Challenging the relation between cores masses and stellar masses: from W43-MM1 to the ALMA-IMF large program

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Special credits to:
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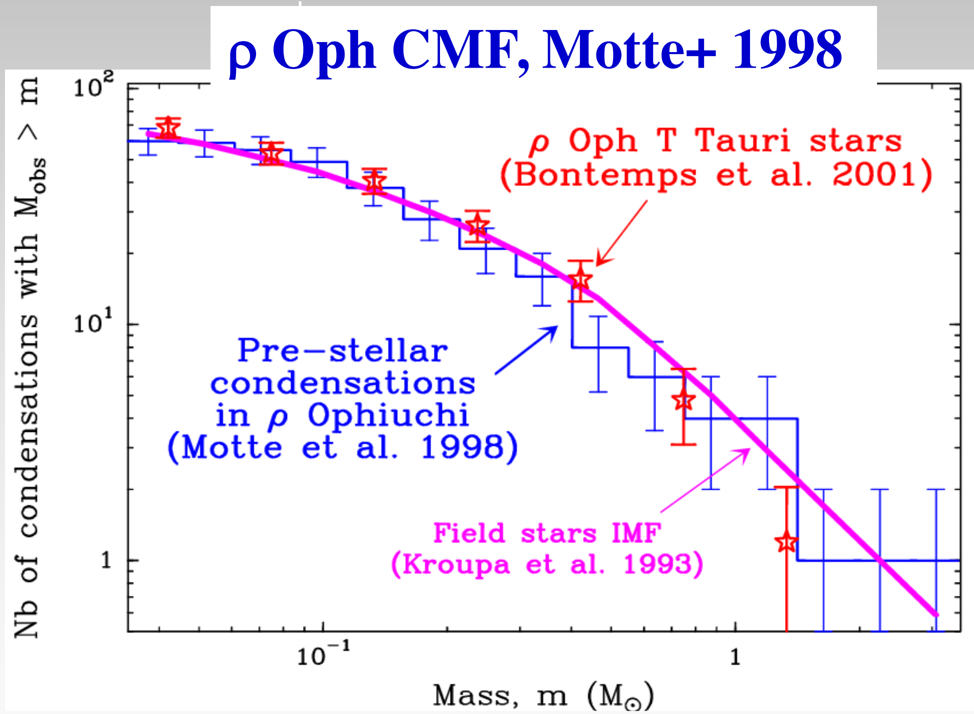
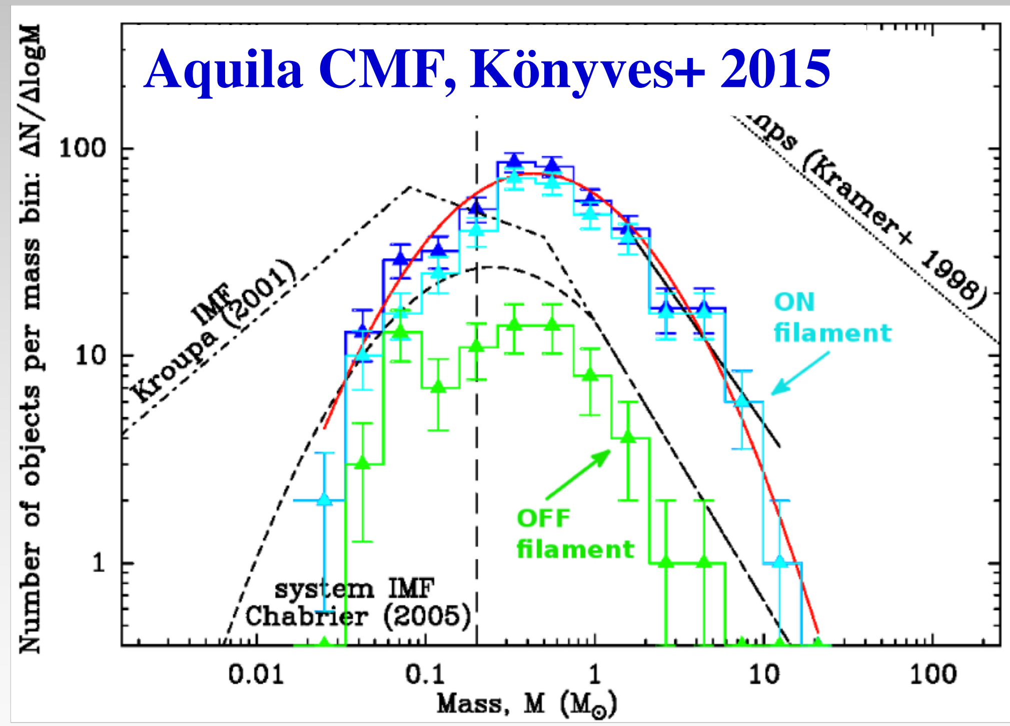
The ALMA-IMF team: *PIs* F. Motte, F. Louvet, A. Ginsburg, P. Sanhueza,
co-Is including J. Bally, C. Battersby, V. Chen, N. Cunningham, R. Galvan-Madrid, A. Guzman, X. Lu, L. Maud, F. Olguin, J.F. Robitaille, K. Tatematsu, …

1/ The CMF / IMF similarity in low-mass SF regions

Submm ground-based, Herschel, and NIR extinction surveys of the past 2 decades (Motte+ 1998, 2001; Testi & Sargent 1998; Johnstone+ 2000; Stanke+ 2006; Alves+ 2007; Nutter & Ward-Thompson 2007; Enoch+ 2008; André+ 2010; Könyves+ 2015, …).





