Galaxy-wide star formation: zooming in from panoramic Galactic Plane surveys to 1000au-scale with ALMA

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&

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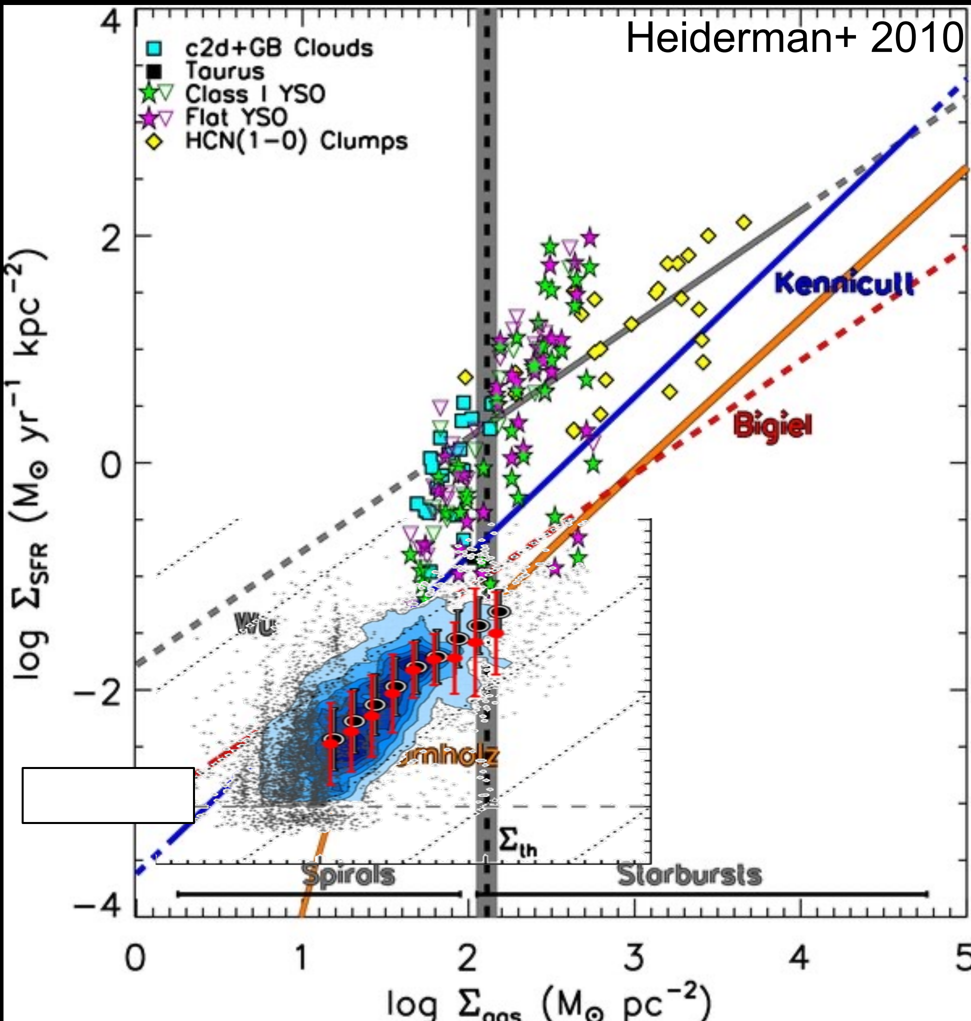
ECOGAL

European Research Council

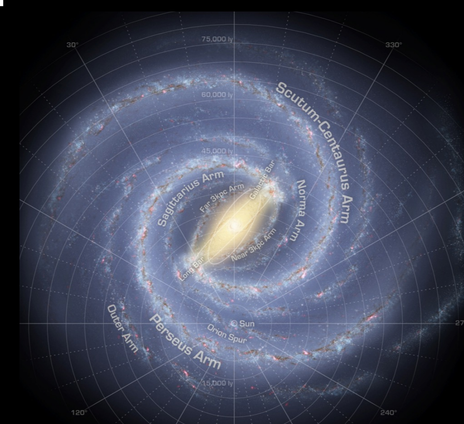
5th Workshop on Millimeter Astronomy in Italy, Bologna, 12-14 June 2023

Basic Rationale for star-formation-driven large Galactic Surveys

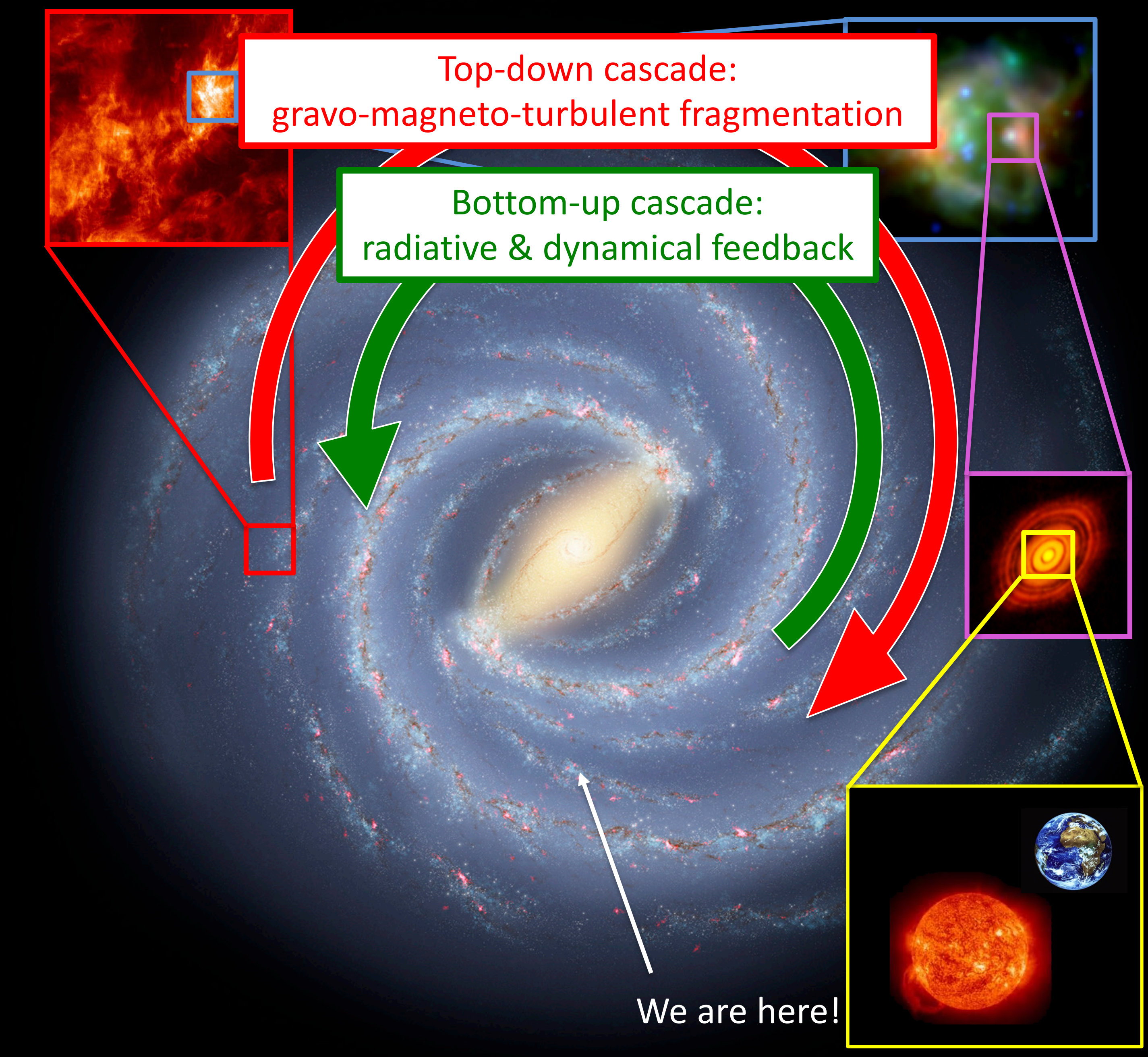


Aim: Identify the critical parameters that govern the formation and evolution of dense cluster-forming clumps within the diversity of environmental conditions:

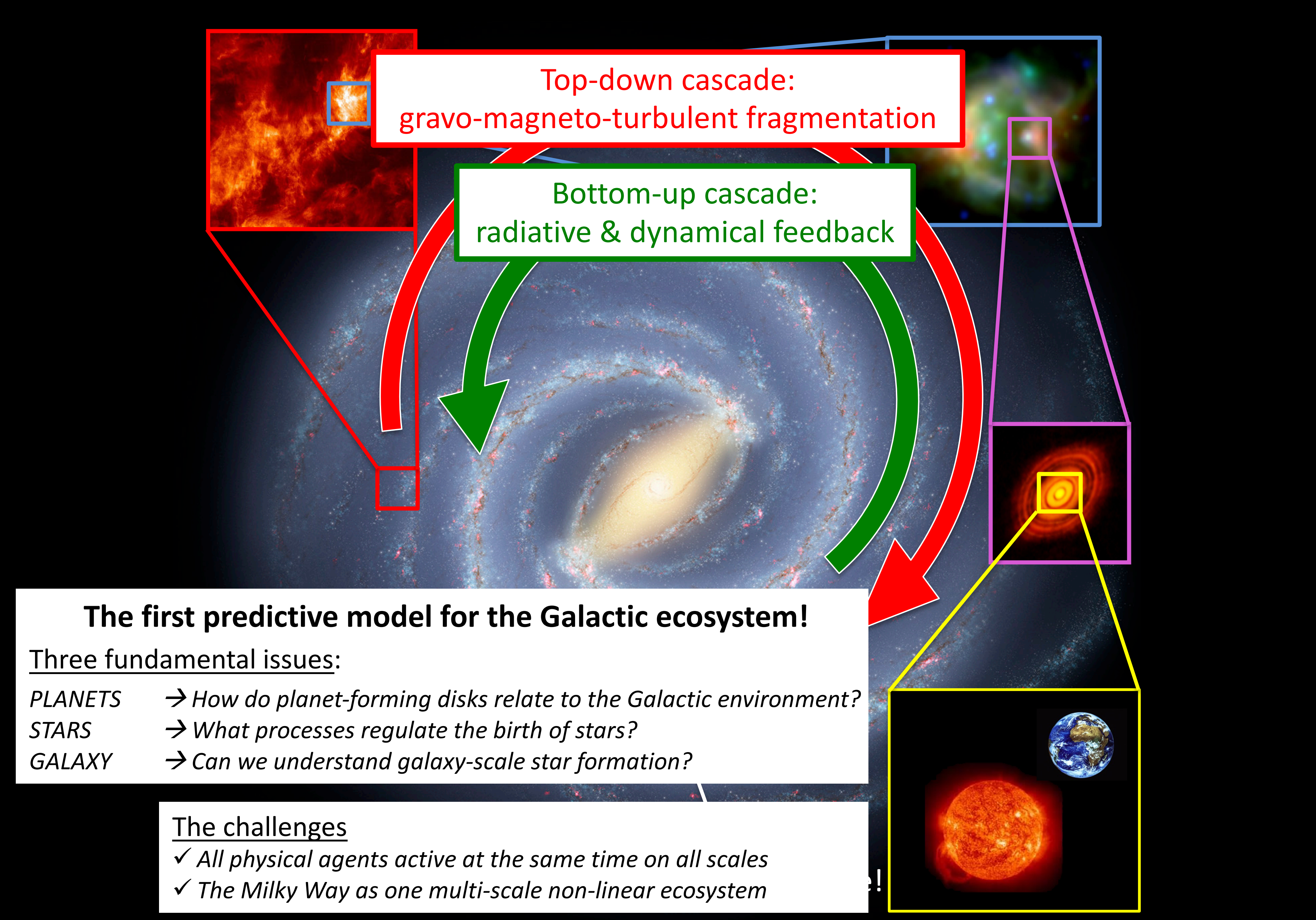
- Spontaneous/triggered SF ?
- Star Formation on/off Filaments ?
- Depending on the position in the Galaxy
- w.r.t. Spiral Arms
- etc.



understand if & how the mix of the ingredients conspire to determine a global Star Formation law



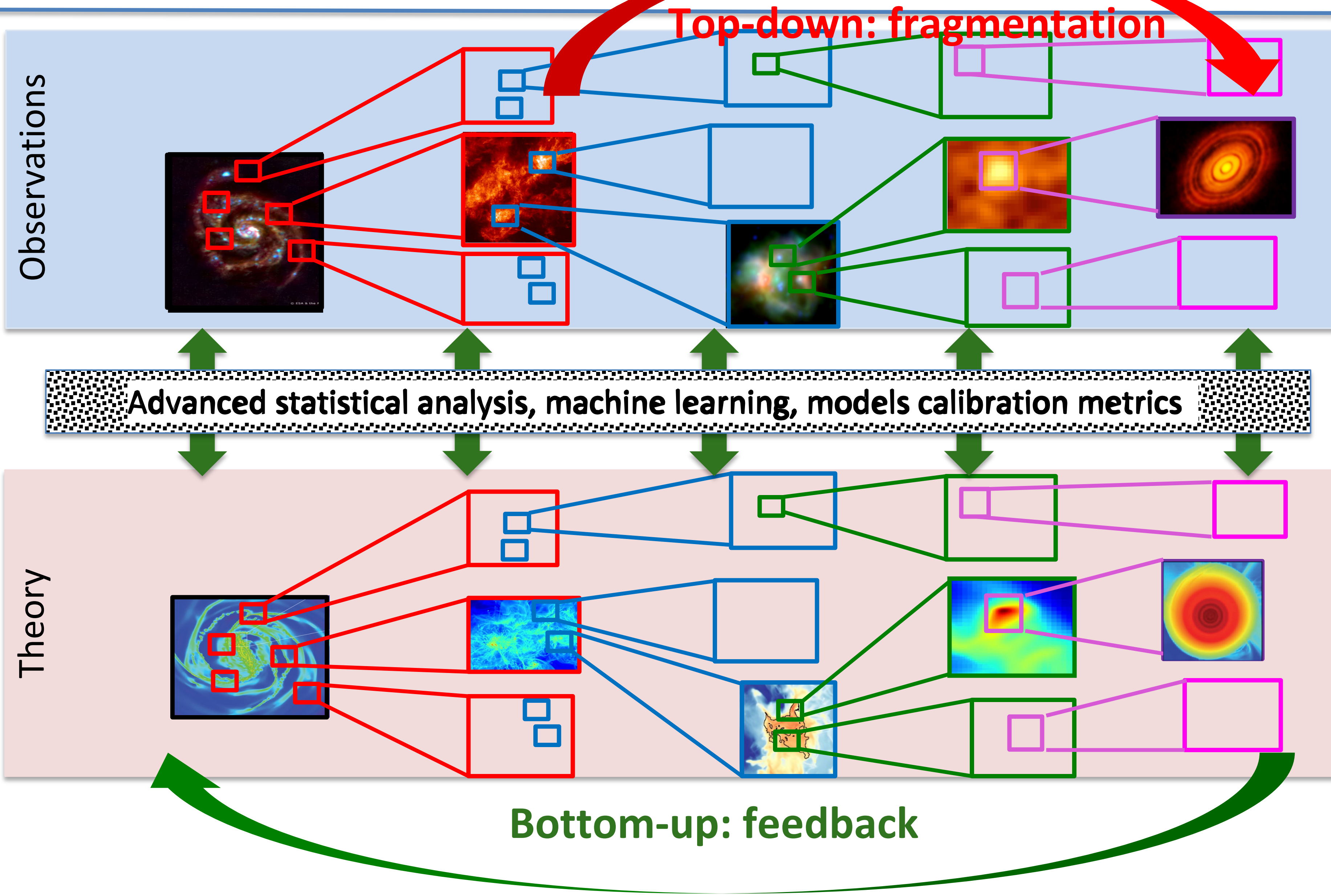
Realistic illustration of Milky Way (NASA/JPL-Caltech)



Realistic illustration of Milky Way (NASA/JPL-Caltech)

ECOGAL

Our strategy: connection and statistics



SurveysSurveysSurveysSurveysSurveysSurveys…

Table 1: List of most representative surveys covering the Galactic Plane

Surveys facilities	λ or lines	Surveys notes
		Ground-based
Columbia/CfA	CO, ^{13}CO	9 - 25′ resolution (*Dame et al.*, 2001)
DRAO/ATCA/VLA	HI-21 cm OH/Hα-RRL/1-2GHz cont. 5GHz cont.	IGPS: unbiased HI-21cm 255°$\leq l \leq$ 357° and 18°$\leq l \leq$ 147° (*McClure-Griffiths et al.*, 2001; *Gibson et al.*, 2000; *Stil et al.*, 2006) + THOR: unbiased HI-21cm/OH/Hα-RRLs/1-2GHz cont. 15°$\leq l \leq$ 67° (Beuther et al. in prep.)+ CORNISH: 5GHz continuum 10°$\leq l \leq$ 65° (*Hoare et al.*, 2012)
FCRAO 14 m	CO, ^{13}CO	55″ resolution. Galactic Ring Survey (*Jackson et al.*, 2006) + Outer Galaxy Survey (*Heyer et al.*, 1998)
Mopra 22 m	CO, ^{13}CO, N_2H^+, (NH_3 + H_2O) maser, HCO^+/$H^{13}CO^+$ + others	HOPS: (*Walsh et al.*, 2011; *Purcell et al.*, 2012), MALT90: $\sim$ 2000 clumps 20° $\geq l \geq -60$° (*Foster et al.*, 2013), Southern GPS CO: unbiased 305°$\leq l \leq$ 345° (*Burton et al.*, 2013), ThrUMMS: unbiased 300°$\leq l \leq$ 358° (*Barnes et al.*, 2013), CMZ: (*Jones et al.*, 2012, 2013)
Parkes	CH_3OH maser	Methanol MultiBeam Survey (*Green et al.*, 2009)
NANTEN/ NANTEN2	CO, ^{13}CO, $C^{18}O$	NGPS: unbiased, 200° $\leq l \leq$ 60° (*Mizuno and Fukui*, 2004) + NASCO: unbiased in progress, 160° $\leq l \leq$ 80°
CSO 10 m	1.3 mm continuum	Bolocam Galactic Plane Survey (BGPS), 33″ (*Aguirre et al.*, 2011)
APEX 12 m	870 μm continuum	ATLASGAL, 60°$\geq l \geq -80$° (*Schuller et al.*, 2009)
		Space-borne
IRAS	12, 25, 60 and 100 μm cont.	3-5′, 96% of the sky
MSX	8.3, 12.1, 14.7, 21.3 μm cont.	Full Galactic Plane (*Price et al.*, 2001)
WISE	3.4, 4.6, 11, 22 μm continuum	All-sky (*Wright et al.*, 2010)
Akari	65, 90, 140, 160 μm continuum	All-sky (*Ishihara et al.*, 2010)
Spitzer	3.6, 4.5, 6, 8, 24 μm continuum	GLIMPSE+GLIMPSE360: Full Galactic Plane (*Benjamin et al.*, 2003), (*Benjamin and GLIMPSE360 Team*, 2013) + MIPSGAL, 63°$\geq l \geq -62$° (*Carey et al.*, 2009)
Planck	350, 550, 850, 1382, 2098, 3000, 4285, 6820, 10^4 μm cont.	All-sky, resolution $\geq$5′ (*Planck Collaboration et al.*, 2013a)
Herschel	70, 160, 250, 350, 500 μm cont.	Hi-GAL: Full Galactic Plane (*Molinari et al.*, 2010a)

