Galactic star formation with NIKA2 (GASTON): Quantifying filament convergence and its link to star formation

Nicolas Peretto, Andrew Rigby
Cardiff University, UK

And the GASTON team

On behalf of the NIKA2 collaboration

2nd of July 2021, Observing the millimeter Universe with the NIKA2 camera

Filaments and star formation

- Interstellar filaments are known to exist for a while

The snake nebula (B72)

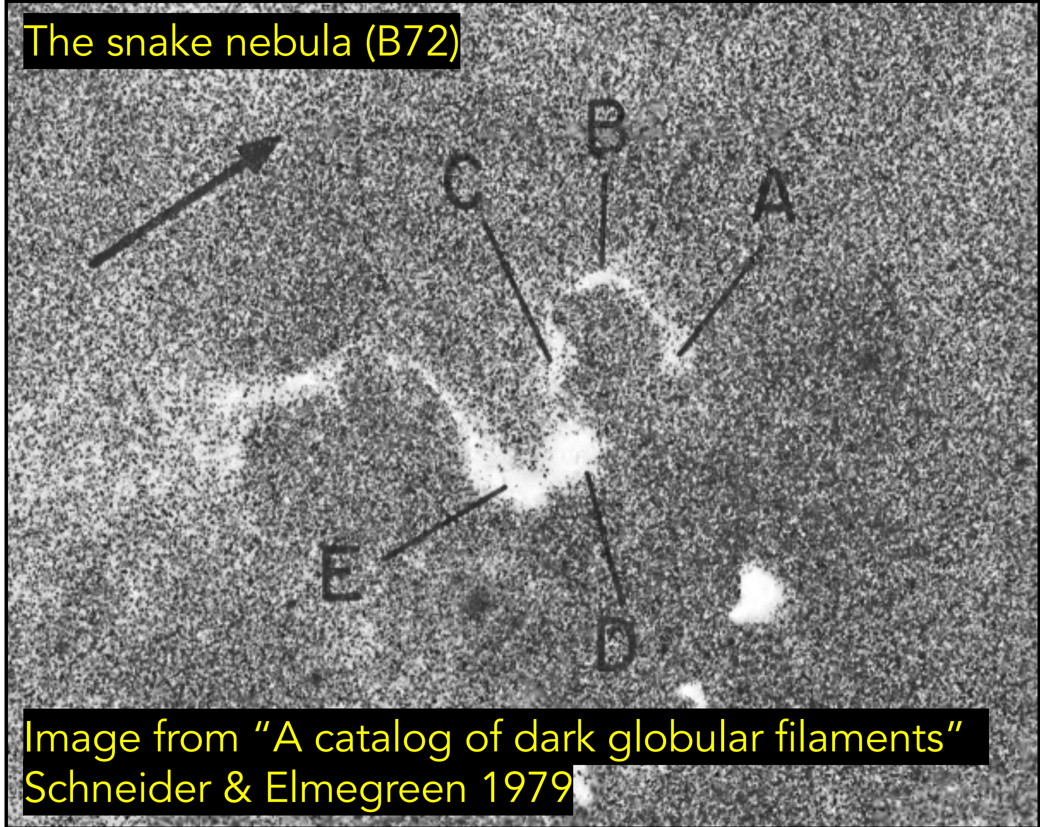


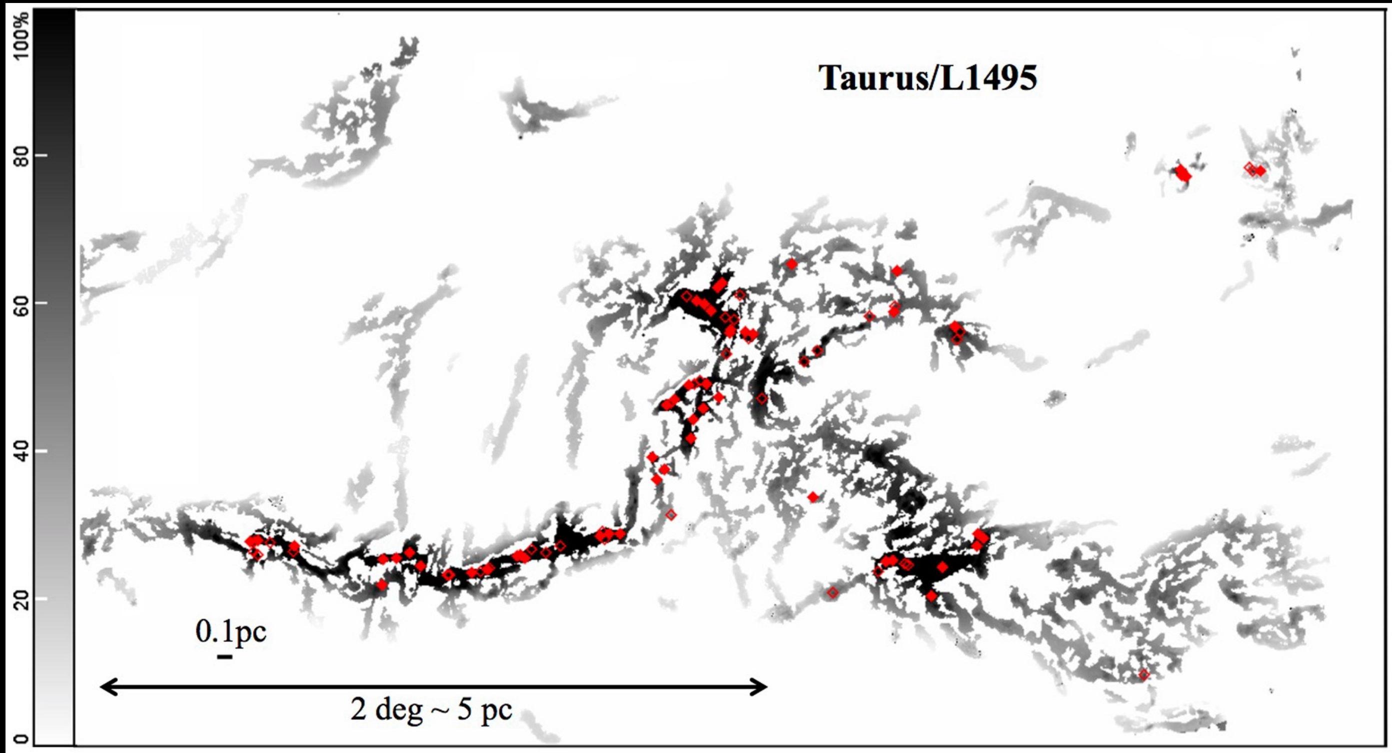
Image from "A catalog of dark globular filaments"
Schneider & Elmegreen 1979

- While already a link between filament fragmentation and dense "globules" was established, the link between such structures and star formation was not.

