

POSSIBLE PROJECTS FOR THE EXTENSION OF CoRoT

following the discussion held during the German CoRoT CoI meeting in Tautenburg
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BASICS:

CoRoT III should be driven by exoplanets.

CoRoT III will run in parallel to Kepler, which could be extended until 2017.

Potential future space-based transit surveys are PLATO and TESS (Latham et al.) and ELEKTRA (Beichman et al.) from the USA.

Continuing the survey mode would yield potentially more hot Jupiters and perhaps another CoRoT-7b planet. But we would have to compete with Kepler and there is no way to confirm super earths in the magnitude range observed by the exo field (11 to 16 mag). It might still be interesting to find new hot Jupiters, but we don't know how many good fields are left.

FIELDS:

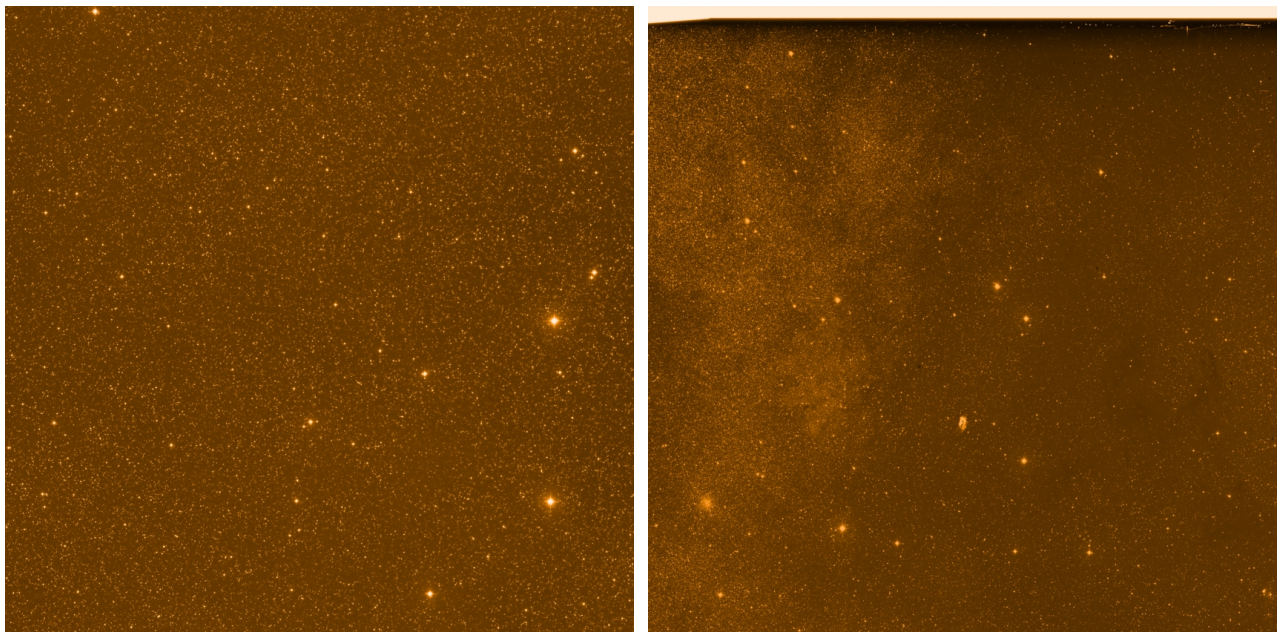


Figure 1: left, the FOV of SRa03, a "good" field where 3 planets were found. Right, the FOV of SRc01, a "bad" field where no planet was found.

Center fields seem to be not good enough for new surveys (perhaps it is better to re-observe known targets or define a new project) whereas in anticenter fields there seems to be room for new discoveries.

1st PROPOSAL: CoRoT III, THE BRIGHT STARS SCOUT

Find small planets around bright stars in the Asteroseismology channel.

