Background: Column Density Map from Herschel Observation of Galactic Plane
Hi-GAL project - field centered at (l,b))=(224° ,0°)

Filamentary Structures in the Galactic Plane

Morphology, Physical conditions and relation with star formation

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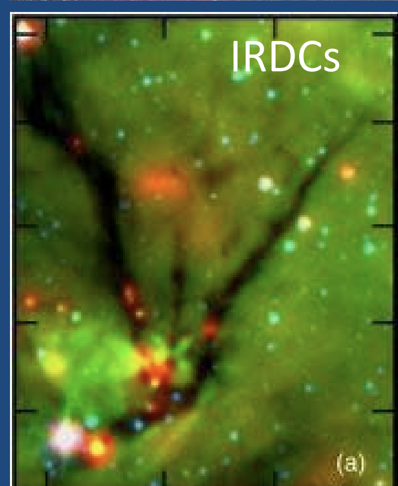
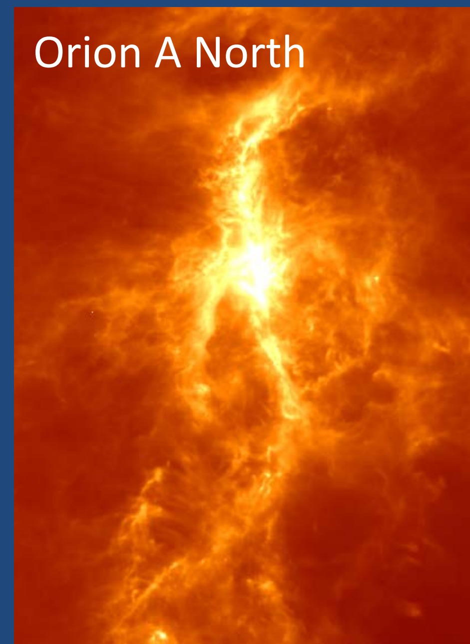
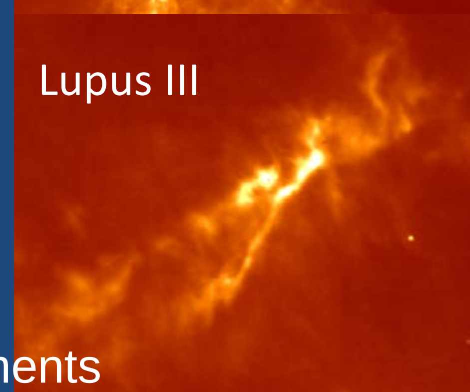
Observations

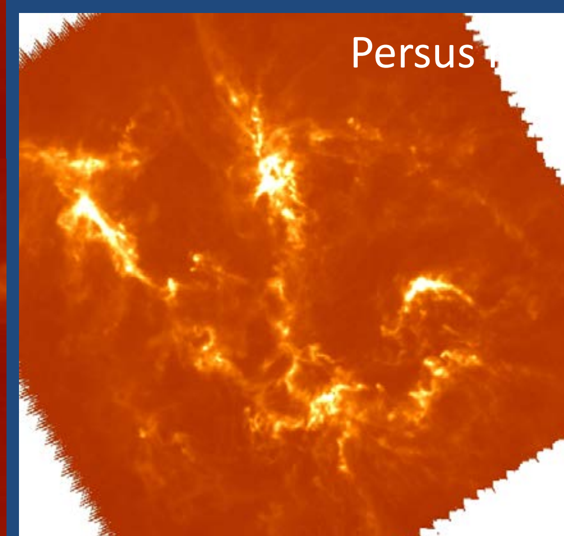
Observations show that gas and dust in <u>star forming molecular clouds</u> (SFMCs) are often arranged in a filamentary pattern.







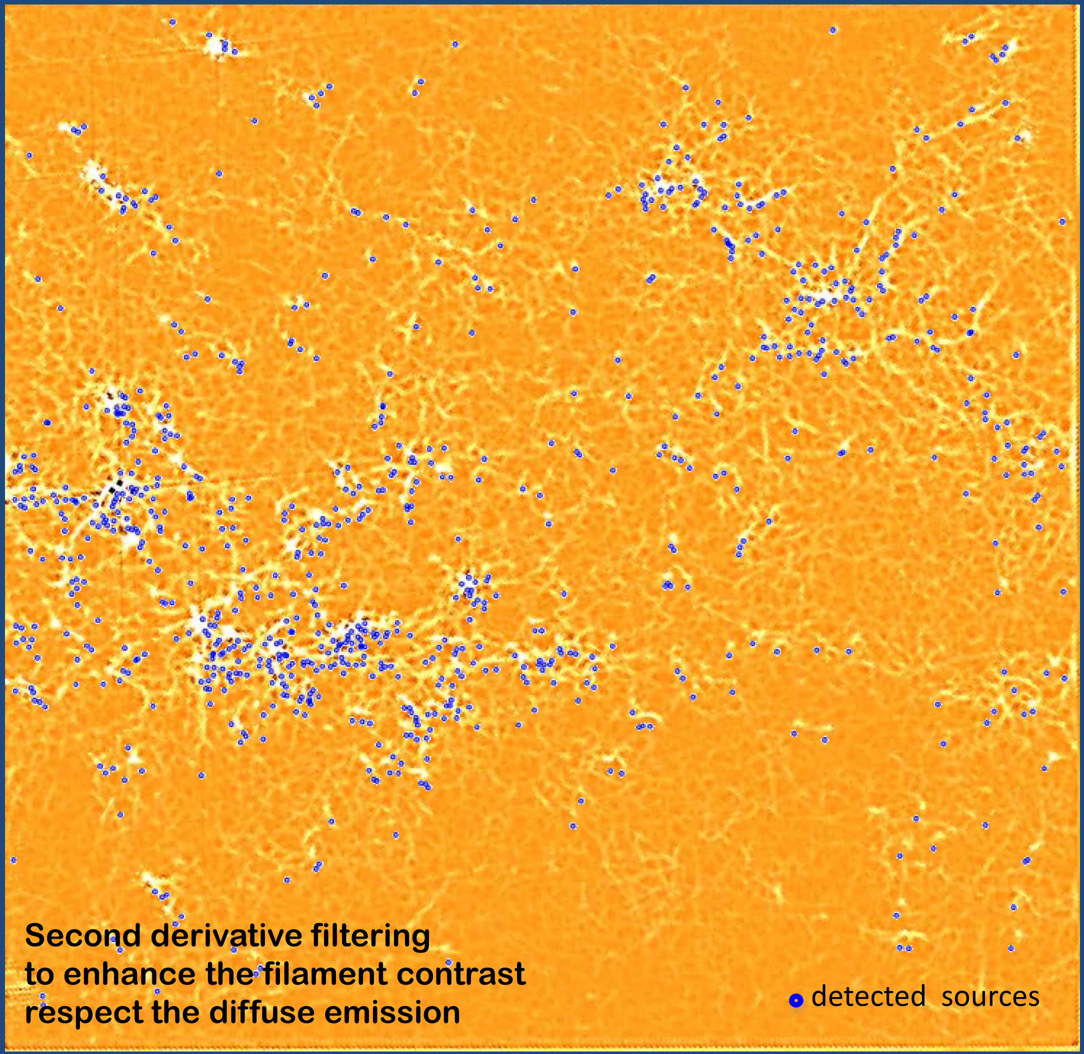
Network of filaments



Optical data
NIR data
MIR data
FIR/Submm

Few well defined filaments

Herschel shown that filaments are found everywhere and not only in the SFMCs. Typical structure of the cold phase of ISM.



2° x2° map of the Galactic Plane centered at l=59° ($\lambda = 250$ µm) observed with Herschel in the framework of the Hi-GAL survey. (Molinari et al. 2010)

Evidence: Clumps and cores are associated with the filamentary pattern. (Andre' et al. 2010, Molinari et al. 2010)

Filamentary structures have a key-role in the process that concentrate the material from the diffuse ISM.

