A SEDIGISM view on ATLASGAL filaments and Nessie

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MAX-PLANCK-GESELLSCHAFT

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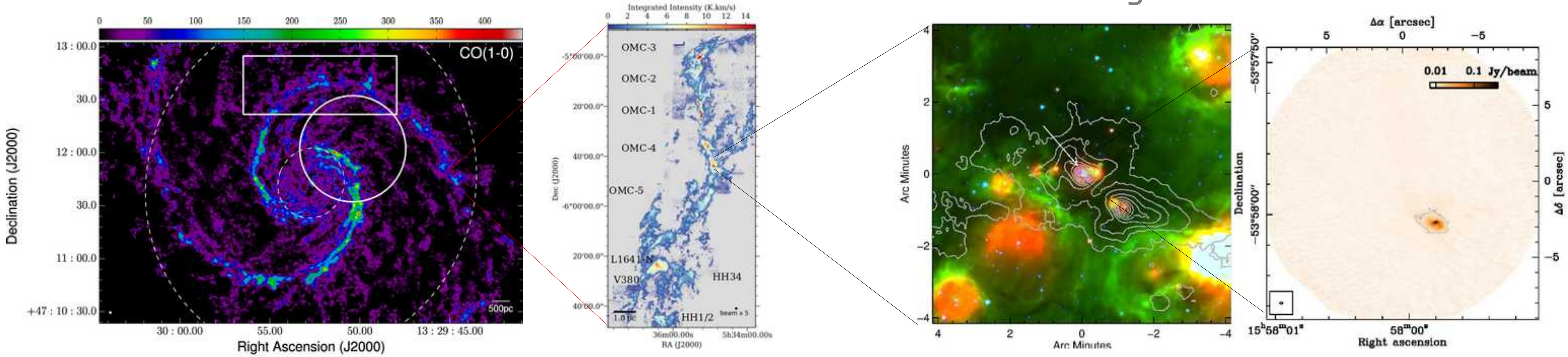
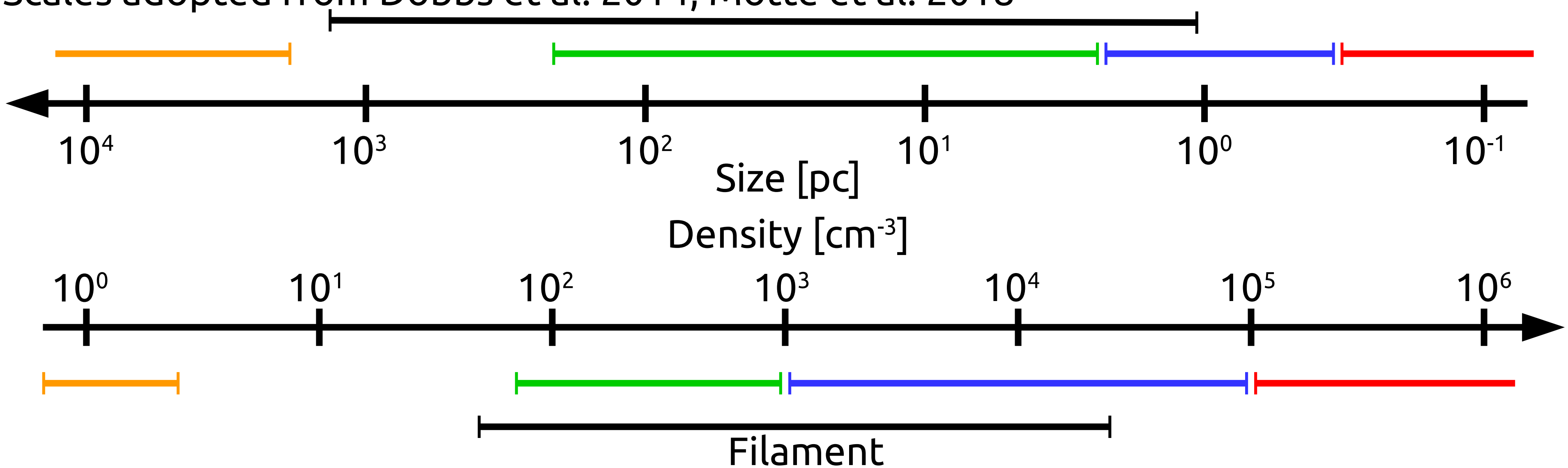
Size and density scale

Schinnerer et al. 2017 | Suri et al. 2019 | Csengeri et al. 2018



Galaxy | Cloud | Clump | Core

Scales adopted from Dobbs et al. 2014, Motte et al. 2018



Filaments ubiquitous in the Galaxy and cover a large range of scales

ATLASGAL filaments in SEDIGISM

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Astronomy & Astrophysics

SEDIGISM: the kinematics of ATLASGAL filaments*

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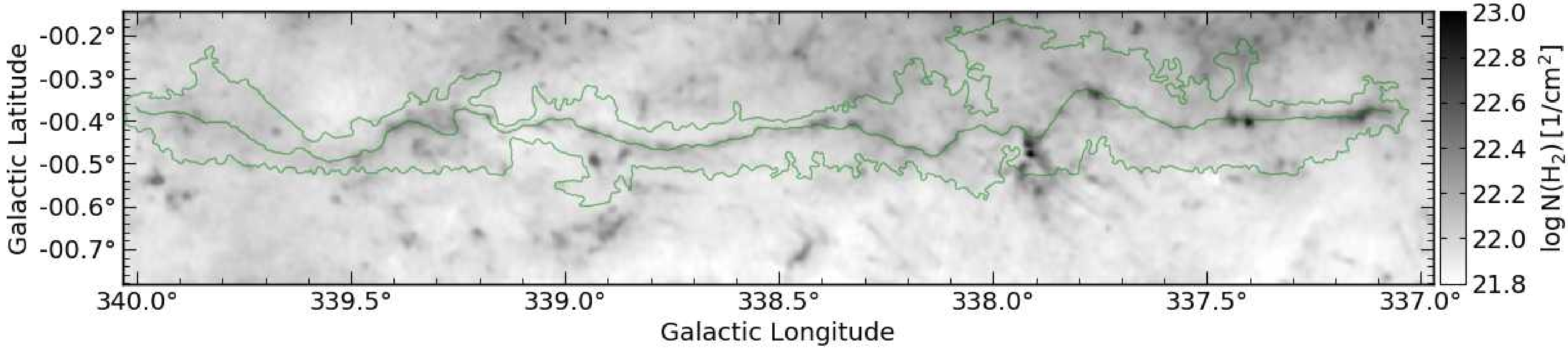
The extended filamentary Nessie cloud



Filament Candidates

ATLASGAL survey

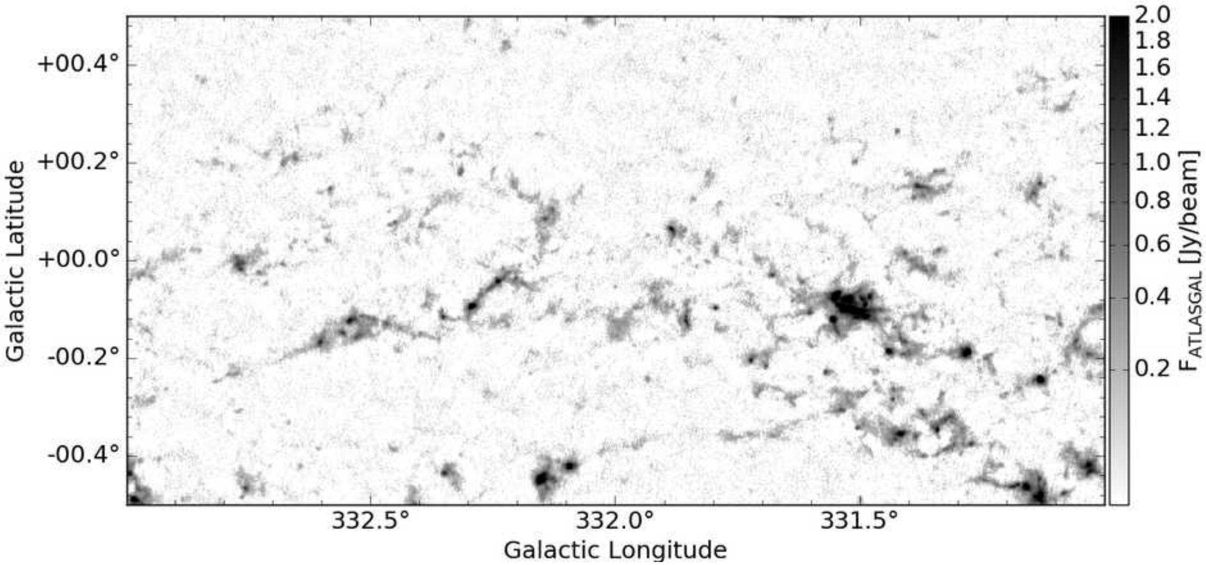
APEX Telescope Large Survey of the Galaxy (Schuller et al. 2009)

870 μm dust emission

-80° < l < 60°, |b| < 1.0°, at resolution of 19.2”

Sensitivity of 40–70 mJy/beam for the 1σ RMS noise

Showing filamentary structures



ATLASGAL filament candidates

One of the largest catalogs of filamentary structures by Li et al. 2016

Structures identified by DisPerSE (Sousbie 2011)

- **517 filamentary, high column density, molecular clouds**
- + more complex structures

Only 2D data → False identification due to projection effects

Are these filaments continuous structures?

→ velocity information

Automated Analysis

Skeleton position in SEDIGISM

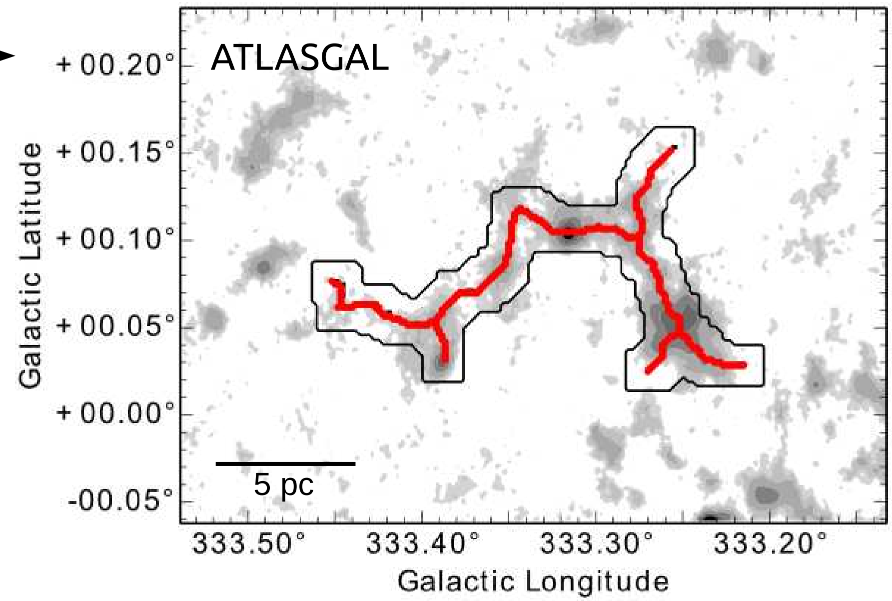
Averaging over the skeleton spectra

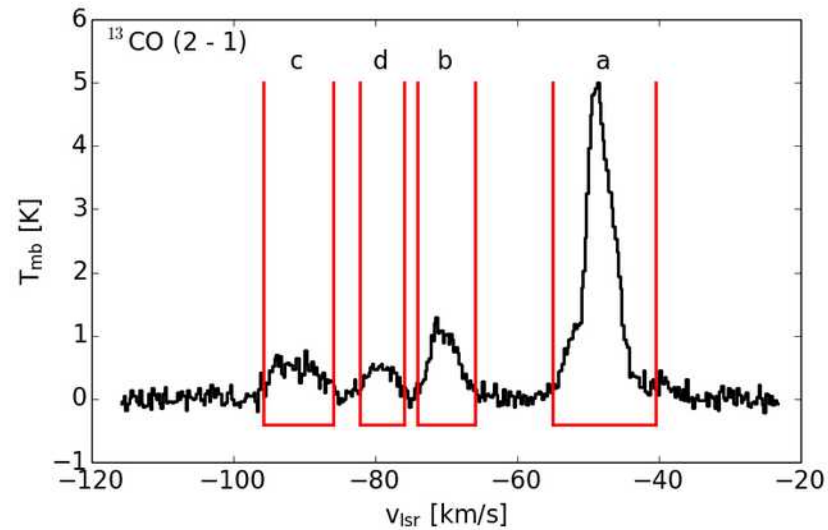
Identify velocity components of emission

per component

Deriving kinematics over the skeleton

For $^{13}CO(2-1)$ and $C^{18}O(2-1)$ calculating the integrated intensity, peak velocity, velocity dispersion

