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OGLE-TR-211 – a new transiting inflated hot Jupiter from the OGLE survey and ESO LP666 spectroscopic follow-up program ⋆

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ABSTRACT

We present results of the photometric campaign for planetary and low-luminosity object transits conducted by the OGLE survey in 2005 season (Campaign #5). About twenty most promising candidates discovered in these data were subsequently verified spectroscopically with the VLT/FLAMES spectrograph.
One of the candidates, OGLE-TR-211, reveals clear changes of radial velocity with small amplitude of 82 m/sec, varying in phase with photometric transit ephemeris. Thus, we confirm the planetary nature of the OGLE-TR-211 system. Follow-up precise photometry of OGLE-TR-211 with VLT/FORS together with radial velocity spectroscopy supplemented with high resolution, high S/N VLT/UVES spectra allowed us to derive parameters of the planet and host star. OGLE-TR-211b is a hot Jupiter orbiting a F7-8 spectral type dwarf star with the period of 3.68 days. The mass of the planet is equal to $1.03 \pm 0.20\ M_{\rm Jup}$ while its radius $1.36\ ^{+0.18}_{-0.09}\ R_{\rm Jup}$. The radius is about 20% larger than the typical radius of hot Jupiters of similar mass. OGLE-TR-211b is, then, another example of inflated hot Jupiters – a small group of seven exoplanets with large radii and unusually small densities – objects being a challenge to the current models of exoplanets.

Key words. planetary systems – stars: individual: OGLE-TR-211

1. Introduction

The discovery of the first transit of an extrasolar planet in HD209458 (Charbonneau et al. 2000; Henry et al. 2000) opened a new era in the extrasolar planet field – the epoch of searches for extrasolar planets with large scale photometric surveys. While this channel of finding exoplanets developed relatively slowly in the first couple of years after that discovery, the last two years brought a fast acceleration due to maturing of the search methods. At present about 25 transiting planets are known (cf. *http://obswww.unige.ch~pont/TRANSITS.htm)* constituting about 10% of all known exoplanets.

Transiting planets play especially important role among the known exoplanets. These are the only objects for which the most important parameters like radius, mass and density can be precisely derived from observations providing direct comparison with models and, thus, allowing better understanding of the exoplanet structure and evolution. Also a large variety of follow-up observations can be performed on transiting system allowing, for example, studies of planetary atmospheres, search for other planetary companions etc.

Transiting planets are discovered via two channels: photometric follow-up of spectroscopically found exoplanets and classical transit method approach – large scale photometric surveys providing transiting candidates that have to be then verified and confirmed spectroscopically. Both approaches have been successful in providing examples of very large diversity among transiting planets – regular hot Jupiters, very hot Jupiters on extremely short 1–2 day period orbits, inflated objects with radii much larger than expected from modeling or small Neptune-sized objects. Large number of new extrasolar transiting planets are expected to be discovered in the next couple of years from

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⋆ Based on observations made with the FORS1 camera and the FLAMES/UVES spectrograph at the VLT, ESO, Chile (programmes 07.C-0706, 076.C-0122 and 177.C-0666) and 1.3-m Warsaw Telescope at Las Campanas Observatory, Chile.

the space missions like Corot or Kepler, in particular small size planets undetectable in ground-based searches.

The Optical Gravitational Lensing Experiment (OGLE) was the first successful photometric survey that discovered large number of transiting candidates that were subsequently verified spectroscopically (Udalski et al. 2002a,b,c, 2003). Five of these candidates, OGLE-TR-56, OGLE-TR-113, OGLE-TR-132, OGLE-TR-111 and OGLE-TR-10 turned out to be extrasolar planetary systems (Konacki et al. 2003; Bouchy et al. 2004; Konacki et al. 2004; Pont et al. 2004; Bouchy et al. 2005; Konacki et al. 2005), the first extrasolar planets discovered with the transit method. Moreover, two planet-sized stars of lowest known masses were also found (Pont et al. 2005b, 2006). Beside that the OGLE photometric transit campaigns provided a huge observational material allowing better understanding the problems of photometric transit searches, data systematics etc. (Gould et al. 2006; Pont, Zucker & Queloz 2006).

OGLE transit campaigns have been conducted every year since 2001. Results of the spectroscopic follow-up of candidates discovered during the Campaign #1 (2001) and #2 (2002) were published by Bouchy et al. (2005) and Pont et al. (2005a), respectively. Recently, analysis of the near threshold candidates from the Campaign #2 led to the discovery of the sixth OGLE transiting exoplanet, OGLR-TR-182 (Pont et al. 2007).

