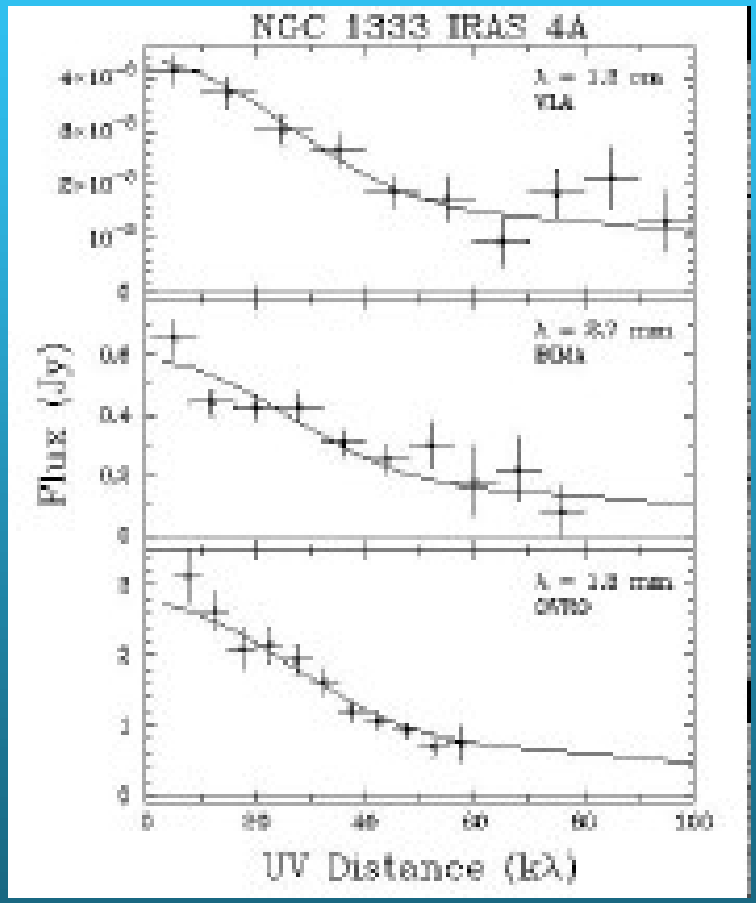
Millimetre Science with the AT

Astrochemistry with mm-Wave Arrays

G.A. Blake, Caltech

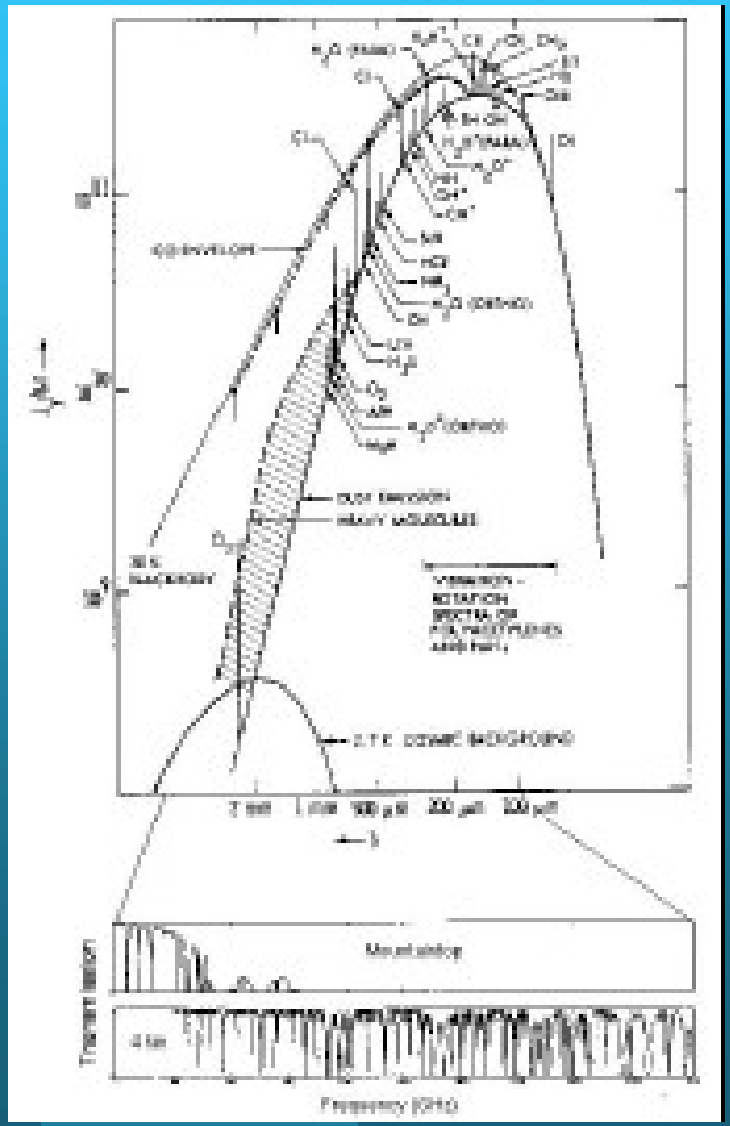
29Nov 2001

mm-Arrays: Important Features



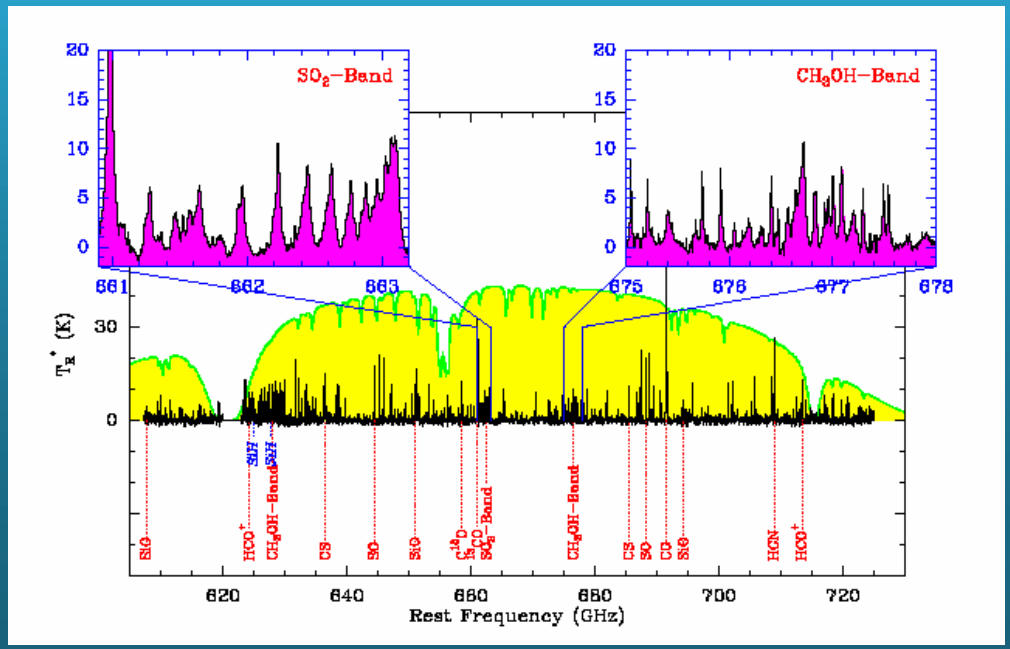
- Spatial Filtering
- Transform to image plane
- Cross Correlation

(Sub)Millimeter Astrophysics



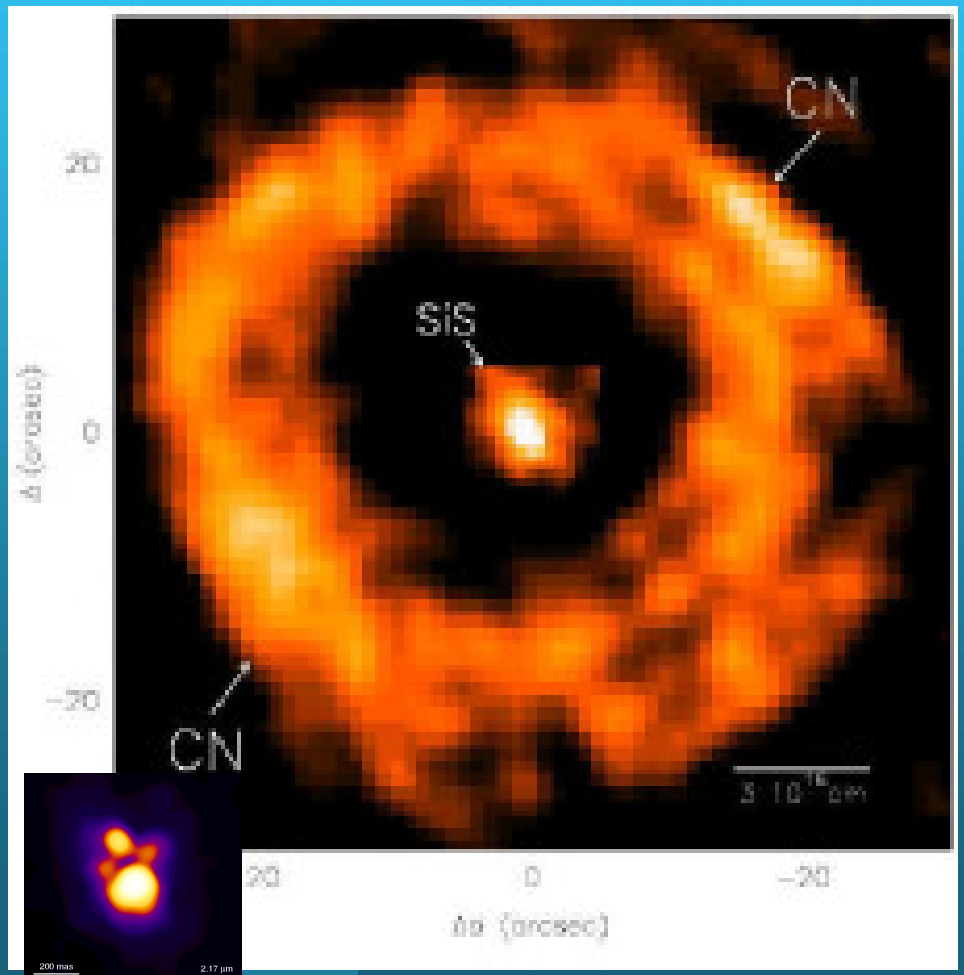
- Thermal emission from cool dust, gas
- High frequency non-thermal tail
- Uniquely high spectral resolution possible

