

The Latest in Radio Astronomy Surveys of Star Formation Towards the Center of our Galaxy

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(Northwestern University)

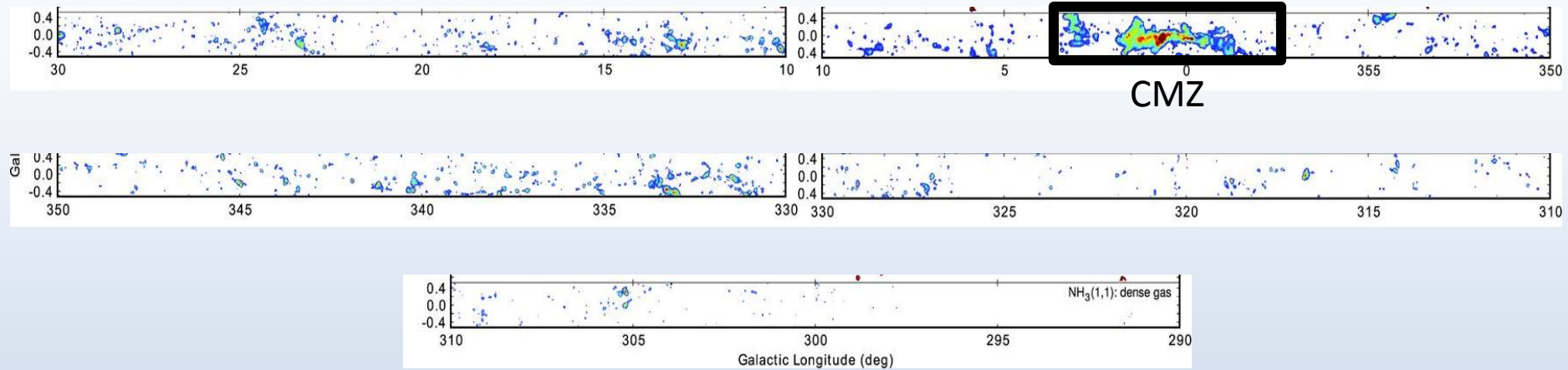
F. Yusef-Zadeh
(Northwestern
University)

J. Ott (National Radio
Astronomy Observatory)

Search for Water and
Ammonia towards the
Galactic Center (SWAG)

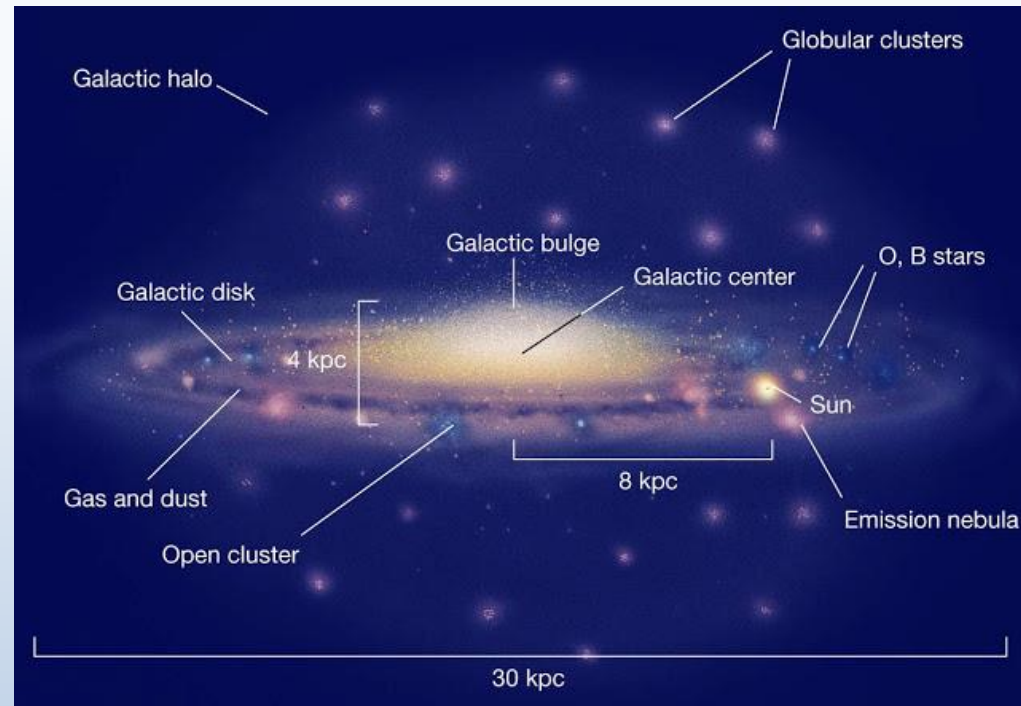


The Galactic Center: Central Molecular Zone (CMZ)

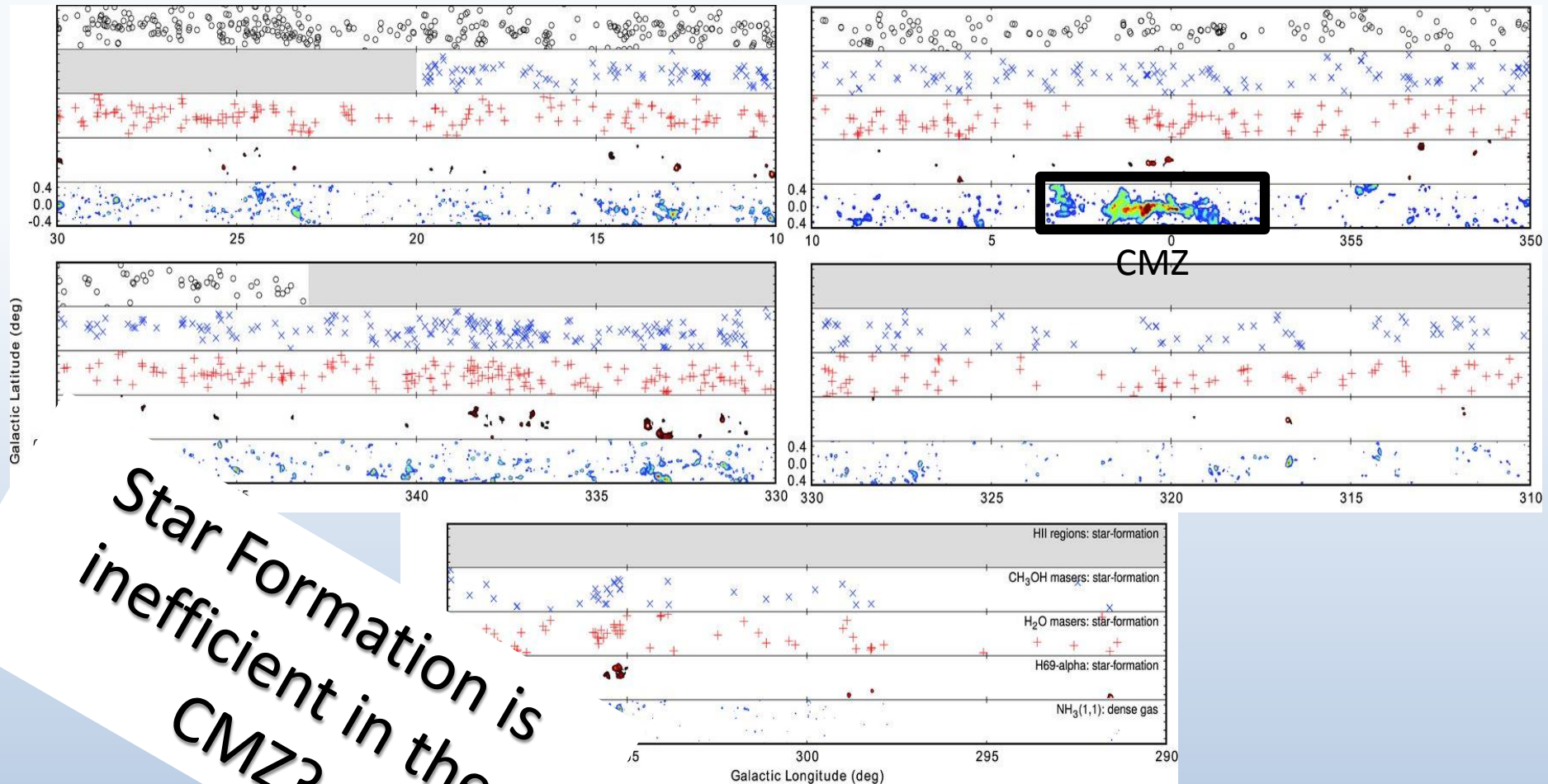


The Galactic Center: Central Molecular Zone (CMZ)

- Inner ~ 400 pc
- Molecular Gas
 - 5 % ($\sim 5 \times 10^7 M_{\odot}$)
 - Dense ($\sim 10^4 \text{ cm}^{-3}$)

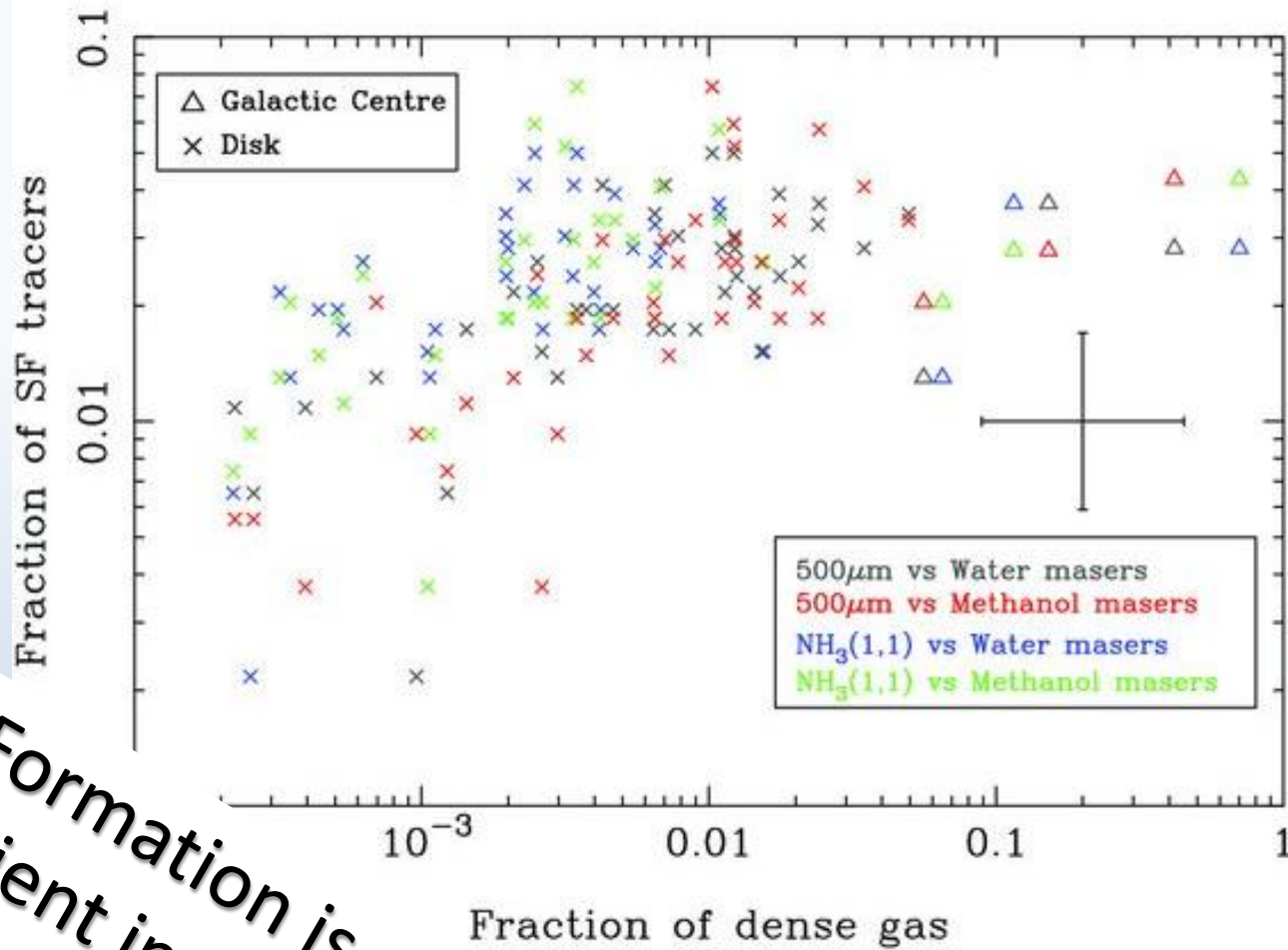


The Galactic Center: Star Formation in the CMZ



Star Formation is
inefficient in the
CMZ?

Star Formation in the CMZ



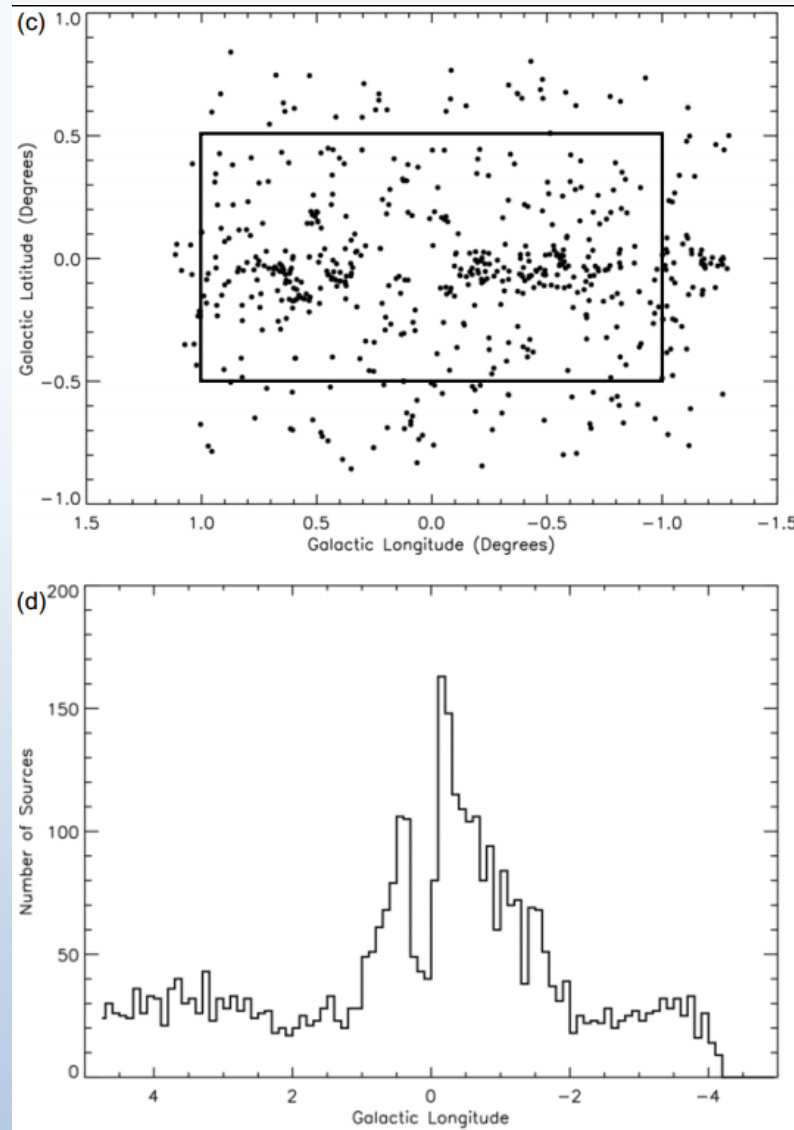
Star Formation is inefficient in the CMZ?

