Radial velocity confirmation of K2-100b: A young, highly irradiated, and low density transiting hot Neptune

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MNRAS, 2019, 490, 698 (arXiv:1909.05252)

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ABSTRACT

We present a detailed analysis of HARPS-N radial velocity (RV) observations of K2-100, a young and active star in the Praesepe cluster, which hosts a transiting planet with a period of 1.7 days. **We model the activity-induced radial velocity variations of the host star with a Gaussian Process framework and detect a planetary signal of 10.6 +/- 3.0 m/s which matches the transit ephemeris** , and translates to a planet mass of 21.8 +/- 6.2 Earth Masses. **This is the first mass measurement for a transiting planet in a young open cluster** . The relative low density of the planet, 2.04 +/- 0.66 g/cm³, implies that K2-100b retains a significant volatile envelope. We estimate that the planet is losing its atmosphere at a rate of 10^{11}-10^{12} g s^{-1} due to the high level of radiation it receives from its host star.

Radial velocities and stellar activity

We got **78 RV measurements with HARPS-N** to measure the planet mass of K2-100b. But, K2-100 is a young star, it is magnetically active, it has active regions on its surface. **Active regions on stellar surfaces give rise to quasi-periodic variations in the apparent stellar RV**. They can be very difficult to disentangle from the planetary signal, specially for young and fast-rotating stars. Fortunately, the activity/symmetry indicators give us hits about the stellar surface, we can then use them to correct the RVs for activity induced signals.

Multi-dimensional Gaussian Process

Rajpaul et al. (2015) created a novel and powerful approach to disentangle planetary and activity signals with a multi-dimensional Gaussian-Process (GP) approach. Long story short, **when modelled simultaneously, activity/symmetry indicators guide the GP to track only the activity, making it possible to recover the planet signal**.

Results

We coded the multi-dimensional GP approach into pyaneti (Barragán et al., 2019) and we recover a RV semi-amplitude of

$10.6\pm3.0 \mathrm{ms}^{-1}$

which translates into a planet mass of

21.8 ± 6.2 $M_\oplus$

Figure 1 shows the RV, logR'_HK, and BIS timeseries together with the inferred models. We also show the phase-folded RV along with the data points in Figure 2.

