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PREFACE

The Symposium "Variable Phenomena in Close Binary Stars" was held in Budapest, Hungary, between 7 and 10 March 1988 at Konkoly Observatory, as part of the biennial conference series of the multilateral cooperation "Stellar Physics and Evolution" subproject "Binary Stars".

Binary systems represent one of the most interesting, exciting and puzzling objects in modern astrophysics. In particular, interacting binaries have become very important in recent years. Very many phenomena to be explained in connection with dwarf novae, novae, Wolf-Rayet stars, symbiotic stars, etc. need the assumption of interactions between binary star components. Over the past decades the concept of mass exchange and mass loss has become one of the most fruitful ideas in astronomy.

Besides these very fruitful theoretical developments we can recognize enormous progress in observational methods too. Unfortunately not all of these new techniques are available to us. Nevertheless, especially in X-ray astronomy, in the extension of classical photometry to longer wavelengths and in high time-resolution photometry our development is significant. In recent years we have also seen some progress in computer technique both with regard to observations and to the reduction of data.

We now present the proceedings of the conference. I should like to thank all those who assisted in organizing the conference and in producing this volume. Finally our thanks go to the Hungarian Academy of Sciences for their financial support of the conference.

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THE ACCRETION DISC IN OY Car DURING RISE TO OUTBURST

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The eclipsing binary OY Carinae with the orbital period of 91 minutes belongs to the class of ultra-short period dwarf novae of SU UMa type. The eclipses of the accretion disc permit one to determine its dimensions and surface brightness distribution. The observations of OY Car obtained by *Vogt (1983)* were used. These unique observations contain two highly symmetric eclipses recorded during rise to a normal outburst (E=2) and shortly after maximum light was reached (E=15). These two eclipses differ strongly in their shapes. This is connected with the changes of disc brightness distribution at the beginning of an outburst. The highly symmetric eclipses indicate that the surface brightness distribution of the disc is axisymmetric, so we can describe it by a simple function f(r). Other unknown parameters are the disc's outer radius r_d and the fractional luminosity of the white dwarf l_1. The principal geometric parameters, namely the mass ratio q, the inclination angle i and the radius of the white dwarf r_1 are also unknown. To perform the solution of the two eclipses a new numerical code, described in detail in a previous paper *(Wlodarczyk 1986)*, was used.

This code - applicable to the case of symmetric eclipses - is based on the conventional model of dwarf novae, containing a Roche lobe filling cool star and a mass-gaining white dwarf, surrounded by an accretion disc. The disc is stretched in the orbital plane from r_1 to r_d. In the simplest model (d_1) the disc is assumed to be flat with the thickness h=0. We first estimate the geometric parameters q and i. To do this the second eclipse (E=15) was analysed and the distribution of σ (q,i) was found, where σ is the mean square deviation from observations. The function σ (q,i) presented in Fig. 1 has two minima but only one of them lies on the line i(q) established for OY Car by *Cook (1985)*. We adopt the values of q and i corre-

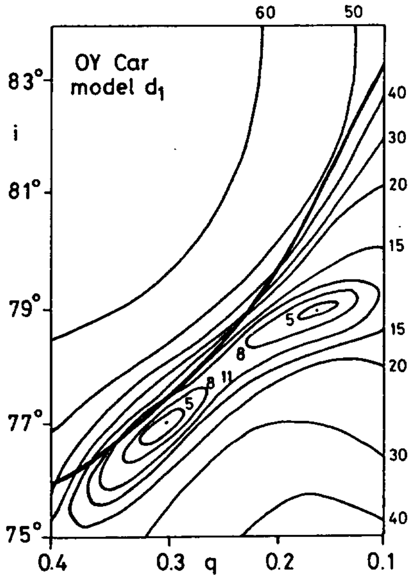

Figure 1.

sponding to this minimum ($q=0.30$, $i=76\overset{\circ}{.}9$). Such parameters are very close to those inferred by *Bailey and Ward (1981)*.

For our value of q the relation $r_1(q)$ *(Cook 1985)* gives $r_1=0.013$. The further calculations were made in two steps. The final solution of the two eclipses is presented in Fig. 2. It is clearly seen that during rise to a normal outburst ($E=2$) the outer parts of the accretion disc became the dominant source of light in the system. Such photometric behaviour is consistent with the model of dwarf nova eruption presented by *Smak (1984)* in case A. Shortly after maximum the distribution $f(r)$ roughly resembles that known from the stationary accretion disc model but could not be interpreted as a model with a constant accretion rate $\dot{m}$. A more detailed analysis of OY Car is due to be published in Acta Astronomica. This work was supported in part by the Polish Academy of Sciences (grant CPBP - 01.11).

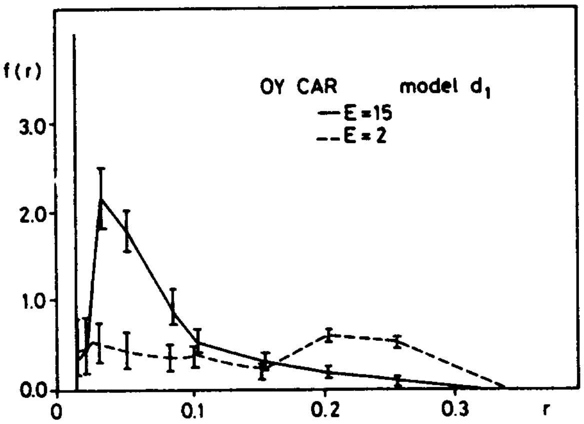

Figure 2.

References:

Bailey, J., Ward, M., 1981, M.N.R.A.S., 194, 17P.

Cook, M.C., 1985, M.N.R.A.S., 215, 211.

Smak, J., 1984, P.A.S.P., 96, 5.

Vogt, N., 1983, Astron. Astroph., 128, 29.

Wlodarczyk, K. 1986, Acta Astron., 36, 395.

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DIP FEATURES IN THE LIGHT CURVE OF TT ARIETIS

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Information on dip features in the optical light curve of TT Arietis, observed both in optical and X-ray wavelengths, is presented. These features are probably related to mass exchange in the system. A coordinated program for detailed observations and analysis of light drops is proposed to better understand the nature of the source.

TT Ari is thought to be an accreting (magnetic?) white dwarf in a close low-mass "nova-like" binary, the orbital period of which amounts to about 3.3 hours. In 1985, a complex coordinated observation program was run in the Intercosmos cooperation involving ground-based instruments as well as the EXOSAT X-ray satellite *(Wenzel et al., 1986, Hudec et al.,1987)*.

TT Ari AS DIPPING SOURCE

The existence of narrow X-ray and related optical drops in the orbital light-curve of TT Arietis was first mentioned by *Jensen et al. (1983)* as a result of coordinated X-ray (Einstein) and optical observations. The observed wavelength-dependence of the decrease in X-rays has indicated that photoelectric absorption was probably responsible for the observed decrease. However, only one such event was detected.

More details were obtained during the coordinated program of EXOSAT X-ray and optical observations in 1985 *(Wenzel et al. 1986 and Hudec et al. 1987)*. Two well pronounced X-ray drops were revealed within the 11^h monitoring interval. For one of the dips simultaneous optical data were obtained showing an analogous feature. Similar dips were also revealed in some parts of the additional optical data (e.g. *Rössiger, 1987, Kraicheva et al. 1987)*.

Until now, more than 10 well pronounced dips have been revealed at optical wavelengths with typical durations between 1 and 10 minutes and amplitudes between >0.3 and ~ 2 mag. In X-rays, 3 well pronounced dips have been observed lasting ~ 15 min. and representing more than 90% decrease of the total X-ray flux of the source. Thus the central X-ray source in the system was almost fully obscured during these intervals. The reality of the presence of these narrow absorption features seen both in X-rays and optical light is now supported by the detection of more than 10 such events and also by the simultaneous detecting of dips in both spectral ranges. The duration of X-ray dips is longer than that of those simultaneously observed in the optical region (Einstein satellite X-ray/optical: 17/7 min EXOSAT: 15/8 min.). Analysis of the X-ray light curve based on EXOSAT observations has revealed a possible dip recurrence period of $3^h\ 33^m$, however, the third dip is less pronounced. No dip recurrence could be found in the Einstein X-ray data because of many gaps in the data set.

In the optical region, the dips seem to occur randomly with no clear relation to the phase of photometric or spectroscopic period. Some of the decreases exhibit double, triple or even more complex nature.

The dips are probably caused by photoelectric light absorption of the main light source in the TT Ari system (disc component) by structures related to mass exchange in the system. The second light source in the system (the secondary star component) is relatively faint, below 16.5 mag. in B. This upper limit was derived from faintness of the whole system during the very low state (superminimum) observed before 1985 when accretion probably stopped. Thus the strong drops exceeding 1 mag. may also be caused by this.

Need of more data

Although the reality of dips in the curve of TT Ari seems to be proved, more observational data are needed for a better understanding of this phenomenon. We thus suggest that another stage of coordinated ground-based optical observations of TT Ari be carried out in the near future, e.g. during the observing seasons Summer/Autumn 1988 or 1989. The second main aim of this program should be a more detailed monitoring of changes between the different shapes of orbital light curves of TT Ari as mentioned by *Wenzel et al. (1986)*.

References:

Hudec, R., et al.: 1987, Astrophys. Space Science 130, 255.

Jensen, K.A., Cordova, F.A., Middledith, J., Mason, K.O., Grauer, A.D., Horne, K., Gomer, R.: 1983, Ap. J. 270, 211.

Kraicheva, Z., Antov, A. and Genkov, V.: 1987, Inf. Bull. Var. Stars No. 3093.

Roessiger, S.: 1987, Inf. Bull. Var. Stars No. 3007.

Wenzel et. al.: 1986, Astr. Inst. of the Czechosl. Acad. Sci. Preprint 38 p:1-44.

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PHOTOMETRIC BEHAVIOR OF THE X-RAY SOURCE TT ARIETIS DURING 1985 - 1986

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The belonging of TT Arietis to VY Scl objects included in our investigation programme, prompted us to initiate observations of this system in August 1985 when the extended programme of coordinated X-ray and optical observations of TT Arietis began. During the past three seasons, besides estimates of the brightness of the star in the standard UBV system, the behavior of the object for 3 hours during the night of August 22/23 1985 was followed and seven observational runs were carried out in the "u" region for the period 1986-1987. The observations were performed using a photoelectric photometer attached to the 60 cm Cassegrain telescope of the National Astronomical Observatory employing a photon counting technique. Star "c" *(see Wenzel et al. 1986)* served as the comparison star. For transformation of the instrumental u,b,v stellar magnitudes to the standard UBV magnitudes during 1987 the relations

$$\Delta V = \Delta v + 0.1 \ \Delta (B-V)$$

$$\Delta (B-V) = 0.89 \ \Delta (b-v) + 0.034 \ \Delta (b-v) \ \bar{X}$$

$$\Delta (U-B) = 0.89 \ \Delta (u-b) + 0.062 \ \Delta (u-b) \ \bar{X}$$

were used. The integration time was 10 sec. The results of these observations are the following:

1. During all the nights of the observations TT Ari was near maximum

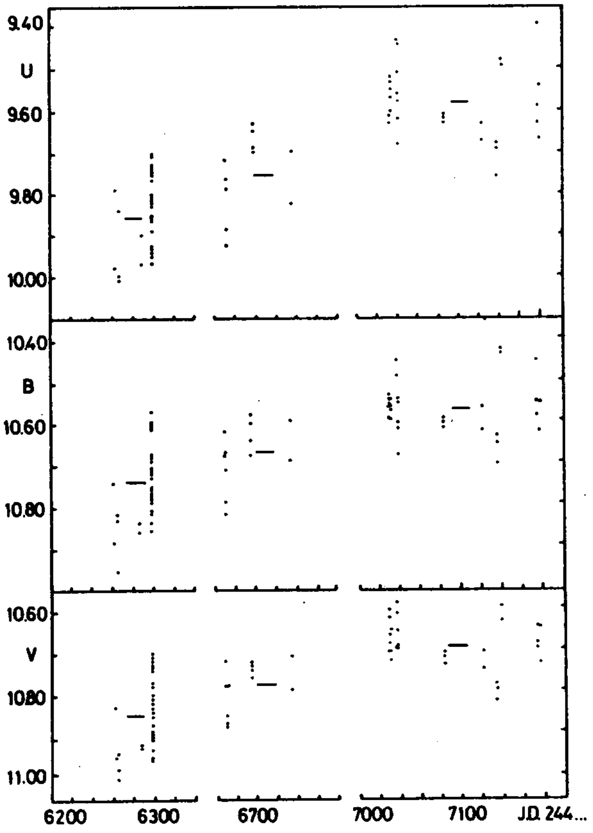

Figure 1.

light: this may be seen from Fig. 1. where all our estimates of the brightness of the star are plotted. From this figure it is seen too, that the brightness of the star fluctuates around an increased maximum mean value from 1985 to 1987. The mean of the resulting points yields the following magnitudes for TT Ari in 1985: V = 10.85, B = 10.75, U = 9.86. For 1987 the mean magnitudes are V = 10.69, B = 10.57, U = 9.58. An increase of average brightness in 1987 by 0.16 mag in V, 0.18 mag in B and 0.28 mag in U in comparison to 1985 can be suspected. The difference from average UBV magnitudes for 1985 given in a previous paper *(Kraicheva et al. 1987)* and this present paper is due to the inclusion of an additional 24 estimates of brightness from 22/23. 08. 1985. In our opinion this gives a clearer idea for the interval of variations of the brightness.

Table 1.

