Stellar formation efficiency at high densities

Fabien Louvet **3rd year PHD** **CEA-AIM**

F. Motte (AIM) ; A. Gusdorf (ENS) ; A. Maury (CEA)

The enigma of massive star formation

OB stars (M > 8 Msun) have a key role in the Galaxy

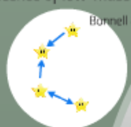
- Heat their parent molecular cloud
- Drive powerful solar winds
- Blast wave -> triggered star-formation
- Enrich their environment with heavy material

But their formation remains poorly understood.

The model of low-mass star-formation does not apply

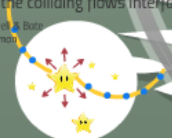
The radiative pressure stops the accretion

Coalescence of low-mass stars



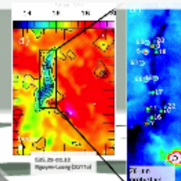
Cores sustained by turbulence

Building at the colliding flows interface



Formation in clusters

Massive stars form in massive dense cores (MDCs)



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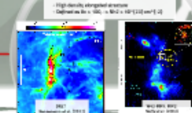

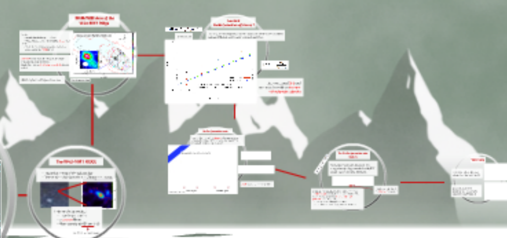

GESF 2014, Marseille

Prezi

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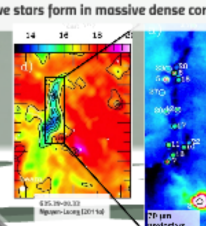
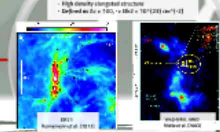
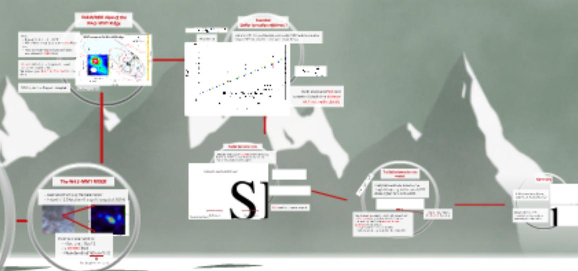


Massive stars form in RIDGES





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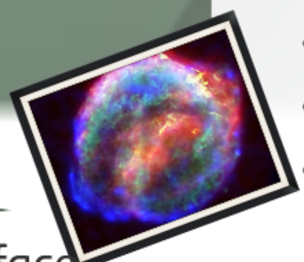

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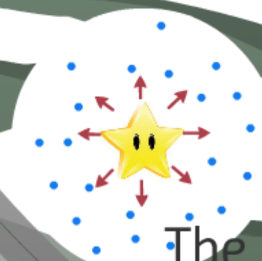

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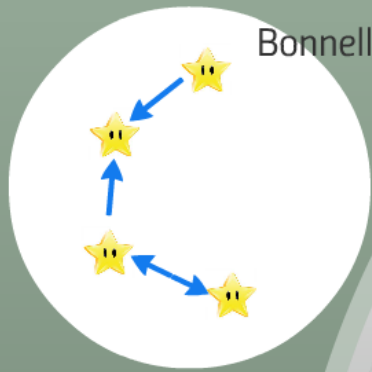
Coalescence of low-mass stars