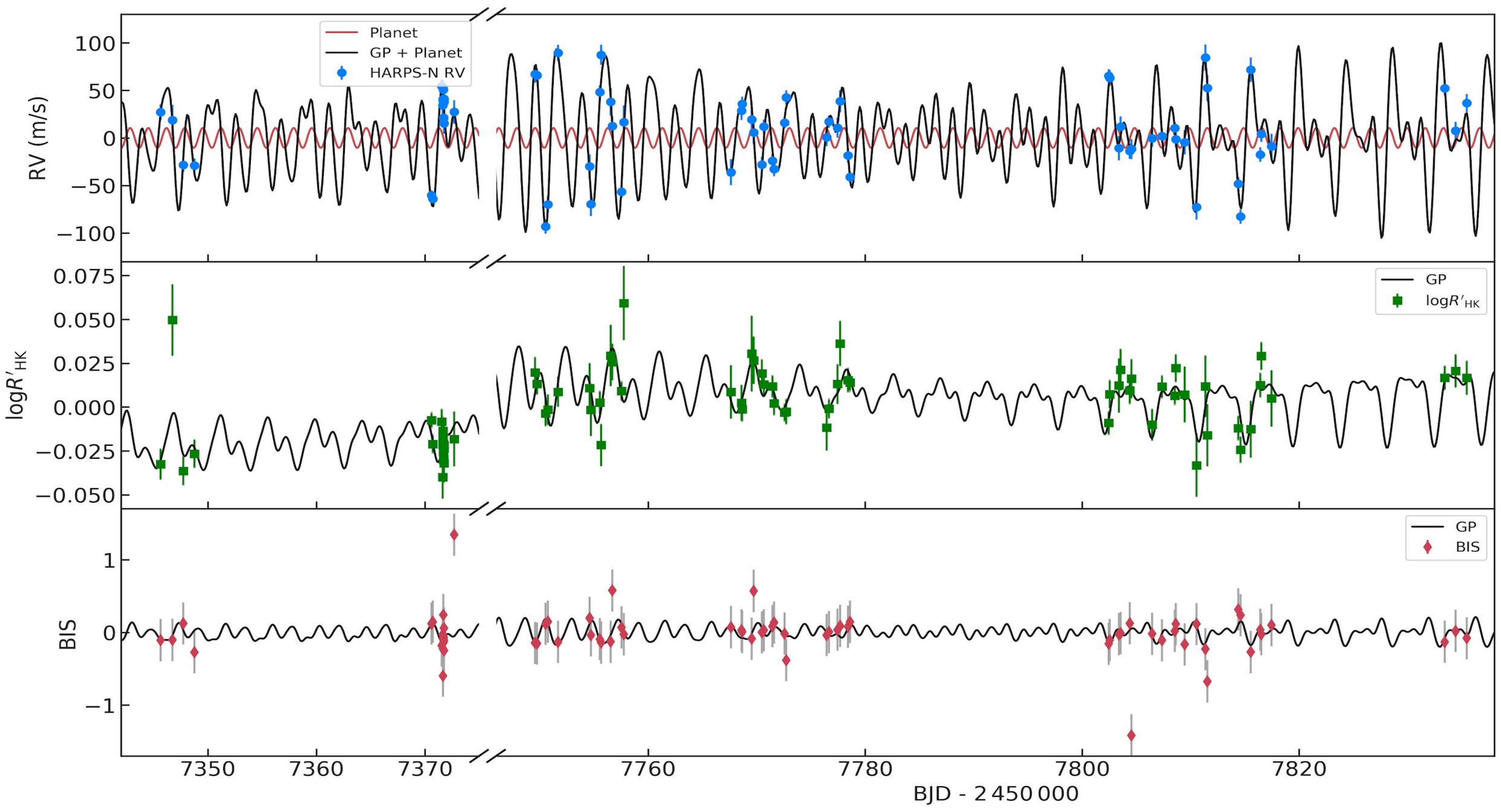


Figure 1: Radial velocity (top), log R'_HK (middle) and BIS (bottom) time-series. All time-series have been corrected by the inferred offset. Inferred models are presented as solid continuous lines. Measurements are shown with filled symbols with error bars. Grey error bars account for the jitter. We note that there is a gap between 7375 and 7746 BJD - 2 450 000 where there were no measurements.

