NON-RADIAL PULSATIONS IN COMPONENTS OF SYMBIOTIC STARS

N.I. BONDAR and V.V. PROKOFÉVA
Crimean Astrophysical Observatory, Nauchny, Crimea, Ukraine 98409;
E-mail: bondar@crao.crimea.ua

(accepted April 2004)

Abstract. Photometric observations of symbiotic stars in the blue and in the red spectral regions make it possible to reveal non-radial oscillations both of the cool and of the hot components. Light variations of red giants in the symbiotic systems CI Cyg and AG Peg show several periods in the 10–80^{d} range, interpreted as p-mode pulsations. These modes are excited by a bright spot produced by radiation flux from the hot component. The spot moves on the red giant's photosphere at a velocity close to the sound speed. During the active phase of the symbiotic star CH Cyg, at least 25 frequencies of oscillations in the 150–6000 s range of periods were found in the light of the white dwarf. Their features correspond to non-radial g-modes. In the frame of 2D gas dynamical non-adiabatic models, the interaction between gas flows and the accretion disk leads to formation of a system of shock waves propagating towards the compact object, which is one of possible mechanisms to excite non-radial pulsations of white dwarfs in symbiotic systems.

Keywords: stars, symbiotic – white dwarfs – stars, pulsations – stars, individual, AG Peg, CH Cyg, CI Cyg

1. Pulsations of Red Giant Components of Symbiotic Systems

Non-radial pulsations of stars are excited due to mechanisms providing energy transfer. Such mechanisms can work in complex systems like binary stars. According to Kosovichev and Skulskii (1990), oscillations in the Hα flux of β Lyr with a period of $1\overset{d}{.}85$ can be produced by a system of quadrupole fundamental modes ($l = 2, m = 0, \pm 2$) excited in the bright component by a tidal wave. General properties of non-radial pulsations are a large number of periods, stability of phases during a long time, changes of amplitudes with time. The power spectrum shows different series of frequencies at different times.

Observational evidence for pulsations in red components of symbiotic stars comes from long-term photometry. A period of $37\overset{d}{.}2$ was found in the radiation from the symbiotic star CI Cyg in 1978–1986, whereas the periods of $50\overset{d}{.}2$ and $78\overset{d}{.}4$ were observed during 1988–1989 (Belyakina and Prokoféva, 1991; Taranova, 1987). The physical conditions in the red component of CI Cyg allow to expect the appearance of non-radial p-modes in its upper layers. The hot component's radiation produces a bright spot on the surface of the red giant, which moves due to its asynchronous rotation. The competition between mode-exciting and mode-damping processes leads to changes of periods.

Astrophysics and Space Science **296:** 161–164, 2005.

The presence of non-radial oscillations with periods of $10\overset{d}{.}7$ and $9\overset{d}{.}9$ in the light of the red giant was revealed in the analysis of photometry for AG Peg (Belyakina and Prokoféva, 1992). These periods remained the same during 1100 days. The source of excitation of these oscillations can be similar to that described for CI Cyg. The authors calculated that the terminator line on the giant's atmosphere moved at a velocity of 12–6 km/sec, compared to the sound speed of 9 km/sec, and the generated acoustic waves could produce non-radial p-modes in the red giant.

2. Pulsations of the White Dwarf in the Peculiar Symbiotic Binary CH Cyg

The active state of the symbiotic system CH Cyg usually begins as a strong outburst that leads to a several-fold increase of its brightness. In order to study the rapid brightness variability of the white dwarf of CH Cyg, the data obtained at the Crimean Astrophysical Observatory on four nights during June 13–August 22, 1982, when the star was in maximum brightness (Bondar' and Shakhovskaya, 2001), was analyzed. The observations were made using a 70 cm telescope with a five-channel spectral scanner; the time resolution was 20 sec. The continuum flux was registered in narrow (23 Å) bands, during 1–1.2 h in each of the four nights. A total of 646 measurements of continuum brightness at λ3737 Å were obtained. The standard error (about $0\overset{m}{.}01$) was estimated using comparison star observations.

To search for significant frequencies, a procedure of data prewhitening with selected frequencies was used. The cleaning was made by programs providing analysis of discrete data. The power spectrum calculated for the whole observational data (Breger, 1990) shows five remarkable groups of frequencies in the range of 24–250 c/d (Figure 1a). It seems that the noise level is reached near the frequency

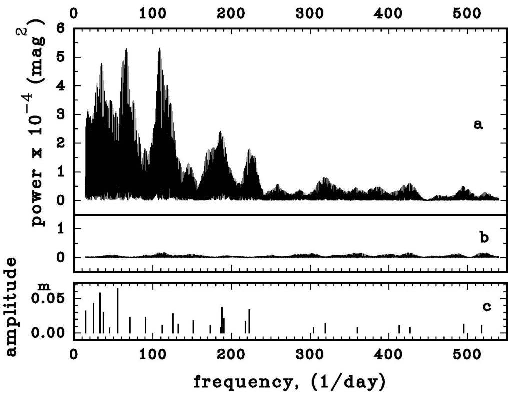

Figure 1. The power spectrum for the whole observational data set (a) and the residuals after consecutive prewhitening with the 25 determined frequencies (b); the schematic frequency distribution of the detected oscillation modes and their mean amplitudes (c).

