Shaping the ISM:

The impact of galactic structure in M83

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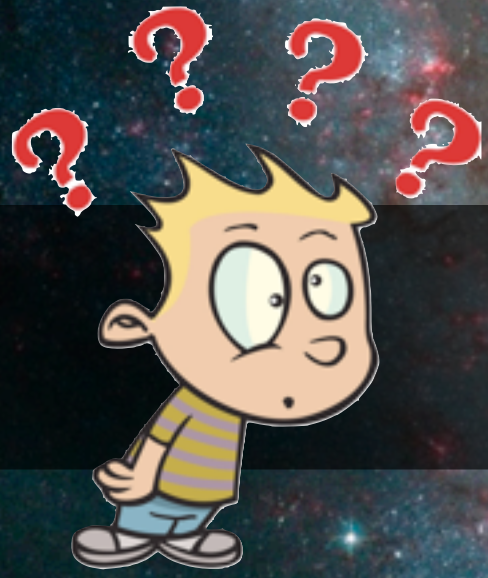
The BIG question

Why do we see galactic spirals?

Because there are more stars in the spiral!



But why?

The BIG question

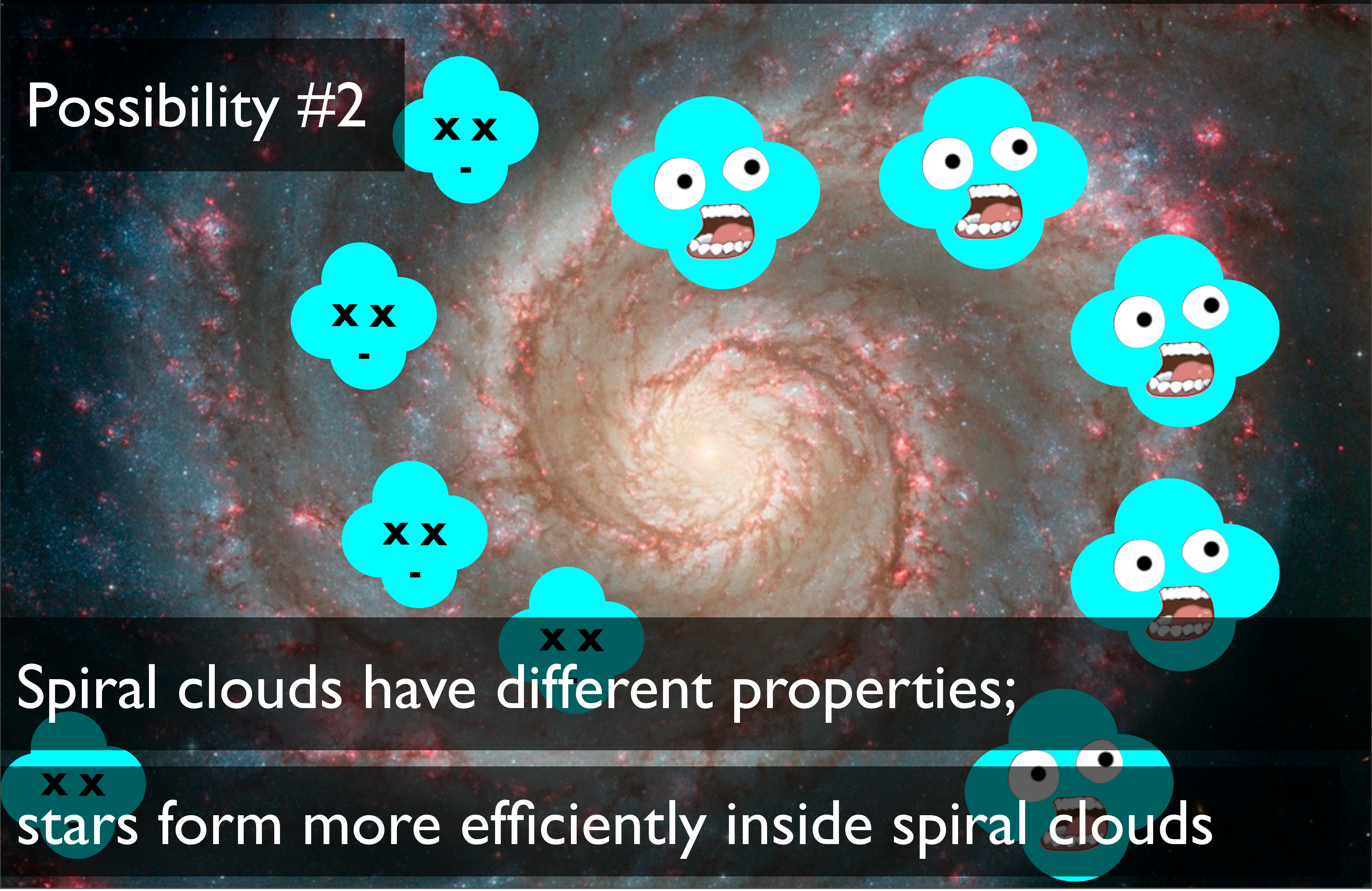
Possibility #1

Spiral contains more clouds than other disc regions;

star formation $\propto$ gas fuel

The BIG question

Possibility #2



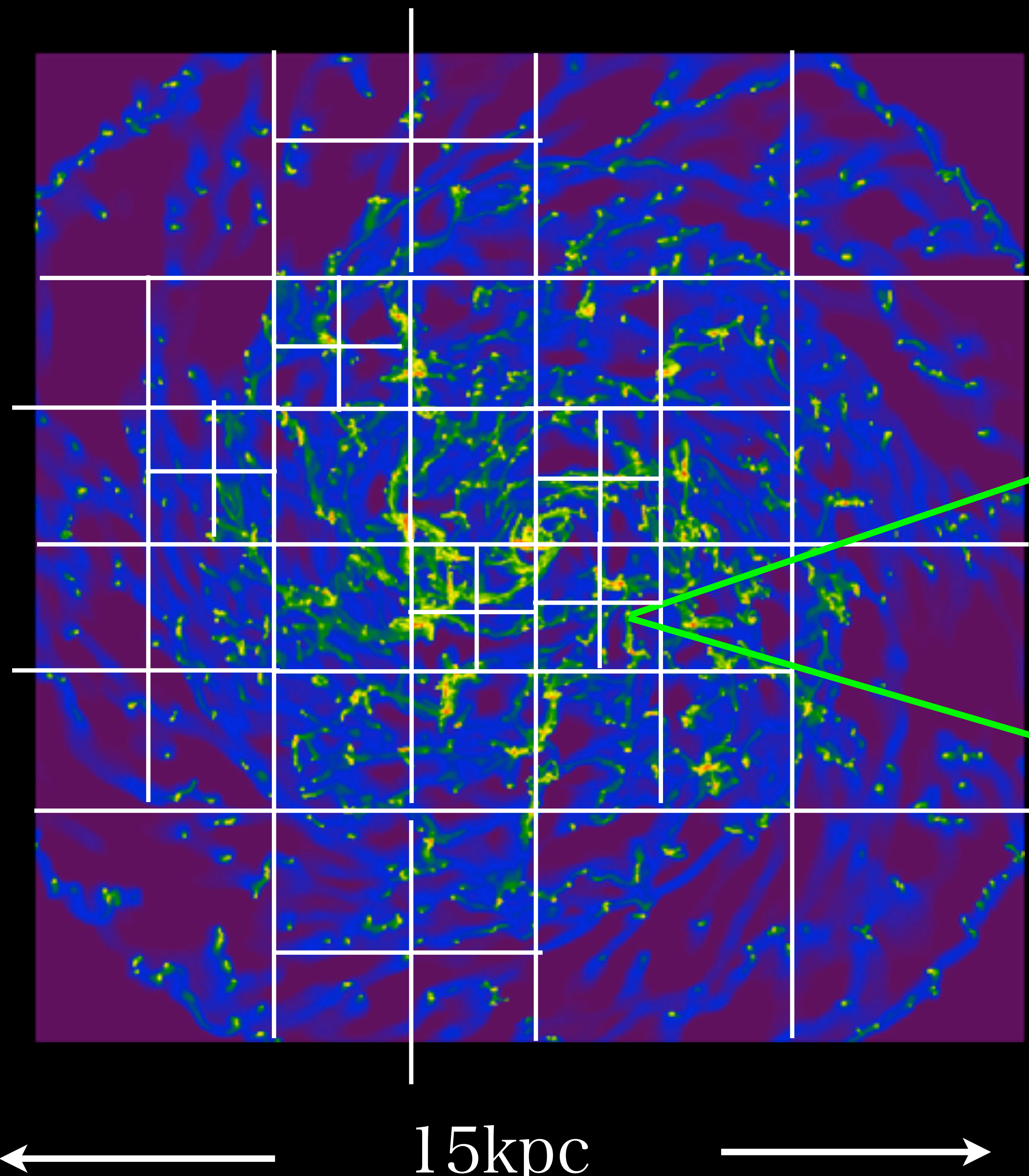
Spiral clouds have different properties;

stars form more efficiently inside spiral clouds

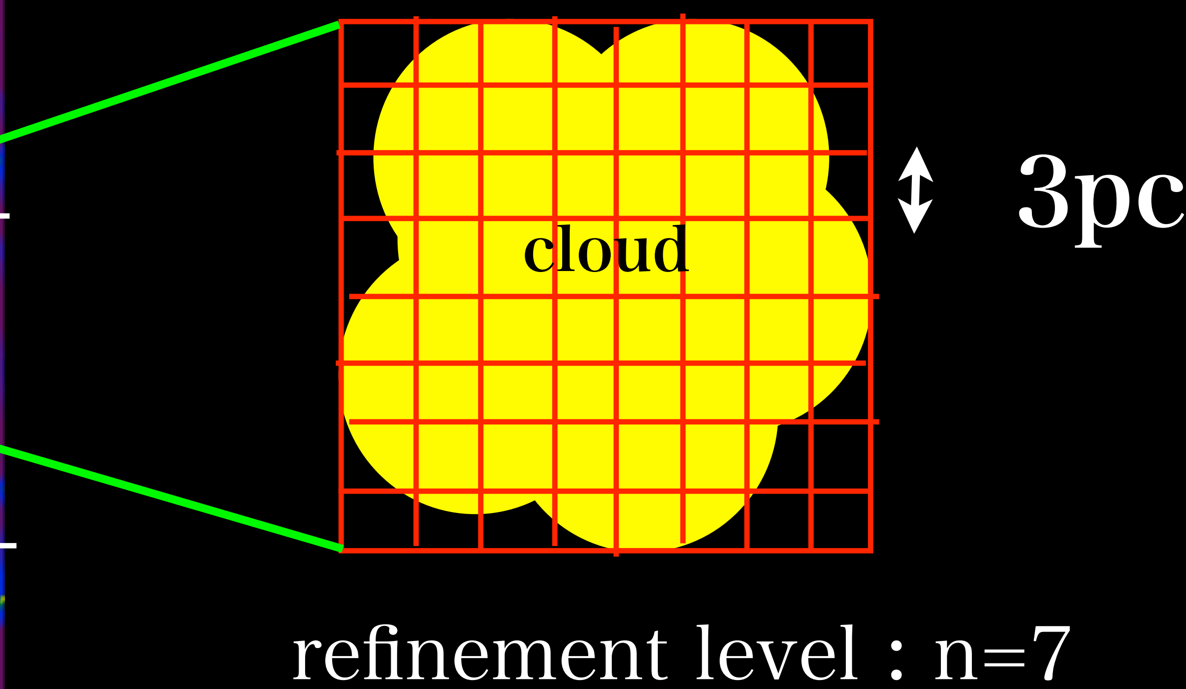
Model details

Box size: $(50\mathrm{kpc})^3$

Root grid: $(128)^3$



M83: Grand design spiral + bar



Radiative cooling: $T > 300\mathrm{K}$

No star formation or feedback

(focus is cloud evolution)