In this paper we present results of the OGLE Campaign #5 conducted in 2005 and spectroscopic follow-up of the best transiting candidates detected in these data. A new transiting extrasolar planetary system OGLE-TR-211 was found among them. In the following Sections we provide the details of the photometric and spectroscopic observations of OGLE new candidates and derive parameters of a planetary companion in OGLE-TR-211 system.

2. OGLE planetary transit campaign #5

OGLE planetary transit campaigns became a standard part of the OGLE observing schedule. About 75% of observing time is devoted to this sub-project of the OGLE survey every southern fall – from February to April. The OGLE planetary campaign #5 was conducted by OGLE in the 2005 observing season from February 2, 2005 to June 23, 2005. Observations were carried out with the 1.3-m Warsaw Telescope at Las Campanas Observatory, equipped with 8192×8192 pixel CCD mosaic camera (Udalski 2003). The observing strategy was similar to that of the previous campaigns, in particular #3 and #4 (Udalski et al. 2004). Because the experience gathered during the spectroscopic observations of the first OGLE candidates indicated troubles in reasonable spectroscopic follow-up of the faintest objects from typical OGLE candidate lists, the exposure time during Campaign #5 was shortened to 120 seconds. This allowed to add one more field increasing the number of observed fields to four and covering about 1.4 square degrees of the Galactic disk regions in the Carina constellation. The cadence time for each of these four fields was about 16 minutes and their equatorial coordinates are listed in Table 1. All observations were collected through the *I*-band filter. The median seeing of the all observations was about 1.1 arcsec. Altogether about 1320 images of each of the fields were secured during the Campaign. Also a few *V*-band observations were taken for color information and CMD construction.

Table 1. Equatorial coordinates of the fields observed during the OGLE Campaign #5.

Field	RA(J2000)	DEC(J2000)
CAR107	10:47:15	−62:00:25
CAR108	10:47:15	−61:24:35
CAR109	10:42:10	−62:10:25
CAR110	10:42:15	−61:34:35

Collected data were reduced in similar way as those of Campaigns #3 and #4 (Udalski et al. 2004). The selection of transit candidates was also performed similarly: all non-variable objects, that is those with the *rms* of the average magnitude of all observations smaller than 0.015 mag, were subject to detrending algorithm of Kruszewski & Semeniuk (2003) and then transit search procedure using the BLS algorithm of Kovács et al. (2002). Altogether light curves of about 50000 stars were analyzed. The list of transiting candidates was prepared after careful visual inspection of candidates that passed the BLS criteria. Clear false cases triggered, for example, by noisy light curves were removed, as well as objects with the depth of transits larger than 50 mmag, those with clear signature of ellipsoidal effect indicating massive secondary, those with clear V-shape of transits indicating grazing eclipses of a binary star and those with the number of individual transits smaller than three. For all the candidates the limits on the size of a transiting companion were calculated as in Udalski et al. (2004). All candidates with the companion having the lower limit of radius larger than 0.2 $R_\odot$ were removed from the final list.

Table 2 lists the transit candidates from the OGLE Campaign #5 that passed the photometric search criteria. The naming convention follows the standard OGLE convention, i.e., OGLE-TR-NNN. About twenty candidates for transiting planetary systems were found. These objects were selected as targets for spectroscopic follow-up observations conducted under the LP666 Program. Photometry of all selected candidates is available from the OGLE Internet archive at *ftp://ftp.astrouw.edu.pl/ogle/ogle3/transits/tr201-219/*

3. Spectroscopic follow-up

Spectroscopic follow-up observations of the OGLE Campaign #5 transit candidates were carried out during three observing slots allocated to the LP666 program in April/May 2006, February 2007 and April 2007 on VLT with the FLAMES spectrograph. Also, part of the Geneva group observing time under program 07.C-0706, on the same instrument in February 2006 was used. Unfortunately the weather conditions during all these observing runs were exceptionally unfavorable with many cloudy or large seeing nights (> 2 arcsec) what considerably limited the results. In particular after the initial screening of all candidates only the most promising objects were further observed. The remaining objects, contrary to the previous follow-up observations (Bouchy et al. 2004; Pont et al. 2005a), were left without full further characterization. The strategy of the spectroscopic follow-up was identical as described by Pont et al. (2007).

