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THE COROT EXOPLANET PROGRAMME: AN OVERVIEW OF RESULTS

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Abstract. We present some highlights of the exoplanet programme of the CoRoT satellite, after 5.5 years of life. 27 planets have been discovered and we review here the global properties of the sample and highligth some of the most important results: the detection of Corot-7b, the first truly rocky planet, two peculiar brown dwarves, a long period planet, several blaoted planets, several hot, yet excentric, Jupiter as well as two systems of small planets.

Keywords: CoRoT satellite, brown dwarfs, exoplanets, Planets and satellites: detection

1 The CoRoT satellite and its operations

CoRoT, is a satellite dedicated to high accuracy stellar photometry. Launched end 2006 by a good old faithful Soyuz on a polar orbit, it accomplished 5.5 years of operation without any major failure but the loss of two CCDs due to cosmic hits. This review concentrates on the exoplanet program which aims at detecting the slight diming of a star when one planet of its retinue transits in front of the stellar disk.

The satellite features an afocal telescope of 27 cm pupil diameter, made with 2 parabolic mirrors, followed by a 6 lenses dioptric camera which provides a field of view of several square degrees. A very long baffle avoids light from the terrestrial horizon to enter the telescope.

The focal plane accomodates 4 CCD of 2048^2 pixels, two of them for astero-sismology and two for the exoplanets programme. The exoplanet field is of $3.45°^2$ (half today since the lost of one CCD).

The observing strategy is based on the peculiarity of the polar orbit: CoRoT can monitor continuously a direction in the sky perpendicular to the orbit, with the sun *in the back* during 6 months and then flips on itself to start monitoring the opposite direction. This means that up to 150 days of continous observation on each field are possible. 22 fields have already been observed: 8 short and 14 long.

To detect transiting exoplanets, one monitors thousands of stars in the field and tries to locate on few of them at least 3 transit events that are periodic.

In this quest, the ennemies are the false positives which produce a signal that mimics a transiting planet, but actually are not the fact of any planet. This happens when the star is a Grazing Eclipsing Binary (GEB), or when there is an Eclipsing Binary in the Background (BEB), or when the target is an Eclipsing Binary in a dwarf/giant system. Because those false positive are much more frequent than actual planetary transits, follow-up from the ground is mandatory: the CoRoT community has mobilised its strengths around several ground-based instruments in Radial Velocity (Harps, Sophie, Keck), precise photometry (CFH, Canarias), Adaptive Optics (VLT).

2 Performances and global statistics

145 000 Light Curves were obained on the 22 fields. It resulted an amazing diversity of behaviour and clearly one great legacy of CoRoT will be a huge data set to study stellar variability. For the whole range of stellar magnitudes, the measured noise on all candidates is within the expectation, i.e. just slightly larger than the photon noise, allowing detection of small super-earth planets, at least for $mR < 14$. This capability of CoRoT was indeed demonstrated with Corot-7b.

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CoRoT team has analyzed 10^5 stars and confirmed (so far) 27 substellar objects : 25 transiting planets and 2 brown dwarves. All were detected in long runs (i.e. duration > 70 days). There has been on the average 200 to 300 detections of periodic events per run, i.e. 2 to 3 % of the monitored stars. Among them only 1 to 4 cases revealed to actually be planets, i.e. 0.5 - 2% of those periodic cases. This low figure is not a surprise. On Fig. 1, where a normalized planet detection number is presented with respect to duration and for different fields, we note a rather large scattering of detection yeld. A detailed analysis by Cabrera et al. pointed out the role of interstellar extinction to explain this effect : it limits the detection capabiliity by dimming stars which would be the most interesting statistically.

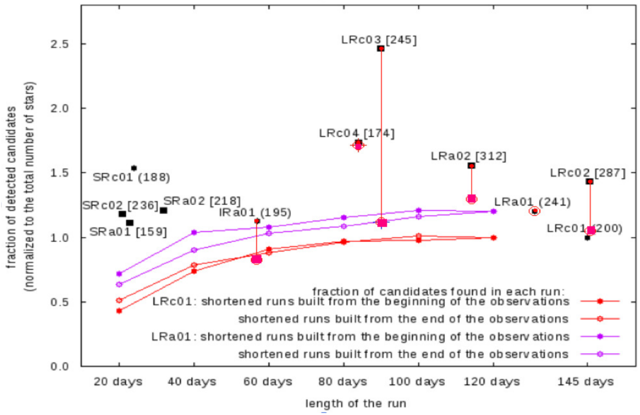

Fig. 1. Detection rate, normalized to the star number for different fields, vs time. Most of the detection are secured after 60 days. The vertical lines indicate the effect of an artificial reddening on this rate, explaining the scattering of number of detections between the fields.

