What is a Filament?

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SF Physics - Energy Balance

• Gravity: \[ E_G = -\frac{3}{5} \alpha \frac{GM^2}{r} \]

• Pressure: \[ E_P = \frac{3}{2} \int \rho \big( \sigma_t^2 + \sigma_{nt}^2 \big) dV \]

• Magnetic field: \[ E_B = \frac{1}{8\pi} \int B dV \]

• Turbulence, Fluid Dynamics \[ dV^2 \sim L^{0.5} \]

\[ M_J = \left( \frac{4\pi}{3} \right) \rho R_J^3 = \left( \frac{\pi}{6} \right) \frac{c_s^3}{G^{3/2} \rho^{1/2}} \approx (2 M_\odot) \left( \frac{c_s}{0.2 \text{ km s}^{-1}} \right)^3 \left( \frac{n}{10^3 \text{ cm}^{-3}} \right)^{-1/2} \]

• Feedback: Supernova, outflow, bubbles …
Sheet or Cylinder?

Goldsmith et al. 2008

Chapman et al. 2011
Andre et al. 2012
Hacar et al. 2013

accretion?

Substructures?
Cyanopolyyne - HC$_3$N

\begin{itemize}
  \item HC$_3$N 2-1 18.2 GHz
  \item 5-4 45.5 GHz
  \item 10-9 91.0 GHz
\end{itemize}


Formation and evolution of interstellar filaments
Hints from velocity dispersion measurements\textsuperscript{*}***

D. Arzoumanian, Ph. André, N. Peretto, and V. Kőnyves

These results suggest that the velocity dispersion observed at a single position toward a filament provides a reasonably good estimate of the velocity dispersion of the entire filament. Nevertheless, mapping observations of a broader sample are needed to confirm these conclusions.

An interstellar filament is an elongated structure characterized by small column density variations along its crest (less than a factor of 3; see Fig. 3-left). Therefore, the velocity dispersion variations induced by the trend $\sigma_v \propto L^{1/2}$ found in Sect. 5 below for supercritical filaments remain small (≈2) along a given filament.
Densitometer

\[
\begin{align*}
N(\text{HC}_3\text{N}) & = 10^{12} \text{ cm}^{-2} \\
\Delta V & = 1 \text{ km s}^{-1}
\end{align*}
\]

\[T_k = 15 \text{ K} \]

\[T_k = 10 \text{ K} \]

HC3N as densitometer (Li & Goldsmith 2012, ApJ)
Filament - Cylinder

Taurus B213 Filament

Elongation: 1d ~ 2.4 pc
Cross: 3' ~ 0.12 pc
Extinction: Av = 10 ~ 10^{22} \text{ cm}^{-2}
Density: n = 10^4 \text{ cm}^{-3}

LOS Dimension: 0.33 pc ~ 2.7'
Simulated observation shows how Orion A looks like in front of a bright infrared background. Denser and more compact absorption feature. (Ren et al. 2015 in prep.)

\[
\tau_{8\mu m} = K_{8\mu m} \Sigma = 7.5 \left( \frac{\Sigma}{g \text{ cm}^{-2}} \right).
\]

\[
I_{\nu,1} = e^{-\tau_{\nu}} I_{\nu,0},
\]

- (Butler & Tan 2013)
“Pearls on a string”

Cores in Orion 1 to 30 $M_{\text{sun}}$

Appear to be unstable against gravitational collapse

Maybe forming next generation of stars

Li, Velusamy, Goldsmith, & Langer 2007
The Magic of NH$_3$

\[ T_R = 41.5 \text{K}/\ln [1.06 \times C(1, 1) \times R^{12}], \]  
(1)

where $C(1, 1)$ is a numerical factor determined as

\[ C(1, 1) = 0.003 + 2.26 R^{\text{sm}} + 0.00032 e^{5.38 R^{\text{sm}}}, \]  
(2)

which is based on fitting the simulated NH$_3$ (1, 1) spectra based on a grid of opacities and line width. The kinetic temperature is then (Paper I)

\[ T_k = 3.67 + 0.307 \times T_R + 0.0357 \times T_R^2. \]  
(3)
“SuperCritical”?

VLA+GBT

High Res. Ammonia Images

T, V, and dV

Li, Kauffmann, Zhang, Chen, 2013, ApJL
Is Orion a HMSF?

The locations of the Orion cores on the Mass-Radius diagram for the young stellar cores (Kauffmann & Pillai 2010): high-mass prestellar objects (HMPOs, left panel) and IRDCs (right). The cores above the gray shadowed area may have potential to form high-mass stars.

It shows that the two Orion KL cores are high above the trend for the IRDCs, indicating the probability of becoming HMPOs. It also shows that the young high-mass cores in IRDCs (dark region) are scarce.

Zapata et al. 2011
Ren & Li 2014, 2015
Core Physics: Resolution

A massive core in Orion

d=417pc
D=0.04pc  20”
m=50 \, M_{\odot}

Temperature profile
T=10K constant value

Fig. 1. Density properties.

BE vs Power Law
COREFIT

- Iterative inversion of multi-wave length data and SED data, providing estimates of density and temperature structure of a cold core. Three Components: The forward generator + A core finding tool + The iterative profiling tool. (Yue, Li, Marsh, Chapman 2015 in prep.)
Fig5. The profiles of 1200µm continuum image difference between BE and p.w.l models with different beam sizes.

ALMA: Configuration C34
1' resolution - S/N > 20
SHARP: 350micron Pol

Chapman, Li, Novak, Schnee 2015, in prep
Measuring Filaments

Li & Goldsmith 2012 ApJ

Li et al. 2013 ApJL

Ren et al. 2014

Density

Temperature

Dynamic
“Fila-mental” Questions

- **Characteristic scale:** 0.1pc, Sonic scale from ISM shocks (Padoan & Juvela 2001)?
- **Substructures and superstructures:** fiber, bundle, bones, fork, ridge, hub …
- **Gas Flow and Accretion:** flow along or accrete onto?
- **Magnetic field:** configuration and strength
- **Cores:** HMPO? collapse? (COREFIT …)

more data (B and V) to distinguish physics