Tracing High Mass Star Formation Using Methanol and Excited Hydroxyl Masers

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Outline

- Massive Star Formation and the problems
- Masers: methanol & Excited OH
- Masers & Massive Star Formation
- The Methanol MultiBeam Survey – An Update
- Class I Survey: 44 GHz masers & CS (1–0)
- Conclusions

Star Formation

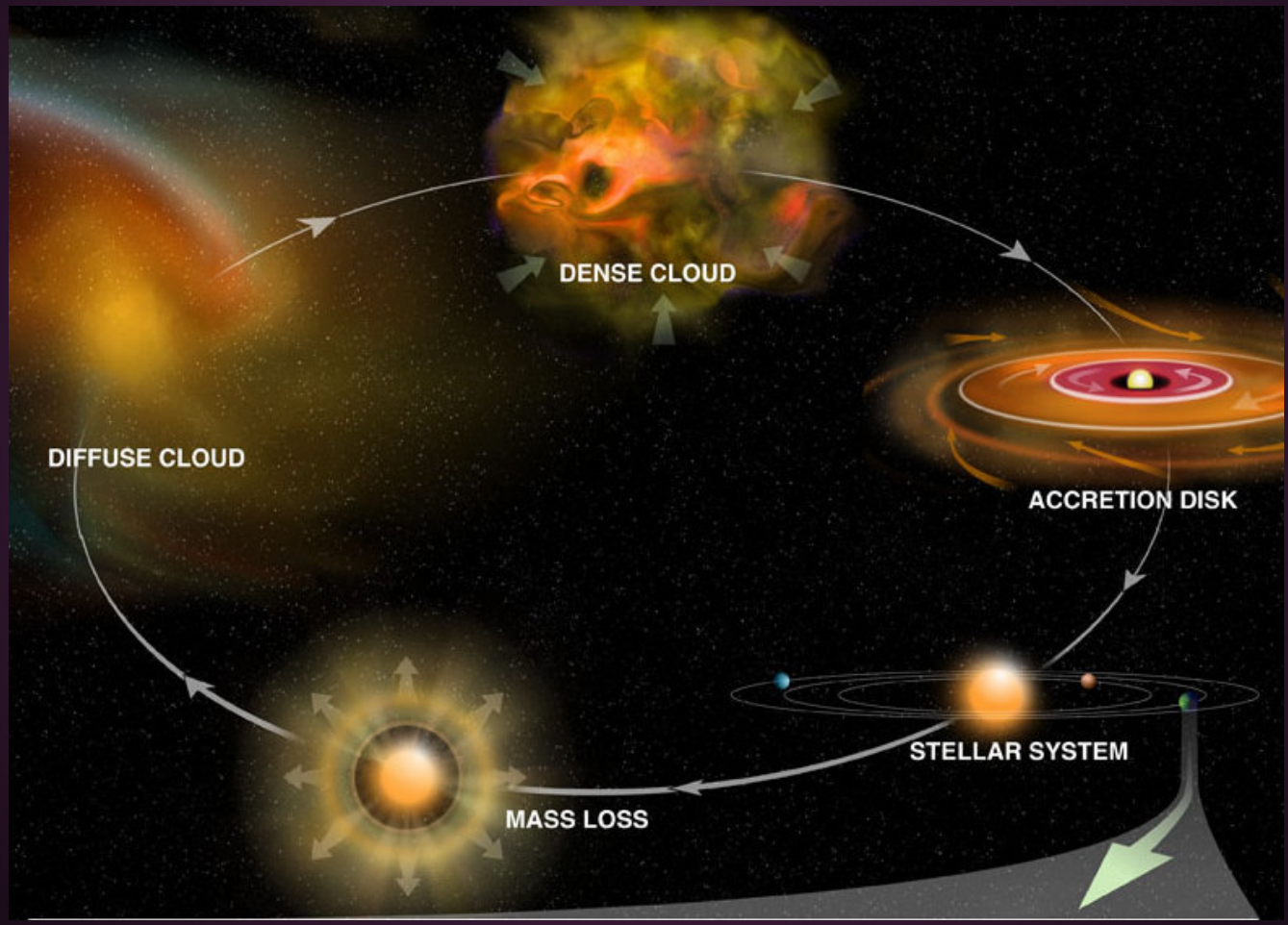


Image credit: NRAO

Star Formation

- We understand low mass star formation however high mass star formation is not yet completely understood.
- Why do we not completely understand massive star formation?
  - Form in giant dust and gas clouds, view obscured
  - Form in clusters – feedback effects
  - Distance at which they form – spatial resolution
  - Relatively short formation and lifetime compared to low mass stars

