



Loránt Sjouwerman, NRAO

The BAaDE collaboration (UNM/NRAO, UCLA, JIVE)

The BAaDE VLA/ALMA 43/86 GHz SiO maser survey in the Galactic Bulge



National Radio Astronomy Observatory

Enabling forefront research into the Universe at radio wavelengths



Outline

- Bulge Asymmetries and Dynamic Evolution
 - The BAaDE project
- Topics:
 - Source selection in the infrared
 - Obtaining line-of-sight velocities in detections
- Results
 - VLA and ALMA data
- Summary

The BAaDE collaboration

- Co-PI's:
 - Loránt Sjouwerman &
 - Ylva Pihlström (UNM)
- Co-I's:
 - Mark Claussen (NRAO)
 - Mike Rich & Mark Morris (UCLA)
- Students:
 - Isaiah Santistevan, Cameron Trapp & Michael Stroh (UNM)
 - Luis Henry Quiroga-Nuñez (JIVE/Leiden)
 - ..
- collaborators also at JPL, UCLA, Leiden, JIVE, ..

National Science Foundation Grant 1517970

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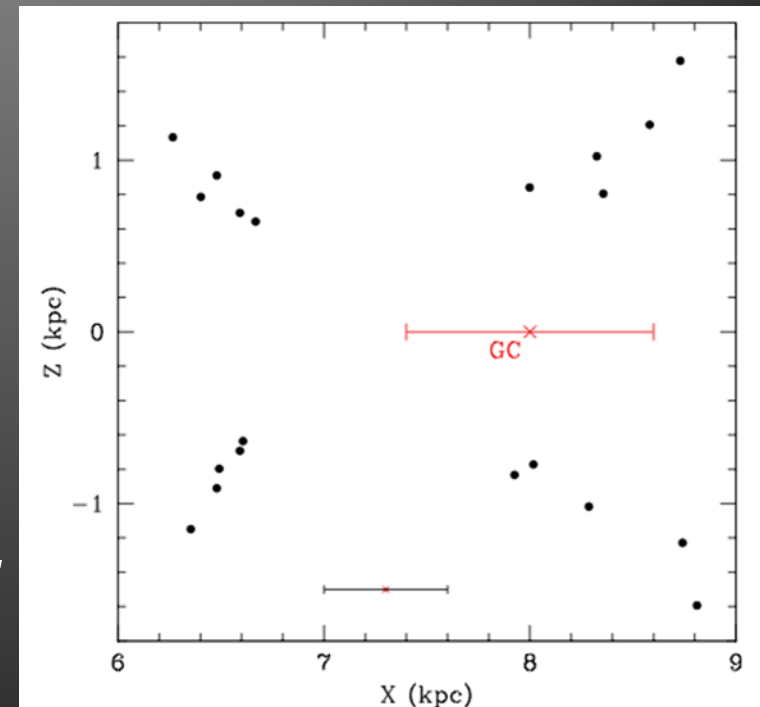
Scientific motivation

- Better understand Galaxy formation
 - Structure, age, chemical composition, kinematics
- Classical Bulge or “buckling”?



