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

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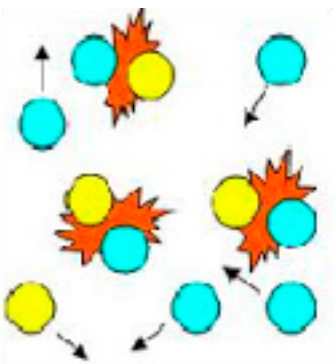
With some help from: S.L. Breen, S.P.Ellingsen and C.H. Jordan

Methanol Masers

different transitions of the molecule

Class I

Pumped by collisions



Shocks caused by various phenomena

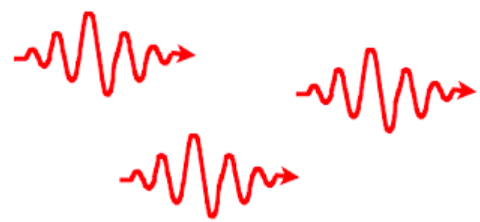
Widespread masers:
44 and 36 GHz + others

"Spots" are often spread out over large area

www.astromasers.org
Methanol MultiBeam Survey

Class II

Pumped by radiation



Close to YSO

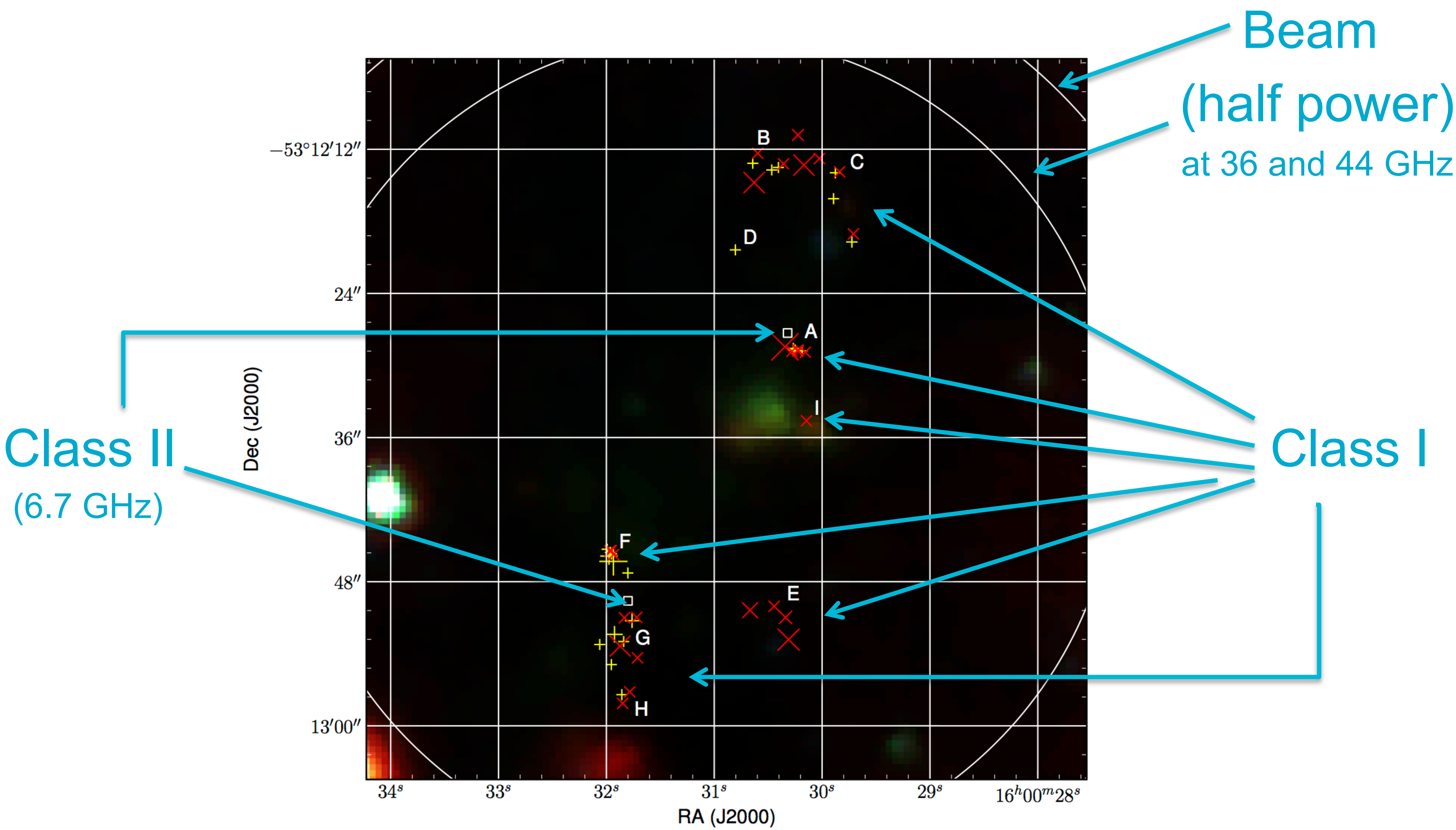
Widespread masers:
6.7 and 12 GHz

Compact at arcsec resolution

Australia Telescope Compact Array

Why interferometry?

- Essential to reduce biases



G329.03-0.20 (from Voronkov et al.; 2014, MNRAS, 439, 2584)

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

(Voronkov et al. 2014, MNRAS, 439, 2584)

② Follow-up of MMB 6.7 GHz masers at 36 GHz

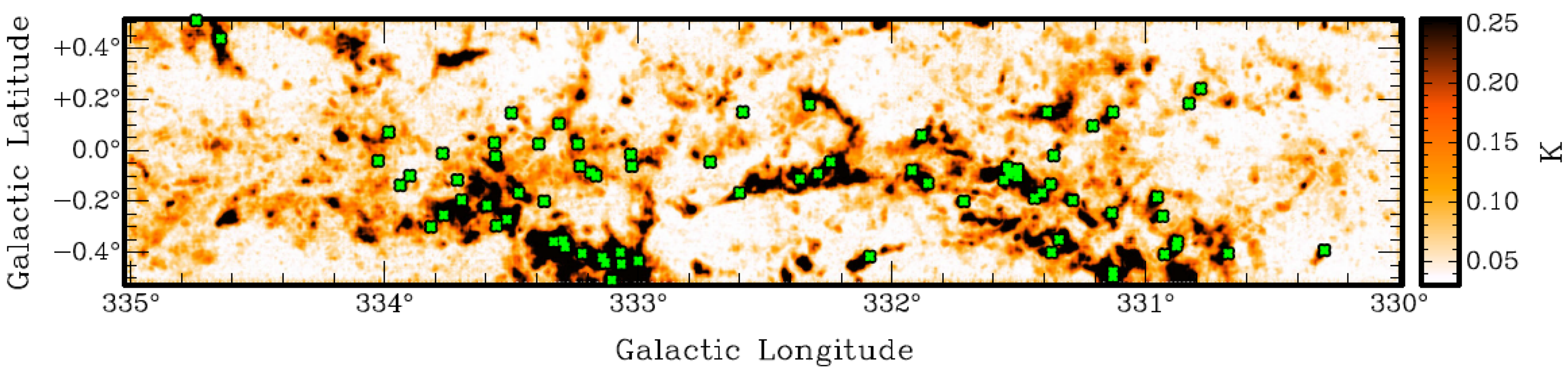
- Observed l=330-345, partially reduced
- Many simple sources

