Dynamics at the Crossroads of the Galactic Disk and Bar with RSG SiO Masers

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Probing Milky Way Dynamics

BAaDE has shown we can use SiO masers to probe the properties and dynamics of the evolved stellar population in the Milky Way, with Asymptotic Giant Branch (AGB) stars. We take a similar approach with Red Supergiants (RSGs) to study the dynamics at kinematically interesting regions, where the endpoints of the bar meet the spiral arms. As RSGs originate from high-mass stars and they are found in massive star clusters, they can therefore be probes of these regions. Similar to BAaDE, we use SiO maser emission to derive line-of-sight velocities, starting with a VLA 43 GHz SiO maser survey of 653 sources denoted as possible RSGs via SIMBAD. **This work then uses SiO maser emission in Red Supergiants (RSGs) to bridge together dynamical information from the evolved older bulge/bar with the younger disk.**

Classification of SiO Emitting RSGs

To form a set of diagnostic tools to classify a source as an RSG, a combination of methods will be used: (a) spectral confirmation, (b) color-magnitude diagrams (CMDs), and (c) SiO maser properties.

(a) Spectroscopy has been conducted for ≈9% of the sources in our VLA sample [1,2].

(b)CMDs are effective in separating stars according to evolutionary state. We will create these with distances determined via spectral energy distributions (SEDs) in the near-IR and mid-IR, following the work done for AGBs in the BAaDE sample [3]. Distance-independent estimates include the Q-parameter where 2MASS IR colors are used ($0.1<Q1<0.5$ mag and $0.5<Q2<1.5$ encloses almost half of known RSGs) [4]. Indeed, these Q-parameters have been successfully implemented [5], demonstrating agreement between Q parameters and RSG spectroscopy.

(c) SiO masers are found both in AGB stars and RSGs, but the masers in RSGs typically have a broader line width, shown in Figure 1. Looking at the line width in any combination with available CMDs, Q-parameters, and spectroscopic data will be sufficient in classifying our sources as RSGs.

