Discovery and study of the physical properties of high-mass prestellar (and protostellar) cores

Maxime Valeille-Manet

Fabien Louvet, Frédérique Motte, Sylvain Bontemps, Timea Csengeri

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- Effective Jeans mass
- Turbulent and magnetic supports

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- Formation dominated by dynamics
- Weaker supports

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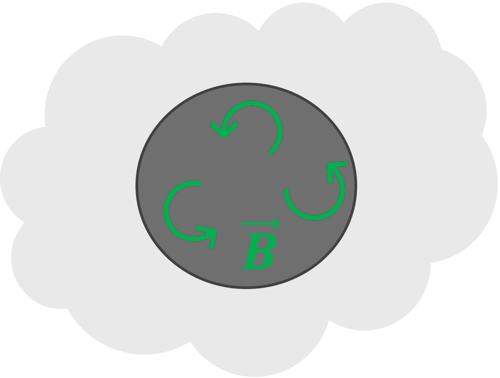

High-mass prestellar core

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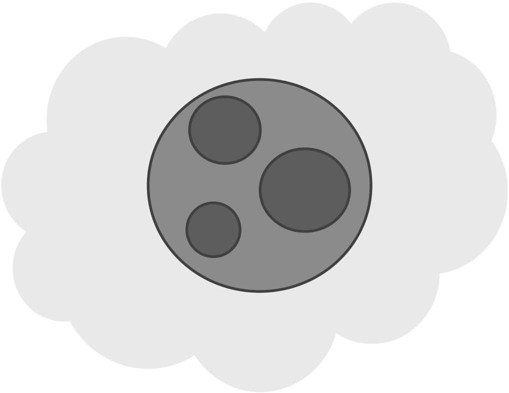

Low-mass prestellar cores

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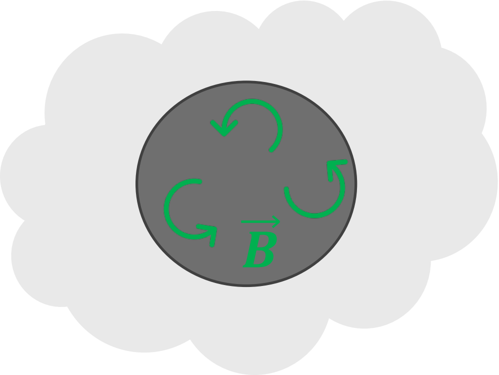

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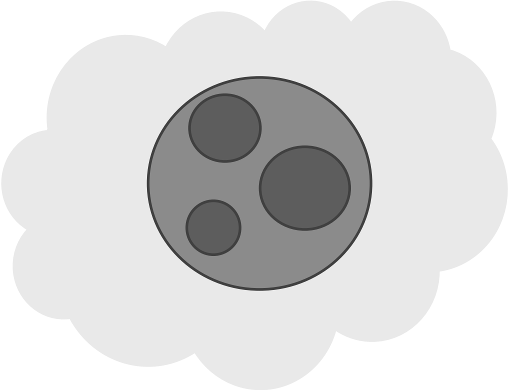


Low-mass prestellar cores

What does the mass reservoir available for forming massive stars look like? Does it exist? → **Systematic research of these objects!**

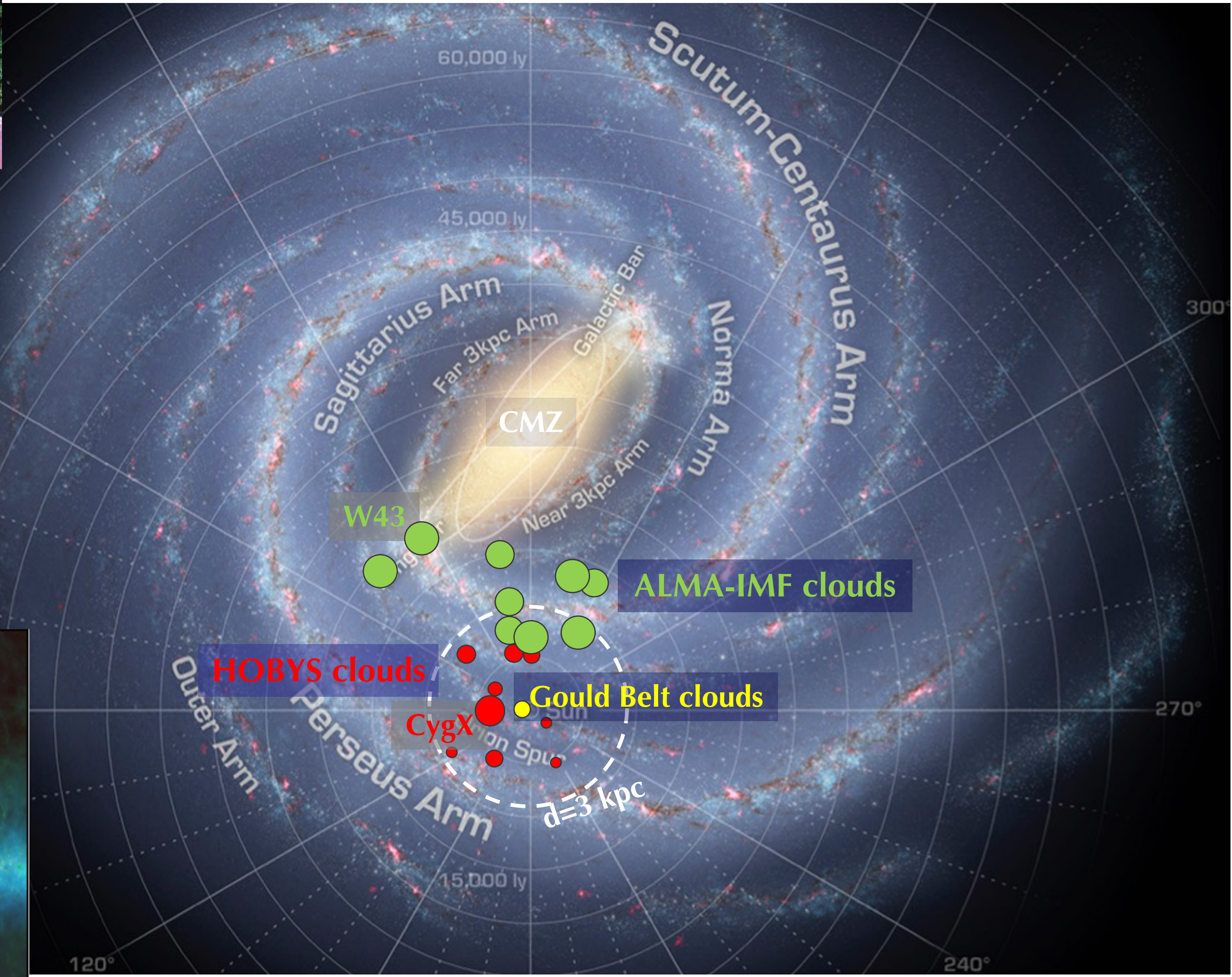
ALMA-IMF large program

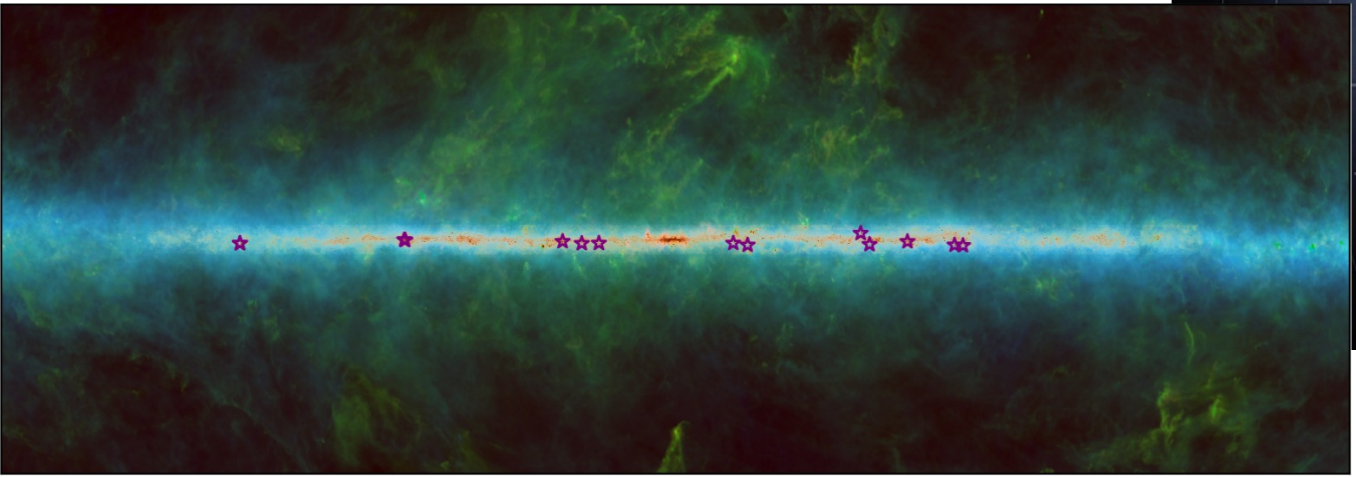
PI: F. Motte

- A large sample of massive protoclusters at d<6kpc
- More representative of Milky Way star-forming clouds
- At various evolutionary stages
- Between 800 and 1500 cores (~2000 to 4000 au)

See Motte+ 2022, Ginsburg+ 2022, Cunningham+ 2023, Louvet+ 2024 for presentation and dataset papers

Figure adapted from Hurt & Benjamin 2008





Credit : A. Ginsburgh

From the 200 most massive ATLASGAL clumps *(Csengeri+ 2017)*

Prestellar vs protostellar cores

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Combination of two tools to search for outflows:

- Spectral: the spectra On the source is compared to the spectra of its environment (Off) → On-Off method
- Spatial: molecular outflow maps

Accretion-ejection process → Protostar associated to an outflow
See Valeille-Manet+ 2025

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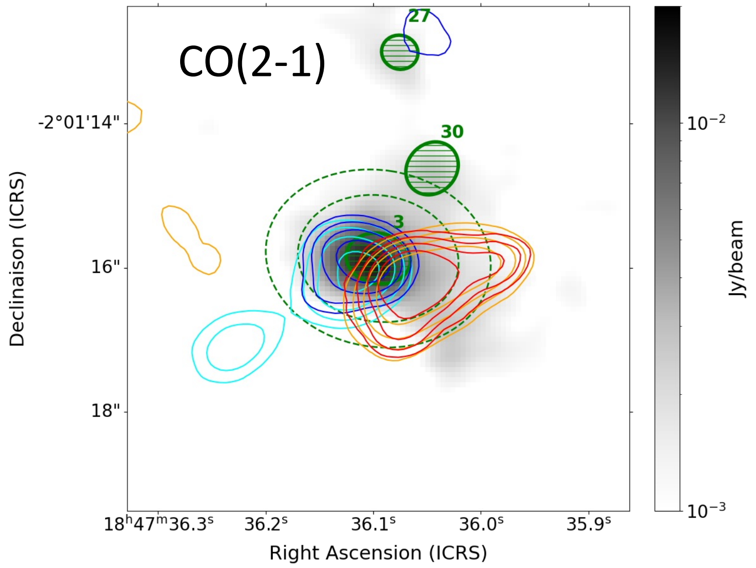

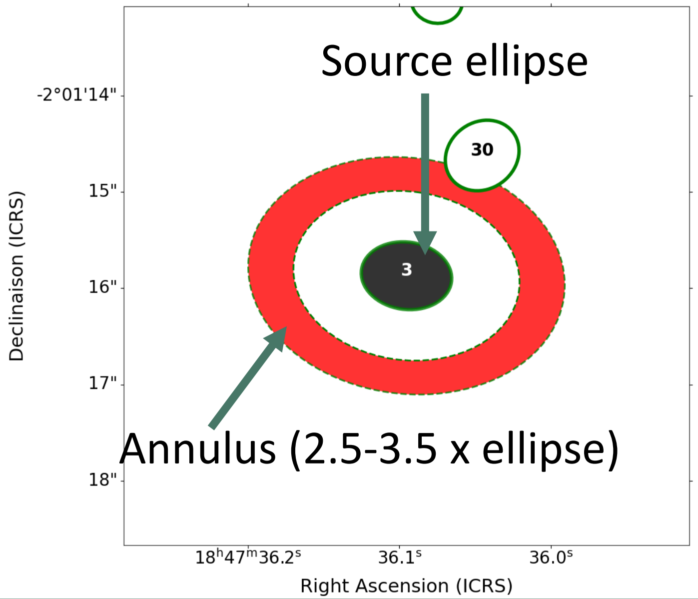

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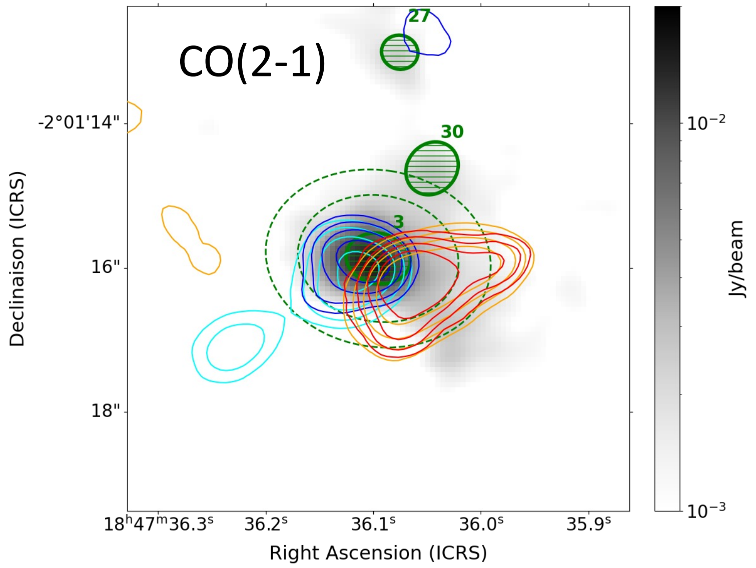

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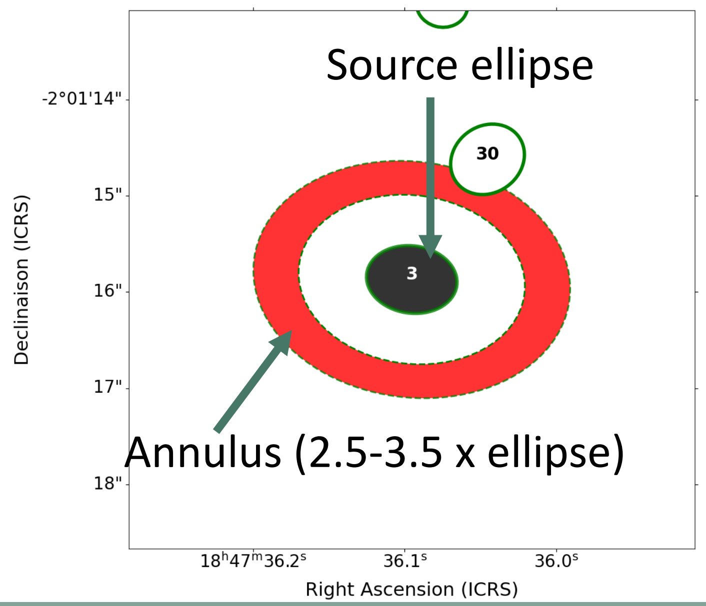
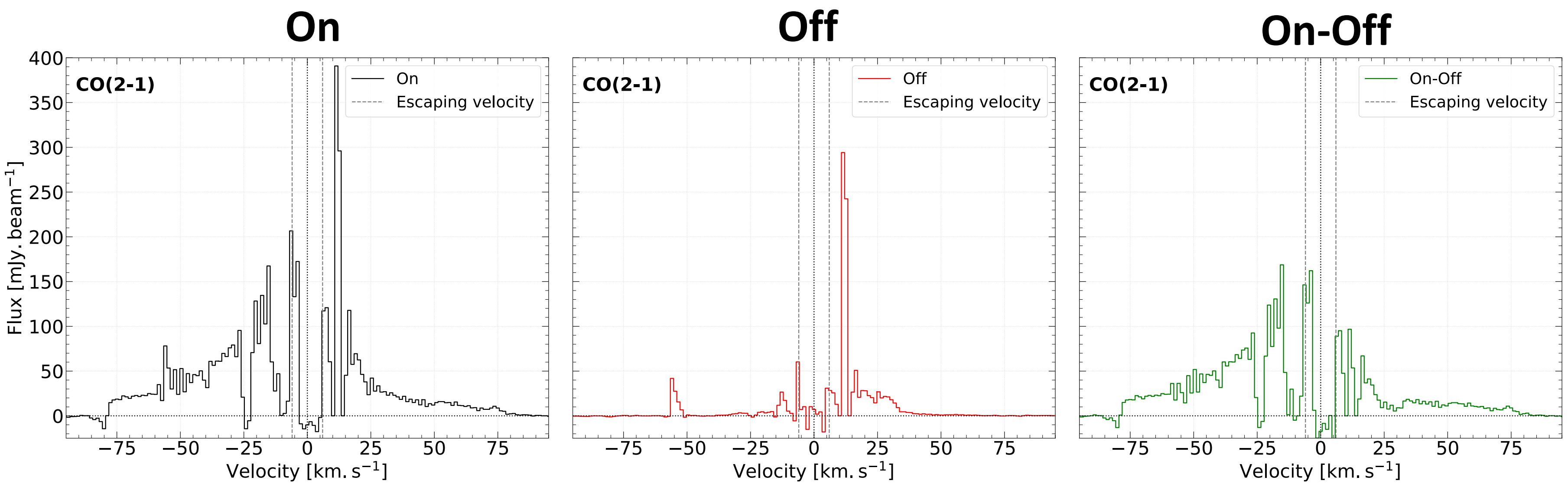
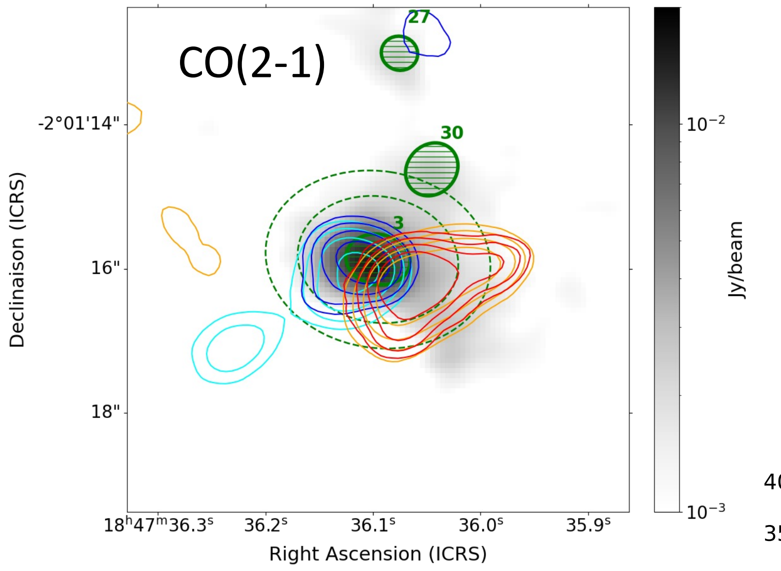
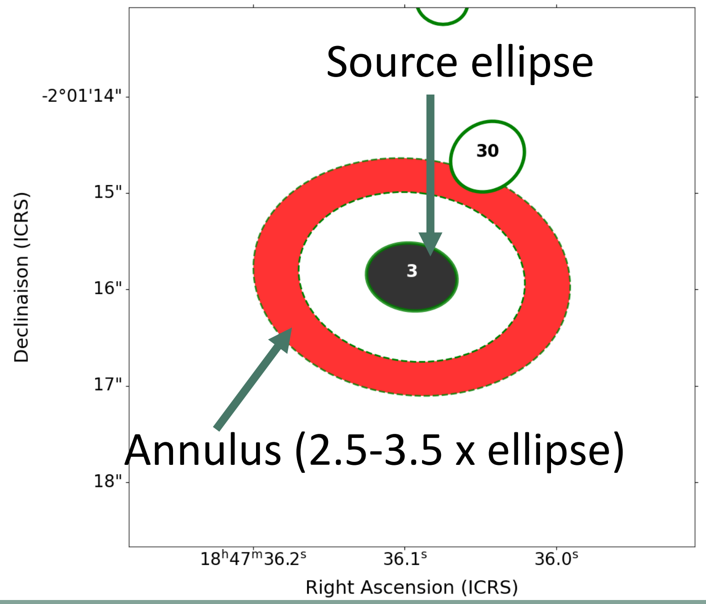




