Filaments in Orion: A first look of the L1641 clouds with Herschel

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Outline

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- Orion A Molecular Cloud
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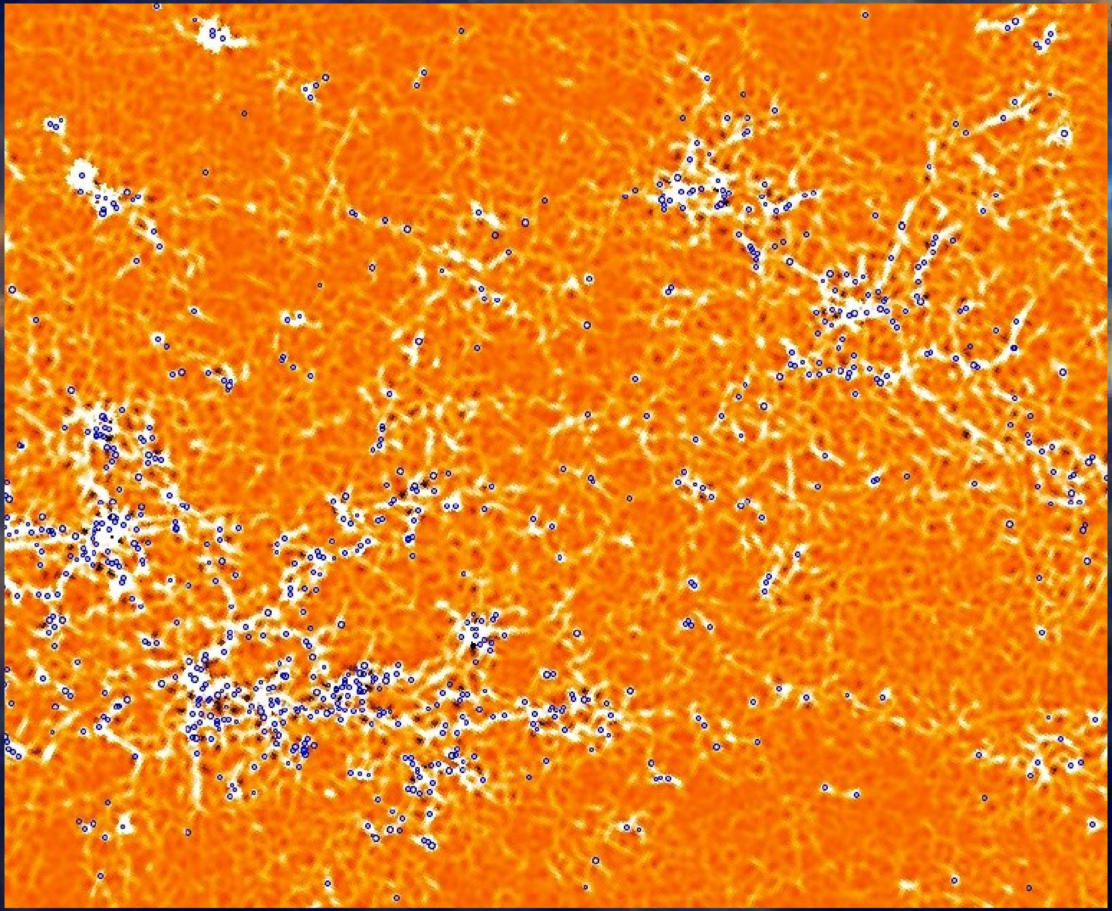
Star Formation & Filaments

Stars are a natural consequence of supe-rsonic turbulence within self-gravitating, molecular clouds (McKee & Ostricker 2007; Ballesteros-Paredes et al. 2007; Elmegreen & Scalo 2004; Mac Low & Klessen 2004).

Most molecular clouds are observed to have filamentary structure (e.g. Orion A, Lupus, Taurus) and the forming stars are very often found to form along those filaments (Molinari et al. 2010a) suggesting that such structures are the preferred loci of star formation.

However the origin of such structures is not clear.



Molinari et al. 2010; Multidirectional 2nd derivative image of the l=59° field of HiGAL

Star Formation & Filaments

Filamentary structure in molecular clouds can arise from collisions of randomly directed flows in hydronamic turbulence models (Klessen et al. 2004; Jaspen et al. 2005).

Uniform cylinders of gas approaching along a common symmetry axis develop a 'splash' pattern of filaments directed radially outward in the collision plane (Vazquez-Semadeni et al. 2007; Heitch et al. 2008).

The formation of protostars in the central part of a cloud can 'sculpt' radially directly filaments due outflows removing lower density gas from between them (Li & Nakamura 2006).

In magnetically dominated models ambipolar diffusion allows gravitational instabilities to condense in filaments once the turbulence of the cloud dissipates (Nakamura & Li 2008).

Parsec-scale flows, from the winds and shocks of OB associations and HII regions, can sweep up a low density medium and compress existing condensations in new filamentary structure (Elmegreen & Lada 1977; Wilson et al. 2005).

