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

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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.

The star: K2-100

- K2-100 (EPIC 211990866) is a bright (V=10.52 mag) G-dwarf.
- Member of the Praesepe cluster (NGC 2632, M44)
- The star was observed by K2 on its Campaign 5.
- Mann et al., (2017) validated the planetary nature of a 1.67 days transit signal.
- This young world, K2-100b, is a hot Neptune, and its bright host star made it a good candidate for further characterisation.

But...

Young host stars rotate rapidly and are magnetically active. This gives rise to quasi-periodic variations in the apparent stellar RV. We need a fancy technique to disentangle planetary from activity signals.

DATA

Photometry

- *K2* observed K2-100 in Campaign 5 in long-cadence mode (30 min).
- *K2* re-observed K2-100 in Campaign 18 in short-cadence mode (2.5 min).
- Ground base photometry from MUSCAT2 and ARCTIC (Stefansson et al., 2018).

Spectroscopy

- We acquired 78 spectra of K2-100 with the HARPS-N.

pyaneti
Barragán et al., (2019)
https://github.com/oscaribv/pyaneti

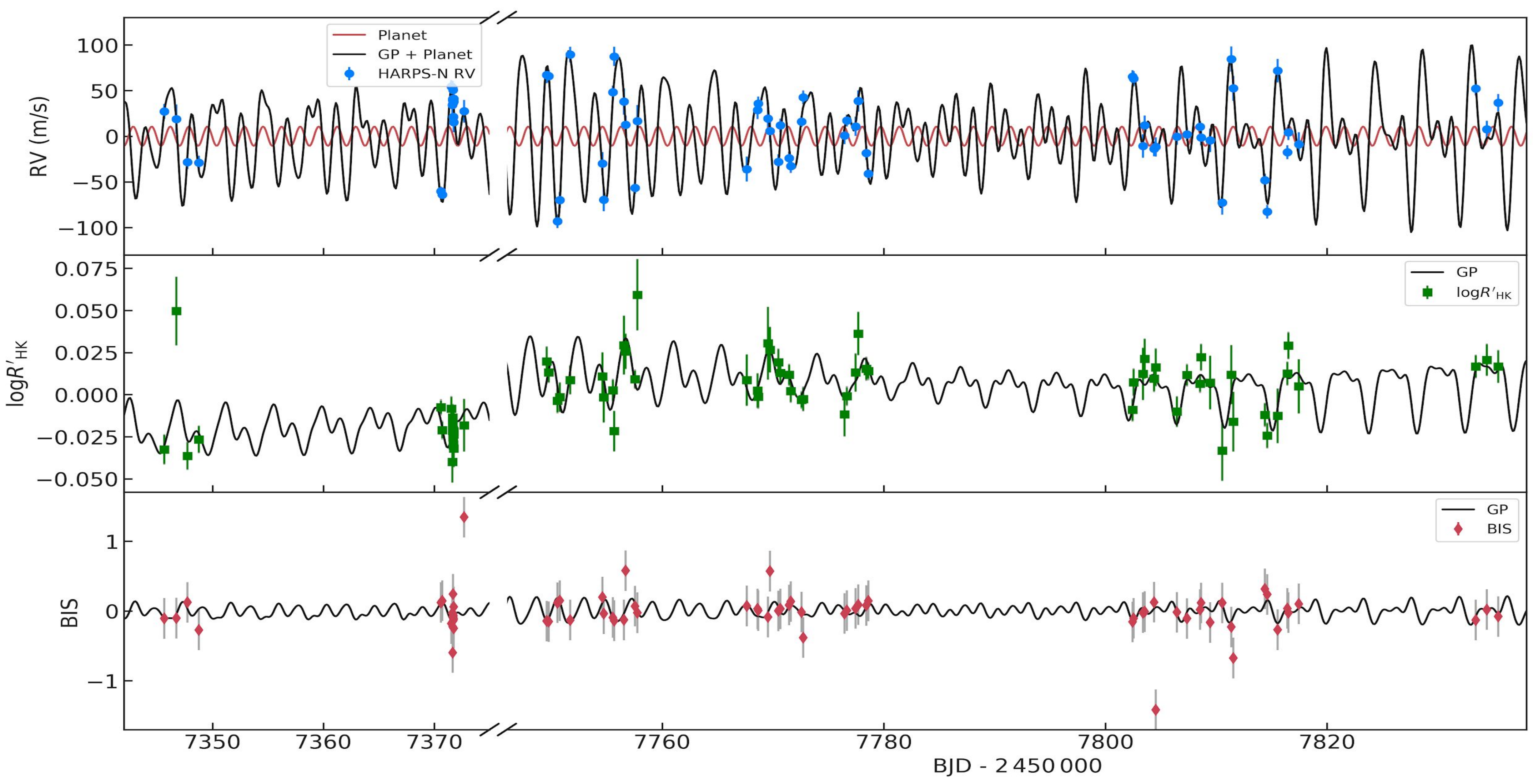
Try pyaneti

We will make all data and code public soon, stay tuned!

