IMF origin and episodic accretion constrained by a rich cluster of massive cores and outflows

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Special credits to:
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Open questions

1) What is the origin of the stars' mass distribution (IMF)?

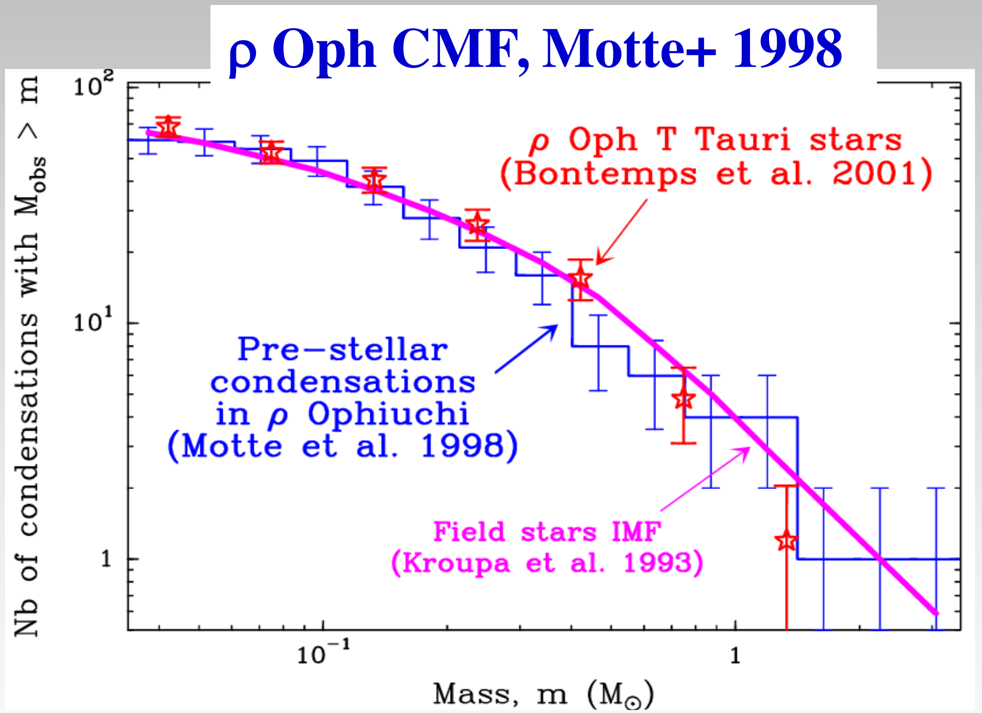
→ build the cores' mass distribution (CMF)

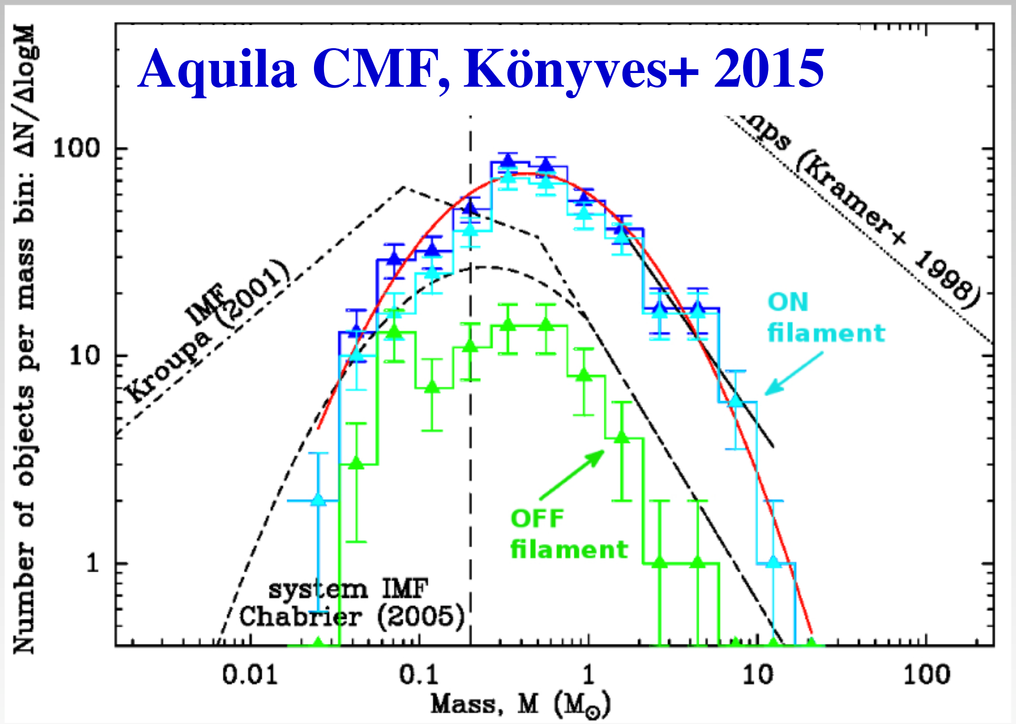
2) What do protostellar ejections tell us about the accretion process?

→ study the time-variability of protostellar outflows

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 seems determined by fragmentation at the prestellar stage

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 sub-fragmentation and stellar 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 (~ 10^5 yr) = true CMF,

vs IMF integrated over several episodes of SF, ages ~ 10^6 – 10^7 yr

- Is star formation continuous or does it evolve with time?

