HERSCHEL Gould Belt Survey

iaps

National and Kapodistrian
UNIVERSITY OF ATHENS

Nature vs Nurture: The relative importance of the Where and How in forming (massive) stars

D. Polychroni, et al.

European Union
European Social Fund

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EDUCATION AND LIFELONG LEARNING
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MANAGING AUTHORITY

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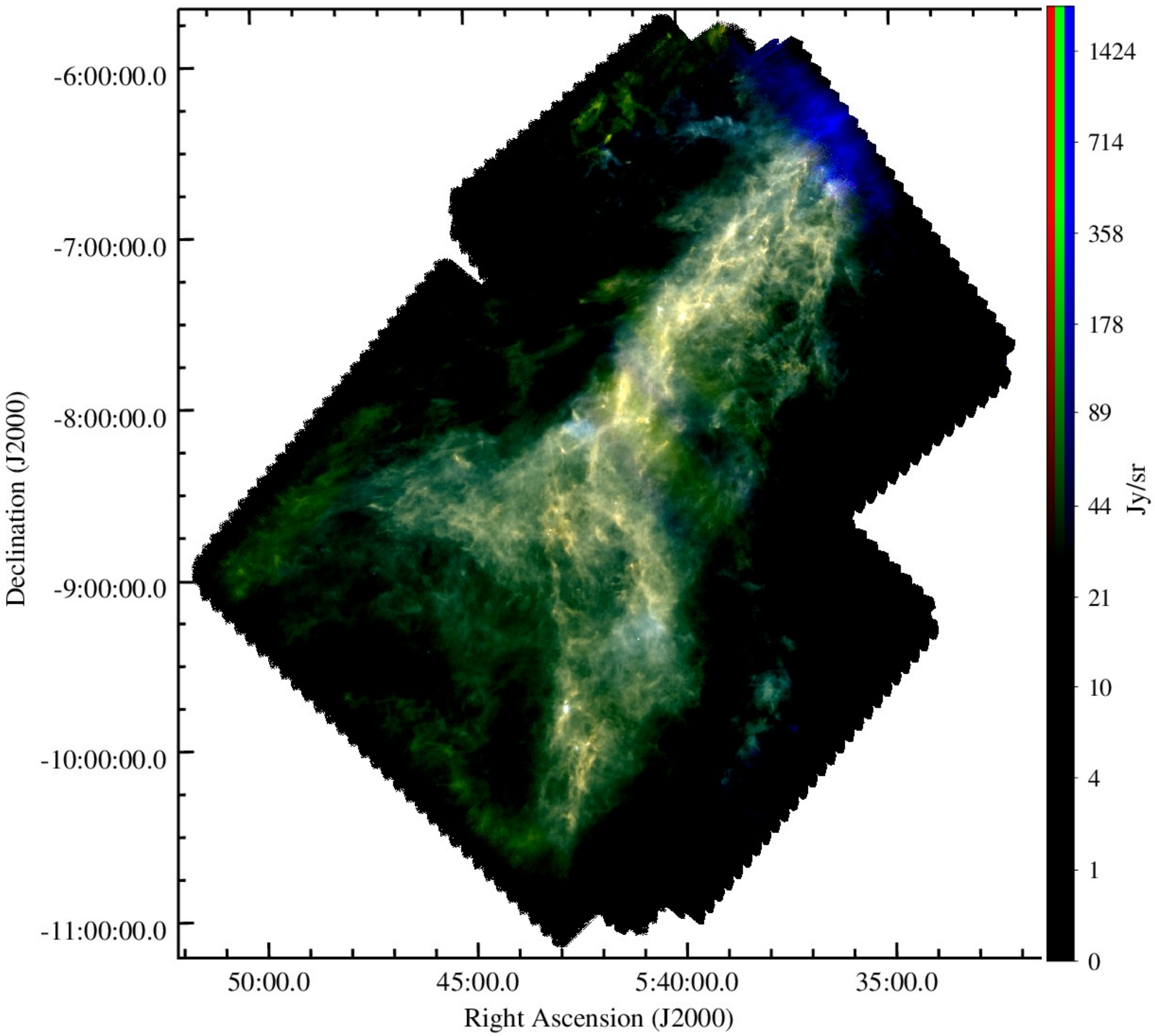
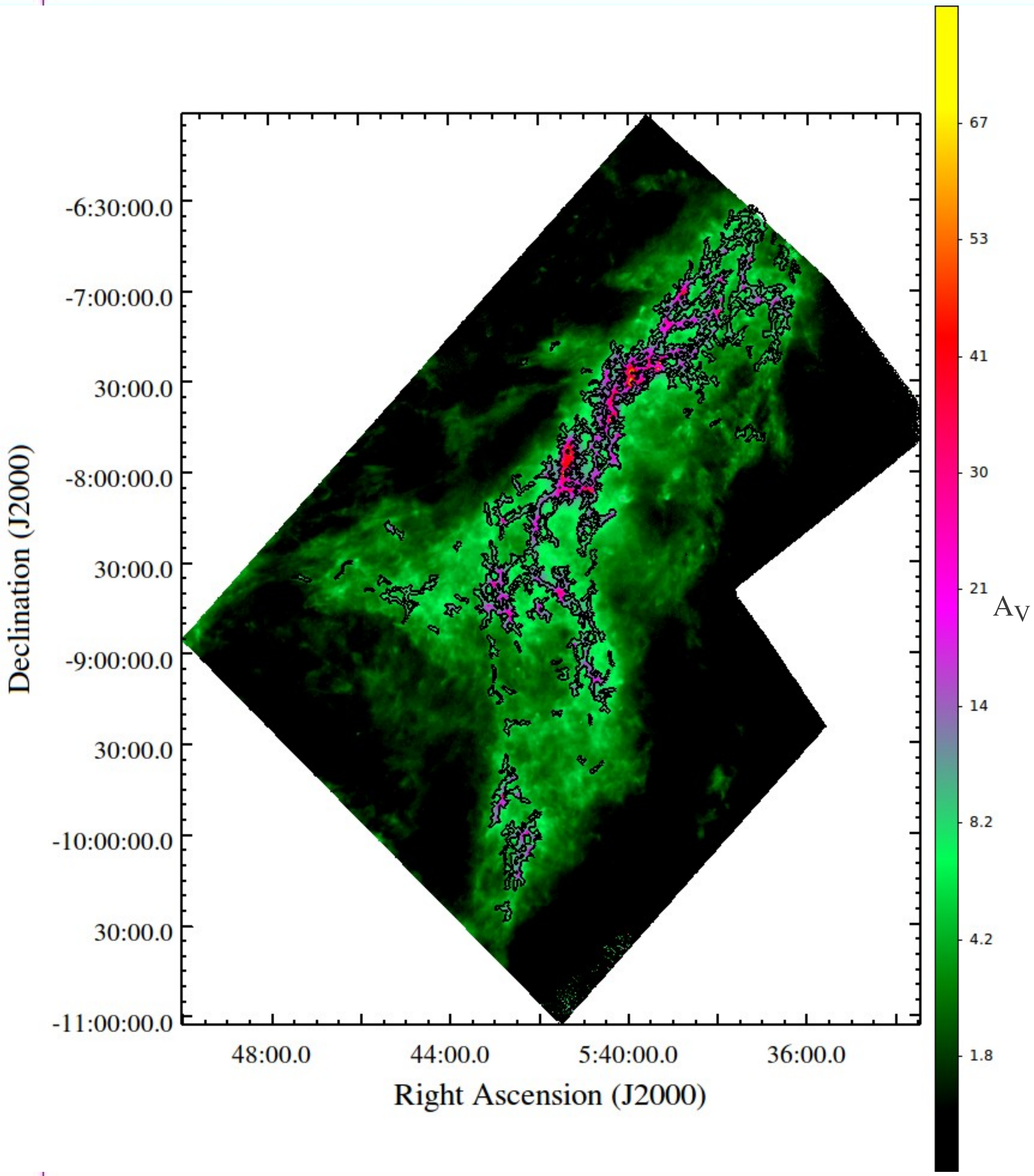
The L1641 Clouds with Herschel



Polychroni D., et al., 2013, ApJ, 777, L33

Filaments

(Schisano et al. 2014, ApJ, 791, 27)



Pattern recognition algorithm:

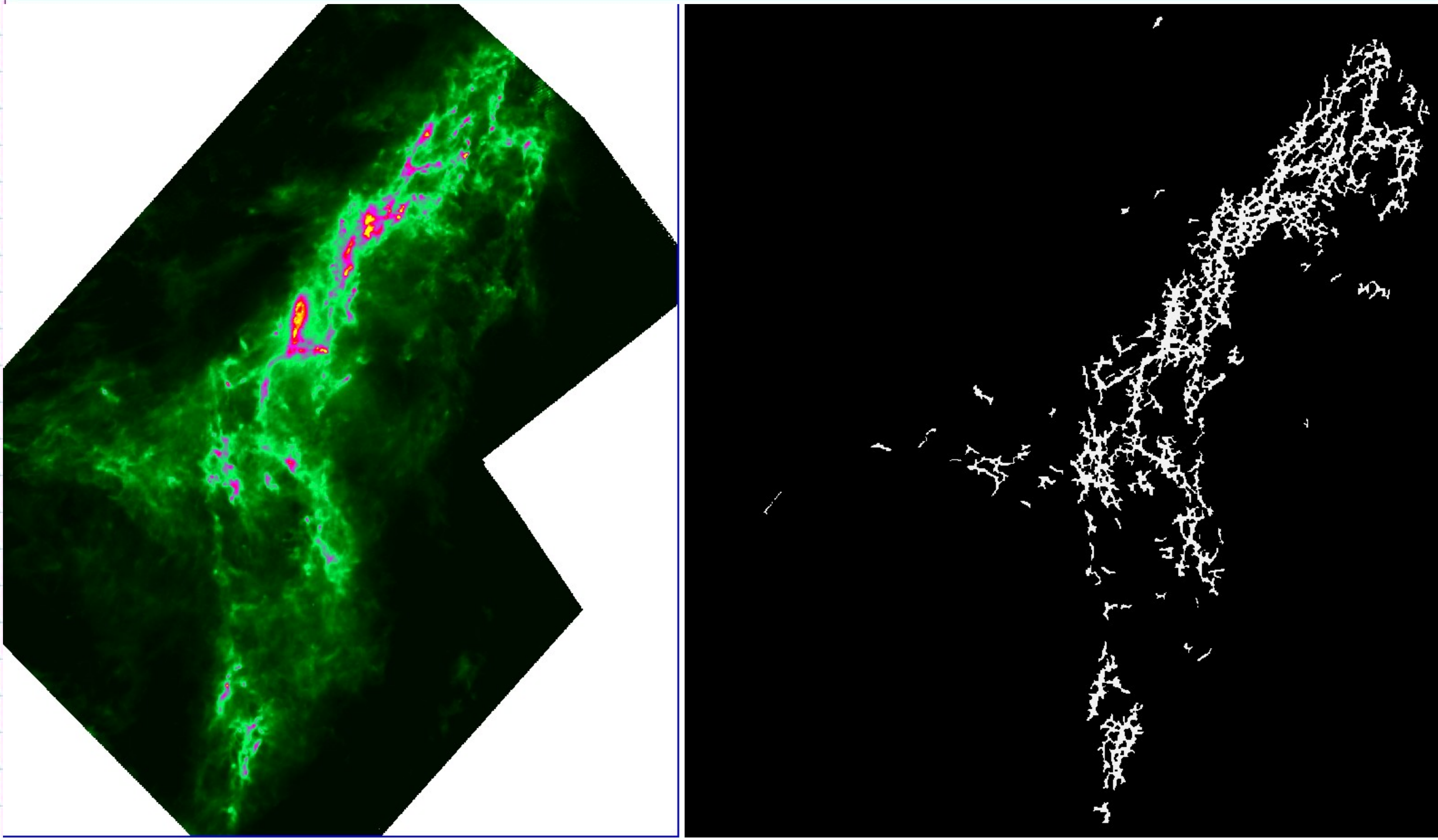
Start from the 2nd derivative of the column density map and compute the eigenvalue of the Hessian matrix at each pixel.

Select the regions where the curvature along one of the eigen-directions exceeds a certain threshold. Such threshold defines the minimum variation in the contrast that is accepted to separate a filamentary region from its surroundings.

Afterwards, morphological operators are applied to determine the central pixels of the identified regions. Those with few pixels or those that do not have an elongated shape are rejected.

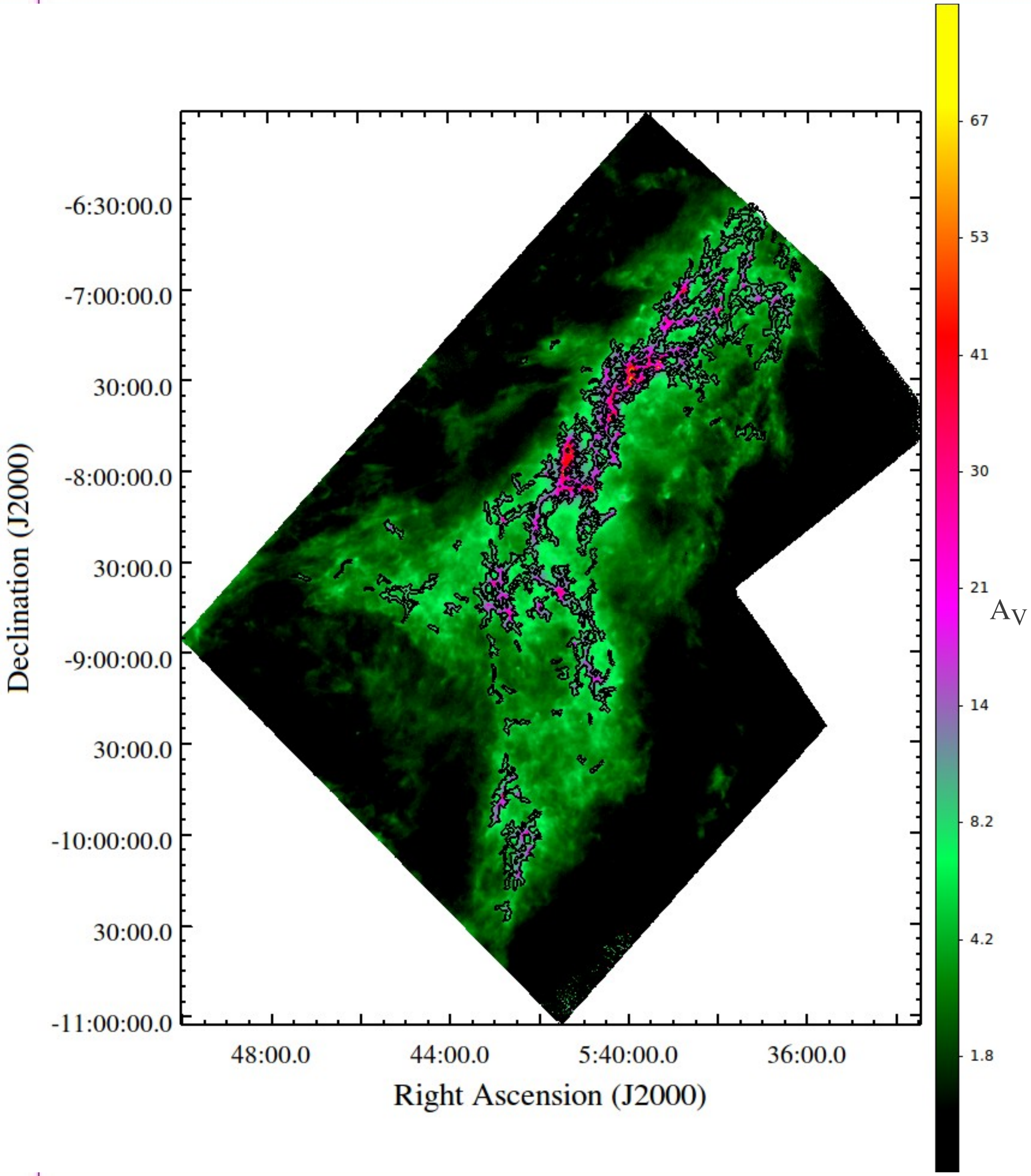
Filaments

(Schisano et al. 2014, , ApJ, 791, 27)



Filaments

properties



Average deconv. FWHM: 0.15 pc
Lengths: 0.5 to $\sim$ 9 pc
Temperatures: 12 to 13 K
Masses: ~ 5 to 5×10^3 $M_\odot$

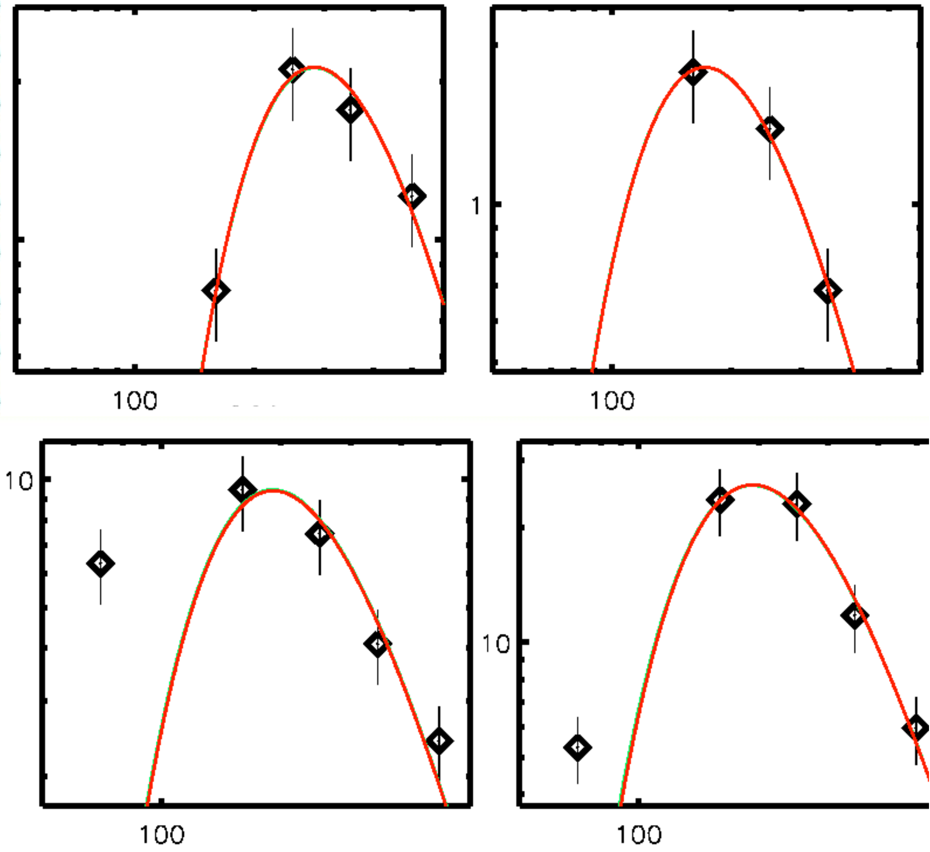
These values are in broad agreement with the findings of Nagahama et al. (1998); any divergence is likely due to the lower resolution of their ^{13}CO $J = 1 \rightarrow 0$ data (2′ versus 36″) and the use of slightly different distances to the cloud (484 pc instead of 414 pc).

Source Detection & Photometry

We used CUTEX (Molinari et al. 2010) to identify and extract sources. We bandmerge the catalogue keeping only those sources that have detections in 3 consecutive bands & good SEDs.

We fit the SEDs with an optically thin grey-body model using a fixed dust emissivity $\beta=2$ and dust opacity $\kappa_{THz}=0.1 cm^2 g^{-1}$ (Beckwith et al. 1990; Hildebrand 1983)

We find in total 493, of which 109 we classify as proto-stellar and 384 as starless based on the existence of a 70 micron (and also 24μm) object (Stutz et al 2013; Megeath et al 2012; Dunham et al. 2008).