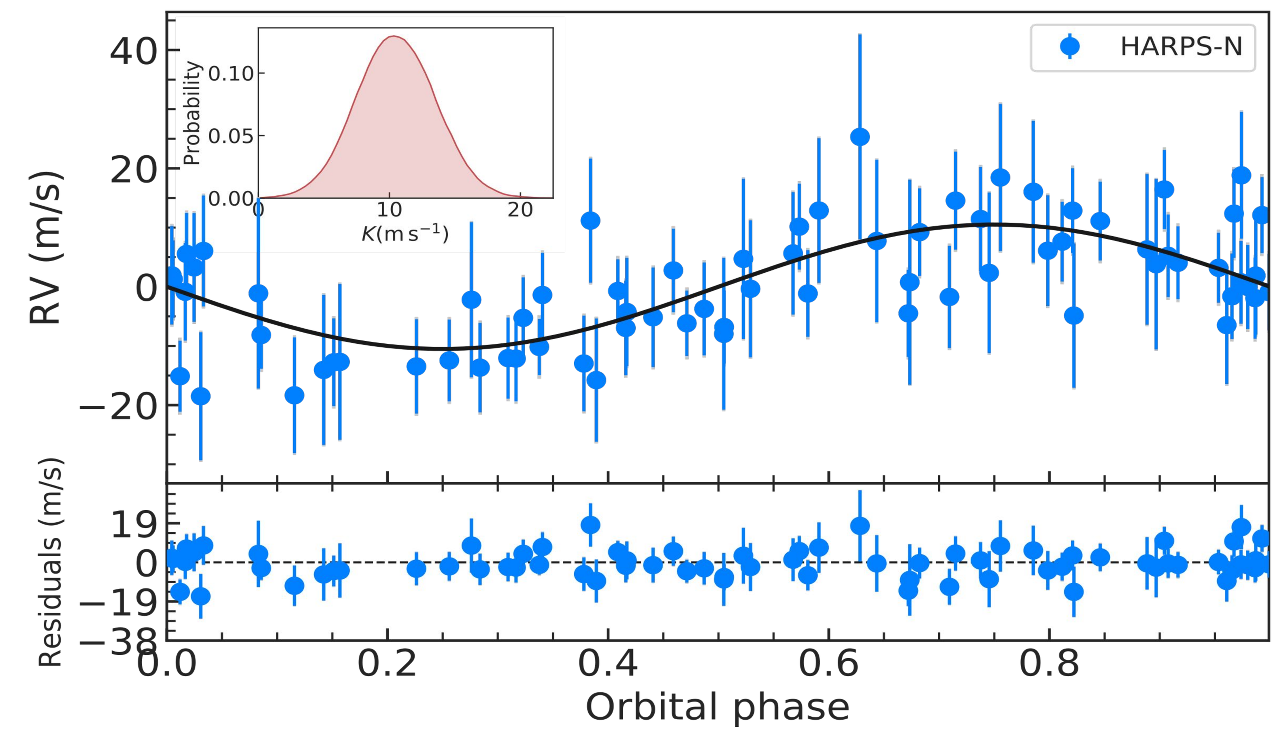
Methods

We used the multi-dimensional Gaussian Process (GP) approach described by Rajpaul et al., (2015) which assumes the RV with activity/symmetry indicators are generated by the same latent GP.
We coded this approach into pyaneti (Barragán et al., 2019) and modelled all data.

