Molecular Gas & the Nuclear Starburst in NGC 253

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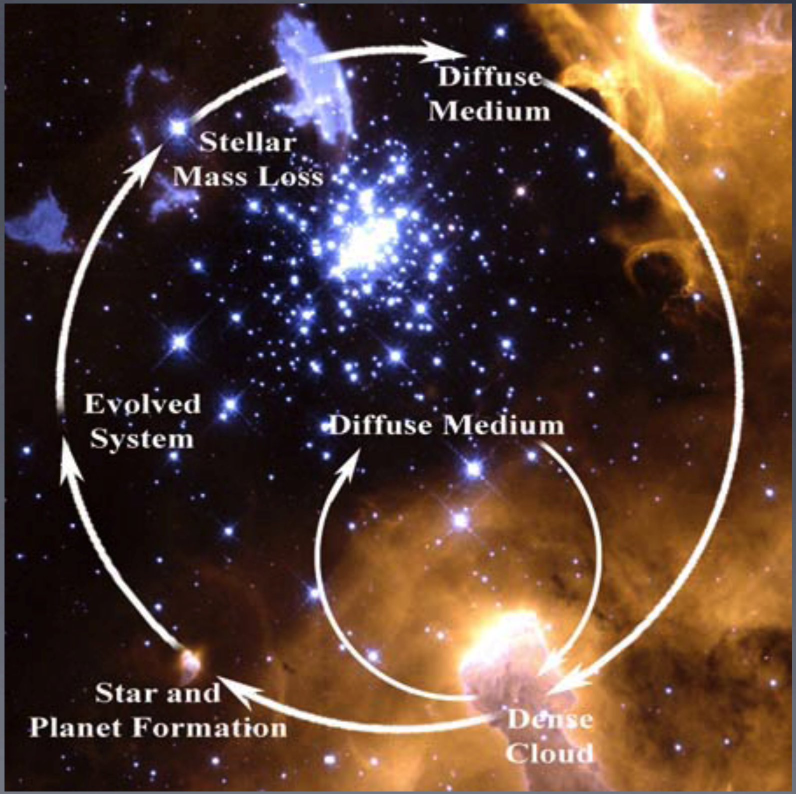
1. Overview of Molecular Gas and Star Formation
2. The Galaxy Sample and NGC 253
3. The galactic ecosystem in NGC 253

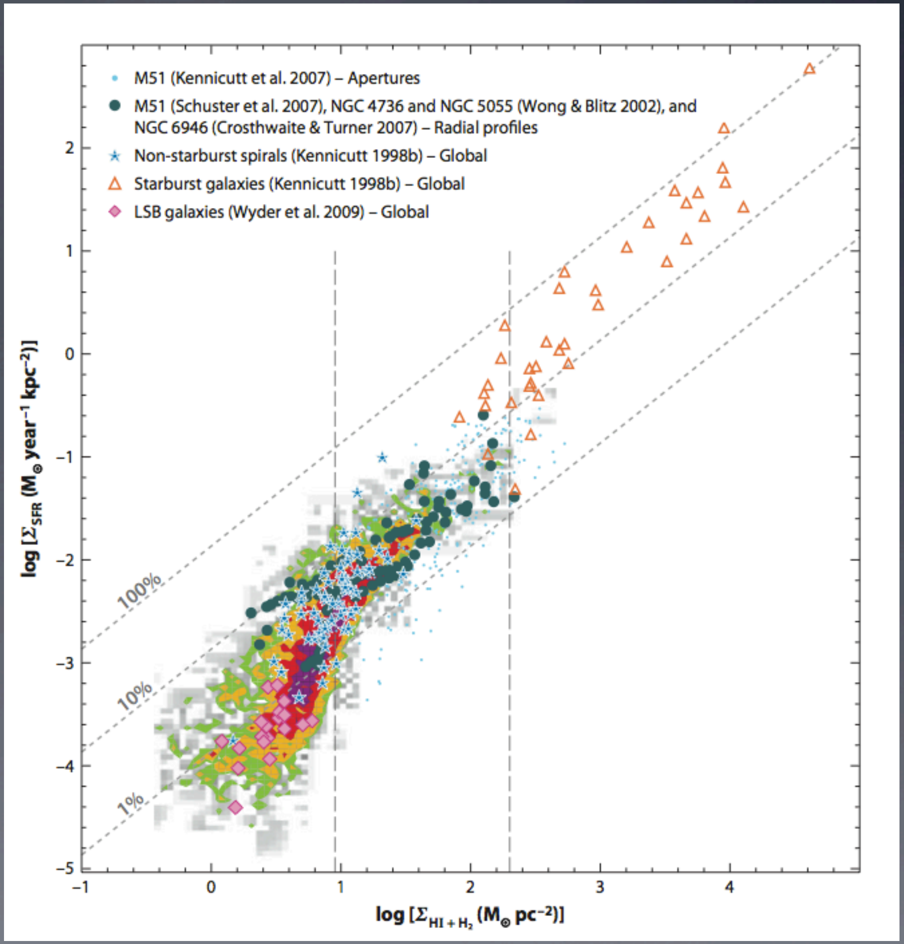
From Gas to Stars

1. Gas exists in a diffuse atomic phase within a galaxy (Kpc)
2. Formation of molecular clouds (10-100 pc)
3. Fragmentation into clumps and cores(0.1-1pc)
4. Core contraction to form stars(AU)
5. Stars feed energy, metals, and momentum back into the cloud



Various Starburst Definitions

- The SFR cannot be sustained over some fraction of the Hubble time
- Current SFR exceeds past SFR by order much greater than one
- SFR efficiency is much higher than “normal” star forming galaxies



Bigiel et al 2008, Kennicutt et al. 2012

Project Overview

- The WIDAR Correlator is capable of providing 8 GHz of bandwidth.
- We can observe multiple spectral lines at once with the same conditions. (atmosphere, UV coverage, sensitivity, ….)
- How does the galactic ecosystem change with SFR?
- How does SF influence the galactic environment?
- What properties of the ISM are important for understanding Star Formation?
- What is the anatomy of a galaxy?

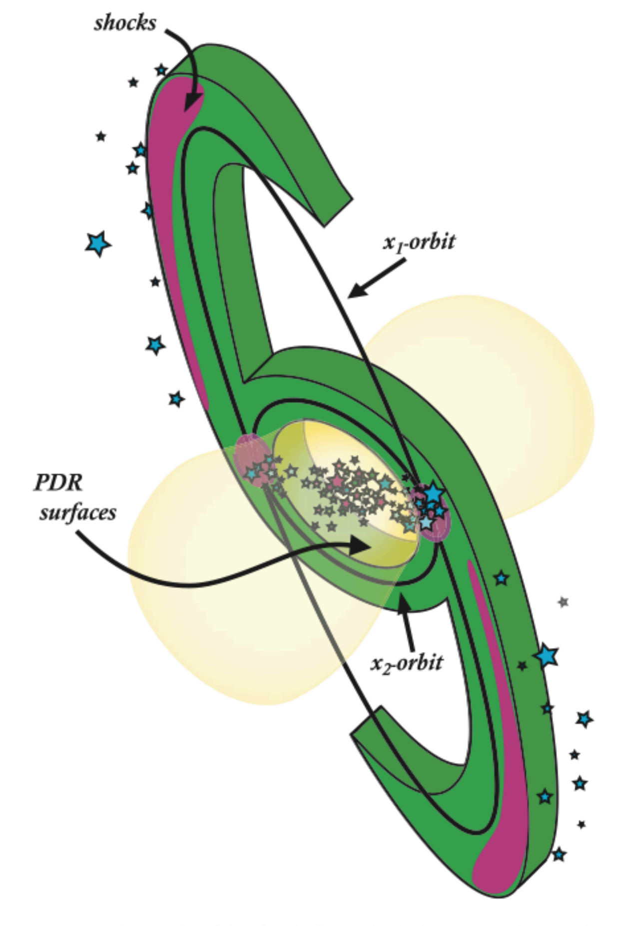


FIG. 10.—Schematic of the chemical and physical structure of the nucleus of IC 342.

