A Diagnostic EVLA K-band Survey of 25 Massive Protostellar Objects

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NRAO

How Do Massive Stars Form?

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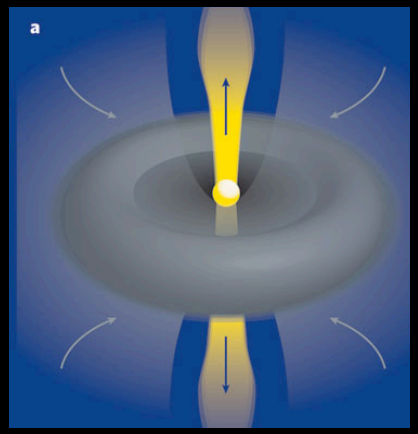
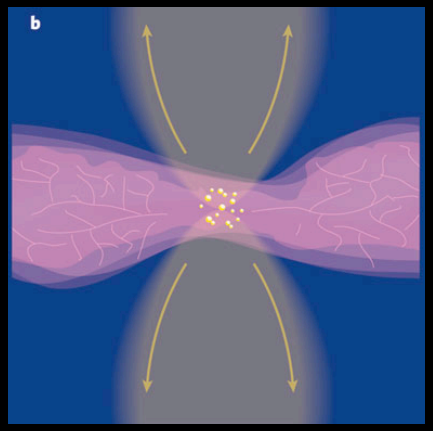
Its difficult to determine observationally because massive stars are:

- At large distances (> 1 kpc)
- Very deeply embedded during earliest phases (obscured shortward of mid-IR)
- Forming in clusters

0.1 pc ~20,000 AU



Low Mass



High Mass

- Catch them while they are young
- Develop observation-based evolutionary sequence
- Understand role of cluster feedback

A Sort of Sequence with Many Caveats

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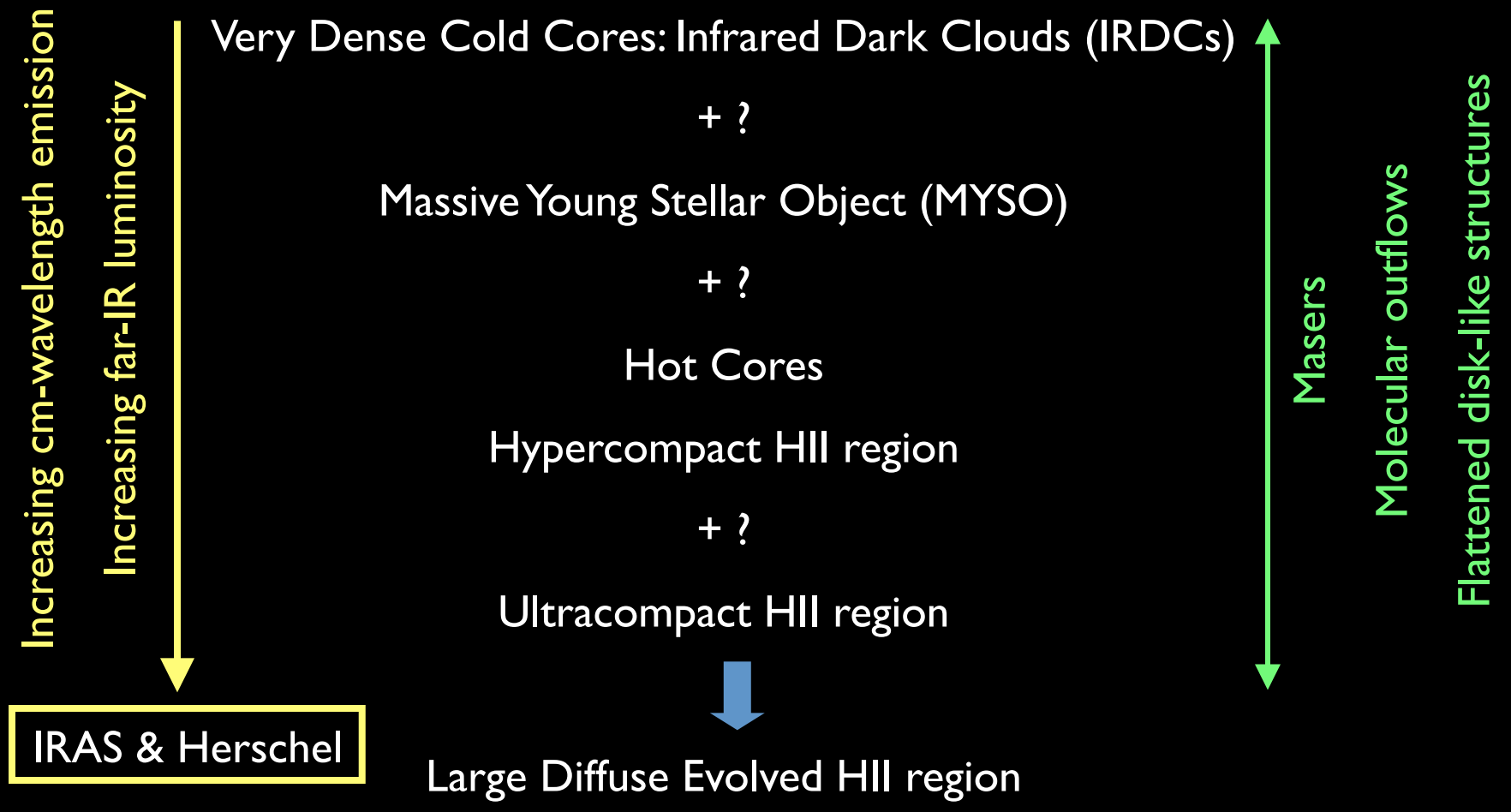

To date attempts to define a clear observationally based evolutionary sequence from this zoo of phenomenon have used heterogeneous datasets…

WIDAR Allows us to Observe Many Diagnostic Tracers Simultaneously!

