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REM photometry of the exoplanetary system CoRoT-2b

F. Borsa[1,2] and E. Poretti[2]

[1] Università degli Studi Bicocca, Milano, Italy
[2] INAF – Osservatorio Astronomico di Brera, Via E. Bianchi 46, I-23807 Merate, Italy
e-mail: `ennio.poretti@brera.inaf.it`

Abstract. The number of extrasolar planets is rapidly growing, while their characterization is still in progress. The space mission CoRoT opened new frontiers in this field, owing to the intrinsic high–precision of its photometric measurements and to the long time baseline on which targets are monitored. CoRoT uses the method of transits to detect exoplanets. Complementary observations from ground in the infrared passbands were performed with the Rapid Eye Mount (REM) robotic telescope.

Key words. Techniques: photometric - planetary systems

1. Introduction

The transit method for the search for extrasolar planets can give us details about the planet in a quite straightforward way. The transit of a planetary body in front of its parent star is a merely obscuration effect, owing to the difference in the surface temperatures and to the intrinsically low temperature of the planet. Therefore, the depth of the transit should not depend on the wavelength, except for the effect of the stellar limb-darkening. This also allows finding false positives in transiting planetary candidates (Tingley 2004), preventing the use of a lot of telescope time for the spectroscopic follow–up.

So far sixty-nine extrasolar planets[1] have been discovered transiting their parent star. Nearly half of them has been studied with photometric follow-up observations in the near and medium infrared, mainly using the Spitzer Space Telescope (Désert et al. 2009) and the Hubble Space Telescope (Carter et al. 2009). The only example in literature of the study of a planetary transit observed at different optical wavelengths is that of HD 209458b (Knutson et al. 2007).

The space mission CoRoT [2] (COnvection, ROtation and planetary Transits; Baglin et al. 2006) was initially conceived to perform the asteroseimic study of ten stars, but later on it was upgraded with a planet finding program to observe simultaneously up to 12,000 stars in the magnitude range 11.5–16.0 (Barge et al. 2006). Details about the Italian contribution to the CoRoT mission can be found in

Send offprint requests to: E. Poretti

[1] See the continuously updated encyclopaedia at `http://exoplanet.eu`

[2] The CoRoT space mission was developed and is operated by the French space agency CNES, with participation of ESA's RSSD and Science Programmes, Austria, Belgium, Brazil, Germany, and Spain.

Poretti et al. (2007a), Poretti et al. (2007b) and Poretti et al. (2008). Since the goal was to detect the transits of small–size planets, it would have been very difficult to distinguish the resulting small effect from the stellar activity without information on the colour variations. For this reason a bi–prism was located in the focal block of the instrument, between the dioptric objective and the plane of the detectors. The image of each target is a small, low–resolution spectrum whose area is about 300 arcsec^2 on the sky. The photometry is performed in three different colours, roughly red (R), green (G) and blue (B), but there is not an exact system of reference: CoRoT coloured photometry is relative to the target. This because the shape of the mask and its extension toward the blue depends on several parameters and, among them, the magnitude and the position of the given star.

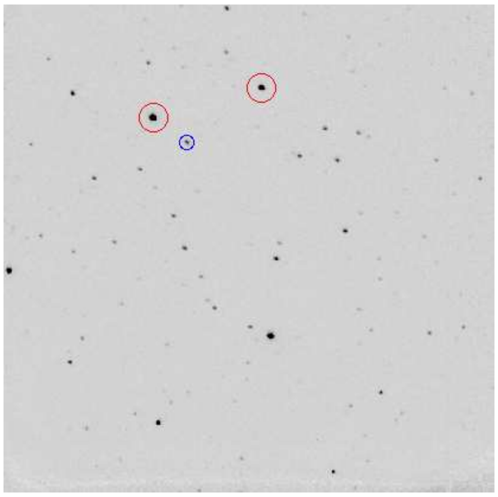

Fig. 1. The field of sky observed with REM. The small circle represents the star CoRoT-2, while large circles the comparison stars. North is at the top, East at the left. The field of view is 10′x10′.

2. CoRoT-1b, 2-b and 3-b

CoRoT-1b (Barge et al. 2008) is the first planet discovered by the CoRoT mission during its Initial Run. It orbits a G0V-type star of magnitude V=13.6, radius 1.11 ± 0.05 $R_\odot$, mass 0.95 ± 0.15 $M_\odot$ and $T_{\rm eff}$ = 5950 ± 150 K. The planet has a very low medium density, and this could be consistent with a low metallicity (Burrows et al. 2007); this would be in agreement with the apparent low metallicity of the star ([M/H]= −0.30 ± 0.25).

CoRoT-2b (Alonso et al. 2008), discovered during the Run LRc01, orbits a K0V-type star of magnitude V=12.57. This star, with mass 0.97 ± 0.06$M_\odot$, radius 0.902 ± 0.018$R_\odot$ and $T_{\rm eff}$ = 5625 ± 120 K, is particularly active, with two different groups of spots separated by about 180° in longitude. The two groups rotate with periods of 4.52 and 4.55 days, while the rest of the photosphere seems to have a more slow cycle with a period of about 28.9 days (Lanza et al. 2008). Follow-up ground-based observations permitted to measure the Rossiter-McLaughlin effect, revealing an angle of 7.2° between the orbital axis of the planet and the rotational axis of the star (Bouchy et al. 2008).