Orion KL, CSO



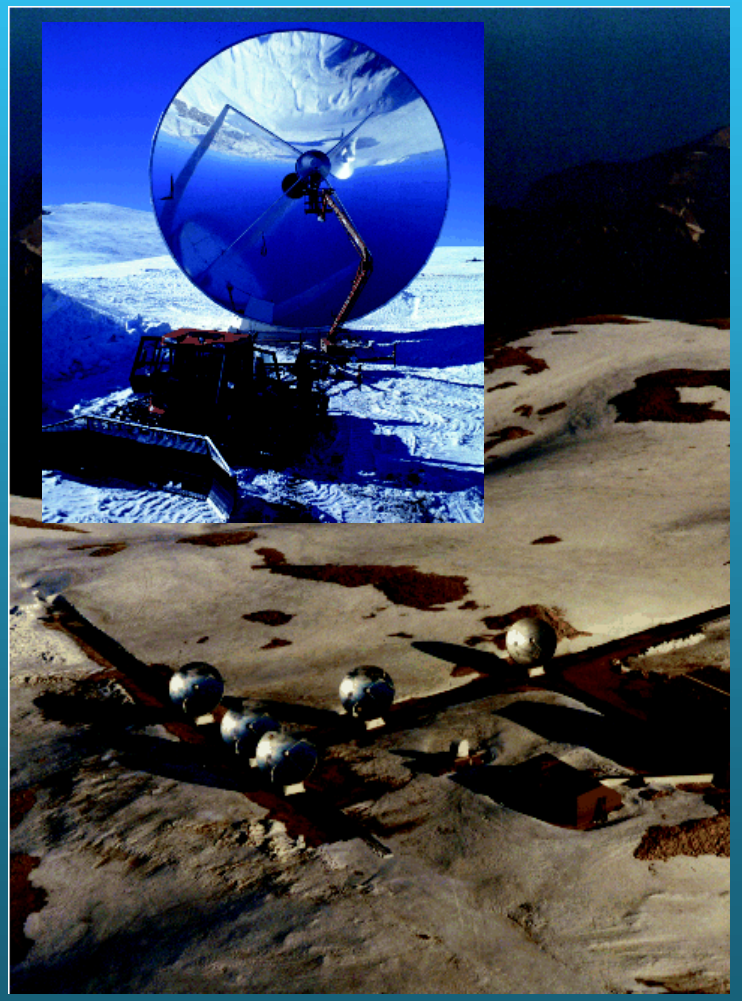
Late Type Stars and mm-Arrays

IRC+10216



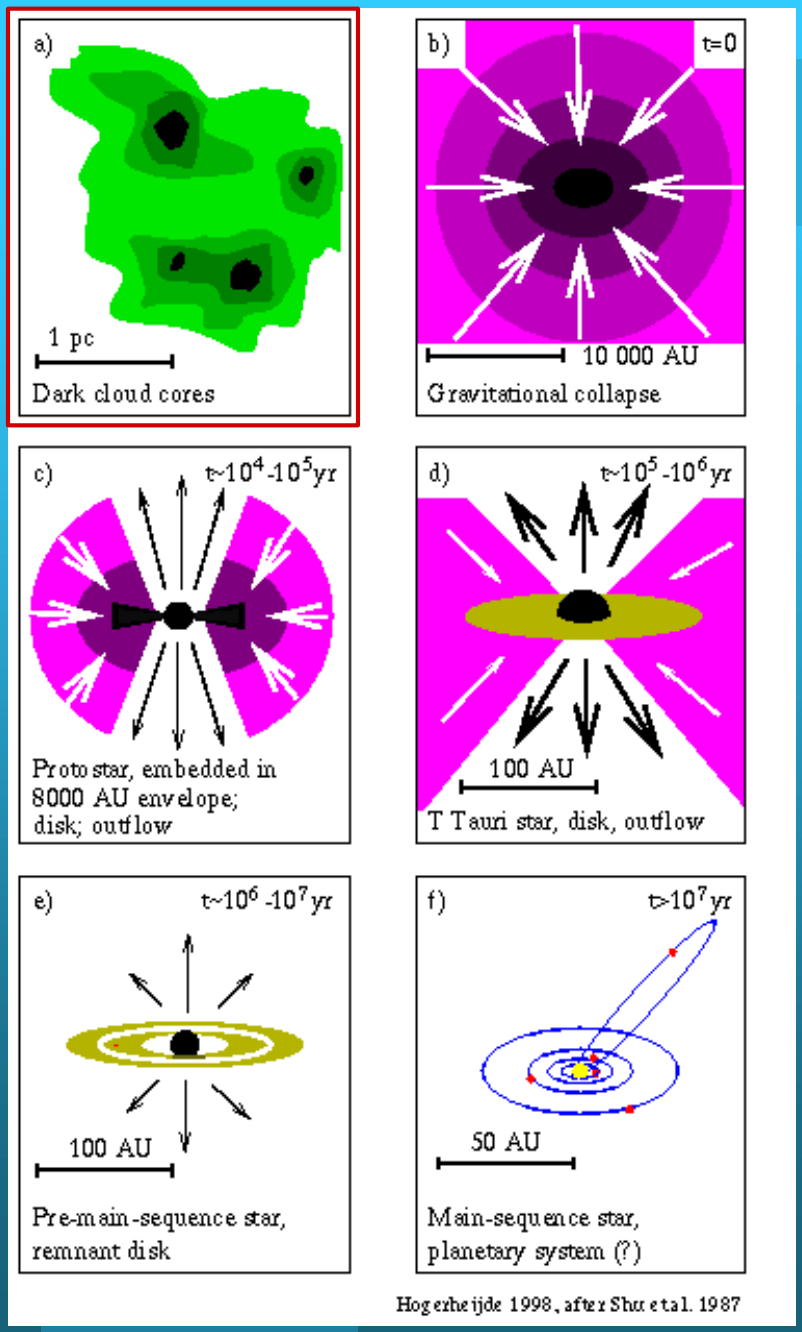
2 μm AO image

Plateau de Bure (6 15 m's)



Young Stars & Arrays

What size ranges are present?

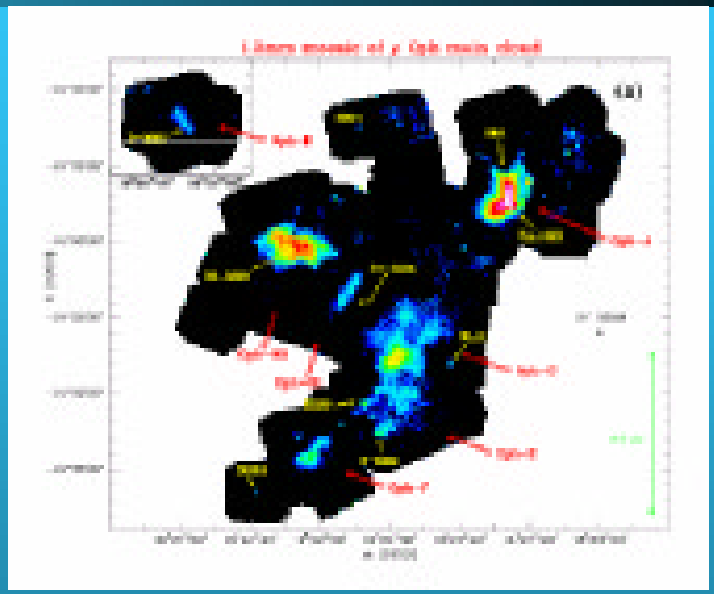


Hogerheijde 1998, after Shu et al. 1987

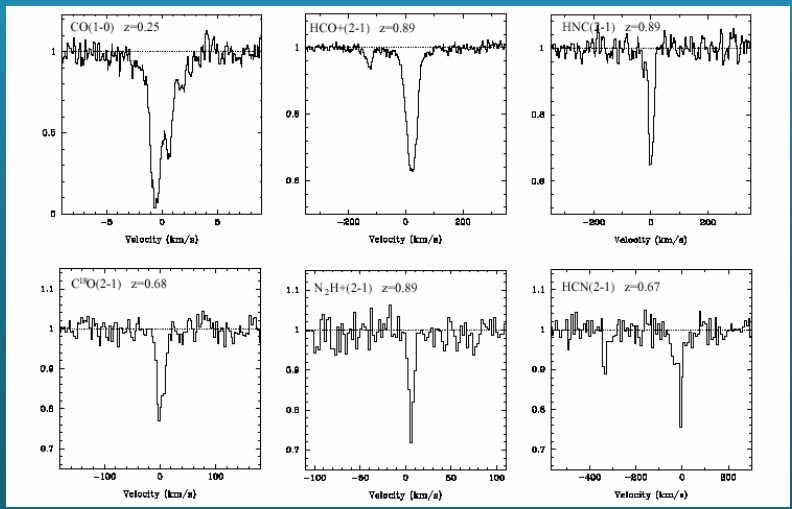
Component	Size (AU)	Taurus (″)	Orion (″)	Chemical Characteristics
Pre-stellar core	>10,000	> 70	> 20	Ions, Long-chains (HC_5N, DCO^+, ...)
Cold envelope	5000	35	10	Simple species, Heavy depletions (CS, N_2H^+, ...)
Warm inner envelope	500	3	1	Evaporated species, High-T products (CH_3OH, HCN, ...)
Hot core (high-mass only?)	500	...	2	Complex organics (CH_3OCH_3, CH_3CN,... vib. excited mol.)
Outflow: direct impact	<100–500	<0.7–4	<0.2–1	Si- and S-species (SiO, SO_2, ...)
Outflow: walls, entrainment	100–1000	0.7–7	0.2–2	Evaporated ices (CH_3OH, ...)
Disk	100	0.7	0.2	Ions, D-rich species, Photoproducts (HCO^+, DCN, CN, ...)
PDR, compact H II regions (high-mass only)	100–3000	...	0.2–7	Ions, Radicals (CN/HCN, CO^+)

Absorption Spectroscopy w/mm-Arrays

IRAM 30m

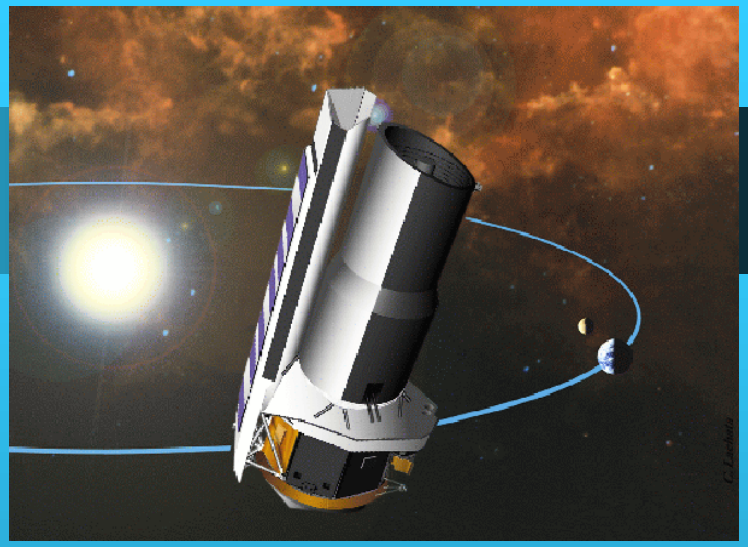


PKS1830
High z
features



Arrays filter out extended cloud!

