The Physics and Chemistry of High Mass Star Forming Regions

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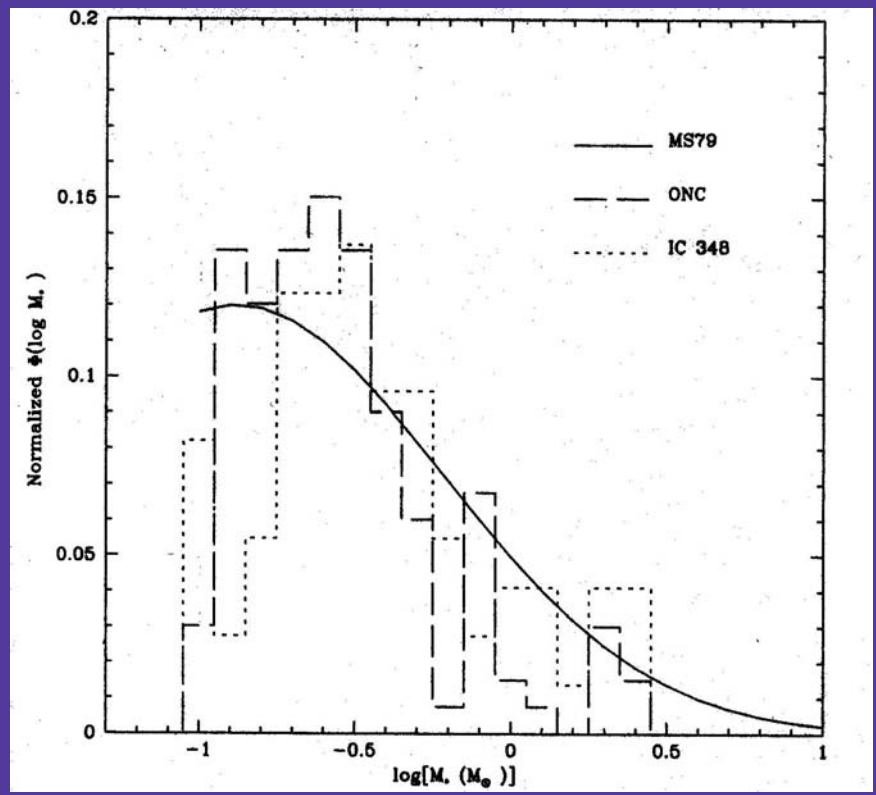
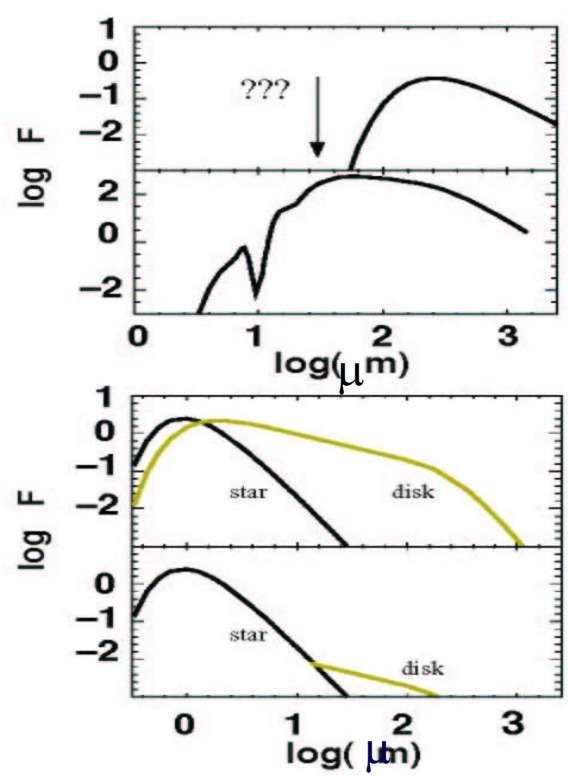
High Mass Stars (M > 10 Solar Masses)