Filaments and star formation

- Herschel Space Observatory legacy: The ubiquity of interstellar filaments and their relation to core formation (André+2010; Molinari+2010)

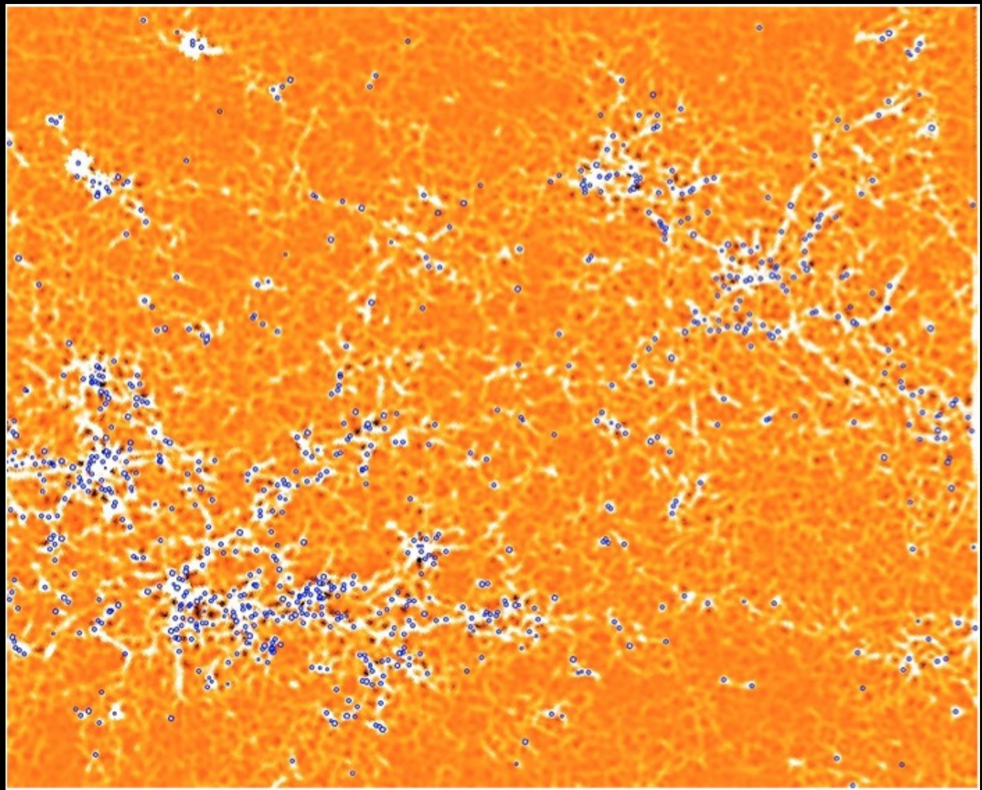
- Nearby star-forming clouds: Individual dense filaments fragment into a set of prestellar cores



Marsh+2016, André+2017

Filaments and star formation

- Herschel HiGAL: Same qualitative pictures but different scales!



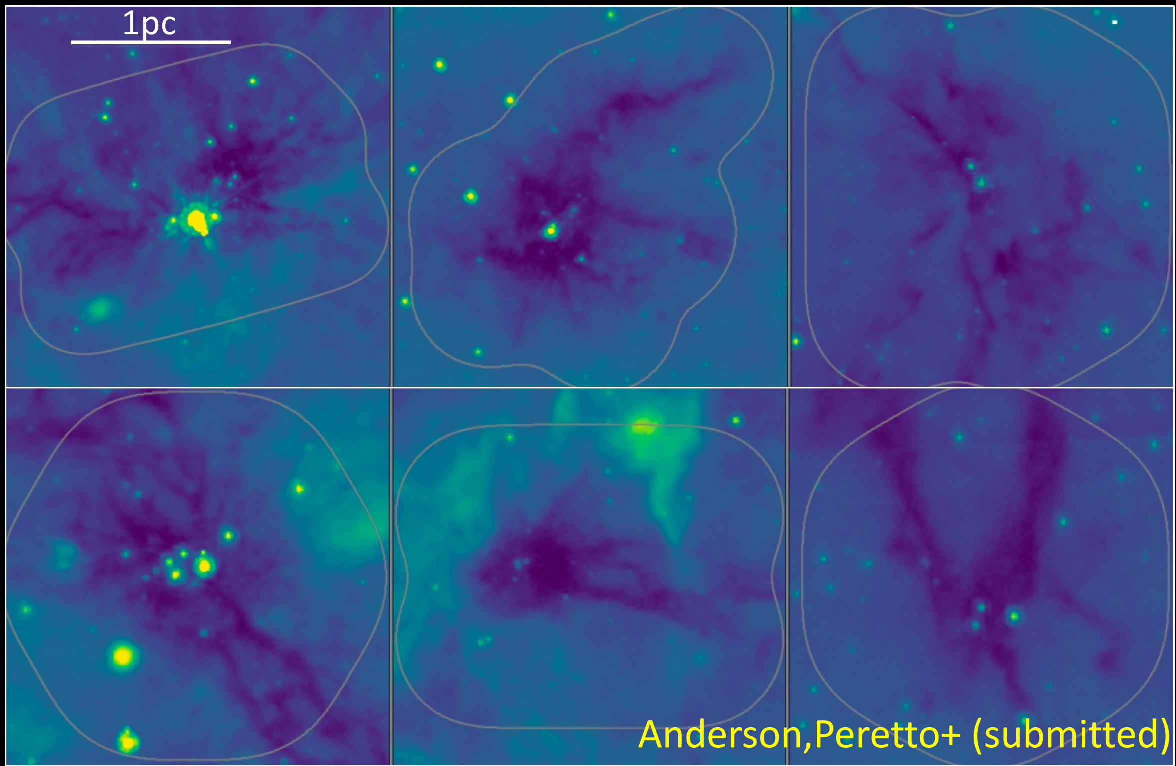
Molinari+2010

- Dense filaments and compact sources are closely related to each other (Molinari+2010; Schisano+2020)

