Possible Distortion Effect on The Pulsation of Eclipsing Binary Components

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Abstract

Possible effect of tidal and rotational distortions on the pulsational period in pulsating components of eclipsing binaries is investigated. An approximation formula for the pulsation period P of distorted component as a function of distortion parameters; namely the mass ratio $q = M_2/M_1$ and $r_0 = R/a$ is derived and used in exploring the P variation on the equipotential surface. It was found as expected that the tidal distortion and P variation in phase increases with increasing q and r_0. The P value on the equipotential surface of the primary component of an eclipsing binary become maximum at point closest to first Lagrangian point at phase zero and decreases with decreasing local radius. However, the overall variation in phase seems always less than $....percent$ which may not be observable. An observational test on the primary component of the semi-detached binary AB Cas is presented and discussed in terms of the predictions.

1 Introduction

New class of pulsating stars as components of eclipsing binaries was discovered recently (Mkrtichian et al.,2002). they can be detached and semi-detached binaries (Soydugan et al..2006). Soydugan et al.(2006) provided a catalogue of binaries with at least one component in the instability strip of the H-R diagram. In the case of a pulsating component in a close binary star system, one can not neglect the distortion of the component. Due to proximity in close binary systems, the components are tidally elongated towards each other and flattened by rotation. Such distortions are expected to have an effect on the period of pressure waves travelling inside the star. The components of eclipsing binaries observed in orbital planes (since $i \approx 90$ are visible allaround the equatorial belts. Thus any observable inhomogenity on the surfaces can be detected through observations covering one complete orbital revolution. Any observable change of the pulsation period over the components of eclipsing binaries can also be detected on the light curves of such systems.

In present work we investigate the possible effect of rotational and tidal distortions on the pulsation period of the distorted components of eclipsing binaries.

2 Pulsation Period of Distorted Stars in Binaries

General form of the equation of hydrodynamic motion in equilibrium is as follows:

$$\nabla \mathcal{P} = \rho \nabla \Psi \tag{1}$$

where $\mathcal{P}, \rho, \Psi$ are the pressure, density and the total potential respectively. For a constant density surface, the equation takes the form; $\mathcal{P} = \rho\Psi$ where the potential Ψ contains three terms; the gravitational potential U, the rotationally distorted potential V_r, and the tidally distorted potential, V_t:

$$\Psi = U + V_r + V_t \tag{2}$$

Rotationally and tidally distorted binary components are considered to be in equilibrium in equipotential surfaces. $\mathcal{P} = \rho\Psi$ equation requires that on equipotential surfaces the density ρ and pressure $\mathcal{P}$ should also be constant.On the other hand, the fundamental pulsation period P can be estimated by the period of pressure wave which travel to the center of the star and back, and thus it can be written (see Vitense 1989, Volume I, p.163), as:

$$P \approx \frac{2r}{c_s} \tag{3}$$

in terms of the local radius r of the star in any (or observed) direction, and the speed of sound c_s in the medium. It is known that; $c_s = \sqrt{\gamma\frac{\mathcal{P}}{\rho}}$ in terms of the adiabatic index γ (the ratio of specific heat capacity at constant pressure to volume), pressure P, and density ρ of the medium.

For constant pressure and density surfaces the c_s should also be constant all over the surface if temperature dependency is neglected. Actually, the speed of sound is directly proportional to the square root of the temperature of the medium for ideal gas approximation, however this proportinality is neglected in this study. Thus, the fundamental pulsation period P would be only r dependent quantity, as from Eq. (2.3) and equation of speed of sound;

$$\frac{P}{P_0} \approx \frac{r}{r_0} \tag{4}$$

for constant c_s values on the equipotential surfaces. The radius r of the distorted component in any direction in polar coordinates $\theta\hat{A}$ and ϕ is given by Kopal (1978), as

$$\begin{aligned}\frac{r-r_0}{r_0} = {} & r_0^3\{qP_2(\lambda)+n(1-\nu^2)\} \\ & +r_0^4\{qP_3(\lambda)\} \\ & +r_0^5\{qP_4(\lambda)\} \\ & +r_0^6\{qP_5(\lambda)+3[qP_2(\lambda)+n(1-\nu^2)]^2\} \\ & +r_0^7\{qP_6(\lambda)+7q[qP_2(\lambda)+n(1-\nu^2)]P_3(\lambda)\} \\ & +r_0^8\{qP_7(\lambda)+8q[qP_2(\lambda)+n(1-\nu^2)]P_4(\lambda)+4q^2P_3^2(\lambda)\}+...\end{aligned} \tag{5}$$