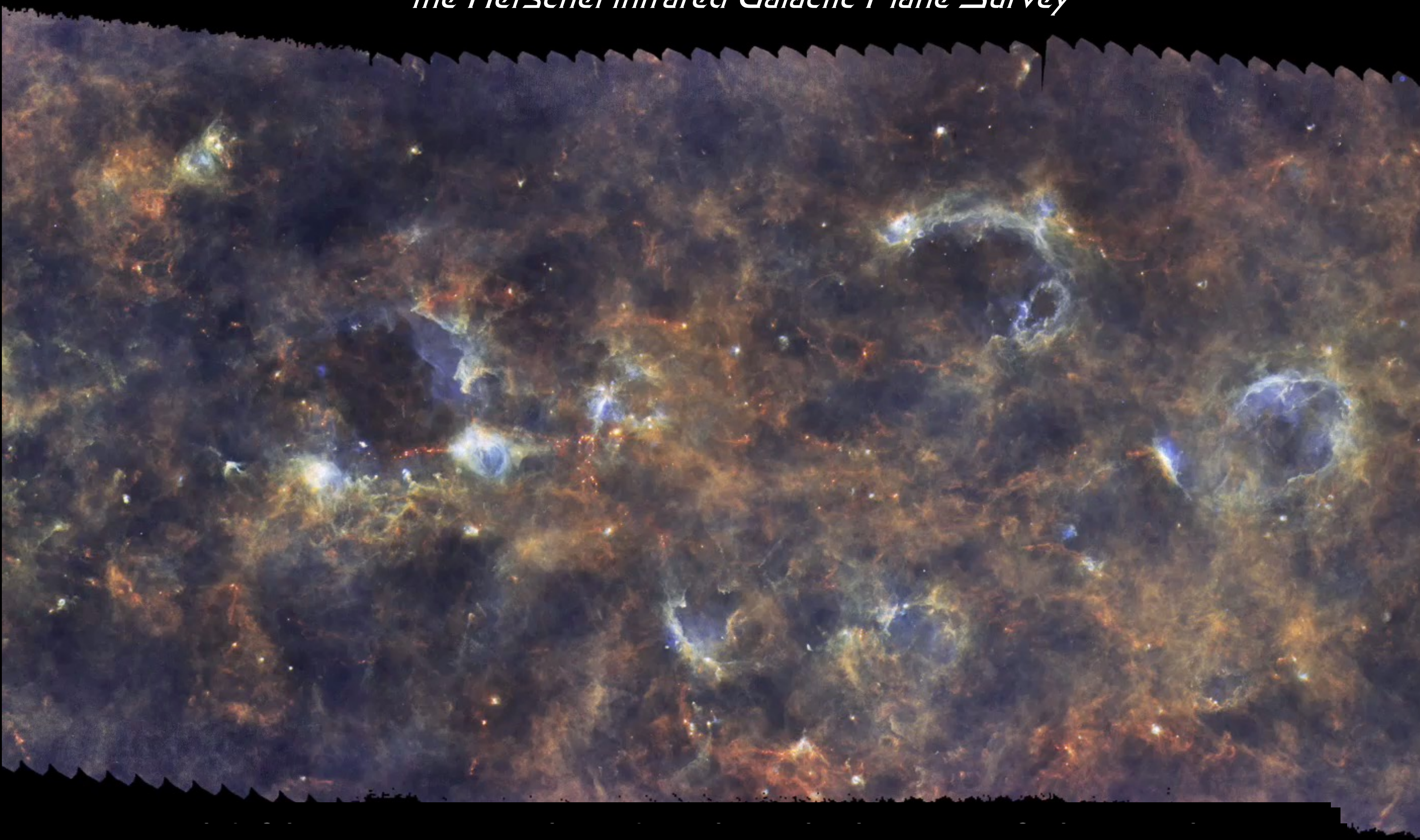
Molinari+ 2014, PP VI

Molinari et al. 2016

Hi-GAL

70-160-250μm composite

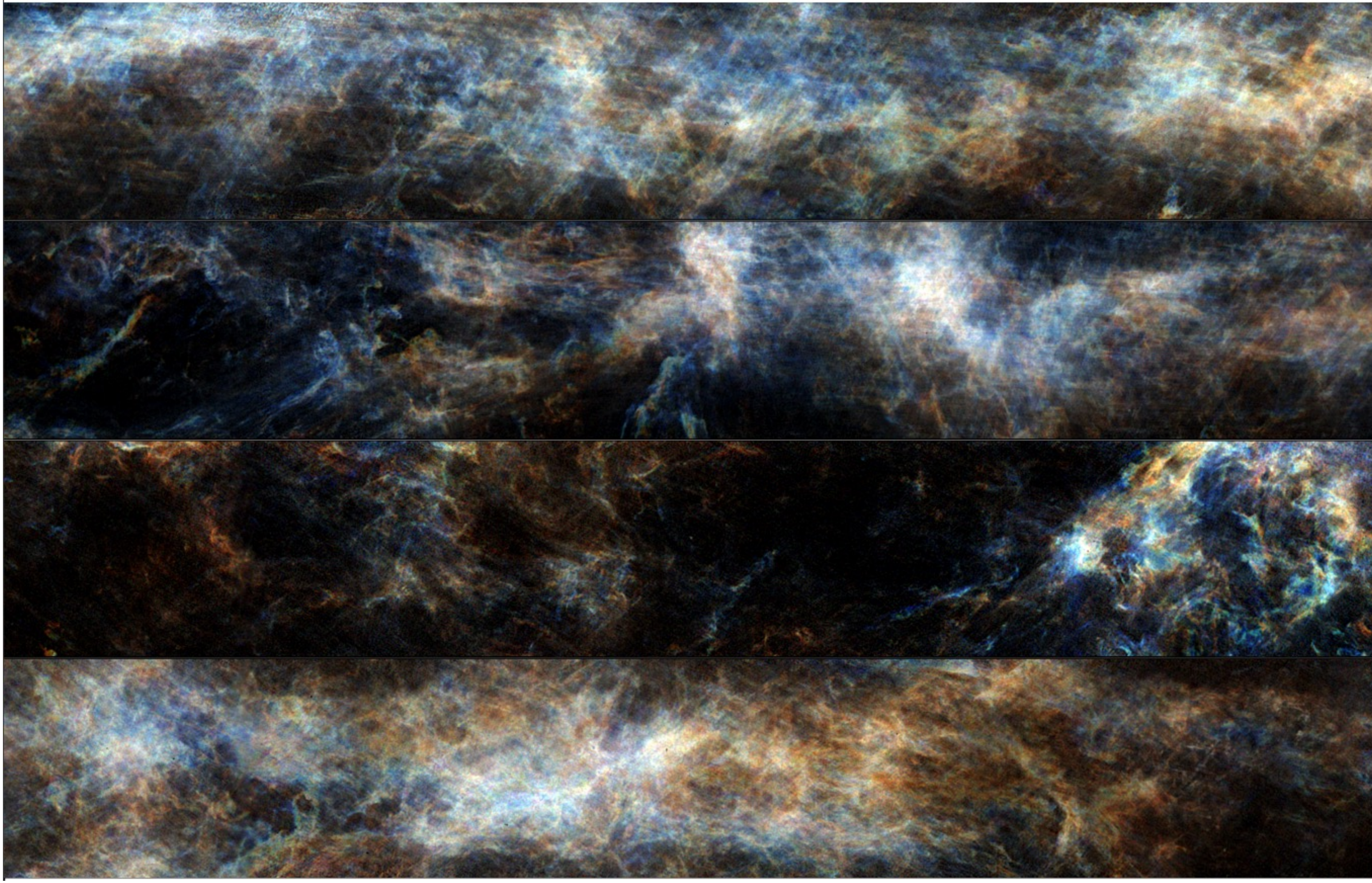
the Herschel infrared Galactic Plane Survey



from cold starless clumps to hot HII Regions

HI filaments and Galactic dynamics

J.D. Soler; THOR collaboration

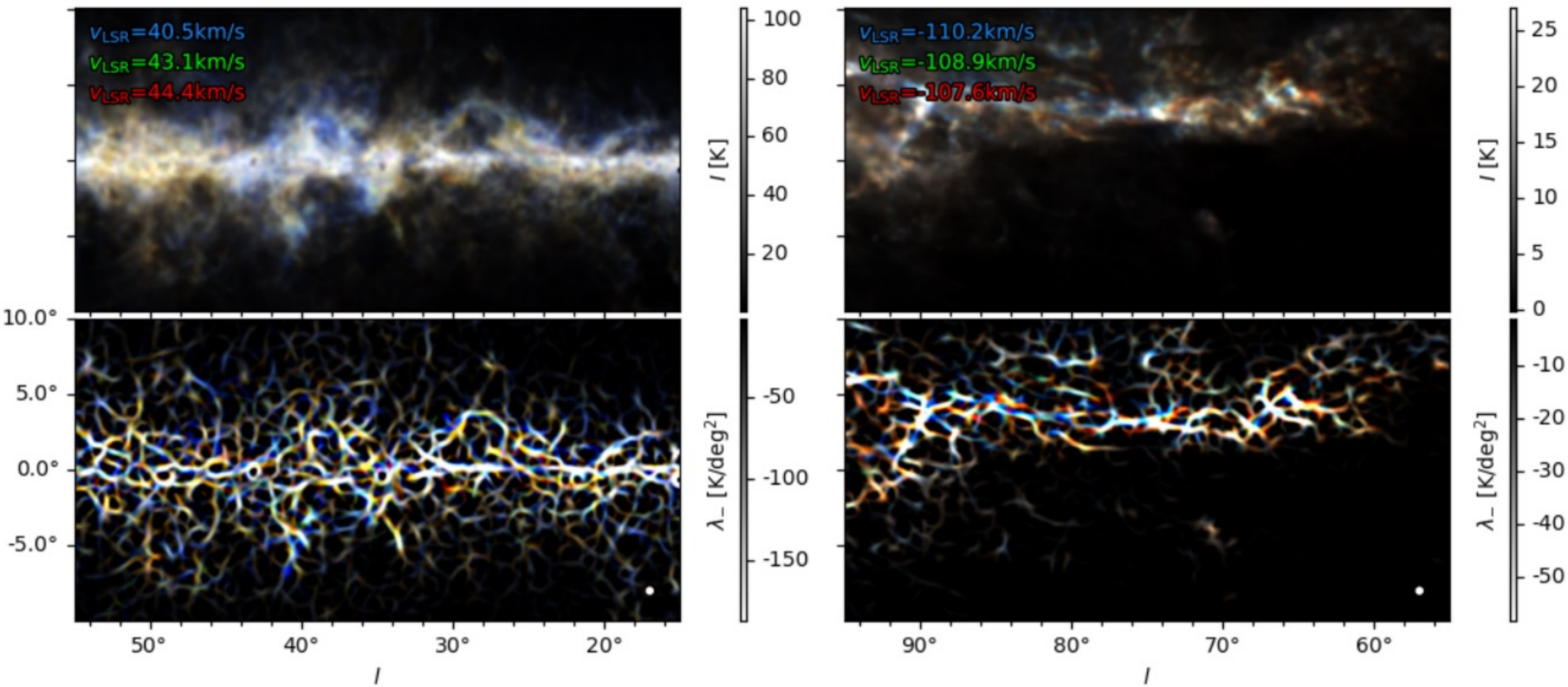


Atomic filament orientation

Soler, J.D. et al. 2022.

Inner galaxy

Outer galaxy



Atomic filament orientation

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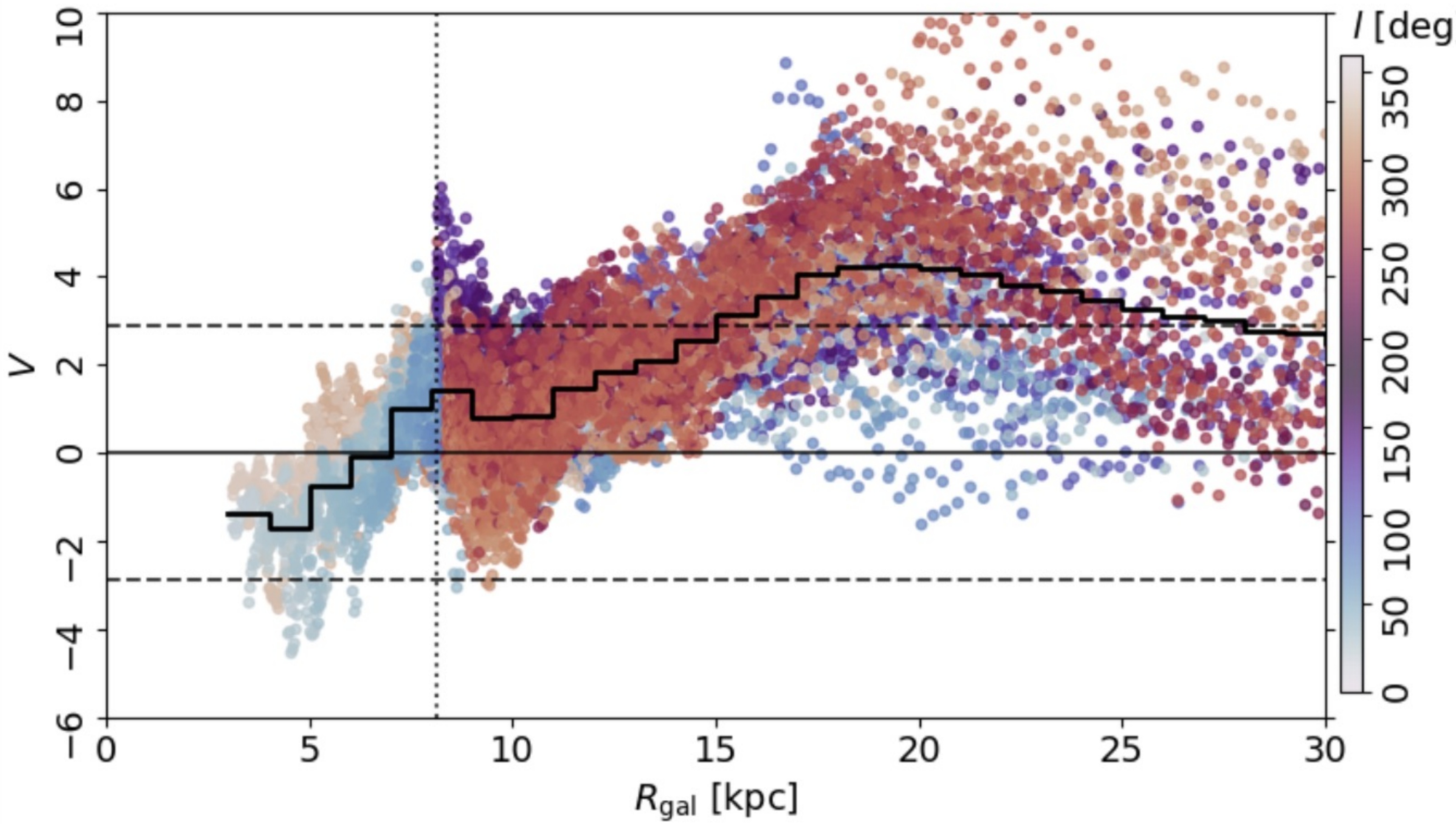
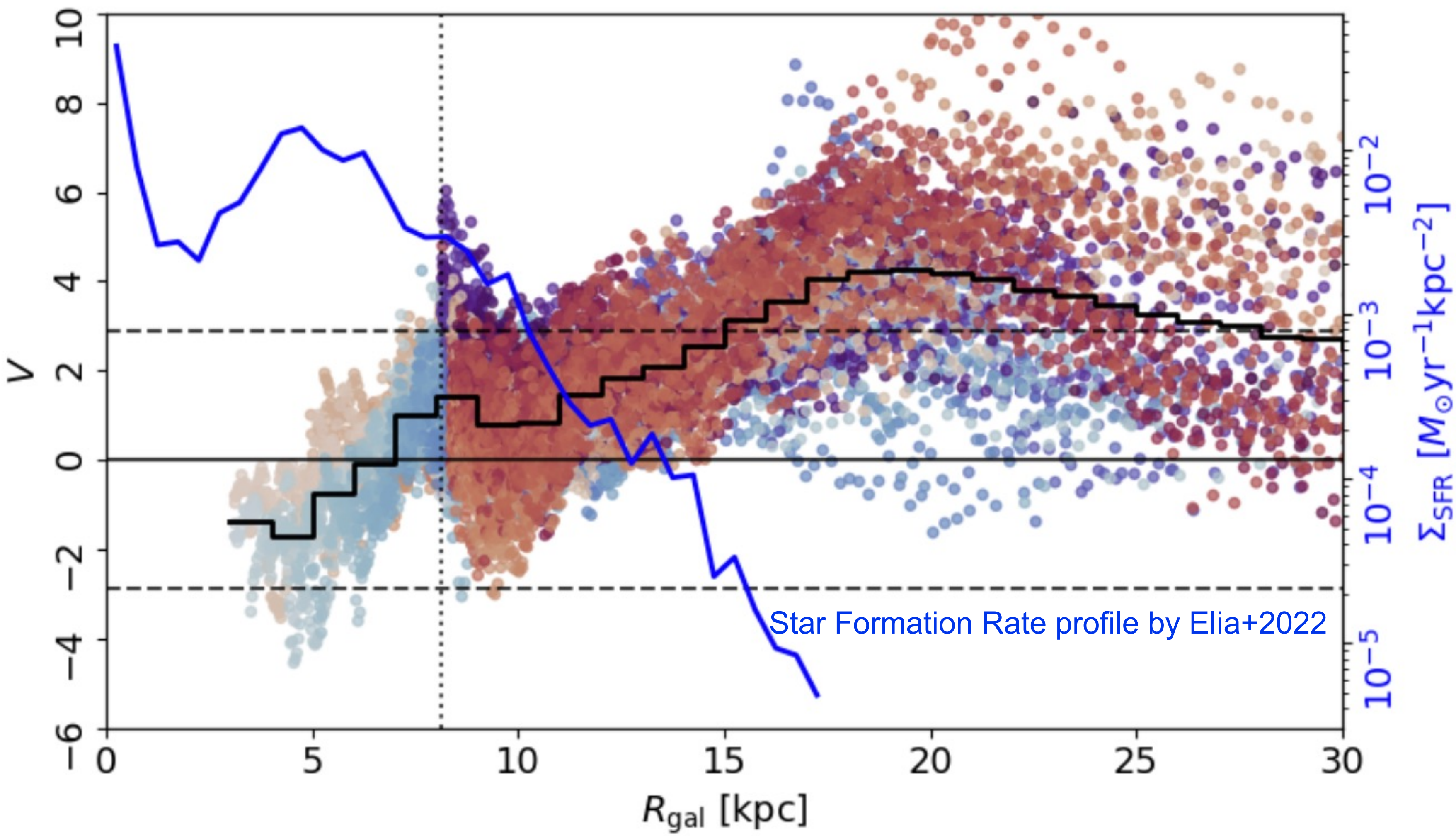


V is the projected Rayleigh statistics, tested for specific orientation angles:

- V>0 → mostly parallel to the Galactic Plane
- V<0 → mostly perpendicular to the Galactic Plane

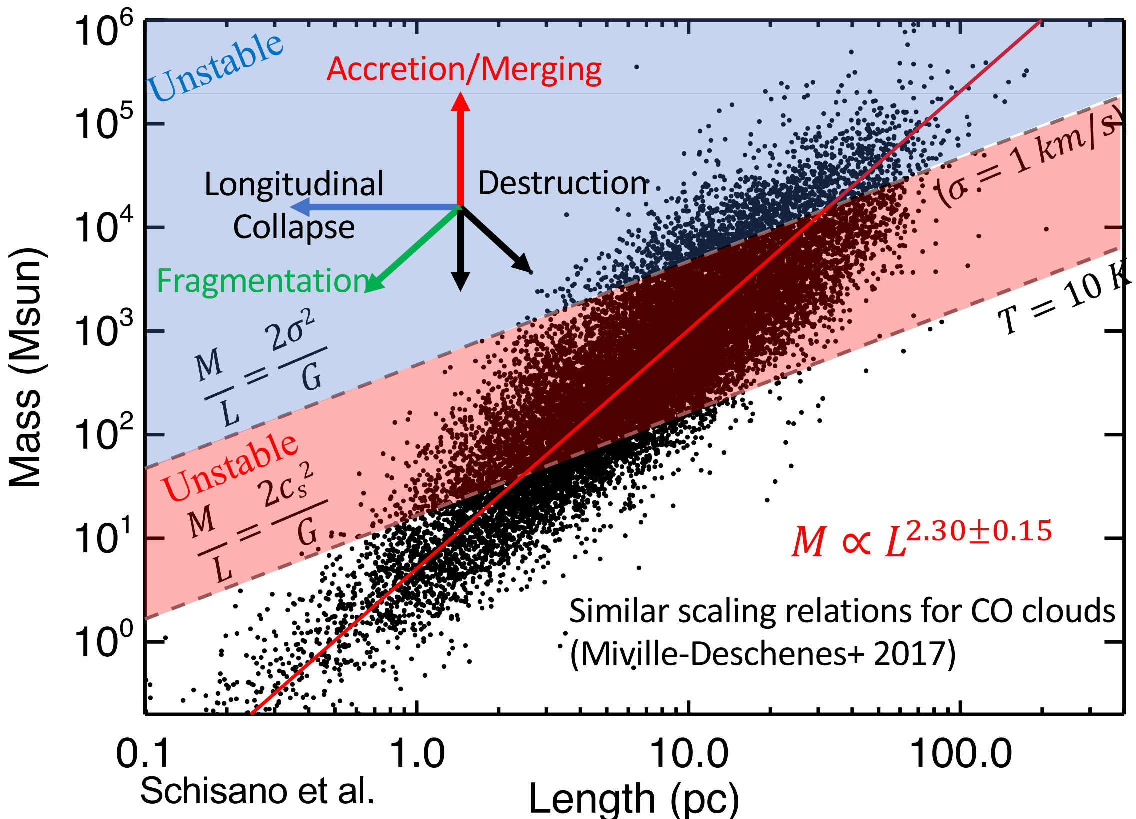
Atomic filament orientation and star formation

Soler, J.D. et al. 2022.