- Clusters form at the junction of filaments (Schneider+2012)

Filaments and star formation

- Hub filament system: network of converging filaments (Myers 2009)

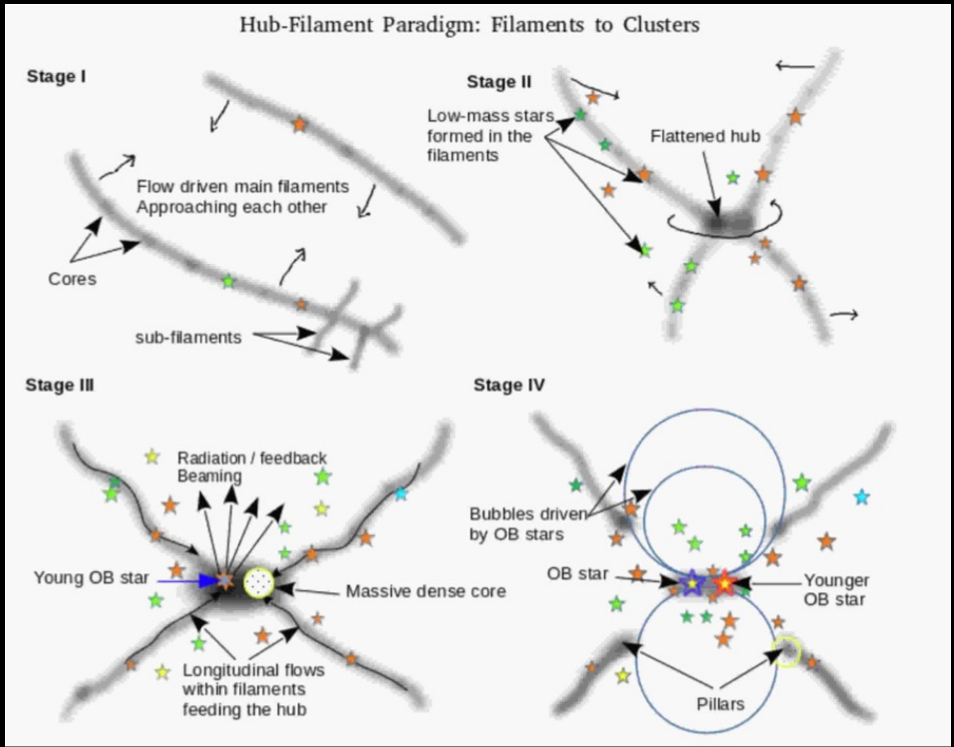


- Morphology suggestive of cloud collapse
- Indications that these are privileged sites for massive star formation

(e.g. Peretto+2013,2014; Williams+2018)

Filaments and star formation

- A proposed scenario for massive star formation within hubs (Kumar+2020)



- Collision of filaments lead to the formation of a dense region at the intersection
- The density-enhanced region collapses and fragments
- Stars with M > $100M_{sun}$ form only in hubs
- Hubs and single filaments are formed via different mechanisms

Aim of the study

- What is the relation between single star-forming filaments and hubs? Do they represent different populations of filaments? Or do they trace different evolutionary stages of cloud evolution?

  -> Provide a quantitative definition of what a hub is

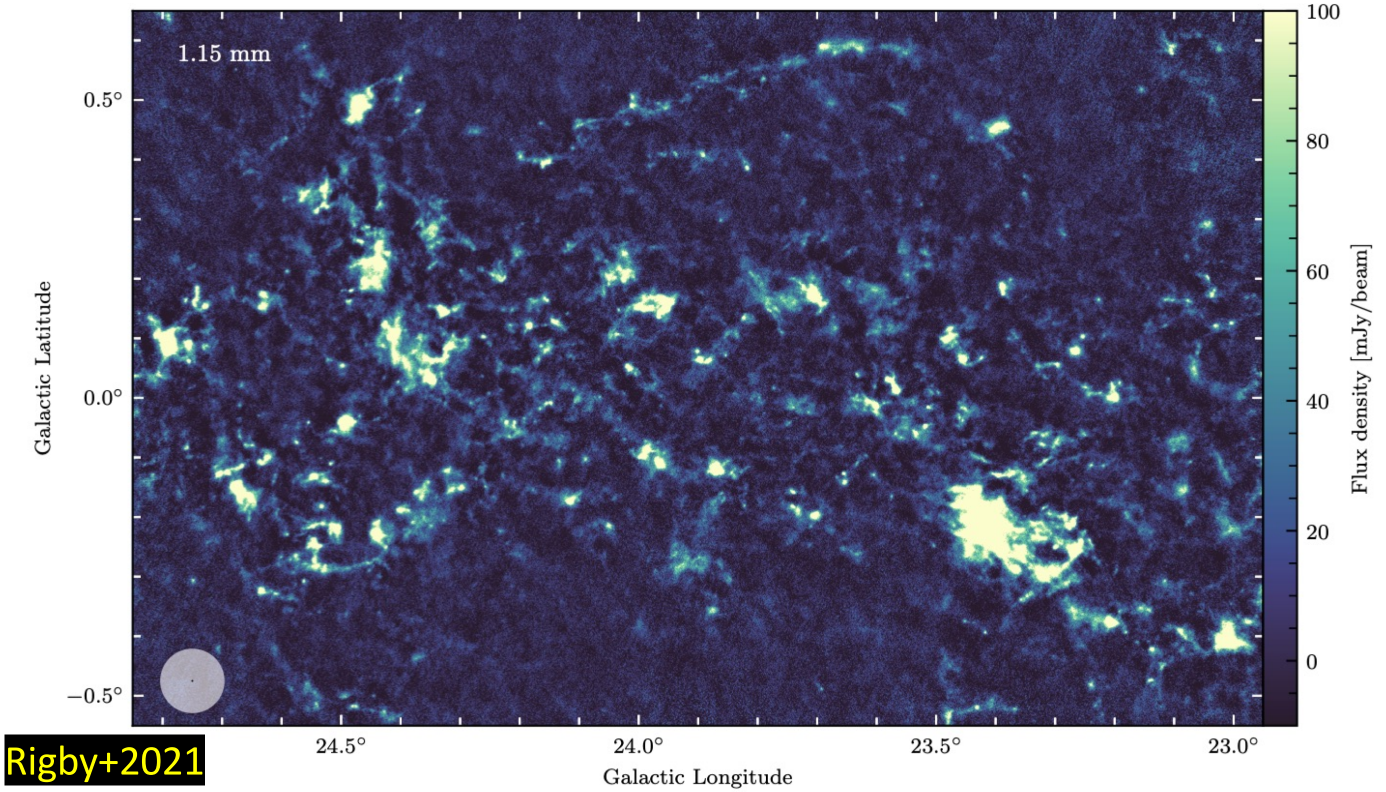
  -> Determine the fraction of filaments that found themselves within hubs

