Circumstellar SiO Masers in Red Supergiants

Bridging BAaDE and BeSSeL

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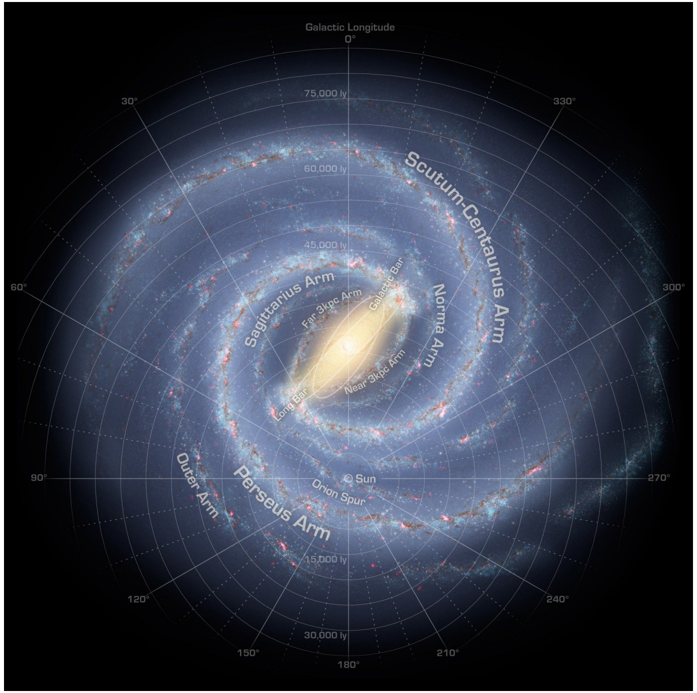
Introduction

Aim: To bridge dynamical and structural models of the older bulge/bar with the younger disk, done with BAaDE and spiral structure with BeSSeL. Learn more about SiO maser emission in RSGs, can we use this to find more?

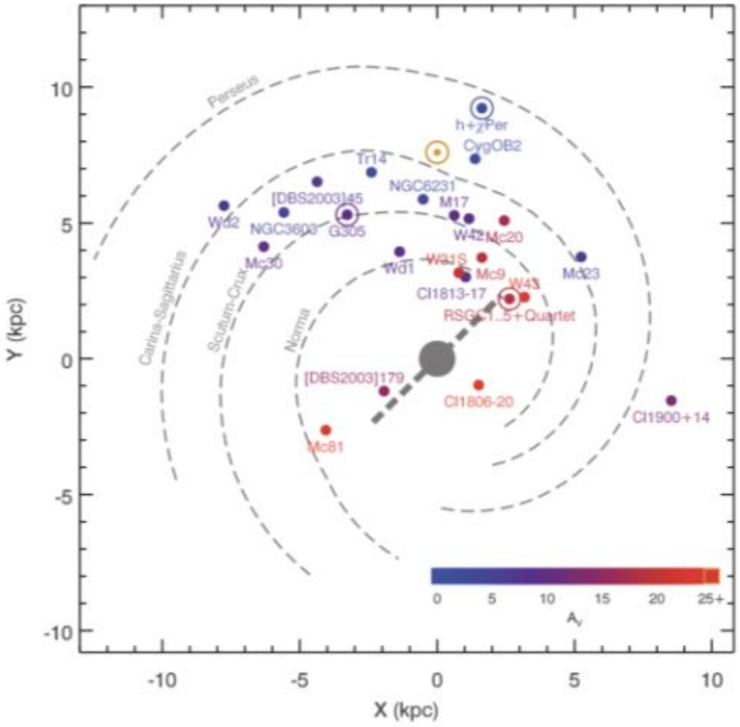
- Probing regions that are obscured in optical/infrared.
- Potential RSG survey of 653 sources at 43GHz with the VLA.
  - SiO maser emission to measure kinematic properties
  - Determine how the bar and spiral arms might be dynamically related
  - Can we find more RSGs on the far side of the bar?