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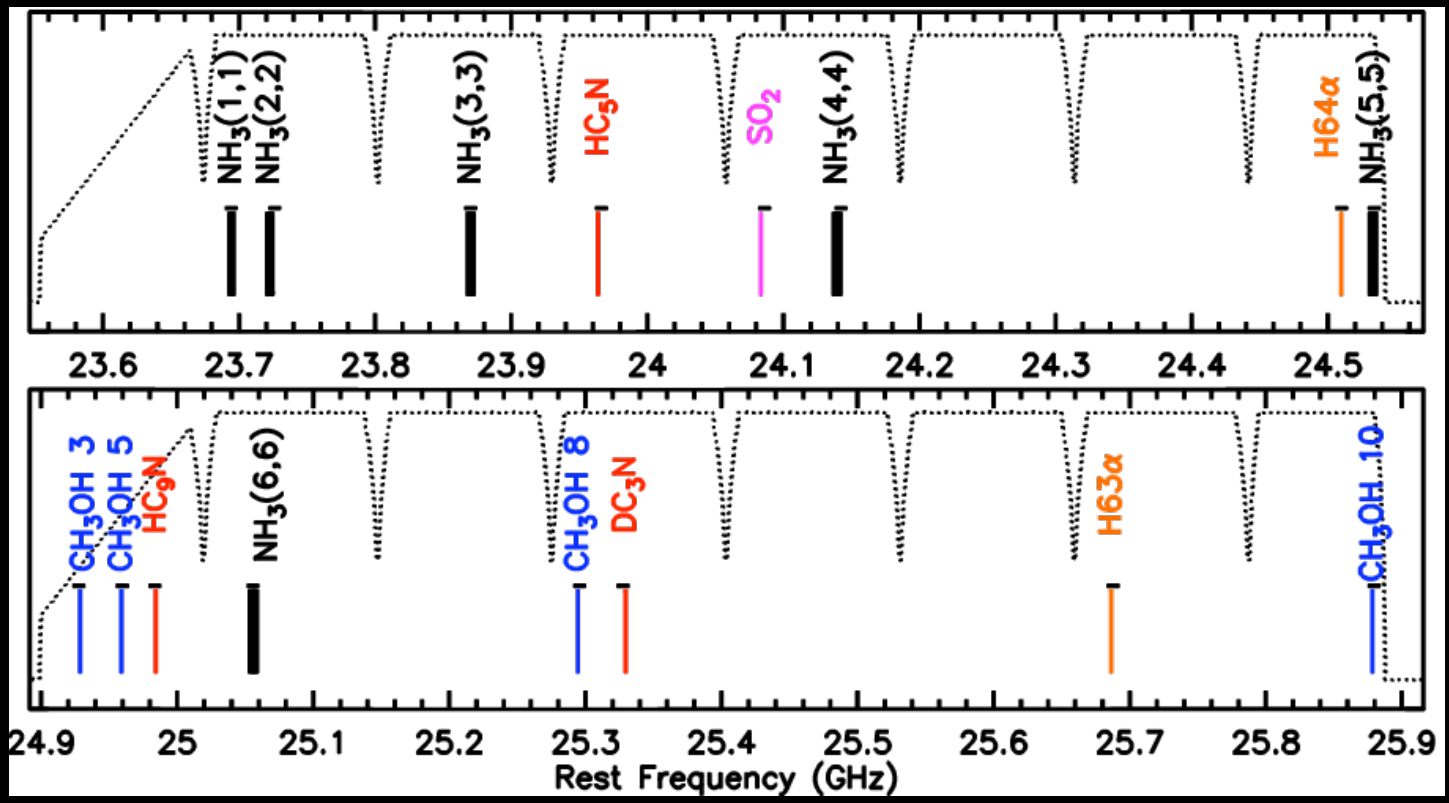
16 x 8 MHz subbands with 0.4 km/s channels

- Ammonia 1,1 to 6,6 (Temperature, density, and kinematics)
- Methanol, SO_2 (Masers and hot core tracer)
- HC_5N, HC_9N, DC_3N (Trace formation history of gas)
- 2 Radio Recombination Lines (Kinematics of ionized gas)
- Decent continuum bandwidth from line-free regions (Ionized gas)



Early Test Result: NGC6334

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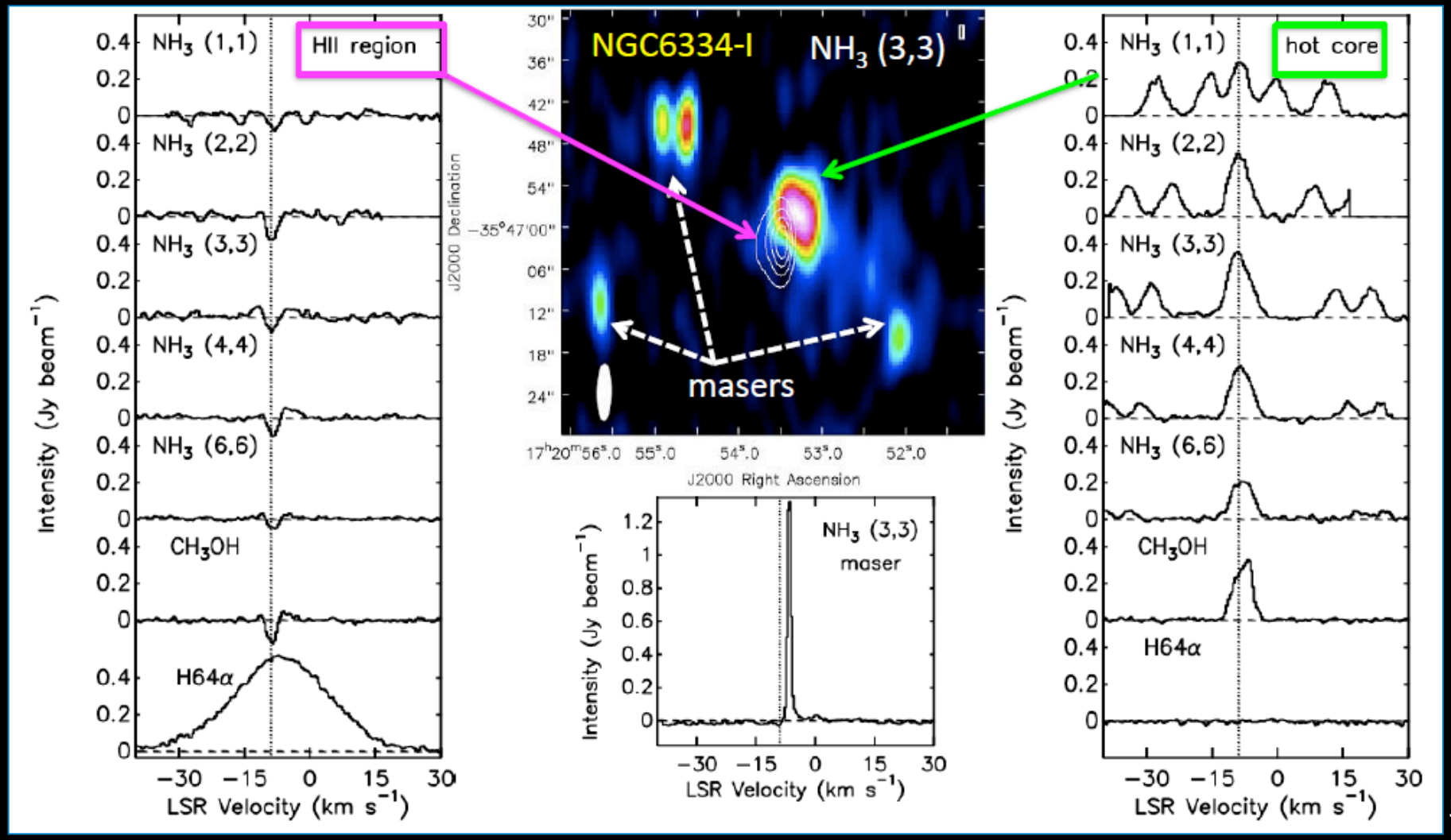
- *Protocluster with 2 hot cores and an ultracompact HII region at D~1.6 kpc*
- *10-minutes on-source*
- *Used 8 narrow (8 MHz) sub-bands*



