Secondary Eclipse Photometry of WASP-3b and WASP-4b with *Spitzer*

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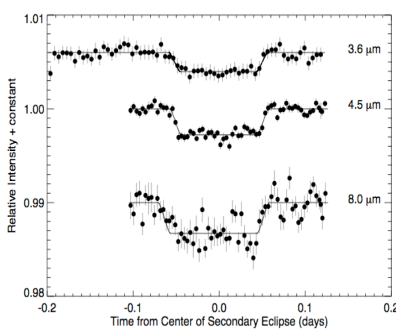
Overview

We present photometry of the giant extrasolar planet WASP-3b at 3.6, 4.5, and 8.0 μm and the planet WASP-4b at 3.6 and 4.5 μm taken with the Infrared Array Camera on board the *Spitzer Space Telescope*. We find secondary eclipse depths for WASP-3b that are well fit by model emission spectra exhibiting a temperature inversion in the upper atmosphere. The eclipse depths for WASP-4b are well fit by model emission spectra with water and other molecules in absorption, similar to those used for TrES-3 and HD 189733b. Depending on our choice of model, these results indicate that this planet has either a weak dayside temperature inversion or no inversion at all. We also find no evidence for an offset in the timing of either secondary eclipse and place a 2σ upper limit on |ecos ω| for both planets.

Eclipse Depths and Times



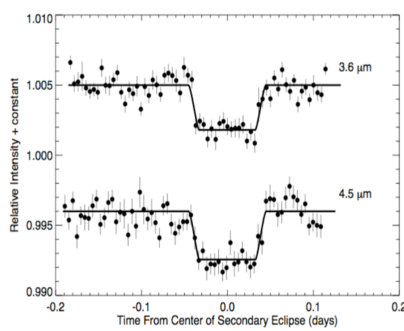


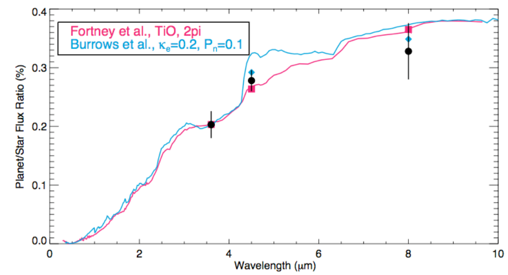
Fig. 1 & 2 - Photometry of WASP-3b (left) and WASP-4b (right) after decorrelation *vs.* time from center of secondary eclipse. In order to correct for intrapixel sensitivity, which causes the measured flux to vary with the star's position on the array, we fit the data with linear or quadratic functions of the *x* and *y* positions. We fit the 8.0 μm data, which does not exhibit intrapixel sensitivity, with an exponential function of time. We use a Markov Chain Monte Carlo method with10^6 steps to simultaneously determine the transit depth, timing of the eclipse, and the corrections for intrapixel sensitivity.

Summary of Secondary Eclipse Results

Planet	Wavelength (μm)	Depth	Eclipse Offset (minutes)
WASP-3b	3.6	0.203% ± 0.023%	1.4 ± 2.8
WASP-3b	4.5	0.278% ± 0.018%	0.0 ± 3.0
WASP-3b	8.0	0.328% ± 0.048%	4.4 ± 2.4
WASP-4b	3.6	0.319% ± 0.031%	0.5 ± 1.3
WASP-4b	4.5	0.343% ± 0.027%	0.1 ± 1.9

Table 1 - Eclipse depths and offset from time of predicted center of eclipse. Predicted center of eclipse times for WASP3-b and WASP-4b are derived from the ephemeris in Winn et al. (2009) and Gibson et al. (2008), respectively.

Atmosphere Models: WASP-3b



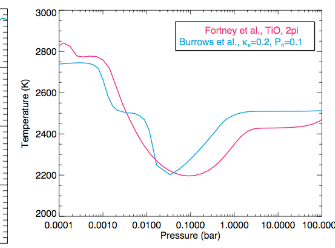
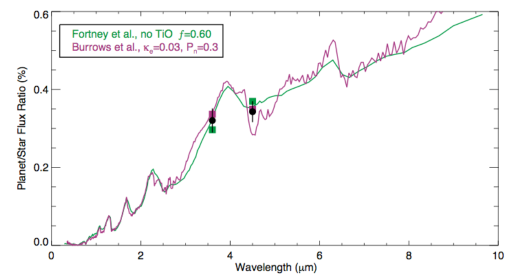


Fig. 3 (left) - Dayside planet/star flux ratio *vs.* wavelength for two model atmospheres with the band-averaged flux ratios for each model superposed (squares). The measured contrast ratios are overplotted (black circles).
Fig. 4 (right) - Dayside pressure-temperature profiles for the two model atmospheres in Figure 3.

The magenta model in Figure 3 is derived from one-dimensional, plane-parallel atmosphere codes following Fortney et al. (2008). This best-fit Fortney et al. model for WASP-3b contains TiO in equilibrium abundance and has dayside only energy redistribution. The best-fit Burrows et al. model for WASP-3b (blue) has a high concentration of an unknown stratospheric absorber with κ_e =0.2 cm^2/g and relatively efficient dayside to nightside circulation with dimensionless redistribution parameter, P_n=0.3. The dayside pressure-temperature profiles for these two models displayed in Figure 4 exhibit a strong temperature inversion in the upper atmosphere.

Atmosphere Models: WASP-4b



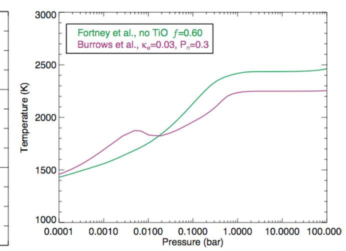


Fig. 5 (left) - Dayside planet/star flux ratio *vs.* wavelength for two model atmospheres with the band-averaged flux ratios for each model superposed (squares). The measured contrast ratios are overplotted (black circles).
Fig. 6 (right) - Dayside pressure-temperature profiles for the two model atmospheres.

The best-fit Fortney et al. model for WASP-4b (green) contains no TiO (resulting in no inversion in the P-T profile in Figure 6) and geometric redistribution factor f=0.60, resulting in a very hot dayside. The Burrows et al. model (purple) contains a small amount of stratospheric absorber with κ_e=0.03 cm^2/g and relatively efficient day-night circulation with P_n=0.3. The pressure-temperature profile in Figure 6 shows that this best-fit Burrows et al. model exhibits a modest temperature inversion for pressures below 0.01 bars, much weaker than the archetype inverted atmosphere HD 209458b. The absence of a strong inversion might be explained by the modestly enhanced activity level of WASP-4b's G7V host star, which could increase the amount of UV flux received by the planet, therefore reducing the abundance of the unknown stratospheric absorber in the planetary atmosphere as suggested in Knutson et al (2010).

Fortney, J. J. et al. 2008, ApJ, 678, 1419
Knutson, H. A. et al. 2010, ApJ, 720, 1569
Gibson, N. P. et al. 2008, A&A, 492, 603
Winn, J. N. et al. 2009, AJ, 137, 3826