CO(2-1) and SiO(5-4) lines are used

Prestellar vs protostellar cores





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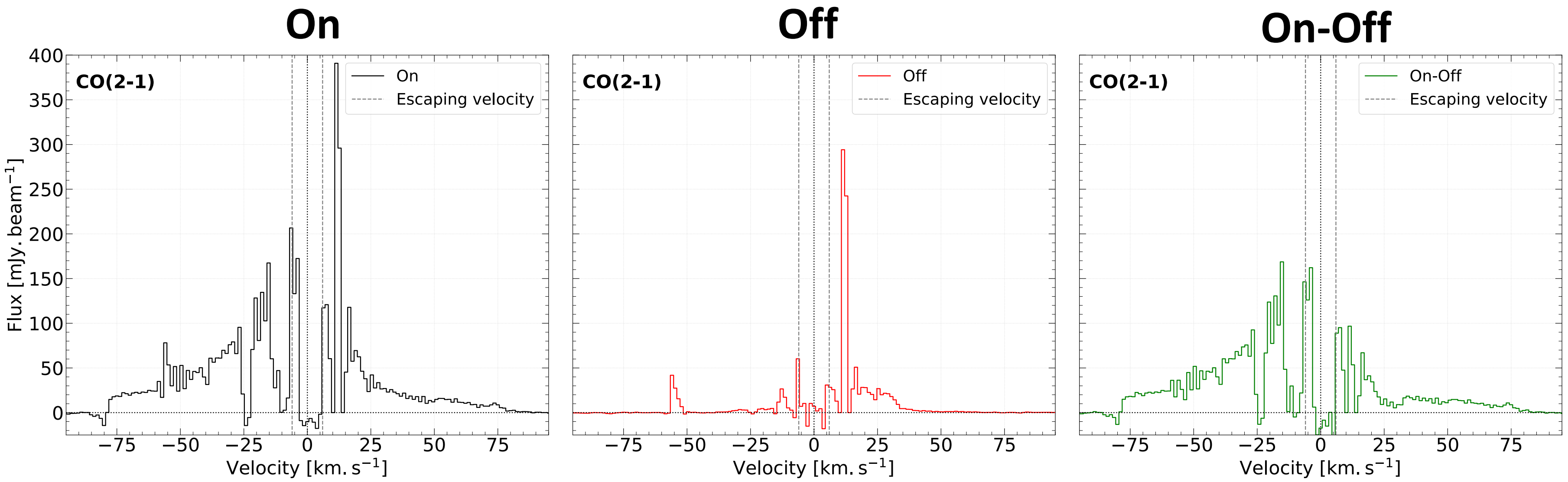
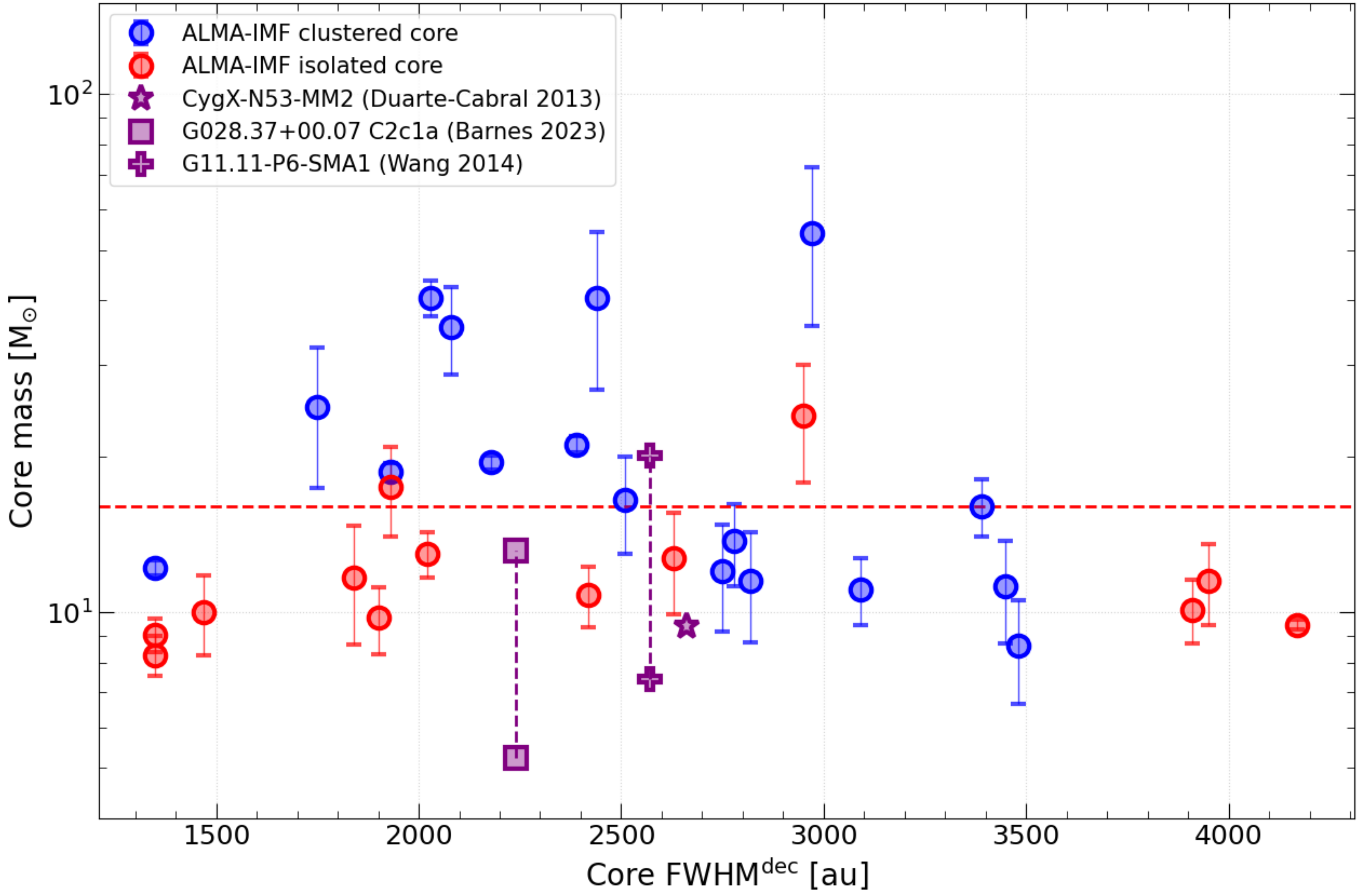


CO(2-1) and SiO(5-4) lines are used

266 protostellar cores out of 960 cores *(Nony, Valeille-Manet+ in prep)*

A sample of high-mass prestellar cores

Valeille-Manet+ 2025



- 30 prestellar cores with 12 high-mass ($M > 16\ M_\odot$)
- $8 - 54\ M_\odot$
- 1350 to 4200 au
- $4{\times}10^6$ to $2{\times}10^8\ cm^{-3}$

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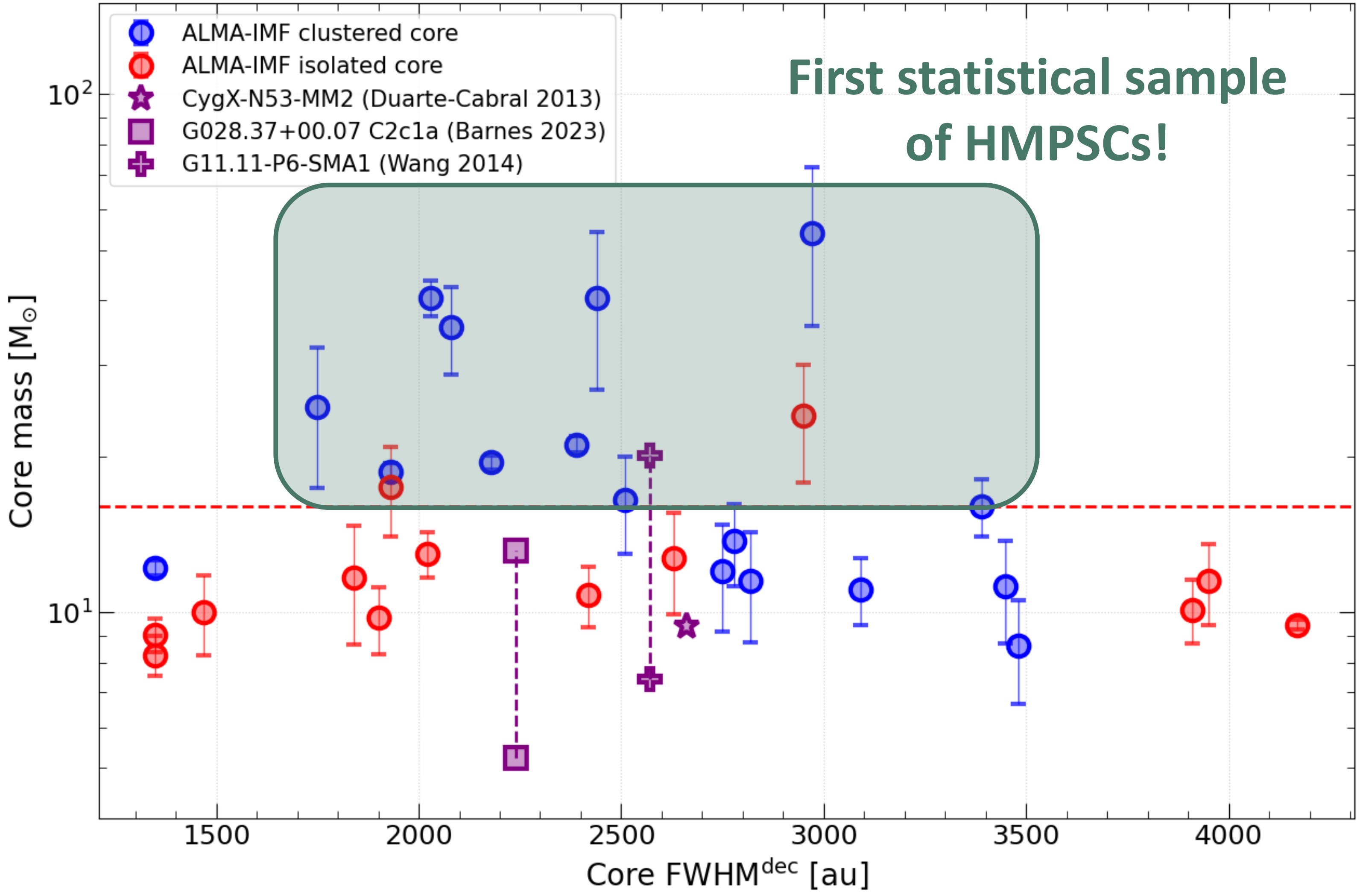

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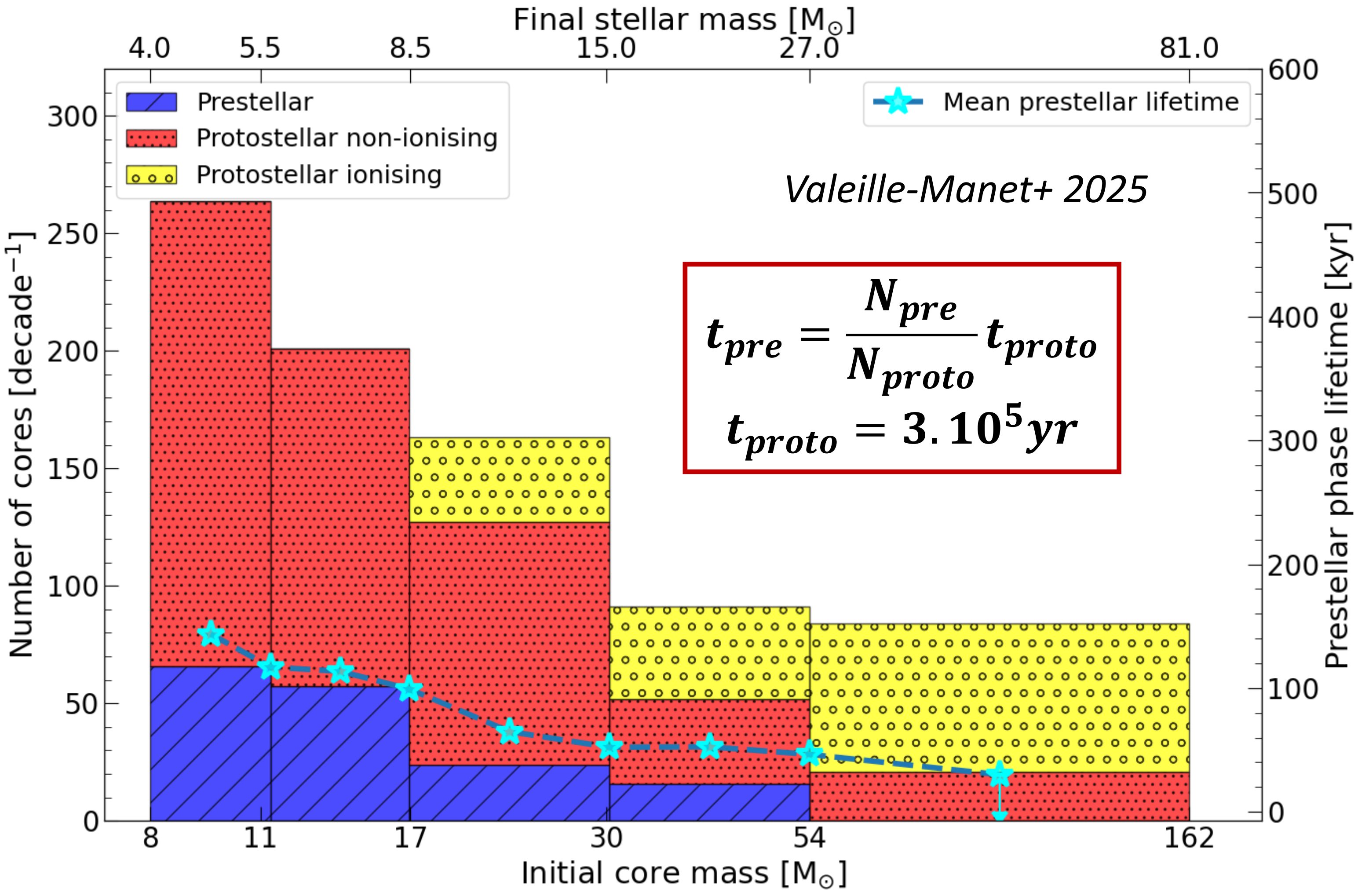
High-mass prestellar phase lifetime