The Sample & Data

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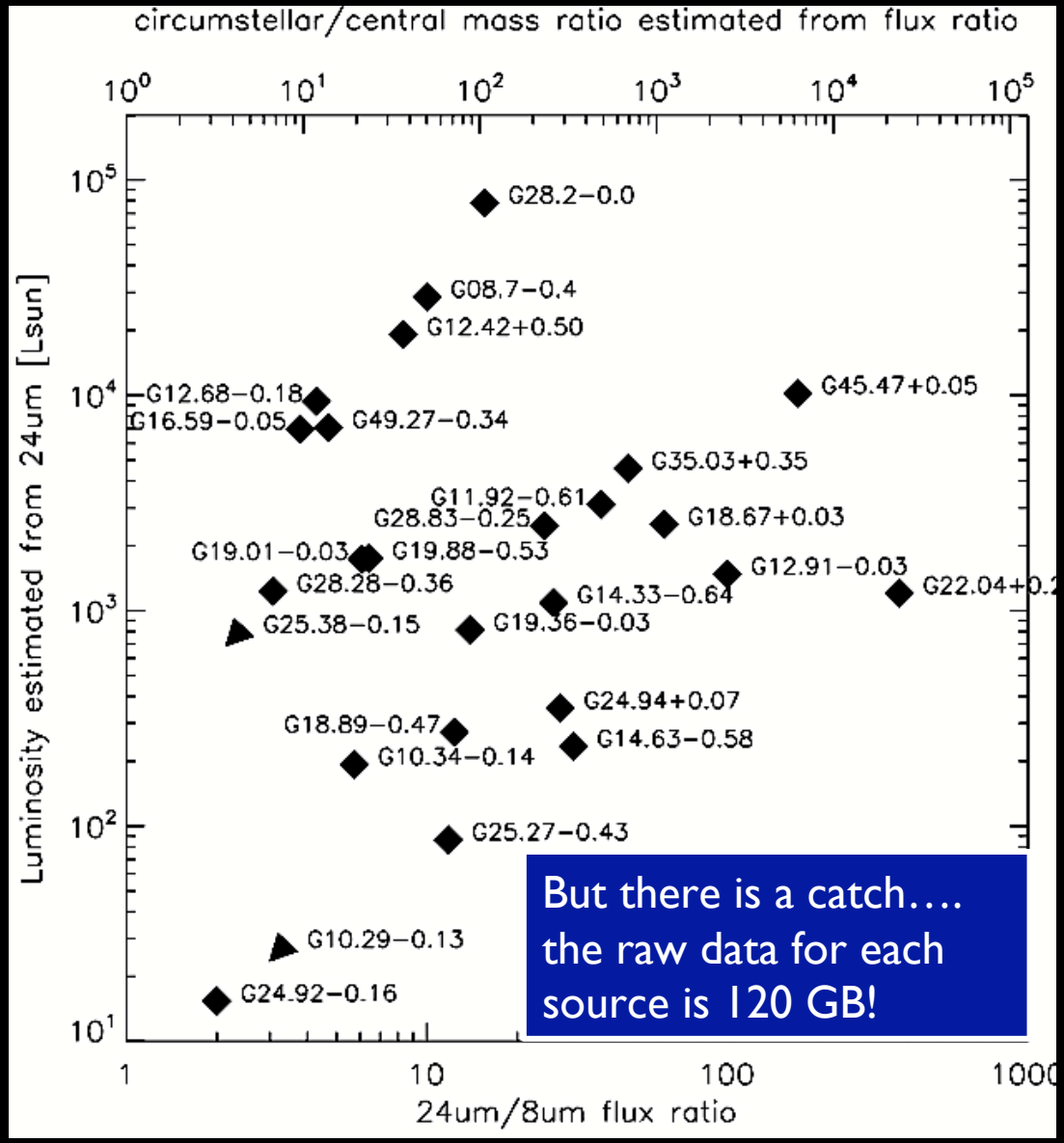
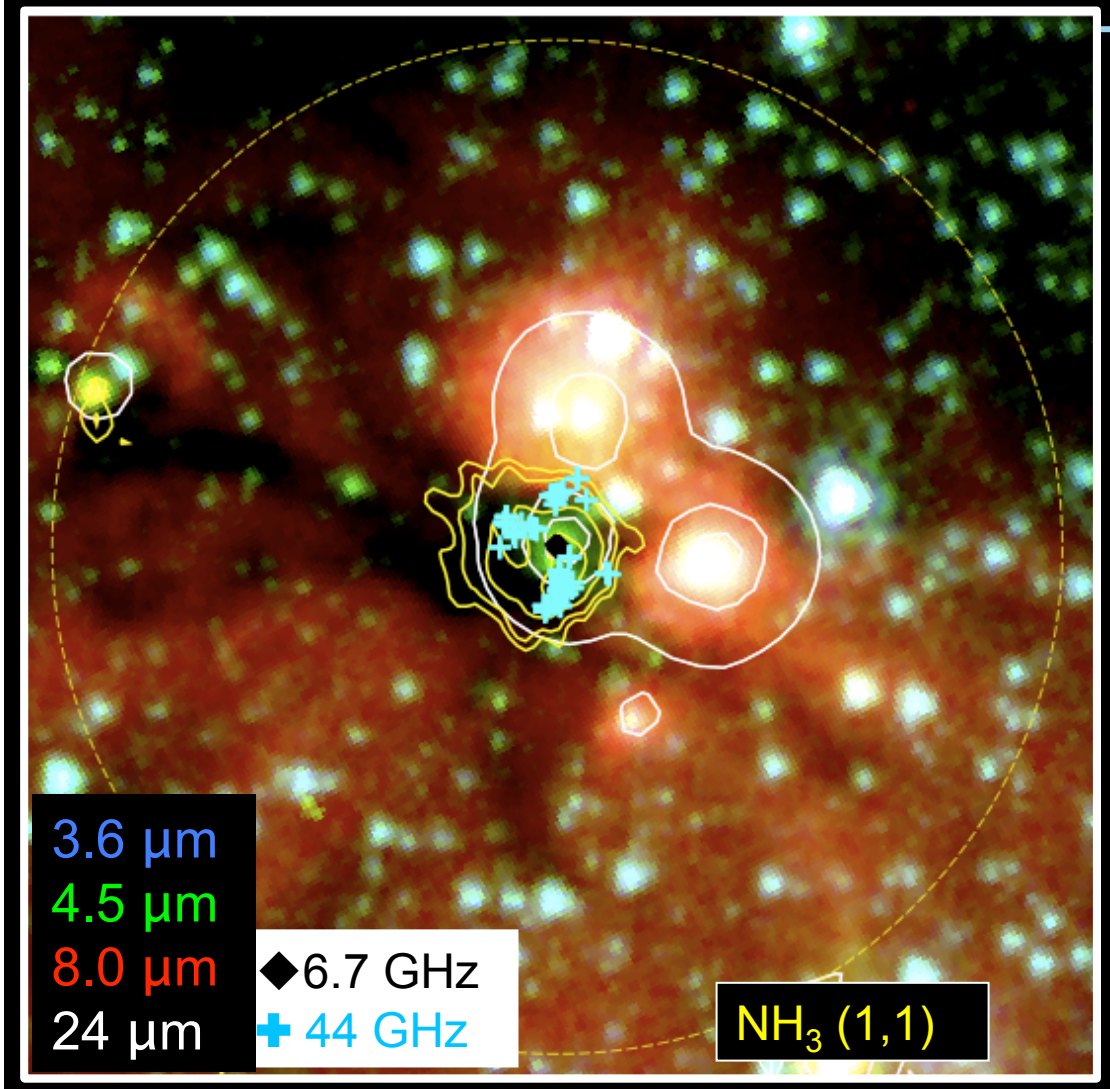