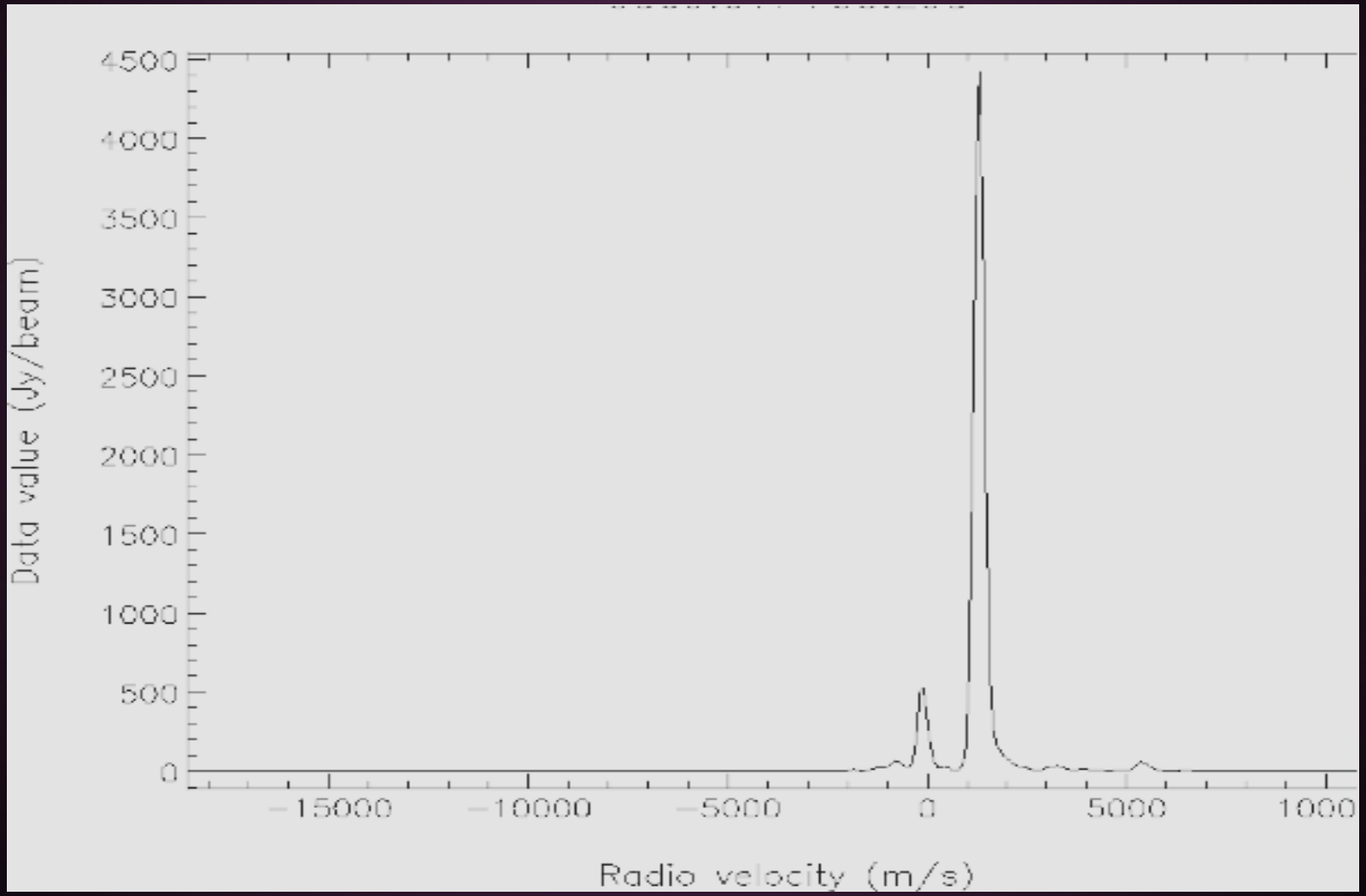
Massive Star Formation – The Problems

Once the core reaches 8 solar masses the radiation pressure exerted from the core is enough to halt accretion. But, we have observed stars as large as 100 solar masses

How do High Mass Stars form?

- increased accretion
- Merging of lower mass protostars

6.7 GHz Methanol Spectrum



Methanol Masers

Two classes of Methanol masers:

Class I: 6.7 GHz, 12 GHz

Radiatively pumped, associated with H_2O, OH masers, submillimeter sources, hot cores.

Class II: 25 GHz, 44 GHz, 95 GHz