Question 1: Is the CMZ inefficient
at forming stars?

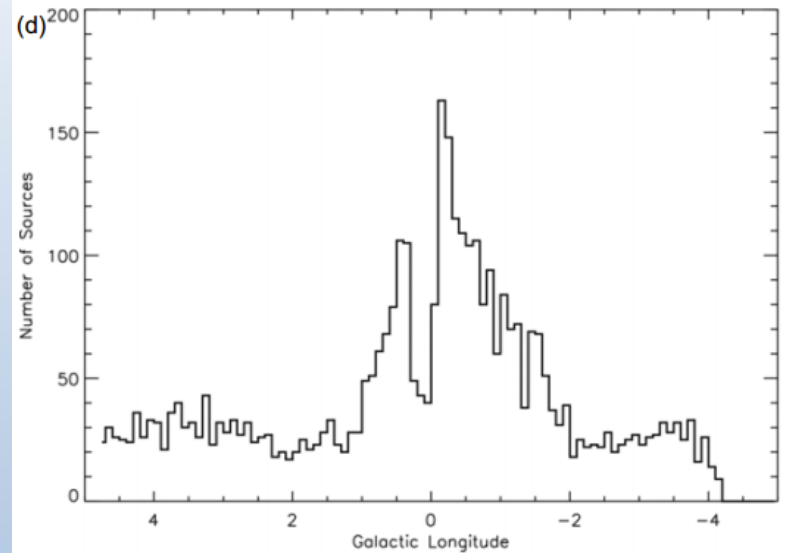
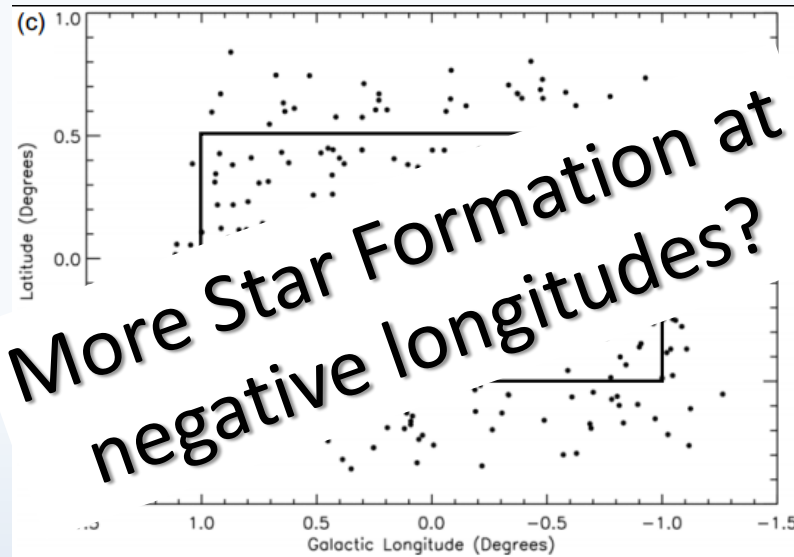
Possible Solution:

Conduct a sensitive untargeted survey that
can detect more star formation

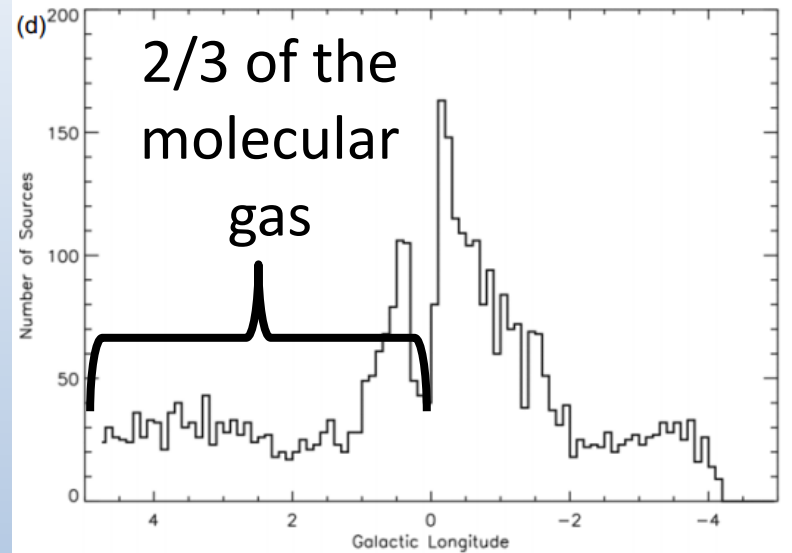
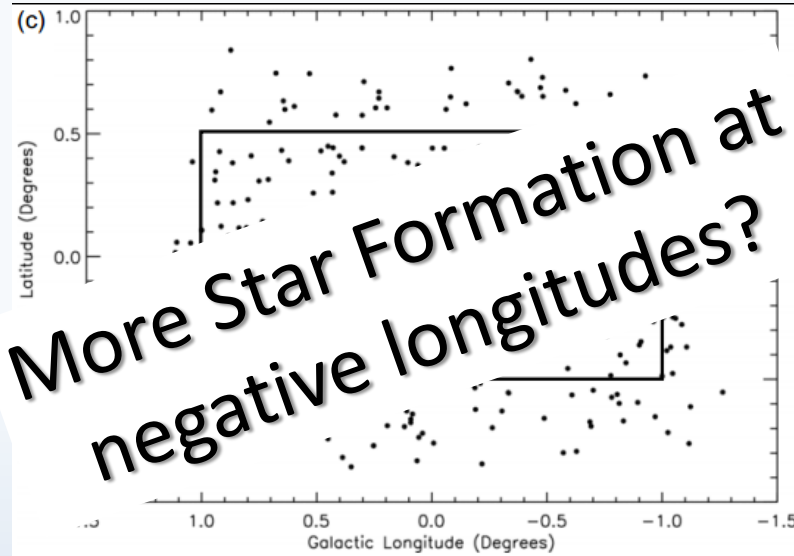
Distribution of Star Formation