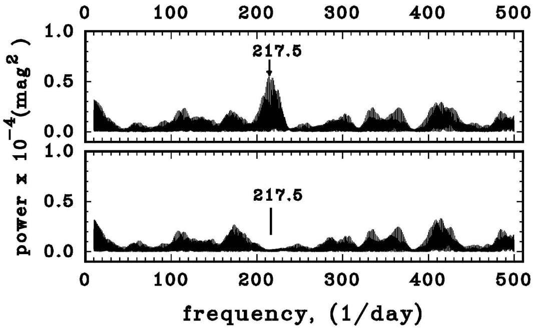

Figure 2. The power spectra of the data before (top) and after (bottom) the prewhitening with the 217.5 c/d frequency.

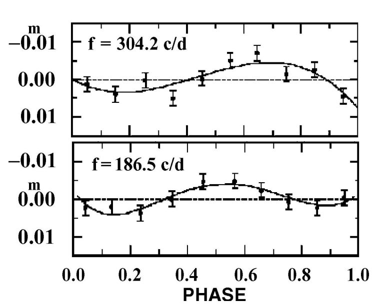

Figure 3. The phase diagrams for the 304.2 and 186.5 c/d periods. The vertical bars are standard errors in phase bins with widths of 0.1.

of 445 c/d, but actually it was reached only after consecutive prewhitening of data with 25 detected frequencies (Figure 1b). The distribution of these frequencies and the mean oscillation amplitudes are displayed in Figure 1c. Sample results after prewhitening with a selected frequency and phase diagrams are shown in Figures 2 and 3, respectively.

To estimate the confidence level for all of the detected frequencies, we determined the signal-to-noise ratios, $S/N = A_\nu/\sigma_\nu^2$. We found $S/N > 10$ only in four cases, and for one case, it was equal to 7. The ratio A_m/σ_m was higher than 4 for 24 frequencies, and only in one case this value was about 3.5. Here A_m is the oscillation amplitude and σ_m is the standard error.

The power spectra for individual nights show instability of amplitudes from night to night. Short-term amplitude variations are one of the properties of non-radial pulsations. For CH Cyg, we found periods of oscillations from 150 s to 6000 s. This range is wider than the 400–2000 s interval known for eigenoscillations of single white dwarfs. This indicates that the physical conditions near the hot component of this symbiotic system during its active state are more complicated compared to single white dwarfs.

3. Discussion

Typical models of gas flows in symbiotic stars make it possible to suggest a possible mechanism of excitation of eigenmodes. The system of CH Cyg contains a M6–M7 red giant and a hot star classified as a white dwarf. The cool component does not fill its Roche lobe and loses matter via stellar wind (10^{-6}–10^{-8} $M_{\odot}$ per year). Part of this matter is accreted onto the white dwarf, and some matter is added to the gaseous envelope. According to Mikolajewski et al. (1990), the mass of the white dwarf in CH Cyg is about 0.58 $M_{\odot}$, the system's luminosity is estimated as 10–70 $L_{\odot}$ during quiescence and about 300 $L_{\odot}$ in the active phase. The authors suggested that the star's active state was related to the accretion disk around the white dwarf.

The mass transfer in binary systems, where the red giant does not fill its Roche lobe, depends on parameters of the wind. In the case of a weak wind, a stable accretion disk is formed. Bisikalo et al. (1997) show how systems of shock waves appear in the disk. The group velocity of these waves is directed towards the compact object. We suppose that the shock waves reaching the white dwarf's surface can excite g-modes of non-radial pulsations. These processes can be considered a source of excitation for g-modes in hot components of symbiotic stars, in particular, of CH Cyg.

References

Belyakina, T.S. and Prokoféva, V.V.: 1991, *Sov. Astron.* **35**, 154.

Belyakina, T.S. and Prokoféva, V.V.: 1992, *Bull. Crim. Astrophys. Obs.* **86**, 42.

Bisikalo, D.V., Boyarchuk, A.A., Kuznetzov, O.A. and Chechetkin, V.M.: 1997, in: J. Mikolajewka (ed.), *Physical Processes in Symbiotic Binaries and Related Systems*, Copernicus Foundation for Polish Astronomy, Warsaw, Poland, p. 83.

Bondar', N.I. and Shakhovskaya, N.I.: 2001, *Astrophysics* **44**, 46.

Breger, M.: 1990, *Commun. Asteroseism.* **20**, 1.

Kosovichev, A.G. and Skulskii, M.Y.: *Sov. Astron. Lett.* **16**, 103.

Mikolajewski, M., Mikolajewska, J. and Khudyakova, T.N.: 1990, *Astron. Astrophys.* **235**, 219.

Taranova, O.G.: 1987, *Sov. Astron. Lett.* **13**, 173.