Bonnell & Bate

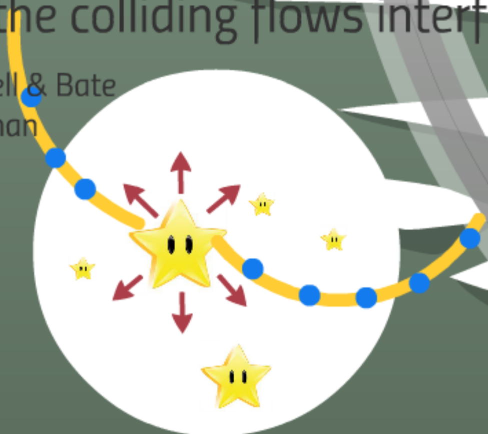


Cores sustained by turbulence

McKee & Tan

Building at the colliding flows interface

Bonnell & Bate
Hartman



Prezi

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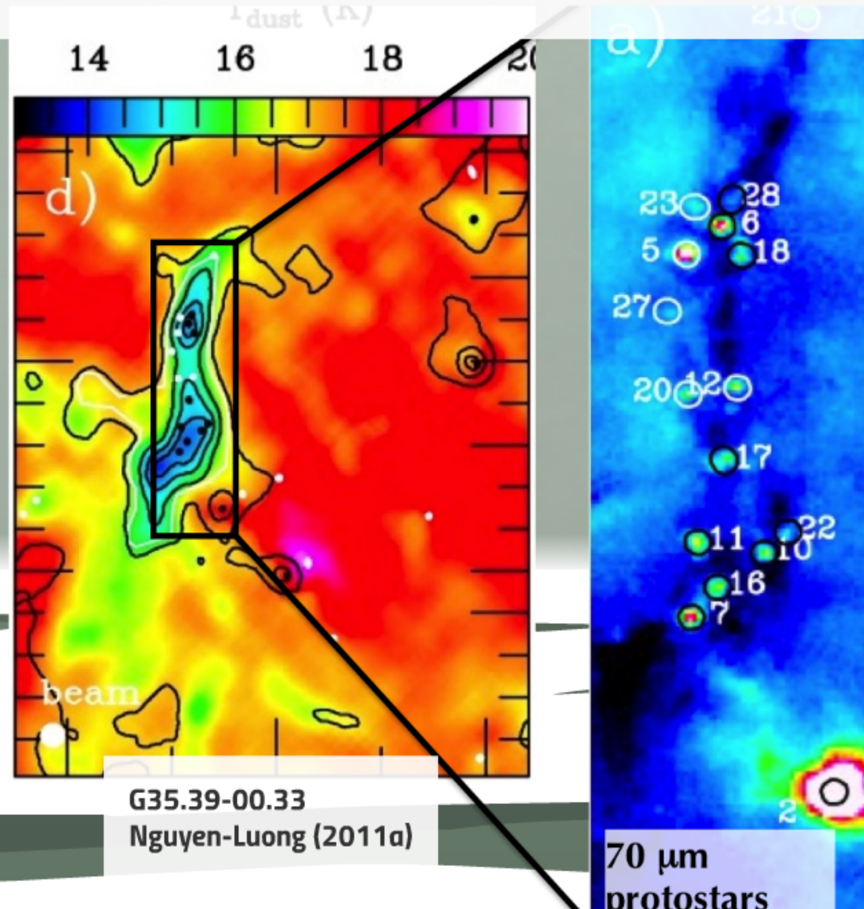
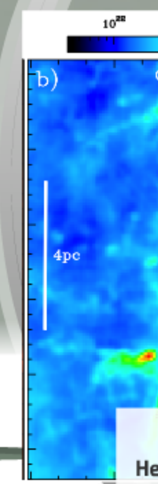