To understand the physical process underneath it is necessary to study a statistical sample of filaments in different enviroments.

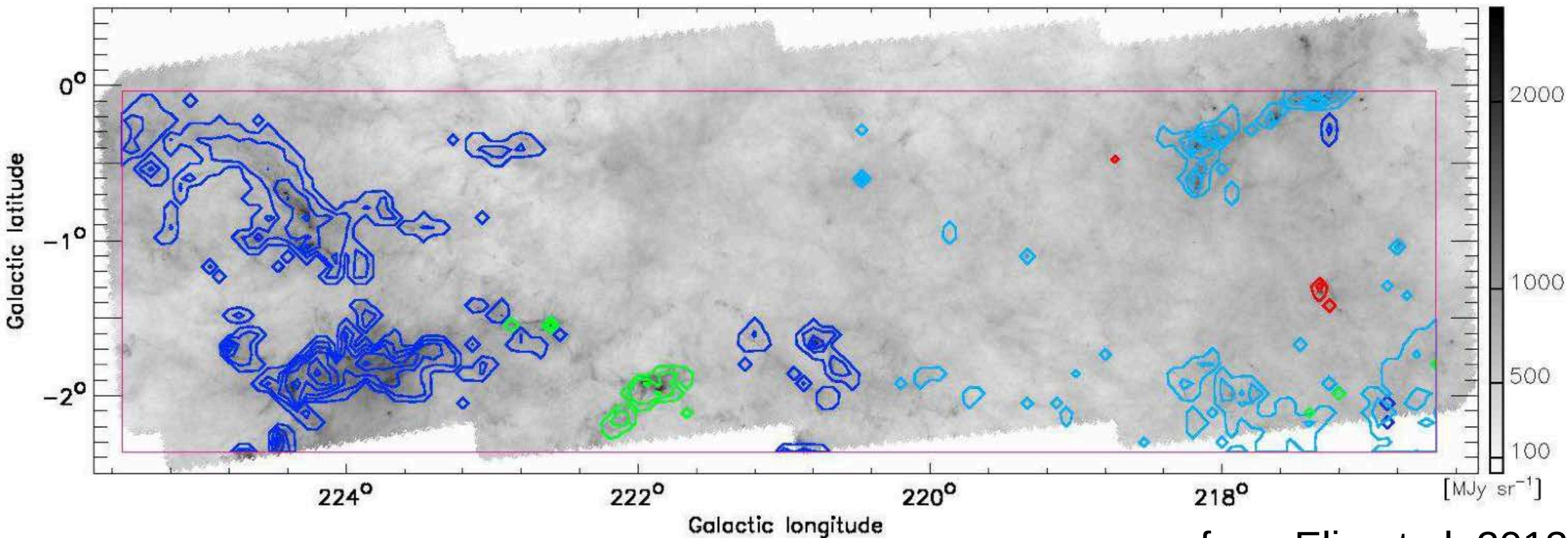
One of the goal of VIALACTEA project is to use the Hi-GAL survey to build up an unbiased catalog of filamentary structures in the GP to determine:

Morphological Properties (length, width, aspect ratio, distribution) linked to the filament formation process (sweeping/compression of matter, slab fragmentation etc).

Physical Properties (mass, mass per unit length, temperature, column density, radial profile, degree of concentration)
Comparison with filament models (Ostriker et al. 1964, Fiege et al. 2000,2004, Fishera & Martin 2012)

Correlation with the embedded source properties
(shapes, elongation, multiplicity, reciprocal distances – scales of filament fragmentation, masses, evolutionary stage)

SPIRE map @ 250 µm



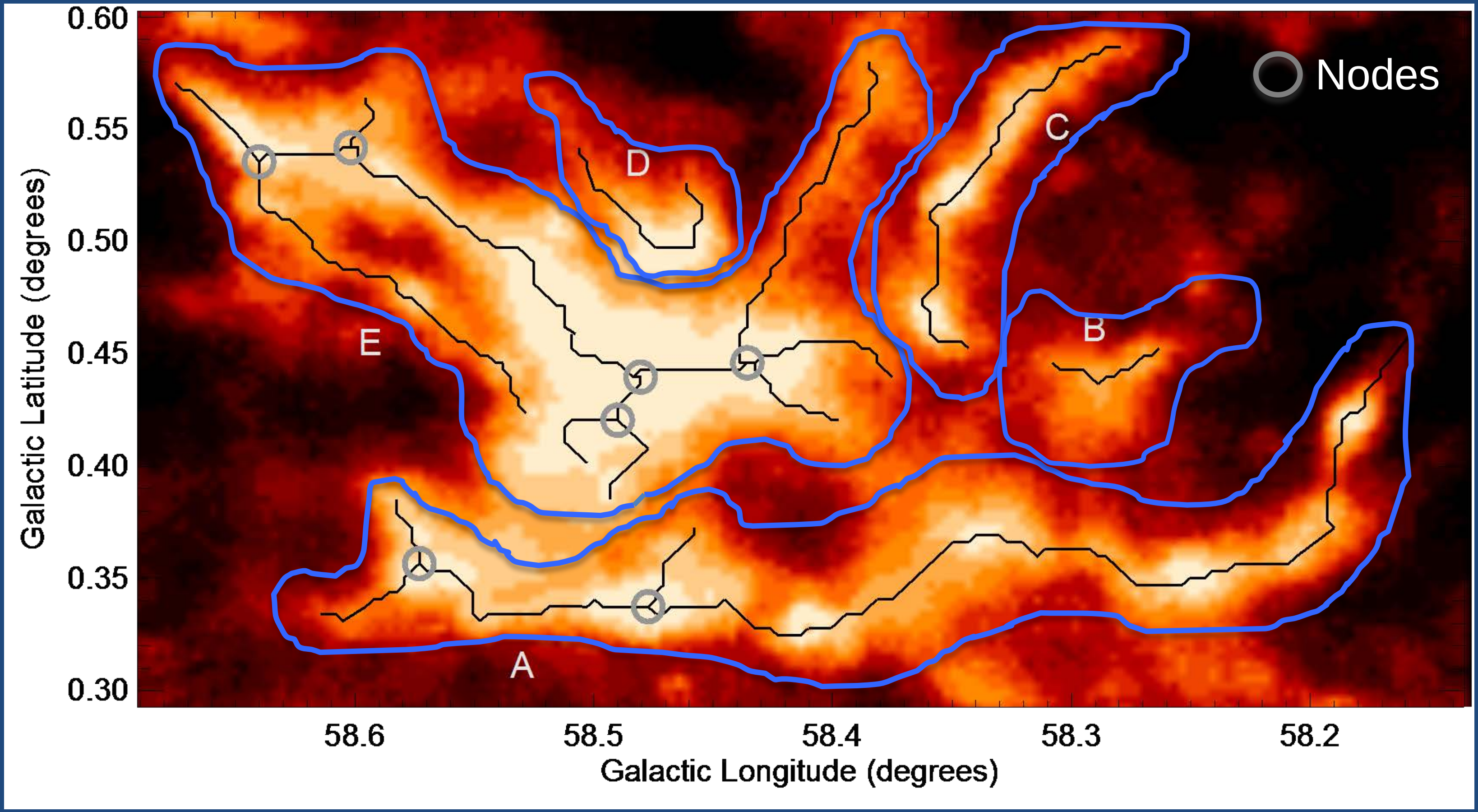
from Elia et al. 2013

3° quadrant data – region from l = 216.5° to 225.5°

Contours from NANTEN CO(1-0) data (Mizuno & Fukui 2004).

