The Nature of OH/IR Stars in the Galactic Centre Region

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Abstract. We report on infrared observations of stars in a field of $30'$ near the galactic centre. All these objects were previously detected as OH (1612 MHz) maser sources. The resulting infrared colours and luminosities are compared with results for other samples of OH/IR stars in the Galaxy. We find a large range of luminosities and thus ages. The question of the existence of two distinct populations of OH/IR stars near the galactic centre is addressed. The dust-to-gas mass loss ratio, which depends on metallicity, is on average twice as high for the group with high circumstellar shell expansion velocities than for the group of stars with lower expansion velocities.

1. Introduction

As low and intermediate mass stars approach the end of their lifes they go through a relatively short phase lasting about $10^5 - 10^6$ yr which is known as the Asymptotic Giant Branch (AGB) phase. Miras, carbon stars and OH/IR stars are all examples of AGB stars. This phase is characterized by long-period pulsations (P= 200 - 2000 days) with bolometric amplitudes up to 1 mag and high mass loss rates ($> 10^{-7} M_{\odot}/yr$). The mass loss also dominates the appearance of the star. The circumstellar shell totally obscures the underlying red giant star, and the shell itself is detectable as a strong infrared source at wavelengths around 10 μm, where the stellar luminosity is reemitted by the cool dust shell. In the shell several types of masers may be present depending on the physical conditions in the shell. Most often the OH maser at 1612 MHz is the strongest of these masers. The fact that these giants are very bright ($L_* \gtrsim 5000 L_\odot$) and are observable at infrared and radio wavelengths makes them interesting objects for studying the galactic centre which is very obscured at the visible wavelengths.

OH/IR stars span a broad range of ages; the age difference between low mass (1 $M_\odot$, 10^{10} yrs) and higher mass (6 $M_\odot$, a few 10^8 yrs) OH/IR stars is more than an order of magnitude. It was shown (Baud et al. 1981) that the expansion velocity of the circumstellar shell is usually larger for OH/IR stars with smaller velocity dispersions. Because the final outflow velocity is determined by radiation pressure on dust in the circumstellar shell(Schutte and Tielens, 1989 and Habing et al. 1994), it is expected that both the total luminosity and the metallicity of the star play a role in this.

In a survey for OH 1612 MHz masers with the VLA, 134 OH/IR stars were detected (Lindqvist et al. 1992a). The first goal of this survey was to study stellar velocities in the galactic centre region (Lindqvist et al. 1992b). The kinematical behaviour of this sample gave an indication that also there different populations of OH/IR stars may be involved: stars with high expansion velocities seem to rotate in a flatter system than those with low expansion velocities. The aim of the present work[1] is to study the luminosities, masses and ages of the OH/IR stars in the galactic centre.

2. Observations

We selected 32 OH maser sources, all roughly within a $28' \times 28'$ area, centered on SgrA. Twenty-four of these OH masers were monitored for OH variability (Van Langevelde et al. 1993) allowing us to determine mean bolometric magnitudes corrected for variability.

The sample was observed in 1990, 1991 and 1993 with the ESO 2.2 m and 3.6 m at La Silla (Chile) and the 3.8 m United Kingdom Infrared Telescope (UKIRT) at Mauna Kea (Hawaii) in the wavelength range of 1.2 to 20μm.

For all sources we had accurate VLA positions ($\sim 0.2''$) which facilitated their identification. Observations were done using IR cameras at the shortest wavelengths (up to 4μm) and traditional single channel photometers at longer wavelengths.

To convert the observed magnitudes at various wavelengths to mean bolometric magnitudes corrections were made for interstellar extinction and source variability.

[1]Based on observations collected at the European Southern Observatory, La Silla, Chile and UKIRT, Mauna Kea, Hawaii.

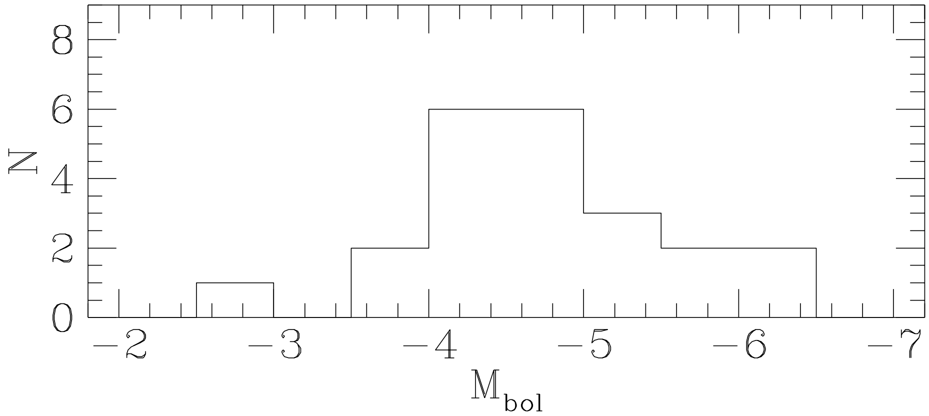

Figure 1. Distribution of bolometric magnitudes

3. Kinematic populations

Lindqvist et al. (1992b) showed that within the original sample of 134 stars statistically significant kinematic differences are seen when the OH/IR stars are divided into two groups based on the expansion velocities of their shells (V_{exp} respectively smaller and larger than 17 km/s). The high expansion velocities generally trace more luminous, and hence one assumes, more massive and thus younger OH/IR stars.