- Targets span wide range in luminosity and M_{core}/M_*
  - IRDCs (Infrared Dark Clouds)
  - EGOs (Extended Green Objects; Cyganowski et al. 2008); e.g. MYSO candidates
  - A few known HCHII, and UCHII regions

- 3.5 hour tracks
- 2' primary beam
- Resolution ~10,000 AU
  - 2-4 kpc D-config
  - 4-6 kpc C-config
- Line sensitivity (0.4 km/s channels):
  - 3 mJy/channel/beam
- Continuum sensitivity:
  - ~ 0.2 mJy/beam

G22.04+0.22 (D=3.6 kpc)



Resolution: 3.6” x 2.4” (~10,000 AU)

EVLA

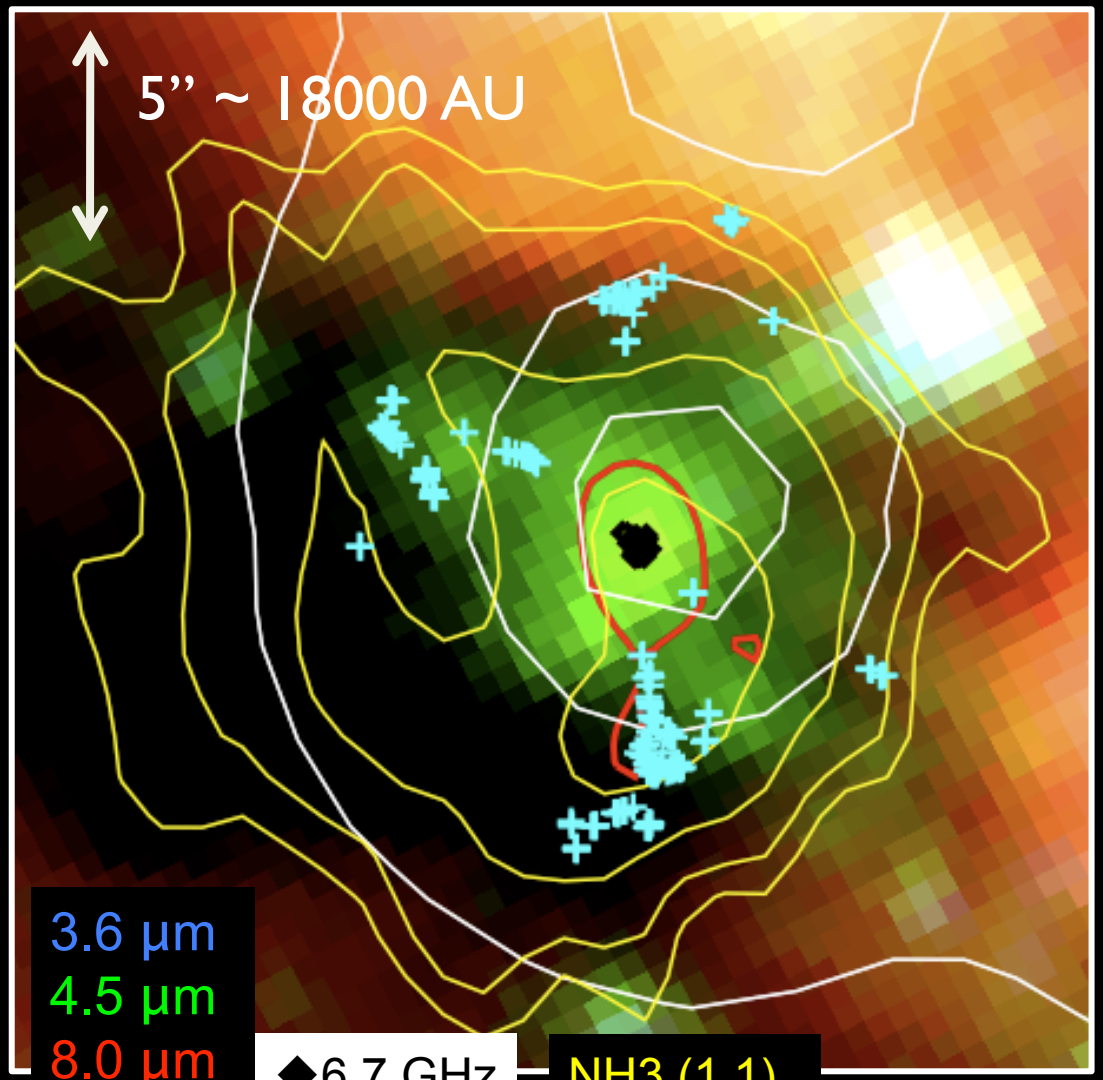
An EGO in an IRDC with significant 24 μm emission

Strong 6.7 GHz (massive star formation) and 44 GHz (outflow tracer) methanol masers (Cyganowski et al. 2009)

NH_3 (1,1) core detected toward the EGO and nearby protostar

Zoom: G22.04+0.22 (D=3.6 kpc)

EVLA



A compact high T region is located toward the center traced by NH3 (6,6)

