# SEARCHING FOR SIGNATURE OF HOT JUPITERS: THE POTENTIALITY OF THE SPECTROPHOTOMETRY FOR TRANSITING PLANET DETECTION AND THE STUDY OF THEIR ATMOSPHERES

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## HOT JUPITERS: WHAT ARE THEY?

They are gas giant planets that generally have orbital periods shorter than 10 days, meaning that they orbit around their host stars at very close distances (<0.1 Astronomical Unit (AU) ).

## AIM OF THE PROJECT

We aim to test the spectrophotometric technique to detect two Hot Jupiters: **WASP-18b**, one of the largest Hot Jupiters observed; **WASP-19b,** provided with a molecule-rich atmosphere. We intend to unravel the planets' signatures by analysing absorption features that are commonly found in exoplanetary atmospheres, such as the sodium band and the helium triplet, and draw comparisons on the physical properties of our target objects.

## SPECTROPHOTOMETRY: WHAT IS IT?

We use spectrophotometry to measure flux changes as a function of wavelength. As the planet orbits around its host star, the light it reflects varies: no light is reflected while the planet passes behind the star (secondary eclipse) however, some is reflected when it enters and leaves the eclipsing phase; thus, the spectrum obtained from subtracting the star eclipse spectrum from the star + planetary dayside spectrum accounts for both emission and reflection (Madhusudhan, 2019, ARA&A ,57, 617).

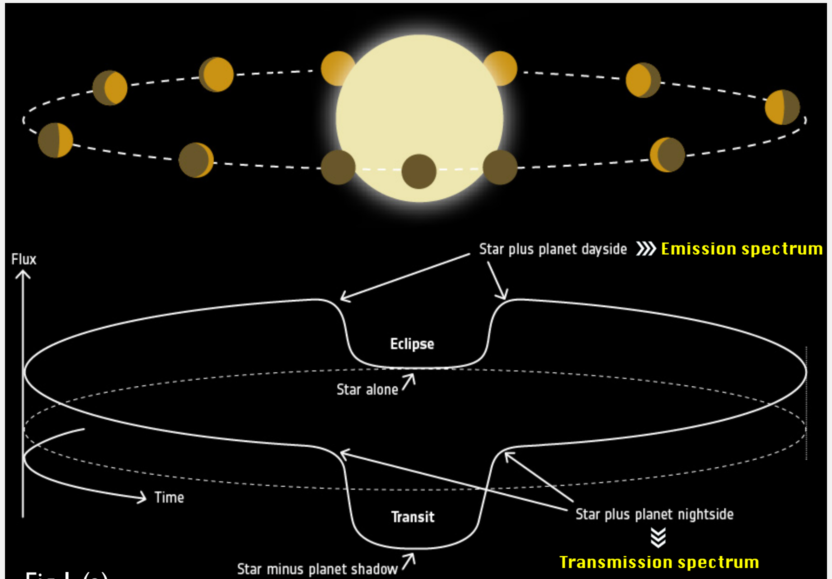


Fig. 1 (a)

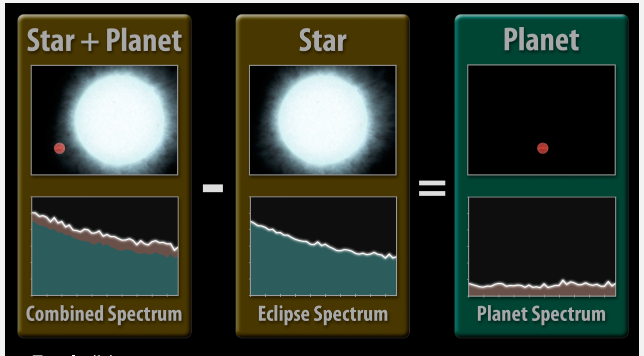


Fig. 1 (b)

A combined analysis of the light curve and emission spectra can be used to detect planets and reveal the chemical composition of the their atmosphere.

# METHODS & RESULTS

We write a Python code to perform the following tasks:

1. Obtaining and classifying the spectra of our target objects according to the orbiting phase of the planet (during or out of secondary eclipse);
2. Spectra with the best signal-to-noise ratio (SNR) are normalised, co-added and averaged to obtain a single spectrum for the in/out-of eclipse phases (Fig.3);
3. We integrate the single-observation spectra over regular bands of 50nm to obtain the associated photometric points and explore the variability of the system (Fig.4).

