Maser Studies with ATCA

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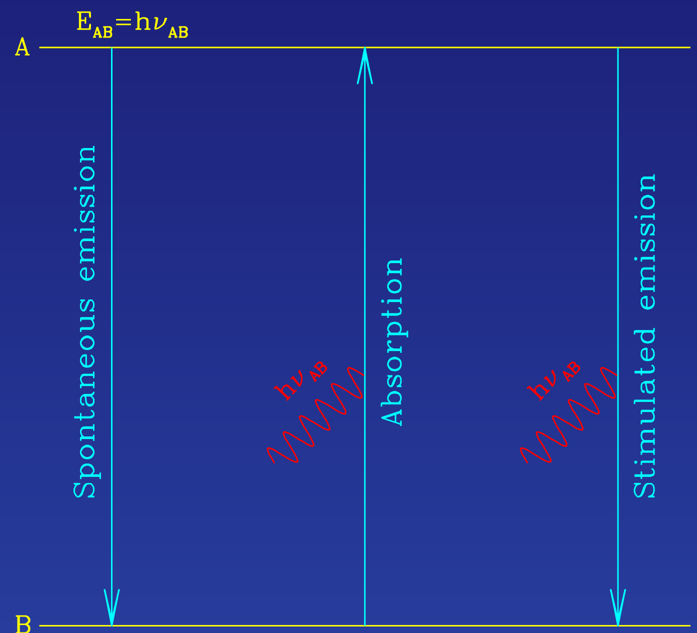
- What is a maser?
  - A spectral line formed under special conditions (population inversion)
  - Strong masers have narrow lines
  - High brightness temperature



- Maser action is possible in a limited number of molecular transitions
- In general, it is harder to create a maser at high frequency (ALMA is unlikely to find many new masers)
- Different masers have different behavior, a presence of the particular maser says something about physical conditions
- Bright masers are often used as tools (e.g. to locate regions of star-formation, to measure the parallax, to be a calibrator source, etc)

Where do we find masers?

- Star-forming regions in our Galaxy
  - High-mass (OH, H_2O, methanol (both classes), a few SiO)
  - Low- and intermediate-mass (OH, H_2O, class I methanol)
- Supernova remnants (OH)
- Late-type stars and circumstellar environment (OH, H_2O, SiO, SiS, probably HCN)
- Extragalactic masers

  (also known as kilomasers, megamasers, etc)
  - Star-forming regions in LMC (OH, H_2O, class II methanol)
  - Late-type stars in LMC (SiO, OH)
  - Star-forming regions in other galaxies (OH, H_2O)
  - galactic nuclei (H_2O)

Molecule	Frequency (GHz)
ethylaldehyde	1.1
hydroxyl	∼1.7
hydroxyl	∼4.8
formaldehyde	4.8
hydroxyl	∼6.0
methanol (class II)	6.7
methanol (class I)	9.9
methanol (class II)	12.2
hydroxyl	∼13.4
silicon sulphide	18.2
methanol (class II)	19.9
water	22.2
ammonia	22.7
ammonia	22.8
methanol (class II)	23.1
methanol (class I)	∼25
methanol (class II)	28.9

Molecule	Frequency (GHz)
methanol (class I)	36
methanol (class II)	37.7
methanol (class II)	38.2
methanol (class II)	38.4
silicon monoxide	43.1
methanol (class I)	44
methanol (class I)	84
methanol (class II)	85.5
silicon monoxide	86.2
methanol (class II)	86.6
methanol (class II)	86.9
methanol (class I)	95
methanol (class I)	104
methanol (class II)	107
methanol (class II)	108
silicon monoxide	128.4
silicon monoxide	130.2

Masers in Galactic SFR: what ATCA can do?

- Observe the Southern Sky!
- Astrometry with an arcsecond accuracy or better

  Required to search for any associations in the crowded environment of (massive) star-forming regions.

