WOLF 503B: SUPER EARTH OR SUB-NEPTUNE?

Alex Polanski†, Ian Crossfield†

CARMENES, CPS, HARPS-N, PFS Collaborations & Spitzer DDT-14292 Team

Department of Physics and Astronomy - University of Kansas†

KU ExoGroup

Background

In 2018, Peterson et al added to the hundreds of planets disovered by the Kepler/K2 missions when they announced the discovery of a planet orbiting the K-dawrf Wolf 503 [4]. With a radius of $2.030^{+0.076}_{-0.073}$ $R_\oplus$, Wolf 503b sits above the Fulton radius gap thought to be attributed to the photoevaporation of a planet's atmosphere by UV and X-Ray radiation [1]. Its size combined with the relative brightness of its host star (J-mag 8.3) made this new planet a particularly good candidate for follow up investigations. Here we present:

- **Newly determined mass and bulk composition via radial velocity observations.**
- **A factor of 4 reduction in the uncertainty of the transit time with the addition of a Spitzer transit observation.**

Radial Velocity Analysis

Lacking a mass measurement, the radius alone of Wolf 503b presents two possibilities for its bulk composition [4]:

- A high density, rocky composition with a mass range of 10-14 Earth masses.
- A low density, gas-rich composition giving masses from 5 to 8 Earth masses.

These scenarios are characterized by very different RV amplitudes (K):

- Rocky Composition ⟶ K = 4-6 m/s
- Gas-rich Composition ⟶ K = 2-3 m/s

Radial velocity is a powerful tool for understanding bulk composition!
The Eccentricity was held at 0 as the evidence was not strong enough to support the additional parameter.

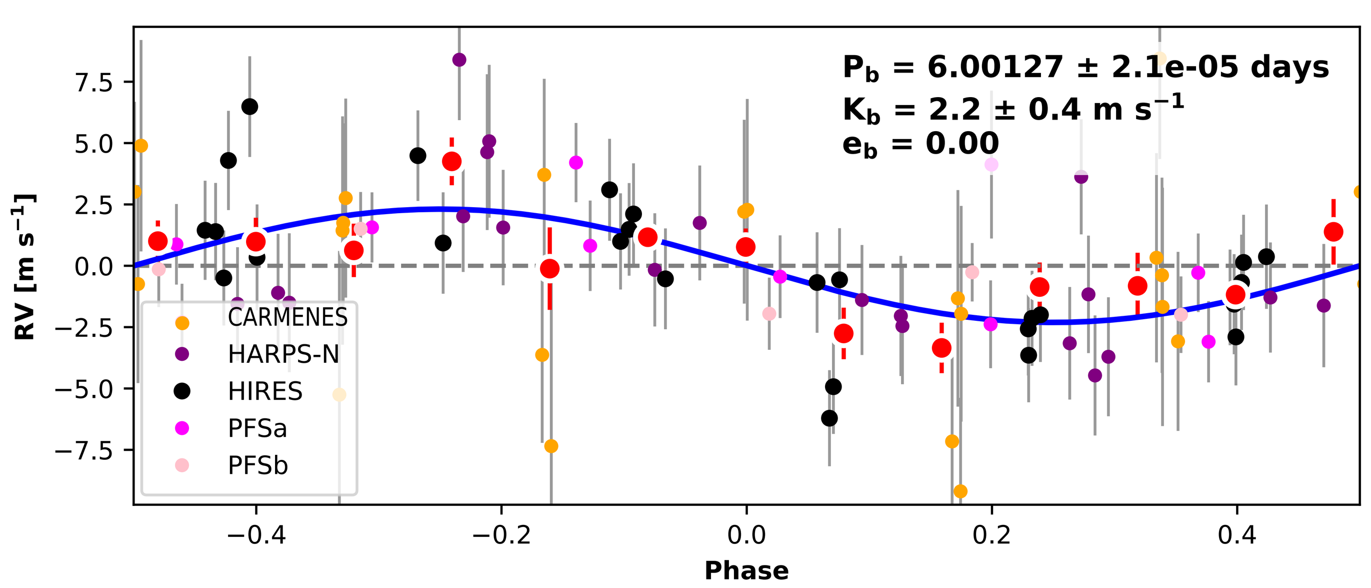

Fig. 1: RVs phase-folded to the ephemeris of Wolf 503b. The maximum likelihood model is plotted while the orbital parameters listed in Table BLANK are the median values of the posterior distributions. The thin blue line is the best fit model. Red circles are the same velocities binned in 0.08 units of orbital phase.