Meier and Turner 2005

Molecular Tracers

- CO (Carbon Monoxide): 115.271 GHz
  - Molecular Gas Tracer
- NH_3 (Ammonia): 23.6945 – 27.4779 GHz
  - Temperature and Dense Gas tracer.
- H_2O (Water): 22.2351 GHz,
  - Traces Shocks, collisionally excited maser. YSO, AGB stars, and AGN tori.
- CH_3OH (Methanol): 36.1639 GHz,
  - Class I maser, collisionally excited, shock tracer.

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Galaxy Sample

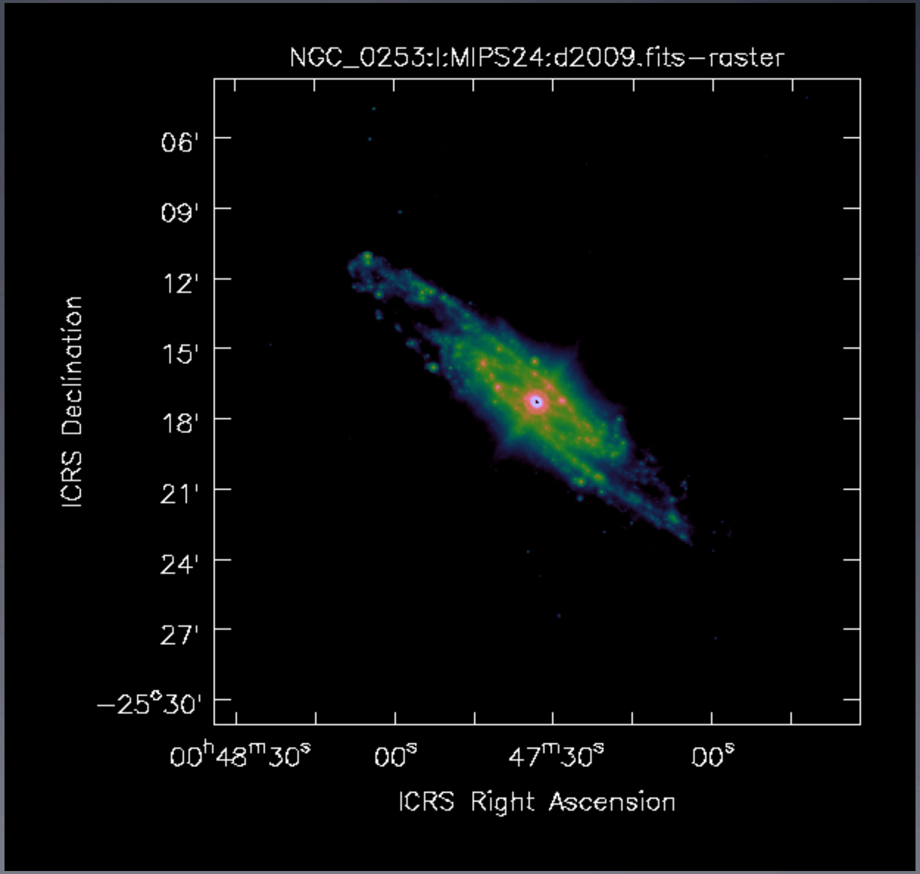
Galaxy	D[MPC]	SFR [$M_\odot$ yr $^{-1}$]	Comments
IC 342	3.0	1.5	Face on spiral
NGC 6946	5.2	1.4	Face on spiral, buried nuclear SF
NGC 253	3.5	5	Barred spiral, nucleated starburst
NGC 2146	3.9	11	Peculiar barred spiral, LIRG(almost)




T.A. Rector/University of Alaska Anchorage, H. Schweiker/WIYN and NOAO/AURA/NSF; Gemini Observatory/Travis Rector, University of Alaska Anchorage; SSRO/PROMPT/CTIO; T.A. Rector (University of Alaska Anchorage) and H. Schweiker (WIYN and NOAO/AURA/NSF)

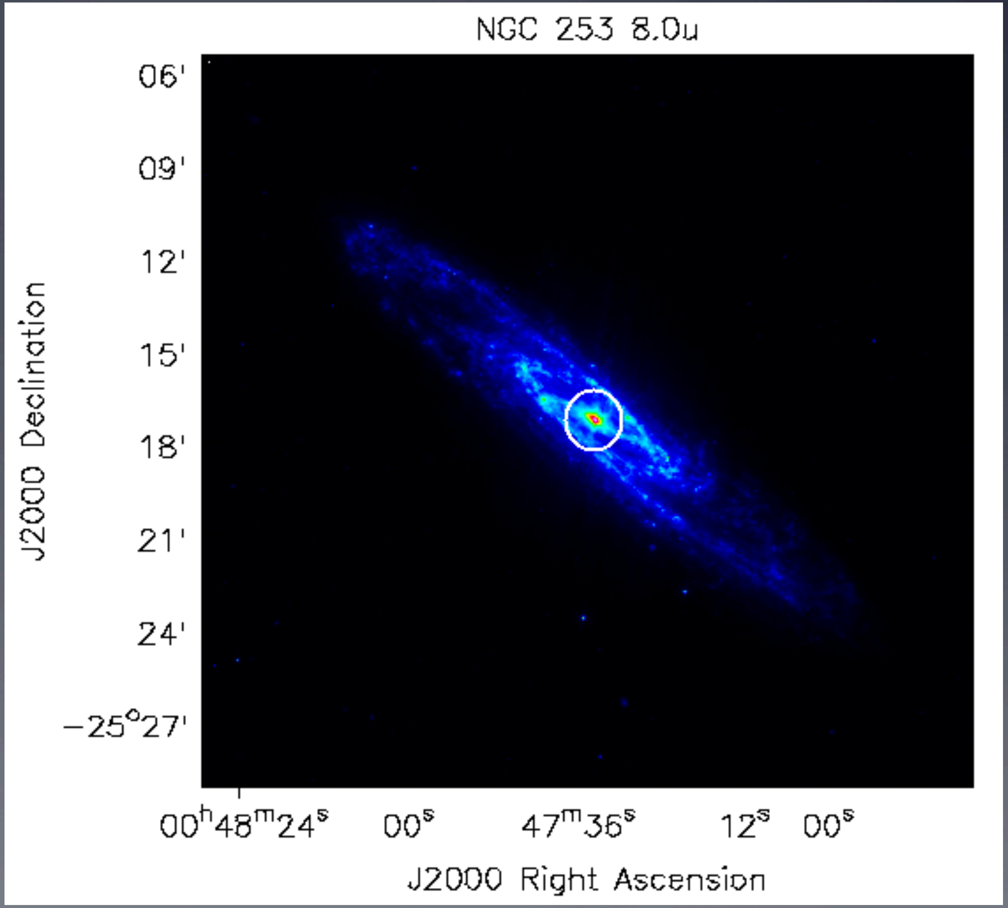
NGC 253 in detail

- Distance= 3.5 Mpc
- V_{sys}=235 km s^{-1}
- Barred spiral galaxy
  Class: SABc
- Nucleated star burst ~3$M_{\odot}$ yr^{-1}
- Total SFR ~5$M_{\odot}$ yr^{-1}
- Molecular outflow rate ~9$M_{\odot}$ yr^{-1} (Bolatto et al 2013)