③ Blind survey at 7mm (42-44 and 48-49 GHz) = MALT45

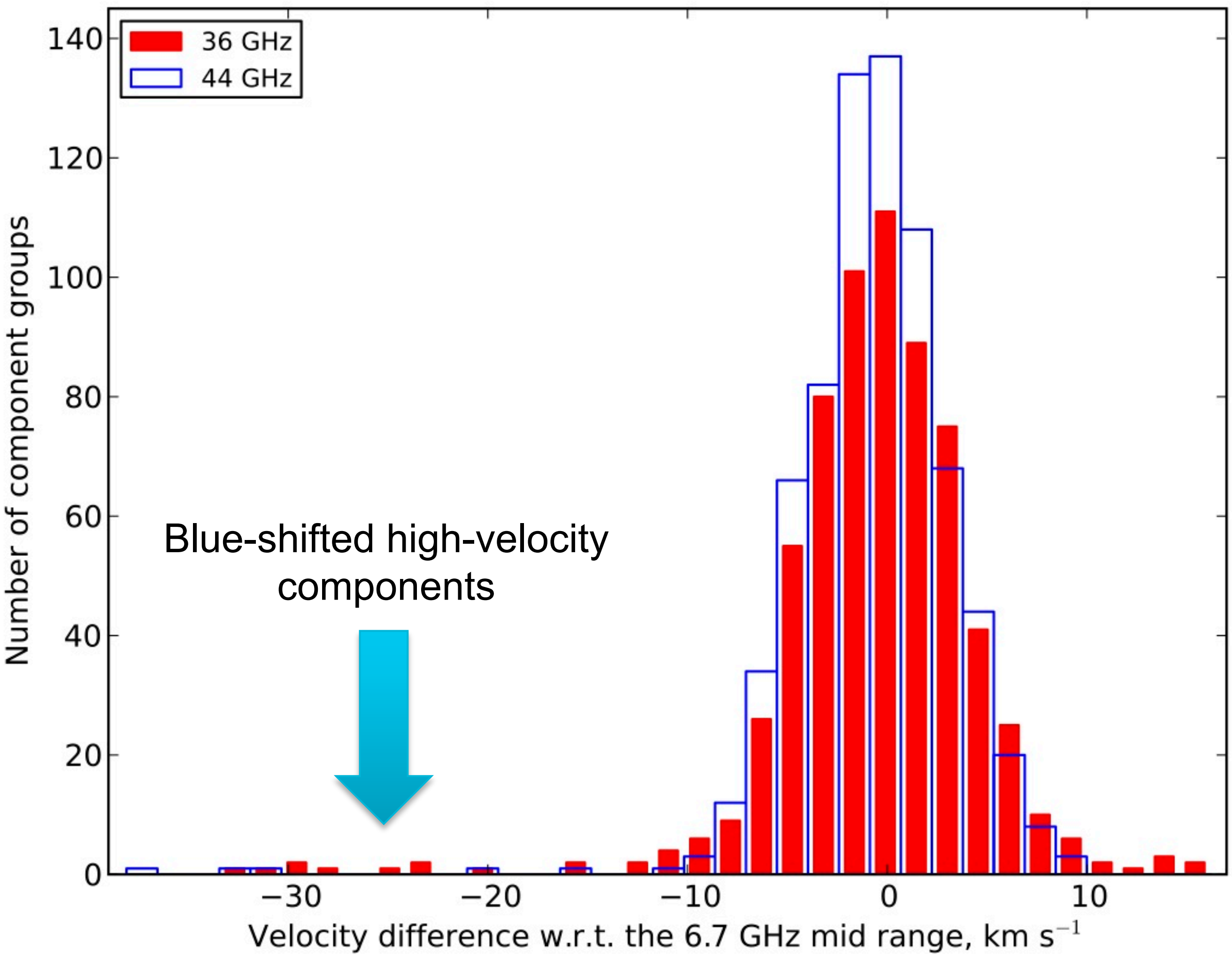
- The survey itself used ATCA as 6 single dishes, but 44 GHz masers were followed up in the interferometry mode
- Found 42 sources without known maser association

+ Shari's talk

(Jordan et al. 2015, MNRAS, 448, 2344 and Jordan et al. 2017, MNRAS, 471, 3915)



