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Turbulence Variations in Cepheids

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1. Introduction

From radial velocity measurements obtained with a cross-correlation technique, the variation of turbulence during the pulsation cycle is studied for a sample of 40 Cepheids. We will propose a new way to separate classical and s-Cepheids. More complete results will appear in a forthcoming paper (Bersier & Burki 1995)

2. The residual width

The radial velocities have been measured with the spectrometer CORAVEL (Baranne et al. 1979), whose cross-correlation function (CCF) is fitted with a Gaussian, giving the radial velocity V_r, the width σ_{obs}, the depth H and the continuum, normalised to 1. The pulsation broadens the lines and thus also the CCF. In the Gaussian approximation one can write

$$\sigma_{obs}^2 = \sigma_{inst}^2 + \sigma_{puls}^2 + \sigma_{res}^2 \qquad (1)$$

where σ_{obs} is the observed width, σ_{inst} is the instrumental width, σ_{puls} is the additional width caused by the pulsational velocity field and σ_{res} contains all the other effects (turbulence, rotation, magnetic field, etc.). To be less affected by the noise in the data, a Fourier series has been fitted to each curve of σ_{obs}. With numerical simulations, one is able to synthesise the additional Doppler width due to pulsation, with a high accuracy. The instrumental width being well known for CORAVEL, the computation of σ_{res} is then straightforward. One then has a curve in phase for σ_{res}. From this curve, we determined the maximum residual broadening σ_{max} (observed at or very close to minimum radius), and the width σ_0 that the star would have if it did not pulsate. As shown by Bersier & Burki (1995), σ_0 is slightly higher than the mean value of σ_{res}.

3. The link between σ_{res} and turbulence

Luck & Bond (1989) gave atmospheric parameters for $\sim$ 160 supergiants and Cepheids, in particular the microturbulence. We searched in this sample all the stars that have also been measured with CORAVEL and we calculated σ_{res} according to eq. (1) with $\sigma_{puls} = 0$ for supergiants. We then quadratically subtracted the instrumental width to obtain σ_{res}. Figure 1a) shows the relation between the microturbulence ξ_t and σ_{res}. The equation of the straight line is $\xi_t = 0.286\,\sigma_{res} + 1.49$.

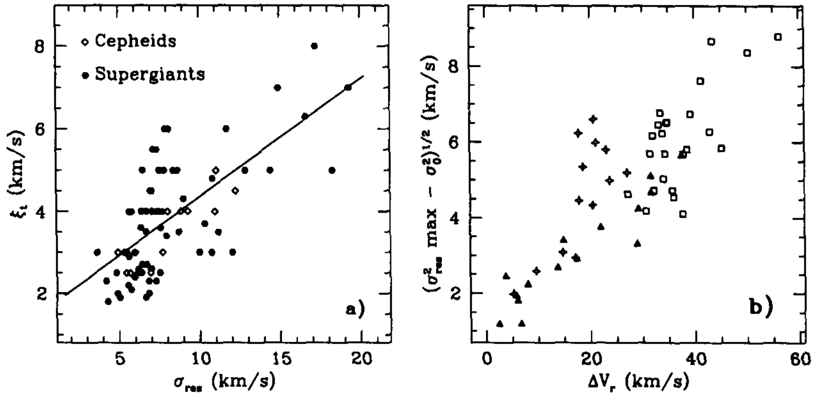

Figure 1. **a)** The relation between the microturbulence ξ_t and the residual width. The solid line is the regression for supergiants and Cepheids. **b)** The correlation between $\sigma^2_{max} - \sigma^2_0$ and the amplitude ΔV_r. Squares are for classical Cepheids, stars for s-Cepheids and triangles for V473 Lyr

4. Separation between classical and s-Cepheids

The quantity $(\sigma^2_{max} - \sigma^2_0)^{1/2}$ is viewed as the maximum excess turbulence that the star has compared to what it would have without pulsation. There is a clear separation in amplitude between classical and s-Cepheids. In Fig. 1b) are also plotted the points computed for the exceptional Cepheid V473 Lyr, whose amplitude varies by a factor 15 on about 1200 days (Burki 1994). The s-Cepheids are at relatively low amplitude whereas classical Cepheids are more or less along a straight line. The cause of this separation is not clear. One can imagine that for the s-Cepheids, as the amplitude increases, more and more energy is transferred in small-scale motions (turbulence) than in large-scale motion (re-expansion of the atmosphere), whereas for classical Cepheids, $\sigma^2_{max} - \sigma^2_0$ remains proportional to the amplitude. This could be related to the fact that most s-Cepheids are probably overtone pulsators. This way to separate classical and s-Cepheids gives new informations on the difference between these two classes.

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References

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