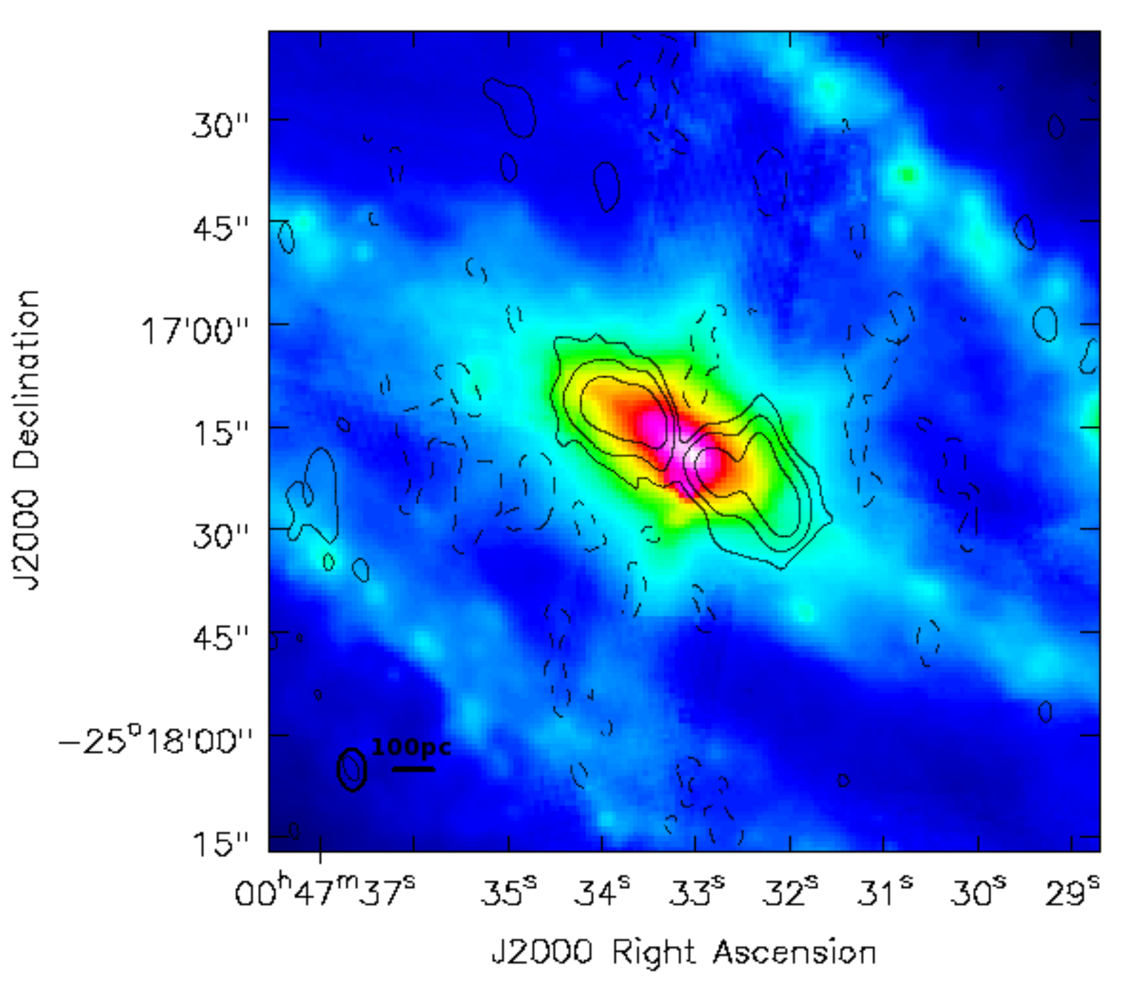


Observations

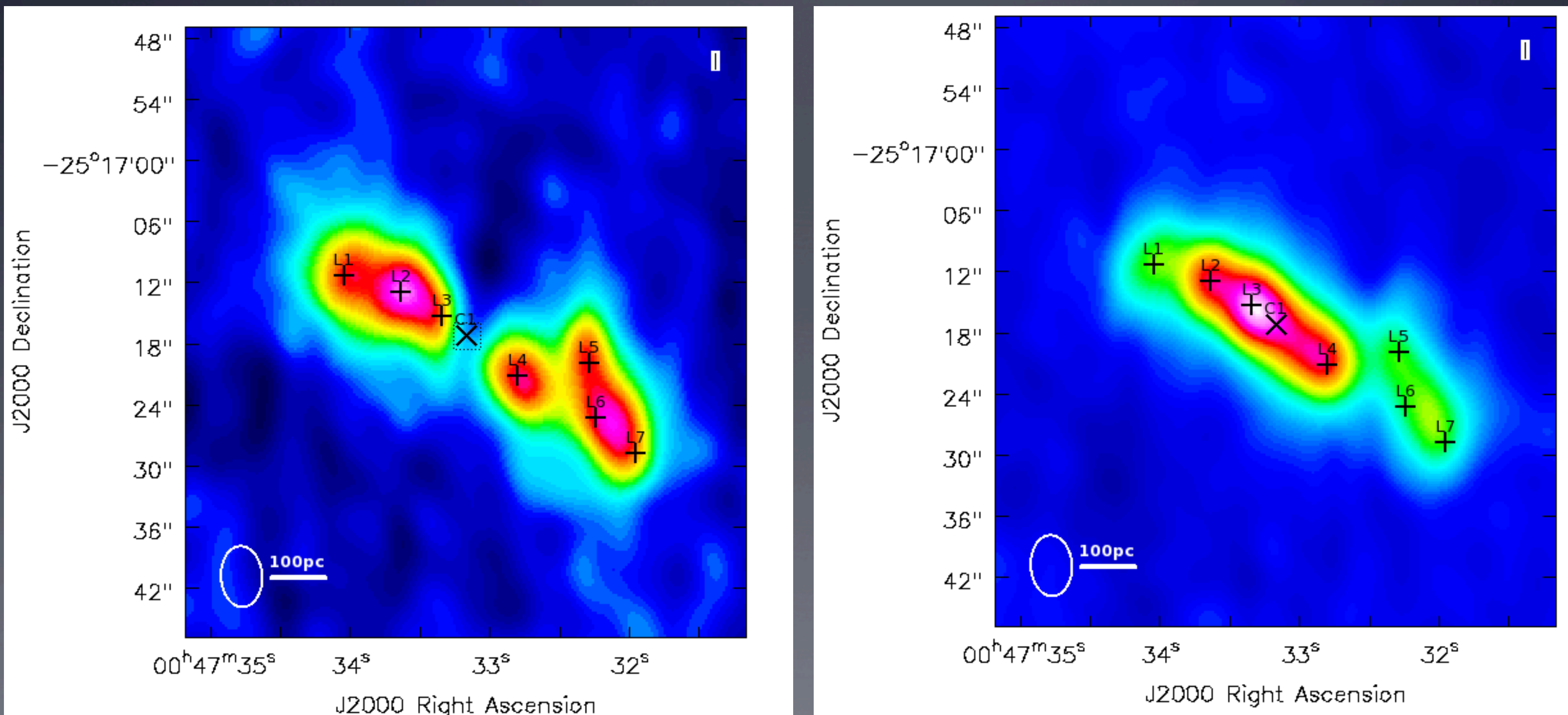
- K and Ka band, D configuration
  - Ammonia (1,1) to (5,5) transitions 23-25GHz
  - Water(6-5) 22.3GHz
  - Methanol(4-3) 36.2GHz
- Primary beam: ≈2 arcmin
- Resolution: ≈6x4 arcsec
- RMS: ≈ 0.6 mJy/chan
- 3.5 km/s /channel



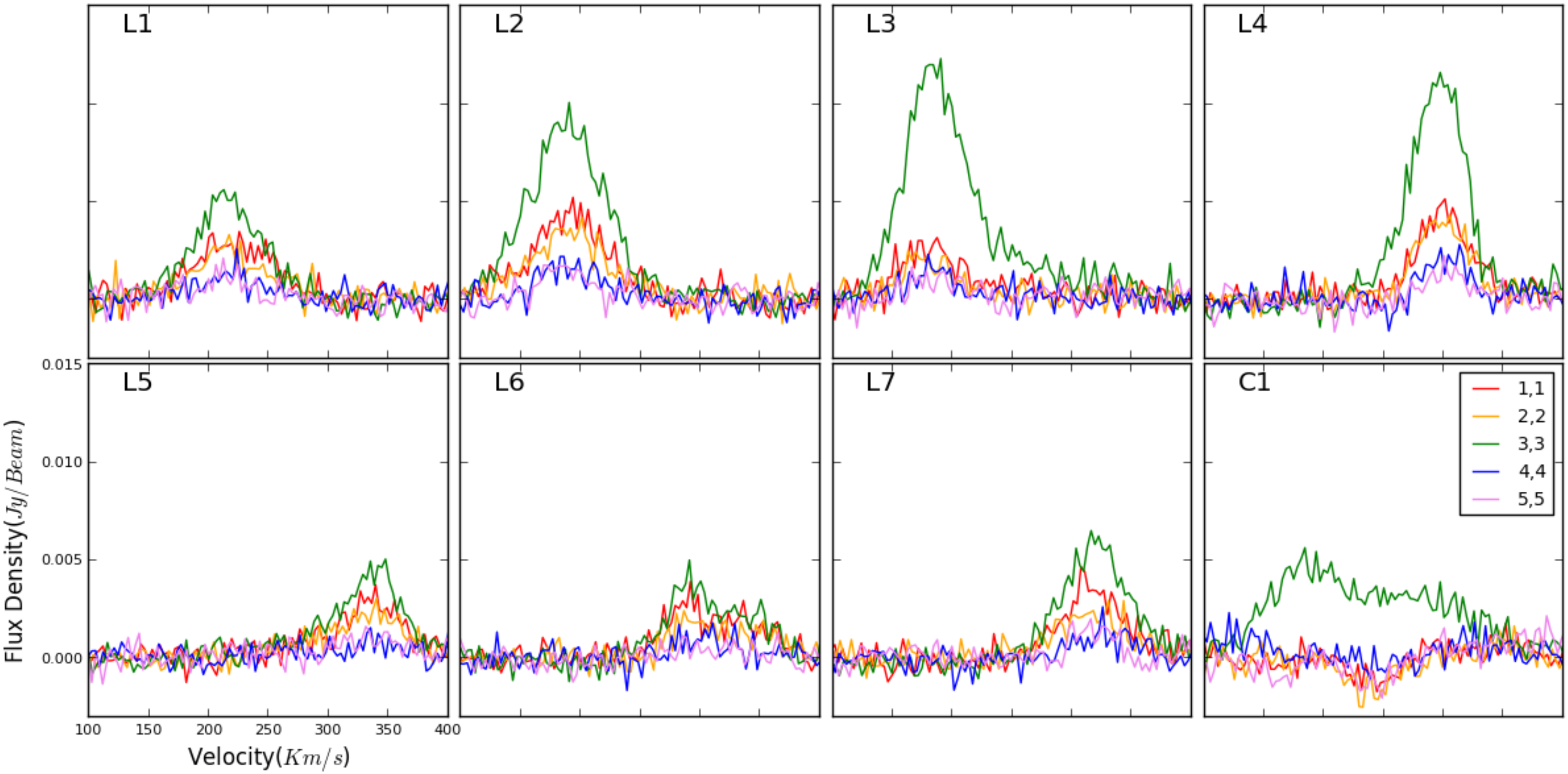
Ammonia(NH_3(1,1))



