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The Space Stellar Photometry Mission COROT: Asteroseismology and Search for Extrasolar Planets

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Abstract. The main scientific objectives, asteroseismology and search for extrasolar planets for the COROT photometric mission are presented, and its interest in terms of stellar variability. A description of the payload, details of the scientific program, the ground based preparatory observations and bibliography can be found at http://www.astrsp-mrs.fr/corot/ pagecorot.html.

Key words. Space—photometry—asteroseismology—extrasolar planets.

1. The asteroseismology programme

COROT will realise both an "exploratory programme", to detect oscillations in a large variety of stars and to classify the asteroseismologic properties of stars in the Hertzprung-Russel diagram, and a more specific one called "central programme" for a detailed study of a few stars, specially chosen to test the hydrodynamics of the internal layers and the physical state of the stellar cores.

1.1 *The exploratory programme*

Its purpose is to determine the domain of stellar parameters for which oscillations are detectable, and the relation between the amplitudes of the solar-like oscillators and their global characteristics.

To achieve this, one has to observe a sample of objects with a variety of stellar parameters, i.e. mass, age, chemical composition, state of rotation...but with moderate signal to noise ratio. A frequency resolution of 0.5 μ Hz is sufficient for this purpose, corresponding to observing runs of 10 to 20 days. Stars down to the 9th magnitude are appropriate targets; 5 to 10 targets will be observable at the same time. Let us note that COROT is up to now the only seismology project which has this multiplex capability.

Several tens of stars will have to be followed, corresponding to a total observing time of at least 2 to 4 months.

1.2 *The central programme*

It is more ambitious and more time consuming than the exploratory one; it corresponds to the second step in the development of space asteroseismology. It aims at observing very precisely a small set of objects, selected for their diagnostic power. The choice of these targets will be partly based on the results of the exploratory phase.

Using the solar case as a template, we fix the accuracy of the frequency measurement at 0.1 μ Hz to have access to mode profiles and rotational splitting and to measure precisely the distribution of the mode frequencies. For a 6th magnitude star, the detection threshold will be less than 1 ppm. For A and F stars close to the main sequence, it will then be possible to measure the size of the convective cores, the size of the outer convective zones and their helium content or the rotation profile of δ Scuti stars.

A least 5 runs are planned, during which one bright star (the main target) and several fainter ones in the surrounding field of view will be followed.

2. The exoplanet programme

The detection of a telluric planet is a major challenge and is expected to be the next big step in astronomy, and recent discoveries of a few tens of giant planets have upset our vision of the formation of planetary systems. A sensible approach for the search and study of extrasolar planets around stars is first searching for giant exoplanets, then searching for telluric ones, and finally spectroscopically analysing them, with an emphasis on telluric ones.

The first step has been made with the discovery of 51 Peg b in 1995, but presently we do not have an unbiased statistics of these planets. The second objective is ONLY accessible to the COROT mission (or to similar ones, such as KEPLER or EDDINGTON, which are not approved yet). The third one will be the main goal of future very ambitious missions which will probably fly in a few decades.

This detection of telluric planets around solar type stars is very difficult because of their small masses. Before the achievement of ambitious space projects (interferometers, coronographs), only gravitational amplification and transits are available on a short or mid term. The transit method is the only one which allows the precise determination of the orbital period and the size of the planet. Yet this method needs a high precision photometry (10^{-3} to 10^{-4}) and continuous observations during a long period (several months). Particularly well adapted to the telluric planets, it can also detect giant extra-solar planets (detectable by spectroscopy from the ground) and determine their albedo.

As COROT is devoted to stellar photometry, aiming at both a high precision and a long observation time, the search for exoplanets by the transit method can easily be integrated in the payload and in the mission profile.

Presently, we do not know the statistical distribution of telluric exoplanets as function of their size. In fact, we do not even know if they exist! Though COROT is not a mission devoted specifically to telluric exoplanets detection, it will demonstrate the “existence theorem”. This piece of information is crucial for the future projects which will aim to perform the spectroscopy of such objects.

One major difficulty in the detection of a planetary transit is to get rid of false alarms due to photometric variations of stellar origin, as stellar activity. To do so a dispersive element (prism) has been included in the exoplanet field giving a little spectrum (3–4 resolution). It has been shown that this coloured information decreases significantly the false-alarm probability. In order to estimate the number of possible transits due to telluric planets, we have to estimate the number of solar type stars escorted a priori with at least one planet. Since 50 % of the young stars have a dust disc, it is reasonable to assume a priori that half of the stars have got telluric planets and that 20% of them have got planets whose radius is superior to the earth. The number of events depends on the radius and the distance of the planet to its parent star, so it is difficult to give numbers. With a photometry optimised up to $m_v = 15.5$ (which corresponds to the COROT field with a hundred thousand stars observed during the mission) the expected number of detections is:

- 25 planets having a radius of 1.6 earth radius at 0.3 a.u.
- 40 planets having a radius of 2 earth radius at 0.3 a.u.
- A few planets of around 2 earth radius in the “habitable” zone thanks to the chromatic information.
- Several hundreds of hot Jupiters and Uranus like planets, with detailed light curves.

3. The additional programmes and the stellar photometry data base

COROT will provide extremely long and uninterrupted sequences of photometric data of more than hundred thousand stars, of magnitude between 12 and 16, acquired by the exoplanet field. The time sampling is 15 minutes, the accuracy on an individual measurement is a few 10^{-4}, and the duration varies from 10 to 150 days. For the brightest ones two colours will be available, with the same accuracy. The only available data of this type come from the microlensing surveys, with looser time sampling (1 day) and very rough photometry (1%). They have shown that these sets of wide complete samples are extremely useful to probe scenarios of evolution and stellar physics. They nicely complement seismology of much smaller samples of targets.

For instance, COROT will obtain light curves of binary stars, with a level of precision which will allow to study tidal modulations and tidal lags which can provide a direct measurement of the viscosity of the stellar material.

Colour photometry can supply, through the use of surface tomography, relevant information concerning the evolution of cold spots and differential rotation axes of single and binary stars and can give a direct measurement of limb and gravity darkening laws.

For stellar activity, the high photometric precision and long time series provided by COROT will allow us to extend· the analysis of the dependence of magnetic activity upon rotation to moderately active stars and moderate rotators, thus providing powerful observational tests to dynamo theories.

Analogous to planets, comets will produce transits detectable by COROT; Kuiper Belt objects of very small size could also be observed.

To perform such studies called “Additional Programmes”, scientists will bid against an Announcement of Opportunity to access data and/or observing time.

4. Mission requirements

To achieve the scientific objectives, the mission lifetime has to reach at least 3 years, and the programme asks for long and continuous exposures on the same targets, as to reach the frequency resolution of 0.1 μ Hz up to 150 days are necessary. The Small Mission of CNES Programme imposes a low altitude orbit; polar inertial orbits are the only ones to allow 150 days continuously on the same field. To avoid eclipses and straylight from the Earth, the observable zone is restricted to two circles, centered on the equator, in opposite direction, with a radius of approximately 12 to 14 degrees.

The selection of targets inside these fields is the responsibility of the Scientific Council. The working group on "Ground Based Programme" is responsible for gathering all the data necessary to make this choice.