# Mass determination of K2-19b and K2-19c from radial velocities and transit timing variations

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## 1. Introduction

We present FIES@NOT and HARPS-N@TNG radial velocity follow-up observations of K2-19, a compact planetary system hosting three planets, of which the two larger ones, namely K2-19b and K2-19c, are close to the 3:2 mean motion resonance. An analysis considering only the radial velocity measurements is able to detect only K2-19b, the largest and more massive planet in the system.

We used the FIES high-res mode, which provides a resolving power of R=67 000 in the spectral range 3600 – 7400 Å. The signal-to-noise ratio (SNR) of the extracted spectra is about 20-25 per pixel. We also acquired 7 additional high-resolution spectra (R 115 000) with the HARPS-N, the extracted spectra have a SNR per pixel of 15-23.

We used the TRADES code to simultaneously model both our RV measurements and the existing transit-timing measurements. This TTVs, 20 measure, are published by Narita et al. (2015).

Our analysis repeats therefore the pattern that masses derived from TTVs are lower than masses from RVs, as noted previously byWeiss & Marcy (2014), in our case with the combined RV and TTV analysis producing an intermediate mass-value.

## 2. RV data analysis

We initially fitted a one-planet Keplerian model to the FIES and HARPS-N RV data, we assumed that the observed Doppler shift is caused only by the largest transiting planet K2-19b (Fig. 1). We fixed both orbital period (Porb ) and mid-time of first transit (T0 ) to the values given by Armstrong et al. (2015). We note that using different ephemeris, those provided by Narita et al. (2015), Barros et al. (2015) and Sinuko et al. (2015) – gives consistent results well within the error bars.

Adopting the orbit inclination given in Barros et al (2015) and assuming the stellar mass of M = 0.918 ± 0.064 $M_{O}$, the RV semi-amplitude variation and orbit eccentricity imply a mass of Mb = 71.7±6.3$M_{jupiter}$ for K2-19b.

We also attempted to detect the Doppler reflex motion of K2-19c by fitting a two-planet Keplerian model to the FIES and HARPS-N RV data. The best fit solution provides however a non-significant improvement of the Bayesian information criterion (BIC). We concluded therefore that K2-19c cannot be detectedin our RV data.