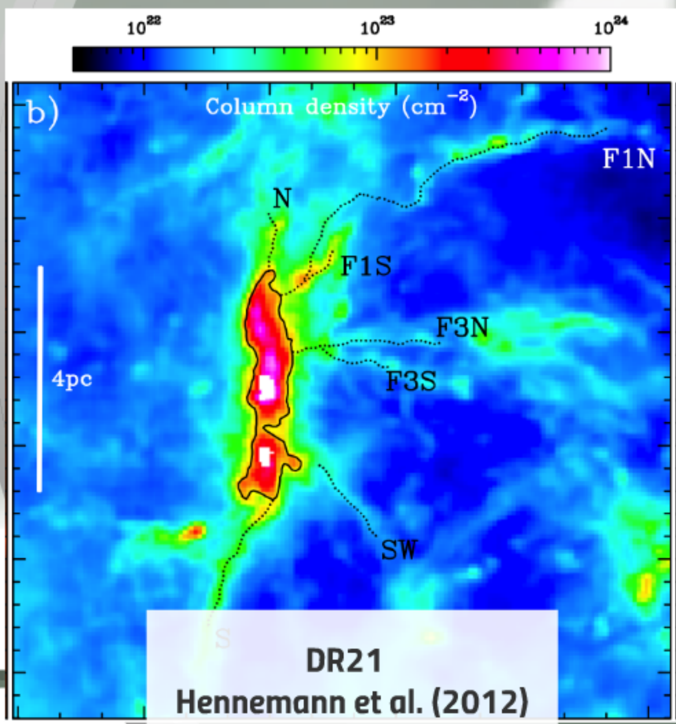
G35.39-00.33
Nguyen-Luong (2011a)



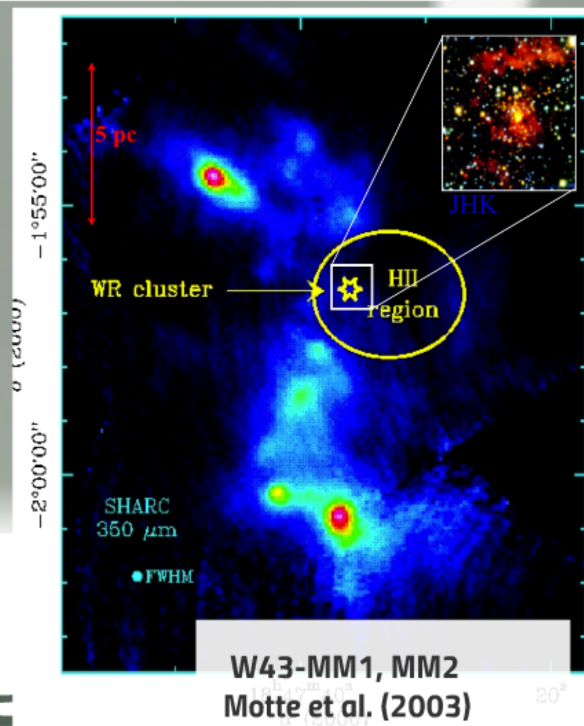
~0.1 pc, with density of $\sim 10^7$ cm^{-3}

Massive stars form in RIDGES

- High density elongated structure
- Defined as Av > 100, -> Nh2 > 10^{23} cm^{-2}



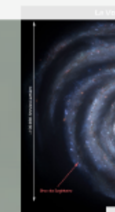
DR21
Hennemann et al. (2012)



W43-MM1, MM2
Motte et al. (2003)

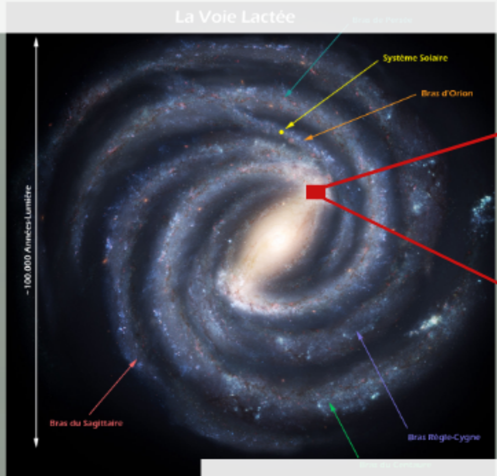
- Dynamical structures
- Accreting material

