Characterization of COROT seismology targets

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ABSTRACT

We have started to build preliminary entry catalogues of potential targets for the COROT seismology programmes. In order to complete our a priori knowledge on each one of these potential targets, a vast ground-based effort was initiated to determine the fundamental parameters (T_{eff}, $\log g$, [Fe/H], $v \sin i$, etc...) of the 1,100 potential targets of the COROT central and exploratory asteroseismology programmes. We use echelle spectrographs at OHP (Elodie spectrograph), and Sutherland (Giraffe spectrograph), as well as a semi-automatic photometric telescope near Granada. We plan to complement these observations with spectroscopic runs at ESO (1.52m+FEROS) and La Palma (INT+ESA-MUSICOS). With data collected at all these sites, we are setting up a database of high (35,000 - 40,000) resolution echelle spectra and Strömgren photometric data for all of these stars. We intend to gather all of these data, as well as the determined parameters and characteristics, in a single database accessible by the community.

1. The COROT programmes

The COROT operations are based on two programmes.

The *COROT central programme* is based on a series of at least 5 sequences of 150-days monitoring of the target fields. The focal plane of COROT, composed of 4 frame-transfer CCD, will be divided in two fields 1.2 x 2.4 degrees each: the asteroseismology field and the exoplanet field.

Each asteroseismology field contains one or two bright stars, either solar-type with $m_{\rm V} \leq 6$ (F or G main sequence stars) or δ Scuti with $m_{\rm V} \leq 9$, which are the main targets of the mission. In addition, about 10 fainter stars ($m_{\rm V} \leq$ 8-9) of all spectral types will be monitored at the same time in each asteroseismology field.

The sequences of the central programme will be 5 month long. Every 6 months, the line-of-sight will be flipped by 180° in order to keep the Sun on the backside of the payload. In the remaining 1 month between the end of a central programme sequence and the flipping maneuver, stellar fields will be monitored for about 10-30 days, constituting the *COROT exploratory programme*. The objective of these observations will be an exploration of stellar oscillations all across the HR diagram. In each field of this exploratory programme, up to 10 stars will be monitored, with magnitudes $m_{\rm V} \leq 8 - 9$, of all spectral types, on or near the main sequence.

2. Entry catalogues for seismology

The most important asteroseismology targets of this mission are the bright stars of the central programme. The targets of the seismology central programme must be such that stellar fields exist in their immediate vicinity that comply with the requirements of the exoplanet search programme (sufficient stellar density, absence of bright source or nebulosity, etc...). Based on these requirements, the fields around each potential seismology bright target were examined, and a first selection of adequate targets was achieved.

These first steps of the COROT target selection resulted in a list of potential seismology targets for the central programme. Out of the 123 bright ($m_{\rm V} \leq 6$) F or G dwarfs or sub-dwarfs in the declination band accessible by the telescope, 39 comply with the exoplanet search requirements. For the δ Scuti stars, we find that 10 of them brighter than $m_{\rm V} = 9$ would be observable.

During all its lifetime, COROT will observe in the same general direction of the sky, near the pole of its orbit, so that the observations do not suffer Earth occultation. With this observing contraint added to the requirements above, we determined two possible choices for the general observing direction of the telescope, both centered at zero declination.

The target fields for the exploratory programme must be located in the same area of the sky. This is why we built additional catalogues containing all stars with $m_{\rm V} \leq 8 - 9$, excluding giants on the basis of Hipparcos data when available, in the two nominal directions of pointing. This yields in particular a catalogue of more than 1000 stars of all spectral types, as potential targets for the exploratory programme.

The two possible scenarios of observation are indicated in Fig. 1, showing the potential targets of the central seismology programme in the plane of the sky.