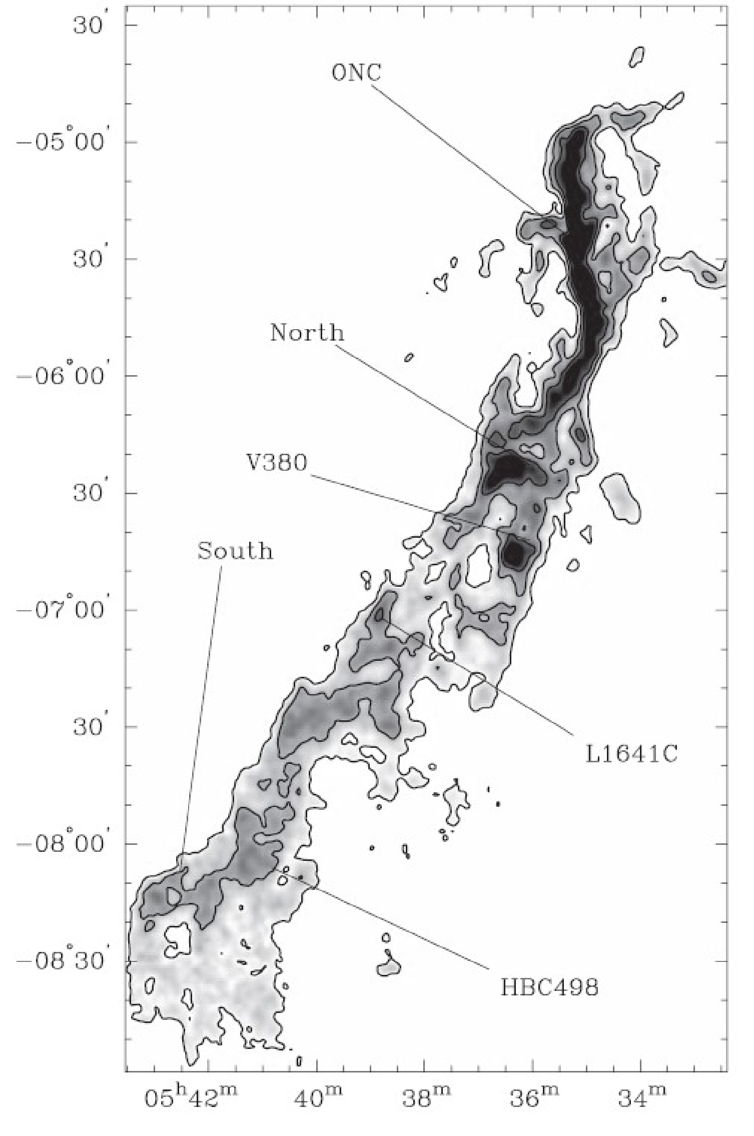
Orion A Molecular Cloud
(the southern bit)

Part of the nearest Giant Molecular Cloud complex (415-420pc) in the Orion constellation.

The cloud is found to have a mass of ~10^5 $M_\odot$. Most of this mass is concentrated in the ONC region (Kutner et al. 1977; Madalena et al. 1986).

Bally et al. (1987) mapped Orion A in ^{13}CO and find that ~25% of the mass of the cloud is located in the integral shaped filament structure.

The regions from L1641N and lower are very often collectively called the L1641 cloud (e.g. Allen & Davis 2008). These regions exhibit largely low mass star formation and contain prominent Herbig-Haro objects and H_2 jets (e.g. HH1/2; HH34)



Orion A cloud in ^{13}CO (Bally et al. 1987)

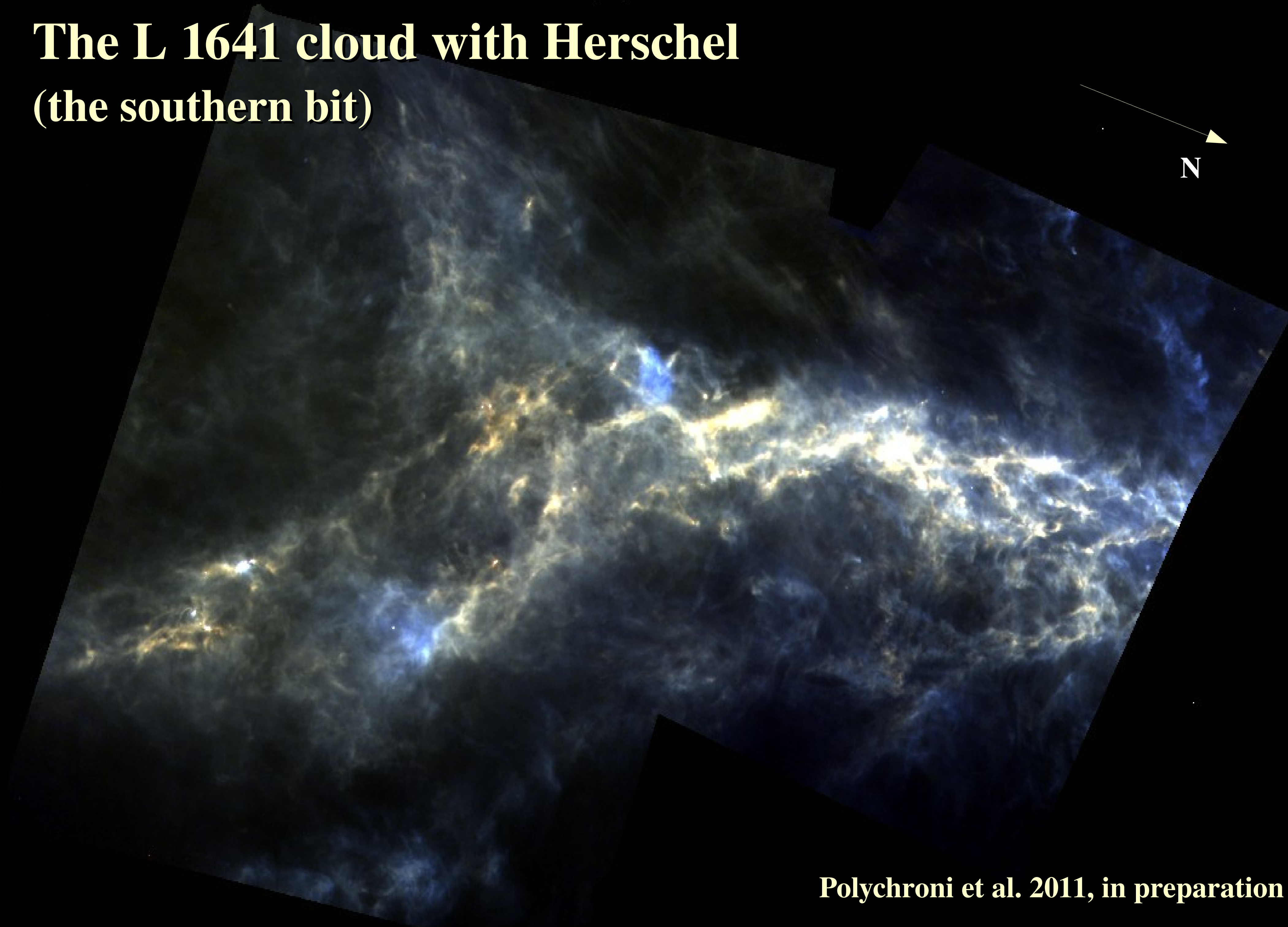
The L1641 Cloud with Herschel

The L1641 Cloud was observed with the Herschel Space Observatory as part of the Gould Belt Guaranteed time key project on October 2010, using the parallel mode, i.e. using *PACS* at 70 & 160 μm and *SPIRE* 250, 350 & 500 μm simultaneously.

