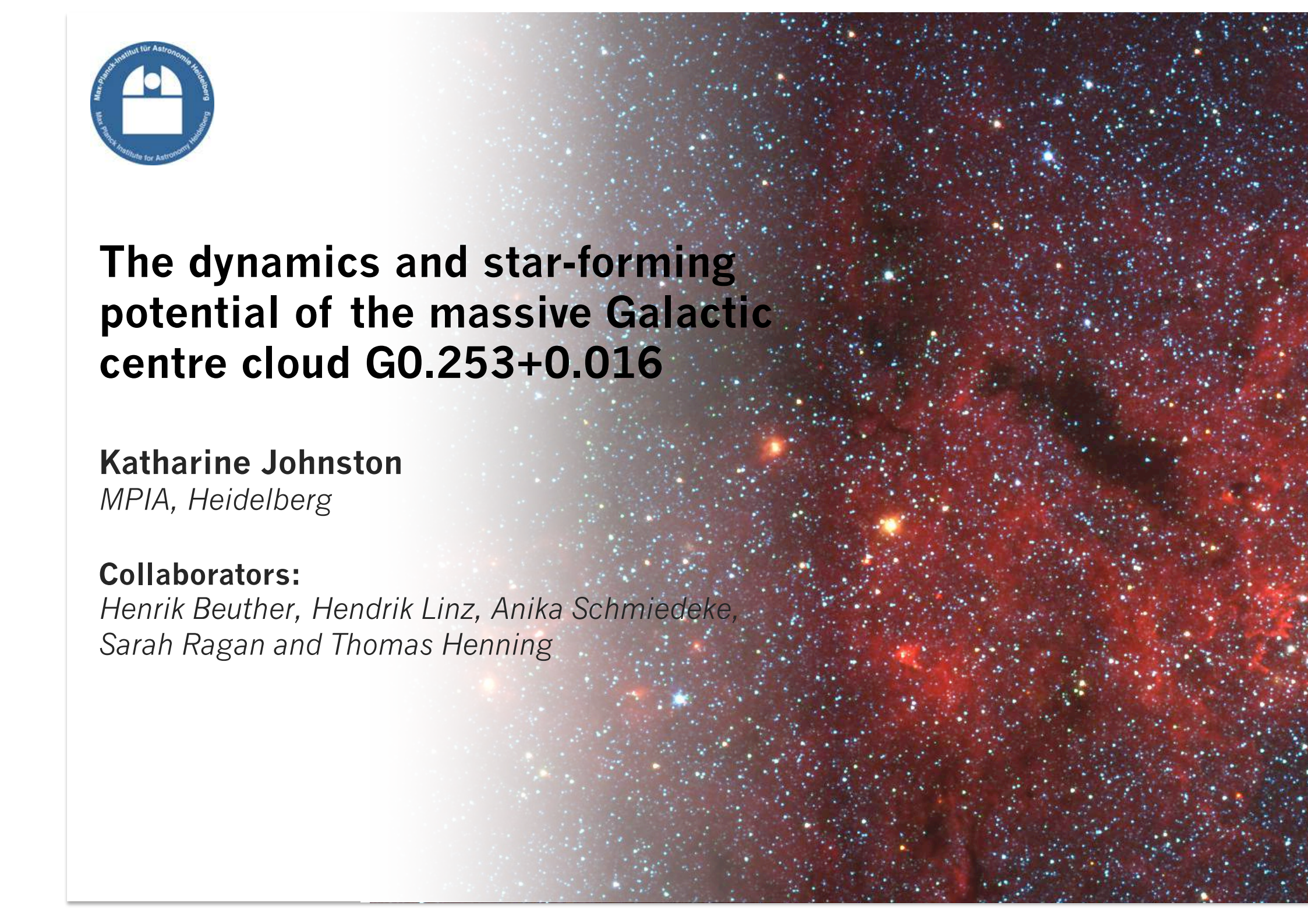
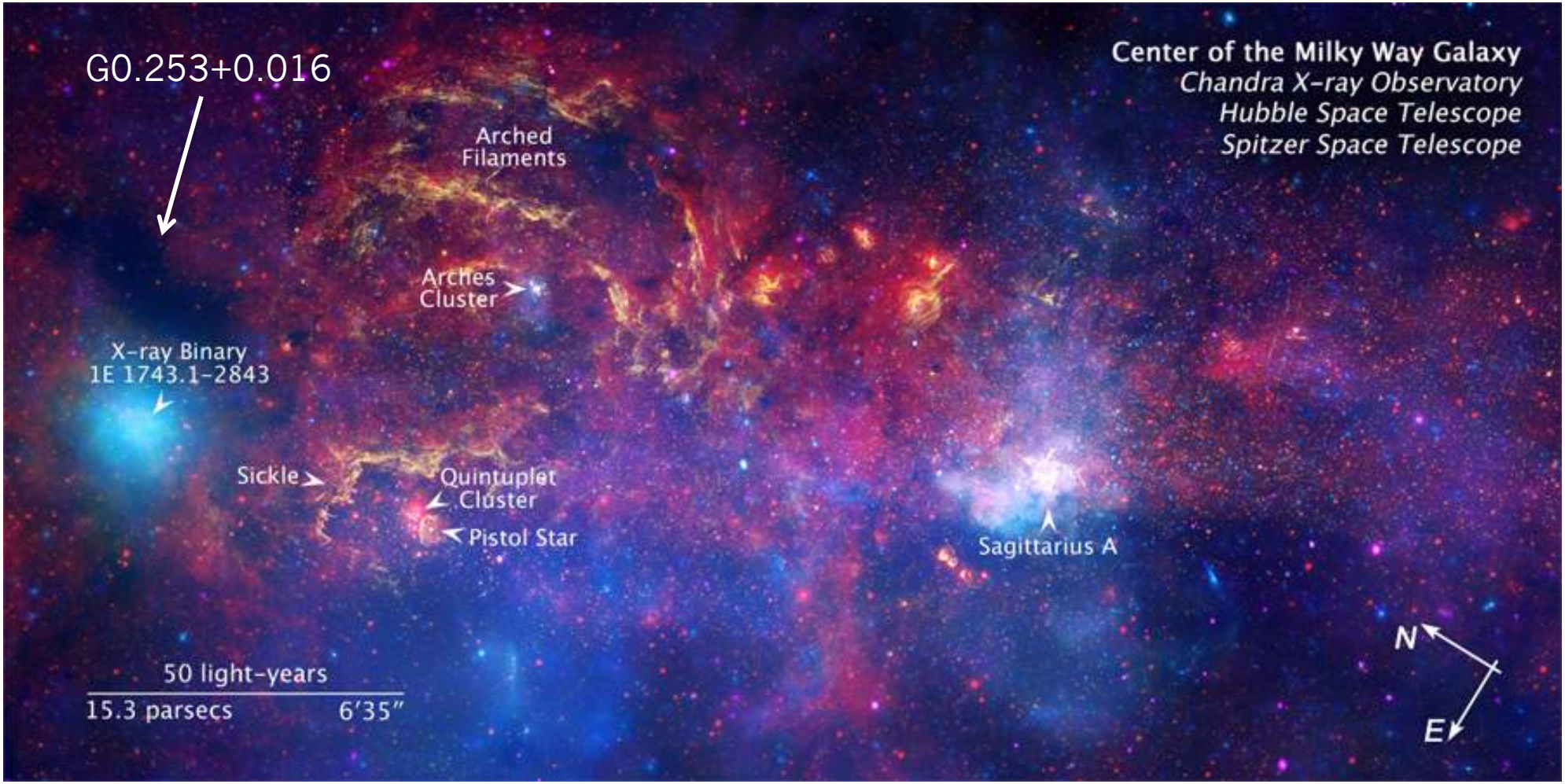


The dynamics and star-forming potential of the massive Galactic centre cloud G0.253+0.016

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 x 10^4 – 6 x 10^5 cm^{-3}

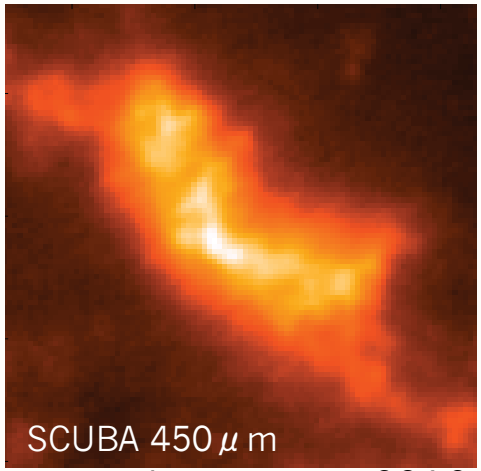
High mass: 0.8 – 7 x10^5 M_{sun}

Geometric mean **radius**: 2.8 pc

Peak **column density**: 4.4 x 10^{23} cm^{-2} (H_2)

Linewidths ~ 5 – 20 km/s

(Lis+1994, Lis & Menten+1998, Lis+2001, Longmore+2012, Immer+2012, this work)