3. Needed information on COROT targets

For an optimal selection of the bright stars of the central programme, it is essential to gather as much a priori information as possible on all potential targets. In particular, a precise and reliable knowledge of their effective temperatures, surface gravities and detailed abundances is necessary. In addition, indications of their surface rotation rates, or their projected rotation velocities, is required to optimize the target selection. We also need to eliminate multiple stars in which the components have similar types, and finally we need to be aware of all peculiarities of each selected target (such as, e. g., high activity level). Finally, we need to check for the presence of polluting nearby sources, that might affect the photometric algorithms that will be run both onboard and on the ground. Given the importance of the final selection of the targets of the COROT seismology central programme, that will determine the choice of the orbit ascending node, we consider it necessary to gather all of this information prior to target selection. In addition, a precise knowledge of all fundamental parameters of each selected target ($T_{\rm eff}$, $\log g$, abundances, rotation) will be necessary during the data analysis phases to better constrain the stellar interior models.

We also need some a priori information on the fainter potential targets of both the central and the

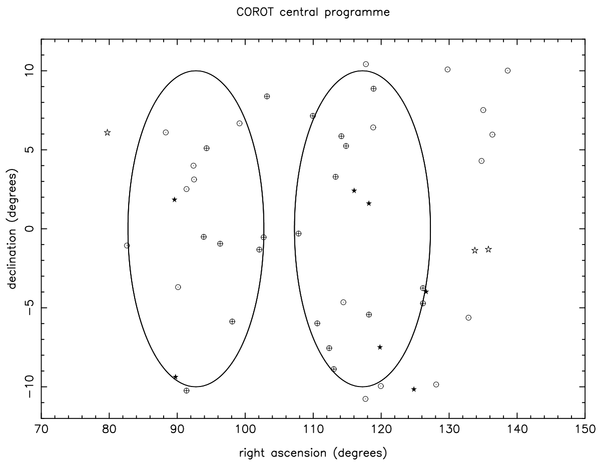

Fig. 1.— Potential targets of the COROT seismology central programme. The circles are bright solar-type stars (F and G-type, luminosity class IV or V), while the asterisks are δ Scuti stars. The right ascension axis is represented modulo $180°$ so that targets for both seasons are plotted next to each other (crossed circles and filled asterisks for $\alpha \leq 180°$, dotted circles and empty asterisks for $\alpha > 180°$). The two possible scenarios are indicated by the black ellipses.

exploratory programme in order to select those that COROT will observe. First of all, we need their spectral types, luminosity classes and metallicities, to ensure that the selected targets will provide a sufficient coverage of the parameter space in order to reach a sufficient exploration of stellar oscillations. We also need to make sure that the rotational velocities of the selected targets are well distributed. Finally, it is also important to exclude multiple systems with components of similar types, and to evidence any peculiarity of the potential targets. All of this information is required to perform an optimized target selection for the exploratory programme.

Once the selection of the targets of the exploratory programme is complete, it will also be necessary to derive for these sources the same information as for the bright stars of the central programme: $T_{\rm eff}$, $\log g$, abundances, rotation, this information being needed for improving the scientific return of the seismological data.

4. Ground-based observations in preparation for COROT

While we already have some knowledge of the characteristics of the COROT potential brights targets of the central programme, we note that the potential targets of the exploratory programme are not well-known, and in particular we lack knowledge of the luminosity class, metallicity, and rotation velocity of most of them. Besides, their spectral types, as taken from stellar catalogues, are sometimes not reliable, and their eventual multiplicity is often ignored. In addition, the knowledge of even the bright targets of the central programme is not sufficient to allow us to optimize their selection. In particular, the determinations of their effective temperatures, surface gravities, and metallicities are not precise enough, and most of them have no measurement of their surface rotation. In most cases, there is no detailed abundance analysis available.

This is why we decided to launch an ambitious ground-based programme to answer all of these questions, and gather all of the necessary information on the COROT potential targets. This programme has several components.

