28

PRISMA: A mission to study interior and surface of stars

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Abstract

New technics such as asteroseismology are able to sound the deep interior of stars and to provide the data that will constrain the modelisation of the core. This information will be combined with data collected from the stellar surface which give direct access to measurements of the radiative losses, angular momentum losses and distribution of active structures. From the two sets of data, the key role of the convection zone will be clarified, as the convection zone excites the waves that propagate through the whole star and generates the magnetic field that structures the stellar surface. The PRISMA mission was developed to collect the data needed for detecting the oscillations by very accurate photometry (micromagnitude) and to derive the surface activity and rotation from accurate ultraviolet spectroscopy. A short description of the model payload is given with the observational constraints related to the needed accuracy of measurements. Following the non-selection by ESA in may 1993, some following perspectives are described.

28.1 Introduction

The sounding of the stellar interior can be traced either by neutrino detection or by reconstruction of the path of travelling waves perturbing the surface. Asteroseismology is the study of such waves detected either in brillance or in velocity fluctuation. Up-to-now the use of such fluctuations (Grec et al, 1980; Frohlich and Toutain, 1992) has been proven to be a powerful diagnostic tool to modelise the solar interior (Gough, 1985). The stellar surface vibrates with modes of increasing number as they propagate down to the deep interior or are reflected near the surface. The detection of those modes is related to the resolution on the stellar surface. Low modes, such as $l = 0, 1$ and 2 penetrate in the deepest part of the star, near the core, and can be detected from the global measurement of the star. High modes, e.g. 500-1000, penetrated only few hundredth of stellar radius and can only be detected with high resolution on the surface. All the range of modes have been detected on the Sun, but on star where the surface cannot be resolved we have only access to low modes (0,1,2 and 3). The oscillations of late-type stars are driven by stochastic fluctuations of the convection envelopes and the oscillations detected are believed to be excited in the layers immediately below the photosphere. The magnetic field generation inside the star is detected by the manifestation of star activity either in the form of dark spots in the photosphere or of bright plages in the chromosphere and the corona. The magnetic field generation is probably generated through a (or a multiple) dynamo process at the base of the convection zone in the case of the Sun (Belvedere et al, 1991). In late-type stars such a process can be envisaged. Following the path opened by EVRIS (Baglin, 1994) the PRISMA mission (Probing Rotation and Interior of Stars: Microvariability and Activity, Appourchaux et al, 1993a and 1993b) has been proposed to study the interior of stars using simultaneous observations of the global intensity fluctuation and of the manifestation of activity at the surface and in the atmosphere.

28.2 Scientific objectives and requirements

The broad scientific objectives are:

- the study of the structure, evolution and dynamics of stellar interiors.
- a determination of constraints on models of magnetic field generation by dynamo processes.

Through the use of two differents tools, asteroseismolgy and measurement of activity, the data needed to fulfill the scientific objectives will be collected:

i) asteroseismology:

- the purpose is to test and improve models of stellar structure and evolution. This will yield a better parameterization of physical processes (mixing length, equation of state, opacities), as well as a reliable determination of the basic stellar parameters (mass, age, chemical composition).

- the second purpose is a measurement of stellar internal rotation. This

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will give an observational basis to models of angular momentum loss and transport.

- another goal is the study of mode excitation processes.

These goals will be reached by the observation of the frequencies, amplitudes and lifetimes of eigen-modes of oscillation.

ii) stellar activity:

- the major purpose is to study the emergence of the magnetic field at stellar surface (which will provide tests of dynamo and convection models, when combined with the results of the asteroseismology experiment), and the processes of energy deposition in atmospheric layers.

- another goal is the precise determination of surface rotation rates (which yield estimates of differential rotation when combined with the results of the asteroseismology experiment).

These goals will be reached by monitoring, during the stellar rotation, the temporal evolution of several UV and X-ray emission lines, probing various levels in the stellar atmosphere. The resulting time-resolved 3D picture of the atmosphere will provide the topology of the surface magnetic field and the vertical structure of the atmosphere.

28.3 Constraints and payload

The quantities to be measured (table 1) are: - a - the intensity of visible light within a very large band pass with a very good photometric accuracy with a sensitivity better than 10^{-6} magnitude in amplitude per frequency band with 1.- 0.4 μHz resolution (10-30 days of continuous observation on the same stars).

Two photometric telescopes are used to fulfil this objective. The Large Photometer (with a collecting area equivalent to 40 cm diameter) is able to collect simultaneously the flux from a few stars (m_v smaller than 8) within a field of 1.5 x 1.5. The Small Photometer (15 cm diameter equivalent area) points in another direction and collects simultaneously the flux from a few stars (m_v smaller than 6) within a 3 x 3 field.

- b - the flux and profiles in UV lines which measure the stellar activity level: e.g. MgII l2796, HeII l1640, CIV l1550 and HI La l1216 with few percent photometric accuracy. It needs to be complemented by the flux in one X- ray channel (e.g. l170). The activity segment comprises on one hand a telescope selecting stars within the 1.5 x 1.5 field of view of the Large Photometer to feed a cross-dispersed spectrograph (with performances similar to the IUE high resolution mode), and on the other hand a 15 cm diameter, normal incidence, multilayer telescope. The two telescopes are aligned with

Table 28.1. *Quantities to be measured (from Lemaire et al.,1991). WD and CV stand respectively for white dwarfs and cataclysmic variables. The last column indicates the instrument : (a) ≡ photometer; (b) ≡ UV spectrometer; (c) ≡ XUV telescope*

Observable	Sensitivity scale	Time	Sampling time	Typical stars	
	10^{-7} mag	1 month	1 min	Bright	*a*
Frequencies	0.02-20 mHz			solar type	
Amplitudes	10^{-6} mag	1 month	1 min	variables $m_v = 8$	*a*
Rotational splittings	10^{-4} mag	1 month	sec.	WD,CV	*a*
	0.05	P_{rot} 0.5-50 day	1 min	Bright solar-type	*b*
UV-line	0.05	P_{rot}	$P_{rot}/5$	solar type	*b*
profiles	0.10	P_{rot} flare	10 min.	Bright solar-type	*c*
X-ray flux	0.10	P_{rot}	$P_{rot}/5$	solar type	*c*

the Large Photometer pointing axis and the UV spectrometer samples stars in the field to cover the phase of the star rotation.

To accomplish the scientific objectives of the PRISMA mission, within the two nominal years, a special scheme of observation has been studied that allows the recording of more than one hundred stars distributed in the Hetzprung- Russel diagram nearby the main sequence and including two open clusters. Within the choice of several hundreds of fields, a preliminary catalog has demonstrated the possibility of filling this set when staying one month over each field to obtain the photometric spectral frequency resolution.

28.4 Conclusion

The coupling of asteroseismology and surface activity measurements is a powerful tool to diagnose the stellar interiors. The PRISMA mission proposed this goal. Following the selection procedure at ESA (European Space Agency) in April-june 1993 the mission was not selected. Nevertheless on the line are appearing 2 missions to study the stellar interiors:

- COROT (Catala et al, 1993), a CNES (Centre National d'Etudes Spatiales) study to continuously look at few bright stars during several months in order to have a very accurate measurement of frequencies to derive precise informations on stellar structure.

- STARS (Jones et al, 1993), an ESA study to look at several hundreth of stars with emphasis on clusters that can be used to calibrated several parameters of the internal structure.

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