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Pulsating Components of Eclipsing Binaries: New Asteroseismic Methods of Studies and Prospects

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Abstract. We give a brief review on the present status of our research of A-F pulsating components of semi-detached Algol-type systems. We suggest a new asteroseismic approach for estimating the evolutionary stage of the mass-accreting components of Algols during rapid and slow mass-transfer phases, asynchronization and differential rotation.

1. Introduction

The asteroseismic studies of mass-accreting components of semi-detached eclipsing binary stars (EBS) is still in its embryonic stage. Only three of these forgotten stars were known in the instability strip until 2000: AB Cas, Y Cam, and RZ Cas. The Central Asian Network collaboration's survey done in 2000 – 2001 (Mkrtichian et al., 1998) resulted in the discovery of three new EBS: R CMa (Mkrtichian & Gamarova, 2000), AS Eri (Gamarova et al., 2000), and TW Dra (Kusakin et al., 2001). These stars represent now a well defined group of pulsators among Algol-type systems situated inside the instability strip (see Fig. 1) and are therefore attractive for seismic studies. In Table 1 we list all known members of this group.

2. Definition of the group

From an evolutionary point of view, pulsators in Algol-type systems are not normal main-sequence δ Scuti stars as there are the components of detached EBS. They have undergone considerable interaction throughout their lives, both via mass accretion and through changes of their internal structure. At present they are in a state of permanent mass accretion and hence not in a thermal equilibrium. This group can be therefore be defined as : **"The (B)A-F spectral type mass-accreting main-sequence pulsating stars in a semi-detached Algol-type system"**.

Table 1. Algol-type eclipsing binaries with pulsating primary components.

Name	Sp (Prim. + Sec.)	$P_{\rm orb}$ (days)	$P_{\rm puls}$ (min)
Y Cam	A7 V + K1 IV	3.3056	95.7, 98.7
AB Cas	A9 V + K1 V	1.3668	83.9
RZ Cas	A3 V + K0 IV	1.1953	22.4
R CMa	F0 V + K IV	1.1359	67.9
AS Eri	A3 V + K0 III	2.6642	24.4, 22.7, 23.4
TW Dra	A6 V + K0 IV	2.8068	80

3. Mode detection and mode identification in eclipsing binaries

The basic problems in asteroseismic studies are the mode detection and the mode identification. An inclination close to 90 degrees of the orbital/rotation axis and an approximate equator-on view of the components are the most favorable conditions for photometric and spectroscopic detection of sectorial and $\ell = +m$ =even modes. During prime minima the secondary component eclipses the pulsating one and thus acts as a periodic geometric spatial filter with an accurately known variable shape. This produces specific pulsation amplitude and phase changes of the non-radial pulsation (NRP) mode depending on the quantum number ℓ, m of the spherical harmonic (Nather & Robinson, 1974) and on the geometry of the eclipse. Accurate mode identification is therefore possible by modeling and comparison with observables (NRP photometric and radial velocity amplitude, phase and spectroscopic line-profile variations).

4. New tools in studies of binaries

Tidal effects in close binaries force the components' rotation to become synchronous and the orbit to become circular. However, there are at least several tens (including RZ Cas) among well studied systems with asynchronous rotation. The asynchronism in Algols is not well explained yet. There are at least two hypotheses suggested as an explanation of asynchronism in Algols. The first hypothesis is that asynchronous systems have recently passed a rapid mass transfer/accretion (RMT) phase (young Algols) during which they spun up due to angular momentum accretion from the mass-losing component. Hence the asynchronous Algols are at the start of a slow mass transfer/accretion (SMT) phase and hence not yet in synchronism. The second hypothesis is that the rotational velocities determined from the observed $v \sin i$ are overestimated and variable in a time due to a rapidly rotating optically thick quasi-stationary accretion disks and/or strong differential rotation of the surface layers which are spun up due to accretion of matter.

