Sodium cell spectrophotometer for detection of stellar oscillations

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ABSTRACT: This paper describes the new version of our instrument used for detection of stellar oscillations. It is planned to use it next year for observations of Procyon and α Cen in order to confirm the results already obtained. Because the prototype used in these first attempts did not succeed to be photon noise limited, it has been significantly redesigned in order to improve the situation regarding every source of noise.

1. Introduction.

Already described in its principle (Fossat et al. 1982), the instrument acts as a very stable filter with two narrow bands (about 0.1 Å each) centered on the laboratory wavelengths of the sodium lines D1 and D2. The exact location of these spectral windows in the stellar spectrum depends then on the relative line of sight velocity between the telescope and the star (figure 1). By adequately selecting the observing season, the orbital motion makes possible to measure the flux in one wing of the sodium absorption stellar lines. A small Doppler shift of these lines produces the measured variation of flux in the narrow bands of the filter.

The filter itself is a single so-called Cacciani-cell magneto-optical filter (Cacciani et al. 1970). It consists of Na vapour in a longitudinal magnetic field between two crossed polarizers. The latter cut off all of the stellar spectrum, except for those wavelengths for which the vapour, due to magneto-optical effects, changes the state of polarization. The advantages of this sodium cell filter are essentialy a very good intrinsic spectral stability, and a high level of photon efficiency for such a narrow filter. The major inconvenient is the very drastic limitation of use to the pair of Na D lines. They are not always the best choice, they do not give access to stars hotter than late A spectral type, and the filter does not allow much degree of freedom on the choice of the

J. Christensen-Dalsgaard and S. Frandsen (eds.), Advances in Helio- and Asteroseismology, 513–516.
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https://doi.org/10.1017/S0074180900158619 Published online by Cambridge University Press

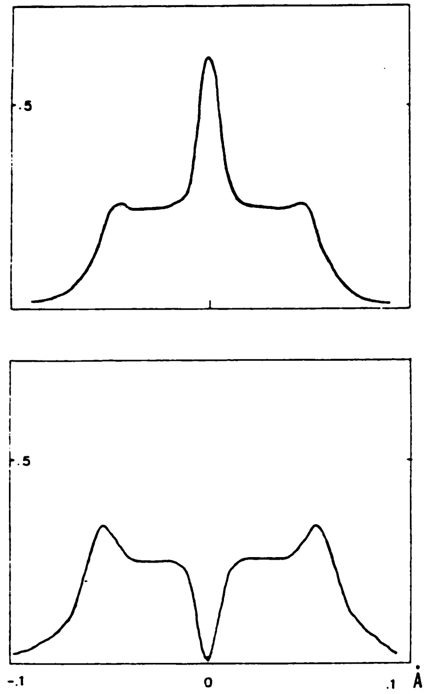

Fig 1. The two curves are the transmission of the filter constituted by the sodium cell between two crossed polarizer respectively for D1 and D2.
The bandwidth and the transmission depend on the optical path in the cell and on the magnetic field value. Here the optical depth is about 30 and the magnetic field is about 1500 Gauss.

observing date for a given star. Also, the photon noise resulting of the use of only two narrow spectral bandwidths limits the use of the instrument to the brightest stars at the focus of the largest telescopes. However, not very many other instruments have been succesful so far in asteroseismology. We then feel that despite its limitations, it is worth continuing to develop this one for a while.

2. Description.

The figure 2 shows the optical scheme of the instrument. The Barlow lens adjusts the optical aperture of the telescope to the one of the instrument itself. The interferential filter selects a 20 Å bandwidth centered at 5893, including both D1 and D2 stellar lines. The magnetic field and the sodium vapour temperature are adjusted to optimize the bandwidth shape and the optical transmission within this bandwidth (see Agnelli et al, 1975, for detail). The second calcite polarizer is a Foster prism, which geometrically splits in two perpendicular beams the two states of linear polarization. The direct beam contains the monochromatic signal, while the other one is used as a reference to correct for atmospheric fluctuations (transparency and scintillation).