Technical limitations:

- the sismo channel can observe stars between magnitudes 5.4 and 9.2 (Auvergne et al. 2009 A&A, 506; similar figures in Boissard et al. from the CoRoT Book).
- the CoRoT Eyes cover a surface centered in the right ascension 18h50m in the "center" direction and 6h50m in the "anticenter" direction with 10 degrees radius (Deleuil et al. 2009, AJ, 138).
- we can process up to 50 windows in the sismo channel (Gisbert Peter).
- the pointing of the telescope takes around 1 week, so the runs should not be shorter than 20 days (the SRa03, where 3 planets were discovered, lasted 25 days). CoRoT could observe then up to 6 or 7 short (20 days long) runs per season (12/14 runs per year).

Targets available:

-Table 1 shows the number of dwarf stars for a given magnitude range within the CoRoT Eyes, following the catalogue PPMXL (which should be complete down to this magnitude range). A dwarf star is defined as having J-K color under 0.5 (which should be a reasonable approximation at this magnitude range). The FOV of CoRoT is 1 square degree per CCD approx.

direction	magnitude range (r1)	total number of dwarf stars in the CoRoT Eyes	average number of dwarf stars per square degree
anticenter direction	<9.5	2117	7
	<11	9753	31
center direction	<9.5	950	3
	<11	4870	16

-Assuming 6 runs per pointing, one could observe 42 dwarf stars brighter than 9.5 in the anticenter direction and 18 dwarf stars brighter than 9.5 in the center direction per year. This is around 60 stars. Assuming that 30% of stars have planets smaller than Jupiter with orbital periods below 50 days and a transit probability of 5% (for a period of 10 days), then the expected yield of planets would be: $0.3 \times 0.05 \times 60 = 1$ planet per year. However, such a planet would be potentially very interesting.

-In case CoRoT could reach down to magnitude 11, these figures would be increased by a factor of 4.

-Another potential interesting target are M-dwarfs. It is difficult to obtain a complete catalogue of M-dwarfs, but the estimations are no more than a handful available in each CoRoT Eye. In any case, there would be no more than 1 M-dwarf per FOV and given their typical magnitude, they would have to be observed in the exo channel.

Future considerations:

This step and stare phase observing bright stars overcomes the problem of the FU of faint targets, but has a low potential planet yield.

One would have to study more in detail the period distribution of exoplanets to interpret a negative result.

One would have to address the interpretation of single transit events.

