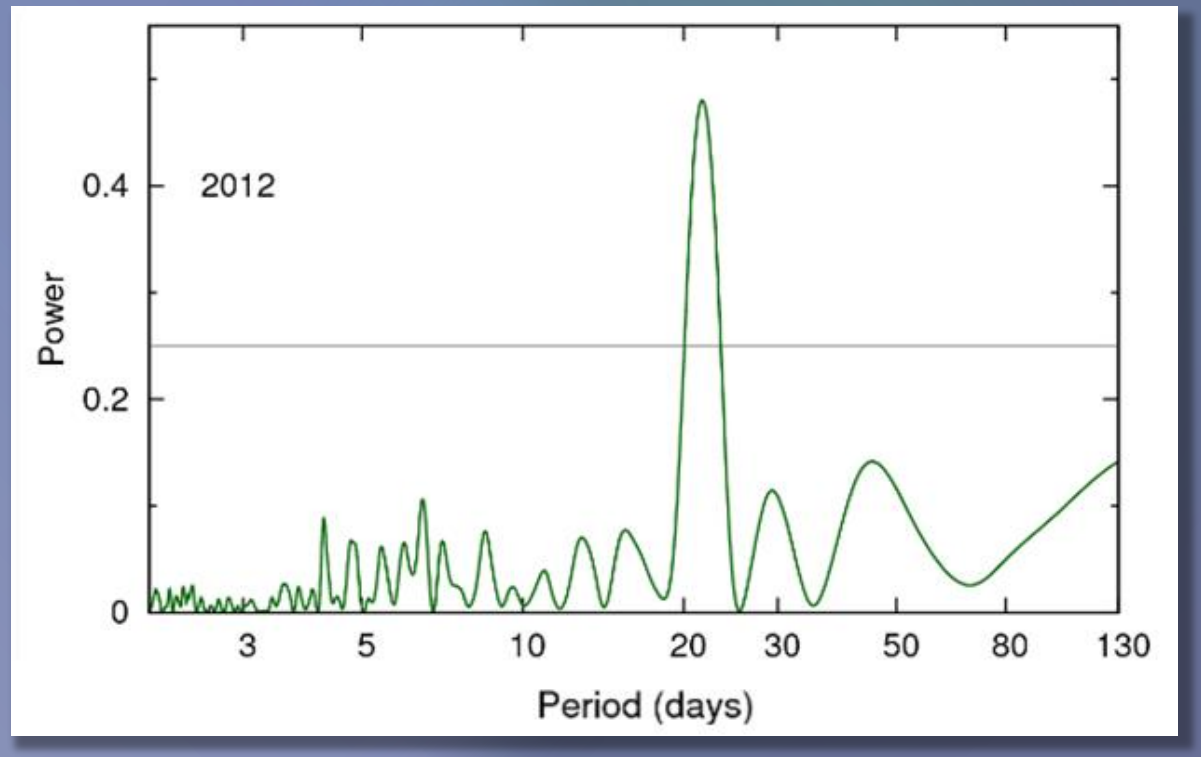


Image credit: WASP-South (Coel Hellier)

