Highlights of Spanish Astrophysics VII, Proceedings of the X Scientific Meeting of the Spanish Astronomical Society held on July 9 - 13, 2012, in Valencia, Spain. J. C. Guirado, L.M. Lara, V. Quilis, and J. Gorgas (eds.)

Photometric follow-up of transiting exoplanets with the INTA-CAB robotic telescope

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Abstract

We present some photometric results obtained by our group as part of a photometric follow-up of transiting exoplanets carried out with the INTA-CAB 50-cm robotic telescope at Calar Alto Observatory (Almería, Spain). We show light curves of WASP-10, HATP-20 and HATP-32 and, after that, we fit our results with theoretical models in order to obtain some parameters as the central times of transits, depths and the transit durations of this extrasolar planets.

1 Introduction

Extrasolar planets (or exoplanets) have been extensively searched during the last two decades. As a result of this effort, since 1995 - when the first exoplanet was discovered by [8] -there are now more than 800 confirmed exoplanets (to date, 838 exoplanets are listed in the Extrasolar Planets Encyclopaedia (http://exoplanet.eu)). Most of the planets have been detected with the radial velocity method (using high resolution spectrographs), but other techniques are also good to detect extrasolar planets. The second most productive indirect technique of detection is the transit method . When a planet crosses (or transits) in front of its parent star, the observed brightness of the star drops by a small amount. The amount by which the star dims depends on its size and on the size of the planet, among other factors.

1.1 Transiting exoplanets

Here we show photometric results of the following transiting exoplanets:

- WASP-10b is the name of the exoplanet orbiting the parent star WASP-10. It was discovered in 2008 by [3]. It transits its host star every 3.092 days [3] and is a massive

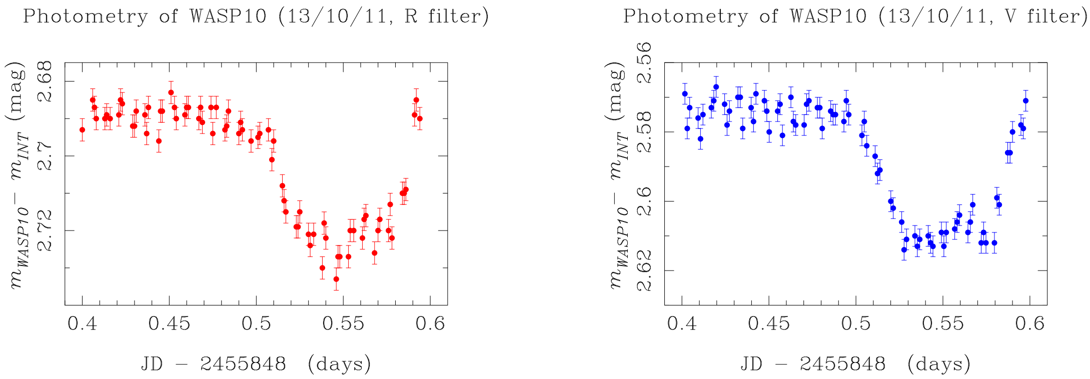

Figure 1: Transit light curves of WASP-10 observed with the INTA-CAB 50-cm robotic telescope in the *R* band (left) and the *V* filter (right) on the night of 2011 October 13. Differential magnitude is plotted versus time (Julian Day). We could observe this star before the beginning of the transit of WASP-10b.

exoplanet (~ 3 M_J). The star WASP-10 has an apparent magnitude in the *V* band of 12.7 and its spectral type is K5.

- HATP-20b is a transiting exoplanet discovered in 2010 by [2]. It orbits a moderate bright V= 11.34 dwarf star of spectral type K7 on a circular orbit, with a period of ~ 2.875 days.

- HATP-32b is an extrasolar planet discovered in 2011 by [5]. It has a period of ~ 2.15 days and orbits the star HATP-32. Its host star has an apparent magnitude in the *V* band of 11.29 and its spectral type is late-F-early-G.