Component	Color	Integrated Channels	Distance (Kpc)	% of emission
I	Blue	$-0.5 < v_{lsr} < 21.5$	1.1	69.2
II	Cyan	$21.5 < v_{lsr} < 36.5$	2.2	26.2
III	Green	$36.5 < v_{lsr} < 45.5$	3.3	4.5
IV	Red	$45.5 < v_{lsr} < 65.5$	5.8	0.4

Filament - Definition



We define as filament any extended feature covering a portion of the 2D map with an elongated, cylinder-like, shape with a relatively higher brightness contrast respect its surrounding. We filter out small regions (shorted than 3 times the beam)

Filament = One single region - (Global)

Branch = Single segment and portion of the filament (Local)

Identifying Filaments

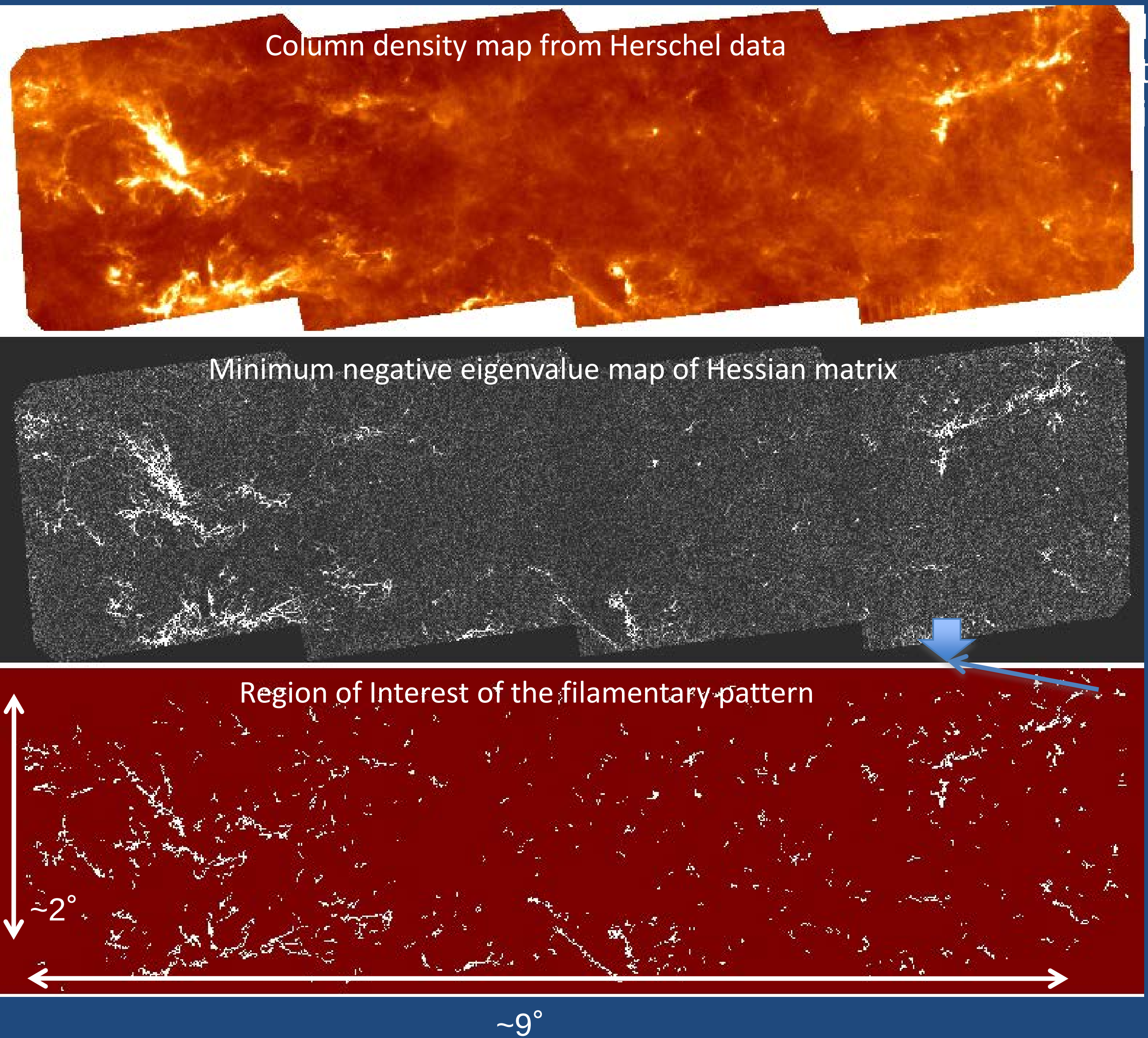
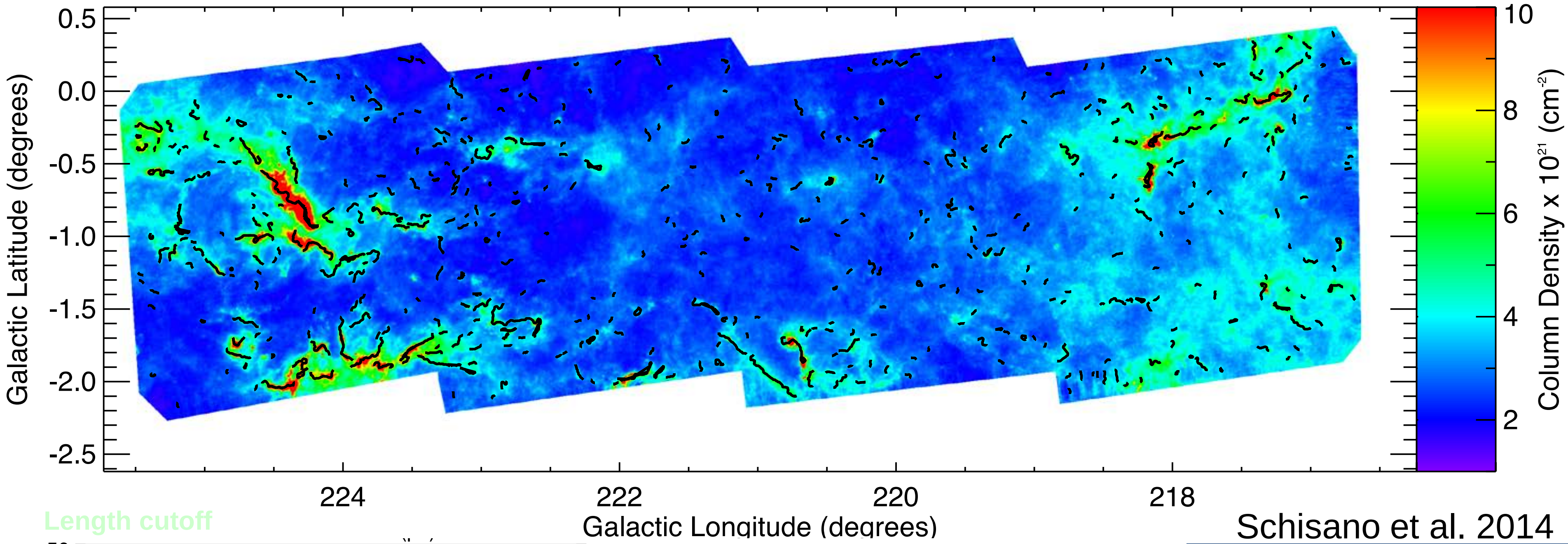


Image processing techniques to trace filamentary structures in an automatic, unbiased way.

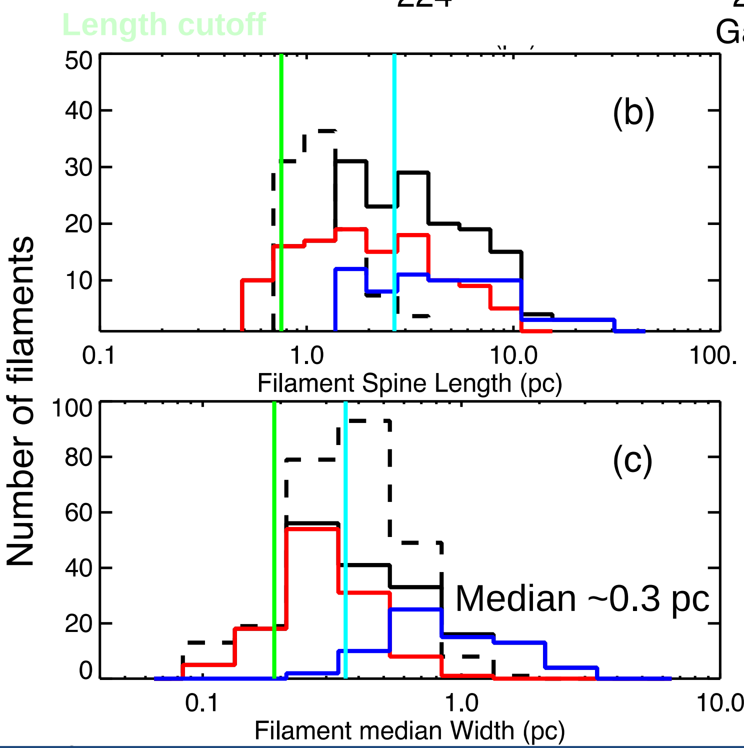
We compute the Hessian matrix and its eigenvalues to classify pixels on the basis of how cylinder-like is the local intensity distribution.

