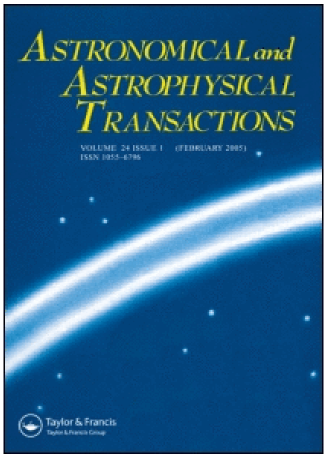
This article was downloaded by:[Bochkarev, N]
On: 29 January 2008
Access Details: [subscription number 788631019]
Publisher: Taylor & Francis
Informa Ltd Registered in England and Wales Registered Number: 1072954
Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Astronomical & Astrophysical Transactions

The Journal of the Eurasian Astronomical Society

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Rapid dynamic processes in Ap star atmospheres

Ismailov

Online Publication Date: 01 January 2003
To cite this Article: Ismailov (2003) 'Rapid dynamic processes in Ap star atmospheres', Astronomical & Astrophysical Transactions, 22:4, 467 - 480
To link to this article: DOI: 10.1080/10556790310001608846
URL: http://dx.doi.org/10.1080/10556790310001608846

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.informaworld.com/terms-and-conditions-of-access.pdf

This article maybe used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Astronomical and Astrophysical Transactions
Vol. 22, Nos. 4–5, August–October 2003, pp. 467–480

RAPID DYNAMIC PROCESSES IN Ap STAR ATMOSPHERES

N. Z. ISMAILOV*

Shemakha Astrophysical Observatory, National Academy of Sciences of Azerbaijan, 370001,
Baku, Istiglaliyyat St. 10, Azerbaijan

(Received February 13, 2003)

Long-term observations with short exposures in 1999–2001 allowed us to reveal the rapid variation in light velocities and equivalent widths of various spectral lines in the spectra of Ap stars χ Psc and γ Equ with pulsation periods 17 min and 12 min respectively. To determine the pulsation periods more precisely, a frequency analysis has been applied. Our observations show that, apart from the variability related to an axial rotation of the star, two more types of variability in an observable group of stars have been detected: firstly, short-term oscillations with 12–17 min periods; secondly, a relatively slow variability with 1.5–2.5 h characteristic times. The short-term spectrum variability is shown to be observed for all programmed stars, but only χ Psc and γ Equ spectra variations are periodic. The second, a slower type of spectrum variability (1.5–3 h), is also reliably observed for χ Psc and γ Equ stars. According to the observed spectral characteristics, the star θ Aur may be referred to a subgroup of roAp stars.

Keywords: Ap stars; Spectral observations; Variability

1 INTRODUCTION

About 30 years ago, rapid periodic brightness oscillations with amplitudes of magnitude 0.005–0.02 were detected in visible photometric bands of magnetic Ap stars. According to Percy (1973), the brightness variation of a peculiar star 21 Com has a period of 30 min. Short periods of brightness variations for these stars were also observed by Wood (1968) and Kurtz (1978). Since then a group of roAp stars has been noted for rapid variation in the brightness.

Nowadays, of the 4 known roAp stars, only four stars display a rapid variation in the oscillatory-type spectrum HR 1217 (Matthews et al., 1988), α Cir (Hatzes and Kurster, 1994), γ Equ (Kanaan and Hatzes, 1998; Aliev and lsmailov, 2001), χ Psc (Aliev and Ismailov, 2000a). Observational features of this star group have been described in the reviews by Weiss (1986), Shibahashi (1987), Kurtz (1990), Matthews (1992) and Weiss et al. (2000). As a rule, the roAp stars show non-radial p-mode pulsations in the period range from 4 to 17 min and are located on the cold classically unstable branch of the Hertzsprung-Russel (HR) diagram. As they are at the stage of hydrogen burning, they are magnetic rotators. Also, roAp stars are probably oblique rotators (Kurtz, 1990) whose directions of magnetic and pulsation axes do not coincide. The observational features of roAp stars evoke great

---

* E-mail: nismailov@bakililar.az, box1955n@yahoo.com

ISSN 1055-6796 print; ISSN 1476-3540 online
DOI: 10.1080/10556790310001608846

interest for the scientific community. To study problems of stellar astroseismology, this star group is of utmost importance. The object of the present paper is a concise description of the results of spectral observations of Ap stars recently obtained to search for a rapid variation in their spectra.

χ Psc (HD 220825, type Sr, Cr, Eu) is one of the bright representatives of peculiar Ap stars with the spectral class A0–A2. Different workers give different values and have obtained different estimates for the rotational velocity of this star. For example, Boyarchuk and Kopylov (1964) have obtained $48\,\mathrm{km\,s^{-1}}$ for v sin i (v is equatorial speed and i the inclination of the rotation axis to the line of sight, v sin i is a projection of equatorial speed to the direction of the line of sight), and Preston (1970) reported a value of $34\,\mathrm{km\,s^{-1}}$. Pyper and Adelman (1983) have obtained a rotational velocity $\mathrm{v\,sin\,i} = 38\,\mathrm{km\,s^{-1}}$ and an axial inclination $\mathrm{i} = 8^\circ$ to the visual axis.

Photometric observations by Rakos (1962) (B, V) and Blanco et al. (1969) (UBV) showed a change in the brightness with an amplitude of magnitude 0.02 spread in 0.01, with the brightness curves differing from one another owing to the poor choice of standard stars by these workers. Van Genderen (1971) has obtained a slightly corrected value of the brightness period change equal to $\mathrm{P} = 0.5853$ days. Aliev's (1975) spectral observations showed good agreement for the period changes with such a period for the spectral parameters of χ Psc as well. Kreidl and Schneider (1989) have detected a brightness change with the period of 1.4200 ± 0.0005 days, from narrow-band photometry, and Kerschbaum and Maitzen (1989) have detected a period of 1.412 ± 0.001 days from 19 points with the help of observations in the u band of Stromgren photometry.

Previous observations revealed a variable magnetic field on the star surface with extreme values of -400 and $+200$ G (Didelon, 1983) and -400 and $+190$ G (Leroy et al., 1994).

Star γ Equ (HD 201601) is one of the well-studied stars among roAp (Sr, Cr, Eu) stars with very narrow spectral lines and a spectral class A7I is a slow rotator with a period of 74 years (Leroy et al., 1994). According to speed photometry (Martinez et al., 1996), at least four unstable oscillation modes have been revealed. According to Scholtz et al. (1997), during 1995–1996 the star radial velocities showed a rapid change from -16.81 to $-4.28\,\mathrm{km\,s^{-1}}$. These workers assumed that γ Equ was a long-period binary system with large eccentricity. Mkrtichian et al. (1998) showed that the data of Scholtz et al. (1997) did not agree with their results of measuring 758 radial velocities of γ Equ obtained during 1994–1996.