Model details

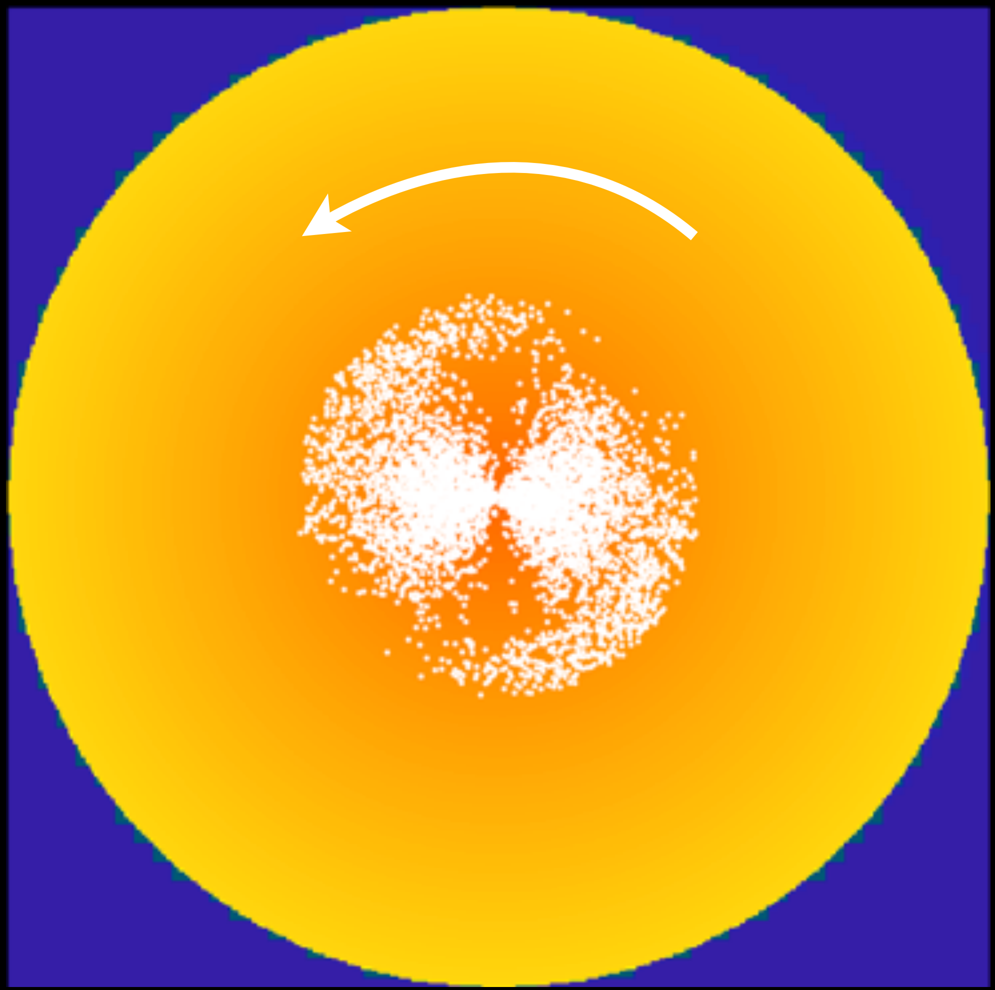
Observational gas distribution:

$$\rho(r,z) = \rho_0 \exp\left(-\frac{r}{2265\mathrm{pc}}\right) \mathrm{sech}^2\left(\frac{z}{100\mathrm{pc}}\right) \mathrm{M}_\odot/\mathrm{pc}^3$$

(Lundgren et al, 2004)

Stellar potential:

10^5 star particles in disc, bar & spiral



Bar and spiral stars rotate with pattern speed, $54\mathrm{km/s/kpc}$. (2Mass data, Hirota, 2009)

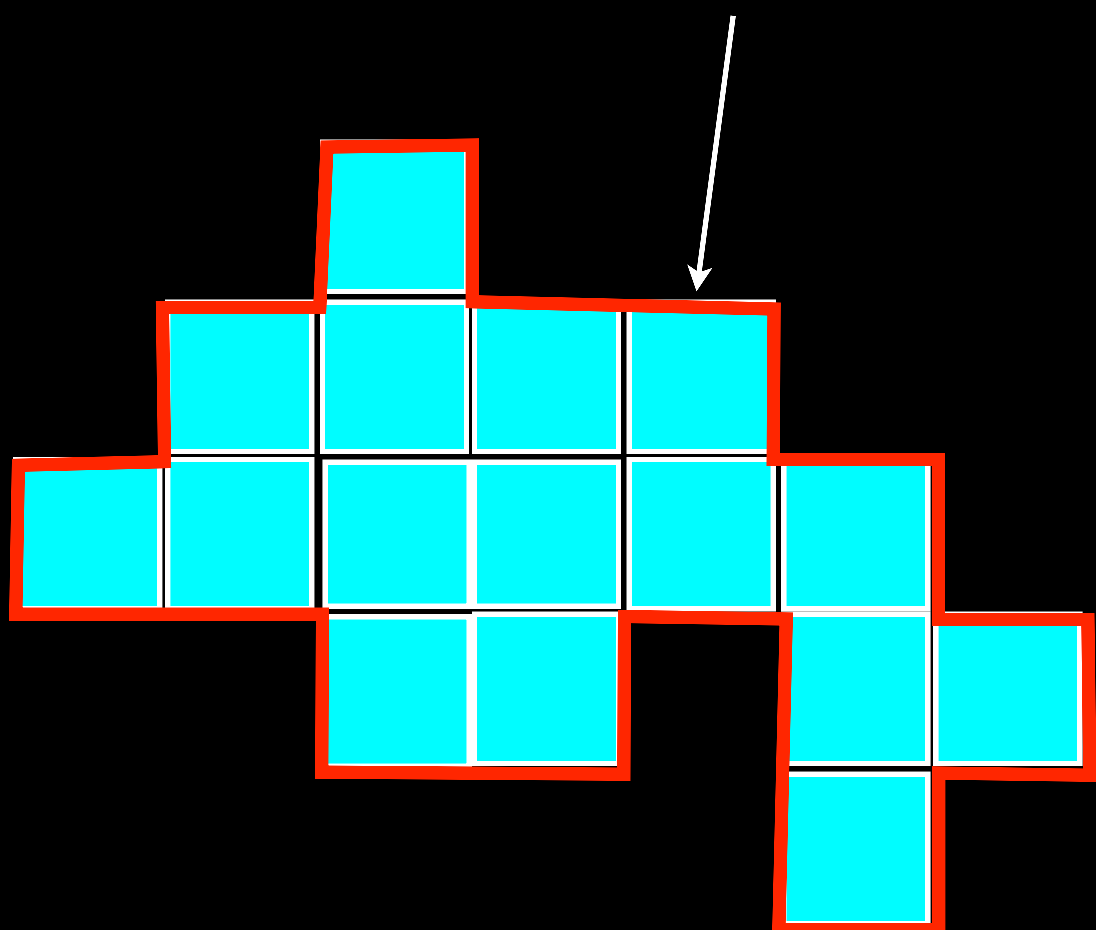
Disc stars are fixed.

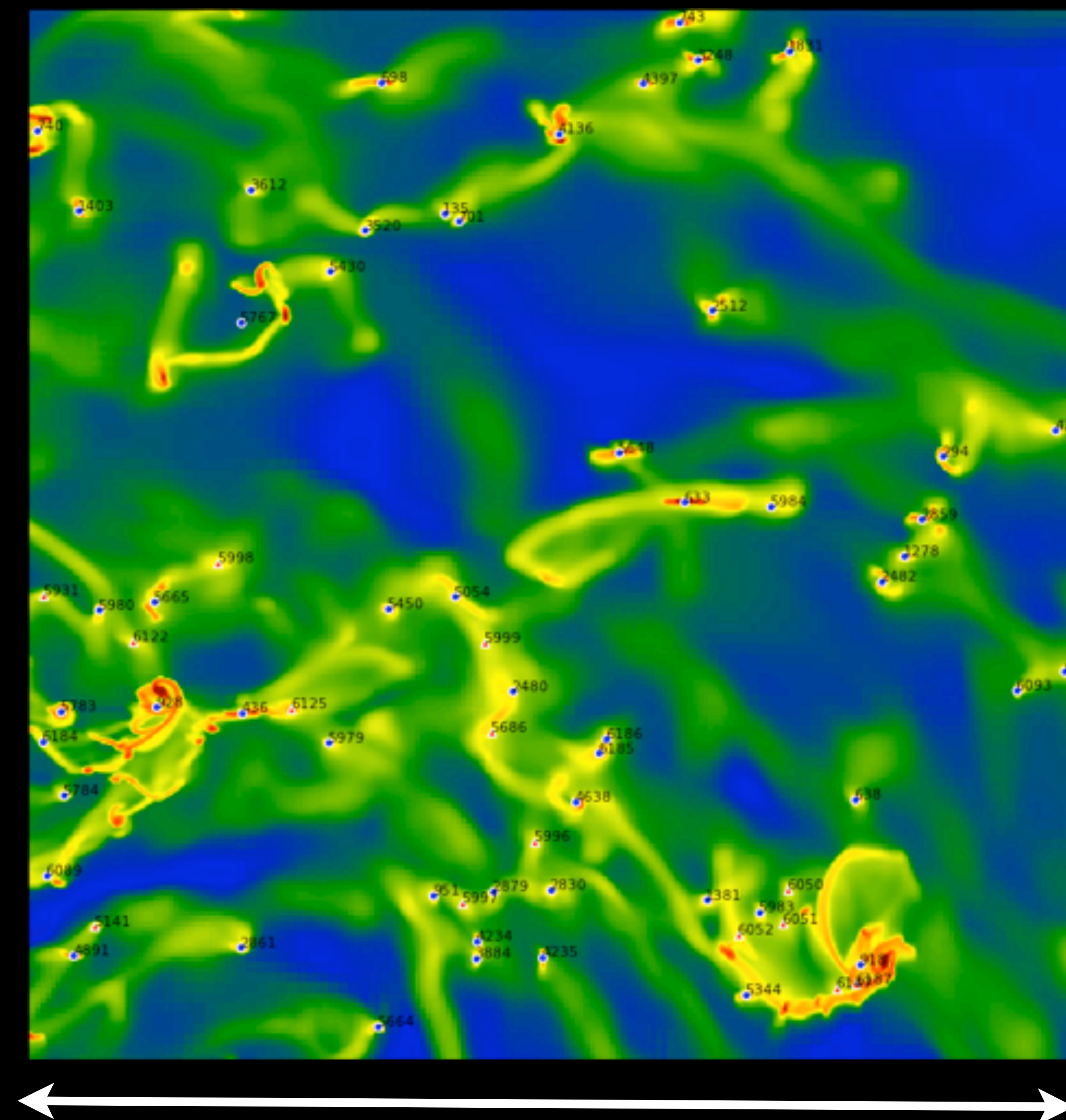
Dark matter:

Static NFW profile (Navarro et al, 1997)

Model details

Find contour in the gas density field at $n_{\mathrm{HI}} > 100\,\mathrm{cm}^{-3}$





Clouds are tracked through the simulation

Global evolution

Co-rotation radius (~ 2.5 kpc):

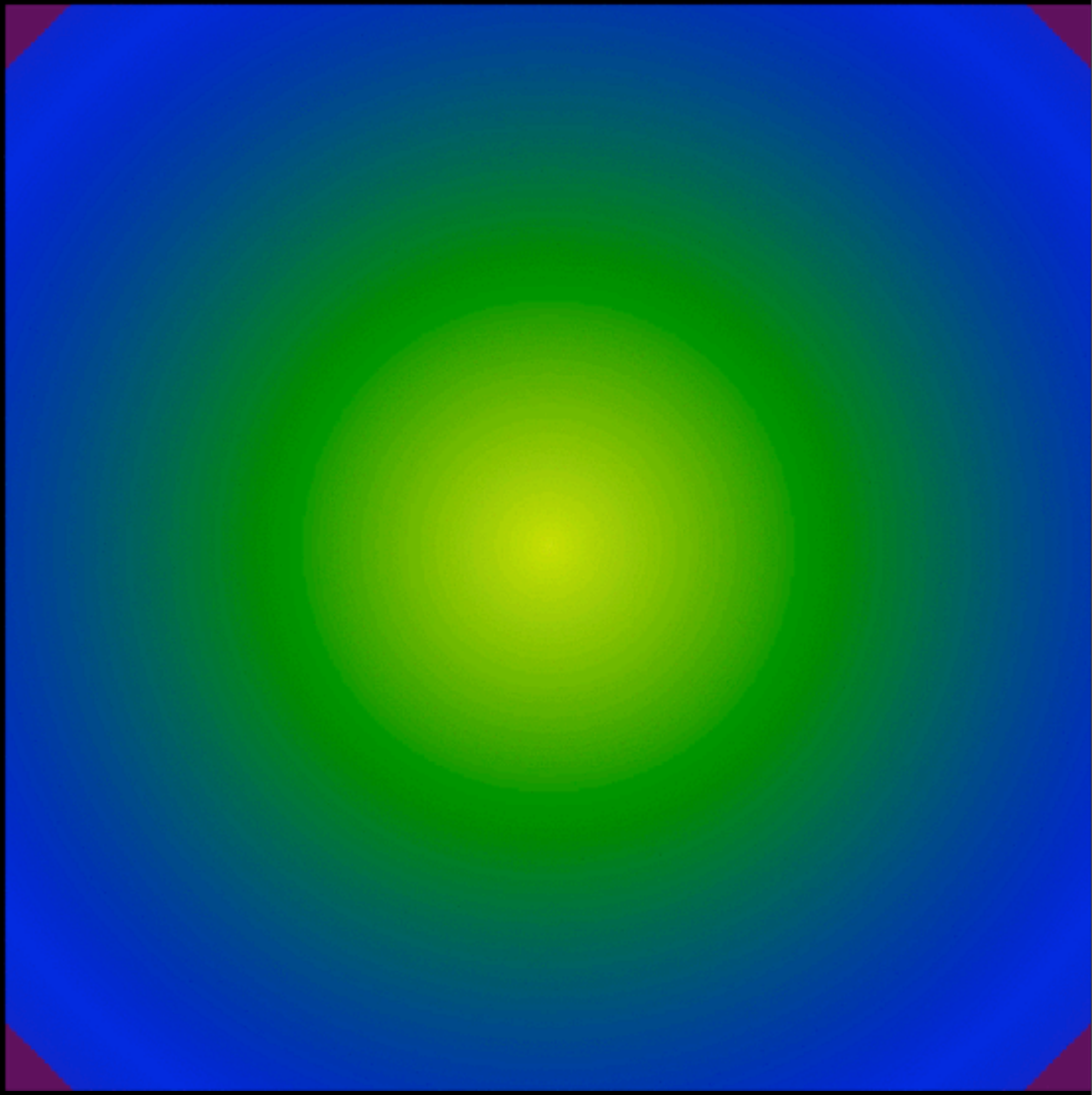
Outside, gas is stirred by the bar to gain angular momentum.