  -> Determine properties of compact sources within hubs and non-hubs

GASTON: the l24 field

- The most sensitive millimetre view of a slice of the Galactic plane

- NIKA2 guaranteed time
- 92% complete
- 2.2 sq. degree map
- rms@1.2mm:
  3.6 mJy/beam
- rms@2mm:
  1.3 mJy/beam

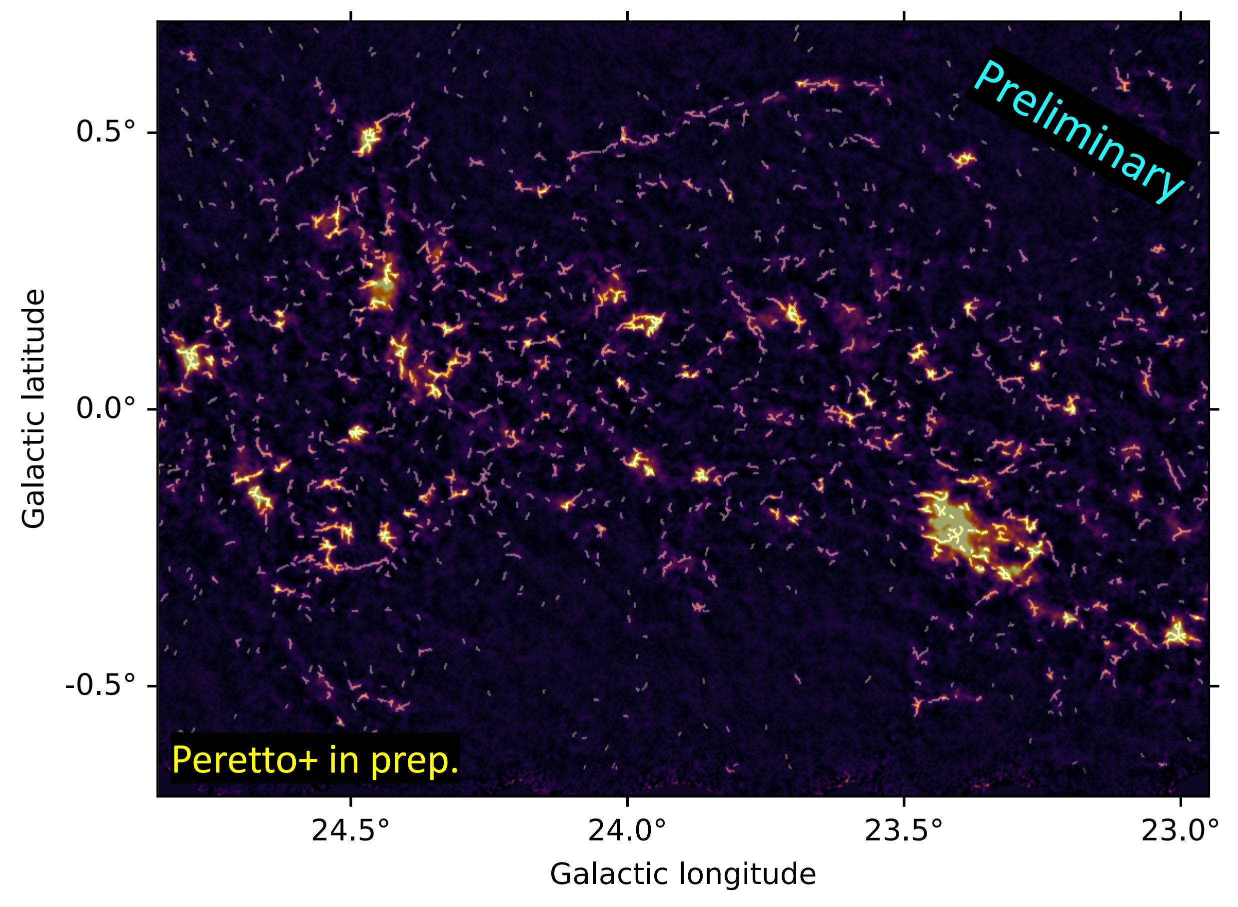


Rigby+2021

- More than 1400 compact sources, hundreds of star-forming clumps

GASTON filament identification

- Use of 2[nd] derivative + thinning algorithm to obtain skeletons (Schisano+2014; Orkisz+2019)
- Only filaments longer than 3 beams are kept
- Total of ~2600 filaments identified