Using high-precision observations, Kanaan and Hatzes (1998) revealed a variation in the star's radial velocities $\mathrm{V_r}$ of 100–$1000\,\mathrm{m\,s^{-1}}$ from different spectral lines. The radial velocity change for different lines is shown to agree with the pulsation period of 12 min, which is in the range of the same modes as obtained from photometry in the paper by Martinez et al. (1996). Malanushenko et al. (1998) revealed a variation in $\mathrm{V_r}$ values with an amplitude of about $1000\,\mathrm{m\,s^{-1}}$ from the lines Pr III and Nd III. These workers detected two of the four values of the periodic pulsation frequencies revealed previously from the photometry by Martinez et al. (1996).

Cowley et al. (1969) established a bright component of the visually binary system ADS 4566, below called θ Aur (HD 40312 = HR 2095 = 37 Aur), to be an Ap star with an A0p Si spectrum. From Winzer's (1974) UBV photometric data a brightness variability period of 1.3717 days was obtained. The magnetic field, according to Borra and Landstreet (1980), and the Hβ index, according to Musielok and Madej (1988), change with a period of 3.618 days. From the recent data obtained by Hatzes (1991) the period is 3.611 87 days. According to Adelman's (1997) uvby observations, the brightness also changes with the rotational period $\mathrm{P} = 3.6187$ days.

Rice et al. (1984) showed that a small change in the star spectrum continuum to be observed only at certain instants. According to Hatzes (1991), the Si distribution is observed in the form of a small spot at the latitude +50° where the magnetic field is negative. Also, a ring-shaped belt of Si distribution is observed along the magnetic field equator.

2 OBSERVATIONS AND RESULTS

Our observations were made using the Coudé echelle spectrometer of 2 m focus of the telescope of Shemakha Astrophysical Observatory, National Academy of Sciences of Azerbaijan. Its dispersion is 3–5 Å mm^{-1}, with a 530 pixels × 580 pixels charge-coupled device matrix being used. The Ap star spectrograms were obtained during 1–3 h with short exposures. The spectral resolution is $\mathrm{R} = 30\,000$. About 200 spectrograms were obtained for programmed stars and standards with the Hα line signal-to-noise ratio of 80–120. The total spectrum range $\lambda = 4300$–6700 Å is covered with the matrix window in 40 orders. The observation procedure and spectral material have been described in the papers by Aliev and Ismailov (2000a; 2001). Table I presents a log for individual programmed stars. The second and third columns of the table presents the instants of the beginning and end respectively of the observation run in Julian dates (JDs). The fourth and fifth columns list the numbers of spectrograms and the mean values of the temporal resolution for one spectrum of a given run.

To achieve a high precision of the positional measurements from spectrograms, it is important to plot a dispersion curve in orders. The programme packet presents a solar spectrum catalogue in which the values of laboratory wavelengths are given to an accuracy of ±0.0001 Å. The dispersion curves were constructed from the daylight spectrum. The mean dispersion error is $\sigma \approx 0.08$ Å in each order; the rms deviation of each reference line in the dispersion curve is $\sigma \approx 0.003$–0.006 Å. This means that each measurement of the line position may be estimated to an accuracy of ±0.15–0.30 km s^{-1}. In practice, owing to distortion of the spectral line, the accuracy of measurements may amount to 0.5–0.9 km s^{-1} for individual line positions. The mean error of measuring equivalent widths does not exceed 5%.

After selecting (non-blended) relatively pure spectral lines of different orders from red and blue range, radial velocities and equivalent widths of up to 15 spectral lines, Hα, Hβ, Mg I, Mg II, Fe I, Fe II, Cr II, Si II and Ti II, were measured for each star. To perform a

TABLE I Log of Observations of Ap Stars χ Psc, γ Equ and θ Aur

Ap star	Start of observation	End of observation	Number of spectra	Mean exposure time (min)
χ Psc	JD 2451057.4417	JD 2451057.4993	15	5
	JD 2451058.3549	JD 2451058.4243	13	6
	JD 2451075.4614	JD 2451075.4861	3	6
	JD 2451076.3681	JD 2451076.3889	3	5
	JD 2451450.4056	JD 2451450.4771	13	5
	JD 2451451.4444	JD 2451451.4903	8	4
	JD 2451452.4389	JD 2451452.5160	12	6
	JD 2451453.3611	JD 2451453.4097	13	6
γ Equ	JD 2451451.3507	JD 2451451.4306	13	6
	JD 2451452.3188	JD 2451452.4201	18	7
	JD 2451453.2965	JD 2451453.3458	11	6
	JD 2451744.4431	JD 2451744.4799	10	7
	JD 2451768.3306	JD 2451768.3403	2	6
	JD 2451769.3826	JD 2451769.3875	2	6
θ Aur	JD 2451450.4972	JD 2451450.5681	32	2.8
	JD 2451451.5118	JD 2451451.5493	10	3
	JD 2451453.4188	JD 2451453.4444	9	4

frequency Fourier analysis for measured parameters, Scargle's (1982) method, as modified by Horne and Balinas (1986), was applied. The code for the period search algorithm was written by I. I. Antokhin and some methodical questions connected with the algorithm's application are presented by Antokhin et al. (1995). Some results on the frequency analysis of spectral - parameters were given in the papers by Aliev and Ismailov (2000b; 2001). In the present paper, we sum up the results obtained and conclusions arrived at for individual programmed stars.

2.1 χ Psc

Figure 1 presents the time dependences of radial velocities for the Hα, Hβ, Mg II (4481 Å), Cr II (4836 Å) and Si II (5041 Å) spectral lines for separate series. Changes in V_r are seen to