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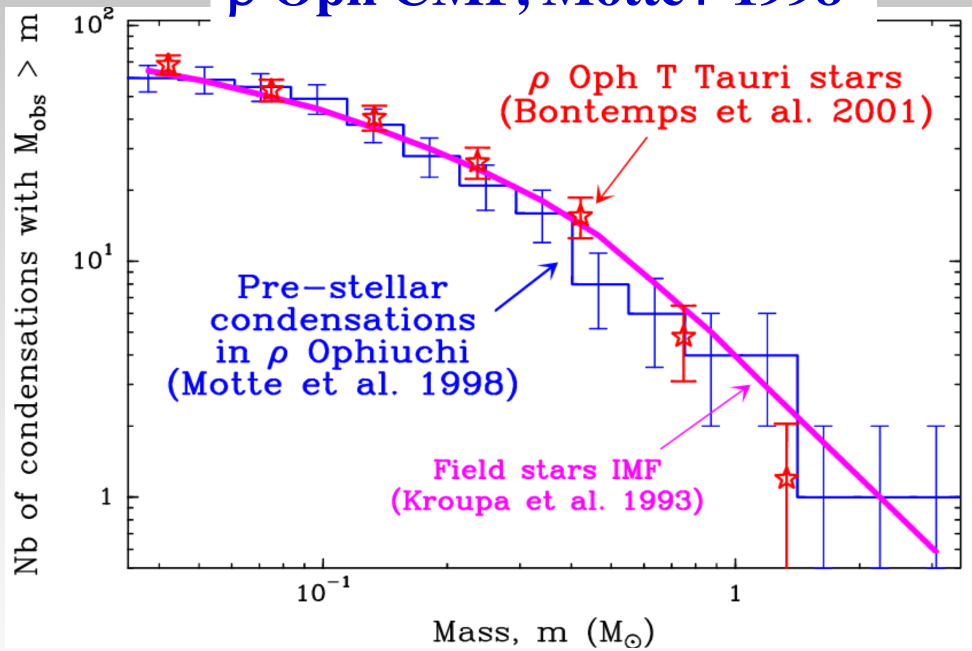
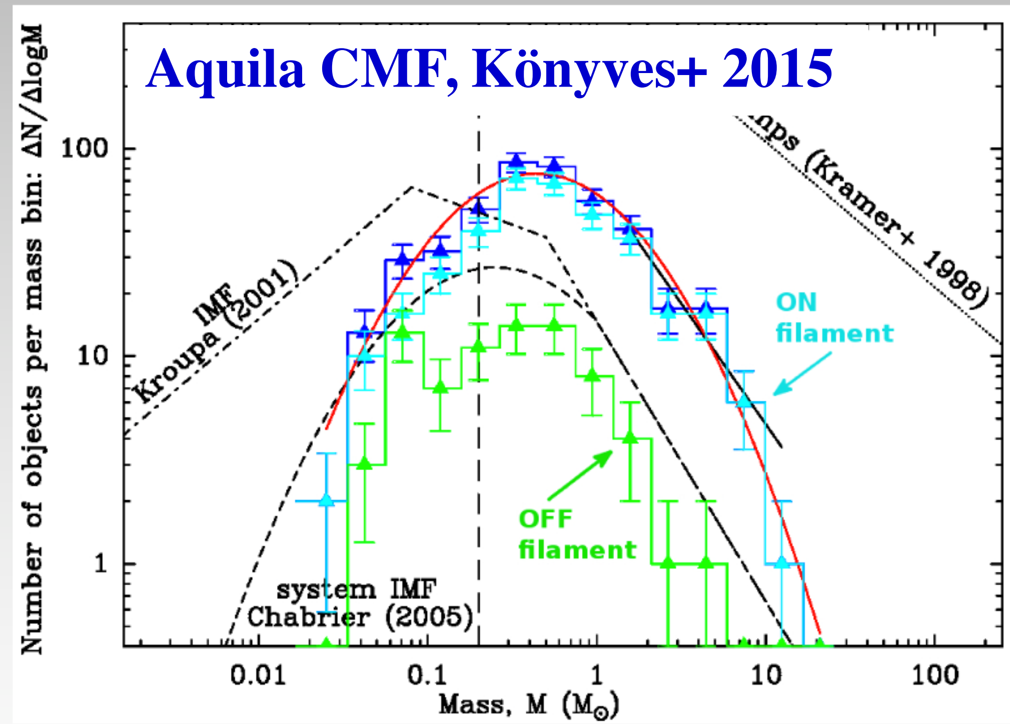
ρ Oph CMF, Motte+ 1998





The IMF seems determined by fragmentation at the prestellar stage

From studies limited to <10 $M_\odot$ cores…

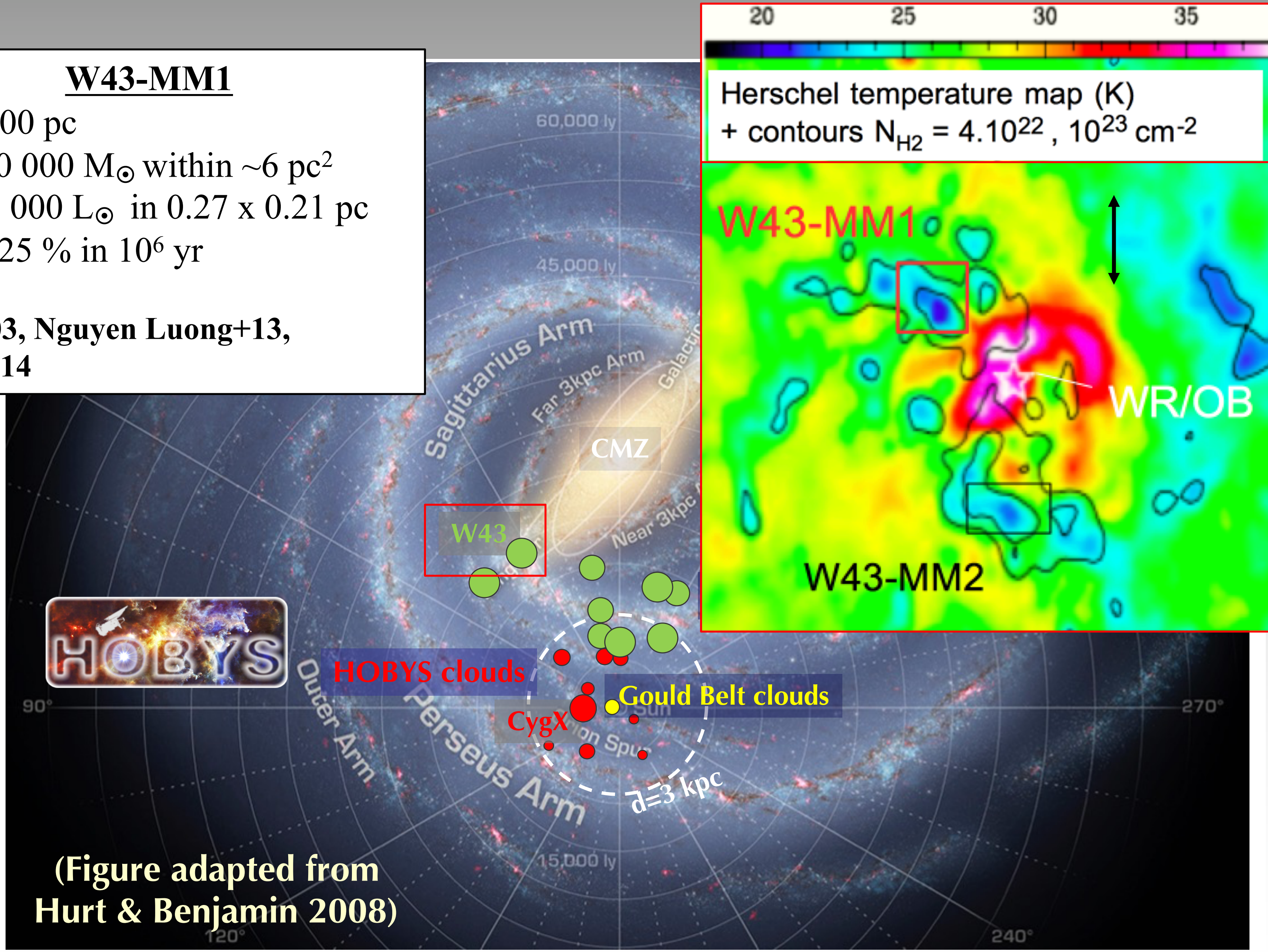
… in regions not typical of the main mode of star formation in galactic disks.

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



(Figure adapted from Hurt & Benjamin 2008)

1/ W43-MM1: ALMA data

ALMA Cycle 2 and 3 data:

- 12m + 7m (ACA) arrays

→ 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)

- line-free band + wide band (2 GHz)

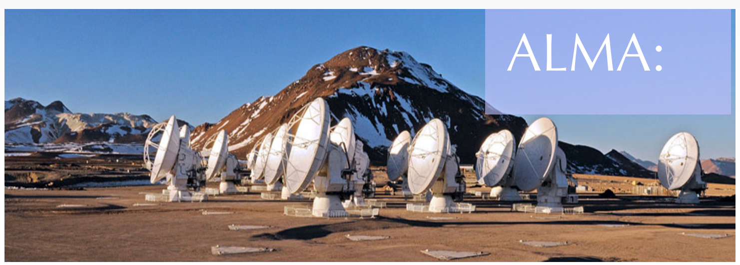


Table 1. Basics parameters of the merged data spectral windows.

