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CoRoT and asteroseismology.

Preparatory work and simultaneous ground–based monitoring

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Abstract. The successful launch of the CoRoT (COnvection, ROtation and planetary Transits) satellite opens a new era in asteroseismology. The space photometry is complemented by high–resolution spectroscopy and multicolour photometry from ground, to disclose the pulsational content of the asteroseismic targets in the most complete way. Some preliminary results obtained with both types of data are presented.

Key words. Stars: emission-lines, Be – Stars: individual: HD 50087 – Stars: individual: HD 50844 – δ Sct

1. Introduction

The satellite CoRoT (COnvection, ROtation and planetary Transits) has been successfully launched from Baïkonur into a nearly perfect orbit by a new Soyuz II–1-b rocket on December 27, 2006. It performs photometric observations of stars with unprecedented high accuracy. Its goal is twofold: the study of stellar interiors (the asteroseismic part) and the search for extrasolar planets (the exoplanetary part). The CoRoT mission is a French–led one (75%; the Principal Investigator is Annie Baglin, Meudon Observatory), but also Spain, Austria, Belgium, Germany, Brazil and ESA are involved. After an initial participation which collected a wide interest in the national community, the Italian Space Agency ASI withdrew the official support to the project.

The mission has an unique instrument: a 27–cm aperture telescope equipped with two CCDs for each scientific case. The selected CoRoT direction of pointing is a double–cone (the CoRoT eyes) centered at α=6h50m/18h50m (galactic Anticenter/Center), $\delta = 0^o$; the radius of each eye is 10^o. To achieve its goals, CoRoT will uninterruptedly observe five fields for 150 d each (long runs). The field–of–view of each pointing is 1.3x2.7 deg^2. In the asteroseismic channel this will result in high–precision photometry, with an expected noise level in the frequency spectrum of 0.7 ppm (parts per million) over a 5 d time baseline for a $V \sim$6.0 star. Michel et al. (2006) give a very detailed discussion of the Seismology Programme

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of CoRoT and stress the importance of the asteroseismic approach to the open questions of stellar physics.

We remind that in the exoplanetary channel CoRoT monitor simultaneously up to 12000 stars in each long run in the 11.0< V <16.0 range. Thus, during the expected 2.5–y satellite lifetime, a total of 60,000 light curves will be produced at a sampling rate of 8 min. The extrasolar planets are detected by measuring the weak decrease of the star flux due to the transit of a planet in front of the star disk. Barge et al. (2006) describe the methods which will be used to extract the transit signature from the data and also comment the scientific impact of the mission; Poretti et al. (2006) describe the Italian contribution to this exoplanetary research.

At the moment, all the on-board systems are working as efficiently as predicted, in some cases significantly better than expected. Therefore, it is not surprising that the analysis of the raw data (i.e., not all the sources of noise have been taken into account yet and removed from the data) already disclosed the first exoplanet, CoRoT-Exo-1b[1].

2. The survey of the fields around primary targets: the Serra La Nave contribution

Despite the ASI withdrawal, a group of researchers still remained active on various aspects of the CoRoT mission. Poretti (2003) described the Italian contribution to the preparatory work to select the asteroseismologic targets and to build up the GAUDI archive. In that part of the Italian contribution, the Telescopio Nazionale Galileo played a crucial role in completing the observational tasks on time to respect the tight time schedule. After those observations, the short list of the candidate primary targets was issued. We would like to stress here a subsequent relevant contribution, i.e., the observations carried out with the FRESCO (Fiber–optic Reosc Echelle Spectrograph) instrument mounted at the 0.91–m Cassegrain telescope of the Serra La Nave mountain station (1725 m above sea level) of the Osservatorio Astrofisico di Catania. About 120 stars have been monitored in the spectral range from 430 to 680 nm (R=21,000 in the cross–dispersion mode). Thanks to these observations it has been possible to search for secondary targets located around the already selected primary ones, particularly in the 8.0< V <9.5 range. Indeed, this range was not covered by the previous surveys performed at ESO and Haute Provence Observatory, where the limiting magnitude was V <8.0 in the complete area of the CoRoT eyes. As an example of the usefulness of Serra La Nave observations, Figure 1 shows the spectrum of a newly discovered Be star.

