The Impact of Interferometry on the Detection of Large Molecules

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ALMA basics:

Angles: resolution of ALMA

$$\theta('') = 0.2\ \lambda(\mathrm{mm})/\mathrm{baseline(km)}$$

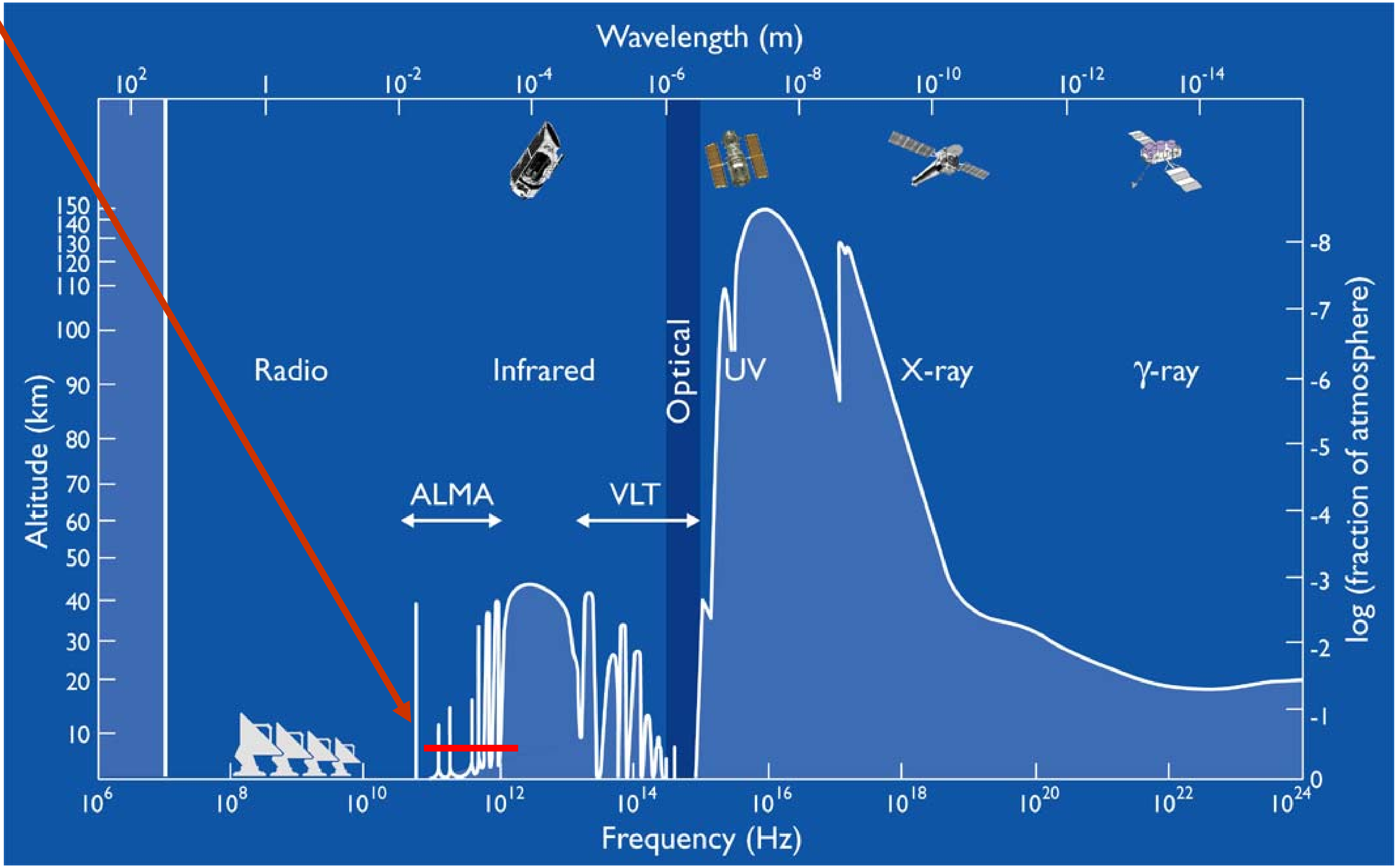
(at λ=3 mm, baseline 150m, θ=3.5'')

For 50 antennas+ACA, λ=3 mm,, ΔV=3 km s^{-1}, 1^h on get ΔT_{RMS}=4.0 mK, S_ν=0.5 mJy

(*Sensitivity calculator for 12m dishes)*:
http://www.eso.org/projects/alma/science/bin/sensitivity.html

Opacity of the Atmosphere

In mm, sub-mm, need an excellent site



VLA Compact Configuration

Inner part of the compact configuration of the Very Large Array.
(Note the large separation between dishes).

