# Water Masers in the Central Molecular Zone

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## Introduction

The Central Molecular Zone (CMZ) covers roughly the inner 500 pc of the Milky Way and contains a large amount of dense gas: 3~5 $\times 10^7$ $M_\odot$ which is 5-10% of the $H_2$ content of entire galaxy [1]. There is an asymmetric gas distribution in this region where 75% is at positive longitude, which is where most Young Stellar Objects (YSOs) are located [2]. Since $H_2O$ masers trace YSOs and evolved stars, do the masers follow the same asymmetry? The CMZ also contains several dozen molecular clouds and is the nearest extreme environment with star formation conditions and activity [3]. Gas temperatures, pressures, and turbulent Mach numbers are much higher than other regions in galaxy [1]. Do these conditions affect the spectral properties of the $H_2O$ masers?

## Water Masers

The maser of interest is the 22 GHz $H_2O$ $6_{16}$-$5_{23}$ rotational transition. There are necessary three conditions required for maser emission to happen: a locally large abundance of the molecule, appropriate conditions for population inversion, and velocity coherence along the line of sight [4]. The water masers are thought to be pumped in postshock regions due to collisions with $H_2$ density to be around $10^8$-$10^{12}$ cm$^{-3}$ [5]. These masers trace collimated jets and protoplanetary disks associated with YSOs [6] and are thought to be detectable toward the stellar atmosphere of Asymptotic Giant Branch stars [7]. Does the source or surrounding environment affect the kinematics of the maser?

## Data

The Survey of Water and Ammonia in the Galactic Center (SWAG) is a molecular line survey. SWAG used the Australia Telescope Compact Array and targeted ~42 spectral lines with a frequency range of 21.2-25.4 GHz. The observations were carried out with a spatial resolution of ~27" and a spectral resolution of 0.4 km s$^{-1}$. This range includes six meta-stable $NH_3$ lines, $CH_3OH$, HNCO, and the 22 GHz $H_2O$ maser line. The maser detections are gathered from the cube using the python package *astrodendro*. The minimum value to be considered a detection was 5σ above the noise. Gaussian fitting was used to extract line information for sources that had up to 10 peaks in a single spectrum.