Table 2 includes the column with spectroscopic status resulting from the collected spectra. Only one candidate turned out to be a very promising planetary candidate revealing low amplitude radial velocity variation in phase with photometric ephemeris, namely OGLE-TR-211. It was then extensively observed during all following spectroscopic runs what allowed to confirm its planetary nature. Three more candidates do not show significant radial velocity variations. Nevertheless, the confirmation of their planetary nature seems to be impossible as the lack of variation does not necessarily proves the presence of a planetary companion. Table 3 lists these objects and provides the upper limits on

Table 2. Planetary and low-mass object transit candidates from the OGLE Campaign #5 conducted in 2005.

Name	RA [2000]	DEC [2000]	Period [days]	T_0 [Hel.JD]	I [mag]	Depth [mag]	Status
OGLE-TR-201	10:48:31.61	−62:01:01.8	2.3680	2453404.860	15.6	0.016	fast rotator
OGLE-TR-202	10:46:06.06	−61:52:11.3	1.6545	2453404.438	13.6	0.017	not observed
OGLE-TR-203	10:49:32.04	−61:35:38.2	3.3456	2453406.178	15.6	0.014	not observed
OGLE-TR-204	10:47:39.44	−61:19:00.8	3.1097	2453405.515	14.8	0.026	SB2
OGLE-TR-205	10:45:53.40	−61:09:22.1	1.7501	2453404.601	16.0	0.015	not observed
OGLE-TR-206	10:45:22.00	−61:28:28.8	3.2658	2453403.246	13.8	0.006	no variation
OGLE-TR-207	10:40:10.41	−61:53:55.5	4.8170	2453406.978	14.3	0.021	SB2
OGLE-TR-208	10:39:54.18	−61:58:07.7	4.5025	2453406.567	15.3	0.022	SB2
OGLE-TR-209	10:40:56.27	−62:14:20.2	2.2056	2453403.657	15.0	0.022	no variation
OGLE-TR-210	10:40:44.21	−62:13:21.6	2.2427	2453403.012	15.2	0.032	fast rotator
OGLE-TR-211	10:40:14.51	−62:27:19.8	3.6772	2453406.271	14.3	0.008	planet
OGLE-TR-212	10:43:37.95	−61:45:01.5	2.2234	2453404.170	16.3	0.016	blend?
OGLE-TR-213	10:43:00.85	−61:51:10.2	6.5746	2453403.301	15.3	0.036	SB2
OGLE-TR-214	10:44:27.96	−61:35:35.7	3.6010	2453403.090	16.5	0.023	SB1
OGLE-TR-215	10:43:48.69	−61:40:00.3	4.9237	2453407.616	14.8	0.016	no variation
OGLE-TR-216	10:42:02.43	−61:20:16.0	1.9763	2453403.064	14.6	0.011	blend?
OGLE-TR-217	10:40:59.73	−61:30:38.4	5.7208	2453404.104	16.1	0.037	no ccf
OGLE-TR-218	10:41:12.74	−61:28:20.8	2.2488	2453404.697	14.5	0.020	fast rotator
OGLE-TR-219	10:40:53.40	−61:43:15.1	9.7466	2453405.683	15.1	0.032	SB2

Table 3. OGLE transit candidates with no significant radial velocity variation.

Object	K limit [m/sec]	Mass limit [M_{Jup}]
OGLE-TR-206	< 59	< 0.42
OGLE-TR-209	< 16	< 0.16
OGLE-TR-215	< 63	< 0.52

radial velocity semi-amplitudes, K, at the 2-sigma level and the corresponding maximum mass of a potential planet for a 1 $M_\odot$ host star.

4. OGLE-TR-211 candidate

OGLE-TR-211 turned out to be the most promising candidate for a transiting planetary system from the OGLE Campaign #5 sample. After the initial spectroscopic follow-up observations confirming this status it was decided to allocate considerable amount of observing time for precise characterization of this object. OGLE-TR-211 is relatively bright ($I \approx 14.3$ mag) in the OGLE sample. Its equatorial coordinates are listed in Table 2 while Figure 1 shows the finding chart – $2' \times 2'$ OGLE I-band image.