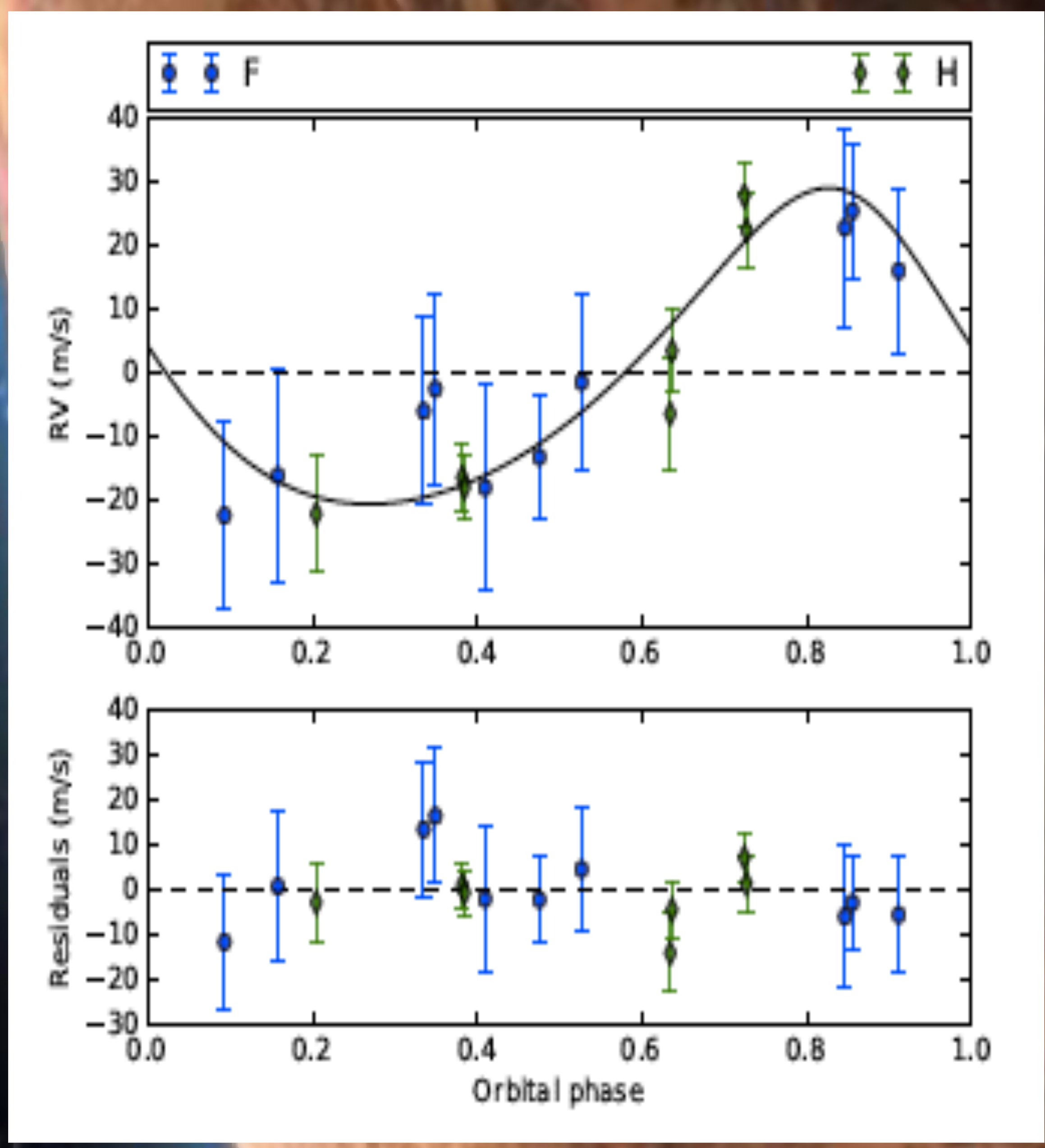


**Fig. 1. FIES (blue circles) and HARPS-N (green diamonds) RV measurements of K2-19 phase folded to the orbital period and time of first transit of K2-19b.The thick black line mark the best-fitting Keplerian model.**

Figure 2 shows the simulated data points from the best-fit solution overlaid on the observed data. The derived planet masses are Mb= 57.7±6.2 and Mc= 9.4±3.6 $M_{jup.}$

