EPSC Abstracts
Vol. 13, EPSC-DPS2019-411-2, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Warm Neptunes : a sweet spot for atmospheric characterization

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Abstract

Observations of exoplanets during the transit of their host star allow us to probe the structure and composition of their atmospheres. The intense stellar energy input into exoplanets on short orbits can lead to a dramatic expansion of their upper atmosphere, and the loss of massive amounts of gas escaping into space. Recently, spectrally-resolved UV observations of the warm Neptune GJ436b with the Hubble Space Telescope revealed the largest atmospheric structure ever detected [1], a tail of hydrogen extending over more than 10 millions of km [2]. This discovery raised questions as to the origin and continued existence of low-mass planets like GJ436b at the fringes of the Neptunian desert of close-in planets.

New light was shed on these questions thanks to the discovery of a giant hydrogen exosphere around another warm Neptune bordering the desert, GJ3470b [3]. Hubble observations obtained in the frame of the Panchromatic Comparative Exoplanet Treasury program (PanCET, P.I. D. K.Sing & M. López-Morales) revealed that the atmosphere of GJ 3470b occults up to 35% of the star at Lyman-alpha wavelengths. Analyzing the Doppler shift of the atmospheric absorption signature, temporally and spectrally resolved over the transit, allowed determining the spatial and dynamical structure of the hydrogen gas escaping the planet. GJ436b and GJ3470b display striking differences, which can be understood by the high-energy environment of their M dwarf host stars shaping their upper atmosphere and affecting the planets' evolution [4] [5]. These detections show that much larger atmospheric signals can be retrieved from the upper atmosphere of moderately irradiated, low-mass planets. Many such systems will be discovered in the coming years by transit (TESS, CHEOPS, PLATO) and velocimetry (CARMENES, ESPRESSO, SPIRou, NIRPS) surveys, and the development of new tracers of atmospheric escape like helium at infrared wavelengths offers thrilling perspectives for their characterization with high-resolution ground-based spectrographs.

References

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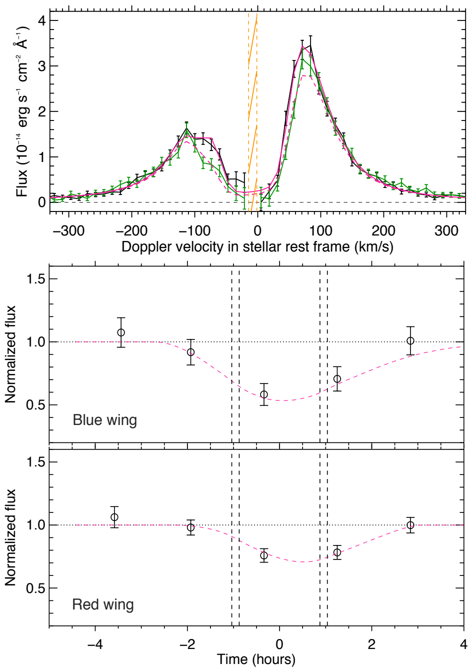

Figure 1: Lyman-α spectrum of the M dwarf GJ 436 observed with the *Hubble Space Telescope* during the transit of its warm Neptune companion (green spectrum) and outside of its transit (black spectrum). Strong absorption signatures are detected in both wings of the line, and are well explained by a dense extended atmosphere of neutral hydrogen (in the red wing) that escapes into an exospheric tail shaped by stellar radiation pressure (in the blue wing). These conclusions are derived from 3D numerical simulations with the EVE code [4] (solid and dashed magenta profiles show theoretical out- and in-transit spectra). Bottom panels display the observed and theoretical light curves within the absorbed spectral ranges.