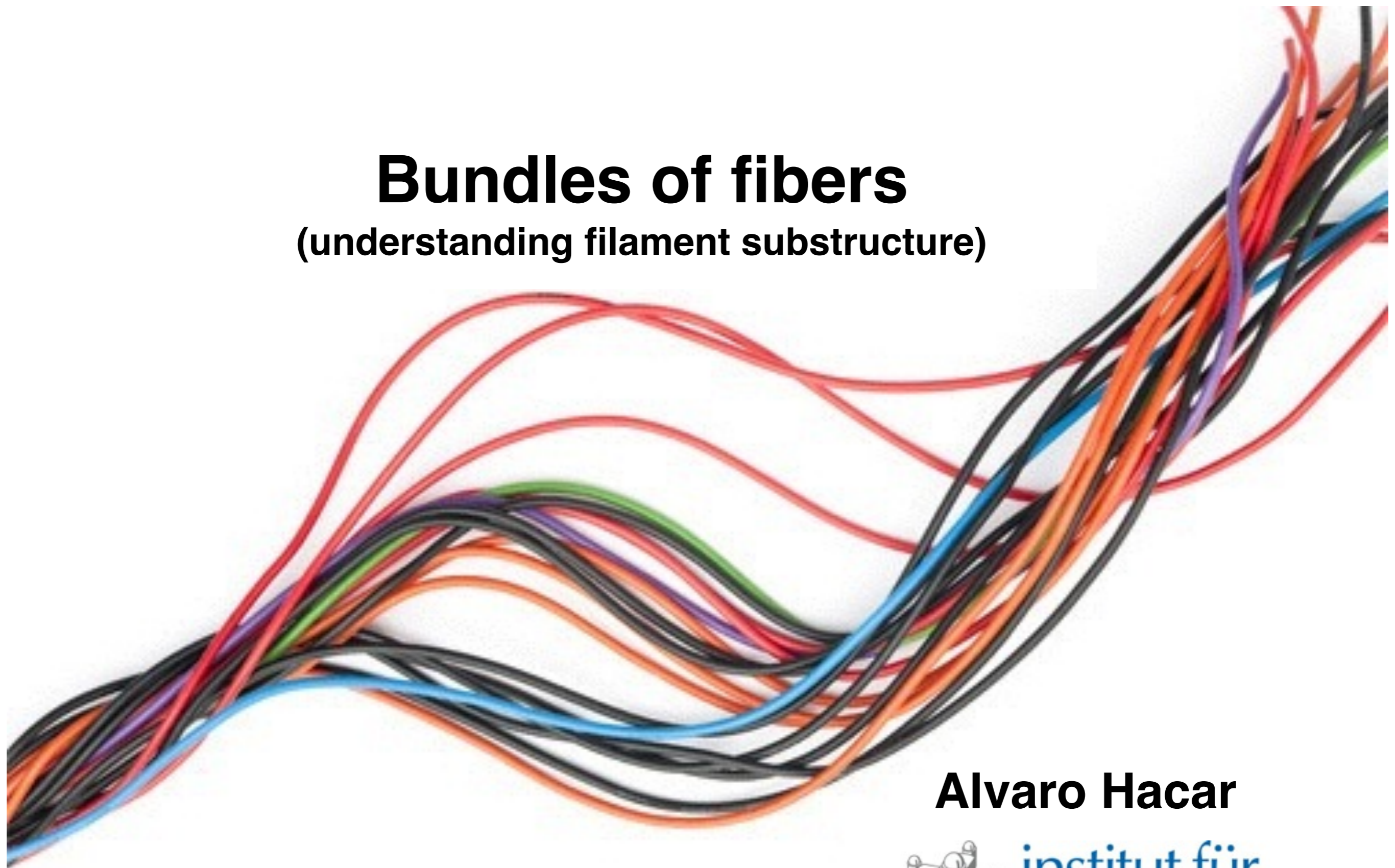


Bundles of fibers

(understanding filament substructure)



Alvaro Hacar

Filamentary Structures in Molecular Clouds
NRAO, Oct. 10th-11th 2014

Filamentary nature of MCs and SF

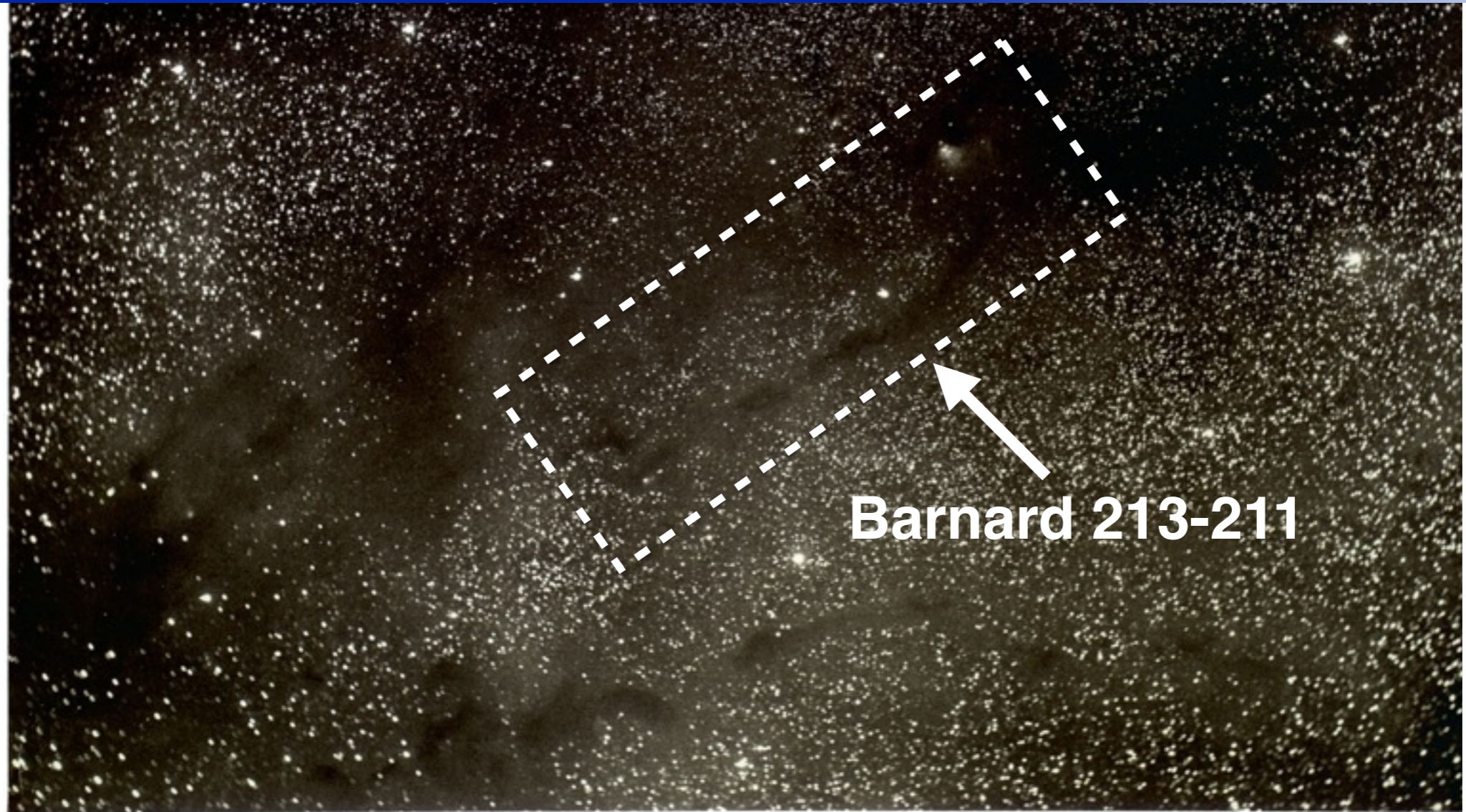


Barnard's optical plate 1907

“Among the most surprising things in connection with these nebula-filled holes are the vacant lanes that so frequently run from them for great distances. These lanes undoubtedly have had something to do with the formation of the holes and with the nebula in them.”