A common area of ~ 4.6x3 degrees was mapped in two orthogonal directions.

To reduce the data we used archival scripts prepared in the Herschel Interactive Processing Environment (HIPE, Ott 2010), partially customized compared to the standard pipeline. The obtained time ordered data (TODs) of each bolometric detector were then processed further by means of dedicated IDL routines and finally maps were created using the FORTRAN code ROMAGAL (Traficante et al. 2011)

The L 1641 cloud with Herschel
(the southern bit)



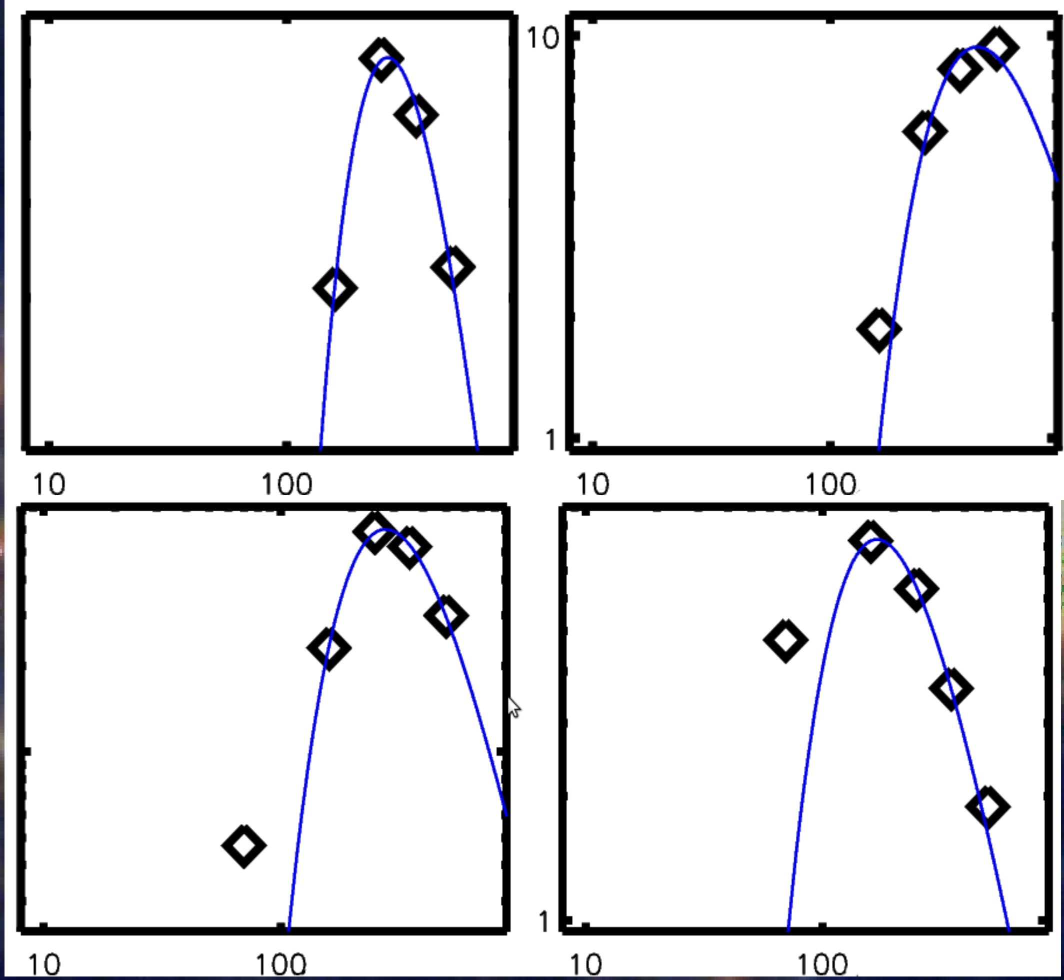
Polychroni et al. 2011, in preparation

Source Detection & Photometry

We used the CUrvature Threshold Extractor Package (CUTEX, Molinari et al. 2011) to identify and extract sources all 5 bands. The sources are identified as peaks in the second derivative images of the original Gould Belt maps. An elliptical Gaussian fit is used to provide the integrated flux, the apparent size and the peak intensity.

The resulting 5 catalogues were then merged so as only sources with S/N >5 and sources detected in at least 3 consecutive bands were selected.

