Numerical Simulations of Filament Formation and Fragmentation

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with Eve Ostriker
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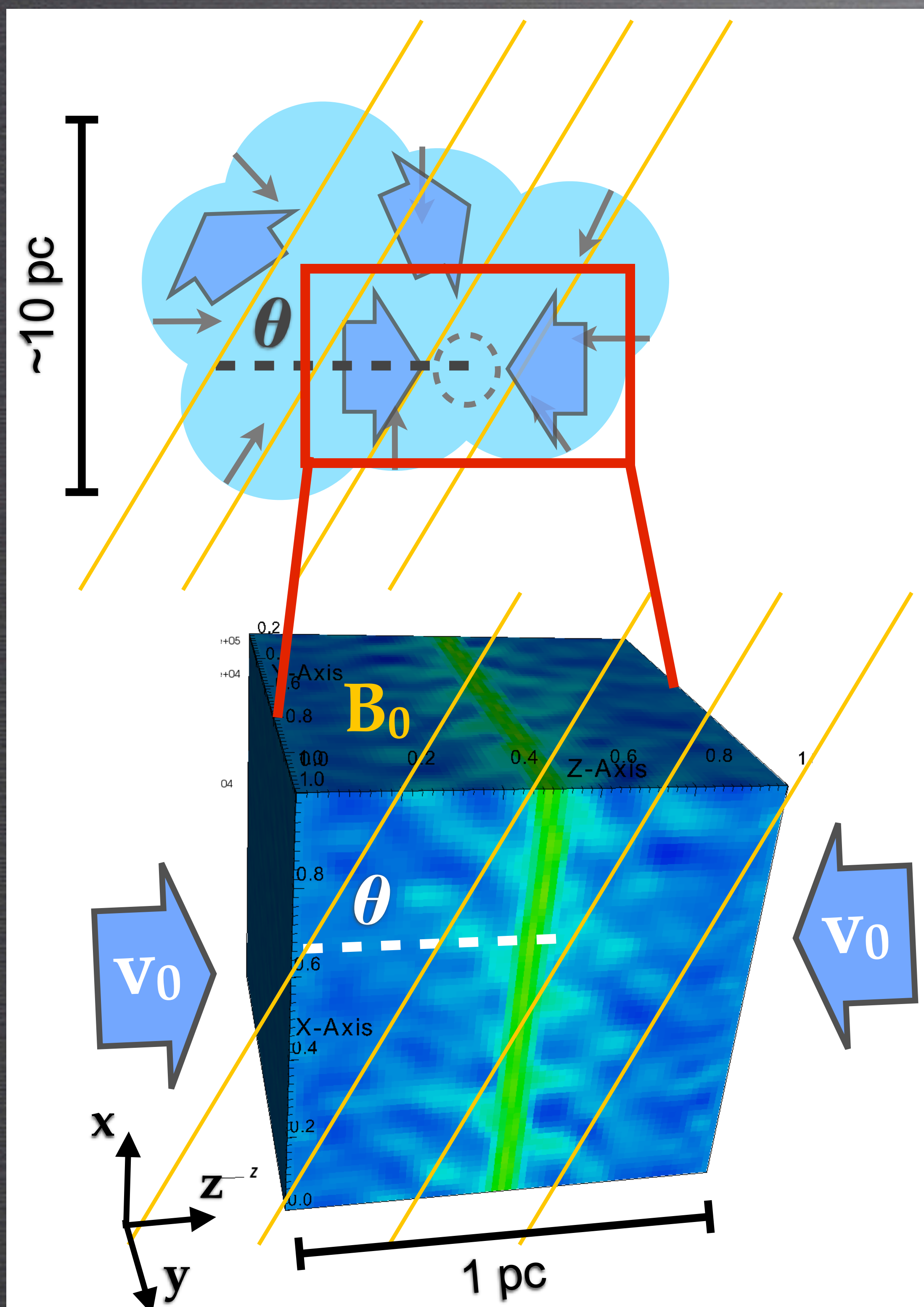
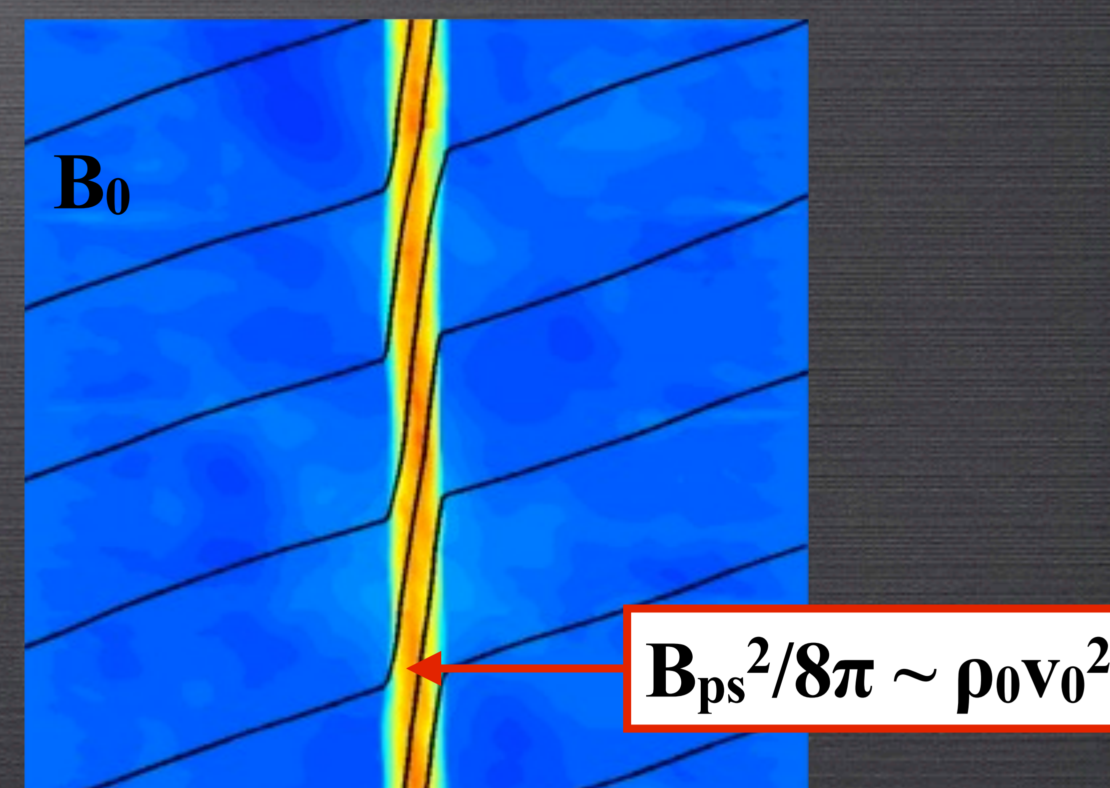
and The CLASSy Collaboration