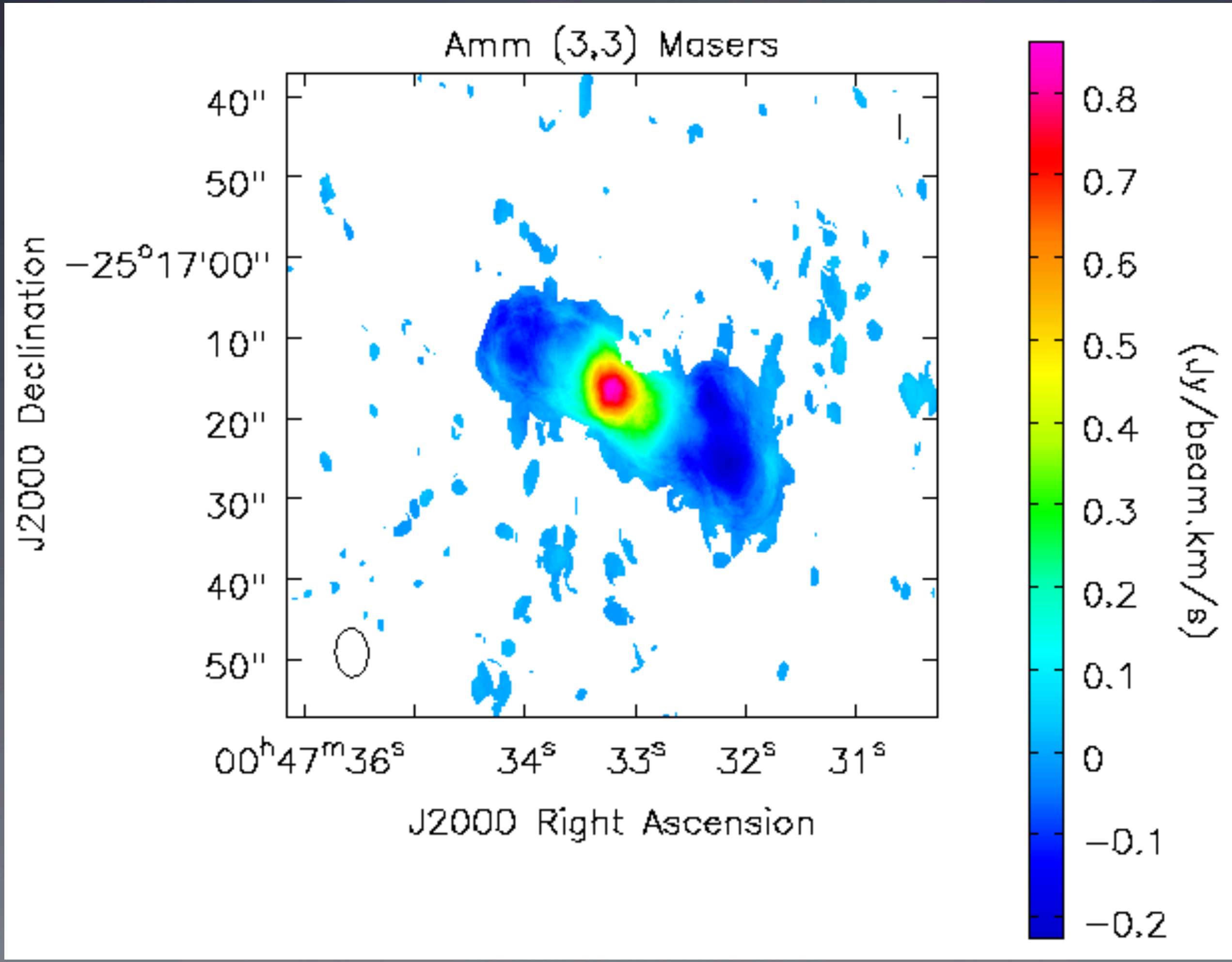
Ammonia(1,1) & (3,3)