Longmore+ 2012

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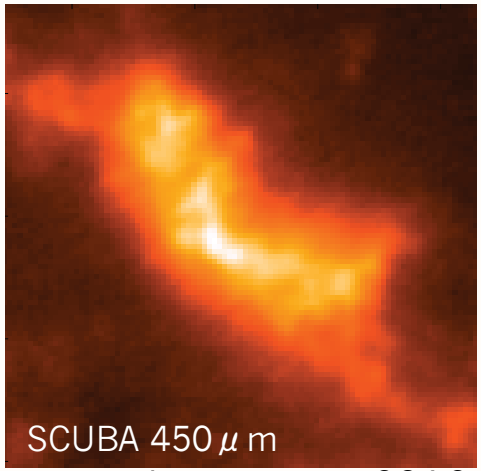
Projected 45pc from the Galactic Centre

Cold dust temperature: ~18 – 30 K

Dense: $2 \times 10^4 - 6 \times 10^5$ cm^{-3}

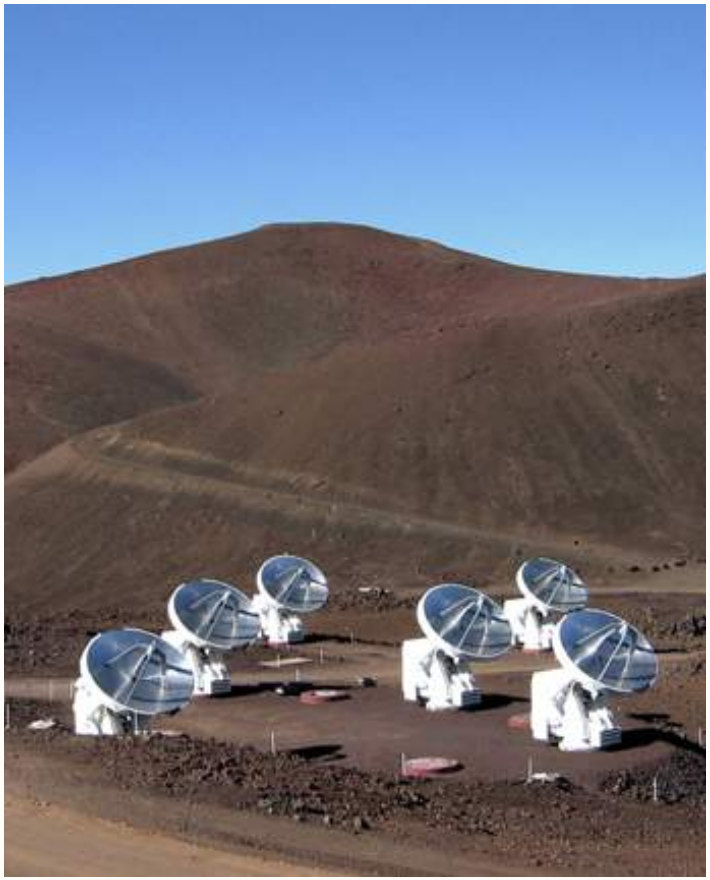
High mass: 0.8 – 7 x10^5 M_{sun}

However… minimal evidence for ongoing star formation



Longmore+ 2012

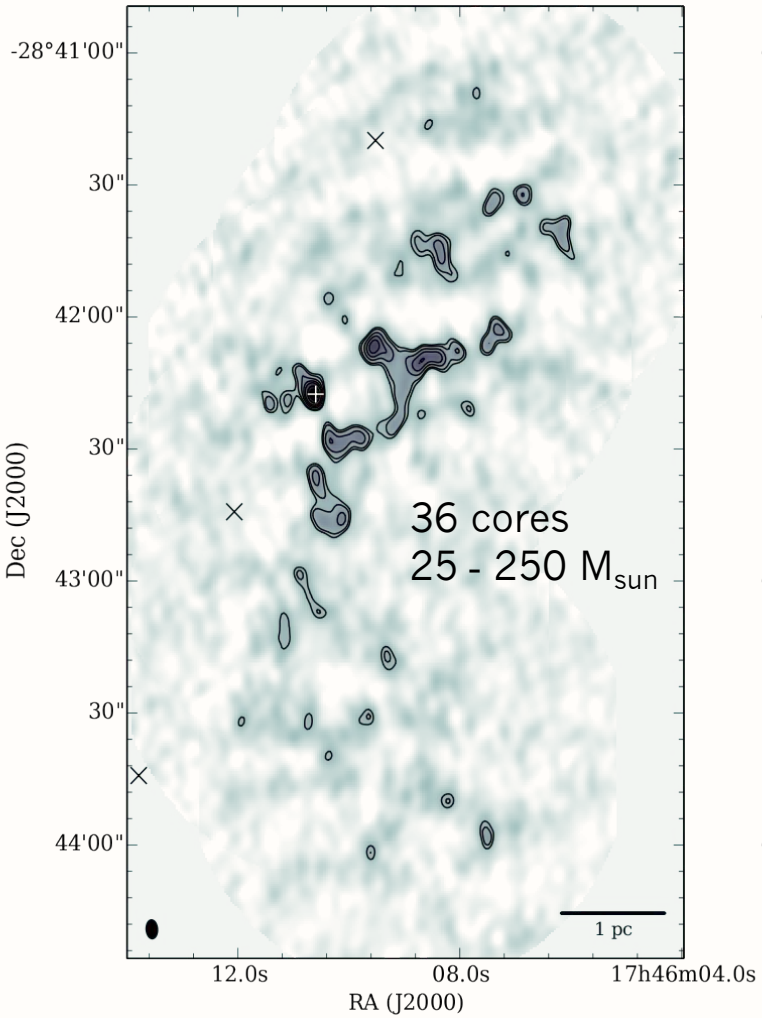
SMA and IRAM 30m Observations



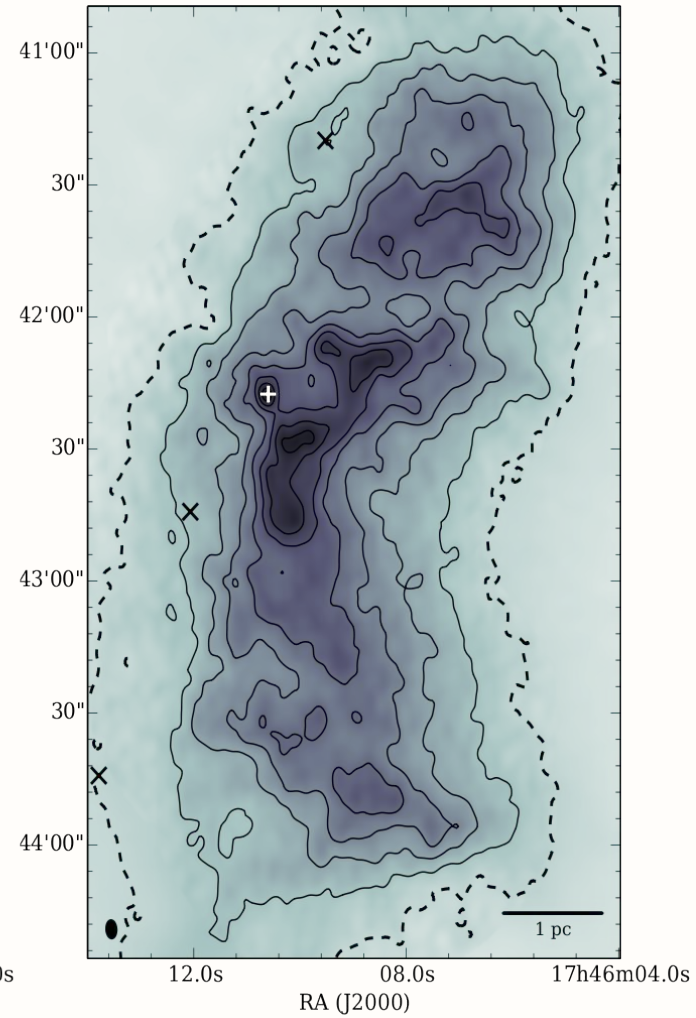
ν ~ 218.9 and 230.9 GHz (1.3 and 1.37mm)
Angular resolution ~4 x 3" (~0.15 pc)
Spectral resolution: 1.1 kms^{-1}
Line **and** Continuum observations

