THE KUKARKIN-PARENAGO RELATION FOR DWARF NOVAE AND NOVAE

L.I. ANTIPOVA
Astronomical Council of the USSR Academy of Sciences,
Moscow, U.S.S.R.

ABSTRACT. The period-amplitude relation and the period-energy relation for dwarf novae and novae are discussed. The total outbursts energy is shown to be a more suitable characteristic of the outburst than its amplitude.

Fifty years ago Kukarkin and Parenago (1934) established that there was a linear relation between the logarithm of an outburst period and its amplitude expressed in magnitudes for dwarfs and recurrent novae. This relation supposes that outbursts of classical novae must also reoccur. Since then, this relation has been revised and specified many times (Kopilov, 1954; Efremov and Kholopov, 1966).

Kholopov and Efremov (1976) established the period-amplitude relation for dwarf and recurrent novae using the data available by 1976. They found that dwarf and recurrent novae followed the same period-amplitude relation, however there was a gap 6000 days wide between them.

New important data obtained recently led us to reexamine this problem.

The new outburst of WZ Sge which was originally considered to be a recurrent novae occured in 1978. The visual and ultraviolet observations of WZ Sge during the outburst showed, however, that there is no evidence of ejecta. The behavior of WZ Sge is typical for dwarf novae during their outbursts (McGraw, 1979; Crampton and Hutchings, 1979; Bailey, 1979; Ortolani et al., 1980; Holm et al., 1980). Now it is classified as a dwarf novae with an extraordinarily large amplitude.

WX Cet was considered to be a typical novae (its outburst was observed in 1963). A study of Harvard patrol plates revealed three further outbursts (Gaposchkin, 1976a, 1976b). Due to the close resemblance of WX Cet and WZ Sge, Bailey (1979) proposed that these

Paper presented at the IAU Colloquium No. 93 on 'Cataclysmic Variables. Recent Multi-Frequency Observations and Theoretical Developments', held at Dr. Remeis-Sternwarte Bamberg, F.R.G., 16–19 June, 1986.

Astrophysics and Space Science **131** (1987) 453–459.

objects together with UZ Boo form a distinct subgroup of dwarf novae which is characterized by very strong and very rare outbursts. The investigation and comparison of the spectra of WX Cet and WZ Sge at minimum brightness also showed their close resemblance (Downes and Margon, 1981).

VY Aqr was considered to be a recurrent novae (with outbursts in 1907 and 1962). A new outburst occured in 1983. Several outbursts were also found on old plates. Thus the outburst period of VY Aqr is significantly shorter than it was thought formerly. VY Aqr proves to be a cataclysmic variable.

The period-amplitude relation is usually built with the aid of the data of the General Catalogue of Variable Stars (GCVS) (Kukarkin et al., 1969) and its Supplements. The scattering of amplitude values for certain periods is about $\pm 2^m$. The magnitude at the minimum brightness of dwarf novae does not remain constant, but fluctuates slightly. The magnitudes at maximum brightness for different outbursts are also different. The GCVS gives the lowest and the highest brightnesses recorded for every star. It is clear that the outburst amplitude calculated on the basis of the GCVS data is not the best characteristic of the outburst intensity. The scattering of points would decrease when the amplitude is defined as the difference between the mean level of the minimum brightness and the mean level of the outburst brightness and then the mean amplitude for a large number of outbursts is derived.

