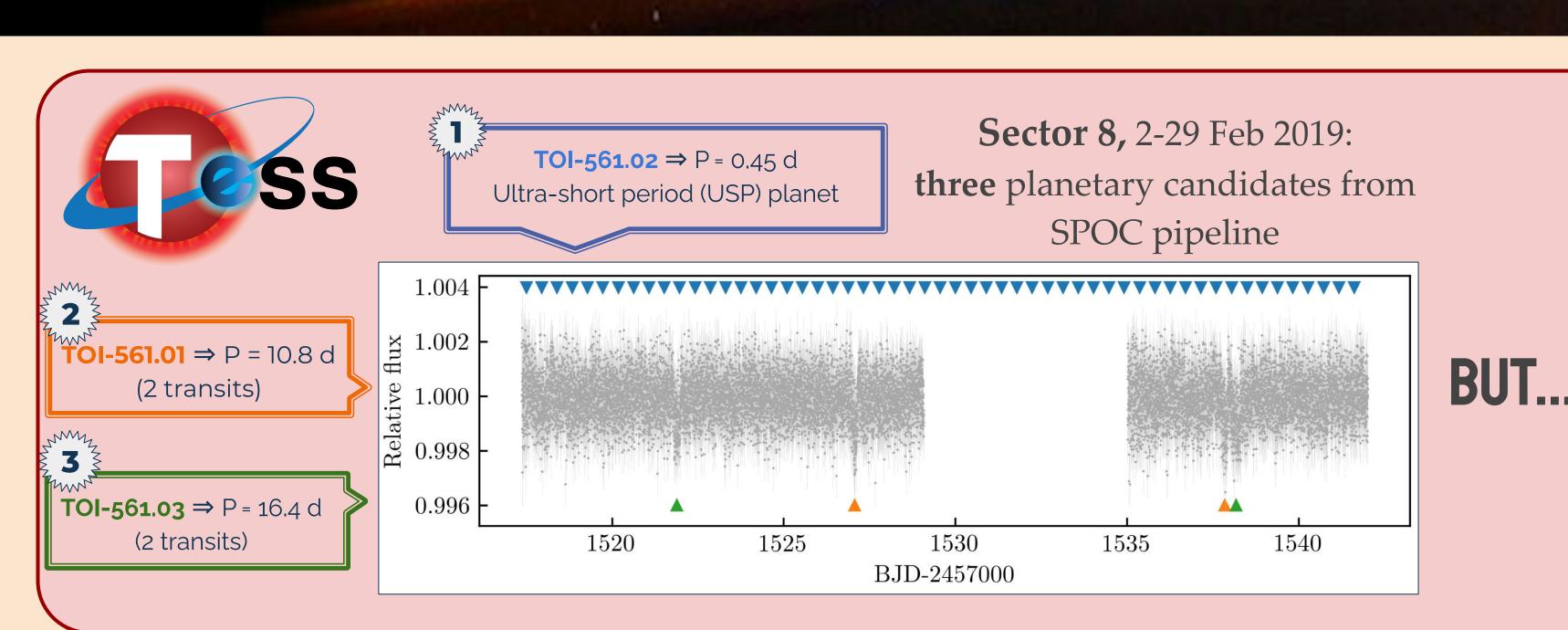




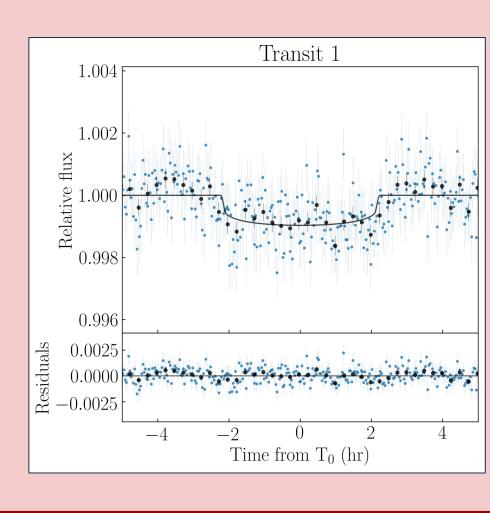
TESS, HARPS-N and CHEOPS: a joint effort to characterize the unexpected planetary system around TOI-561

Gaia Lacedelli<sup>1,2</sup>, L. Malavolta, L. Borsato, G. Piotto, D. Nardiello & the HARPS-N and CHEOPS Teams

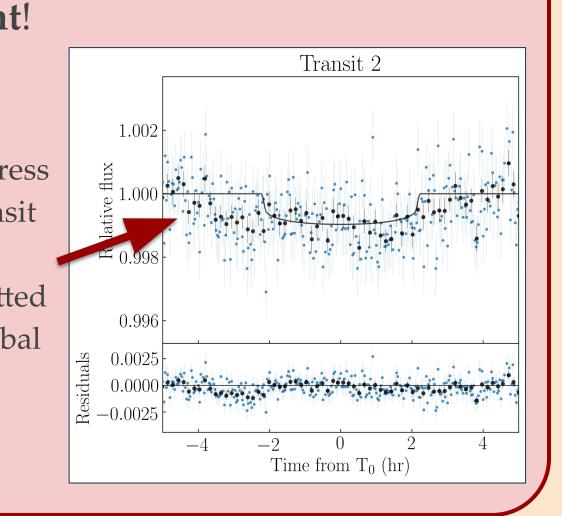
<sup>1)</sup> Università degli Studi di Padova, Italy <sup>2)</sup> INAF-OAPD, Italy