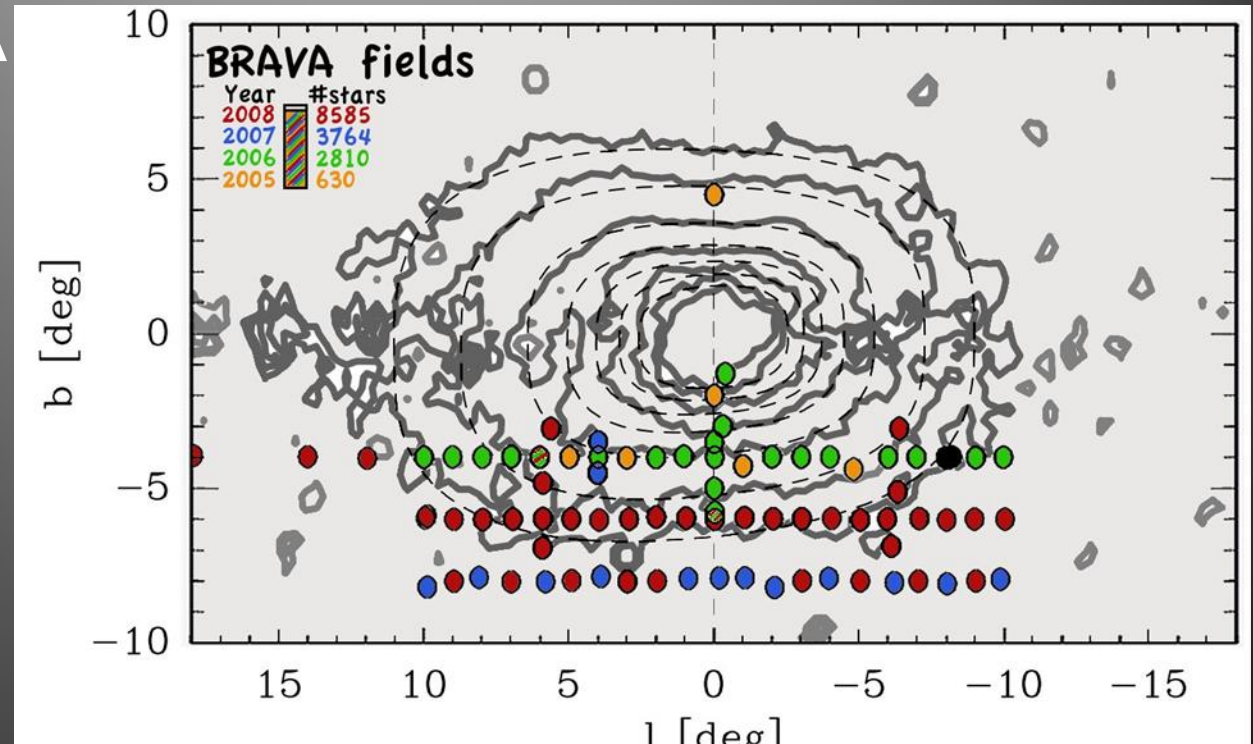
Orbits, features in Bulge/Bar?

- Central part of Galaxy dominated by a bar
 - Cylindrical rotation, tri-axial or boxy bulge
 - Howard et al. 2008, Rich et al. 2007
 - X-shaped structure in RC **
 - McWilliam & Zoccali 2010
- *Significantly more details about orbits, orbit families, in these regions is desirable.*