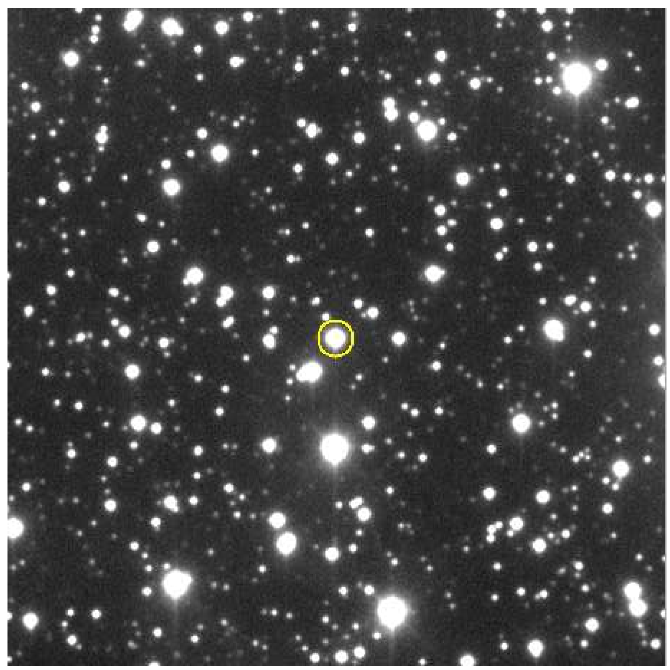

Fig. 1. Finding chart for OGLE-TR-211. Size of the I-band OGLE subframe is 120" × 120", North is up and East to the left.

4.1. Photometry

The original OGLE 2005 season photometric data covered eight partial transits. When folded with the period of 3.677 days they revealed a clear transit about 8 mmag deep. The estimated lower limit of the transiting companion radius was 0.12 $R_\odot$ making OGLE-TR-211 a very good candidate for a transiting planet.

Due to limited, ≈3 months long, duration of the OGLE Campaign the photometric period has limited accuracy of the order of $\approx 10^{-4}P$ or even worse in the case of low depth transits. To confirm presence of transits in OGLE-TR-211 and refine the ephemeris OGLE observed the star in the next observing seasons: 2006 and 2007. The first additional transit data points were collected yet in January 2006 providing a necessary confirmation and update of the photometric orbit for the coming spectroscopic follow-up observations. Up to June 2007 eight additional transits of OGLE-TR-211 were covered. Thanks to over two years long baseline these observations allowed us to derive precise photometric ephemeris of OGLE-TR-211, listed in Table 5.

Very small depth of transits combined with ≈5 mmag accuracy of individual OGLE measurements makes the determination of precise shape of transit difficult. Therefore, similarly to other cases of OGLE transiting planets, it was decided to conduct a photometric follow-up of this object on much larger telescope. Three photometric runs on VLT with the FORS camera were performed in the period of March/June 2006.

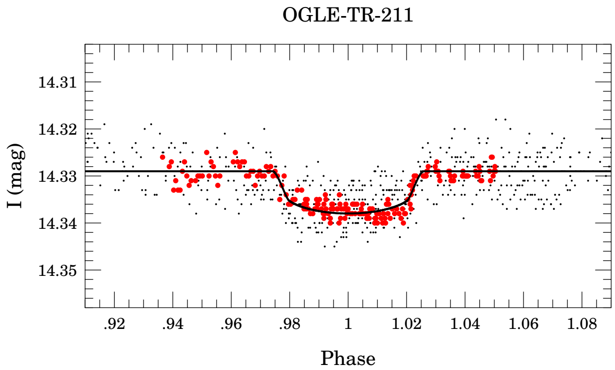

Fig. 2. Light curve of OGLE-TR-211. Small dots indicate OGLE data points while large dots VLT observations. Continuous line represents the best model of the transit.

The first run VLT images of OGLE-TR-211 were obtained on March 16, 2006 through the *V*-band filter with the exposure time of 8 seconds. They cover the pre-ingress, ingress and bottom of the transit. Unfortunately the egress of the transit was missed. Two additional runs were carried out on May 25, 2006 and June 30, 2006. In these cases observations were obtained through the *V* and *R* filters and exposure time varied from 25 to 80 seconds depending on seeing. Unfortunately, both these runs cover practically non-variable part of the transit light curve: the May observations – flat bottom of the transit with only a small trace of starting egress at the very end, the June observations – only post transit light curve with the very end of egress at the beginning. Thus, the full reconstruction of the precise VLT light curve OGLE-TR-211 became difficult.