Barnard 1907

Filamentary nature of MCs and SF



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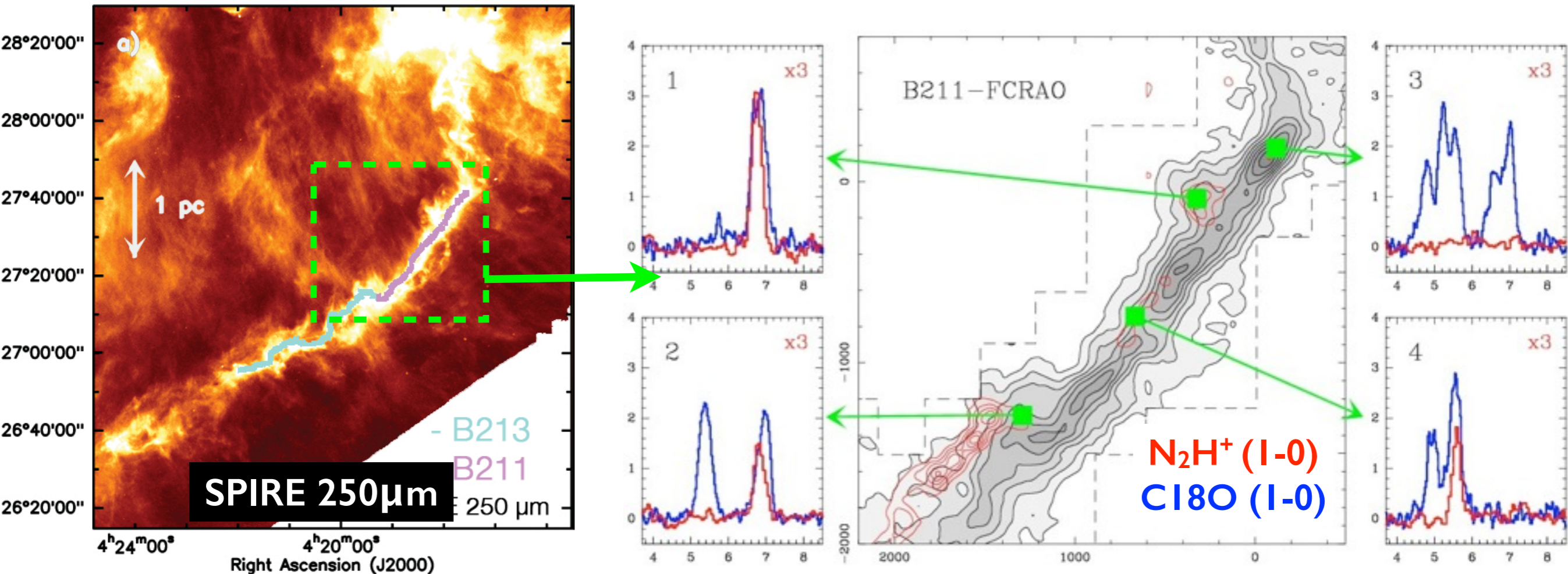
Barnard 1907