Optical surveys of the Bulge

- e.g. BRAVA

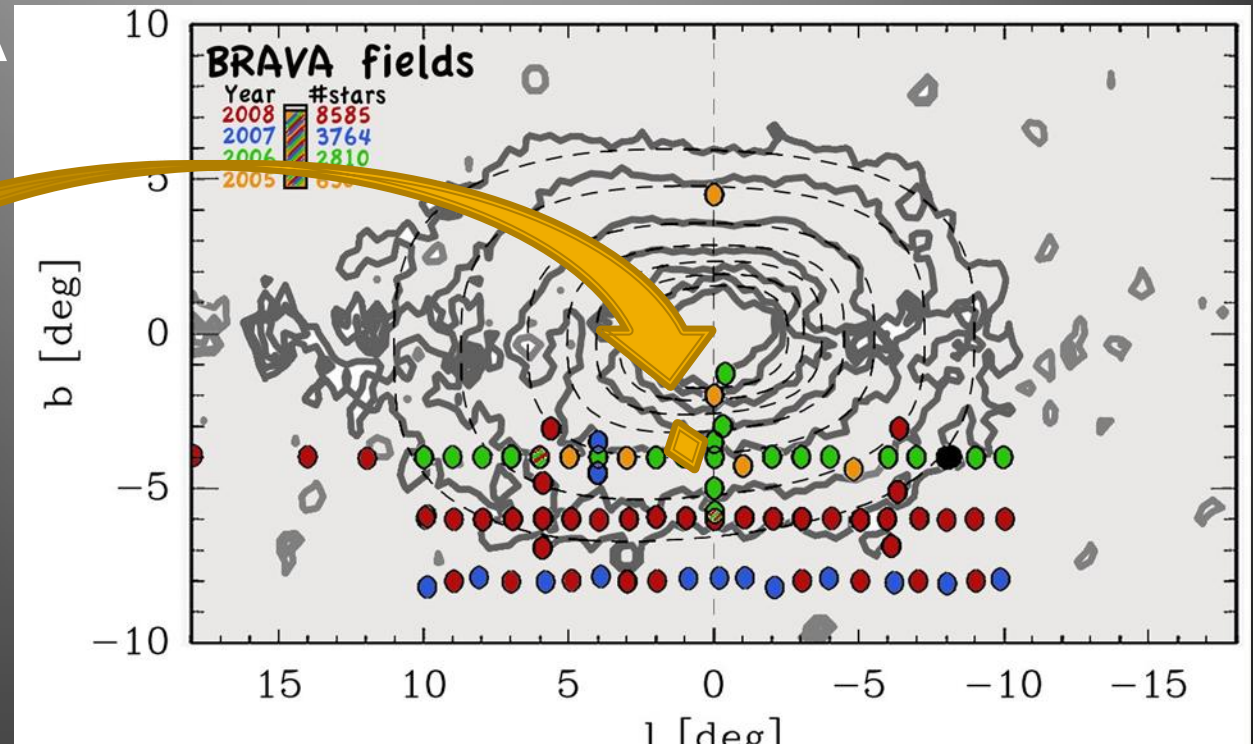


- Cannot penetrate in Plane/Bulge region

Optical surveys of the Bulge

- e.g. BRAVA

- Baade's Window



- Cannot penetrate in Plane/Bulge region

The BAaDE project:

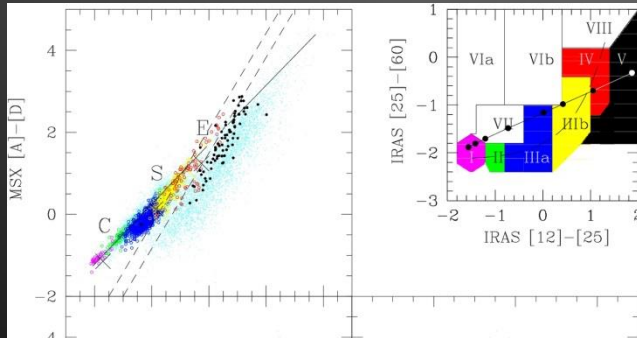
- Aim: to significantly improve models of the dynamics and structure of the inner Galaxy using *radio* detected point-masses probing into regions not reachable with optical surveys.
- Surveying up to ~34,000 stars for SiO maser emission using both VLA and ALMA.
- Using VLBA for detailed orbit characteristics in a subsample of the sources.

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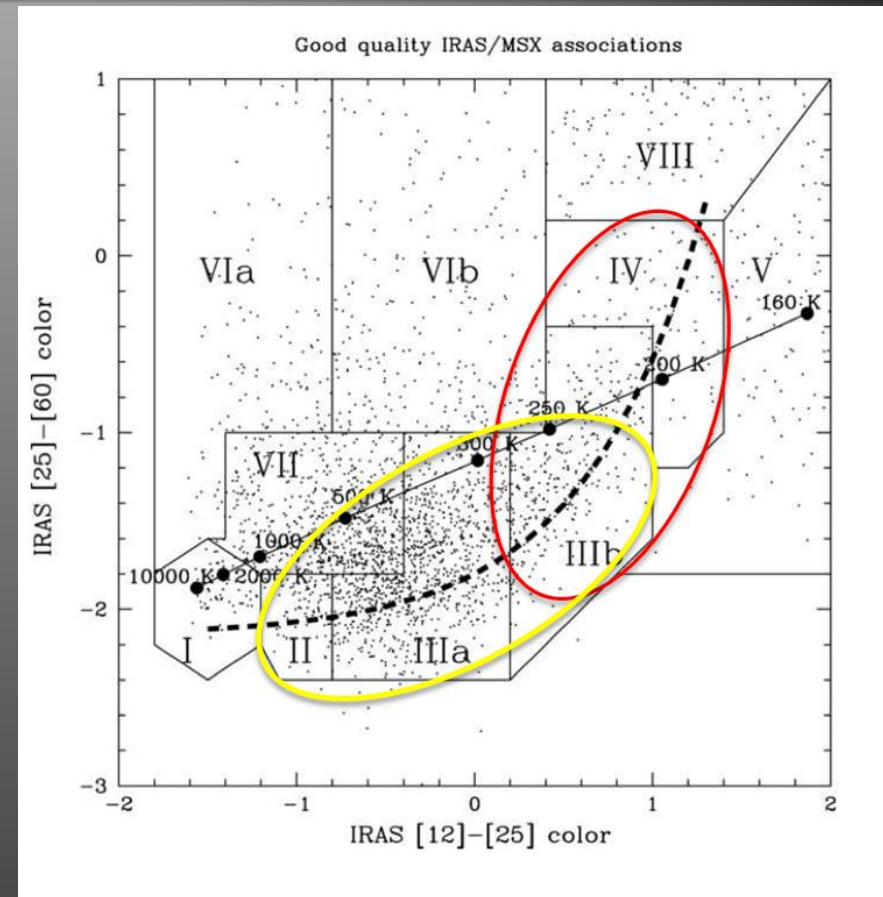
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Source selection in the infrared