The VLT data were reduced using the OGLE data pipeline (Udalski 2003), based on the Difference Image Analysis (DIA) method. Because the March run that defines well considerable part of the transit shape was obtained in the *V*-band, only *V*-band images from the remaining runs were used. To have similar time resolution and lower the scatter of the March observations these data were binned to have an effective resolution of 3 minutes. The March light curve indicates that the transit depth is about 8 mmag – practically identical with that resulting from OGLE observations what is reassuring. Therefore the May data were adjusted in such a way that the observed flat bottom of the transit corresponds to the level of the bottom observed in March. Similarly, the June photometry was shifted so the post-egress part of transit corresponds to the pre-ingress part observed in March. Finally, the VLT photometry was folded with the photometric period resulting from OGLE observations. Figure 2 shows the reconstructed VLT light curve of OGLE-TR-211 plotted using large dots and overimposed on the OGLE light curve (small dots).

The VLT data were also reduced using the DecPhot PSF fitting software (Gillon et al. 2006). While the results were generally similar, due to difficulties with the normalization between runs this photometry was not used for further analysis of OGLE-TR-211.

4.2. Radial velocity follow-up

Twenty high-resolution spectroscopic observations of OGLE-TR-211 were obtained with the FLAMES/UVES spectrograph on VLT during four spectroscopic follow-up runs. Strategy of observations and reduction procedures were identical as in Pont et al. (2007). The resulting radial velocities of OGLE-TR-211 are listed in Table 4. Similarly as in Pont et al. (2007) we added 45 m/sec error in quadrature to the photon noise radial velocity errors to account for possible systematic errors.

Table 4. Radial velocity measurements for OGLE-TR-211.

Date [JD-2450000]	Phase	VR [km s^{-1}]	VR$_{\rm rectified}$ [km s^{-1}]	σ_{VR} [km s^{-1}]
3793.81192	0.3889	18.784	18.784	0.055
3794.75446	0.6452	18.866	18.866	0.053
3852.50001	0.3487	18.720	18.720	0.053
3853.51724	0.6254	18.875	18.875	0.053
3854.54151	0.9039	18.841	18.841	0.051
3855.50251	0.1652	18.711	18.711	0.055
3855.59958	0.1916	18.816	18.816	0.060
3858.49787	0.9798	18.906	18.906	0.054
3881.57542	0.2556	18.766	18.766	0.053
4143.83440	0.5753	18.860	18.860	0.046
4144.71247	0.8141	18.911	18.911	0.046
4145.72709	0.0900	18.762	18.762	0.048
4149.81577	0.2019	18.681	18.681	0.047
4150.77874	0.4638	18.891	18.891	0.046
4203.55370	0.8156	18.745	18.925	0.046
4204.51070	0.0759	18.623	18.803	0.046
4205.59031	0.3695	18.657	18.837	0.046
4207.70041	0.9433	18.658	18.838	0.046
4208.68020	0.2097	18.578	18.758	0.046
4209.61470	0.4639	18.517	18.697	0.049

After two 2006 runs it was clearly found that the radial velocities of OGLE-TR-211 follow the photometric period and reveal $\approx$ 100 m/sec semi-amplitude variation in appropriate phase with planetary interpretation. However, during the last 2007 April run, it was noted that while this variation is clearly seen, the zero point of radial velocities shifted by about 180 m/sec. This is considerably larger shift than the shifts noted by Pont et al. (2007) during analysis of the recently discovered transiting planet OGLE-TR-182.

Although it cannot be fully ruled out that the shift has some instrumental origin it is more likely that it corresponds to the real change of the average radial velocity. Unfortunately, the collected dataset is too limited to draw any sound conclusions about its origin. We can only speculate that it may be caused by the presence of additional companion in the OGLE-TR-211 system having wide orbit with a period of several years. Further additional spectroscopic observations are necessary to verify this interpretation.

For the purpose of characterization of the planetary companion of OGLE-TR-211 the mean shifts of each observing run compared to the first one were fitted. Only the shift of the April 2007 run turned out to be statistically significant, It was subtracted from original radial velocities. Rectified radial velocities of OGLE-TR-211 are also listed in Table 4.

Because blending of an eclipsing star with a bright third light source can cause radial velocity variation comparable with planetary signal, line profiles of the spectra of OGLE-TR-211 were examined for correlation of the average line bisectors with phase and observed radial velocities (e.g., Santos et al. 2002; Torres et al. 2004). No such correlation was found allowing to rule out blending scenario.