2 Observations

We present some light curves obtained by the Robotic Telescopes Group of Centro de Astrobiología (placed in the campus of INTA in Torrejón de Ardoz, Madrid, Spain). These results are part of a photometric follow-up of known transiting exoplanets carried out with the 50-cm robotic telescope at Calar Alto Observatory (Almería, Spain). The telescope is a f/10 classical Cassegrain reflector with equatorial fork mounting. It is remotely operated from Madrid.

At the time the observations were done, the telescope was equipped with a 4008 x 2672 Finger Lakes Instrumentation (FLI) ProLine PL11002M Interline CCD camera. The pixel scale was 0.37 arcsec/pixel and the total field of view 24 x 16 arcmin^2. An external filter wheel allows to select up to 12 filters, five of them being the Johnson-Cousins standard system (U,B,V,R,I) for optical photometry. We present transit light curves of WASP-10,

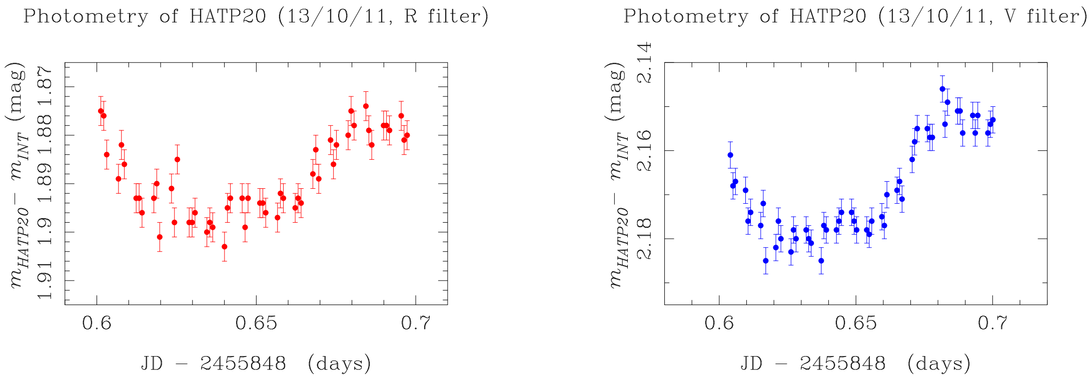

Figure 2: Transit light curves of HATP-20 observed with the INTA-CAB 50-cm robotic telescope in the R filter (left) and the V band (right) on the night of 2011 October 13. Differential magnitude is plotted versus time (Julian Day).

HATP-20 and HATP-32 taken in October 2011. The filters used were R and V in all cases. For WASP-10, exposure times were 85 s in the R filter and 95 s in the V band. In the case of HATP-20, the exposure time was 50 s for the R band and 55 s for the V filter. For HATP-32, the brightest of the three targets, only 42 s in the R filter and 46 s in the V band were taken.

3 Photometry

We used a pipeline for the automatic reduction of data consisting of two independent parts. The first one makes standard CCD corrections as well as the search of the exact solution for the WCS (done by calling Astrometry software online http://www.astrometry.net/use.html). The second part must be done separately when using images of different objects and/or filters. In this way, for each data set, the system performs the differential photometry of the target with respect to a collection of suitable comparison stars found in that set. We consider that a star is a good candidate to be a reference (comparison star) if it is close in magnitude to that of the target and it is enough constant over the whole series. More details about this can be found in [4].

In Fig. 1 we display the transit light curve of WASP-10 observed with the R and V bands on the night of 2011 October 13, whereas in Fig. 2 we show the photometric results obtained for HATP-20 using the R and V filters (also 2011 October 13). Finally, in Fig. 3 we present the transit light curve of HATP-32 in the R and V bands on the night of 2011 October 4. Differential magnitude is plotted versus time (Julian Day). In this last case we could not observe the beginning of the transit. The photometric error was estimated from the dispersion in the light curve of a comparison star (see [4] for further details). The errors obtained were 3 mmag for the transit light curves of WASP-10 and HATP-20 (R and V filters), 3 mmag for the photometric results of HATP-32 (in the R band) and 2 mmag for

