Kepler's Optical Phase Curve of the Exoplanet HAT-P-7b

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One of several methods for detecting exoplanets is to measure sequences of transits (*1*). To date, about 50 transiting exoplanets have been discovered by ground-based observations and CoRoT (*2*), among them HAT-P-7b (*3*). The Kepler mission (*4*) was launched on 6 March 2009 to detect Earth-size exoplanets. We collected 10 days of photometric data on 52,496 stars during the commissioning phase, which included data for HAT-P-7b. The data were processed by using the standard Kepler pipeline (*4*).

To estimate the detectability of the occultation of HAT-P-7b when it passes behind the star, we fit the data with an empirical model (Fig. 1) consisting of a transit of a limb-darkened star, a non–limb-darkened occultation, and a sinusoid for the phase variation between transits (*4*). The fit resulted in an orbital period of 2.204802 ± 0.000063 days, a transit depth of 6726 ± 11 parts per million (ppm), and an occultation depth of 130 ± 11 ppm, corresponding to an 11.3σ event for the combined set of four occultations. The residuals following this fit have a root mean square of 60 ppm. The peak in the phase variation of the planet is 122 ppm above the flux level just outside of transit. The phase variation represents the combination of the light reflected by the atmosphere of the planet as well as the thermal emission of the atmosphere. The flux levels near transit and during occultation are within 1σ.

Kepler's photometric detection of the optical phase curve and occultation of HAT-P-7b confirms the prediction based on theoretical models (*3*, *5*, *6*). The depth of the occultation and the shape and amplitude of the phase curve indicate that HAT-P-7b could have a strongly absorbing atmosphere and inhibited advection to the night side. If the planet has a completely absorbing atmosphere, its dayside temperature is estimated to be 2650 ± 100 K. The position in phase of the occultation is consistent with zero orbital eccentricity, as expected from the radial velocity variation. Analogous detections of emitted and reflected light and an occultation were reported for the very hot exoplanets CoRoT-1b (*7*) and CoRoT-2b (*8*).

The detection of the occultation without systematic error correction demonstrates that Kepler is operating at the level required to detect Earth-size planets. The signal from a Sun-Earth analog (~84 ppm) in an Earth-like orbit of a 12th-magnitude star will be at a comparable level of statistical significance.

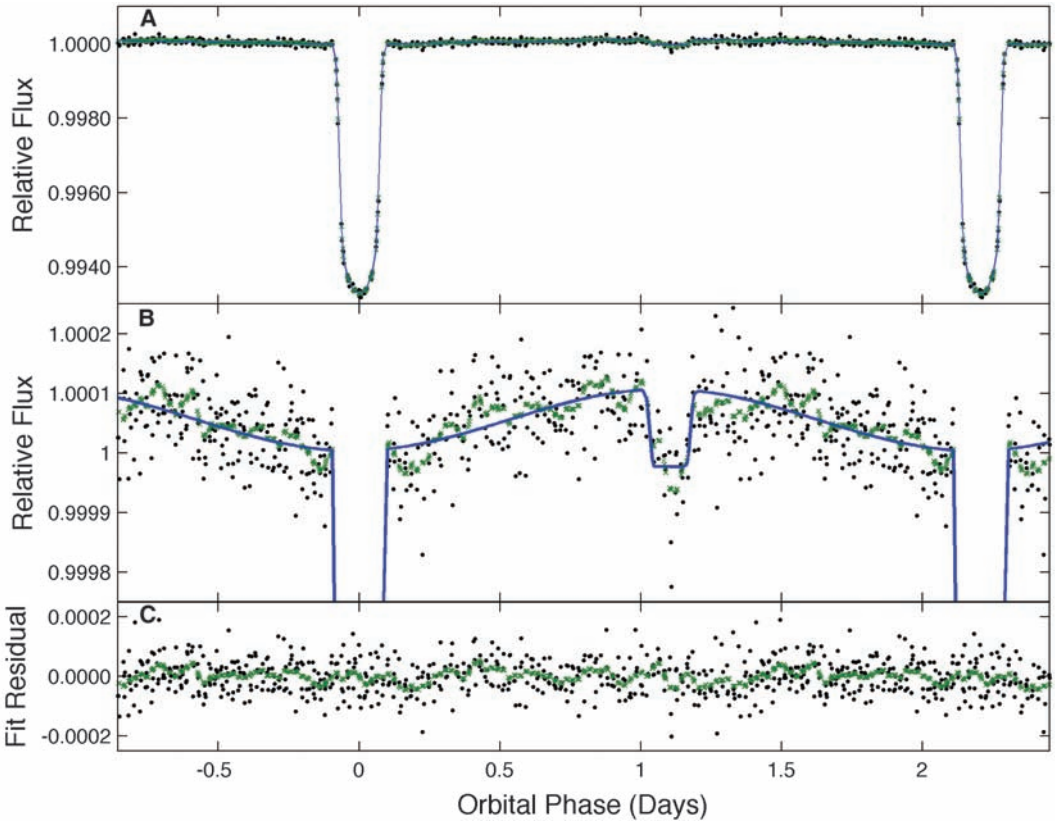

Fig. 1. Light curve for HAT-P-7b obtained by folding 10 days of data by the fitted orbital period. The black dots are the measurements. The green × marks are 0.1-day moving averages over the data. The blue line is a simple fit. (**A**) Light curve showing full depth of transit. (**B**) Expanded view to show phase curve and occultation. (**C**) Residuals from fit.

References and Notes

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Supporting Online Material

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Materials and Methods
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