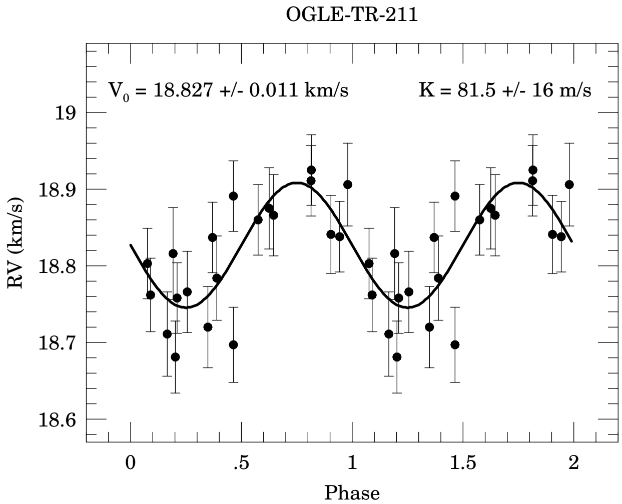

Fig. 3. Radial velocity observations for OGLE-TR-211, phased with the photometric transit ephemeris. Solid line represents the best fit assuming no eccentricity. Two periods are presented for clarity.

Table 5. Parameters of the OGLE-TR-211 system.

Period [days]	3.67724 ± 0.00003
Transit epoch [Hel. JD]	2453428.334 ± 0.003
VR semi-amplitude [m/s]	82 ± 16
Semi-major axis [AU]	0.051 ± 0.001
Radius ratio	0.085 ± 0.004
Orbital angle [°]	> 82.7
Light Curve Model:	
OGLE *rms* [mmag]	4.1
VLT *rms* [mmag]	1.6
Radial Velocity Model:	
rms [m/s]	48
$T_{\rm eff}$ [K]	6325 ± 91
$\log g$	4.22 ± 0.17
η [km s^{-1}]	1.63 ± 0.21
[Fe/H]	0.11 ± 0.10
Star radius [$R_\odot$]	$1.64^{+0.21}_{-0.07}$
Star mass [$M_\odot$]	1.33 ± 0.05
Planet radius [$R_{\rm Jup}$]	$1.36^{+0.18}_{-0.09}$
Planet mass [$M_{\rm Jup}$]	1.03 ± 0.20

4.3. Host star spectroscopy

To derive parameters of the host star of OGLE-TR-211 high resolution spectra were obtained with the UVES spectrograph on VLT working in the slit mode on May 7 and 8, 2007. The spectra were summed so the coadded spectrum reached a S/N of about 100 in the $\lambda \approx 6707$ Å Lithium line region. Measurements were done following the method described in Santos et al. (2006). The results are listed in Table 5. Temperature and gravity indicates that the host star is a dwarf of F7-8 spectral type and metallicity somewhat larger than solar.

4.4. OGLE-TR-211 parameters

The parameters of OGLE-TR-211 were derived with the standard method used in the case of the previous OGLE planets (Bouchy et al. 2004; Pont et al. 2007). The photometry with red noise value equal to the photon noise was fitted for P, T, b, R/R_* and a/R_*. Eccentricity of the orbit in the final fitting was assumed to be zero, as practically all the observed orbits of short period transiting planets are circularized by tidal interactions. Also our preliminary fit of the radial velocity curve with the orbital period fixed at the photometric value yielded eccentricity $e = 0.16 \pm 0.22$, consistent with circular orbit at better than 1σ level.

Then the radius and mass of the host star were estimated with the maximum likelihood method combining the observed spectroscopic parameters of the host star and Girardi et al. (2002) stellar evolution models. Table 5 lists the parameters of the host star and transiting planet in the OGLE-TR-211 system.

It has to be noted that the transit shape is not precise enough to determine the inclination angle very precisely. Nevertheless, the size of the planet is relatively well constrained thanks to the accuracy of the stellar spectroscopic parameters.

The O–C weighted *rms* scatter around the final photometric model of the OGLE-TR-211 system is equal to $\sigma = 1.6$ mmag and $\sigma = 4.1$ mmag for the VLT and OGLE dataset, respectively. The weighted *rms* of radial velocity observations relatively to the best fit is $\sigma_{\rm RV} = 48$ m/s.

