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The Dushak–Erekdag Survey of roAp Stars

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Abstract. The search of roAp stars at Mt. Dushak–Erekdag Observatory was started in 1992 using the 0.8 m Odessa telescope equipped with a two-star high-speed photometer. We have observed more than a dozen stars so far and discovered HD 99563 as roAp star while BD + 8087 is suspected to have rapid oscillations. Negative results of our observations for the search of rapid oscillations in four stars in NGC 752 are also discussed.

Key words. Stars: chemically peculiar—stars: oscillations—stars: variables: other—techniques: photometric.

1. Introduction

The first rapidly oscillating Ap (roAp) star was discovered by Kurtz in 1978 at the South-African Astronomical Observatory (SAAO). Details of the discovery and further studies are given in Kurtz (1990) and Kurtz & Martinez (2000). Some roAp stars have multiple modes of pulsations and they are valuable for asteroseismological studies.

Out of the 32 known roAp stars so far, about 84% were discovered in the southern hemisphere from SAAO by Kurtz (1990), Martinez *et al.* (1991) and Martinez & Kurtz (1994a, b). In order to investigate the cause for this asymmetric distribution in the two hemispheres of the sky, a number of surveys were carried out for discovering northern roAp stars (e.g., Matthews & Wehlau 1985; Heller & Kramer 1988; Nelson & Kreidl 1993). Until 1998 only two northern roAp stars were discovered. Later, the Vienna Survey (Handler & Paunzen 1999) and the Nainital–Cape Survey (Girish *et al.* 2001) discovered two more northern roAp stars, one by each group.

We commenced our survey programme for roAp stars in 1992 using the Odessa 0.8 m telescope with a two-star high-speed photometer (Dorokhov & Dorokhova 1994a) at the Mt. Dushak–Erekdag Observatory, Copet Dag Mountains, Central Asia, Turkmenistan. We started with the test observations of the well-studied roAp star HR 1217 (Dorokhov *et al.* 1994b). The results showed that the seeing at the observatory site and the instrumentation quality meet the precision requirements for photometry of roAp stars. The next section describes criteria used for the candidate selection. Details of the observations and the results obtained so far are given in the remaining part of the manuscript.

2. Candidate selection

Martinez *et al.* (1991) presented the detailed searching scheme based on Strömgren photometry. We used initially their photometric criteria and extracted the list of

Table 1. List of candidate Ap stars observed to detect rapid oscillations.

Star	m_v	α (2000)	δ (2000)	Sp	Sp (Rn)
Field region					
HD 15257	5.38	2 28.2	+29 40	F0	
HD 17317	8.3	2 47.5	+21 21	A5p	
HD 99563	8.17	11 27.3	−08 52	F0	F0 Sr
HD 115606	8.3	13 18.0	+13 00	A2	A2 Sr
HD 217401	8.0	23 00.3	+14 00	A2p	A2 Sr
HD 276625	10.0	04 35.5	+41 08	A7	A7 CrEu
HD 281367	9.95	03 59.2	+32 43	A7	A8 SrEu
HD 281886	8.9	04 17.6	+31 26	F0p	F0 Sr
BD +8087	9.64	02 49.4	+81 26	Ap	F0 SrEu
NGC 752 cluster region					
R142, BD+36363	10.6			F2V	
R145, BD+36365	10.4			F0III	
R160, BD+37431	10.5			F2III	
R201	11.1			F3	

candidates from uvbyβ Catalogue (Hauck & Mermilliod 1990, 1998). Later on, we also used the catalogues of Renson (1991); Lebedev (1986); Klochkova & Kopylov (1986), etc. for identifying Sr, Cr, Eu peculiarities in the stars. Candidates were selected from both field and cluster regions. Table 1 gives a list of stars which were chosen as candidates for observation. This table lists HD numbers, visual magnitudes, positions, spectral types from HD catalogue and spectral types from catalogue by Renson (1991) for all the observed stars. Star numbers provided by Rebeirot (1970) in NGC 752 are given along with BD catalogue number. Searching for roAp stars in clusters is an interesting idea. Asteroseismology of cluster stars presents fundamental tests to the theories of stellar structure and evolution. Similar attempts have been undertaken earlier (e.g., Matthews *et al.* 1988) but without success hitherto. NGC 752 provides an ideal test of a variety of evolutionary phenomena and it seems suitable due to the fact that it contains plenty of early F type stars. This intermediate-age ($\sim$ 1.8 Gyr) open cluster has been comprehensively investigated by Daniel *et al.* (1994). According to Niedzielski & Muciek (1988) all selected stars are peculiar but, unfortunately, its Strömgren indices do not fall within the limits indicated for roAp stars by Martinez *et al.* (1991).

3. Observations and data reductions

The photometric observations were done with 10 or 20 sec integrations with occasional interruptions for sky background measurements. Whenever possible, we observed a comparison star in the second channel of the photometer. Even if the comparison star's data have not been directly used for the light curve of target star (due to large differences in magnitudes or of spectral types), the second channel data were adapted for estimation of the sky transparency behavior in the investigated frequency region.

