Molecular Gas & the Nuclear Starburst in NGC 253

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2. The Galaxy Sample and NGC 253
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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

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?

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$_2$O (Water):** 22.2351 GHz,
  - Traces Shocks, collisionally excited maser. YSO, AGB stars, and AGN tori.

- **CH$_3$OH (Methanol):** 36.1639 GHz,
  - Class I maser, collisionally excited, shock tracer.
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<td>Face on spiral</td>
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<td>NGC 6946</td>
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<td>NGC 253</td>
<td>3.5</td>
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<td>Barred spiral, nucleated starburst</td>
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<tr>
<td>NGC 2146</td>
<td>3.9</td>
<td>11</td>
<td>Peculiar barred spiral, LIRG(almost)</td>
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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
- $V_{sys} = 235 \text{ km s}^{-1}$
- Barred spiral galaxy
  - Class: SABc
- Nucleated star burst $\sim 3M_\odot \text{ yr}^{-1}$
- Total SFR $\sim 5M_\odot \text{ yr}^{-1}$
- Molecular outflow rate $\sim 9M_\odot \text{ yr}^{-1}$ (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\(\text{NH}_3(1,1)\)
Ammonia(1,1) & (3,3)
Ammonia Spectra
Ammonia Masers
Temperatures
Temperatures
Water Masers

Integrated Flux

Peak Flux
Water Spectra

![Graphs showing water spectra with velocity in GHz on the x-axis and flux density (Jν) on the y-axis.](image)
Water Masers

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

- $V_{\text{exp}} = 50 \text{ km/s}$
- $\sim 100\text{pc} \text{ diameters}$
- 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 $\sim 1-2M_\odot$
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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