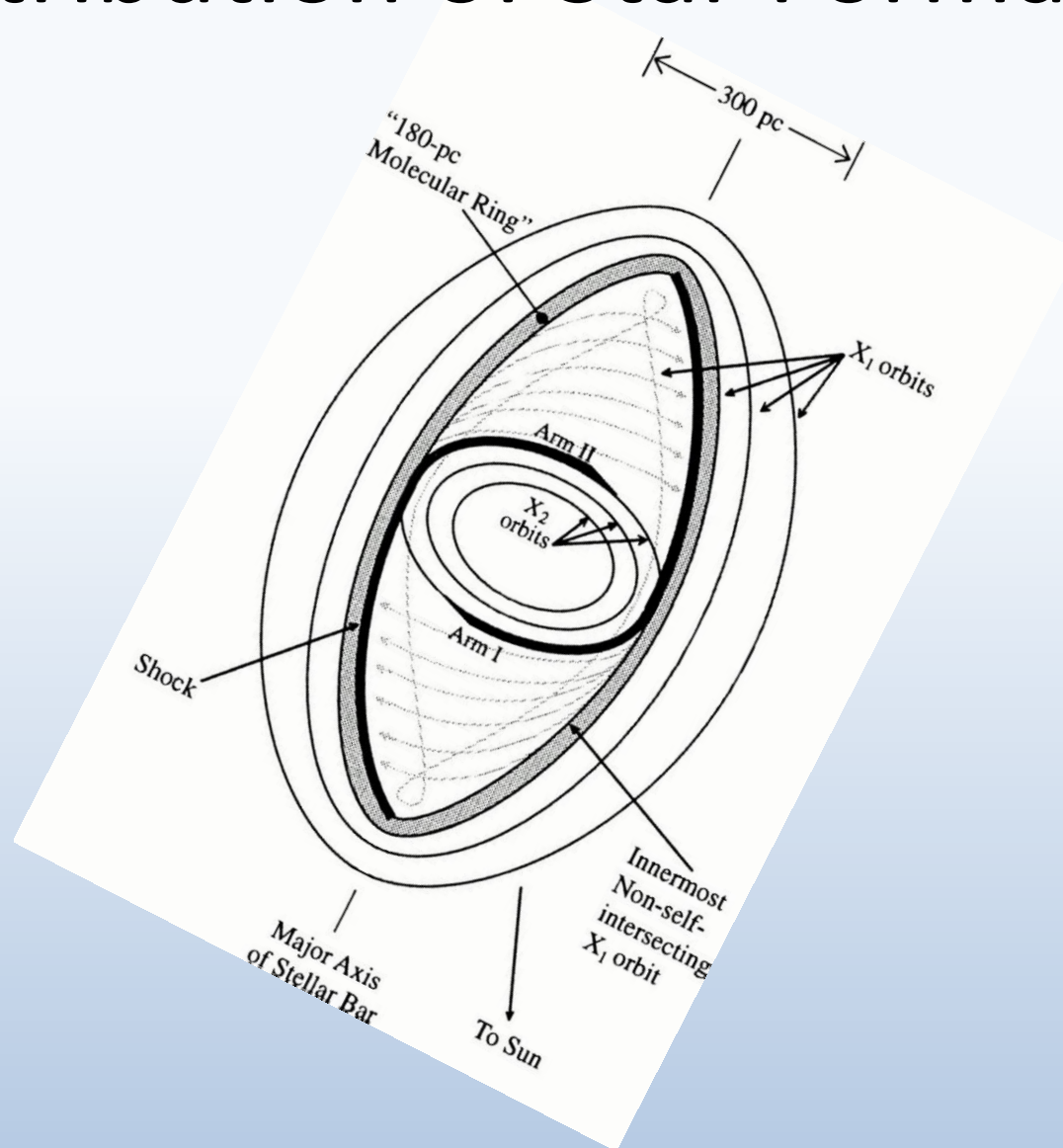
Distribution of Star Formation



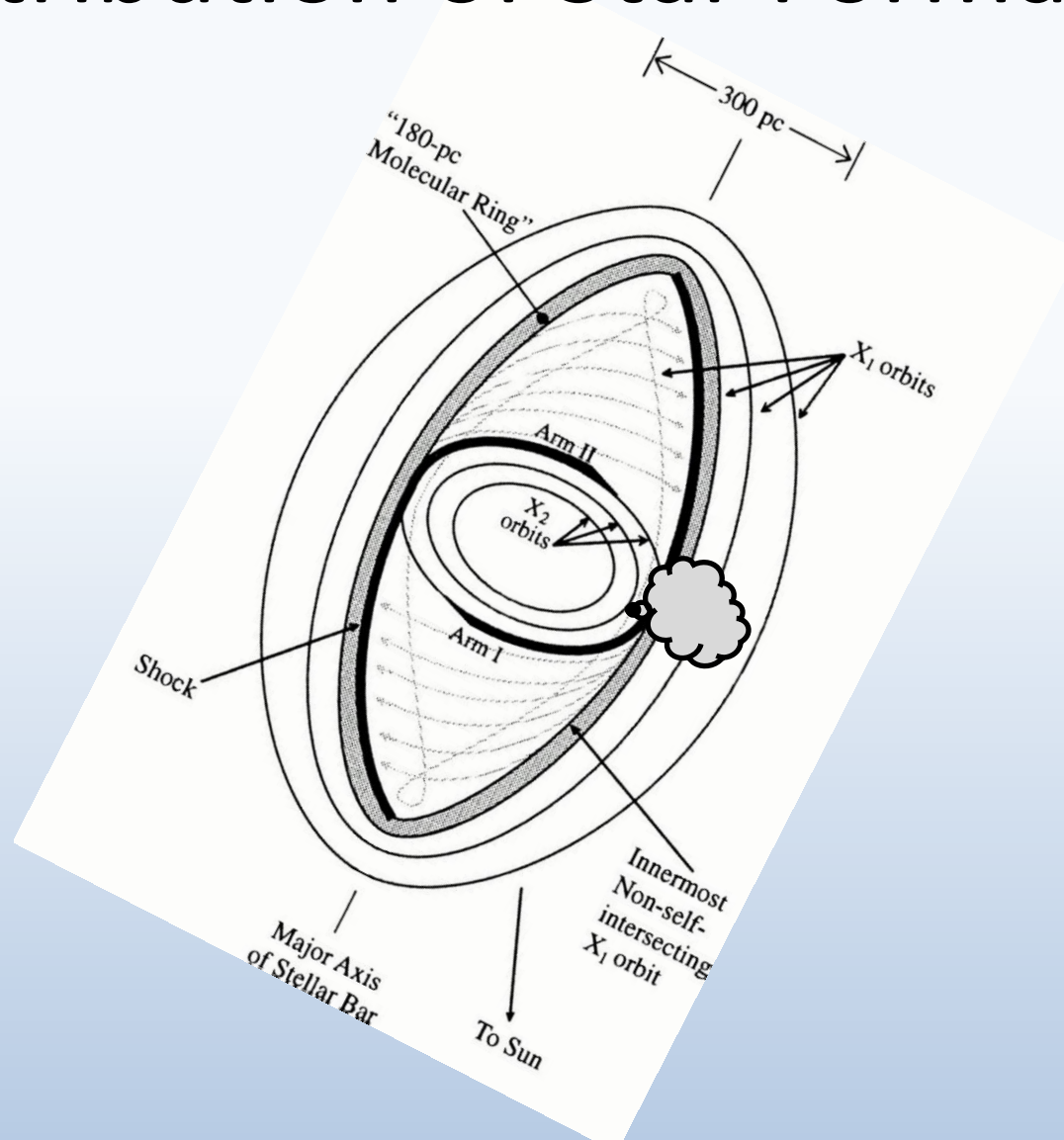
Distribution of Star Formation



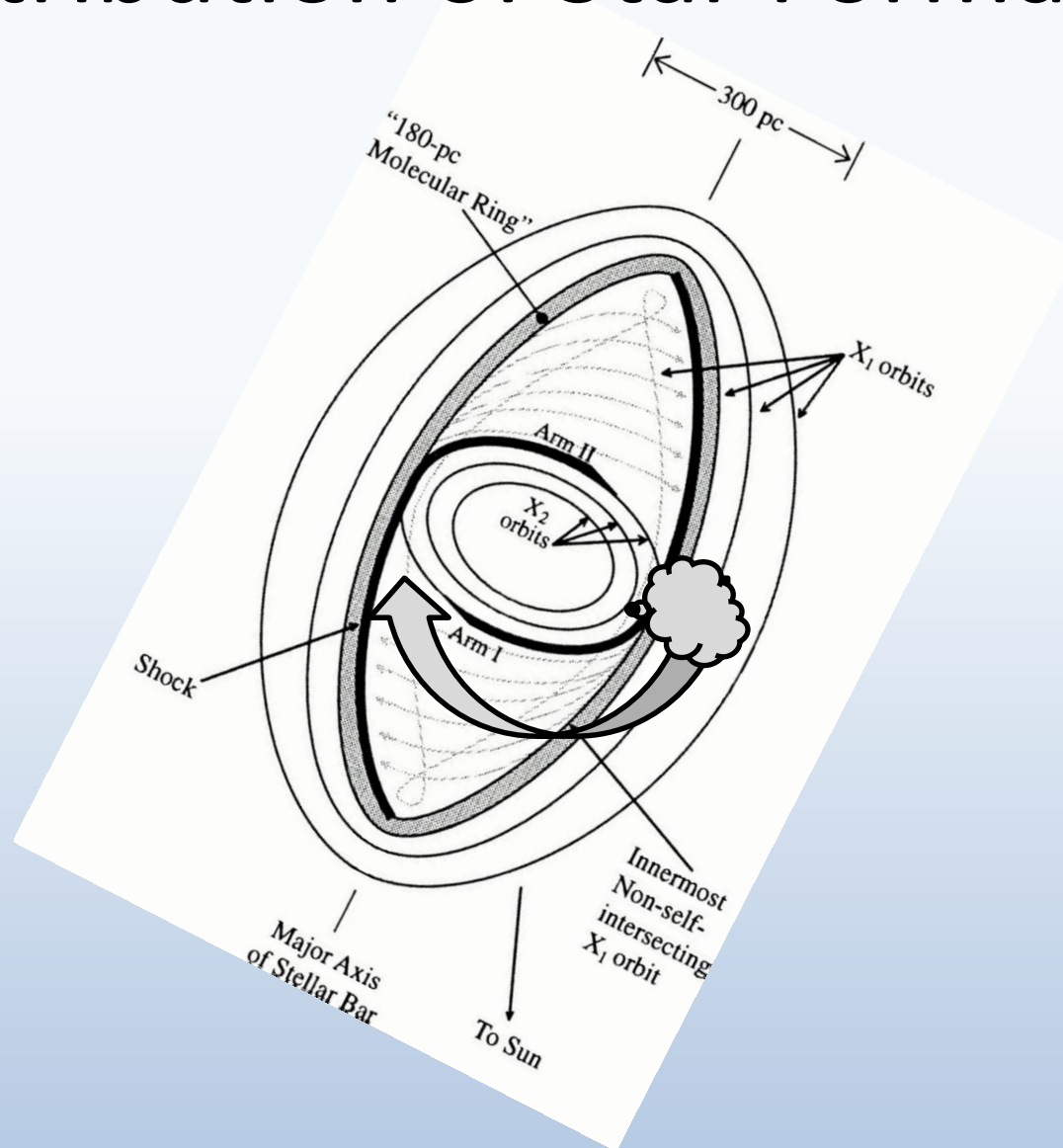
Distribution of Star Formation



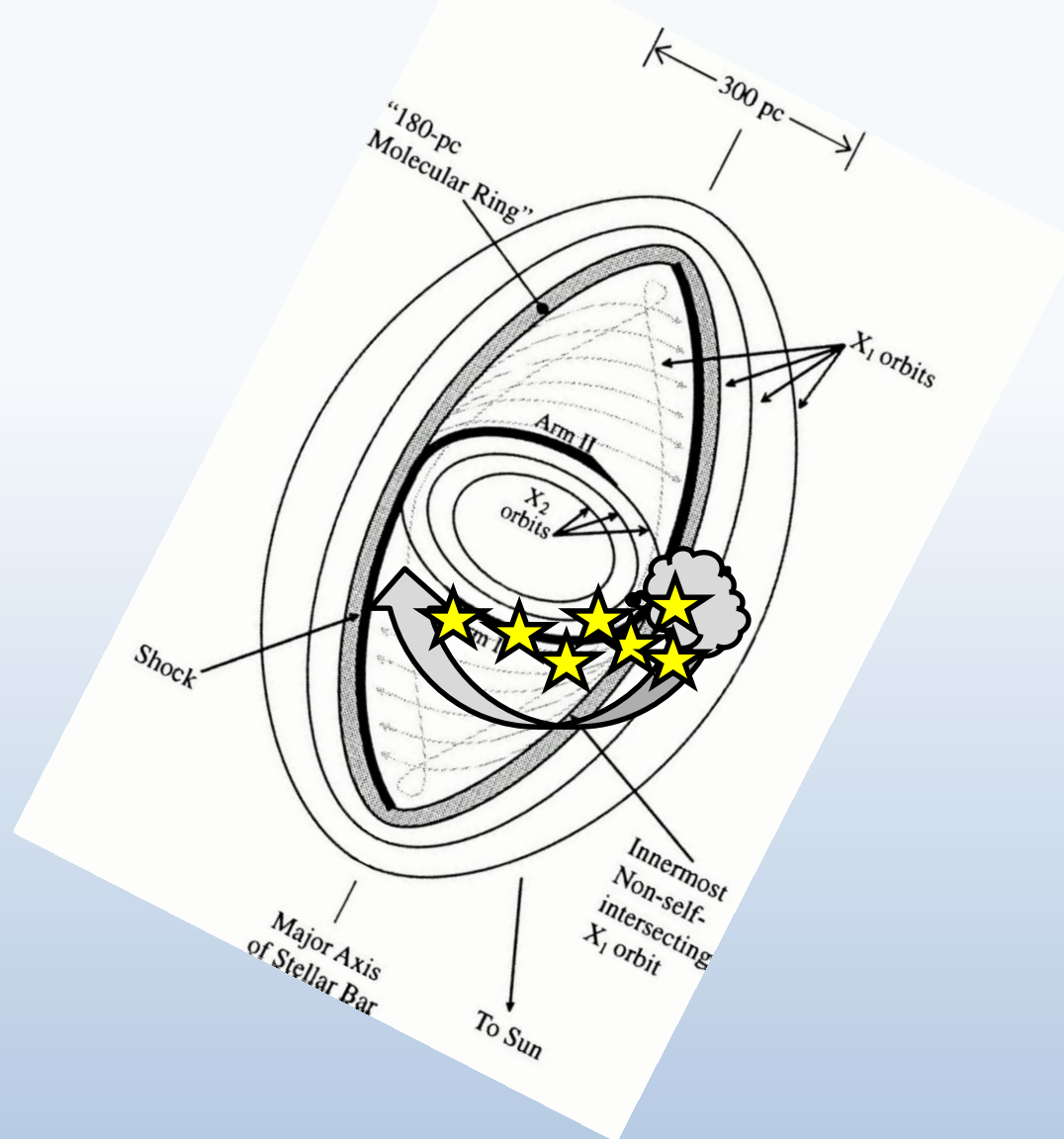
Distribution of Star Formation



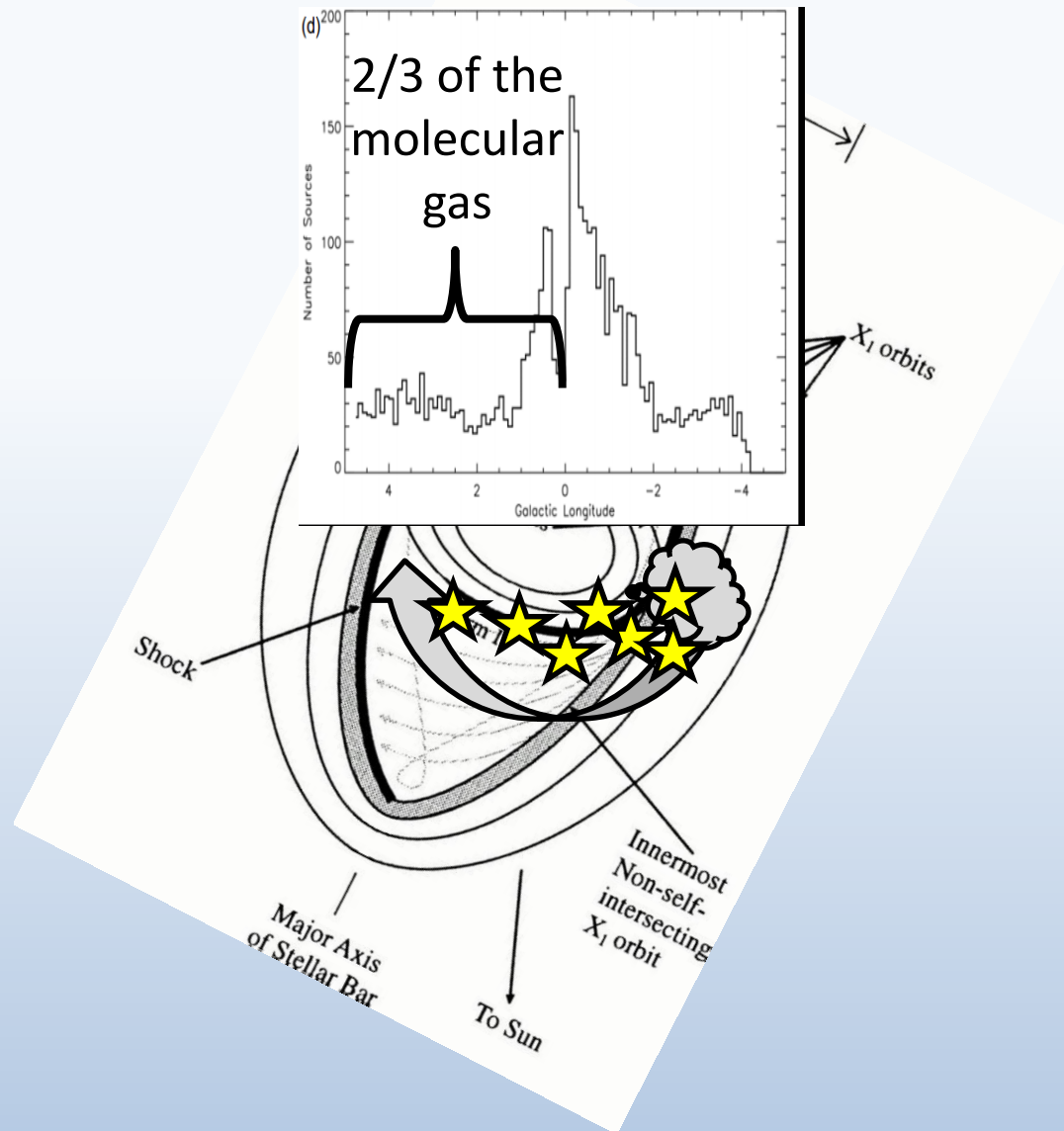
Distribution of Star Formation



Distribution of Star Formation



Distribution of Star Formation



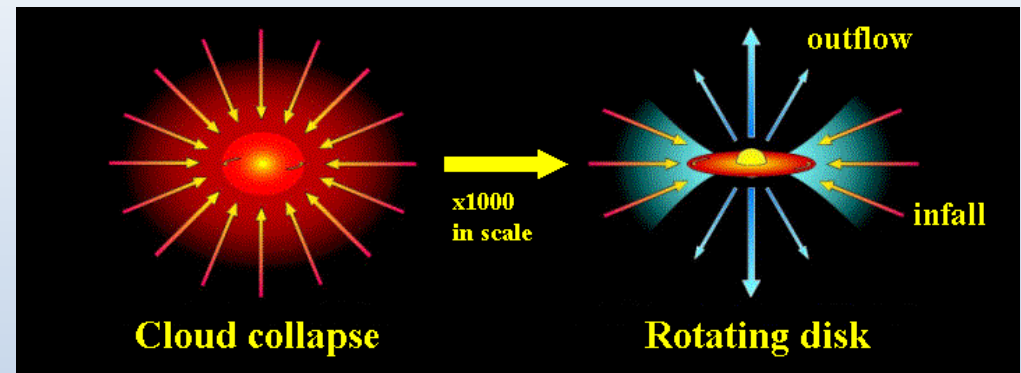
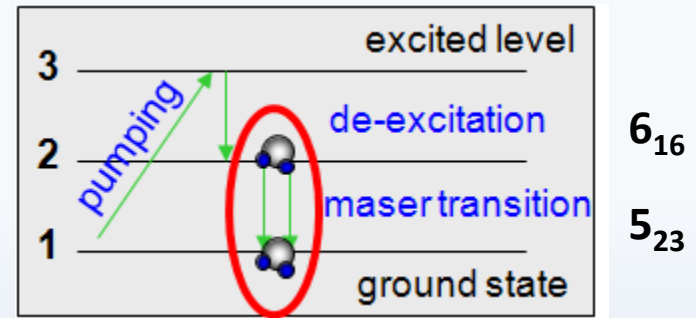
Question 2: Is the distribution of star formation asymmetric?

