ρ PUPPIS: THE POSSIBILITY OF NON-RADIAL PULSATIONS

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ABSTRACT. The profiles of spectral lines in the high resolution (R=80,000) and high signal to noise ratio (S/N more than 300) VLT spectrum of ρ Pup are not symmetric. Under the assumption that the asymmetry of the observed profiles is introduced by non-radial pulsations we estimated the pulsational degree l=3, the azimuthal order m=1, and amplitude of pulsation 15 km s^{-1}. The projected rotational velocity of the star is near $v \sin i$ =3.5 km s^{-1}. The obtained synthetic spectrum yield the better fit to the observed one in comparison with earlier known parameters.

Key words: stars: oscillation – stars: variables (ρ Pup, δ Scuti) – stars: individual (ρ Pup)

1. Introduction

ρ Pup (HR 3185, HD 67523) is a prototype of the group of metallic-line pulsating variables (Rodriguez & Breger 2001).

The enhanced metal abundance in the atmosphere of ρ Pup has been confirmed by Greenstein (1948), Bessell (1969), Breger (1970) and Kurtz (1976), however, the chemical composition was not yet determined in details with the use of a new high resolution and high signal to noise spectra.

As one of the bright star of the south sky ρ Pup (B=3.24, V=2.81, Sp F6 II) was an object of the first radial velocities surveys. The first radial velocities estimates (Reese 1903) revealed the variability with the peak-to-peak amplitude of 8.4 km s^{-1}.

The photometric variability of ρ Pup was detected considerably latter (Cousins 1951), and the star was considered as a radial monoperiodic pulsator (Campos & Smith 1980 and references therein). Only Mathias et al. (1997) found the evidence for additional two possible secondary non-radial pulsations (NRPs) at frequencies of 7.8 c/d and 6.3 c/d at a very low level.

ρ Pup with the sharp and well-defined lines was a "launch pad" for the line profile analysis (Aerts et al. 2008 and references therein) and a Van Hoof effect searching (Mathias et al. 1997).

2. Asymmetry of line profiles

For the present investigation we used the spectrum of ρ Pup from the VLT archive (Bagnulo et al. 2003) with the spectral resolving power R=80,000 and the signal to noise ratio S/N more than 300. Under this resolution the asymmetry of line's profiles in the observed spectrum becomes clearly detected. The reason of this asymmetry is, evidently, the line profile variations produced by NRP (see, for example, Aerts et al. 1992, Aerts et al. 1993). Yushchenko et al. (2005) detected this effect in the spectrum of δ Sct .

The use of the last version of URAN software (Yushchenko 1998) allow us to find the appropriate quantum numbers and amplitudes of the NRP for ρ Pup. The disk of the star was divided by several thousands regions. The number of these regions, the profile of pulsation over the stellar surface and the projected rotational velocity were selected to adjust the observed profile.

The synthetic spectra at the different distances from the center of the disk were calculated by Kurucz (1995) SYNTHE code. Only the velocity fluctuations have been taken into account. Integration over the stellar disk resulted in synthetic profile disturbed by NRP.

The Least Square Decomposition (LSD) profile (Reiners & Royer 2004) constructed from 34 clean iron lines was used as a mean observed profile to fit it by synthetic spectrum disturbed by NRP.

Figure 1 (upper panel) shows the observed profile of ρ Pup and the synthetic spectrum disturbed by NRP with the pulsational degree l=3, the azimuthal order m=1, the pulsational amplitude of 15 km s^{-1}, and additionally broadened by rotation with the projected rotational velocity $v \sin i$ =3.5 km s^{-1}. For the obtained synthetic profile the amplitude of pulsation occurs somewhat higher than the observed amplitudes 9.5 - 11.5 km s^{-1} found in different investigations by Yang et al. (1987) and Campos & Smith using Fe I and Fe II lines.

