Bulge Asymmetries and Dynamic Evolution

BAaDE Project Update

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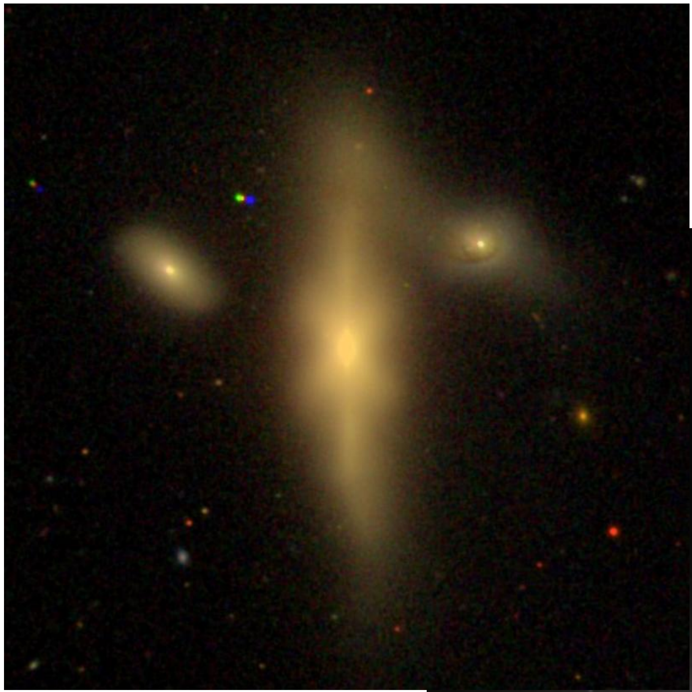
and the
BAaDE collaboration at UCLA, UC Boulder, Leiden & JIVE

Scientific Motivation

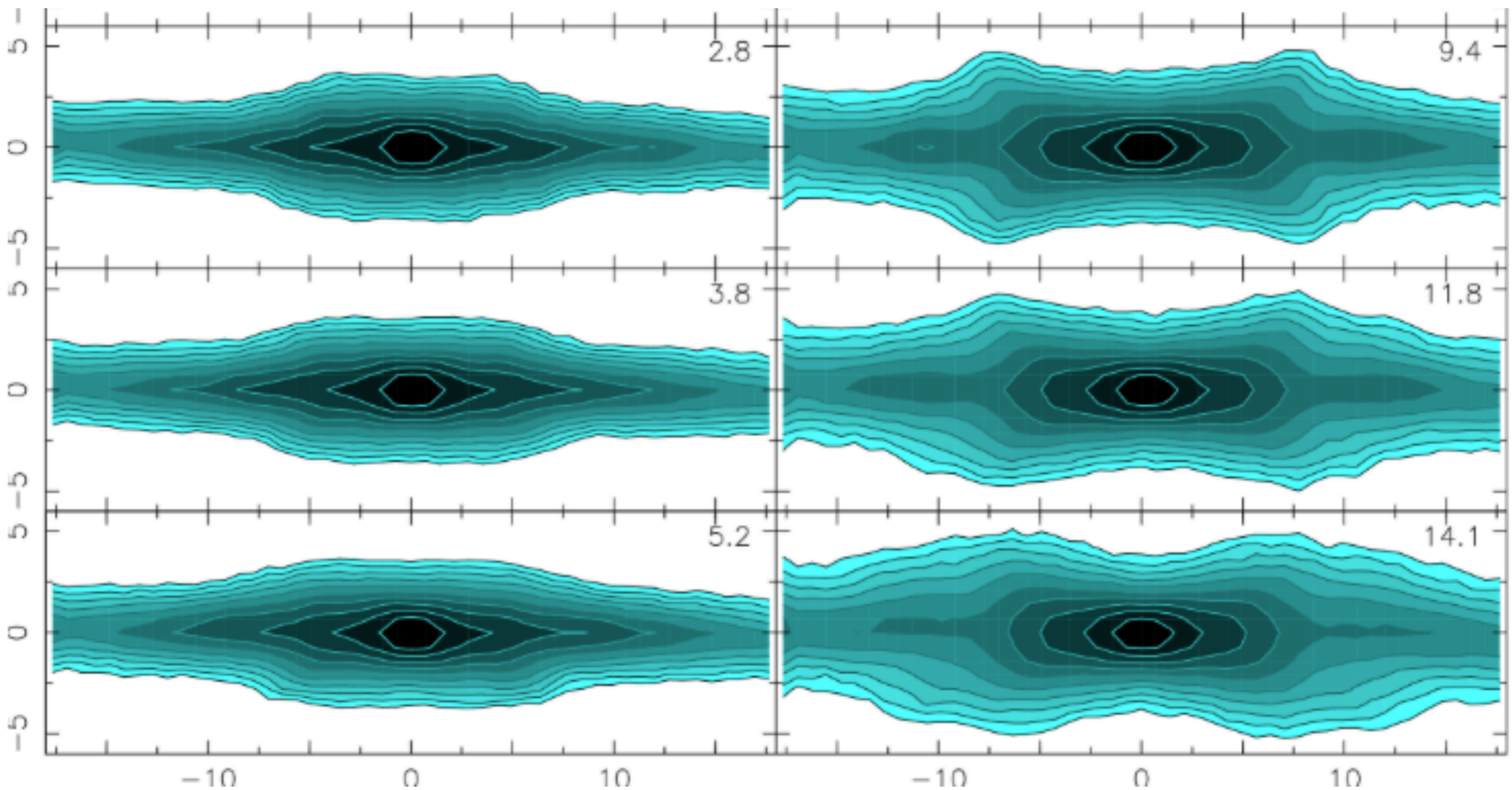
Studying the Milky Way in detail to understand galaxy formation.

- Details about structure, age, chemical composition kinematics



What are the details of the orbits in the bulge/bar?