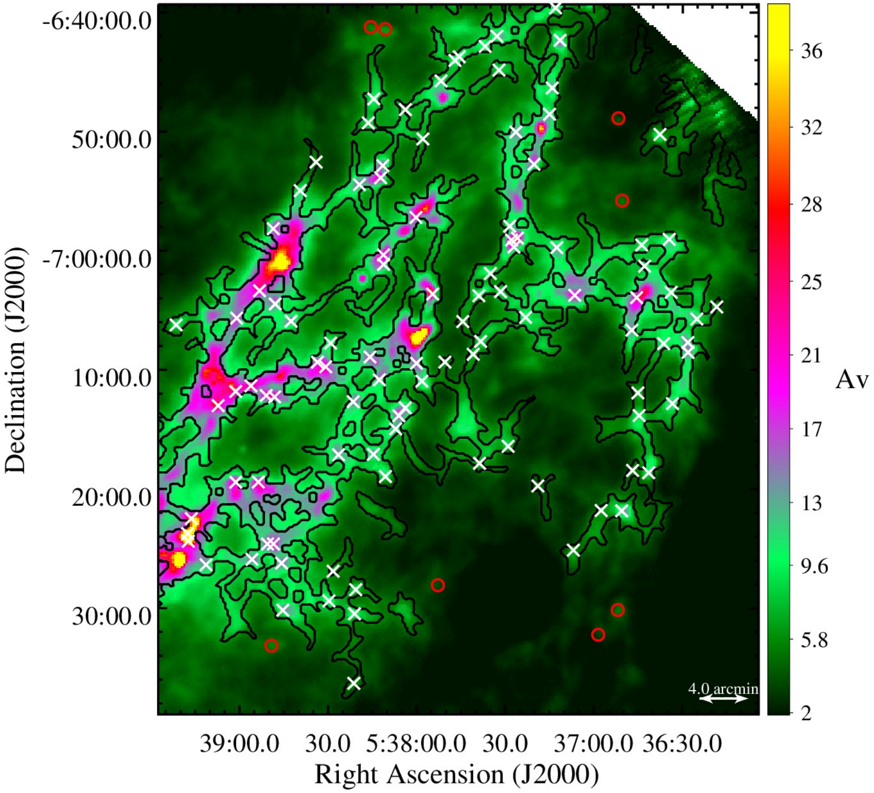
We check which of our sources have a size smaller than 0.1 pc and use the $M_{obs}/M_{BE}=1.0$ (Rygl et al. 2013) criterion to distinguish between gravitationally bound *pre-stellar* sources (84%) and the *starless* gravitationally unbound sources (16%).

Pre-stellar sources *on* and *off* filaments

67% of the cores are located *on* the filaments, of which 229 are pre-stellar, 92 are starless and 83 are proto-stellar.

Of the cores located *off* the filaments 19 are pre-stellar, 44 are starless and 26 proto-stellar.

92% of the sources *on* filaments are pre-stellar, which drops to 68% when considering sources *off* filaments.



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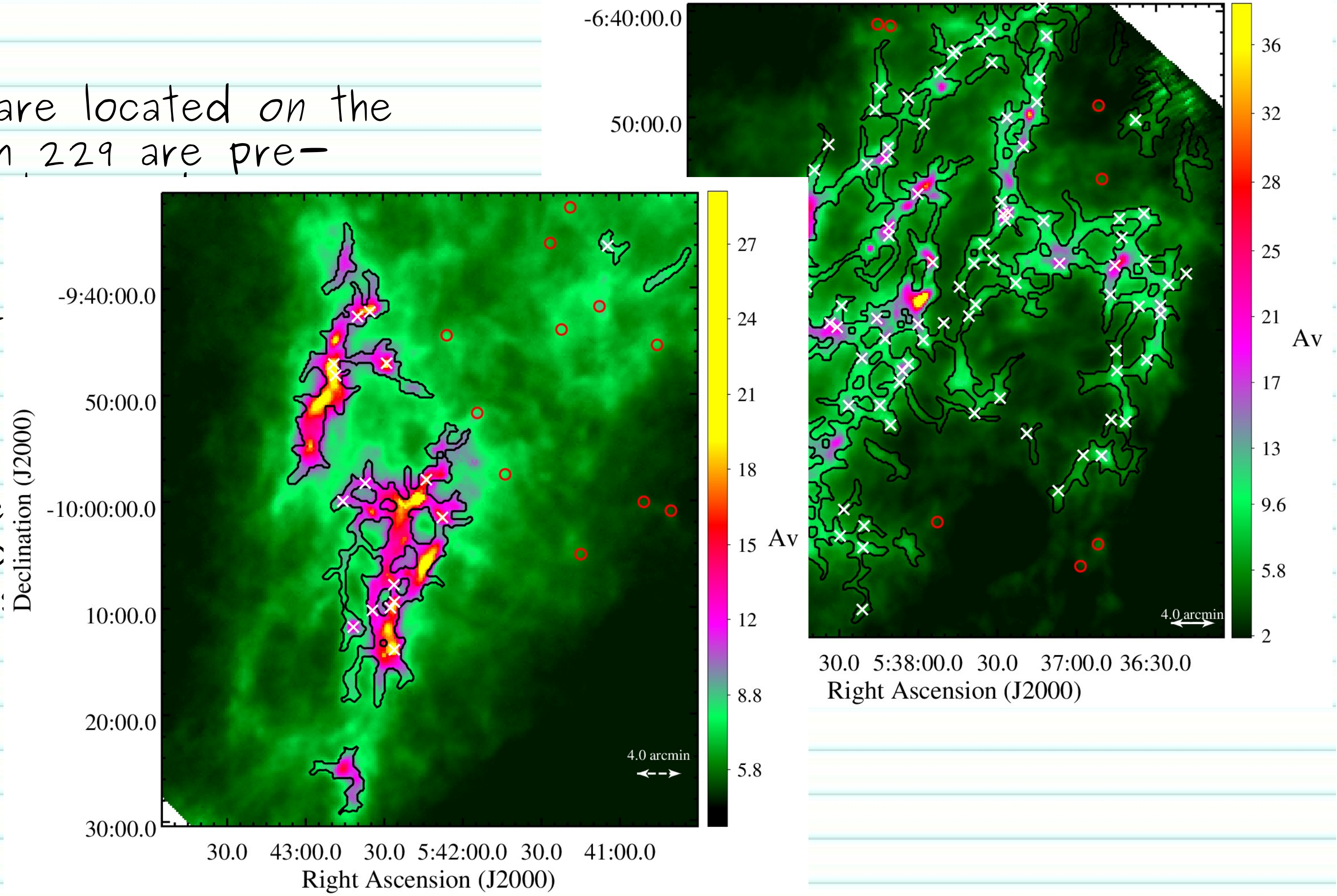

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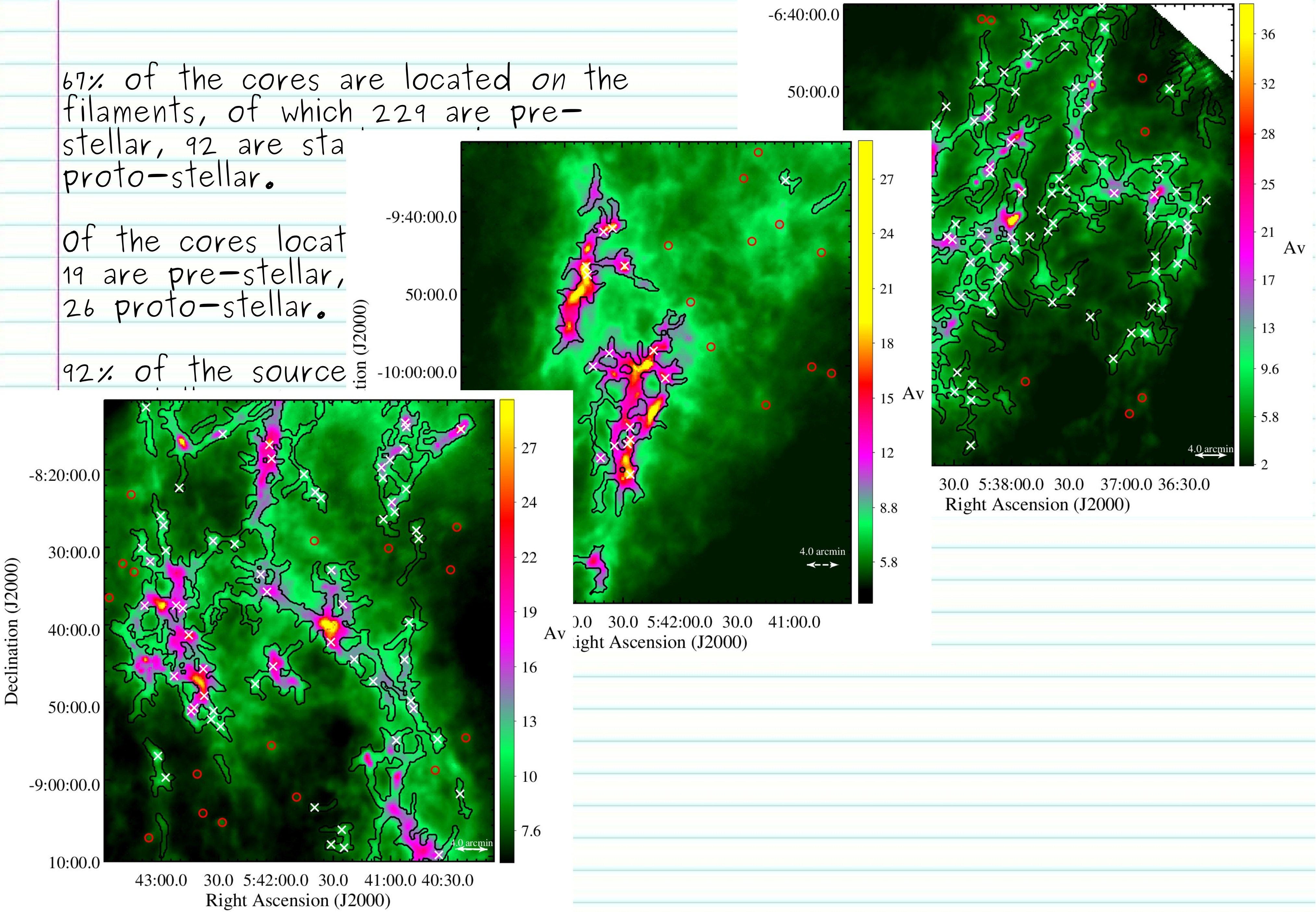

