Structure of Filaments Formed by Shock Compression

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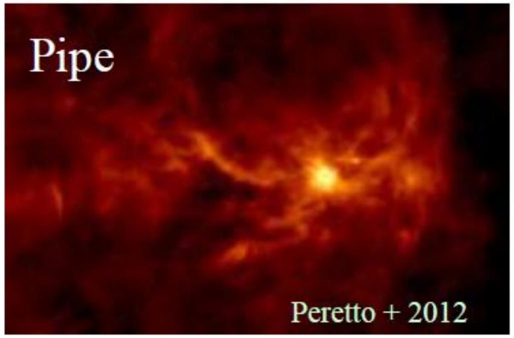
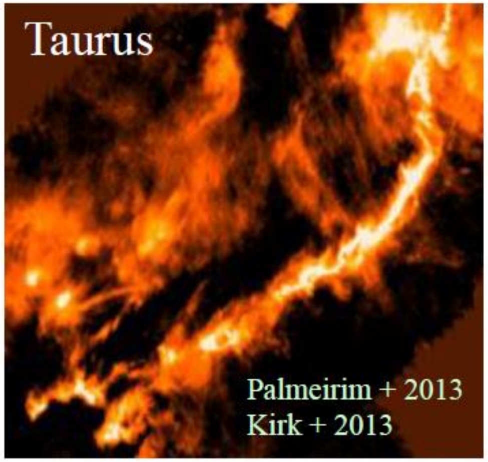
ＤＴＡ シンポジウム　「星形成を軸に俯瞰する役割とその観測的検証」

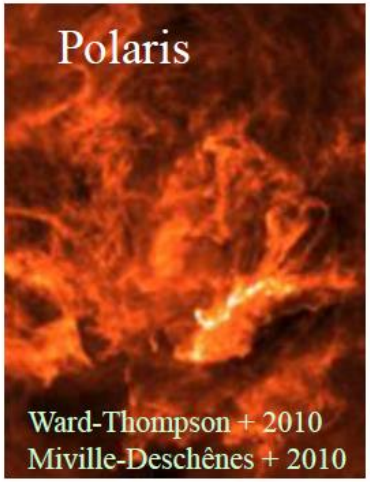
Star Formation in Filamentary Molecular Clouds