## Results

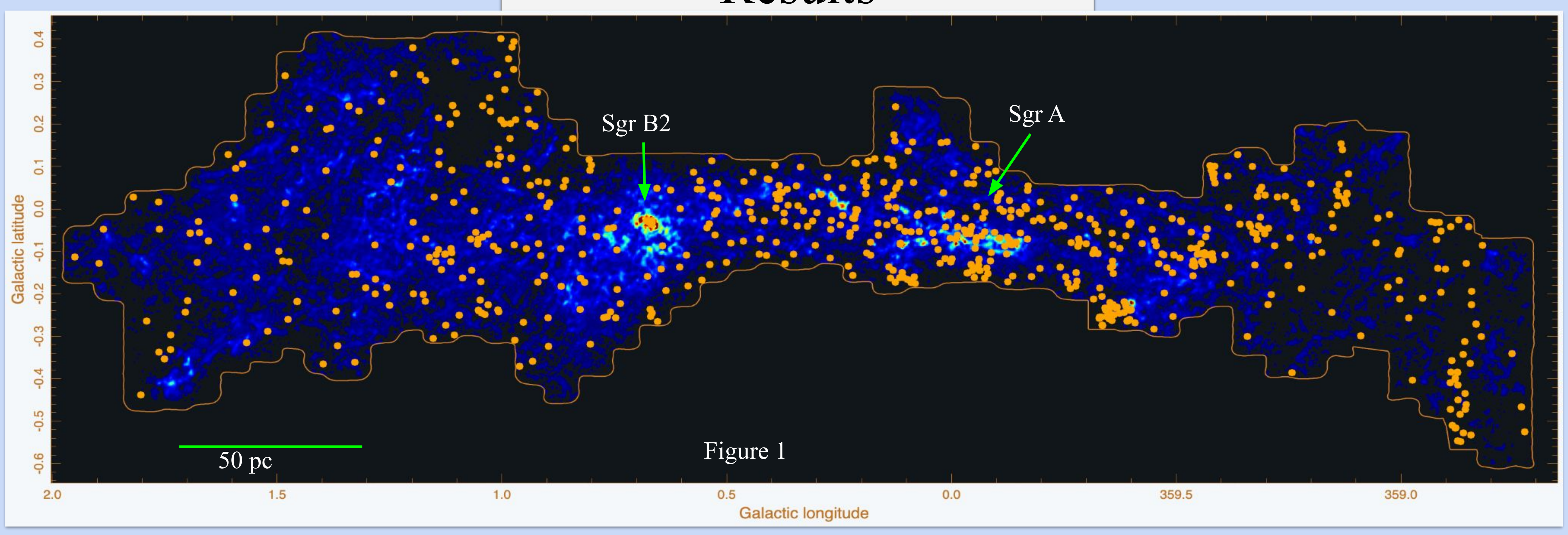
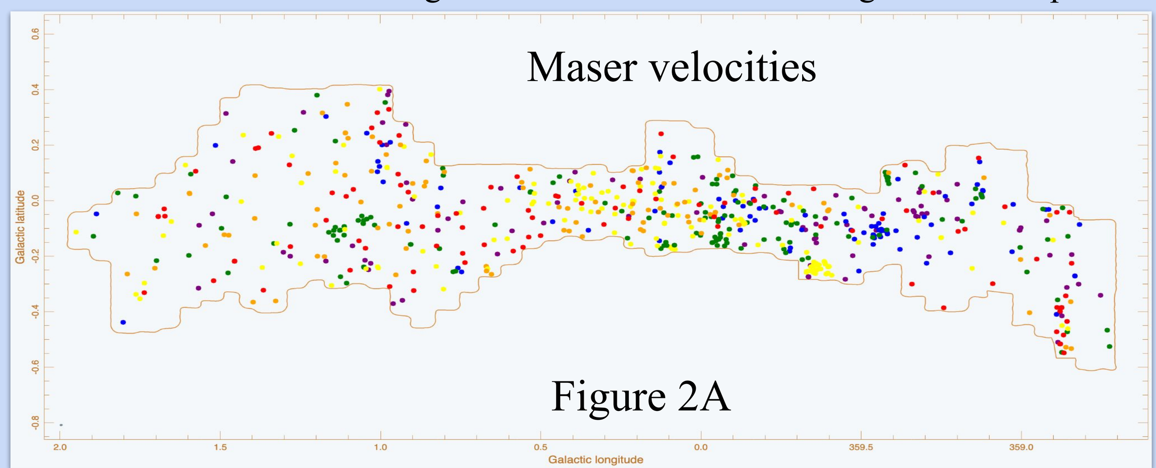
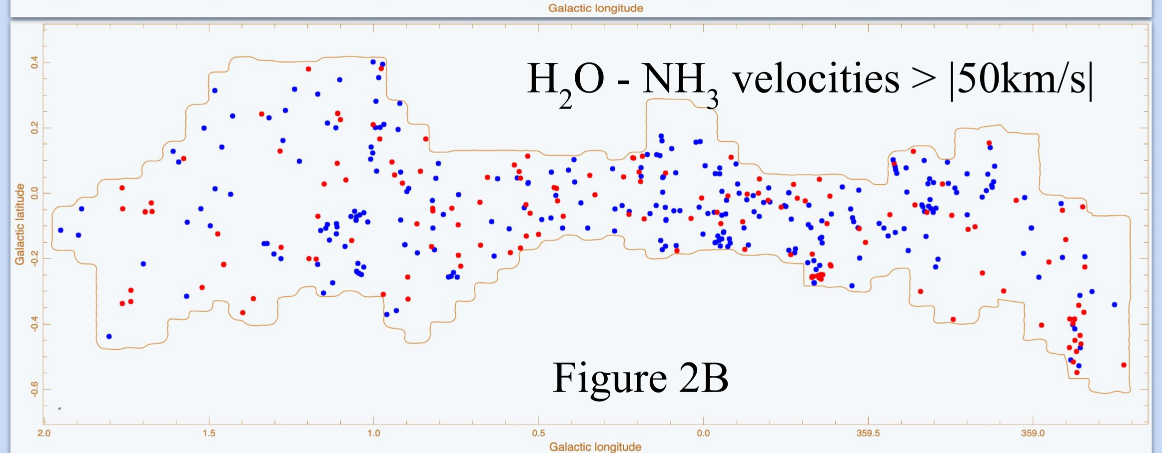



Figure 1: Maser locations as orange circles are plotted over an integrated intensity $NH_3$ (3,3) map (in blue). Sources near Sgr B2 are missed due to masking large sidelobes from Sgr B2.



