Photometric Follow-up Observations of OGLE-TR-10

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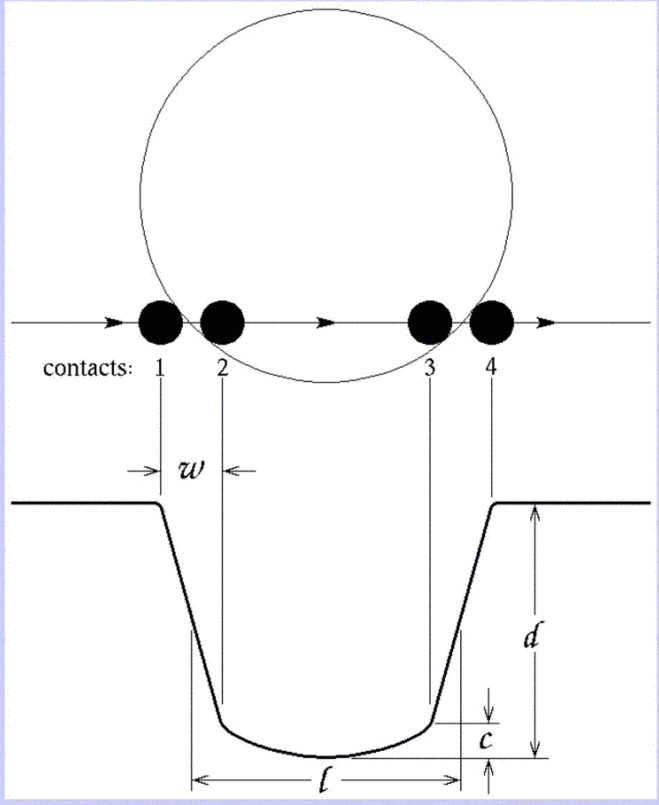
Recent projects

- 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

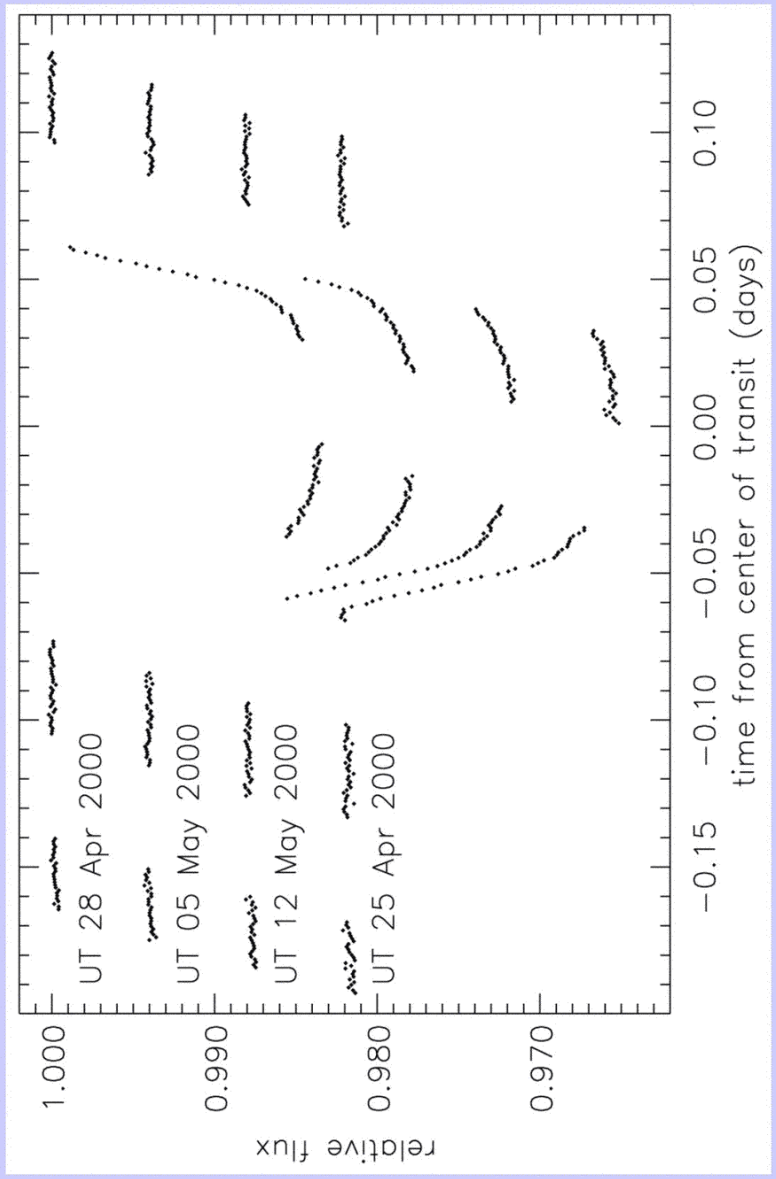
Motivation

- 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?