Kinematic complexity within B213-L1495

Continuum

vs

Molecular Lines

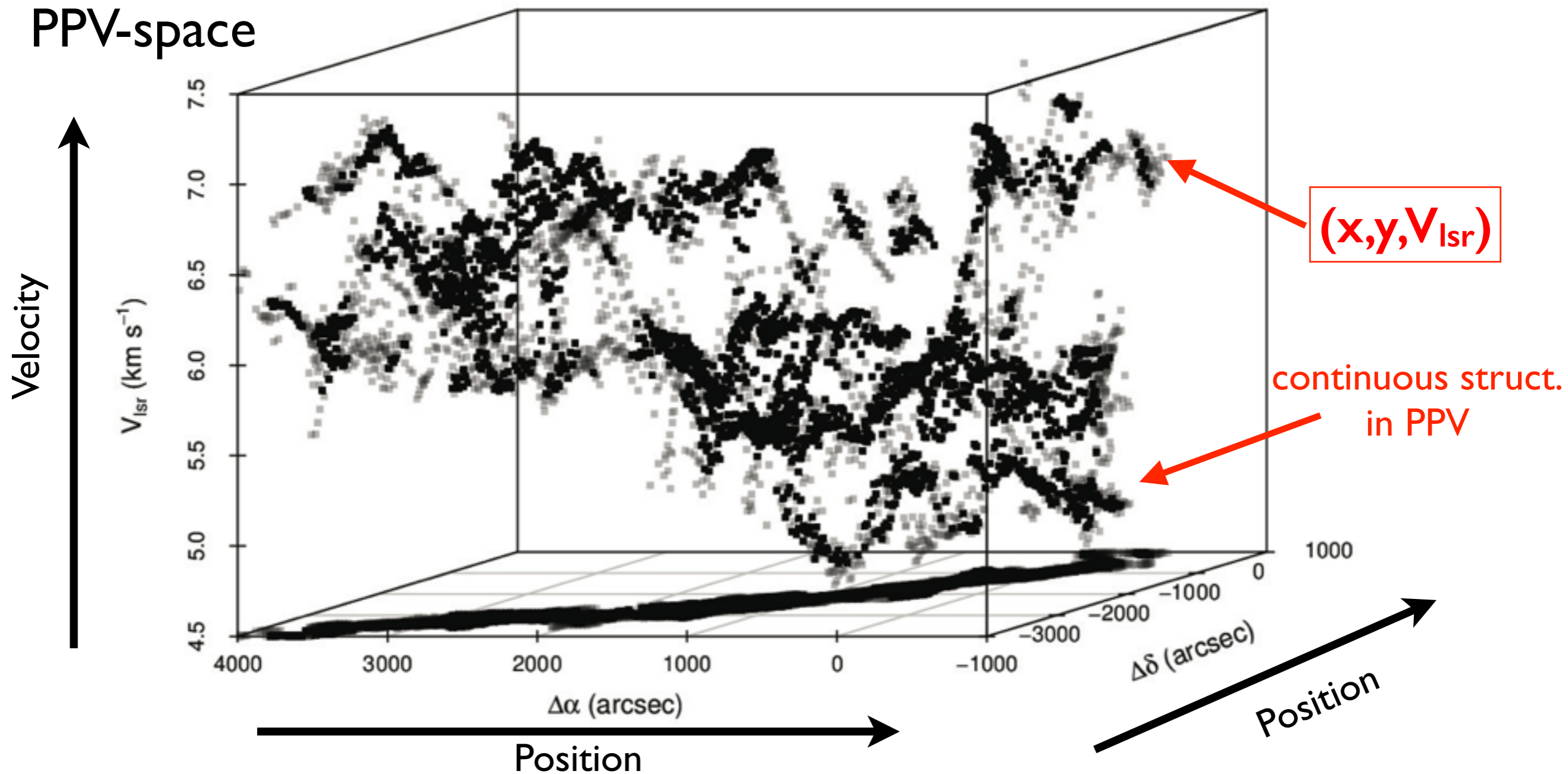


Palmeirim+ 2013

Hacar+ 2013

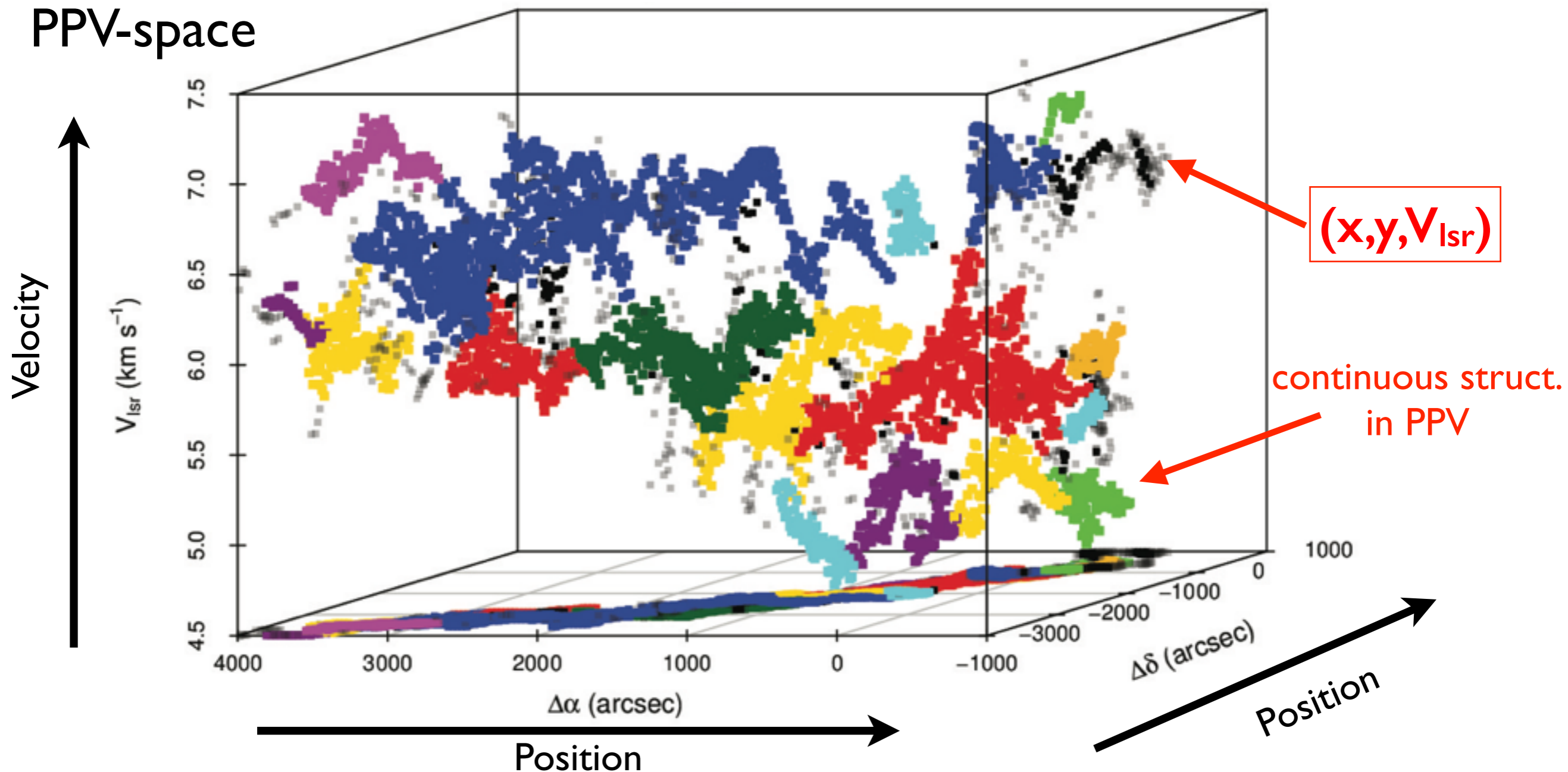
- B213-L1495 = active star-forming filament in Taurus ($D=140\text{pc}$)
 ~ 40 YSOs + 20 cores, $L \sim 10\text{pc}$ & $M \sim 700 M_{\odot}$
- Geometrically simple structures in continuum present a complex kinematic structure when observed in mm-lines

Velocity coherent substructure



- Multiple velocity-coherent structures found within B213
- All continuous in PPV space, presenting smooth velocity gradients
- Reconstruction using Friends-In-Velocity (FIVE, Hacar+ 2013)

Velocity coherent substructure



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Velocity coherent substructure

PPV-

Velocity

$V_{\text{lin}} \text{ (km s}^{-1}\text{)}$

Properties:

- 35 structures
- Aspect ratio $> 3 - 4 \rightarrow$ Filamentary
- Length $\sim 0.6 \text{ pc}$
- $M_{\text{lin}} \sim 15 M_{\odot} \text{ pc}^{-1} \rightarrow$ equilibrium
- σ_{NT} and $\sigma(V_{\text{lsr}}) \sim C_s \rightarrow$ (tran-)sonic

\Rightarrow 35 velocity coherent filaments

(see also Hacar & Tafalla 2011)

(V, V_{lsr})