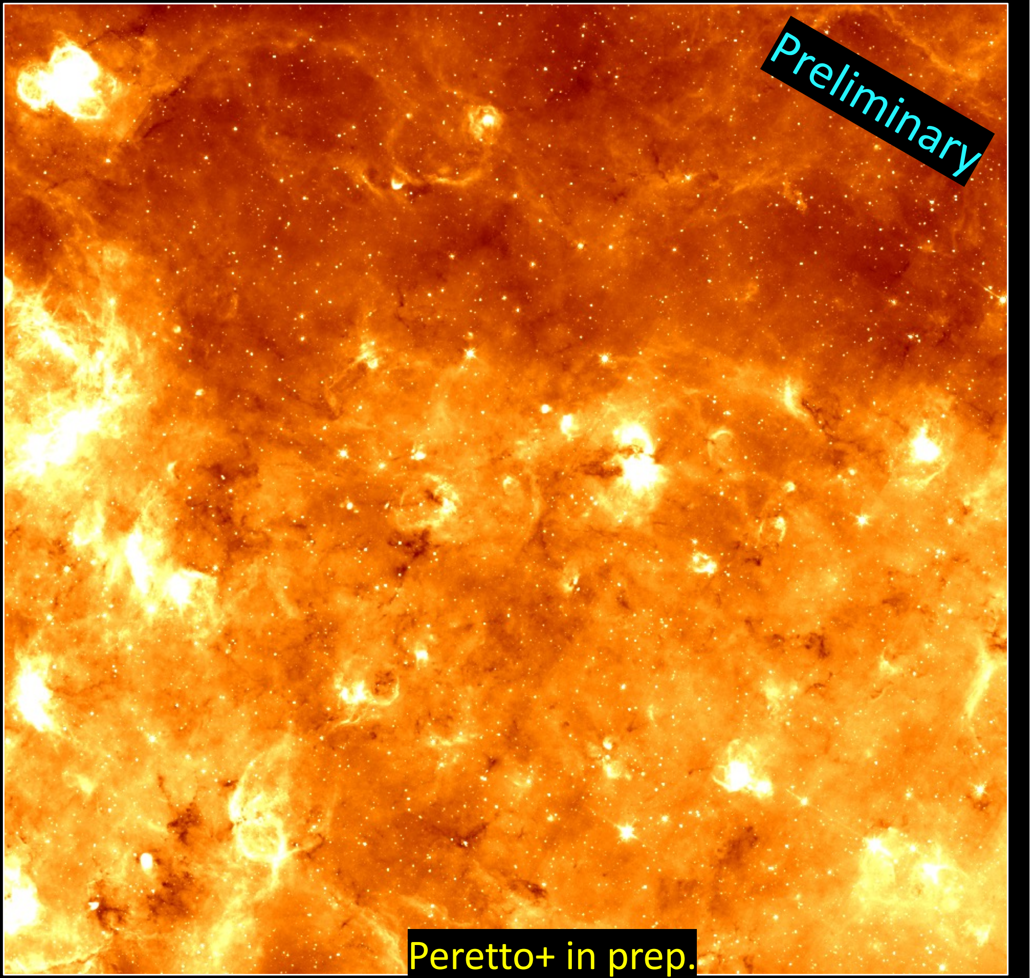


GASTON filament identification

- Are identified filaments reliable? Can we trace IR dark hub structures?

  -> Comparison with 8micron extinction features

8micron + filament skeleton



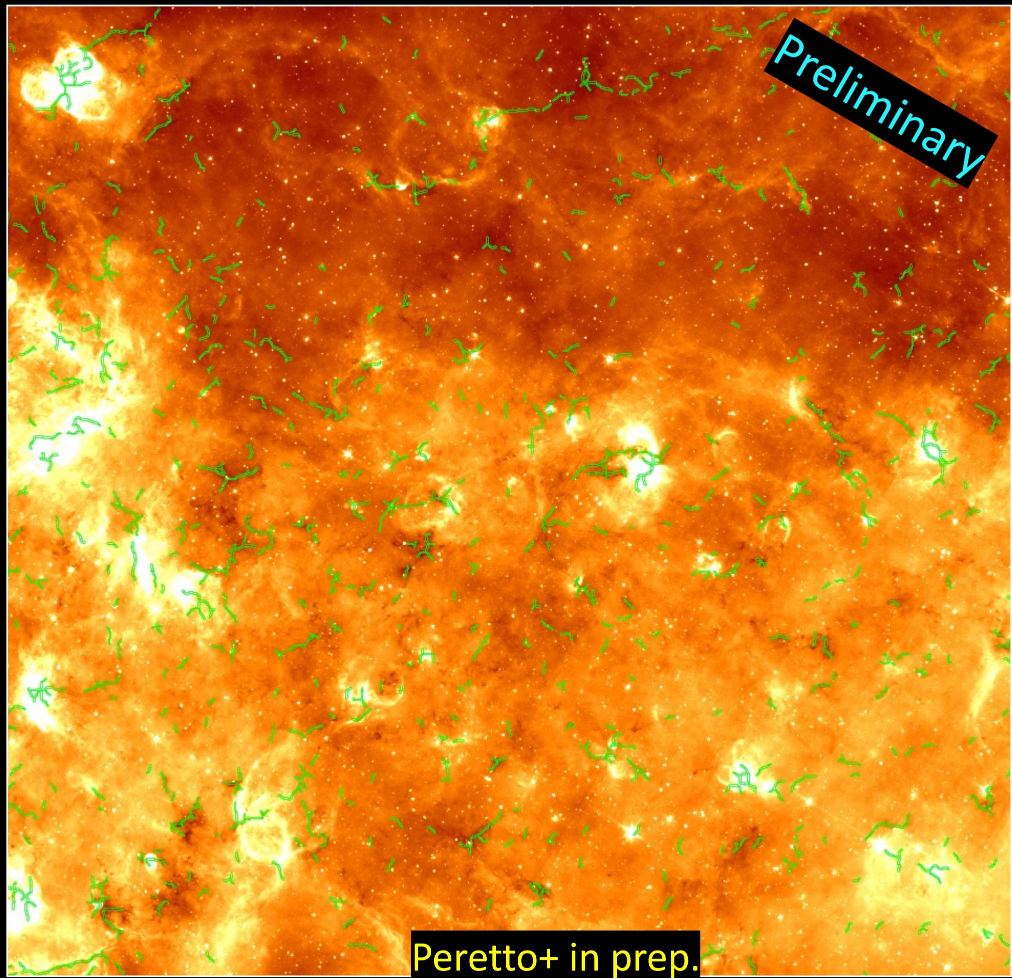
GASTON filament identification

- Are identified filaments reliable? Can we trace IR dark hub structures?

  -> Comparison with 8micron extinction features

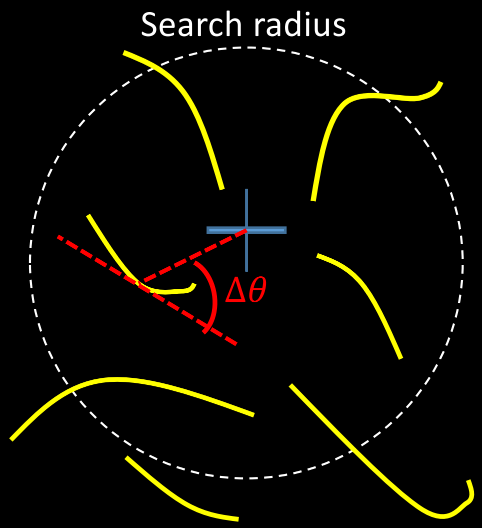
- Despite a factor 5 difference in angular resolution between IRAM30m/NIKA2 and Spitzer/8micron we find excellent agreement