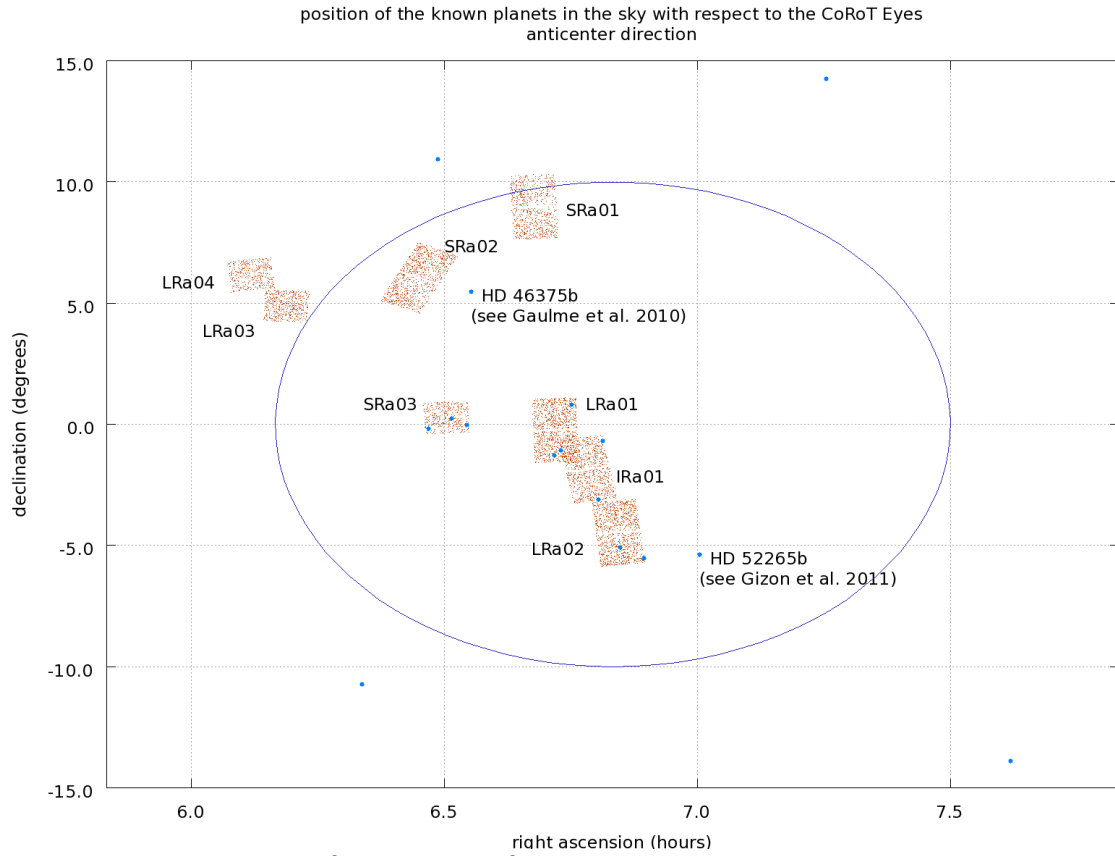


Figure 2 shows the position of the CoRoT fields observed with the exo channel in the anticenter direction. The blue dots are known planets. The only transiting planets in the CoRoT Eyes are those discovered by CoRoT. The rest are radial velocity planets with no known transits observed.

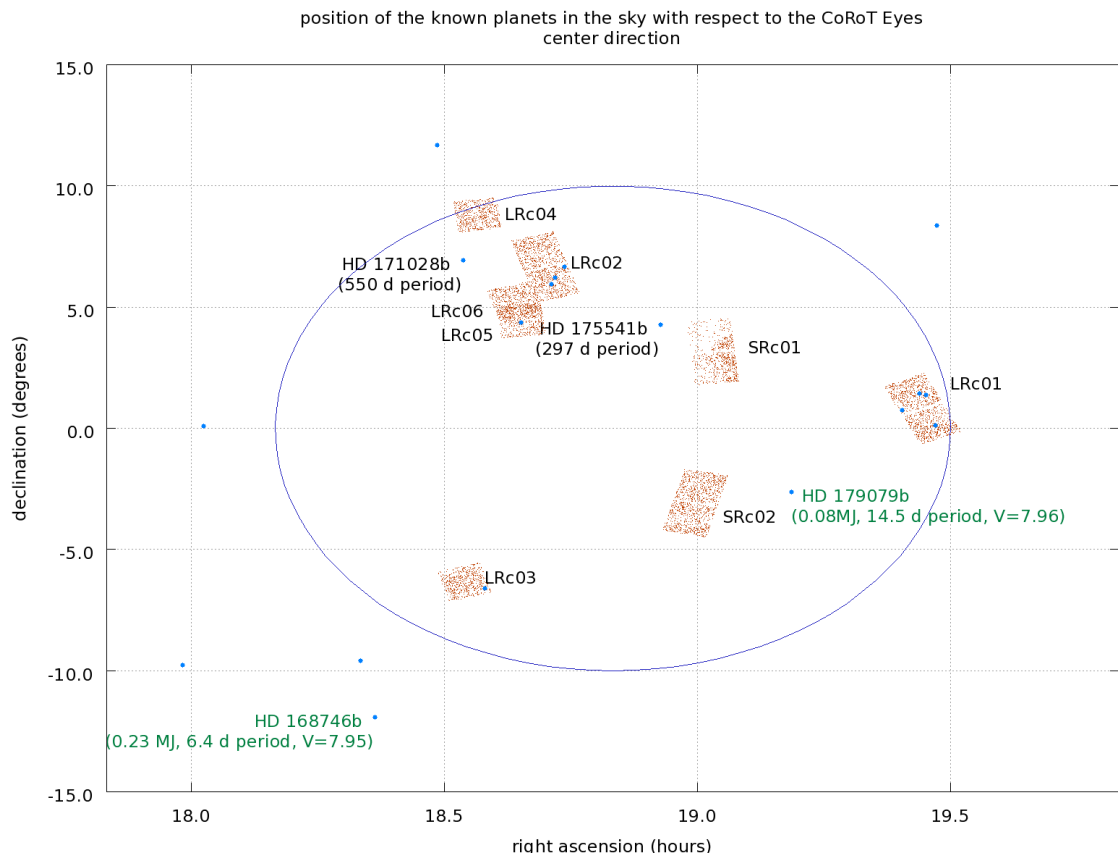


Figure 3 same as Fig. 2 but for the center direction.

