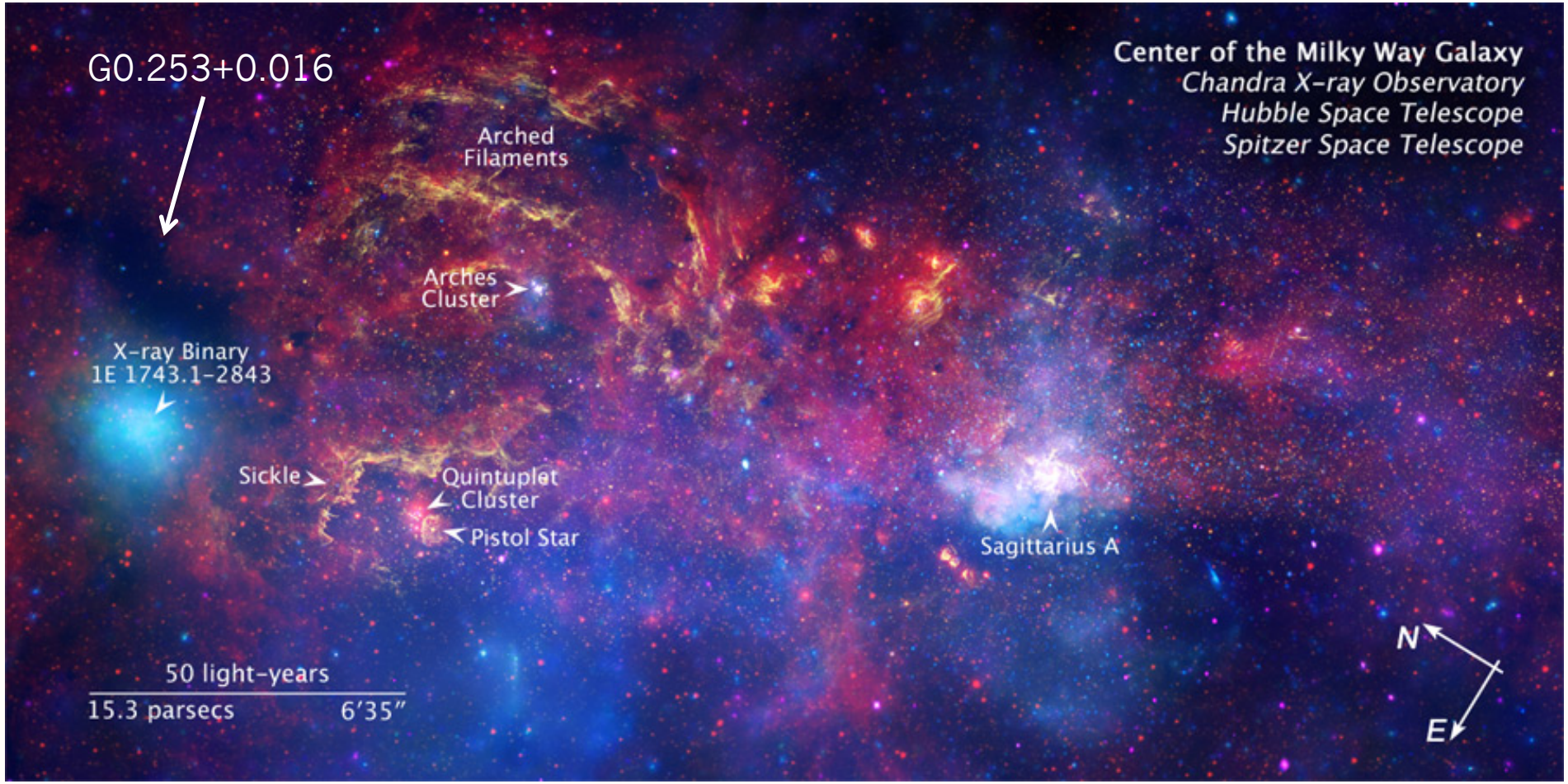
The dynamics and star-forming potential of the massive Galactic centre cloud G0.253+0.016

Katharine Johnston
MPIA, Heidelberg

Collaborators:
Henrik Beuther, Hendrik Linz, Anika Schmiedeke, Sarah Ragan and Thomas Henning

The Galactic Centre Infrared Dark Cloud G0.253+0.016



Credit: Hubblesite

The Galactic Centre Infrared Dark Cloud G0.253+0.016

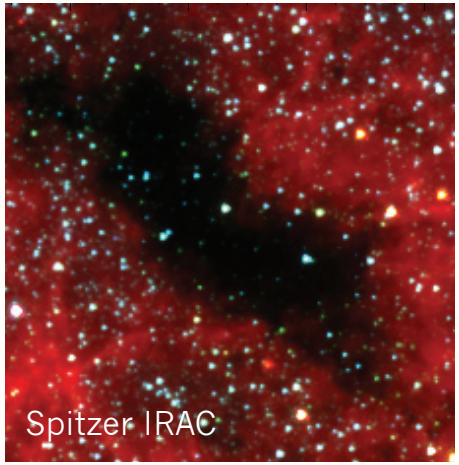
Projected 45pc from the Galactic Centre

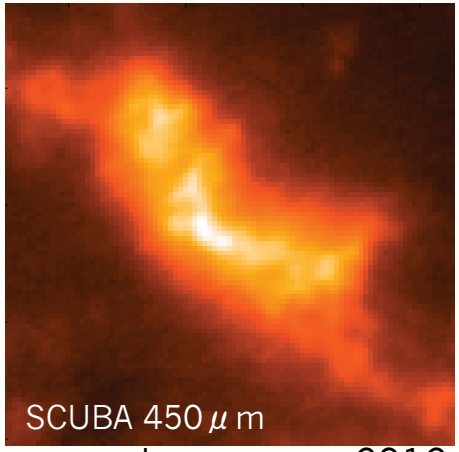
Cold dust temperature: ~18 – 30 K

Dense: 2×10^4 – 6×10^5 cm^{-3}

High mass: 0.8 – 7 $\times 10^5$ M_{sun}

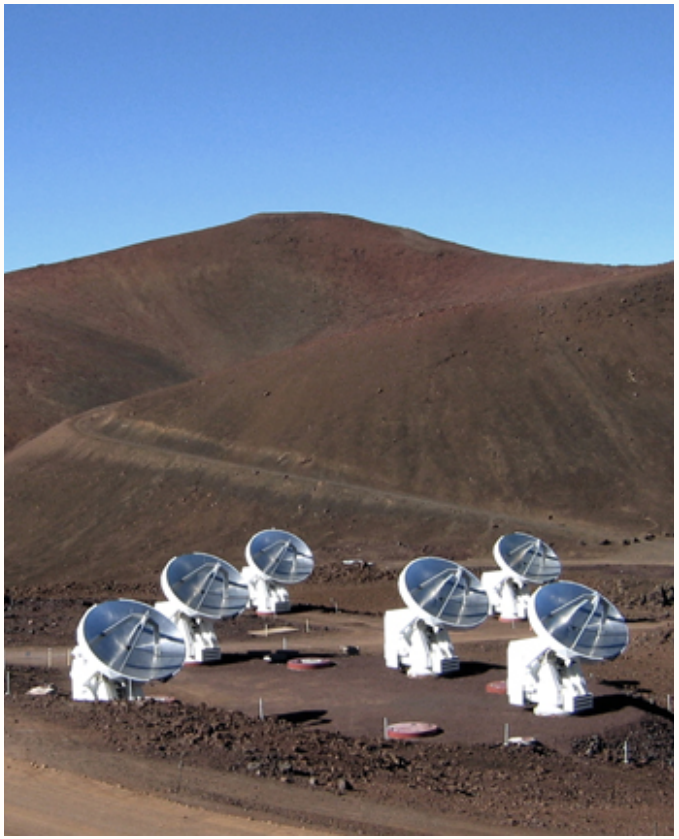
However... minimal evidence for ongoing star formation





