Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
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SWAG: Distribution and Kinematics of an Obscured AGB Population toward the Galactic Center

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Abstract. Outflows from AGB stars enrich the Galactic environment with metals and inject mechanical energy into the ISM. Radio spectroscopy can recover both properties through observations of molecular lines. We present results from SWAG: "Survey of Water and Ammonia in the Galactic Center". The survey covers the entire Central Molecular Zone (CMZ), the inner $3.35^\circ \times 0.9^\circ$ ($\sim$480×130 pc) of the Milky Way that contains $\sim 5\times10^7\,M_\odot$ of molecular gas. Although our survey primarily targets the CMZ, we observe across the entire sightline through the Milky Way. AGB stars are revealed by their signature of double peaked 22 GHz water maser lines. They are distinguished by their spectral signatures and their luminosities, which reach up to $10^{-7}\,L_\odot$. Higher luminosities are usually associated with Young Stellar Objects located in CMZ star forming regions. We detect a population of $\sim$600 new water masers that can likely be associated with AGB outflows.

Keywords. stars: AGB and post-AGB, ISM: molecules, Galaxy: center, radio lines: stars

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1. SWAG

SWAG ("Survey of Water and Ammonia in the Galactic center") is a Large Project ($\sim$460 h on-source) to observe the entire CMZ (inner 500 pc) of the Milky Way with the Australia Telescope Compact Array (Krieger *et al.* 2017, Jäschke 2018, Ott *et al.* 2018 in prep.). We target 42 molecular lines and wideband continuum in the 21.2-25.4 GHz range across $\sim$6500 individual pointings. The spatial resolution is $\sim$20" ($\sim$0.8 pc) with up to 0.4 km s^{-1} spectral resolution. The line list contains typical shock, photon-dominated region, density, and temperature molecular tracers, as well as radio recombination lines. The list includes the $6_{16} - 5_{23}$ 22 GHz water (H_2O) maser and multiple ammonia lines.

2. Water Masers toward the CMZ

H_2O masers are typically associated with shocked regions, where density and temperatures are high enough to pump and invert the water level populations by collision, and path lengths long enough for amplification. 22 GHz is one of the brightest and best accessible water masers. Maser conditions are typically met in outflows, frequently in Young Stellar Object (YSOs) jets or envelopes of Asymptotic Giant Branch (AGB) stars.

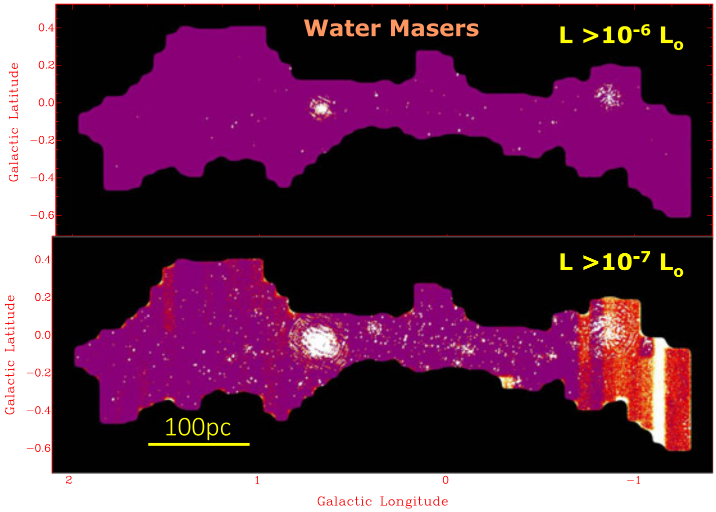

Figure 1. 22 GHz water masers toward the CMZ. **Top panel:** Masers with luminosities $> 10^{-6}\,L_\odot$; **Bottom panel:** Masers with $L > 10^{-7}\,L_\odot$. The distribution considerably broadens on the faint end.

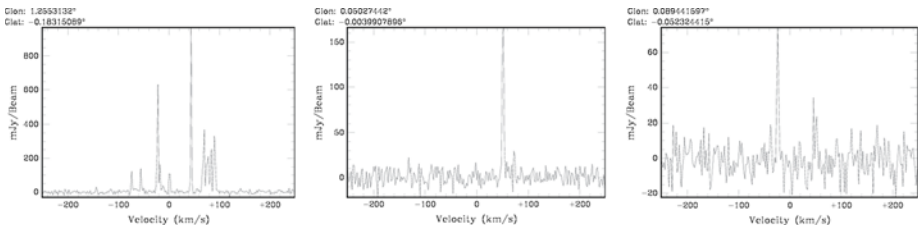

Figure 2. Sample spectra for different maser luminosities. Faint masers tend to show a second, even weaker velocity component, separated by typically $\sim$80 km s^{-1}.

The CMZ contains star forming regions and indeed we detect bright water masers that we associate with YSOs (Rickert 2017). In the upper panel of Fig. 1, we show masers with luminosities $> 10^{-6}\,L_\odot$ (assuming Galactic Center distance of 8.5 kpc for all sources). These masers appear to be frequently associated with dense molecular gas.

When the luminosity threshold is lowered by an order of magnitude to $\sim 10^{-7}\,L_\odot$, the distribution changes and widens in Galactic Latitude and Longitude. Overall, the masers follow more the Galactic potential than the distribution of dense gas in the CMZ. In addition, the weaker masers frequently show a second velocity component, with an average separation of $\sim$80 km s^{-1}. High luminosity masers, in contrast, typically show many more individual components at a greater velocity variation. Example spectra are shown in Fig. 2. The spatial distribution and spectral signatures of the newly detected, faint population of $\sim$600 masers (density of $\sim$200 deg^{-2}) is in agreement with a population of predominantly AGB stars across the entire Milky Way. The velocity separation of the maser components suggests that the traced AGB stars show expansion velocities with typical values around $\sim$40 km s^{-1}.

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