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The robustness of using near-UV observations to detect and study exoplanet magnetic fields

Jake D. Turner, Duncan Christie, Phil Arras, and Robert E. Johnson
Department of Astronomy University of Virginia, Charlottesville, VA 22904, United States (jt6an@virginia.edu)

Abstract

Studying the magnetic fields of exoplanets will allow for the investigation of their formation history, evolution, interior structure, rotation period, atmospheric dynamics, moons, and potential habitability. We previously observed the transits of 16 exoplanets as they crossed the face of their host-star in the near-UV in an attempt to detect their magnetic fields (Turner et al. 2013; Pearson et al. 2014; Turner et al. in press). It was postulated that the magnetic fields of all our targets could be constrained if their near-UV light curves start earlier than in their optical light curves (Vidotto et al. 2011). This effect can be explained by the presence of a bow shock in front of the planet formed by interactions between the stellar coronal material and the planet's magnetosphere. Furthermore, if the shocked material in the magnetosheath is optically thick, it will absorb starlight and cause an early ingress in the near-UV light curve. We do not observe an early ingress in any of our targets (See Figure 1 for an example light curve in our study), but determine upper limits on their magnetic field strengths. All our magnetic field upper limits are well below the predicted magnetic field strengths for hot Jupiters (Reiners & Christensen 2010; Sanchez-Lavega 2004). The upper limits we derived assume that there is an absorbing species in the near-UV. Therefore, our upper limits cannot be trusted if there is no species to cause the absorption.

In this study we simulate the atomic physics, chemistry, radiation transport, and dynamics of the plasma characteristics in the vicinity of a hot Jupiter using the widely used radiative transfer code CLOUDY (Ferland et al. 2013). Using CLOUDY we have investigated whether there is an absorption species in the near-UV that can exist to cause an observable early ingress. The number density of hydrogen in the bow shock was varied from $10^4 - -10^8\ cm^{-3}$ and the output spectrum was calculated (Figure 2) and compared to the input spectrum to mimic a transit like event (Figure 3). We find that there isn't a species in the near-UV that can cause an absorption under the conditions ($T = 1 \times 10^6$ K, semi-major axis of 0.02 AU, solar input spectrum, solar metallicity) of a transiting hot Jupiter (Figure 3). Therefore, our upper limits can not be trusted. We can eventually use CLOUDY to explore the escaping atmospheres from hot Jupiters. We can still use our data to constrain the atmospheric proprieties of the exoplanets.

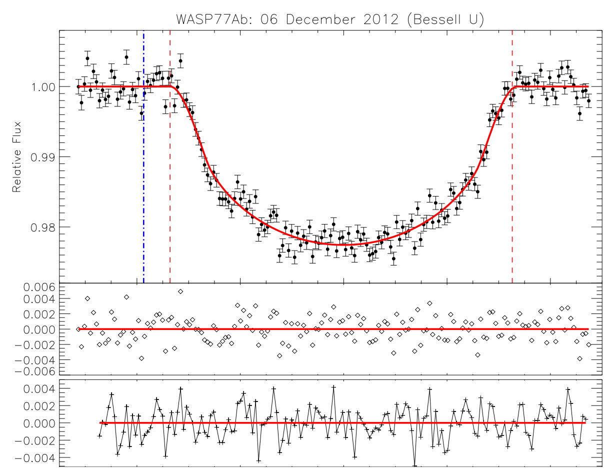

Figure 1: Near-UV light curve of WASP-77b (Turner et al. in press). The best-fitting model obtained from the EXOMOP is shown as a solid red line. The blue dot-dashed is a reasonable estimate of when the ingress should have started. The residuals are shown in the second panel. The third panel shows the residuals of the transit subtracted by the mirror image of itself. All our light curves show no near-UV asymmetries.

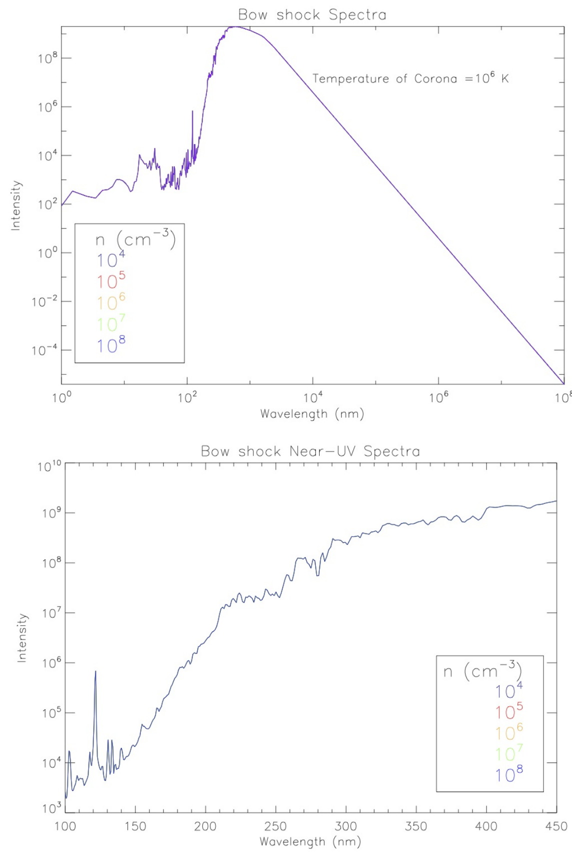

Figure 2: Output spectrum from CLOUDY of the bow shock at different number densities in the bow shock. **Top:** The full spectrum of the bow shock (x-ray to Radio). **Bottom:** The near-UV spectrum of the bow shock.

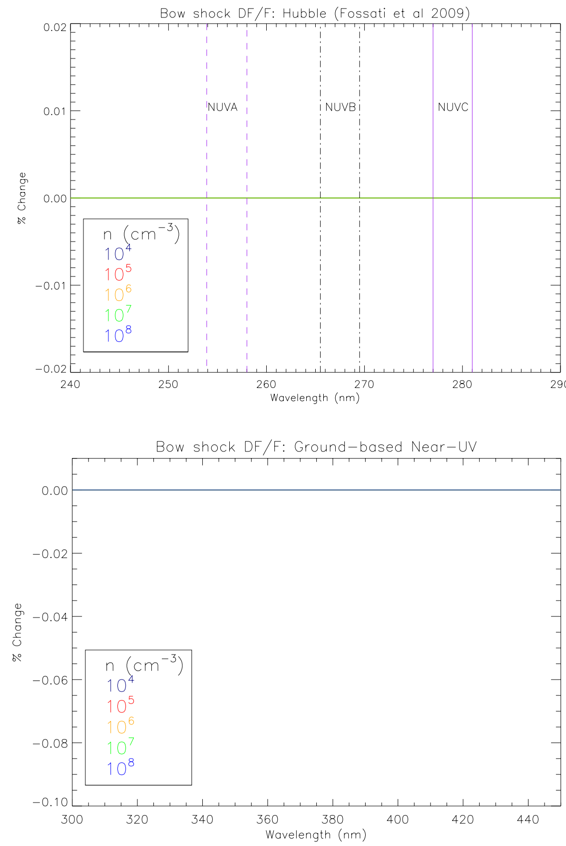

Figure 3: Change in flux of the output bow shock spectra at different number densities in the bow shock. We observe no detectable changes in flux due to a bow shock being in front of its host star. **Bottom:** Change in flux of the near-UV spectrum observed from the ground (300-440 nm; Turner et al. 2013; Pearson et al. 2014; Turner et al. in press). **Top:** Change in flux of the near-UV spectrum observed by Fossati et al. 2009 (the NUV filters are shown).

References

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