The aim of our work is to establish the period-energy relation using current data. At first thirty dwarf novae with extended series of observations were selected for this aim. Using their light curves the mean outburst energy in relative units (relative to the radiation energy at minimum brightness) was determined for every star. The dwarf novae systems are very similar. There are no great differences in their luminosities and temperatures at minimum brightness. According to Schmidt-Kaler (1962), their mean absolute magnitude at minimum brightness is $+7.2^m$, and Kraft and Loyten (1965) give $+7.5^m$. We assume that the dwarf novae have the same minimum luminosity, i.e. the relative units are also the same. The combined period-energy relation is given in Figure 1b. For comparison the period-amplitude relation for the same dwarf novae was derived from GCVS data. It is shown in Figure 1a. One can see from the figure that the majority of the dwarf novae forms a sequence, several stars falling below it. According to the current conception, a dwarf novae is a close binary system consisting of a white dwarf (primary) and a cold component (secondary); the outburst is connected with the primary. The outburst amplitude is usually determined from visual observations. For most dwarf novae the secondary visual luminosity is low, and in general the total system luminosity is defined by the primary luminosity. It is interesting to note that all stars below this sequence have a common property: in their spectra there are evidences of a cold component. Probably the cold component makes the main contribution to the total visual luminosity of such a system. Therefore the

