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Theoretical understanding of radial-velocity pulsations observed in roAp stars

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Abstract. High-resolution spectroscopic time-series of rapidly oscillating Ap stars show evidence that standing and running waves can co-exist in their atmospheric layers. In order to understand these observations we have carried out a theoretical analysis of the pulsations in the outermost layers of these stars. By using the analytical solutions for the velocity components appropriate to the model considered we derive an estimate of the velocity component parallel to the line of sight averaged over the visible stellar disk, and derive the relative amplitude and the phase for our model as a function of height in the atmosphere.

Key words: stars: oscillations – techniques: radial velocities – waves

1. Introduction

High-resolution spectroscopic studies of rapidly oscillating Ap stars (roAp) show evidence that standing and running waves can co-exist in their atmospheric layers (e.g. Kurtz *et al.*, 1992; Kurtz *et al.*, 2006; Ryabchikova *et al.*, 2007; Sachkov *et al.*, 2007). The present study attempts to provide a theoretical understanding for those observations.

2. Theoretical modeling and results

We consider an isothermal atmosphere in a plane-parallel approximation, a dipolar magnetic field, an observer located pole-on in relation to the magnetic field axis and assume that, in the region studied, the magnetic pressure is much larger than the gas pressure. Starting from the results of Sousa and Cunha (2007 a) we determined the expression for $v_{\rm int}$, the pulsation velocity component parallel to the line of sight averaged over the visible stellar disk (see Sousa, Cunha 2007 b). By fitting v_{int} to a function of the form A$\cos(\sigma t+\phi)$, we derive the phase ϕ and the dimensionless amplitude A, for our model as function of height (see Fig. 1).

The spectral lines from which the observed velocity is derived may be homogeneously distributed, or they may be concentrated in particular regions of the stellar surface. In Fig. 1 we consider these two possibilities. The amplitude diagrams show an overall increase in the outward direction resulting from the

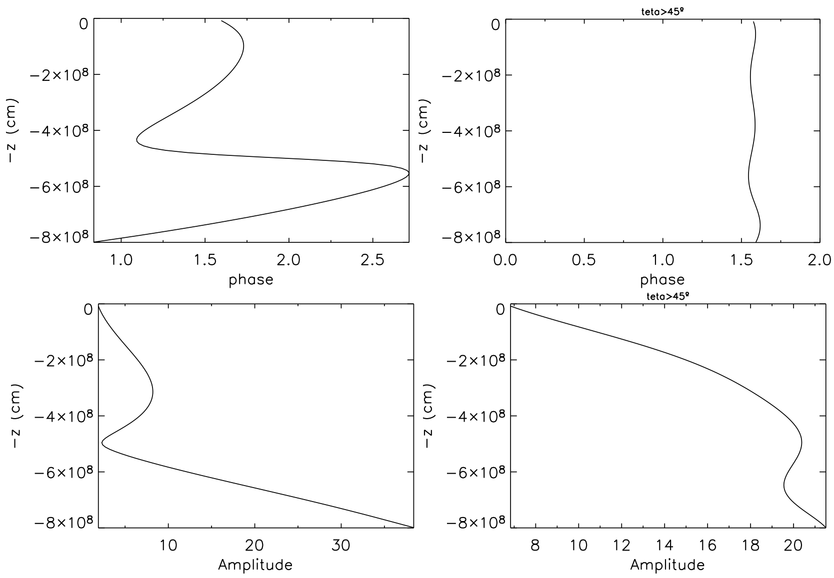

Figure 1. Amplitude and phase diagrams. z is the local vertical coordinate, defined as zero at the photosphere and increasing outwardly. The two left panels show the case when velocity is integrated over the whole stellar disk; the two right panels show the case when the velocity is integrated over $\pi/4 < \theta < \pi/2$.

decreasing density with height. The patterns observed in the phase diagrams are the result of summing two waves, one outwardly-running acoustic wave and one standing magnetic wave, in different proportions. When the acoustic contribution is dominant we see a running wave propagating outwards; when the magnetic contribution is dominant we see a standing wave, and when the two waves have similar contributions the phase is such that it might look like a wave propagating inwardly. We therefore suggest that what is observed in high-resolution spectroscopic time-series of roAp stars results from the superposition of different contributions of acoustic and magnetic waves.

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