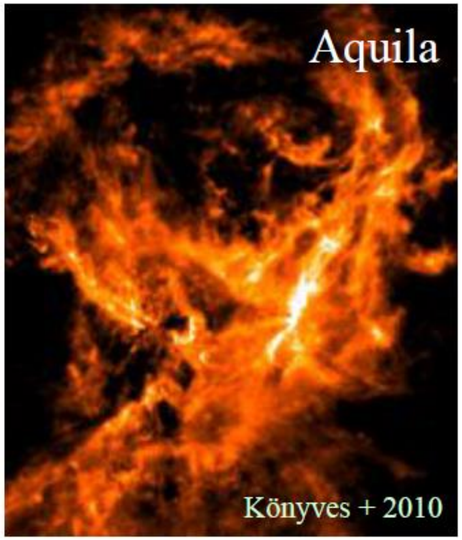
Herschel Gould Belt Survey

Most of dense cores is associated with filaments





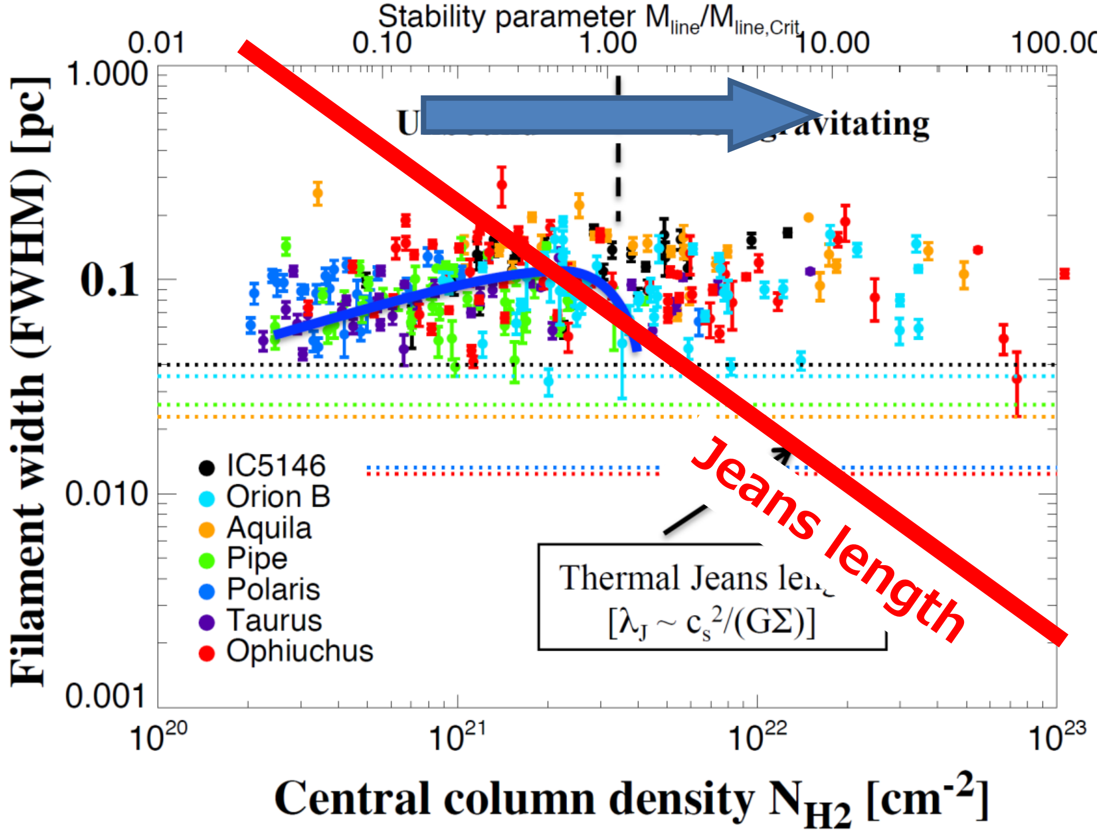


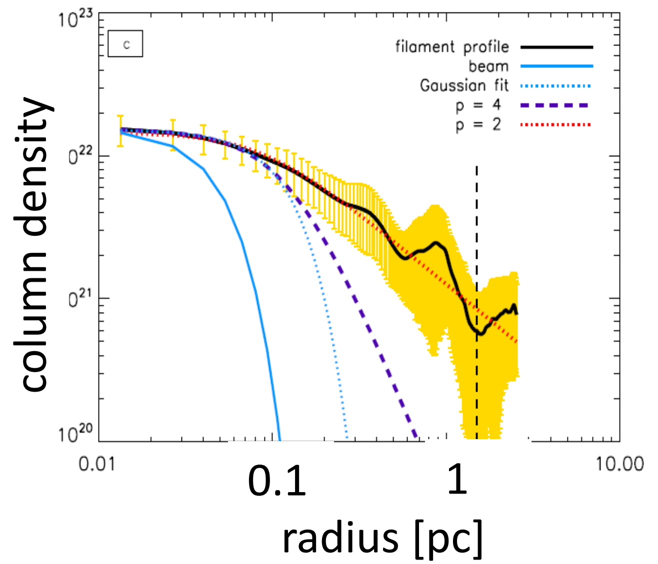


from PP6 slide by P. Andre

Width of Filaments

Arzoumanian et al. 2011



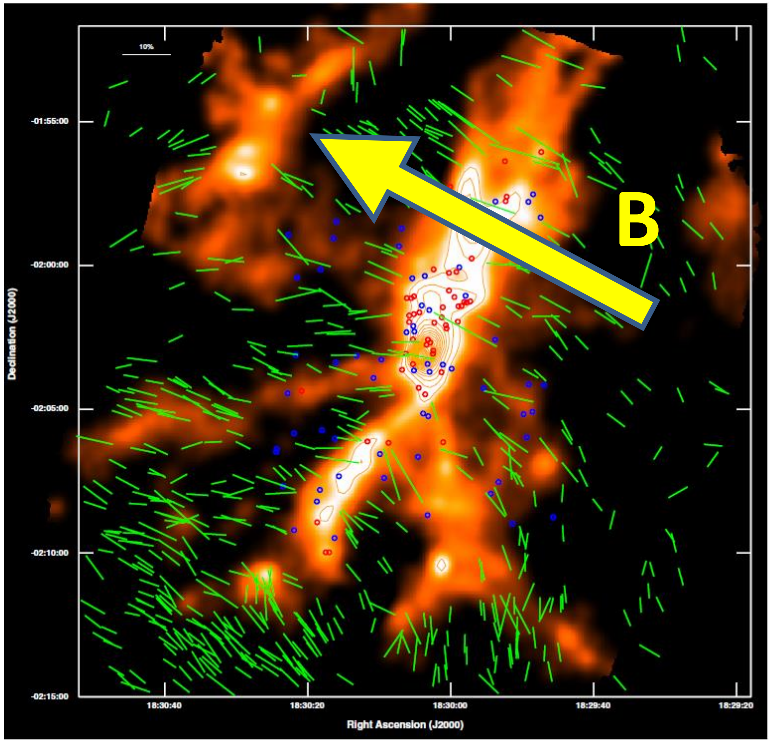


The width of filaments appears to be constant regardless of the central column density.

← contradict simple expectation

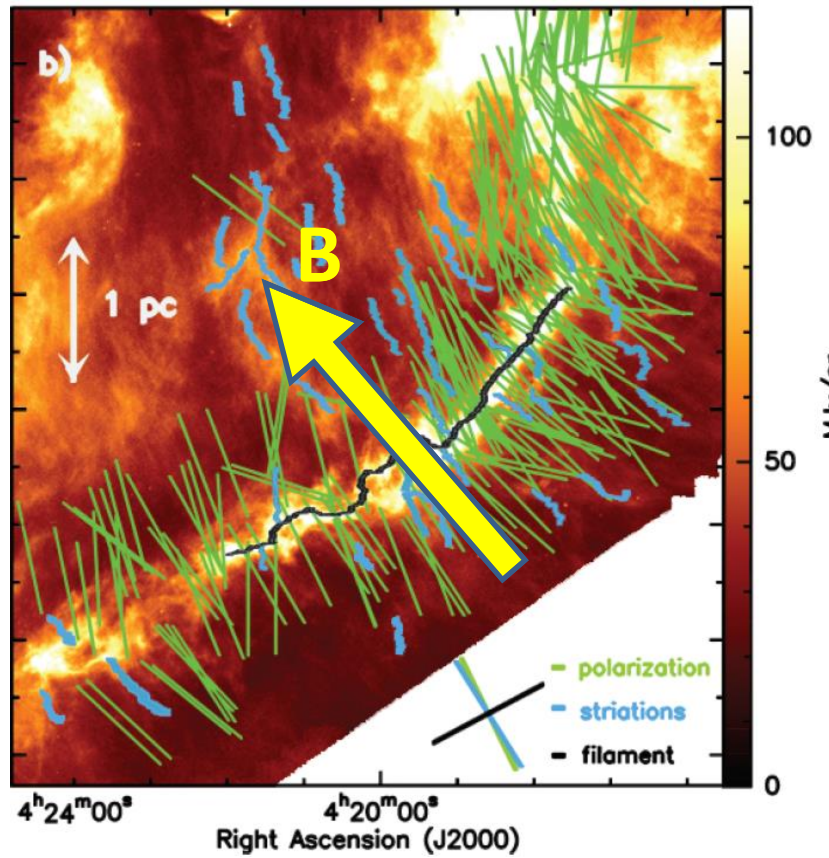
Magnetic Field (MF)

Serpens South



Sugitani et al. 2011

Taurus



Palmeirim et al. 2013

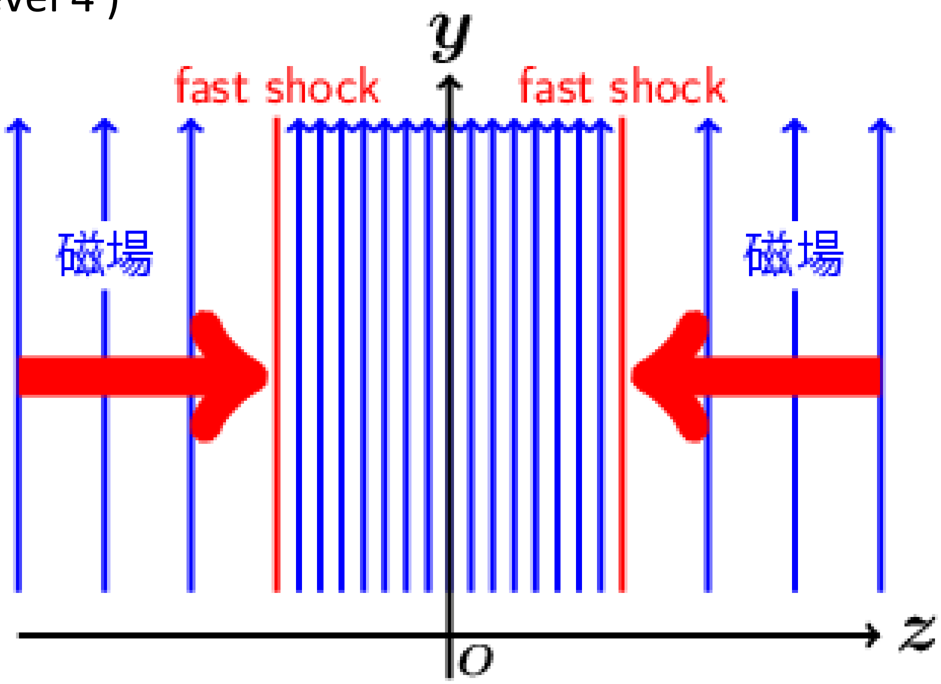
Massive filaments ⊥ B, Striations ∥ B

MF should be important in the dynamics of filaments.

Filament Formation by Shock Compression

ISM is frequently disturbed by shock compression
driven by supernovae, expansion of HII region, ⋯

- **Head-on collision along z axis,**
- **Method：AMR (Sfumato**,Matsumoto 2006)
  - Resolution：**512³** @ level 0　(up to level 4)
- $-3.6\ \mathrm{pc} < x, y, z < 3.6\ \mathrm{pc}$
- $\rho_0 = 100\mu m_{\mathrm{H}}$
- $V_0 = 3\ \mathrm{km/s}$
- $\delta v = 1\ \mathrm{km/s}$

