Molecular Clouds roasted by Starburst Clusters

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BallyFest, Visegrad, May 28, 2025


47 Tuc (VLT)


Omega Centauri (VST)

Introduction

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Forming Super Star Clusters in the Central Starburst of NGC 253

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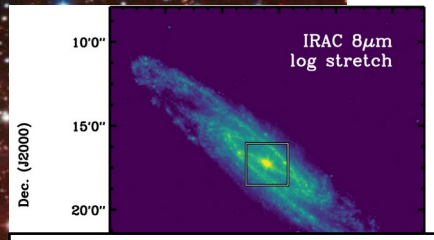
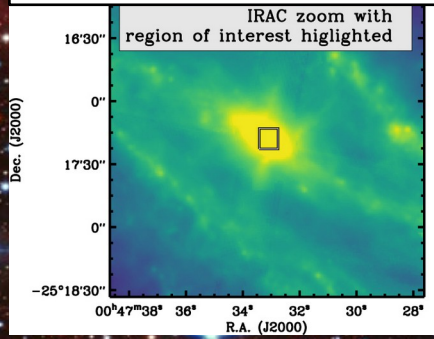
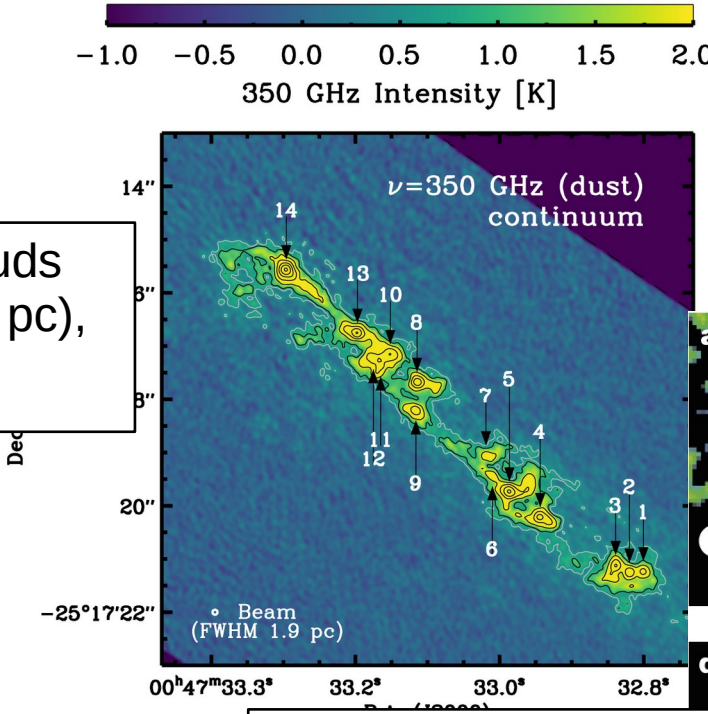
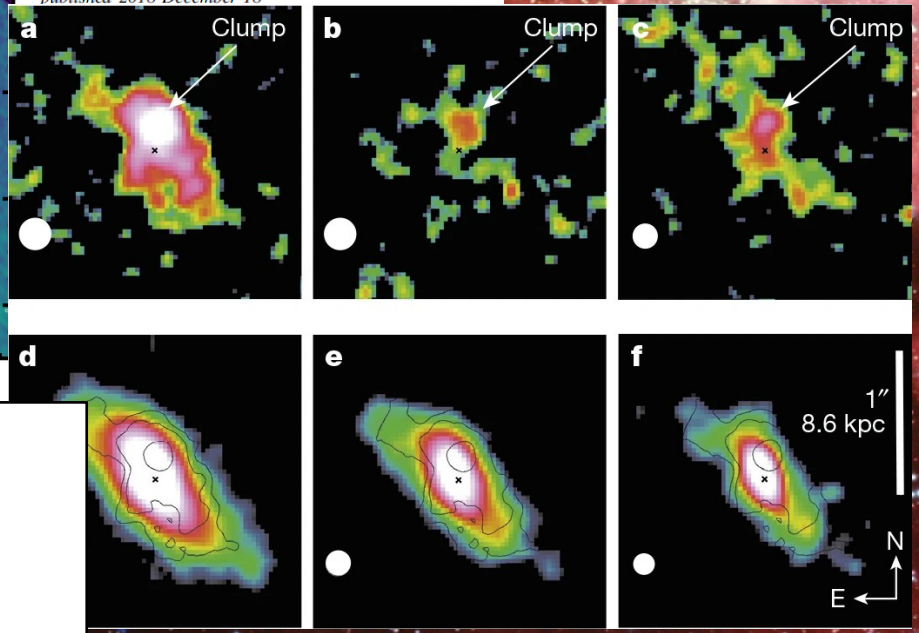


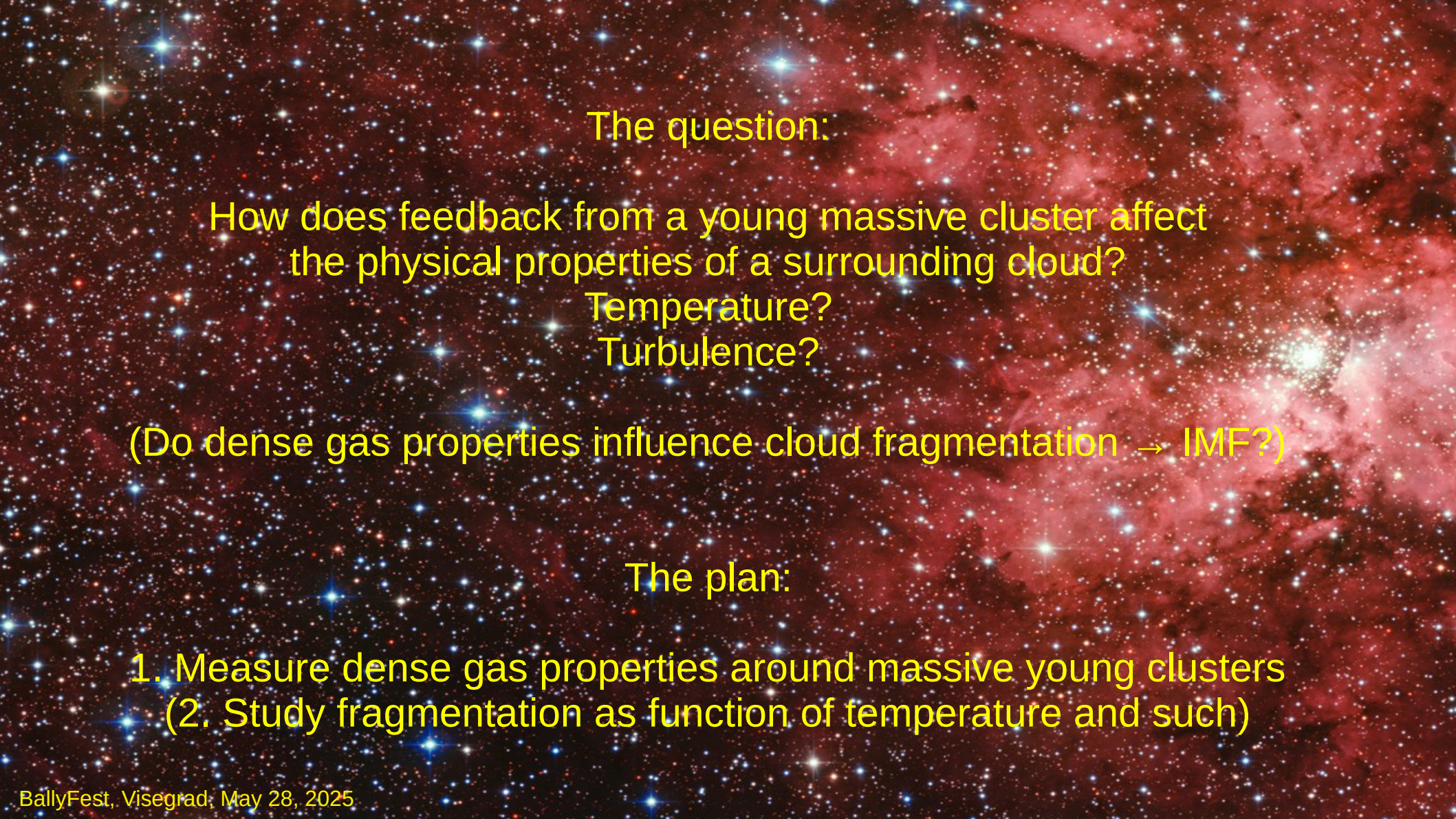


Massive compact clouds (~$10^{5\text{-}6}$ M_{sun} within few pc), star forming





Zanella ea 2015, Nature 521, 54: massive (10^{9} M_{sun}) kpc-sized clumps



The question:

How does feedback from a young massive cluster affect
the physical properties of a surrounding cloud?
Temperature?
Turbulence?

(Do dense gas properties influence cloud fragmentation → IMF?)

The plan:

1. Measure dense gas properties around massive young clusters
(2. Study fragmentation as function of temperature and such)

Introduction

Table 1
Properties of the Super Star Clusters in the Galaxy

Name	l (deg)	b (deg)	D (kpc)	Age (Myr)	$\log(M_{\rm phot}/M_{\odot})$	Radius (pc)	IR Nebulosities	Reference[a]	Reference[b]
Arches	0.12	0.02	8.0	2.0	4.3	0.4	No	1	
Quintuplet	0.16	−0.06	8.2	4.0	4.0	2.0	No	1	
RCW38	268.03	−0.98	1.7	⩽1.0	...	0.8	Yes	2	
Westerlund 2	284.25	−0.40	5.4	2.0	4.0	0.8	Yes	3	7, 8
Trumpler 14	287.41	−0.58	2.6	2.0	4.0	0.5	No	4	
NGC 3603	291.62	−0.52	7.0	2.0	4.1	0.7	Yes	5	This work
Westerlund 1	339.55	−0.40	5.2	3.5	4.5	1.0	No	6	
[DBS2003]179	347.58	0.19	7.9	3.5	3.8	1.2	Yes	3	

Notes. Column 1: name of cluster; Columns 2 and 3: position of cluster; Column 4: distance; Column 5: age of cluster; Column 6: mass of cluster; Column 7: radius of cluster; Column 8: association of IR nebulosities.

References.

[a] Papers of clusters: (1) Figer et al. 1999; (2) Mizutani et al. 1987; (3) Pfalzner 2009; (4) Ascenso et al. 2007; (5) Harayama et al. 2008; (6) Clark et al. 2010, 2005.

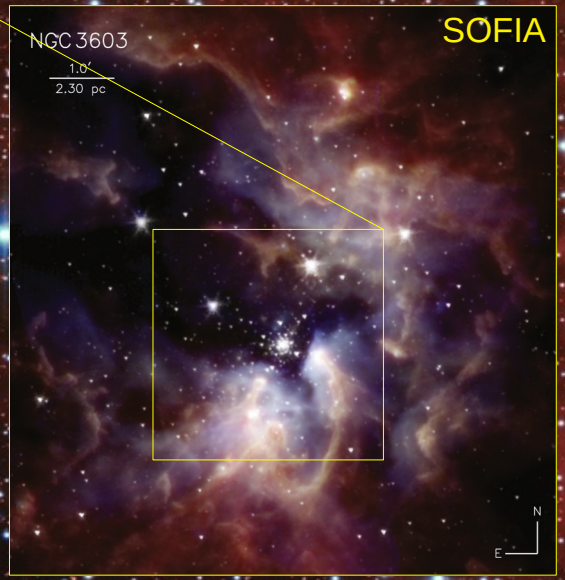
[b] Papers of molecular clouds: (7) Furukawa et al. 2009; (8) Ohama et al. 2010.