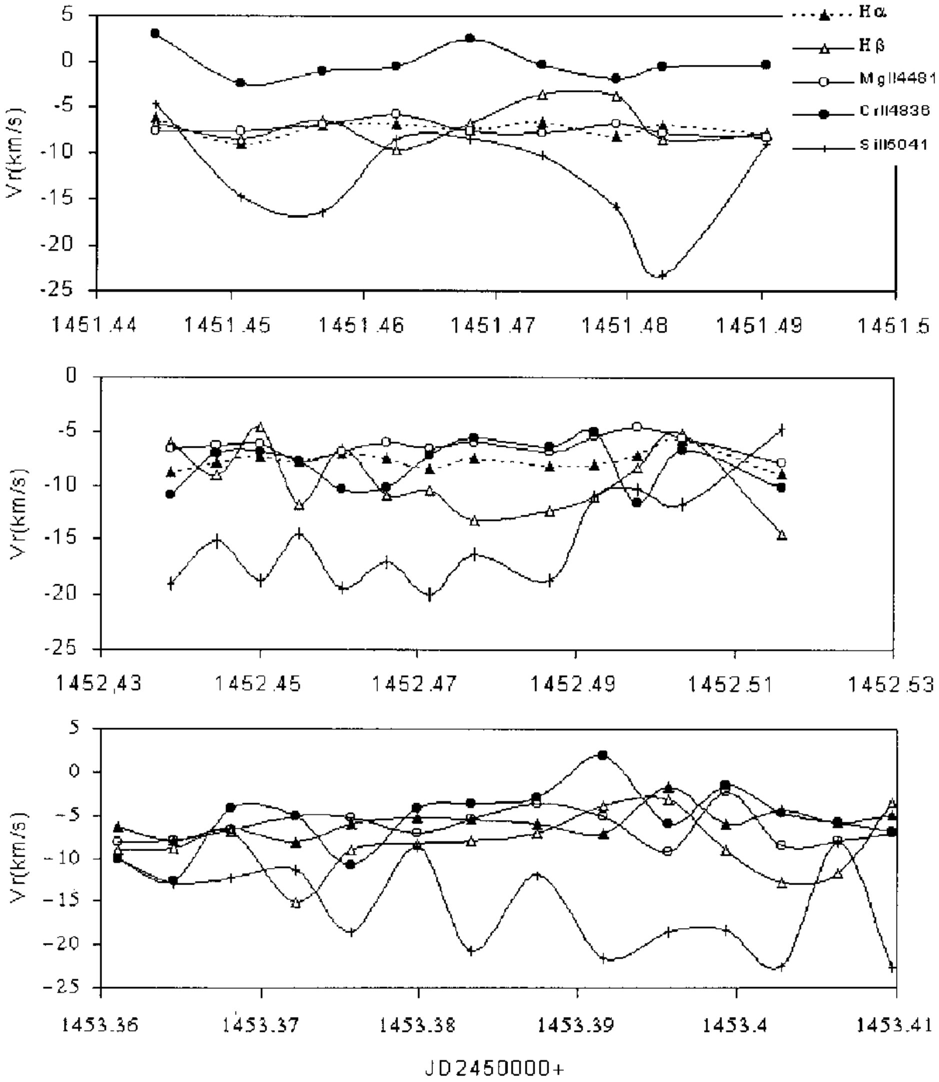


FIGURE 1 Time variations in the radial velocities V_r of some spectral lines of χ Psc in separate series.

differ for individual lines of the separate series, with a variability of oscillatory type being observed for 1.5–2 h. During the observations of some series, oscillation amplitudes may increase or decrease up to their complete disappearance. The oscillation amplitudes of radial velocities for the usual lines range from 5 to 10 km s^{-1} and from 20 to 30 km s^{-1} for lines of peculiar elements such as Cr II and Si II.

The frequency analysis revealed mainly three modes of the significant frequency corresponding to periods $P_1 = 0.585 \pm 0.025$ days, $P_2 = 0.0119 \pm 0.008$ days and $P_3 = 0.0096 \pm 0.006$ days. The period P_1 corresponds to the axial rotation period of the star, which was previously detected by Van Genderen (1971).

A more probable value of the χ Psc pulsation period is $P_2 = 0.0119$ days $= 17.28$ min, since this has been more frequently observed on the power spectrum diagrams as a strong peak. Aliev and Ismailov (2000a) were the first to report its existence.

The frequency analysis in the range 0–120 days^{-1} showed the existence of the oscillatory period $P_3 = 0.0096$ days $= 13.8$ min, which does not prove to be strictly periodic in different diagrams. We have not found any stable frequency near $\nu = 0.6\ \text{days}^{-1}$, whose existence was reported by Kreidl and Schneider (1989) as well as by Kerschbaum and Maitzen (1989), although sometimes a peak at the corresponding frequency was observed from some parameters.

Figure 2(a) presents the dependence of the mean radial velocities on a phase of period P_2, averaged over the phase in 0.05P, and their rms deviation. The value of the mean radial velocities is shifted to zero as they are corrected for the star mass centre radial velocity $V_0 = -5.3 \pm 0.5$ km s^{-1}. Hence, we have obtained a satisfactory periodicity in phase for V_r values. At the bottom of Figure 2(b) is the dependence of the intensity of the magnetic field of the star on the oscillatory period P_2, according to the data obtained by Borra and Landstreet (1980). In spite of using the data obtained by different workers, the magnetic field of the star is seen to show a definite dependence on the pulsation period P_2.

Using the half-width values FWHM of approximately 1.08 ± 0.05 Å for the Mg II (4471 Å) line for the mean radial velocity of χ Psc, we obtain $v \sin i = 38 \pm 2$ km s^{-1}. Assuming that the star has an axial rotation period $P = 0.583$ days for possible values of A0–A3 star radii equal to (2.6–3)$R_\odot$, the equatorial rotational velocity may be estimated to be about 250 km s^{-1} and the orbit inclination angle with respect to the line of sight to be $i = 9 \pm 1°$.

2.2 γ Equ

To investigate the star spectrum, the Fe I, Fe II, Mg I, Mg II, Ti II and Cr II lines as well as the Hα and Hβ lines have been chosen. The mean heliocentric value V_r for γ Equ, 16.48 ± 0.3 km s^{-1}, is obtained from the Fe I, Mg I and Fe II lines; this is in good agreement with the data obtained by Mktrichian et al. (1998) within errors. Later, the values of V_r on the figures were shifted to zero by subtracting the mean value of V_r. The results of measurements in separate series have shown that we observe variation in V_r some lines from one spectrum to another. Figure 3 presents the change in the radial velocity of the Fe I (5171 Å), Mg I (5172 Å) and Cr II (4836 Å) spectral lines on the first night of observations. Figure 3(b) presents the time change in V_r in the second observation run from the Fe I (5162 Å), Fe II (5169 Å), Cr II (4836 Å) and Hα lines.

As seen from Figure 3, two types of change are observed simultaneously:

(i) a rapid pulsation with a short-time change;
(ii) a relatively slow change during the characteristic time of about 1.5 h;

