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The False Positive probability of *CoRoT* and *Kepler* planetary candidates.

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Abstract

We estimate the False Positive Probability of *CoRoT* and *Kepler* planetary candidates, and review critically previous results present in the literature. The obtained estimates are compared with the results from the ground-based radial velocity follow-up carried out with the HARPS and SOPHIE spectrographs for these two space missions.

1. Introduction

The *CoRoT* and *Kepler* space missions are dedicated to finding transit-like events caused by extrasolar planets in orbits aligned with the line of sight from Earth. Hundreds of such events have been detected by these missions, thanks to the high-precision of their photometry as well as to the long continuous baseline of their observations, which is only possible from space.

Out of all detections, only a small fraction are actually produced by planetary objects. The rest are in fact astrophysical objects, mimicking a planetary transit to a high degree of precision. Some of these false positives can be promptly discarded by detailed analysis of the light curve that permitted their detection. However, this screening process is not completely efficient, and among the planetary candidates that have passed all these tests, there remains an unknown number of false positives. The fraction of filtered candidates that are produced by systems other than transiting planets is called the False Positive Probability (FPP).

The fact that the FPP is in general non-zero is the reason why ground-based radial velocity (RV) follow-up is a crucial step in identifying planetary objects. Only by a precise measurement of the mass of the transiting object and a thorough analysis of the stellar line profile can we conclude on its nature unambiguously. However, if the FPP is reliably estimated to be small enough, the use of planet *candidates* to perform statistical studies of planetary characteristics may be justified, similarly to what is done for planet candidates detected from RV surveys, a fraction of which are in actuality low-mass objects in low-inclination orbits.

Therefore, since the rapidly-growing number of transiting planet candidates makes it increasingly difficult to confirm each one individually by means of RV measurements, a precise and reliable estimation of the FPP is of great importance to obtain the greatest scientific return from the data acquired by *CoRoT* and *Kepler*, as well as to fully exploit the data that will be obtained from future missions, like PLATO.

2. The False Positives

Some of the most common astrophysical systems that can mimic planetary transits are grazing eclipsing binaries, low-mass stellar objects, and blended stellar systems.

Grazing eclipsing binaries can usually be discarded easily by means of light curve analysis, since they produce a characteristic V-shaped transit. This type of False Positive is easily identified in RV follow-up campaigns, since they produce a large amplitude signal. Similarly, low-mass stars also produce a large RV signal easily identifiable.

On the other hand, the most common impostors are usually eclipsing binary stars blended by a brighter star, either physically bound to the pair or aligned with our line of sight by chance. These are also the harder systems to identify using follow-up observations, since they can produce a variety of signals, from no variation at all to very large amplitudes. This kind of astrophysical false positives is one of the main concerns for *CoRoT* follow-up (Almenara et al. 2009), due to the large size of the photometric mask used to obtained the light curves. Strong efforts are being devoted to develop methods to identify these objects from RV and photometric data (Moutou et al. 2011, in prep).

3. The *CoRoT* and *Kepler* FPP

Previous estimations or measurements of the FPP of the *CoRoT* and *Kepler* space missions exist in the literature. Almenara et al. (2009) analyse the first three extended runs of *CoRoT* observations, and report that 83 % of the initial targets detected are discarded by analysis of the discovery light curve alone. Additionally, of the remaining 17%, about 40% was resolved by ground-based follow-up observations, and of those, little more than 10% turn out to be actual planets. This means that the *CoRoT* FPP as estimated from the initial runs of the mission is about 90%. About half of the followed-up candidates turn out to be eclipsing binaries diluted by the light of a third star. This is mainly due to the large *CoRoT* PSF and mask used to perform the onboard aperture photometry.

A similar analysis done for *Kepler* based on very preliminary results from the follow-up programme estimate an FPP in the range from 40% to 76% (Gautier et al. 2010). Other estimations range from below 2% to around 30%, depending on the "quality" of the candidate (Borucki et al. 2011).

A more detailed estimation of the FPP expected for this mission has been recently published by Morton & Johnson (2011), based on Galactic population models and a series of assumptions about the efficiency for discarding false positives from *Kepler* photometry alone. Since the Kepler mission employs the novel method of analysing the stellar flux centroid during transit events to drastically reduce the sky area in which the blended binary system could reside, the probability of a blended stellar system being at the base of the observed photometric variability is reduced drastically. Thus, the false positive probability (FPP) has been estimated to be under 10 % for all range of transit depths.

However, the *CoRoT* FPP estimated using the same method, is below 30% (Morton & Johnson 2011), which is in clear disagreement with the observed FPP, even if only diluted binaries are considered.

4. Ground-based RV follow-up

The required RV follow-up for the *CoRoT* mission is mainly performed using the HARPS spectrograph at La Silla observatory, in Chile, and the SOPHIE spectrograph, at the Observatoire de Haute-Provence, in France. These two key facilities have been employed since the beginning of the *CoRoT* mission and the data acquired can therefore be promptly exploited to study the fraction and nature of the False Positives observed by *CoRoT*.

Recently, a large programme to follow-up the publicly available *Kepler* planet candidates with SOPHIE has been started (see Santerne et al., this volume). These data allow to produce for the first time a measurement of the *Kepler* FPP based on RV follow-up. As such, it should be able provide a direct comparison with the FPP estimated from "first principles".

5. Method

We analyse critically the assumptions used in previous estimations of the *Kepler* FPP, and show how they might bias the result, if incorrect. Then we test the Morton and Johnson hypotheses and final estimations using the results obtained from the SOPHIE RV follow-up. To do this, we consider the biases produced by the target selection and instrument precision.

The larger database obtained throughout years of *CoRoT* follow-up allows us to fine tune the method employed to estimate the FPP, so that it agrees with the observed values. This improved method is then used to produce a more reliable estimation of the *Kepler* False Positive probability, as well as a first preliminary computation of the FPP expected for PLATO.

6. Results

We find that some of assumptions used in the previous *Kepler* FPP estimation are not compatible with the observed data. For example, the assumption that no undiluted binaries escape the filtering process is false, since a number of this kind of false positives has been identified with SOPHIE. This fact certainly increases the *Kepler* FPP.

Additionally, using the first months of SOPHIE RV follow-up, we estimate the *Kepler* FPP from observations. Finally, we use the *CoRoT* follow-up database to calibrate our estimation of the FPP for this mission, which is then applied to *Kepler* and PLATO.

References

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