Longmore+ 2012

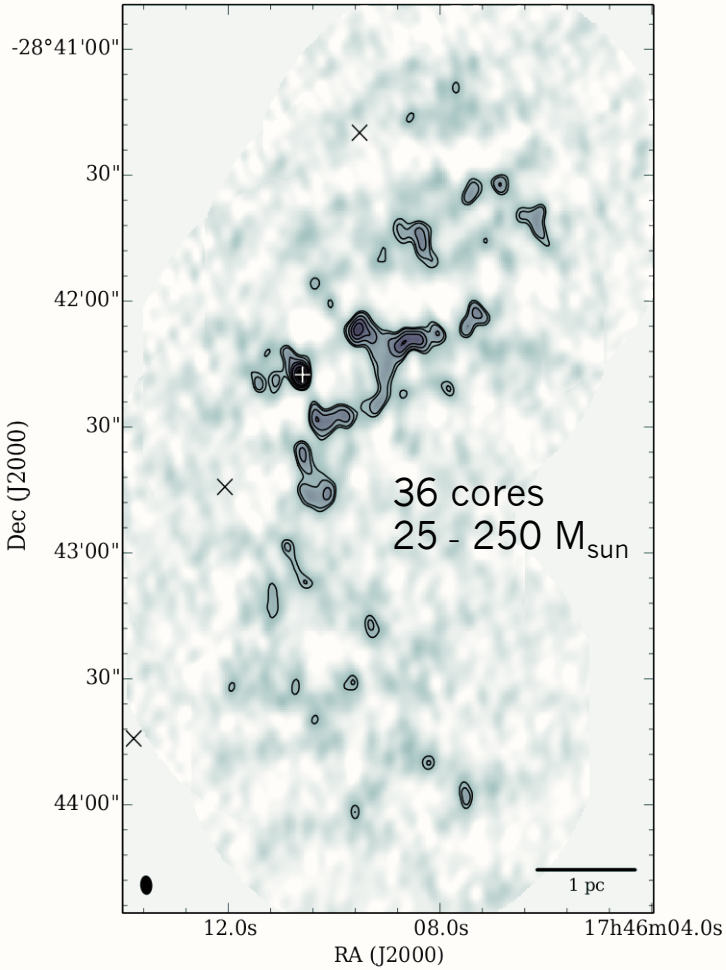
SMA and IRAM 30m Observations



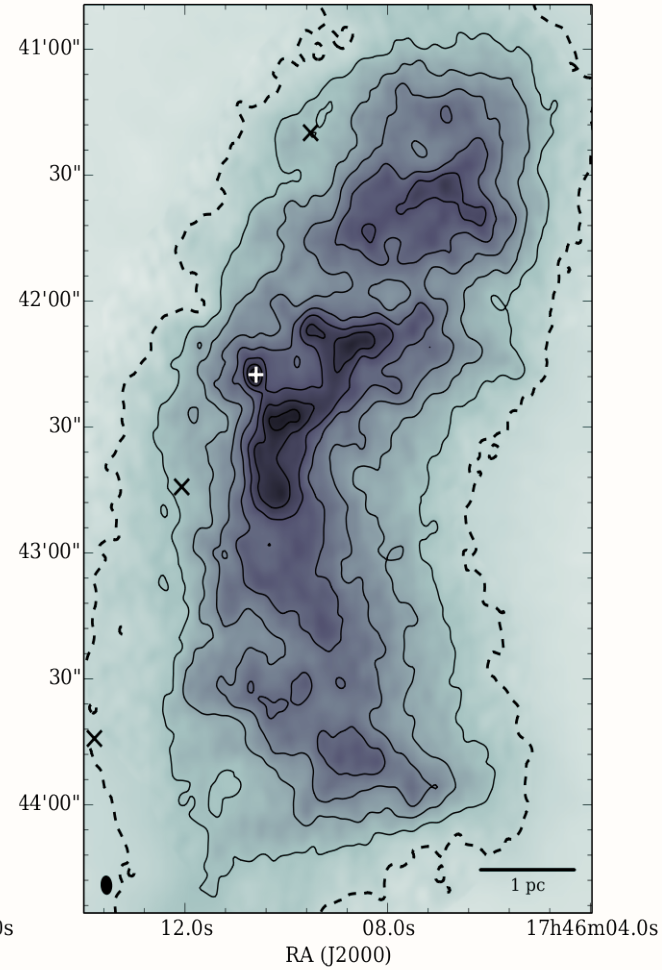
ν ~ 218.9 and 230.9 GHz (1.3 and 1.37mm)
Angular resolution ~4 x 3" (~0.15 pc)
Spectral resolution: 1.1 kms^{-1}
Line **and** Continuum observations

ν ~ 217.3 and 233.0 GHz
Angular resolution ~12" (~0.5 pc)
Spectral resolution: 0.3 kms^{-1}
Line observations

The density structure of G0.253+0.016

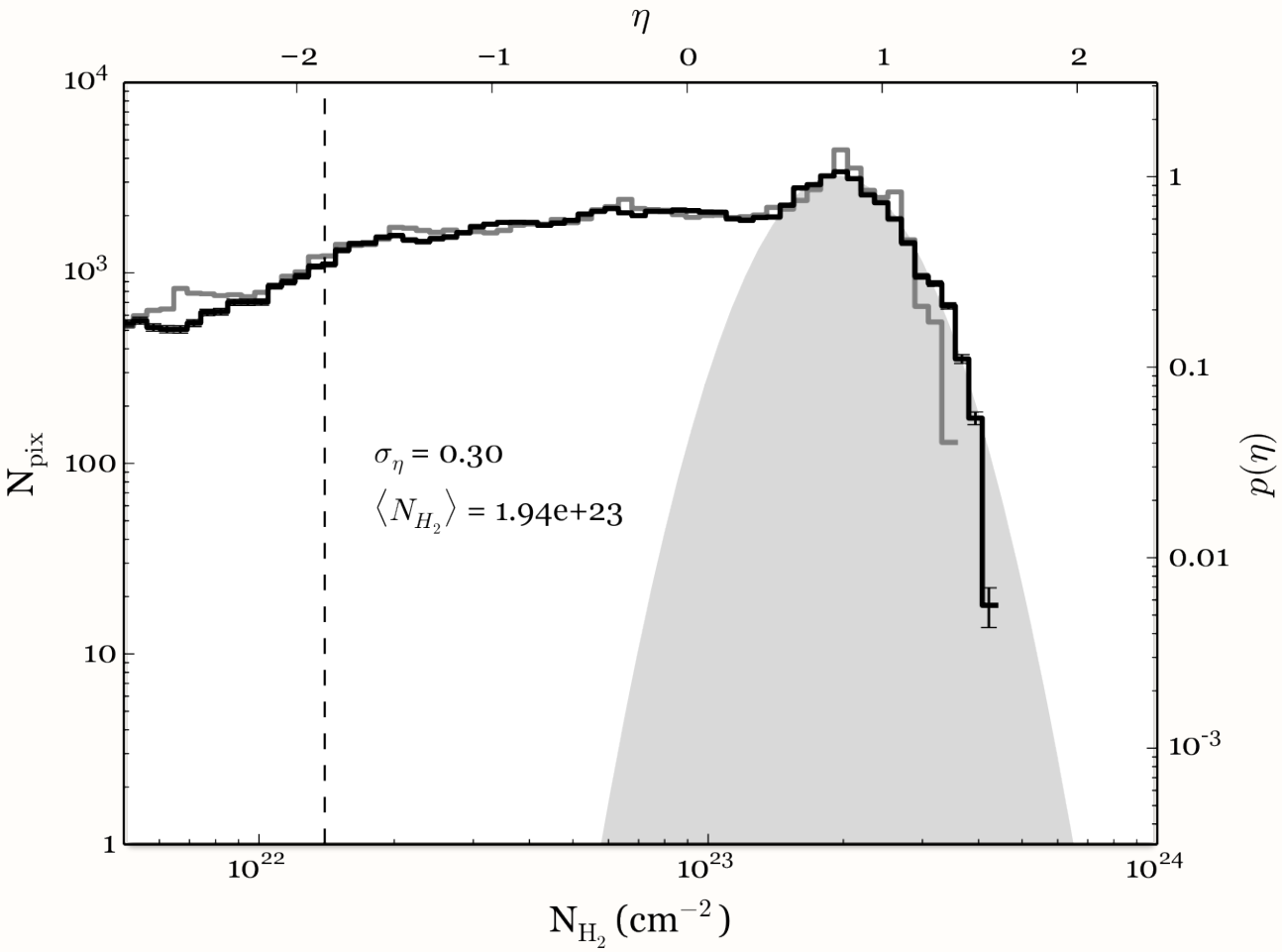


SMA 230.9 GHz or 1.3mm dust continuum emission



Combined SMA and scaled SCUBA 450 μm dust emission

Column density PDF



PDF has no power-law tail

No indication of gravitational collapse or star formation

Column density threshold for star formation

Is there a density threshold for star formation which applies to all clouds?

(e.g. Lada+2010, Heiderman+2010)

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G0.253+0.016 should produce ~40 YSOs with >15 M_{sun} which are not observed

(see Kauffmann+2013)

Can turbulence explain SFR~0?

Virial Mass: $M_{\rm vir} = \frac{5R\sigma_v^2}{G\alpha_{\rm vir}}$

For a bound cloud or core with radius R:

$$N_{th} \propto M_{vir}/R^2 \propto \sigma_v^2$$

Can turbulence explain SFR~0?

Scaled threshold column density by ratio of σ_v^2:

$$N'_{th} = N_{th}\left(\frac{\sigma_{\rm Brick}}{\sigma_{\rm Gal.disk}}\right)^2$$

14 km/s

2.5 km/s

$$\boxed{N'_{th} = 0.75\ g\ cm^{-2}}$$

But still expect 10 YSOs >15 M_{sun}!