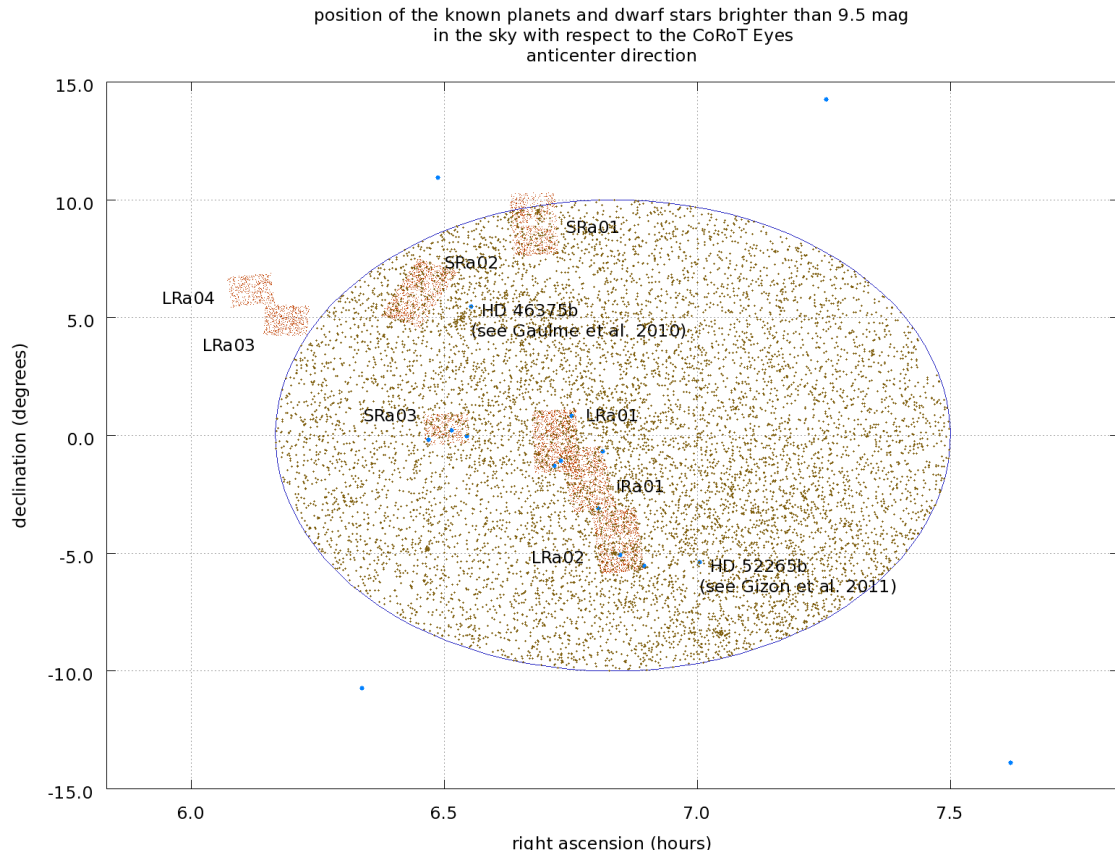


Figure 4 shows the distribution of the stars brighter than 9.5 in the anticenter direction.