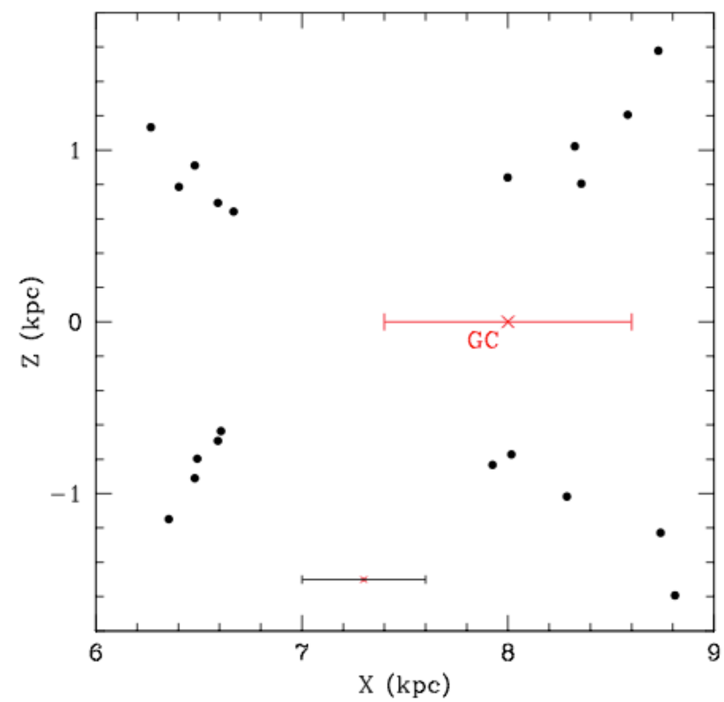
- Central parts of the MW dominated by a bar
  - Supported by cylindrical rotation, signature of tri-axial or boxy bulges (Howard et al. 2008, Rich et al. 2007)



Martinez-Valpuesta et al. (2006)

Additional Features & Complications

- X-shaped structure found thought to be dominated by the metal rich bar (from modeling, e.g., McWilliam & Zoccali, 2010)
- HV population in the Northern bulge (Nidever et al. 2012)
- Fermi data interpreted as dark matter concentration offset from the Galactic center (Su & Finkbeiner 2012)



=> *Significantly more details about orbits, and orbit families, in these regions is desirable.*

The BAaDE project

Aim: To significantly improve models of the dynamics and structure of the Galactic bulge and the inner Galaxy.

- Using radio detected point-masses probing into regions not reachable with optical surveys ($-6<b^{\circ}<6$).

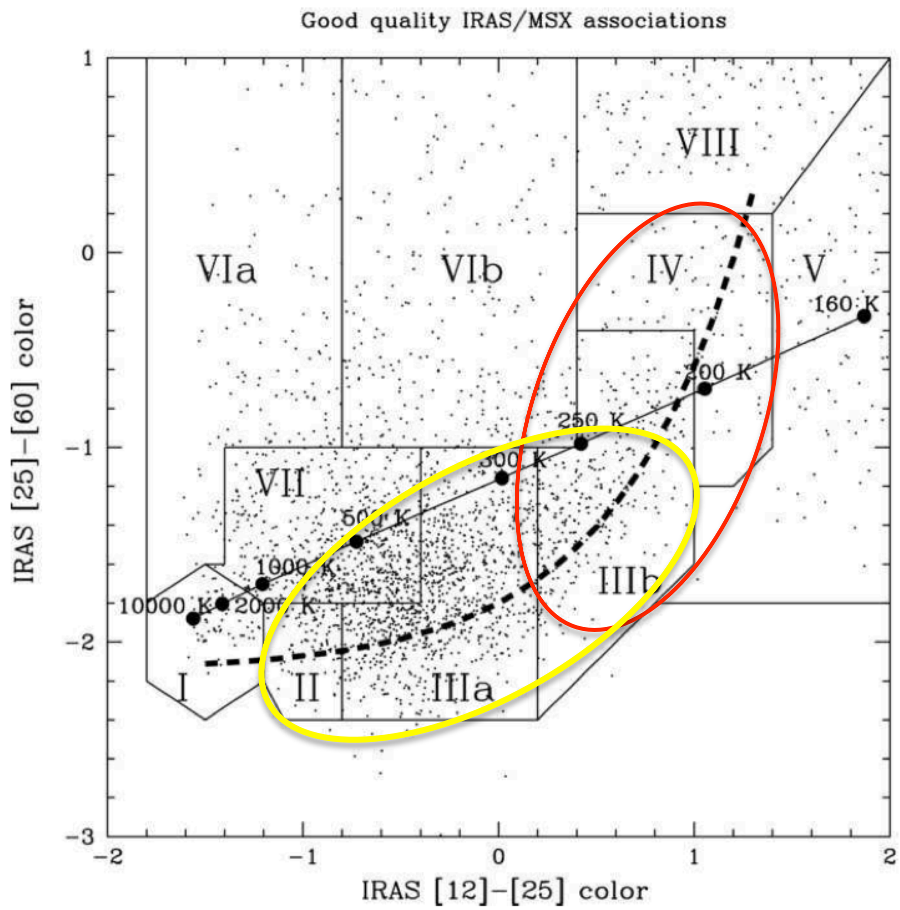
- Surveying up to ~34,000 stars for SiO maser emission using both VLA and ALMA.
  - Direct line-of-sight velocity distributions obtained

- Using VLBA for detailed orbit characteristics in a subsample of the sources.

OH and SiO maser stars

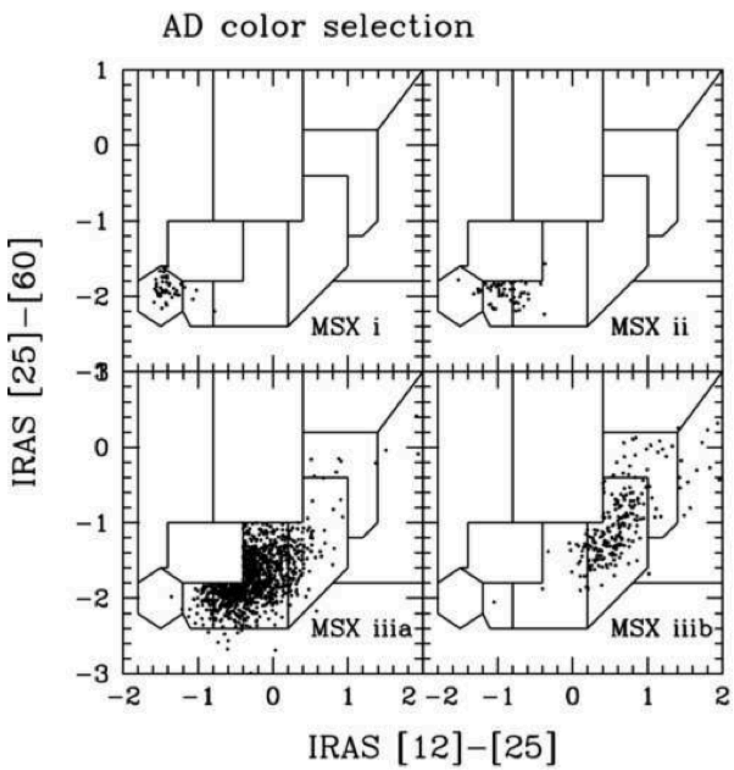
- Masers in OH/IR stars have previously been used for kinematical studies of the Milky Way (e.g., Habing et al. 2006)
  - Only 3000 OH maser stars in MW

- IRAS colors predictive of finding sources with circumstellar material.



