Distances to Extragalactic RR Lyrae Stars Using IRAC2

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1. Introduction

Extragalactic distances based on Pop-II stars are of great importance to check the Cepheid distance scale and its zero point since Pop-II objects like RR Lyrae stars are not calibrated using the distance to the Pleiades but provide a truly independent approach.

Longmore et al. (1986) showed that there exists a well-defined Period-Luminosity relation for RR Lyrae stars when using the mean K magnitude as the luminosity indicator, and Longmore et. al. (1990) have made extensive investigations of RR Lyrae stars in Galactic globular clusters. The K band is an excellent band to use for distance estimates because it is fairly insensitive to metallicity and to uncertainties in the reddening, two problems which haunt most optical calibrators.

IRAC2 mounted on the 2.2-m ESO/MPI telescope has enabled us to observe stars down to about 19th magnitude in about an hour (half of the time is spent on sky measurements) making it feasible to observe RR Lyrae stars in the LMC. The big field (2′ × 2′) compared to previous cameras also enables us to cover a significant part of globular clusters in the LMC and thus to observe several RR Lyrae stars simultaneously. We describe here some test observations on the old LMC globular cluster NGC1841 (Walker 1990), in which we successfully measured 11 RR Lyrae stars in a single field, and we present some preliminary results.

2. Observations and Photometry

On September 9, 1992 we obtained six images of the cluster shifted randomly within a ≈ 25″ diameter region. The exact position was chosen with the help of a finding chart from Walker (1990) in such a way as to maximize the number of RR Lyrae stars in the field of view, and also making certain that we included stars covering a large range in period. Each image was actually an average of ninety 3-sec images, and was followed by a similar integration on a sky position about 200″ south of the cluster.

From each source image we subtracted the average of the bracketing sky frames and then rebinned the image by a factor of two before shifting and stacking the results to produce the image shown in Figure 1. The frames were stacked by taking the median of the six frames whereby the bad pixels were efficiently eliminated except for the bad rows at the lower left. The final image comprises the area in common to the six frames and the FWHM of the stars is a mediocre 1.4″.

Although we could not identify the RR Lyrae stars in the individual frames, DAOPHOT succeeded in finding 11 of the variables in the stacked frame. The DAOPHOT ALLSTAR programme furthermore succeeded in measuring stars down to 19.5 mag and the estimated uncertainty of an 18.5 mag star is about 0.2 mag.

The instrumental magnitudes were transformed to the standard system using a number of faint standard stars ($8 < K < 9.5$) and corrected for extinction assuming $E(B-V) = 0.18$, following Walker (1990), giving $A_K = 0.1 \times 3.1\ E(B-V) = 0.06$ mag. This low value of the absorption illustrates one of the important features of the infrared Period-Luminosity relation, namely the weak sensitivity to uncertainties in the reddening estimates.

3. Results

Walker (1990) determined the periods for these stars and using these periods together with the K magnitudes derived here, we can construct a $\langle K \rangle$-logP diagram (Fig. 2). Although we have not observed the mean K magnitude, $\langle K \rangle$, but just the K magnitude at a random phase for each star, the uncertainty introduced on each datum from this simple approach is less than 0.2 mag for each point because the amplitude in the K band is only about 0.3 mag peak-to-peak. From the typical shape of the K light curve for these stars, it is expected that most of the stars will be slightly brighter (≈ 0.1 mag) than the mean value and a few stars will be significantly fainter (≈ 0.2 mag). The large number of stars helps to average out this error and the resulting relation can be established reasonably well. We find a best fitting straight line of the form