BIMA: ten 6m antennas, A_g=283m^2

OVRO: Six 10.4 m antennas, A_g=510m^2

Plateau de Bure: Now with six 15m antennas: A_g=1060 m^2

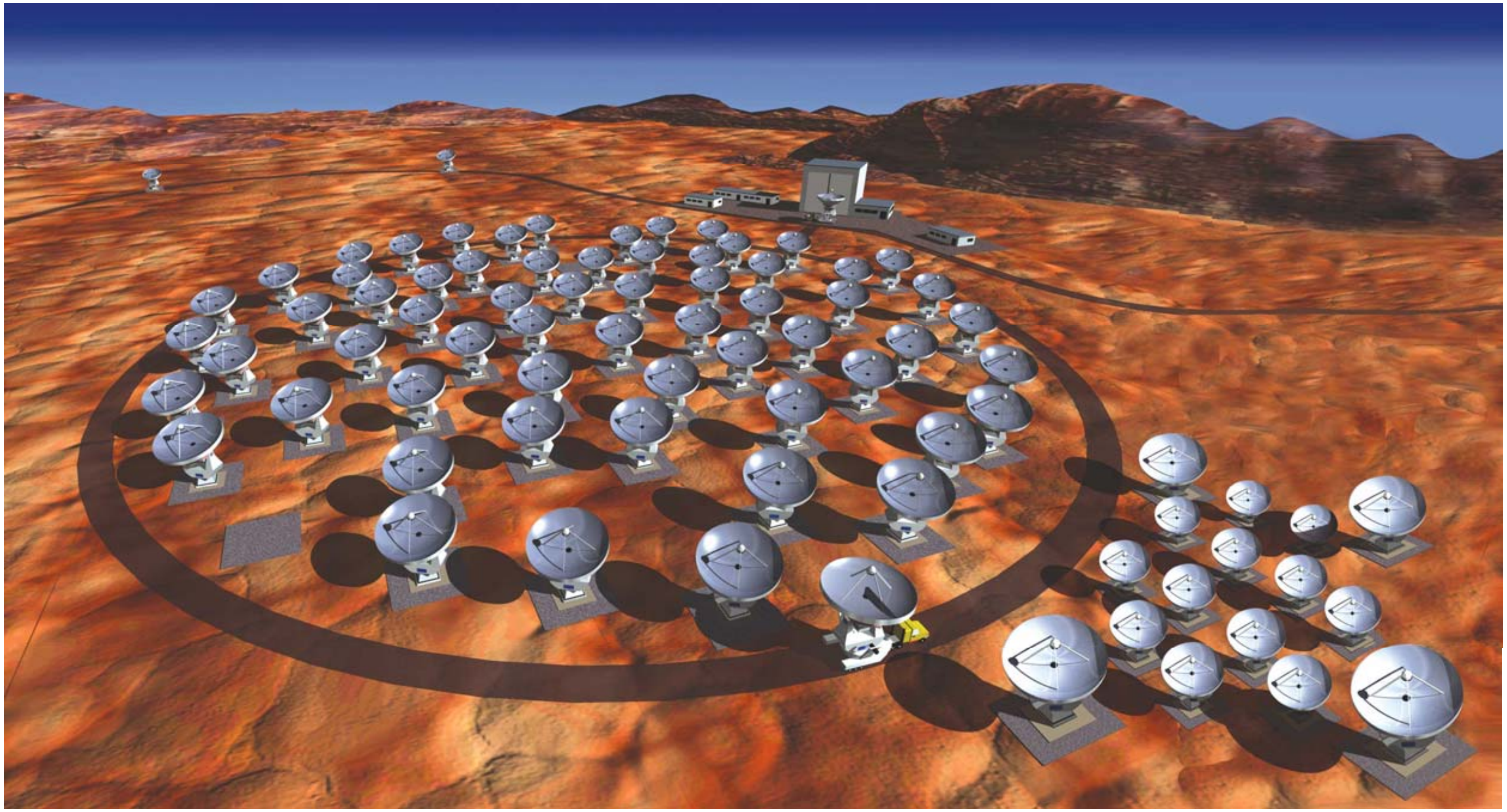
(One antenna added after photo taken)

CARMA: six 10.4m, nine 6m, eight 3.5m dishes

A_g=842m^2

ALMA + ACA: Early Sci 09/10; A_g up to 7238m^2 (64) + 913m^2 (four 12m single dish +twelve 7m)

