LOW COLUMN DENSITY FILAMENTS IN THE LUPUS MOLECULAR CLOUD

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ABSTRACT

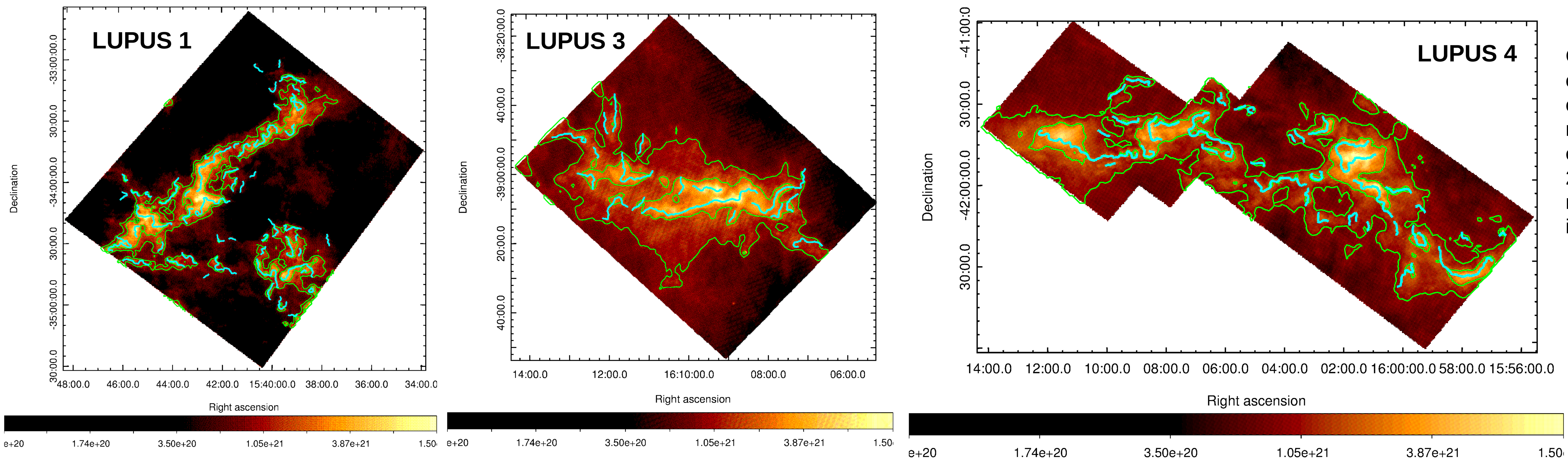
The Lupus complex is one of the nearest molecular clouds where the formation of low mass stars can be studied. Within the Herschel Gould Belt Survey Key Program the three main star forming regions of the complex, Lupus 1, 3 and 4, were mapped with unprecedented sensitivity in five far infrared bands. The Herschel maps revealed the filamentary structure of the three clouds. Filaments in the Lupus clouds have quite low column densities and most have masses per unit length lower than the maximum critical value for radial gravitational collapse. We find that also filaments that are thermally subcritical contain dense cores that may eventually form stars. This is an indication that in low density filaments the critical condition for the formation of stars may be reached only locally and is not a global property of the filament. Finally, in Lupus we find multiple observational evidences that magnetic field play a key role in filaments formation and confinement.

COLUMN DENSITY MAPS

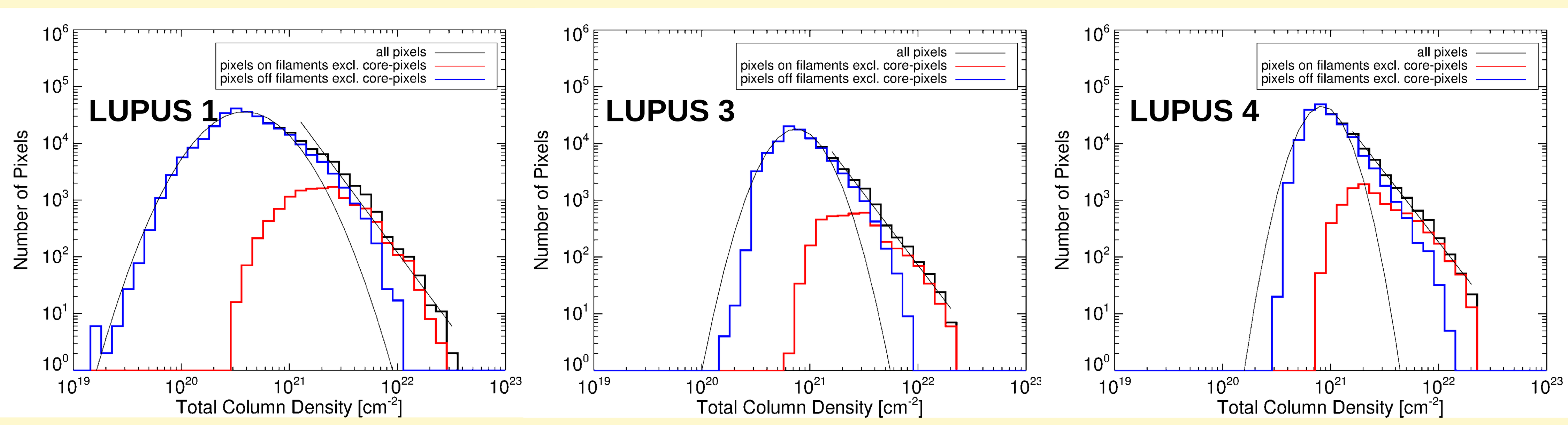
The column density maps of the three Lupus regions have been derived by applying a grey body fit to the intensity of each pixel of the four Herschel maps obtained at 160, 250, 350 and 500 µm, smoothed at a common spatial resolution of 36". In the grey body fitting we assumed a dust opacity of $\kappa_{300\mu m}$= 0.1 cm^2g^{-1}, a grain emissivity parameter β=2, and a mean molecular weight µ=2.8. These are the standard values used in all works based on the Herschel Gould Belt Survey data.