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

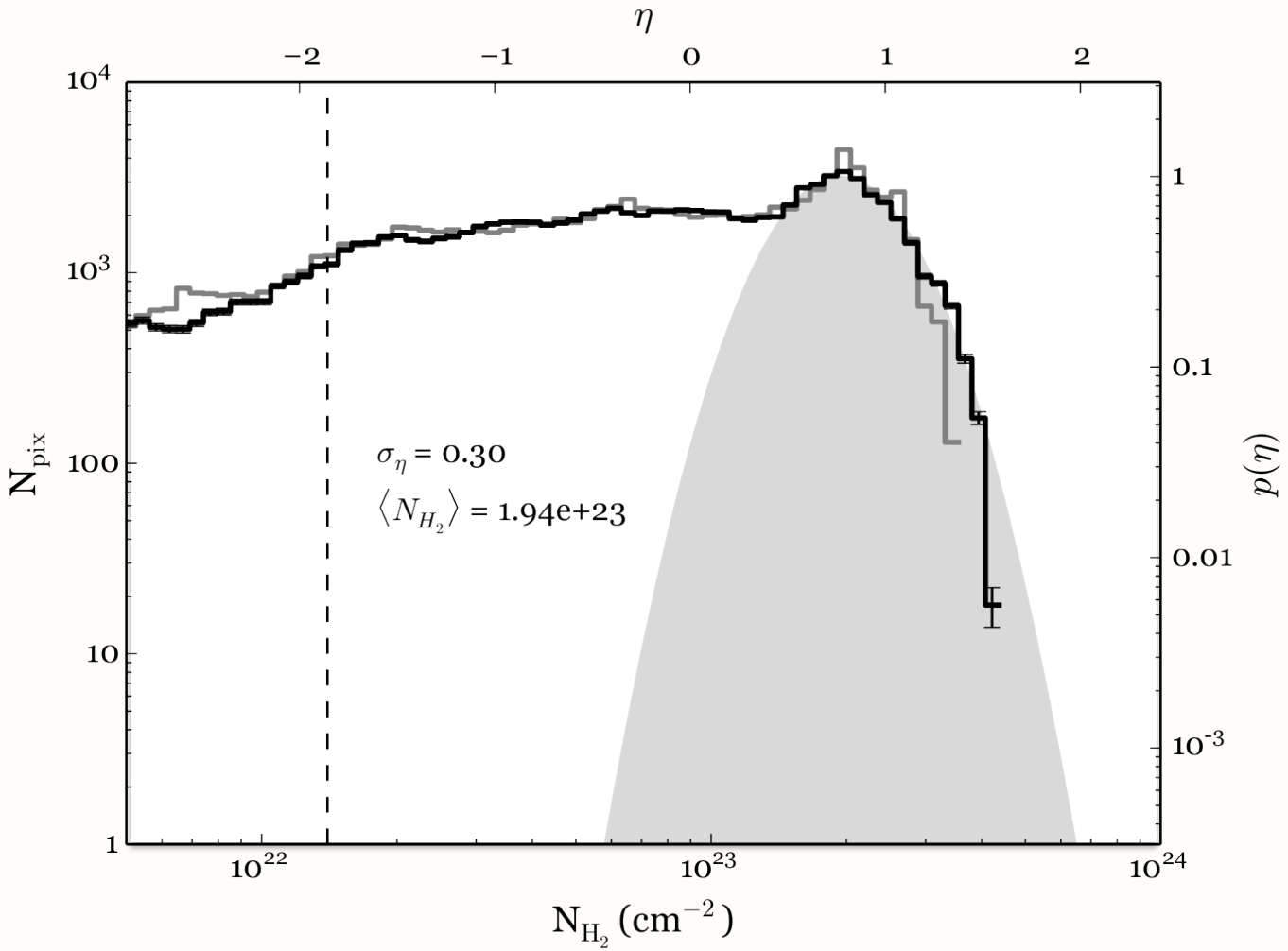


SMA 230.9 GHz or 1.3mm dust continuum emission



Combined SMA and scaled SCUBA 450 μm dust emission

Column density PDF



PDF is log-normal!

No indication of gravitational collapse or star formation

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 (=7.7)*

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)

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)

Column density threshold for star formation

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

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

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

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

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

Audience Participation!

Option 1:

The kinetic temperature of the gas traced by H_2CO ratios is 100s of K on size-scales of ~0.15 pc

Option 2:

Shock tracers and broad linewidths in the south of the cloud indicate G0.253+0.016 is colliding with another cloud at ~70 km/s

Option 3:

The CMZ is an elongated structure, orientated with SgrB2 closer to the Sun than Sgr A*

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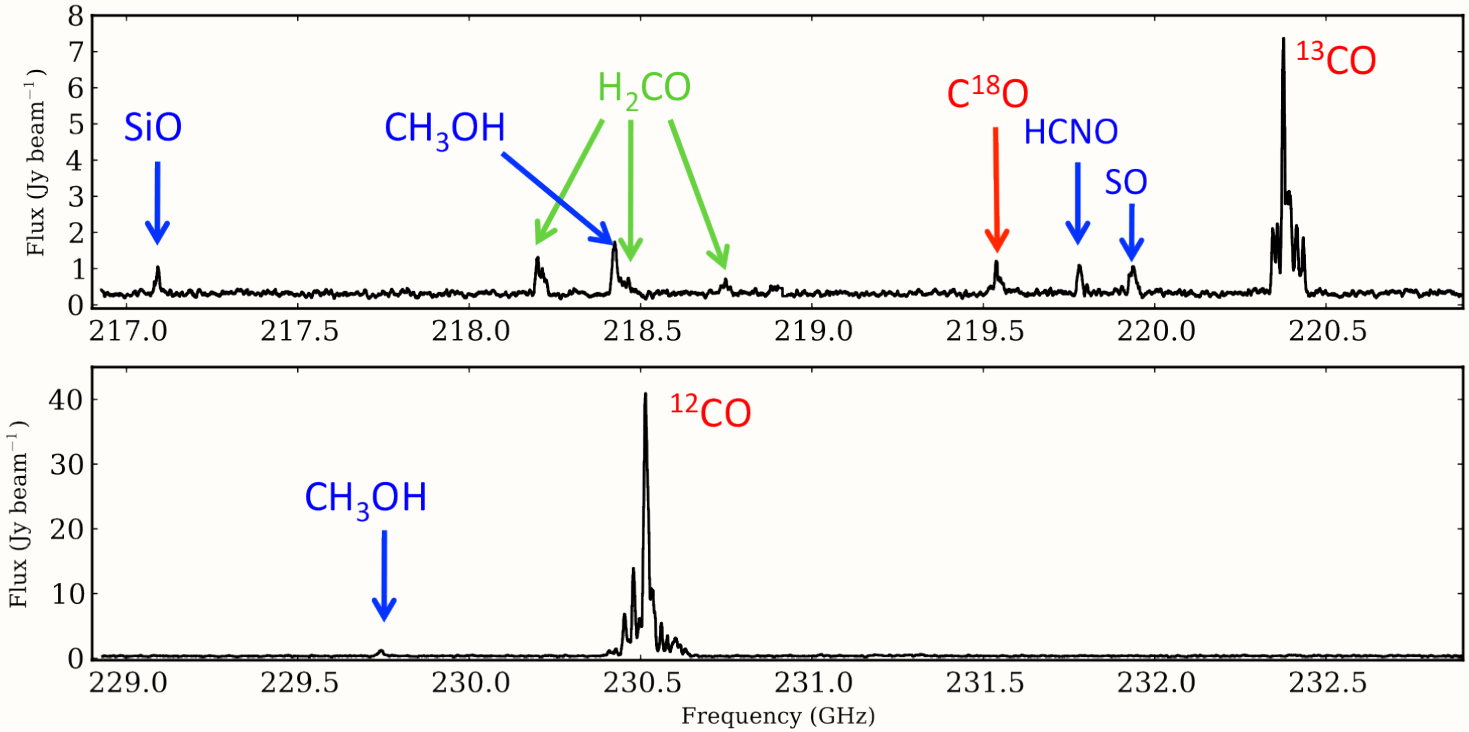
SMA Detected Lines



Detected lines:

SiO, CH_3OH, HNCO, SO – Shock tracers

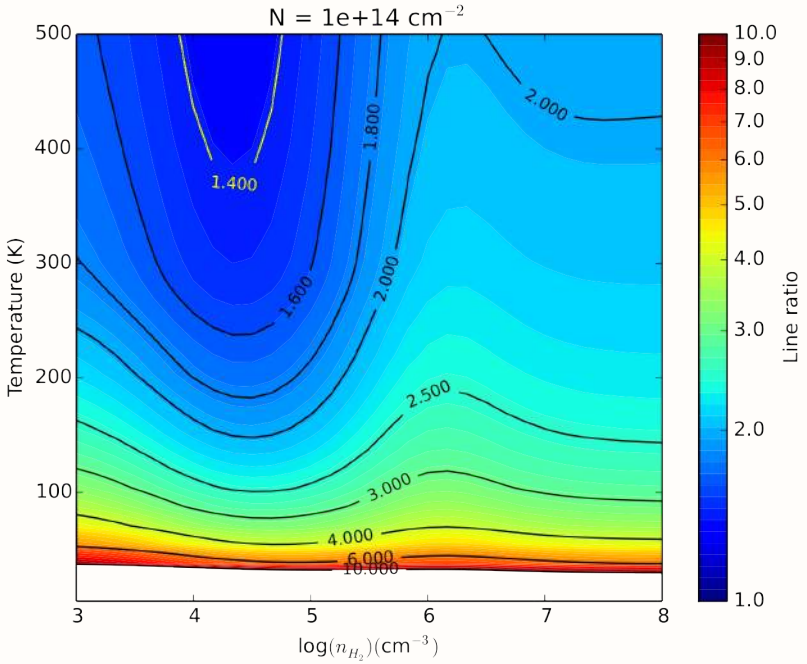
^{12}CO, ^{13}CO, $C^{18}O$ – Diffuse gas tracers

