

# SCIENTIFIC PERFORMANCES FOR THE EXOPLANET CHANNEL

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## ABSTRACT

The performance of CoRoT in the detection of planetary transits was estimated using different approaches, from simple modeling to more elaborate tests in which detection is performed in “realistic” conditions. Some emphasis is placed on the tests made on synthetic light-curves accounting for instrumental noises, expected “stellar noises” due to stellar variability and various types of ambiguities due for example to eclipsing binaries. These tests were performed within the CoRoT community, by the various teams working on transit detection. Two collective exercises were organized, with a twofold aim: (i) to test CoRoT’s capability to detect and identify planetary transits when placed in realistic conditions, (ii) to acustom the different teams to work in common and be prepared to a collaborative analysis of the true CoRoT data. The impact of the chromatic device is also discussed, and it is checked that in a number of cases, splitting the photometric aperture into three channels helps the discrimination of background eclipsing binaries.

## 1. INTRODUCTION

CoRoT will produce a large number of light-curves with a 8.5 mn time resolution, over 150 days for the long runs and 20-40 days for the short runs. These light curves will be the first ones obtained from space with a noise level much lower than if obtained from the ground. They will be also free from the disturbing night/day interruptions. The capacity to detect planetary transits in star light-curves depends: (i) on the level of instrumental noise (as

for example residual of the correction of jitter and breathing); (ii) on the variability of the target and the background; (iii) on the quality of the filtering and detrending processes; (iv) on the performance of the detection algorithms. The scientific performance does not only depend on the detection capability but also on the capacity to characterize at best the detected events and to discriminate true planetary transits from a number of ambiguities: eclipsing binaries or features due to the stellar variability. This paper presents various attempts to assess the capacity of CoRoT to identify in the light curves the signature of true planetary transits.

When analysing a light curve, the transit of a planet in front of the disk of its parent star may be confused with the eclipse of stars in a binary system. However, the two events can be distinguished in a number of cases. Indeed, for eclipsing binaries, the shape and depth of the eclipses depend on the size (and spectral type) of the two companions: (i) eclipses have a V shape when the stars are nearly identical with a grazing incidence (e.g.) (Borucki et al., 2001); (ii) successive eclipses have different depths when the two stars are not identical; (iii) stellar eclipses generally have a longer duration than planetary transits.

Thus, transit reconstruction will be a crucial tool to help discriminate eclipsing binaries from transiting planets. Such a discrimination will be much more difficult for the low S/N candidates and will require complementary observations. The problem can be tricky when a partly overlapping background star is an eclipsing binary of identical components or features only primary transits because the companion is too faint. The situation can mimic a planetary transit on the target (foreground) star. In this case

a color discrimination could be tried for the brighter stars. Indeed, only if the superposition of both PSFs is almost perfect, spurious transits due to the background star should not be present in the three colors. For every target with a planet candidate, ground-based complementary observations would have to be conducted as well (see M. Deleuil et al., this book) to determine at best the planet parameters.

## 2. FIRST ESTIMATES

The non ambiguous detection of photometric variations of the order of  $10^{-4}$  requires a large number of photons. Identifying a series of transits is less demanding, since it is sufficient that the small decrease of the flux during a transit be larger than  $k$  time the rms of the noise. In the case of only one or two transits during a full observation run of 150 days, a value  $k = 6$  can be convenient. However, when the transit number is larger than 3, the periodic nature of the event allows to reduce the requirement on the value of  $k$ . For example, with 6 successive transits, individual detections at  $2.5\sigma$  can be sufficient. The signal corresponding to a transit with depth  $\Delta F/F$ , duration  $\Delta t$  on a star flux equal to  $N_e$  is  $S = N_e \Delta t (\Delta F/F)$ , with an associated photon noise equal to  $(N_e * \Delta t)^{0.5}$ . In the case of CoRoT the detection of a transit with a good confidence level ( $S/N \geq k$ ), neglecting limb darkening effect and assuming a zero impact parameter ( $p=0$ ), is possible when the magnitude of the star  $m_V$  is less than:

$$13.6 + 5 \log \frac{(\Delta F/F)}{2 \cdot 10^{-4}} - 5 \log \left( \frac{k}{3} \right) + 2.5 \log \left( \frac{\Delta t}{10} \right) + 2.5 \log C$$

where  $C$  is the change in  $N_e$  as a function of the color, for a given magnitude (the transit duration  $\Delta t$  is expressed in hours). For a given transit event the above relation provides the limiting magnitude for the possible detection of the event. For a given spectral type, the number of detectable transits is:

$$N_{tr} = 0.78 N_{10} \left( \frac{D_{max}}{10 pc} \right)^3 Pr \frac{\Delta \Omega}{4p}$$