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}]

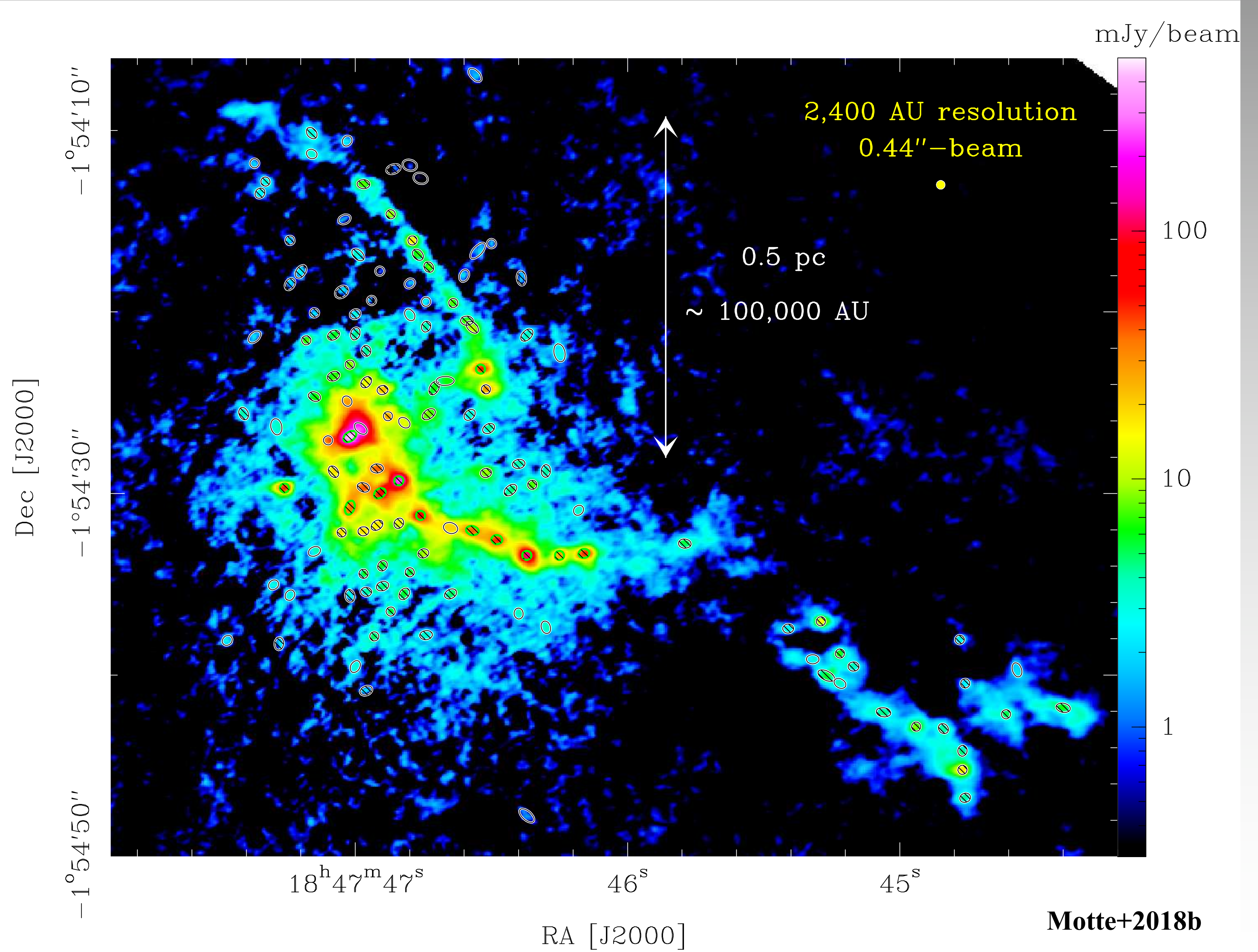
Motte+2018b

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

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

Cores' mass calculated from dust continuum emission ($S^{\rm int}$)
- including a correction for optical thickness
- dust temperature $T_{\rm d}$ estimated with PPMAP (Marsh+15)

1/ W43-MM1: continuum image and core extraction



Motte+2018b

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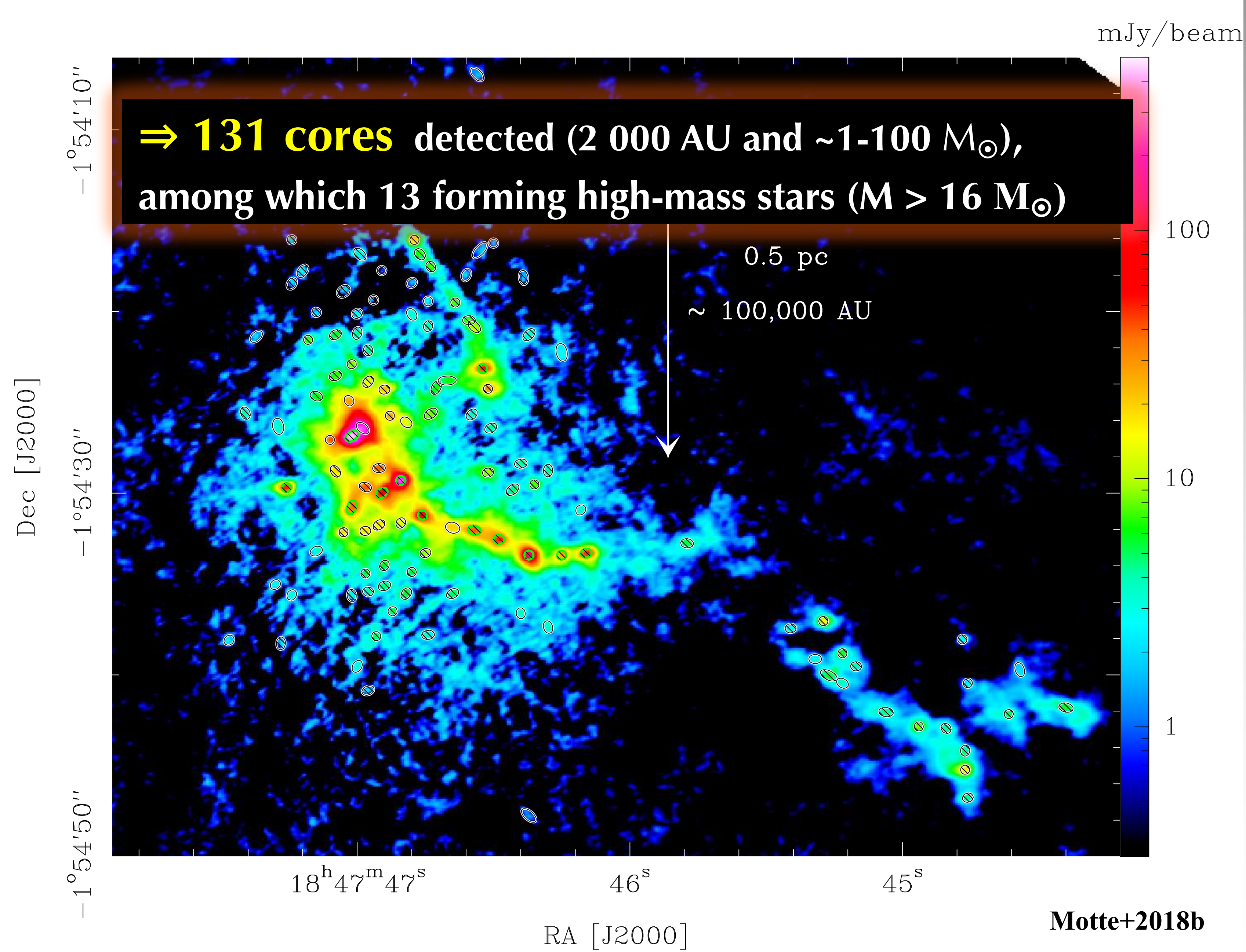


