How does Milky Way (local group) Star Formation talk to high-z?

(are there) Very Massive Stars in the Galaxy?

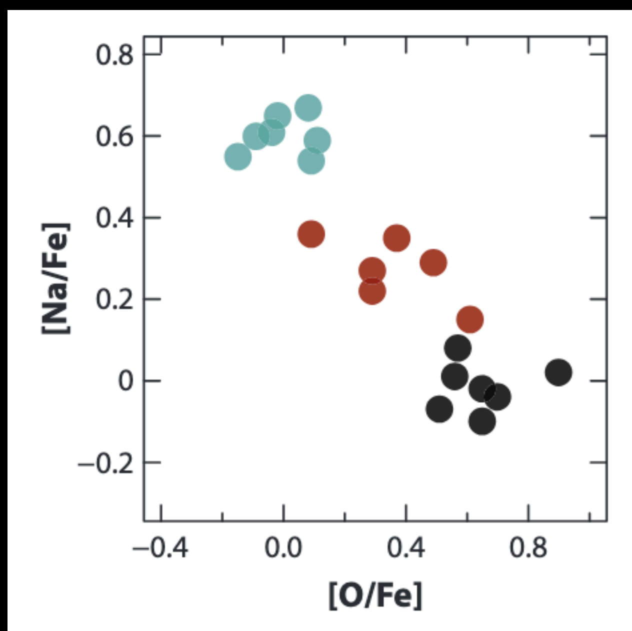
Actually in the schedule:
How do the most massive stars form? (What bounds the IMF?)

Adam Ginsburg @ Puzzles of Star Formation May 2025

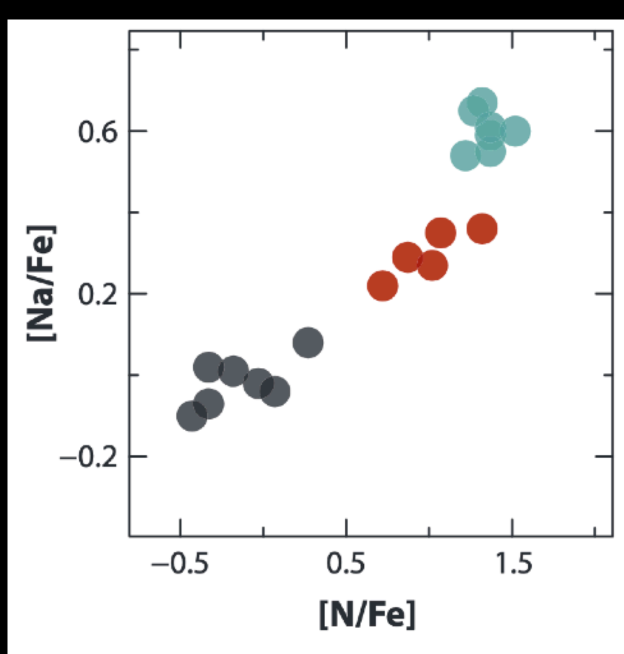
Context: Very Massive Star elemental feedback

Na-O anticorrelation is
observed in globular clusters

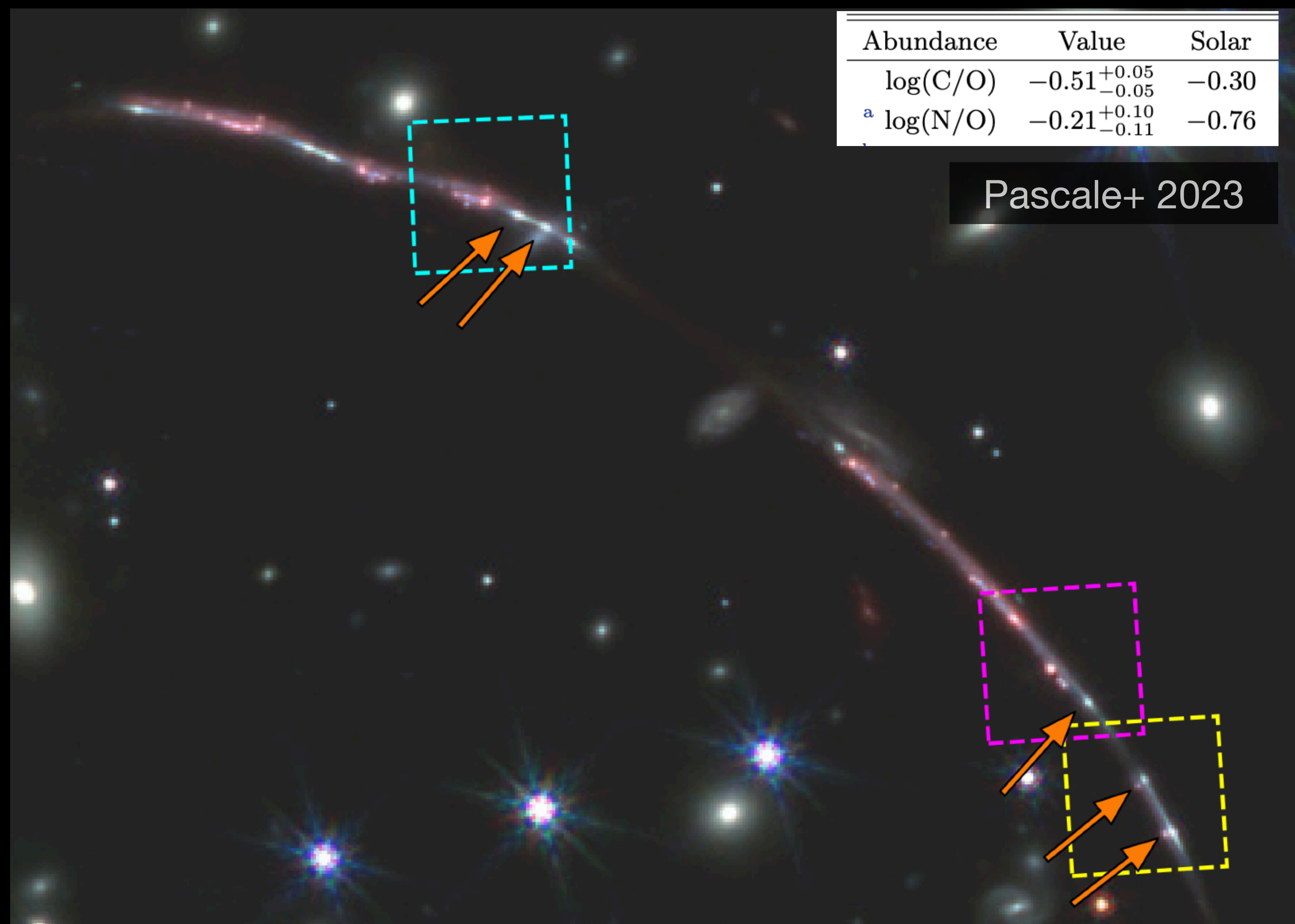
(Bastian & Lardo 2018)