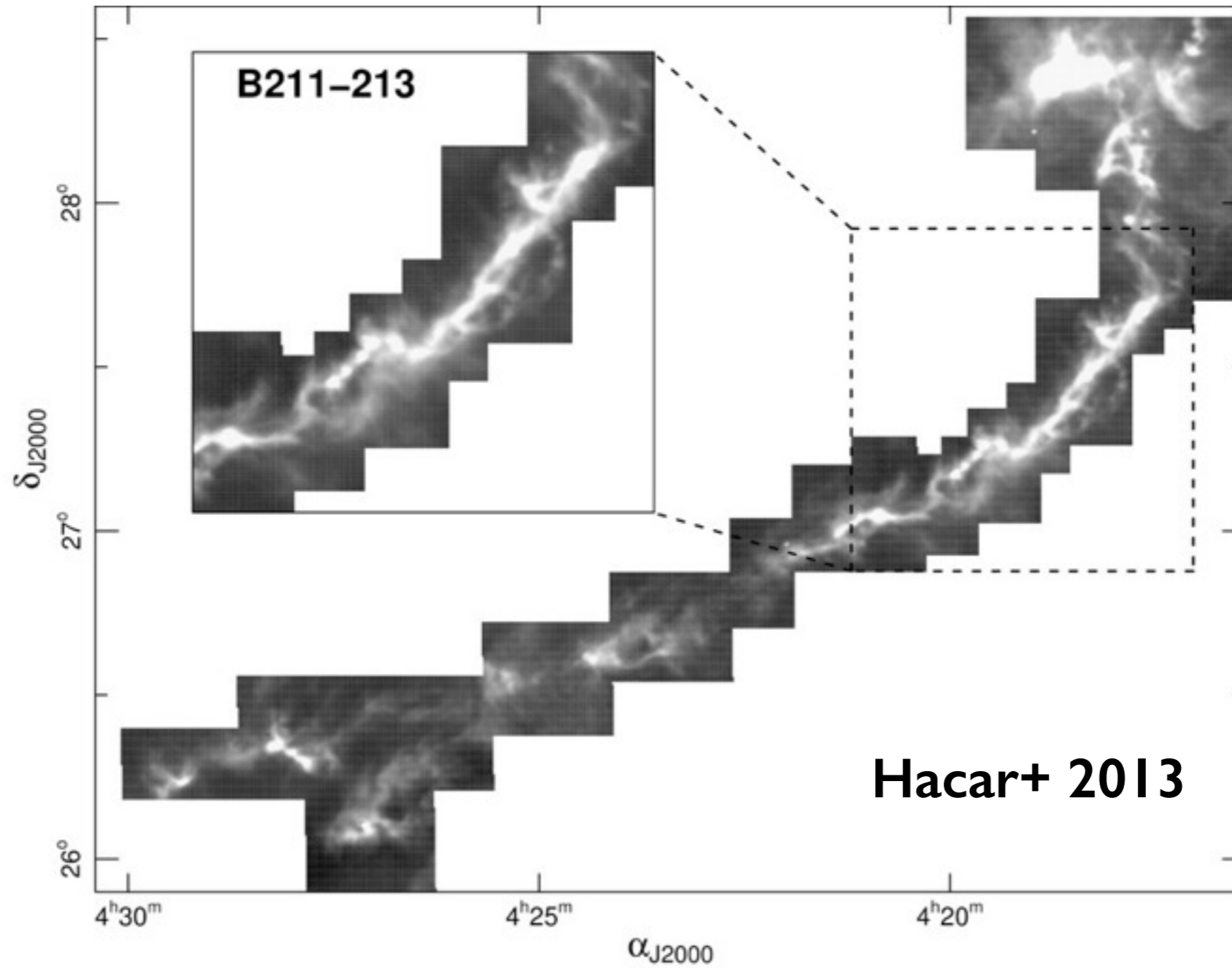
ous struct.
PPV

• Mu

• All

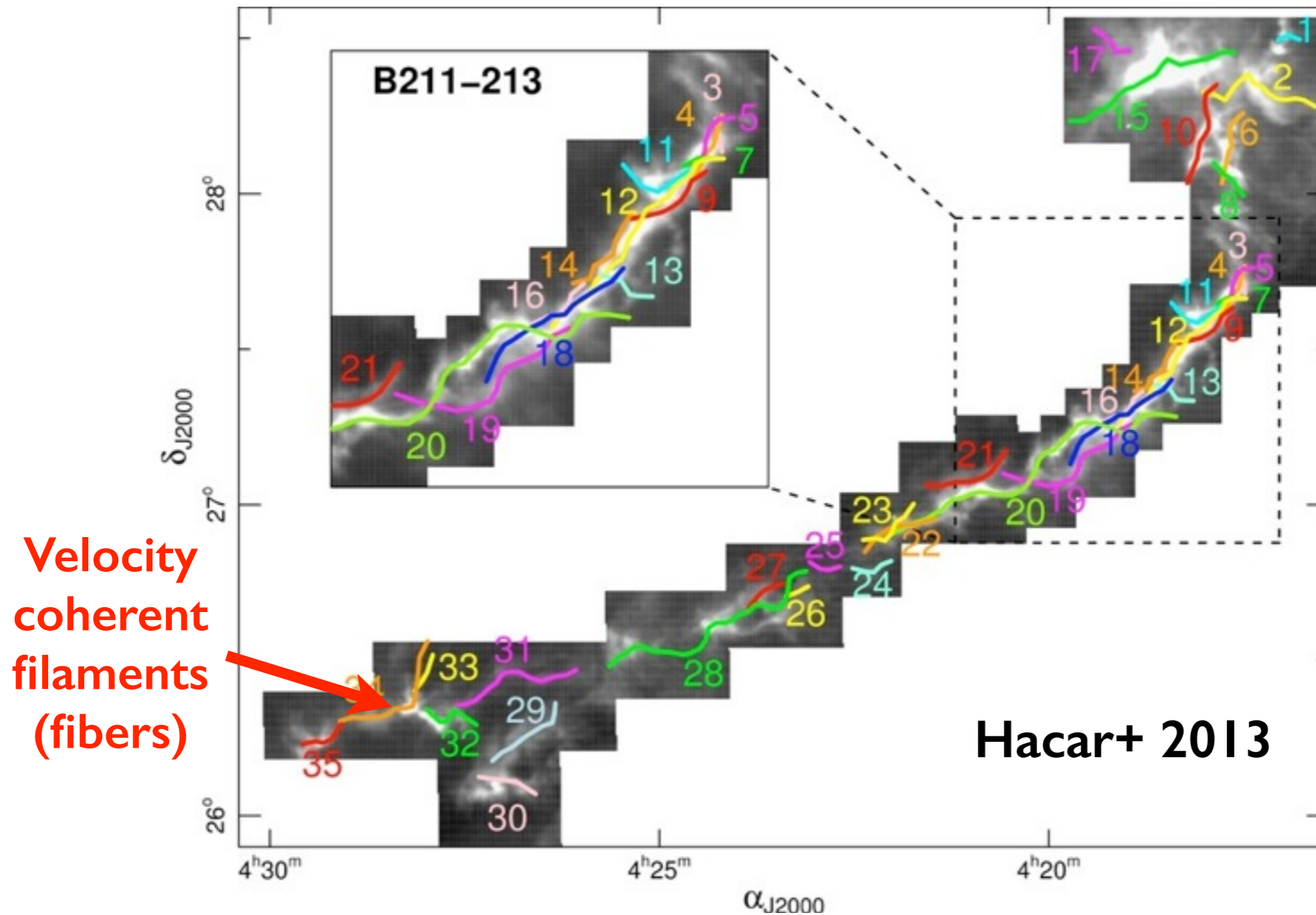
• Reconstruction using Friends-in-Velocity (FIVE, Hacar+ 2013)

Filaments within filaments



Background: Herschel SPIRE Archive Image
Gould Belt Project (PI: P. Andre)
see also Palmeirim+ 2013

