Spitzer lightcurves of the ultra-short period, massive hot Jupiter WASP-18b

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Background image of WASP-South courtesy of David Wilson

Abstract

WASP-18b is a massive hot Jupiter exoplanet (10 M_{Jup}) which orbits an F6V star with an orbital period of only 0.94 days.[1] We present preliminary results from a Spitzer campaign to observe lightcurves at 3.6-μm and 4.5-μm covering an entire orbit of the planet. The principal aim of these observations is to map the distribution of thermal emission from the planet over its surface from the phase variation observed in these lightcurves. This phase variation gives a direct measurement of the efficiency of heat distribution from the day-side to the night side of the planet. The phase variation may also show on offset in the position of the hot-spot on the planet's surface from the sub-stellar point due to zonal winds.

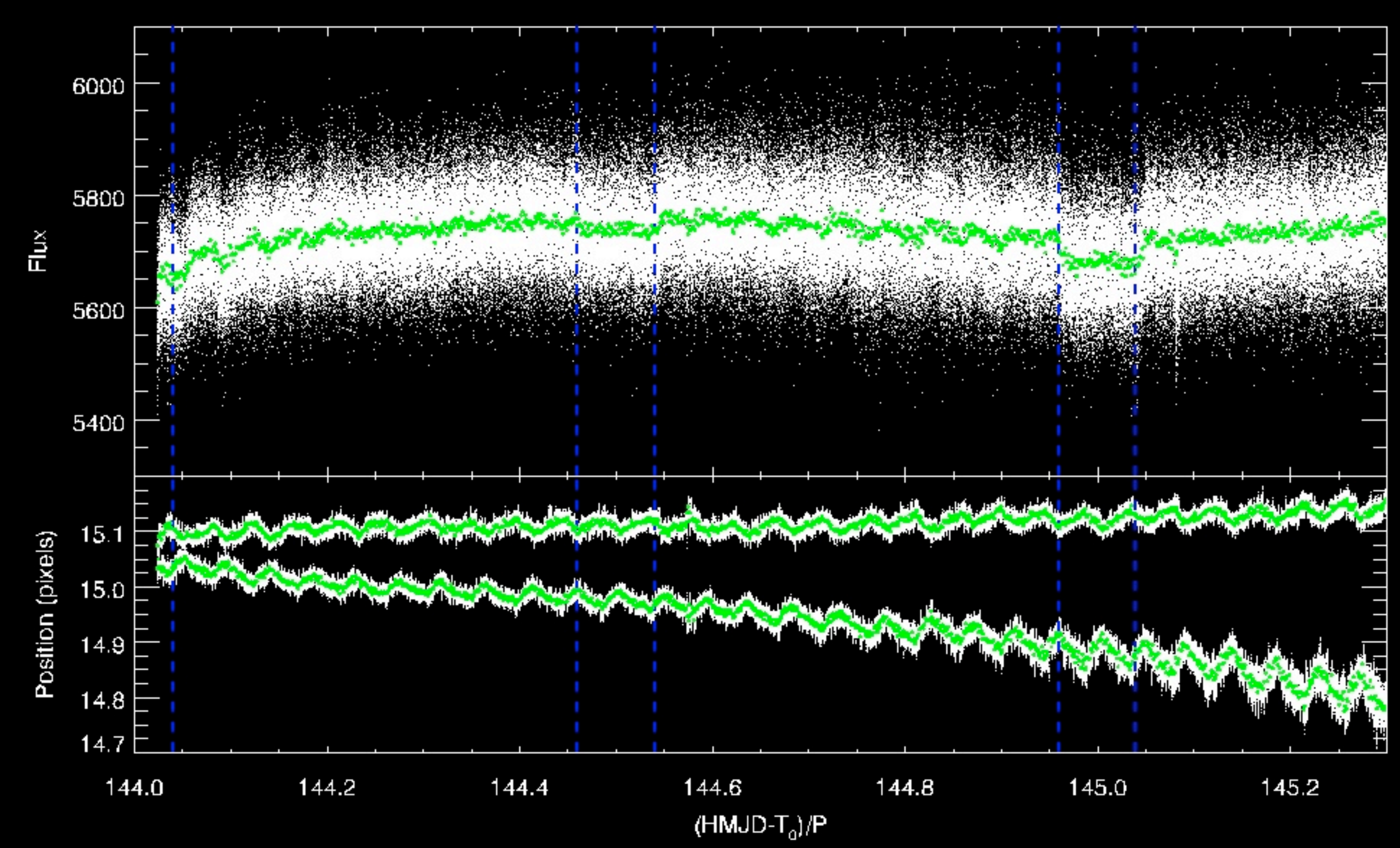

Figure 1 *Raw fluxes measured using optimal photometry plotted against orbital cycle (P=0.94145d). The limits of the eclipse and transit phases are indicated (blue dashed lines) The mean fluxes in 0.001 phase bins are shown in green. The transit, eclipse and phase variation are visible but the photometry is clearly affected by systematic errors related to the position of the star on the detector (lower panel).*