The IMF is at least partly determined by fragmentation at the pre-stellar stage

Studies limited to <5 $M_\odot$ stars…

in regions not typical of the main mode of star formation in galactic disks.

1/ Assumptions behind the CMF/IMF comparison

1. Measured core mass = total mass available to form a star

- ➢ What about the impact of accretion streams toward high-mass cores?
- ➢ What about multiplicity?

2. Uniform gas-to-star mass conversion of cores, ε (m) = cst

- ➢ Does ε increase with core density like in clumps (e.g., Louvet+ 2014)?

3. Snapshot = true CMF, i.e. lifetime independent of the core mass

These effects should cancel out to keep the CMF/IMF shapes so similar.

⇒ Central limit theorem?

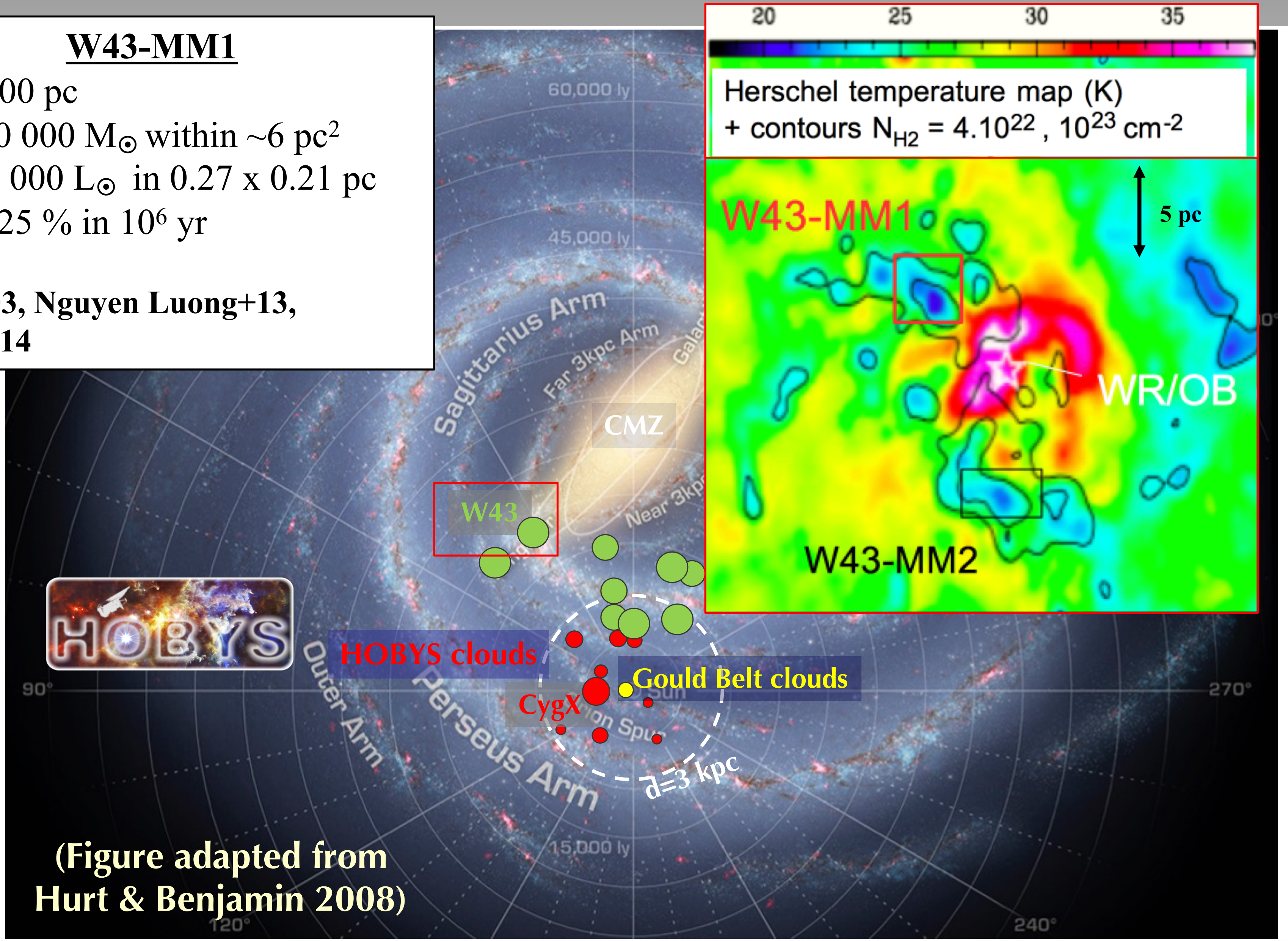
⇒ Or obs. uncertainties too large to see that IMF is not so universal?