Planetary Parameters

Parameter	Credible Interval	Units
K	2.24 ± 0.4	m s^{-1}
M	4.95 ± 0.9	$M_\oplus$
ρ	$2.31^{+0.52}_{-0.47}$	g cm^{-3}
R_p/R_*	$0.0302^{+0.00036}_{-0.00035}$	–

New Orbital Parameters

To be able to observe a planet's transit long after its discovery, we need strong constraints on when a transit will occur. Since the uncertainty in a predicted time of transit scales with the uncertainty in the period catching a second transit event can constrain the period further.

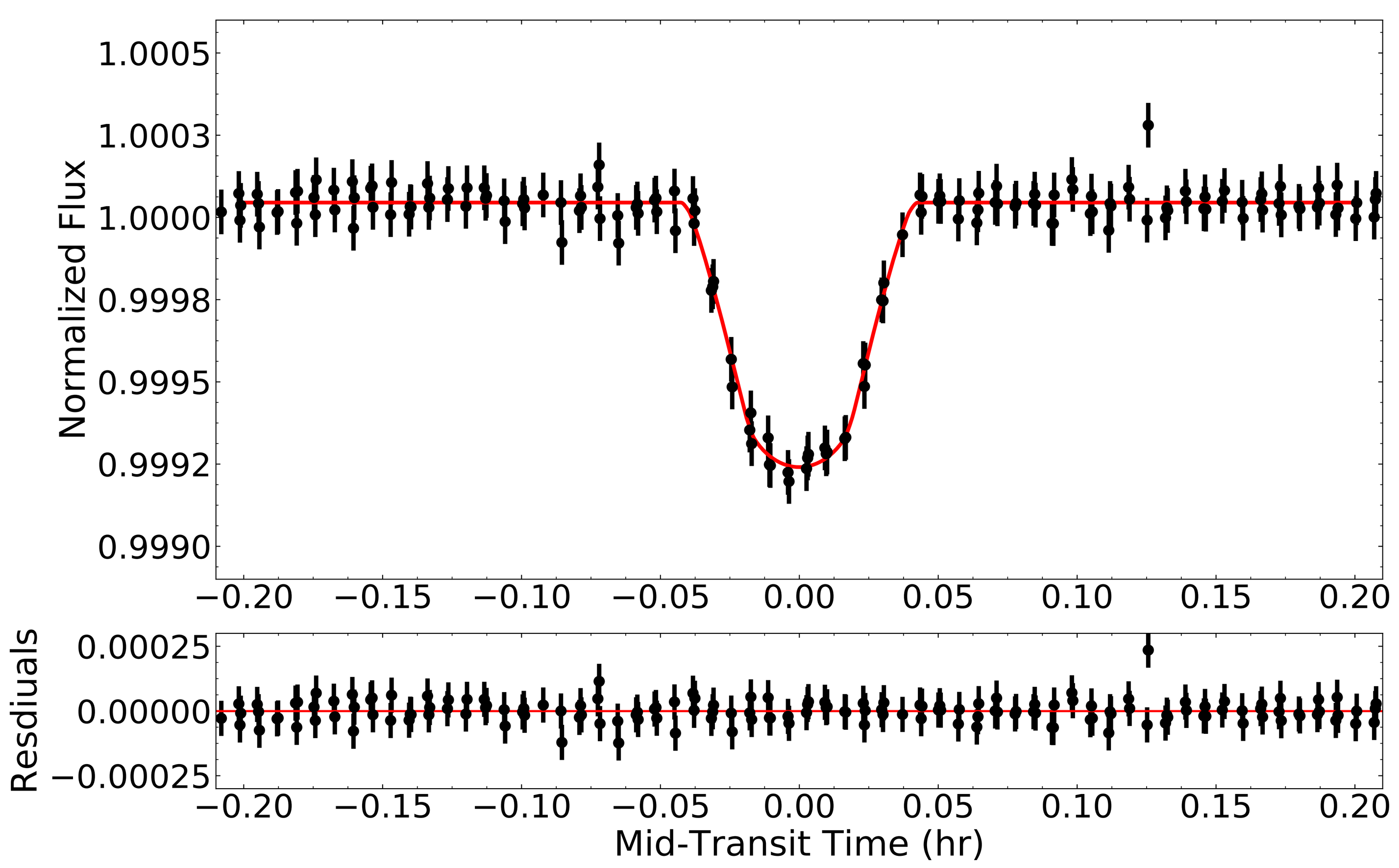

Fig. 3: Original K2 transit observation. Wolf 503b orbited its star 102 more times until we observed it again with Spitzer.

Combining K2's lightcurve with Spitzer's we obtained...

- An improved value of the orbital period: **P = 6.00127 $\pm$ 0.000021** Days
- A 3σ uncertainty in the transit time of 36 minutes at the beginning of the JWST era, improved from nearly 3 hours with K2 photometry alone.