SIRTF



- IRAC (mid-IR cameras, 3.6 4.5, 5.8, 8.0 μm)
- MIPS (far-IR cameras, 24, 70 160 μm, R=20 SED mode)
- IRS (5-40 μm long slit,R=150, 10-38 μm echelle, R=600)

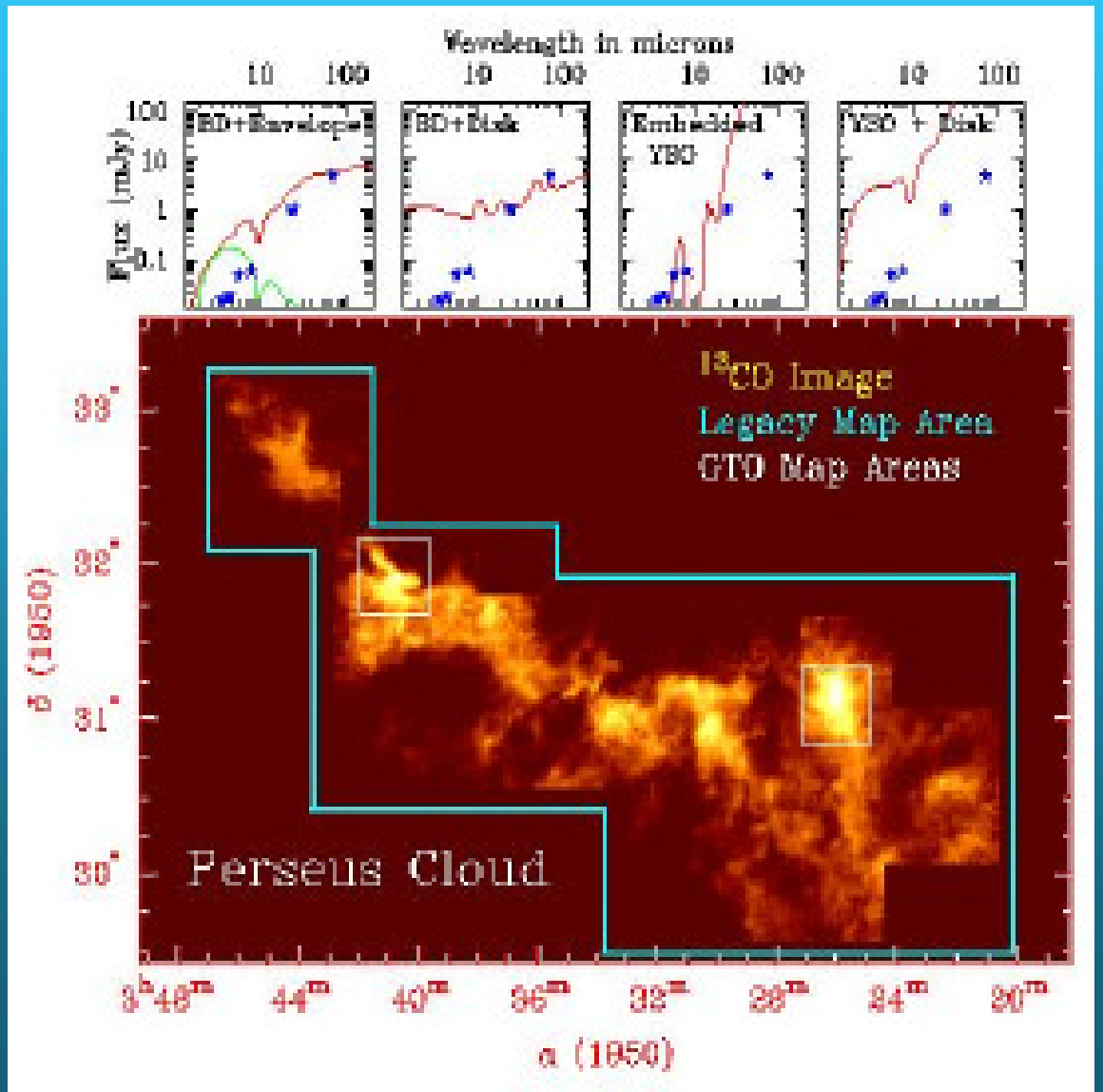
01 Dec 2002 launch

- GTO observations
- Legacy program
- General observations

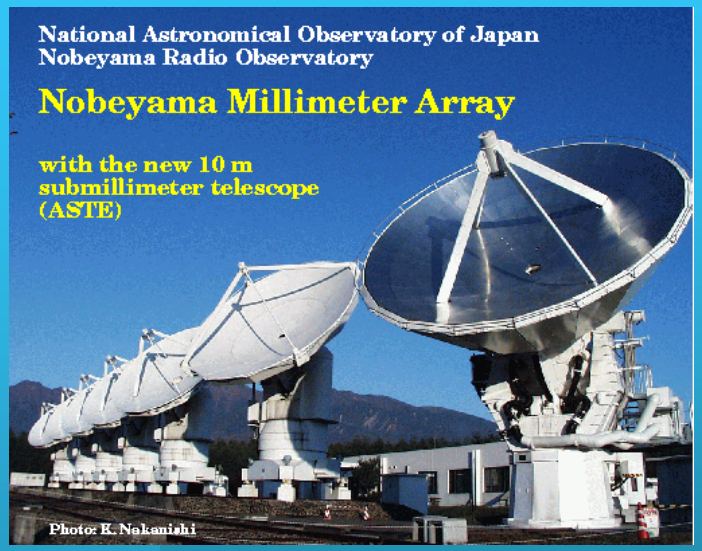
SIRTF – Mapping Large Clouds

Evans et al.
Legacy Team

Perseus, Cha, Lupus, Oph, Serpens + Isolated cores



Large Scale Structure? Single dish or…



Ideally, single dish should be ~twice array dish diameter for good (u,v) overlap…

Use Mopra to start, good single dish pointing essential.

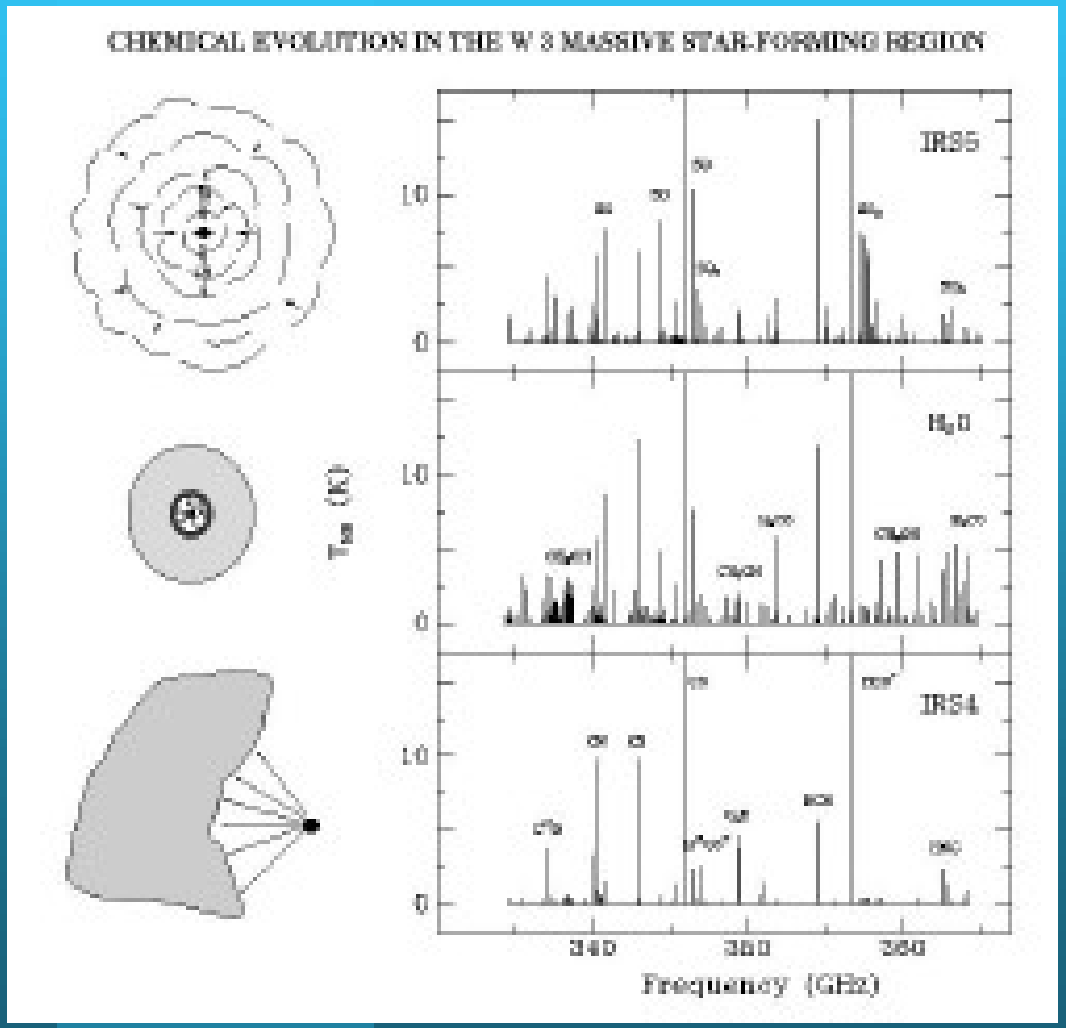
Heterogeneous Arrays:

CARMA = BIMA + OVRO + SZ Array (8 3.5m telescopes)

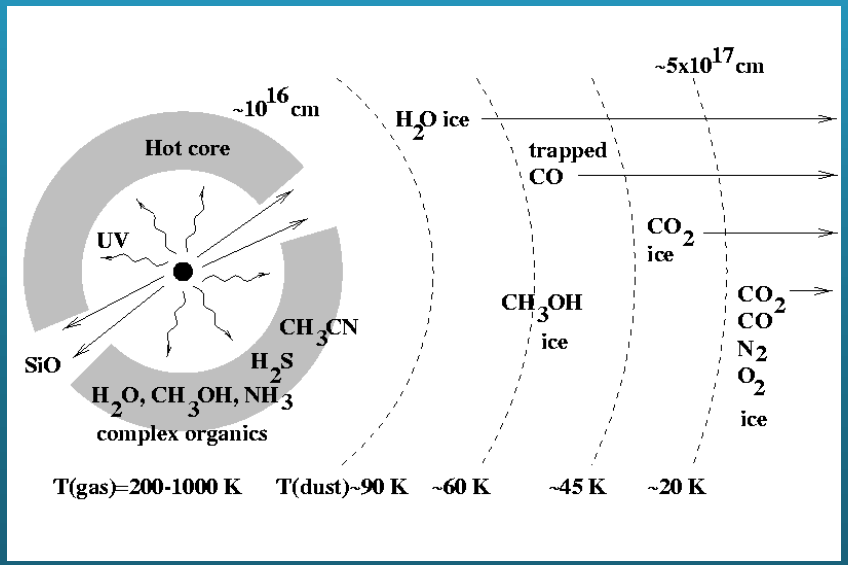
SUP submitted
2002 road
2003 move OVRO
2004 move BIMA
2005 full operations

Juniper Flat

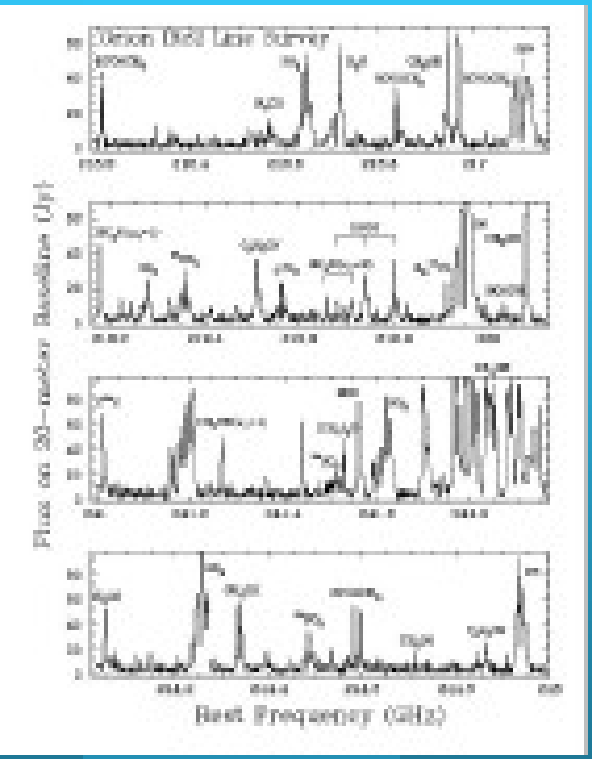
Chemistry and Massive Stars:



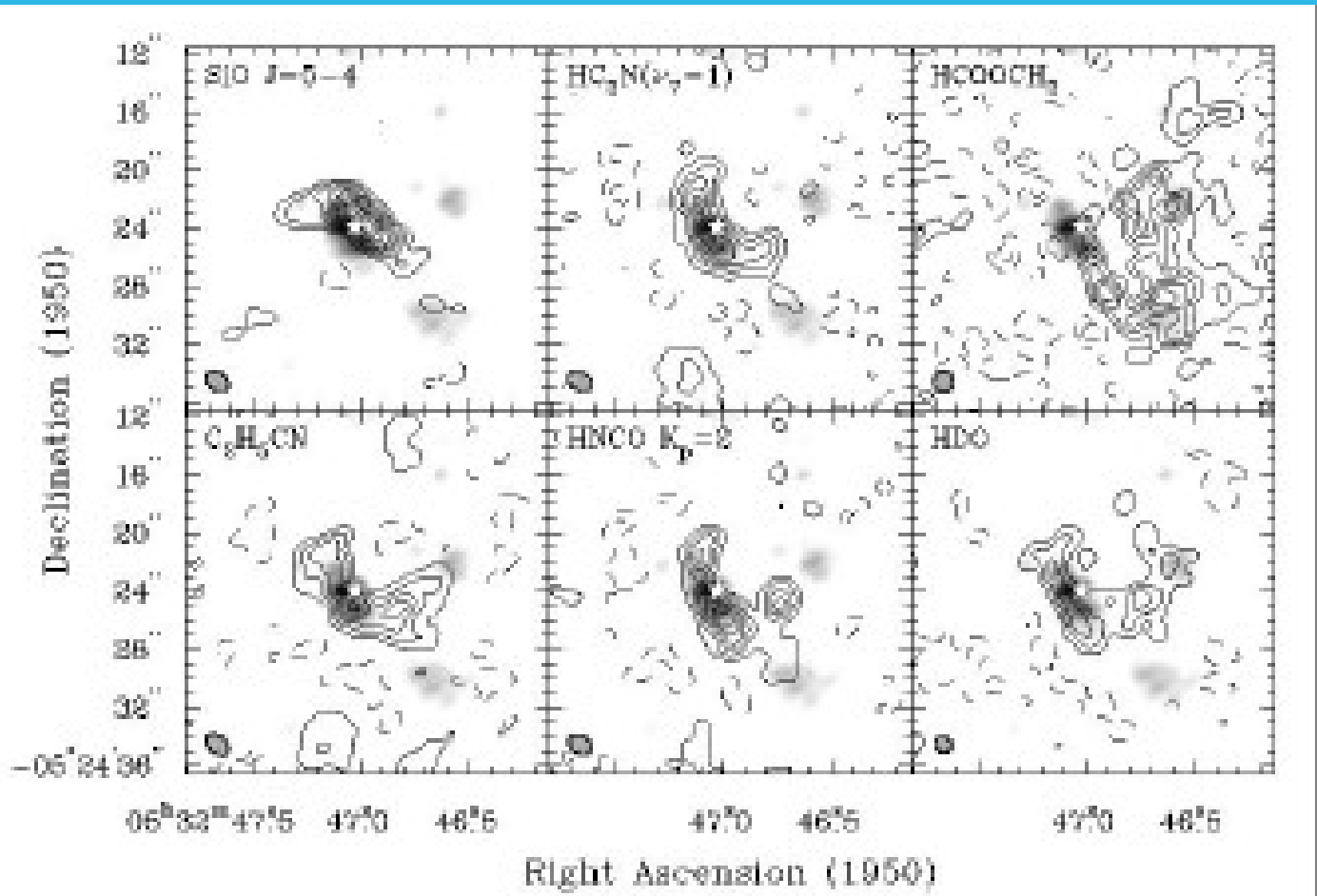
- Embedded at main sequence
- Large area heated, shocked
- Extensive chemistry



Orion as a Hot Core Test Case:

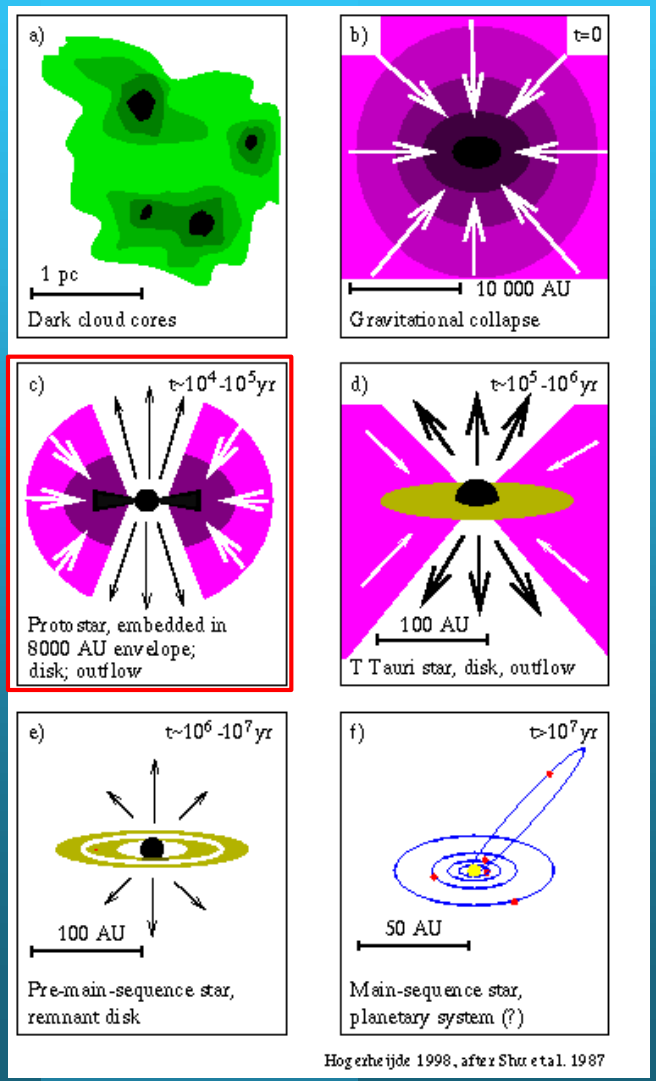


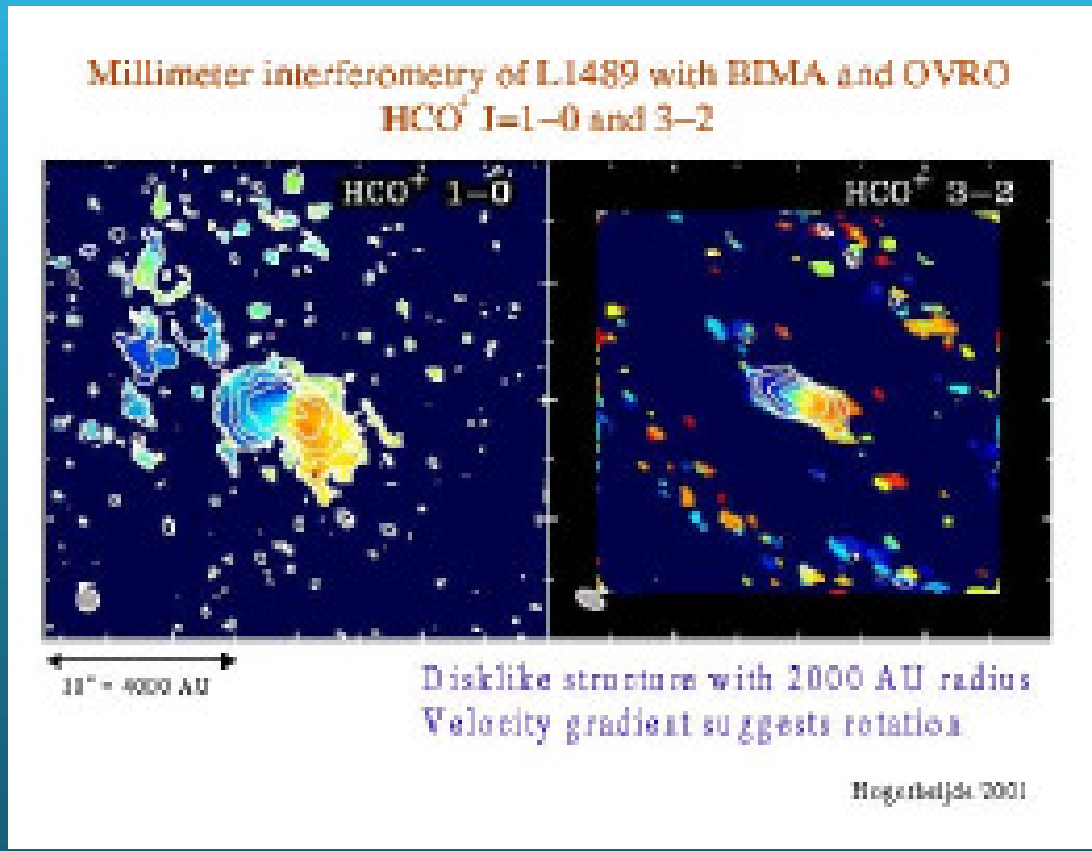
Bright lines, complex spatial structure!



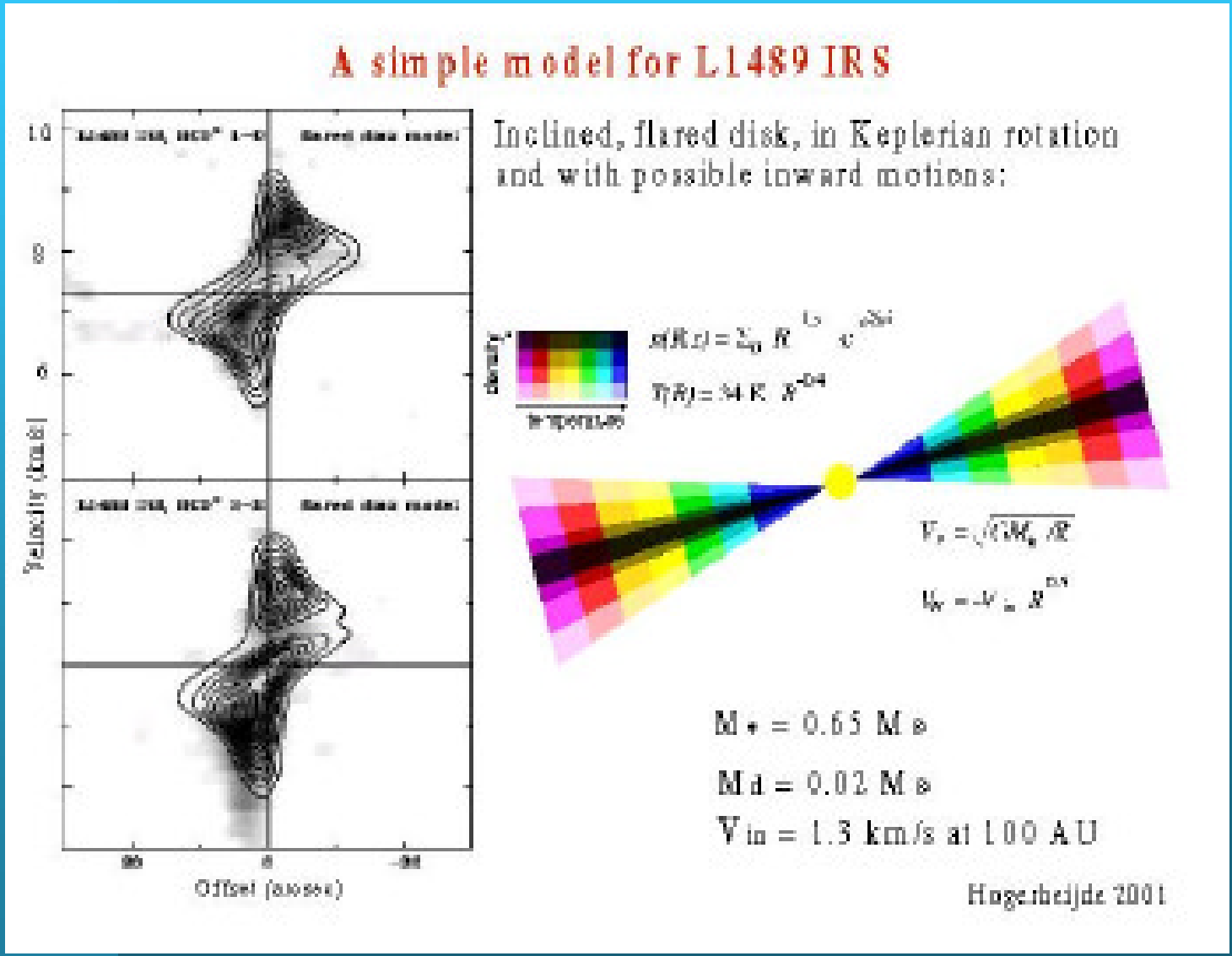
The Dynamic Envelopes Around YSOs

- Dust + Gas = n(R),T(R),f(R)
- Polarization (B field support)?



