Cores, filaments and bundles: Hierarchical core formation in the B213 Filament in Taurus

(Hacar et al 2013, A&A, 554, A55)

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1.- Observations

- B213 is the most prominent filamentary structure in Taurus.
- It consists of ∼700 $M_\odot$ of molecular gas extending over 10 pc.
- It is an active star-forming region that contains about 20 dense cores, some prestellar and some protostellar, and ∼ 40 YSOs.
- We have observed B213 in both $C^{18}O$ (1-0) and N_2H^+ (1-0) lines with FCRAO (> 46 000 spectra Nyquist sampled).
- In addition, we have obtained partial 850 μm continuum maps with APEX-LABOCA.
- We have also compared our results with archive Herschel maps.

2.- Multiple velocity components in B213

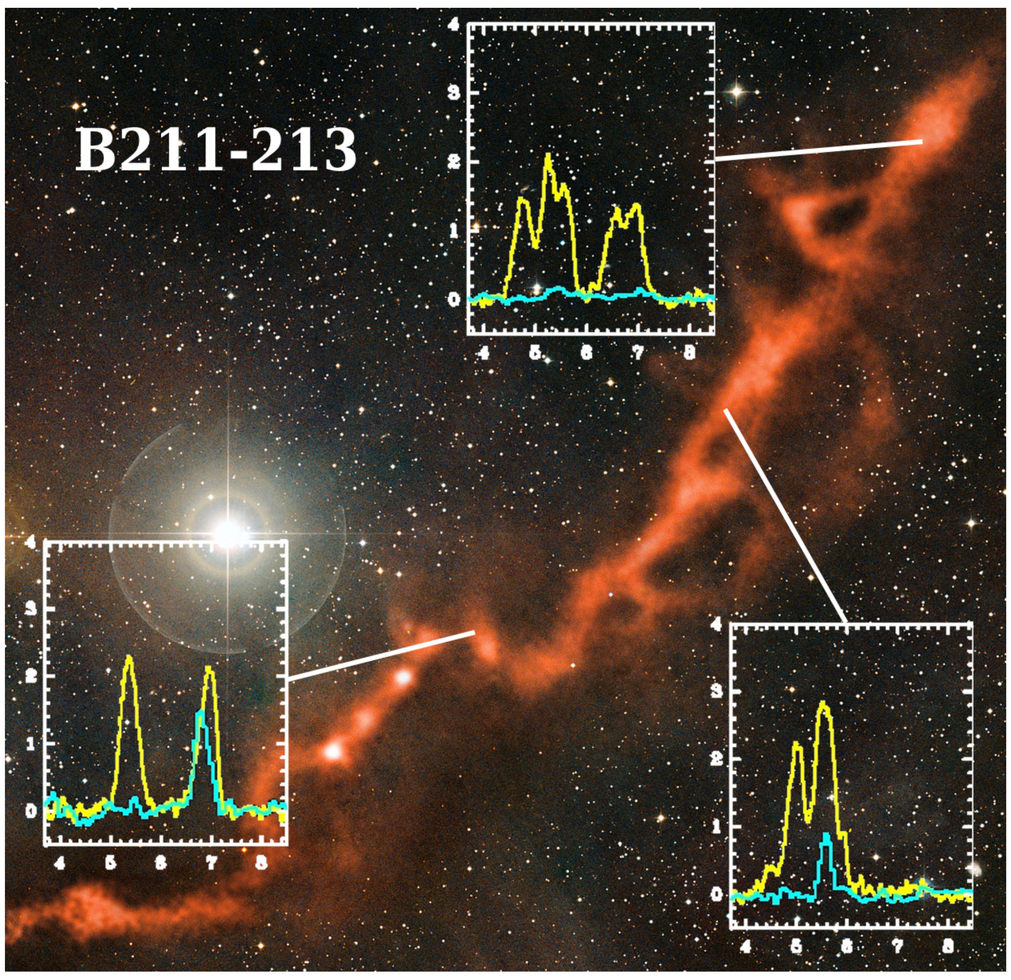

Fig.1: Optical image (background) of the B211-213 subregion compared to the LABOCA Continuum emission at 850 μm (orange). The small boxes show some illustrative spectra of $C^{18}O$ (yellow) and N_2H^+ (blue).

- Although simple when observed in the continuum, B213 exhibits a very rich kinematic structure.
- Up to 5 different velocity components can be seen in some $C^{18}O$ spectra.
- When detected, the N_2H^+ emission is always associated with one of the $C^{18}O$ components.