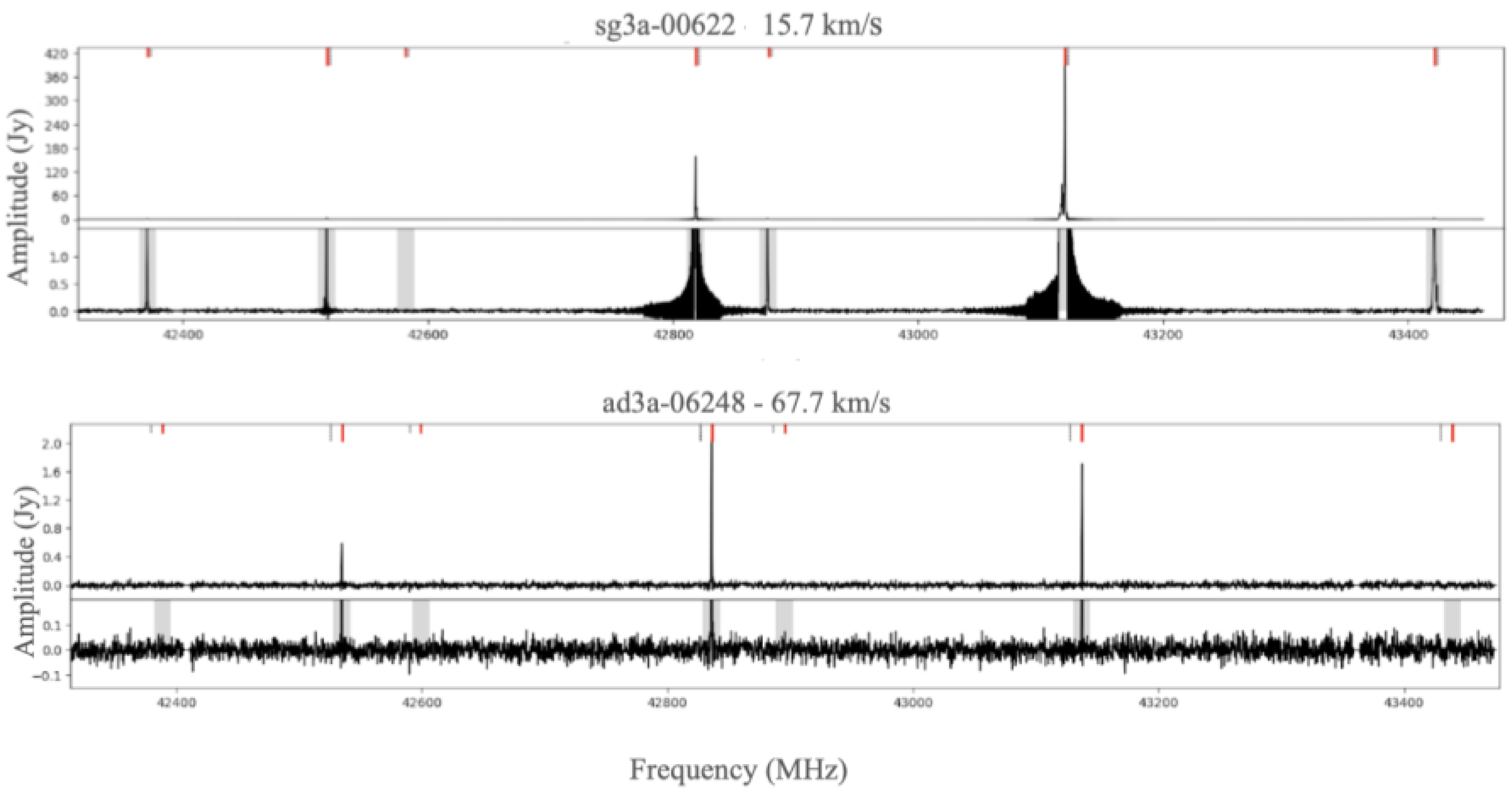

Figure 1: (Top) VLA SiO emission spectra for an RSG candidate showing detections of J=1-0 v=0,1,2, and 3 plus two isotopologue lines. Red longer bars indicate J=1-0 transitions for 28SiO, shorter ones indicate transitions for different isotopologues of Si (29SiO and 30SiO). (Bottom) A comparable SiO emission spectra for an AGB star from the BAaDE survey showing J=1-0 v=1,2, and 3. emission lines. Despite the spectral ringing in the top spectrum, it can be seen the bottom AGB spectrum is significantly narrower in the line shapes.

Investigating the far side of the bar

RSGs are located close to their birthplace which allows us to investigate the dynamics of the Milky Way through young, massive clusters. They have been found in massive clusters near the intersection of the near side of the bar and the Scutum-Crux arm at Galactic Longitudes between 24° and 29°, shown in Figure 2. [6,1]. RSGs are ideal for identifying massive stellar clusters on the far side of the bar as they are IR-bright, a wavelength less affected by dust compared to in the optical. In addition, a subset of these stars display exponentially amplified SiO maser emission in the radio [7], allowing stellar velocities to be determined across the Galaxy. We therefore start with existing data from the near side of the bar to narrow down the typical IR properties of the SiO masing RSGs, allowing a more constrained list of far side RSG candidates to be constructed using IR data. These candidates will be observed in SiO maser emission using ALMA to derive velocities, allowing us to investigate the dynamics at the far side of the bar.

