SOFIA-FORCAST Imaging Survey toward the Galactic Giant HII Regions : II. M17

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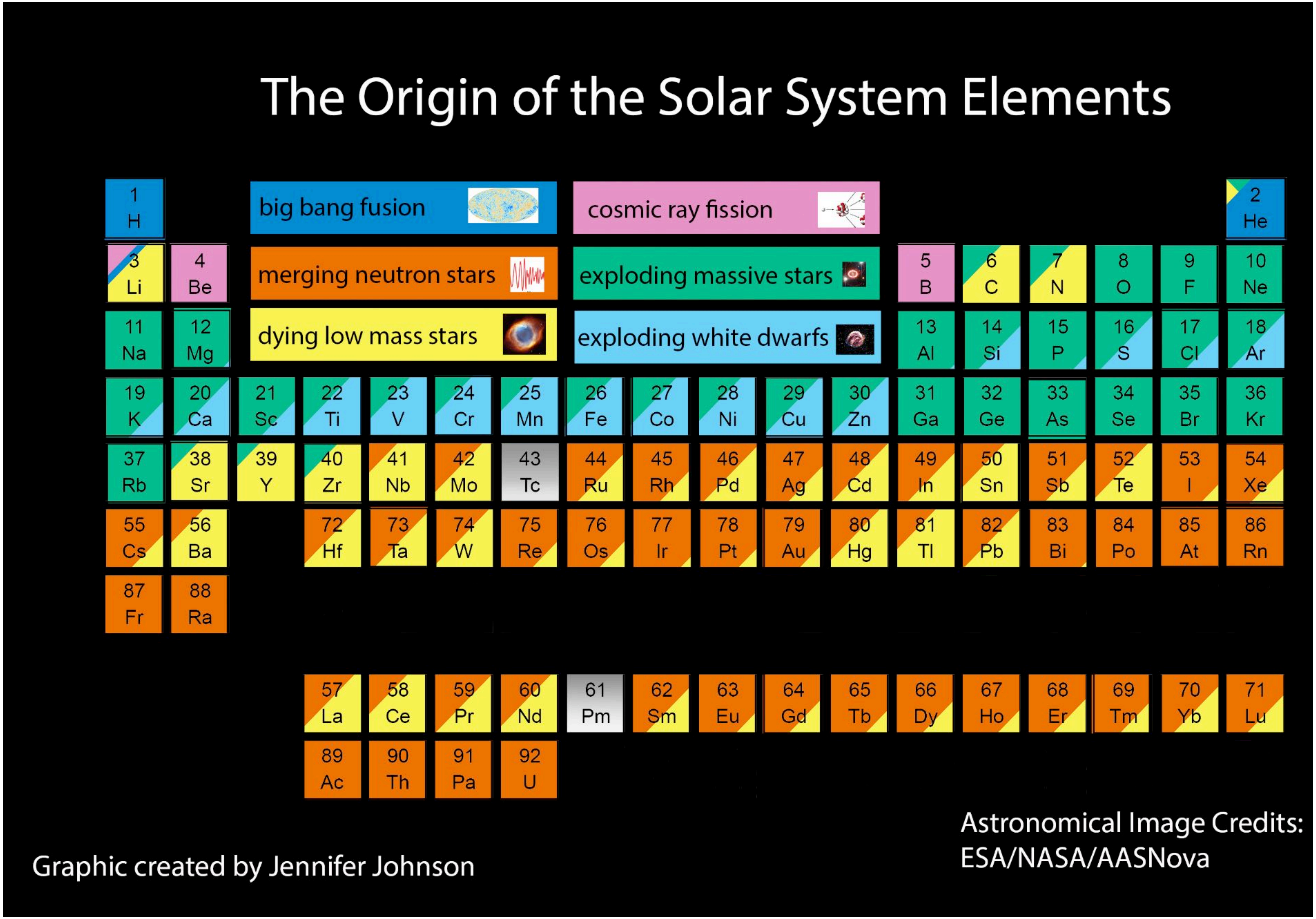
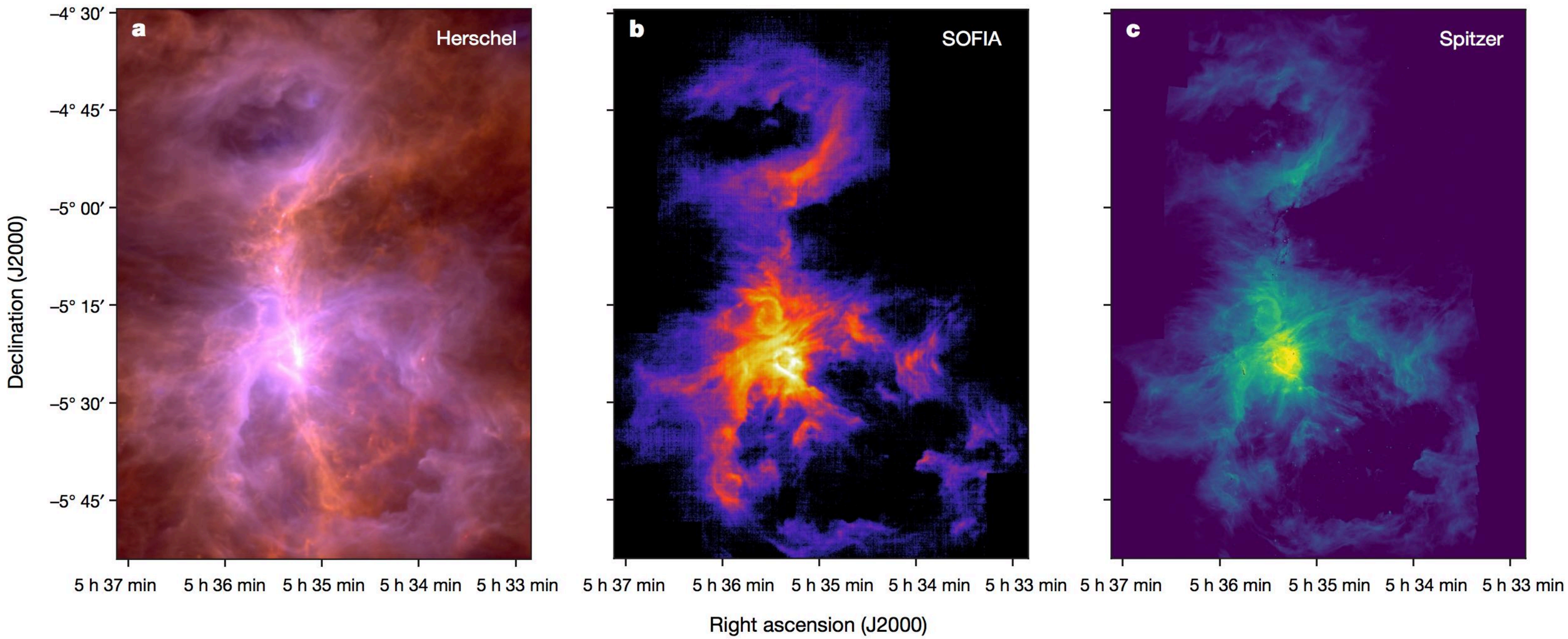
Why massive stars are important?

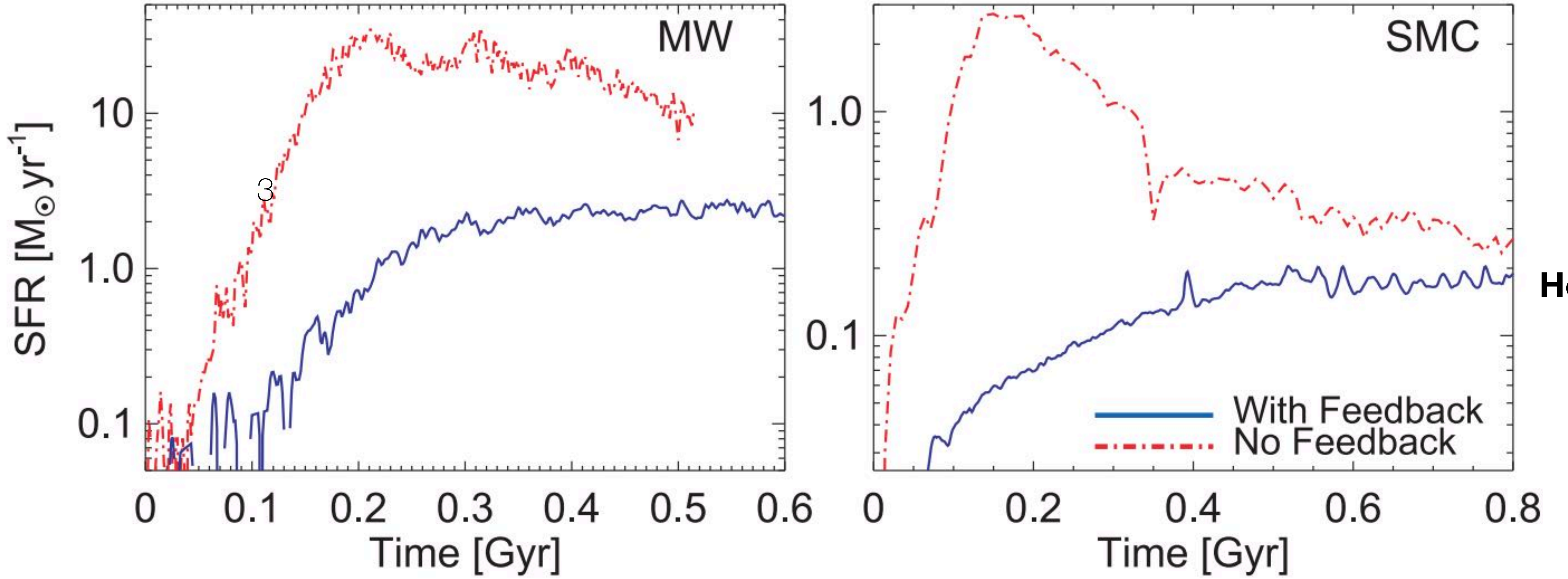
Reason #1 - Chemical Input



Why massive stars are important?

Reason #2 - Energetic feedbacks





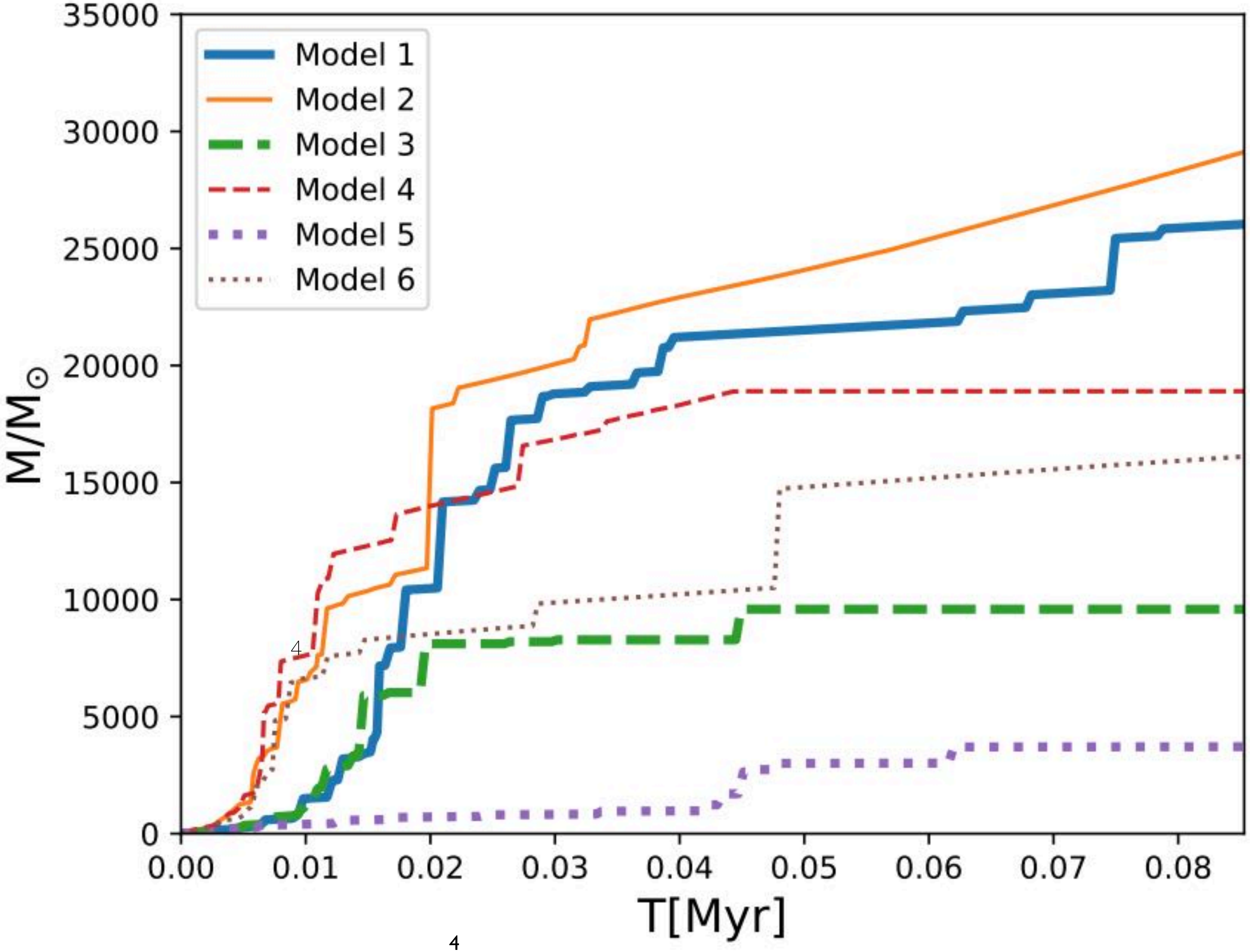
Hopkins ea 2019

The enormous massive star feedback can be a critical source to form and maintain the shapes of the environmental GMCs!

Alister Seguel ea 2019

Why massive stars are important?

Reason #3 - Seeds of SMBHs



Evolutionary sequence of Massive stars and star clusters

(Beuther et al. 2007)

Cores to stars

→ High-mass starless cores (HMSCs)

→ High-mass cores harboring accreting low/intermediate mass protostar(s) destined to become a high-mass star(s)

→ High-mass protostellar objects (HMPOs)

→ Final stars

Clumps to clusters

→ Massive starless clumps

→ Protoclusters

→ Stellar clusters

Two simple stages

- Infrared Quiescent (Infrared Dark Clouds)
- Infrared Bright (GHII regions)

Giant HII (GHII) regions are…

- well known active massive star forming regions.
- bright across almost all wavelengths.
- only IR bright objects you can recognize easily from external galaxies.

Thus, it is important to study Galactic GHII regions to understand star formation even in external galaxies.

