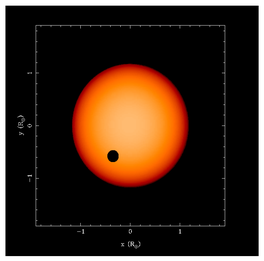

System Parameters of the Transiting Extrasolar Planet TrES-1

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As part of a graduate student observational techniques course, we present an investigation of the transiting extrasolar planet TrES-1 using previously published data and new observations obtained at Mt. Laguna Observatory in 2004 Oct. We employ the binary star modelling program "ELC" to simultaneously fit the multicolor photometry and radial velocity curve. From the ELC model we derive a revised, fully self-consistent set of system parameter estimates. Our results agree with Alonso et al (2004).

Introduction

As of early 2005, 135 extrasolar planets have been discovered (Schneider 2004), nearly all of which have been found through measuring periodic radial velocity Doppler shifts in the spectrum of the planet's parent star. Of these 135 systems, only seven exhibit transits of the planet across the host star's disk. When the transit light curve is modelled along with the radial velocity data, the planet's orbital characteristics (inclination, separation, period, eccentricity) and its physical characteristics (mass and radius relative to that of the host star) can be accurately determined.

HD 209458b, the first transiting extrasolar planet discovered (Charbonneau et al. 2000, Henry et al. 2000), has a radius of 1.35 R_{Jup} and a mass of 0.69 M_{Jup}. These parameters clearly establish this as a gas-giant type planet (Brown et al. 2001). Five more transiting planets have been discovered by the Optical Gravitational Lensing Experiment 'OGLE' (Konacki et al. 2003, 2004; Bouchy et al. 2004; Pont et al. 2004); however, follow-up study of these OGLE planets is difficult because they orbit faint stars in crowded fields. Radii and masses range from 1.0-1.3 R_{Jup} and 0.53-1.35 M_{Jup}.

The Trans-Atlantic Exoplanet Survey (TrES) is a network of small-aperture, wide-field telescopes searching bright stars for planetary transits. TrES-1 is the first planetary discovery by the TrES network and marks the first discovery of an extrasolar planet around a bright star by the transit method (Alonso et al. 2004). The relatively bright K0V host star (V = 11.79) allows for a detailed analysis of the system. Alonso et al. find a radius of 1.08 R_{Jup} and a mass of 0.75 M_{Jup}. The authors point out that although the estimated masses of TrES-1 and HD 209458b are similar, the radius of TrES-1 is about 20% smaller, hence in better agreement with planetary evolution models. Additional spectroscopic observations of TrES-1 by Sozzetti et al. (2004) have been used to refine the radius and mass to 1.04 R_{Jup} and 0.76 M_{Jup}.

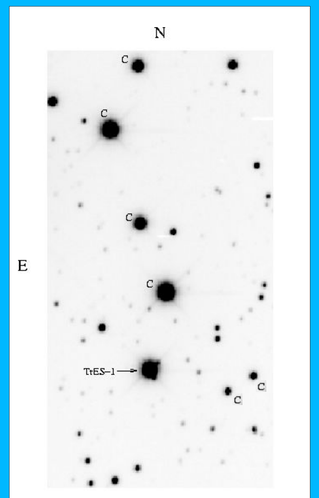
Using data provided by Alonso et al. and an additional transit light curve observed during a graduate course in Astronomical Techniques (Astr 680) at San Diego State University (SDSU), we report a work in progress on determining a revised set of stellar and planetary parameter estimates.

Observations and Modelling

R-band CCD observations were made on 2004 Oct 5 using SDSU's Mount Laguna Observatory (MLO) 1-m telescope. TrES-1 and six comparison stars of similar magnitudes (see Fig. 1) were observed in photometric conditions with seeing varying from 1.6 to 2.0 arcseconds. Images were reduced using IRAF. The final R-band light curve (see Fig. 2) was derived using aperture photometery with DAOGROW algorithm in IRAF. The MLO light curve was binned in time and a quadratic fuction was fitted to the out of eclipse portions in order to remove a slight secular trend. We combined this light curve with the Alonso et al. (2004) observations: B, V, I, g, r, and z-band light curves, and radial velocity measurements.