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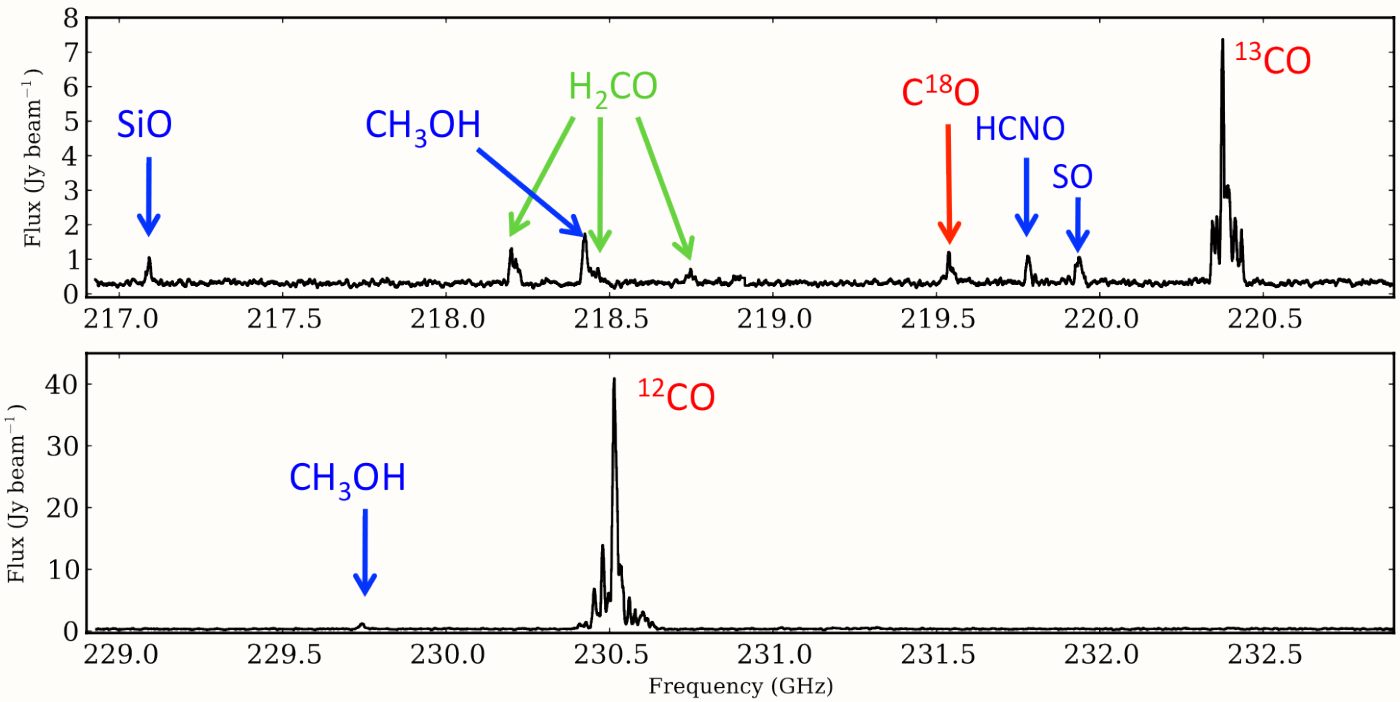
Other aspects… background/average density, evolution?

SMA Detected Lines



Detected lines:

SiO, CH_3OH, HNCO, SO – Shock tracers

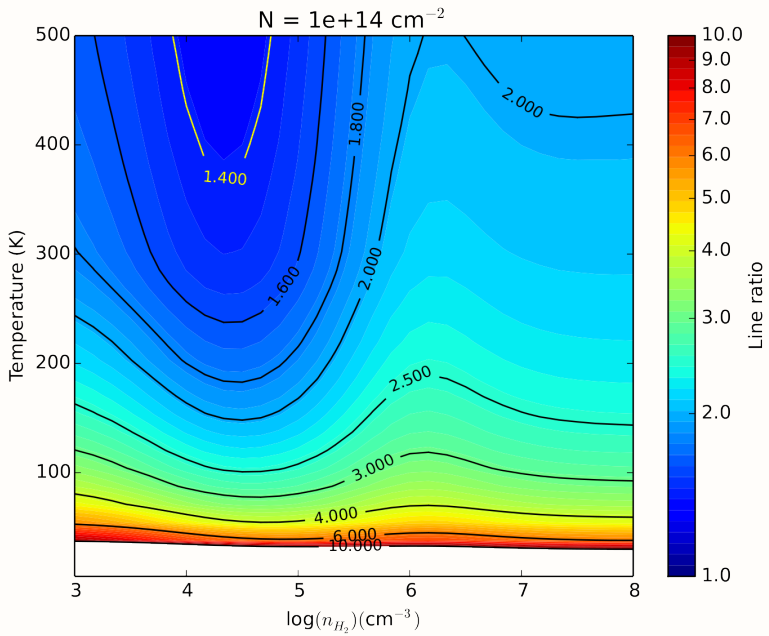
^{12}CO, ^{13}CO, $C^{18}O$ – Diffuse gas tracers

H_2CO – Dense gas tracer, temperature probe

Temperature from H_2CO

Ratio between integrated flux:
H_2CO $3_{03} \rightarrow 2_{02}$ / $3_{21} \rightarrow 2_{20}$

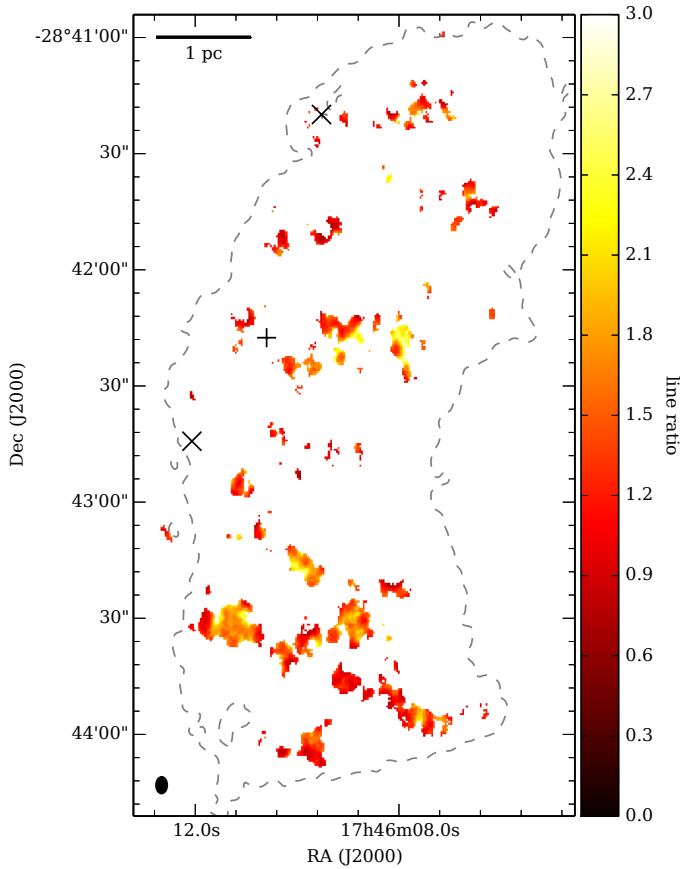
$N(H_2) \sim 10^{23}\ cm^{-2}$ $X(H_2CO) \sim 10^{-9}$



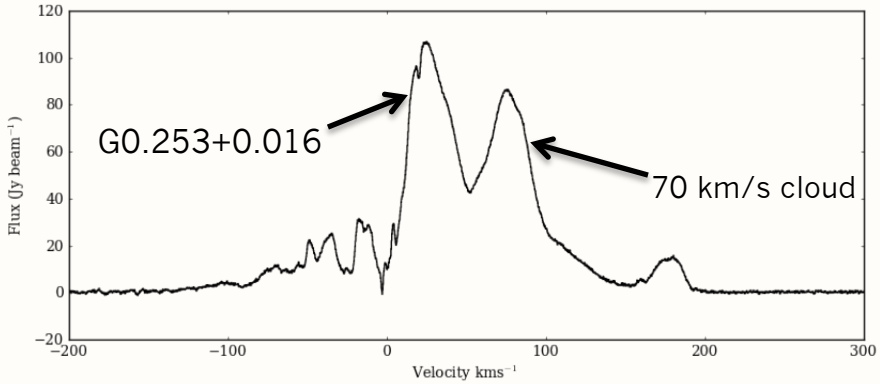
$n \sim 10^4 - 10^5\ cm^{-3}$ **T ~ 100s of K**

(see Mills & Morris 2013 and Rodriguez-Fernandez+2001)