The maximum distance,  $D_{max}$ , is a function of the apparent magnitude and of the reddening.  $N_{10}$  is the number of stars of this spectral type and contained in a sphere of a radius 10pc (Scalo, 1984) centered on the Sun.  $Pr$  is the probability that the orbital plane of the planet be correctly oriented and  $\Delta \omega$  is the solid angle of the field of view containing the target stars. The numerical factor 0.78 comes from the limb darkening (assumed to be that of the Sun) and also from the sum over the possible impact parameters.

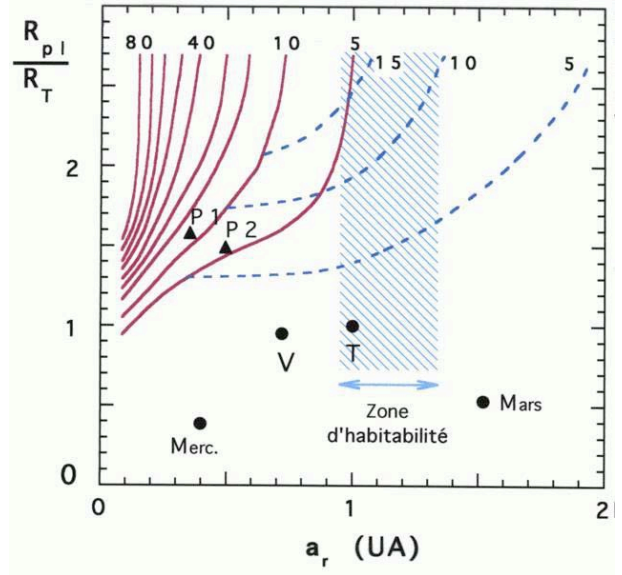


Figure 1. Absolute upper limits on the number of planets detectable by CoRoT, assuming photon-noise only, and that 20% of the stars have a planet with radius  $R_p$  located at a distance normalized to  $a_r$  (i.e. the distance normalized in term of the parent star luminosity -see text). Full lines correspond to a requirement of a minimum of three transit during the 150 days period. Dashed lines assume that single transit events are also detectable with the same  $S/N$  threshold. The positions of the terrestrial planets of the solar system and the planets of the pulsar PSR 1257 + 12 are indicated as dots and triangles, respectively. The hatched area corresponds to the habitable zone of the star.

Figure 1 gives the number of detections expected during the nominal duration of the mission (2.5 years), assuming that each star has a probability of 20% to have a planet with radius  $R_P$  located at a distance from the star that is normalized, in term of the parent star luminosity, to  $a_r = a(L_*/L_\odot)^{0.5}$ . With such a normalization the black body temperature of the planet no more depends on the planet's parent star, what is very convenient when discussing habitability. If each star has several planets, these numbers must be summed up. The figure gives, in the star-distance/planet-radius plane, the location where terrestrial planets can be detected. The planet temperature will be considered the relevant parameter (the distance from the star to the planet directly ensues from the luminosity) since it is clearly related to physical constraints such as the sublimation of material.