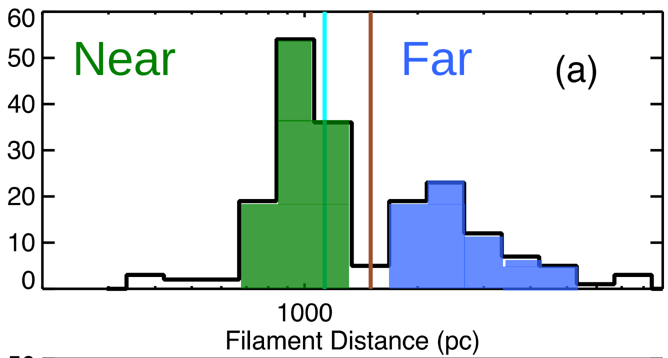
Thresholding and morpho-logical operators analysis.

Schisano et al. 2014



Schisano et al. 2014





Red - near filaments

Blue - far filaments

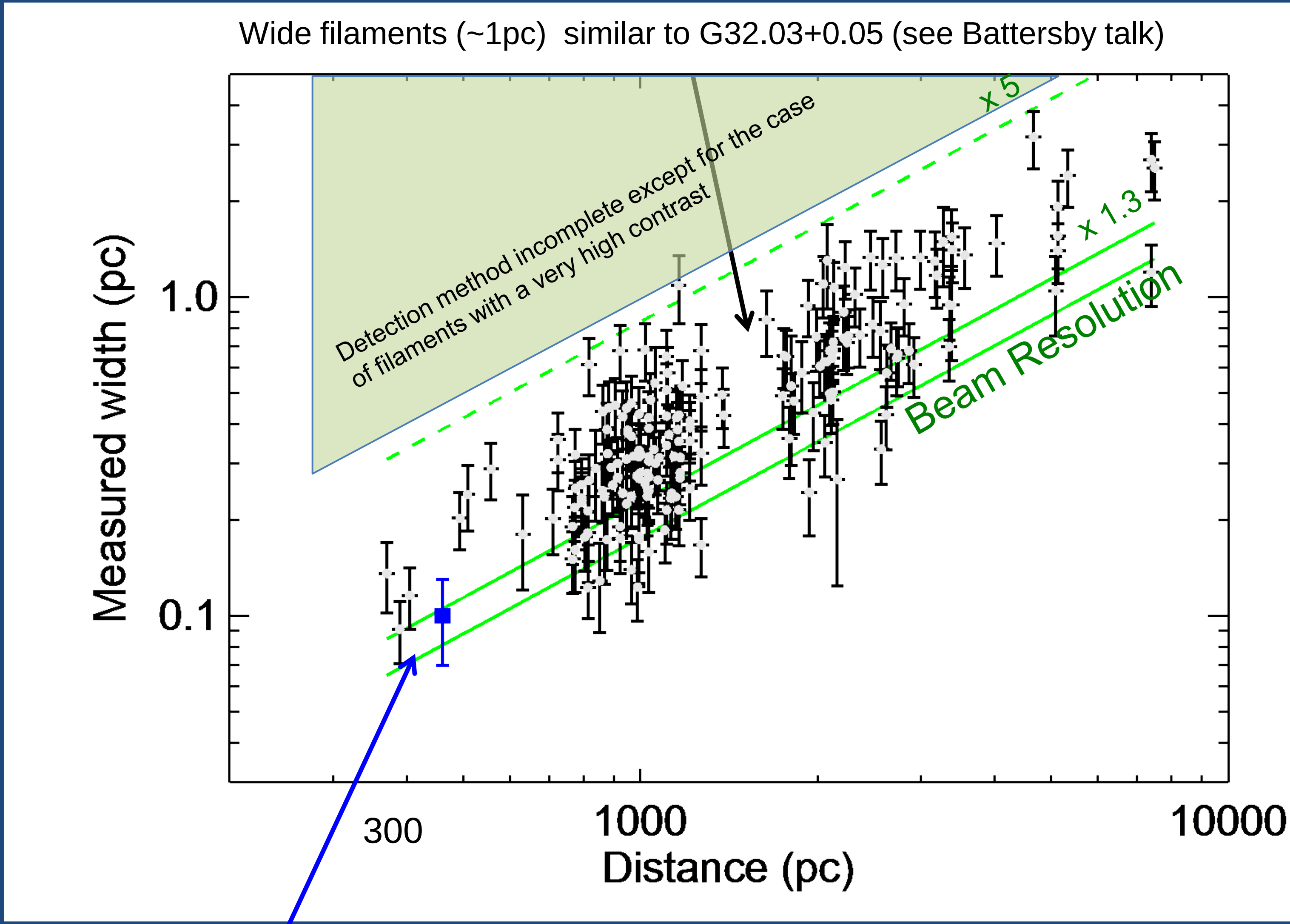
We identify ~500 filaments in the field and ~2000 branches.

Distances through spatial association with clumps and radial velocity measurements from NANTEN CO (1-0) data (Elia et al 2013, data Mizuno & Fukui 2004) possible for ~40% of detected filaments(lack sensitivity and coverage in CO data).