Fukui ea 2014, ApJ 780, 36

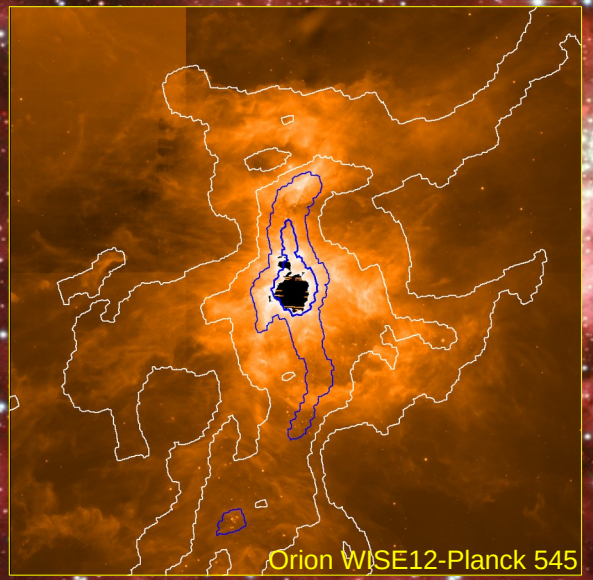
NGC 3603

… in a nutshell:

- Starburst cluster ~1-2x10^4 M_{sun}
- Several 10 O-type stars, 3 WR stars (e.g., Melena ea 2008, AJ 135, 878)



20+37μm (+Herschel 70μm + Spitzer 3.6μm)



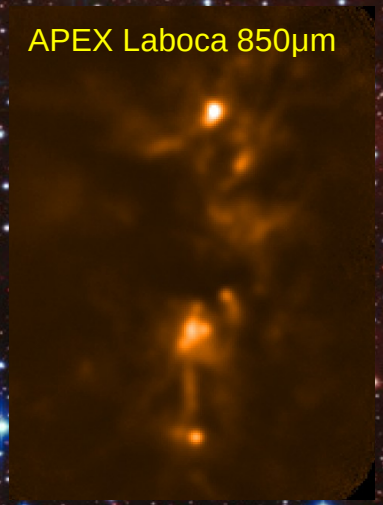
Brandl ea 1999, A&AL 352, L69
Brandner ea 2000, AJ 119, 292
Nürnberger & Petr-Gotzens 2002, A&A 382, 537
De Buizer ea 2024, ApJ 963, 55

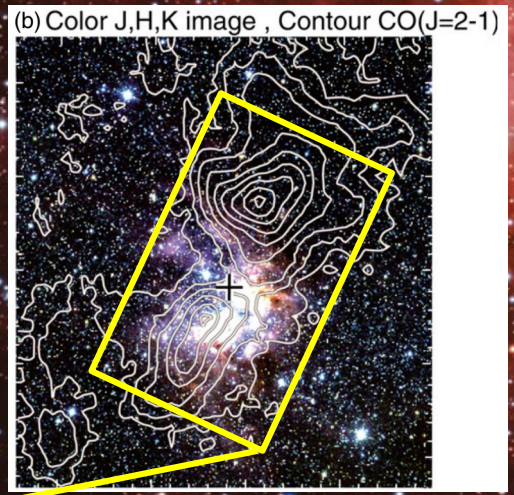
NGC 3603

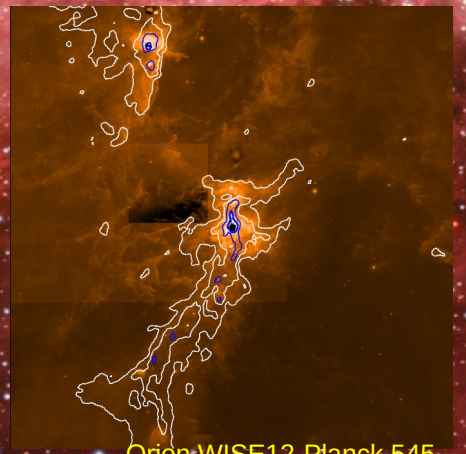
… in a nutshell:

- Starburst cluster ~1-2x10^4 M_{sun}
- Several 10 O-type stars, 3 WR stars (e.g., Melena ea 2008, AJ 135, 878)
- Giant molecular cloud ~10^5 M_{sun} (Fukui et al. 2014, ApJ 780, 36)
- Dense gas ~10^4 M_{sun} (e.g., Nürnberger ea 2002, A&A 394, 253)
- Masers, embedded IR sources, etc…

(e.g., Nürnberger & Stanke 2003, A&A 400, 223; Di Cecco ea 2015, ApJ 799, 100, De Buizer ea 2024, ApJ 963, 55)