RESULTS



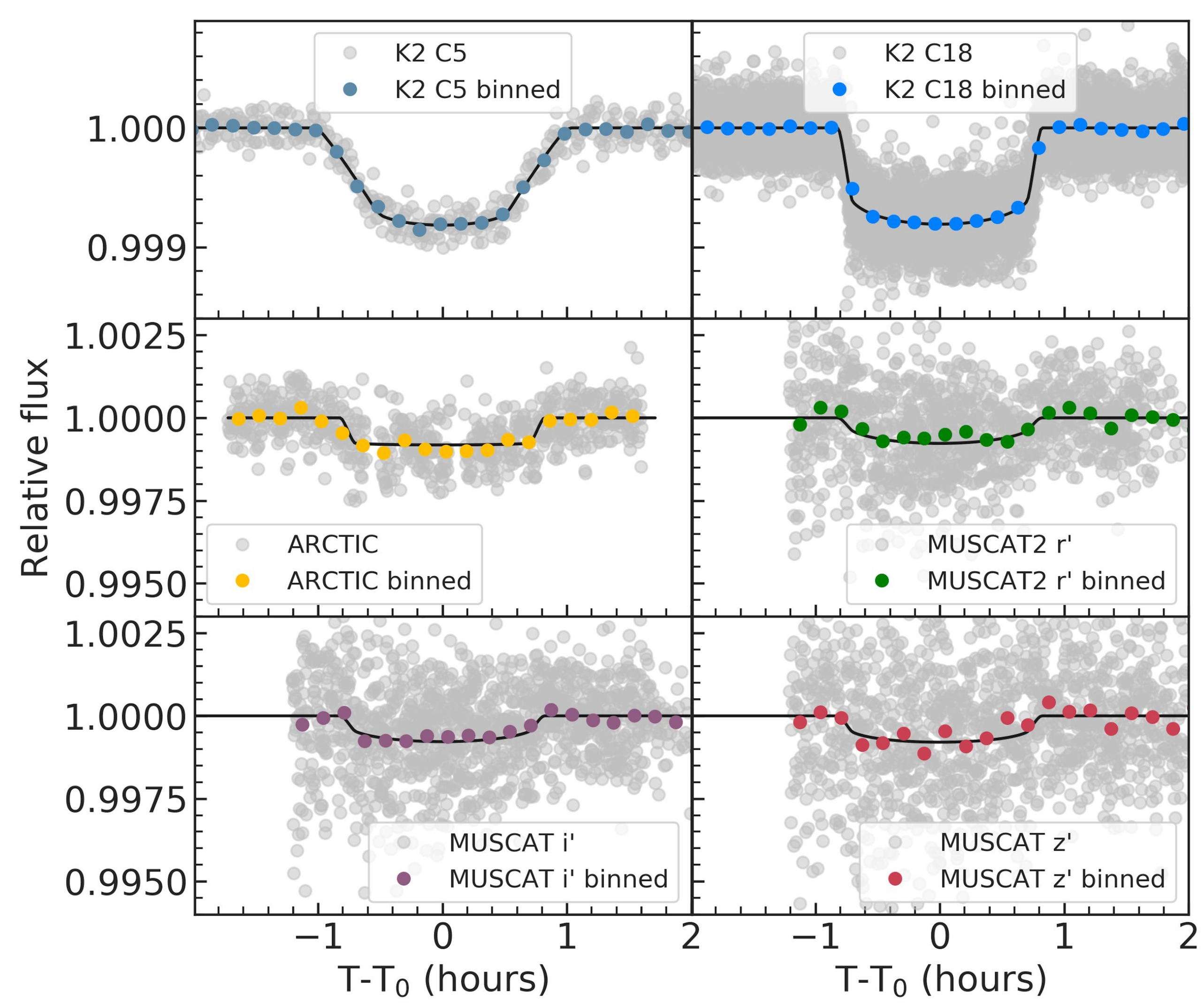
Radial velocity (top), log R'_HK (middle) and BIS (bottom) time-series. All time-series have been corrected by the inferred offset. Inferred models are presented as solid continuous lines. Measurements are shown with filled symbols with error bars. Grey error bars account for the jitter. We note that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



