OVERSTABILITY OF NONRADIAL PULSATIONS IN ROTATING EARLY TYPE STARS

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We present the result of nonadiabatic analysis for nonradial pulsations in uniformly rotating main sequence models.

The angular dependence of the amplitude of a nonradial pulsation mode with an azimuthal order m in a rotating star is represented by a sum of terms proportional to spherical harmonics $Y_l^m(\theta, \phi)$ with $l = |m|, |m|+2, \ldots$ (even mode) or $l = |m| + 1, |m| + 3, \ldots$ (odd mode; see e.g. Saio and Lee 1991 for detail). (In this paper we consider only even modes.) This property makes the analysis complex compared with the case without rotation, in which a single Y_l^m expresses the angular dependence of a given mode. In our numerical analysis the summation is truncated, in which only first two terms are taken into account. Lee and Saio (1987) give the differential equations for nonadiabatic nonradial pulsations in a uniformly rotating star. Treating the angular frequency of rotation as a free parameter, we applied the nonadiabatic analysis to a main-sequence evolutionary model, for which the effect of rotation is neglected.

The adopted main-sequence model has the following properties; $15M_\odot$, $X = 0.70$, $Z = 0.03$, $\log L/L_\odot = 4.53$, $\log R/R_\odot = 1.00$, $\log T_{\rm eff} = 4.395$, and $X_{\rm center} = 0.159$. The location of the model on the HR diagram is close to ϵ Per, for which Gies and Kullavanijaya (1988) have found nonradial pulsations with $-3 > m > -6$.

Low order p- and g-modes are excited by the κ-mechanism which works at the opacity peak at $T \sim 2 \times 10^5$K (Dziembowski and Pamyatnykh 1993, Gautschy and Saio 1993). Since rotation modifies the amplitude distribution of a nonradial pulsation mode, the rotation influences the stability as well as the frequency spectrum especially for large $|m|$ (m is the azimuthal order of mode). Some of our results for $|m| = 6$ are presented in Fig. 1, which shows how the real parts of frequency, ω_r, (in the co-rotating frame) change with the angular frequency of rotation Ω. In this figure ω_r and Ω are normalized by $\sqrt{GM/R^3} = 7.79 \times 10^{-5}\mathrm{s}^{-1}$.

A perturbation analysis in terms of Ω gives $\omega_r = -mC\Omega + O(\Omega^2)$, where C is a small number obtained from the displacement vector of a given nonradial

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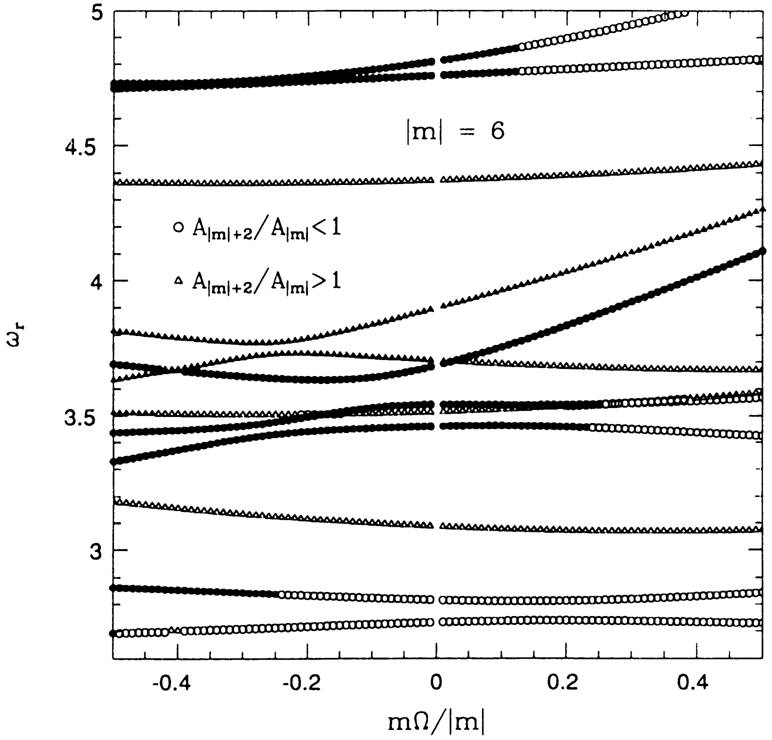

Fig. 1. The real part of oscillation frequency in the co-rotating frame versus $m\Omega/|m|$ for $|m| = 6$, where Ω is the angular frequency of rotation. Circules (triangles) indicate modes for which the amplitude of $l = |m|$ component ($A_{|m|}$) is larger (smaller) than that of $l = |m| + 2$ component ($A_{|m|+2}$). Filled symbols are for overstable modes. The modes with $m > 0$ are retrograde in the co-rotating frame.

pulsation mode for $\Omega = 0$. As seen in Fig. 1 the value of C differs from mode to mode, and for some mode C is negative. Since different modes have different $d\omega_r/d\Omega$, many avoided crossings exist in the plane of pulsation frequency versus rotation frequency.

Fig. 1 indicates that modes tends to be stabilized at large $m\Omega$. Some retrograde (in the corotating frame) modes ($m > 0$) which are overstable when Ω is small are stabilized when Ω becomes large enough.

In summary, prograde ($m < 0$) modes tend to become overstable when Ω is large. This property is more apparent for modes with larger $|m|$.

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