THE SYSTEM OF SECONDARY PERIODICITIES AND RESONANCES BASED ON β LYRAE MAGNETIC FIELD

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ABSTRACT. Original integral interconsistent and interconnected magnetohydrodynamical system of periodicities and resonances over their long-time variabilities is developed. The study is based upon three different observed secondary periods in β Lyrae system and taking into account geometrical features of the non-standard magnetic field in a losing star, as well as due to the asynchronizm of the orbital and rotational periods.

Key words: Stars: binary: cataclysmic; stars: individual: AM Her, TT Ari, BZ Cam.

1. Introduction

It should be recognized that after twenty years of magnetic field research of the β Lyrae system (Skulsky 1985, 1986, 1990; Skulsky and Plachinda, 1993) our comprehension of the subject appears to be insufficient. Existence of the losing star (hereafter, loser) as the magnetic rotator in an interacting close binary system should produce complex causal relationships and their detection could occur unexpectedly. Recently we have shown this with the example of the first stage of nature studies of the three mostly observable secondary periods in their detected relationship with the magnetic field geometry of the loser (Skulsky, 2000). To develop our ideas we present here certain results of further studies of nature of this phenomenon. Firstly, we will characterize these secondary periods and elaborate the matter of the issue.

2. To physics of observational second periods.

The first of these periods has a century-old prehistory of researching the long-term changes of the light curve. However, similar and reliable data concerning such changes in the shape of the light curve between its two extremes, namely with the duration of 240d and (275±20)d respectively, were presented in relatively recent studies by Alduseva and Kovalenko (1976) and Guinan, (1989). Yet, Van Hamme et al., 1995 found the period of (283.39±0.26)d due to the deviations from 150 years-averaged light curves; and Harmanec et al., 1996 found the period of (282.425±0.070)d with the amplitude of A=$0.^m0326 \pm 0.^m0.0008$ with the similar procedure for the averaged light curve using the most accurate observations available over the last 36 years. Only then, was the secondary period of (283±1)d considered a fact. It was unclear why such a considerable difference (much more than 3σ) in 0.965d for the value of this period was obtained by the two groups of scientists, as well as the reasons of existence of this period itself and its physical nature.

The second of these periods, a much shorter one of 4.74d was given in Harmanec's et al. (1996) as well. This period is detected by the deviations from averaged curves of radial velocities of strong emission lines (which were obtained with the use of the most accurate available measurements along with our CCD-observations at the 2.6 m telescope - Skulsky and Malkov, 1992; Skulsky, 1993). They have assumed certain causal relationships between long- and short-term periods (let us denote them as T and T_1 respectively) and orbital period P, which is more conveniently to express analytically as:

$$T_1^{-1} = 3(P^{-1} - 2T^{-1}) \qquad (1)$$

Trying to understand the nature of secondary periodicity, we have noticed (Skulsky, 2000) that the period T_1 in the scale of orbital cycle is almost in phase agreement with the first extremum of magnetic field of the loser. This was considered rather strange, since the third independently observed 1.85d secondary period (which is the seventh part of the orbital period) with high amplitude of variable parameter, which we had discovered earlier while performing the absolute spectrophotometry in the H_α a line (Burnashev and Skulsky, 1980), was also clearly revealed during observations of magnetic field strength at the loser surface (Skulsky, 1990; Kosovichev and Skulsky, 1990; Burnashev and Skulsky, 1991). Therefore, we had sufficient background to assume, that there could exist a certain causal relationships between these three observable secondary periods. This is more so if we take into consideration the existing, already clear correlations of magnetic field strength curves with change curve the flux of radiation with phase in H_α a line, with the radial velocity curves of emission lines (Burnashev and Skulsky, 1991; Skulsky and Malkov, 1992; Skulsky, 1993).

Having analyzed the relationship between T_1 and T_2, we presumed (Skulsky, 2000) that: there should exist yet another secondary period with the duration of $T_2 \cong T_1 + T/2$ in the β Lyrae system, which is physically similar to T_1 (it means period T_2 should be in phase coincidence with the second extremum of magnetic field of the loser, and periods T_1 and T_2 should reflect the magnetic field axis orientation); period T_2 should be determined by an equation similar to the (1) equation; long-term period T could arise as (analogue) the particular case of beating period for two much shorter paired periods T_1 and T_2. This equation was found to be expressed as follows:

$$T_2^{-1} = P^{-1} + 4T^{-1} \qquad (2)$$

Solving the system of equations (1) and (2) brings forth in the simple relationships

$$P = \frac{9T_1T_2}{3T_1 + 2T_2} \qquad and$$

$$T = \frac{18T_1T_2}{3T_1 - 2T_2} = \frac{2T_1T_2P}{4T_1T_2 - P(T_1 + T_2)}, \qquad (3)$$

which remind us of classical formulas for the resulting period and beating period of the oscillations with close periods:

$$T_{res} = \frac{2T_1T_2}{T_1 + T_2} \qquad and \qquad T_{bt} = \frac{T_1T_2}{T_2 - T_1}. \qquad (4)$$