The four 12m dishes in the lower right are for total power measurements



Comparison for 3 mm

Instrument	Point Source sensitivity*	largest structure#	largest FOV
CARMA	3.7 mJy	80’’	177’’
PdeB	3.2	19’’	41’’
ALMA(50+ACA)	0.5	all	88’’

*****_One hour on source, with a 3 km s^{-1} wide resolution, & equal receiver noise temperature, weather conditions_

#_In the past, in some cases, single dish and interferometer data have been combined, but these were on a case by case basis. For ALMA this possibility will be the norm. Also calibrations will be more secure, better S/N ratios_

Astronomical Facts for Discoveries of Interstellar Molecules

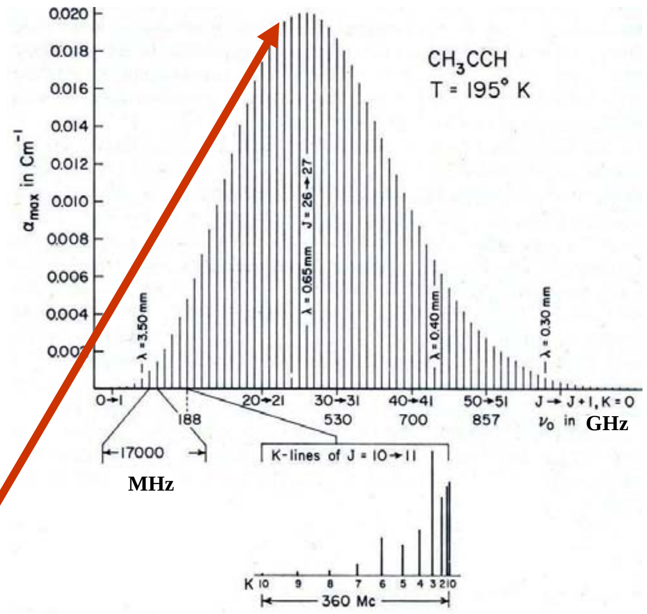
- Need *<u>at least</u>* 10 lines clearly detected with a good S/N ratio (for some high profile cases, even more!)
  - There are exceptions such as H_2D^+
- These lines must fit a single population
  - Implies quasi equilibrium distribution
- ***<u>Under No Circumstances</u>*** can there be instances where allowed transitions are not found
- With interferometers, the lines ***<u>must</u>*** have the same positions

Mundane Facts

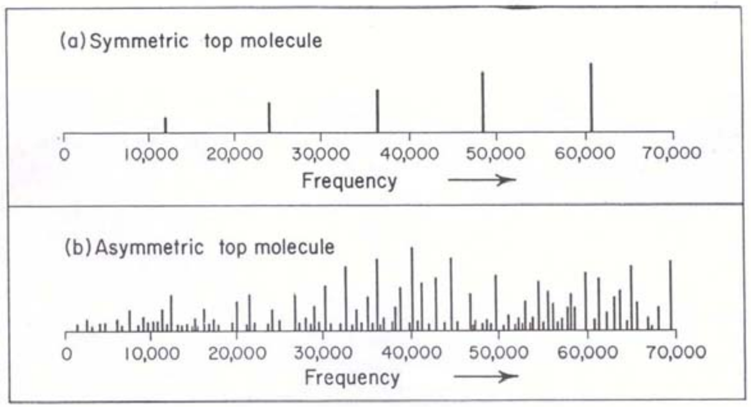
Energy of Upper level

Populations of linear molecules increase as ~(2J+1) & symmetric tops
As ~$(2J+1)^2$, until a given J, then sharply fall as ~$e^{-\Delta E_u/kT}$
Thus should not seek highly excited lines in cold or low density sources.

Units:
100 GHz=4.8K



Asymmetric Top
Total population ~$T^{1.5}$



Want to
get near the max of population
Also at higher frequencies, more emission

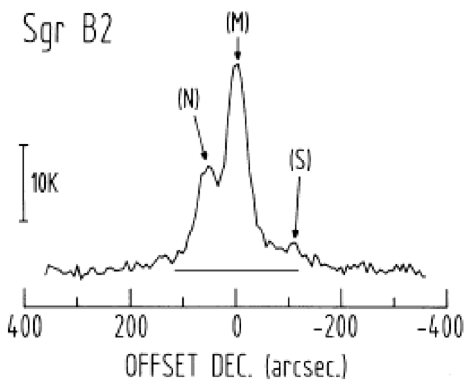
The asymmetric top molecules have
Many more transitions! The populations are
Spread over many more energy levels. If one
measures only a line, one may not be able to
detect rare species.