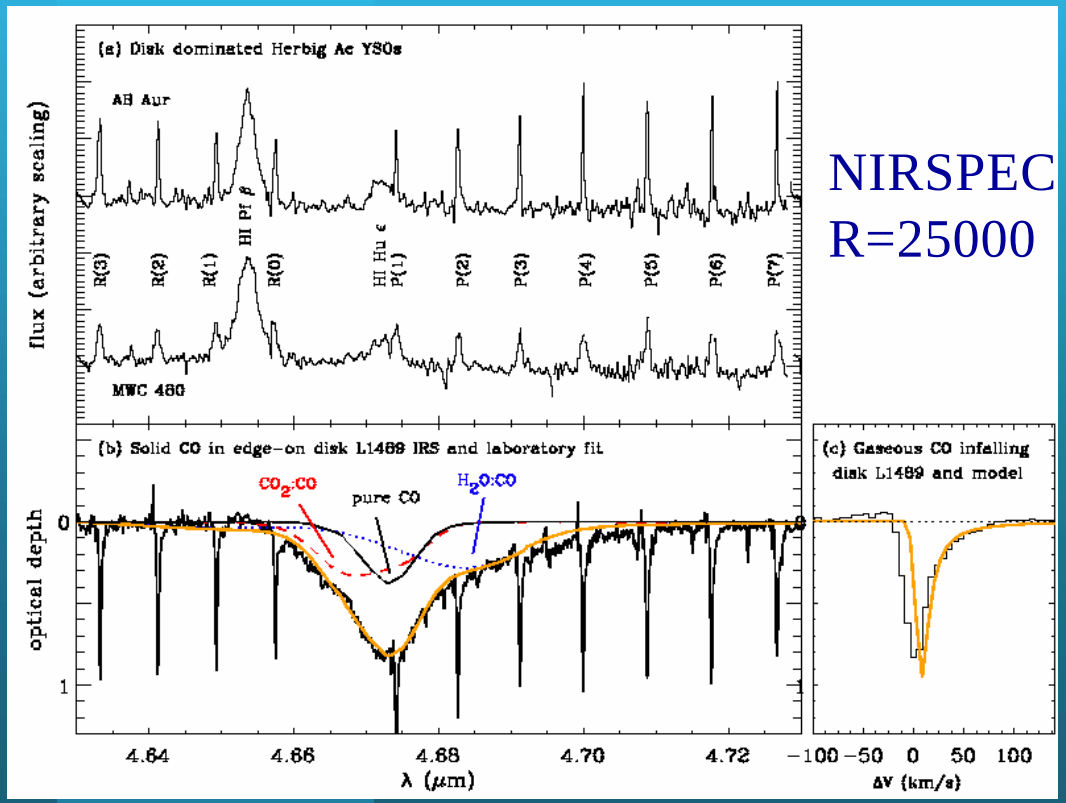


The Dynamic Envelopes Around YSOs. II



Complementary IR Envelope/Disk Studies

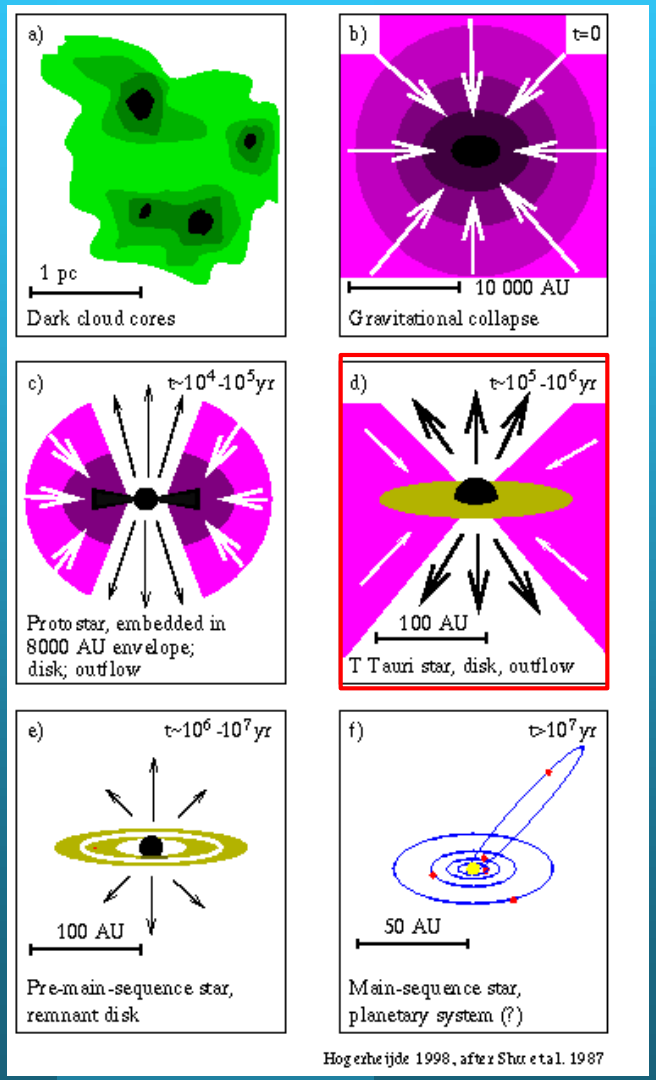
CO M-band, infall to ~0.1 AU in L1489.



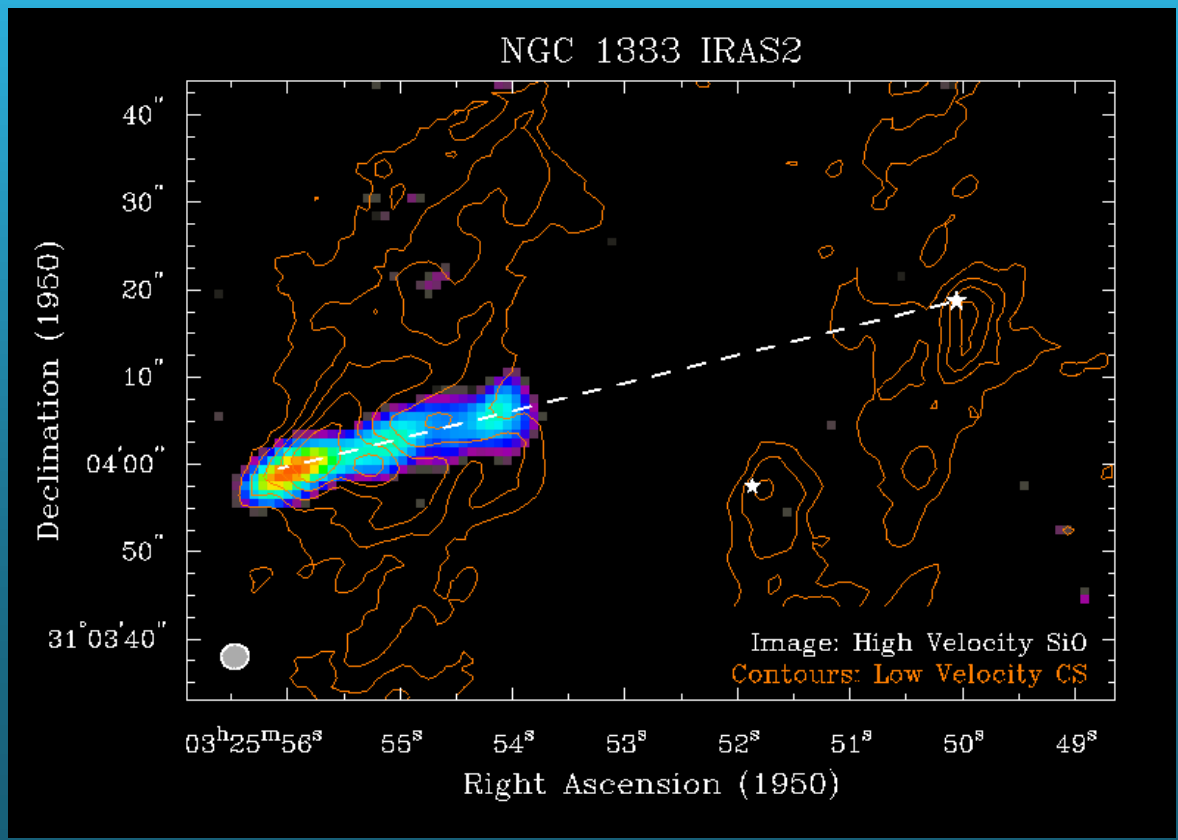
NIRSPEC
R=25000

VLT

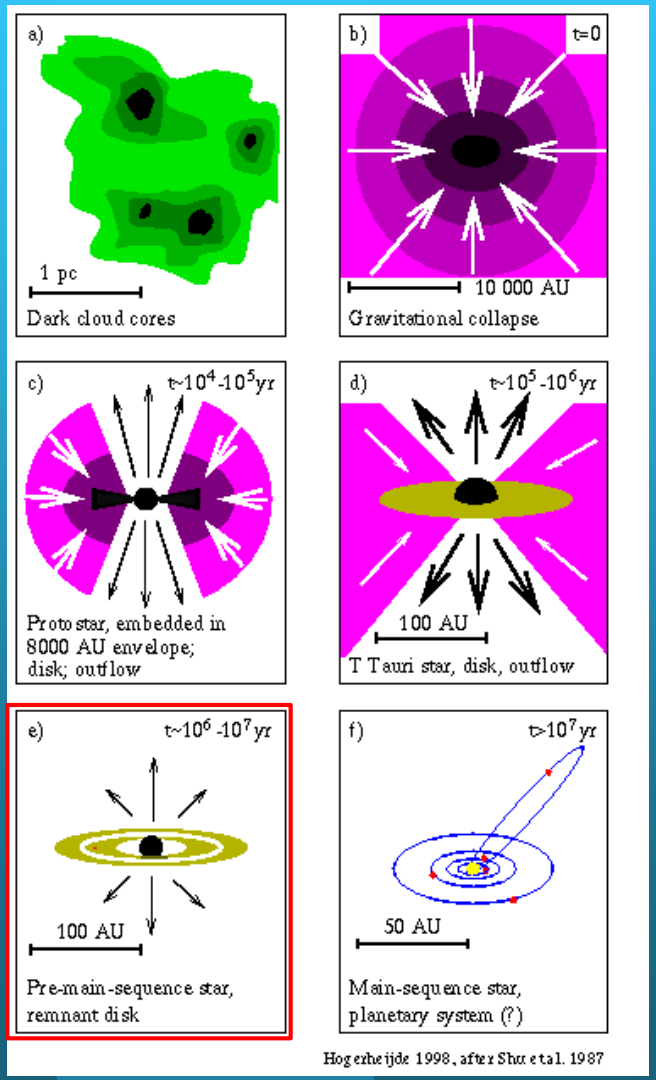
Molecules in the Outflows from Young Stars



mm-arrays can be used to study all outflow phases, even those that are highly extincted. Velocity resolution critical!

