The multi-planet system TOI-421

A warm Neptune and a super-puffy mini-Neptune

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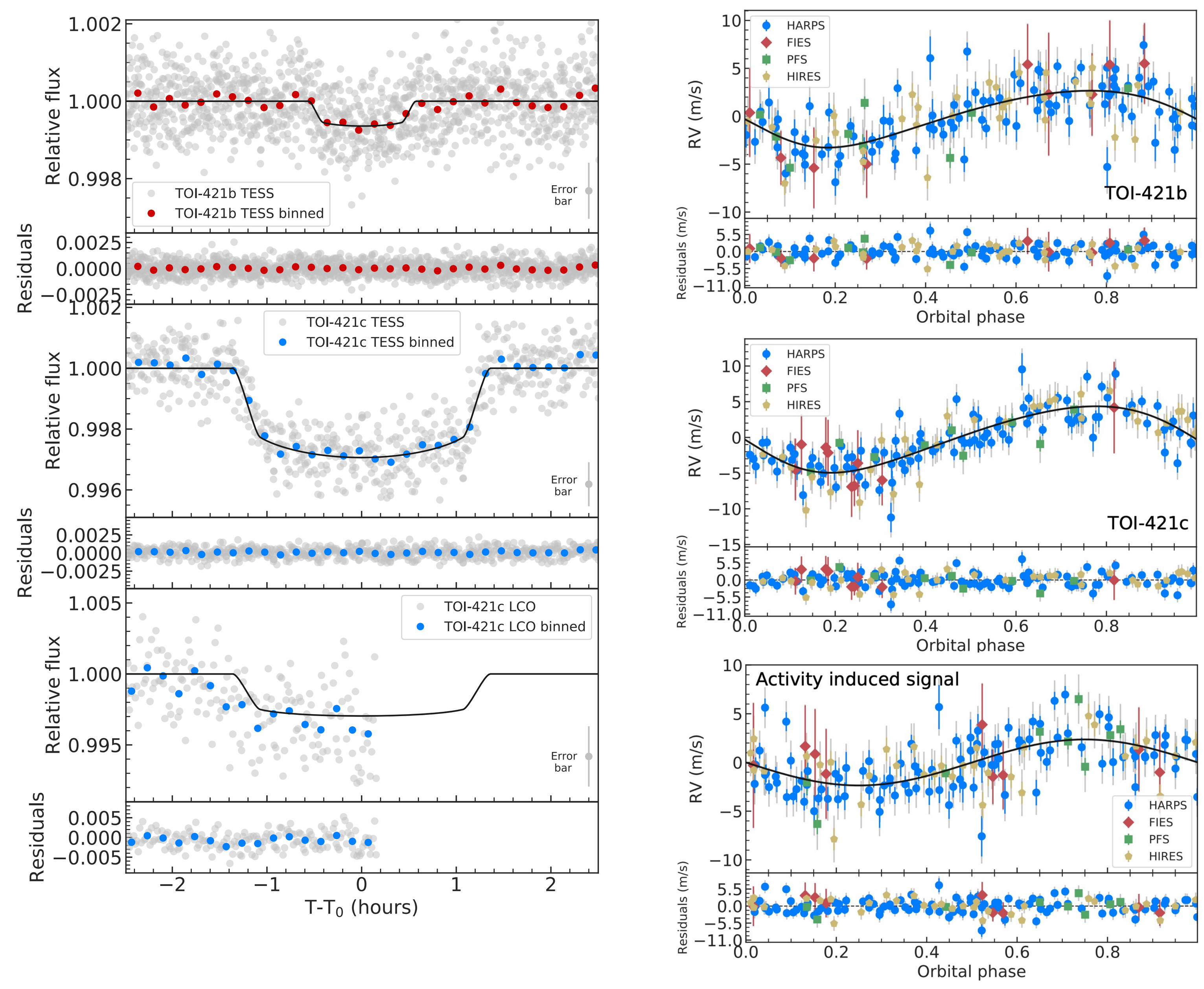
Introduction

Since July 2018 *TESS* has been scanning the sky and performing a photometric search for planets transiting bright stars. *TESS* is expected to detect ~10,000 transiting exoplanets (Barclay+2018). More than 1,000 planet candidates have been revealed, with dozens of confirmed planets so far, some of which are multi-planet systems (e.g. Quinn+2019). Multi-planet systems are prime targets for testing planetary formation and evolution theories. Orbiting the same star, they offer an opportunity to simplify the assumptions of initial conditions and compare planets with different sizes and compositions in the same system. Such systems are also interesting for transmission spectroscopy, which allows us to characterize planetary atmospheres and compare them at different levels of incident stellar flux.

