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IS THE PERIOD-LUMINOSITY RELATION OF AGB STARS UNIVERSAL?

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Abstract. One characteristic of AGB stars is their large amplitude variation due to pulsation. I studied the behaviour of the pulsational properties of Long Period Variables (LPVs) in different galactic environments such as the galactic Bulge, the LMC and SMC. I have shown that the Bulge LPVs follow nearly the same Period-luminosity relation in these three different environments. In the infrared, the PL relation of AGB stars is *universal*. Therefore AGB stars can be seen as excellent extraglactic distance indicators.

1 Introduction

AGB stars are dominated by dynamical phenomena like pulsation and shock waves. They are long-period variables (up to $\sim 2000^d$) with large amplitude variation (Mira Variables have amplitudes in the Visual greater than 2.5 mag). Therefore only hydrodynamical model atmospheres can reproduce the observed molecular features (see e. g. Aringer et al. 1999; Alvarez et al. 2000). The study of molecular features covering a whole pulsational cycle are essential to understand the interaction between pulsation, the resulting propagation of shock waves, dust formation and mass loss.

Based on the regularity of the lightcurve, one distinguishes between Mira-type variables (regular pulsational behaviour), semiregular Variables (SRVs) and irregular variables (no periodicity in the light variation). Recently, thanks to the microlensing searches, such as MACHO, EROS and OGLE, high quality light curves were obtained for the galactic Bulge, LMC and SMC which allows to study the pulsational properties of AGB stars. PL relations of AGB stars show four parralel sequences (A-D). Large-amplitude Mira variables are located at the top of sequence C are are fundamental pulsators. On the other hand, semiregular variables are located on sequences A and B and pulsate in first, second or third overtone mode. Stars located on sequence D are multi-periodic and their origin is still unknown.

2 Long-period Variables in different galactic environments

Do different galactic environments influence the fundamental physical parameters of pulsating AGB stars?

The Spitzer infrared satellite has now surveyed the LMC (SAGE; Meixner et al. 2006) and the NGC 6522 field (Baade's window) at mid-IR wavelengths with sensitivities unobtainable from the ground. Each of these surveys used the IRAC camera at 3.6, 4.5, 5.8 and 8 m and the MIPS camera at 24 m. The SAGE data have been publicly released; the NGC 6522 data were reduced by M. Stute (Uttenthaler et al., 2009, submitted). Cross-correlating the known AGB variables with the SPITZER data I found that they obey period-luminosity relations in the mid-infrared (mid-IR) similar to those seen at K_S (2.14 μm), even at 24 μm where emission from circumstellar dust is expected to be dominant. Their loci in the M, log P diagrams are essentially the same for the Large Magellanic Cloud (LMC) and for NGC 6522 in spite of different ages and metallicities. I have included a number of AGB stars from the solar neighbourhood for comparison using synthetic IRAC photometry. Fig. 1 contains the five M vs $\log P$ diagrams for the GC field and the LMC, superimposed to show their similarity. Dots correspond to the dominant period of each star. Miras, defined here to have MACHO amplitudes > 1.5 have the symbol ($\times$). The very long periods associated with many SRVs are given the colour magenta for the LMC and green for NGC 6522. The scatter due to depth effects is much greater in the NGC 6522 than in the LMC field.

