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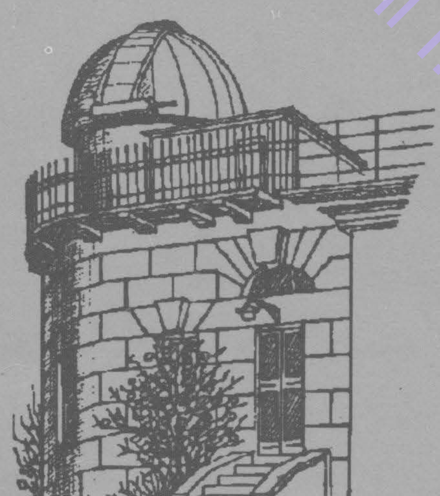

UKRAINE * ODESSA

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PREFACE

The publication of the **'Izvestiya'** *(Publications) of the Astronomical Observatory of the Odessa State University is continued now, after a 30-year time interval. The publishing activity of the University was stopped in 1963, with the Volume 5 of the 'Proceedings'. It consisted of two issues, and contained the results on the meteor investigation during the Program of the International Geophysical Year (1957-1958). Since the beginning in 1947, ten issues of the 'Publications' were edited by Professor V.P.Tsessevich (1907-1983), the Corresponding Member of the Ukrainian Academy of Sciences. They consisted of 74 scientific papers written by the Observatory's research workers, and of the monograph 'Investigation of the eclipsing variable stars' (vol.4) written by V.P.Tsessevich on the base of the observations of 252 objects. One may overview the main scientific directions of the investigations carried during fifteen years after the Second World War.*

During the recent three decades, the scientific image, the research facilities and the staff have markedly changed. Nearly 130 staff members work now at the Observatory, in the close collaboration with the staff of the Astronomical Chair of the Odessa State University. Among them there are 4 doctors of sciences and 23 candidates of sciences, several doctorants and research students. During 10 recent years, more than 500 scientific papers were published, 60 of them - in the prestige translated journals, 70 - directly in the foreign journals. More than 30 astronomical telescopes are designed and created at the Observatory, of which two are 80-cm ones are working successfully at our observational stations. Some telescopes manufactured in Odessa are working in different astronomical institutions of our country, three are located in Baya (Hungary), Svidnik (Czecho-Slovakia) and at the observational station of the Moscow Institute of Astronomy (Equador). All the telescopes are equipped with the modern instrumentation for the photometric and spectral observations, including TV technique and computers.

The oldest scientific directions are the following:

* astrometry based on the meridian circle observations;
* photometric comet and meteor investigation;
* visual and photometric observations of the light curves of eclipsing and physically variable stars, determination of the elements of orbits.

In the recent decades, new methods and scientific directions were developed, such as the precise electrophotometry, middle-dispersion stellar electrospectroscopy. The high-dispersion and CCD spectroscopy and multicolor polarimetry are being obtained in other observatories of our country and are being reduced in Odessa. The investigation of the physics of the cold stars, of the structure and evolution of the eclipsing and cataclysmic binary stars, of the spectral classification and magnetic field of the pulsating variables, of the chromospheric activity and multyperiodicity, of the emission of the artificial satellites, of the density fluctuations and the atmospheric extinction, are being developed during the recent decades.

The catalogue work was carried out on the photometric properties of the stars, interstellar extinction and special distribution of the stars, photometric and cinematic properties of the asteroids. The study of the meteor matter enabled us to discover the transplanetary meteor radiants, to compile the catalogues of the orbital elements and light curves of more than 500 meteors. Twenty one astrometric catalogues of the precise positions were published during 30 years, as well as the catalogues of the spectral energy distribution for 500 stars in the range 320-900 nm. The collection of the patrol photographic and photovisual plates consists of more than 80 000 negatives, and is third in the World. There is a Depository of the unpublished photoelectric observations of the variable stars. The library receives the main astronomical editions and has more than 50 000 entries.

Thus, the Observatory possesses a necessary scientific and engineering potential for its advanced work. In the nearest future, a new 1-m telescope (built in Odessa) will be put into operation, the 1.5m telescope is being constructed, as well as other modern equipment. One may expect the further increase of the efficiency of the investigations, the main results of which will be published in the present 'Publications'.

Valentin G. Karetnikov,
The Editor

RELATIONS BETWEEN THE ABSOLUTE CHARACTERISTICS OF THE COMPONENTS OF THE DIFFERENT-TYPE ECLIPSING BINARY SYSTEMS

V.G.KARETNIKOV

Abstract. By using our compiled catalogues of the characteristics of 303 eclipsing binaries with the constant and variable orbital periods, we computed the «Mass-Luminosity», «Mass-Radius» and «Mass-Temperature» relationships. These relationships are analyzed, the coefficients vary from one type of the eclipsing systems to another. It is assumed that the changes of the coefficients are of the evolutionary origin. The sequence of the studied systems according to the ages of the components is proposed.
Key Words: Stars: Binaries; Stars: Evolution

The eclipsing binary stars being simultaneously the photometric and spectroscopic binary systems allow the most accurate determination of the main absolute characteristics : the masses M_i, radii R_i, temperatures T_i, luminosities L_i of the stars and the separation A between them. The accuracy of the determination of these characteristics amounts to 5 per cent (Popper, 1980), thus it is possible to determine accurately the relationships between the parameters of the stars and their systems. At the same time, the different types of the eclipsing binary systems are at the different evolutionary stages, and one may compare the coefficients of the relationships with the evolutionary status. This paper is devoted to the empirical investigation of this problem.

The main astrophysical relationships «Mass-Luminosity», «Mass-Radius» and «Mass-Temperature» were studied by many investigators. The most recent results of high reliability were obtained by Svechnikov (1986) for the components of the systems with the detached Main-Sequence stars (MS-systems). For the stars of other types of the eclipsing systems, the similar relationships did not yield the significant results. However, it was known, that the subgiants do not obey the derived relationships. Recently the new data on the absolute characteristics of the components of the binary systems were obtained, thus making actual the study of the main relationships for all types of the eclipsing binaries.

The data for such study were taken from the two compiled catalogues published by Karetnikov and Andronov (1989). The first Catalogue contains the data for 127 eclipsing systems with the secular period changes ($Q \neq 0$). The second Catalogue contains the data on 176 eclipsing binaries with the constant orbital periods ($Q=0$). Both catalogues contain information on 75 MS-systems, 8 systems similar to W UMa (SimCW), 25 W UMa-type systems (CW), 89 contact early pairs (CE), 80 semi-detached (SD), 13 systems with a detached subgiant (DS), and 13 AR Lac-type binaries (AR).

From the Catalogues' data, we computed the dependencies of the type

$$\begin{aligned} M_{B_i} &= a + b \log M_i \\ \log R_i &= c + d \log M_i \\ \log T_i &= e + f \log M_i \end{aligned} \qquad (1)$$

separately for the different types and the systems with the constant and variable periods. Here M_{B_i} - is the bolometric absolute magnitude. For all approximations, the correlation coefficients k and the error estimates σ were computed. The results are shown at Tables 1-3, where n - is the used number of the objects, the index '1' corresponds to the more massive component of the binary. Six objects were excluded from the analysis. These are MS-systems WX and ZZ Cep with the poorly known parameters; YY Gem and CM Dra, the classification of which is ambiguous; as well as RR Cen and AW UMa from the groups od SimCW and CW systems.

The analysis of the data presented in Tables 1-3 shows a good agreement of the results obtained for the MS systems with those published by Svechnikov (1986). All the results are of the high significance at th 0.0-2.0 level. The results of the lower significance are avoided. They appeared, if there is the unsufficient number of pairs and/or the characteristics are very similar. These are CW and SimCW systems, the masses of the stars are from 0.2-2.0 solar masses, as well as the AR systems with the masses of 0.6-2.3 solar masses. For these objects, the intervals of the radii and temperature's changes are not wide as well. If one takes into account the difficulties and the uncertainties of the determination of their absolute characteristics, the low significance of the relationships will be quite natural.

The numerical values of the coefficients show their systematic changes while investigating the systems from the not-evolved ones to the objects with the higher evolutionary age, containing the subgiants in the SD, DS and AR-type systems. Thus one may study, how the main secondary characteristics of the stars depend on the mass. Let us represent the relationships in the form:

$$L_i \sim M_i^{\alpha}, \qquad R_i \sim M_i^{\beta}, \qquad T_{eff\,i} \sim M_i^{\gamma}, \qquad (2)$$

where $\alpha = -0.4b$, $\beta = d$, and $\gamma = f$.

As one may see, the power index , corresponding to the dependence of the luminosity on the mass, is at its maximum for the MS stars (excluding DS_1 for $Q = 0$ and $n = 4$), the initial evolutionary stage of the eclipsing systems. The lowest values of

α correspond to the primary stars of the SimCW systems. Similar behavior proceeds in the values of γ, slightly different - in the values of β.

The investigation of the significance of the coefficients of the equations (1) showed, that the relationships are mainly unsignificant, if the number of objects is low. This is the case for the majority of the relationships for SimCW, Cw, DS and AR systems with $Q \neq 0$, and sometimes with $Q = 0$. Suggesting that this situation is due to the low number of the data, one may exclude from the analysis the mass dependence of the luminosities, masses and temperatures of the SimCW, CW, DS and AR-type systems. The number of the systems for other groups is sufficient for the reliable analysis of the variations of the coefficients from one type to another.

The results of the comparison of the power coefficients are shown in Table 4, where the eclipsing binaries are located according to the suggested evolutionary sequence. In fact, the most evolutionary young is the less massive component MS_2 of the Main Sequence type system. The most evolved must be the subgiant SD_2 in the semi-detached system. It is not only inconsistent with the modern evolutionary conception, but confirms the latter numerically. As regards the exclusions from the mentioned above binaries, which were not shown in Table 4, one may note, that the available data on the CW, DS and AR systems are unsufficient for the reliable location of them onto the suggested evolutionary sequence.

The analysis of the dependencies shows, that the parameters α, β and γ are changing differently for the systems with the constant and variable orbital periods. The coefficients α and γ are monotonically decreasing during the evolution. The coefficient β is changing in a more complicated manner, because for the contact and semi-detached systems, the radius of the star filling (or nearly filling) its Roche lobe star depends not only on the mass, but on the orbital separation as well. Thus the obtained values of β must be interpreted very carefully.

The subdivision of the eclipsing binaries into the groups with the constant and variable periods points out the difference in the processes, which take place for the different manner of the mass transfer. According to Huang (1963), the constancy of the orbital period may indicate that the ratio of the accreted to the ejected matter is strongly determined. In this case, the changes of the coefficients α, β and γ are larger. For the variable orbital periods, there are no restrictions on the accretion and ejection rates, and the dependence of the main characteristics on mass is not so clear.

Thus one may see that the dependence of the luminosities, radii and temperatures of the stars is changing during the evolution of the eclipsing binaries. The result is statistically significant for the MS, CE, SD systems, and one may suppose that the location of the subsytems according to the sequence shown in Table 4, may have the evolutionary sense. This idea may be confirmed by the present results, as well as by the general considerations on the evolutionary status of the MS and CE systems (containing the Main Sequence stars), and the SD-type binaries (containing the highly evolved subgiant star). The stars of other types (SimCW and CW with the Main Sequence Stars as well as the systems with one (DS) or two (AR) subgiants) need the further investigation.

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Table 1 The coefficients of the 'Mass-Luminosity' relation for the stars of the different-type eclipsing systems

Type	$Q \neq 0$				$Q = 0$			
	a	b	k	n	a	b	k	n
MS_1	4.31	-9.00	0.99	15	4.48	-9.79	0.98	56
	±0.20	±0.29	±0.03		±0.15	±0.24	±0.02	
MS_2	4.32	-9.02	0.99		4.42	-9.90	0.97	
	0.20	0.20	0.03		0.15	0.33	0.03	
$SimCW_1$	4.38	-3.31	0.99	3	4.30	-2.69	0.97	4
	0.04	0.38	0.11		0.06	0.50	0.18	
$SimCW_2$		Correlations are not significant			4.55	-9.42	0.95	
					0.42	2.18	0.22	
CW_1		Correlations are not significant		11	4.88	-6.29	0.82	13
					0.19	1.34	0.17	
CW_2		Correlations are not significant			4.33	-4.86	0.65	
					0.45	1.71	0.23	

CE_1	3.69	-7.76	0.98	23	3.43	-8.00	0.99	6
	0.27	0.38	0.05		0.13	0.17	0.02	
CE_2	3.09	-8.28	0.95		2.66	-7.29	0.95	
	0.34	0.61	0.07		0.20	0.31	0.04	
SD_1	4.06	-8.69	0.98	62	4.44	-9.20	0.98	18
	0.12	0.22	0.02		0.23	0.41	0.04	
SD_2	1.45	-5.84	0.85		1.28	-3.58	0.60	
	0.20	0.46	0.07		0.45	1.19	0.20	
DS_1	5.04	-12.02	1.00	11	3.36	-7.87	0.98	9
	0.08	0.26	0.02		0.36	0.57	0.07	
DS_2		Correlations are not significant			0.70	-5.12	0.86	
					0.51	1.15	0.19	
AR_1		Correlations are not significant		7	3.44	-7.54	0.80	6
					0.57	2.86	0.30	
AR_2		Correlations are not significant				Correlations are not significant		

Remark: The index 1 and 2 after the type correspond to the primary (the star of the higher mass) and the secondary, respectively.

Table 2 The coefficients of the 'Mass-Luminosity' relation for the stars of the different-type eclipsing systems

Type	Q ≠ 0				Q = 0			
	c	d	k	n	c	d	k	n
MS_1	0.12	0.59	0.97	15	0.11	0.70	0.92	56
	±0.03	±0.04	±0.07		±0.03	±0.04	±0.05	
MS_2	0.11	0.55	0.99		0.08	0.70	0.91	
	0.02	0.02	0.04		0.02	0.04	0.06	
$SimCW_1$		Correlations are not significant		3	0.07	0.48	0.97	4
					0.01	0.08	0.17	
$SimCW_2$		Correlations are not significant			0.04	0.79	0.98	
					0.02	0.11	0.14	
CW_1	0.01	0.04	0.68	11	0.00	0.69	0.85	13
	0.02	0.15	0.25		0.02	0.13	0.16	
CW_2		Correlations are not significant			-0.01	0.63	0.74	
					0.04	0.17	0.20	
CE_1	0.00	0.96	0.92	23	0.12	0.66	0.95	66
	0.06	0.09	0.08		0.02	0.03	0.04	
CE_2	0.15	0.83	0.88		0.16	0.63	0.93	
	0.06	0.10	0.11		0.02	0.03	0.04	
SD_1	0.09	0.71	0.92	62	0.04	0.74	0.81	18
	0.02	0.04	0.05		0.08	0.14	0.15	
SD_2	0.56	0.46	0.71		0.62	0.38	0.55	
	0.02	0.06	0.09		0.05	0.14	0.21	
DS_1	0.01	1.28	0.96	4		Correlations are not significant		9
	0.09	0.28	0.21					
DS_2		Correlations are not significant				Correlations are not significant		
AR_1		Correlations are not significant		7		Correlations are not significant		6
AR_2		Correlations are not significant				Correlations are not significant		

Table 3 The coefficients of the 'Mass-Temperature' relation for the stars of the different-type eclipsing systems

Type	Q ≠ 0				Q = 0			
	e	f	k	n	e	f	k	n
MS_1	3.75 ±0.02	0.58 ±0.03	0.98 ±0.05	15	3.76 ±0.02	0.59 ±0.03	0.95 ±0.05	56
MS_2	3.76 0.02	0.59 0.03	0.99 0.04		3.76 0.01	0.63 0.02	0.96 0.04	
$SimCW_1$		Correlations are not significant		3	3.77 0.01	0.20 0.07	0.90 0.31	4
$SimCW_2$		Correlations are not significant			3.76 0.04	0.72 0.22	0.92 0.28	
CW_1		Correlations are not significant		11	3.74 0.01	0.35 0.10	0.71 0.21	13
CW_2		Correlations are not significant				Correlations are not significant		
CE_1	3.83 0.03	0.40 0.04	0.89 0.10	23	3.83 0.01	0.45 0.02	0.95 0.04	66
CE_2	3.83 0.02	0.47 0.03	0.95 0.07		3.84 0.02	0.41 0.03	0.88 0.06	
SD_1	3.81 0.01	0.47 0.02	0.93 0.05	62	3.80 0.03	0.50 0.05	0.93 0.09	18
SD_2	3.80 0.01	0.36 0.03	0.82 0.07		3.80 0.03	0.24 0.08	0.63 0.19	
DS_1	3.71 0.06	0.64 0.19	0.92 0.28	4	3.79 0.03	0.44 0.05	0.96 0.11	9
DS_2		Correlations are not significant			3.78 0.04	0.39 0.09	0.86 0.19	
AR_1		Correlations are not significant		7		Correlations are not significant		6
AR_2		Correlations are not significant				Correlations are not significant		

Table 4 The values of the coefficients α, β, γ for the stars in the eclipsing binary systems, according to the sequence of their evolutionary stage

Type	Q ≠ 0			Q = 0		
	α	β	γ	α	β	γ
MS_2	3.61 ±0.12	0.55 ±0.02	0.59 ±0.03	3.96 ±0.13	0.70 ±0.04	0.63 ±0.02
MS_1	3.60 0.12	0.59 0.04	0.58 0.03	3.91 0.10	0.70 0.04	0.59 0.03
SD_1	3.48 0.09	0.71 0.04	0.47 0.02	3.68 0.16	0.74 0.14	0.50 0.05
CE_2	3.31 0.24	0.83 0.10	0.47 0.03	2.92 0.12	0.63 0.03	0.41 0.03
CE_1	3.10 0.15	0.96 0.09	0.40 0.04	3.20 0.07	0.66 0.03	0.45 0.02
SD_2	2.34 0.19	0.46 0.06	0.36 0.03	1.43 0.48	0.38 0.14	0.24 0.08

V 367 CYGNI

E.V.MENCHENKOVA

Abstract. The spectral and photometric investigations of the W Ser-type star V 367 Cyg have been carried out. The comparison of the observed parameters of the stellar components of the system V 367 Cyg with the theoretical ones for the main-sequence stars of the same mass has shown the considerable excesses of the radii and luminosities of both components of the system. The whole complex of the observed characteristics of the bright (at present less massive: $M_1 = 2.3 M_\odot$) component is well described by the current evolution theory of close binary systems of medium mass. At the same time, it is shown that the luminosity of the secondary component cannot be explained within the framework of the disc accretion model, suggested by Plavec (1980a)to describe the observed properties of W Ser-type stars.
Key Words: Stars: Binaries: Individual : V 367 Cyg

In 1923, Merrill paid attention to V 367 Cyg (HD 198287-8,BD 38° 4235, SAO 70517,ADS 14314) for the first time. He discovered the strong emission H_α line in its spectrum (Merril,1923). Ten years later, a spectral variability of the star was found (Christie, 1932). In 1930, Humason classified V367 Cyg as an β Lyr-type eclipsing binary star and determined the photometric elements of its orbit for the first time (Humason,1930). After that, the star was extensively studied visual, photographic (Kukarkin, 1932; Filin, 1949), photoelectric (Kalv and Pustylnik, 1975; Kalv, 1978; Akan, 1985,1987; Fresa, 1966; Heiser, 1962,1966; Lindemann and Hauch, 1973; Walker, 1971; Wood, 1955; Wood and Lewis, 1955; Young and Snyder, 1982), polarimetric (Shakhovskoy, 1964; Appenzeller, 1966;Bidelman and Wolfire,1981) and spectral (Karetnikov and Perekrestnyi, 1973; Abt, 1954; Aydin et al., 1978; Christie, 1933; Hack et al., 1984; Heiser, 1961; Sanfort, 1950; Underhill,1954)•methods. The observations of V 367 Cyg have been obtained at IUE and EINSTEIN (Plavec, 1976,1979,1980b,1981; Guinan et al., 1984, Plavec and Polidan, 1976; Plavec and Koch, 1978).

Photometric investigations. V 367 Cyg has a light curve of β Lyr-type with the different brightness of the maxima and the different depths of the asymmetric minima. In the light curve, there are effects of the ellipticity, reflection and bright lines. The small light fluctuations give an occasion to suspect a physical instability of the star (Wood, 1955; Heiser, 1962; Fresa, 1966). However, the optical pulsations exceeding 1 per cent of the stellar luminosity have not been found (Nevo et al., 1975). The earliest photographic observations already showed the differences of the light curves obtained by the different observers and at different epochs (Heiser, 1962). Later, the photoelectric observations (Akan, 1987) confirmed the existence of the long-term variations of the light curve of V 367 Cyg. The detailed analysis of the variability of the light curve of V 367 Cyg made by Akan (1987) has shown, that the light fluctuations take place not only at the maxima, but exist also at the ascending and the descending branches of both minima, being more pronounced in the blue light. According to Wood and Lewis (1955), the colour of the system changes with phase not significantly (less than 0.04 mag). On the other hand, the detailed photometric analysis of the light variations (Young and Snyder, 1982) has shown a slight increase of the color index (b-y) at the middle of the primary eclipse. This may be a result of the increase of the contribution of the secondary component to the total flux from the system. In (u-b), there was the sure sudden increase in the ultraviolet, synchronized with the primary mid-eclipse. Young and Snyder (1982) interpreted this fact as a manifestation of the hot central source (again either a star, or an accretion zone on a star, or both). The comparison of the color curves obtained within the 25-year interval has shown, that the system V 367 Cyg was redder in 1960, than in 1985 (Akan, 1985; Heiser, 1962).

The peculiarities of the light curve of V 367 Cyg make more difficult to obtain the solution of the light curve and the determination of the elements of the orbit. Nevertheless, the first attempts to obtain the photometric solution had been already made by Kalv and Pustylnik (1975), Heiser (1962), Fresa (1966). The results of these calculations indicate that the both components of the system have a very large sizes, and, at least, one of them overfills its Roche lobe. The analysis of the photoelectric light curve of V 367 Cyg has been made by Li and Leung (1987) by the 'synthesis' method in frame of the Wilson-Devinney (1971) model. Unfortunately, it has not solved the problem of the interpretation of the photometric observations of V 367 Cyg. The obtained parameters (radii, luminosities) are more reliable, but considerably differ from the analogous characteristics of the normal main sequence stars of the same masses. Both components of the system have the considerable excesses of the luminosities and radii (Tab.1). The obtained excesses may be a result of the evolutionary peculiarities of the system. Also, it is possible, that they are the consequence of the simplifications assumed while solving the light curves. There are two main causes, which can change the ratio of the luminosities and of the radii of the components of V 367 Cyg:

1. the discrepancy of the used model with the real geometry of the system.
2. not taking into account the influence of the circumstellar matter on the light curve of the system.

The model of Wilson-Devinney (1971) applied by Li and Leung (1987) for the determination of the absolute elements of V 367 Cyg had represented the forms of the both components of the system as the equipotential surfaces in the Roche model. At the same time, the whole observational data testify that the more bright and now less massive component of the system fills its Roche lobe and loses matter through the point L1. This matter, coming into the vicinity of the secondary component, forms an accretion disk near it. This accretion disk can seem as a false photosphere around the secondary component. Therefore, the solution of the light curve of V 367 Cyg should be made in a model with a disk-like secondary component. Such a model was elaborated by Antokhina (1988) and was successfully used for the analysis of the photoelectric light curves of the some peculiar binary systems (RY Sct, BM Ori, SS 433). Taking into account the distortion of the light curve by the circumstellar matter, the ratio of the luminosities and the dimensions of the components may be changed. The theoretical analysis of the light curves of close binaries with common scattering envelopes (Pustylnik and Einasto, 1984, 1985) had shown, that the ratio of the depths of light curve minima is determined not only by the luminosities of the components. It also depends on the luminosity of the envelope L(env), which is connected with the following parameters: τ (env), L_2 /L_1 , A, q, l (env). While solving the light curves of the binary systems with the developed circumstellar matter, it is necessary to take into account the contribution of the circumstellar matter to the total light curve of the system. However, for V 367 Cyg, this is impossible at present, because of the complicated structure of the circumstellar matter contained in this system.

The light curves have been solved by the synthesis method according to the program elaborated by Antokhina (1988). Two models were used: the system in the frame of the Roche model and the system with a geometrically thick disk around the secondary component. The photoelectric curve obtained by Fresa (1966) from 1957 to 1960 and based on 456 individual observations was used. To solve the light curve in frame of the Roche model, the shapes of the stars were approximated by the equipotential surfaces. The rotational and tidal distortion of the shapes of the components was taken into account. The intensity of the radiation emitted from an elementary surface area was determined according to the stellar temperature, limb darkening, gravity darkening and the reflection. In the model, having a geometrically thick disk, the shape of the primary component was approximated by an equipotential surface in the Roche model. The form of the secondary component was approximated by a ellipsoid with an equatorial semiaxis a and a polar semiaxis b. The temperature distribution along the ellipsoid's surface was computed according to the law:

$$T(r) = T_p \ (b/a)^{0.5}$$

Close and equivalent accuracy solutions have been obtained both in the Roche model and model with disk-like secondary component. The absolute parameters of V 367 Cyg are collected in Table 1. The obtained radii and luminosities are considerable greater than the same characteristics of the zero-age main-sequence stars of the same masses (as well as in (Li and Leung, 1987)).

Particularly, the luminosity excess of the secondary component can be caused by the influence of the circumstellar matter on the light curve of the system. According to the results obtained by Pustylnik and Einasto (1985,1987), the account of the contribution of the circumstellar matter can decrease the estimated value of the luminosity of the secondary component by 2-3 times. However, it can not explain the observed luminosity excess, which, obviously, indicates the evolutionary peculiarities of the system.