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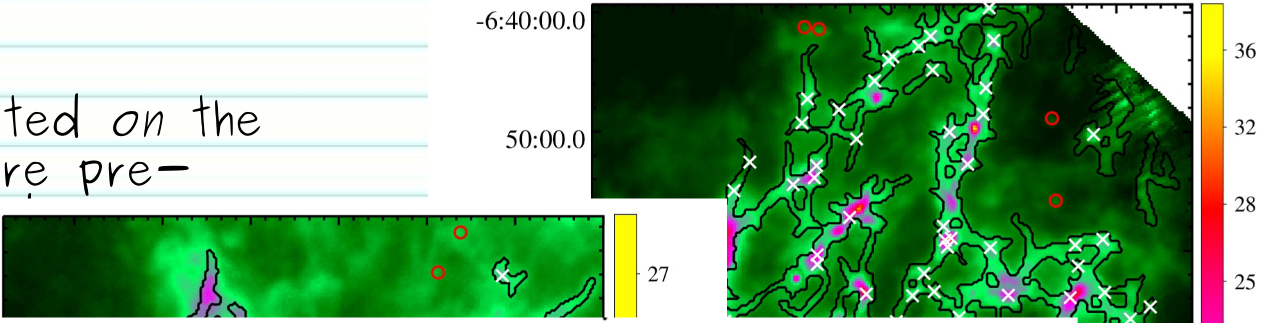
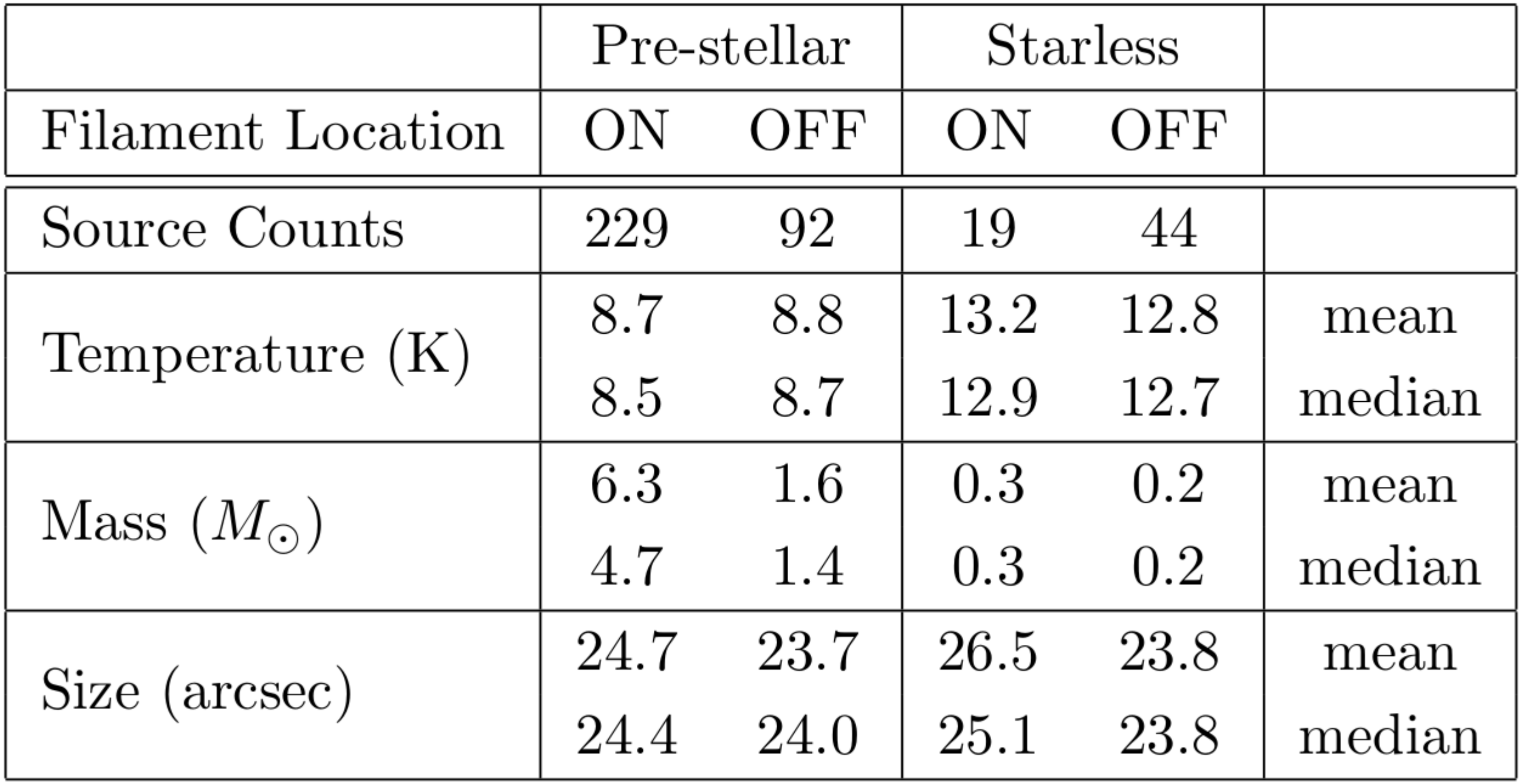
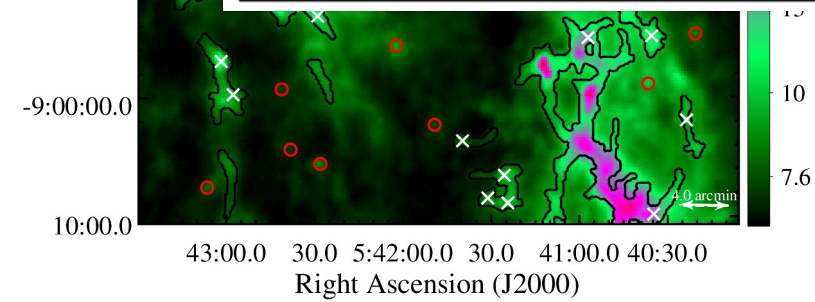
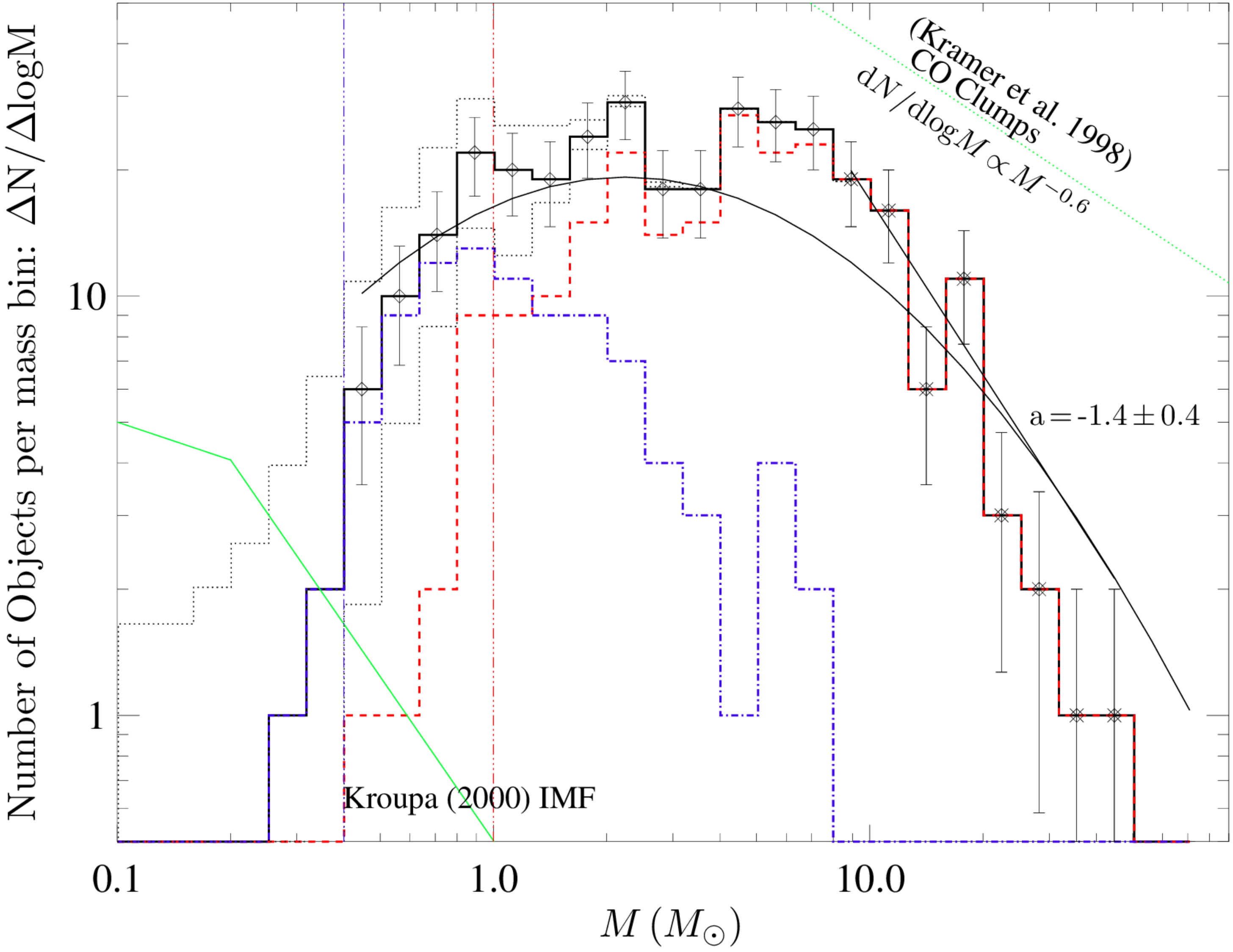




	Pre-stellar		Starless		
Filament Location	ON	OFF	ON	OFF	
Source Counts	229	92	19	44	
Temperature (K)	8.7	8.8	13.2	12.8	mean
	8.5	8.7	12.9	12.7	median
Mass ($M_\odot$)	6.3	1.6	0.3	0.2	mean
	4.7	1.4	0.3	0.2	median
Size (arcsec)	24.7	23.7	26.5	23.8	mean
	24.4	24.0	25.1	23.8	median