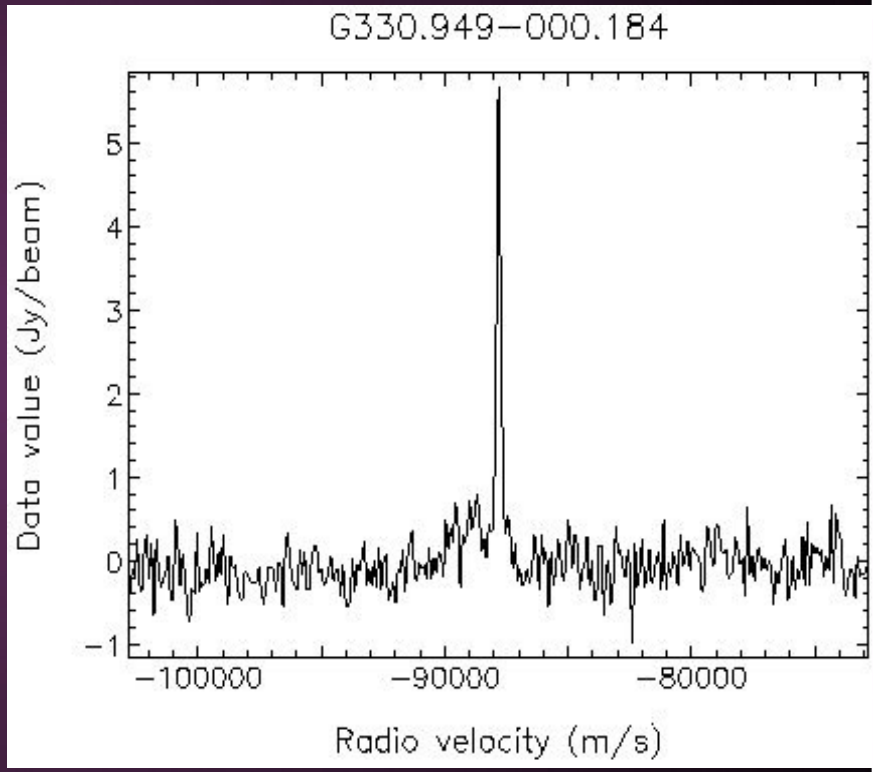
Collisionally pumped, offset from the known centers of star formation and other masers.

6.7 GHz Methanol Maser

- Brightest of the known methanol masers
- Only associated with regions of high mass star formation
- Initially discovered from searches of IRAS sources at sites of UC HII regions– higher resolution imaging shows they are offset
- Minier (2001), Walsh (1998): associated with submm & mm continuum: earlier stage of star formation. Purcell (2007) masers associated with hot cores.
- Evolutionary Sequence?