1/ W43-MM1: a "mini-starburst" protocluster

W43-MM1

- d = 5500 pc
- M ~ 20 000 $M_\odot$ within ~6 pc^2
- L ~ 20 000 $L_\odot$ in 0.27 x 0.21 pc
- SFE ~25 % in 10^6 yr

Motte+03, Nguyen Luong+13, Louvet+14



1/ W43-MM1: ALMA data

ALMA Cycle 2 and 3 data:

- 12m + 7m (ACA) config.

→ Scales 0.5″-20″ (~ 0.01-0.5 pc at 5.5 kpc)

- 8 spectral windows at **1.3 mm**
- 33 fields mosaic

Mass completeness ~1.6 $M_\odot$

Cores extraction:

- Using *getsources*, a multi-scale algorithm (Men'shchikov+2012)
- On line-free band + full band (2 GHz)

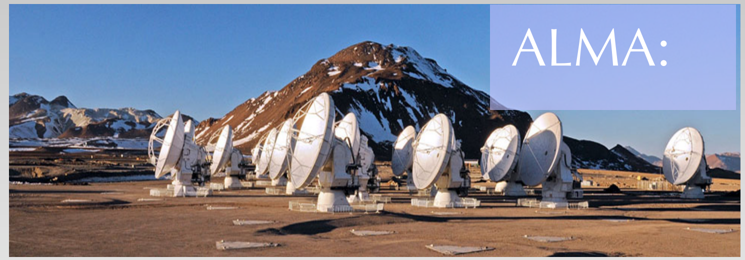


Table 1. Basics parameters of the merged data spectral windows.

Spectral window	ν_{obs} [GHz]	Bandwidth [MHz]	Resolution ["]	Resolution [km s^{-1}]	rms [a]
SiO(5-4)	217.033	234	0.48	0.3	2.5
CO(2-1)	230.462	469	0.46	1.3	3.1
^{13}CS(5-4)	231.144	469	0.46	0.3	3.1
Continuum	233.4	1875	0.43	1.3	1.9

(a) 1σ rms in [mJy beam^{-1}]