Velocity distribution – 2014 paper



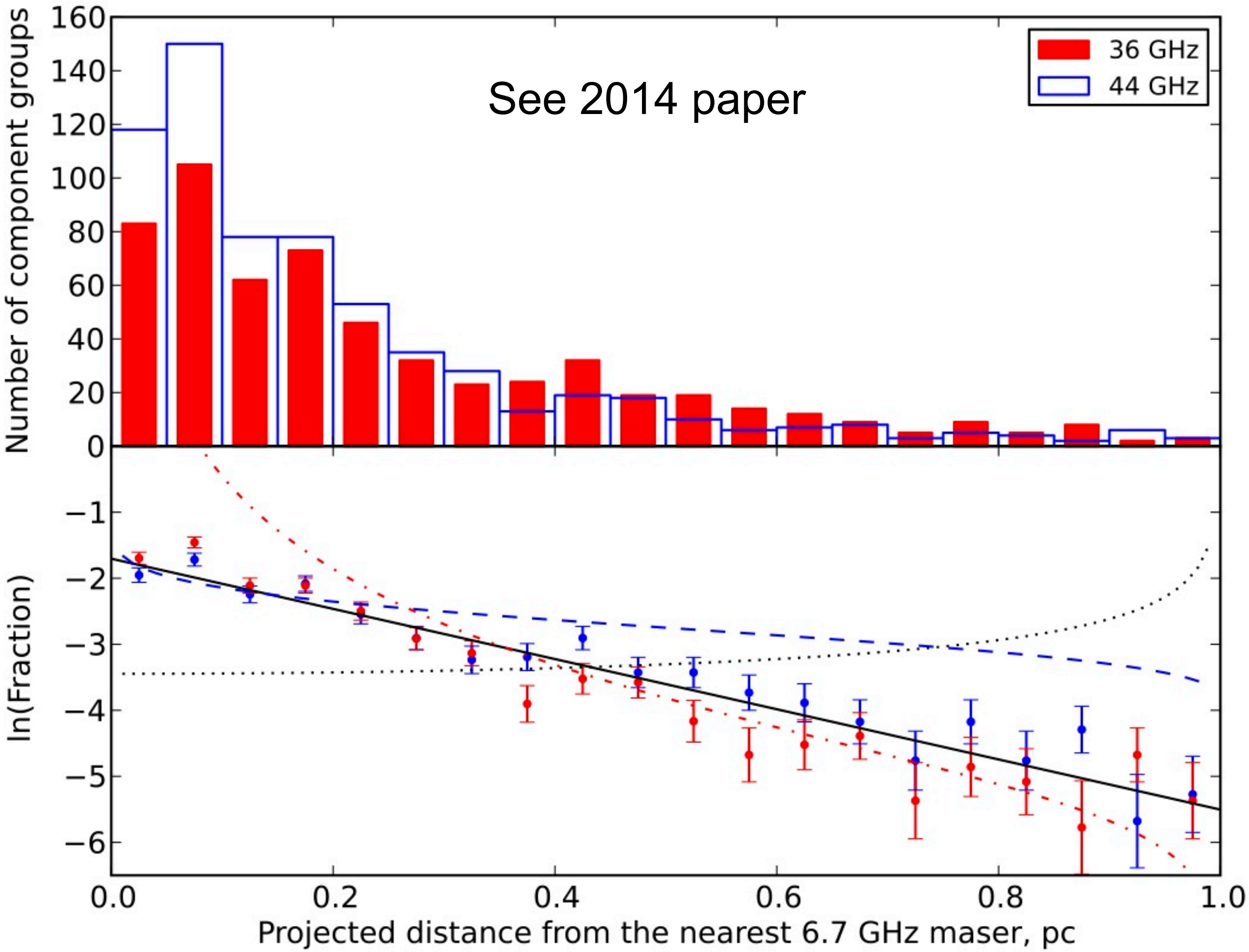
- Middle of the 6.7 GHz velocity range often used as an estimate of the systemic velocity
- Small but significant mean
- High-velocity components are blue-shifted and seen predominantly at 36 GHz

- 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±0.06 km s^{-1}, σ=3.65±0.05 km s^{-1}
44 GHz: mean -0.57±0.07 km s^{-1}, σ=3.32±0.07 km s^{-1}

Orientation? See the poster by Sobolev et al.