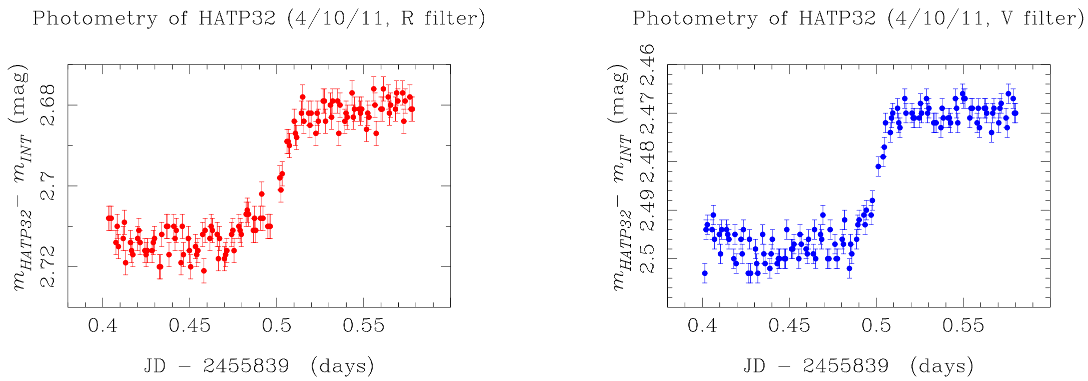

Figure 3: Transit light curves of HATP-32 observed with the INTA-CAB 50-cm robotic telescope in the R band (left) and the V filter (right) on the night of 2011 October 4. Differential magnitude is plotted versus time (Julian Day). In this case we could not observe the beginning of the transit.

HATP-32 in the V band.

4 Parameters of exoplanets

We know that photometric observations of the transit of a planet can be used to derive the orbital and physical parameters of this planet (see [11] or [12]). Thus, once we have obtained the transit light curves, we want to determine some parameters of the exoplanets observed.

[6] demonstrated in their theoretical work that short-term changes of the time of the transit can be caused by the presence of other exoplanets or moons in the system (see also [1] and [7]). Furthermore, [9] showed in their theoretical work that potential long-term changes in the duration of the transit may be the consequence of orbital precession of exoplanets. For these reasons, it is very important to obtain the parameters that we present in subsection 4.2.

4.1 Exoplanet Transit Database

We used the Exoplanet Transit Database (ETD) (see http://var2.astro.cz/ETD) to fit our photometric results. ETD is a project of the Variable Star and Exoplanet Section of the Czech Astronomical Society. We used the web-form of ETD for processing the light curves showed before.

We assumed that the planet and the star are dark and limb darkened disks, respectively, and that the planet is much smaller than the star. We modelled the planet trajectory as a straight line over the stellar disk with impact parameter

$$b = a \cos i / R_* \tag{1}$$

where a is the semimajor axis, i is the orbit inclination and R_* is the radius of the host star. For more details of the fitting procedure see [10]. Thus, a simple analytical model of the transit is used to calculate the central times of transits, depths and the transit durations.

4.2 Results

For the exoplanet WASP-10b we obtained a central time of transit (or midtransit time) of JD 2455848.5488 $\pm$ 0.0008, a duration of 134.9 $\pm$ 3.9 minutes, and a depth of transit of 0.033 $\pm$ 0.002 magnitudes. In the case of HATP-20b, the midtransit time was JD 2455848.6380 $\pm$ 0.0013, the duration of the transit 109.3 $\pm$ 4.2 minutes and the depth 0.022 $\pm$ 0.003 magnitudes. Finally, the results for the exoplanet HATP-32b were JD 2455839.445 $\pm$ 0.003 for the central time of the transit, as well as 192.3 $\pm$ 10.9 minutes and 0.029 $\pm$ 0.002 magnitudes for the duration and depth of the transit, respectively.

Acknowledgments

The authors would like to acknowledge financial support from the INTA budget for Astrobiology up to the year 2009, and the Spanish programme AYA2009–14000–C03–02 starting in 2010. We also thank Computer Staff at Calar Alto Observatory for their help when solving some problems at the observing site.

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