Beam resolution @ 1.1 kpc

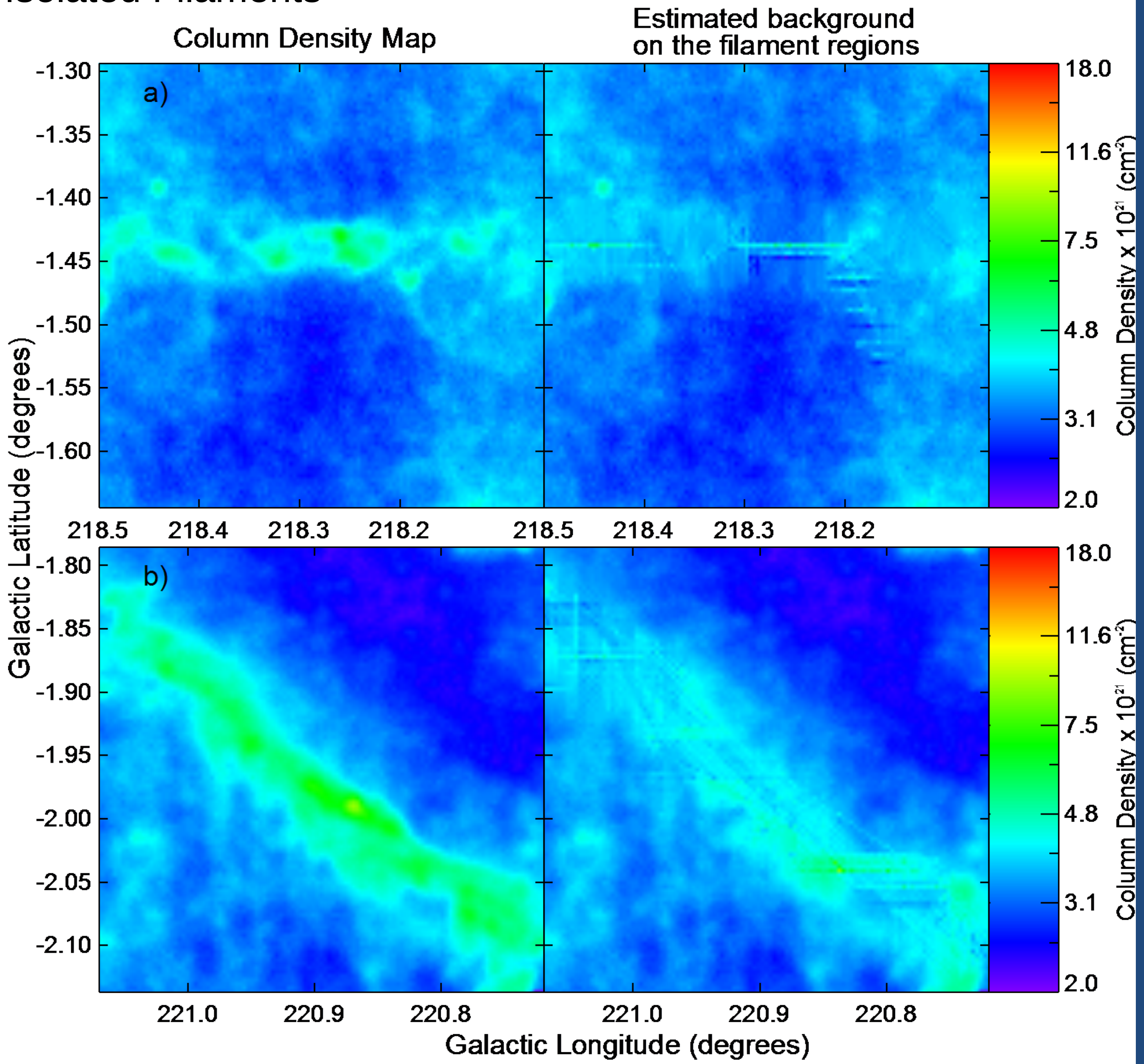
Widths estimated as FWHM of the Gaussian fit to radial profile

