Mapping the 36 GHz Methanol Masers

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What is to come:

- Background
  - What are astrophysical masers?
  - Methanol masers
- Data Collection
- Data Reduction
- Analysis
- Conclusions/Discussions
- Questions
What is a Maser?

- Microwave Amplification by Stimulated Emission of Radiation
- Population inversion
  - More molecules in upper energy states
- Exponential amplification of transitioning molecules
What does this look like?

$E_2$

$E_1$
Astrophysical Masers

- Masers that naturally occur in space
- Emitted radiation has same energy as difference between two states
- Common types:
  - Water: H₂O
  - Hydroxyl: OH
  - Formaldehyde: H₂CO
  - Methanol: CH₃OH
Methanol (CH$_3$OH) Masers

- Many different transitions result in masers
- Locations:
  - Star-forming regions
  - Supernova Remnants
  - Galactic Center
- Two different types:
  - Class I
  - Class II
Class I

- Excited by shocks
- Along outflows from continuum sources
- Common transitions:
  - $J_0-(J-1)_1 A^+$ series
    - $7_0-6_1$ at 44.070 GHz
  - $J_2-(J-1)_1 E$ series
    - $5_2-5_1$ at 24.959 GHz
    - $6_2-6_1$ at 25.018 GHz
  - $J_{-1}-(J-1)_0 E$ series
    - $4_{-1}-3_0$ at 36.169 GHz
Class II

- Located near continuum sources
- Ultra Compact HII regions
- Common transitions:
  - (J-1)$_1$-J$_0$ A$^+$ series
    - $5_1$-$6_0$ at 6.7 GHz
  - E series
    - $2_0$-$3_{-1}$ at 12.2 GHz
- Some have shared energy states with class I masers, so they cannot occur at same locations
  - 44 GHz and 6.7 GHz
What can CH$_3$OH masers tell us?

- Velocity of gas
- Characteristics of gas flow
- Trace shocks
- Star formation
Source Selection and Data Acquisition

- 12 Star forming regions
- Previously detected 36 GHz CH$_3$OH masers
  - Haschick and Baan (1989)
  - Pretap et al. (2008)
- EVLA in D or DnC configuration
- 9 July - 15 August 2010
Data Reduction

- NRAO Astronomical Image Processing System (AIPS)
- Calibration
  - Quasars
  - Self-calibration
- Image cubes
  - Spectral channels
- Located and mapped masers
Data Analysis

- **Velocity**
  - Fixed sky frequency: 36.169265 GHz
  - Convert to LSR velocities
    - NRAO Online Dopset Tool
- **Mapped along with other transitions**
  - 44 GHz
    - Verify various models (temperature and density dependency)
    - Commonalities in excitation conditions
Correlations with other transitions

(0,0) R.A. 18:00:30.4 Dec. -24:04:00.0 (J2000)

The black “X” marks the position of a continuum source we detected. (0,0) is R.A. 23:13:45.0 Dec. 61:27:36.0 (J2000)
SgrB2

- Two pointings (SgrB2 N and M)
- Not much correlation with 36 GHz and 44 GHz

(0,0) R.A. 17:47:20.4 Dec. -28:23:05.0 (J2000)
Some 44/36 GHz overlap; velocity
36 GHz trace the eastern edge of the outflow
Along evacuated cavity
   - NH₃ agreement
Edge of higher density CH₃OH
Interface of molecular material in shocked environments
Conclusions

- Correlations between 36 GHz and 44 GHz
  - 1 source had strong 36/44 overlap
  - 2 sources had moderate correlation
    - 36 GHz masers outnumber 44 GHz
  - 2 sources had only 1 overlap
    - 44 GHz outnumber 36 GHz
  - 1 source had no overlap
  - 4 sources did not have any 44 GHz data

- Density dependency
Future Work

- Find more information on sources of interest
- Gain more knowledge about:
  - Environments in which the masers are found
  - Find commonalities in the sources
  - Class I CH$_3$OH masers
    - Relationships between various transitions
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Questions?