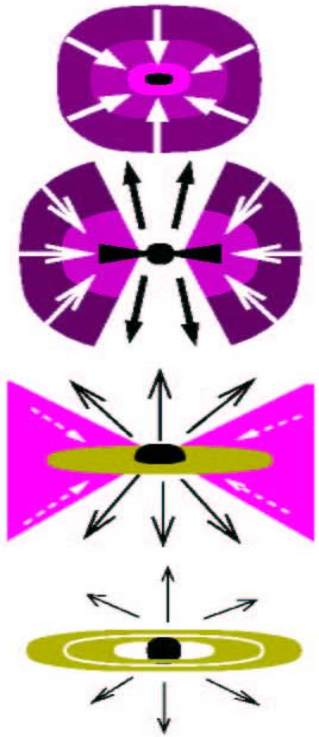
- Generally thought to form in groups
- These stars strongly affect nearby clouds
- End their lives as either SNe or Black Holes
- Disproportionately stir up the ISM
- Produce heavy elements during their lives (as do AGB stars)
- Where high mass stars form, also find formation of intermediate and low mass stars (i.e., stellar mass distributions described by Salpeter, Scalo, etc.)

Stellar Mass Distributions



CLASSIFICATIONS OF PROTOSTARS





CLASS 0
(main accretion phase)
Size: 10000 AU; t=0

CLASS I
(late accretion phase)
Size 8000 AU; $t=10^4$–10^5 yr.

CLASS II
(optically thick disks)
Size 200 AU; $t=10^5$–10^6 yr.

CLASS III
(debris disks ?)
Size 200 AU; $t=10^6$–10^7 yr.