Mathias et al. (1997) using only the H_α, Fe I λ 6393,

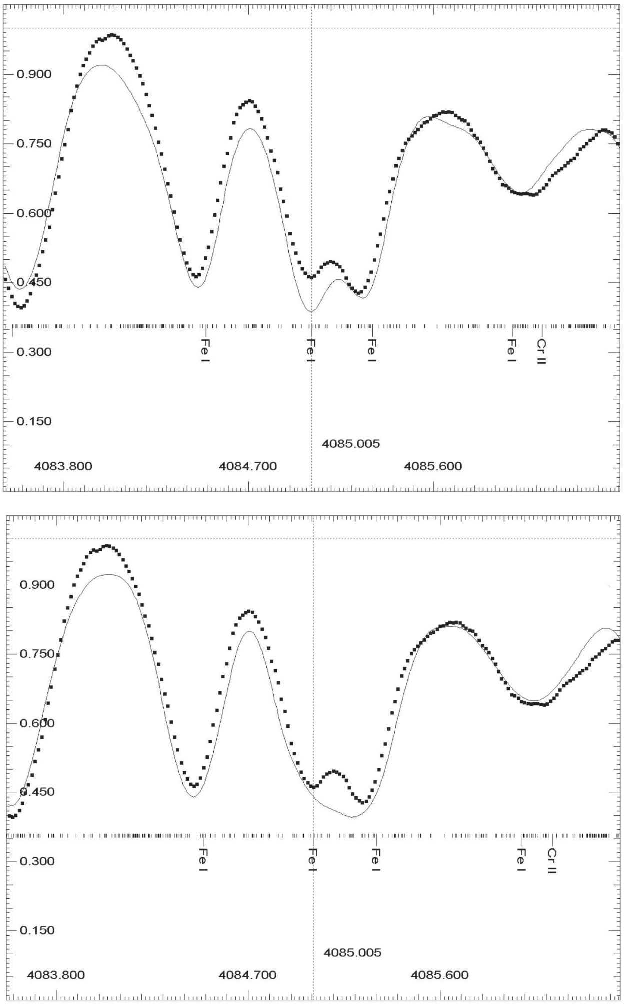

Figure 1: The observed (points) and synthetic (lines) spectra of ρ Pup in the vicinity of of Fe I λ 4085.005 Å line. The axes are the wavelength in angströms and the relative fluxes. The wavelengths of the spectral lines involved in the calculations are marked at the foot. For the strongest lines the identifications are given. The position of the Fe I λ 4085.005 Å line is marked by a vertical dotted line. Synthetic spectrum is convoluted with two sets of parameters. Upper panel: l=3, m=1, amplitude of pulsation 15 km s^{-1}, $v \sin i$ =3.5 km s^{-1}. Bottom panel: zero amplitude of pulsation, $v \sin i$ =15.3 km s^{-1}.

and Ca I λ 6122 lines found the observed amplitudes of 8.6 km s^{-1} and theoretical fit with amplitudes of 5.6 km s^{-1} of the radial pulsation (see also Aerts 1996).

However, the model with their value of $v \sin i$ =15.3 km s^{-1} fits the VLT spectrum too rough: the isolated lines may be fitted with comparable precision but the close pairs of lines cannot be reproduced with a rather high value of rotational velocity (Fig. 1, bottom panel).

The existence of NRP is in a contradiction with the commonly accepted persuasion that ρ Pup is a radial pulsator. However, from radial velocity variations Mathias et al. (1997) also identified the NRPs of a low-degree axisymmetric mode ($l = 3$; $m = 0$) and the one which is clearly non-axisymmetric ($m \neq 0$) besides of radial pulsations.

3. Conclusion

We are going to use the VLT spectrum of ρ Pup for the investigation of the chemical composition of the star, the dynamics of the atmosphere can not be found using the single spectrum. However, the spectrum synthesis method needs in the reliable profiles of spectral lines, that is why we were forced by high quality observed spectrum to find this profile and to clarify its physical meaning.

We assumed that the shape of the profile of ρ Pup may be explained by NRPs and found the appropriate combination of quantum numbers and amplitudes. The additional broadening could be explained by rotation with the projected rotational velocity $v \sin i$ =3.5 km s^{-1}. Our combination of parameters fits the observed VLT spectrum better than the previously found projected rotational velocity ($v \sin i$ =15.3 km s^{-1}: Mathias et al. 1997).

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