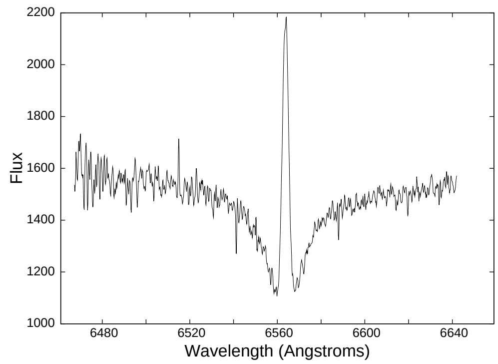

Fig. 1. The Hα line of HD 50087 shows the emission peak typical of Be stars. The spectrum has been obtained at Serra La Nave Observatory with the FRESCO spectrograph.

3. The first asteroseismic targets

Table 1 lists the stars which have been observed in the asteroseismic CCDs in the IR01, i.e., in the observing run (60 d long) immediately following the start of scientific activities. The excellent CoRoT performances are proved by the detection of the fingerprint of the asteroseismic oscillations, i.e., the regular spacing of the peaks in the power spectrum of a solar–like star[1]. As a preparatory work for the CoRoT mission, we planned spectroscopic observations to detect line–profile variations in the spectra of the asteroseismic targets. We

[1] see http://www.cnes.fr/web/5891-corot-decouvre-sa-premiere-exoplanete-.php

Table 1. Targets of the IR01, ordered according to decreasing brightness. The stars observed at ESO are in italic.

Star		V	Sp.	Notes
HD	*50747*	5.45	A4	SB2
HD	49933	5.78	F2V	
HD	50890	6.03	G6	Giant
HD	50820	6.27	B3IV	Be, SB2
HD	50170	6.86	F2	
HD	*51106*	7.35	A3m	SB2
HD	*50846*	8.43	B5	Eclip. variable
HD	*50844*	9.09	A2	δ Sct
HD	50773	9.36	A2	
HD	*292790*	9.48	F8	

are applying to the CoRoT targets the know–how we acquired in several years of ground–based studies on some classes of pulsating stars (δ Sct, β Cep, γ Dor, Be, ...). In particular, a Large Programme has been granted at the FEROS@2.2m ESO-MPI instrument (fifteen nights per semester for four consecutive ESO periods), covering the first 1.5 y of the CoRoT lifetime. Moreover, other Large Programmes will be carried out at the Observatoire de Haute Provence (using the new SOPHIE@1.92m instrument) and at the Calar Alto Observatory (using the FOCES@2.2m instrument).

Only the analysis of the line–profile variations will allow us to identify the excited modes, since in the stars located in the instability strip and on the upper Main Sequence the regular spacing is destroyed by the mode selection operated by nonlinear effects. Figure 2 shows an example of evident line–profile variations in the spectra of the δ Sct star HD 50844. The mean line–profile has been calculated for each R=48,000 spectrum; the nonradial modes are seen as propagating waves across the spectral line. For an example of mode identifications in δ Sct stars see Zima et al. (2005).

In Table 1 the targets observed during the first runs at ESO, OHP and Calar Alto are indicated in italic. In addition to HD 50844, line–profile variations have been detected in the spectra of the γ Dor HD 49434 and of the Be star HD 50209. All the FEROS spectra have been reduced by the Brera team and delivered to the teams responsible for the data analysis