Filaments on different scales

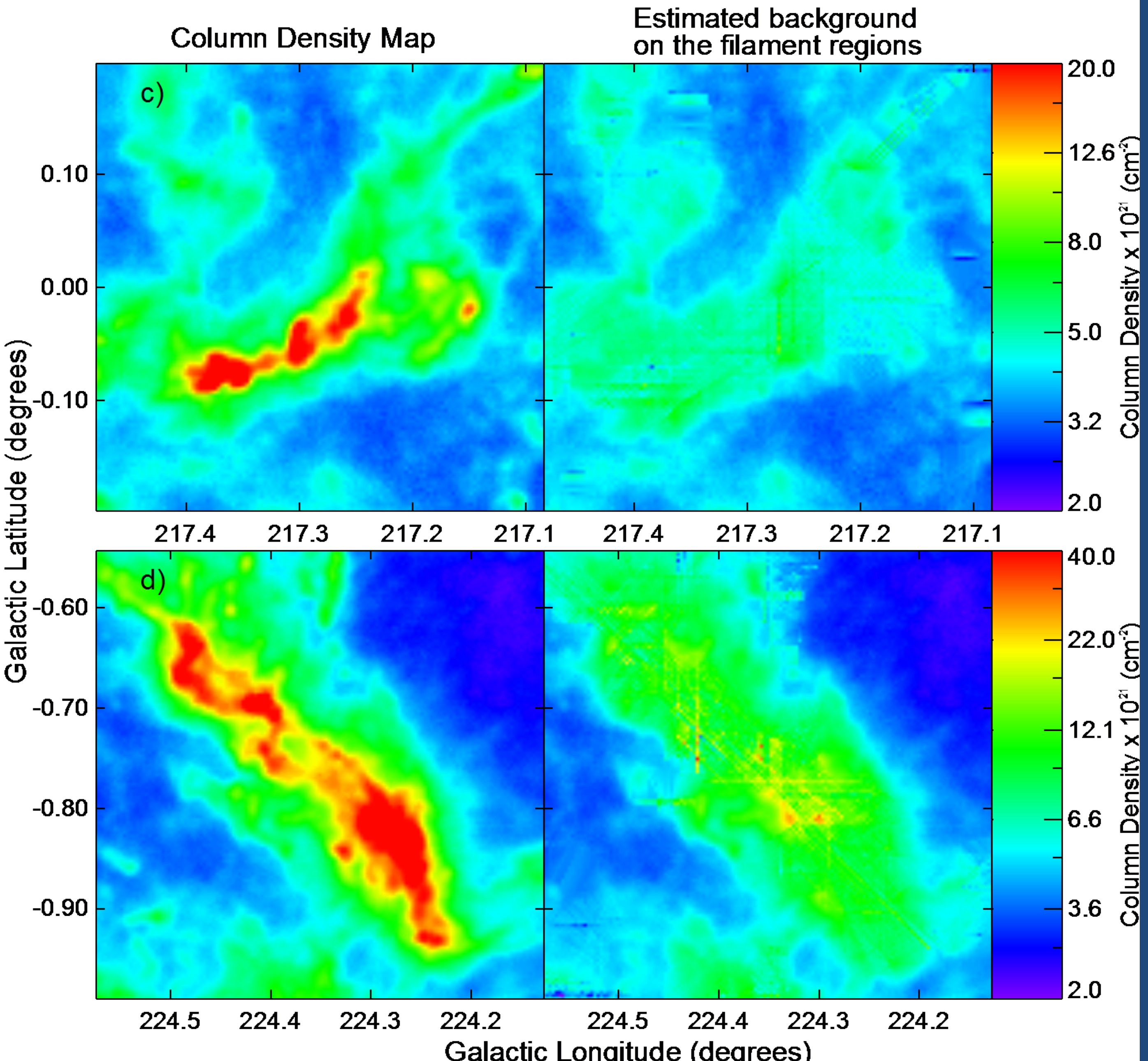


IC 5146 (Arzoumanian et al. 2011) d = 460 pc

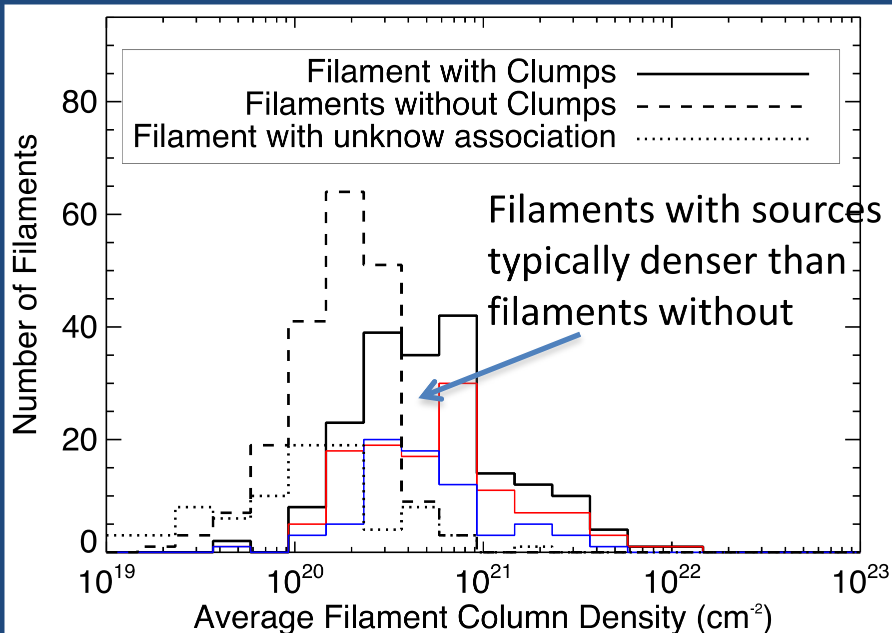
Isolated Filaments

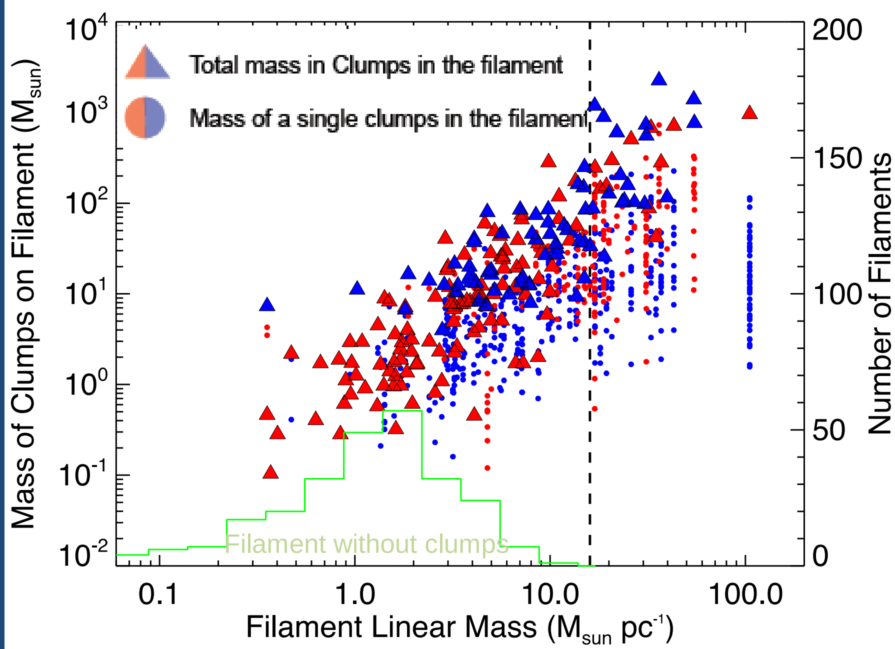


Filaments embedded in dense enviroment



Filaments and Star Formation (Global region)





~74% of the compact sources identified in the field lies within the borders of a filament.

Differentiation between filaments hosting sources (generally embedded) and filaments lacking of them (generally isolated).

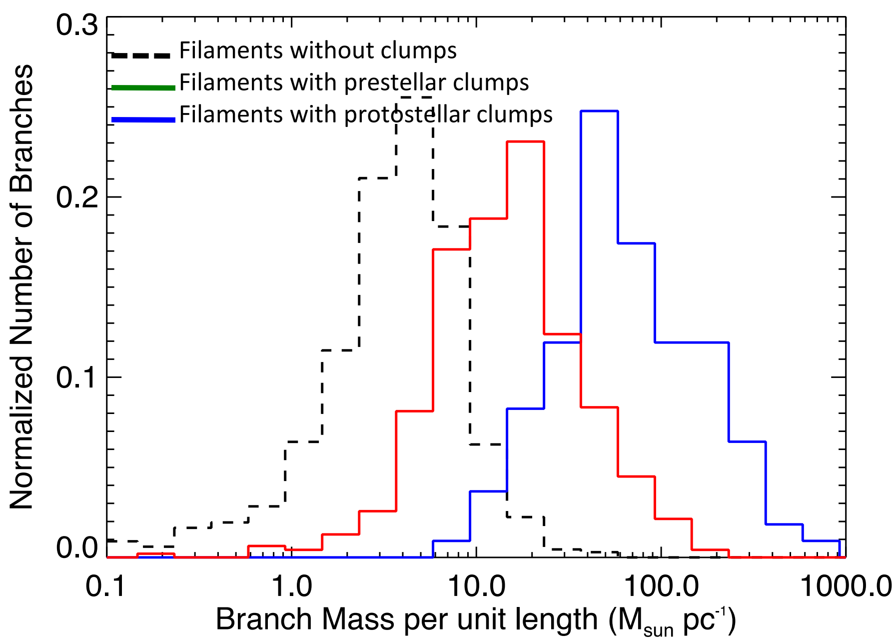
50% of detected filaments do not host compact sources

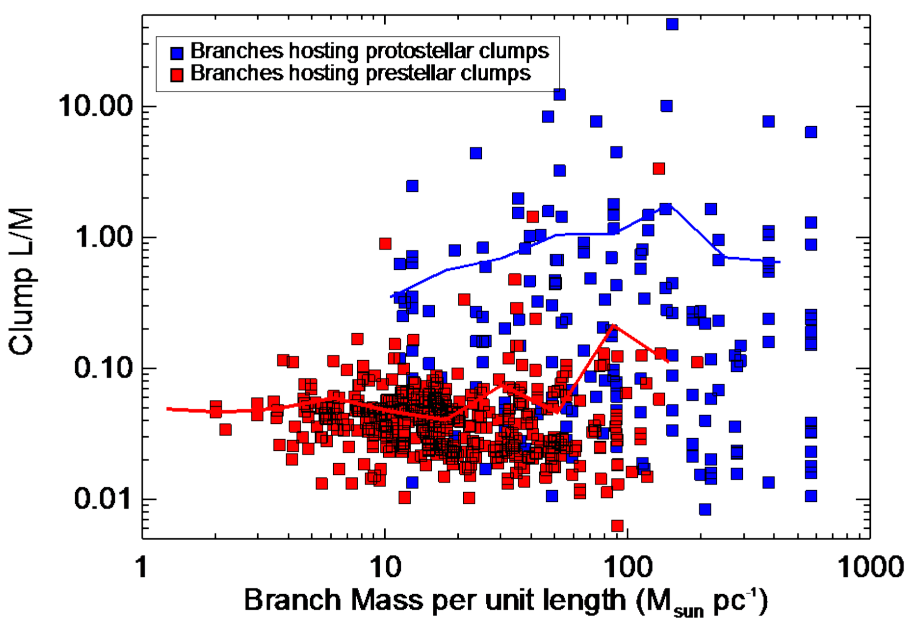
Red - near filaments
Blue - far filaments

Mass per unit length estimated as average column density in the whole filaments times the mean width, formally correct for the case of straight filaments without variations along the spine and constant width.

Filaments embedded in dense enviroment have uncertainty on the total mass.

Filaments and Star Formation (Local region - Branches)





Classification of the branches based on the most evolved object found within.

The branches hosting protostellar clumps (detection at 21 and 70 μm) are locally unstable against gravity even if the overall structure might be potentially subcritical.