Na-N correlation



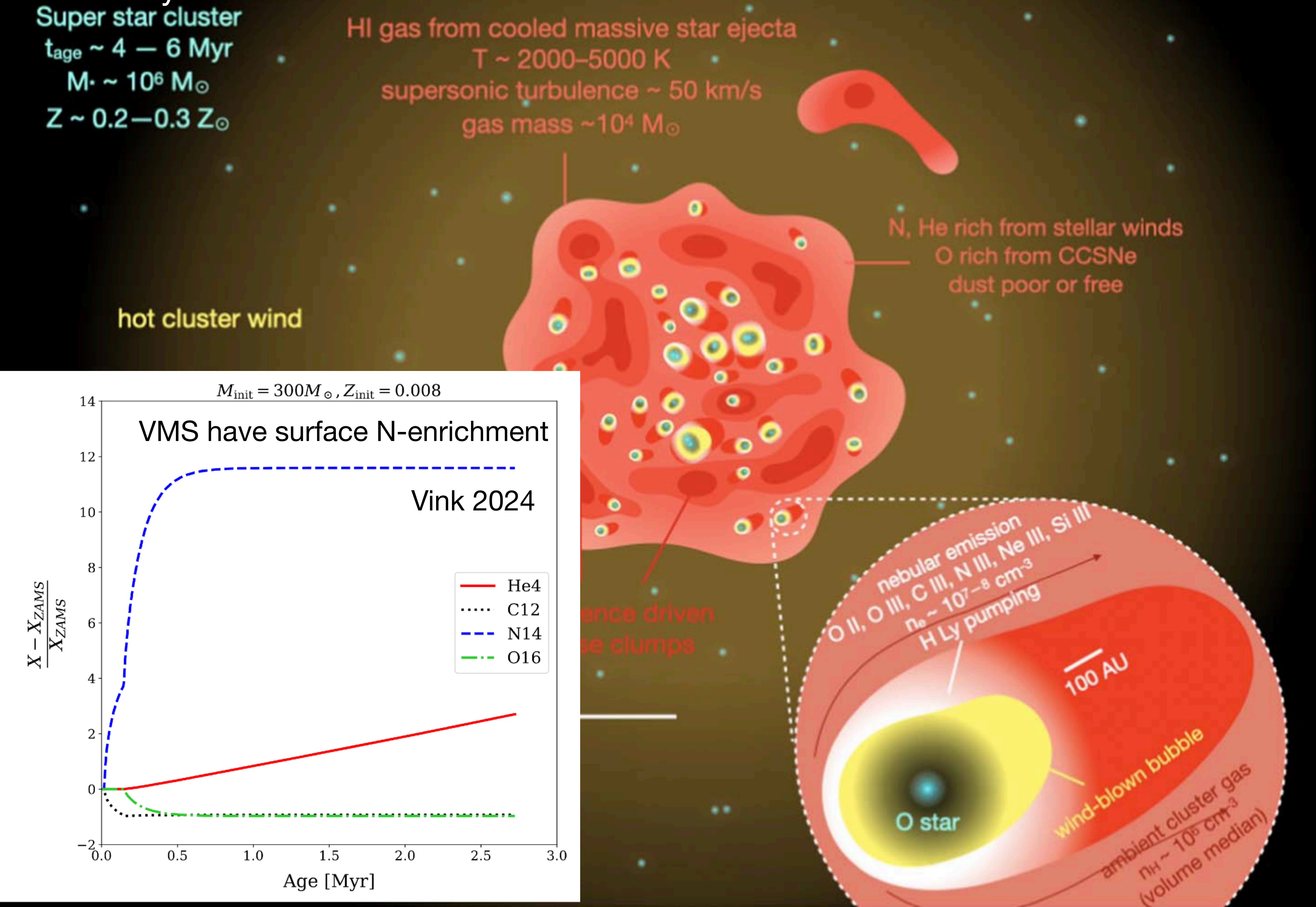
Nitrogen-enhanced gas is seen in the z=2.37 “Sunburst Arc”



Abundance	Value	Solar
$\log(C/O)$	$-0.51^{+0.05}_{-0.05}$	-0.30
[a] $\log(N/O)$	$-0.21^{+0.10}_{-0.11}$	-0.76

A model for "Godzilla"