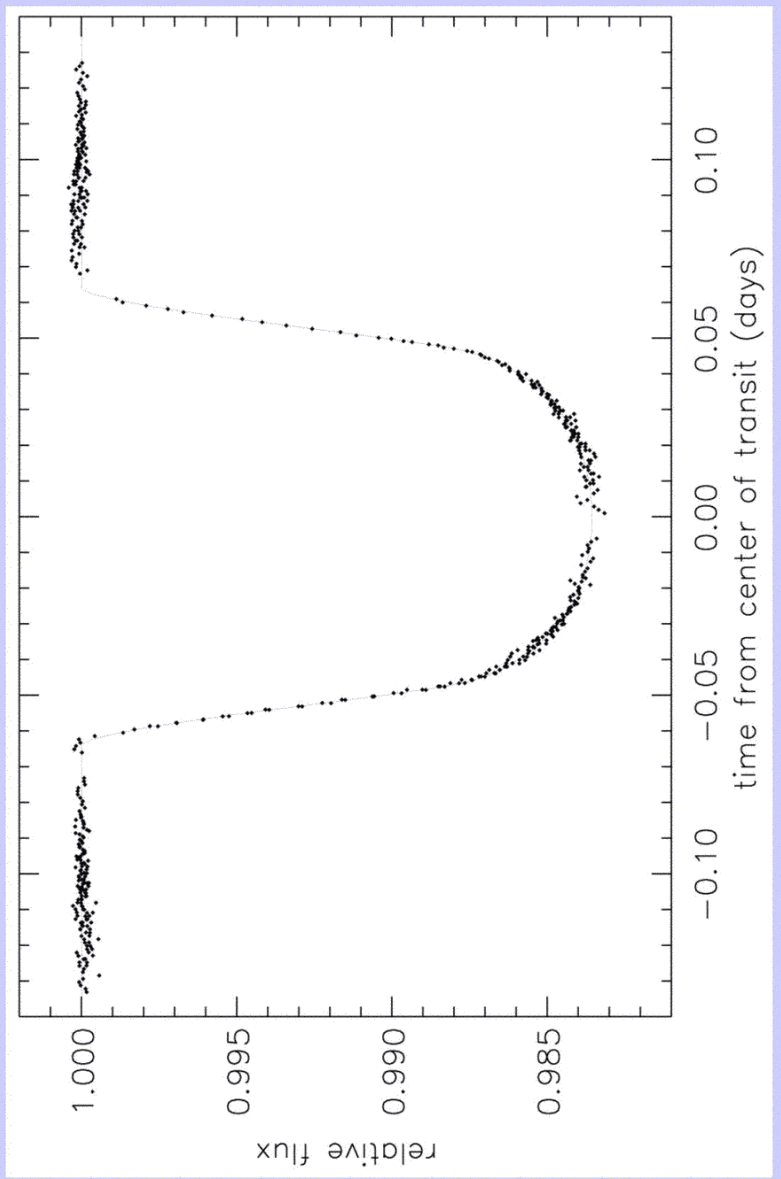
Brown et al 2001

HD209458



Brown et al 2001

HD209458

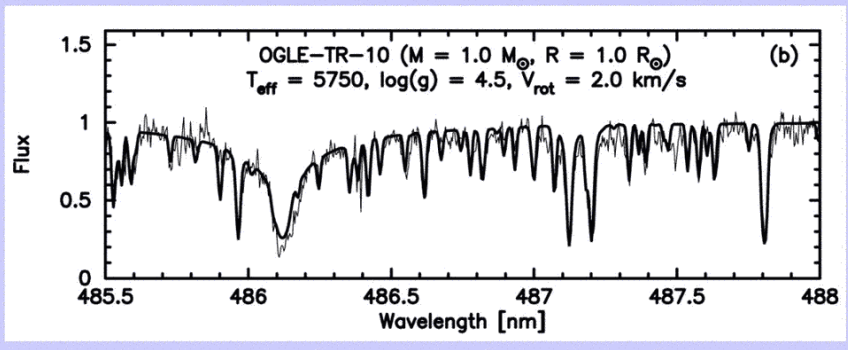


Brown et al 2001

Why observe OGLE-TR-10?