Excited Hydroxyl Masers

- OH is the most commonly observed maser species
- The 6035 MHz excited OH maser is commonly observed with 6667 MHz CH_3OH maser at sites of massive star formation
- OH masers undergo Zeeman splitting in the presence of a magnetic field resulting in linear and circular polarization – making them an excellent tracer of magnetic fields



Masers and Massive Star Formation

- So far 6667 MHz methanol and 6035 MHz excited OH masers are only observed at sites of massive star forming regions (such as YSOs, hot molecular cores, UCHII regions), making them powerful probes of the regions.
- Masers trace a variety of physical conditions: density, temperatures
- Possible to determine the magnetic fields from the Zeeman splitting in the excited OH energy level transitions

The Methanol MultiBeam Survey

JBCA and the ATNF are currently involved in a galactic survey for 6667 MHz methanol masers and 6035 MHz excited OH masers.

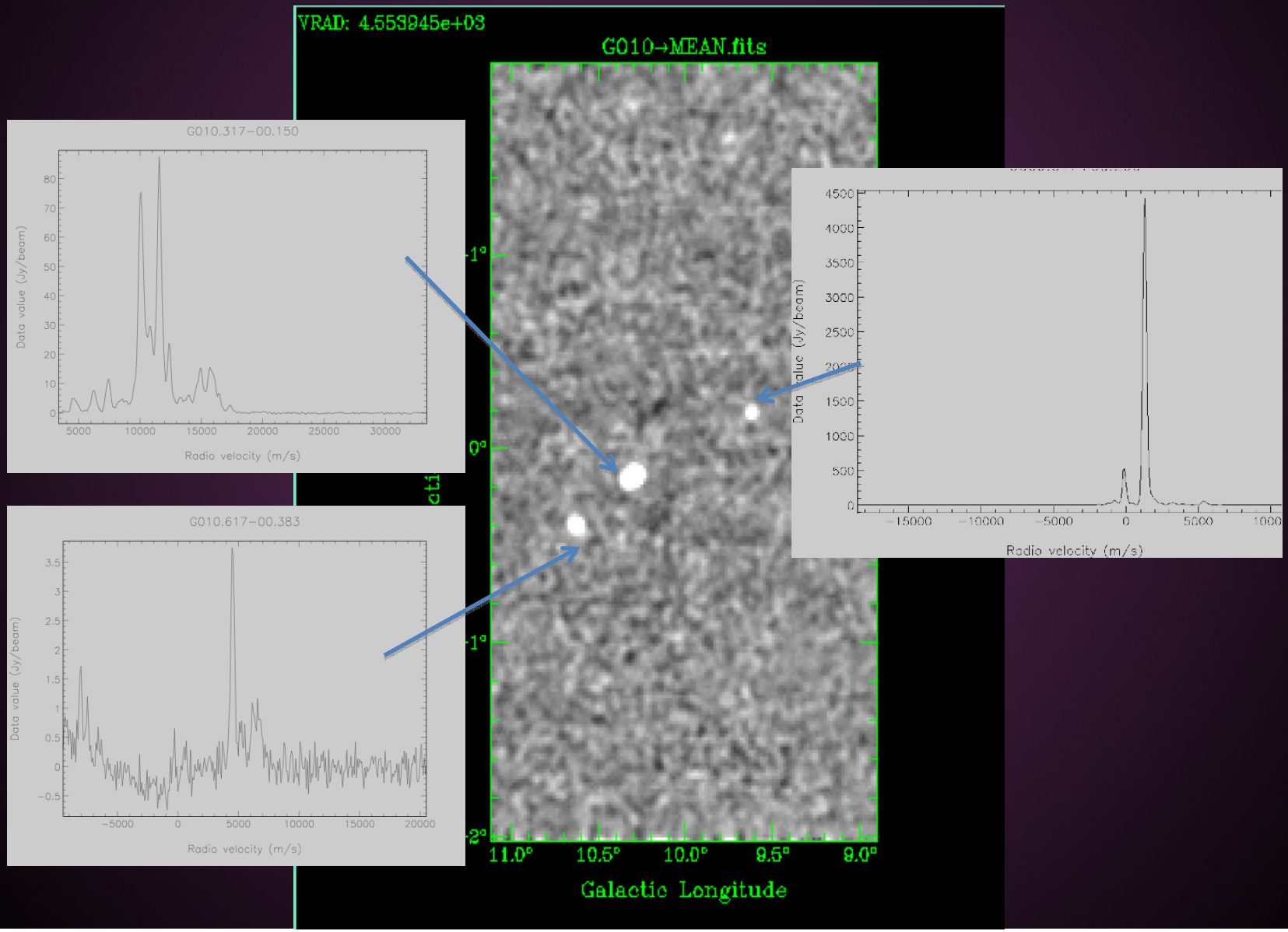
Purposely built 6–7 GHz 7 beam receiver to survey the Galactic Plane