Inside, gas loses angular momentum.

↓

Shock in both directions

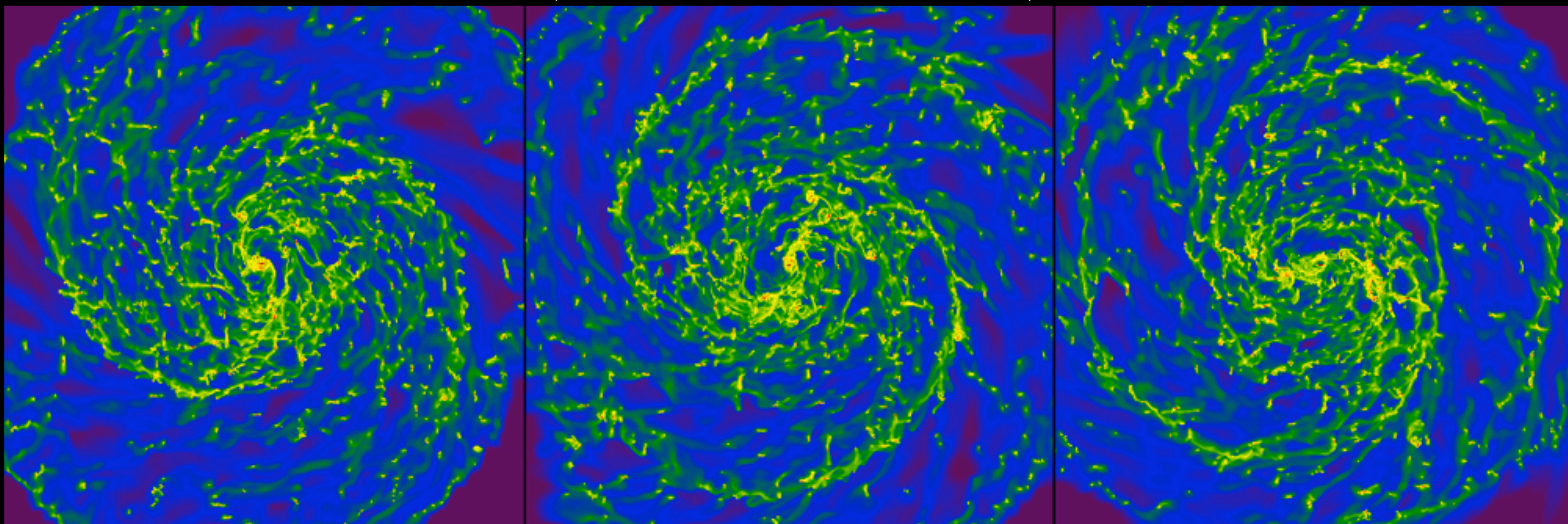
Gas then settles into grand design



15kpc

Global evolution

15 kpc

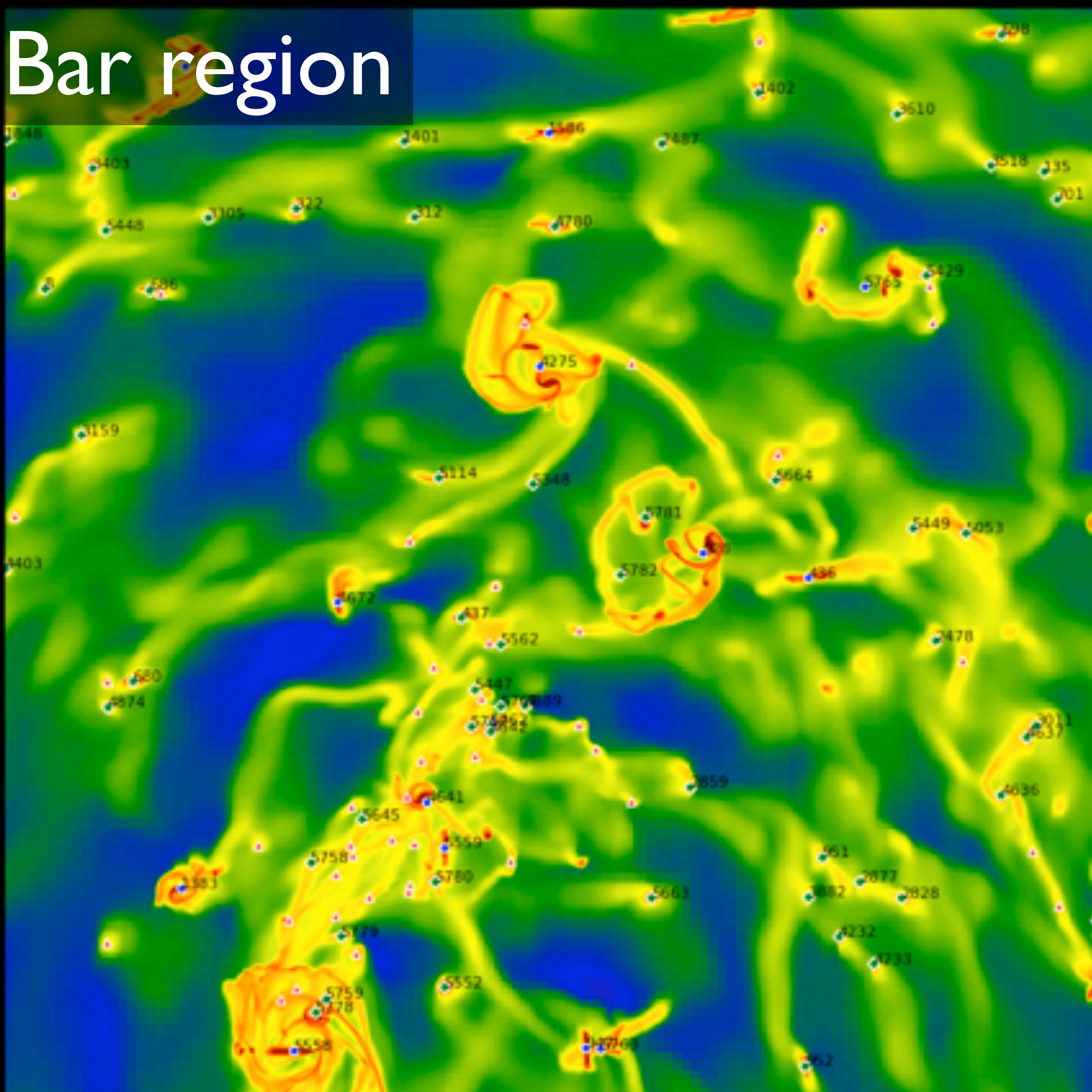


200 Myr　　240 Myr　　280 Myr

Spiral rotation time: ~120 Myr

Orbital period at 8 kpc: ~ 240 Myr

Global evolution

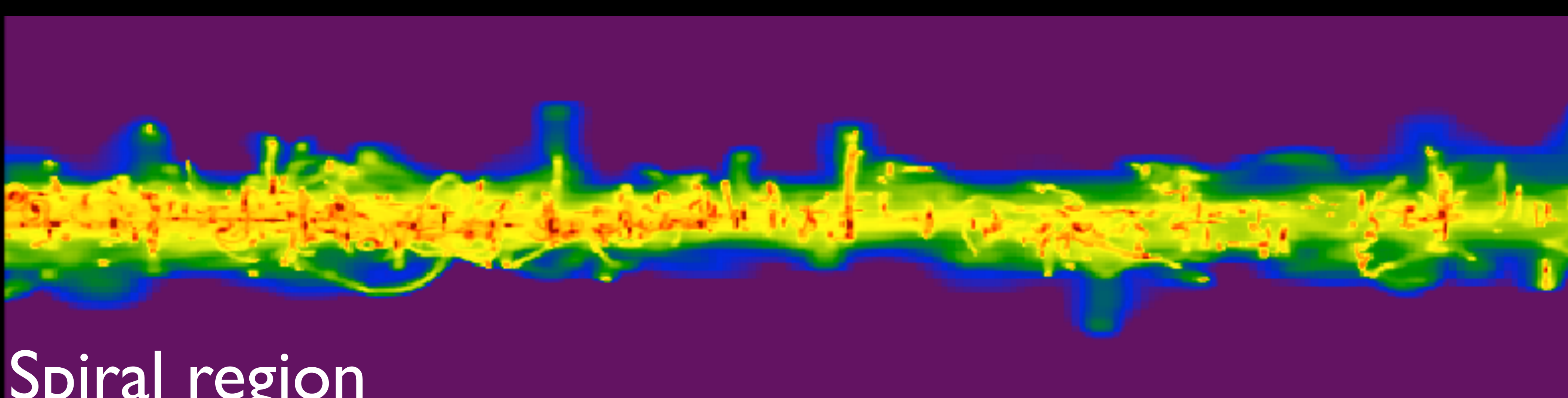


~ 3 kpc

zoom zoom zoom

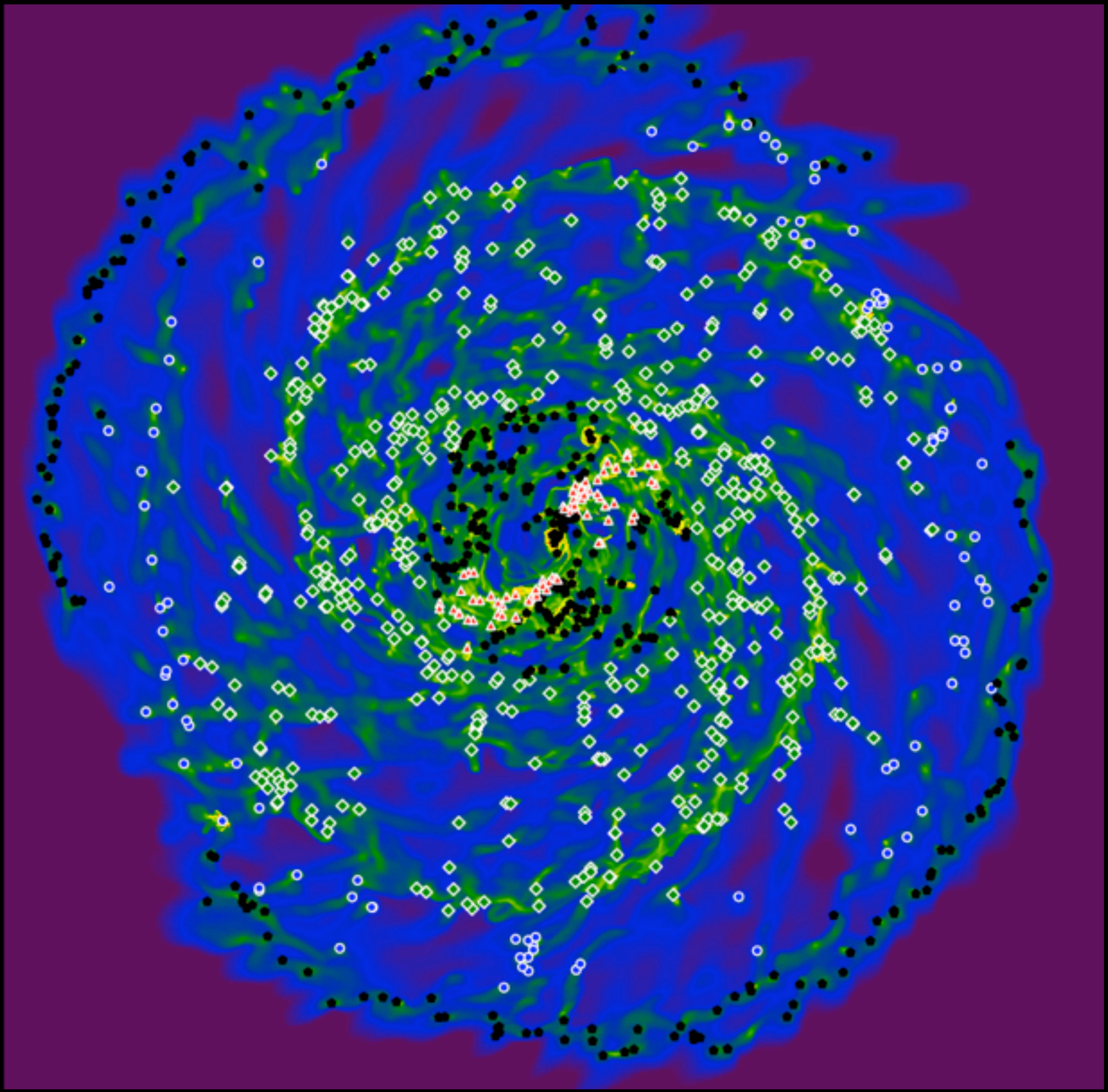
Clouds exist in a highly interactive environment