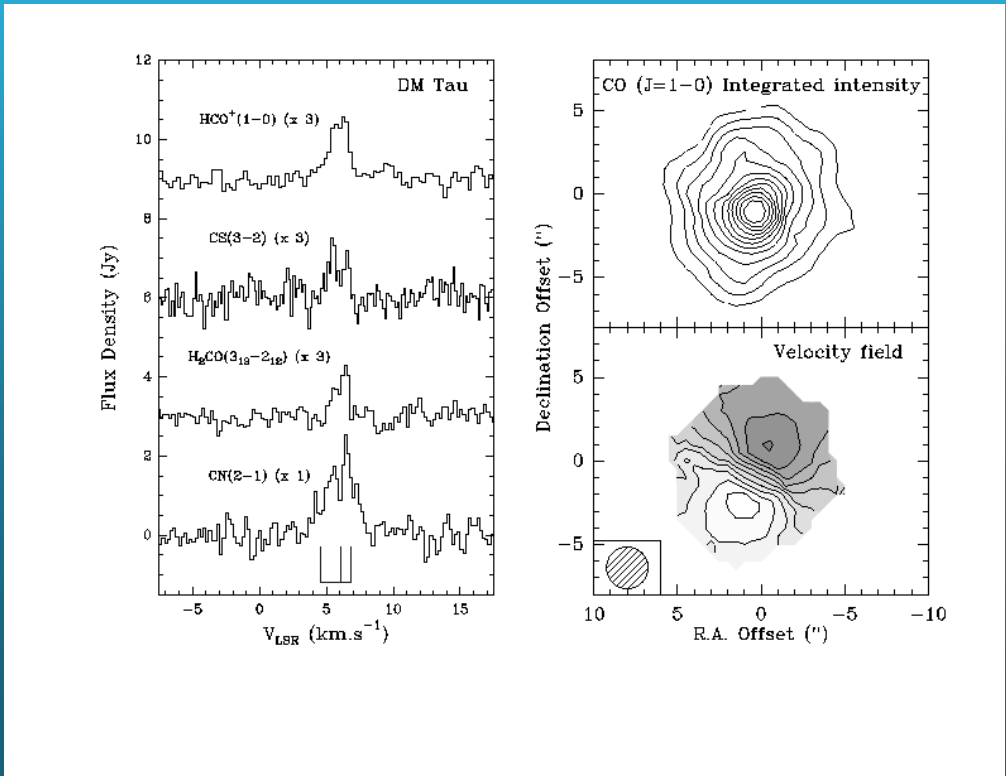


Chemistry in YSO Accretion Disks. I



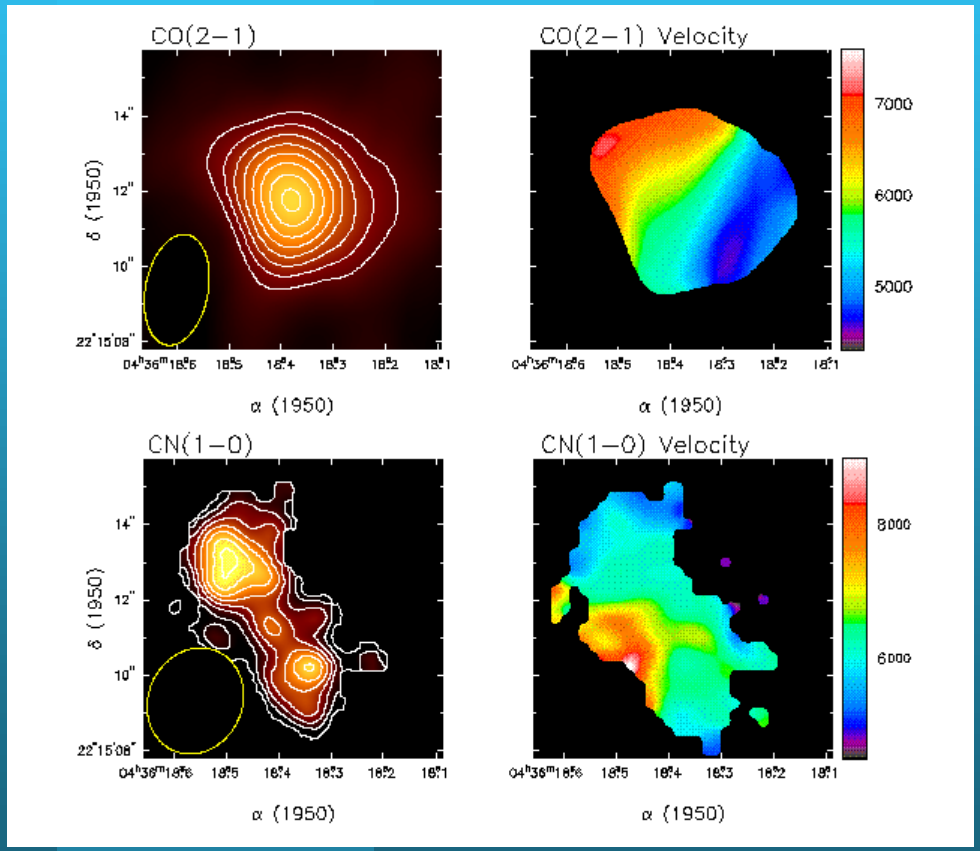
- Line shapes constrain disk orientation, size
- T Tauri, HAe disks well isolated
- Line ratios constrain n,T,chemistry (1 map+spectra)

DM Tau, PdBI

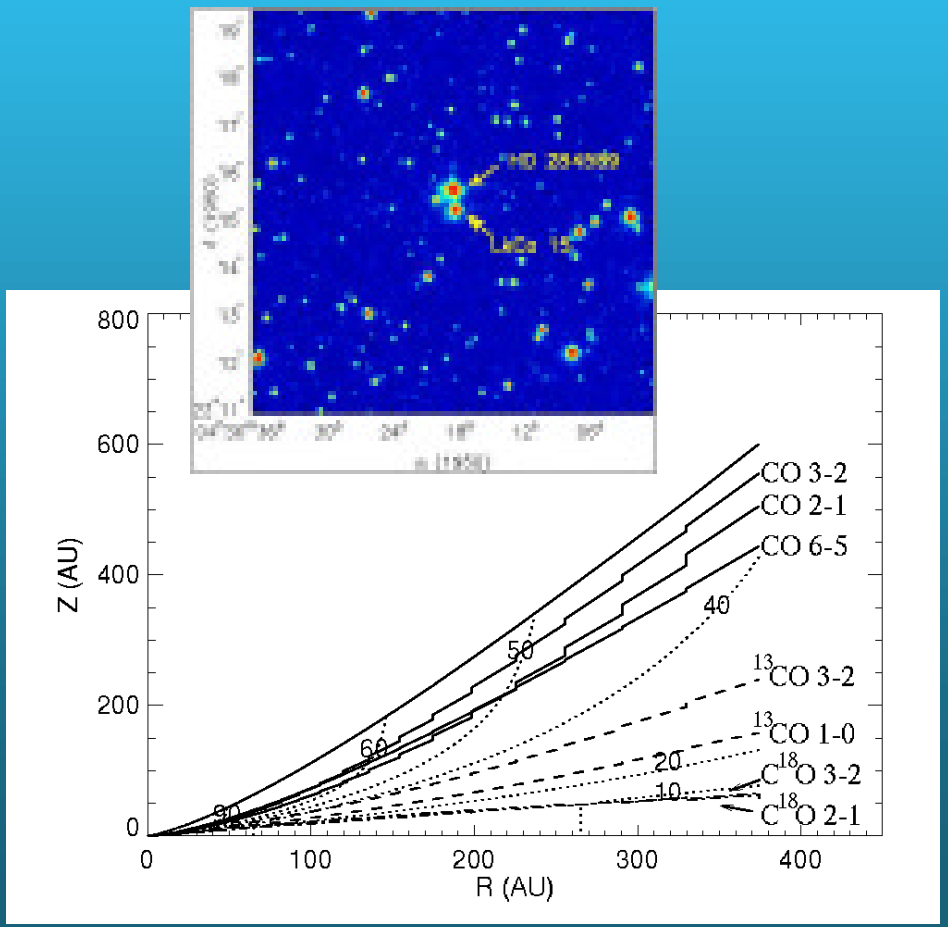


Chemistry in YSO Accretion Disks. II

LkCa 15 Disk, OVRO



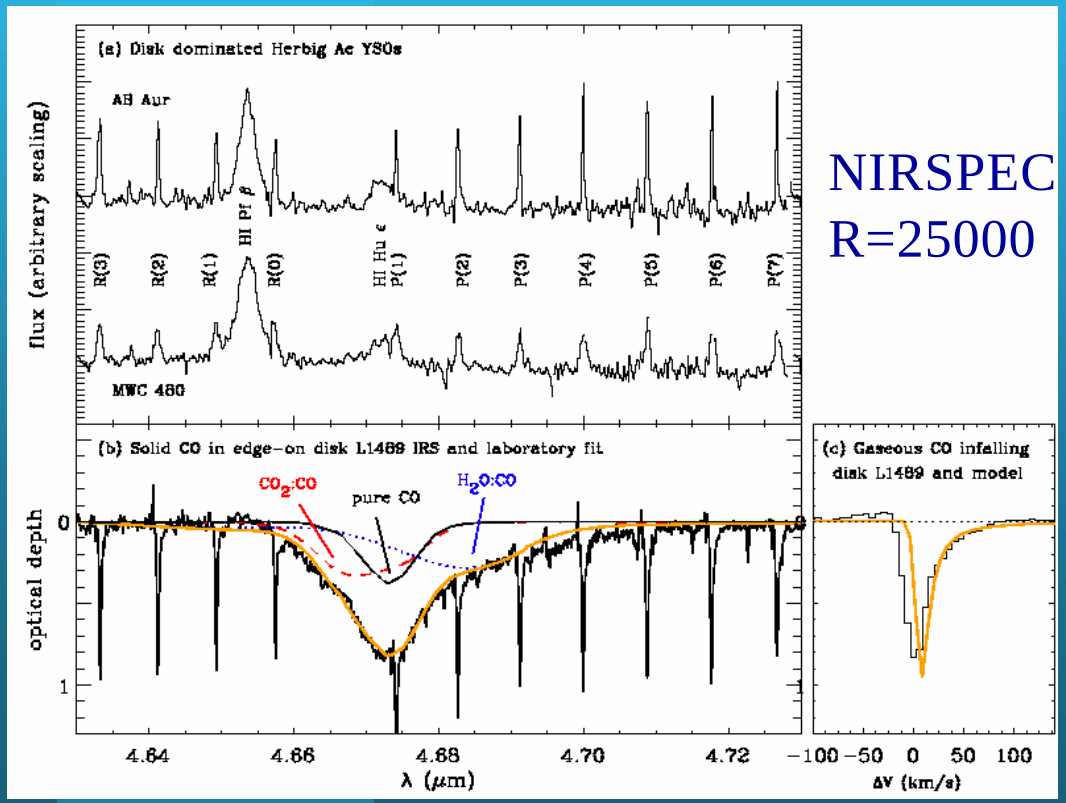
Photochemistry near the disk surface?