FILAMENTS

In order to characterize the filamentary structure of the clouds we applied an algorithm that uses the eigenvalues of the Hessian matrix of the column density map to identify the border of the filament, defined as the place with the maximum variation of the density field along any direction (Schisano et al., 2014). The spine of the filament is then derived by applying a morphological operator of thinning to pixels inside the borders, connected with a Minimum Spanning Tree technique.

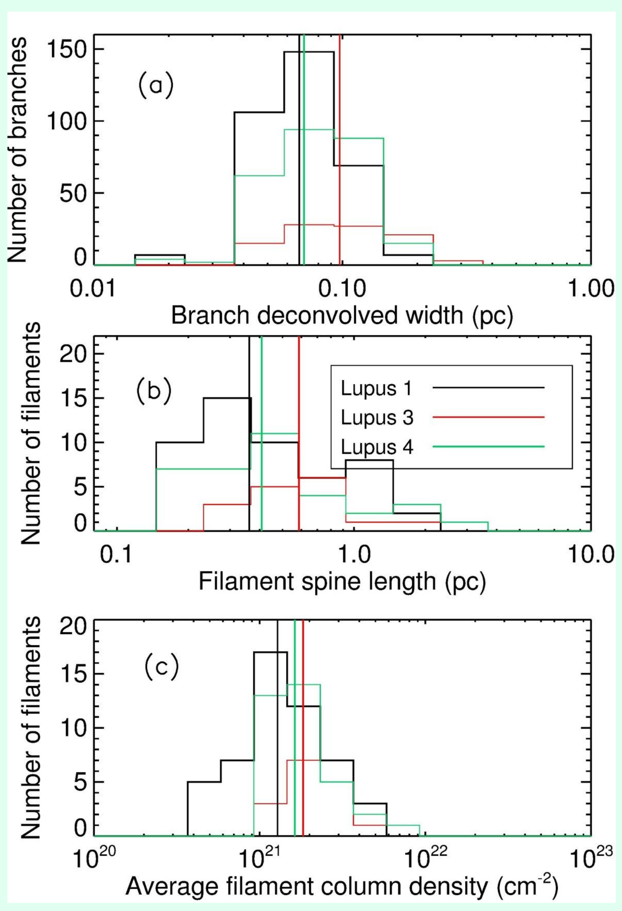


Column density maps of the three Lupus clouds. Green contours mark levels of visual extinction of 1 mag and 2 mag. Cyan lines mark the spine of the identified filaments.



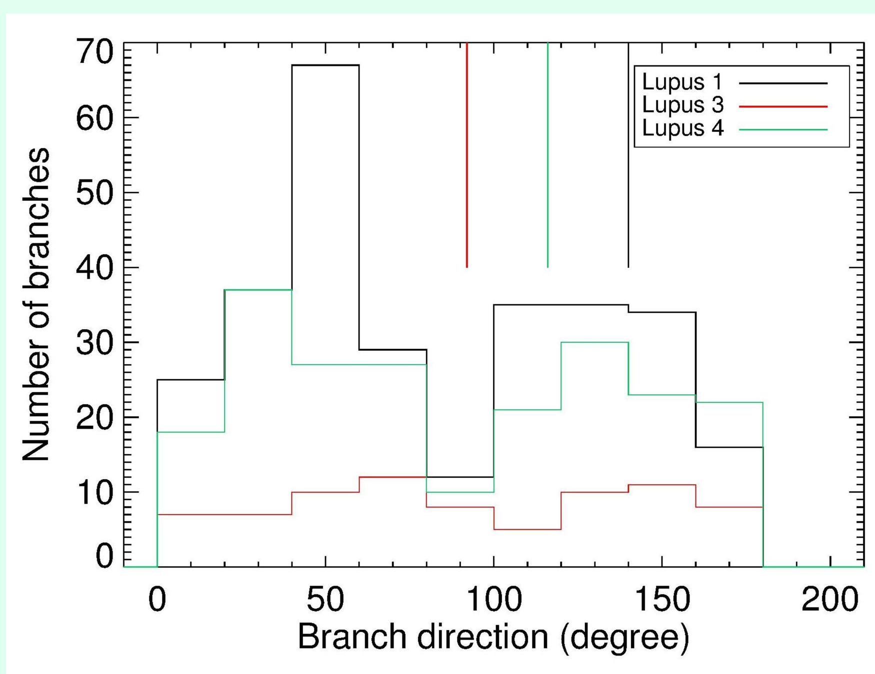
PDFs of the column density maps of Lupus 1, 3 and 4. The continuous black lines represent the log-normal fit of the low column density pixels and the power-law fit of the high column density pixels.