The distribution of the observed mean $M_{\rm bol}$ as shown in Fig. 1 indeed shows a quite large range ($-6 \lesssim M_{\rm bol,mean} \lesssim -4$), indicating a range in masses ($1 \lesssim M_{\rm i} \lesssim 4 M_{\odot}$) and thus ages.

In Fig. 2 two quantities are plotted against the expansion velocity. The comparison between circumstellar expansion velocity and radial velocity dispersion is taken from Lindqvist et al. (1992b). Each of the black dots represent an average of about 10 stars. Although the scatter is considerable there is a clear trend towards smaller velocity dispersions for OH/IR stars with larger expansion velocities.

The group of OH/IR stars with smaller expansion velocities has a narrow range of mean M_{bol} with an average value of -4.5. This is about the same value as was found by van der Veen and Habing (1988) for a sample of OH/IR stars in the bulge, suggesting that this subgroup may be related to that OH/IR star population. The dispersion that was found by Lindqvist et al ($\sigma = 82$ km/s) may be smaller than what is found for the bulge but their determination excluded the extreme velocity sources. By including them we find ($\sigma = 110$ km/s) in agreement with the value for the bulge. Also the expansion velocities here have the same range as what is found in the bulge.

The group of OH/IR stars with high expansion velocities, with a flatter kinematical distribution, however, have a broader distribution showing the same range in luminosities as was found for the total sample. It thus contains objects with the same luminosities as the smaller expansion group but almost half of it's group has luminosities higher than 10,000 $L_{\odot}$ ($M_{bol} < -5$). This "disk-like" population thus contains a large spread in ages.

It is not clear that this disk-like population is connected with the galactic exponential disk. On basis of modeling of the distribution of OH/IR stars de-

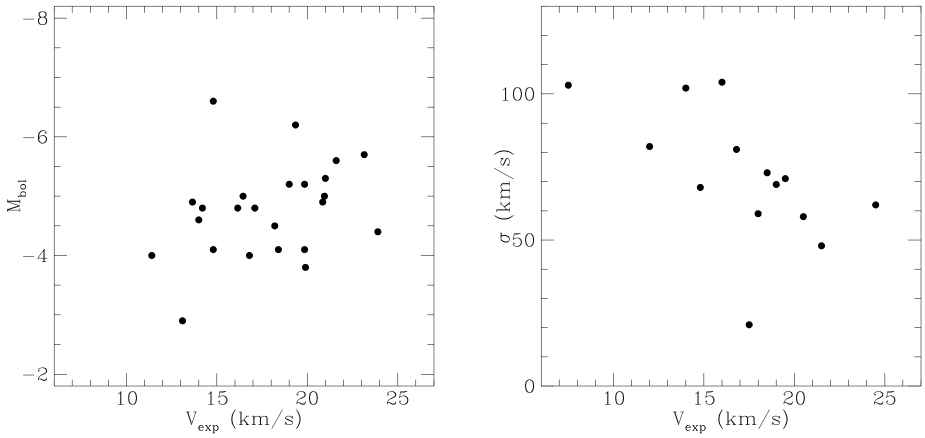

Figure 2. Distribution versus the circumstellar shell expansion velocity of a) the bolometric magnitudes (this study) and b) radial velocity dispersions (Lindqvist et al. (1992b))

tected in an IRAS based survey (te Hekkert et al. 1991) by Dejonghe (1992) one expects to find about 100 objects at the centre of the Galaxy. Blommaert et al. (1994) however, show in a VLA survey along the galactic plane that a simple continuation of the exponential disk as observed at longer longitude and higher latitude is not likely as the number of OH/IR stars drops rapidly for $l \leq 10°$.

3.1. Metallicities

The expansion velocity of the circumstellar shell is dependent on both luminosity and metallicity (Schutte and Tielens, 1989 and Habing et al. 1994). The group of OH/IR stars with high expansion velocities is really extreme in this sense. We find that their luminosities are certainly not extreme in comparison with what is found for OH/IR stars in the disk, nevertheless no other OH/IR stars in our Galaxy are known with expansion velocities as high as these in the galactic centre. It indicates that the metallicities of this group must be very high.

For both groups the luminosities are different, but not enough to explain the difference in expansion velocity. It would then follow that the metallicity is the main reason for the difference in the expansion velocities. This would be reflected in the ratio of the gas- ($\dot{M}_{\rm g}$) and dust-mass loss ($\dot{M}_{\rm d}$),

$$\mu = \dot{M}_{\rm g}/\dot{M}_{\rm d} \propto L_*^{0.5}\ v_{\rm exp}^{-2}$$

which is believed to depend on metallicity (van der Veen 1989). The $\langle L_*^{0.5}\ v_{\rm exp}^{-2}\rangle$ of the high expansion velocity group is only half as high as that of the low expansion velocity group (0.21 ($\pm$0.05) against 0.38 ($\pm$0.10)) indicating that the kinematically more “flattened” group is more metal-rich than the low expansion velocity group. This is also found by Spaenhauer et al. (1992) who claims that for K and M giants in Baade’s window the dispersions in latitude are significantly smaller than in longitude but that this is strongest for the metal-rich ones.

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