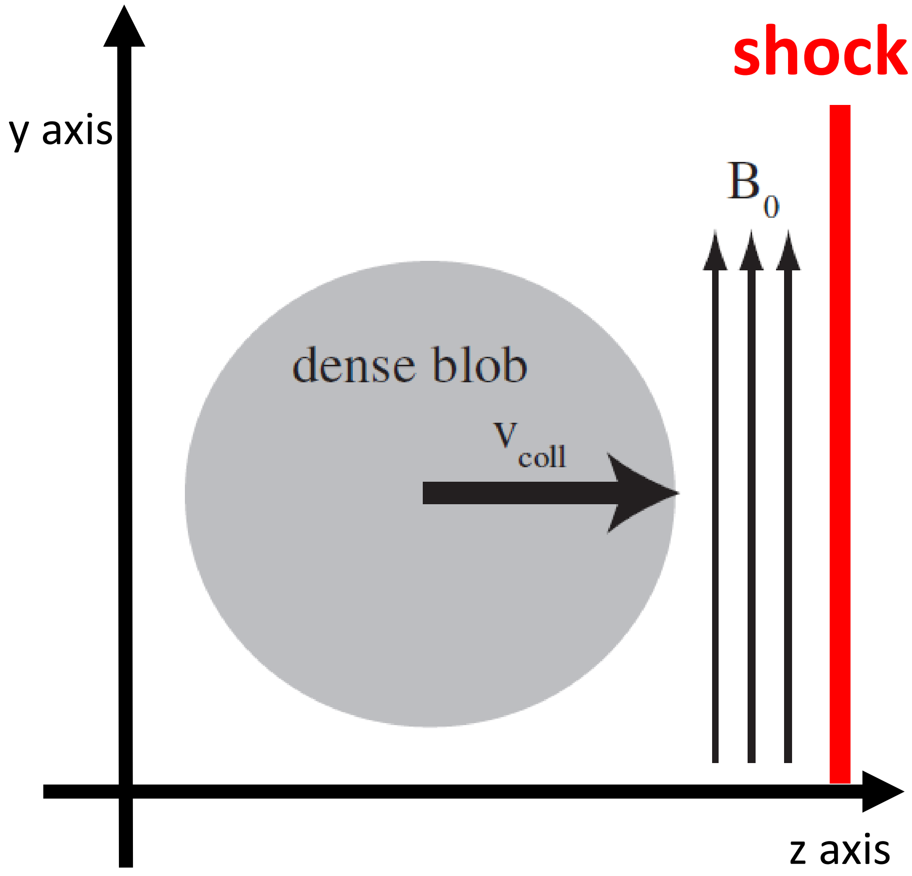


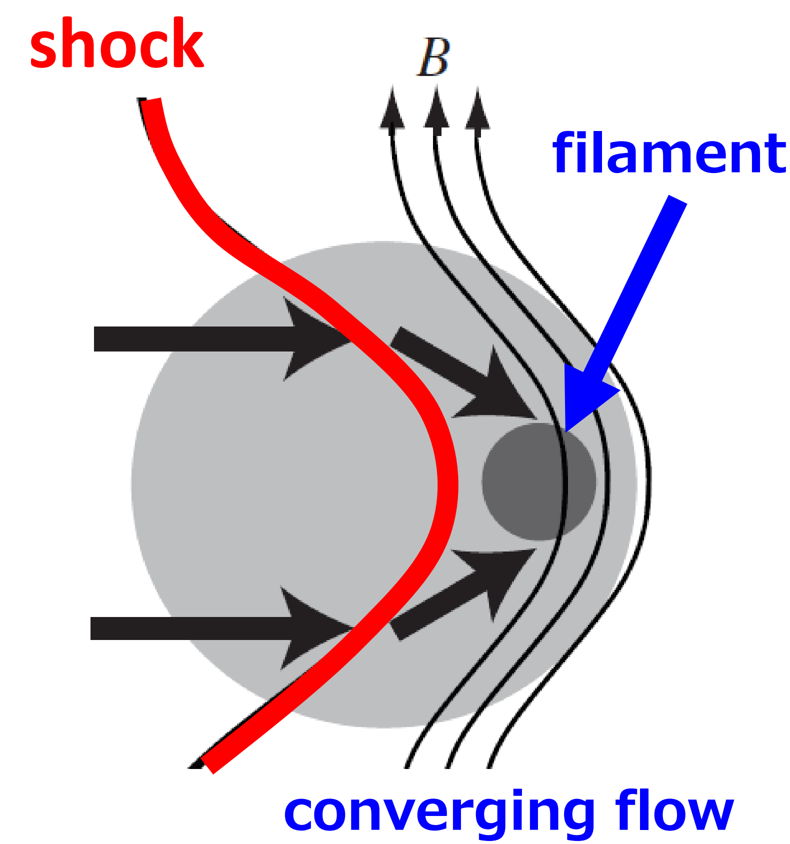
Two cases

Large B ($\beta = 0.1$), $\mathrm{B}_0 = 6.3\mu\mathrm{G}$
Small B ($\beta = 0.5$), $B_0 = 2.8\mu\mathrm{G}$

Filament Formation Mechanism

Inoue & Fukui (2013)





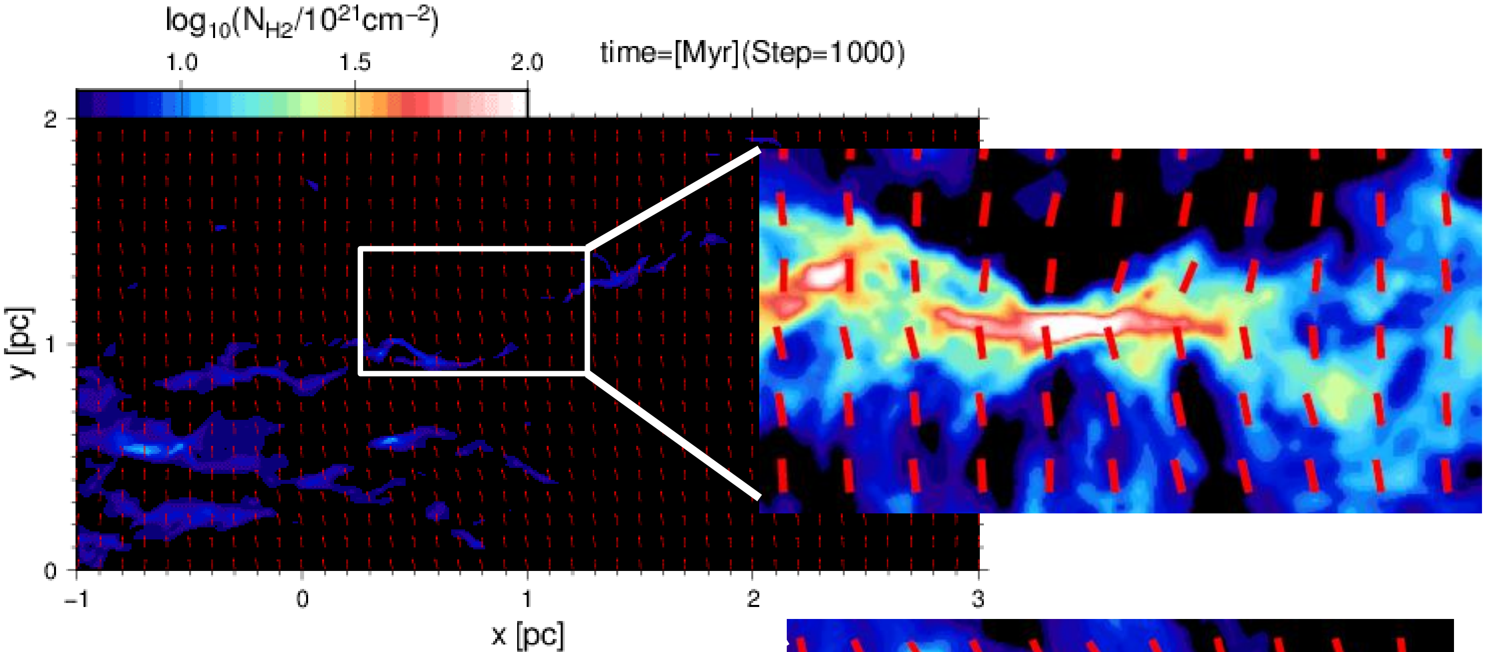
At least in the initial stage, filaments are formed by the purely MHD effect.