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 parameters

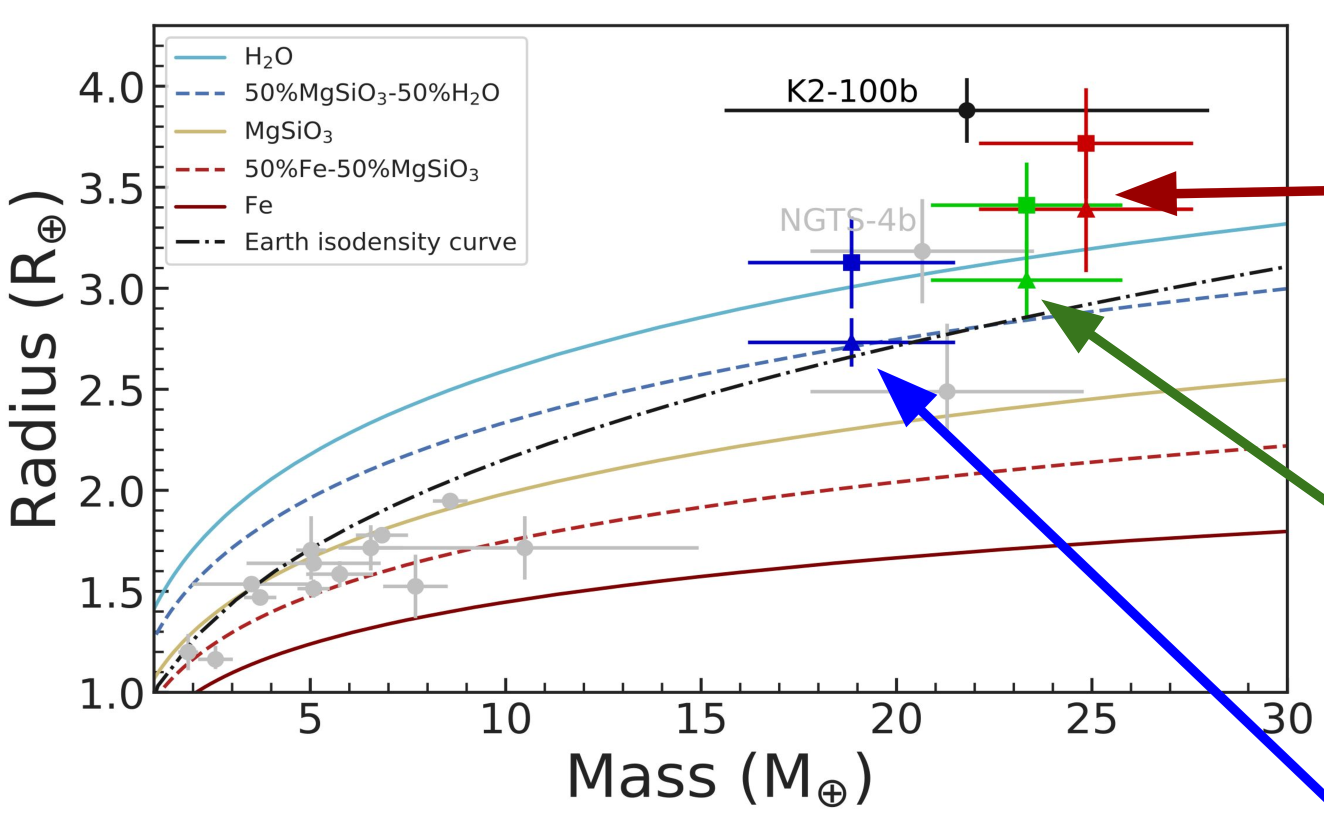
Orbital Period (days)	1.6739035 +/- 0.0000004
Transit epoch (BJD-2,450,000)	7140.71941 +/- 0.00027
Radial velocity semi-amplitude (m/s)	**10.6 +/- 3.0**
Planet Mass (Earth masses)	**21.8 +/- 6.2**
Planet Radius (Earth radius)	3.88 +/- 0.16
Planet density (g/cm³)	2.04 +/- 0.66
Orbit semi-major axis (AU)	0.0301 +/- 0.0014
Equilibrium temperature (*K*)	1841 +/- 41
Insolation (Earth units)	1915 +/- 170



K2-100b transits. Each panel shows a flattened light curve from different instruments folded to the orbital period of K2-100b. Black lines show the best-fitting transit models.

K2-100b's atmospheric evolution models

- We employed the atmospheric evolution scheme described by Kubyshkina et al., (2018, 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).



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).

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

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

Take home

- We measured a mass of 21.8 +/. 6.2 Earth Masses for K2-100b, a 3.88 +/- 0.16 Earth Radii planet transiting a star in the Praesepe cluster.
- We estimated that the relative high irradiation received by the planet implies that its atmosphere is currently evaporating.
- This makes of K2-100b an excellent laboratory to test photo-evaporation models.
- 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*.

References

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