The Core Mass Function



The Core Mass Function

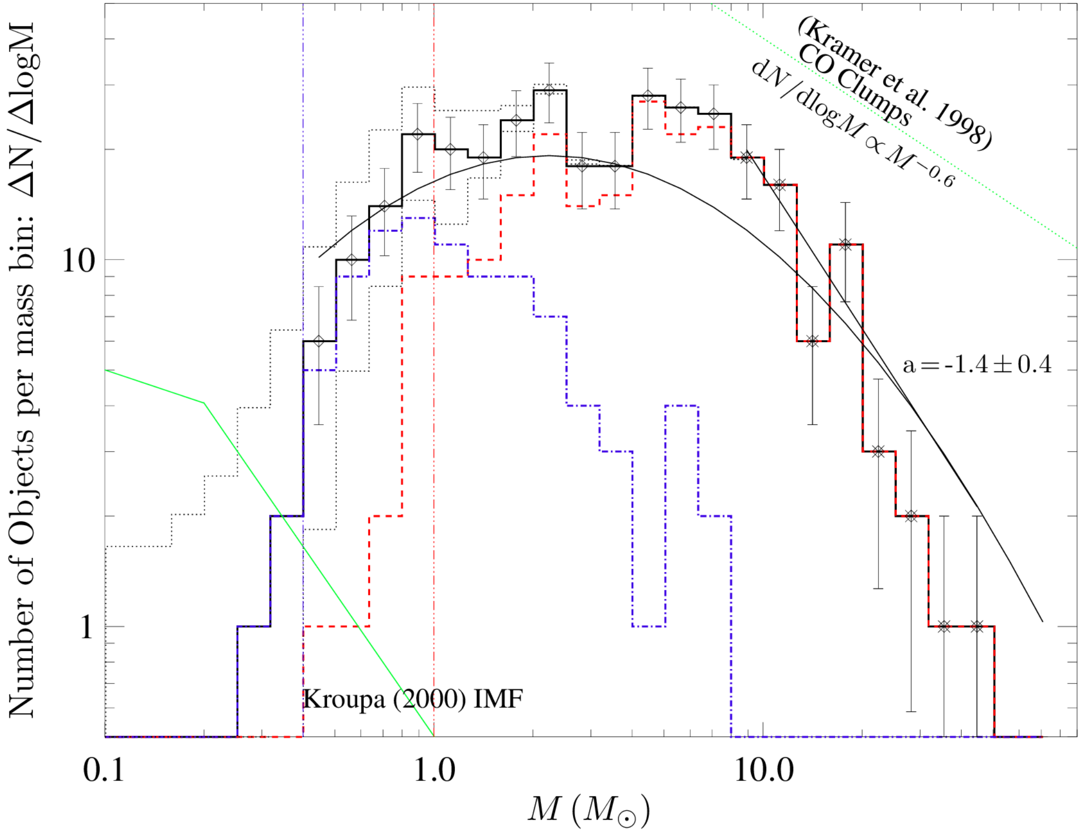
The masses of the pre-stellar cores range between 0.2 and 55 $M_\odot$. The distribution flattens between 1$M_\odot$ and 4$M_\odot$ (Padoan & Nordlund 2011). The power law fit to the high-mass end of the CMF (−1.4±0.4) agrees very well with previous estimates for Orion A (slope −1.3; Ikeda, Sunada & Kitamura 2007).

In red we plot the pre-stellar cores *on* filaments (71%) and in blue those *off* them (29%). The distributions peak at 0.8$M_\odot$ and 4.0$M_\odot$ for cores off and on the filaments.

The slope of the CMF is driven by the sources located *on* the filaments, while the flattening of the CMF is a result of the sources located *off* the filaments.

→ Due to the difference of column densities between the filaments and the rest of the cloud, we estimate 2 completeness limits using synthetic sources.

For the filaments we find that our core sample is complete (@ the 80% level) down to 1.0$M_\odot$ while *off* the filaments we are complete down to 0.4$M_\odot$.



What does all this mean?

That we find more gravitationally bound cores *on* filaments can be explained twofold:

→ Filaments are regions of strong emission in a localised space in the clouds. **Fainter objects**, potentially unbound, are **not easy to detect towards filaments** (i.e. higher mass completeness limit).

→ Cores located *on* filaments find themselves in a much different environment than cores *off* them. It is possible that **the larger external pressure** from the filament coupled with the **larger reservoir of gas** available allows for **more cores to gravitationally collapse**.

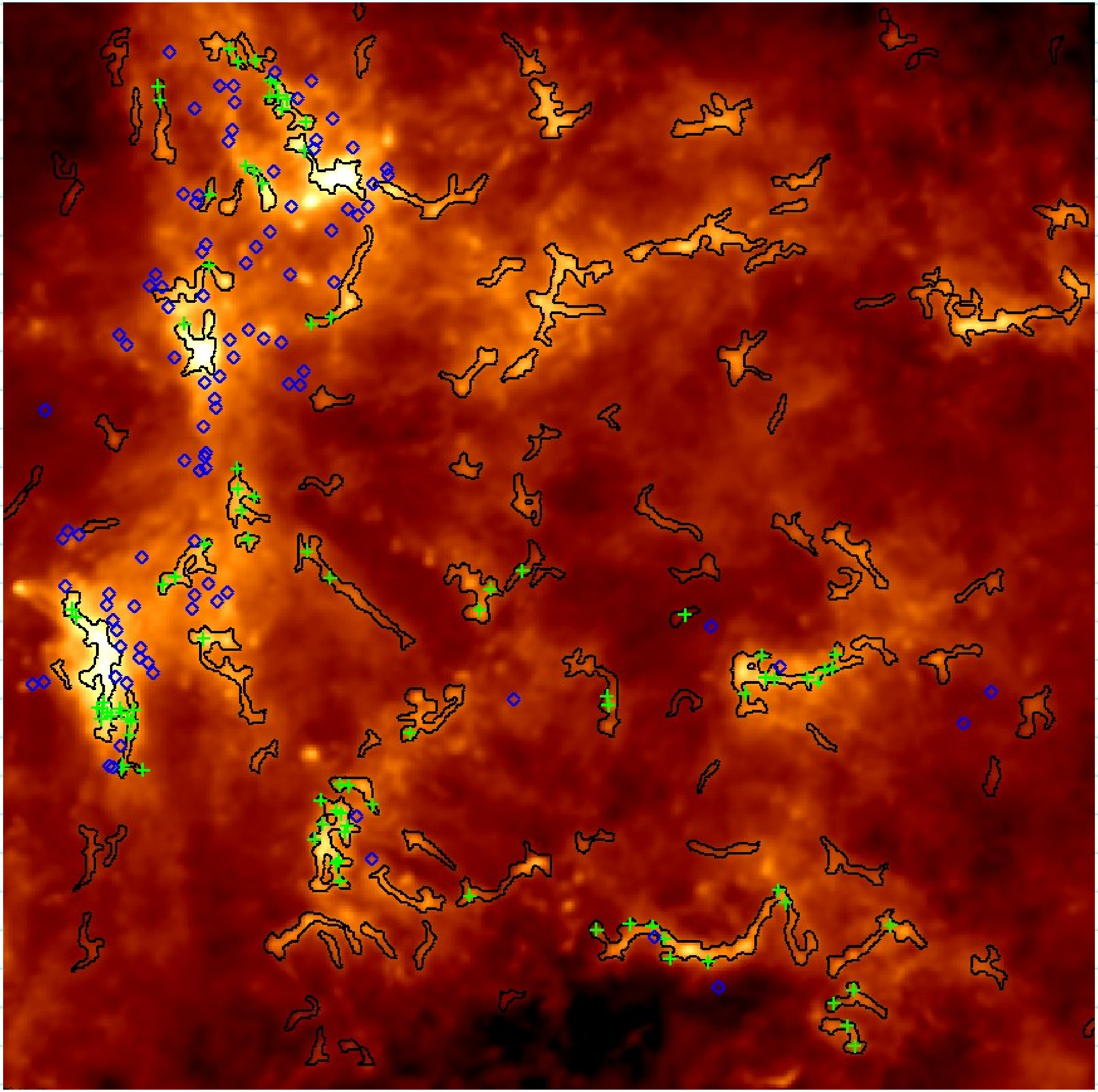
We also find that there are two separate mass distributions of the pre-stellar cores *on* and *off* filaments.

As **filaments have higher column densities** than the rest of the cloud, objects formed in situ have a **larger reservoir of mass** to accrete from, forming in general **higher-mass objects**, than those *off* them.

The dense **cores** may still **form in the same general way *on* or *off* the filaments**, but the **different environments** these cores find themselves in may result in **different mass distributions**.

→ This results in the **higher core formation efficiency** measured **on the filaments** with respect to the whole of the cloud, making the filaments the **preferred, but not unique, star formation site**.

But...