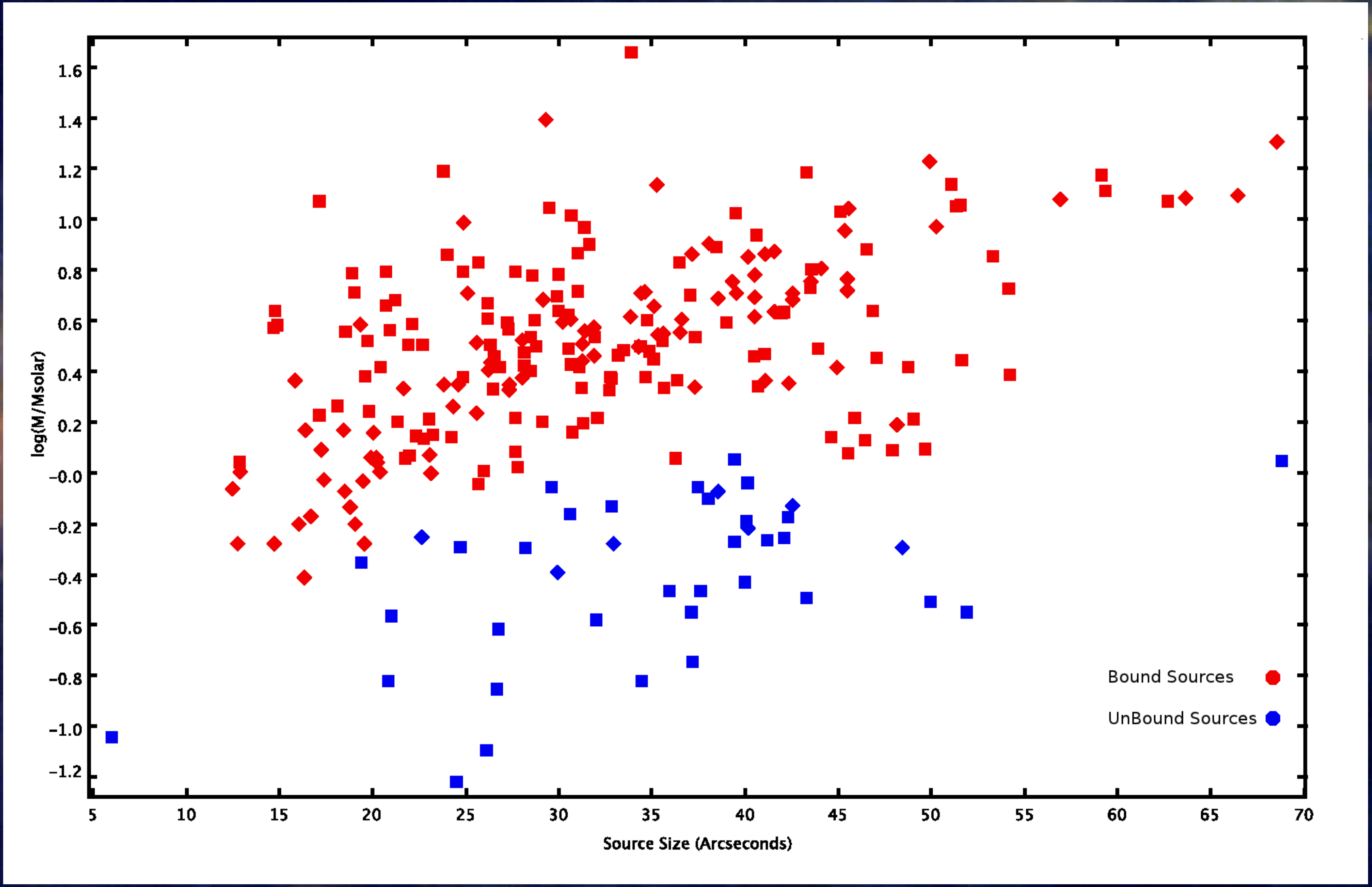
We fitted the Spectral Energy Distributions of our sources with a grey-boy model (Elia et al. 2010) to derive their properties and clas-sifiy them as pre/proto-stellar objects.



Total number of sources: 344

	ON Filament	OFF Filament
Pre-stellar (B):	128	91
Pre-stellar (U):	8	33
Protostellar:	64	25

The Properties of Pre-Stellar Sources



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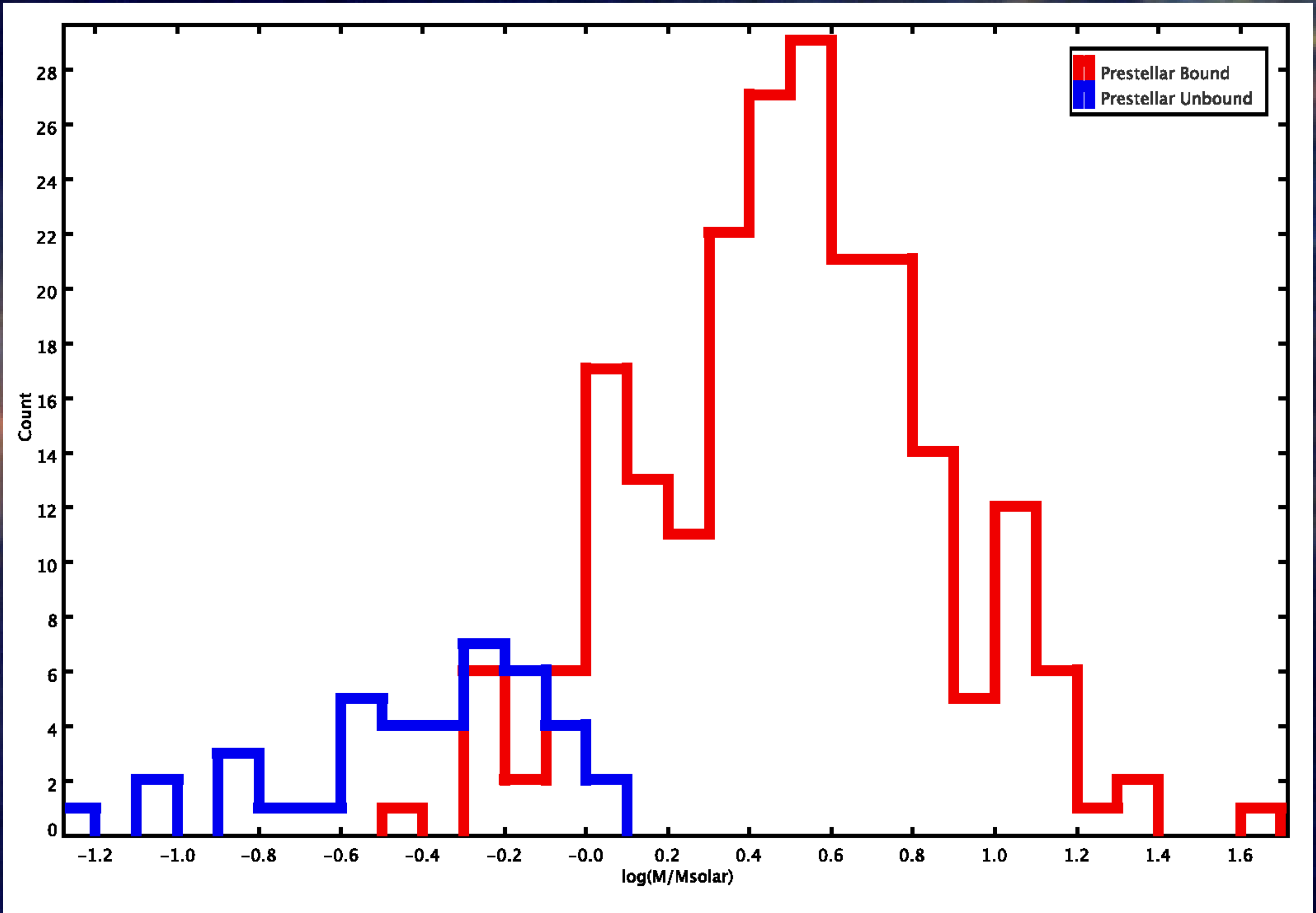