[NASA 2023]

Research Goals

1. Classification of SiO emitting RSGs
   a. Are our sources RSGs?
   b. Are there properties of SiO emitting RSGs that we can use to search for more
2. Investigating the far side of the bar
   a. Can we derive parameters to expand our search to regions of interest



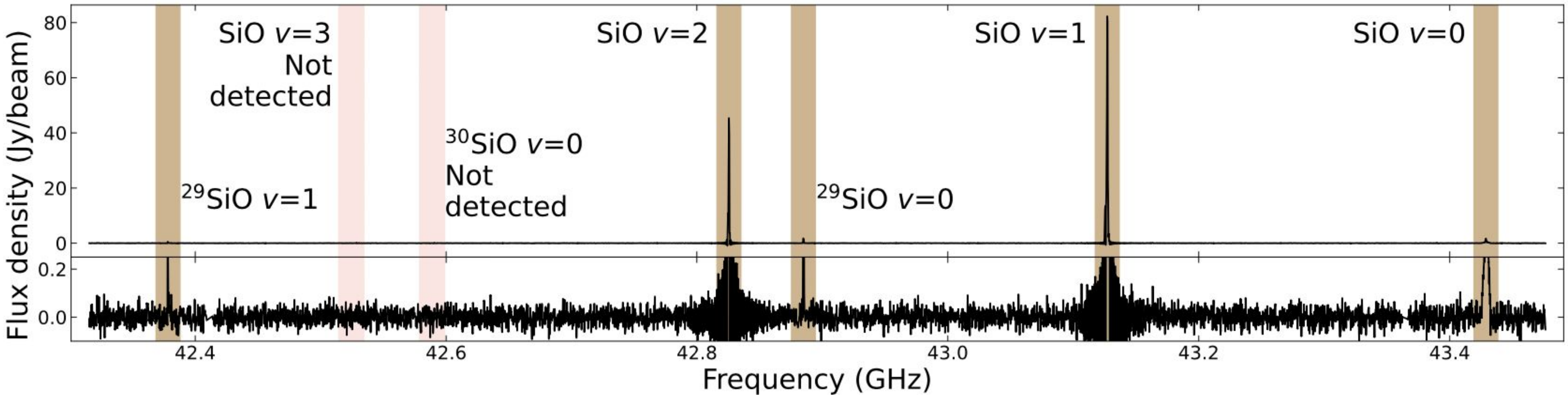
[Davies et al. 2012]

Why look at SiO maser emission?

- SiO v=1 emission is not blue-shifted or red-shifted compared to the central star (unlike OH and H_2O masers)

Why RSGs?