Surveying ±2° in latitude over the full 360° Galactic longitude.

New plans for the receiver to move to the Effelsberg 100m telescope in Germany.

Survey began January 2006

The MMB: Source Detection



The MMB: Initial Results

- The survey is over 90% complete in the southern hemisphere after 111 days of observations.
- 865 methanol masers have been observed with 373 being new detections of high mass star formation regions
- Over 120 excited OH masers have been detected with 35 being new detections
- All masers will be followed up for interferometric positions using ATCA, MERLIN, VLA
- All methanol positions are also being followed up for 12 GHz methanol masers using Parkes telescope
- All 6035 MHz maser positions will be followed up for 6030 MHz excited OH masers.

Class I Survey: Motivation

An unbiased survey for Class I 44 & 36 GHz methanol masers.

Ellingsen 2006: compared GLIMPSE colours of the exciting sources to Class I and Class II methanol masers:

Compared colours of Class II methanol maser sources with and without Class I masers.

Sources with Class I masers are redder GLIMPSE colors: Class I ➔ younger objects

Class I Survey: Motivation

Pratap 2008:

Unbiased survey of Molecular Clouds for 44 GHz and 36 GHz Class I methanol masers.

Sources with 36 GHz emission stronger than 44 GHz show no sign of NIF or centimeter radio continuum. Those with 44 GHz appear more evolved – showing UC HII and mm continuum emission

Ratio of intensities of 36 GHz line to the 44 GHz line gives an evolutionary status of the exciting source.

Agrees with modelling:

36 GHz appear at temperatures <100K

44 GHz appear at 80–200K

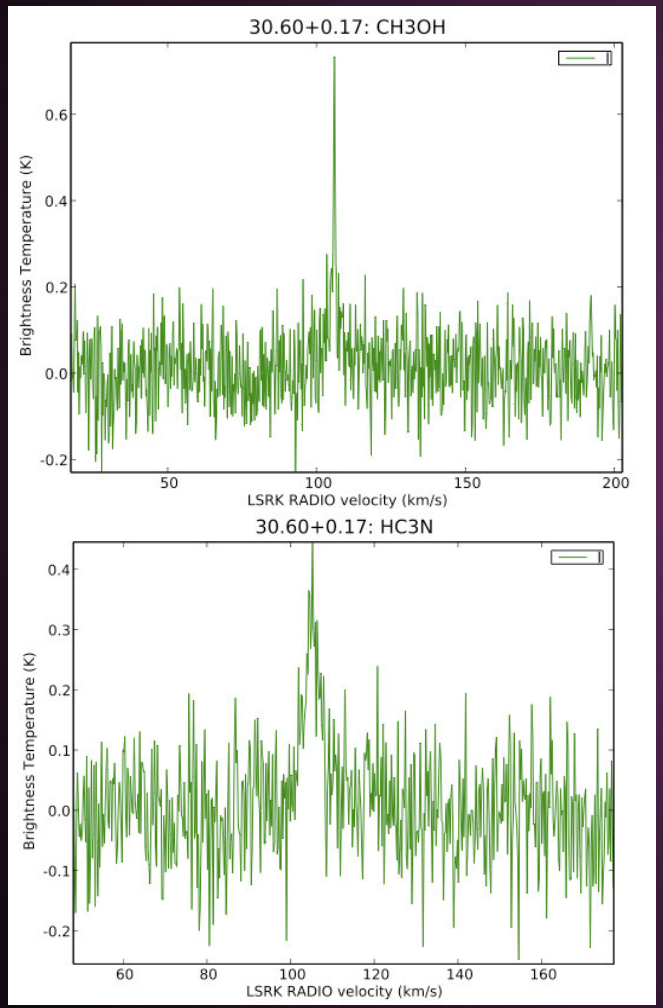
Class I Survey

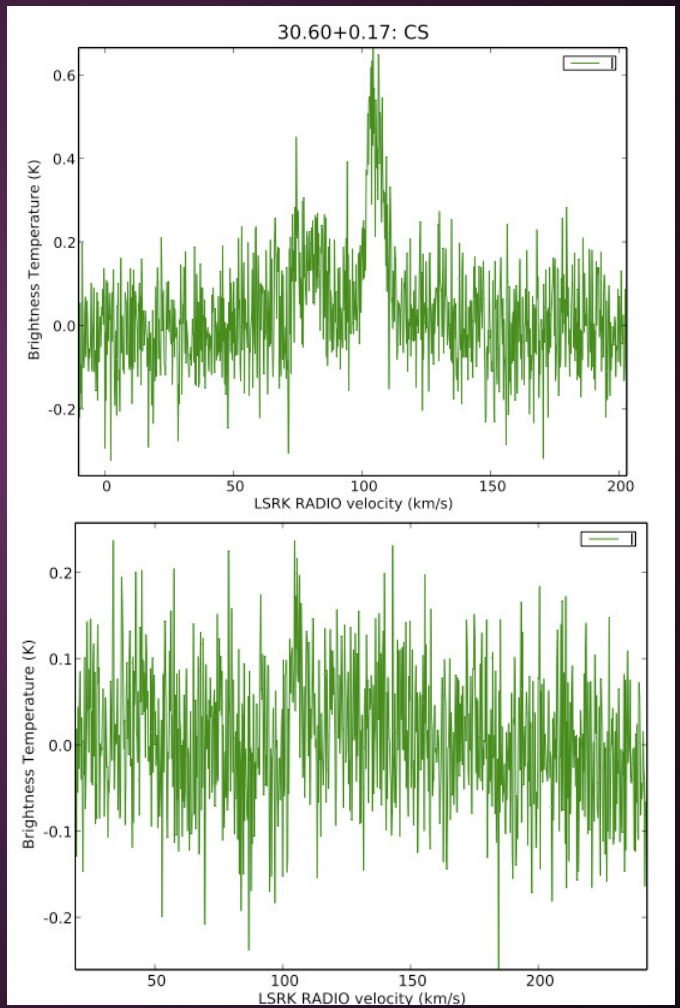
Surveyed under 1 sq degree of the Galactic Plane
|b| <0.25° 29.85° ≤ l ≤ 31.85° using the new MOPRA 7mm receiver over 11 days Oct 2008 + 7 days in Jan 2009

Surveyed for 44 GHz and will follow up all 44 GHz sources for 36 GHz emission

All 44 GHz detections followed up with ATCA and VLA

Class I Survey: Mopra Capabilities





Class I Survey: Initial Results

Definite 44 GHz masers: 25 (~ 16 have 6.7 GHz associations)