Disc thickness is achieved through cloud interactions

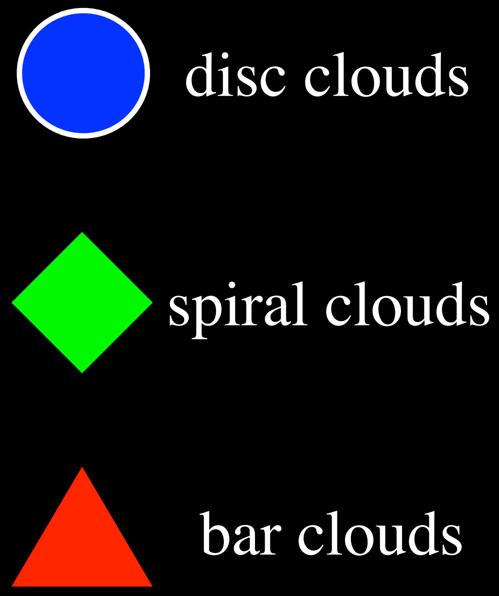


~ 1.25 kpc

Global evolution



cloud definition



Cloud properties

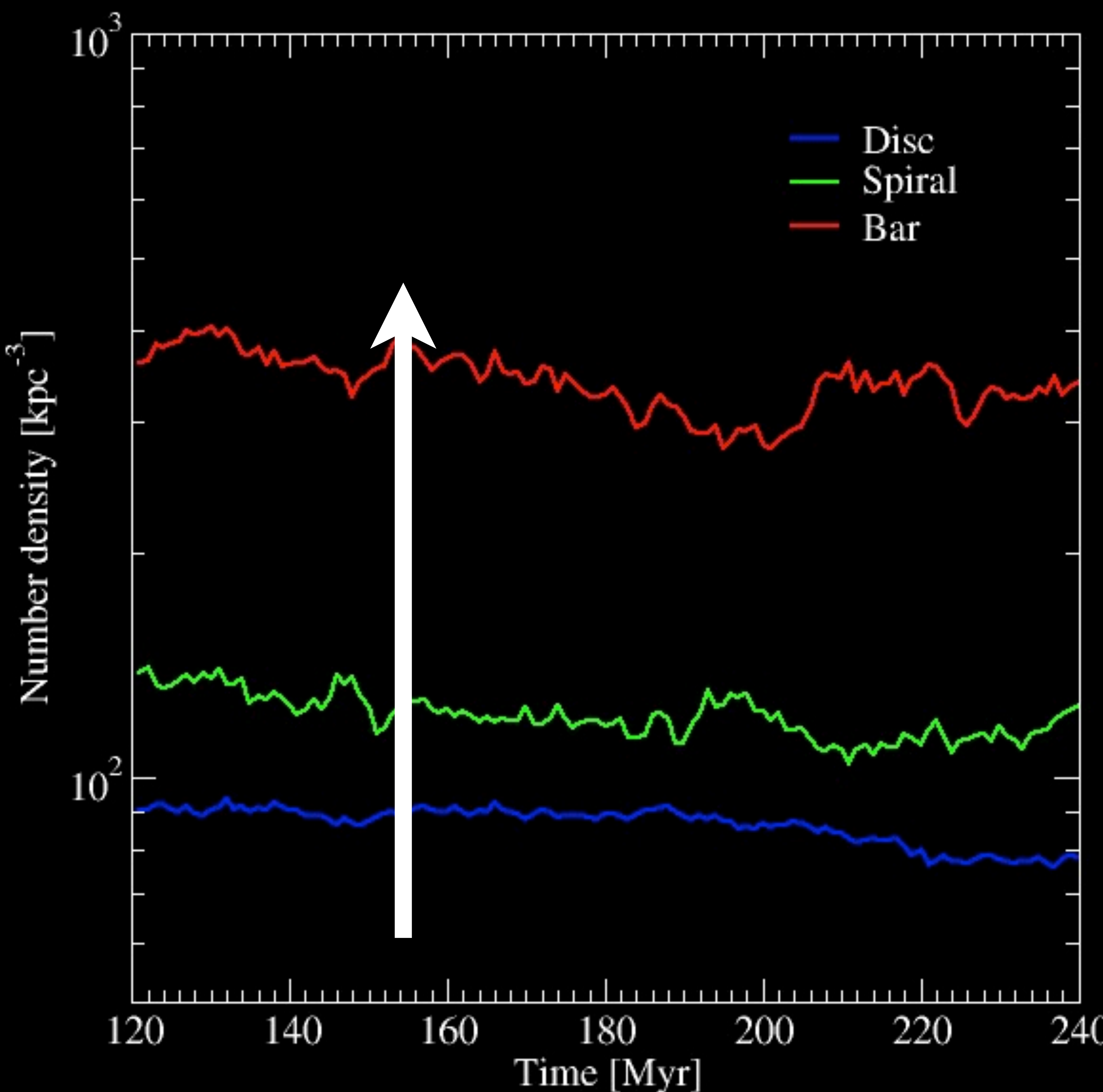
Cloud number density

Clouds more densely packed in bar and spiral regions.

bar

spiral

disc



Cloud properties

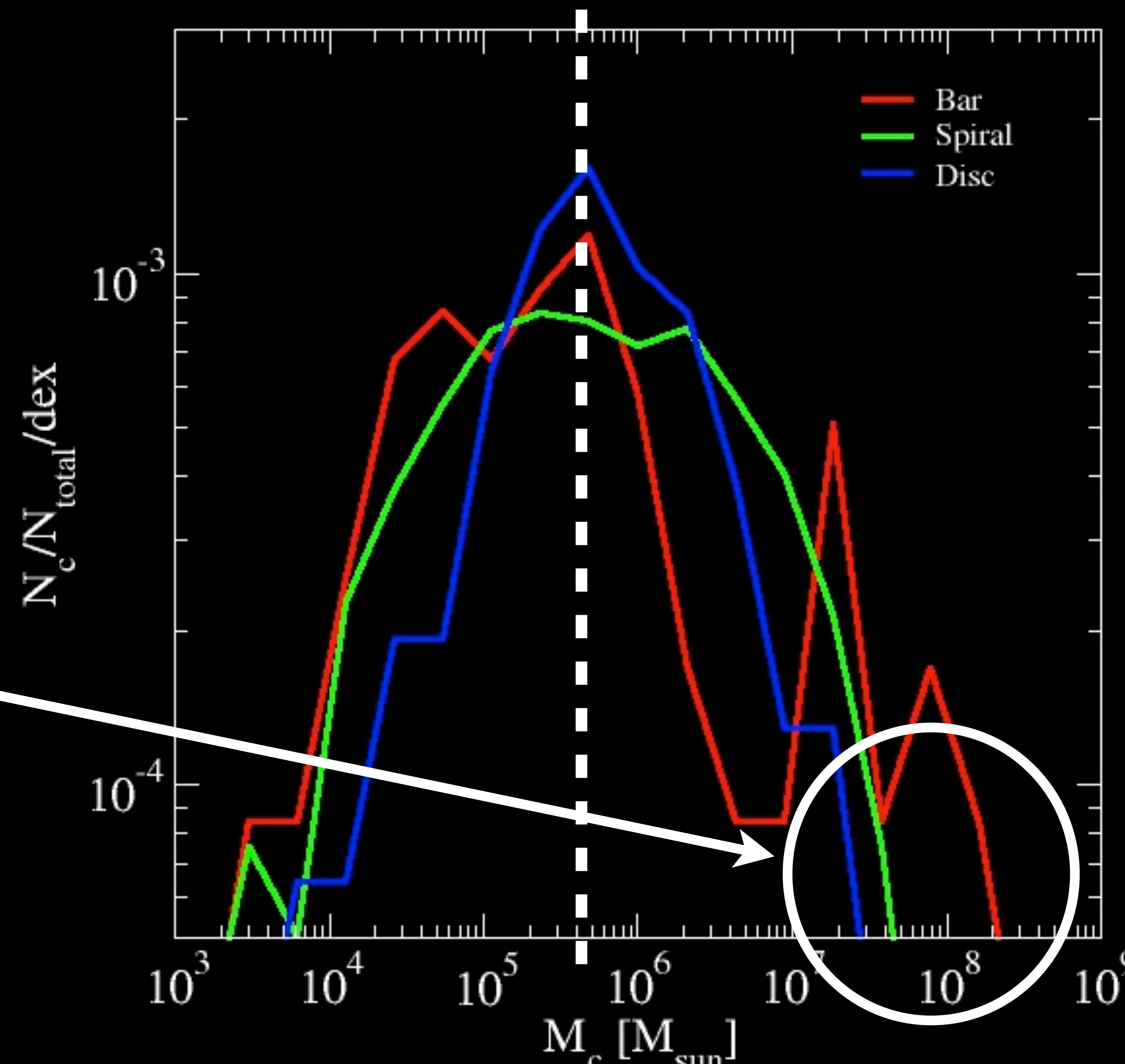
Mass profile:

Median mass $\sim 4 \times 10^5 \, M_\odot$

constant between environments

Maximum mass:

bar > spiral > disc



Cloud properties

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Median mass $\sim 4 \times 10^5 \, M_\odot$

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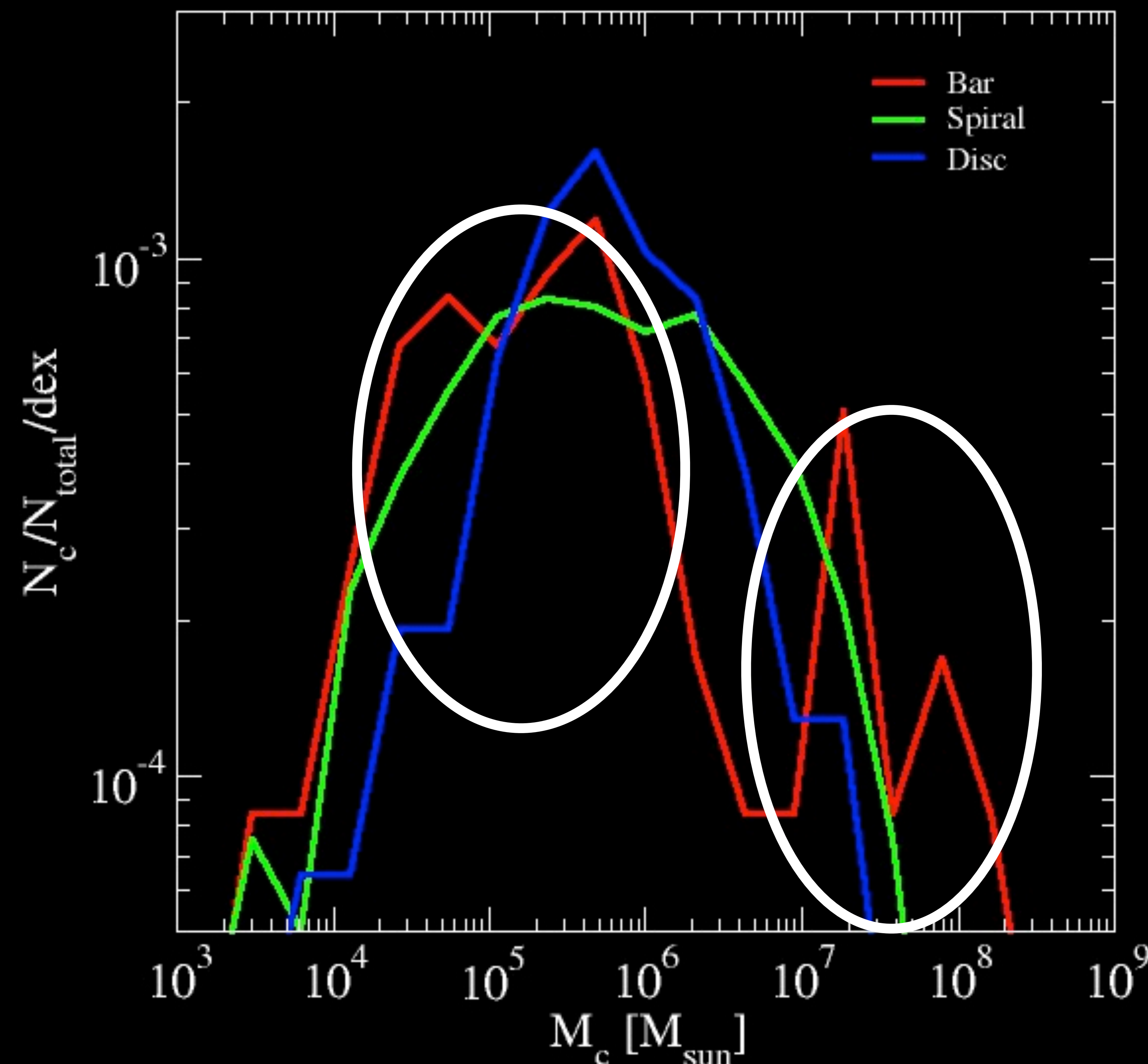
Maximum mass:

bar > spiral > disc

GMAs found in bar region

Split population of low and high mass bar clouds



Cloud properties

Radius profile:

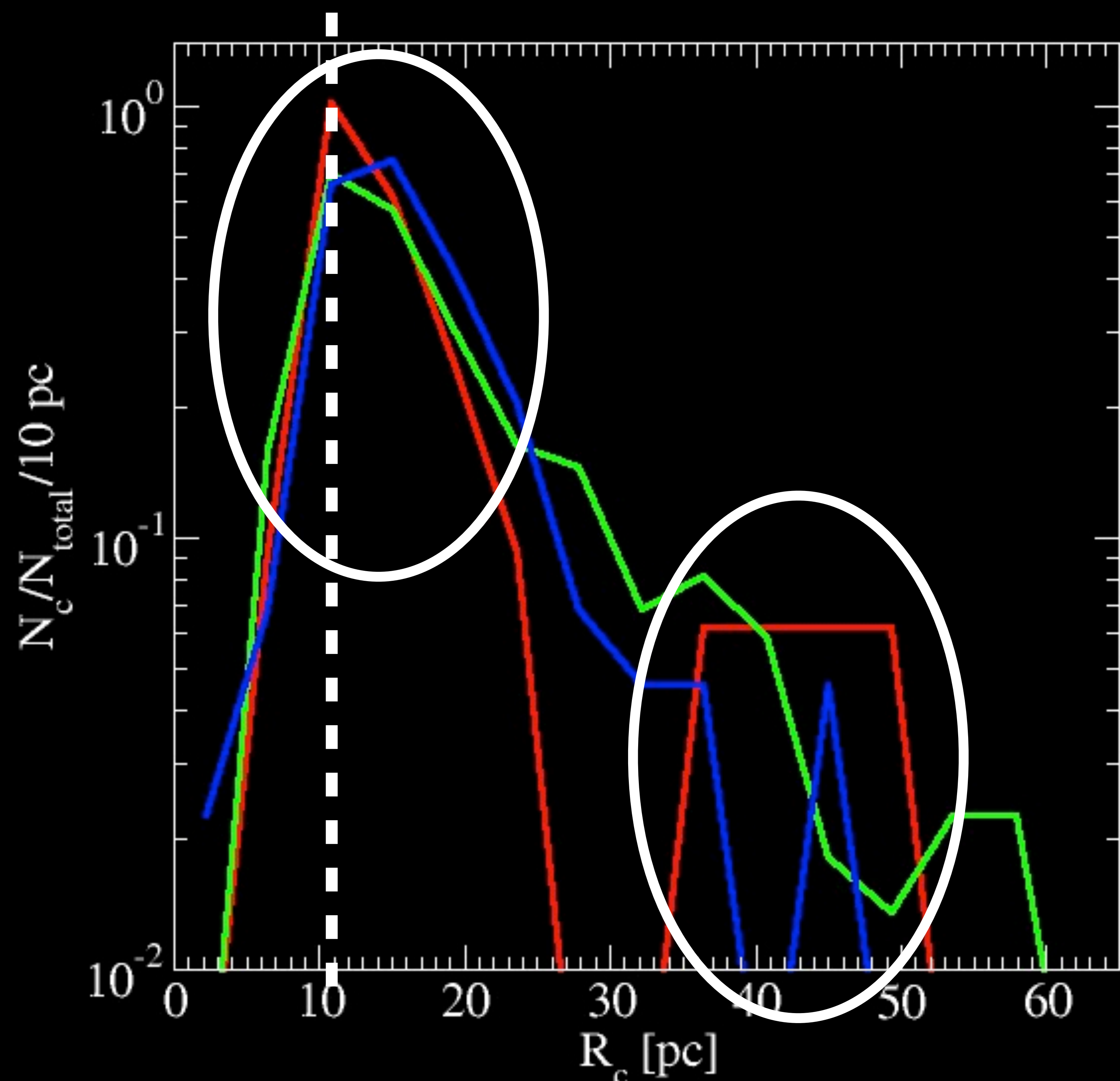
Median radius $\sim 10\,\mathrm{pc}$

constant between environments

Maximum radius:

bar > spiral > disc

Duel population in bar clouds



Cloud properties

Size-Mass relation:

Good fit with Milky Way data...

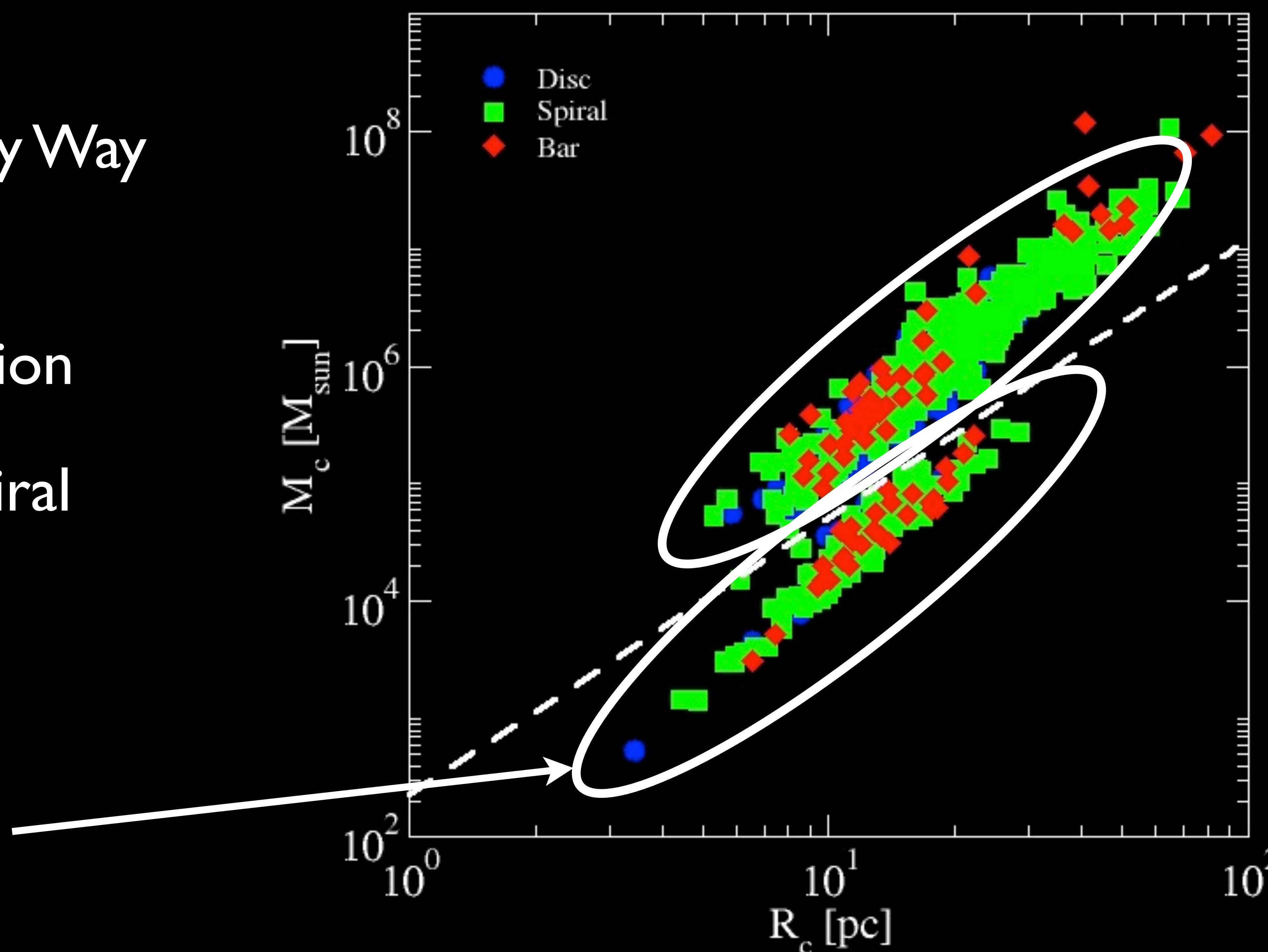
Clear dual population

Found in all bar, spiral and disc

Bar: 38 %

Spiral: 23 %

Disc: 11 %



Largest fraction for bar clouds

White dashed: $r = 288M^{2.36}$
(Roman-Duval+ 2010)

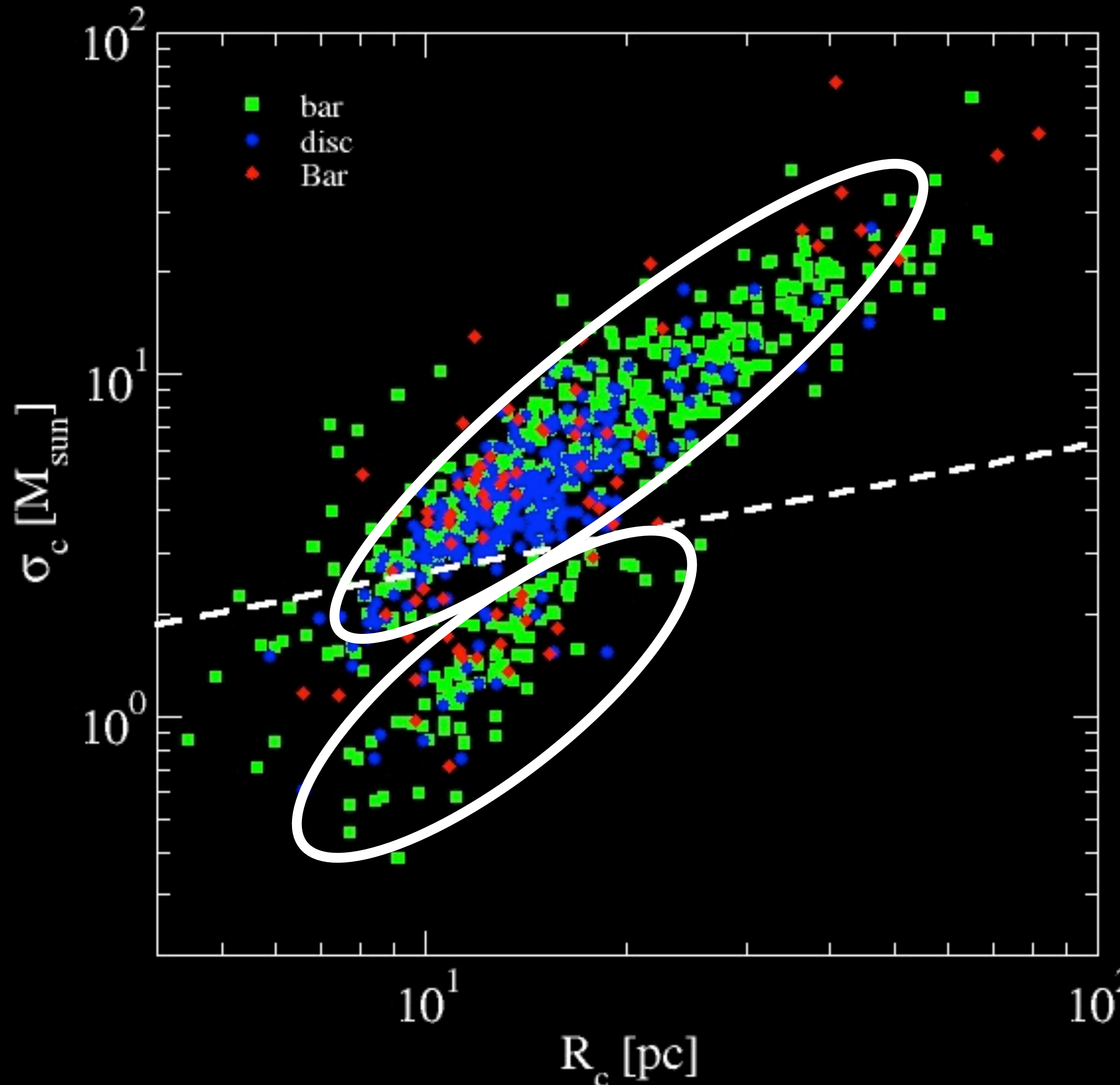
Cloud properties

Size-Linewidth relation:

Clouds typically have a higher velocity dispersion than observed.