Average line ratio : 1.4
Corresponding to: $T_K > 320$ K



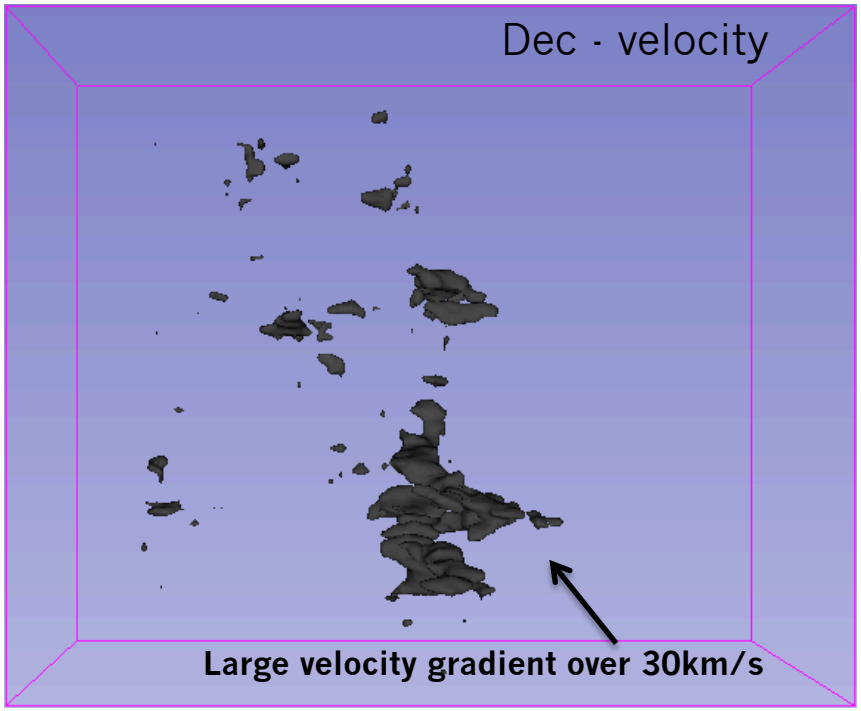
Evidence for Cloud Collisions



IRAM 30m ^{12}CO

Black: CH_3OH

Green: ^{13}CO



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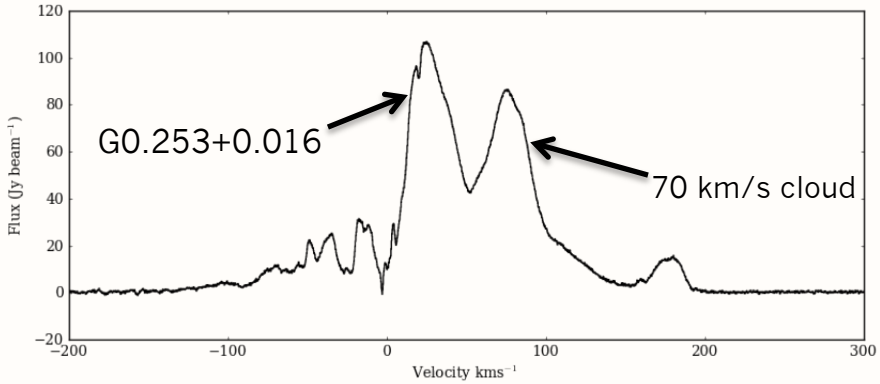

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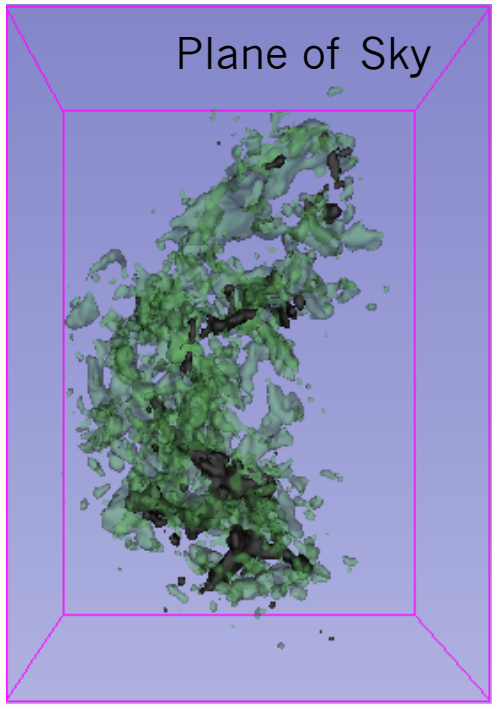

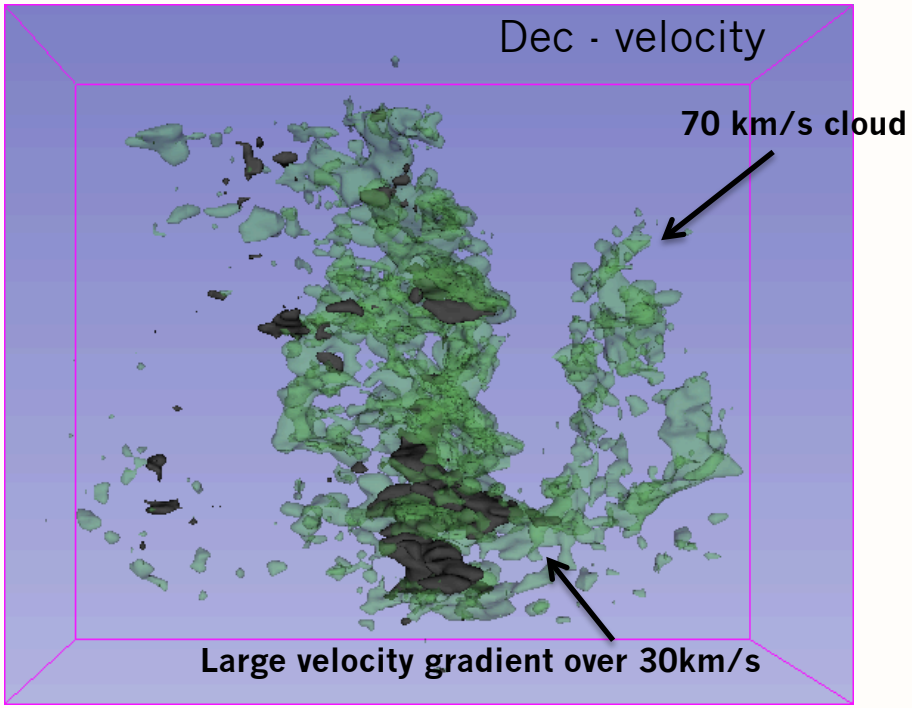

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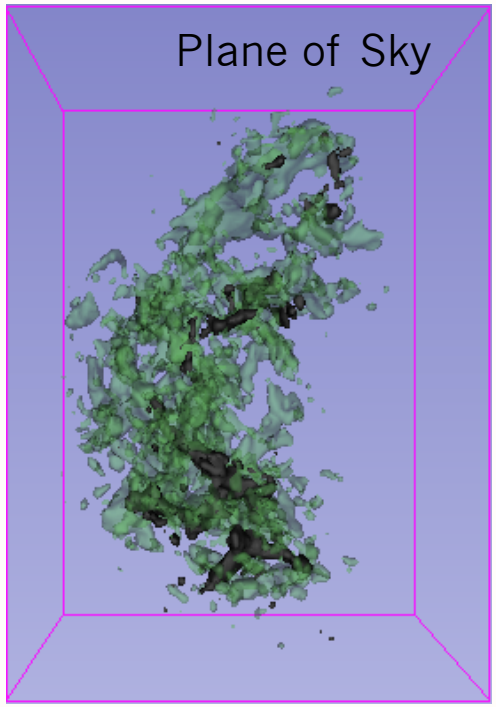
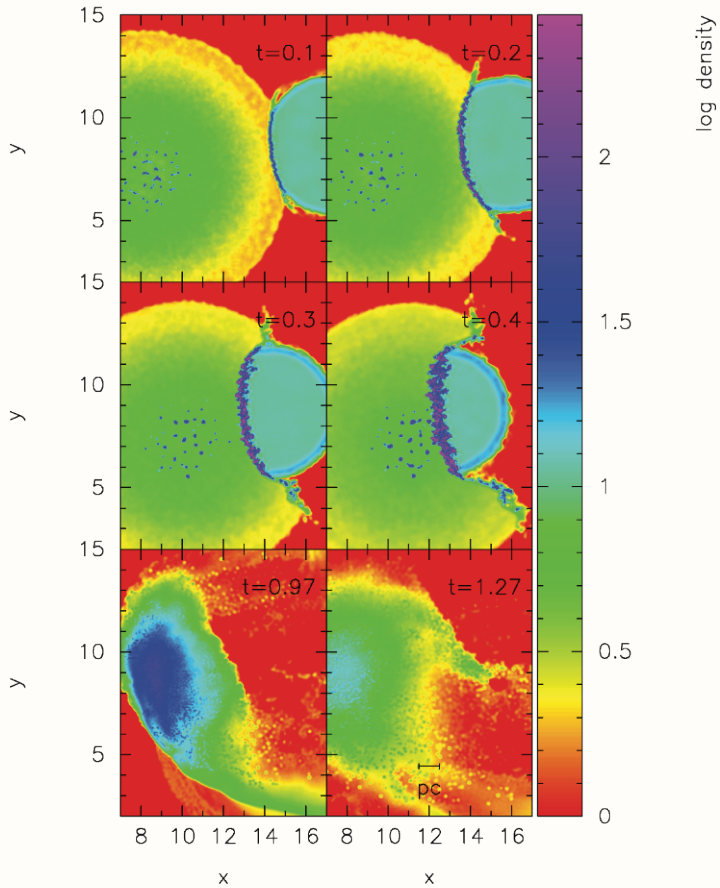