after Ch. Lada,
figs: M. Hogerheijde

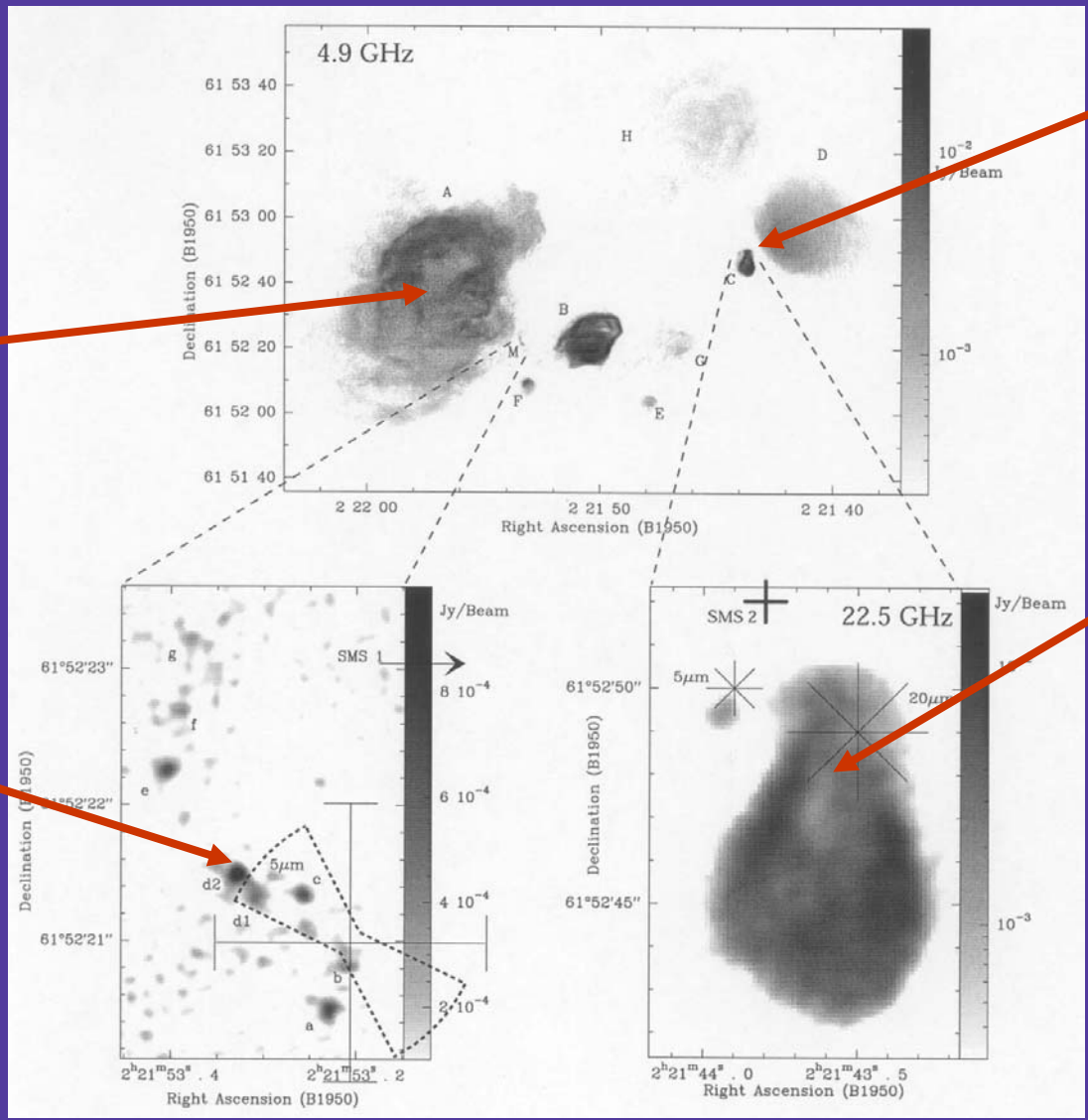
6cm Continuum Image of the W3 Region

Taken
with the VLA
by Tieftrunk et al

In the east, well developed HII region

W3A

In IRS5, find proper motion of two compact continuum sources, CO outflow and water vapor masers



In the west find IR and sub mm sources.

Hypercompact HII region

These free-free continuum images have sub arc second resolutions. The dust continuum and molecular line images have much lower angular resolutions