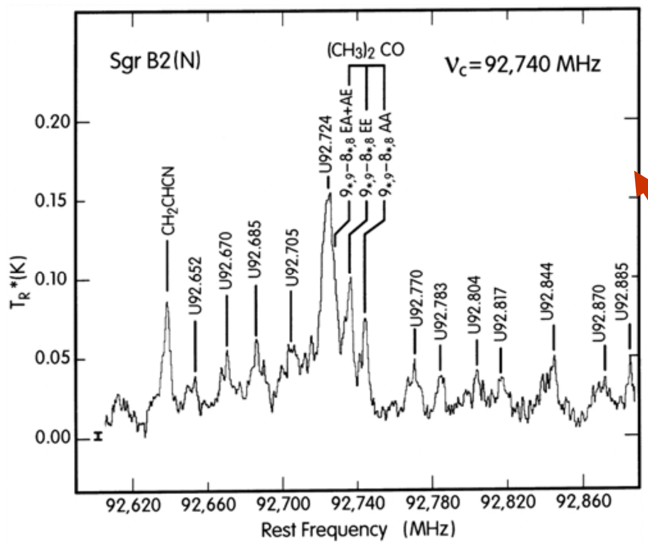
History

- Up to now the ***only*** molecule found with an interferometer is acetic acid (with BIMA confirmed with OVRO)
- Some sources preferred for certain types of molecules
  - large complex species in SgrB2(N)-LMH)
  - long carbon chains in TMC-1, a cold source (T_k=10K) in Taurus
- Even within a given source, some components have larger abundances of complex molecules (SgrB2(N)-LMH)

Test Case for ALMA: SgrB2(N)

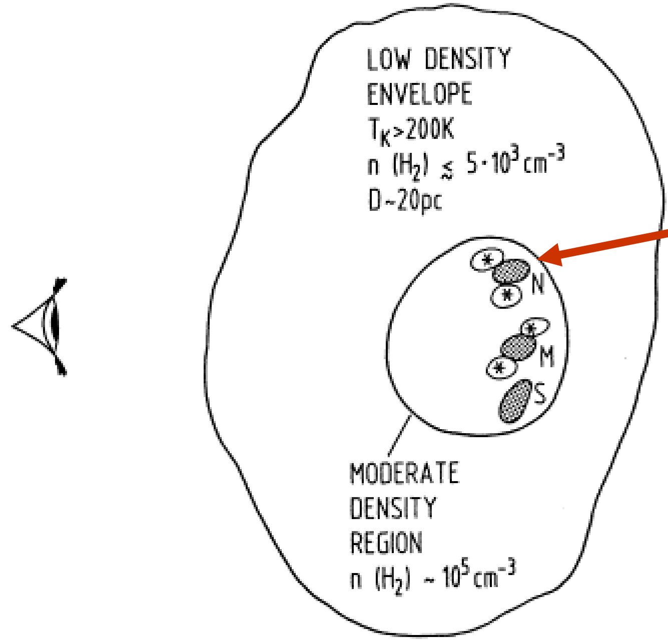
1.3 cm continuum toward SgrB2





From the KP 12m Dish.

A model of SgrB2 from 1.3 cm NH_3 data; the envelope temperature is now thought to be about 700 K from ISO lines of ammonia