CoRoT planets on the R vs M diagram

CoRoT planets cover a broad range of densities, from 0.21 to 55 g cm^{-3}. CoRoT indeed extended the mass range of transiting planets towards both extremes, with on one side Corot-15b whose mass is 65 M_{Jup} and on the other side Corot-7b, with .015 M_{Jup}. While the first one is a bona fide brown dwarf, another probable brown dwarf is Corot-3b which is right at the theoretical frontier between a planet and a brown dwarf.

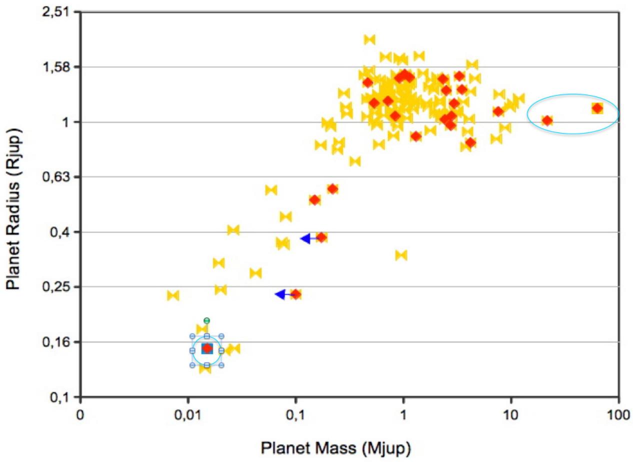

Fig. 2. The CoRoT planets (red diamonds) on the Radius / Mass diagram. The oval at right identifies the two brown dwarves and the circle at left the rock solid Super-Earth Corot-7b.

Periods of transiting systems

If we consider the distribution of orbital periods on Fig. 3, CoRoT appears to be unbiased towards both extremes: Corot-7b was for a time the shortest period ever detected, while three medium periods of 9 to 13 days and one long period of 95 days were also detected.

Massive companions for massive stars ?

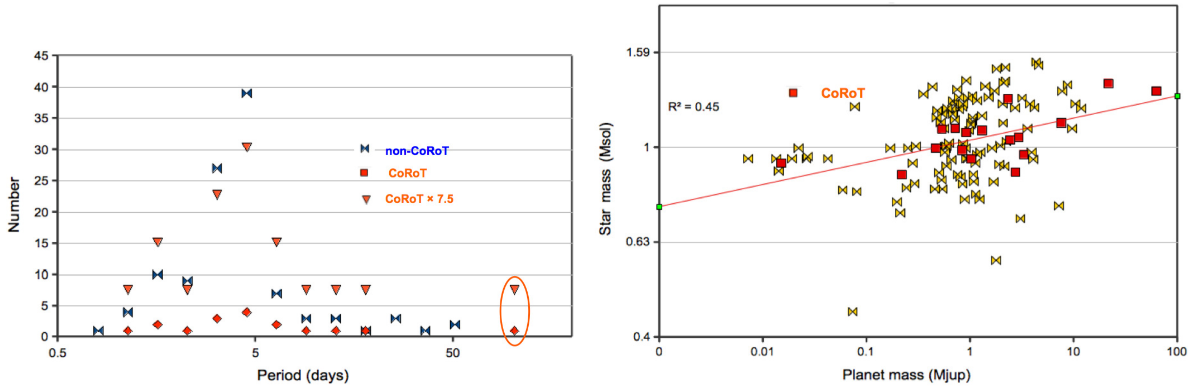

Fig. 3. Left: histogram of periods of CoRoT planets (red triangles and diamonds) and of all transiting planets (diabolo); CoRoT is on the average more efficient at rather long period. **Right:** diagram of planetary mass vs stellar mass for CoRoT (red) and other transiting planets (yellow), the line indicate a trend.

The plot of planet mass versus stellar mass (Fig. 3) indicates a significant trend for massive stars to form massive planets. This is not unexpected, considering the currently favoured core-accretion scenario for planet formation.

2.1 Highlights

Table 1 gathers the characteristics of the most peculiar planets detected by CoRoT. Among them let's distinguish more particularly:

- Corot-9b, a long period (95.3 days) planet on a Mercury-like orbit; it deserves the qualification of *temperate* planet (Deeg et al. 2010);
- Corot-3b, with a mass of 22 M_{Jup}, is it a Super-planet or a brown dwarf ? (Deleuil et al. 2008)
- Corot-15b, a bona-fide orbiting brown dwarf (Bouchy et al. 2011) ;
- Corot-8b, a Neptune-like planet of 0.22 M_{Jup} mass (Bordé et al. 2010) ;
- Corot-11b, and Corot-2b, two bloated planets of radius 1.4-1.5 R_{Jup} (Gandolfi et al. 2010; Alonso et al. 2008) ;
- Corot-10b, Corot-16b, Corot-20b, Corot-23b, four hot Jupiters which are however on eccentric orbits: a clear constraint on the quality factor Q_p of tidal dissipation (Bonomo et al. 2010; Ollivier et al. 2011; Deleuil et al. 2011; Rouan et al. 2012) ;
- Corot-24b,c the first multi-transit system of CoRoT, with two small planets of 0.10 and 0.17 M_{Jup} (Alonso & al. 2012) ;
- Corot-7b, with a radius of 1.7 R_{Earth} and a mass of 7.3 M_{Earth}, it was the first confirmed rocky planet with a density and composition that are close to the Earth's ones (Léger et al. 2009; Queloz et al. 2009). Since it must be tidally locked, its two hemispheres, the bright and the dark one, present an extremely high contrast in temperature (2200K vs 50K) and a lava ocean must occupy a large fraction of the bright side. A continent of frost H_2O, CO_2 is probably found on the dark side. Corot-7 is also the first case of a system with 2 Super-Earths, one in transit, since radial velocity measurements allowed the discovery of Corot-7c, a planet of 8.4 M_{Earth} and period 3.79 days. A third planet is even suspected.