Filaments within filaments

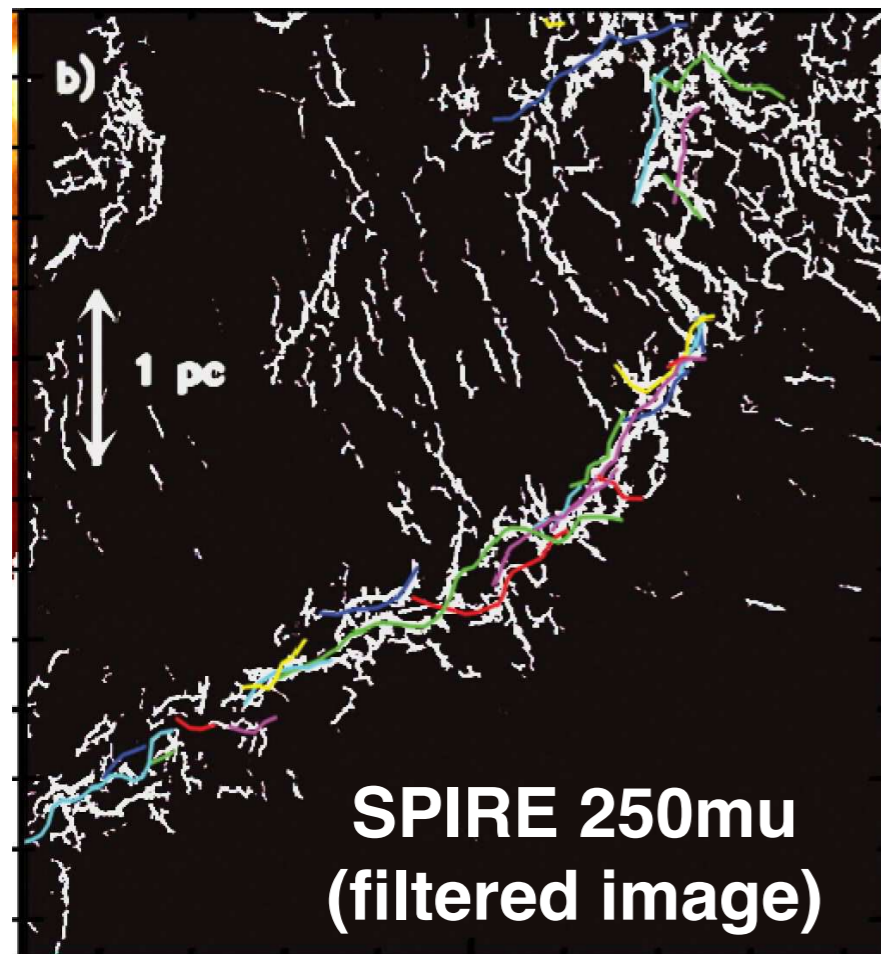


Background: Herschel SPIRE Archive Image
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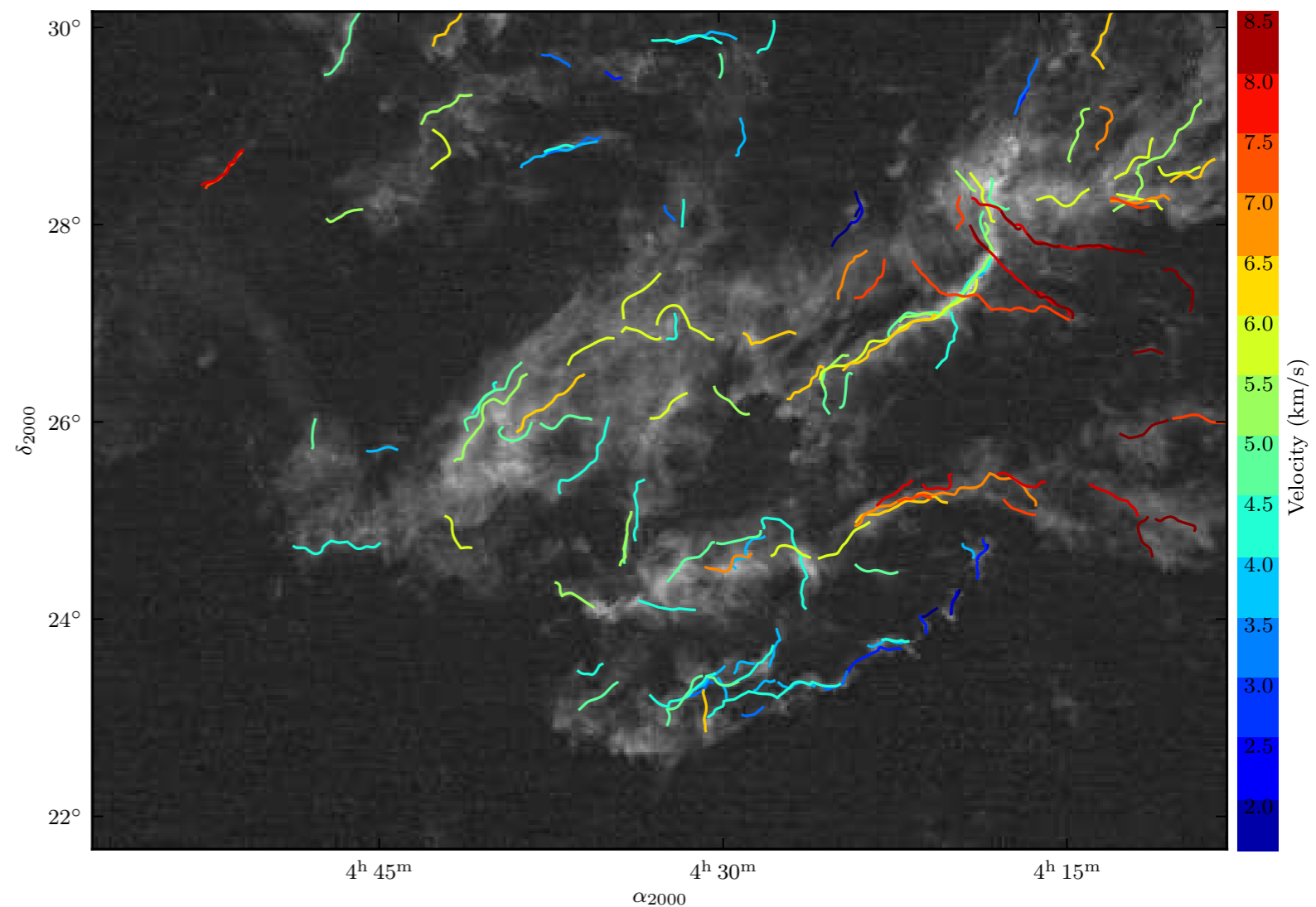
- B213 = 35 velocity-coherent filaments (fibers) forming a **bundle**
- Apparently supercritical filament but actually a collection of (sub-)critical fibers

Fibers in Taurus: new observations

André et al PPVI

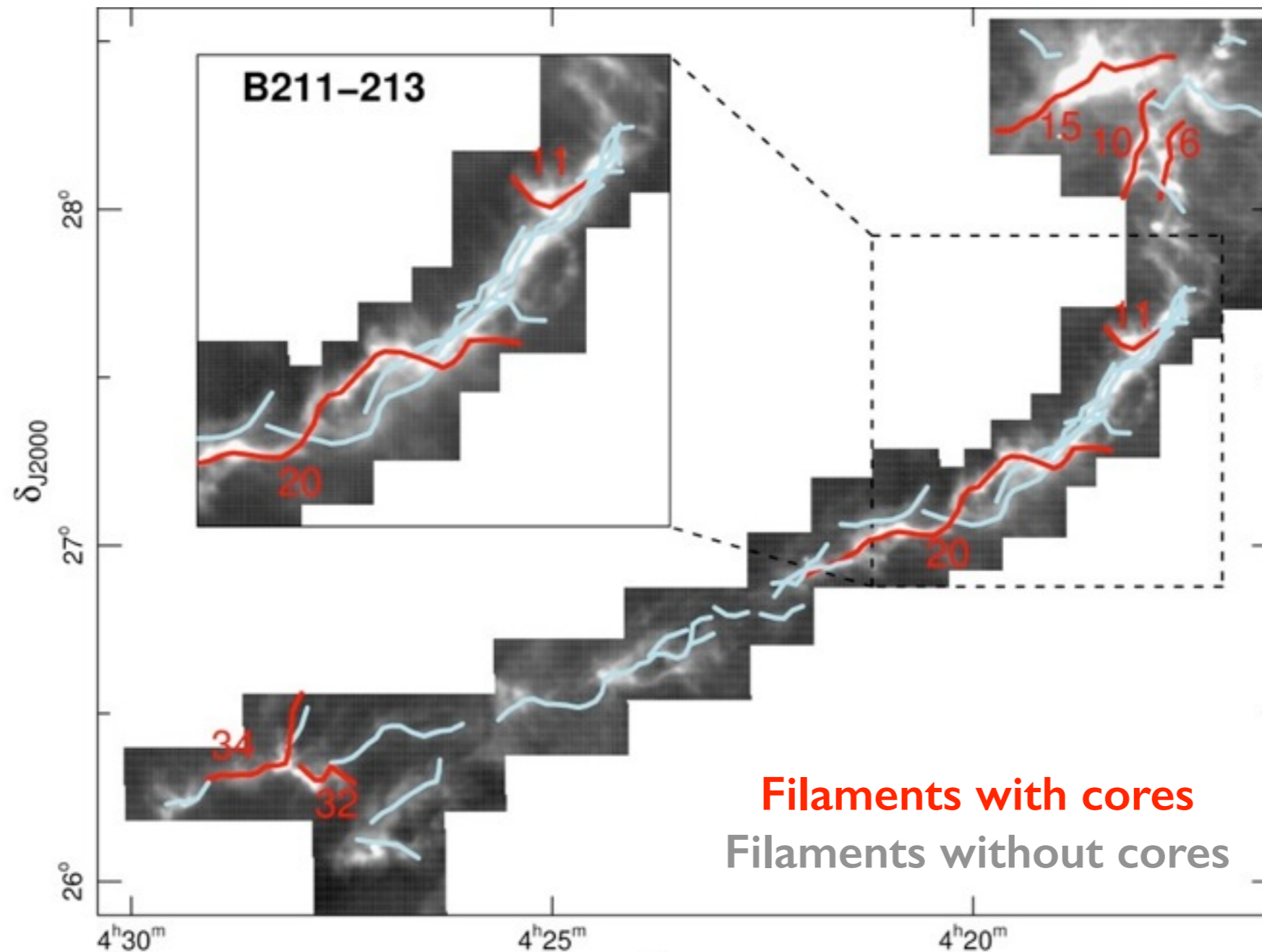


Panopoulou+ 2014



- B213 fibers confirmed by Herschel (André+2014)
- >100 filaments in Taurus (Panopoulou+2014)
- Additional (tran-)sonic fibers identified in Perseus, IC5146, Oph...

