**Abstract**

HAT-P-7b is a hot Jupiter with mass 1.7 M\(_{\oplus}\) orbiting an F6 star with an orbital semi-major axis only four times greater than the radius of its host star. The HAT-P-7 light curve features Doppler, phase and ellipsoidal variations caused by the gravitational perturbation of the shape of the star by the close-orbiting planet. The Kepler Space Telescope recorded photometry from May 2009 to June 2011 (Quarters 1-9), spanning 355 orbital phases. We find a ~10 ppm perturbation to the average transit light curve that we attribute to a temperature decrease on the surface of the star, phased to the orbit of the planet. This cooler spot is consistent with planet-induced gravity darkening, slightly lagging the sub-planet position due to the finite response time of the stellar atmosphere. The brightness temperature of HAT-P-7b in the Kepler bandpass is \(T_b = 2733 \pm 21\) K and the amplitude of the deviation in stellar surface temperature due to gravity darkening is approximately ~0.18 K.

**Analysis: Primary Transit**

- Fit each transit individually to find mid-transit times and generate precise ephemerides
- Phase-fold to create a composite light curve, fit theoretical model by Mandel & Agol (2002) to composite light curve using Levenburg-Marquardt least-squares (see Fig. 1)
- No evidence for significant transit timing variations

**Analysis: Gravity Darkening**

- The anomaly is not consistent with typical magnetically-driven star spots
- One possible explanation is planet-induced gravity darkening:
  - The tidal distortion of the star due to the planet causes a decrease in the surface gravity near the sub-planet region
  - There is a corresponding decrease in stellar surface temperature and brightness near the sub-planet region
  - “Few 0.1 K” change predicted by Jackson et al. (2012)
- Here, we construct a simple model to characterize the plausibility of planet-induced gravity darkening as an explanation for the anomaly in the residuals

**Analysis: Secondary Eclipse**

- We masked the eclipse and fit to model phase curves to account for the significant phase variation effects, Doppler beaming, planetary reflection
- We fit a Mandel & Agol (2002) model eclipse light curve to each eclipse individually (see Fig. 3)
- Mean eclipse depth \(D = 69.1 \pm 3.8\) ppm
- We find a geometric albedo of \(<0.03\), consistent with other observational and theoretical predictions for hot Jupiters (see Barclay et al. 2012, Christiansen et al. 2010)
- If we assume that all of the flux from the atmosphere of the planet is thermal emission, we find the brightness temperature \(T_b = 2733 \pm 21\) K

**Discussion**

- The phase-lag of the gravity-darkened spot, \(\Delta t\), can be computed analytically from first-principles by

\[
\Delta t \sim \sqrt{\frac{3k_B T}{5GM_H}}
\]

- The temperature (\(T\)) and surface gravity (\(g\)) at the photosphere, where the dark spot manifests, can be inferred from simulations of stellar atmospheres
- Using such models by Kurucz, our observed response time measured by the phase lag of the dark spot, 1.06 \(\times\) 10\(^{-4}\) s, is consistent with the Eq. 1 prediction (\(\Delta t \sim 1.02 \times 10^{-4}\) s)
- This supports our hypothesis that the perturbation seen in the transit light curve is due to the time-dependent gravity-darkened response of the stellar atmosphere to the passage of the planet
- The detection of the spot is not statistically unequivocal due its small amplitude, though additional Kepler observations should be able to verify the astrophysical nature of the anomaly