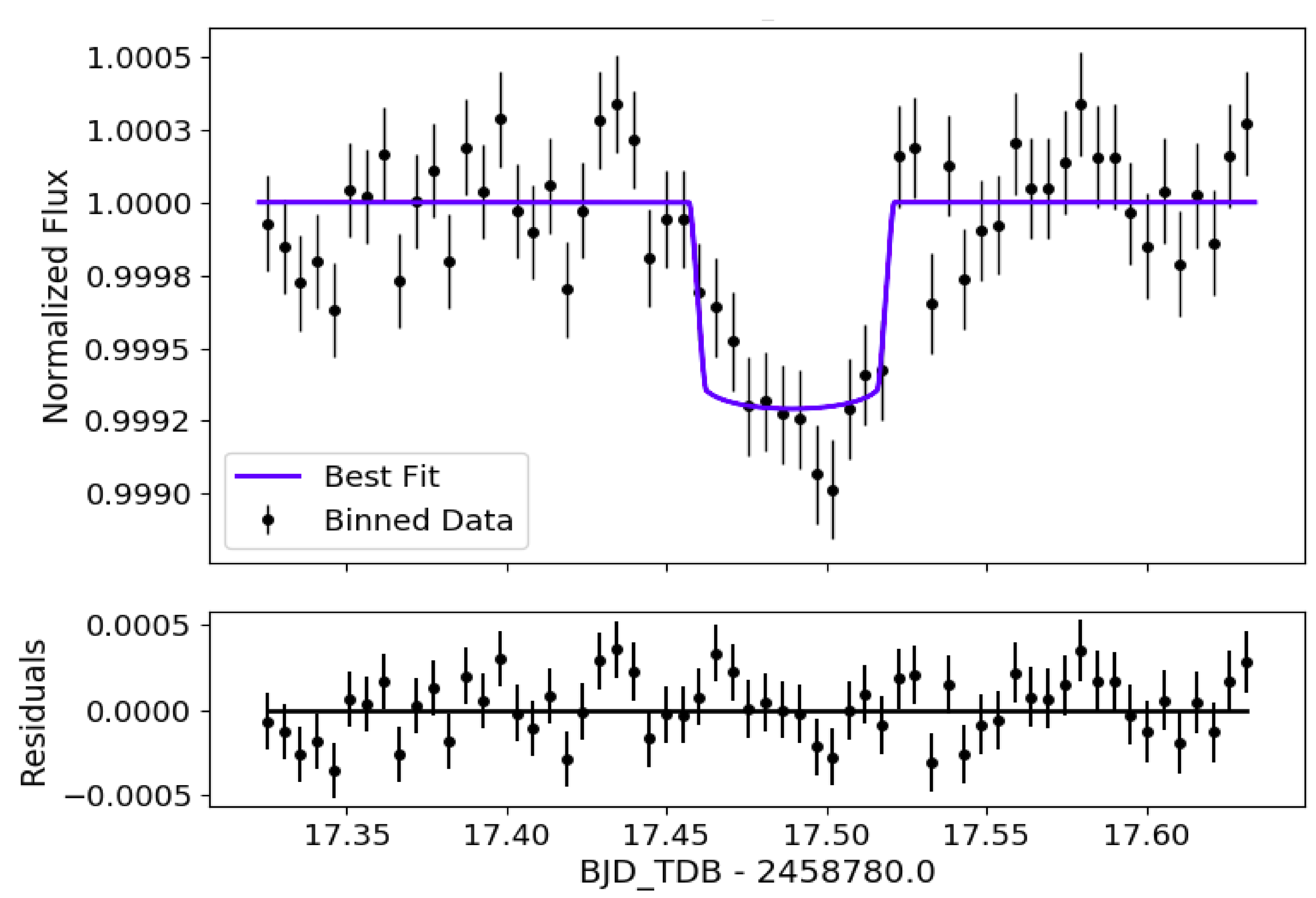

Fig. 4: Transit curve of Wolf 503b as seen with the Spitzer Space Telescope.

Results

From this analysis we can finally begin to put Wolf 503b in context. What we have found is summarized with the following:

- Wolf 503b is a 4.95 $M_\oplus$ planet, with a mean density of 2.31 ± 0.55 g cm^{-3}.
- Comparing to the interior models of Valencia et al. (2011), we find that Wolf 503b is consistent with an Earthlike core with either an H2O mass fraction of 47 +/- 8.5 %, or a H2/He mass fraction of <0.15% (at 95% confidence).