Motte+2018b

1/ Core Mass Function within the W43-MM1 ridge

Slope ɣ = −0.96 ± 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

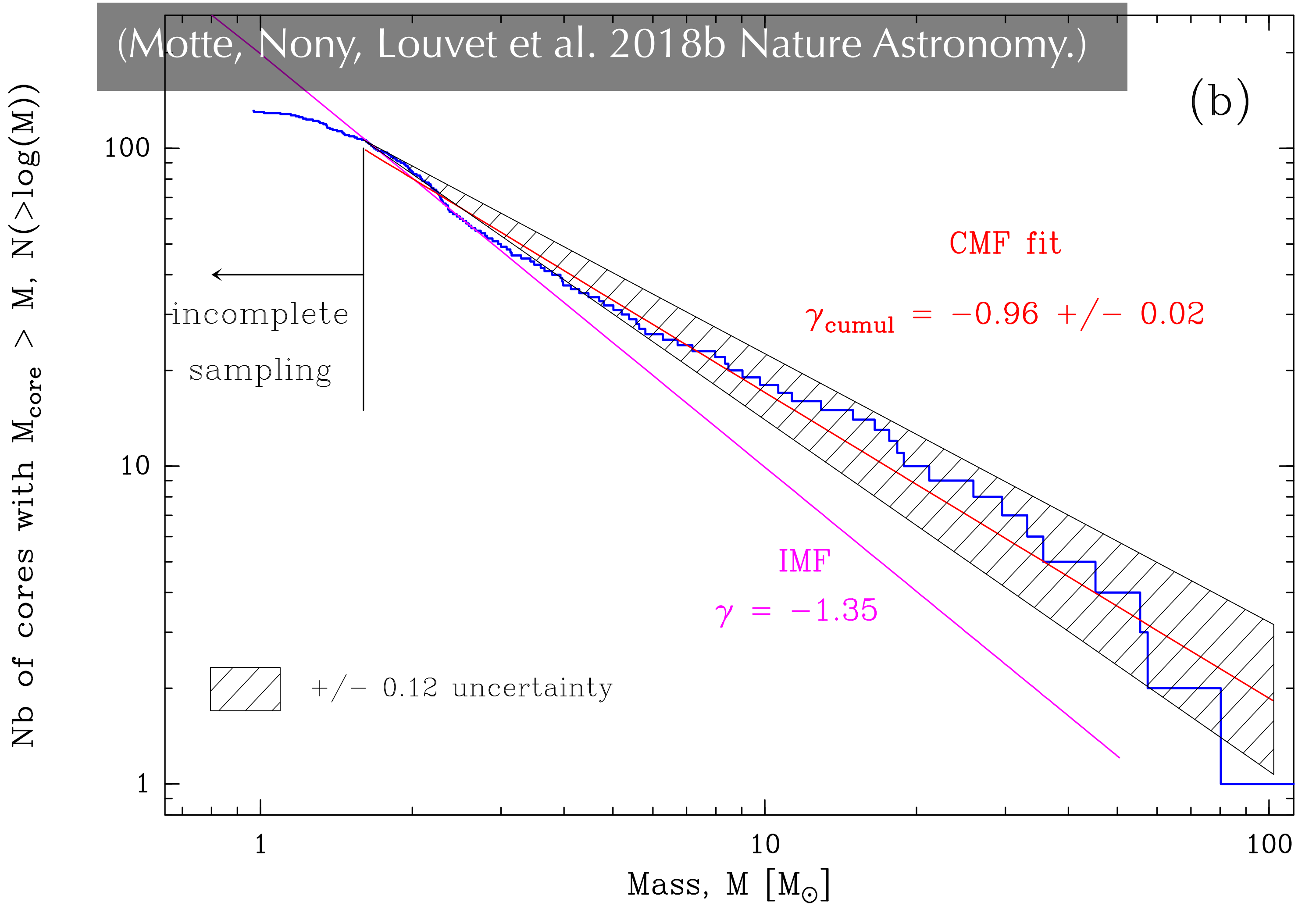
⇒ Flatter

- New episodes of filament and core formation

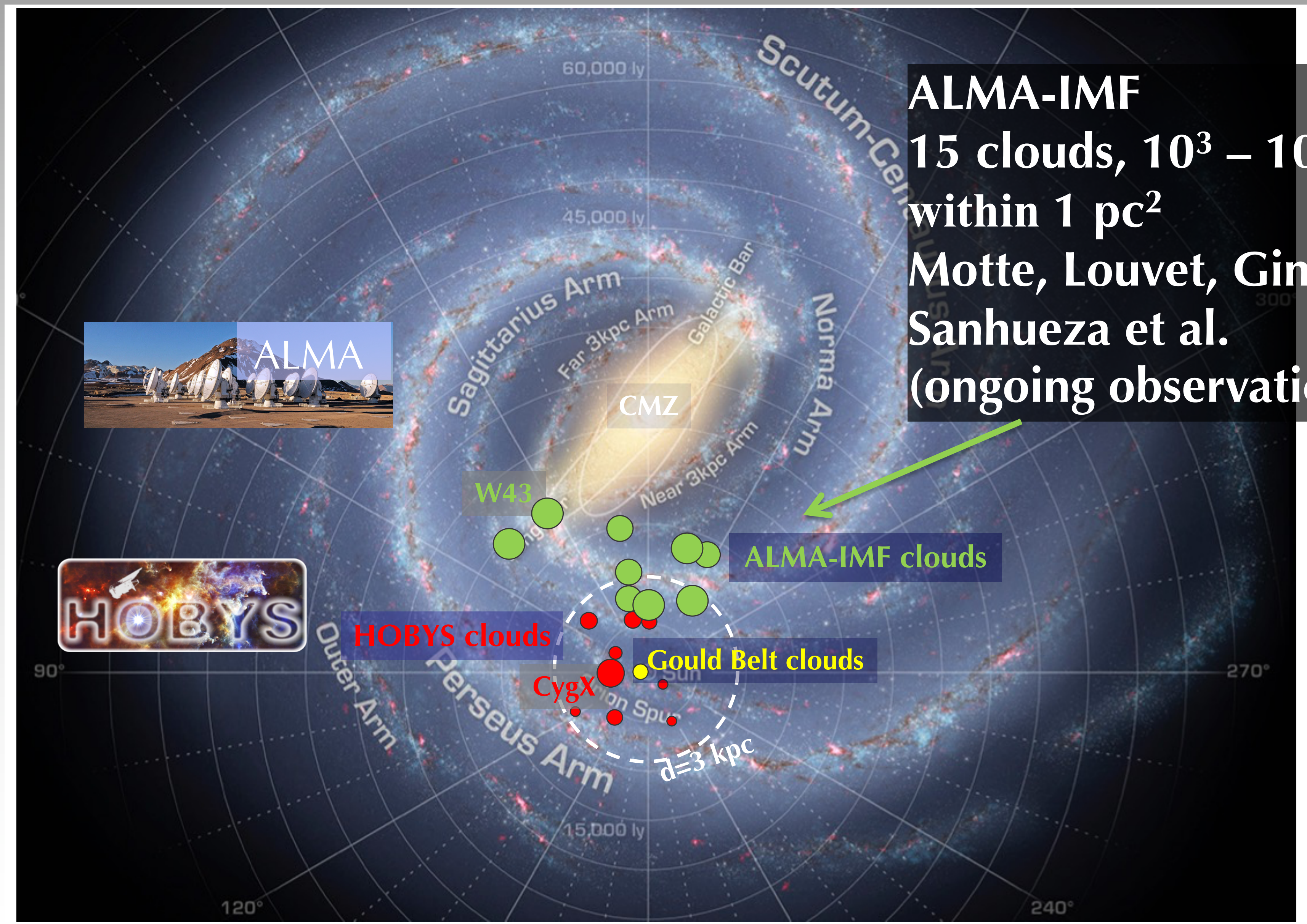
⇒ maybe steeper…