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$$t_{proto} = 3.10^5 yr$$

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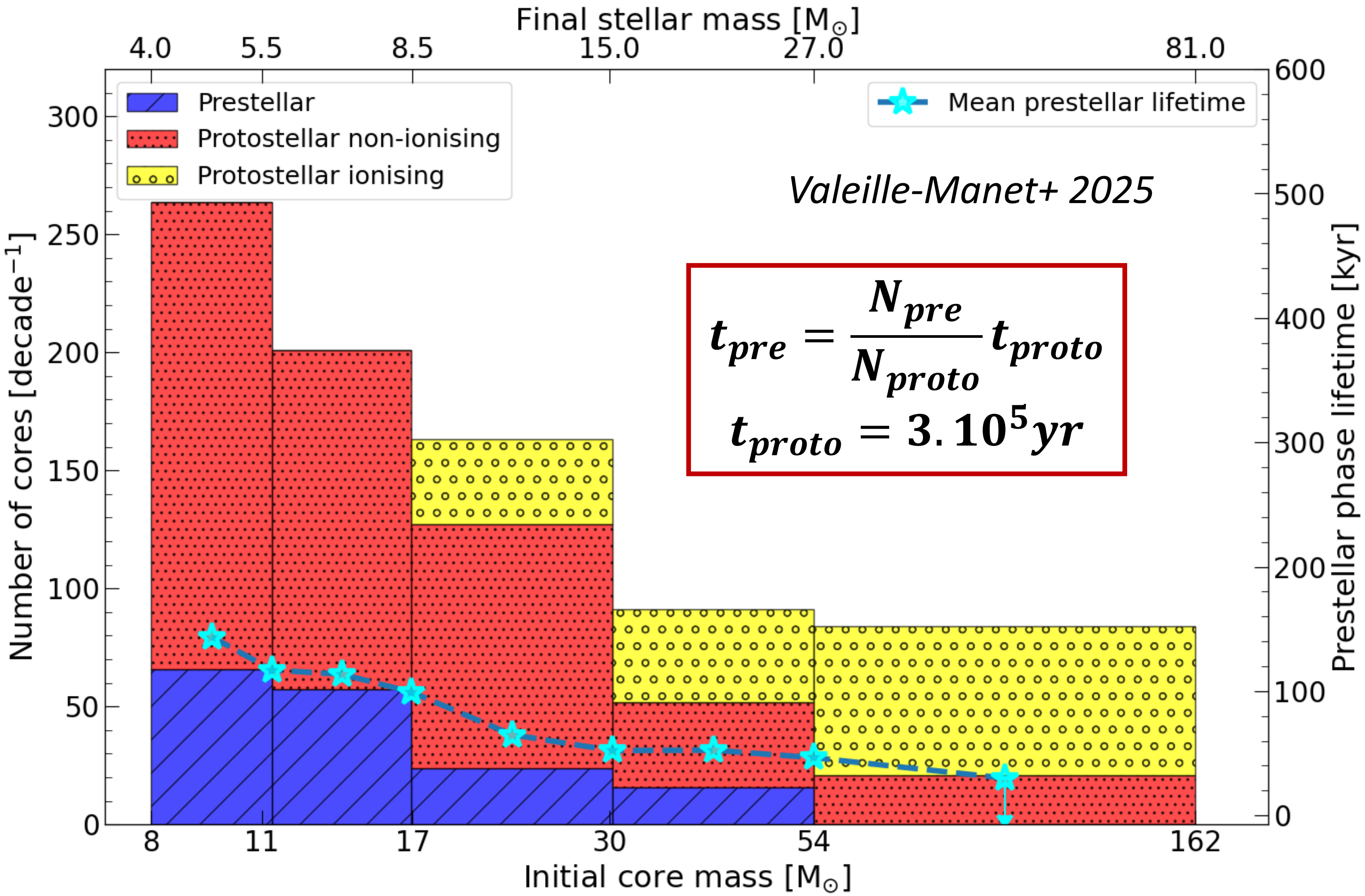

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t_{psc} ranges from 150 to 50 kyr

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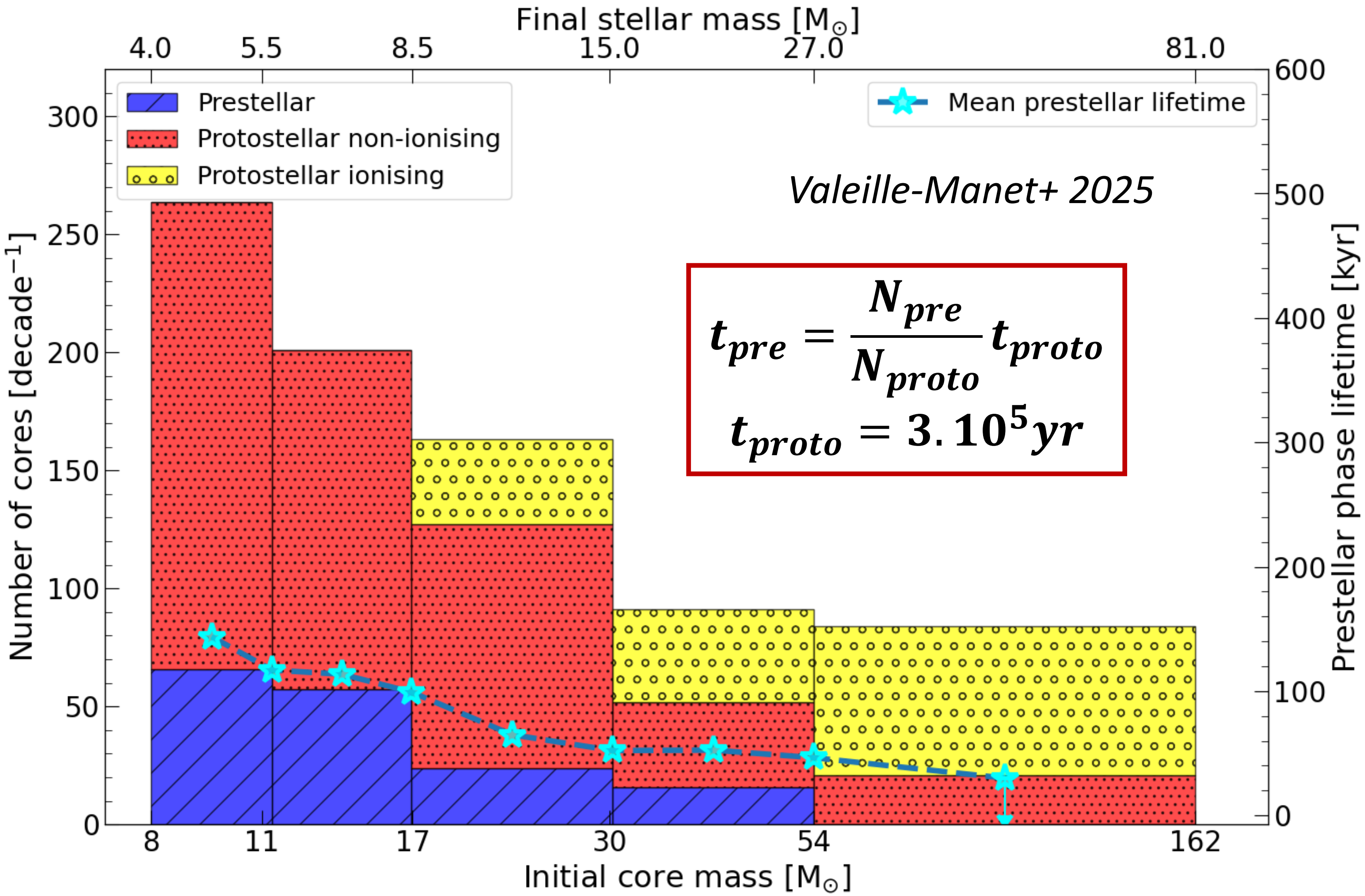

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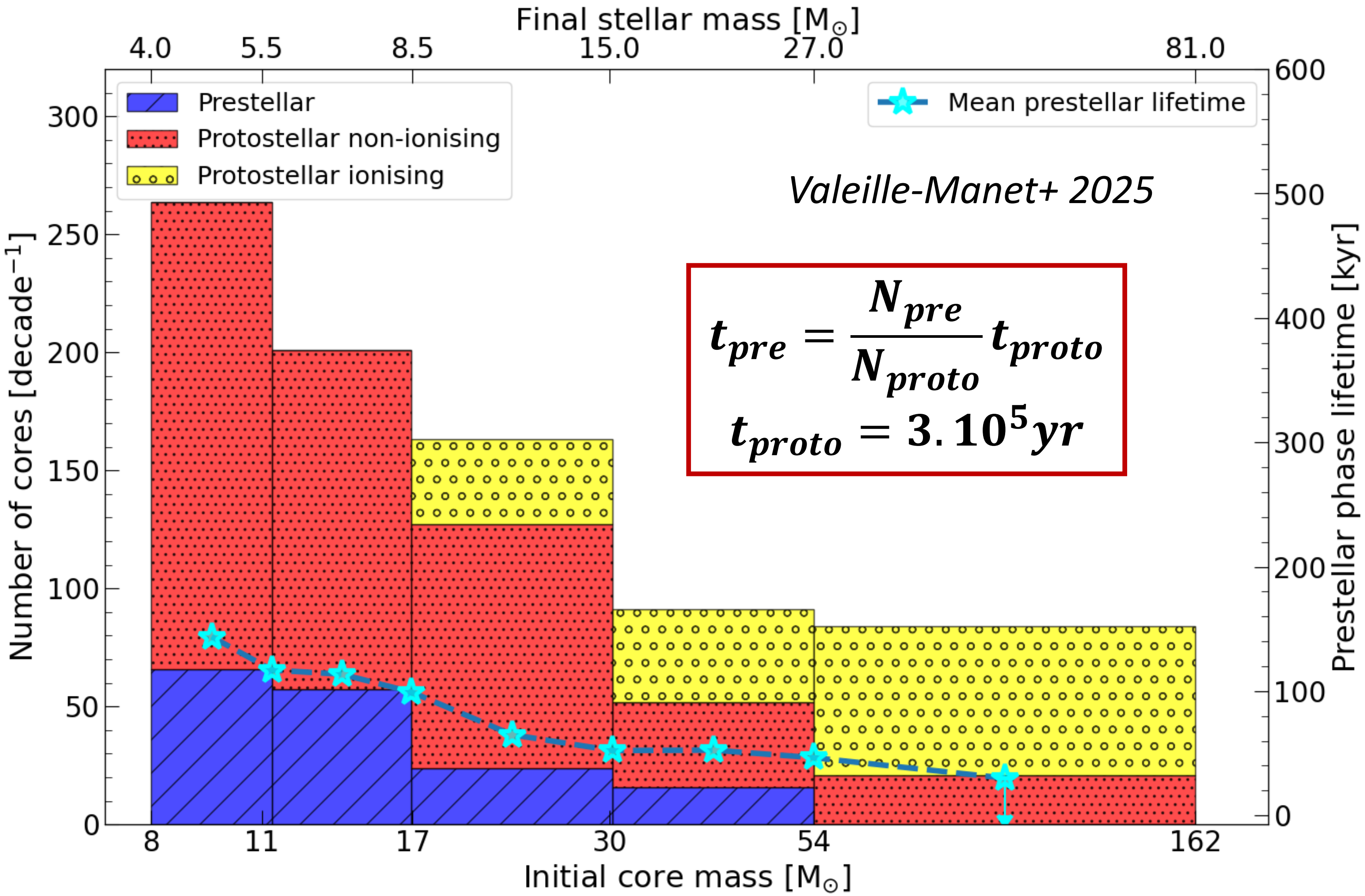

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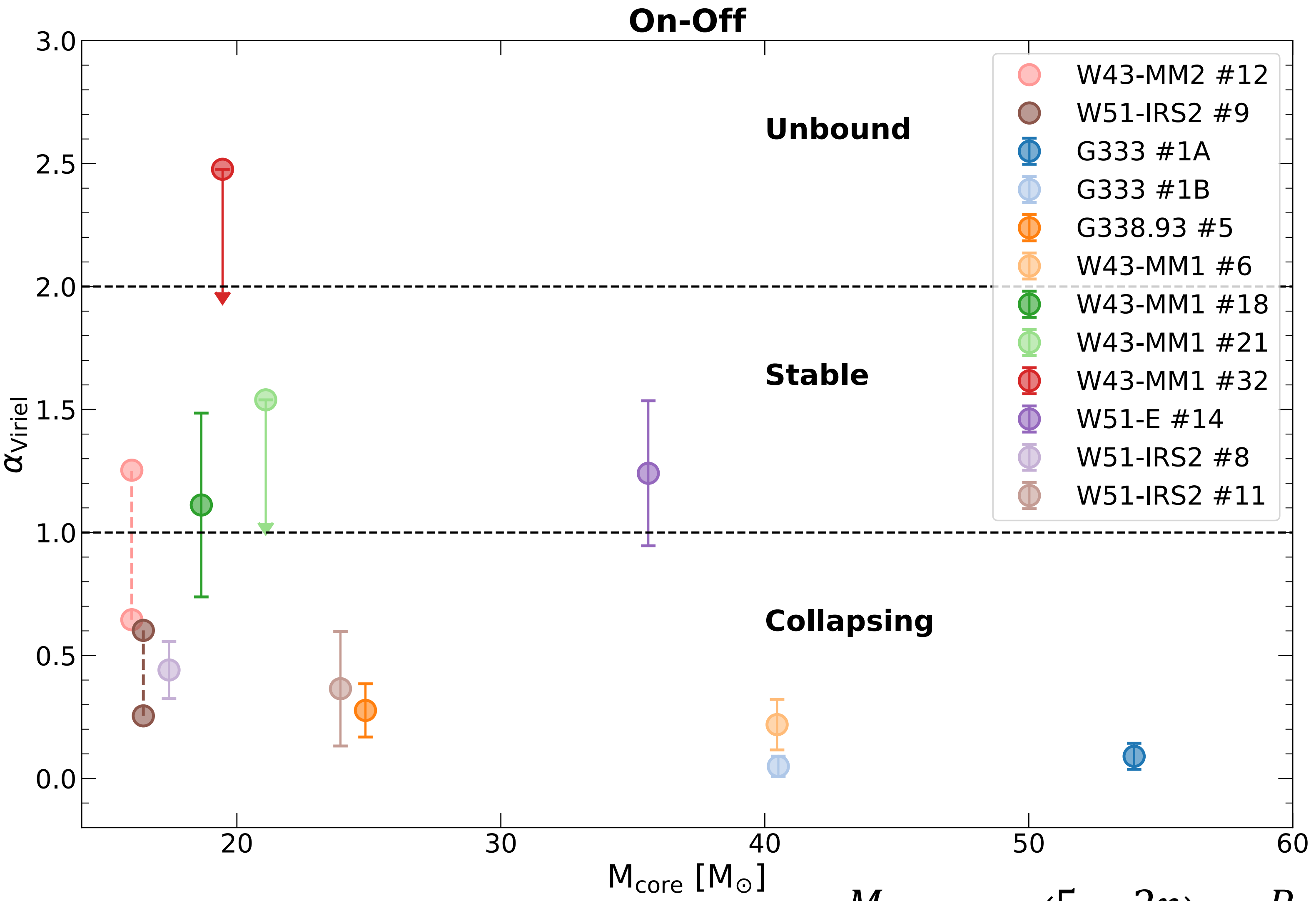
Need for additional support against gravitational collapse?

Turbulence

Magnetic support

Are cores stable?



Turbulence: DCN(3-2) and ^{13}CS(5-4)

Valeille-Manet+ in prep

$$\propto = \frac{M_{vir}}{M_{core}} = 3\left(\frac{5-2n}{3-n}\right)\frac{R}{GM_{core}}\sigma_{turb}^2$$

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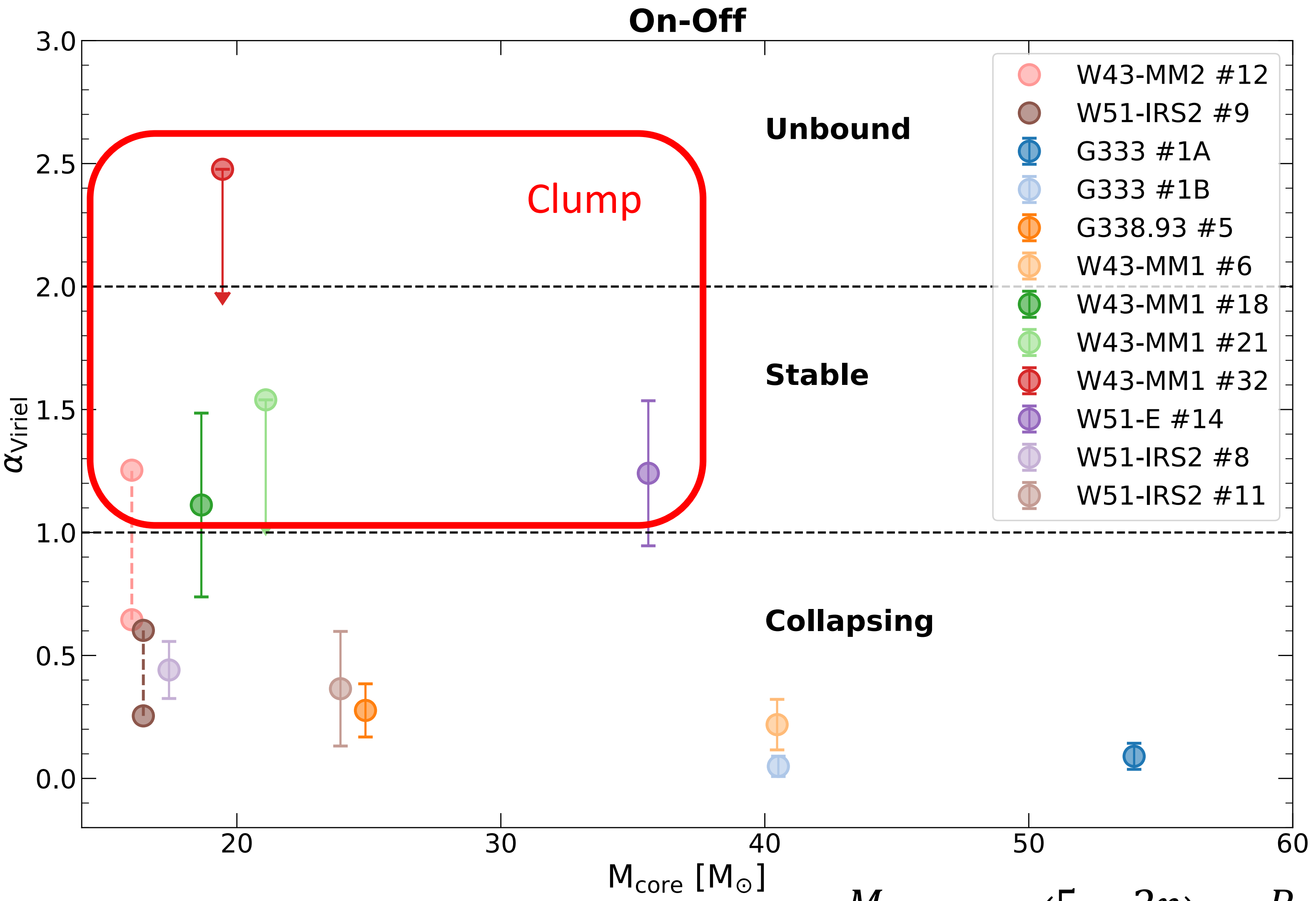