Are super star clusters formed by cloud collisions?
(Fukui+ 2013, Higuchi+2014)



Anathpindika+2011

Conclusions

- Column density PDF has no power-law tail, consistent with no or little star formation
- Not one column density threshold for star formation! Increased due to turbulence and background average density
- High gas temperatures on size-scales traced by the SMA beam (~0.15 pc)
- Evidence for cloud collision with another cloud at 70 kms^{-1}

See our paper on astro-ph!
arXiv:1404.1372

Column density PDF

$$\sigma_s^2 = \ln\left[1 + b^2 \mathcal{M}_s^2 \, \beta/(\beta + 1)\right]$$

Dispersion in the 3D density PDF
(Padoan & Nordlund 2011, Molina+ 2012)

b - ratio of compressive to total power in the turbulent driving (=0.4)

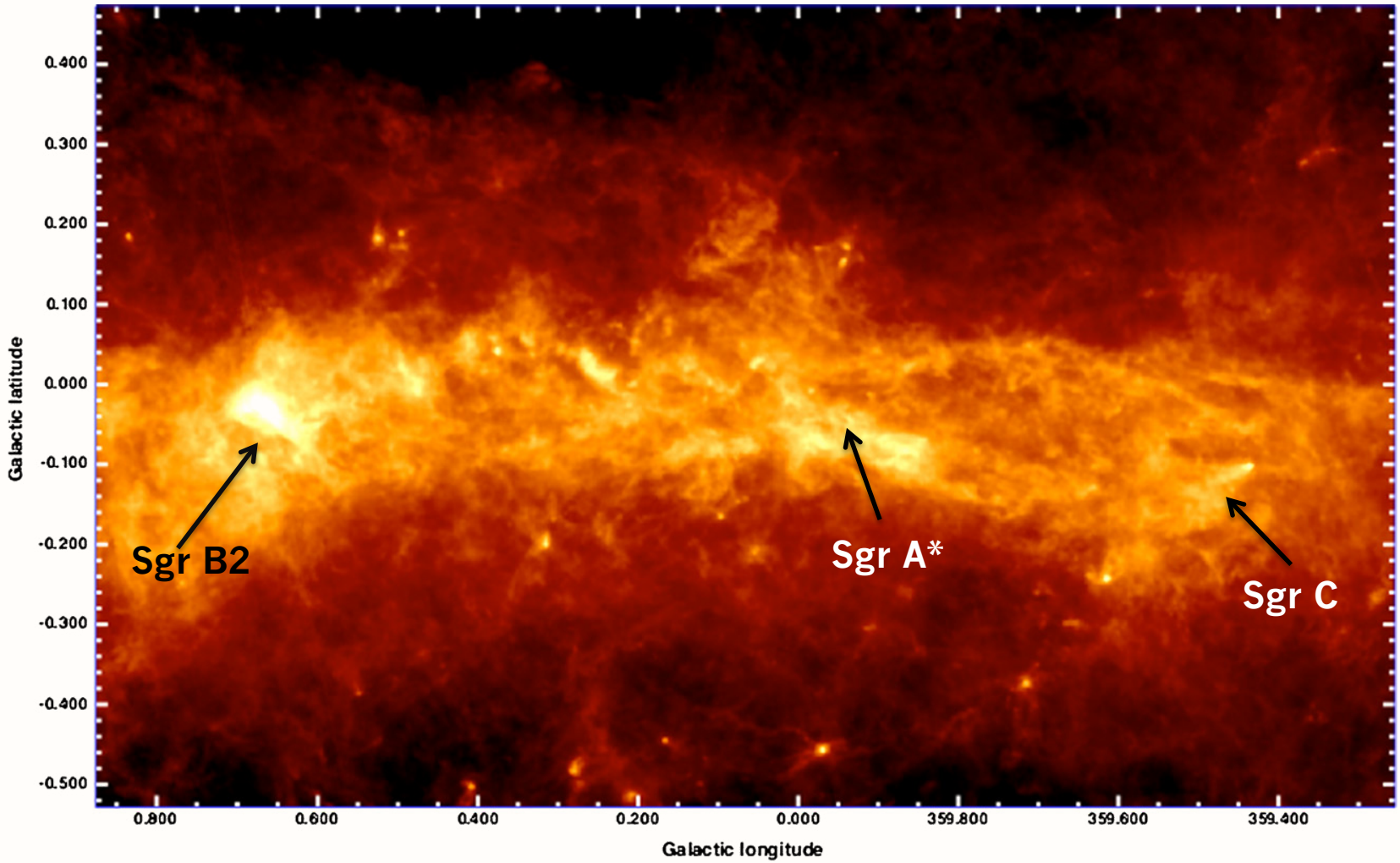
M_s - Mach number (=7.6)

β - ratio of gas to magnetic pressure ($\beta = 8\pi\rho c_s^2/B^2$)

$\sigma_s = \xi\sigma_\eta \qquad \xi = 2.7 \pm 0.5$ *(Brunt+2010)*

For σ_η = 0.30, B = 0.5 mG required to produce the observed PDF
Measured value: 0.1 mG to a few mG (Ferrière +09)

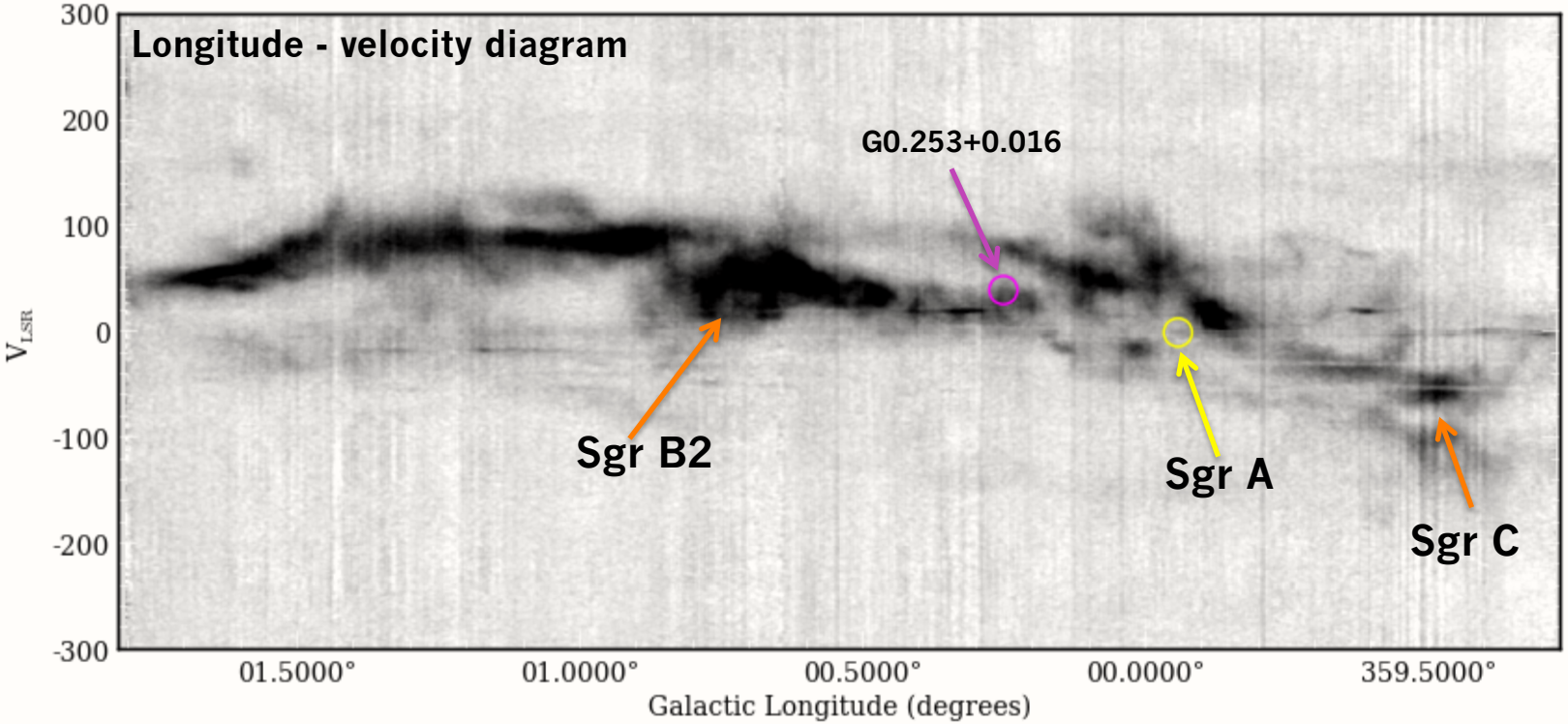
The Galactic Centre Environment



Herschel SPIRE 250μm image of the Galactic center region (Molinari+2011)

The Galactic Centre Environment

HNC from MOPRA 3mm survey of Central Molecular Zone (Jones+ 2012)