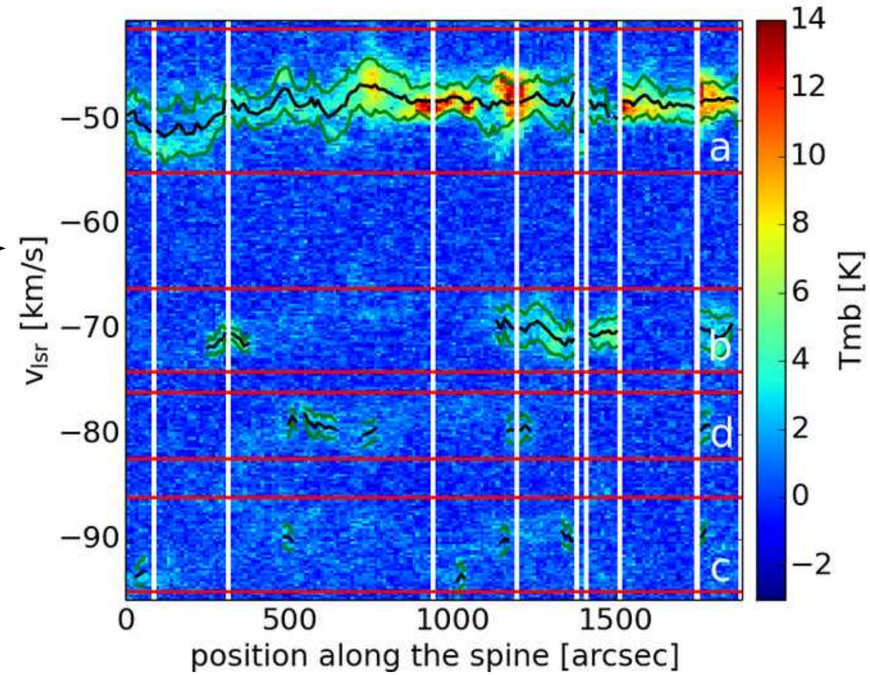




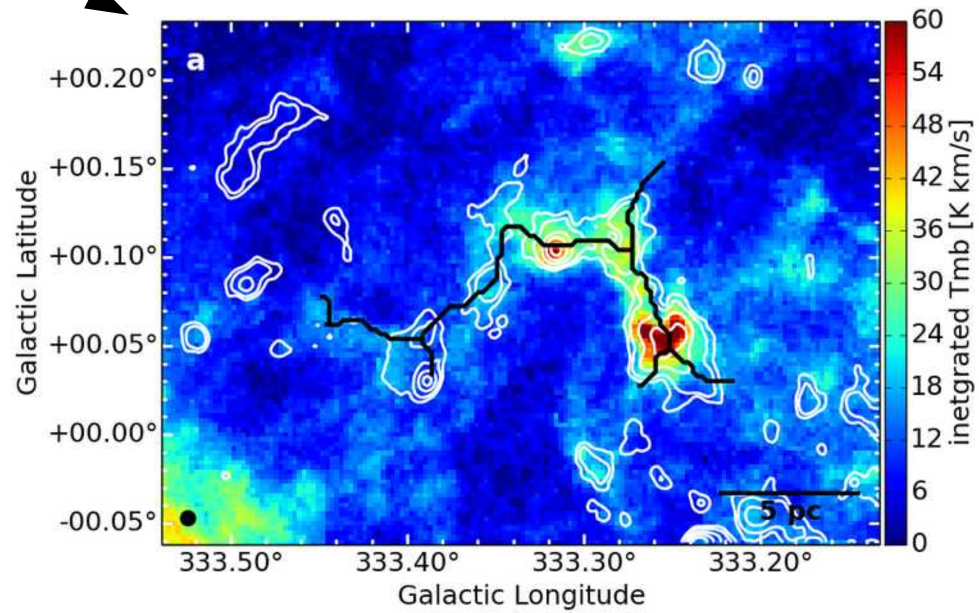
Automated Analysis

per component

Deriving kinematics over the skeleton → Position-velocity plot along the skeleton



Integrated intensity map → Integrated ^{13}CO emission; mass estimates



2D pixel-to-pixel correlation with ATLASGAL

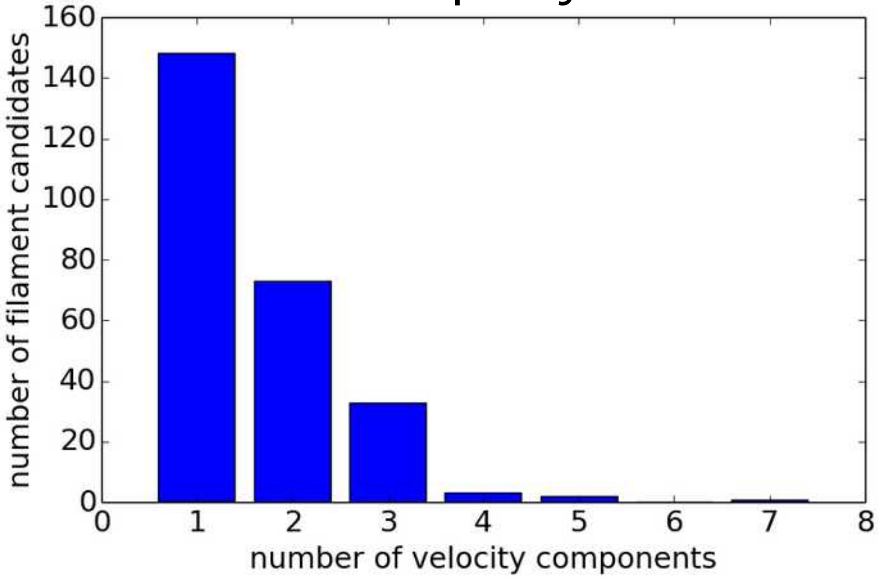
Categorization in 4 groups

robustness ↑

- Fully correlated (180 components)
- Partially correlated (191 comp.)
- Diffuse correlated (51 comp.)
- Uncorrelated (390 comp.)

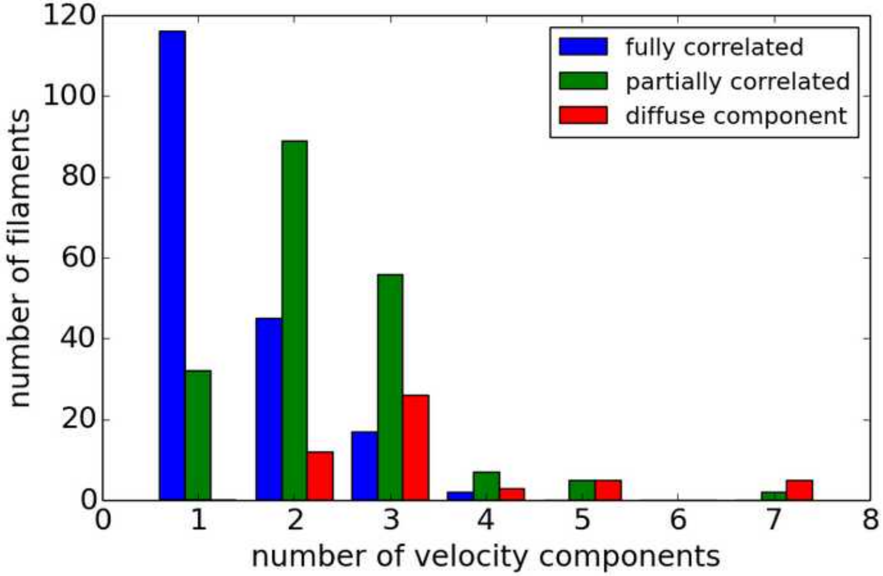
Results

Multiplicity

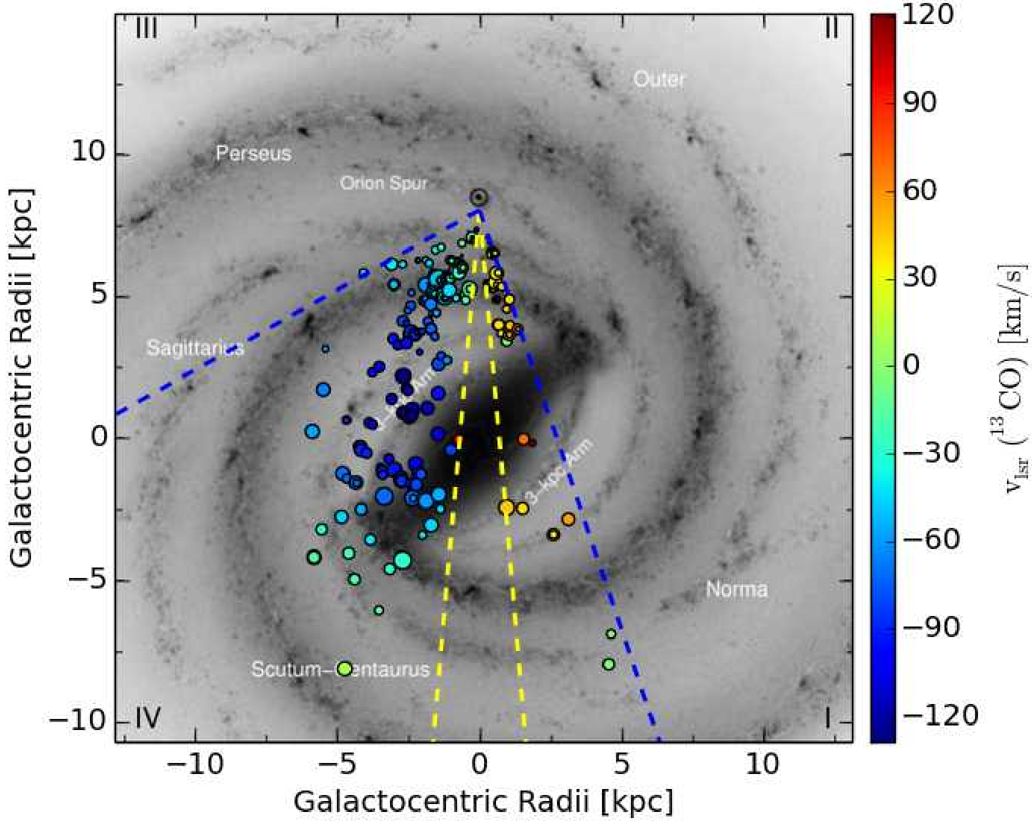


- 53% of the candidates have 1 velocity component
- 23 (8%) show no correlated component