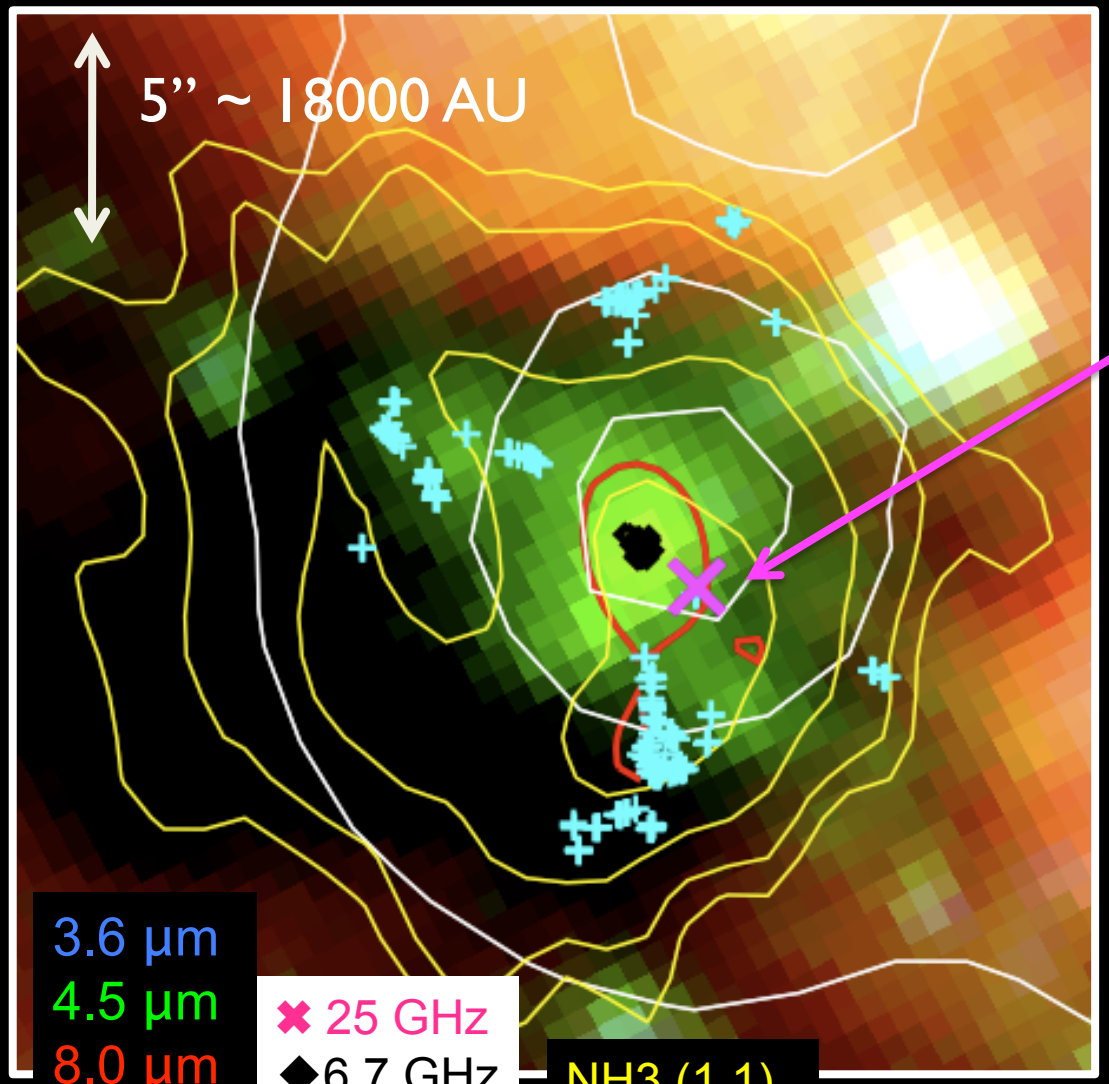
- Not clear if there are two protostars or if southern source is a jet

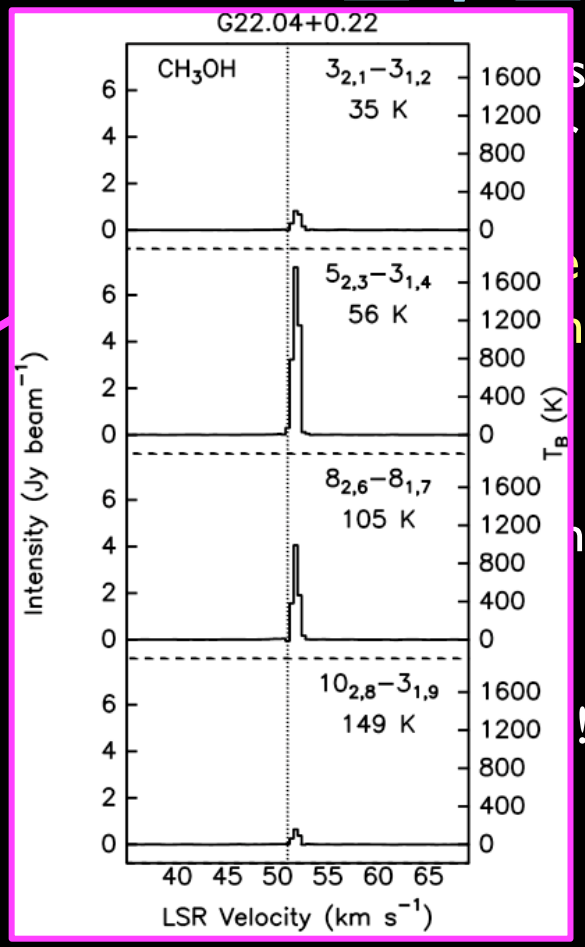
No centimeter continuum emission detected (< 0.1 mJy/beam at 3.6 cm; Cyganowski et al. in prep)!

Resolution: 3.6” x 2.4” (~10,000 AU)

Zoom: G22.04+0.22 (D=3.6 kpc)

EVLA





25 GHz methanol maser emission toward peak 44 GHz maser location

Resolution: 3.6" x 2.4" (~10,000 AU)

Zoom: G22.04+0.22 (D=3.6 kpc)

