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Metallicity dependence of some parameters of Cepheids

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Abstract
Dependence of phenomenological properties of Cepheids on the heavy element abundance is studied. It is found that the amplitude of the pulsation depends on the metallicity of the stellar atmosphere.
Keywords: *Cepheid variable, pulsation, metallicity*

1 Introduction

Metallicity has a very important role in Cepheids. Nowadays its influence on the PLC relation is a frequently discussed topic of research papers. But we only know little or nothing about other effects of metallicity. Kovács and Zsoldos (1995) and Jurcsik and Kovács (1996) worked out a method to determine the value of $[Fe/H]$ from the shape of the light curves of RR Lyrae stars. Zsoldos (1995) tested this method for Cepheids too, and found a similar relation.

An extensive project has been initiated for studying the effect of heavy element abundance of Cepheids on various pulsational properties of these radially oscillating stars. Here we present the first results on the metallicity dependence of the photometric and radial velocity amplitudes.

2 Data collection

We collected the periods, the amplitudes of the light curves in different colours, radial velocity curves and metallicity of galactic Cepheids. Thanks to the recently aroused great interest there are about 150 Cepheids in our galaxy with known $[Fe/H]$ value. The periods were taken from the DDO Database (Fernie et al., 1995), the amplitudes from three catalogues (Fernie et al. (1995), Szabados (1997), Berdnikov et al. (2000)) and the metallicities from the following publications: Eggen (1985), Giridhar (1986), Fry and Carney (1997) , Groenewegen et al. (2004), Andrievsky et al. (2002a, 2002b, 2002c) , Andrievsky et al. (2004, 2005), Luck et al. (2003), Kovtyukh et al. (2005).

In some cases the amplitudes of the light curves had quite different values as determined by different authors. Thus we omitted the stars, if the differences were larger than 0.1 mag. For stars having several published metallicity values, we averaged these data.

3 Metallicity dependence

3.1 Photometric amplitude – [Fe/H]

First we studied the period–amplitude diagram. Kraft (1960) explored first this relation and he determined an upper envelope to the points on the $\log P - \Delta B$ and $\log P - \Delta V$ diagrams. Eichendorf and Reinhardt (1977) derived a method for constructing envelopes to point diagrams and calculated an upper envelope for ΔB. Their sample contained 255 galactic Cepheids.

Because more comprehensive catalogues have been published since then, we could repeat this study by fitting two parabolae (Fig. 1). These curves fitted better the dip near $\log P = 1$ than polynomials. The equations of the parabolae are given in Eq.(1) and (2). There are three stars (FF Aur, AC Cam, SU Sct) that lie far above the envelope. It is possible, that they are not classical Cepheids.

$$A_B = 1.41 - 5.5 \times (\log P - 0.73)^2 \qquad \log P < 1 \tag{1}$$

$$A_B = 2.15 - 10.0 \times (\log P - 1.3)^2 \qquad \log P > 1 \tag{2}$$

We investigated the metallicity dependence of the deviation of the amplitudes from the estimated maximum amplitude ($\Delta B_{max} - \Delta B_*$) for the given period. If a star has a companion, its light variation decreases because of the

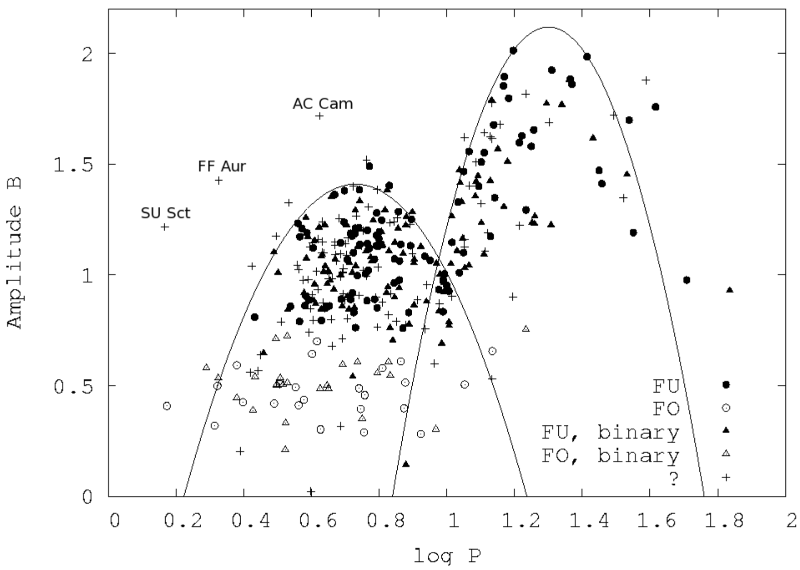

Figure 1: *Upper envelope for ΔB. The two curves are the fitted parabolas. FU: fundamental mode, FO: first overtone, ?: we have no information about pulsation mode. The three stars marked with their names may not be classical Cepheids.*

smaller variation of the intensity ratios. First overtone pulsators also have lower amplitudes. If only the solitary Cepheids (at least those without any known companion), pulsating in the fundamental mode are plotted, there is a definite trend (Figure 2). In the case of higher metallicity the amplitude decreases compared to the upper envelope (i.e. the maximum possible value). The equation of the straight line fit is given in Eq.(3) where DEV is the deviation from the upper envelope.

