NEW CATALOG OF DISTANCES AND LIGHT CURVE PARAMETERS OF CLASSICAL CEPHEIDS

L.N. Berdnikov

Sternberg Astronomical Institute, 13 Universitetskij prosp., Moscow 119992, Russia, *berdnik@sai.msu.ru*

ABSTRACT. A new version of the catalogue of distances and light-curve parameters for galactic classical Cepheids is presented. The catalogue lists amplitudes, magnitudes at maximum light, and intensity means for 515 stars in $UBVRI$ filters of the Johnson system and $(RI)_C$ filters of the Cron-Cousins system. The distances are based on our multicolour set of PL relations and on our Cepheid-based solution for interstellar extinction law parameters and are referred to an LMC distance modulus of 18.25.

Key words: Stars: Cepheids: light curves; Stars: Cepheids: distances

1. Introduction

In 1981 we started our long-term program of regular photoelectric photometry of Galactic classical Cepheids. By now we have already obtained a total of more than 70 000 measurements in the $UBV(RI)_C$ system for almost 600 objects both in the Northern and Southern sky. Most of our observations have been published by Berdnikov (1986, 1987, 1992a-g, 1993), Berdnikov and Turner (1995a,b, 1998a,b, 2000a,b, 2001a,b, 2004a,b,c), Berdnikov and Vozyakova (1995) and Berdnikov et al. (1998). All our observations are available in the INTERNET at:

http://www.sai.msu.su/groups/cluster/CEP/PHE/cepheids-16-03-2006.zip

Earlier (Berdnikov et al. 2000) we used our observations, in combination with those published by other authors, to determine distances and light-curve parameters for Galactic classical Cepheids with available photoelectric photometry in the $BVRI$ filters of the Johnson system and $(RI)_C$ filters of the Cron-Cousins system. The resulting catalogue contained homogeneous data for 455 stars and proved to be a very useful tool for the study of the distribution and kinematics of Cepheids in the Milky Way (Kervella et al. 2001, Alessi et al. 2003, Sitnik 2003, Tammann et al. 2003, Ngeow and Kanbur 2004, Sakai et al. 2004, Sandage et al. 2004, Bono et al. 2005, Sabbadin et al 2005, Soszynski et al. 2005). Since the publication of this catalogue we have collected extensive photoelectric data which, combined with published photometry, allows us to increase the number of stars with reliable light curves by ~15 per cent. This made it necessary to prepare a new version of our catalogue, which we present in this paper.

2. Light-curve parameters

In our previous work (Berdnikov et al. 2000) we derived the Cepheid light-curve parameters for photometric passbands BVRI of the Johnson system and for the $(RI)_C$ filters of the Cron-Cousins system. In this version of the catalogue we derived light-curve parameters for U passband as well.

To derive light-curve parameters in the $UBVRI(RI)_C$ filters we first selected for each Cepheid and filter the observations that most accurately outlined the shape of the light curve. In most of cases these were either our own observations or those of Gieren (1981), Dean et al. (1977), Coulson and Caldwell (1985), Moffet and Barnes (1984), and Pont et al. (1997) whose photometric systems are virtually identical to our own. We then fitted the light curve, either on the entire [0, 1] phase interval or on its subintervals, by a Fourier series (with 3 to 45 terms), a spline, or a second-to-tenth-order polynomial and joined the resulting fragments to obtain the so-called master light curve. We then used the linear least squares technique to reduce all other observations to the photometric system of the master curve (a detailed description of the algorithm can be found in Berdnikov 1992f) with subsequent refinement of the initial master curve based on all available observations. We used the final master curve to determine the principal parameters of the light-curves: magnitude at maximum light, amplitude, and intensity-mean magnitude.

Reduction of $\sim$ 130 000 photoelectric observations in our Cepheid data bank (Berdnikov 1995) yielded reliable and accurate light curves for 647 Cepheids including 515 classical ones.

3. Distances

We inferred the distances to Cepheids using the light-curve parameters derived as described above and the following procedure suggested by Berdnikov et al. (1996b):

(1) We use the period-colour relation by Dean et al. (1977) to determine the intrinsic colour, $(<B> - <V>)_0$, and the colour excess:

$$E_{\rm B-V} = (<B> - <V>) - (<B> - <V>)_0.$$

In the absence of accurate $<B>$ magnitude we first determine the intrinsic colour

$$(<V> - <m_\lambda>)_0 = <M_V> - <M_\lambda>,$$

using PL relations for $<M_V>$ and $<M_\lambda>$ from Berdnikov et al. (1996b). We then calculate the corresponding colour excess E_{V-m_λ} and convert it into E_{B-V} using interstellar extinction law parameters from Berdnikov et al. (1996a,b).

