

## Studies of chemically peculiar stars

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**Abstract.** This thesis is on the framework of the “NainiTal-Cape Survey” programme for searching photometric variability in chemically peculiar stars, initiated in 1997 at the ARIES, NainiTal, India, in collaboration with the South African Astronomical Observatory, Cape Town and ISRO, Bangalore. This paper presents the corresponding results. The Am stars HD 98851, HD 102480, HD 13079 and HD 113878 were discovered to exhibit a  $\delta$  Scuti type of variability. Photometric variability was also discovered in HD 13038, for which the type of peculiarity and variability is not yet fully explained. The null results obtained in this survey are also presented and discussed, as they provide an interesting data reference for upcoming studies.

*Keywords :* stars: chemically peculiar — stars: variables: other –  $\delta$  Scuti

### 1. Introduction

The chemically peculiar (CP) stars are a group of stars having peculiar surface elemental abundances. These abundance anomalies can be detected by evidencing abnormally strong and/or weak absorption lines in the optical stellar spectra. The range of the effective temperatures of CP stars is about 6500 to 25000 K (Lanz 1993). In this temperature range, the physical process called *diffusion process* takes place; this process is understood as being responsible for the stellar peculiarity (Vauclair et al. 1974). The present investigation focuses on two classes of CP stars which are of special interest from the asteroseismologic point of view, namely the A-peculiar (Ap) and the A-metallic (Am) stars. Both classes correspond to stars lying in the spectral range of late A to early F. The Ap stars are characterized by an over-abundance of Si, Cr, Sr, Eu and other rare

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earth elements. The magnetic field's strength of the order of few kilo Gauss are found. The Am stars exhibit an under-abundance of Ca and/or Sc, and an overabundance of heavy metals. The corresponding magnetic field is not detectable in these stars. Very interestingly, a few Ap stars show photometric variability with periods in the  $\approx [5 - 21]$  min range. These are known as rapidly oscillating Ap (roAp) stars (Kurtz 1990). In contrast to the roAp stars, some Am stars exhibit photometric variability similar to the  $\delta$  Scuti stars. The corresponding periods range from  $\approx 18$  min to as long as  $\approx 7$  hr. The theory of the underlying mechanisms leading to pulsations in these two classes of stars is far from being complete. This is partly due to the quite restricted number of stars which are known in these somewhat new classes of variables. For example, hardly 33 roAp stars are currently known, among which only 3 belong to the northern hemisphere's sky. Consequently, a number of survey programmes have been, or are being carried to try to detect pulsational variability in CP stars (*e.g.* Martinez 1992, Martinez et al. 1994a, 1994b, Handler 1999, Dorkhova et al. 2005). In this framework, the "NainiTal-Cape Survey" was started in 1997 at the ARIES to search for both long and short-term flux variations in peculiar stars (Seetha et al. 2001). The author's thesis work is fully devoted to support this programme.

## 2. Summary of the thesis dissertation

The thesis focuses on photometric and spectroscopic observations of CP stars. The amplitude of the flux's variations in CP stars represents typically a few milli-magnitudes. In order to improve our chances to detect new variables, we had to inspect a large number of candidates. This strategy requires a considerable amount of telescope time. Furthermore, the detection of such small amplitude variations requires regular photometric sky conditions as long as a very stable and devoted photodetector. Such a survey sets consequently many constraints on the astronomical environment which will support the observations. It turned out that the astronomical site of Nainital and the corresponding observing facilities could fulfill these requirements, and make such an intensive and demanding study successful. The photometric observations of the Ap and Am stars were carried out with a three-channel fast photometer attached to the 104-cm Sampurnanand telescope of the ARIES (Ashoka et al. 2001, Sagar 1999). Our candidates for the survey comprised both Ap and Am stars selected from the catalog of CP stars (Renson et al. 1991, Renson 1994). A total of about 80 stars were observed several times during the period Oct 1997 to May 2003. The strategy adopted for this work was to observe each object for one to two hours during several nights. If any candidate was found (or suspected) to show some photometric variability in the preliminary observations, then follow-up observations were carried out in order to further investigate the variability and/or to refine the detected periods. The photometric data reduction chain consist of the dead-time correction for the PMT counts, the subtraction of the linearly interpolated sky's background and the extinction correction as a function of the air mass. The presence or absence of coherent periodic signals in the light curves, were analyzed using a fast algorithm (Kurtz 1985) based on Deeming's DFT for equally spaced data (Deeming 1975). Complementary low

