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Analysis of Kepler Observations of HAT-P-7 b

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Abstract

HAT-P-7 b is among the hottest hot Jupiters ever discovered. Its orbital distance of about 4 stellar radii from an F star suggests the planet has a dayside temperature in excess of 2700 K. Moreover, HAT-P-7 b exerts tremendous tidal influence on its host star, significantly distorting the star's equilibrium shape. Prompted in part by these expectations, the Kepler mission observed the HAT-P-7 system in its short-cadence mode (i.e. 60 second integration times) from May 2009 till December 2010. Previous analyses of the first 10 days of Kepler observations (quarter 0) by [1] found evidence for atmospheric emission from the planet's dayside. A subsequent analysis [2] of the next 34 days of observations (quarter 1) showed evidence for ellipsoidal variations of the tidally distorted host star. Since then, another 90 days (quarter 2) of Kepler data have been made public, nearly tripling the number of planetary transits observed. This increase in the number of transits allows more complete removal of other systematic variations, facilitating a search for planetary variability. We present preliminary results of our analysis of the publicly available Kepler transit data of HAT-P-7 b. Our analysis provides improved constraints on transit parameters. The next steps in our study will involve analysis of ellipsoidal variations exhibited by the host star and a search for meteorological variability in the planet's phase curve.

1. Introduction

HAT-P-7 b was discovered by [3] and was among the few transiting planets in the Kepler field-of-view discovered from the ground. The host star is a slightly evolved F-type star with an effective temperature of 6350 K, and, with a semi-major axis of only 4 stellar radii (0.0377 AU), HAT-P-7 b was expected to have a dayside temperature ~ 2700 K. [3] obtained radial velocity data to confirm the planet's existence and also allowed an estimate of the planet's mass. Their results indicated the planet has a mass of 1.78 Jupiter masses and a radius of 1.36 Jupiter radii, indicating it is a gas giant. Analyzing the Kepler quarter 0 (Q0) data, [1] detected a secondary eclipse, as the planet passed behind the host star, with a depth of 130 ppm, suggesting a dayside temperature of 2650 K. Using Kepler quarter 1 (Q1) data, [2] showed flux from the system increased by 37 ppm as the planet passed through quadrature, consistent with variations in the host star's projected surface area resulting from its tidal distortion (ellipsoidal variations). We extended these studies by analyzing all publicly available Kepler data (Q0-Q2), tripling the number of analyzed transits (59) and allowing a search for planetary variability. So far, we have completed our analysis of the primary transits and plan to continue to analyze the ellipsoidal variations and planetary phase curve, in hopes of finding signs of atmospheric variability.

2. Analysis

After analyzing the noise properties of the Kepler and accounting for the presence of correlated noise, we isolated 14 hr segments of the Kepler data, centered on the primary transits. We employed a standard limb-darkened transit model [4] and a Levenberg-Marquardt (L-M) chi-squared minimization scheme to fit the mid-transit times and search for transit-timing variations. (So far, we've found none.) With these mid-transit times, we phased up and averaged all 59 transit curves. We then used a Markov Chain Monte-Carlo (MCMC) code to fit the shared transit parameters, duration, the ratio of the planet's to the star's radius (R_p/R_*), the impact parameter, and the quadratic limb darkening coefficients (LDCs) γ_1 & γ_2, to the average transit curve. Holding these parameters fixed, we re-fit the mid-transit times. We iterated between the L-M and MCMC fitting several times until mid-transit times converged. Figure 1 below shows the resulting transit curve fits, and Table 1 shows our fit parameters, along with 1-σ uncertainties.

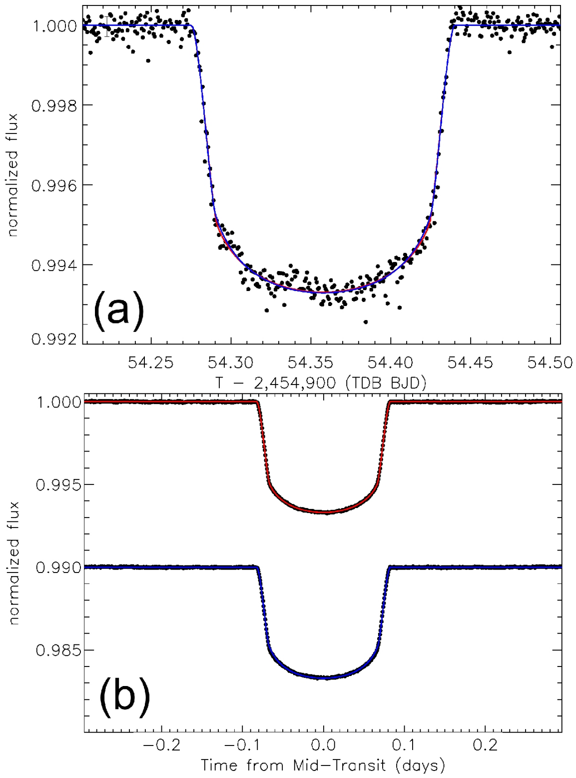

Figure 1: (a) A typical individual transit, the first observed during Kepler Q0. The red curve is the best-fit curve allowing the LDCs to float (2nd column in Table 1), while the blue curve is the best-fit holding them fixed (solution NOT shown in Table 1). (b) The stacked transit data and best-fits. Red and blue curves have the same meaning as in (a) and are offset for clarity.

Table 1: Transit Parameters

Parameter	Values	1-σ unc.
Period (days)	2.2047338	0.0000008
E (TDB BJD)	2454954.3576	0.0001
Duration (days)	0.14787	0.00007
R_p/R_*	0.07758	0.00005
Impact param.	0.498	0.003
γ_1	0.345	0.008
γ_2	0.182	0.01
(semi-major axis)/R_*	4.15	0.01
Inclination (deg)	83.1	0.1

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