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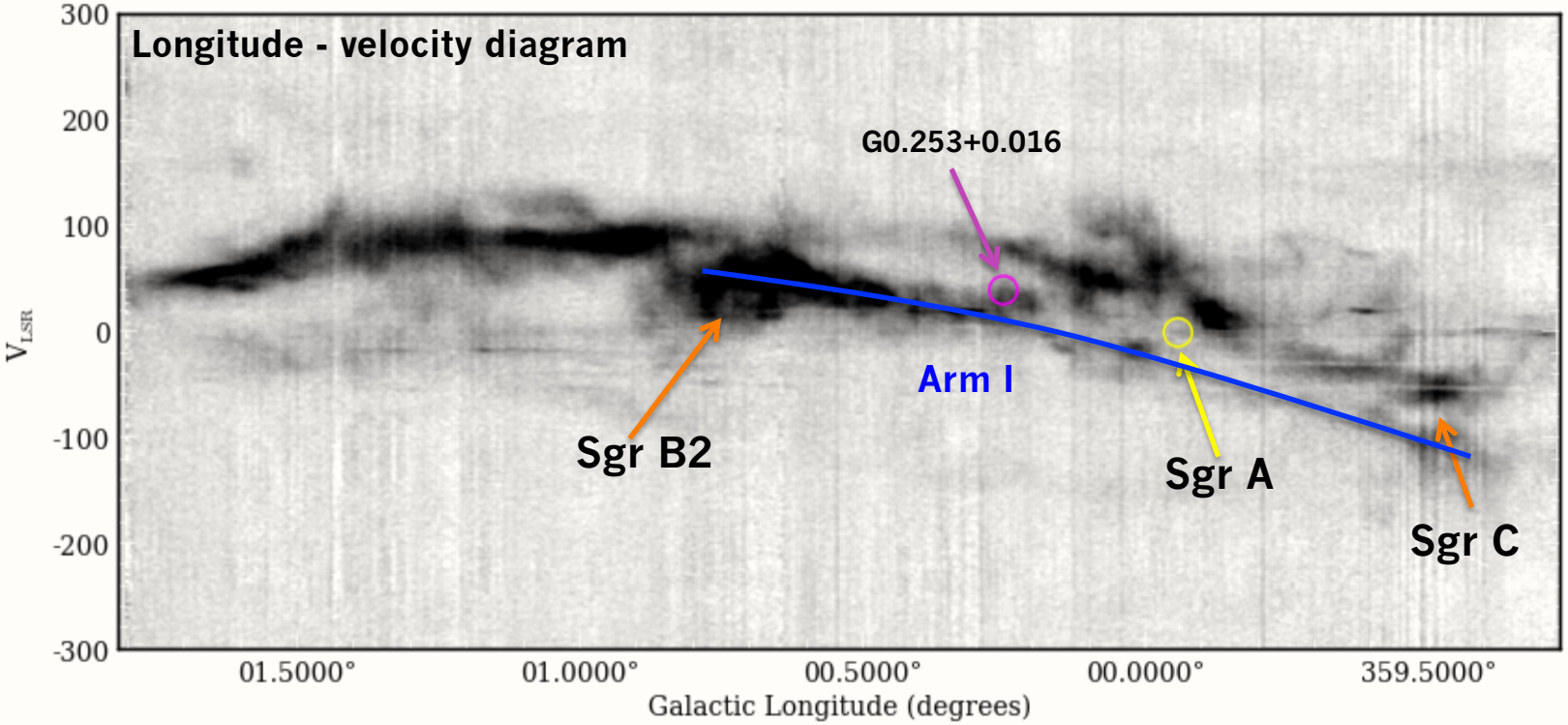

(Arm I and Arm II originally shown in Sofue+ 1995)

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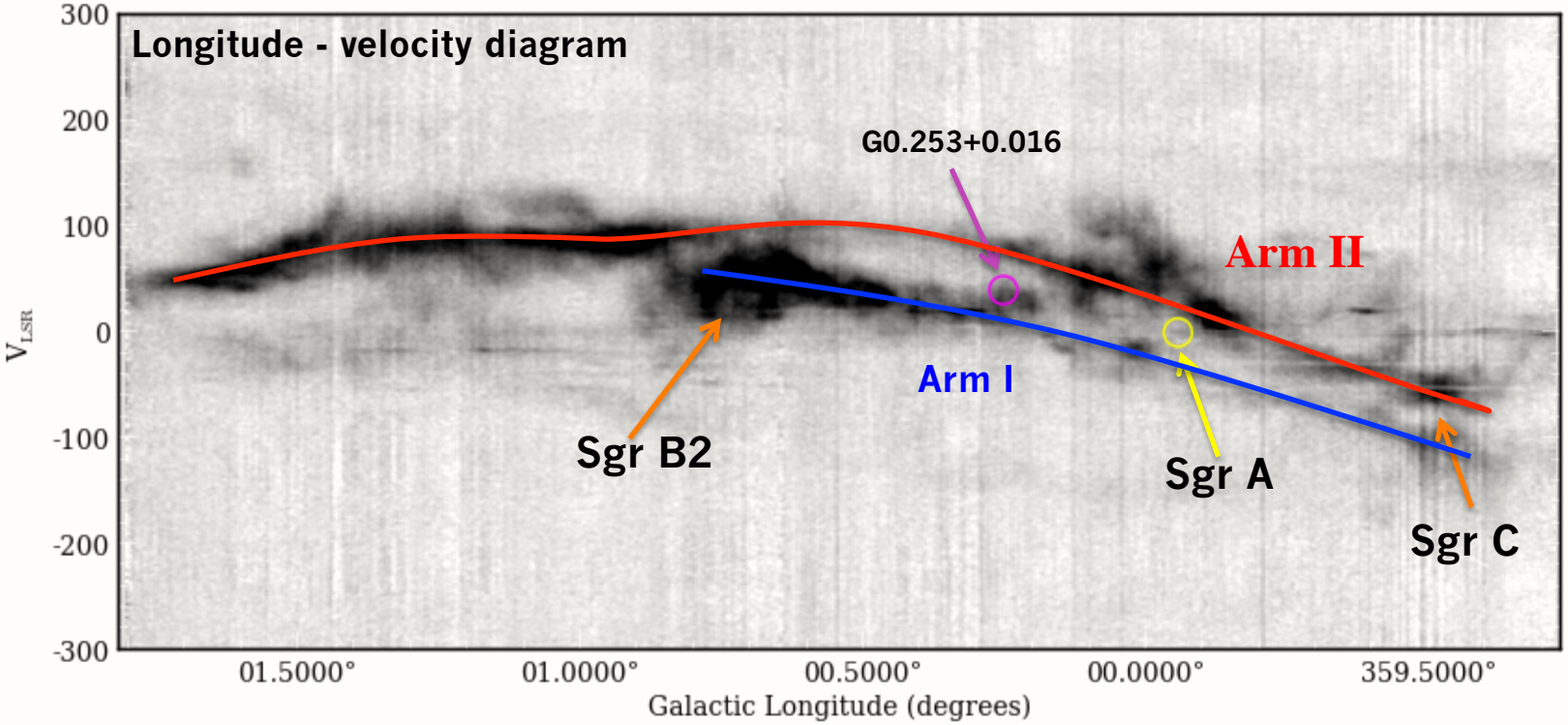

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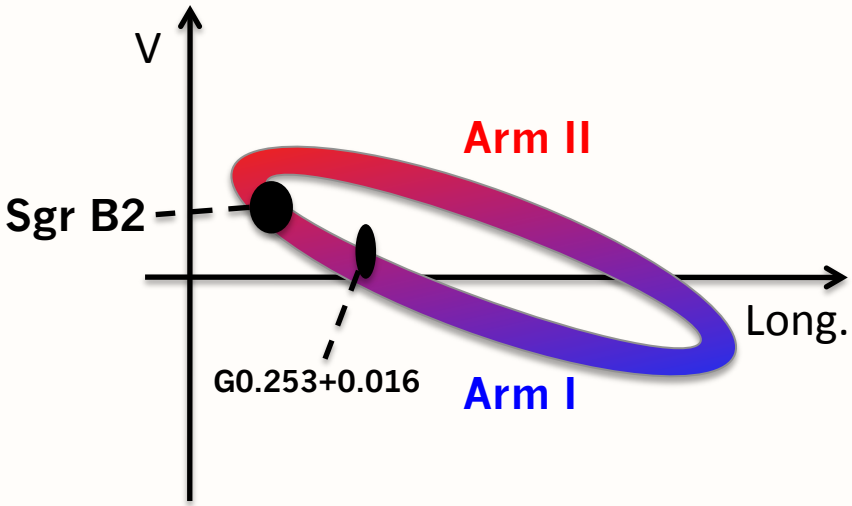

