The Exoplanet Program of the CoRoT Space Mission

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Abstract. CoRoT is a space mission devoted to high precision star photometry. To be launched in 2005, CoRoT will use the transit method to discover new planets: likely some highly-coveted terrestrials and, quite certainly, a large number of close-in giants. Our knowledge on these “hot” planets will encounter a significant breakthrough due to a strong sample enlargement and to the possibility to measure the planet mass from ground-based radial velocity follow-up. Here, we present in some details the planet detection capability of CoRoT. Planetary radii will be measured down to Uranus size around solar type stars. Orbital periods will be determined from three detected transits up to 75 days. The possibility to detect more than one planet in a system is also addressed.

1. Introduction

CoRoT is a CNES space mission with 20% European participation. Half of its field-of-view is devoted to the detection of extra-solar planets using the transit method. The instrument is a 27 cm afocal telescope with a wide-field camera, optimized for accurate photometric measurements. Besides planet searches, CoRoT will also detect stellar oscillations (Baglin et al., 2001) and will produce new results on the photometric variability of the main-sequence stars, a knowledge that transit detection will also benefit.

Within a field of view of 3.9 square degrees CoRoT will monitor simultaneously up to 12,000 stars during five time slots of 150 day duration. During the 2.5 year satellite lifetime, a total of 60,000 light curves will be produced at a sampling rate of 8 minutes. In addition, after each long observation run the pointing direction of the satellite will have to be changed enabling 1 or 2 short observation runs of 20 days. During these short runs CoRoT will observe other sky fields within a few degrees of the main ones, so that some 120,000 additional light curves will be also produced. The range of magnitude of the CoRoT’s exoplanet targets is 11.5–16. For the brightest stars color information will be also available and will help discriminating single transit events from stellar artifacts.

The photometric accuracy for the exoplanet targets will be of the order of a few $10^{-4}$ (section 3) in one hour integration time and for a star with $m_v = 14$. The different kinds of planets accessible by CoRoT are presented below.

2. Close-in Giant Planets

A significant breakthrough in our knowledge of this giant planet family is expected from the wide sample CoRoT will bring us back. Indeed, radial-velocity surveys
Figure 1. Relative depth of the transit versus planet radius (in Earth radii). The smallest planets correspond to the crossing of horizontal lines (CoRoT detection threshold) and curves, and depends on spectral type and magnitude of the star.

have revealed the existence of planets similar to the famous 51Peg b (Mayor and Queloz, 1995) and established the first statistics on this new kind of objects. Today, these are 17 (/102) planets separated by less than 0.1 AU from their star which are known. These objects are the easiest to detect from space with the transit method and CoRoT will be able to find their radius distribution. Furthermore, a RV follow-up of the stars identified by CoRoT to host a planet is of utmost importance. It will give access to: (i) a determination of the planet mass and density; (ii) a wide field of potential studies (internal structure of close-in giant planets, evolution theories, etc...). When we account for the 180,000 available light curves, and if we drop 50% of the targets due to their radius or binarity, up to 200 such planets (mass > 0.1\(M_{\text{Jup}}\) and period < 10 days) are expected, following prediction based on the present RV statistics and the derived mass distribution (Mayor et al., this book).

Another way to study close-in giant planets with CoRoT would be to detect the periodic variations of the star light reflected by the planet and to estimate the planet albedo. Such a possibility has been explored for bright targets in the Seismology channel (Guillot and Vannier, personal comm.).

Although transit detection is easier for dwarf stars than for other spectral types, since transit depth scales as \(1/R_{\text{star}}^2\), CoRoT will be able to discover hot giant planets around giant stars of type earlier than G5 (Fig. 1) and, thus, will explore the occurrence of planet formation in a wide range of the HR diagram.
3. Smaller Planets

As the observation runs will last at maximum 150 days, the longest planetary periods accessible by CoRoT will be around 75 days. Identifying longer periods, from single or dual transit events, cannot be excluded but will require confirmation by complementary observations. The orbital domain accessible by CoRoT is thus mainly inside 0.25 AU or 0.5 AU following the spectral type.