### 3. THEORETICAL EXPECTATIONS

A statistical estimate of the expected number of planets that CoRoT will detect has been further performed by Bordé et al., (2003), using models of the stellar populations of the galaxy developed at Besançon Observatory (Robin & Crézé, 1986). The detection capability is estimated taking into account the effect of crowding and of stellar variability. We refer to the paper for details; only the conclusions are repeated here. Bordé et al., (2003) used realistic distributions of stars as a function of their visual magnitude  $V$  and their spectral type  $Sp$  in a  $3.5^\circ \times 2^\circ$  target field, centered in the direction of the galactic Anticenter ( $l_{II} = 210^\circ$ ,  $b_{II} = 0^\circ$ ). It contains  $\approx 16\,000$  dwarfs with magnitudes between 11 and 16.5, and spectral types between B0 and M5. The number of dwarfs as a function of  $V$  roughly follows a geometric progression with a ratio of 2.0-2.5 and the whole sample peaks at spectral types F5-G0. The statistical estimate is based on the assumption that every dwarfs in the synthetic field are orbited by one planet.

The detection method used by Bordé et al., (2003) is a simple cross-correlation procedure, similar to the matched filter approach of Jenkins et al. (1996) and applied after a preprocessing of the data to remove the irrelevant long terms stellar variations. The number of the detected planets depends on the radii and (reduced) orbital distances of these planets, on the system inclination, on the magnitude and spectral type of their parent stars and on the probability that at least three transits can be observed during a 150-day run. The computations are performed assuming that all the detectable planets have the same radius  $R_P$  and are positioned at the same reduced orbital distance  $a_r$ .

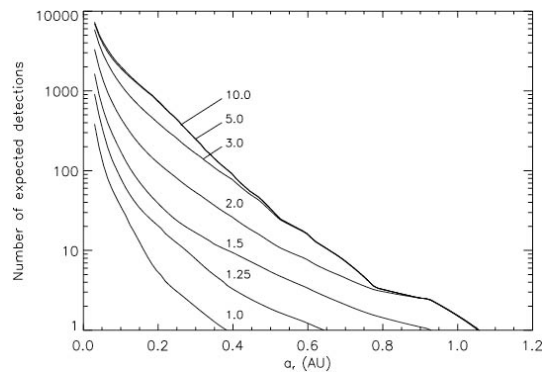


Figure 2. Absolute upper limits on the number of expected detections for a 2.5yr CoRoT mission as a function of the reduced orbital distance for various planetary radii (expressed in unit of the Earth radius). It is assumed that each star has one planet of the labelled radius positioned at the considered distance. The ripples appearing for high  $a_r$  are an effect of the finite size of the spectral type bins, and of the requirement on a minimum of 3 transits.

The results show that terrestrial planets (with radius 1-2  $R_\oplus$ ) are within reach of CoRoT provided their effective temperatures are  $\geq 500$  K (see figures 2 and 3). Besides, we can tell from the almost superimposed 5 and 10  $R_\oplus$  curves that CoRoT reaches its full discovery potential as soon as  $R_P \geq 5 R_\oplus$ .

With respect to the spectral type, we found that a detection peak shifts progressively from M2 to K2 for terrestrial planets ( $R_P \leq 2 R_\oplus$ ), then to G2 for Uranus-class objects ( $R_P \simeq 3 R_\oplus$ ) and F7-G2 for giant planets ( $R_P \geq 3 R_\oplus$ ). This can be attributed to the properties of the stellar sample itself that peaks around F5-G0. The detection histograms against magnitude show a general shape that strongly reflects that of the original stellar distribution. As one goes deeper in magnitude, the number of detections keeps increasing, because on one hand there are more stars, and on the other hand the detected planets are essentially hot objects frequently transiting in front of their parent stars.

Therefore, from this theoretical approach of the detection performance, we conclude that CoRoT targets should primarily be chosen among dwarfs later than F2 and with magnitudes up to 16.5. Besides, the effect of a high stellar variability and of crowding in a field of view has been also investigated. It is found that a strong stellar variability may have significant consequences on the integrated number of detections. In the case of the terrestrial planets, this number: (i) is reduced by a factor 3-4 if the stellar variability is 10 times larger than that of the Sun; (ii) vanishes if the stellar variability is 50 times larger (terrestrial planets become out of reach). A proper combination of the coloured channels should help to remove part of this noise and, consequently, are expected to improve the detected planet score.