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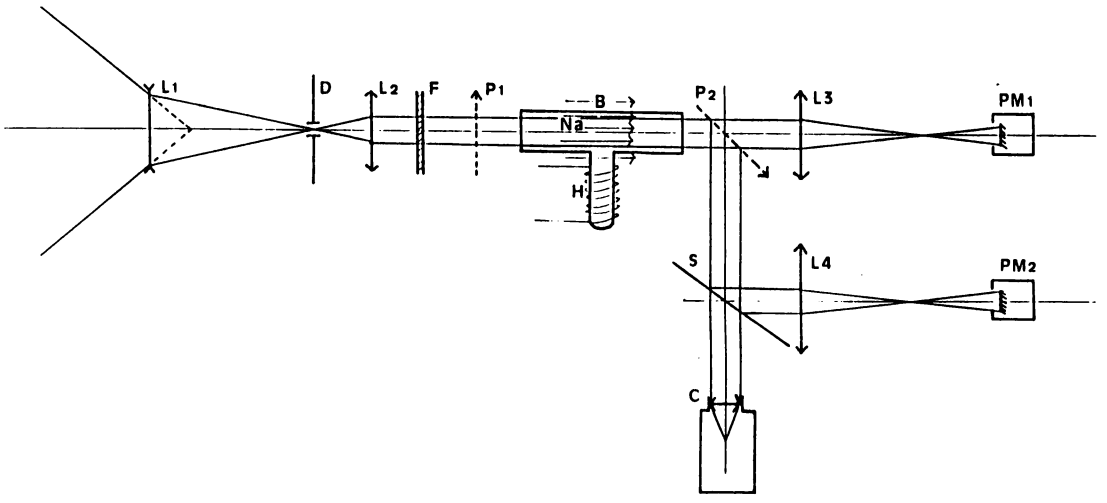

Fig 2. Optical scheme of the instrument.The beam passes through a Barlow lens L1, the diaphragm D, the second lens L2, the interferential filter F, the polarizer P1 before the sodium-cell which is heated and is inserted in a magnetic field. At the output, it is split in two different polarizations by the Foster prism P2. The two beams then feed the photomultipliers PM1 and PM2. C is a guiding T.V. camera.

The sodium-cell is something new as compared to the one used in our prototype instrument. The hot sodium vapour inside a vacuum cell chemically reacts with the glass. This reaction results in a darkening of the cell windows, and our prototype cell had a lifetime not longer than a few nights.

The new concept (suggested by A. Cacciani) consists of introducing into the cell a neutral gas (Argon) to limit the free-path of sodium atoms to the center of the cell and avoid condensation on the optical windows. In this design, the optical part of the sodium cell is not heated, and the lifetime in increased to several months, quite long enough compared with the usual duration of an observing allocated time on any large telescope.

The photomultiplier is chosen to have the highest quantum efficiency and its dark current is reduced to a non disturbing level simply by cooling it.

In our prototype, the major source of noise (with clear sky) was an insufficient rejection of guiding errors. The two beams being geometrically separated after the Foster prism, their random motions due to guiding could never be entirely corrected by division. This situation will be improved by putting a T.V. camera directly in the reference channel beam. It will make possible to guide automaticaly the telescope on our star, and independently of the interface between the telescope and the instrument.

No test have yet been made as the instrument is now under construction. The expected performance for a photon-noise limited observation is the detection, with a signal-to-noise ratio of 3(a

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three-sigma level), of a 50 cm/s velocity amplitude per single mode by observing a zero magnitude star with a four meter telescope during one night. Therefore, a few nights of observations should provide a sufficient confidence in the detection of oscillations of solar amplitudes. On the other hand, the day-night alternance will always degrade the resolution by introducing fringe systems which have typically the same frequency separation as the pairs of eigenmodes of degree 0 and 2, or of degree 1 and 3. This problem has long been studied and debated in the case of the sun, and results in the several projects of wordwide networks that you know. Although it is not yet reasonably conceivable to organize a worldwide network of stellar observations, we plan to do a first step in this direction, by a joint observation using two large telescopes separated of about 12 hours in longitude. Our initial target will be Procyon, in february 1988, observed simultaneously from Mauna Kea with the CHF 3.6 meter telescope, and from Zelentchuk with the SAO 6 meter telescope.

References.

Agnelli G., Cacciani A., Fofi M.: 1975 *Solar Physics* **44**,509

Cacciani A., Cimino M., Fofi M.: 1970 *Solar Physics* **11**,319

Fossat E., Decanini Y., Grec G.: 1982 in C.M. Humphries (ed) *Instrumentation for Astronomy with Large Optical Telescopes*, 169

Gelly B., Grec G., Fossat E.: 1986 *Astron. Astrophys.* **164**,383

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