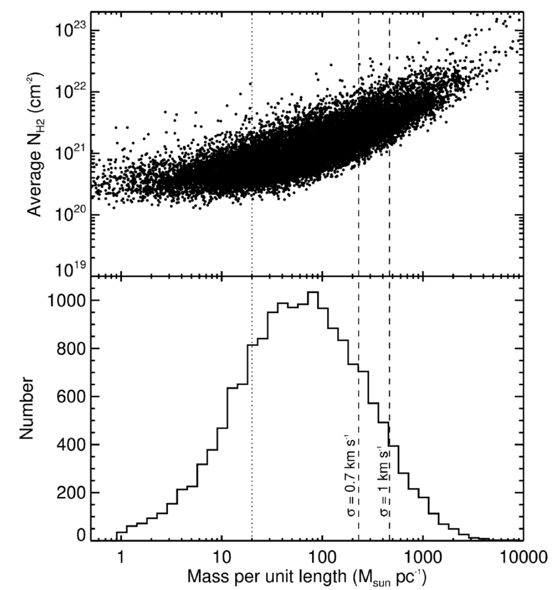


The change in the HI filament orientation is most likely due to the energy and moment input from supernova feedback

Size – Mass relationship of filamentary dust clouds



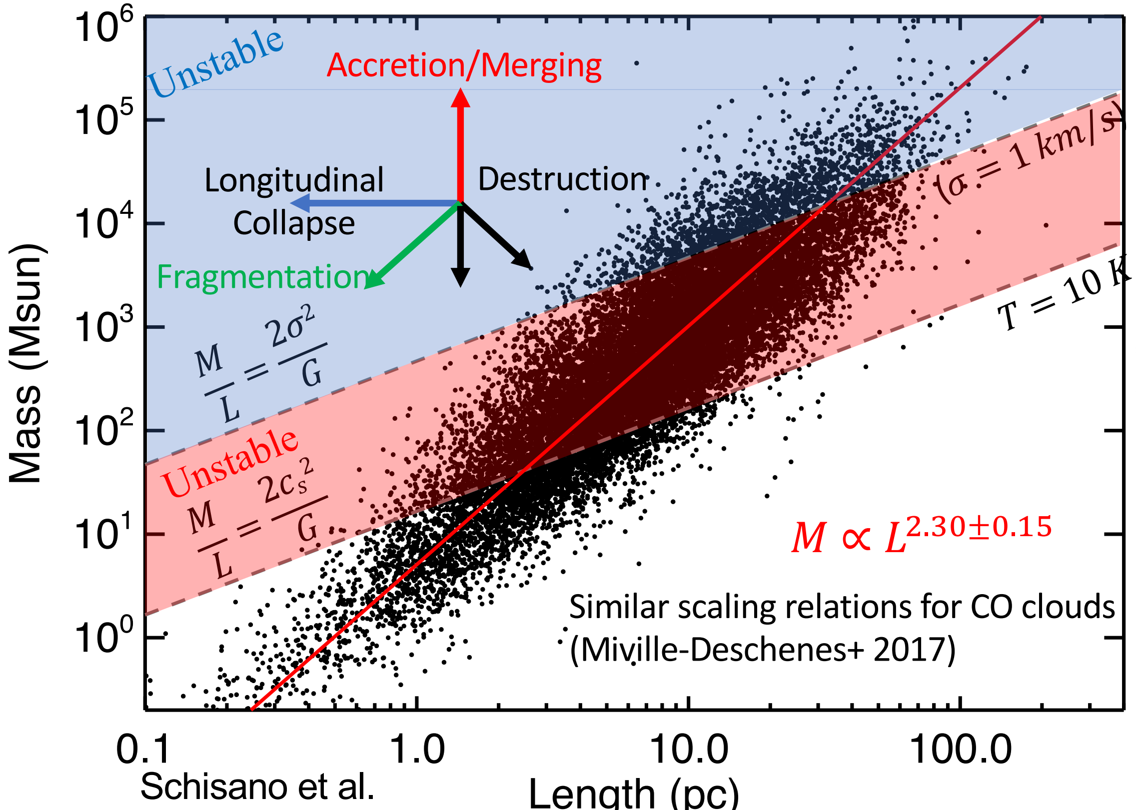
Schisano et al. 2020



Equilibrium configuration for isothermal cylinder with thermal (c_s) and non-thermal (σ^2) support.

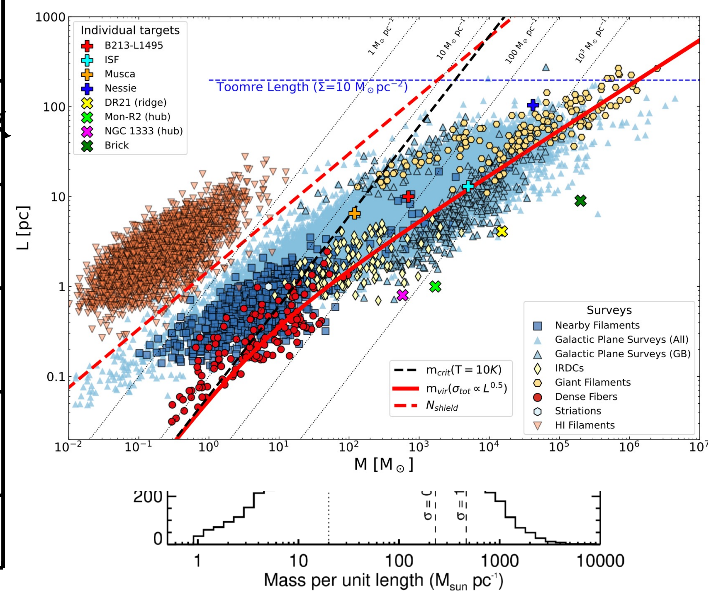
A relatively low ~1 km/s velocity dispersion acting as a turbulent support would be sufficient to stabilize most of the detected structures (if cylinder-like).

Size – Mass relationship of filamentary dust clouds



Schisano et al. 2020

Data discussed in Hacar et al. 2022 PPVII review and compared with other filamentary features.



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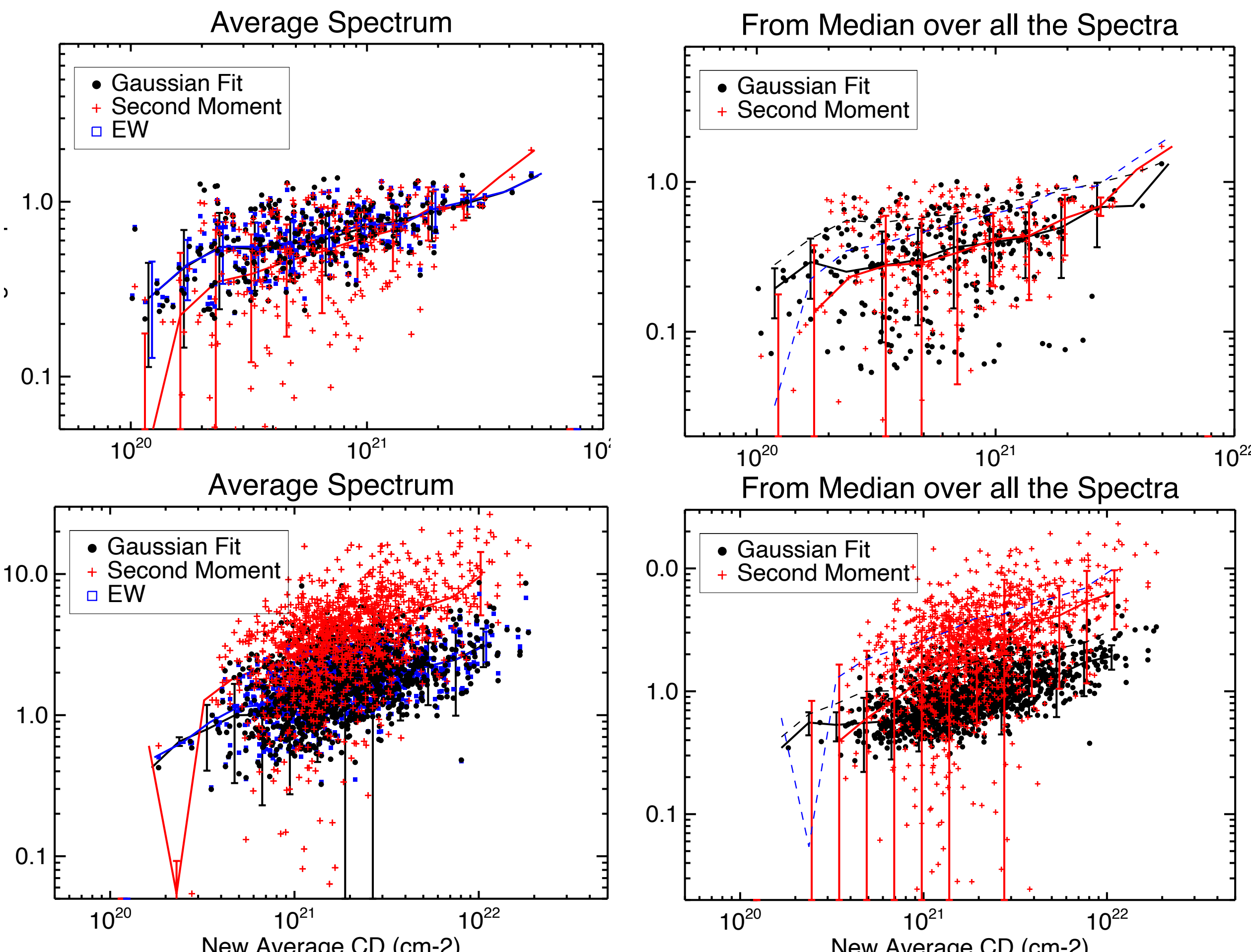
Relation on dynamical state of filamentary clouds



Dust continuum

Top: EOGS survey

Outer Galaxy 140 < l < 194

Bottom: SEDIGISM survey

Inner Galaxy: 350 < l < 300

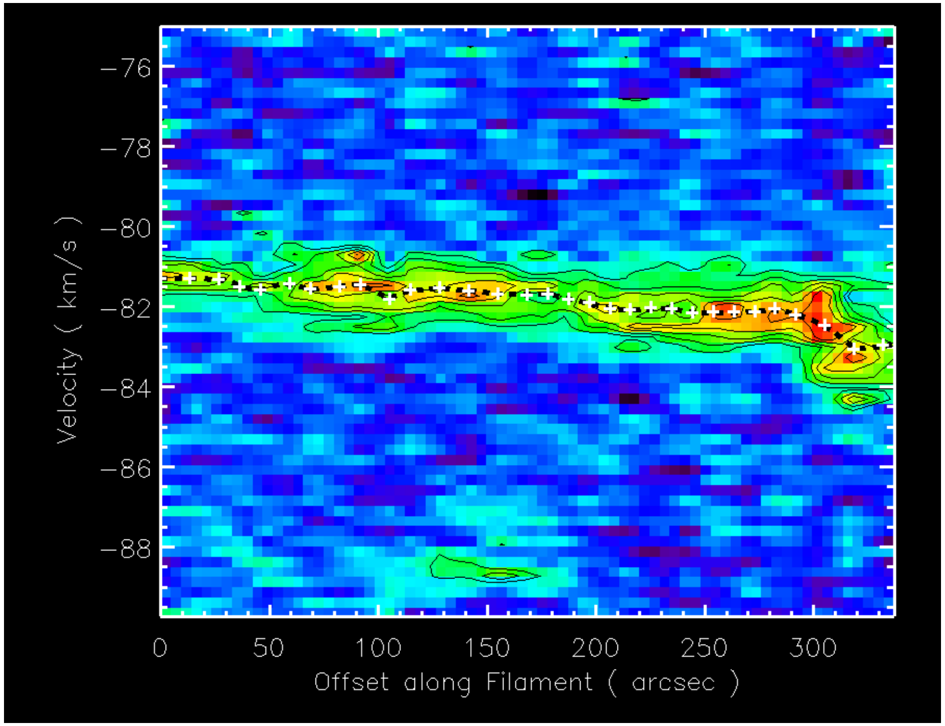
Clouds with the minimum overlap along the line of sight.

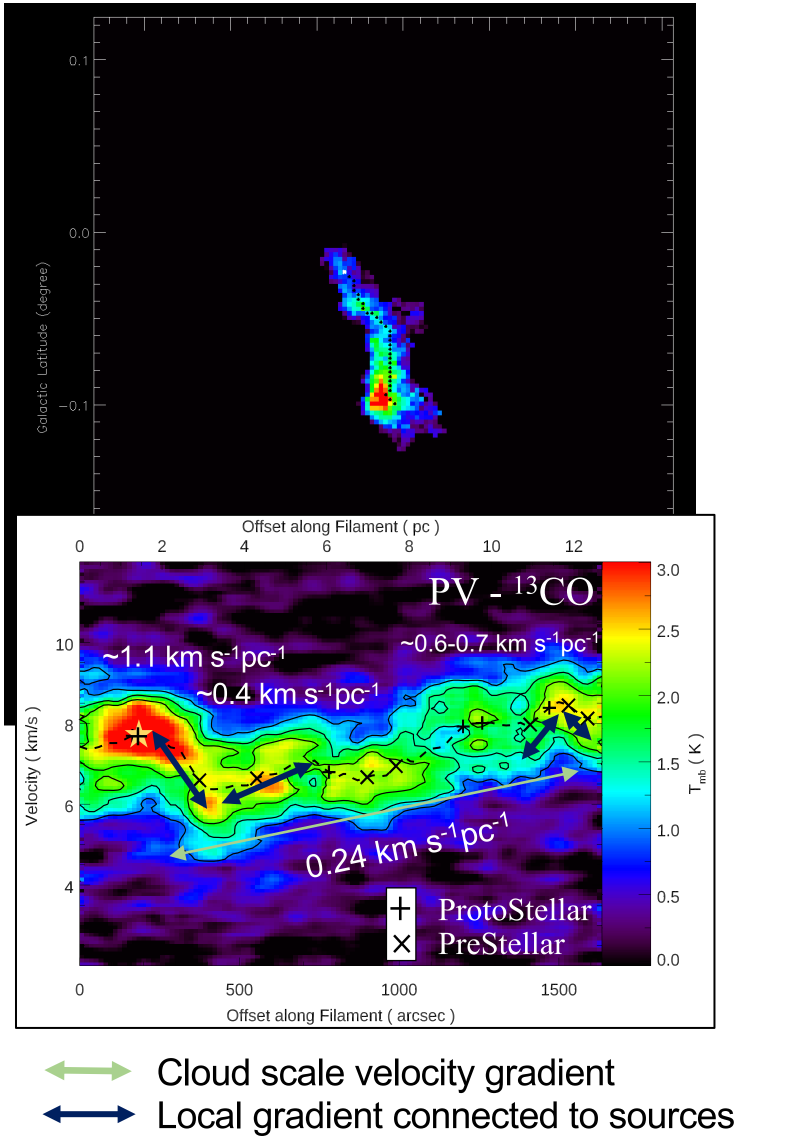
Velocity dispersion σ are between 0.5-3 km/s (cloud stabilization).

They are systematically larger when evaluated over the average spectrum than from statistical analysis of all pixels → hints of shifts of velocity peak over the entire cloud.

Schisano+, in prep.

Investigation of the kinematic in filamentary clouds





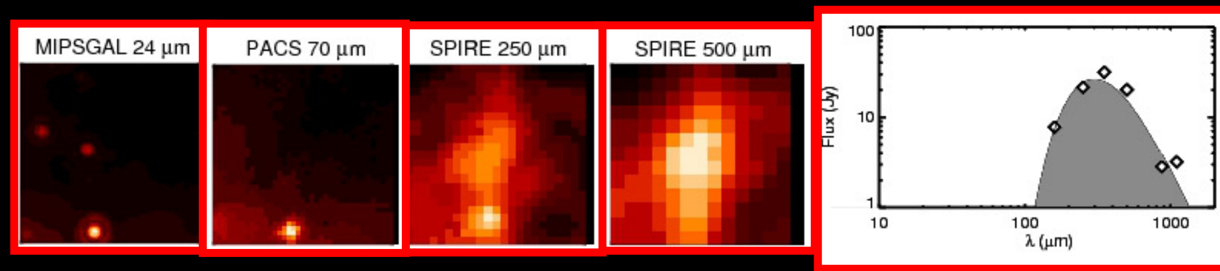
Larger gradiens of several ~ km/s/pc are measured close to compact sources

Systematic study of the velocity shifts on a sample of clouds.

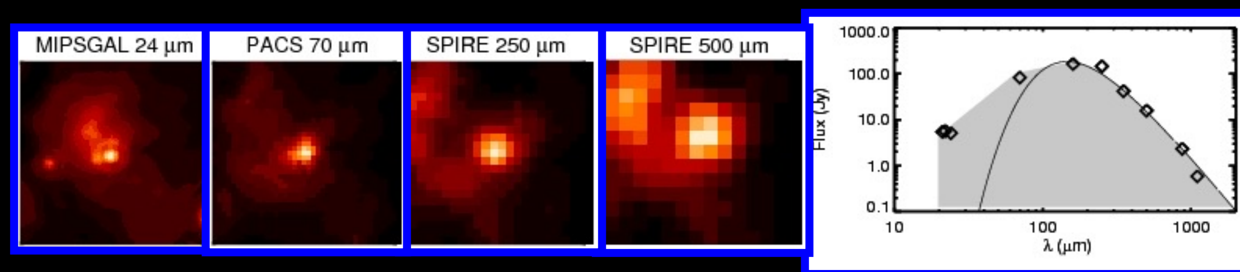
Longitudinal gradients connected to the influence of massive sources, possibly depending on cloud formation or the surrounding environment.