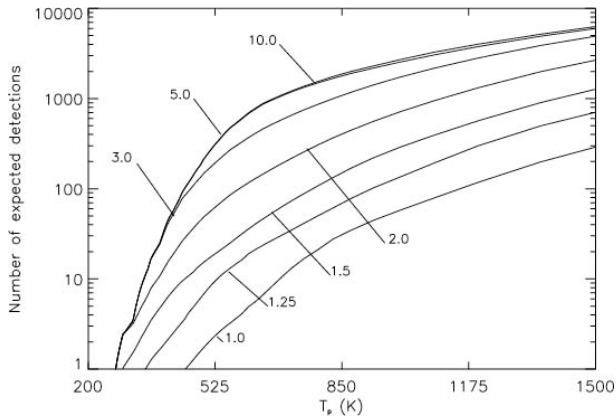


Figure 3. Same as fig. 2 but the upper limits on the number of expected planets is expressed as a function of planet effective temperature (expressed in unit of the Earth radius). It is assumed that each star have one planet of the labelled radius with the considered effective temperature.

Inside the mask of a given target, a part of the flux (expected to be small) will come from background stars or from polluting stars, some of which can be variable. This will add to the photometric measurements an extra noise with a time dependence which is similar to the target star variability. This extra variability noise has been mimicked using the stellar densities of the Besancon model and the variability of stars scaled from the measurements of the Geneva group and the Hipparcos mission (Grenon, 1993; Eyer & Grenon, 1997). These simple estimates show that the extra variability induced by the background stars is a systematic effect that causes a loss of  $\simeq 10\%$  of the detections.

With these theoretical estimations, it is shown that CoRoT should have the capacity to detect numerous exoplanets, not only Jupiter and Uranus-class ones, but also hot terrestrial planets, if they exist. Hot terrestrial planets should be mainly gathered around 14-15th magnitude K2-M2 stars, Uranus-class planets around 15th magnitude G2 stars and giant ones around 15-16th magnitude F7-G2 stars. The number of detections increases with the magnitude of the parent star up to  $V=16$ , reflecting the original stellar distribution. However, only hot and frequently transiting planets may be found around faint stars.

These historically early theoretical estimates have thus provided a first basis on which to estimate upper limits on the CoRoT detection efficiency. However, we want to stress they must not be considered as predictions of the CoRoT detection efficiency. Indeed, they do include only photon

noise but not instrumental noises and the effect of crowding and confusion by background eclipsing binaries. This is the reason for the more realistic approach presented below.

#### 4. TESTS IN “REALISTIC” CONDITIONS

In complement to the theoretical approach, the Exoplanet Group hence decided to perform a series of blind detection tests. The first exercise (BT1 hereafter) aimed at a comparison of light-curve analysis methods, performed in realistic conditions of noise and signal, in order to assess the detection performance. A detailed description of BT1 is reported in Moutou et al., (2005). A second exercise (BT2) tested the ability to characterize detected transits and to discriminate transiting planets from eclipsing binaries, using detailed analysis and three-color information.

##### 4.1. Light curve simulation

Simulated CoRoT data were first produced using an end-to-end instrument simulator and reducing the level of noise in an appropriate way to account for the first order correction that will be made in the CoRoT pipeline. Then, synthetic light curves were built from these data by combining others components: modeled stellar micro-variability and astrophysical signals (from a transiting planet, an eclipsing binary or a variable star).

- Instrumental noises

The instrument model (Auvergne et al., , 2003) includes: (i) environmental perturbations, such as light scattered by the Earth, radiation flux, Attitude Control System, jitter and temperature variations, (ii) instrumental noises such as photon noise, flat-field noise, read-out noise, zodiacal light. The exposures corresponding to the crossing of the South-Atlantic anomaly are not usable, so that the final data contains a large number of quasi-periodic gaps (typical duration of 30 min each interval of 1.7 h) that should be handled by the detection algorithms (see Fig. 4). The contribution of the scattered light was partially corrected; it represents the dominant systematic effect in the CoRoT instrumental noise and, consequently, we have deliberately chosen a conservative value for its level of correction.

