LEAVITT VARIABLES: THE BRIGHTEST CEPHEIDS VARIABLES and their IMPLICATIONS for the DISTANCE SCALE

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Abstract. Two low-amplitude variable supergiants in the Large Magellanic Cloud, S65-08 and S65-48 are each found to have periods of approximately 250 days. The optical data suggest that these stars are high-luminosity cepheid variables falling more than one magnitude brighter than any other known Cepheids in the LMC. Confirmation of the cepheid nature of these stars comes from their H-band magnitudes which place them accurately on a simple linear extrapolation of the narrower infrared Period-Luminosity relation. So it appears that the cepheid Period-Luminosity relation extends up to $M_V \sim -8.5$. To honour the astronomer who discovered the first of these highest-liminosity Cepheids, we have sub-classified the variables with log P > 1.8 as being "Leavitt variables". As soon as these long-period variables are discovered in other external galaxies, reliable distances should be possible out to $(m-M) \sim 30$.

I. Introduction

It is a commonly held belief that Cepheids span a period range extending from 1 to 50 or 60 days (cf. Cox 1980 or Strohmeier 1972) but this is a somewhat constrained view imposed by our galactic perspective. It has in fact been known since the discovery of the PL relation for Cepheids by Leavitt (1907) that the relation extends to periods beyond 200 days. The discovery and calibration of the longest-period (and hence brightest) Cepheids is important since these stars are fundamental to the determination of reliable distances to nearby galaxies.

Comprehensive reviews of the status of the extragalactic sample with the inevitable emphasis on the Magellanic Cloud Cepheids have been published by Madore (1983) and more recently by Feast (1984). It is emphasized by these reviewers and has been noted before (Sandage and Tammann 1968) that in the optical, the longest-period Cepheids (log P > 2.0) are somewhat deviant from a simple linear Period-Luminosity relation as extrapolated from shorter periods. Sandage and Tammann (1968) considered this apparent flattening in the Period-Luminosity relation beyond 100 days to be intrinsic to the calibration. On the other hand, Madore (1982) has argued that based on a reddening-free formulation of the Period-Luminosity relation, the same data indicate no curvature and that excess differential reddening of the four LMC Cepheids might offer a natural explanation. Obviously, small number statistics play an im-

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portant role in such an evaluation; from all points of view, a larger sample or complimentary observations would be desirable.

II. The New Variables S65-08 and S65-48

Recently, Grieve (1983) has completed a photoelectric program monitoring all of the brightest Magellanic Cloud intermediate-type supergiants using the Las Campanas 61cm reflector of the University of Toronto. The purpose was to discover the frequency and type of light variations to be found in these stars. Low-amplitude variations ($\Delta B < 0.5$ mag) could easily have been missed in the early photographic surveys and extrapolation of the period-amplitude diagram (e.g., Schaltenbrand and Tammann 1970) would suggest that very long-period Cepheids might be expected to have small amplitudes. The recent observations of Eggen (1983) confirm this suspicion.

S65-08 is of spectral type G2 Ia (Ardeberg et al. 1972); and with a radial velocity of +311 km/s (Brunet et al. 1973) it is a confirmed member of the LMC. It is now known that S65-08 is a variable with an amplitude of approximately 0.3 mag at V and 0.1 mag in (B-V). A period gram analysis of the V data yields a best-fitting period of 250 days. A second low-amplitude supergiant variable has been pointed out by Eggen (1983). This star, S65-48, was found to have a V amplitude of 0.3 mag. Grieve (1983) has also observed this star and in combining these data, a period of roughly 250 days has been found. Ardeberg et al. (1972) give the radial velocity of S65-48 as +311 km/sec confirming its membership in the LMC. They also quote a spectral type of F8 Ia while Morgan and Keenan (1973) consider it to define the super-supergiant type F8 0.

Fig. 1. The <V> Period-Luminosity relation for 33 LMC Cepheids for which both V and H observations are available.