Thus $\frac{P}{P_0}$ in Eq. (2.4) can be rewritten with the help of Eq. (2.5), as

$$\begin{aligned}\frac{P}{P_0} \approx {} & 1+r_0^3\{qP_2(\lambda)+n(1-\nu^2)\} \\ & +r_0^4\{qP_3(\lambda)\} \\ & +r_0^5\{qP_4(\lambda)\} \\ & +r_0^6\{qP_5(\lambda)+3[qP_2(\lambda)+n(1-\nu^2)]^2\} \\ & +r_0^7\{qP_6(\lambda)+7q[qP_2(\lambda)+n(1-\nu^2)]P_3(\lambda)\} \\ & +r_0^8\{qP_7(\lambda)+8q[qP_2(\lambda)+n(1-\nu^2)]P_4(\lambda)+4q^2P_3^2(\lambda)\}+...\end{aligned} \tag{6}$$

where P_0 is the hypotetical mean pulsation period for the mean radius r_0

3 Theoretical Predictions

Eq. (2.6) allows us to estimate the variation of pulsation period on the distorted surface of the pulsating binary components. It is expected by considering Eq. (2.6) that in orbital plane (for $\theta = 90^o$), for example, $\frac{P}{P_0}$ ratio varies around a constant value, being maximum during primary eclipse when $\phi = 0^o$ and minimum during quadrature when $\phi = 90^o$ or 270^o. q, r_0 and ϕ dependent $\frac{P}{P_0}$ variation is represented in Fig. 1 for $r_0 = 0.15(0.02)0.25$ and $q = 0.2$ and 0.8. Additionally, Fig. 2 shows the calculated $\frac{P}{P_0}$ values for well-known pulsating primaries in Algol type binaries whose physical parameters are taken from Budding et al. (2004).

Figure 1: Calculated period ratio versus phase relation for star have $q = 0.2$ (left panel) and $q = 0.8$ (right panel) for different r_0. $\frac{P}{P_0}$ values are increasing with q values at eclipses phases ($\Phi = 0.0$ and 0.5)