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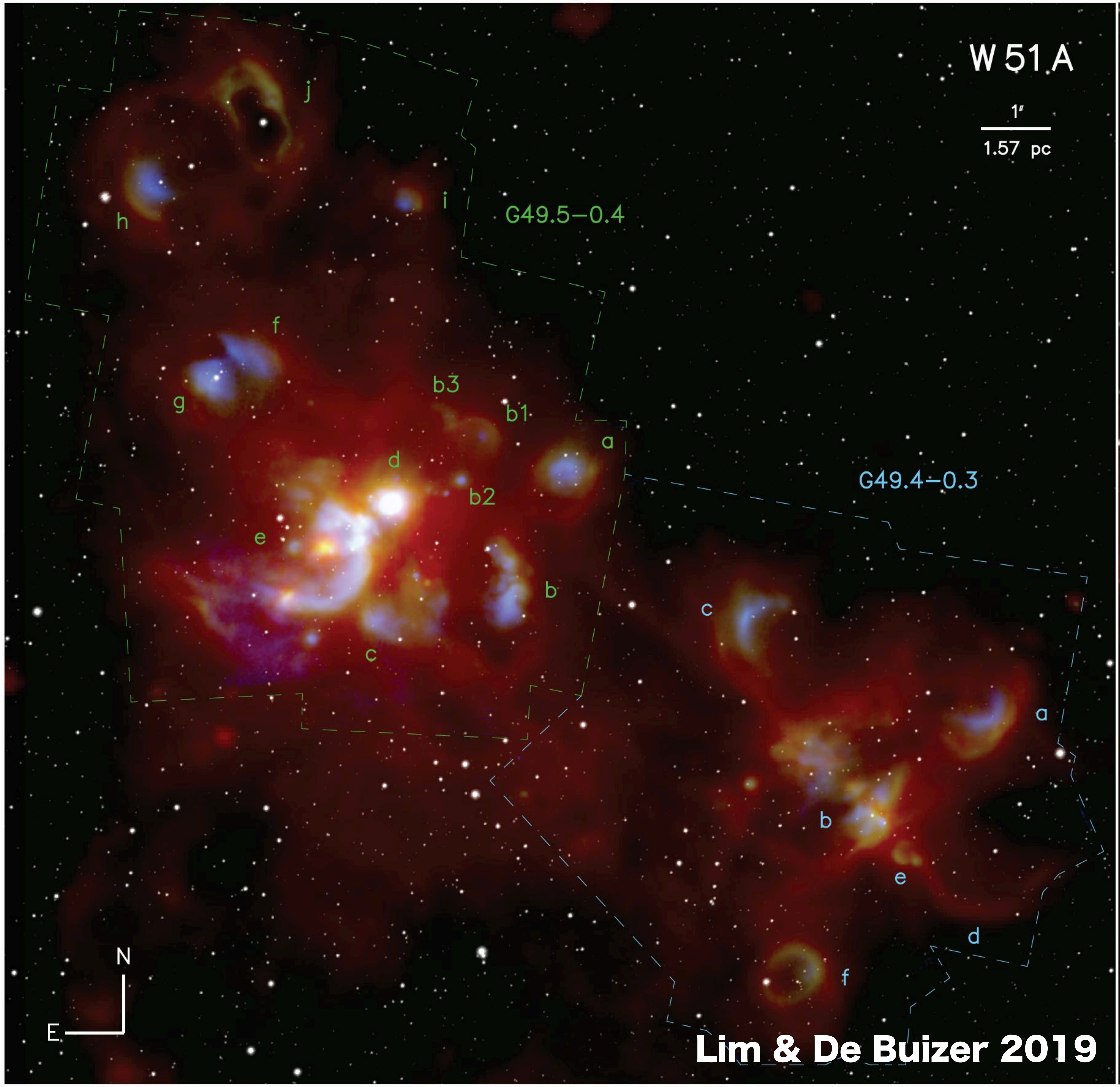
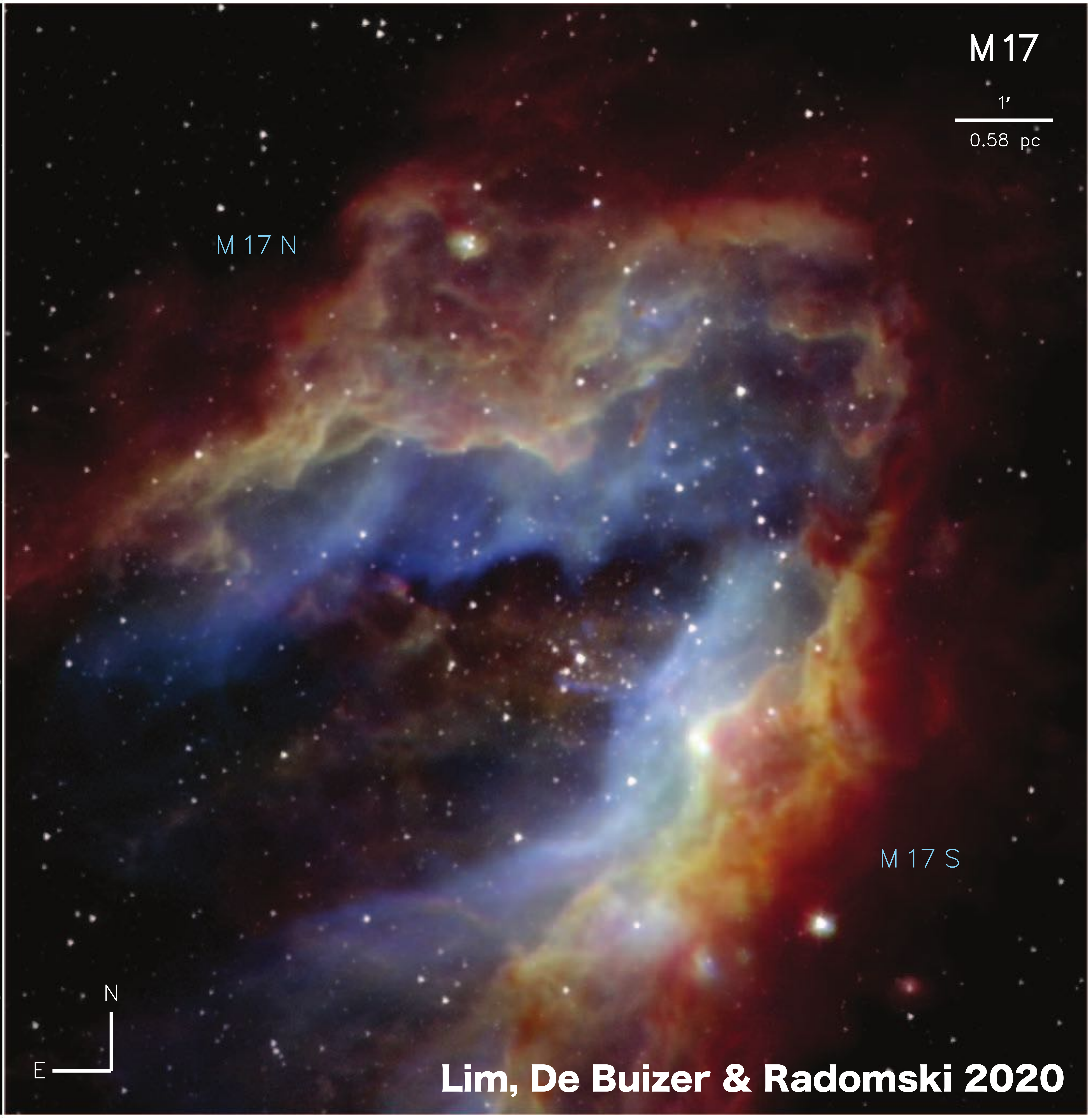
- W51A : one of the most massive Galactic GHII regions (Lim & De Buizer 2019)
- M17 : one of the closest GHII regions in from Sun (Lim, De Buizer & Radomski 2020)

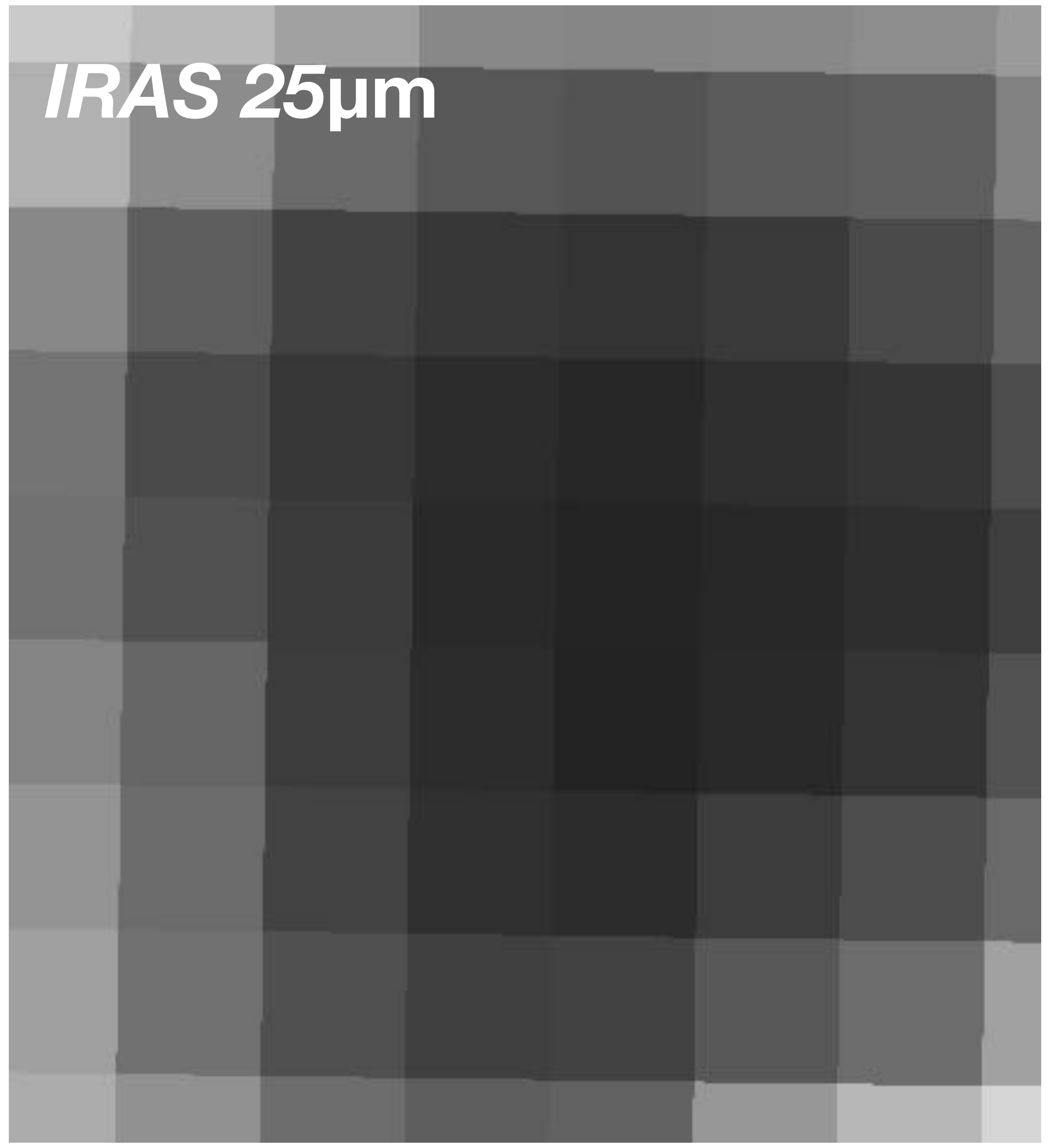


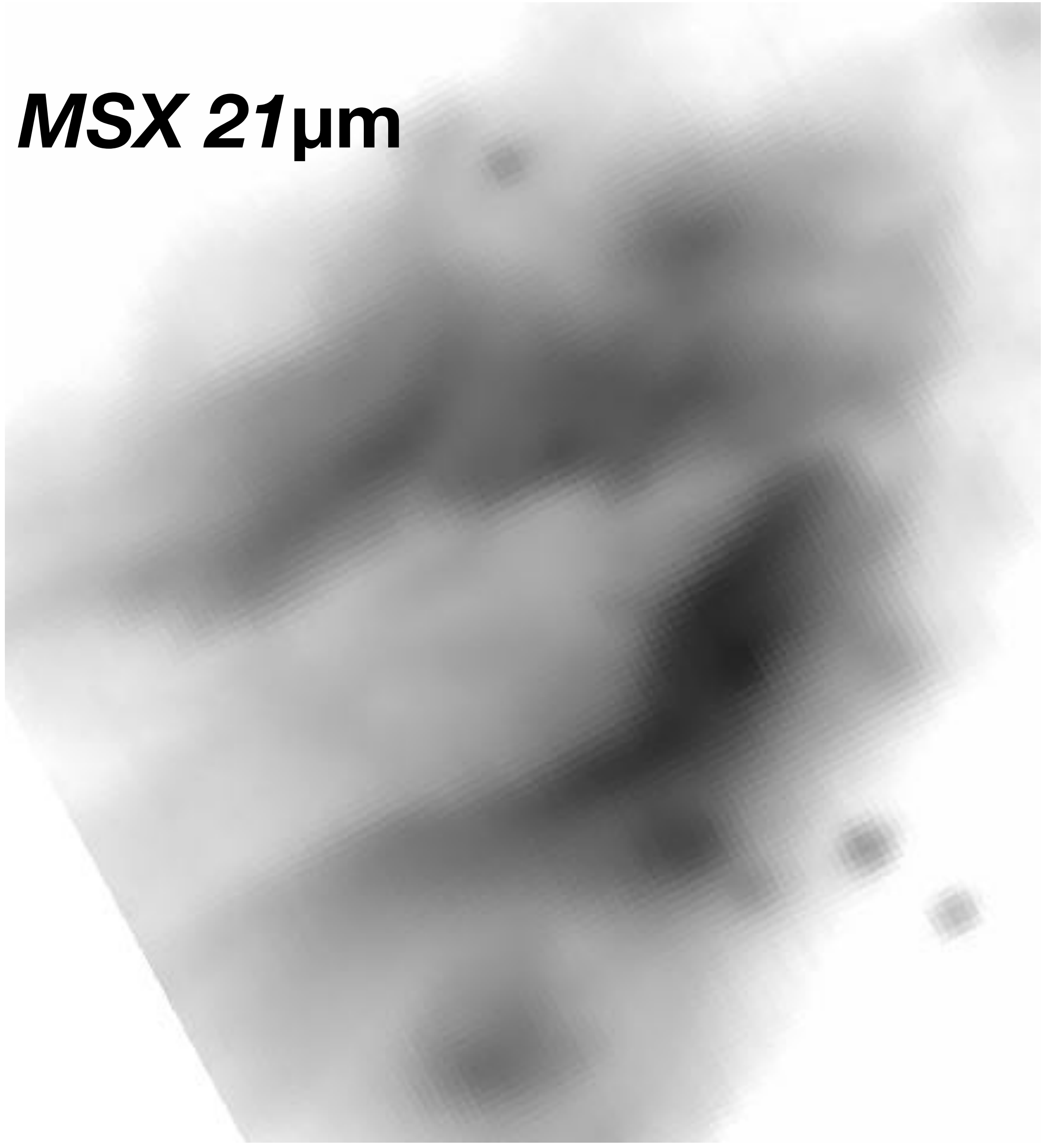


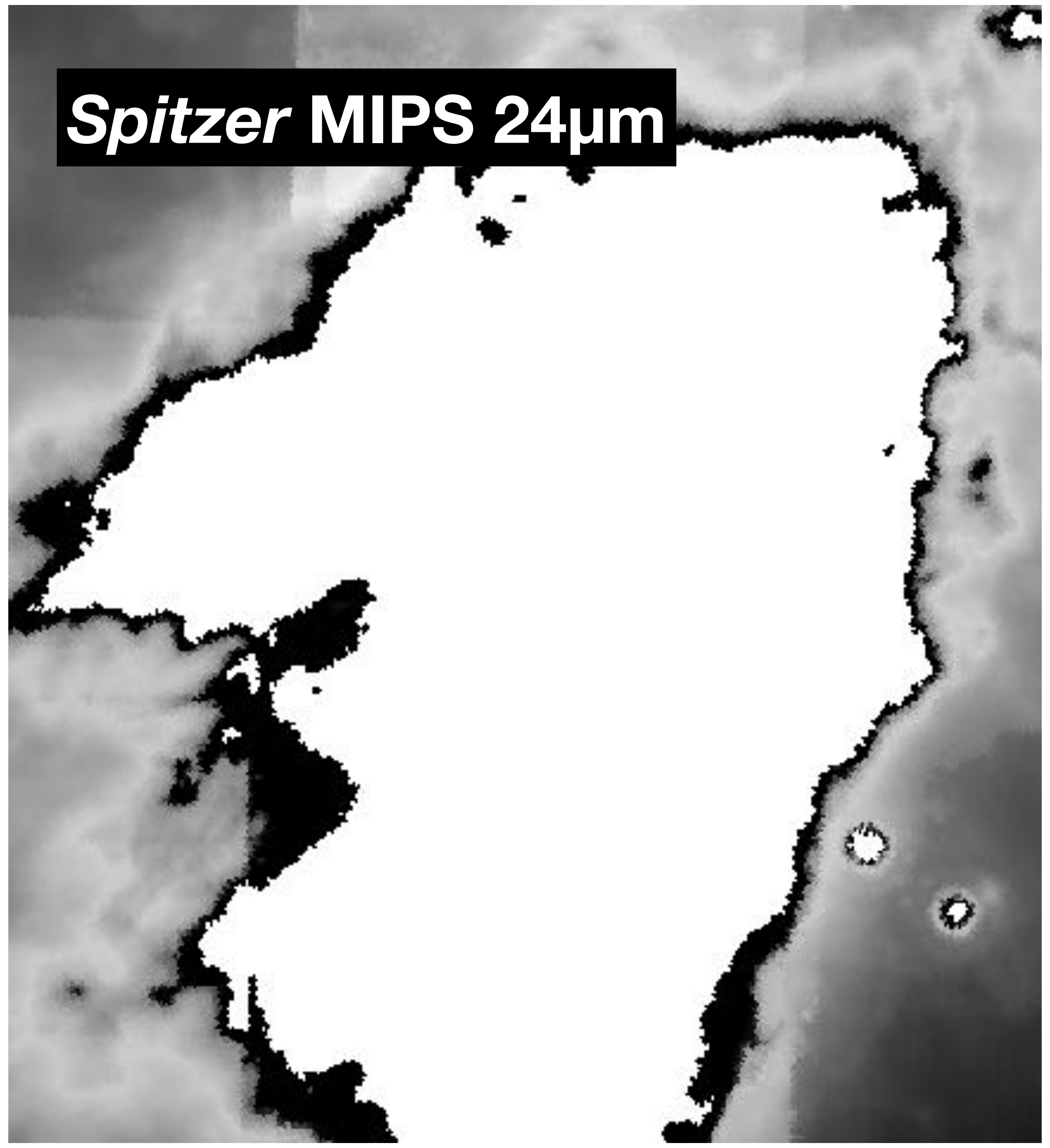
D~5.4kpc

D~2kpc

Blue - 20μm, Green - 37μm, Red - 70μm, White - 3.6μm





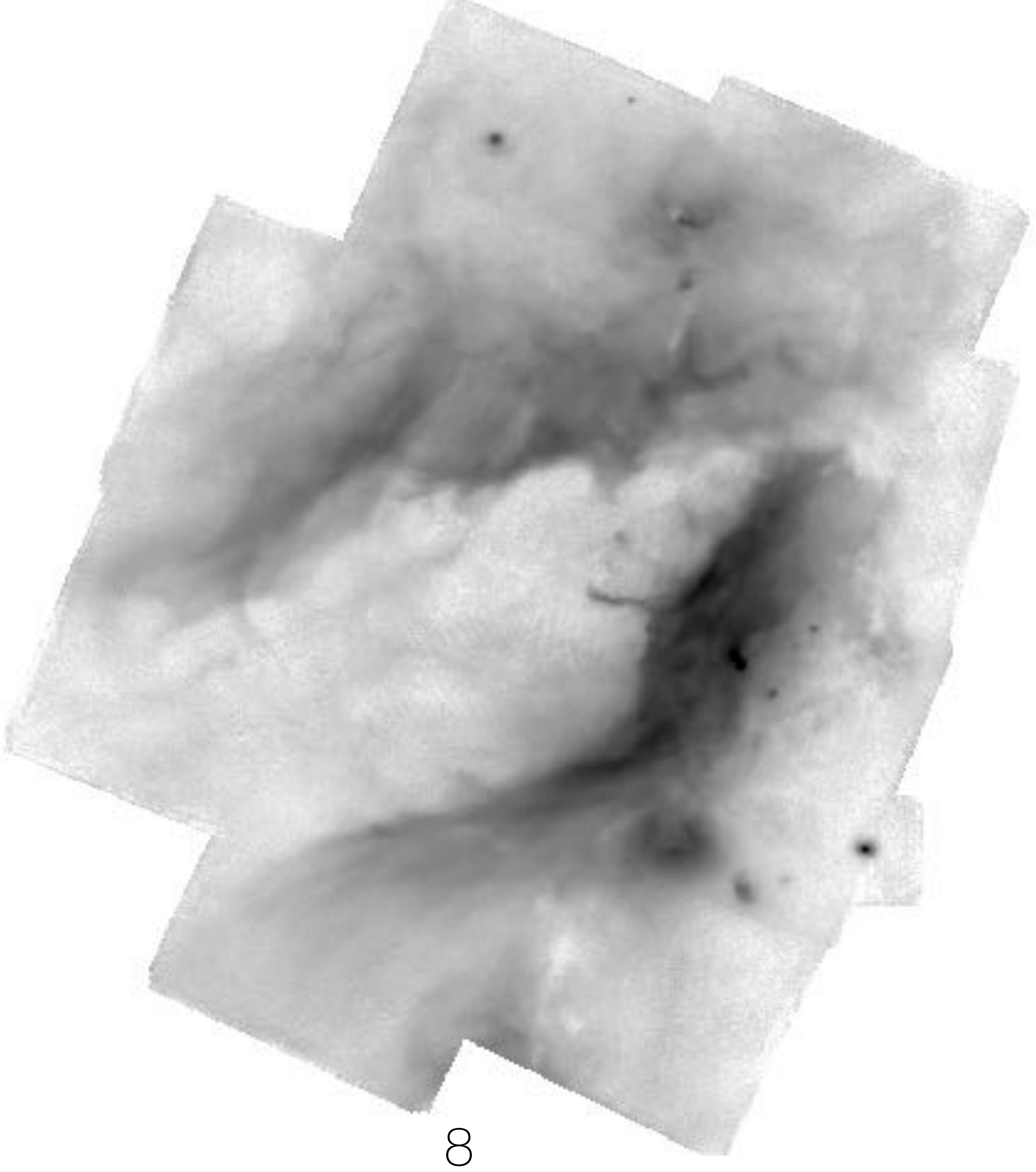


Why we need SOFIA?