These relationships have confirmed our assumptions and their studies have led to the detection of several other periods. For example, more fully set of periods associated with the season of 1980, taking into account the variability of the orbital period (corresponding corrections were made in the equation (1) by Harmanec et al., 1996), is expressed as follows (Skulsky, 2000):

$$\begin{aligned} P &= 12.9355d, \\ T_1 &= 4.746634d, \\ T_2 &= 10.932617d, \\ T &= 282.42524d, \\ P_{bt} &= 2T = 564.85158d, \\ T_{res} &= 6.619338d, \\ P_{rot} &= P_{mag} = 2T_{res} = 13.238675d \end{aligned} \qquad (5)$$

Finally, this has allowed us to make certain conclusions, most of them also presented in the paper of Skulsky, 2000:

1. Secondary periods of T_1, T_2 and T are in the causal resonance interaction between each other and the orbital period.

2. When expressing T_1 and T_2 periods as the phase fractions of the orbital period their determinations is preset by the structure and geometry of magnetic field of the loser, and they are almost projections of magnetic field dipole axis to the orbital plane.

3. When rotational and magnetic periods of the loser rotation are equal, their values are P_{rot}=P_{mag}=2T_{res} (due to (4) formula Tres is resulting for periods T_1 and T_2, which are strictly connected with the geometry of magnetic field of the loser), which exceed the orbital period by several percents, but then the beating period of the orbital and rotational periods of the loser is equal to P_{bt}=2T and is the fundamental one, and observations-based period T being its first harmonics, by its physical nature is a running tidal wave at the loser surface.

4. Difference in ΔT=0.965d between T values, obtained by the deviations from averaged light curves by two groups of scientists Van Hamme et al., 1995 and Harmanec et al., 1996, is the consequence of variability of the orbital period and is caused by the observation sampling which were used for formation of these independent light curves (time difference of the efficient formation is equal to 60 years, and increment of the orbital period over these years is ΔP=0.0131d, which caused corresponding changes of related periods T1, T2 and T; in this case period T=(282.425$\pm$0.070)d concerns the averaged light curve with the center in the season of 1980, and the period T=(283.39$\pm$0.26)d – in the season of 1920 respectively.

3. Interconnected magnetohydrodynamical system of periodicities.

Therefore, yet before starting the present study, we already had the unconventional concepts about the nature of the observed secondary periods and even discovered three new periods T_2, P_{rot}, P_{bt}, thus reaching a certain level of confirmation of the asynchronism of the loser. To the aggregate, conclusions made and the new set of periods claim also that there exits certain group of interconsistent periods in the β Lyrae system, with the pair of adjusted periods T_1 and T_2 being the basic one. This fact convinced us to perform a deeper study of the nature of secondary periodicity in the β Lyrae system, which was based on the following statements and predictions: there are two axes in the β Lyrae system (gravitational axis, passing through the centers of the both components, and magnetic axis of the loser), which spatial location is considerably different along the phase of the orbital period, and this effects on the passing of physical processes in the system; the real magnetic field of the loser has a complex configuration and its magnetic axis could not be the straight line of the classic dipole, in particular, presented above set of the secondary periods could be considered as the result of about $\pm 0.01P$ discrepancy of T_1 and T_2 periods (as phase fractions of the orbital period), with the values of phase angles of the averaged axis of magnetic field dipole (due to the observations at the 6 m telescope and solution of averaged magnetic field strength curve, the field maximum and minimum are equal to 0.355P and 0.855P – Skulsky, 1990; Burnashev and Skulsky, 1991).

In other words, our predictions are based on the statement of non-standard magnetic field structure (one may predict its noticeable quadrupole component, loser asynchronism should be important here as well). This reinforces our assumption that the straight line passing through the loser center and phases of 0.355P and 0.855P of field maximum and minimum of the averaged magnetic field strength curve, is only an imaginary dipole axis, and the real magnetic field dipole is either a little curved or has some other deviations from a line (let us call it "broken dipole") and appears at the loser surface in another phases of the orbital cycle. However, it corresponds to the phase angles of the periods T_1=4.746634d=0.366946P and T_2=10.932617d=0.845164P (by the calculations for the light curve, presented by Harmanec et al., 1996, which we have centered for the season of 1980). In this case one may predict that the pair of adjusted periods T_1 and T_2 is not unique as well, and the group of already discovered periods should be the fragment of yet more full system of periods, which are in a causal relationship between each other. One of them should be the period of 1.85d which we had discovered earlier. It is also observed at the magnetic field strength curve of the loser.