resolution spectroscopic observations were required to derive the physical parameters of the discovered variables. These observations were also carried out from the ARIES . In addition, intermediate resolution spectroscopic observations were obtained from the Vainu Bappu telescope at Kavalur (OMR spectrograph) to identify the elements which have abnormal strength. The spectroscopic data reductions were performed using the standard data reduction package “IRAF”.

This survey has led to the discovery of five new pulsating variables. Briefly, these stars are presented below, along with the null results obtained during the survey work. Apart from these  $\delta$  Scuti type variables, rapid oscillations of period 7.5 min was discovered in (roAp) star HD 12098. The corresponding results are reported by Girish et al. (2001).

## 2.1 HD 98851

HD 98851 was discovered to be pulsating with periods of 1.34 and 2.70 hr. The light curves of this star exhibit conspicuous alternating high and low amplitudes maxima, with a nearly sub-harmonic period ratio of 2:1. This discovery is of major importance, as this is the first CP star found to show such photometric variations. Further observations of this star would give more insight on the possible presence of  $g$ -mode oscillations, and on the possible existence of a binary system in which the secondary would be an invisible compact object (Joshi et al. 2003).

## 2.2 HD 102480

The marginal Am star HD 102480 was also discovered to be pulsating with periods of 2.6 and 1.4 hr. This star exhibits a variability pattern similar to that of HD 98851, with alternating high and low amplitude maxima. The periods of the pulsations are however different (Joshi et al. 2003).

## 2.3 HD 13079

The Am star HD 13079 was found to be pulsating with a period of about 78 min, suggesting that this is a pulsator in the fundamental mode. The Hipparcos parallax, narrow-band photometry and broad band photometry clearly suggest that the star lies close to the MS. Weak Ca lines were evidenced in our spectroscopic observations, unambiguously classifying the star as an Am star (Martinez et al. 1999).

## 2.4 HD 13038

HD 13038 was observed to be pulsating with two prominent periods of 28 min and 34 min. Due to the presence of nearby frequencies, a beating effect is noticeable in the light curves. The pulsational period of this star is much longer than those of the roAp stars and shorter than the  $\delta$  Scuti stars. Due to the lack of spectroscopic observations, the spectroscopic peculiarity could not be established (Martinez et al. 2001).

## 2.5 HD 113878

A  $\delta$  Scuti type of variability was discovered in HD 113878, with a pulsation period of 2.31 hr. Abt (1984) showed that the stars HD 98851, HD 102480, HD 113878 and HD 104202 do not show the classical difference of five subtypes between the K-line type and metallic-line types. These stars are however classified as Am stars by their strong Sr II lines, weak  $\lambda 4226$  CaI line, and other indications of their general abnormality. Among these stars, HD 98851, HD 102480 and HD 113878 show some photometric variability, as detailed in this thesis. If the star HD 104202 exhibits a variability pattern similar to that of the other three objects, then these stars may form a new group of variable stars.

## 2.6 Null results

All the negative results of our observations are compiled in the form of an atlas<sup>1</sup>. It must be noted that the appearance of a star in this atlas does not completely exclude it to be variable. This atlas merely records that these stars were non-variable during the corresponding observation period, or that the noise was too high to detect any variation. If these candidates are re-observed in photometric sky conditions, some of them will most probably show some variability. The Nainital-Cape survey is aimed at discovering new variable CP stars, thereby improving our understanding about their pulsation mechanisms. Five  $\delta$  Scuti like CP variables have been discovered, plus one roAp star (Girish et al. 2001). This survey an ongoing project for which new observing facilities are being developed, in particular collaborative spectro/photometric observations between ARIES and other Institutes.

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<sup>1</sup>The tables and amplitude spectrum of the null results are available upon request from the author.

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