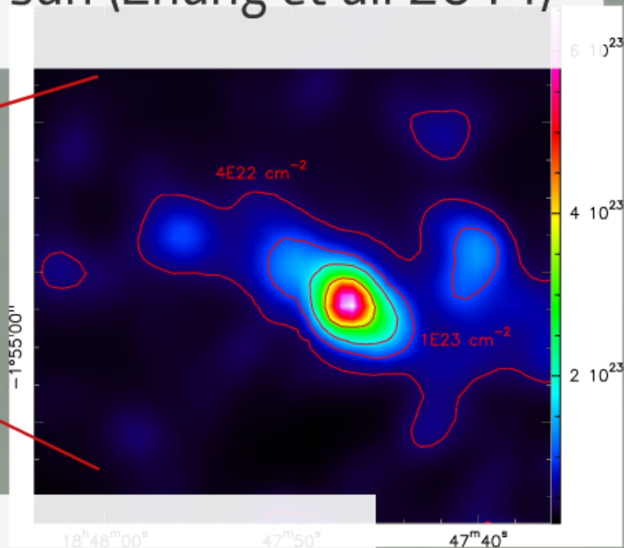
- Located
- Distant



The W43-MM1 RIDGE

- Located at the tip of the Galactic bar
- Distant of 5.5 kpc from the sun (Zhang et al. 2014)





Extreme characteristics:

- ~3 pc long / 8 pc^3
- > 20 000 Msun
- Mean density of 4E4 cm^{-3}

Density of low-mass cores

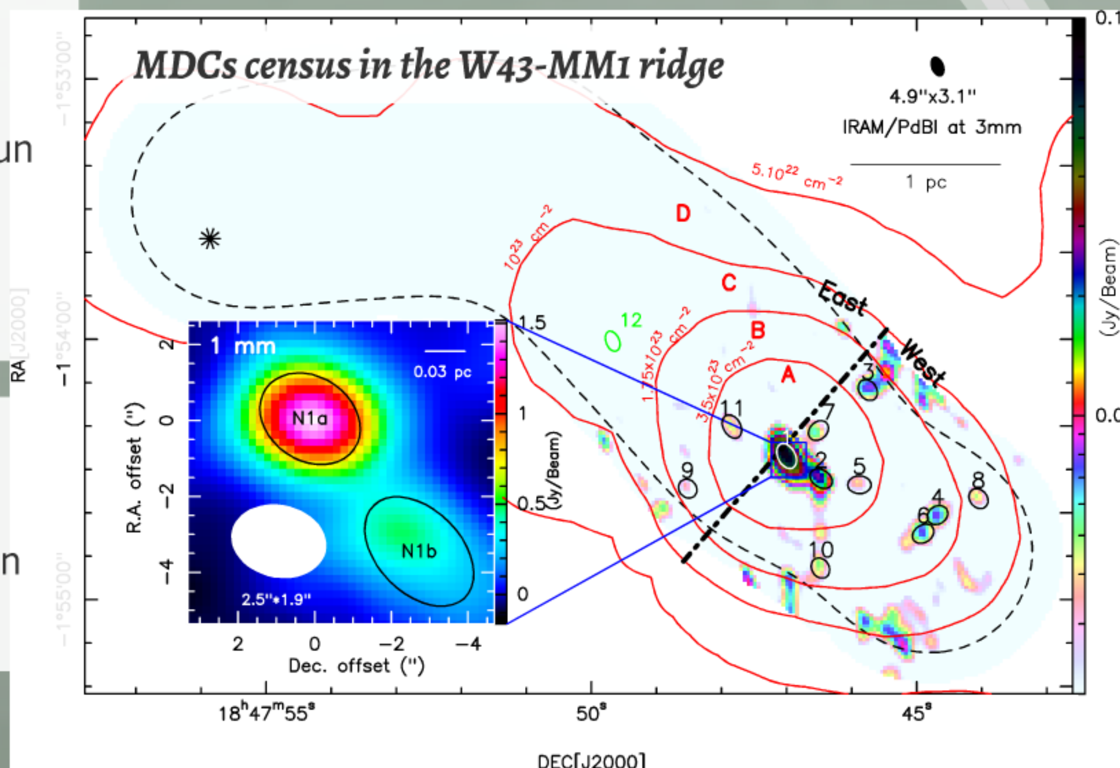
IRAM/PdBI view of the W43-MM1 Ridge

3mm:
- Revealed a cluster of 11 MDCs
- MDCs Masses range from 100 to 2100 Msun

1mm:
- Finds the most massive young stell object ever observed (~1000 Msun)