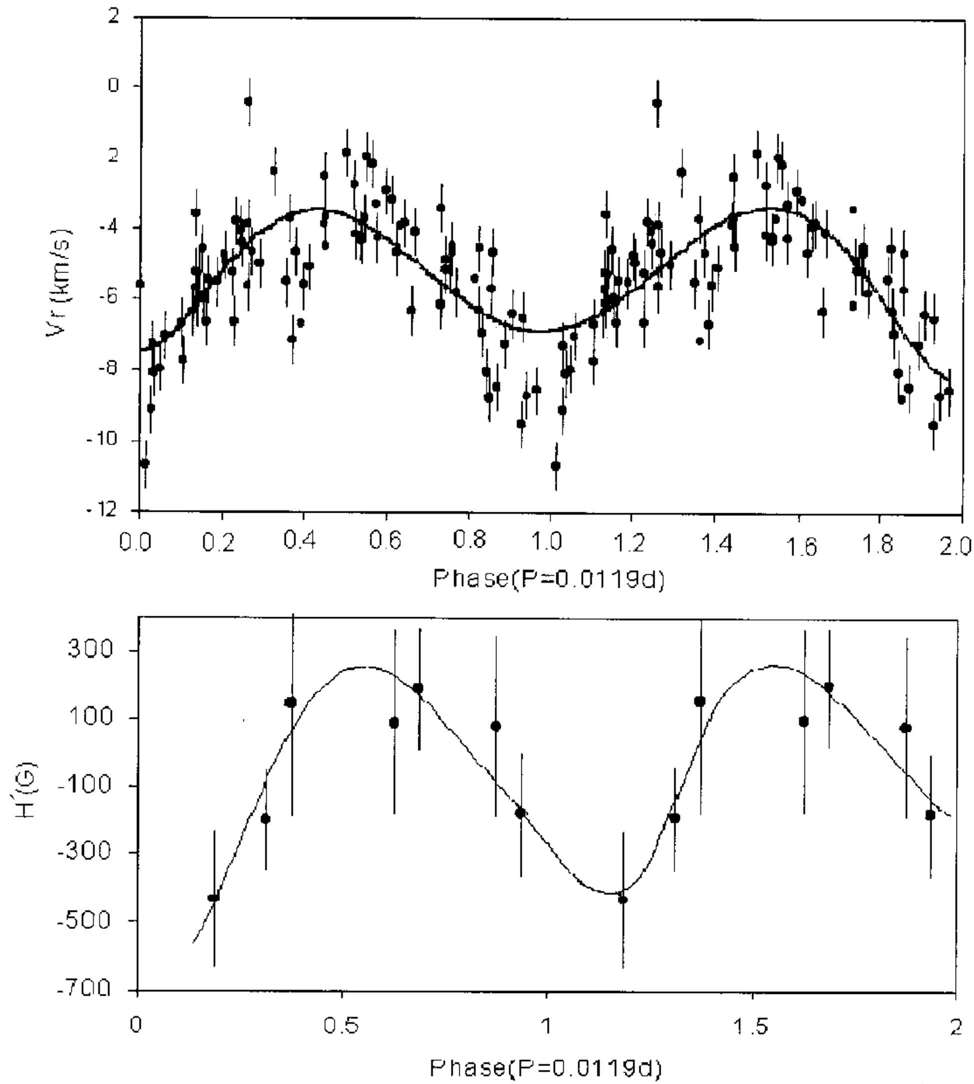


FIGURE 2 The phase diagram (a) for the mean radial velocity for all measured spectral lines with step 0.05P in the oscillating period P_2 and (b) for the magnetic field strength obtained by Borra and Landstreet (1980) in the oscillation period P_2.

Both types of change are well marked in Figures 3(a) and (b) in both the first and the second observation runs; the first run shows two minima and a maximum, and the second run two minima and two maxima. Similar oscillations of V_r values are observed in the rest of the observation runs as well. In other words, relatively slow changes in the V_r values are observed, and against the background of the latter there occur short-time pulsations for about 1.5 h. The short-time pulsation amplitude also changes from a maximum to its detection limit.

A frequency analysis has been performed for V_r of the Fe I (5162 Å), Mg I (5172 Å), Fe II (5169 Å), Cr II (4836 Å) and Ti II (4468 Å) lines. From the frequencies detected, we chose the four often observed and whose power spectrum exceeds the 3σ level for the Cr II and Fe II lines. These frequencies $\nu_1 = 96.665$ days^{-1} (1119 μHz), $\nu_2 = 114.385$ days^{-1} (1324 μHz),

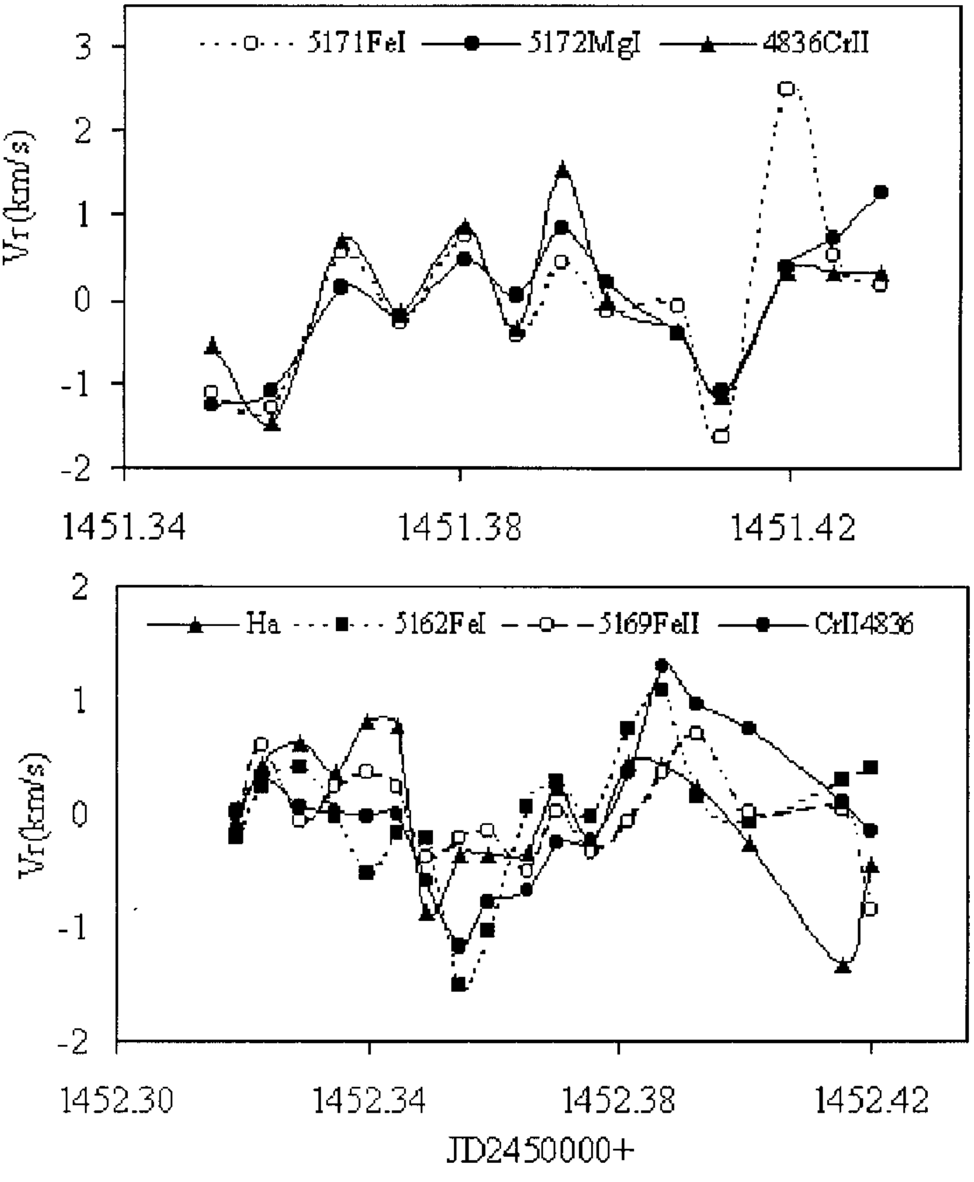


FIGURE 3 Time variations in the radial velocities for some spectral lines of γ Equ in series.