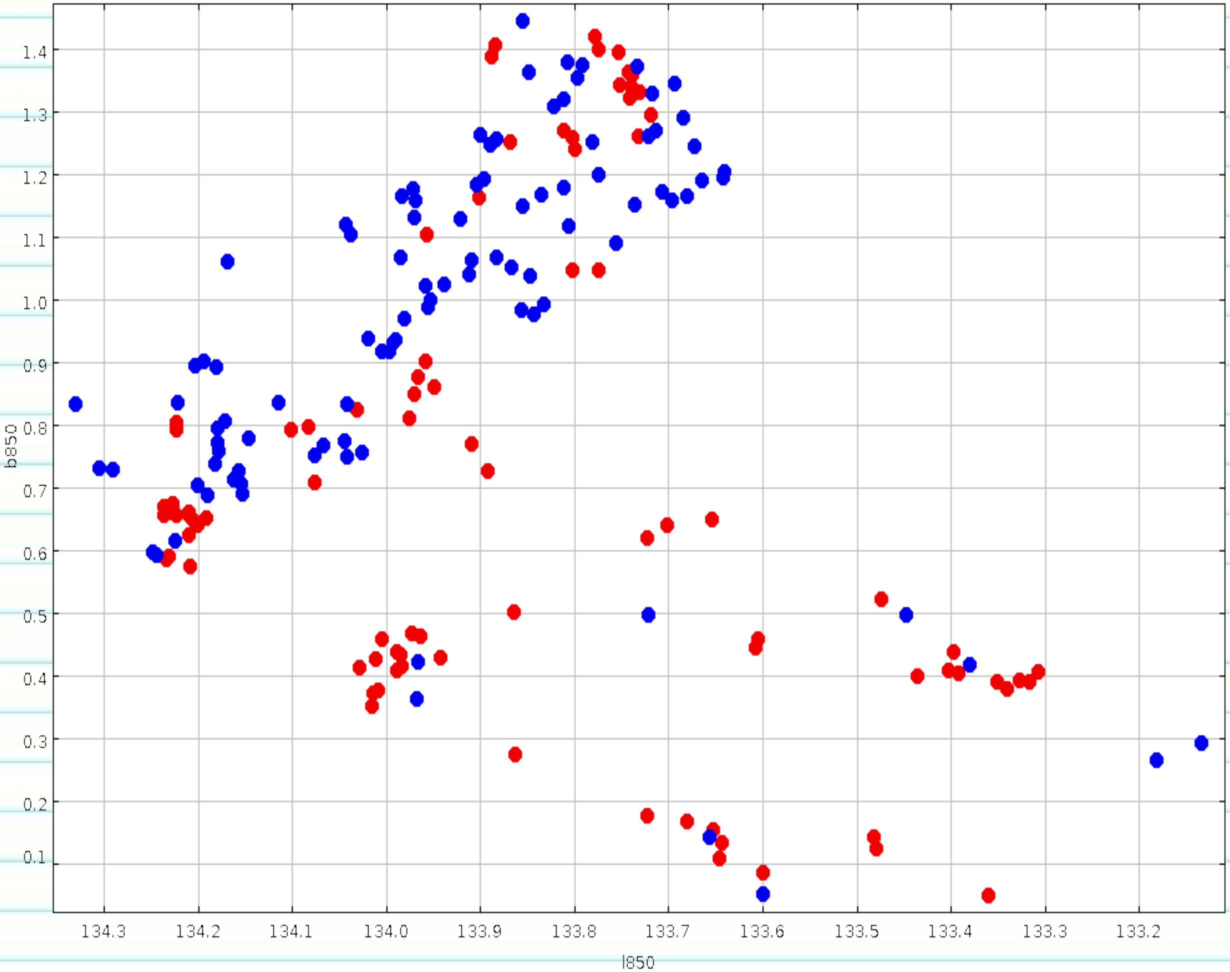


But...

The W3 GMC is a site of high mass star formation (@2kpc) induced by the adjacent expanding W4 HII super-bubble region.

Here we find that of 197 pre-stellar cores we find that they are split 50-50 *on* and *off* filaments.

But W3 on the HDL region of W3 – the triggered region – of 140 cores there 66% are *off filaments*, while in the LDL region of a total of 53 cores only 17% are *off* filaments.



The Core Mass Function

Background flux contribution

We compare the input fluxes of the synthetic sources with the respective ones measured by CuTEx, using the SPIRE 250 μm band as reference.

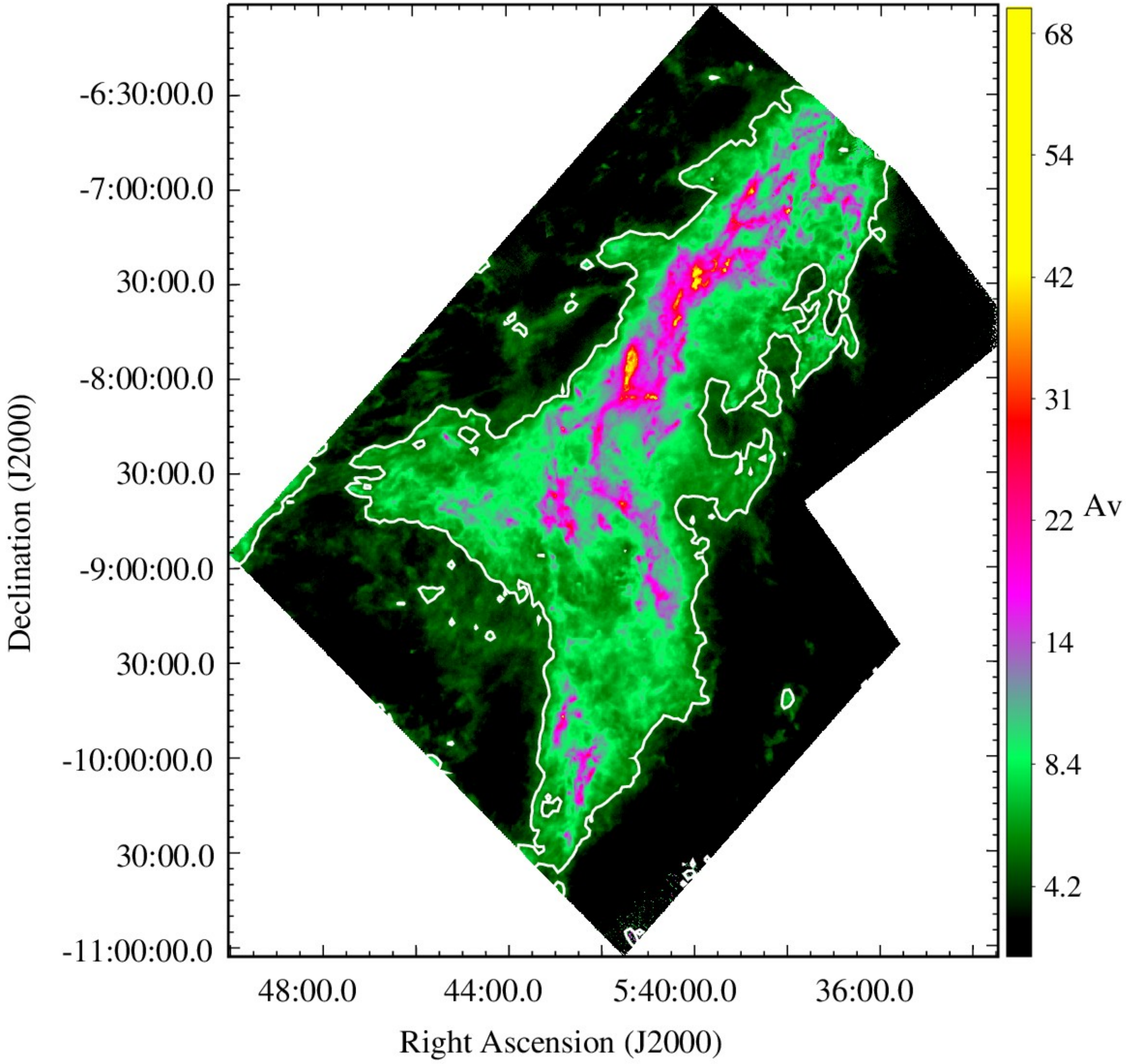
→ convert the input and measured fluxes to masses and bin them in the same way as the observed sources.
→ for each bin we compute the fraction of synthetic sources within 20% of the input value
→ from that we derive the 1-σ uncertainty (due to background contribution) associated to each of the bin centres.

We created 10^5 synthetic populations of 500 sources for the *on* and *off* filament mass distributions using Monte Carlo extractions. For each synthetic source we

- determine to mass bin it belongs to
- extract its measured mass value, assuming a gaussian distribution with the σ parameter determined above and centred on the mass value of the bin centre.
- rebin the mass distribution of each population as for the observed sources
- for each bin record the minimum and maximum values among the 10^5 populations for the *on* and *off* filament mass distribution and for the total one.

For these sources the 1-σ relative error is of the level of 50% or higher. Above the completeness limit, however, the background flux contribution is not significant enough to affect the results of this study.

Column Density & Mass



Derived from pixel-to-pixel SED fitting of the 160, 250, 350 and 500 µm bands. The white contours trace extinction higher than 2 magnitudes.

Using a distance of 414 pc and
$N_{H_2} = 9.4 \times 10^{20} A_V$ (Bohlin et al. 1978)
we get a mass of 3.7×10^4 M⊙.

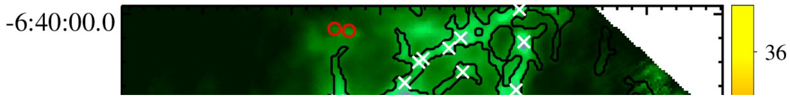
Within the filaments the total mass is estimated around 1.16×10^4 M⊙ which represents 31.4% of the total mass of the L1641 clouds.