Correlation vs. Multiplicity



Galactic distribution of filaments

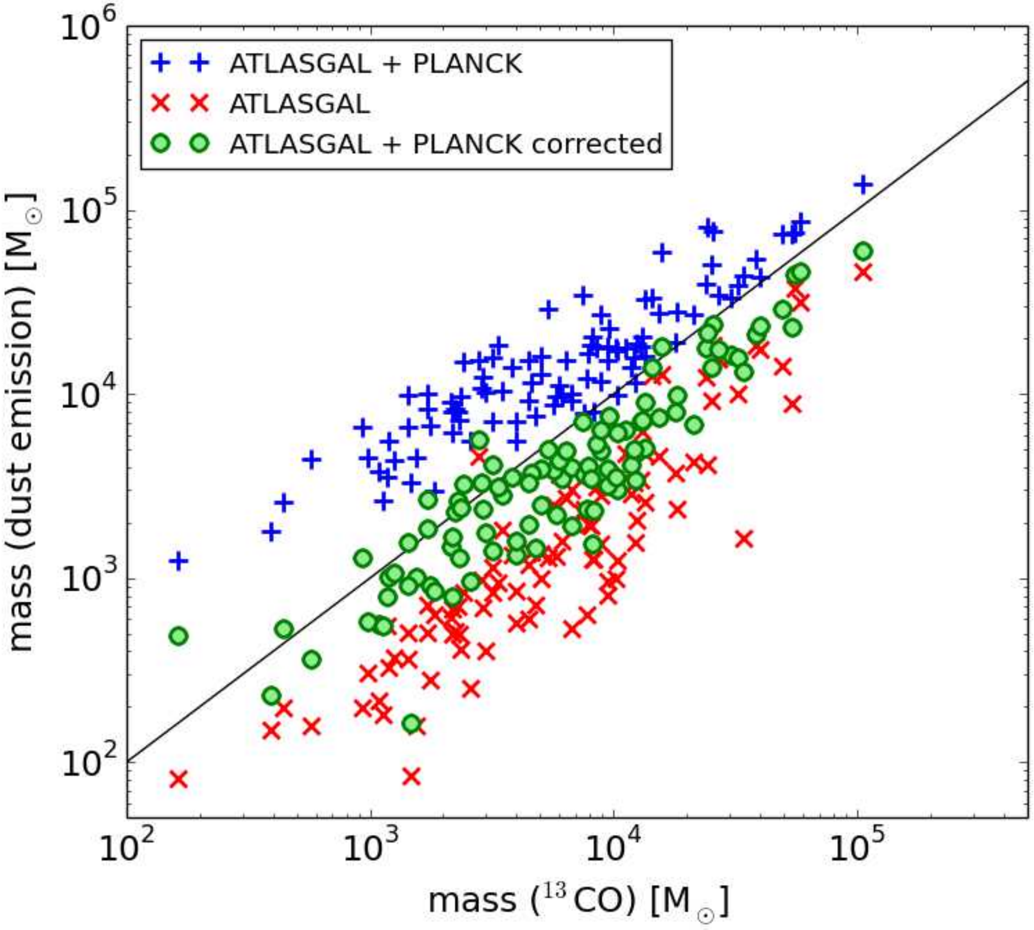


Artist's impression of the Milky Way (Robert Hurt)

Comparison of masses

Mass (13CO)

- Using 13CO X-factor (Schuller et al. 2017)
  $N(\mathrm{H_2}) = 1 \cdot 10^{21}\,\mathrm{cm^{-2}}\,(\mathrm{K\,km\,s^{-1}})^{-1} \cdot \mathrm{W}(^{13}\mathrm{CO}(2-1))$
- Is this a good assumption?



ATLASGAL (Schuller et al. 2009)

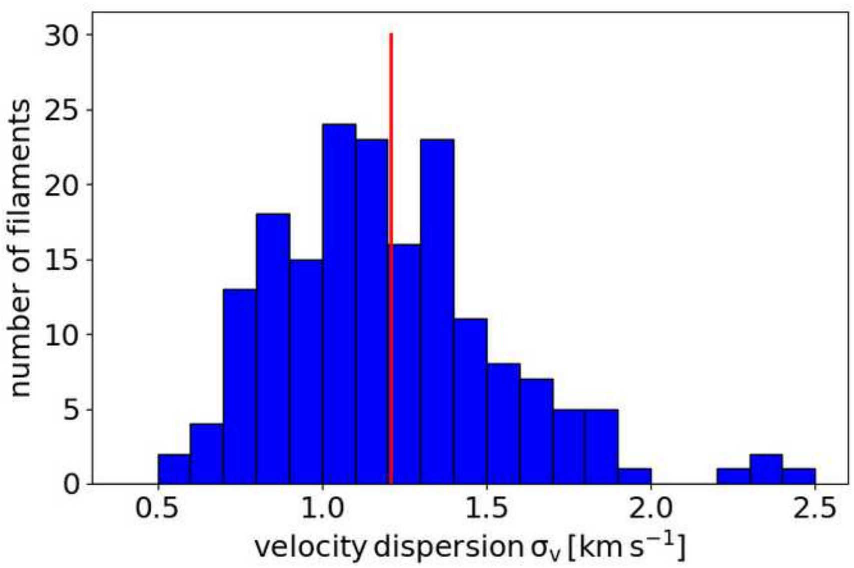
- Only small scale, dense gas

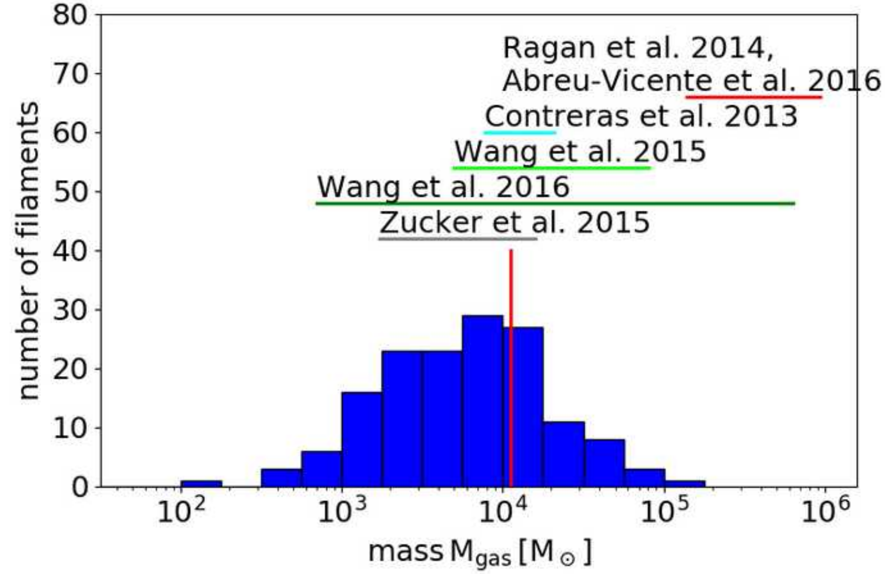
ATLASGAL+PLANCK (Csengeri et al. 2016)

- Additional line-of-sight emission

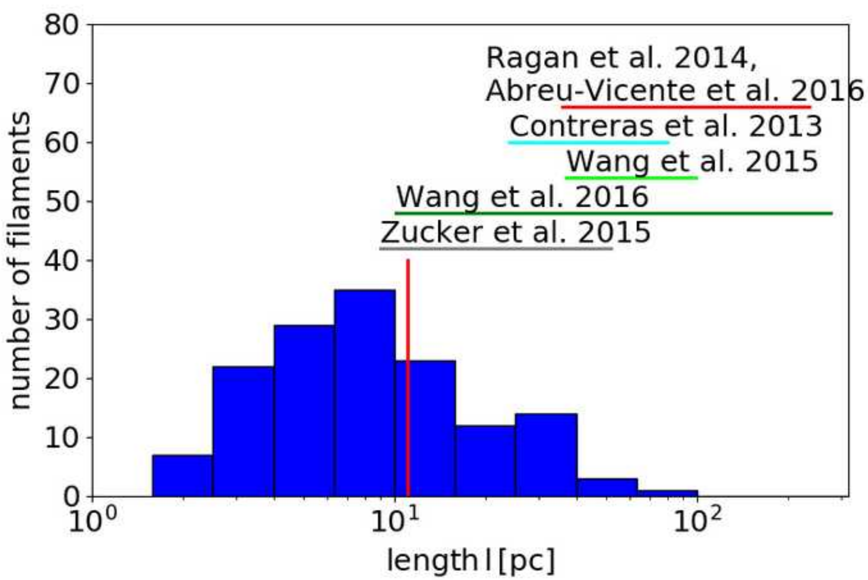
→ subtracting line-of-sight emission

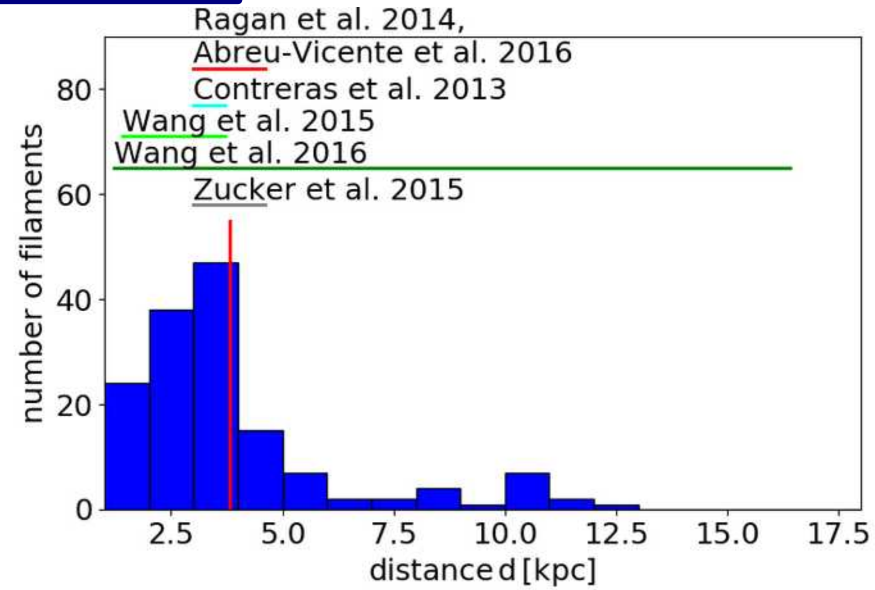
Results and comparison to GMF samples





No clearly peaked distribution





Mass radius dependency

^{13}CO is extended

→ **Where is the outer radius?**

We compare with Plummer and Gaussian filament profiles

We find agreement with Plummer profile:

- Inner radius limited by resolution: **R_{flat}= 0.1 pc**
- Power-law index of **p = 1.5**

  p = 1.5 – 2.5 (Arzoumanian et al. 2001)

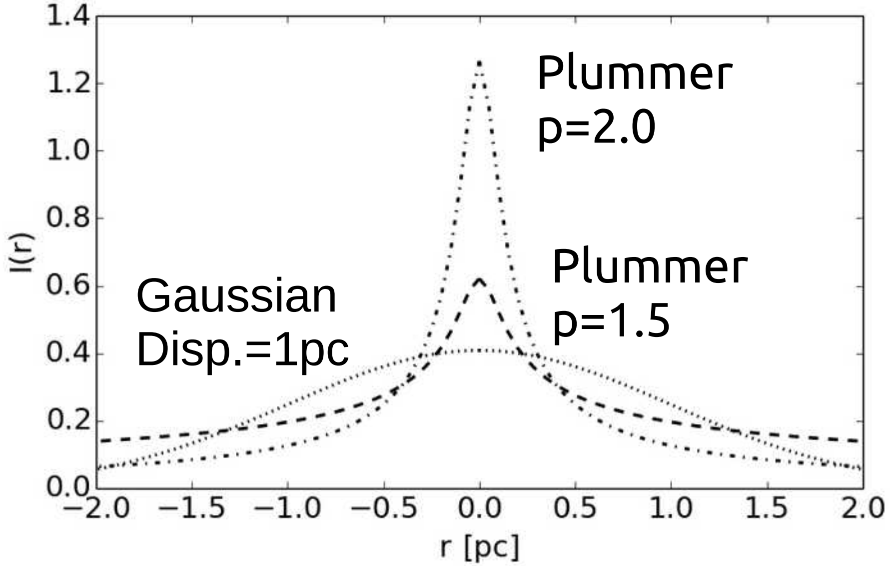
→ **Outer radius and therefore Mass is not well-defined!**