Joint analysis

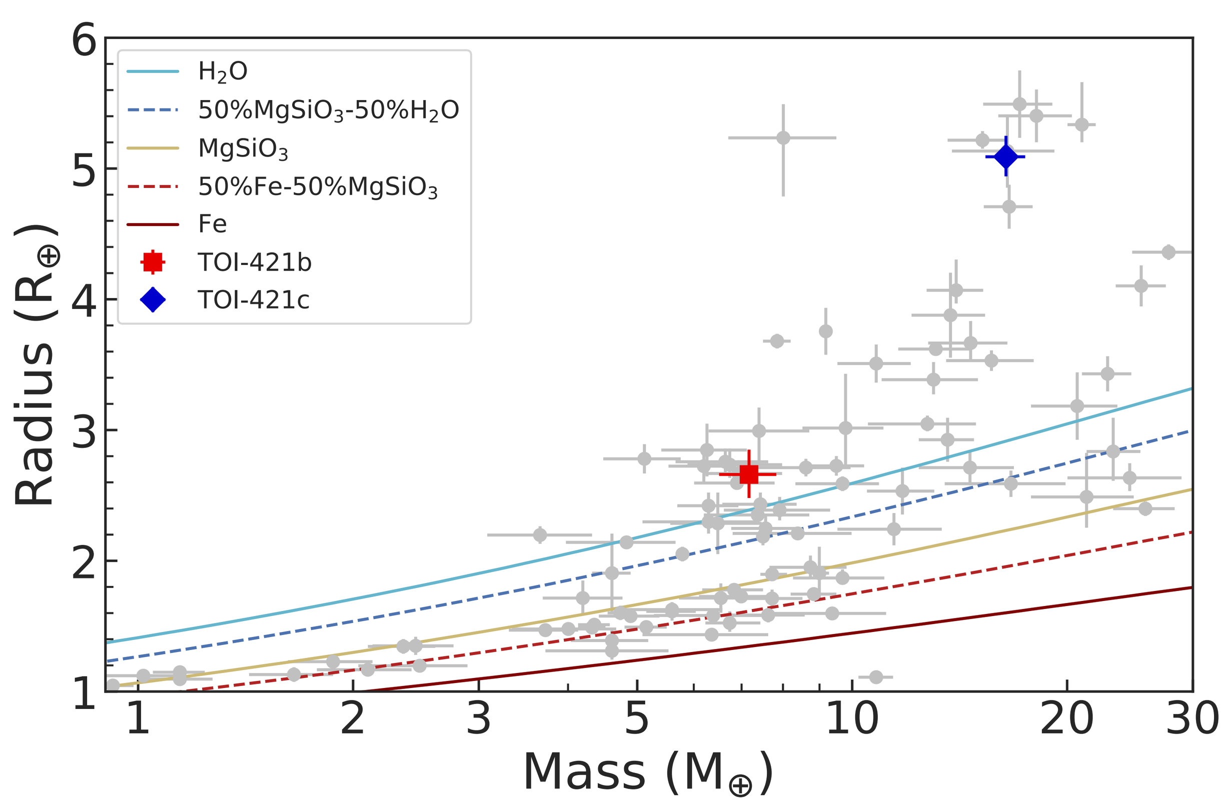
We performed a global analysis of our radial velocity and transit data with the open-source code pyaneti (Barragán+2019., MCMC sampling approach), in order to obtain the system's parameters.

Planet	P_{orb} (days)	Radius ($R_\oplus$)	Mass ($M_\oplus$)	T_{eq} (K)
b	5.19672	2.68	7.17	981.4
c	16.06819	5.09	16.42	673.6



Results

The figure below shows the position of TOI-421 b and c in the mass-radius diagram along with the sample of small planets ($Rp \leq R_\oplus$) whose masses and radii have been measured with a precision better than 20%. Given their positions with respect to theoretical mass-radius relations, both planets are expected to host an atmosphere dominated by light elements, namely H and He.