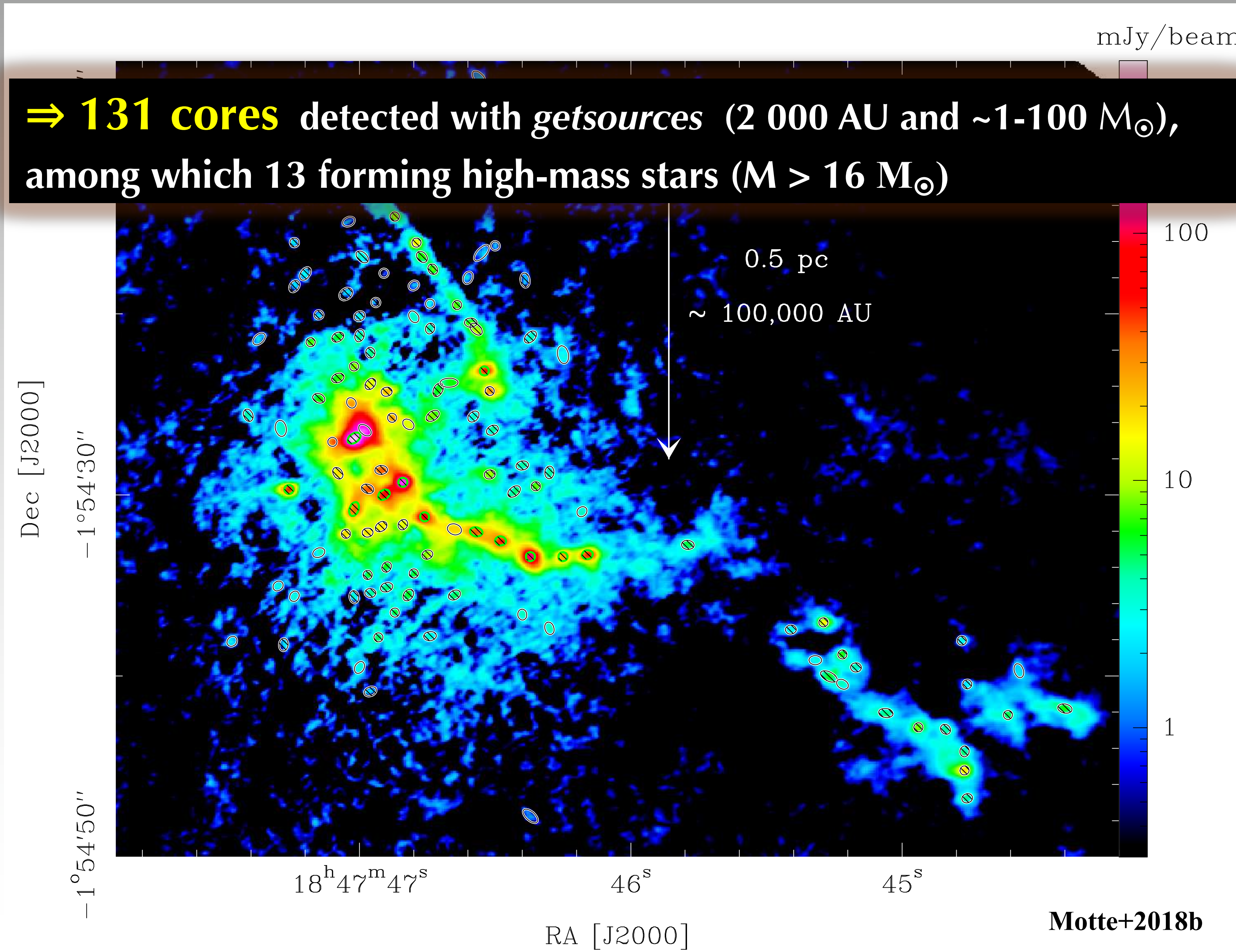
Motte+2018b

$$M_{\rm core} = -\frac{\Omega_{\rm b}\, d^2}{\kappa_{1.3\rm mm}} \ln\left(1 - \frac{S^{\rm peak}_{1.3\rm mm}}{\Omega_{\rm b}\, B_{1.3\rm mm}(T_{\rm d})}\right) \times \frac{S^{\rm int}_{1.3\rm mm}}{S^{\rm peak}_{1.3\rm mm}}$$

$$= -M^{\rm opt\,thin}_{\rm core} \times \frac{\Omega_{\rm b}\, B_{1.3\rm mm}(T_{\rm d})}{S^{\rm peak}_{1.3\rm mm}} \ln\left(1 - \frac{S^{\rm peak}_{1.3\rm mm}}{\Omega_{\rm b}\, B_{1.3\rm mm}(T_{\rm d})}\right),$$

Cores' mass (gas +dust) calculated from dust continuum emission, including a correction for optical thickness

1/ W43-MM1: continuum image and core extraction

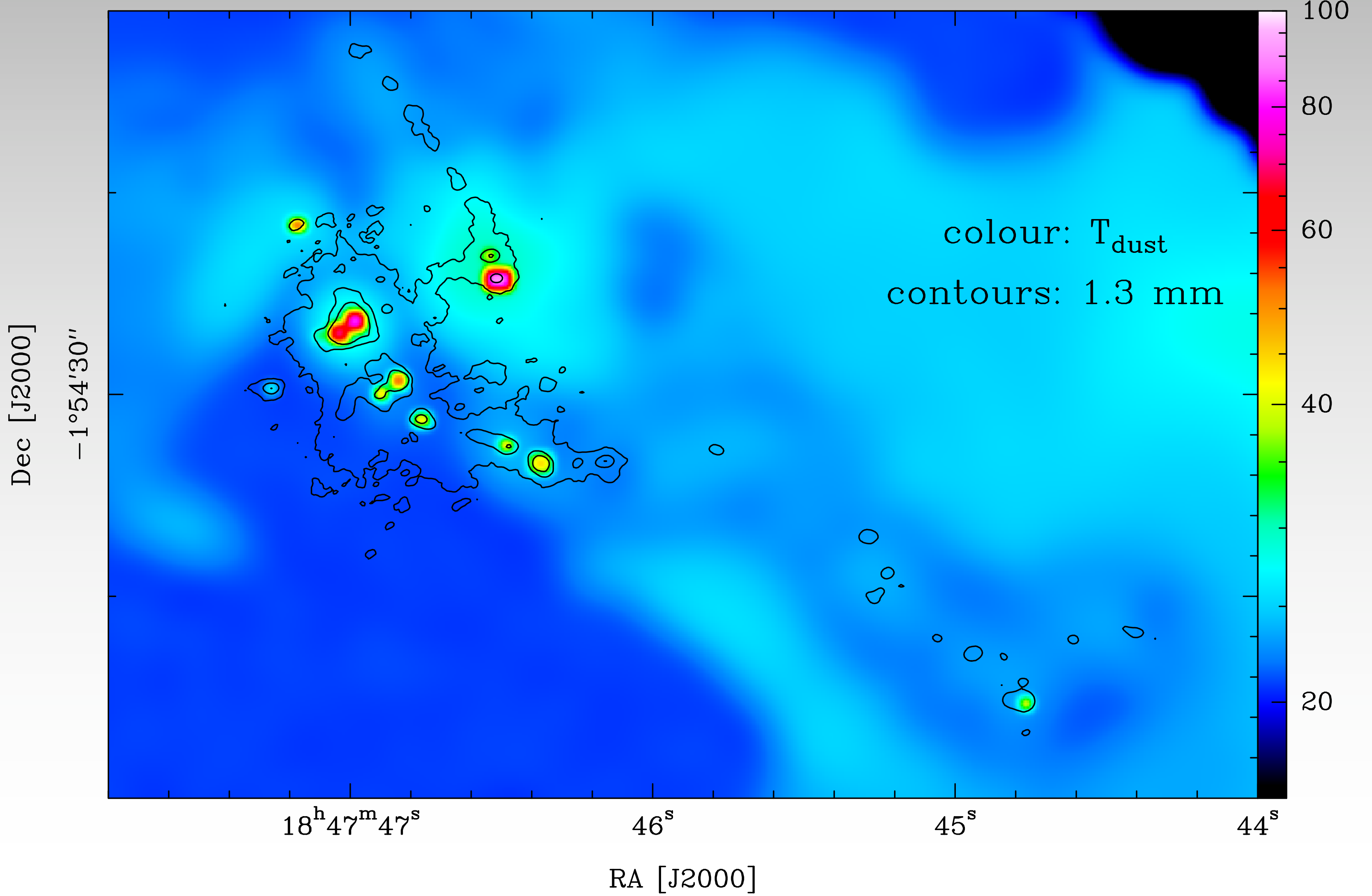


⇒ **131 cores** detected with *getsources* (2 000 AU and ~1-100 $M_\odot$), among which 13 forming high-mass stars ($M > 16\ M_\odot$)

