THE OGLE-TR-56 STAR–PLANET SYSTEM

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Abstract. We simultaneously fitted light and velocity data for the star–planet system OGLE-TR-56 with the Wilson–Devinney (WD) binary star program. We solved for orbital and planet parameters, along with the ephemeris using all currently available observational data. Parameters for the star (OGLE-TR-56a) were kept fixed at values derived from spectral characteristics and stellar evolutionary tracks. Our results are in good agreement with parameters obtained by other authors and have slightly smaller errors. We found no significant change in orbital period that may be due to orbital decay.

Keywords: eclipsing binaries, extrasolar planets, OGLE-TR-56

1. Introduction

The Optical Gravitational Lensing Experiment (OGLE) has provided a wealth of light curve data. The 2001–2002 campaign (OGLE III) has revealed 137 stars with low-amplitude transits that may be caused by low-mass companions, several of which possibly being extrasolar planets (Udalski et al., 2003). Konacki et al. (2003) found OGLE-TR-56 to be a solar type star ($T = 5900\,\mathrm{K}$ and solar metal abundance) with radial velocities indicative of a planetary companion. Their original announcement was based on only three velocities that appeared to agree phase-wise with the light data. Follow-up high-resolution spectra (Torres et al., 2004) yielded an additional eight velocities and confirmed prior results. The OGLE database now contains over 1100 photometric observations (http://bulge.astro.princeton.edu/∼ogle/ogle3/transits/ogle56.html) of OGLE-TR-56, including 13 transits, and 11 radial velocities.

Extrasolar planets that transit their stars provide tight constraints on the orbital inclination and, when coupled with radial velocity data, allow the determination of planetary masses and sizes. Parameters of the parent star still need to be determined independently. The temperature can be estimated from the star's spectral characteristics, while the mass and size can be derived from stellar evolutionary models (Cody and Sasselov, 2002; Sasselov, 2003). We demonstrate the use of a general binary star program to model light and velocities of stars with transiting extrasolar planets. The model is that of Wilson (1979) including the latest updates (Wilson and Van Hamme, 2003). We simultaneously solve the available light and velocity data of OGLE-TR-56 and compare our results with other solutions in the literature.

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2. Analysis and Conclusions

A star–planet (or other low-luminosity object) system, with transits and radial velocities for the star only, is analogous to a single-lined spectroscopic and eclipsing detached binary. In the WD program, adjustable radial velocity related parameters

TABLE I
OGLE-TR-56 parameters

Parameter	This paper	Torres et al. (2004)
T_0 (HJD)	$2452444.73945 \pm 0.00097$	2452075.1046 ± 0.0017
P_0 (days)	1.2119198 ± 0.0000041	1.2119189 ± 0.0000059
a (AU)	0.0225 ± 0.0028	0.0225 ± 0.0004
V_γ (km s^{-1})	-48.317 ± 0.026	-48.317 ± 0.045
$i(^\circ)$	80.94 ± 0.40	81.0 ± 2.2
g_1, g_2	0.32, 0.32	
F_1, F_2	0.06, 1.0	
T_1 (K)	5900	
T_2 (K)	1900	
A_1, A_2	0.5, 0.5	
Ω_1	4.419 ± 0.083	
Ω_2	1.5492 ± 0.0012	
$q = M_2/M_1$	0.0013289	0.00132
x_1, y_1 (I)	0.596, 0.256[a]	0.56 ± 0.06[b]
$L_1/(L_1 + L_2)$ (I)	0.99998 ± 0.00016	
Derived parameters		
$\langle r_1 \rangle$	0.2264 ± 0.0043	
$\langle r_1 \rangle / \langle r_1 \rangle_{\rm lobe}$	0.3450 ± 0.0054	
$\langle r_2 \rangle$	0.0268 ± 0.0007	
$\langle r_2 \rangle / \langle r_2 \rangle_{\rm lobe}$	0.506 ± 0.013	
$M_1(M_\odot)$	1.04 ± 0.39	1.04 ± 0.05
$R_1(R_\odot)$	1.10 ± 0.14	1.10 ± 0.10
$M_{\rm bol\,1}$	4.45 ± 0.28	
$\log(L_1/L_\odot)$	0.12 ± 0.11	
$\log g_1$ (cm s^{-2})	4.37 ± 0.28	
$M_2(M_{\rm JUP})$	1.45 ± 0.55	1.45 ± 0.23
$R_2(R_{\rm JUP})$	1.26 ± 0.16	1.23 ± 0.16
$\log g_2$ (cm s^{-2})	3.35 ± 0.28	
Density (g cm^{-3})	0.89 ± 0.48	1.0 ± 0.3