Spectral investigations. The results of the spectral investigations of V 367 Cyg are very contradictory. This is explained by the fact, that the system is surrounded by a significant gaseous envelope, which determines the main features of the observed spectrum. This fact strongly complicates the investigation of the stars of the system. If usually we have to search for the evidence on the existence of the circumstellar matter in a system, for V 367 Cyg the problem is a contradicting one: the most careful investigations are needed to detect the stellar features in the spectrum of V 367 Cyg. In the literature, we have found 12 determinations of the common spectral type of the system from F2 ev (Christie, 1933) to B8 Ia (Wilson, 1974) and 7 determinations of the individual classifications of the stellar components from F2 e + F5 (Polidan, 1970) to A2 + A8 (Gaposchkin, 1953). The elements of the spectral orbit have been determined three times and show a marked difference in the determination of the K and velocities and the functions of masses f(M) (Abt, 1954; Heiser, 1961; Aydin et al., 1978). The masses of the components are still uncertain: from 1.5 $M_\odot$ + 1.28 $M_\odot$ (Abt, 1954) to 19 $M_\odot$ + 12 $M_\odot$ (Li and Leung, 1987).

No one of the investigators of V 367 Cyg could succeed in finding the lines of the secondary component in the spectrum. Therefore, from the curve of the radial velocities, only the function of masses has been determined, from which (and general considerations) the stellar masses have been calculated. In works (Heiser, 1961; Aydin et al., 1978), the blue component in the lines Mg II λ 4481 A was found at some phases. However, because of the absence of the correlation the displacement of this detail with the phase of an orbital period, the authors of these works had concluded, that this component forms in the circumstellar matter.

From 1981 to 1989, we made the spectral observations of V 367 Cyg at the 6-meter telescope of SAO of the Soviet Academy of Sciences, and at the 2-meter telescope of the ROZHEN observatory of the Bulgarian Academy of Sciences. 46 spectrograms were obtained with the dispersion of 9, 18 and 28 A/mm within the range λ 3700 - 6800 A. The results of these investigations were published in the works (Karetnikov and Menchenkova, 1983, 1986,1987; Menchenkova and Pavlenko, 1989,1990; Glazunova and Menchenkova, 1989; Menchenkova and Kovachev, 1990; Menchenkova, 1990). It has been shown, that only the line Mg II λ 4481 A and the wings of the hydrogen lines are formed in the atmosphere of the bright star of the system. The stellar component is observed in the line K Ca II λ 3934A, but because of the strong blending by the line

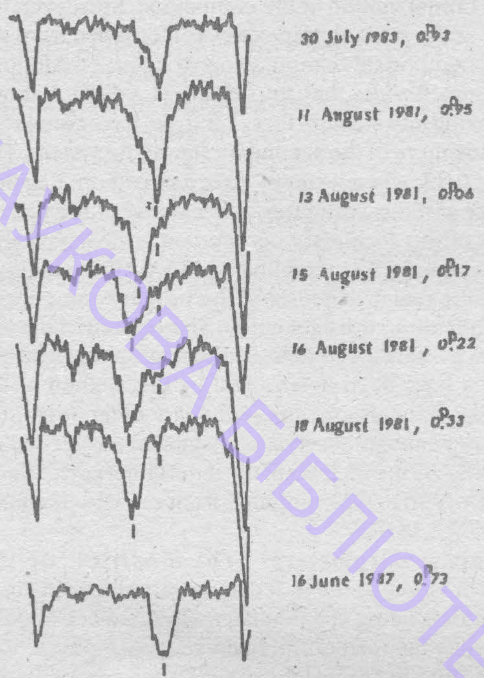

Fig. 1 The spectrum of V 367 Cyg in the region near the line Mg II 4481 A on the different orbital phases. The positions of the primary and secondary components are marked.

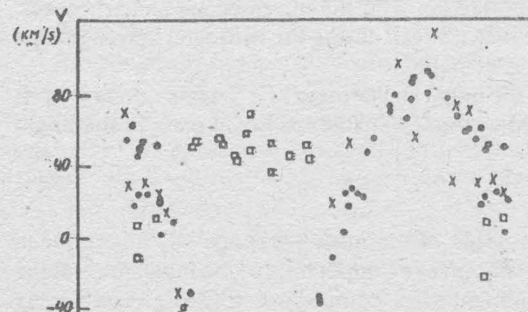

Fig. 2 The curves of the radial velocities for two components of the line Mg II 4481 A. O - the primary component of the line, □ - the secondary component of the line, ● - the data obtained by Heiser (1961), X - the data obtained by Aydin et.al. (1978).

of interstellar calcium and other neighboring lines of the spectrum, it can not be used to study the parameters of the stellar atmospheres.

From the lines Mg II λ 4481 A and of the hydrogen lines H_γ, H_δ, H 9 - H 13, the parameters of the atmosphere of the bright star of the system have been determined by the method of model atmospheres. For the comparison with the model calculations, we have used the observations obtained near the phase of the secondary minimum, in order to decrease a possible influence of the secondary component and of the circumstellar matter on the characteristics of the lines. In this time, the secondary component and the area near the point L1 are eclipsed, and, therefore, they make a minimum contribution to the total spectrum of the system. Using the net of the equivalent widths of the line Mg II λ 4481 A computed by Topilskaya (1987) for the models with 10000 K T (eff) 17000 K, lg g = 3.0, 3.5, 4.0 and V(tr) = 2.5 km/s and 10 km/s, we have estimated the effective temperature and turbulent velocity in the atmosphere of the bright star of the system: T (eff) = 12000 K - 14000 K, V (tr) = 10 km/s, if log N (Mg) = log N_O (Mg) and log g = 3.0 - 4.0. We have not considered the models with T(eff) 10000K since the stellar temperature cannot be lower than that of the envelope which is estimated to be about 9500 K (Karetnikov and Menchenkova, 1985).

We estimated the rotational velocity of the bright star of the system V 367 Cyg by using the calibration curve from Zajkova and Udovichenko (1988) and the semiwidth of the line Mg II 4481 A. This value is V sin i = 50 km/s. It is lower than the mean value for the main sequence stars of the same spectral class.

By using the net of the models calculated by Kurucz (1979) for the stars of the spectral type O -G, we have made comparisons between the observed profiles of the lines H_γ and H_δ, and the theoretical ones. It was found that the wings of the hydrogen lines H_γ and H_δ can be equally well described by three models:

T (eff) = 12000 K, log g = 2.5
T (eff) = 16000 K, log g = 3.0
T (eff) = 20000 K, log g = 3.5

For the 'single-value' determination of the parameters of the atmosphere of the bright star of the system, we had to consider the higher terms of the Balmer series. The synthetic hydrogen spectrum for the lines H 8 - H 14 computed by Pavlenko (Menchenkova and Pavlenko, 1989) according to the method of Grim (1967) realized in the ATLAS-5 program (Kurucz, 1970) was used for these three models. It should be noted, that the difference between the wings of the lines in these models is small. For the models with T (eff) = 12000 K, log g = 2.5 and T (eff) = 16000 K, log g = 3.0, this difference does not exceed the errors of observations. Nevertheless, the usage of the additional criteria allows to limit the range of the suggested values T(eff) and log g. The best agreement of the observational data with the theoretical computations has been obtained for models with T(eff) = 12000 K - 16000 K. In this case, the spectral type of the bright star of the system V 367 Cyg is B8 or earlier. From the other side, the absence of the helium lines in the spectrum of the system may argue, that the spectral type of the bright star of the system (with a normal chemical composition) cannot be earlier than B8. Summing up the results of the analysis of all stellar features in V 367 Cyg spectrum, we have arrived a conclusion, that the temperature of the bright star of the system is about T(eff) = 12000 K and log g = 2.5. As has been found in the process of our investigations, the line Mg II λ 4481 A shows the composite profile, which besides the primary component contains a fainter one. The displacement of this faint component agrees with the phase of the orbital motion of the secondary star of the system (Fig.1).

The radial velocity curves for the two components of the line Mg II λ 4481 A are shown at Fig.2. At the same figure, the radial velocity curves for the bright component obtained by Heiser (1961) and Aydin et al.(1978) are shown. The radial velocity curve of the secondary component of the line Mg II λ 4481 A agrees with the orbital motion of the companion. Moreover, the ratio of the intensities of the components of this line coincides with the ratio of the stellar luminosities (determined from the photometry) of about $L_2 / L_1 = 0.4$ (Heiser, 1962). The spectral types of the components cannot strongly differ. That follows from the absence of the considerable color variation during the primary minimum. Besides that, the line Mg II λ 4481 A shows a slight dependence on the temperature within the spectral interval B 8 - A 8. Taking into account these facts, we have concluded that the secondary component of the line Mg II λ 4481 A is formed in the atmosphere of the secondary star of the system. The absence of the secondary component of the line Mg II λ 4481 A at the phase 0.73, when it should have a maximum negative displacement, may be caused by an additional absorption by the circumstellar gaseous structures, more dense at the phases near the secondary maximum. However, at the phases 0.93 - 1.0, the line of the secondary component is observed with certainty. The orbital elements have been calculated as follows. The initial values of the K_1 (amplitude) and γ (the velocity of the center of masses of the system) have been determined from the curve of the radial velocities of the primary component. The initial epoch T_0 has been taken equal to the moment of the primary minimum in the light curve. The eccentricity e and the periastron angle ω have been set arbitrary. Then the parameters T_0, e, ω have been defined more precisely with the method suggested by Lavrov (1987). The final values of K_1, γ, T_0, e, ω have been determined by the method of the differential corrections. In order to calculate the theoretical curve of the radial velocities for the secondary component, the same values of the elements γ, e and $\omega + 180^\circ$ have been used (because not enough observational data on the secondary, component during the second half of the period). K and T have been determined by the method of the differential corrections. The orbital elements for the primary and secondary components of the system V367 Cyg computed from our observational data, are presented in Table 2. The stellar masses are $M_1 = 2.3 M_\odot$ and $M = 3.6 M_\odot$.

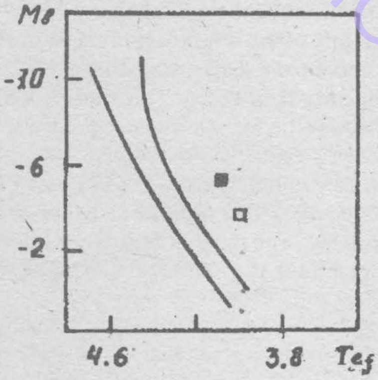

Fig. 3 The positions of the components of V 367 Cyg in H-R diagram. ■ - bright component, □ - companion.

Evolutionary status and initial parameters. The position of the components of the V 367 Cyg system as well as the H-R diagram are shown in Fig.3. The lines mark the positions of the stars being at the initial main sequence and the positions of the stars, which have just completed the main sequence phase. The excesses of the luminosity and radius of the bright component can be easily explained by the evolutionary theory of close binary systems of intermediate mass.

The bright, initially more massive (at present less massive) component has already evolved, leaved the main sequence, filled its Roche lobe and is losing matter now. The large orbital separation, together with the intermediate stellar masses, indicates, that the mass exchange phase began during the hydrogen burning in the layer source (case B events) or at later stages.

By using the relation between the initial stellar mass M_0 and its remnant mass after the first mass-loss episode M_R, we estimated the initial mass of the bright component of the system M_{10}:

$$M_R / M_\odot = 0.1 (M / M_\odot)^{1.4}$$

$$M_{10} = 9.4 M_\odot$$

As the fast stage of the mass exchange has not yet been finished, this value gives an upper limit of the initial mass of the primary component. The comparison with the evolutionary tracks computed for the close binary systems of intermediate masses (Iben and Tutukov, 1985) has shown, that the initial mass of the bright component should be within the range of $6.95 M_\odot$ - $9.85 M_\odot$ (Fig.4). We have taken $M_{10} = 8 M_\odot$ as an initial mass of the bright component and determined the main-sequence lifetime of the primary t_{1MS}, the mass of the remnant of the primary after the first mass-loss episode M_{1R}, the mass helium core of this remnant M_1 (He) and a time of the first stage of matter exchange t_B.

$$t_{1MS} = 2.76 \cdot 10^7 \text{ years}$$

$$M_{1R} = 1.84 M_\odot$$

$$M_1(He) = 1.11 M_\odot$$

$$t_B = 1.38 \cdot 10^4 \text{ years}$$

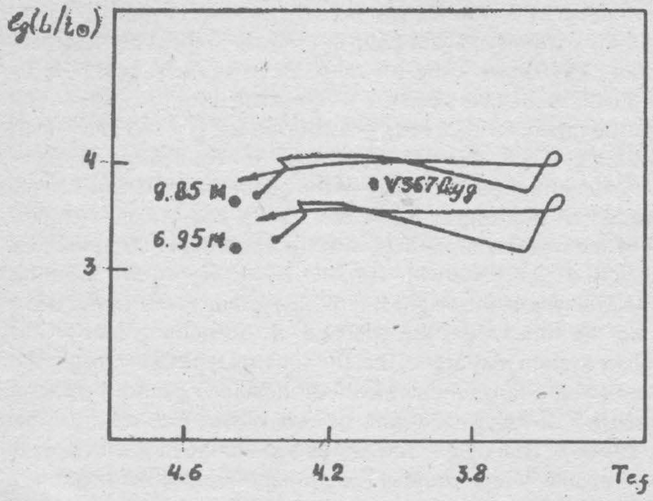

Fig. 4 The comparison between the parameters of the bright component of the system V 367 Cyg and the theoretical evolutionary tracks.

Because the system is being observed during the fast stage of the first mass-loss episode, after the bright component of the system has leaved the main sequence, the age of the system can be estimated 2.76×10^4 yrs. The accepting secondary component of the system has also the considerable excesses of radius and luminosity. However, if the radius excess of the secondary component can be easily explained within the model with the accretion disk near the nondegenerate star, the luminosity excess of the secondary component is impossible to describe by this model. We estimated the accretion luminosity, assuming that the accepting component is a main sequence star with mass $M_2 = 3.6 M_\odot$ and radius $R_2 = 3 R_\odot$ (the observed size of the secondary component apparently may correspond to the accretion disk). The main-sequence lifetime of the secondary accepting component of the system (now the star with mass $M_2 = 3.6 M_\odot$) cannot be less than $t_{2MS} = 2.03 \times 10^8$ yrs. That is ten times more than of the primary star ($M_{10} = 8 M_\odot$, $t_{1MS} = 2.76 \times 10^7$ years). Consequently, the time required for the more massive primary component to leave the main sequence and to lose a considerable part of its mass, is shorter than the main sequence lifetime of the secondary component (assuming that only own evolution of the companion is considered, without taking into account the accretion influence). The mass-loss rate of the bright component has been determined according to the period variation taken from Kreiner and Ziolkowski (1978): $\dot{M} = 6.7 \times 10^{-6}$ $M_\odot$/yr. It can be used as an upper limit for estimating the accretion on the secondary component

$$L_{ac} = G \dot{M} M / R = 251 L_\odot$$

As one may see, L_{ac} is of the same order with the own luminosity of the secondary companion ($M_2 = 3.6 M_\odot$, $L_2 = 114 L_\odot$). The total luminosity of the accepting component (star + accretion disk) is equal to

$$L_{2total} = (L_2 + L_{ac}) = 365 L_\odot$$
$$\log(L_{2total} / L_\odot) = 2.56$$

That is by a factor of ten less than the observed one. Thus, we are convinced, that the accretion cannot explain the observed luminosity excess of the secondary component. Before that moment, we supposed, that the accretion did not influence on the evolution of the accepting component. In fact, the matter added to the accepting component is not in the thermal balance. The accepting star accrates in the thermal time scale of the losing mass primary component, which differs from its own thermal time scale. It leads to the fast increase of the accepting component sizes, the filling up the Roche lobe with it and creating the contact configuration. The theoretical calculations of the evolution of the accepting component have shown, that its Roche lobe has been filled and the contact configuration has been created after the transfer of about $\sim 0.1 M_\odot$ in the systems with masses $5 M_\odot + 2 M_\odot$ (Benson, 1970) and only $0.05 M_\odot$ in systems with masses $1.5 M_\odot + 1 M_\odot$ (Yungelson, 1973).

As soon as the contact configuration come into existence, the common envelope losing the mass and angular momentum is formed. The fact that V 367 Cyg is closed to a contact configuration is shown by the whole complex of the spectral and photometric investigations testifying the presence of the hot optically dense plasma in the system. Moreover, the results of the analysis of the photometric observations of V 367 Cyg (Li and Leung, 1987) have shown, that the degree of overcontact of the system seems to have been growing from 0.0 % (or 0.6 % undercontact) to 5 % and to 9 % overcontact through the years from 1957 to 1960 and to 1973.

Using the statistical relations, we have estimated the initial parameters of V 367 Cyg. According to the conclusions of Popov (1968), the primary component in the systems with total mass close to (8-12) $M_\odot$ loses 75 % of its mass during the matter exchange process. 90 % of this matter go away from the system. Svechnikov (1969) has obtained same results for the stars with $(M_1 + M_2) \sim 11 M_\odot$. According to our determinations, the initial mass of the bright component of the system V 367 Cyg is $8 M_\odot$. Consequently, it has been lost $\sim 6 M_\odot$ during the first Roche-lobe-filling phase and only 10 % of this mass ($0.6 M_\odot$) has been added to the secondary component. The main part of this matter has been lost from the system. In this way, the initial mass of the secondary component is $\sim 3.0 M_\odot$, and the total initial mass of the system is $8 M_\odot + 3 M_\odot$.

The main difficulty in calculating the initial orbital elements is to determine the angular momentum loss from the system during the mass transfer event. We have estimated the initial semimajor axis, assuming that (according to Massevich and Tutukov (1988)), the energy required for the matter ejection from the system is taken from the orbital energy of the system:

$$\alpha_{CE} M_{1R} M_2 / A_f = M_{10}^2 / A_0 ,$$

where A_0 and A_f are the initial and final semimajor axes, respectively, M_{10} and M_{1R} are initial and final masses of the Roche-lobe-filling component, M_2 is the mass of the companion, α_{CE} is the efficiency of the transformation of the orbital energy into the energy required to eject mass from the system, $\alpha_{CE} = 1$. By using the numerical values, we obtained $A_0 = 410 R_\odot$, and the initial period of the system (according to the Kepler third law) $P_0 = 293$ days. It should be noted, that due to the considerable uncertainty of the parameters α_{CE} and M_{10}, M_2, the obtained value A_0 can be some less than in reality. However, even a small increase of the initial semimajor axis can be the reason, that the primary fills its Roche in a case C event with the white dwarf formation after a common envelope phase. While in the case B event, the helium star is formed at first.

Table 1. Absolute dimensions of V 367 Cygni

Parameter	Our results			Results of Li and Leung (1987)	
	Component 1	Component 2		Component 1	Component 2
		Roche model	Disk model		
A , R_O	53			93	
M , M_O	2.3		3.6	19	12
R , R_O	18	19.6	21.5	39	31
L , erg/s	$24 \cdot 10^{37}$	$1.3 \cdot 10^{37}$	$1.7 \cdot 10^{37}$	$9.4 \cdot 10^{37}$	$2.4 \cdot 10^{37}$
T , K	12000	9850	10100	11600	9300
R(ZAMS),R_O	2		3	6	4
L(ZAMS)e/s	$0.9 \cdot 10^{35}$	$0.5 \cdot 10^{36}$		$3.1 \cdot 10^{38}$	$5.1 \cdot 10^{37}$

Table 2. Orbital elements of V 367 Cygni

Parameter	Our results		Abt(1954)	Heiser(1961)	Aydin at al.(1978)
	Component 1	Component2	Component 1		
K , km/s	86.7	55.2	51.3	93.2	96.5
γ , km/s	1.6	1.6	-2.8	-4.6	15.0
ω	65.8	65.8	-	-	-
e	0.06	0.06	0.07	-	0.03
Asini,10^6 km	22.14	14.09	13.1	23.8	24.7
M $\sin^3 i$, M_O	2.14	3.36	-	-	-
f(M)	1.24		0.259	1.56	1.72

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SPECTRAL AND POLARIMETRIC STUDY OF CLOSE BINARY SYSTEMS XZ CEP AND V 448 CYG WITH A COMPOSITE SPECTRUM

L.V.GLAZUNOVA, G.V.MANILOVA

Abstract. The main parameters of the close binaries V448 Cyg and XZ Cep were determined. Computation of the chemical composition of the atmospheres of their primary components showed the existence of the hydrogen deficiency in them. The polarimetric measurements allowed to establish the sparse structure of the circumstellar envelopes.

Key words: Binaries: spectroscopy, polarimetry
Binaries: Individual: XZ Cep, V448 Cyg

XZ Cep and V448 Cyg are the representatives of the not numerous group of close binary systems, which have passed the phase of the mass exchange, and at present have the components of the similar luminosity, so one may observe the composite spectrum of the system. This allows to investigate the spectrum of the evolved star, which has lost a considerable part of its initial mass. Incidentally, such component (primary) shows a higher luminosity, despite its mass is significantly lost during the exchange process, and now is less than the mass of the other component (secondary).

Photometric, spectral and polarimetric observations show the presence of a circumstellar envelope in these systems, and allow to specify the structure of this envelope and its main parameters.

Based upon the high-dispersion spectral material obtained in 1981-1984 at the 6-meter telescope of the Special Astrophysical Observatory, the new spectral elements of the orbits of XZ Cep and V448 Cyg were obtained (Glazunova, 1985, 1986a). They are listed in Table 1. The spectral elements of XZ Cep were obtained for the first time. The star with a higher luminosity has proved to have a lower mass as compared with the companion. All the photometric elements of orbit, which were published earlier, were obtained without considering this fact. The new photometric elements of XZ Cep were obtained by Glazunova (1989). The elements and the absolute parameters of the system are listed in Table 1. Our spectral elements for V 448 Cyg are essentially different from those obtained by other authors. From the high-dispersion spectra, the nature of the significant distortion of the radial velocity curve of the secondary was found. The equivalent line widths of the primary star have proved to be much larger than those of normal stars of the same spectral type. This appears as the strong blending of the hydrogen and helium lines of the secondary star, the radial velocities of which were determined. The high dispersion of the obtained spectra allowed us to resolve these blends.

The spectral types and luminosity classes are presented in Table 1 for both components of the investigated systems (Glazunova and Karetnikov, 1985, Glazunova et al., 1986).

The spectral investigation of the primaries allowed to estimate the abundance of helium, nitrogen and carbon, by using the theoretical curves-of-growth. The overabundance of helium and nitrogen and the deficiency of carbon was found. These results as well as the place of the system's components at the Hertzsprung- Russell diagram (according to the parameters listed in Table 1, and the known age of V448 Cyg system belonging to NGC 6871 cluster, i.e. $6 \cdot 10^6$ years) allows to make a conclusion, that the exchange in both systems has started at the end of the hydrogen-burning phase in the core of initially more massive star (case AB). At present, the system XZ Cep has passed the phase of the mass exchange and is at the intermediate detached phase; V448 Cyg is at the end of the exchange phase, and the primary component continues on losing mass in the nuclear time scale (Glazunova, 1986b). The presence of such a stage is peculiar for the evolutionary AB case. The system with initial parameters: $M_{10} = 16 \cdot M_\odot$, $M_{20} = 15 \cdot M_\odot$, $A_0 = 27R_\odot$, $P_0 = 3^d.04$, $X_0 = 0.043$is the most adequate for all the calculated models of evolution of close binary stars with the AB-case exchange. During the exchange phase, the primary components have lost about 54 and 37 per cent of their initial mass, for V448 Cyg and XZ Cep, respectively.

For the investigation, we used the values of the equivalent widths of these stars obtained from the spectral material with the dispersion D=9Å/mm, as well as the values published by Glazunova and Karetnikov (1985) and Glazunova et al.(1986). The equivalent widths of all the light elements have proved to be larger than those of the standard stars of the same spectral characteristics (Peters, 1976, Wright et al., 1964), what is the main spectral peculiarity of the primary components of V448 Cyg and XZ Cep. This phenomenon is present even at such phases of an orbital period, when the influence of the circumstellar gaseous envelope is at minimum. It does not disappear after the reduction to the system of equivalent line widths of standard stars (Peters, 1976, Wright et al.,1964).