$$\langle K \rangle = -2.3(\pm 0.5)\log P + 17.06(\pm 0.10). \quad (1)$$

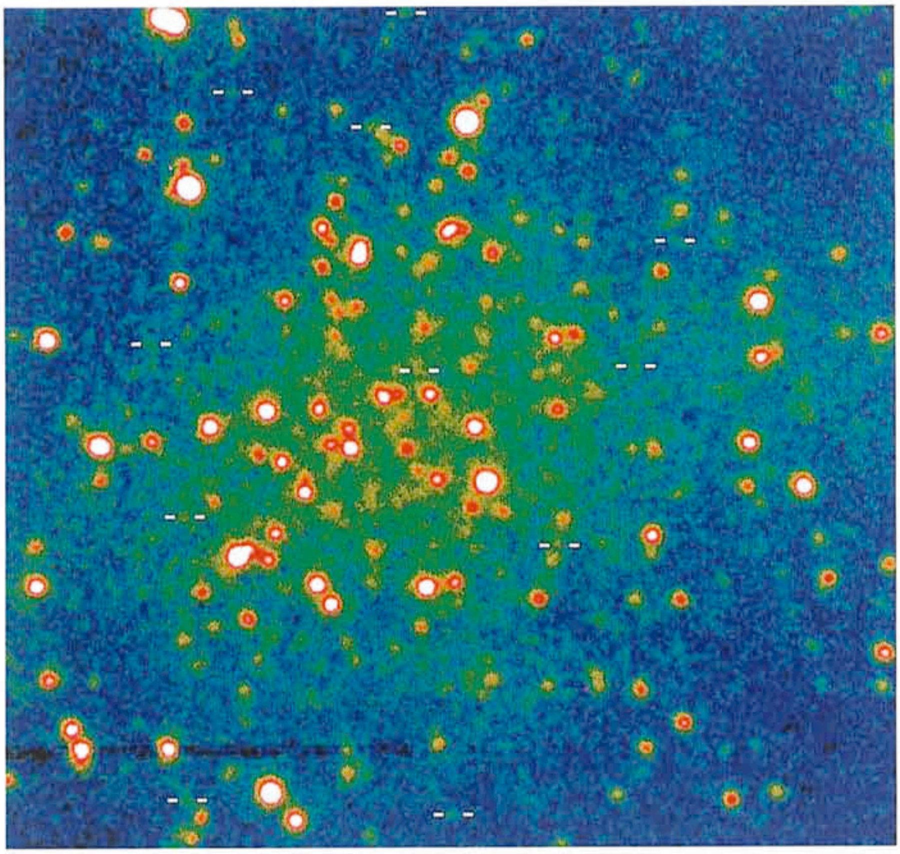

Figure 1: *K-band image of NGC1841 as seen by IRAC2 with the measured RR Lyrae stars marked. The image is made of a stack of 6 individual frames each of which is made up of ninety 3-sec integrations giving a total of 27 minutes of integration. The frame contains only the area covered by all six frames (≈110″×110″) and is thus slightly smaller than the field covered by a single exposure.*

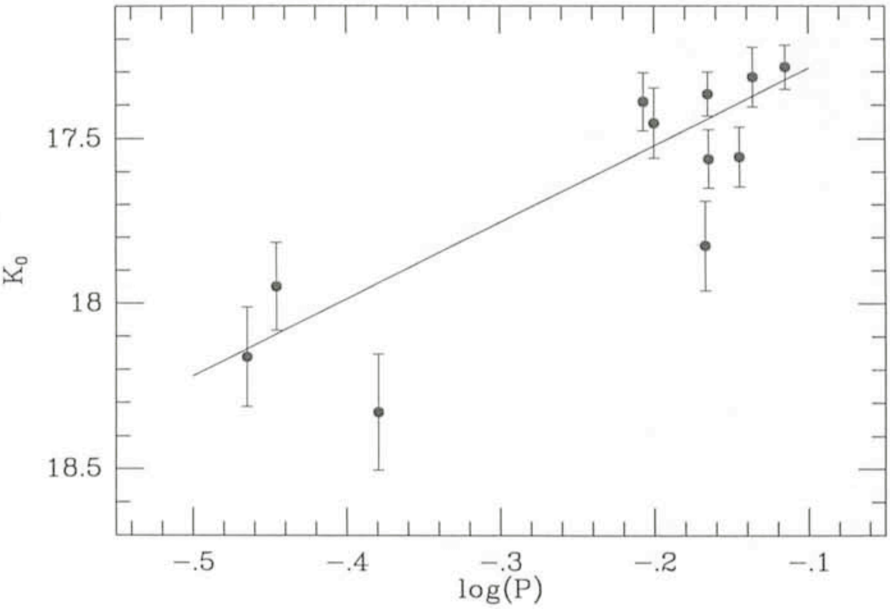

Figure 2: *The Infrared Period-Luminosity relation as derived from the RR Lyrae stars of NGC1841. The line is the best fitting line through the weighted data points.*