Red – With only prestellar clumps
Blue – With protostellar clumps

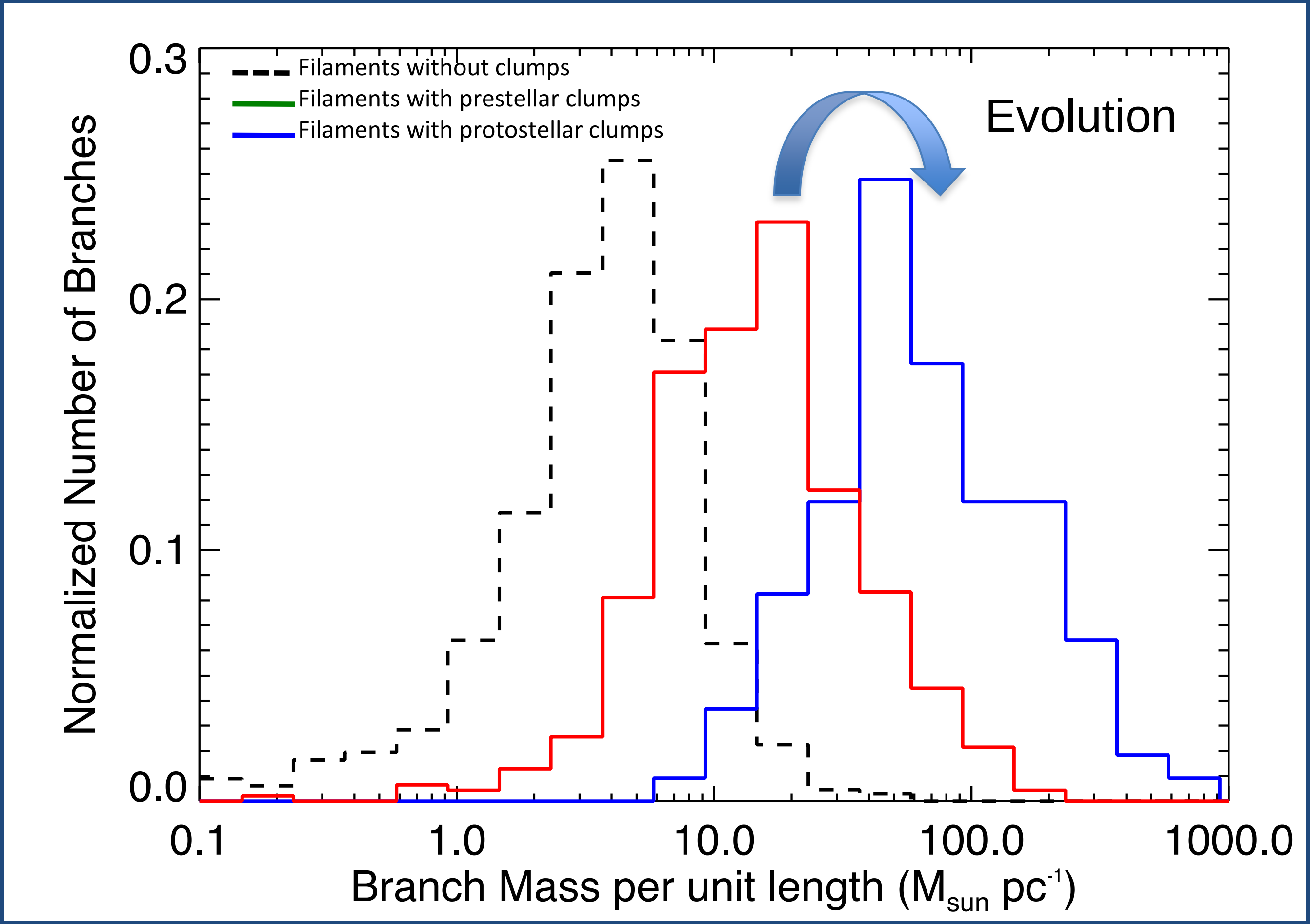
Two scenarios:

-) the increase in mass per unit length is due to the evolution
(filament accretion or contraction)

-) the branches with higher mass per unit length have a higher star formation rate.

Median L/M ratio higher in branches hosting at least one protostellar clump.

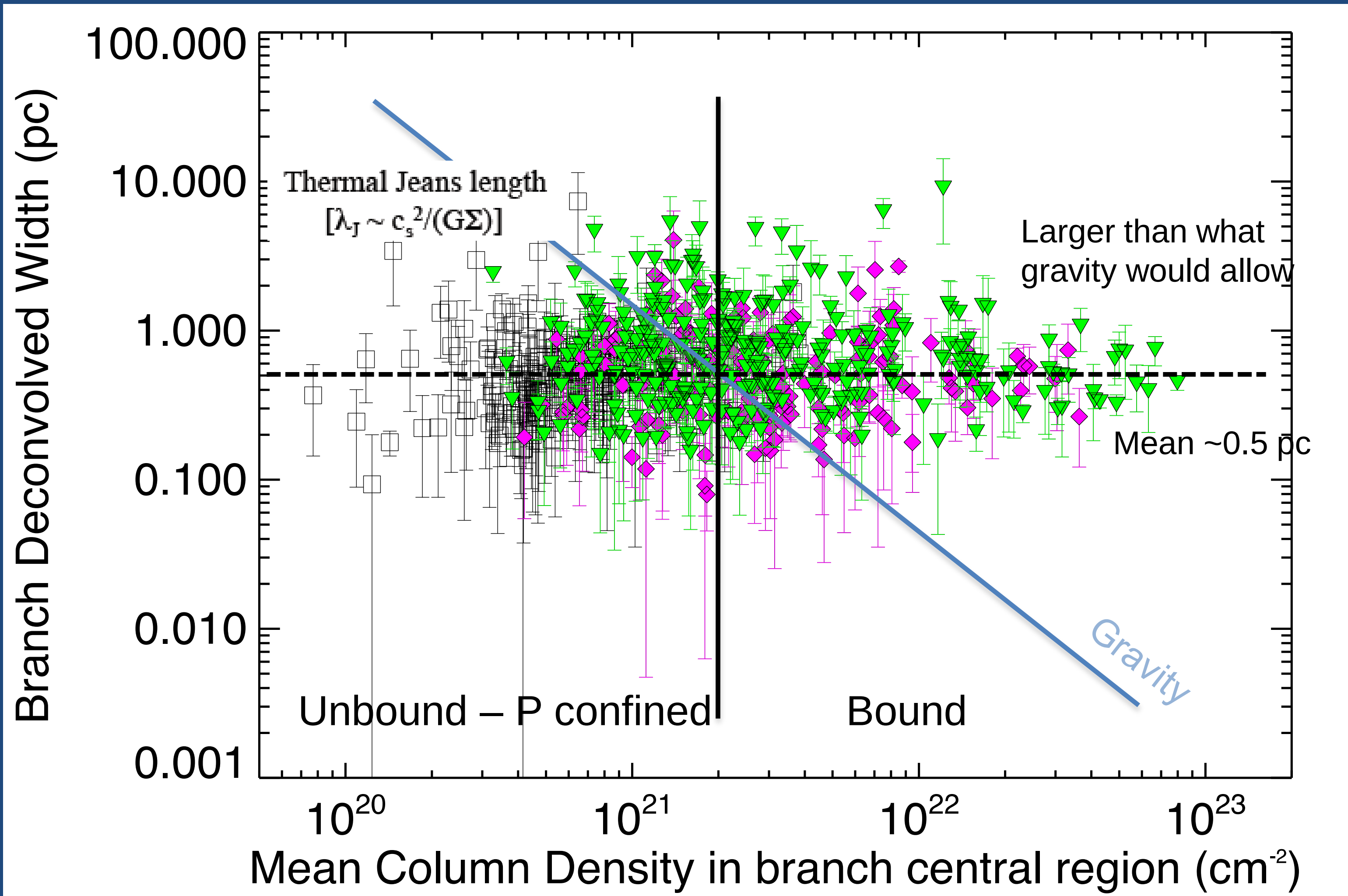
Filaments and Star Formation (Local region - Branches)



Fast formation of the filaments with the elongated structure and at least some initial seeds are formed at the same time.

Moderate accretion rates needed ~10^{-4} Msun pc^{-1} yr^{-1} from the data.

Like in Arzoumanian et al. 2011



□ Filaments without clumps $N^c_H \sim 10^{20} - 2 \times 10^{21}$ cm^{-2}

◇ ▽ Branches with clumps Average N^c_H (excl. overdensities) ~ $7 \times 10^{20} - 8 \times 10^{22}$ cm^{-2}

Summary

Filaments are found everywhere in the Galaxy. Not all the filament are the same!

We identify structures based on their appearance on the 2D map integrated along the line of sight. tracing in such a way very different types of filaments in the portion of the Galactic Plane between $216.5^\circ < l < 225.5^\circ$.

Most of the clumps (74% of the sample) identified in the region fall within the border of filaments.

Their lengths ranges between ~ 1 pc up to ~30 pc, widths between 0.1 pc and 2.5 pc and average column density between 10^{20} cm^{-2} and 10^{22} cm^{-2}.

