HV 1369, a Cepheid at a possible depth of 32 KPC in the Small Magellanic Cloud

Genderen, A.M. van

Astron. Astrophys. 101, 289–291 (1981)

ASTRONOMY AND ASTROPHYSICS

HV 1369, a Cepheid at a Possible Depth of 32 Kpc in the Small Magellanic Cloud

A. M. van Genderen

Leiden Observatory, Postbus 9513, 2300 RA Leiden, The Netherlands

Received May 25, accepted June 22, 1981

Summary. HV 1369 (P = 31^d) in the SW part of the SMC appeared to be far too underluminous for its period in a photometric (VBLUW system) study (van Genderen, 1977). New VBLUW photometry seems to support its long period. A comparison with the brightnesses of ten other Cepheids distributed all over the SMC with similar periods, show that HV 1369 is possibly 32 ± 7 kpc more distant than these ones. This fact is in accordance with the concept of a large depth at the SW part of the bar up to 23 kpc based on distance differences of optical objects (Florsch et al. 1981). It is also in accordance with the possibility that an H I arm exists in that area, extending backwards in the line of sight (Hindman, 1967).

Keywords: Cepheids - variable stars - photometry - Small Magellanic Cloud

1. Introduction

Recently a great depth of the Small Magellanic Cloud (SMC) is suggested by Azzopardi and Breysacher (1979), even up to 15 kpc by Ardeberg and Maurice (1979) and at the extreme southern part of the bar up to 23 kpc by Florsch et al. (1981).

During a photometric study (VBLUW system) of SMC Cepheids in the SW part of the bar, one Cepheid HV 1369 (P = 31^d, see for coordinates Sect. 2) showed to be at least 0.5 mag fainter than one would expect from its period (van Genderen, 1977, hereafter called Paper I). On account of its colour indices, interstellar extinction could not explain this underluminosity. The possibility of an incorrect period had to be taken into account, otherwise HV 1369 should lie more than 15 kpc further than the other Cepheids of the investigated sample.

The new observations necessary to check the period are discussed in this note as well as the implications for the depth of the SMC.

2. The Observations, the Light Curve and the Period

HV 1369 has the equatorial coordinates: $\alpha(1975) = 00^h41^m8$ $\delta(1975) = -73^\circ14'$, the Harvard coordinates: x = 9758 y = 8337 and the Wesselink coordinates ξ = -2959 and η = -2074. A finding chart with Wesselink coordinates is given by van Genderen (1969: Fig. 2 p. 265).

The new VBLUW observations (Walraven system) have been made in 1975 and 1977 with the same telescope and equipment as those from 1971/1972 (Paper I). Particulars of the photometric system and the transformation formulae to obtain the V and B-V mag of the UBV system (with subscript J) are given in Paper I and in the quoted references. The same comparison star has been used again. The individual observations will be published elsewhere.

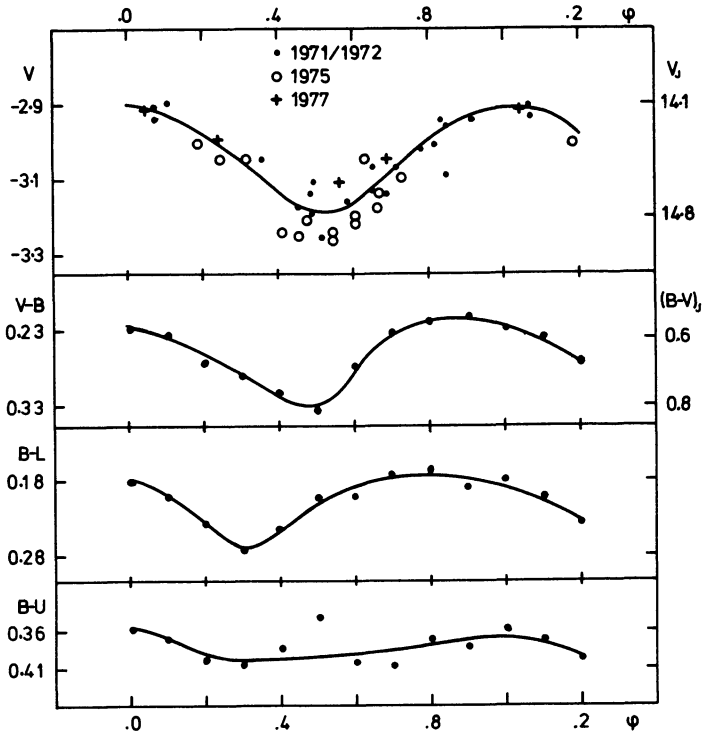

Fig. 1. First panel: the light curve of HV 1369 in V (of the VBLUW system) in log int. scale at the left and in V_J (of the UBV system) in mag at the right. Second to fourth panel: the smoothed colour curves. At the right of the V-B panel the equivalent scale in mag for $(B-V)_J$ of the UBV system.