- IRAS color-color for AGB:
 - OH masers (red)
 - ~3000 over entire Galaxy
 - SiO masers (yellow)
 - Potentially 1000's more
 - Cannot use IRAS in plane
- MSX color-color: ("iiii"=blue)



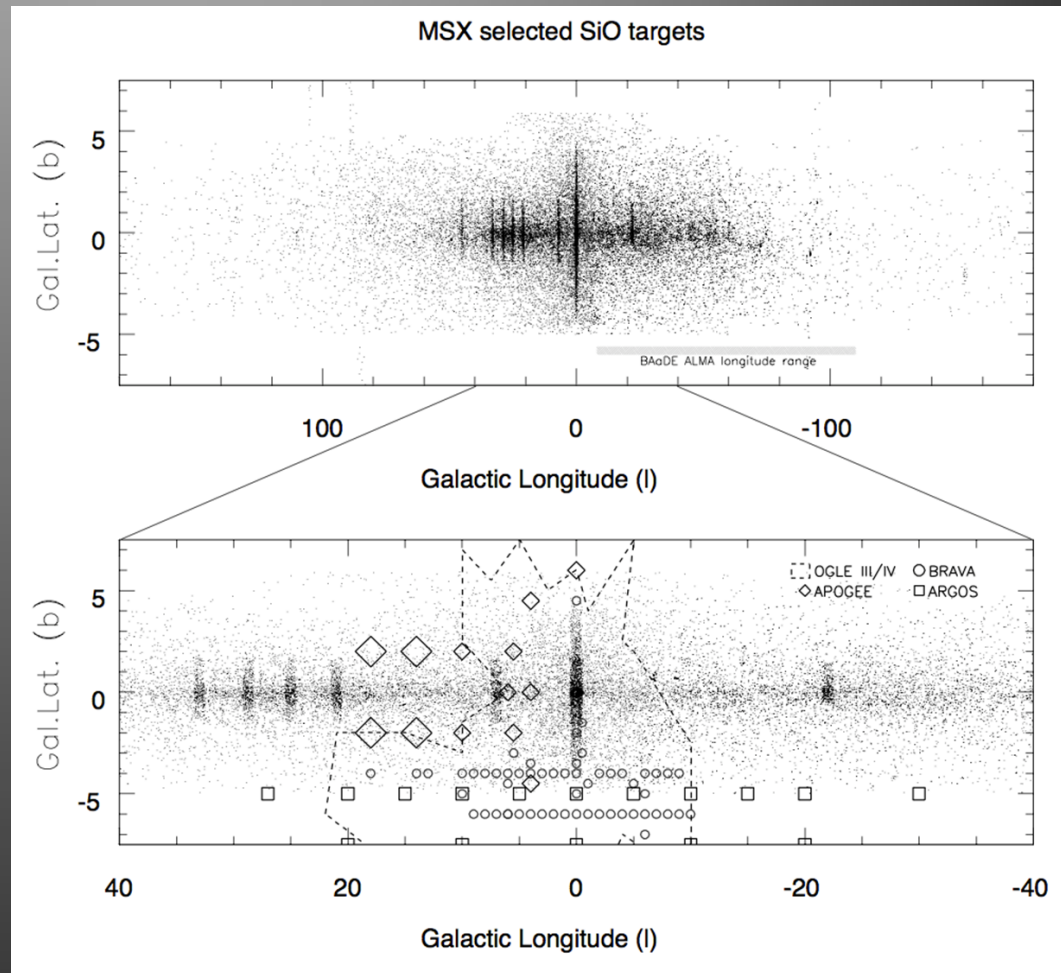
Sjouwerman et al. 2009



Van der Veen & Habing 1988

MSX selection versus optical

- MSX PSC 2.3 ($0 < l^\circ < 360$, $-6 < b^\circ < 6$)
⇒ ~19,000 region iia for the VLA
⇒ Another ~14,000 with ALMA
- SiO maser detection rate in this selection is 50-90%
Sjouwerman et al. 2009
- Expect ~20,000 new velocities
- Samples the Galactic plane where optical surveys do not reach and where dynamics are most revealing