[a]Logarithmic limb darkening law.
[b]Linear limb darkening law.

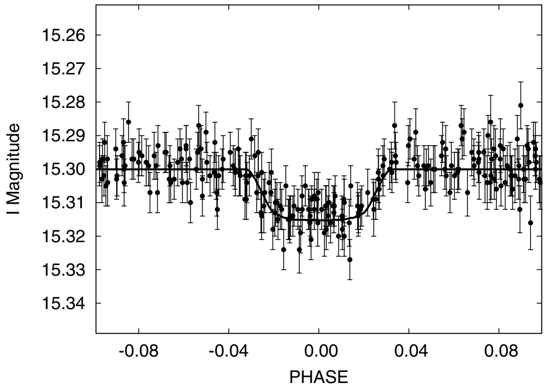

Figure 1. Phased *I* band observations of OGLE-TR-56 and computed curve.

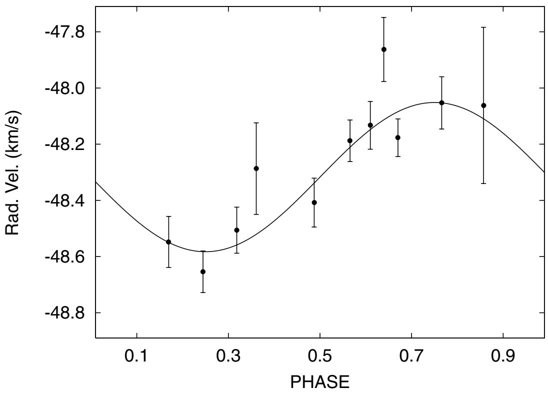

Figure 2. OGLE-TR-56 radial velocities (Torres et al., 2004) and solution curve.

are the semi-major axis (a), systemic velocity (V_γ) and mass ratio (q). In a single-lined binary, q cannot be determined from the velocity curve. A value for the mass ratio needs to be adopted, and the mass of the star can then be computed from Kepler's Third Law after a and P have been obtained from the fitting process. We selected q ($q = M_{\mathrm{planet}}/M_{\mathrm{star}}$) so that Kepler's Third Law yielded a stellar mass consistent with that derived from evolutionary models (1.04 $M_\odot$, see Sasselov, 2003). Time instead of phase was the independent variable, and ephemeris parameters (reference epoch T_0, period P, and possibly dP/dt) were fitted together with the other parameters. We adopted a logarithmic limb darkening law with coefficients x, y from Van Hamme (1993). The star's rotation rate (F_1) was set to 0.06 corresponding to a rotational period of 20 days (Sasselov, 2003). Data were assigned individual weights inversely proportional to the square of their listed mean errors. Table I lists solution parameters, including standard errors of parameters that were adjusted. Parameters obtained by Torres et al. (2004) are listed for comparison. The agreement is very good. Figure 1 shows the observed light curve near the transit together with our solution curve. Radial velocities are shown in Figure 2. We checked for tidally induced orbit decay as discussed by Sasselov (2003). Including dP/dt as an adjustable parameter did not indicate a value significantly different from zero.

The WD program lends itself very well to modeling star–planet transit curves and radial velocities. We also note that the stellar radius, found by fitting the light curve data, agrees very well with the value found by other authors who fit evolutionary tracks. The program's ability to fit ephemeris parameters, including dP/dt, will provide a useful tool for checking orbital decay of extrasolar planet systems.

Acknowledgements

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