Figure 1 depicts the light- and smoothed colour curves. The upper panel shows the light curve in V (in log int. scale) at the left. The V_J scale of the UBV system (in mag) is indicated at the right. The observations made in different seasons are represented by different symbols. The ephemeris used in Paper I were taken from Payne-Gaposchkin and Gaposchkin (1966):

J.D. max = 2424332.829 + $31^d.024$ E

The 1975 and 1977 observations indicated at once, that a slight revision of the period was necessary:

J.D. max = 2441191.3 + $30^d.925$ E

(the zeropoint is arbitrary and taken at $\Phi = 0$). The new period has an estimated uncertainty of $\pm 0^d.030$. The scatter in the light curve can be largely attributed to the faintness of the star, although it seems that some systematic differences between several seasons is present. However this effect is smaller (as well as the scatter) in the B band, which has the largest response.

Phases were also derived with periods between 13 and 20^d, the period range in which the observed brightness would be normal. However without success.

3. The Colour Curves and the Blue Companion

Since the colour curves show more scatter than those in V and B, especially the B-U curve, we show in the other panels of Fig. 1 the smooth V-B, B-L and B-U curves (in log int. scale). The dots represent the differences between the readings of the smooth V (5467 A), B (4325 A), L (3838 A) and U (3633 A) curves at regular phase intervals of 0.1. Since the intensities in the W (3255 A) band seldom surpassed the sky brightness, a U-W curve cannot be given. At the right of the V-B panel the equivalent value of the UBV system: $(B-V)_J$, is shown in mag scale.

From the discussion in Paper I it was made clear, that this Cepheid has a blue companion, probably an early B type star: its colour indices were much too blue and the amplitudes of the light curves in B, L and U too low. The effect of the blue companion is also at once evident from the colour curves in Fig. 1 when compared with normal Cepheids (Pel, 1976).

4. Discussion

Before we proceed the discussion on HV 1369 as a Cepheid of population I, we should consider the possibility that the variable is a galactic foreground RR Lyrae star or a population II Cepheid of the SMC.

If the star is an RR Lyrae star ($M_V \sim 0.5$) its distance should then be ~ 6 kpc, the z distance ~ 4 kpc and its distance to the galactic centre ~ 9 kpc. The chance to find there an RR Lyrae variable must be considered as small. The colour indices V-B and B-L are unlike that of RR Lyrae stars, which can be checked with the V-B/B-L diagram of Lub (1979, Fig. 2). Only an unlikely high reddening of $E_{V-B} \geq 0.14$ or $E_{(B-V)_J} \geq 0.3$ mag could move HV 1369 into the domain of the RR Lyrae stars, while the generally accepted value for the galactic reddening into the direction of the SMC is not much more than ~ 0.05 mag. Further the B-U index of HV 1369 is too blue for RR Lyrae stars by about ~ 0.1 and no reddening can eliminate that.