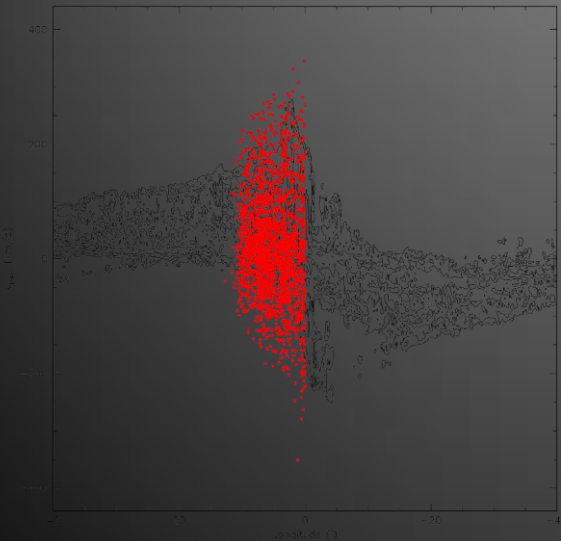


Obtaining line-of-sight velocities

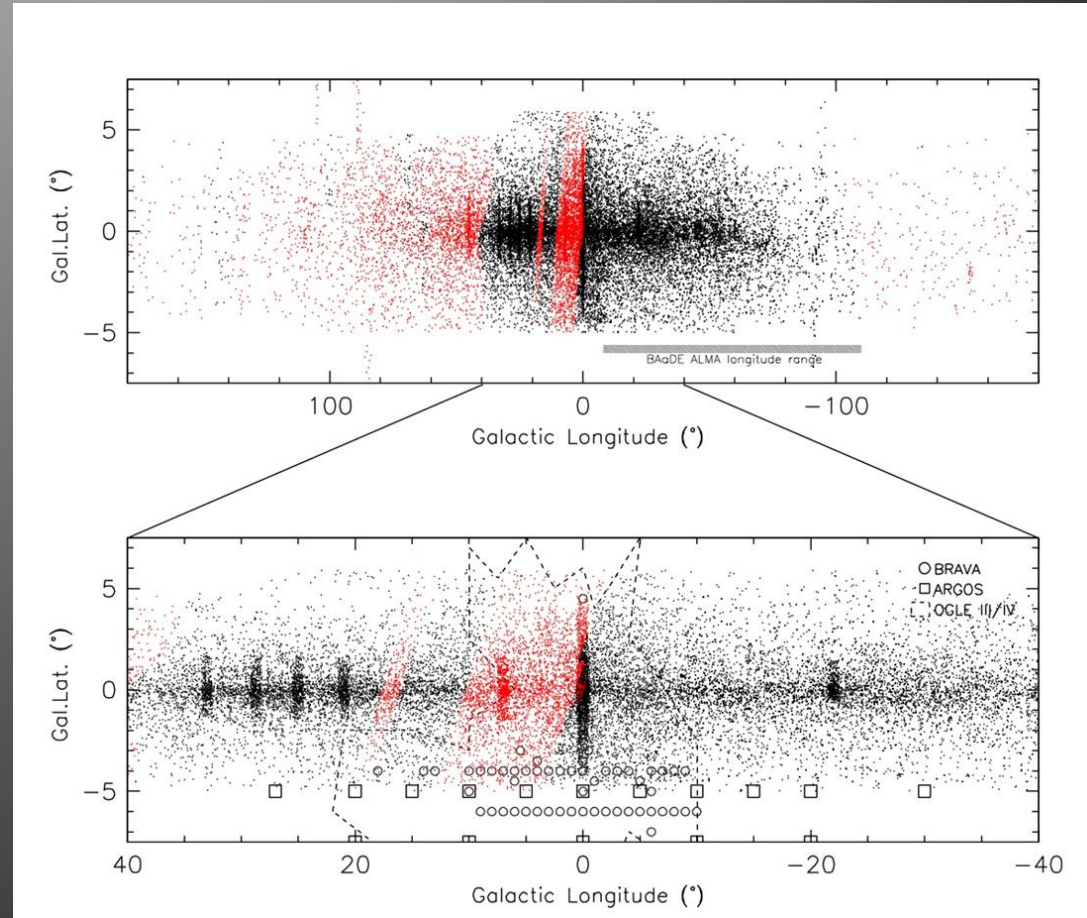
■ Current status

- VLA 7000 **
- ALMA 200 **

l-v diagram for CO (contours) and BAaDE SiO maser stars (points)