**Fig. 2** – We use calibrated intermediate-resolution spectra of XSHOOTER, an instrument located on the Kueyen Telescope (in the middle of this picture), the second Unit of the Very Large Telescope at the Paranal Observatory, Chile. It provides the largest wavelength coverage (300-2500 nm) and flux-calibrated spectra therefore it is suitable for our research. Image Credits: Miguel Claro.

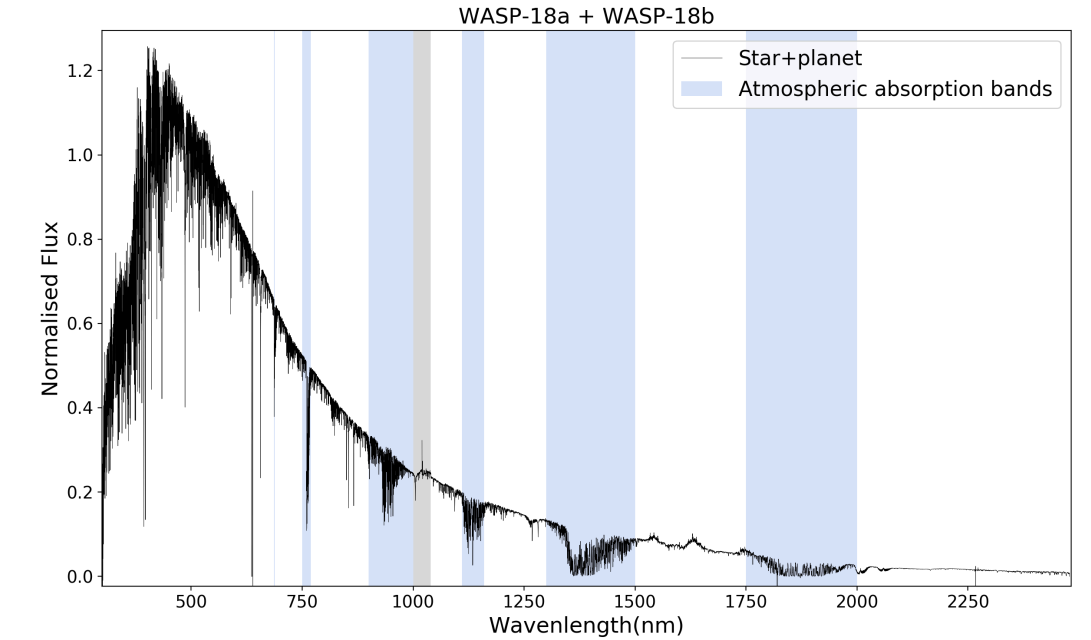



**Fig. 3** - The UV, visible and infrared (IR) arms are combined to produce a full spectrum of the WASP-18 system while the planet is in its out-of-eclipse phase. The grey shaded area represents the transition between the visible and IR arms, which is excluded from further analysis because of its poor calibration level. Atmospheric absorption bands also interfere with the planetary signatures hence we will not consider them.