Filaments 2014, NRAO

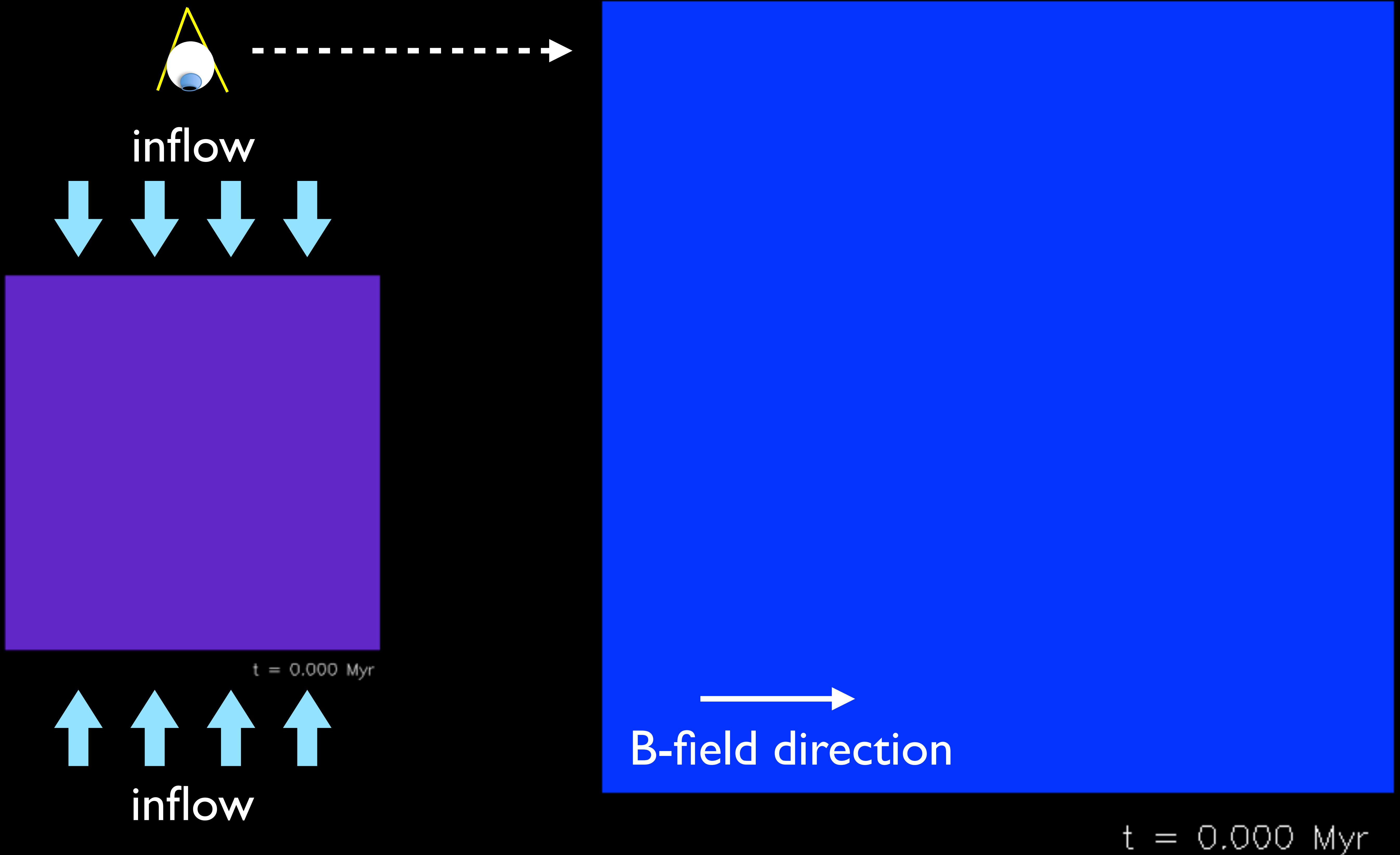
Simulation Setup



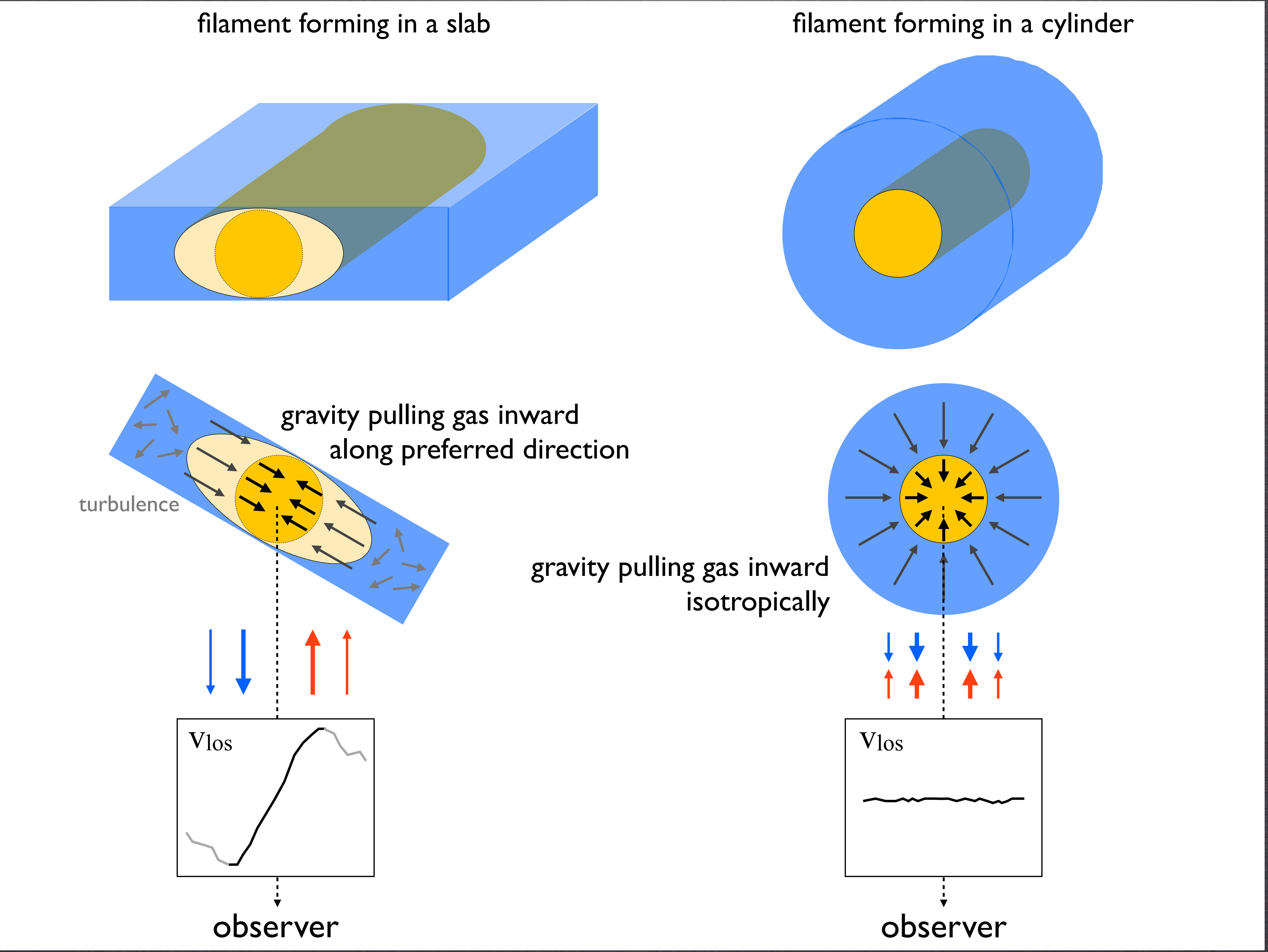
- Include:
  - self-gravity
  - perturbation field
  - ambipolar diffusion
- cloud density:
  - $n_0 = 1000\ \mathrm{cm}^{-3}$



