ON THE FORMATION OF THE MOST MASSIVE STARS IN THE GALAXY

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THE FORMATION OF THE MOST MASSIVE STARS

Accumulated evidence shows that massive ($M_\star > 8 M_\odot$) stars form by *similar* processes than low-mass stars.

- Up to what Mass does this hold?
- New physical processes?

- The 'really' massive stars (O-type, $M_\star \geq 15\,M_\odot$, $L \geq 10^5\,L_\odot$) likely start to burn hydrogen *before* they reach their final mass (Bernasconi & Maeder 96, Zinnecker & Yorke 2007; see however, Hosokawa & Omukai 2009)

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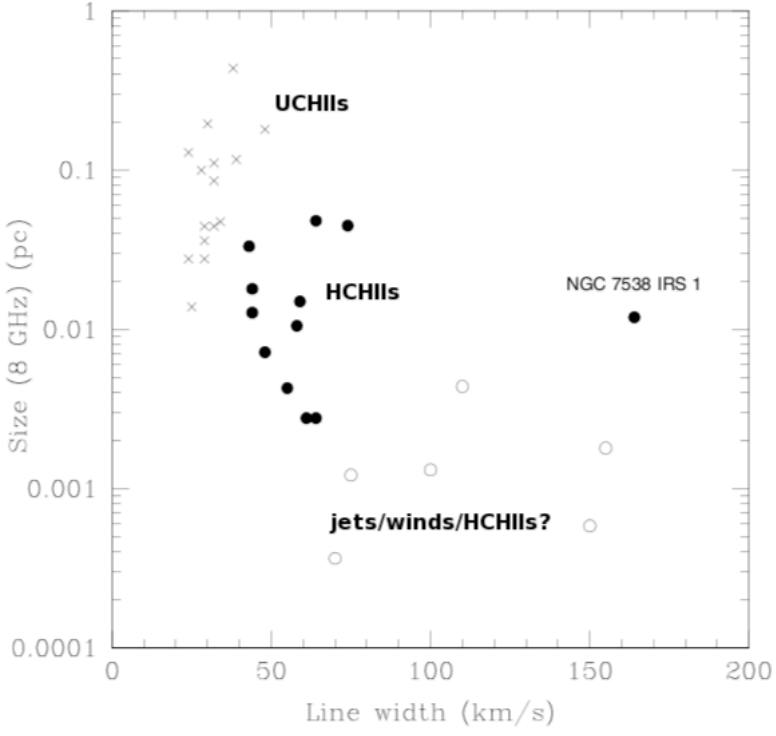
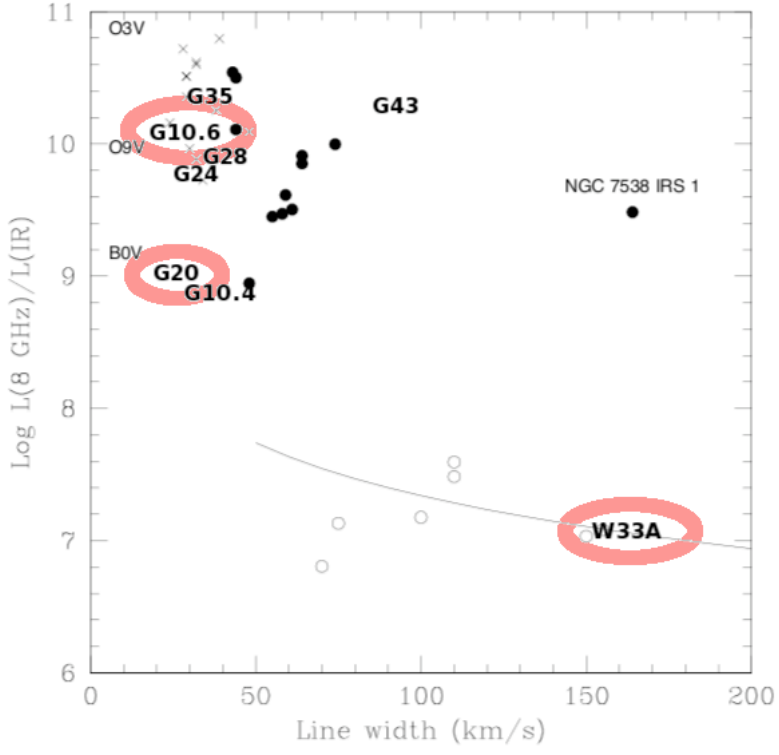
WHAT IS THE NATURE OF THE IONIZED GAS?

Initially maybe 'radio jets' or stellar winds, afterwards ionized accretion flows?