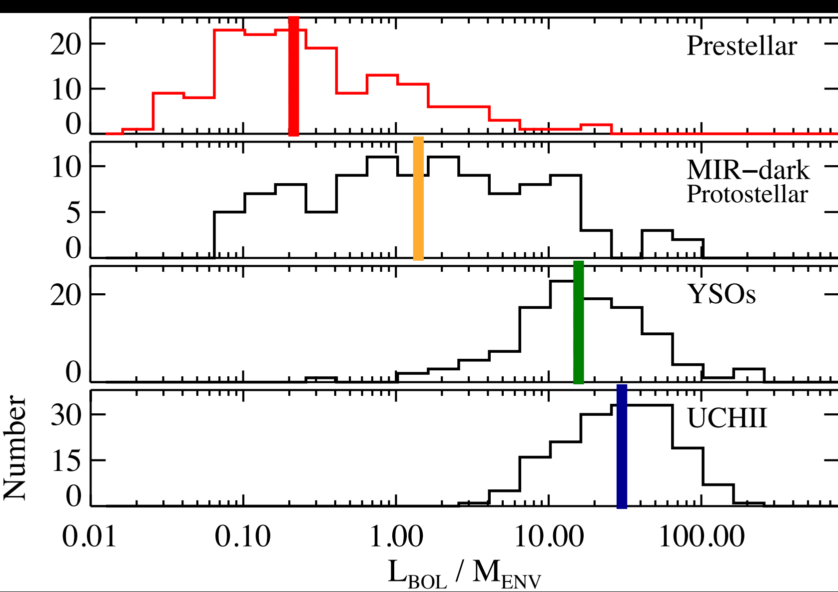
Tracing the evolution of Dense Clumps

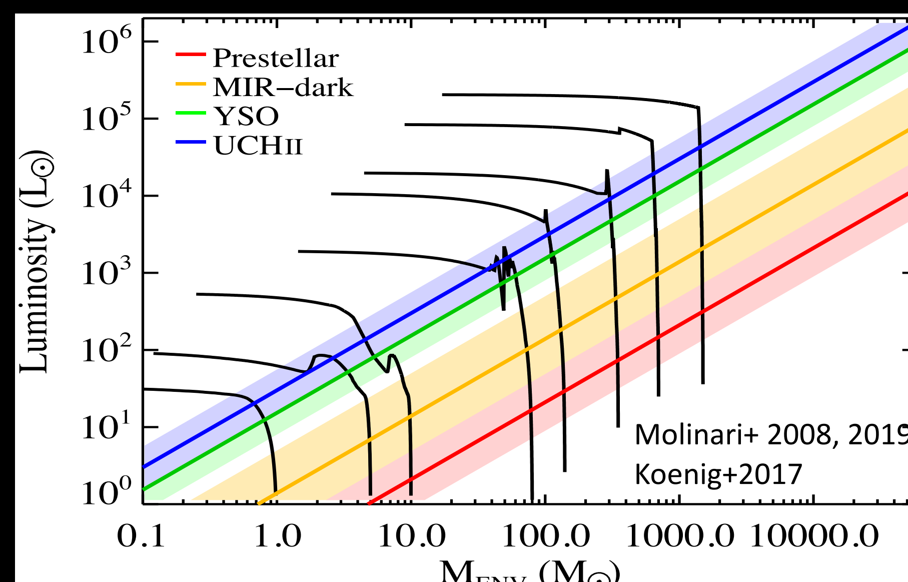
Prestellar



Protostellar







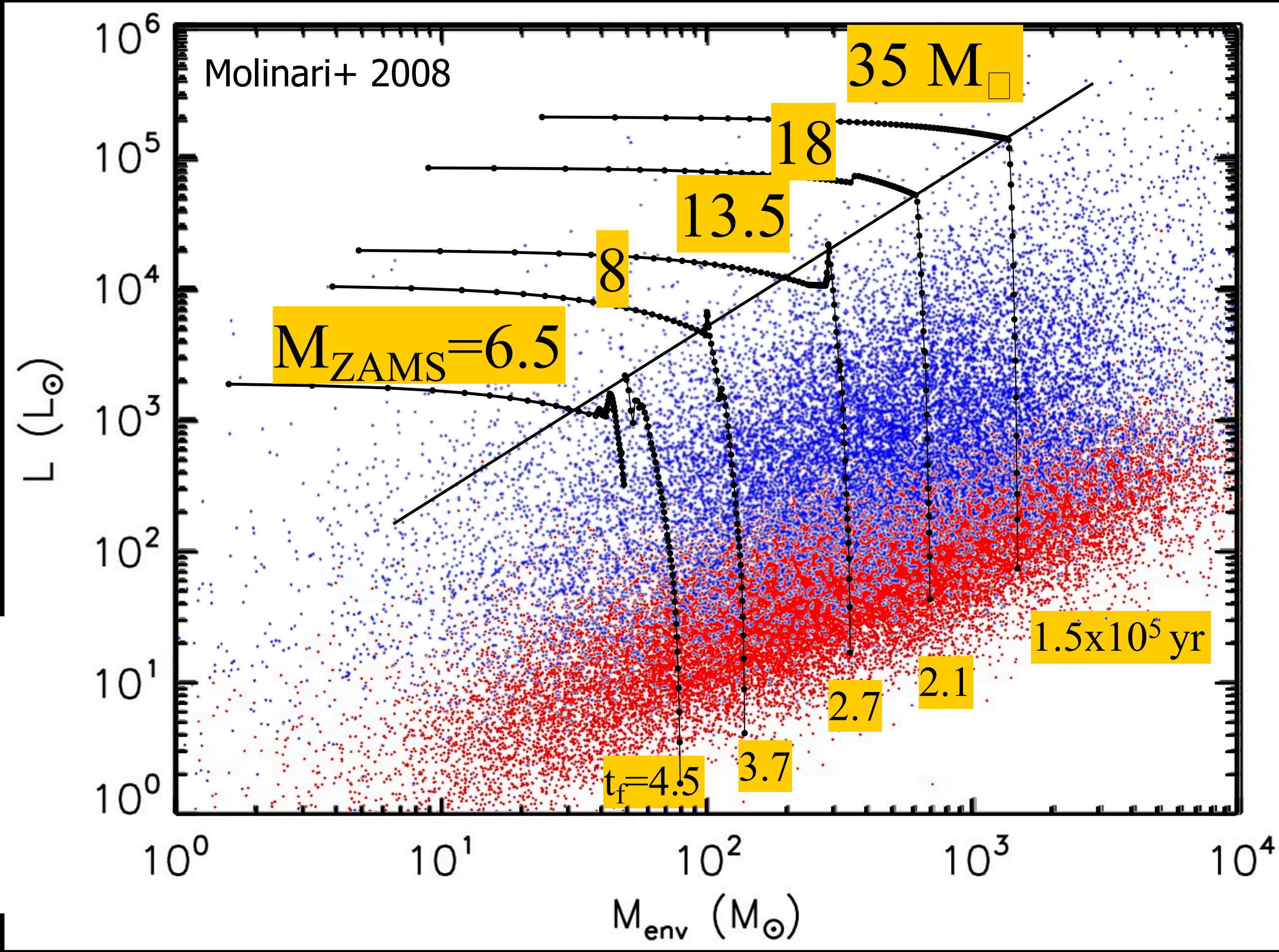
Star Formation Rate from protostellar clumps counts

Comparison of Hi-GAL PROTOSTELLAR clumps statistics in the L_{bol} *vs* M_{env} plot against evolutionary predictions (McKee & Tan 2003, Molinari+2008).

For each clump:
final ZAMS masses M_{ZAMSi}
formation times t_i

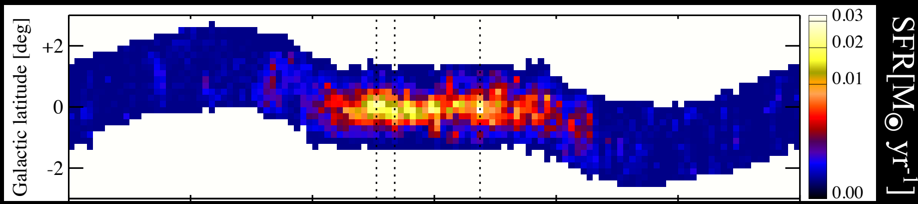
$$SFR_C = \sum_i M_{i,ZAMS} / \tau_i$$

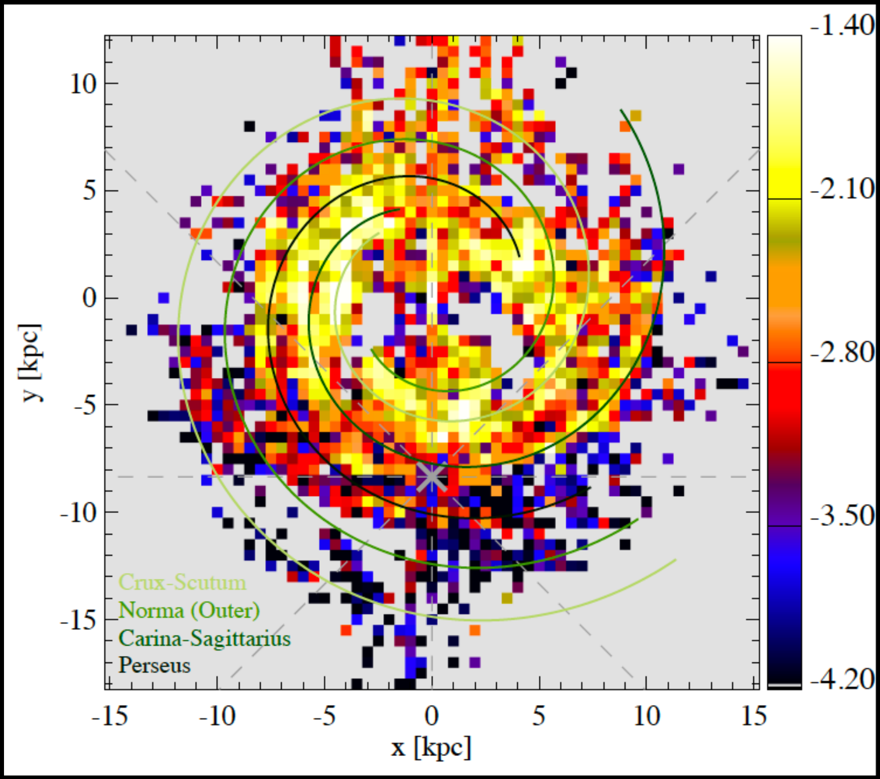
SFR ≈ 2.0 ± 0.7 $M_\odot\ yr^{-1}$
(Elia+2022)

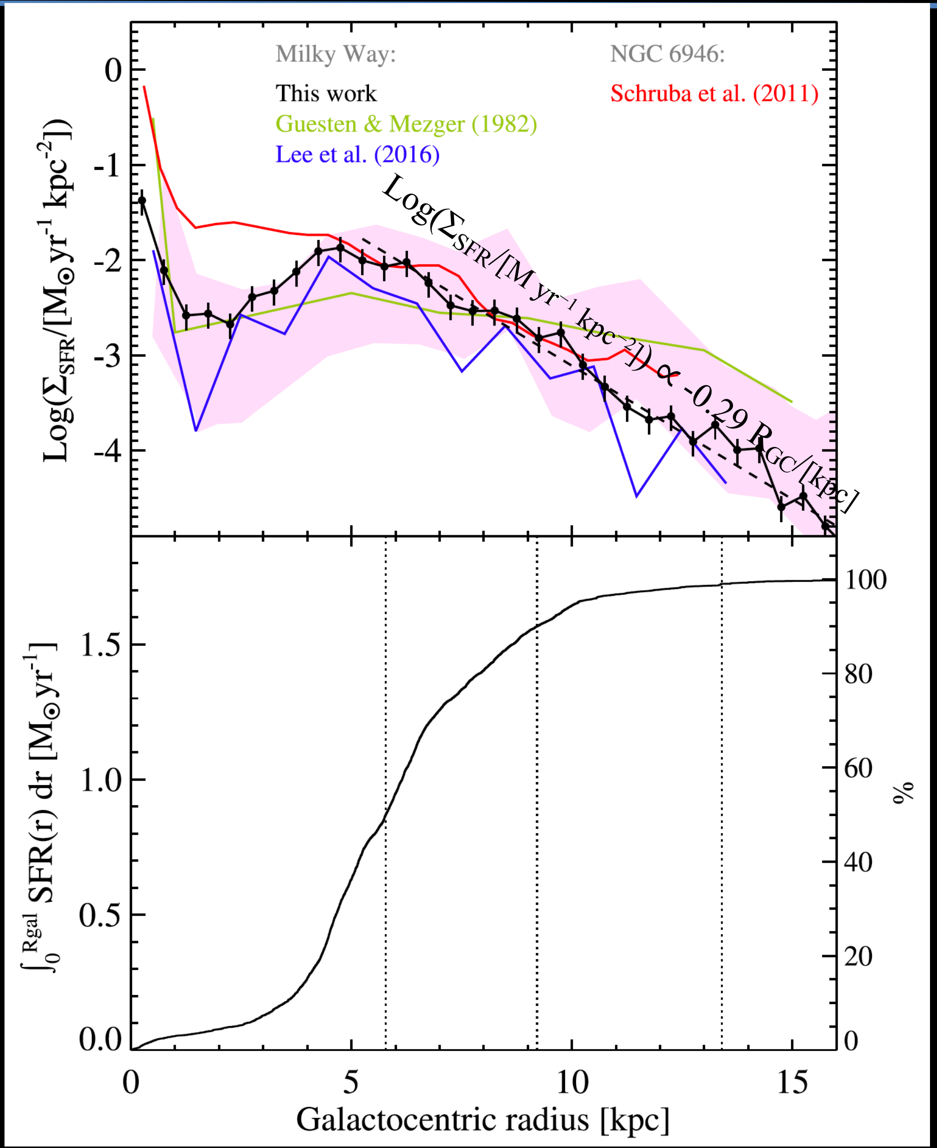


Prescriptions account for cluster formation (Veneziani+2017) and are verified against nearby clouds estimates from direct YSO counts (Baldeschi+2017a,b)

SFR distribution throughout the Galactic plane

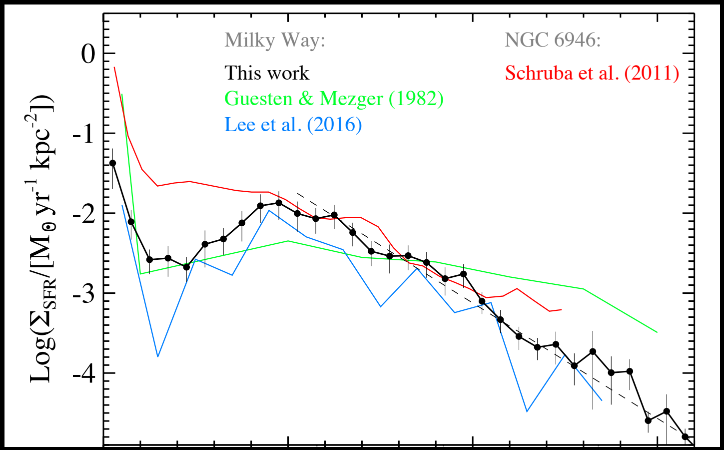


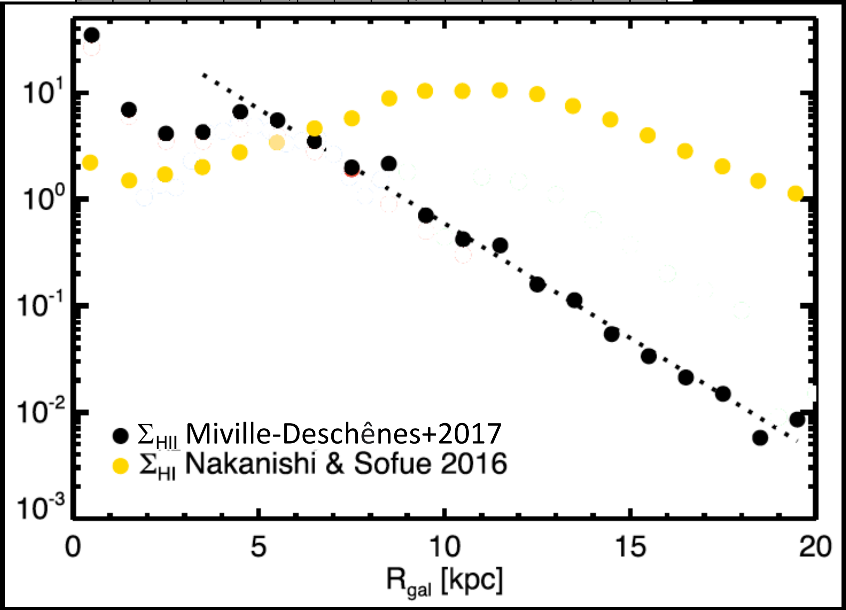




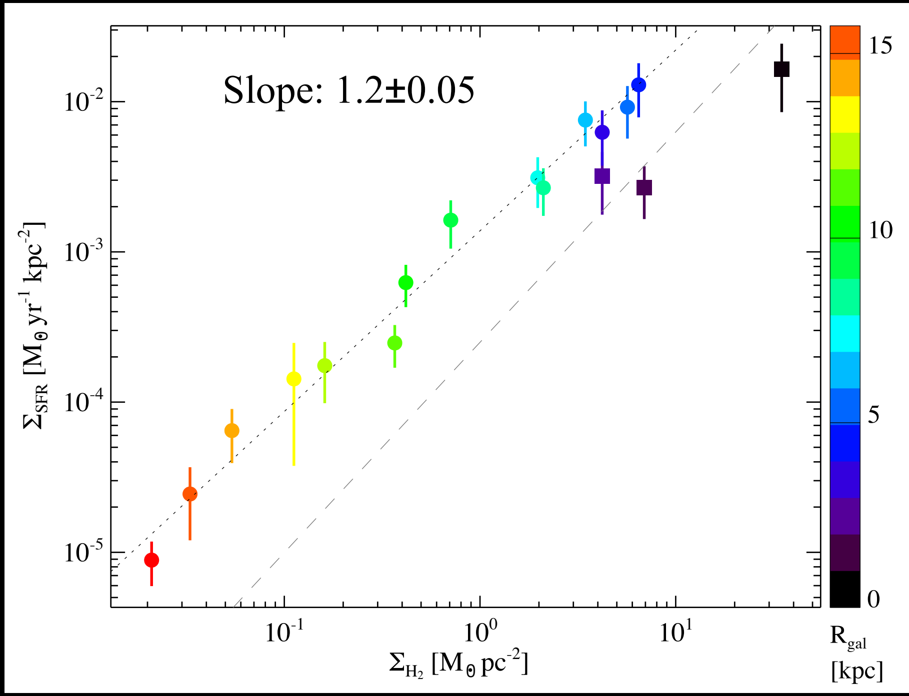
K-S relation for Galactocentric rings

$\Sigma_{SFR} \propto \Sigma_{H_2}{}^{n}$





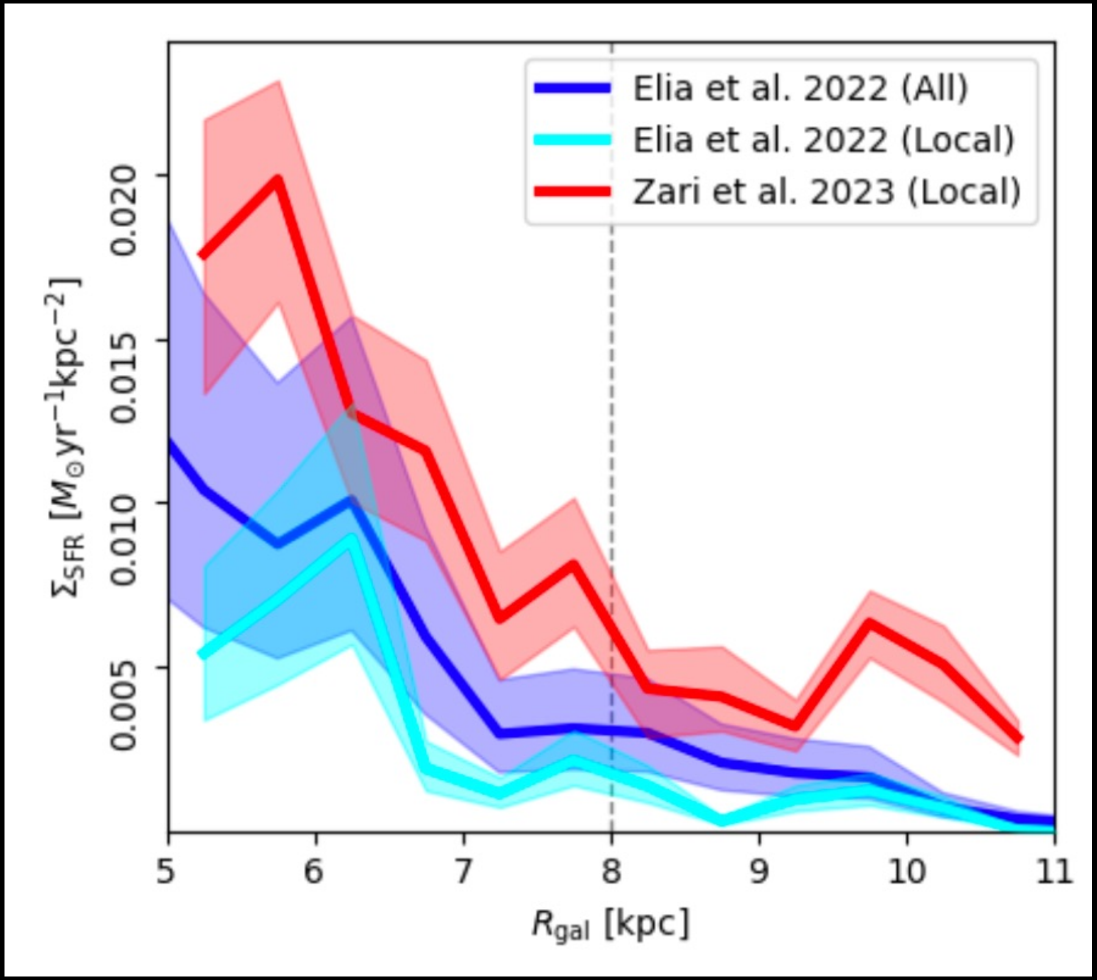
(Elia+2022)



A power-law between Σ_{SFR} and Σ_{HII} is found for R_{GC} > 3 kpc, whereas this doesn't work with Σ_{HI}.

