Estimating distances to AGB stars using IR data

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Abstract. We present a method to estimate distances to AGB stars, utilizing the rich infrared data sets available for these infrared-bright targets. The method is based on the assumption that stars with intrinsically similar properties (metallicity, initial mass, etc.) produce similar spectral energy distributions (SEDs) and similar luminosities. We here discuss the results for AGB stars belonging to the BAaDE survey sample whose distances were calibrated using the template SEDs of stars with their VLBI parallaxes. As VLBI parallaxes are only known for a handful of sources, the resulting templates only cover a small subset of the BAaDE sample. Additional methods to derive suitable templates will therefore also be required. The work on expanding the template set is promising, although more fine tuning is still needed.

Keywords. Asymptotic giant branch stars, Milky Way, infrared, spectral energy distributions

1. Motivation

The Bulge Asymmetries and Dynamical Evolution (BAaDE) project has delivered line of sight velocities of more than 10,000 AGB stars in the Milky Way, primarily in the bulge region. To incorporate these velocities into dynamical models and to distinguish between different AGB populations, it is crucial to estimate the distances and 3D positions of these stars. Distance estimates would also enable luminosities and mass-loss rates to be evaluated. The vast majority of BAaDE AGB stars lack reliable Gaia parallaxes, hence we are exploring alternative methods to determine distances to AGB stars. The proposed method is advantageous as it builds on utilizing existing infrared catalogs, and can be used for AGB stars throughout the Galaxy.

2. Methodology

The initial assumption is that stars with similar intrinsic properties produce similar SEDs and are of similar luminosity. To test whether the spectral energy distributions (SED) of a template and a target star has similar characteristics, we use three different colors: 2MASS [J]-[K], MSX [A]-[D], and [K]-[A]. 2MASS J and K bands have wavelengths of 1.235 μm and 2.159 μm, and 8.28 μm and 14.65 μm in MSX A and D bands, respectively. After extinction correction, a distance estimate is extracted by scaling the individual target SED fluxes with a distance-calibrated template SED.

3. Comparison to VLBI and Gaia parallax data

To test the method, we selected 26 sources with known VLBI parallaxes Xu *et al.* (2019). A single VLBI source (R Cnc) was used as a template to calculate SED distances

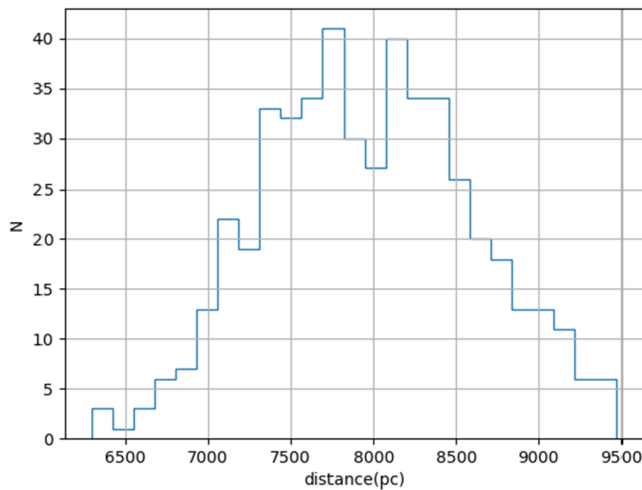**Figure 1.** Histogram of obtained SED distances for the BAaDE sources with $|l| < 1°$ and $|b| < 1°$.

to the other VLBI sources. A good agreement was achieved, with all SED distance estimates ending up within 2σ of the VLBI parallax distances. In addition to R Cnc, several other sources were used as templates, consistently reproducing a close correlation between the VLBI and SED distance estimates.

As we obtained good agreement with VLBI parallax distances, we continued testing with the subset of BAaDE sources that had Gaia parallaxes with parallax errors $< 20\%$ ($\sim 1,000$ objects). Initially this resulted in no obvious correlation. However, Andriantsaralaza *et al.* (2022) points out difficulties for Gaia in providing reliable parallaxes for the obscured AGB stars, even for sources with parallax errors $< 20\%$. They also point out that for brighter Gaia sources the errors are underestimated, and the relative parallax errors therefore must be corrected (for a source having $8 < G < 12$, the error gets underestimated by a factor of 2.5 whereas for $G < 8$, the error gets underestimated by a factor of 5). Following their recommendation resulted in a much smaller sample, but now a clear correlation between the Gaia parallax and SED distances was obtained.

4. Expanding template set with Galactic Center sources

As there are only a small set of AGBs with VLBI and/or reliable Gaia parallaxes, a larger set of templates must be defined to cover the full property range of the BAaDE sample. Sources with $|l| < 1°$ and $|b| < 1°$, and with absolute line-of-sight velocities > 100 km s^{-1} were selected to form a sample most likely to be located close to the Galactic Center, in the bulge region. We adopted a distance of 8.178 kpc (Abuter *et al.* 2019) for a single source used as the template, and then obtained distances to the other sources. The distribution of source distances can be seen in Figure 1, showing that the targets are all within the bulge region as expected.

Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1743921323002648

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