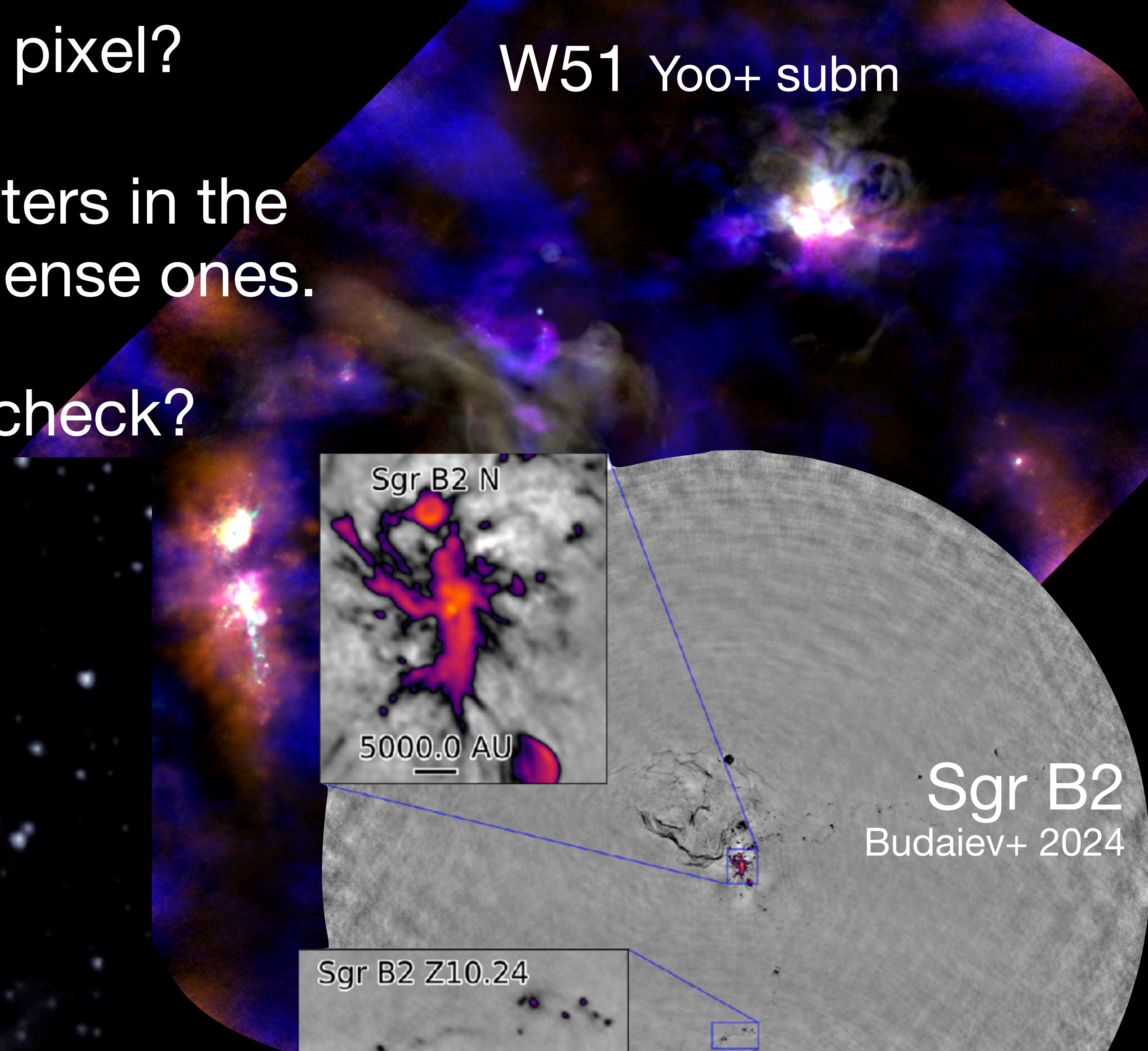
Cartoon by Pascale & Dai 2024

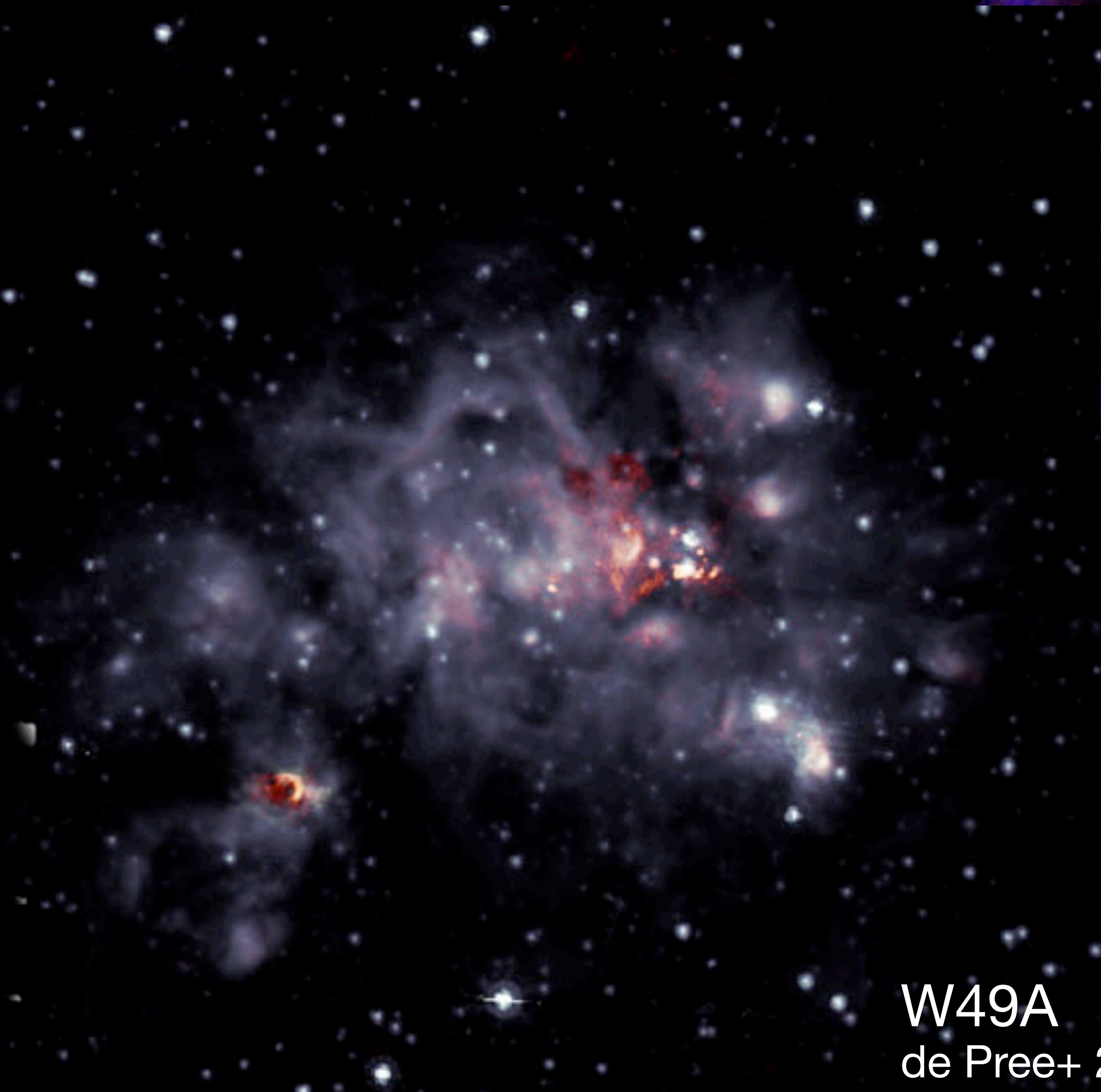


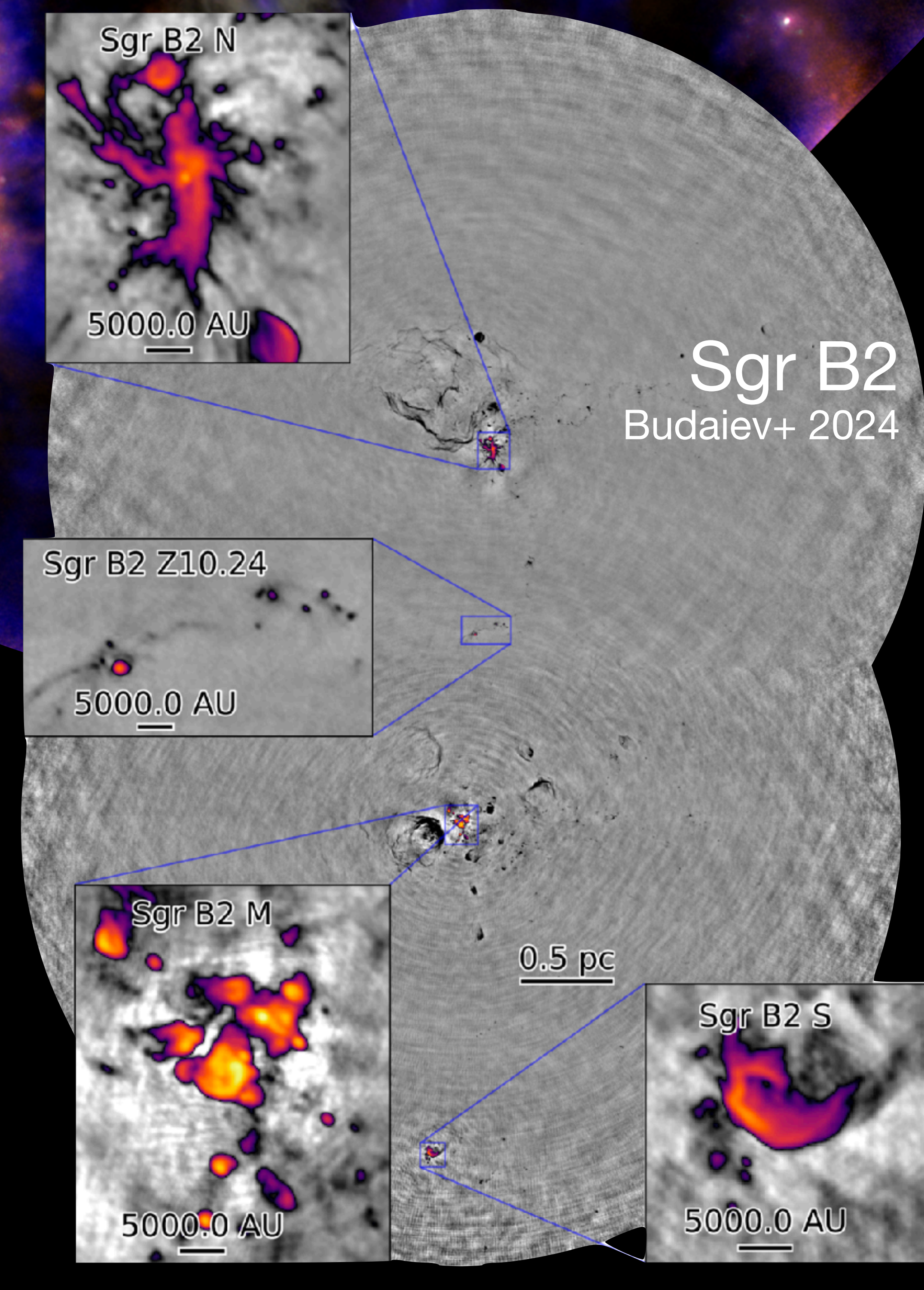
So what’s really happening in their 1 pixel?

We don’t have $10^6\ \mathrm{M}_\odot$ forming clusters in the Galaxy, but we have some big and dense ones.

Do we have any VMS? How do we check?