The possible interpretations of the anomalous enlargements of the equivalent widths (4-10 times) of all the light elements in the spectra of the primary components of V448 Cyg and XZ Cep are the following:

1) the atmospheres of these stars differ qualitatively from those of normal stars (eg. by the hydrogen deficiency);

2) W_λ can be enlarged due to the higher microturbulent velocities as compared with the normal stars. In order to obtain the quantitative characteristics of the considered phenomenon, we carried out the analysis of the spectra of the investigated stars by using the method of the 'model atmospheres' (Klochkova et al., 1985). We used the computer code elaborated by V.V.Tsymbal, based on the programs ATLAS6 and WIDTH6 (Kurucz, 1979). The main parameters of the components T_{eff} and log g were obtained earlier, by using the spectral type (Glazunova and Karetnikov, 1985, Glazunova et al.,1986), mass and the stellar radius (Glazunova, 1989, Ashbrook, 1942):

V448 Cyg: $T_{eff} = 20000\ K \pm 300\ K$, $\log g = 3 \pm 0.5$

XZ Cep : $T_{eff} = 22500\ K \pm 300\ K$, $\log g = 3 \pm 0.5$

The rotation velocities of the primary components are 130 km/s and 113 km/s for V448 Cyg and XZ Cep, respectively (Glazunova, 1986b). Therefore it was of great importance to take into account the blending while calculating the values of W_λ. The blends' components necessary for W_λ -calculations were obtained from the computations of the synthetic stellar spectra. The parameters of the broadening of the helium lines due to the square Stark effect were taken from Barnard et al.(1974), for other lines - from Grim (1978), oscillators' strengths of the lines - from Kurucz and Peytremann (1975). For the computations, we used different values of the microturbulent velocity (5,10,15,20 km/s) and of the helium abundance (from 0.1 to 0.9), until the empiric equivalent width of each element became consistent with the calculated one. The calculations showed, that the degree of the W_λ- enlargement differs for different elements with the same helium abundance. For the majority of the calculated lines (Si III, Si IV, O II, Al III, Mg II, Fe III), the best agreement with the observed W_λ for both stars was obtained for the models with the hydrogen deficiency in the range from ε_{He} 0.4 to 0.9 (with the account of errors of the observed equivalent widths) and with the high microturbulent velocities: V = 20 km/s for V448 Cyg and 15 km/s for XZ Cep. Incidentally, in order to explain the considered anomalies in the behavior of the lines of the light elements, it was necessary to add some nitrogen overabundance (0.18 dex for V448 Cyg and 0.3 dex for XZ Cep in the model with $\varepsilon_{He} = 0.9$) and some carbon deficiency ($\sim$1 dex for both stars) to the hydrogen deficiency. We verified the presence of the hydrogen deficiency in the atmospheres of the investigated stars by computing the values of W_λ for the Balmer lines for the models with the main parameters mentioned above, and varying the hydrogen abundance. The computations were carried out by using the 'BALMER' program (Kurucz, 1979). The calculated equivalent line widths of H_β, H_γ, H_δ have proved to fit those in the spectra of both stars for the models with ε_{He} from 0.8 to 0.9 (with the account of errors the values of observed equivalent widths).

Thus, the anomalous enlargement of the lines of all the light elements in the spectra of the primary components of V448 Cyg and XZ Cep can be satisfactory explained in virtue of the assumptions on the hydrogen deficiency and microturbulent velocities in atmospheres of the investigated stars.

The results the linear polarimetry of XZ Cep in three bands are published by Saute and Martel(1979). The observed values of the parameters of polarization at maximum light they interpreted as corresponding to the interstellar polarization. The values of the intrinsic polarization obtained in the above mentioned manner allowed the authors to make a conclusion on the sparse structure of the gaseous envelope in the system.

The polarimetric investigation of V448 Cyg carried out in U, B, V, R, I - color bands is described by Shakhovskoy et al.(1992). In this work, the variability of the parameters of polarization was found for the first time in all the color bands. The amplitude of variation of the degree of polarization (P) in band U, for example, is more than 0.4 per cent (σ_p = 0.05 per cent), that of the variation of the position angle (Θ) is more than 30^0 ($\sigma_\Theta = 4.4$). The interstellar component was found as well as the constant component of the intrinsic polarization with a flat spectrum in the observed polarization. The evaluation of the Fourier harmonics of the normalized Stokes parameters allowed to find a contribution of the intrinsic polarization. It shows a spectral dependence inherent to the Be-stars. The constant component of the intrinsic polarization is probably connected with an extended disk-like optically thin scattering envelope, whereas a variable one - with the relatively dense condensations near the inner Lagrangian points of the system. The mass of the extended envelope and the mass loss rate in the system are about $1.5 \cdot 10^{-8} M_\odot$ and $8.68 \cdot 10^{-7} M_\odot$/yr, respectively.

Thus, the analysis of the spectral and polarimetric data on the investigated systems allows to establish the sparse structure of the circumstellar gaseous envelopes surrounding them.

Table 1. The parameters of XZ Cep and V 448 Cyg

Parameter	**XZ Cep**	**V 448 Cyg**
K_1 (km/s)	224.8 ± 7.7	246.5 ± 3.6
K_2 (km/s)	174.7 ± 4.4	96.3 ± 7.6
γ (km/s)	−4.8 ± 5.5	13.8 ± 2.5
e	0.04 ± 0.06	0.00 ± 0.02
ω_1	77^0 ± 2	-
ω_2	210^0 ± 2	-
$a_1 \sin i$	15.745 ± 0.546	22.101 ± 0.323
$a_2 \sin i$	12.204 ± 0.313	8.550 ± 0.719
$M_1 \sin^3 i$ ($M_\odot$)	14.62	7.65
$M_2 \sin^3 i$ ($M_\odot$)	18.81	19.60
Sp_1	B1.5 II	B1.2 Ib
Sp_2	B1.1 V	O8.9 V
$\log g_1$	3.26	2.92
$\log g_2$	3.9	3.99
ξ_t (km/s)	15	23
i	$88.4^0 \pm 0.3^0$	-
r_1	0.326 ± 0.002	-
r_2	0.245 ± 0.002	-
L_1	0.54 ± 0.02	0.69
L_2	0.46 ± 0.02	0.31
M_1 ($M_\odot$)	14.20	8.14
M_2 ($M_\odot$)	18.11	20.85
R_1 ($R_\odot$)	13.0	16.7
R_2 ($R_\odot$)	9.8	7.61
M_{v1}	-4.4	-5.7
M_{v2}	-3.9	-4.8

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DETERMINATION OF THE ORIENTATION OF THE ACCRETION COLUMNS IN MAGNETIC CATACLYSMIC VARIABLES

I.L. ANDRONOV

Abstract. Methods for the determination of the orientation of accretion columns in magnetic cataclysmic variables based on the observations of the circular and linear polarization, X-Ray flux and profiles of emission lines are discussed. The non-uniformity of the density distribution through cross-section of the accretion columns leads to significant changes in the resulting spectra in two polarizational modes as compared with the 'homogeneous plasma slab'model. Simplified expressions for the circular polarization provides an additional relation between the inclination i and the magnetic latitude β. Similar relations may be established from the X-Ray and spectral observations. However, by interchanging the values of i and β one will obtain the same phase relationship. The only direct method obtain the true values for i and β is based on polarization position angle changes. Real columns are non-stationary and not axisymmetric, which significantly affect observed characteristics. Observations of polars show long-term orientation changes of the accretion column with respect to the binary system. However, observations to date do not allow one to distinguish between the 'swinging' and 'idling' dipole models.

Key Words : Stars: Binaries: Magnetic: Accretion Columns
Stars: Individual: AM Her, EF Eri, MR Ser

INTRODUCTION. In 1976, S.Tapia (1977) discovered significant linear and circular polarization in the emission of AM Her. These polarization changes occur with the same ~3-hour period, as the photometric and spectral characteristics. Krzeminski and Serkowski (1977) found a similar phenomenon in AN UMa, thus arguing for the existence of a class of exotic objects, which they called 'polars'. According to the 'standard model' (Chanmugam and Wagner, 1977; Stockman, 1977 and references therein), these magnetic cataclysmic variables are binary systems consisting of a Roche lobe filling secondary and a magnetic white dwarf (WD) primary onto which accretion occurs via an accretion column (AC). The strong (20-70 MGs) magnetic field of the primary disrupts the formation of a disk. Reviews may be found in Kruszewski (1978), Chiappetti et al. (1980), Lamb (1985), Liebert and Stockman (1985), Voykhanskaya (1989), Aslanov et al.(1989) and Cropper (1991).

The strong magnetic field leads to a fast ($< 10^3$ yrs) synchronization of the rotation of the WD with the orbital motion (cf. Andronov,1987a). After such synchronization changes in the orientation of the magnetic axis of the WD with respect to the non-degenerate secondary may exibit a 'limit-cycle' behaviour as predicted by the 'Swinging Dipole' model (Andronov, 1987b). The changing orientation of the magnetic field in the vicinity of the inner Lagrangian point modulates the accretion rate (Andronov, 1984a) and thus the luminosity of the accretion column. Based on observations these changes were suspected by Bailey and Axon (1981), but the question concerning whether the WD is 'idling' or 'swinging' remains unsolved (cf. Andronov, 1992).

In this Paper we briefly discuss methods for the determination of the orientation, published earlier, and present the results of a simplified approach to the observations of the circular polarization and of the 'base' component of the emission lines.

INHOMOGENEOUS ACCRETION COLUMNS. We will use an AC which is tall and thin, despite the fact that models for some systems argue for a 'polar cap' rather than an AC. In previous papers (Andronov, 1990, 1992) we studied isothermal ACs with a non-uniform density distribution. To compute the fluxes in two independent polarizational modes we used the analytic approximation for the absorption coefficients derived by Pavlov et al.(1980). They suggested the homogeneous plasma slab, for which the intensity in the jth polarizational mode is proportional to $r(\tau_j) = 1-exp(-\tau_j)$, where is the optical depth of the jth mode. Thus, if for both polarizational modes $\tau_j >> 1$ the corresponding intensities are equal and no polarization may be observed. Similar results may be obtained for all models of the ACs with abrupt limits. Let the electron number density distribution be of the form

$$n(x,y,z)=n_0 f(x,y,z) \qquad (1)$$

where n_0 - is the characteristic density, and $f(x,y,z)$ is a dimensionless function of the coordinates. Here z-axis is directed along the AC's axis. The observer is located in the $y = 0$ plane.

Due to the finite mass of the AC, the integral

$$F(z)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y,z)\,dx\,dy \qquad (2)$$

must be finite. Other physical speculations about the structure of the stationary AC suggest that each curve of equal density

$$f(x,y,z) = const(z)$$

is a single closed line. For a symmetric AC this function may be rewritten in the form

$$f(x,y,z) = g(u,z), \tag{3}$$

where $u^2 = (x/a)^2 + (y/b)^2$, and a and b are the characteristic linear dimensions of the elliptic AC along the x- and y- axes at the height z.

If the function $g(u,z) > 0$ for all u, the inhomogeneity of the AC causes a significant dependence of the 'effective' AC's radius on the optical depth τ even if $\tau > 1$. The values

$$\tau = \chi_j n_0 f(x,y,z)\, dx, \tag{4}$$

where χ_j - are the absorption coefficient in the j^{th} polarizational mode (Pavlov et al., 1980). We studied the following two limiting cases:

$$g(u,z) = \exp(-u^2/2) \tag{5}$$

and

$$g(u,z) = 1/(1+u^2) \tag{6}$$

The first approximation corresponds to the electron number density which rapidly decreases with a distance from the AC's axis. The second one (cf. Wang and Frank, 1981; Stockman and Lubenow, 1987) makes the integral (2) infinite, thus such a model may be applied for the AC with the abrupt limit $u < u^0$. If $u > u^0$ then $g(u,z) = 0$. The corresponding expressions for the fluxes, as well as the computations of the polarization and spectra were published by Andronov (1990, 1992). In short, the 'effective radius' of the column $r(\tau)$ is proportional to τ for $\tau < 1$. For $\tau > 1$ the function $r(\tau)$ depends strongly on the shape of the function $n(x,y,z)$. For the homogeneous plasma slab, or homogeneous cylinder, with large $r(\tau) \approx 1$. For the 'normal distribution', $r(\tau) \approx (2 \log \tau)^{1/2}$. The largest slope corresponds to the 'Lorentz shape', see Eq.(6), where $t(\tau)\ \infty\ \tau$ while $\tau < u$. In the opposite case $\tau > u$ and the function $r(\tau) \approx u = const(\tau)$. The fluxes from real accretion columns are believed to depend on τ in an intermediate manner as compared with the limiting cases discussed above. Obviously, models may be significantly complicated since other effects may be taken into account. However, we did not compute the two-layer model like that proposed recently by Wu and Chanmugam (1988). The main polarizational effects are discussed in the monograph of Dolginov, Gnedin and Silantjev (1979).

MAGNETIC AXIS CROSSES THE CELESTIAL SPHERE. Despite the complicated dependence of the polarization and fluxes on the model parameters, some conclusions may be made from the qualitative analysis of the linear and circular polarization. The sign of the circular polarization depends on the angle between the line of sight and the magnetic field lines. Thus the linear polarization reaches its maximum simultaneously with the zero-crossing of the circular polarization, i.e. when the AC's axis lies orthogonal to the line of sight. Let α - is the angle between them, which may be obtained from the expression

$$\cos\alpha = \cos i \cos\delta + \sin i \sin\delta \cos(2\pi(t-t_0)/P) \tag{7}$$

where i is the inclination (i.e. the angle between the rotational axis and the direction to the observer) i, δ is the angle between the rotational axis and the AC's axis, t is the trial time, P_{orb} is the rotational period of the WD (coinciding with the orbital period), and t_o corresponds to the initial phase. Some authors prefer to use the 'latitudes' of the observer $(90^0 - i)$ and of the AC $(90^0 - \delta)$ (cf. Kruszewski, 1978).

One may see, that the Eq. (7) is symmetric with respect to the model parameters i and δ. Thus interchanging them will not change the dependence of $\alpha(t)$. Estimates of i and δ from each characteristic of the emission which depends only on α and not on the position angle does not allow one to obtain the true sequence of i, δ or δ, i in principle.

For $\alpha = 90^0$, $\cos\alpha = 0$, and

$$\varepsilon = \cot i \cot\delta = -\cos(\pi\Delta\varphi), \tag{8}$$

where $\Delta\varphi$ is the phase difference between the zero-crossings of the circular polarization. Here there is an uncertainty in the sign of $\cos(\pi\Delta\varphi)$, because the values $\Delta\varphi$ and $1 - \Delta\varphi$ are both phase intervals in the same sense, but they correspond to the opposite magnetic poles of the WD. The sign depends on whether the active column and the observer are located on the same or opposite hemispheres of the WD. If they are on the same hemisphere, then the value on the right side of Eq.(8) must be positive.

From Eq.(8) one may not obtain both values i and δ, but may estimate the dependence of $\delta(i)$ or $i(\delta)$. Kruszewski (1978) obtained the value ε =-0.62 for AM Her, whereas Chanmugam and Wagner (1977) originally found ε =-0.68. Kruszewski (1978) also pointed out, that the values of ε are wavelength-dependent, thus arguing for possible differences in the effective orientation of the magnetic field in the region, effectively emitting at the corresponding wavelength.

POSITION ANGLE OF THE POLARIZATION: THE ONLY WAY TO DETERMINE THE INCLINATION ? The position angle Θ of the linear polarization may be obtained from the expression

$$\cot\Theta = \cos i \cot\psi - \cot\delta \operatorname{cosec}\psi \sin i \tag{9}$$

where Θ is arbitrary set to zero, if $\psi = 0$. Generally, $\psi = 2\pi(t - t_\Theta)/P_{orb}$ (Chanmugam and Wagner, 1977; Stockman, 1977).

Efimov and Shakhovskoy (1981, 1982) studied phase changes of the linear polarization on the $'p_x - p_y'$ diagram and estimated the orientation for the systems AN UMa and AM Her.

Meggit and Wickramasinghe (1982) pointed out, that

$$d\Theta/d\psi = \cos i \tag{10}$$

when the angle $\alpha = 90^0$ and the Eq.(8) is valid. They obtained $63^0 < i < 76^0$ for AM Her. According to Kruszewski (1978) $i = 65^o$ and $\delta = 143^o$ for AM Her ('far pole') or $\delta = 180^0 - 143^0 = 37^0$ ('closest pole'). Piirola et al.(1985) obtained from Eq.(8) the values $67^o > \delta > 53^o$ for V, and $61^o > \delta > 45^o$ for I, adopting $30^o < i < 46^o$. Barrett and Chanmugam (1984) and Brainerd and Lamb (1985) obtained the values $i = 46^0$ and $i = 35^0$ $(\delta = 58 \pm 5^0)$ respectively. Piirola et al.(1985) fitted the position angle at all available phases by using Eq.(9).

Discrepances in the results may be partially explained by the insufficient accuracy of the position angle determination and its derivative. Another possibility is due to physical variability. However, in the latter case one has to suggest that the AC moves above the surface of the WD with a characteristic time-scale comparable with the orbital period. This is strange enouth because the rotation of the white dwarf is believed to be nearly synchronous (within one part in 10^{-4}) with the orbital motion.

DIFFERENT COLORS OF THE ACCRETION COLUMN: SIMPLIFIED CONSTRAINS FROM ECLIPSES. The polarizational phase curves are wavelength-dependent, as was originally found by Tapia (1977). This suggests that the cyclotron emission from the AC originates as a sequence of some first cyclotron harmonics (Gnedin and Sunyaev, 1973; Tapia, 1977). One may conclude, that each part of the column emits at different wavelengths, because the cyclotron frequency of the s^{th} harmonic is proportional to the magnetic field strength, i.e. $w \propto s/r^3$ where r is the distance from the center of the dipole (Priedhorsky and Krzeminski, 1978). The part of the column at the distance r is eclipsed, if

$$\cos\alpha < - r_{WD}/r_i \tag{11}$$

where r_{WD} is the radius of the white dwarf. Combining (7) and (10), one may obtain the system of equations for each wavelength λ_i :

$$a + b\cos\pi\Delta_i = -(1-(r_{WD}/r_i)^2)^{1/2} , \tag{12}$$

where Δ_i is the phase duration of the eclipse of the cyclotron emission at a given wavelength, $a = \cos i \cos\delta$, and $b = \sin i \sin\delta$. Here are three unknown parameters: a,b and r_1 (because for the dipole field approximation, the values

$$r_i/r_1 = (\lambda_i/\lambda_i)^{1/3} = (\omega_1/\omega_i)^{1/3} \tag{13}$$

are known). This system may be solved, if there are circular polarization curves obtained in at least three spectral bands.

Another possibility is to use an approximation for the circular polarization of the emission from the AC, the height of which is much more than the width (adopted from Gnedin and Pavlov (1975), cf. the expressions 5.111,5.112 of Dolginov et al. (1979))

$$q = 2(\omega_B/\omega)\cos\alpha \;\; |\sin\alpha|\gamma/(1+|\sin\alpha|), \tag{14}$$

where ω_B is the cyclotron frequency , ω is the trial frequency, and γ is some coefficient. If one will use the trial frequency $\omega = s\,\omega_B$ for the s^{th} harmonic then, at the phase of the mid-eclipse,

$$sq_{0i} = \frac{2(a+b)\sqrt{1-(a+b)^2}\;\gamma_i}{1+\gamma_i\sqrt{1-(a+b)^2}} \tag{15}$$

whereas at the phase 0.25 earlier or later (practically one has to use the mean value),

$$sq_{0.25\,i} = \frac{2a\sqrt{1-(a+b)^2}\;\gamma_i}{1+\gamma_i\sqrt{1-a^2}} . \tag{16}$$

The inverse equations are

$$\gamma_i = \frac{s\,q_{0i}}{(2(a+b)-s\,q_{0i})\sqrt{1-(a+b)^2}}$$

$$\gamma_i = \frac{s\,q_{0.25\,i}}{(2a - s\,q_{0.25\,i})\sqrt{1-a^2}} \tag{17}$$

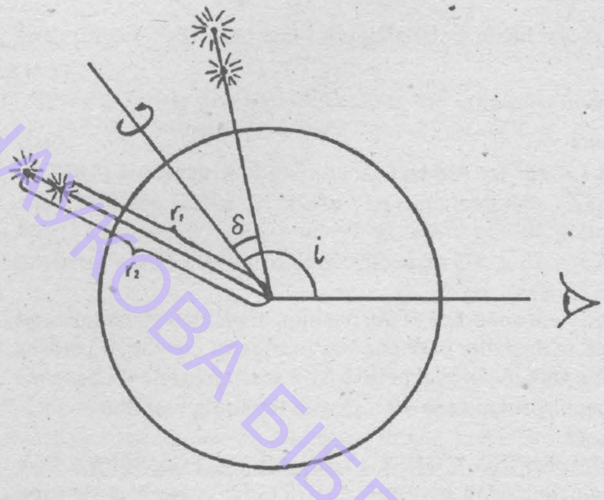

Fig. 1 The schematic model of the white dwarf and the accretion column in MR Ser. Upon suggestion, each part of the accretion column emits radiation at the cyclotron frequency $s \cdot \omega_B$, corresponding to the magnetic field strength B at the distance r .

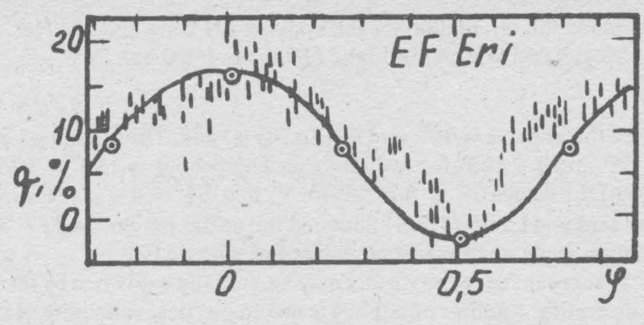

Fig. 2 The circular polarization changes of MR Ser: crosses are original observations of Liebert et al.(1982); filled circles are the adopted points corresponding to the values of q_0 and $q_{0.25\,i}$; the solid line is the calculated (Eq.(14)) changes with eclipse by the white dwarf; the broken line - the calculated changes without eclipse.

If we have observations in two spectral bands, than, varying r_1, one may consecutively obtain r_2 (Eq.13), a, b (Eq.12). The value r_1 must satisfy two eq.(17) for the same values of $\gamma_1, \gamma_2 ...$, (they may be slightly different for the different spectral bands).

Using this algorithm for the observations of MR Ser=PG1550+191 (Liebert et al., 1982), we obtained for s=1 the values $i = 56^0 \pm 6^0$ ($124^o \pm 6^0$ for the 'far pole' model), $\delta = 23^0 \pm 6^0$, $\gamma = 0.12 \pm 0.01$, $r_1 = (1.24 \pm 0.08)\ r_{WD}$ (0.407μm), $r_2 = (1.50 \pm 0.10)\ r_{WD}$ (0.727 μm).

The eclipse durations $\Delta_1 = 0.39 \pm 0.02$, $\Delta_2 = 0.29 \pm 0.02$. The deviation of our values of i and δ from that ($i = 45^0 \pm 5^0$, $\delta = 40^0 \pm 5^0$) of Brainerd and Lamb (1985) do not exceed 3σ. The scheme of the system is shown in Fig.1. The corresponding curves are shown in Fig.2, as well as the positions of the eclipses. Because the region of the emission in the given spectral band is an extended one, the observed eclipses are not abrupt. It may be noted that we used only four points from the two curves (marked by pluses), but the curve fitting is satisfactory despite so many assumptions.

For AM Her we used the observations of Bailey and Axon (1982) with the spectral bands centered at 0.55, 0.68 and 0.83μm, and the 'far pole' model of Kruszewski (1978). The eclipse durations are Δ_i = 0.40, 0.37 and 0.34 ($\pm$ 0.01), respectively. The results are the following: $\gamma = 0.110 \pm 0.015$, $i = 67^0 \pm 6^0$, $\delta = 119^0 \pm 6^0$, $r_1 = (1.21 \pm 0.07)\, r_{WD}$, $r_2 = (1.30 \pm 0.12)\, r_{WD}$, and $r_3 = (1.39 \pm 0.09)\, r_{WD}$.

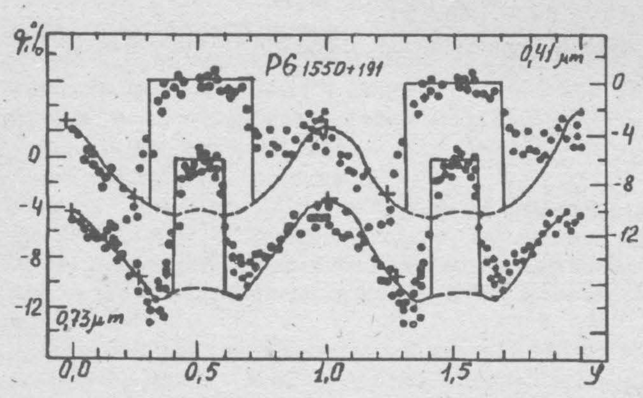

Fig. 3 The observed, by Bailey and Axon (1981), and calculated changes of the circular polarization of AM Her. The legends are as in Fig.2.

The corresponding curves are shown in Fig.3. The values of i and δ are similar to that ($i = 65^o$, $\delta = 143^o$) of Kruszewski (1978). This 'far-pole' model may not contradict the 'nearest pole' model of Brainerd and Lamb (1985), Piirola et al. (1985) and Andronov (1986b), if there are two simultaneously accreting poles which are emitting at different spectral bands (Kruszewski, 1978). Both poles outside the eclipses will give the same phase dependence of cos α and Θ, the inclination of the column(s) with respect to the white dwarf may lead to the discrepancy in δ .

For the one-band observations of the systems without eclipse of the accretion column, the orientation may be determined by using the values $q_0, q_{0.25}$ and $q_{0.5}$ and substituting them into Eq.(14). For observations of EF Eri (Bailey et al., 1980), we obtained $i = 75^0$, $\delta = 18^0$ (or opposite sequence) and $\gamma = 0.218$ suggesting s = 1. Polarization curve is shown in Fig. 4.