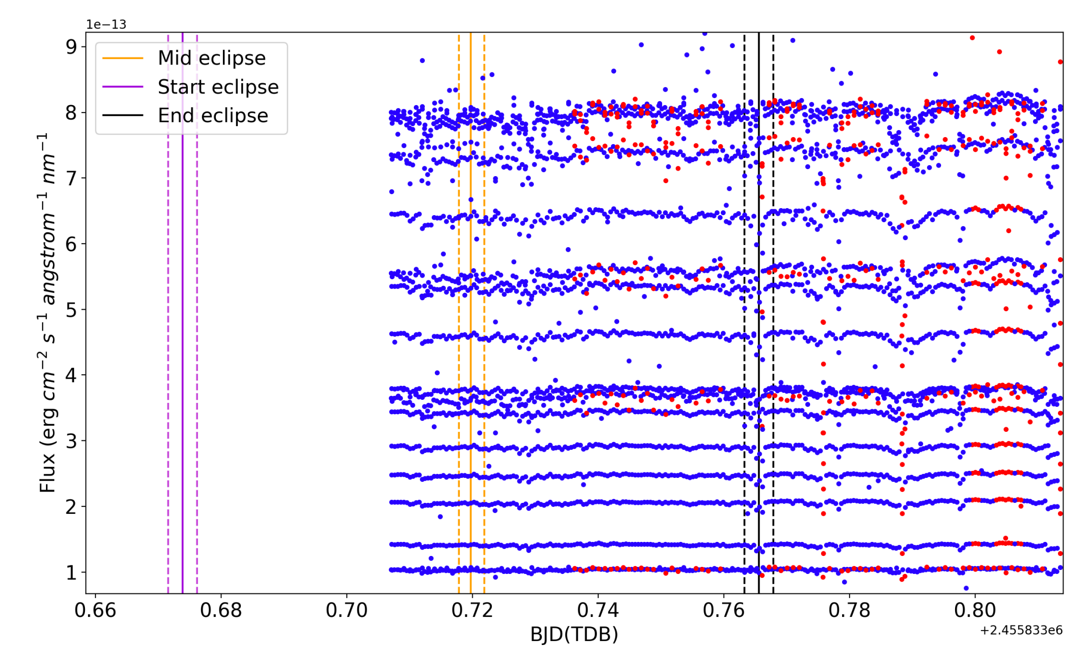
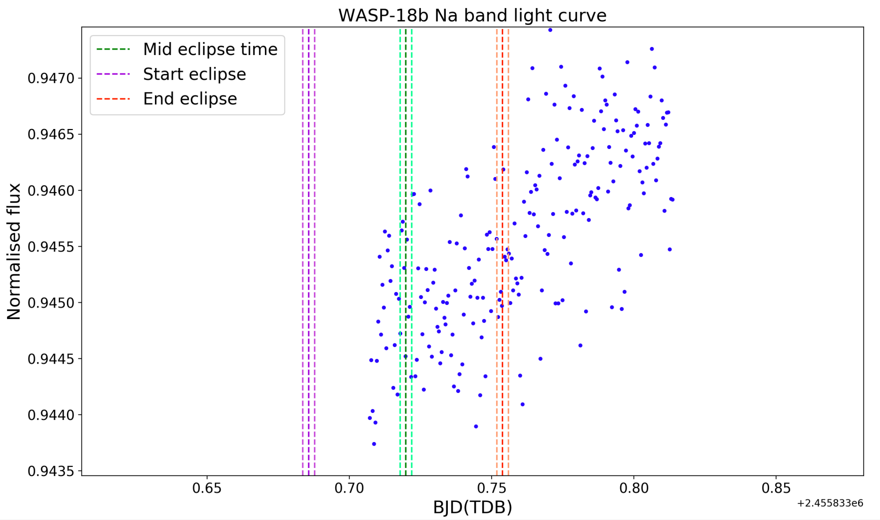



**Fig. 4** – Photometric points for WASP-18b are computed and plotted against the time expressed in Barycentric Julian Days (BJD). Blue / Red points correspond to spectra with a good/bad SNR. The start, mid and end timings of the secondary eclipse of the planet are over-plotted with their uncertainties. We can see that even spectra with a good SNR have uncertainties in the calibration of 10-15%, which prevents from detecting any planetary signature (~ 3%).



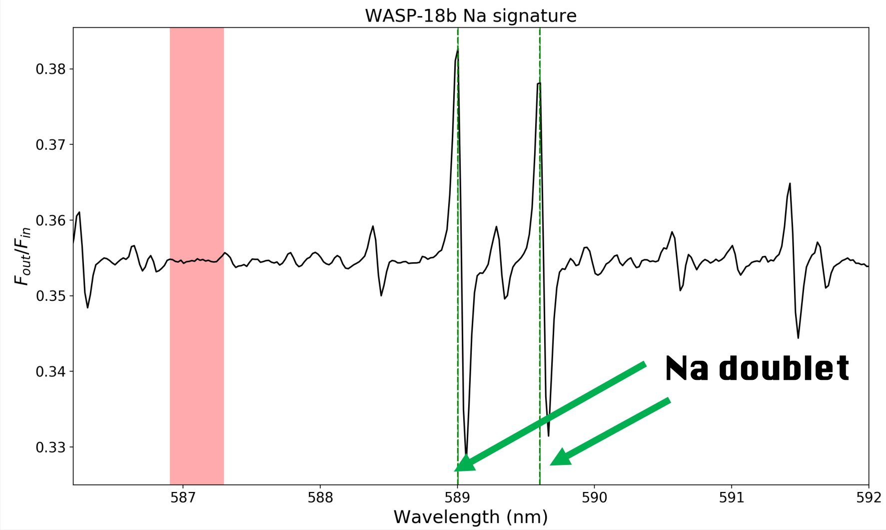
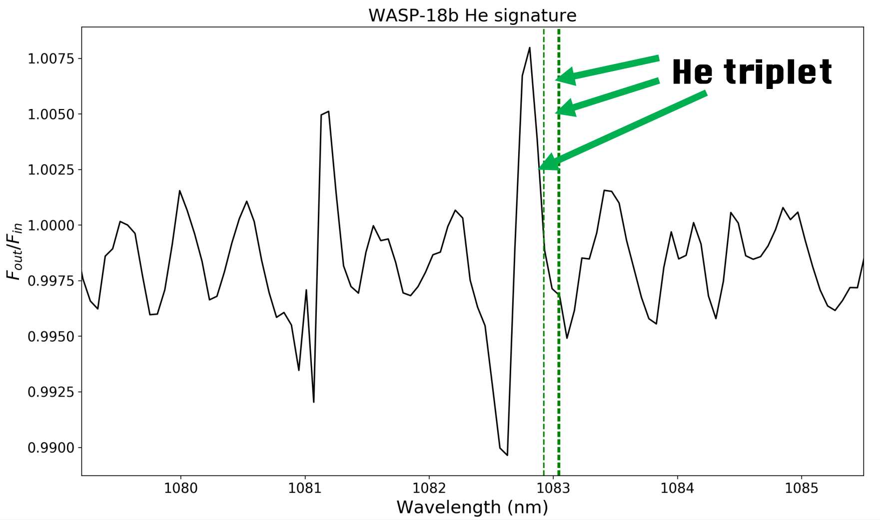




