# High Resolution Submm Observations of Massive Protostars

Crystal Brogan (NRAO/NAASC)

*T. R. Hunter (NRAO), R. Indebetouw (UVa), Y. L. Shirley (U. of Arizona), C. J. Chandler (NRAO), R. Rao (ASIAA), A. P. Sarma (DePaul)*

## Open Questions

- Stellar density?
- Role of jets and disks?
- Evolutionary sequence?

ERA of ALMA, Madrid, Spain, Nov. 13, 2006

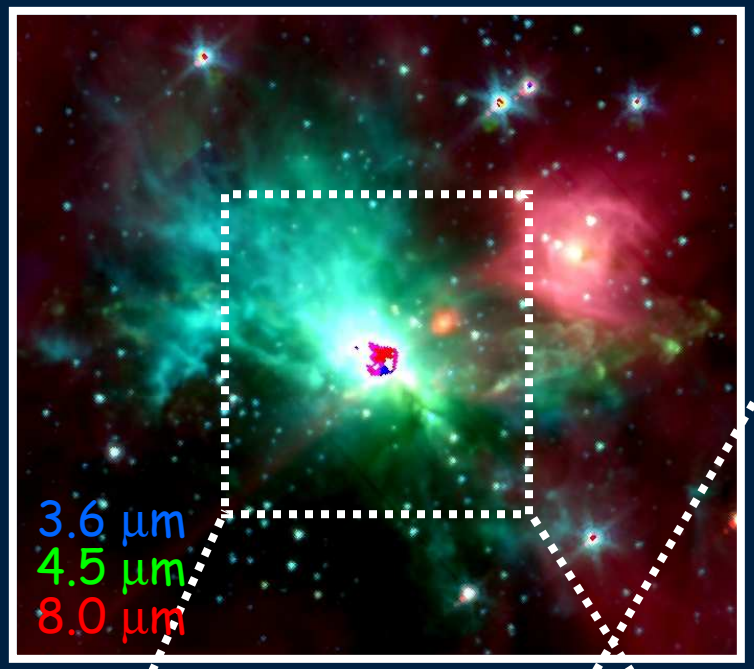
# The Submillimeter Array Observations:
## CepA-East, NGC 7538 IRS1, G5.89-0.39

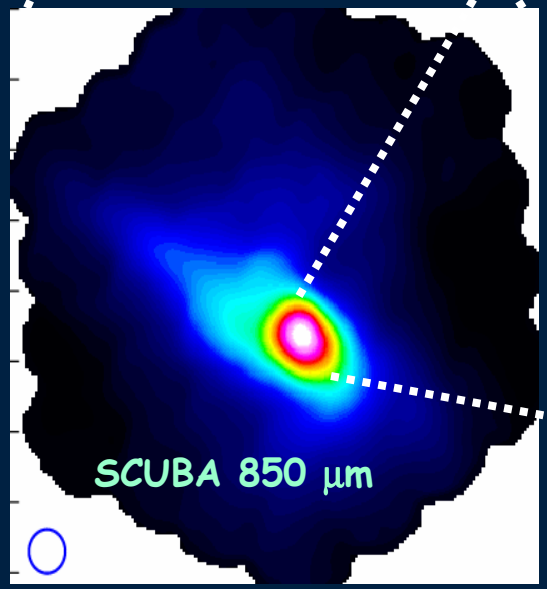
- Eight 6-m antennas
- 2 Sidebands each 2 GHz wide separated by 10 GHz
- 345 GHz tuning centered at 336 / 346 GHz
- Resolution ~2" in compact configuration, <1" extended
- Continuum rms noise ~ 10 mJy/beam
  - Only line free channels used
- Line rms noise ~ 300 mJy/beam

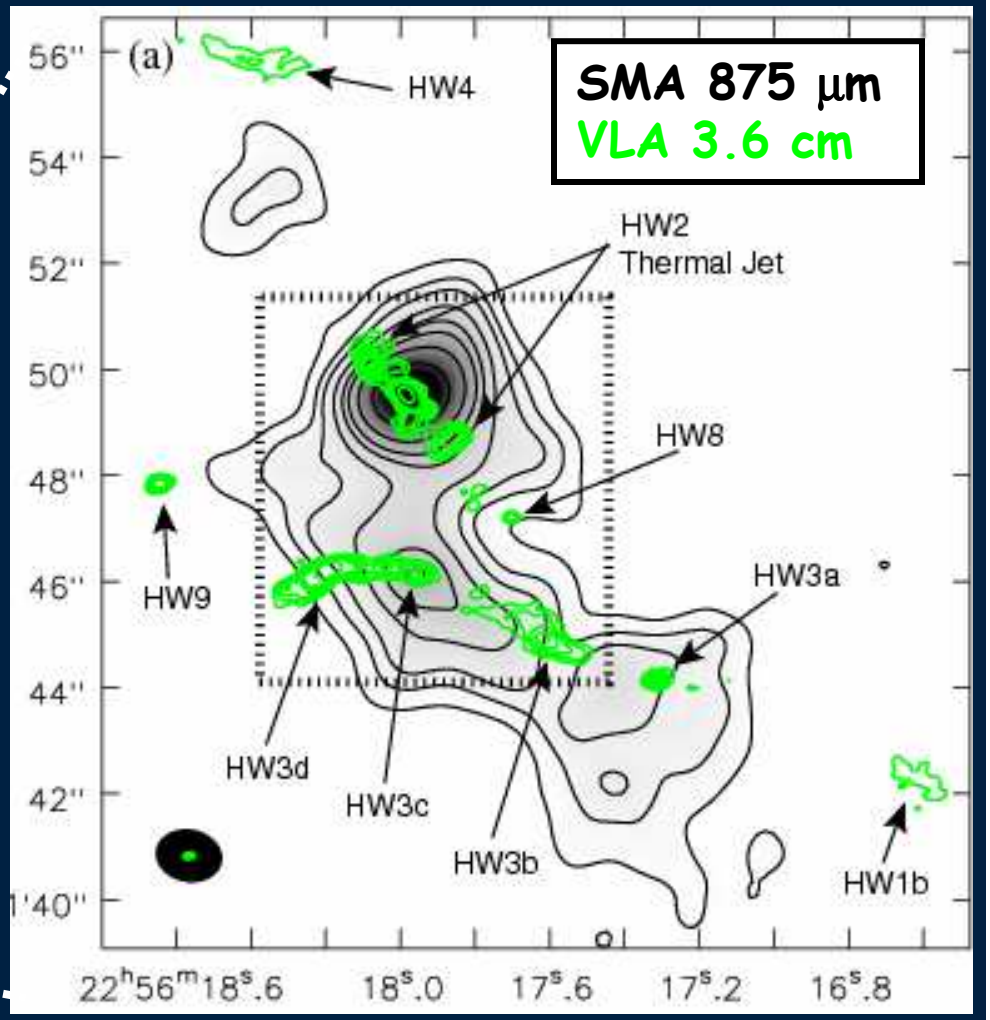
**ALMA will improve resolution and spectral sensitivity by more than factor of 25!**