It leaves us to consider the possibility that HV 1369 could be a population II Cepheid (or W Virginis star) in the SMC. Little is known about this type of variables in the SMC. Payne-Gaposchkin and Gaposchkin (1966) only found three of them with periods of 15, 17 and 107^d. They clearly lie ~ 1.5 to 2 mag below the mean P-L relation of the population I Cepheids (Payne-Gaposchkin and Gaposchkin), similar to the globular cluster Cepheids (e.a. Kwee, 1968). The last ones are assumed to be identical to the galactic population II Cepheids, of which the distances and absolute brightness could not be derived so far. The adopted agreement between the two groups of population II variables are mainly based on photometric (light curve characteristics) and spectroscopic considerations. Anyway, HV 1369 lies less than 1 mag below the mean P-L relation and thus seems to be too bright for a population II Cepheid. The light curve of HV 1369 is slightly atypical for a population I Cepheid in the period range around 30^d, but no good comparison is possible with population II Cepheids of similar periods, because of their scarceness. Neither does its light curve fit within Kwee's (1967) classification criteria for light curves of known population II Cepheids. A comparison of the colours is also difficult, since no VBLUW photometry of population II Cepheids is available, apart from W Vir (Oosterhoff and Walraven, 1966). In the UBV system population II Cepheids can be distinguished from population I Cepheids by the feature that the U-B colour has almost reached the bluest value before maximum brightness (Kwee, 1967). For HV 1369 this is more or less also the case for B-L, but the B-U curve (the Walraven L and U bands are situated in the Johnson U band) is almost flat. Actually these curves are very typical for population I Cepheids with blue companions (Pel, 1976). Blue companions among population I Cepheids and other F type supergiants are no exception at all: they occur in at least 25% of the investigated cases (e.a. Paper I, Pel, 1978; van Genderen, 1980; Parsons, 1981). The conclusion is that HV 1369 is likely no population II Cepheid either.

The 1971/1972 observations combined with the new ones, resulted in more reliable photometric parameters for HV 1369. Its position in the V-B/B-L diagram (Paper I) did not change much, while in the V-B/B-U diagram it moved upwards by ~ 0.07. The intensity means of the light- and colour curves in the UBV system are as follows: $V_J = 14.40$ and $(B-V)_J = 0.63$.

Since we are interested in the distance modulus of HV 1369 relative to the other Cepheids (of population I) in the SMC, the foreground reddening can be ignored. Further we should actually correct for interstellar extinction in the SMC, which cannot be ignored. A glance at the distribution of Cepheids in the HR diagram, situated in different areas, clearly shows that those in the denser areas of the SW part of the bar are on the average redder than those in the outskirts and the NE part of the bar (van Genderen, 1969 Fig. 17). Since it is difficult to find reliable individual extinction corrections, we can sail round this problem by making use of the HR diagram as shown in Fig. 2. Here the observed brightnesses of HV 1369 and ten other SMC Cepheids with similar periods can be compared. The influence of the reddening with R = 3 is shown by the arrow at the left top corner. Distance differences will increase the scatter in vertical direction.

The large dot in Fig. 2 represents HV 1369, while the other symbols represent the Cepheids (periods in days added) taken from the following sources: Paper I (small dots): MK_g and HV 10357 (both corrected for a blue companion), HV 1451 (note that the $(B-V)_J$ in Table 3 should be read as 1.07) and HV 1501; Butler (1976) (plus signs): HV 847, HV 1967, HV 840, HV 2064 and HV 11182; Madore (1975) (square): HV 819.

Similar to the procedure of Paper I we corrected the photometric parameters of HV 1369 for the blue companion, so that its position in the two-colour diagrams as well as its light amplitudes became more or less normal. We took into consideration that the SMC Cepheids show an ultra violet excess with respect to the galactic Cepheids as a result of the metal underabundancy by a factor five (Paper I, Pel et al. 1981).

The B type star lies possibly in the range $-2.8 > M_V > -4$, adopting a foreground extinction of $A_{V_J} = 0.15$ mag and an internal extinction in the SMC of $A_{V_J} = 0.6$ mag (Paper I). For HV 1369 the possible range of the change of the intensity means is as follows: a drop in V_J by 0.15 to 0.40 mag and a reddening of $(B-V)_J$ by 0.12 to 0.25 mag respectively. The so obtained corrected position of HV 1369 is indicated in Fig. 2 by the

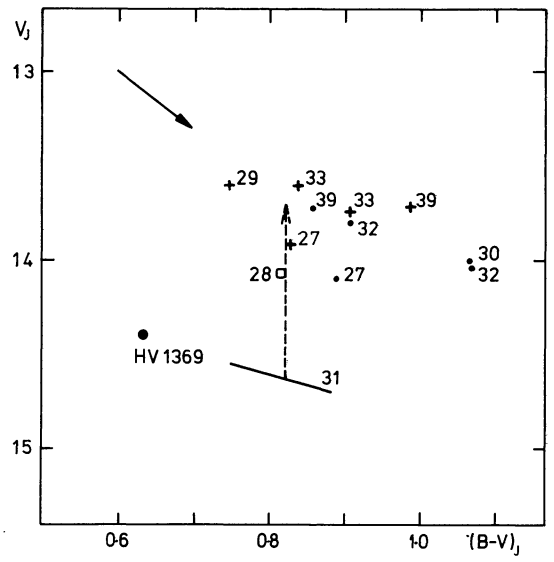

Fig. 2. The HR diagram with the observed position of a number of SMC Cepheids with periods around 30^d (periods in days are indicated). See for the explanation of the symbols Sect. 4. Large dot: HV 1369 uncorrected for the presence of the blue companion; oblique line: possible range of the position of HV 1369 after correction for the blue companion. The arrow in the left top corner is the reddening path.

oblique line.