- Astrophysical signals

The characteristics of the signals included in the light curves were chosen to cover most possible combinations rather than to reproduce the expected

characteristics of real samples. To simulate the contribution of astrophysical events able to mimic planetary transits, we inserted grazing binaries, background binaries or variable stars. The later refer to fainter objects included in the same aperture, 3 to 7 mag fainter than the main target. In the case of grazing eclipses, the binary star is the main target itself. The algorithms of Mandol & Agol (2002) and Wichmann (1998) are used to simulate the light curves of eclipsing binaries. Finally, planet transits were simulated, with the idea to test limitations and to explore the borders of detectability. The planet size spans the range from  $1.6 R_{\oplus}$  to  $1.3$  Jupiter radius. The period domain is from 4 days to 90 days. Target stars with planetary transits are chosen at “directed” random, with the aim of exploring the regions near the limit of detectability. The transit light curves are simulated with the aid of the Universal Transit Modeler (Deeg, 1999), including a realistic treatment of the limb darkening of stars (Barban et al., 2003).

- BT1

For the first blind test we simulated only white band light-curves and the appropriate photometric mask was selected from the magnitude and temperature of the target. The time sampling of the simulated light curves is 8.5 min, on a duration of 150 days, as will be the case for the CoRoT long observing runs. Flux variations due to the stellar micro-variability are simulated using two independent models, described in Lanza et al. (2003, 2004) and in (Aigrain & Irwin, 2004); see also Moutou et al., (2005) for more specific applications to the case of CoRoT BT1. The effects of star variability are usually thought to be strong limitations for transit detection. As end products of our simulations, we used 55 different light curves, scaled and resampled to avoid excessive similarity between the light curves. The final sample of light curves for BT1 contained a thousand of elements composed as described above for a sample of stars that resembles the stellar population of CoRoT fields. In total, 964 light curves do not contain any signal due to a transiting planet or an EB/variable star. The package of BT1 light curves were supplied to the detection teams with information neither on their content nor on the way they were calculated, whether the number of hidden planets or the nature of injected noise sources.

- BT2

For the second blind tests exercise the light curves were produced in the same way as in BT1 but for the three CoRoT coloured bandpasses. Photometric apertures were divided into three parts, according to the specifications of the exoplanet program. It was also necessary to include the chromaticity of the stellar micro-variability, with an impact that changes according to the spectral types. The package of the BT2 exercise contained 237 light-curves in the red,

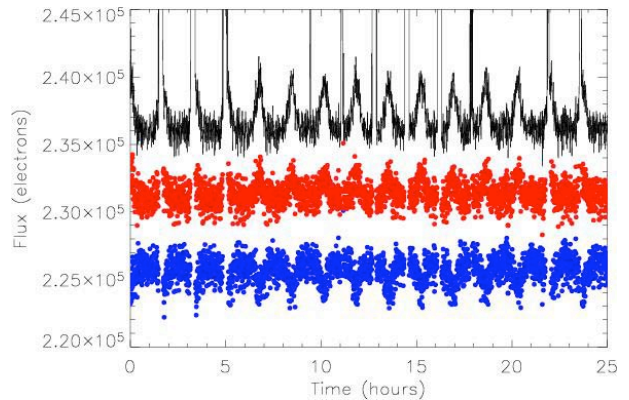


Figure 4. Example of an instrumental light curve before (top) and after the partial correction of scattered light (once underestimated (middle), and once overestimated (bottom)). The sharp peaks in the upper plot are due to the SAA crossing; they become gaps in the output light curves.

green, blue channels of CoRoT. All of them include an astrophysical event which is either a planetary transit or a star eclipse; they were supplied to the various analysis teams with prior knowledge of the star, such as magnitude and spectral type. This knowledge is not fundamental for transit detection but can obviously help in the identification and characterization of the detected events. For BT2, background eclipsing binaries were simulated with a distance and magnitude difference to the target stars that reflects the actual content of a typical CoRoT PSF. The spatial separation of the three-color photometric apertures is thus tested as a discrimination tool between planetary transits occurring on the target, and star eclipses occurring in a nearby star (within typically  $10''$ ). The chromaticity difference between features of the stellar activity and true planetary transits can be also tested as a tool to remove possible ambiguities.