# The Many Protostars of CepA-East

d=0.73 kpc

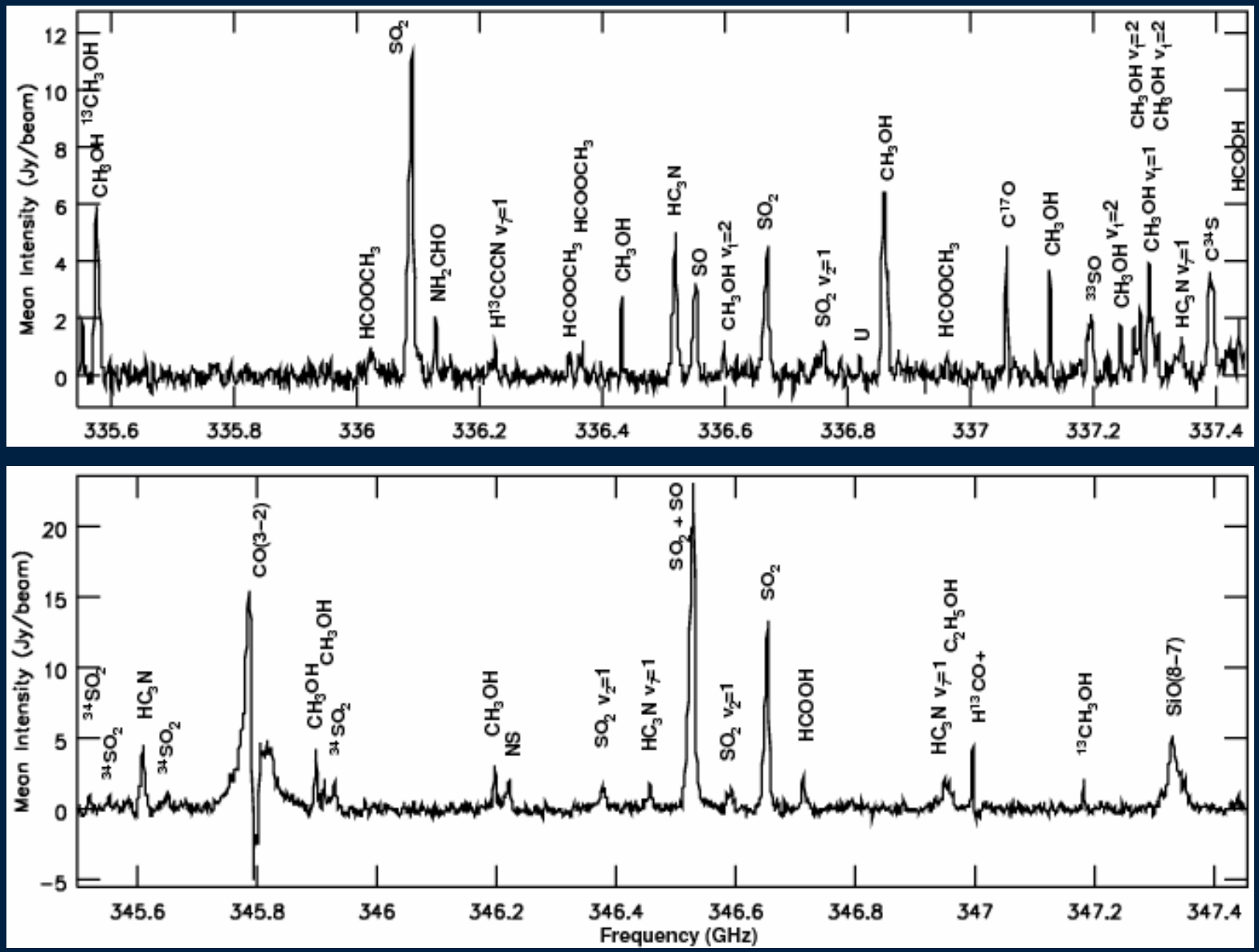


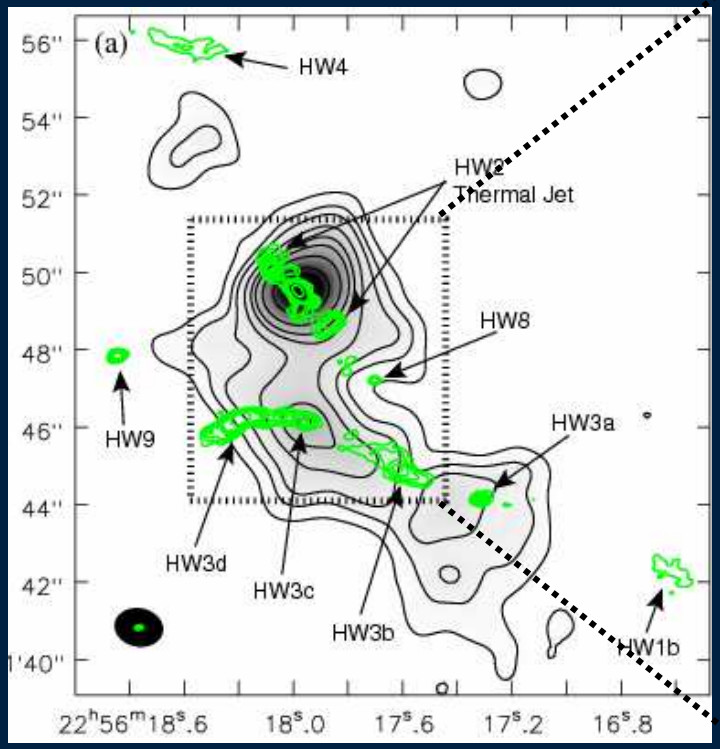

resolution 1.″3 x 1.″0

# CephA-East Line Forest

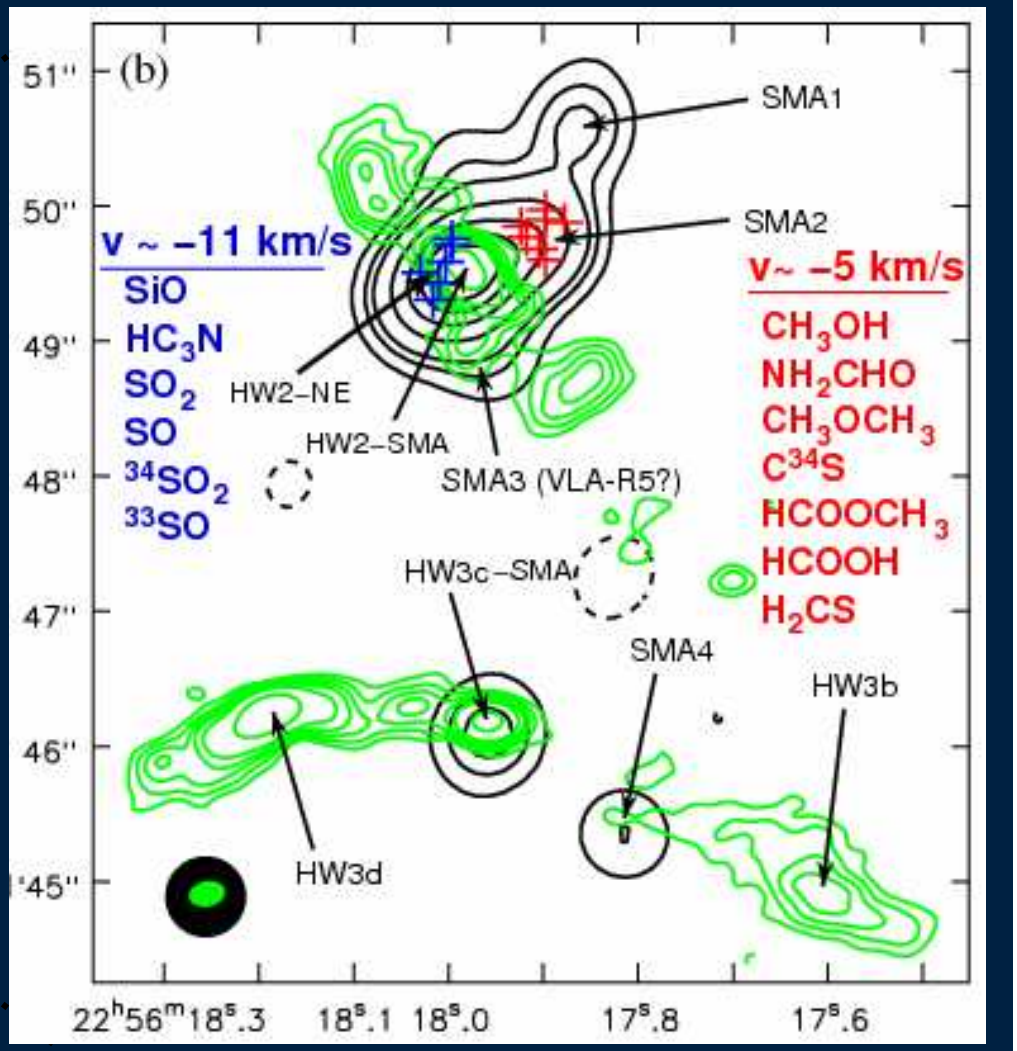



Spectra are similar to that of OrionA single dish data (Schilke et al. 1997)

# Chemical Differentiation



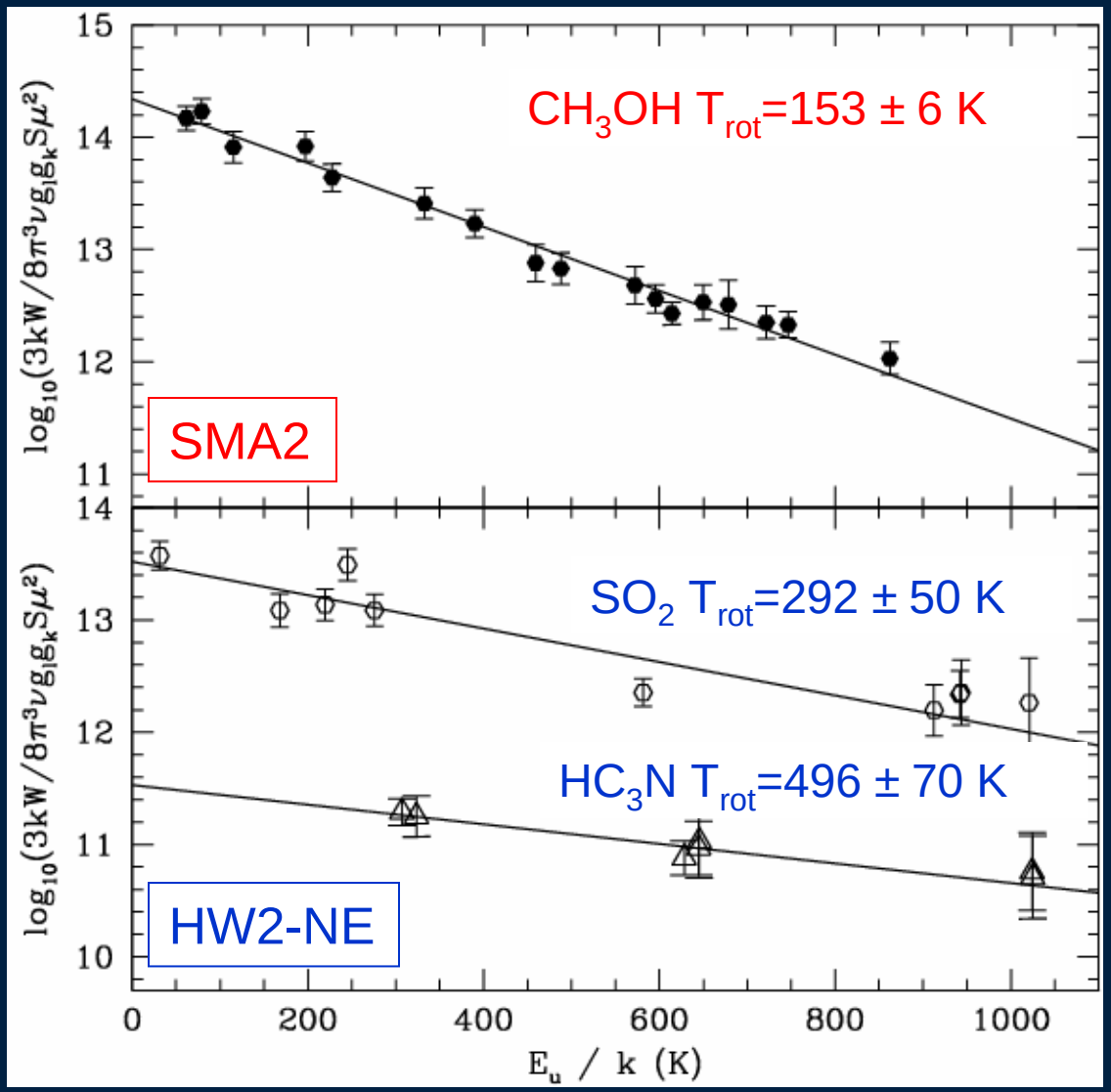

SMA 875 μm
VLA 3.6 cm

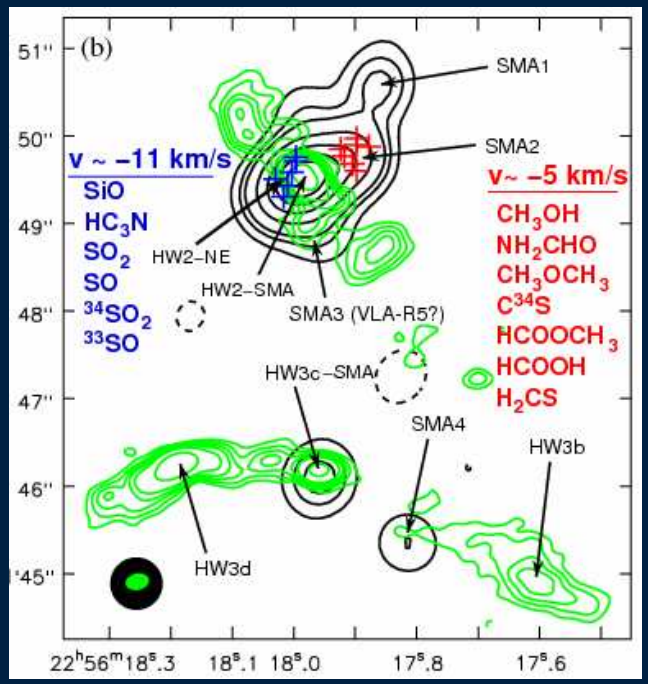



resolution 0."6

$n_{protostars} = 8 \times 10^5\ pc^{-3}$

# CepA-East Temperatures

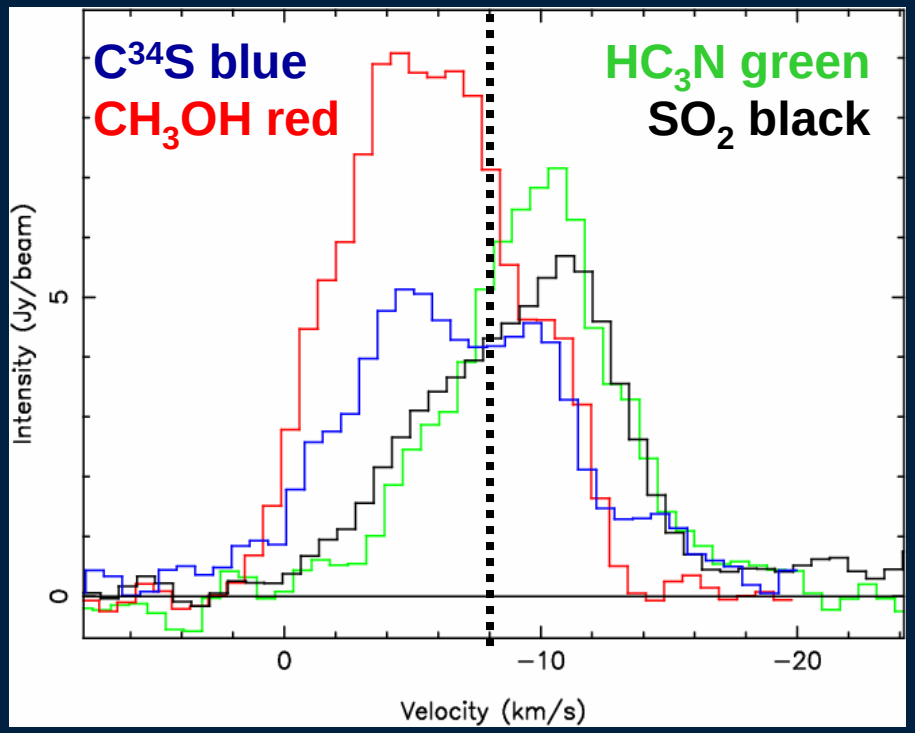


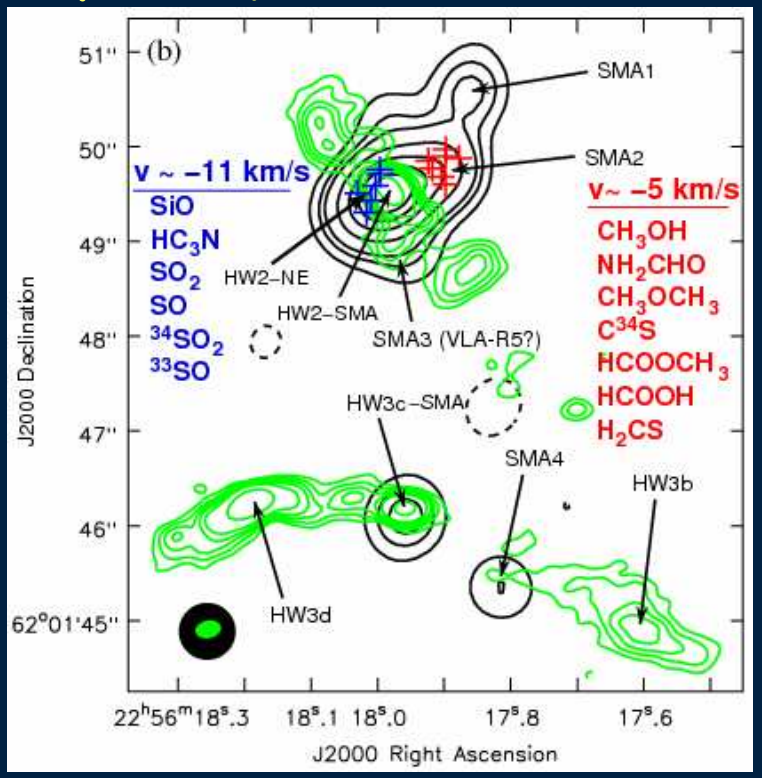




$CH_3OH$ and $SO_2$ corrected for optical depth effects. For $CH_3OH$, max $\tau$~30!

$T_{rot}$ 2x higher than reported by Martin-Pintado et al. (2005) based on 30m data – probably a beam dilution effect