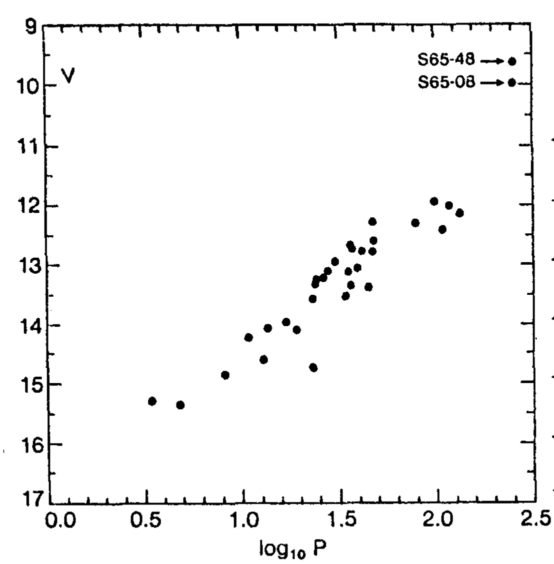
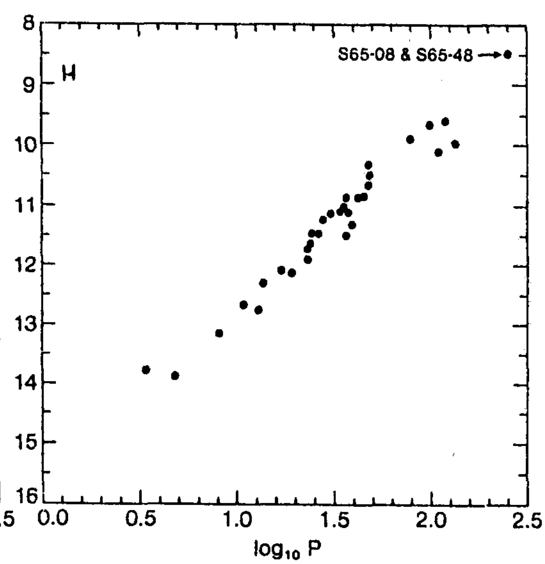


Fig. 2. The <H>Period-Luminosity relation for 33 LMC Cepheids. including the two new Leavitt variables at 250 days.



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In Figure 1, we present the V Period-Luminosity relation for the photoelectrically observed LMC Cepheids as compiled by Madore (1984). Neither individual nor statistical corrections for foreground or external reddening have been applied to the data. Also plotted are the intensity-averaged <V> magnitudes of S65-08 and S65-48. As can be seen, the V Period-Luminosity relation does in fact continue linearly from the shorter periods to the region unambiguously defined by these two new Cepheids. The curvature in the Period-Luminosity relation suggested by the previous data sample is not confirmed for substantially longer periods.

As a further powerful check in establishing that the intrinsic Period-Luminosity relation extends in a linear fashion out to 250 days, we obtained JHK observations for S65-08 and S65-48 using the Dupont 2.5m at Las Campanas, Chile in January, 1983. Figure 2 shows the position of these stars in the infrared H-band relation. The data defining this relation for the previously catalogued Cepheids are intensity-mean averages obtained by the techniques outlined in Welch et al. (1984) using the data in McGonegal et al. (1982) and additional data to be published. As can be seen the new Cepheids fall precisely where they would be expected to be based on a simple linear extrapolation of the H Period-Luminosity relation.

III. Implications and Discussion

Sandage (1984) has suggested that the flattening in his calibration of the apparent <B> Period-Luminosity relation can be put to good practical use, in the sense that only approximate periods are needed at the long-period end in order to obtain reasonable distances. Inspection of his Figure 1 or equivalently Figure 5 in Sandage and Tammann (1968) reveals that in practice this apparent flattening could be used to give distance moduli good to ± 0.2 mag (rms) for periods in the interval 60 to 160 days (i.e., log P = 2.0 ± 0.2).

However, using a strictly linear Period-Luminosity relation has a two-fold advantage. Firstly, the scatter in the infrared Period-Luminosity relation is so small that periods, in fact, need not be determined with great accuracy anywhere along the relation. For instance, for a Cepheid whose true period is 100 days, any determination between 80 to 125 days will also suffice to give and H-band distance modulus good to ± 0.2 mag (rms). Secondly, and perhaps more importantly, a linear Period-Luminosity relation greatly extends the potential of Cepheids as distance indicators.

When Henrietta Leavitt (1907) plotted the periods and magnitudes of the variable stars that she had been studying in the Magellanic Clouds "... she realized that her discovery could be used as an indicator of intrinsic brightness, but was prevented from pursuing the subject any further ..." (Berendzen, Hart and Seeley 1976). Not only did she discover the Period-Luminosity relation but she discovered the longest-period members of that class -- none of which were known locally. Others soon identified Leavitt's Harvard variables with galactic Cepheids and so the relation that she found does not bear her name. Now as a tribute to the

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discoverer of the objects that have and will continue to play a key role in the extragalactic distance scale, we plan to refer to the sub-class of these variables beyond log P ∿ 1.8 as Leavitt variables. With these objects in the calibration, galaxies at least an extra magnitude further in distance modulus can now be calibrated by traditional methods.

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