Possible Solution:

Use an untargeted survey that isn't susceptible to absorption

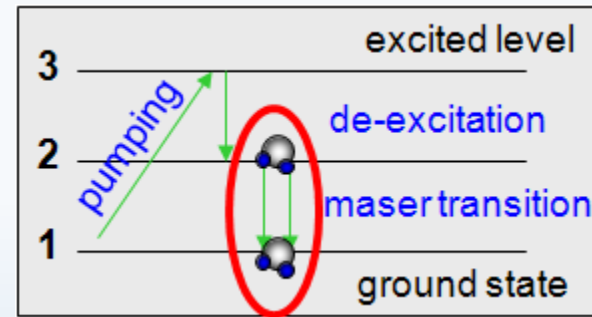
Water (22 GHz) Maser

- Collisionally Pumped
- Bright
- Don't suffer from absorption
- Not Unique to Star Formation
- Not many (37)



Methanol Masers (6.7 GHz)

- **Radiatively Pumped**
- **Biased towards high mass ($\geq 8 M_{\odot}$)**
- Don't suffer from absorption
- Bright (100s Jy)
- Not many (23)



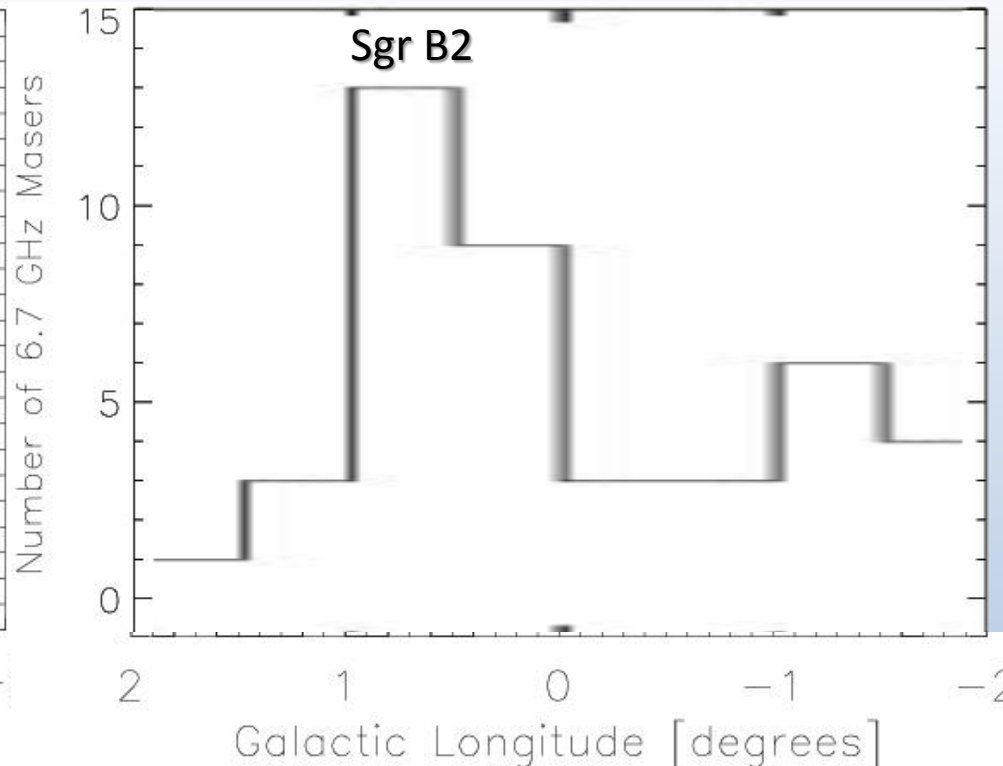
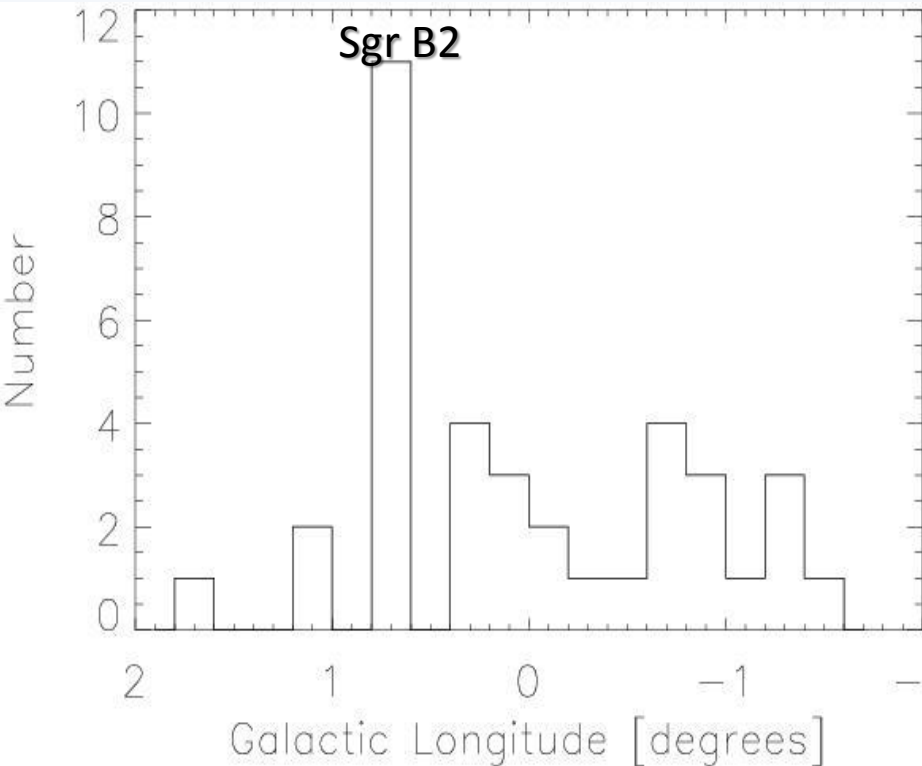
Previous Works:



Water
masers



Methanol
masers



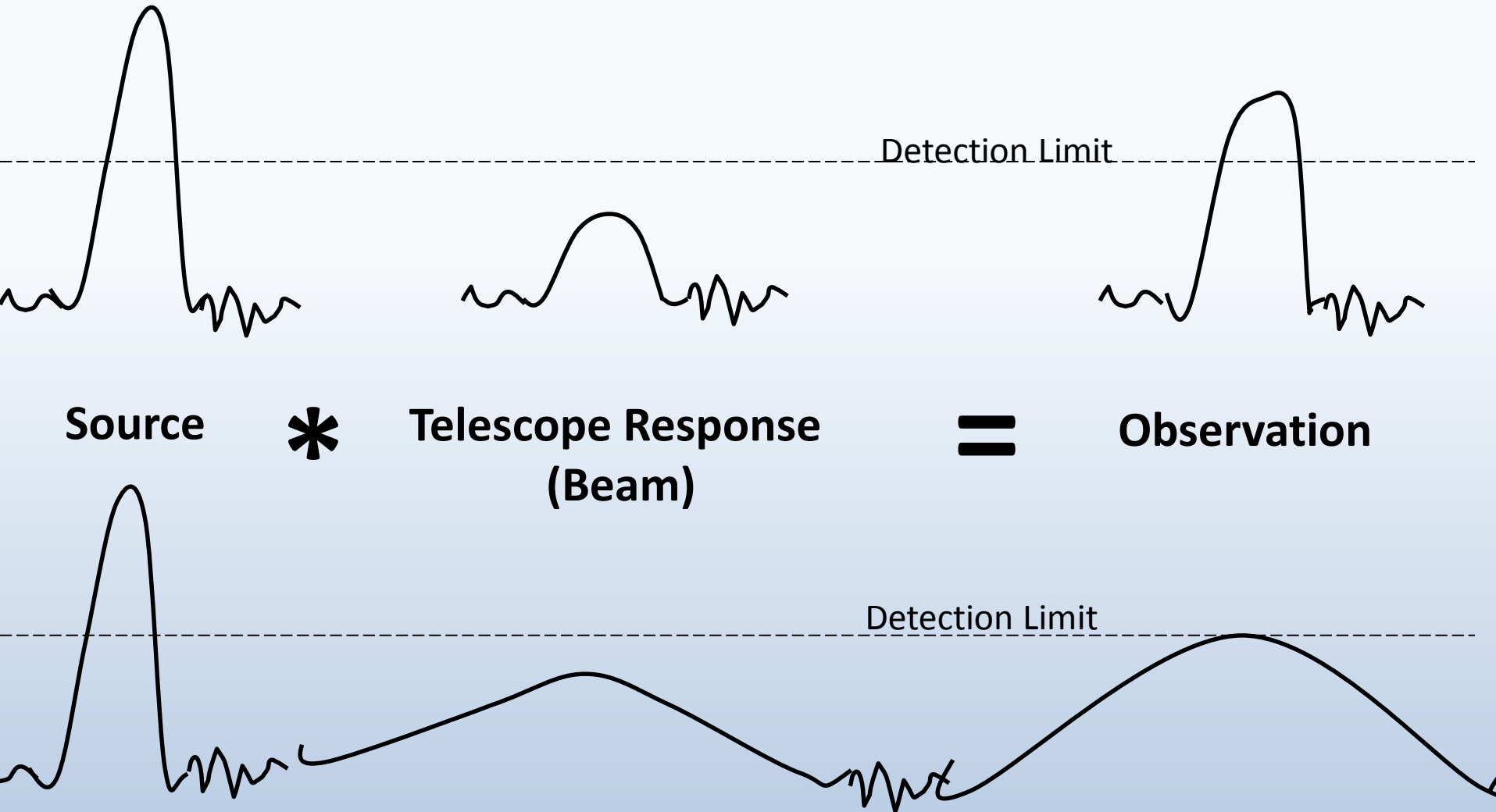
Solution:

Conduct high resolution high
sensitivity survey of water and
methanol masers

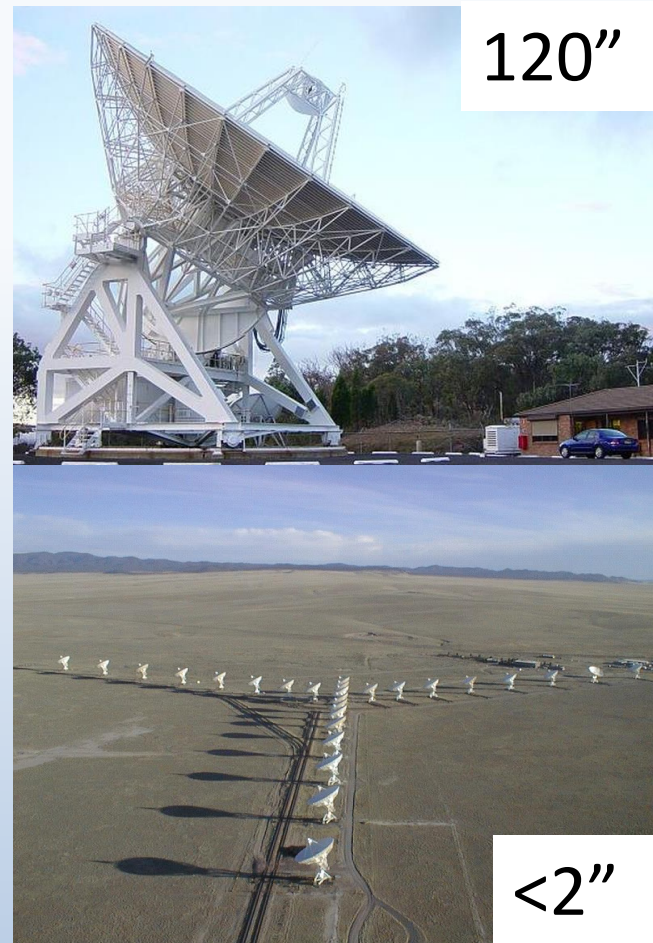
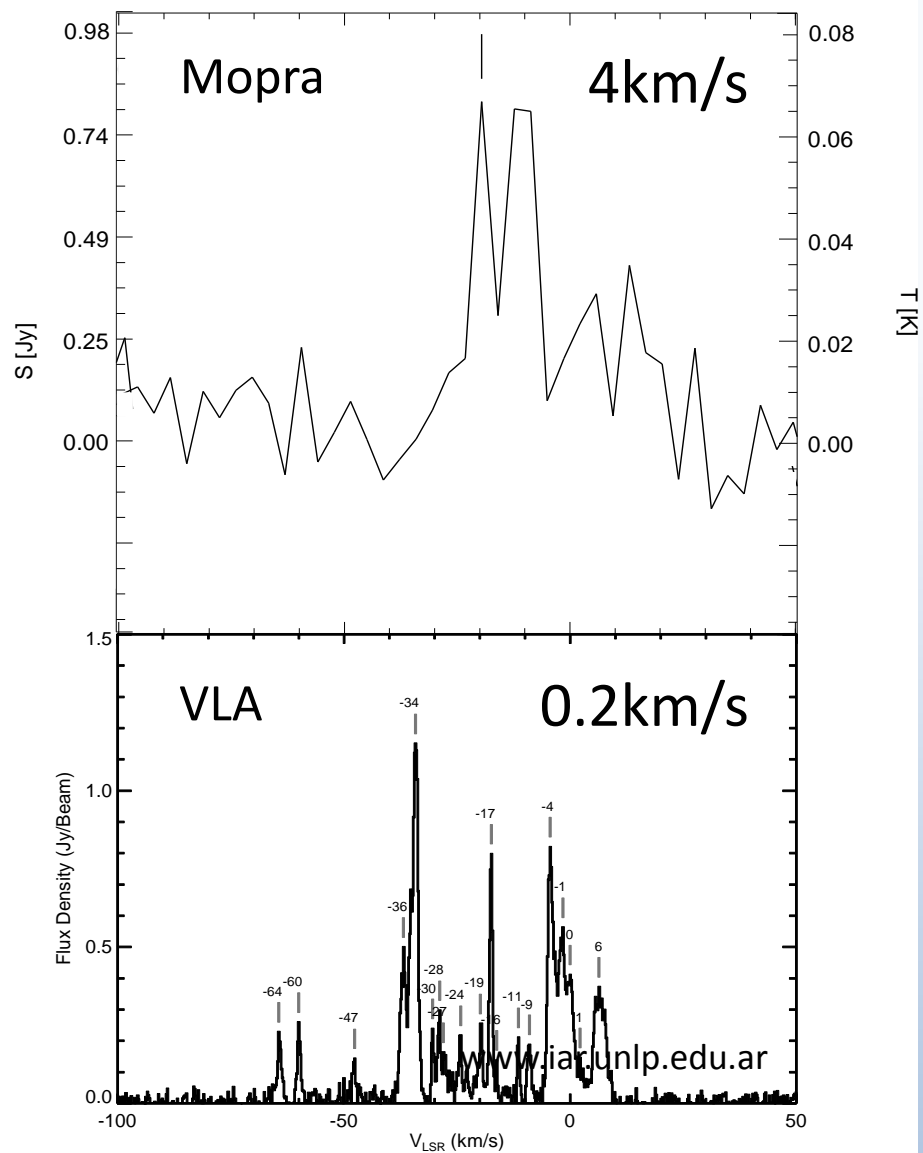
My Work: VLA



High resolution=more detections



My Work: VLA vs Mopra resolution



Chambers et al. 2014 A&A 563

Finley, D., NRAO and Associated Universities, Inc.