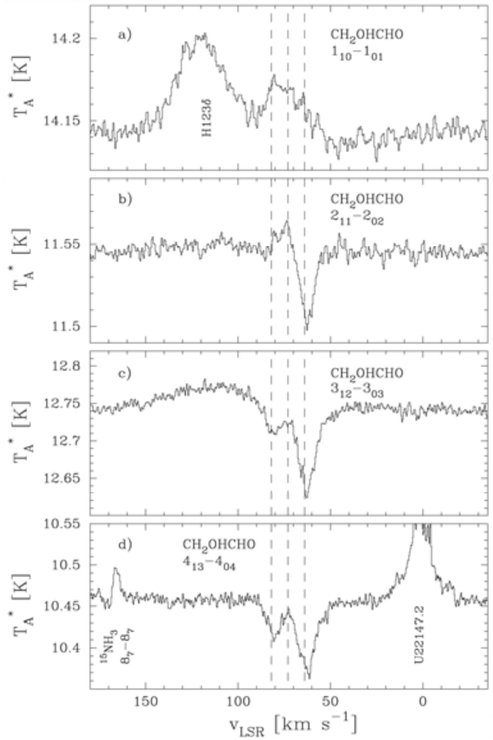
LMH

The cross-hatched regions have H_2 densities of order 10^7 cm^{-3}

Additional Data

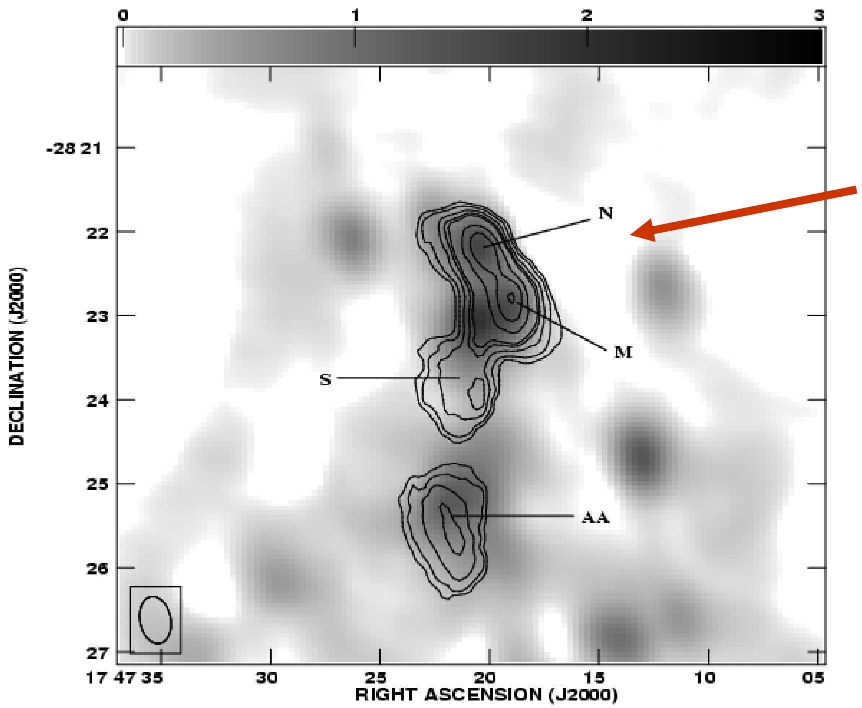
- Hollis et al. (2004) find 4 transitions toward SgrB2(N) which give a value of T_R=8K
  - This is in contrast to the mm lines that gave T_R of ~50 K
  - Hollis et al. speculate that there are two regions, one warm and the other cold.

<u>Surprising since NH_3 data shows that all gas in Galactic Center is hot</u>



A surprising result is that complex species may arise from an extended region in SgrB2

Evidence from Chengalur & Kanekar (2003) measurements of acetaldehyde (CH_3CHO) at 30 cm



Integrated line intensity traces the continuum: This transition is probably a weak maser, but this species must be extended over arc minutes

What Can ALMA Do?

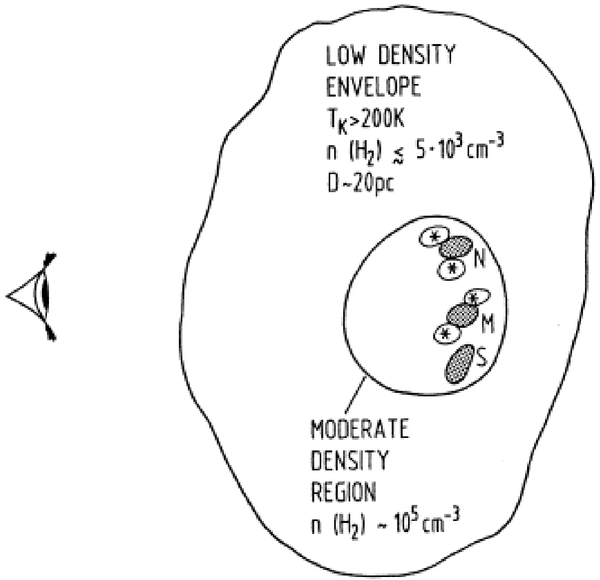
- In Sgr B2, want to be able to detect species known to be there already.
  - Glycolaldehyde, Acetic Acid, Acetone, Ethylene Glycol, methyl formate, etc.
  - Obtain accurate positions and sizes to model chemistry
  - Search for new species
    - Sensitivity better than any other mm/sub-mm facility
    - Has the total power i.e. ‘zero spacing’ information
    - At least as good as large dishes for spread out emission, better than any instrument for very compact emission.