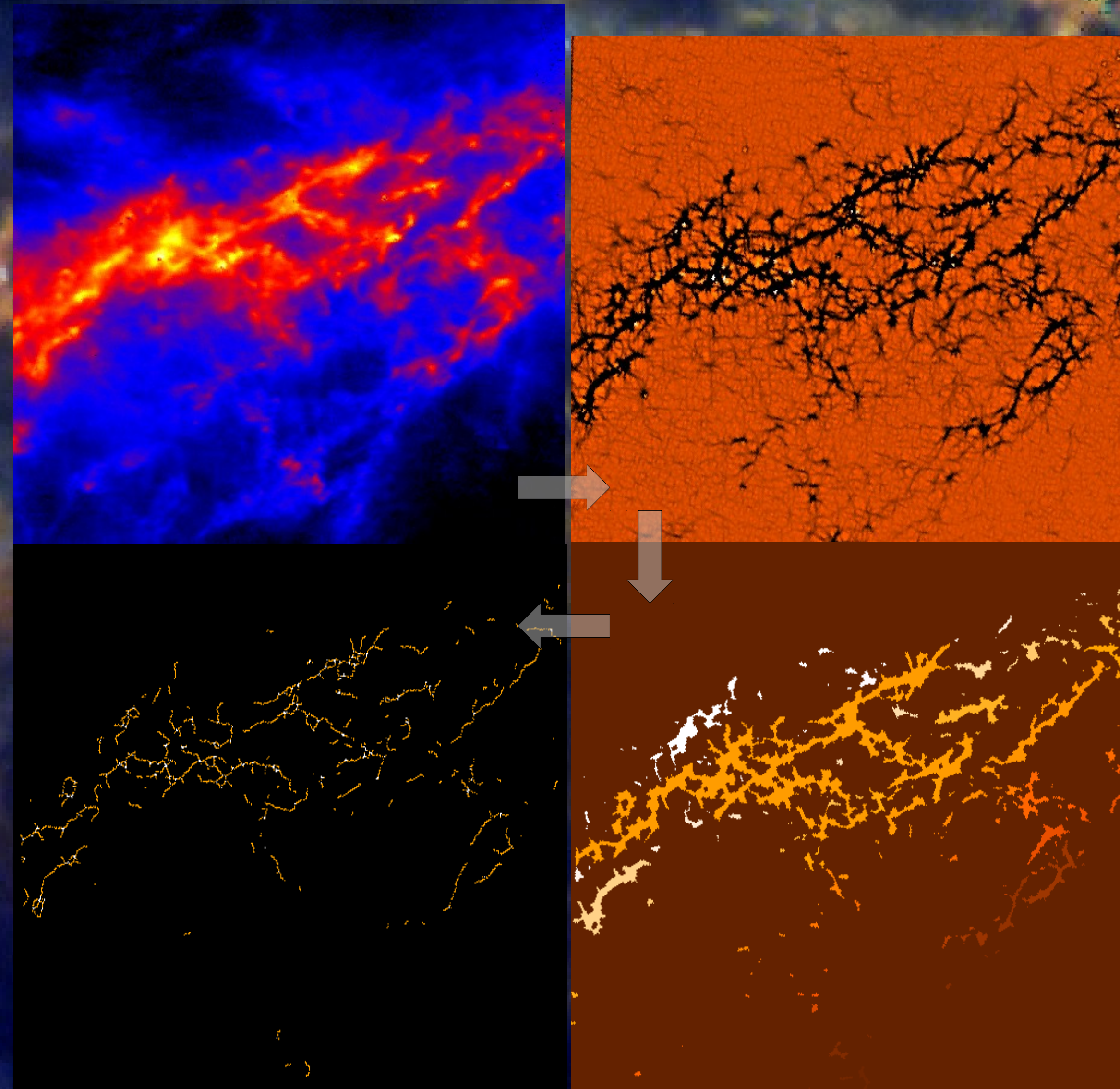
Filament Detection

We fit grey-body SEDs at each pixel in our 5 maps and derive the density per pixel across the map.

