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Looking for planetary candidates in the *CoRoT* Long Run LRc10

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Abstract. We analysed the public data of the *CoRoT* Long Run LRc10 looking for planetary candidates. In a first step we removed outliers and trends caused by stellar activity and instrumental problems. Then we applied the Box-fitting Least Squares (BLS) algorithm to detect periodic decreases in luminosity. From all the significative transit detections, we selected the ones that passed different checks. For the 7 planetary candidates found, we applied a new "ad hoc" normalization and fitted the orbital parameters, to verify their reliability. Using the stellar temperature information, we could estimate the dimensions that the candidates should have if confirmed. Our research method demonstrated to be sensitive to candidates with hypothetic dimension up to $\sim$3.5 R_{Earth} on stars of mag V$\simeq$14.

Key words. Methods: data analysis – Techniques: photometric – Planetary systems

1. Introduction

After an irrecoverable failure occurred in early November 2012, the *CoRoT* mission (COnvection, ROtation and planetary Transits, Baglin et al. 2006) was switched off in June 2014. It left us a huge archive to explore, having completed 26 observing runs spanning 2137 days of observations. Despite the withdrawal from the Consortium operating the space mission, Italy contributed to the scientific profile of the project, ensuring the ground-based observation of the asteroseismic targets and contributed to solve several light curves of variables and stars hosting exoplanets (Poretti et al. 2007a,b, 2008; Borsa & Poretti 2011, 2012; Poretti et al. 2013).

In the context of the exoplanetary science, the transit method is the one that permits to have more information about the planet, thus transiting planets are the most interesting to study. New techniques of detrending stellar activity can increase the sensitivity to small transits (and thus small planets), bringing to the discovery of new exoplanets even on data already exploited and analysed with other detrending methods.

2. First detrending and transit search

We concentrated on the analysis of the *CoRoT* Long Run LRc10, the last observed by the satellite, whose light curves (5276 in total) became publicly available in July 2014. The

Table 1. Number of significative light curves after the different analysis steps used.

Number of LC	Steps
5276	LRc10 light curves
124	After BLS
45	Light curves with transits
7	Planetary candidates

first step in the analysis of the light curves was the removal of trends and jumps caused by stellar activity and instrumental problems. Stellar activity is one of the major problems when looking for small planetary signals both photometrically and spectroscopically, and we are working on ways to resolve these issues (Frustagli G., Laurea thesis). We first discarded any data flagged as bad by the satellite (e.g., all the data taken during the passage through the South Atlantic Anomaly). Then we normalized the whole light curve with a 2nd degree polynomial, to remove possible long term trends. After this, we divided it in 1 day intervals, normalizing each interval with a 4th degree polynomial. In this way, we could take into account for any stellar activity and remove it, reducing also the impact on the light curve of any instrumental problem. Once having the whole Long Run homogeneously normalized, we applied the Box-fitting Least Squares algorithm (BLS; Kovács et al. 2002) to each of the 5276 light curves, to detect any periodic decrease in luminosity. We set as the limits of our research periods from 1.2 days (to reduce the impact of spurious frequencies as the sidereal day, or multiples of the orbital period of the satellite) to 15 days (to limit the amount of computer time and to have a good statistics).

We found 124 light curves that passed the BLS selection, among which 45 light curves with periodic transits. Using different criteria such as the transit shape and depth, odd/even transits comparison, presence of evident secondary eclipses, we were able to further slim down the list of possible planetary candidates to 7 objects (Table 1).

3. "Ad hoc" detrending

For the most promising transit signals, we applied a new normalization, specifically dedicated to the target, knowing a priori the transit parameters. Following Borsa & Poretti (2013), we selected the parts before and after each transit, and normalized the whole transit by the fit of a 2nd degree polynomial on these two parts. After phase-folding the normalized transits, we fitted them with the software TAP (Transit Analysis Package, Gazak et al. 2012). When chromatic data were available, we fitted simultaneously the transits of the 3 different *CoRoT* colours, keeping the orbital period fixed and imposing a common solution for the other orbital parameters i (the inclination of the system with respect to the line-of-sight), a/R_s (the ratio between the semimajor-axis and the radius of the star) and t_0 (the time of mid-transit).

