Isotopic SiO Maser Emission from the BAaDE Survey



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Atacama Large Millimeter/submillimeter Array
Karl G. Jansky Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

BAaDE – Bulge Asymmetries and Dynamical Evolution

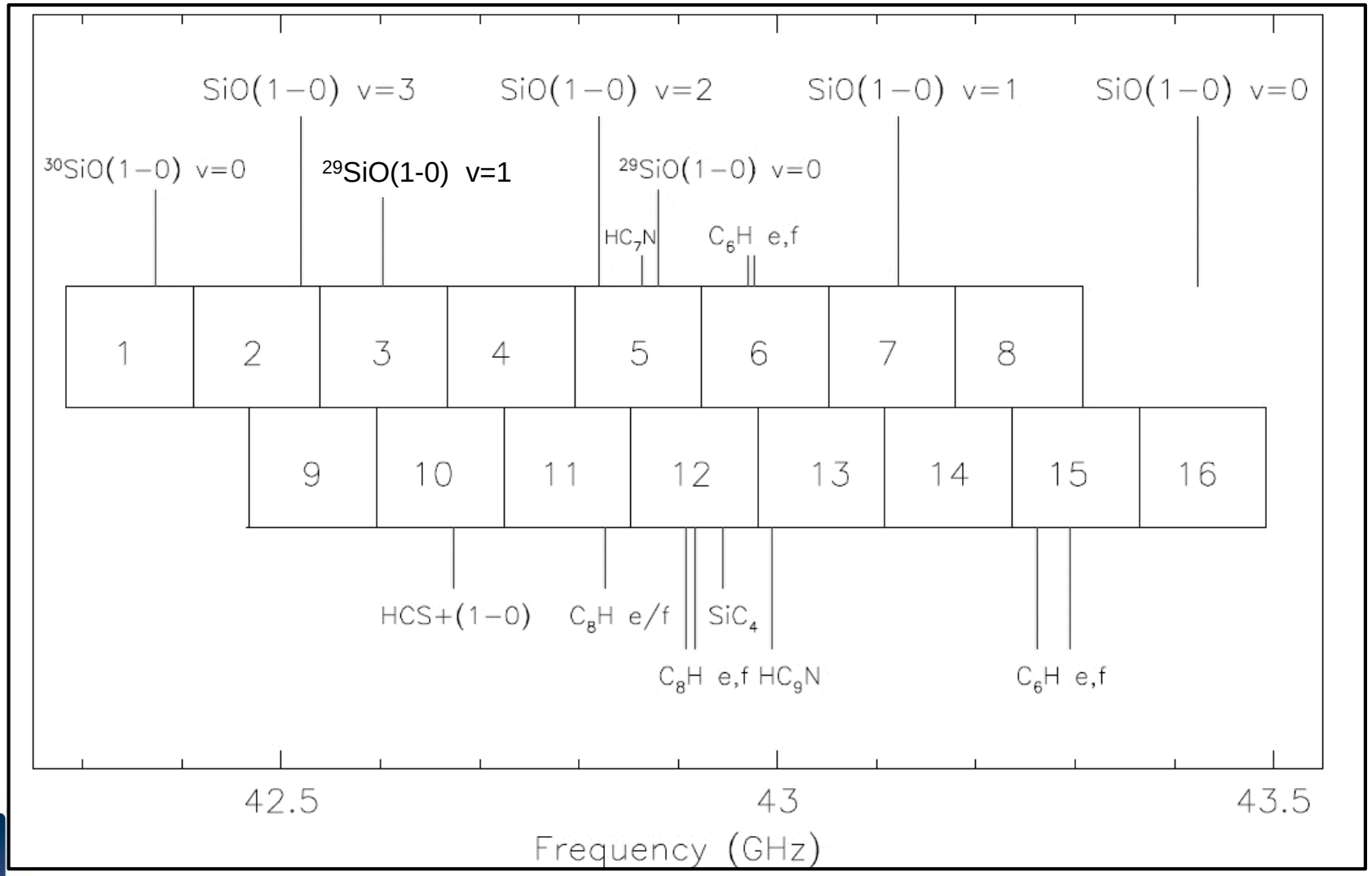
- BAaDE - survey up to ~34,000 SiO maser stars along the Galactic Plane, concentrating in the Bulge and Inner Galaxy. Primary purpose is to study dynamics and kinematics of the Bulge and Bar.