Adressed by the ALMA-IMF LP

(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)

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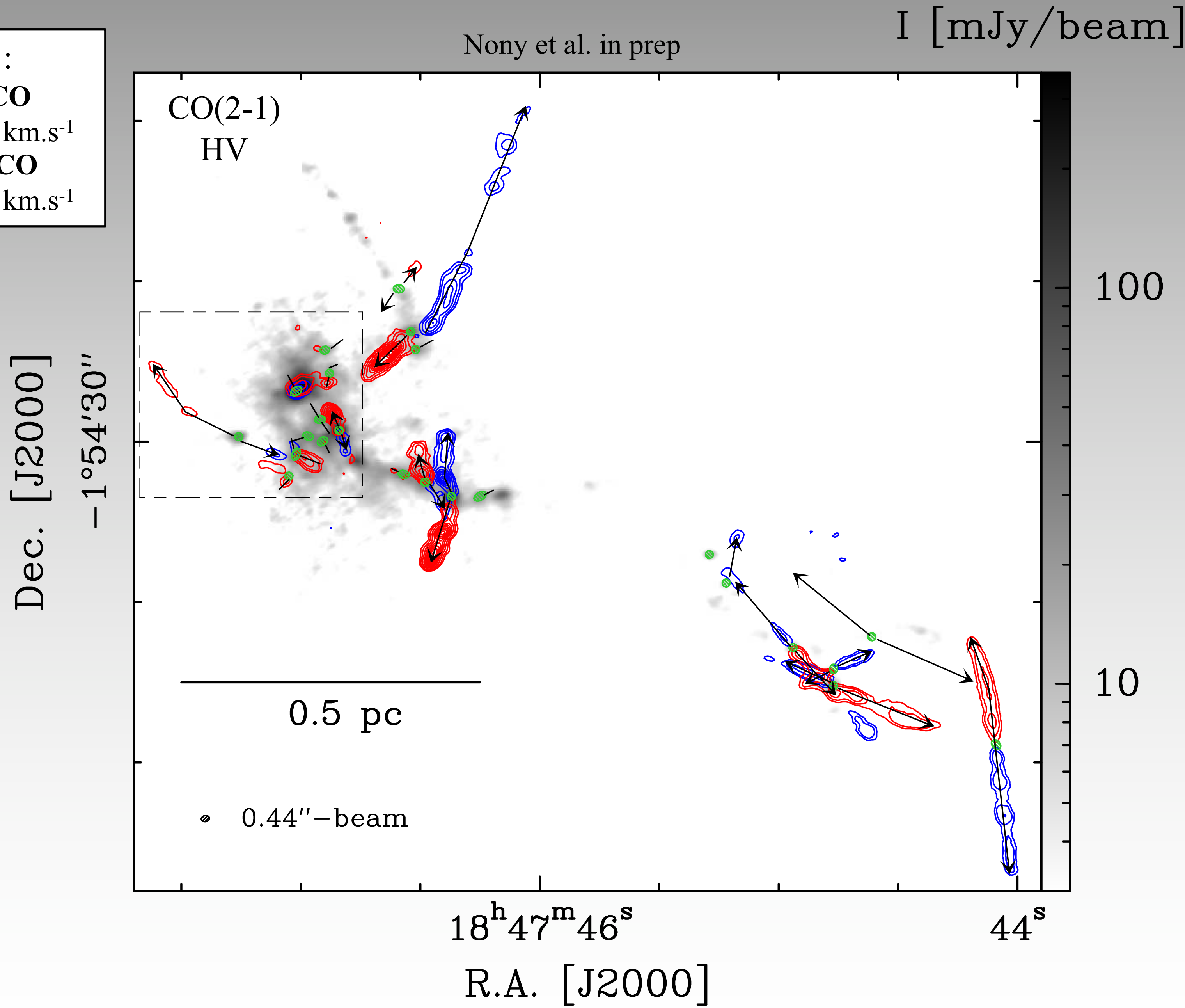
2/ A cluster of outflows

colour code :
Low-velocity CO
ΔV = ΔV = 10 : 30 km.s[-1]
High-velocity CO
ΔV = ΔV = 30 : 70 km.s[-1]



