Formation, Detection, and Characterization of Extrasolar Habitable Planets
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Eliminating Noise at the Box-fitting Spectrum

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Abstract. Non gaussian sources of erros need to be taken into consideration when searching for planetary transits. Such phenomena are mostly caused by the impact of high energetic particles on the detector (Pinheiro da Silva *et al.* 2008). The detection efficiency of transits, therefor, depend significantly on the data quality and the algorithms utilized to deal with these errors sources. In this work we show that a modified detrend algorithm CDA (CoRoT Detrend Algorithm; Mislis *et al.* 2010) using a robust statistics and an empirical fit, instead of a polynomial one, can eliminate more efficiently gaps in the data and other long-term trends from the light-curve. Using this algorithm enables us to obtain a reconstructed light-curve with better signal-to-noise ratio that allows to improve the detection of exoplanet transits, although long term signals are destroyed. The results show that these modifications lead to an improved BLS (Box-fitting Least Squares; Kovács, Zucker & Mazeh 2002) algorithm spectrum. At the end we have compared our planetary search results with CoRoT (Convection, Rotation and planetary Transits) satellite chromatic light-curves available in the literature.

Keywords. Detrend Algorithm, Exoplanets, Photometry, Space Astrophysics

1. Introduction

The algorithms to deal with non-gaussian noise and trends appearing in light-curves are as important as the planetary transits algorithms. The light-curve gaps can be originated by many sources. In the case of CoRoT satellite data, those effects are caused mainly by the impact of high energy particles and also the failures of the detector in the form of hot or dead pixels (Rauer & Erickson 2007). The presence of stellar activity and thermal variations can also induce trends that contribute to the decrease of the detection probability and introducing false positives.

The development of algorithms that can deal with such errors is constantly progressing. In the search for extrasolar planets using the transit method, in particular, several projects to develpo such algorithms have been proposed. In the literature, we can find algorithms for filtering and correcting effects based on residual minimization (Mazeh, Tamuz & Zucker 2007, Ofir *et al.* 2010) using the quiescent reference stars (Kim *et al.* 2009), or residual minimization and signal reconstruction (Kovács & Bakos 2008), or using statistical information provided by chromatic light-curves (Mislis *et al.* 2010). However the most challenging task is to deal with sudden fluctuations caused by the impact of charged particles. These fluctuations occur due to the heating of the sensor which becomes difficult to associate a single decay function applicable to all events. The durations of these fluctuations vary with the aggravating factor implying a permanent defect or failure of the pixel (Pinheiro da Silva *et al.* 2008).

2. Detrend & Planet Search

The methodology used to detrend the CoRoT light-curves in this work is based on the CDA (CoRoT Detrend Algorithm) proposed by Mislis (2010). In this method, long-term trends are removed using a polynomial fit and a statistical search is done to locate displacements among three color channels. We introduce an improvement of this algorithm called CDAM (CDA modified). We replace the polynomial fit by a resistant moving average in order to increase the sensitivity to sudden fluctuations in the data. We also implement a more robust statistics in the algorithm.

The detection of planetary transits was done using the BLS (Box-fitting Least Squares) (Kovács, Zucker & Mazeh 2002). This algorithm aims to minimize a step function over the folded light-curve in several trial periods. The identification of transits using BLS was conducted using a semi-automated code in two steps. First, we filtered out the light-curves that did not present a transit profile based on statistical parameters obtained from the information provided by the BLS power spectrum. In the second step, we visually classified the filtered results adopting the criteria proposed by Rauer & Erickson (2007).