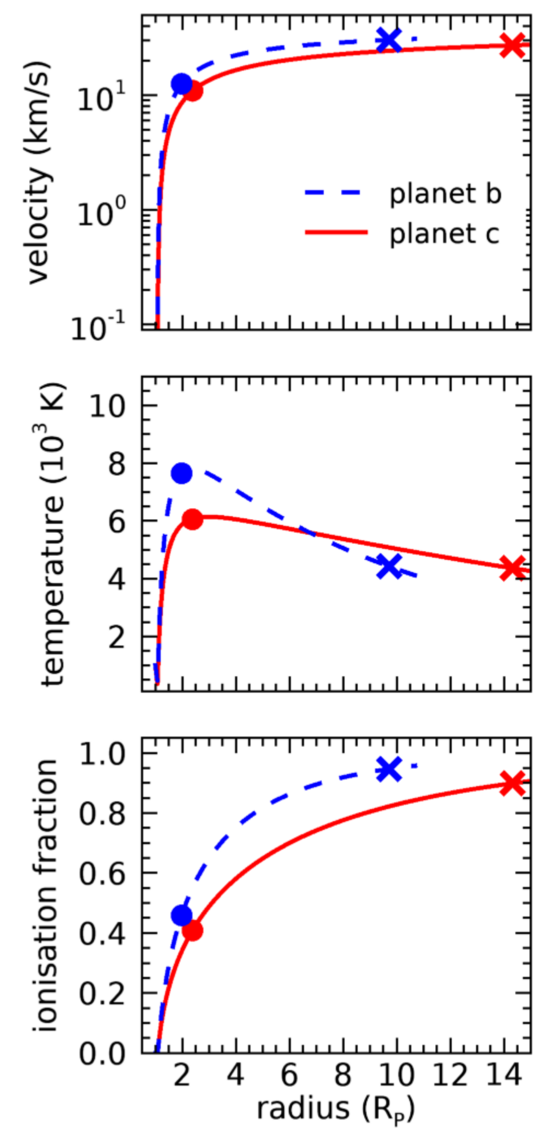


Attractive system for atmospheric characterization

➢ Hydrogen escape

Our model (Allan & Vidotto 2019) predicts comparable, strong hydrogen escape in both planets b and c.

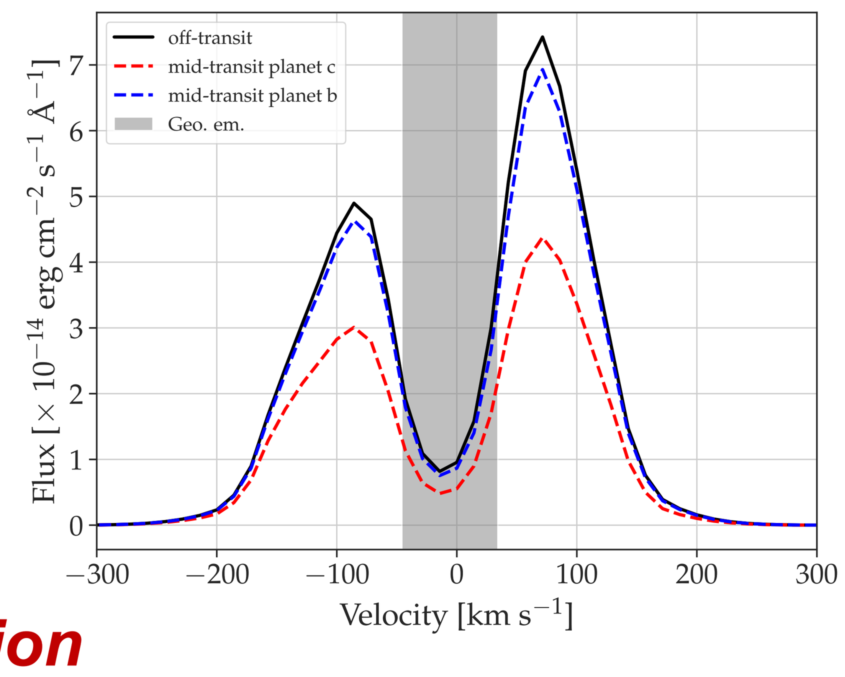
TOI-421 b	TOI-421 c
Escape rate = 4.3×10^{10} g/s	Escape rate = 4.2×10^{10} g/s
R_{roche} = 9.7 R_p	R_{roche} = 14.3 R_p
Escaping speed = 30 km/s	Escaping speed = 28 km/s