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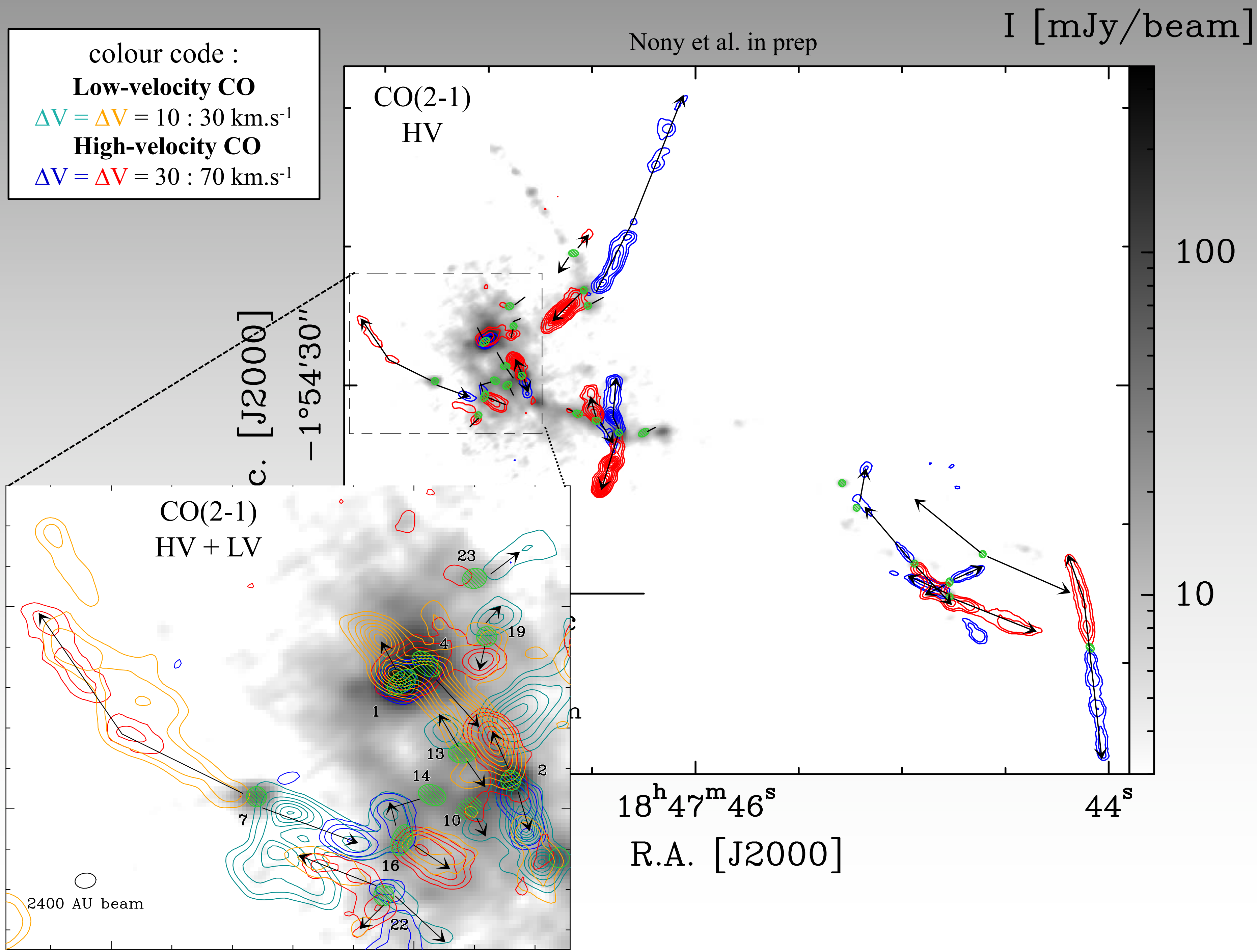

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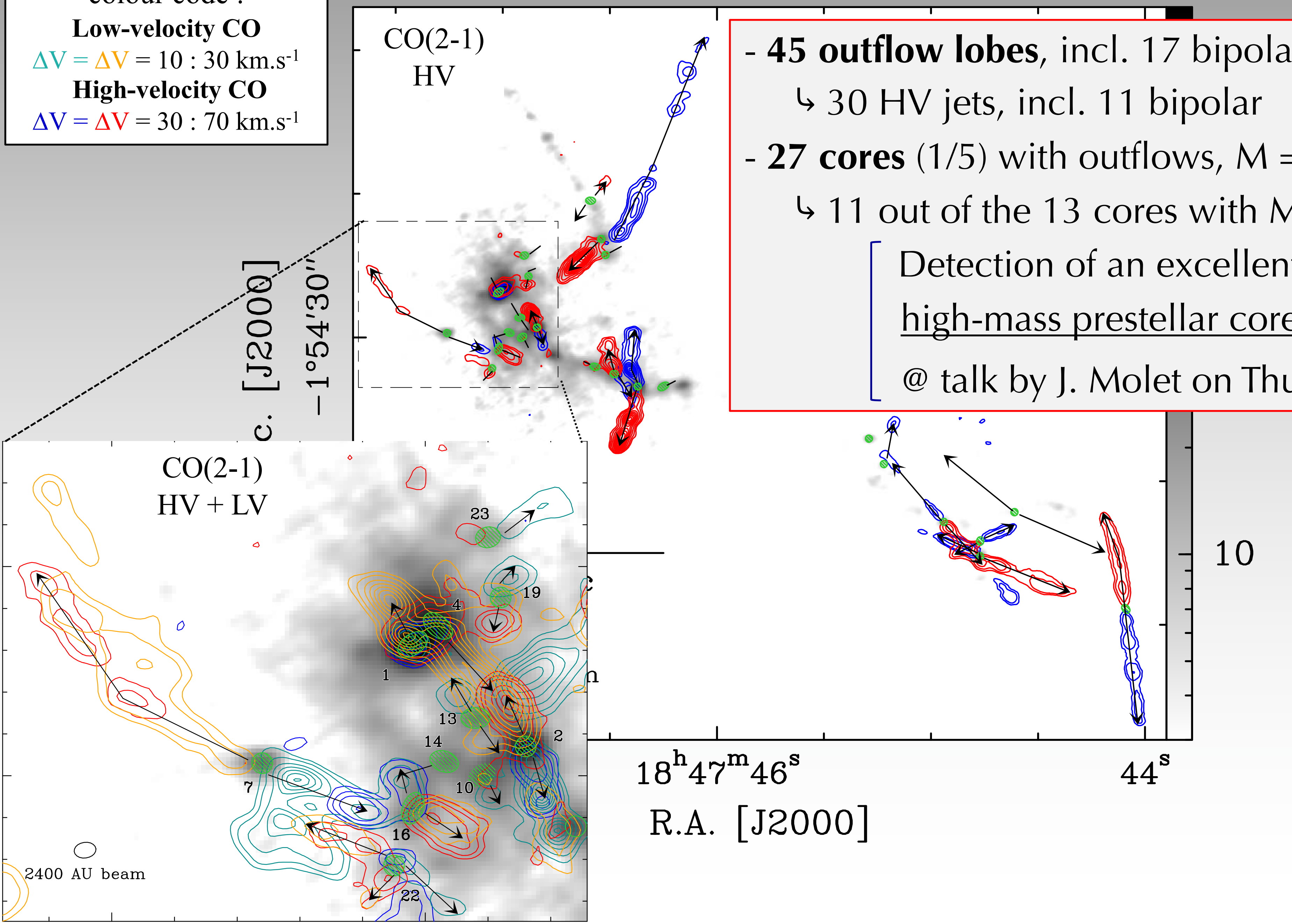
- **45 outflow lobes**, incl. 17 bipolar
  ↳ 30 HV jets, incl. 11 bipolar
- **27 cores** (1/5) with outflows, M = 1-100 M$_\odot$
  ↳ 11 out of the 13 cores with M > 16 M$_\odot$

  Detection of an excellent
  high-mass prestellar core candidate
  @ talk by J. Molet on Thursday