Disk transport timescales?

Complementary IR Envelope/Disk Studies

CO emission at 4.7 μm, 0.1-10 AU gaps? Other species?

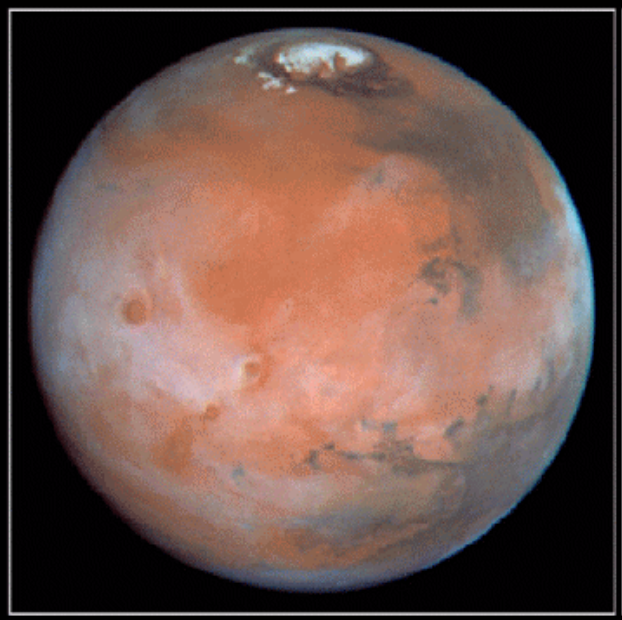


NIRSPEC
R=25000

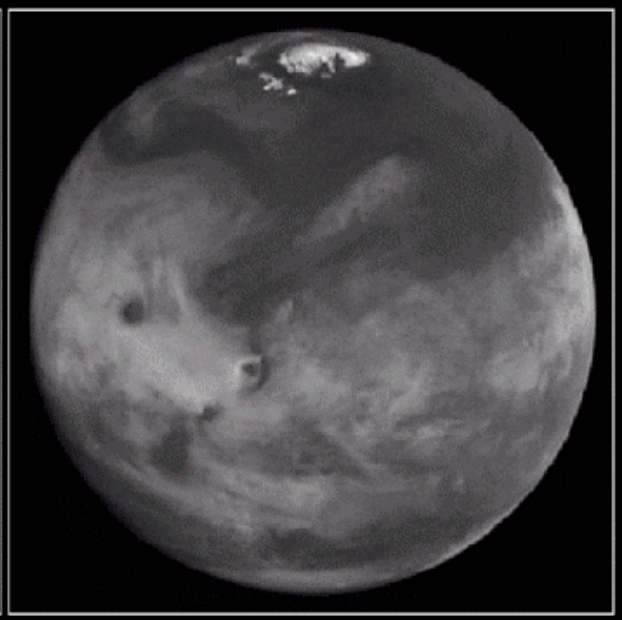
VLT

Planetary Science with Millimeter Arrays. I.

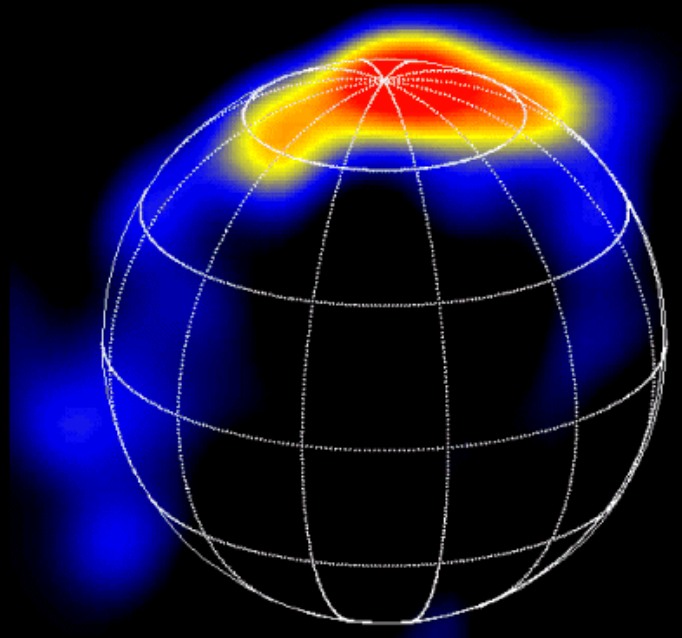
Mars Opposition - March 1997



HST WFPC2-
Color composite[1]
Surface features



HST WFPC2-
Blue filter (410 nm)[1]
Cloud structure



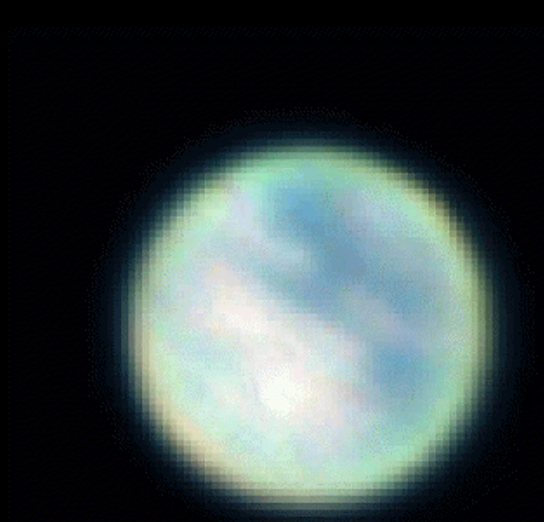
OVRO - Integrated HDO
Emission (1.3 mm)[2]
Water vapor distribution

[1] P. James (U. Toledo), T. Clancy (SSI), S. Lee (U. Colorado), and NASA

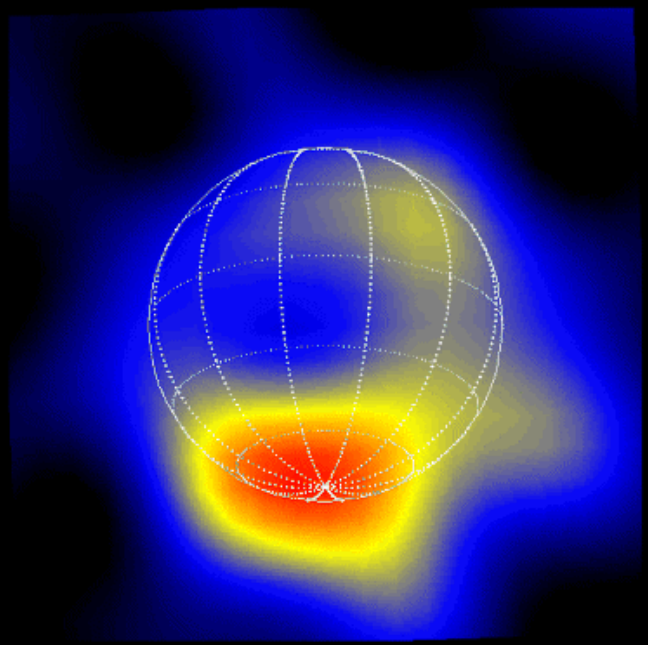
[2] M. Gurwell (CfA), D. Muhleman (Caltech)

Planetary Science with Millimeter Arrays. II.

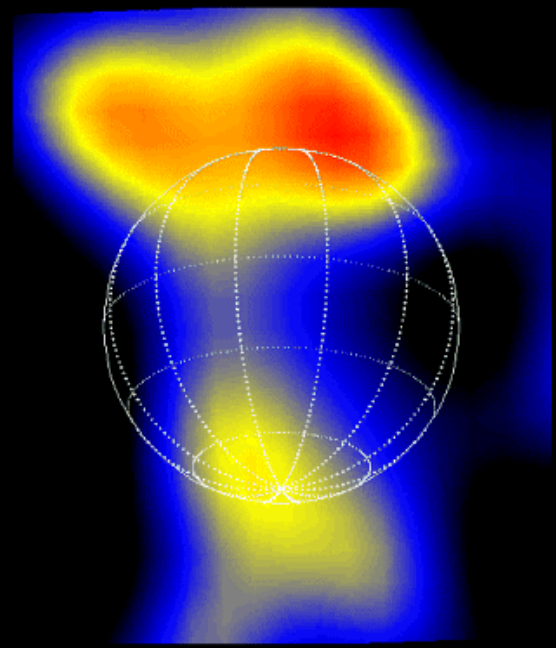
Titan's Atmosphere - December 2000



Keck I - Near IR
Adaptive Optics[1]
Cloud/haze structure and surface features



OVRO -
Integrated CH_3CN
Emission (239.1GHz)[2]



OVRO -
Integrated HC_3N
Emission (236.5 GHz)[2]

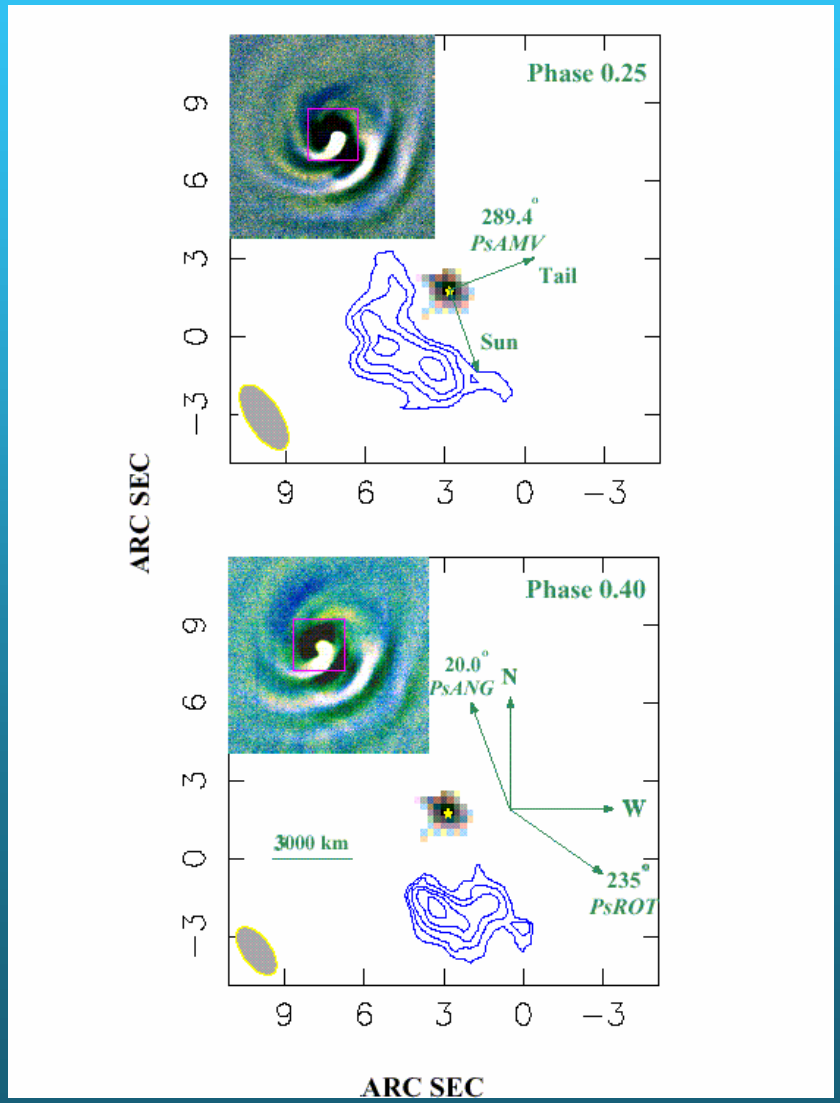
Latitudinal (seasonal?) variation of molecular abundances in the upper atmosphere