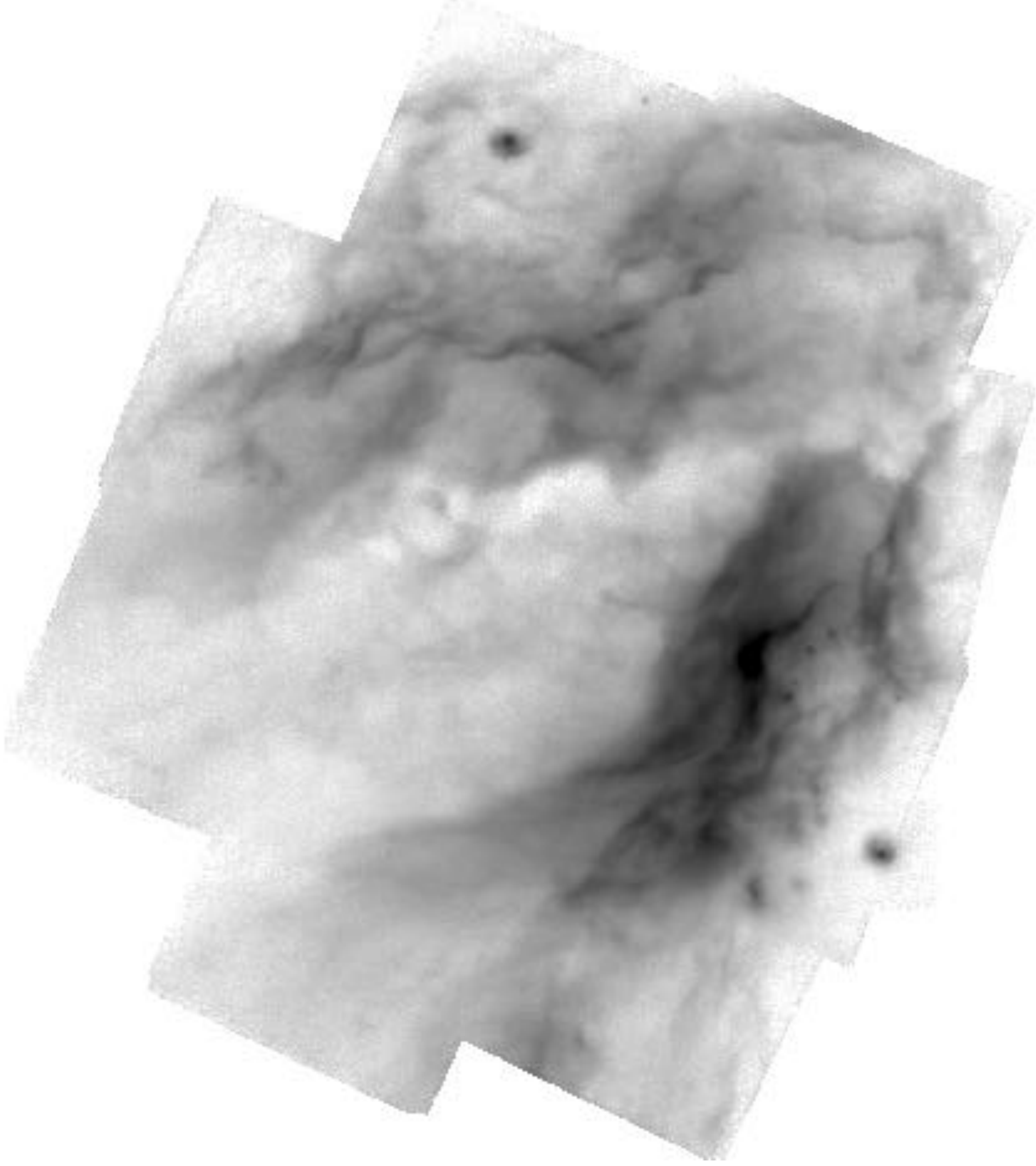
Angular resolutions of
Space/Airborne Telescopes

IRAS ~ 1x4 arcmin
MSX ~ 18 arcsec
Spitzer-MIPS ~ 6 arcsec
SOFIA-FORCAST ~ 3 arcsec

SOFIA FORCAST 20μm



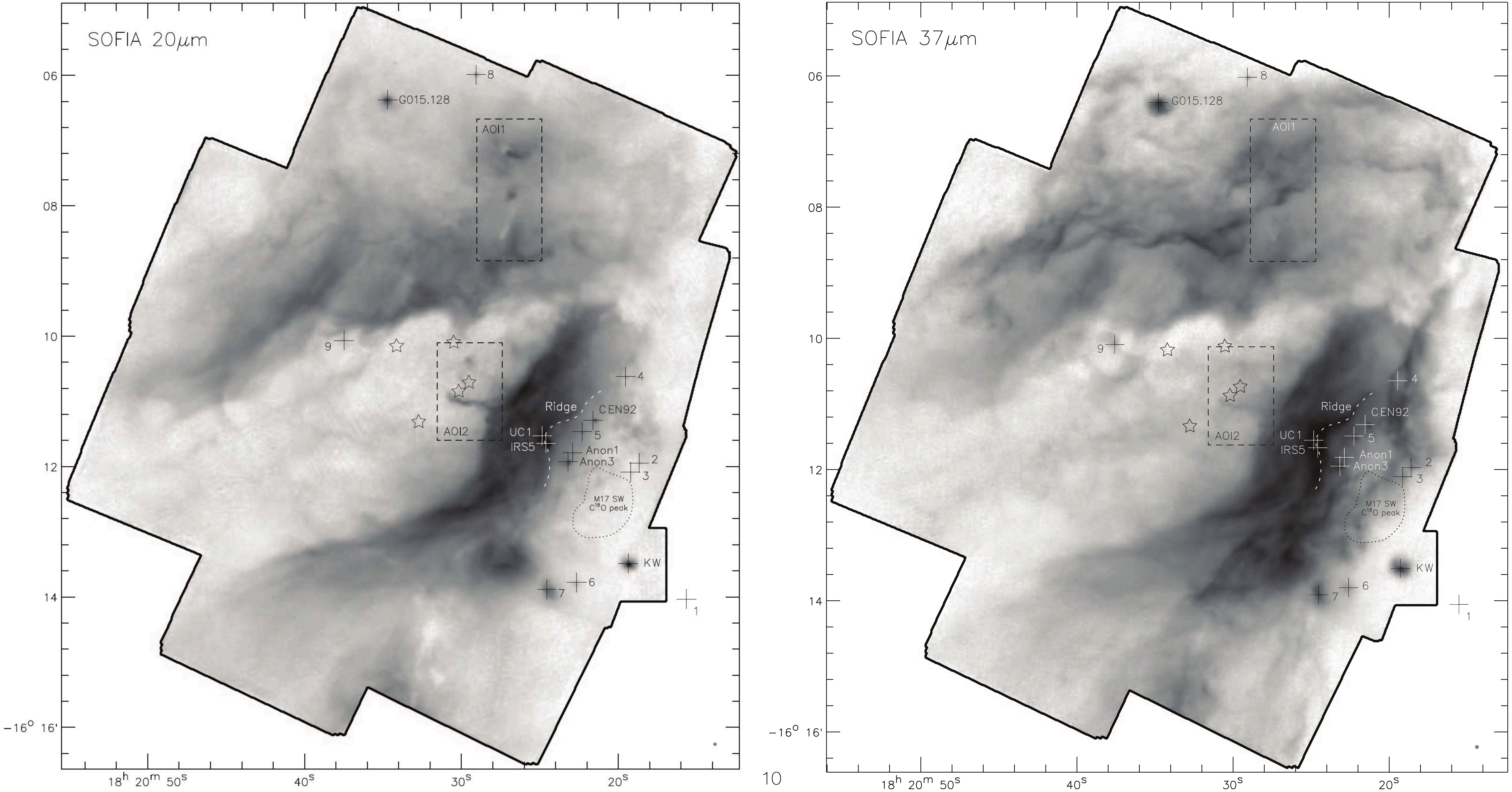
SOFIA FORCAST 37μm



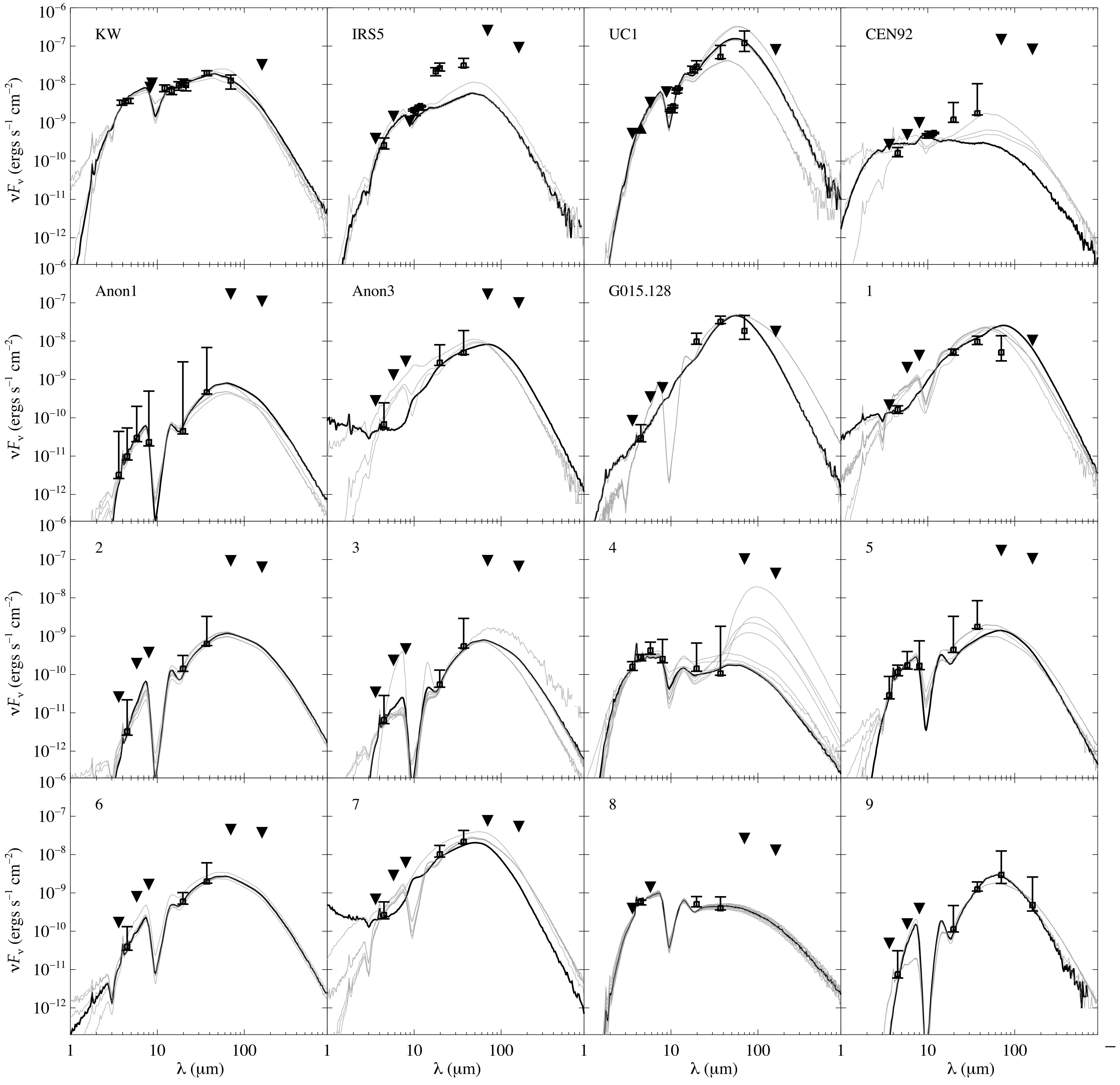
Result 1.
We have found an embedded population of MYSOs.