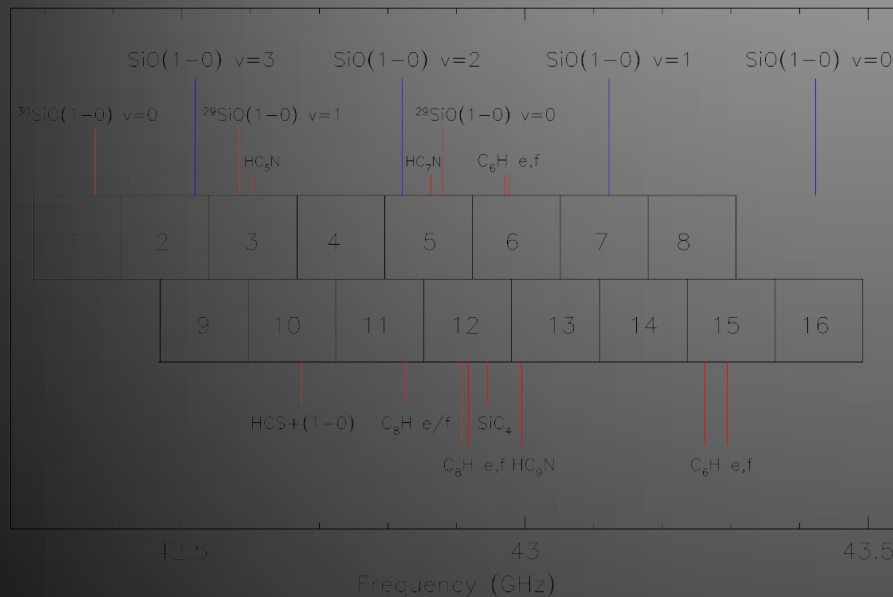


CO - Dame et al. 2001



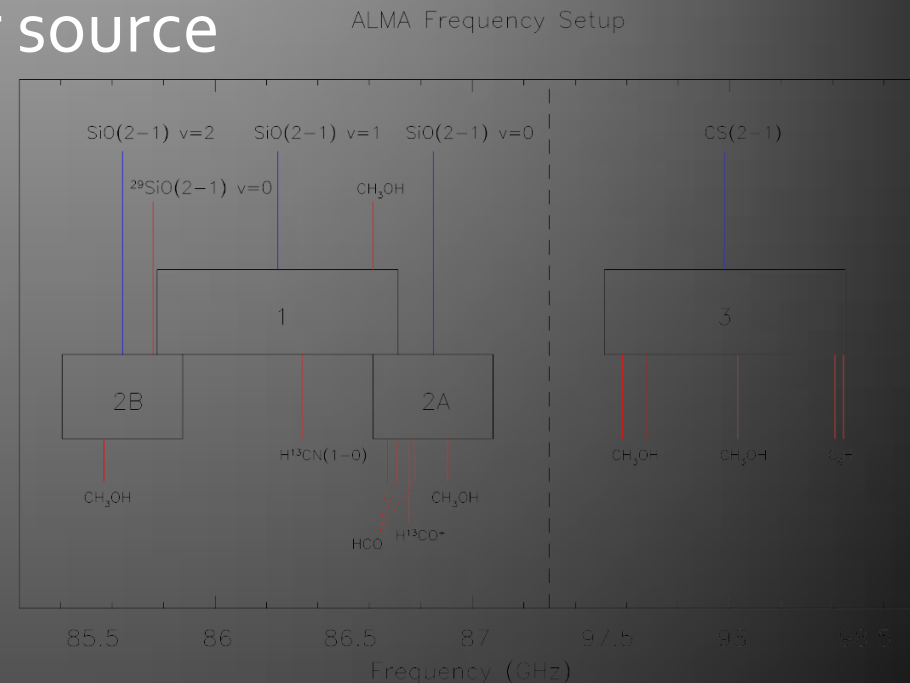
Observational setup

- Multiple maser lines, also lines for C-rich **
- Less than one minute per source