SFR from dense clumps and MS stars

SFR estimated from IMF-weighted star counts matching statistics of O, B and A stars (Gaia & APOGEE) from Zari+2023

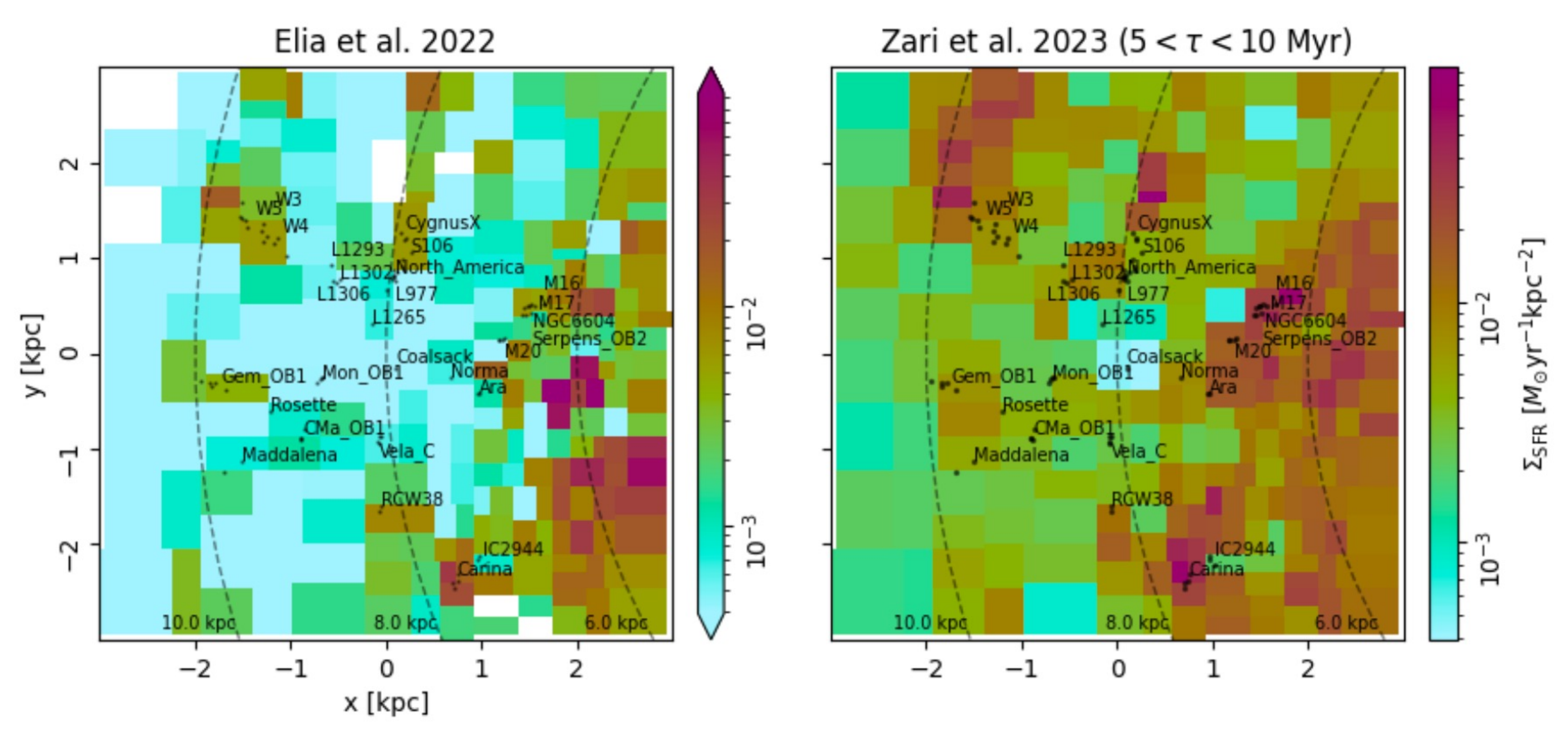


Comparison with the Hi-GAL based result from Elia+2022 shows a factor 2 difference between the two estimates of SFR !!

It is remarkable that two completely independent methods agree so well !!

(Soler+2023, in prep.)

SFR from dense clumps and MS stars

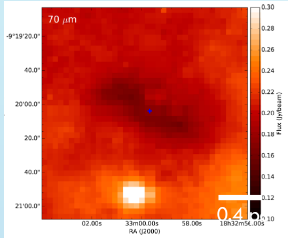


Dense Hi-GAL clumps

O, A, B stars with τ<10Myr

Overall local morphological resemblance between the two tracers is remarkable as well, possibly implying that Star Formation has been going on steadily for the past tens of Myrs. (Soler+2023, in prep.)

The critical role of the environment in the dynamics of gas flowing



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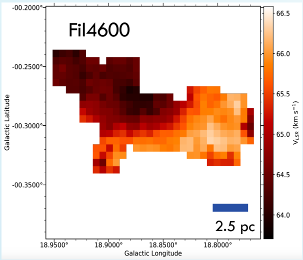

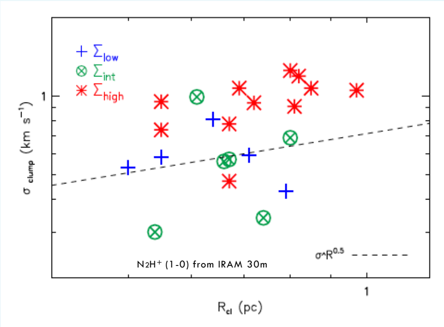

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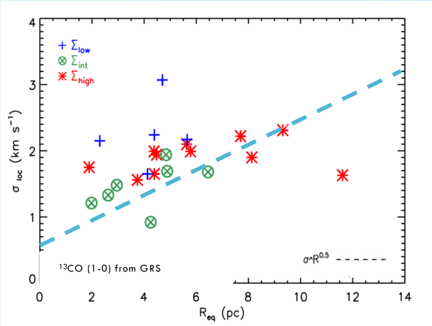
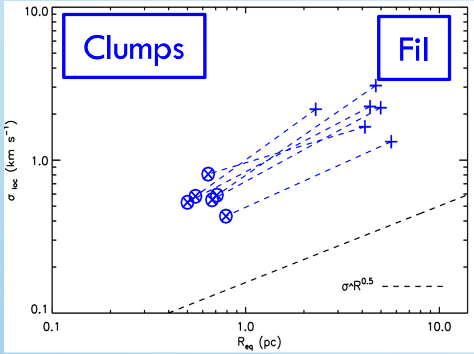
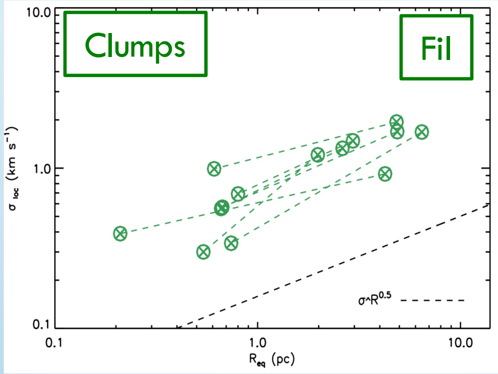
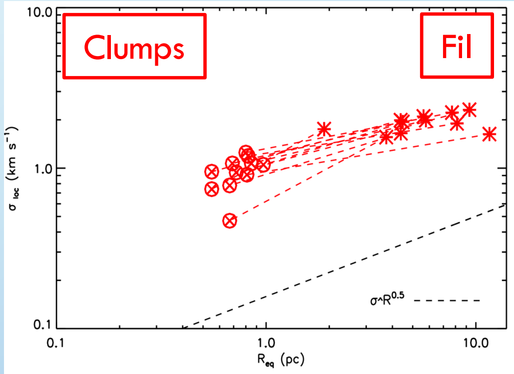




$\sigma \sim R^{0.68}$



$\sigma \sim R^{0.60}$

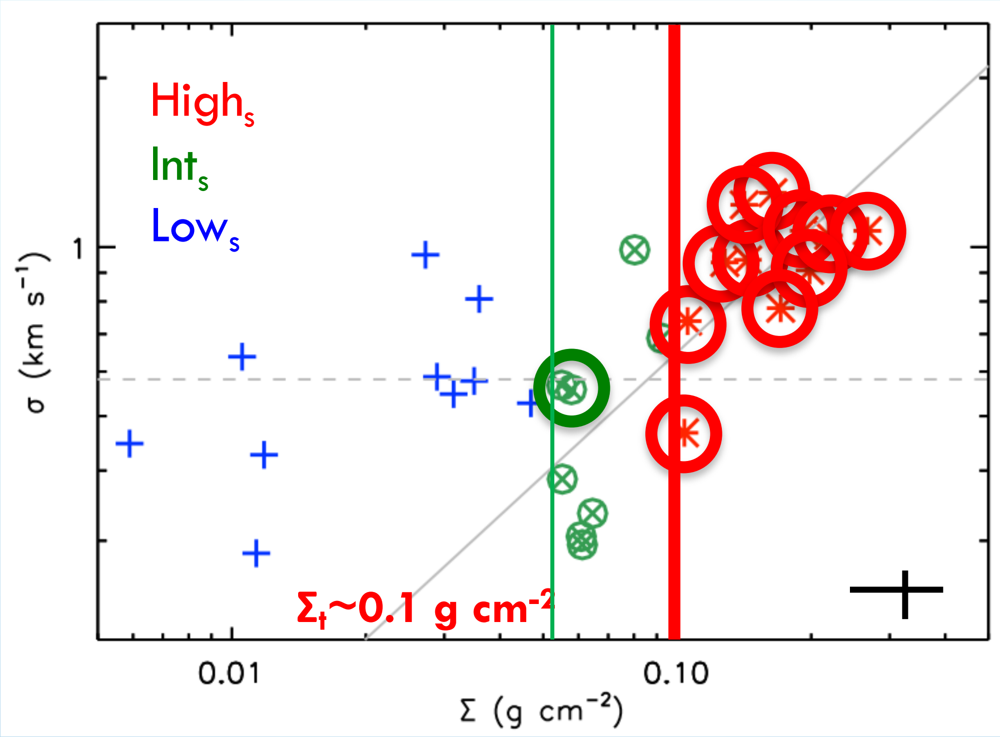


$\sigma \sim R^{0.38}$

$\sigma \sim R^{0.7}$ in Taurus region
Fuller & Myers (1992)

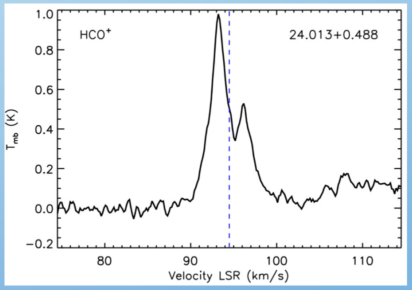
Traficante+2020

The σ vs. Σ relation (clumps only)

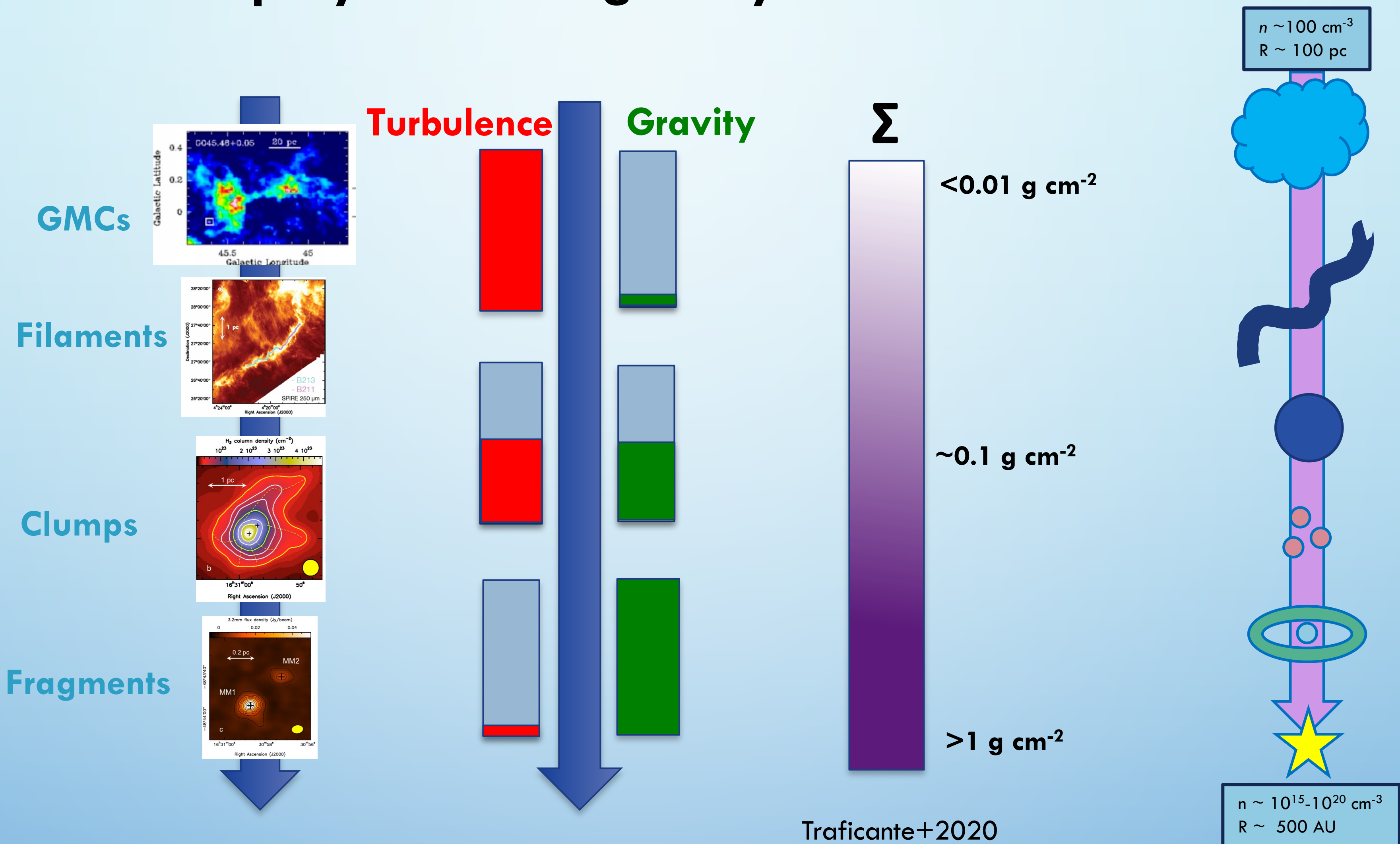


Tan+ 2014
Traficante+ 2018a

Clumps with evidence of dynamical activity and/or gravitationally driven motions (**infall**) at the pc scales (asymmetric HCO^+ spectra)

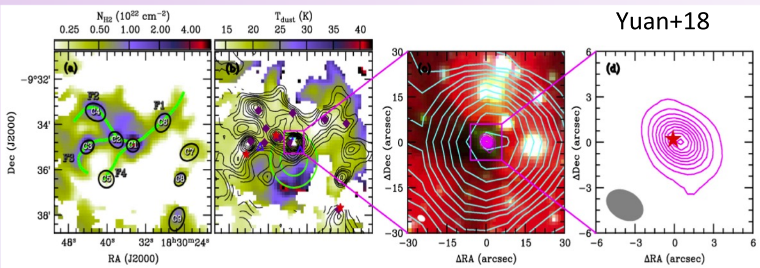


The interplay between gravity and turbulence



What is the (preferred) mechanism to form clusters and high-mass stars?

- The (high-mass) star-formation mechanism is a multi-scale, highly dynamic process



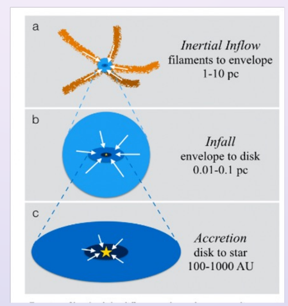
Yuan+18

- The flow of gas and energy from large to small scales **ultimately determine the accretion mechanisms onto the fragments**, e.g.: the separation between fragments could be:

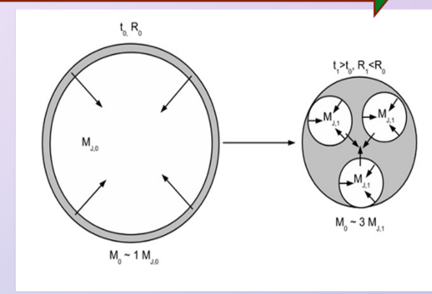
larger than the thermal Jeans length (→support by local turbulence)

compatible with the thermal Jeans length (→ free-falling)

100% turbulence → 100% gravity



Padoan+2020

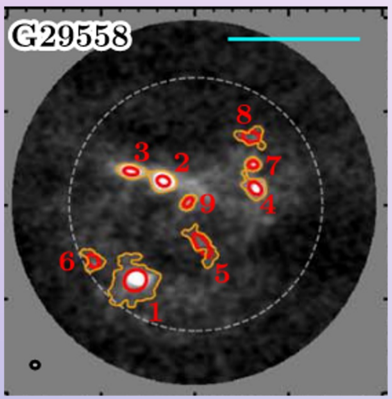

Vazquez-Semadeni+2019

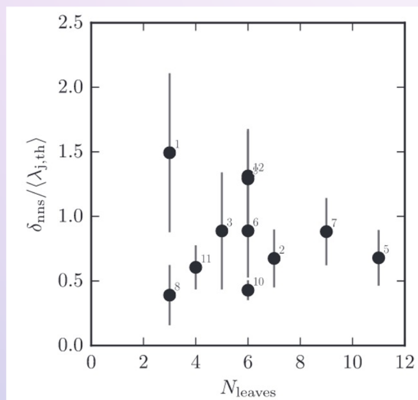
- How many fragments are embedded in each (massive) star-forming clump?
- How are they spatially distributed within each star-forming clump?
- Do all these fragments form simultaneously? How does the fragmentation evolve with time?