Fertile vs. Sterile fibers

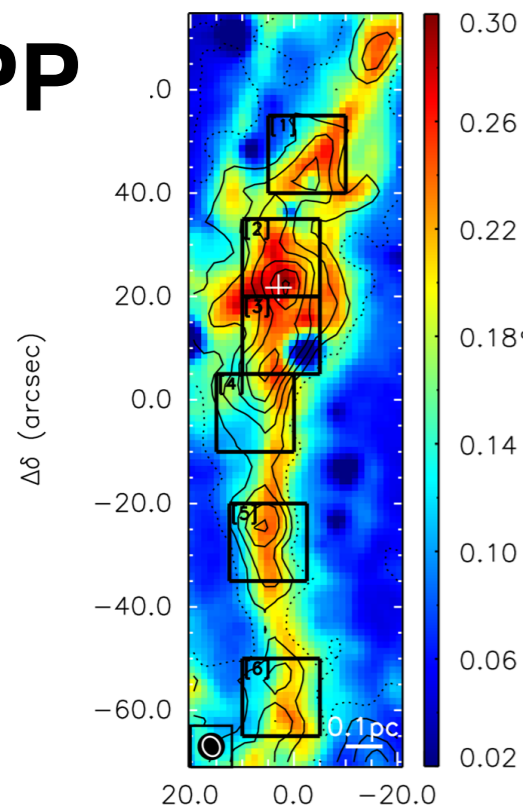


Background: Herschel SPIRE Archive Image
Gould Belt Project (PI: P. Andre)
see also Palmeirim+ 2013

- Cores formed inside these ~ 0.5 pc length, (tran-)sonic fibers
- But only few fertile fibers form cores ($\sim 1/4$; high SFE) $\rightarrow M_{\text{lin}} \gtrsim M_{\text{Ost}}$
- While most of them remain sterile ($\sim 3/4$; SFE ~ 0) $\rightarrow M_{\text{lin}} \lesssim M_{\text{Ost}}$