Van der Veen & Habing 1988
Habing 1996

Target selection from MSX



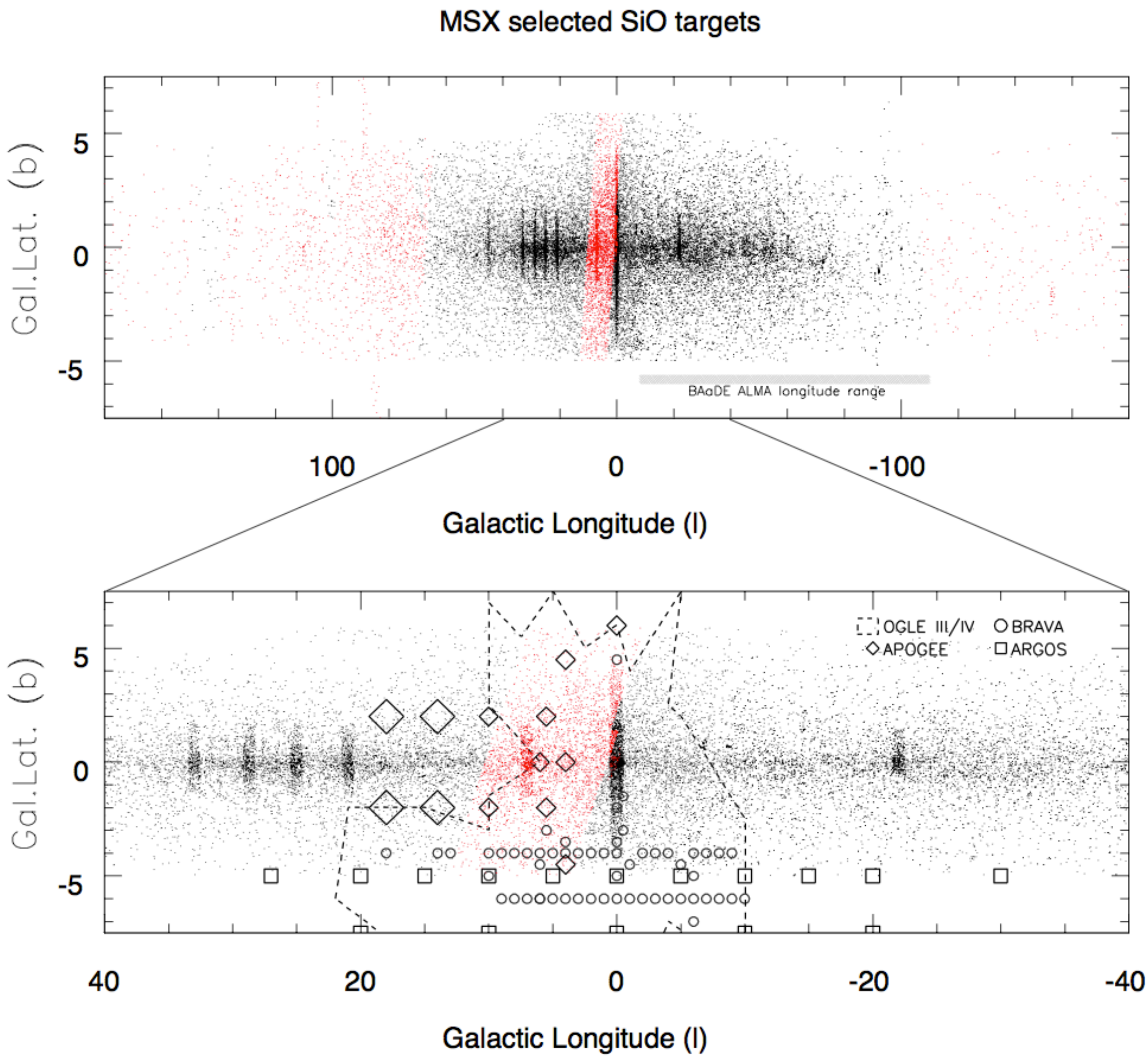
- Stellar sources within certain MSX color regions can be expressed similar to IRAS color regions
- In these regions the detection rate of SiO masers is between 50-90%.

Sjouwerman et al. 2009,
Messineo et al. 2002.

MSX PSC 2.3 (0<*l*°<360, -6<*b*°<6)

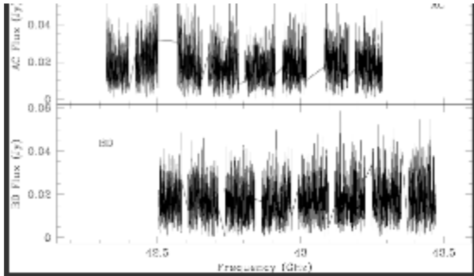
⇒ ~19,000 out of 440 000 sources for MSX color regions ii, iiia and iiib

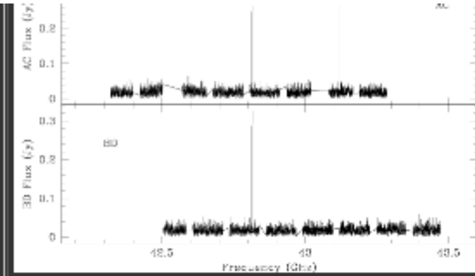
⇒ Another ~14,000 with ALMA

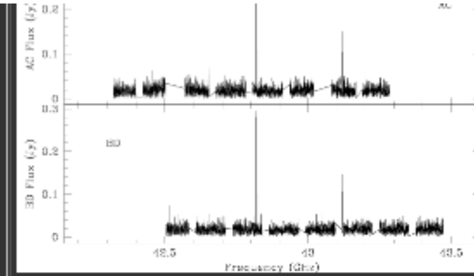

MSX selected SiO targets
Gal.Lat. (b)
5
0
-5
BAaDE ALMA longitude range
100
0
-100
Galactic Longitude (l)
OGLE III/IV
BRAVA
APOGEE
ARGOS
Gal.Lat. (b)
5
0
-5
40
20
0
-20
-40
Galactic Longitude (l)