- *Strömgren photometry:* we perform Strömgren uvby-Hβ photometry of all COROT potential targets, both for the central and exploratory programmes. We use the semi-automatic photometric 80cm telescope at Pico de la Veleta (Spain). These data will be used to derive estimates of $T_{\rm eff}$, $\log g$, metallicities, for the majority of these potential targets. These observations are almost complete.
- *High resolution echelle spectroscopy:* these additional observations are necessary to obtain an independent and precise measurement of $T_{\rm eff}$, $\log g$, of the detailed element abundances, and of the projected rotation velocity. Besides, echelle spectra can allow us to detect multiple systems, as well as any spectroscopic peculiarity that could have an impact on the target selection. These spectroscopic observations are being conducted on 2m-class telescopes equipped with high resolution echelle spectrographs (R=30,000- 40,000): OHP 1.93m/Elodie, SAAO 1.9m/Giraffe. We plan to include as well observations from 2.5m INT/MUSICOS and from the ESO 1.5m telescope equipped with the FEROS spectrograph. We estimate that a total of 200 nights are required to complete this programme of observation of about 1,100 stars, which is about half-completed today.
- *High angular resolution imaging:* these observations are important to know where polluting nearby sources are located to include this information in the photometric algorithms, and eventually to exclude stars from the target list in the most difficult cases. We plan to search for polluting sources within a few arcmin around each selected star, using digitized Schmidt plates, then to perform adaptive optics imaging observations (e. g., with the AOB of CFHT) in the immediate vicinity of the stars (up to 1 arcmin).
- *Ca II H & K index monitoring:* this type of observations is necessary to characterize the level of activity of the targets, and to determine their surface rotation period by detecting the rotational modulation of the Ca II H & K index. Although this will be possible only for the most active stars in the target list, we believe that the knowledge of the activity level and the surface rotation period is sufficiently important to justify this effort.

5. Some results

About half of the high resolution spectra have been already obtained and reduced. We first examine the mean photospheric profiles of the stars, using the Least-Square Deconvolution technique (Donati et al. 1997). This method, using the information contained in the many lines in the spectrum, is very efficient for the accurate measurement of the projected rotation velocity, as well as for detecting multiple systems. We have already detected in this way several SB2 systems that were not reported in the literature.

We have also detected tiny photospheric profile variations for several stars. In particular, the stars HD 49434, HD 46304, HD 171834 and HD 164259, observed continuously for several hours, show photospheric perturbations crossing the line profile from blue to red in a characteristic time scale of 1 hour, which is typical for the perturbations created by nonradial oscillations of δ Scuti stars. A detailed analysis of these photospheric perturbations is under way.

We have also started a detailed analysis of the highest S/N ratio spectra, aimed at deriving accurate values of $T_{\rm eff}$, $\log g$, and element abundances in these stars.

For most of the spectra of the potential targets of the exploratory programme (1,100 spectra), we need to develop some kind of automatic stellar classification algorithm to derive their effective temperature, surface gravity and metallicity. Several methods are being tested, among which the "tgmet" algorithm (Katz et al. 1998, Soubiran et al. 1998), which compares the observed spectrum with those of a reference library, built in the same conditions, and returns the few library spectra that resemble most the observed one. Another promising approach is based on neural networks, on which a small group is working at Observatoire Midi-Pyrénées.

6. A stellar spectroscopic and photometric database

The data acquired during this preparation work, as well as the derived stellar fundamental parameters and characteristics can be assembled in a database, which we intend to build in the coming months or years. This database could include the following information, for each star:

– full visible spectrum at 30,000 or 40,000 resolution
– Strömgren uvby-H$_\beta$ photometry
– $T_{\rm eff}$, $\log g$, [Fe/H] from photometry
– $T_{\rm eff}$, $\log g$, abundances from spectroscopy
– radial velocity, $v \sin i$
– multiplicity, peculiarities
– variability index

It could also include various useful tools, such as reduction packages, Kurucz codes and models, line lists, etc...).

We note that the use of such a database would certainly go beyond the framework of COROT, and be a perfect tool for programmes such as statistical studies of rotation velocities, stellar activity, binarity, stellar abundances, etc... It can also be used for the preparation of other asteroseismology space missions, such as the danish MONS project.

REFERENCES

Donati J.-F., Semel M., Carter B. D., Rees D. E., Cameron A. C., 1997, MNRAS 291, 658

Katz D., Soubiran C., Cayrel R., Adda M., Cautain R., 1998, A&A 338, 151

Soubiran C., Katz D., Cayrel R., 1998, A&AS 133, 221