- Stars color-selected from MSX survey on 8 – 15 micron color. Previous studies have shown that given a specific color selection, > 50% detection rate of SiO masers is achieved.

- BAaDE was begun in 2013 on the VLA, using D and C configurations, with a spectral setup shown next slide and with 250 kHz resolution (~1.7 km/s). Central velocities of detected masers can be estimated to ~0.1 km/s. VLA survey complete earlier this year. Detection rate is ~70%.

- VLA setup arranged for observing not only the ^{28}SiO masers at 7mm (4 vibrational states), but also the ^{29}SiO v = 0 (42.88 GHz), ^{29}SiO v = 1 (42.58 GHz) and the ^{30}SiO v = 0 (42.37 GHz) in the lowest rotational transition.

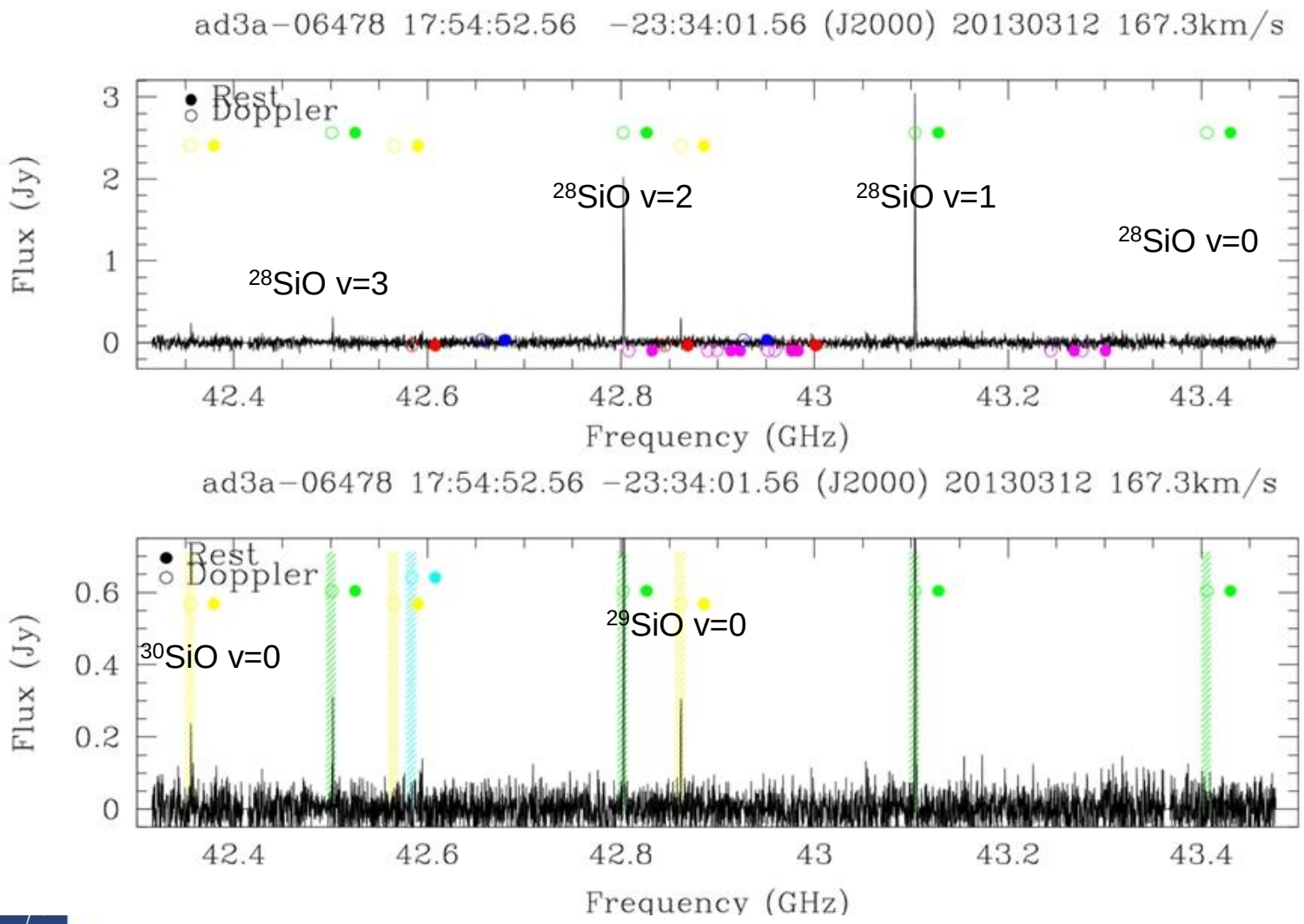
BAaDE VLA Observing Setup



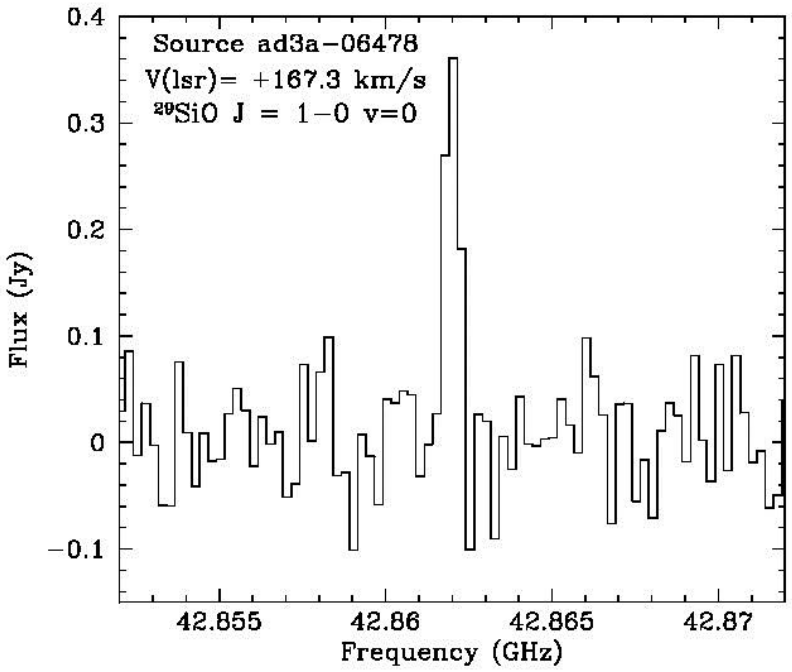
Background on Isotopic SiO Masers

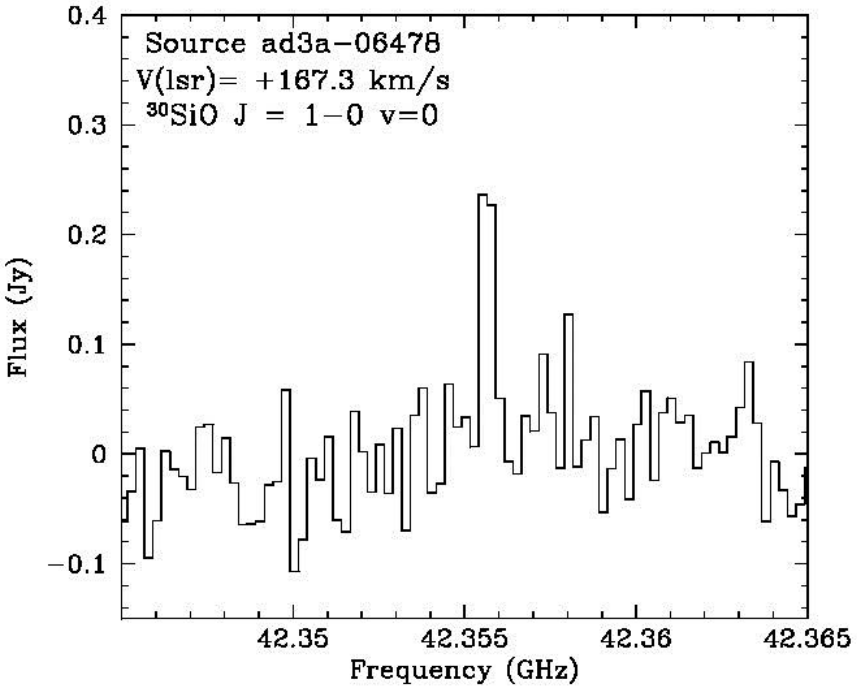
- Since early 1990s clear that there are problems with pumping isotopic SiO maser species (e.g. Cernicharo, Bujarrabal, & Lucas 1991).
- Olofsson et al. as far back as 1981 introduced the hypothesis of line-overlap pumping, and several papers in the 90s investigated the importance of line overlaps (e.g. Gonzalez-Alfonso & Cernicharo 1997 developed a non-local radiative transfer code).
- Herpin & Baudry 2000 used LVG code and 40 rotational levels for each of v = 0 to 4 vibrational states and each of the isotopic species and found that they could explain a lot of the observed line intensities and made new predictions. For ^{29}SiO, they found that infrared line overlaps could explain the observations.
- In the mid-to-late 2000s, VLBI observations of isotopic lines (Soria-Ruiz et al. 2005, 2007} found that the VLBI maps of the ^{29}SiO v =0, J = 1-0 lines in evolved stars were similar in nature to ^{28}SiO maps, i.e. they showed tangential amplification. These investigators suggested that a larger sample of VLBI maps of the isotopic masers will help to understand the line-overlap pumping of the SiO masers.