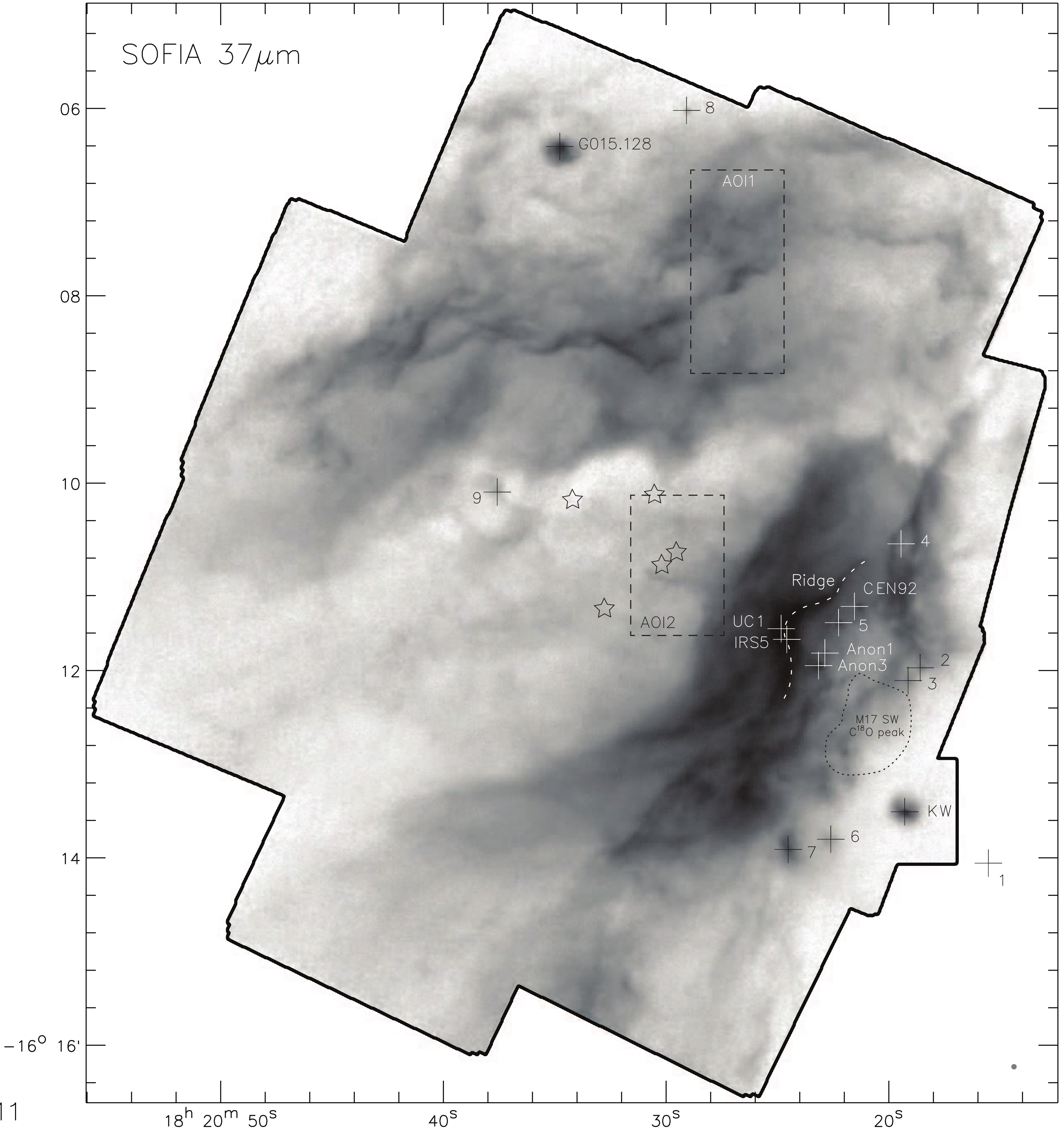
MYSO Candidates

Lim ea 2020



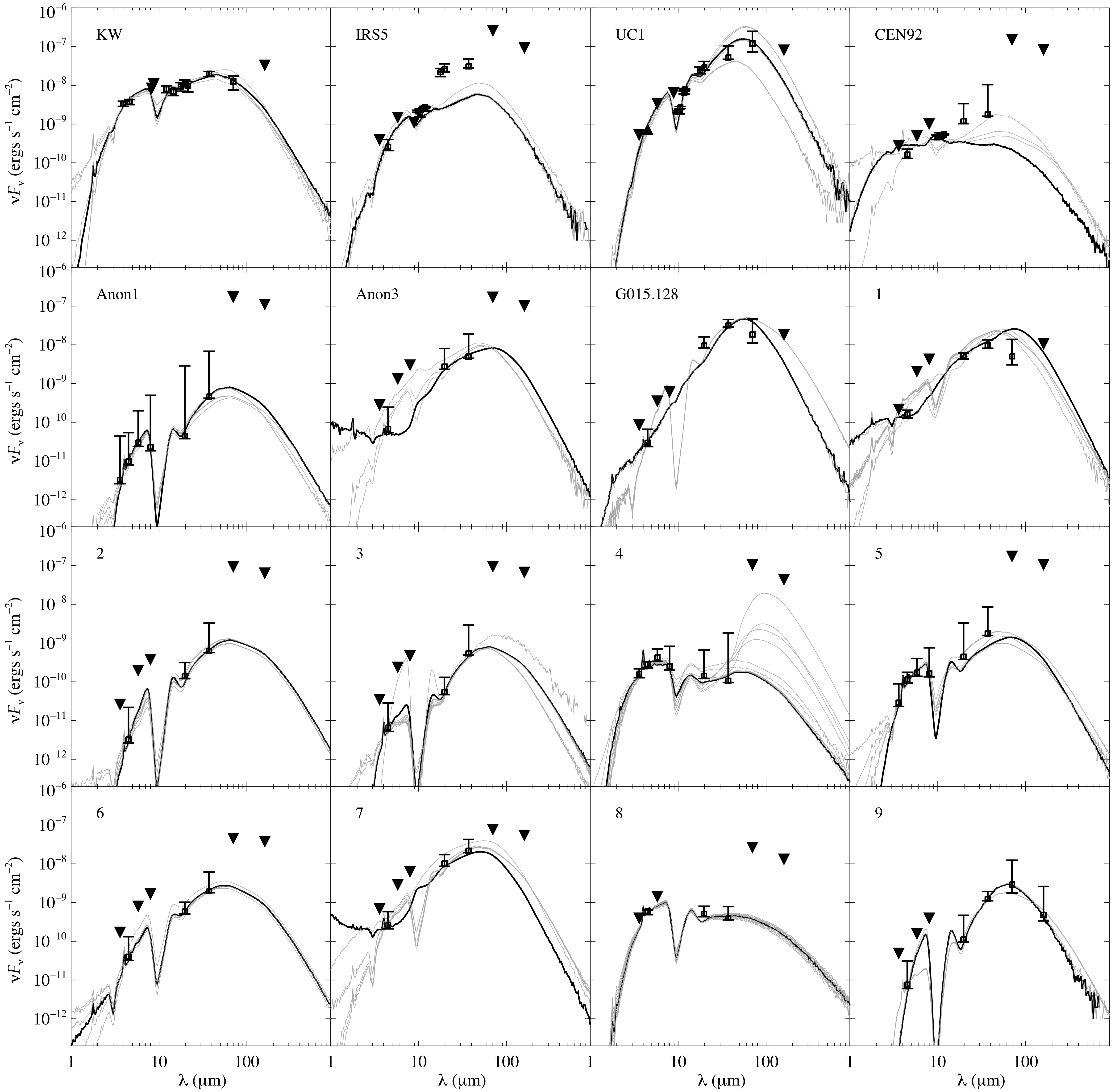
MYSO Candidates

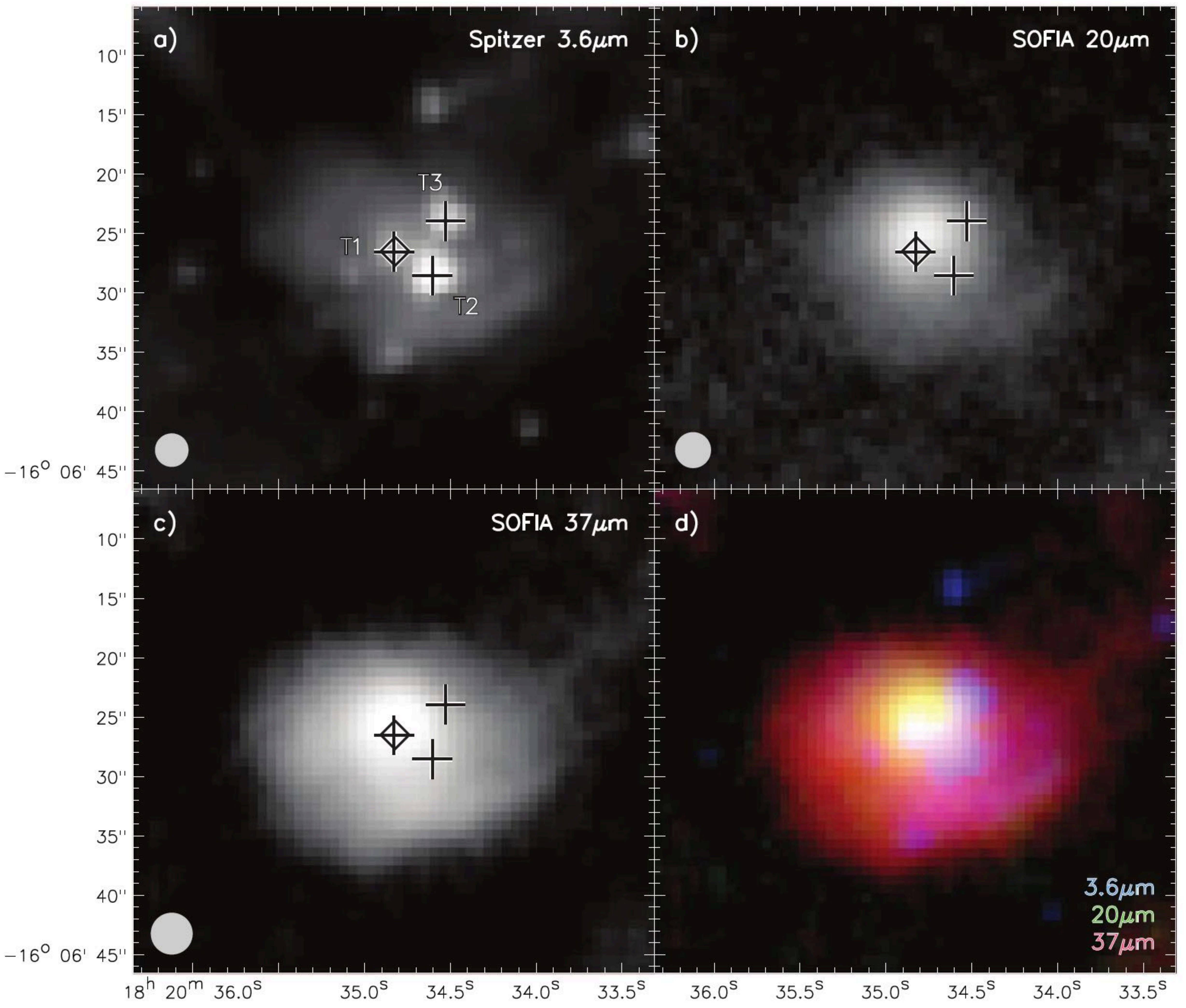




Lim ea 2020

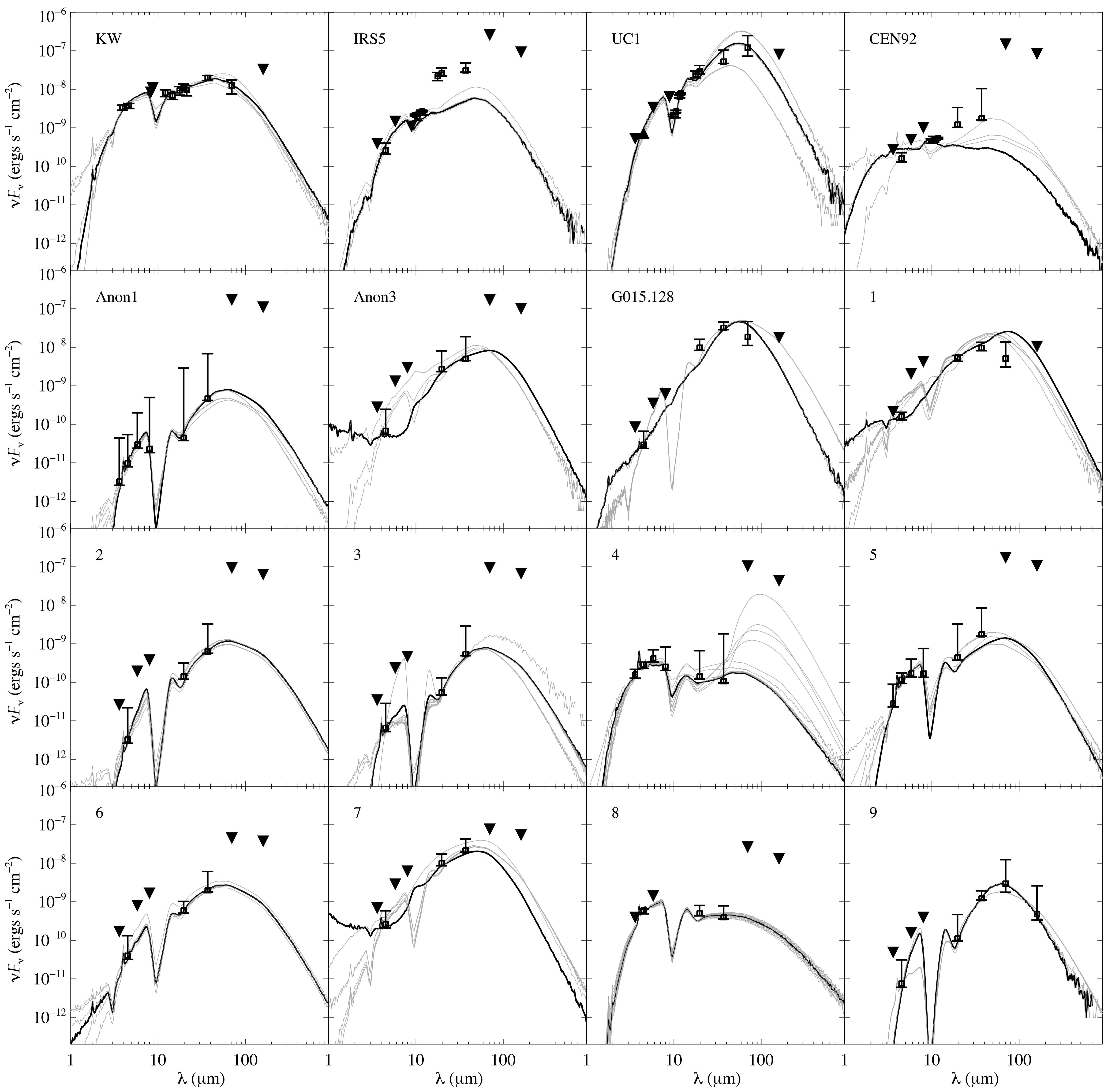
MYSO Candidates





Lim ea 2020

MYSO Candidates



Lim ea 2020

- 7 / 16 SOFIA sub-components and point sources are under MYSO criteria.
- 4 / 7 MYSO are first defined (suggested) in this study.
- Note that we found 41/47 MYSOs from W51A. The distance may matter.
- 20 & 37 µm data points are necessary to achieve the envelop SEDs.

Result 2.
The entire M17 cloud does not seem to be coeval.

Proto-cluster Evolution

Lim ea 2020

Virial analysis

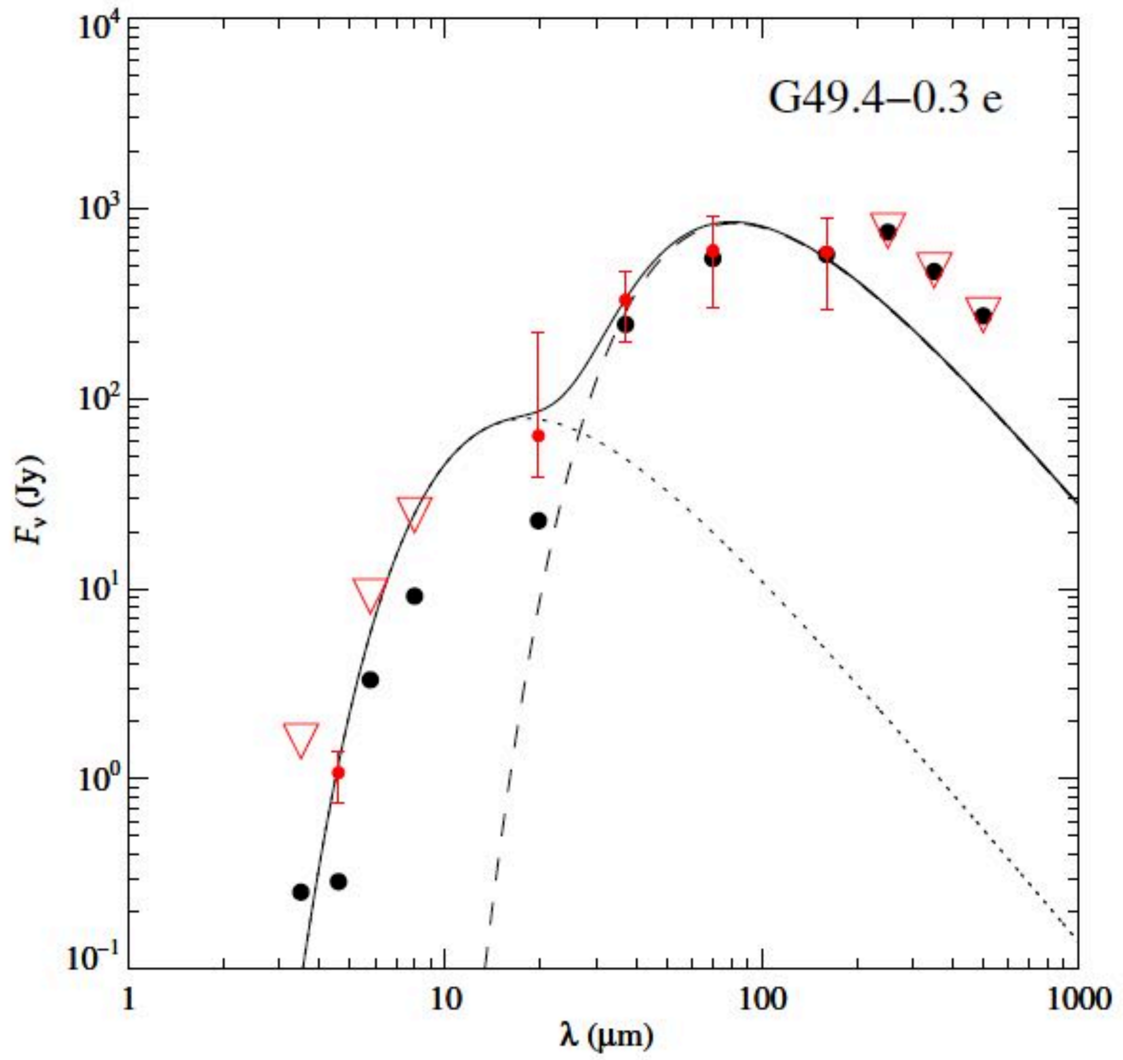
$$\alpha_{\rm vir} = \frac{2\mathcal{T}}{|\mathcal{W}|} \approx \frac{5\sigma^2 R}{GM}$$

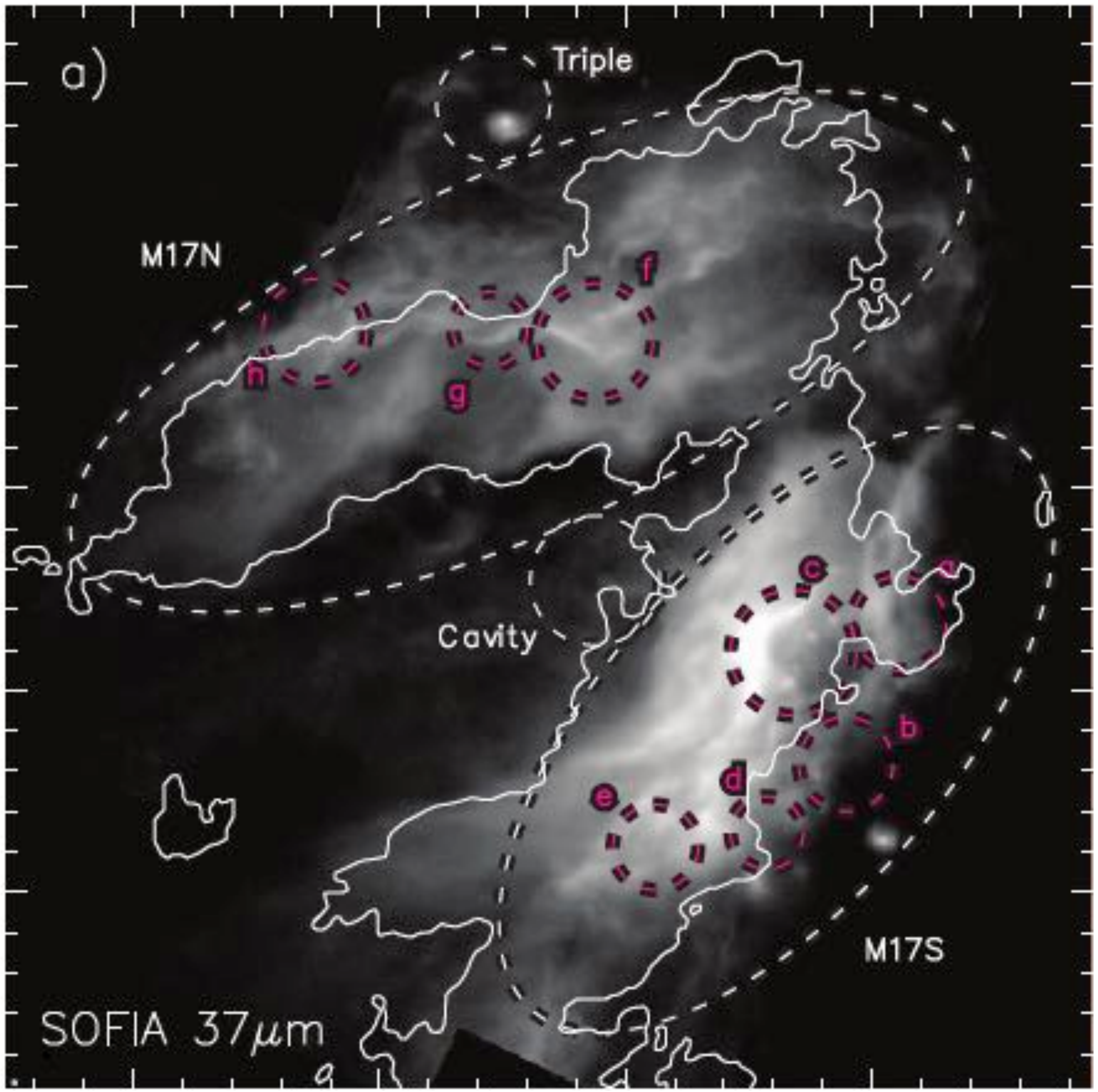
(Bertoldi & McKee 1992)

Higher α_{vir} may indicate the later clump evolutionary stages (i.e. more internal feedback makes higher kinetic energy).