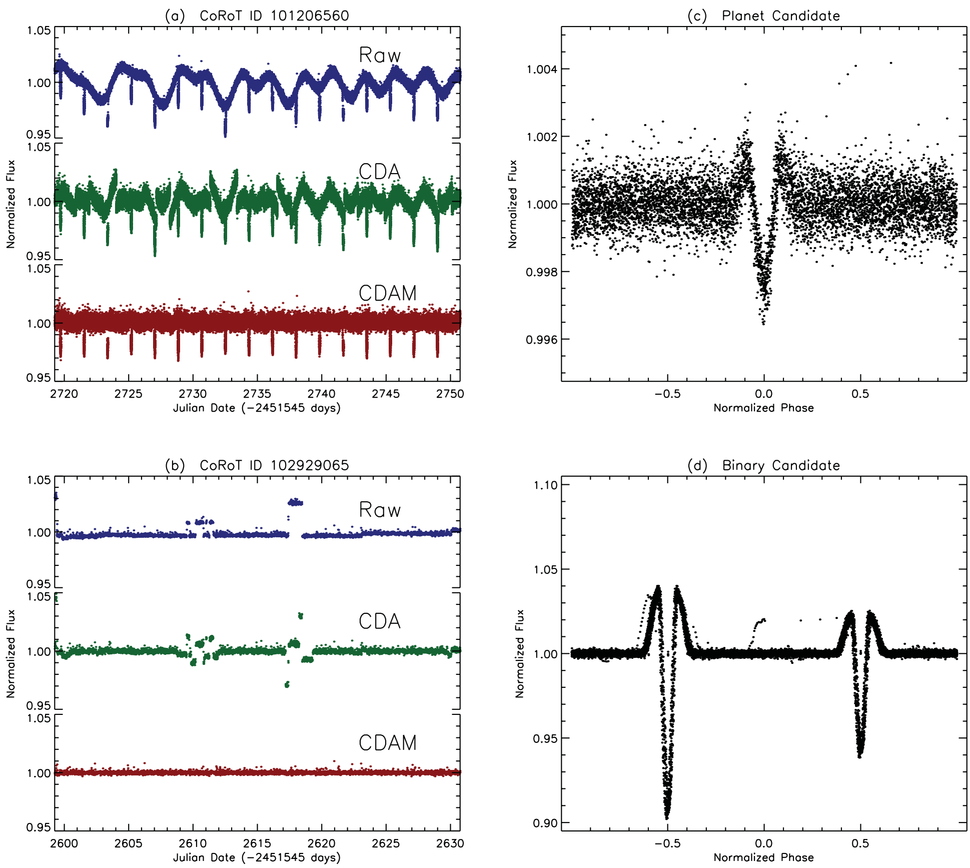

Figure 1. (a) and (b) Comparison of detrending methods. Blue data refers to original lightcurve, green to CDA method and red to our improvements (CDAM). (c) Phase folded light-curve for a new exoplanet candidate. (d) Phase folded light-curve for a new eclipsing binary candidate.

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3. Results

The implementation of CDA has significantly improved the deterending process performed on the light-curves. In Figure 1 (a) and (b) we show the efficiency of the gap-removal as well the removal of the long term stellar activity. Effectively removing stellar oscillation of the light-curves provides a cleaner periodogram returned by the search algorithm (BLS) without many of the behaviors that are not due to planetary transits or eclipsing binary stars thus improving real detections. The chart shows Corot id 0102929065 gaps which can affect the search algorithm by introducing potential false detections and trends in the power spectrum. In (c) and (d) we show the phase folded light-curve for new transiting candidates.

Our study involves the analysis of 48,406 light-curves related to the chromatic channels of the Runs IRa01, LRc01 to LRc06, LRa01 to LRa04, SRc01 to SRc02 and SRa01 to SRa03. From these results we have identified 434 transiting candidates. Compared to those published by the CoRoT team (Cabrera *et al.* 2009, Carpano *et al.* 2009, Carone *et al.* 2012, Cavarroc *et al.* 2012 & Erikson *et al.* 2012) our filtering methodology was able to identify 69% of the planets discovered by the mission. Approximately 96% of the transit signals were detected according to the literature although many planet candidates were identified as binary stars. In our final list, the number of binaries is small compared to the literature due to distortions introduced by detrend algorithm in the shape of the transit and consequently rejected by the filtering method of pre-candidates.

Despite the good results with the detrend algorithm, our greatest achievement was the compilation of a list of 238 new candidates for the not published public runs. For the other 196 candidates, 96% of transits are found in the literature and two new discoveries were made. It is important to mention that we use one single search method so we can not compare results to improve the detection of false positives as the standard procedure of the CoRoT team.

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