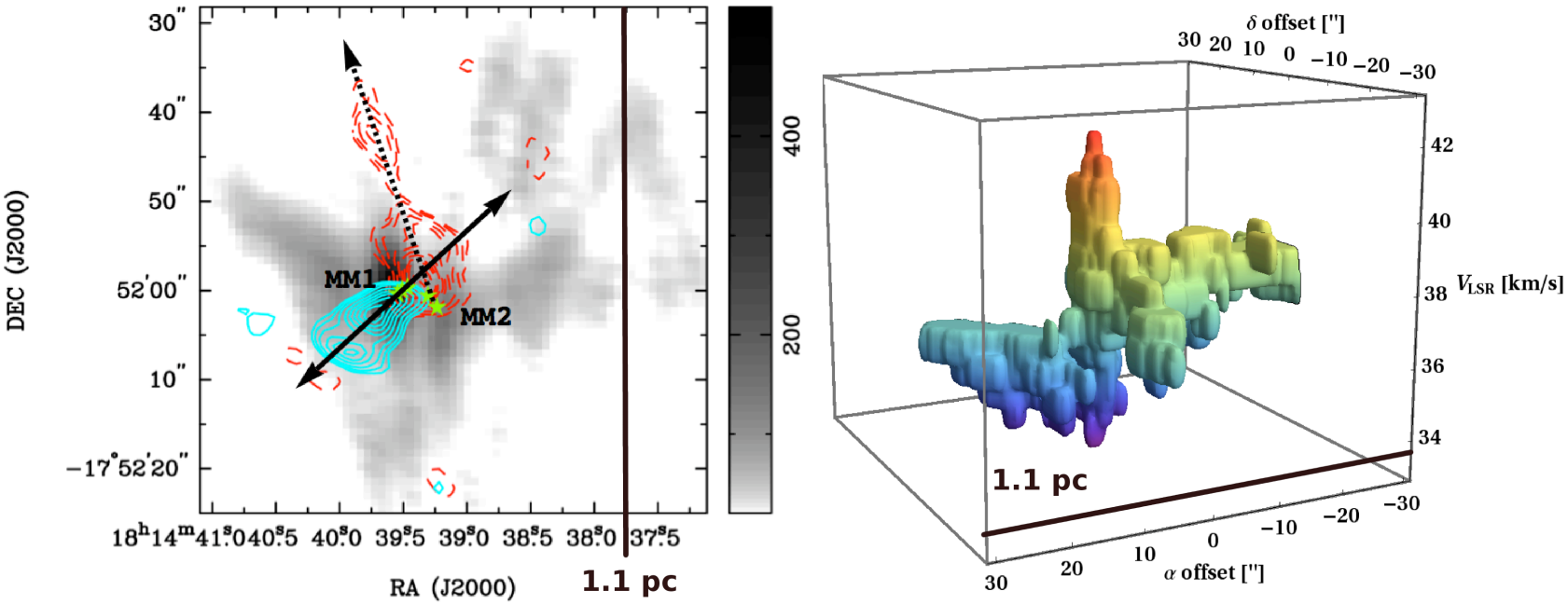


Figs: modified from Hoare+07

THE ONSET OF IONIZATION (W33A)

W33A: **massive-star formation at the center of merging filaments**

$L_{8GHz}/L_{bol} \approx 1.3 \times 10^{7}$ W Hz^{-1} L$_{\odot}^{-1}$ ($L \approx 1 \times 10^{5}$ L$_{\odot}$)