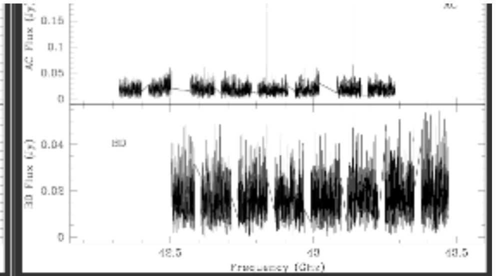
Status and initial results

- Observed about 3,600 stars (7,500 allocated so far) with the VLA
- Line of sight velocities derived for a subset of these (1,200)
- Appears to be a different population than the CO disk, with larger velocity dispersions.
- To be compared to models
  - Results in various mean velocity and velocity dispersion distributions
- All data placed on project web page.
  - http://www.phys.unm.edu/~ylva/baade









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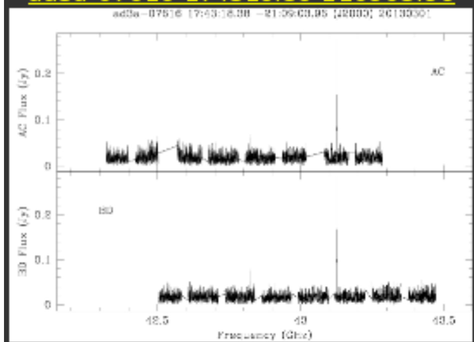

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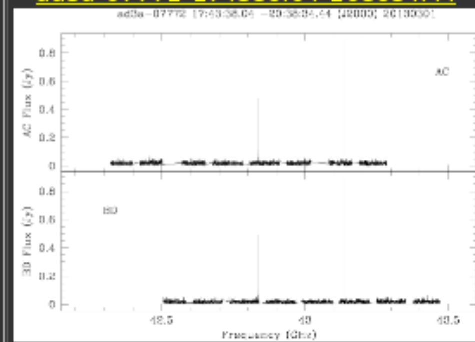

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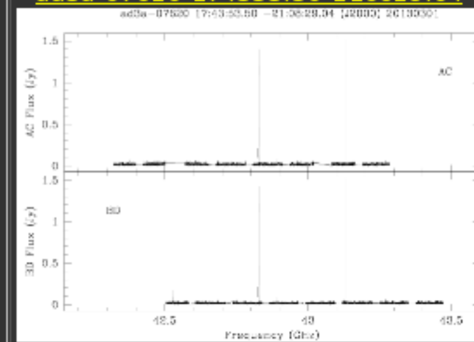

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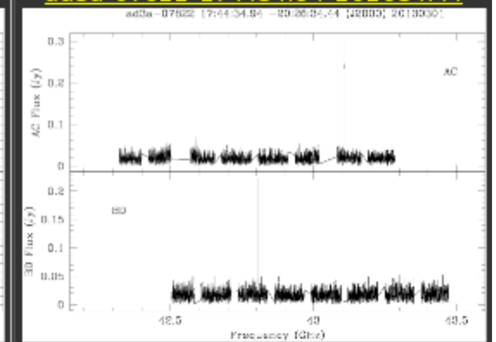

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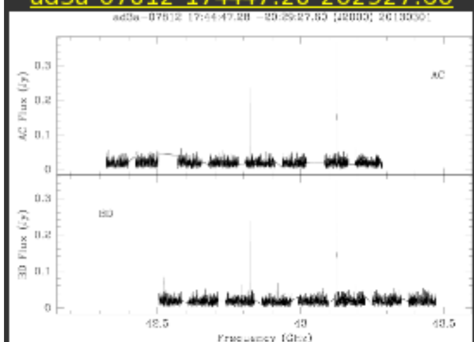

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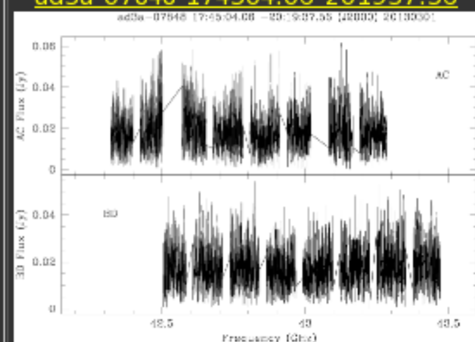

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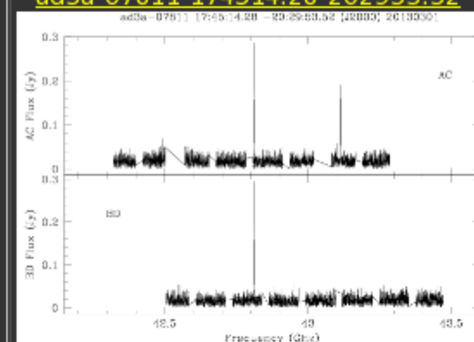

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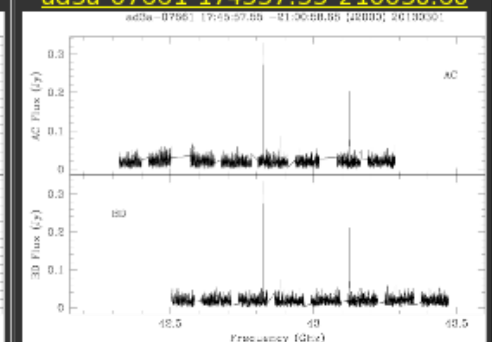

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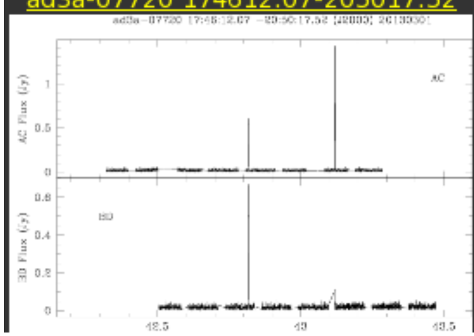

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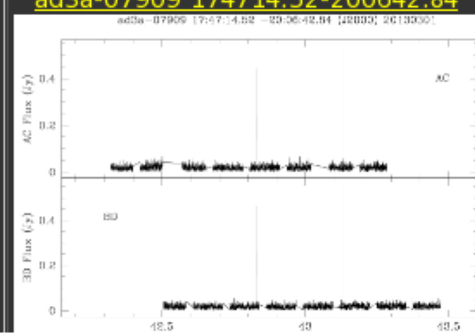

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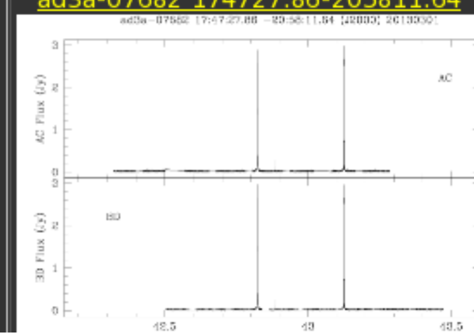