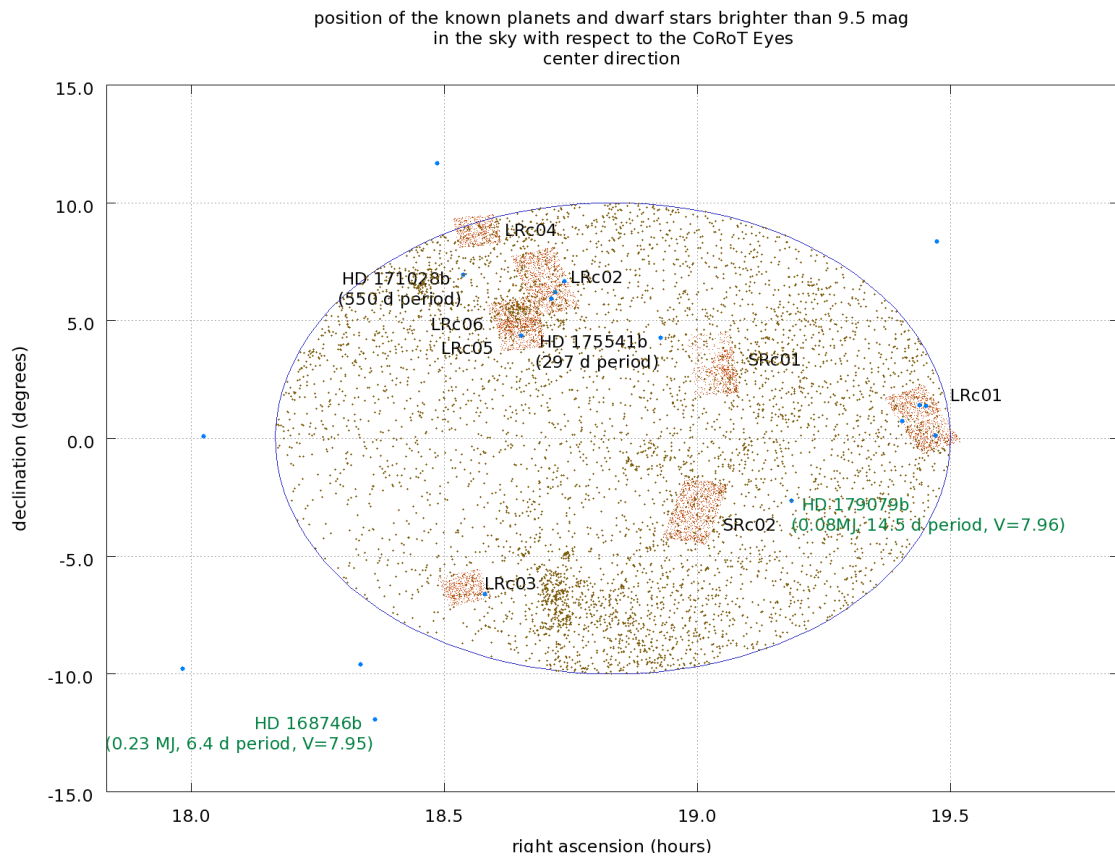


Figure 5 same as Fig. 4 but for the center direction.