Orion
Hot Core
A "chemistry factory" in the sky

Trapezium stars, which ionize the HII region

Bar, an Edge-on *Photon Dominated Region*

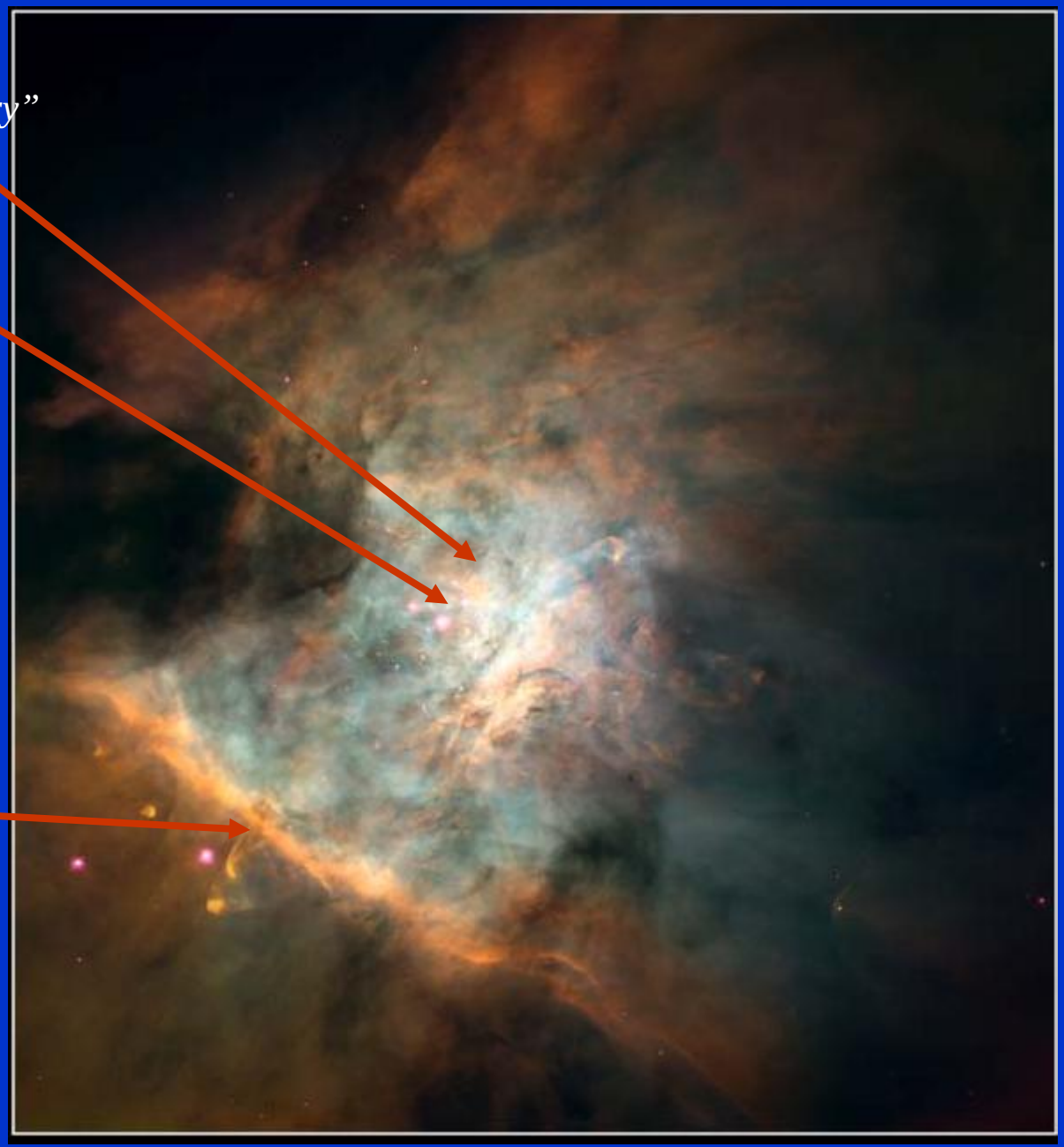


Photo From HST (O'Dell)

The molecular cloud in Orion is extended north-south, behind the HII region

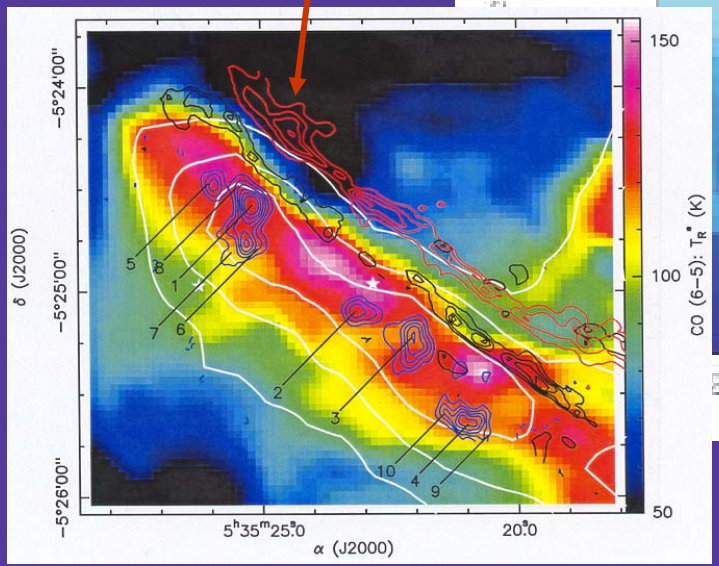
Map of integrated emission of the J=7-6 CO line