My Surveys

- ATCA water (SWAG)
- VLA methanol
- OTF VLA water (imaging)
 - LARGE data size >70 TB

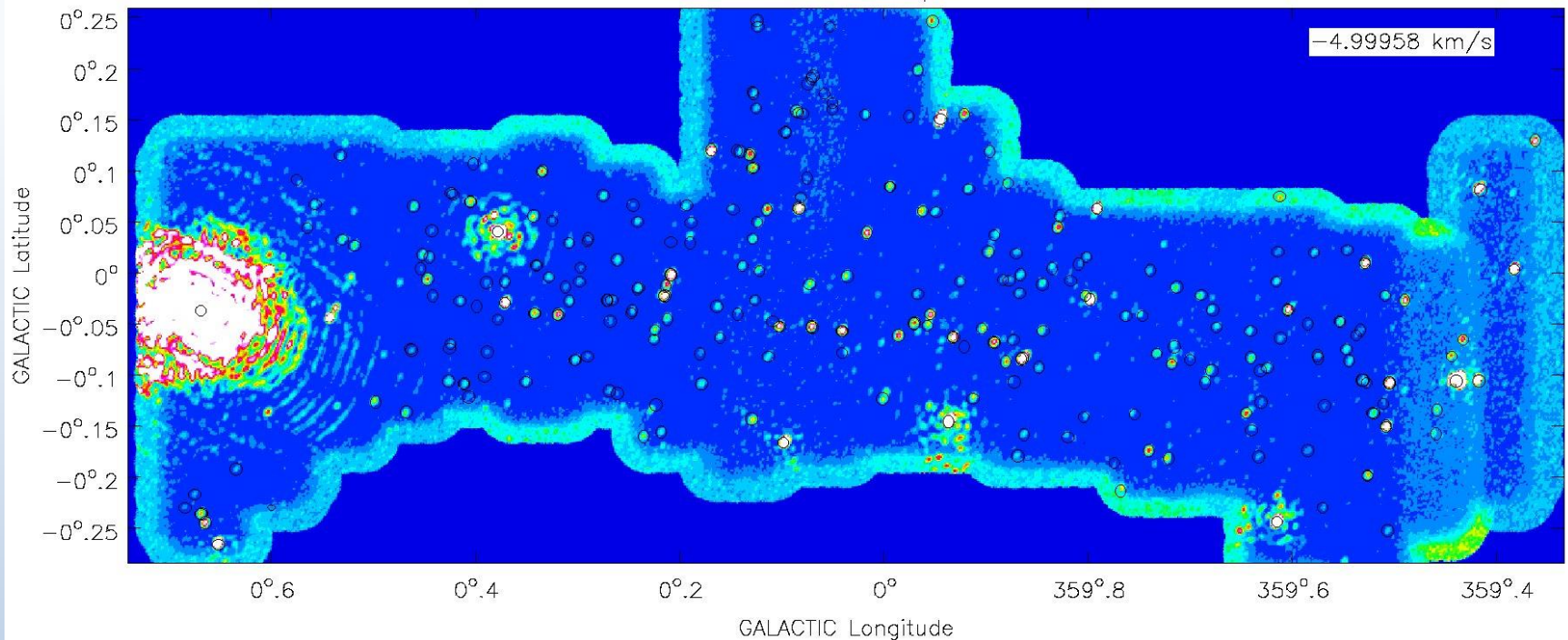


My Work: ATCA Water Survey

- ~250 maser *locations*
 - factor of 6 improvement

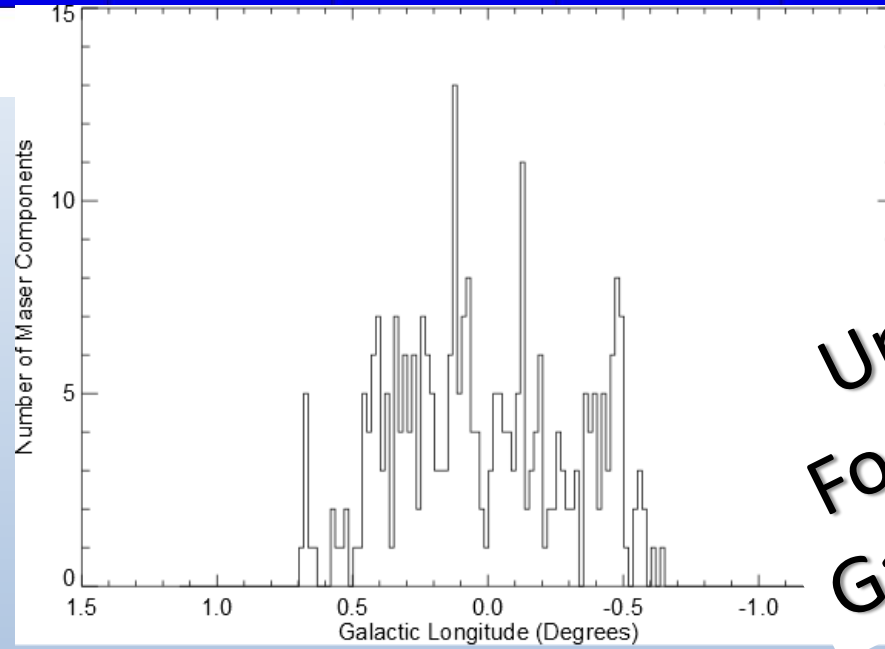
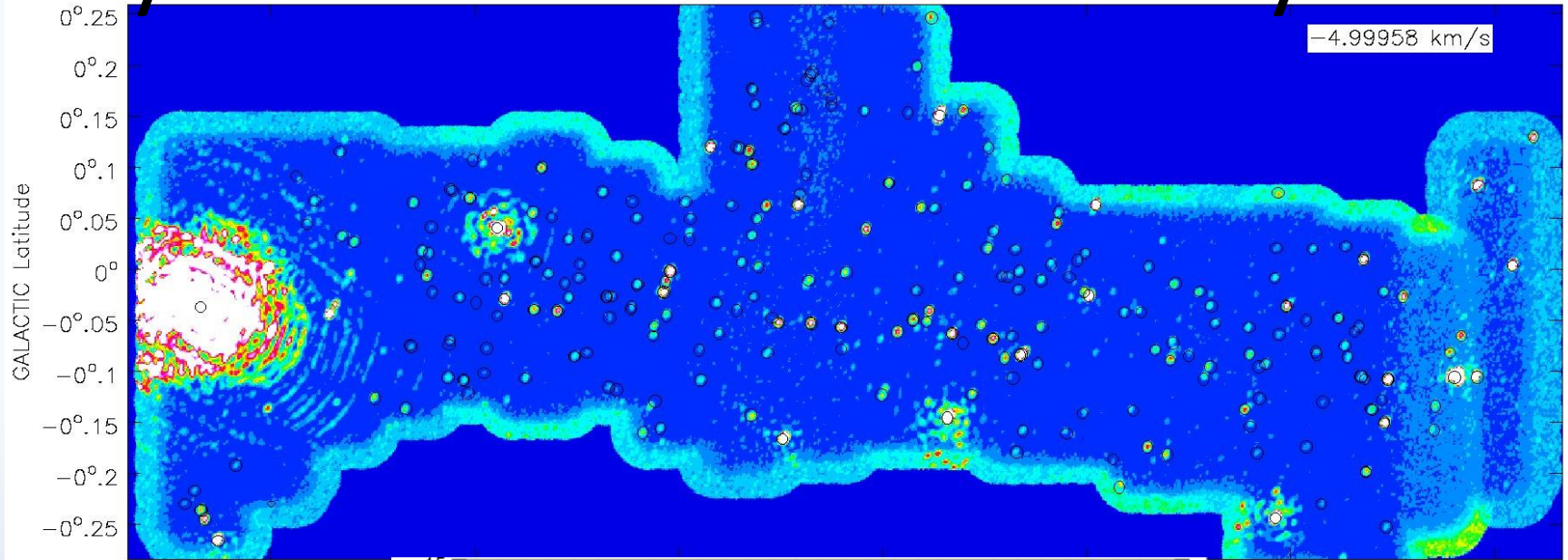


H2O.2kms.mom-2.map-raster



Calibrated and imaged by Nico Krieger (Max Planck Institut für Astronomie)

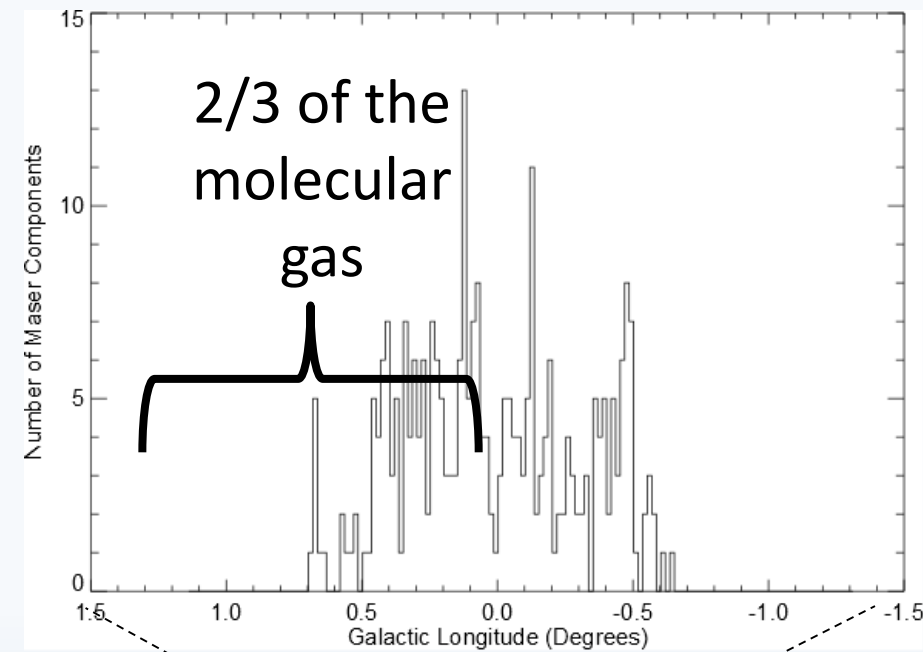
My Work: ATCA Water Survey



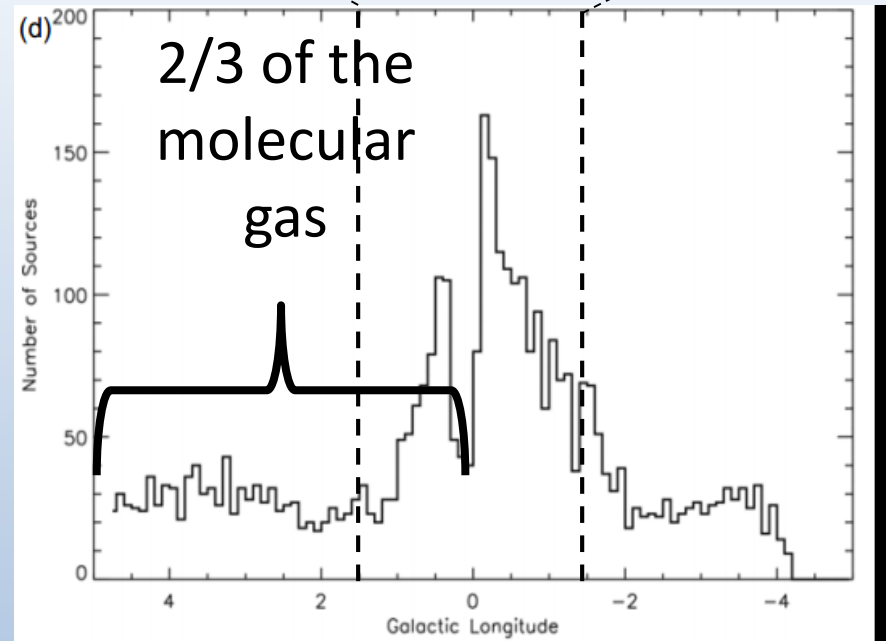
Uniform Star
Formation along
Galactic longitude