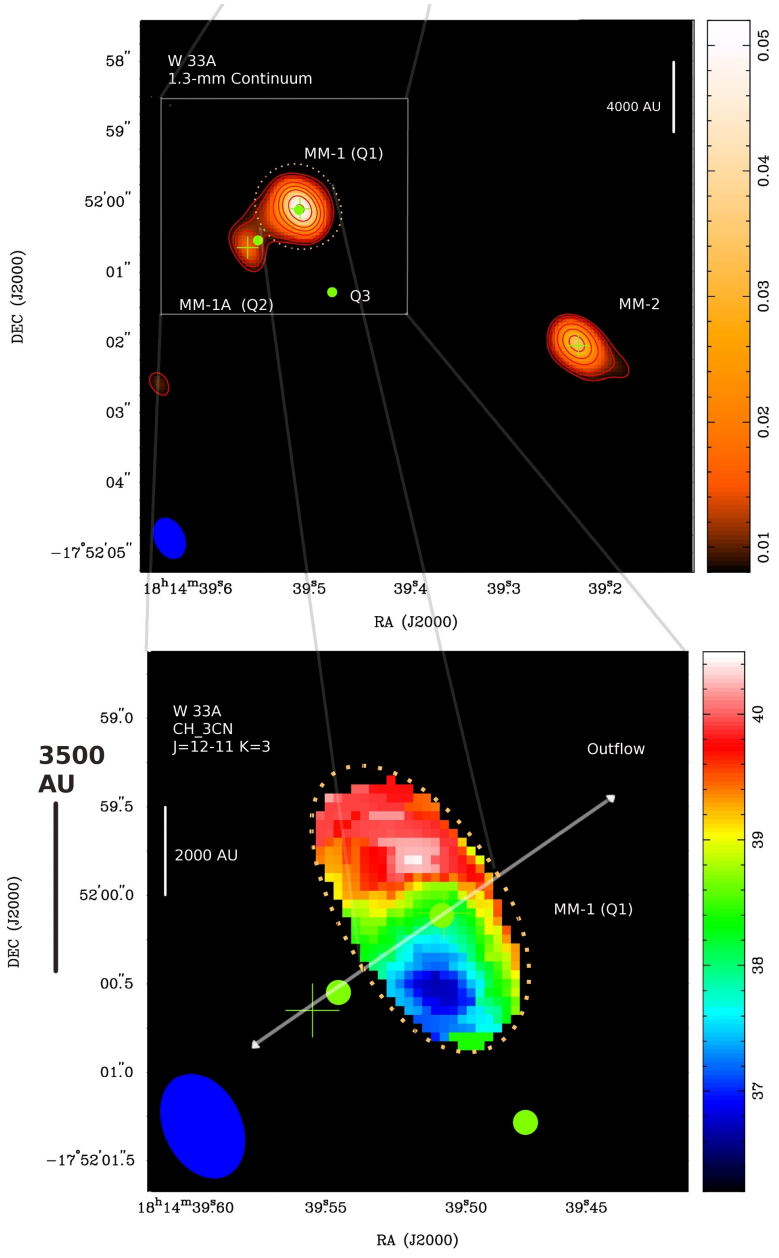


Figs: from Galván-Madrid+10, ApJ in press, 1 arcmin = 1.1 pc

Left: NH_3 (2,2) integrated (gray), CO 2–1 (contours). *Right*: Pos-Pos-Vel NH_3 (2,2)

THE ONSET OF IONIZATION (ZOOM INTO W33A)

The VEX-only data shows rotating disk/toroid perpendicular to the main outflow ($M_\star \approx 10 M_\odot$)



