

Amplitude Saturation in β Cephei Models - Preliminary Results

R. Smolec, P. Moskalik

Copernicus Astronomical Centre, Bartycka 18, 00-716 Warsaw, Poland

We present preliminary results concerning amplitude saturation in β Cephei models. Using a nonlinear approach we have investigated the amplitude limitation mechanism in β Cephei stars. In our approach radial modes have been treated as representative for all acoustic oscillations. We have studied pulsation properties of several models (7–20 M_{\odot} , $Z = 0.02, 0.015$) using radiative Lagrangian hydrocodes (essentially those of Stellingwerf 1974, 1975). Nonlinear limit cycles (monoperiodic full-amplitude oscillations) have been calculated through Stellingwerf's (1974) relaxation technique, which also provides information about limit cycle stability.

In our main survey ($Z = 0.02$) only the fundamental and the first overtone modes are linearly excited. Nonlinear growth rates have been used to determine the modal selection (see e.g., Stellingwerf 1975). We found that fundamental mode pulsation is dominant. First overtone pulsation is restricted to intermediate masses and to the vicinity of the blue edge. The first overtone and the fundamental mode pulsation domains are separated by either-or or narrow double-mode domains.

Predicted single-mode saturation amplitudes have been compared to amplitudes observed for monoperiodic β Cephei variables (Fig. 1, left). Predicted amplitudes are significantly higher. The amplitudes may be lowered by decreasing the metal abundance of the models, Z . We have found that for $Z = 0.015$, the decrease of model amplitudes is not sufficient. At the same time the instability strip shrinks and leaves a lot of stars beyond the blue edge. By lowering Z we are not able to match simultaneously the observed amplitudes and the instability strip.

The predicted amplitudes may be easily lowered to the observed level if one assumes collective saturation of the pulsation instability, by n similar acoustic modes. In this hypothetical multimode solution, amplitudes of individual modes are a factor of $\sim \sqrt{n}$ lower than in the single-mode solution. Using linear code of Dziembowski (1977) we have determined the number of linearly unstable acoustic modes for models of different masses, located in the centre of the main sequence band. This number doesn't vary much along an evolutionary track and thus, was assumed to be representative for all models of a given mass. The number of unstable modes is much higher than the number of detected modes in the multiperiodic β Cephei variables. Nonlinear simulations (Nowakowski 2005) also show that not all unstable modes take part in the saturation process. Thus, we have arbitrarily assumed that only one third of the linearly unstable modes take part in the saturation. Amplitudes rescaled under the assumption of collective saturation are presented in Fig. 1 (right). Using only part of the linearly unstable acoustic modes, we have lowered the theoretical amplitudes to the observed level. Thus, we argue that collective instability saturation is sufficient to explain the observed amplitudes of the β Cephei pulsators. A possible difficulty of this model is that the predicted pulsation-induced broadening of spectral lines might be higher than observed. We discuss this problem in Smolec & Moskalik (2007).

In several of our radiative models we have found numerically robust, double-mode behaviour, with radial fundamental and first overtone modes simultaneously excited. This form of pulsation is encountered only in intermediate mass models (10–11 M_{\odot}). Depending on the specific model, the origin of double mode pulsation can be traced to one of two different mechanisms: either to the non-resonant coupling of the two excited modes, or to the $2\omega_1 \simeq \omega_0 + \omega_2$ parametric resonance.

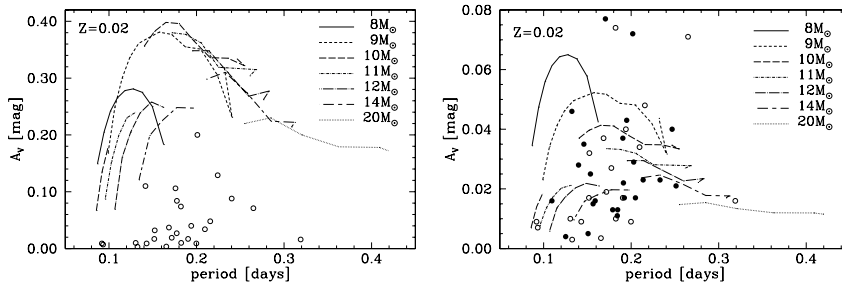


Figure 1: Predicted single-mode saturation amplitudes (left) and amplitudes assuming collective saturation by several acoustic modes (right). For comparison, amplitudes of monoperoiodic (open circles) and multiperoiodic (full circles) β Cephei stars are plotted.

Full results of this analysis (including a discussion of non-uniform filling of the theoretical instability strip by β Cephei variables and detailed study of the double-mode models) are presented by Smolec & Moskalik (2007).

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