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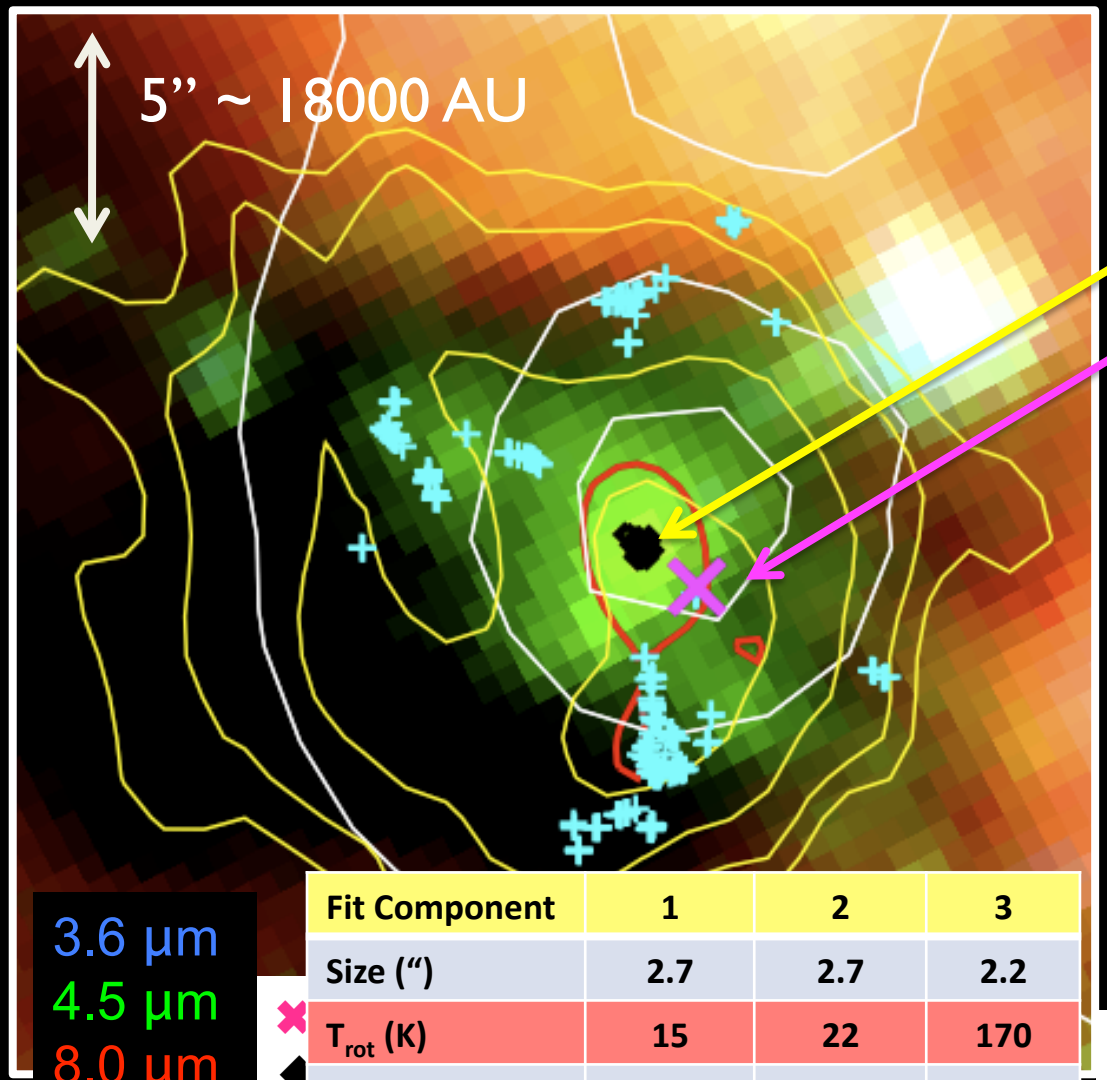

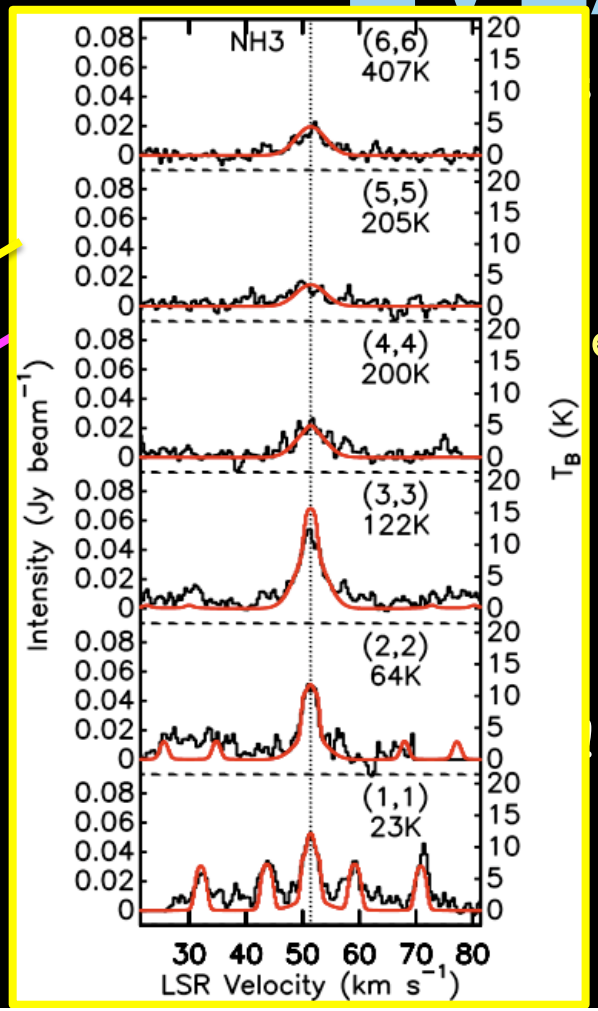

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Fit Component	1	2	3
Size (“)	2.7	2.7	2.2
T_{rot} (K)	15	22	170
Log(N) (cm^{-2})	15.0	16.7	16.0
Vlsr (km/s)	51.4	51.4	51.4
ΔV (km/s)	1.1	1.5	6.0

Strong and complex NH_3 spectra with signs of outflow

Resolution

G35.03+0.35 (D ~ 3.4 kpc)