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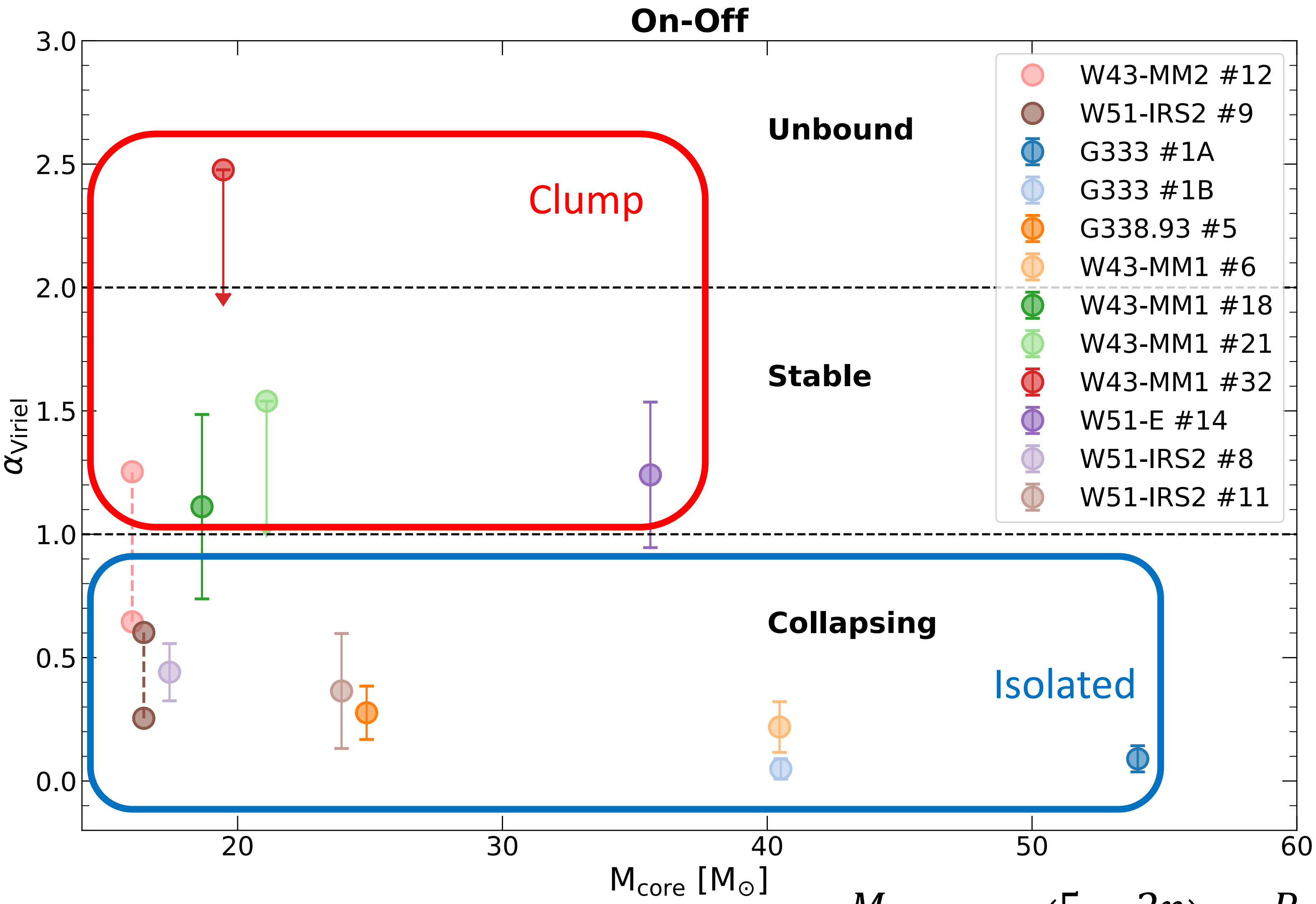

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Turbulence is not enough to stabilize ~2/3 of the cores against gravitational collapse

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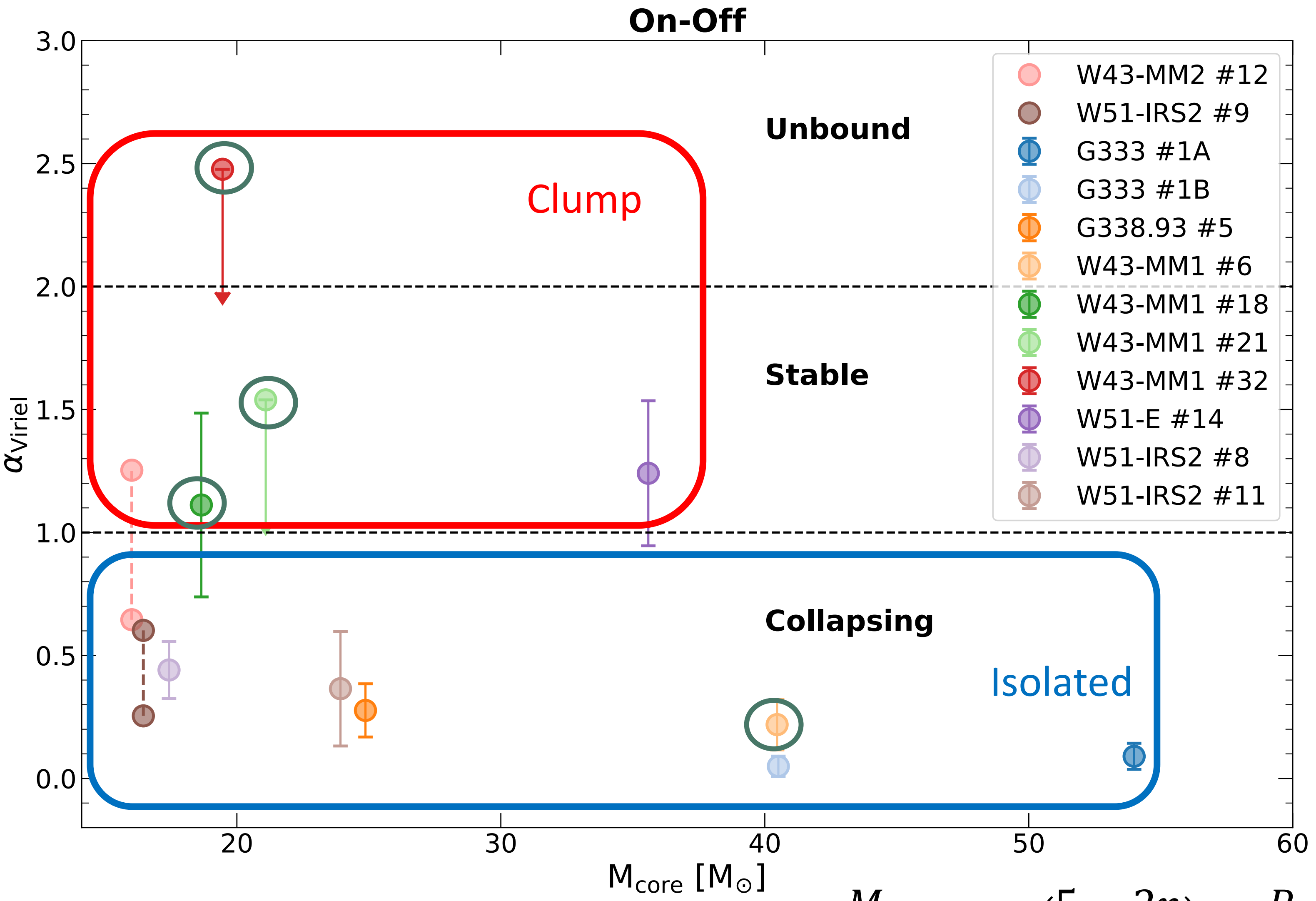

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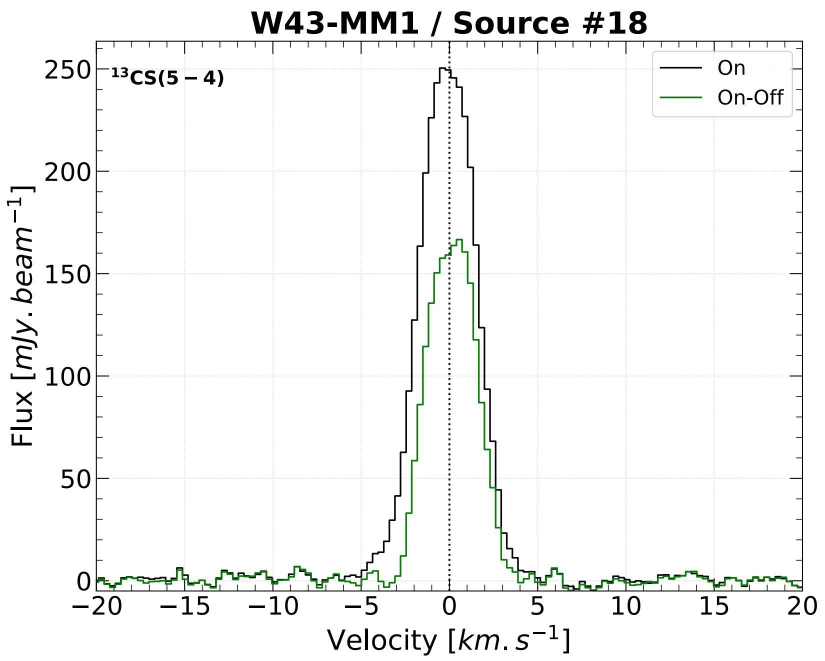
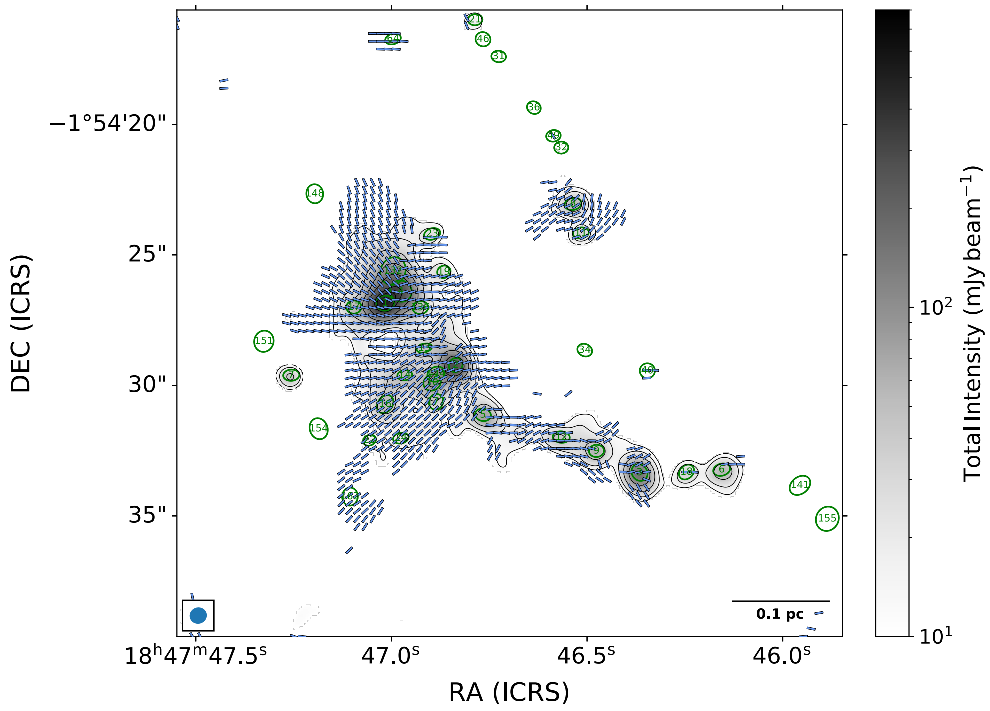
Need for an additional magnetic field between 5 and 50mG

My new postdoc project

A complete virial analysis of the protocluster W43-MM1





Line data (ALMA-IMF): Turbulence

+

Polarisation data: Magnetic field

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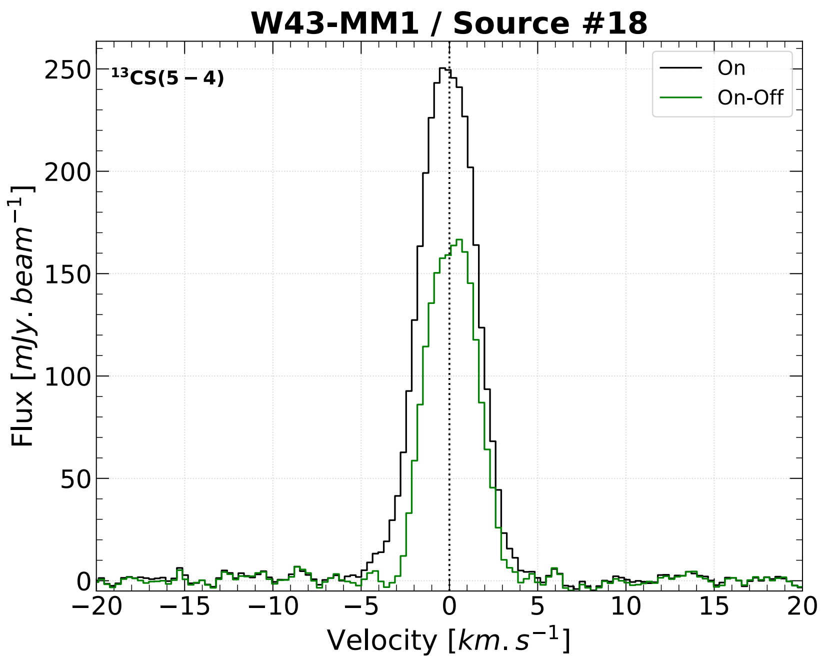
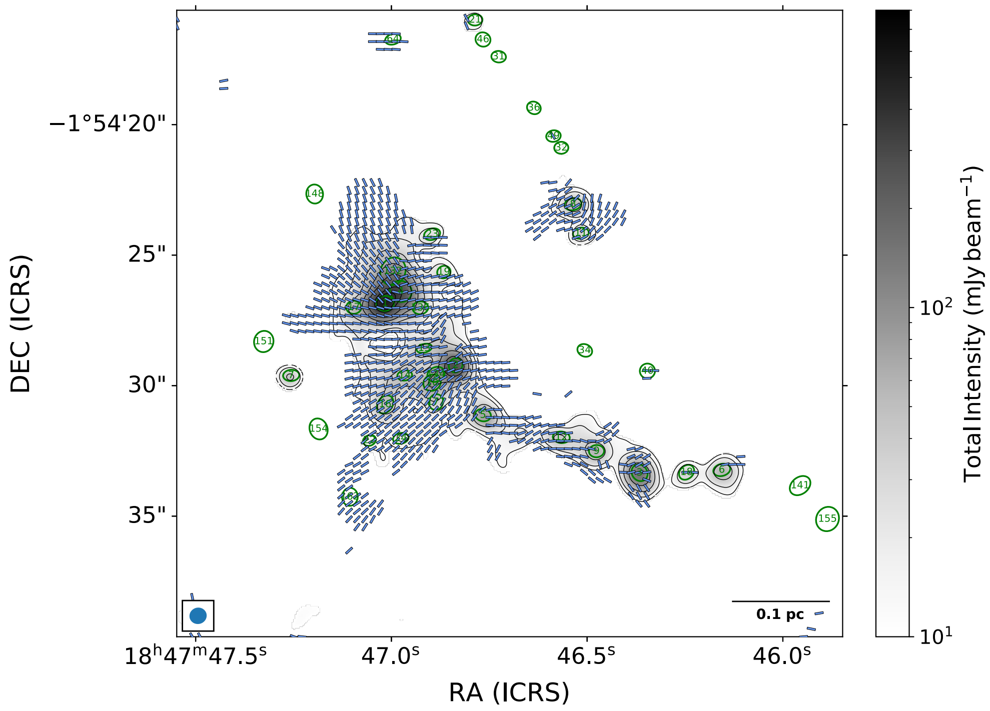