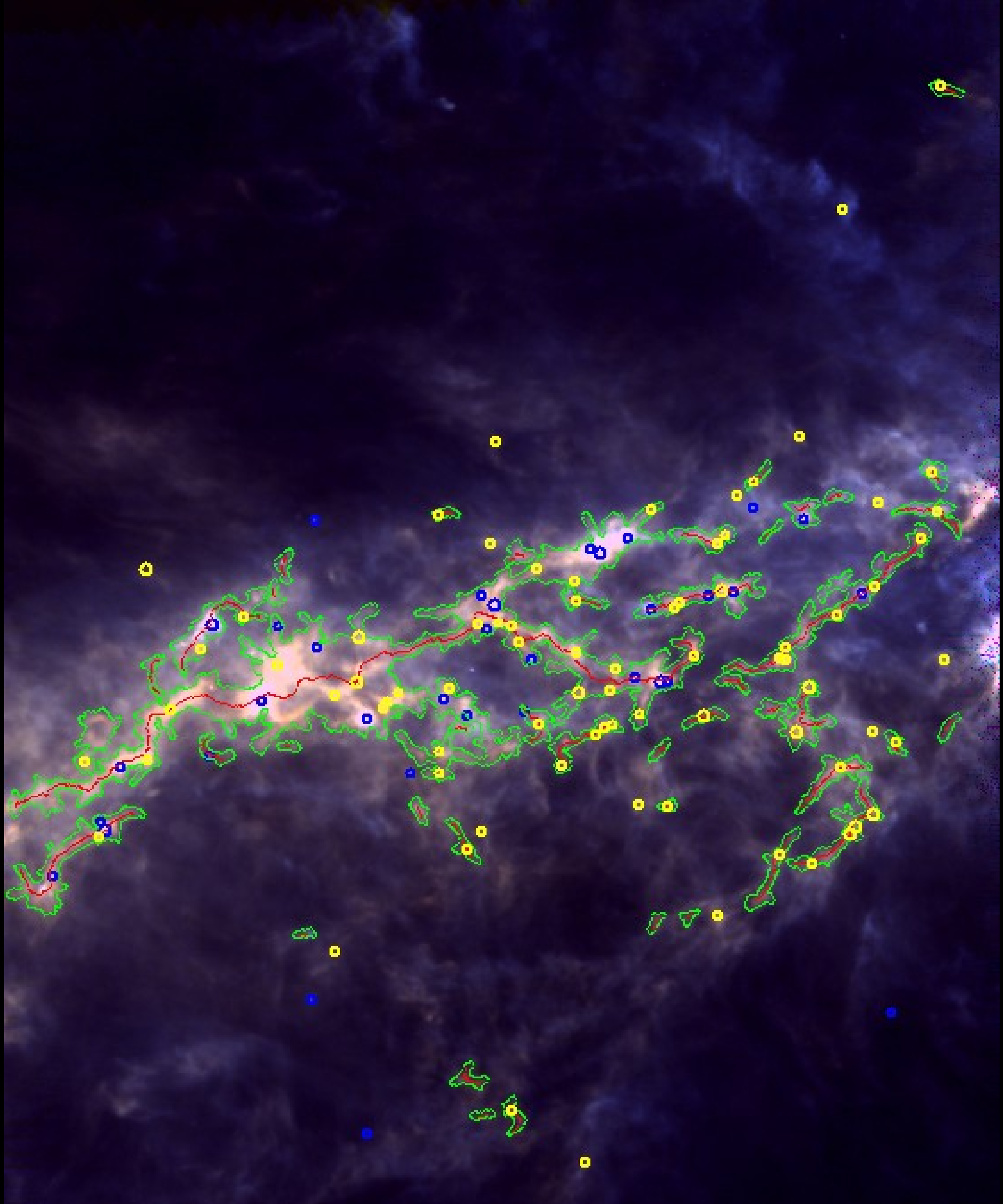
We then take the 2nd derivative of that image and determine the eigen values of the curvature per pixel. Low eigen values signify low curvature and thus we follow the 'spine' of a filamentary structure.

We then group attached filamentary structures in individual filaments.

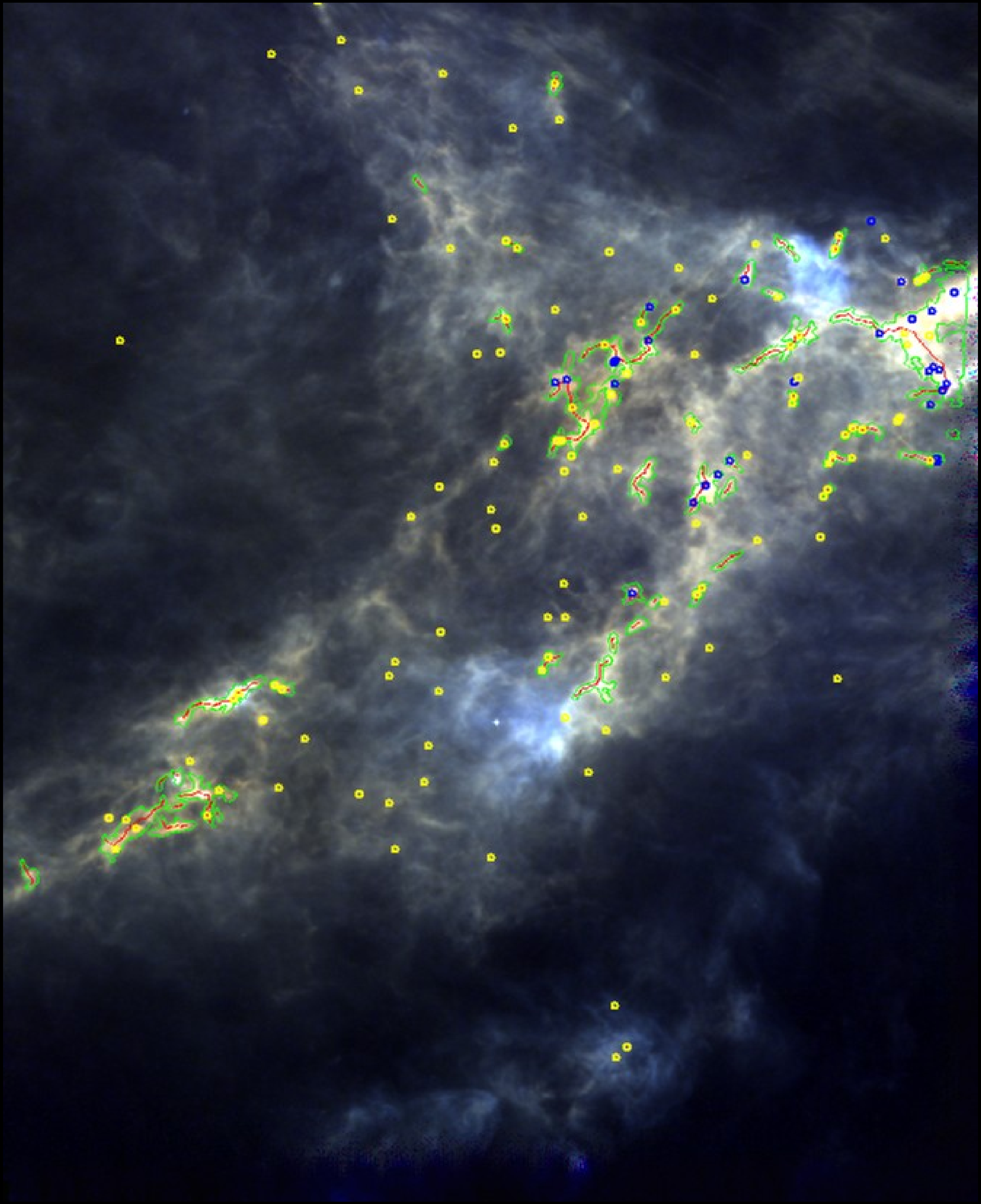
We define as filaments structures with column density > 10^{24} cm^{-3}.