Motte+2018b

1/ W43-MM1: Temperature map

Dust temperature (T_d) estimated from 2.5″ PPMAP images (Marsh+2015) using Herschel, LABOCA, SABOCA, ALMA, PdBI maps from 70 μm to 3 mm and 0.5 to 36″
+ local heating of protostars



1/ Core Mass Function within the W43-MM1 ridge

Slope $\gamma = -0.96 \pm 0.13$ on 1.6-100 $M_\odot$: CMF much flatter than the IMF (-1.35)

=> It would suggest an atypical IMF for stars of 1-50 $M_\odot$ (ε=50%). (Schneider+18)

Or CMF evolution:

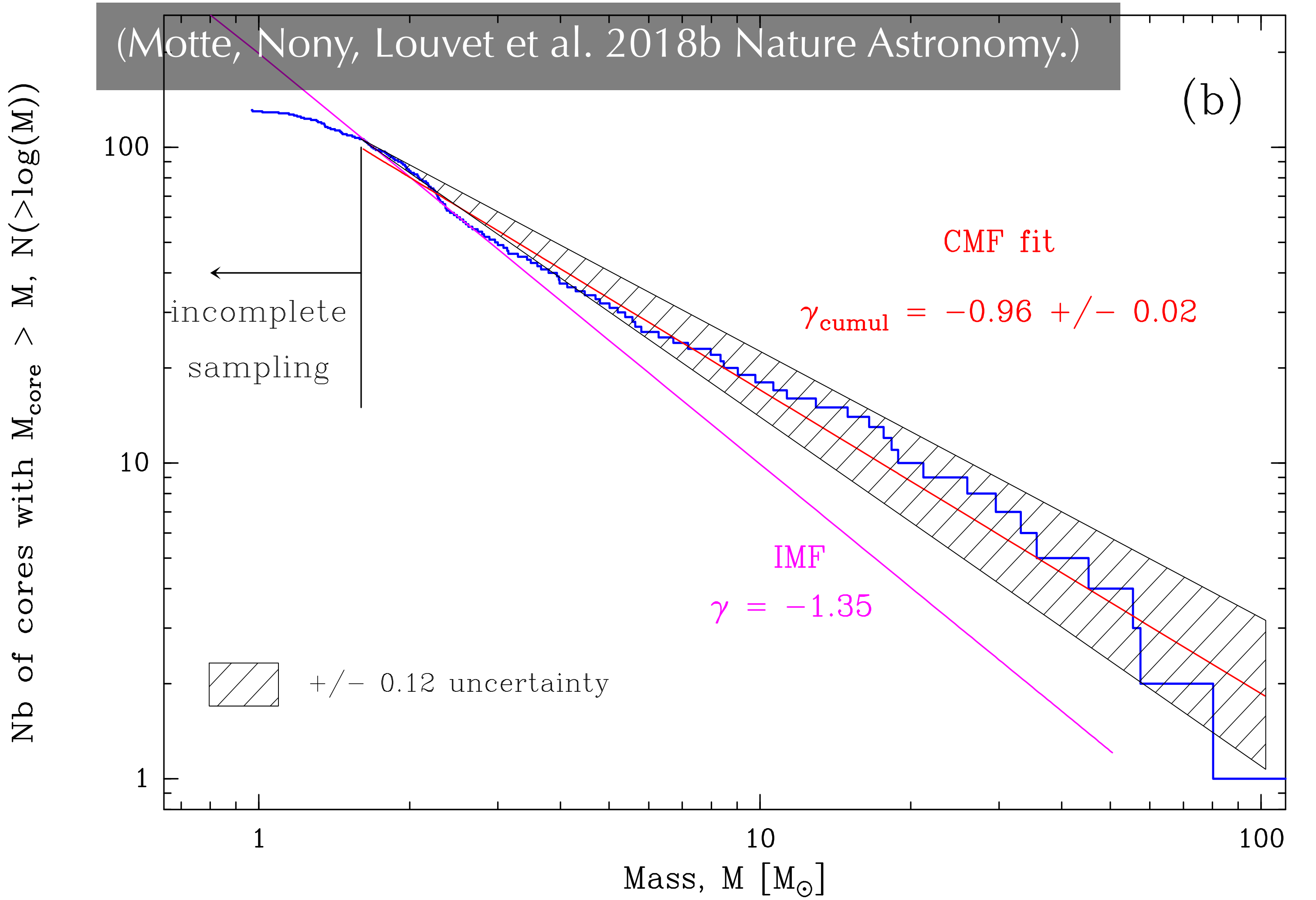
- Continuous mass growth of massive cores