Line data (ALMA-IMF): Turbulence

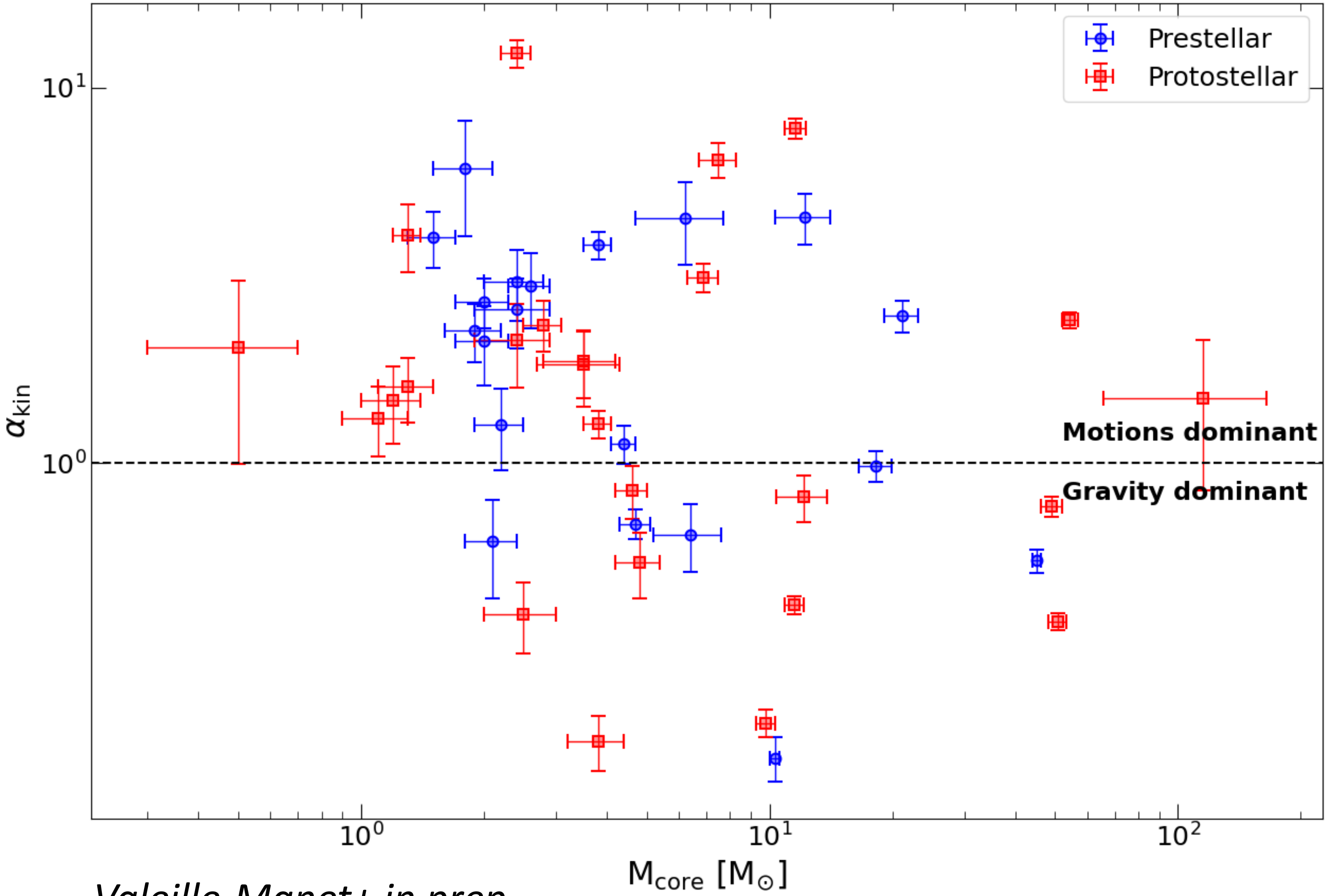
+

Polarisation data: Magnetic field

Virial analysis at all masses at both pre and protostellar stages

$$\propto = \frac{M_{vir}}{M_{core}} = 3\left(\frac{5-2n}{3-n}\right)\frac{R}{GM_{core}}\left(\sigma_{turb}^2 + \frac{1}{6}\sigma_{alf}^2\right)$$

Virial analysis: turbulence investigation



Valeille-Manet+ in prep

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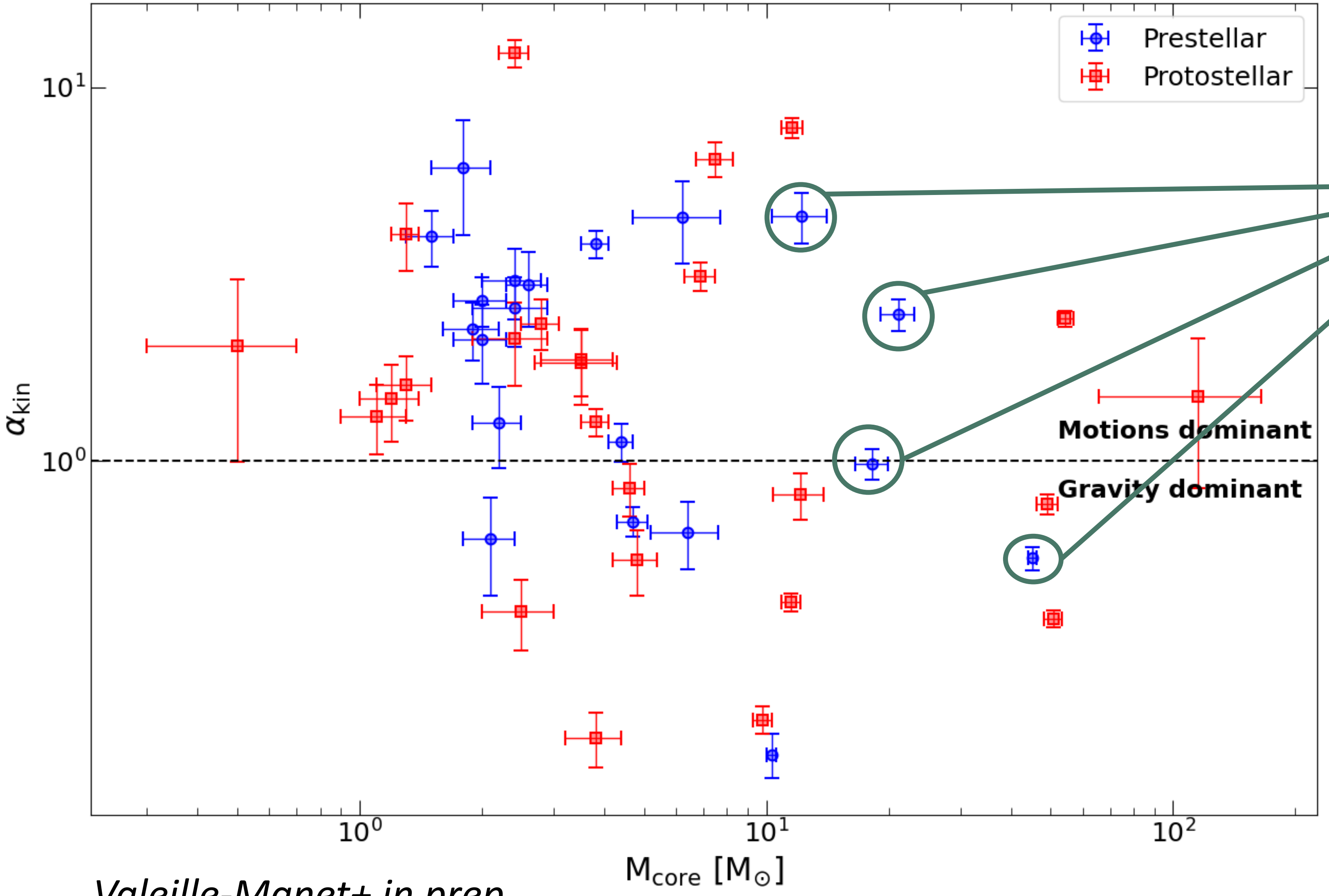


Valeille-Manet+ in prep

HMPSC of W43-MM1

Magnetic part undergoing...

Conclusions and perspectives

- **New sample of prestellar cores with 12 high-mass ($M > 16\ M_{\odot}$) mainly located in clumps**
- **Lifetime of the massive prestellar phase $> 10\ t_{ff}$, but shorter than the low-mass phase**
  - Dynamical formation
  - Need for additional supports against gravity
- **Turbulence analysis of the 12 most massive cores**
  - Presence of turbulence, insufficient for more than 50% of the cores
  - Possible additional magnetic field
- **Present and future works:**
  - Virial analysis of W43-MM1 combining line and polarisation data
  - Pre and protostellar catalogs using the On-Off method for all ALMA-IMF cores *(Nony, Valeille-Manet et al, in prep)*
  - Investigate the fragmentation of cores : need for high-resolution data

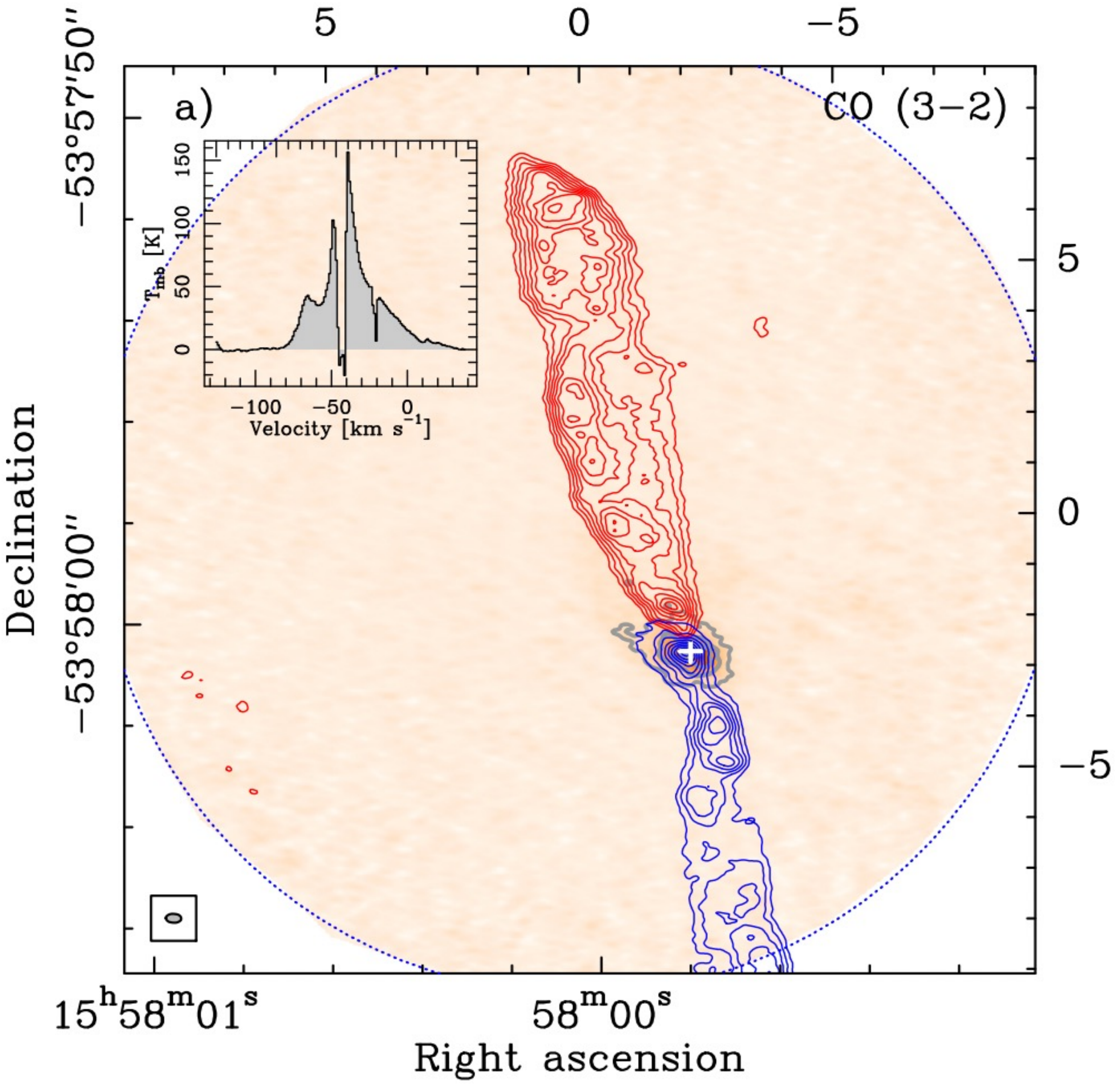
Thank you for your attention !

A new systematic method

- **Separate prestellar from proto-stellar cores and try to find high-mass prestellar cores candidates**

- Determine automatically outflows of protostars by using **CO(2-1) and SiO(5-4) rotational lines**

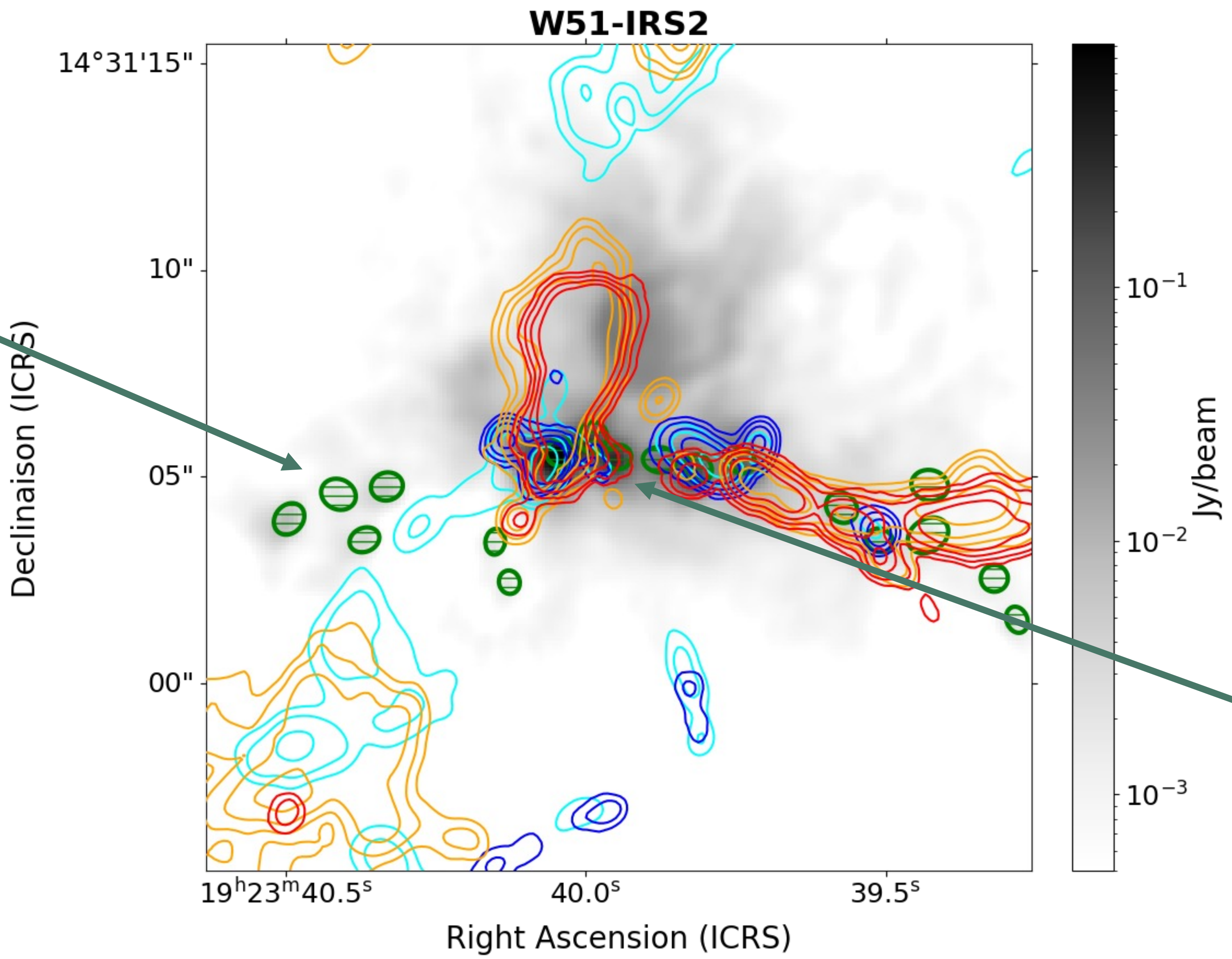
- Apply the method to the ALMA-IMF survey → need to be systematic



