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# Simultaneity and Flux Bias between 43 and 86 GHz SiO Masers

**Michael C. Stroh**[1], **Ylva M. Pihlström**[1,2] **and Lorant O. Sjouwerman**[2]

[1]Department of Physics & Astronomy,
The University of New Mexico, Albuquerque, NM 87131
email: `mstroh@unm.edu`

[2]National Radio Astronomy Observatory

**Abstract.** Using quasi-simultaneous observations of 86 stars with known SiO maser emission, we searched for systematic differences between the strengths of the 43 and 86 GHz $v$=1 maser lines. Although for individual stars there is wide scatter between the line strengths spanning nearly an order of magnitude, there is no evidence of a systematic difference between these line strengths for the entire sample.

**Keywords.** Masers, stars: late-type, infrared: stars, radio lines: stars

## 1. Introduction

The Bulge Asymmetries and Dynamical Evolution (BAaDE) project aims to explore the complex structure of the inner Galaxy and Galactic Bulge, by observing SiO maser lines in red giant stars using the 43 GHz receivers at the Very Large Array (VLA) and the 86 GHz receivers at the Atacama Large Millimeter/submillimeter Array (ALMA). A fundamental assumption for the BAaDE project is that stars emitting 43 GHz SiO maser emission also harbor 86 GHz masers, and vice versa. This appears to be a commonly accepted fact, supported by, for example, Sjouwerman *et al.* (2004) who noted that out of 39 sources displaying 86 GHz SiO maser emission, 38 also produced 43 GHz masers. What is less clear, however, is whether there is a statistically significant difference in the flux density of 43 GHz versus 86 GHz masers. Such a difference could have an impact on the analysis of the BAaDE sample, as the VLA and ALMA samples are observed to the same noise levels and the ALMA sample covers the far side of the bar ($-110° < l < 0°$) while the VLA sample covers the near side. Here we present near-simultaneous observations of the 43 GHz and 86 GHz SiO maser lines in a set of 86 stars to test whether one line is consistently brighter than the other.

## 2. Observations

The Australia Telescope Compact Array (ATCA) allows the 43 GHz and 86 GHz SiO transitions to be observed quasi-simultaneously. Given that the 86 GHz system at ATCA requires longer integration times compared to the 43 GHz to reach similar rms noise, the targets selected were the brightest masers in our sample. Whereas this selects for mostly nearby sources, it also selects for an average metallicity.

For the detected maser lines, self calibration was applied and the data was smoothed into 1 km/s bins for final line detections. A line is considered a detection if the velocity integrated flux density in at least one 1 km/s bin is at least five times the rms noise. For each detected line, a final velocity integrated flux density is calculated by integrating over a 3 km/s bin centered on the peak.

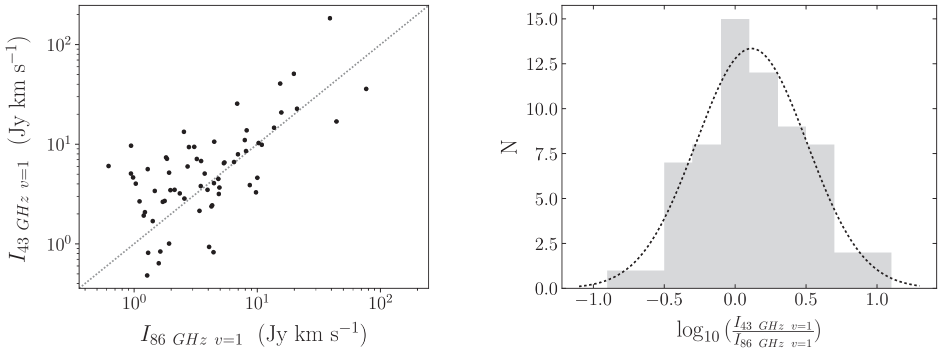


**Figure 1.** Left: Comparison between the velocity integrated flux densities for the two $v$=1 lines. Right: Histogram of ratios with a best-fit Gaussian over-plotted.

## 3. Results

We detected the SiO 43 and 86 GHz $v$=1 lines in 81 and 66 sources respectively and 86 GHz $v$=1 non-detections are likely due to poor observing conditions resulting in high rms noise. On average, the relative strengths of the 43 GHz and 86 GHz v=1 lines are equal based on the scatter plot of the line intensities (Fig. 1a) and the histogram of the line ratio distribution (Fig. 1b). While the data shows a very broad range of line ratio values, the scatter is centered around a line ratio of one and the center of the Gaussian fit is consistent with a ratio of one. The center and standard deviations of the Gaussian from the least squares fit to the logarithm of the line ratios are $0.12 \pm 0.05$ and $0.39 \pm 0.05$ respectively.

As we observed thinner shells, our results follow the trend outlined by Nyman *et al.* (1993), where the 43 GHz line gets successively weaker in thinner envelopes. However, our results do not demonstrate a turnover into a consistently brighter 86 GHz line for Mira-type envelopes, as has been previously suggested by modeling of SiO maser emission in Miras (Humphreys *et al.* 2002) and in observations of smaller Mira samples (e.g. Pardo *et al.* 1998). We note that our sample is much larger than other samples studied, and the large spread of line ratios likely can explain some earlier observational results indicating the 86 GHz line would be brighter.

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