L_{bol}/M_{dust}

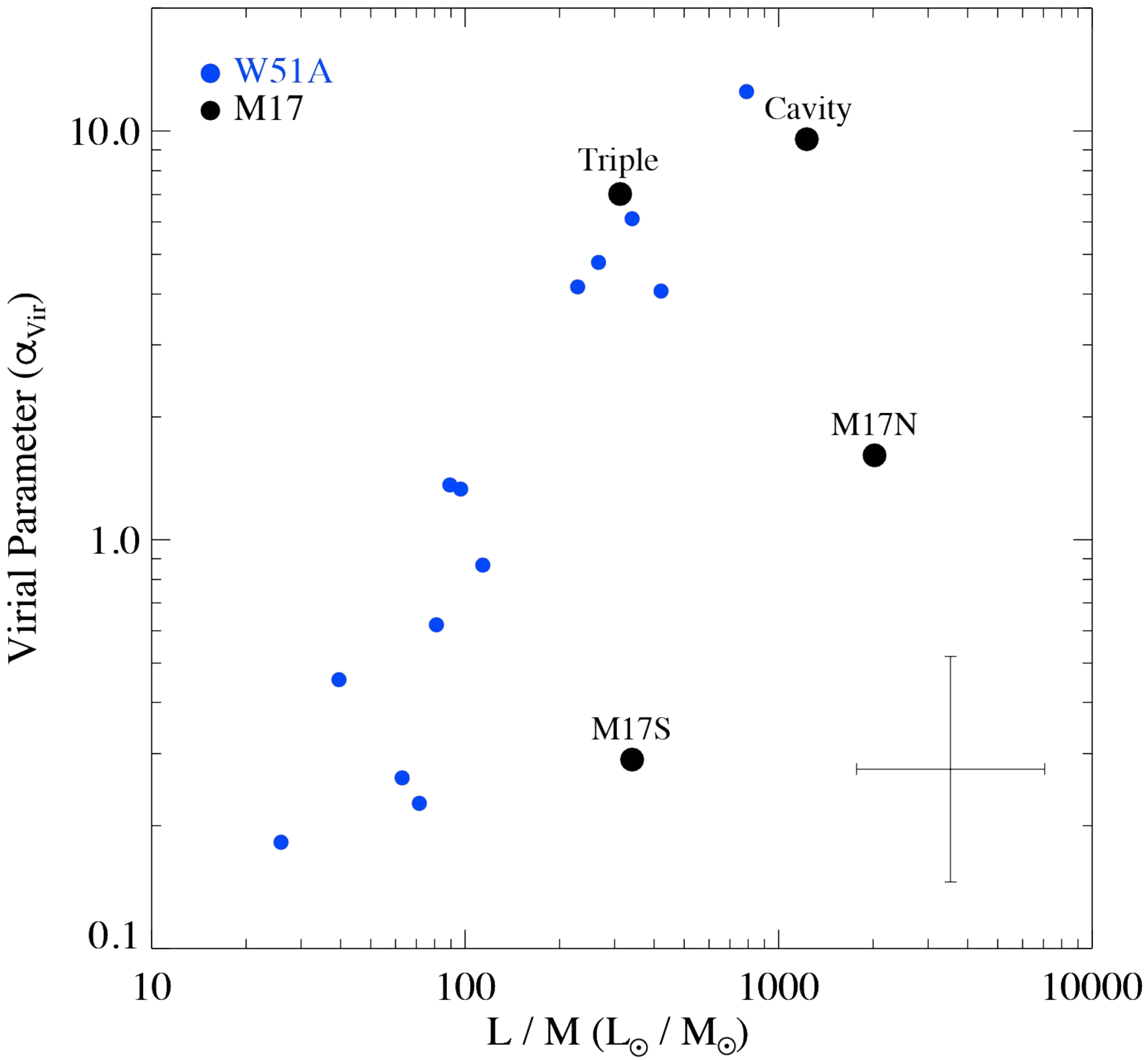
Higher L/M might indicate older clump due to more formed stars and less dust mass (used to make stars).

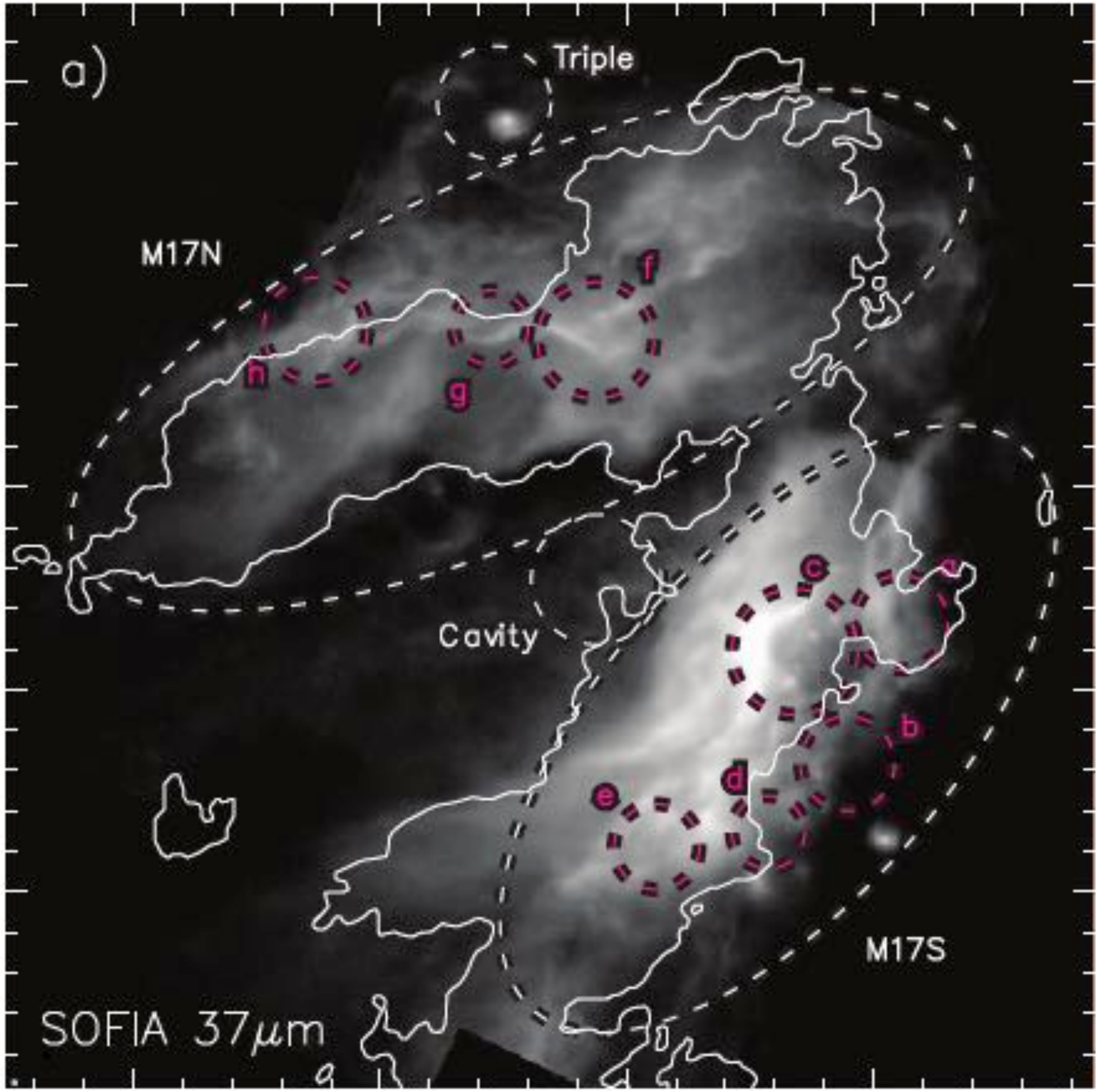




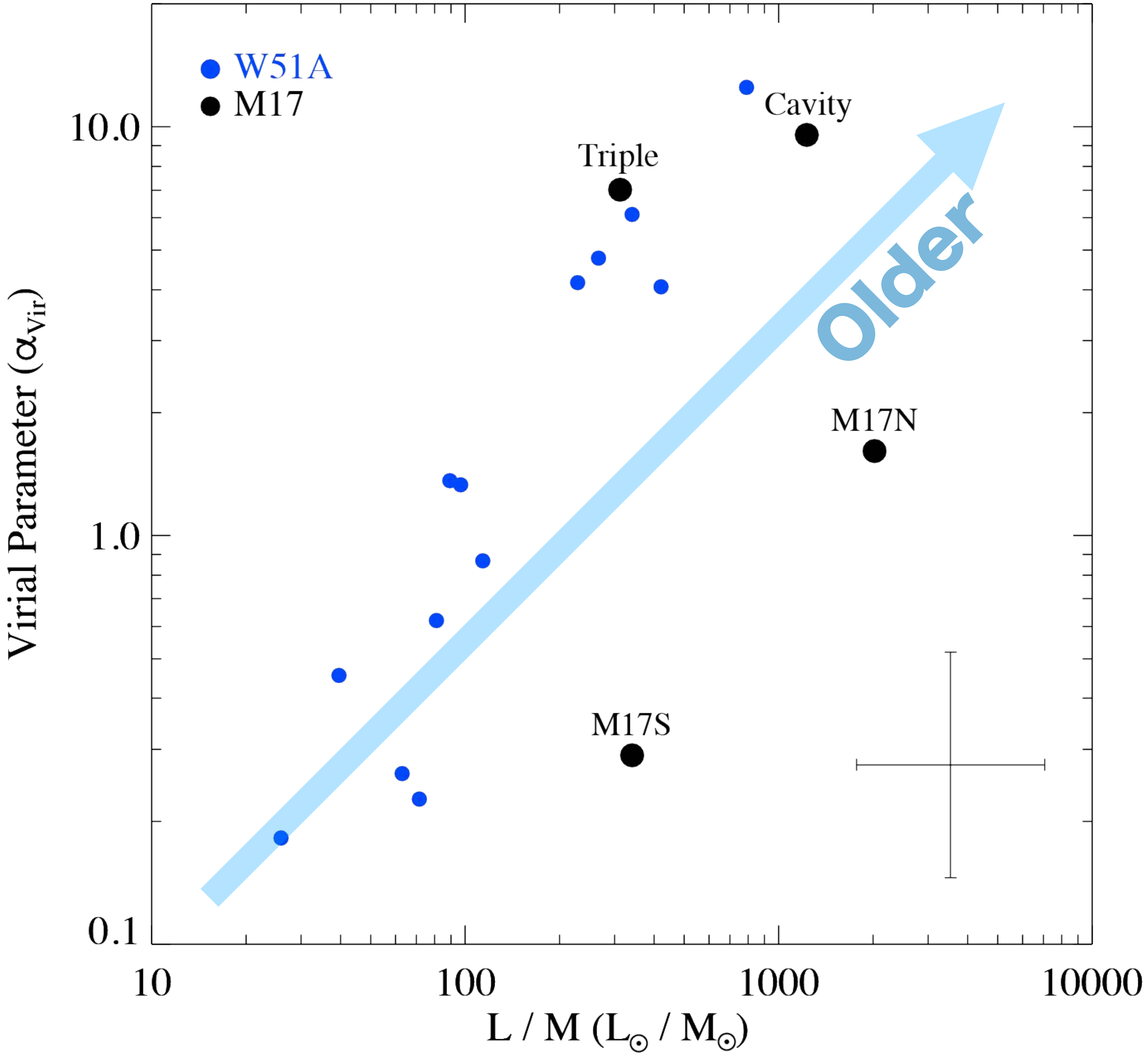
Lim ea 2020

Proto-cluster Evolution
α_{vir} vs. L/M





Proto-cluster Evolution
α_{vir} vs. L/M



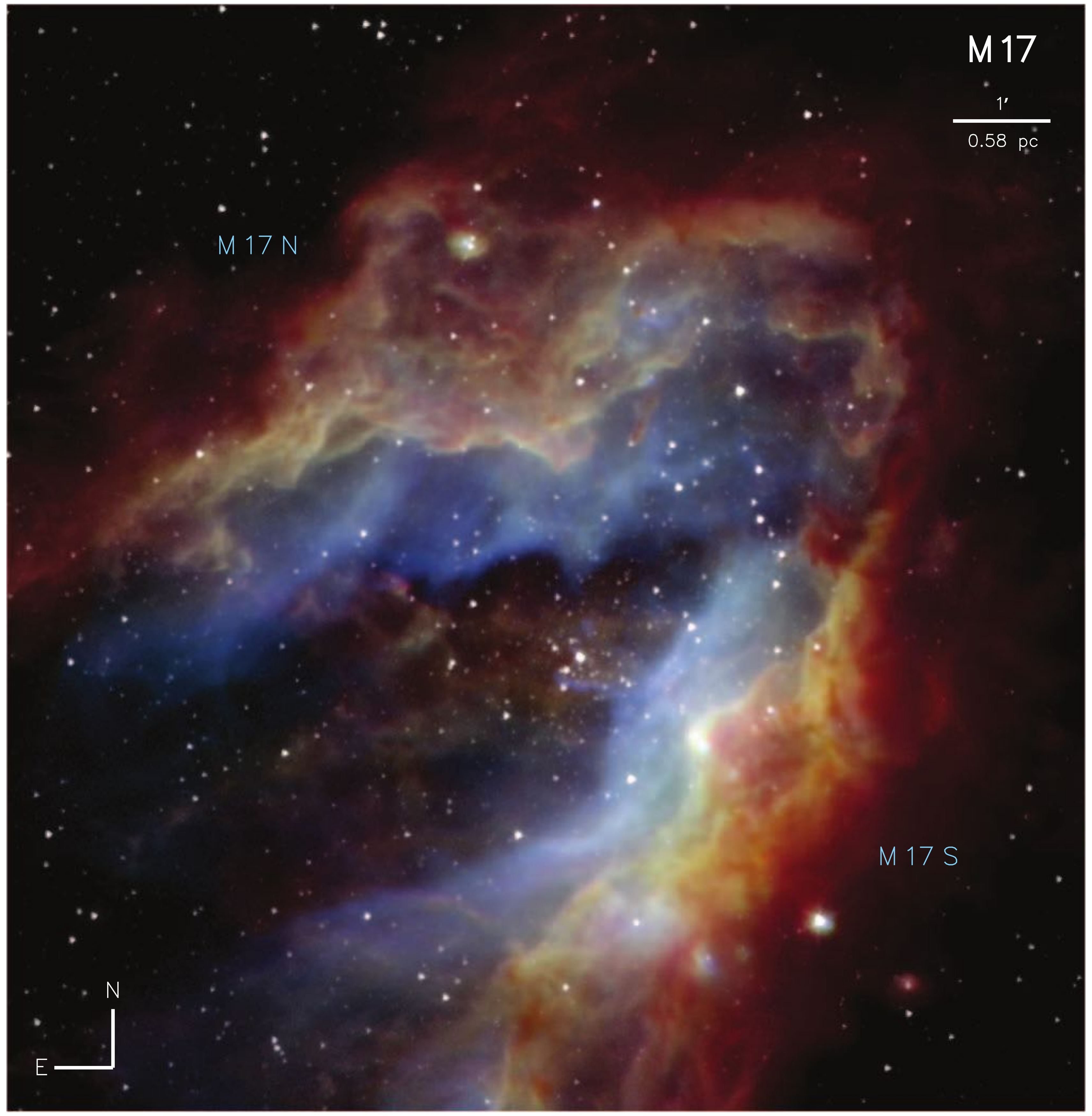
- As of W51A case, M17 also shows various evolutionary stages of porto-cluster thus structures in M17 are not coeval.
- The Cavity region is a massive stellar clusters (including NGC6618) and shows highest α_{vir} and L/M values.
- M17N seems to be older than M17S.
- Both M17N and M17S seem to be far from the main trend. We assume this is due to the PDR contamination.

Lim ea 2020

Result 3.
We found possible 20μm contamination by [SIII] line.

20μm images contaminated by [SIII]

Lim ea 2020



Why so

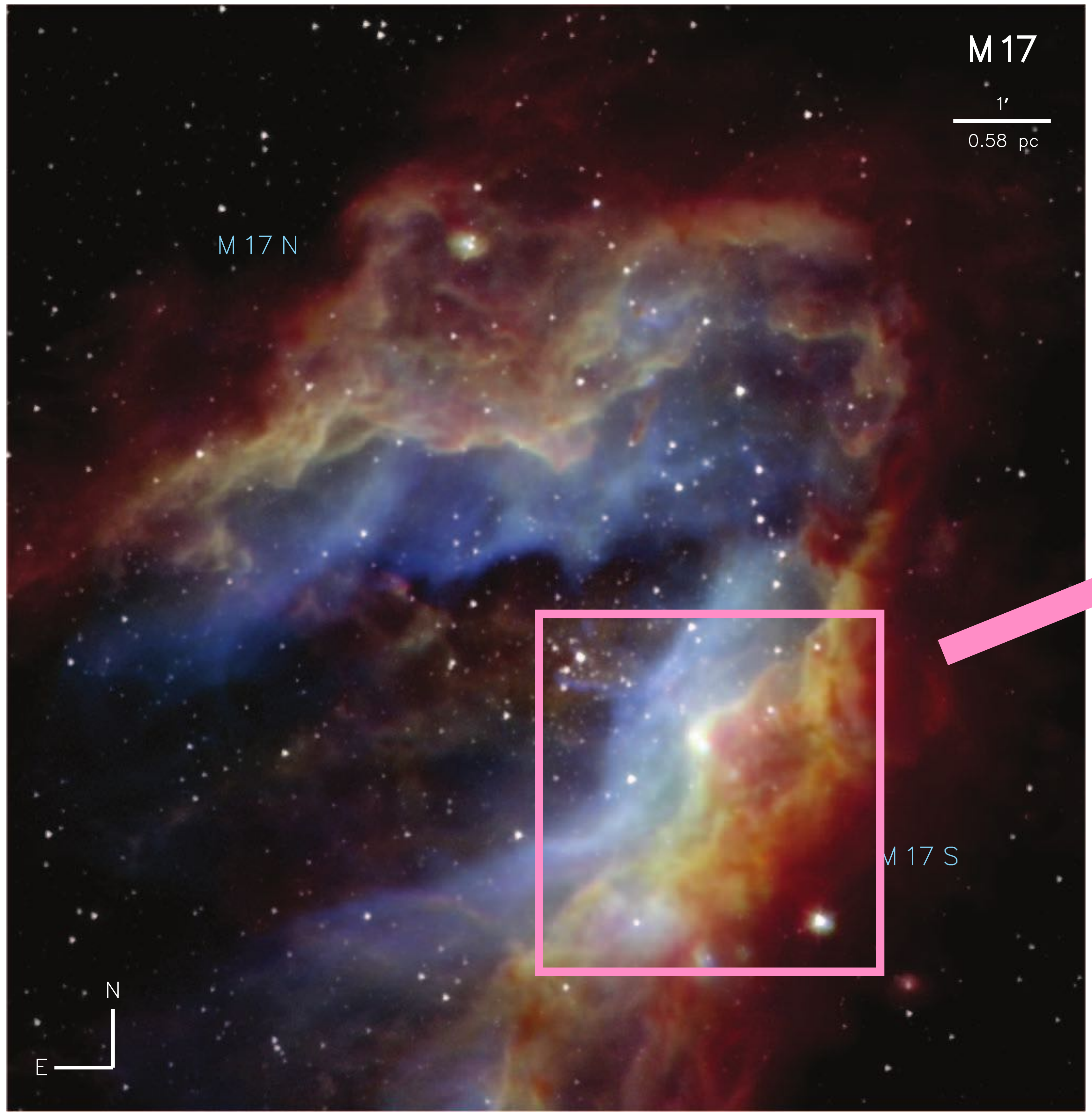
~~serious?~~

different?