⇒ Flatter

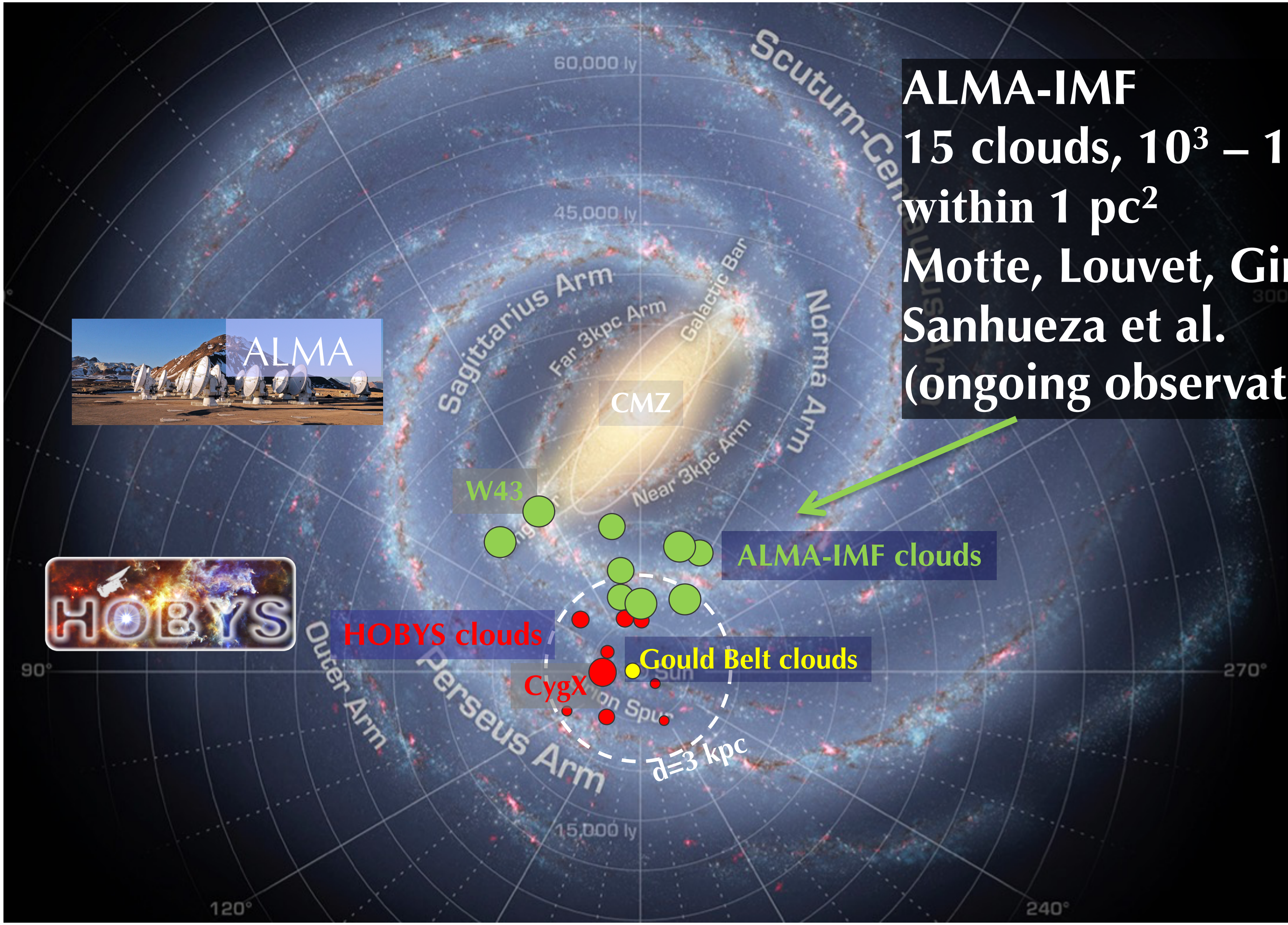
- New episodes of filament and core formation

⇒ maybe steeper…

(Motte, Nony, Louvet et al. 2018b Nature Astronomy.)



