THE ABUNDANCE OF HELIUM AND STELLAR PULSATION

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ABSTRACT. Radial gradient of relative amplitude of the light variation F_V for galactic classical Cepheids is found. The gradient has different signs for two cases: $P > 8^d$ and $P < 8^d$. For $P > 8^d$ the gradient is negative. This gradient is caused by gradient of helium content in the primordial clouds, where Cepheids were born. In agreement with theoretical calculations, the amplitude increase with an increasing of the helium content. For this dependence the following calibration was obtained:

$[He/H] = (F_V - 0.54)\, dex$

$Y = 0.55F_V - 0.03$

In case $P < 8^d$ the amplitude (and also asymmetry parameter M-m) is mainly affected by metallicity.

Key words: Stars - abundances, Stars - classical Cepheids

Introduction

Determination of helium abundance in the classical Cepheids is an essential problem, because [He/H] value becomes a crucial parameter in the theoretical modelling of the pulsating stars. Here we propose a new method of determination of the He content for Cepheids with $P > 8^d$. A dependence between amplitude and He abundance follows also from the numerical calculations by Stobie (1969), Cogan et al.(1980).

It is known, that light amplitudes for Cepheids strongly depend on period P, therefore we can use a relative amplitude F_V (amplitude parameter, Kraft 1960). The amplitudes were taken from the compilative cataloques by Berdnikov (1987) and Fernie (1995).

It appeared that there exists the radial gradient of F_V for our Galaxy and for two cases $-P < 8^d$ and $P > 8^d$ this gradient has different signs. It means that in this two cases the amplitude is affected by two different factors. Let us consider these two cases separately.

Cepheids with $P > 8^d$

The following gradient of amplitude upon galactocentric distance R_G were obtained:

$$dF_V/dR_G = -0.009\, kpc^{-1} \quad (1)$$

Little is left to be supposed that for the case $P > 8^d$, the amplitude gradient is mainly affected by the gradient of the helium content, which generally exists in the Galaxy. HII region were used for determinations of the He abundance gradient:

$$d[He/H]/dR_G = -0.009\, kpc^{-1} \quad (2)$$

Knowing that the Cepheids (the descendants of B-stars) are formed from the molecular clouds with different chemical composition, one can suppose that gradient of He (and other elements) content found using the Cepheids, reflect the galactic gradient.

During the evolution from the main-sequence B-star to the red giant, a Cepheid rapidly ($\approx 10^3$ yr) crosses the instability strip. In the red giant region Cepheids suffer the dredge-up and their envelopes become helium enhanced (Iben 1965). Therefore, crossing the instability strip for the second time, the Cepheids must pulsate with an increased amplitude.

It is clear that primordial helium abundance (which is inherent to B-stars and HII regions) can take place only in the Cepheids that first crossing the instability strip. Up to now we have found only two such Cepheids: V1162 Aql (Andrievsky et al. 1996) and V636 Cas (Kovtyukh et al. 1996). Both Cepheids have a small amplitude and solar - like CNO abundances.

The helium abundance in HII-regions is similar to that in B-stars from the solar neighbourhood (average abundance $log\ He/H = -1.08$, Adelman 1986). One can suppose that Cepheids first crossing the instability strip have the same mean abundance as for the B-stars ($-1.08\, dex$). The average F_V amplitude for Cepheids first crossing the instability strip is equal to 0.54. Therefore, comparing (1) and (2) we obtain the following calibration (for Cepheids with $P > 8^d$):

$$[He/H] = F_V - 0.54 \quad (dex) \quad (3)$$

$$Y = 0.55F_V - 0.03 \quad (4)$$

The relations (3 - 4) allow to obtain the helium content in upper layers of the Cepheids' atmosphere. It is useful for calculation of the Cepheids pulsational models. It can be also used as a diagnostic tool in a study of helium abundances in different stellar systems and for investigation of the He gradient in other galaxies.

Cepheids with $P < 8^d$

The metallicity, as well as helium content, strongly affects the pulsational activity of Cepheids with $P < 8^d$. A presence of positive amplitude gradient for Galaxy (232 stars):

$$dF_V/dR_G = 0.018\, kpc^{-1} \quad (5)$$

testifies about dominant role of metallicity in the influence on the amplitude comparing with influence of helium content. Therefore, in this case we have to calibrate the dependence $[Fe/H] \sim A$.

For the $[Fe/H] \sim A)$ calibration we used, first of all, well known determinations of Cepheids metallicity based on the high-resolution spectral analysis and data obtained in Washington photometrical system.

The following relation between the various parameters of classical Cepheids are taken:

$$[Fe/H] = 0.739\,(M - m) + 0.064\,P - -0.284\,F_V - 0.425 \quad (6)$$

(asymmetry parameter $M - m$ is the interval between the phases of maximum (M) and minimum (m) of the light curves).

This solutions is valid for Cepheids with $P < 8^d$ and has a standart deviation σ (one star) =0.15 dex, which is only slightly poorer than the best spectroscopic determination.

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