3.- Analysis of kinematically rich datasets

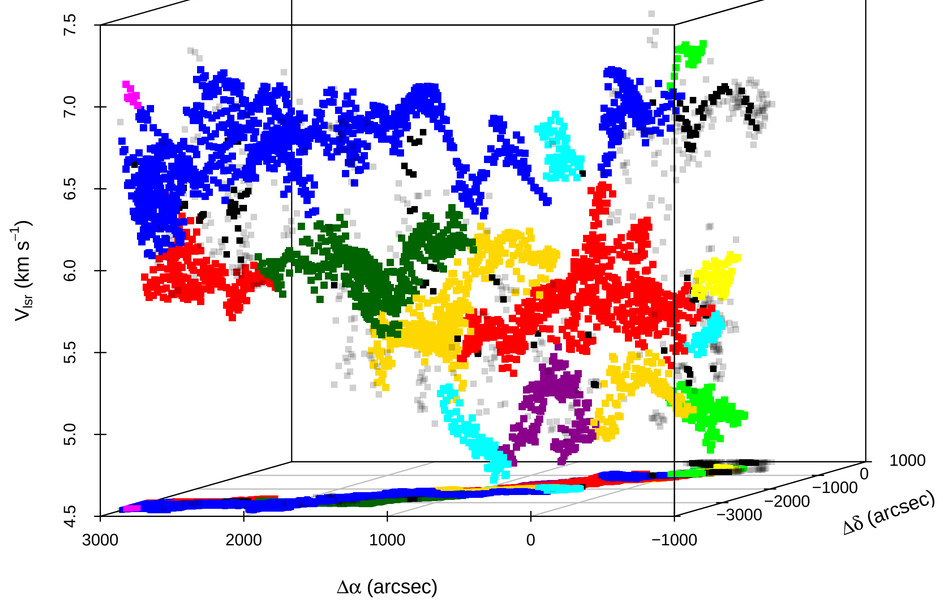

Fig.2: Fitted velocity-centroids ($C^{18}O$ & N_2H^+) (dots) and velocity-coherent structures identified by FIVE (color coded) in PPV-space within the B211-213 region.

- We have fitted gaussians to each observed spectrum.
- When the fitted velocities are plotted in the Position- Position-Velocity space (PPV), they reveal that B213 is a **network of overlapping filaments**.
- Each filament has a continuous velocity field and often contains oscillations.
- We have created an algorithm to disentangle automatically the filaments of B213 called FIVE (Friends-In-VElocity)
- FIVE uses a friends-of-friends approach to identify coherent structures in the PPV-space.