The **youngest** phases: 70 µm-quiet clumps (or L/M < 1 Molinari+16): Svoboda+19; Sanhueza+19

Svoboda+19

- 12 massive clumps (400 ≤ M ≤ 4000 $M_{\odot}$)
- Resolution of ≤ 3000 AU

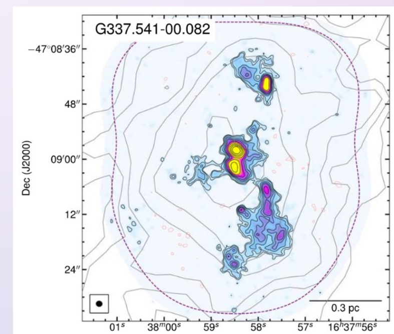


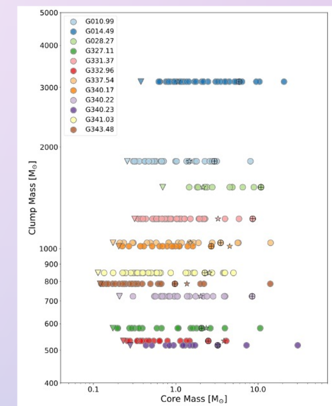


- All BUT 1 clump fragmented with high degree of fragmentation
- Hierarchical fragmentation process with fragments separation ~ thermal Jeans length

ASHES pilot survey - Sanhueza+19

- 12 massive clumps
- Resolution of ≤ 4500 AU

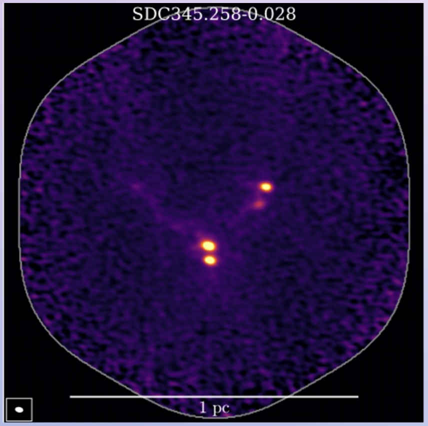


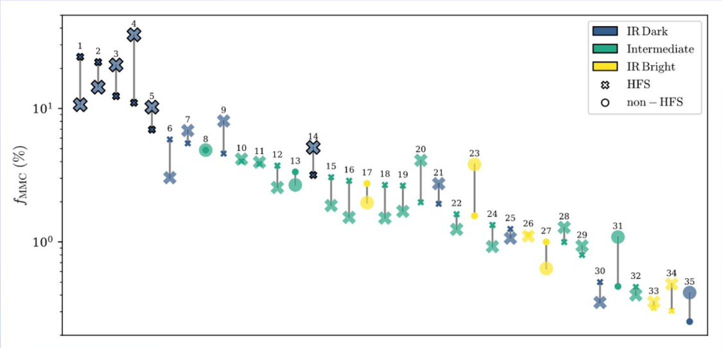


- All clumps show a high degree of fragmentation (13-41 fragments)
- Hierarchical sub-clustering (rather than centrally peaked clustering)
- Fragments separation compatible with thermal Jeans fragmentation
- No correlation between fragment mass and clump mass

Clump-fed fragments in hub-filament systems: Anderson+21

- 6 hub-filament systems in IRDCs ($135 \leq M \leq 3700\ M_\odot$) - combined with the sample of 29 massive clumps of Csengeri+17
- Resolution of ~ 6000 AU
- Core temperature ~15-45 K -> different evolutionary stages

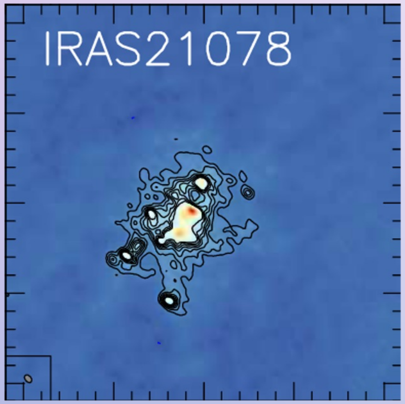


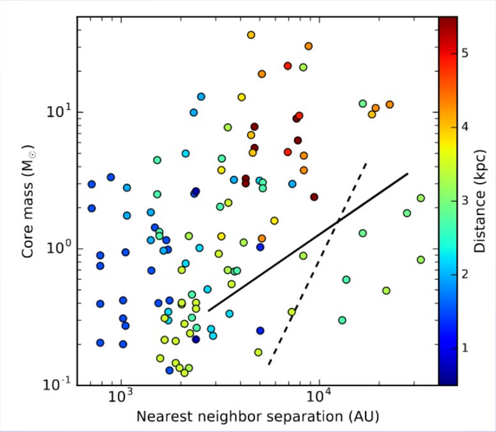


- Clumps show various degree of fragmentation
- Evidence of clump-fed systems
- The most massive fragment has already gathered a large percentage of the clump mass during the very early stages of evolution

Fragmentation in evolved high-mass star formation: the CORE NOEMA large survey (Beuther+18)

- 20 high-mass star-forming regions ($40 \leq M \leq 6200\ M_{\odot}$) all with $L > 10^4\ L_{\odot}$
- Resolution of ~ 1000 AU

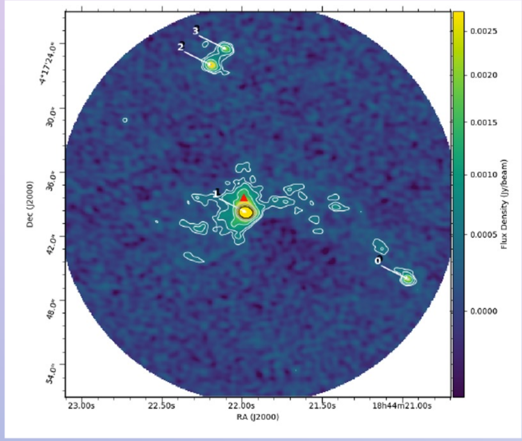


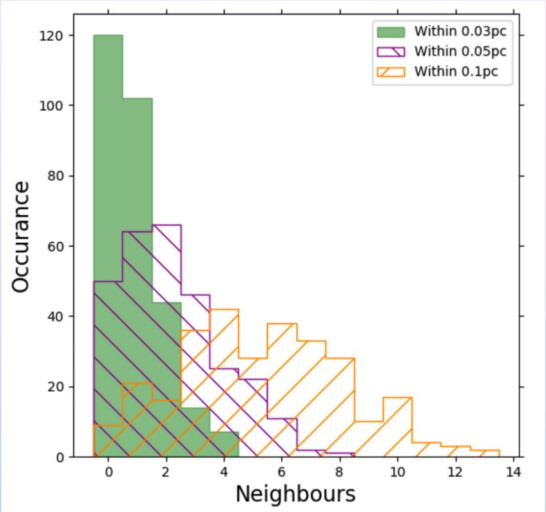


- A large variety of fragmentation properties: from single cores up to ~20 fragments
- Distance between fragments compatible with thermal Jeans fragmentation (or even smaller)
- Distance between fragments independent of core masses

Fragmentation in luminous high-mass star formation: the TEMPO survey (Avison+22, in prep.)

- 38 high-mass star-forming regions ($135 \leq M \leq 3700\ M_{\odot}$) with $L > 10^3\ L_{\odot}$ and $0.4 \leq L/M \leq 2600\ L_{\odot}$
- Clumps span evolutionary phases from 22µm-quiet to 70µm/22µm ~ 1
- Resolution of ~ 3500 AU

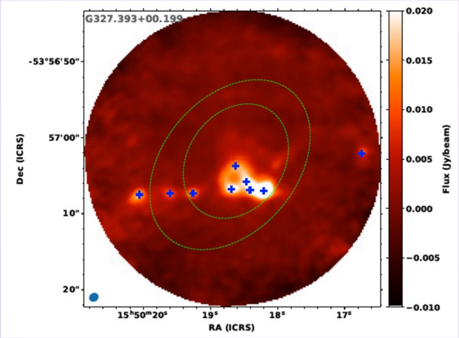


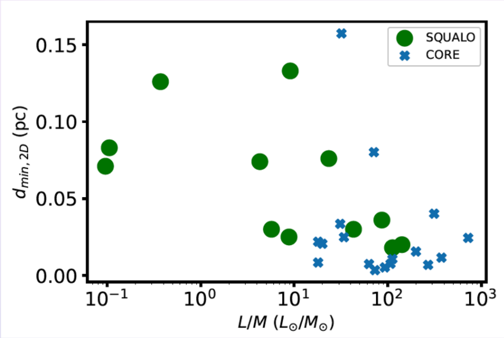


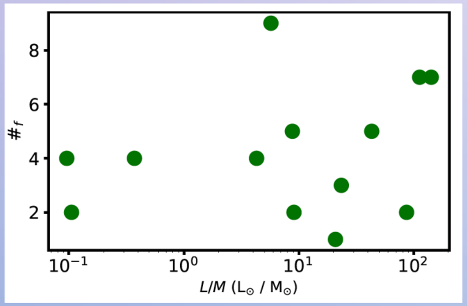
- All clumps are fragmented: 3-13 fragments in each object
- Distance between fragments compatible with thermal Jeans fragmentation in 60% of the objects
- For ~15 clumps fragmentation scales either $<0.5\ \lambda_J$ or $>1.5\ \lambda_J$

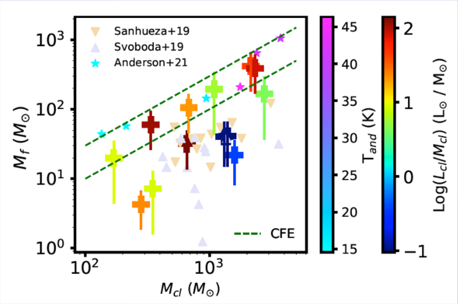
The evolution of fragments with time ($0.1 \leq L/M < 150$) in globally-collapsing clumps: SQUALO (Traficante+22, subm.)

- 13 massive clumps ($170 \leq M \leq 2800\ M_{\odot}$)
- All clumps have signatures of global collapse at ~1pc scale and at various evolutionary stages (Traficante+18a, b)
- Resolution of ~ 4000 AU







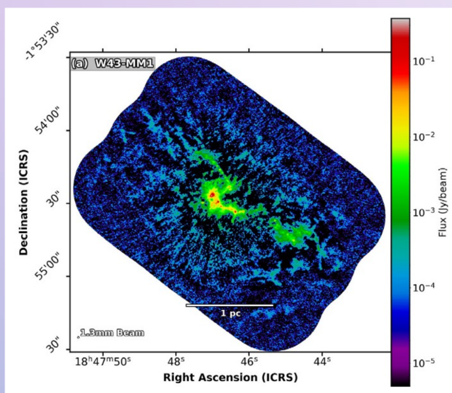


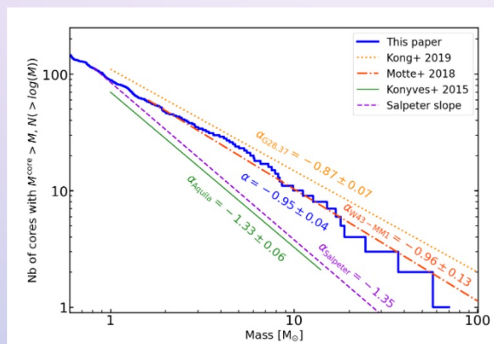
- All BUT 1 clump fragmented with various degree of fragmentation, independently from the evolutionary phase
- The minimum distance between fragments decreases with evolution
- Total mass of fragments is higher in more massive clumps

The next step: ALMA large programs (ALMA-IMF & ALMAGAL)

ALMA-IMF: Investigating the origin of stellar masses (Motte+2022)

- 15 extreme protoclusters (2500 ≤ M ≤ 33000 $M_\odot$) mapped at 1mm and 3mm, including e.g. the W43 mini-starbust complex
- Sensitivity down to ~0.5 $M_\odot$ and spatial resolution of ~2000 AU





FIRST RESULTS

- ~700 cores with masses 0.15 ≤ M ≤ 250 $M_\odot$ (Motte+22; Ginsburg+22)
- evidence of top-heavy core mass function in W43-MM2/MM3 (Pouteau+22)
- Similar chemical composition and excitation of most of the COMs in W43-MM1 hot cores (Brouillet+22)

and **ALMAGAL...**

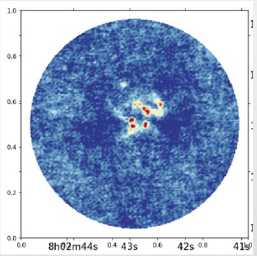
ALMAGAL: ALMA Large project

The first **statistically significant and complete survey** of massive star-forming clumps in our Galaxy

Q1: **What are the physical processes governing the fragmentation of cluster forming clumps, and how do they evolve with time?**

- Mass distribution
- Mass segregation
- Fragmentation properties

Dust continuum

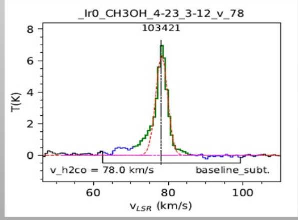


Q2: **How do high-mass cluster-forming cores gain mass? How is this influenced by internal feedback from cores into clump gas?**

- Core kinematics
- Outflows
- Clumps-cores gas dynamics

Line analysis

(+continuum)

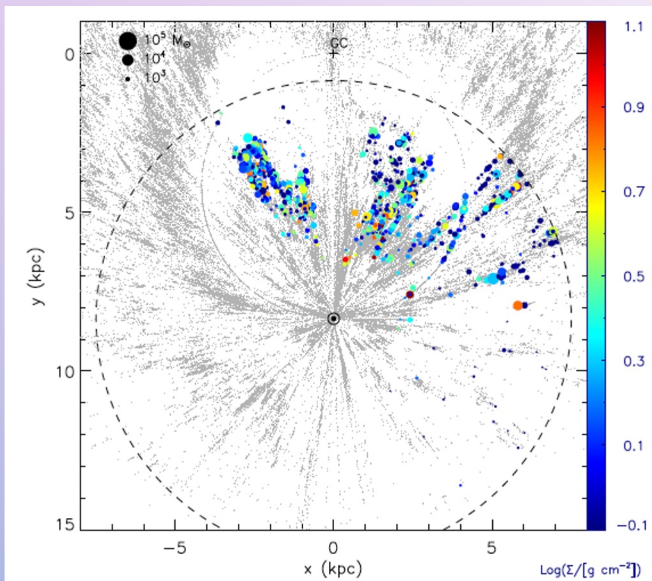


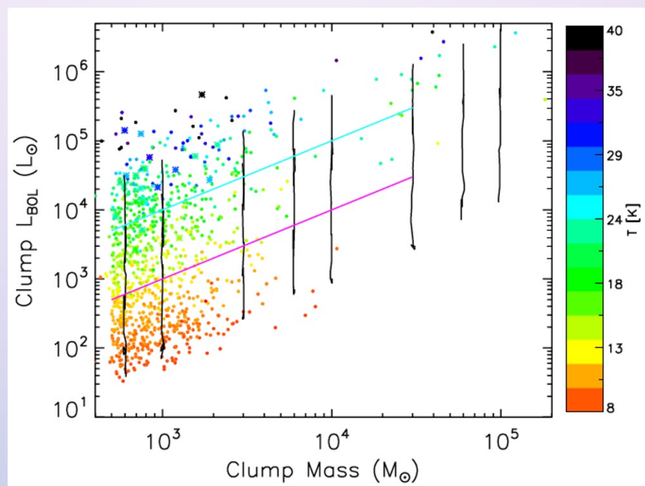
From the ALMAGAL proposal

ALMAGAL: ALMA Large project

The first **statistically significant and complete survey** of massive star-forming clumps in our Galaxy

1017 clumps ALMA Band 6
(1.3mm)





Modified from Elia+17, 21

$\mathbf{\Sigma} \geq 0.1$ g cm^{-2}
M ≥ 500 M $_\odot$
d $\lesssim 7.5$ kpc
$\boldsymbol{\delta} < 20°$

$10^{-2} \lesssim$ **L/M** $\lesssim 10^3$ $L_\odot/M_\odot$

from the near Tip of the Galactic Bar to the third quadrant **the sample is complete for the selection criteria**

ALMAGAL: ALMA Large project

The first **statistically significant and complete survey** of massive star-forming clumps across the Galactic disk

1017 clumps

Band 6

(1.3mm)

- **538 NEAR** sample ($d \leq 4.5$ kpc) - (ACA-7M + C-2 + C-5)
- **479 FAR** sample ($4.5 < d < 7.5$ kpc) - (ACA-7M + C-3 + C-6)

88 h

ACA 7M: ~10'' HPBW: 45.8''

Up to **1.6 pc** @ d=7.5 kpc

118 h

- **TM2** (C-2 / C-3) : 1.2''/0.6''
- **TM1** (C-5 / C-6) : 0.3''/0.15''

1000 AU spatial res.

0.3 $M_\odot$ mass limit

for the whole sample

Spectral windows: 4 units

spw 0: centered at 217.925 GHz, bandwidth 1875 MHz at 1.3 km/s
spw 1: centered at 220.000 GHz, bandwidth 1875 MHz at 1.3 km/s
spw 2: centered at 218.300 GHz, bandwidth 468 MHz at 0.3 km/s
spw 3: centered at 220.600 GHz, bandwidth 468 MHz at 0.3 km/s

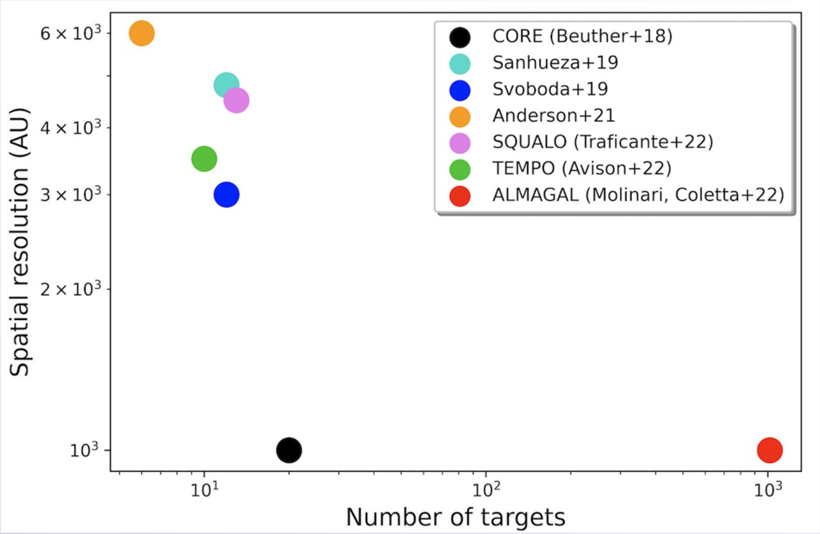
Main species covered:

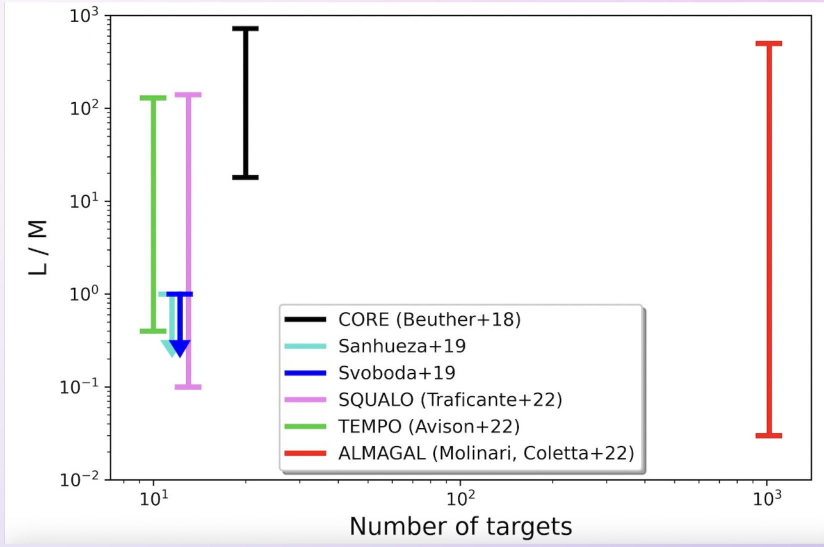
spw 0: SiO, DCN, H_2CO, c-C_3H_2
spw 1: SO_2, $C^{18}O$, HNCO, SO, ^{13}CO, CH_3CN, $CH_3{}^{13}CN$
spw 2: H_2CO
spw 3: ^{13}CO, CH_3CN, $CH_3{}^{13}CN$, HNCO