$$v_{\mathbf{converge}} > v_{\mathbf{ff}}$$

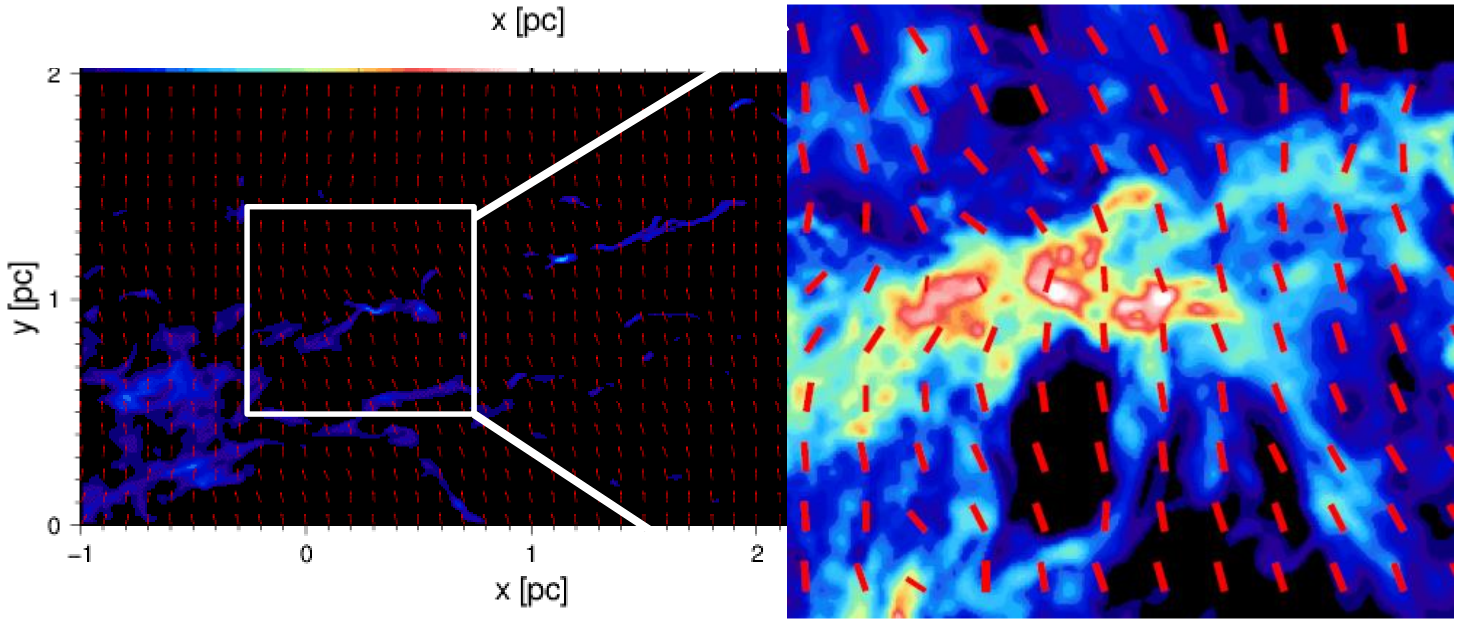
Column Density Distribution

red line:
B direction

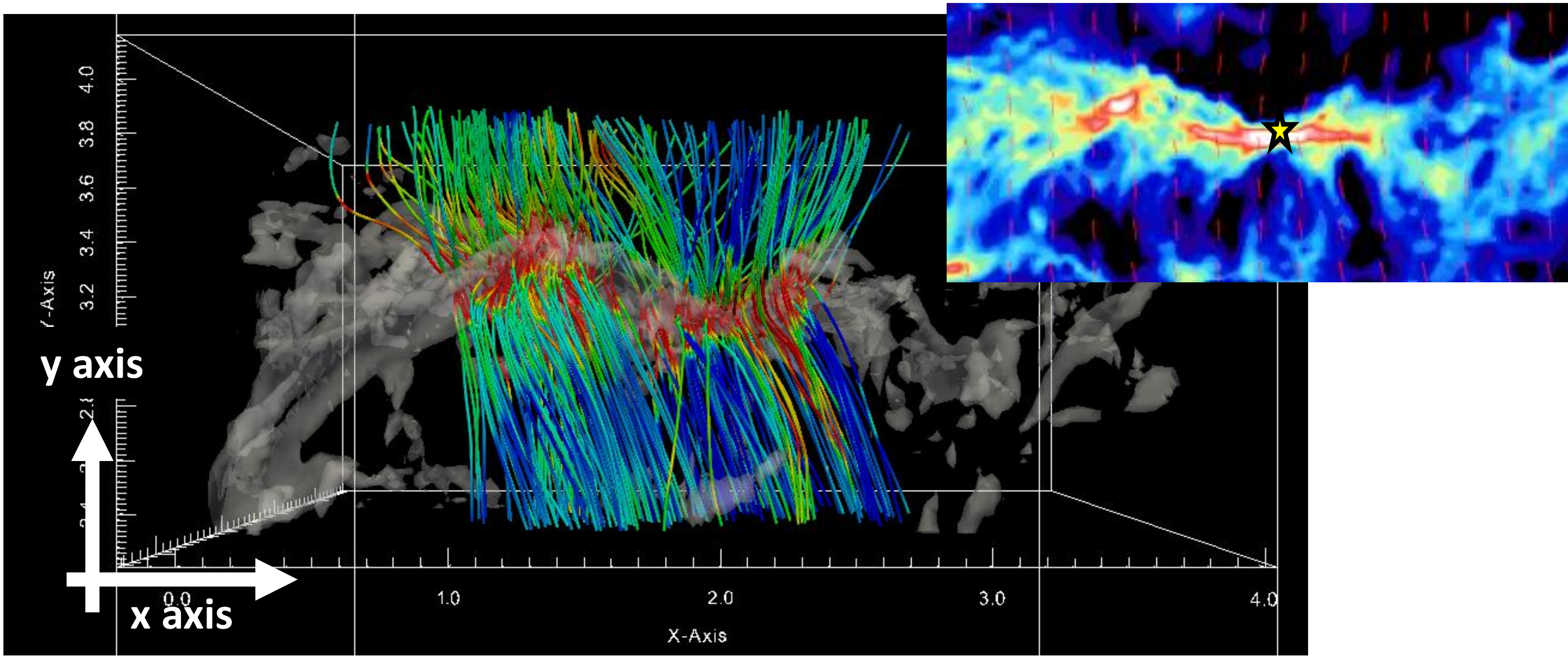
Large B

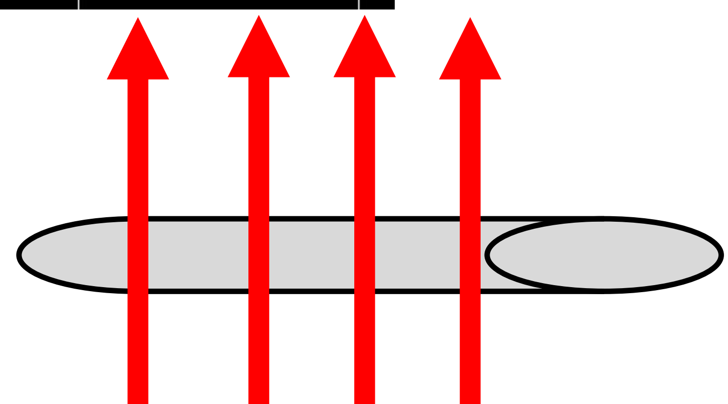


Small B



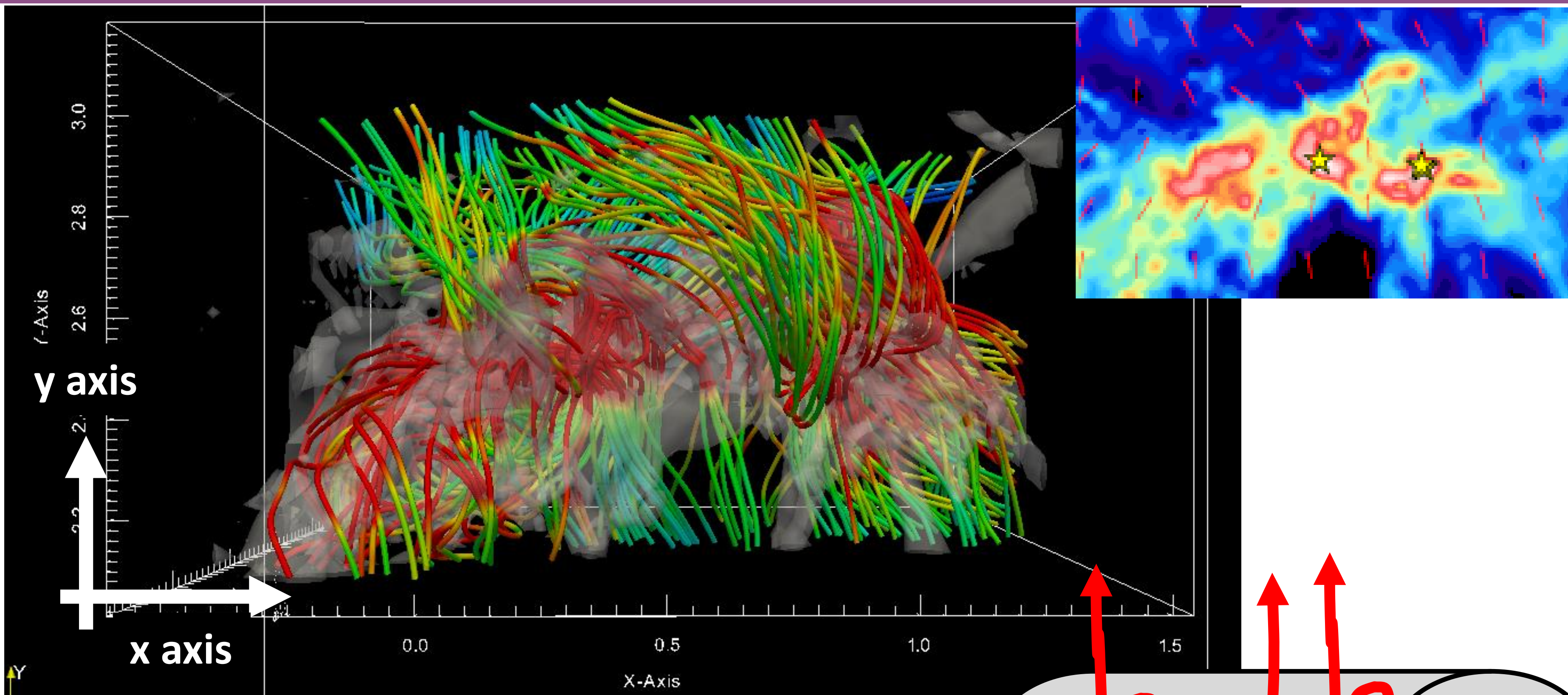
MF Configuration for Large B

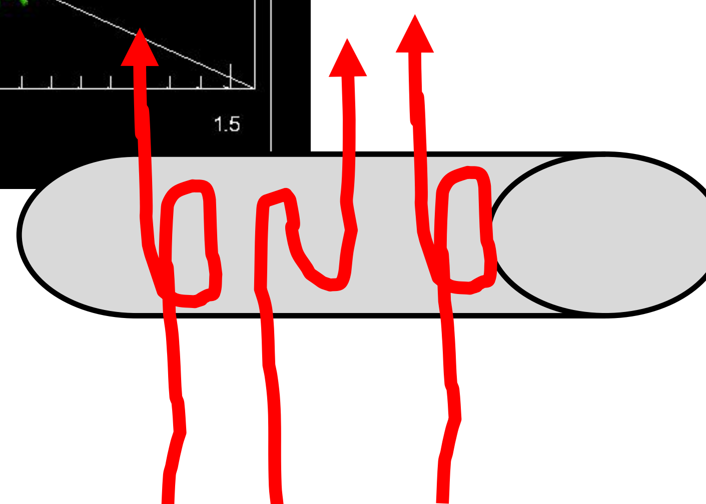




- ✓ **MF is ordered.**
- ✓ **"Ribbon-like" structure is formed.**

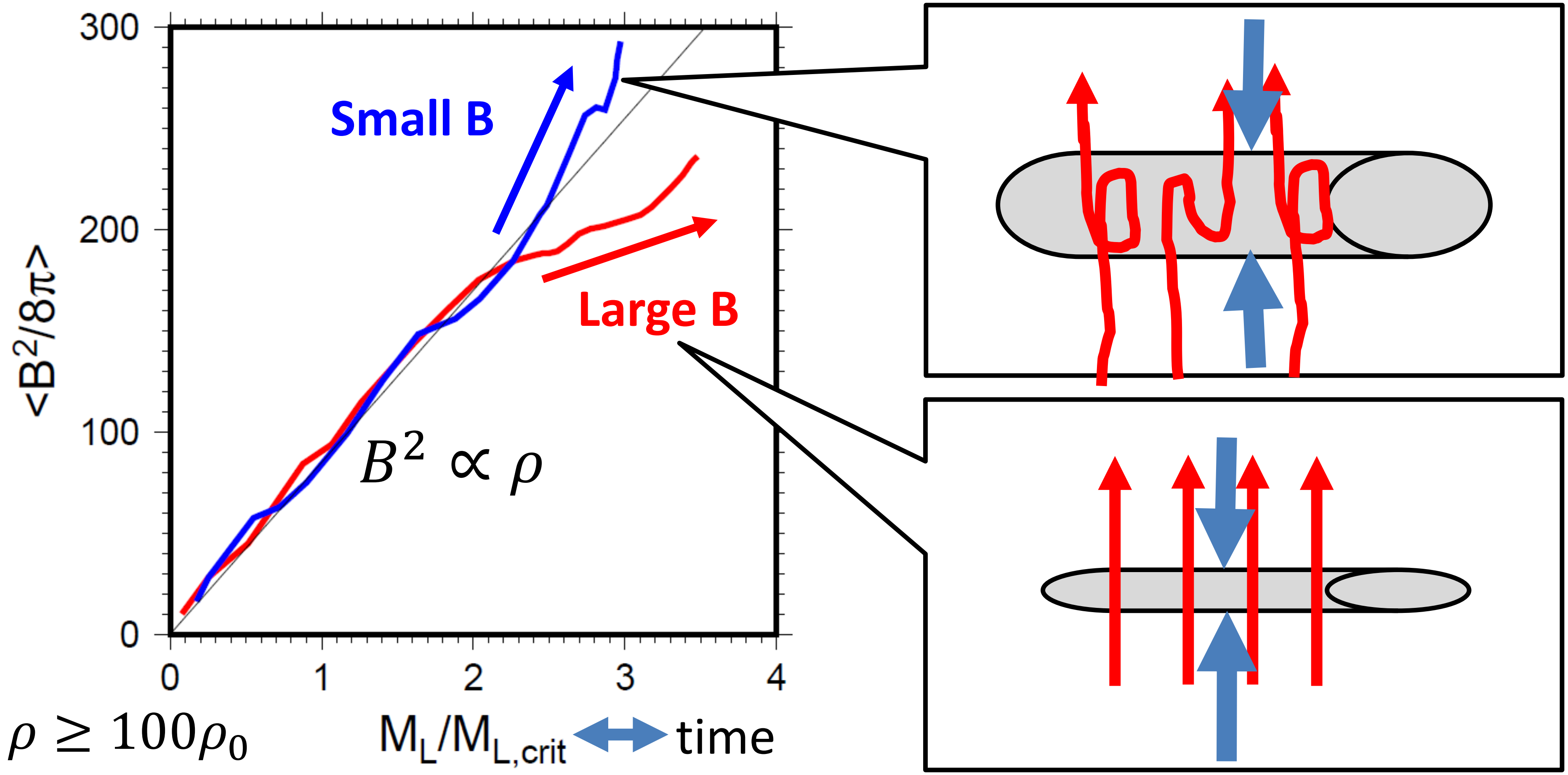
MF Configuration for Small B





- ✓ B has a complex structure inside the filament.
- ✓ B is ordered outside the filament