We estimate the mass within a radius of

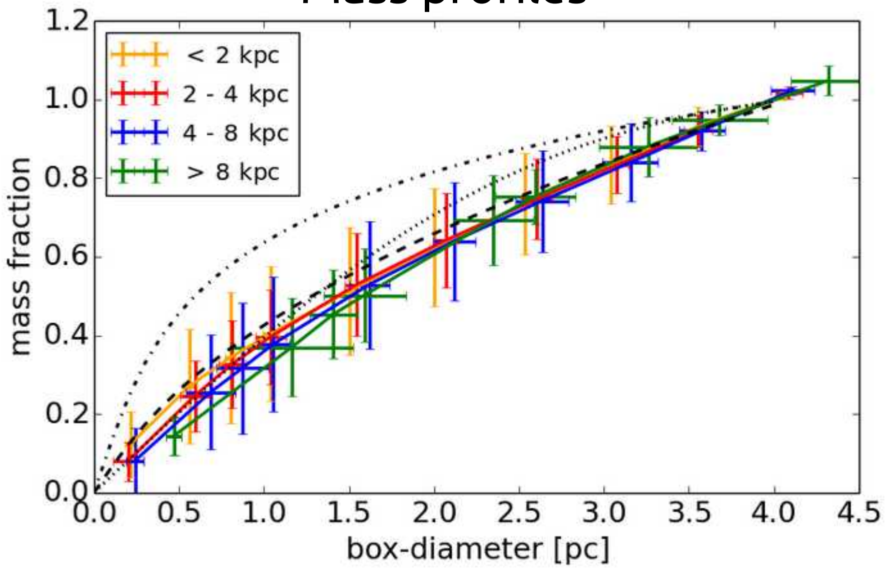
$R = t_{SF} * \sigma_v$

t_{SF} = 2 Myr (~ star formation size scale)

Profile models



Mass profiles



Stability of filaments

Line-mass: mass per unit length; $m = \frac{M}{l}$

Critical line-mass:

thermal: thermal+non-thermal:

$$m_{\text{crit,th}} = \frac{2c_s^2}{G} \qquad m_{\text{crit,tot}} = \frac{2(c_s^2 + \sigma_{\text{nt}}^2)}{G}$$

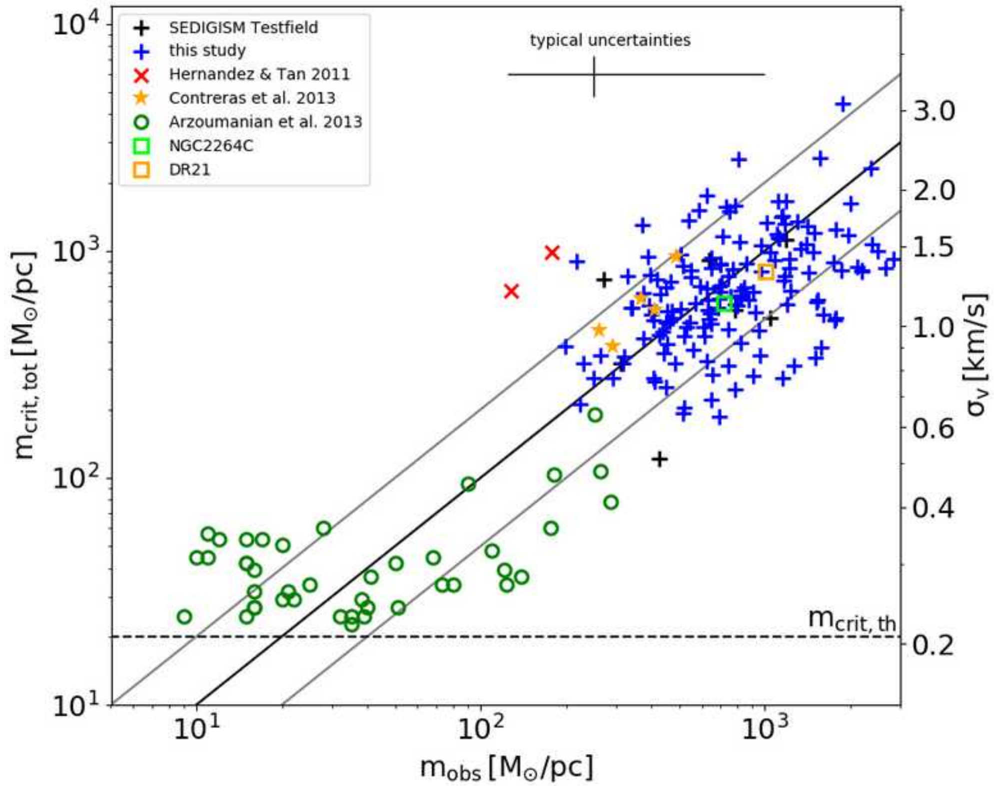
(Chandrasekhar & Fermi 1953, Ostriker 1954)

For $m > m_{crit}$ → radial collapse

For $m < m_{crit}$ → external pressure to confine the filament

(Inutsuka & Miyama 1992)

Mattern+2018b



We find: $m \propto \sigma_v^2$

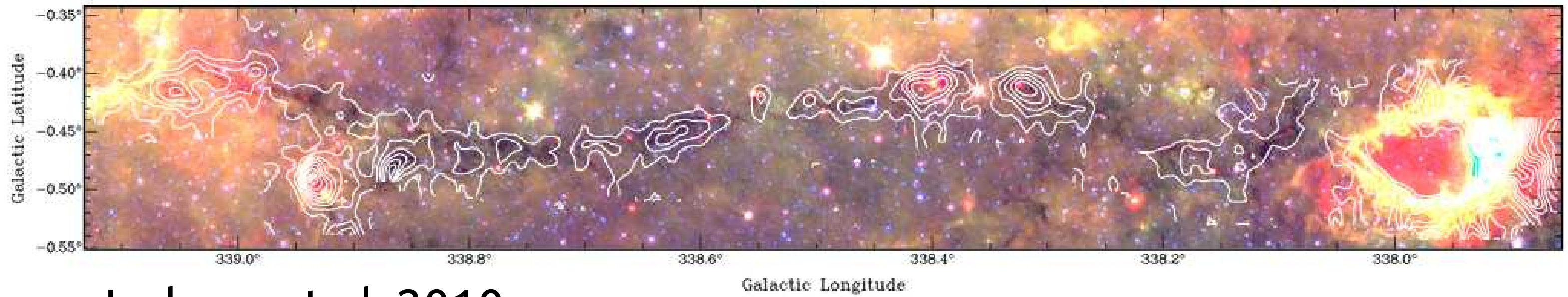
$$\alpha_{vir} = \frac{5\,\sigma_v^2 R}{G\,M} \;\Rightarrow\; \Phi_{vir} = \frac{m_{crit}}{m_{obs}} = \frac{2\,\sigma_v^2 l}{G\,M}$$

Summary 1

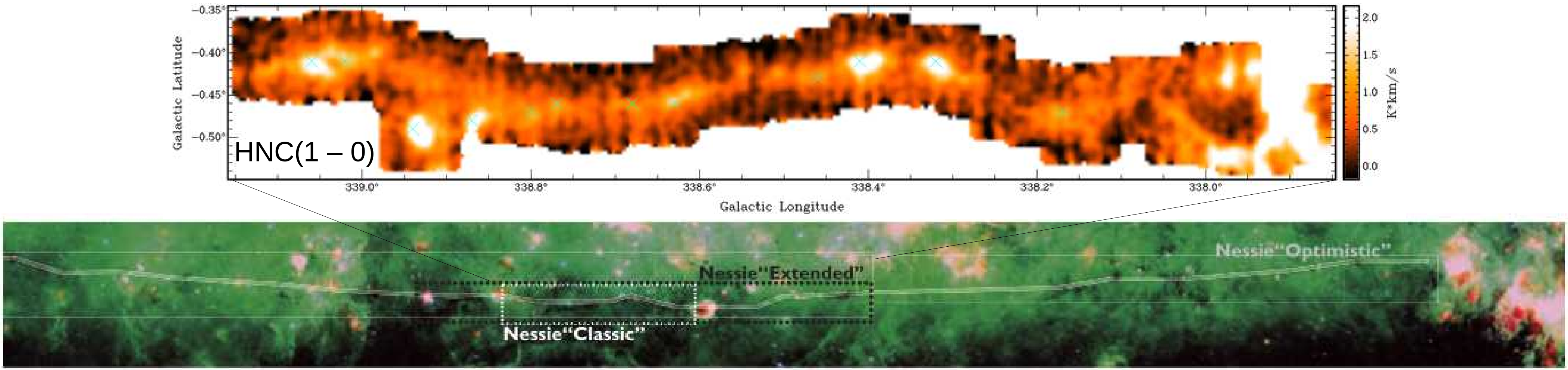
- Half of ATLASGAL detected filament candidates are continuous objects
- What is the average filamentary molecular cloud?
  - Filament profile is Plummer-like p=1.5 → mass not well-defined, $^{13}CO(2-1)$ traces the diffuse surrounding gas
  - No single typical structure, but a range of parameters

- ATLASGAL networks of filaments and complexes were not included
- More efficient to identify velocity coherent filaments from line surveys, like SEDIGISM
  - See talk by Kartik Neralwar

Nessie



Jackson et al. 2010



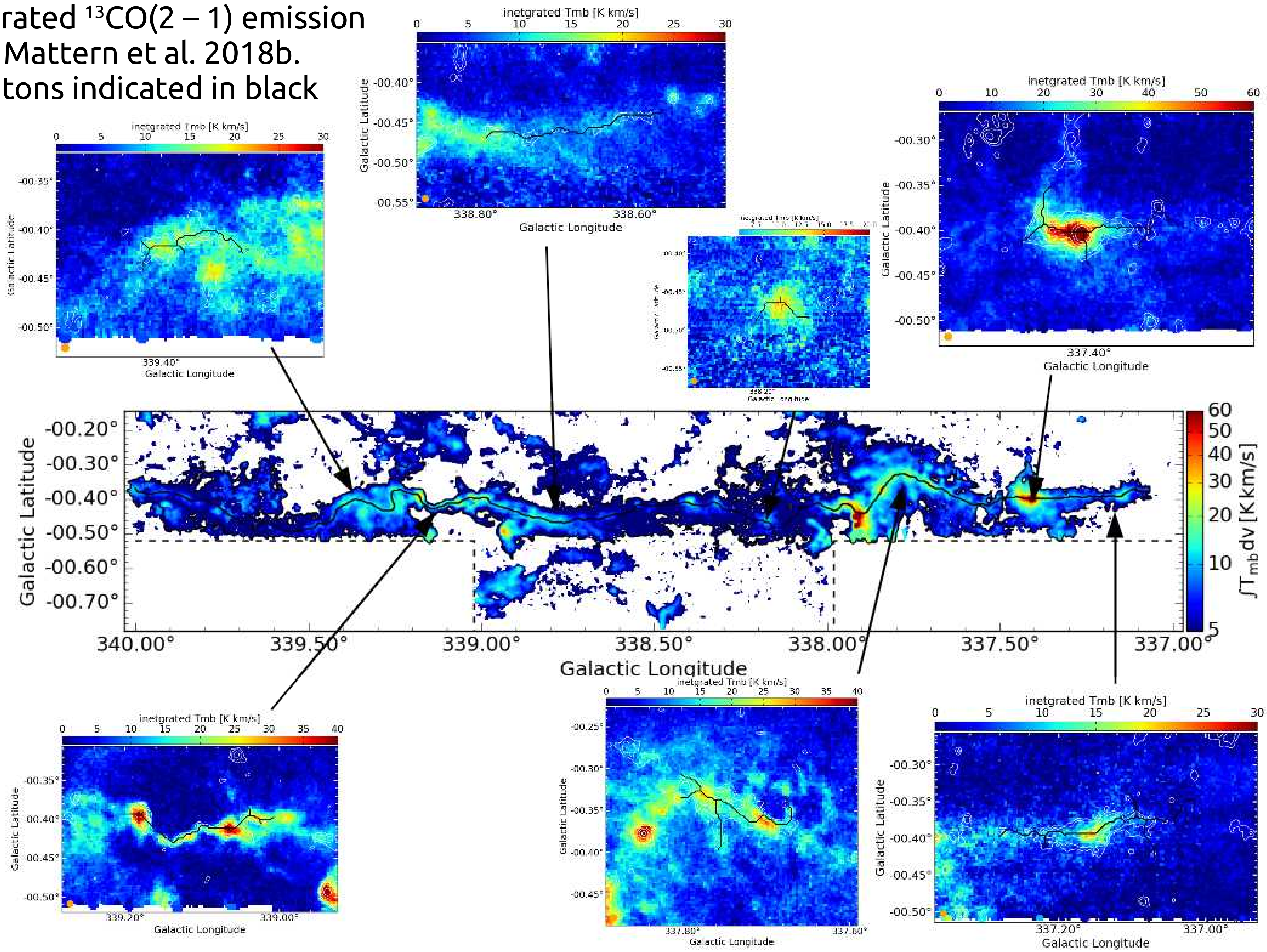
Goodman et al. 2014, MIPS 24 μm, IRAC 8.0 μm, IRAC 5.8 μm