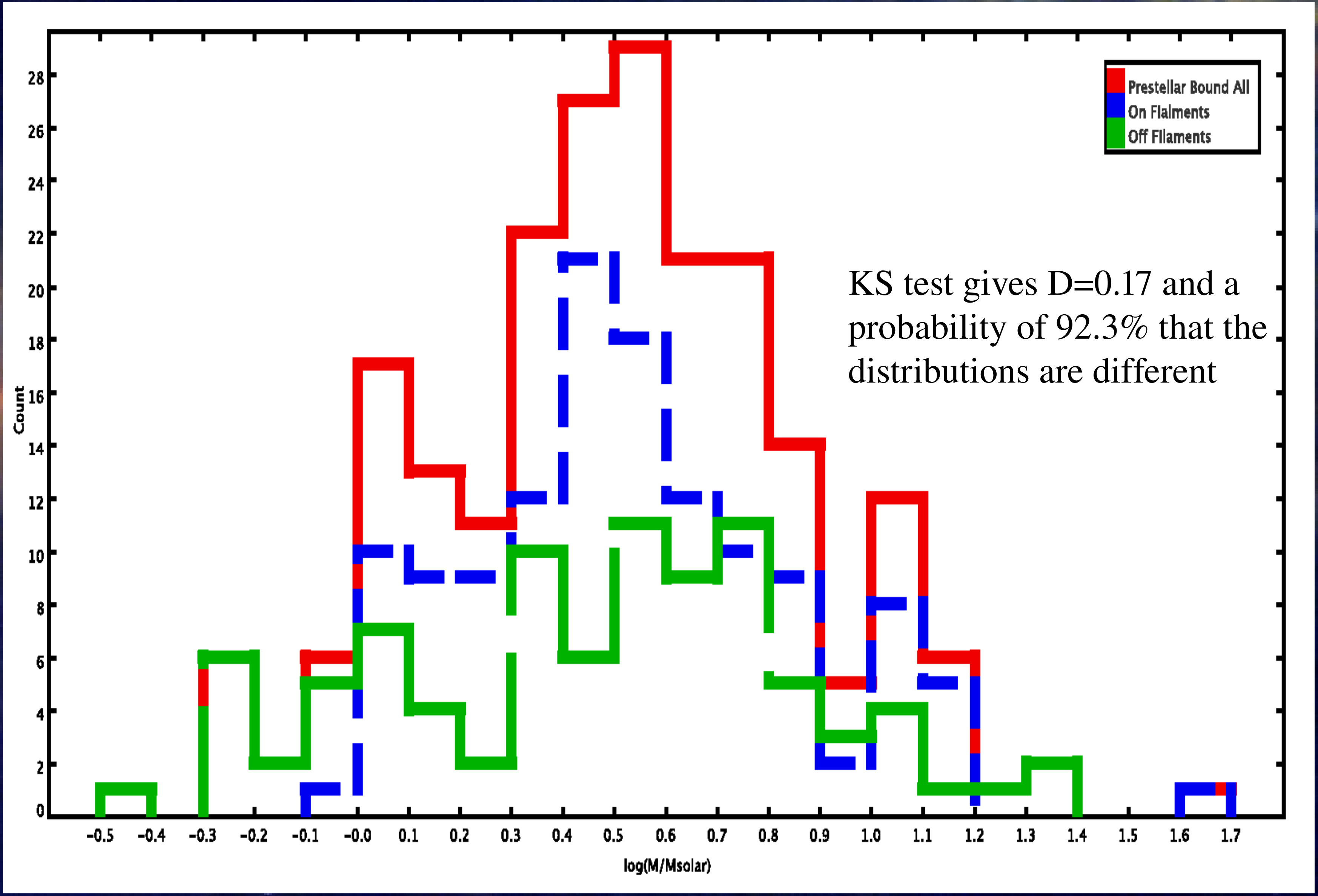
Sources on Filaments



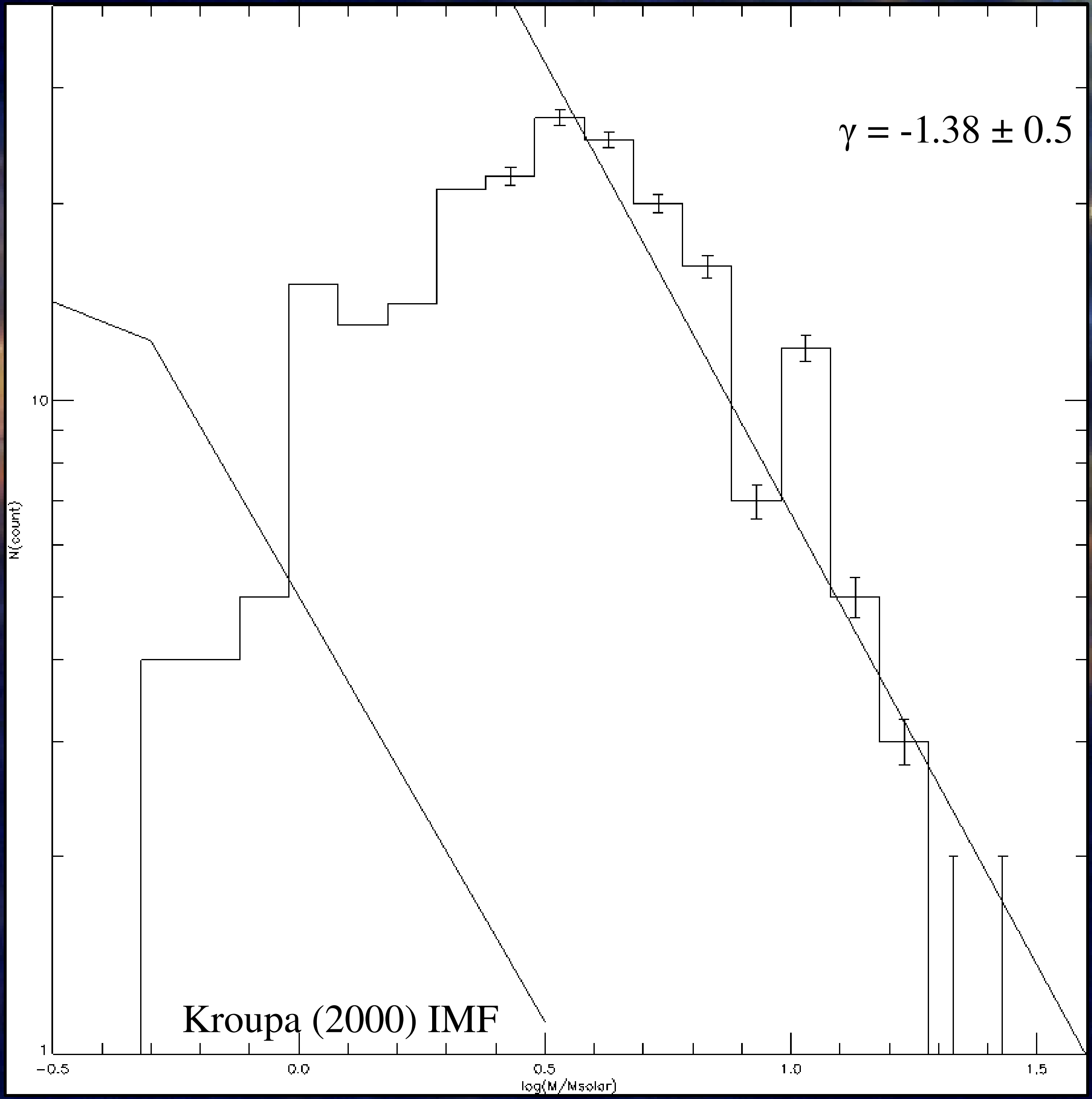
Sources on Filaments



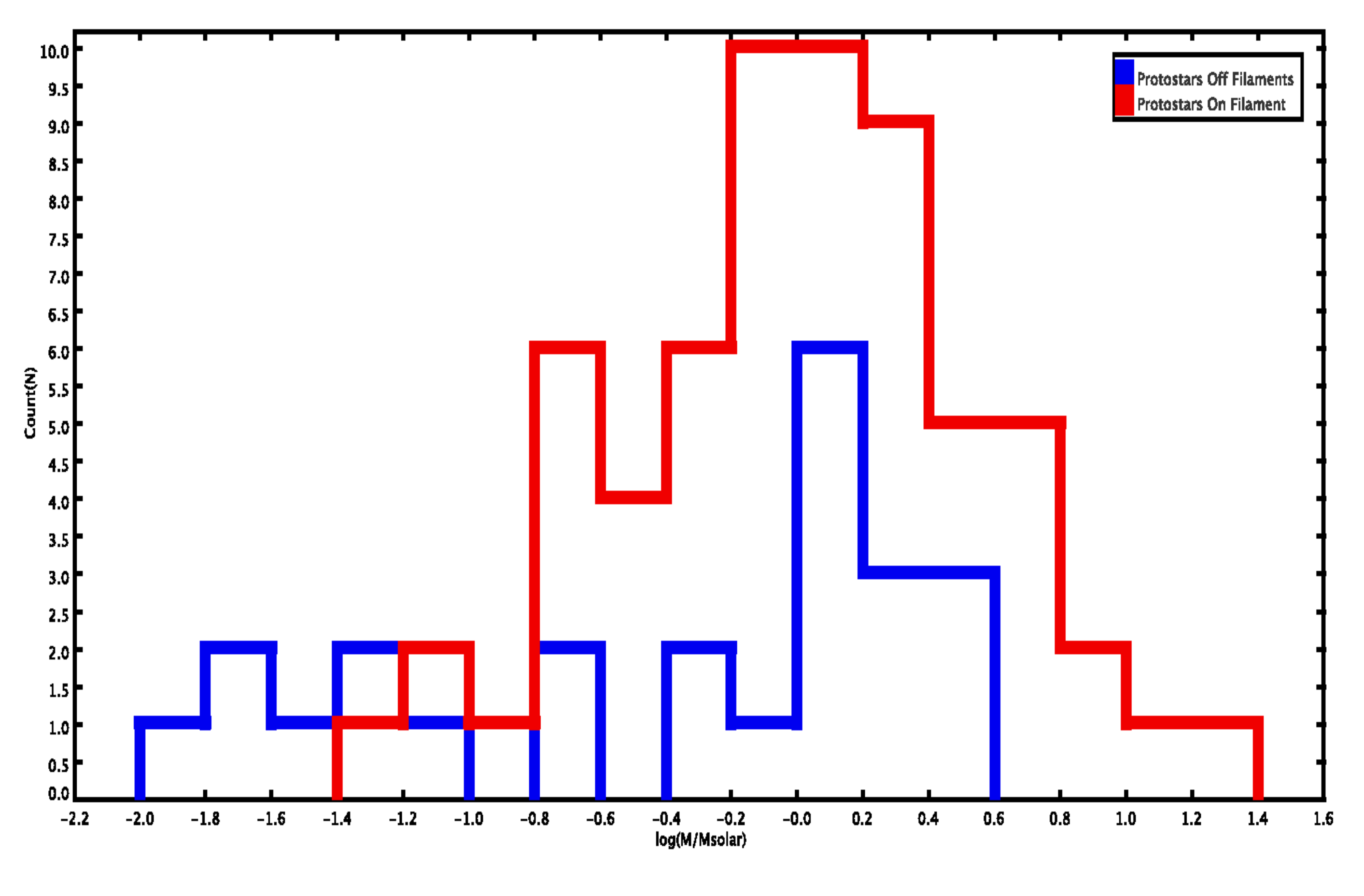
Mass Distributions



The Core Mass Function



Proto-stellar objects



Summary & Conclusions

- We have observed the L1641 cloud with Herschel in parallel mode.
- We find that this region contains many filaments all following the same direction (north west to south east).
- We have used CUTEX to derive a total of 308 objects, of which 219 are pre-stellar and 89 are proto-stellar.
- We find that of those, 128 pre-stellar and 64 proto-stellar objects are on filaments.
- We fit the CMF (pre-stellar objects only) of the region and find a slope of γ=-1.38±0.5 which is consistent with previous estimates (e.g. Johnstone et al. 2006). We also see a break in the CMF at $M=9.3M_{\odot}$ which might be the result of the different mass distribution of the sources on and off the filaments.
- We see a tentative trend of more massive objects forming on filaments.