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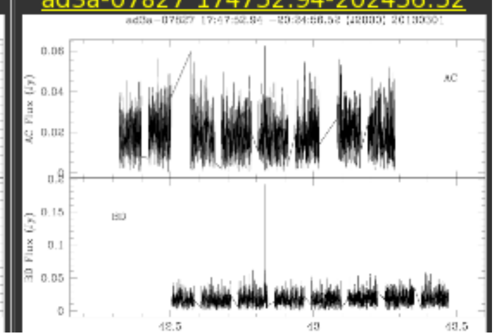

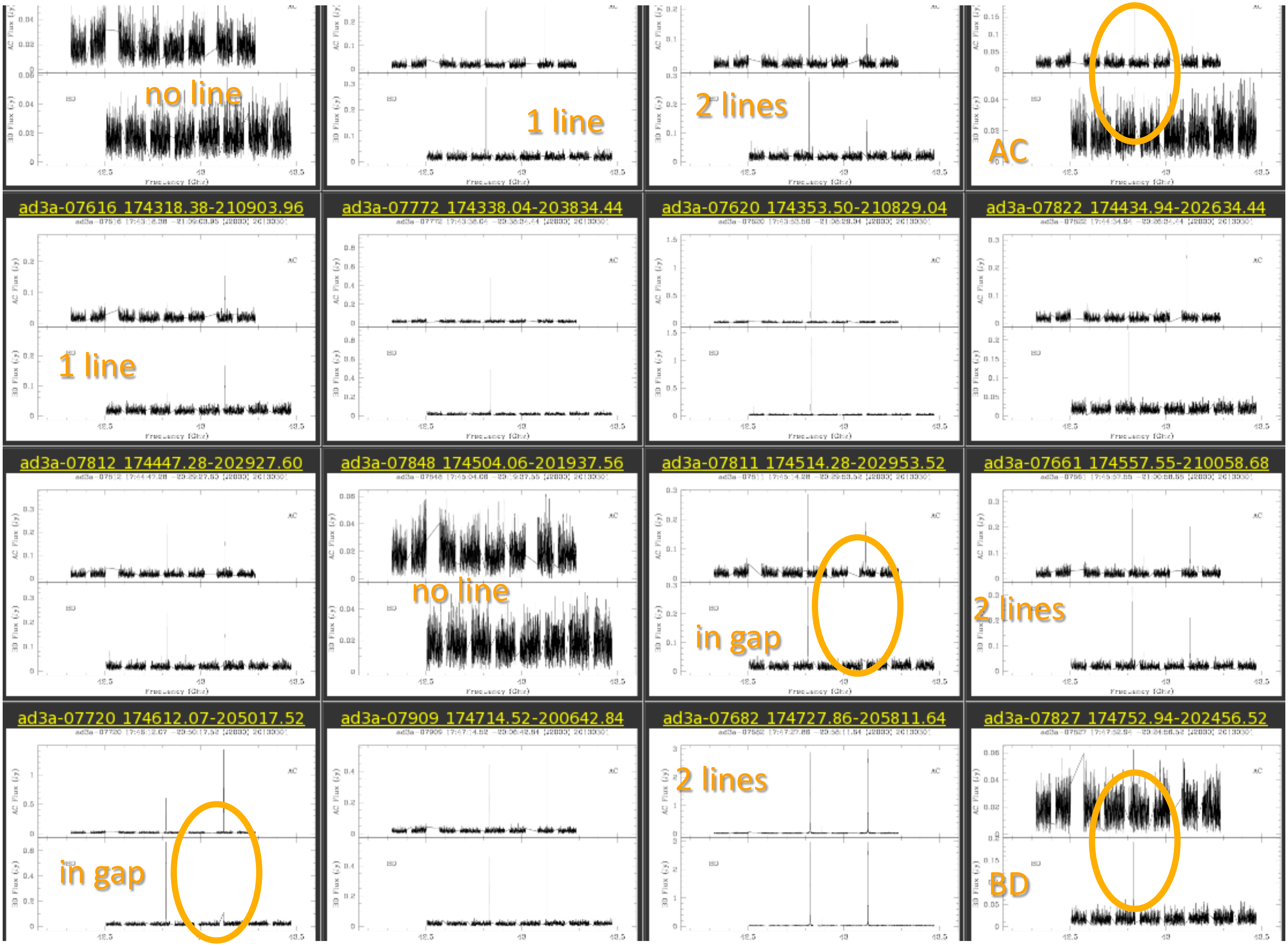
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1 line
2 lines
AC
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1 line
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no line
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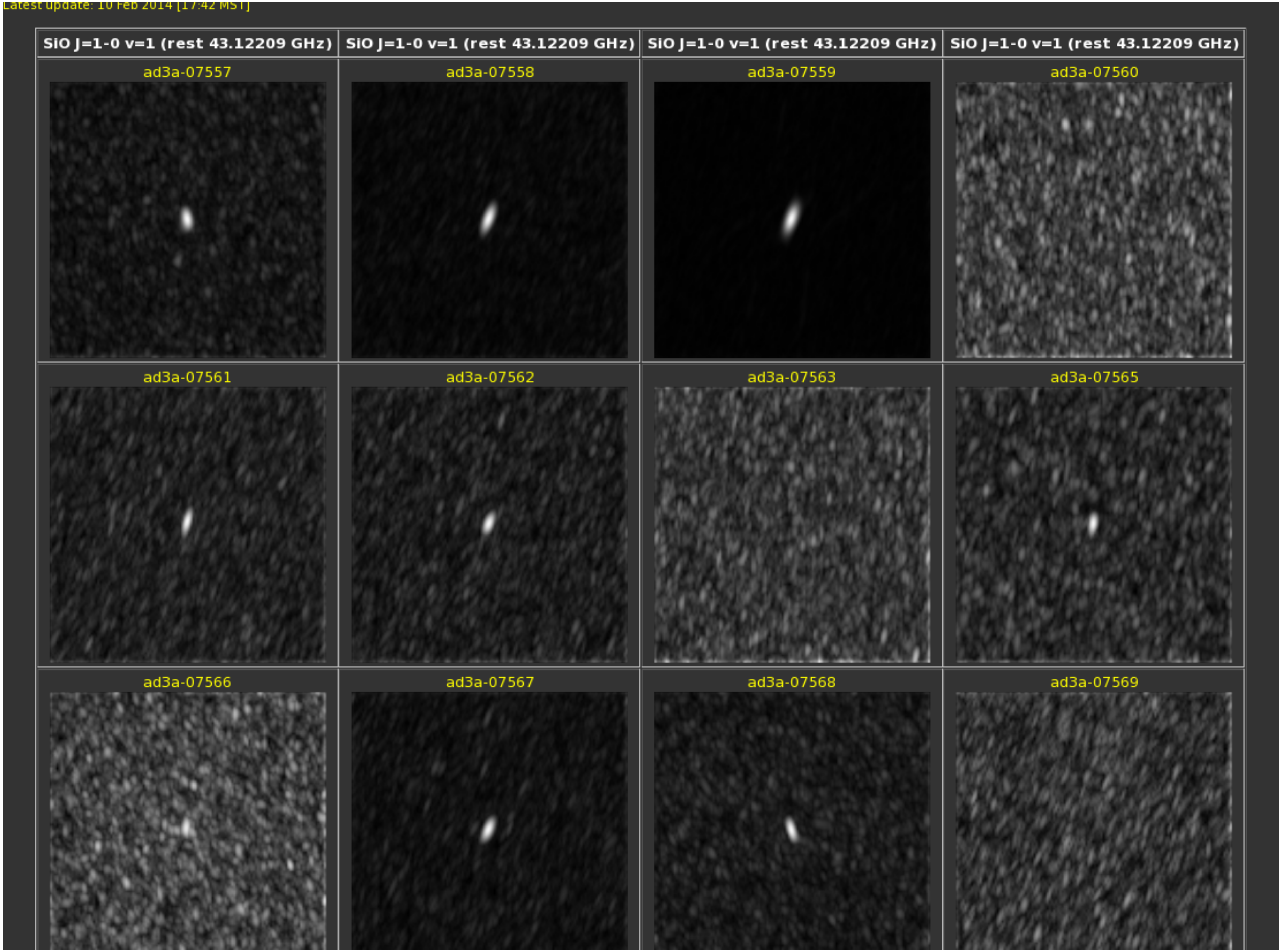
in gap
2 lines
BD