MF inside Massive Filament



MF inside the filament increases with the line mass.

✓ For large B, the increasing rate of MF reduces. → "ribbon-like" filament formation

✓ For small B, the increasing rate of MF appears to be enhanced.

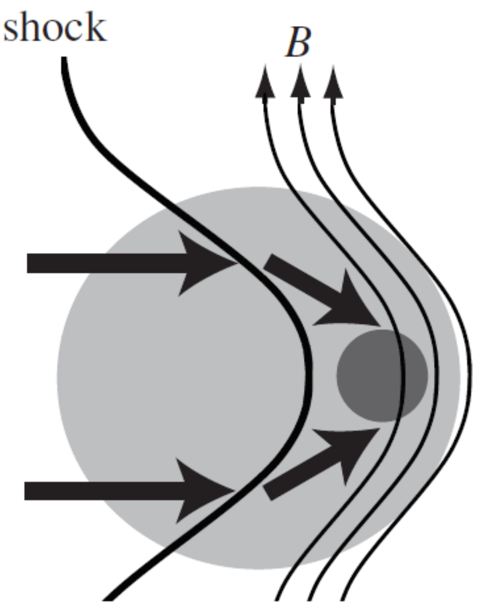
Dynamics in Postshock Region

Model	$B_{\rm sh}$ $\left(\frac{B_{\rm sh}^2}{8\pi} \sim \rho_0 V_0^2\right)$	$\rho_{\rm sh}$	$C_{\rm A,sh}$
Large B	75	14	$10c_s(0.67V_0)$
Small B	75	4	$5c_s(0.33V_0)$

If the initial perturbation is nonlinear,
shock fronts deform significantly.