H_2CO – Dense gas tracer, temperature probe

Temperature from H_2CO

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

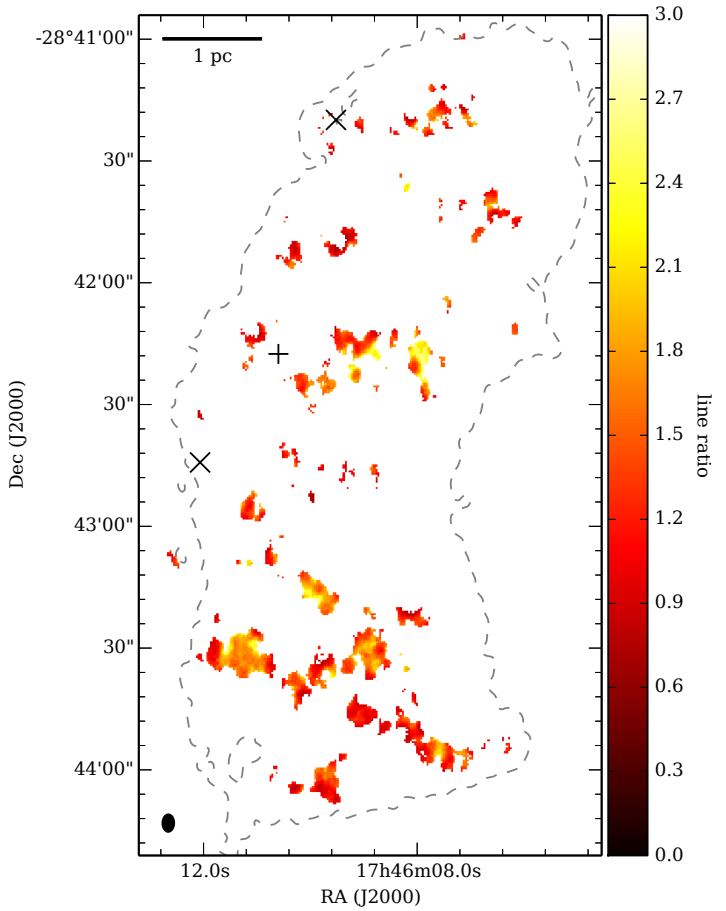
$N(H_2) \sim 10^{23}\ cm^{-2}$ $X(H_2CO) \sim 10^{-9}$



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

(see Mills & Morris 2013, A. Ginsburg's work)

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



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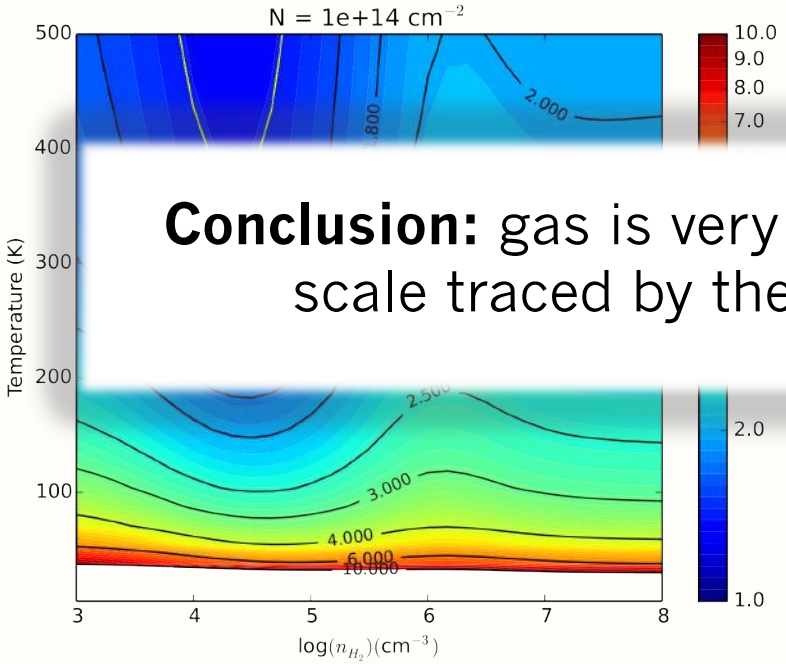

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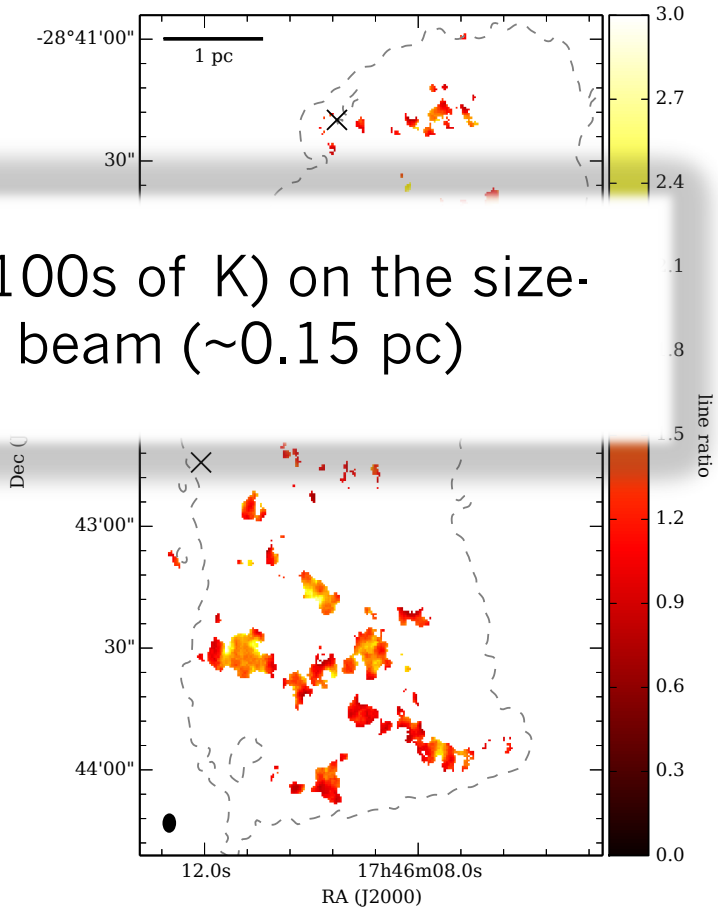

Conclusion: gas is very hot (100s of K) on the size-scale traced by the SMA beam (~0.15 pc)

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

(see Mills & Morris 2013, A. Ginsburg's work)

Conclusions

- Column density PDF has no power-law tail, consistent with no or little star formation
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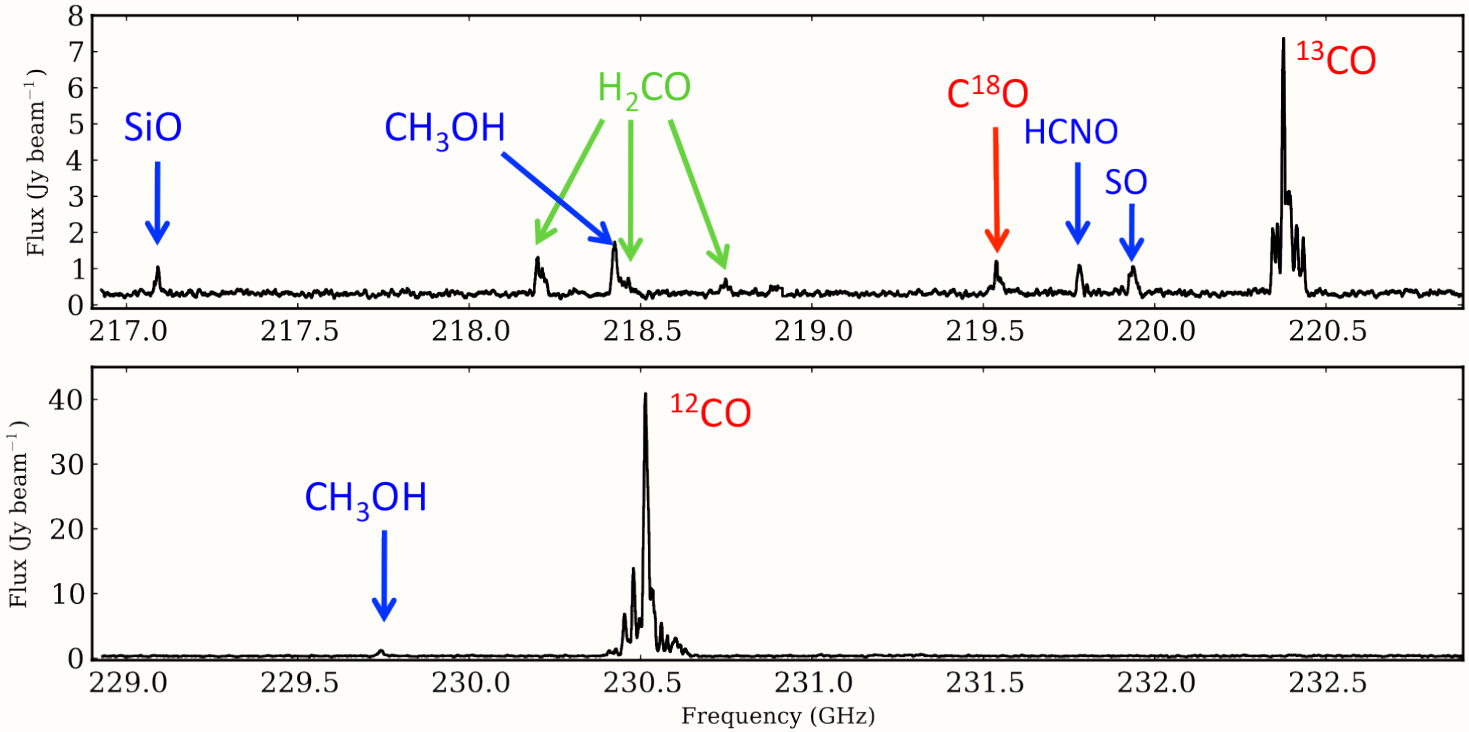