4.- Velocity-coherent filaments in B213

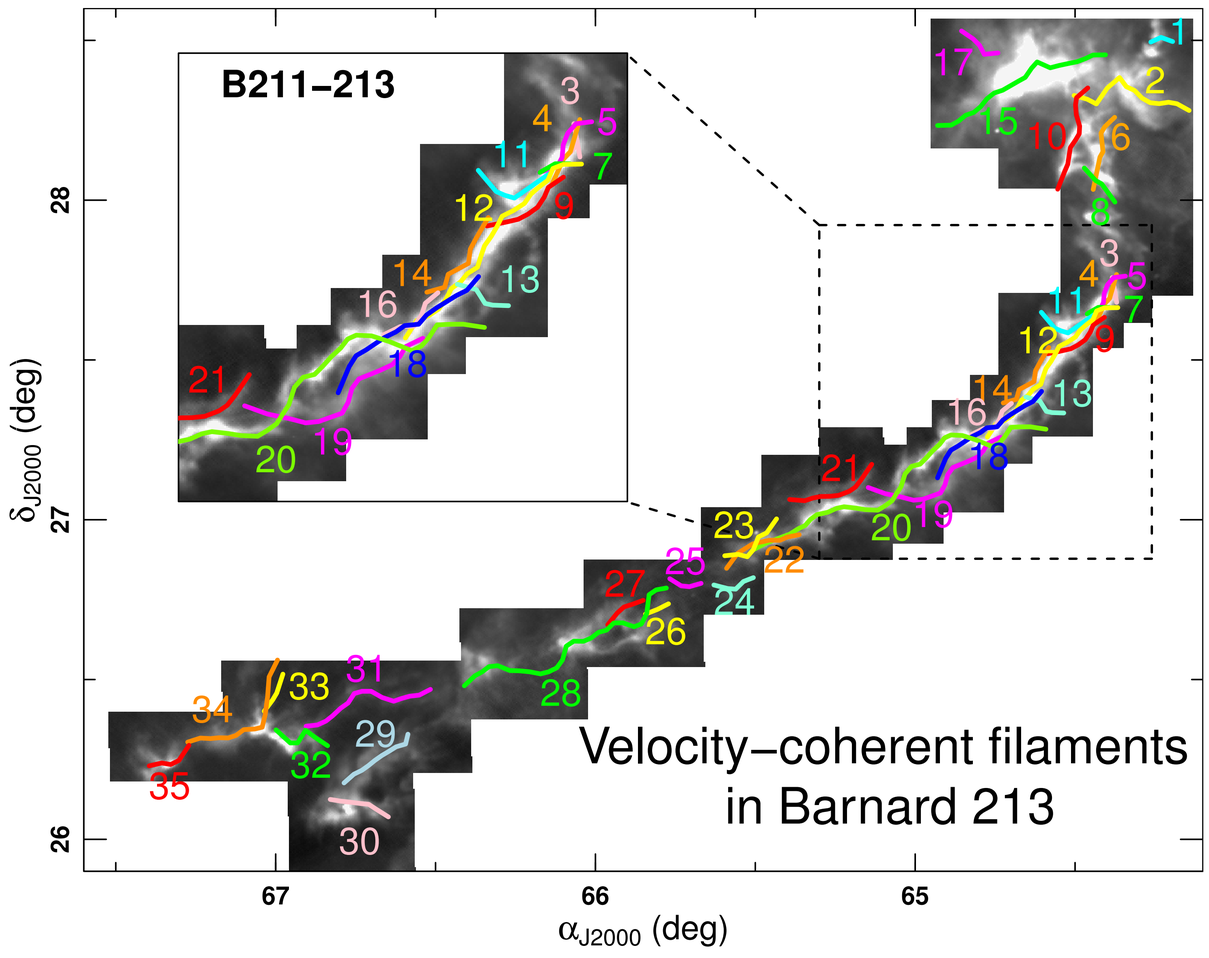

Fig.3: The 35 velocity-coherent filaments (colors) automatically identified by FIVe in Barnard 213 superposed on an archive Herschel SPIRE map (background; Herschel Gould Belt Project, PI: P. André; see also Palmeirim et al 2013) .

- We have identified **35 velocity-coherent filaments** forming a bundle in B213.
- These filaments have typical lengths of ∼ 0.6 pc and linear masses of $M_{lin} \sim 15\ M_\odot\ pc^{-1}$.
- Their non-thermal linewidths and velocity excursions are of the order of the sound speed.
- Most of these filaments coincide with structures visible in the Herschel PACS/SPIRE maps (Fig.3).
- Velocity information is critical to understand the underlying structure of star-forming regions.

5.- Core clustering

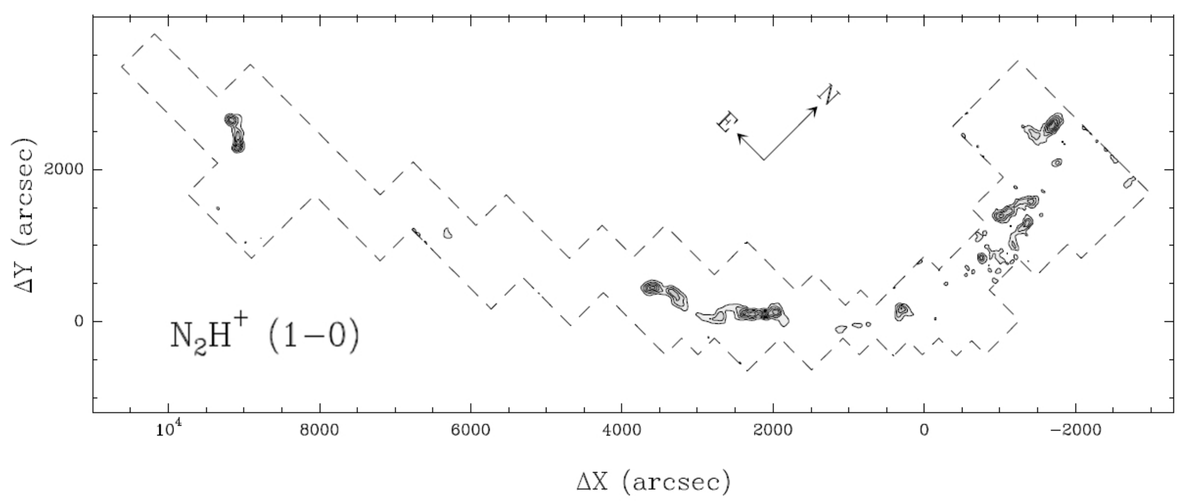

Fig.4: N_2H^+ (1-0) integrated emission map of B213 (rotated by 45deg). The distribution of the 19 cores identified within this region shows that these objects are already clustered before the formation of the stars.

- We identify 19 dense cores using N_2H^+ (1-0) emission maps (Fig. 4).
- The dense cores within B213 are located in groups (clustering) with a typical distance between cores of ∼ 0.25pc.
- All the cores are formed within velocity-coherent filaments.
- Only a small fraction of these filaments (∼ 1/4) are fertile and contain all the cores within these region, while most of them (∼ 3/4) remain sterile.
- Dense cores form by the fragmentation of those fertile filaments with little change in their velocity field (as previously found in L1517, Hacar & Tafalla 2011).

6.- Conclusions: Hierarchical core formation in Taurus

- Our results indicate that the formation of cores occurs hierarchically.
- First, all the gas of the cloud at densities between 10^3-10^4 cm^{-3} is highly structured forming velocity-coherent filaments
- After that, only few of these filaments fragment quasi-statically and form cores.
- The velocity-coherent filaments at scales of ∼ 0.5pc result key for the star formation process: these objects are the first sonic structures condensed out of the turbulent ambient gas and the first dominated by gravity.
- More information: **Hacar et al 2013, A&A, 554, A55**