SiO Maser Stars in the Milky Way Nuclear Stellar Disk

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The Milky Way has a stellar disk structure similar to that observed in the central regions of external spiral galaxies. This structure is known as the Nuclear Stellar Disk (NSD) and extends +/-2° along the Galactic Plane (see Fig.1). The NSD is mainly composed of old stars. The origin of the NSD itself remains obscure. Key information to solve the issue is expected from the kinematics of these old stars, which should have traced somehow in their star formation history (10^7~10^9 years ago). These old stars contain Mira variables. They often have SiO maser activity. The strength and sharpness of the emission line makes it easy to measure the radial velocities of these stars even in the NSD. Before the ALMA era, the kinematics has been obtained by observing SiO maser emission in Mira variables, which were found through IR observations (e.g. Deguchi et al. 2004, Fujii et al. 2006). High sensitivity of ALMA enables to perform an unbiased survey of SiO maser stars in the NSD (e.g. Paine & Darling 2022, Tsuboi et al. 2025). In addition, there is an ongoing astrometric observing program for old stars in the NSD with an IR space-borne telescope called JASMINE (Gouda et al .2021, Kawata et al. 2024). Together, the 3D motions of these stars will be constructed from their proper motions and radial velocities to infer the origin of the NSD.

The survey data of the Central Molecular Zone (CMZ) obtained with ALMA has been released (2021.1.00172.L, P.I. Longmore Steven). Although this survey intends to image molecular clouds in the CMZ, the frequency range contains the SiO v = 1 J = 2-1 maser line. The survey area covers most of the NSD (see Fig.2) with the modest angular resolution (1~2"). We searched for SiO maser stars in the NSD using the survey data. About 700 SiO maser stars were detected and their LSR radial velocities and positions were measured with accuracies of 3 km s^{-1} and ~0.1", respectively.

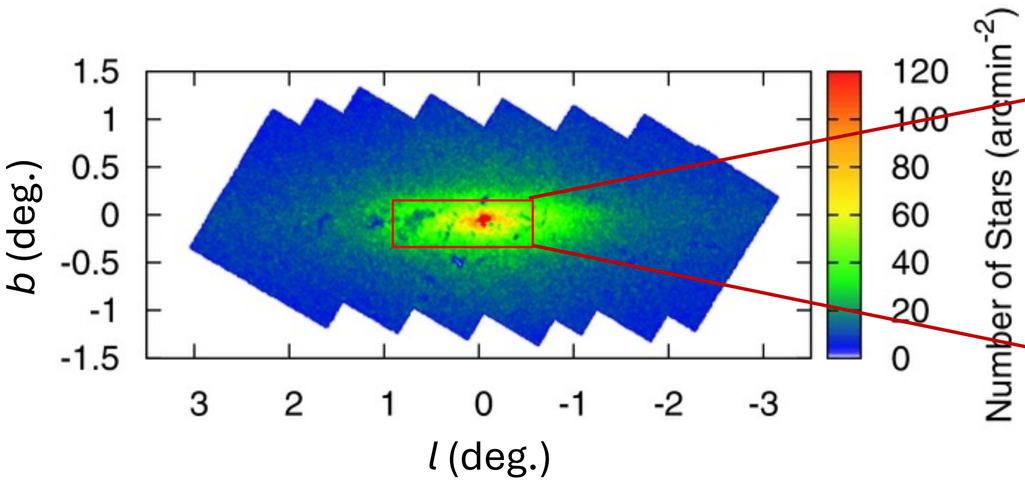

Fig.1 Stellar number density of the Milky Way Nuclear Stellar Disk by NIR observations (Nishiyama et al. 2013)

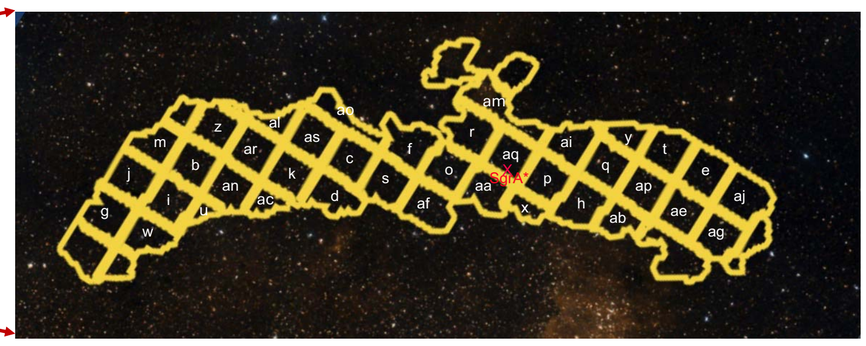

Fig.2 Survey area of the Central Molecular Zone (CMZ) with ALMA (2021.1.00172.L, P.I. Longmore Steven)