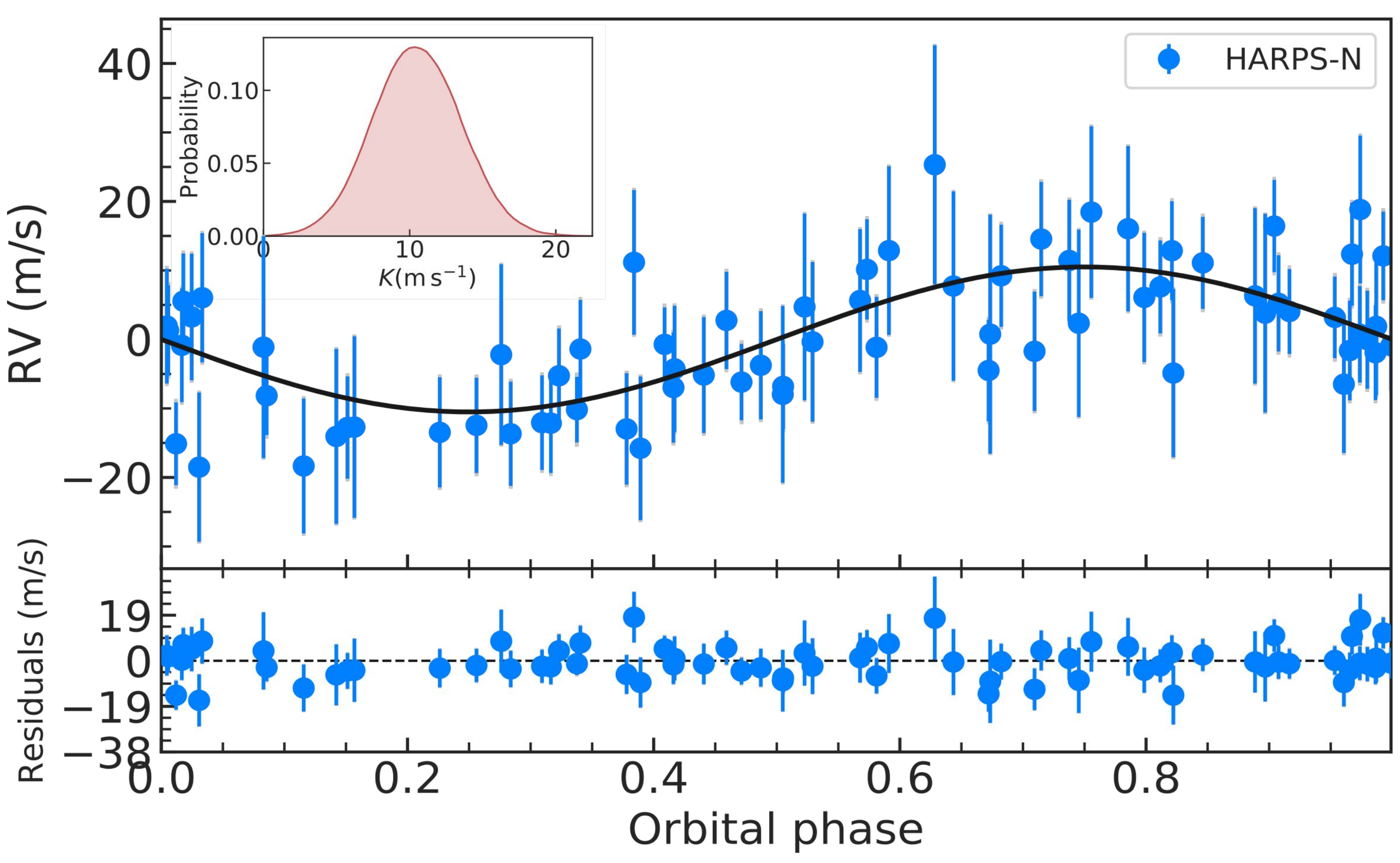
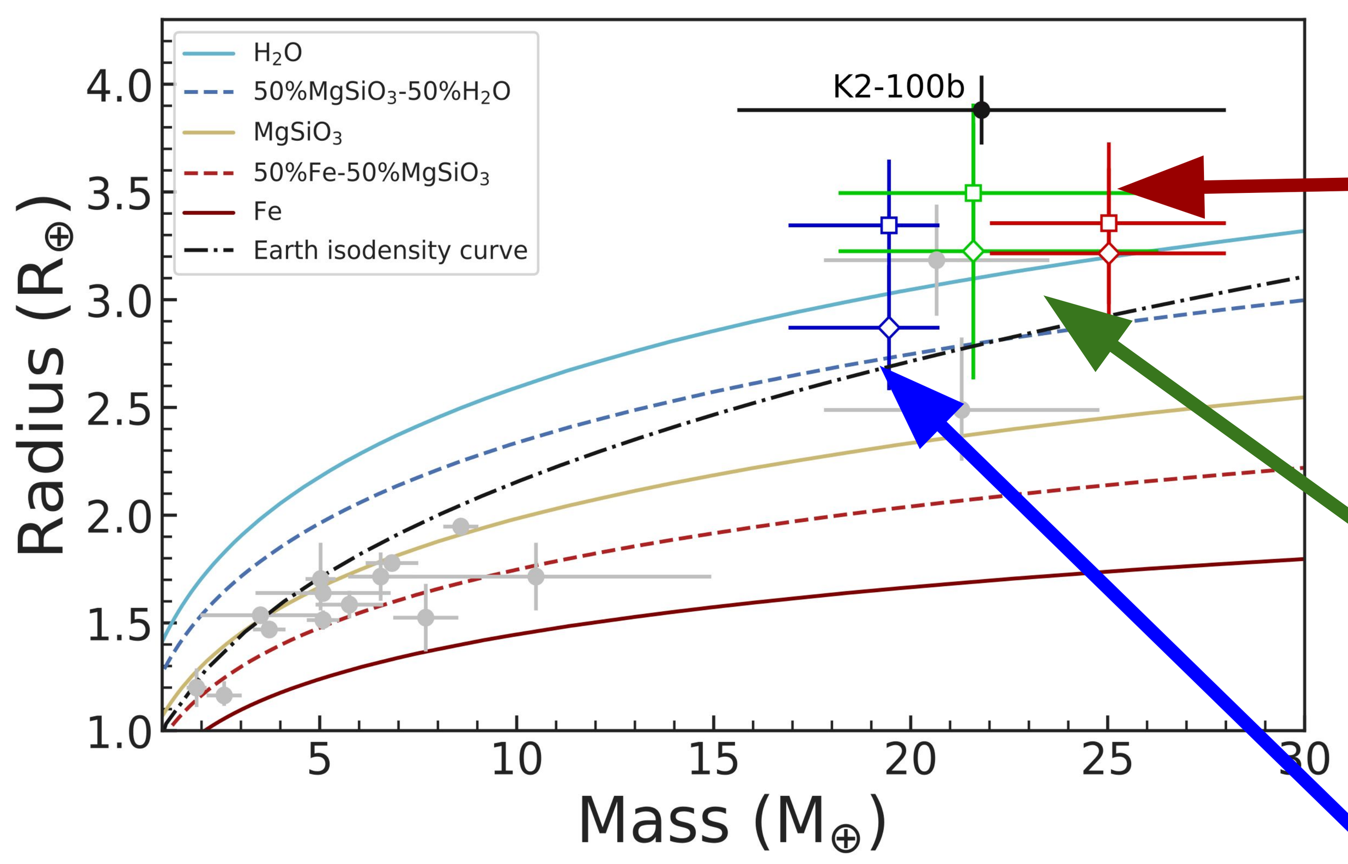