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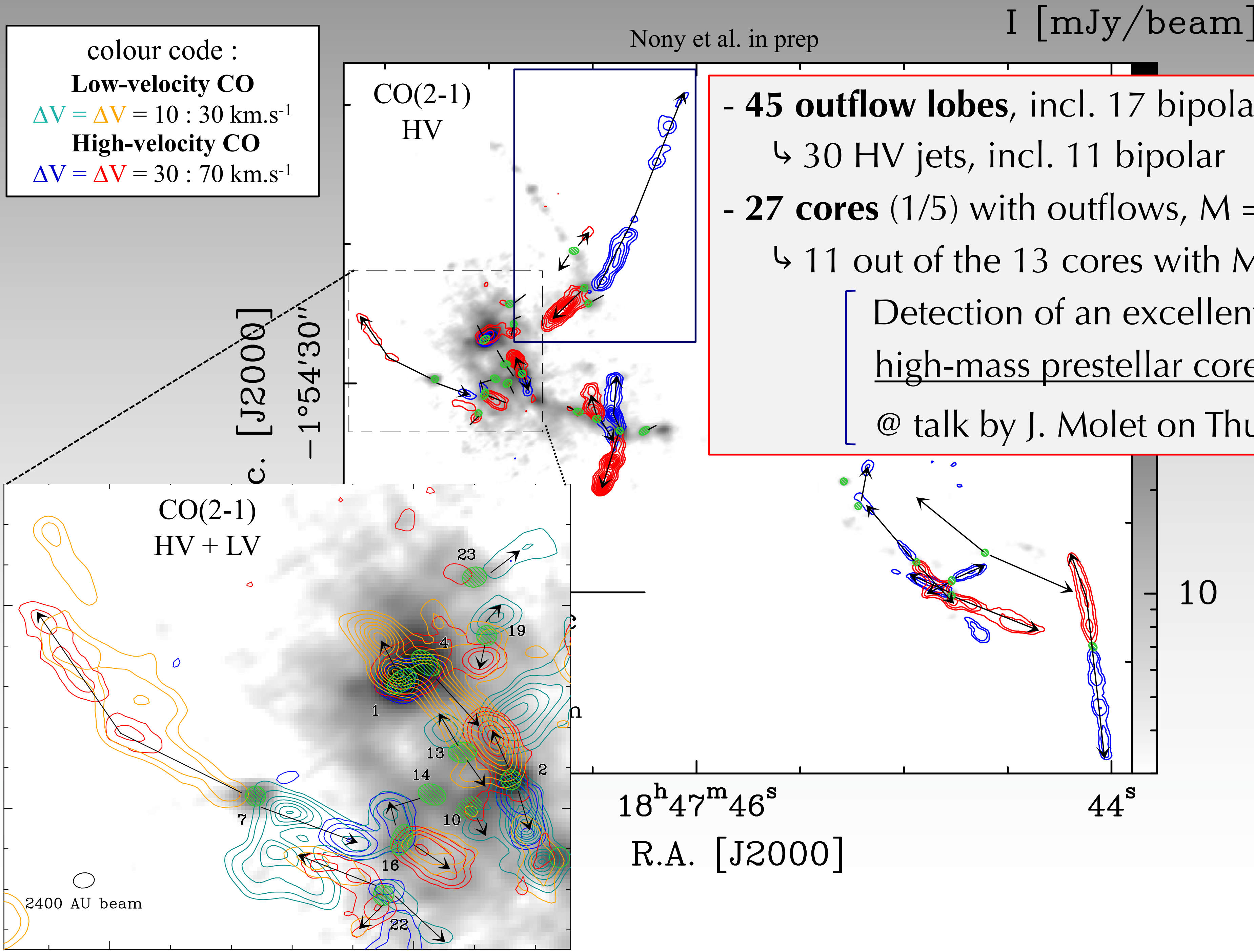

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2/ Characterize episodic ejection