$\nu_3 = 110.335$ days^{-1} (1277 μHz) and $\nu_4 = 124.505$ days^{-1} (1440 μHz) correspond to periods of 14.897, 12.589, 13.051 and 11.566 min respectively. The frequency ν_4 was observed within ± 70 μHz in the spectra of 80% of the lines under investigation and was assumed to be the most probable value of the pulsation period. Thus, our observations revealed the two most probable frequencies ν_2 and ν_4, which correspond to 1324 ± 80 μHz and 1440 ± 70 μHz respectively. These pulsation mode values are very close to the period values presented by Malanushenko et al. (1998) as well as to those from spectral observations by Aliev and Ismailov (2000a) and Kanaan and Hatzes (1998).

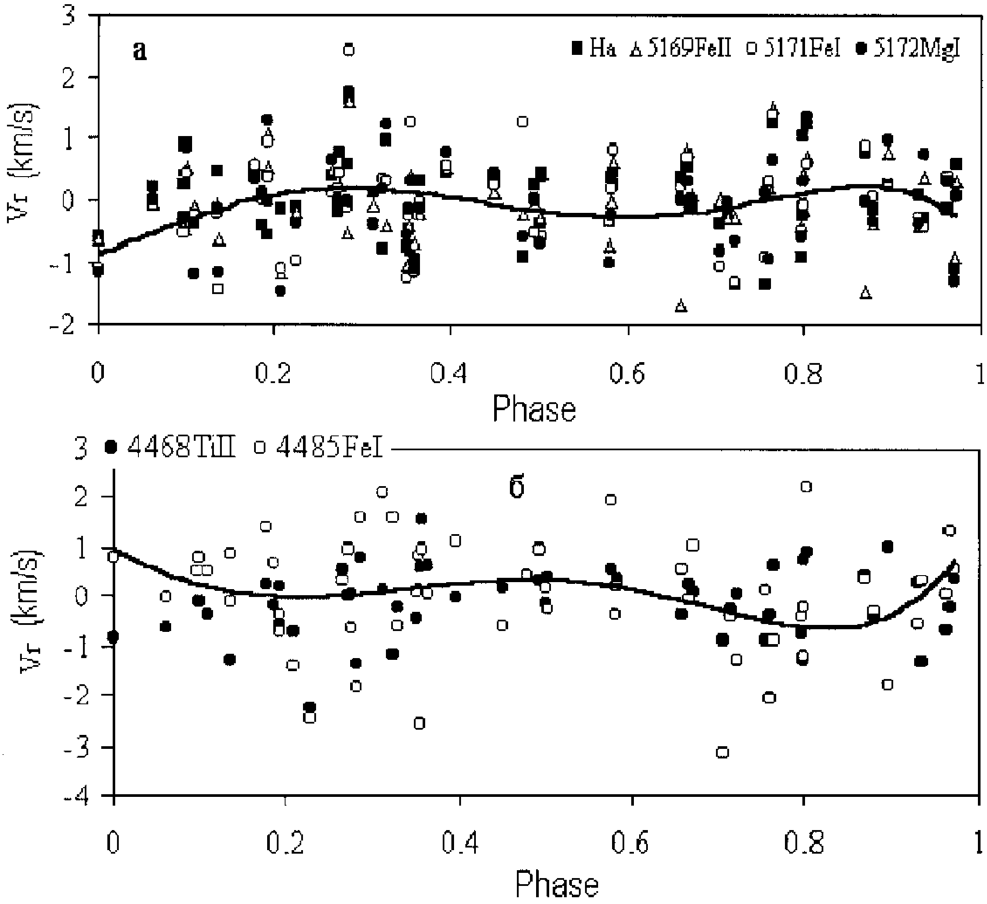


FIGURE 4 A phase diagram of radial velocities of some spectral lines for the pulsation period $P_4 = 0.0080 \pm 0.002$ days.

It should be noted that not one constant value but different, very close period pulsation values have been observed.

In Figure 4 we present a phase convolution of the pulsation period $P_4 = 0.0080 \pm 0.002$ days of all radial velocity values from the measured lines except the hydrogen lines. Two humps are observed during the period with phase maxima being near 0.3 and 0.8. As an epoch onset, JD 2451451.4118 was chosen, which corresponds to the absolute minimum of V_r values in the first observation run and to the maximum deviation of radial velocities V_r from the mean value. The maximum dispersion of the radial velocities does not exceed $\pm 3\,\mathrm{km\,s^{-1}}$ for all lines (Fig. 3), whereas the mean amplitude values of V_r are 1–2 $\mathrm{km\,s^{-1}}$ for some lines. For example, Figure 4 presents phase curves convolved over the period value $P = 0.008$ days. As seen from Figure 4, some observed lines are opposite in phase to the pulsation period. Figures 4(a) and (b) show the lines whose values change synchronously. The grouping was performed by convolving each line separately over a given pulsation period, and the resulting curve was approximated by a fifth-power polynomial. Later, the grouping was performed in the shape of the mean V_r curve. The Fe II (5169 Å), Fe I (5171 Å) and Mg I (5172 Å) lines proved to be in one group (Fig. 4(a)), and the Ti II (4468 Å) and Fe I (4485 Å) in another (Fig. 4(b)). The Cr II lines measured in the blue

