A period-luminosity relation for Mira variables in the Large Magellanic Cloud (Nature 291, pp303-304, 1981).

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Mira variables are very bright objects in the IR ($\sim 2\mu$m) so that they can be seen to large distances and through heavy interstellar absorption. Provided that they have well defined lumiosities they should therefore be ideal indicators of galactic and extragalactic distances. Luminosities are also essential for understanding the physical state and pulsational characteristics of these stars which may be at the final stage of stellar evolution before planetary nebula formation[1−3]. A period-luminosity relation has been established for galactic Miras[4], but the intrinsic scatter in the relation is largely unknown. We report here periods and bolometric magnitudes for Miras in the Large Magellanic Cloud (LMC) which show a period-lumiosity relation with very small scatter.

A search for red variables on visible light photographs of the Magellanic Clouds has been described elsewhere[5]; 12 Mira variables were found in a field of 0.3 deg^2 in the Bar of the LMC and periods with an error of $\sim$ 10 days were determined. Details will be published elsewhere. Each star was observed at least three times in the period 1976-80 using the IR photometer[6] on the 1.9-m reflector at Sutherland. An InSb detector was used and the system is believed to be linear to better than 0.1 mag. The mean standard errors of single observations at J, H and K are 0.07, 0.04 and 0.04 mag respectively. Confusion by stars in the reference beam prevented satisfactory results for one star, which has been omitted from the discussion, and may also be responsible for the excessive red colour found for number 153. The observations do not define the light curve as a rule, so that the mean J, H and K magnitudes were found and the bolometric magnitude estimated by fitting a black-body curve[4]. The results are given in Table 1. The mean range of K in the present data is 0.5 mag, so the error in a bolometric magnitude will exceed the purely photometric errors noted above.

The 11 stars are assumed to be a homogeneous sample of M-type Miras similar to those in our own Galaxy. The colours in the visible and IR regions are consistent with this except for C7 which has been found spectroscopically to be a carbon star (T.L.E., in preparation). Its exclusion would make virtually no difference to the adopted period-luminosity relation.

The data of Table 1 are plotted in Fig. 1, which also shows the best fitting straight line. This has the equation

$$m_{\rm bol} = 19.25 - 2.09\,\log P(\rm days)$$

The r.m.s. deviation of a single star is only 0.22 mag, much of which is attributed to the small number of observations. A selection effect cannot be ruled out for the longer period stars, which are faint visually, but the sample is believed to be complete for those with $P \leq 300$ days. The intrinsic scatter may thus be very small and is less than the value of 0.25–0.30 mag found for classical cepheids

Table 1: Bolometric magnitudes of Mira variables

Star	P(days)	m_{bol}
C38	131	14.85
C48	175	14.18
C11	200	14.40
C20	207	14.57
120	213	14.40
141	260	14.13
110	266	14.60
C7	314	14.03
153	360:	14.13:
49	390	13.67
105	430	13.51

if no colour term is included[7]. This in turn implies that the instability strip is narrow.

The LMC distance modulus from classical Cepheids is 18.69 mag (ref. 7), so the absolute bolometric magnitudes are

$$M_{\mathrm{bol}} = 0.56 - 2.09\ \log P$$

The slope of the period-luminosity relation may be fitted to the bolometric magnitude calibration for galactic Miras to give

$$M_{\mathrm{bol}} = 0.76(\pm 0.11) - 2.09\ \log P$$

Double weight has been given to the 12 stars in ref. 4 with individually known distances. The difference between the zero points of the galactic and Magellanic calibrations is not significant. Adoption of the galactic zero point would imply a distance modulus for the LMC of 18.5 mag.

The question arises whether the application of this result to distance determination would be vitiated by intrinsic differences between the stars observed in different systems. Feast[8] has argued that there is little possibility of confusion between Mira variables and the red supergiant variables of large amplitude. There is a possibility, as in the case of other objects used as standard candles, that the luminosities depend on the metal abundance. The satisfactory agreement between the zero points found for Mira variables in the Galaxy and the LMC indicates that any such difference is small.

Observations of a larger sample of stars, with more complete coverage of the light cycle, should allow an improved calibration to be found from Magellanic data alone. It seems clear from our results that Mira variables should indeed be good distance indicators.

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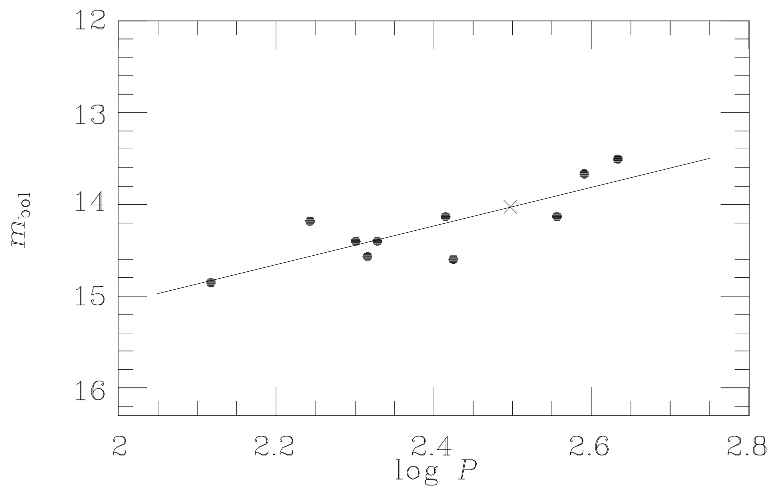

Figure 1: m_{bol} for LMC Miras plotted against log P (days). ×, The carbon star. The best fitting linear regression line is shown.

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