Structure Studies

- Example:SgrB2
  - ALMA will produce new information about structure and dynamics of both the cores and the envelope
  - Determine where the

    molecules such as

    CH_3CHO are produced
  - Determine heating source for extended gas



ALMA Data for SgrB2

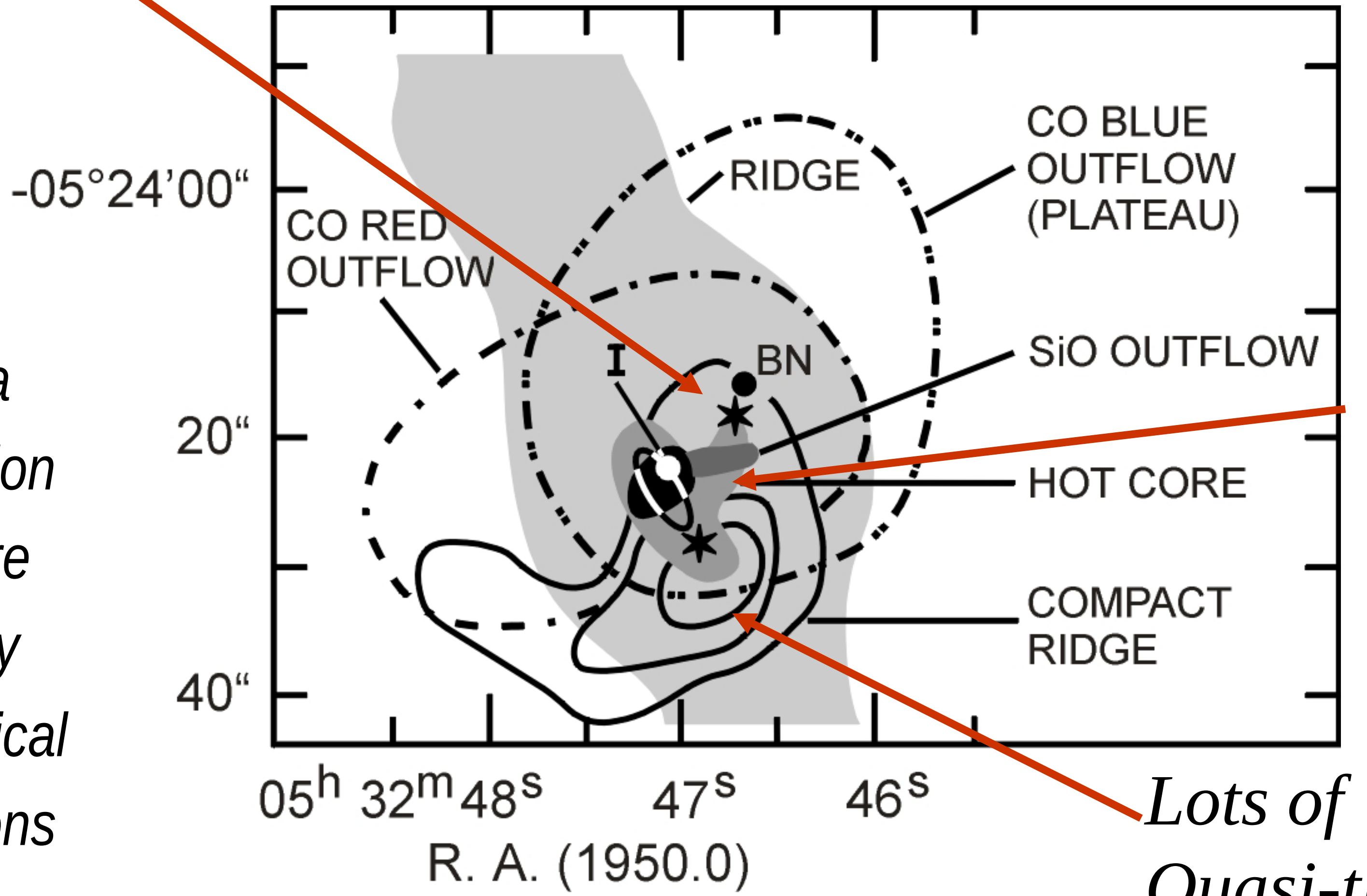
- ***<u>In each 8 GHz wide band, have 16 spectrometers for each polarization.</u>***
  - Each of the spectrometers can be tuned individually in the band
  - Can measure 16 spectral regions simultaneously
- With single dish flux density measurements have all spatial scales to the angular resolution given by the largest interferometer baseline spacing
  - In this case 4”
- At 3 mm, can detect lines of acetone found with the KP 12m dish in 1^h (on source) with a 10:1 S/N ratio if the emission is spread over the whole KP 12m beam. If the emission is compact, the result is better.
  - with a 3 km s^{-1} velocity resolution reaches the sensitivity of previous searches
  - Each of the spectrometer covers 1,500 km s^{-1}
  - This covers a 50’’ region. To image all of SgrB2 continuum sources require a mosaic of 9 positions.
  - Could also image the dust continuum
  - Total time of 15 hours with calibrations
- Total number of data points is 10^8 (5,625 spatial x 16.384 frequency)