# Velocity Gradients Don't Always Equal Rotation…

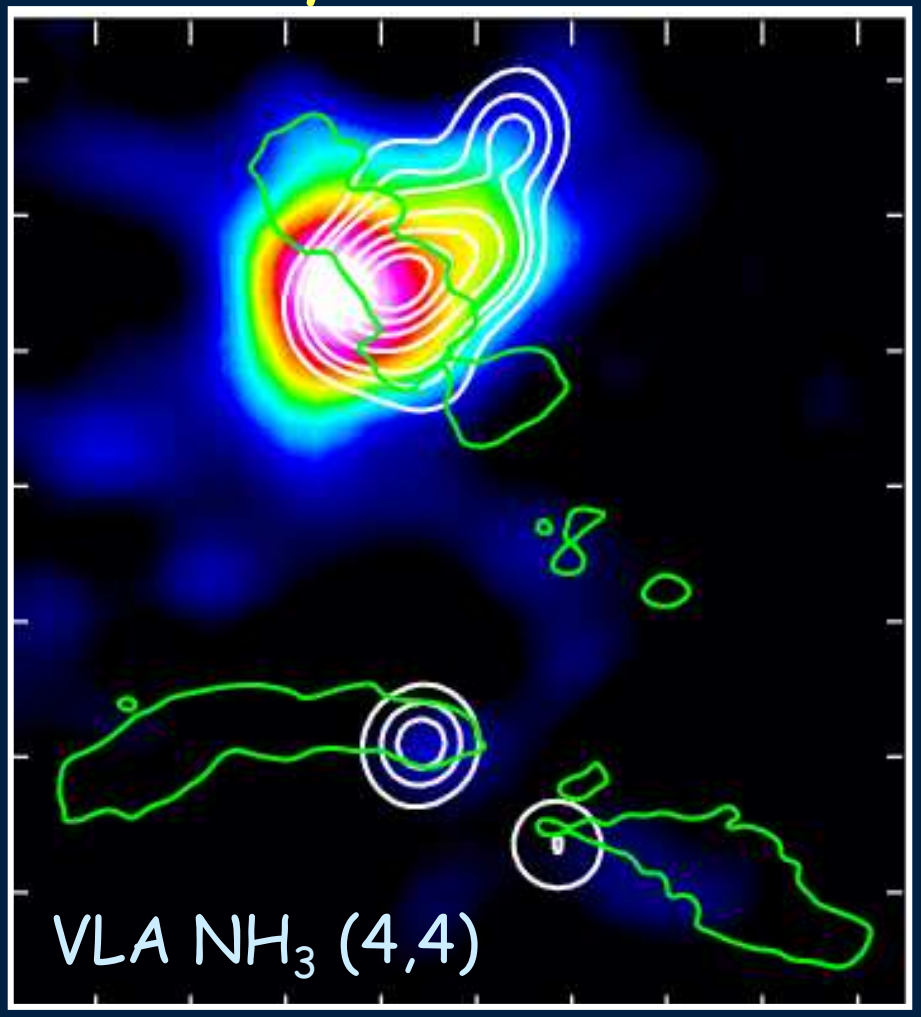



Insufficient spatial resolution causes apparent velocity/position gradient

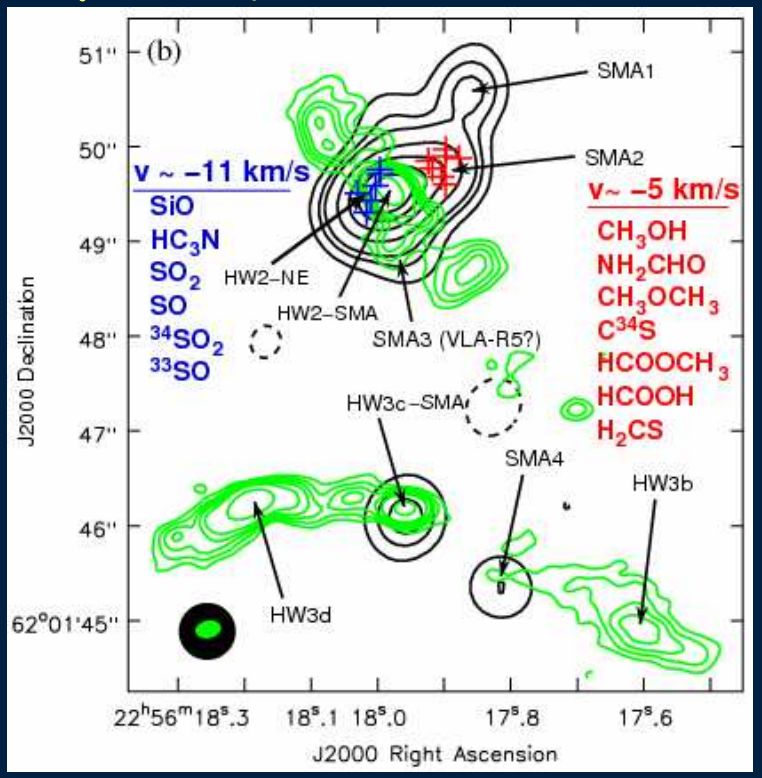
No evidence for a disk as reported by Patel et al. (2005)

# Velocity Gradients Don't Always Equal Rotation…

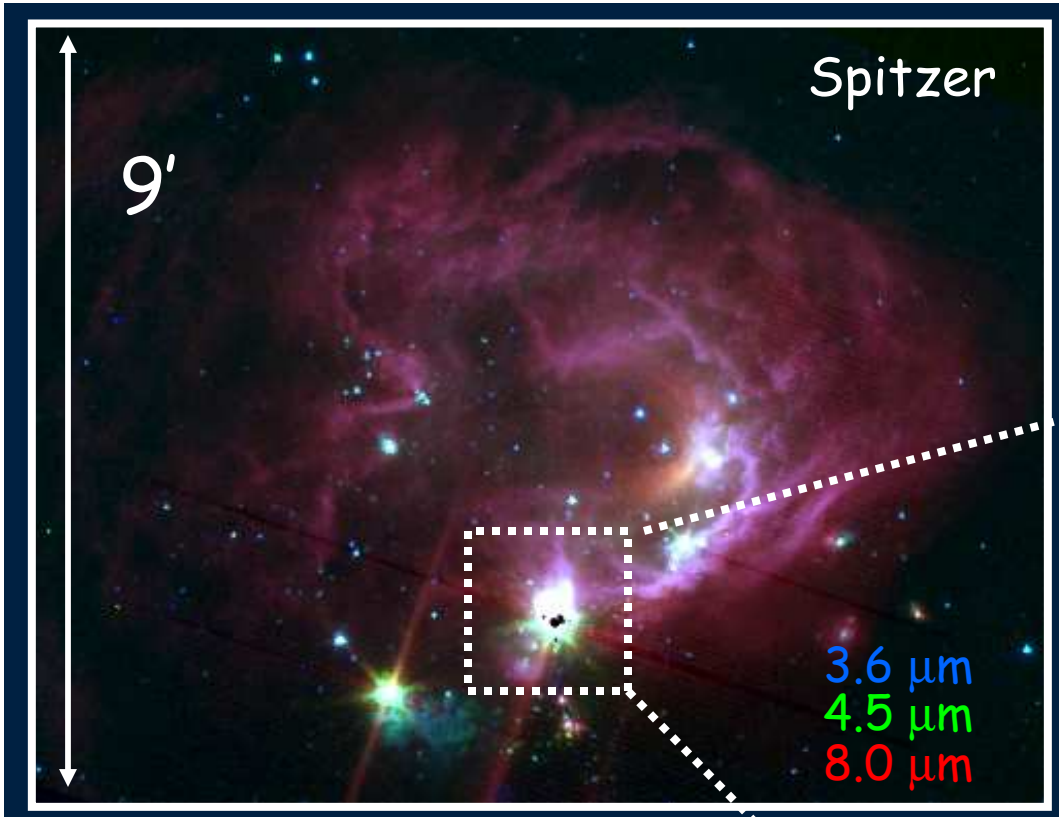



No evidence for a disk as reported by Patel et al. (2005)

Also see Comito et al. (in prep.)



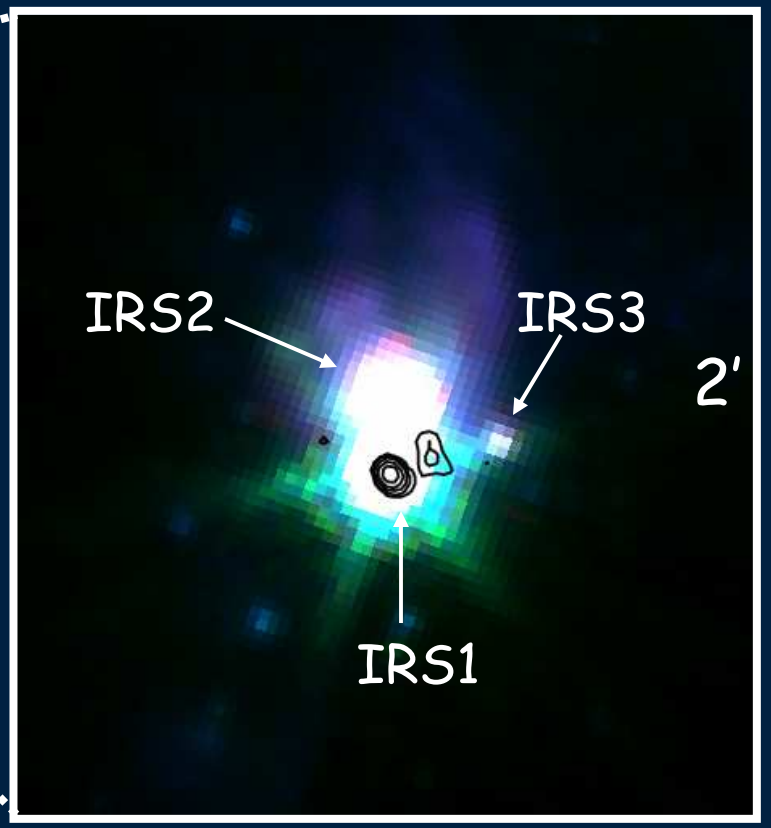

- Detection of $NH_3$ (4,4) confirms high temperatures, and positions of HW2-NE, and SMA2.
- HW2-NE shock interaction at base of jet rather than protostar as suggested by Martin-Pintado et al. (2005)?