- Period established with sufficient accuracy to predict transit times to with 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



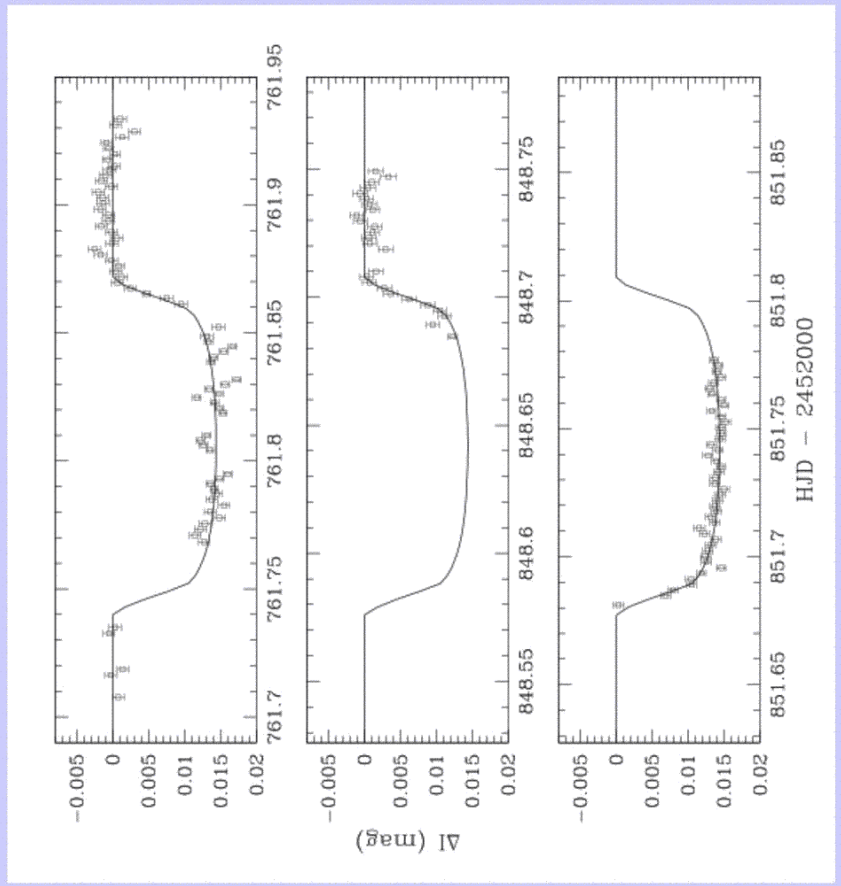
- T_{eff} = 5750 +/- 80 K
- log g = 4.5 (3.5-4.6)
- [Fe/H] = 0.0 +/- 0.2
- V_{rot} = 2 km/sec (1-4 km/sec)

$M_* = 1.0 +/- 0.05\ M_{sun}$

$R_* = 1.0 +/- 0.1\ R_{sun}$

Konacki et al (2003)