## 4.2. Detection performance

Conducted in 2004, the BT1 detection exercise allowed to draw the following conclusions:

- Different transit detection methods were tested, ranging from ad-hoc procedures built from scratch to seasoned algorithms used in existing ground-based surveys (OGLE and BEST) and for future space missions (CoRoT and Kepler). Together, they offered a global view of the most possible approaches to light curve detrending and transit detection algorithms. The results show that specialised algorithms can detect transit signals down to the noise limit. It turned out also that rather simple procedures can identify most detectable transit signals, but

that the additional effort necessary to develop refined detection algorithms is really worthwhile to recover the shallower detectable transits (potentially the most interesting events).

- The most sensitive analysis was performed with periodic box-shaped detection filters. The BT1 thus confirms that the Box-Least-Square algorithm is more sensitive to faint transits, a result which also appears in the theoretical comparison performed by Tingley (2003). It is also interesting to note that the detection algorithm alone does not make all the difference. The way the light curves are filtered and detrended beforehand also has a strong impact on the detection limit and on the false alarm rate.
- The microvariability of sun-like stars seems to be a limiting factor only in extreme cases, when the fluctuation amplitudes are large and the star is faint. It is found that, in the majority of cases, the variability of star does not prevent the detection of planetary transits.
- The generation of false positives seems to be method-dependent, what is good news for removing them from the future lists of the CoRoT transit candidates.
- Background eclipsing binaries were wrongly identified as planetary transits in most simulated CoRoT white light-curves; this result confirms that contamination by background stars is the main limiting factor (this result motivated the second blind test based on colored light-curves and focusing on discrimination/characterization).

Figure 5 shows the results against the main parameters that affect detection sensitivity: transit depth  $d$  and transit number  $n$ . The non-detected events are all situated below the empirical detection curve  $d \simeq 2 \cdot 10^{-3} n^{-1/2}$ , except in one peculiar case. This empirical “law” may overestimate the minimum detected size when the number of transits is small. It also does not account for the detrending of systematics, which may have an unpredictable impact on the detection. The detection capability of CoRoT derived from BT1 summarizes in minimum radii of detected planets, as in Table 1. It appears that a 3-day  $1.1 R_{\oplus}$  planet around an M0 dwarf star would probably be detected.

As expected, the “realistic approach” derived a performance which is lower than the theoretical estimates presented in sections 2 and 3. It may be that we considered too conservative levels of noise corrections in the detection test, so that the smallest planets get undetectable. It is, however, more likely that including some systematics in the residual instrumental noise simulated a detection exercise closer to reality compared to previous ideal conditions. The detection and characterization of “hot Uranus” is not

Table 1. Minimum planet radius for F0V, G0V, K0V, and M0V stars in unit of Earth radius, corresponding to the empirical detection curve estimated by the blind test, which possibly overestimates the minimal radius of the detected planets at the longest periods. The star radii are 1.5, 1.1, 0.85, and 0.6 solar radius, respectively (Allen, 2000).

Period	F0V	G0V	K0V	M0V
50-day	5.6	4.0	3.2	2.2
10-day	3.75	2.75	2.1	1.5
3-day	2.8	2.0	1.6	1.1

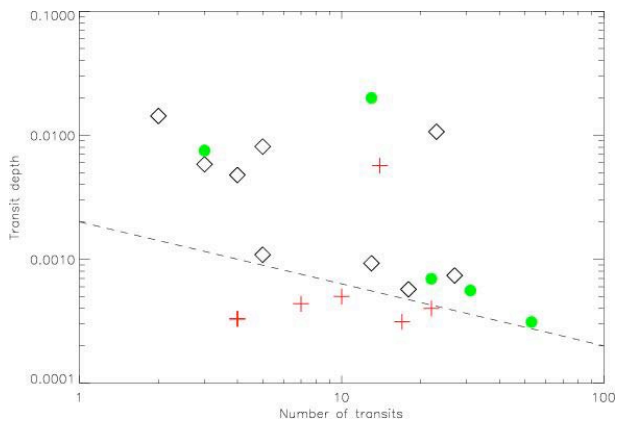


Figure 5. Transit depth versus transit number in the CoRoT BT1. Plus signs indicate the non-detected events, diamonds show the events detected independently by five different groups and filled circles correspond to 1 to 4 detection occurrences. The dashed line thus shows the border of the simulated CoRoT detection limit (proportional to  $n^{-1/2}$ ). The only plus sign above the detection line is a grazing planet on a faint fluctuating star.

put into question and still remains the main goal of the CoRoT mission.