Structure Formation

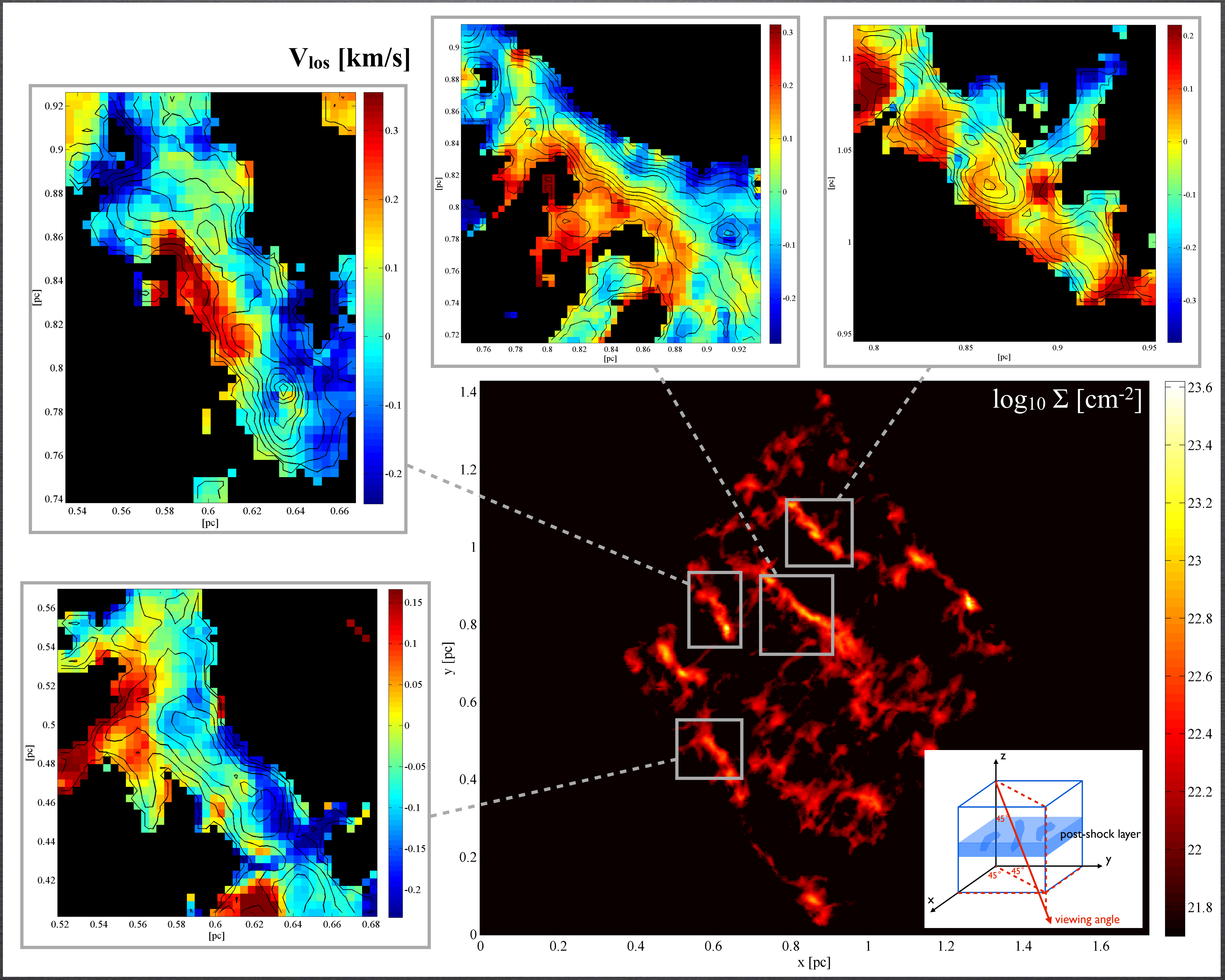


Kinematics