These numerical solutions show, that the parameter γ is constant within observational errors for the fixed star, but different for different spectral bands. With changing s, the parameters i and δ are changing not significantly, contrary to γ . From theoretical considerations, the values of γ must lie in the interval from 0.30 to 1.57 (Gnedin and Pavlov, 1975). For AM Her, this corresponds to s=3,4,5 or 6. The corresponding magnetic field strength at the pole of the white dwarf is B=50 to 100 MGs, intermediate between the values 260 MGs (Voykhanskaya

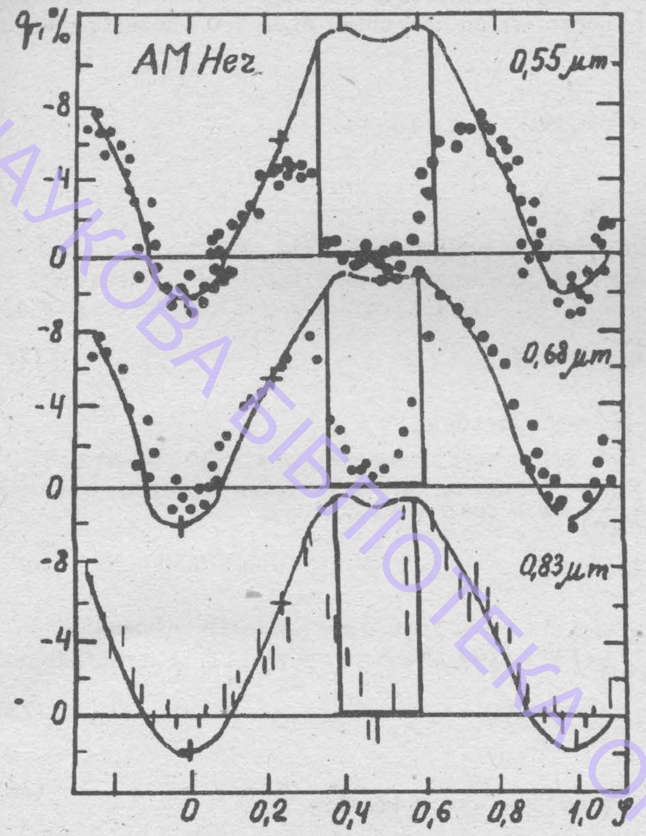

Fig. 4 The observed, by Bailey et al. (1980), and calculated changes of the circular polarization of EF Eri. The legends are as in Fig.2, with an additional point corresponding to $q_{0.25\,i}$.

and Mitrofanov, 1980) and 20 MGs (Schmidt et al., 1981). The dilution of the cyclotron emission by the contribution of the stellar components leads to a decrease of the value of q, thus to a decrease in the 'observed' value of γ and an increase in s.

This model is very crude. In principle, one must take into account the true three-dimensional functions of the distribution of the electron number density, velocity and the magnetic field. However, estimates of i and δ from the eclipse width may give the additional information for model constrains.

X-RAY CURVES: THE 'POLAR CAP' MODEL. Besides the polarimetric observations, the orientation may be estimated from the soft X-ray curves. Andronov (1986b) computes a set of models for the beamshape of soft X-ray emission produced in an axially symmetric 'polar cap'. No 'optically thin' model gives a satisfactory approximation to the observations of AM Her (Hearn and Richardson, 1977). Therefore the extinction corresponding to the density distribution (5) is taken into account. For some values of the model parameters, the following ranges are obtained : $51^0 < i < 64^0$, $30^0 < \delta < 34^0$ (or opposite), in exellent agreement with the mentioned above 'near pole' model.

The soft X-Ray flux will be re-emitted in the bottom parts of the AC, thus the region of its origin will not be two-dimensional, and will extend to some height above the surface of the white dwarf. This region will be 'boiling', resulting in rapid variability in a time-scale of seconds (Andronov, 1987c).

EMISSION LINE PROFILES: THE WINGS ORIGINATE CLOSE TO AC ? The optical spectra of polars are characterized by the presence of the strong emission lines of hydrogen and helium, the shape of which is very complex and variable (cf. Cowley and Crampton, 1977). According to Burenkov and Voykhanskaya (1980) during the low luminosity state the lines have many peaks, which argues for the motion of separate plasma blobs rather than a homogeneous accretion flow. With increasing luminosity the lines become smoother, indicating the formation of an accretion column (AC).

Following Andronov (1984b), let us consider the profile of the emission line arising at the AC near the magnetic pole of the white dwarf. Let $f(v/v_0, \alpha, r)\,dv\,dr$ be a flux at the wavelength corresponding to the velocity v in the co-moving reference frame which appears from the element of AC at the distance r from the center of the white dwarf. Here $v_0(r)$ - is the characteristic velocity, which affects the line width, and α - is the angle between the line of sight and the AC's axis (directed to the center of the white dwarf). In the reference frame related to the white dwarf, one may write the general expression

$$F(v,\alpha) = \int_r dr \cdot f((v - v_r \cos\alpha)/v_0, \alpha, r). \tag{18}$$

The luminosity of the AC's element is

$$L(\alpha, r) = \int_{-\infty}^{\infty} f(v/v_0, \alpha, r)\, dv. \tag{19}$$

The total luminosity is equal to

$$\int_r L(\alpha, r) = \int_{-\infty}^{\infty} F(v,\alpha)\, dv. \tag{20}$$

Let us introduce the function

$$F_n(\alpha) = \int_r dr \int_{-\infty}^{\infty} v^n f(v/v_0, \alpha, r)\, dv. \tag{21}$$

The function $f(v/v_0, \alpha, r)$ is symmetric with respect to the argument v. This is valid while suggesting the Doppler effect, Zeeman effect, and the collisional broadening. Thus, for integer values of m, one may obtain $F_{2m+1} = 0$. The mean values of are the following:

$$<v^n> = \frac{1}{F_0(\alpha)} \int_{-\infty}^{\infty} v^n (f(v - v_r \cos\alpha)/v, \alpha, r)\, dv =$$

$$= \frac{1}{F_0(\alpha)} \int_r dr \int_{-\infty}^{\infty} (v_1 + v_r \cos\alpha)^n f(v_1/v_0, \alpha, r)\, dv_1,$$

$$<v> = <v_r> \cos\alpha \tag{22}$$

$$<v^2> = \frac{F_2(\alpha)}{F_0(\alpha)} + <v_r^2> \cos^2\alpha,$$

$$<v^3> = 3\frac{F_2(\alpha)}{F_0(\alpha)} <v_r> \cos\alpha + <v_r^3> \cos^3\alpha$$

Here

$$<v_r^n> = \frac{1}{F_0(\alpha)} \int_r dr \cdot L(\alpha, r)\, v_r^n. \tag{23}$$

The mean-squared thickness of the line is

$$M_2 = <v^2> - <v>^2 = \frac{F_2(\alpha)}{F_0(\alpha)} + (<v_r^2> - <v_r>^2)\cos^2\alpha. \tag{24}$$

The asymmetry is proportional to the quantity

$$M_3 = <v^3> - <v>^3 - 3M_2 <v> =$$

$$= (<v_r^3> - 3<v_r^2><v_r> + 2<v_r>^3)\cos^3\alpha. \tag{25}$$

Thus, the asymmetry of the lines appears to be due to the velocity gradient of the plasma motion. If the magnetic axis crosses the celestial sphere then the asymmetry changes its sign. Simultaneously the mean-squared thickness reaches its minimum. Otherwise these characteristics are changing in phase (or in the opposite phases).

The orbital changes of M_2 and M_3 are determined by the orientation of the AC in the rotating frame. Taking into account the expression (7), one may rewrite (24) and (25) in the form:

$$M_2 = A^2 + \widetilde{B}^2 \cos^2\alpha \tag{26a}$$

$$M_3 = C(D + E\cos\Psi)^3 \tag{26b}$$

where

$$C = (<v_r^3> - 3<v_r^2><v_r> + 2<v_r>)B^{-3}.$$

If the function $L(\alpha, r)$ may be expressed as the product $L_1(\alpha) \cdot L_2(r)$, the parameters A, $\widetilde{B}$, and C do not depend on α. By using the method of the Least squares, and solving the system of the equations

$$a_0 + a_1\cos\Psi_k + a_2\sin\Psi_k + a_3\cos 2\Psi_k + a_4\sin 2\Psi_k = M_{2k},$$

$$k = 1 \dots N \tag{27}$$

(where N - is the number of the observations), one may obtain the coefficients $a_0, \dots, a_4$. They are related to the model parameters :

$$A^2 + F^2 + \frac{1}{2}G^2 = a_0,$$

$$2FG\cos\Psi_0 = a_1,$$

$$2FG\sin\Psi_0 = a_2,$$

$$\frac{G^2}{2}\cos 2\Psi_0 = a_3,$$

$$\frac{G^2}{2}\sin 2\Psi_o = a_4. \tag{28}$$

Here $F = \bar{B}\cos i\cos\delta$ and $G = \bar{B}\sin i\sin\delta$.

The system of 5 equations with 4 unknowns (A, F, G, Ψ_0) may be reduced to 2 equations with 3 parameters$(\bar{B}, i, \delta)$ by obtaining the values of F and G from (28), i.e.,

$$G = \sqrt{2\sqrt{a_3^2 + a_4^2}}\quad ,$$

$$F = \pm\sqrt{a_1^2 + a_2^2}\;/2G\,. \tag{29}$$

The sign of F is to be choosen so that Ψ_0 will be close to the phase of the minimum radial velocity. Thus the spectral observations alone may allow one to write the relation

$$\cot i\,\cot\delta = F/G \tag{30}$$

Substituting the values of F and G into (26.b), one may estimate the value of C . The parameter C allows one to estimate the dependence of $L(\alpha, r)$ on r. For $L(\alpha, r)\,\alpha\, r^{-1/2}$, and $v_r\,\alpha\, r^{-1/2}$ (free fall approximation), one may obtain

$$\frac{<v_r>}{\bar{B}} = 2\sqrt{\beta(\beta-1)}\,,$$

$$C = \frac{\beta-1}{\beta+\frac{1}{2}} - \frac{3(\beta-1)^2}{\beta(\beta-\frac{1}{2})} + \frac{2(\beta-1)^3}{(\beta-\frac{1}{2})^3}\,,$$

$$\bar{B} = \frac{v_0}{2\beta-1}\sqrt{\frac{\beta-1}{\beta}}\,. \tag{31}$$

Here β is the model parameter, which may be calculated from (31) by using the value of C . The next step is to obtain $<v_r>/\bar{B}$. The function $C(\beta)$ is monotonically decreasing with increasing β , crossing zero at $\beta = 1.5$.

The distance is related to the velocity, thus the dummy variable r may be substituted by v_r. If v_r is proportional to the free-fall velocity,

$$L(\alpha, r)\,dr \;\infty\; L(\alpha, r_o v_0^2/v_r^2)\frac{dv_r}{v_r^3}\,. \tag{32}$$

Here v_0 - is the maximum radial velocity corresponding to the distance r_0 . Thus if the function $L(\alpha, r)$ decreases faster than $r^{-1.5}$, the major contribution would correspond to the high-velocity regions (otherwise to the low-velocity regions). The broadening will smooth the line, but qualitatively will not affect it.

The observed radial velocity is

$$v_{obs} = \gamma + v_{orb}\sin i\,\sin(\Psi - \Psi_1) + \frac{<v_r>}{\bar{B}}(D + E\,\cos(\Psi - \Psi_0))\,. \tag{33}$$

Here γ corresponds to the center of mass, $v_{orb}\sin i$ - is the projection of the velocity of the white dwarf onto line of sight. From the sinusoidal fit to v_{obs} , one may extract the contribution of the orbital motion of the white dwarf. The angle between the projection of the AC's axis onto the orbital plane and the line of centers is $\Delta\Psi = \Psi_1 - \Psi_0$.

Thus the mean-squared width of the line is at minimum if the angle α is close to 90, or is at maximum (the hottest regions are eclipsed by the white dwarf). This prediction agrees qualitatively with the observations of AN UMA (Schneider and Young, 1980), because the X-Ray minimum coincides in phase with the minimum of the relative flux and the full width at half-maximum and the maximum of the circular polarization. This may be interpreted as the eclipse of the emission in X-Rays and in spectral lines (the minimum of the continuum light appears slightly earlier).

However, for the quantitative interpretation, a detailed study of the phase dependencies of the observed characteristics of the emission lines are needed. The comparison of the observations with the model computations may allow one to detect other possible sources of the emission lines (e.g. the accretion flow and the heated part of the atmosphere of the secondary). If the lines have their origin near the accretion column, the derived expressions may allow to determine its orientation.

ROTATIONAL EVOLUTION OF THE WHITE DWARF: 'SWINGING' OR 'IDLING' ? The orientation of the accretion columns with respect to the white dwarf underwent changes, probably of cyclic character, which one may see from the photometric and polarimetric observations of AM Her, QQ Vul and apparently some other polars (Andronov, 1987a). For AM Her, the values of δ vary from 28^0 to 41^0 ($i=64^0$), or from 58^0 to 69^0 ($i=35^0$), i.e. with the total amplitude $11-13^0$ (Shakhovskoy et al., 1992; Andronov, 1992). The variations of the 'longitude' Ψ_p in AM Her has $\approx 28^0$ which is twice as large (Andronov, 1987a and references therein). However, the number of the available times of sign reversal of circular polarization is not sufficient to obtain the $\Psi_p(t)$ and $\delta(t)$ curves, and to choosen between the model of the 'swinging' (Andronov, 1987a) or 'idling' (Campbell, 1983) dipole. Thus regular polarizational observations of polars are needed.

The problem of the rotational evolution of the white dwarf is closely linked with the problem of the long-term brightness variations of polars. Since the time of discovery of 'high' and 'low' states by Hudec and Meinunger (1976) the following models were proposed:

a) changes of the irradiation in the vicinitiy of the inner Lagrangian point by the emission from the compact primary and subsequent changes of the accretion rate (Basko and Sunyaev, 1973; King and Lasota, 1984);

b) changes of the accretion rate due to the 'Magnetic Valve' mechanism (Andronov, 1984a), i.e. the modulation by the changing orientation of the magnetic field in the vicinity of the inner Lagrangian point;

c) changes of the accretion rate due to the solar-type activity of the secondaries (Bianchini, 1990), for which the changes are often abrupt ('switchings'), rather than quasi-sinusoidal (Andronov and Shakun, 1990); possible minor changes of the distance between the stars due to the presence of the planet-like third body (Andronov, 1992);

d) 'switchings' of the accretion from one pole to another during 'swingings' or 'idlings'. If the column is located at the 'far side' of the white dwarf, an 'inactive state' may be observed even if the accretion rate is not reduced.

THE BOTTOM PART OF THE ICEBERG: THE COLUMNS ARE INCLINED, ELLIPTIC, THICK, BOMBARDED, BOILING, DOUBLE ... The above discussed approximations correspond to the case of axially symmetric columns. However, in real objects, ACs may significantly deviate from the symmetric shapes and thus disturb the phase curves of polarization and fluxes. For the stationary AC, one has to take into account the following primary effects: a) the inclination of the column; b) its ellipse-like shape; c) deviation from the self-similarity.

The inclination is important for the bottom parts of the column, which may be eclipsed at certain phases. The effect reduces with increasing height in the AC (Andronov, 1986a). The ellipticity of the cross-sections of the AC may lead to an additional distortion of the phase curves if the AC is optically thick for cyclotron emission (Andronov, 1992). The third effect must be computed numerically from the self-consistent equations of the column's structure and emission.

In the above mentioned models, the height of AC was assumed to be much larger than its width. This is possibly the case for the 'true' polars (AM Her type), whereas for the intermediate polars (DQ Her type), these dimensions are more similar (cf. Chanmugam and Frank, 1987; Canalle and Opher, 1991).

The problem becomes much more compicated if accretion occurs onto both poles and there are two columns with independent parameters. Such models for AM Her itself were discussed by Kruszewski (1978), Piirola et al.(1985) and Wickramasinghe et al. (1991). If the dipole is shifted from the center of the WD then the magnetic field may be of different strength and direction in two columns. Such an 'offset dipole model' may lead to the revolutionary changes in the 'standard' model of polars, where the magnetic field is believed to be strong enough to determine the plasma motion from the vicinity of the inner Lagrangian point. If two columns are existing simultaneously, without 'switchings' then the radius of the magnetosphere must be much smaller as previously suggested. In this case, the angular momentum transfer must be redetermined, because the synchronization of the rotation of the white dwarf with the orbital motion seems to be very strange.

The stationary models are only the intermediate approximations. The accretion stream is not homogeneous, the separate 'blobs' become long and thin while moving to the white dwarf, thus the AC is 'bombarded' by 'spaghetti' (Panek, 1980) and may not be stationary. Even for homogeneous accretion flow, the AC's structure may undergo drastic changes on a time scale of seconds (Langer et al., 1982). Such ultrarapid QPOs may arise from single 'spaghetties' and last for some dozens of seconds. Such possible exotic types of instability, as the 'boiling', 'tornado' or 'beacon' columns, may be excited (Andronov, 1987c).

Despite the corresponding fast variations are usually smoothed during the observations, the polarization and spectra computed for the 'stationary' and 'non-stationary' AC may differ significantly. Thus 3-D time-dependent models need to be computed, despite the fact that the number of parameters which need to be determined is quite large.

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THE SHOCK WAVE HEATING MECHANISM OF PULSATING STAR CHROMOSPHERES

S.M. Andrievsky, G.A. Garbuzov

Abstract. A mechanism is suggested which explains the origin and variability of chromospheric emission in the centres of the MgII h and k lines in the spectra of pulsating stars. According to the model the emission originates from gas heated by a shock wave passing though the outer layers of the star's atmosphere.
Key words: Star: Pulsing star

Introduction. The chomospheric emission in the resonance doublet lines of MgII, CaII and in some lines of CI, CIV, SiIV with higt excitation potentials are observed in Cepheids β Dor, ξ Gem and δ Cep. The emission flux in these lines is on the average less than that of stationary stars. At maximum chromospheric activity of the pulsating stars, the emission flux amounts to the values characteristic of nonvariable stars. Such an emission testifies to the existence of a high temperature plasma in the chomosphere and transition zone (Parsons, 1980, Schmidt and Parsons, 1984a, schmidt and Parsons, 1984b).

Of extreme importance were investigations of chromospheric activity of pulsating stars of A-F spectral types carried out by Fracassini and Pasinetti (1982) and Fracassini et al. (1983). The authors detected emission in the MgII h and k lines in δ Sct type stars: τ Cyg, β Cas, ρ Pup. (The most detailed investigations made for ρ Pup has shown that the emission flux varies with the pulsation phase). In τ Peg, χ^2 Boo, o^1 Eri the emission can be suspected. According to Ulmschneider (1979) nonvariable A-type stars show no emission in the MgII h and k lines. Thus, the chromospheric emission oroginating in pulsating stars, and its variability with the phase of pulsation, can be interpreted as a result of periodic inflow of enegy into the outer star's layers. A shock wave (SW) generated by pilsation is a carrier of such an enegy in pulsating stars.

This paper considers the heating mechanism of layers radiating chromospheric lines of Sct-type stars. The main problem is, whether the radiation of the outer atmospheric layers, heated sa a result of the SW passing, can provide values of fluxes which are consistent with the fluxes observed in the lines and with their variability.

Calculation and results. The SW motion is associated with regions of high electron temperature and ionization degree in the atmosphere. The boundary of this region coincides with the SW front whereas its extension is determined by the SW velocity and the efficiency of the radiative cooling of the gas. Physical conditions behind the SW front and their time dependences can be determined by solving the equation of state of the hydrogen ionization and the energy balance of the gas. A complete description of the system of differential equations is given in the work by Garbuzov and Andrievsky (1986). It should be noted here that the system determines the variation of concentration of electrons n_e with time, the concentration of L_α-quanta n_α, the electron temperature T_e and the temperature of the ions T_i.

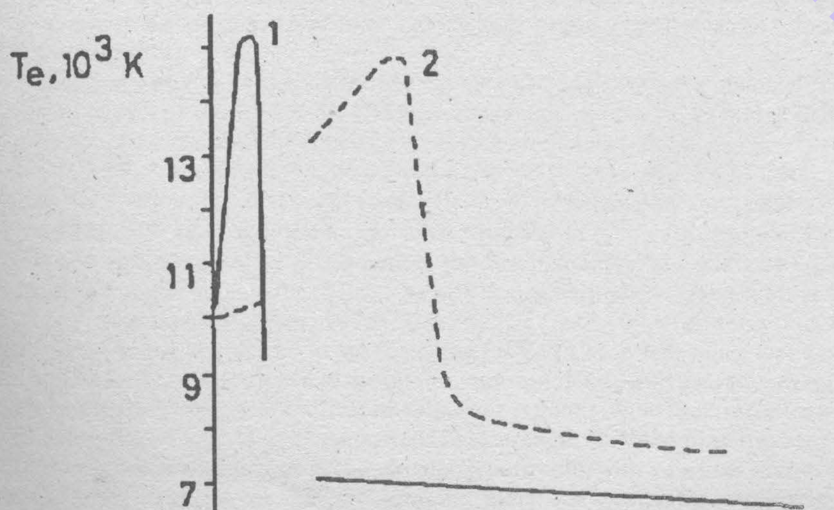

Fig. 1 The electron temperature sa a function of time for $n = 10^{11}\text{cm}^{-3}$ (1) and $n = 10^{10}\text{cm}^{-3}$ (2).

A case of a hydrogen plasma with an admixture of metals ($n_m = 10^{-4} n$) is considered. The system of equations has been solved for the interval $n = 3\times10^{12} - 5\times10^{9}\ cm^{-3}$ under the following initial conditions: $t_0 = 0$ (the moment of passing the front of SW through a point with a present value n), $n_{e0} = 10^{-3} n, n_{\alpha 0} = 0$, $T_{e0} = 10^4$ K. $T_{i0} = 5\times 10^4$ K. For the SW velocity we adopt $D = const = 30\ \text{kms}^{-1}$. In Fig.1 the electon temperature is shown varying behind the SW front for two different values of the density in the star's envelope. If the relations $T_e(t)$ and $n_e(t)$ behind the front of a SW are known, one is able to construct a space distribution of electronic temperature and electronic density in outer layers of the envelope of a pulsating star. Here we assume that the distribution of the hydrogen number density in the envelope of the δ Sct-type star determined by T_{ef} and is characteristic of the star ρ Pup. The T_e-distribution for three diferent subsequent positions of the

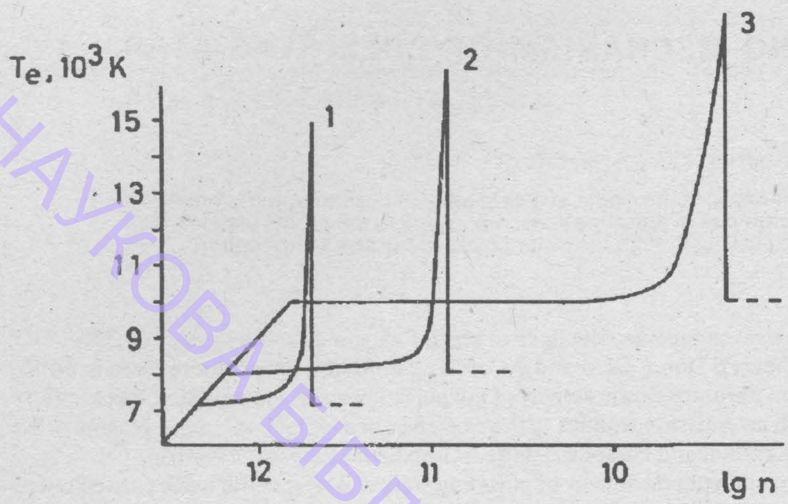

Fig. 2 The electron temperature distributions sa a function of the height of the shock wave front:

1 - the front is at the point with $n = 8 \cdot 10^{11} cm^{-3}$,

2 - at $n = 2 \cdot 10^{11} cm^{-3}$,

3 - at $n = 1.6 \cdot 10^{11} cm^{-3}$.

SW front in the star's envelope is given in Fig.2.

Taking into account the distribution of and found and allowing for the shock character of the transition into the excitation level of ion MgII, it is easy to calculate the emission flux in the MgII h and k lines generated by the heated region. The parameter R(MgII) determined by the relation of emission flux in the MgII h and k lines to the bolometric luminosity of the star for ρ Pup varies from a value 10^{-5} (when the SW front is at the point with $n = 3\times10^{12}$ cm^{-3}) to 10^{-6} (when the front is shifted to the point with $n = 5\times10^{9}$ cm^{-3}). According to the data by Fracassini et al. (1983) we can determine that the value R(MgII) observed for ρ Pup varies from 10^{-5} to 5×10^{-6} which is in good agreement with the theoretical estimations.

Thus we can make a conclusoin that the chromospheric emission observed in the MgII h and k lines in pulsating stars are to a great extent determined by the radiation of a gas heated by a pulsating shock wave.

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ON THE MAGNETIC VARIABILITY OF PULSATING STARS.

S.N.Udovichenko, Yu.S.Romanov, M.S.Frolov.

Abstract. The variations of the effective magnetic field strength of the magnetic stars α^2 CVn, β CrB and of the pulsating stars RR Lyr and V 474 Mon are studied on the base of the spectrograms oftained at the 6-m telescope. The variation with the phase of the $0^d.567$ pulsating period was found in RR Lyr. Our results together with the Babcock's observations in the 1950s show that the mean field depends on the phase of the $40^d.9$ Blazhko period, presumably because the rotational and the magnetic axes are not coinciding. For V 474 Mon, is not possible to clear up the character of such variation.

Key Words : Stars: Pulsating, Stars: Magnetic Stars: Individual (RR Lyr, V 474 Mon)

Introduction. At the beginning of 1950th, Horece Babcock started to carry out the extended program of the observations of the stellar magnetic fields with the aid of the circular-polarization analyzer with a calcite crystal. The Babcock's (1958) catalogue contained the results on 89 stars with the significant magnetic fields and included 70 peculiar stars (Ap), 7 stars with the lines of metals (Am), and 12 - of other types, including few pulsating stars (Babcock, 1958). Several measurements of the magnetic field of two classical cepheid variables - FF Aql and η Aql and 22 measurements of the magnetic field of the pulsating star RR Lyr were published there. The Cepheid-variable FF Agl and η Aql shows maximum negative field corresponding - 250 + 38 Gauss and 85 + 85 Gauss.

The magnetic field of RR Lyr reversed its polarity from time to time; the maximum positive strength was + 1170 Gauss and the maximum negative strength - 1580 Gauss. Contrary to Babcock (1958), Preston (1967) found no magnetic field of RR Lyr in 1963-1964 within the observational errors.