Water vs IR Distributions

Water

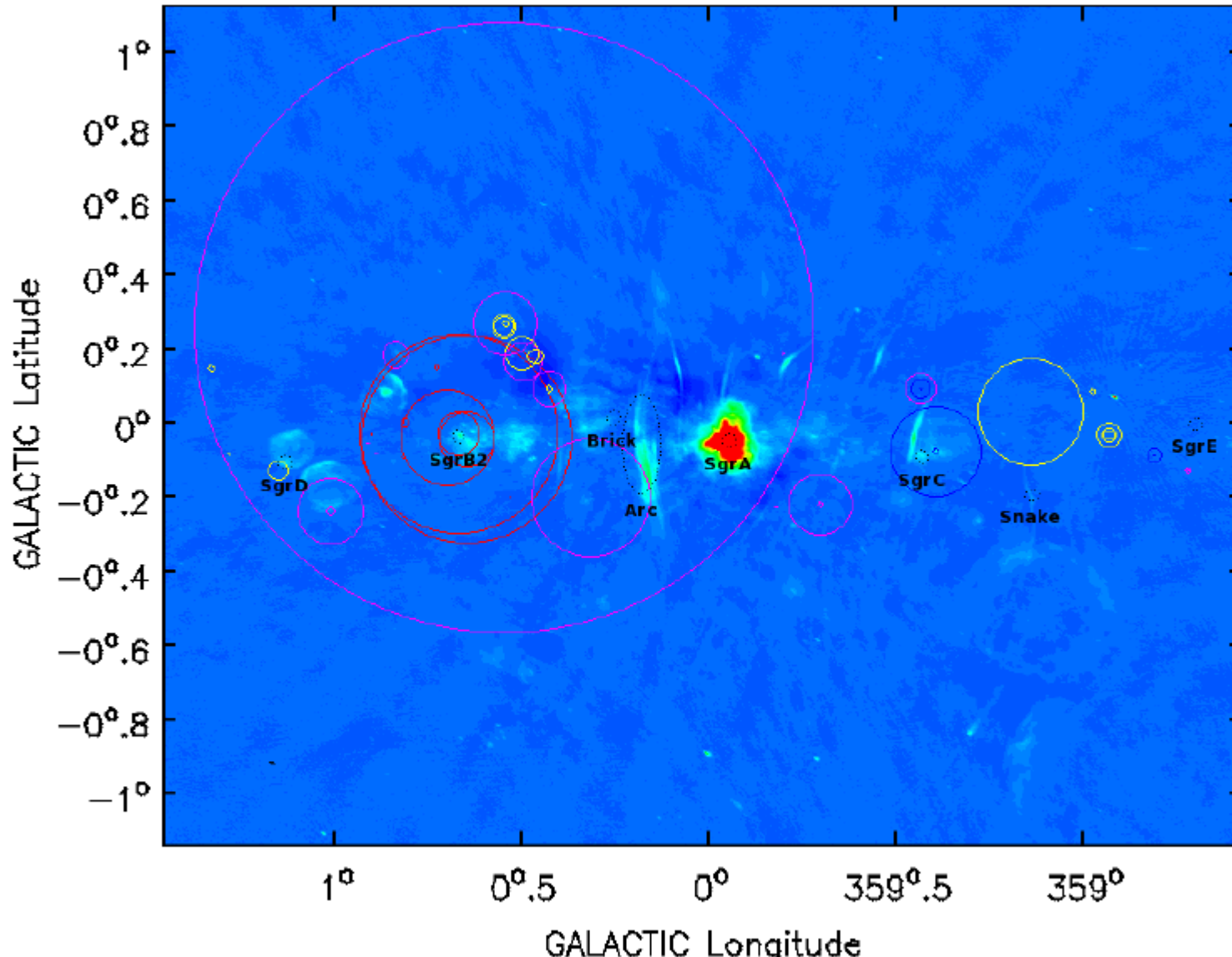


IR



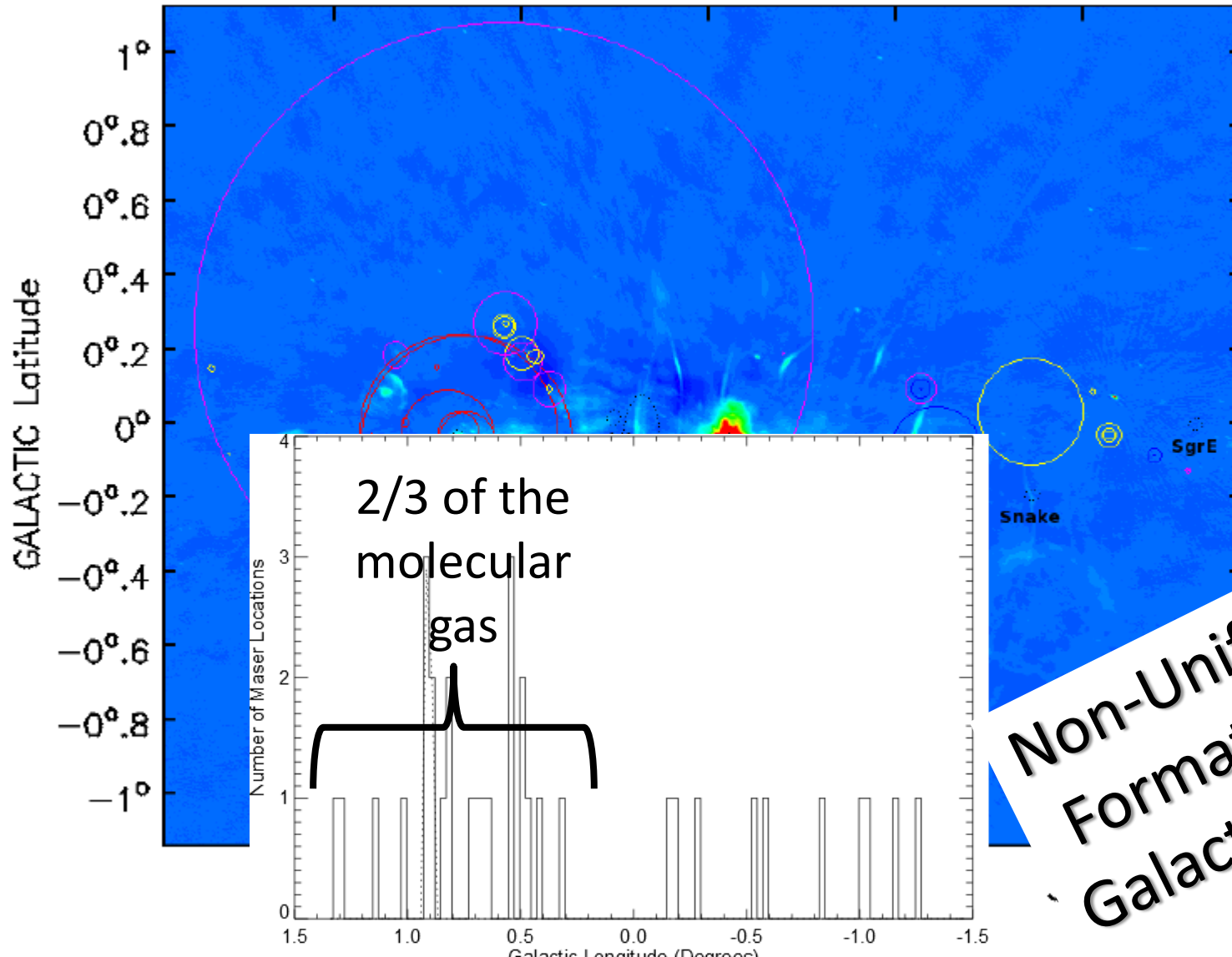
My Work: VLA Methanol Survey

- ~50 maser locations



My Work: VLA Methanol Survey

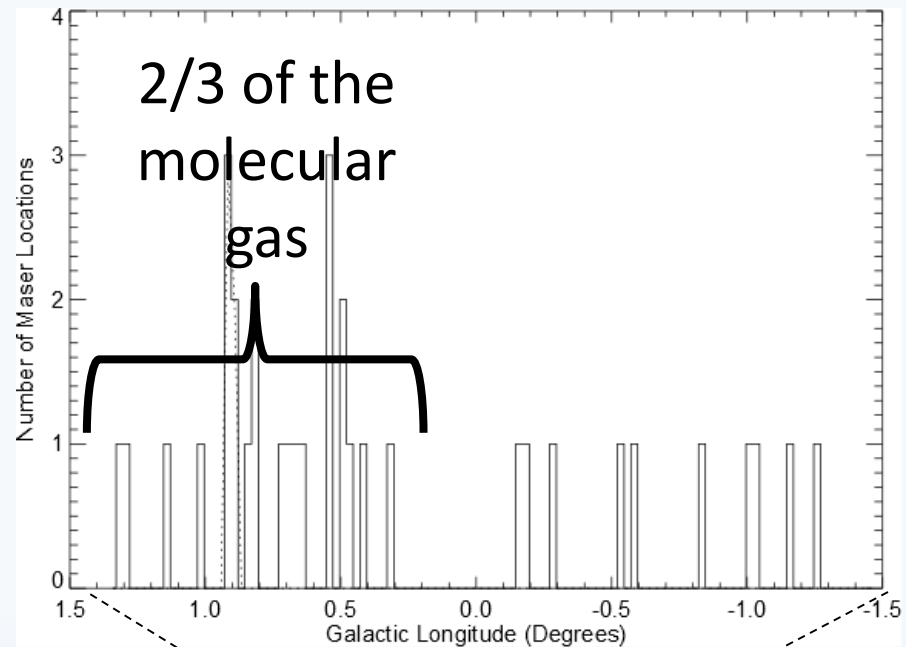
- ~50 maser locations



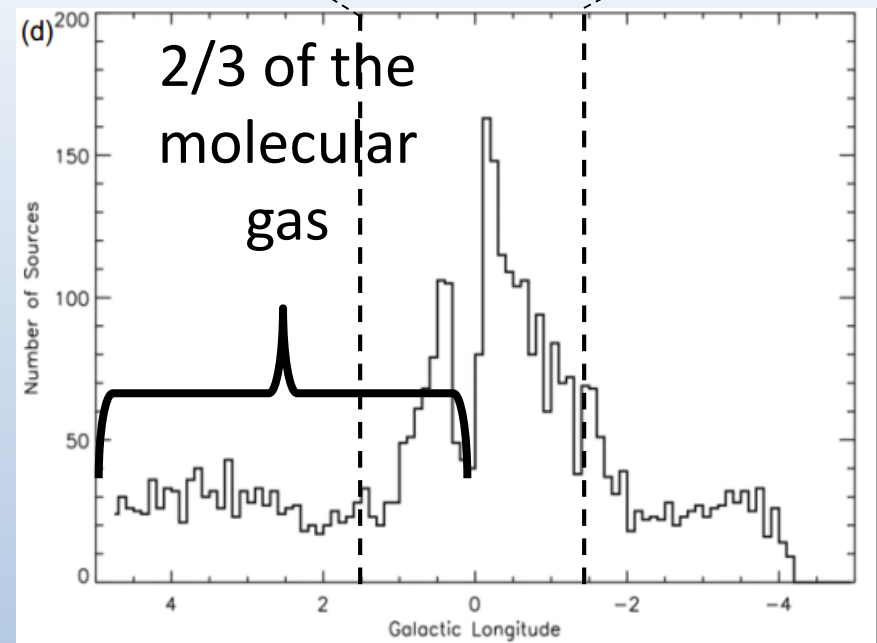
Non-Uniform Star
Formation along
Galactic longitude

Methanol vs IR Distributions

Methanol

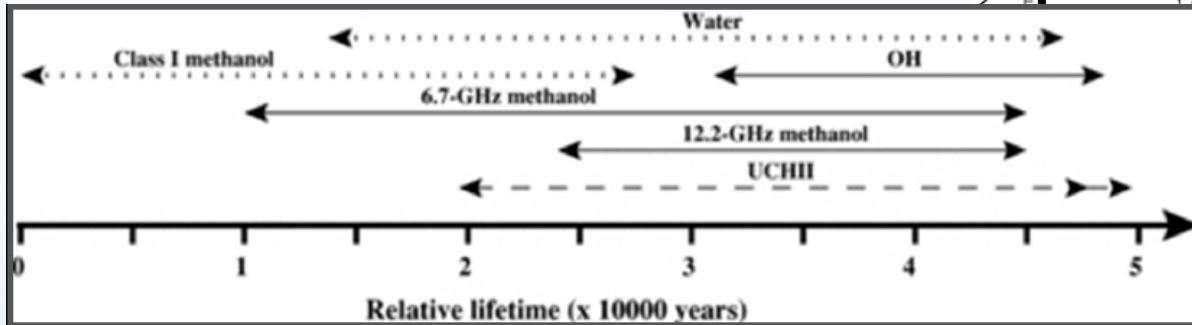
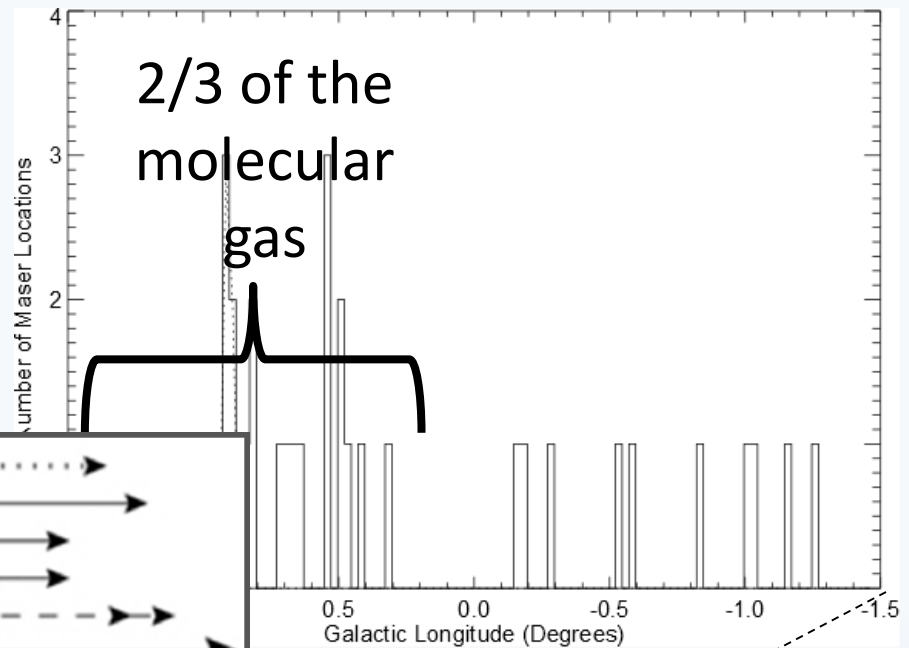