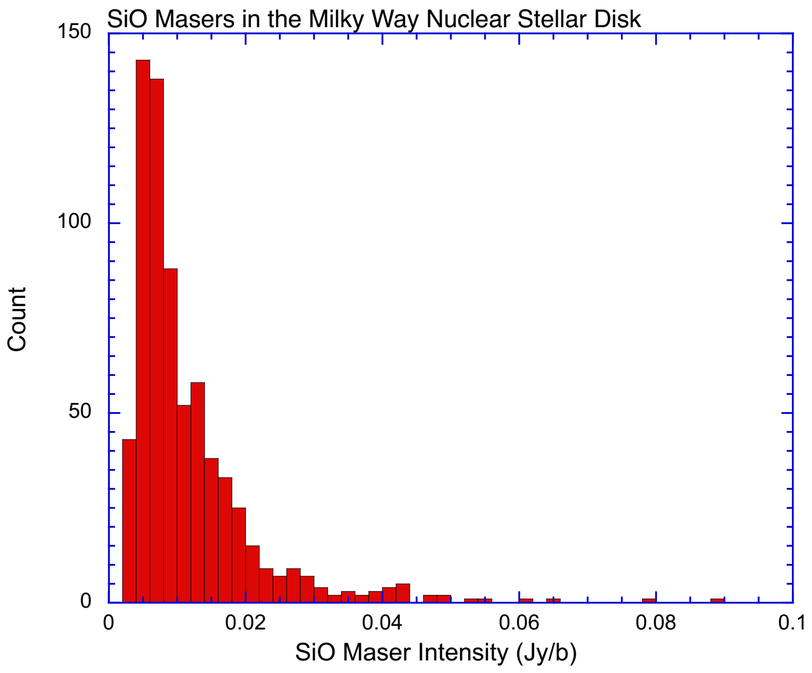

Fig.3 Intensities of the detected SiO maser stars.

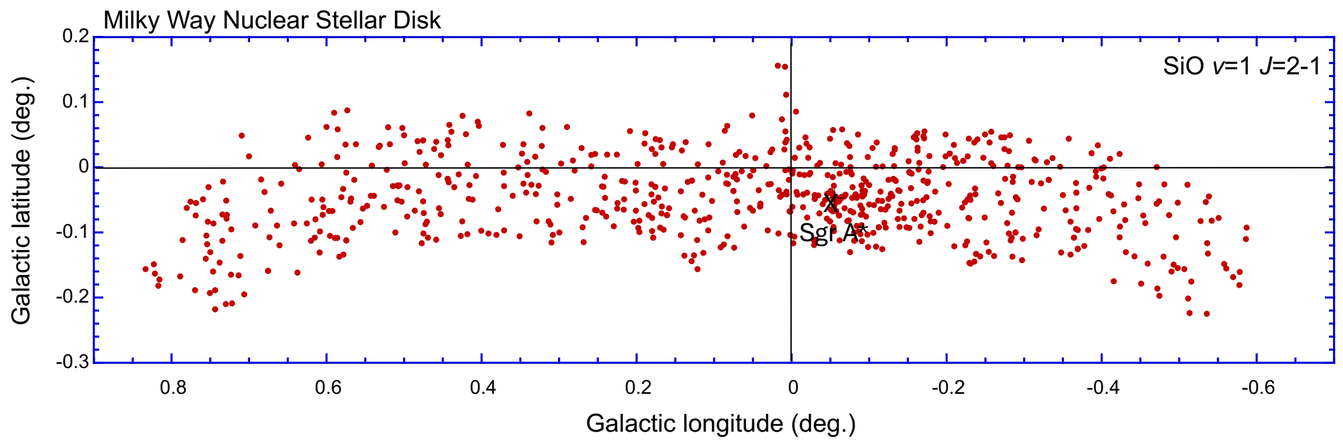

Fig.4 Positions of the detected SiO maser stars. The cross shows the position of Sgr A*.

