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The Transit Detection Algorithm DST and its application to CoRoT and Kepler data

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Abstract

Transit detection algorithms are mathematical tools used to detect the presence of planets in the photometric data of transit surveys. Space missions are exploring the parameter space of transit surveys towards small planets where classical algorithms do not perform optimally, either due to the low signal to noise ratio of the signal or to its non-periodic characteristics. We present an algorithm addressing these challenges and its performance in an application to CoRoT and Kepler data.

1. Introduction

The generally accepted characteristics of the transit of a planet are a short, small, periodic decrease of the (assumed) constant luminosity flux of the star caused by passage of the opaque planet in front of the stellar disk, as seen from the point of view of the observer. Transits are short because the duration of a transit is roughly proportional to the ratio of the radius of the star over the semi-major axis of the orbit of the planet [13]. This means that even for the shortest known period exoplanets orbiting at 3 or 4 stellar radii, such as 55 Cnc e [14], WASP-19b [6], WASP-43b [8], Kepler-10b [3], CoRoT-7b [11], or WASP-18b [7] the duration is smaller than one tenth of the orbital period.

The arrival of the space-based surveys of exoplanets such as CoRoT [1] and Kepler [2] has placed transit surveys in the region of the parameter space were transits are not short, in terms of hours, any more. For example, the transit of CoRoT-9b lasts 8h [5]. In parallel, the detected signals are not small neither. In this case there are two tendencies, on the one hand towards really shallow transits, such as those of the terrestrial planets 55 Cnc e, CoRoT-7b or Kepler-10b, but on the other hand towards transits of small planets around small stars, which makes possible the detection of Earth-sized planets from ground, such as the case of GJ-1214b [4] . Finally there are detections of transits which are not periodic any more. The transit timing variations of Kepler-9c [9] reach an amplitude of 140 minutes, comparable with the length of the transit, in a time span of 200 days.

We present a new detection algorithm, called DST (*Détection Spécialisée de Transits*) addressing some of the challenges that face current and future (PLATO) transit surveys. This algorithm aims at a specialized detection of transits by improving the consideration of the transit shape and the presence of transit timing variations.

2. The Transit search algorithm

A light curve is a time series of the photometric observations of a star. Mathematically, it can be seen as a collection of pairs time-flux and coded as a function. We can define a model to the transit using a function with constant value out of transit and a parabola-shape to describe the occultation (in comparison to a box-shaped model like BLS [10]). To detect the presence of a periodic transit like feature, we use the test statistic defined by [12].

3. Application to Kepler and CoRoT data

We have compared the performance of this model and its detection statistic with the widely used algorithm BLS and we have proved that it improves the transit detection capacity. The significant reduction of the fit residuals improves the test statistics for the detection of giant and dwarf planets. Figure 1 illustrates the improvement in the detection efficiency in the case of the terrestrial planet CoRoT-7b.

We have also analyzed Kepler public data with our algorithm finding some planetary candidates not published before.

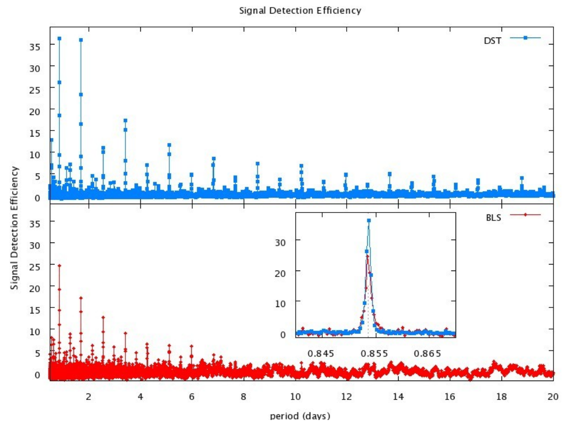

Figure 1: Value of the Signal Detection Effiency (SDE) of BLS and DST for the light curve of CoRoT-7b. The enclosed figure shows in detail the region around the measured orbital period of this planet, indicated by a vertical line.

4. Summary and Conclusions

We have described a new algorithm for transit detection using an analytic model for the shape of a transit and providing an improved detection statistic. We have compared the performance of the new transit detection technique, DST, with that of a widely used technique: the BLS algorithm and we have analyzed representative test cases of planet detection in the CoRoT and Kepler data set. We have concluded that DST produces a better Signal Detection Effciency than BLS due to the improved description of the transit signal and to the improved definition of the test statistics in all the relevant cases for transit surveys: terrestrial planets, giant planets, and eclipsing binaries. This algorithm presents other advantages, such as the flexibility of the definition of the region in transit, with their implications for the search for planets experiencing significant transit timing variations and transiting multiple planet systems

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