4. If exoplanets: orbital solutions

Taking as reference the temperature value found in the *CoRoT* FITS files, and assuming the stars being on the main sequence, we estimated a radius for the parent star of each candidate, and thus for the hypothetic planetary candidate (Fig. 1). The candidates span different transit depths around different spectral types of stars. Their dimensions would range between $\simeq$0.3 and $\simeq$1.7 R_J. Figure 2 shows as the orbit of the candidates would look like in case of planetary nature.

We were able to find planetary candidates, not publicly known before our analysis, with orbital periods ranging from $\simeq$0.7 to $\simeq$7.7 days: our analysis revealed to be sensitive also to periods outside the imposed research limits, thanks to the detection of harmonics in the frequency spectra.

5. Two interesting candidates

One of our most interesting candidates, number I, shows hints of secondary eclipse (Fig. 3). In such a case the most plausible explanation is a binary star. However, a planetary system is also possible. Indeed, due to the large depth of

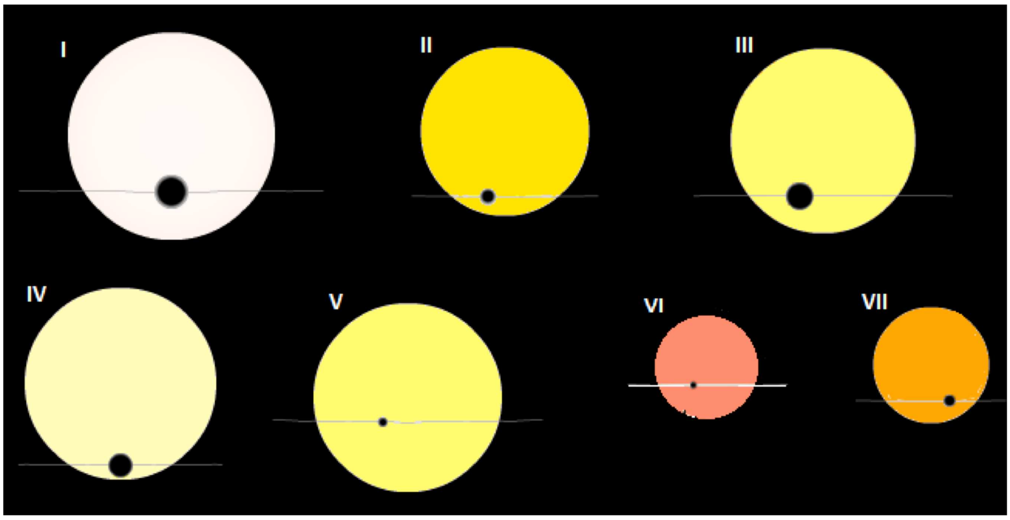

Fig. 1. If exoplanets, the dimension of the exoplanetary candidates with respect to that of their host stars.

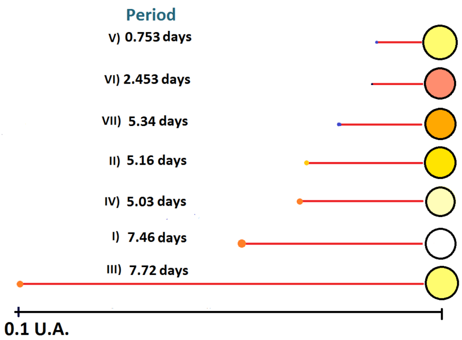

Fig. 2. If exoplanets, periods and semimajor-axis of the planetary candidates found.

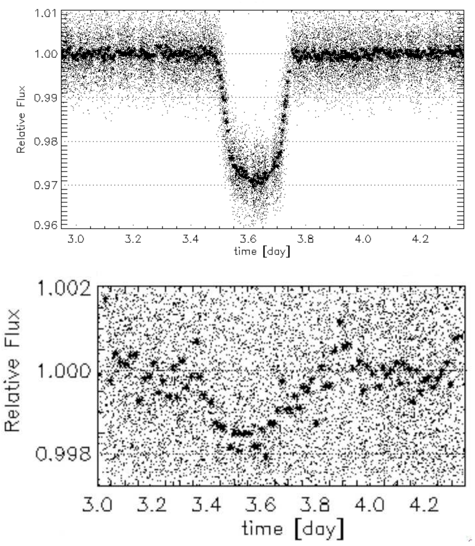

Fig. 3. *Top panel*: Primary transit of candidate number I. *Bottom panel*: Secondary eclipse of candidate number I.

the transit, the reflected light by the planet can contribute to the total flux and the occultation results in a drop of luminosity. Due to the stellar activity, it is not possible to verify the shape of the light curve outside eclipses and then put in evidence the reflection effect in function of the orbital phase.