5. Discussion

Parameters of the transiting companion of OGLE-TR-211 host star indicate that it is a planetary object belonging to the hot Jupiter class of extrasolar planets. It brings the total number of extrasolar planets discovered by the OGLE survey to seven – significantly lowering the discrepancy between the number of typical hot Jupiters and shortest period very hot Jupiters in the OGLE sample of extrasolar transiting planets.

OGLE-TR-211b orbits an F7-8 main sequence star. The system parameters closely resemble that of the recently discovered system HAT-P-6 (Noyes et al. 2007) with the only difference that the host star in OGLE-TR-211 is more metal abundant by ≈ 0.2 dex. The position of the planet on the mass-orbital period diagram is similar to the position of other transiting exoplanets of similar mass and period supporting the relation noted first by Mazeh, Zucker & Pont (2005).

While the mass of a new hot Jupiter OGLE-TR-211b is very similar to the mass of another hot Jupiter OGLE-TR-182b recently found by Pont et al. (2007) its radius is about 20% larger. The mean density of OGLE-TR-211b is about 0.5 g/cm^3, placing it among a group of seven objects with the lowest densities: Tres-4, HD209458, HAT-P-1, WASP-1, HAT-P-4 and HAT-P-6 (Kovács et al. 2007). All these objects have inflated radii compared to other transiting hot Jupiters of similar mass. Such planets pose a problem to the planetary models and are crucial objects for testing the proposed scenarios explaining "bloated" hot Jupiters (Burrows et al. 2007; Guillot et al. 2006). It is worth noting that the metallicity of the OGLE-TR-211 host star falls in the middle of the range of metallicities of "bloated" Jupiters host stars (recently increased significantly by the HAT-P-6 system) suggesting that metallicity cannot be the only parameter responsible for inflating the radii of hot Jupiters.

On the other hand, the characteristics of the OGLE-TR-211 system reinforce the association of "bloated" close-in giant planets with strong irradiation from the host star. Figure 4 shows the

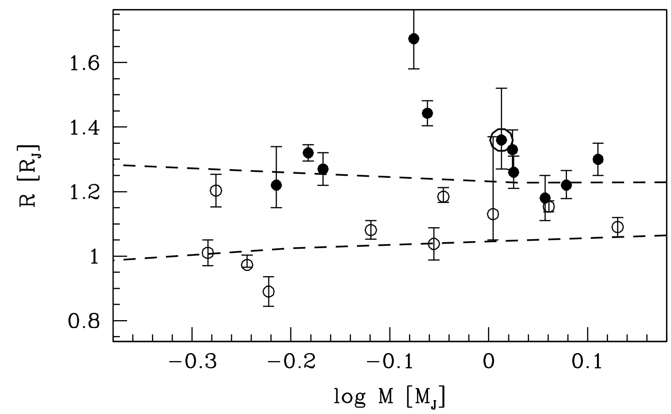

Fig. 4. Mass-radius diagram for transiting hot Jupiters. Closed symbols indicate host stars with $T_{\rm eq} > 1500$ K. OGLE-TR-211 is indicated by the circled dot. The lines show the models of Guillot (2005) in two extreme cases: cold gas planet with a $15 M_{\oplus}$ core and $T_{\rm eq} = 2000$ K planet without core. The five large planets with radius error bars above the upper models are all strongly irradiated.

mass-radius diagram for the presently known transiting planets, classified according to their equilibrium temperature. [1]

All anomalously large planets have equilibrium temperatures hotter than 1500 K. This would require an increasingly unlikely coincidence if the anomalously large radii were explained by dynamical effects such as obliquity tide or eccentricity pumping by an unseen companion (Winn & Holman 2005). It rather tends to favor explanations directly linking the excess of radius with the incident flux like such as proposed by Guillot et al. (2006) (that a fraction of the incident flux energy is converted to mechanical energy by a yet undetermined physical process) – over explanations with a more indirect causal relation, such as that put forward by Burrows et al. (2007) and Chabrier & Baraffe (2007) invoking increased opacity or internal density gradients.

As we already noted in Section 4.2 the mean level of radial velocity variation of the OGLE-TR-211 host star was shifted by about 180 m/sec during the last April 2007 run. Although the real nature of this shift is unknown at this stage the tempting explanation is that it is caused by the presence of additional companion, possibly of planetary or stellar nature, in the OGLE-TR-211 system. If confirmed by additional follow-up observations, OGLE-TR-211 would be the first multi-planetary system with a transiting planet or the first moderately-wide binary system hosting a transiting hot Jupiter.

