PHOTOMETRIC FOLLOW-UP OBSERVATIONS OF OGLE-TR-10

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Recent projects

- Deep, wide-field searches for irregular satellites of the giant planets
- Deep searches for Kuiper belt objects
- KH15D circumbinary disk system
- Dynamics of dust in disk systems
- Long-term stability of extrasolar planetary systems
- Follow-up observations of extrasolar planetary transits

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Motivation

- Radial velocity observations determine
  - Orbital period
  - Eccentricity
  - Argument of periastron
  - $M_p \sin I$
  - Presence of other planets
- Transit observations determine
  - Orbital period
  - $R_p/R_*$
  - $a/R_*$
  - Inclination
  - Stellar limb darkening parameters
  - Eccentricity, in some cases
  - Presence of other planets?

Brown et al 2001
Why observe OGLE-TR-10?

- Period established with sufficient accuracy to predict transit times to within an hour (Udalski et al 2001)
- No large amplitude radial velocity variations detected (Konacki et al 2001)
- No spectral evidence of a blend (Konacki et al 2001)
- No evidence of ellipsoidal variability or other out of transit variations (Sirko and Paczynski 2003)

Stellar Characteristics of OGE-TR-10

- $T_{\text{eff}} = 5750 \pm 80 \, \text{K}$
- $\log g = 4.5 \, (3.5-4.6)$
- $[\text{Fe/H}] = 0.0 \pm 0.2$
- $V_{\text{rot}} = 2 \, \text{km/sec} \, (1-4 \, \text{km/sec})$

$M_* = 1.0 \pm 0.05 \, M_{\odot}$

$R_* = 1.0 \pm 0.1 \, R_{\odot}$

\[ \frac{R_p}{R_\star} = 0.11 \pm 0.01 \]
\[ \frac{a}{R_\star} = 8.3 \pm 0.1 \]
\[ i = 90.0 \pm 2 \]

\[ \frac{R_p}{R_\star} = 0.09 \pm 0.01 \]
\[ \frac{a}{R_\star} = 7.8 \pm 0.5 \]
\[ i = 88.2 \pm 2 \]
Observations

- Magellan-II 6.5m telescope at Las Campanas Observatory, Chile
- MagIC, 2kx2k pixels, 4 read amplifiers (one in each corner of the chip), 20 sec read time
- Alternated 30 sec I-band exposures and 60 sec B-band exposures.
- 2 May 2003 UT (full transit), 28 July 2003 UT (partial transit), 31 July 2003 UT (partial transit)
Data Reduction

- Cross talk, overscan, trim, flat field, shutter timing corrections
- Sub-pixel registration of images
  - Creates high signal-to-noise reference image by median combination of 15-20 best images
  - Solves for coefficients of a convolution kernel that matches stellar point-spread-function of reference image to the individual exposures
  - Subtracts transformed reference image from individual images
  - Performs photometry of residuals

Analysis

- Model parameters:
  - $t_c = \text{epoch of transit center}$
  - $T = \text{orbital period}$
  - $R_p/R_*$
  - $a/R_*$
  - $i = \text{inclination}$
  - $u_1$ and $u_2 = \text{quadratic limb darkening parameters}$

Used tools of Mandel and Agol (2002)
Dr. Matt Holman, Harvard (KITP Planet Formation 3-02-04) Follow-Up Photometry of Ogle Candidate Planets

Stellar Limb Darkening

\[ I(\mu) = I(1) - u_2(1 - \mu) - u_1(1 - \mu)^2 \]

Mandel and Agol 2002

Charbonneau et al 2003
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Conclusions

- OGLE-TR-10 appears to be a near-twin of HD209458, although we cannot rule out all possible blend scenarios.
- T = 3.101287 +/- 0.000001 days
- \( t_c = \text{HJD 2452761.8060 +/- 0.0003} \)
- \( a/R_\star = 8.3 +/- 0.1 \)
- \( p = R_p/R_\star = 0.11 +/- 0.01 \)
- \( R_p = 1.1 +/- 0.1 \) R\(_J\)
- \( i = 90 +/- 2 \) deg

Future Work

- Observe OGLE-TR-56 to determine the planetary radius.
- Begin transit timing experiments to place limits on the presence of other perturbers.
- More radial velocity measurements of OGLE-TR-10 to confirm presence of planet.
Perturbations of transit times

\[ a_1 = 0.04 \text{ AU}, \ a_2 = 0.09 \text{ AU} \]
\[ m_1 = 1 \text{ M}_J, \ m_2 = 1 \text{ M}_J \]

\[ a_1 = 0.04 \text{ AU}, \ a_2 = 0.0635 \text{ AU} \]
\[ m_1 = 1 \text{ M}_J, \ m_2 = 0.05 \text{ M}_J \]

(See also Bodenheimer et al 2003)