Latest update: 10 Feb 2014 [17:42 MST]
SiO J=1-0 v=1 (rest 43.12209 GHz)
SiO J=1-0 v=1 (rest 43.12209 GHz)
SiO J=1-0 v=1 (rest 43.12209 GHz)
SiO J=1-0 v=1 (rest 43.12209 GHz)
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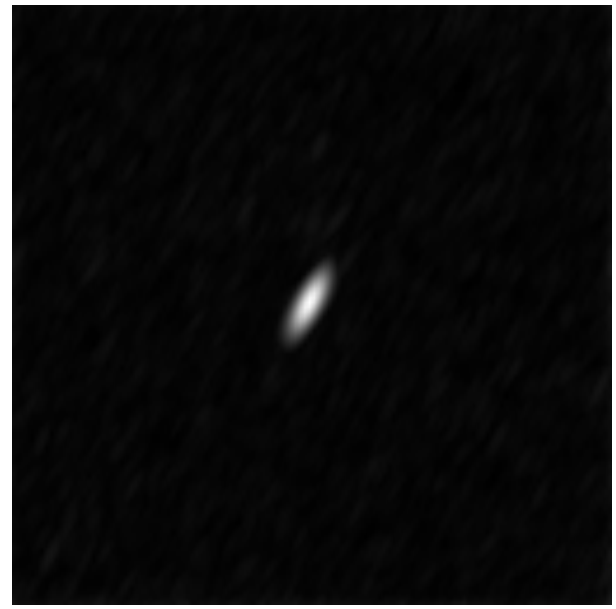
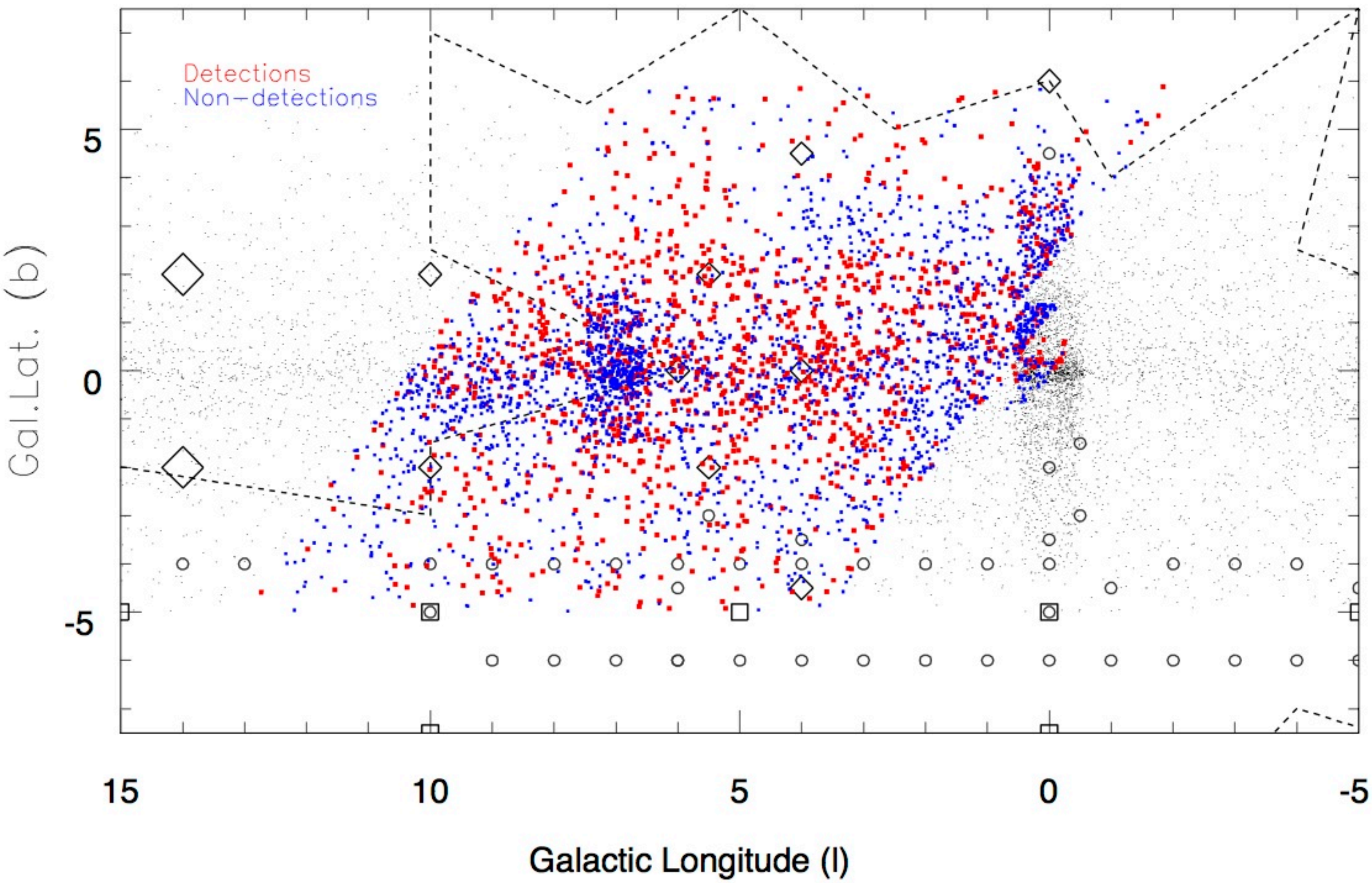
ad3a-07569