Magnitude estimates of TT Arietis during 1987

J.D. 244...	V	B-V	U-B
7032.4803	10.70 ±0.01	-0.14 ±0.02	-0.99 ±0.01
.4908	10.68 ±0.01	-0.09 ±0.01	-0.96 ±0.01
.5024	10.60 ±0.02	-0.04 ±0.02	-0.95 ±0.01
.5181	10.62 ±0.01	-0.09 ±0.02	-1.00 ±0.02
7033.4502	10.66 ±0.02	-0.12 ±0.03	-0.99 ±0.01
.5786	10.70 ±0.01	-0.11 ±0.01	-0.99 ±0.02
.5852	10.72 ±0.01	-0.15 ±0.02	-1.05 ±0.01
.5887	10.65 ±0.01	-0.09 ±0.01	-0.99 ±0.01
7039.4425	10.58 ±0.01	-0.13 ±0.01	-1.02 ±0.01
.5610	10.61 ±0.01	-0.12 ±0.02	-0.98 ±0.03
.5664	10.69 ±0.02	-0.14 ±0.03	-0.99 ±0.02
7040.3920	10.65 ±0.01	-0.11 ±0.02	-1.10 ±0.05
.5470	10.79 ±0.01	-0.11 ±0.01	-1.00 ±0.01
.5549	10.69 ±0.01	-0.08 ±0.02	-0.99 ±0.01
.5608	10.69 +0.01	-0.09 ±0.02	-1.03 ±0.01
7085.4282	10.71 ±0.02	-0.12 ±0.02	-0.96 ±0.02
.4339	10.73 ±0.02	-0.11 ±0.02	-1.00 ±0.02
.4394	10.71 ±0.01	-0.12 ±0.02	-0.98 ±0.02
7123.3657	10.74 ±0.02	-0.12 ±0.02	-0.99 ±0.03
.3706	10.70 ±0.01	-0.14 ±0.01	-0.89 ±0.03
7137.2016	10.78 ±0.01	-0.16 ±0.02	-0.94 ±0.01
.2071	10.82 ±0.01	-0.12 ±0.01	-0.94 ±0.01
.2123	10.79 ±0.01	-0.16 ±0.01	-0.95 ±0.01
7142.3450	10.59 ±0.01	-0.17 ±0.02	-0.95 ±0.02
.3497	10.63 ±0.01	-0.20 ±0.02	-0.94 ±0.04
7177.2586	10.68 ±0.01	-0.13 ±0.01	-0.96 ±0.02
.2662	10.64 ±0.02	-0.19 ±0.03	-1.06 ±0.01
.2726	10.69 ±0.02	-0.11 ±0.02	-0.95 ±0.01
7179.2072	10.64 ±0.01	-0.09 ±0.02	-1.01 ±0.02
.2131	10.73 ±0.01	-0.11 ±0.01	-0.95 ±0.02

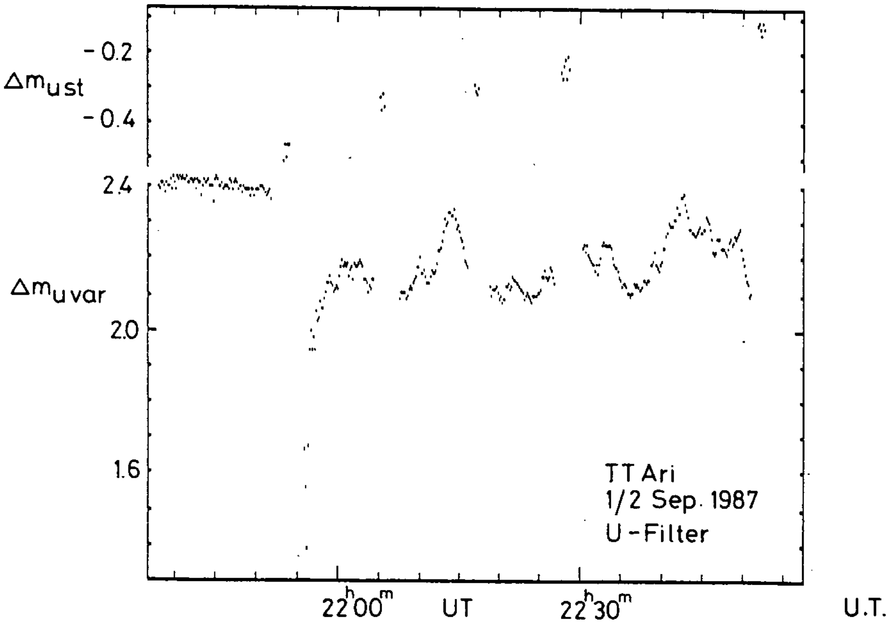

Figure 2.

2. The colour indexes on the individual nights during these 3 observing seasons were in the intervals -0.04 to -0.2 for (B-V) and -0.84 to -1.0 for (U-B), but in 1987 a few (U-B) values exceeding -1.0 were observed (Table 1 in *Kraicheva et al. 1987* and Table 1 in this paper).

3. The three-colour measurements from August 22/23 1985 show a well-expressed maximum. The start and the end of the observations are in the neighborhood of brightness minima (Figure 1 in *Kraicheva et al. 1987*). The wave shaped variations are 0.25 mag in V and 0.32 mag in B and U. This is in agreement with the results of coordinated observations *(see Hudec et al. 1987)*.

4. The observing run during the night of November 2/3 1986, besides rapid variations with an amplitude up to 0.25 mag, showed an unusually deep dip in the brightness ($\Delta u \sim 2.3$ mag) of about 10 minutes long. Seven minutes later a new dip of the of the brightness with an amplitude up to 0.8 mag and a duration of about 10 minutes occurred (see Kraicheva et al.1987). One of the purposes of our observations during 1987 was to test the reality of these "anti flares". Details concerning the observations can be found in Table 2.

TABLE 2   Observing runs of TT Arietis during 1986 - 1987

Date	Start time	Length	Integration time	A max	t
	(UT)		(s)	(mag)	(min)
1986 Nov 2	$21^h\ 31^m$	$1^h\ 00^m$	10	0.28	3
1987 Aug 25	23 30	2 05	10	0.25	5
1987 Aug 31	23 10	1 50	10	0.30	5
1987 Sep 1	21 55	2 50	10	0.28	7
1987 Dec 7	21 15	1 20	10	0.25	3
1987 Dec 12	20 35	1 15	10	0.45	6
1988 Jan 18	17 35	2 25	10	0.32	5

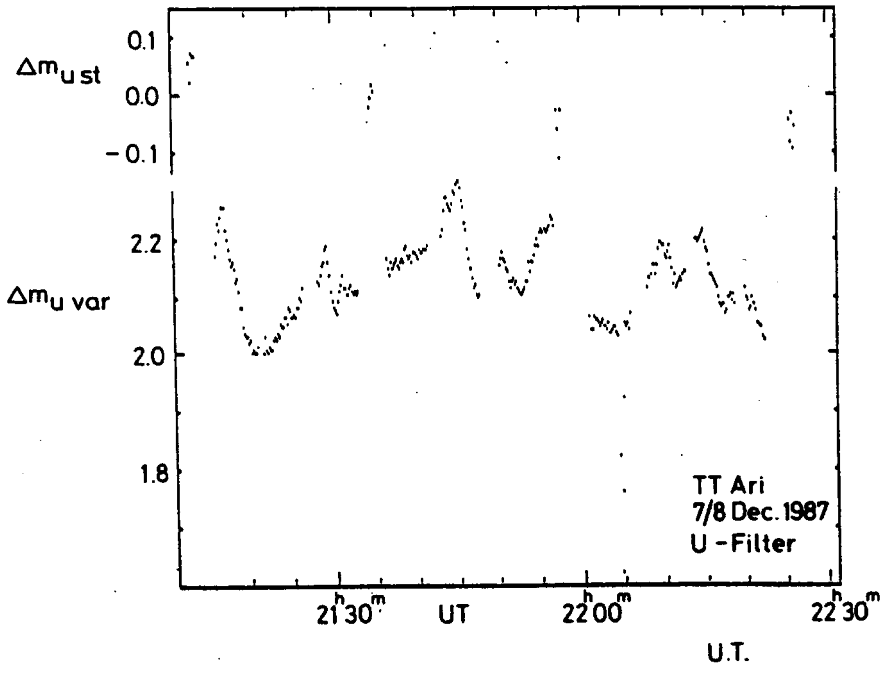

Figure 3.

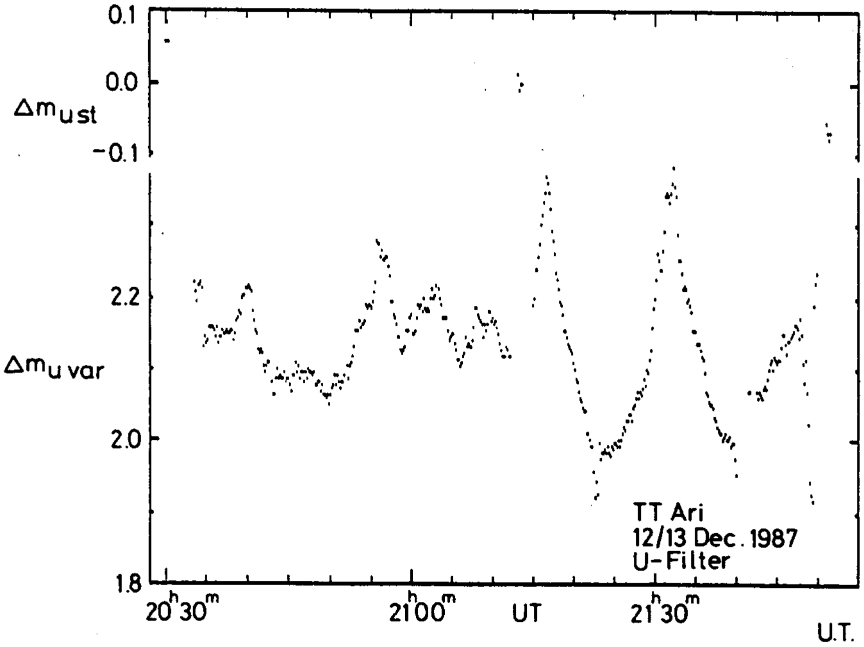

Figure 4.

Generally for the six 1987 nights the star was observed for 11^h 40^m. For this time only twice did we observe a decrease of brightness larger than 0.4 mag. The observations during the night of Sep 1/2 1987 began with a dip in the brightness up to 0.8 mag, that can be seen in Fig. 2 where a portion of the light curve of TT Ari on this night is shown. The star reached the maximum light for 3 - 4 minutes. The second dip of the brightness, with an amplitude 0.6 mag, was observed during the night of December 7/8 1987 (Fig. 3). For the first 6 - 7 minutes the star decreased in brightness by 0.2 mag and in the following 2 minutes it decreased further by 0.4 mag. For the next 3 minutes the star reached the maximum light again. *Rössiger (1987)* also observed a deep dip in brightness up to 0.9 mag in the "b" region.

5. All our observing runs during 1987 show rapid variations of the brightness with maximum amplitude for separate runs from 0.25 to 0.45 mag. Figure 4 shows the run on December 12. During this night the maximum amplitude reached 0.45 mag. The maximum amplitudes for the other runs are given in column 5 of Table 2. In column 6 of the same table the time scales of those changes are presented. It can be seen that the brightness

of the star varies by several tenths of the magnitude for time scales of 3 - 7 minutes.

References:

Hudec, R., et al. 1987, Astrophys. Sp. Sci., 130, 255.

Kraicheva, Z., Antov, A., Genkov, V., 1987, I.B.V.S. No. 3093.

Rössiger, S., 1987, I.B.V.S. No.3007.

Wenzel, W., et al. 1986, Astron. Inst. of the Czechosl. Acad. of Sci. Preprint 38, p.:1 - 44.

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NEW STATISTICS ON DWARF NOVAE

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By processing the data of the 4th edition of *Ritter's (1987)* Catalogue of Cataclysmic Binaries... (and a few additional items of information) I rederived some statistical relations. Let P be the orbital period: M_2 and R_2, secondary mass and radius: and C, the cycle length.

Owing the Roche conditions, P is closely connected with R_2, and the rather well defined log P - M_2 curve (Fig. 1) shows that the secondary component comes very near to the mass-radius relation of the main sequence stars. The white dwarf's masses affect this relation only slightly. The deviations occurring with GK Per (and perhaps AE Aqr and BV Cen) indicate that their secondaries are in a process of evolution.

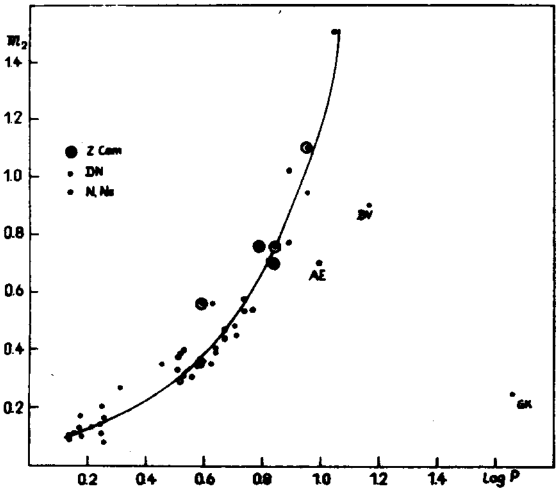

Figure 1.

Much less pronounced however is the Kukarkin-Parenago relation, which using only the Ritter data, turns out to have the form of

$$A = 0.5 + 1.85 \log C$$

(see Fig. 2 top). The large dispersion of the dots cannot simply be put down to the inaccuracy of A and C. In point of fact, it is interesting to observe that the dots lying below the regression line mainly correspond to either large or small values of P, while those lying above the line correspond to values of P that are near the much discussed period gap between about 2^h and 3^h. In a word, we are being confronted with an A - log P - log C relation. Thorough analysis led, by means of linear regression and neglecting EX Hya, to these results (Fig. 2 bottom):

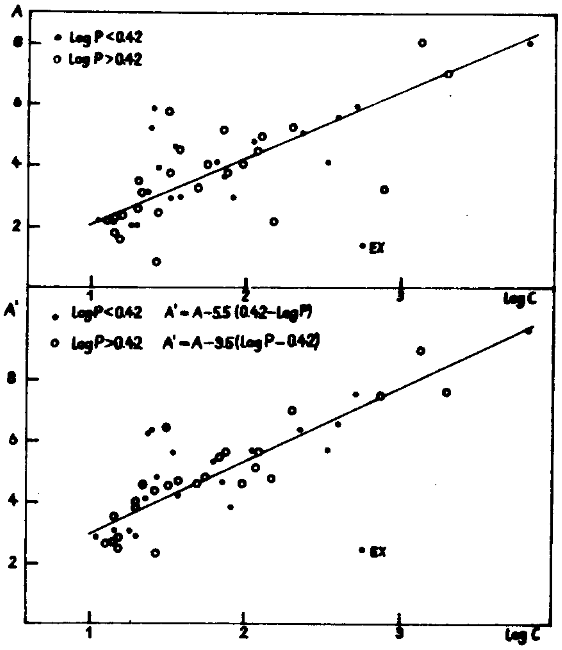

Figure 2.

$$A = -1.4 + 5.5 \log P + 2.25 \log C \qquad (P \leq 2^h)$$

$$A = 2.4 - 3.5 \log P + 2.25 \log C \qquad (P \geq 3^h)$$

By plotting log P against log C and taking the brightness amplitude A as the parameter the correlations become even more obvious (Fig. 3). It

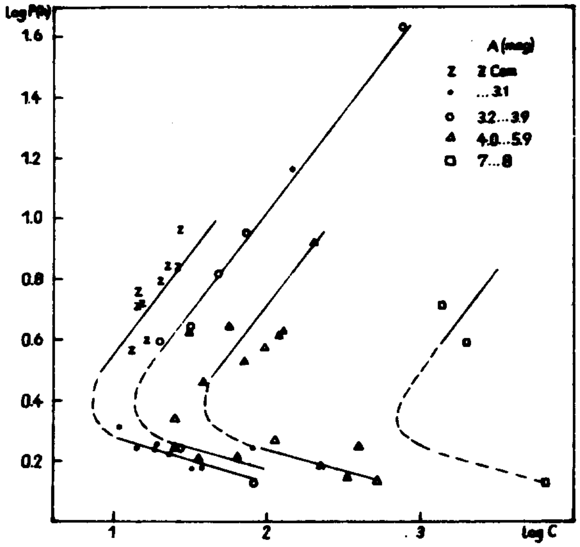

Figure 3.

is remarkable that for each A interval, C has a minimum near the period gap. (The dotted lines through the period gap are drawn only for clarity's sake). The results can be represented in the following form (Fig. 4.):

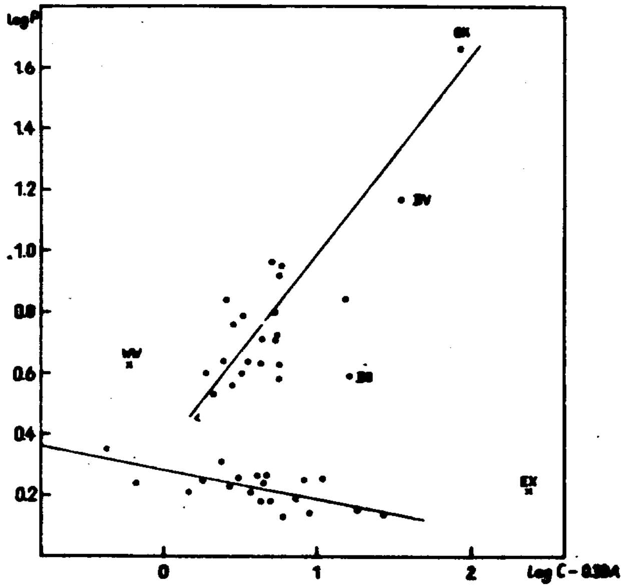

Figure 4.

$$\log P = 0.28 - 0.10\,(\log C - 0.30\,A) \qquad (P \leq 2^h)$$

$$\log P = 0.35 + 0.64\,(\log C - 0.30\,A) \qquad (P \geq 3^h)$$

EX Hya largely deviates from this relation. It is an extreme intermediate polar, surely having a disturbed accretion disk. Figure 3 shows that for fixed P, there are objects of very different values of A and C. They differ in their mass transfer rates, $\dot{m}$, a factor of more than 100. This effect was already discussed in detail by *Patterson (1984)*. The point is: What is the reason for objects of similar physical and geometrical properties differing so largely in $\dot{m}$? Perhaps this phenomenon is due to the varied efficiency of magnetic braking - or the objects are living in different states of the "hibernation cycle" of novae (if the hibernation theory is taken to be correct, see for example *Shara et al. (1986)*. Another question is: Why do objects of the same amplitude show a minimum of the cycle length near the period gap? The answer depends on the position you argue from. According to the disk instability hypothesis of dwarf nova eruptions, near the accretion disc must have a minimum in its capability for storing matter. According to the fluctuating mass transfer hypothesis, however, the secondary in systems near the period gap must become dynamically unstable in shorter intervals, but smaller in quantity. One day, perhaps, a theoretical interpretation of our findings will help to decide which of the two hypotheses is in accordance with fact, and which is the real cause for the existence of the period gap.