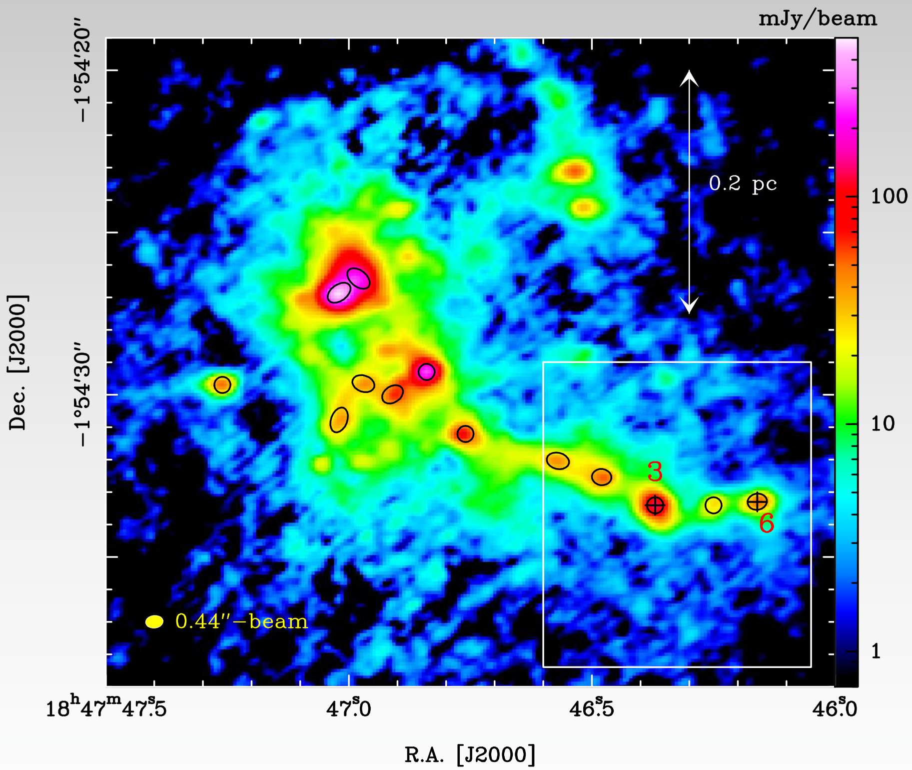
1/ The ALMA-IMF Large Program



ALMA-IMF
15 clouds, $10^3 - 10^4\ M_\odot$ within 1 pc^2
Motte, Louvet, Ginsburg, Sanhueza et al.
(ongoing observations)

2/ Physical properties of cores

Zooming on the tip of the main filament …



… 2 cores with similar masses,

Core	FWHM	S_{peak}	T_d	M_{core}	α_{vir}
	[AU]	[mJy/beam]	[K]	[$M_\odot$]	
#3	1200	109 ± 2	45 ± 1	59 ± 2	0.2
#6	1300	46.8 ± 2	23 ± 2	56 ± 9	0.2-0.3

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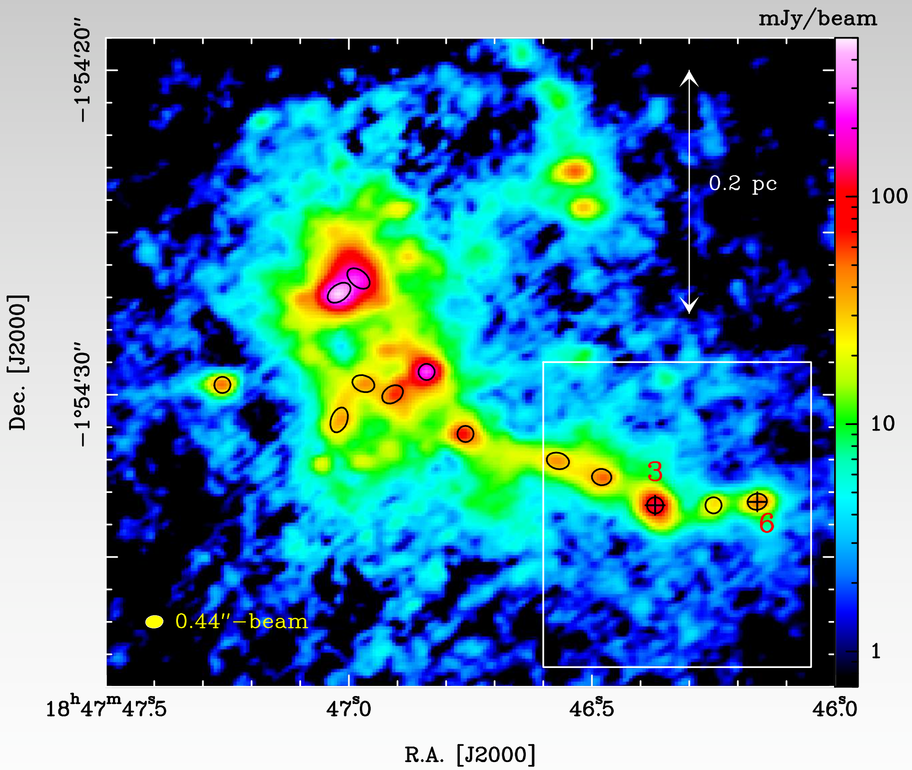

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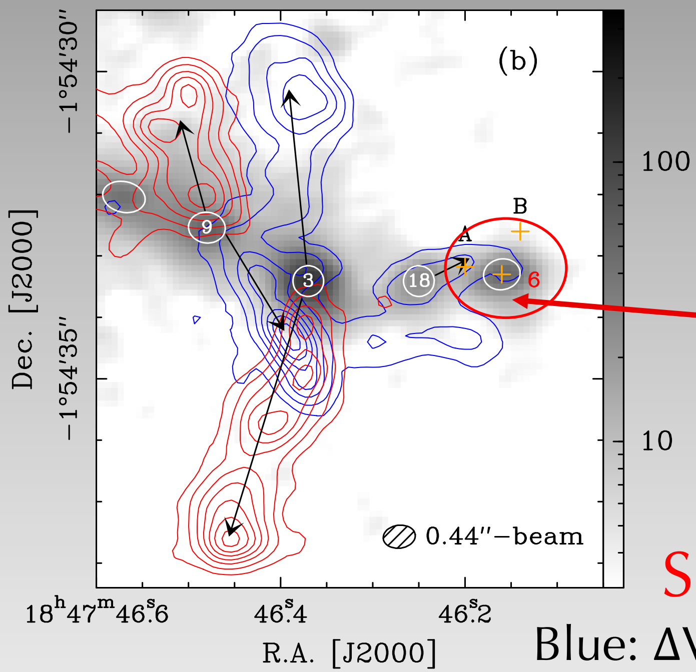
… *gravitationally bound* ($\alpha_{vir} < 1$),