Csengeri et al, 2018

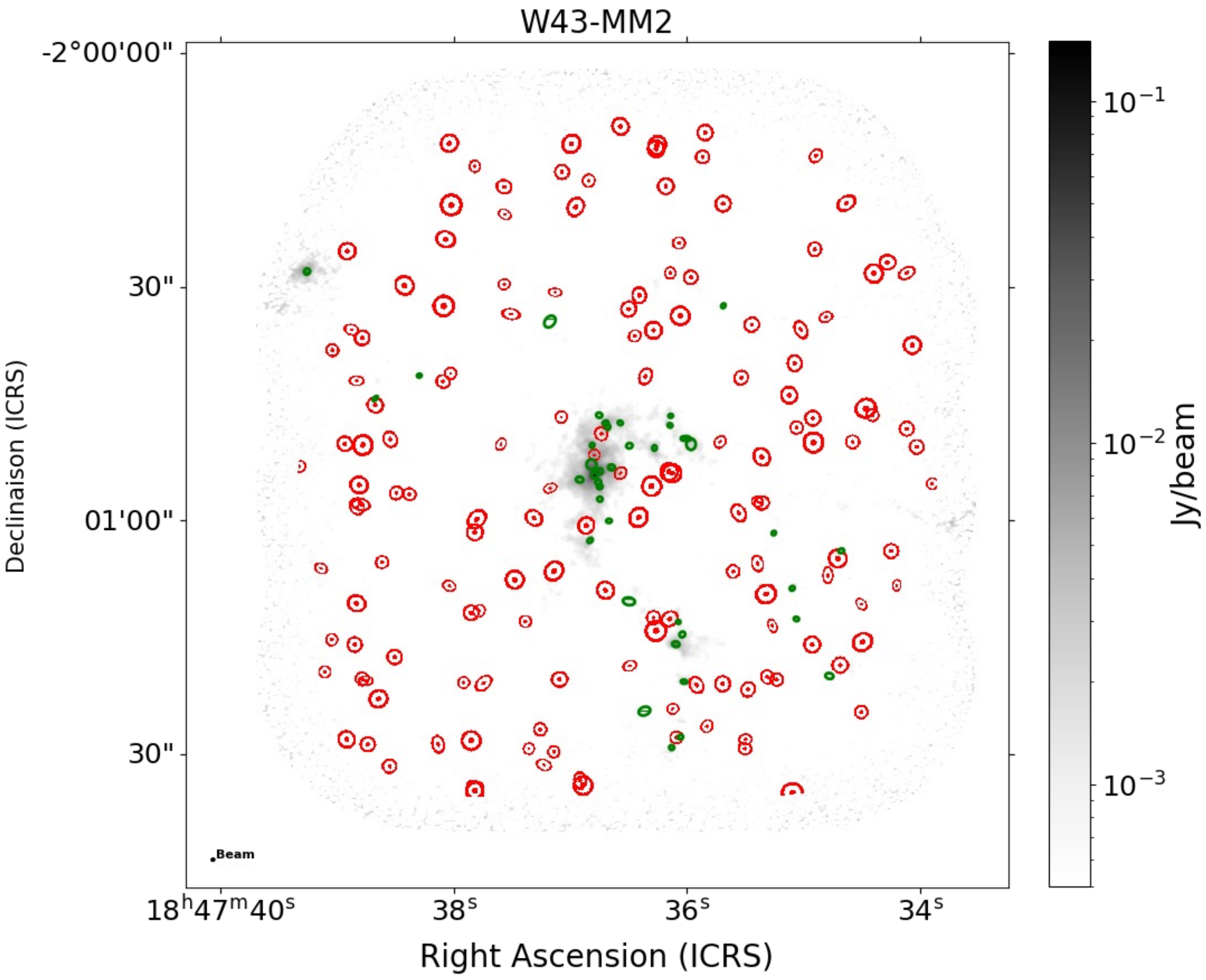
Complexity of molecular outflow maps

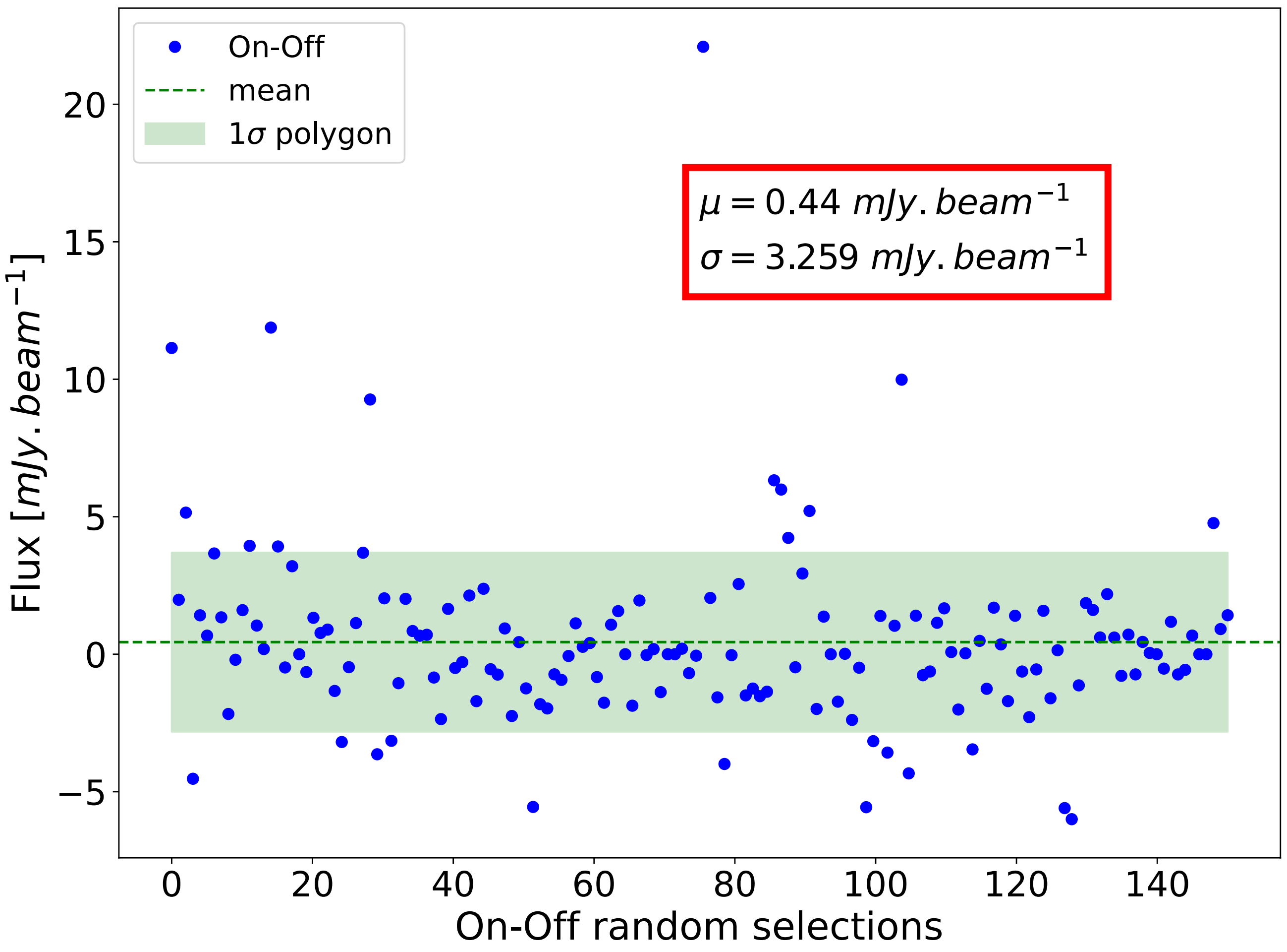
Cores more isolated



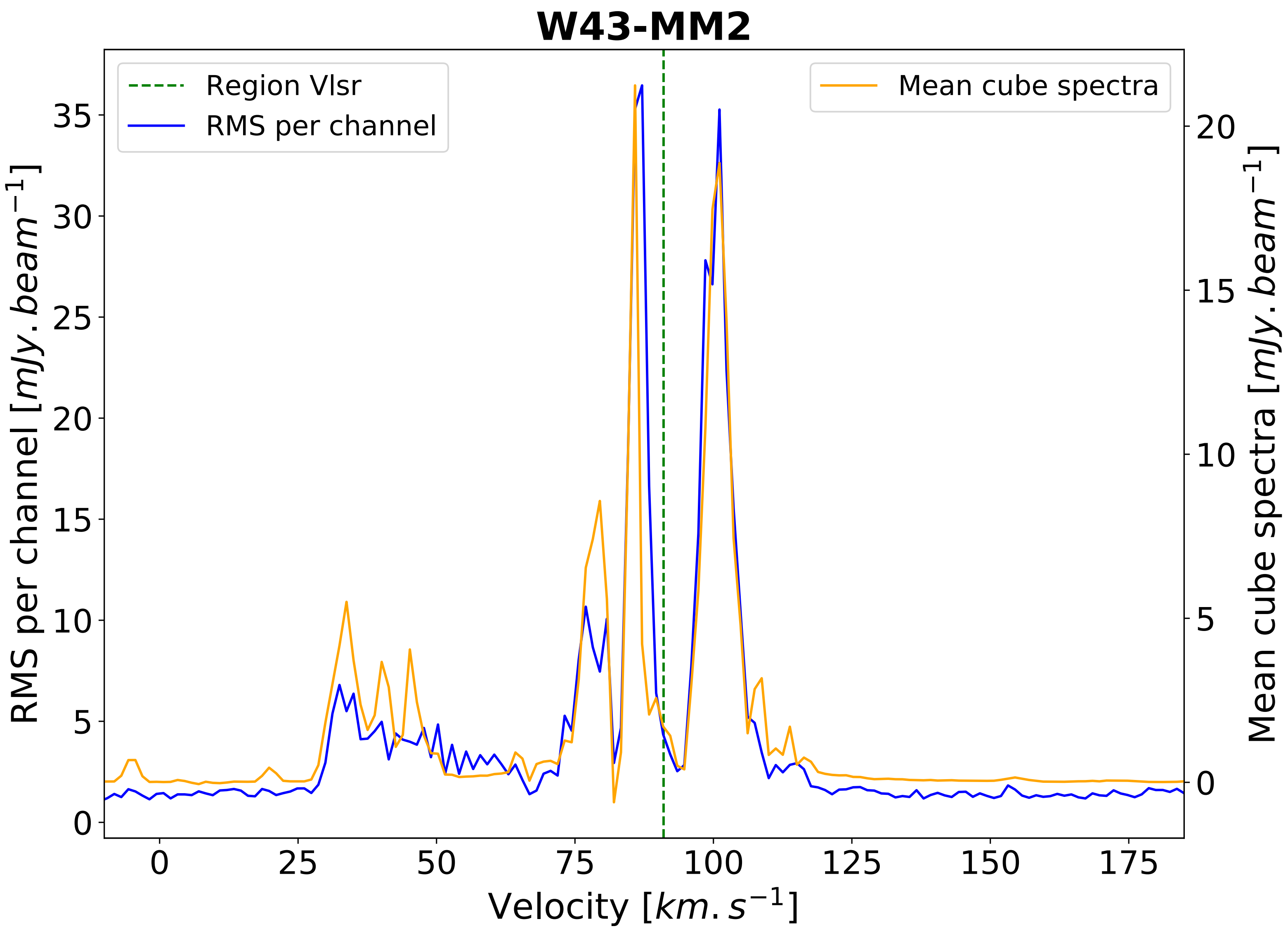
Complex clump

Noise estimate in one channel

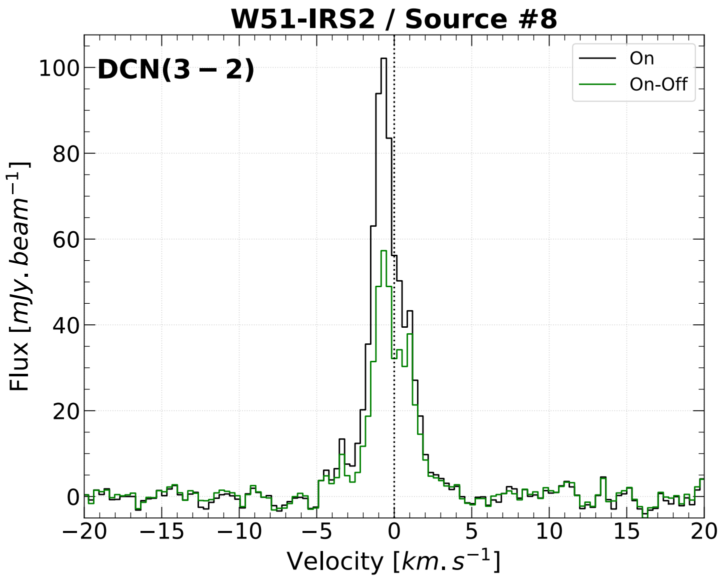


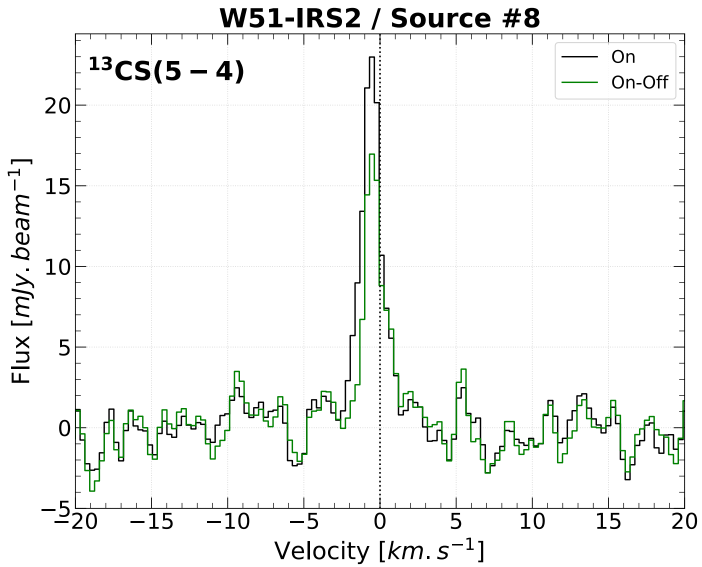


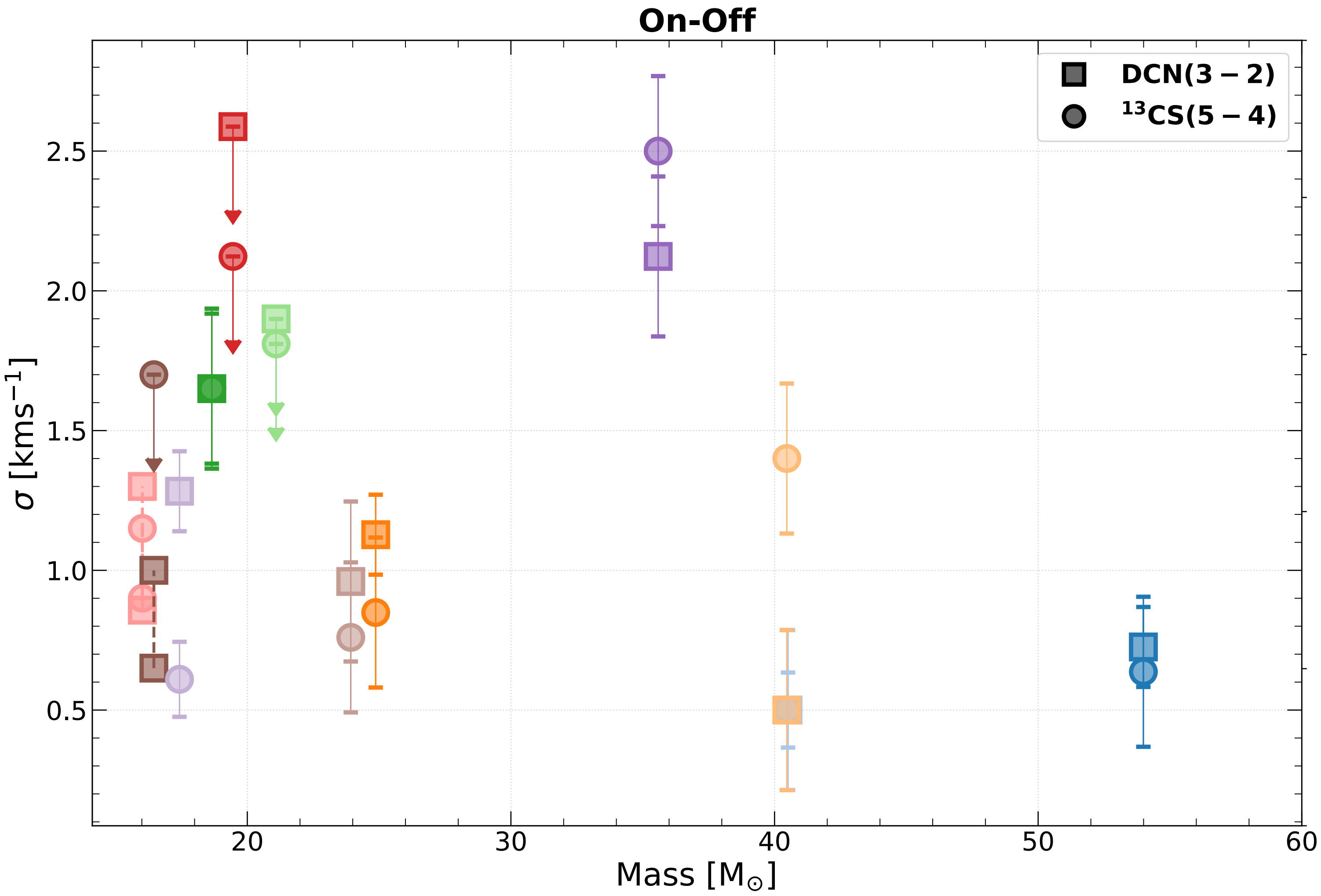
RMS spectrum



Investigating the turbulence

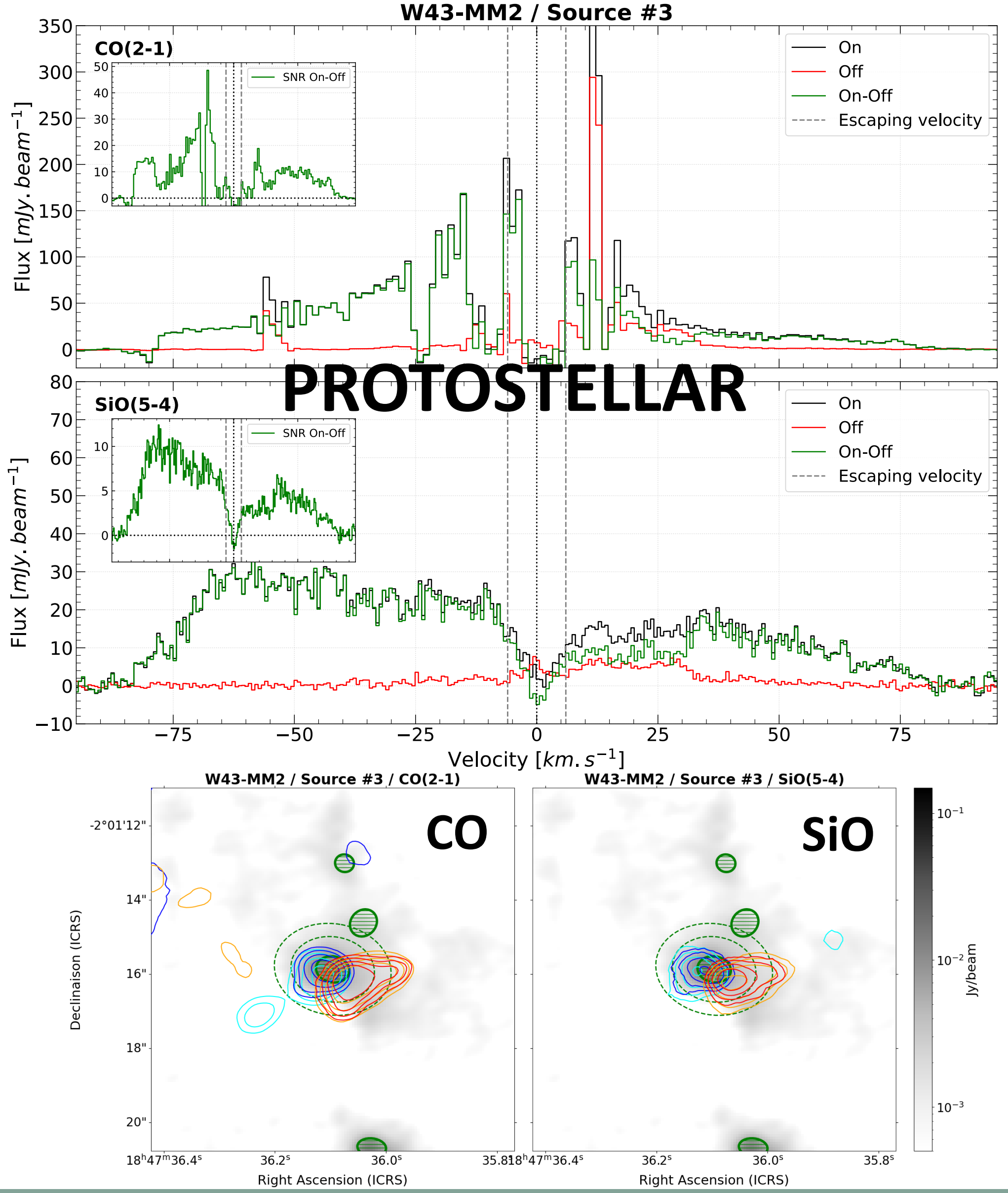


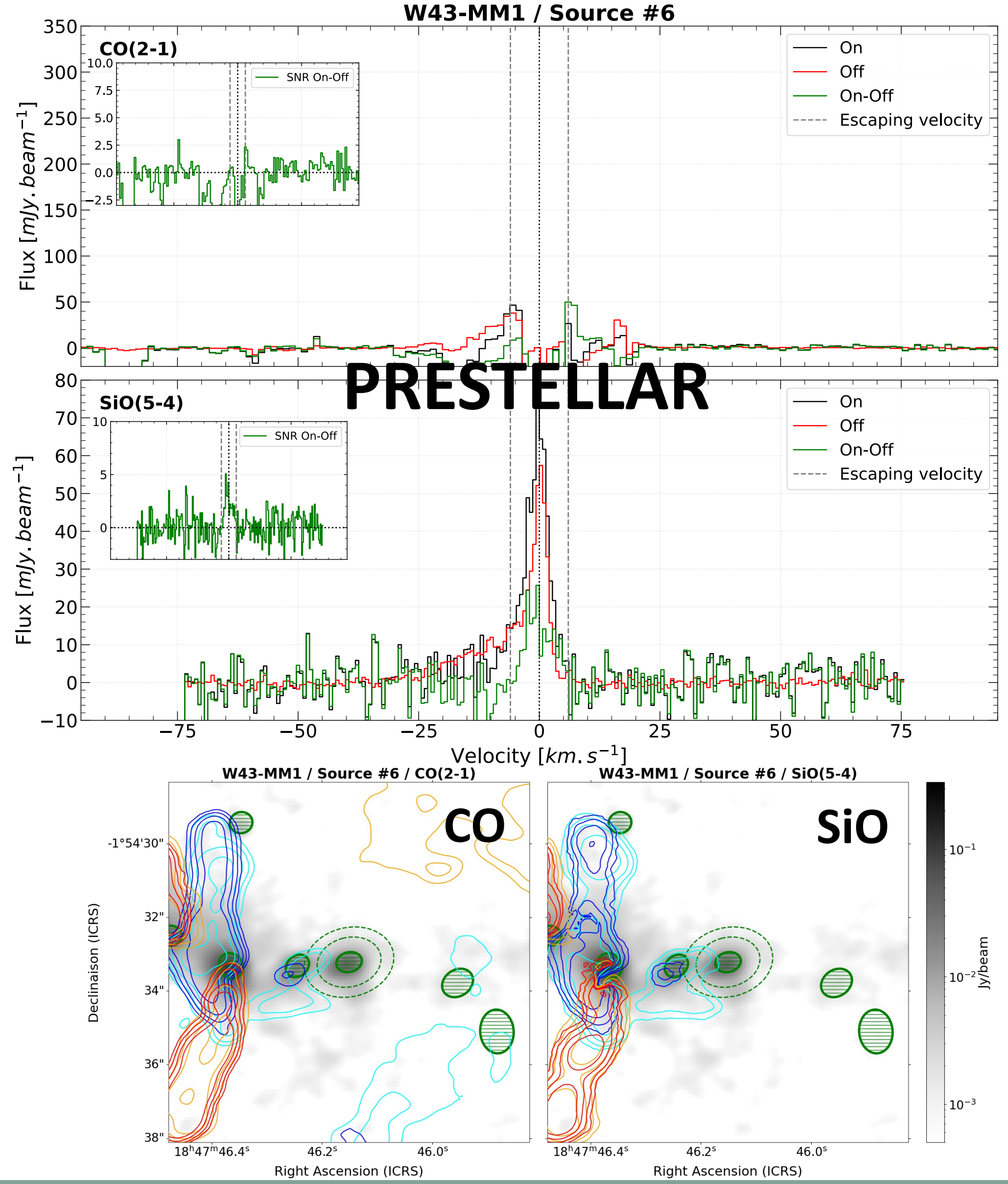




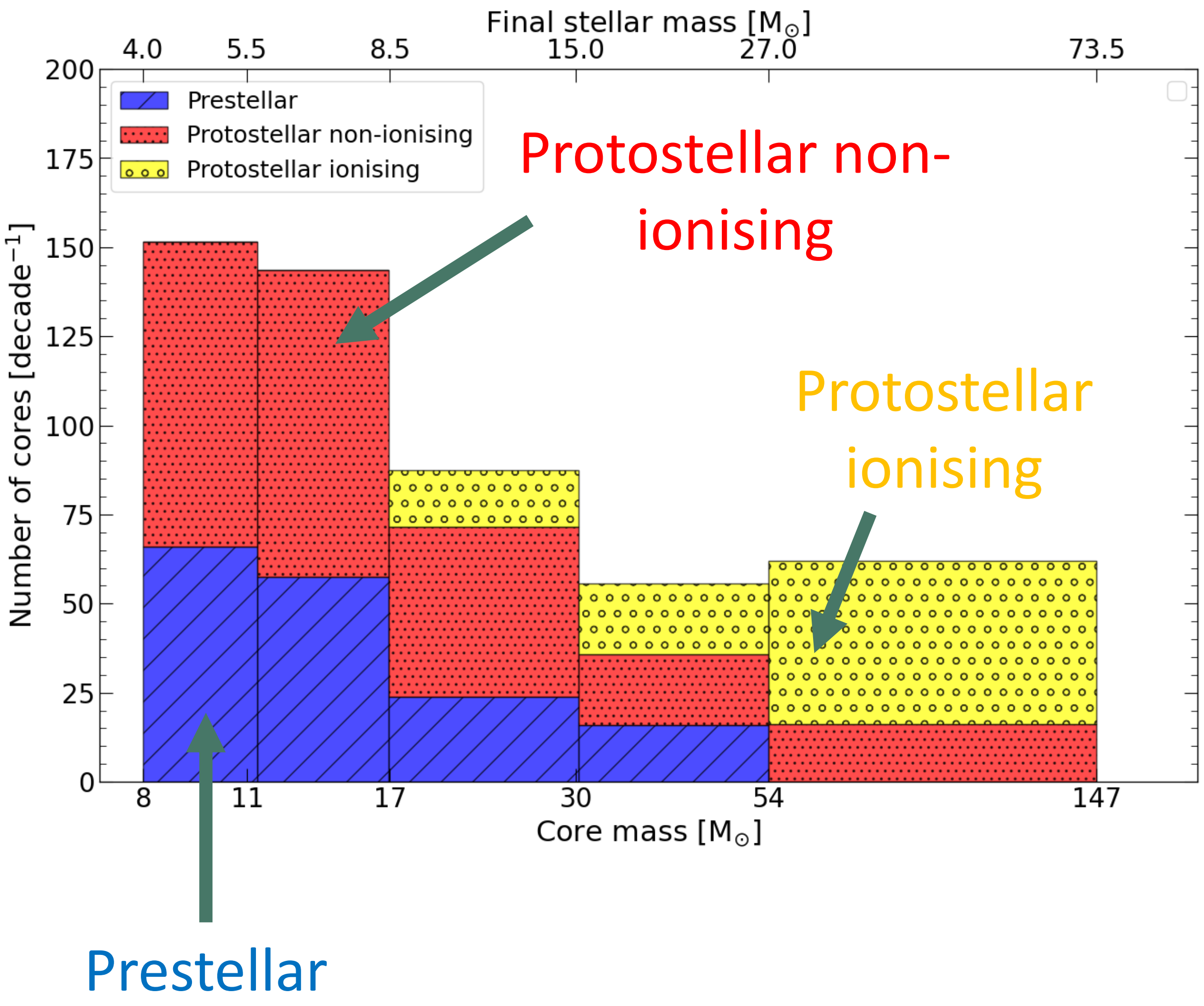
Valeille-Manet et al, in prep

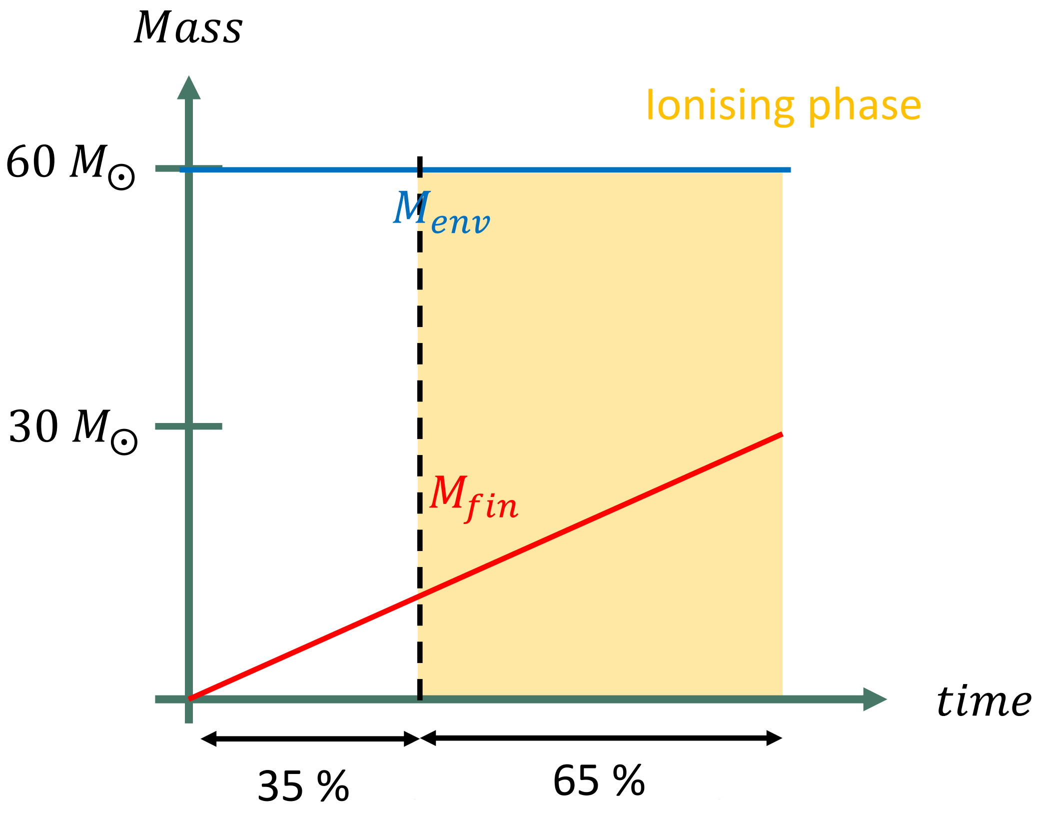
Cores ID


W43-MM2 / Source #3
CO(2-1)
SNR On-Off
On
Off
On-Off
Escaping velocity