Distribution of the separations from YSO



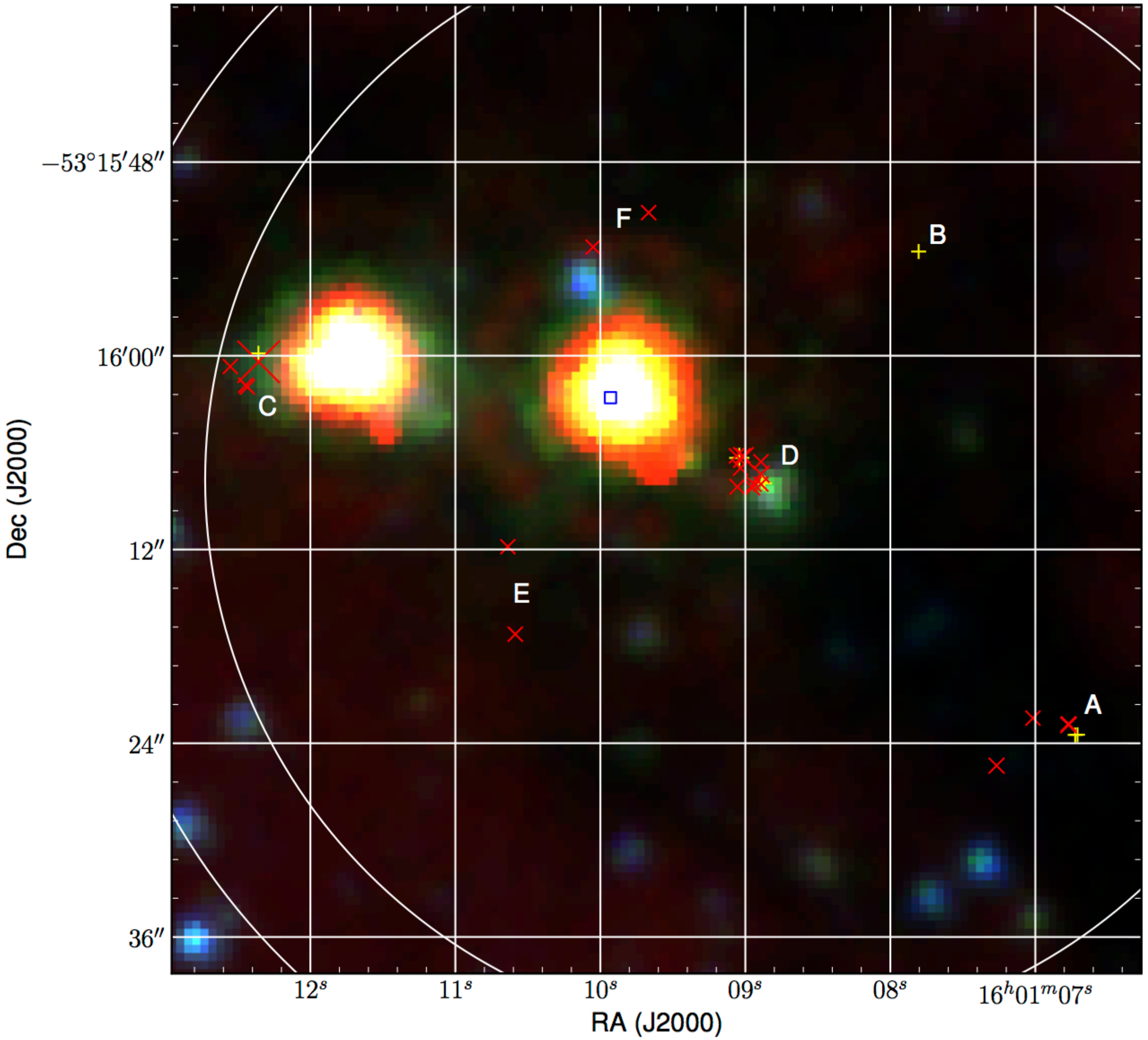
The class II methanol maser at 6.7 GHz traces the YSO location

The distribution is well approximated as an exponential decay with 263±15 mpc scale

The same distribution within uncertainties for 36 and 44 GHz masers

Distance estimate?

