Pulsation of Rotating Magnetic Stars

H. Shibahashi, M. Takata

Department of Astronomy, University of Tokyo, Japan

Recently, one of the rapidly oscillating Ap stars, HR 3831, has been found to have an equally split frequency septuplet, though its oscillation seems to be essentially an axisymmetric dipole mode with respect to the magnetic axis which is oblique to the rotation axis (Kurtz et al. 1992; Kurtz 1992). In order to explain this fine structure, we investigate oscillations of obliquely rotating magnetic stars by taking account of the perturbations due to the magnetic fields and the rotation. We suppose that the star is rigidly rotating and that the magnetic field is a dipole field and its axis is oblique to the rotation axis. We treat the effects of the rotation and of the magnetic field as perturbations. In doing so, we suppose that the rotation of the star is slow enough so that the effect of the rotation on oscillations is smaller than that of the magnetic field. Under these assumptions, we can show that the oscillation eigenfunction represented in the zero order by the spherical degree l has mainly perturbed components represented by the degree $l \pm 2$. In the case of $l = 1$ like the roAp stars, those first-order components are octapole, and it is these octapole components that are responsible for the observed septuplet fine structure of the amplitude spectrum of HR 3831 (Shibahashi and Takata 1992). The spherical harmonic expressed in terms of the spherical coordinates with respect to the magnetic axis is written in terms of $(2l + 1)$ spherical harmonics of the same degree l with respect to the line-of-sight. Hence the pulsation of the spherical degree l in the zero-order of obliquely rotating magnetic stars is observed as a $(2l + 5)$-fine structure of the frequency spectrum $\{\omega - (l + 2)\Omega, ..., \omega, ..., \omega + (l + 2)\Omega\}$. The fine structure is asymmetric with respect to its central frequency because of the perturbation due to the Coriolis force. These features are qualitatively consistent with Kurtz et al.'s (1992) recent observational results, and provide theoretical justification of Kurtz's (1992) decomposition of the amplitude spectrum of HR 3831 by a series of spherical harmonics. The degree of asymmetry of the fine structure is independent of the geometrical configuration but depends on the ratio of the Coriolis force and the Lorentz force. Then it allows us to get information about the magnetic fields, the rotation, and the geometrical configuration of the star from the oscillation data.

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