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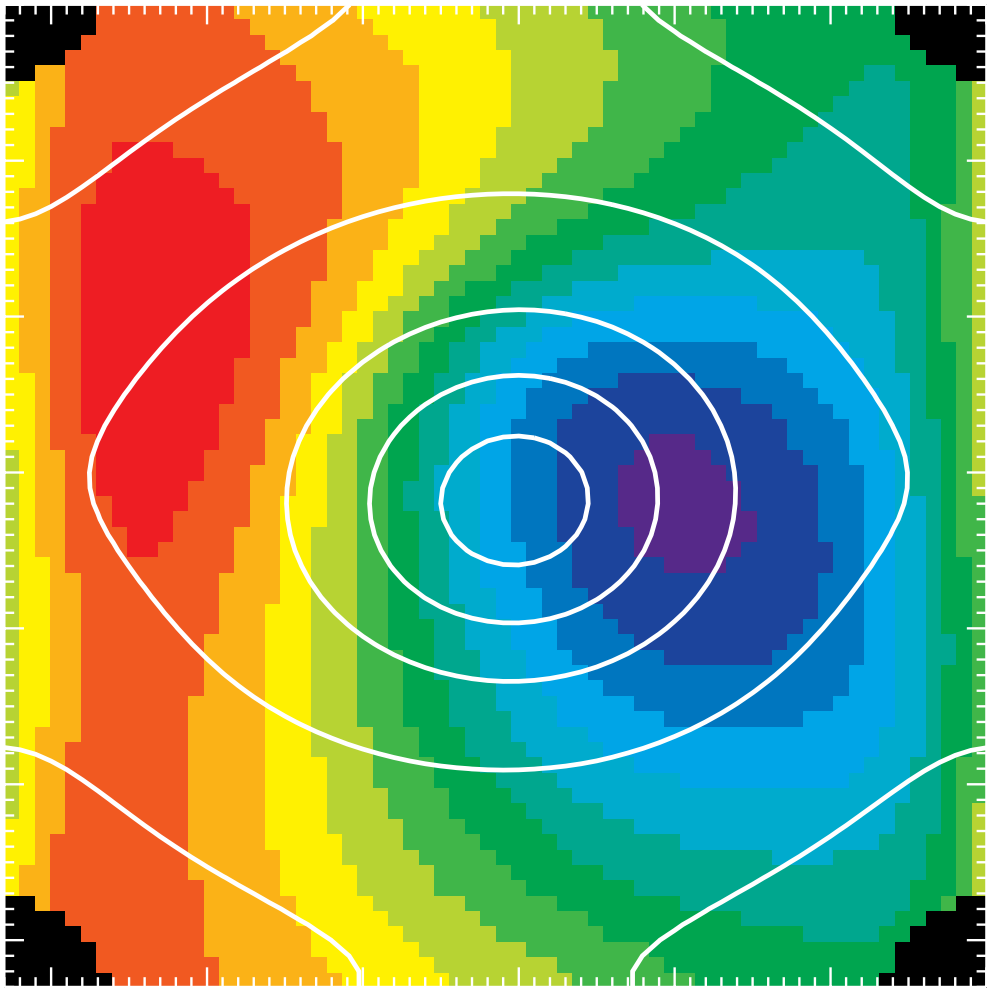
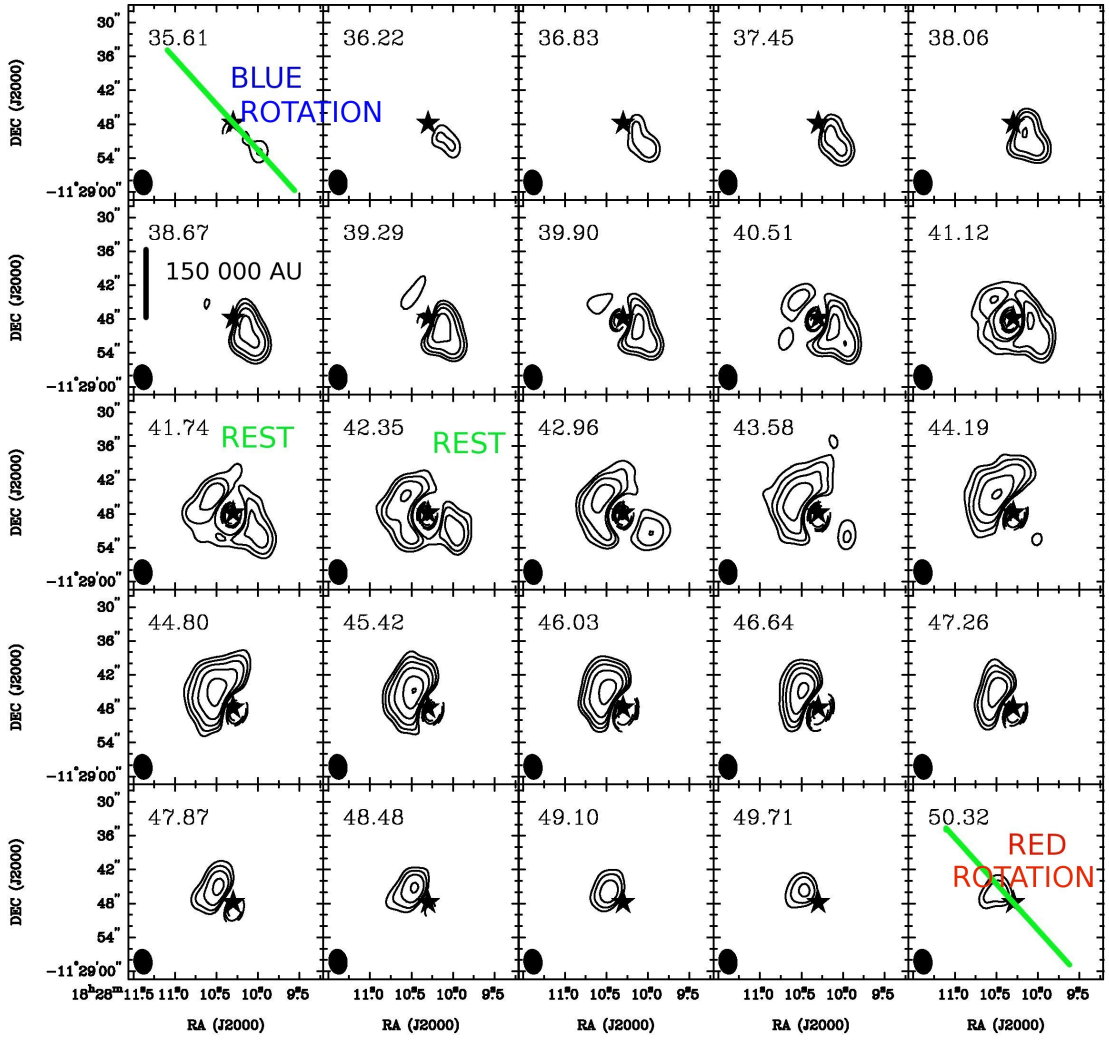
Using RT code MOLLIE to model molecular lines of disk with spiraling envelope (e.g., Keto & Zhang 2010 for IRAS 20126)...work in progress