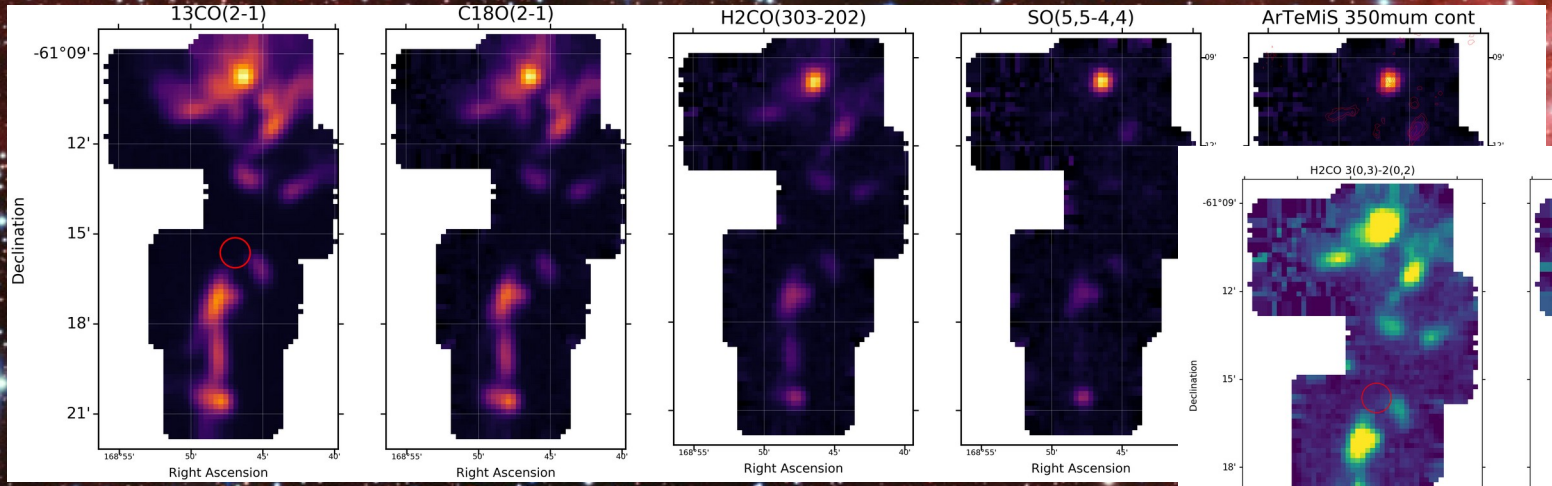


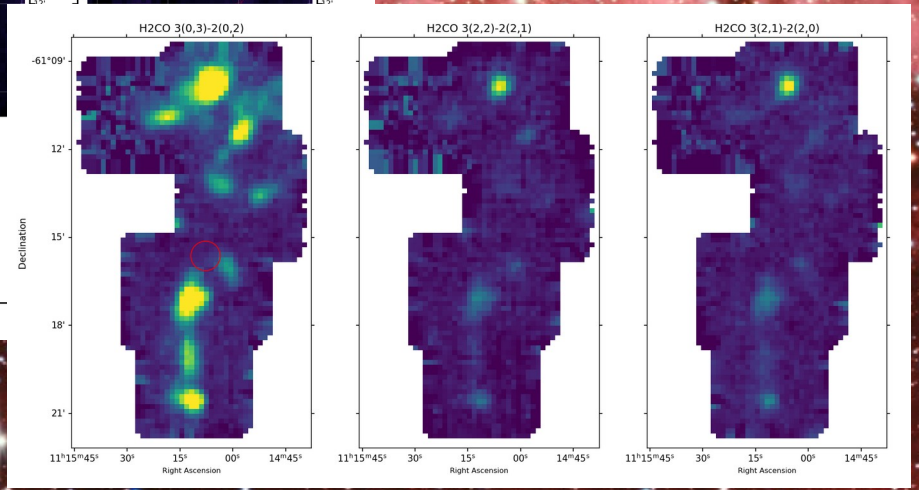




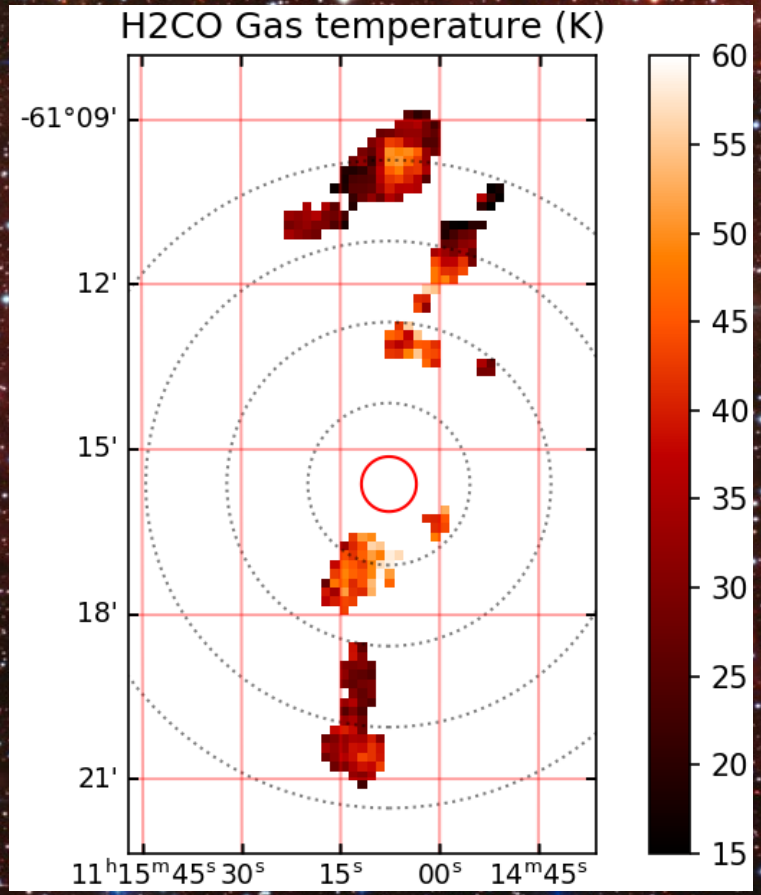
H_2CO temperature in NGC 3603

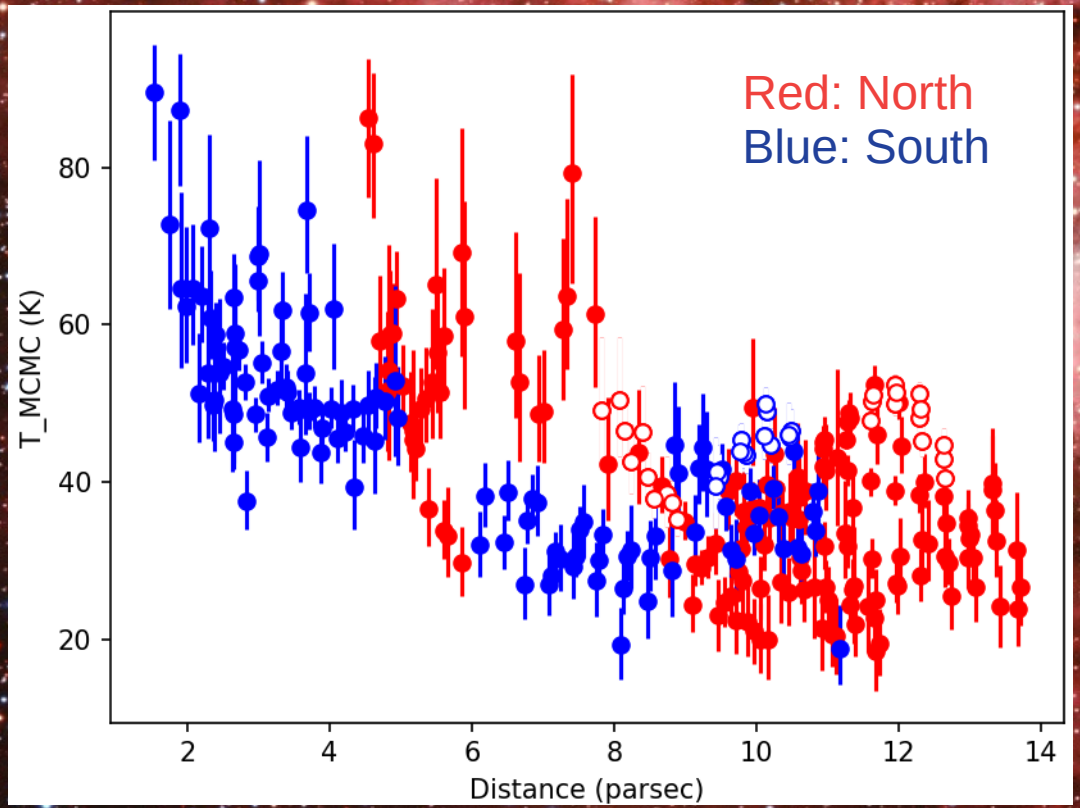
Full spectral line map of the densest portion of the clouds
APEX PI230/nFLASH
Spectral setup: 213-221GHZ (LSB); 229-237GHz (USB)
~60h of telescope time in Sept.-Dec. 2019, Dec. 2020



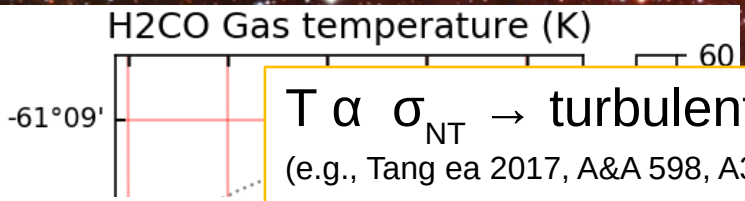


H_2CO temperature in NGC 3603





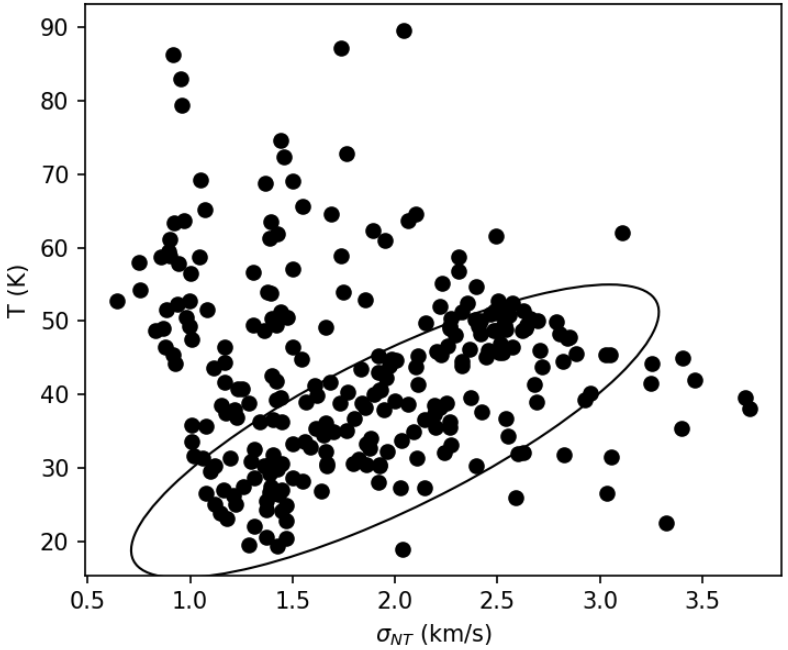
H_2CO temperature in NGC 3603: clues on the heating mechanism?

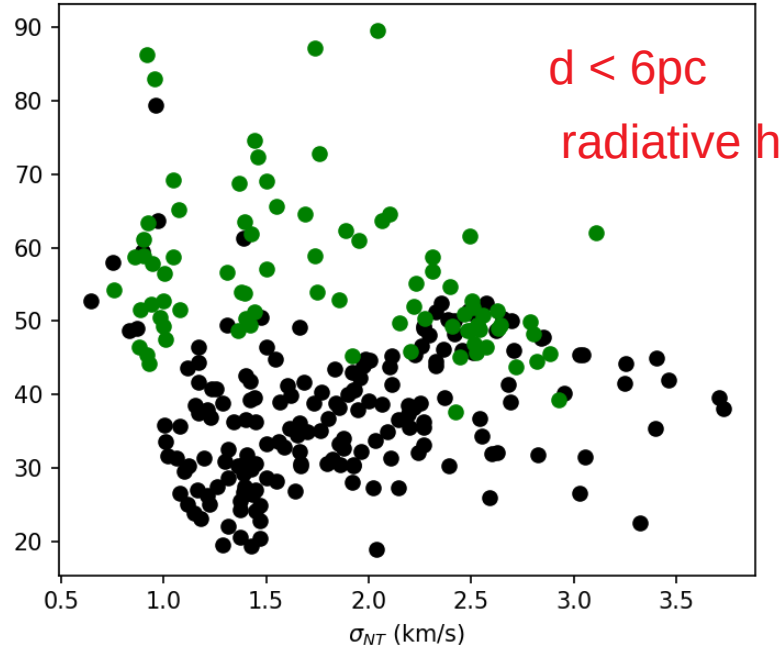


T α σ_{NT} → turbulent heating

(e.g., Tang ea 2017, A&A 598, A30;

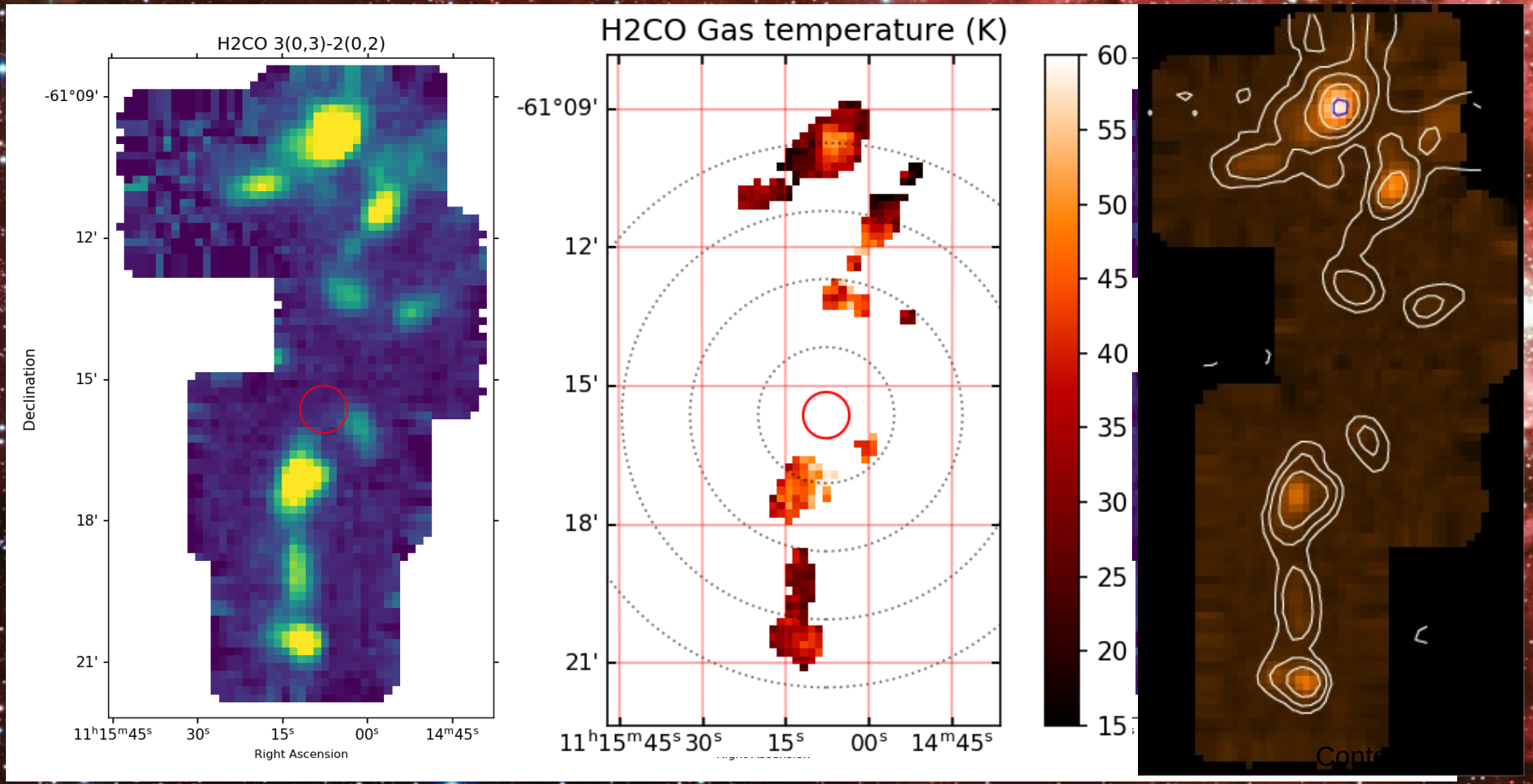
Ginsburg ea 2015, A&A 586, A50)