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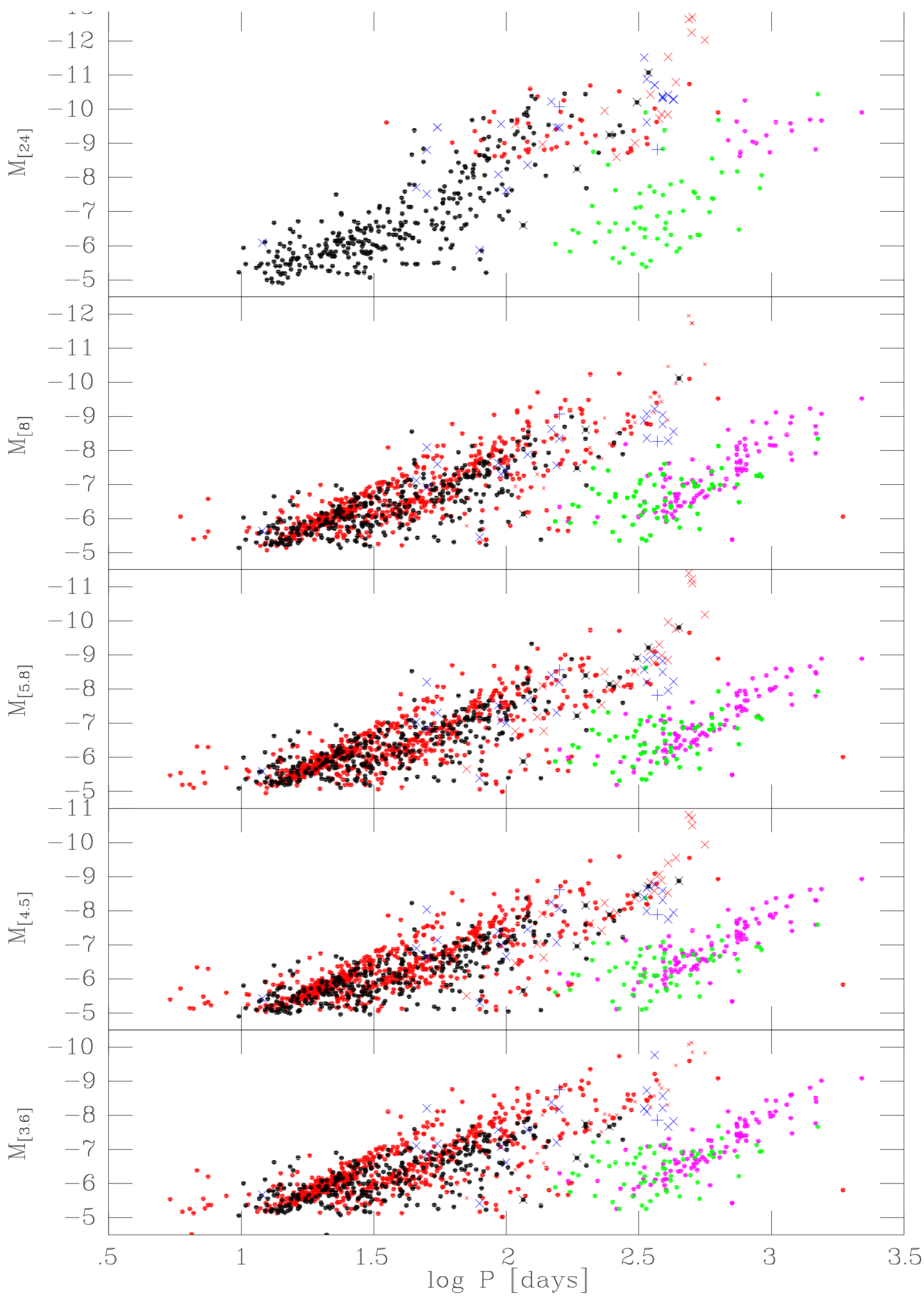

Fig. 1. log P vs Spitzer magnitudes. Red dots are the LMC SRVs (principal periods), red ×s the LMC Miras, magenta dots the LMC subsidiary long periods and black and green the same respectively for NGC 6522. The principal M, $\log P$ sequences are clearly visible. Note that the LMC data are limited in sensitivity at 24μm (from Glass et al. 2009)

3 Long-period Variables in the Galactic Center

In order to investigate more the universality of the PL relations, I studied the probably most metal-rich field in our Galaxy, the Galactic Center region. Glass et al. (2001) conducted a K-band (2.2 μm) survey for variable stars covering 24 × 24 arcmin^2 (56 × 56 pc at a distance of 8 kpc) and centred on the GC in a study spanning 4 years. The majority of the variable sources they found were, as expected, Miras and OH/IR stars with periods ranging from 150 d to about 800 d. Uncertainty as to the foreground extinction unfortunately precluded any detailed comparison of their luminosities with similar populations in other well-studied areas, such as the solar neighbourhood, Baade's window, and the Magellanic Clouds, where period-luminosity relations have been determined.