(PARTIALLY) IONIZED ACCRETION FLOWS (G20.08–0.14)



G20.08N: **rotation and infall in pc-scale flow feeding center**

$L_{8GHz}/L_{bol} \approx 1.1 \times 10^9$ W Hz^{-1} L$_\odot^{-1}$

($L \approx 7 \times 10^5$ L$_\odot$)

Fig: NH_3, frames $\approx$ 30” $\approx$ 1.8 pc

Galván-Madrid+09, ApJ

(PARTIALLY) IONIZED ACCRETION FLOWS (ZOOM INTO G20.08–0.14)

All the SMA-VEX lines show a velocity gradient indicating **rotation in a similar direction than the pc-scale flow!**

$M_\star \approx 34\ M_\odot$

Redshifted NH_3 absorption at $\theta_B \approx 0.5'' \Rightarrow$ **infall**

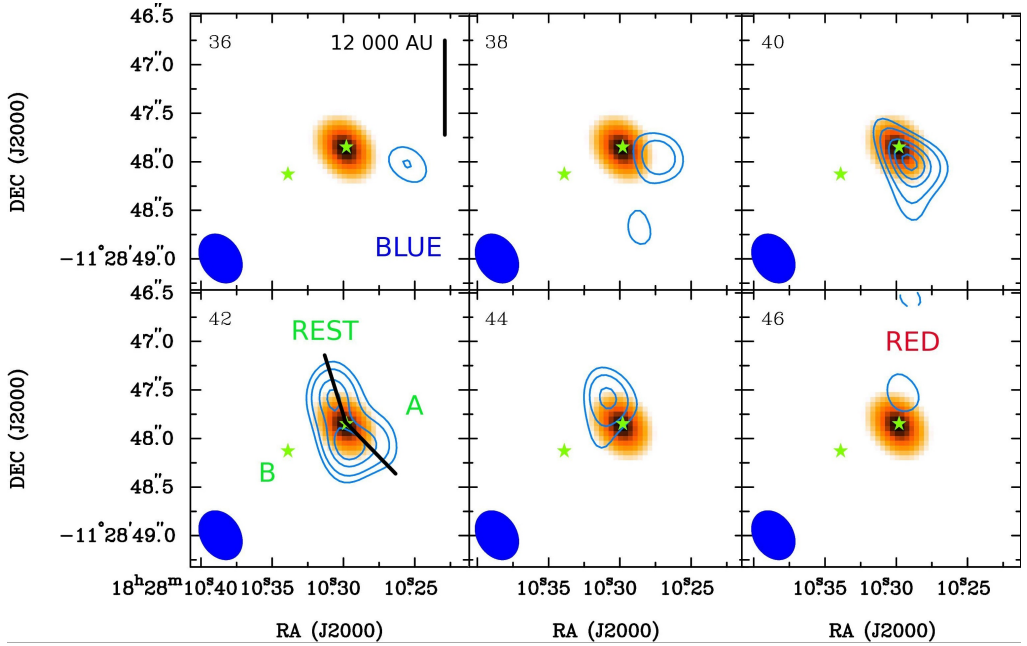


Fig: SMA-VEX. Contours: $CH_3CN\ J(K) = 12(3) - 11(3)$
Color: H30α recombination line