### 4.3. Discrimination tests

The main goal of BT2 was to test the characterization and discrimination capacities of the algorithms developed by the various teams of the CoRoT community. To this end all the light curves in the BT2 contained a photometric event due either to an eclipsing binary or to a transiting planet. Three types of eclipsing binaries are contaminating the planetary transit sample: grazing eclipsing binaries, binaries with a small-radius secondary (Pont et al., 2005, 2006), and any eclipsing binary on a nearby faint star. Preliminary results of BT2 were obtained by several teams and presented at CW10, and the exercise is still in progress for more definitive conclusions. The shape of the light curve, the transit duration, the presence of a secondary eclipse and the independent detection of the events in the three spectral channels of CoRoT have been used. In one third of the simulated light curves, the colour information successfully discriminated a background binary. In 50% of the cases, the detection of the secondary eclipse with significant difference in depth proved very efficient in pointing towards binaries. About 25% of the transit events were however detected with a periodicity which is a factor of 2 uncorrect. This is caused by secondary eclipses which have a similar depth than primaries. Such cases will be only resolved by mass determination through radial-velocity follow-up observations.

The BT2 exercise also offers the opportunity to disconnect detrending processes and detection algorithms. The intermediate filtered light curves were shared among the teams in this goal, which will help optimizing the detection chain for real CoRoT data. From preliminary results of the BT2, the CoRoT colours thus seem to be significantly useful to discriminate transits on the target star from eclipses on a background star, as expected. More precise evaluation of this discriminative power is still necessary and the in-depth analysis remains on progress. Let us remember that these channels do not correspond to fixed wavelengths but to target dependant spectral bandpasses (the bandpasses depend on the colour temperature and the magnitude of the target star; see Barge et al, this volume). The discrimination then is mainly spatial, as an offset background binary would not equally contribute to the three-colour light curves.

### 4.4. Statistical estimations

A number of ground based surveys recently confirmed that planetary transit signals can be easily

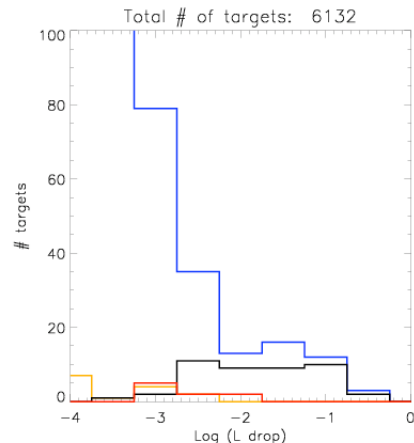


Figure 6. Estimated number of target transiting planets (red), target eclipsing binaries (black), background eclipsing binaries (blue) and background planets (orange), ordered in function of the luminosity drop. Targets planets or binaries are those associated to the brightest star in the corresponding CoRoT mask. Background planets or binaries are those associated to weaker (background) stars. The calculation was made for a galactic centre field and only one CoRoT CCD (2 are available for the exoplanet channel).

confused with the signal of background eclipsing binaries. In the case of OGLE the number of confirmed planets is 5 over a total of 137 transit candidates and it was found that the ambiguities in the detected events can also arise from triple systems with a diluted companion or from the eclipse of the target by a very small star. It is hence crucial to estimate the number of expected false alarms in the case of CoRoT. In particular, this will allow to estimate the amount of ground-based follow-up observations needed to ascertain the planetary nature of transit candidates.

On this basis, a simulator (CoRoTflux<sup>1</sup>) has been developed to reproduce lightcurves in crowded fields and in the conditions of CoRoT. Its goal is not to produce lightcurves with realistic instrumental noise but rather to simulate a CoRoT field of view, and in particular the number of transiting planets and eclipsing binaries in the field (both as target stars and in the numerous background stars that contaminate each mask).