Blue - 20μm, Green - 37μm, Red - 70μm, White - 3.6μm

20μm images contaminated by [SIII]

Lim ea 2020



We have been fortunate enough to find ISO observation toward this region.

Blue - 20μm, Green - 37μm, Red - 70μm, White - 3.6μm

20μm images contaminated by [SIII]

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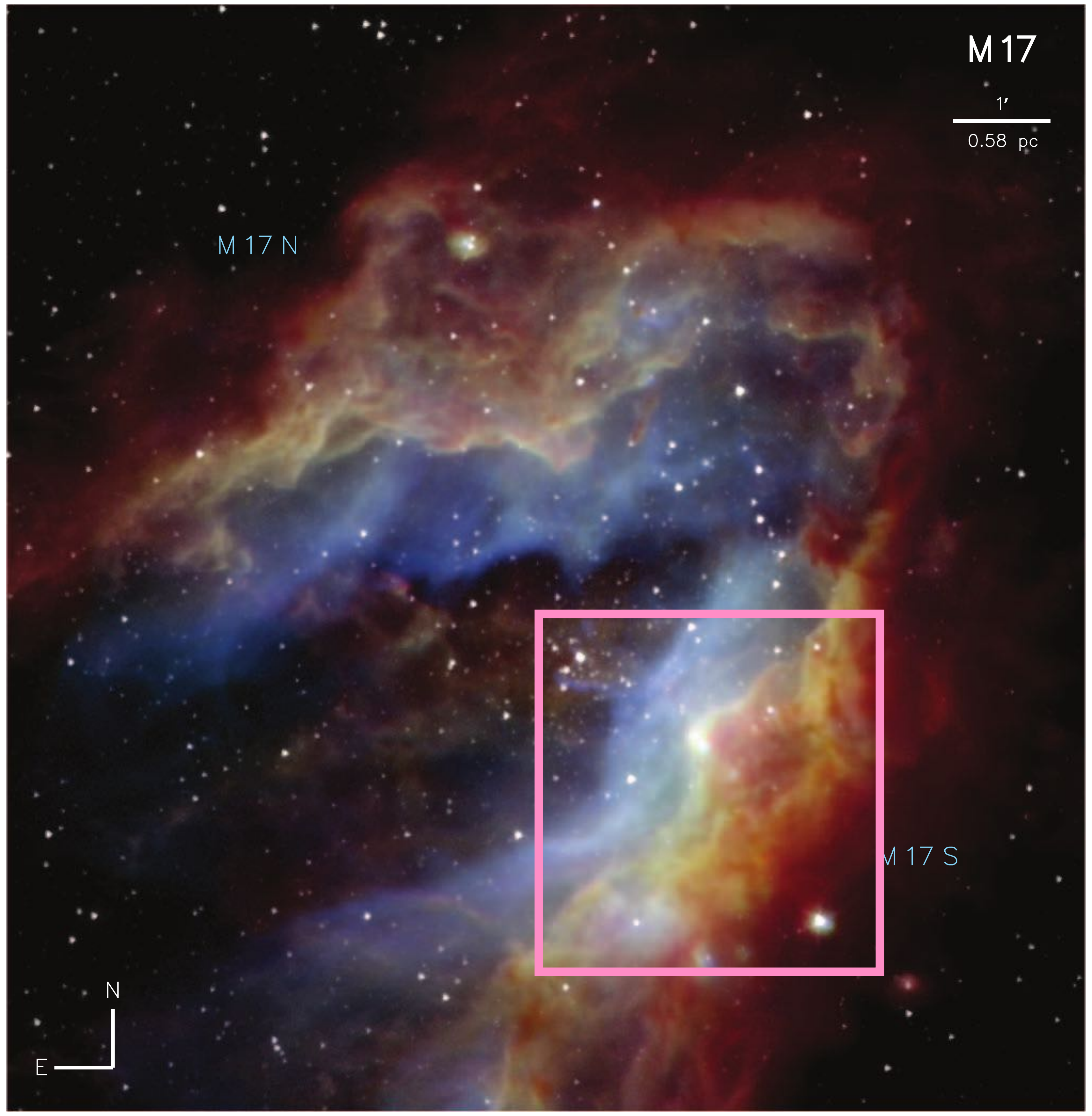
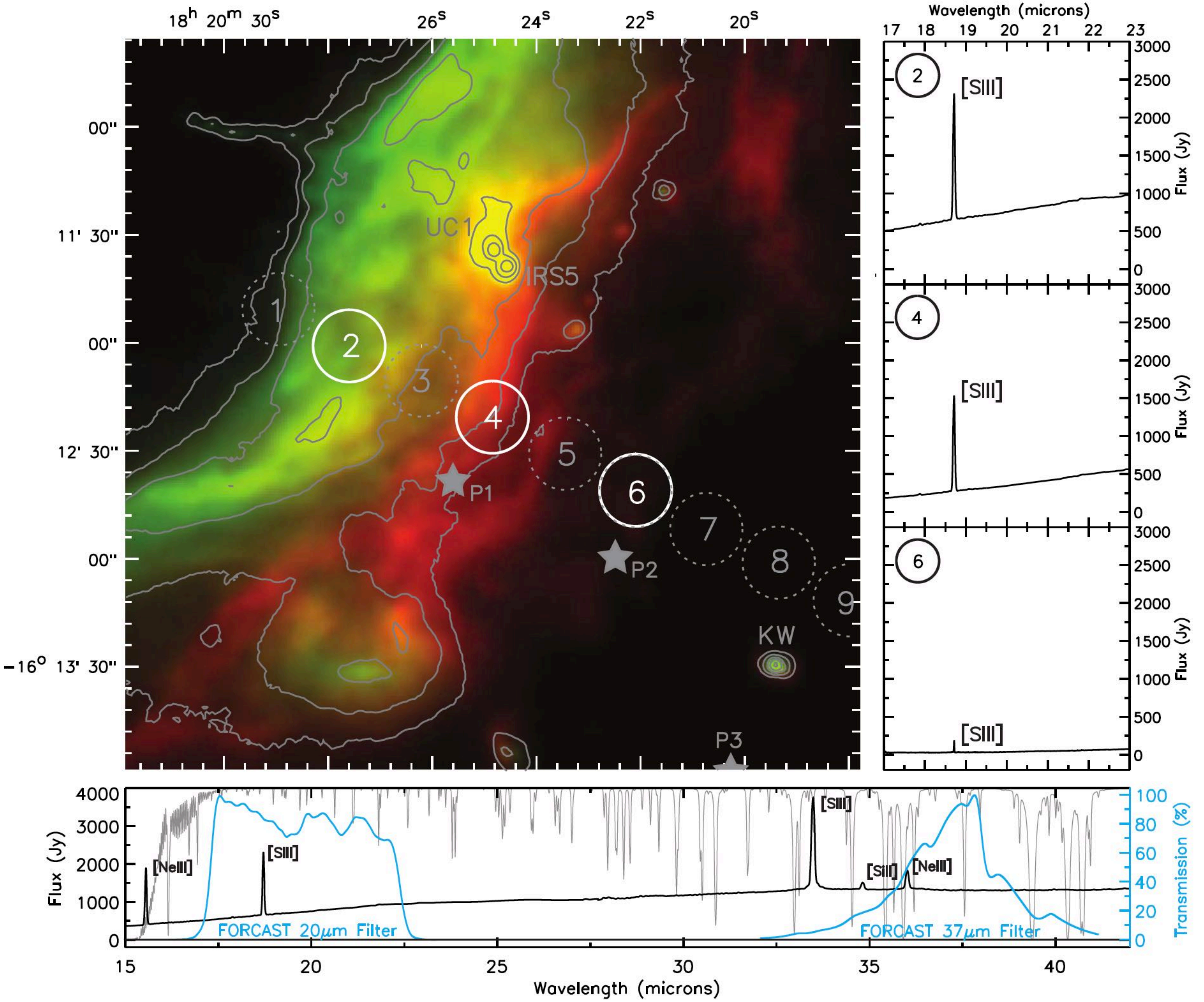
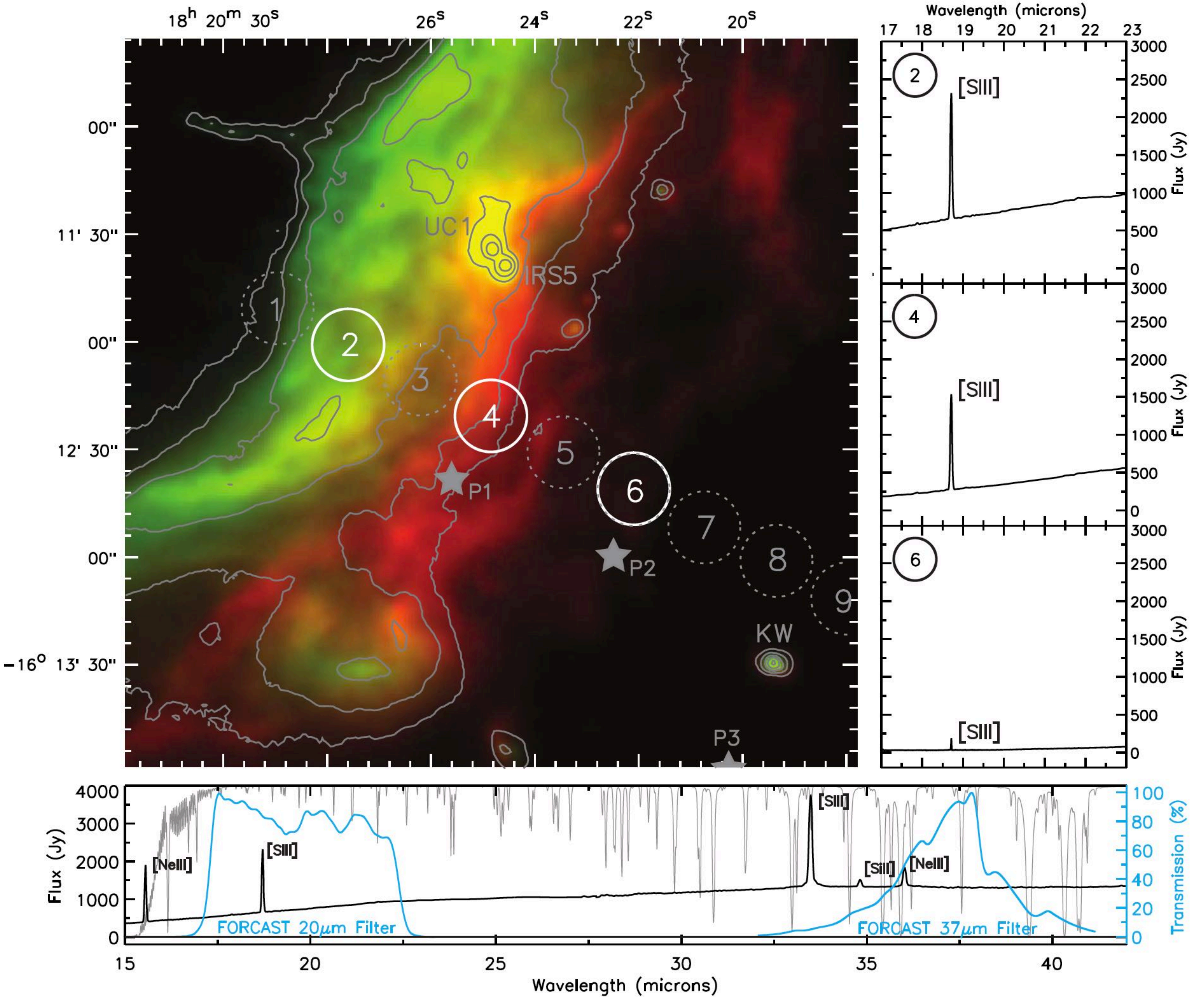




Green - 20µm, Red - 37µm

20μm images contaminated by [SIII]

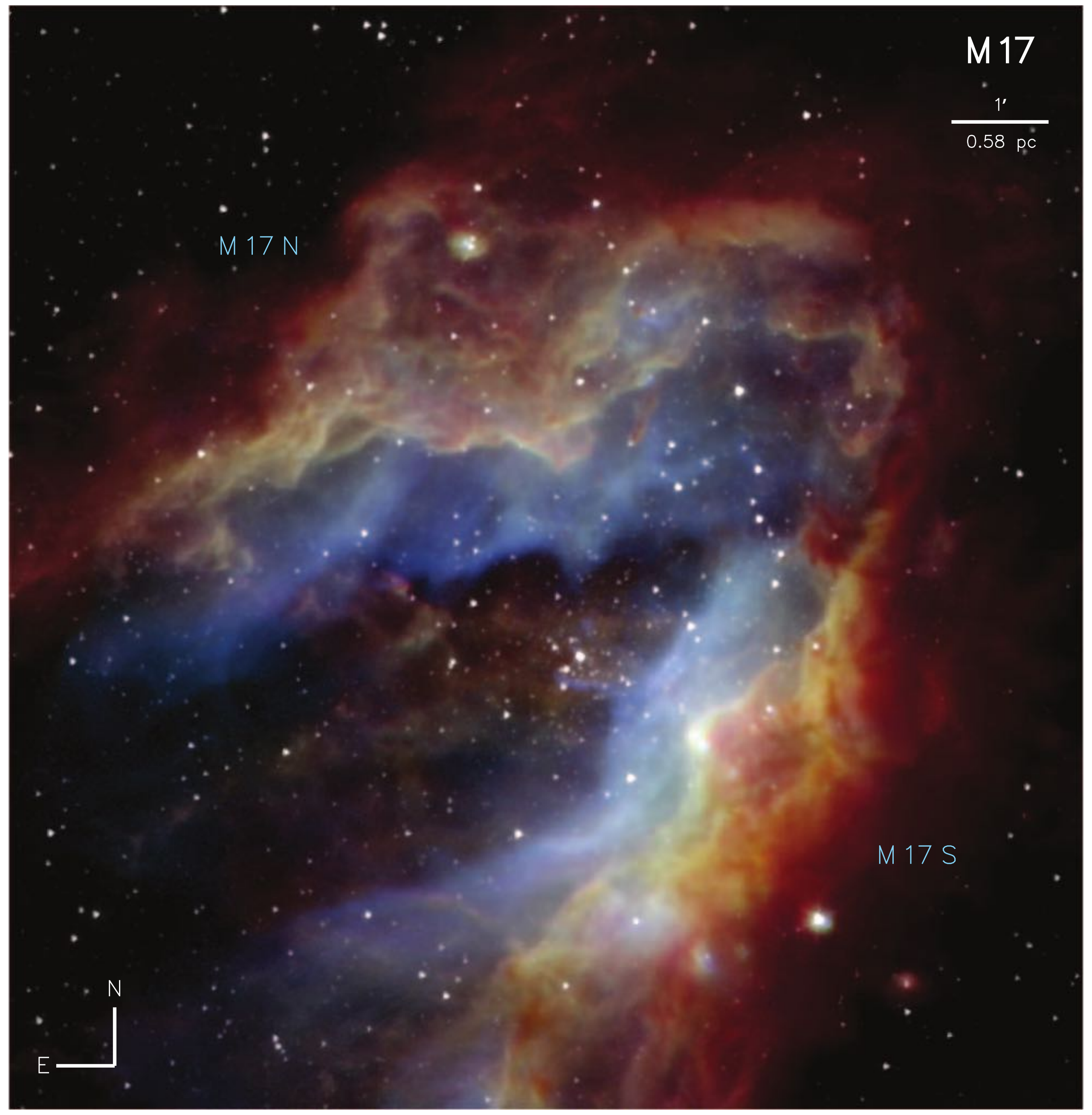
- 20µm images are quite unique comparing to other wavelength regimes.
- The ISO archival data show the significant enhancement of the [SIII] line at PDR regions.
- 20µm imaging would be a good tracer for ionized regions of Galaxy.