References:

Patterson, J., 1984, Astrophys. J. Suppl. Ser. 54, 443.

Ritter, H., (1987) Astron. Astrophys. Suppl. Ser. 70, No. 3, 335.

Shara, M.M., Livio, M., Moffat, A.F.J., Orio, M., 1986, Astrophys J. 311, 163.

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ON THE ECLIPSES OF WHITE DWARFS IN DWARF NOVAE

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There are three ultra-short period dwarf novae - HT Cas, OY Car and Z Cha - in which the wite dwarf is totally eclipsed. This effect is clearly seen only during quiescence when the fractional luminosity of the white dwarf is biggest. Unfortunately, the total occultation of the white dwarf is superimposed on the eclipses of an accretion disc with a bright spot. Consequently, it is very difficult to reconstruct and to select the detailed shape of the eclipse of the primary star. The eclipse of the white dwarf contains information on the nature of the central object at the accretion disc. Due to disc accretion we might expect that the central star has a bright equatorial zone. Such a white dwarf was found in Z Cha by Smak in 1986. In general, the central object could be the typical white dwarf or a white dwarf with its lower hemisphere occulted by an optically thick disc. It could also be a white dwarf surrounded by a boundary layer or it could be a star with bright polar caps due to a strong magnetic field. A combination of these cases could also be considered.

In this paper theoretical eclipse profiles and their derivatives are calculated for the following different configurations of the central object (Fig. 1):

a_1) a white dwarf with the limb darkening coefficient $x = 0$

a_2) a white dwarf as above but its lower hemisphere is occulted by a dark disc

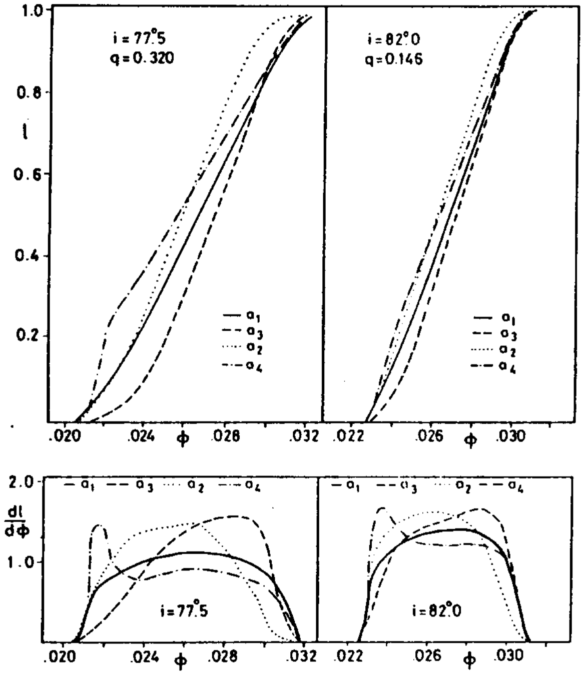

Figure 1.

a_3) a white dwarf with a bright equatorial boundary layer: in this case the surface brightness distribution was adopted in the form $I \sim \cos^n \Theta$ where Θ is the latitude measured from the equator of the white dwarf, and the width of the bright belt is then defined by the exponent n

a_4) a white dwarf with bright polar caps: in this case $I \sim \sin^n \Theta$

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STARLIGHT RE-EMISSION AND SCATTERING BY A PRECESSING ACCRETION DISC RELEVANT TO THE PARAMETERS OF THE Cyg X-1 = V1357 Cyg X-RAY BINARY

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Photometric and polarimetric variations resulting from re-emission and scattering starlight by an oblique precessing accretion disc are considered. From analysis of observational data of Cyg X-1 it follows that the disc is optically thick and precesses towards orbital motion. The scattering is not important ($\leq 10\%$ in B band) for intensity variations but it produces some polarimetric effects. The disc radius is $r_d = 0.12-0.15$ a (where a is the distance between the component centres-of-mass), i.e. the disc fills as little as 40-50% of the entire Roche lobe. The precession angle is $j = 15^\circ-20^\circ$, the system inclination angle $i = 55^\circ-65^\circ$. The direct disc precession is probably due to the moment of the forces transferred to the disc by the gas stream outflowing from the star.

The optical components of high-mass X-ray binaries are high-luminosity hot stars. In the case of moderate or low X-ray luminosity of such a system, the re-emission and scattering of the optical-component light by the accretion disc form the main mechanism of disc radiation. According to the present-day concepts, the disc may either lie in the binary-system plane or be oblique and processing. In many cases, the long-term variability found or suspected in numerous X-ray binaries *(Priedhorsky, 1987)* is probably due to disc precession. In particular, the long-term photometric and polarimetric variability of Cyg X-1 may well be explained in terms of such a model *(Karitskaya, 1979, Kemp et al., 1983, 1987).*

In the case of precessing discs tilted out of the orbital plane, reemitting and scattering the light of the second component, the character of the variations in the radiation field parameters (the intensity I, the Stokes parameters Q and U describing the linear polarization) is defined first of all by the variations of the disc illumination by the star *(Karitskaya 1981a,b)* which varies with both the orbital phase Φ and with precession phase δ, more accurately, with $\varphi=\Phi+\delta$. The "-" sign means that the precession is in the direction of the orbital motion, the "+" sign corresponding to the reverse direction. Moreover, the conditions vary for the disc visibility which is a function of δ. Thus, the Stokes parameters $I(\Phi)$ $Q(\Phi)$ and $U(\Phi)$ are strong functions of the angle j of disc inclination to the binary-system plane and of the precession phase δ.

The intensity and the linear polarization of star radiation scattered by a precessing accretion disc have been calculated by *Karitskaya (1981a, b)* and *Bochkarev and Karitskaya (1988a)*. In the case of pure electron scattering the linear polarization variation amplitude may reach 3% and the intensity and the polarization vary both with the precession phase δ and with the orbital phase Φ of a binary system due to changes in the mutual position of the scattering disc, the star and the observer's line of sight. Contrary to the case of discs in the orbital plane, at $j \neq 0$, the third and higher harmonics appear in the Fourier spectra of I, Q and U.

The accretion discs atmospheres are not pure electron scattering. The true absorption is of great importance in them. Therefore, the field parameters of the emission scattered by the disc and their dependence on phase Φ are determined by the single-scattering albedo

$$\Omega = \varkappa_s / (\varkappa_s + \varkappa_a) \qquad (1)$$

where $\varkappa_s$ and $\varkappa_a$ are respectively the coefficients of scattering and true absorption. The single-scattering albedo Ω is generally a function of depth in the disc atmosphere and of coordinates on the disc surface. Any detailed models for accretion disc atmospheres have not been constructed yet, so the dependences are unknown. Therefore, we limited ourselves to calculating the field of disc-scattered radiation in terms of the approximation Ω = const. *(Bochkarev and Karitskaya 1988a)*. In the case of starlight scattering by disc the intensity I is a strong function of Ω at $0.7 \leq \Omega$ and varies at $\Omega \leq 0.7$ a bit more rapidly than according to the Ω^1 law. The dependence of the Stokes parameters Q and U on Ω is slightly stronger than in accordance with the linear law. The dependences of I, Q, U on the phases Φ and $\delta$and on the angle j remain, generally, the same as for $\Omega = 1$.

The first candidate for black holes, the high-mass X-ray binary Cyg X-1, has been studied in great detail both photometrically *(Kemp et al. 1987)* and polarimetrically *(Kemp 1980a, 1984)*. The linear polarization of the emission from Cyg X-1 varies by 0.25%. The second harmonic of orbital period $P_o = 5^d\!.6$ is fundamental with full variation $2A_2 = 0.18\%$ (A is amplitude). Furthermore, the first $(A_1 = 0.02\%)$ and higher (up to fifth) harmonics of P_o are observed to be much weaker *(Kemp 1980a)*. In addition, there are variations with period $P_p = 294^d$ *(Kemp et al. 1983)*.

The optical component is the main source of accretion disc heating in Cyg X-1 *(Karitskaya, 1981a)* In this case the disc surface temperature is 12000 K. The contribution of the intrinsic emission of such a disc to the system brightness does not exceed 3% *(Bruevich et al., 1978, Karitskaya 1981a)*. According to *Bochkarev and Karitskaya (1983)*, the variable polarization component of the intrinsic emission from a precessing disc inclined at $j \sim 10^o$ does not exceed 1% of the emission from the disc. Therefore, the contribution of this mechanism to the Cyg X-1 polarization variability is $\leq 0.03\%$. The intrinsic polarization of the emission from the Cyg X-1 optical component due to its tidal distortion is expected to be $\leq 0.025\%$ *(Bochkarev et al. 1985)*.

Now consider the polarization variability due to starlight scattering by the disc of Cyg X-1. The surface-normal component of gravitational acceleration g corresponds to $\log g = 1.5 - 2$. Thus, according to *Bochkarev et al.(1985)*, we get $\Omega = 0.4$ at $T = 12000$ K. In this case at the angle $i = 45^o \pm 20^o$ expected for Cyg X-1 *(Bochkarev et al. 1975)*, even a disc in the orbital plane which fills the Roche lobe $(r_d = 0.3a)$ may give rise to 0.25% polarization variability *(Bochkarev, Karitskaya, 1988a)*. The disc inclination to the orbital plane will lead to a larger amplitude of polarization variability.

However the observed ratio between the first and the second harmonics of polarization variability contradicts the considered mechanism. As shown by *Karitskaya (1981a)*, amplitude A_2 of the second harmonic P_o of the oblique disc polarization is in practice independent of the angle j up to $j = 20\text{-}30^o$. At $\Omega = 0.4$ and $r_d = 0.3a$, we get $A_2 = 0.11\%$ which is close to the observed value of 0.09%. However, the polarization of radiation from the disc comprises a strong first harmonic A_1 which rises with j, namely,

$0.8\ A_2 \leq A_1$ at $0 \leq j$. The observed A_1/A_2 ratio is 0.2 *(Kemp 1980a, 1984)*. In the absence of an additional polarization source compensating for the variations with A_1, the scattering of the emission from the star by the accretion disc accounts for not more than 25% of the polarization observed in Cyg X-1. Besides, the dependence of A_2 on the δ phase found by *Kemp (1984)* (the A_2 value reaches its maxima at $\delta = 0.25$ and 0.75) does not fit the oblique precessing disc for which the A_2 value is peaking at $\delta = 0$. It may be concluded from the dependence $A_2(\delta)$ that, probably, less than half of the A_2 value is due to the precessing accretion disc.

The high A_2/A_1 value most probably means that the main contribution to the variable polarization of the emission from Cyg X-1 is from the optically thin gas located asymmetrically with respect to the optical star. In confirmity with the assumptions made by *Kemp (1980b)* the variable polarization may be related to the hot spot at the accretion disc rim.

Thus, the above analysis shows that the starlight scattering by the disc is not the main mechanism of polarimetric variability of Cyg X-1. The contribution of the mechanism to the observed polarization variability does not seem to exceed 25-50%. From this, concerning the Ω value of ~ 0.4 expected for the disc, it follows that the accretion disc dimension does not exceed 0.2a, that is 60% of the X-ray source Roche lobe dimension.

Now let us examine the radiation intensity of an oblique precessing disc re-emitting the optical-component light as applied to Cyg X-1. As in the case of starlight scattering, the oblique processing accretion disc gives rise to photometric variability with precession period P_p (the δ phase) (due to the variation of disc visibility conditions) and with a period defined by the sum of, or the difference between, the frequencies of the precessional and orbital rotations (the phase φ) (due to the variations of the disc heating conditions). The intensity of radiation can be expanded to a Fourier series with these frequencies (the corresponding φ and δ) *(Bochkarev, Karitskaya, 1988b)*. The harmonic amplitudes of the expansion are functions of the angles of precessing j and of system inclination i, the relative radii of the disc r_d and the star r_*, the angular distribution of disc radiation intensity (generalization of the limb darkening coefficient U), the dependence of the radiation flux spectral density on the temperature ($\beta = d\ \ln F/d\ \ln T$) and the disc to star brightness ratio (γ). So one can determine these parameters by comparing the harmonic amplitudes with the observational ones, the coefficients u, β, γ, being derived from the model atmosphere. For Cyg X-1 in the B band:

$\beta=2.0$, $\gamma=0.13$, $u=-0.06$. In the case of the Cyg X-1 disc the star radiation is absorbed in the outer layer of the atmosphere. This leads to a weak outward gradient of temperature and the limb darkening coefficient turns out to be slightly negative. The reflection albedo is $A \sim 0.2$. The light scattering contribution to the photometric variability (B band) is $\leq 10\%$.

The data of the detailed analysis *(Kemp et al., 1987)* of the V 1357 Cyg photometric variability in B band have been used to find the amplitudes A_δ, A_φ, $A_{\delta\varphi}$, $A_{2\varphi}$ and $A_{2\delta}$ at a $(1.2-2.5)\,\sigma$ significance level for each of the amplitudes. In the fractions of 10^{-4} of the system brightness, we get $2A_\delta = 70\pm35$, $2A_{2\delta} = -43\pm35$, assuming that the precession is towards orbital motion we get $2A_\varphi = 71\pm27$, $2A_{\delta\varphi} = 39\pm35$, $2A_\varphi = 39\pm17.5$, assuming that the precession is opposite, which corresponds to the case of slaved disc we get $2A_\varphi = -5\pm29$, $2A_{\delta\varphi} = 42\pm37$, $2A_\varphi = 84\pm19$.

Qualitative analysis has shown that the amplitudes found cannot be fitted to the slaved-disc model with precession opposite to orbital motion The assumption of precession opposite to orbital motion is in better agreement with the optically-thin disc model: in the latter case, however, the amplitudes A_φ and A_δ cannot be fitted to each other at a level better than $\chi^2 \simeq 3$. At the same time, all the amplitudes (except $A_{2\delta}$) and the first harmonic of the orbital period of linear polarization of optical emission from Cyg X-1 are in agreement, at the level of a 5-value total $\chi^2 < 1$ (up to $\chi^2 = 0.5$), with the model of an optically-thick disc precessing towards the orbital motion of the system with the parameters

$$r_* = 0.4-0.45, \quad r_d = 0.12-0.15, \quad i = 55-65^\circ, \quad j = 15-20^\circ$$

(in agreement with *Kemp et al. (1987)*). The second (main) harmonic of linear polarization was not examined because, on the basis of what has already been said, it is irrevelant to the accretion disc.