[1] 3-color image from J,H, and K' AO images (Keck AO team)

[2] M. Gurwell (CfA), D. Muhleman (Caltech)

Comets with mm-Arrays

Hale-Bopp Jets, OVRO



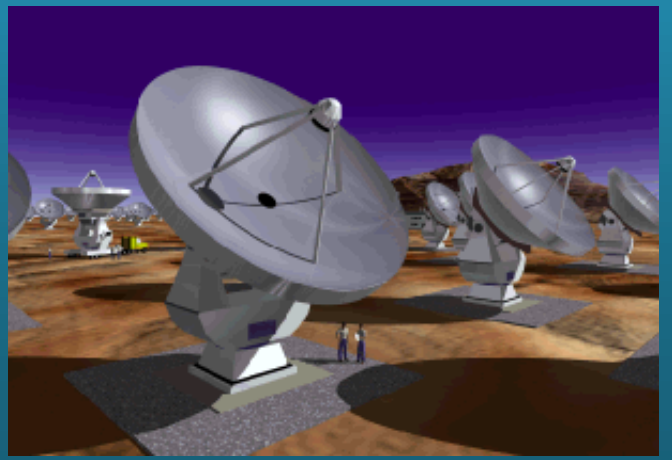
Comae are LARGE, so good zero spacing flux or models mandatory!

Jets, however, are compact.

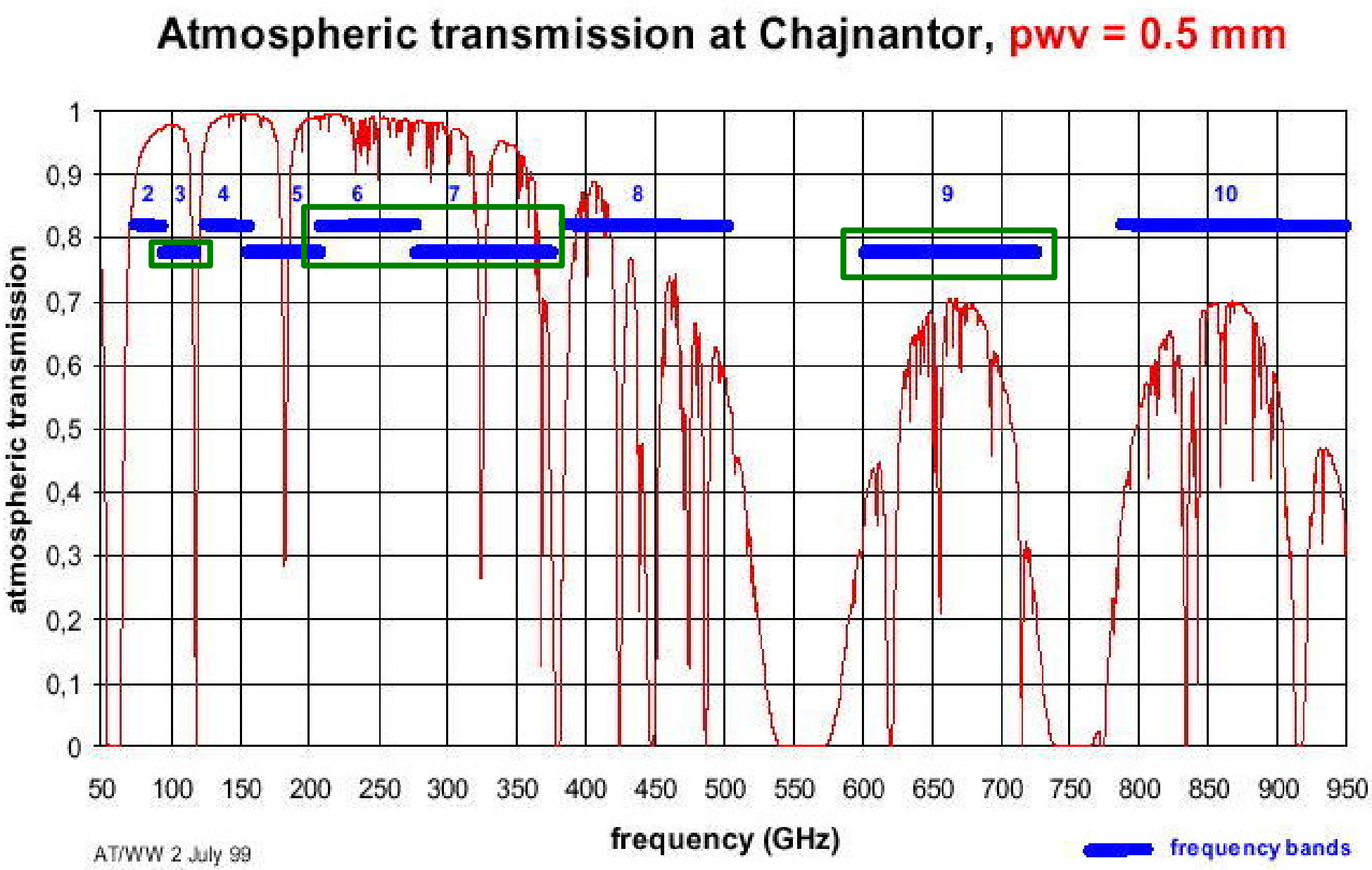
Future Submm Arrays - ALMA

64 12m's
SIS, 8 GHz IF

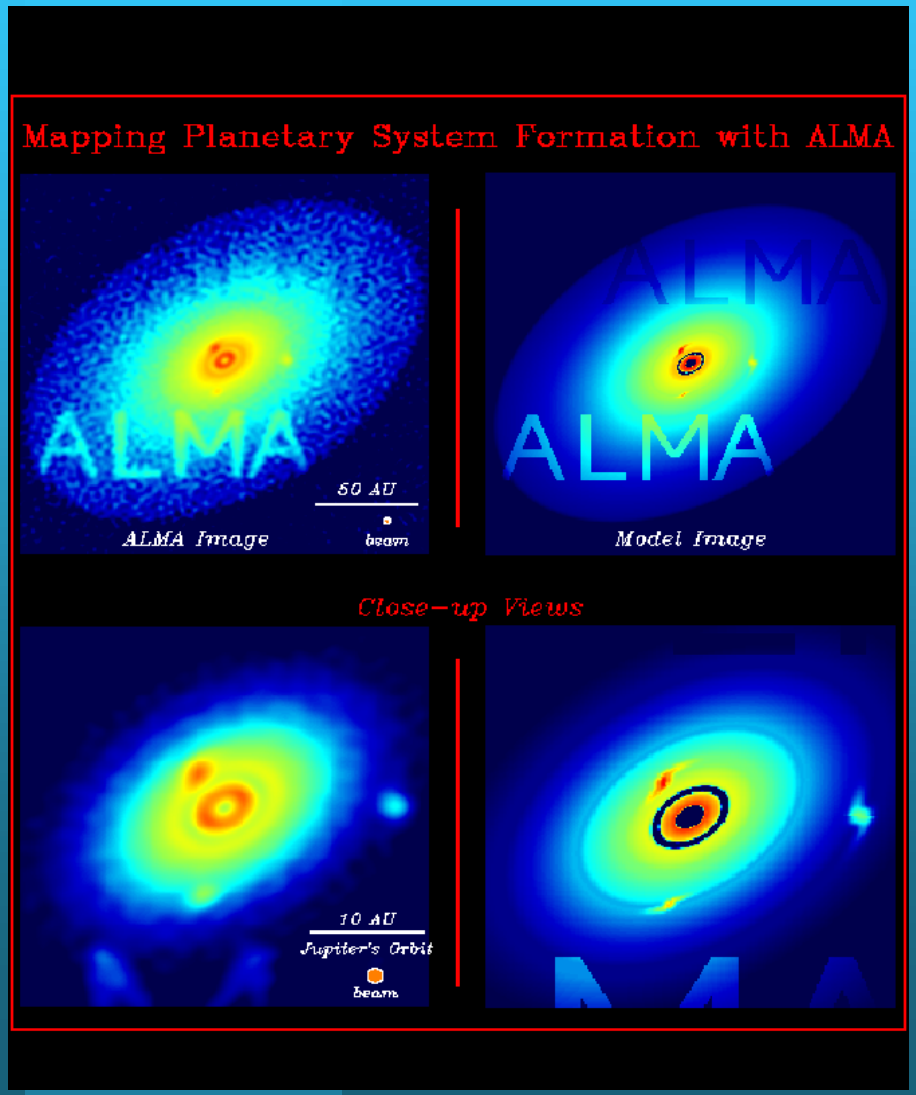
Construction
FY02
approved.



2011

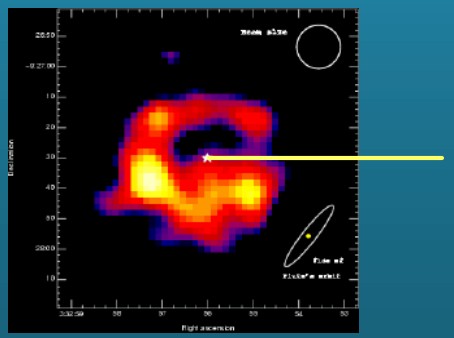

Atmospheric transmission at Chajnantor, pwv = 0.5 mm
atmospheric transmission
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
2
3
4
5
6
7
8
9
10
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
frequency (GHz)
AT/WW 2 July 99
frequency bands

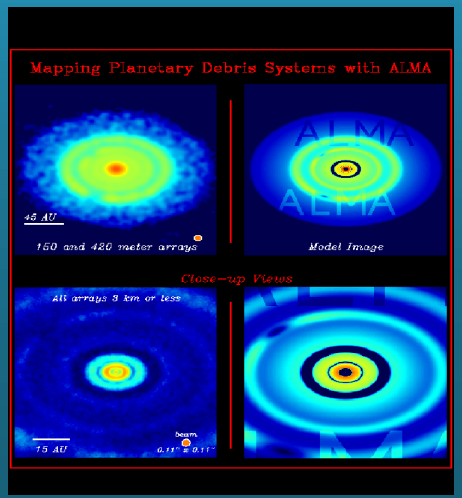
Future Submm Arrays – ALMA. II



ALMA will be incredibly sensitive – Disk images will be possible in continuum to a resolution of <1 AU!

Little is known about the Southern sky at high angular resolution…





Conclusions

-Wealth of opportunities for the ATCA, start with small sources that exploit the excellent sensitivity (disks, absorption line studies…), then move toward mosaics as the system improves.

- Make aggressive use of public datasets on nearby clouds and galaxy (2MASS, SIRTF) and on the new submillimeter single dish capabilities in Chile.

- ATCA not just an ALMA pathfinder, excellent complementary science even after 2011.