$$[Fe/H] = -0.09(\pm 0.03) + 0.27(\pm 0.10) \times DEV \qquad (3)$$

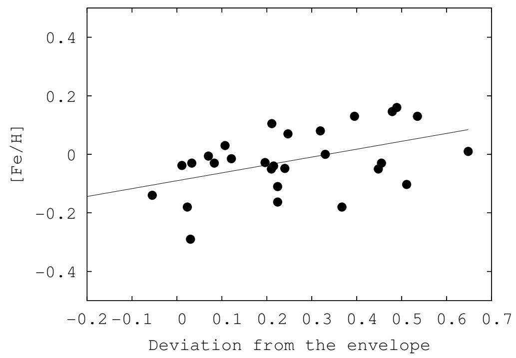

Figure 2: *Deviation from the envelope for solitary, fundamental mode Cepheids.*

3.2 Amplitude ratio – [Fe/H]

We defined the amplitude ratio as the ratio of the radial velocity and the B band photometric amplitude ($AR = \Delta V_{rad}/\Delta B$). The relation between metallicity and AR and the linear fit is presented in Figure 3 and Eq.(4). The fit applies only to the solitary and fundamental mode Cepheids, but all the other groups show similar relation.

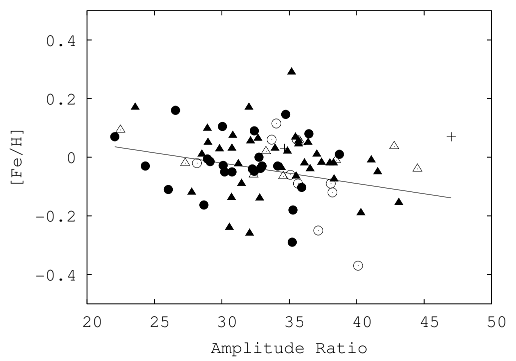

Figure 3: *Metallicity dependence of the amplitude ratio. Symbols are the same as in Fig. 1.*

$$[Fe/H] = 0.19(\pm 0.10) - 0.007(\pm 0.003) \times AR \tag{4}$$

3.3 Slope parameter – [Fe/H]

If we plot the amplitude of the light variations in different colors compared to the amplitude measured in B band vs. $(1/\lambda)$, the distribution of the points will be roughly linear (Fernie, 1979). Szabados (1997) defined the slope parameter as the slope of the straight line fitted to these points.

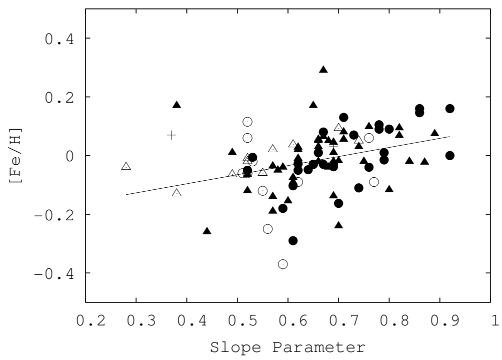

Figure 4: *Metallicity dependence of the slope parameter. Symbols are the same as before.*

Fig. 4 shows the relation between metallicity and the slope parameter. It is visible that the metallicity affects the slope of the line. The higher the [Fe/H] the larger the slope parameter, i.e. the amplitude decreases quicker with the increase of the wavelength. Probably this is due to the change (of the strength) of the mechanisms that govern the pulsation. The result of the linear fit is given in Eq.(5).

$$[Fe/H] = -0.22(\pm 0.06) + 0.31(\pm 0.10) \times SP \tag{5}$$

where SP is the slope parameter. The fit applies only to the solitary and fundamental mode Cepheids again, but all the other groups show similar behaviour and the differences are not significant.

4 Summary

We analysed the metallicity dependence of three parameters related to the light variation and radial velocity amplitudes of galactic Cepheids. We showed that all these parameters (deviation from the upper envelope on the $\log P$–ΔB diagram, amplitude ratio and slope parameter) show a definite relation with $[Fe/H]$. These are not exactly defined relations, rather tendencies (note that the errors of $[Fe/H]$ are generally $0.05 - 0.10$). A deeper analysis of metallicity dependence on pulsation properties of Cepheids is in progress.

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