- Identified as dark cloud on Spitzer infrared images
- It is likely to be located within the Scutum-Centaurus spiral arm (?)
- It is located in the Galactic mid-plane
- The first Giant Molecular Filament identified and studied

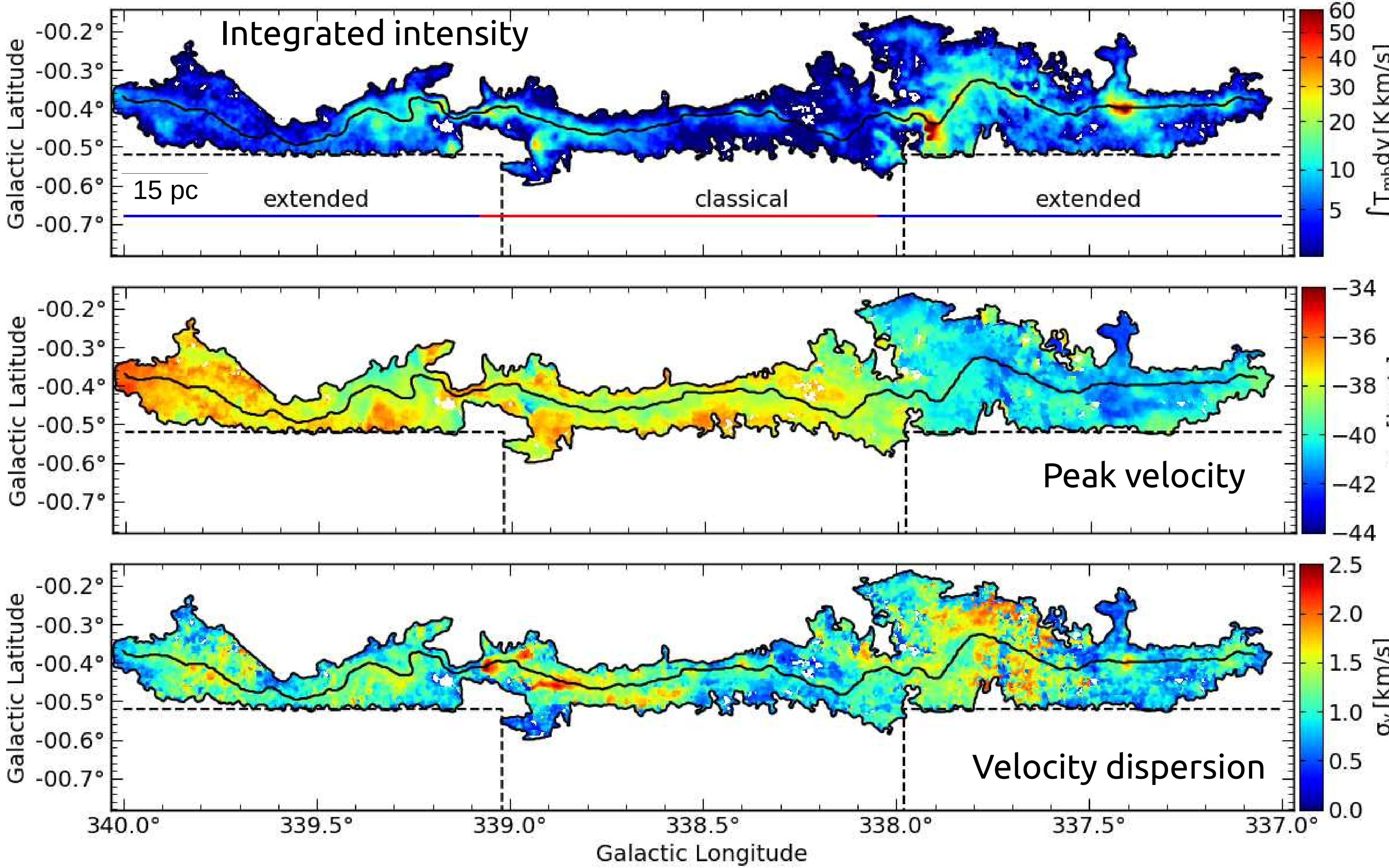
(Jackson et al. 2010, Goodman et al. 2014, Ragan et al. 2014)

Extended Nessie in SEDIGISM

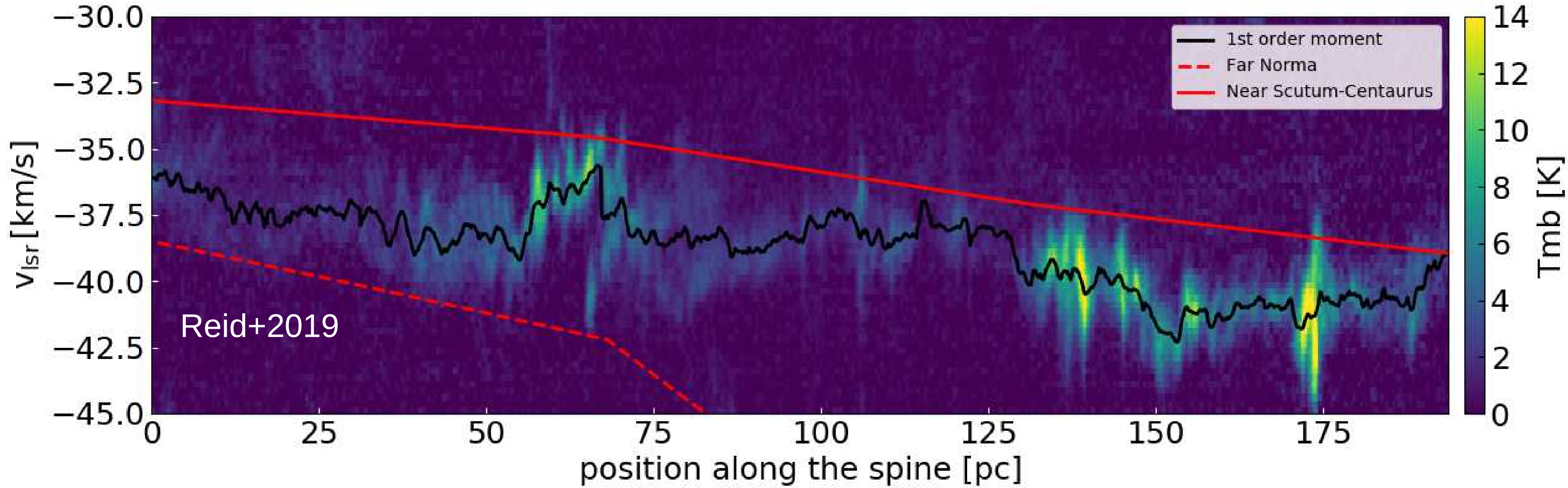
Integrated $^{13}CO(2-1)$ emission from Mattern et al. 2018b. Skeletons indicated in black

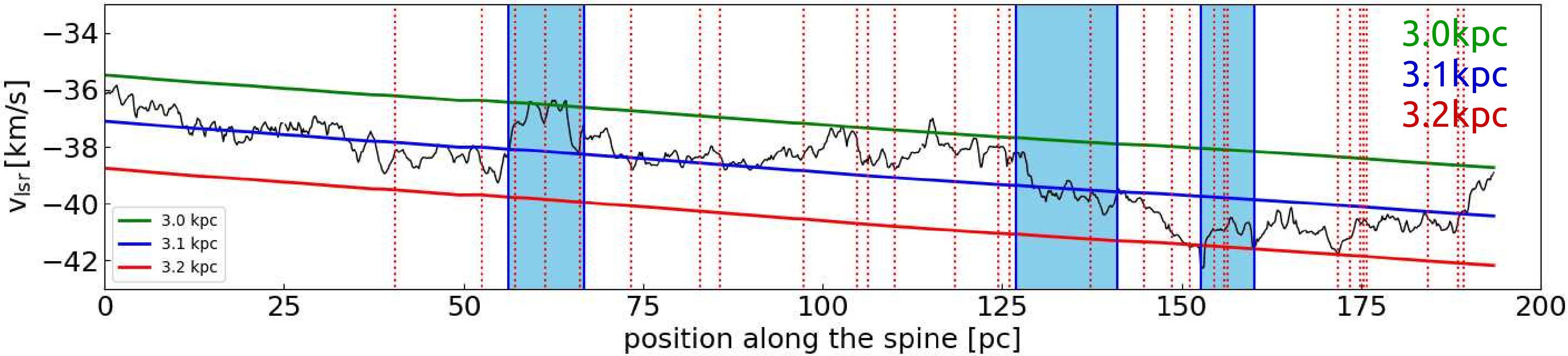


Moments of the extended Nessie



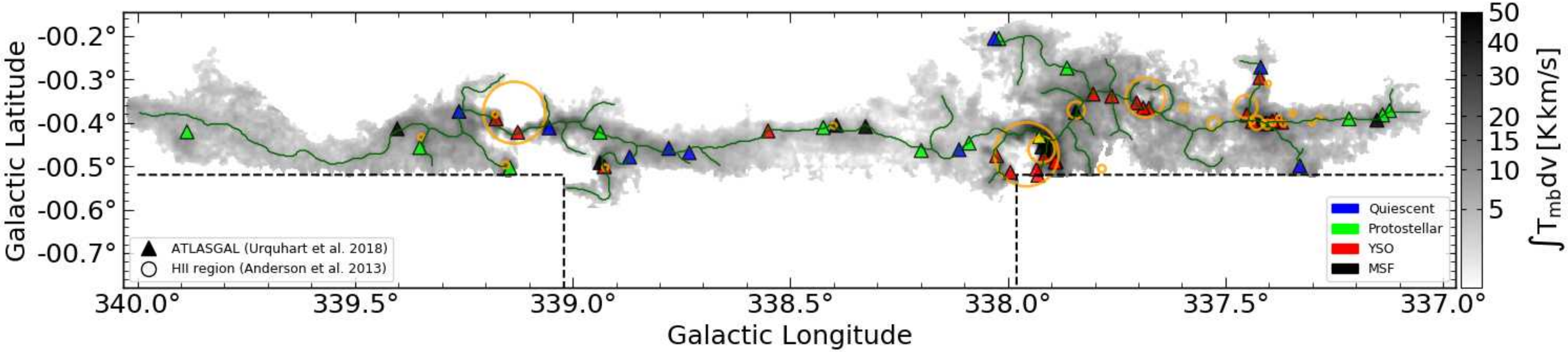
Velocity structure



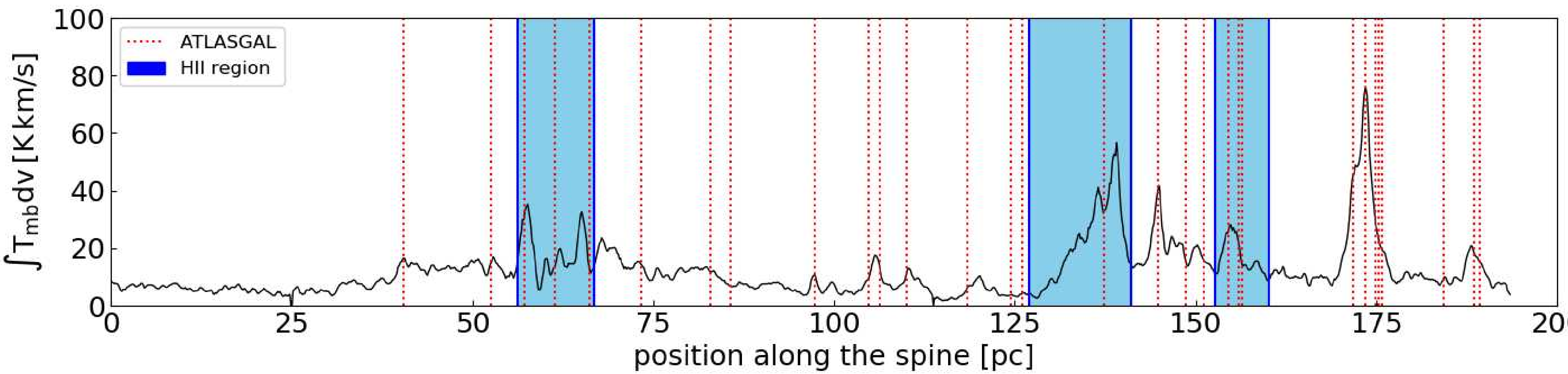


Velocity in agreement with Galactic rotation (Brand&Blitz1993) at 3.1kpc from the sun