Basic observational problems occur for checking these hypotheses. The currently determined parameters of Algols in the SMT phase do not allow to

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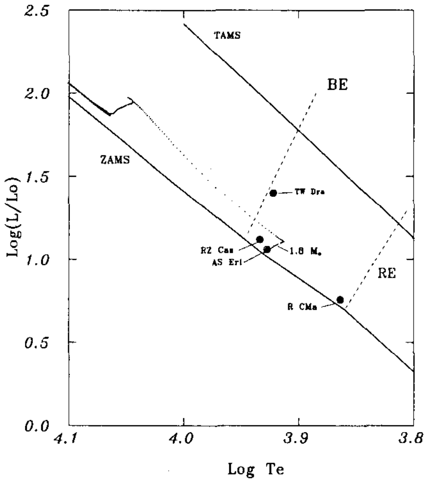

Figure 1. The location of recently discovered pulsating gainers in a log $T_{\rm eff}$-log L diagram. The blue (BE) and red (RE) edges of the instability strip are shown by dashed lines. The dotted line shows the typical evolutionary track of a $1.8 M_\odot$ mass-accreting component in a $3.0 M_\odot + 1.8 M_\odot$ system (after De Greeve, 1993).

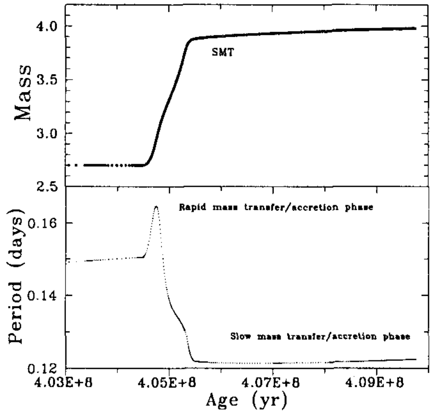

Figure 2. The evolutionary accretion-driven mass changes of a mass-accreting component (upper panel) and calculated pulsation period changes for fundamental radial oscillations (lower panel) in the 2.7 $M_\odot$ mass-accreting component of a $3M_\odot$+$2.7M_\odot$ binary system. Evolutionary calculations of binary systems (De Greeve, 1993) were used.

determine their age nor evolutionary status (as is possible for non-interacting detached or single main-sequence stars using the evolutionary tracks), due to the uncertainties in the estimates of mass transfer, mass-accretion and mass-loss rates. We therefore need new accurate methods for the determination of a) rotational periods of components in Algols, b) accretion-driven differential rotation, c) the status of systems in an SMT phase.

The pulsations of a mass-accreting component allow to use new approaches for solving these problems. The rotational splitting of low-degree NRP modes can provide a very precise estimate of the internal rotation. On other hand, the rotational splitting of high-degree ($\ell > 10$) modes trapped in sub-photospheric layers in the equatorial regions (where one expects a strong accretion-driven differential rotation) can give a precise estimation of the differential rotation. Moreover, the mass accretion should result in changes of the average density of the star and accordingly in changes of the pulsation frequencies. Figure 2 shows the evolutionary period changes of the fundamental radial mode calculated from the evolutionary models of De Greeve (1993) during the MS, RMT and SMT phases in a $3M_{\odot}{+}2.7M_{\odot}$ binary model with a $2.7M_{\odot}$ mass-accreting component. As is well visible in Fig. 2, the evolutionary accretion-driven pulsation period changes expected in the gainer are :

- negative ($10^{-6} - 10^{-7}$) - at the late stage of the RMT phase;
- negative ($10^{-7} - 10^{-9}$) - at the beginning of the SMT phase;
- zero - in the middle stage of the SMT phase;
- positive - at the late stages of the SMT phase.

The sign of the pulsation period changes is therefore an indicator of the evolutionary stage of the mass-gaining component. The young Algols in the RMT and the early SMT phases can therefore be discriminated from those in the other stages on the basis of strong negative pulsation period changes. For gainers of a given mass and age it should be possible to find simple relations between the mass accretion rate and the pulsation period changes.

5. Conclusions and future work

We have presented new asteroseismic approaches for the study of Algol-type systems with a pulsating component. These approaches should be elaborated on in detail based on new grids of evolutionary models of close binary systems and checked observationally during future multisite campaigns.

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