Another interesting candidate, number III, could be analysed using the multicolour *CoRoT* photometry (Fig. 4). The light curves of the transits are a bit scattered, especially in the Blue colour. A careful analysis has to be applied, also taking into account the limb-darkening effects (Borsa & Poretti 2013). After the determination of the photometric depths, we obtained planetary radii in good agreement within error bars: $R_P/R_\star = 0.16 \pm 0.01$ in red light, 0.15 ± 0.01 in green light, and 0.16 ± 0.02

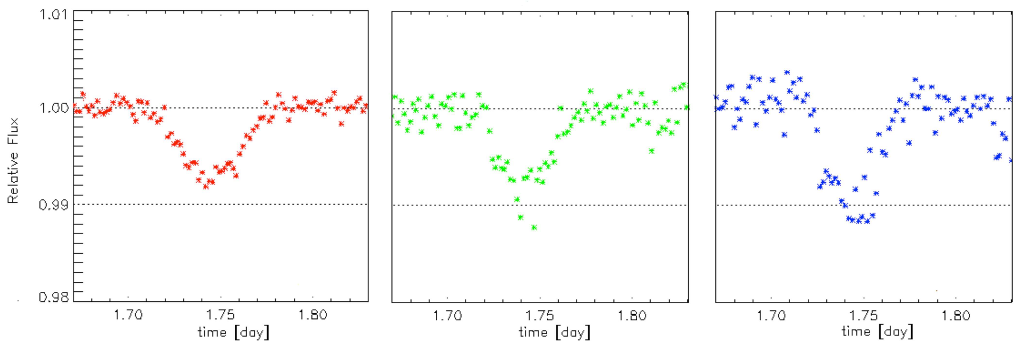

Fig. 4. Chromatic transits for candidate number III. The transit depth is compatible in all the three *CoRoT* colours.

in blue light. This result supports the possible planetary nature of the transiting body.

6. Conclusions

The analysis of the data of the *CoRoT* Long Run LRc10 resulted to be a very exciting exercise for a Bachelor thesis (Zannoni 2014). The techniques to remove outliers and trends caused by stellar activity and instrumental problems require the clever application of several procedures. From all the significative transit detections, we selected the ones that passed different checks, finding 7 planetary candidates. Our research method demonstrated to be sensitive to candidates with hypothetic dimension up to ~3.5 R_{Earth} on stars of mag V≃14. We plan to investigate by photometry and spectroscopy the 7 candidates, in order to confirm or discard their planetary nature. *CoRoT* left us a huge archive to explore: its investigation may reveal lots of still undiscovered peculiarities, from the new exoplanets to unique variable stars (e.g., Poretti, Baglin, & Weiss 2014).

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References

Baglin, A., et al. 2006, ESA Special Publication, 1306, 33
Borsa, F. & Poretti, E. 2011, Mem. SAIt Suppl., 16, 80
Borsa, F. & Poretti, E. 2012, Mem. SAIt Suppl., 20, 25
Borsa, F. & Poretti, E. 2013, MNRAS, 428, 891
Gazak, J. Z., et al. 2012, Advances in Astronomy, 697967
Kovács, G., et al. 2002, A&A, 391, 369
Poretti, E., et al. 2007a, Mem. SAIt, 78, 624
Poretti, E., et al. 2007b, Mem. SAIt Suppl., 11, 169
Poretti, E., et al. 2008, Mem. SAIt Suppl., 12, 98
Poretti, E., et al. 2013, Astrophys. Space Sci. Proc., 31, 39
Poretti, E., Baglin, A., & Weiss, W.W. 2014, ApJ, 795, L36
Zannoni, A. 2014, Bachelor degree Thesis, Università degli Studi di Milano