OGLE-TR-10 I-band light curve

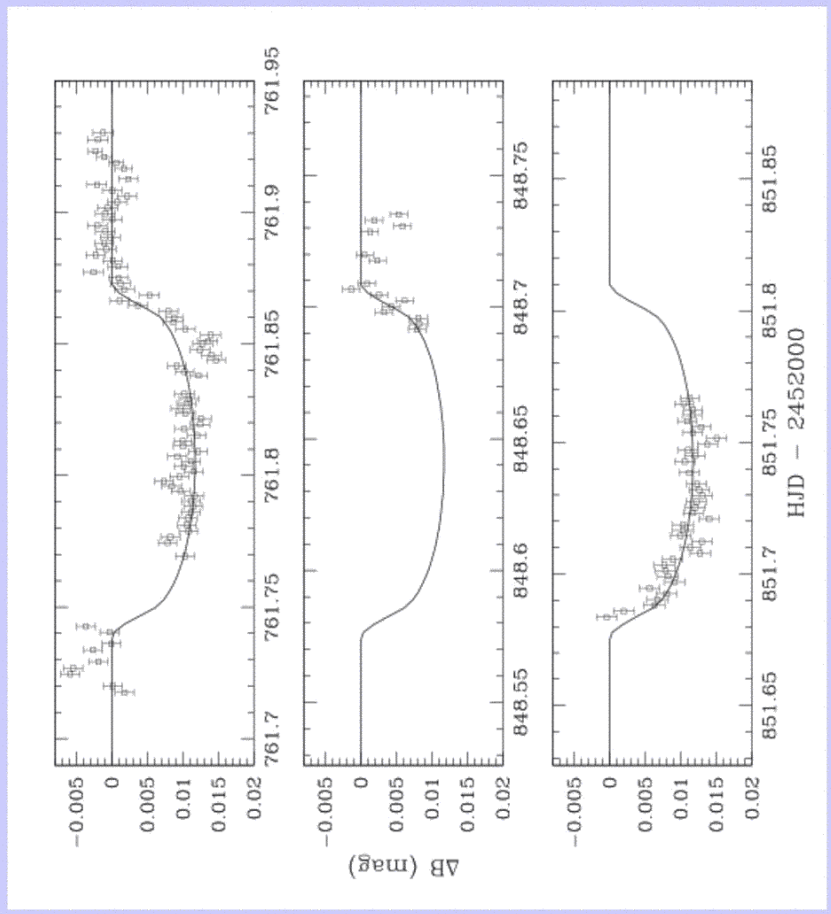


$R_p/R_* =$ 0.11 +/- 0.01

$a/R_* =$ 8.3 +/- 0.1

$i =$ 90.0 +/- 2

OGLE-TR-10 B-band light curve



$R_p/R_* =$ 0.09 +/- 0.01

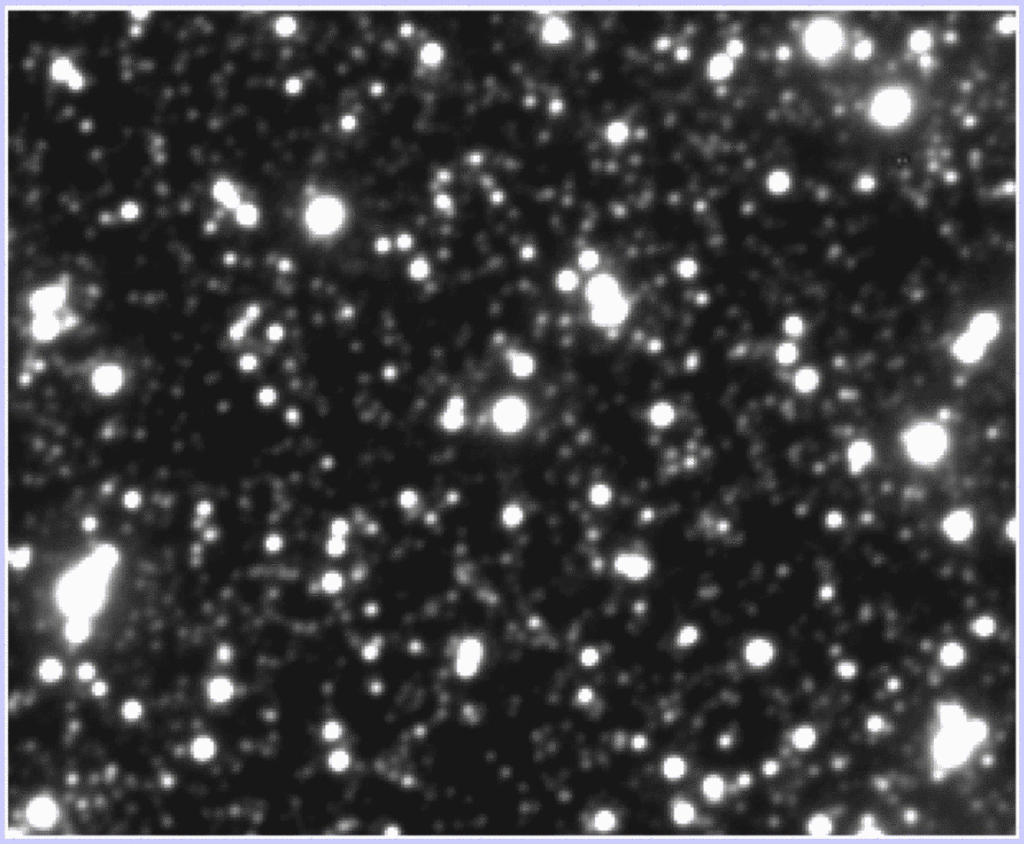
$a/R_* =$ 7.8 +/- 0.5

$i =$ 88.2 +/- 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)

