



Search for SiO masers in nearby Miras pulsating in the first overtone mode

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Abstract. We studied the period-K magnitude (P–K) relations of nearby Mira and Mira-like variables with relatively good Hipparcos parallaxes. They form at least two prominent sequences on the P–K plane, corresponding to the sequences C (Mira variables pulsating in the fundamental mode) and C' (Mira variables pulsating in the 1st overtone mode), that were found in the LMC. As a part of an ongoing study to see the differences between the Mira variables pulsating in the fundamental and the 1st overtone mode, we searched for SiO masers in the nearby variables on the sequences C' and C using the Nobeyama 45m radio telescope. We observed 28 selected nearby Mira and Mira-like variables without previous maser observations, and found 3 new emitters. The observational result shows that there is few or no SiO maser emitters pulsating in the 1st overtone mode.

Key words. Stars: AGB and post-AGB – Stars: variables – Radio lines: stars

1. Introduction

After the pioneering work by Wood (2000), variable stars in the Large and Small Magellanic Clouds (LMC and SMC) have been studied by many authors (e.g., Cioni et al. 2001, Noda & Takeuchi 2003, Kiss & Bedding 2003, Ita et al. 2004a, Groenewegen 2004, Soszyński et al. 2004, Raimondo et al. 2005, Fraster et al. 2005), with each author using different time-series photometric database (i.e., MACHO, OGLE, MOA, EROS).

Ita et al. (2004a) suggested that there are at least two dominant pulsation modes among Mira variables. One is the fundamental mode,

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and the other is the 1st overtone mode. Then, what determines the dominant pulsation mode of Mira variables? Comparing various observable quantities between the two groups will give us clues to answer the question. Following this idea, Ita et al. (2004b) compared the NIR photometric properties between the two modes and showed that: (1) they separate on the period- $J - K$ colour diagram; (2) the pulsation amplitudes of the 1st overtone Miras are smaller than those of the fundamental ones.

To know their differences in more detail, the imaging data alone is no longer sufficient. The spectroscopic data, radio data, mid-IR data and so on would bring us new insights. In this regard, the Magellanic Clouds (MCs) are

technically a bit far for such observations. Therefore, we decided to leave the MCs and revisit our own Galaxy. Throughout this paper, we will use the word “Mira-like variables” instead of “Semi-Regular variables”, because the boundary is blurred between the Miras and SRa variables.

2. Observation and Result

2.1. Source Selection

Because the Galactic variables are near, we can observe them in every possible wavelengths and with any desired observational styles. However, there is a critical disadvantage when compared with studying variable stars in the MCs; the distances to the Galactic objects are usually difficult to know. Therefore, we restricted our sample stars to the Mira and Mira-like variables with relatively good Hipparcos parallaxes (ESA 1997).

The target stars are selected from Bedding & Zijlstra (1998), Whitelock & Feast (2000) and Knapp et al. (2003) on conditions that: (1) The spectral types are M or S; (2) $\frac{\Delta\omega}{\omega} < 0.44$, where ω and $\Delta\omega$ are the parallax and its error, respectively. Ninety five stars satisfy these criteria. Among them, 28 stars are observable from Nobeyama ($\delta > 30^\circ$) and without previous SiO maser observations.

2.2. Observation using Nobeyama 45m radio telescope and the Result

As a part of an ongoing study to see the intrinsic differences between the fundamental and the 1st overtone Mira, we searched for SiO masers ($J=1-0$, $\nu=1$ and 2 at the rest frequencies of 43.122 and 42.821 GHz, respectively) towards the above 28 selected nearby Mira and Mira-like variables. The observation was carried out with Nobeyama 45m radio telescope in June 2005. As a result, we found 3 new SiO maser emitters (AS Her, BG Cyg and UU Dra). Details of the observation will be described in the future paper (Ita et al. in preparation).

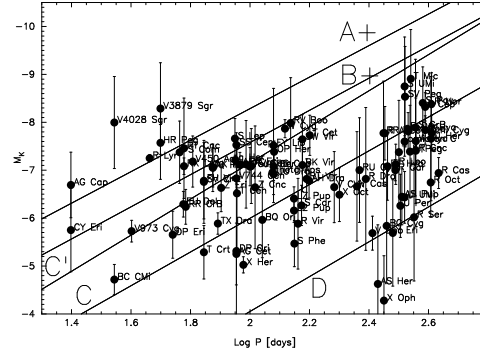


Fig. 1. P–K diagram of nearby oxygen-rich Mira variables with M/S spectral type and relatively good ($\frac{\Delta\omega}{\omega} < 0.44$) Hipparcos parallaxes. The lines show the sequences of variable stars in the LMC as given by Ita et al. 2004a, whose zero-points are shifted by 18.5 mag to account for the distance to the LMC.

3. Discussion

3.1. P–K diagram of nearby Miras

Fig.1 is the P–K diagram of nearby oxygen-rich Mira and Mira-like variables with relatively good Hipparcos parallaxes. Note that this figure includes stars that cannot be observed from Nobeyama. The pulsation periods and K magnitudes were taken from Bedding & Zijlstra (1998), Whitelock & Feast (2000) and Knapp et al. (2003). For the star SV Peg, the General Catalog of Variable Stars (GCVS, Kholopov et al. 1992) lists its pulsation period of 144.6 days, but we adopt 332.0 days by analyzing data from the VSOLJ¹. Due to the errors in Hipparcos parallaxes and the large dispersions in mass and metallicity, we don’t see the tight P–K relations as those in the LMC. However, it is clear that the Mira and Mira-like variables in our Galaxy are likely to pulsate in the wide variety of pulsation modes just like the LMC variables. Also, there seems to be many Galactic counterparts of Mira variables pulsating in the 1st overtone mode.

¹ <http://www.kusastro.kyoto-u.ac.jp/vsnet/VSOLJ/vsolj.html>

conflicting result with Patel, Joseph & Ganesan (1992), who suggested that a large value of radius may allow a larger path length for the gain of the maser, and hence a greater maser luminosity. However, our observational result does not favor this idea, because the 1st overtone mode pulsators should have larger radii than those of the fundamental mode ones, if compared with the same pulsation period (e.g., figure 1 in Whitlock & Feast 2000).

To determine the dominant pulsation mode of each star more quantitatively, we calculated the direct distance from each data point (Log P, K) to the sequences C and C', and adopted the nearer corresponding pulsation mode. The Fig.3 is the IRAS two color diagram of sample stars showing the correlation between the SiO maser emission and the mass-loss and also the pulsation modes. It is believed that SiO maser emission is strongly connected to the mass-loss. However, we don't see such strong correlation in the figure. Instead, the SiO maser emission is likely to be more of a pulsation mode issue.

Unfortunately, there are few or almost no long-period 1st overtone Miras in our sample (in fact, there are few or almost no long-period 1st overtone Miras within the Hipparcos's range). Therefore, we cannot conclude that the fundamental pulsation mode is the necessary condition for SiO maser emission. We have to wait for the results of GAIA satellite till when she will drastically increase the number of galactic Mira variables with good parallaxes.

4. Conclusions

The relevance between the SiO maser emission and the pulsation modes of nearby Mira variables were studied by adding the new observational data (3 detections and 25 non-detections) to the previous studies. As far as the present data suggests, it is likely that the SiO maser emission favors the fundamental pulsation mode.

Acknowledgements. This paper makes use of the data from the Hipparcos satellite, IRAS satel-

lite, GCVS and the VSOLJ database. This research is supported in part by the Grant-in-Aid for Encouragement of Young Scientists (B) No. 17740120 from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

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