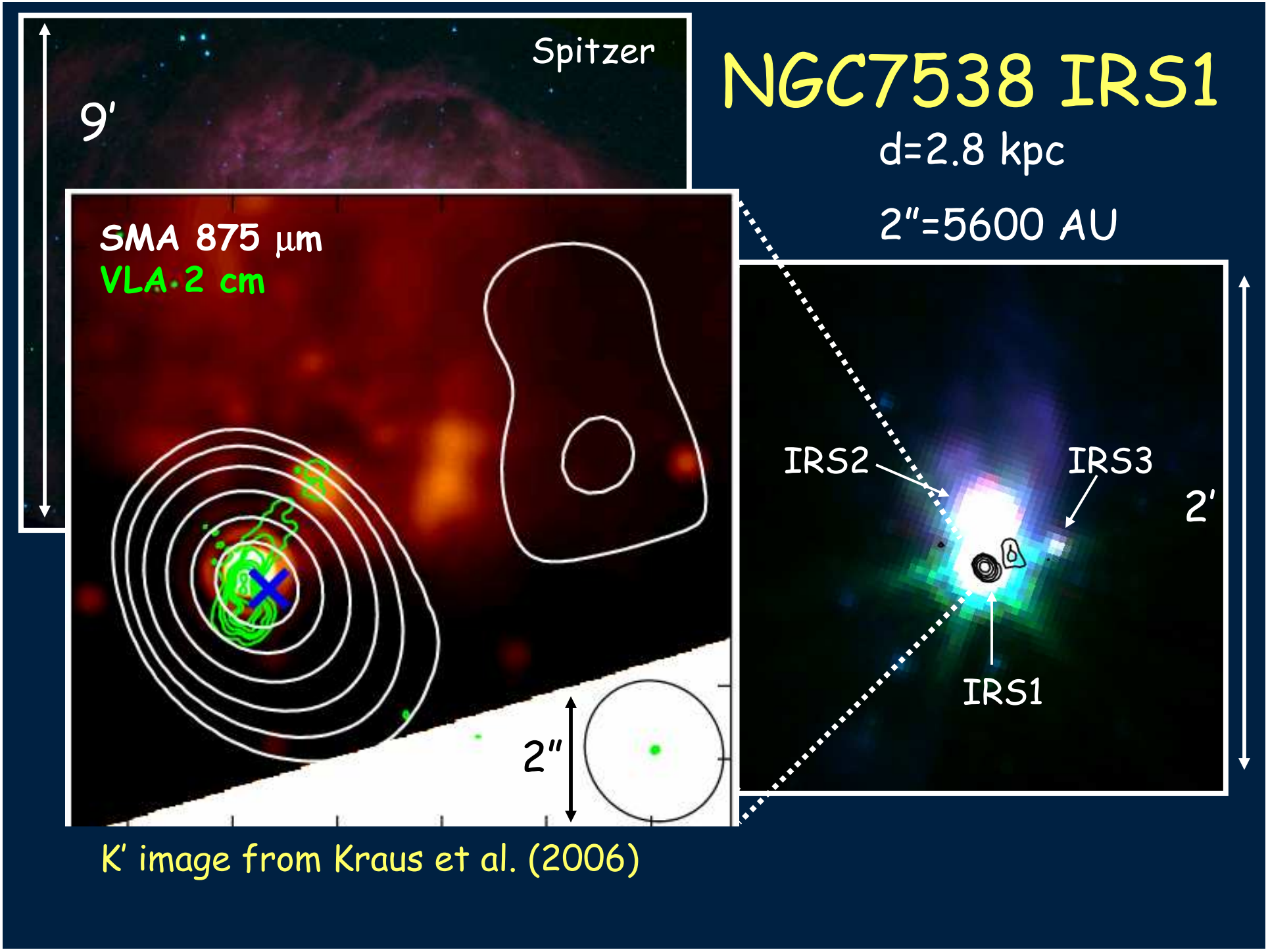



# NGC7538 IRS1

d=2.8 kpc

2″=5600 AU





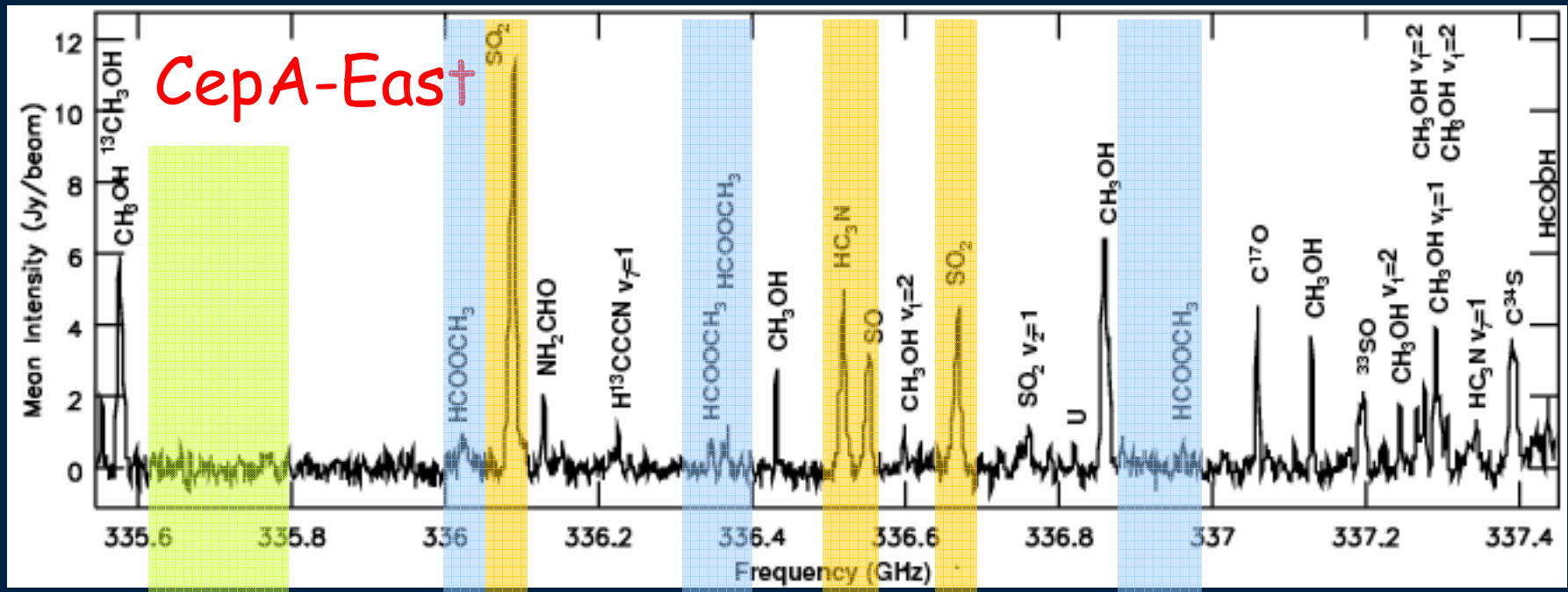

# NGC7538 IRS1

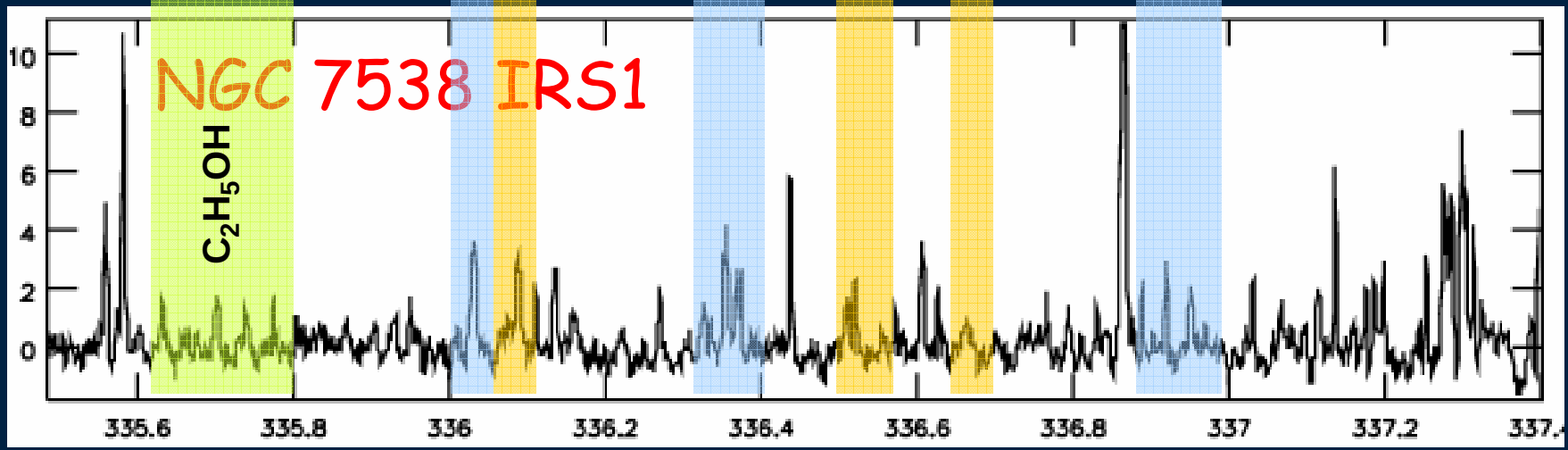
d=2.8 kpc

2″=5600 AU

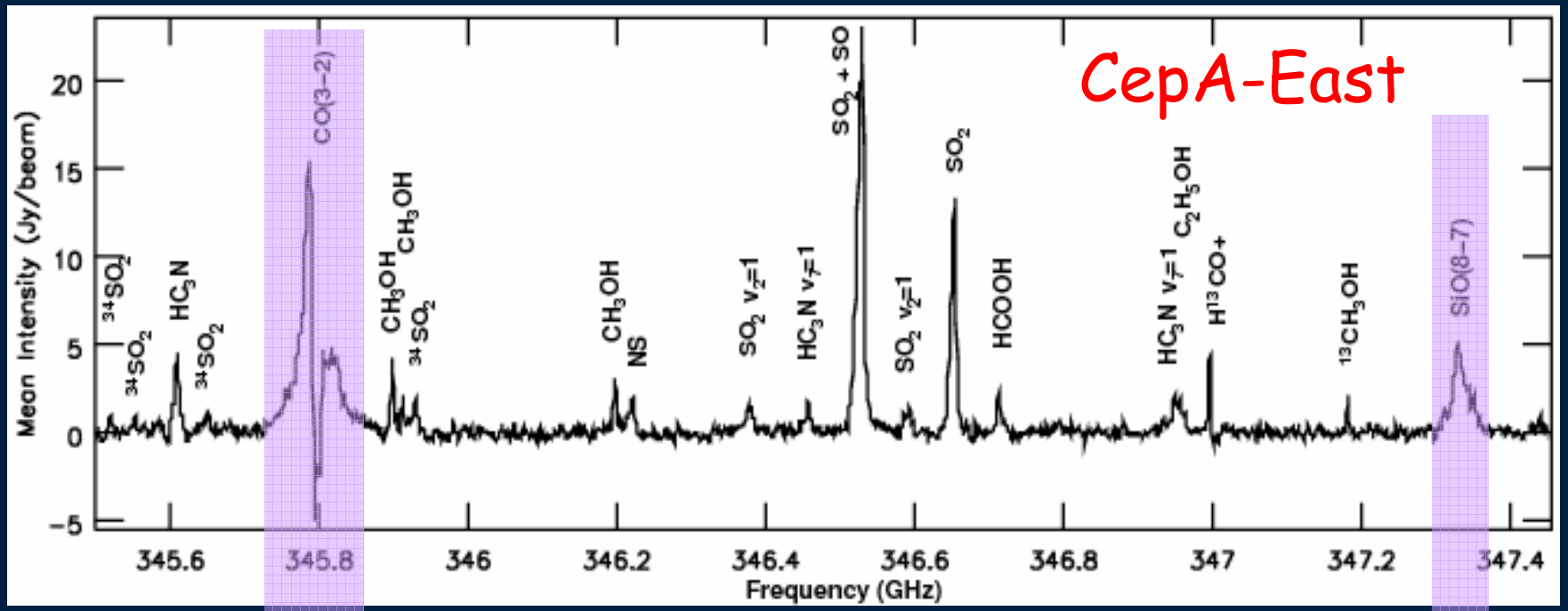
K′ image from Kraus et al. (2006)

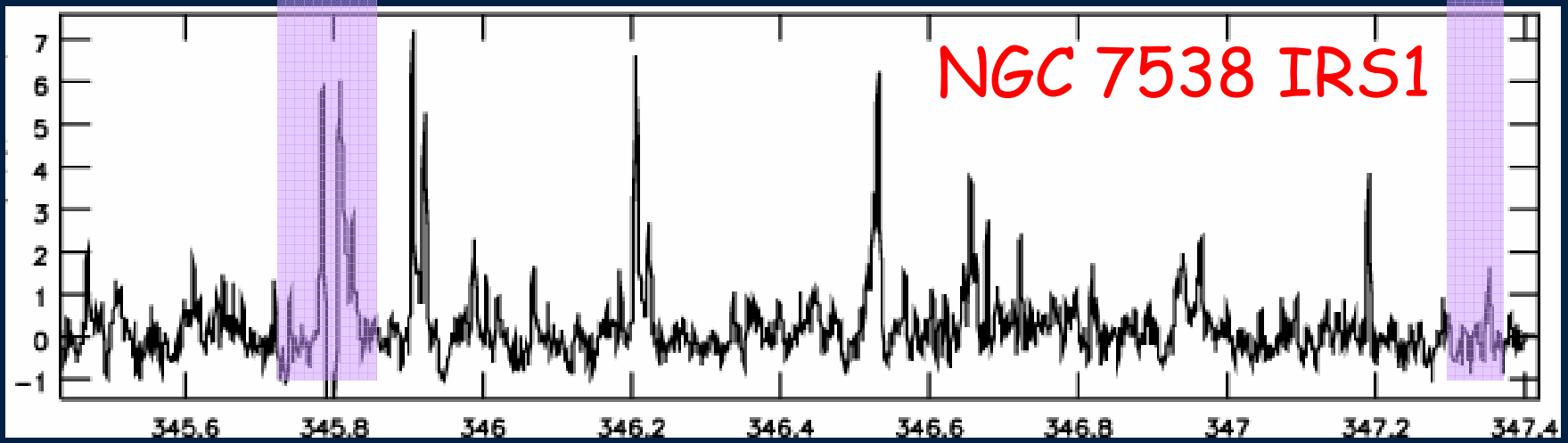
# NGC 7538 Line Forest Comparison-I



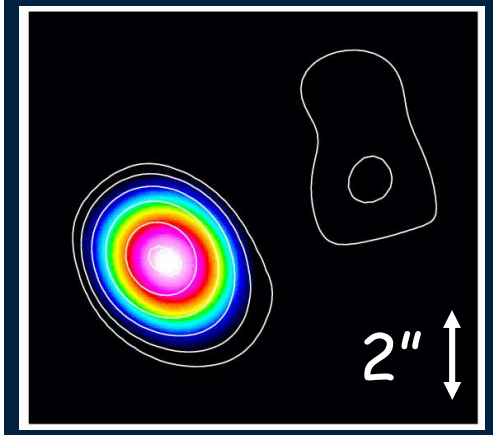



# NGC 7538 Line Forest Comparison-II

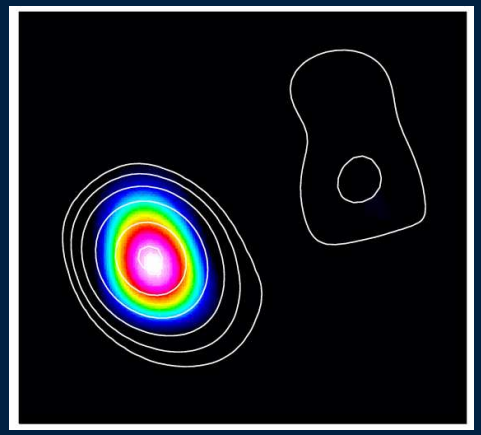


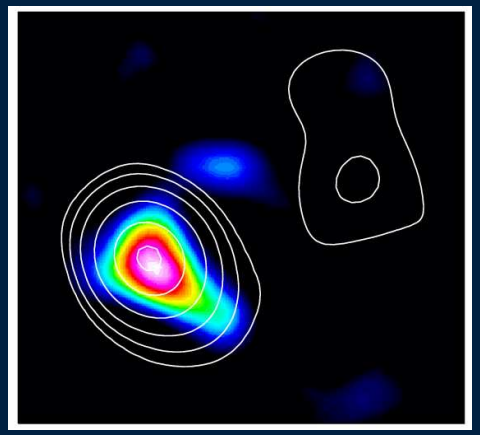
# Distribution of Molecules in NGC7538 IRS1