These ideas are presented at the figure, where the loser and gainer are defined with the cross-section of their Roshe surface in the orbital plane. The magnetic field dipole axis of the loser (according to the solution of averaged magnetic field strength curve it passes along the phases of 0.355P and 0.855P) is designated by the thin straight line H_α. Phase angles 0.367P and 0.845P, which correspond to the periods T_1 and T_2 of the "broken dipole", are given with the thicker lines. Assuming that the direction of these lines corresponds to the direction of real magnetic field axis, which spatial location does not depend on the gravitational axis of the binary system, we see that the determination of T_1 and T_2 periods as the phase angles in relation to the gravitational axis is arbitrary. Such angles for example could be counted from the 0.5P phase also; one of them could be counted from the 0.0P phase and the other one from the 0.5P phase or, vice versa. There are eight such variants of adjusted pairs of periods. We will present here only the results of the interaction of four of them. Let us denote as $T_{1,I}$ and $T_{2,I}$ the first variant of adjusted and paired periods which corresponds the set of periods (5). Another three variant II-IV are given in the table, and these pairs of adjusted periods according to the figure above are defined as follows: $T_{1,II}$=0.5P-$T_{1,I}$ and $T_{2,II}$=P-$T_{2,I}$; $T_{1,III}$=$T_{1,I}$ and $T_{2,III}$=$T_{2,I}$-0.5P; $T_{1,IV}$=$T_{2,I}$ and $T_{2,IV}$=$T_{1,I}$+0.5P. Values of three corresponding resulting periods $T_{res,I}$ are also given in the table, which are calculated from the formula (4) as well as the value of $T_{res,I}$.

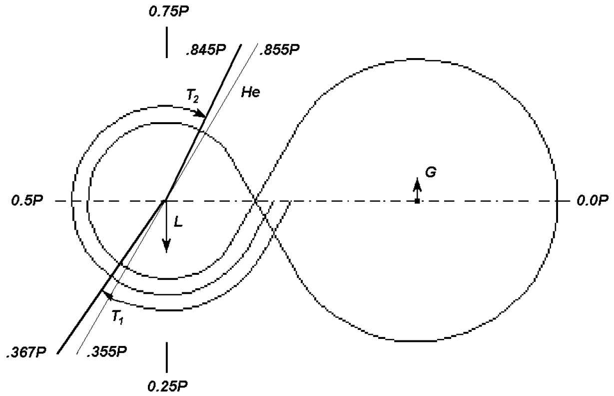

Figure 1: Sketch of the β Lyrae system.

II variant

$$T_{1,II} = 1.721116d = 0.133054P$$
$$T_{2,II} = 2.002883d = 0.154836P$$
$$T_{res,II} = 1.851340d = 0.143121P$$
$$P/T_{res,II} = 6.9871 \cong 7$$

III variant

$$T_{1,III} = 4.74663d = 0.366946P$$
$$T_{2,III} = 4.464867d = 0.345164P$$
$$T_{res,III} = 4.601441d = 0.355722P$$
$$P/T_{res,III} = 2.8111 \cong 14/5$$

IV variant

$$T_{1,IV} = 10.932617d = 0.845164P$$
$$T_{2,II} = 11.214384d = 0.866946P$$
$$T_{res,IV} = 11.071707d = 0.855916P$$
$$P/T_{res,IV} = 1.1683 \cong 7/6$$

Looking at this table let us emphasize, firstly, interadjustment of resulting periods which are multiple with high accuracy to (1/14)P: $T_{res,II}$/P=2/14; $T_{res,III}$/P=5/14; $T_{res,IV}$/P=12/14. There are also very accurate resonance relationships: $3P_{bt} = 131P_{orb}$

$= 128P_{rot}$ or $11P = 30T_{1,I} = 13T_{2,I}$, and they are satisfied for the data of Van Hamme et al., 1995 as well as for the data of Harmanec et al., 1996, which averaged light curves are separated with the interval of 60 years. However, the next two results are much more important from the physical point of view. The first states the fact of coincidence of $T_{res,II}$ with the accuracy of 0.001d with the secondary period of 1.85d, which was firstly detected with high amplitude of variable parameter in absolute spectrophotometry of β Lyrae in H_α line (Burnashev and Skulsky, 1980) and was also clearly revealed during observations of magnetic field strength at the loser surface Skulsky, 1990. We can now state that all three observable secondary periods with the duration of 1.85d, 4.74d and 282.425d are causally interconnected. The second result fixes the coincidence of $T_{res,III}$ and $T_{res,IV}$ with the accuracy of 0.001P with the values of 0.355P and 0.855P of magnetic field extrema, obtained on the base of solution of averaged magnetic field strength curve, formed by the observations of 1980-1988 at the 6 m telescope – Skulsky, 1990; Burnashev and Skulsky, 1991. We can also state now that observed values of magnetic field extrema are averaged, but could be simply calculated if configuration of real magnetic field of the loser reminds the "broken dipole", i.e. it is not the field structure with classic dipole.

3. Conclusion

Main conclusion is that the loser as the component, which is at the final stage of intensive matter loss in the close binary system and at the same time as magnetic rotator of complicated configuration of magnetic field, produces a self-adjusted magnetohydrodynamic system of periods and resonances part of which has already been discovered from methodically different observations of β Lyrae. We see the theoretical background for this new phenomenon in the concepts of parametric resonance when the losing mass of magnetic rotator is a variable parameter. At the stage of active mass transfer to more massive satellite it leads to the observable increase of the orbital period and to the observable changes in the whole magnetohydrodynamic system of the secondary periods.

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