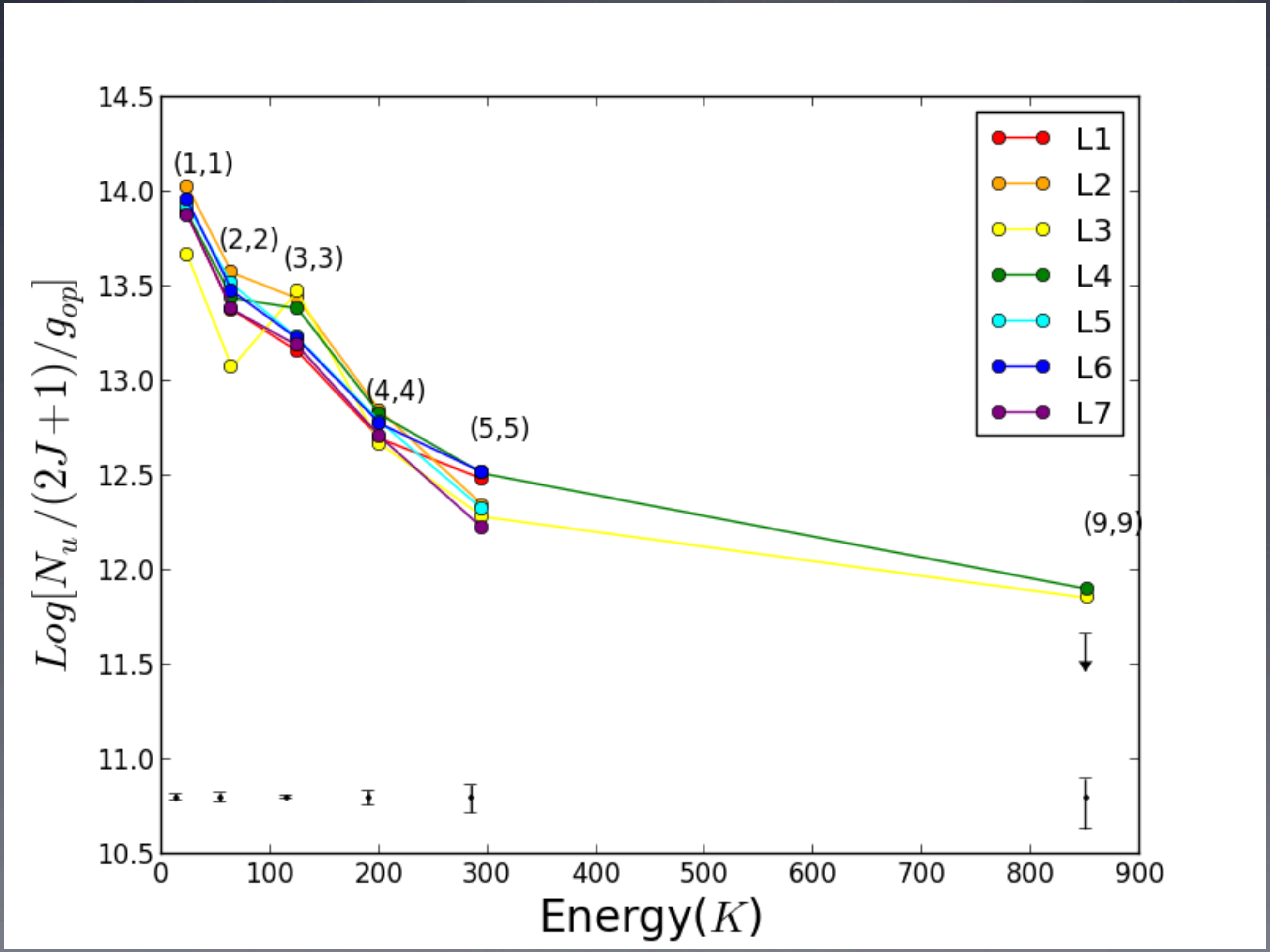
Ammonia Spectra



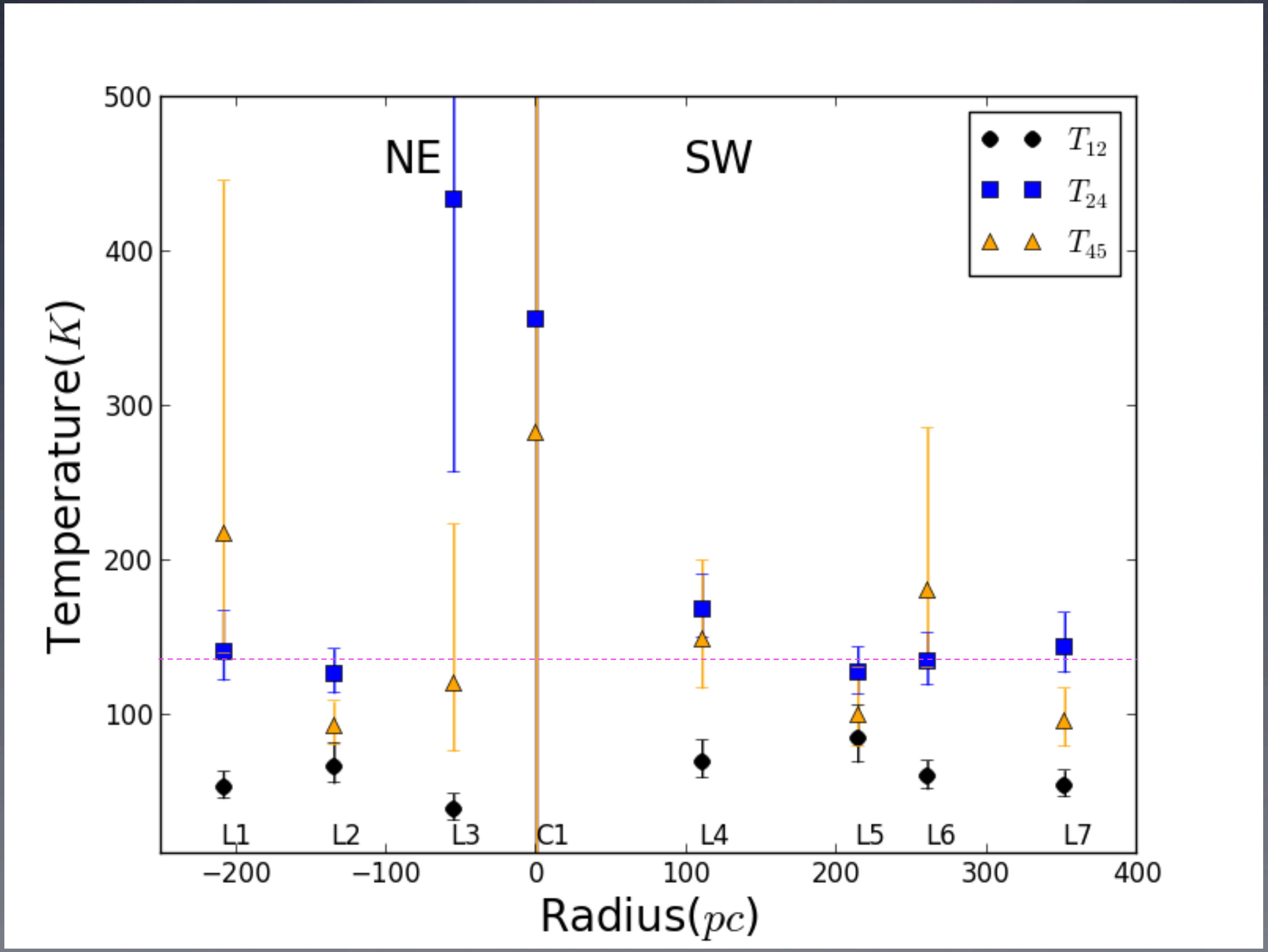
Ammonia Masers



Temperatures

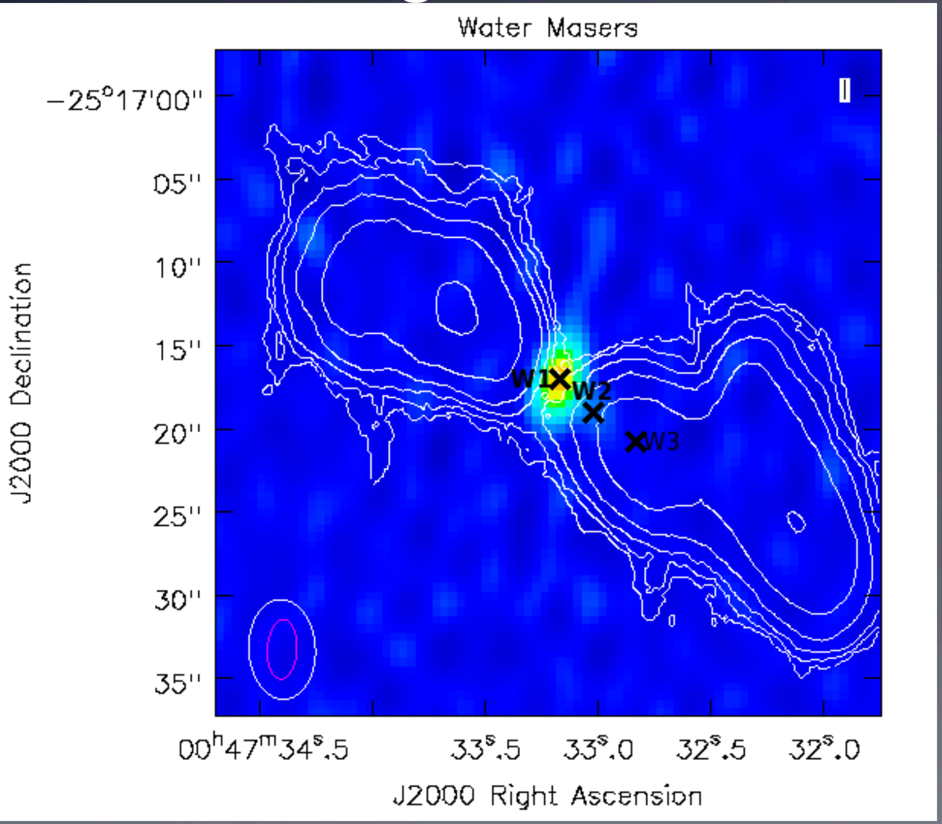


Temperatures