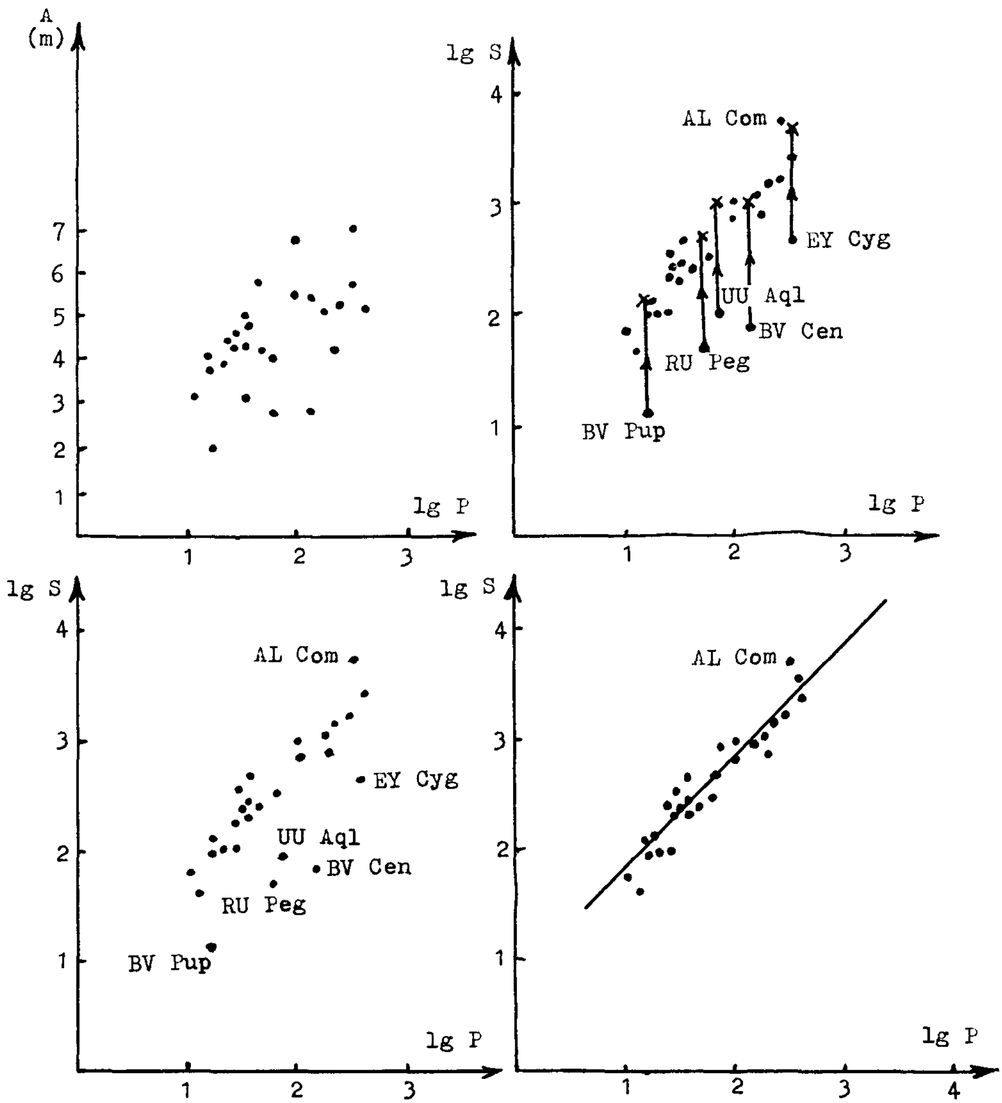

Figure 1. Period-energy relation for dwarf novae:
a-The period-amplitude relation for dwarf novae on the basis of the GCVS;
b-The period-energy relation for the same stars;
c-The amplitude corrections taking into account the secondary influence;
d-The final diagram of the period-energy relation for dwarf novae.

https://doi.org/10.1017/S0252921100105202 Published online by Cambridge University Press

outburst amplitude must decrease. It is likely that these stars lie below the period-energy sequence. Let us assume that the contributions of the primary and the secondary to the total system luminosity are equal if lines of both components are seen in the spectrum. Then an amplitude correction can be calculated. Such a correction for the stars below the common sequence is shown in Figure 1c, and the final diagram of the period-energy relation for dwarf novae is given in Figure 1d.

Several conclusions can be derived from Figure 1:

1. The scattering of the points in Figure 1d is less than in Figure 1a. Therefore one may conclude that the energy is more suitably characteristic of the outburst intensity than its amplitude, i.e. it is necessary to take into account not only the outburst amplitude but also its duration.

2. When the secondary is taken into account, good results are obtained, and our current conception that the outburst is connected with the white dwarf is supported.

3. The total outburst energy is proportional to the cycle length, according to the current conception about the nature of dwarf novae.

An attempt of establishing a period-energy relation for SU UMa-type stars was made (Figure 2). In this figure, each star is represented by two points corresponding to a normal outburst and a supermaximum. The dotted line gives the period-energy sequence for dwarf novae. It is interesting to note that the inclination of the lines connecting the points corresponding to the normal outbursts and the supermaxima practically coincides with the inclination of the period-energy sequence for dwarf novae. This means that the total outburst energy is also proportional to the energy accumulation time, but the energy accumulation reservoirs for normal outbursts and for supermaxima are different, i.e. these outbursts originate from different regions.

The position of the WZ Sge subgroup stars (dwarf novae with very strong and very rare outbursts) is shown in Figure 3a. Because of the lack of data, the outburst energy cannot always be estimated. Therefore the position of these stars on the period-amplitude sequence is also shown (Figure 3b). Here the amplitude values for each star are estimated as the average value for a large number of outbursts, The WZ Sge-type stars fall within the limits of the sequence for usual dwarf novae. Note that the gap between dwarf novae with small and large amplitudes is less than according to previous data (Kholopov and Efremov, 1976). This fact is due to the discovery of a number of unknown outbursts of some stars when revising old plates; this allowed us to specify periods and types of these stars. For example, WX Cet, discovered in 1963 as novae, proved to be a cataclysmic variable (four outbursts of this star are known). It is possible that the gap is connected with observational selection effects and would disappear when other, unknown outbursts would be discovered. Some novae with unusually small amplitudes may be candidates in this gap.

