Planetary Transits of the Trans-Atlantic Exoplanet Survey Candidate TrES-1b

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Abstract The AAVSO compiled 10,560 CCD observations of the suspected exoplanet transit object TrES-1b covering seven complete transit windows, three windows of partial coverage, and coverage of baseline non-transit periods. Visual inspection of the light curves reveals the presence of slight humps at the egress points of some transits. A boot strap Monte Carlo simulation was applied to the data to confirm that the humps exist to a statistically significant degree. However, it does not rule out systemic effects which will be tested with campaigns in the 2005 observing season.

1. Introduction

The Trans-Atlantic Exoplanet Survey (TrES) has announced the discovery of a planet, having 0.75 ±0.07 Jupiter masses, transiting the star GSC02652-01324 (2MASS J19040985+3637574), a $V = 11.79$ magnitude, K0V-type star, R.A. $19^{h}04^{m}09\overset{s}{.}8$ Dec. +36° 37' 57" (J2000) (Alonso *et al.* 2004). The Transitsearch.org project (Seagroves *et al.* 2003), in collaboration with the AAVSO, compiled observations from professional and amateur astronomers of predicted transits in the summer and autumn of 2004. Analysis of the photometry suggests possible post-eclipse brightening episodes after the egress portion of the TrES-1b light curve.

2. Observations

The AAVSO compiled 10,560 CCD observations of TrES-1b covering seven complete predicted transit windows, three windows of partial coverage and coverage of baseline non-transit periods (Figure 1; Table 1).

The amateur observations were done individually using a variety of equipment, comparison stars, and reduction software. Different filters were also used. For the plotting of the phase diagram (Figure 2) the observations were transformed to a common zero point. Uncertainties for the individual observations are available along with the entire raw data set upon request to the AAVSO.

Additional photometry were provided by personnel at three observatories. The U.S. Naval Observatory Flagstaff Station 1.0m telescope observed in *B* using with a large set of Landolt standards (Landolt 1992) having a range of color and airmass. IRAF was used for all reductions. Observations were also provided by the Gettysburg College Observatory with a Photometrics CH-350 camera (SITe 003B back illuminated 1024K chip) on a 16" f/11 reflector, with standard Bessell filters (Bessell 1995). IRAF was used for flat-fielding, dark correction, bias subtraction, and MIRA for the photometry. In addition, The New Mexico State University 1m telescope at Apache Point Observatory observed using an Apogee AP7p camera with a 512×512 thinned backside illuminated SITe chip.

3. Analysis

Visual inspection of the light curves reveals the presence of slight humps at the egress points of some transits (Figure 3). These humps have amplitudes of around 0.005 magnitude and occur around 90 minutes after the transit midpoint. While most individual observations had uncertainties greater than 0.005 magnitude, when combined the uncertainty could be reduced by a factor inversely proportional to the square root of the number of stacked observations. A boot strap Monte Carlo simulation was applied to the data to determine the statistical significance of the humps. Given a suitably large sample size, the bootstrap method redistributes the existing data randomly, generating a synthetic data set. If done numerous times the procedure allows uncertainties in the data to be quantified without any assumption of a Gaussian distribution. A model for the egress portion of the transit was developed to fit the egress shape:

$$m = 0.1cos(0.071t + 0.5)e^{-0.040t} + 1 \quad (1)$$

where m is the amplitude in magnitudes and t is the time from the transit midpoint in minutes. 2,000 bootstrap runs were made on the datasets and post curve fit models. The results confirm that the suspected hump is statistically significant. Bissinger's dataset was tested twice for verification and returned a mean of 1.01026 (95% confidence level) and 1.01025 (95% confidence level), indicating a high level of reproducibility. High-precision photometry during the 2005 observing season is needed to confirm the brightening episodes.

4. Acknowledgement

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References

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Seagroves, S., Harker, J., Laughlin, G., Lacy, J., and Castellano, T. 2003, *Publ. Astron. Soc. Pacific*, **115**, 1355.
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Table 1. Observed TrES-1b Transit Windows.

Transit Date (JD)	*Observers (Filter)*
2453250	Vanmunster (*V*)
2453253	Paakkonen (*V*), Starkey (*V*), Vanmunster (Unfiltered)
2453256	Leadbeater (Unfiltered)
2453268	Kaiser (*V*), Marschall (*R*), Michalik (*V*)
2453271	Durkee (*V*), Gary (*V*), Starkey (*V*)
2453274	Henden (*B*)
2453277	Bissinger (Unfiltered)
2453280	Bissinger (Unfiltered), Gary (*V*)
2453283	Bissinger (Unfiltered)
2453286	Bissinger (Unfiltered), Gary (*V*), Holtzman (*V*)
2453289	Bissinger (Unfiltered)