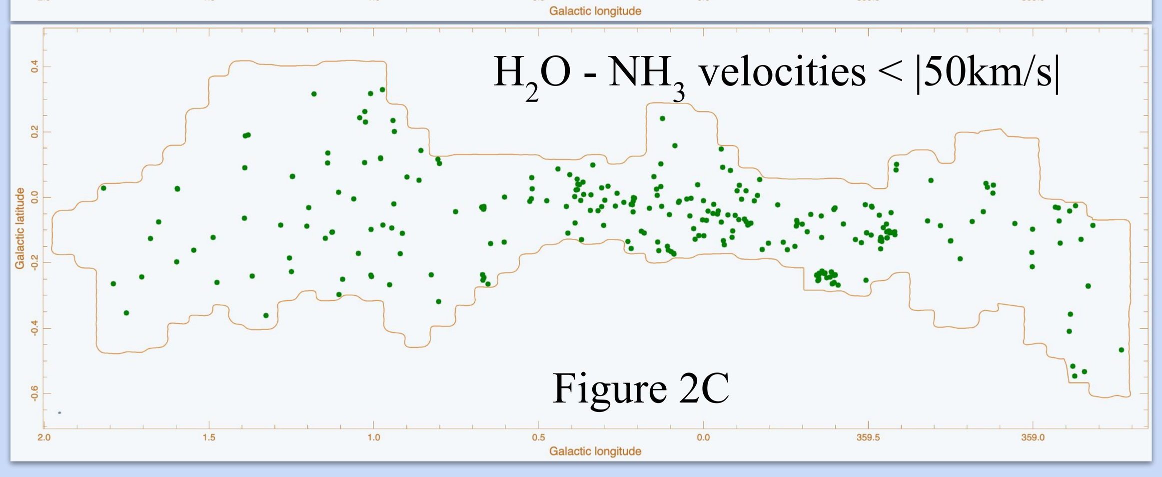




Figure 2: Shows maser positions vs velocities within field of view. A) Colors indicate average maser velocities. In ascending order: purple, blue, green, yellow, orange, red. Yellow is the start of redshifted velocities. B) & C) Colors indicate the difference between the maser and ammonia velocity. The velocities were taken from the centroid of the largest amplitude in each spectra. The meaning of the colors are as follows: Red > 50 km/s, Blue < -50 km/s, and Green is everything in between.

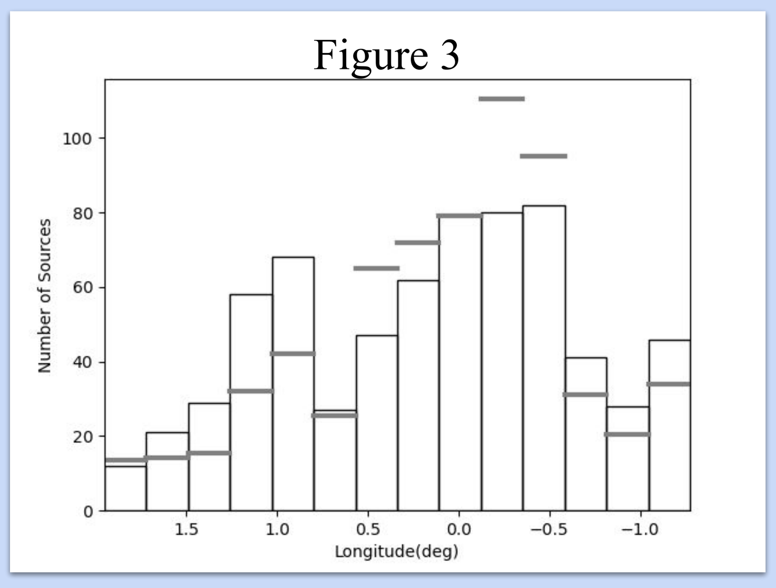



Figure 3: Histogram of number of sources vs longitude. The gray lines represent number of sources scaled by the non-uniform area coverage.