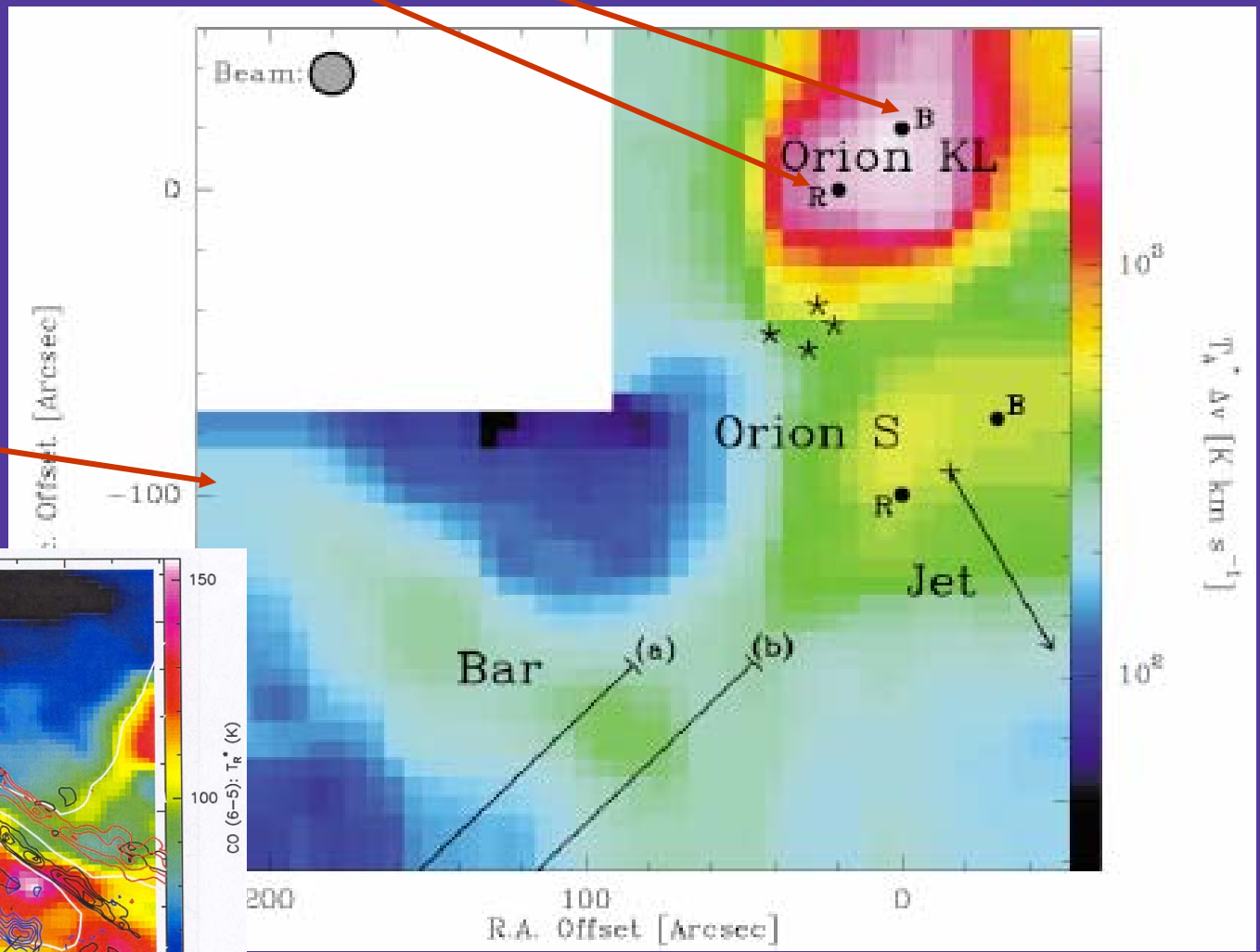
KL outflow red and blue wings

This region contains outflows, PDR's and complex molecules

Well studied PDR

Lis & Schilke

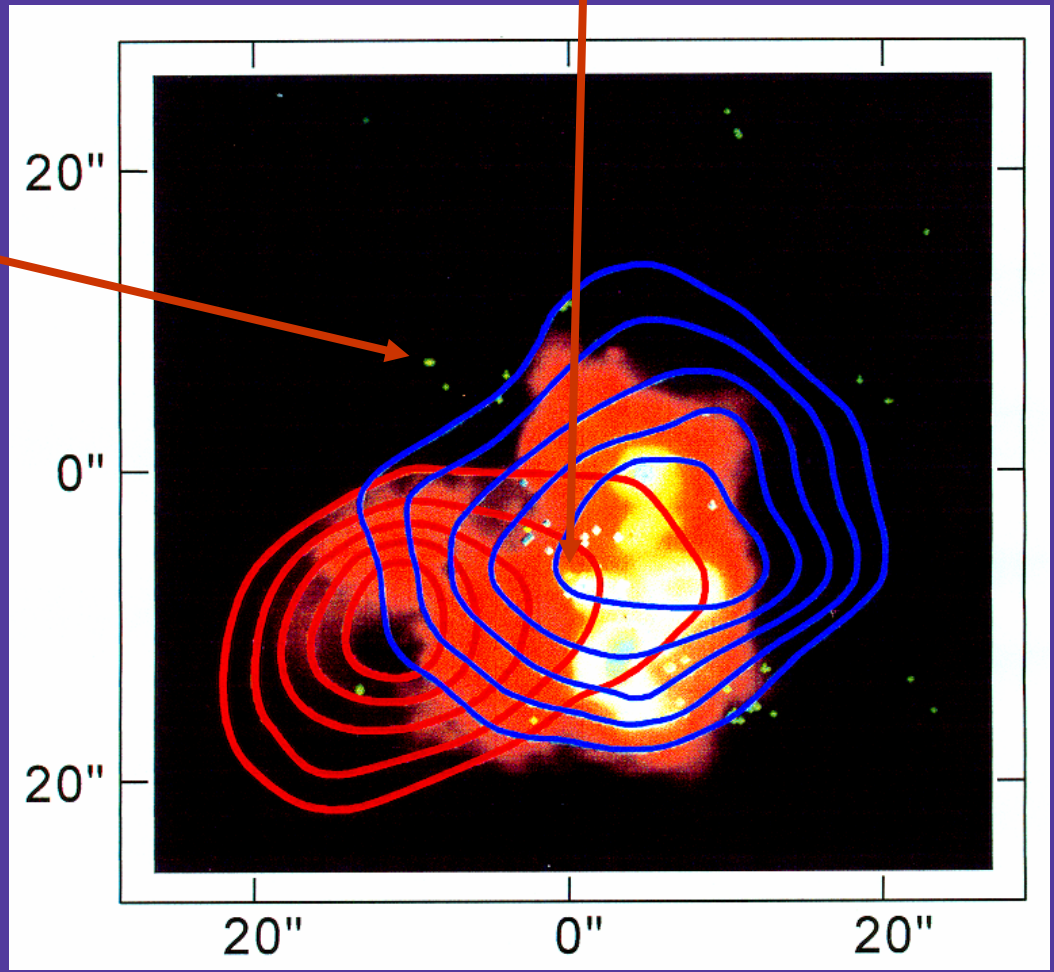




Wilson et al. 2001 ApJ 557, 240

Position of source ‘I’, a young stellar object thought to cause the outflow

The small crosses represent positions of 22 GHz water vapor masers with proper motions