The direct precession of the disc may be due to the moment of the forces transferred to the oblique disc by gas stream out-flowing from the optical star *(Bochkarev, Karitskaya, 1988b)*. In this case the precession period is

$$P_p = 2\,\pi\,(v_{Kepl}/v)\;t/\tau_d \cos j$$

where v_{Kepl} and v are respectively the Kepler velocity of motion at the disc rim and the velocity of gas stream impact against the disc, t is the time within which the matter "leaks" from the rim to the interior of the disc. The observed P_p value of 294^d at $j = 15\text{-}20^o$ arises if $t \approx 10^d$, which agrees with the absence of delay of the X-ray variations with P_p relative to the optical emission variations with P_p. To the direct precession lead also the forces exerted on the disc by stellar wind and radiation pressure *(Kemp, 1988)*. The small value of t is probably due to the disturbance produced in the outer regions of the disc by the gas stream.

References:

Bochkarev, N.,G., Karitskaya E.,A., Shakura, N.,I., 1975. Sov. Astron. Lett. 1, 118.

Bochkarev, N.,G., Karitskaya, E.,A., 1983, Sov.Astron. Lett., 9, 6.

Bochkarev, N.,G., Karitskaya, E.,A., Sakhibullin, N.,A., 1985, Ap. Sp. Sci., 108, 15.

Bochkarev, N.,G., Karitskaya, E.,A., 1988a, "The true absorption effect on the field of radiation of starlight-scattering accretion discs" - in: Symp. COSPAR/IAU, Sofia. Adv.Space Res.

Bochkarev, N.,G., Karitskaya, E.,A., 1988b, "Starlight re-emission by a precessing accretion disc relevant to the parameters of the Cyg X-1= V1357 Cyg X-Ray binary. In: Symp. Cospar/IAU. Sofia. Adv. Space Res.

Bochkarev, N.,G., Karitskaya, E., A., et al. 1986, Sov. Astron., 30, 43.

Bruevich, V.,V., Kilyachkov N.,N., et al., 1978, Sov. Astron. Lett. 4, 292.

Karitskaya, E.,A., 1979, Sov. Astron. Circ., 1088, 1.

Karitskaya, E.,A., 1981a, Thesis for Candidate Degree, Moscow.

Karitskaya, E.,A., 1981b, Sov. Astron., 25, 80.

Kemp, J.,C., 1980a, Astron. Astropys., 91, 108.

Kemp, J.,C., 1980b, Ap. J., 235, 595.

Kemp, J.,C., Barbour, M.,S., Henson, G.,D., et al. 1983, Ap.J. Lett. 271, L65

Kemp, J.,C., 1984, Preprint.

Kemp, J.,C., Barbour, M.,S., Henson, G.,D., et al. 1983, Ap.J.Lett.,271, L 65.

Kemp, J.,C., Karitskaya, E.,A., Kumsiashvili M.,I., et al 1987, Sov. Astron.,31, N2.

Kemp, J.,C., 1988. private communication

Priedhorsky, W.,C., 1987, Preprint LA-UR-86.39000.

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OBSERVATIONAL EVIDENCE ON THE ASYMMETRY OF THE ACCRETION COLUMNS IN CLOSE BINARY SYSTEMS

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The magnetic field in AM Herculis-type binary stars is sufficiently large to cause the accretion flow to be channelled along field lines, and above the magnetic pole of the white dwarf an accretion column forms, which is the main source of the X-ray, UV, optical and near-IR emission *(Chanmugam and Wagner 1977, Stockman et al. 1977,* see also the recent reviews of *Lamb (1985)* and *Liebert and Stockman (1985))*. However, the angle Θ between the magnetic axis and the column's axis deviates from zero, thus the column's axis is inclined with respect to the surface of the white dwarf (see *Andronov 1986a,b,* for details). In this case, the orbital changes of flux, radial velocities and polarization may be sufficently asymmetric.

The statistical dependence of the photovisual light curve of AM Her on its luminosity in the "active" state was derived by *Andronov (1985)*. It is highly asymmetric and, with increasing luminosity, the main maximum (hump) tends to be more prominent. The second maximum was not a constant feature of the light curve, contrary to the earlier observations of *Szkody and Brownlee (1977)* and *Gilmozzi et al. (1978)*. Thus the position and structure of the accretion column may have undergone long-term changes, as was originally pointed out by *Bailey and Axon (1981)* on the basis of photometric and polarimetric data.

Such changes may occur due to the cyclic variations of the orientation of the magnetic axis of the white dwarf in relation to the rotating binary stellar system, which are excited thereby making the accretion possible *(Andronov 1983, 1987a)*. This model of "swinging dipole" may be able to interpret the following phenomena observed in AM Herculis itself and in some other object of the same class:

a) cyclic variations of luminosity, which may be caused by the dependence of the "magnetic valve" conductivity on angle Θ.

b) cyclic variations of the phases of minima detected in AM Her (Andronov et al. 1982) and QQ Vul *(Andronov and Fuhrmann 1987)*.

c) correlation between the above mentioned phenomena *(Smykov and Shakun 1985)*.

Another source of the column's asymmetry is connected with the heterogenity of the accretion flow (see *Andronov 1987b* for a review). The initial plasma "blobs", while moving along field lines are transferred to long plasma "strips", so called "spaghettis", which bombard the shock at the top of the accretion column. In each "spaghetti" the cyclic variations of the structure existing during the penetration of such a "strip" through the shock may appear. Such a quasi-periodic oscillations usually interfer, and one may observe the sum of practically independent variations. The possible "global" oscillations of the column predicted by *Langer et al. (1982)* may be strongly affected by such "spaghetti".

However one may provide an observational test for choosing the more realistic model. In the "active" state, the number of "spaghetti" is larger than in the case of the "intermediate state". At smaller luminosity one may study the single flares ("spaghetti") or, at least, the smaller number of them, and thus may estimate their physical parameters. Because the structure of the column (and thus the characteristic "Noisar" frequency) depends on the value $\dot{m}/A$ (accretion rate per unit surface of the column's base), one may predict the increase of the "Noisar" cycle duration with decreasing luminosity in the "global" model. In the case of the "spaghetti" model the "coherence duration" is considered to increase as well, because of the increasing length of a single strip.

Thus, observations of the ultrashort-time variability of AM Her-type stars are very much needed to obtain the statistical dependence of the "Noisar" characteristics (intensity, frequency and coherence duration") on luminosity and orbital phase (presumably in the "active" state, to study the asymmetry of the column). This observational task needs time, but the results may be really important for investigating the exotic objects known as "AM Her-type stars".

References:

Andronov, I.L., 1983, Astron. Tsirk. No. 1267, 4.

Andronov, I.L., 1985, Pis'ma Astron Zhurn., 11, p.207.

Andronov, I.L., 1986a, Astron. Zhurn., 63, 274.

Andronov, I.L., 1986b, Commun. Konkoly Obs. Hung. Akad. Sci., 86, p.369.

Andronov, I.L., 1987a, Astrophys and Space Sci., 131, 557.

Andronov, I.L., 1987b, Astron. Nachr., 308, 229.

Andronov. I.L., Banny, M., Korotin, S.A., Yavorsky, Y.B., 1982, Astron. Tsirk., No. 1225, 4.

Andronov, I.L., Fuhrmann, B., 1987, Inform. Bull. Var. Stars. No. 2976.

Bailey, J., Axon, .I., 1981, Mon. Not. R. Astr. Soc., 194, 187.

Chanmugam, G., Wagner, R.L., 1977, Astrophys. J., 213, L13.

Gilmozzi, R., Messi, R., Natali, G., 1978, Astron. Astrophys., 68, L1.

Lamb, D.Q., 1985, in: "Cataclysmic Variables and Low-Mass X-Ray Binaries", eds. D.Q. Lamb, J. Patterson. (Reidel, Dordrecht) p.179.

Langer, S.H., Chanmugam, G., Shaviv, G., 1982, Astrophys J., 258, 289.

Liebert, J., Stockman, H.S. 1985, in: "Cataclysmic Variables and Low-Mass X-ray Binaries", eds. D.Q. Lamb, J. Patterson, (Reidel, Dordrecht), p. 151.

Smykov, V.P., Hakun, L.I., 1985, Astron. Tsirk., No. 1384, 3.

Stockman, H.S., Schmidt, G.D., Angel, J.R.P., Liebert, J., Tapia, S., Beaver, E.A., 1977, Astrophys. J., 217, 815.

Szkody, P., Brownlee, D.E., 1977, Astrophys. J., 212, L113.

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CLOSE BINARY SYSTEMS IN LATE EVOLUTIONARY STATE

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A lot of new observational and theoretical data have been published during the last decade concerning the close binary systems at a late stage of evolution. In this connection the Catalogue of Close Binary Systems at Late Stage of Evolution (editor: A.M. Cherepashchuk) has recently been prepared at Sternberg State Astronomical Institute Moscow. The authors of this catalogue are: A.A. Aslanov, D.E. Kolosov, N.A. Lipunova, T.S. Khrusina and A.M. Cherepashchuk. The catalogue is due to be published at the end of 1988 by Moscow University Press. The catalogue contains about 300 objects of different kinds: β Lyr and W Ser type systems, WR+OB binaries, run-away OB stars, X-ray binaries of different types (massive and low-mass X-ray binaries, X-ray transients, bursters, QPO, etc.), the SS 433 object, single line WR stars with probable relativistic companions, pre-cataclysmic variables, cataclysmic variables, symbiotic stars, intermediate polars, polars and binary radio-pulsars.

For the majority of the systems, the finding charts and reference stars are presented in the catalogue. The catalogue is likely to be of use both for theoreticians and for observers because it contains basic parameters of close binary systems: masses, radii, luminosities of the stars, magnitudes, spectral types, periods, etc.

Many properties of close binary systems at the late evolutionary state are well explained by the modern theory of evolution of close binaries with mass exchange. Our investigations of WR stars in eclipsing binary systems allow us to estimate the correct values of radii and temperatures of these stars. Based on our results the WR stars are helium-rich remnants formed as a result of the first mass exchange in massive close binaries.

The discovery of optical eclipses in the unique object SS 433 allows us to estimate the basic parameters of this massive X-ray binary. Judging from our interpretation of optical eclipses in the SS 433 system, this object is a massive X-ray binary system (similar to Cyg X-1 or Cen X-3) in an advanced stage of evolution: at this stage the star is overfilling its Roche lobe. Due to very high mass transfer in this system an optically bright accretion disk is formed around the relativistic companion. Thus, SS 433 is a massive X-ray binary system at the supercritical accretion regime.

A number of single-line WR stars have recently been discovered as close binary systems containing low-mass companions which may be neutron stars accreting in a strong stellar wind of WR star.

Mass determinations of X-ray pulsars in X-ray binary systems have been made as well as of black hole candidates. The masses of X-ray pulsars do not exceed 3 M_o - this being the theoretical upper limit for neutron stars predicted by Einstein's theory of general relativity. The mean value of the mass of X-ray pulsars (neutron stars) obtained from analysis of 7 X-ray binary systems is 1.4 M_o. All black hole candidates have a mass that exceeds 3 M_o and none of the 4 black hole candidates shows periodic pulsations of the X-ray radiation characteristic for the magnetic rapidly rotating neutron stars.

The search for relativistic companions for OB run-away stars by spectroscopic and photometric methods is now in progress at Moscow's Sternberg State Astronomical Institute.

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RESULTS OF PHOTOELECTRIC OBSERVATIONS OF V 533 HERCULIS

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At the Workshop of the head of Project I "Complex Investigations of Stars and Stellar Systems" of the Problem Commission "Physics and Evolution of Stars" of the multilateral cooperation of the Academies of the Socialist Countries, held in Suzdal in 1985, the star V 533 Herculis was included in the program of cooperative investigations for the coming two years within a new structure of the Commission. Additionally, it had earlier been suggested that we observe this star photoelectrically at Abastumani Astrophysical Observatory of the Georgian Academy of Sciences using the AZT-11 telescope.

The nova V 533 Her is of significance in the sense that light variations were observed with the period 63.6 sec, though no such variations were observed later *(Robinson and Nather 1983)*. Moreover, the orbital period of the star is believed to be equal to 0.28 day *(Ritter 1984)*. However this value needs to be confirmed. The fact that some long-period light variations with an amplitude of more than 1.0 mag. as well as the light variations during the night with the amplitude of about 0.2 mag. were observed at Peking Observatory, attracts one's attention.

The star V 533 Her was observed at Abastumani Astrophysical Observatory from April - June, 1986 with a two channel electrophotometer attached to the AZT-11 telescope. The electrophotometer was designed and manufactured at the observatory. The primary mirror of the telescope is 1.25 m, the equivalent focal length being 16 m. The photometer offers the possibility of simultaneously measuring the stars removed from each other at an angular distance of up to 22'.

Within 7 nights the light of the star was measured in B filter during

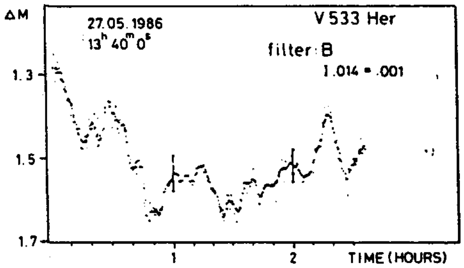

Figure 1.

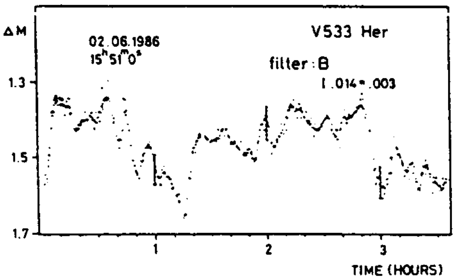

Figure 2.

a few hours at night. The longest observation lasted 3.5 hours. The star "E" from *Löchel's* paper *(1966)* served as the comparison. The integration time was 10 sec. Due to the fact that at a distance of 12'' from V 533 Her there is a star fainter than that under investigation by 2 magnitudes, we used a 16'' diaphragm in our observations. The results are given in Figs. 1-4. The time is plotted along the X-axis and the magnitude difference between the comparison star and the variable along the Y-axis. Each point is obtained by averaging two observations. On average, the error of a measurement is 0.016 mag. The slipping mean values are plotted as well. Their measurement error is, on average, 0.005 mag. It is seen that within a night there are some irregular variations with an amplitude of 0.3 - 0.4 mag. confirming *Hao Xiang-Liang's* and *Mei Bao's* results *(1984)*. Comparison of observations performed on different nights shows certain differences in the character of the light variation. Single observations were averaged merging every 30 points into one. Then using the elements:

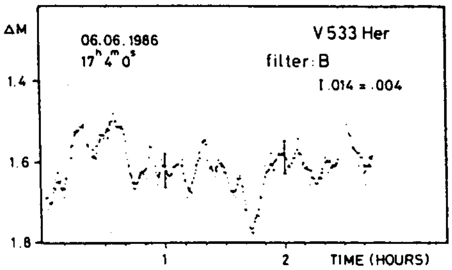

Figure 3.

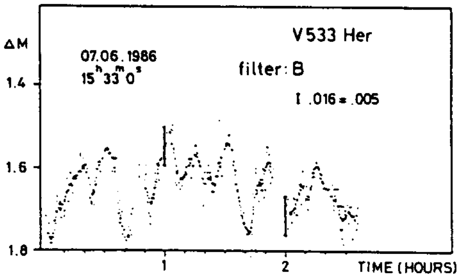

Figure 4.

$$\mathrm{Min}_{\odot} = 2446565.4579 + 0^{d}.28\ E$$

we reduced them to the same period.