Since we could obtain only short duration observations (1 to 2 hours), we developed methods for cleaning of the data obtained under not very good atmospheric conditions.

Low-frequency atmospheric and instrument trends of the data were removed by using Butterworth's filter (see Otnes & Enochson 1978). A rectangle filter was applied to comparison star data for smoothing. The programs PERIOD (Breger 1990), FOUR (Andronov 1994) and Period98 (Sperl 1998) were used for the frequency analysis. Summary of the results are given in the following section.

4. Results

From 1993 to 1997, five candidate stars of the field regions were investigated. The Fourier spectra of 4 stars namely HD 15257, HD 17317, HD 115606 and HD 217401 did not show variability in the frequency region 50–400 c/d (Dorokhova 1997). However, our persistent efforts have been rewarded with a discovery of new roAp star HD 99563 in 1997. Further details are described.

4.1 *Discovery of rapid oscillations in Ap star HD 99563*

HD 99563 classified as F0 in HD catalogue and F0 Sr in the Ap and Am stars catalogue by Renson (1991), its Strömgren indices (H$\beta = 2.830$, $\delta m_1 = 0.000$ and $\delta c_1 = -0.109$) fall into the limit provided by Martinez *et al.* (1991). The star belongs to a binary system ADS 8167, B component ($9.^m9$) is located at an angular distance of $1''.7$.

We observed HD 99563 during 2 hours on the night of 12th/13th May 1997 under non-photometric sky conditions with a comparison star ($\alpha(2000) = 11^h 27^m 54^s$, $\delta(2000) = -09\,^\circ 01'.5$) in channel 2. We presented its preliminary results at 26th Vienna Workshop on CP stars (Dorokhova & Dorokhov 1998) and Odessa "Variable stars" conference (Dorokhova 1997). In this paper, the data are reanalyzed and the dominant frequency has been refined. Fourier spectrum of HD 99563 revealed the most prominent peak (Fig. 1) at frequency $f = 130.4 \pm 0.6$ c/d (period 11 min and semi-amplitude 3.51 ± 0.3 mmag). The light curve of HD 99563 with the best-fit sinusoid of period 11 min is shown in Fig. 2.

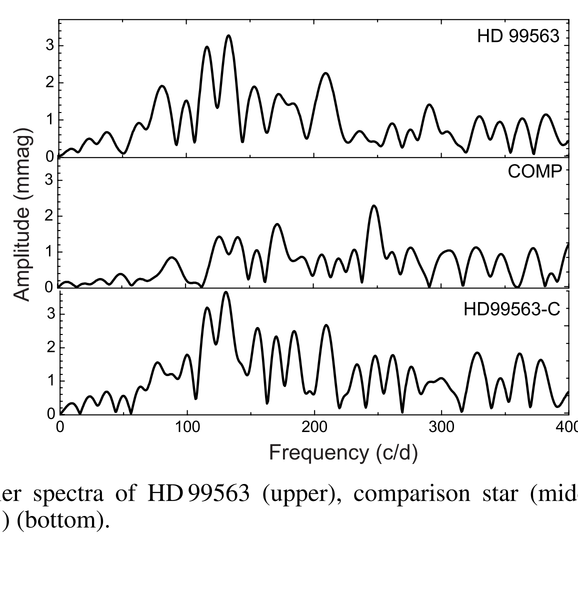

Figure 1. Fourier spectra of HD 99563 (upper), comparison star (middle) and difference (HD 99563-comp.) (bottom).

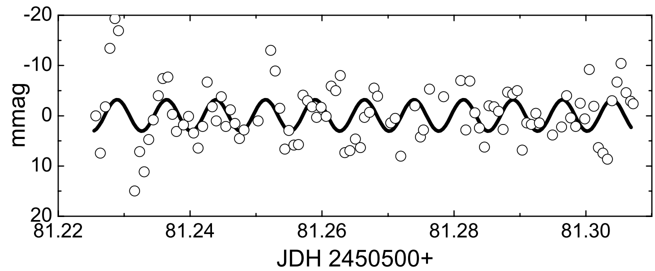

Figure 2. A light curve of HD 99563. The solid line is a least-squares fit of 11 min period.

Table 2. Journal of high-speed photometry observations during 2001–2003. All observations were obtained in *B* photometric pass band. The last two columns are duration of observations in hours and mean deviation in amplitude for the target star in the high-frequency region.

Star	Date	ΔT (hr)	σ (mmag)
HD 276625	20.11.2001	1.5	1.0
HD 281367	21.10.2001	2.2	1.6
HD 281886	24.10.2001	2.5	1.0
BD +8087	12.11.2001	2.0	3.2
	17.07.2003	5.3	1.8
	18.07.2003	5.4	1.6
	19.07.2003	2.8	3.1

A year later Handler & Paunzen (1999) had confirmed our conclusions concerning high frequency variability of HD 99563 with APT at Fairborn Observatory, Arizona. They noted that Mt. Dushak–Erekdag Observatory was the second Northern Hemisphere observatory in which roAp star had been discovered.