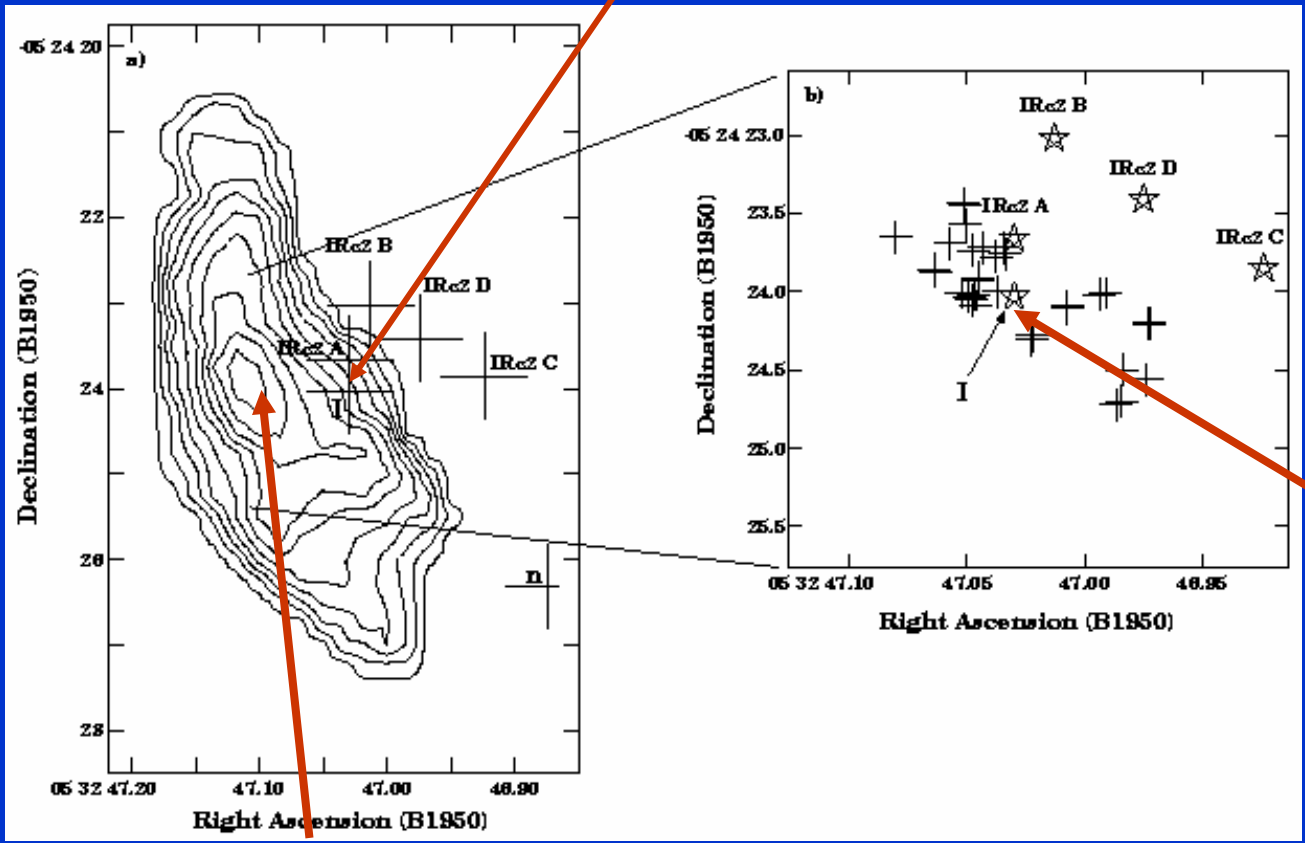
The colors show the location of the IR continuum

Recently small regions of vibrationally excited HC_3N found in the Hot Core By Martin-Pintado etal. (2000)

Associated with the IR sources is the Orion Hot Core, a chemically rich region southeast of ‘I’. This region contains a large amount of complex molecules such as ethyl cyanide