Later Detre and Szeidl (1973) have suggested, that the discrepancy between these observations may arise due to the 4-yr period of the star, thus Babcock (1958) had registered the magnetic maximum, and Preston (1967) - the magnetic minimum. Balazs-Detre (1959) also suggested the variations of the magnetic field with a 41-day period of the Blazhko effect, which may be a rotational period of the star. At the same time, a long-time variability of the magnetic field with a 4-yr period may occur similar to the solar magnetic cycle.

The premise for suggestion these authors the fact Babcock's (1958) measurements had carried out maximum of 4-yr cycle. The extreme field values correspond the maximum and minimum of 41-st period amplitude.

The observations of the Zeeman shift for several type of cepheid variable (Weiss et al., 1980) showed some positive results. According these data, three δ Cep-type stars: β Dor, W Sgr, η Aql and one W Vir-type star κ Pav showed the variations of the effective magnetic field with an amplitude up to 500 Gauss. The variation of magnetic field strength occurred with the phase of the stellar pulsation.

The attempts to measure the magnetic field of the group of δ Scu-type stars were failed due to the high rotational velocities. However, some stars of this type have a modulation period , small rotation velocities and are suitable for the measurements of the Zeeman shift.

Observations. The spectrograms of some pulsating stars were obtained at camera 2 of the main stellar spectrograph of the 6-m telescope during 1978 - 1984. The magnetic stars α^2 CVn and β CrB were observed as well, as the magnetic field standards, and were used for checking the measurement technique.

The basic objects of the observations were RR Lyr and V474 Mon. RR Lyr is the prototype of the pulsating horizontal-branch stars that occur so often in the globular clusters. Both photometrically and spectroscopically, it is one of the most thoroughly studied pulsating variables. Prolonged photometric monitoring has yielded a basic $0^d.566867$ period of the light variation; a secondary $40^d.8$ period, the Blazhko effect; and auxiliary 123^d and 4-yr periods as well. V474 Mon (HD 40535) is a variable star of the δ Sct-type with the primary period of the light variation ($0^d.1361260$) and the secondary period ($7^d.746$) (Romanov, Fedotov, 1979). The star has special features interesting for the researcher of the pulsating stars. The ratio of the secondary period to the basic one for V474 Mon resembles that observed in RR Lyr-type stars. The star exhibits the unusually large modulation of the photometric amplitude with the secondary period (Millis, 1973) and the multiperiodicity (Shobrock and Stobie, 1974). Unfortunately, the number of the spectral observations is not sufficient to investigate the radial velocities. The measurements of magnetic field strength for V474 Mon has been not carried out. For these observations, we used the achromatic analyzer of the circular-polarization with a Fresnel rhomb as the phase shifter, and a calcite crystal. The height of the spectra on the photographic plate was nearly 0.3 mm. Since 1982, the Kodak 103a-O emulsion was hypersensitized by hydrogen to shorten the exposures, using the method developed at the Odessa Observatory (Bondarenko, 1984). This method allows to increase the image density threefold, without any significant increase of the fog density. The time interval between the successive spectrograms varied from 5 to 60 min, depending on the photometric phase and the sky conditions. The spectra span the 3900-5000 A wavelength interval. The Zeeman shifts between the σ-components of the spectral lines were measured with a comparator having an oscilloscope display for setting on the lines (Udovichenko,

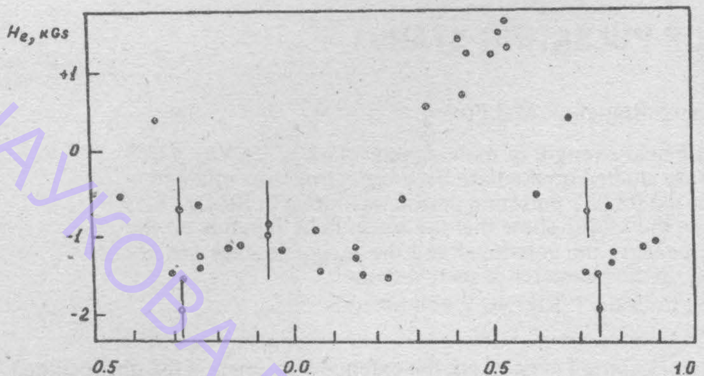

Fig. 1 Magnetic data for α^2 CVn. Filled circles - are the observations of Babcock (1963), Preston and Sturch (1967), and Glagolevsky et al. (1978); open circles - are our observation.

Romanov, 1985). The shifts were determined for all the lines and converted into the effective magnetic field strengths by the expression

$$H_e = 52.7 \left(\frac{4500}{\lambda}\right)^2 F \frac{\Delta S}{Z} ,$$

where λ - is the wavelength in Angstroms, F [A/mm] - is the dispersion, Δ S - is the line shift in microns and z - is the Zeeman-splitting factor. The probable errors of the measurements for each plate varied from 100 to 500 Gauss, depending on the number of the measured lines and the density of the spectrogram. The values of the Lande g-factor for the lines between 3900 and 4600 A were adopted from Babcock (1962) and Romanyuk (1984).

<u>Results.</u> a) α^2 CVn, β CrB

Our data on the magnetic field of these stars are compared with that of other authors. The magnetic field strength variations for α^2 CVn are shown at Fig.1 (Babcock ,1963, Preston and Sturch, 1967, Glagolevsky at al. 1978) and are denoted by the filled circles. Our measurements are denoted by the open circles. The magnetic field strength variations for β CrB are shown at Fig.2 (Preston and Sturch,1967; Wollf and Bonsack, 1972) and denoted by the similar symbols. These figures show, that the values of the magnetic field strength for α^2 CVn and β CrB agree with those obtained by the other authors at all phases.

The phases were computed according to the ephemeris:

JD 2434217^{d}.50 + 18^{d}.487 E for β CrB (Preston and Sturch, 1967);

JD 2419869^{d}.720 + 5^{d}.46939 E for α^2 CVn (Farnsworth, 1932).

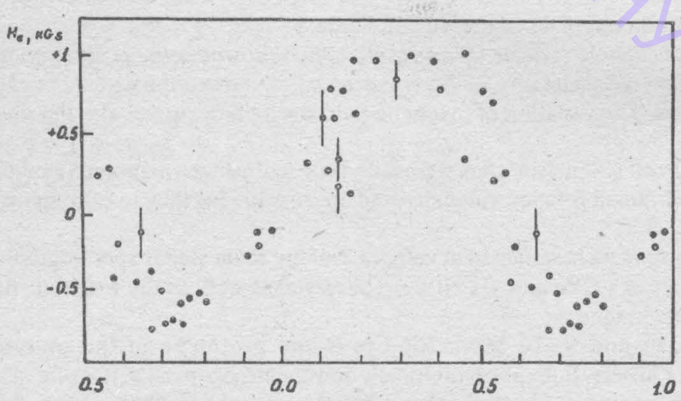

Fig. 2 Magnetic data for β CrB. Filled circles -are the observations of Preston and Sturch (1967), Wolf and Bonsack (1972); open circles - are our observations.

b) RR Lyr.

The individual curves of the magnetic field variations, obtained during the different observational sets, are shown separately at Figs.3-6 . The vertical bars correspond to the probable error of the measurement of the mean field strength, for each plate. In August, 1978 (Fig.3) the amplitude of the field variation was 1 kGauss; the maximum negative field occurred at phase 0.5. In September, 1982 (Fig.4), the polarity was positive and the field strength varied with a 1.5-kGauss amplitude; the maximum positive field was observed at phase 0.0. In July, 1983 (Fig.5) the field had again become negative, and the amplitude was about 1 kGauss. In October, 1984 (Fig.6) the field strength practically not varied (from -400 to +400 gauss) and was comparable with the observational errors. The phases of the basic pulsation period were computed according to the ephemeris:

HJD Max =2442995^{d}.405 + 0^{d}.566867 E (Firmanyuk,1984).

It may be fruitful to search for the dependence of the magnetic field on the phase of the secondary period (the Blazhko effect) and to compare the results with Babcock's observations. In order to establish the Blazhko phases, we have assembled all photoelectric observations of RR Lyr, and have computed the elements separately for the epoch of Babcock's observations, and for 1978-1983:

Max HJD = 2414856^{d}.408 + 40^{d}.945 N, for 1947-1961,

Max HJD = 2437551^{d}.316 + 40^{d}.885 N, for 1963-1983.

The magnetic field variation for RR Lyr with the phase of the Blazhko effect are shown at Fig.7. The figure illustrates, how the magnetic field of RR Lyr depends on the Blazhko-effect phase. Please note, that when all the observations of the past 30 yr are brought together, the average field strength does tend to vary with the 41^{d} period of the Blazhko effect. This result may

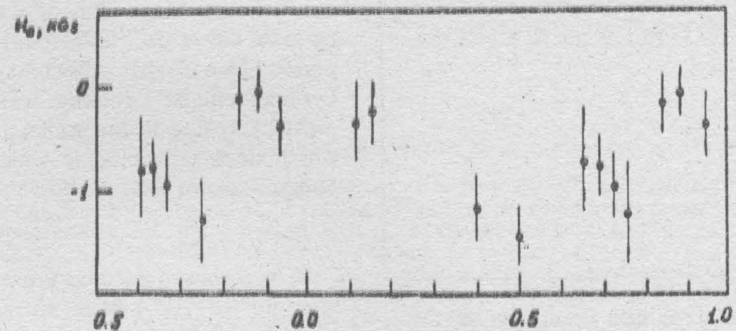

Fig. 3 Variation of the effective magnetic field strength of RR Lyr with phase of the main period (August 20-21, 1978).

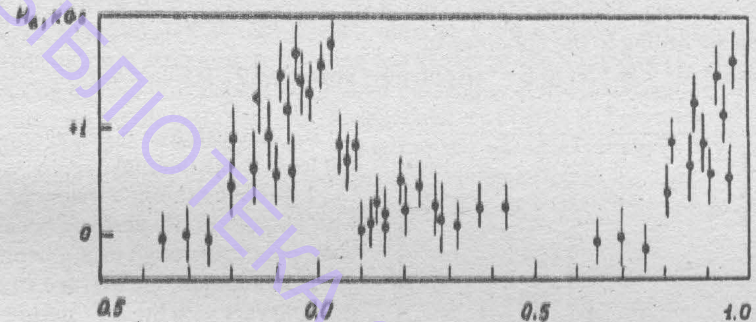

Fig. 4 Variation of the effective magnetic field strength of RR Lyr with phase of the main period (September 25-28, 1982).

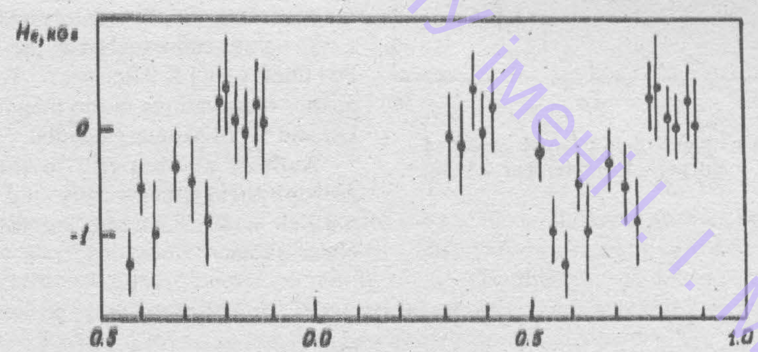

Fig. 5 Variation of the effective magnetic field strength of RR Lyr with phase of the main period (July 18 and 20, 1983).

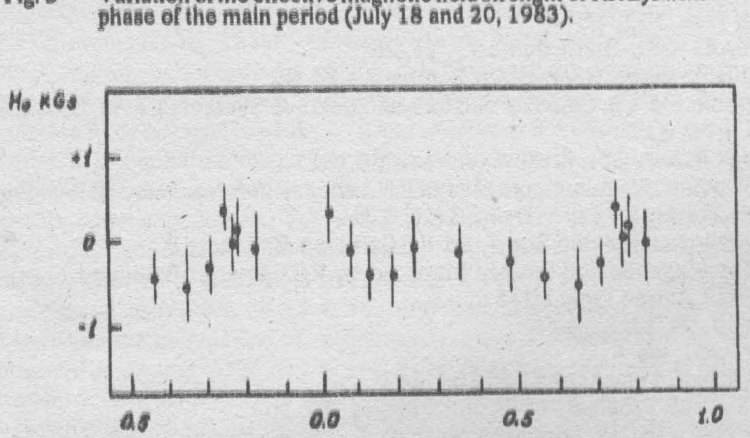

Fig. 6 Variation of the effective magnetic field strength of RR Lyr with phase of the main period (October 10-13, 1984).

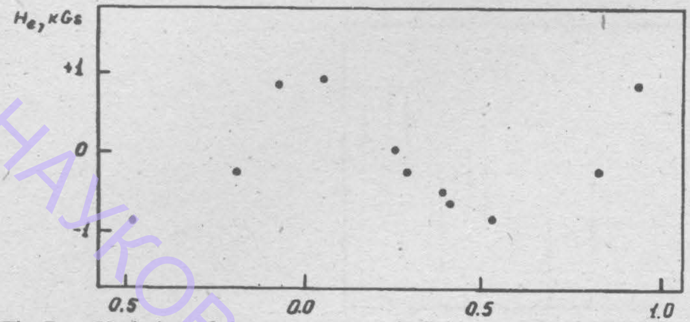

Fig. 7 Variation of the mean magnetic field strength of RR Lyr with phase of the Blazhko effect.

confirm the suggestion of Balazs-Detre and L.Detre (1962), based on the Babcock's observations, that the period of the Blazhko-effect may be manifested by the RR Lyr magnetic field polarity. This 41^{d} field variability is most likely due to the stellar rotation around the axis, which does not coincide with the magnetic axis (the oblique-rotator model).

c) V474 Mon.

The results of the measurements of the magnetic field strength for V474 Mon are shown at the Fig.8. The scatter of data may be probably caused by the observational errors as well as by the influence of the non-radial waves onto the absorption lines. The Fig.8 shows, that value of the magnetic field strength varies in phase with period of the stellar pulsation. However, it is not possible to clear up the character of such variations . The phases of the fundamental pulsation period were calculated according to the ephemeris:

Max HJD = $2441661^{d}.1668 + 0^{d}.13612600\,E$ (Romanov, Fedotov,1979).

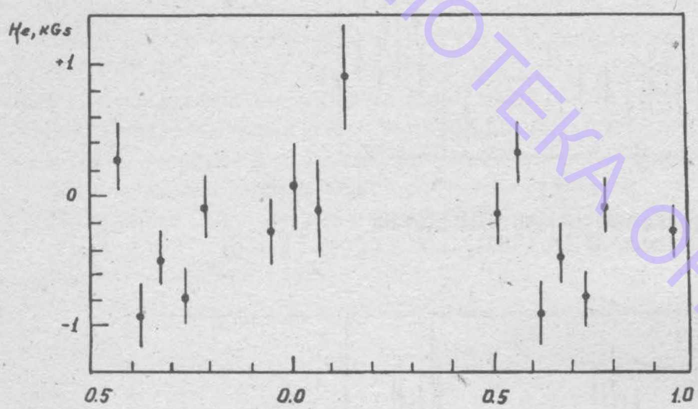

Fig. 8 Variation of the effective magnetic field strength of V 474 Mon with phase of the main period (September 25-28, 1982).

4. Conclusions. Several conclusions may be pointed out from these findings:

1. RR Lyr exhibits a magnetic field variability in phase with its pulsations, perhaps because of the compression wave passing through its atmosphere.

2. In addition, the average strength and the polarity of the field vary with the 41^{d} period of the Blazhko effect.

3. This longer-term Blazhko variability of the magnetic field presumably indicates that the star is rotating with a 41^{d} period around an axis, inclined to the magnetic axis. Such an interpretation is supported by the v sin i values estimated from the 4481 Mg II and 4476 Fe I lines: v sin i $\leq$ 9 km\sec. To solve this problem, the further observations of the magnetic field strength of RR Lyr and V474 Mon are needed.

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CHEMICAL COMPOSITION OF THE ATMOSPHERES OF THREE GIANTS IN HYADES

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Abstract. The abundances and physical conditions in the atmospheres of three Hyades giants have been investigated by using the high-dispersion (5.6 A/mm) spectra obtained at the 6-m telescope of the Special Astrophysical Observatory. The empirical analysis of the deviations from LTE for the Fe lines with the low and high excitation potentials showed the slight differences within the limits of the determination errors. The abundances of 22 chemical elements the atmospheres of the K-giants derived by the method of the model atmospheres differ from the solar one. Underabundance of O and overabundance of Na of about 0.5 dex and of elements after Y of about 0.2 dex are established.
Key Words : Stars: late giants, chemical composition

The investigation of the chemical composition of the Hyades stars nearest to the Sun [distance modulus m-M = 3.3 (Kholopov, 1981)] covers a wide range of astrophysical problems: a more precise definition of an initial main sequence, the refinement of a scale of the galactic distances, the testing the theory of the nucleosynthesis and of the star formation, of the presence of the overshooting etc. In this Paper, we present the results of the investigation of three Hyades giant-stars. Table 1 contains a list of the stars and their characteristics (Komarov et al.,1979): HD number, stellar name, V-stellar magnitude, B-V - color index, SP - spectral type, π'' -parallax. δ Tau star is a spectro- scopic binary, an assumed component is a late M - subtype dwarf (Griffin and Gunn, 1977). The estimation of the mass of the Hyades giant-stars from the tracks of Paczynski (1970) gives the value $M \approx 2M_{\odot}$ where $M_{\odot}$ is the Solar mass. By using the expression of Masevich and Tutukov (1988):

$$T = 7.6 \cdot 10^{9} \frac{1 + 30\,Z}{(M/M_{\odot})^{3.7}} \cdot \left(\frac{0.23}{Y}\right)^{1.6} \text{ years,}$$

where Y,Z are the abundances of helium and heavy elements, one may determine the age, when a giant-star with a mass 2 reaches the peak of giants branch: $T = 9.3 \cdot 10^{8}$ years (Kholopov, 1981).

Table 1. Characteristics of the giant-stars in the Hyades cluster

HD	Star	V	B-V	Sp	π''
27371	γ Tau	3.64	0.99	KO III	0.023
27697	δ Tau	3.76	0.98	KO III	0.016
28305	ε Tau	3.54	1.02	KO III	0.018

The analysis of the chemical composition of the Hyades stars made by different authors has shown, that the metallicities [Fe/H] obtained from the spectrophotometric and photometric observations of the stars are different, the latter being by 0.1-0.2 dex higher than the spectrophotometric ones. Commonly, the spectrophotometric determination of [Fe/H] gives the values of 0.1-0.3 dex, the photometric one gives 0.2-0.3 dex, the reticon observations yield 0.2 dex (Branch et al.,1980). The aim of our investigations is to solve the problem on the abundances in the atmospheres of γ Tau, δ Tau, ε Tau - stars based upon the analysis of the spectrograms with high spectral resolution obtained at the 6-m telescope of the Special Astrophysical Observatory. The spectrograms of the giant-stars were obtained in 1984 by V.G.Klochkova, V.E.Panchuk and I.F.Bikmaev at the first camera of MSSP BTA on the Kodak 103aF - plates within the wavelengths from 5300 to 6700 A with the dispersion 5.6 A/mm. It was possible to obtain such a material only due to the reconstruction of the first camera of MSSP (Gajour et al.,1986). The spectrogram recording was made by a using the microphotometer at SAO in direct intensities.

The continuum was plotted from intensities peaks. In order to identify the lines, a synthetic spectrum was used, which was calculated by using the SYNT (Tsymbal, 1980) computer code for the wavelength range $\lambda\lambda$ 5300-6700 A. For the computations, we used model of the atmosphere (Bell et al., 1978) with the parameters: effective temperature T_{eff} = 5000 K, logarithm of gravity log=3.0, solar abundances. To specify the absorption lines identification, the Solar Atlas (Moore et al.,1966) was used as well as the Catalogue of equivalent widths W_λ of the lines in the spectra of K-M-giants created at the Odessa Astronomical Observatory by V.F.Karamysh et al. The selection of the unblended and least blended lines was made with the account of the spectrogram resolution (0.15-0.20) and possible errors of the oscillator strengths in Kurucz-Peytremann's(1975) list used for the calculation of the synthetic spectra. The equivalent widths W_λ in the spectra of the examined stars were determined according to the 'log W_λ - R_λ' - relation from the residual intensity R_λ. This relation has been derived from the unblended lines. The values of W_λ determined in the present paper and that from the spectral material with a dispersion of 15A/mm (Mishenina, 1985) correspond to the value of the correlation coefficient about 0.98 (Mishenina et al.,1987). Let us consider briefly the selection of the parameters of the model atmospheres, which were used for the determination of the chemical composition of the atmospheres of the investigated stars. The effective temperature was determined by using the several methods:

a) from the scales of the effective temperatures: from the scale (Ridgway et al.,1980) constructed by using the direct radii measurements, it was found that T_{eff} =4800 K; from the scale (Burnashov, 1983) constructed mainly from the results of the absolute stellar spectrophotometry, it is established that T_{eff} = 5000 K;

b) the color indices B-V selfconsistent with the models of atmospheres (Bell et al., 1978) give the lowest values of T_{eff} = 4700 K;

c) in assuming the photosphere radiation to be the Planck's one in atomic lines and molecular bands, most absorption-free, at the spectral bands with $\lambda\lambda$ 4600, 6100 and 7550 A, the temperatures obtained are 5050 K;

d) the effective temperature determined by using the method of the spectral indices (Burnashov, 1983) is about 4930-4940; Motrich (1990) has obtained the value 5020- 5025 K;

e) the effective temperature determined by using the method of the photometric indices applied to the results of Geneva photometry is equal to 4930$\pm$15 K (Korotina et al.,1988).

The gravity of the studied stars is determined as follows:

a) from the bolometric stellar magnitude found by using the bolometric corrections (Burnashov, 1983) and the belonging of stars to the cluster, the value is obtained log g = 2.6-2.7;

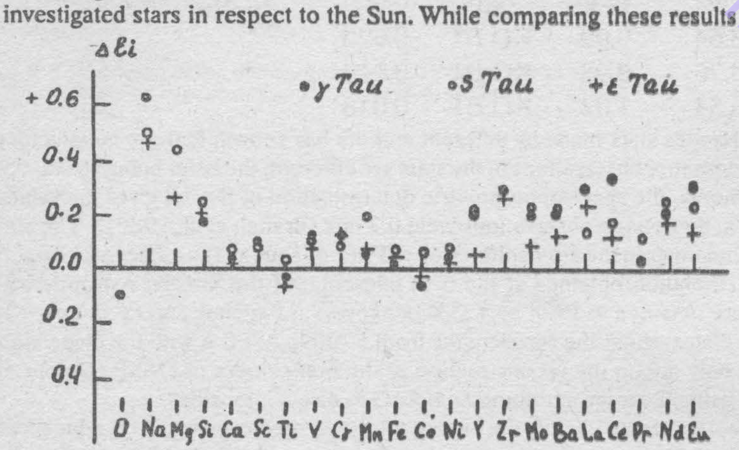
b) from the spectral indices (Burnashov, 1983) log g = 2.9-0.09; from the paper (Motrich, 1990), log g = 2.6-0.03;

c) from the photometric indices (Korotina et al., 1988), log g = 2.6-0.04;

d) from the condition of the ionization equilibrium for the lines of neutral iron (Mishenina et al., 1986) log g = 2.7-0.1 (D=15A/mm) and for the lines of neutral iron and titanium in the present work, log g = 2.83-0.4 and 2.8-0.1, respectively. Taking into account the mentioned above values, the computations of the abundances were made for the model with T_{eff} = 5000 K, log g= 2.25 and 3.0 and with solar abundance, for two values of the turbulent velocities V_t = 1.6 and 1.8 km/s. The more detailed data on the choice of the model parameters and the turbulent velocity one may find in Mishenina et al.(1986). The oscillators' strengths log gf are mainly taken from Gurtovenko and Kostyk (1980), Kostyk (1982), Perekhod (1988) and, in some cases, from Kurucz and Peytremann (1975), Boyarchuk and Boyarchuk (1981).

In order to compare the abundances in the stellar atmospheres with the solar ones, the chemical composition of the solar atmosphere was calculated with the same atomic line parameters as for the investigated stars. The model of the solar atmosphere HSRM (Kurucz, 1970) was used, the equivalent widths W_λ were taken from Moore et al.(1966). The calculations of the abundance of the chemical elements in the atmospheres of the stars and the Sun were made by using the WIDTH-6 computer code.

At Figure 1, the distribution of the abundance of the chemical elements corresponding to log g = 2.8 is shown for the investigated stars in respect to the Sun. While comparing these results with that of Nomoto and others (Branch et.al.1980), one may see, that the chemical composition of Hyades giant-stars is related to their origin from the interstellar medium enriched by the different contributions of the heavy metals due to the explosions of the Type-I and Type-II Supernovae.



For the purpose of a more detailed investigation of the physical conditions in the atmospheres of cool stars, it is of interest to study the non-LTE case.

For one of the investigated stars, we made earlier an empirical analysis from the lines of neutral iron (Mishenina, 1987). In the work there were used 15 lines with $\chi \le 3.5$ eV and 90 lines with $\chi > 3.5$eV. The values of the iron abundance log determined from the lines with high and low excitation potential are practically coinciding. In the present work, the list of neutral iron lines in the atmospheres of α, δ and ε Tau is enlarged. The results are shown in Table 2, where $\log E_{Fe}$ (lg g) - is the iron abundance determined from the different values of log g =2.25 and 3.0 for the lines with high and low excitation potential of low level.