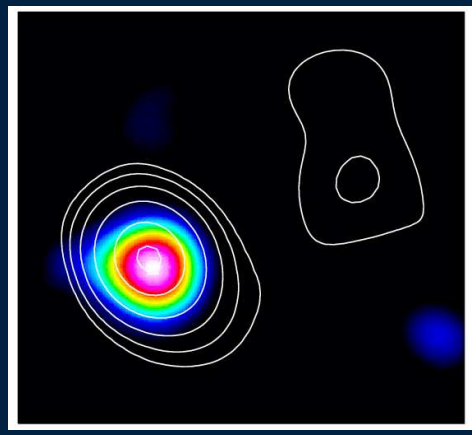

$CH_3OH$



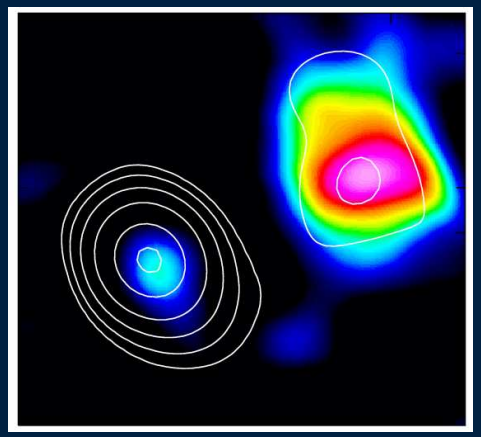
$C_2H_5OH$



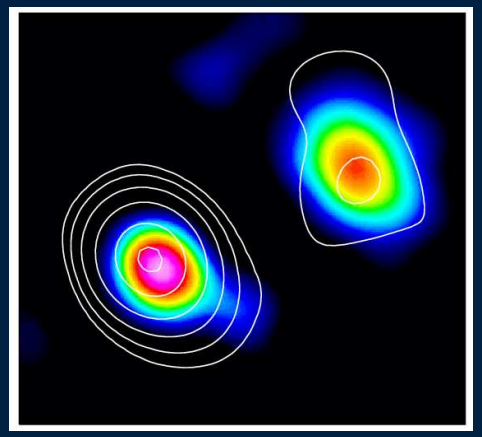
$HC_3N$



$SO_2$

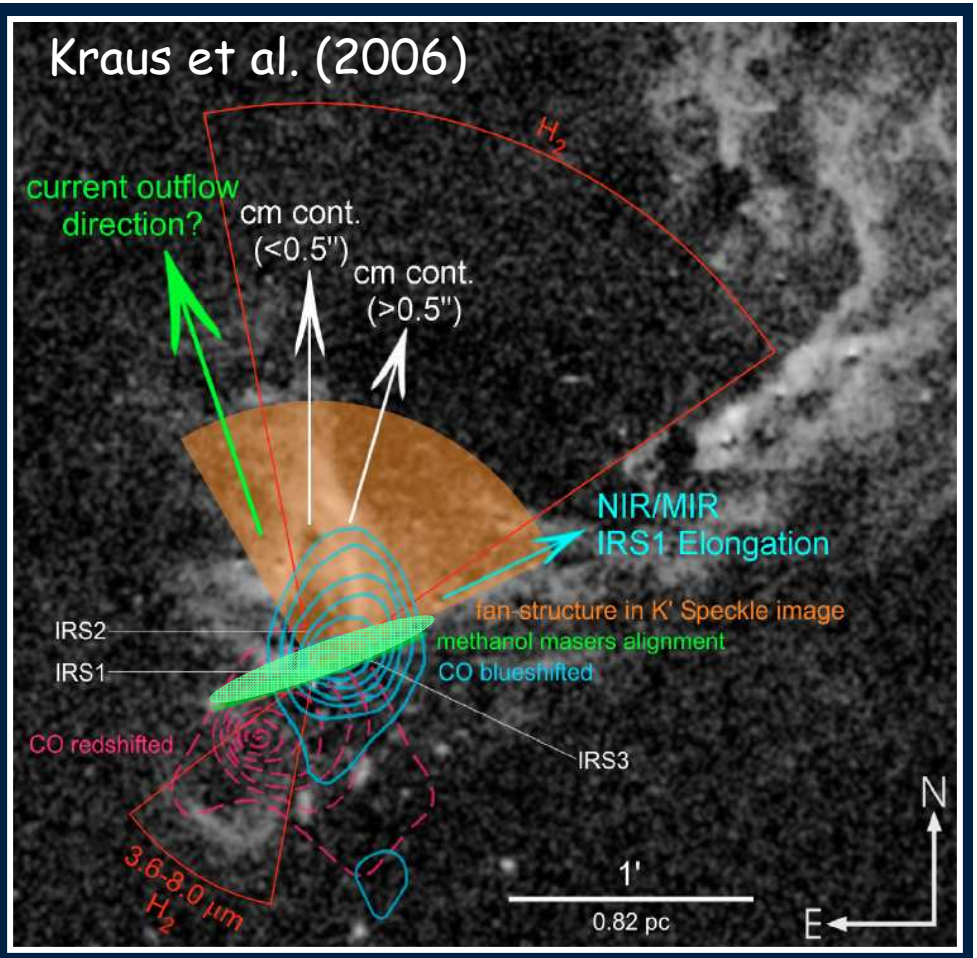


$C^{17}O$



$C^{34}S$

# Methanol in IRS1: Outflow and Disk?

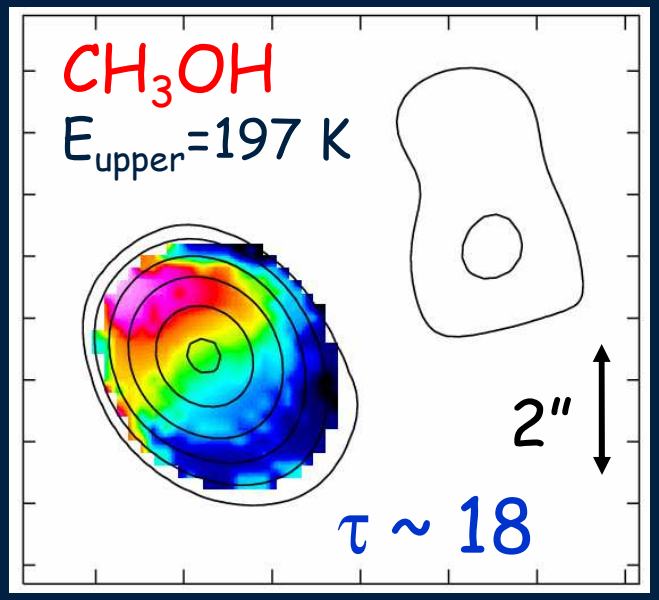


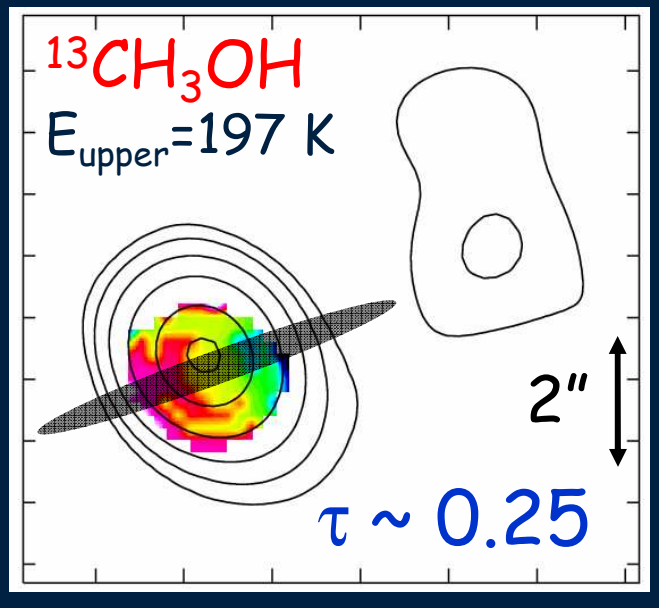

$CH_3OH$ maser disk at P.A.=-70°
Pestalozzi et al. (2004); Minier et al. (2000, 2001)

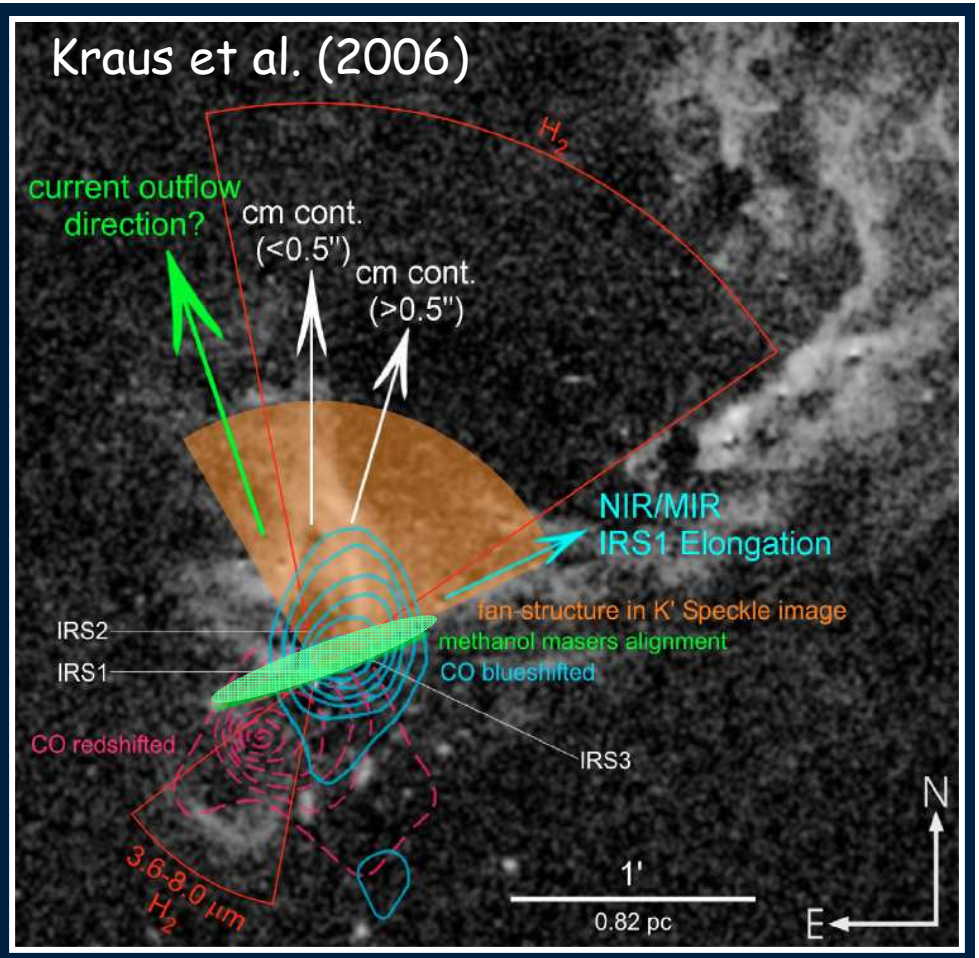
Mid-IR dust has similar elongated morphology
Kraus et al. (2006); De Buizer & Minier (2005)

Evidence for Jet Precession, P=280 years
Kraus et al. (2006)

# Methanol in IRS1: Outflow and Disk?



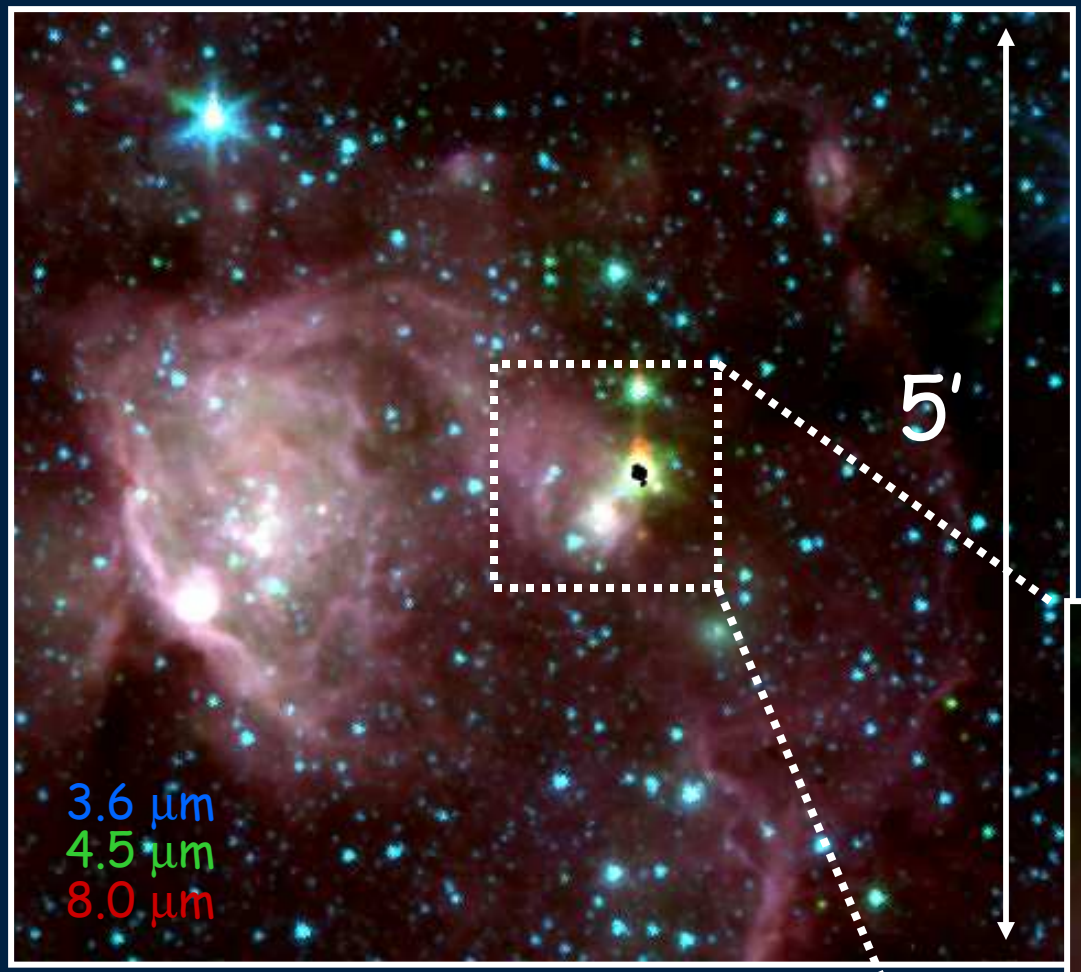




IF interpreted as Keplerian disk with radius < 0.7″ (r=2000 AU) and Δv=4 km/s, M < 32 $M_\odot$ consistent with maser and spectral type estimates