8micron + filament skeleton



Filament convergence parameter

- Building a metric for filament convergence f_c for each pixel

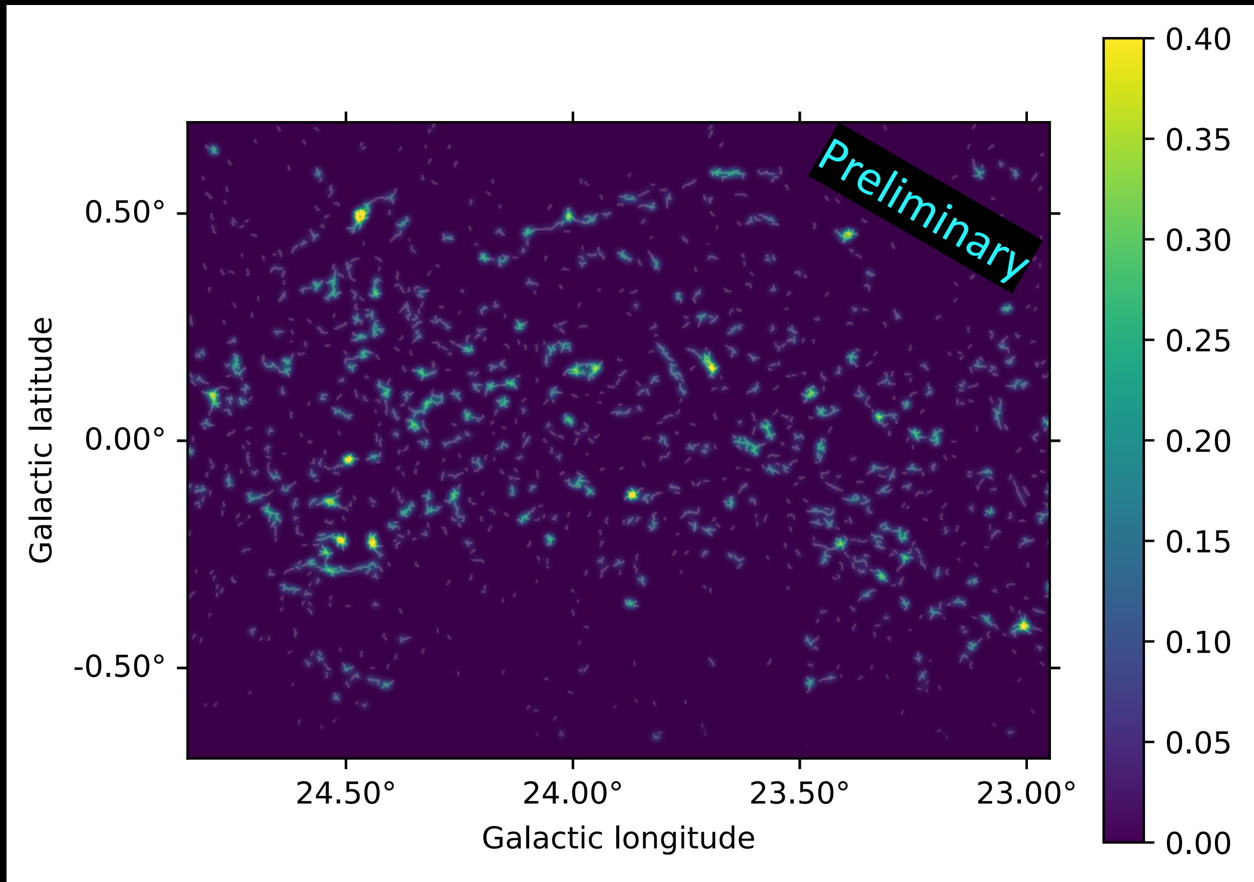


$$f_c = N_{fil} \frac{\sum_{i=1}^{N_{pix}} \cos(\Delta\theta)}{C_n}$$

- $\Delta\theta$: Angle between radial direction from centre of search radius and skeleton pixel, and the filament direction at that particular skeleton pixel
- N_{fil}: total number of filaments entering the search radius
- N_{pix}: total number of skeleton pixels entering the search radius
- C_n: normalisation constant

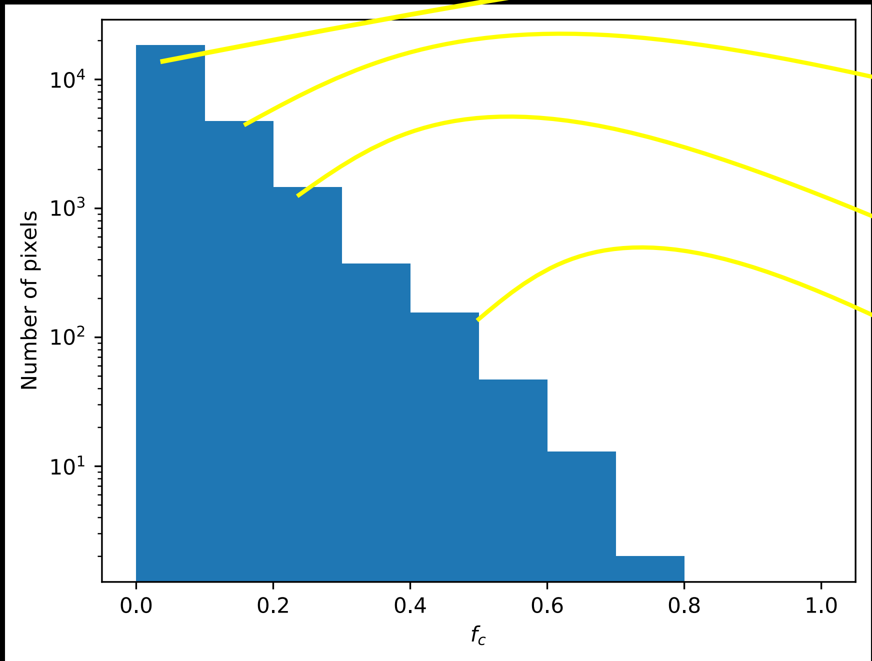
Convergence map

- GASTON convergence map for a search radius of ~1pc (40″ at 5kpc)
- f_c values range from 0 to 0.7
- Clear identifiable convergence spots



Quantitative definition of a hub

- What f_c values correspond to hubs?