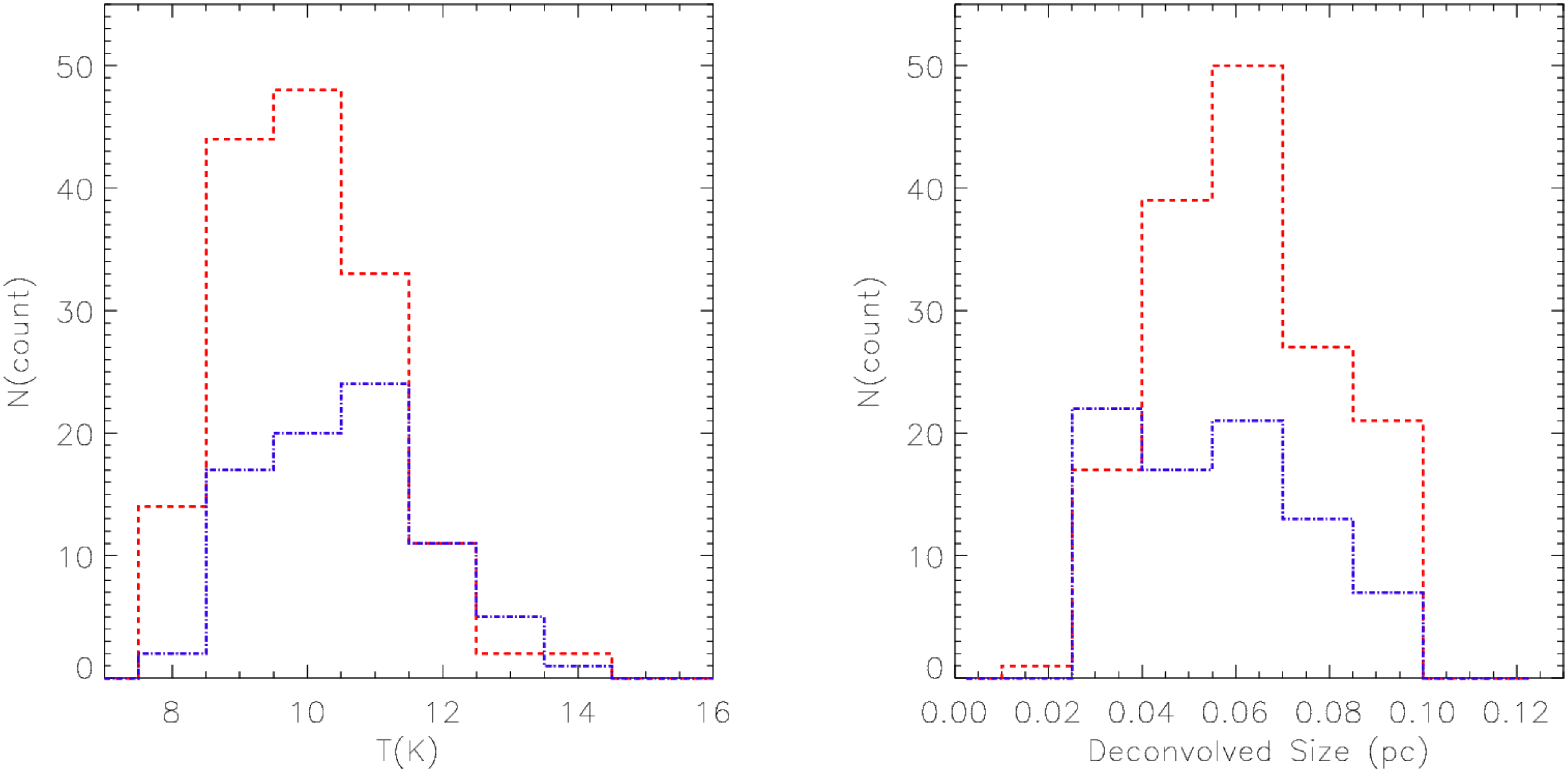
Using the standard CFE equation:

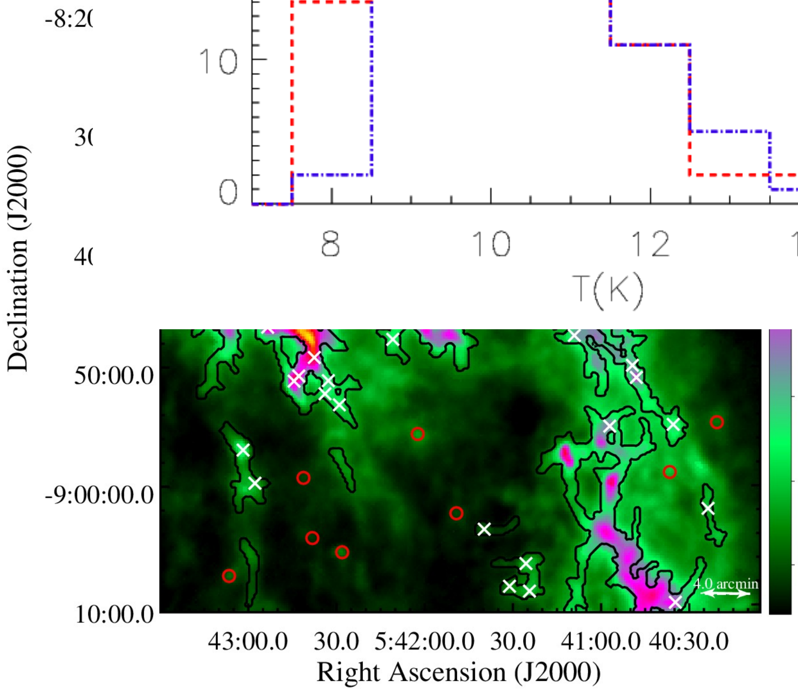
$$M_{cores} / (M_{cloud} + M_{cores})$$

we calculate that the CFE of the L1641 MCs is 4%. This value increases to 12% for dense cores on filaments as well as the total mass within these filaments.

Pre-stellar sources on and off filaments







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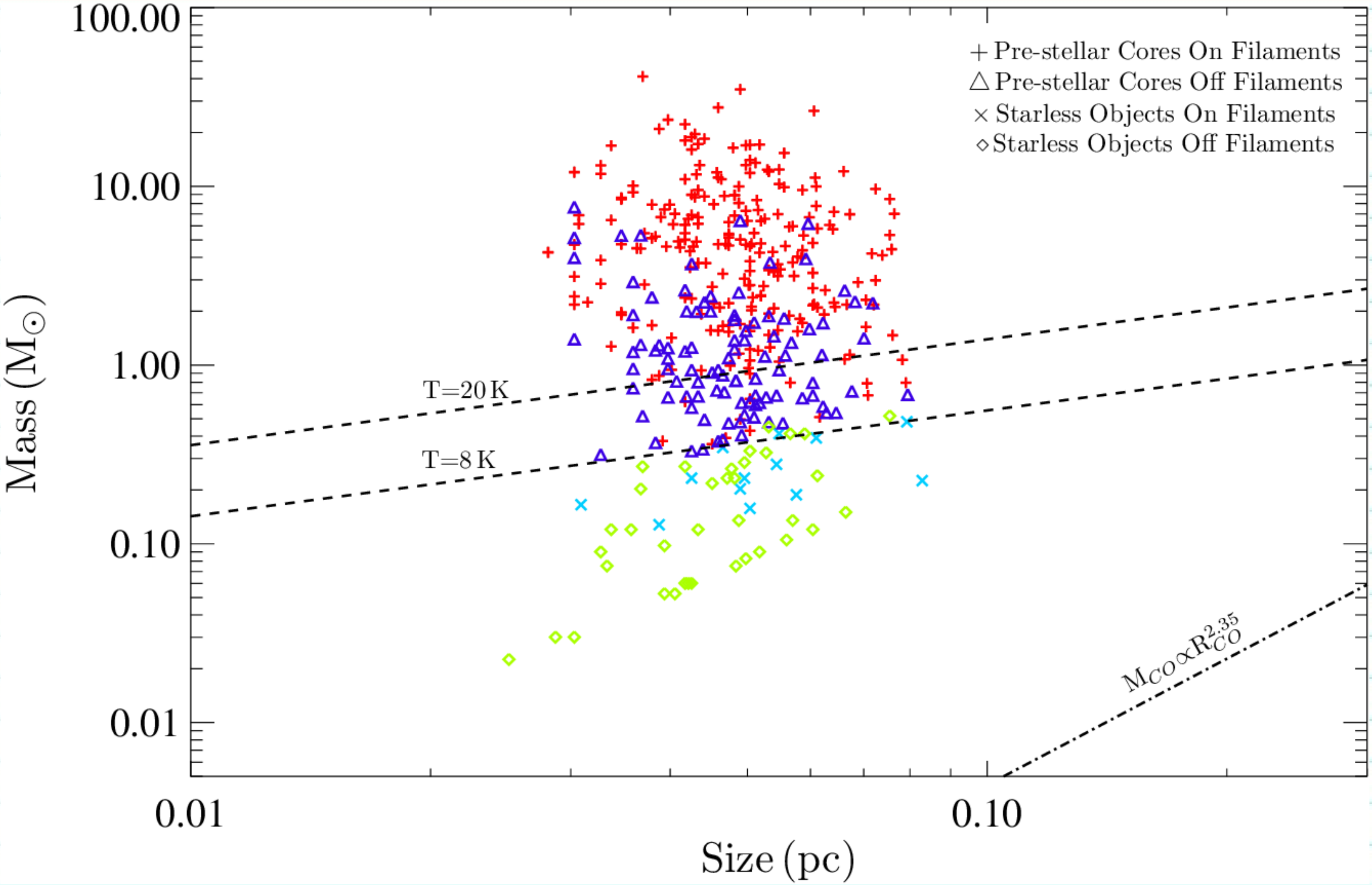