(2) If the mean magnitude, $<K>$, is not available directly from observations (Berdnikov et al. 1996a), it is derived from formula (5) or an appropriate formula from Table 7 in Berdnikov et al. (1996b) based on known $<V>$ and $<m_\lambda>$. Here m_λ can be any of the B, R, I, $R_{\rm C}$, or $I_{\rm C}$ filters. The galactocentric distance of the star, which is required to allow for the abundance gradient in the disk, is calculated from the preliminary heliocentric distance inferred from $<B>$, $<V>$, and log P. To this end, we adopt $R_0 = 7.1$ kpc, where R_0 is the distance of the Sun from the Galactic centre. Note that we derived the formulas used to infer $<K>$ from, say, $<B>$, $<V>$, log P, and $R_{\rm g} - R_0$ without adopting any specific value for the abundance gradient in the galactic disk. Each of these formulas simply establishes a relation between two observed colours (e.g., $<V> - <K>$ and $<B> - <V>$), the period, P, and the difference of galactocentric distances of the star ($R_{\rm g}$) and the Sun (R_0). The coefficients at $R_{\rm g} - R_0$, if combined with some relation connecting abundance differences into colours, can be used to estimate the abundance gradient.

(3) $<K>$ is then corrected for interstellar extinction:

$$<K>_0 = <K> -0.274 \cdot E_{B-V}.$$

(4) The absolute magnitude of a star is then determined from the following formula:

$$<M_K> = -5.462 - 3.517 \cdot (\log P - 1).$$

(5) The true distance modulus is then calculated as:

$$DM_0 = <K>_0 - <M_K>.$$

(6) And, finally, the distance $r_{\rm hel}$ (in kpc) is given by:

$$r = 10^{0.2\cdot(DM_0-10)}.$$

The distances thus derived are on a short distance scale consistent with an LMC distance modulus of 18.25 (Berdnikov et al. 1996b).

3.1 The catalogue

The resulting light-curve parameters and distances of 515 Galactic classical Cepheids are summarised in the table. The first column of the table gives the name of the Cepheid; the second column, its variability type according to GCVS (Kholopov et al. 1985-1987). The third column gives the fundamental period P_0, which is equal to the observed variability period for most of the Cepheids (DCEP or CEP type in GCVS). We assumed that small-amplitude Cepheids (DCEPS type in GCVS) are first-overtone pulsators and therefore calculated their fundamental periods by dividing the GCVS value by a factor of 0.716−0.027·log P as found by Alcock et al. (1995) and slightly modified by Feast and Catchpole (1997). Note that we give P_0 only up to the third digit after the decimal point because this precision is sufficient for distance determination. More accurate period values can be found in the GCVS.

The fourth column gives the heliocentric distance. The fifth column indicates how the intensity-mean $<K>$ magnitude was derived. K means that it is known directly from observations; V, Rc, Ic, and I, that it was inferred from observed $<B>$ and $<V>$, $<V>$ and $<R_{\rm C}>$, $<V>$ and $<I_{\rm C}>$, $<V>$ and $<I>$, respectively. The subsequent columns give light-curve parameters – amplitude, magnitude at maximum light, intensity-mean magnitude, and quality of a light curve (one to nine) – for each of the filters U, B, V, $R_{\rm C}$, R, $I_{\rm C}$ and I.

The catalog itself is available on request. The complete paper is to be published elsewhere.

4. Conclusion

Our analysis of all available photoelectric photometry of Galactic Cepheids in filters U, B, V, R, and I of Johnson's broad-band system and filters $R_{\rm C}$ and $I_{\rm C}$ of the Cron-Cousins system yielded reliable and accurate light curves (at least in two filters) for 515 classical Cepheids. For these stars we derived accurate light-curve parameters (amplitudes, magnitudes at maximum light, and intensity means) and distances. The resulting catalogue will be used to analyse the properties and space distribution of Cepheids and to investigate the structure and kinematics of the Galactic disk. The data can also be used to test theories of stellar pulsation and late stages of stellar evolution.

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