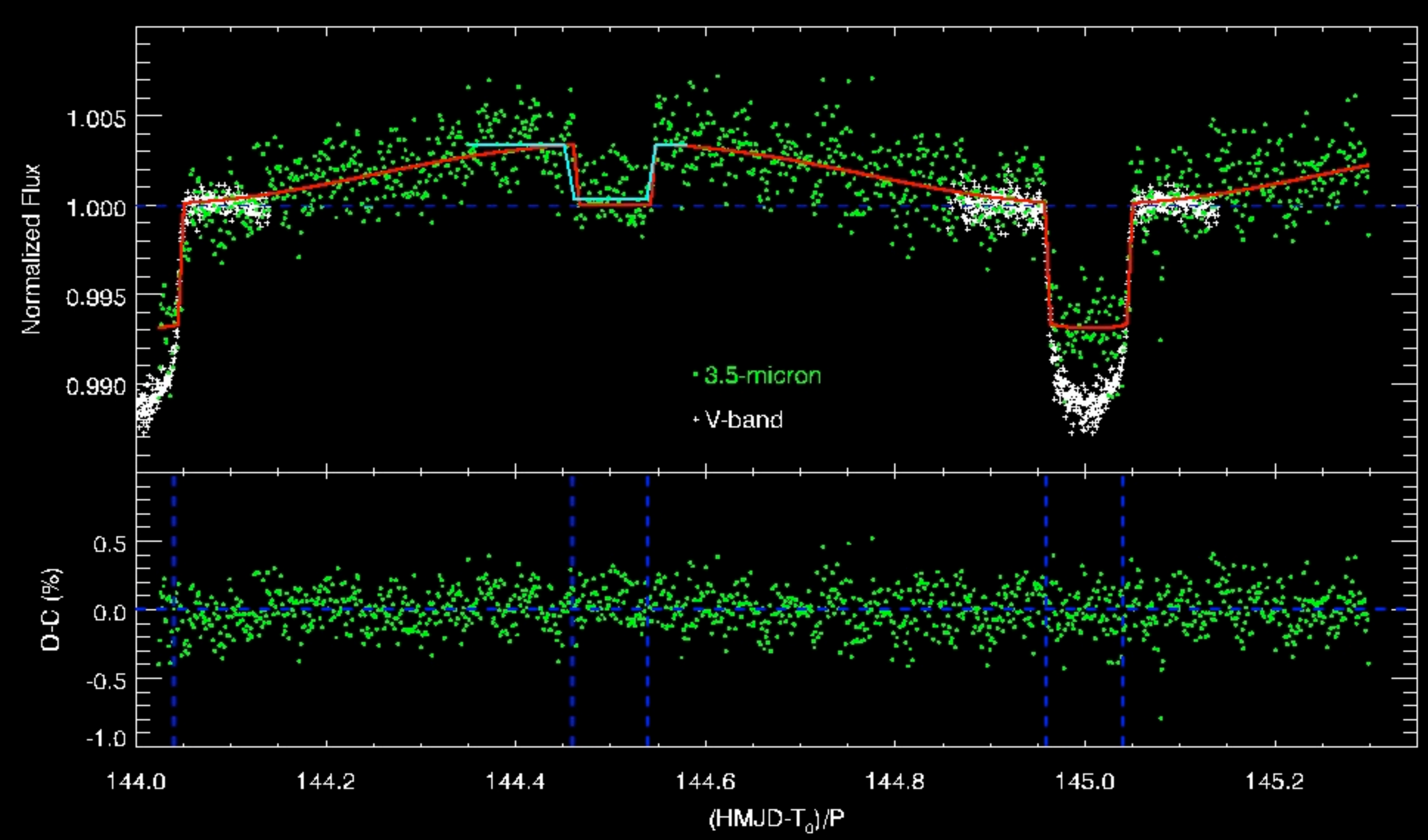

Figure 2 *Flux corrected for systematic errors in 0.001 phase bins (green points) according to our best-fit model (red). V-band transit data[2] are shown with small white crosses. The flux level at mid-secondary eclipse is shown with a blue, dashed line. The parameters of the 3.6-μm eclipse derived from cryogenic Spitzer data by Nyemeyer et al.[3] are indicated by cyan lines. Residuals from the fit are shown in the lower panel. The eclipse and transit phases indicated in the lower panel (blue dashed lines).*