Hershel column density map provides cloud masses and cloud densities.
We define regions A, B, C and D as shells (russian dolls)

ALMA cycle 2 -> Proposal accepted



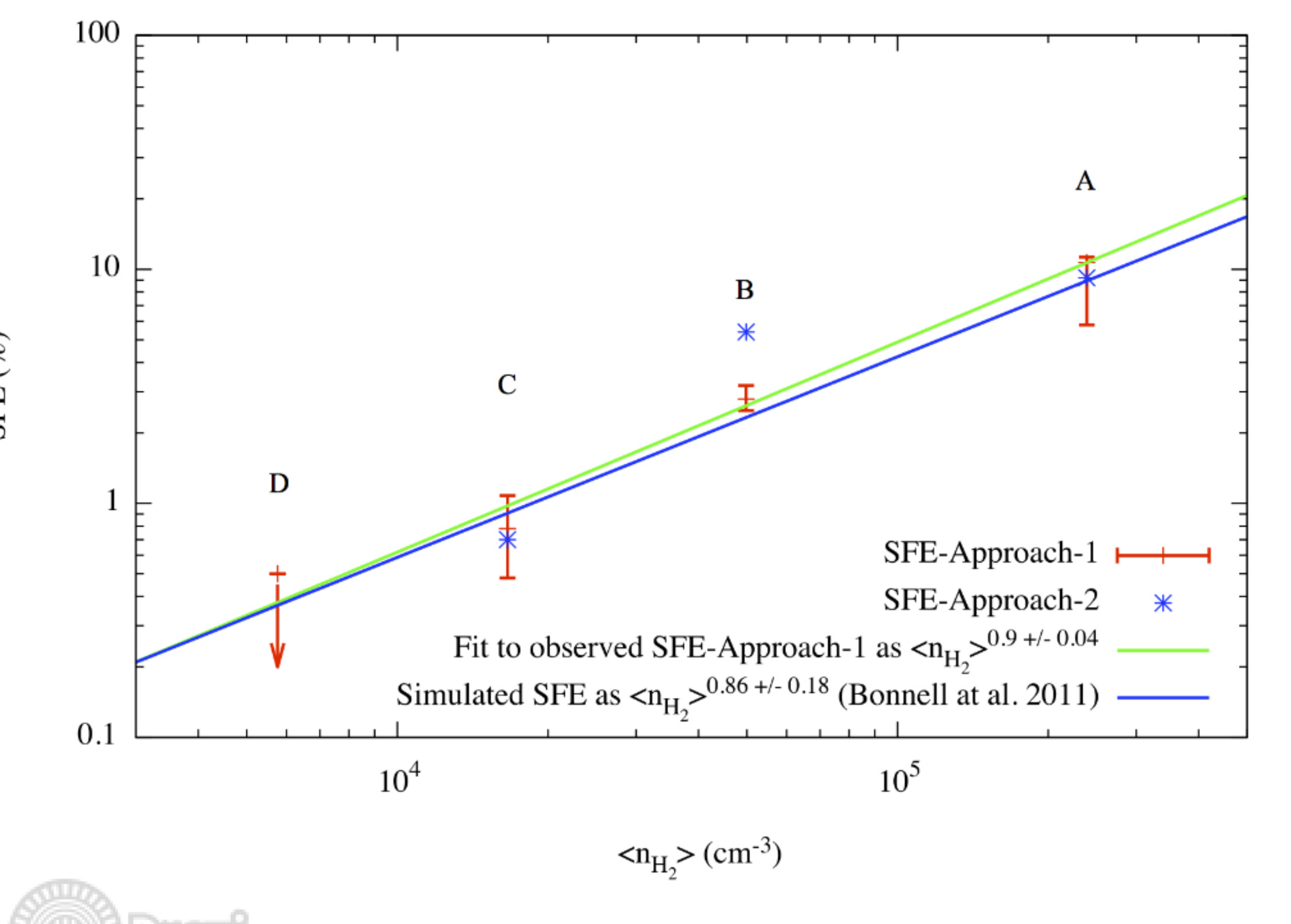
From Louvet et al. (2014)