→ If B_0 is small,
converging flow can be **super-Alfvenic**.
B is bended during the filament formation.

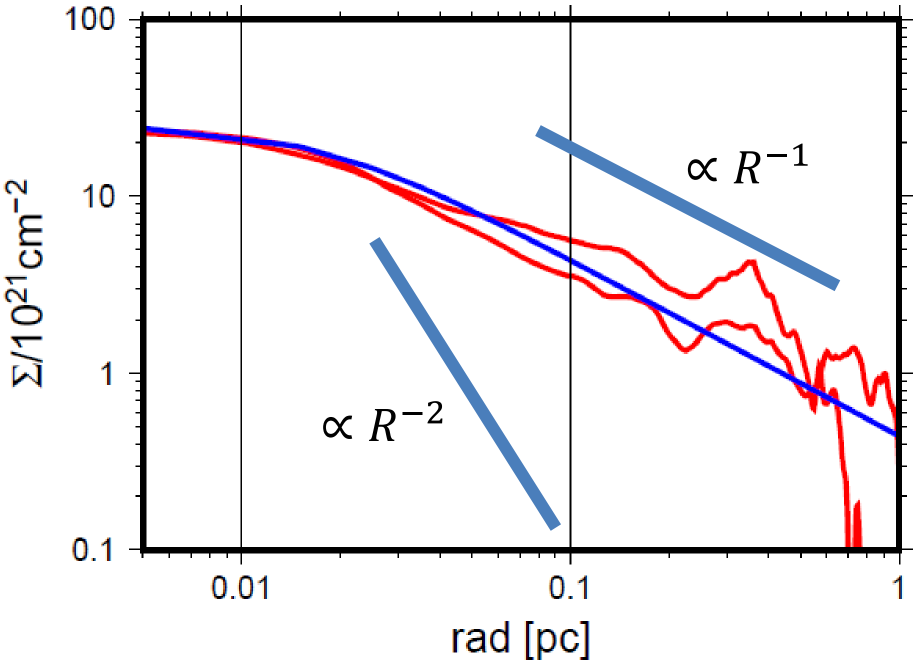
$$B_{\rm crit} = B_{\rm crit}(V_0, B_0, \delta v)$$

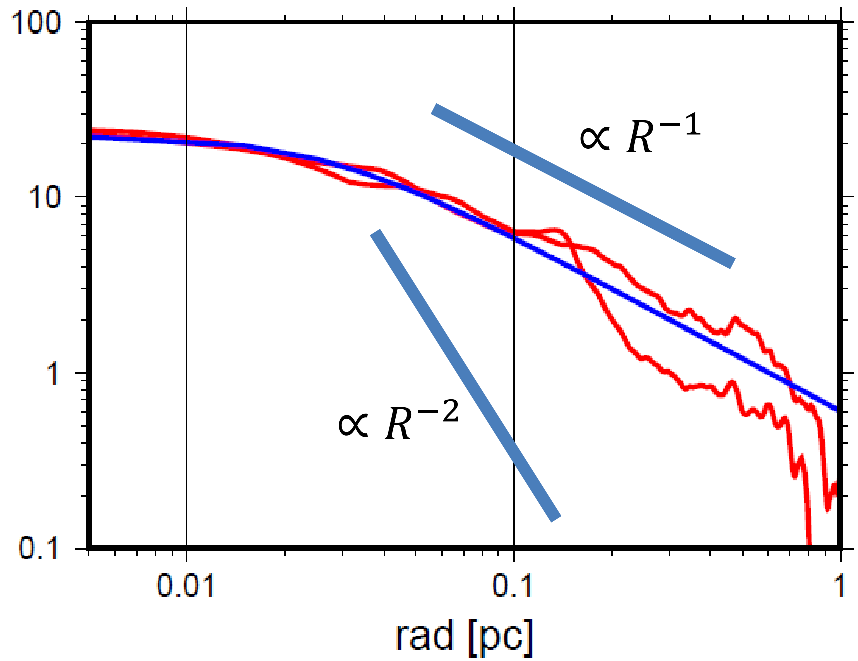


Radial Profile

filaments are identified by DisPerSE (Soubie et al. 2011)