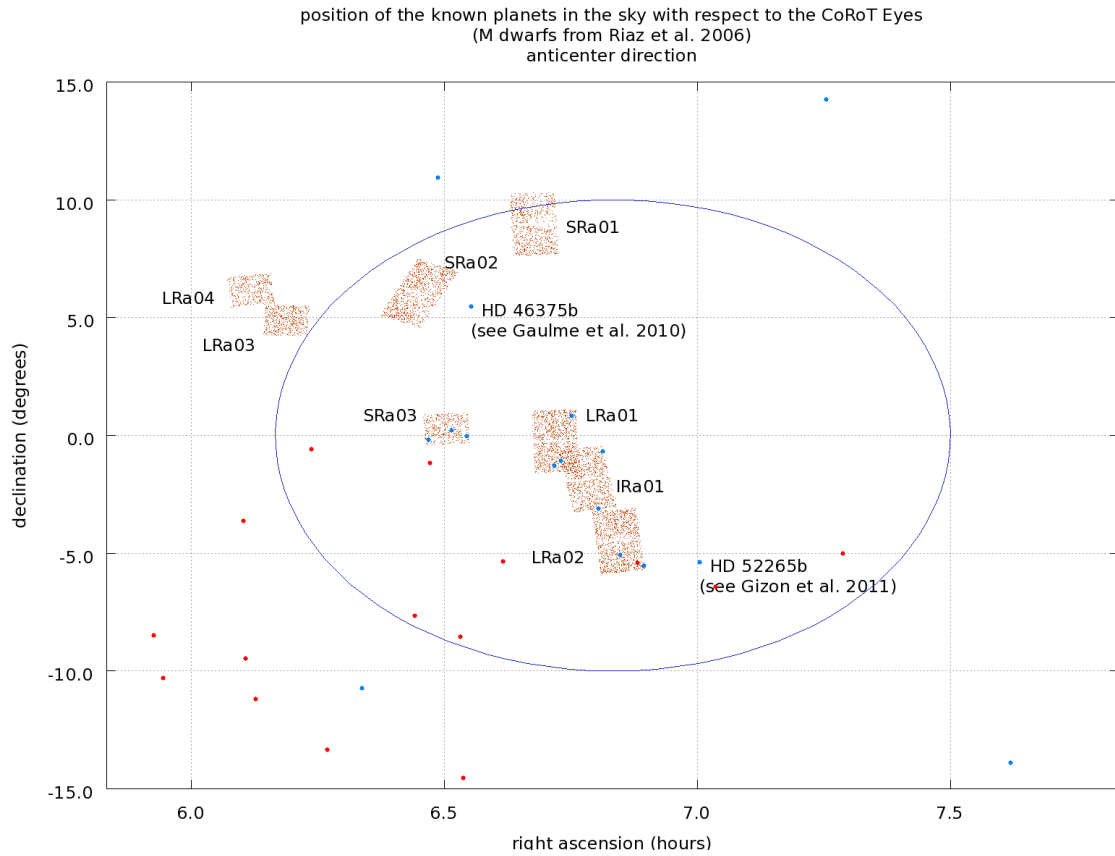


Figure 6 shows the distribution of known M-dwarfs in the anticenter direction.

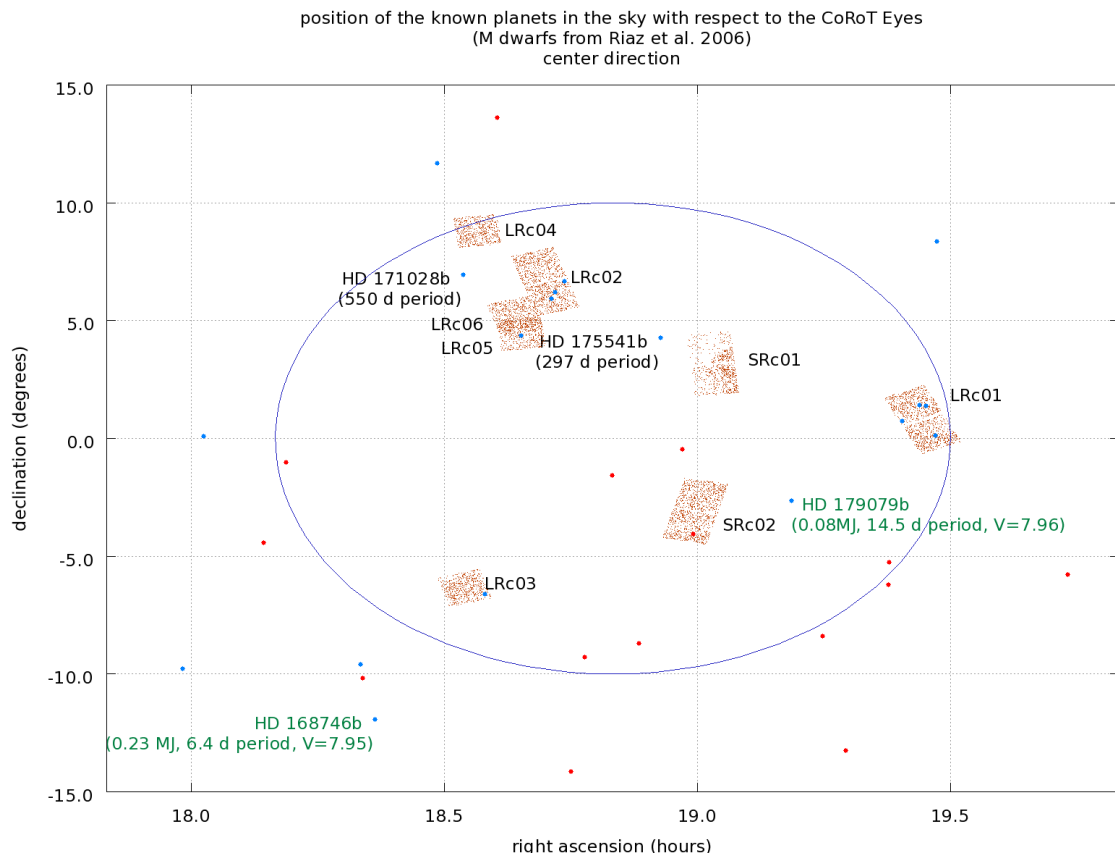


Figure 7 same as Fig. 6 but for the center direction

2nd PROPOSAL: OBSERVE KNOWN PLANETS IN THE SISMO FIELD

To observe planets known from RV surveys to characterize the host star via asteroseismology and try to detect smaller planets in the system via transits and/or reflected light.