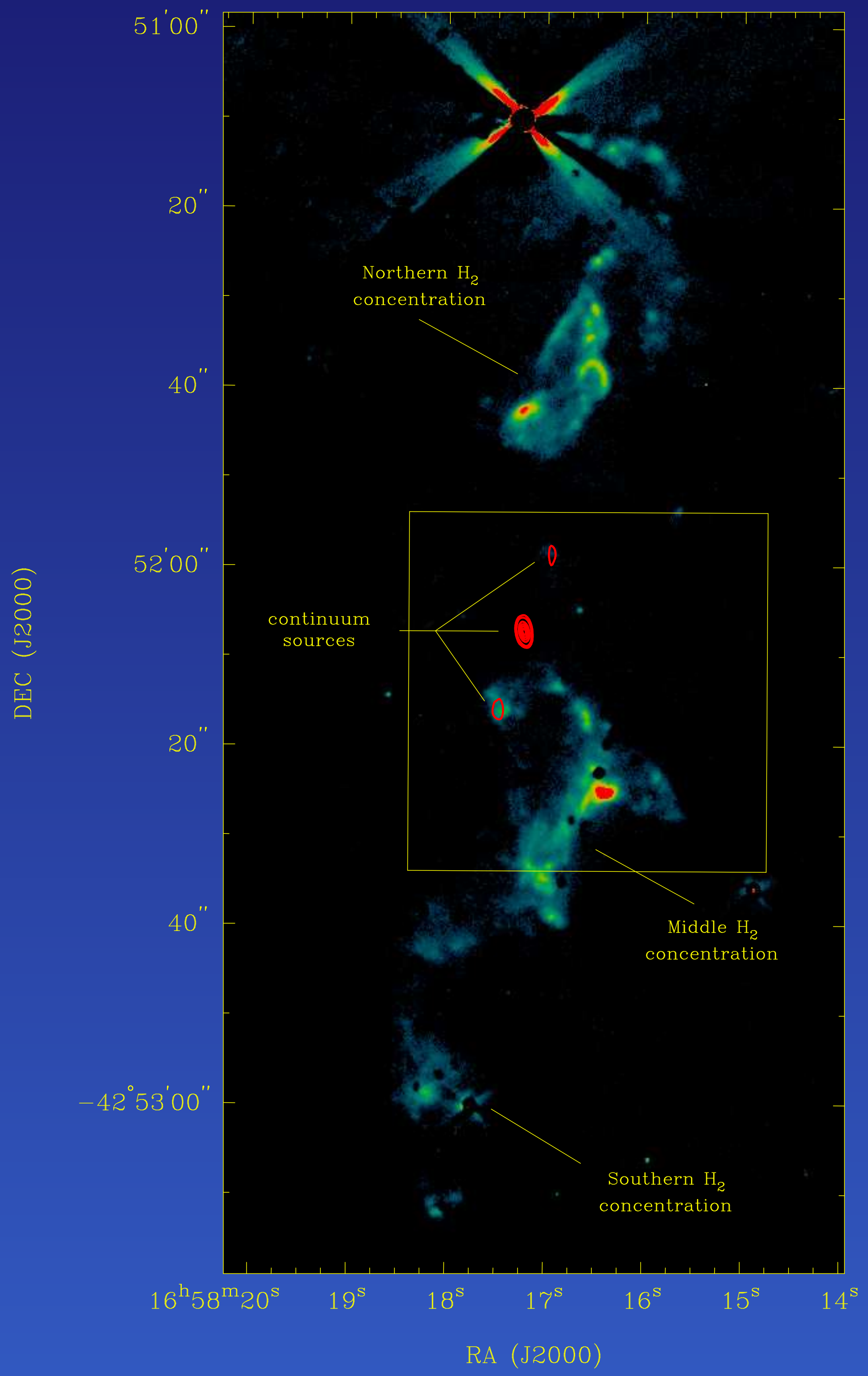
- Surveys (including blind surveys) of various high frequency transitions.

  Mopra can do this as well. However, ATCA can do the job faster and a follow-up is required anyway to get good positions.