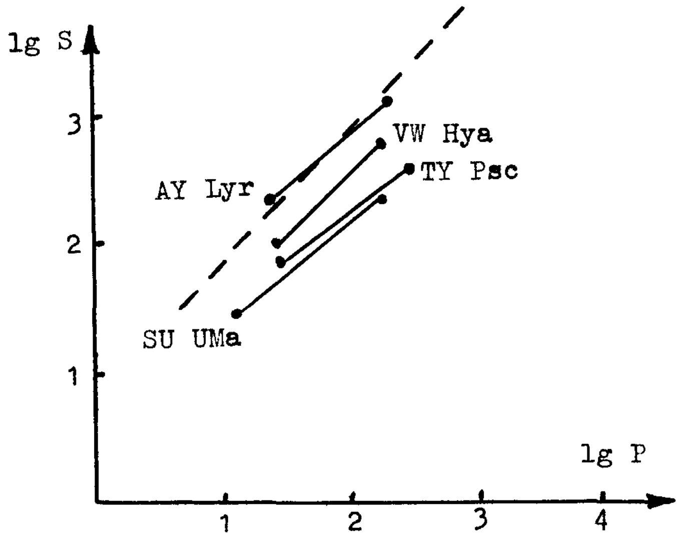

Figure 2. The period-energy relation for SU UMa-type stars.

Between recurrent novae there are objects that have only primary lines in their spectrum and objects that have also traces of the secondary lines. The orbital periods of recurrent novae are very different; for example T CrB is often classified as a symbiotic star. However, after taking into account the amplitude correction, due to the influence of the secondary, all recurrent novae fall on the period-energy sequence for dwarf novae. This confirms the conclusion of McDonald (1983), that a thermonuclear runaway is not followed by recurrent novae outbursts.

According to the current conception the classical novae outbursts are connected with their binary nature. The reason for the outburst is a thermonuclear runaway in the hydrogen-rich matter lost by a cold component and accreted by a white dwarf. This novae outburst model is followed by recurrent outbursts: the outburst takes place when the mass of an accretion layer reaches a critical value; a significant fraction of this matter is ejected during the outburst; the accumulation of a new accretion layer takes place between outbursts. Therefore a period-energy relation should exist for classical novae, however because of the different special energy production, the inclination of this sequence is expected to be different. Unfortunately, it is impossible to check this, because the period between outbursts of a classical novae is estimated to be about 10^5 years. Pskovskii (1974) supposed (on the basis of the analysis of old chronicles) that the classical novae GK Per and V603 Aql had already flashed earlier. The periods of the outbursts were estimated to be 1062 and 1793 years, respectively. The attempt to derive the period-energy dependence for classical novae using these data was not a succes. It is possible that the identification with an outburst mentioned in the

https://doi.org/10.1017/S0252921100105202 Published online by Cambridge University Press