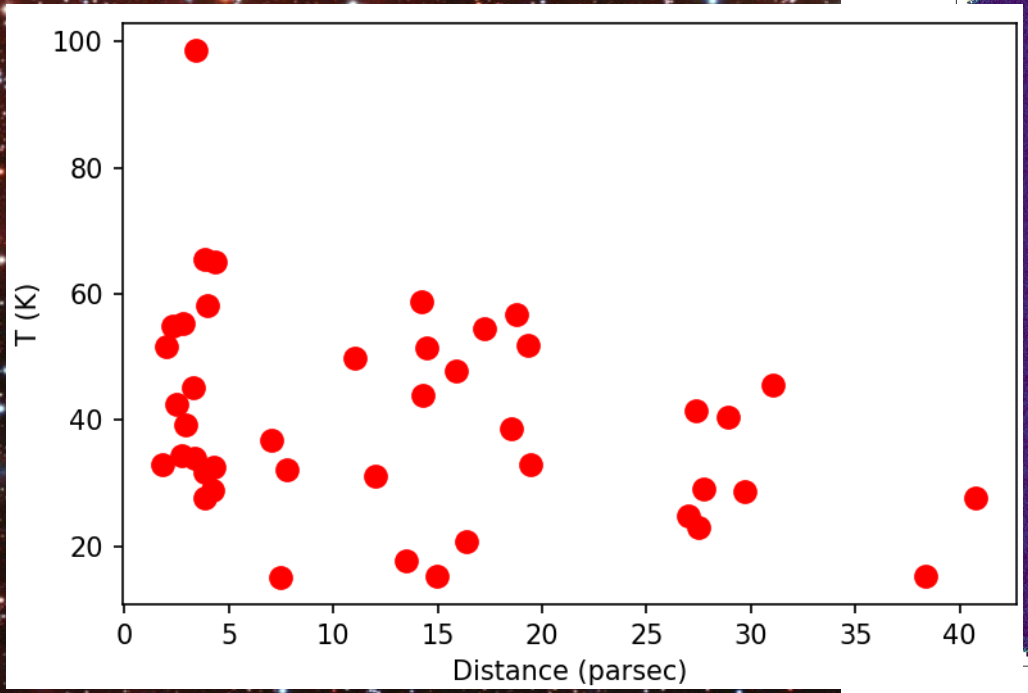
H_2CO temperature in NGC 3603

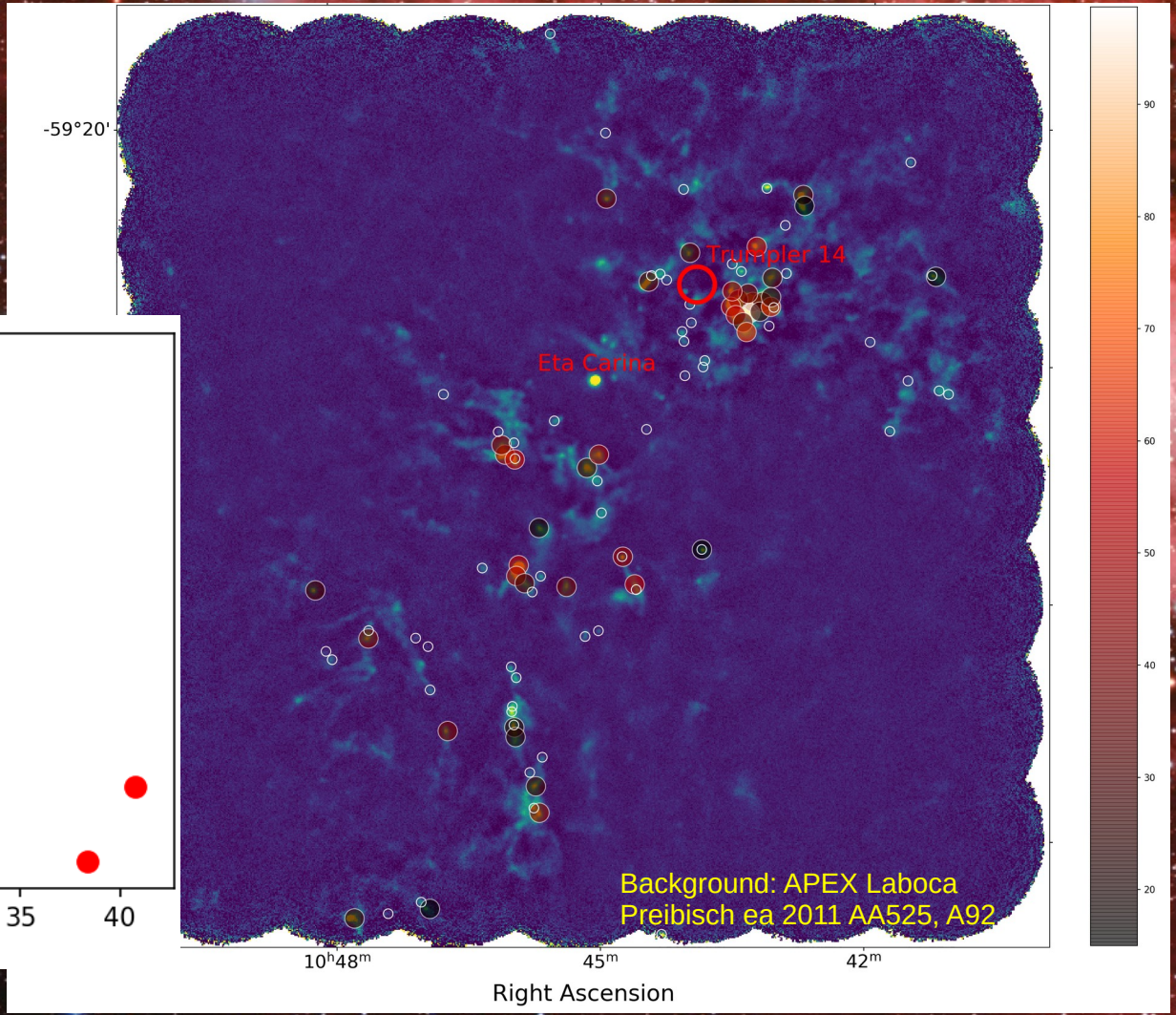
N_2H^+ (3-2)



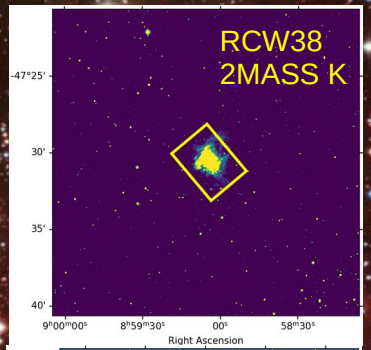
H_2CO temperature elsewhere: Carina

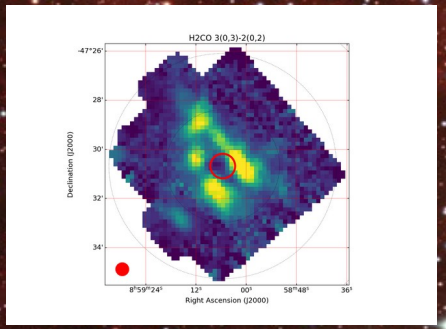
d ~ 2.3 kpc
> 70 O-type stars
Few x 10^5 M_{sun} molecular gas

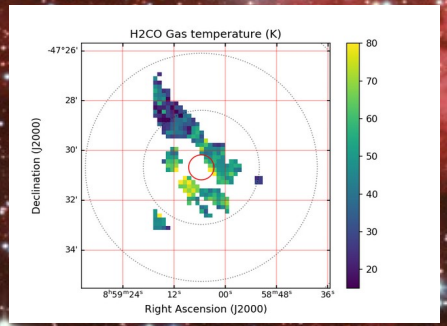


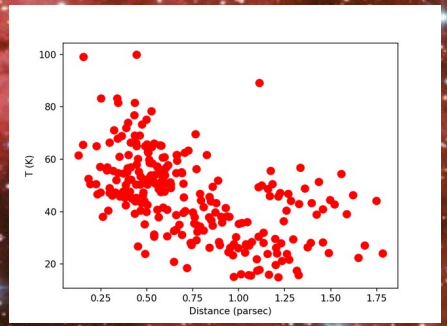


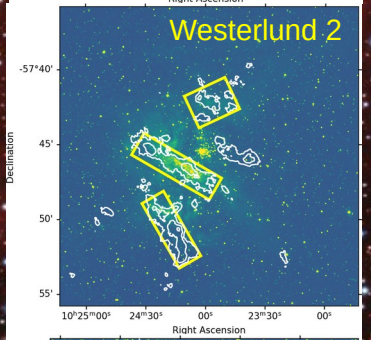
H_2CO temperature elsewhere: more clusters… ongoing/preliminary

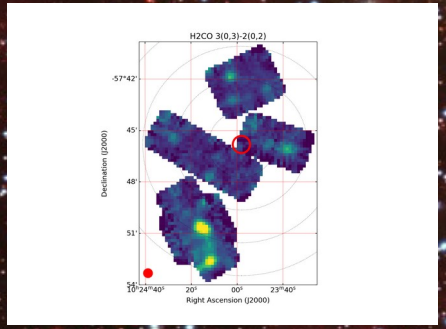


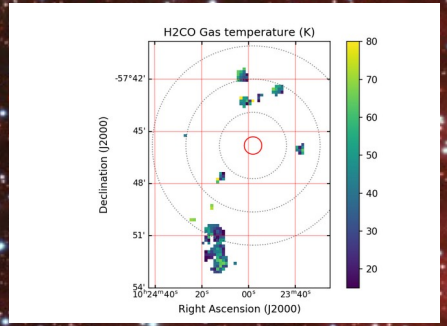


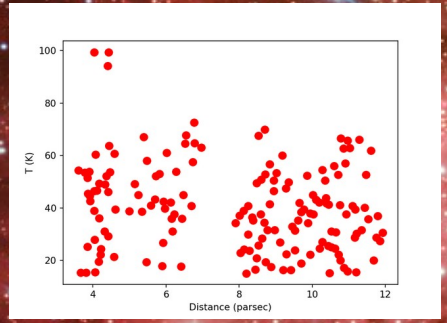


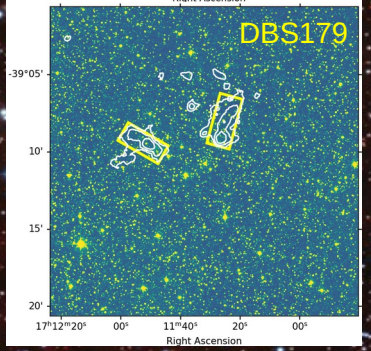


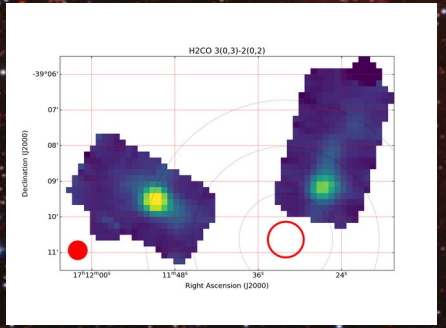


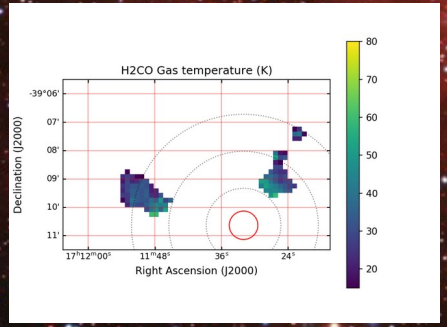


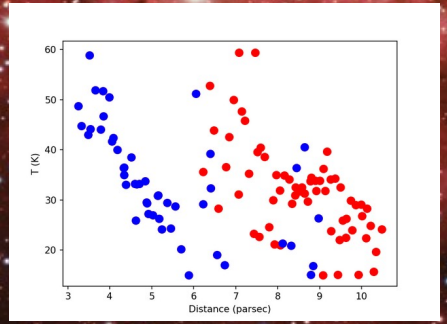












Summary - temperature

NGC 3603: closest Galactic relative to young Super Star Clusters:
Dense gas in surrounding clouds is heated by the cluster
But: *Very cold (<20 K) gas may still exist in densest cores close to cluster*

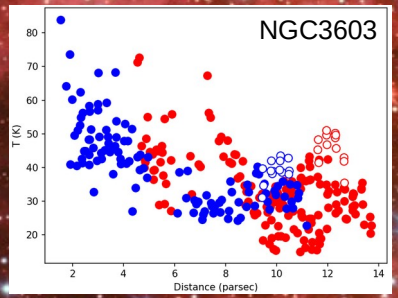
DBS[2000]179: heating on scales of a few parsec

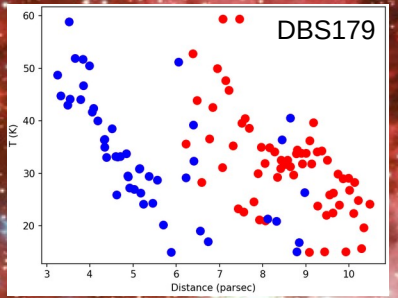
30 Dor: heating on 10-20 parsec scales
(Indebetouw et al. 2024, arxIv:2405.07931)

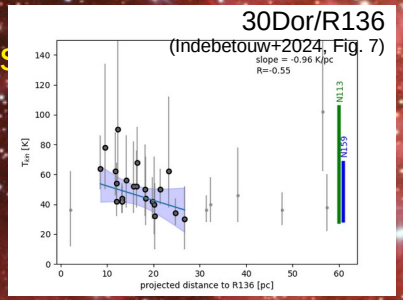
RCW38: smaller, lower mass cluster: dense gas in surrounding is
heated by the cluster (on smaller scales than in NGC3603)

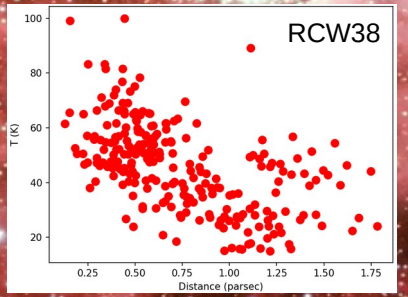
Westerlund 2: no clear evidence for centrally dominated heating
too evolved?