Spatial spread and near/far distance



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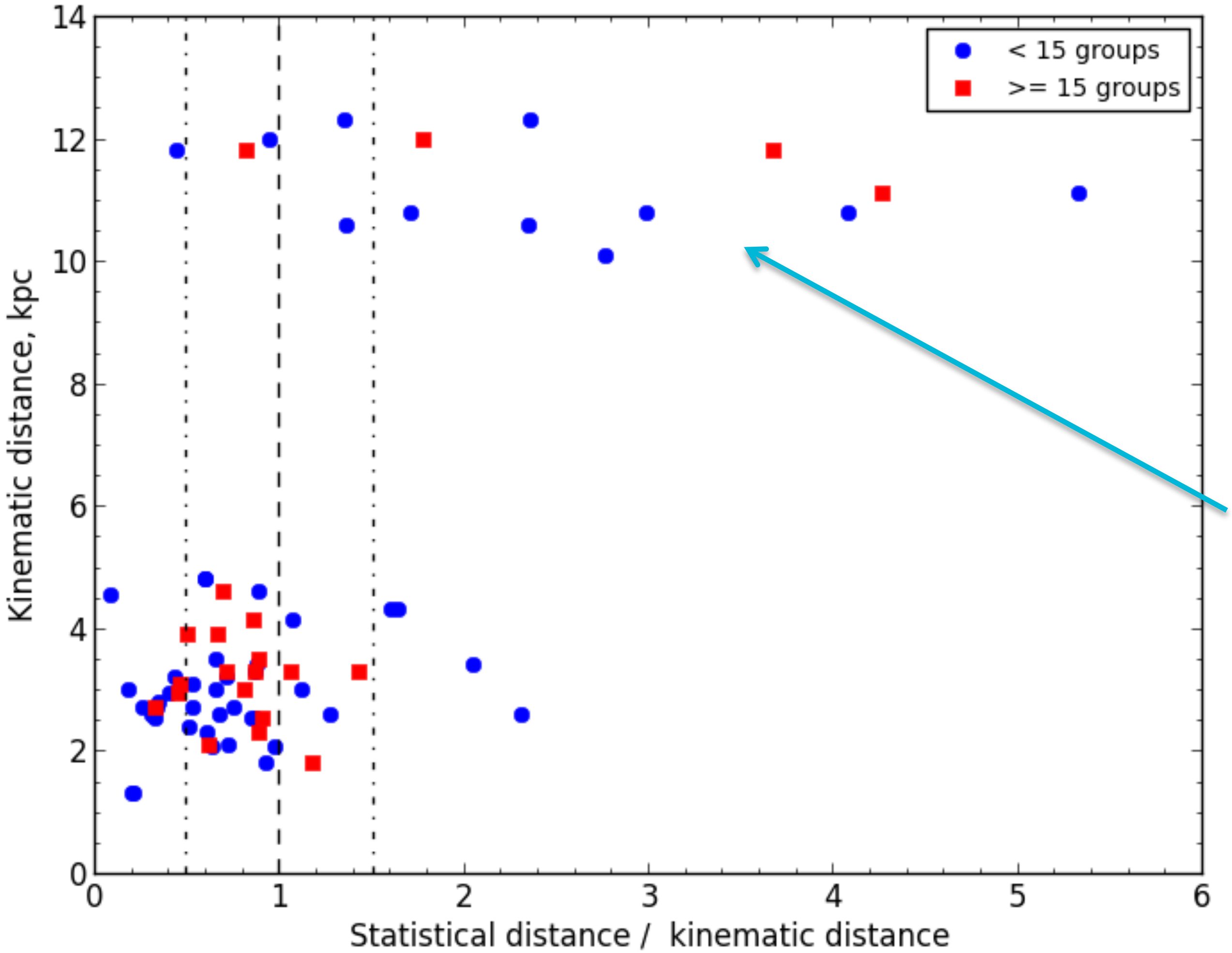
Class I masers can serve as a “statistical ruler” to help with near/ far distance ambiguity resolution

Linear offsets are expected to be well below 1 pc

Larger offsets probably mean that a wrong distance has been assumed

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)