OGLE-TR-10 I-band reference image



Data Reduction

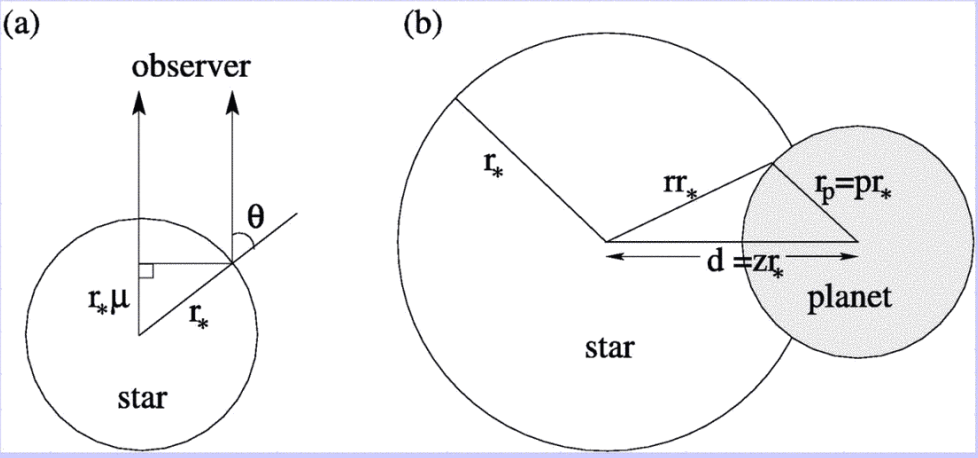
- Cross talk, overscan, trim, flat field, shutter timing corrections
- Sub-pixel registration of images
- ISIS 2.1 Image subtraction package (Alard & Lupton 1998, Alard 2000)
  - Creates high signal-to-noise reference image by median combination of 15-20 best images
  - Solves for coefficients of a convolution 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 = epoch of transit center
  - T = orbital period
  - R_p/R_*
  - a/R_*
  - i = inclination
  - u_1 and u_2 = quadratic limb darkening parameters

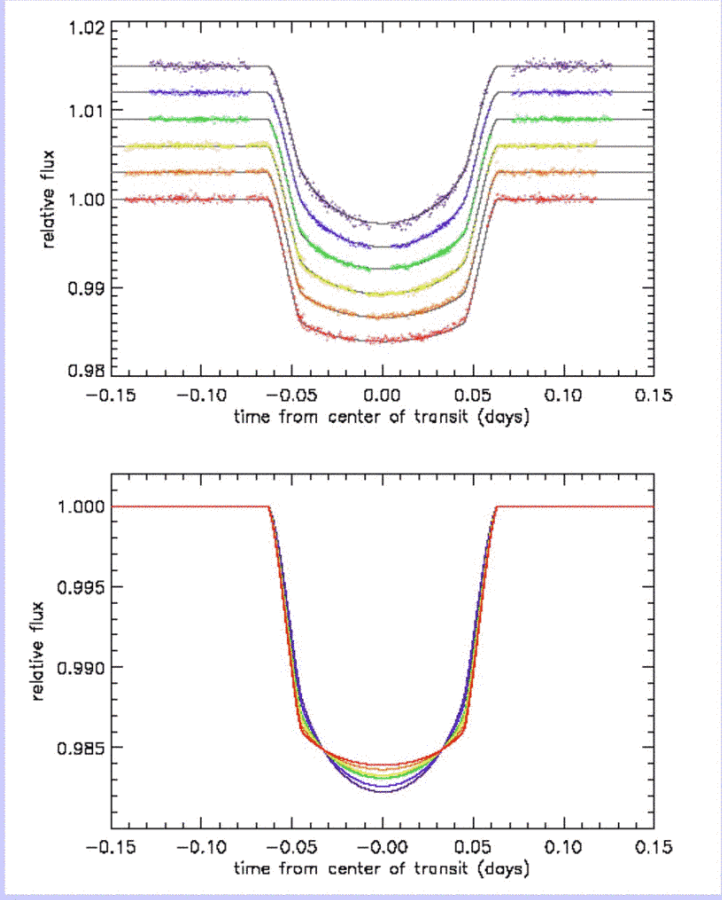
Used tools of Mandel and Agol (2002)