IR

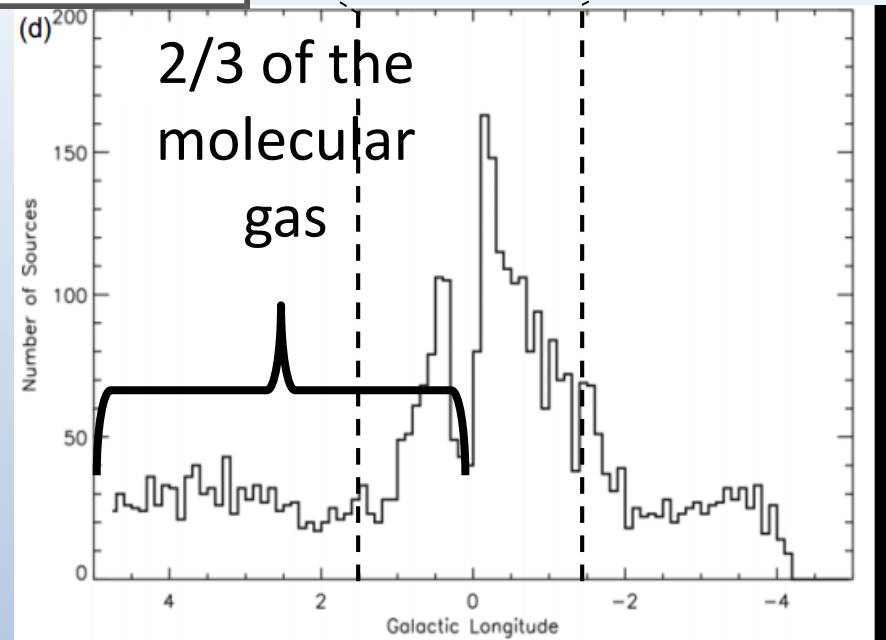


Methanol vs IR Distributions

Methanol

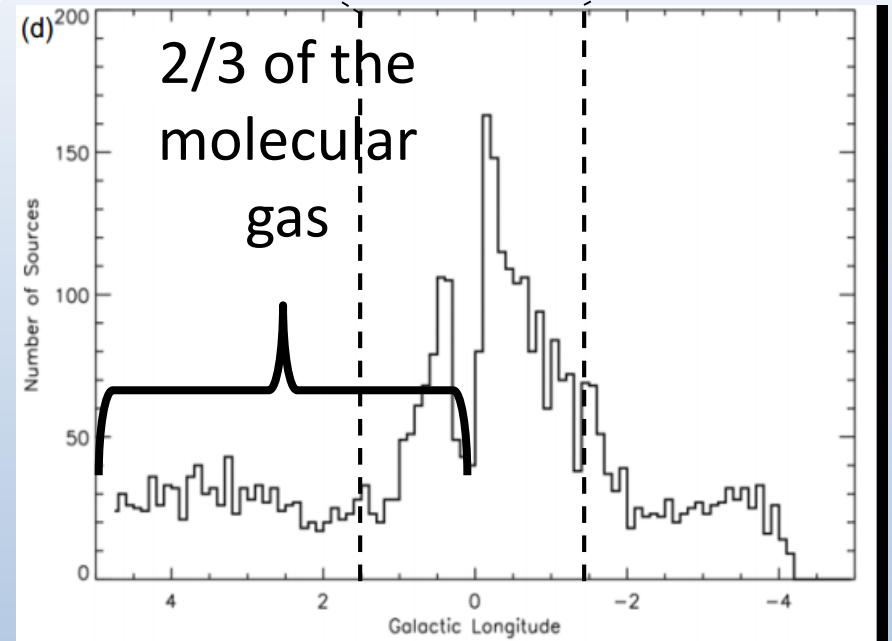
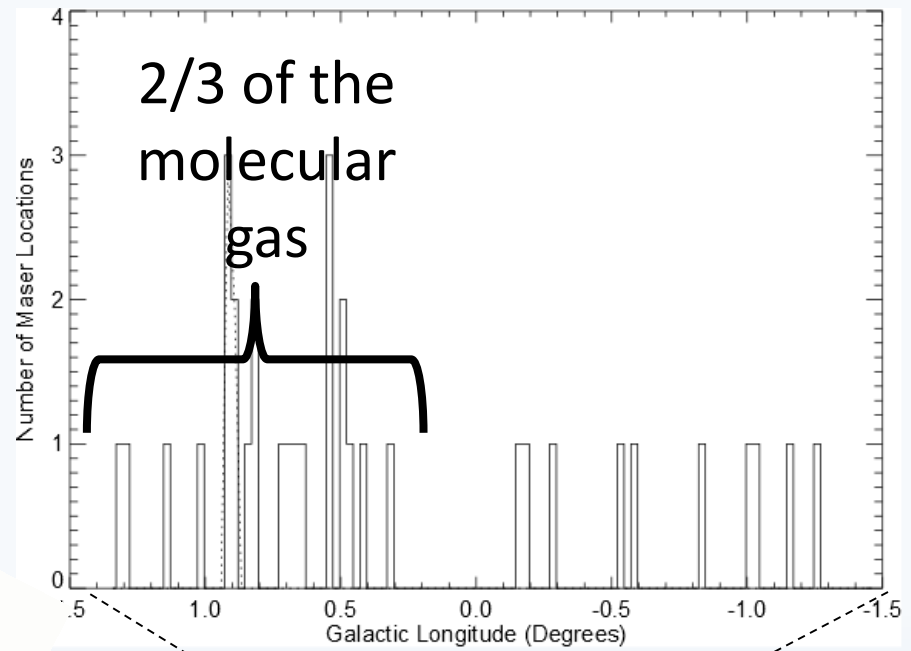
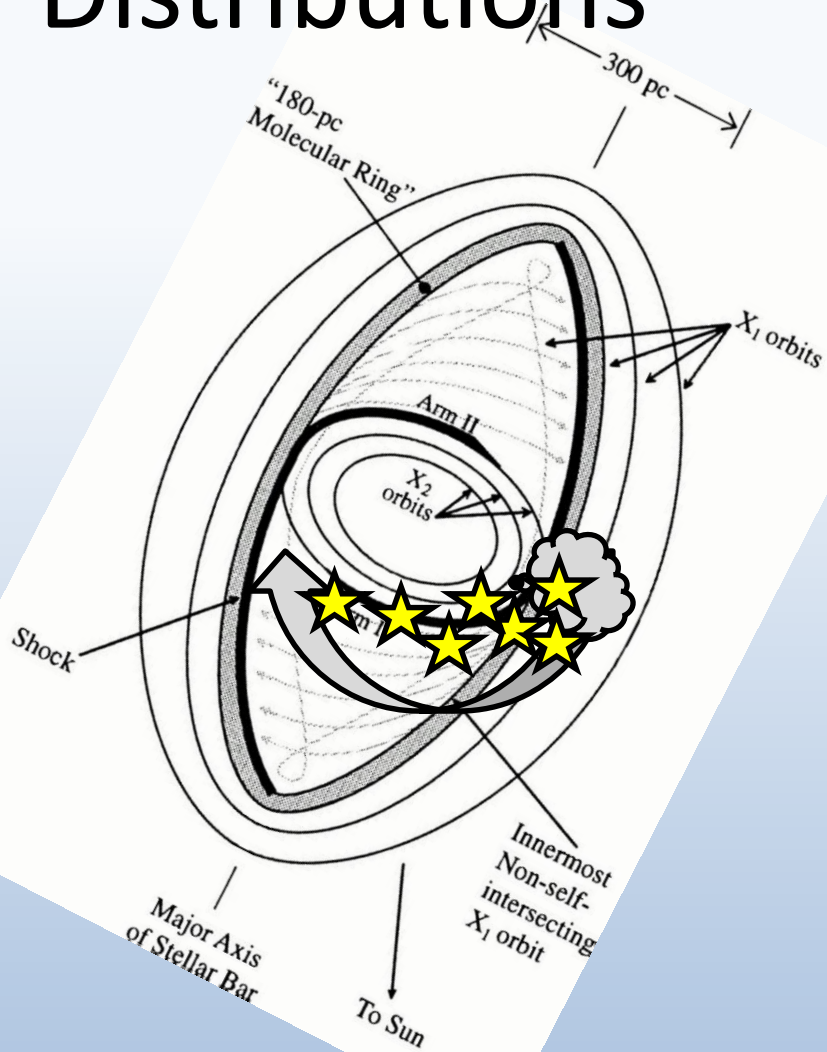


IR



Methanol

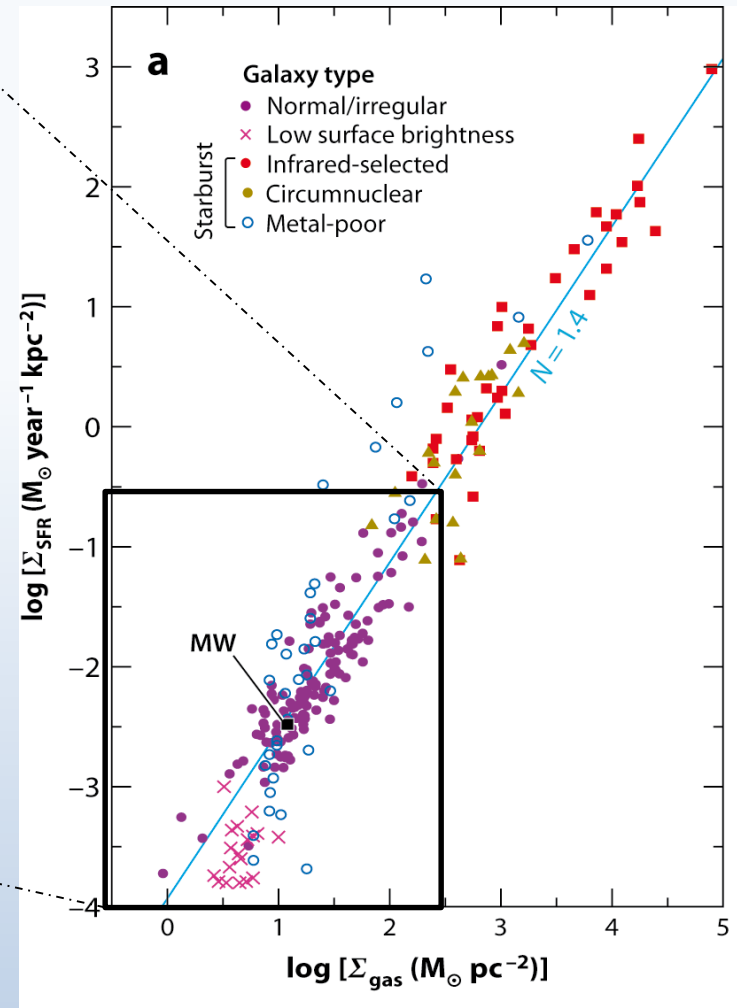
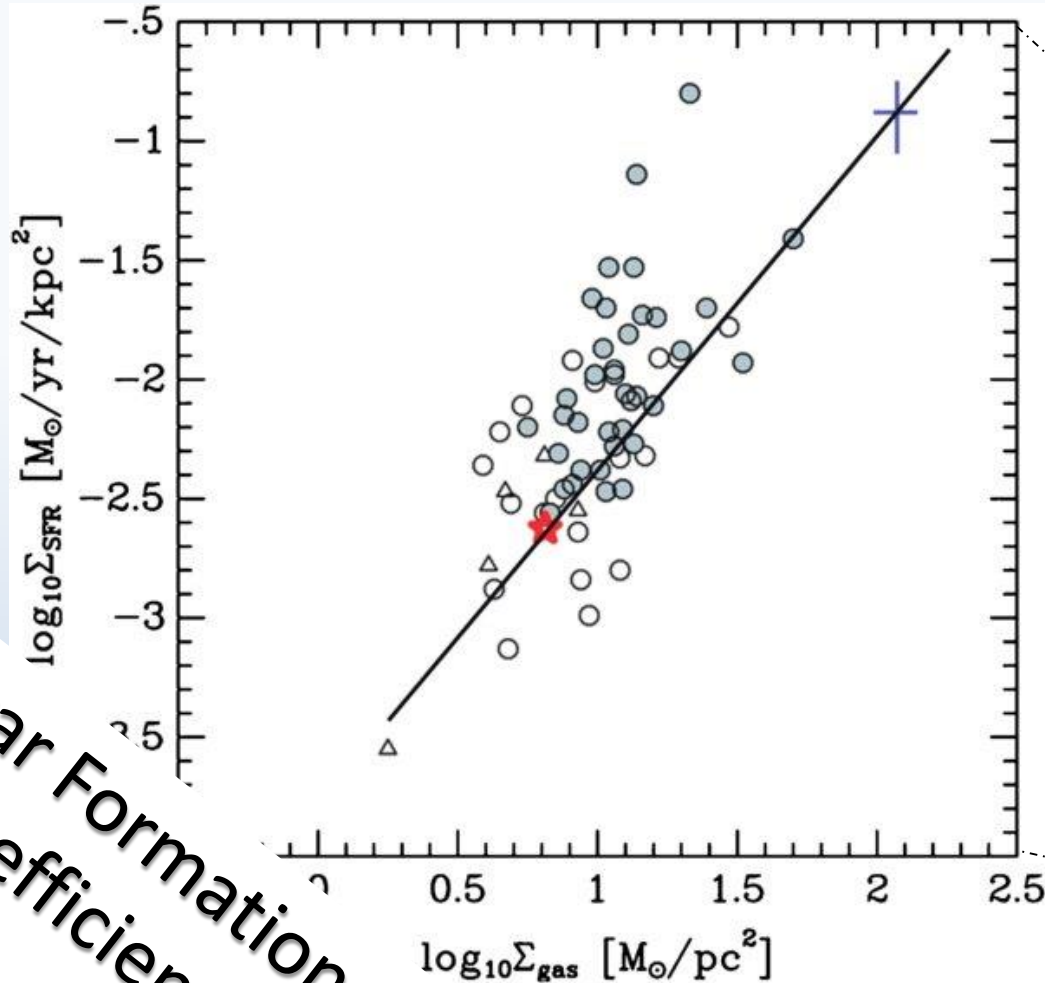
Methanol vs IR Distributions



Summary

- Low number of young stellar objects per mass of gas in CMZ
- Conducted 1st high resolution surveys of water and methanol masers in CMZ, got many new detections
- Water masers are uniformly distributed along Galactic longitude, methanol masers are not