Intensity structure and massive clumps



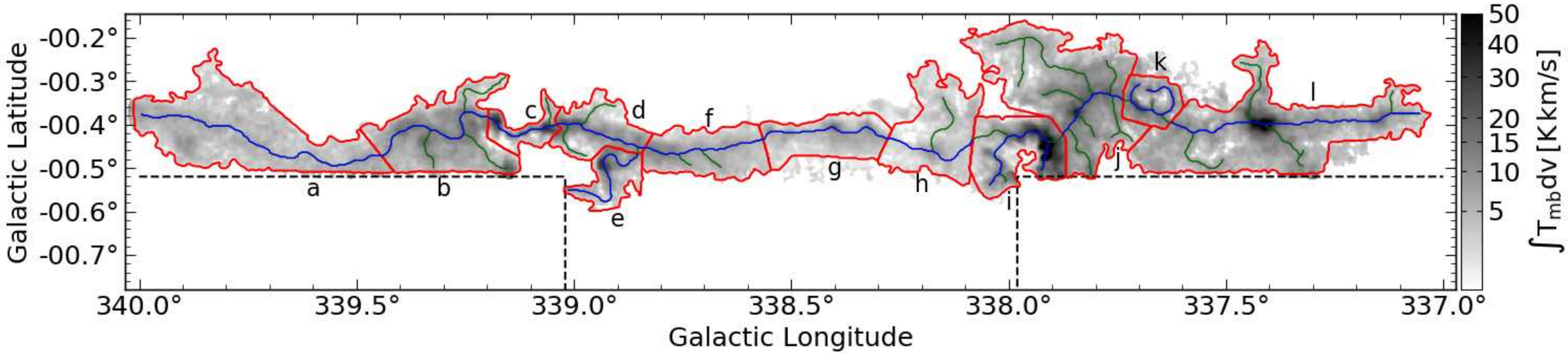
ATLASGAL provides a catalog of massive clumps and their **evolutionary phase**
(Contreras et al. 2013, Urquhart et al. 2018)



Variations in intensity → fragmentation?

(see Mattern+2018a)

Dividing Nessie

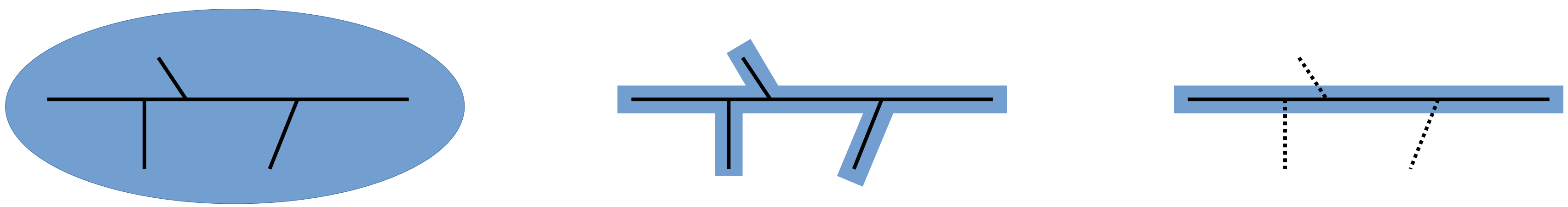


Morphologies

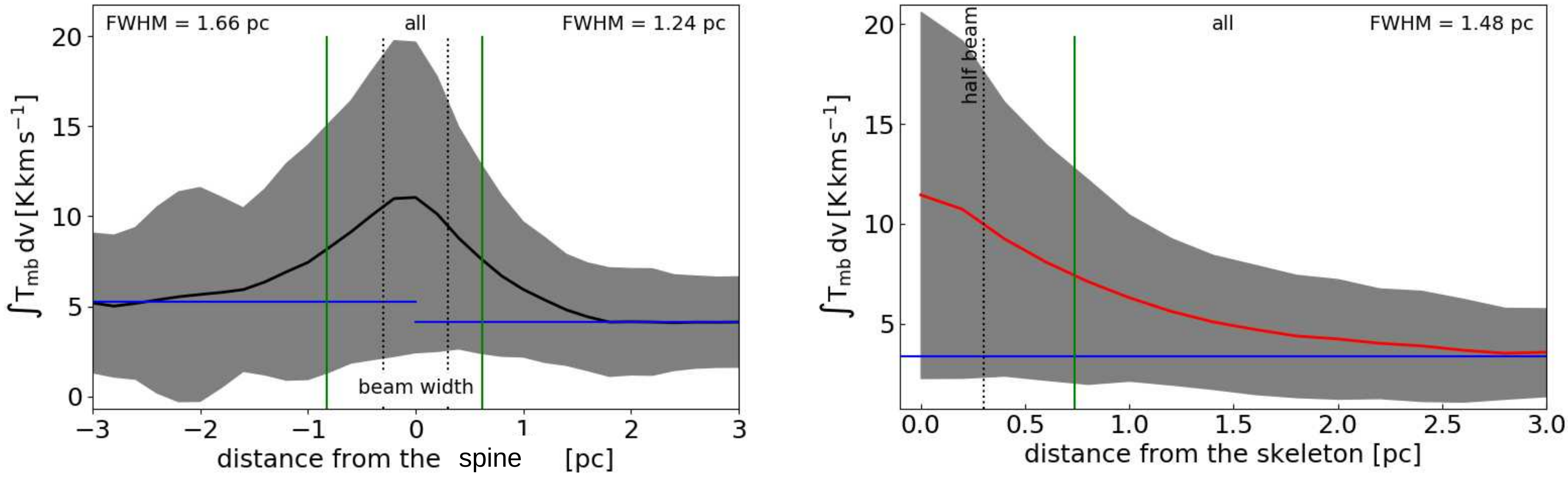
Cloud
e.g. Duarte-Cabral+2020

Skeleton
e.g. Mattern+2018b

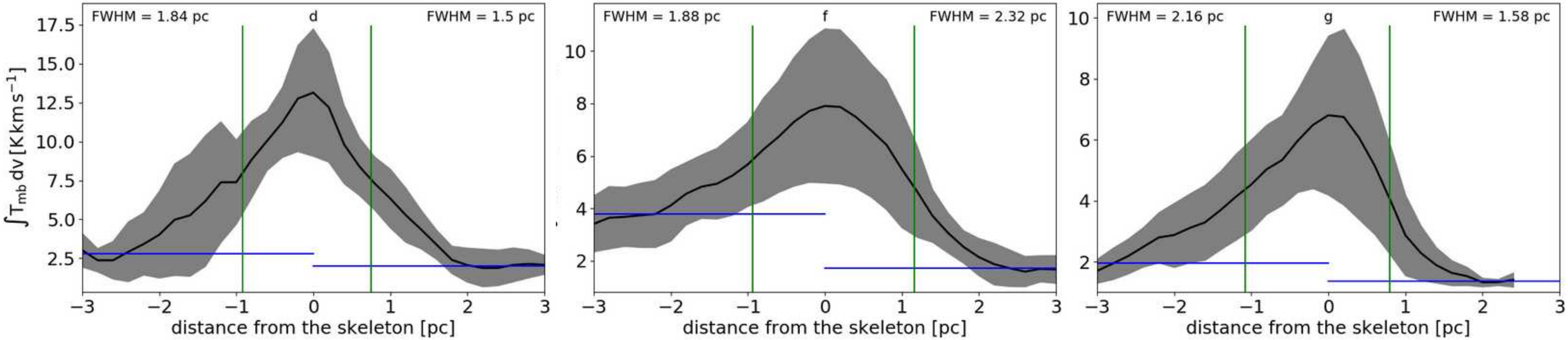
Spine
e.g. Arzoumanian+2019



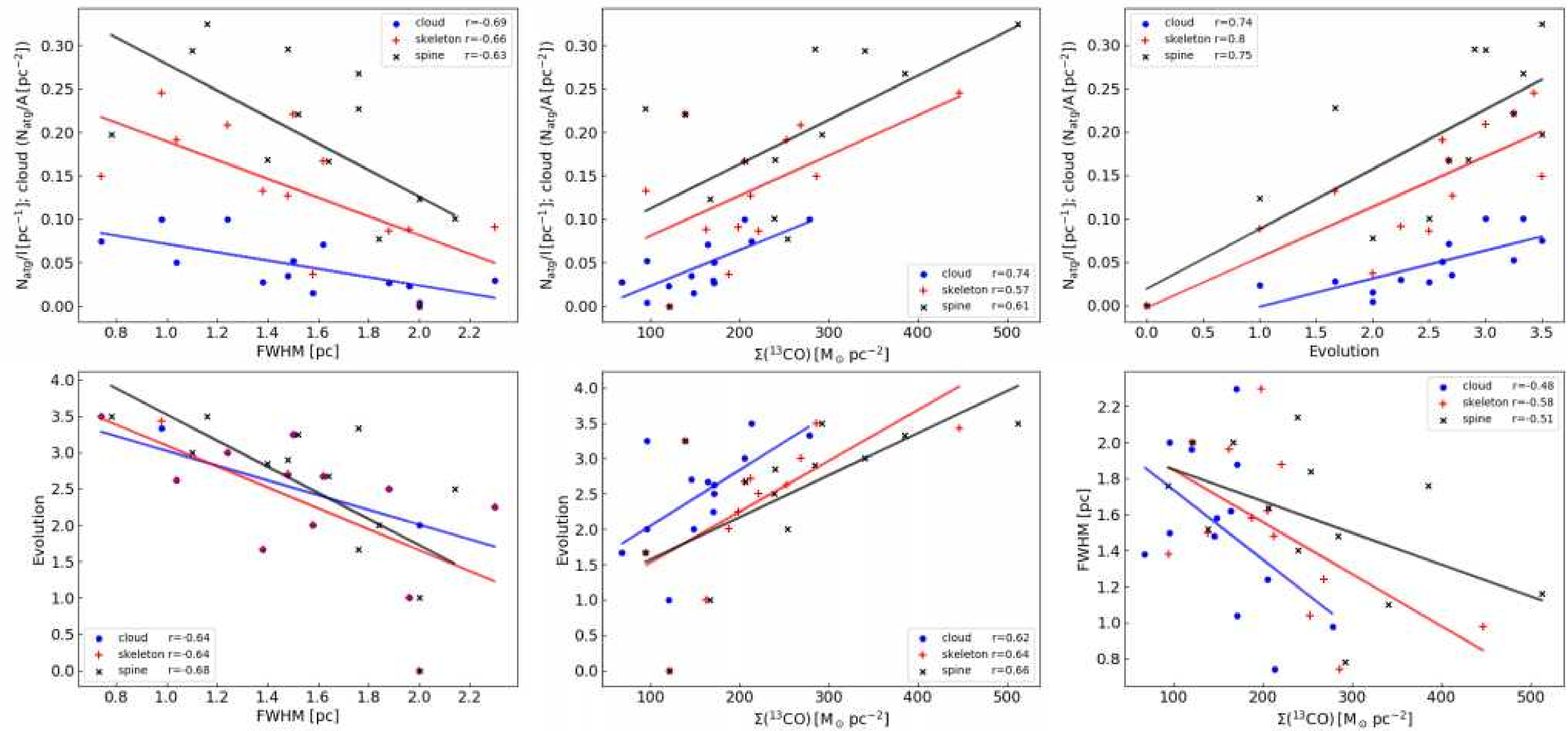
Profiles



FWHM estimates based on the mean intensity per distance bin.