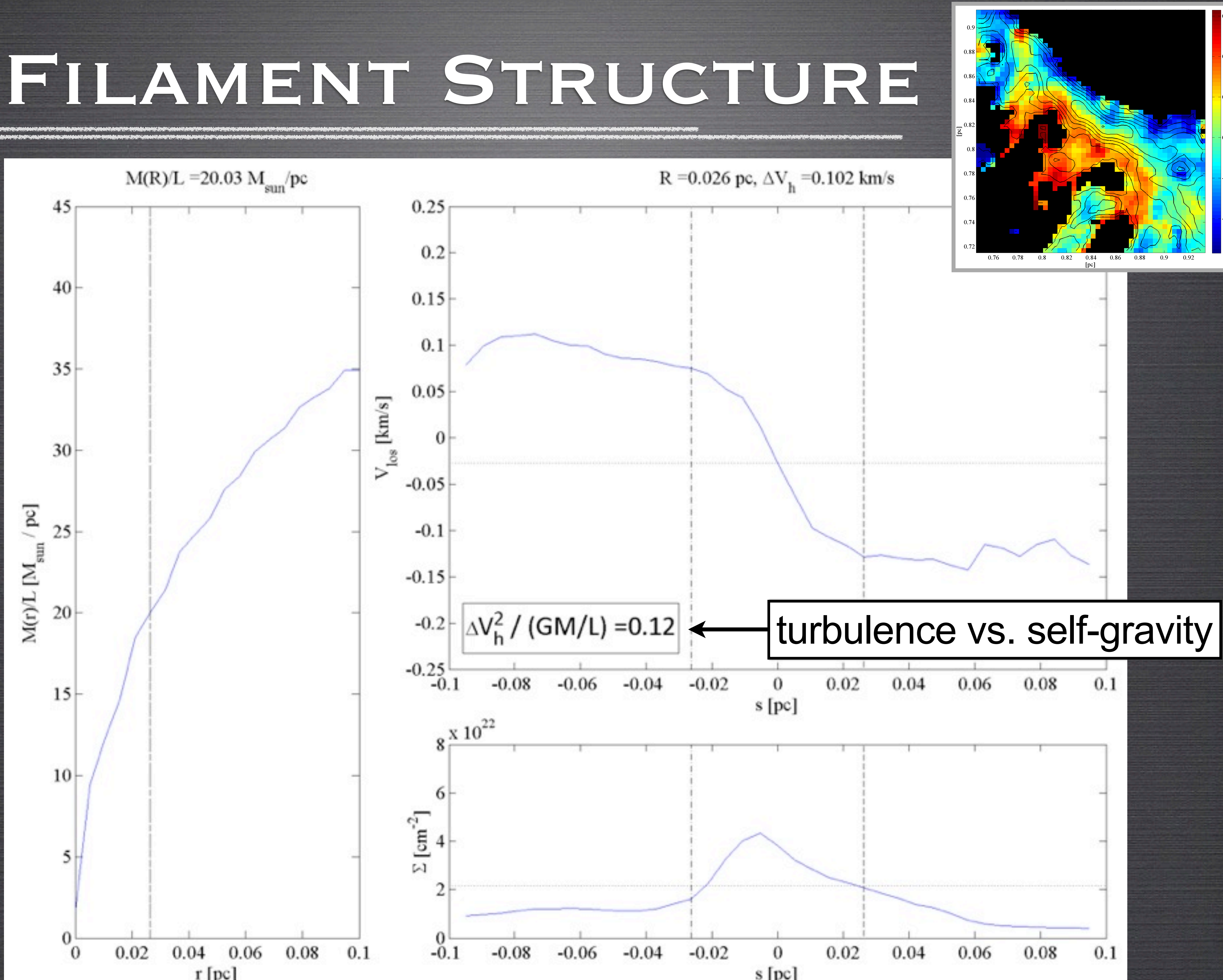
(Mundy et al. *in prep.*)