VLA - 43 GHz

most sources display more than one line: very reliable velocities



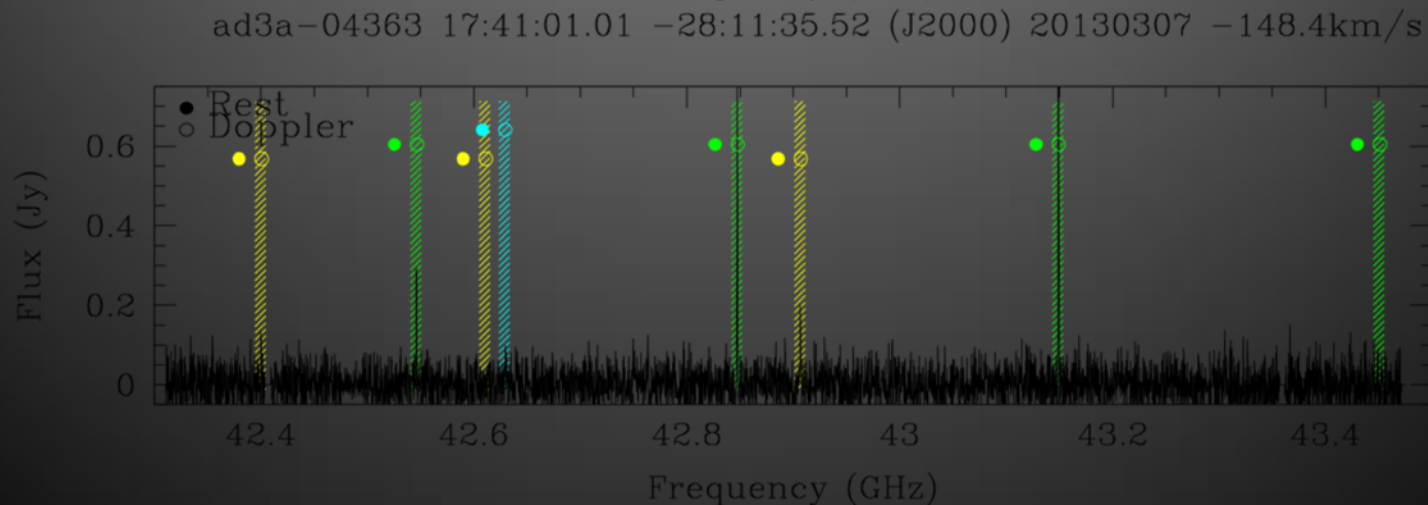
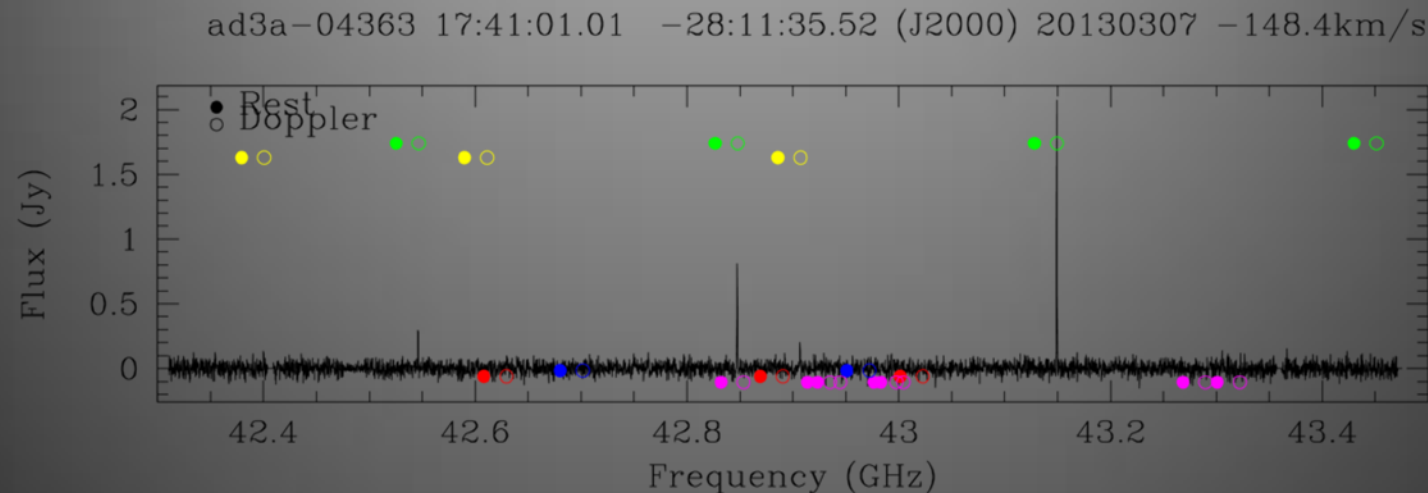
ALMA - 86 GHz