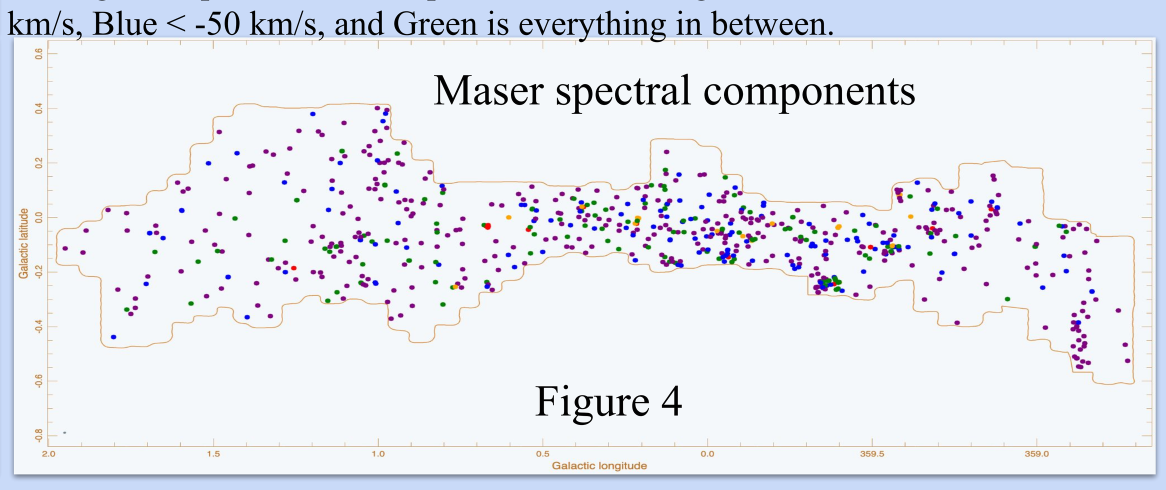
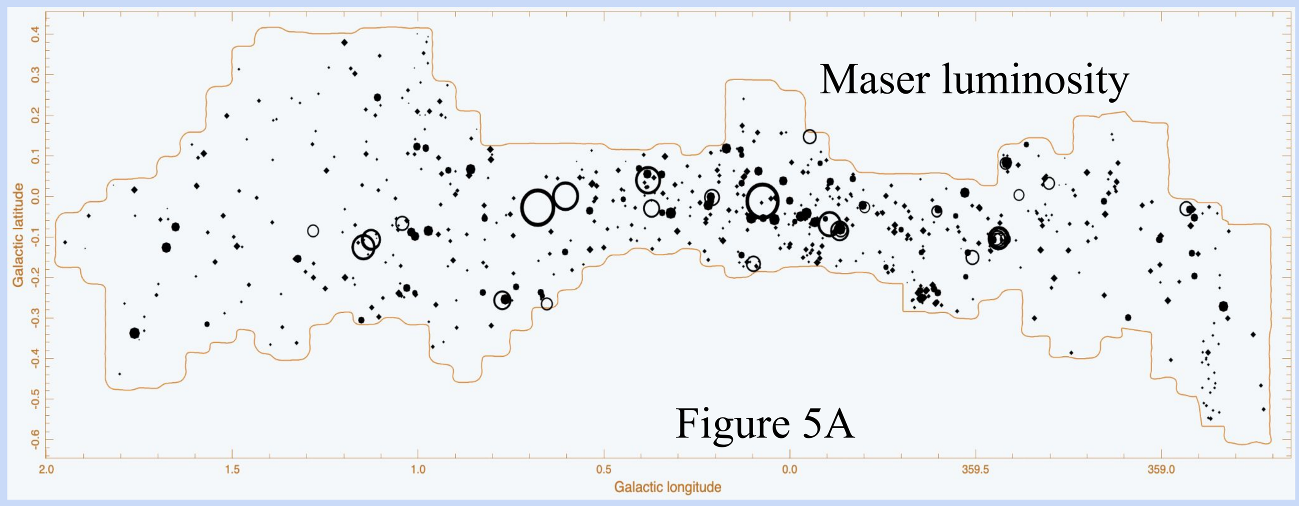



Figure 4: Shows maser positions within field of view vs number of spectral components. Colors indicate 1, 2, 3-6, 7-10, and 10+ peaks as purple, blue, green, orange and red, respectively.