Dual population also seen

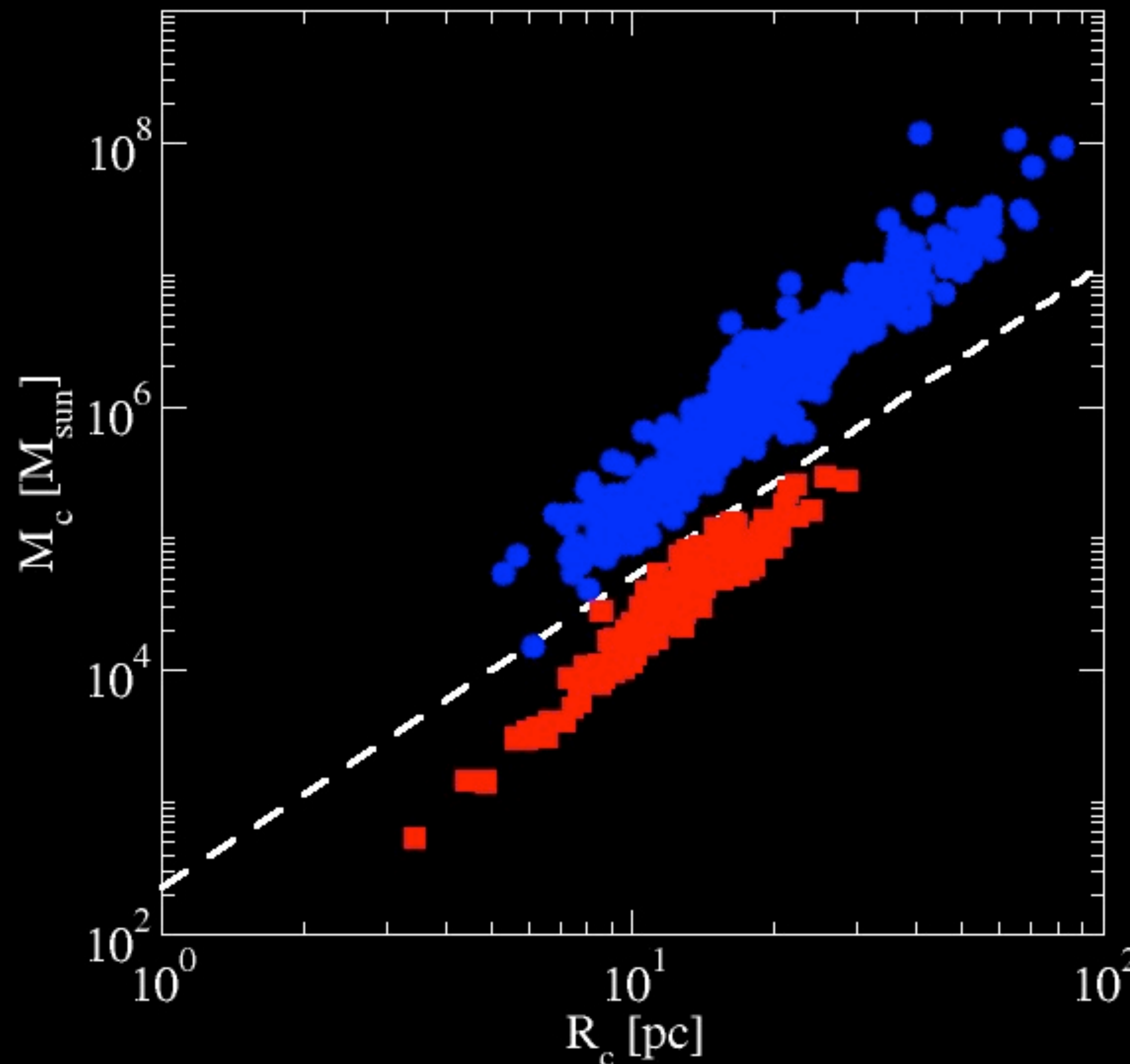
Are these the same clouds?