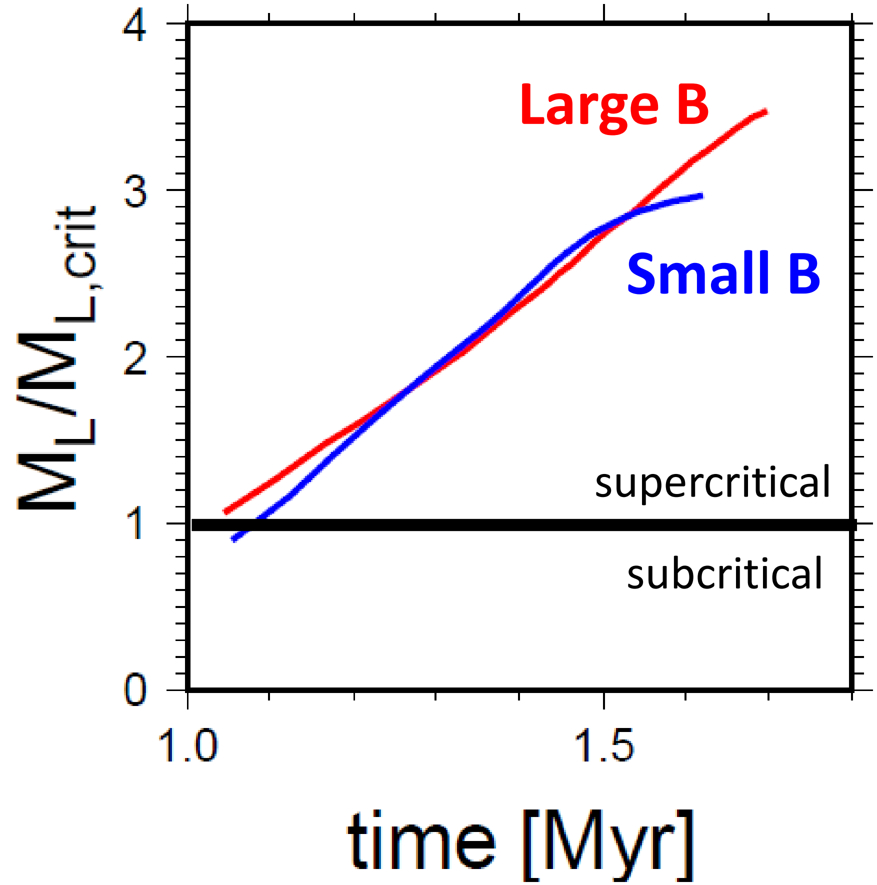
Large B **Small B**

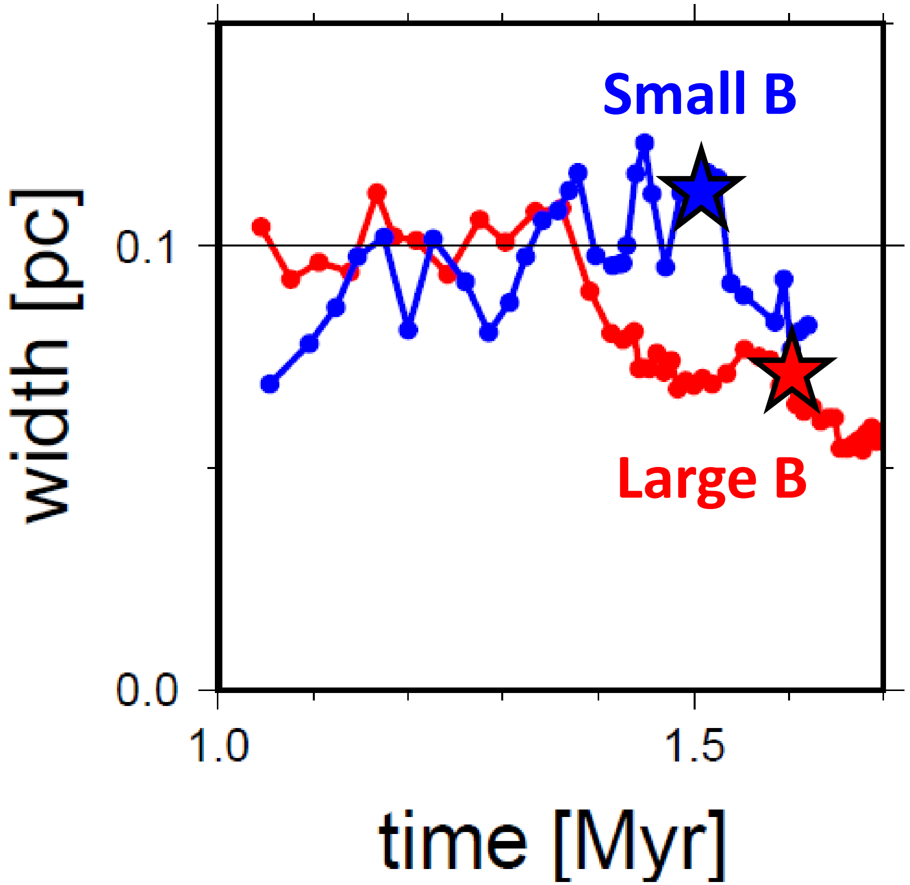




- The slope of the radial profile is smaller than the equilibrium profile.

Time Evolution of Width





At least for the initial phase, the width appears to be 0.1 pc.
For large B, star (sink) forms after the formation of “ribbon” (width decreases)
For small B, the width is remains 0.1 pc at the star (sink) formation.

Summary

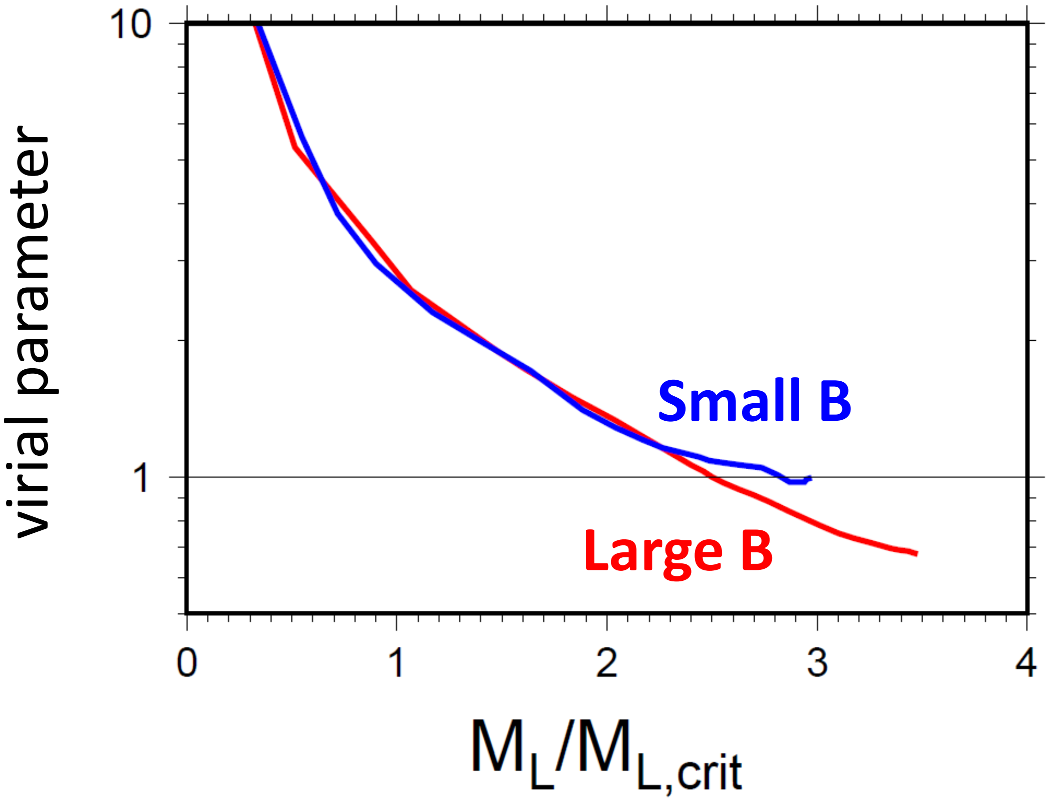
- We investigate the formation of filament driven by shock compression.
- At least in the initial phase, filaments are formed by converging flow whose speed is larger than the free-fall velocity.
- **For Large B**
  - **MF structure is coherent inside filaments.**
  - **Filament is highly flattened (ribbon-like).**
- **For Small B**
  - **MF structure is complex inside filaments.**
  - **MF is roughly ordered outside filaments (stretching)**

Future Works

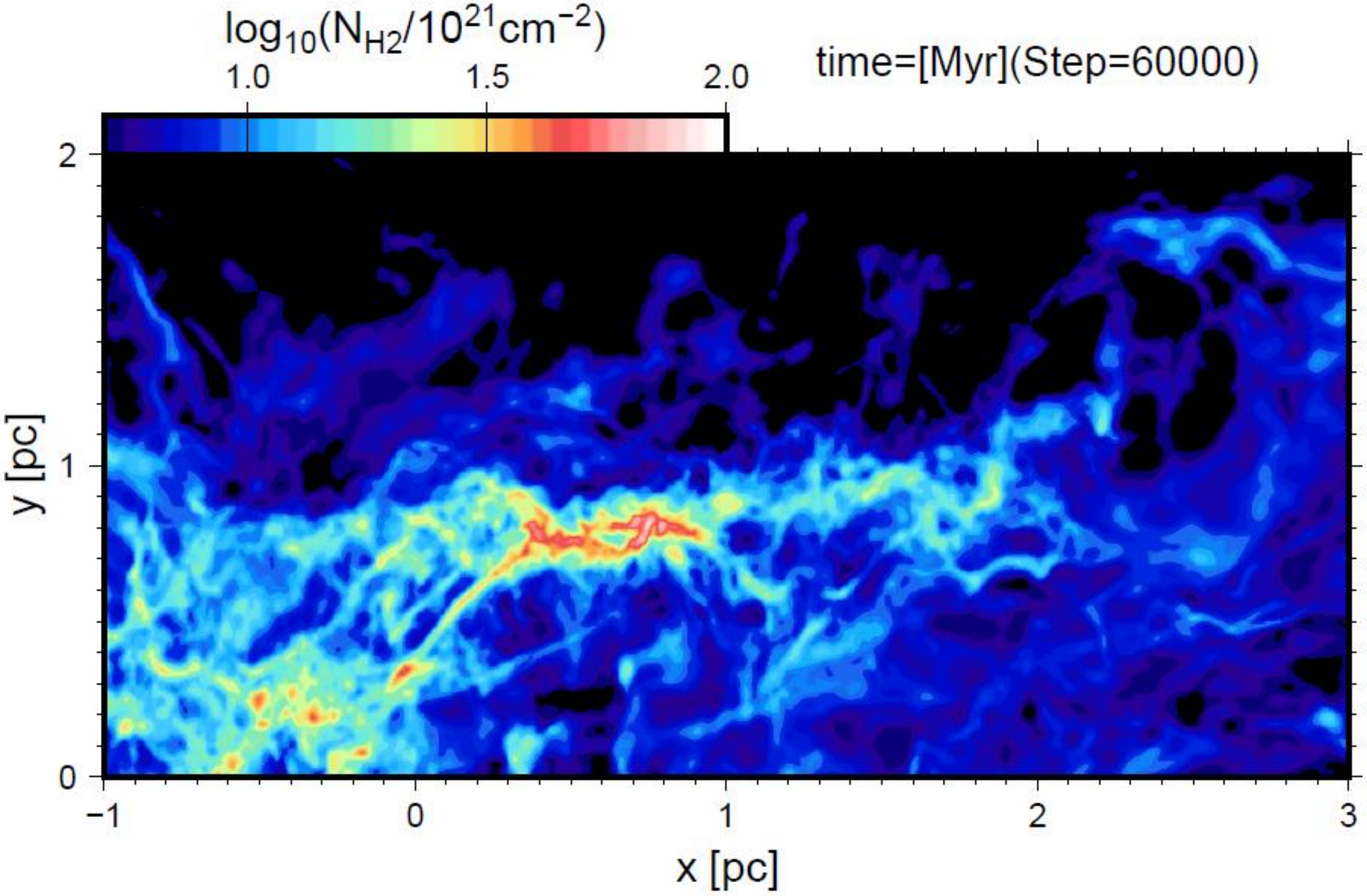
- ✓ Parameter Survey
  - ● How the structure of MF depends on $B_0, V_0, \delta v$.
- ✓ Development of Analytical Model