Flux [$mJy.beam^{-1}$]
PROTOSTELLAR
SiO(5-4)
Velocity [$km.s^{-1}$]
W43-MM2 / Source #3 / CO(2-1)
W43-MM2 / Source #3 / SiO(5-4)
CO
SiO
Declinaison (ICRS)
Right Ascension (ICRS)
Jy/beam


W43-MM1 / Source #6
CO(2-1)
SNR On-Off
On
Off
On-Off
Escaping velocity
Flux [$mJy.beam^{-1}$]
PRESTELLAR
SiO(5-4)
Velocity [$km.s^{-1}$]
W43-MM1 / Source #6 / CO(2-1)
W43-MM1 / Source #6 / SiO(5-4)
CO
SiO
Declinaison (ICRS)
Right Ascension (ICRS)
Jy/beam

Massive prestellar phase lifetime



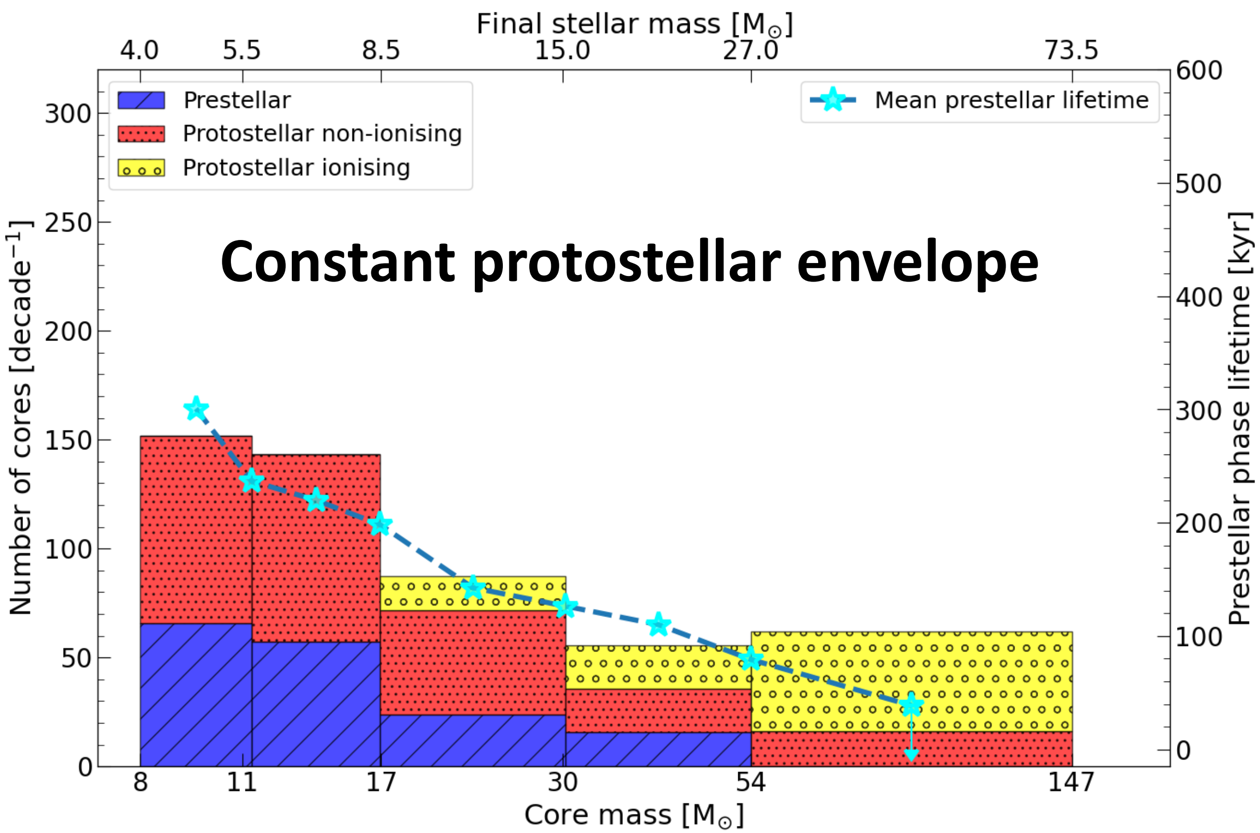


Catalogs of cores with ionising sources retrieved

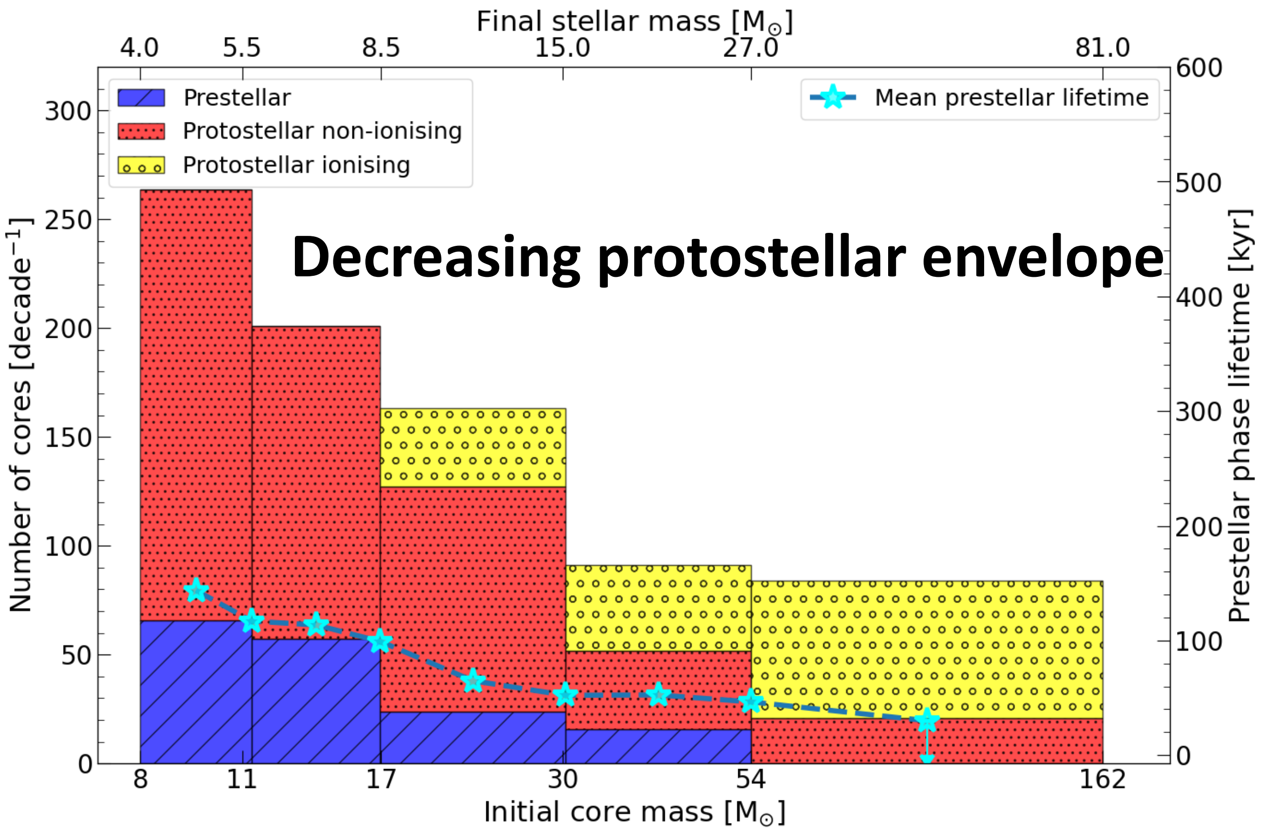
Correction of the number of ionising sources missing (Duarte-Cabral et al, 2013 ; Hosokawa & Omukai 2009)

