Interferometry of class I methanol masers, statistics and the distance scale

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Methanol Masers

Class I
- Pumped by collisions
- Shocks caused by various phenomena
- Widespread masers: 44 and 36 GHz + others

Class II
- Pumped by radiation
- Close to YSO
- Widespread masers: 6.7 and 12 GHz

“Spots” are often spread out over large area

Compact at arcsec resolution

different transitions of the molecule
Why interferometry?

- Essential to reduce biases
Surveys mentioned in this talk

1. Interferometric survey of southern masers, quasi-simultaneously at 36 and 44 GHz = 2014 paper
   - Only ~23% of emission components detected in both transitions

2. Follow-up of MMB 6.7 GHz masers at 36 GHz
   - Observed l=330-345, partially reduced
   - Many simple sources

3. Blind survey at 7mm (42-44 and 48-49 GHz) = MALT45
   - The survey itself used ATCA as 6 single dishes, but 44 GHz masers were followed up in the interferometry mode
   - Found 42 sources without known maser association
Middle of the 6.7 GHz velocity range often used as an estimate of the systemic velocity

Small but significant mean

High-velocity components are blue-shifted and seen predominantly at 36 GHz

MALT45: velocities of 44 GHz methanol masers vs. various molecular tracers (e.g. CS), $\sigma \sim 1.5$ km s$^{-1}$

36 GHz: mean $-0.57 \pm 0.06$ km s$^{-1}$, $\sigma = 3.65 \pm 0.05$ km s$^{-1}$

44 GHz: mean $-0.57 \pm 0.07$ km s$^{-1}$, $\sigma = 3.32 \pm 0.07$ km s$^{-1}$

Orientation? See the poster by Sobolev et al.
The distribution is well approximated as an exponential decay with $263\pm15$ mpc scale. The class II methanol maser at 6.7 GHz traces the YSO location. The same distribution within uncertainties for 36 and 44 GHz masers. Distance estimate?

See 2014 paper
Spatial spread and near/far distance

Class I masers can serve as a “statistical ruler” to help with near/far distance ambiguity resolution.

Linear offsets are expected to be well below 1 pc.

Larger offsets probably mean that a wrong distance has been assumed.

G329.07-0.31
Distance estimate using class I masers?

- It may be handy for l~0 sources without parallax measurement.
- Mean separation is the scale (263 +/- 15 mpc)
- Does not work very well for distant sources: sensitivity/resolution?
- Number of “spots” can be a problem
- Extension to sources without 6.7 GHz?
More evolved sources (with OH masers) have more spread out class I masers, both spatially and in velocity domain.

MALT45: same trend, although smaller spreads.

MMB 36 GHz follow-up: also simpler sources.
Summary

• Class I masers trace well the systemic velocity
  – Better than the middle of velocity range of associated 6.7-GHz masers
  – The standard deviations for velocity offsets w.r.t. various dense gas tracers are about 1.5 km/s as opposed to about 3.5 km/s for the 6.7-GHz mid-range
  – There seem to be systematic offsets in velocity

• Linear separations of class I maser emission components from associated 6.7 GHz maser follow the exponential distribution with rather good accuracy.
  – Scale is $263 \pm 15$ milliparsecs
  – It can be used to estimate distance (mean linear offset is the scale)
    – with decent number of “spots”, this method is accurate to a factor of two
    – there are problems for distant sources. Not enough sensitivity/resolution?
    – hidden variables, e.g. evolutionary trends?
  – It can help to disambiguate kinematic distance (in reality, far -> near)
Thank you

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