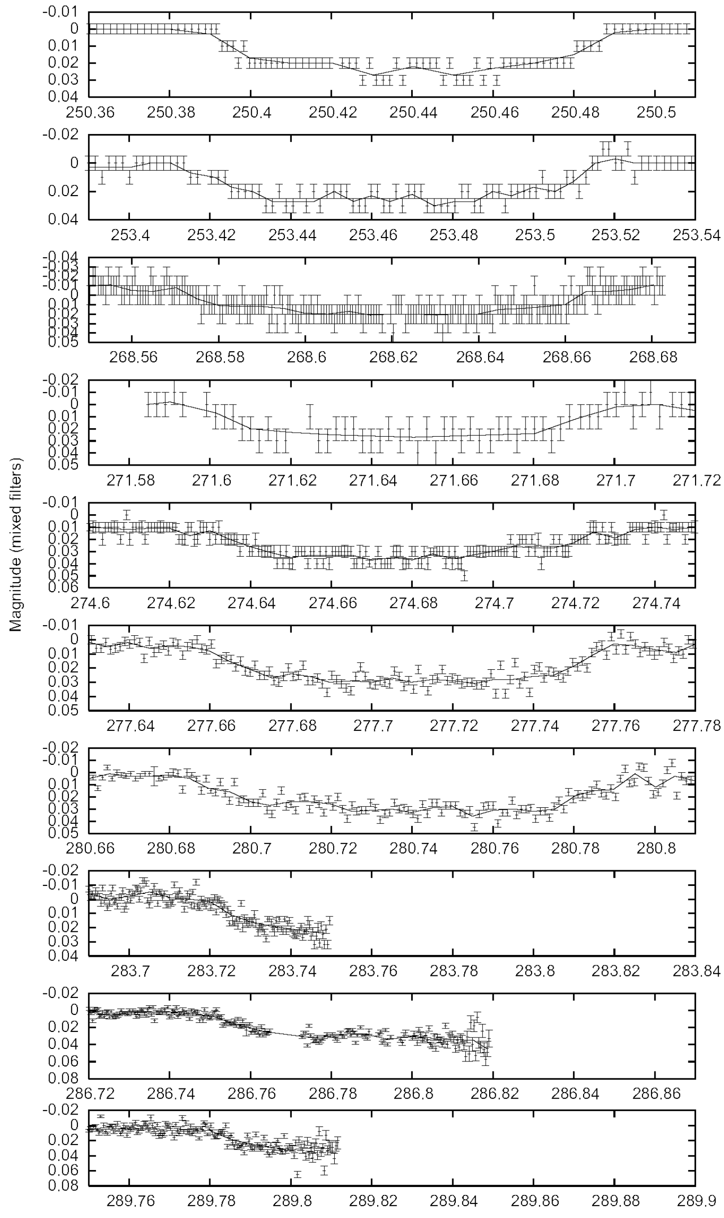

Figure 1. Light curves of ten transits of TrES-1b. Average line is 0.005d. For readability, lower precision data were omitted when higher precision coincident data were available. All measurements and individual uncertainty values are available from www.aavso.org.

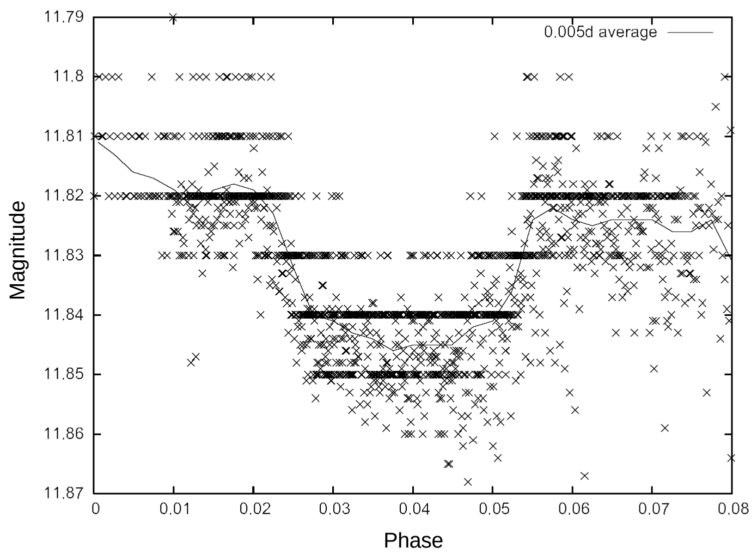

Figure 2. Phase diagram of TrES-1b with a 3.030065d (Alonso 2004) period beginning at epoch JD 2453250.3204. Observations were a mix of filtered and unfiltered data which were offset to a common zeropoint. Banding is caused by observers who report 0.01 magnitude accuracy.

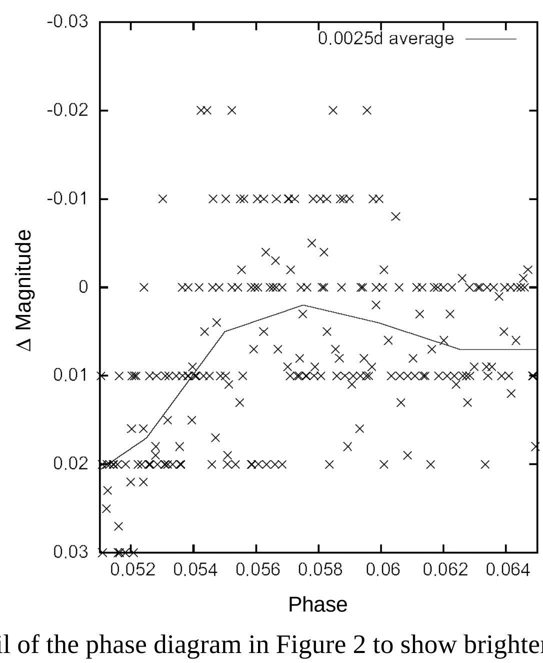

Figure 3. Detail of the phase diagram in Figure 2 to show brightening during the egress.