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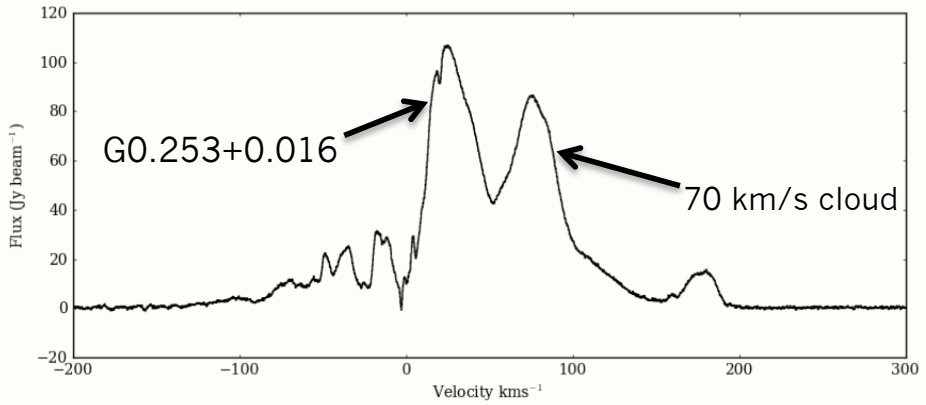
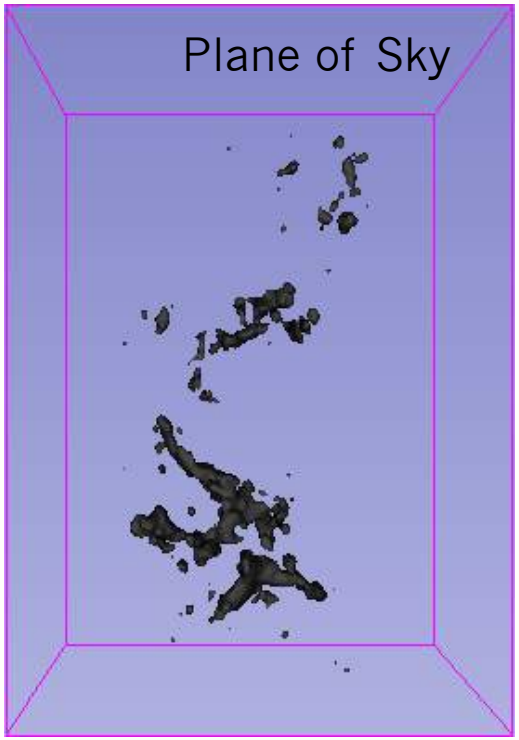
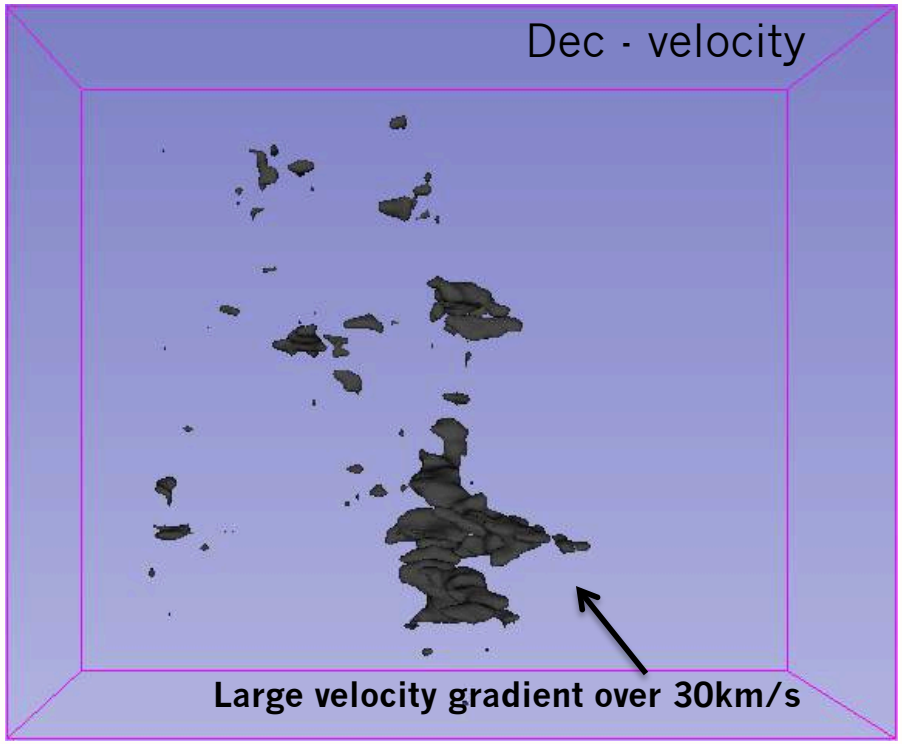


IRAM 30m ^{12}CO

Black: CH_3OH

Green: ^{13}CO





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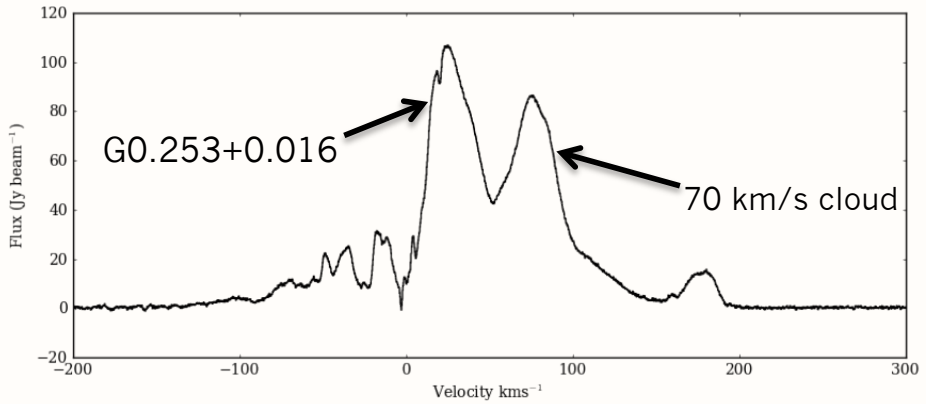

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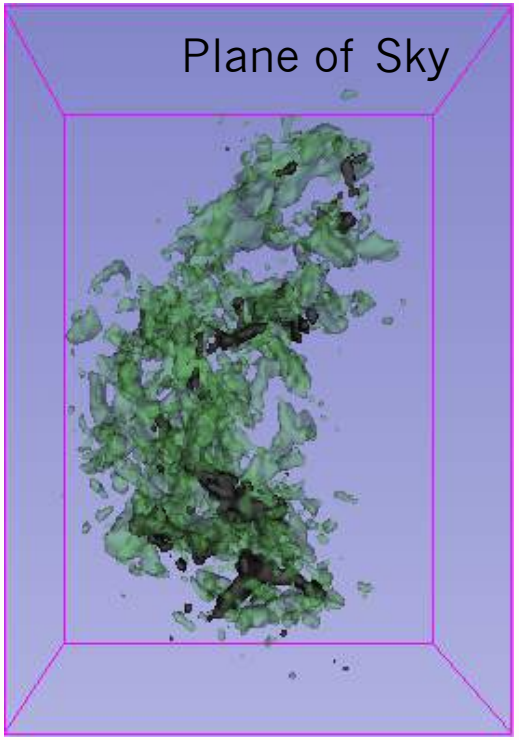

