Filamentary Structures in Star Forming Regions

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Abstract: Herschel maps reveal the rich and complex structure of molecular clouds with gas and dust arranged in filaments, often containing embedded pre/proto-stellar cores. Filamentary structures are ubiquitous and are believed to play an active role in star formation, being the intermediate products of the compression and the sweeping of matter by the turbulence present in the molecular cloud. Despite their importance, few studies on filaments are still available in the literature, mostly due to the difficulties in identifying them in an objective way. Here we present the first results of an automatic algorithm, still under development, able to detect filamentary structures on the maps of the Galactic plane observed by the Herschel Space Telescope in the framework of the Hi-GAL survey.

1. Filaments and their Connection with the Star Formation

The current accepted paradigm of star formation predicts that stars form naturally by the action of turbulence within a self-gravitating molecular cloud (see e.g. the review by McKee & Ostriker 2007). Numerical simulations show that the large-scale turbulence by compressing and sweeping the matter, is able to build up a complex network of coherent (filamentary) structures (Klessen 2001, Heitsch et al. 2008). Within such filaments or in their intersections the density enhancements on spatial scales smaller than the local Jeans length, thus those density fluctuations become quickly unstable and collapse forming highly clustered protostellar cores.

The filamentary pattern predicted by gravo-turbulent scenario has been observed in several star forming regions, like Orion (Mitchell et al. 2001), Perseus (Hatchell et al. 2005) and Taurus (Hartmann et al. 2002). Recent observations conducted with Herschel confirmed that filaments are visible everywhere in the active star-forming regions. More important, those observations detected pre/protopstellar cores spatially associated with the filaments (Molinari et al. 2010; Men'shchikov et al. 2010), in agreement with the theory of star formation triggered by the large-scale turbulence. Filaments are then an intermediate stage in the star formation process, that is mostly unexplored.

2. The Automatic Filament Detection

We used image processing techniques to develop a code for identifying filamentary structures. Our approach relies on a filtering using the second derivative to determine the intensity shape near each pixel. Elongated elliptical-like patterns are traced by the eigenvalues (λ₁, λ₂) and the eigenvectors (x₁, x₂) of the Hessian matrix computed at each pixel by selecting those ones whose the local intensity shape is concave down along the two principal axes (λ₁, λ₂, x₁, x₂). Noise impact on the derivative filtering is reduced by smoothing the images with specific anisotropic diffusion filters (Perona & Malik 1990) that preserve the filaments edges. Finally different morphological operators (Gonzales & Wood 2002) are applied on the RoI to determine the position of the filament and the coherence of multiple nearby structures for future multi-scale analysis.

3. Investigating Morphological and Physical Properties of Filaments

Applying the filament detection algorithms on various maps we plan to build up a robust catalog of filaments for which we will determine morphological (length, width) and physical (mass and temperature) properties. Lengths and widths provide an indirect probe of the original turbulence that compressed the matter (Nagai et al. 1998). Masses and temperatures are determined by modelling the spectral energy distributions built integrating the emission in the RoI at different wavelengths (see Figure 3). First indications from a limited sample of 8 filaments, 4 of which are shown in Figure 3, suggest that they have masses between 20 - 400 M☉ and temperatures in the range 10-20 K, in agreement with the fact that filamentary structures are not expected to represent an homogeneous class definite by particular physical properties. However larger samples have to be investigated before drawing any further conclusion.

References:

Aragón-Calvo et al. 2007, A&A 474, 315

Mitchell et al. 2001
Molinari et al. 2010, PASP, 122, 314
Perona & Malik 1990, IEEE 1127