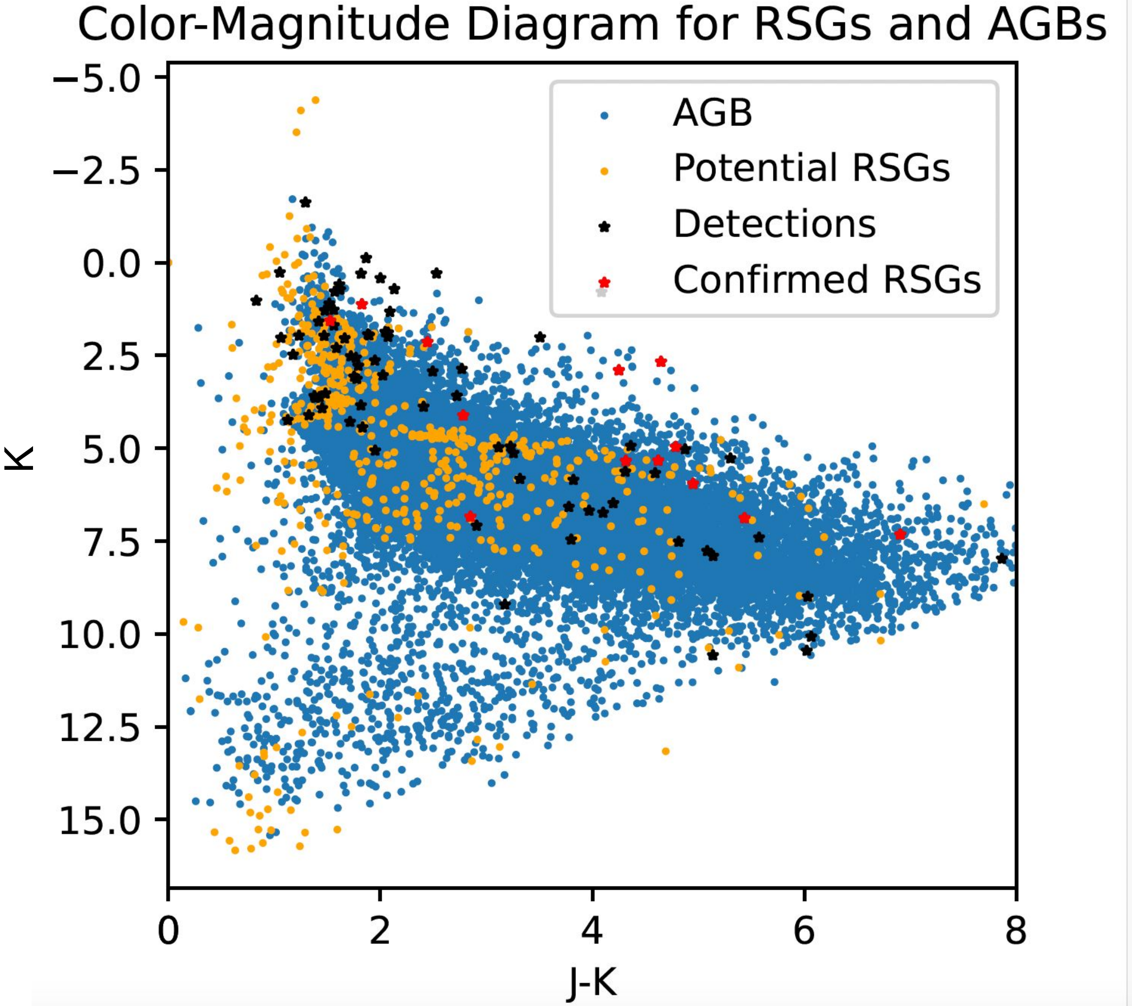
- RSGs stay close to their birthplace, learning about their kinematics can give us information on regions of interest
- Complimentary to the older BAaDE AGB sample
- Help us understand properties of RSG circumstellar envelopes and pumping mechanisms



VLA Survey

653 sources listed as potential RSGs

- Observed at 43GHz with the VLA in A-configuration (longest baselines, highest angular resolution)
- 91 sources with SiO maser emission observed
- Data analysis done in AIPS



Limits on Detections

Part of the work is trying to determine how often SiO maser emission is associated with RSGs

- Roughly 15% expected (Verheyen et al. 2012)
- We have a 14% detection rate overall and 20% in sources we know to be RSGs

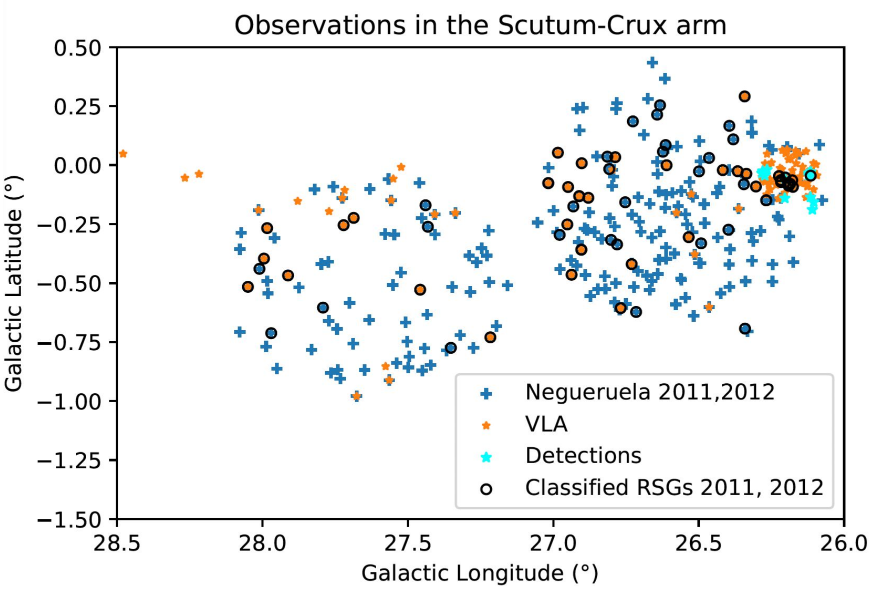
Limits on detections depend on properties of the circumstellar shell