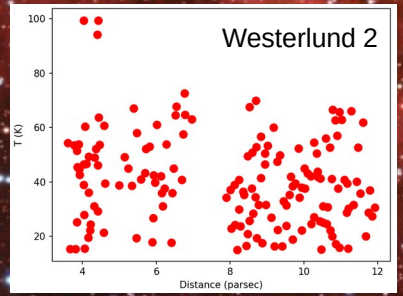
Carina: more dispersed massive star population:
no large scale effects obvious

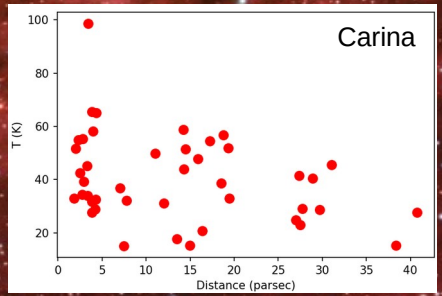






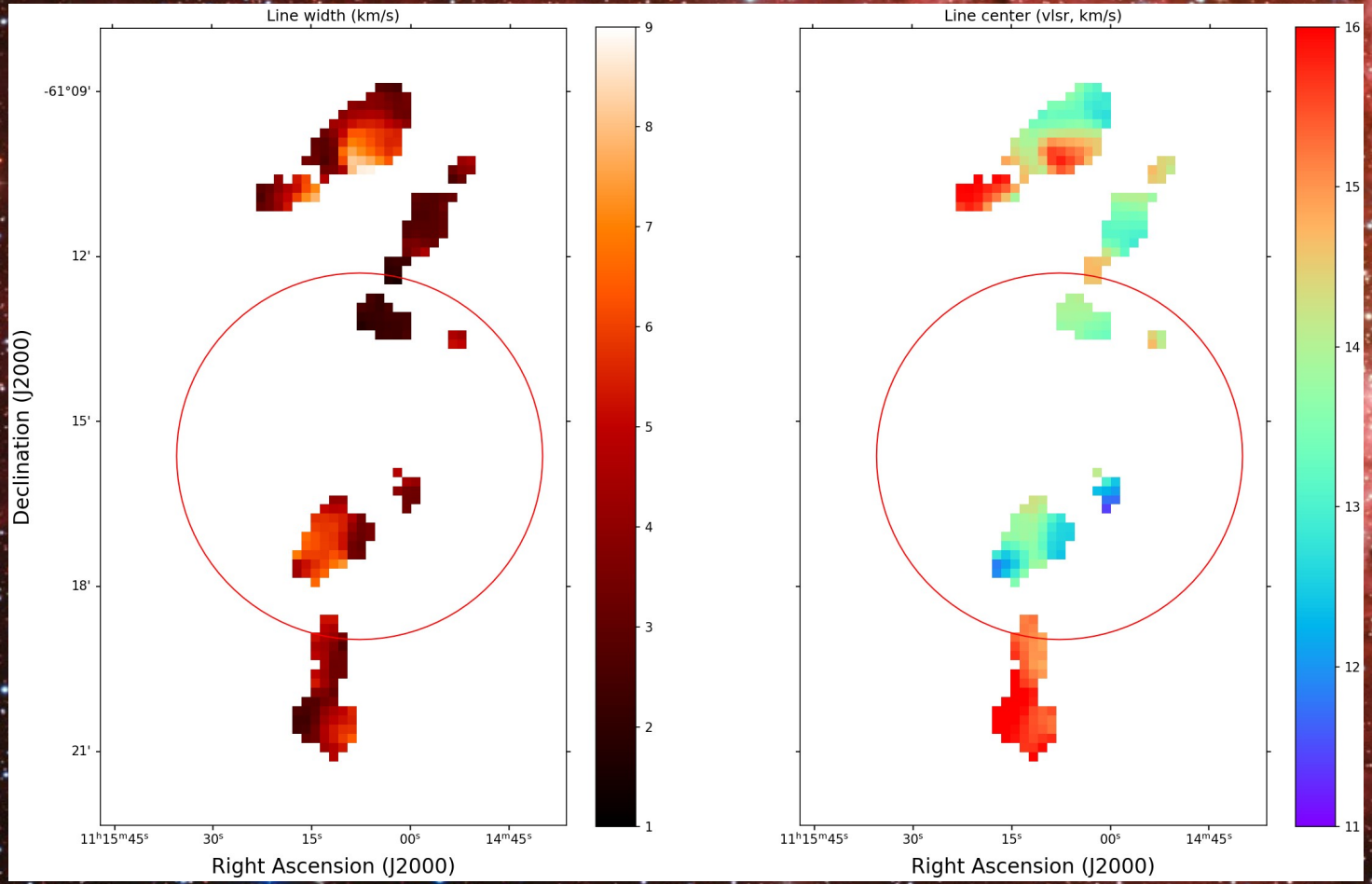






Turbulence?

H_2CO...



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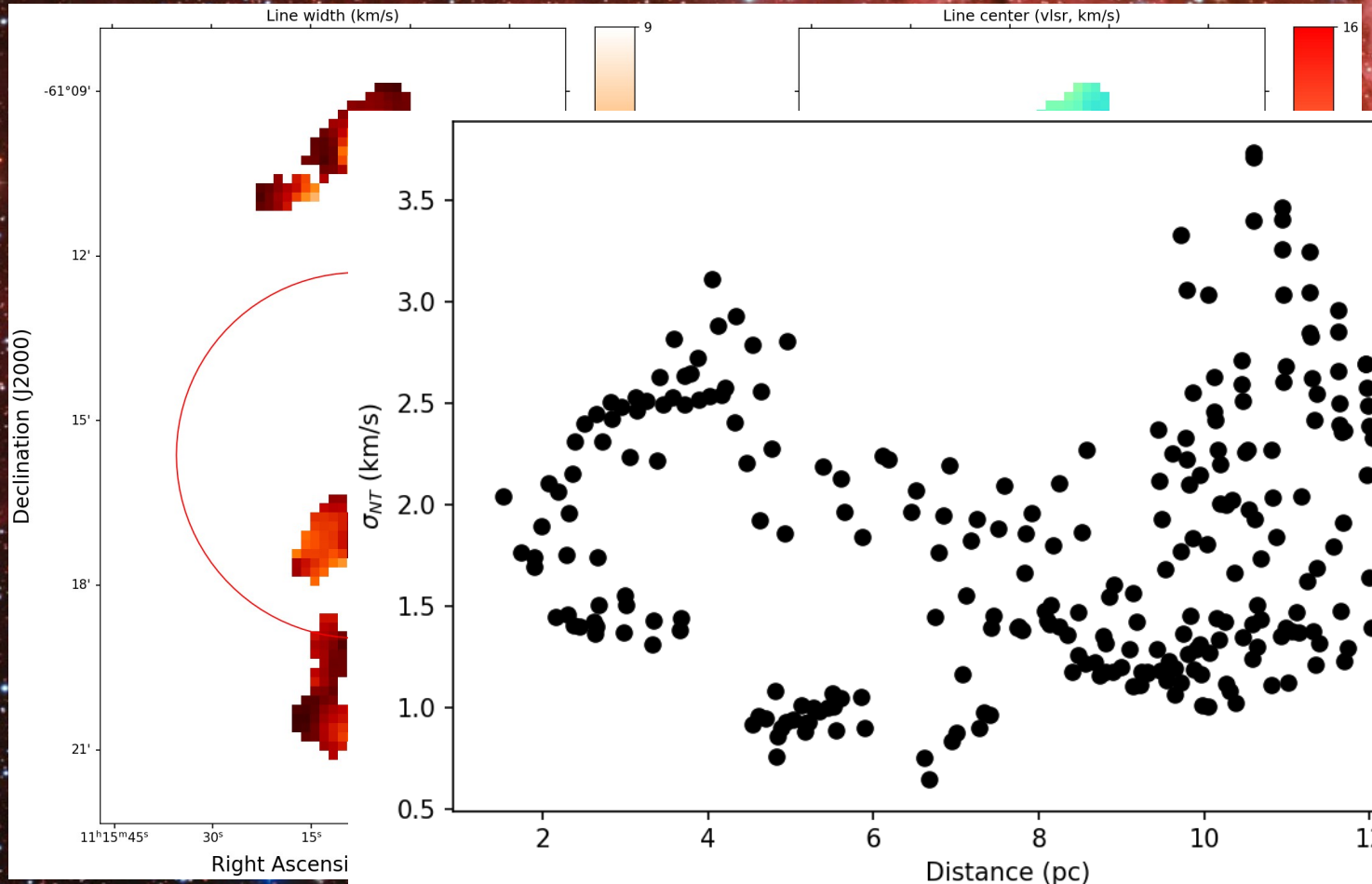
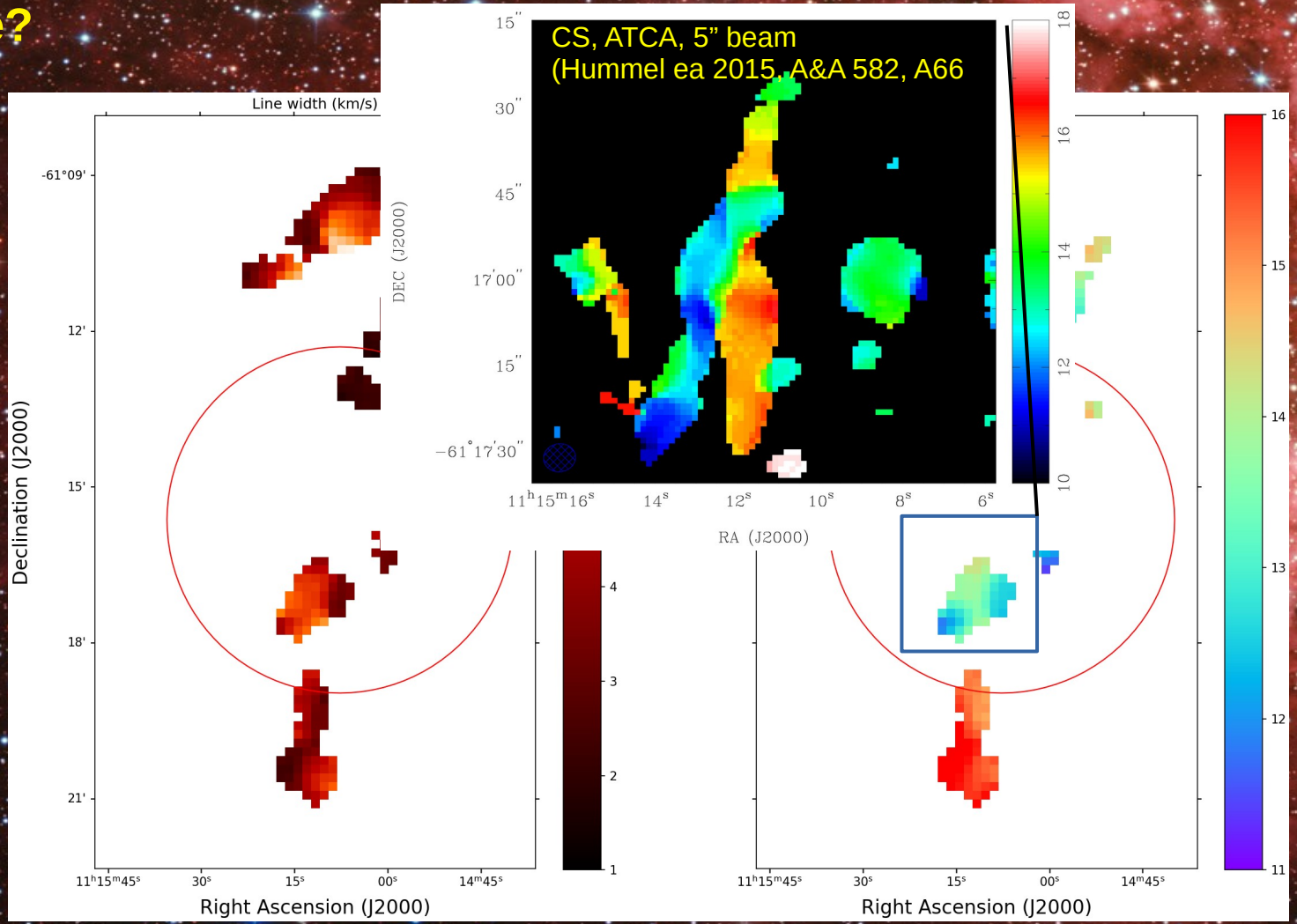