In order to do so, a population of stars from magnitude 11 to 22 is randomly drawn on the basis of the Besançon model of the Galaxy corrected to real stellar counts. The multiplicity of these stars and the orbital distribution of their companions is drawn on the basis of the work of Duquennoy & Mayor (1991). The frequency of planetary companions and their

<sup>1</sup>CoRoTflux is available from the web on <http://www.obs-nice.fr/guillot/corotflux>

orbital distributions are drawn from results inferred from the radial-velocimetry surveys of solar-like stars in the case of giant planets. In the case of the smaller planets, little is known on their frequency of occurrence and various distributions have been tested. The stellar field thus calculated is randomly put on one CoRoT CCDs. 6000 targets from magnitude 11 to 16 are then selected. Apertures mimicking the CoRoT masks are attributed to each target stars as a function of their magnitude. The amount of signal due to the target star but also to other smaller stars in the entire mask (up to  $\sim 120$  pixels in size) can then be extracted leading to a global observed luminosity drop for each selected event.

A typical result for the galactic centre is shown in Figure 6, in which the number of expected target planets, target eclipsing binaries and background eclipsing binaries is shown as a function of the luminosity drop of the events. The results confirm the work of Brown, (2003) and show that background eclipsing binaries are a concern when trying to detect transiting giant planets and become a major problem for smaller planets. In terms of detectable events, an examination of the CoRoTlux results in a fiducial case and using the results of the BT1 indicates that about 70-90 detectable candidates (including very deep eclipsing binaries) are to be expected for a typical 150-days long run (2 exoplanet CCDs). For most of the cases ( $\sim 4/5$ ), a close examination of the lightcurve should suffice to reject them as eclipsing binaries (due to the presence of secondary eclipses, the transit shape and duration and modulation of the lightcurves). We expect that 16-32 "planetary" candidates should remain and will have to be followed carefully by ground telescopes in photometry and radial velocimetry. Among these, half a dozen planets should be present, but we expect a small number of unsolved systems to remain and potentially require a lot of telescope time.

The conclusion of these statistical estimations is that roughly 1/3 of the ambiguities should not be solved by deep light curve analysis and will require follow up observations. From numerical estimates it is found that some 10-20 imposters in a field of view will require follow up observations.

A word of caution however: these statistical analyses have to be validated on real data, in particular using real stellar fields (instead of idealized ones), and realistic noise. We stress that the number of events given here are indications and that they depend on the details of the stellar field (density, crowding, ratio of dwarfs to giants, stellar properties...) on the amount of noise in the signal (systematics) and on the signal to noise threshold used to separate what is "detectable" from what is not. Furthermore, the population of small close-in planets is presently unknown, and their detection directly depends on how frequent they are because only those orbiting the less numerous bright stars will be detectable by CoRoT.

In all cases, these results confirm the importance of a careful, dedicated follow-up of the transit candidates by ground-based telescopes.

## 5. CONCLUSIONS

This paper summarizes the various performance estimates of CoRoT in planet detection and identification, from theoretical expectations and statistical estimates to real-case blind exercises.

They show that the central science case of the CoRoT exoplanet search concerns hot Uranus like planets. This class of planets appears to be quite populated, as shown by recent discoveries: only a few years after the required accuracy is achieved by radial velocity instruments, ten planets with minimum mass below 0.1 Jupiter mass are known today.

Except HD69830d, they all have periods shorter than 40 days and thus represent the typical planets that CoRoT will discover. The much larger number of stars that CoRoT will monitor (at least 60000 in long runs), compared to radial velocity surveys at the highest accuracy (less than 100), is partly balanced by the requirement on the orbital inclination for transit detection. The recent successes of "hot Uranus" discoveries are good indications that CoRoT will play a major role in the detection and characterization of this kind of planets. Terrestrial planets could also be detected around the coolest stars of the CoRoT fields, but the low occurrence of M dwarfs will make their potential detection quite unlikely.

CoRoT should bring the first data about the abundances and the orbital distributions of Uranus-class to terrestrial exoplanets. These constitute key information for the ambitious followers like Darwin (Léger et al. , 1996; Fridlund et al., , 2000) and NASA's Terrestrial Planet Finder Beichman et al., (1999).

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