The central $2.0^{o} \times 1.4^{o}$ of the GC have been mapped with Spitzer/IRAC between 3.6 and 8.0 μm. Ramírez et al. (2008) performed point-source extraction on the IRAC data and published a confusion-limited catalogue of point sources that also included photometry from 2MASS. Schultheis et al. (2009) obtained based on these data a high resolution interstellar extinction map of the Galactic Center. It combines observations of the RGB/AGB population with the newest isochrones (Marigo et al. 2008). I used this map to deredden the LPVs in the GC region.

Fig. 1 shows clearly that the slopes of the period-magnitude relations at the IRAC wavelengths for the Glass-LPVs are similar to those of the LMC. This suggests that any dependence of the log P vs. $IRAC$ relations on abundance, if present at all, must be small. Within the uncertainties, there is no evidence for a significant difference between the period-magnitude relations in the LMC and in the GC. This is in agreement with Whitelock et al. (2008) who found, after reanalyzing published lightcurves of AGB variables in the LMC, similar zero points in the period-M_K relations for systems with different metallicities. They did not, however, include in their analysis the variables towards the GC, which is thought to be the most metal-rich environment.

I conclude that the period-luminosity relations of LPVs in the Infrared seem to be universal in the wavelength range between 2.2 and 24 μm. Therefore AGB stars can be seen as excellent extragalactic distance indicators

4 Perspectives

While much progress has been obtained in the Long-period Variables study in the galactic Bulge, the LMC and SMC (due to the microlensing surveys), the knowledge of LPVs in the solar neighbourhood is still poorly limited. The current picture of LPVs in the solar neighbourhood remains sketchy because of the small sample sizes.

The ESA mission GAIA will provide in the next decade besides precises parallaxes also light curve information due to repeated observations. With GAIA we should get a complete census of Long-period Variables inside the solar neighbourhood as well as inside our Galaxy.

Projects like super-MACHO, OGLE-IV continue to observe the Magellanic Clouds and Galactic Bulge region and will provide us with even more and better sampled light curves.

References

Alvarez R., Lançon A., Plez B., Wood P. R., 2000, A&A 353, 322

Aringer B., Höfner S., Wiedemann G., Hron J., Jørgensen U. G., Käufl U. U., Windsteig W., 1999, A&A 342, 799