Correlation of parameter



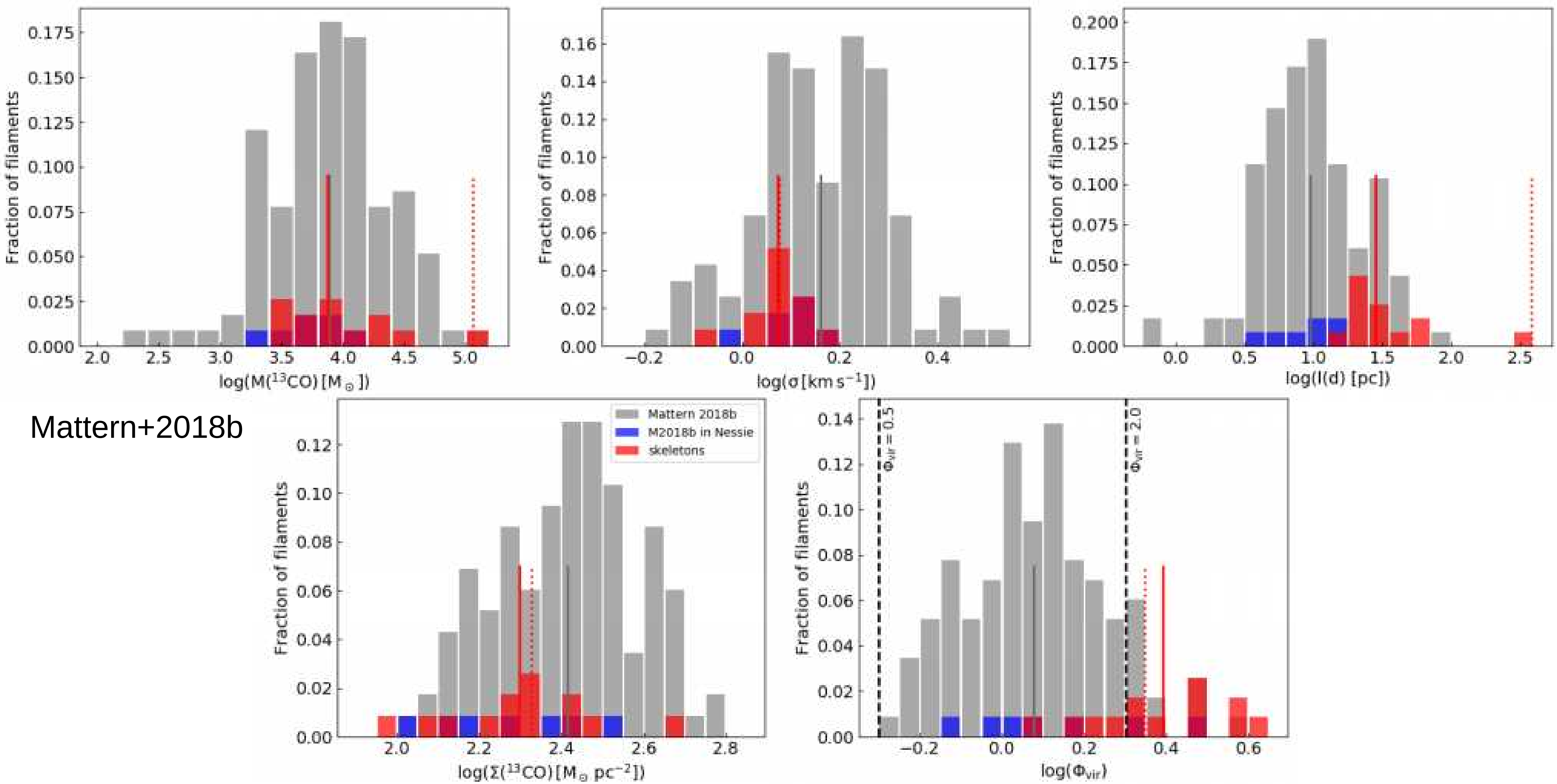
Higher surface density – lower FWHM

↓

more ATLASGAL clumps – more evolved clumps

Low number statistics

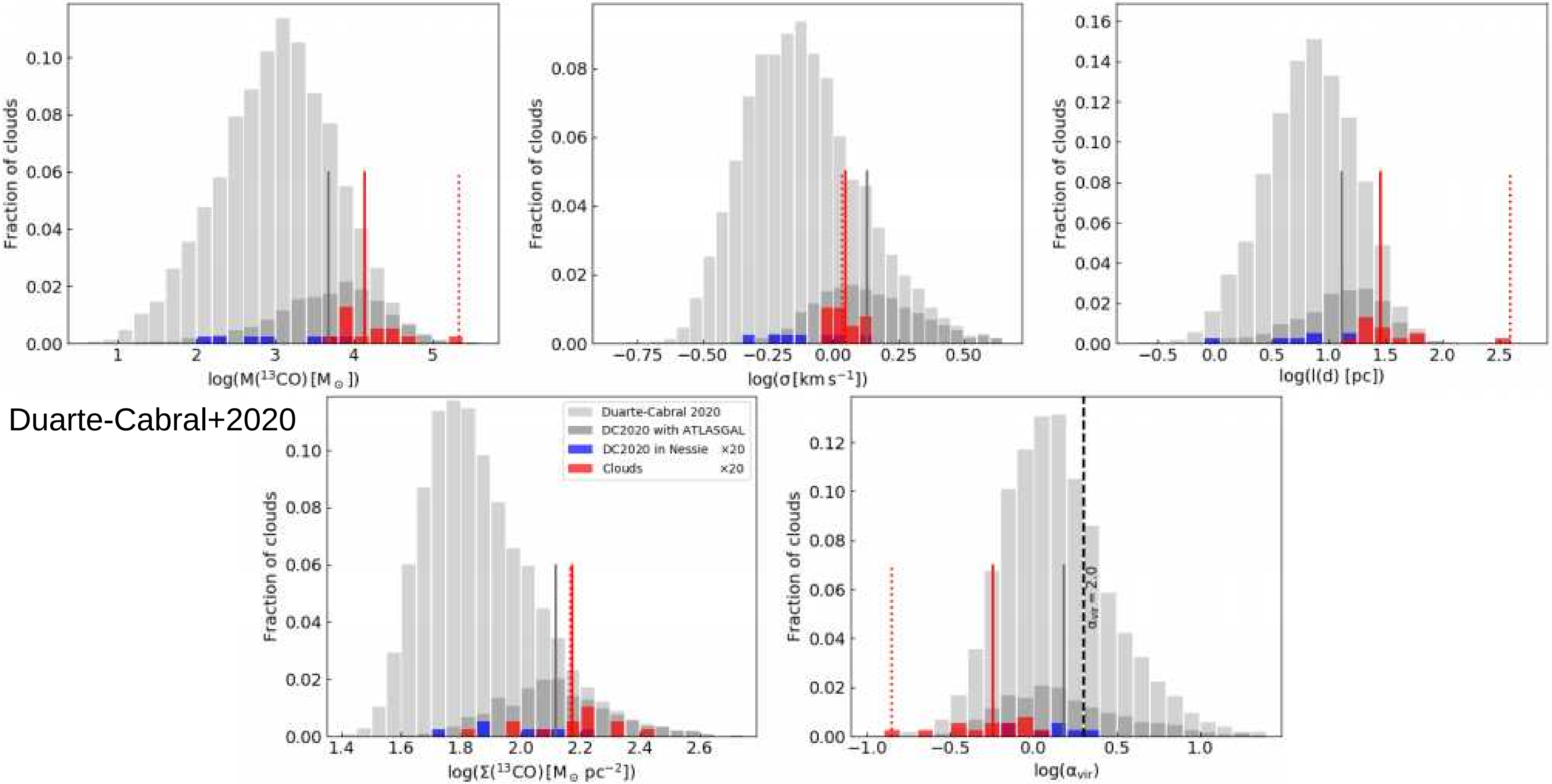
Comparison with ATLASGAL filaments



Mattern+2018b

Nessie parts are similar to Galactic filaments, but **not all are gravitationally bound.**

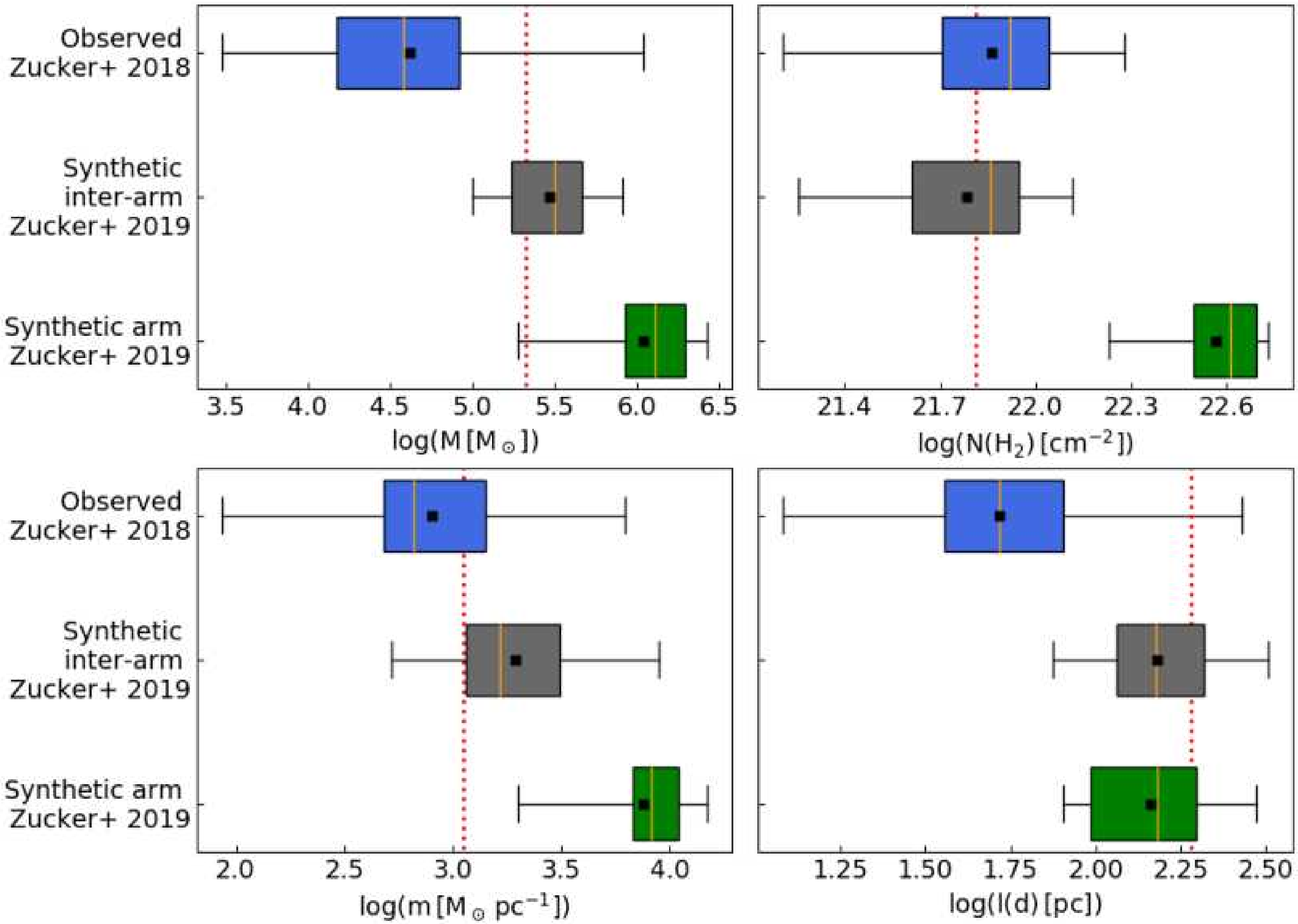
Comparison with SEDIGISM clouds



Duarte-Cabral+2020

Nessie parts are similar to Galactic clouds with ATLSGAL clumps, and **gravitationally bound**.