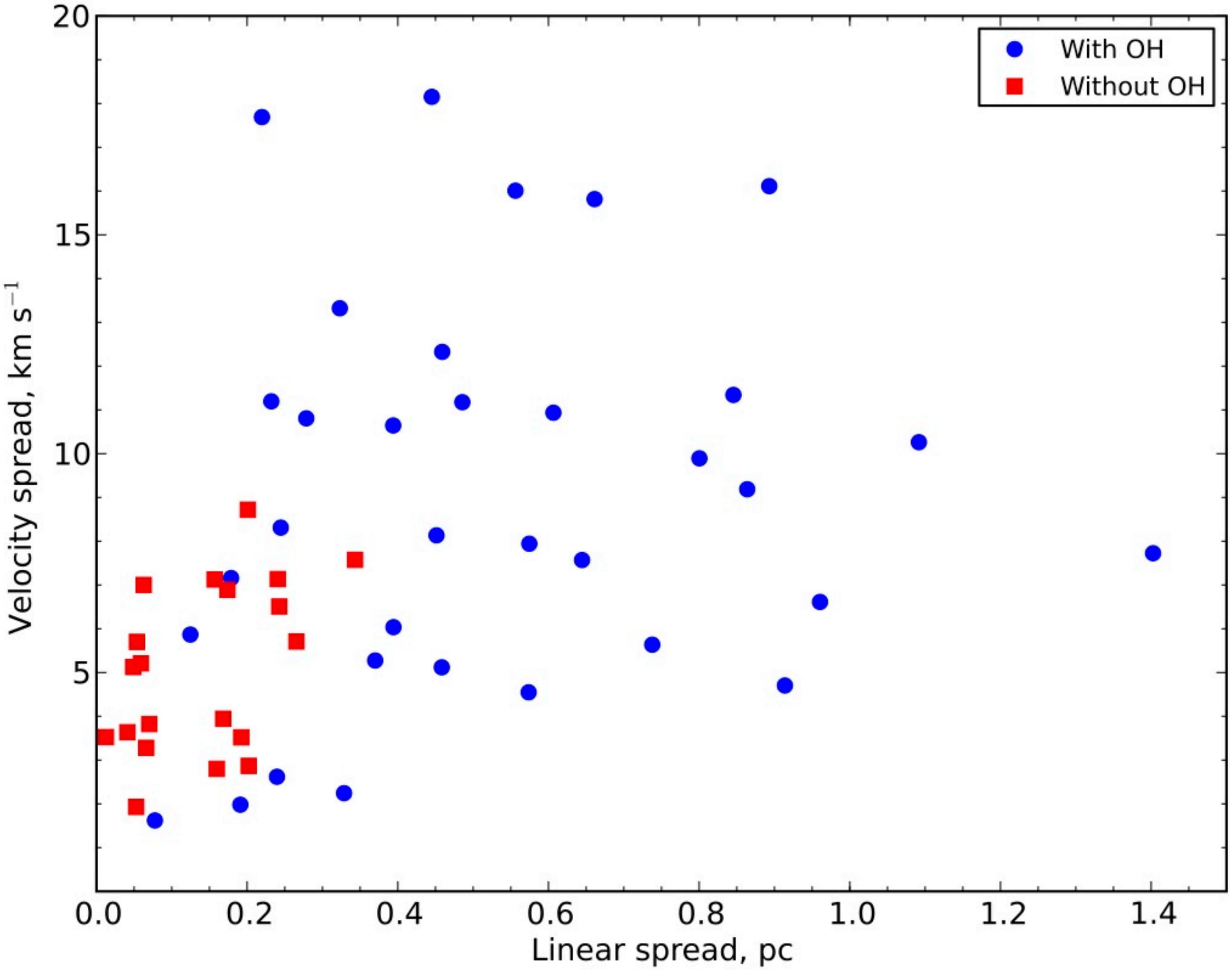
Does not work very well for distant sources:

sensitivity/resolution?

Number of "spots" can be a problem

Extension to sources without 6.7 GHz?

Velocity and spatial spread – 2014 paper



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±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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