➢ Lyα prediction

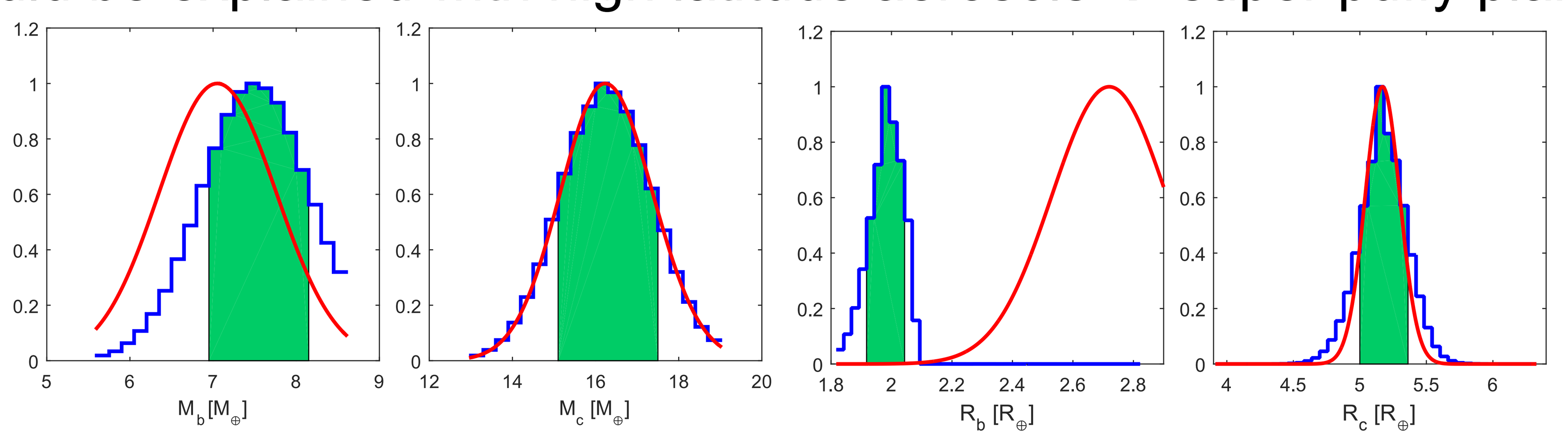
We predicted Lyα transit absorptions of 35% for TOI-421 b and 53% for TOI-421 c.

Figure shows the Lyα line profiles at the spectral resolution of the G140M grating of the STIS spectrograph on HST.