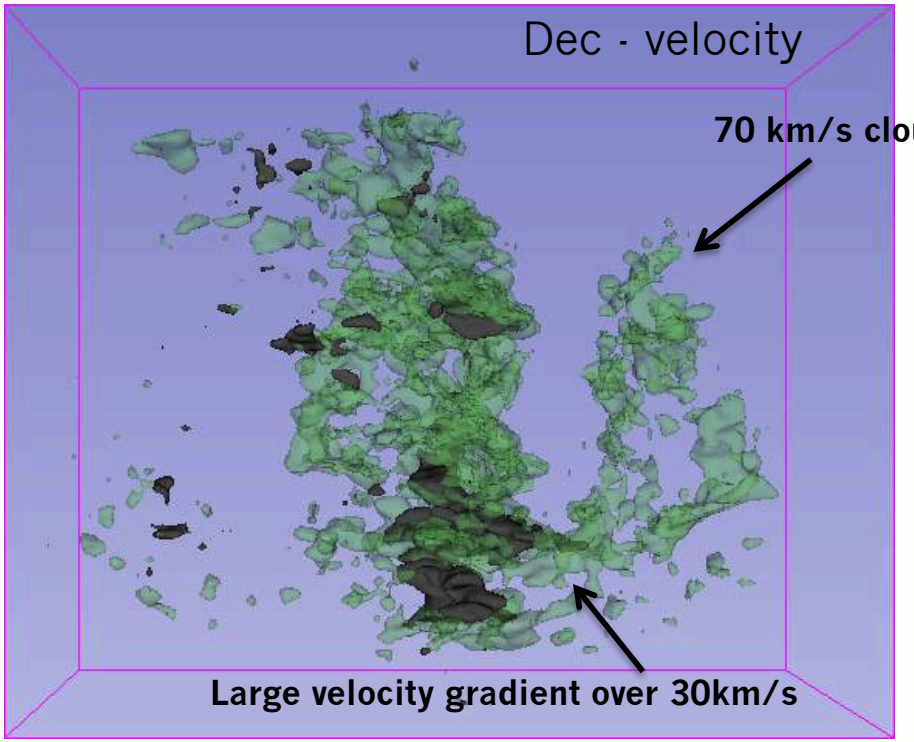

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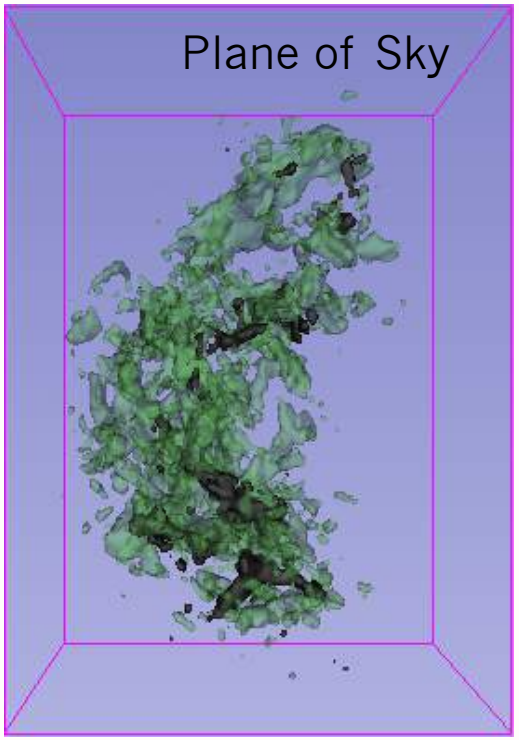
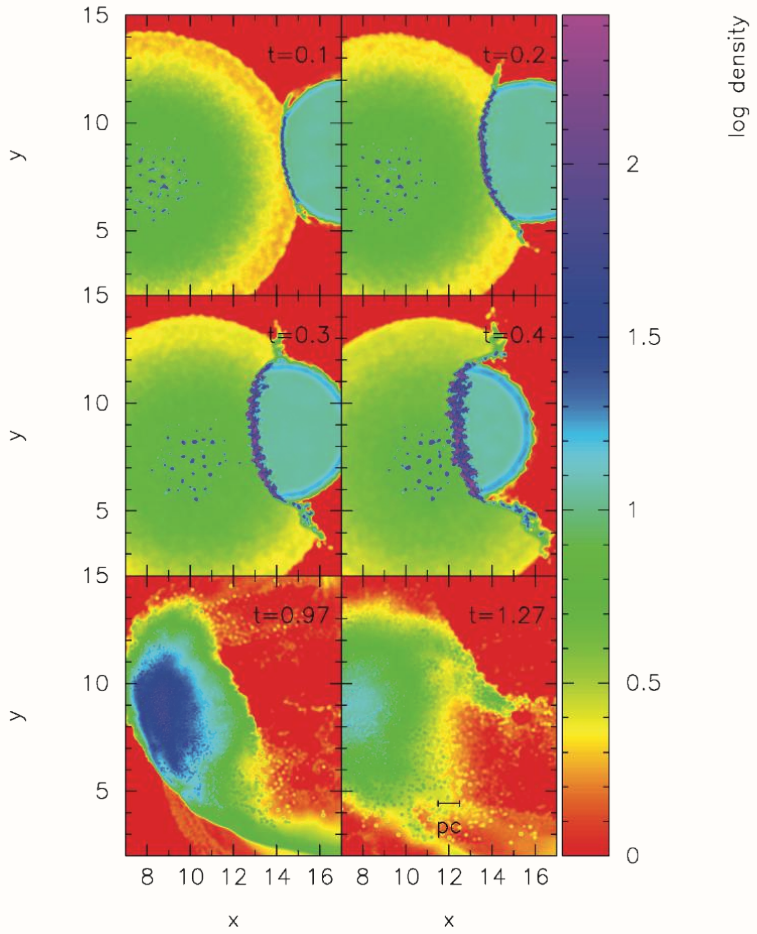


Are super star clusters formed by cloud collisions?
(Fukui+ 2013, Higuchi+2014)



Anathpindika+2011

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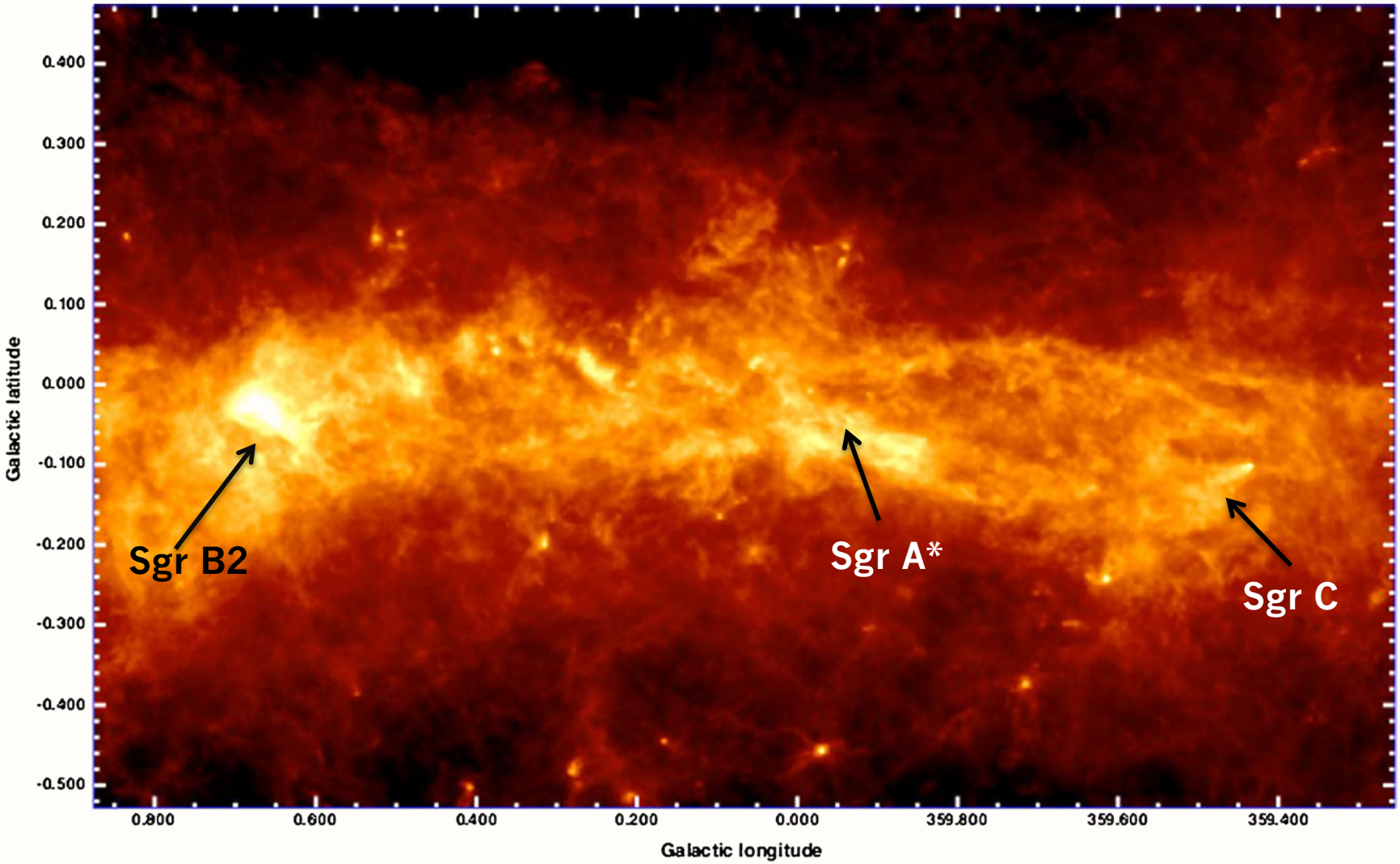
The Galactic Centre Environment