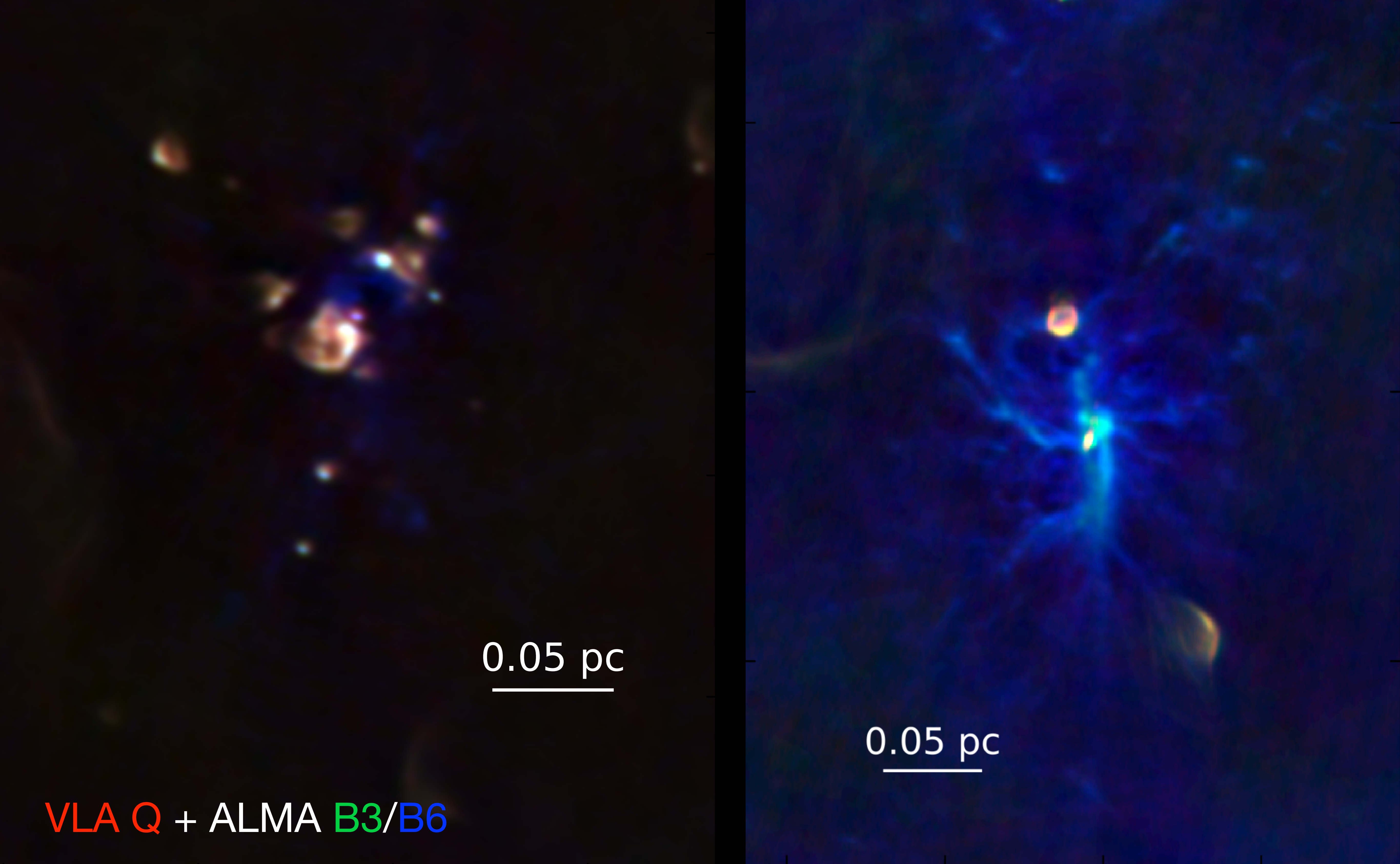




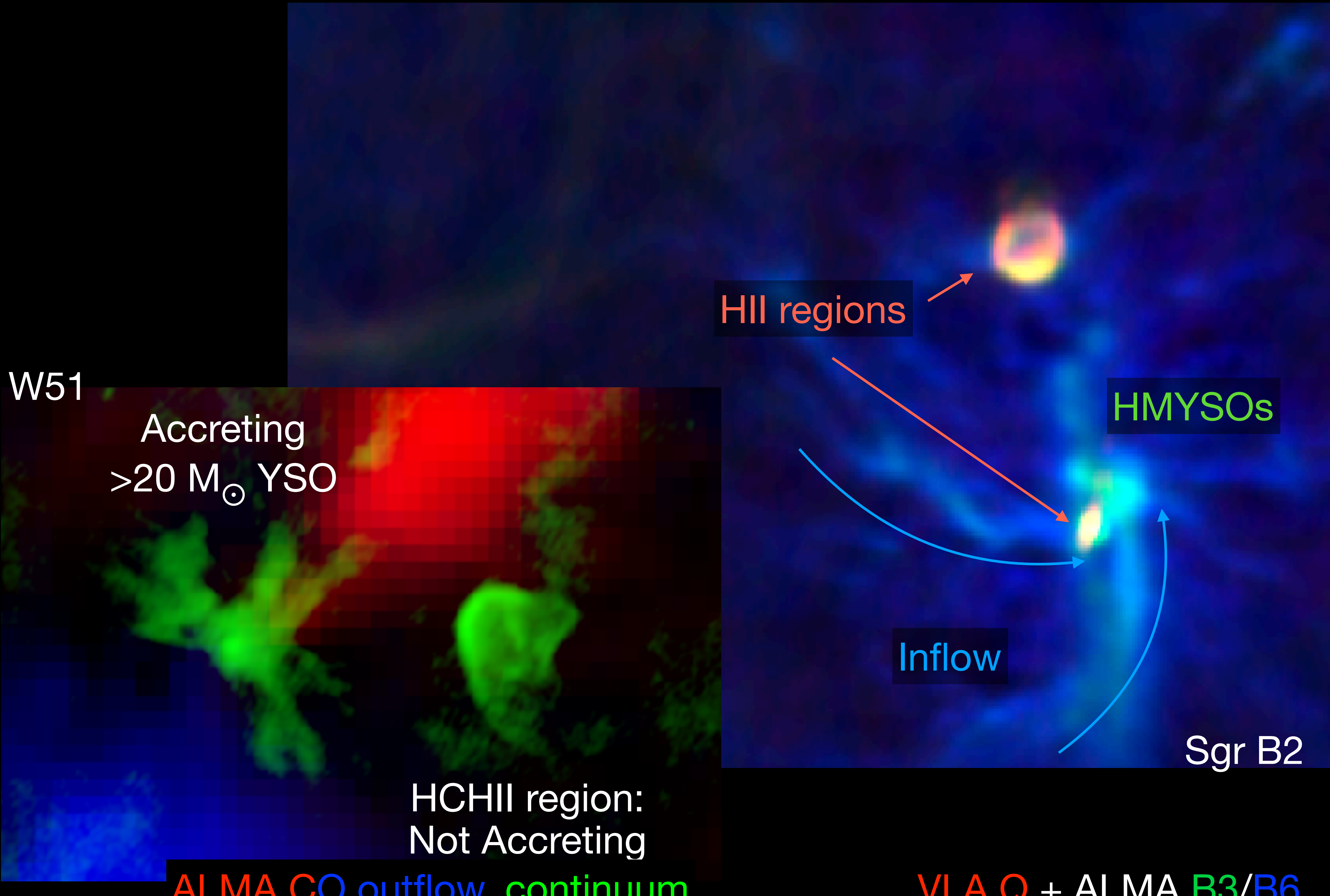


Sgr B2: Our Galaxy’s densest clusters

HII regions are pressure-bound (Meng+ 2022)