This result is in excellent agreement with the relation found for galactic RR Lyrae stars by Jones et al. (1992) using the Baade-Wesselink method, which is

$$\langle M_K \rangle = -2.33(\pm 0.20)\log P - 0.88(\pm 0.06). \quad (2)$$

While it might be coincidental that the slopes agree so well, the result clearly indicates that the slope $d\langle K \rangle / d \log P$ determined for Galactic RR Lyrae stars can also be applied to low metallicity RR Lyrae stars in the LMC, and the relation can thus be used to determine the distance to such stars.

From the above equations we derive a distance modulus of 17.94 ± 0.15 to NGC1841, where the uncertaintly reflects internal errors only. This value is in excellent agreement with the results of Walker (1990) when adjusted to a common zero point. He derives a value of 18.19 from the $\langle M_V \rangle$–[Fe/H] relation assuming a value of +0.5 mag for $\langle M_V \rangle$ at [Fe/H] of −2.2 dex. Jones et al. (1992), on the other hand, find a value of +0.67 mag more appropriate based on the same Baade-Wesselink results that provides the basis for Eq. 2. Correcting the modulus of Walker (1990) accordingly, we derive a modulus of 18.02 mag.

To further constrain the slope, we are attempting to obtain more data at different phases to decrease the scatter due to the random phasing of the data points and to improve the S/N for the faintest of the stars. Finally, we intend to measure stars in more LMC clusters to increase the sample size.

For a discussion of the adopted zero points see e.g. Carney et al. (1992) and Cacciari et al. (1992).

NGC1841, being located almost 15 degrees from the bar, is known to be far from the centre of the LMC. Walker (1990) argues that NGC1841 is approximately 0.3 mag closer than the LMC centre and adding in this offset leads to a modulus of 18.24 to the centre of the LMC. This is about 0.3 mag closer than suggested by the most recent Cepheid calibration (see Feast 1991), but in good agreement with other LMC RR Lyrae data (e.g. Walker 1992). A similar difference between distances based on RR Lyrae's and Cepheid's found by Saha et al. (1992) in the Local Group galaxy IC1613, suggest that there is a problem either with the zero point of one or both of the methods or that there are still effects like differences in chemistry which are not taken properly into account in the various methods.

In conclusion we must stress the importance of the big efforts that are currently being put into the better understanding of the various distance calibrators as well as their zero points.

References

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The Great Annihilator in the Central Region of the Galaxy

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1. The Sepulchral Silence of the Hypothetical Super-Massive Black Hole

For two decades gamma-ray astronomers observing the galactic centre region with many balloon and satellite-borne instruments have been reporting intermittent radiation from the annihilation of positrons with electrons. Positrons are electrons of positive charge that annihilate when they meet ordinary matter, producing pairs of photons of 511 keV, the rest-mass energy of the annihilated particules.

The sporadic appearance of this type of gamma radiation in the central region of our Galaxy indicated the existence of a compact object (or objects) capable of fabricating enormous quantities of positrons in short periods of time. The poor angular resolution of the detectors used until recently gave wide latitude to the belief that the mysterious compact source of positrons could be a black hole of several million solar masses residing at the dynamic centre of the Galaxy.

However, the French gamma-ray telescope SIGMA on board the Russian satellite GRANAT has recently found[1] that the strongest source of 511 keV gammas is not at the dynamic centre of the Galaxy, but 50 arcminutes away from it (Fig. 1). On October 13–14, 1990, SIGMA detected from this source