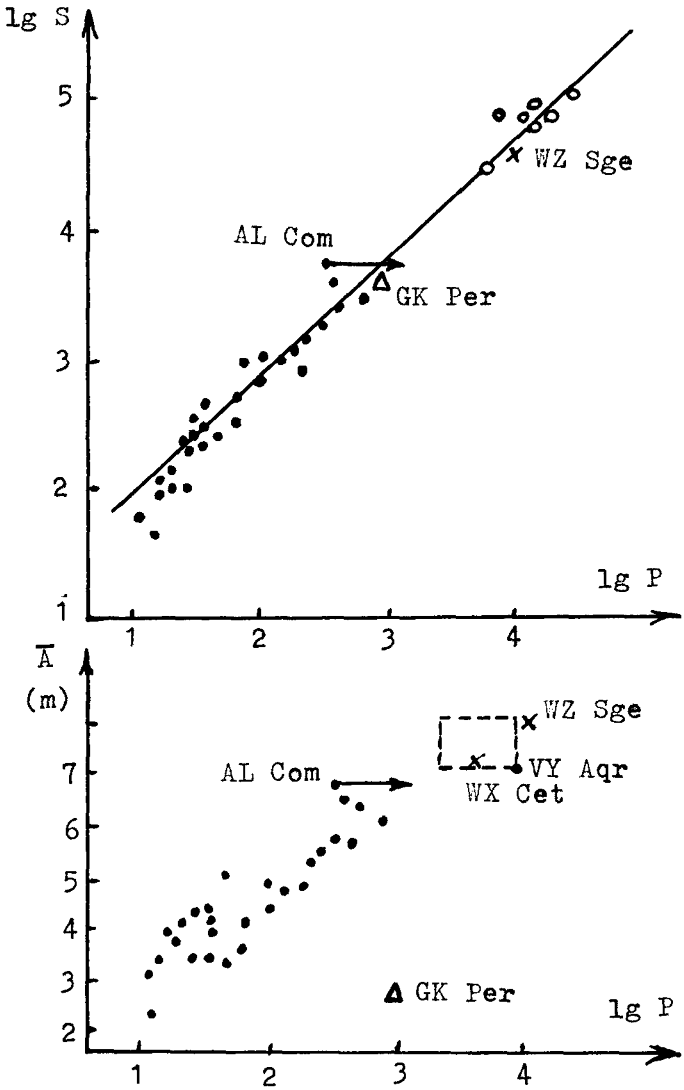

Figure 3. The period-energy relation (a) and the period-amplitude relation (b) for cataclysmic variables:
- -dwarf novae;
- -recurrent novae
- -WZ Sge subgroup stars;
- -GK Per.

chronicles is uncertain.

Finally a few comments about GK Per. After the 1901 outburst it is at minimum brightness. It is known that this post-nova behaves like a dwarf novae: its magnitude increases by $2\text{-}3^m$ every 2-3 years. Estimating the energy of these small outbursts and correcting the amplitude for the influence of the secondary (the spectrum of GK Per is sdBe + K2 Vp), one may conclude that this novae does not follow the period-amplitude relation, but falls on the period-energy sequence. There is probably a parameter which defines the outburst shape (correlation between amplitude and duration) with the same total energy.

If this is true for classical novae, one can understand why only one outburst of the novae HR Del was recorded. The outburst amplitude of this very slow novae is only 8^m, and according to the amplitude-period relation the interval between the outbursts is to be small. Because of long duration of the outburst the total energy is higher than that of a fast novae. Therefore the interval between outbursts is to be longer than that of fast novae. This conclusion is also true for the very slow novae RR Tel.

REFERENCES

Antipova L.I., 1977. Astron. Zh., 54, 68.
Bailey J., 1979. Monthly Notices of R.A.S., 189, 41P.
Downes R.A., Margon B., 1981. Monthly Notices of R.A.S., 197, 35P.
Efremov Yu.N., Kholopov P.N., 1966. Astron. circ., N384, 1.
Gaposchkin S.I., 1976a, IBVS, N1204.
Gaposchkin S.I., 1976b. Bull. Am. Astron. Soc., 8, 520.
Holm A.V., Wu Chi-Chao, Sparks W.M., Schiffer F.H., Boggess A., 1980. "Close Binary Stars: Observ. and Interpretat". Dordrecht, e.a., 447.
Kholopov P.N., Efremov Yu.N., 1976. Variable Stars, 20, 277.
Kopilov I.M., 1954. Doklady Akademii Nauk SSSR, 99, N4, 515.
Kraft R.P., Luyten W.J., 1965. Astrophys. J., 142, 1041.
Kukarkin B.V., Paranego P.P., 1934. Variable Stars. 4, 251.
Kukarkin B.V., Kholopov P.N., Efremov Yu. N., Kukarkina N.P., Kurochkin N.E., Medvedeva G.I., Perova N.B., Fedorovich V.P., Frolov M.C., 1969. General Catalogue of Variable Stars. Moscow.
McDonald J., 1983. "Cataclysmic. Var. and Relat. Objects", 72 Colloq. Astron. Union. Haifa, 77.
MacGraw, 1979. IAUC N3311.
Ortolani S., Rafanelli P., Rosino L., Vittone A., 1980. Astron. Astrophys., 87, 31.
Pskovskii Yu.P., 1974. "Novae and Supernovae", Moscow, ed. Science.
Schmidt-Kaler Th., 1962. Kleine Veröff der Remeis-Sternwarte Bamberg, 34, 109.
van Paradijs, 1983. Astron. Astrophys., 125, L16-L18.