CoRoT-3b (Deleuil et al. 2008), discovered in the Run LRc01, orbits an F3-type star of mass 1.37 ± 0.09$M_\odot$, radius 1.56 ± 0.09$R_\odot$ and $T_{\rm eff}$ = 6740 ± 140 K, with a magnitude V=13.29. CoRoT-3b was defined as an inhabitant of the "brown dwarf desert". With its mass of 21.66 $M_{\rm Jup}$ it could be either a low-mass brown dwarf or the member of a new class of "superplanets", because it is on the border between planets and stars.

3. REM observations

The importance of the limb–darkening effect decreases when the wavelength increases. Hence, the light curve of a planetary transit becomes progressively similar to a box at longer wavelengths. Therefore, it should be possible to give stronger constraints on the value of the planetary radius performing infrared observations.

We observed the field of CoRoT-2 (Fig. 1) with the Rapid Eye Mount (REM) telescope (Zerbi et al. 2003). The transit of CoRoT-2b was successfully detected on three different nights (August 12th, 26th and September 16th, 2008), but a light curve covering the complete

Table 1. Limb-darkening coefficients for CoRoT-2 for the bandpasses H, J, K and R observed by REM, and values of R_P/R_S and R_P calculated with the fit on the light curves.

Colour	γ_1	γ_2	R_P/R_S	$R_P[R_{\rm Jup}]$
H	–0.0083	0.4287	0.1415 ± 0.0170	1.24 ± 0.15
J	0.1195	0.3554	0.1459 ± 0.0205	1.28 ± 0.18
K	0.0077	0.3544	0.1461 ± 0.0351	1.28 ± 0.31
R	0.3586	0.3113	0.1450 ± 0.0117	1.28 ± 0.11

transit was obtained on the last night only. We obtained light curves in the three near infrared bandpasses H (102 measurements), J (100), and K (93) with the infrared imaging camera REMIR and the light curve in R (232 measurements) with the visibile imager ROSS. We observed the transit for a total of 10 hours and 7 minutes, acquiring images with a 40 sec exposure.

We reduced the images by performing differential photometry with IRAF[3]. The different transits were folded using the period obtained from the CoRoT data (Fig. 2). To fit the transit, we used the coefficients of limb-darkening calculated from the Claret (2000) tables for the bandpasses H, J, K and R (Table 1).

In the fit the only free parameter was R_P/R_S. As orbital parameters we used those calculated from the sum of R, G, and B curves. The error bars on the transit depth were calculated from the errors outside of the transit and on the flat part of the transit. The scatter in the data is quite large. In particular, it makes it difficult to establish the level outside the transit, considering that owing to scheduling problems, we could observe only a short phase interval. Notwithstanding, the results are compatible with the ones obtained from the CoRoT data.

In Fig. 2 we superposed all the different wavelengths transits of CoRoT-2b observed with REM. The shapes and depths of the transits do not seem to differ, both because of the

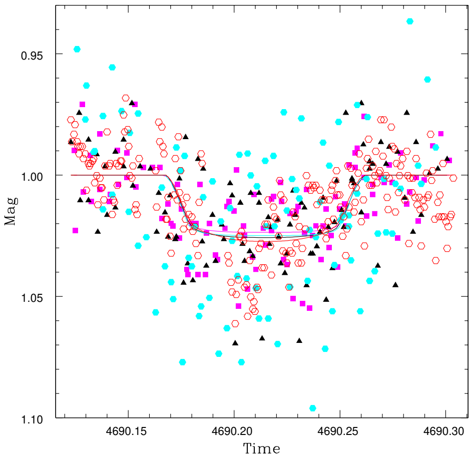

Fig. 2. Transit of CoRoT-2b at the four different wavelenghts observed with REM. The empty circles indicate ROSS *R* data; triangles, squares and full circles the REMIR *J*, *H* and *K* data, respectively.

close wavelength intervals and of the large dispersion of the measurements. The values of R_P/R_S (Tab. 1) calculated from the REM light curves, although compatible due to the large errors involved, are sistematically smaller than the ones at shorter wavelenghts (0.167, see Tab. 1 in Alonso et al. 2008). It is possible that in the infrared the radius of the star is larger, due also to the presence of dust around the stellar disk.

We performed the same observations with REM for the transit of CoRoT-1b. It was observed in 2008 on November 27th, 30th and December 3rd, 6th, with the only complete transit on December 3rd. We analyzed the data, but due to the faint magnitude of the star (13.6)

[3] The Image Reduction and Analysis Facility (IRAF) software is provided by the National Optical Astronomy Observatory (NOAO), which is operated by the Association of Universities for Research in Astronomy (AURA), Inc., under contract to the National Science Foundation.

and to the lack of good comparison stars in the field of view, the standard deviation of the data is greater than the order of magnitude of the transit. Even if a fit was performed and the expected transit was found, the results are not significative.

4. Conclusions

We faced the study of the CoRoT-2 system by using observations at near infrared wavelength, by obtaining results that were not as obvious as expected. Indeed, the follow–up photometric observations carried out with the REM telescope yielded us hints about possible atmospherical particularities, resulting in R_P/R_S values slightly different from those obtained at shorter wavelegth.

We are confident that the study of planetary transits in different colours can be useful to detect peculiarities which can help in the characterization of the atmospheres of extrasolar planets. This is probably true not only in the infrared, but even at optical wavelengths.

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