virial parameter

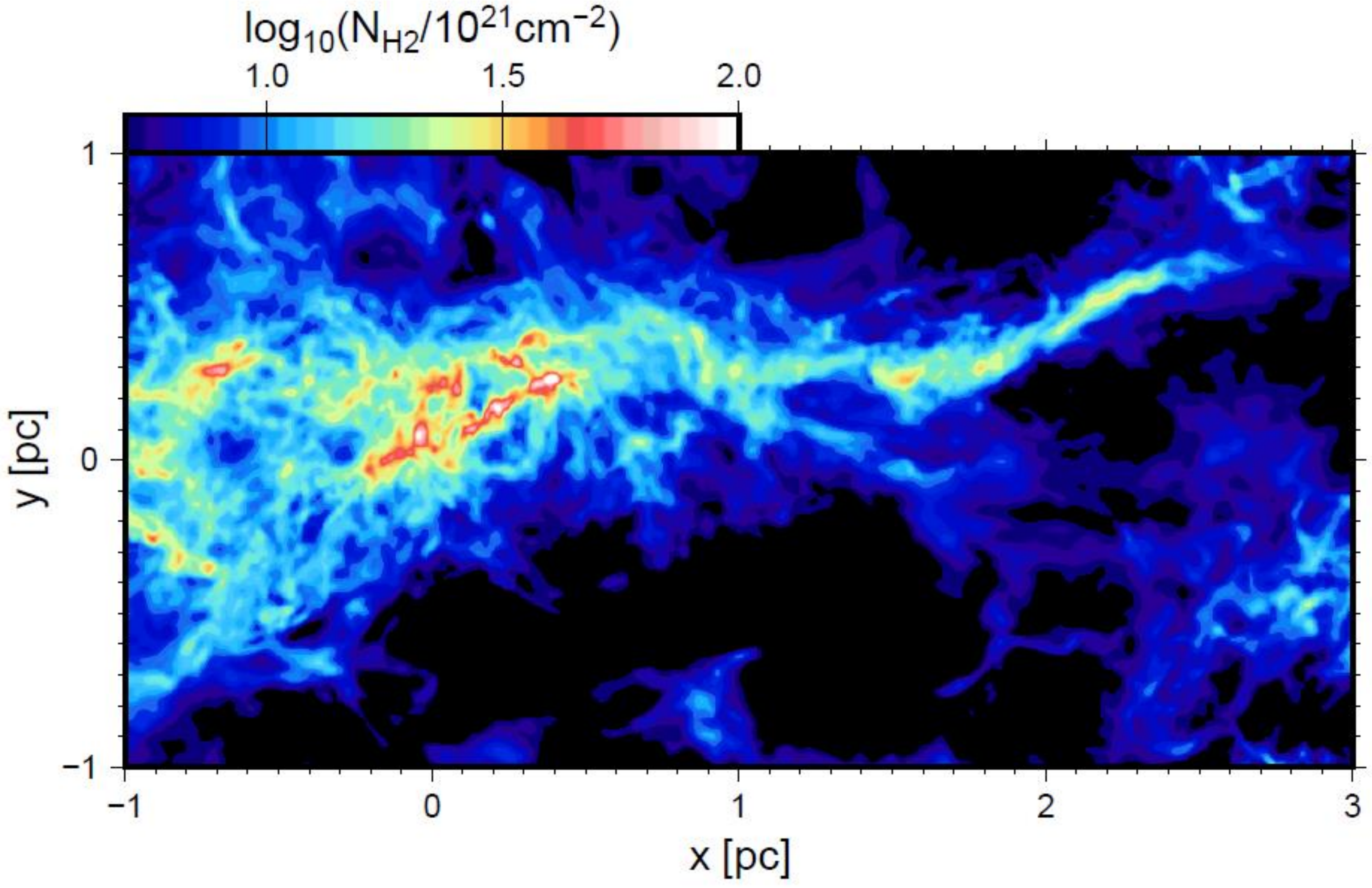
$$\text{virial parameter} \equiv \frac{\left(2\int P dA + \frac{\int B^2 dA}{8\pi}\right)}{G M_{\mathrm{L}}^2}$$

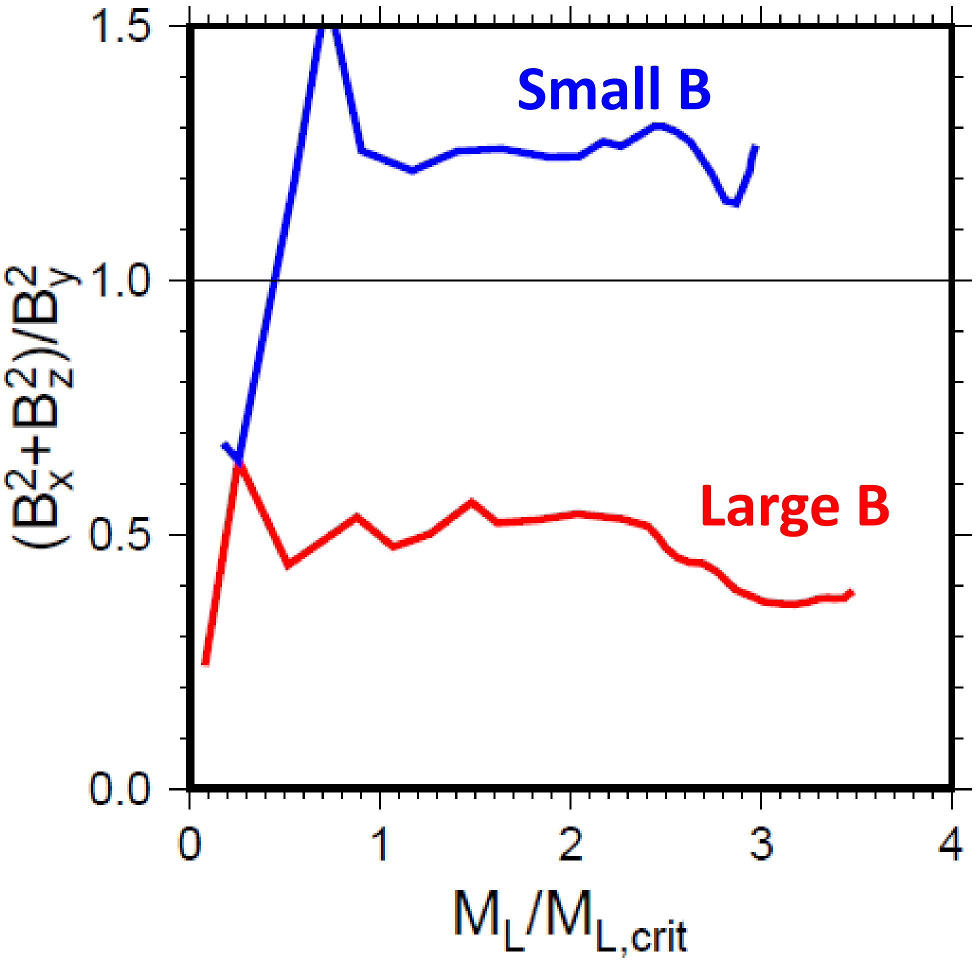


Large B $(\theta = \pi/4)$



Small B ($\theta = \pi/4$)




Small B
Large B
1.5
1.0
0.5
0.0
0
1
2
3
4
$(B_x^2+B_z^2)/B_y^2$
$M_L/M_{L,crit}$