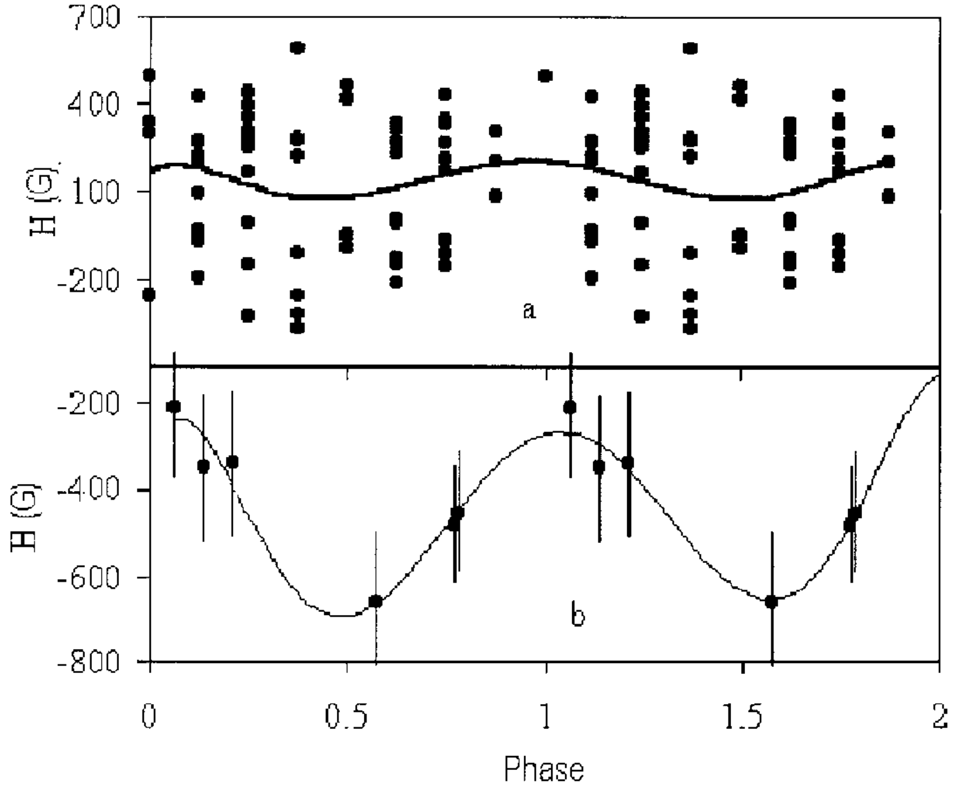


FIGURE 5 Phase diagram for the magnetic field strength based on measurements by (a) Bonsack and Pilachowski (1974) and (b) Borra and Landstreet (1980) for period P_4.

part of the spectrum behave unpredictably, and they cannot be included in either of these line subgroups. It should be noted that the singled-out line groups are divided in wavelength as well. The first group of lines is formed closer to the red part, and the second group to the blue part of the spectrum.

Beginning with Babcock's (1958) paper, the magnetic field of γ Equ has been measured repeatedly by many workers. These measurements were performed by different methods and accuracies; thus it is difficult to relate the observed changes in the magnetic field of the star to the pulsation period that we have detected. According to Bonsack and Pilachowski (1974), the magnetic field of the star changes with a period of about 72 years and fluctuates with respect to the mean curve. To reveal a definite connection with the magnetic field of the star, we have considered more homogeneous observations by Bonsack and Pilachowski (1974) which cover the period from 1960 to 1973 (60 measurements) as well as relatively new data obtained by Borra and Landstreet (1980) (6 measurements).

Figure 5(a) presents a phase curve of the magnetic field of γ Equ convolved over the period pulsations that we have found according to the data obtained by Bonsack and Pilachowski (1974). This plot resembles Figure 2, where we have drawn a curve of radial velocities of a given star. Since the array, according to the data determined by Bonsack and Pilachowski (1974), covers a long period of observations, in different seasons we possibly observe star pulsations in antiphase as well. These data are well convolved with the pulsation period. The data Borra and Landstreet (1980) using another method are also described well

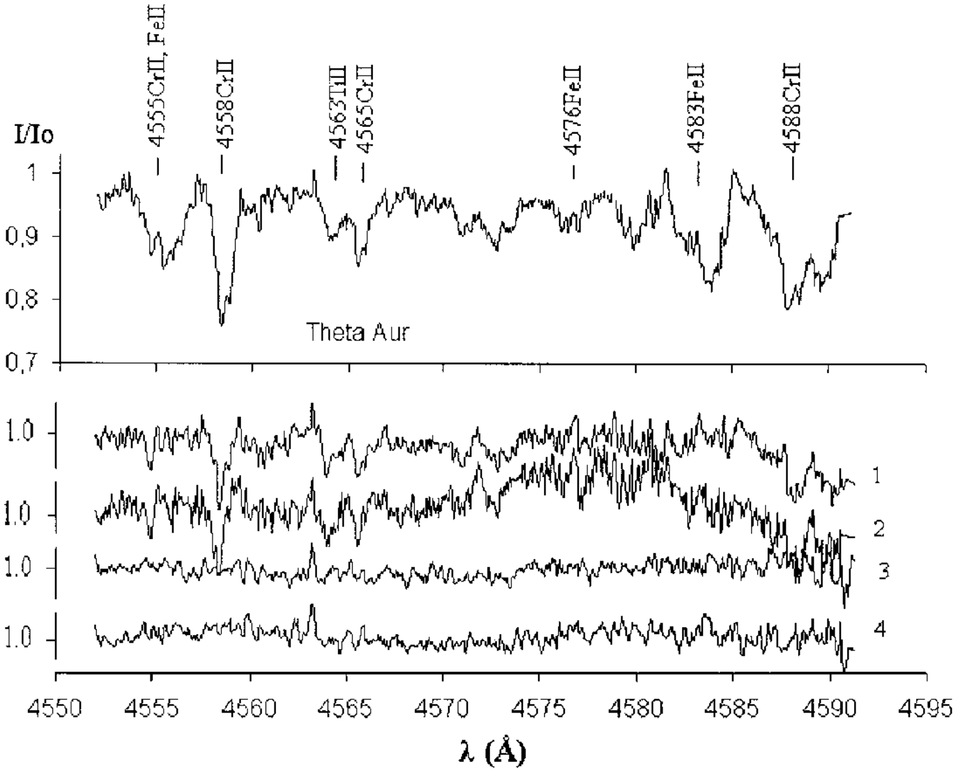


FIGURE 6 A residual spectrum obtained by dividing the spectra on different nights of observation by the specified spectrum of the star. The numbers corresponds to the following dates: spectrum 1, JD 2451450.5076; spectrum 2, JD 2451450.5097; spectrum 3, JD 2451451.5347; spectrum 4, JD 2451453.4215.

by the pulsation period of γ Equ. The mean line in Figure 5(b) is a result of approximation by a sixth-power polynomial. Both curves in Figures 5(a) and (b) show a coincidence of the phase maximum at the phase 0.4.

2.3 **θ** Aur

As indicated in the paper by Rice et al. (1984), during five nights of observations in 1981–1982 they did not obtain clear changes in the star spectrum. To verify the spectral changes that we have obtained from some lines of the spectrum, we divided the spectra of the same domain by the spectrum on JD 2451450.5056. Figure 6 presents a residual spectrum in the domain of the Si II (5041–5056 Å) lines obtained by dividing spectrograms for different nights by the above-mentioned star spectrum. The numbers for each relation in Figure 6 correspond to the following dates: spectrum 1, JD 2451450.5076; spectrum 2, JD 2451450.5097; spectrum 3, JD 245451.5347; spectrum 4, JD 2451453.4215. Spectra 1 and 2 revealed a considerable number of residuals. It should be noted that both spectra were obtained on the first night of observations. Similar results were observed in the domains of the Cr II (4558 Å) line as well.