Table 2. Results of non-LTE analysis.

	$\chi \le 3.5$			$\chi > 3.5$		
	γ Tau	δ Tau	ε Tau	γ Tau	δ Tau	ε Tau
$\lg E_{Fe}$ (2.25)	4.41	4.44	4.41	4.47	4.45	4.44
$\lg E_{Fe}$ (3.0)	4.37	4.39	4.36	4.44	4.41	4.40

With the increasing number of lines with $\chi \le 3.5$, some difference in the abundance for the lines with low and high excitation potential is noticed in case of γ Tau, which ranges within the determination error; the differences are at minimum in the case of δ Tau and ε Tau stars. In the analysis of the atmospheres of the K-giants from the given observational material and using the Bell models (Bell et al.,1978) and the work on the equivalent line widths, the usage of the LTE-assumption is quite justified. In order to detect a finer non-LTE effect, a higher resolution ($\Delta\lambda < 0.1$) and the analysis of line profiles are needed.

The precision of abundances determination constitutes 0.20 dex from the iron lines and other elements represented by the numerous lines, and not higher than 0.5 dex for the elements represented by one or two lines. To increase the number of lines and the reliability of elements' abundances determination after the iron peak, we have investigated all the lines of these elements found by the different authors in the spectra of the late-type stars. In spite of the fact, that in the spectra of the K-giants there are identified about 160 lines of the elements starting with yttrium, only 21 lines remained after the careful analysis. The difference in the solar abundance determination in the case of the neodymium amounts to the unit value from the separate lines that may be due to the poor precision of oscillators' strength determination or equivalent widths of these lines in the solar spectrum ($\lambda_1 = 5431.52$, $\log E_{\lambda_1} = -10.51$, $\lambda_2 = 5442.26$, $\log E_{\lambda_2} = -9.57$).

The abundance of the elements' in the atmospheres of the Hyades K-giants is nearly solar. The oxygen deficiency, excess of sodium by ~ 0.5 dex and of the elements starting with yttrium by 0.2 dex have been found.

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THE FORMATION AND DISSIPATION OF A METEOR COMA

E.N.KRAMER, I.S.SHESTAKA

Abstract. The results of reduction of instantaneous fireball photographs are presented. The observational data testify to the fact that linear dimensions of the region radiating after the meteor's flight amount to tens and hundreds of meters, and in the case of particularly bright fireballs to some kilometers. The suggested by authors hypothesis of synchronous length change of the region of fireball afterglow alongside with its light variation is verified. The analysis of the spectral photograph obtained by authors with the method of instantaneous exposure shows that the afterglow proceeds mainly to radiation in H and K lines of CaII. Several mechanisms of ionized atoms afterglow of the meteor substance are discussed. Photometric profiles of the instantaneous images of meteors are compared with theoretical calculations made both on the supposition of the parent body fragmentation and on that of afterglow of ionized atoms of meteor substance. The conclusion on a joint effect of both above-mentioned mechanisms is obtained.

Key words: instantaneous meteor photograph, the luminosity of fragments ejected from parent body, afterglow of meteor plasma.

Penetrating into the dense atmosphere layers, a meteor body reaches the temperature of melting. During a meteor body flight, the small particles and the melted droplets break away from its surface. At the same time, the evaporation of meteor substance takes place both from the surface of a meteor body itself, and from those of particles and droplets - a luminous region (a meteor coma) is forming around the meteor body.

The evaporated meteor atoms lose their cosmic velocities during a few collisions, and in 10^{-4} - 10^{-5} s they are not capable to excite themselves and to radiate (Opik, 1950). Hence, if the meteor luminosity is caused by the evaporated atoms only, the dimensions of the luminous region would not exceed a few free path lengths - about few meters (Babadzanov and Kramer, 1965) and the meteor image would be practically a dotty-like.

But as far back as the fifties, McCrosky (1955,1958), Jacchia (1955), Halliday (1958), Hawkins and Southworth (1958) discovered the large dimensions of meteor luminous regions, by analyzing the blending of shutter breaks on meteor images. As instantaneous photographs of the bright meteors have shown, the length of the luminous meteor coma amounts to tens and hundreds of meters, and, in case of fireballs - to some kilometers. In addition, the instantaneous images of bright meteors have comet-like forms: the bright head part of an image turns gradually into the tail, and extends along the meteor body trajectory.

The meteor coma extension may be caused either by a lag of the ejecting fragments from a parent body (PB) or by an afterglow of the meteor atoms and ions that lose their cosmic velocities almost completely. In the first case, the ejected fragments decelerate, lag behind the PB and continue to evaporate, and the evaporated meteor substance is shining behind the PB (Levin, 1961,1963; Jacchia et al., 1965; Levin and Simonenko, 1966,1967; Simonenko, 1967,1969,1973a,1973b, 1974; Lebedinets and Portniagin, 1967; Musij and Shestaka 1968; Novoselova 1971).

In the second case, the meteor atoms and ions, which remained behind the PB, decelerate to the thermal velocities at the given height. Then they have not enough kinetic energy for the collision excitations and luminescence. But they are able to shine due to the exchange excitations or recombinations. In this case, the head part of a meteor can go far ahead a nearly motionless luminous coma. Thus the dimensions of the latter must change synchronously with the brightness of the meteor itself.

The luminescence of a meteor coma as a result of a quasicontinuous separation from a PB of a large number of the fragments (the first mechanism) was discovered both at ordinary meteor photographs (Ceplecha, 1953;Kramer, 1960,1967,1968a) and at the instantaneous ones (Babadzanov and Kramer, 1967b,1968; Kramer et al.1976,1979).

Nevertheless, there are many facts, which cannot be explained by the disintegration of the PB only. These are dependence on wakes' lengths on meteor brightness, the synchronous changes of wakes' lengths with meteor brightness and meteor flares too, the observational dimensions of wakes. We give, as an example, the analysis of the instantaneous images (IIs) of the fireball, which was photographed on August 13, 1974.

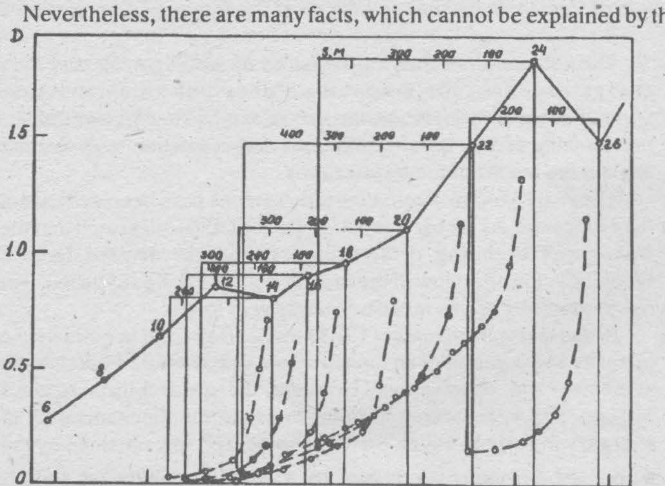

Fig. 1 The photometric profiles of instantaneous images of the fireball photographed on August 13, 1974.

The photometric profiles of the IIs of the 1974.08.13 fireball are given in Fig. 1, where x is a measured distance of any point of the meteor image from its disappearance point, D is a corresponding photographic blackening. The solid line represents the D-changes of the head part of instantaneous images (Figures 6 to 26, at empty circles there are numbers of corresponding IIs) and the dashed lines represent the in situ distances (s) of some points of images (Ns 14 to 26) from the head of the corresponding image (the distance scale in meters is shown by means of horizontal lines which come from the corresponding image number).

Figure 1 displays the obvious wakes' lengths vs the meteor brightness. It is seen clearly on the IIs of Ns 24 and 26, which are obtained during the flare and the depression of the

Thus the conclusion is forced upon, that the meteor ions' afterglow and the luminescence of the PB fragments separated in the process of quasi-continuous fragmentation are capable to explain the observed variety of photometric meteor profiles. But in this case, it is necessary to reveal the mechanism of the ionized atoms' origin in a meteor coma. Two suggestions are possible:

1) a forming of ionized atoms of Ca and other elements of meteor substance takes place in a fast meteors' coma itself,

2) the twice ionized atoms of Ca are forming in a meteor coma due to a very large energy of the fast meteors' collisions with the dense layers of the atmosphere, then the duplicate H and K Ca II is emitting as a result of the radiative recombination of the twice the ionized atoms of Ca.

In the first case, some processes can result in the calcium ions' excitations. Firstly, it is an excitation caused by an electron impact

$$Ca^{+} + e \rightarrow Ca^{+*} + e \ .$$

At second, it is a transmission of an excitation to calcium ions by the air atoms (molecules) or ions

$$Ca^{+} + A \rightarrow Ca^{+*} + A \ ,$$

$$Ca^{+} + A^{-} \rightarrow Ca^{+*} + A + e \ ,$$

$$Ca^{+} + A^{+} \rightarrow Ca^{+*} + A \ .$$

A third, it is a change of the charge due to the excitation

$$Ca^{+} + A^{+*} \rightarrow Ca^{+*} + A \ .$$

Here A is a neutral atom (molecule) of air, A^{+} , A^{-} - are the air ions and e is an electron. The index (*) indicates the state of the excitation.

Since the luminosity intensity of the excited calcium ions is directly proportional to their numbers that decrease according to the exponential law due to the recombinations, the afterglow intensity of the meteor coma obeys the same law. According to the second suggestion, the luminosity intensity of a meteor coma is directly proportional to the numbers of Ca III ions recombinating per second.

The corresponding reaction can be described by means of the following system of the differential equations

$$\begin{cases} \dfrac{\partial n_j}{\partial t} = -D_a \cdot \Delta n_j - p_j n_j n_e \ , \\ \dfrac{\partial n_e}{\partial t} = -D_a \cdot \Delta n_e - p_e n_e^2 \ , \end{cases}$$

where n_j , n_e - are number densities (concentrations) of Ca II ions and electrons, respectively, D_a - is the coefficient of the ambipolar diffusion, p_j - is the coefficient of the radiative recombination, and p_e -is the adhesion coefficient. Integrating this system over the cross-section of the ionized column, and passing over to linear concentrations, one may obtain the expression for the intensity of radiation:

$$J(t) = \tau_j \frac{\partial \alpha_j}{\partial t} = \frac{\tau_j p_j \alpha_i^{(0)} \alpha_e^{(0)}}{2\pi r_0^2 \left(1+\dfrac{4D_a t}{r_0^2}\right) \left[1+ \dfrac{P_e \alpha_e^{(0)}}{8\pi D_a} \cdot \ln\left(1+\dfrac{4D_a t}{r_0^2}\right)\right]^{1+p_j/p_e}} \ ,$$

where τ_j - is the coefficient of the luminous efficiency of Ca II ions, α_j and α_e - are the linear concentrations of Ca III ions and the negative ions, respectively, r_o - is an initial radius of the meteor- ionized column (Kashcheev et al., 1967). The index (o) corresponds to the values of α_j and α_e at $t=0$.

Suggesting, that the linear concentration of electrons is not changing during the afterglow and remains equal to N, the last equation turns into the following expression

$$J(t) = \tau_j p_j N \alpha_j^{(0)} \exp\left(-p_j N t\right) \ .$$

If t=0, i.e. in the head part of meteor

$$J(0) = \tau_j p_j N \alpha_j^{(0)}$$

Hence, it follows

$$\frac{J(t)}{J(0)} = \exp(-p_j N t) \ .$$

We calculated the value of $p_j N$, by using the two points of the photometric profile of the wake obtained from the observations. It proved to be equal to $2.5 \cdot 10^{2}$ cm^2/s. In case of atomic ions, the radiative recombination coefficient is equal to $p_j \sim 10^{-12}$ cm^3/s (Kashcheev et al., 1967), hence, the linear concentration of the negative ions $N = 2.5 \cdot 10^{14}$ electrons/cm. In fact, this value is larger (Kashcheev et al.,1967). The above-mentioned value of $p_j N$ was used for the calculations of the theoretical decrease of the afterglow

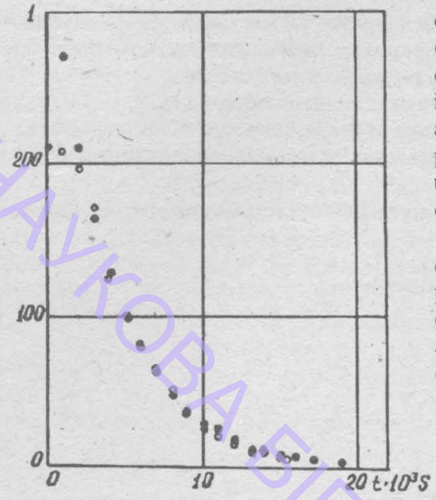

Fig. 3 The observational (dots) and theoretical (open circles) luminosities of the afterglow in the meteor tail.

of a meteor coma. As one may see at Fig. 3, the theoretical (open circles) and measured (dark circles) intensities of the wake luminosity coincide satisfactory. There is the intensity excess observed above that of the theoretical one in the head part of an instantaneous image only. This can be explained easily because, at first, in a head part of a meteor image an effect of the photographic diffusion is not taken into account (this doesn't affect the tail part of a meteor image) and, at second, the calculation of the afterglow was carried out under the assumption, that the luminosity of the meteor coma had resulted from radiation of H and K Ca II only.

The real meteor phenomena are complicated to a far greater extent than the models considered in this paper. The thorough investigation of the instantaneous meteor photographs argues, that, simultaneously with a parent body fragmentation, an evaporation of meteor particles, the collision excitations and the radiation of the evaporated meteor atoms, there is the afterglow of the excited atoms and ions, and also the lighting of smallest dust particles by radiation of the meteor head part.

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EVOLUTIONARY TRACKS OF SHORT–PERIODIC METEOR SWARMS

E.N.Kramer, I.S.Shestaka, Yu.M.Gorbanev

Abstract. The relations of the meteor streams with comets and asteroids are determined by means of the physical and dynamic properties of these bodies. The mathematical model is considered for the short-periodic meteor stream, the particles of which are ejected from the asteroid 3200 Phaeton with the velocities of about 700 m/s. It is shown, that in this case, the original comparatively compact meteor stream is dispersed gradually under the influence of the secular perturbations. At present, after 20000 years, the streams' orbits are crossing the ecliptic plane along the nearly closed narrow band, the distribution of their arguments of perihelia turning to the uniform one as well as the sporadic background. Owing to this, the opportunity arises to observe simultaneously the very faint meteor showers only at the Earth and other terrestrial planets. The existence of the abundant annual Geminid meteor shower doesn't agree with the considered model and test the suggestion that the particles of this stream were ejected from the Phaeton either not long ago or at small velocities of about tenths of a meter per second, since the meteor stream ejected only at such velocities remains comparatively compact and highly productive one throughout many thousand years. Since the secular perturbations result in the oscillations of the line of apsides of the stream's orbits (with the period of about 30-40 thousands of years) and in changes of the argument of the perihelion of about 360 , the stream approached the Earth four times during this interval and produced the corresponding showers. It is shown that such showers are occurring in different epochs, not during the same year, as some scientists erroneously supposed.

Key words: origin and genetical relations of meteor swarms and asteroids.

The similarity of orbits of the well-known meteor swarm Geminids and the object 1983 TB (3200 Phaeton) served as the groundbase of the hypothesis on their mutual genetical relation (Hughes 1983, Whipple 1983). The parent body (PB) of the Geminids, sought for a long time, seemed to be found. Although the considerable scattering of the observed values of the semimajor axes of swarm's orbits ($1{,}1 \leq a \leq 1{,}67$ AU) initials us to suggest in this case the improbably large velocities (about 1-5 km/s) of particles' ejections from Phaeton.

There isn't any common opinion on the nature of Phaeton itself. Is hasn't a noticeable coma, rapidly rotates with the period about 4 hours and its brightness varies with the amplitude of about 0.4^m. These properties as well as the too high values of the Tisserand invariant (T=0,8661) and an albedo ($p_v = 0.11$) are the distinctive features of the asteroid origin (Green et al. 1985, Hartmann 1987).

On the other hand, as Green et al.(1985) have shown, Phaeton does not reveal the spectral similarity with the main asteroidal types. In this connection, and on the basis of the infrared observations, which suggest an albedo of Phaeton of 0.11 and its relatively high surface conductivity (Green et al.1985), Davies (1985,1986) concluded that the object is possibly the extinct comet composed of a rocky core. This core was formed as a result of the comet ageing blocking a release of nucleus volatile components and a coma formation.

However, the lifetimes of the comets with the orbits, the perihelion distances of which are as small as that of Phaeton, are not exceeding one or several revolutions around the Sun (Lebedinets, 1984). This may be confirmed by the comets P/Brorsen, P/Tempel-Swift and P/Neujmin-3, which existed at their orbits during 5, 4 and 2 revolutions, respectively, despite their perihelion distances of 0.65, 0.75 and 1.34 AU are much larger than that of Phaeton.

As the estimates show, the equilibrium temperature of a subsolar point of Phaeton at its perihelion amounts to 900 K under the assumption of a blackbody approach. However, the melting temperature (T_m) of cometary ices is much lower, namely:

The ices,	CO ,	CH_4,	C_2H_2,	NH_3,	HCN ,	H_2O
T_m, K ,	74 ,	91 ,	192 ,	196,	260 ,	272

It may be noted, that the subsolar part of Phaeton finds itself at temperature from 300 to 900 K over a year (about 380 days). Hence it is not worth doubting, that under such conditions, the ice nucleus dooms to evaporate completely during one or several revolutions around the Sun. So, Phaeton is most probable a stone-like fragment of an asteroid, the diameter of which equals to 5-6 km (Green et al., 1985; Hartmann et al., 1985).

The search for an appropriate mechanism of the particles' ejection from an asteroidal body failed to be a successful so far. The collisions at the asteroid belt (Hunt et al.,1986; Riabova, 1989) cannot account for either the observed Geminids aphelia' distribution nor a monomodality of the observed meteor shower.

Apparently it is for this reason, that the majority of scientists use the Phaeton particles' ejection mechanism similar to the disintegration of the comet nucleus (Fox et al., 1983; Jones and Hawkins, 1986; Babadzanov and Obrubov, 1986; Bel'covich and Riabova, 1989), despite the chemical and minerological composition of asteroids is drastically different from those of comets.

Recently a number of papers have been published (Babadzanov and Obrubov, 1986, 1987a, 1987b), in which the possibilities of generating of several (4 or 8) showers by the same swarm are discussed. In the opinion of these authors, the Earth encounters such showers throughout one and the same year. At first, the talk is about Geminids.

From this point of view, Babadzanov and Obrubov supposed that, at first, the ejection velocities from Phaeton had amounted to 670 m/s (owing to that there was an appreciable initial dispersion of semi-major axes) and, at second, the swarm's age had been nearly equals to 20 000 years (such an age was necessary to ensure the dispersion of the arguments of perihelion about 360° for the orbits with the semi-major axes from 1.0 to 1.7 AU).

We carried out the modelling of the Geminids' swarm forming and evolution under the same suggestions as well. In addition, we proceed from facts, that in the spatial twice averaged three-body problem, the system of equations of the perturbed body assumed three integrals (Moiseev,1945):

$$a = const\,, \tag{1}$$

$$\mu = p^{1/2}\cos i = const\,, \tag{2}$$

$$[W] = const\,, \tag{3}$$

where a, i — are the orbital elements, p is its parameter.

Confining ourselves to the first approximation at the Legendre polynomial expansion of the disturbing function $[W]$, M.Lidov (1961) obtained the third integral in the following form:

$$\nu = e^{2}(\,0.4 - \sin^{2}i \cdot \sin^{2}\omega) = const\ . \tag{4}$$

It holds true for bodies' orbit that approach closely the perturbing planet. In the case of the Geminids ($Q \leq 4$ AU), all the above equations are valid.

It is known, that the meteor showers occur, when the swarms generating them are approaching the Earth. Such approaches may be detected by means of the finding positions of the points of the swarm orbits that are crossing the ecliptical plane at present. In general, for this purpose, the secular perturbations of the swarm orbits should have been calculated in the given time interval which is equal to 20 000 years for Geminids.

Since we are interested in the general qualitative trend of the swarm evolution under the influence of secular perturbations, we are decided to imitate the orbital elements' perturbations by the functional dependencies, following the examples of Riabova (1989) and Bel'covich and Riabova (1989).

The perturbations of the argument of perihelion (ω) and the orbital eccentricity (e) can be represented in the following form:

$$\omega = \omega_{0} + 360^{\circ}\, t/p\ , \tag{5}$$

$$e = e_{b} + A\,\sin\left[2(\omega - 45^{\circ})\right]\ . \tag{6}$$

The e_b and A parameters are found from the system of equations:

$$\begin{cases} e_{b} - A = e_{\min}\ , \\ e_{b} + A\sin\left[2(\omega_{0} - 45^{\circ})\right] \ = \ e_{0}\ , \end{cases}$$

where e_{min} and e_0 are given by:

$$e_{\min} \ = \ (2.5\,\nu)^{1/2}\ , \qquad e_{0} \ = \ 1 - q_{0}/a\ ,$$

and q_0 - is the perihelion distance of the parent body, e_0 is the initial value of the orbital eccentricity of the ejected particle (here and after the index " o " indicates the initial orbital elements at the moment of ejection).

The period P of the oscillations of the argument of perihelion may be expressed by the empirical formula $P = 56800/a^2$ which was obtained from the analysis of the 85 most precisely determined Geminid orbits (Kramer and Shestaka, 1987).

The initial dispersion of the semi-major axes are given by

$$a = a_{b} + \alpha \cdot C\ ,$$

where a_b - is the parent body semi-major axis, C is a random variation of the semi-major axis, and α_n is a factor, the values of which are in the range from -3.00 to +3.00.

During the modelling of the swarm orbits' evolution, the following elements of the Phaeton orbit were chosen as the initial ones (Babadzanov and Obrubov, 1987b):

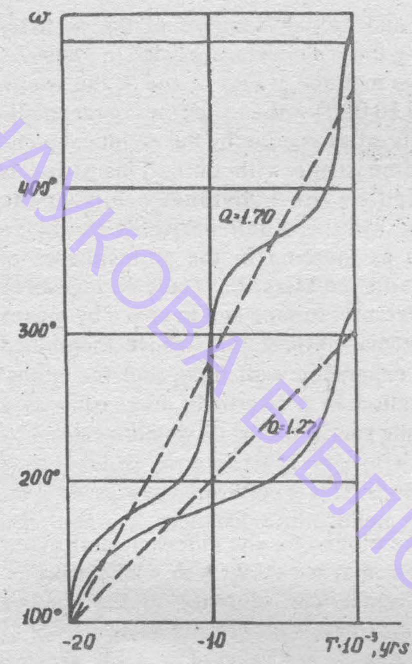

Fig. 1 The argument of perihelion ω vs time for the semi-major axes 1.27 and 1.70 AU (solid curves - the results of the numerical integra-tions, dased lines - the results of calculations by means of eq. (5).

$$a_0 = 1.271\,AU\,,$$
$$e_0 = 0.898\,,$$
$$\omega_0 = 100.0^o\,,$$
$$\pi = \omega_0 + \Omega_0 = 220.0^o\,,$$
$$i_0 = 16.7^o\,.$$

These values were obtained by means of calculations of the secular perturbations 20 000 years ago. An inclination of the osculating orbit can be obtained easily from (2):

$$i = \arccos\left\{\mu/[a\,(1-e^2)]^{1/2}\right\}.$$

The quasistationary parameters μ and ν were obtained for each orbit from the equations (2) and (4) and the initial values e_0, i_0, ω_0 and a.

In the modelling process, the certain values of α_n in the range from -3.00 to +3.00 were ascribed to each orbit. Hence, the semi-major axes will be in the range from 0.67 to 1.87 AU, if the factor C = 0.20.

Such a range of a was chosen in order to take into account the various mechanisms of the ejection, including the ejection as a result of the collisions of the asteroid-like body with the bodies, which are moving in the circumsolar nearly circular orbits.

The velocities of impact ejections amount from 0.5 to 1.5 km/s in the case of the collision velocities equal about 10 ... 30 km/s (Melosh, 1984). It can be clearly seen, that in the case of Phaeton, the collision velocities amount to 29.8 km/s at its perihelion and 12.8 km/s at the aphelion.

We carried out the modelling of orbits' perturbations according to the above-mentioned procedure. The ejection velocities amounted to 2.7 km/s. Such velocities provide an initial dispersion of the major semi-axes ranging from 0.67 to 1.87 AU. In Table 1, the part of the set of the computations is given. Here the present cross-sections of a swarm by the ecliptical plane are given for the semi-major axes of the individual orbits, which values range of an ecliptical longitude L and a heliocentric distance R of a node corresponding to each argument of perihelion. These are

$$L_a = \Omega\,, \quad R_a = [a\,(1-e^2)]/(1+e\cos\omega)$$

for the ascending node, and

$$L_d = \Omega + 180^o\,, \quad R_d = [a\,(1-e^2)]/(1-e\cos\omega)$$

for the descending one.

The structure of the model swarm depends on the accuracy of the approximation of the argument of perihelion by the Eq. (5): Fig. 1 shows the argument of perihelion vs time for the semi-major axes 1.27 and 1.70 AU: the straight lines correspond to ω calculated by (5), and the curves correspond to the 'exact' value ω calculated by the numerical integration of the equations of motion. It is clearly seen, that the differences between the 'exact' values ω and the approximated ones by (5) do not distort a general trend of an argument of perihelion increase with time.