Some Example Spectra

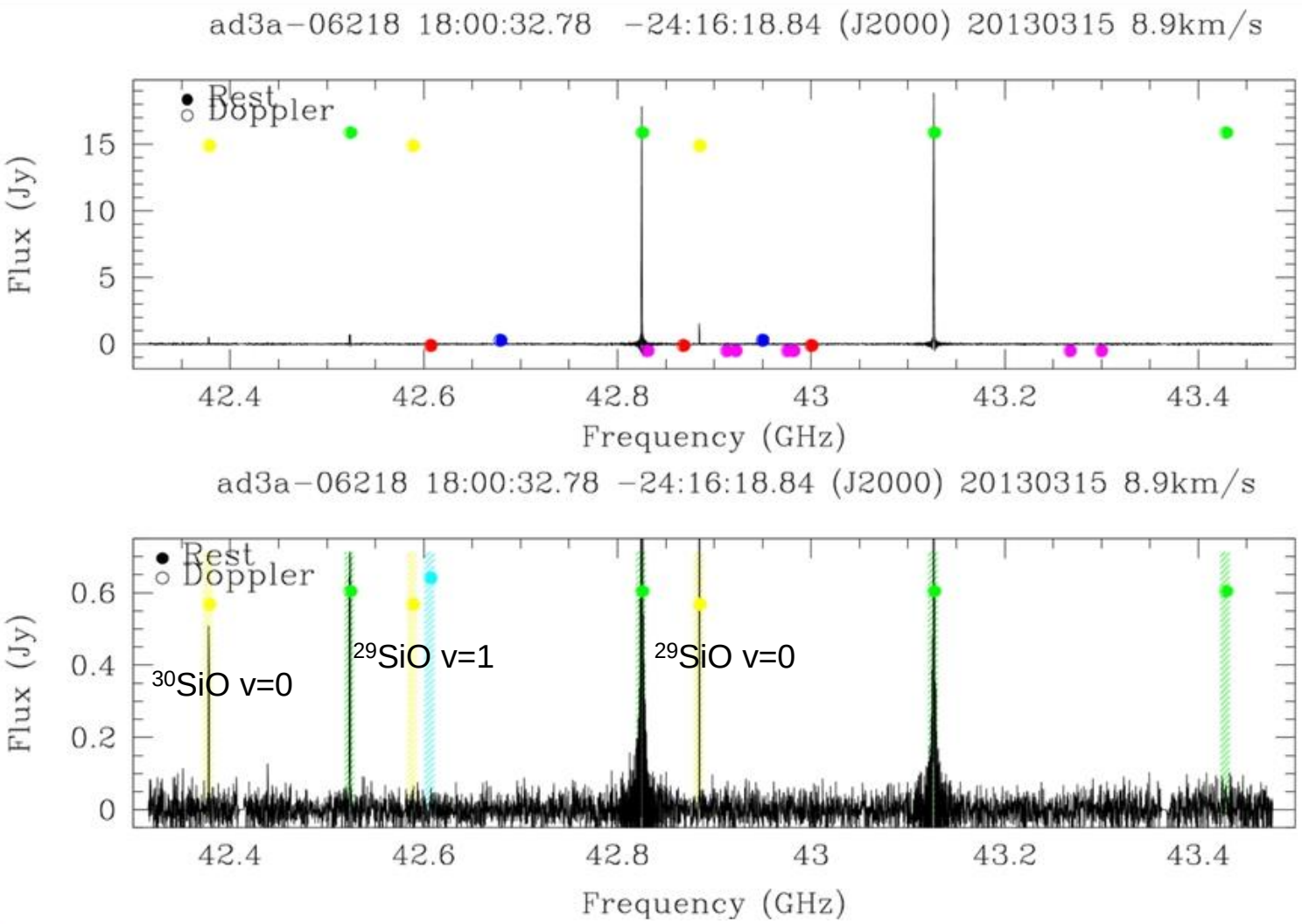


Zoom-in Example Spectra

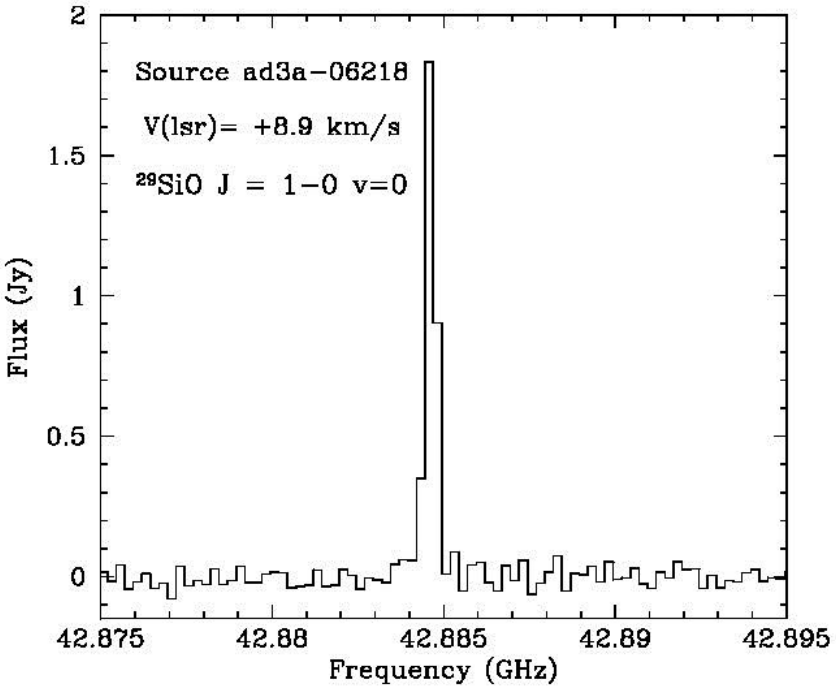


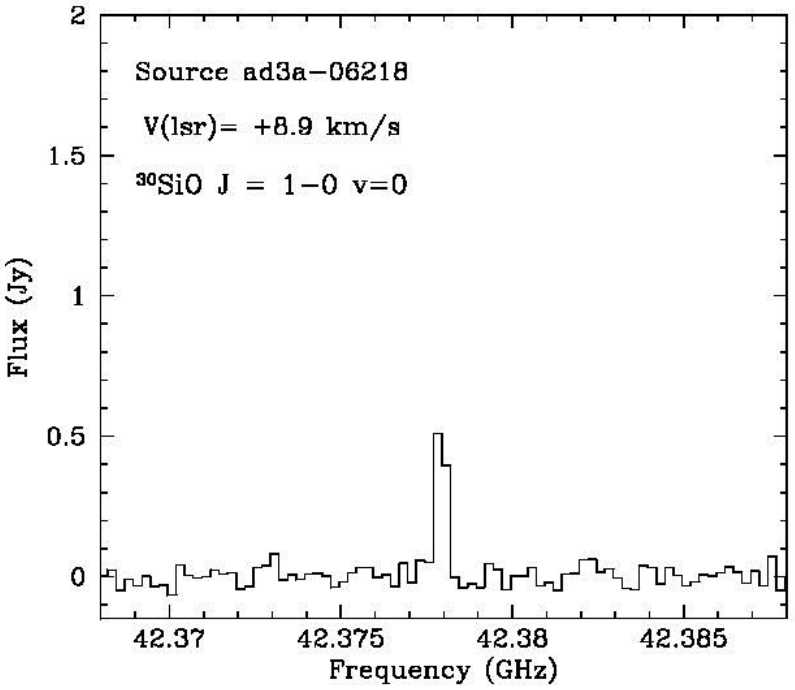


Some Example Spectra

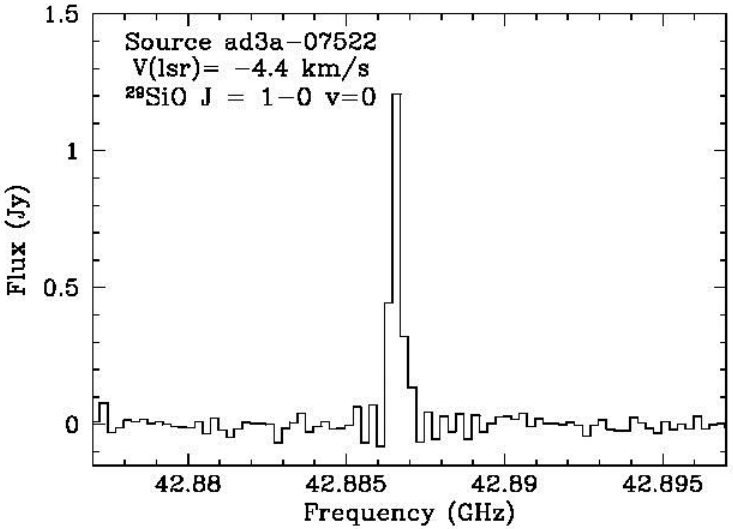


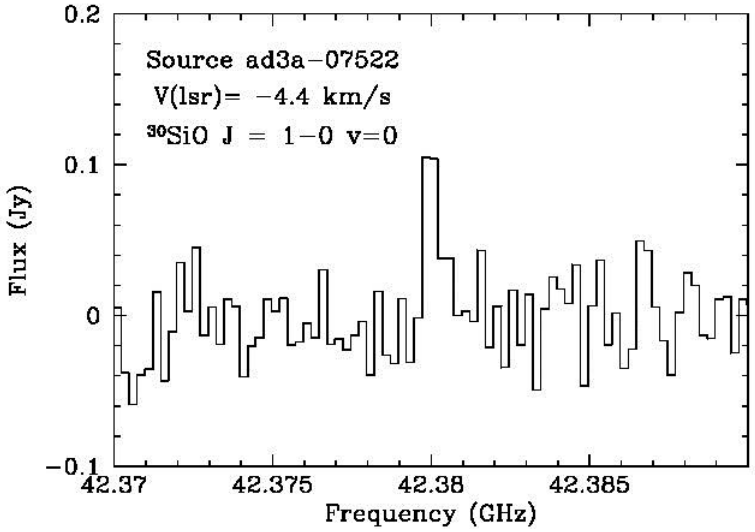
Zoom-in Example Spectra

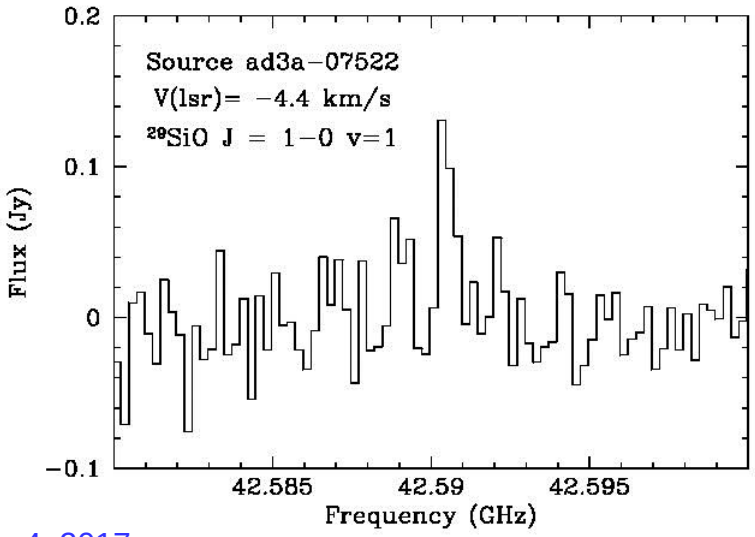




Zoom-in Example Spectra







Some Statistics

- Of ~3600 targets in the 2013 run, ~360 or 10% show isotopic maser emission
- That 10% reflects the ^{29}SiO v = 0 transition (detected in ~360 objects)
- The ^{30}SiO v = 0 transition is detected in ~4% of the targets (~150 objects)