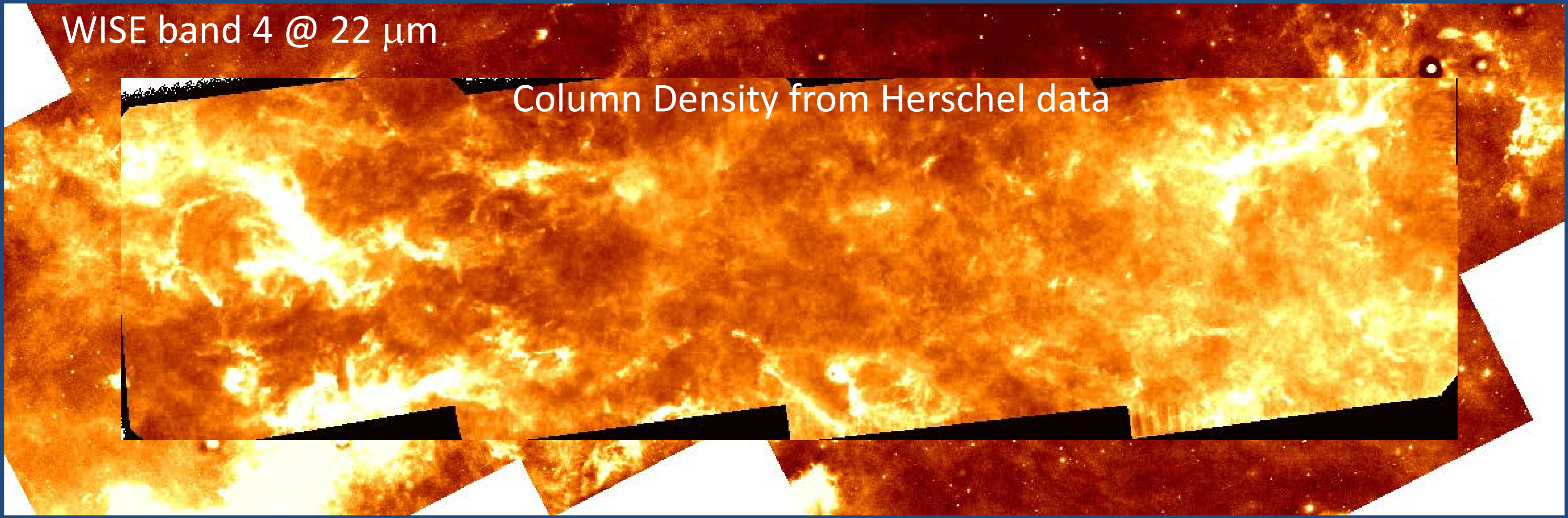
Filaments are founded isolated or embedded in dense enviroments. The embedded filaments have larger linear densities and average column densities. They are mostly associated with presence of clumps. Isolated filaments might have or not clumps, the one without clumps have always linear densities lower than the expected critical one.

Filaments with associated protostellar clumps are locally unstable against gravity even if the overall structure might be potentially subcritical.

We suggest that there is a fraction of initial seeds for the clumps are formed at the stage of the filament formation. The evolution of those seeds is decoupled from the evolution of the filaments at the early stages.

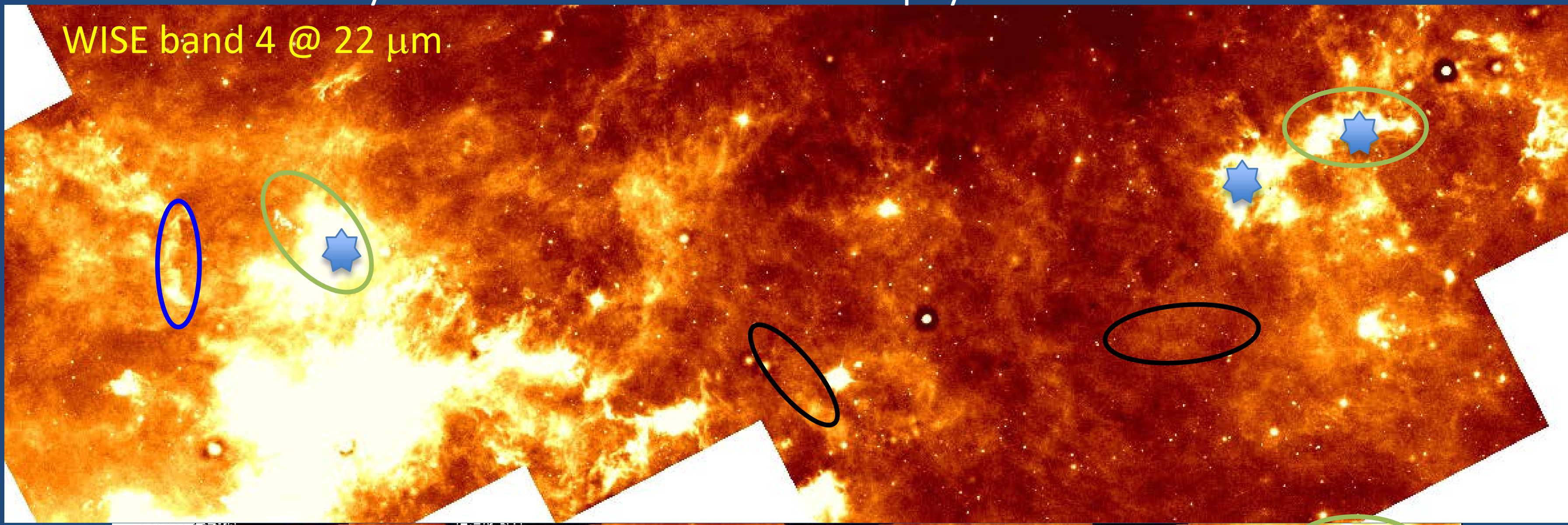
After their formation the filaments increase their linear densities (if possible) thought accretion from their enviroment.

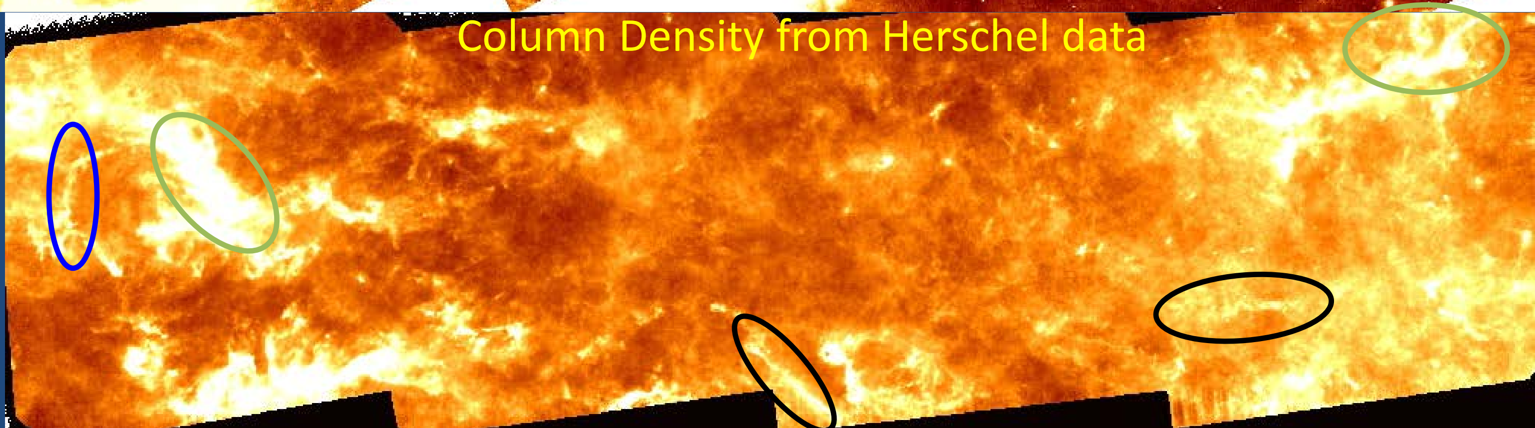
Importance of ancillary data – Mid Infrared



Importance of ancillary data – Mid Infrared

Is it possible to classify "filaments" based on further informations?
Are they all alike or is there a different physic on their formation?





Arc-like structure – line of sight effect of a 3D spherical shell / bubble (?)
Infrared Dark Clouds on a low emission background (Outer Galaxy)
Shocked region induced by HII region associate with the stellar cluster

Known stellar cluster