The Core Mass Function

Background flux contribution – On Filaments

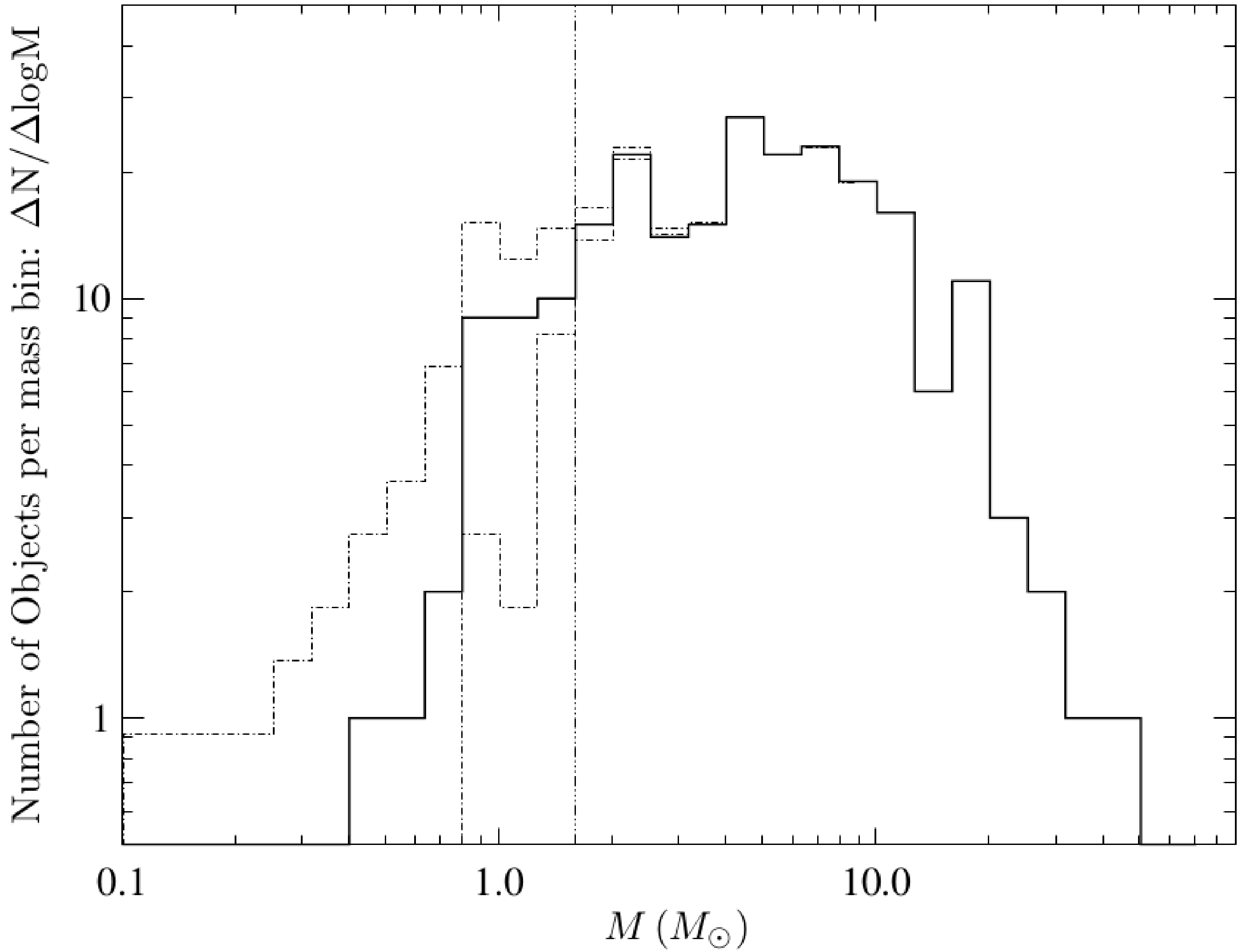

Fig. 10.— The CMF of the pre-stellar sources *on* filaments. The dash-dot lines indicate the variability that can result from background flux contribution on the sources. The vertical line indicates the completeness limit of the source detection.

The Core Mass Function

Background flux contribution - Off Filaments

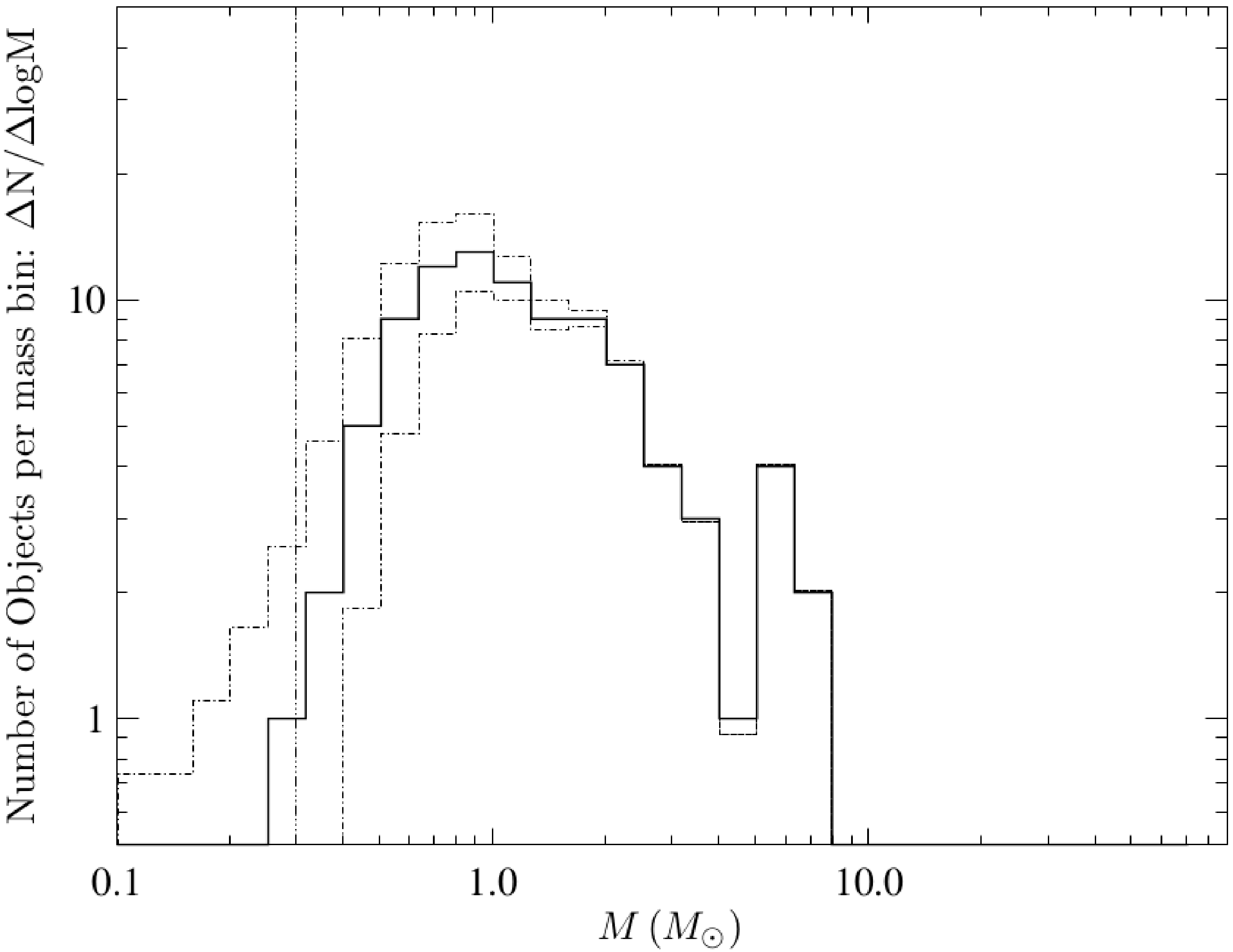

Fig. 11.— The CMF of the pre-stellar sources *off* filaments. The dash-dot lines indicate the variability that can result from background flux contribution on the sources. The vertical line indicates the completeness limit of the source detection.

The Core Mass Function

Background flux contribution – On & Off Filaments

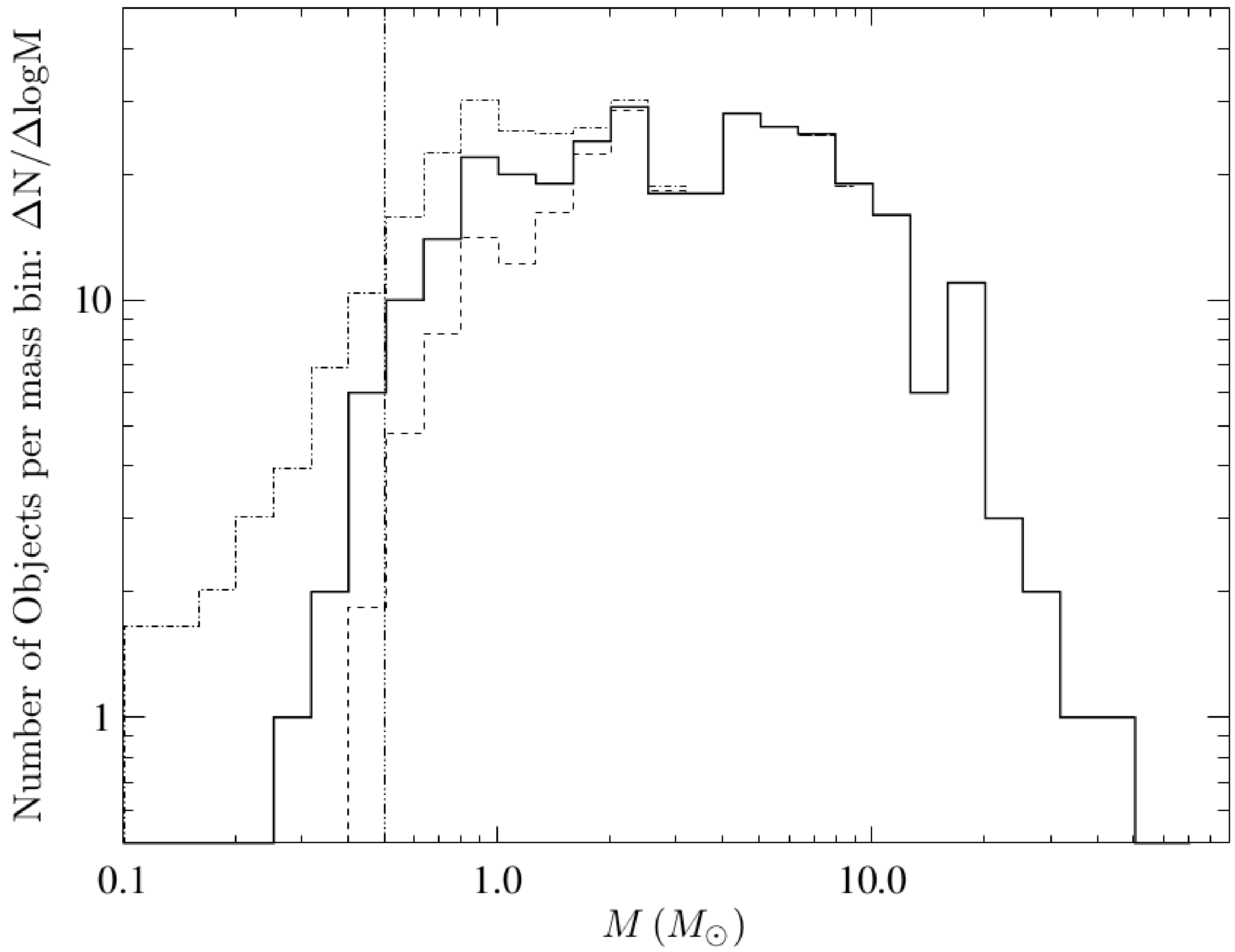

Fig. 9.— The CMF of all pre-stellar sources. The dash-dot lines indicate the variability that can result from background flux contribution on the sources. The vertical line indicates the completeness limit of the source detection.

The Core Mass Function