$f_c = 0.04$

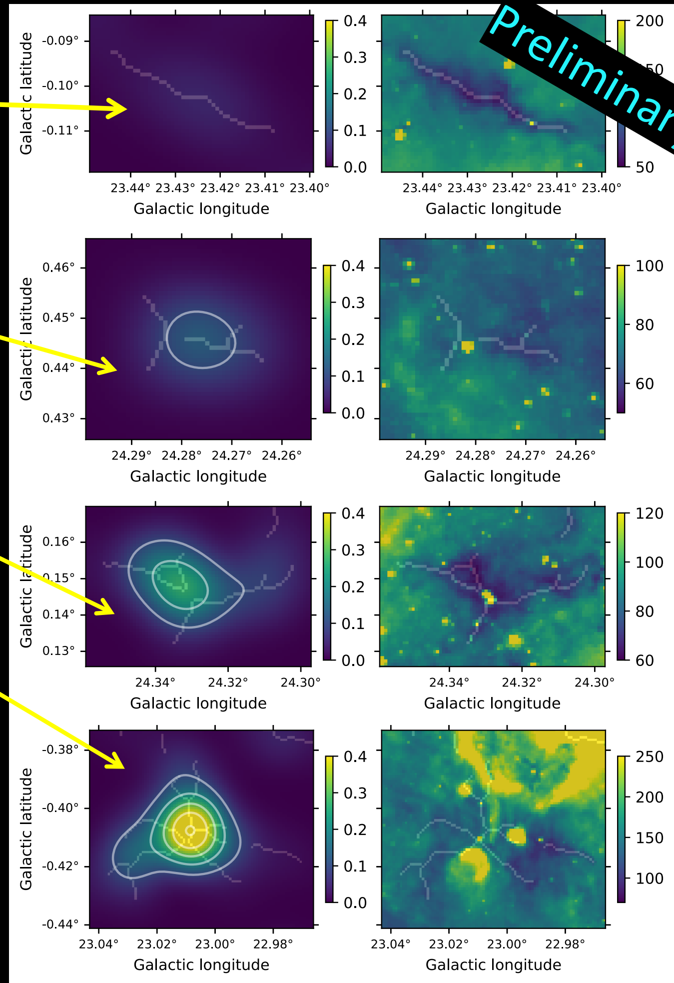
$f_c = 0.13$

$f_c = 0.26$

$f_c = 0.50$

f_c (col. and cont.) + skeleton

8micron+ skeleton



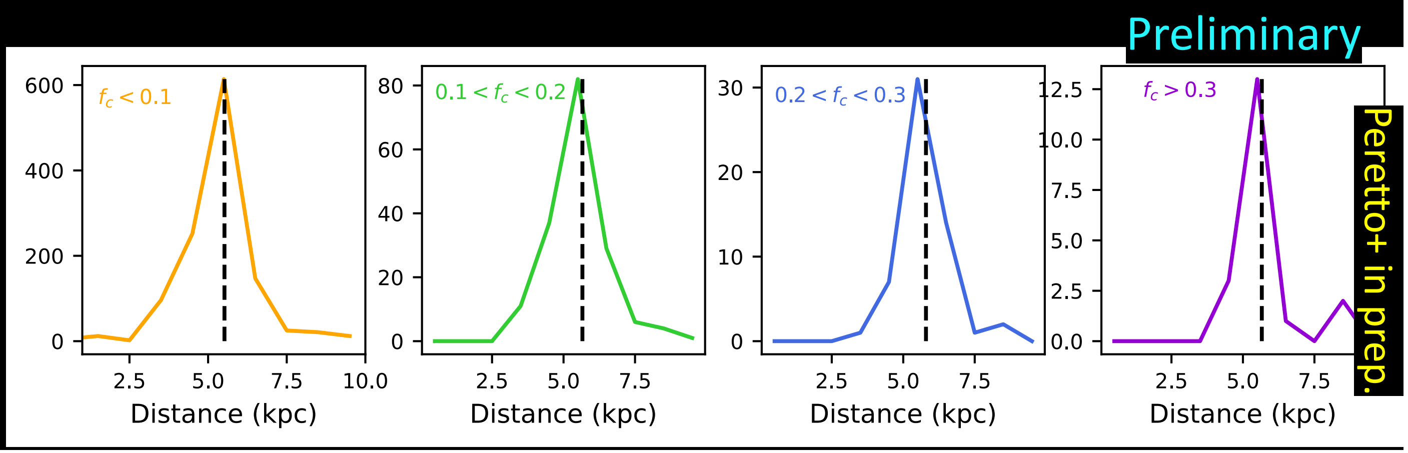
- We define hubs as regions with $f_c \geq 0.2$

Compact sources and filament convergence

- Only 5% of the skeleton pixels are within hubs:
  Hubs are not common

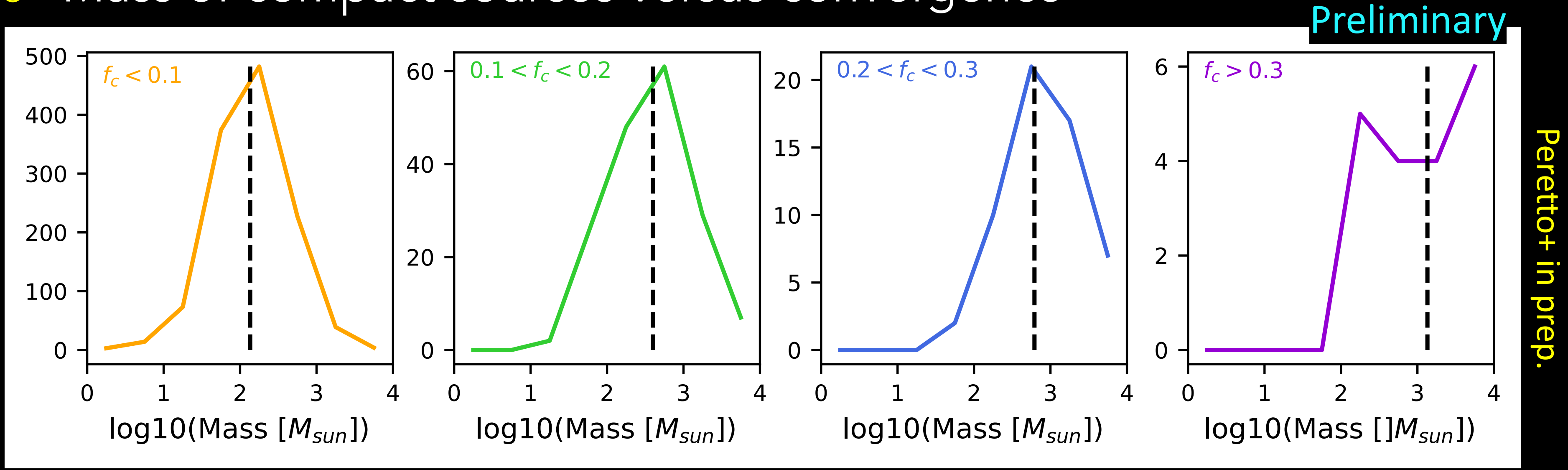
- Only 8% of GASTON compact sources from Rigby+2021 are located within hubs: Most sources are associated to single filaments or simple filamentary structures $f_c < 0.2$

