Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
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Infrared light curves of dusty & metal-poor AGB stars

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Abstract. The effects of metallicity on both the dust production and mass loss of evolved stars have consequences for stellar masses, stellar lifetimes, progenitors of core-collapse SNe, and the origin of dust in the ISM. With the DUST in Nearby Galaxies with Spitzer (DUSTiNGS) survey, we have discovered samples of dusty evolved AGB stars out to the edge of the Local Group with metallicities down to 0.6% solar. This makes them the nearest analogs of AGB stars in high-redshift galaxies. We present new infrared light curves of the dustiest AGB stars in 10 galaxies from the DUSTiNGS survey and show how the infrared Period-Luminosity (PL) relation is affected by dust and metallicity. These results have implications for the efficiency of AGB dust production at high-redshift and for the use of the Mira PL relation as a distance indicator.

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Understanding how the dust contribution of evolved stars is affected by changes in metallicity is critically important for understanding the origin of dust in the Universe, especially dust that has been seen at high redshift (e.g., Valiante *et al.* 2009; Dwek & Cherchneff 2011; Rowlands *et al.* 2014; Michałowski 2015). Mira variables are radial pulsators that pulsate primarily in the fundamental mode. As they levitate material out the large radii, the material cools, condenses into dust, and is driven out into the ISM by radiation pressure. We can probe this mechanism by measuring the pulsation periods of evolved stars in the infrared, and using their infrared colors to determine the dust content. We can then study the link between dust production and pulsation by investigating both the dust content and the pulsation in the same star. However, dusty objects are often faint or not detectable in optical and near-IR variability surveys. To detect the dustiest stars, we monitored DUSTiNGS targets at 3.6 and 4.5 microns (Fig. 1). By probing samples of nearby metal-poor dwarf galaxies, we can also study the effects of metallicities down to less than one hundredth solar and constrain the dust production rates of evolved stars in these environments

Recent observations including those from the *Spitzer Space Telescope* and the DUSTiNGS survey have already discovered samples of evolved stars producing dust in nearby metal-poor dwarf galaxies (Boyer *et al.* 2015a,b, 2017, Whitelock *et al.* 2018). Multi-epoch observations of each of these galaxies have highlighted the evolved stars through their variability, and with additional observations (using new and archival data) we have now been able to confirm the nature of these sources and study their pulsation behaviors (Fig. 2). Results have shown that while the infrared Mira PL relation is affected by changes in the *Spitzer* [3.6]−[4.5] color (shown to correlate well with the dust content) it is unaffected by changes in metallicity down to ∼0.6% solar. This is encouraging for the prospect of using the relation as a distance indicator, and for AGBs as dust producers at high redshift.

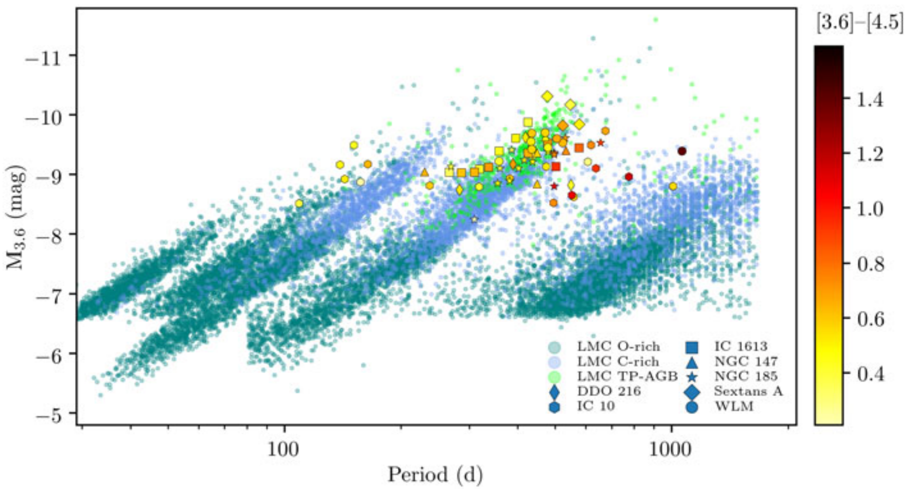

Figure 1. The P-L relation of the DUSTiNGS sample with the color showing the [3.6]−[4.5] color and galaxy membership shown using shapes. Also shown is the MACHO-SAGE sample from Riebel *et al.* (2015) containing oxygen- and carbon-rich AGB stars and more evolved and dusty TP-AGB stars of both types.

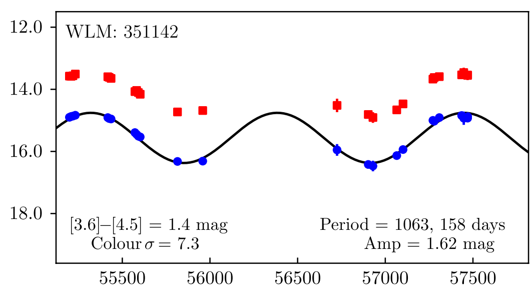

Figure 2. The lightcurve of one of our high-confidence long-period variables, with the Julian date vs. absolute 3.6 (blue) and 4.5 μm (red) magnitudes. Also shown are best-fit and second-best-fit pulsation period, best-fit amplitude, the [3.6]−[4.5] color and its standard deviation.

In addition to *Spitzer* data, we have *Hubble Space Telescope* medium-band photometry for each of the DUSTiNGS galaxies. The sensitivity of the observations reaches down below the tip of the red giant branch, ensuring adequate sensitivity for detecting all but the most dusty and obscured evolved stars. Through a method developed by Boyer *et al.* (2017), we have used the F127M, F139M, and F153M colors to clearly disentangle the carbon- and oxygen-rich evolved stars, which produce carbonaceous and silicate-rich dust, respectively. It is expected that the dust production of oxygen-rich evolved stars should be limited by the initial metallicity, as dust grain condensation should require s-process elements as seed nuclei. These results show that contrary to this, oxygen-rich AGBs have now been seen producing considerable dust at metallicities as low as 5% solar.

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