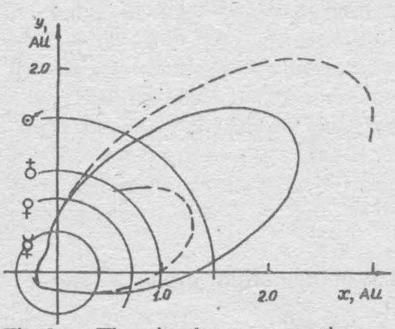

Fig. 2 The simultaneous section of the modelling meteor swarm by the ecliptical plane for epoch 1950,0 (solid curves - for the ascending node, dashed curves - for the descending node).

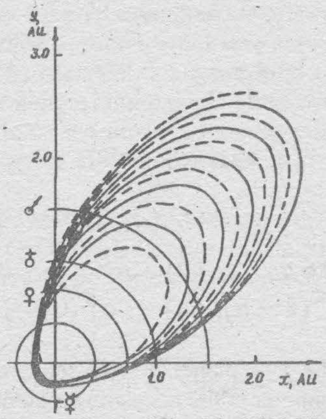

Fig. 3 Same as Fig. 2 but 60000 years after.

At Figs. 2 and 3, the simultaneous cross-sections of the swarm modelled for epoch 1950.0 and 60 000 years later, are shown. Here the orbits' projections of the terrestrial planets are plotted. It is seen, that the modelled swarm crosses four times the orbits of Mercury, Venus and Mars, as well as that of the Earth. The ecliptical longitudes LP of these planets during the expected meteor

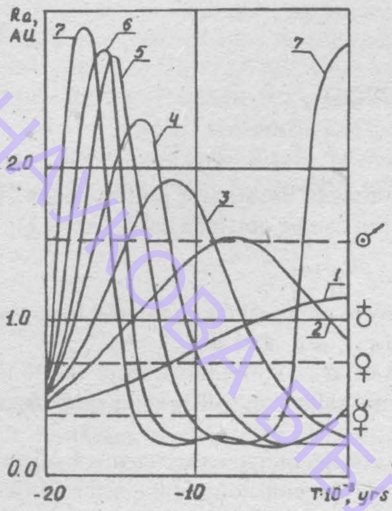

Fig. 4 a The heliocentric distances R_a and R_d vs time for the different semi-major axes: 1 - 0.67, 2 - 0.87, 3 - 1.07, 4 - 1.27, 5 - 1.47, 6 - 1.67, 7 - 1.87 AU.

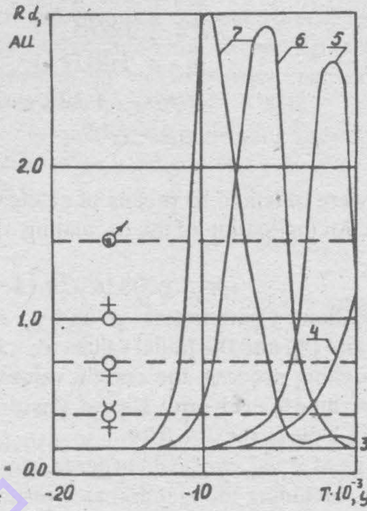

Fig. 4 b Same as Fig. 4a.

showers and orbital elements of the particles generating these showers, are listed in Table 2.

As one may see at Figs. 2 and 3, the swarm modelled 20 000 years ago has the characteristic feature: its cross-section by the ecliptical plane forms some stripe with time. This stripe is penetrated by the individual orbits of the particles' swarm. Such particles could be observed as meteors in the atmospheres of Venus, Earth and Mars, and could be registered on the Mercury' surface and in space by means of the special devices. The above-mentioned stripe is expanding with time, and the orbits' concentration in a swarm is decreasing as a result of the spatial orbits' dissipation caused by their initial dissipation and the secular perturbations. This is confirmed by Figs. 4 (a, b), where the heliocentric distances R_a and R_d vs time are plotted for the different semi-major axes. As one may see at Figs. 4ab, a kind of orbits' sorting by the semi-major axes takes place under the influence of the secular perturbations, namely: its own set of perturbed elements e, i, ω, Ω and its own point of the intersection with the ecliptical plane corresponds to each value of a. However, the repeated encounters (four and more) during the same year of the same swarm with the Earth, take place for the orbits, which have strictly definite and different semi-major axes, hence different geocentric velocities. In the case of the Geminids, the modelled the semi-major axes were equal to 0.68, 0.95, 1.31, 1.55 and 1.76 AU (1950.0).

Thus, the supposed high velocities of particles' ejections from the parent body shall have to result inevitably in the sharp decreasing of the simulated meteor showers productivity as far as to even their merging with the sporadic meteor background. In addition, the definite and different values of semi-major axes should correspond to each of the shower. In fact, only one Geminids' shower is observed, the semi- major axes of which range from 1.1 to 1.7 AU.

As for three other showers, which, according to Babvadzanov and Obrubov (1987b), are originated by the same swarm of meteor particles ejected from Phaeton, one of them - the Daytime Leonides - was not detected at all, the second one - the 11 Canis Minorids - was found in 1964 by means of the telescope observations (in the photographic catalogues there are only 4 meteors with the velocities from 35 to 40 km/s, which belong this shower), and finally the third shower - the Daytime Sextantids - displays an insignificant activity too. All that more contradicts with the model of the unique meteor swarm originating four annual showers than confirms it.

The steady swarm of fragments is forming in the case, when the velocities of particle ejection from the parent body's surface don't exceed tens of meters per second. In such a swarm the fragments have the orbits similar to those of the parent body. The swarm itself approaches the terrestrial planets one time over some thousand years.

Probabilities of such approaches were studied by Kramer and Shestaka (1987). They obtained the equations for the determination of the parameters of the meteoroids' orbits at the moment of their approaching an orbit of the j -th planet:

$$p^2 + \varepsilon_j p + \eta_i = 0, \qquad (7)$$

where

$$\varepsilon_j = a_j (0.6\, a_j / a - 2) - \mu^2 ,$$
$$\nu_j = a_j \mu^2 (2 - a_j / a) + a_j^2 (0.4 - \nu),$$

a_j - is an average value of the semi-major axis of the j -th planet, a - is a semi-major axis of meteoroid' orbit, μ and ν - are the parameters given by (2) and (4), p is a parameter of the osculating meteor' orbit.

Solving the equation (7), one may find two values of the parameter p of the orbit approaching the orbit of the j -th planet. It should be noted, that the probability of these bodies encountering is not equal to zero under the following conditions only:

$$\Delta = 1/4\, \varepsilon_j^2 - \eta_j \geq 0, \qquad (8)$$

$$p_K < p_{\max} = a(1 - 2.5\nu), \qquad (9)$$

where k is equal to 1 or 2.

It is clearly seen that three cases are possible: a) discriminant Δ of the equation (7) is negative ($\Delta < 0$); then the body's orbit and that of the planet are never crossed and the probability P_j of their encountering is equal to zero: b) $\Delta \geq 0$, but only one value p_K satisfies the condition (9); in this case the probability $\overline{p}_j$ is given by

$$P_j = \frac{\tau_j^2}{\pi a^{3/2} \sin i} \left(3 - \frac{a_j}{a} - \frac{2\mu}{a^{1/2}}\right)^{1/2} \left(2 - \frac{a_j}{a} - \frac{P_k}{a_j}\right)^{-1/2}, \quad (10)$$

where τ_j - is the radius of a sphere of capture of the j-th planet, k is equal to 1 or 2;

c) $\Delta \geq 0$ and both values p_K satisfy the condition (9), then P_j is given by

$$P_j = \frac{\tau_j^2}{\pi a^{3/2}} \left(3 - \frac{a_j}{a} - \frac{2\mu}{a^{1/2}}\right)^{1/2} \times$$

$$\times \left[\left(2 - \frac{a_j}{a} - \frac{\overline{p}_1}{a_j}\right)^{-1/2} \frac{1}{\sin i_1} + \left(2 - \frac{a_j}{a} - \frac{\overline{p}_2}{a_j}\right)^{-1/2} \frac{1}{\sin i_2} \right]. \quad (11)$$

It is obvious, that four values of the argument of perihelion of a disturbed body's orbit correspond to each p_K. In consequence of this, in the second case this orbit four times approaches the orbit of the j-th planet during one revolution of the line of apsides; in the third case, such approaches take place eight times. And they occur at different times, but not during the same year.

It should be noted, that according to the accepted expression for the collision probability (Opik, 1951), it is equal to zero when the perihelion distance fixed for a given epoch of an osculation exceeds an average semi-major axis of a perturbing planet, i.e. $q > a_j$. But a probability given by (10) or (11) can be not equal to zero in this case too.

The convincing example of this is the asteroid 1580 Betulia with the following orbital elements : a = 2.194 AU, e = 0.4901, and q = 1.1119 AU. According to Opik (1951), the collision probability of this asteroid with the Earth cannot be calculated, since the expression $(2 - 1/a - \overline{p}) < 0$. Nevertheless, in this case the equation (7) has two real roots: $\overline{p}_1 = 1.482$ and $\overline{p}_2 = 0.872$. Both roots satisfy the condition (9), in consequence of which the probability of Betulia collision with the Earth prove to be equal to $1.1 \cdot 10^{-8}$. This result is confirmed by the numerical integration of the equations of motion of Betulia: according to these calculations, the orbit of Betulia crosses the Earth's orbit eight (!) times during the complete period of the changing of ω.

One more example is the asteroid 1866 Sysiphus. It moves in the orbit with the perihelion distance q = 0.871 AU. According to the classic Opik's formula, the probability of encountering Sysiphus and the Earth is equal to $9.52 \cdot 10^{-10}$. However, the numerical integration of the asteroid's motion equations, if taking into account the major planets' perturbations, shows that the Sysiphus and Earth orbits did not cross during last 40 000 years. Using the equations (7)-(11), we obtained the same result: since the discriminant of equation (7) is less than zero, one may say that the encounter does not occur.

Betulia, Sysiphus and Phaeton are the typical representatives of the Aten-Apollo-Amor asteroids, the number of which exceeds 120 at present. Above 70 of them move in orbits with the perihelion distances $q < 1.0167$ AU, and over 20 asteroids approach the Earth closer than $d_{ph} = 0.026$ AU (d_{ph} is the minimum distance between Phaeton and the Earth). It should be expected, that such asteroids generate more intensive showers, than the Geminids do. Recently even the theoretical radiants of the AAA-asteroids were calculated (Drummond 1981,1982; Olsson-Steel 1987,1988). However, up to now, no shower related to the asteroids has been detected.

Nevertheless, Babadzanov and Obrubov (1989,1991) and Babadzanov et al.(1990,1991) continue to allege that many short-period swarms as well as the Geminids and the Quadrantids originate from four to eight meteor swarms. Moreover, they believe, that such showers must be observed during the same year. However, we have shown earlier, that their hypothesis is not substantiated.

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Table 1. The points of the intersection of the orbits of the meteor particles ejected from Phaeton with the ecliptical plane (a model)

a, AU	ω	L_a	R_a, AU	L_d	R_d, AU
0.97	219.5	0.5	0.886	180.5	0.204
0.99	224.5	355.5	0.775	175.5	0.202
1.01	229.6	350.4	0.670	170.4	0.200
1.05	240.0	340.0	0.491	160.0	0.197
1.09	250.9	329.1	0.360	149.1	0.200
1.13	262.1	317.9	0.274	137.9	0.254
1.17	273.8	306.2	0.225	126.2	0.335
1.21	285.9	294.1	0.204	114.1	0.493
1.25	298.4	281.6	0.203	101.6	0.493
1.29	311.3	268.7	0.214	88.7	0.775
1.33	324.6	255.4	0.231	75.4	1.237
1.41	352.4	227.6	0.262	47.6	2.465
1.45	6.9	213.1	0.266	33.1	2.555
1.49	21.8	198.2	0.259	18.2	2.017
1.53	37.1	182.9	0.242	2.9	1.287
1.57	52.8	167.2	0.222	347.2	0.731

Table 2. Ecliptical longitudes of the planets during the expected meteor showers and their orbital elements

Planet	L_P	Orbital elements of particles, that generating the meteor showers on the planets					
		ω	Ω	i	e	q	a
	(degrees, 1950.0)					AU	
Mars	69.0	331.0	249.0	45.1	0.833	0.226	1.350
	75.4	144.8	75.4	45.7	0.866	0.240	1.787
Earth	61.0	159.0	61.0	38.4	0.729	0.185	0.682

	5.4	214.6	5.4	41.2	0.850	0.189	0.951
	81.6	318.4	261.4	41.2	0.850	0.197	1.313
	355.7	44.3	175.7	42.1	0.870	0.202	1.549
	86.2	133.8	86.2	42.8	0.883	0.206	1.763
Venus	353.1	226.9	353.1	35.5	0.828	0.172	1.001
	90.7	309.3	270.7	37.5	0.863	0.176	1.285
	346.9	53.2	166.8	38.4	0.866	0.180	1.572
	94.3	125.7	94.3	38.9	0.182	0.180	1.744
Mercury	331.7	248.3	331.7	28.1	0.870	0.140	1.082
	109.2	290.8	289.2	28.2	0.885	0.141	1.227
	329.3	70.7	149.3	28.6	0.912	0.141	1.615
	111.0	109.0	111.0	28.7	0.917	0.142	1.706

Table 3. The asterois approaching the Earth within the distances about 0.1 AU

Asteroids	r , AU	Asteroids	r , AU
12101 Oljato	0.0001	1984 KD	0.034
1981 Midas	0.0008	1954 XA	0.036
1937 UB Hermes	0.0010	1620 Geographus	0.037
1982 DB	0.0053	1566 Icarus	0.040
2340 Hathor	0.0064	1979 VA	0.046
1986 JK	0.0069	1959 LH	0.046
2135 Aristaeus	0.0078	3122 1981 ET3	0.054
2101 Adonis	0.013	1980 AA	0.054
3361 1982 HR	0.013	1685 Toro	0.057
3362 Khufu	0.018	1985 PA	0.066
6343 P-L	0.020	1983 TF2	0.067
1986 PA	0.021	2063 Bachus	0.068
1982 XB	0.022	1984 KB	0.070
1983 LC	0.023	2606 Seneca	0.071
1978 CA	0.024	1917 Cuyo	0.073
3200 Phaeton	0.026	1943 Anteros	0.074
1862 Apollo	0.027	1915 Quetzalcoatl	0.076
6344 P-L	0.027	1983 TO	0.078
2102 Tantalus	0.028	1866 Sisyphus	0.092
1979 XB	0.033	1973 NA	0.095
		2062 Aten	0.098

DO GENETICALLY RELATED COMET PAIRS AND GROUPS EXIST?

I.S.Shestaka

Abstract. In connection with the discoveries of the new comets 1982b and 1982c, 1988e and 1988g, the orbits of which have the essentially similar elements, the problem of existence of the cometary groups with the similar orbits and their genetical relationship are considered. The similarity of the quasistationary parameters , and the Tisserand invariants Ti is used as a criterion for the selection of comets in the groups. This criterion has been verified on comets of the Kreutz' family and comets approaching closely the Jupiter. It is shown that this criterion is quite feasible one for selection of comet groups related genetically.

Key Words: Comet pairs, groups, genetical relations.

The idea on the genetical relations of some comets and their common origin was initially expressed by H.Kreutz (1888, 1891,1901) a hundred years ago, while investigating four comets with the similar orbits - 1843 I,1880 I, 1882 II and 1887 I, each of these 'grazing' the Sun by passing it at the distance from 7000 to 1200000 kms. Since that time, many investigators have put their attention to the problem of the existence of the genetically related comet groups. Using the different criteria, they tried to find all the possible groups of comets and to make their reality scientifically grounded.

In the fifties-sixties of the 20th century, J.Porter (1952,1963) discovered about 15 comet groups according to the similarity of the orbits. Porter assumed a great range of the comets' perihelion distances in these groups, which sometimes exceed 3.4 AU. The search for the family groups was based upon two criteria by E.Opik (1971): the Bernulli probability criterion and the statistic criterion on the basis of the visible orbits' similarity. Due to this approach, he succeeded in discovering of 97 comet groups, each including from two to seven comets with three inherent elements. According to the Opik's calculations, the probability of their random coincidence is not more than 10 . Such a large number of comet groups, selected from the Catalogue containing 472 comets, initiated F.Whipple (1977) to reconsider the question on the degree of their reality. Using the Monte Carlo method and the elementary theory of probability, he came to the conclusion that the degree of orbits' elements similarity in the groups selected by Opik (with the exception of solely several pairs) does not exceed the expected value in the random grouping of comets. In 1979, E.N.Kramer et al.(1979) made a search for the comet groups from the Catalogues of J.Porter (1961) and B.Marsden (1972), by using a well-known D-criterion of R.Southworth and G.Hawkins (1963). They found seven groups, in each of which the mutual phase distance D between the orbits satisfy the condition D. The authors did not exclude the possibility of a common origin of the comets belonging to the same group. L.Kresak (1982) and B.Lindblad (1985) quite independently considered a problem on the reality of the comet groups with the similar orbits. For this purpose, Kresak investigated the sample of 546 long-periodic comets and found 38 pairs with D as well as five groups containing three and four comets. In order to estimate the reality or the random appearing of such groups, Kresak also considered two random samples of the same volume. Discovering only slight prevalence of small values of D for the real comets as compared to the random samples, Kresak came to the conclusion on the absence of the comets' genetical relations existence in the groups with the similar elements. B.Lindblad (1985) investigated 599 long-periodic comets, and by using the D-criterion, he found five pairs and two groups with 4 and 7 comets each, including the Kreutz's family comets. The reality of these pairs and groups as well as Kresak's those was estimated by comparing with the groups found in the random samples. As a result, Lindblad has made a conclusion, that at the level reliability 2 σ, the groups of comets with the similar orbits are not found more often than in the samples with random orbits' distribution. The problem of the randomness of comets' combinations in pairs and groups seemed to raise no doubts and the hypothesis on the reality of physical and genetical relations of comets in groups had apparently to be burried and forgotten at long last. Only the Kreutz's family - universally recognized - was considered as an exception. However, the life sometimes presents us the sudden gifts. Such gift was embodied as a discovery of two new comets in 1988 - Levy (1988e) and Shoemakers-Halt (1988g) - with essentially similar orbits (see Table 1). As soon as the discovery was made, the problem again was facing the scientists: whether the wonderful coincidence of the comets' orbits was a random one, or there was a physical and genetical relation between them. Based upon a striking similarity of orbits' elements, and taking into account the fact, that the comets were at the angular distance of 20 degrees at the moments of the discovery, and passed the perihelion in 76 days one after another, Marsden (1988) suggested, that in this case there were two fragments of the same parent comet with a semimajor axis 750 AU. The comet was splitted during one of the previous perihelion passages. As our calculations have shown, the scatter velocity of these fragments are about to 9.7 m/s. We cannot exclude the possibility, that the parent comet was splitted into several fragments rather than into two ones (there is a sufficient number of examples) or that the separated fragments themselves may continue the splitting. As a result, these fragments might appear to the observers as some independent comets (as was the case with the fragments of the Biela's comet nucleus). Naturally, one may expect, that the orbital elements of such comets are to be distinctly similar and may be found in Catalogues. Indeed, in the "Catalogue of Comet Orbits" (Marsden,1986), there are some comets, the orbital elements which are close enough to those of the comets 1988e and 1988g (see Table 1). The similarity of the orbits may confirm the above mentioned suggestion on the common origin of some of them at least. A bit earlier, in 1982, two comets were discovered - 1982b and 1982c - which most probably are the fragments of the P/Du Toit comet nucleus (or together with it are fragments of another primary comet). In 1985, A.Carusi et al. (1985) made a suggestion on the relationship of two more comets - Van Biesbroeck and Neujmin 3. All the above-mentioned facts initiate us once more to return to the problem on the reality of existence and genetical relations comets with the similar orbits using the quite different criteria. In spatial twice restricted problem of three bodies, the system of equations of the motion of the perturbed body, assumes three integrals: - the semimajor axis remains constant

$$a = \text{const}, \tag{1}$$

÷ the vector projection of an angular moment of the body on the normal to the plane of motion of a perturbative planet remains constant

$$\mu = [q\,(1+e)]\cos i = \text{const} \tag{2}$$

and the averaged perturbative function also remains constant (Moiseev, 1945)

$$[W] = \text{const.} \tag{3}$$

The latter equation, for the Hill's case, takes the following form (Lidov, 1961)

$$\nu = e^2\,(0.4 - \sin^2 i\,\sin^2\omega) = \text{const.} \tag{4}$$

From the Jacoby's integral, it also follows, that the Tisserand invariant Ti remains constant

$$\text{Ti} = (1-e)/q + 0.1686\,[q\,(1+e)]^{1/2}\cos i = \text{const.} \tag{5}$$

It has been shown earlier (Kramer and Shestaka 1983, 1987), that the variations in μ and ν (under the influence of the secular perturbations and Pointing-Robertson effect) do not exceed 5-10 %.

Due to the constancy of μ, ν and Ti parameters, one can suggest, that the comets of the common origin should keep on the close values of these parameters during their evolution. Therefore, if among the well-known comets, there are the parent groups, but not the random ones, they should be expected to have the similar parameters of μ, ν and Ti.

In order to estimate a possible range of such a similarity, we have investigated the above parameters in the periodic comets, the orbital elements of which have changed drastically after the close approachings to Jupiter. In Table 2, we present the orbital elements and the μ, ν, Ti parameters for a number of comets for two moments: before their close approaches to Jupiter (upper line) and after such approaches (bottom line). As one may see from Table 2, even the considerable variations in the orbital elements may result in rather close quasistationary parameters μ and ν. The Tisserand invariant Ti practically not changing at all.

Thus, it seems justified, that the comets may be subdivided into the groups according to the similarity of all the quasistationary parameters μ, ν and Ti.

First of all, we have considered a well-known family of Kreutz comets, the genetic relations of which leave no doubts. Within a total number of known comets of this family - 23, the two groups have been selected consisting of 4 and 19 comets, with inherent close values of μ, ν, Ti (see Table 3). The first group includes 1843 I, 1882 II, 1963 V and 1965 VIII comets, the Tisserand invariant of which does not exceed 0.0060. The second group includes 1880 I, 1887 I, 1945 VII, 1970 VI, as well as 15 comets discovered with the board coronographs mounted at the spacecrafts SOLWIND and SMM (Marsden, 1989). The Tisserand invariant for this comets' group ranges from 0.0129 to 0.0214.

Using the same similarity criterion of μ, ν, Ti parameters, we have selected some groups of comets from Marsden's (1979) Catalogue, which are shown at Table 4. In addition to the similarity of the above mentioned quasistationary parameters, we inferred, that the comets of the common origin, which underwent no close approaches to the big planets, must keep up the similar values of the perihelion distances and the orbital eccentricities. At Table 4, there are 14 groups containing from two to three comets. It is not impossible, that the comets entering these groups, are related genetically like the latter three groups: Du Toit-Hartley, Neujmin 3 -Van Biesbroeck and Levy- Shoemaker-Halt.