- Need a thick enough shell

Our Sources

How do we know our sources are RSGs?

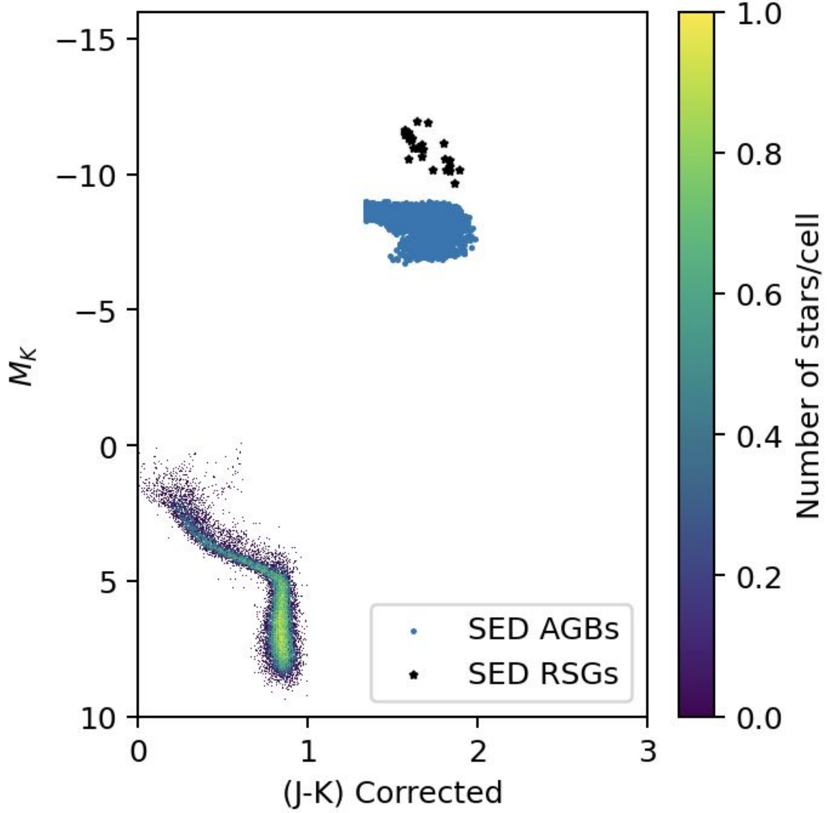
- Spectral confirmation
  - Neguerela et al. (2010,2011,2012) Has sources spectrally confirmed as RSGs (we had ~60 of these with VLA)
- CCDS/CMDS
  - Deriving distances for our sources
  - Placing our sources on the HR diagram to see their evolutionary state
- SiO emission properties
  - Wider line width from RSGs (~20 km/s) than AGB (~5 km/s)



Estimating Distances

- Template SED with known VLBI parallax (Bhattacharya et al. 2024)
- Fit to template based on MSX and 2MASS colors
- Apply equation to obtain distance relative to this source at each wavelength
- Median distance for each source is taken to be the calculated distance