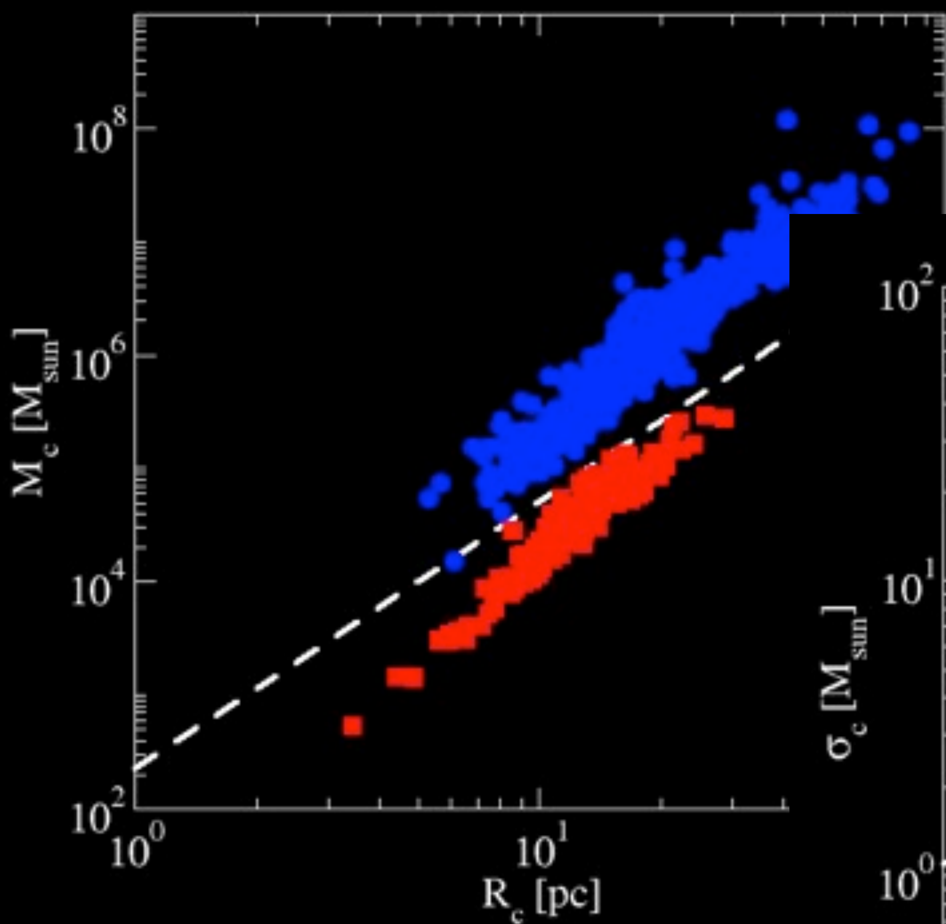
Larson: $\sigma = 1.1 R^{0.38}$

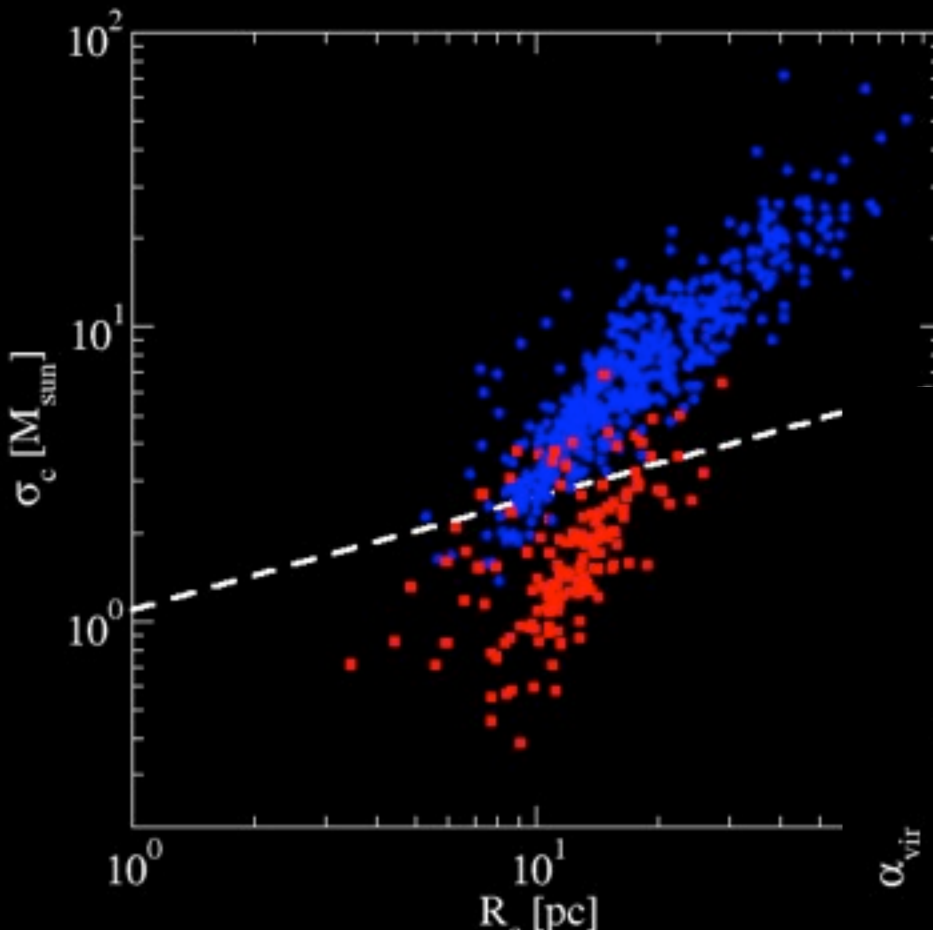
Cloud properties

Define populations
using size-mass relation

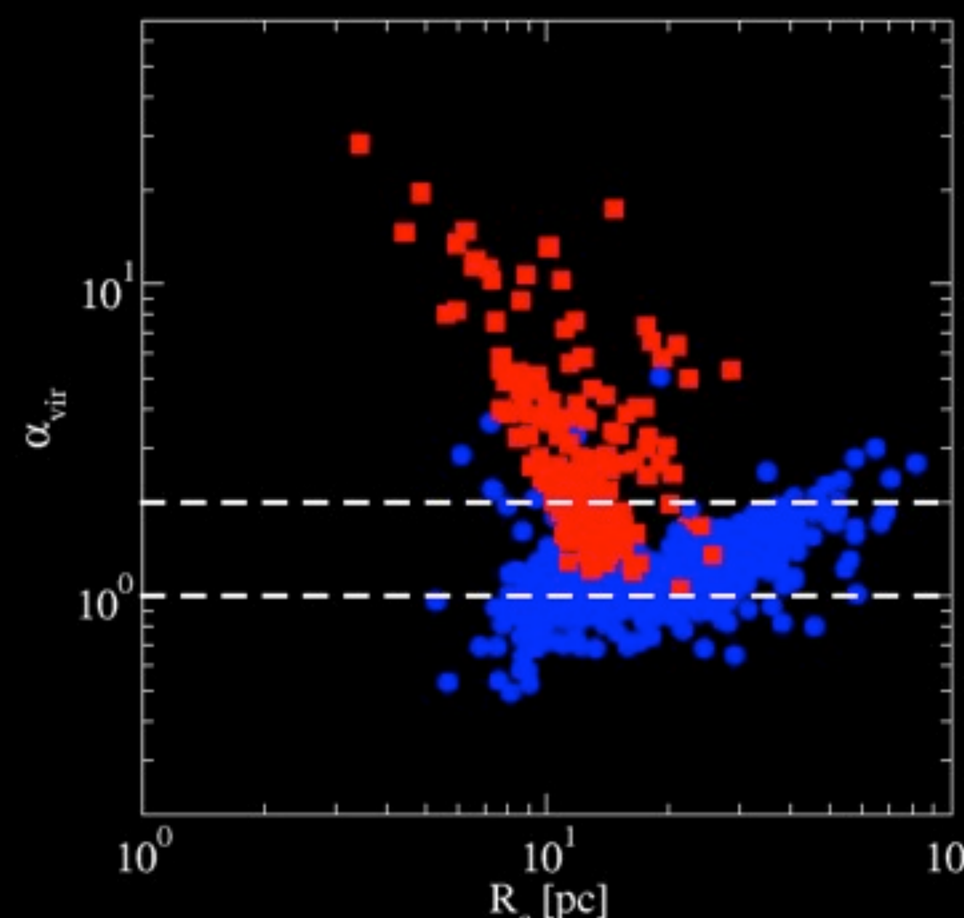


Cloud properties



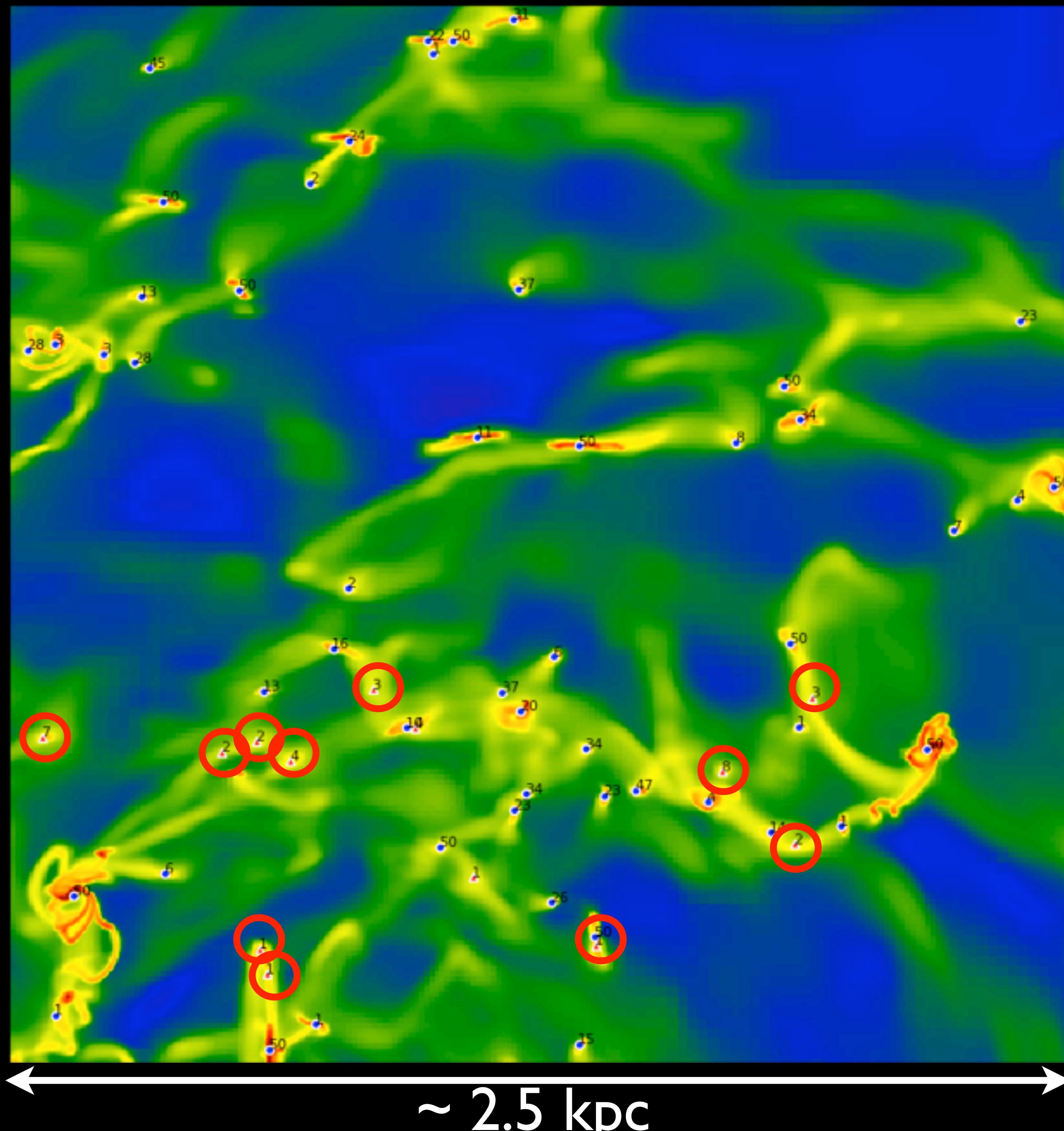


Clouds typically less bound



Same clouds in second population in size-linewidth relation

Cloud properties

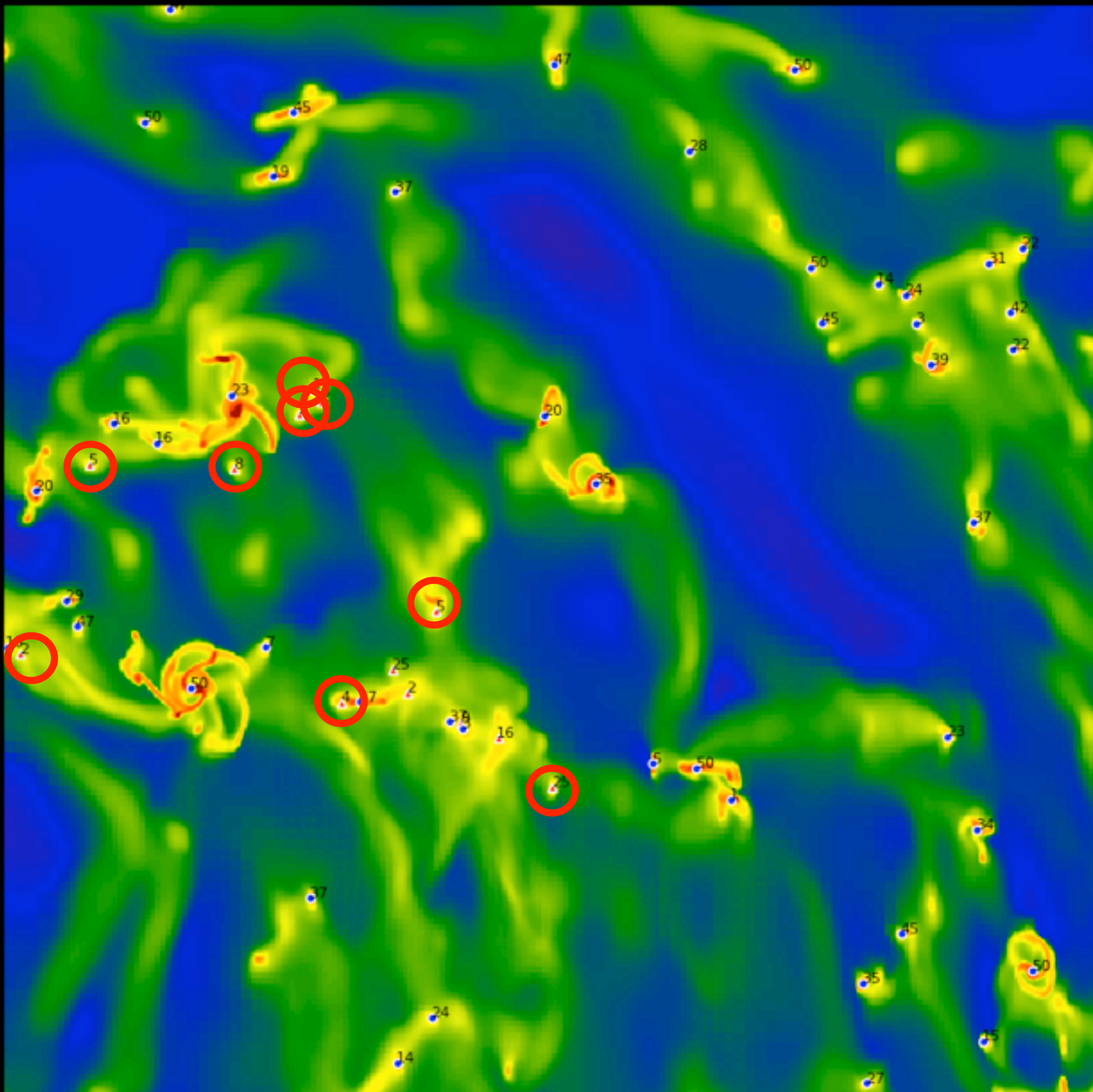


'red' clouds typically short lived.

Mostly 1-2 Myrs

Formed along filaments which either disperse or are accreted onto larger cloud

Cloud properties



~ 2.5 kpc

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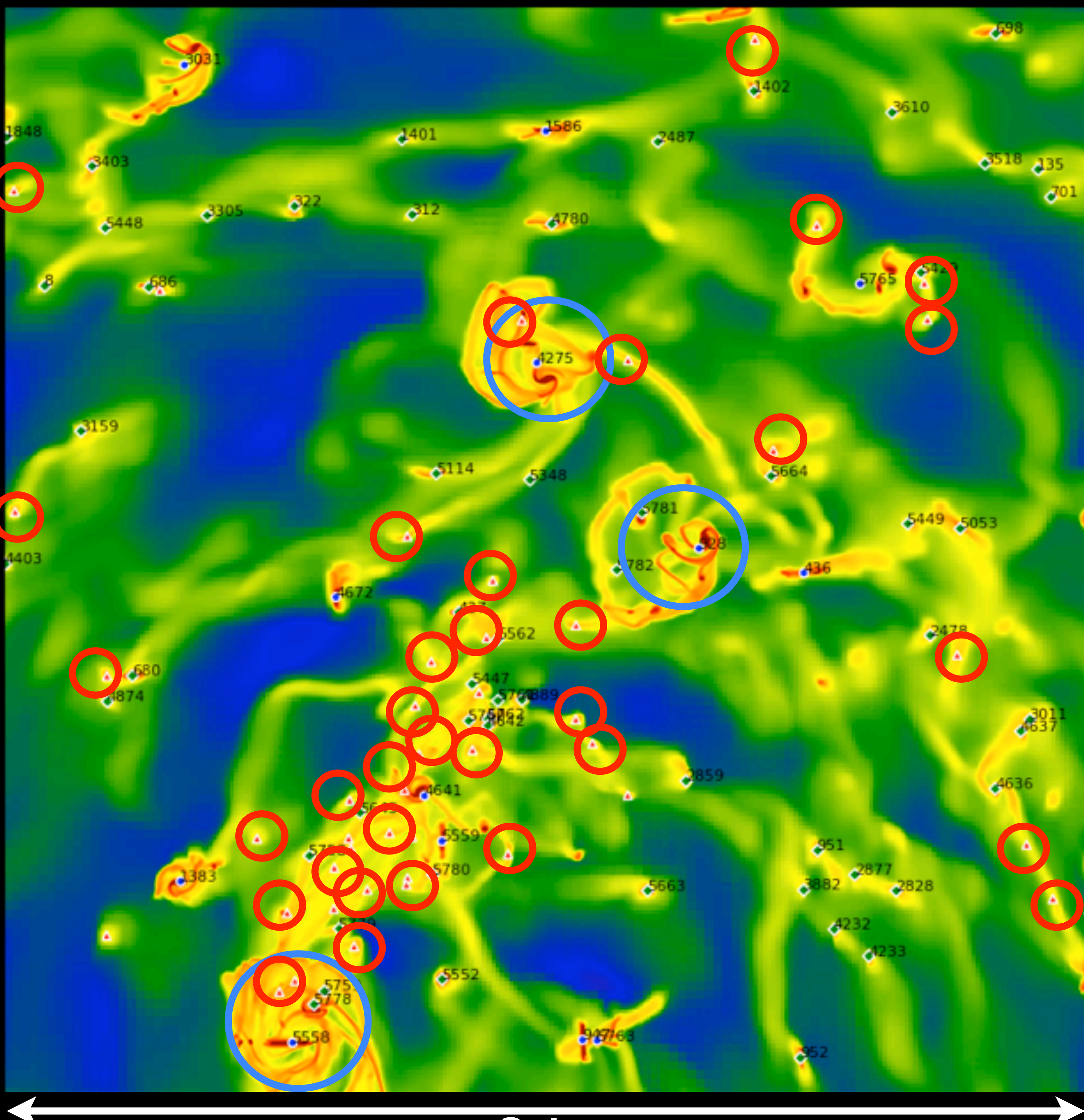


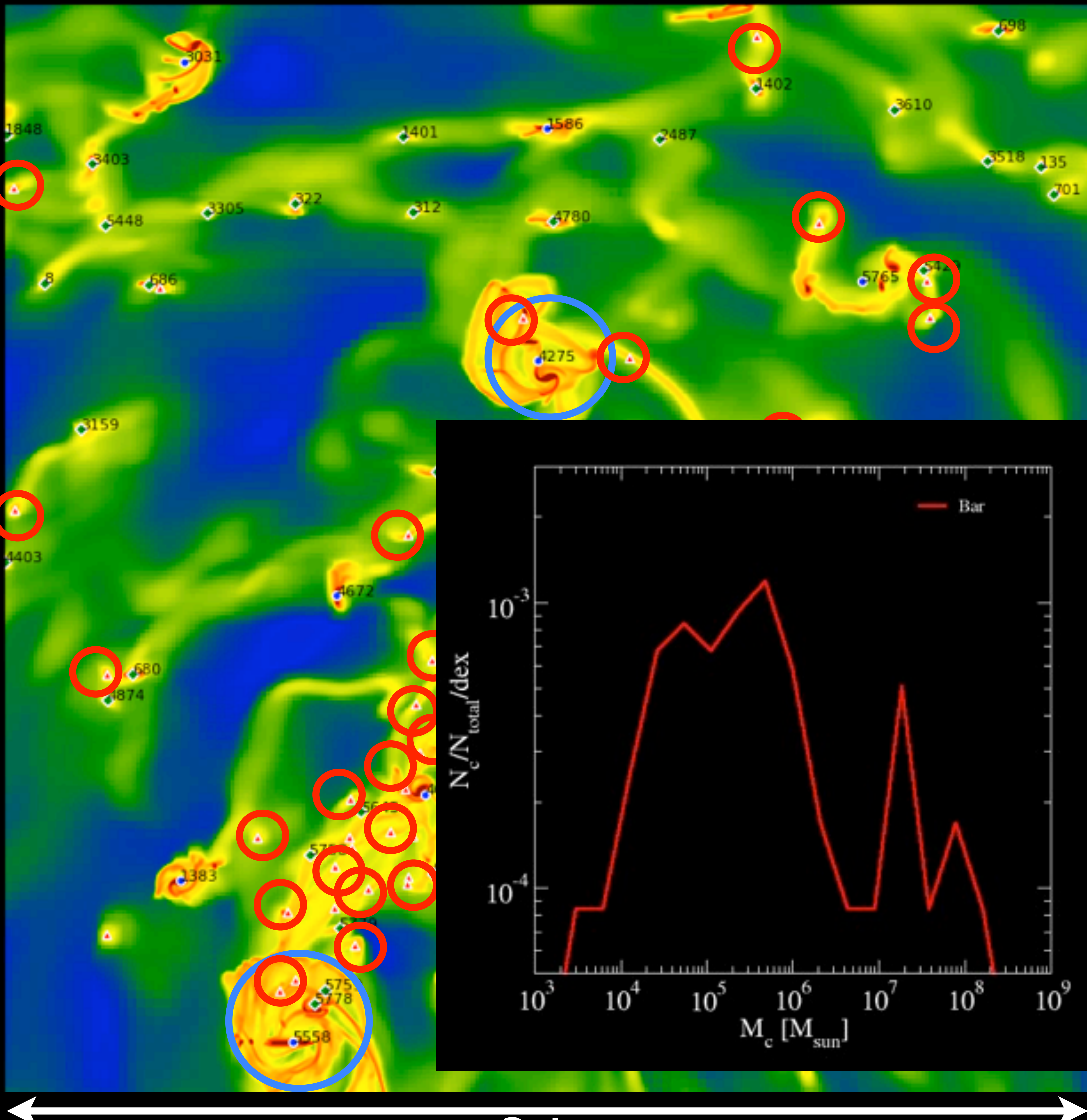
~ 3 kpc

Bar region:

Many ‘red’ transient clouds

Also, massive GMAs that cannibalise nearby clouds

Cloud properties



~ 3 kpc

Bar region:

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Cloud properties

Cloud-collision driven star formation rate:

mass

$$\Sigma_{\rm SFR} = \frac{\epsilon f_{\rm sf} N_A M_c}{t_{\rm coll}}$$

(Tan, 2000)

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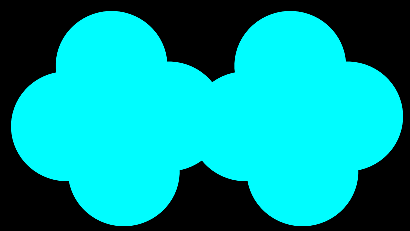
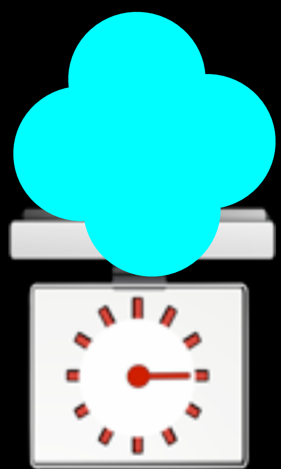


cloud surface number density

Cloud properties

Cloud-collision driven star formation rate:



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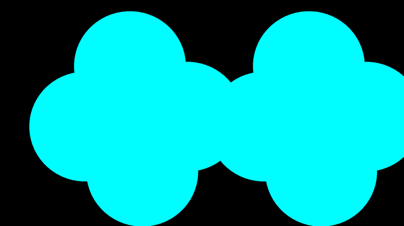
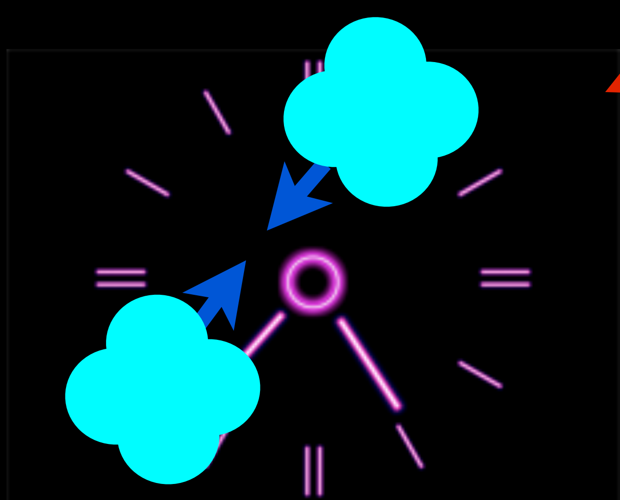


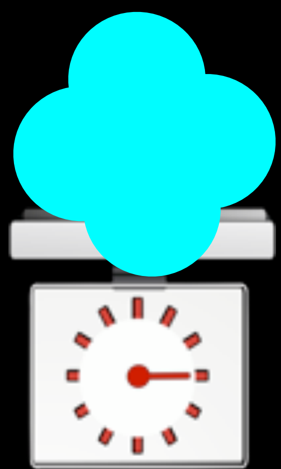
cloud surface number density



Collisional time

Cloud properties

Cloud-collision driven star formation rate:



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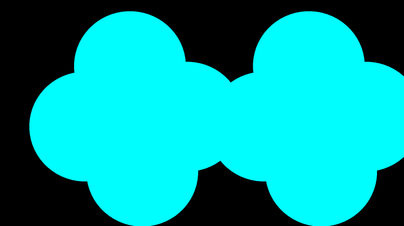
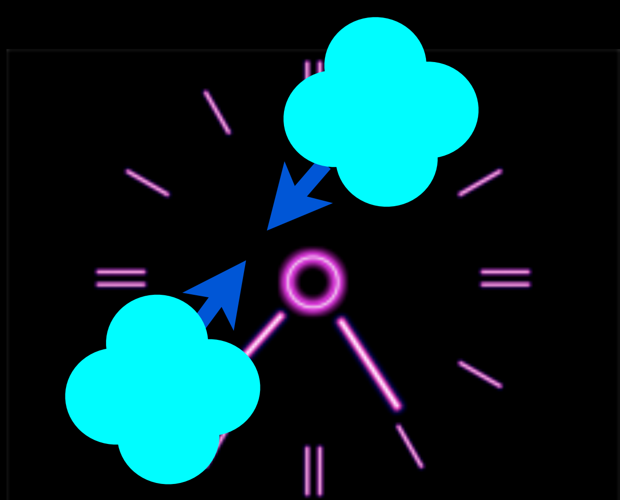
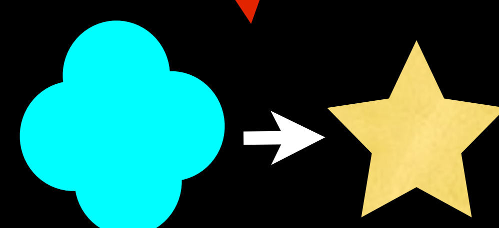


cloud surface number density



Collisional time



Star formation efficiency

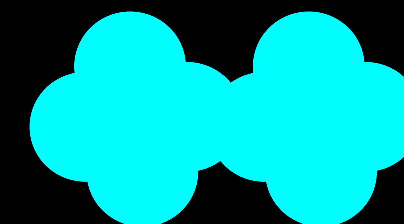
Cloud properties

Cloud-collision driven star formation rate:

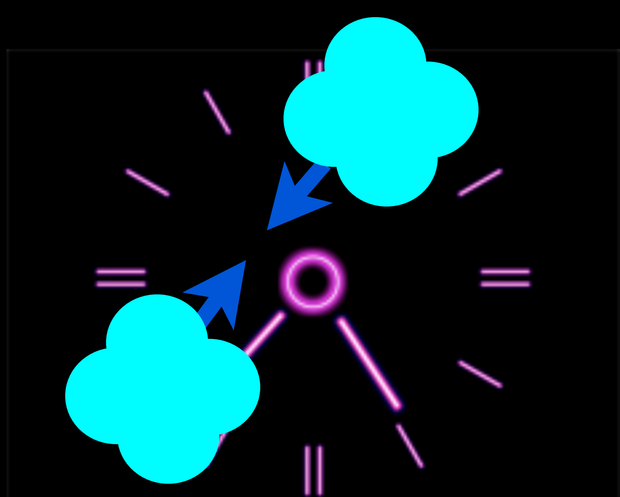
mass

$$\Sigma_{\rm SFR} = \frac{\epsilon f_{\rm sf} N_A M_c}{t_{\rm coll}}$$

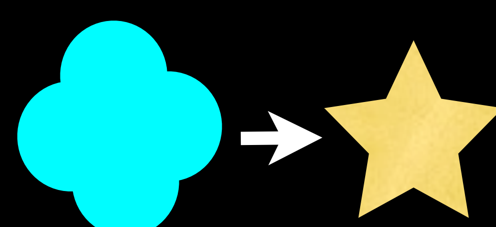
(Tan, 2000)



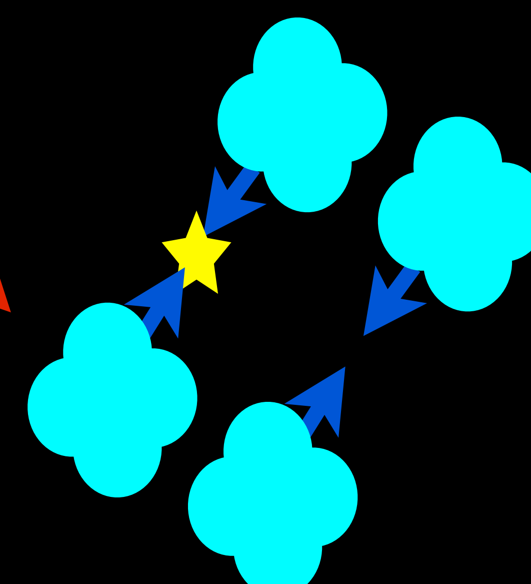
cloud surface number density



Collisional time



Star formation efficiency



Fraction of collisions that result in stars

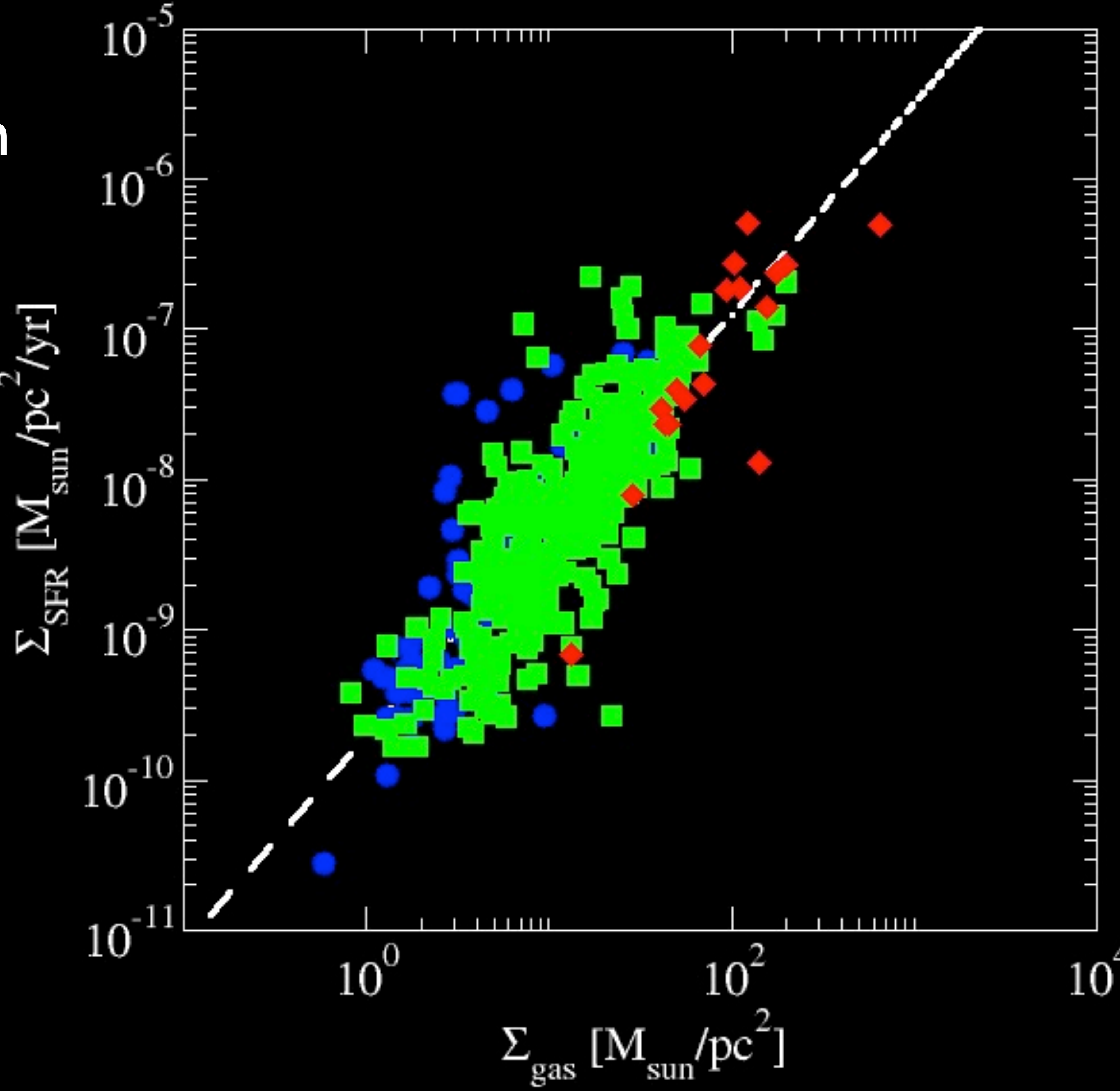
Star formation rate

Good fit along the Schmidt-Kennicutt Relation

Number of mergers / cloud ~ constant

Higher number density in bar region therefore gives higher SFR.

Averaged over 500 pc sq.



Conclusions

- "Typical cloud" similar in bar / spiral / disc environment

$$M \sim 4 \times 10^5 \, \mathrm{M_\odot}$$
$$R \sim 10 \, \mathrm{pc}$$
$$\sigma \sim 3 - 5 \, \mathrm{km/s}$$

- 3 different types of cloud:

Transient:	lifetime 1-2 Myr, unbound
Typical:	lifetime < 15 Myr, borderline bound
T-Rex (GMA):	lifetime +++ Myr, borderline bound

- Clouds live in a violent, interactive environment