- Study of thermal environment of masers

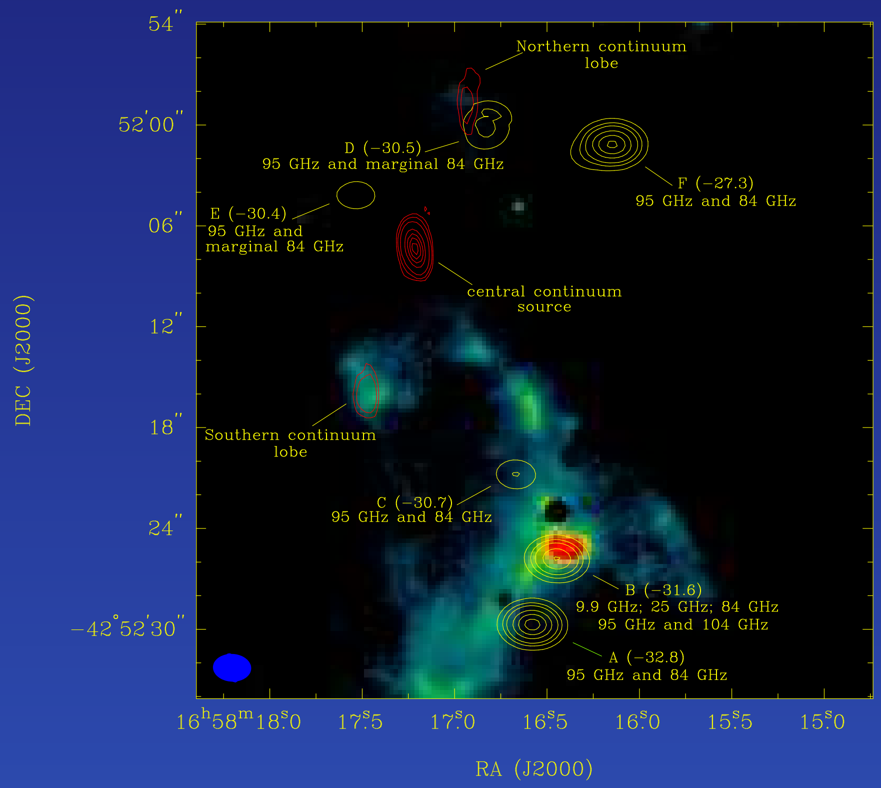
  For example, making images of various outflow tracers.

- Polarisation studies
- Multi-transition studies of the pumping



Astrometry and multi-transition study

G343.12-0.06 (IRAS 16547-4247)



- Not enough spatial resolution to study individual spots in detail
- CABB helps to reduce overheads
- Spectral resolution 0.02 km/s or better

Surveys of Galactic masers

- Currently overheads are very substantial

  Narrow bandwidths are used to get a good spectral resolution, but it results in a small velocity coverage $\longrightarrow$ separate setups for small groups of sources.

- CABB is expected to solve the overhead problem
- High frequency blind surveys can also accommodate thermal lines to study the environment of masers

  However, the uv-coverage can be a problem for thermal lines. In addition, thermal line studies usually require short baselines, while masers would benefit from long arrays. Some tradeoff is possible.

- Polarisation studies

  Neglected in the past (except for OH), as people usually opted for a higher spectral resolution.

Stellar/circumstellar masers and supernova remnants

- Supernova remnants
  - Leave OH masers for ASKAP
  - Searches for other molecules/transitions are possible with ATCA
- Late-type stars and circumstellar masers
  - Need VLBI resolution for detailed study
  - ATCA can be used for searches and monitoring
- Extragalactic masers
  - CABB essentially opens this new field because the bandwidth of the present system is not enough
  - Southern location: more sources
  - Main science: search for objects like NGC4258 for VLBI follow-up
  - Current receiver limits the search of H_2O megamasers up to z=0.4 or so, megamasers at larger z are already known.

Summary

- ATCA was a very productive instrument for maser-related research in the past and will remain such in the future
- CABB will open completely new opportunities (e.g. megamasers, series of transitions) and reduce overheads for types of observations which are possible now
- High spectral resolution modes and frequency coverage are essential
- Suggstions for improvement (in the order of priority)
  - CA06 equipped with a 3mm receiver and movable to the main track
  - Larger hybrid configurations
  - New receivers to close the gap from 10 to 16 GHz
  - Extension of the 3mm band to at least 108 GHz