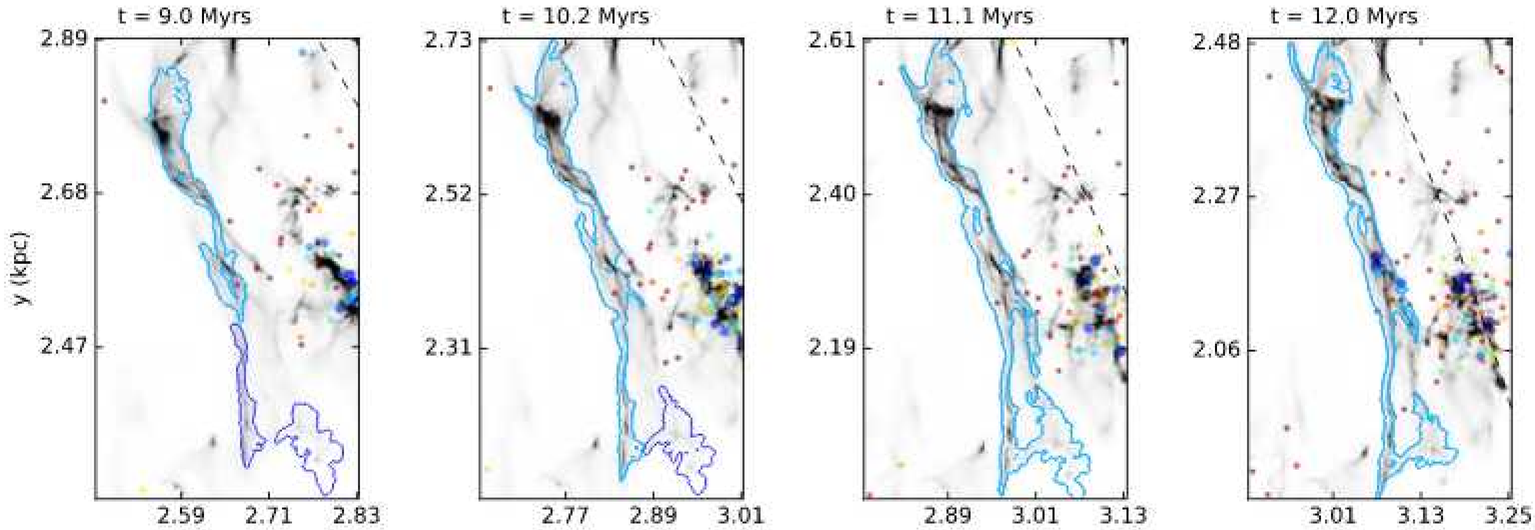
Comparison with large filaments



Nessie is one of the longest and most massive large filaments.

Nessie is similar to synthetic inter-arm filaments

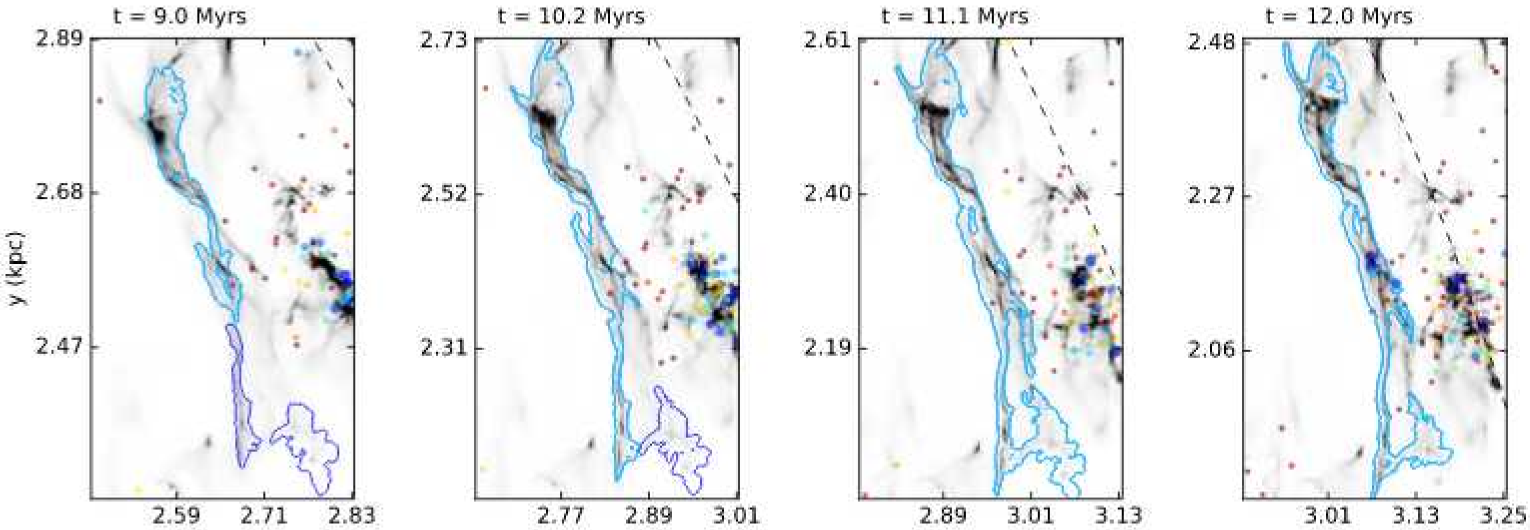
Simulations



Duarte-Cabral & Dobbs 2017 studied the evolution of giant molecular filaments:

- Giant filaments form only in the inter-arm region from gas clouds entering the shear-dominated region.
- They become more well defined and aligned with the arm when approaching the arm potential
- They are rather pressure confined than gravitationally bound as a whole
- Star formation takes place in local high density regions.
- They get broken by stellar feedback or differential forces

Simulations



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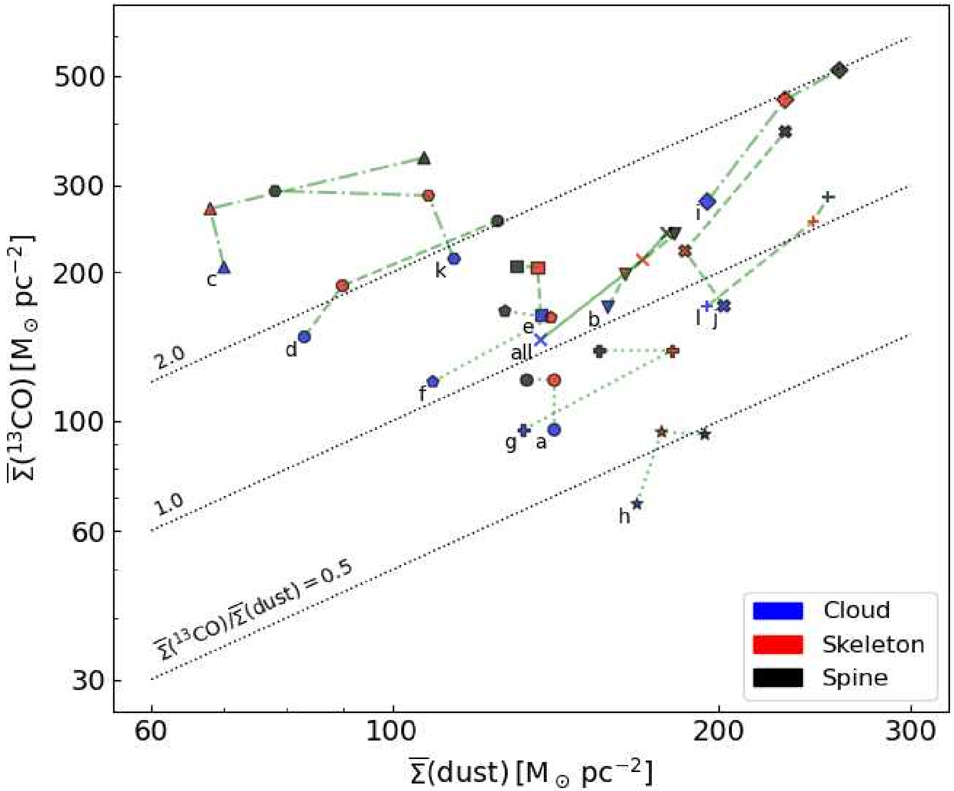
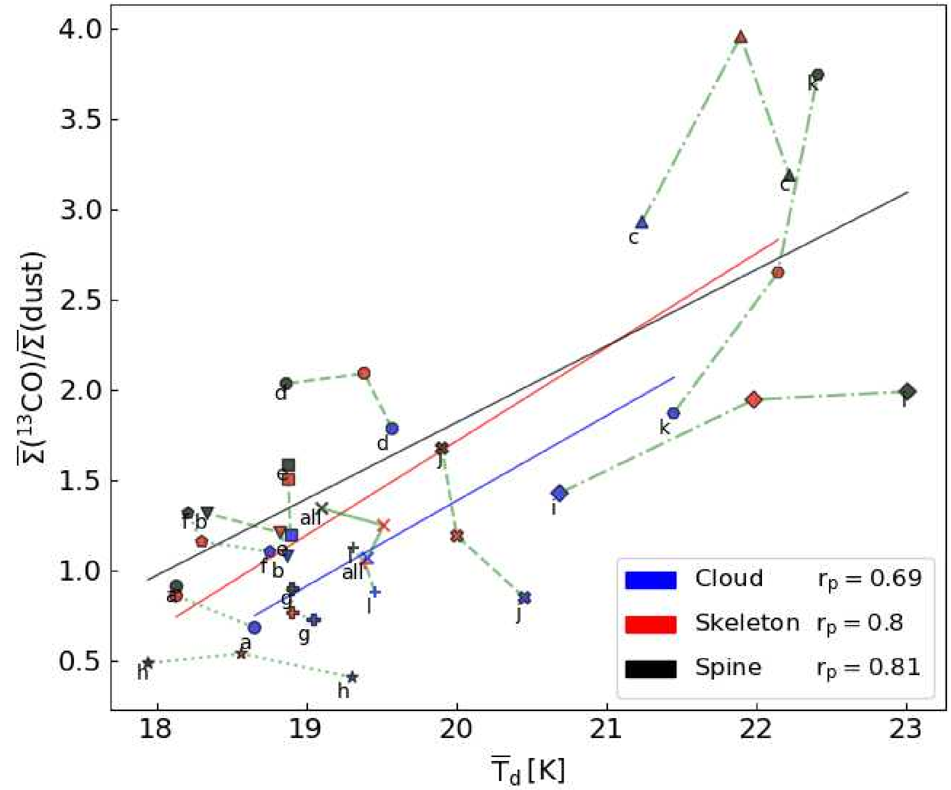
- They get **broken by stellar feedback** or differential forces

If Nessie is not in the spiral arm, where is the spiral arm?

Dust continuum versus ^{13}CO





Summary 2

The extended Nessie filament is:

- At a distance of ~3.1 kpc with an inclination close to 0 deg
- Continuous in position-position-velocity space, ~190 pc long, ~9 pc wide
- An inter-arm cloud, located close to the Scutum-Centaurus spiral arm?
- Only marginally gravitatinally bound, but substructures are
- Actively star- forming as traced by massive, possibly high-mass star-forming, clumps
- About to be dispersed by feedback

Star formation correlates with the gas (surface) density, but not line-mass (low sample)

Nessie follows the evolution described in Duarte-Cabral & Dobbs 2017