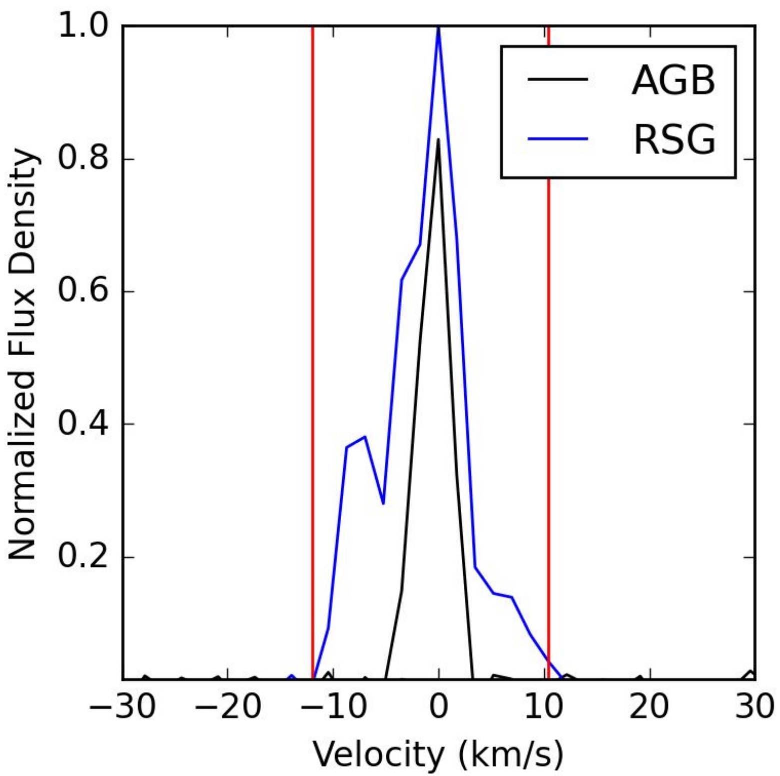
$$d_{\lambda,\mathrm{tgt}} = d_{\mathrm{tmpl}} \left(\frac{F_{\lambda,\mathrm{tmpl}}}{F_{\lambda,\mathrm{tgt}}} 10^{\frac{-Z_\lambda A_{K_S}}{2.5}} \right)^{1/2}$$



SiO Emission Line Widths

SiO maser line widths are likely larger for RSGs (ΔV >20 km/s) compared to ΔV ~ a few km/s in AGBs, which could separate the groups

- Plotting FWZM of sources with SiO maser emission to see if our sources are consistent with these values
- Considering widths where values are > 5σ



Searching for Sources at the Far side of the bar

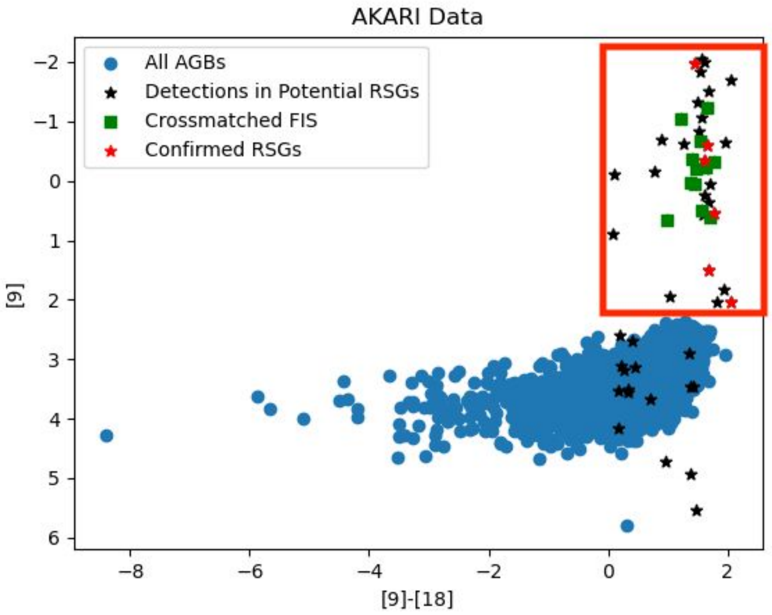
Can we use properties of sources we believe to be SiO emitting RSGs to find more at the far side of the bar?