Figure 2: RV curve of K2-100 folded to the orbital period of K2-100b. HARPS-N data (blue circles) are shown following the subtraction of the instrumental offset and GP model. Grey error bars account for the jitter. The Keplerian solution is shown as a solid line. Top-left inset displays the posterior distribution for the Doppler semi-amplitude, *K*.

K2-100b's atmospheric evolution models

- We employed the atmospheric evolution scheme described by Kubyshkina et al., (2019).
- We estimate the atmospheric evolution assuming the star evolves as a fast (> 3 d), medium (>3 d and <8 d), and slow rotator (> 8 d).



If K2-100 evolves as a fast rotator implies that K2-100b has a large core which will be able to retain a significant fraction of gas envelope after 5 Gyr

If the star evolves as a medium rotator, after 5 Gyr, K2-100b will end as a Earth-density core with a relative thin gas envelope

If the star evolves as a slow rotator, K2-100b will end as a Earth-density core after 5 Gyr

Figure 3: Mass *vs* radius diagram for planets which receive an insolation > 650 (Lundkvist et al., 2016) larger than the Earth (grey circles). The location of K2-100b is marked with a black circle. Its predicted planetary mass and radius at 2 and 5 Gyr is shown by squares and triangles, respectively, with colours corresponding to different initial rotation rates XUV fluxes for the star: fast/high (red), moderate (green) and slow/low (blue).

Conclusions

We showed how, by combining RV with activity indicators, we can disentangle planetary and activity RV variations for young active stars. These results encourage the RV follow-up of young or active stars to be discovered with missions such as TESS and PLATO. We measured a mass of 21.8 ± 6.2 $M_\oplus$ for K2-100b, a 3.88 ± 0.16 $R_\oplus$ planet transiting a star in the Praesepe cluster.

The fantastic thing about K2-100b is that (no matter your favourite stellar evolution model) is currently evaporating! It is likely that with K2-100b we see the previous stage of all the older high irradiated planets. This makes K2-100 an excellent laboratory to test photoevaporation models.

References

- Barragán O., Gandolfi D., Antoniciello G., 2019, MNRAS, 482, 1017
- Kubyshkina D., et al., 2019, ApJ, 879, 26
- Lundkvist M. S., et al., 2016, Nature Comm., 7, 11201
- Mann A. W., et al., 2017, AJ, 153, 64
- Rajpaul V., et al.,, 2015, MNRAS, 452, 2269

All our models suggest that K2-100b is currently evaporating!