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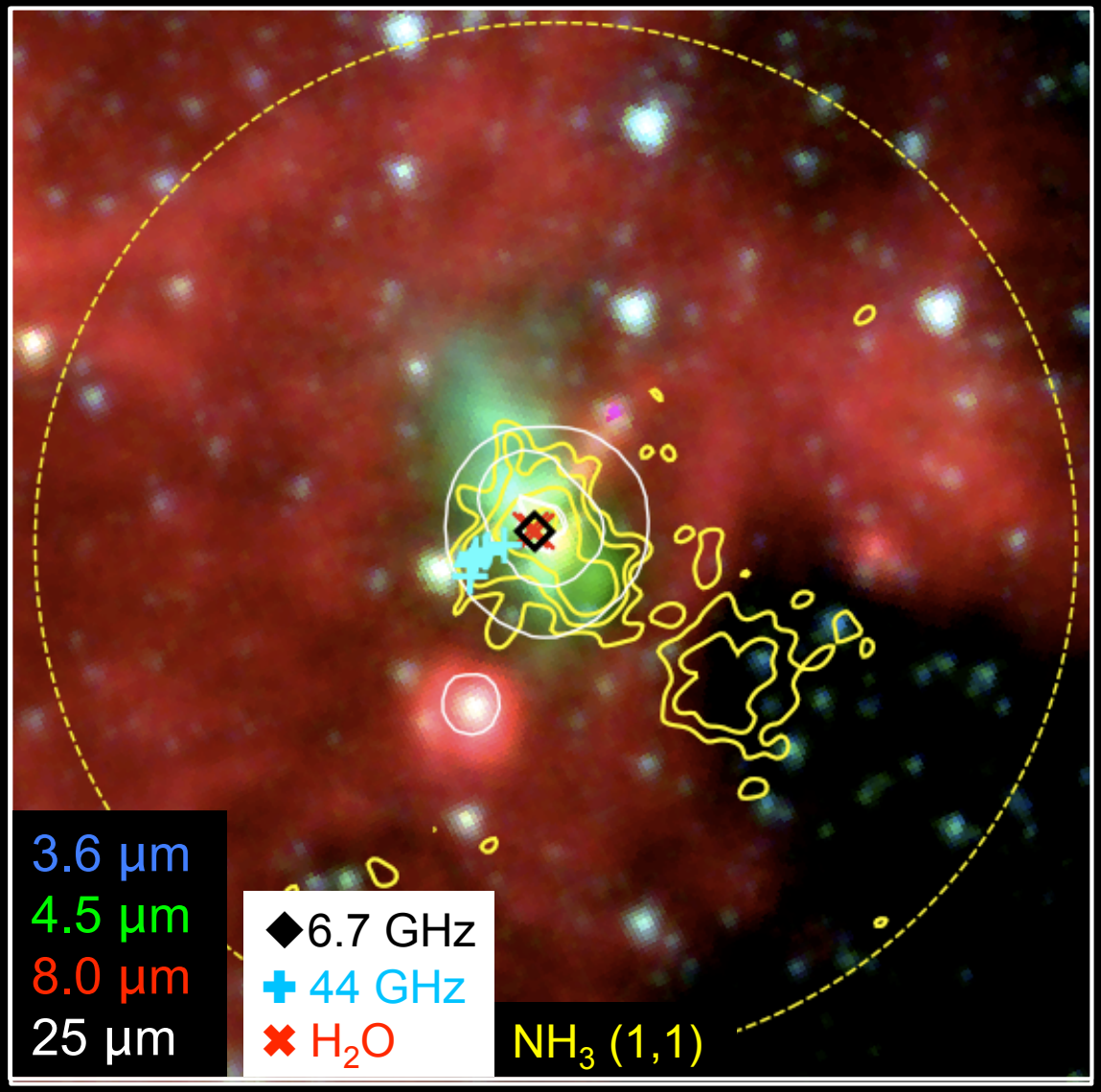

Resolution: 3.6" x 3.0" (~11,000 AU)

An EGO with significant 24 μm emission

Strong 6.7 GHz (massive star formation) and 44 GHz (outflow tracer) methanol masers (Cyganowski et al. 2009)

H_2O Masers (Forster & Caswell 1989)

NH_3 (1,1) core detected toward the EGO and nearby IRDC

Zoom: G35.03+0.35 (D~3.4 kpc)