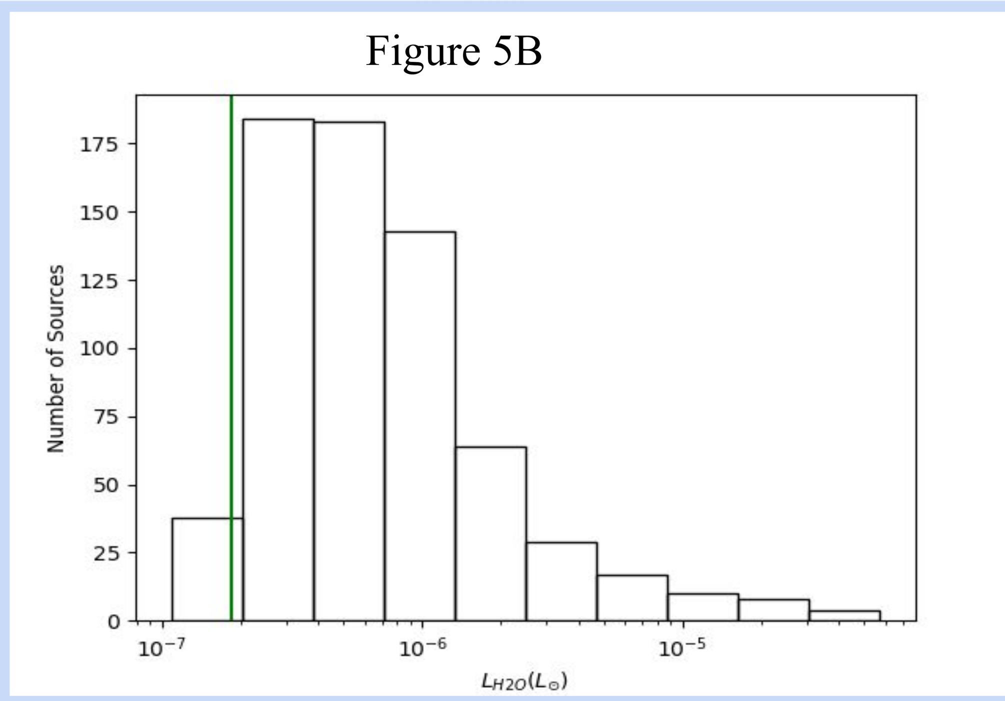




Figure 5: A) Shows maser positions vs luminosity. Larger circles represent higher luminosities. B) Histogram of luminosity of the masers. The green line represents a maser with a mean 5σ luminosity.

## Takeaways

***Preliminary*** results are as follows:

- 703 masers detected at ≥ 5σ. 22 masers have 10 or more spectral components [Figure 1 & 4].
- The masers are more symmetric than that of the gas [Figure 3]. The masers that agree in velocity to $NH_3$ tend to be more closely related to the gas distribution at around $0.5^\circ \lesssim l \lesssim 0.2^\circ$ [Figure 2C].
- A majority of the detected masers have single peaked spectra (383); the next highest amount being two peaks (146), which might relate to young and old stars, respectively [Figure 4].
- The amount of masers drops sharply at $L>10^{-6}$ [Figure 5B] which is similar to $H_2O$ luminosity for evolved stars from [8]. The more luminous $H_2O$ masers agree with the luminous $NH_3$ features.

## Future Work

- Finish building a robust catalog from the cube
- Identify the objects that produce each $H_2O$ maser
  - How does the source change the average $H_2O$ maser spectral properties?
- Correlate $H_2O$ maser velocity to outflow velocities, velocity of the gas, and H II regions.
- Compare other maser transitions, such as SiO and $CH_3OH$, to the detected $H_2O$ masers at the same location.

References
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This research made use of astrodendro, a Python package to compute dendrograms of Astronomical data (http://www.dendrograms.org/)