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

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

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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
  - 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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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:** ("iiia"=blue)

Sjouwerman et al. 2009

Van der Veen & Habling 1988
• MSX PSC 2.3 \((0^\circ \leq l < 360^\circ, -6^\circ \leq b < 6^\circ)\)

\[ \Rightarrow \sim 19,000 \text{ region iiiia for the VLA} \]

\[ \Rightarrow \text{Another } \sim 14,000 \text{ with ALMA} \]

• SiO maser detection rate in this selection is 50-90%  
  Sjouwerman et al. 2009

• Expect \sim 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 **

CO - Dame et al. 2001
Observational setup

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

VLA - 43 GHz
ALMA - 86 GHz
most sources display more than one line: very reliable velocities
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VLA data results

- Typical detection at 43 GHz; rate about 70%

```
ad3a-04363 17:41:01.01 -28:11:35.52 (J2000) 20130307 -148.4km/s
```

![Graph showing typical detection at 43 GHz with a rate of 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