Possible 44 GHz masers: 31

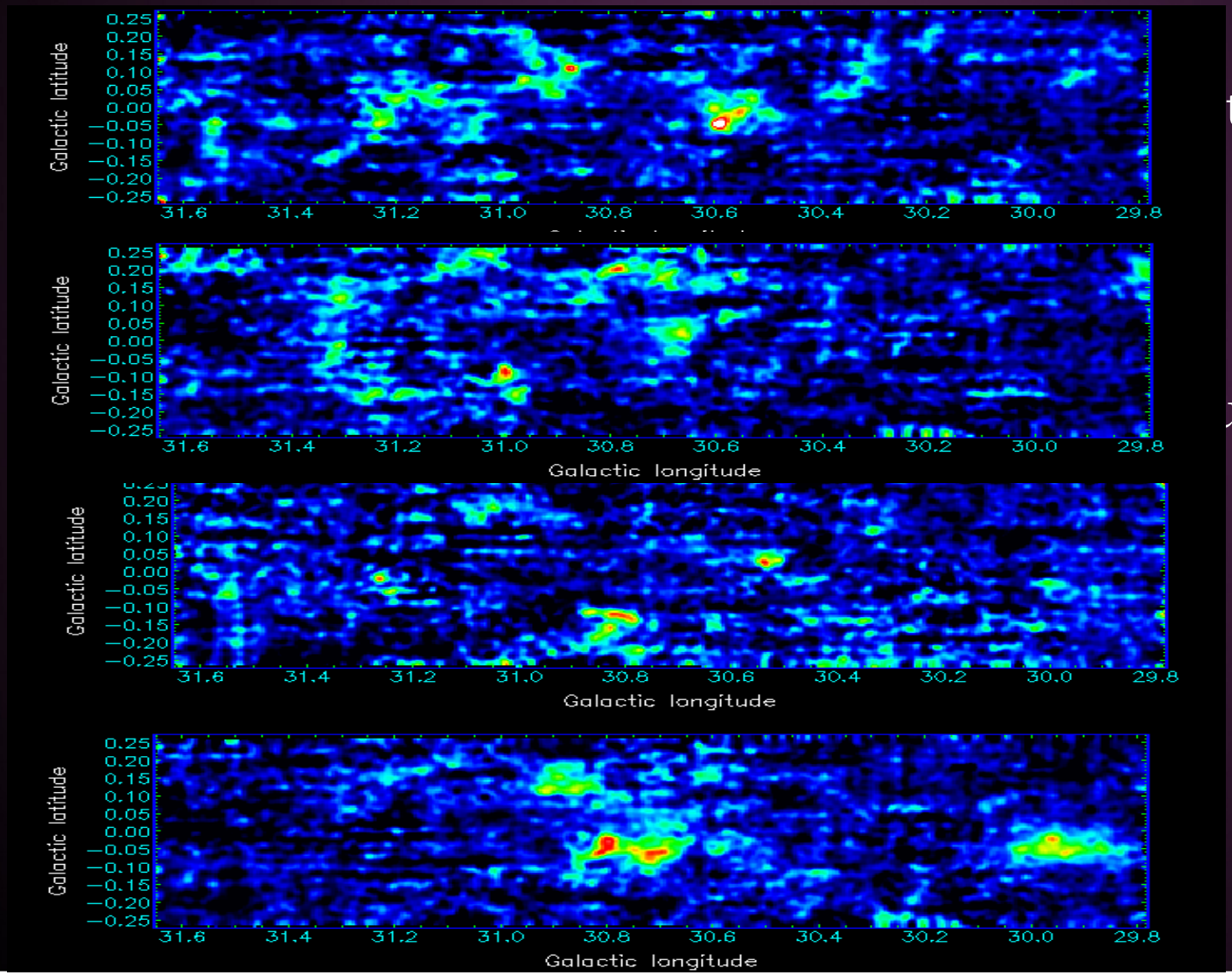
Class II 6.7 GHz masers in same region: 35

Future: re-observe possible 44 GHz

observe all 44 GHz sites for 36 GHz

Using ATCA follow up all 44 GHz positions

Class I Survey: CS (1–0)