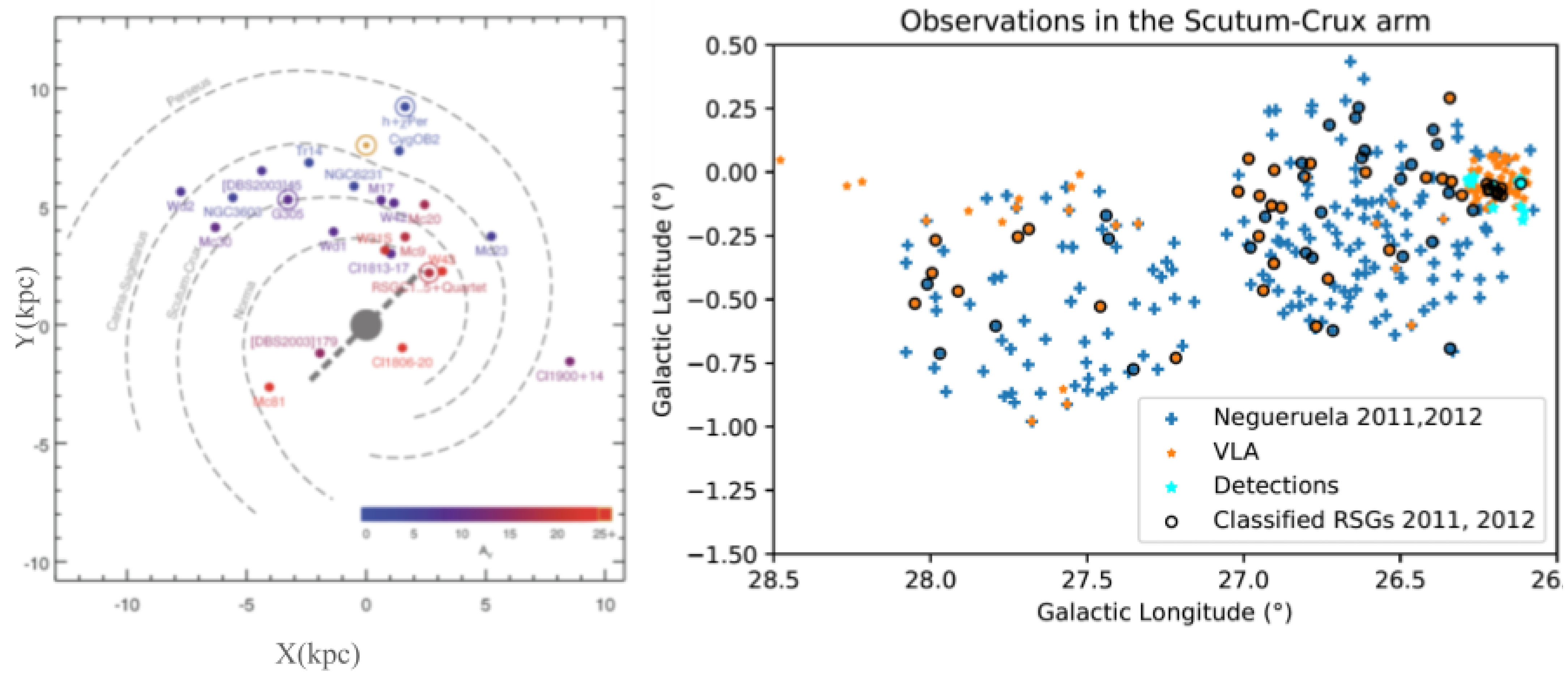

Figure 2: (Left) Taken from Davies et al. 2012 [6], top-down view of our galaxy showing the locations of massive stellar clusters. The yellow circle/dot indicates the location of the Sun. Dashed lines outline the spiral arms, and the thick dashed line the orientation of the bar. (Right) Positions of targets from Negueruela 2011, 2012 [1,2] and the recent VLA observations. Circles denote targets classified as RSGs spectroscopically, and the remaining blue and orange plus signs are consequently sources which were not confirmed to be RSGs. Orange Stars indicate VLA sources, cyan stars are the current detections.

Conclusions

- SiO masers in RSGs can be used to derive the line-of-sight velocities to our sources, probing the dynamics in our surveyed regions.
- We will use CMDs, spectroscopic confirmation and SiO spectral features to constrain our definition of RSGs to identify a set of candidate SiO emitting RSGs at the far side of the bar, to be observed by ALMA.
- The SiO maser detection rate was 14% for the 653 SIMBAD–selected targets. Applying more stringent requirements for a target RSG classification, this rate increases to 20%. This classification is applied to our ALMA target list pre-observing to optimize the detection rate.

References and Acknowledgments

[1] Negueruela, I. et al. 2011 AA, 528, A59 [2] Negueruela, I. et al. 2012 AA, 541, A36 [3] Bhattacharya et al. (2024, submitted) [4] Messineo, M. et al. 2016 ApJL, 822, L5 [5] Negueruela, I. et al. 2010 AA 513, A74 [6] Davies, B. et al. 2012 MNRAS, 419, 1860 [7] Verheyen, L. et al. 2012 AA, 541, A36