Figure 7 presents the dependence of radial velocity values of the Cr II and Si II spectral lines on the spectrogram number. A break in the lines indicates another observation run. As a whole, the values of V_r of the above-mentioned lines do not show considerable changes

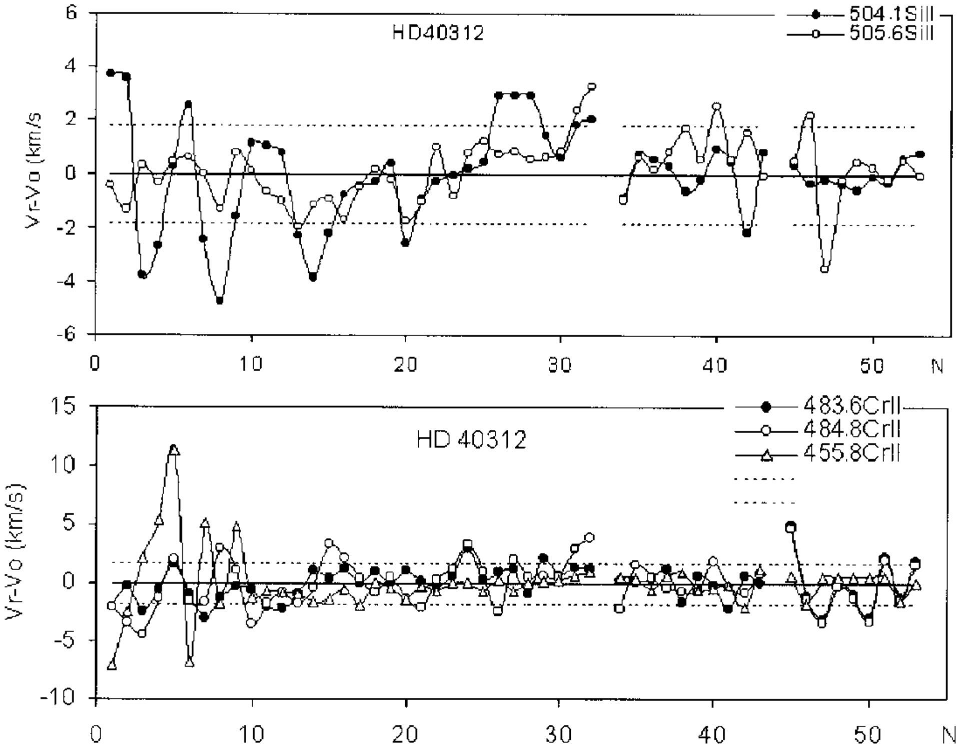


FIGURE 7 Variation in the radial velocities for some spectral lines of θ Aur in a sequence of series of observation. $V - V_0$ is the difference between the radial velocities of a given spectral line from that of the mass centre of the star, and N is the number of spectra in separate series of observations.

within $\pm 3\sigma$, except for the beginning of the first run of observations on JD 2451450. Here a change in the values of V_r of both elements has been observed.

Figure 8 presents a phase curve of the magnetic field according to the data obtained by Borra and Landstreet (1980), a brightness curve obtained from Adelman's (1997) data as well as values of the radial velocities and equivalent widths of the Si II, Cr II and Fe II spectral lines. The spectral parameters that we have studied are seen to vary synchronously as the star rotates. It should be noted that the Si-type stars show pronounced peculiar properties in the Cr II lines too.

3 CONCLUSION

Based on the spectra obtained in 1998–2000 with high temporal and spectral resolution, a rapid periodic variation in the spectrum of the Ap star χ Psc with the period $P = 0.012 \pm 0.0005$ days (17.28 ± 0.72 min) was revealed. Variability of oscillatory type is observed during 1–3 h for radial velocity values, equivalent widths and other spectral parameters with increasing and decreasing amplitudes. More active changes have been obtained in the Cr II, Si II and Ti II spectral lines. The maximum values of the radial velocity amplitude are different for different lines and change from 5 to 50 km s^{-1}. Taking into account the characteristic time of variability, one may estimate characteristic dimensions of active regions in the χ Psc atmosphere as 5000–50 000 km.

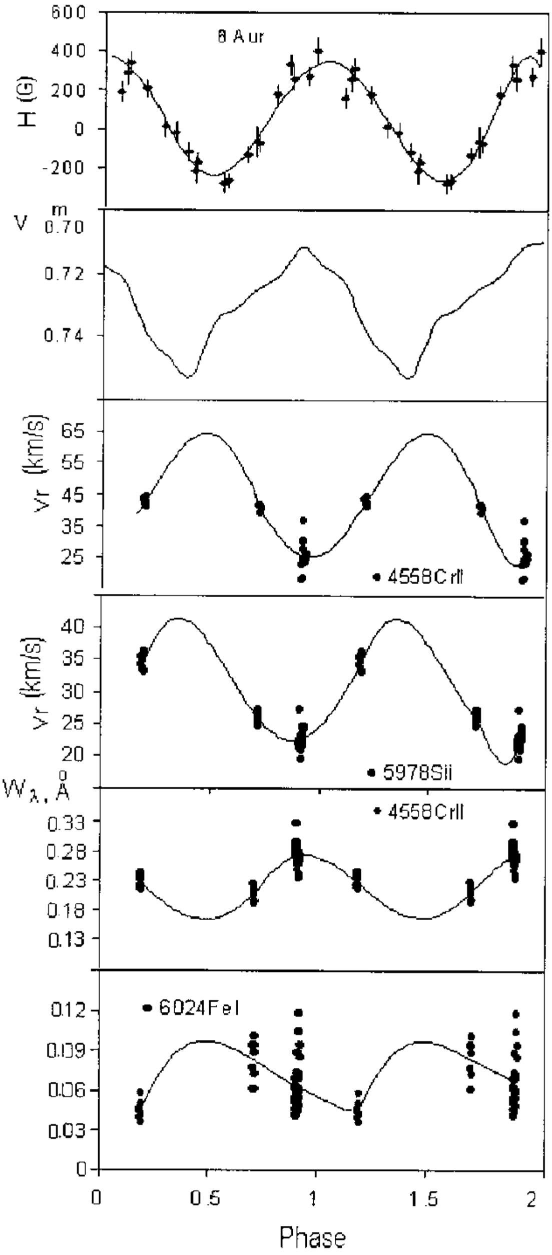


FIGURE 8 Phase curves: magnetic field H from the data obtained by Borra and Landstreet (1980), brightness V (Adelman, 1997), mean of radial velocities V_r and equivalent widths W_λ of the Si II, Cr II, and Fe II spectral lines.

For the γ Equ star the results of frequency analysis from radial velocity measurements of different lines have shown the existence of some close pulsation modes corresponding to $1440 \pm 70\,\mu$Hz (11.57 min). The equivalent widths, half-widths, residual intensities of most lines and magnetic field intensity obtained by different researchers show a periodic variation in the pulsation period. We assume that the variation in the magnetic field affects directly the physical phenomena taking place in the atmosphere of a star. These results suggest the existence of real dynamic processes which may change physical conditions in the atmospheres of stars being considered.