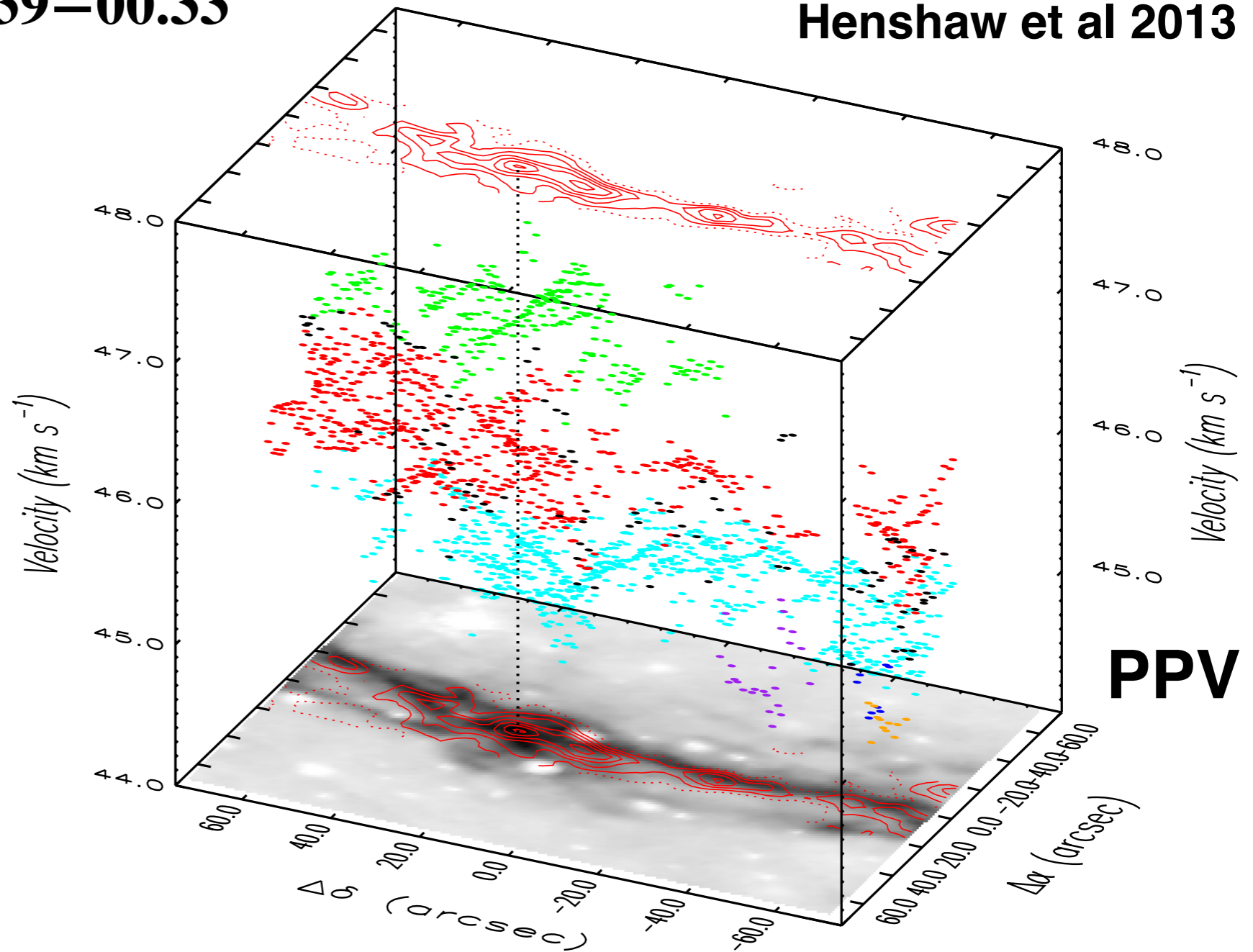
IRDC as bundles of fibers

PP



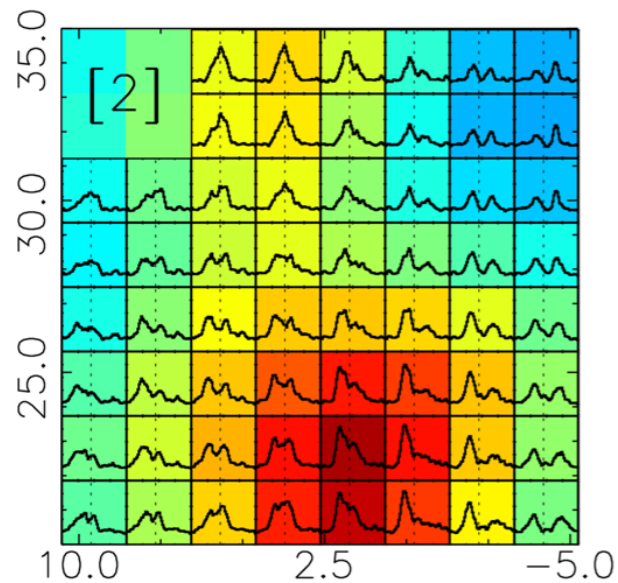
G035.39-00.33

Henshaw et al 2013



PPV

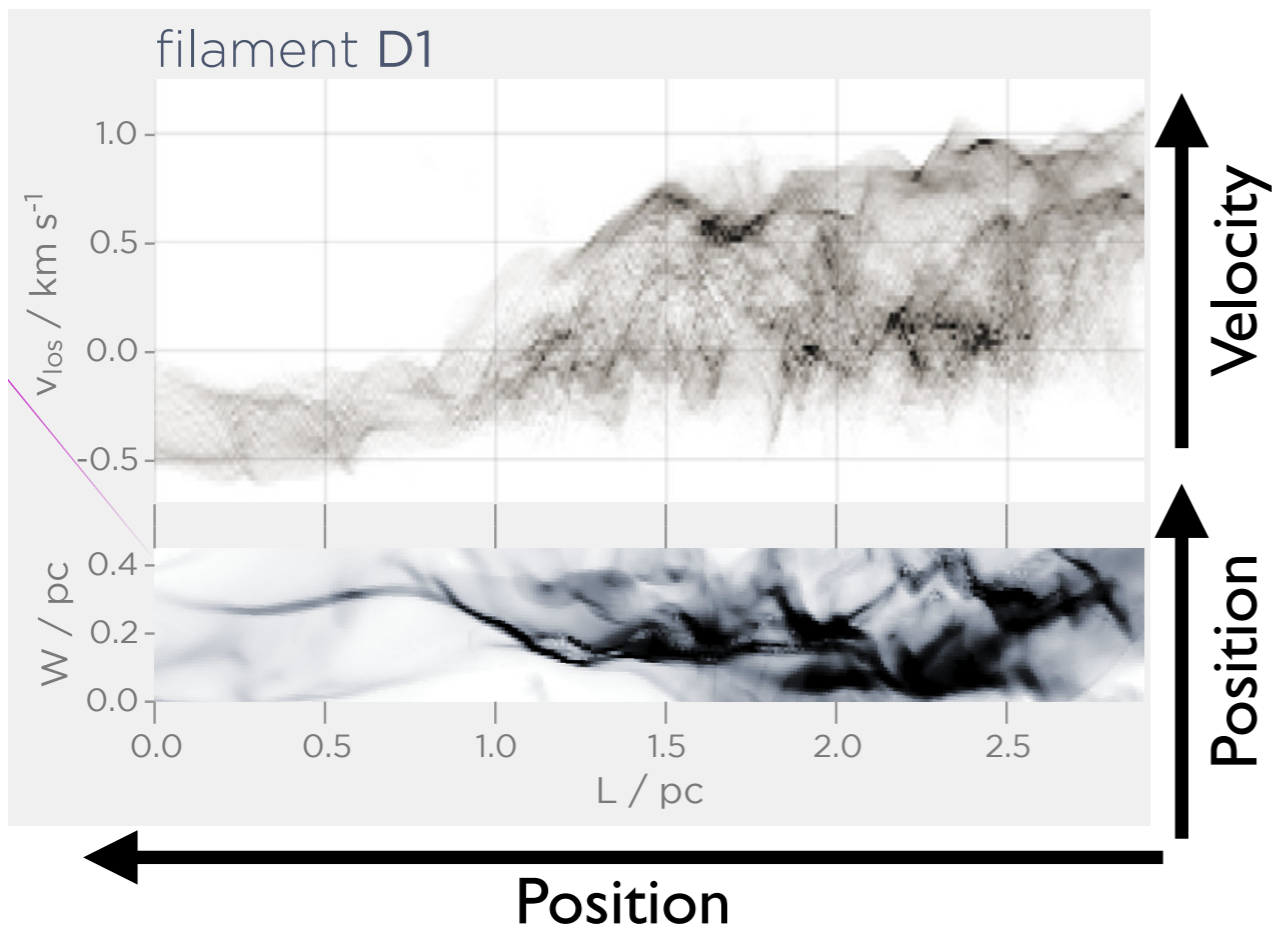
representative spectra



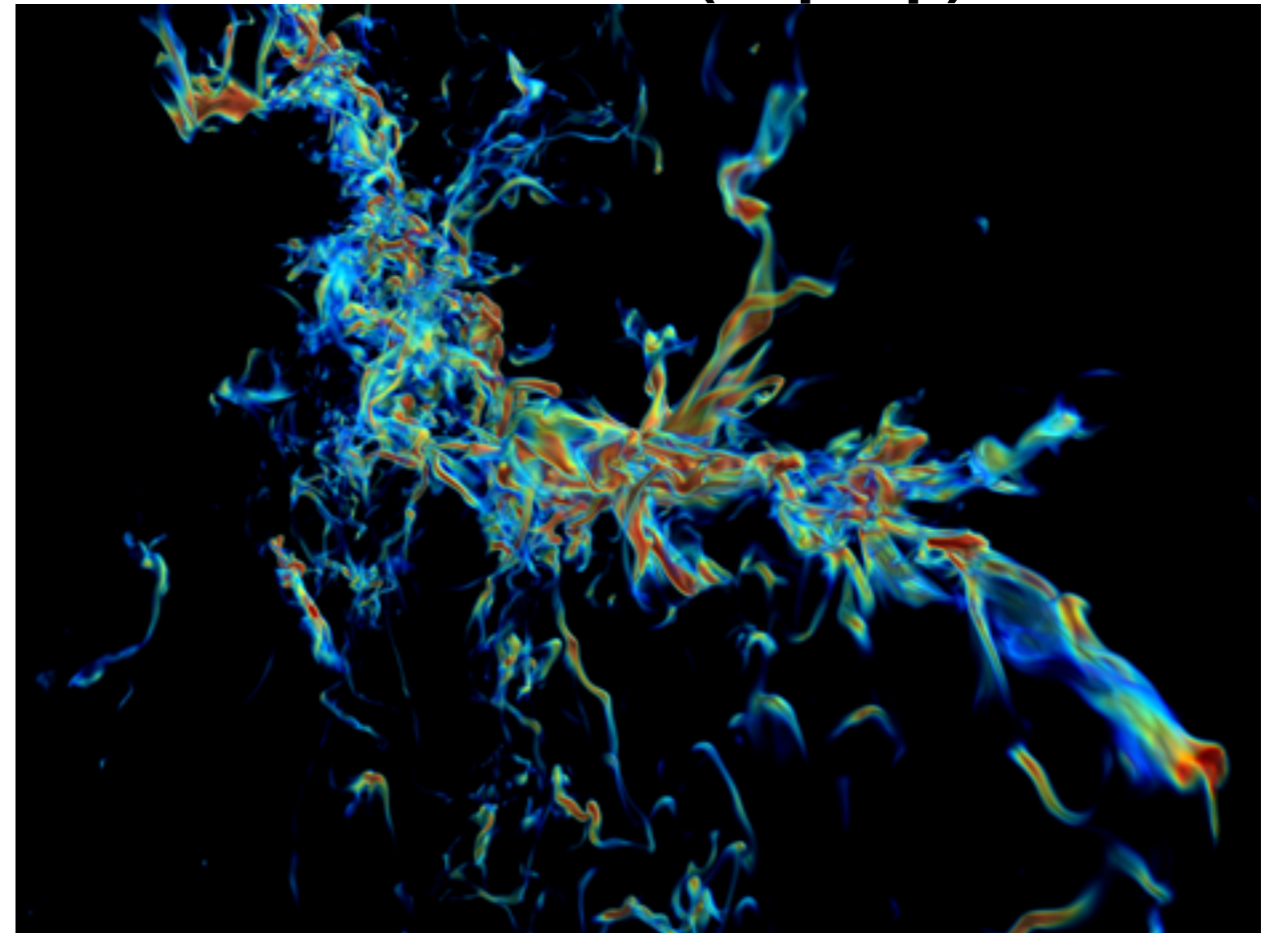
- Strong similarities between local and distant clouds
- Multiplicity + complex velocity structure