Figure 5 shows a corresponding curve. As can be seen not all the phases overlap equally well. But judging by our results it can be concluded that the light curve does not show any pronounced light variations with the period of 0.28 day suggested earlier. It might be that apart from the 6 hours period in this case we are dealing with some more harmonics with

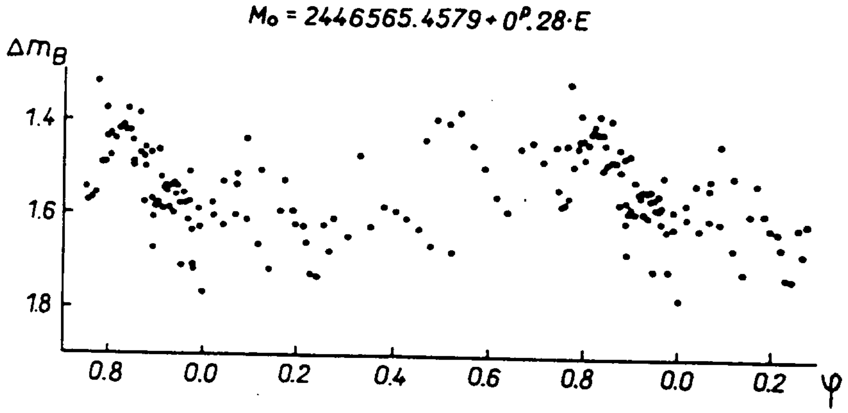

Figure 5.

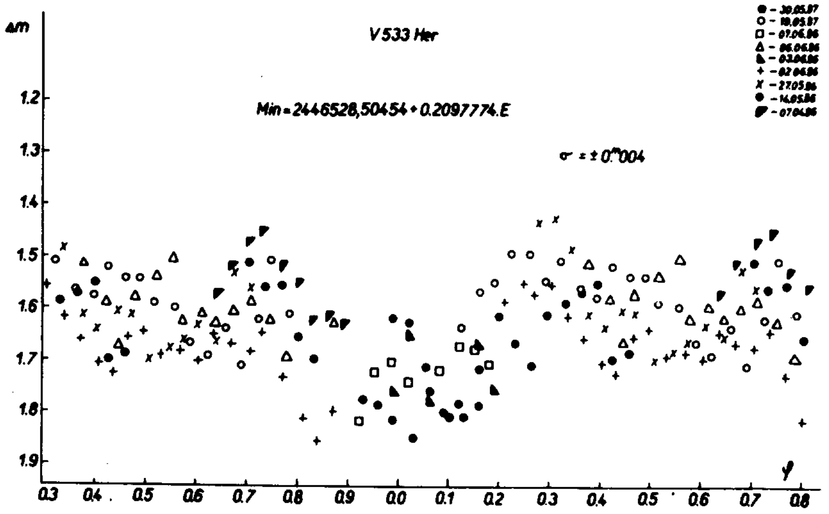

Figure 6.

shorter periods superimposed on this particular period. In order to solve the problem once and for all further observations are needed - and it is just that is envisaged by our program.

In addition, it should be noted that in *Hutching's paper (1987)*, the author gives a new spectroscopic period of the star : $0\overset{d}{.}209774$. Using this new period and selecting the epoch according to our observations a mean curve is plotted in B by averaging the observational data with 30 points into one.

Figure 6 shows that our photoelectric observations confirm Hutching's spectroscopic data through in our observations there occur certain irregular light variations during the night.

Consequently, to finally establish the nature of the light variations for the star under study, more detailed analysis of the data obtained must be carried out.

The results obtained for two pairs of parameters q,i ($q=0.320$, $i=77\overset{\circ}{.}5$ and $q=0.146$, $i=82\overset{\circ}{.}$) are presented in Figure 1. Only the egress branches of the eclipses are reproduced here.

The phase $\Phi_{1/2}$ at which half the flux is eclipsed occurs nearest phase zero for case a_1 and furthest for case a_3. Such large differences in the half width of the eclipse, especially for $q=0.320$, produce only slight differences in the relation i(q). A detailed analysis is due to published in Acta Astronomica.

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References:

Hao, X-L., Mei, B., 1984, Inf. Bull. Var. Stars, No. 2611.

Hutchings, J.B., 1987, P.A.S.P., 99, 57.

Löchel, K., 1966, Mitt. Ver. St. 3, Heft 7, 213.

Ritter, H., 1984, Astr. Asrophys. Suppl. Ser., 57, 385.

Robinson, E.L. and Nather R.E., 1983, Ap. J. 273, 255.

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PREVIOUS OPTICAL FLARE IN THE SHORT PERIOD RS CVn SYSTEM SV Cam

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Short period RS CVn stars are active stars showing "solar-like" activities. They display all the surface phenomena of our Sun, viz. spots flares, chromospheric activity, etc. In the case of the RS CVn systems however, all these activities are much more pronounced, sometimes even by orders of magnitude. This situation is somewhat different in the case of observed optical flares. There have been only two reported unquestionable optical flare events in RS CVn systems. Both of them occurred in a short period RS CVn system: in SV Cam *(Patkós 1981)* and in XY UMa *(Zeilik et al. 1983)*. Although *Srivastava (1983)* reported some "flare-like activity" in AR Lacertae, no other observed optical flare is known in RS CVn systems.

Therefore the question remains: Why do we not observe optical flares in long period or regular RS CVn systems? These systems are very well observed and show flare activities in other wavelengths. In view of this, it is very important to study RS CVn systems showing optical flares. Table 1 contains the main characteristics of SV Cam and XY UMa.

Table 1.

	SV Cam	XY UMa
(eclipse) period	0.59	0.48
brightness	8.40 - 9.11	9.50 - 10.17

distortion wave ampl.	0.1	0.11
mass ratio (hotter/cooler) (solar units)	1.0/0.7	0.95/0.70
radius (hotter/cooler) (solar units)	1.2/0.7	0.98/0.73
spectra	G2-3 V / K4 V	G2-5 V / K5 V

The two systems are very alike. In both cases it is questionable which component is the active one. According to *Geyer (1976)* in the case of XY UMa the primary component is: - in the case of SV Cam the migrating distortion wave goes through both the primary and the secondary minima. Therefore, we have to assume that the spot activity of the system originates from both the hotter and cooler component. The flare activity itself originates with greater probability from the secondary component because two of the reported flares occurred at the bottom of the primary minimum when the hotter component is eclipsed.

Table 2 contains the main characteristics of the observed flares:

Table 2

	SV Cam			XY UMa
orb. phase	0.61	0.97	0.99	0.57
duration (min)	43	18	9	30
ΔU (mag)	0.12	0.15	0.05	0.33
ΔB (mag)	0.05	0.06	0.03	0.13
ΔV (mag)	0.03	0.03	-	0.09

Because optical flares are so limited in these systems, it might be important to mention, that I have observed a previous optical flare in

SV Cam at J.D. 2441960.4585 . The observation material was published *(Patkós 1982, page 86.)* without mentioning the three point flare event observed only in the U light curve. The main characteristics of this previous optical flare were the following:

orbital phase	0.71
duration (min)	38
ΔU (mag)	0.8

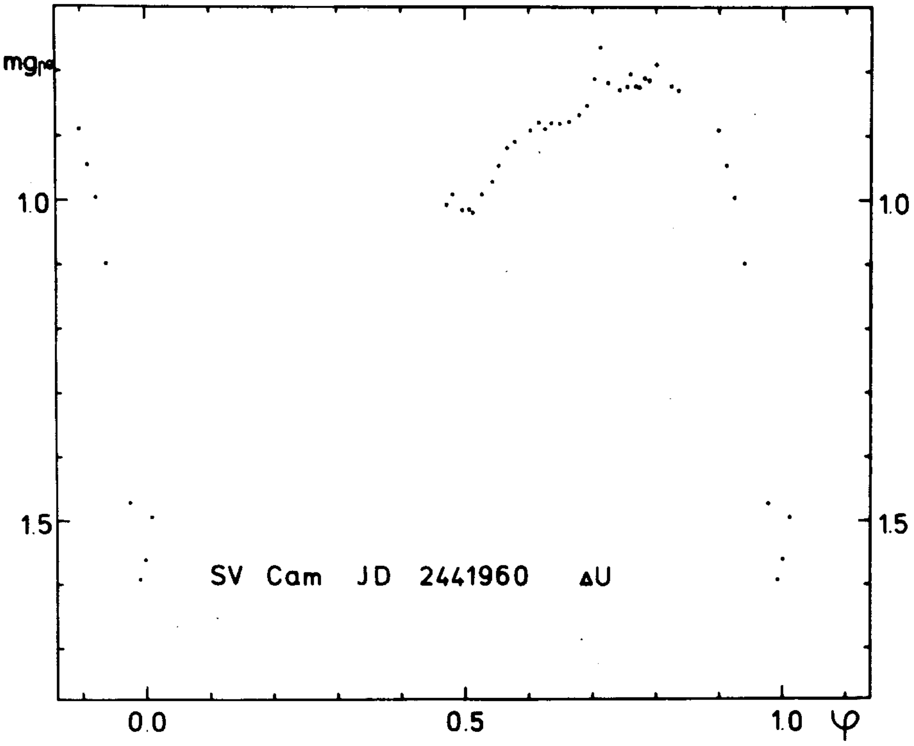

Figure 1.

As the observed light curve (Fig. 1.) shows, in the time interval following the flare there were also some flare-like spikes in the observed

U light curve of SV Camelopardalis.

References:

Geyer, E.H., 1976, in:"Structure and Evolution of Close Binary Systems" p.:313, eds.:P. Eggleton et al.

Patkós, L.: 1981, Astrophys. Lett. 22,p.1.

Patkós, L.: 1982, Comm. Konkoly Obs. No 80.

Srivastava, R., K.: 1983, Inf. Bull. Var. Stars. No. 2450.

Zeilik, M., Elston, R., Henson, G., Smith, P.: 1983 in: Activity in Red-Dwarf Stars, IAU Colloquium No. 71. p.411. eds: P.B. Byrne, M., Rodono: Reidel Dordrecht

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PERIOD CHANGES IN THE CLOSE BINARY SYSTEM QQ CASSIOPEIAE

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New photoelectric observations of QQ Cas were obtained and the epochs of minima were derived. The secular variations of the period have been found and an explanation for their causes is suggested.

The variable star QQ Cas (BD +59°2765 = BV 73) was discovered by *Kippenhahn (1955)*. The complete list of the photographic epochs of minima was published by *Busch (1975)*. Three new epochs of minima are included in the paper of *Braune and Lichtenknecker (1986)*.

The light curve given by *Busch (1975)* is clearly of β Lyrae-type. The spectral type of one component is B2, the spectrum of the second component is not known.

As the star has very rarely been observed in the last two decades, we put it into the observational program at Skalnate Pleso Observatory. The observations were obtained with the photoelectric photometer installed in the 0.6/7.5 m reflecting telescope in the years 1985-1987. During seven nights, over 1400 observations (in B region) were obtained. The observations are due to be published elsewhere. The derived epochs of minima are in Tab. 1.

Table 1.

J.D. hel.	m. e.	type of min.
2446743.3985:	±0.0025	pri
6756.2465	±0.0025	pri
7060.4305	±0.0015	pri
7061.5030	±0.0010	sec

The spread of the individual epochs of minima in the O - C diagram published by *Busch (1975)* is very wide. Many published epochs are actually the epochs when the star has been found to be fainter. Therefore we decided to divide the whole observational period into 18 intervals. The limits of the intervals as a rule coincide with the season in which no observation was obtained. As the shift of the secondary minimum was not observed we grouped together the primary and the secondary minima. The number of observed minima in one interval varies from 9 to 23. Thus we obtained 18 mean epochs of minima. Due to their large deviation, one mean epoch of minimum and the visual epoch of minimum from the table published by *Braune and Lichtenknecker (1986)* were omitted. Two epochs of minima obtained by *Zonn and Semeniuk (1959)* included in the list of *Busch (1975)* were not used for the calculation of mean epochs of minima but were used directly for the ephemerides calculation.

The recent calculation of elements published by *Braune and Lichtenknecker (1986)* has shown that the period is longer when the observations obtained only in recent years are used. The ephemeris with the secular term derived by us is as follows:

$$\text{Min. I.} = \text{J.D. } \underset{\pm 38}{2434330.1918} + \underset{\pm 43}{2.14204474}E + \underset{\pm 11}{1.71} * 10^{-9}E^2$$

The mean error of the secular term is relatively low and thus the increase of the period is a real effect. The observational period was divided into two parts for which linear ephemerides were computed. The linear ephemeris before J.D. 2435000 is:

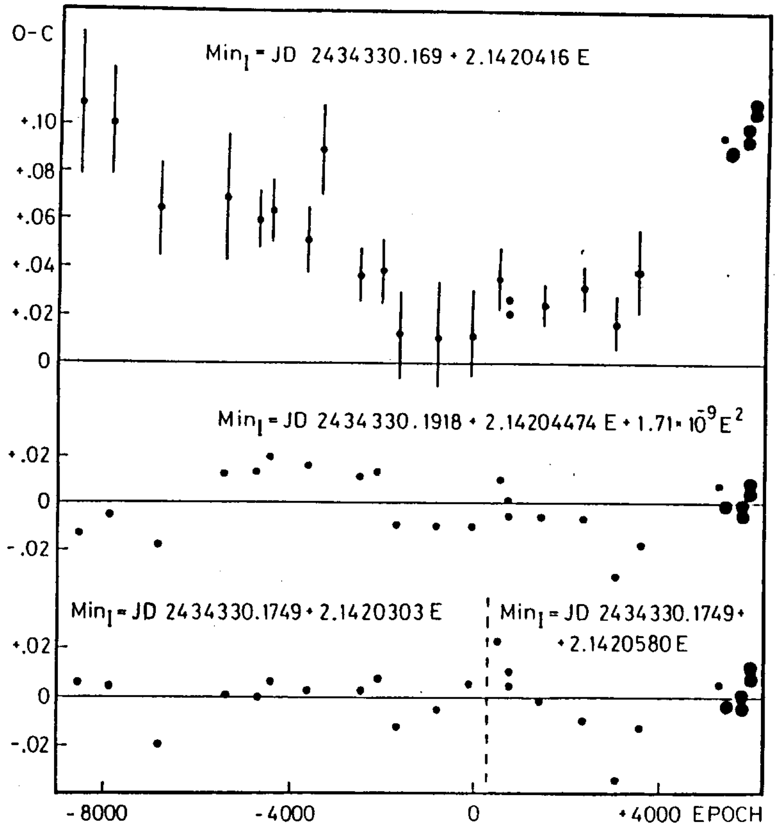

Figure 1.

Min. I. = J.D. 2434330.1749 + 2.14203027E
±47 ±96

The linear ephemeris for the time interval after that date is:

Min. I. = J.D. 2434330.1726 + 2.14203027E
±47 ±14 .

The sum of $(O - C)^2$ values is very close being by 3.5 percent lower for linear ephemerides.

The secular increase of the period can be explained within the scope of the mass transfer theory or by the light-time effect. For the mass loss we obtain the value of $\Delta m/m = 5.8 * 10^{-7}$ per year. After removing the quadratic term the rest of the deviations could be explained by a non-uniform mass transfer if these deviations are real.

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References:

Braune, W., Lichtenknecker, D., 1986, BAV Rundbrief 38, 1.
Busch, H., 1975, Mitt. der B.H. Bürgel-Sternwarte Hartha 8, 15.
Kippenhahn, R., 1955, Kl. Veröff. Remeis Sternw. Bamberg 9, 4.
Zonn, W., Semeniuk, I., 1959, Acta Astron. 9, 159.

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OPTICAL BEHAVIOUR OF THE POLAR AM HERCULIS

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AM Herculis is the prototype star of a subgroup of cataclysmic binaries consisting of a white dwarf as primary, and a low-mass main sequence star as the secondary component. This type of close binary is characterized, on the one side, by a strong magnetic field of the white dwarf of about $B \approx 10^7 - 10^8$ Gauss and, on the other side, by a gas stream originating from the main sequence star. This gas stream spills over to the primary and is conducted by the magnetic field. This process causes an accretion column on the magnetic pole of the white dwarf which is facing the secondary. The existence of an accretion disc around the primary can also be expected.