frames $\approx 5'' \approx 60\,000$ AU ≈ 0.3 pc

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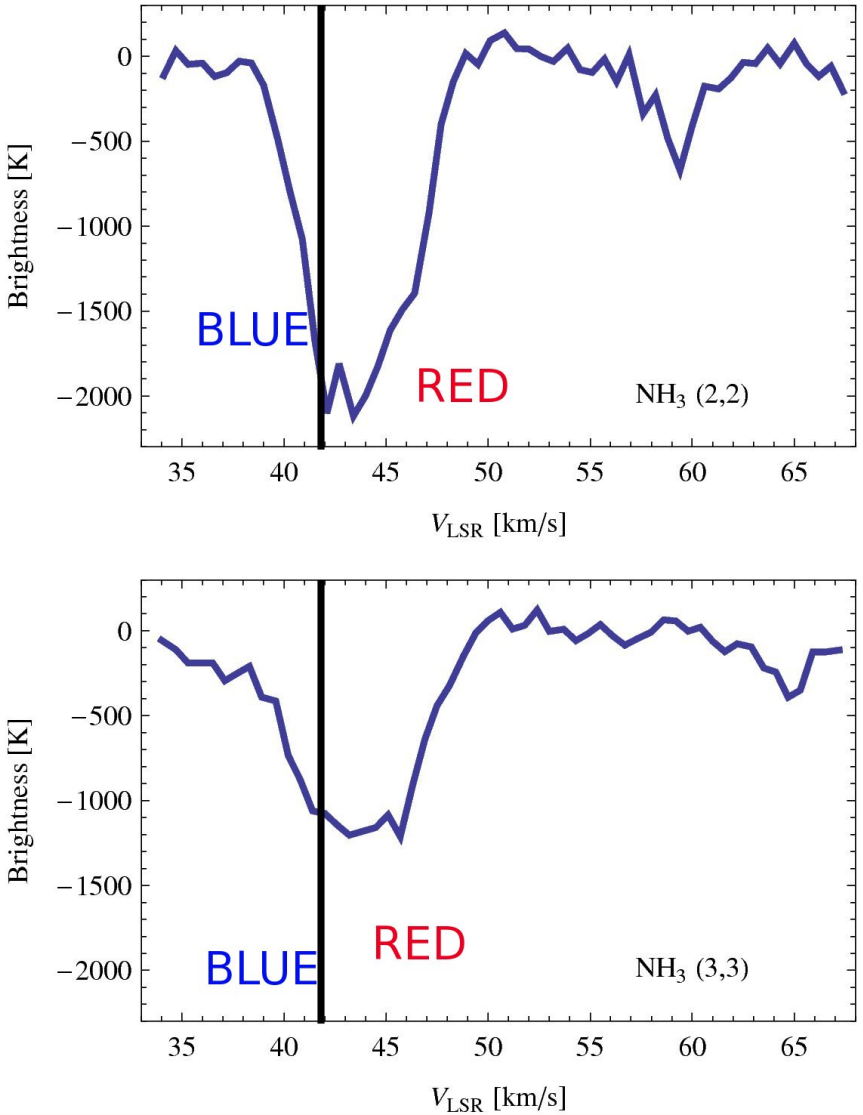

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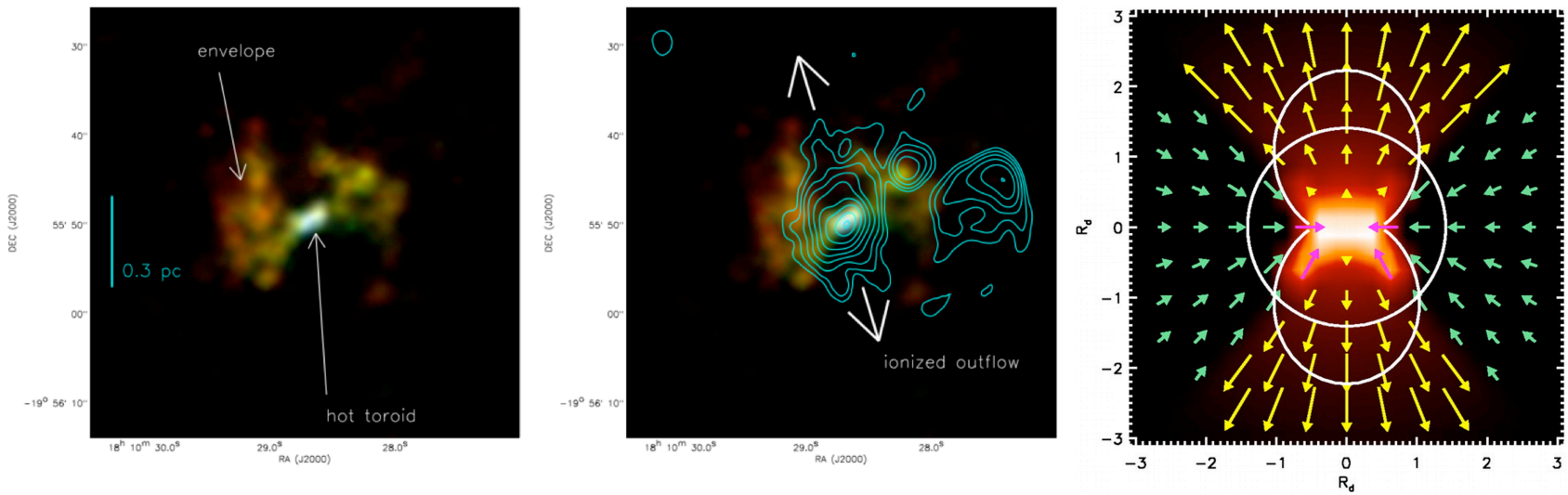
IONIZED ACCRETION FLOWS (G10.6–0.4)