Bundles: recent simulations

Moeckel & Burkert 2014



Klein et al (in prep)



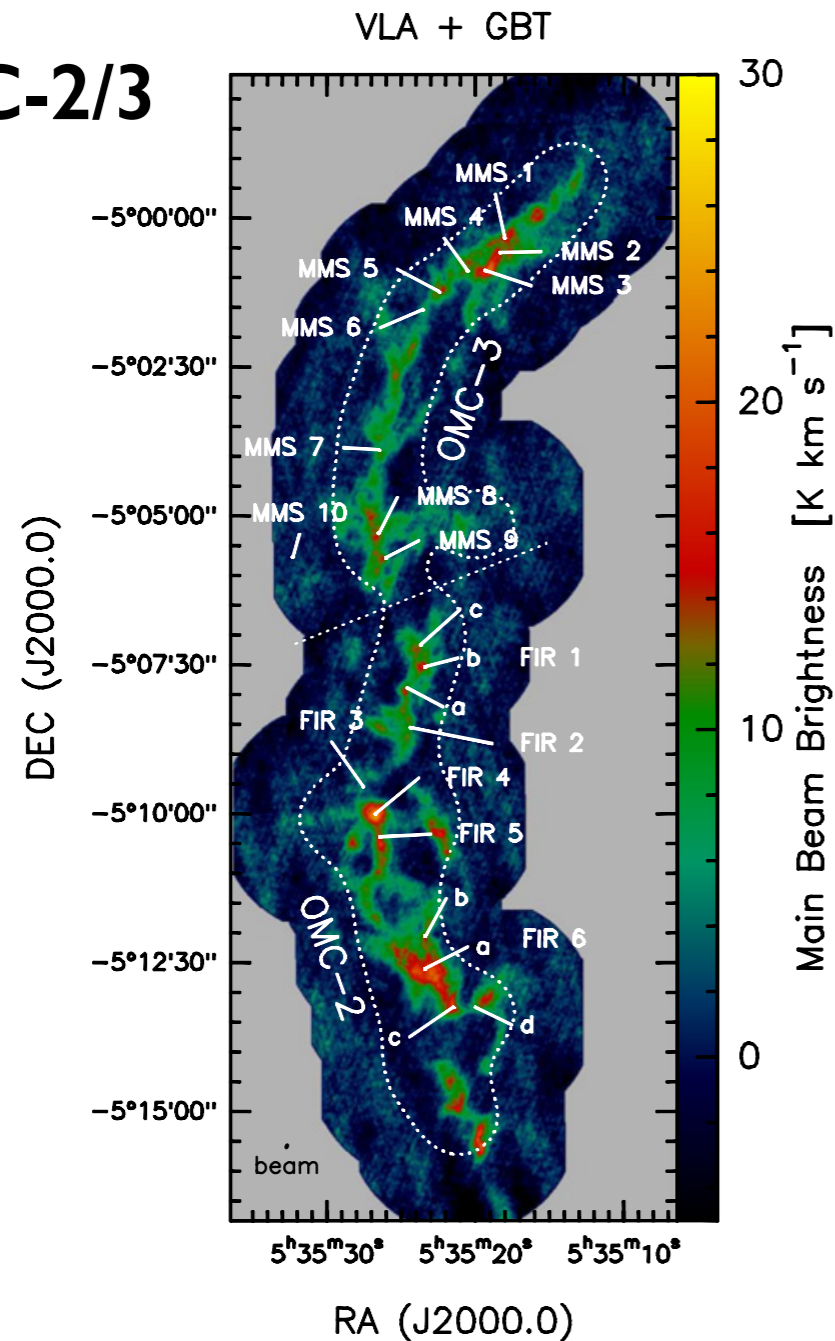
- Reproduced by hydro-simulations (Moeckel & Burkert 2014, Smith 2014)
- Although also in models including B (Klein et al)
- Fibers are present in all kind of simulations:
filaments are not “cylindrical objects” but complex bundles of fibers

Conclusions

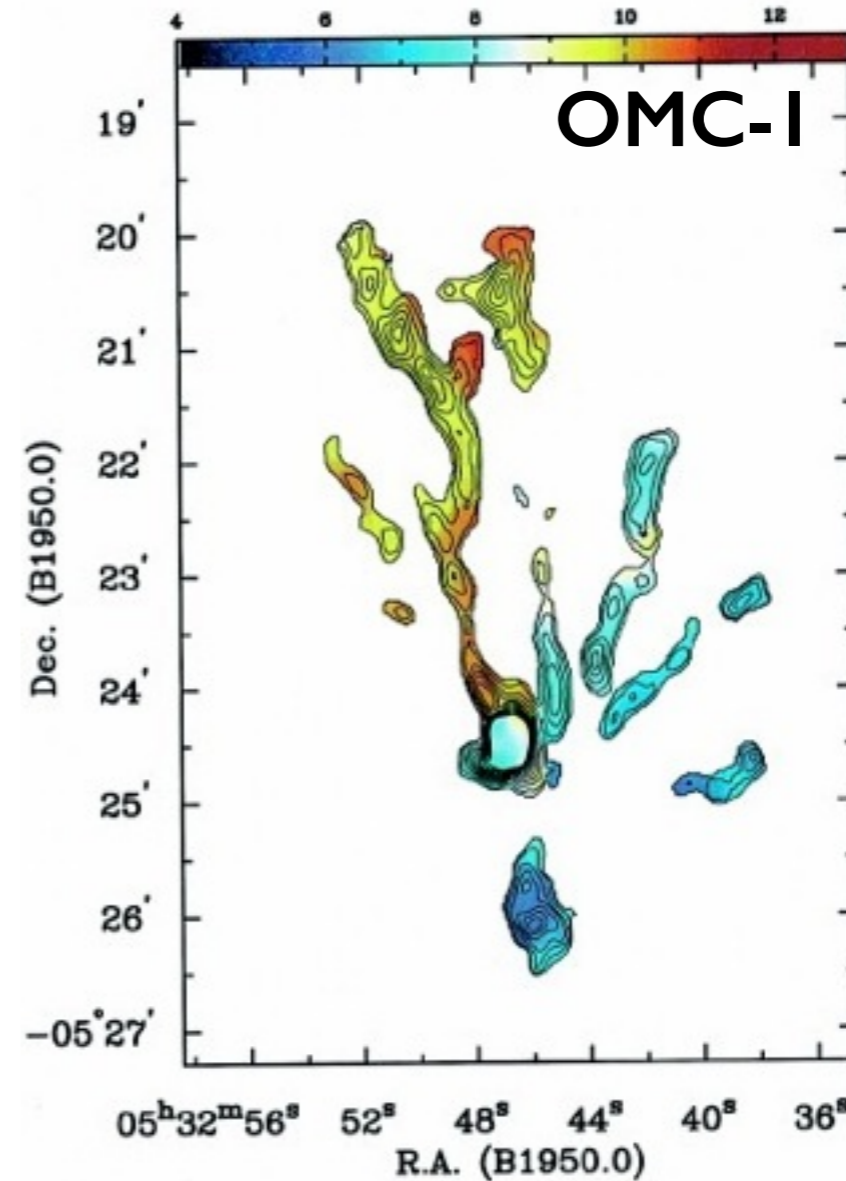
- Gas kinematics key for our understanding of the internal substructure of Molecular clouds
- Fibers \Rightarrow fundamental building blocks
 - Present in all kind of environments
 - Sonic-like structures naturally created as part of the turbulent cascade
 - Cores & Stars are formed from the fragmentation of only those gravitationally unstable (and fertile) fibers
- Large scale, complex filaments = Bundles of fibers

Fibers in clusters

OMC-2/3



Li et al 2013



Wiseman & Ho 1998

- Fibers also found in clustered and massive regions
- High-sensitivity, high-resolution observations needed