Stellar Limb Darkening



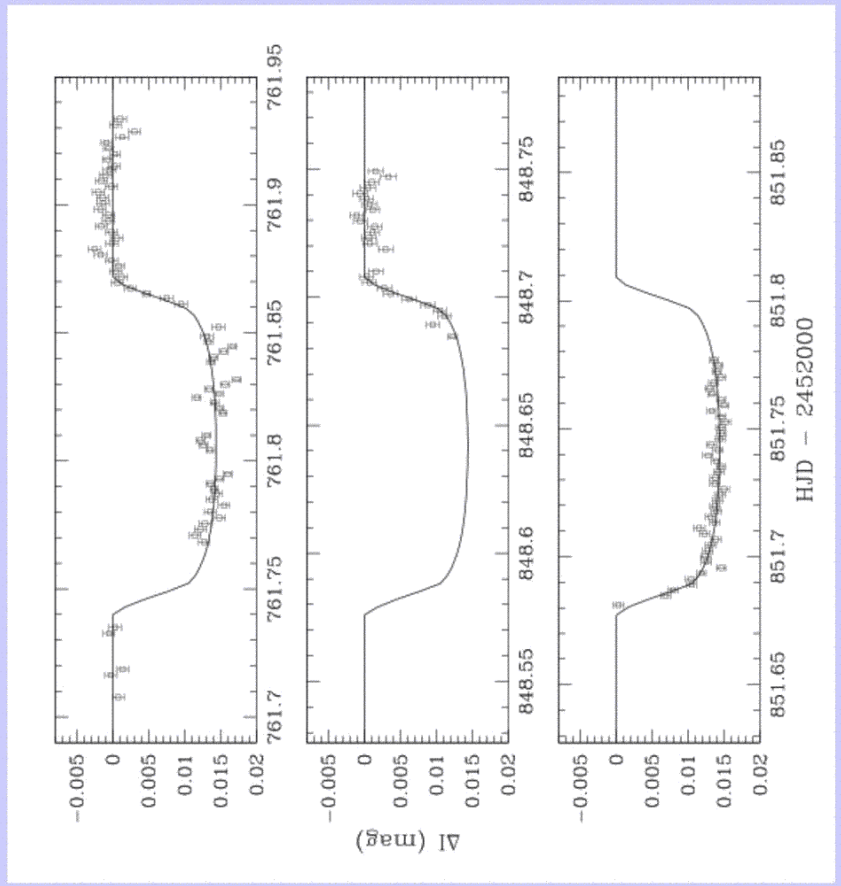
$$\frac{I(\mu)}{I(1)} = 1 - u_1(1-\mu) - u_2(1-\mu)^2$$

Mandel and Agol 2002



Charbonneau et al 2003

OGLE-TR-10 I-band light curve



$R_p/R_* =$ 0.11 +/- 0.01

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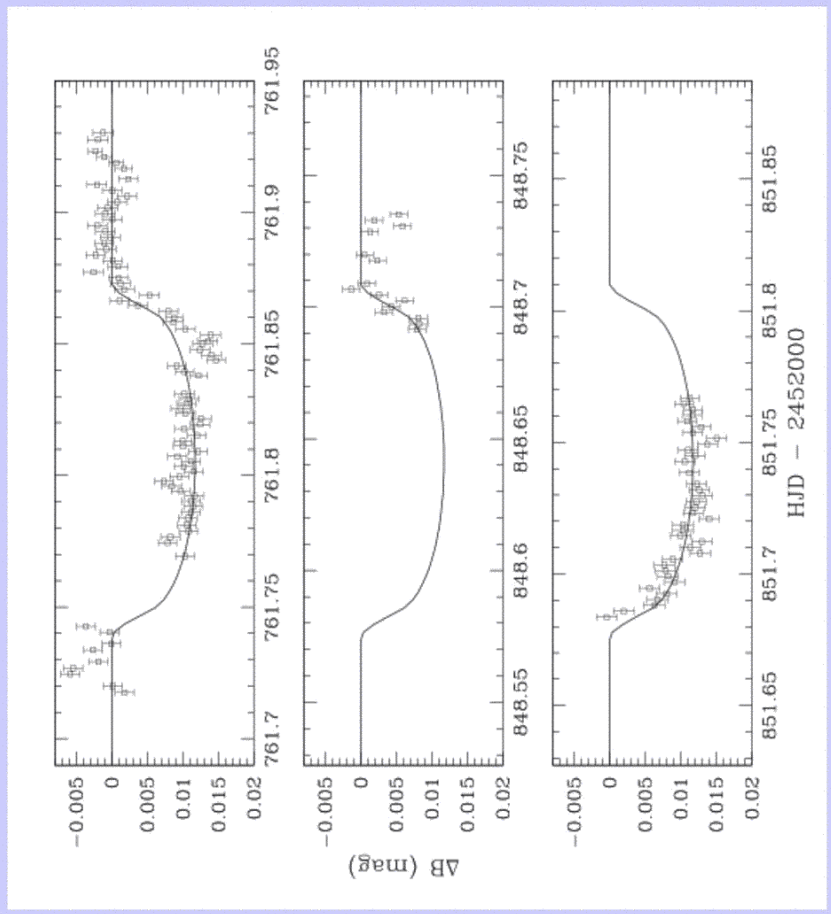
OGLE-TR-10 B-band light curve