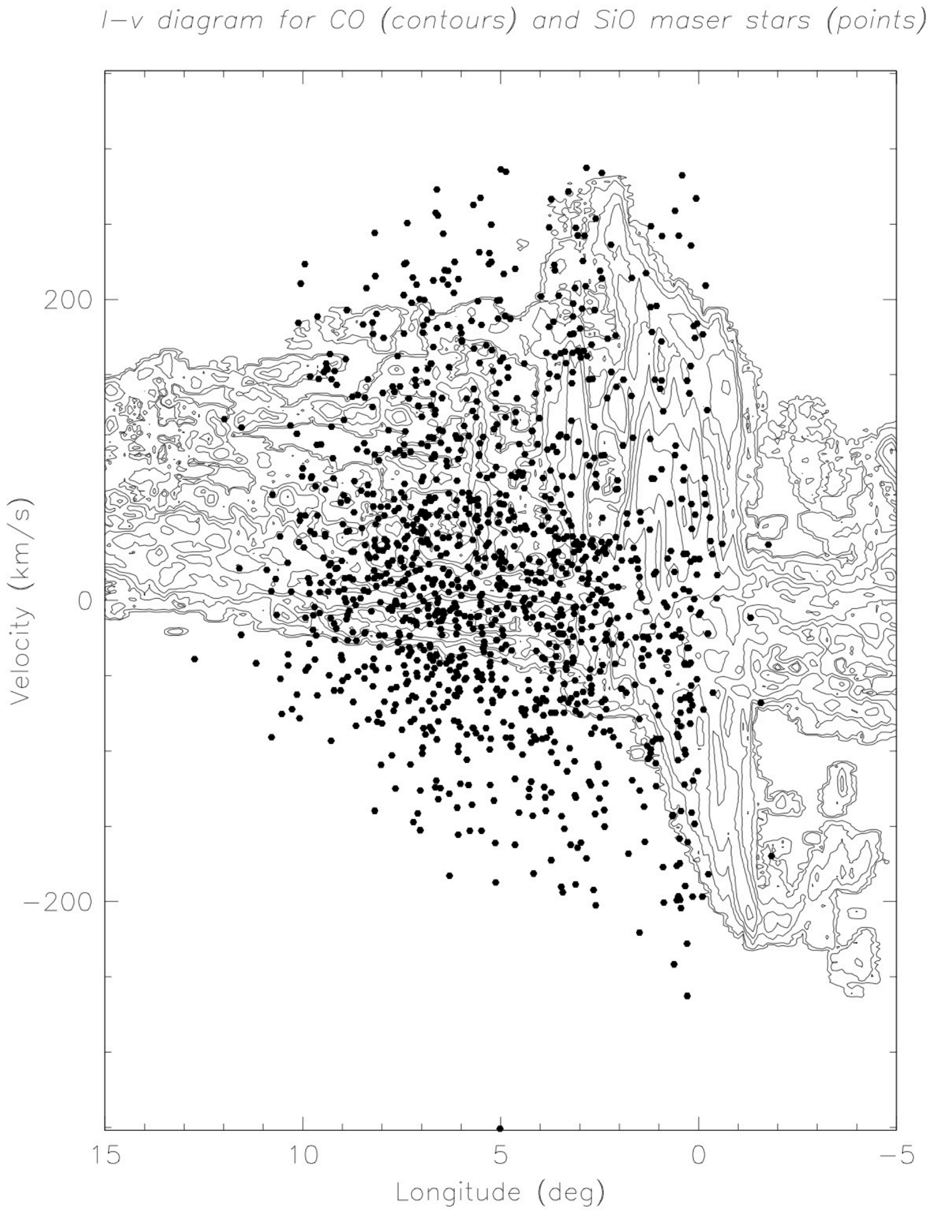
Example single observing run

- Movie using maxmaps of *J*=1-0 (*v*=1) line
- Every image a separate source
- First order detections
  - Improved by using (*v*=2) or other line
  - Image self-calibration
  - Baseband phase transfer
  - Line masking
- Detection rate >70%