There are only a dozen of targets available in the CoRoT eyes (see Figs. 2 and 3). Two of them have short periods and orbit around bright stars (HD 168746 b; 6.4 days period; $V=7.95$; HD 179079b; 14.5 days period; $V=7.96$), but the rest of them have longer periods (from 50 to 2000 days). The feasibility of this project with CoRoT has already been shown in the cases of HD 52265 b (Gizon et al. 2011) and HD 46375 b (Gaulme et al. 2010).

3rd PROPOSAL: SCAN THE WHOLE EYES OF CoRoT

A similar idea to 1 but using the exo channel. The area of each Eye is around 310 square degrees. Given the FOV of CoRoT, which is around 1 square degree, one would need around 300 pointings per direction. If we can observe up to 7 runs per year and direction, CoRoT would need around 40 years to cover the whole area.

To be discussed if the distribution of planets is homogeneous within the CoRoT Eyes, which seems not to be the case. We don't know for sure how many "good" areas are left.

4th PROPOSAL: SURVEY CLUSTERS

The search for transiting planets in clusters usually have lower yields than expected. CoRoT observed a cluster in SRa01 and no planet was detected. The distribution of stars in the anticenter field seems more homogeneous than in the center (see Figs. 4 and 5).

5th PROPOSAL: GOING BACK TO PREVIOUS FIELDS

Advantage:

- TTV-confirmation does not require any RV-follow up
- it is easy to apply
- long-term TTVs can be in the order of hours/days (!), so the effect is quite big

Disadvantage:

- for a mass-determination it requires a multi-transit system, otherwise the solution is degenerated (e.g. Kepler-19b system)
- timing should be as precise as possible which exclude the very shallow candidates that show low SNR (see below)
- it requires long baseline of observations, years and decades are preferable over weeks

Limitations by timing precision:

Estimation is based on Doyle & Deeg (IAUS 213, 80, 2004):

$$\delta T_{\text{TTV}} = \frac{\text{Photometric precision} \times \text{Duration}}{2 \text{Depth} \times \sqrt{N}}$$

here N is the points inside the transit. A typical measurement for a hot Jupiter by Corot means:

photometric precision is: 0.001

Duration: 3 hours

depth: 0.01

N = ~330 (32 sec mode) or ~20 (512 sec mode).

Then we have that we can measure the transit center with a precision of 29 seconds or 120 seconds precision in the case of the 32 sec or 512 sec mode, respectively for the given photometric precision. The same for CoRoT-7b, where Depth=0.00035 is ~10 minutes in the 32 sec mode, so we cannot study any interesting thing because the depth is very small.

Unfortunately, Corot-24 bc system is not a natural target, even if the two planets seems to be in 7:3 resonance (reminder: TTVs are extrem big if you have resonances), because the system is quite faint. In this system we could measure the center of the transit with a precision of ~135 seconds according to the formula above if it was a 12 magnitude object. The TTVs can be in the order of several times ~10 minutes or even hours owing to the near-resonance! If it was a brighter target, we would choose it as a target for TTV-studies.

What we can do with TTVs:

- the circularization time-scale is quite short for hot Jupiters, it is in the order of 20-100 Myrs. So if we have eccentric orbit, then something should excite the orbit. So, hot Jupiters on eccentric orbits are natural targets of TTV-observations.
- in some cases the circularization time scale is estimated to be longer. Even if this is true, it is still possible that there is another object in the system. Borkovits et al. (2011) showed that in some certain, absolutely not extreme triple-configuration can lead to very big changes in the O-C values (see figure below). Eccentric hot Jupiters are subjects of strong perturbations (because they are sensitive for distant, small-mass objects, too!), so they should be re-observed.