The combined light curve and radial velocity data were fit with the binary star modelling program Eclipsing Light Curve "ELC" (Orosz & Hauschildt, 2000) to determine and model the system parameters. With the combination of Alonso et al. (2004) and MLO data, we applied a genetic algorithm optimizer to solve for the best fit (lowest chi-squared) parameters in the TrES-1 system. The results of our analysis are presented in Table 1.

Figure 1
TrES-1 and six comparison stars MLO CCD 2001, R-Band, FOV 2.2' x 4.2'



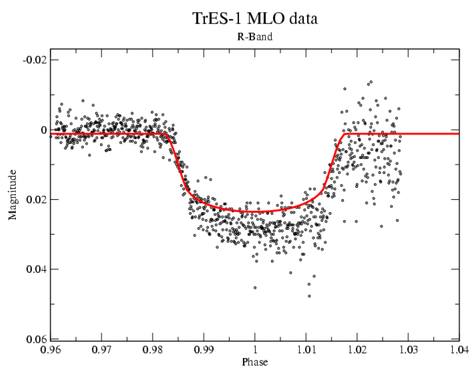
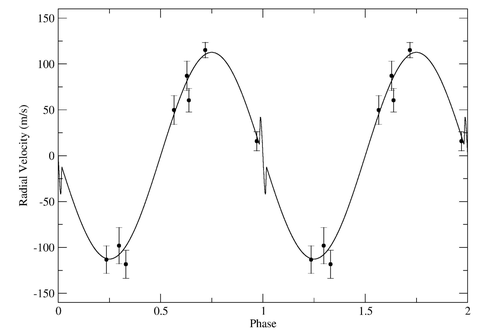


Figure 2
Unbinned transit light curve from MLO and the ELC model fit.

Discussion

We refit the Alonso et al. (2004) data plus an additional light curve from MLO (see Figs. 2, 3, and 4). Our results are completely consistent with those of Alonso et al. (2004). We confirm that the radius of TrES-1 is significantly less than the radius of HD209458b. We observed a time of mid-transit to be T_0 = 2453283.7698 HJD ± 0.0008.

Figure 3
Alonso et al. (2004) Radial Velocity Curve and ELC Fit



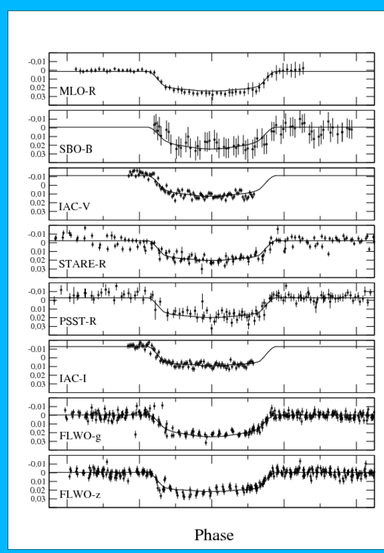


Figure 4
Phased light curves and ELC fits.

Table 1
TrES-1 Orbital Parameters

Parameter	Alonso et al. 2004*		Our Results*
P	3.030065	± 8 X 10^{-6} days	3.030074
T_C	2453186.8060	± 0.0002 (HJD)	2453186.8062
a	0.0393	± 0.0011 AU	0.0393
i	88.5	+ 1.5 / - 2.2 deg	88.5
K	115.2	± 6.2 m s^{-1}	112.7
M_P	0.75	± 0.07 M_{JUP}	0.75
R_P	1.08	+ 0.18 / - 0.04 R_{JUP}	1.1
R_P/R_S	0.130	+ 0.009 / - 0.003	0.130

*Assuming parent star mass of 0.88 solar masses

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