Miras around the Galactic Center

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Abstract. We report results of our near-IR survey for variables in a field of view of 20′ by 30′ towards the Galactic Center (GC), where we detected 1364 long-period variables. We have established a method for the simultaneous estimation of distances and extinctions using the period-luminosity relations for the $JHK_s$ bands. Our method is applicable to Miras with periods in the range 100–350 days and mean magnitudes available in two or more filters. Here we discuss 143 Miras whose distances and extinctions were obtained based on their periods and $H$- and $K_s$-band magnitudes. We find that almost all of them are located at the same distance to within our accuracy, and the distance modulus of the GC is estimated to be $14.58 \pm 0.02 \pm 0.11$ mag. The former error corresponds to the statistical error and the latter to the systematic one which includes the uncertainty of our assumed distance modulus of the LMC ($18.45 \pm 0.05$ mag). We also discuss the large and highly variable extinction towards the GC.

Keywords: AGB stars, Galactic Center, Miras, distance

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INTRODUCTION

The period-luminosity relation (PLR) of Miras has been widely used as a distance indicator, such as measuring distances to nearby galaxies (e.g. [1]). We can also investigate the distribution of Miras in the Galaxy using the PLR. Their important advantage as tracers is that we can obtain a position of each Mira [2]. In this contribution we present results of our near-IR survey of Miras towards the GC. Glass and collaborators [3] conducted a K-band (2.2 µm) survey for almost the same region as ours and detected 409 long-period variables. Our survey is deeper by more than one magnitude and, more importantly, includes the simultaneous monitoring in $J$ (1.25 µm) and $H$ (1.63 µm) as well as $K_s$ (2.14 µm).

OBSERVATION AND ANALYSIS

We carried out a variability survey for a field of view of 20′ by 30′ towards the GC using the IRSF 1.4-m telescope and the SIRIUS near-IR camera sited at SAAO, Sutherland, South Africa. Roughly 90 monitoring data were collected between 2001 and 2008. The detection limit is approximately 16.4, 14.5 and 13.1 mag in $J$, $H$, and $K_s$, respectively. We detected more than 80,000 sources in our field of view, and we found variations of 1,364 stars. We identified the counterparts of 347 variables in the catalogue of Glass et al. [3]. Then we found periods for more than 500 variables, a majority of which are considered to be Miras. The catalogue of variable stars and their time-series magnitudes will be released in our paper which has been accepted for MNRAS [4].

ESTIMATION OF DISTANCE AND EXTINCTION

We make use of Miras in the LMC to calibrate the PLR. 134 Miras in the LMC were selected based on their amplitudes, periods, and colors so as to include oxygen-rich Miras in the period range of 100–350 days (Fig. 1). The period limit is used to exclude objects with thick circumstellar dust and hot-bottom burning stars. The data were taken from the catalogue in [5]. The residual scatter around the obtained PLR, the line in Fig. 1, is less in $K_s$ (0.17 mag) than in $J$ and $H$ (0.19 mag both), but the differences are small. This indicates that the PLR in $J$ and $H$ can also be useful for distance estimation. More importantly, one can also estimate the amount of interstellar extinction by using the PLR in two or more bands. We assume that the distance modulus of the LMC is 18.45 mag. The random error in estimating distances of individual Miras is around 0.2 mag and the systematic error is around 0.11 mag. These uncertainties will be discussed in the forthcoming paper [4].

THE DISTANCE TO THE GC

While $J$-band magnitudes are often unavailable for our objects because of the large extinction, $H$- and $K_s$-band magnitudes are obtained for 143 Miras and we obtained their distance moduli $\mu_0$ and extinctions $A_{K_s}$. We esti-
INTERSTELLAR EXTINCTION

Because we can estimate distances and extinctions for individual Miras, they can be used as tracers to reveal three-dimensional structure. It is possible to study how the extinction changes with distance along various lines of sight, although the low space density of Miras may prevent us from investigating small structures.

In spite that our objects are located at the same distance, the obtained extinctions cover a large range; from 1.5 mag to larger than 4 mag in $A_{K_s}$ except towards the thicker dark nebulae. It also varies in a complicated way with the line of sight. In Fig. 3 we plot the locations of the Miras with extinction values in the galactic coordinate. The sizes of the symbols vary according to $A_{K_s}$ as indicated.

CONCLUDING REMARKS

We have confirmed a method for obtaining distances and extinctions for Miras with periods between 100 and 350 d by making use of their PLR. The technique depends on knowing mean magnitudes in two or more filters in the near infrared. We estimated the distance of the GC to be $8.24 \pm 0.08$ ($\text{stat.}$) $\pm 0.42$ ($\text{syst.}$) kpc. The PLR of Miras is shown to be a powerful tool for studying Galactic structure, although there remains a significant systematic error. It is expected that better calibrations of the PLR will improve the accuracy of the method; this may be achieved by parallax projects such as VERA and GAIA.

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FIGURE 3. Locations of 143 Miras with $A_{K_s}$ obtained, an $H$-band image of the observed field. North in the equatorial system is up, and east is to the left. The obtained extinction for each object is indicated by the size of a circle as shown besides the panel.