ALMA and Orion KL

- Even easier since the Hot Core and Compact Ridge are more concentrated.
- Would need to use narrower velocity resolution, so noise is a factor of 2 larger
- In continuum would also detect the O-B stars and dust continuum in the region.
- To include Orion-S (90” south of KL), would require a 3 position mosaic
  - Total time of 15 hours

Methanol maser

Orion KL: The Classical Hot Core Source



Within a 20" region there are a variety of physical conditions

Lots of NH_3

Lots of Quasi-thermal methanol

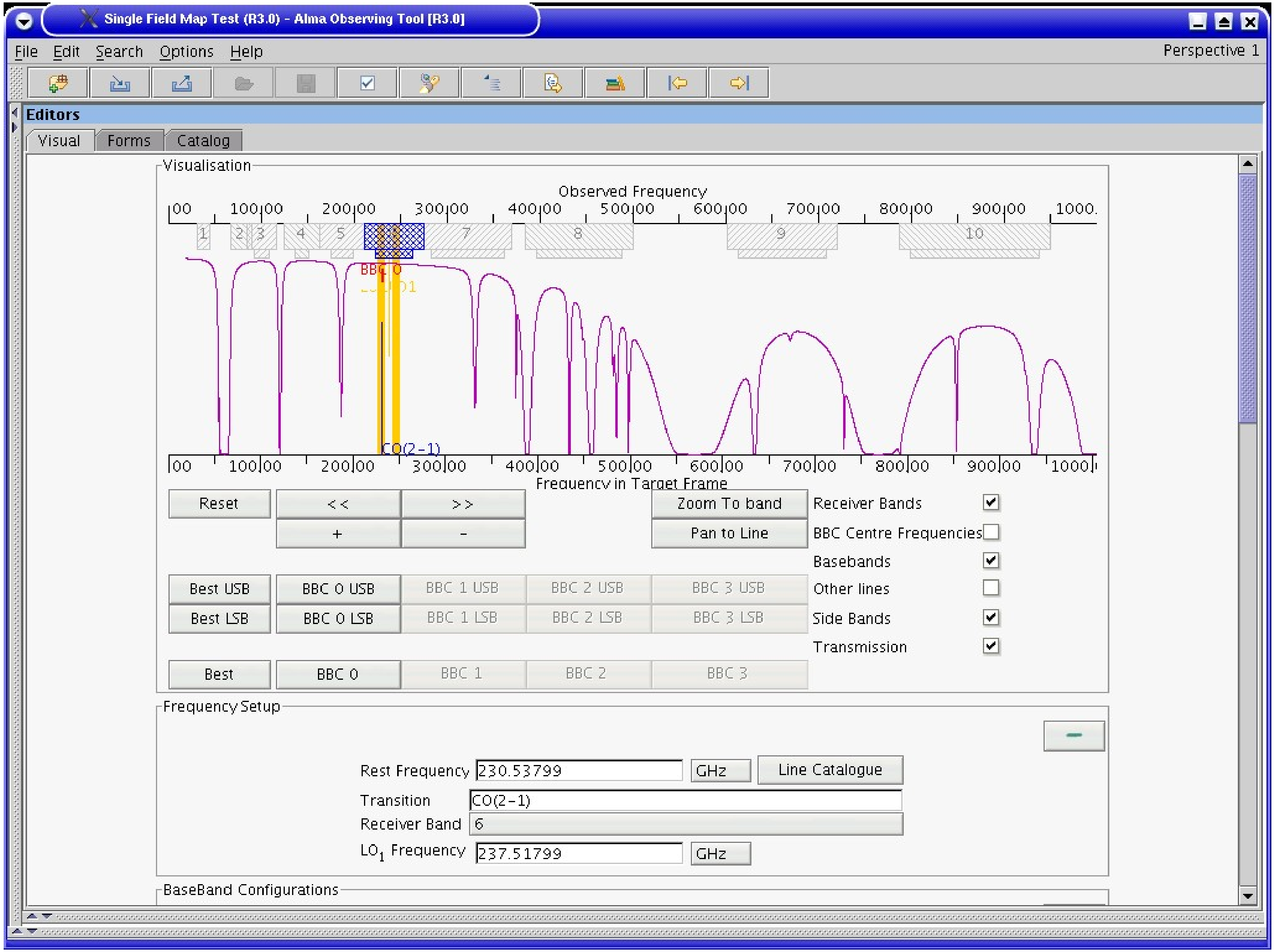
Orion KL Geography

- Hot Core has lots of nitrogen bearing molecules
- The compact ridge seems to favor molecules with more oxygen