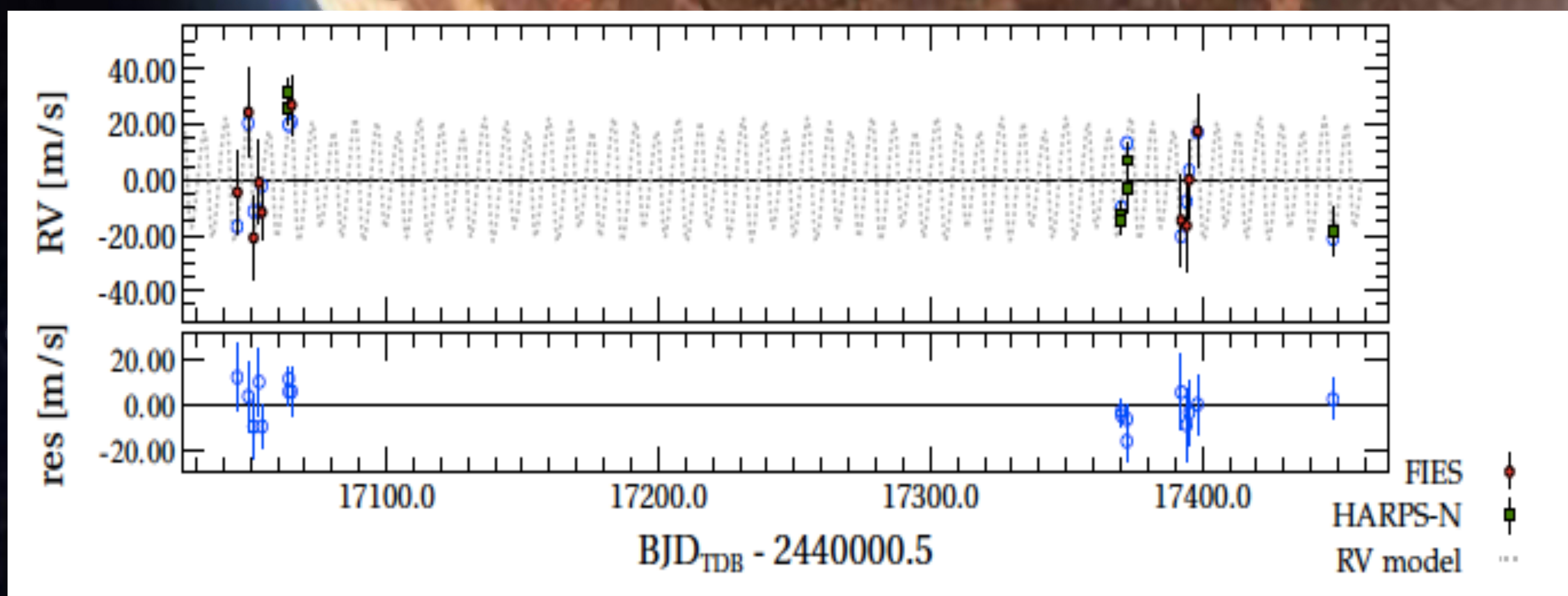


**Fig.2. FIES (red circles), HARPS-N (green squares), and simulated (blue open circle) RV points. The gray dots show the RV model across the observation time window. The residuals to the fit are shown in the lower sub-panel.**

## 3. RV and transit timing analysis

We derived masses and orbital parameters of K2-19b and K2-19c using the code TRADES (Borsato et al. 2014) to simultaneously model RV measurements and TTV data.

We used our FIES and HARPS-N RV along with 20 transit mid-times published by Narita et al. (2015). Given the amplitude of the observed RV peak-to-peak variation ( 40 m/s, Fig. 1), we set a very conservative range of 0< Mp< 100M for the masses of the two planets.To account for the two degenerate solutions found by Narita et al. (2015), we assumed a wide range for the orbital periods, i.e., $P_{orb,b}$= 7.8-8.0 days and $P_{orb,c}$= 11.5-12.5 days. We limited the possible eccentricities to e< 0.5, and let the arguments of periastron,ω and mean anomalies,ν, vary freely.We used the orbital inclinations as given in Barros et al. (2015).

## 4. Results and discussion

We have presented a RV follow-up of K2-19, a K0V star hosting two planets whose orbtial periods are close to the 3:2 meanmotion resonance.

From an analysis based only on RV measurements we estimate that K2-19b has a mass of Mb = 71.7± 6.3$M_{jup}$ . This is significantly larger than the one derived from the TTV analysis by Barros et al. (2015) of 44±12 $M_{jup}$. With an expected RV semi-amplitude variation of K=3m/s, K2-19c is not detected in our RV data.

A combined analysis of RV and TTV measurements resulted however in a lower mass of Mb= 57. 7± 6.2 $M_{Jup}$ for K2-19b. Once again, this value is higher than that derived by Barros et al. (2015).In this same analysis, the mass of K2-19c could also be derived as 9.4±3.6 $M_{jup}$.

This analysis repeats therefore the pattern that masses derived from TTVs are lower than masses from RVs, as noted previously by Weiss & Marcy (2014), in our case with the combined RV and TTV analysis producing an intermediate mass-value. Considering the sparsity of TTV measurements that are supported by RV measurements, this work certainly implies that mass determinations from TTV measurements continue to have to be taken with caution, until a better understanding about the causes that may generate any systematics between RV and TTV derived planet masses is achieved.

## References

- D.Nespral et al, A&A **arXiv:1604.01265**
- Armstrong D. J., et al., 2015, A&A, 582, A33
- Barros S. C. C., Díaz,R. F., Santerne, A., et al. 2014, A&A, 561L, 1B
- Barros S. C. C., Almenara,J. M., Demangeon, O., et al. 2015, MNRAS, 454, 4267
- Borsato, L., Marzari, F., Nascimbeni, V., et al., 2014, A&A, 571, A38
- Narita, N., Hirano, T., Fukui, A., et al. 2015, A&A, 815, 47

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