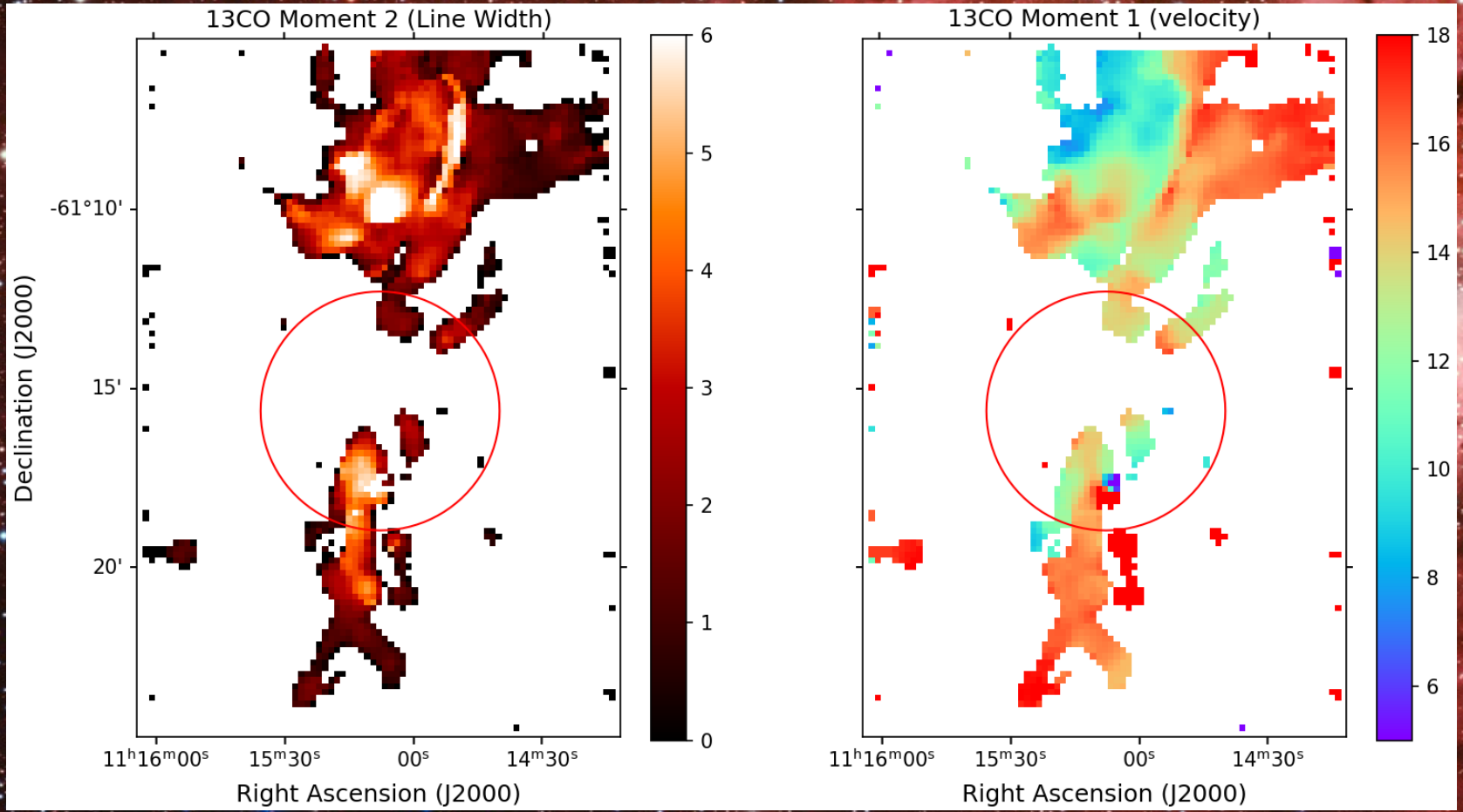
Turbulence?

H_2CO...



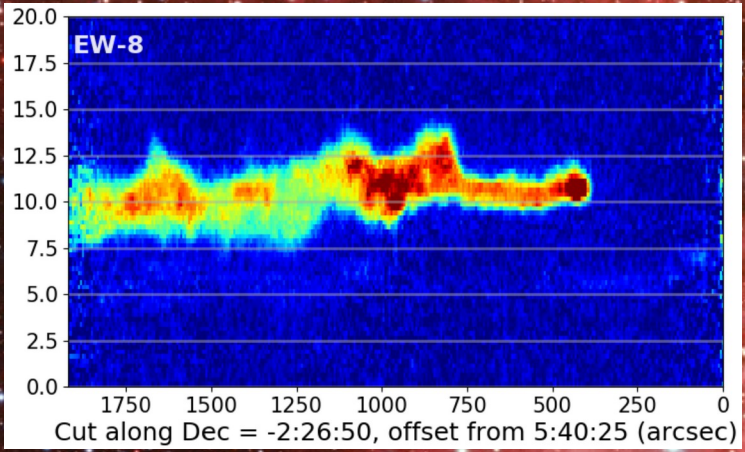
Turbulence?

^{13}CO...



Turbulence?

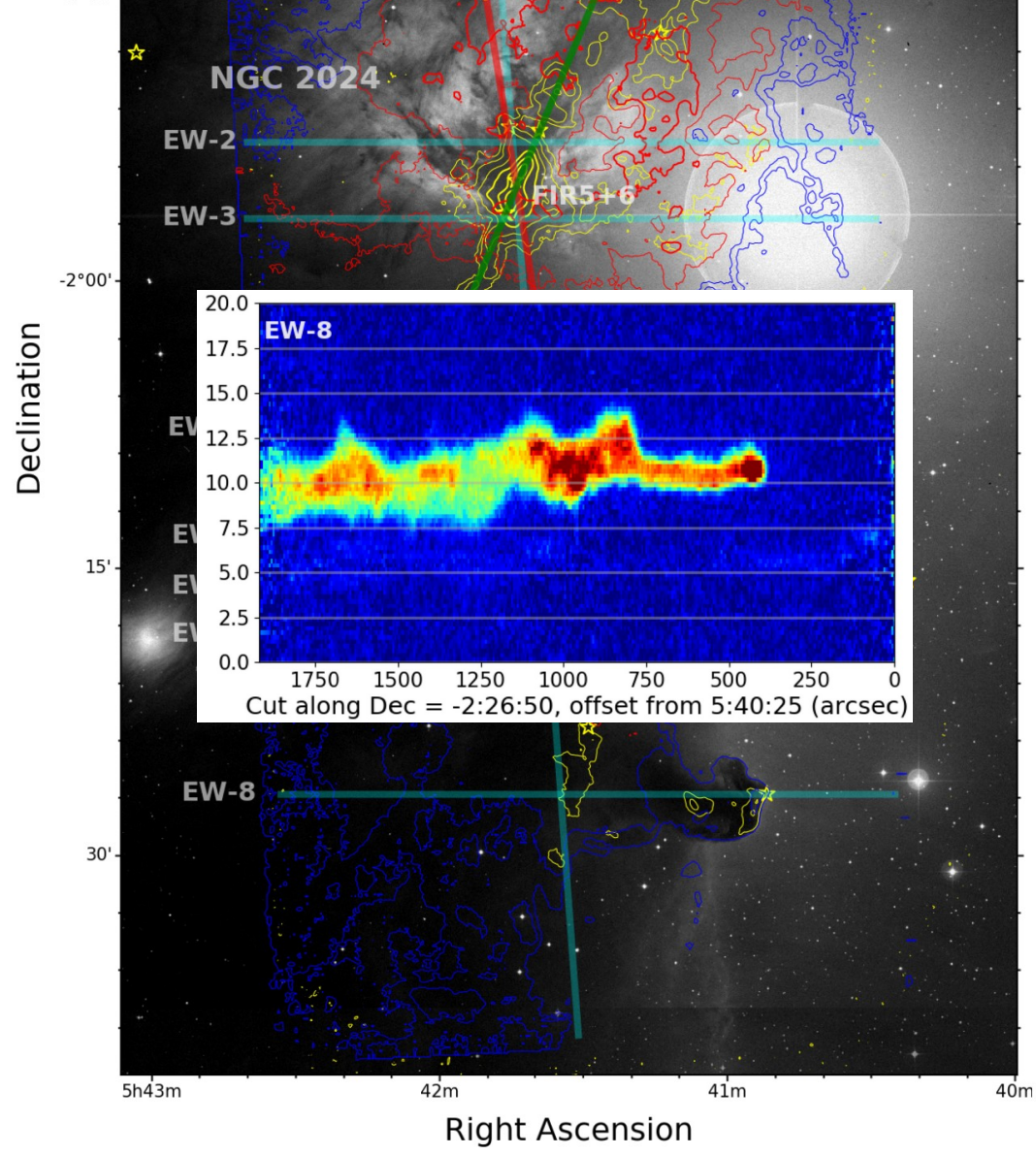
CO?



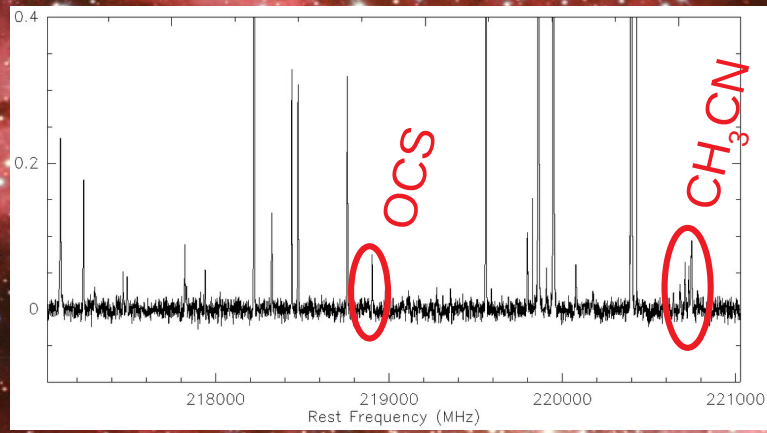
Turbulence?