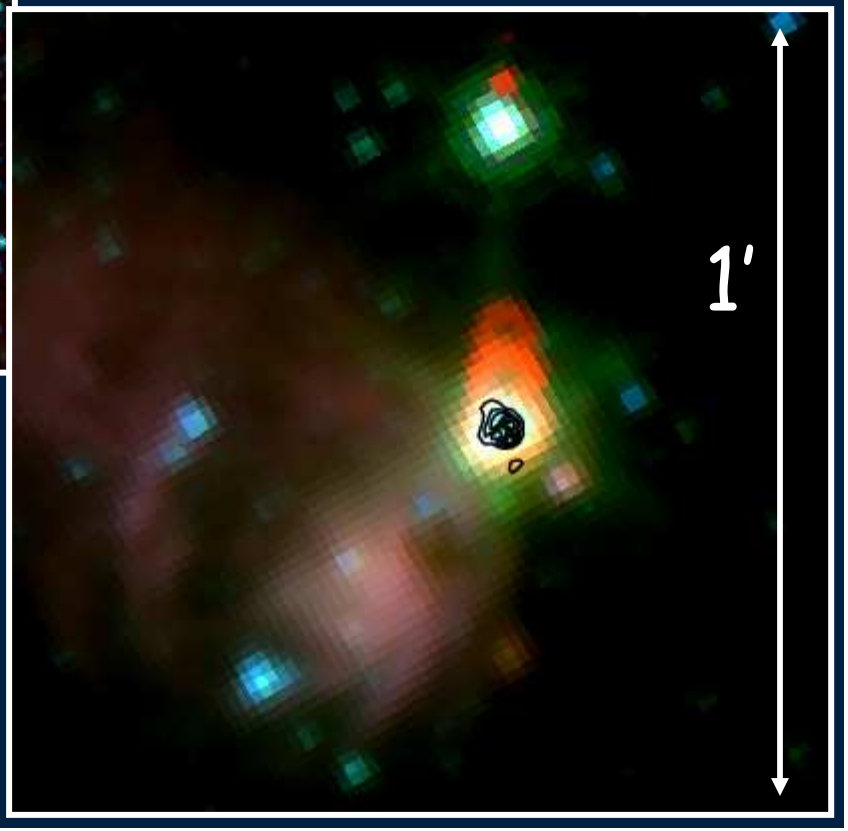
BUT better resolution is needed…

# The Enigmatic G5.89-0.39

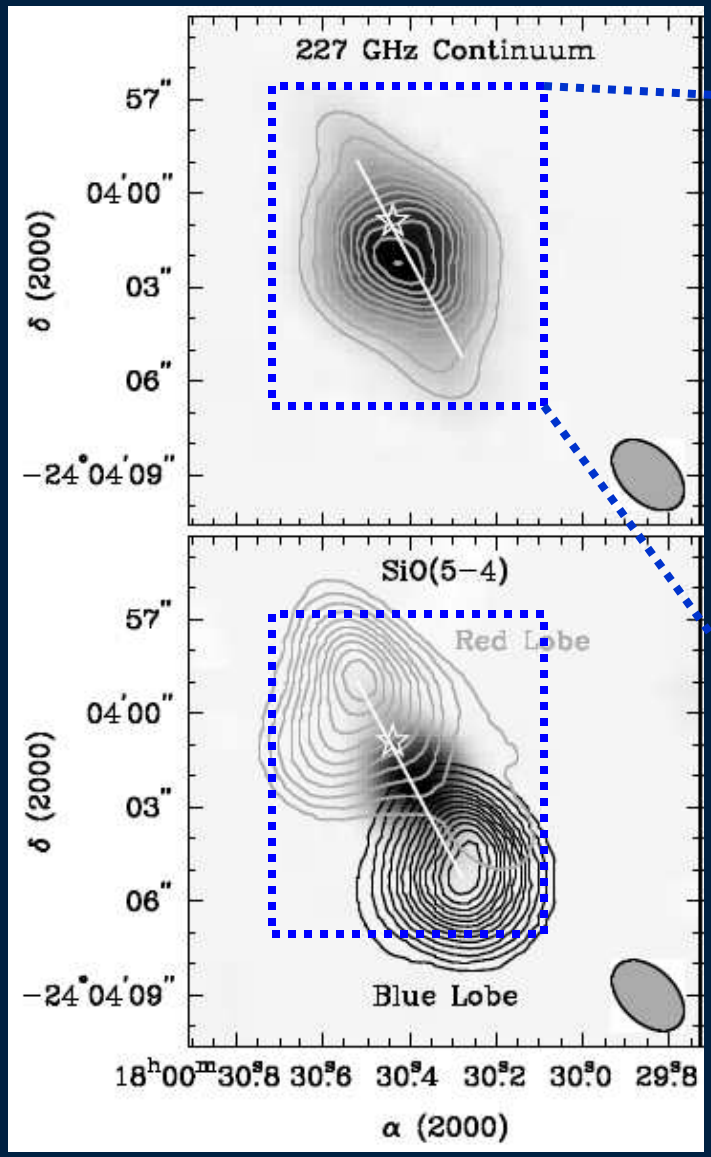
d=2.0 kpc



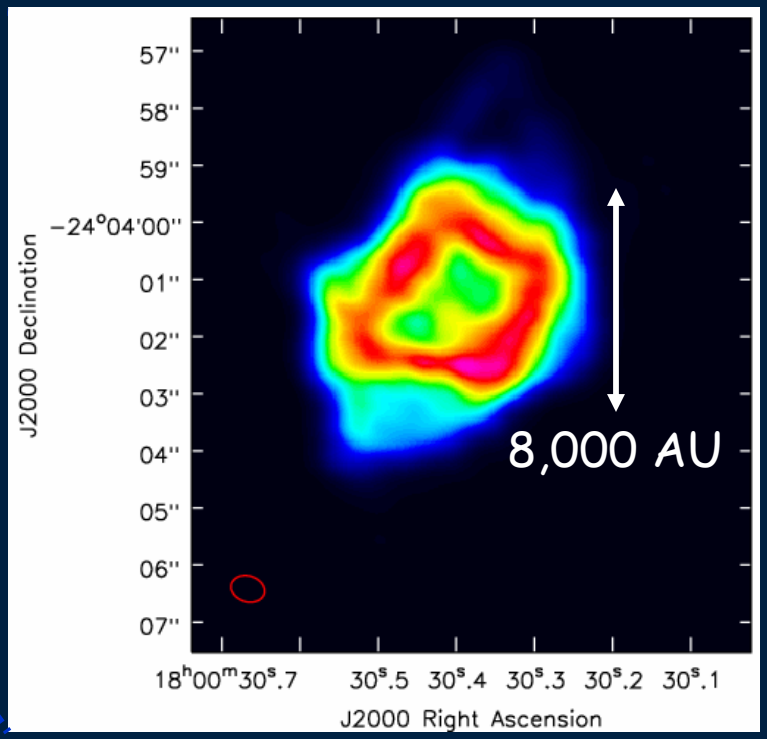

Spitzer GLIMPSE



# Previous High Res. Radio Data



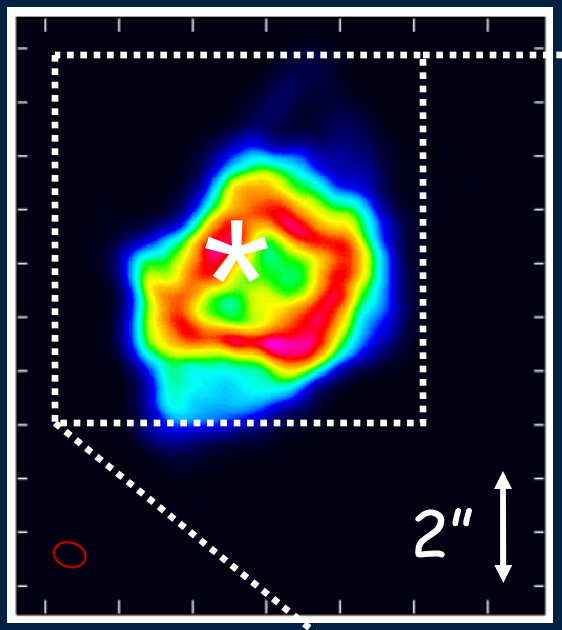

SMA 1.3mm: Sollins et al. (2004) [2."8 x 1."8]



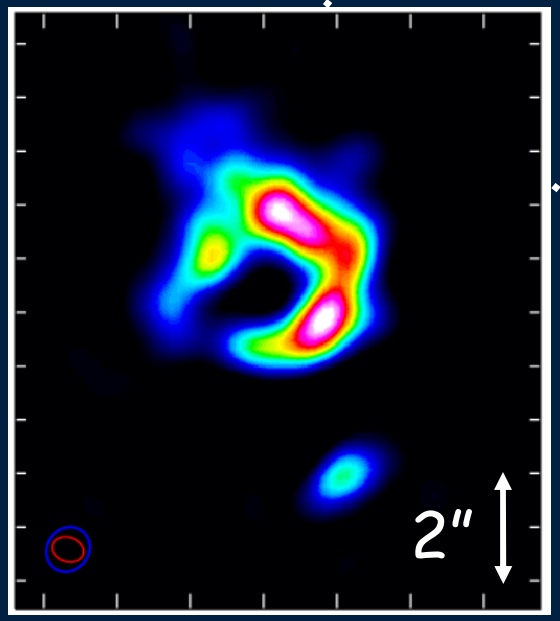

Archival VLA 3.6cm [0."6 x 0."45]

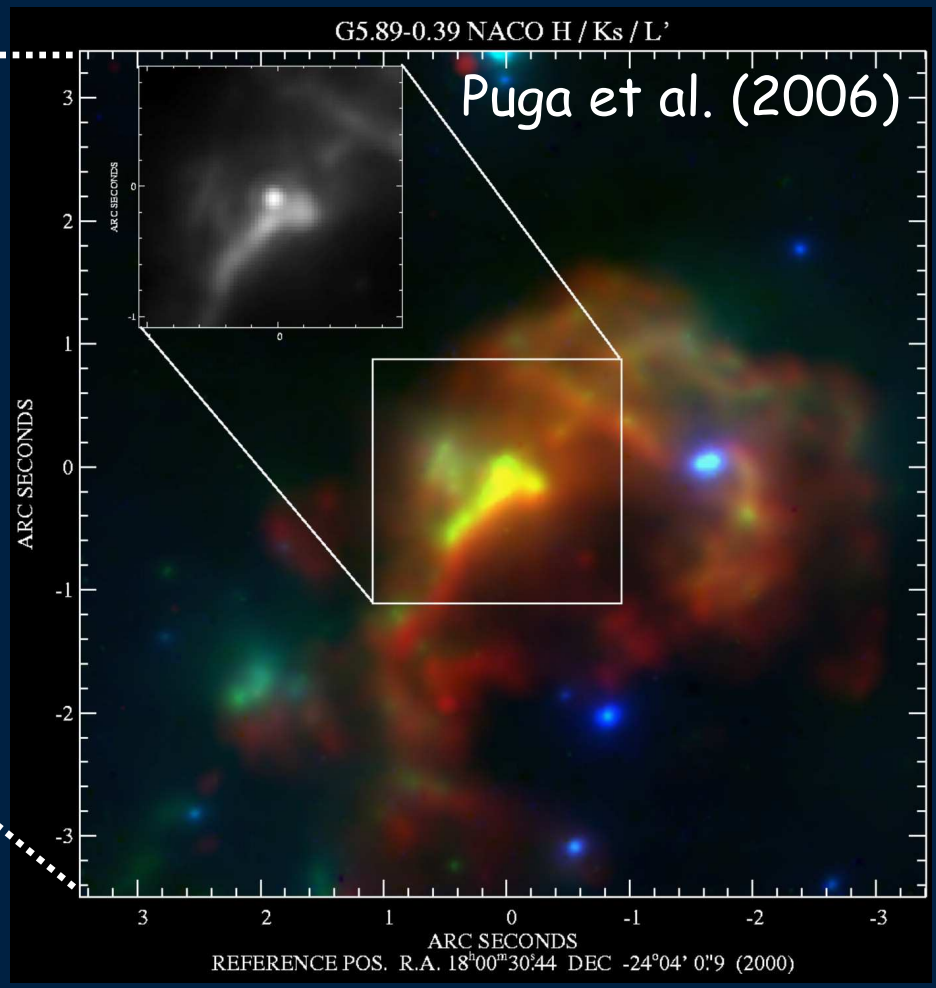
# So Where's the Star in G5.89-0.39?

VLA
3.6 cm




SMA
875 μm



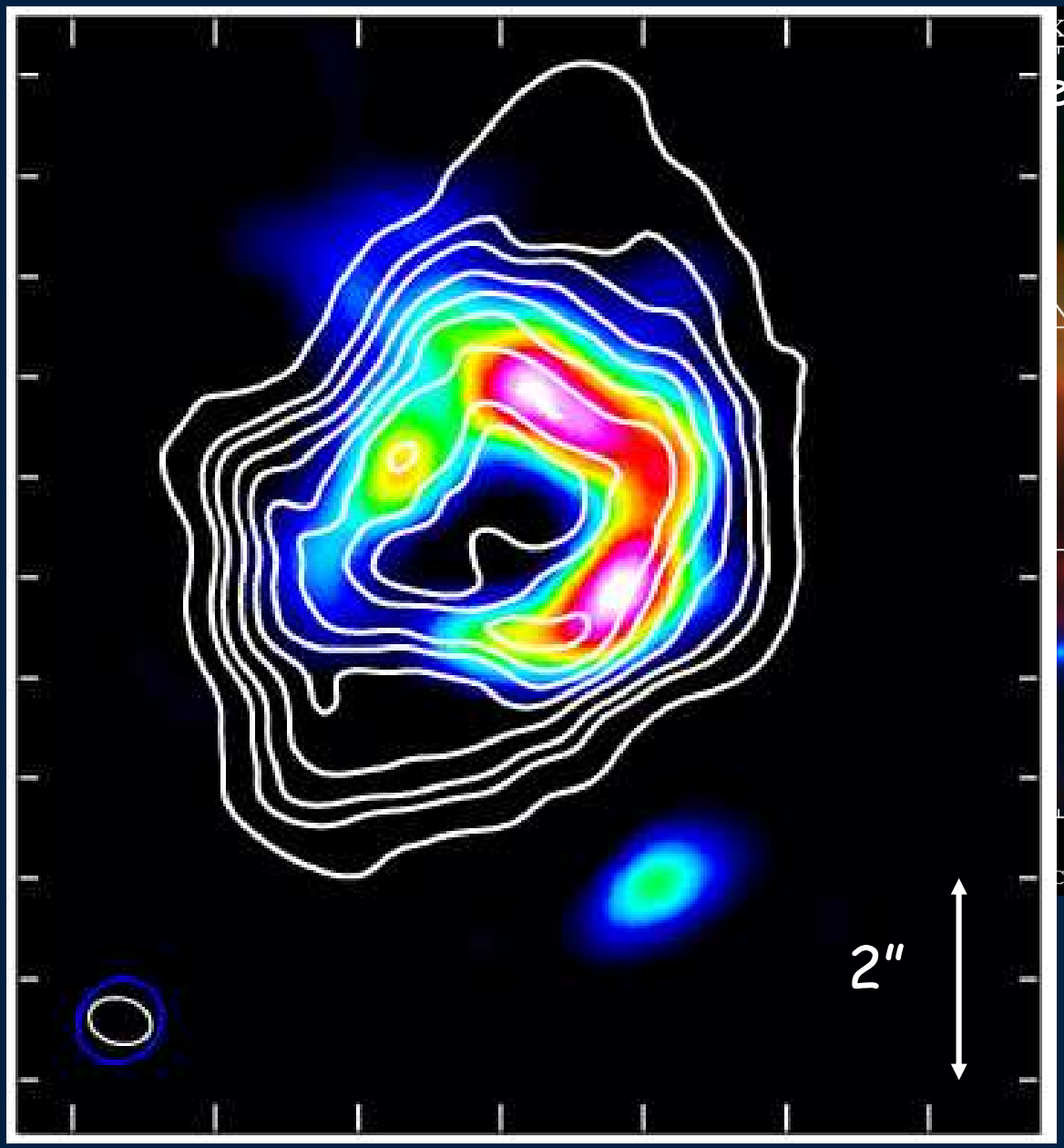

Extended config.