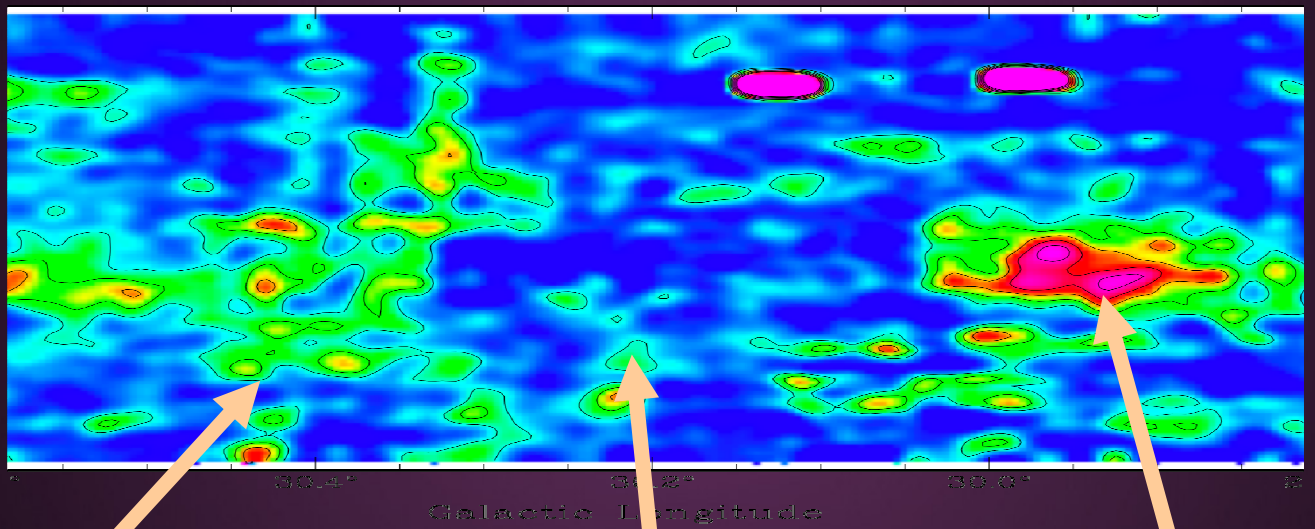


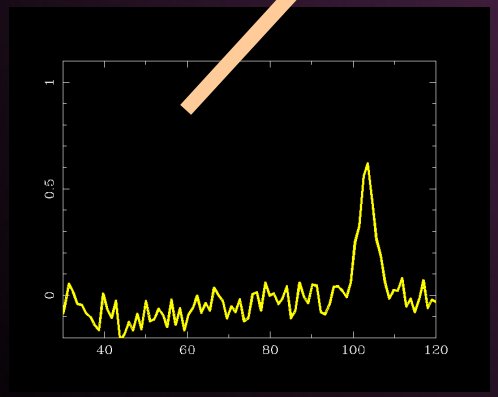
tegrated intensity showing various CS molecular clouds.

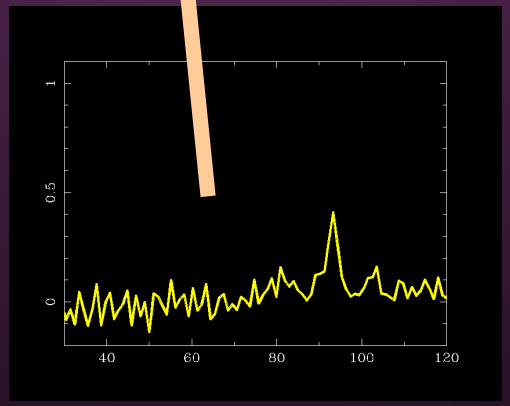
urrently experimenting with smoothing and clump–finding techniques

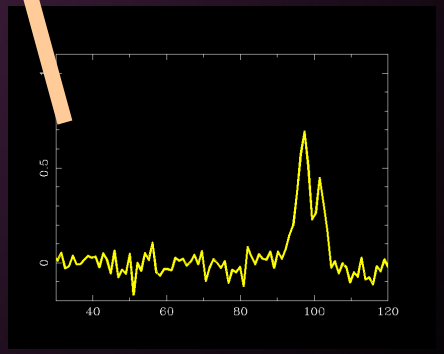
Class I Survey: CS (1-0)

CS(1-0) integrated intensity from 36 to 116 km/s









Conclusions

- Masers are a powerful probe of areas of MSF
- Completion of MMB Survey in Northern Hemisphere & release of first results (soon….)
- MMB: first unbiased statistically complete 6667 & 6035 MHz catalogue
- Completion of Class I Survey: 44 GHz, 36 GHz work and ATCA follow–up:
  - Do the results compare with Pratap 2008?
    Is there an evolutionary Sequence?