1” Resolution Maps of NH_3 and 0.1” Resolution maps of H_2O Masers

Source ‘I’ is thought to be the main heat source and source of the CO outflow



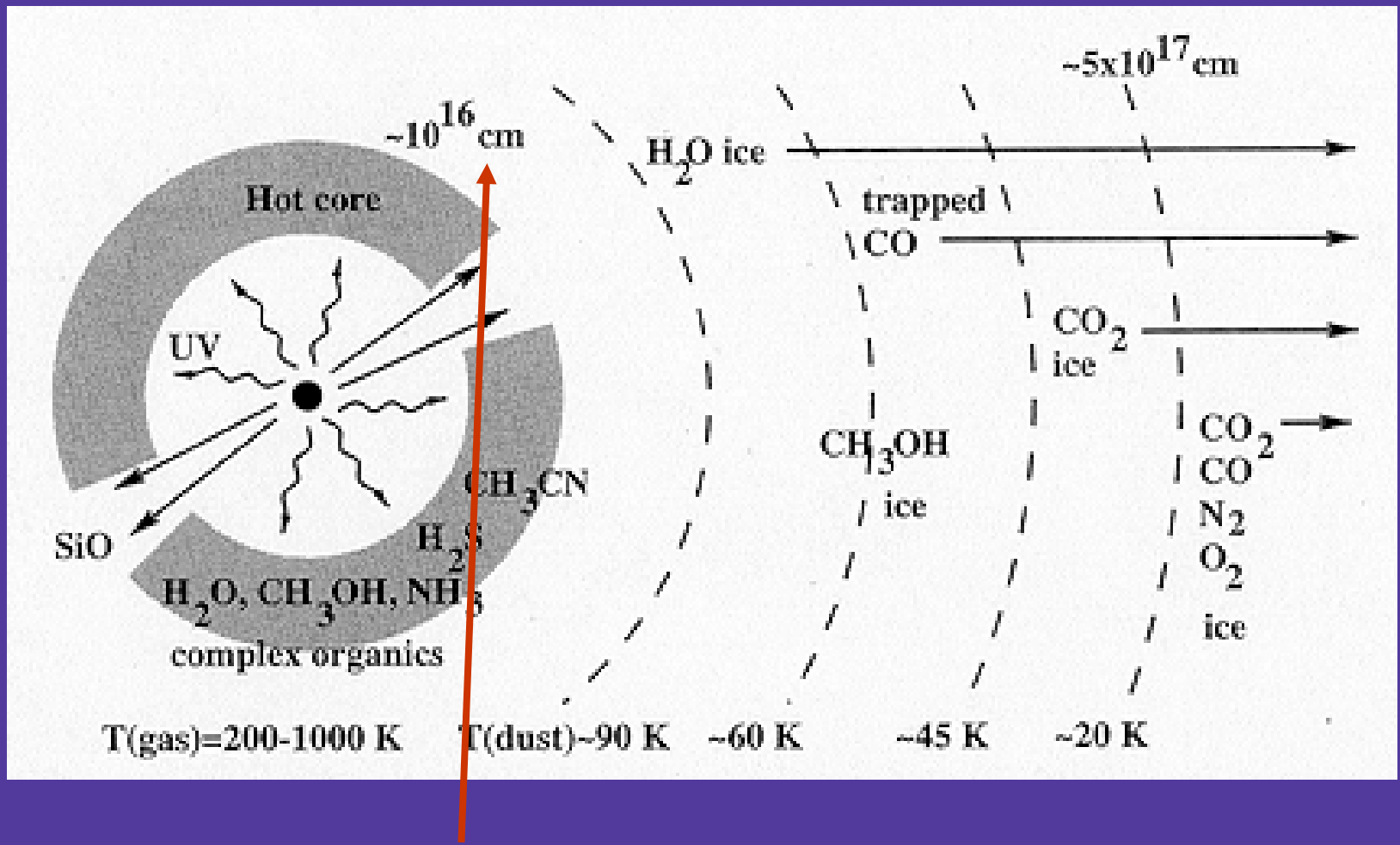
The crosses are 22 GHz H_2O masers. These are centered about the source ‘I’

Recently small regions of vibrationally excited HC3N found in the Hot Core By Martin-Pintado etal. (2000)

Warmest region contains the most complex molecules. This is the distribution of the (J,K)=(10,9) inversion rotation line of NH_3 measured with a 1” angular resolution with the VLA. *(Future: Herschel satellite will measure many water lines with a >13” beam)*

Chemistry in a Hot core

From van Dishoeck & Blake 1998



This distance corresponds to 1.4'' at 500 pc

Star Formation at High Redshift

- First indication of importance of dusty galaxies at high redshift from SCUBA in 1998; these have redshift z=3
- Find mm wavelength CO lines from z=6.42 Quasar (Bertoldi et al. 2003 A&A 409, L47)
- Indicates that metals formed, probably in high mass stars and then expelled into the local ISM
- CO Line data indicate a fairly dense ($10^{3.5}$ -$10^{4.5}$ cm^{-3}) and moderately warm (T=50-100 K) medium in high z objects
- Caution: Small sample and may not be typical
- Important to extend sample but need lots of sensitivity!

The Future: ALMA

With this array one can image small low brightness regions such as protostars or disks around stars

Sixty-four 12-m antennas on an excellent site in Chile. ***This will be the ultimate imaging system***