Constant
Stellar formation efficiency ?

$$SFR \propto M_G \, M_{\odot} yr^{-1}$$

when Av > 8

Lada et al. (2012) implicitly assumes a constant SFE to derive a relation between SFR and cloud mass in regions above 8 mag

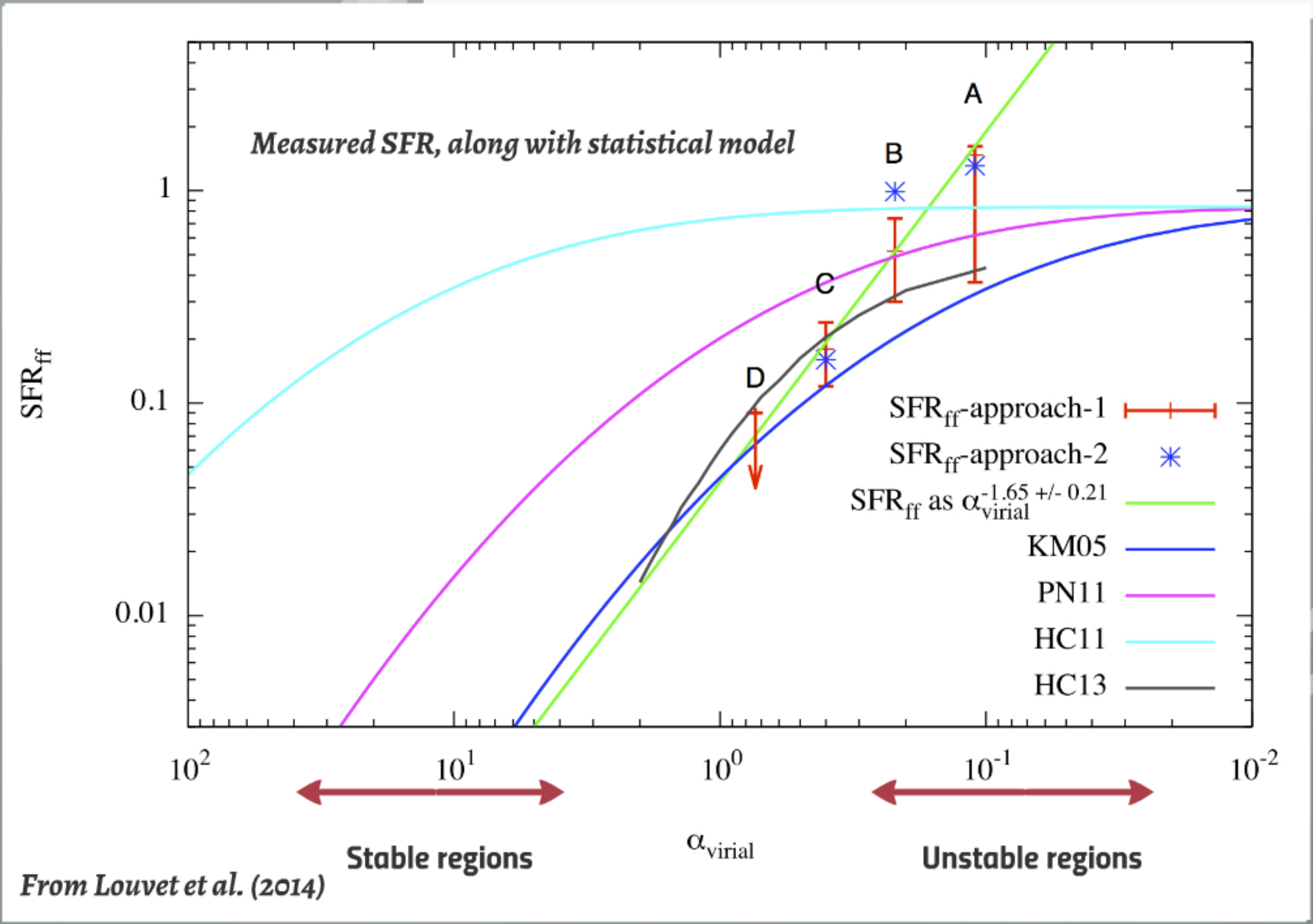


$$SFE = \frac{M_{\star}}{M_{cloud}}$$

Both measured SFE and numerical simulation increase with volumetric density

Stellar formation rate

Statistical models of SFR saturate at low virial numbers (Krumholz & McKee 2005 ; Padoan & Nordlund 2011 ; Hennebelle & Chabrier 2011, 2013)



$$\mathrm{SFR_{ff}} = \mathrm{SFE} \times \frac{\mathrm{t_{ff}^{cloud}}}{\mathrm{t_{ff}^{MDCs}}}$$

$$\mathrm{SFR_{ff}} = \frac{\epsilon}{\phi_t} \int_{s_{crit}}^{\infty} \frac{t_{\rm ff}(\rho_0)}{t_{\rm ff}(\rho)} \frac{\rho}{\rho_0} p(s) ds$$

ALMA cycle 2 -> Proposal accepted