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

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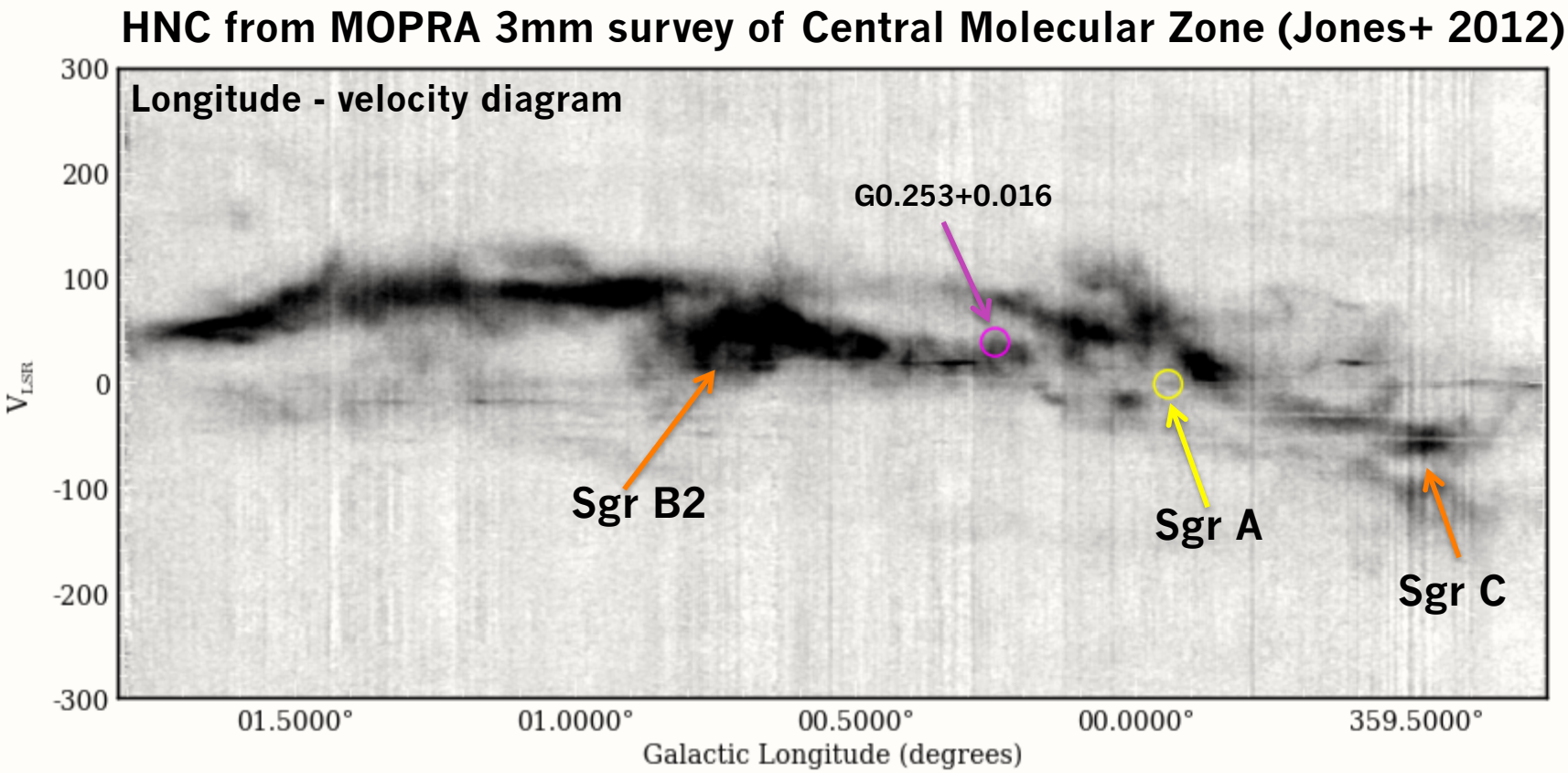

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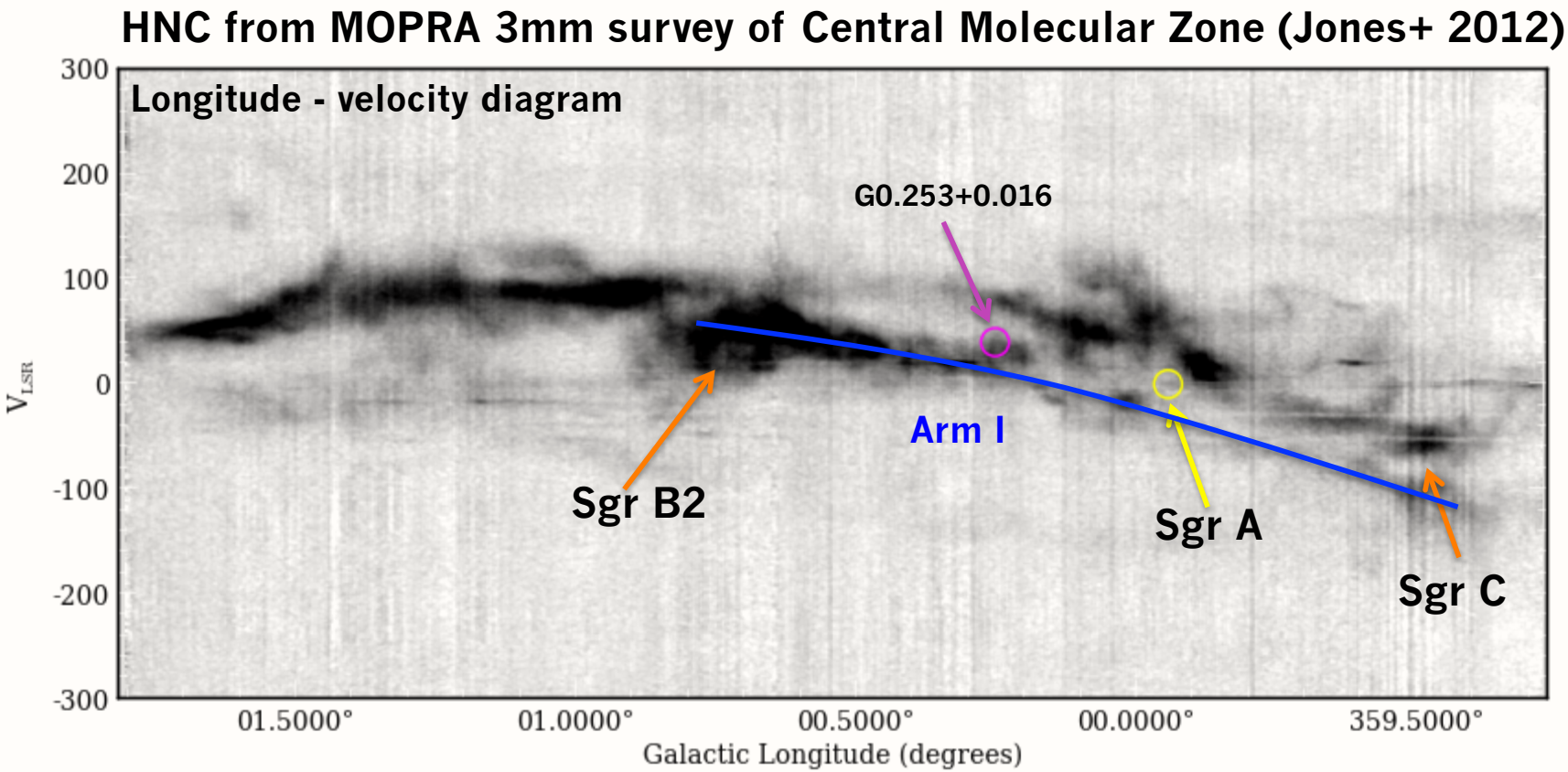

(Arm I and Arm II originally shown in Sofue+ 1995)

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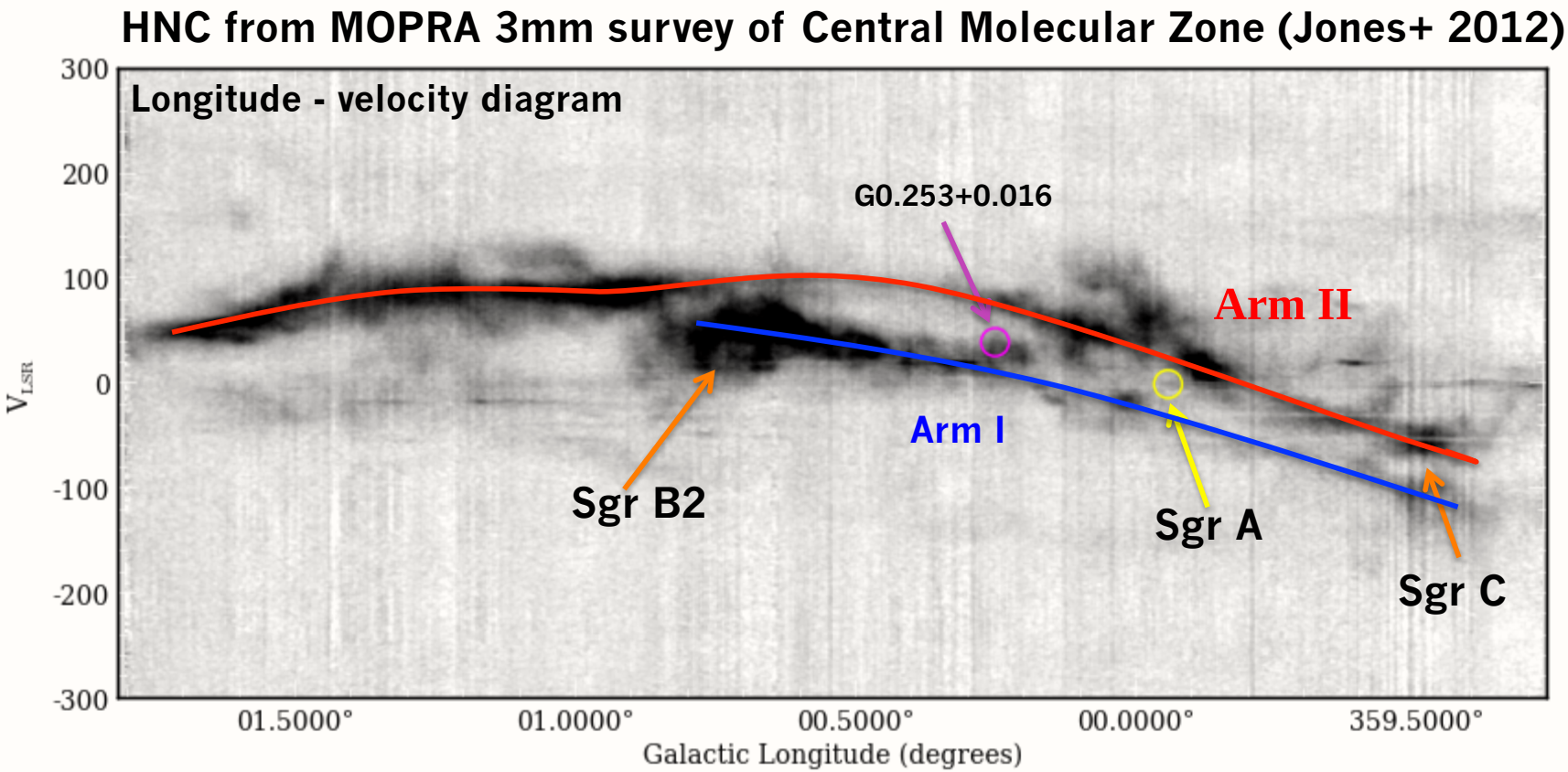