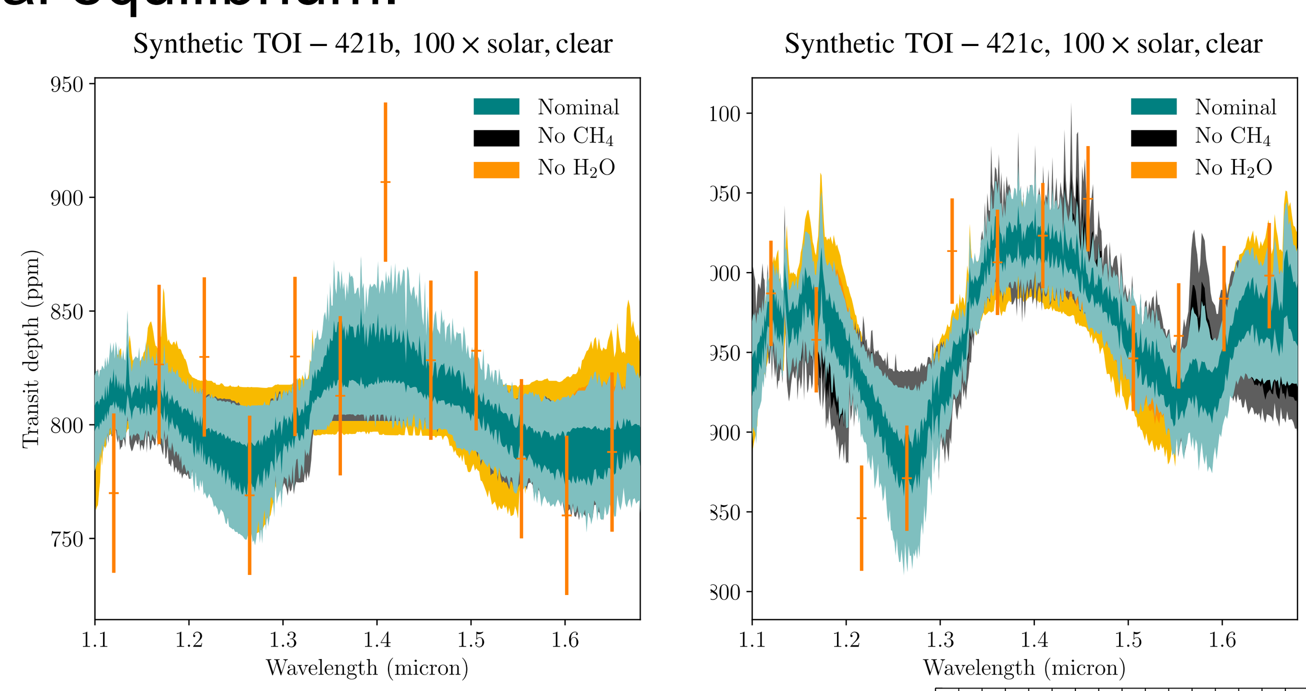
➢ Atmospheric evolution

Given the system parameters, the evolution code (Kubyshkina+2018) found that TOI-421 b always loses its hydrogen atmosphere, regardless of the evolution of the stellar XUV emission. The discrepancy between the simulated and measured parameters could be explained with high latitude aerosols → super puffy planet!



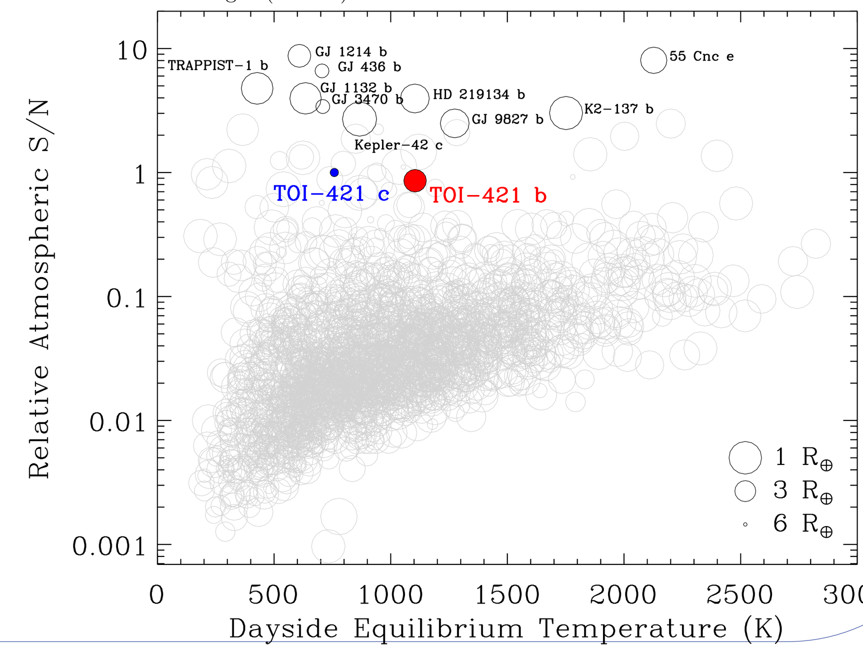
➢ HST WFC3 retrievals

The atmospheric retrievals (Mollière+2019) demonstrated that we can detect CH_4 in the atmosphere of TOI-421 c if the atmosphere is in chemical equilibrium.



➢ JWST

This multi-planet system would be a prime target for the upcoming JWST observations. Indeed, the two planets are among the first 30 targets with the highest expected signal-to-noise ratios.



Bibliography

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