[1] Available at https://dace.unige.chw

WARWICK
THE UNIVERSITY OF WARWICK

The planets

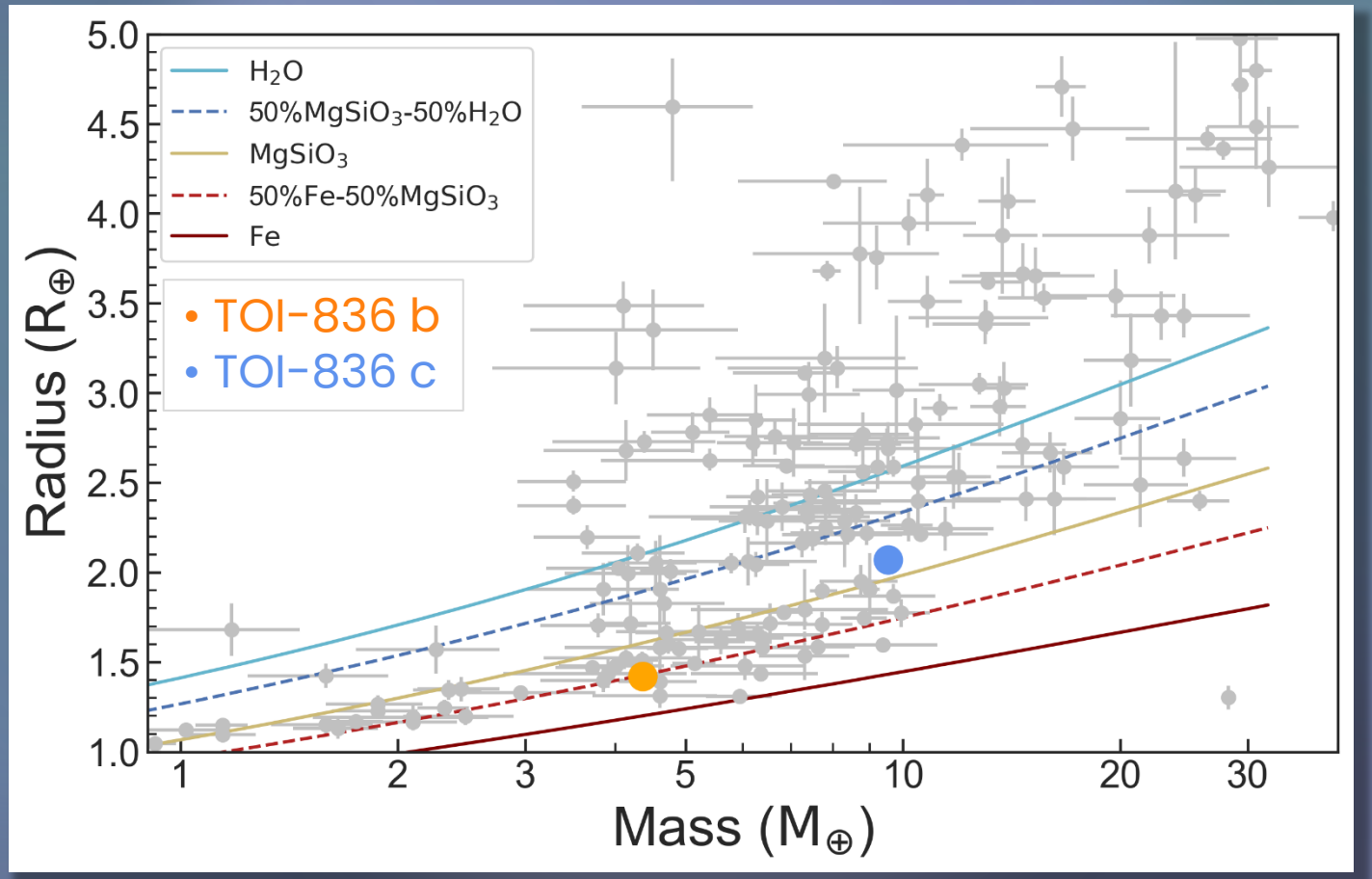
TOI-836 b

- $M_b = 4.36\ M_\oplus$
- $R_b = 1.42\ R_\oplus$
- $P_b = 3.82$ days
- Super-Earth

TOI-836 c

- $M_c = 9.53\ M_\oplus$
- $R_c = 2.07\ R_\oplus$
- $P_c = 8.59$ days
- Mini-Neptune

Mass-radius diagram

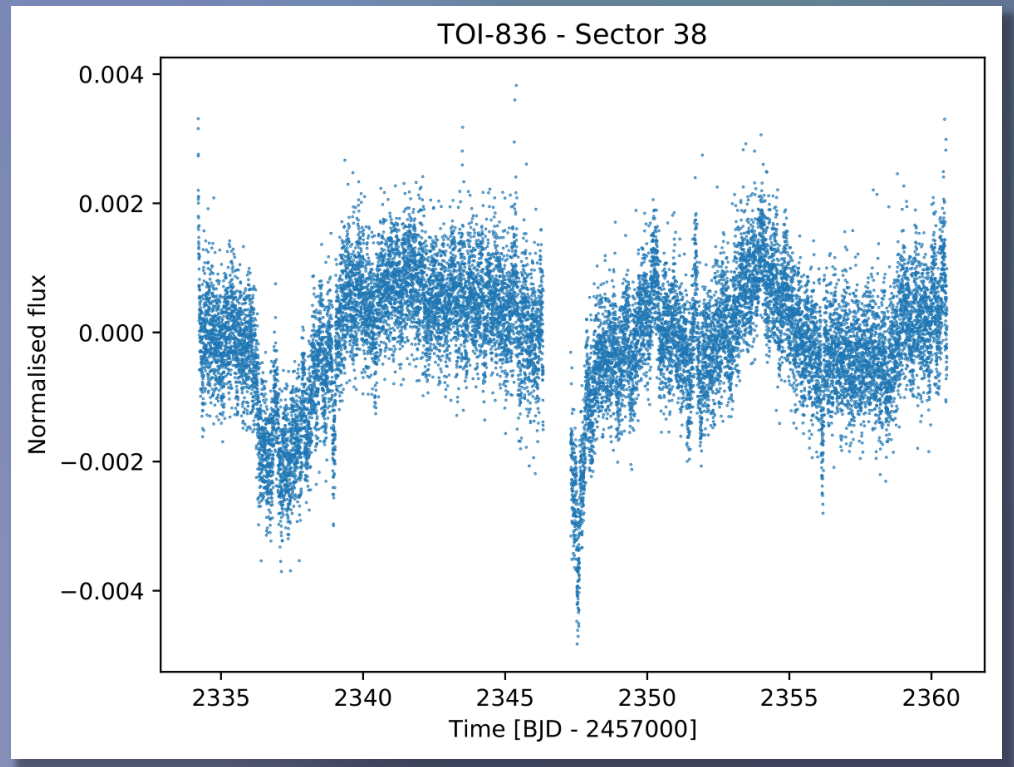


Plotted with `fancy-massradius-plot` by Oscar Barragán, using data from TEPCAT (Southworth, 2011) and composition models from Zeng et al., 2016

WARWICK
THE UNIVERSITY OF WARWICK

Upcoming work and future prospects

- Integrating **TESS sector 38**
- Integrating further photometry and RV data
- Modelling the extent of **TTVs**
- Atmospheric characterisation
- Future CHEOPS observations for planet b



PDCSAP SPOC 2-minute cadence light curve

WARWICK
THE UNIVERSITY OF WARWICK

Acknowledgements

- **Dan Bayliss** – PhD supervision
- **Dave Armstrong** – NCORES program data (HARPS)
- **Johanna Teske** - PFS data
- **Thomas Wilson, Hugh Osborn** – CHEOPS data and assistance
- **Vardan Adibekyan, Sérgio Sousa, Nuno Santos, Elisa Delgado-Mena** – HARPS analysis, stellar parameters
- **Coel Hellier** – WASP-South analysis
- **Ares Osborn, Ed Bryant** – `exoplanet` tutorials and assistance

WARWICK
THE UNIVERSITY OF WARWICK

Thank you!

Any questions?

WARWICK
THE UNIVERSITY OF WARWICK