The radius of the smallest detectable planet can be estimated from blind transit detection in simulated light curves (Defaÿ et al., 2001). These light-curves account for instrumental noise, straylight from Earth, zodiacal light and also on estimate of the stellar variability, scaled from space observations of the Sun. This minimum planet radius depends on the spectral type and magnitude of the star, and on the star-planet distance. The performance level of planet detection by CoRoT is summarized in Table 1 and Figure 1. Note that detectable planets can be as small as the Earth if the parent star is a bright, but very scarce, M0 dwarf. Preliminary spectral classification in the CoRoT fields permits an optimized target selection, storing up dwarf stars and avoiding giants. More generally, planetary radii range from Jupiter size to Earth size, while effective temperature usually remains above 400K. Note that two points are also converging for a strong impact of CoRoT: (i) the planet mass distribution from RV surveys indicates a large proportion of low-mass planet (close to a $1/M$ law); (ii) a RV follow-up of the CoRoT targets is possible with HARPS (Pepe et al., 2000), even for low-mass planets (Bouchy et al., 2003). CoRoT will thus answer the question whether hot terrestrial planets exist and survive.

More details on CoRoT exoplanet detection capabilities can be found in Defaÿ et al. (2001) and in Bordé et al. (2003) which includes a study on the importance of star population and of field crowding.

Table 1. For an A5V, G0V, M0V, G0III star: the transit duration, the maximal star-planet distance (Period=75 days), the probability of correct inclination, the effective temperature range (Albedo=0.2 and 0.8) and the minimal planet radius for a 12 and 15 magnitude star. Jovian planets around G0 giants can be observed around bright stars, up to V=13, and have a large geometrical probability.

<table>
<thead>
<tr>
<th>Star</th>
<th>Transit duration</th>
<th>Max sma (AU)</th>
<th>Proba. transit</th>
<th>$T_{\text{eff}}$ (K)</th>
<th>$V=12$ $R_E$</th>
<th>$V=15$ $R_E$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A5V</td>
<td>9 hours</td>
<td>0.41</td>
<td>1.9%</td>
<td>600–860</td>
<td>2.4</td>
<td>6.0</td>
</tr>
<tr>
<td>G0V</td>
<td>7 hours</td>
<td>0.36</td>
<td>1.4%</td>
<td>370–520</td>
<td>1.7</td>
<td>4.0</td>
</tr>
<tr>
<td>M0V</td>
<td>5 hours</td>
<td>0.26</td>
<td>1.1%</td>
<td>160–220</td>
<td>1.0</td>
<td>2.5</td>
</tr>
<tr>
<td>G0III</td>
<td>25 hours</td>
<td>0.51</td>
<td>5.5%</td>
<td>680–960</td>
<td>10 (0.9$R_{\text{Jup}}$)</td>
<td>–</td>
</tr>
</tbody>
</table>
4. Planetary Systems

Among the planetary systems identified so far, 12 are known to have more than one planet. How CoRoT can contribute to discover multi-planet system? Let us examine various possible cases:

- The star has planets outside the orbit of the detected one. The probability for a transit by another planet drops as $1/a$. Here, note that, in the case of the Solar System, the dispersion in inclination is around 2 degrees (Pluto excluded). This relatively high value weakens the probability for a second detection when a first planet has been found. Of course the radial extent of the system is of importance in the problem. The probability for a second detection is not so bad at short distance from the star (i.e.) the favourite domain of CoRoT. In fact, the possibility to observe another planet outside the orbit of the first one usually relies on other methods: radial velocity for a giant planet up to a few AU, or direct imaging, interferometry or astrometry for giants at larger distances.

- The star has planets inside the orbit of the detected one. In this case, tidal effects probably stir up the orbital inclinations and the chances to get a transit from inner planets are no more very large. Some regions around the star could even be dynamically unstable (Erikson and Rauer, in prep.). Nevertheless, if such planets were present and massive enough, RV follow-up could detect those with the shortest period.

- No planet has been detected by CoRoT. The accurate light curve available with the CoRoT data will be used to estimate some important properties of the star such as: its variability level, its rotational velocity, some limits on the inclination and the masses of the potential planets. Further studies could still lead to the detection of a non-transiting planet!

The combination of various methods for detecting extrasolar planets will be extremely useful to gather information on planetary systems other than the Solar System and to put further constraints on the planetary formation models.

References