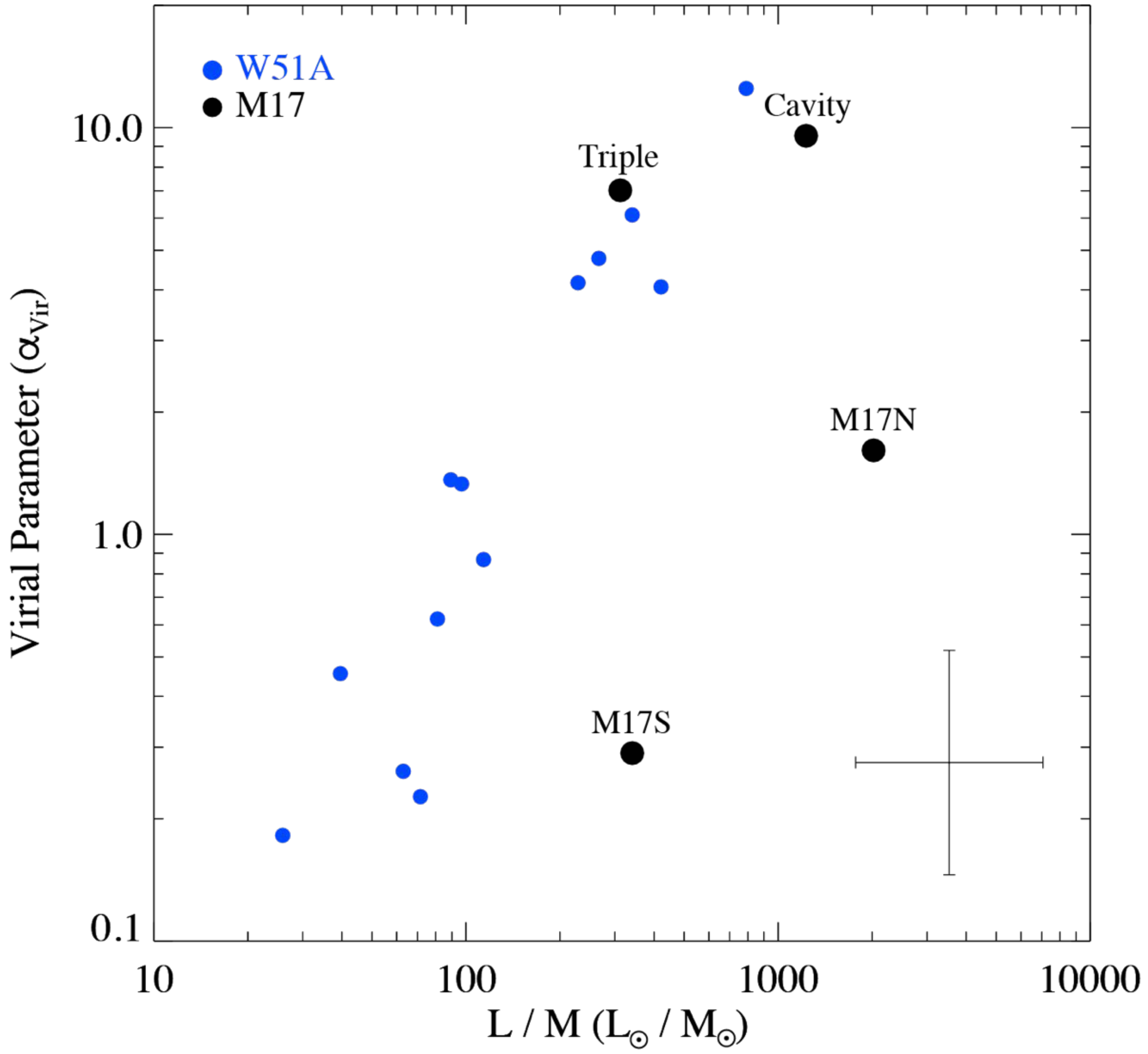


Green - 20µm, Red - 37µm

Summary

- FORCAST 20 & 37μm imaging survey toward Galactic GHII regions is on-going and you now see the second results!
- The SOFIA data revealed a previously hidden population of MYSOs and gave us better understanding the physical nature of several already known sources.
- We find many MYSO candidates identified by other studies are not actually MYSOs.
- Independent evolutionary analyses show the structures in M17 are not coeval.
- FORCAST 20μm imaging is possibly a good tracer for ionized regions ([SIII] line).





Appetizing another study

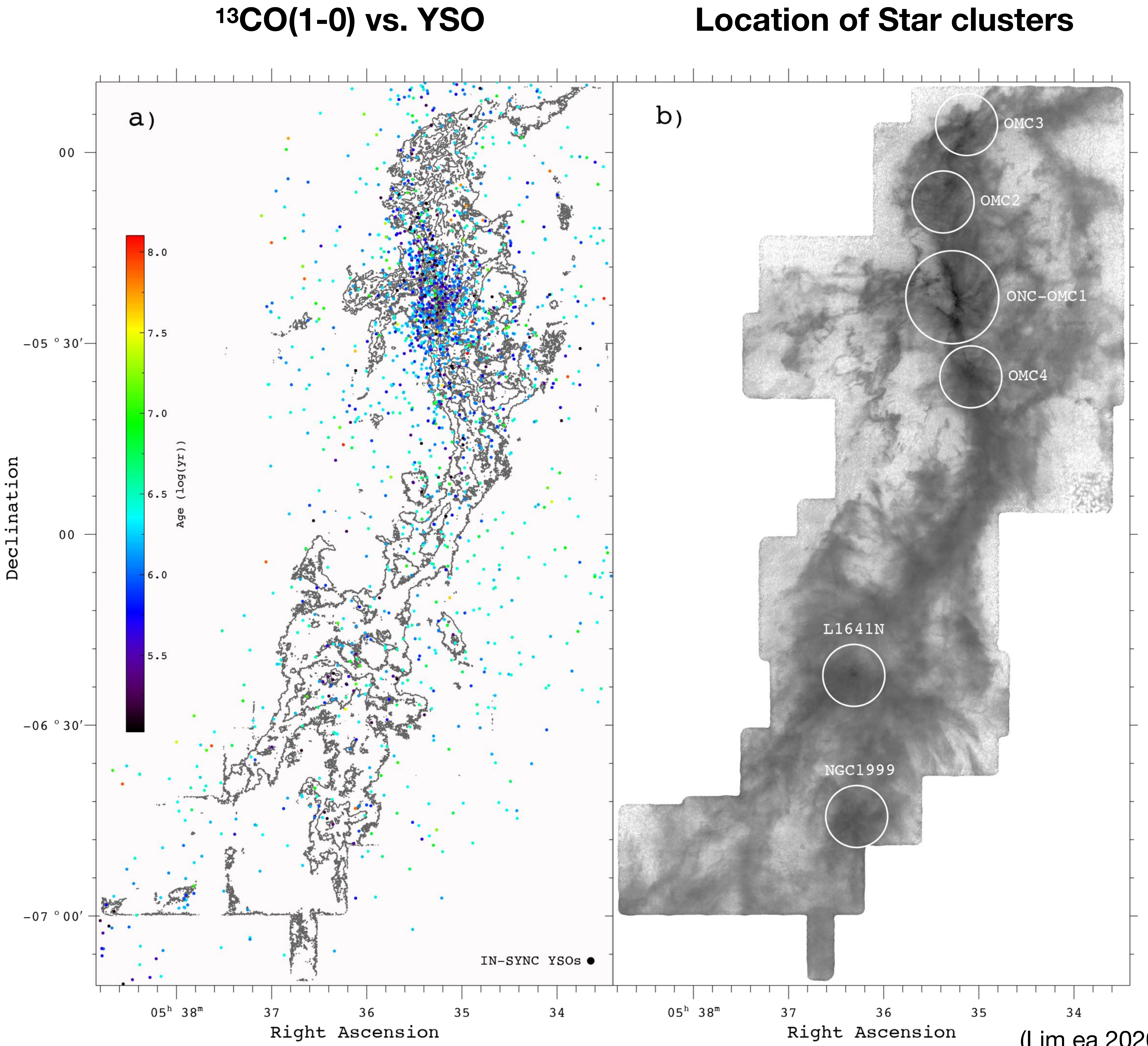
Star Cluster Formation in Orion A

(Investigating how cloud-cloud collision important as a massive star cluster forming mechanism.)

CARMA-NRO Orion survey

(Kong ea 2018)

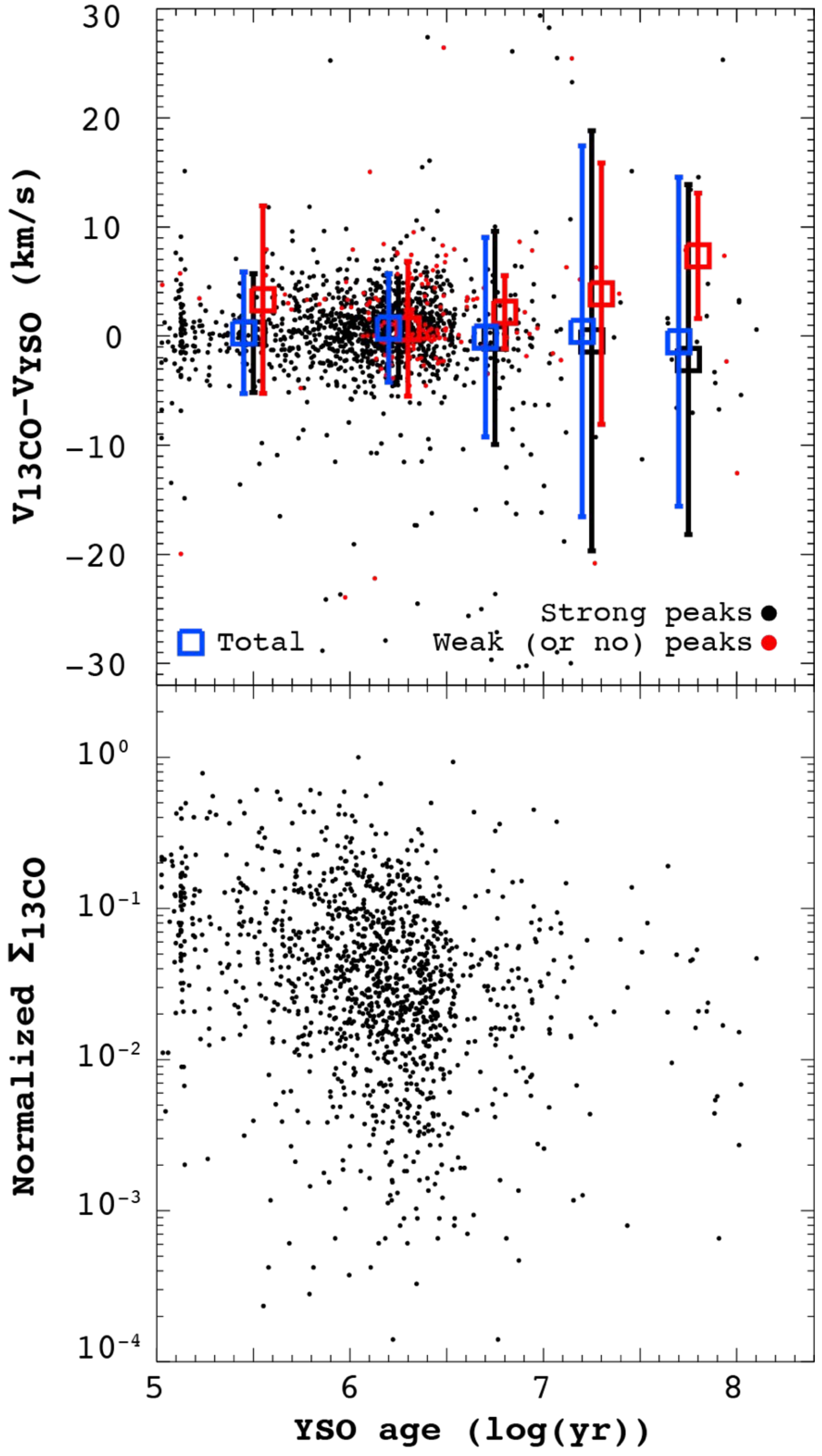
- angular resolution ~5”.
- The closest separation among YSOs in IN-SYNC project is ~6”
- We now can compare the velocity difference and gas column density to the properties of individual YSOs!

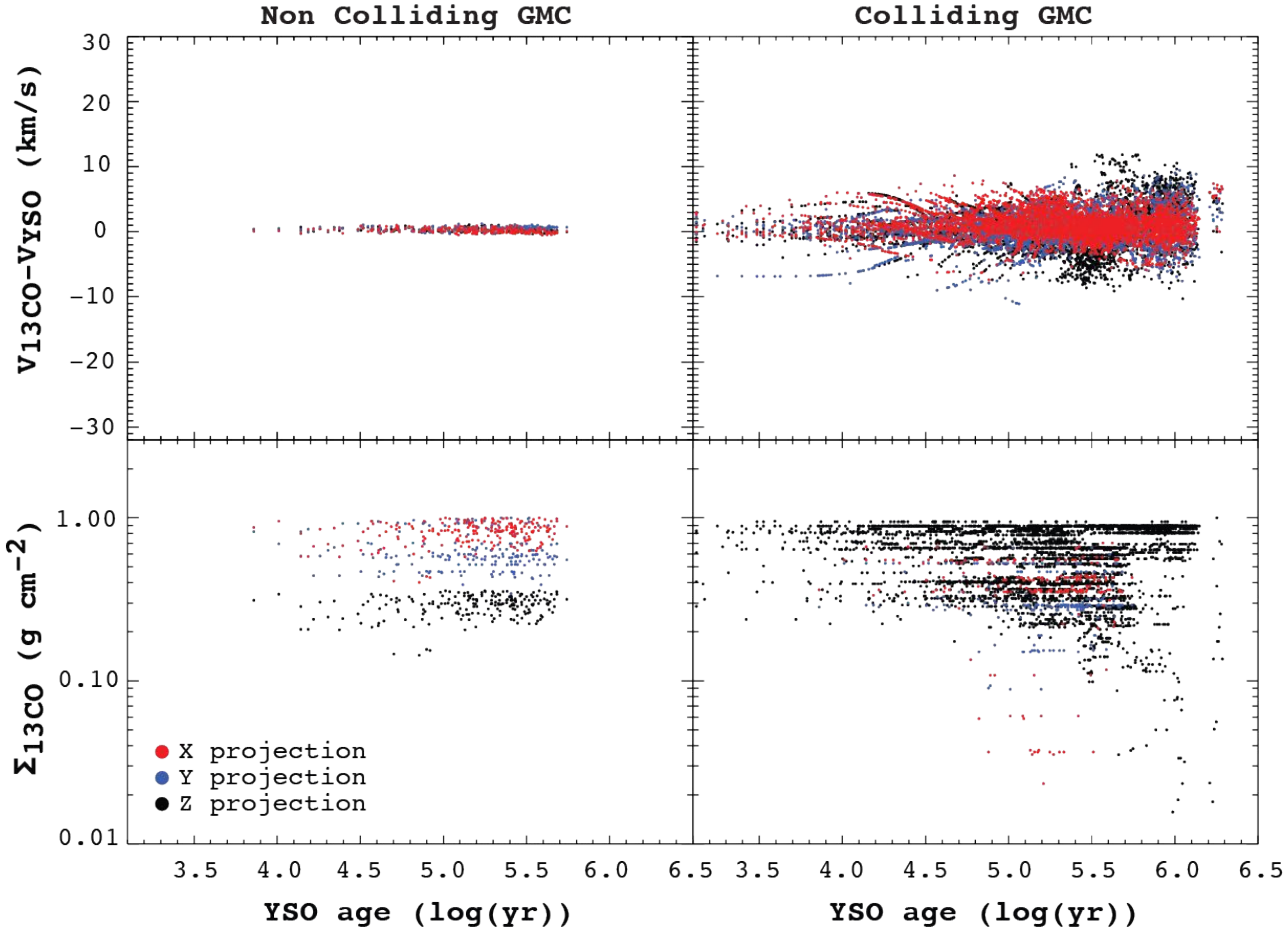


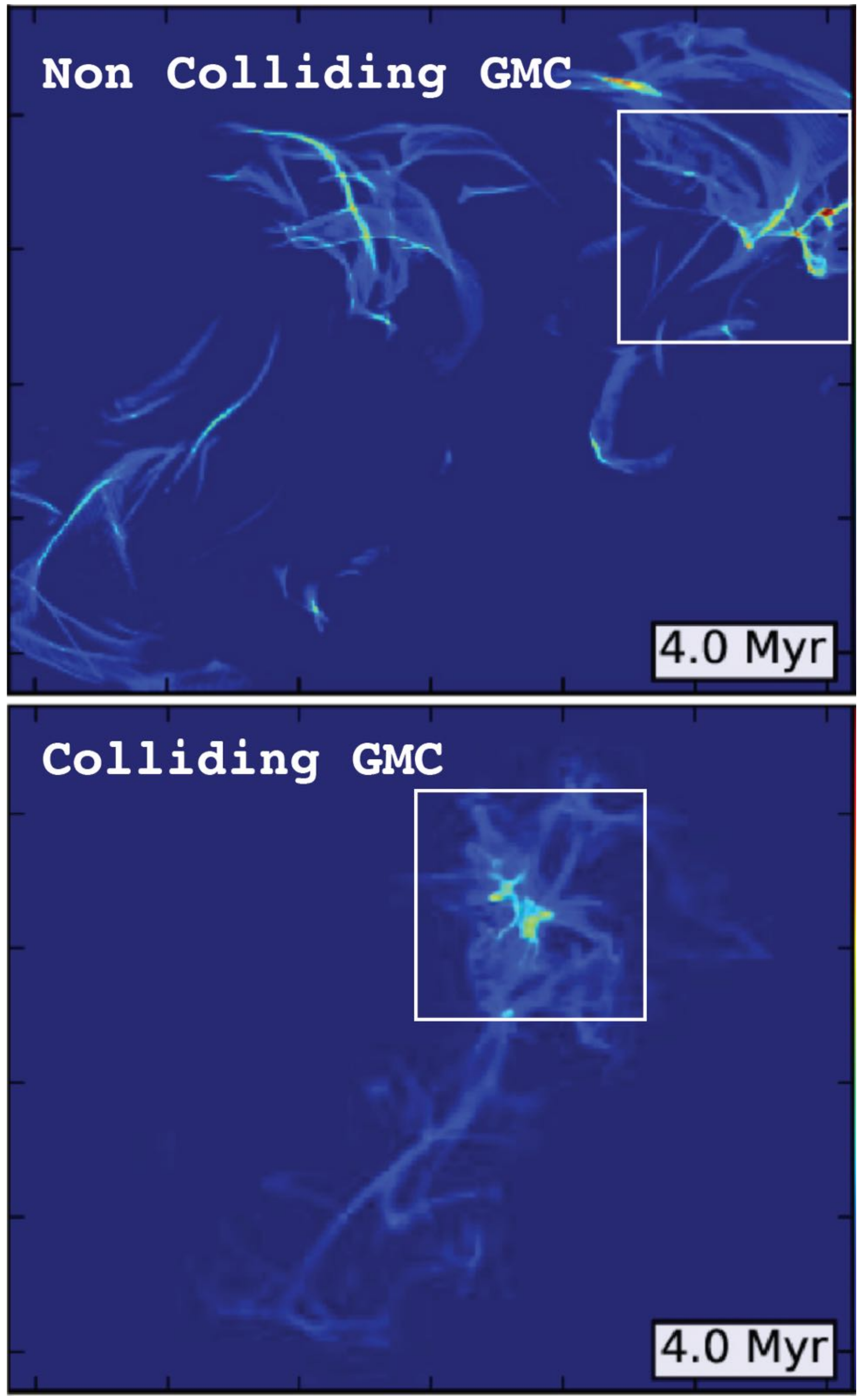
(Lim ea 2020 PASJ)

Result 1. v_{CO} vs. v_{YSO} of Orion A cloud

- Older YSOs have gotten less associated with the dense gas structure.
- Supporting Cloud-Cloud Collision scenario?