Line-of-sight Velocity



(Mundy et al. *in prep.*)

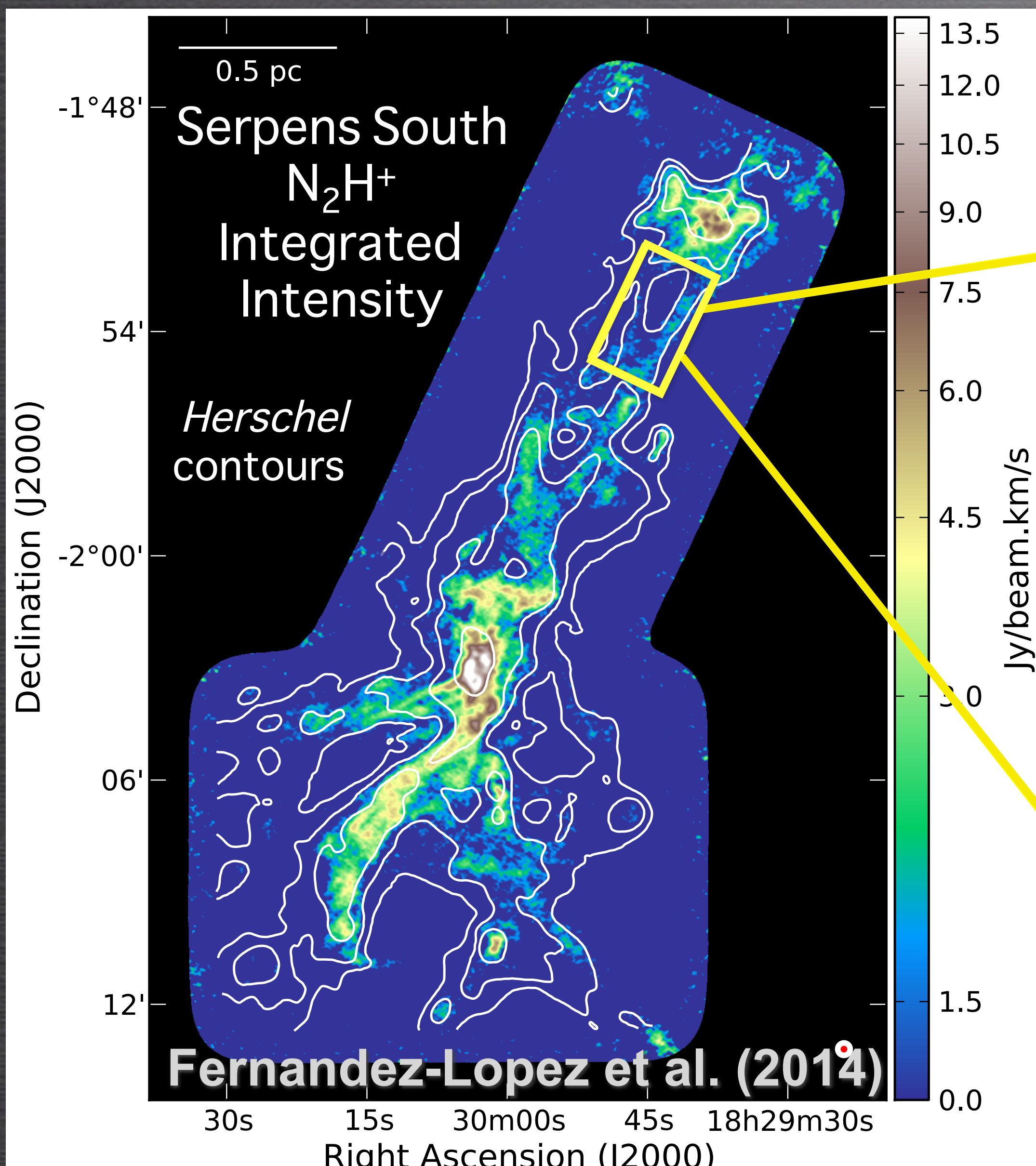
Filament Structure



(Mundy et al. *in prep.*)