Both χ Psc and γ Equ show synchronous changes in the spectral parameters of atmospheric lines and in the intensities of the local magnetic field of the star. Thus we see real rapid dynamic processes which occur in the atmospheres of roAp stars.

For the θ Aur star, two types of spectral change have been revealed. The first type of variation in the parameters of the spectral line is possibly related to the axial rotation period. Synchronous changes in the brightness and the magnetic field intensity of the star ($V_{\max} I = \mathrm{JD}\ 2446337.465 + 3.6187E$) were revealed. The second type of variation in the star spectrum with the characteristic time 15–25 min is uncommon and is probably related to the oscillatory variability in the θ Aur atmosphere.

We have arrived at the conclusion that observed pulsations in the atmospheres of two roAp stars are non-radial, allowing for the observed features and based on the following facts.

(i) The observed rapid pulsations are of resonance type with the characteristic time 1.5–3 h.
(ii) The pulsation period value not exceeding 17 min gives unreasonable values of radial velocities for non-radial pulsations.
(iii) The gas motion velocities in the atmospheres of Ap stars are of the order of the velocity of sound on the star periphery (see for example Severnyi (1988)).

Thus the complex study of the local magnetic field and chemical peculiarities in the atmospheres of Ap stars allows one to understand the nature of seismic processes observed in the atmospheres of Ap stars.

Acknowledgements

The author is grateful to S. G. Aliev for active participation in the observations and to I. Antokhin from the Sternberg Astronomical Institute (Moscow) for giving us the frequency analysis programme.

References

Adelman, S. J. (1997). Publs Astron. Soc. Pacif., 109, 9.
Aliev, S. G. (1975). In: Aslanov, I. A. (Ed.), Magnetic Ap Stars. Baku, Elm, p. 80.
Aliev, S. G. and Ismailov, N. Z. (2000a). Astron. Rep., 44, 738.
Aliev, S. G. and Ismailov, N. Z. (2000b). Dokl. Natn. Akad. Nauk Azer., 56, 138.
Aliev, S. G. and Ismailov, N. Z. (2001). Physica, 7, 42.
Antokhin, I., Bertrand, J.-F., Lamontagne, R. and Moffat, A. F. J. (1995). Astron. J., 109, 80.
Babcock, H. W. (1958). Astrophys. J., Suppl. Ser., 3, 141.
Blanco, C., Catalano, F. and Godoli, G. (1969). In: Detre, L. (Ed.), Non-Periodic Phenomena in Variable Stars, Proceedings of the 4th Colloquium on Variable Stars. Academic Press, Budapest, p. 243.
Bonsack, W. K. and Pilachowski, C. A. (1974). Astrophys. J., 190, 327.
Borra, F. F. and Landstreet, J. D. (1980). Astrophys. J., Suppl. Ser., 42, 421.
Boyarchuk, A. A. and Kopylov, I. M. (1964). Izv. Krimea Astrophys. Obs., 31, 44.
Cowley, A., Cowley, C., Jaschek, M. and Jaschek, C. (1969). Astron. J., 74, 375.
Didelon, P. (1983). Astron. Astrophys., Suppl. Ser., 53, 421.
Hatzes, A. P. (1991). Mon. Not. R. Astron. Soc., 248, 487.
Hatzes, A. H. and Kurster, M. (1994). Astron. Astrophys., 285, 454.
Horne, J. H. and Balinas, S. L. (1986). Astrophys. J., 302, 757.
Kanaan, A. and Hatzes, A. P. (1998). Astrophys. J., 503, 848.
Kerschbaum, F. and Maitzen, H. M. (1989). Astron. Astrophys., 246, 346.
Kreidl, T. J. and Schneider, H. (1989). Inf. Bull. Variable Stars, No. 3282.
Kurtz, D. W. (1978). Inf. Bull. Variable Stars, No. 1436.
Kurtz, D. W. (1990). A. Rev. Astron. Astrophys., 28, 607.
Leroy, J. L., Bagnulo, S., Landolfi, M. and Landi Degl'Innocenti, E. (1994). Astron. Astrophys., 284, 174.
Malanushenko, V., Savanov, I. S. and Ryabchikova, T. (1998). Inform. Bull. Variable Stars, No. 4650.

Martinez, P., Weiss, W. W., Nelson, M. J., Kreidl, T. J., Roberts, G. R., Mkrtichian, D. E., Dorokhov, N. I., Dorokhova, T. N. and Birch, P. V. (1996). Mon. Not. R. Astron. Soc., 282, 243.

Matthews, J. (1992). Publs Astron. Soc. Pacif., 103, 5.

Matthews, J. M., Wehlau, W. H., and Walker, S. Y. (1988). Astrophys. J., 324, 1099.

Mkrtichian, D. E., Samus, N. N., Gorynya, S. V., Antipin, S. V., North, P., Rastorgouev, A. S., Glusukova, E. V., Smekhov, M. G. and Sachkov, M. E. (1998). Inform. Bull. Variable Stars, No. 4564.

Musielok, B. and Madej, J. (1988). Astron. Astrophys., 202, 143.

Percy, J. R. (1973). Astron. Astrophys., 22, 381.

Preston, G. W. (1970). In: Slettebak, A. (Ed.), Stellar Rotation, p. 254.

Pyper, D. M. and Adelman, S. J. (1983). Astron. Astrophys., Suppl. Ser., 51, 365.

Rakos, K. D. (1962). Lowell Obs. Bull., 5, 227.

Rice, J. B., Wehlau, W. H. and Khokhlova, V. L. (1984). Publs Astron. Soc. Pacif., 96, 734.

Scargle, J. D. (1982). Astrophys. J., 263, 835.

Scholtz, G., Hildebrandt, G., Lehmann, H. and Glagolevskij, Yu. V. (1997). Astron. Astrophys., 325, 529.

Severnyi, A. B. (1988). Some Problems of Solar Physics. Nauka, Moscow, p. 102.

Shibahashi, H. (1987). Lecture Notes in Physics. Vol. 274, Springer, Berlin, p. 112.

Van Genderen, A. M. (1971). Astron. Astrophys., Suppl. Ser., 14, 48.

Weiss, G. A., Ryabchikova, T. A., Kupka, F., Lueffunger, T. R., Savanov, I. S. and Malanushenko, V. P. (2000). Publs Astron. Soc. Pacif., 203, 487.

Weiss, W. W. (1986). In: Cowley, X., et al. (Eds.), Upper Main Sequence Stars with Anomalous Abundances, IAU Symposium, Vol. 90. Reidel, Dordrecht, p. 219.

Winzer, J. (1974). PhD thesis, University of Toronto, Toronto, Canada.

Wood, H. J. (1968). Astrophys. J., 152, 117.