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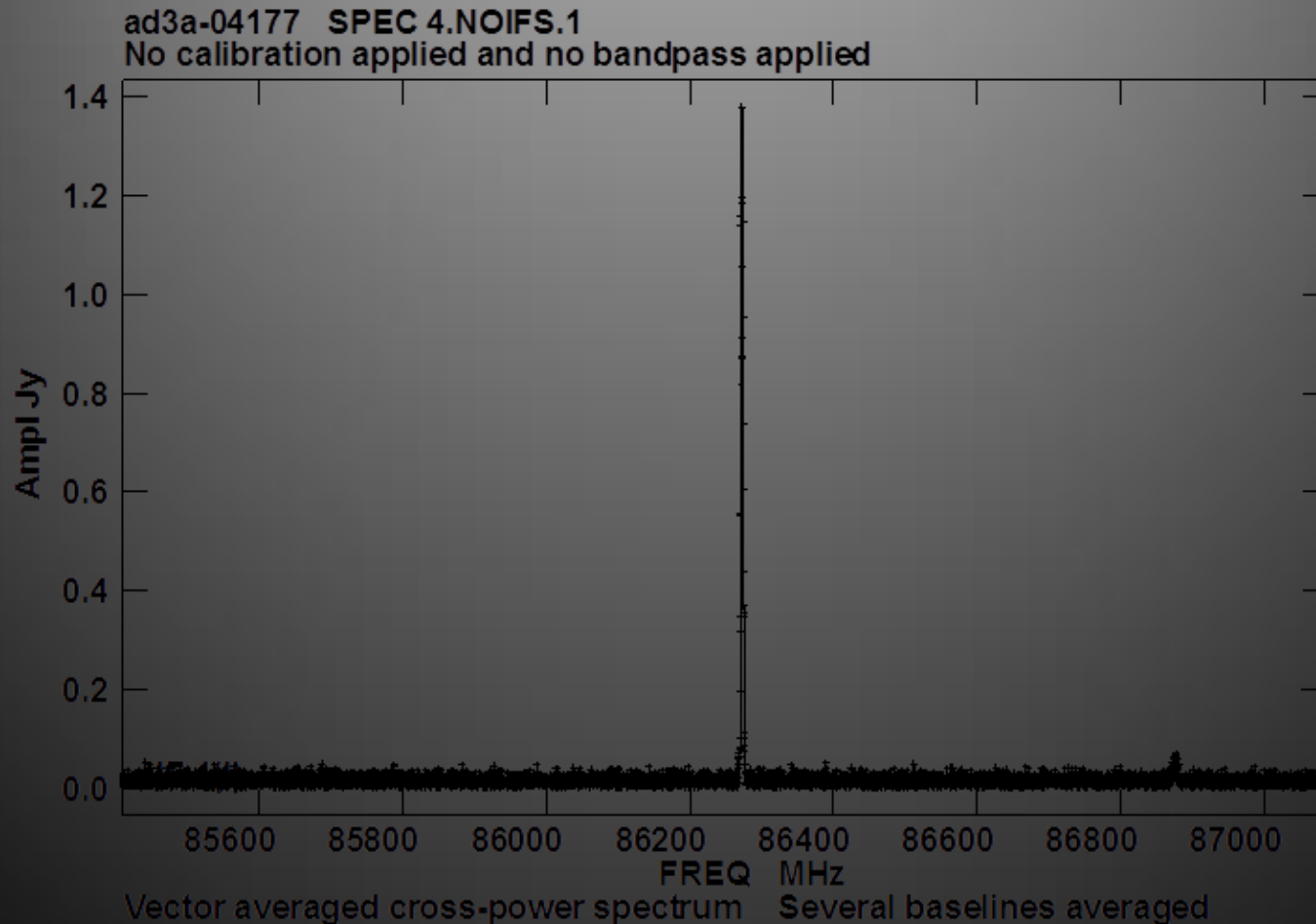
VLA data results

- Typical detection at 43 GHz; rate about 70%



ALMA pilot data results

- Typical detection at 86 GHz; rate about 70%



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Summary

- BAaDE project:
 - Large SiO maser survey in IR color selected AGB stars with the VLA (43 GHz) and ALMA (86 GHz)
 - Thousands of line-of-sight velocities in the Bulge
 - ALMA and VLA great instruments
 - VLBI follow-up for parallaxes and 3-D orbits
- Dynamics and Evolution of the Galactic Bulge
- “only just begun” ...
 - SiO/IR catalog, line ratio's, new calibrators