The CoRoT Legacy Book
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Part III

Major scientific achievements in planetary science

The interest of a high precision photometric instrument like CoRoT for the search of transiting planets has been very early identified, just after the discovery of the first exoplanets. As soon as the first exoplanet transit was observed in 1999, it became a priority. While asteroseismology and planet search did not share exactly the same observing requirements, the mission managed to balance the needs of the two. Since then, we have also learnt how complementary the two techniques could be, as the uncertainties on our knowledge of the host star set fundamental limitations when trying to characterize exoplanets (Chap. IV.4). Measuring both the radius and the mass of exoplanets reveals their nature, and accurate measurements give first constraints to their internal structure and formation mechanisms. In this field, CoRoT has been a precursor for several other space-based missions in search for transiting planets, while being complemented by ground-based transit surveys, mostly sensitive to short-period companions.

During the year which preceded the launch of the instrument, scientists interested in the exoplanets quest decided not to work in parallel but instead to organize themselves as a single international team. Indeed, the project commitment stopped to the delivery to the community of light curves properly reduced and corrected for the main instrumental defaults and ready for scientific analyses. The detection of planetary transits was thus left to the discretion of the various teams at the exception of the real-time detection carried out in the "Alarm mode". The later consisted in a weekly analysis of raw light curves carried out in order to detect the most obvious transits and subsequently tune the time sampling to the cadence of 32-s. This real-time detection aimed at having the possibility to observe the possible forthcoming transit events with the highest temporal cadence, so that to accurately derive their shape. It had however another interesting consequence: for the most promising candidates, it gave the possibility to start follow-up observations very early after the beginning of a run, without a six-month delay.

As the launch date approached, it became clear that a wild competition between the teams was likely to be a brake and to undermine the scientific returns. European scientists thus decided to work as a single team and to set up an organization structure able to allow the fair share of the workload and results. This organization also included the complementary observations, whose need was identified early in the mission preparation phase. Such observations were required first to prepare the exoplanet field selection and optimise the target selection process in a given field according to their spectral type and luminosity class (Chap. IV.5). In a second step, they were also mandatory to identify false positives and gather all information that might help the complete characterization of the planets. There were thus see as a key aspect of the mission and early on, a working group was dedicated to the coordination of complementary observations.

Members of this international collaboration on the Exoplanet program of CoRoT took the name of CoRoT Exoplanet Science Team. They identified the necessary analysis steps to get from the light curves to fully secured and characterized planets: 1) the transit detection; 2) the planet parameters factory; 3) the stellar fundamental parameters; 4) the follow-up observations. All that was toped by a coordination team whose role was to ensure that the work was properly done in a timely manner. Members of the collaboration then choose the tasks they were willing to contribute to, thanks to their expertise or their interest in, with, for each of the task, a team leader in charge of providing the final information to the coordination team. In addition to regular yearly meetings, protected Wiki pages were set up to ensure the free share of the information and of relevant documents. They were also used to organize the work on transit detection in the CoRoT light curves and for the follow-up observations of the planet candidates. The advantages of the wiki format was indeed to allow the dynamical editing of the pages by well-identified users and thus regular updates following the rhythms of results. For example, the transit lists issued by the various members of the detection team were posted on these pages and automatically merged. The final ranking of those that were seen as planet candidates was done by the team members during teleconferences where they together assessed a likely origin of the signal, stellar or planetary, for all the candidates identified in a given run. This analysis resulted in a list of ranked planetary candidates worthy of further complementary observations. In addition to the candidates parameters, including ephemerides to be used for the calculation of forthcoming transit epochs, the list provided also some feedbacks to people that carried out follow-up observations.

The team in charge of the follow-up observations has been operating about more than a dozen of telescopes in Europe, Hawaii, Israel and Chile, with size varying from 1 m to 8 m. They have involved various techniques: photometric observations, high contrast imaging (Guenther et al. 2013), and spectroscopy including radial velocity measurements. This important effort has allowed to filter out more than four hundred of candidates and to characterize a few tens of planets. The various steps of this collaborative work and the results achieved that way on both light curves analyses and follow-up observations are presented in Chap. IV.1.

CoRoT was well adapted to explore the close-in planet population. It has opened the domain of the Super-Earth planets, a population that was not predicted by planet formation models but was later demonstrated by Kepler to be numerous. CoRoT has also shown the existence of close-in brown dwarfs that account for about 10% of the substellar objects it detected. This has also resurfaced the question of what distinguishes massive planets from light brown dwarfs (Chap IV.6). For the later, CoRoT has allowed to measure their radii, bringing the first observational constraints to models (Chap IV.8).

For giant planets, the contribution of CoRoT has been very valuable. Massive planets have been found around host stars that are at odds with the regular solar-type stars on which radial velocity surveys concentrate: fast rotators, active stars and even a case of a planetary system whose host star exhibits pulsations (Chap IV.7). The long duration, high photometric precision of the light curves of their host stars, combined with high precision radial velocity measurements has enabled detailed analyses on the planetary system properties, shedding new light on this population.

Beyond the mere detection, the determination of planets parameters with a much better precision than what could be achieved from the ground has allowed detailed analyses on the planets' composition. Accurate masses and radii have allowed the estimate of the amount of heavy elements in a very large diversity of gaseous planet structures, from 0 to 60% of the planet mass (Chap. IV.3). Obtaining, in addition, the complete set of planet orbital parameters, including the eccentricity, has been valuable to explore the orbital evolution of some systems and to set constraints on the planet migration and theories of tidal interactions (Chap. IV.9.2). Finally, the out-of-transit variations induced by star spots at the surface of active stars give us the opportunity to determine the properties of the stellar spots, to determine the rotation of the host star and to better understand the stellar activity (Chap. IV 9.1). Activity features, however, leave their imprints on both radial velocity diagnostics and on the light curve, distorting the transit profiles in the same time. As a consequence, as illustrated by the CoRoT-7b case which orbits an active star, inferring planet's parameters in presence of stellar activity can be very challenging (Chap. IV.2). This has triggered subsequent studies including on the most appropriate observational approach, showing that CoRoT raised new scientific questions, and opened new fields of research.

More interestingly, CoRoT has been a benchmark for the European exoplanet community. It has triggered a new generation of young scientists that became familiar with ultra-high precision photometry and have acquired expertise in it. In a sense the CoRoT light curves have served also as a starting point to prepare future and more ambitious exoplanet missions such as PLATO. In the rising and competitive domain of exoplanets, CoRoT has also demonstrated the value and efficiency of collaborative work, that benefits from different approaches and complementary expertises.

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