The orbital periods of this group of stars are very short. The period of AM Herculis amounts to $p = 0^d.12892737$, and the corresponding occultation-light-changes of about 0.5 magnitudes are superimposed upon the overall light curve.

This report deals with the long-term behavior of AM Herculis as it appears from observations given by *Hudec and Meinunger (1977)* and by *myself (1982, 1984a, 1984b, 1986a, 1986b, 1987)*. My observations were obtained between 1982 and 1987 on 643 blue-sensitive and 40 photovisual plates of the Schmidt camera (50/70/172 cm) of Sonneberg Observatory from more than 230 nights. Visual observations given by the French Association of Variable Star Observers published in the *AFOEV Bulletin (1982 - 1987)* are included.

The optical, the polarimetric and the X-ray behavior of AM Herculis type stars are mainly determined by the characteristics of their accretion columns. Generally we distinguish two photometric states in this group of stars: The low state, which is given by inactivities in the minimum brightness and the high state, which is caused by X-ray heating.

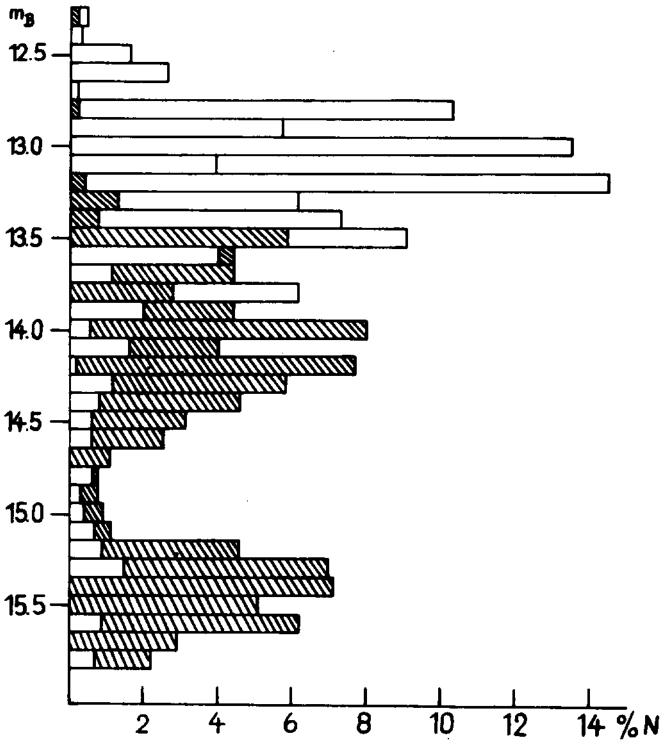

Figure 1.

In the case of AM Herculis the mean levels of the two states can be shown by the brightness distribution of the observations in B and V. In Fig. 1 the brightness distribution in B is given. The hatched areas represent observations obtained from Schmidt plates. The other ones belong to series of observations given by Meinunger and Hudec obtained on sky patrol and astrograph plates of Sonneberg Observatory.

From the brightness distribution in B it can be seen that the low state is characterized by observations between $m_B = 14^m.8$ and $m_B = 15^m.8$ with a mean level of $m_B \_ 15^m.3$. On the other hand all observations between $m_B = 12^m.3$ and $m_B = 14^m.8$ belong to the high state. The mean level

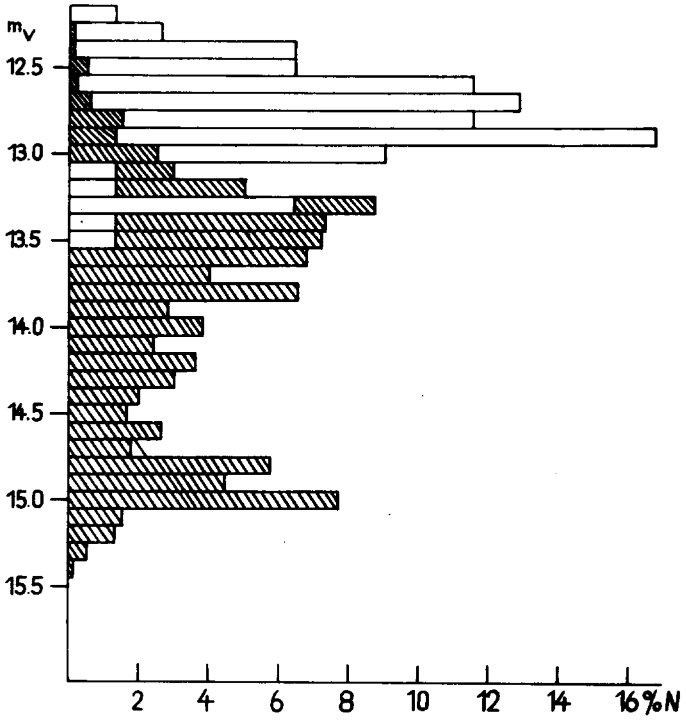

Figure 2.

in this latter state varies with time as can be seen in the following. But this fact is also illustrated in Fig. 1 if one compares the mean level of the observations given by Meinunger and Hudec at $m_B \approx 13^m.0$ with that obtained from my observations at $m_B \approx 14^m.0$.

The brightness distribution obtained from the visual range, shown in Fig. 2, confirms the results obtained from the blue range. Observations of the low state are situated between $m_V = 14^m.5$ and $m_V = 15^m.4$. The mean level there amounts to $m_V = 14^m.83$ taking into account the observations given by Verdenet (AFOEV). In the high state we find observations between $m_V = 12^m.2$ and $m_V = 14^m.5$. The mean levels in the high state vary with time in a similar way to those in the blue range.

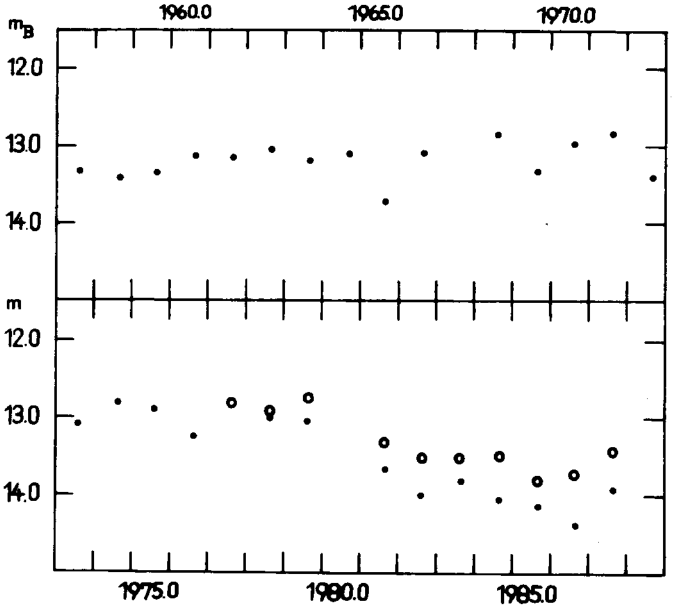

Figure 3.

In Fig. 3 the mean values of the brightness of AM Herculis obtained from all observations of the high state of each season, which represent the seasonal mean levels, are plotted against time, beginning with the year 1957. In this diagram dots characterize the behavior of the mean high state brightness in the blue range: circles characterize the behavior in the visual range.

Figure 3 illustrates the continuous increase in mean brightness between 1957 and 1970 from $m_B = 13^m.4$ to $m_B = 13^m.0$. After a period of 10 years of nearly constant mean brightness, in 1980 the star started a decrease from $m_B = 13^m.0$ to $m_B = 14^m.4$ within the following 6 years. The lowest mean brightness was observed in 1986, that is, just in that year in which the low state had its longest duration - as we can see below. The decrease in mean brightness of the high state between 1980 and 1986 is confirmed by the visual observations.

The long-term behavior of AM Herculis between 1982 and 1987 can be seen from the light curves given in Fig. 4. There, my observations in B are drawn in the upper light curve: the visual ones obtained and published by the AFOEV are grouped in the lower one.

As we can see from the two light curves, there are phases of the low and the high state which vary in an irregular manner. From the curves shown the following general conclusions can be drawn:

1). The durations of the minimum phases, or better of the low state phases, are very different. One of the shortest minima was observed in 1982 between April 15 and September 24. The longest one, on the other hand, amounts to about 290^{d} crossing the observation seasons 1985/86 if we assume that the long-lasting minimum of 104^{d} at the beginning of the series of 1986 is the continuation of the 120^{d} low state at the end of the year 1985.

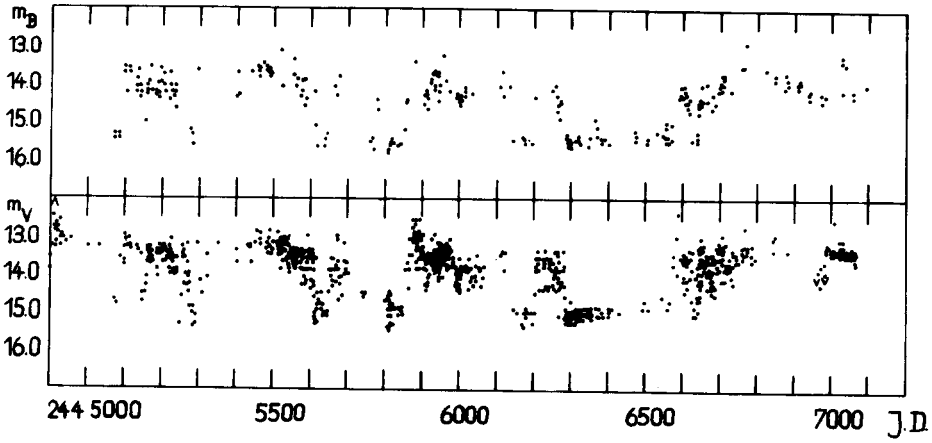

Figure 4.

2). In the high state a flare was observed on July 12, 1983. During this flare the brightness of AM Herculis increased from $m_B = 13\overset{m}{.}74$ to $m_B = 12\overset{m}{.}33$, which is an increase of 1.41 magnitudes within $0\overset{d}{.}024$ This flare proved to be unique: in the series of nights of the following years nothing of this kind was ever observed again.

3). In each case the high state of AM Herculis starts from the and is caused by X-ray heating. Therefore it seems to be especially necessary to investigate the low state, including the influences of the orbital light changes. At Sonneberg Observatory investigations on this subject have started.

References:

AFOEV, 1982-1987, AFOEV Bulletin

Götz, W., 1982, I.B.V.S. No. 2226.

Götz, W., 1984a, I.B.V.S. No. 2459.

Götz, W., 1984b, I.B.V.S. No. 2649.

Götz, W., 1986a, I.B.V.S. No. 2851.

Götz, W., 1986b, I.B.V.S. No. 2967.

Götz, W., 1987, I.B.V.S. No. 3126.

Hudec, R., Meinunger, L., 1977, MVS _7_, 194.

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SPECTRAL PECULIARITIES OF V 367 CYGNI - A CLOSE BINARY SYSTEM AT THE STAGE OF RAPID MASS EXCHANGE

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Of greater actual importance has become the investigation of close binary systems with nonstationary phenomena as objects at the critical stage of their evolution. The system of V 367 Cygni is one of the most interesting objects of this type. This system is at the short-term stage of fast mass exchange as is manifested by the numerous effects observed: light curve deformation, variation in period, emission in lines of Balmer series. The spectrum of V 367 Cygni is a bright example of a "shell"-spectrum and our investigations *(Karetnikov and Menchenkova 1987)* have shown, in the atmosphere of the primary star there are formed only wings of hydrogen lines and lines of Mg II (λ = 448.1 nm). A complete bibliography of papers devoted to the investigation of V 367 Cygni is given in *Karetnikov and Menchenkova (1985)*.

Our research work is based upon spectrograms obtained with the 6 m telescope at SAO of the Soviet Academy of Sciences, the dispersion being 9 and 14 A/mm as well as with the 122 cm telescope of CrAO of the Soviet Academy of Sciences, the dispersion being 37 A/mm. The spectral region investigated ranges from λ= 360 to 490 nm.

The presence of emission in the first terms of Balmer series including the H_γ line is a characteristic peculiarity of V 367 Cyg spectrum throughout the whole period.

The emission intensity in line H_α varies with the phase - amounting to 2.4 at the primary minimum and to 1.1 at the maximum *(Karetnikov and Prekrestnyi 1973)*, in units of a continuous spectrum. Line H_β has a complex structure, the Be profile is of particular interest. Whereas in 1981 the blue and red emission component lines of H_β had different intensity, in

1982 the intensity of the components became similar. This resulted in a central absorption shift as shown by radial velocity measurements: in 1981 the velocity of the latter was -41 km/sec whereas in 1982 it increased to -4 km/sec. Another characteristic peculiarity of V 367 Cygni is the presence of numerous lines of neutral and ionized metals in the spectrum which lines show a practically constant radial velocity and a marked asymmetry. The asymmetry observed seems to be caused by a velocity gradient in the aggregate envelope of the system wherein the line spectrum observed is formed. The most intensive lines of FeII have emission companions. From metal lines using the criteria of spectral classification by Kopylov, we determined the envelope temperature which proved to be equal to 9500^o *(Karetnikov and Menchenkova, 1985)*. From the number of the last line observed of the Balmer series of hydrogen we estimated the concentration of free electrons in the envelope lg n_e = 11.96 (m = 30).

The physical conditions in the envelope of V 367 Cygni were determined by the curve-of-growth method. The curves of growth have been constructed from lines FeI, FeII, TiII, CrII separately for the most interesting phases of the light curve 0.0, 0.2, 0.5, 0.7 when one can expect a change of conditions in the envelope. A mean curve of growth has been constructed as well using mean values of equivalent widths of lines. The results of the determination are given in Table I.

Table I.

	FeI Θ_{ex}=0.82		FeII Θ_{ex}=0.65		TiII Θ_{ex}=0.56		CrII Θ_{ex}=0.61	
	v_t	lg N_τ	v_t	lg N_τ	v_t	lg N_τ	v_t	lg N_τ
$0^d.0$	-	-	33±9	6.11	18±4	6.41	19±9	-
$0^d.2$	-	-	31±3	5.97	22±7	6.88	18±6	5.36
$0^d.5$	15±1	5.88	26±6	5.85	30±7	6.92	22±7	5.44
$0^d.7$	13±1	5.61	26±5	5.93	23±7	6.68	18±5	5.40
	12±2	5.80	27±5	5.85	25±8	6.65	20±5	5.39

The complete absence of stellar origin details in the spectrum is a characteristic peculiarity of the V 367 spectrum, and this markedly impedes investigations into the nature of stellar components. Due to careful position measurements we could detect a single stellar line MgII at λ=448.1 nm whereas investigation of the contours of hydrogen lines H_γ and H_δ has shown that they are of complicated structure, a narrow envelope core being superimposed upon the wide line of atmospheric origin. The radial velocities of the cores of these lines are constant in time and space being equal to -4 km/sec whereas the wings show great shifts with the amplitude up to 160 km/sec and coincidence with the phase of orbital motion of the primary star's system. The wings of these lines appear to be described equally well by three models: $T_{eff} = 12000_o$, lg g = 2.5, - $T_{eff} = 16000^o$, lg g = 3.0, - $T_{eff} = 20000^o$, lg g = 3.5. The consideration of higher terms of Balmer series $H_8 - H_{14}$ with the use of synthetic hydrogen spectra calculated by Pavlenko (Main Astronomical Observatory of the Ukrainian Academy of Sciences) made it possible to limit the temperature range to $T_{eff} = 12000^o - 16000^o$, lg g = 2.5 - 3.0.