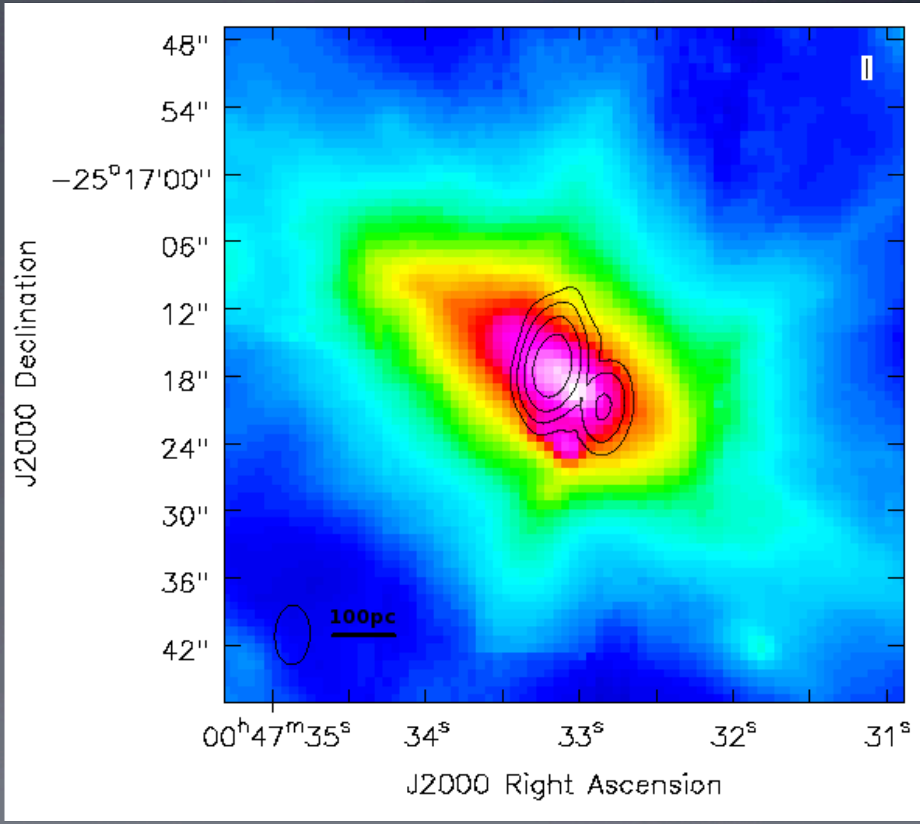


Water Masers

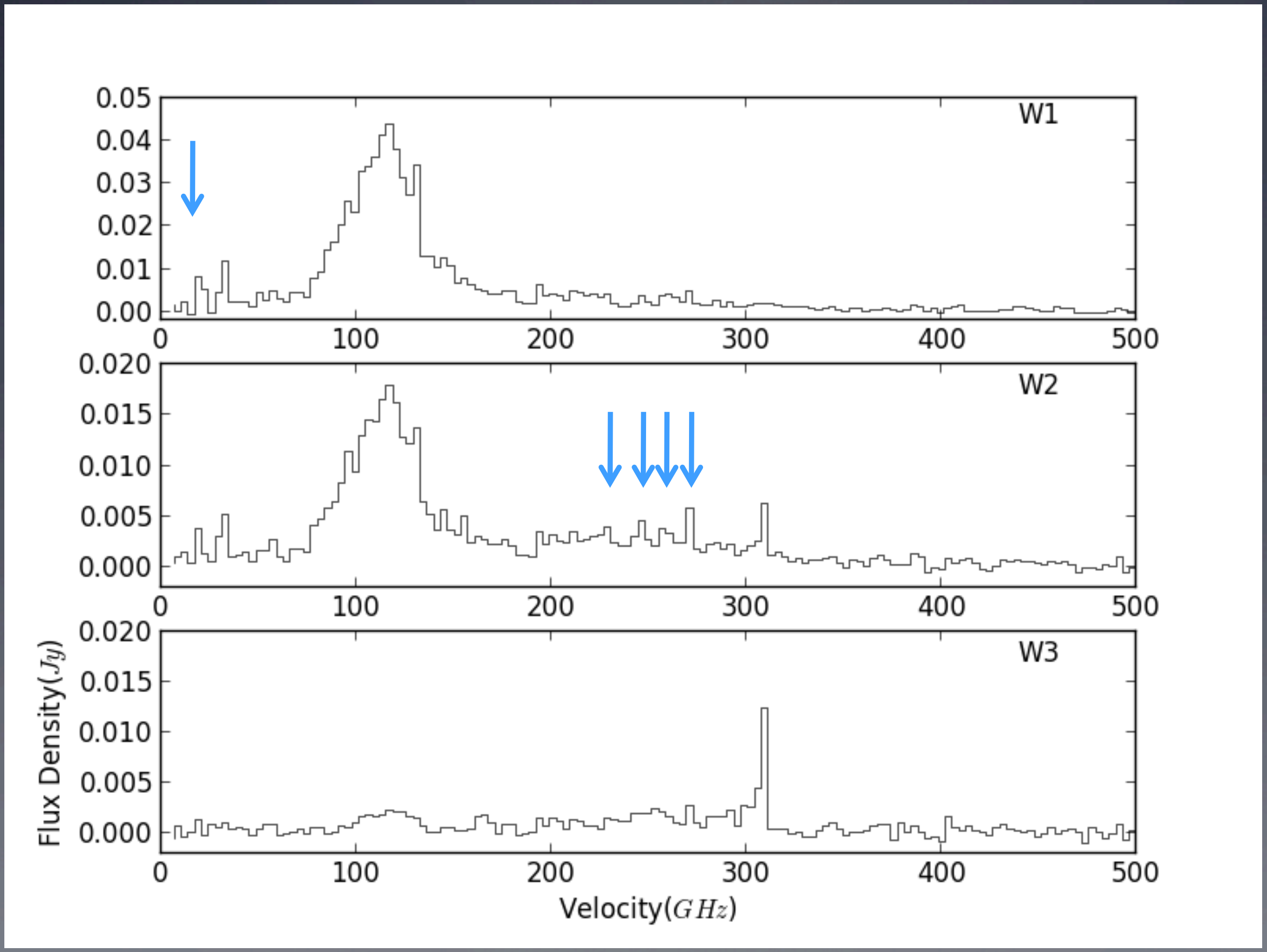
Integrated Flux



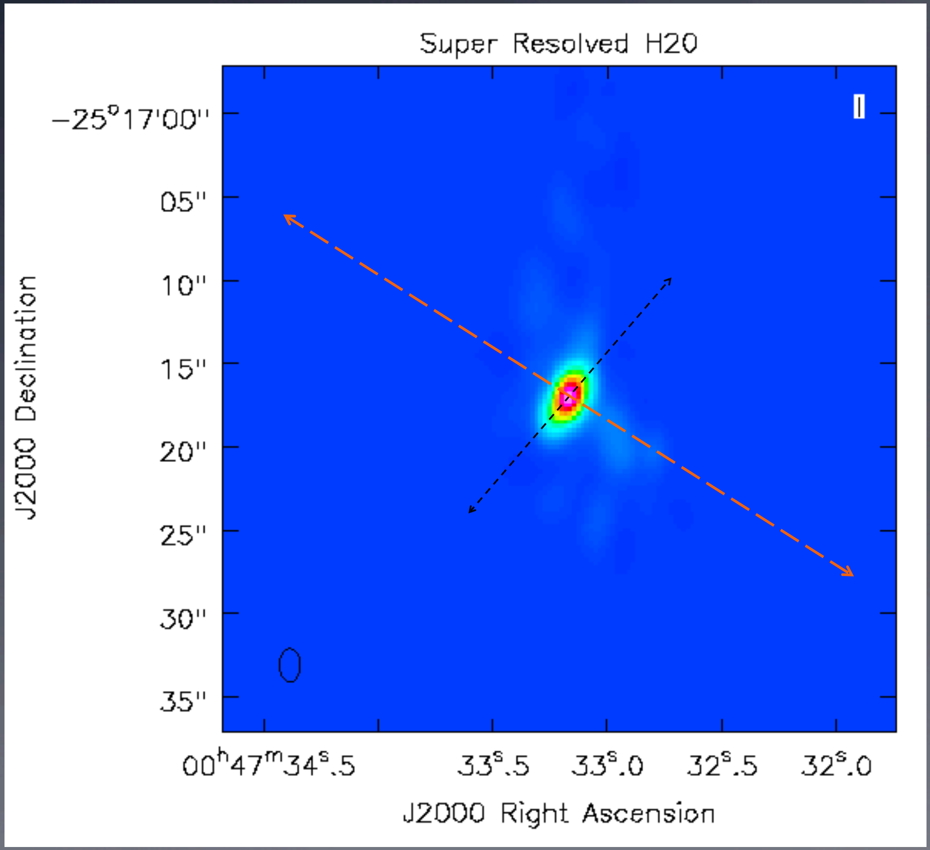
Peak Flux



Water Spectra

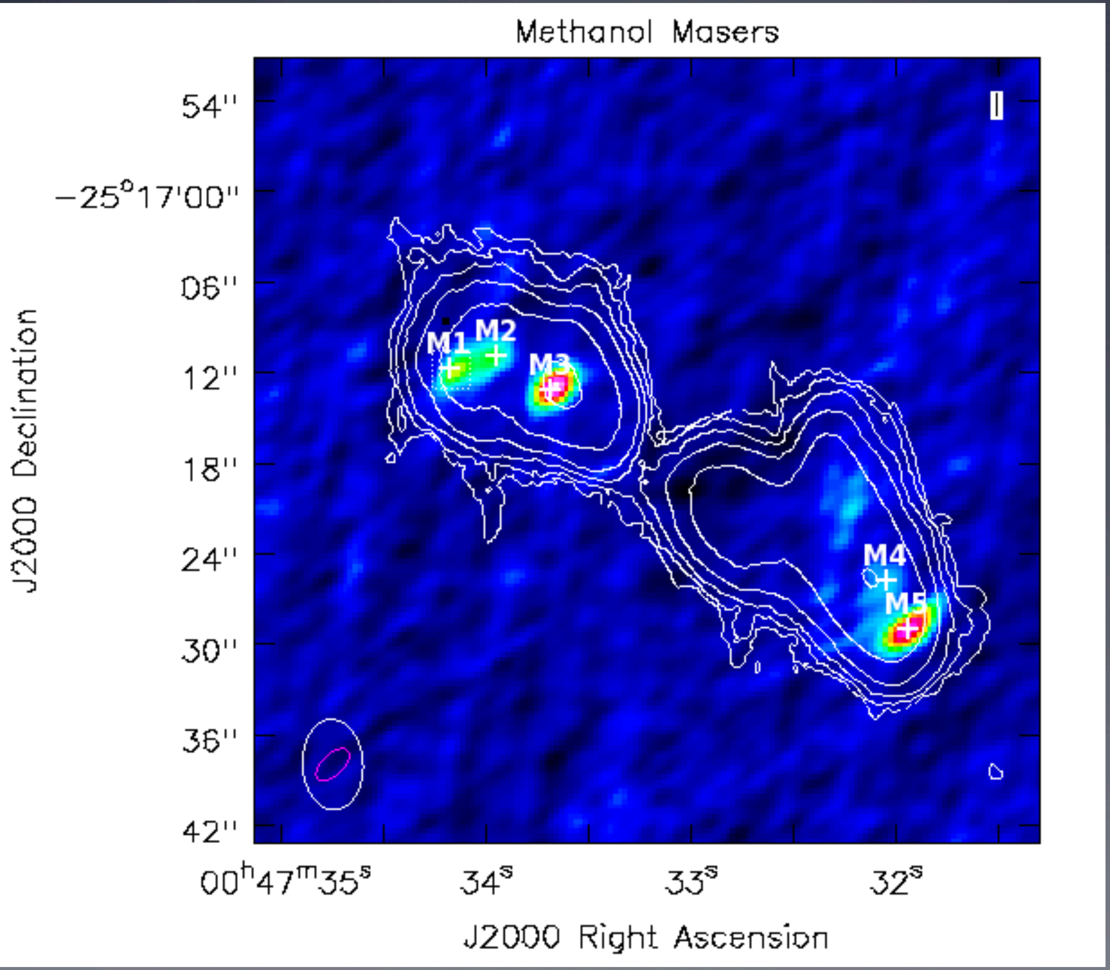