$R_p/R_* =$ 0.09 +/- 0.01

$a/R_* =$ 7.8 +/- 0.5

$i =$ 88.2 +/- 2

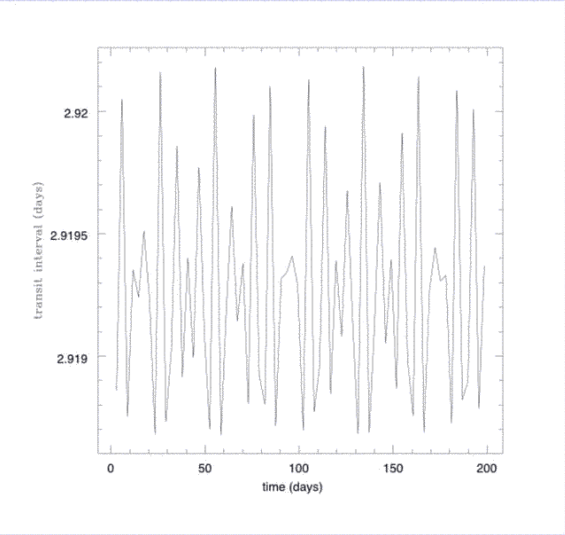
Conclusions

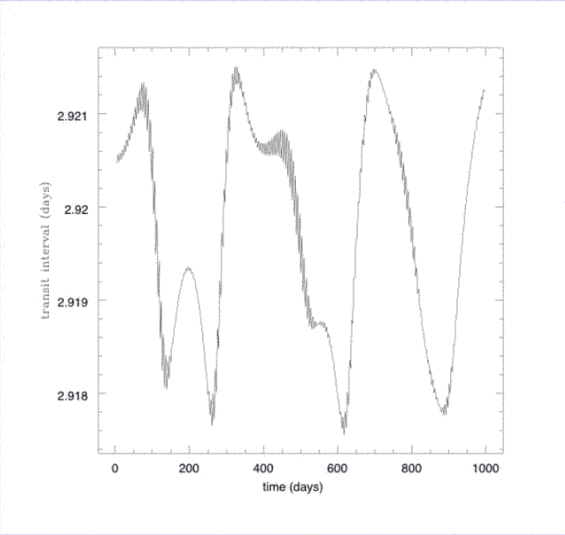
- OGLE-TR-10 appears to be a near-twin of HD209458, although we cannot rule out all possible blend scenarios.
- T = 3.101287 +/- 0.000001 days
- t_c = HJD 2452761.8060 +/- 0.0003
- $a/R_* = 8.3$ +/- 0.1
- $p = R_p/R_* = 0.11$ +/- 0.01
- $R_p = 1.1$ +/- 0.1 R_J
- i = 90 +/- 2 deg

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





$a_1 = 0.04$ AU, $a_2 = 0.09$ AU
$m_1 = 1\ M_J$, $m_2 = 1\ M_J$

$a_1 = 0.04$ AU, $a_2 = 0.0635$ AU
$m_1 = 1\ M_J$, $m_2 = 0.05\ M_J$

(See also Bodenheimer et al 2003)