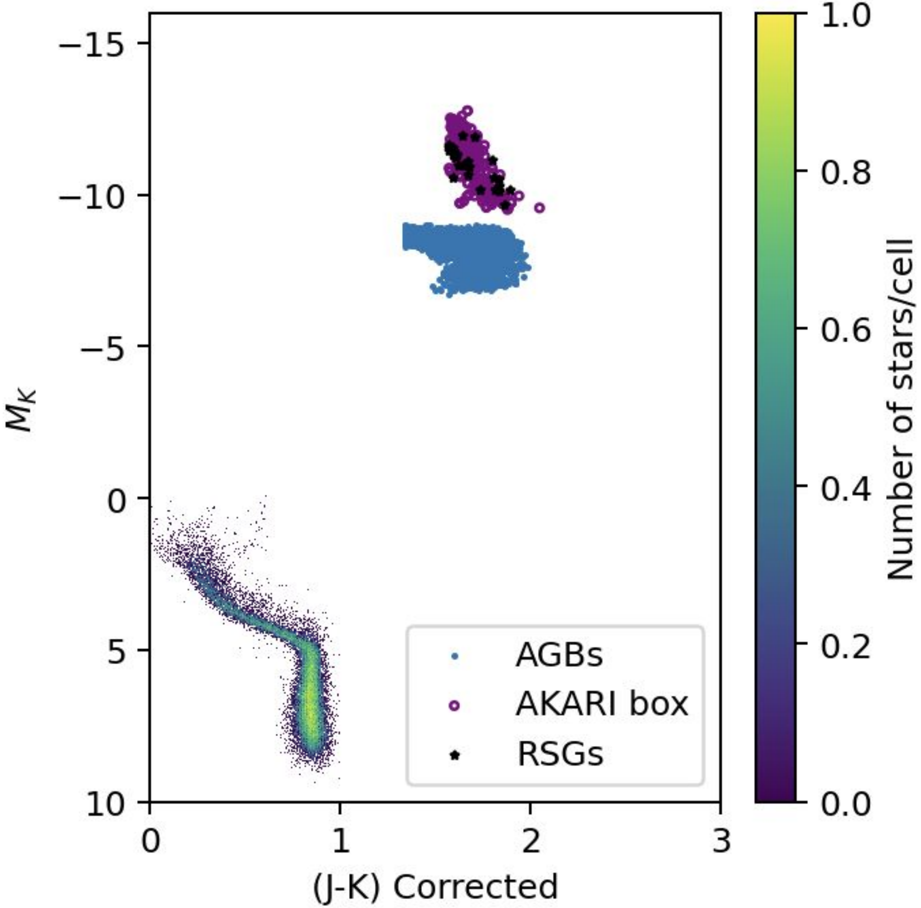
Color-magnitude and color-color diagrams do not show good separation between AGBs and RSGs; we have some with AKARI data for our sample

Applied a color cut ([9]-[18] >0) and a magnitude cut ([9]<3) to search for sources in AKARI at the far side of the bar

- Originally over 28,000 sources

- Color and magnitude cut left us with 602 sources; restricting this to regions where RSGs fall on an HR diagram gives us 283





−15
−10
−5
0
5
10
0
1
2
3
M_K
(J-K) Corrected
AGBs
AKARI box
RSGs
1.0
0.8
0.6
0.4
0.2
0.0
Number of stars/cell

Near-Future Work

1. Determine line of sight velocities
    - Have these for a limited number of our sources
2. Delve further into the far side of the bar
    - Obtain data with ALMA at 43GHz and 86GHz
3. Apply to observe more sources in the near-side of the bar with VLA

Thank You!

Questions?