Why Galaxies Care About AGB Stars: A Continuing Challenge through Cosmic Time
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Astrometric observation of the Galactic LPVs with VERA; Mira and OH/IR stars

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Abstract. We present studies of Long Period Variables (LPVs) in our Galaxy based on astrometric VLBI observations of H_2O and SiO masers. The Galactic Miras and OH/IR stars are our main targets. For Miras, we present the distribution of the LPVs on the $M_{\rm K} - \log P$ plane. Galactic Miras show consistency with PLR in the LMC except for some fainter sources. Parallaxes of the LPVs determined from VLBI and Gaia are compared. There seems to be some offset.

Keywords. astrometry, interferometric, variables, AGB and post-AGB

1. Introduction

The LPVs are 1 to $8\,{\rm M}_\odot$ AGB stars pulsating with a typical period range of 100 to 1000 days. They are in the late stage of their life time, and show a high mass loss rate ($10^{-7}\ {\rm M}_\odot\,{\rm yr}^{-1}$) before they evolve to planetary nebulae. LPVs in the LMC show some period-luminosity relations (PLR), and the PLR is used as distance indicator. Since there is a metallicity difference between the LMC and our Galaxy, it is also important to explore PLRs of Miras in our Galaxy. The PLR of Galactic Miras determined from our study is reported to be $M_{\rm K} = -3.52\log P + 1.09 \pm 0.14$ (solid line in Fig. 1, Nakagawa *et al.* 2016). There are some OH/IR stars showing quite long periods, longer than 1000 days (extreme-OH/IR). They are thought to have initial masses of $\sim 4\,{\rm M}_\odot$ and ages of $\sim 10^8$ yr. Recent studies predict galactic spiral arms bifurcating/merging on time scales of 10^8 yr. So, the extreme-OH/IR stars can be used as a new probe to survey spiral arms structure and its evolution. We started 43 GHz astrometric VLBI observations of two extreme-OH/IR stars, OH127.8+0.0 and NSV25875 from Nov. 2017. Since the evolutional relation between Miras and OH/IR stars is still an open question, sequential studies of LPVs along wide period axis are also crucial.

2. Observation

Miras and OH/IR stars often represent H_2O, SiO, and OH masers, so they are good targets of VLBI. To derive parallaxes, we observe the target maser source and position reference QSO using a phase referencing VLBI technique. Part of the source names of our program are given in Table 1 in Nakagawa *et al.* (2018) together with sources from other studies. Recently, we selected a few samples of extreme-OH/IR stars from the Database of Circumstellar Masers (Engels & Bunzel 2015), and started 43 GHz (SiO maser) astrometric VLBI observations from Nov. 2017.

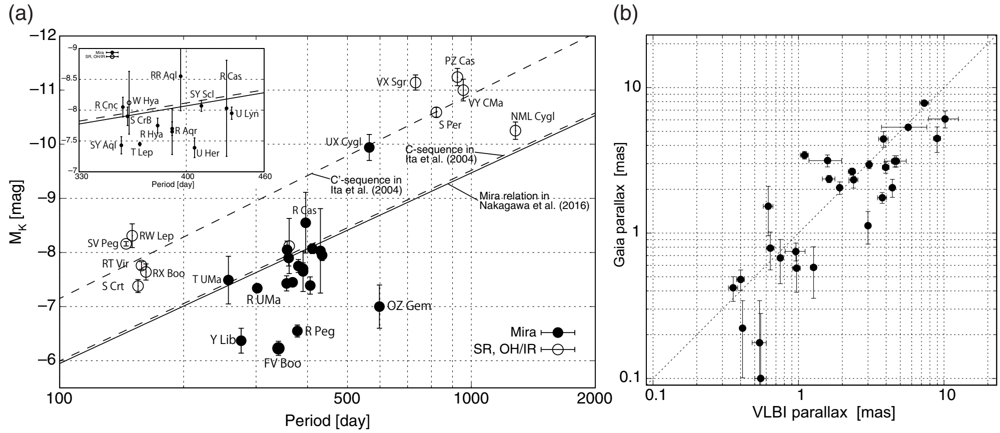

Figure 1. (a) $M_{\rm K}$ of Galactic LPVs obtained from apparent magnitude ($m_{\rm K}$) and VLBI parallaxes. Filled and open circles are results of Miras and other type of variables. Dashed lines are C and C' sequences in Ita *et al.* (2004). (b) Annual parallaxes determined from VLBI (horizontal axis) and Gaia (vertical axis).

3. Results and Discussion

Figure 1(a) shows the $M_{\rm K} - \log P$ diagram. Filled and open circles indicate Miras and other types of variables (SR, OH/IR stars). We find that many Galactic Miras coincide with the C-sequence of the LMC in Ita *et al.* (2004), but some Miras are fainter than the LMC sequence. Though the discrepancy should carefully be investigated, this can indicate different properties of Miras in the LMC and our Galaxy. A 43 GHz phase referencing observation of an extreme-OH/IR star NSV25875 and position reference source J2231+5922 gives a parallax of 0.38 ± 0.13 mas, corresponding to a distance of 2.60 ± 0.85 kpc. The distance was consistent with that estimated from two different methods of kinematic distance and OH maser phase-lag distance.

On 25 April 2018, parallaxes of more than 1.3×10^9 sources were released as Gaia DR2 (https://www.cosmos.esa.int/web/gaia/dr2). Since the larger part of VLBI parallaxes are determined for star forming regions which are deeply obscured by heavy dust and molecular clouds, it is difficult to find counterparts of the VLBI targets in the Gaia DR2 catalog. On the other hand, counterparts of the Galactic LPVs can easily be identified in the Gaia DR2. They are good samples for comparison of parallax from VLBI and Gaia. We compiled VLBI parallaxes from various studies (e.g. Vlemmings *et al.* 2003), and compared them with Gaia parallaxes in Figure 1(b). We see a trend that Gaia parallaxes give slightly smaller values than VLBI parallaxes. There seems to be a small offset between VLBI and Gaia parallaxes, and a more detailed study is needed for better understanding. Since the Galactic LPVs with longer period tend to be fainter in visible band, VLBI astrometry still plays a promising and complementary role even in Gaia era.

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