Also, further additional high accuracy photometric follow-up observations of the OGLE-TR-211 transits are necessary for better constraining the inclination and radius of the planet. Although OGLE-TR-211, similarly to other OGLE transiting planets, is too faint for the currently available facilities to carry out some follow-up observations like IR photometry, the precise long term transit timing allowing search for another planetary objects in the OGLE-TR-211 system is feasible.

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[1] $T_{\rm eq} = T_*((1-A)/4F)^{1/4}(R_*/a)^{1/2}$ using for all planets a Bond albedo $A = 0.3$ and a heat redistribution factor $F = 1/2$.

References

Bouchy, F., Pont., F., Santos, N.C., et al. 2004, A&A, 421, L13
Bouchy, F., Pont., F., Melo, C., et al. 2005, A&A, 431, 1105
Burrows, A., Hubeny, I., Budaj, J., & Hubbard, W.B. 2007, ApJ, 661, 502
Chabrier, G. & Baraffe, I. 2007, ApJ661, L81
Charbonneau, D., Brown, T.M., Latham, D.W., & Mayor, M. 2000, ApJ, 529, L45
Gillon, M., Pont., F., Moutou, C., et al. 2006, A&A, 459, 249
Girardi, L., Bertelli, G., Bressan, A., et al. 2002, A&A, 391, 195
Gould, A., Dorsher, S., Gaudi, B.S., & Udalski, A. 2006, Acta Astron., 56, 1
Guillot, T. 2005, Ann. Rev. of Earth and Planetary Sciences, 33, 493
Guillot, T., Santos, N.C., Pont, F., et al. 2006, A&A, 453, L21
Henry, G.W., Marcy, G.W., Butler, R.P., & Vogt, S.S. 2000, ApJ, 529, L41
Konacki, M., Torres, G., Jha, S., & Sasselov, D. D. 2003, Nature, 421, 507
Konacki, M., Torres, G., Sasselov, D. D., et al. 2004, ApJ, 609, L37.
Konacki, M., Torres, G., Sasselov, D. D., & Jha, S. 2005, ApJ, 624, 372
Kovács, G., Zucker., S., & Mazeh, T., 2002, A&A, 391, 369
Kovács, G., Bakos, G.Á., Torres, G., et al. 2007, ApJ, submitted; astro-ph/0710.0602
Kruszewski, A. & Semeniuk, I. 2003, Acta Astron., 53, 241
Mazeh, T., Zucker, S., & Pont, F. 2005, MNRAS, 356, 955
Noyes, R.W., Bakos, G.Á., Torres, G., et al. 2007, ApJ, submitted; astro-ph/0710.2894
Pont, F., Bouchy, F., Queloz, D., et al. 2004, A&A, 426, L15
Pont, F., Bouchy, F., Melo, C., et al. 2005a, A&A, 438, 1123
Pont, F., Melo, C., Bouchy, F., et al. 2005b, A&A, 433, L21
Pont, F., Moutou, C., Bouchy, F., et al. 2006, A&A, 447, 1035
Pont, F., Zucker, S., & Queloz, D. 2006, MNRAS, 373, 231
Pont, F., Tamuz, O., Udalski, A., et al. 2007, A&A, submitted; astro-ph/0710.5278
Santos, N.C., Mayor, M., Naef, D., et al. 2002, A&A, 392, 215
Santos, N.C., Pont, F., Melo, C., et al. 2006, A&A, 450, 825
Torres, G., Konacki, M., Sasselov, D. D., & Jha, S. 2004, ApJ, 614, 979.
Udalski, A., Paczyński, B., Żebruń, K., et al. 2002a, Acta Astron., 52, 1
Udalski, A., Żebruń, K., Szymański, M., et al. 2002b, Acta Astron., 52, 115
Udalski, A., Szewczyk, O., Zebruń, K., et al. 2002c, Acta Astron., 52, 317
Udalski, A., Pietrzyński, G., Szymański, M., et al. 2003, Acta Astron., 53, 133
Udalski, A. 2003, Acta Astron., 53, 291
Udalski, A., Szymański, M.K., Kubiak, M. et al. 2004, Acta Astron., 54, 313
Winn, J.N., & Holman, M.J. 2005, ApJ628, L159