Valeille-Manet et al, accepted

High-mass prestellar phase lifetime



t_{psc} ranges from 300 to 100 kyr



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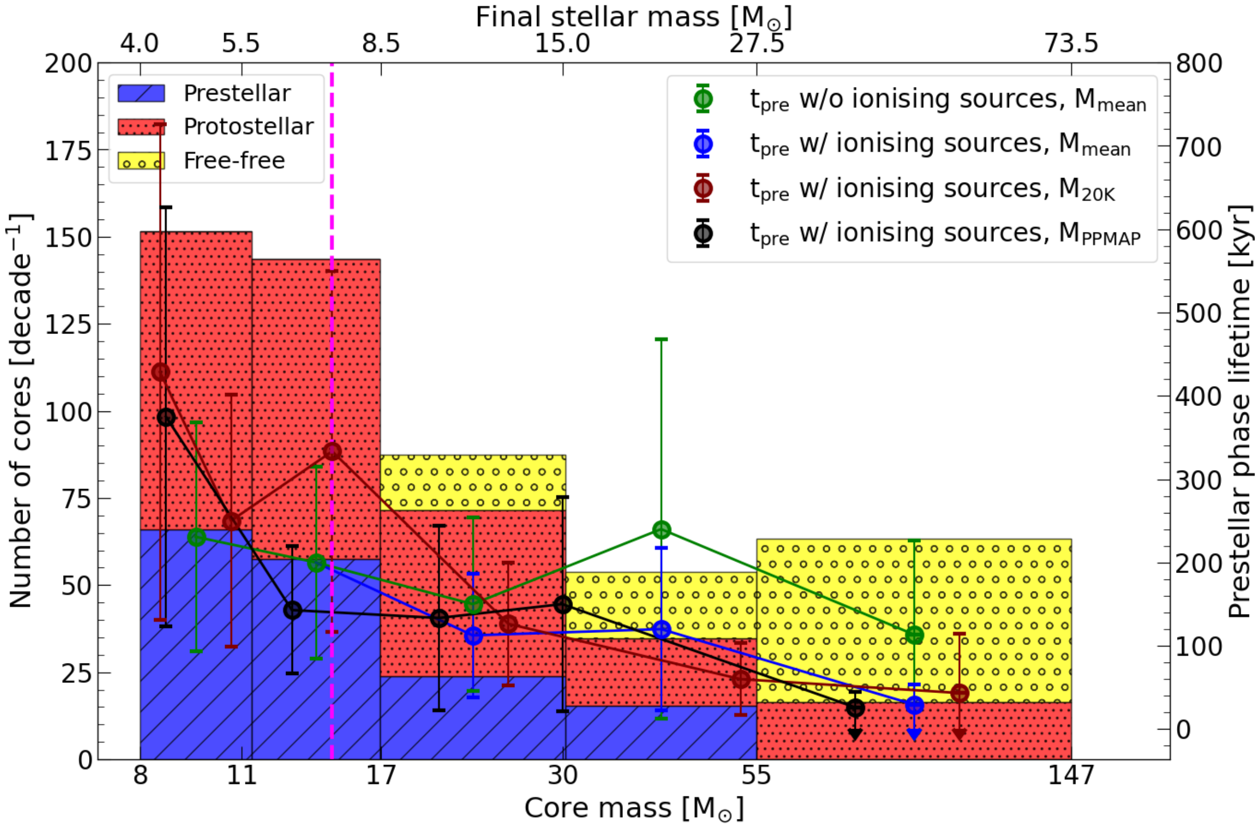
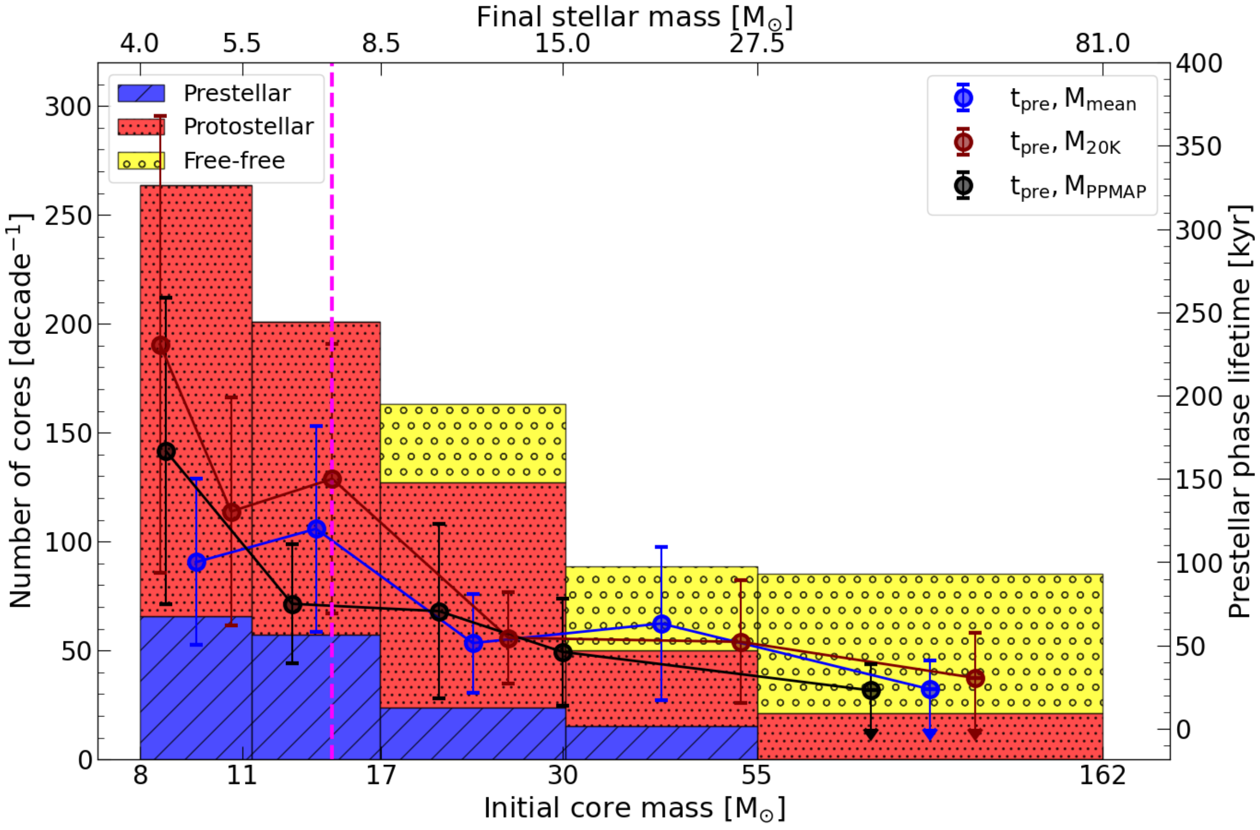




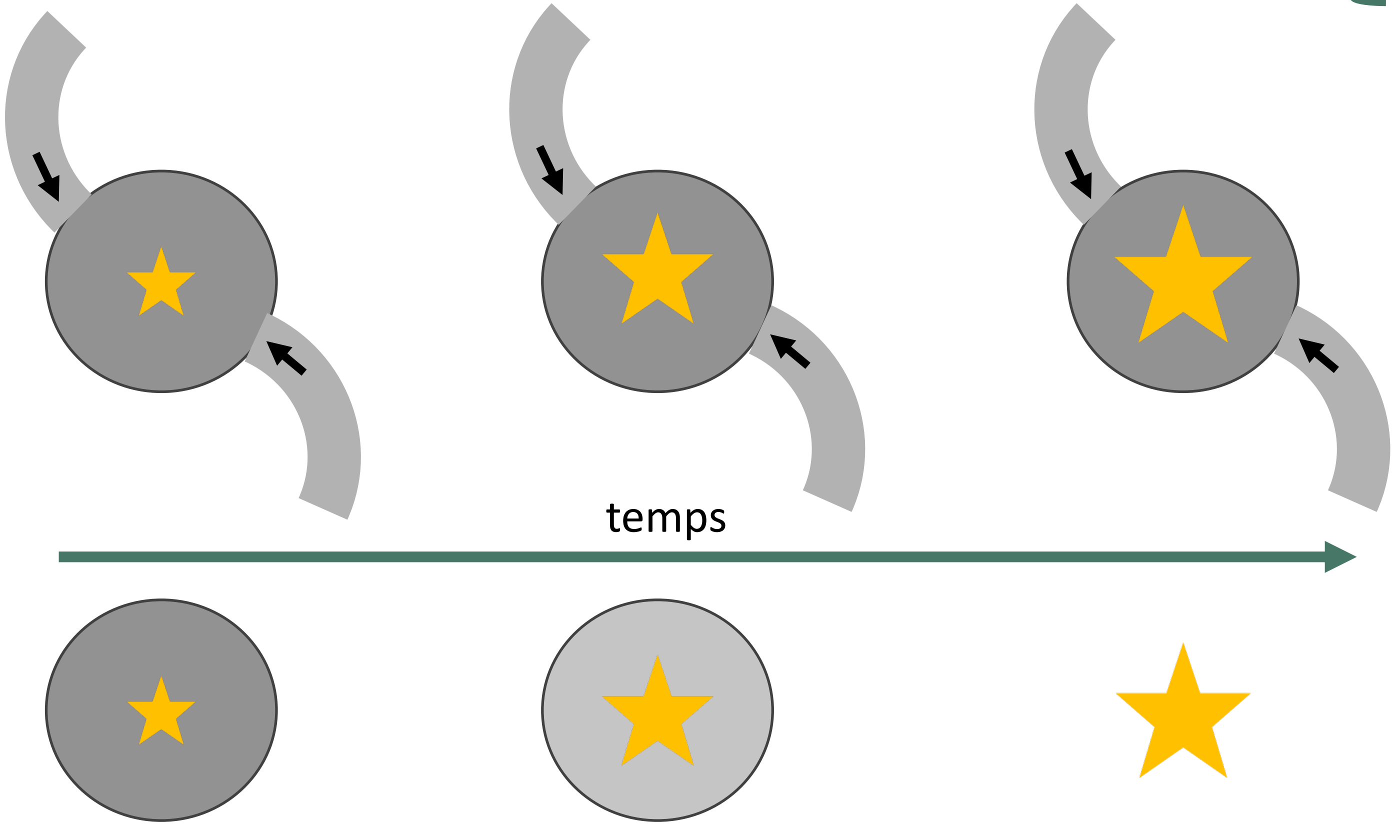
Statistical lifetimes and hypotheses

Prestellar sample

Protostellar sample

$$\begin{cases} t_{pre} = \dfrac{N_{pre}}{N_{proto}} t_{proto} \\ t_{proto} = 3.10^5 yr \end{cases}$$

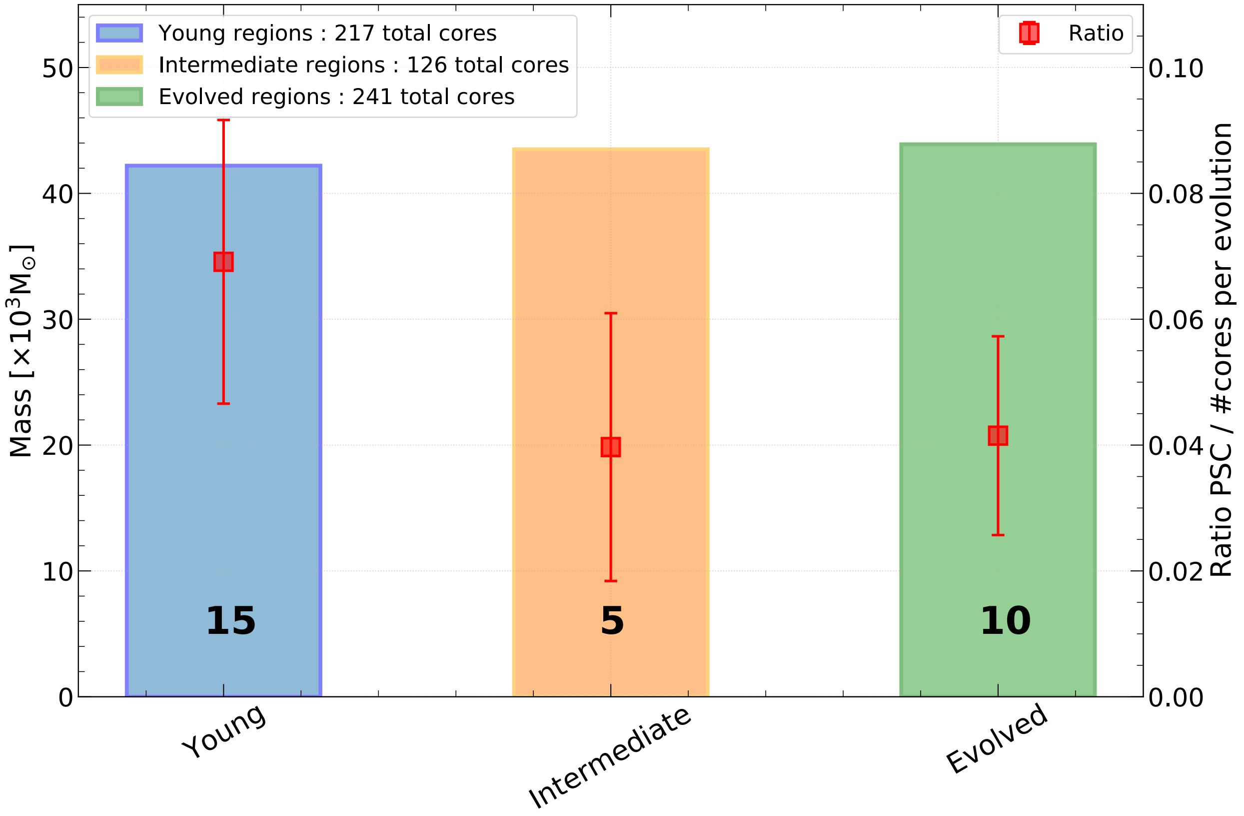
Duarte-Cabral et al, 2013 ;
Mottram et al, 2010

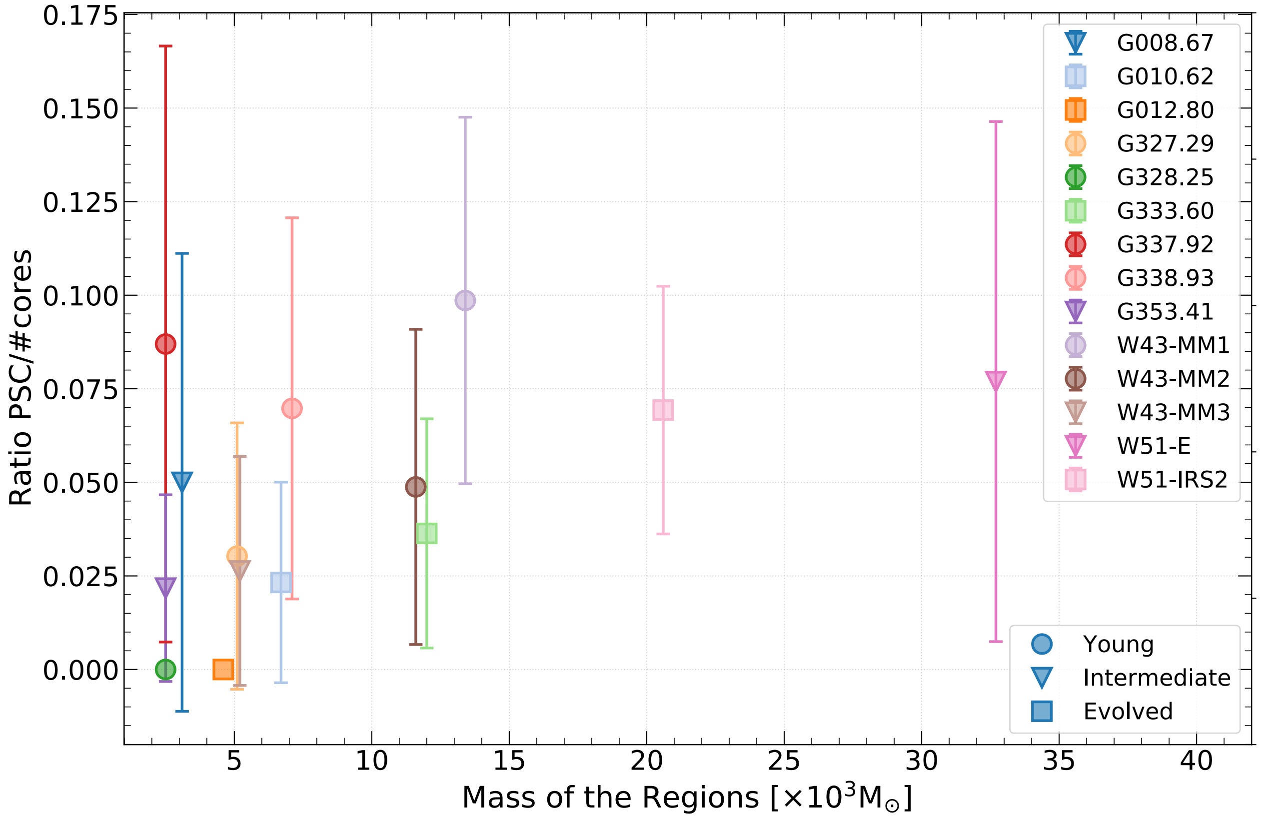


Constant mass of the envelope

Decreasing mass of the envelope

Study per region and evolutionary stage





Fragmentation