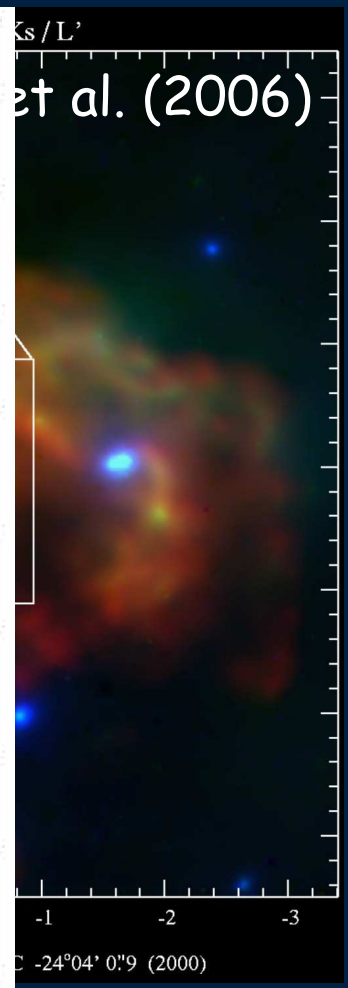
0."87 x 0."76

# So Where's the Star in G5.89-0.39?

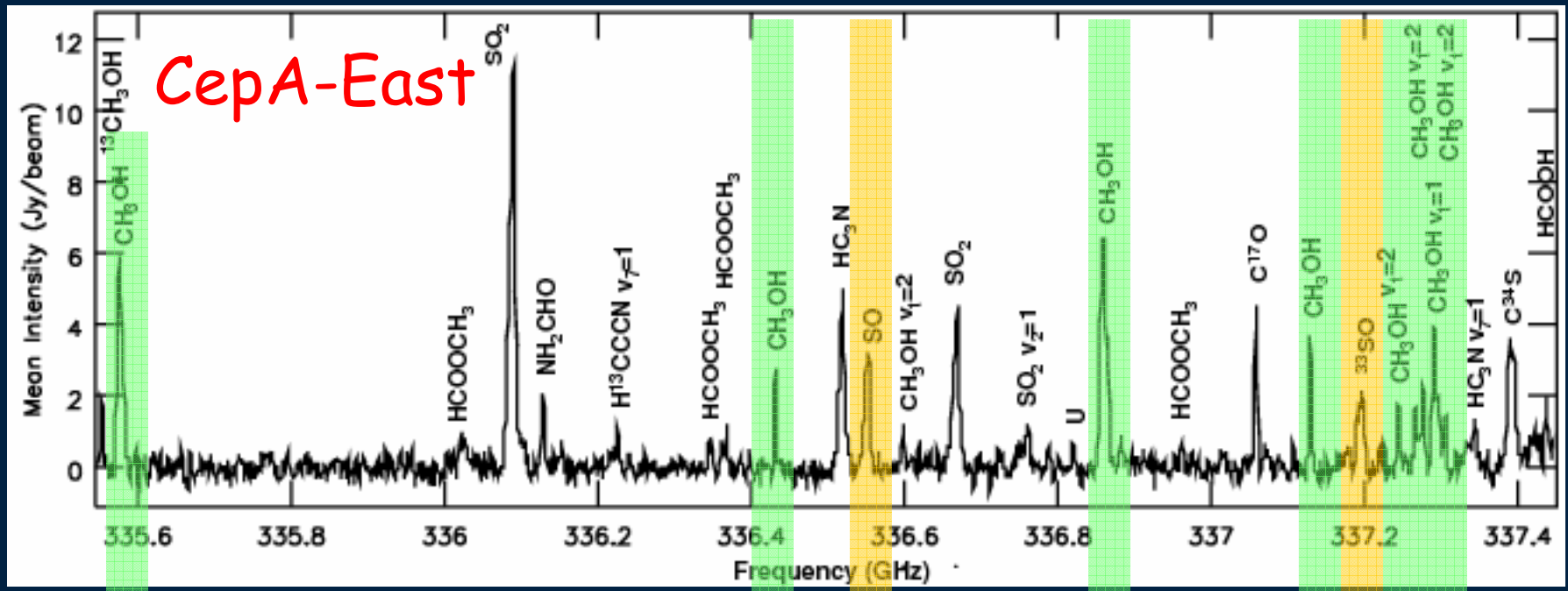
VLA
3.6 cm

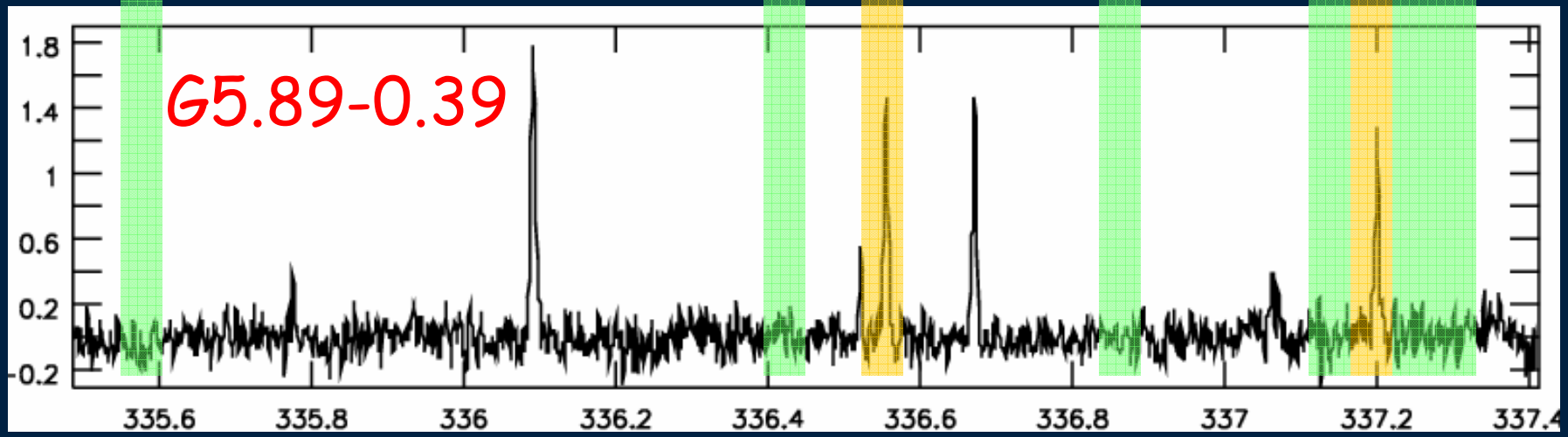
SMA
875 μm



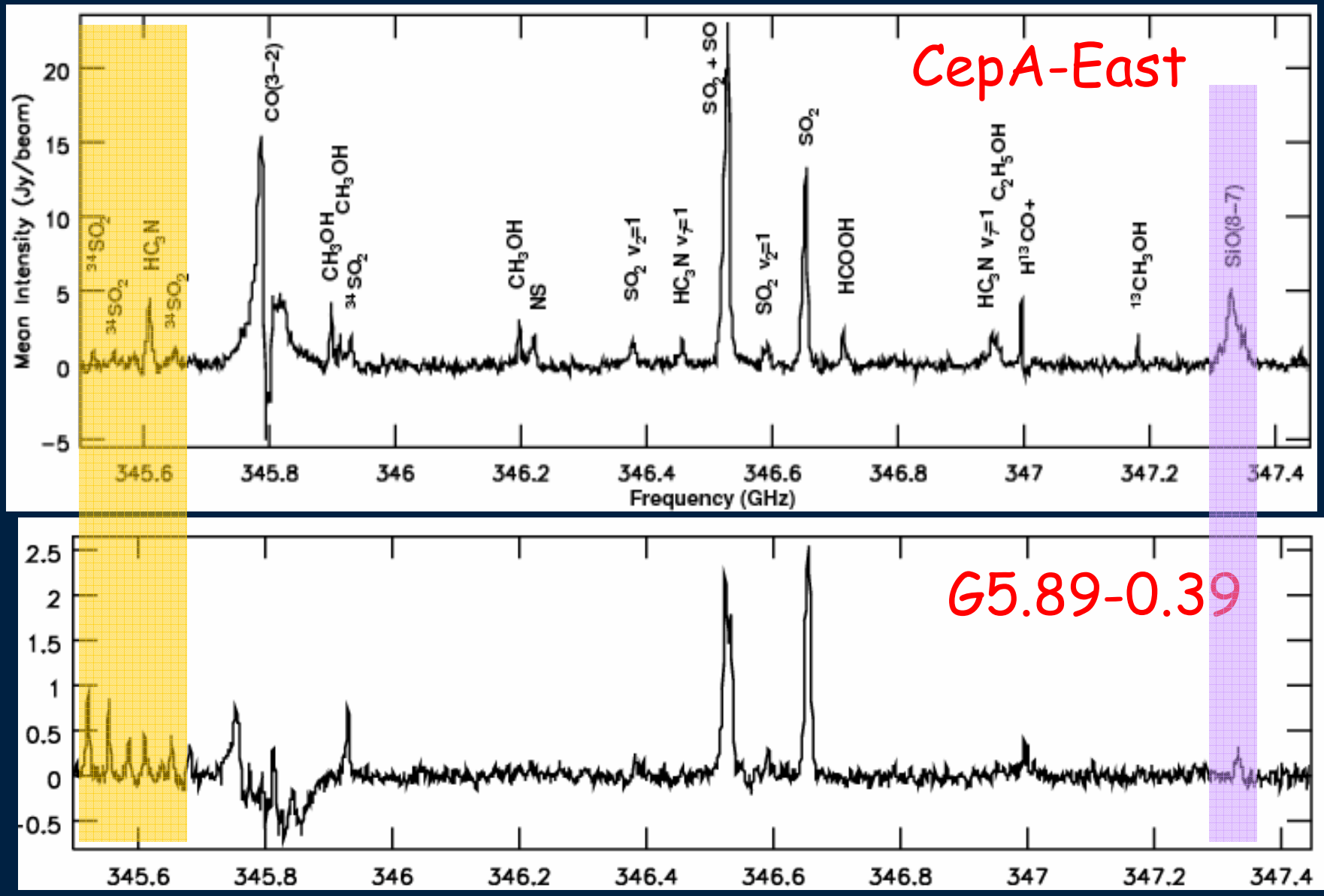



# G5.89 Line Forest Comparison-I

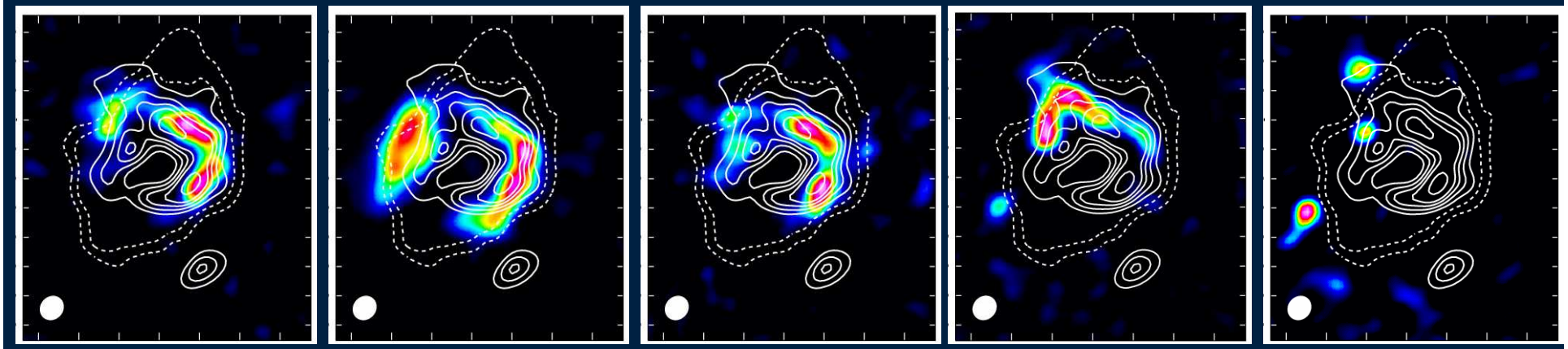


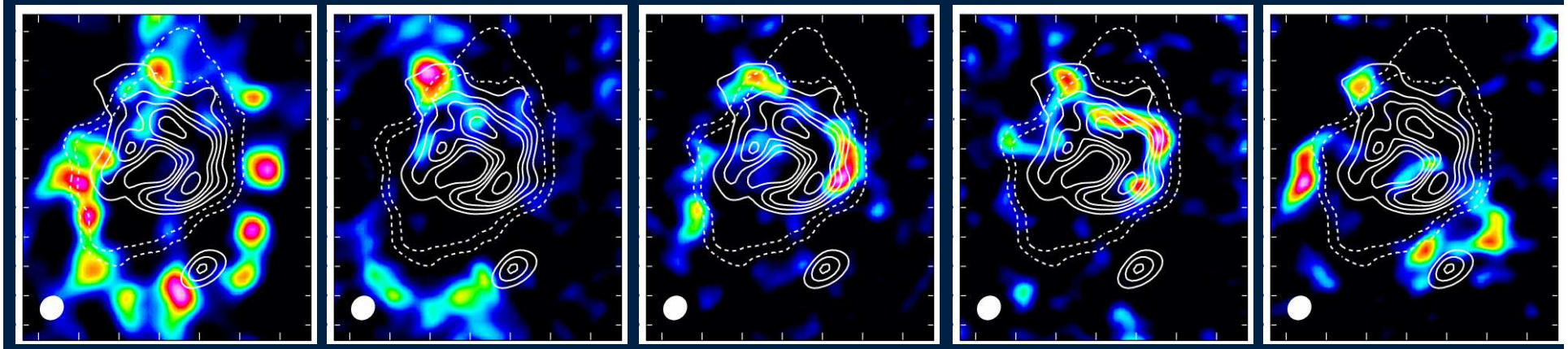
# G5.89 Line Forest Comparison-II



# The Complex Chemistry of G5.89

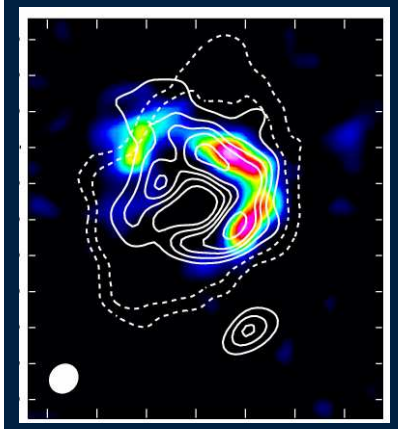


SO $SO_2$ $^{34}SO_2$ $HC_3N$ $CH_3OH$

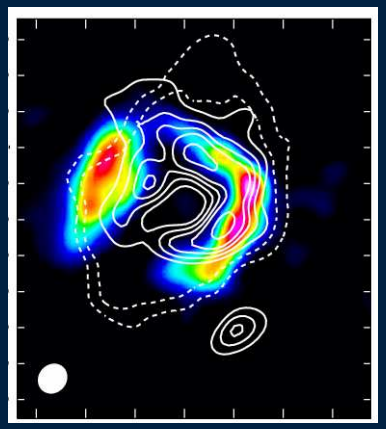


CO $C^{34}S$ $H^{13}CO^+$ $C^{17}O$ SiO

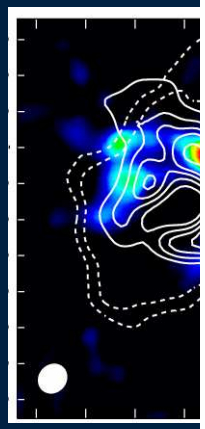
# The Complex Che



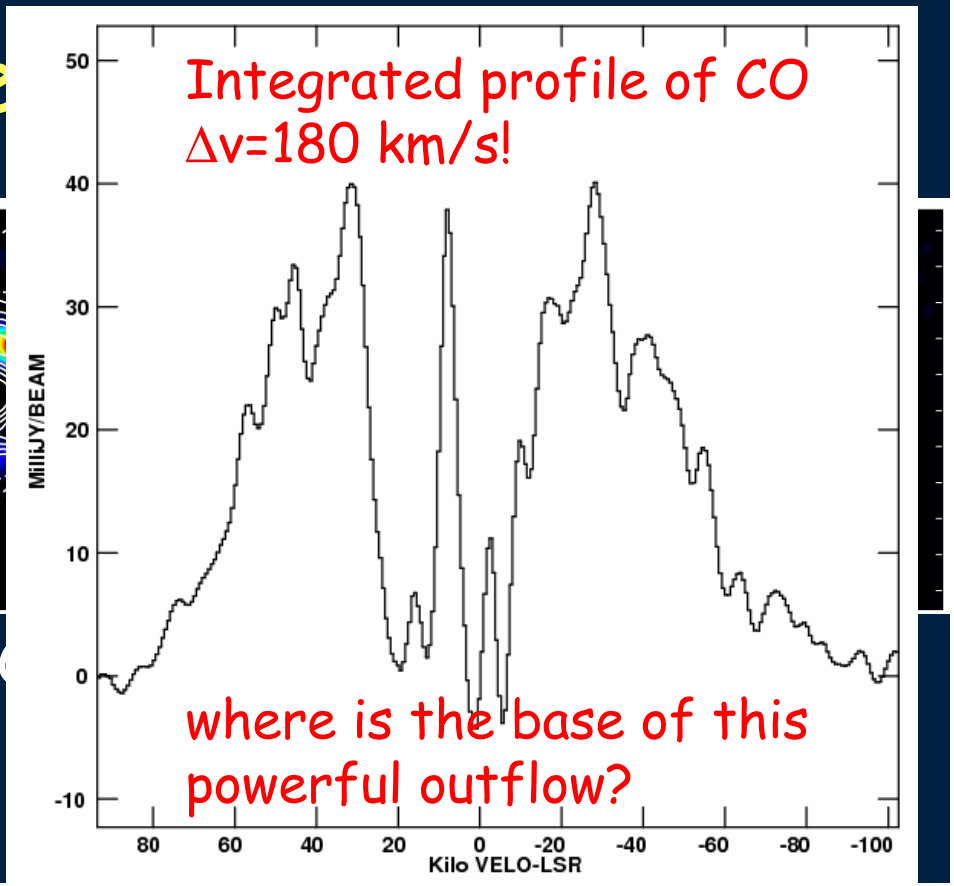
SO

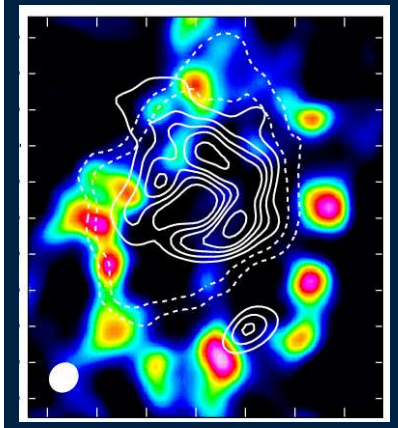


$SO_2$

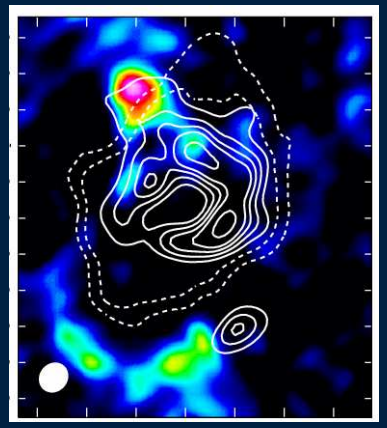


$^{34}S$

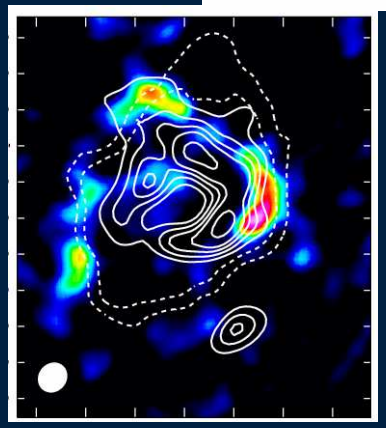


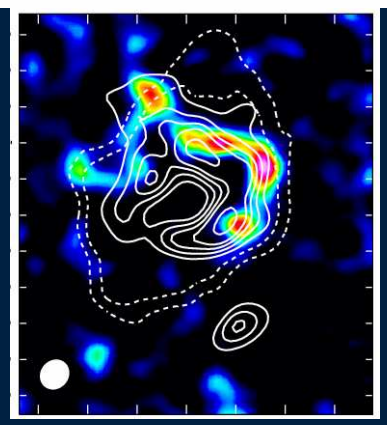
CO



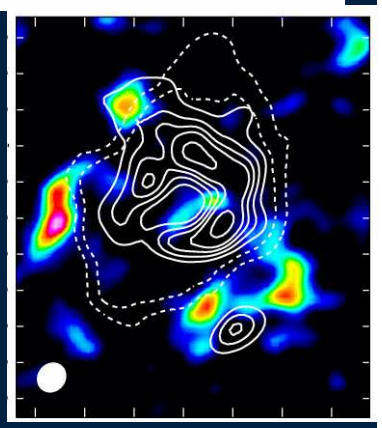
$C^{34}S$



$H^{13}CO^+$



$C^{17}O$

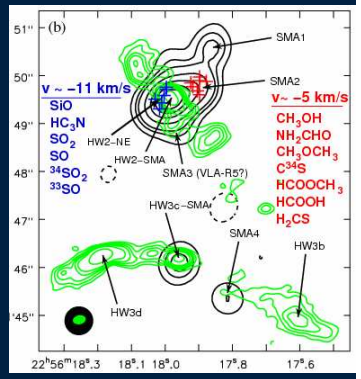