The Probability Distribution Function (PDF) of the column density map of the three regions peaks between (4 – 8)x10^{20} cm^{-2}, values lower than those found in more massive and active regions as Orion and Aquila and much more similar to the values found in Chamaeleon and Polaris, regions width low or null star formation activity (Schneider et al. 2013; Alves de Oliveira et al. 2014). The high-column density tail of the PDFs is dominated by region classified as filamentary (on-filament cores are excluded) and has a power-law shape. This indicates that self-gravity is important in some no-cores portions of the filaments and that locally, the denser material contained in filaments, but still not in confined in a core, may undergo gravitational collapse.



Filaments in Lupus are generally short with a median **length** of ~0.4 pc. The median value of the filament **width** is very close to the typical value of 0.1 pc found in a wide sample of filaments (Arzoumanian et al. 2011). **The average filament column density** ranges from 4x10^{20} cm^{-2} to 10^{22} cm^{-2}. Noticeably, these values are in the lower part of the distribution of filaments column densities found in other regions (Arzoumanian et al 2013; Schisano et al. 2014), and they are closer to the column densities found in non-star or low-mass star forming regions rather than to values typical of more active and high-mass star forming regions.

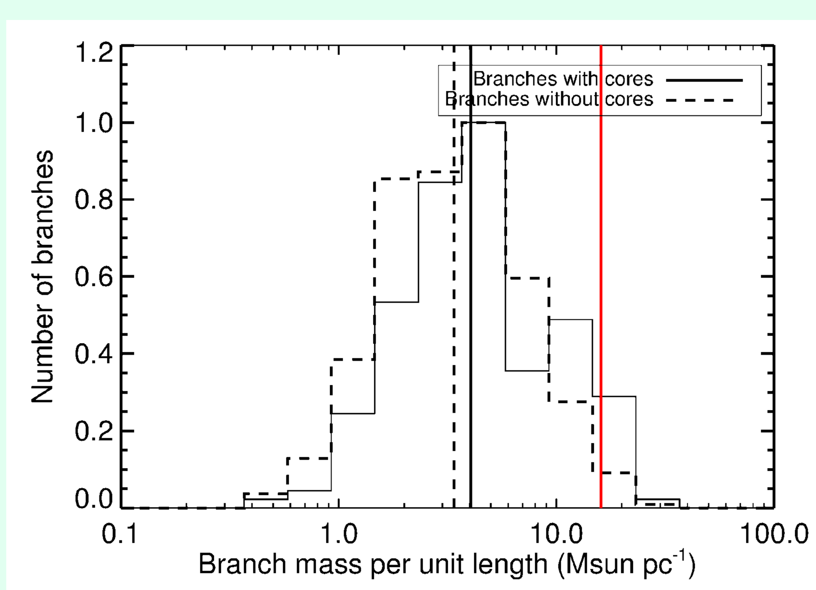
In the three clouds both the range and the median values of the filaments physical parameters are very similar. This result is in agreement with the observed uniformity of the overall star formation properties of the three subregions of the Lupus complex.



Distributions of the position angles of the branches of the filaments of the three Lupus regions. The vertical bars indicate the direction of the magnetic field in each cloud.

The histogram of the **direction (position angle)** of the filaments branches is similar in all the three clouds and shows two peaks: one at ≈ 50° and one at ≈ 140°. One of the peaks is similar to the direction of the local magnetic field in the regions. Therefore, filaments in Lupus are mainly arranged along the direction of the local magnetic field or in the orthogonal direction. This is an indication that the magnetic field may have had a role in the filaments formation and may play a role in their support.

Almost all the Lupus filaments have **average masses per unit length** lower than the maximum critical value for radial gravitational collapse (~16 $M_{\odot}$/pc, for T=10 K). Indeed, no evidence of filament contraction has been seen in the gas kinematics. Interestingly, also filaments that are thermally subcritical contain dense cores, that may eventually form stars. This is an indication that in the low-density filaments global properties, as the average mass per unit length, cannot be used to evaluate the possibility of the filament to form stars and that the critical condition for the formation of stars may be reached only locally.



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