Ionizing Stars & still-growing MYSOs live together



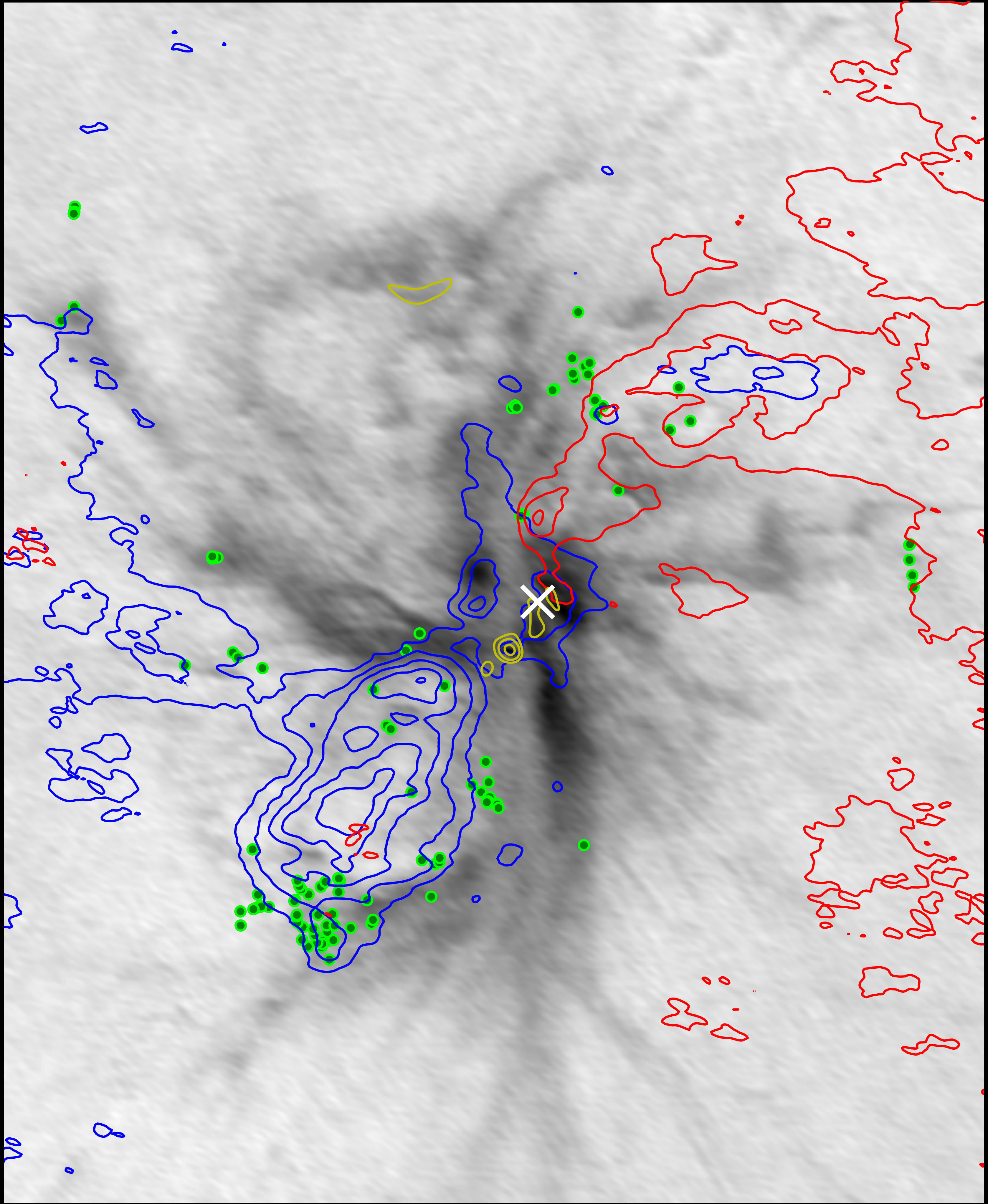
Fed-back material does not all escape

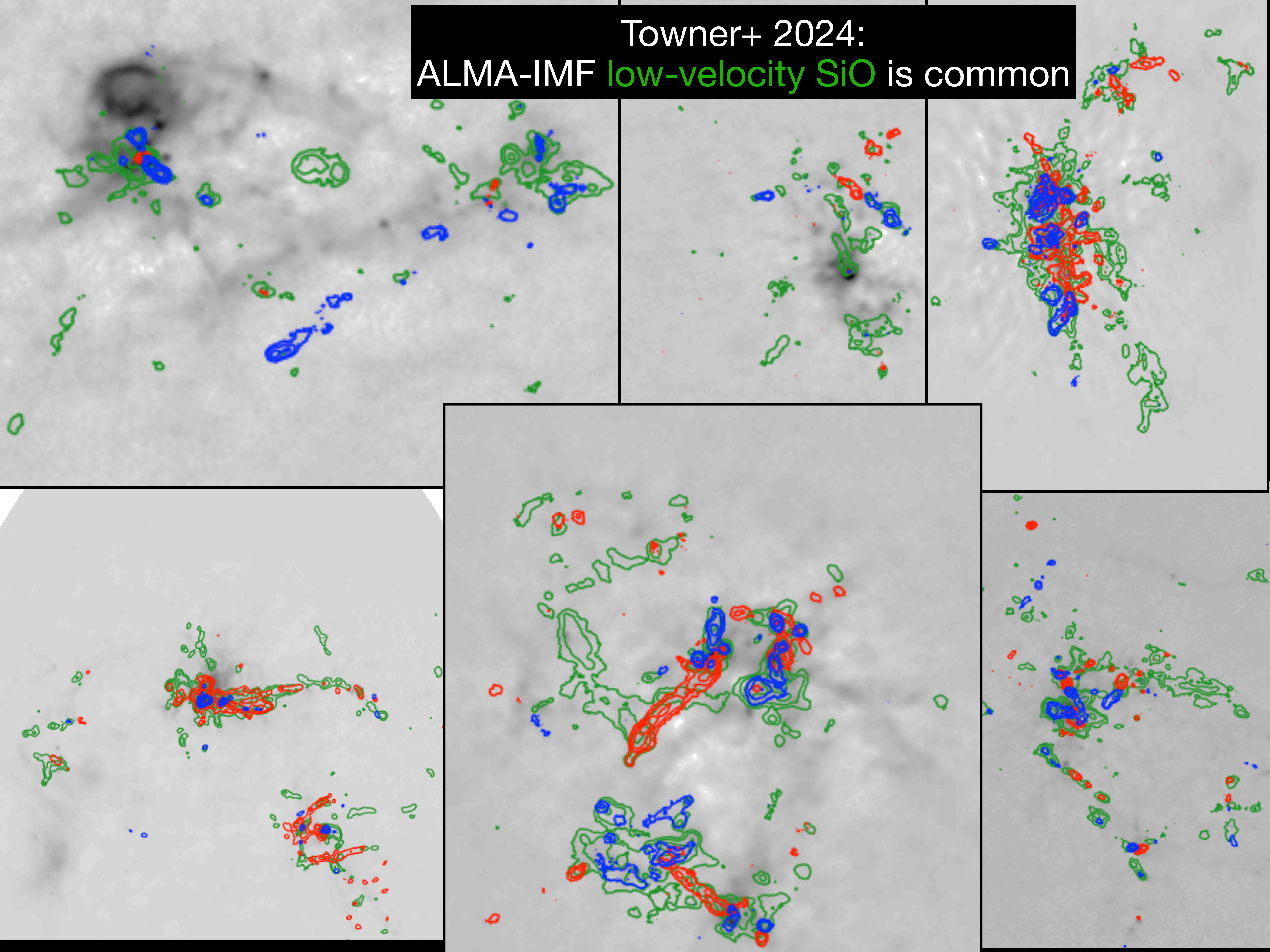
Water Masers show where the SiO outflow impacts the infalling material

(the outflow is low-ish velocity)