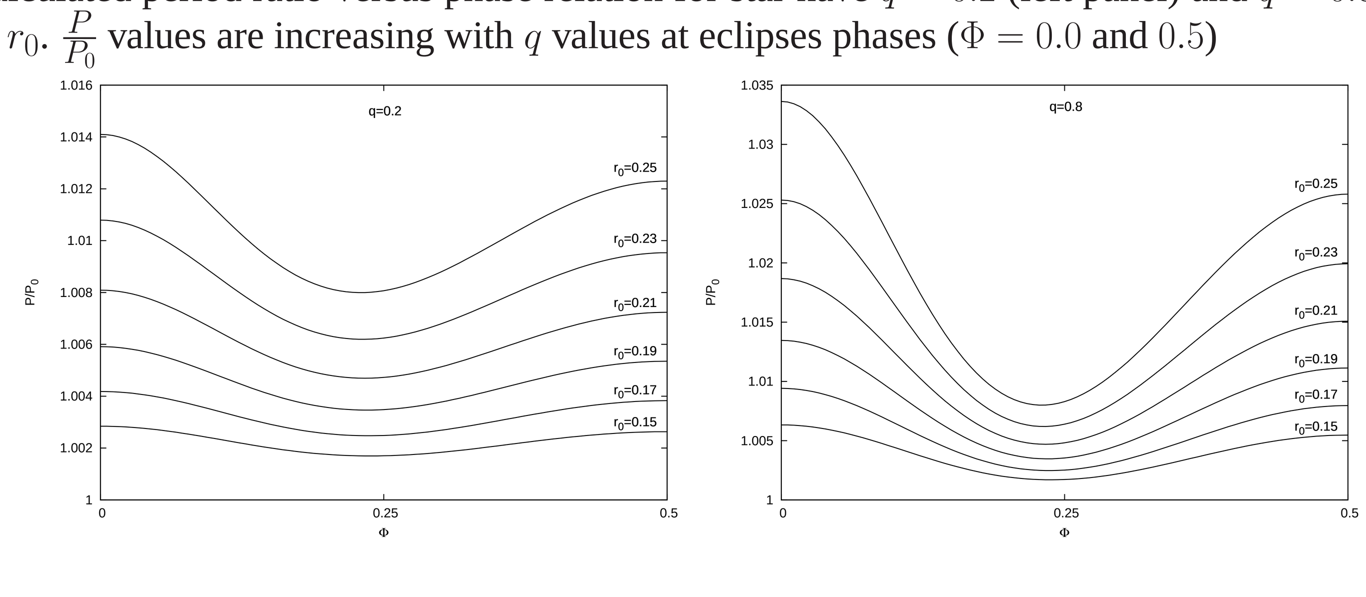
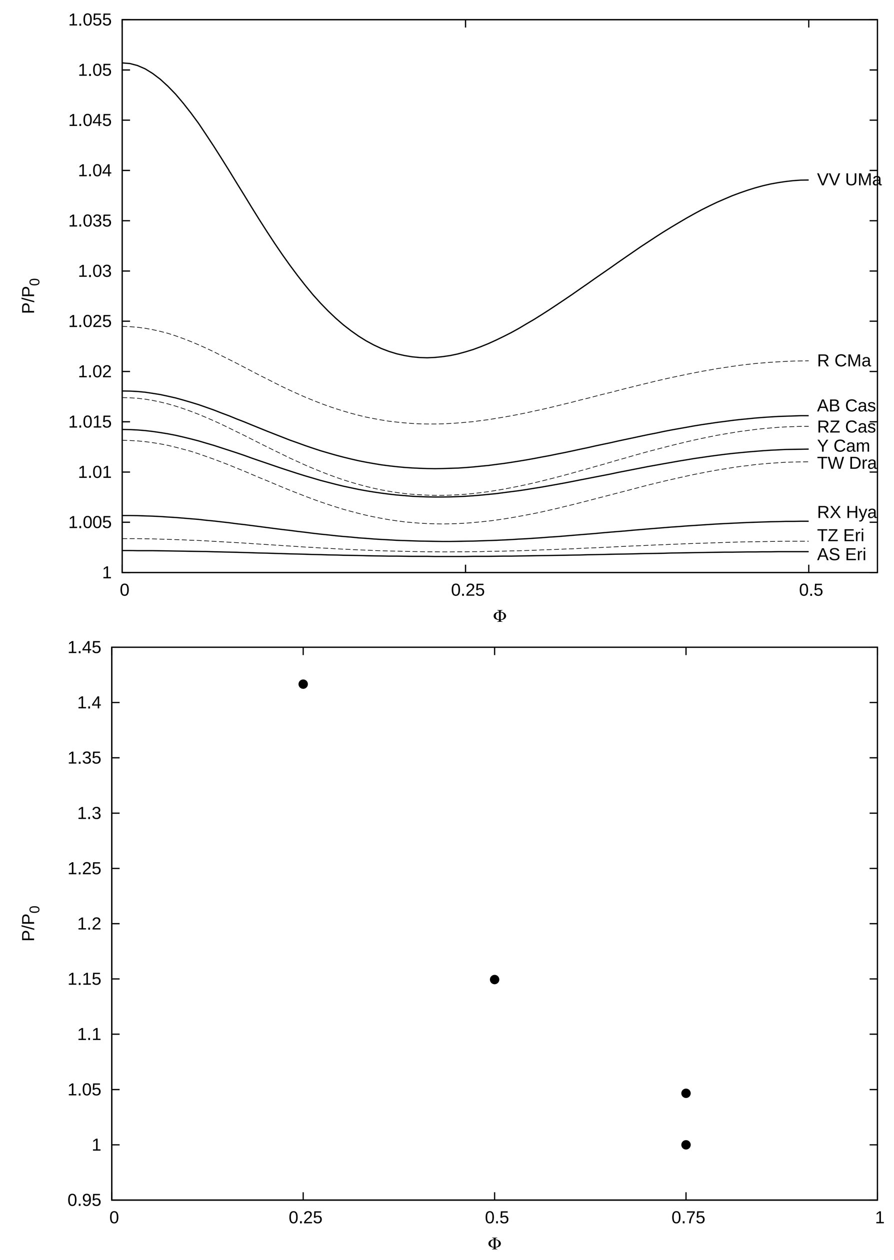