- There is no distance bias regarding f_c: Median distance remains ~5.2kpc



Compact sources and filament convergence

- Mass of compact sources versus convergence

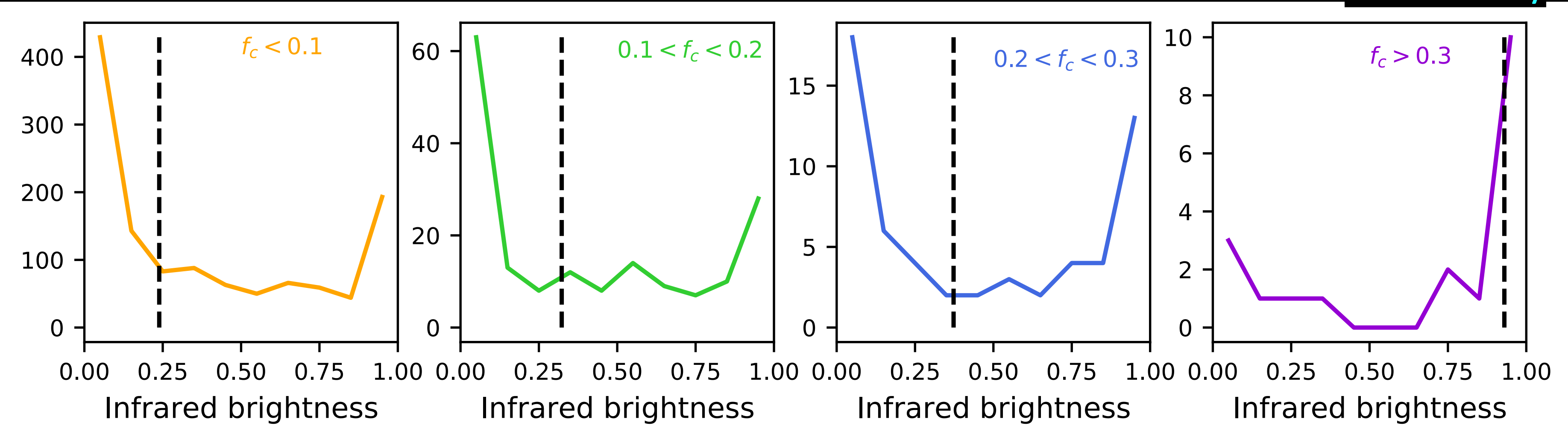


- Mass increases from medians of 135M_{sun} for f_c<0.1 to 1350M_{sun} for f_c>0.3
- But massive compact sources are present in low f_c regions too

Compact sources and filament convergence

- Infrared brightness versus convergence

Preliminary



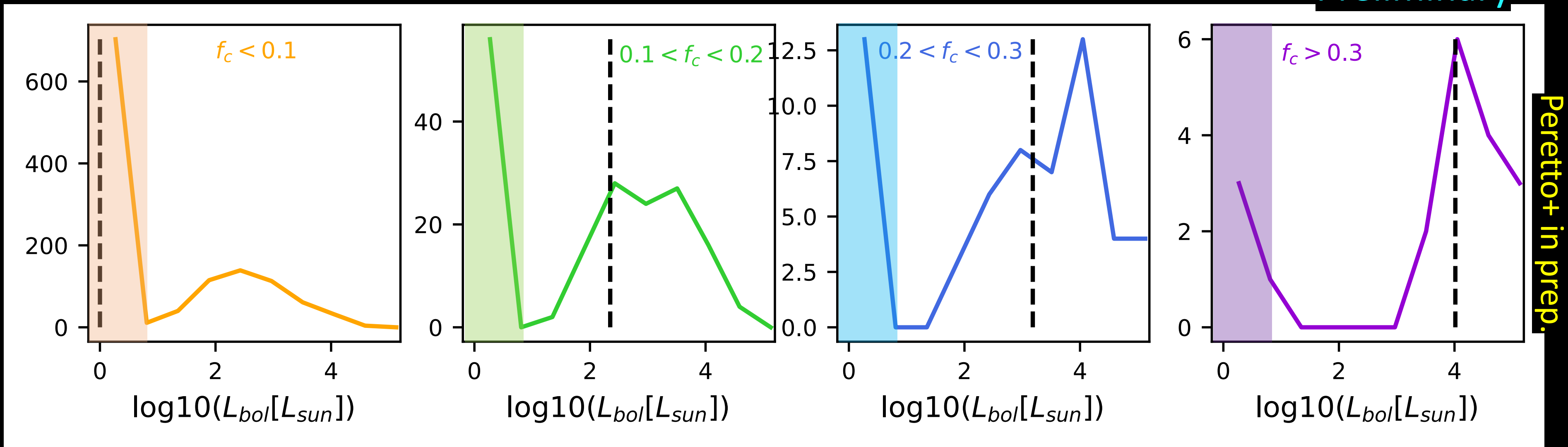
Peretto+ in prep.

- Infrared brightness increases with f_c
- Most sources are infrared dark for f_c<0.1, while most sources are infrared bright for f_c>0.3

Compact sources and filament convergence

- Bolometric luminosity (from 70micron sources) versus convergence

Preliminary



- All source with $L_{bol} > 10^5 L_{sun}$ in hubs ($f_c > 0.2$)
- Median source luminosity in hubs is larger than 10^3 L_{sun} (10^4 L_{sun} for f_c>0.4)

Preliminary conclusions

- Hub filaments represent a small fraction of filament population
- Hubs host, in proportion, more massive, more luminous compact sources than non-hubs
- Hub-hosting clumps are more evolved than non-hub
- No discontinuities observed in compact source properties and convergence parameter
- We propose that the rapid global collapse of clumps is responsible for (re)organising filaments networks into hubs and, in parallel, for leading to mass-growth of compact sources