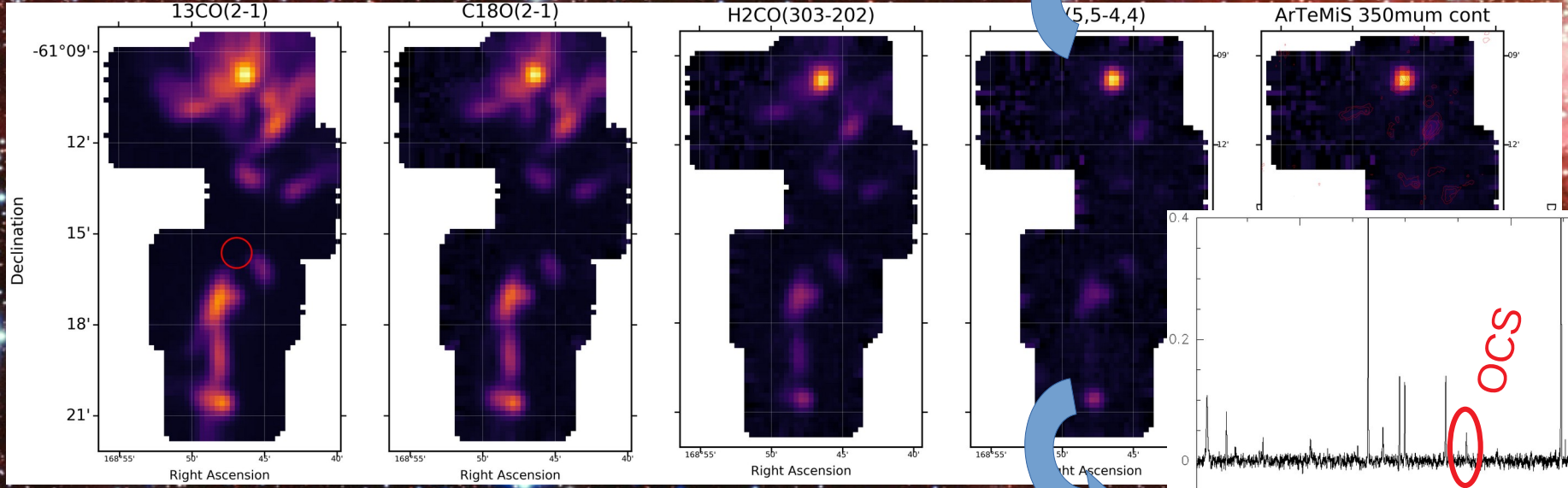
CO?

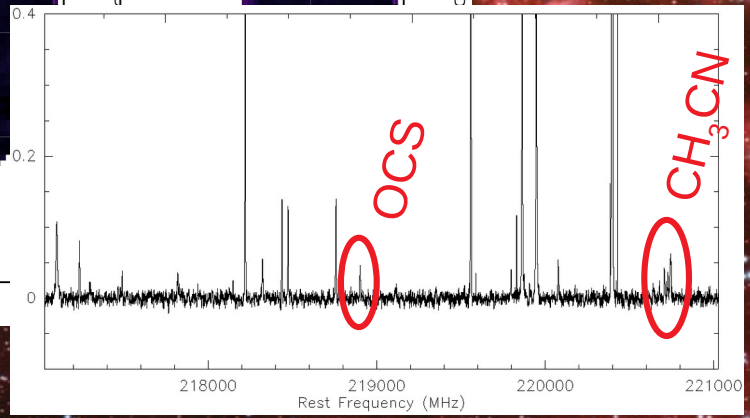
Stanke ea 2022, A&A 658, A178



Where are the YSOs?
- New ‘Hot Cores’ in NGC 3603







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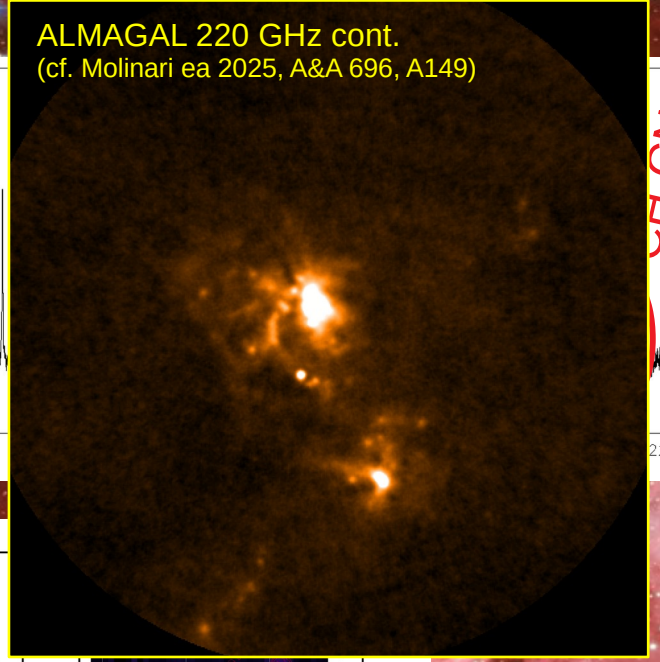
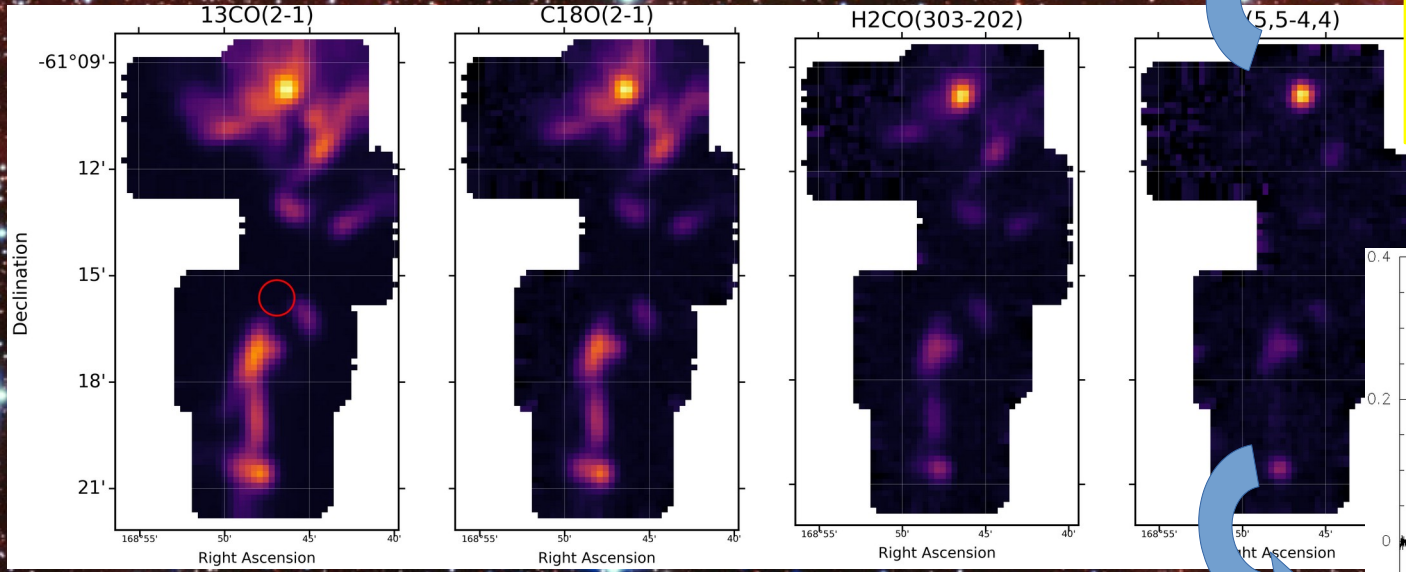
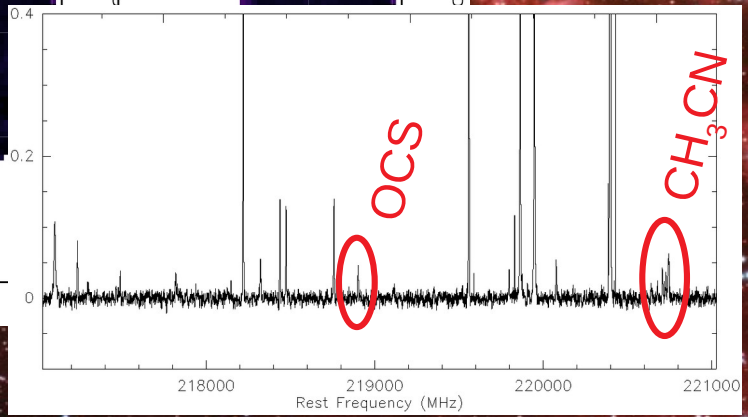
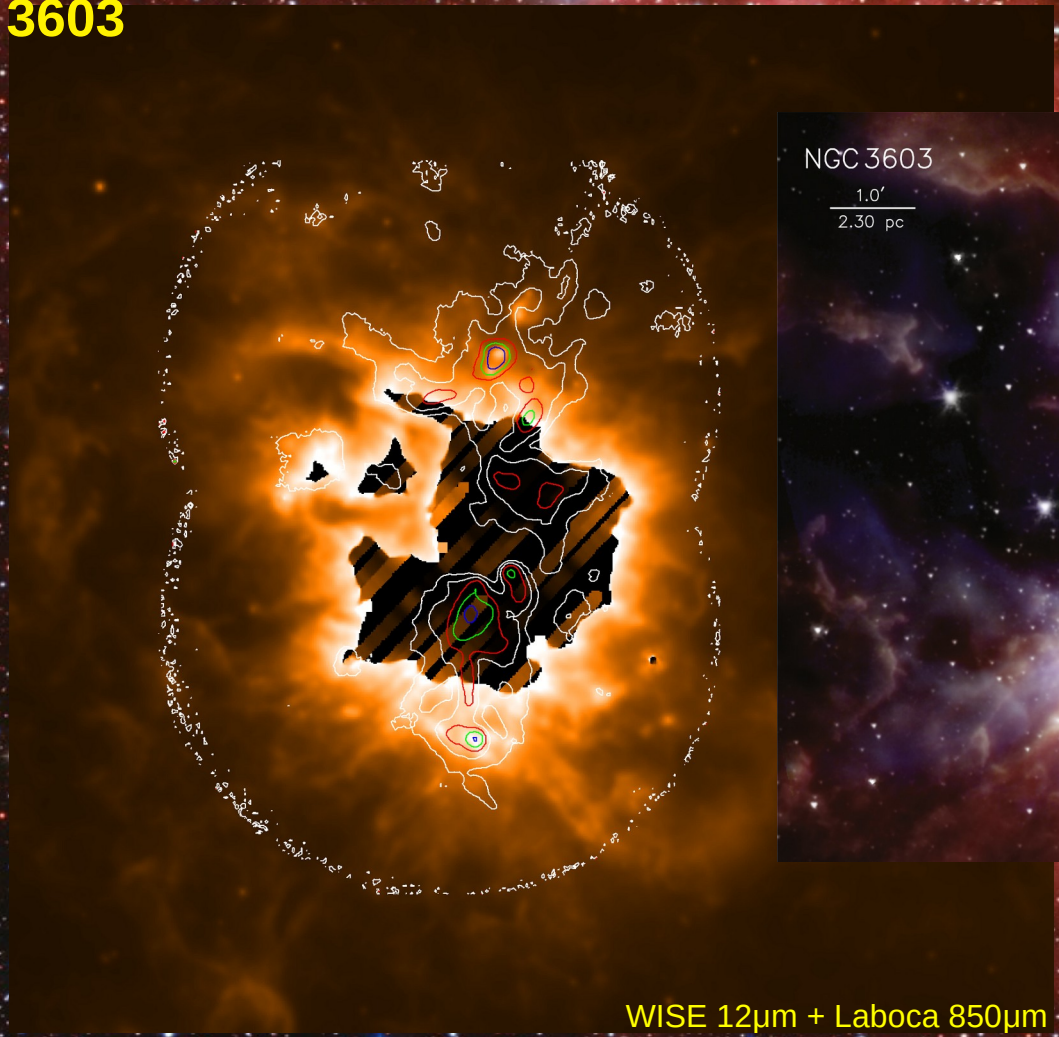
- New ‘Hot Cores’ in NGC 3603