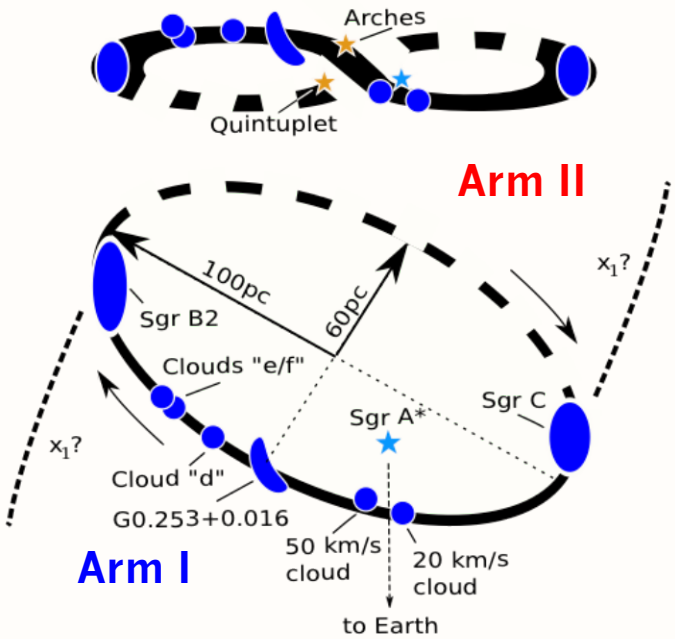

Molinari+ 2011, figure from Kruijssen+ 2013

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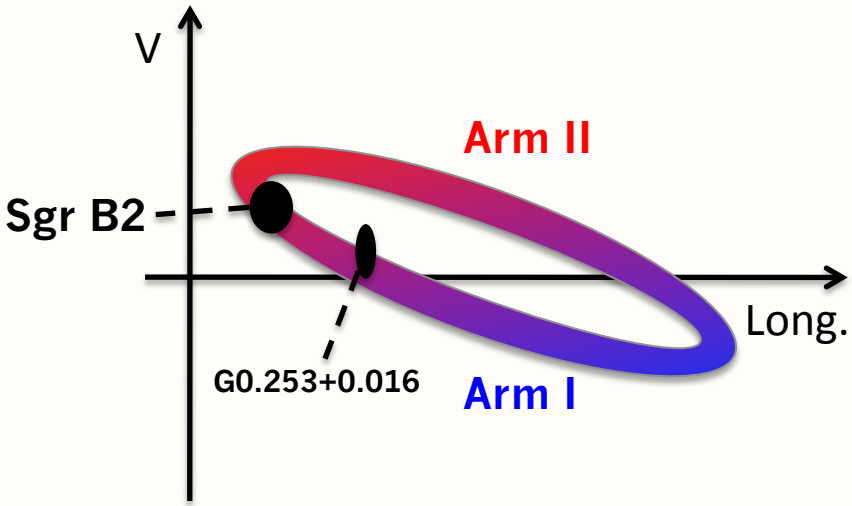

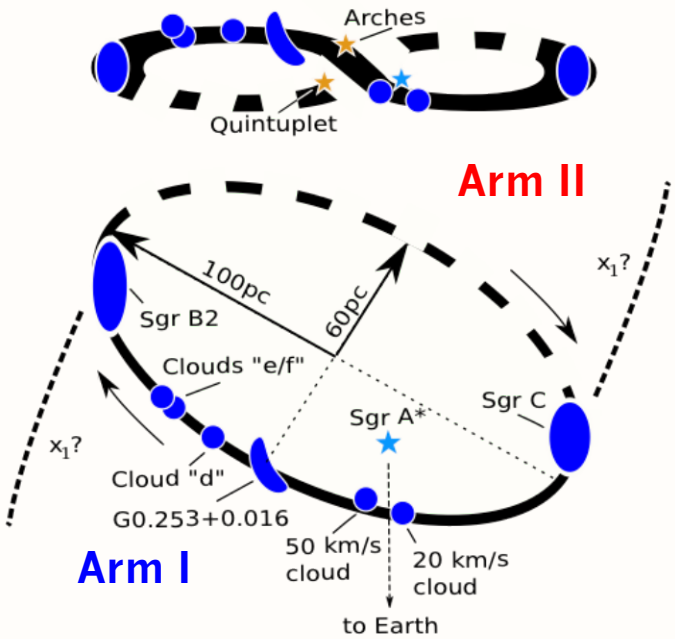

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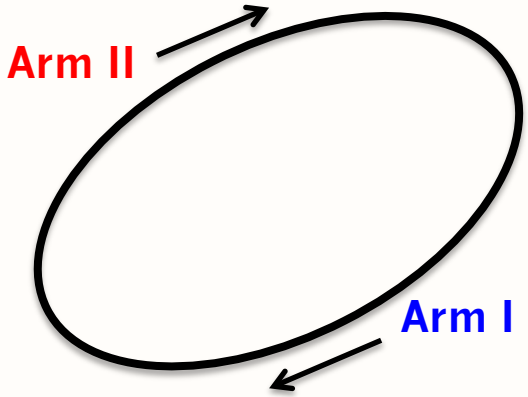
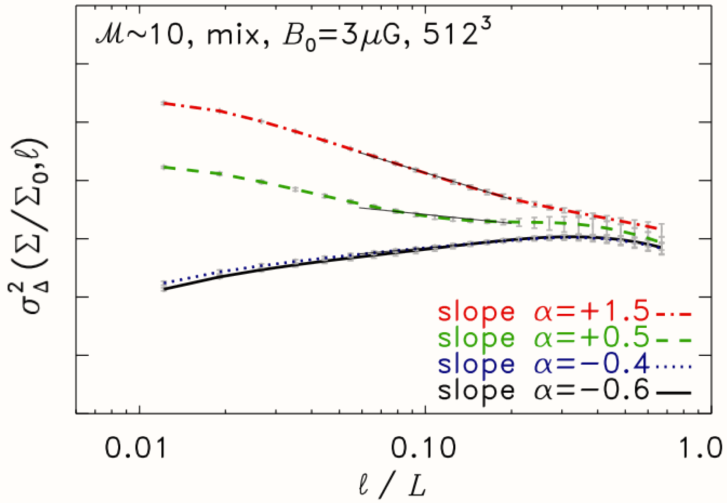


Sawada+ 2004: CO & OH, 70° wrt line of sight
Reid+ 2009: Trig. Parallax
Ryu et al. 2009: X-ray light echo

Δ - variance Spectrum

Theory (simulation)

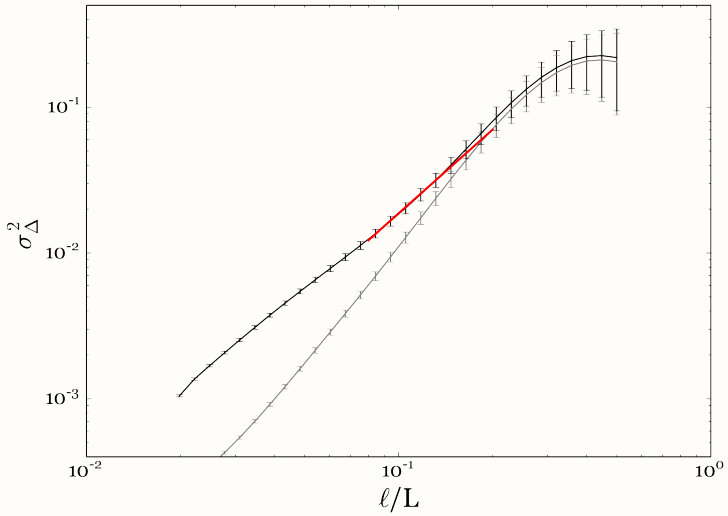


SFE=20%
SFE= 5%
SFE= 0%
t=0 t_{ff}

Increasing α for higher SFE

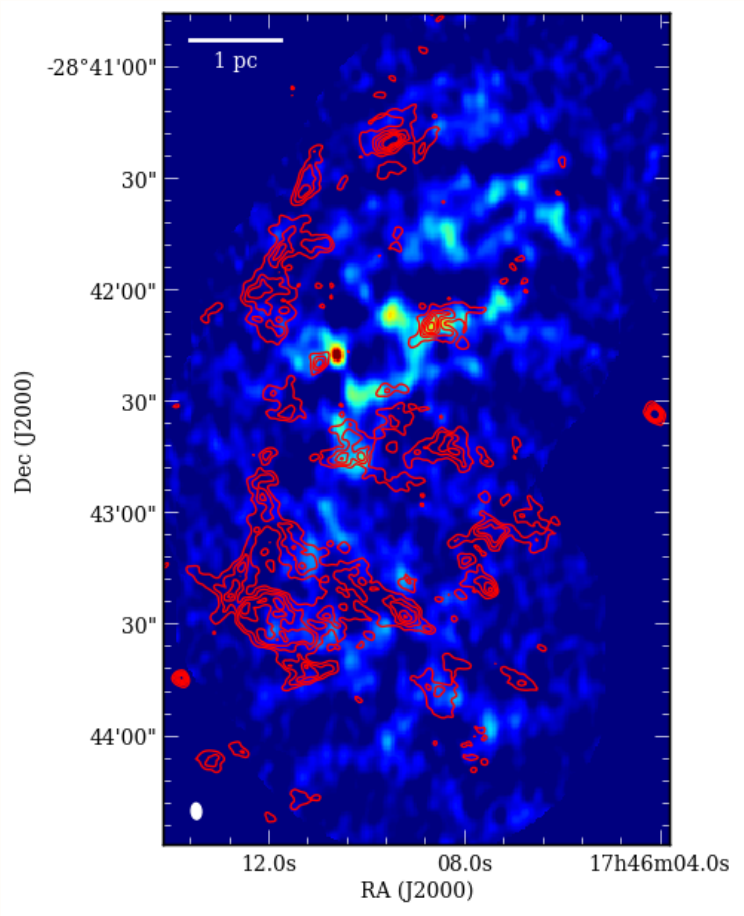
(Federrath+2013)