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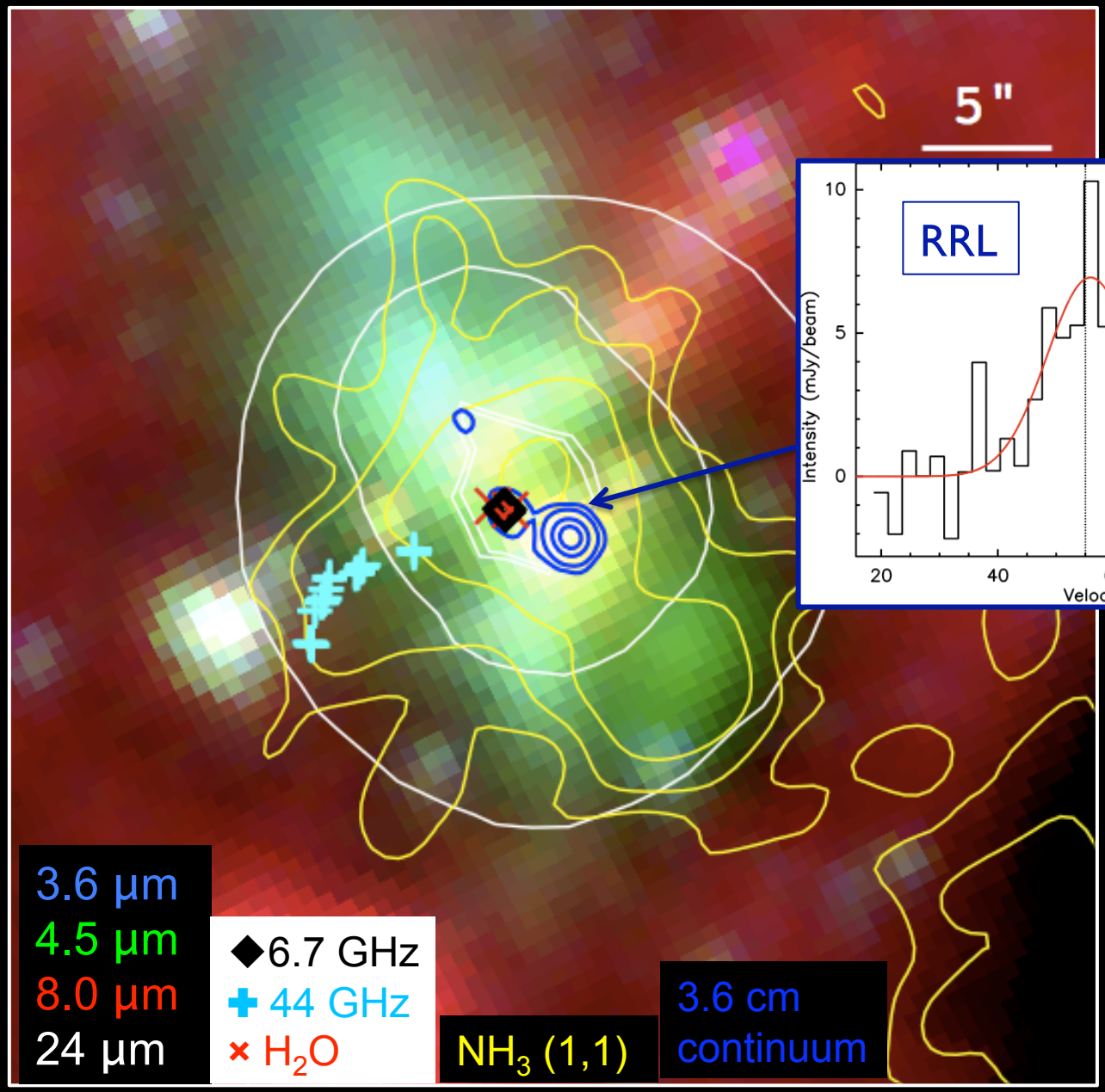
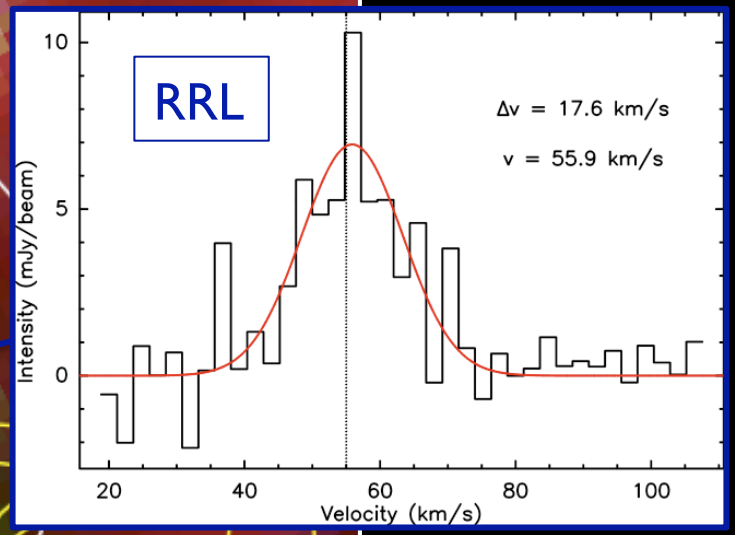
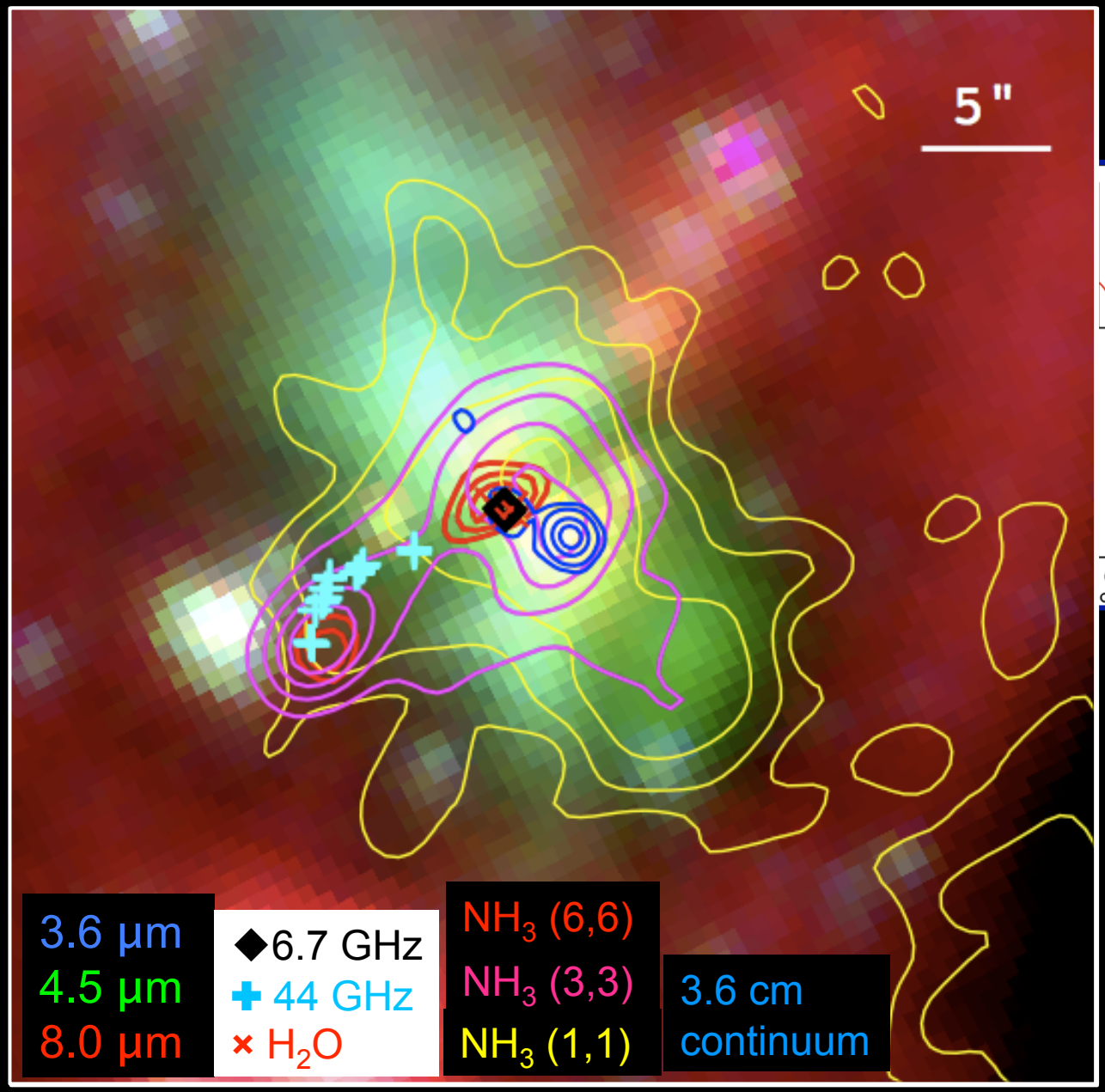


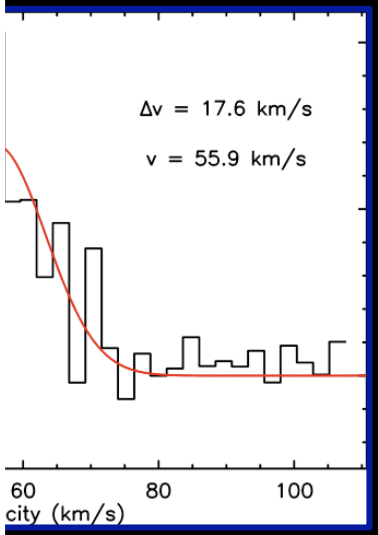


VLA 3.6 cm continuum showing 3 compact sources; one coincident with 6.7 GHz methanol masers (Cyganowski et al. in prep.)

Zoom: G35.03+0.35 (D~3.4 kpc)

EVLA





VLA 3.6 cm continuum showing 3 compact sources; one coincident with 6.7 GHz methanol masers (Cyganowski et al. in prep.)

Summary

EVLA

- WIDAR provides powerful new capability for simultaneous diagnostic observations of massive protostars/protoclusters

- Early results are showing incredible complexity:
  - Temperatures
  - Kinematics
  - Shocks
  - Continuum properties

- Tremendous potential to reveal critical observational signposts of evolutionary state and answer key questions about the formation of massive protostars and clusters

- Stay tuned for conclusions!