Figure 2: Pulsation period change in phase (due to variation in radius r) for the primaries of different close binary systems (upper panel) and the period analysis results of AB Cas (lower panel))



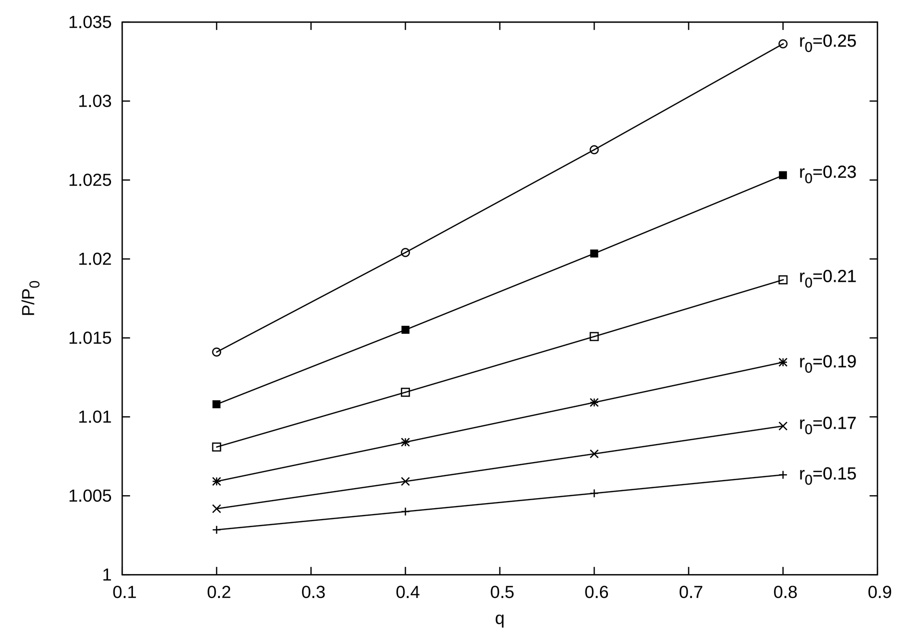
4 Observational test

The observational data (from Soydugan et al.,2003) including pulsations of semidetached Algol system AB Cas were used in testing the expected phase dependence of the pulsation period. The data at different phase intervals are analyzed seperately. However, the variation found did not match with our theoreical estimates. Most important reason of this disagreement can be the insufficent quality of the data for such analysis. Results of the period analysis are shown in Fig 2. It is very important to have higher quality data since we divide the light curve into small phase intervals to find the period at different phases. If measured successisve pulsation periods are different at the same phase due to the fact the ratio of the orbital period to pulsation period is not an integer, non-stop observation without day gaps that covers whole period is hardly needed.

5 Discussion

Even tough we could not proof our predictions observationally because of the scattering of the data, calculations show that the pulsation period P of the tidally distorted components should be phase dependent. The maximum value of P takes place at around $MinI$ due to maximum radius $r = (r_{point})$ in that direction at $\phi = 0$. It was also known that the P variation increases with increasing q and r_0 values. The relation is shown in Fig 3.

Figure 3: PPeriod ratio versus mass ratio relation for fixed values of r_0 and $\phi = 0$.)



References

Budding, E., Erdem, A., Cicek, C., Bulut, I., Soydugan, F., Soydugan, E.,Bakis, V., Demircan,O., 2004, *A & A* 417, 263.
Kopal, Z., 1978, *Dynamics of Close Binary Systems, D.Reidel Publish.Co.*
Mkrtichian, D.E., Kusakin, A.V., Gamarova, A.Yu., Nazarenko, V., 2002, *PASPC*, 259, 96.
Soydugan, E., Demircan, O., Akan, M.C., Soydugan, F., 2003, *AJ*, 126, 193.
Soydugan, E., Soydugan, F., Demircan, O., Ibanoglu, C., 2006, *MNRAS*, 370, 2013.
Vitense, E-B., 1989, *Introduction to Stellar Astrophysics, Cambridge University Press.*