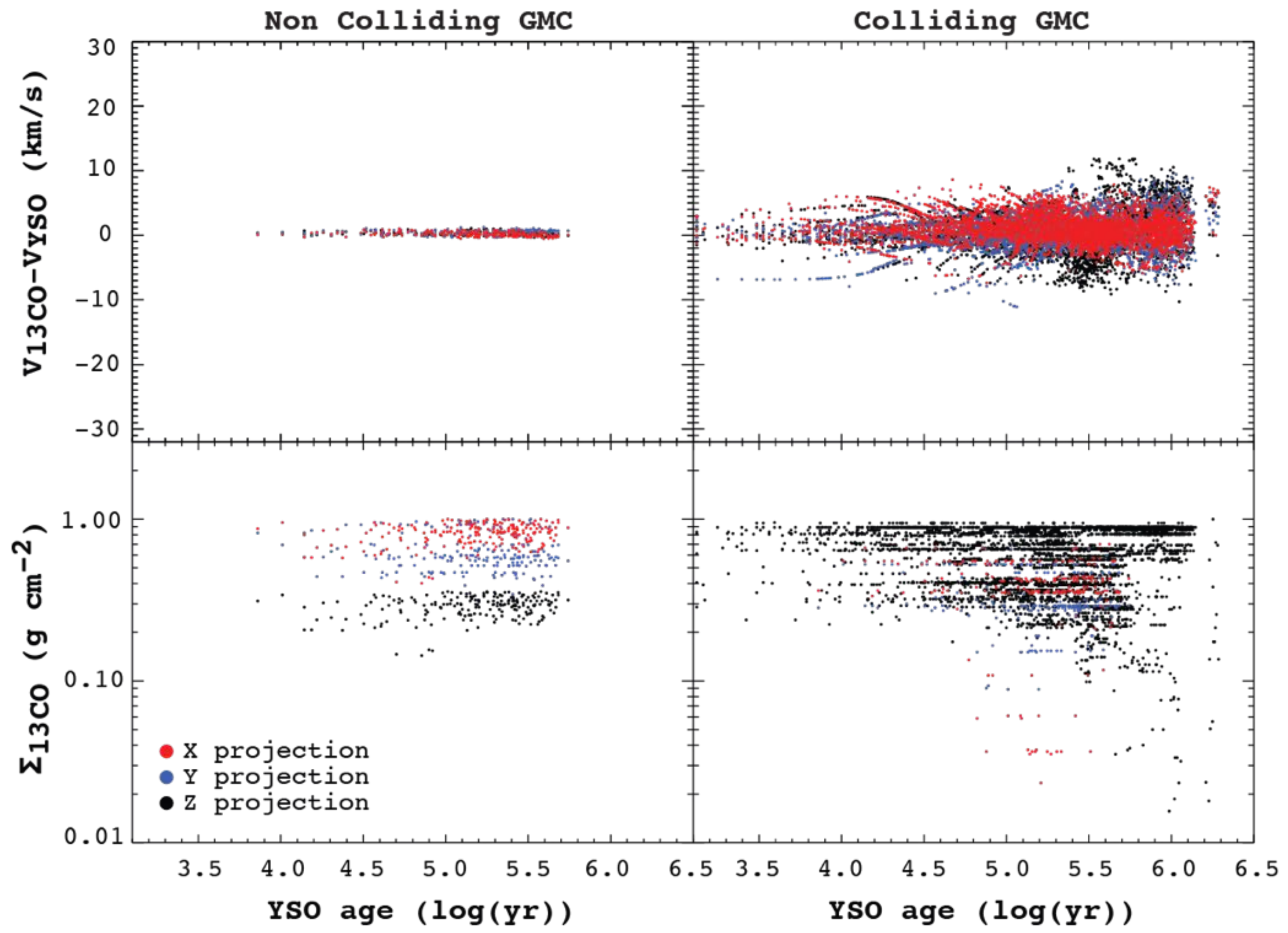


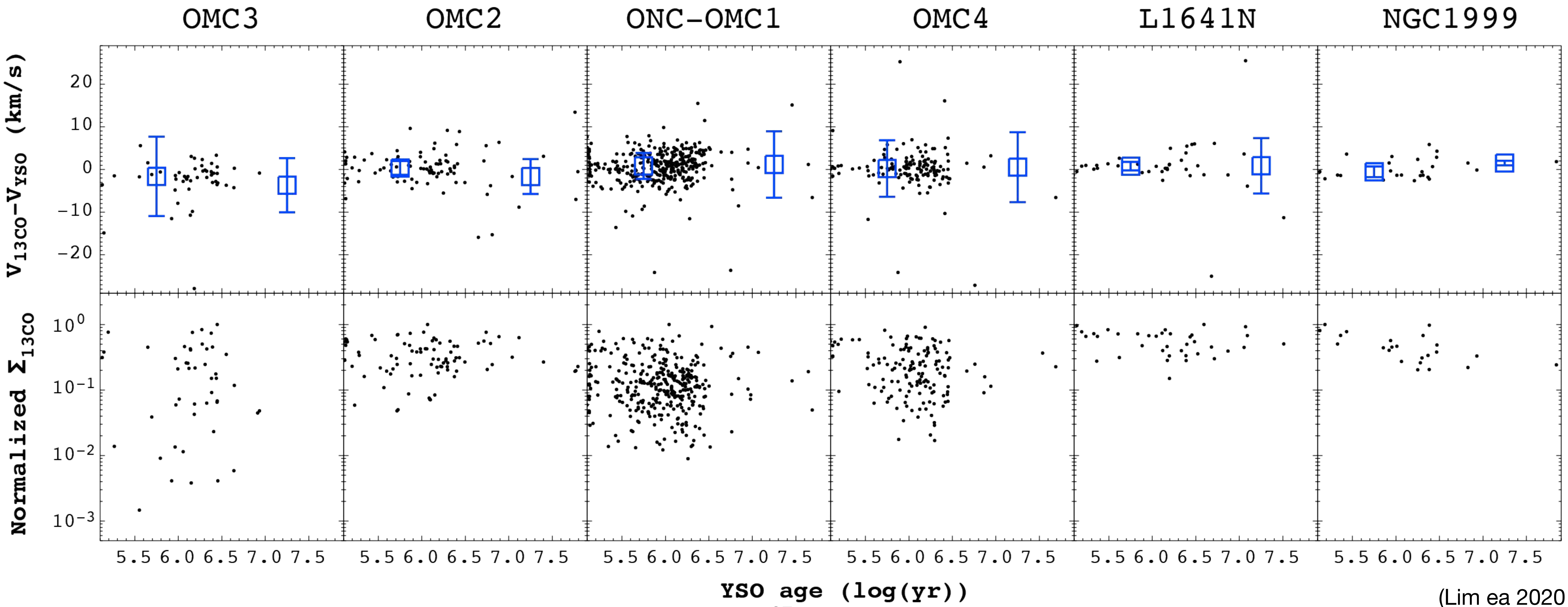
Simulations are based on Wu ea. 2017

(Lim ea 2020 PASJ)

Result 2. v_{CO} vs. v_{YSO} of Star Clusters

- ONC-OMC1, OMC4 and L1641N clusters seem to qualitatively agree with Clouc-Cloud Collision scenario.
- OMC2 and OMC3 do not agree with either scenarios while NGC1999 favors non-colliding.

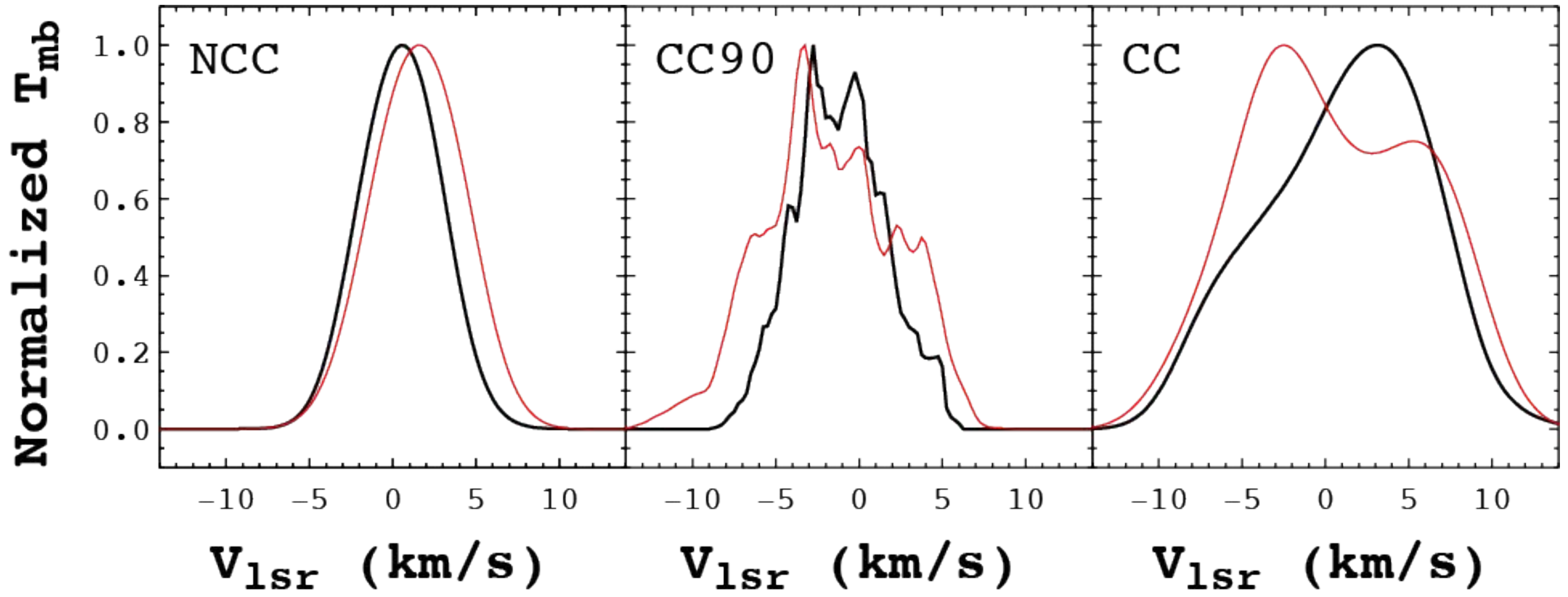


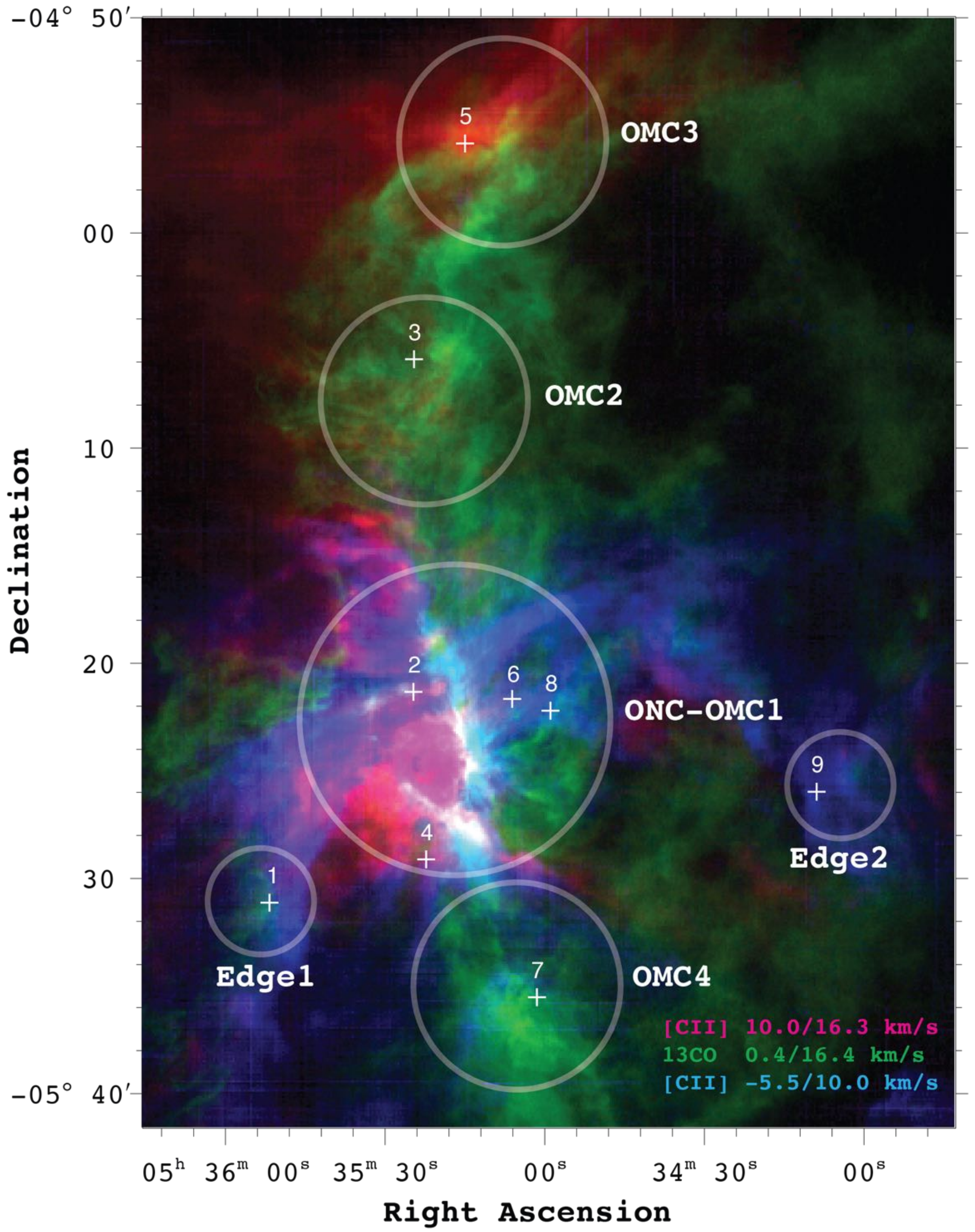


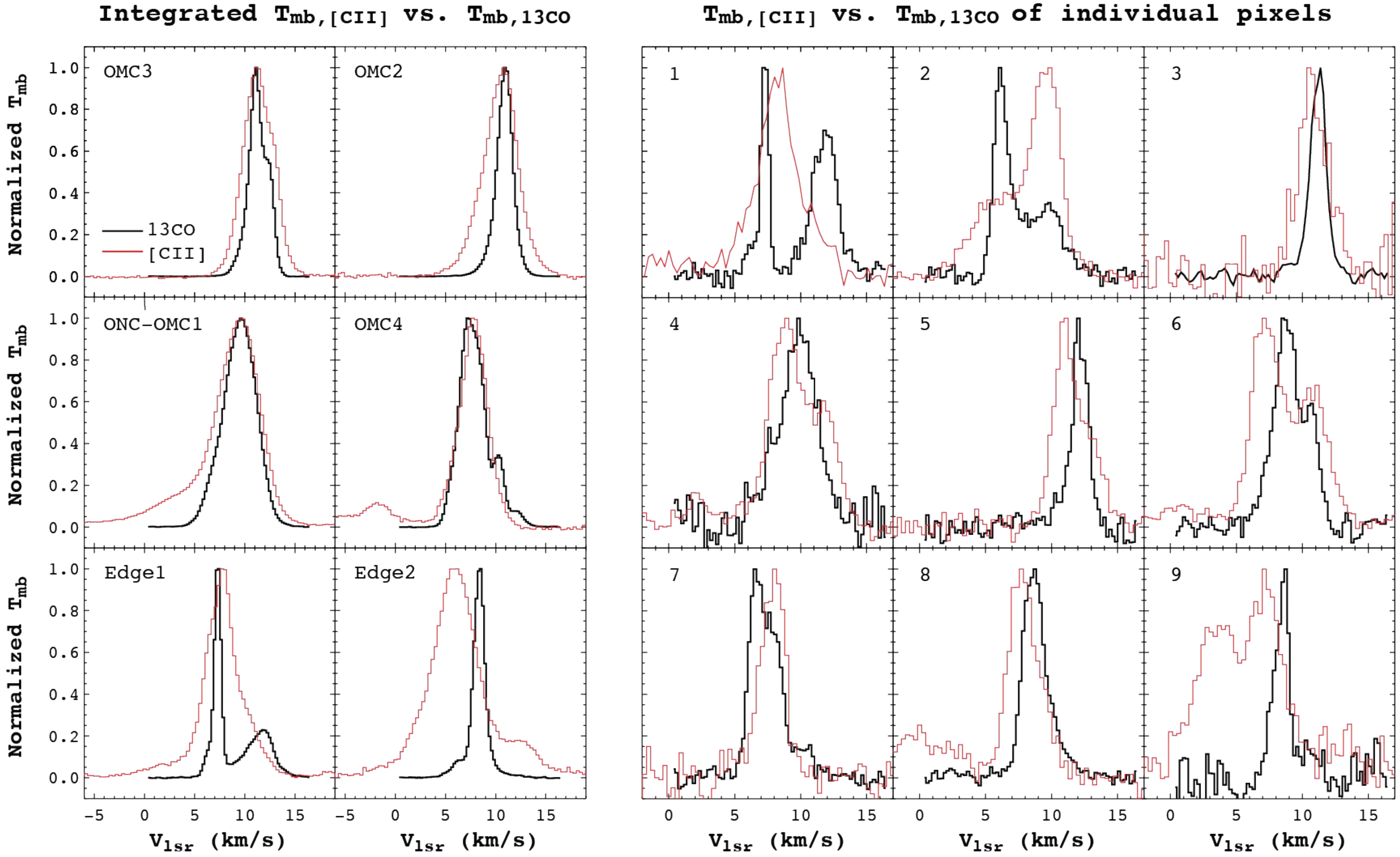
(Lim ea 2020 PASJ)

Result 3. ^{13}CO vs.[CII]

- 13CO and [CII] show spatial and velocity offsets at several locations (local, i.e. individual pixels).
- Supporting Cloud-Cloud Collision scenario?







(Lim ea 2020 PASJ)

Additional Summary

- We utilized three independent survey data to Orion A cloud to trace the history of star cluster formation, especially tested cloud-cloud collision scenario.
- The ^{13}CO vs. YSO analysis shows the older YSO the less the kinematic association between dense gas structure.
- The individual star clusters may favor cloud-cloud collision, especially at the northern part of Orion A.
- The ^{13}CO vs. [CII] of northern part of Orion A shows also slight favoring of cloud-cloud collision scenario.
- Further observational analyses with more complete simulations would confirm or refute the cloud-cloud collision as an important mechanism for star cluster formation in Orion A cloud.