Water Masers

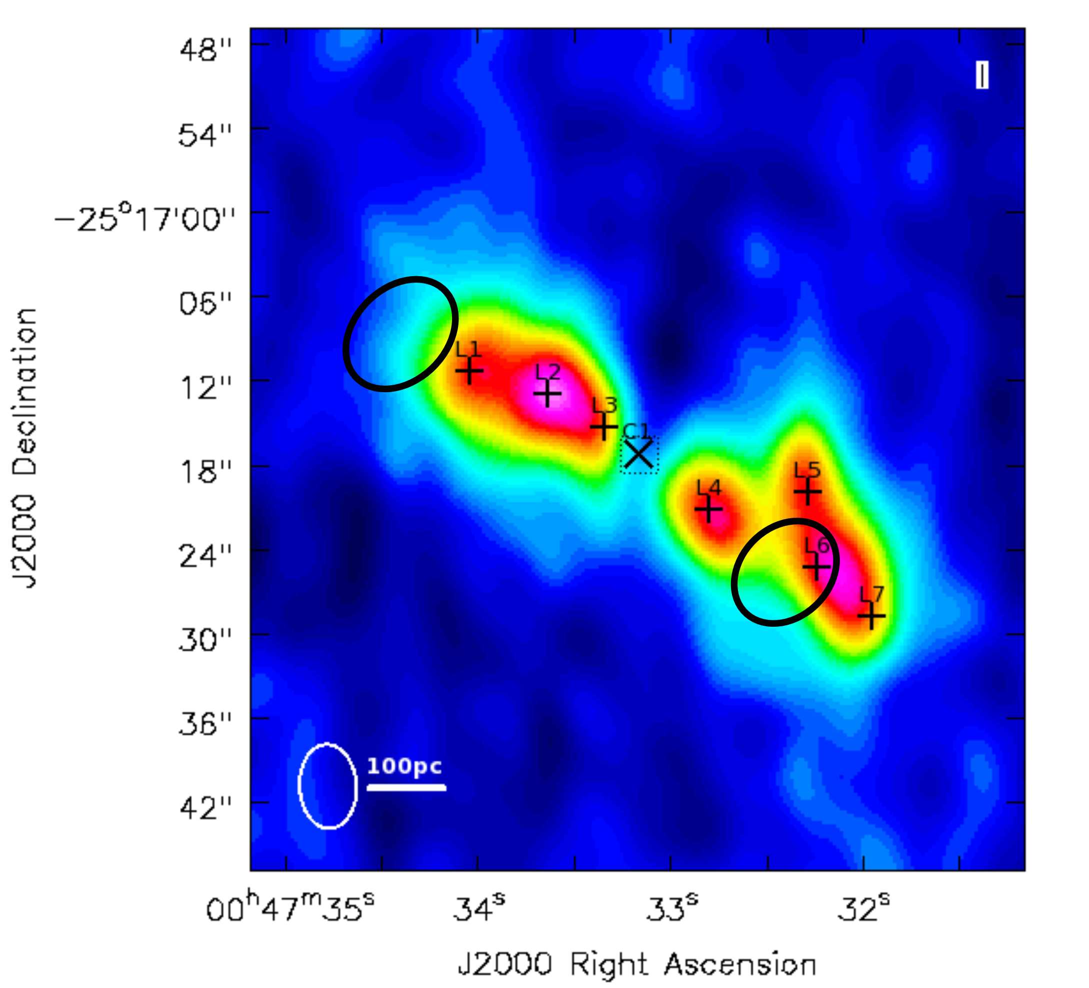


- Super resolved cube 2”x1”
- Extension perpendicular to the bar.
- Dominated by W1
- No resolved velocity Structure
- Likely not an AGN