Data reduction and analysis

- 243,200 IRAC sub-images obtained over 29 hours in Spitzer warm-phase mission at 3.6-μm on 2010-01-23.
- Fluxes measured from calibrated images[a] using new optimal photometry algorithm
  - maximizes signal-to-noise
  - efficient, objective rejection of corrupt data
- Simultaneous de-trending and model fitting algorithm
  - NDE[4] eclipsing binary star model accounts for non-spherical planet shape
  - Phase variation modeled with sinusoids
  - Systematic errors corrected using a look-up table generated from residuals *v.* position (Fig. 3)
  - Markov chain Monte Carlo least-squares fitting

[a]Spitzer pipeline version S18.18

System parameters from Southworth et al. 2009[2]

Parameter	HD 10069	WASP-18b
Mass	1.28 $M_\odot$	10.4 M_J
Radius	1.23 $R_\odot$	1.17 R_J
Effective temperature[a]	6500 K	3000 K

[a]Disk-averaged day-side temperature for WASP-18b from this study

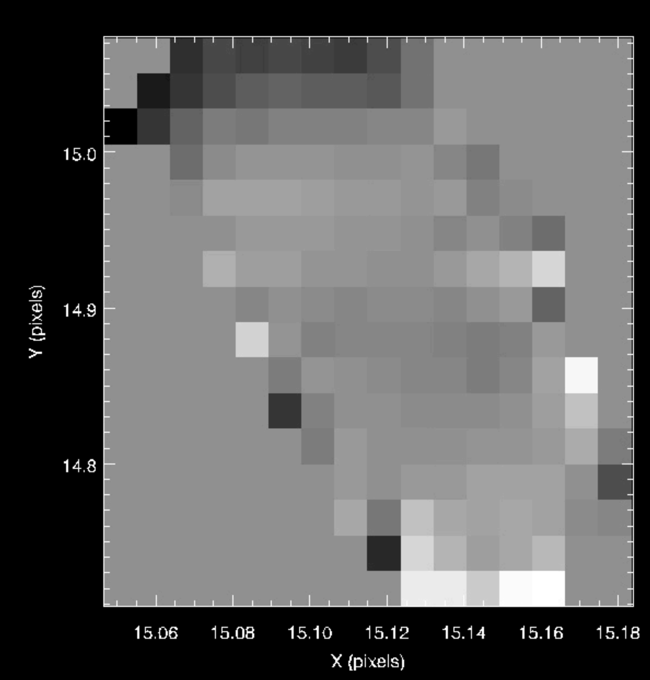

Figure 3 Residuals as a function of the position of the star on the detector shown as a grey-scale (white = +2%, black = −2%). Linear de-correlation of flux against position is used to remove the main trend prior to applying these smaller corrections.

Results and conclusions

- The phase variation due to the extreme irradiation of this planet is 0.34% at 3.6-μm.
- The equilibrium brightness temperature at the sub-stellar point is 3400K and the inferred albedo is A≈0.07.
- The phase variation is symmetrical about the secondary eclipse, i.e., the hottest parts of the atmosphere probed by radiation at 3.6-μm occur close to the sub-stellar point.
- The amplitude of the phase variation is equal to depth of the secondary eclipse, so redistribution of energy to the night side of the planet is very inefficient.
- The transit is significantly less deep in the 3.6-μm lightcurve than in the optical V-band lightcurve. The extra flux at 3.6-μm may be explained by a low-mass M-dwarf companion. This hypothesis will be tested using a similar analysis of a 4.5-μm lightcurve observed on 2010-08-23.

References
1.Hellier, C., et al. 2009, Nature, 460, 1098
2.Southworth, J. et al. 2009, ApJ, 707, 167
3.Nyemeyer et al., 2010, arXiv:1005.1017
4.Nelson, B., Davis, W. D., 1972, ApJ, 174, 617