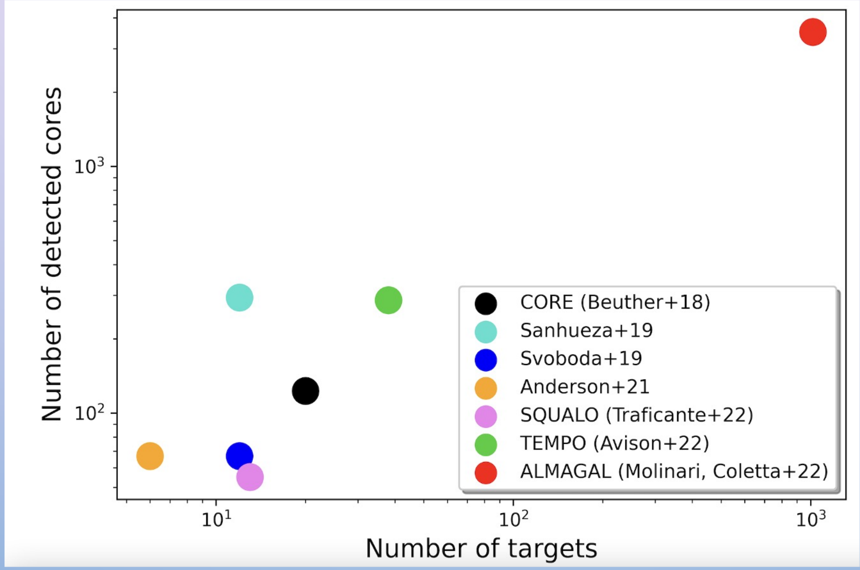
In addition to several, CH_3OH, CH_3CHO, CH_3OCH_3, CH_2CHCN, CH_3CH_2CN transitions

Credits: A. Sanchez-Monge

ALMAGAL in its ecosystem

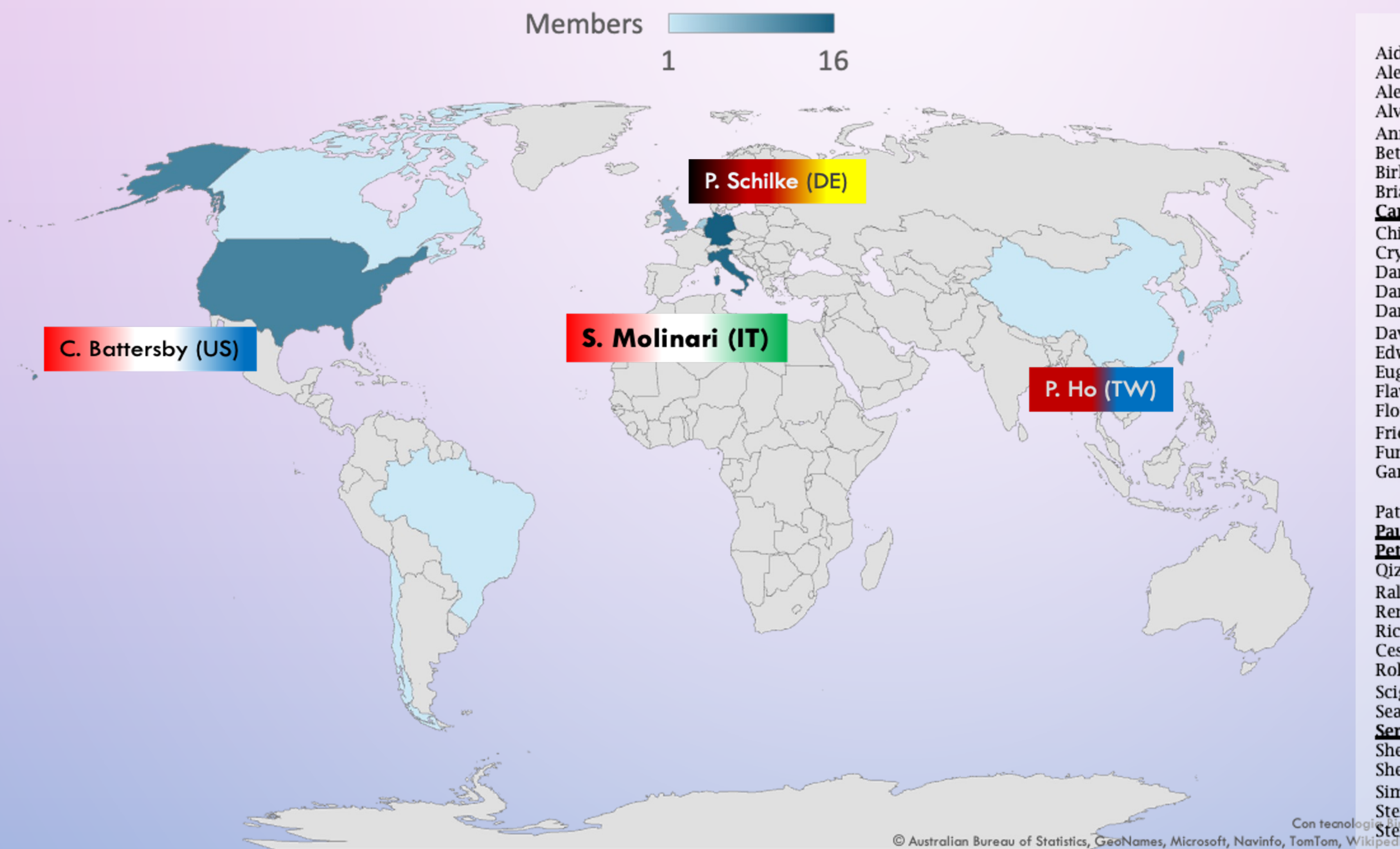






ALMAGAL: a team effort

12 countries 4 PIs ~73 team members



Aida Ahmadi
Alessandro Coletta
Alessio Traficante
Alvaro Sanchez-Monge
Anna Di Giorgio
Beth Jones
Birka Zimmermann
Brian Svoboda
Cara Battersby
Chiara Mininni
Crystal Brogan
Daniel Seifried
Daniel Walker
Darek Lis
Davide Elia
Edwin Bergin
Eugenio Schisano
Flavia Amaral
Floris van der Tak
Friedrich Wyrowski
Fumitaka Nakamura
Gary Fuller

H Perry Hatchfield
Hans Zinnecker
Henrik Beuther
Jennifer Wallace
John Bally
Kahmin Goh
Katharine Johnston
Kazi Rygl
Kee-Tae Kim
Leonardo Bronfman
Leonardo Testi
Luca Moscadelli
Luke Maud
Maite Beltrán
Manuel Merello
Melvin Hoare
Michihiro Takami
Milena Benedettini
Nicolas Peretto
Pamela Klaassen
Patricio Sanhueza

Patrick Koch
Paul Ho
Peter Schilke
Qizhou Zhang
Ralf Klessen
René Plume
Riccardo
Cesaroni
Rolf Kuiper
Scige Liu
Seamus Clarke
Sergio Molinari
Sheng-Li Qin
Sheng-Yuan Liu
Simon Glover
Stefano Pezzuto
Steffi Walch

Tianwei Zhang
Tie Liu
Todd Hunter
Veena VS
Vivien Chen
Ya-Wen Tang
Yanett Contreras
Yi-Jehng Kuan
Yu-Nung Su
Yue Cao
Stuart Lumsden
Sümeyye Suri
Susanne Pfalzner
Thomas Henning
Thomas Möller

ALMAGAL: the data reduction challenge

IAPS – INAF (IT)

OATS – INAF (IT)

U. of Manchester (UK)

Leiden Obs. (NE)

Data Processing Nodes

U. of Cologne (DE)

MPIA Heidelberg (DE)

ASIAA Taipei (TW)

For **each source** we will start having:

- 4 cubes for C-5 or C-6 (extended 12M) 1024 x 1024 x 3840 pixels
- 4 cubes for C-2 or C-3 (compact 12M) 1024 x 1024 x 3840 pixels
- 4 cubes for ACA-7M 1024 x 1024 x 3840 pixels

… plus the same amount of files for the continuum (and line-cube only)

After **combination**, we may end (for each sources) with:

- 4 cubes for C-2+C-5 or C-3+C-6 (12M) 1024 x 1024 x 3840 pixels
- 4 cubes for ACA-7M 1024 x 1024 x 3840 pixels
- 4 cubes for 7M+12M 1024 x 1024 x 3840 pixels

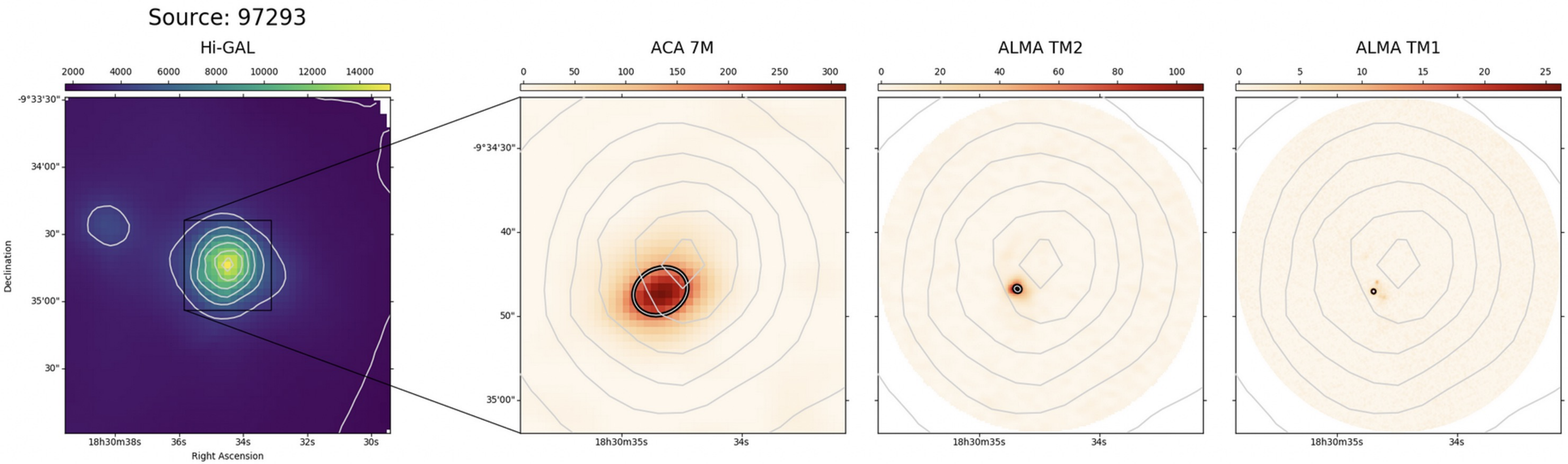
… plust the same amount of files for the continuum (and line-only cubes)

Each run of CASA pipeline to produce the datacubes for joint ACA/C3/C-6 configuration requires:

- RAM ~150 Gb
- HD (temp.) ~ 5 Tb
- ~3-6 days

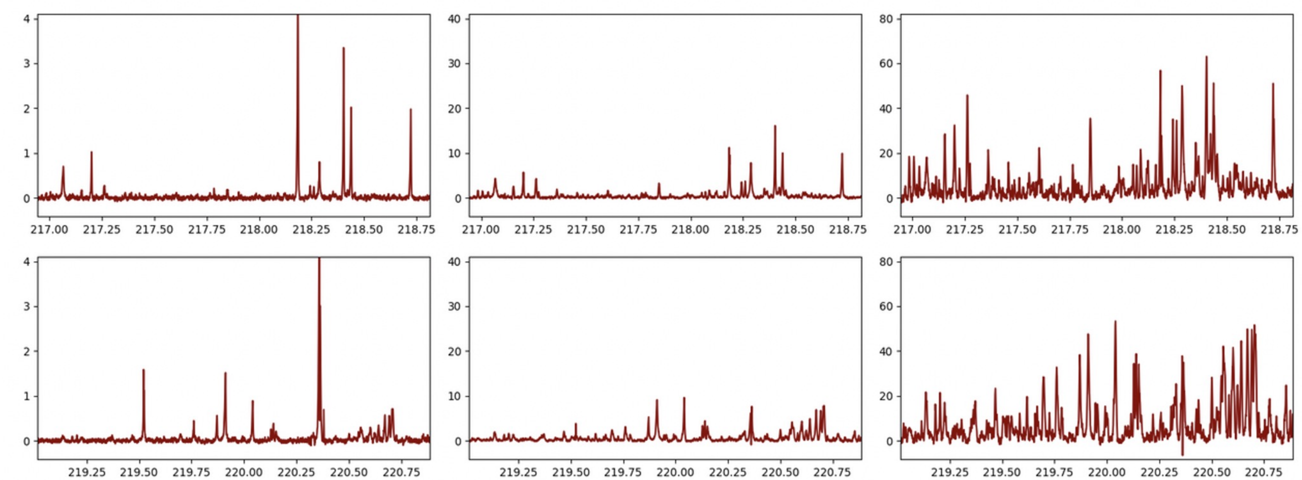
The final dataset will occupy **~500 Tb / 1 Pb**

ALMAGAL in a glance



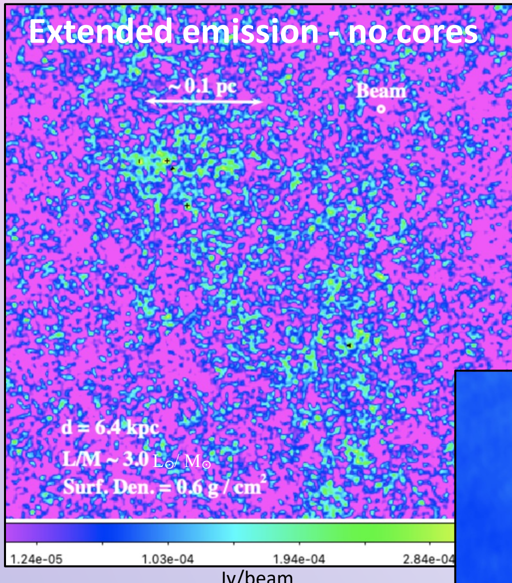
Physical parameters of Hi-GAL source:

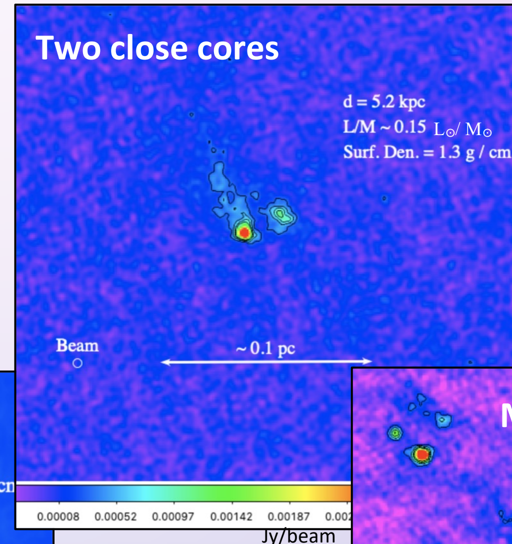
- Distance: 3429 pc
- Mass: 670.6 Msun
- Luminosity: 5385.0 Lsun
- Surface density: 2.75 g/cm^2
- L/M (evolution): 8.03 Lsun/Msun
- Bolometric temperature: 44.5 K