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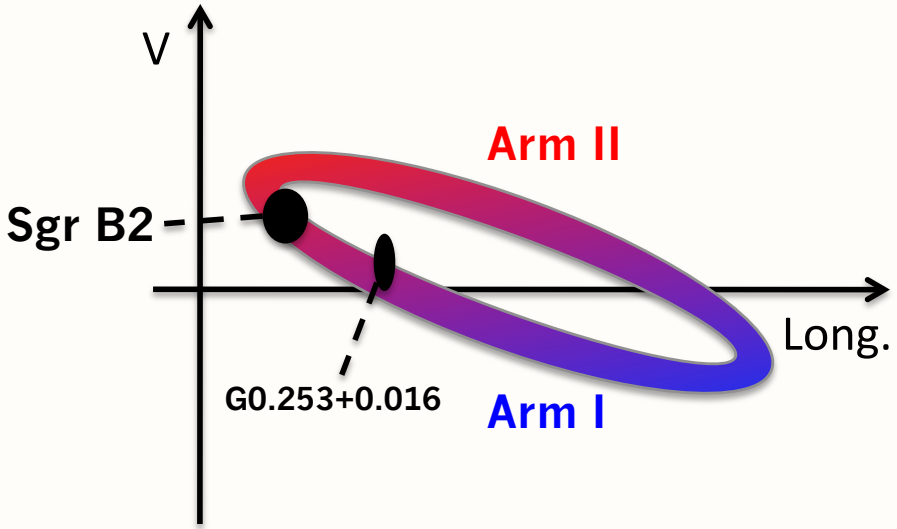

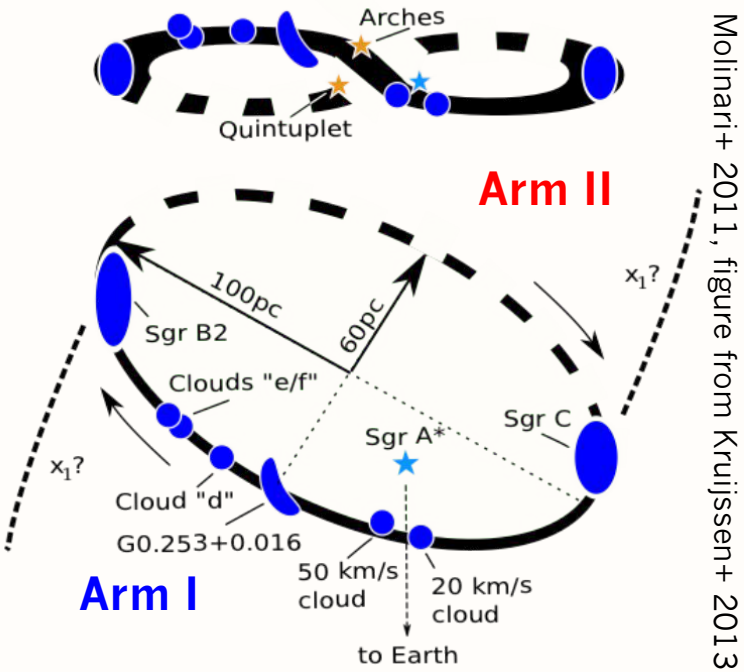

Molinari+ 2011, figure from Kruijssen+ 2013

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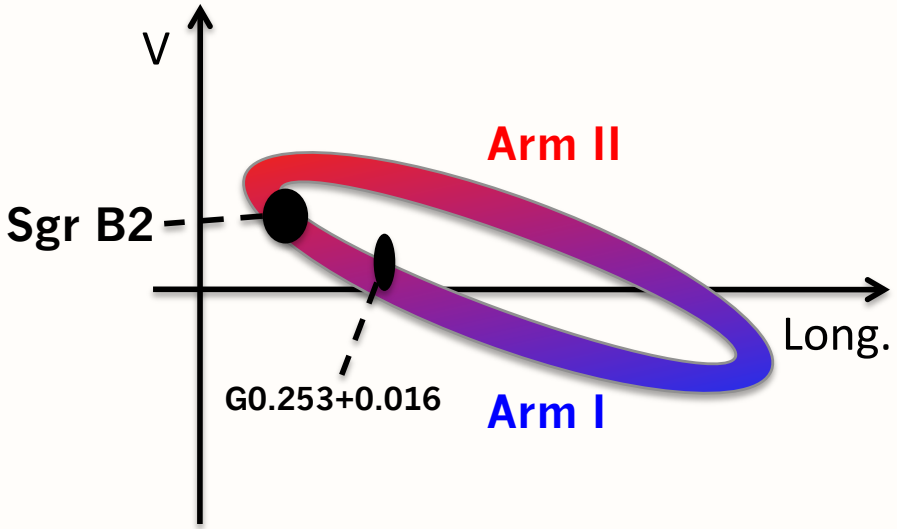

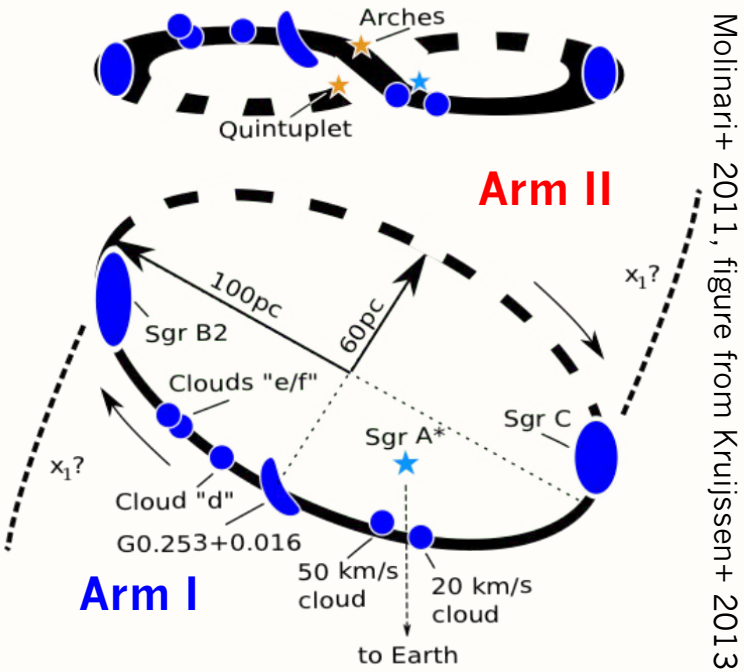

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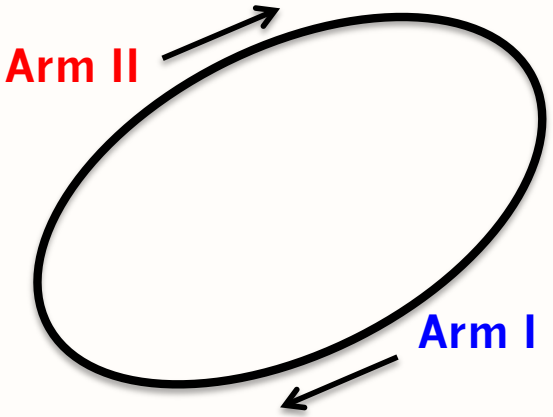

Sawada+ 2004: CO & OH, 70° wrt line of sight
Reid+ 2009: Trig. Parallax
Ryu et al. 2009: X-ray light echo

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