Glass I.S.,Matsumoto, S., Carter, B. S., & Sekiguchi, K. 2001, MNRAS, 321, 77

Glass I.S., Schultheis M., Blommaert J.A.D.L., et al., 2009, MNRAS 395L, L11

Jura M., Kleinmann S. G., 1992, ApJS 79, 105

Kerschbaum F., Hron J., 1994, A&AS 106,397

Marigo P., Girardi L., Bessan A., et al., 2008, A&A 482, 883

Meixner M. et al., 2006, AJ 132, 2268

Ramírez S.V., Arendt R.G., Sellgren K., et al., 2008, ApJS 175, 147

Schultheis M., Sellgren K., Ramirez S., et al., 2009, A&A 495, 157

Whitelock P.A., Feast M.W, van Leeuwen F., 2008, MNRAS 386, 313

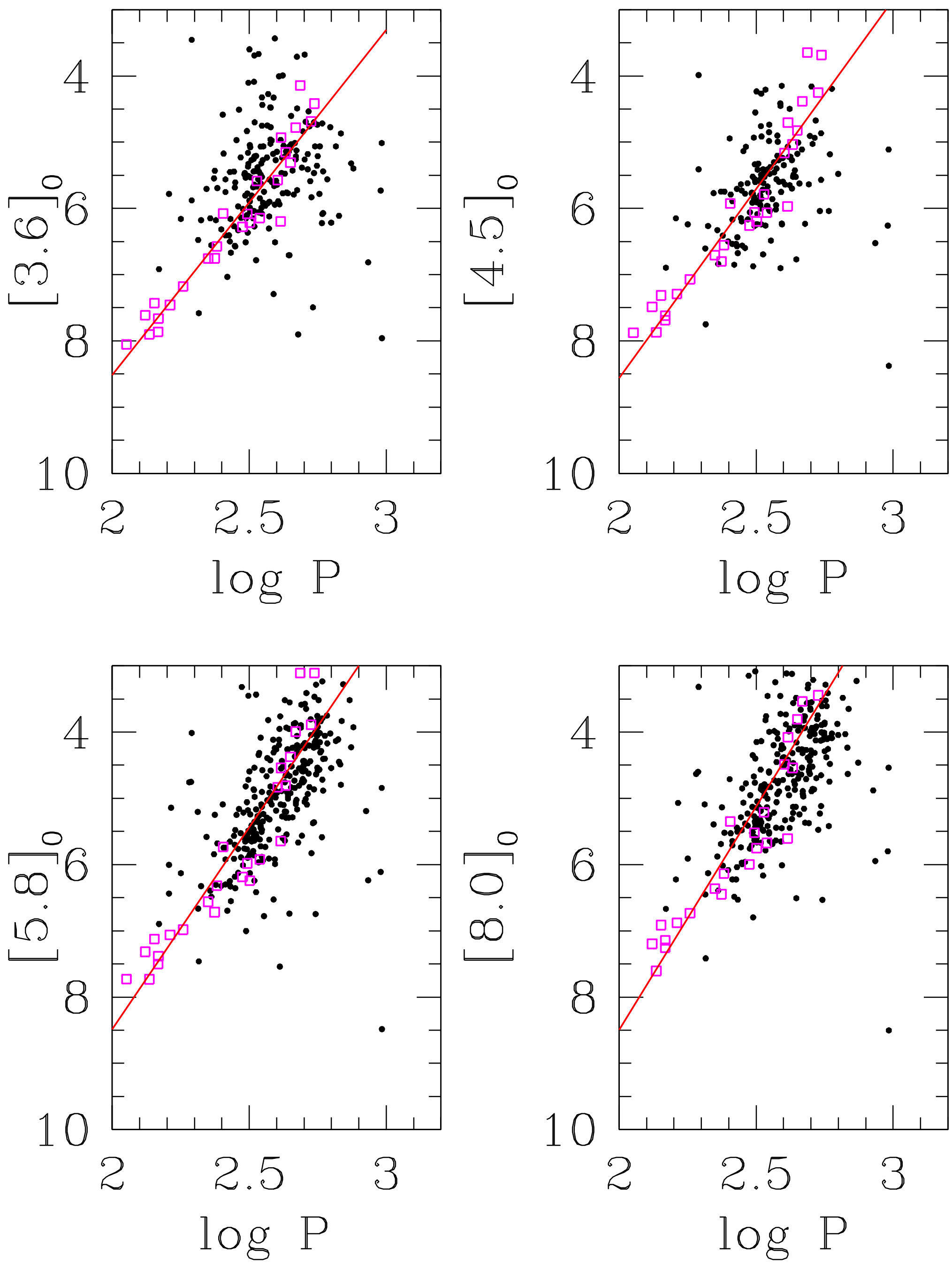

Fig. 2. Dereddened IRAC magnitudes (using the extinction map as described in Sect. 3) vs. log P for LPVs in the Glass et al. (2001) GC field (Glass-LPVs; black dots), where P is the period. Open magenta squares are LMC-AGB stars (oxygen-rich Mira variables). The straight red line is a least-squares fit to the LMC-AGB data set (from Schultheis et al. 2009)