Methanol

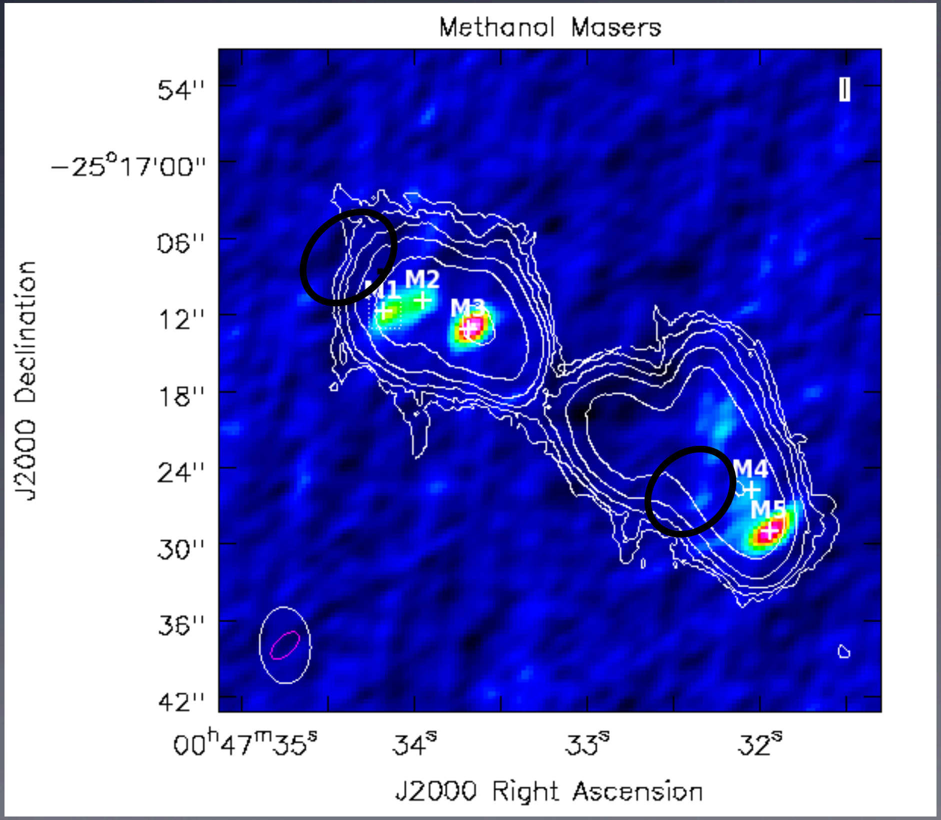

Methanol Masers
54''
−25°17'00''
06''
12''
18''
24''
30''
36''
42''
J2000 Declination
M1
M2
M3
M4
M5
00h47m35s
34s
33s
32s
J2000 Right Ascension

Super Bubbles



- V_{exp}=50 km/s
- ~100pc diameters
- Super Star Cluster or Hypernovae needed for formation
- See Sakamoto et al. 2006

Methanol Masers



- M1 and M2 are seen at the edge of west super bubble
- M4 and M5 are associated with the east Super bubble
- M3 is displaced from the super west super bubble.
- Methanol Mega masers ~1-2$M_{\odot}$

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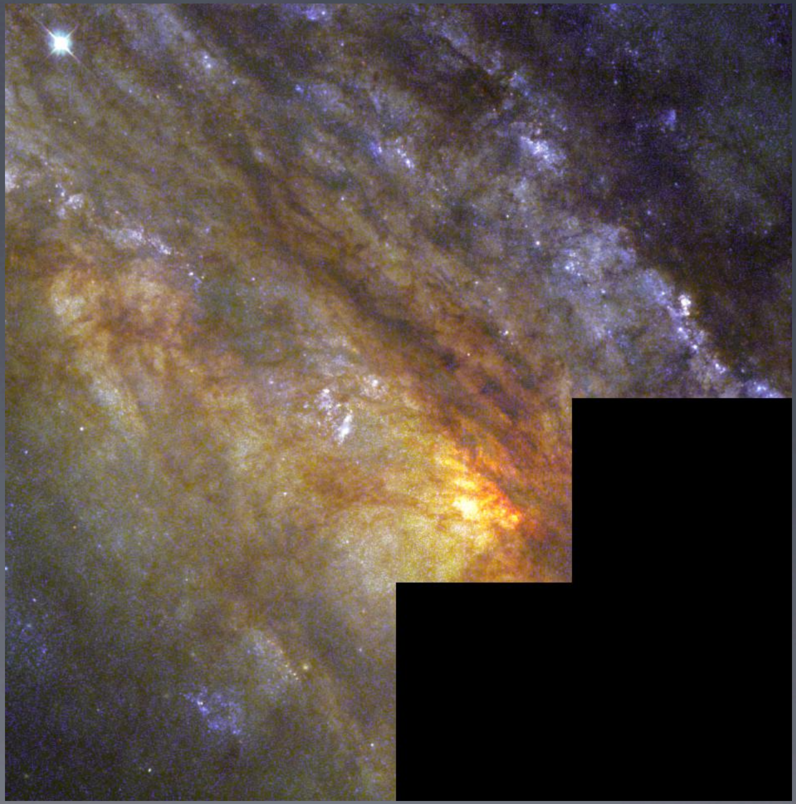
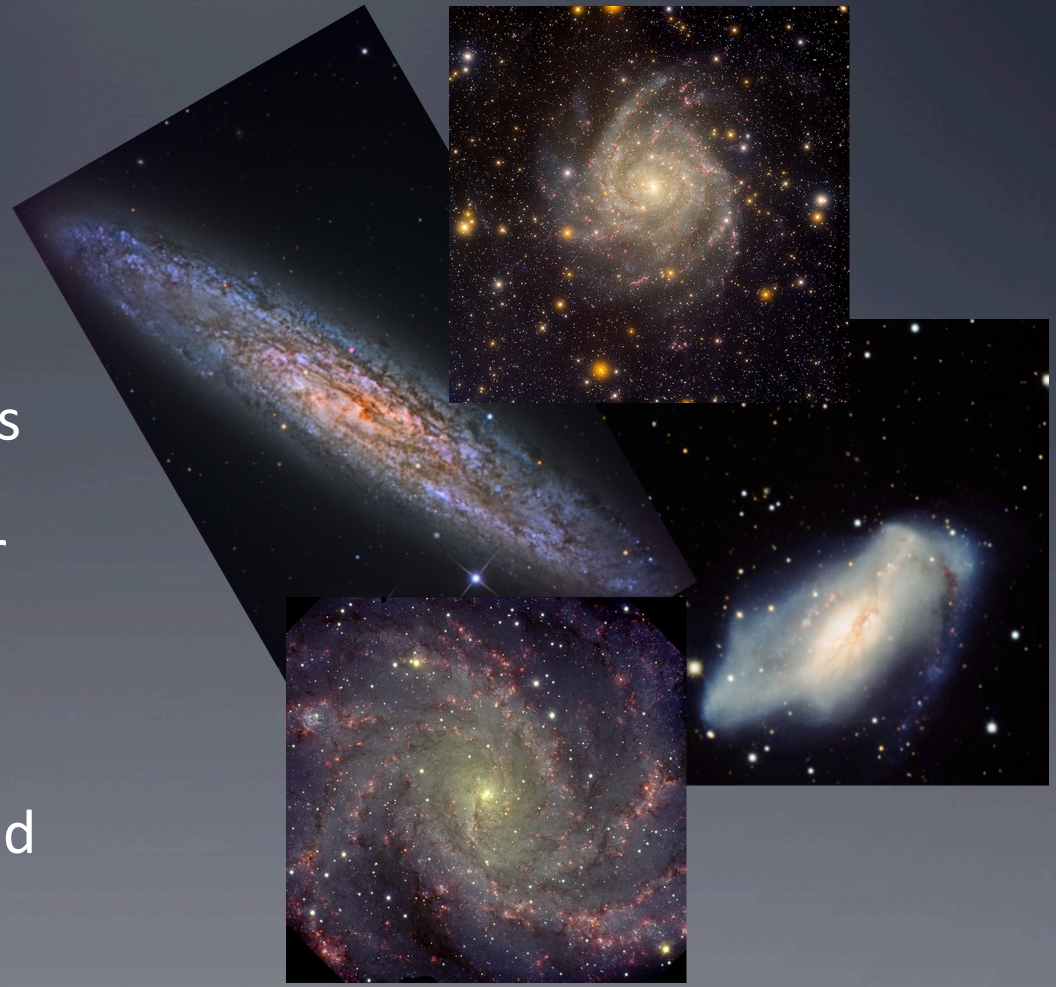
Conclusions

- Dense molecular gas can be described with a single ~130K temperature component
- Masers and high temperature gas associated with most recent star formation.
- 5 new water masers candidates
- Water maser extension seemingly along the outflow. No AGN torus-like velocity components.
- 5 new methanol masers likely associated with shocks in super bubbles.
- No Temperature enhancement associated with super bubble shocks



Future Projects

- Apply the same analysis to the other three galaxies in the sample
- Look for relationships with star formation rates
- Relationships with other structures in galaxies
- Resolved studies of Ammonia, Methanol, and Water Masers




Questions