The most recent planets discovered by CoRoT are:
- Corot-16b : an eccentric hot Jupiter around a faint solar-like star (Ollivier et al. 2011)
- Corot-19b : a low density planet orbirting an old inactive F9-V star
- Corot-24b,c : a probable multi-transit system (Alonso & al. 2012)
- Corot-21b : a doomed large Jupiter around a faint sub-giant star
- Corot-22b : a highly probable small Saturn (Moutou et al. 2011)
- Corot-23b : a dense hot Jupiter on an eccentric orbit (Rouan et al., 2011)

Table 1. Characteristics of the most peculiar planets detected by CoRoT

Name	Period (days)	Mass M_{Jup}	Radius R_{Jup}	ρ g cm^{-2}	excentricity	peculiarity
Corot-9b	**95.27**	.84	1.05	.89	.11	Long period Mercury-like orbit
Corot-3b	4.26	**21.7**	1.01	26.4	0	Super-planet or brown dwarf ?
Corot-15b	3.06	**63**	1.12	55	0	True orbiting brown dwarf
Corot-8b	6.21	**0.22**	**0.57**	1.6	0	A Neptune-like planet
Corot-11b	2.99	2.33	**1.43**	.97	0	Bloated planet
Corot-2b	1.743	3.31	**1.47**	1.29	0	Bloated planet
Corot-10b	13.24	2.75	.97	3.68	**.53**	Eccentric, despite hot Jupiter
Corot-16b	5.35	.535	1.17	.44	**.33**	Eccentric, despite hot Jupiter
Corot-20b	9.24	4.2	.84	8.65	**.56**	Dense and eccentric, despite hot Jupiter
Corot-23b	3.63	2.8	1.05	2.95	**.16**	Dense and eccentric, despite hot Jupiter
Corot-24b	5.11	.1	.24	9.3		Multi-transit system
Corot-24c	11.75	.17	.38	3.9		Multi-transit system
Corot-7b	**.854**	**.0151**	**.15**	10		The first secured rocky planet

3 Extension of the mission

Very recently approved, the extension of the mission until march 2016 will allow to exploit two peculiar niches, in the Kepler era: the capability to point different regions within two cones of radius extended from 10 to 15° and the possibility to measure bright stars. The three programmes that will be favored are : *i)* characterizing planets in the sub-Saturn regime with a focus on stars brigthter tnan mV = 15, this will free telemetry for more imagettes that give access to the centroid determination; *ii)* detection and study of planets already known by RV: this will use the asterosismology CCD and relies on the fact that 20% of Kepler candidates are multi-transit; *iii)* search for giant planets on wide orbits, with re-observation of mono or bi-transit already detected, so that period much larger than 75 days could be discovered.

References

Alonso, R. & al. 2012, A&A, in press

Alonso, R., Auvergne, M., Baglin, A., et al. 2008, A&A, 482, L21

Bonomo, A. S., Santerne, A., Alonso, R., et al. 2010, A&A, 520, A65

Bordé, P., Bouchy, F., Deleuil, M., et al. 2010, A&A, 520, A66

Bouchy, F., Deleuil, M., Guillot, T., et al. 2011, A&A, 525, A68

Deeg, H. J., Moutou, C., Erikson, A., et al. 2010, Nature, 464, 384

Deleuil, M., Bonomo, A., Ferraz-Mello, S., et al. 2011, A&A, submitted

Deleuil, M., Deeg, H. J., Alonso, R., et al. 2008, A&A, 491, 889

Gandolfi, D., Hébrard, G., Alonso, R., et al. 2010, A&A, 524, A55

Léger, A., Rouan, D., Schneider, J., et al. 2009, A&A, 506, 287

Moutou, C., Almenara, J., Alonso, M., et al. 2011, A&A, in press

Ollivier, M., Gillon, M., Santerne, A., Wuchterl, G., & Havel, M. 2011, A&A, submitted

Queloz, D., Bouchy, F., Moutou, C., et al. 2009, A&A, 506, 303

Rouan, D., Parviainen, H., Moutou, C., et al. 2012, A&A, 537, A54