Sgr B2N (right):
Budaiev+ in prep
Schwörer+ 2019

Elsewhere:
Towner+ 2024



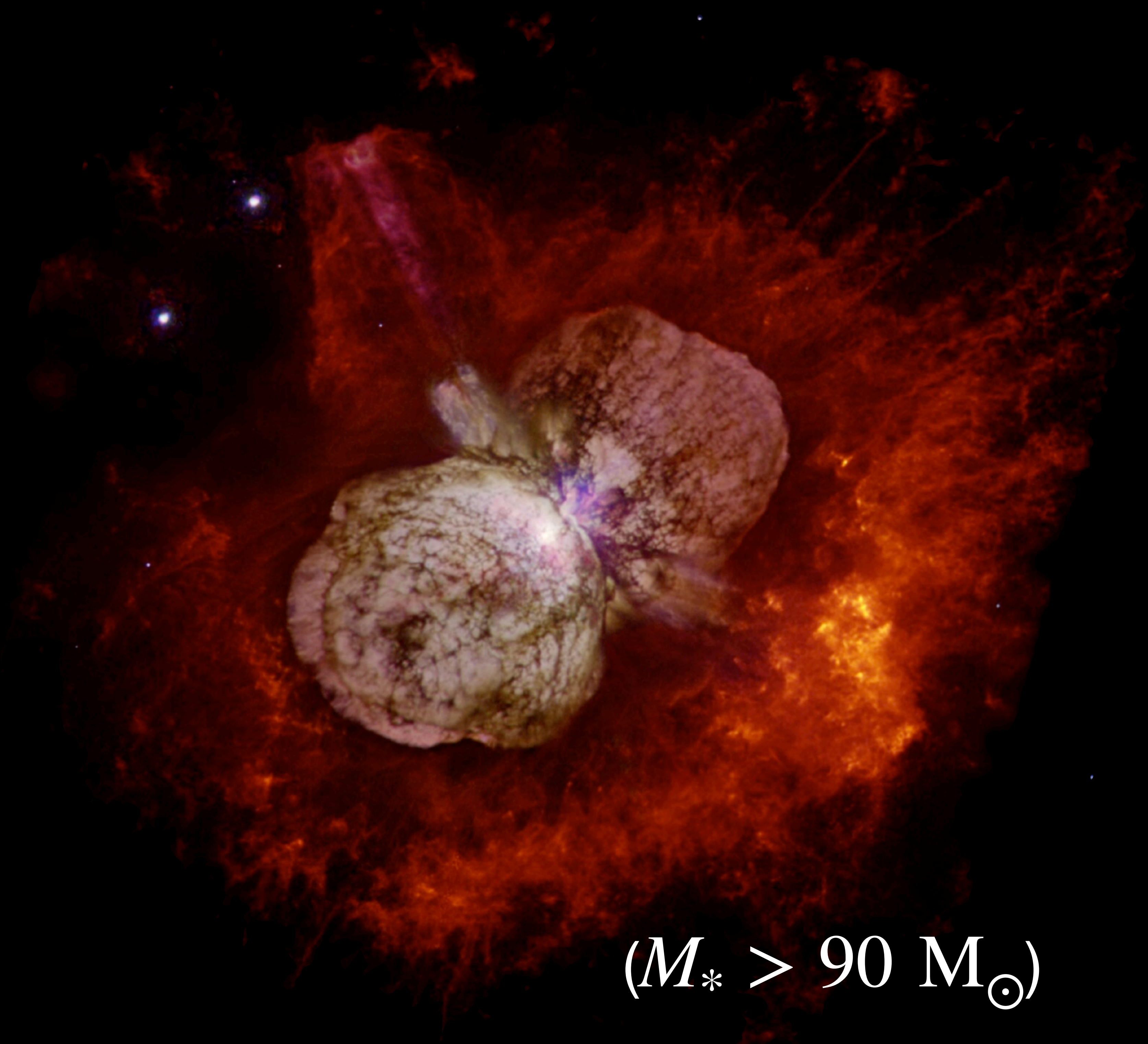

Towner+ 2024:
ALMA-IMF low-velocity SiO is common

So (where) are there VMS?

η Car's explosion includes some nuclear-burnt products

…but it blew up into a vacuum.

Enriched wind only matters if it goes into star-forming gas.



$(M_* > 90\ \mathrm{M}_\odot)$

Thomas Henning, EPoS 2018, 2022, 2024, paraphrased: “But what about the really massive stars?”

While current IMF determinations may still leave some room for variations under extreme conditions (Kroupa 2001), there is significant consensus that the shape of the IMF is nearly universal among galactic regions, with only possible differences at substellar masses (see Bastian et al. 2010 and Offner et al. 2014 for reviews). Even a persistent discrepancy between the IMF of Taurus and of massive clusters like the Orion Nebula Cluster, which suggested an stellar excess around 0.8 $M_\odot$ in Taurus (Briceño et al. 2002), has been recently resolved when the new and more complete Gaia data have been used, suggesting a lack of IMF variations across a range of stellar densities between 3-4 orders of magnitude (Luhman 2018). This universality of the IMF, together with its simple form that includes a single power law connecting the low- and high-mass regimes, suggests that the formation of stars of different masses results from a continuous non bimodal process.

Beuther, Kuiper, Tafalla 2025

Highest-mass star dynamically measured
(VMS = 80+ $M_\odot$)