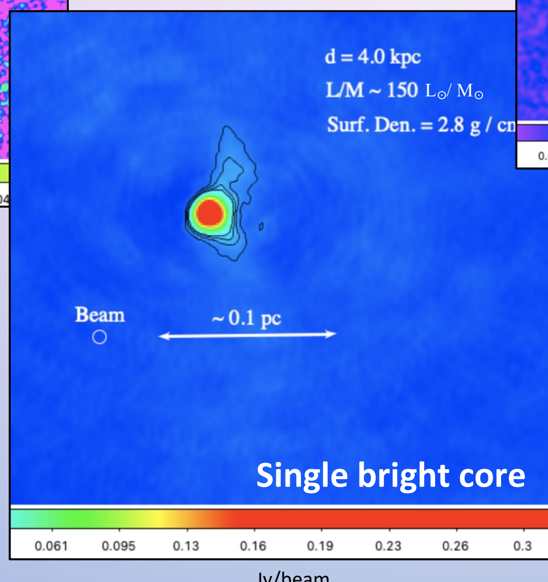


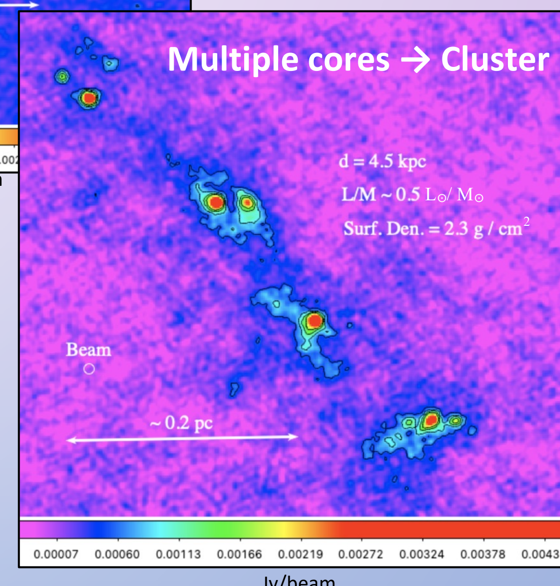
L/M ~ 8

Diversity of cores multiplicity



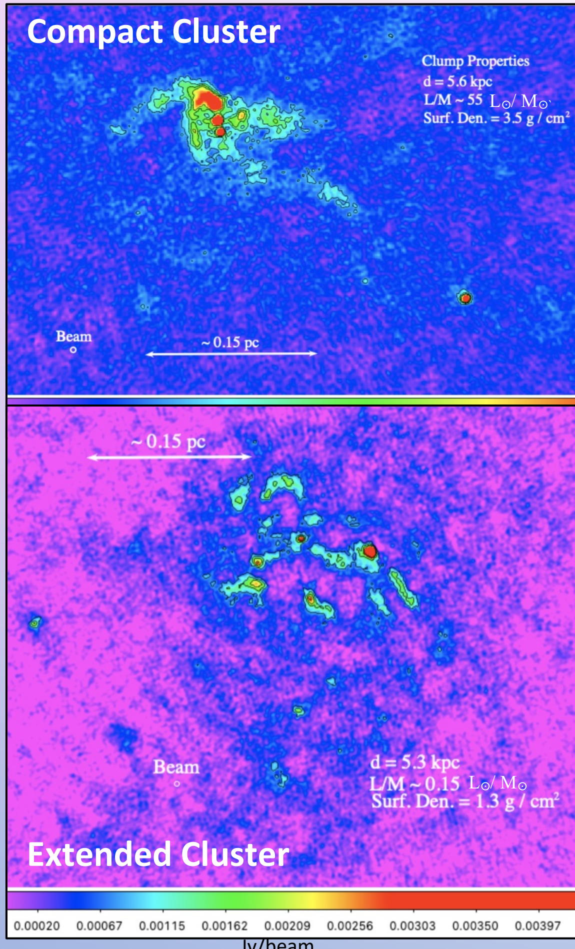


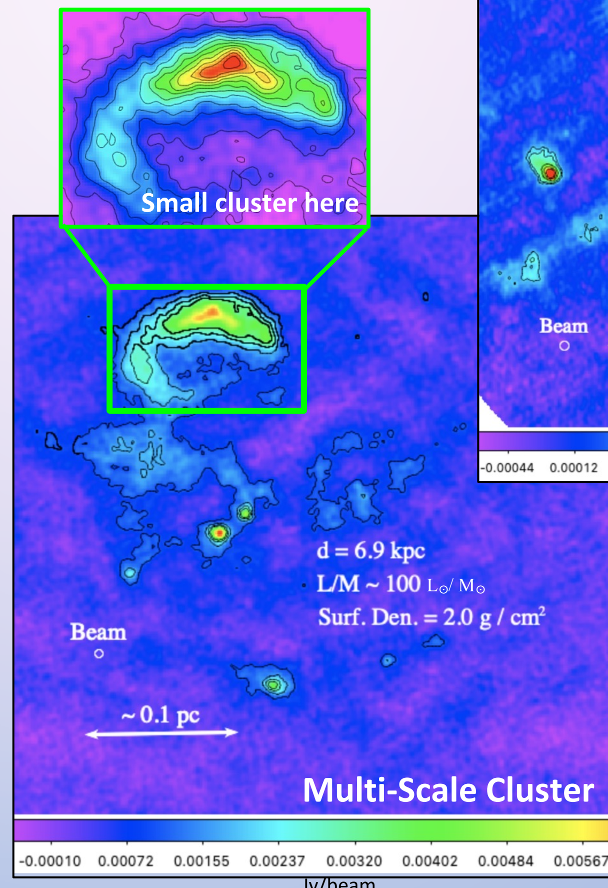


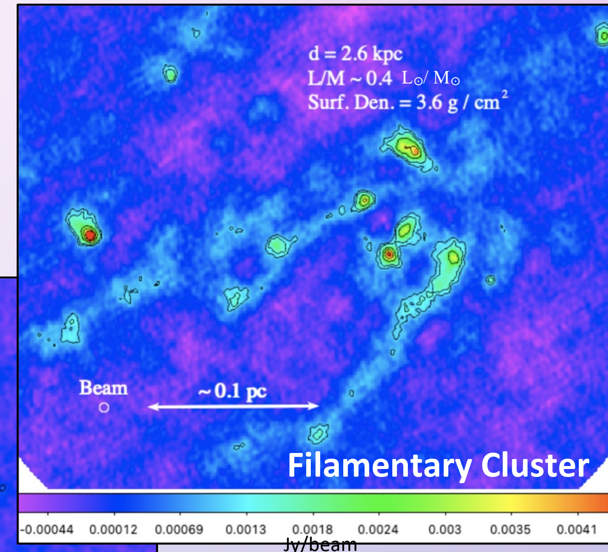


Contour levels at 4, 7, 10, 13- σ

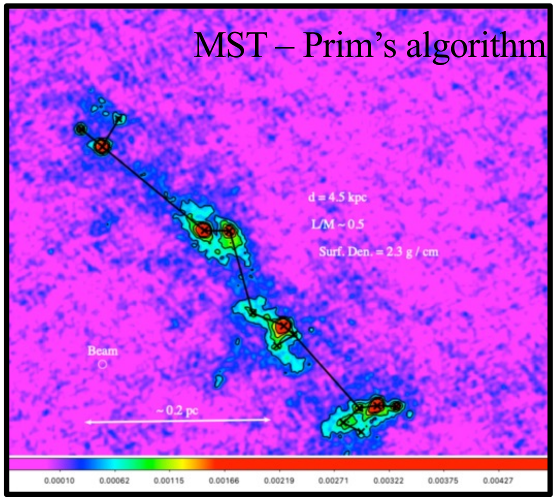
Diversity of cluster morphologies

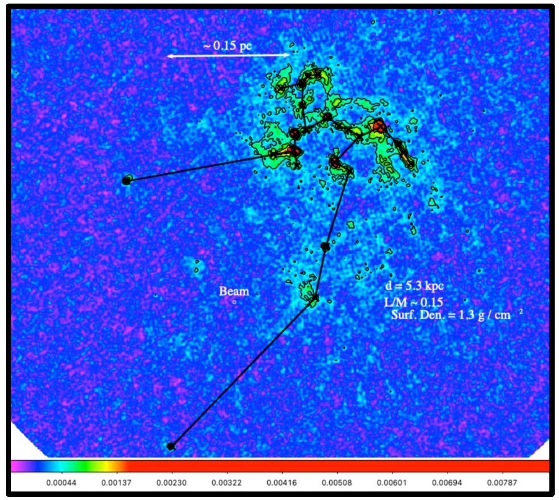


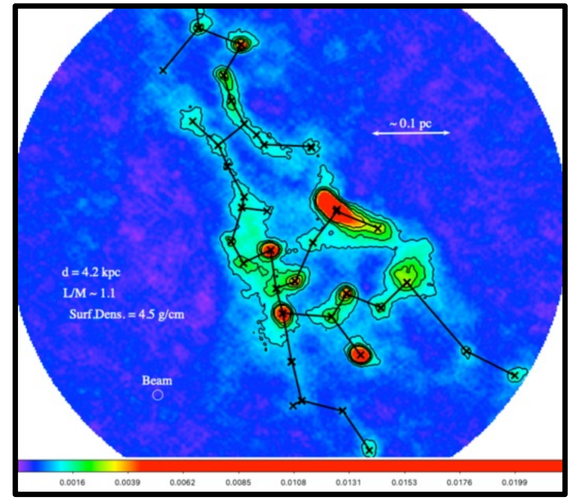


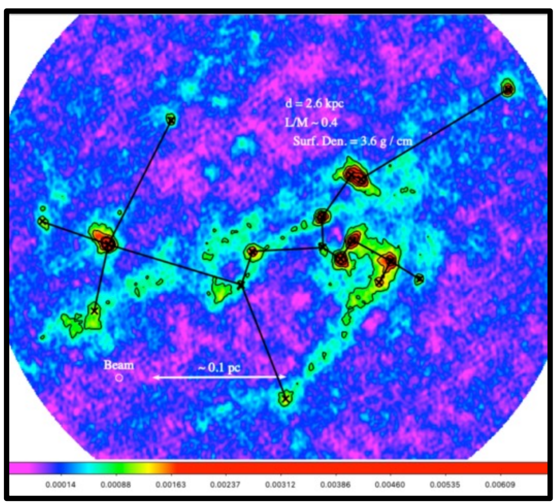


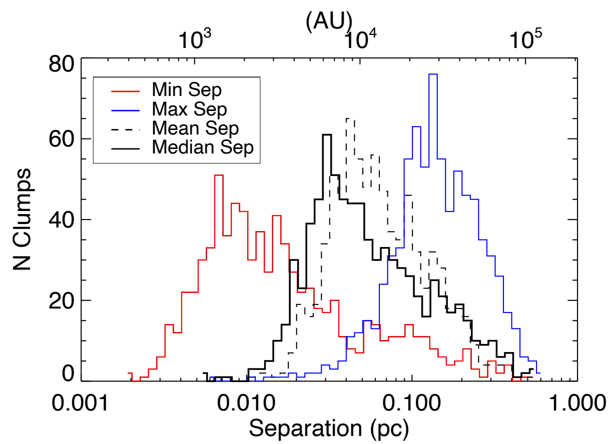
Evaluating the fragmentation of a dense clump: fragments separation

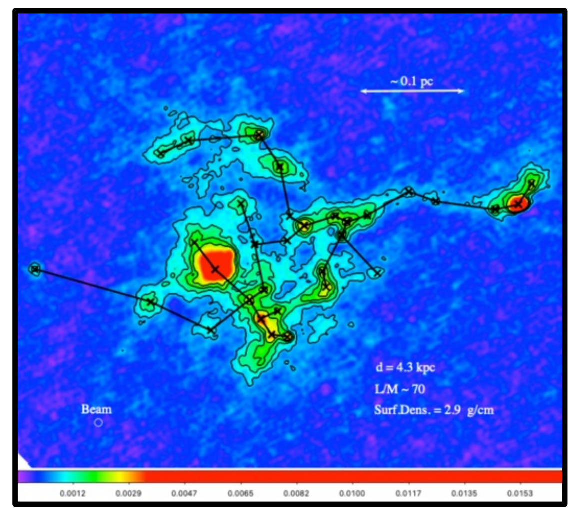










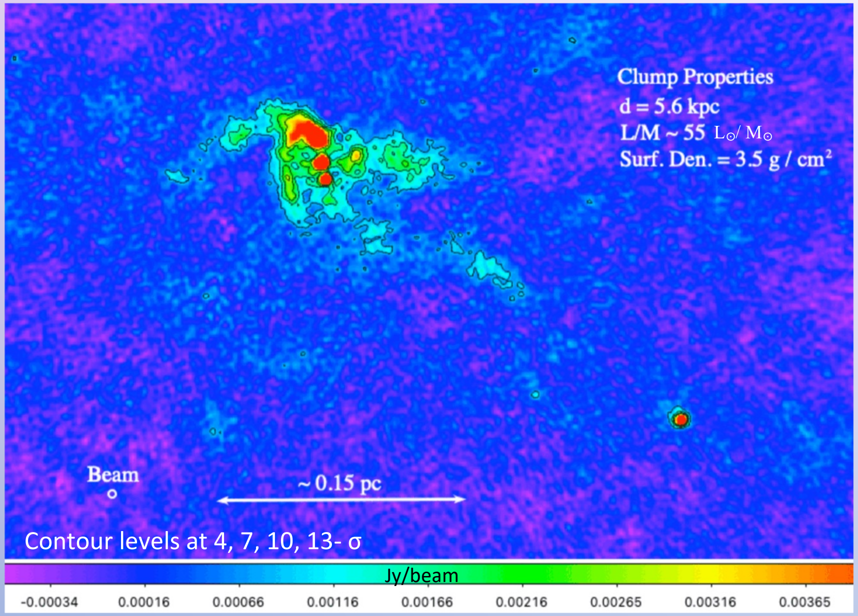


Average Median Separation = 0.06 pc
Average Minimum Separation = 0.013 pc

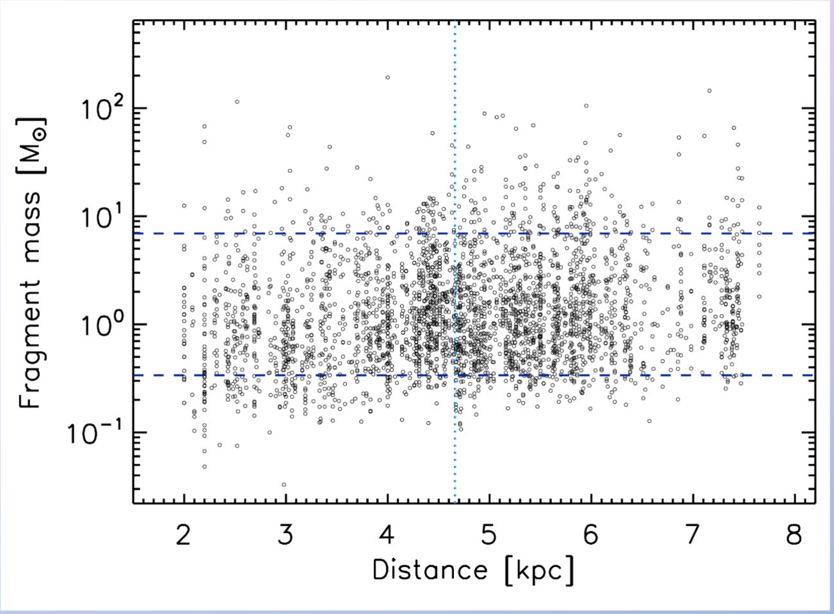
Schisano+ in prep

Continuum source extraction and catalog generation

Identifying and Extracting compact sources with a pipeline based on the CuTEx photometry algorithm (Molinari+2011)



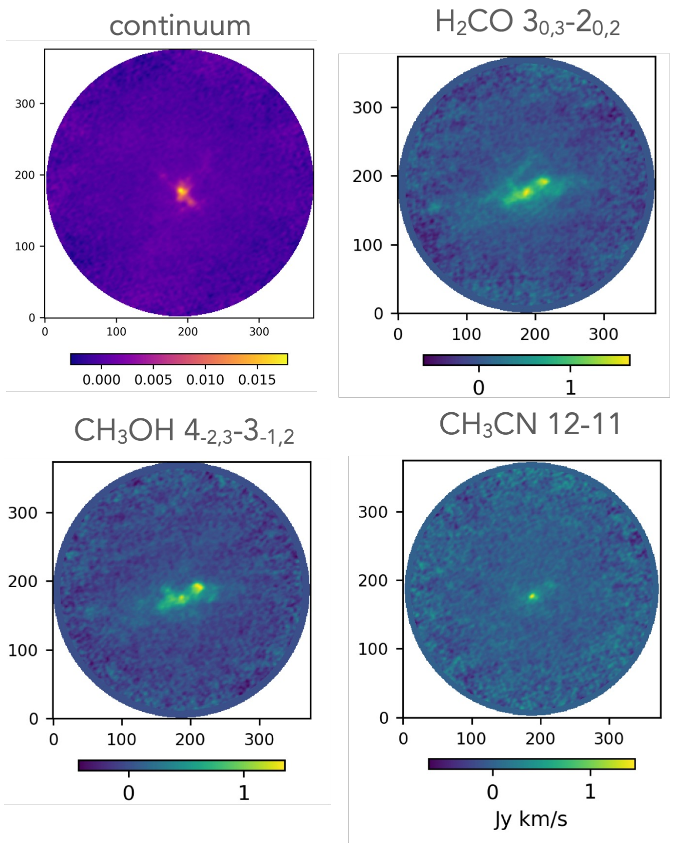
Preliminary catalog with $\gtrsim$6300 fragments identified in 838 clumps



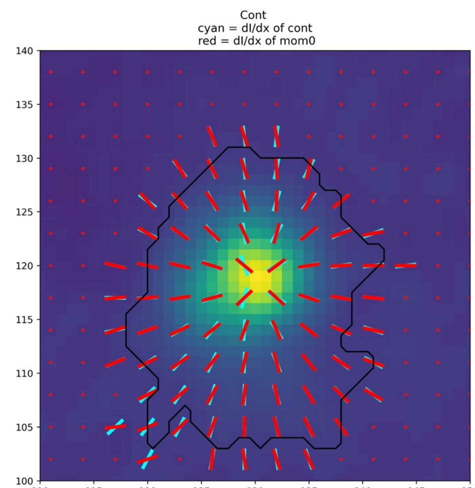
Preliminary results in talk by A. Coletta

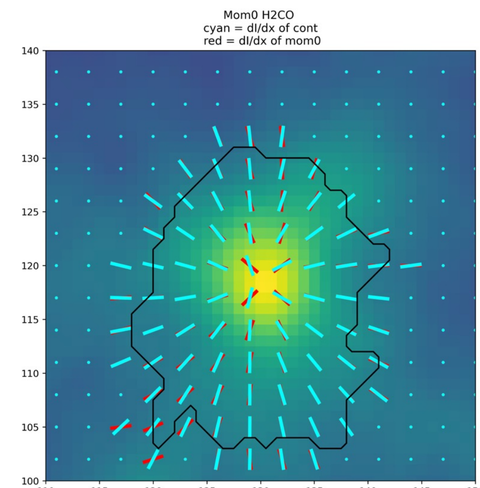
Molecular vs continuum emission morphological comparison with astroHOG

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



- **ALMAGAL spw:** 217-220 GHz
- Selected 7 commonly detected molecular species to **study how they trace the continuum** at different scale
- **astroHOG:** histrogram of oriented gradients method

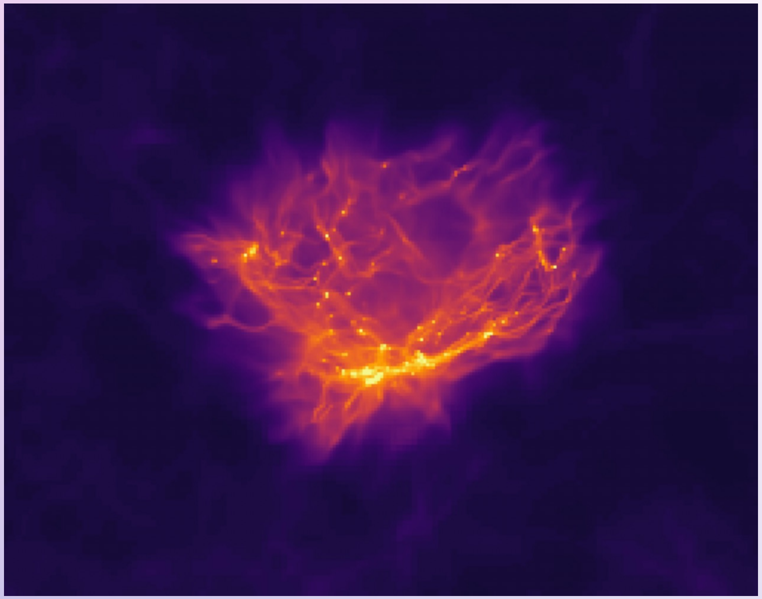


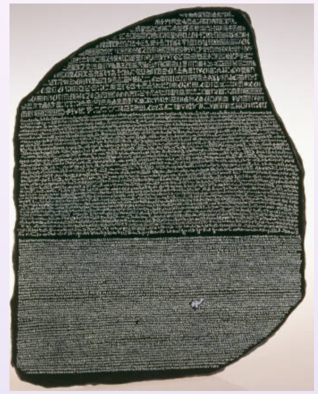


See Talk by C. Mininni

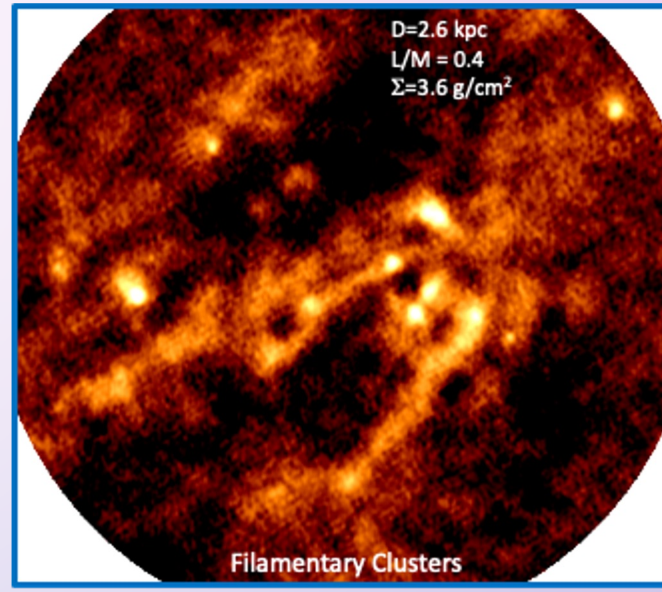
Rosetta Stone: when fantasy meets reality

3D Numerical simulations





2D ALMA Observations



__A library of models @60 AU resol.__

- 2+ seeds
- 2 masses ($M = 500 / 1000\ M_\odot$)
- 2 radii (R = 0.3, 0.6 pc)
- 2 Mach (M = 7 / 10)
- 2 magnetic field intensities
- 2+ jets props.
- HII reg. feedback
- Tracer particles

Radiative transfer and SED: comparison with clump properties

Radiative transfer @1.3mm CASA simulation along different lines of sight

Compare synthetic quantities with observations: N_{cores}, M_{cores}, CFE, Vel. field, …

1) Machinery being built and applied to SQUALO survey
2) Fully applied to ALMAGAL

See poster by Alice Nucara

PLANNED PAPERS

- Compact source catalogue, fragmentation and CMF
- Analysis of core spatial distribution and mass segregation Fragmentation vs
  - Clump evolutionary stage and properties
  - Cores dynamics
  - Line detections and morphological characterization
  - Galactic environment
  - Comparison with simulations
- Kinematic study of cores
- Evolutionary stages of cores from continuum
- Chemical indicator of evolutionary stage
- Outflows
- Infall and accretion
- Deuteration, chemical segregation
- Multiscale analysis of clumps dynamics vs core dynamics
- Large scale flows

Different types of approach and analysis including machine learning approach and PCA analysis

(some) Perspectives

- Following the mass flow from large-scale filaments down to cores with continuity is a critical missing link

  → Proposed ALMA Large Project dedicated to characterising gas dynamics in hundreds of ALMAGAL clumps sitting on filamentary structures imaged with SEDIGISM: "***Panta Rei***" *(A. Traficante)*

- Chacterising large-scale feedback in the Galaxy & pinning down the earliest phases in massive star formation (HC+UCHII)

  → Proposed MeerKAT S-band pilot survey of 16 sq.deg in Q4, aiming to a large-scale survey with MeerKAT+ *(A. Traficante)*

- Taming the elephant in the room: magnetic field

  → ALMA polarization follow-up of ALMAGAL clumps-to-cores
  → Proposed ***BLAST Observatory*** balloon-borne Far-IR polarimeter for Galaxy scale B-field mapping towards filamentary clouds.

- Unveil the evolutive stage of ALMAGAL cores
  → JWST continuum survey to reveal counterparts to ALMAGAL cores

- Re-examine XGAL SF prescriptions based on Milky Way knowledge