G10.6–0.4: **a pc-scale accretion flow around a stellar cluster**

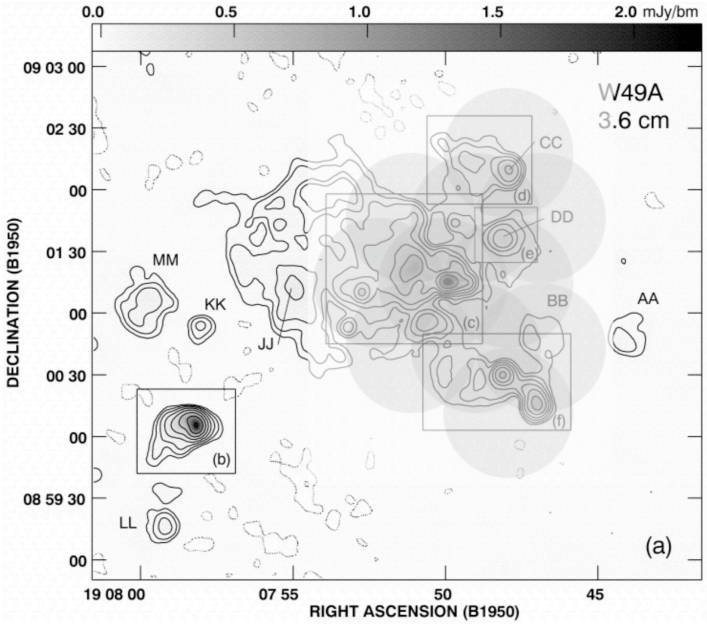
$L_{8GHz}/L_{bol} \approx 1.3 \times 10^{10}$ W Hz^{-1} L$_\odot^{-1}$ ($L \approx 1.2 \times 10^6$ L$_\odot$)

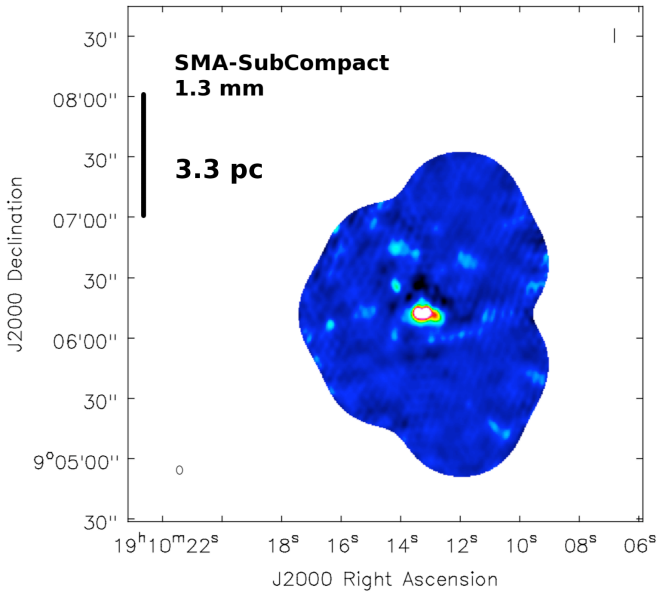


Figs: *Left:* from Liu+10, subm to ApJ, CH_3OH (Red=35 K, Green=60 K, Blue=97K), 10” = 0.32 pc.
Center: Overlay with cm free-free. *Right:* model from Keto 2007.

EXTREME STAR FORMATION (W49A)

SMASHR: multi-conf SMA mosaic of W49A





$L > 10^7\ L_\odot$ observations taken in the past few months (G-M, Liu, et al., work in progress)

- Statistics with dozens of HCHIIs' embedded/naked phases, spectral indices, sizes, dynamics. Compare with simulations of cluster formation with HII region feedback of Peters+10
- W49A may be template to understand extragalactic embedded Super Star Clusters (SSCs) and their 'Ultra Dense' HII Regions