The line MgII (λ = 448.1 nm) is not sensitive to the magnitude of lg g but the equivalent width of the line decrease with the temperature increase. It enabled us to obtain additional information on the physical parameters of the primary star atmosphere of the V 367 Cyg system. It appeared that $T_{eff} = 12000^o - 14000^o$, lg g = 2.5 - 3.0 (assuming that lg N (Mg) = lg N_o (Mg). We failed to elicit any detail which could be identified with the spectrum of the second component. There came as no surprise as the difference of stellar magnitudes of the bright star and a companion according to *Fresa (1966)* is not less than 1.5 mag.

The absence of helium lines is a characteristic peculiarity of V 367 Cyg spectrum though the lines of helium should be observed at the temperature of 12000^o which we determined for the primary star. It should be noted that these lines are confidently observed in the spectrum of the primary star of the β Lyr system having close values of T_{eff} and lg g. The difference between the spectra of these two systems testifies to the fact that V 367 Cygni is at an earlier stage of evolution than β Lyr in which the stage of a fast mass exchange is completed resulting in an enhanced helium abundance: N(He)/N(H) = 1.55 *(Leushin et al. 1979)*. Possibly in the case of V367 Cyg the helium lines are blended to a greater extent by spectral lines of other elements which formation proceeds in a more powerful and more extended envelope.

References:

Fresa, A., 1966, Mem. Soc. Astr. Ital., 37, No.3, 607.

Karetnikov, V.G., Menchenkova, E.V., 1985, Astron. Zh., 62, 542.

Karetnikov, V.G., Menchenkova, E.V., 1987, Problemi astronomii. Part 2. Kiev. Dep in UkrNIINTI N430-Uk87, 2.

Karetnikov, V.G., Prekrestnyi, S.M., 1973, Problemi kosmicheskoi fiziki, v.8, 159.

Leushin, V.V., Nevsky, M.Yu., Snezhko L.I., 1979, Astrofiz. isledowanija Izv. SAO), II, 40.

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SOME REMARKS ON ECLIPSING BINARIES SEEMING TO BE INCONSISTENT WITH GENERAL RELATIVITY

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At the present time the eclipsing binary systems are very important objects of quite different parts of astrophysics due to their numerous advantageous observational and theoretical features. Two of these properties are the possibility of checking different models of the internal structure of stars and the testing of General Relativity (GR) by studying apsidal motion.

There exist a lot of eclipsing systems having well-observable periastron motion. Many of them have reasonable theoretical representation based on several model computations of polytropic stars. The theoretical rates of apsidal motion obtained by predicted internal structure constants are in fair agreement with the observed ones in most cases of the given binary systems. Besides them, we know some binaries showing considerable periastron advance in consequence of GR, due to their special physical parameters. Koch turned attention to such systems in which the relativistic contribution to the net rotation of the line of apsid is comparable with the classical (CL) effect *(Koch, 1973)*. These binaries are EK Cep, α CrB, V1143 Cyg, DI Her and RR Lyn. This list has, since, been supplemented: Giménez proposed 23 candidates and 13 additional eclipsing variables for the study of relativistic apsidal advance *(Giménez, 1985)*. In the last decade some of these systems have gained great importance because these binaries seem to show much slower apsidal rotation than expected from the combined classical and relativistic (CL+GR) effects. We would like to make some additional remarks on this problem.

The above mentioned discrepancies have been discussed by several authors. Except for the attempts to remove the observed differences within

TABLE 1.

ACCEPTED PHYSICAL PARAMETERS OF THE PROBLEMATICAL BINARIES

SYSTEM:	REFERENCES:	M_1 ($M_\odot$)	M_2 ($M_\odot$)	P_{SID} (days)	e	$l(x10^9 cm)$	
						M.w.	P.w.
Y Cyg	*Giménez et al.,1987*	16.7	16.7	2.9963310	0.1456	6.5	6.76
		±4	±4	±37	±10		±16
	a)*Popper,1982*	5.15	4.52	10.5501585*	0.4883	2.0	2.014
DI Her	b)*Guinan & Maloney,1985*	±10	±6	±25	±10		±32
	c)*Martynov & Lavrov,1987*	(a)	(a)	(b)	(c)		
	a)*Popper,1974*	4.53	4.12	2.0287298	0.068	1.8	1.810
AG Per	b)*Giménez et al.,1987*	±7	±6	±91	±1		±26
	c)*Güdür,1978*	(a)	(a)	(b)	(c)		
AS Cam	*Khaliullin & Kozyreva,1983*	3.3	2.5	3.4309475*	0.1695	1.3	1.24
		±1	±1	±16	±14		±4
	a)taken from *Moffat,1984*	2.5	2.5	11.1208715*	0.35	1.0	1.08
V889 Aql	b)*Giménez & Scaltriti,1982*	±5	±5	±111	±3		±20
		(a)	(a)	(b)	(b)		
	a)*Popper,1987*	2.02	1.12	4.4277938	0.120	0.66	0.708
EK Cep	b)*Giménez & Margrave,1985*	±1	±1	±74	±3		±4
	c)*Khaliullin,1983*	(a)	(a)	(b)	(c)		
V1143 Cyg	*Giménez & Margrave,1985*	1.33	1.29	7.6407418	0.540	-	0.604
		±3	±3	±15	±5		±12

M_1 and M_2: masses of the components

e : orbital eccentricity,

M.w.: values of "l", taken from Moffat's work (*Moffat, 1984*),

P.w.: values of "l", resulted from present work.

the range of Newtonian Mechanics, Moffat proposed to interchange GR with a Nonsymmetric Gravitational Theory (NGT) elaborated by himself. From this new theory another formula follows for the yearly rate of apsidal motion, instead of the standard Einsteinian one *(Moffat, 1984)*. This new expression involves a factor, "λ". This "λ" not only reduces the rate but it may also yield a negative sign for it, depending on the value of a constant of integration "l" appearing in the formula of "λ" *(Moffat, 1984)*. With his new theory Moffat could explain the observed behaviour of these peculiar systems. In his article he presented the results of his calculations for μ^1 Sco, Y Cyg, DI Her, AG Per, AS Cam, V889 Aql, EK Cep and PSR 1913+16 *(Moffat, 1984)*. He compared the CL+GR and the CL+NGT combined effects with the observed values of the apsidal motion rates and concluded that NGT can provide a satisfactory explanation for these binary systems.

COMPARISON OF THEORY WITH OBSERVATIONS

As a first step, we repeated the computation of $\dot{\omega}_{GR}$ and $\dot{\omega}_{NGT}$ (contributions of GR and NGT to the total effects) together with the calculation of their mean errors, using the recently published or/and the best known physical parameters of the above mentioned systems (with the exception of μ^1 Sco and PSR 1913+16, but with an additional binary V1143 Cyg).

The accepted parameters and their mean errors are shown in Table 1, with the source references. In the fifth column of this table the sidereal orbital periods can be found with their approximate errors. P_{SID} values are sometimes calculated (indicated with "*"), and in the other cases they are taken from the authors directly (if they were calculated by the author himself). In the last two columns we show the values of the parameter "l" given by *Moffat (1984)* and those resulting from our calculations, using the expression which is valid only for non-degenerated stars (taken from *Guinan and Maloney, 1985*).

In Table 2 we present the theoretical values of $\dot{\omega}_{GR}$ and $\dot{\omega}_{NGT}$ resulting from our calculations (with their errors), and Moffat's $\dot{\omega}_{NGT}$ (Moffat has not published the errors). In the third column, one can see the least erroneous (or in some cases the recently published) observed rates of apsidal motion ($\dot{\omega}_{OBS}$). The results of computations of the Newtonian contributions are taken from several authors, and presented in the last column of Table 2. Their sources with the references are also shown.

Taking into account the data in Table 2, one can establish:

i) The errors of the observed physical parameters of binary systems cause

TABLE 2.

COMPARISON OF THE THEORETICAL AND OBSERVATIONAL APSIDAL MOTION RATES

SYSTEM:	$\dot{\omega}_{OBS}$	$\dot{\omega}^{THEOR}_{CL+NGT}$ (Δ_1)	$\dot{\omega}^{THEOR}_{CL+GR}$ (Δ_2)	$\dot{\omega}^{THEOR}_{GR}$ (this work)	$\dot{\omega}^{THEOR}_{NGT}$	$\dot{\omega}^{THEOR}_{NGT}$ M. W.	$\dot{\omega}^{THEOR}_{CL}$
Y Cyg	7.569	5.588	13.538	0.338	-7.612	-6.55	13.2
	±24			±5	±28.623		
	(a)	(+1.981)	(-5.969)				(b)
DI Her	0.00770	0.0043	0.0426	0.0233	-0.0150	-0.0141	0.0193
	±7	±55	±29	±3	±29		±26
	(c)	(+0.0034)	(-0.0349)				(d)
AG Per	4.735	5.330	7.189	0.259	-1.600	-1.57	6.93
	±36			±3	±1.141		
	(a)	(-0.595)	(-2.454)				(b)
AS Cam	0.136	0.238	0.442	0.085	-0.119	-0.185	0.357
	±15	±98	±33	±2	±67		±31
	(e)	(-0.102)	(-0.306)				(f)
V889 Aql	0.0151	0.0141	0.0205	0.0119	+0.0055	+0.0072	0.0086
	±49			±19	±48		
	(g)	(+0.0010)	(-0.0054)				(b)
EK Cep	0.0823	0.0324	0.0652	0.0362	+0.0034	+0.0117	0.029
	±75	±102	±102	±2	±2		±10
	(h)	(+0.0499)	(+0.0171)				(i)
V1143 Cyg	0.0337	0.0279	0.0419	0.0180	+0.0040	-	0.0239
	±20	±141	±139	±4	±6		±135
	(j)	(+0.0058)	(-0.0082)				(j)

References:
a: *Giménez et al.,1987*
b: *Moffat,1984*
c: *Martynov and Lavrov,1987*
d: *Guinan and Maloney,1985*
e: *Maloney et al.,1986*
f: *Khaliullin and Kozyreva,1983*
g: *Giménez and Scaltriti,1982*
h: *Hill and Ebbinghausen,1984*
i: *Khaliullin,1983*
j: *Giménez and Margrave,1985*

M.W.: Data are taken from *Moffat (1984)*. All rates are in (deg/years).

$\Delta_1 = \dot{\omega}_{OBS} - \dot{\omega}^{THEOR}_{CL+NGT}$; $\Delta_2 = \dot{\omega}_{OBS} - \dot{\omega}^{THEOR}_{CL+GR}$.

very large uncertainties in the output $\dot{\omega}_{NGT}$ values.

ii) The above mentioned input errors give a possibility to determine the general relativistic part with much better accuracy.

iii) The classical effect generally has a large error due to two very uncertain factors, viz. the internal structure constants and the ratio of rotational and orbital velocities (ω_r/ω_K).

iv) With the up-dated physical parameters of these systems the CL+NGT combined effects cannot approximate the observations so well as in Moffat's paper *(Moffat, 1984)*, but it can be done better than by CL+GR.

v) The traditional CL+GR rates are in agreement with the observed ones within the limits of error for V889 Aql, EK Cep and V1143 Cyg. They are considered as nonproblematic systems. Thus, only Y Cyg, DI Her, AG Per and AS Cam show some discrepancies from General Relativity.

vi) The NGT (with classical mechanics) gives an apsidal motion rate (for EK Cep) which deviates from the observed value by almost 5σ! Although the relative error of $\dot{\omega}_{CL}$ is about 34% in this case.

It seems that neither General Relativity nor the Nonsymmetric Gravitational Theory can be retained or rejected without further detailed study of this problem.

NODAL REGRESSION

As a second step, let us consider what follows if we want to keep the GR at any cost.

In this case, obviously, we have to dissect the Newtonian contribution. We have two very uncertain quantities in it, viz. the k_2, k_3, etc. parameters of the internal structure of stars and the ω_r/ω_K ratio. For the former, one can make only rough estimates based upon stellar model calculations: for the latter there is a confusion in the literature. Some authors take for the above mentioned binaries the preliminary (but not confirmed) assumption of $\omega_r/\omega_K=1$, while some others take the well-known formula of the synchronized rotational velocity of the components of an eccentric binary system:

$$\frac{\omega_r}{\omega_K} = 1 + \frac{(12e^2)^{3/8}}{2} \tag{1}$$

to the lowest order in eccentricity *(Zahn, 1977* and *Giuricin et al., 1984)*. The theoretical values of this ratio are 1.30, 1.74, 1.17, 1.34, 1.50, 1.26, 1.80 for Y Cyg, DI Her, AG Per, AS Cam, V889 Aql, EK Cep and V1143

Cyg, respectively.

For DI Her, *Guinan and Maloney (1985)* accepted 3.50 and 3.78 (for the primary and secondary components, respectively). Other authors took equal values for the two components: 3.6 *(Moffat, 1984)*, 3 *(Martynov and Khaliullin, 1980)*, 7 *(Koch, 1973)*. In the cases of EK Cep and AG Per one can find values from 0.8 to 1.4, and from 1 to 2.5, respectively. The ratio is usually taken as 1 for AS Cam and V1143 Cyg, or V889 Aql and Y Cyg. Moffat took 4.7 and 2.4 for the latters, respectively *(Moffat, 1984)*.

Shakura has shown *(Shakura, 1985)*, that if we omit the generally supposed circumstances, namely that the rotational axes of both components are perpendicular to the orbital plane, then we shall be able to rectify the observed discrepancies even under reasonable conditions. He presented two examples supporting this conception. If one takes the rotational axes into the orbital plane ($\alpha_1=\alpha_2=90^\circ$), one will recover the observed $\dot{\omega}_{OBS}$ rates by taking about 3, and 9-10 for the values ω_r/ω_K in the case of AS Cam and DI Her, respectively *(Shakura, 1985)*. This latter fact demands somewhat faster axial rotations but, as Shakura mentioned, it can be compensated by a suitable choice of β_1, β_2 (angles between the rotational axes and the line from the observer to the center of the system). With the appearance of the new part with negative sign in the generalized expression of $\dot{\omega}_{CL}$, the nodal line and the orbital inclination must be affected by secular variations *(Barker and O'Connell, 1978)*.

Nodal regression may also be caused by the perturbations of a third body. This assumption has also been taken into consideration in the case of DI Her *(Martynov and Khaliullin, 1980)*, but at present there exists no observational evidence of its existence. In the case of AS Cam, Al-Naimiy called attention to the existence of an $L_3=0.047$ (at 525 nm) intensity, which can be cancelled out from the solution of the light curve. This may be observational evidence of an about 12 mag faint third member of the system *(Al-Naimiy, 1978)*. V889 Aql also has a possible third body, corresponding to the existence of an $L_3=0.185$ (in V band, *Khaliullin and Khaliullina, 1987)*.

There are some other likely items of observational evidence for the existence of nodal regression in the case of OO Aql *(Demircan and Güdür, 1981)*, IU Aur, AY Mus *(Schaefer, 1981)* and AH Cep *(Mayer, 1987)*. Another possible candidate is α CrB *(Alexander, 1976)*. But for any other eclipsing binaries exact evidence has not been found yet.

The fact that we suppose inclined rotational axes gives rise to some questions about the origin of binary stars and their evolution. Discussion of this problem is not our aim. However, one has to keep in mind that all of the problematical systems are young, with massive components being before or in the main-sequence evolutionary status. The logarithms of their approximate ages are 7.396 for AG Per *(Shibata and Mimura, 1976)* and 7.699 for DI Her *(Popper, 1982)*. The primary of EK Cep is a zero-age main sequence star while its secondary is a pre-main-sequence one *(Popper, 1987)*. V1143 Cyg, which was concluded as a non-problematical system, has a log(t)= 9.2 *(Giménez and Margrave, 1985)*. With respect to the other problematical binaries we had no available data for their age.

For such young systems the characteristic time scale of vanishing of the inclination of the components' rotational axes can easily be much longer than the present age of the systems itself. This question needs further detailed study.