Observation

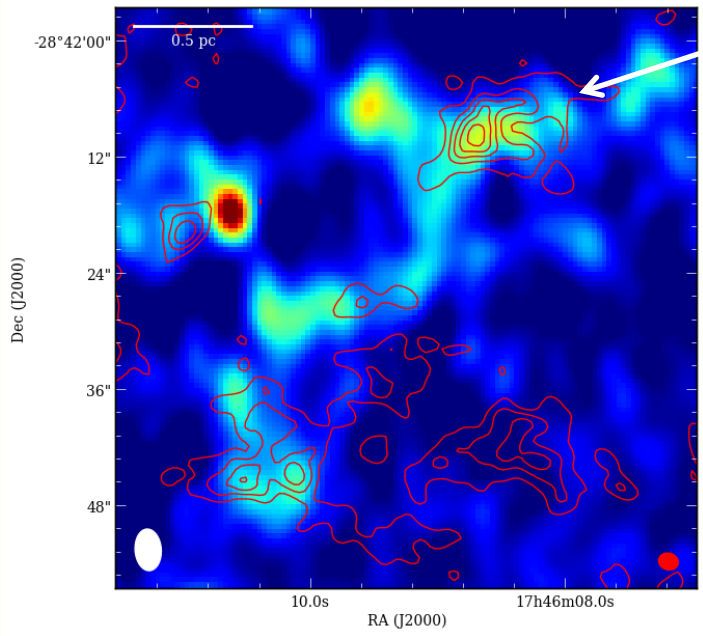


Grey line: SCUBA-only
Black line: combined SMA+SCUBA
Red line: fit to combined SMA+SCUBA Δ-variance
Slope: 1.91 ± 0.04
(corresponding to: $\boldsymbol{\alpha = -1.91 \pm 0.04}$)

Massive star formation in the Brick?



Colourscale: SMA 1.3mm continuum
Red contours: 25 GHz continuum
(Mills+ in prep.)



Early B-star?

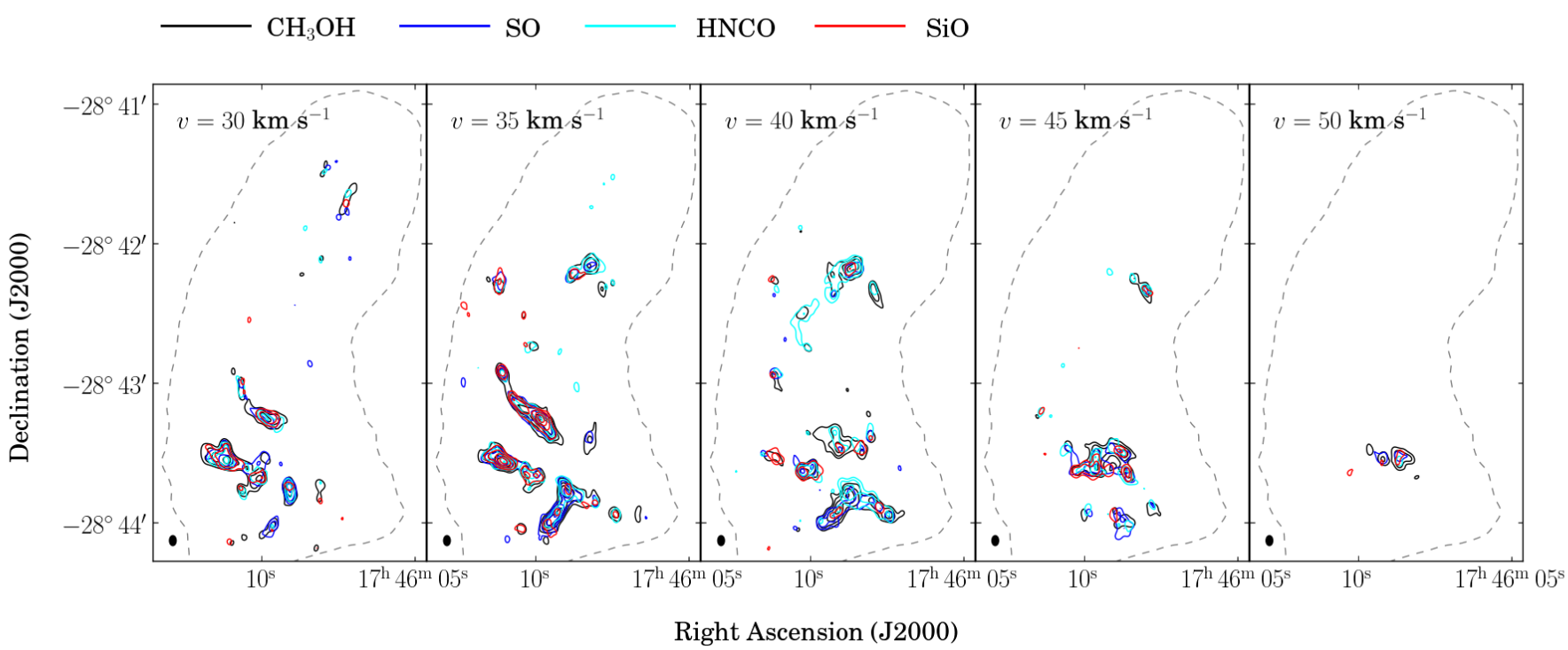
The brightest source at 25 GHz has F_{peak}~0.13 mJy/beam and has a flat spectrum.

F_{peak} (dust, 1.3mm) ~ 120 mJy/beam.

Therefore the extrapolated ionized gas emission does not contribute significantly to the flux of this source at 1.3 mm

Evidence for Cloud Collisions

Shock tracers



Similar distribution to collisionally excited CH_3OH masers at 36 GHz (Mills + in prep.)

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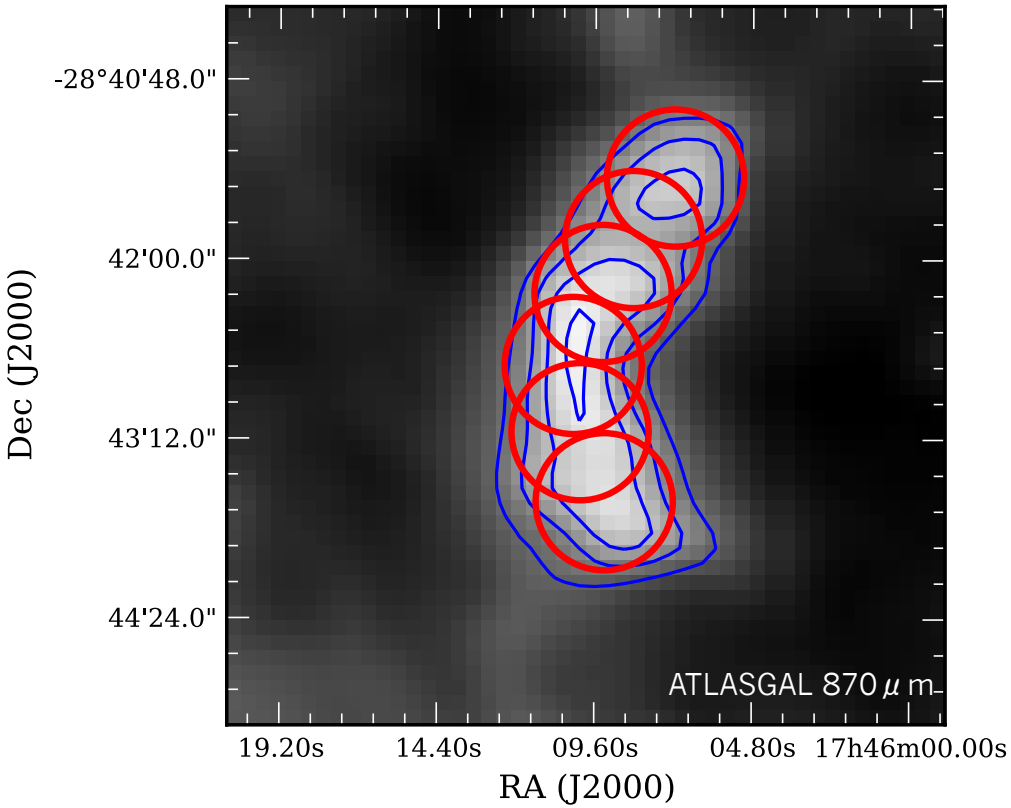

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