High-velocity CO reveal **episodic ejection**

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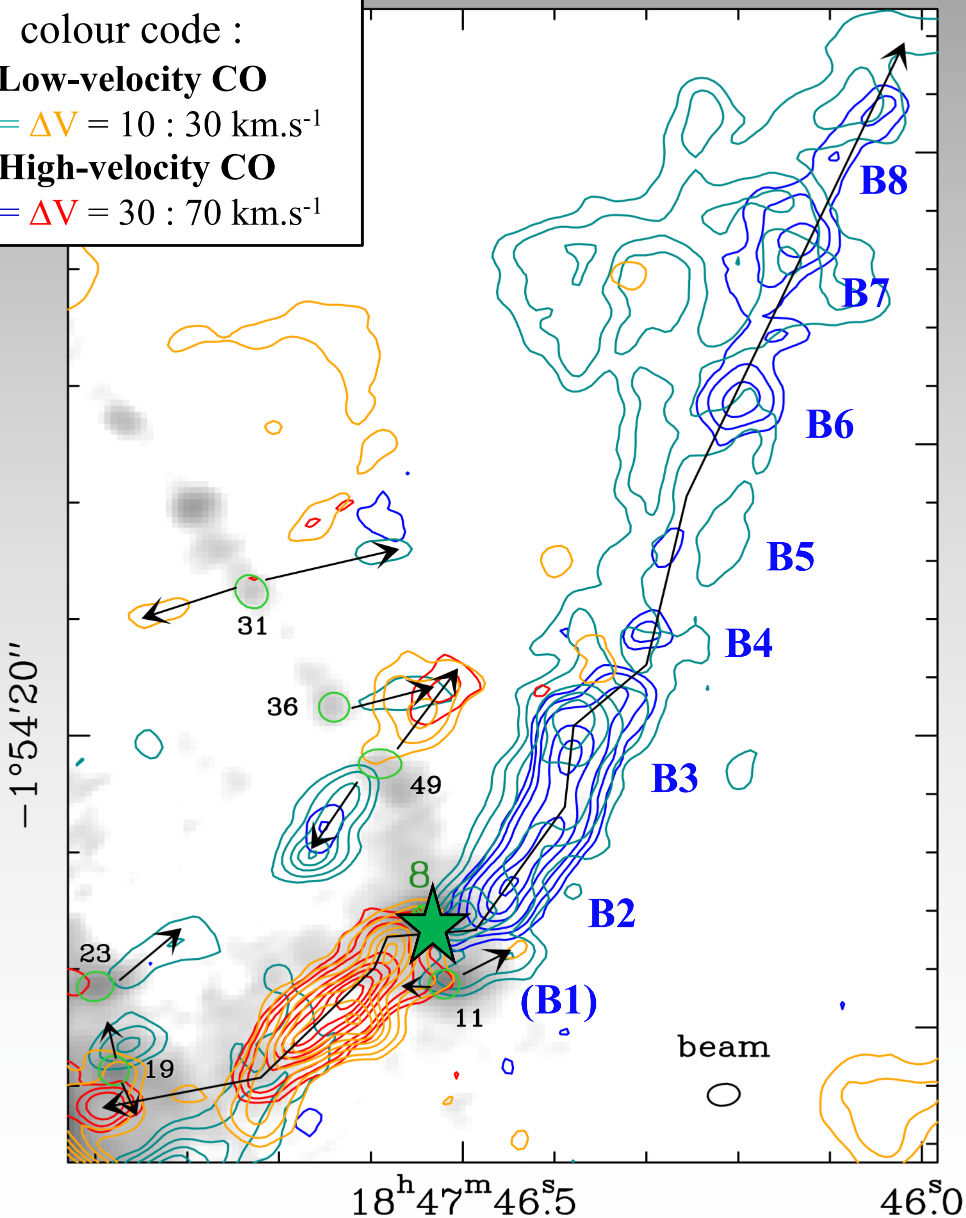
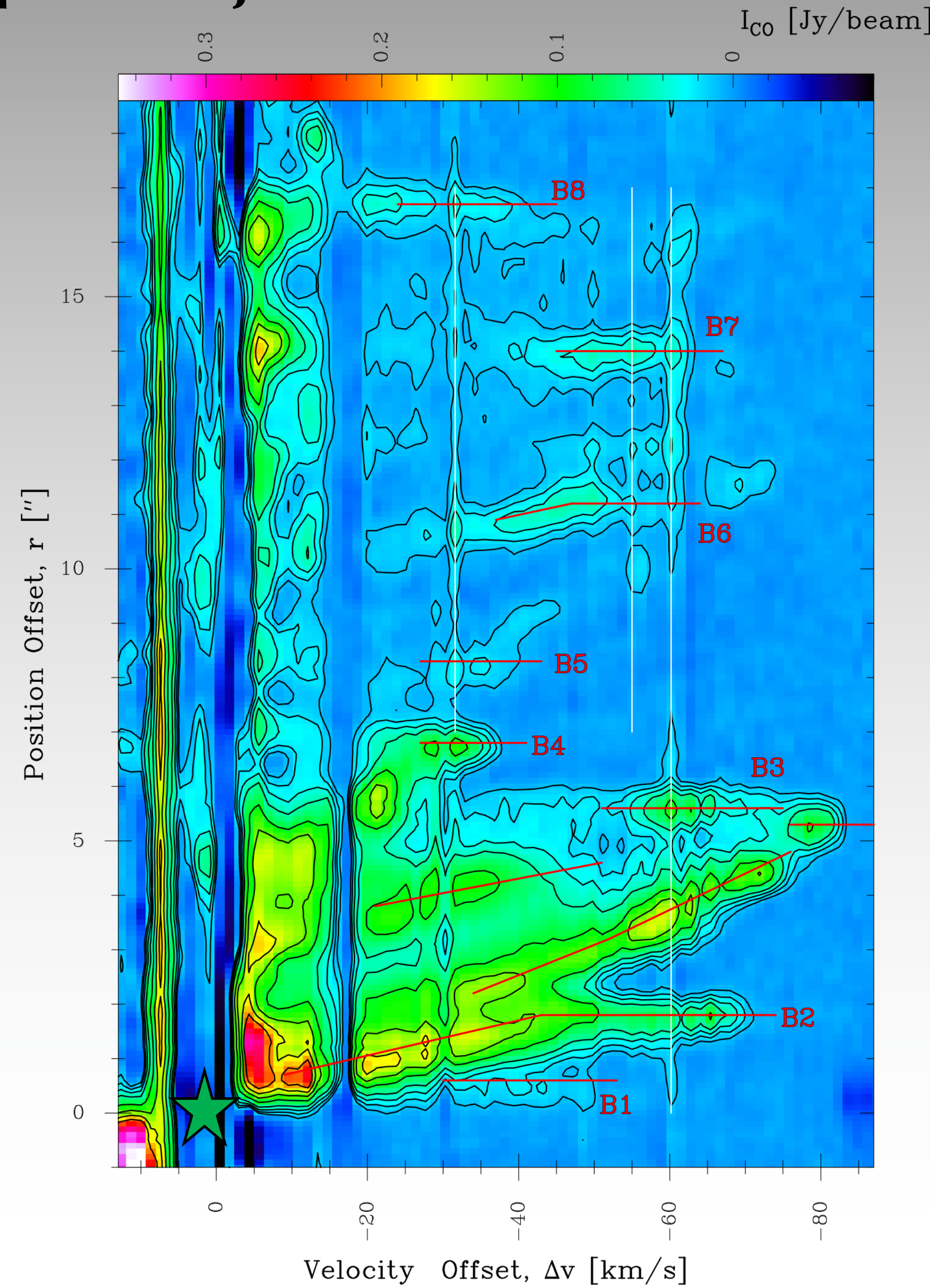


Up to 8 knots detected along this jet



2/ Characterize episodic ejection

Estimation of the time elapsed between 2 knots/ejecta, Δt

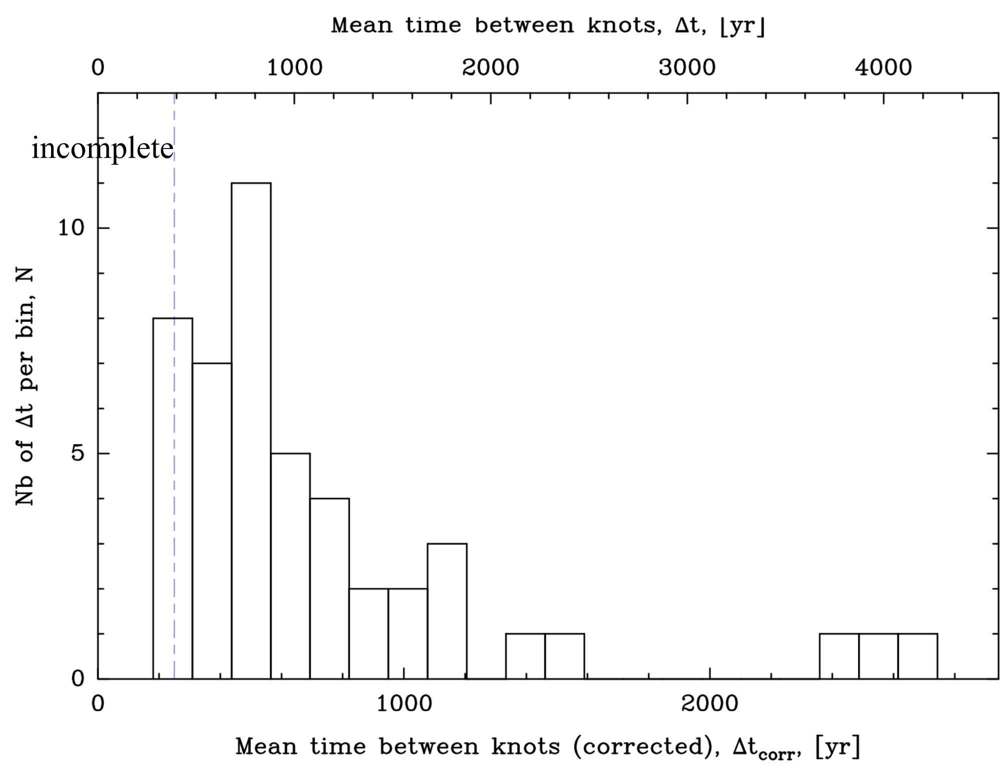
- 48 measures on 22 lobes from 14 cores
- unknown inclination: homogeneous correction with a mean angle of 57.3°

⟹ **episodic ejection with Δt ~ 500 yr** (800 yr before correction)

To be compared to models (see e.g. Vorobyov+18)

to observed timescales of accretion burst/variability

Nony et al. in prep



Conclusion and perspectives

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

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

- The W43-MM1 **CMF is markedly flatter than the reference IMF**

⟹ Do CMF evolve with time? @ALMA-IMF

- **ejection episodicity ~ 500 yr** measured over a large sample of jets

⟹ reminiscent of disk-instabilities?

of episodic inflow of gas from the clump?

⟹ models are needed to interpret the complex accretion/ejection behaviour