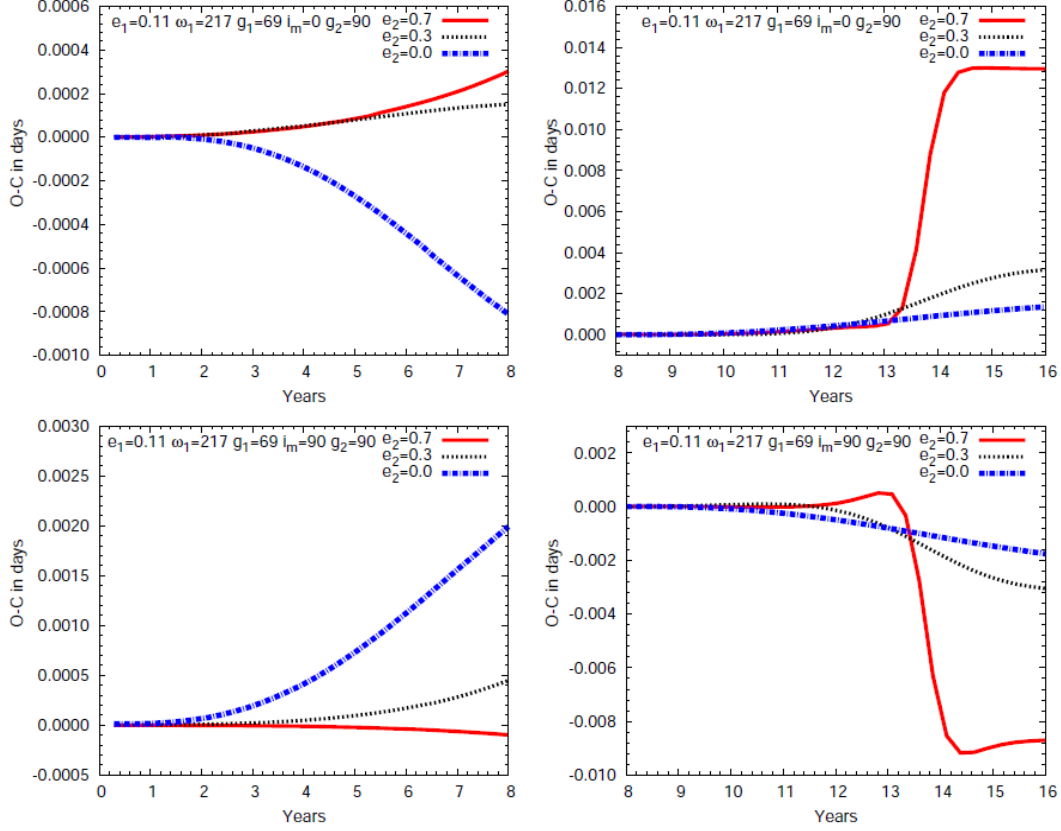


Fig. 6. The first and the second 8 years of $O - C$ -s plotted in the first and the last rows of Fig. 5. The periods of the individual curves were set equal to the respective initial transiting periods.

The transit timing variation effect in CoRoT-9b, assuming that there is an another 5 Mjup object in the system on 27 years (!) orbit (From Borkovits, Csizmadia, Forgacs-Dajka, Hegedus, A&A 528, 53, 2011). Although it was not calculated, but it is easy to imagine what happend if the perturber is closer and the orbit of the inner transiting planet is shorter (the effect is bigger). Different curves are for different eccentricities of the outer hypothetical object.

- the star-planet possible magnetic interactions cause secular TTVs on longer time-scale, and they can be observed from ground, too.
- CoRoT-7b should be a target for TTV. According to R. Dvorak's estimation, there is a significant change in the inclination due to interaction with 7c. This is measurable, because the inclination change will be over 0.2 degrees since the discovery, so we can measure it after 3 years.
- we can also check the evaporation-theories of hot Jupiters. It is stated that hot Jupiters loose 1-2 % of their masses during their lifetime. This cases mass-loss of the system, which is measurable on ~ 5 years baseline. Concerning our first discoveries (from Corot-1b to (let us say) 5b), we can study this.