HD 99563 as one of the most evolved roAp stars turned out to be very interesting. In 1998, the multi-site campaign for the star revealed 8 frequencies in its light curve (Handler *et al*. 2002). In 2002, measurements of the magnetic field of HD 99563 were obtained with VLT (Hurbig *et al*. 2004). It showed unusual variations (Kurtz 2005).

4.2 *Observations of 2001–2003*

During 2001–2003, we observed 4 more candidates (see Table 2). All of them are classified in catalogue of Am and Ap stars (Renson 1991) as cool Ap stars with Sr, Cr or Eu. However, rapid oscilations in their data were not detected. Table 2 is a journal of observations: HD number, date, duration of observations in hours and mean deviation for high-frequency region of the target star in mmag.

We continued observing the northernmost BD + 8087 star. In a single non-ideal photometric night of 2001, target seemed to show oscillations with period of about 11 min and amplitude of 7 mmag. In the data of 2003 once more the peak at 136 c/d was revealed. However, the comparison star data also showed the peak at 142 c/d. The standard deviations of about 3 mmag also indicate the possible rapid variability although that may be due to instrumentation effects for the circumpolar stars.

HD 281886, HD 281367 and HD 276625 did not show the rapid variability during our limited observations. We plan to observe them in future also.

4.3 *Negative results for stars in NGC 752 region*

Four stars of NGC 752 open cluster were observed in 1993. The fourier spectra of these observations are shown in Fig. 4. R142 is a constant star within limits of 1 mmag; the frequency spectrum of R143 showed some peaks with very low amplitudes which however are not stable from night to night, and are therefore attributed to atmospheric

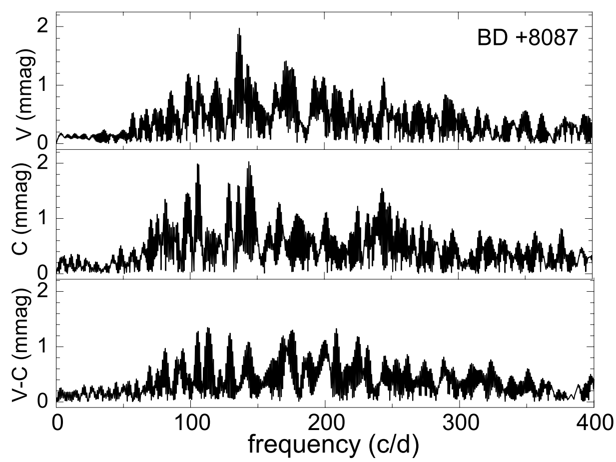

Figure 3. Fourier spectra of BD + 8087 (upper), comparison star (middle) and differences var-comp (bottom).

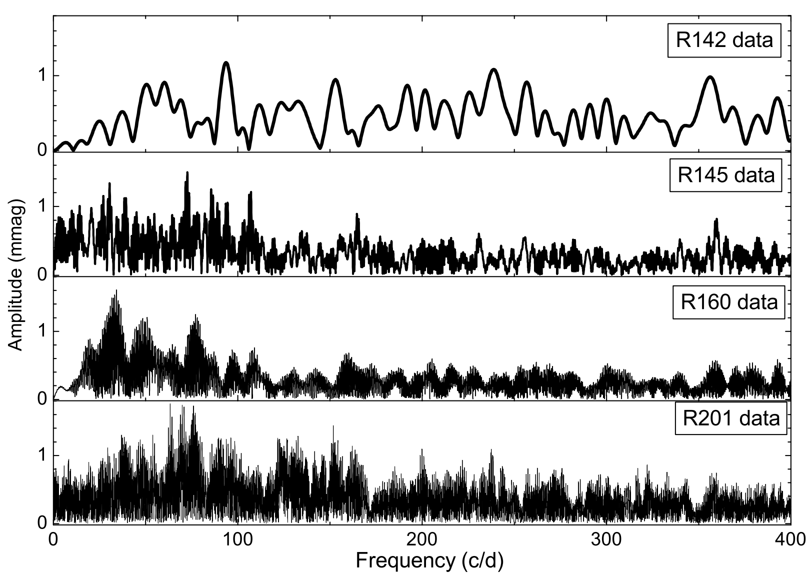

Figure 4. Fourier spectra of NGC 752 objects, the numbers in the right corners are according to Rebeirot (1970).

transparency. In the data of R160, the presence of pulsations of 34 and 77 c/d are suspected but they have very low amplitudes and are again not stable from night to night. The frequency spectrum of R201 shows some peaks in the 60–75 c/d with amplitudes of 2 mmag, which are unstable from night to night and, apparently, caused by variations of atmospheric transparency. We plan to observe them in future with CCD Camera.

5. Conclusions

Comparing with Nainital–Cape survey, which includes observations of $\sim$150 stars so far (see Sagar & Mary 2005), we have observed only a little more than a dozen stars during the last 10 years. Our survey is not extensive mainly due to logistic regions. However, we have been able to discover one northern roAp star and suspect variability in a few other stars. We plan to continue our survey to search for more roAp stars.

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