$$p_s(s) = \frac{1}{\sqrt{2\pi\sigma_s^2}} \exp\left(-\frac{(s-s_0)^2}{2\sigma_s^2}\right)$$

The Stellar formation rate models

Analytical models are based on the integration of a log-normal density PDF above a given density threshold.

$$\mathrm{SFR}_{\mathrm{ff}} = \frac{\epsilon}{\phi_t} \int_{s_{crit}}^{\infty} \frac{t_{\mathrm{ff}}(\rho_0)}{t_{\mathrm{ff}}(\rho)} \frac{\rho}{\rho_0} p(s) ds$$

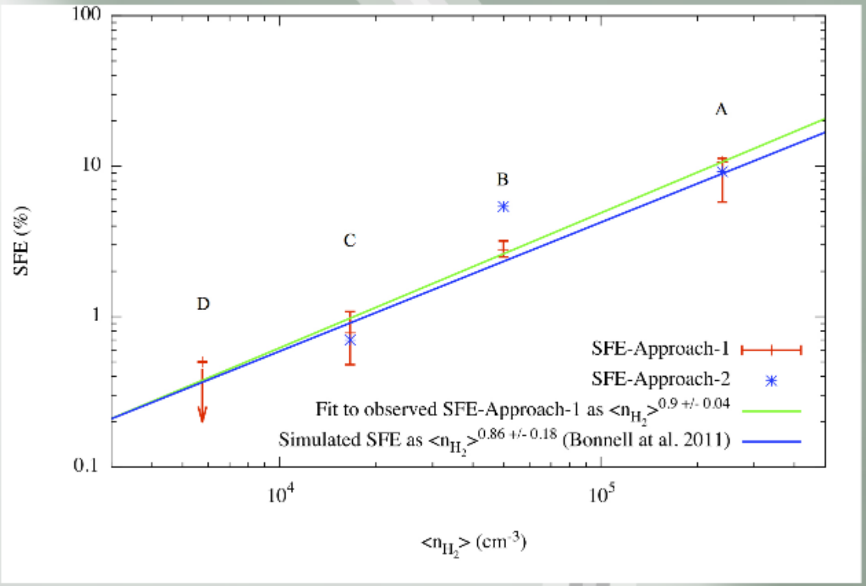
Models mainly differ by the threshold they adopt

Models do not reproduce the W43-MM1 comportment -> Multi free-fall models (Hennebelle & Chabrier 2011 ; Federrath et al. 2012) AND more realistic cloud parameters should be used:

- atypical column density distribution
- turbulence level move aside from the Larson law

Summary

Stellar formation efficiency depends on the cloud density



Observations at high resolution are necessary to constrain the SFR models