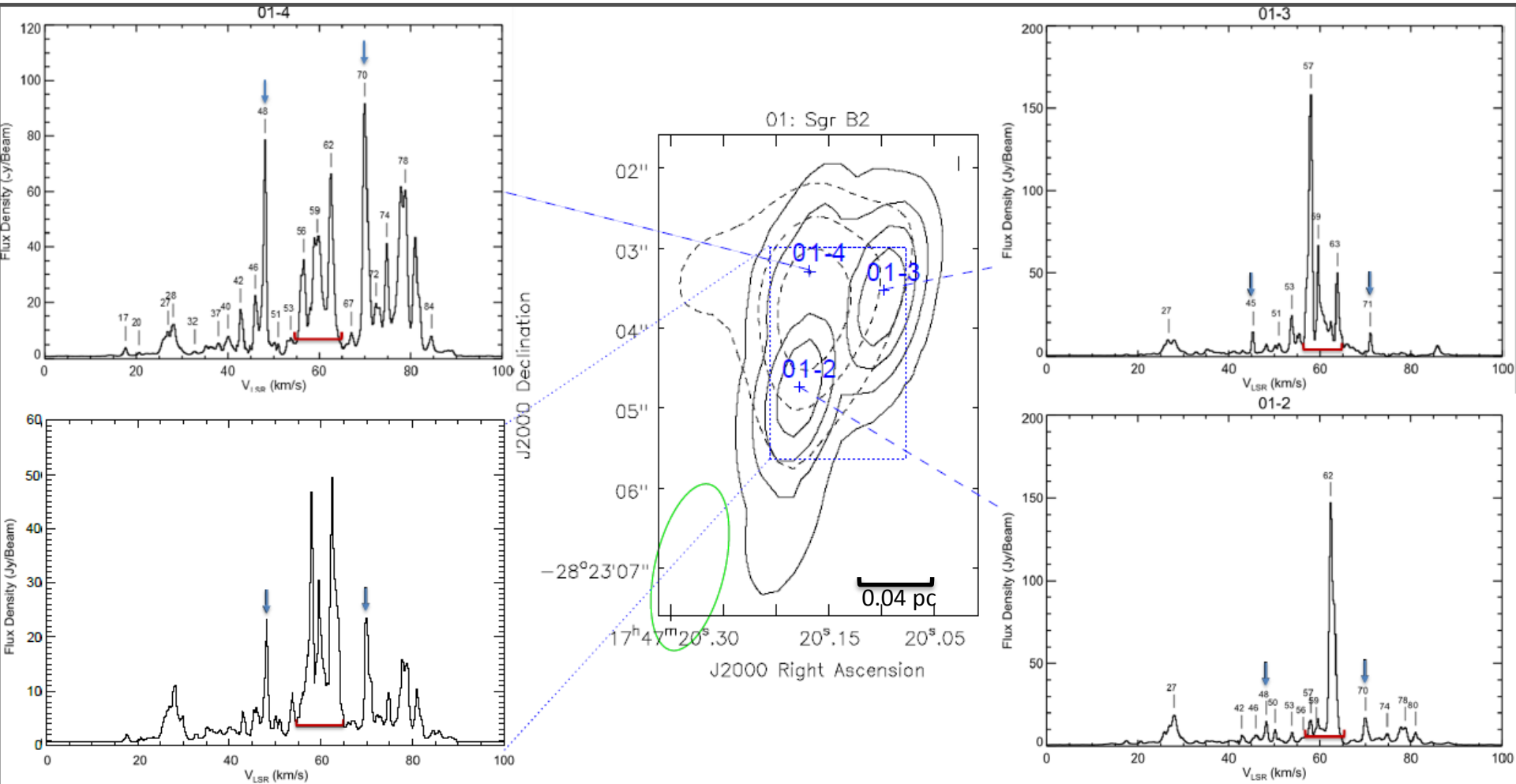
Star Formation across Galaxies



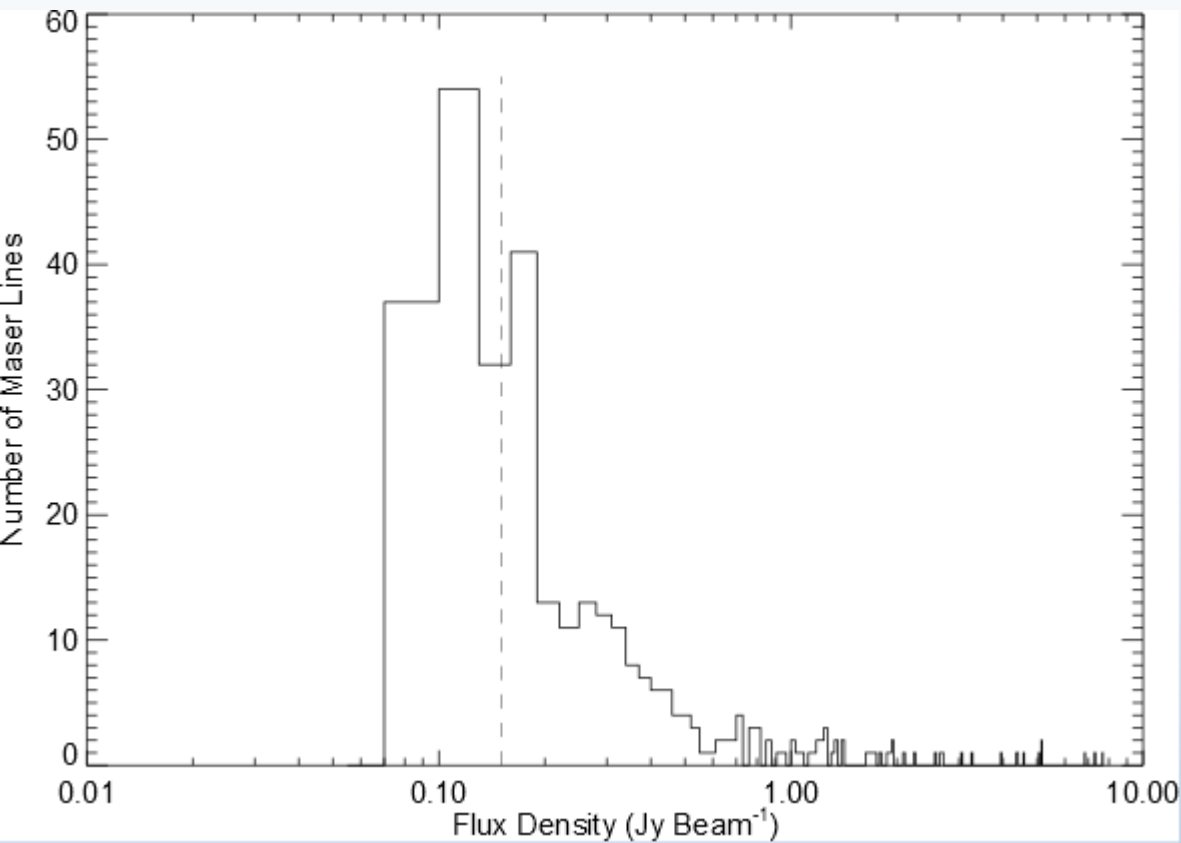
Star Formation is not inefficient in the CMZ?

Current Work: Characterize Spectra

Example: ID outflows



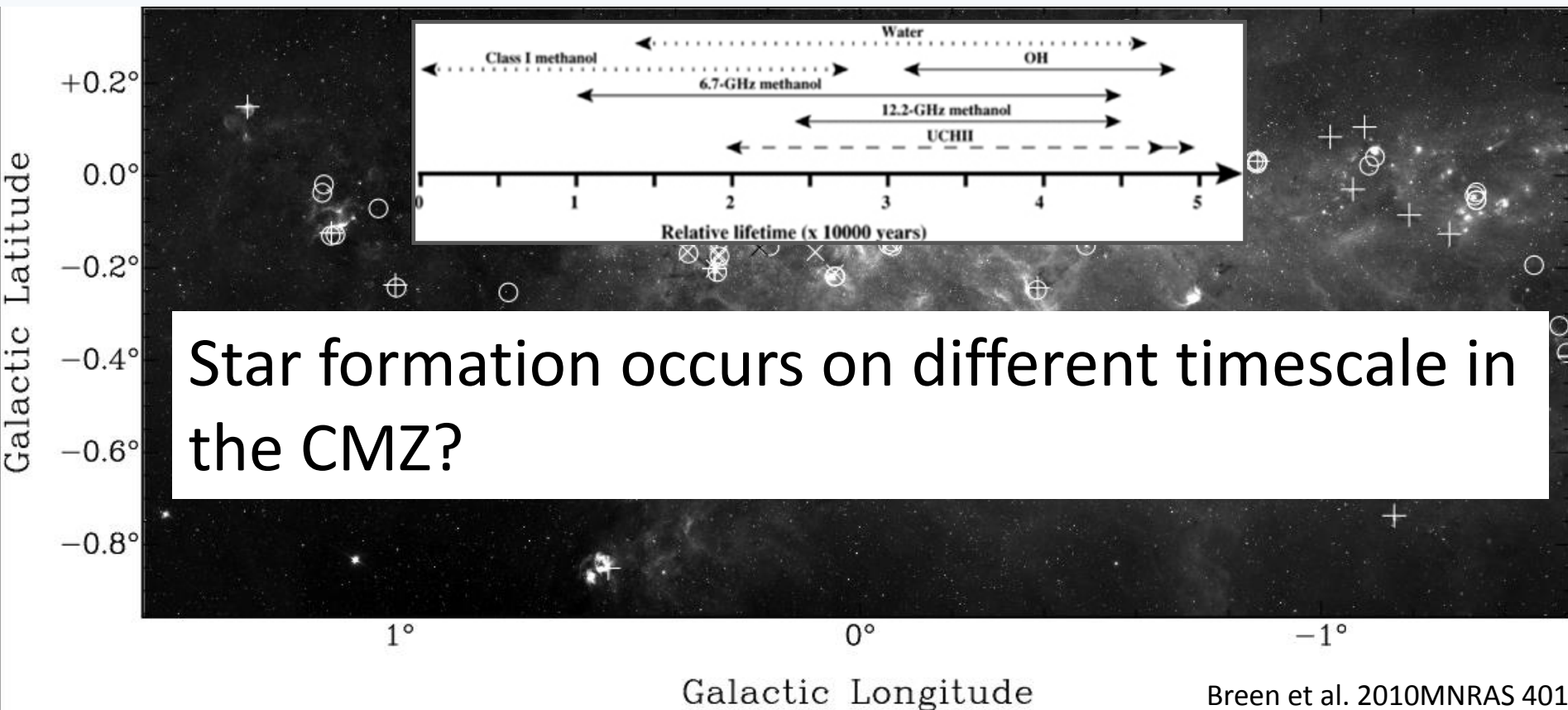
Water Masers: Contaminated by Evolved Stars?



Previous Work: Mopra

+ Water masers (22 GHz)

o Methanol masers (6.7 GHz)



Star formation occurs on different timescale in the CMZ?

The Galactic Center: Star Formation

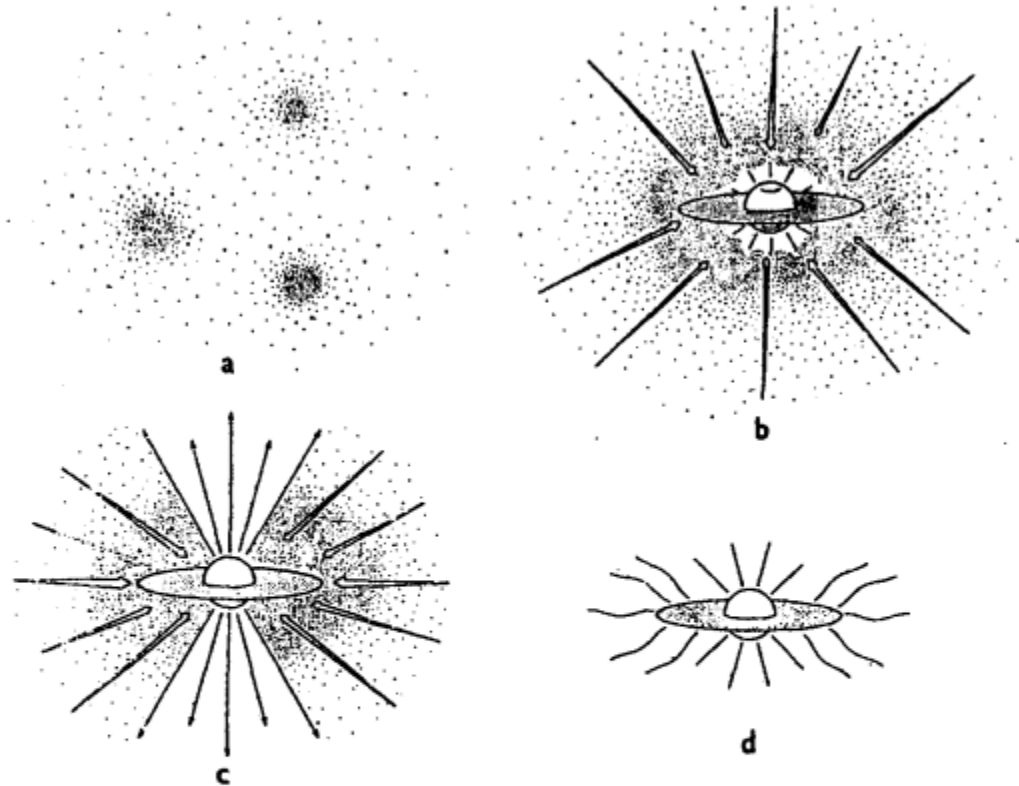
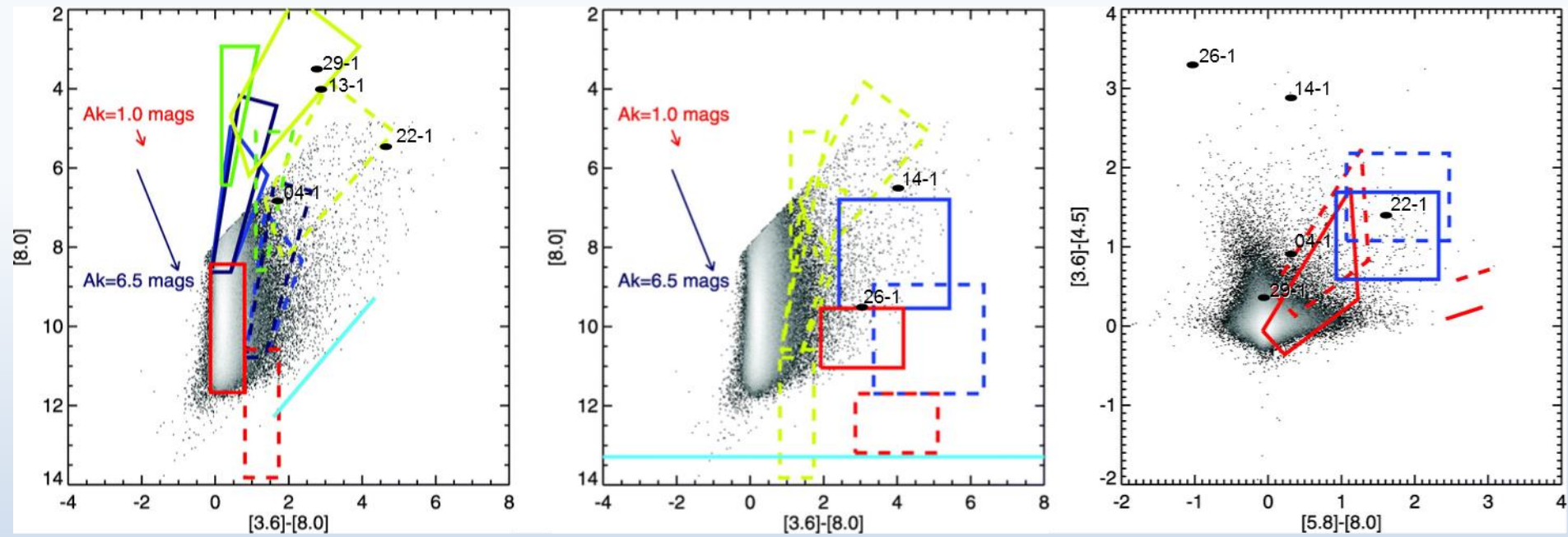


Fig. 2.1. This cartoon illustrates the four stages of star formation. (a) First protostar cores form within molecular clouds. Then, in (b), the protostar builds up from the inside out while the surrounding nebular disk rotates around it. (c) Bipolar flows break out along the rotation axis of the system. Finally, in (d), the surrounding nebular material is swept away, and the newly formed star, with disk, is revealed. From Shu et al. (1987). Reproduced with permission, from the Annual Review of Astronomy and Astrophysics, Vol. 25, ©1987 by Annual Reviews.

Current Work: ID YSOs



Current Work: VLA: Upgrades

- Replaced ALL electronics
 - Receivers
 - Wave guides
 - Cables
 - Correlator
- Improved:
 - Sensitivity
 - Frequency range
 - Frequency resolution