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Table 1. The orbital elements of comets of Levy's and Shoemakers-Halt's group

Comet	ω	Ω	i	e	q, a.u..
	(degrees, 1950.0)				
1988e	326.52130	288.06334	62.80479	0.9978636	1.1741402
1988g	326.47214	288.04196	62.79278	0.9969724	1.1736201
1889 IV	345.8705	287.0100	65.9895	0.997720	1.039727
1964 IX	20.6932	279.7444	67.9668	0.996452	1.259270
1968 V	353.9833	254.0145	61.7700	1.0	1.234003
1946 VI	320.4217	237.6345	56.9684	1.000794	1.136222

Table 2. The orbital elements and quasistationary parameters some comets after their close approaches to Jupiter

Comet	ω	Ω	i	e	q a.u.	μ	ν	Ti
	(degrees, 1950.0)							
Kojima								
1970 XII	198.11	291.14	4.09	0.515	1.631	1.57	0.11	0.5617
1978 X	348.36	154.08	0.89	0.393	2.399	1.83	0.06	0.5612
Wolf								
1918 V	172.93	207.14	25.29	0.559	1.582	1.42	0.12	0.5182
1925 X	160.74	204.45	27.30	0.405	2.435	1.64	0.06	0.5216
Harrington-Abel								
1969 III	338.08	145.89	16.84	0.524	1.773	1.57	0.11	0.5337
1983 XVII	138.58	336.72	10.16	0.539	1.785	1.63	0.11	0.5333
Daniel								
1909 IV	3.50	71.54	19.45	0.603	1.382	1.40	0.15	0.5239
1978 XII	10.83	68.49	20.14	0.549	1.662	1.51	0.12	0.5253
De Vico-Swift								
1844 I	278.93	65.05	2.91	0.617	1.186	1.38	0.15	0.5561
1965 VII	325.35	24.42	3.61	0.524	1.624	1.57	0.11	0.5578

Table 3. Two comets' groups of the Kreutz family

Comet	ω	Ω	i	e	q	μ	ν	Ti
	(degrees, 1950.0)				a.u.			
1843 I	82.64	2.83	144.35	0.9999	0.0055	-0.09	0.07	-0.0037
1882 II	69.59	346.96	142.00	0.9999	0.0078	-0.10	0.07	-0.0038
1965 VIII	69.59	346.30	141.58	0.9999	0.0078	-o.10	0.07	-0.0037
1963 V	86.16	7.24	144.58	0.9999	0.0051	-0.08	0.07	-0.0057
1880 I	82.25	7.08	144.66	1.0	0.0055	-0.09	0.07	-0.0144
1887 I	83.51	3.88	144.38	1.0	0.0048	-0.08	0.07	-0.0134
1945 VII	72.06	350.50	141.87	1.0	0.0075	-0.10	0.06	-0.0162
1970 VI	61.29	336.32	139.07	1.0	0.0089	-0.10	0.07	-0.0170
1979 XI	67.67	344.30	141.45	1.0	0.0048	-0.08	0.11	-0.0135
1981 I	65.43	341.41	140.67	1.0	0.0079	-0.10	0.07	-0.0164
1981 XIII	68.43	345.26	141.70	1.0	0.0061	-0.09	0.07	-0.0146
1981 XXI	77.68	356.87	143.84	1.0	0.0045	-0.08	0.07	-0.0129
1983 XX	78.58	357.98	143.98	1.0	0.0075	-0.10	0.07	-0.0167
1984 XII	56.67	329.74	136.38	1.0	0.0154	-0.13	0.07	-0.0214
1987 XXII	80.59	0.46	144.25	1.0	0.0054	-0.08	0.07	-0.0142
1987 XXV	82.63	2.96	144.46	1.0	0.0063	-0.09	0.07	-0.0153
1988 l	85.88	6.96	144.70	1.0	0.0052	-0.08	0.07	-0.0139
1988 m	82.25	2.50	144.43	1.0	0.0059	-0.09	0.07	-0.0149
1988 n	88.08	9.65	144.78	1.0	0.0051	-0.08	0.07	-0.0139
1988 q	86.14	7.28	144.71	1.0	0.0058	-0.09	0.07	-0.0148
1988 p	84.72	5.54	144.63	1.0	0.0056	-0.09	0.07	-0.0145
1989 q	91.80	14.20	144.78	1.0	0.0046	-0.08	0.07	-0.0132

Table 4. The comets' groups selected with criterion of closeness of parameters μ, ν, Ti

Comets	ω	Ω	i	e	q	μ	ν	Ti
	(degrees, 1950.0)				a.u.			
1905 II	352.35	77.38	30.48	0.615	1.395	1.29	0.15	0.4941
1975 IV	358.01	84.66	30.08	0.581	1.398	1.29	0.13	0.5166
1895 II	167.77	177.06	3.00	0.652	1.298	1.46	0.17	0.5147
1897 II	174.01	147.11	15.70	0.627	1.326	1.41	0.16	0.5197
1873 II	185.19	121.98	12.75	0.553	1.344	1.41	0.12	0.5702
1886 IV	176.85	54.47	12.67	0.571	1.338	1.41	0.13	0.5597
1906 VI	199.49	195.12	14.62	0.584	1.632	1.56	0.13	0.5172
1910 V	199.53	206.78	10.57	0.565	1.655	1.58	0.13	0.5296
1973 V	209.13	59.13	9.50	0.500	1.560	1.51	0.10	0.5749
1981 X	214.61	75.35	5.57	0.507	1.615	1.55	0.10	0.5670
1933 IV	190.56	188.80	10.21	0.348	2.497	1.81	0.05	0.5655
1981 XVII	183.46	215.53	6.66	0.408	2.362	1.81	0.07	0.5560

Table 4. (Continue). The comets' groups selected with criterion of closeness of parameters μ, ν, Ti

Comets	ω	Ω	i	e	q a.u.	μ	ν	Ti
	(degrees, 1950.0)							
1916 II	354.81	114.36	15.53	0.546	1.558	1.50	0.12	0.5435
1951 IX	343.00	127.79	16.35	0.515	1.664	1.52	0.10	0.5483
1958 V	187.03	254.23	18.48	0.540	1.605	1.49	0.09	0.5385
1970 XII	198.11	291.14	4.09	0.515	1.631	1.57	0.11	0.5617
1975 III	169.76	273.19	5.42	0.537	1.568	1.55	0.12	0.5556
1937 V	114.83	58.73	146.41	0.9997	0.803	-1.09	0.15	-0.1841
1956 III	81.01	226.03	147.46	1.0	0.842	-1.09	0.12	-0.1844
1819 IV	350.22	79.15	9.11	0.699	0.892	1.21	0.20	0.5424
1902 II	350.27	221.27	8.30	0.736	0.753	1.13	0.22	0.5409
1792 II	147.18	285.47	131.00	0.906	0.966	-1.39	0.40	-0.2303
1862 II	27.19	327.76	172.10	1.0	0.981	-1.37	0.40	-0.2231
1864 II	151.38	96.78	178.13	0.996	0.909	-1.35	0.40	-0.2340
1982 II	251.67	308.58	2.94	0.601	1.196	1.38	0.14	0.5666
1982c	251.62	308.59	2.94	0.602	1.195	1.38	0.14	0.5660
1982b	254.28	308.45	2.92	0.59	1.179	1.37	0.14	0.5783
1929 III	140.73	158.50	3.69	0.585	2.042	1.79	0.14	0.5059
1954 IV	134.98	148.98	6.59	0.550	2.414	1.92	0.12	0.5104
1988e	326.52	288.06	62.80	0.998	1.174	0.70	0.16	0.1197
1988g	326.47	288.04	62.79	0.997	1.174	0.70	0.16	0.1206

DETERMINATION OF THE SECOND TWILIGHT BRIGHTNESS BY THE METHOD OF THE TWILIGHT PROBING OF THE EARTH'S ATMOSPHERE

Yu.I.ZAGINAILO

Abstract. A new method of 'gradients' for determination of the secondary twilight brightness is proposed, which allows to determine the brightness of secondary twilight directly from the observations.
Key Words: brightness of the sky's nightglow,secondary twilight.

The method of the twilight probing of the Earth's atmosphere was proposed by V.G.Fesenkov in 1923. Let's consider the penetration of the solar rays under the twilight conditions (Fig.1).

Let an observer be on the Earth's surface in the O point and makes measurements of the brightness of the twilight sky B_{obs} in the direction OM, which is determined by the azimuth coordinates Z, A. At the solar depression angle g ($g = \xi - 90$ where ξ - is the angular distance between the Sun and the zenith), the extraterrestrial flux of the solar radiation I_0 is directed along the SM line.

The method of the twilight probing the atmosphere is based on the fact, that under the twilight conditions, the solar radiation is scattered by a thin atmosphere layer (of the order of 20 kms). At Fig. 1, the considered layer is located along the SM line. The atmosphere is located below the SM line, and does not almost scatter the solar radiation, since practically it is not illuminated by the Sun. The atmosphere above this layer is of much smaller density, and scatters the solar radiation much weaker. Instead of the twilight layer, as was proposed by N.M.Staude (1936), the twilight ray (SM) is considered, which determines the mean height of the scattering layer at the fixed solar depression g .

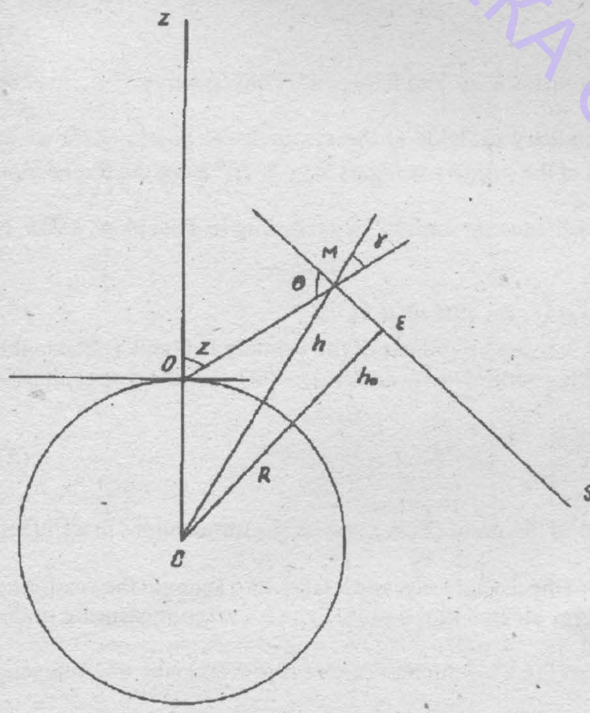

Fig. 1 The solar rays motion under twilight conditions.

As was shown by N.B.Divari (1968), the height of a twilight ray above the Earth's surface depends on the solar depression and on the wavelength of the monochromatic radiation. At the M point, the a twilight ray is intersected with the direction of vision OM. The height above the Earth's surface h of the scattering element, located at the M point, depends on the direction of vision, that is on z and A , on the solar depression and on the wavelength of the monochromatic radiation. The calculations of h for different z, A , g and λ , are presented by N.B.Divari (1968).

Thus some part of the solar radiation, which is scattered at an angle Θ , will be directed to the observer in the M point. Let's designate this sky's twilight brightness as B_1 , and call it the 'brightness of the primary twilights'. Since the atmosphere's density at the heights of 30-120 km (that is, at the heights, where the twilight method is effective) is not large, and decreases rapidly with the height, we may consider that the brightness of the primary twilights is conditioned only by the scattering of the first order, whereas the scattering of higher orders can be neglected.

If the observed brightness of the twilight sky consisted only of that of the primary twilights B_1, then, taking into account the absorption of the solar radiation on the way to the scattering element (that is, on the SM way), and on the way from the scattering element to the observer (i.e., on the MO way), one may determine the scattering capacity of the atmosphere in the M point immediately.

However, the picture of the observed brightness of the twilight sky is complicated by the fact, that at the solar depression angle $g \geq 6^0$, the twilight layer has already been separated from the troposphere rather well, and has become an independent brightness source, that is the radiation of each element of a twilight layer is scattered by the dense troposphere layers lying below it.

Let's denote by B_2 the part of radiation of a twilight layer scattered by troposphere which reaches the observer along the OM-line, and let's call it the brightness of the secondary twilights.

Thus, the observed brightness of the twilight layer B_{obs} may be expressed in the form

$$B_{obs} = B_1 + B_2 + B_{sky} + B_{em} , \tag{1}$$

where B_1 and B_2 - are the brightnesses of the primary and secondary twilights, respectively; B_{sky} is the brightness of the stellar component, which may be determined from the observations; B_{em} is the brightness of the sky's nightglow. It is eliminated by using the narrow-band filters centered in those spectral bands, which are free from the emission lines.

While using the method of the twilight probing of the atmosphere, the account of the brightness of the secondary twilights is the most difficult procedure.

There are some methods (Fesenkov, 1962, 1972; Divari and Zaginailo, 1971), which allow to take into account the brightness of the secondary twilight B_2, that is they enable us to determine the brightness of the primary twilights B_1 from the observed brightness of the twilight sky B_{obs}.

Now we will discuss the most commonly used methods among them.

The first method is the V.G.Fesenkov's (1962) method of measuring the brightness of the twilight sky in two symmetrical points of the solar meridian.

Let the measurements be carried out in the solar meridian before the nightfall in two symmetrical points with the zenith distance z equal to 70^0. Let us designate by z_1 the zenith distance of the observed point on the solar side of the solar meridian and by z_2 - that on the antisolar side of the meridian.

The observed brightness of the twilight sky B_{obs} at the point located on the solar side of the meridian can be expressed in the form

$$B_{obs} = B_1 + B_2 + B_{sky}, \tag{2}$$

where B_1, B_2 and B_{sky} are the brightness of the primary, secondary twilights and of the night sky, respectively, in the point with the zenith distance z_1.

As has been shown by V.G.Fesenkov (1962), at the solar depression angle $g \geq 6^0$, the Earth's shadow is raised above the $z = 70^0$, that is the twilight layer proves to be above the point of the observations $z_2 = 70^0$, and the observed brightness consists only of that of the secondary twilights B'_2 and that of the night sky B'_{sky}

$$B'_{obs} = B'_2 + B''_{sky}. \tag{3}$$

As the measurements are carried out before the nightfall, the brightness B_{sky} and B'_{sky}, and, consequently, B'_2, may be determined directly from the observations.

If we calculate the theoretical ratio of the brightness of the secondary twilights at the symmetrical points of the solar meridian $k = B_2/B'_2$, then it is possible to determine the brightness of the primary twilights at $z_1 = 70^0$ from the Expression (2).

The brightness of the secondary twilights at the point with the coordinates z_0 and A_0, according to Fesenkov, 1955, is determined by the expression

$$B_2(z_0, A_0) = \int\int B_1(z, A) f(\Phi) \varphi(z, z_0) \sin z \, dz \, dA, \tag{4}$$

where the integral is taken from all over the sky. In Ex.(4), $B_1(z, A)$ - is the brightness of the primary twilights (outside the troposphere, that is, the brightness of a twilight layer in the point with coordinates z and A); $f(\Phi)$ is the troposphere's indicatrix of scattering, where Φ - is the scattering angle, and

$$\varphi(z, z_0) = \frac{p^{m_0} - p^m}{m - m_0} m_0, \tag{5}$$

where p - is the transparency coefficient, m -is the atmosphere mass of the point (z, A), m_0 is the atmosphere mass of the point (z_0, A_0).

The Ex.(5) was obtained from the measurements of the brightness of the daylight sky, and it takes into account the scattering by the troposphere of the radiation of each element of the twilight layer located at the point (z, A) when measuring in the direction of the (z_0, A_0) point.

If we consider, that the twilight layer radiation is not polarized, then the k-coefficient can be represented by the following theoretical expression

$$K = \frac{\int\int B_1(z, A) f(\Phi_1) \varphi(z_1, z) \sin z \, dz \, dA}{\int\int B_1(z, A) f(\Phi_2) \varphi(z_2, z) \sin z \, dz \, dA}, \tag{6}$$

where the brightness of the secondary twilight are determined from the Ex.(4).

Having determined from the theoretical considerations the approximate expression for $B_1(z, A)$, V.G.Fesenkov obtained from the Ex.(6) the following values for the k-coefficient:

g^0	6^0	8^0	10^0	.....	12^0	14^0	
k	2,02	1,94	1,86	.....	1,78	1,77	(7)

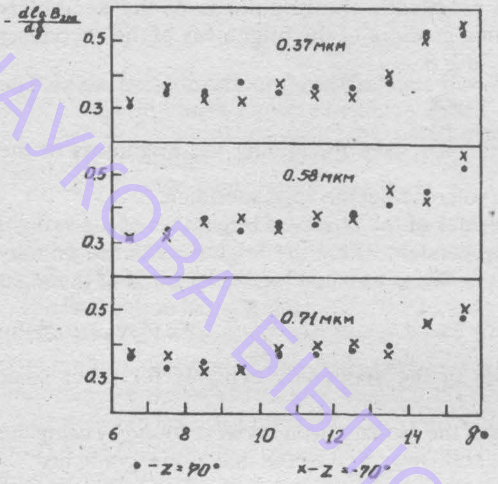

Fig. 2 The brightnesses of secondary twilights computed for the Rayleigh's atmosphere model.

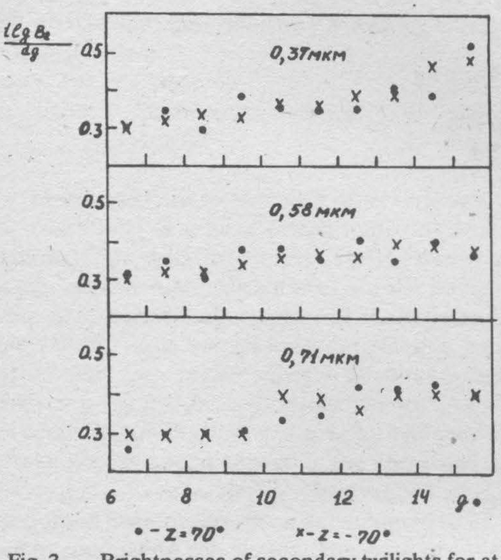

Fig. 3 Brightnesses of secondary twilights for atmosphere model which takes into account the ozone and the atmosphere dust component.

The second method was proposed by N.B.Divari (Divari and Zaginailo, 1971). The primary twilight brightness can be determined by this method from the observed ones in any point of the celestial sphere.

Let the brightness of the twilight sky B_{obs} , and that of the night sky B_{sky} be measured in some point of the celestial sphere. Then the brightness of the primary twilights in this point may be determined by the expression

$$B_1 = k_1 (B_{obs} - B_{sky}) , \qquad (8)$$

where k_1 is the theoretically calculated ratio of the brightness of the primary twilights to the sum of those of the primary and secondary twilights $(k_1 = B_1/(B_1 + B_2))$.

The values of k_1 have been calculated by N.B.Divari for different points of the celestial sphere, for the different wavelengths, or for the different values of the transparency coefficient.

The most essential disadvantage of the methods for account of the secondary twilights results from the fact, that they are based upon these or those model atmospheres. But the real dust particles in lower atmosphere's layers are rather variable, causing the considerable variations in the brightness of the secondary twilights and, consequently, in the observed ones of the twilight sky.

It would be desirable to have the method of account of the brightness of the secondary twilights, which would be independent on the model calculations and would be based only on the observational data. Such a method is proposed below and we will call it as the method of 'gradients'.

We now consider a number of values $k(g)$ (7), determined by V.G.Fesenkov. What is their physical sense?

1. The logarithmic gradient of the brightness of the secondary twilights $-\frac{d \lg B_2}{dg}$ at the symmetric points of the solar meridian is the same.

2. The ratio of the brightness of the secondary twilights at the symmetric points of the solar meridian is always constant for the fixed solar depression.

The second assumption is apparently inconsistent with the reality, and we can neglect it.

We now consider in what way the model calculated by N.B.Divari is related to the first assumption. At figures 2 and 3, the depen- dencies are shown for two symmetric points of the solar meridian $z = 70^0$ of the logarithmic gradient of the brightness of the secondary twilights upon the solar depression for three spectral bands.

The brightness of the secondary twilights have been calculated for the Rayleigh's model atmosphere (Fig.2) and for that taking into account the ozone and dust particles (Fig.3).

As one may see from the figures, the logarithmic gradients of the secondary twilight brightness at the symmetric points of the solar meridian $z = 70^0$ are the same for both model atmospheres. Some scatter of the points can be accounted for the fact, that the models have been calculated for several solar depressions, whereas in the logarithmic gradients' calculation, the values of the brightness of the secondary twilights have been obtained for each depression by the graphic interpolation.

For other symmetric points of the solar meridian, the analogous results were obtained. Thus, the considered methods of the account of the brightness of the secondary twilights are consistent with the fact, that the logarithmic gradient of the brightness of the secondary twilights is the same at the symmetric points of the solar meridian.

Then the procedure of separating the brightness of the secondary twilights won't take much effort.

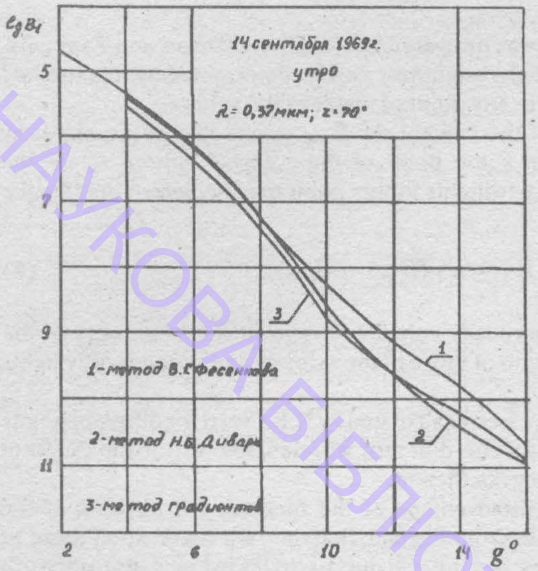

Fig. 4 Brightnesses of the primary twilights computed with different methods in September 14th, 1969 morning ($R = 0{,}37$ mcm, $Z = 70^{o}$;
1 - the method of V.G.Fesenkov;
2 - the method of N.B.Divari;
3 - the gradients' method).

Method of 'Gradients'. The observed brightness of the twilight sky on the antisolar side of the solar meridian at the points, which are occulted by the Earth's shadow, are practically the brightness of the secondary twilights. So, the logarithmic gradient of the brightness of the secondary twilights for these points $-\dfrac{d \lg B_2}{dg}$ is found from the observa- tions. The obtained values $-\dfrac{d \lg B_2}{dg}$ are used for finding the brightness of the secondary twilights on the solar side of the solar meridian.

For this, we used the values of the observed brightness of the twilight sky at rather large solar depression, where the brightness of the primary twilights is practically absent. We subtracted the background of the night sky and, using the previously found values $-\dfrac{d \lg B_2}{dg}$, we may restore the changes of the brightness of the secondary twilights for other solar depressions.

At Fig.4, the brightness of the primary twilights were found by using the methods of V.G.Fesenkov, N.B.Divari and by the that of the 'gradients'.

The usage of the method of 'gradients' for taking into account the secondary twilights and of the method of N.B.Divari (1970,1972) of solving the research problem of the twilights' allows the reliable determination of the optical characteristics of the atmospheric aerosol in twilight probing of the Earth's atmosphere.

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RIGHT ASCENSIONS OF 200 DOUBLE STARS

M.Yu.VOLYANSKAYA

Abstract. This catalogue contains the results of observations of 200 double stars made at Odessa with the Repsold transit circle. The mean epoch of observations is 1986.25, the coordinates are reduced to equinox 2000.0 without taking into account the proper motions. The mean error of catalogue position of R.A. is 0.010^s. The catalogue corresponds to the FK5 system of stellar places.
Key Words: Astrometry: Catalogue, positional observations, meridian circle.

In the present work the right ascensions are given for 200 double stars (DS) observed with the Odessa meridian circle during the period 1985-1988. The meridian circle was also used for observing RRS1 and HLS stars at this time.

The Resolution No.17b adopted at the X-th IAU General Assembly recommends the meridian observations of the double stars unsuitable for photographic observations. Most of the stars from the DS program were not included in the AGK3 and other photographic catalogues. There is also a very little number of visual observations too. However, investigation of DS' proper motions is important for stellar astronomy, thus the above mentioned recommendation remains valid.

The working list was compiled at the Pulkovo observatory by M.S.Zverev (1960). It was improved and extended by F.P.Scott (1967). Our observational list contains 200 double stars for the zone from 0^o to -10^o in declination. For each DS only the brighter component or a preceeding one in R.A. is to be observed. The observations were started in April 1985 and finished in May 1988. The total number of observational nights is 98. The author has made about 2600 observations of right ascensions by using a differential method. Specific difficulties of observations of double stars with the meridian circle should be noted, particularly of those optically close. In connection with this and due to irregular distribution of the program stars in the sky, we have observed a large number of reference stars. Approximately 70% of all the observations are attributed to reference stars selected from "Apparent places of fundamental stars" (1984-1988).

The observations were carried out with the meridian Repsold circle (D=135 mm, F=198cm, magn.200, d of circles=980mm) described by V.V.Konin (1953), B.V.Novopashenny (1959), M.Yu.Volyanskaia et al.(1984). Adopted position of the instrument:

Longitude	2^h 3^m 02.3^s E,
Astronomical latitude	46^o 28' 37.4" N,
Height	55 meters above sea level.

The observations were mainly made following the "Instruction for observations of Faint Stars" (1954). The observations were made with help of a hand-driven impersonal micrometer. The star was bisected all the time of observation (6 central screw rotations). The visual brightness of bright stars was decreased to 7.5-8 magnitude by using a reduction screen mounted in front of the tube objective. Meridian transit of a star is registered with an electron system designed and constructed by I.I.Genovsky (1984) in the Astronomical observatory of the Odessa State University. The system modification was performed simultaneously with observations, thus somewhat complicating and hindering the observations run. During the observations the readings of thermometer were registered each 30 minutes, and those of a barometer-aneroid each hour. Before the observations according to the given program, the author together with A.P.Chelombitko made an examination of pivot errors with contact methods. Pivots had been recently regrinded. It gave no evidence of the existence of any significant errors in the figure of the pivots. No pivot-error corrections have been applied in the compiling of this catalogue. We used the Bessel's expression for calculating R.A. from the observations. In reduction of observations of right ascensions the value of one screw rotation of an ocular micrometer was determined from observations and adopted to be equal to 3.350^s. Periodically the zero contact value was determined which was used in collimation calculation. The error of collimation was measured with the aid of horizontal collimating telescopes locating outside the pavilion. The OAO meridian circle observations have shown that the collimation value is stable for many years and changes slowly. Therefore we determined collimation, constructed a plot of its variations with time, and took the collimation readings for each observation evening from this plot. The azimuth's error-"n" value was determined from all pairs of reference stars close in time with a large declination difference. Since the night observing time in this programe did not exceed 3 hours, we could frequently use 'n-average'. During these time intervals no major alternations were made to the instrument.

The list of the corrections have been applied in right ascensions:

R.A. Micrometer Reading of standard contact: from regular determinations.

Line of Collimation: from collimators.

Diurnal Abberation: computed. Applied as additional collimation correction.

Azimuth Error: from observations of reference stars.

The following corrections were the subject for investigations, and some of the results will be reported later. The corrections are not included in the reported catalogue places. Corrections investigated but not applied:

Personal equation in observation of stellar transits.

Annual variation in correction to collimation.

Corrections assumed to be negligible: Pivot errors.

Apparent place was computed for each star observed by using a modification of the computer code elaborated by Dr. E.V.Chrutskaia (Pulkovo). The probable error of one observation was found to be 0.019^s on average for the zone. In general there are four observations per star, so that the accidental probable error of a catalogue position may be estimated at 0.010^s.

Catalogue positions. - The catalogue positions were obtained by adding the mean (O-C) calculated for the star to the 2000.0 position used to compute the apparent place. The positions are for the epoch of observations.

The catalogue is on the FK5 system of stellar places.

Acknowledgement. I'm thankful to E.V.Chrutskaia(Pulkovo) and N.V.Bazej for their help in computations.

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Description of Catalogue.

Column 1 Serial number
2 DS number
3 DM number
4 Magnitude of each component or total
5 Right Ascension
6 Declination
7 Epoch of Observation (1900+) for R.A.
8 Number of observations in R.A.

Because of technical reasons the Catalogue will be published in the next issue.

ODESSA ASTRONOMICAL PUBLICATIONS

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