Probing the atmosphere of the ‘hot Jupiter’ TrES-1b with HST

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Abstract: The atmosphere of transiting exoplanets can be studied through transmission spectroscopy. A correlation has been observed between hot Jupiter emission spectra and stellar activity levels. We suggest a correlation between optical haze in the transmission spectra of planetary atmosphere and the level of stellar activity. We test this correlation on the HST optical transmission spectrum of TrES-1b, a hot gas giant planet orbiting an active star.

Transmission spectroscopy

The atmosphere of an exoplanet can be studied from its emission spectrum (e.g. using direct imaging, secondary eclipse) or from its transmission spectrum (transit spectrophotometry). A planet transiting in front of its star decreases the stellar brightness by a quantity which depends on the planet’s apparent size (e.g. Charbonneau et al. 2000). Absorption of stellar photons by atoms and molecules in a transiting planet’s atmosphere leads to a larger apparent size of the planet at the absorbing wavelengths. The wavelength dependence of the planet’s apparent radius returns a transmission spectrum of the planet’s upper atmosphere (Seager & Sasselov 2000).

Stellar activity and atmospheric haze

We propose a correlation between stellar activity level and haze in the optical transmission spectra. We suggest that the strong UV radiation from the active host star creates a photochemical haze in the planet’s atmosphere which scatters lights in the visible. We test this hypothesis on the optical transmission spectrum of the hot Jupiter TrES-1b. TrES-1b orbits an active star with activity level between HD189733 and HD209458. Under the suggested correlation, the transmission spectrum of TrES-1b should exhibit haze, similar to HD189733 but more optically thinner (Fig. 3).

Stellar activity and thermal inversion

The emission spectra of several hot Jupiters (Jupiters from Jupiter-size planets) have been observed with multi-wavelength secondary eclipse observations. Some of these planets exhibit no atmospheric thermal inversion. Knutson et al. 2010 present a correlation between no-inversion and stellar activity. Planets around active stars exhibit no thermal atmospheric inversion (Fig. 2) as the increased UV flux from the active host star destroys the high-altitude absorber responsible for the formation of the temperature inversion.

Analysis of TrES-1b

The data used are multi-wavelength optical light curves of three HAC archived visits over TrES-1b transit (Rabus et al. 2009). For each colour light curve, the planet apparent radius in least-square fitted to Mandel & Agol 2002 analytical transit models (Fig. 4). The other transit fitting parameters are fixed to the values derived from the fit to the white light curve. The quadratic limb darkening coefficients are fixed to the optimized values derived from a linear interpolation over the model coefficients (Fig. 5). The uncertainties on the fitted values are derived from the fit.

Challenges: The photometric signatures of occulted and unocculted stellar spots distort the transmission spectrum, so they are corrected from. The transit depth is degenerate between the planet’s radius and the stellar limb darkening, so the latest is carefully estimated (Fig. 5). The different choices of limb darkening coefficients and the study of the individual visits lead to different planet radii and hence to slight differences in the transmission spectrum of TrES-1b.

Conclusions:

The final analysis of the Transmission spectrum of TrES-1b is a work in progress. The transmission spectrum of the hot Jupiter darkening law is fixed to a linear interpolation (red) over the model values (black) derived from the transit. The optimized values are derived from the transit fits with free linear term of the quadratic limb darkening law. The quadratic term is fixed to the model values.