The durations of the two transits of TOI-561.03 (~16 d) are



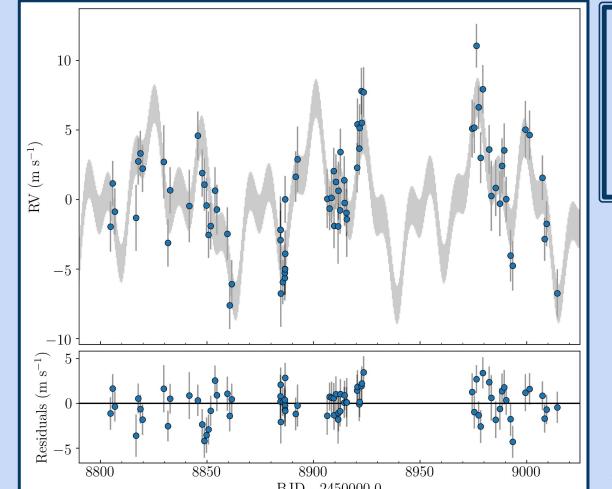
different! Ingress/egress not well fitte by the global model



# lel arps-N

### HIGH A CCURACY RADIAL VELOCITY PLANET SEARCHER - NORTH

The high resolution ( $\mathbf{R} = 115~000$ ), high-stability spectrograph located at the 3.6m Telescopio Nazionale Galileo (TNG@Roque de Los Muchachos Observatory, La Palma), with a nominal RV stability < 1 m s<sup>-1</sup>



82 RVs of TOI-561 (Nov 2019-June 2020)

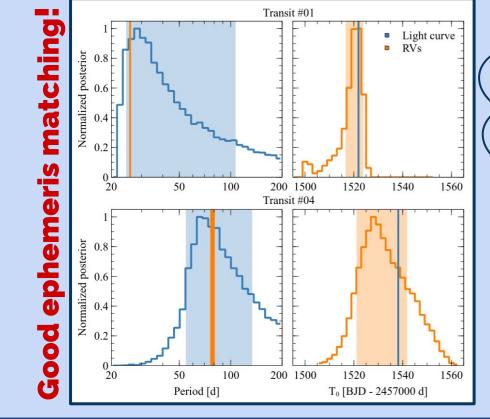
> High-cadence data: 2 points/night (8x) + 6 points/night (2x)

 $> \sigma_{\rm DV} = 1.22 \, {\rm m \, s^{-1}}$ 

Some surprises arose from the RV analysis: in addition to the two inner candidates (at 0.44 and 10.8 days), two additional strong signals were identified in the data, with periods of ~25 and ~77 days.

However, the 3<sup>rd</sup> TESS candidate (**TOI-561.03**, 16d) was **not recovered**, with an upper-limit for the non-detection of 0.5 m/s (implying an almost non physical density of  $< 0.1 \, Q_{\oplus}$ ). Moreover, the candidate at 16d was **making** the 5-planet **system** (3 TESS candidates +2 from RVs) dynamically **unstable**.

THERE IS <u>NO PLANET</u> AT 16 DAYS.. AND THERE ARE **FOUR** TRANSITING PLANETS, NOT THREE!





T0I-56I

# FOUR WELL-CHARACTERIZED TRANSITING PLANETS

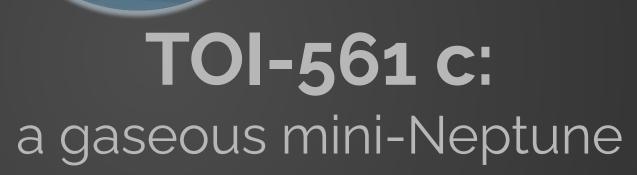
P = 10.78 d $R = 2.88 \pm 0.10 R$  $M = 5.40 \pm 0.98 M_{\odot}$ 

TOI-561 e: a(nother) mini-Neptune

**TOI-561**: an old, metal poor, thick disk star



P = 0.44 d $R = 1.42 \pm 0.07 R_{\odot}$  $M = 1.59 \pm 0.36 M_{\odot}$ 



P = 77.23 d $R = 2.67 \pm 0.11 R_{\odot}$  $M = 16.0 \pm 1.3 M_{\odot}$ 

CHEOPS

## The ESA small mission launched in 2019 which is observing individual stars already known to host planets exploiting ultra-

high precision photometry (20 ppm in 6 hr for  $6 \le V \le 9$ , Benz et al. 2021)

2<sup>nd</sup> HARPS-N campaign CHEOPS TOI-561 observations.

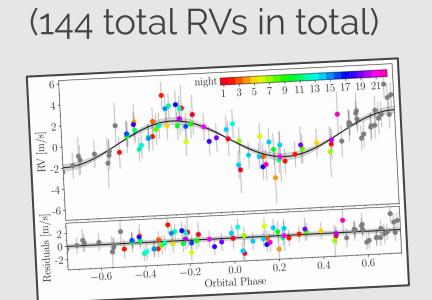
Probe internal structure with

extremely precise

<u>radii</u> (< 3%) and <u>masses</u> (< 10%)

#### Ultra-precise <a href="#">CHEOPS</a> photometry of TOI-561 (Jan-May 2021)

Confirm the planetary architecture





Lacedelli et al. 2021b, in prep.

P = 25.6 d $R = 2.53 \pm 0.13 R_{\odot}$  $M = 11.95 \pm 1.28 M_{a}$ 

TOI-561 d: a mini-Neptune