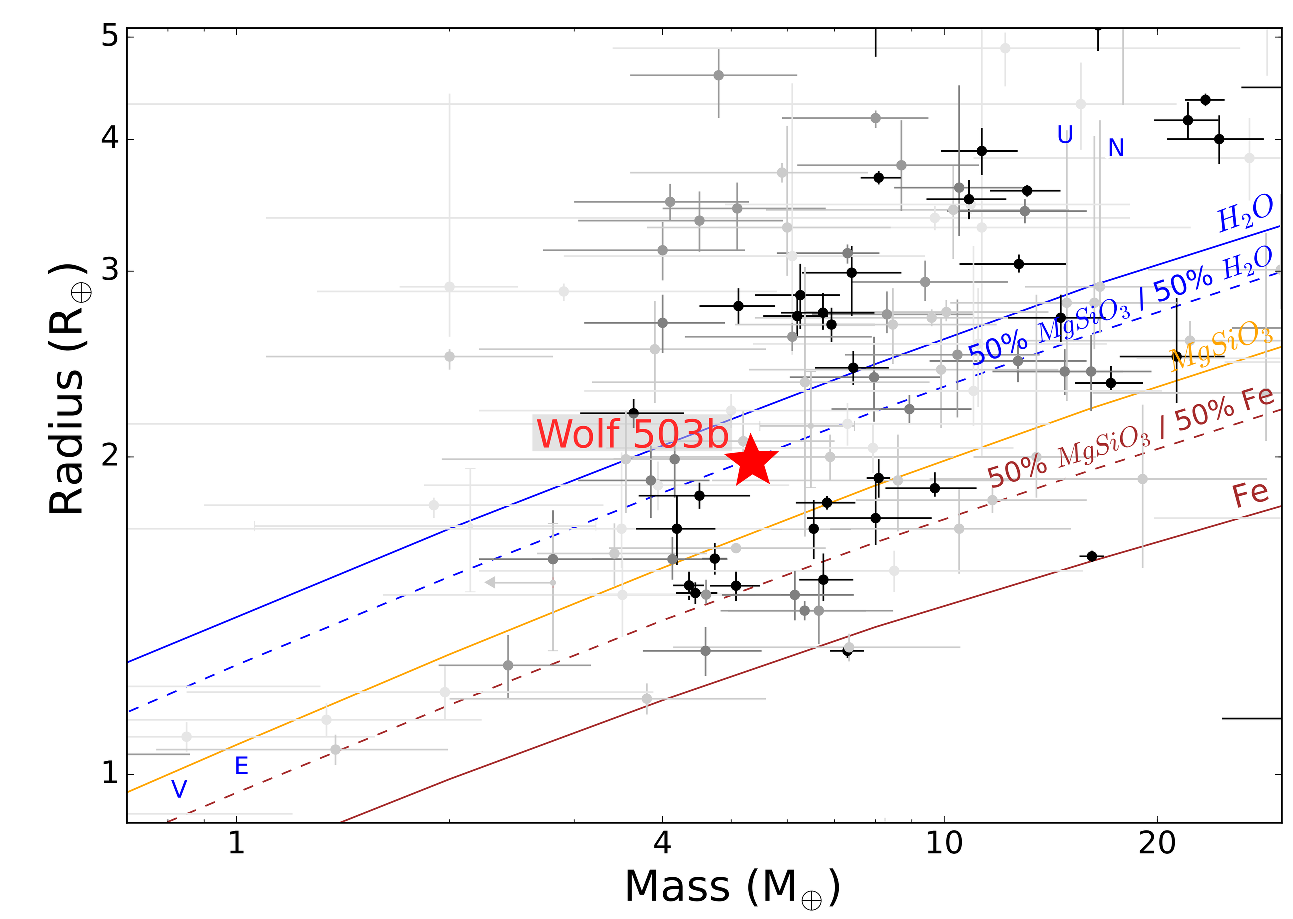

Fig. 5: Wolf 503b's place on a mass-radius diagram. Compositional curves are from the theoretical models of Zeng et al 2016 [5]. Figure adapted from Kosiarek et al 2019 [3].

Potential for Atmospheric Studies

A useful tool for measuring a planet's potential for atmospheric characterization is the Transmission Spectroscopy Metric (TSM) of Kempton et al [2]. **With a TSM of 107, Wolf 503b is among one of the best candidates for further study.** Additionally, the combination of the likelihood for a gas-rich composition and its position near the radius gap shows that this planet can serve as an important subject in understanding what role photo-evaporation plays in planet evolution.

References

[1] Benjamin J. Fulton et al. In: 154.3 (2017). DOI: 10.3847/1538-3881/aa80eb.

[2] Eliza M. -R. Kempton et al. In: 130.993 (Nov. 2018), p. 114401. DOI: 10.1088/1538-3873/aadf6f.

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[4] Merrin S. Peterson et al. In: 156.5, 188 (2018). DOI: 10.3847/1538-3881/aaddfe.

[5] Li Zeng, Dimitar D. Sasselov, and Stein B. Jacobsen. In: 819.2, 127 (2016). DOI: 10.3847/0004-637X/819/2/127.

UNIVERSITY of KANSAS