If the rotational axes are not perpendicular to the orbital plane (or owing to any other reason) a nodal regression occurs, then it must be reflected on the light curve as complicated variations of the depth of minima *(Shakura, 1985, Hegedüs and Nuspl, 1986)*. The general view of such kind of variations has shown (under some simplified conditions) for the concrete example of DI Her *(Hegedüs and Nuspl, 1986)*.

DEPTHS OF LIGHT MINIMA

Our third purpose was to search for the existence of such behaviour of depth of light minima among the above listed stars.

Unfortunately, photometric data in the standard UBV system available to us at the present time, were limited. Numerous visual or/and photographic estimates are not of use because of their inaccuracy and incompatibility with the recently used photometric systems. Some otherwise very good and numerous measurements were also not adopted here since they were given in an instrumental, or in another standard photometric system. We have accepted the measurements published transformed into the Johnsonian standard UBV system. The time variations of minima depth are expected to have about some hundredths of stellar magnitude as their amplitudes, and are expected to have from 60 to 1000 years as their periods.

This work is in progress: published or unpublished UBV data from individual authors and from databases are continuously collected. In view of this, the following remarks represent only a short preliminary report.

All the values of minima depths currently available are shown in Table 3, with the time intervals covered by the individual data series and

TABLE 3: DEPTHS OF MINIMA OF THE PROBLEMATIC BINARIES

SYSTEM:	J.D.	R	Depth of primary minima			Depth of second. minima		
	(-2400000)		(V)	(B)	(U)	(V)	(B)	(U)
Y Cyg	39712-42577	a	0.601	0.602	0.587			
	39712-40528	a	(0.593)	(0.596)	(0.573)			
			±7	±5	±21			
	41127-41229	b	(0.574)	(0.569)	(0.585)			
			±7	±15	±16			
	44081-44083	s					(0.585)	
							±6	
DI Her	38245-38308	c	(0.716)?	(0.719)?		(0.547)?		
			±16 ?	±21 ?		±18 ?		
	(1950-1978)	d	0.715	0.727	0.785	0.577	0.563	0.530
	40016-43718	e	(0.707)	(0.723)	(0.773)	(0.549)	(0.548)	(0.516)
			±5	±6	±6	±6	±6	±7
AG Per	37963-38020	t	(0.273)	(0.276)	(0.286)	(0.253)	(0.261)	(0.241)
			±9	±13	±17	±14	±17	±20
	38351-38363	c	(0.289)?			(0.296)?		
			±10 ?			±12 ?		
	42330	u	(0.266)	(0.267)	(0.284)	(0.263)	(0.267)	(0.275)
			±9	±9	±11	±12	±10	±10
	42384-42757	f	0.282	0.285		0.281	0.277	
			(0.277)	(0.284)		(0.281)	(0.277)	
			±3	±4		±3	±3	
	44897-44915	v	(0.272)	(0.274)		(0.278)	(0.278)	
			±10	±11		±9	±11	
	47118.4458	g	0.285	0.295				
			±13	±18				
AS Cam	(1968-1969)	h		0.61 ?			0.34 ?	
	40556-41011	i	0.620	0.655	0.735	0.395	0.395	0.335
			±11	±9	±19	±11	±9	±19
	41547-42580	j	0.595	0.625		0.390	0.385	
	44937-44971	k	0.593	0.630		0.363	0.355	
			±3	±3		±4	±5	

TABLE 3: (continuation)

SYSTEM:	J.D.	R	Depth of primary minima			Depth of second. minima		
	(-2400000)		(V)	(B)	(U)	(V)	(B)	(U)
AS Cam	44937-44971	k	(0.601)			(0.365)		
			±3			±4		
	46771	l	0.590					
V889 Aql	38932-39655	c	(0.552)?			(0.443)?		
			±19 ?			±21 ?		
	41812-43399	m	(0.546)?			(0.419)		
			±20 ?			±4		
EK Cep	38971-39023	n	1.246	1.326		0.130	0.070	
				(1.327)			(0.070)	
				±6			±2	
	40882-40891	o				(0.106)	(0.074)	
						±4	±6	
	43144-43874	p	(1.20) ?			(0.10) ?		
	43902-44630	q	1.204	1.326		0.115	0.075	
			±3	±3		±4	±6	
			(1.217)			(0.117)		
			±5			±3		
V1143 Cyg	38932-39655	r	0.525	0.533	0.535	0.214	0.213	0.215
			(0.520)	(0.527)	(0.527)	(0.211)	(0.210)	(0.214)
			±4	±4	±4	±2	±2	±3
	40835-41173	o	(0.525)	(0.536)				
			±7	±6				

Remarks:
a: *O'Connell, 1977*
b: *Zaitseva et al., 1971*
c: *Semeniuk, 1968*
d: *Martynov and Khaliullin, 1978*
e: *Martynov and Khaliullin, 1980*
f: *Güdür, 1978*
g: this paper
h: *Hilditch, 1969*
i: *Padalia and Srivastava, 1975*
j: *Gülmen et al., 1976*
k: *Khaliullin and Kozyreva, 1983*
l: *Guinan et al., 1987*
m: *Bernardi and Scaltriti, 1978*
n: *Ebbinghausen, 1966*
o: *Guarnieri et al., 1975*
p: *Hill and Ebbinghausen, 1984*
q: *Khaliullin, 1983*
r: *Snowden and Koch, 1969*
s: *Giménez and Costa, 1980*
t: *Jones, 1969*
u: *Woodward and Koch, 1987*
v: *Giménez et al., 1987*

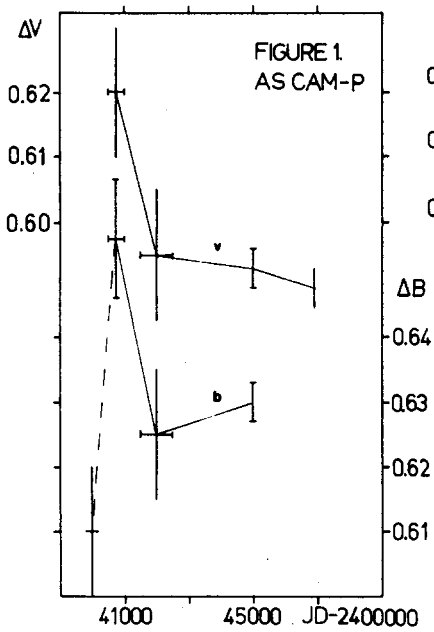

Figure 1.
Depth of pri. min. of AS Cam

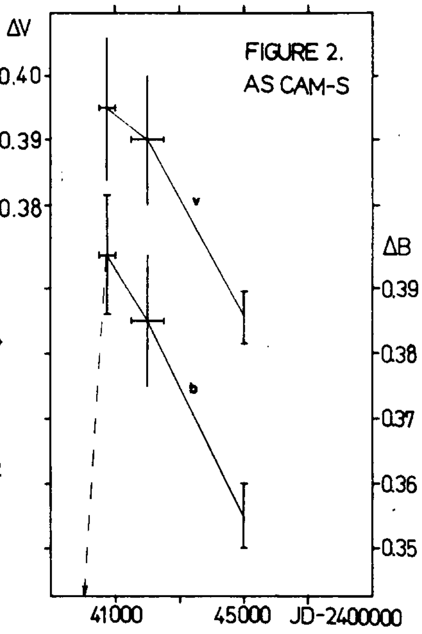

Figure 2.
Depth of sec. min. of AS Cam

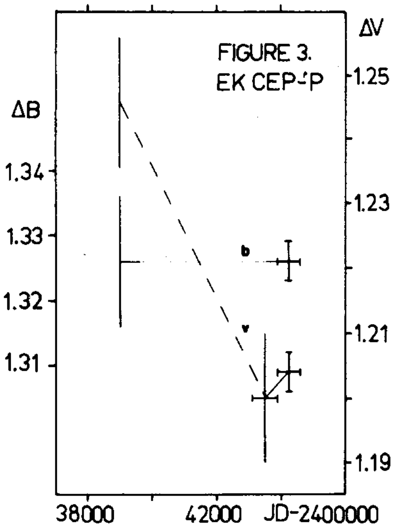

Figure 3.
Depth of pri. min. of EK Cep

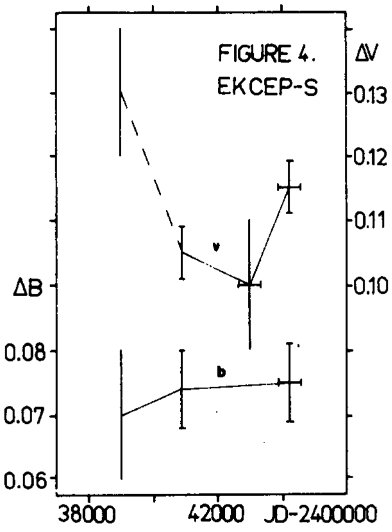

Figure 4.
Depth of sec. min. of EK Cep

(Error bars are closed/opened if they were unpublished/published in the source literatures).

with their sources. The data in parentheses are resulted from our least-squares parabolic fitting to the measured points (very near the center of minima). This was done for lack of published values of the depth of minima, but for some other cases also, in order to check our method and the methods of other authors. The mean value of brightness measurements outside of eclipses was taken as the maximum light level. In some cases, due to the lack of these kinds of measurements we took data from other authors. Establishing the maximum light of the system was sometimes quite difficult because of slight proximity effects or intrinsic variations.

At the moment we cannot say anything about the existence or absence of secular variations of the depth of minima among the problematic systems, and of the constancy among non-problematic ones. The data at our disposal are very few, and are extended to only a short time interval in relation to the time scale of the expected variations.

Two interesting cases having many data are shown in Figs. 1-4. AS Cam is a problematic system. In Figs. 1 and 2 we present the changes of depths of minima, observed in V and B light. The measurements in these two bands can be considered as the check of each other. The error bars of stellar magnitudes are closed in the case of known values, and are open in the case of suspected ones. The first value is very uncertain. Probably it was not made in the standard B band, rather in an instrumental one. AS Cam seems to show a predicted kind of variation.

EK Cep was concluded as a non-problematic system, so it was not expected to show secular variations of minima depths referring to a nodal regression. As one can see from Figs. 3 and 4, the B measurements demonstrate the constancy well, while in the V measurements one can find much deeper minima at the earlier epoch. This latter fact makes it questionable whether those values are really correct.

FINAL REMARKS

It would be advisable to measure the depth of minima from time to time with greater accuracy, with the same (UBV) measuring system and using the same procedure in the standardization and data reduction (making the available data set homogeneous). For the sake of safe verification of the existence (in the cases of Y Cyg, DI Her, AG Per and AS Cam) or absence (in the cases of V889 Aql, EK Cep and V1143 Cyg) of nodal regression we should have high-quality, homogeneous UBV photometric data on the depth of minima, distributed over wide time intervals.

Finally, we would like to call attention to the possibility of independent determination of spatial orientation of the orbit (by polarimetric measurements, see *Rudy, 1979*), and of the true position of rotational axes of the components of a close binary system (by spectroscopic method, see *Rossitter, 1924).* It would be very important to apply these techniques to the problematic eclipsing binaries.

REFERENCES:

Alexander, M. E., 1976, Astrophys. Space Sci. 45, 105.

Al-Naimiy, H. M. K., 1978, Astrophys. Space Sci. 59, 3.

Barker, B. M. and O'Connell, R. F., 1978, in "Physics and Astrophysics of Neutron Stars and Black Holes" (ed. Giacconi and Ruffini) Bologna, Italy, 1978. 437.

de Bernardi, C. and Scaltriti, F., 1978, Acta Astron. 28, 221.

Demircan, O. and Güdür, N., 1981, in "Photometric and Spectroscopic Binary Systems" (ed. Kopal and Carling), Maratea, Italy, 1980. 413.

Ebbinghausen, E. G., 1966, Astron. J. 71, 642.

Giménez, A., 1985, Astrophys. J. 297, 405.

Giménez, A. and Costa, V., 1980, Publ. Astron. Soc. Pacif. 92, 782.

Giménez, A. and Scaltriti, F., 1982, Astron. Astrophys. 115, 321.

Giménez, A. and Margrave, T. E., 1985, Astron. J., 90, 358.

Giménez, A., Kim, C.-H. and Nha, I.-S., 1987, Monthly Notices Roy. Astron. Soc. 224, 543.

Giuricin, G., Mardirossian, F. and Mezzetti, M., 1984, Astron. Astrophys. 131, 152.

Guarnieri, A., Bonifazi, A. and Battistini, P., 1975, Astron. Astrophys. Suppl. Ser. 20, 199.

Guinan, E. F. and Maloney, F. P., 1985, Astron. J. 90, 1519.

Guinan, E. F., Maloney, F. P. and Boyd, P. T., 1987, I.B.V.S. No. 3029.

Güdür, N., 1978, Astrophys. Space Sci. 57, 17.

Gülmen, Ö., Ibanoglu,C., Bozkurt, S. and Güdür, N., 1976, I.B.V.S. No. 1090

Hegedüs, T. and Nuspl, J., 1986, Acta Astron. 36, 381.

Hilditch, R. W., 1969, Observatory 89, 143.

Hill, G. and Ebbinghausen, E. G., 1984, Astron. J. 89, 1256.

Jones, D. H. P., 1969, Acta Astron. 19, 53.

Khaliullin, Kh. F., 1982: Soviet Astron. Tsirk. No. 1214, 1.

Khaliullin, Kh. F., 1983: Soviet Astron. Zhurn. 60, 72.

Khaliullin, Kh. F. and Kozyreva, V. S., 1983, Astrophys. Space Sci. 94, 115

Khaliullin, Kh. F. and Khaliullina, A. I., 1987, Soviet Astron Tsirk. No. 1485, 4.

Koch, R. H., 1973, Astrophys. J. 183, 275.

Maloney, F. P., Guinan, E. F., Boyd, P. T., Donahue, R. A. and Loeser, J. G., 1986, Bull. Amer. Astron. Soc. 18, 985.

Martynov, D. Ya. and Khaliullin, Kh. F., 1978, Soviet Astron. Tsirk. No. 1016, 1.

Martynov, D. Ya. and Khaliullin, Kh. F., 1980, Astrophys. Space Sci. 71, 147.

Martynov, D. Ya and Lavrov, M. I. Letters to Soviet Astron. Zhurn. 13, 218.

Mayer, P., 1987, Bull. Astron. Inst. Czech. 38, 58.

Moffat, J. W., 1984, Astrophys. J. 287, L77.

O'Connell, D. J. K., 1977, Richerche Astron. 8, No. 29, 543.

Padalia, T. D. and Srivastava, R. K., 1975, Astrophys. Space Sci. 38, 87.

Popper, D. M., 1974, Astrophys. J. 188, 559.

Popper, D. M., 1982, Astrophys. J. 254, 203.

Popper, D. M., 1987, Astrophys. J. 313, L81.

Rossitter, R. A., 1924, Astrophys. J. 60, 15.

Rudy, R. J., 1979, Monthly Notices Roy. Astron. Soc. 186, 473.

Schaefer, B. E., 1981, Publ. Astron. Soc. Pacif. 93, 225.

Semeniuk, I., 1968, Acta Astron. 18, 1.

Shakura, N. I., 1985, Letters to Soviet Astron. Zhurn. 11, 536.

Shibata, Y. and Mimura, K., 1976, Sci. Rep. I. 60, 31.

Snowden, M. S. and Koch, R. H., 1969, Astrophys. J. 156, 667.

Woodward, E. J. and Koch, R. H., 1986, Astrophys. Space Sci. 129, 187.

Zahn, J.-P., 1977, Astron. Astrophys. 57, 383.

Zaitseva, G. V., Lyutyi, V. M. and Martynov, D. Ya., 1971, Soviet Astron. Tsirk. No. 662, 1.