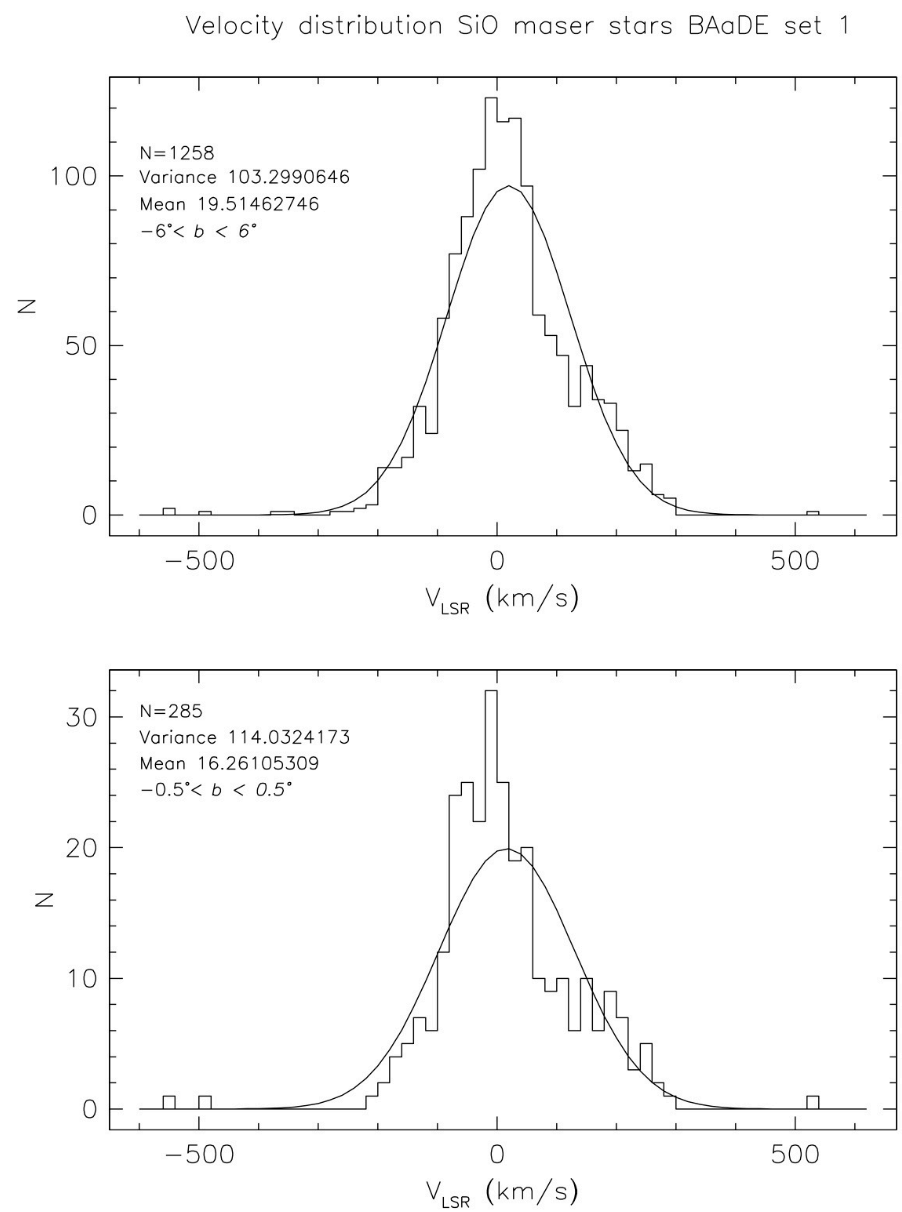
Preliminary detection distribution



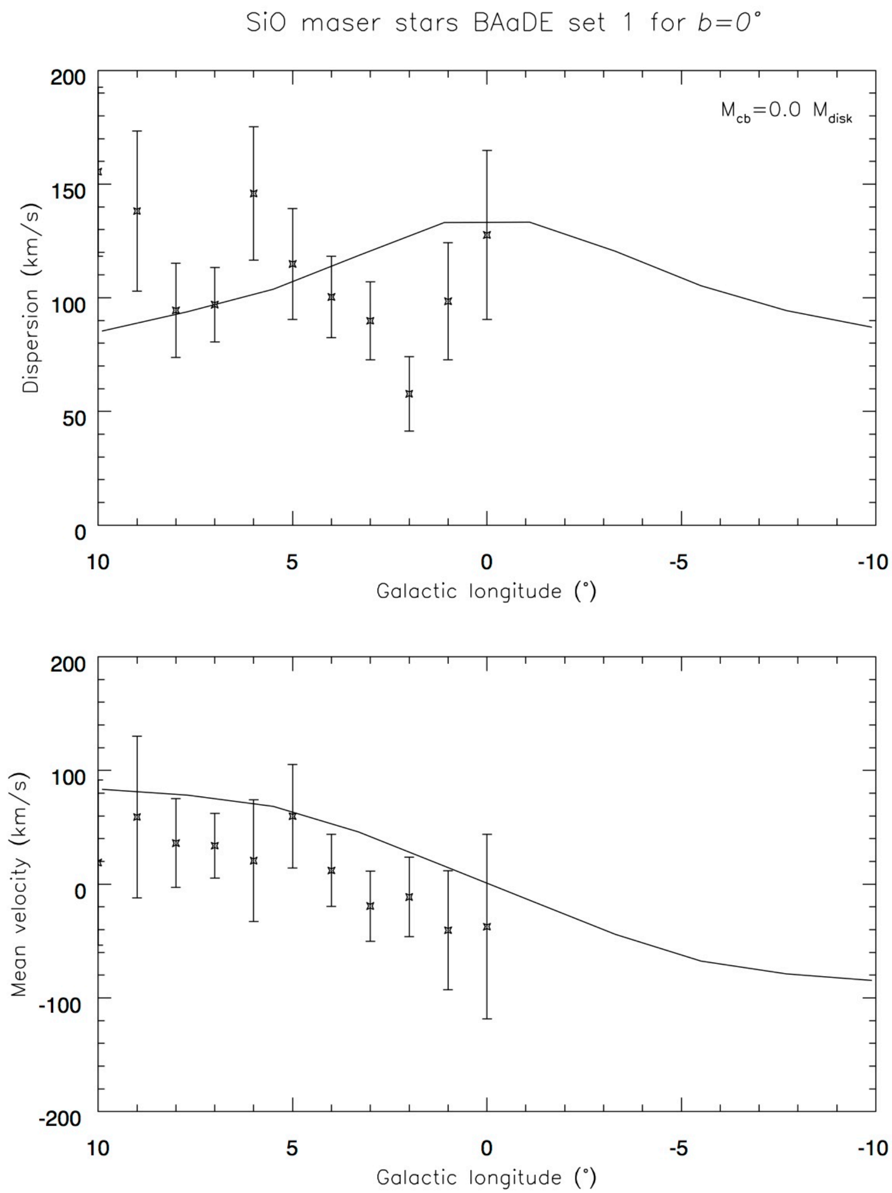


Dame et al. (2001)

- CO distribution along b=0°, and the BAaDE first set of detections.
- Different populations.
- Non circular motions.



Overall velocity distribution



Example of model comparison

Shen et al. (2010) + preliminary BAaDE data.

- Pseudo-bulge and/or classical bulge?

- Little contribution needed from a classical bulge.

(Near)-future steps

1. Look for:
   - Instabilities and asymmetries
   - High-velocity stars, are they an entire population influenced by the bar?

2. Select sources and follow up with VLBA
   - Determine 3D motions, orbits/orbit families

3. Combine with IR data
   - Detections statistics as a function of IR color
   - Can we pre-select O-rich stars?
   - Determine stellar properties, distance

4. Current observations targeting outer parts of the galaxy.

BAaDE collaboration

BAaDE main team members:

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Mark Morris, UCLA
Mike Rich, UCLA
Huib-Jan van Langevelde, JIVE
Harm Habing, Leiden
Nikta Amiri, UC Boulder
Isaiah Santistevan, UNM

Webpage: http://www.phys.unm.edu/~ylva/baade/