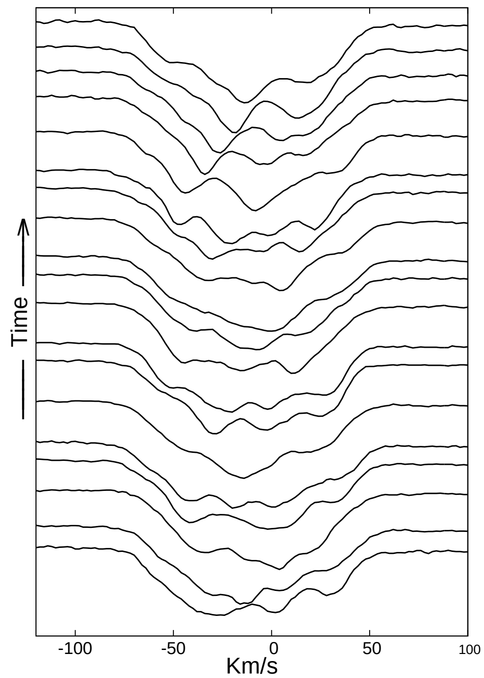

Fig. 2. The signature of nonradial modes are clearly visible in the average profiles of the δ Sct star HD 50844 on the night of January 6th, 2007. The observations were carried out with the FEROS instrument mounted on the 2.2m ESO-MPI telescope at La Silla.

of the respective stars (Nice, Leuven, Granada, and Meudon). Also the observations of the binary stars, carried out mainly to obtain a radial velocity curve and subsequently an orbital solution, revealed intriguing features: HD 50747 is a triple system and one of the components of HD 50846 is a Be star.

In addition to high–resolution spectroscopy, we continued to monitor the asteroseismic targets in multicolour photometry. Indeed, the CoRoT photometry does not supply any colour information, since it is unfiltered. It is well known that phase shifts and amplitude ratios can supply useful constraints to identify pulsation modes (Garrido, 2000). Figure 3 shows an example of *uvby* light curves obtained on HD 50844 at S. Pedro Mártir Observatory; the accuracy of a single point is about 0.002 mag in the

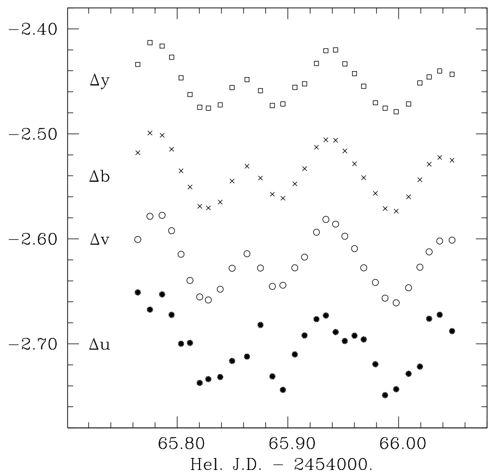

Fig. 3. The *uvby* light curves of the δ Sct star HD 50844 obtained on the night of November 25, 2006 at S. Pedro Mártir Observatory. The magnitude differences have an arbitrary zeropoint.

vby filters and around 0.008 mag in the *u* filter. This photomeric project is performed using the observational nights granted to Brera Astronomical Observatory and is flanked by a similar one at Sierra Nevada Observatory (Spain); the projects use two twin Danish photometers. The photometric observations from ground allow detection of terms with amplitudes of about 1 mmag (Poretti, 2000), while CoRoT will arrive to 2–3 orders of magnitudes smaller (Michel et al., 2006). Therefore, complementary ground–based campaigns can help to identify only the terms with the largest amplitudes. However, by combining the photometric results with the spectroscopic ones we could put some useful and tight constraints on the theoretical models. We stress that CoRoT will supply frequencies free from aliasing effects (thanks to the 150 d continuous observations) and therefore the identification of the exact values of the frequencies is not a severe problem.

4. Conclusions

During all the preparatory activities for the CoRoT space mission the contribution from the Italian community has been very valuable, allowing first the monitoring of stars with V <8.0 in the CoRoT eyes and then that of fainter secondary targets located closely to the primary ones. The use of national (Telescopio Nazionale Galileo) and local (Serra La Nave Observatory) facilities has been decisive and crucial. Also considering the full characterisation of the exoplanetary fields and the study of the interaction between stellar activity and planetary transit detection (Poretti et al., 2006), the Italian researchers provided original and useful inputs to the scientific profile to the mission.

New contributions and a very promising feedback in terms of understanding of the stellar physics are expected from the full exploitation of the ground–based monitoring of the asteroseismic targets.

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