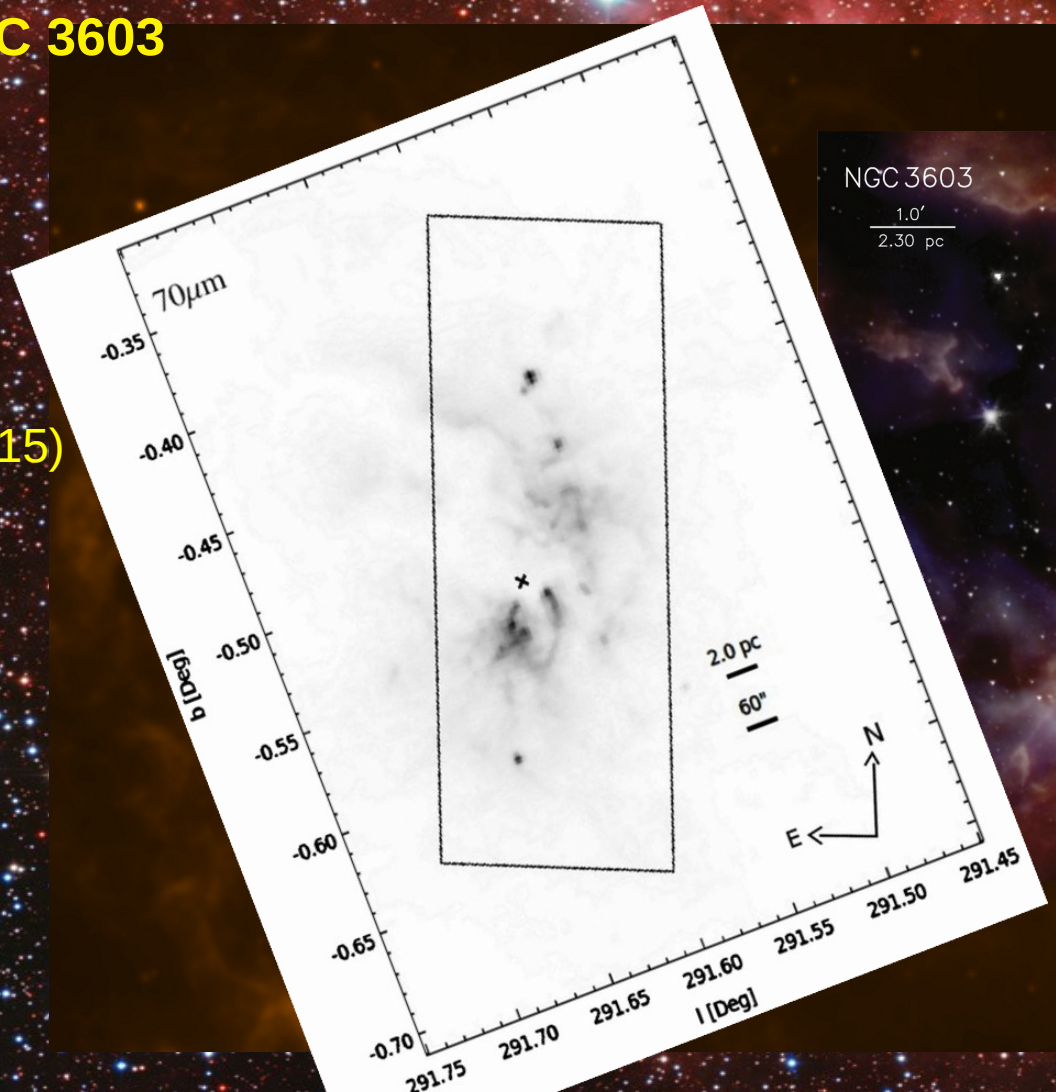
Where are the YSOs?
- IR sources in NGC 3603

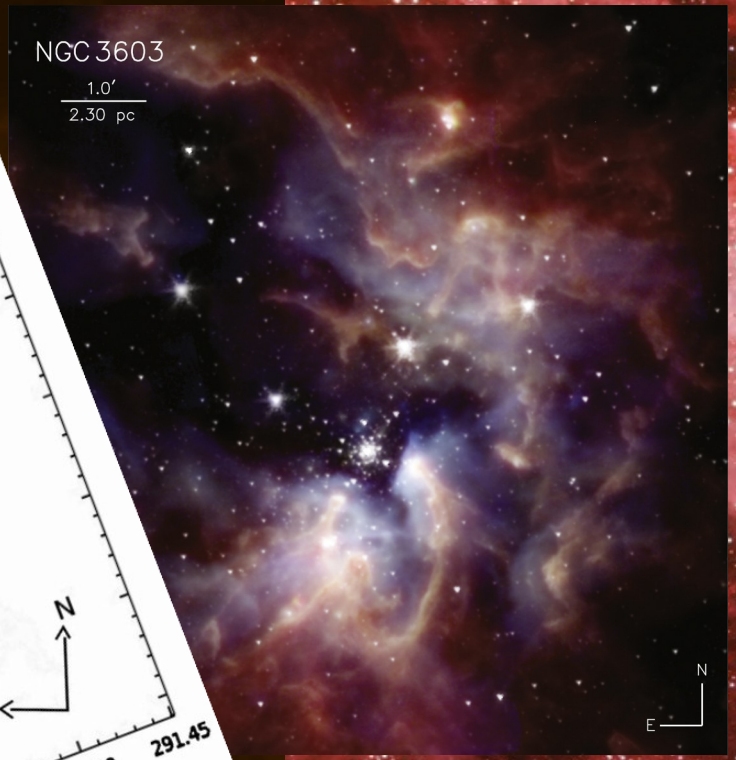


WISE 12μm + Laboca 850μm

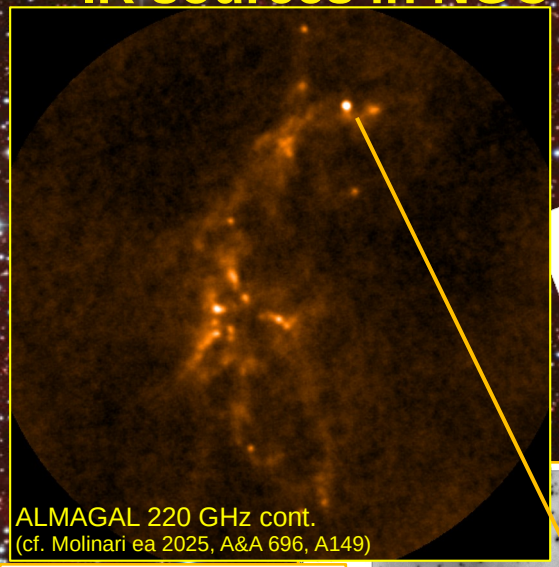
Where are the YSOs?
- IR sources in NGC 3603

Herschel 70μm
(Di Cecco ea 2015)

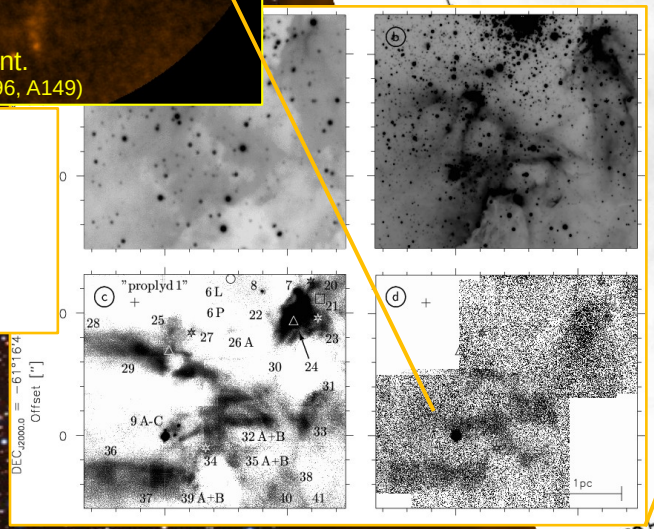


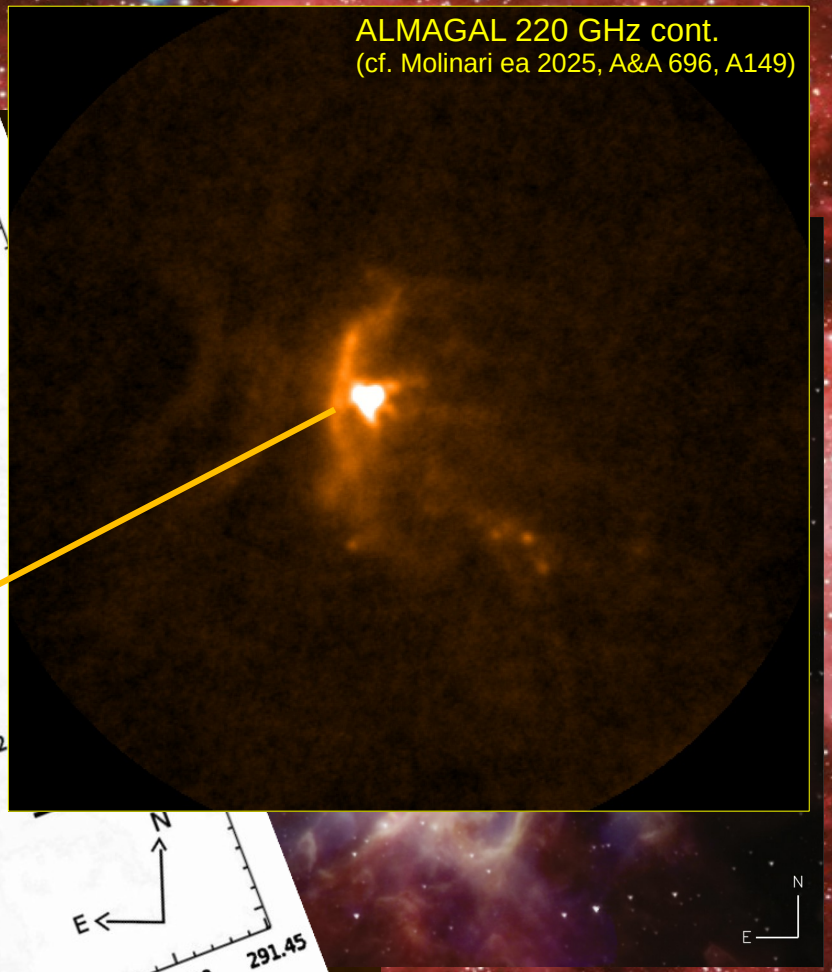


Where are the YSOs?
- IR sources in NGC 3603



IRS 9A (-C -?)
BRIGHT mid-IR
Nürnberger & Stanke 2003, A&A 400,223
Nürnberger 2003, A&A 404, 255





Summary:

- *Massive* young clusters *radiatively* heat dense gas on pc scales
- Massive young clusters don't do much for turbulence (on pc scales – outflows more important)?
  Turbulence decaying quickly in warm compressed regions?
- Triggered star formation in NGC3603: definitely maybe (not?)