It is obvious that HV 1369 is far too low in brightness by $\sim 0.9 \pm 0.15$ mag (vertical dashed arrow). The small vertical scatter of the ten other Cepheids distributed all over the Cloud is remarkable. It indicates that very large distance differences are rare and apparently only confined to the SW part of the bar. According to Florsch et al. (1981) some other Cepheids studied by Isserstedt (1976) and four Wolf-Rayet stars studied by Breysacher and Azzopardi (1978), also show here large distance differences. If we adopt a distance modulus of 19.0 (63 kpc) for the main body of the SMC, HV 1369 lies thus 32 ± 7 kpc more distant. This is the largest recorded depth in the SMC so far. It is however urgently required that such a large distance is confirmed by radial velocity observations. Apparently the SW part of the bar has a trail of matter extending backwards in the line of sight up to half of the present distance between Galaxy and SMC. These optical evidences for an arm in this region supports Hindman's (1967) suggestion based on H I data, that if the SMC had a bar, it could lie in the line of sight near $\alpha = 00^h48^m$ and $\delta = -73^\circ18'$ (thus close to the position of HV 1369).

It would be of importance to investigate whether such a long arm could be the result of gravitational disturbances during narrow passages in the past between the Galaxy and the SMC (e.a. Hunter and Toomre, 1969; Fujimoto and Sofue, 1977) or between LMC and SMC (e.a. Mathewson, 1976).

Acknowledgements. It is a pleasure to thank Dr. K.K. Kwee for his interest and valuable remarks.

References

Ardeberg, A., Maurice, E.: 1979, *Astron. Astrophys.* 77, 277
Azzopardi, M., Breysacher, J.: 1979, *Astron. Astrophys.* 75, 120
Breysacher, J., Azzopardi, M.: 1978, *ESO Scientific Prepr.* 38
Butler, C.J.: 1976, *Astron. Astrophys. Suppl.* 24, 299
Florsch, A., Marcout, J., Fleck, E.: 1981, *Astron. Astrophys.* 96, 158
Fujimoto, M., Sofue, Y.: 1977, *Astron. Astrophys.* 61, 199
van Genderen, A.M.: 1969, *Bull. Astron. Inst. Neth. Suppl.* 3, 221
van Genderen, A.M.: 1977, *Astron. Astrophys.* 54, 737
van Genderen, A.M.: 1980, *Astron. Astrophys.* 88, 77
Hindman, J.V.: 1967, *Australian J. Phys.* 20, 147
Hunter, C., Toomre, A.: 1969, *Astrophys. J.* 155, 747
Isserstedt, J.: 1976, *Astron. Astrophys.* 47, 463
Kwee, K.K.: 1967, *Bull. Astron. Inst. Neth.* 19, 260
Kwee, K.K.: 1968, *Bull. Astron. Inst. Neth.* 19, 374
Lub, J.: 1979, *Astron. J.* 84, 383
Madore, B.F.: 1975, *Astrophys. J. Suppl.* 29, 219
Mathewson, D.S.: 1976, *Proc. Astron. Soc. Australia* 3, 20
Oosterhoff, P.Th., Walraven, Th.: 1966, *Bull. Astron. Inst. Neth.* 18, 387
Parsons, S.B.: 1981, *Astrophys. J.* in press
Payne-Gaposchkin, C., Gaposchkin, S.: 1966, *Smithsonian Contrib. Astrophys.* 9, 1
Pel, J.W.: 1976, *Astron. Astrophys. Suppl.* 24, 413
Pel, J.W.: 1978, *Astron. Astrophys.* 62, 75
Pel, J.W., van Genderen, A.M., Lub, J.: 1981, *Astron. Astrophys.* 99, L1