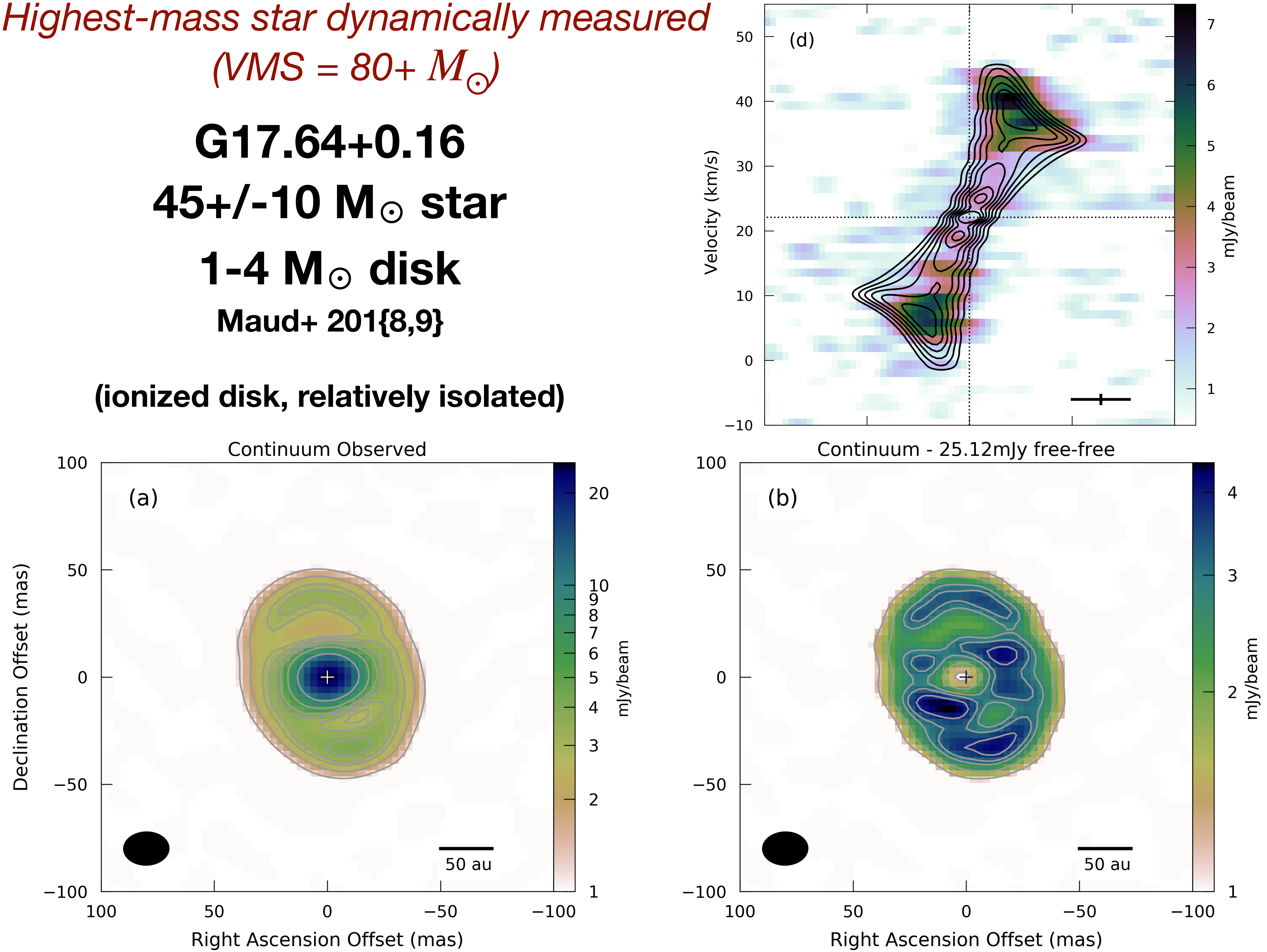
G17.64+0.16

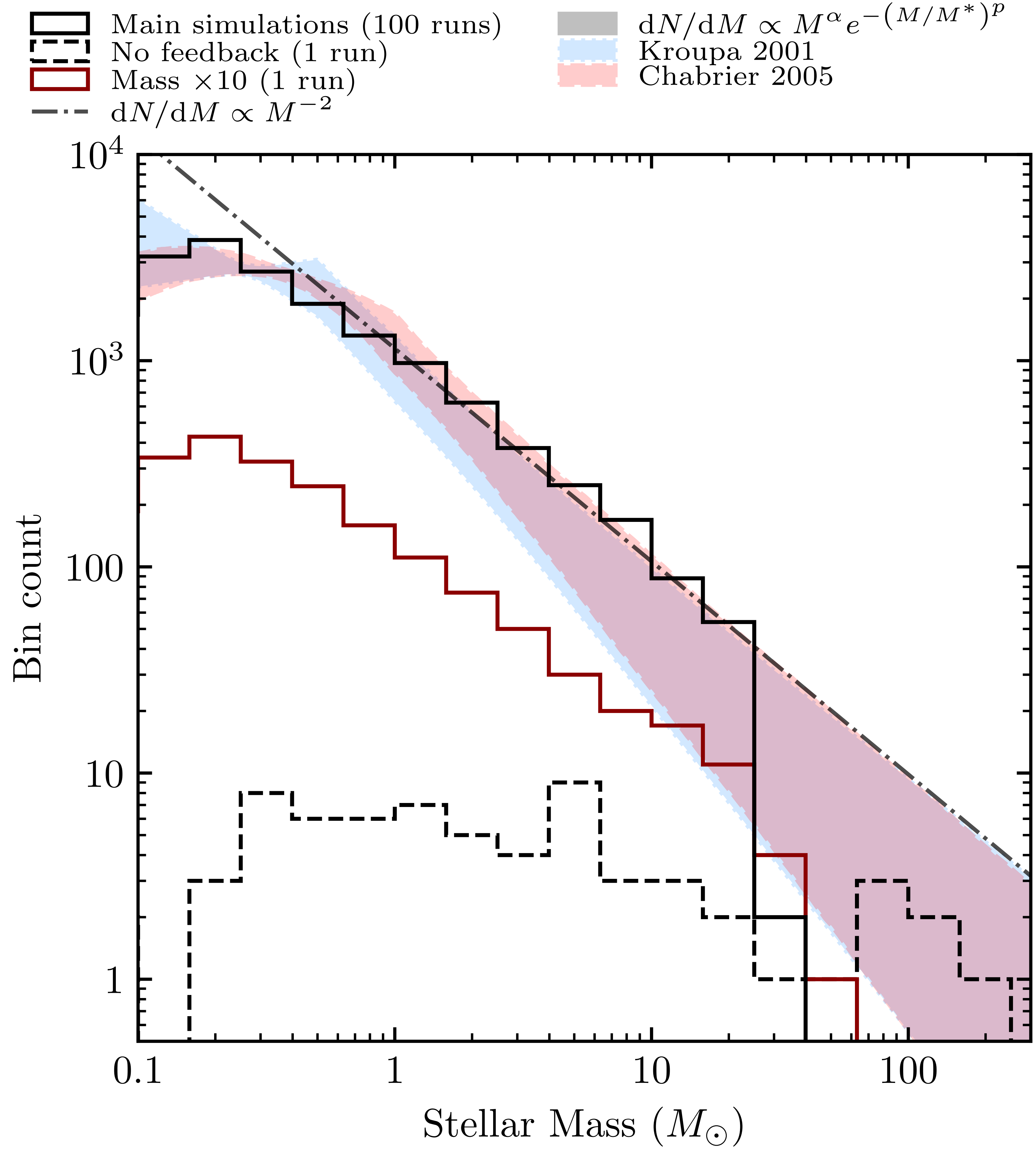
45+/-10 $M_\odot$ star

1-4 $M_\odot$ disk

Maud+ 201{8,9}

(ionized disk, relatively isolated)





Grudic & Hopkins 2023

100 simulations of 2000 $M_\odot$ events ->

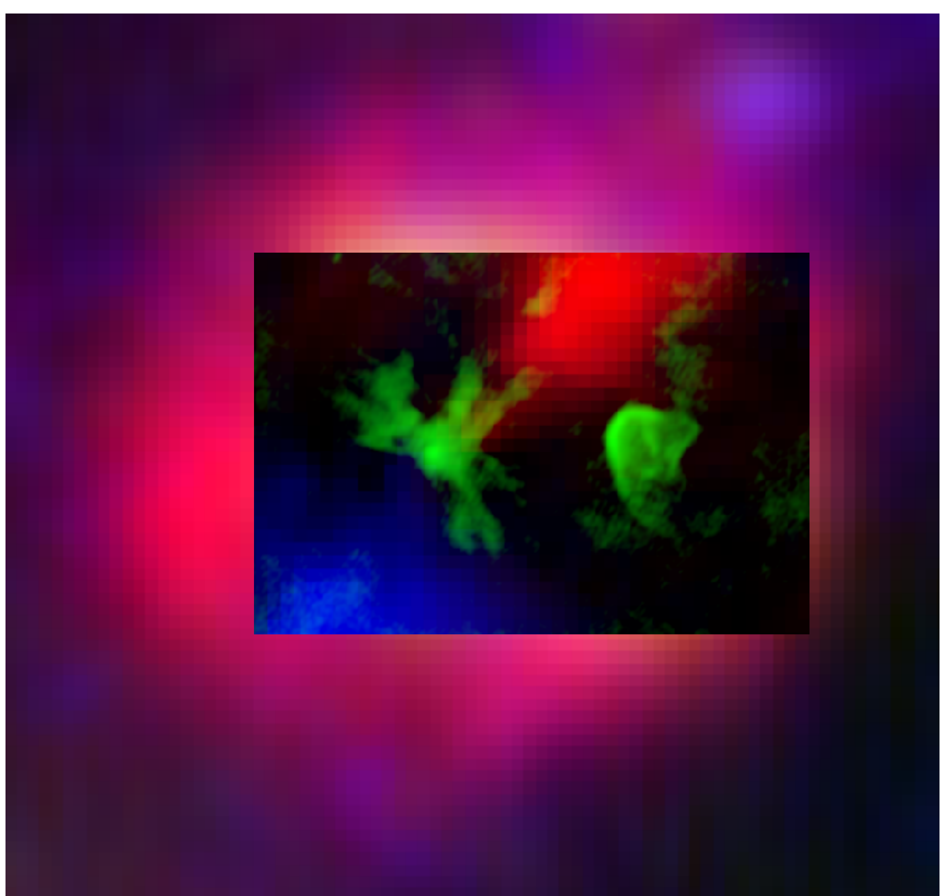
$M_{max} \sim 30\ M_\odot$

(Hosek+ -> shallow IMF in clusters)

Is star formation in dense, massive clusters qualitatively different from "distributed" star formation?

(I think so)

Q: Can high-mass cores form "on their own", or do they need help from neighbors?