**Fig. 5** – ***Left***: to improve the calibration level, we perform the integration over a narrower region (~2 nm) around the Na band. The flux values are normalised with respect to the local continuum (red shaded area in the adjacent plot). As the light curve shows, we correct the calibration level by a factor of 50. While the planet is orbiting behind the star, the star's light curve shows a dip as expected. ***Right***: the ratio between the flux of the out-of-eclipse template and in-eclipse template is plotted against the narrower wavelength range. The signature of the sodium (i.e. green vertical lines) in WASP-18b's atmosphere is >6σ. A similar result is obtained for WASP-19b.



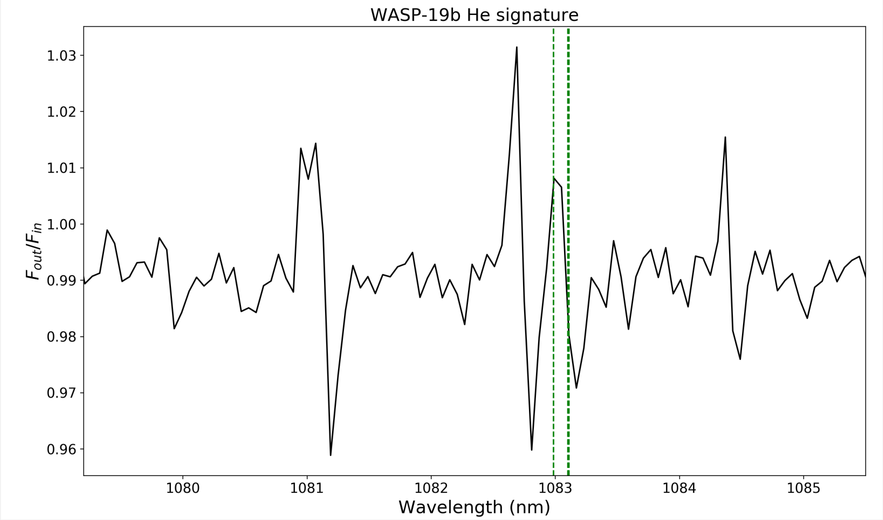




**Fig. 6** – Compared to the sodium band, we do not find a significant helium signature in the atmospheres of the same objects: in both cases, the He feature is <3σ. This leads us to think that the physical properties of the atmospheres of the two planets may be different. Additional results may be obtained by applying our technique to targeted observations, for instance while both planets are transiting in front of their host stars.

SCAN ME

**To watch exoplanet animations, including WASP-19b**

## CONCLUSIONS

- The calibration level of the spectra does not allow a spectrophotometric analysis however, by focusing on narrower bands and using them relative to the continuum, we correct the calibration by a factor of 50, thus achieving a level that allows to use ground-observations to detect planetary signatures usually identified through space-observations;
- The detection of Na in the atmosphere of WASP-18b and WASP-19b is >6σ; no He is detected in either planets.

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