- Outflows are energetic, from source I
- Embedded sources in the Hot Core provide local heating
- This is not really a source for the most complex molecules
  - SgrB2(N)-LMH is the best source (and passes overhead in Chile!)

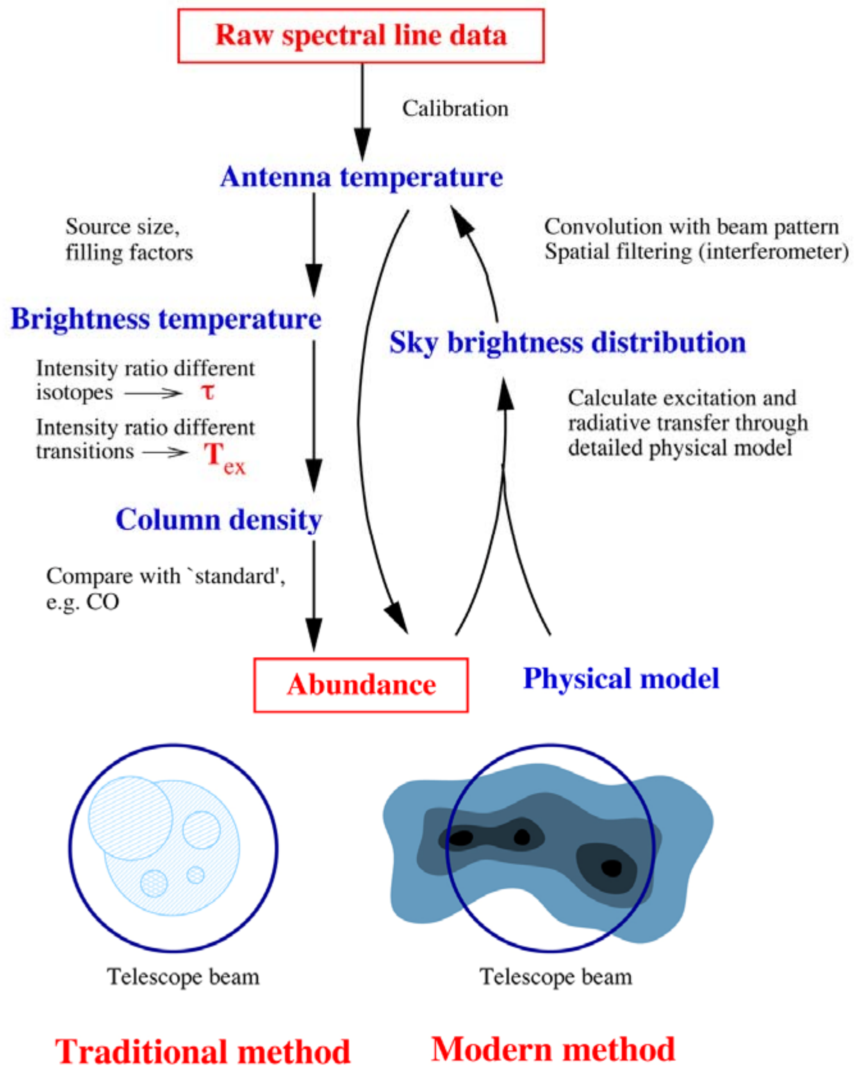
Other Prime Sources

- NGC6334
  - 1.5 kpc from Sun, with source components separated spatially
  - Narrower lines
  - Rich spectrum
  - Less studied but good source for ALMA
  - I(N) interesting—seems to be very young

Example of an ALMA Observe Tool Set Up



How can this amount of data be analyzed and interpreted?



Additional Needs

- Laboratory measurements and complete data bases to aid identifications