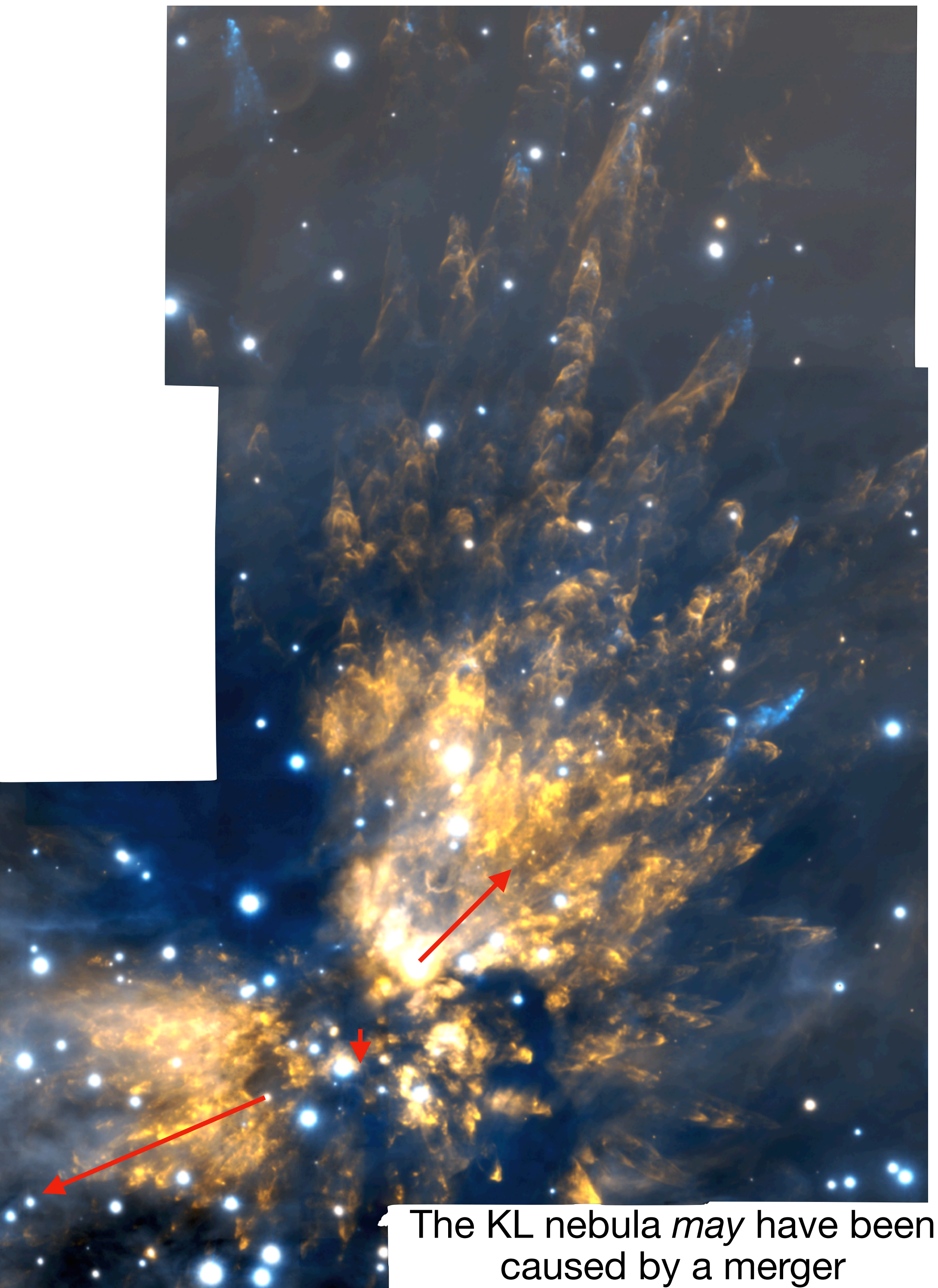


"**Cooperative accretion**" scenario: Ionizing star grew an unfragmented core, then moved away or hit L_{Edd}.

The leftover core forms a big(ger?) star.

Do VMS (M>50) form (only) this way?

Is star formation in dense, massive clusters qualitatively different from “distributed” star formation?



The KL nebula *may* have been caused by a merger

Collisions

Many stars. Small volume.

Smash, boom.
This definitely happens.

Do VMS (M>50) form (only) this way?
What nuclear products get spread?

Are there chemical signatures of VMS?

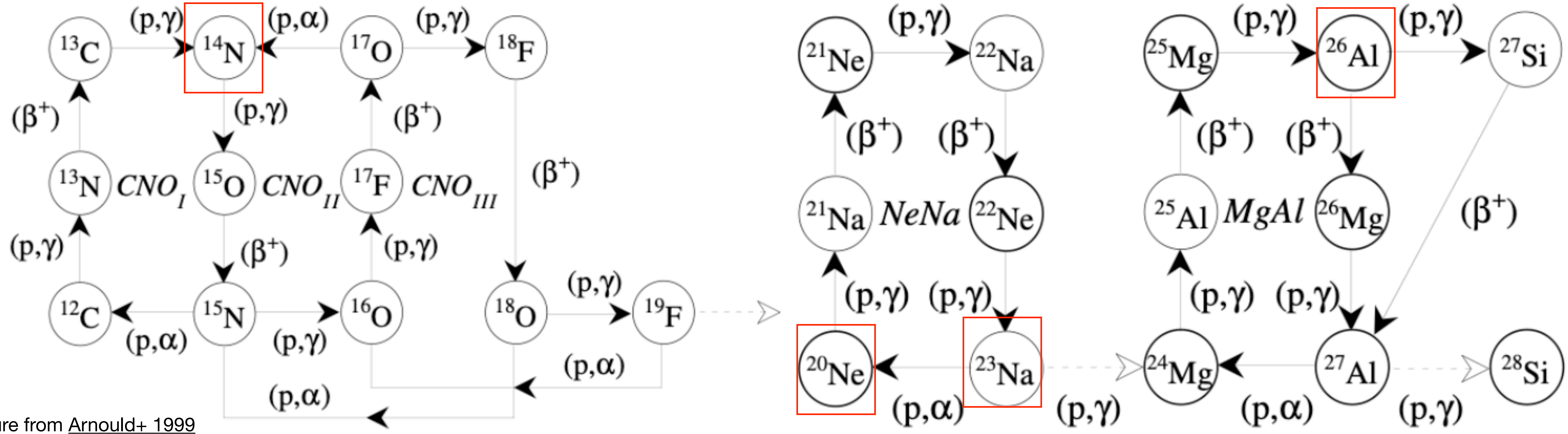
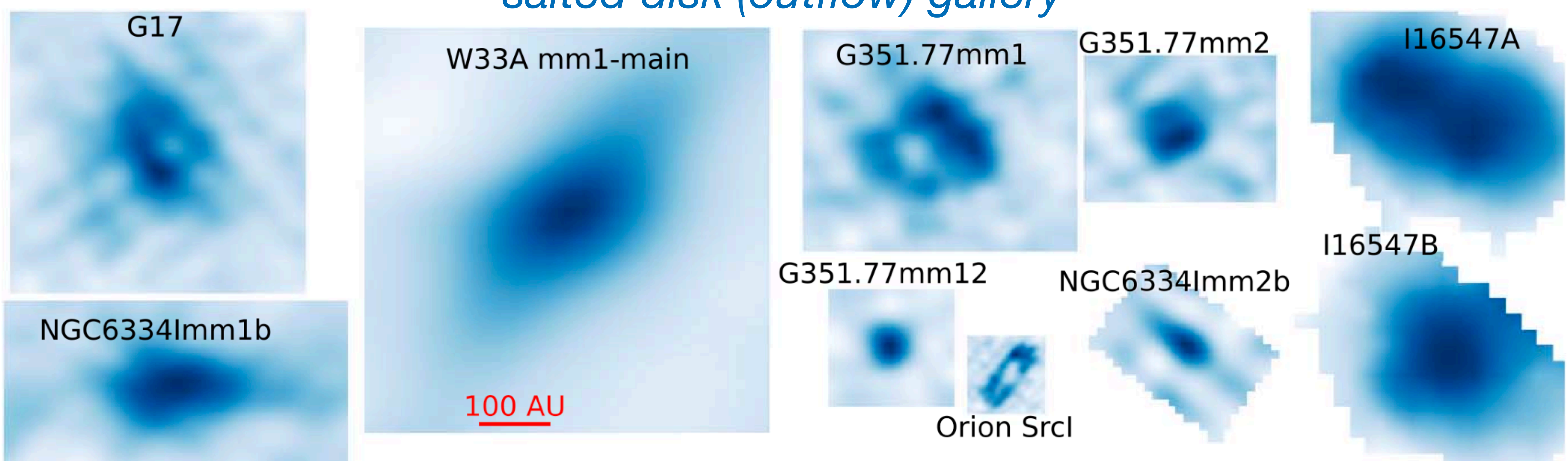


Figure from Arnould+ 1999 via https://arxiv.org/pdf/1611.08855 via Liang Dai

CNO cycle **Ne-Na cycle** **Mg-Al cycle**

or are they always confused with mergers?

salted disk (outflow) gallery



Many observational & theoretical questions

- Overarching: Is M_{max} environmentally dependent?
- Do VMS feed nuclear-processed material to their neighbors?
- Are there observable [not UV/optical] chemical tags for VMS?
  - Do YSO mergers make those same tags?
- Are mergers needed for VMS formation?