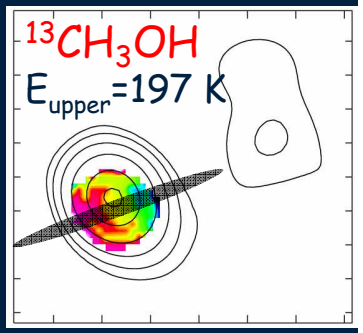
SiO

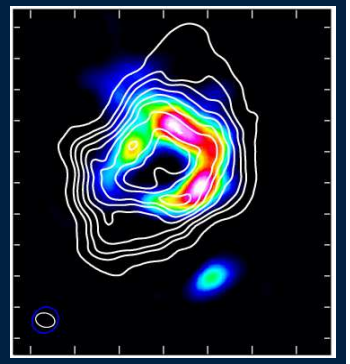
# Summary and Conclusions

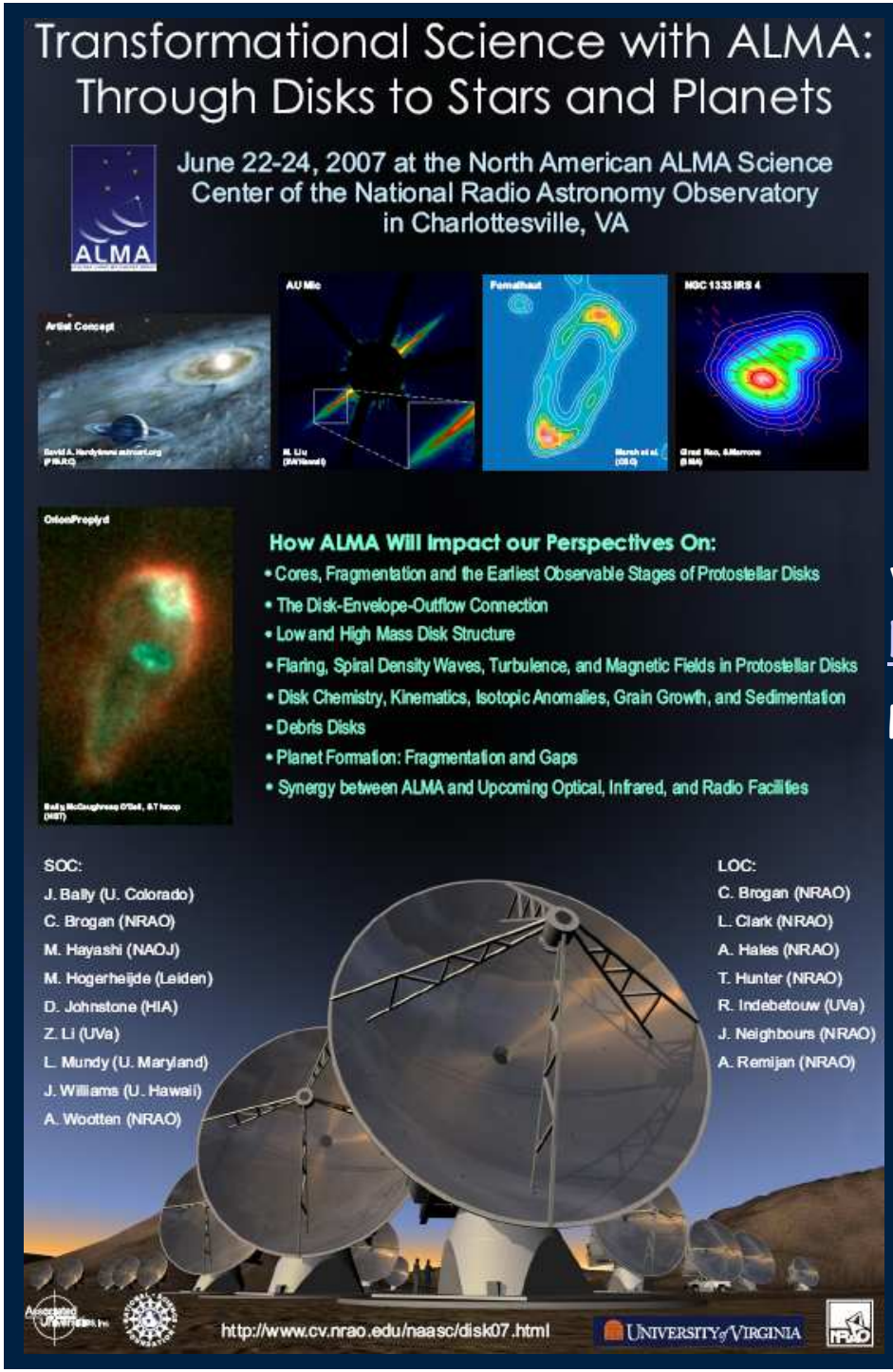
- CephA-East
  - No molecular line evidence for a disk (yet!). There are at least two hot cores and four dust cores in the vicinity of HW2.
  - Analysis of many species is crucial for a complete understanding.
  - Morphology of shock-tracing molecules suggest interaction at base of HW2 jet. VLA $NH_3$ data in excellent agreement with SMA.
- NGC 7538 IRS1
  - Methanol kinematics confirm outflow orientation and possible disk
  - Very little sulfur bearing species ($SO_2$) compared to CephA
- G5.89-0.39 – Where is the powering source?
  - 875 μm continuum is mostly free-free. No point source or bipolar jet. Very little organic molecules. Not a prototypical hot core.

The sensitivity and resolution of ALMA will be essential to understand these chemical and evolutionary differences.






Web:
http://www.cv.nrao.edu/naasc/disk07.html

Pre-registration is now available