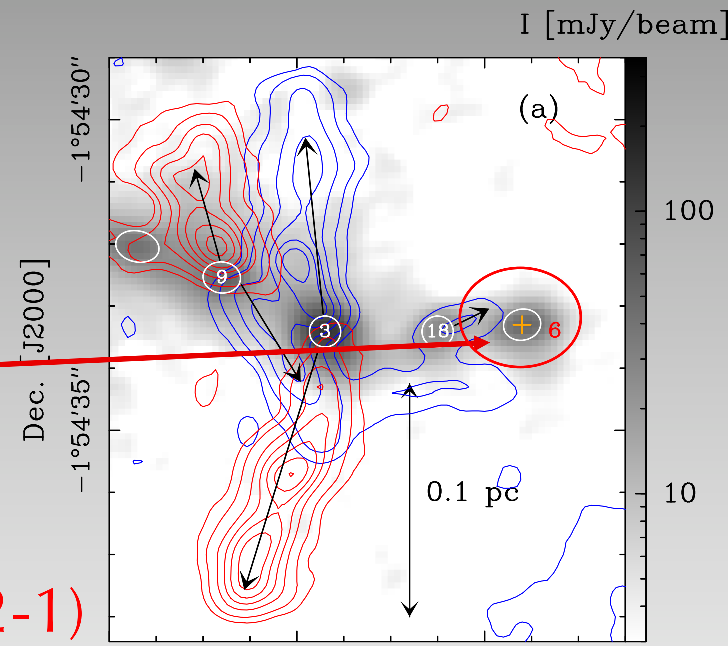
M_{vir} calculated using the $^{13}CS(5\text{-}4)$ line width ($\Delta V \sim 3.5$ km/s)

2/ A high-mass prestellar core candidate



… and with different characteristics !

No outflow detected toward core #6



SiO (5-4)

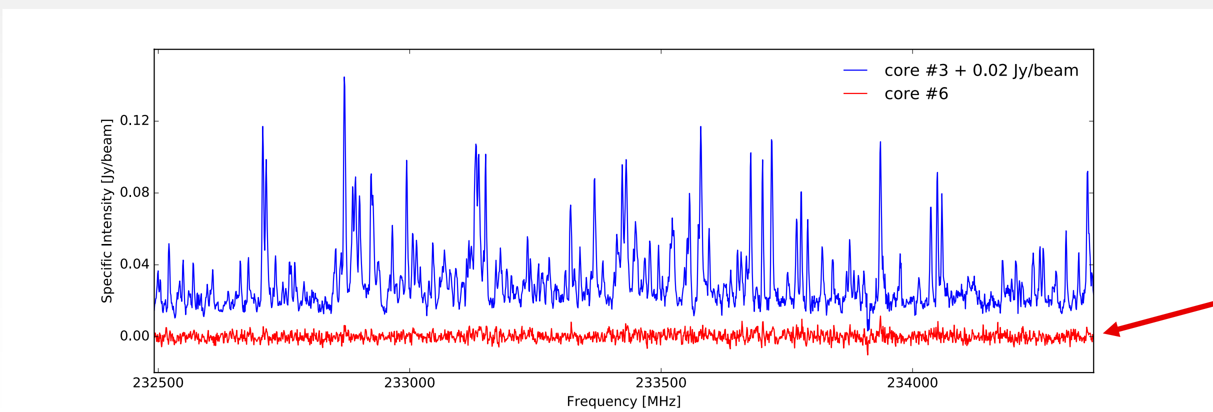
Blue: ΔV = -37 → -7 km/s

Red: ΔV = 7 → 37km/s

CO (2-1)

Blue: ΔV = -60 → -10 km/s

Red: ΔV = 10 → 60 km/s



(Nony, Louvet et al. in prep.)

Very few lines: no hot core emission toward core #6

Conclusion

- **A rich cluster of 131 cores revealed in W43-MM1, with large mass range (2 000 AU and ~1-100 $M_\odot$),**

Among them 13 forming high-mass stars ($M > 16\ M_\odot$)

- **CMF markedly flatter than the reference IMF**:

slope γ = -0.96 ± 0.13 on 1.6-100 $M_\odot$ vs -1.35 for Salpeter

(see also Xing Lu's talk)

- **Detection of an excellent high-mass prestellar core candidate**

Also denser than other candidates (G11P6-SMA1, Wang+2014 and CygXN53-MM2, Bontemps+2010))