- The ^{29}SiO v = 1 transition is detected in ~0.8% of the targets (~30 objects)

- If these stats hold over the entire VLA-BAaDE sample, then would have:
  - ~2000 objects in ^{29}SiO v = 0
  - ~800 objects in ^{30}SiO v = 0 and
  - ~150 objects in ^{29}SiO v = 1
- Some fraction will be observable with VLBI techniques

Quick Conclusions

- BAaDE survey very successful – be sure to catch Lorant's talk tomorrow at 18:00.
- Also, Luis Henry Quiroga Nunez (JIVE) has a poster on BAaDE and GAIA comparisons (P. 43) and Michael Stroh (UNM) has a poster on comparison of 43 (BAaDE – VLA) and 86 GHz masers (BAaDE – ALMA), P.45.

- We have examined the silicon isotopic SiO masers from the first (2013) VLA part of BAaDE at 7mm – ^{29}SiO v =0, ^{29}SiO v = 1, and ^{30}SiO, v = 0 in the ground rotational state.
- By number, the detection rate for these isotopic masers is ~10%, with the ^{29}SiO v = 0 maser being the most prevalent, and generally the strongest, of these 3 isotopic species.
- With this sample, either BAaDE data or follow-up VLA and VLBI observations, will provide a large number of evolved SiO maser stars to study the pumping of SiO masers, including the effects of line overlaps.