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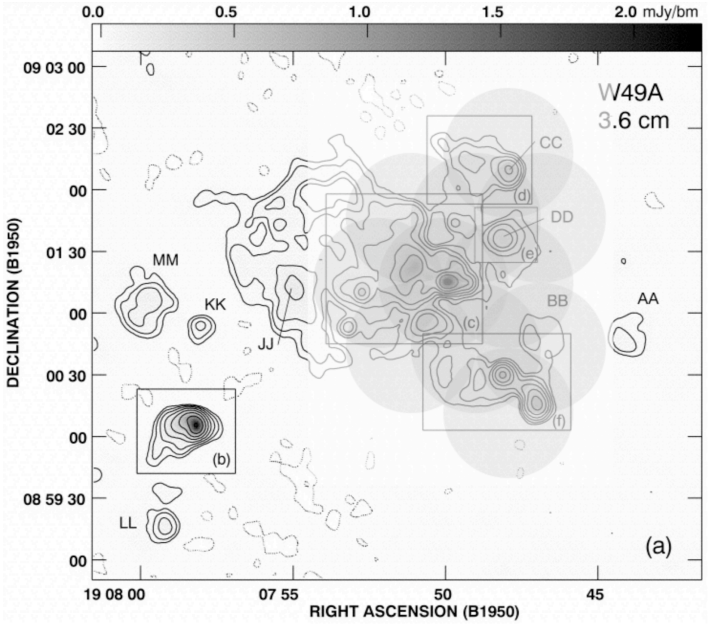

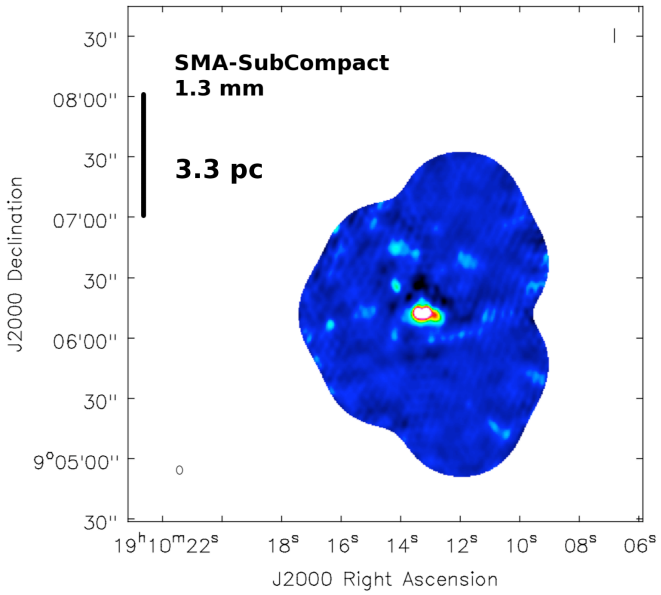

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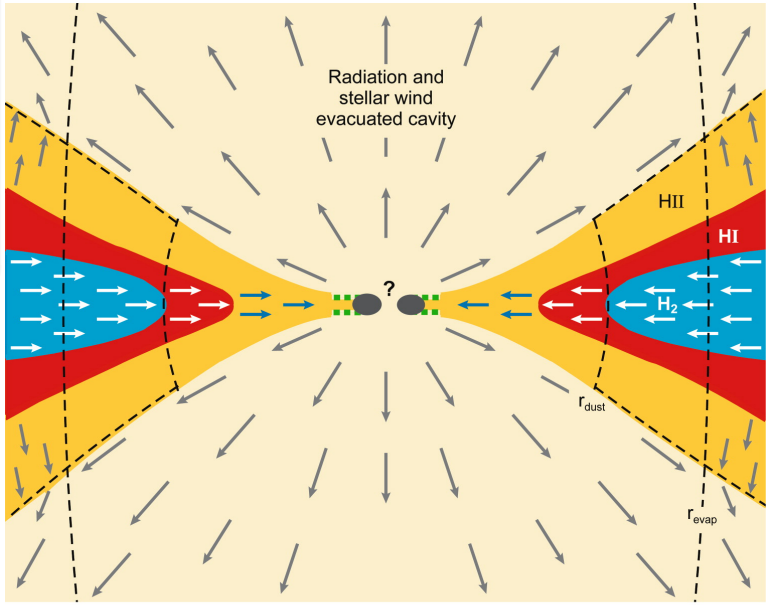
CONCLUSIONS

Stars with $M_\star > 15\ M_\odot$ form by accretion processes similar to lower-mass stars, but with the accretion flow partially ionized (the youngest H II regions *are not* freely-expanding Strömgren spheres).



Zinnecker H, Yorke HW. 2007.
Annu. Rev. Astron. Astrophys. 45:481–563

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- The masses of the cores (0.1-pc scale) are always *a few* $\times 10\ M_\odot$
  $\Rightarrow$ need to *resupply from the outside*.
- Observational evidence of resupply: coherent accretion flows from 1pc to 0.1 pc scales, large-scale infall, converging motions.