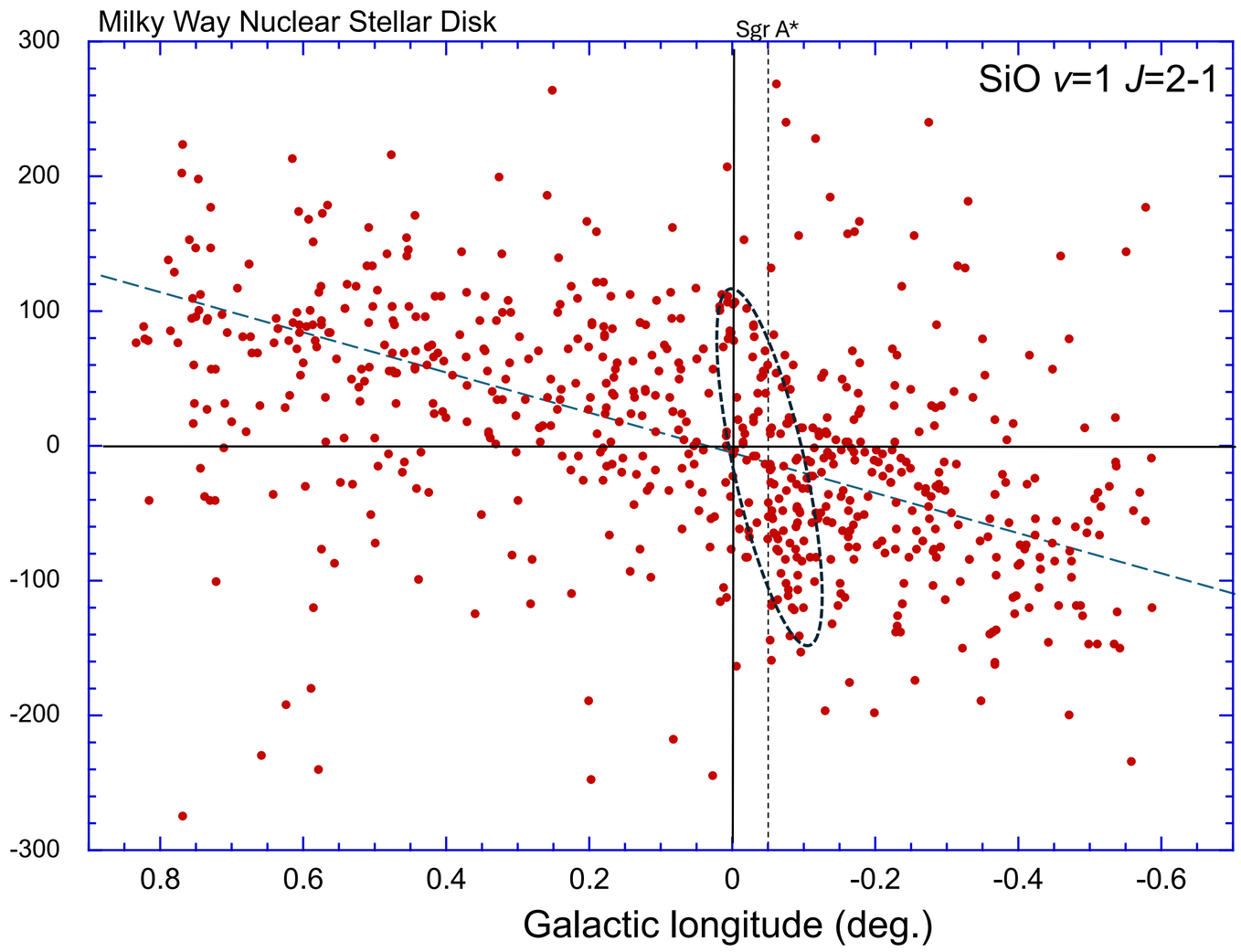

Fig.5 Galactic longitude-LSR velocity diagram. The broken line shows the fitted line for the inclined concentration: V [km/s] = -10.8+153.6Δl [deg.].

Fig. 3 shows the histogram of intensities of the detected SiO maser stars. Several stars have intensities of several hundred mJy/b (max ~730 mJy/b). These may be in the foreground. Most stars are weaker than a several tens mJy/b. The detection number increases rapidly with decreasing intensity. However, below 4 mJy/b, the number decreases. This is probably due to the detection limit. This limit is slightly high than those of previous observations with ALMA (e.g. Paine & Darling 2022, Tsuboi et al. 2025). If a higher sensitivity observation is performed, the detection number would increase dramatically.

Fig. 4 shows the positions of the detected SiO maser stars. The distribution is extended widely along the Galactic plane and somewhat concentrated around Sgr A* (the cross symbol). The concentration corresponds to the NSC. The distribution is consistent with the IR stellar number density distribution of the NSD (see Fig.1).

Fig. 5 shows the Galactic longitude-LSR velocity diagram of the detected SiO maser stars. The inclined concentration is identified although there are many scattered stars. The fitted line (dashed line) for the concentration is given as V[km/s] = -10.8 +153.6Δl [deg.]. Here, Δl is the Galactic longitude offset from Sgr A*. The enclosed mass within Δl = +/-1° (r<150pc) is calculated to be M ~ 8x10^8 Mo from this formula. This is consistent with the previously estimated mass using gas observations. In addition, there is another inclined concentration around Δl = +/-0.1° (r<15pc) (dashed oval) which probably corresponds to the NSC. The fitted line is V[km/s] = -7.1+699.1Δl [deg.]. The enclosed mass is estimated to be M ~ 2x10^7 Mo.

References

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