Observations

- CLASSy results



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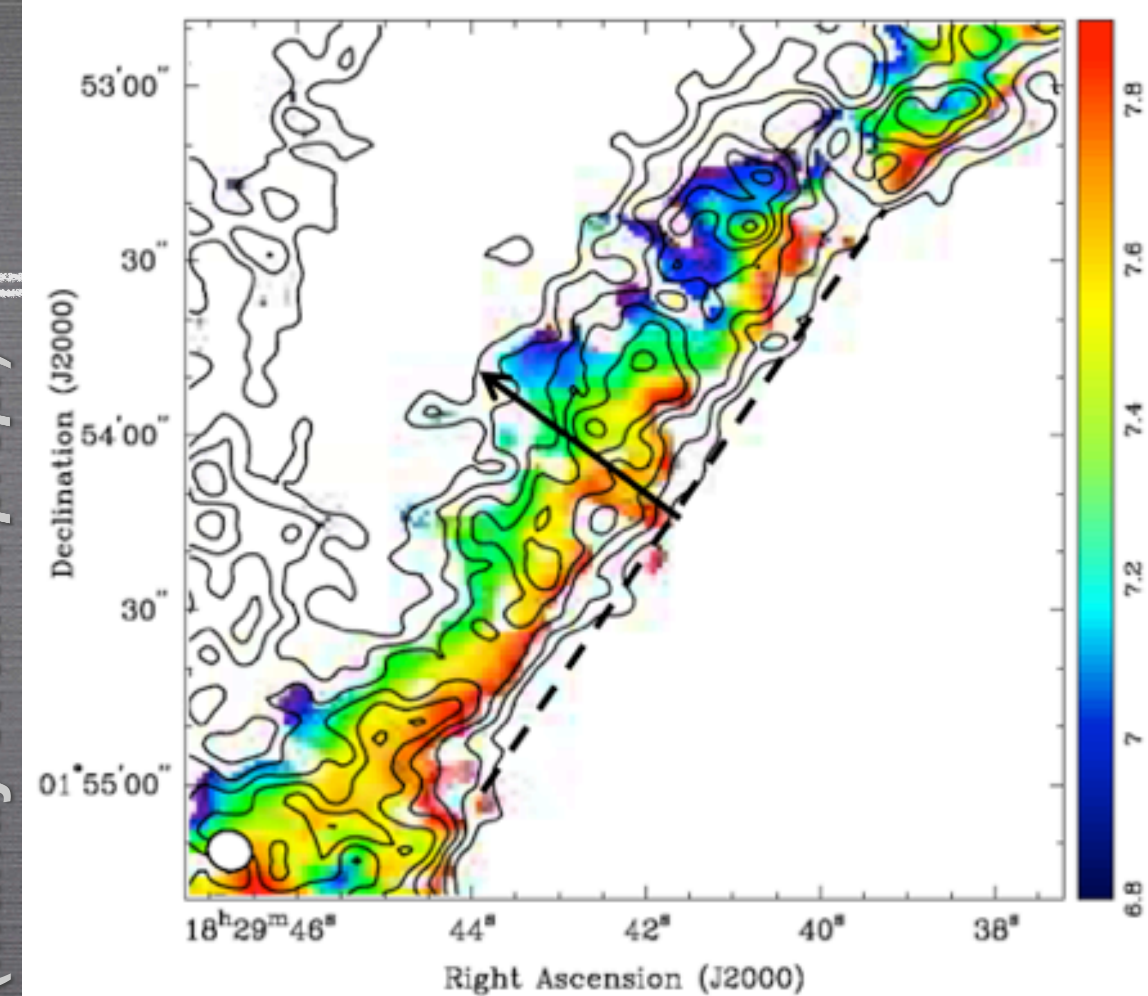
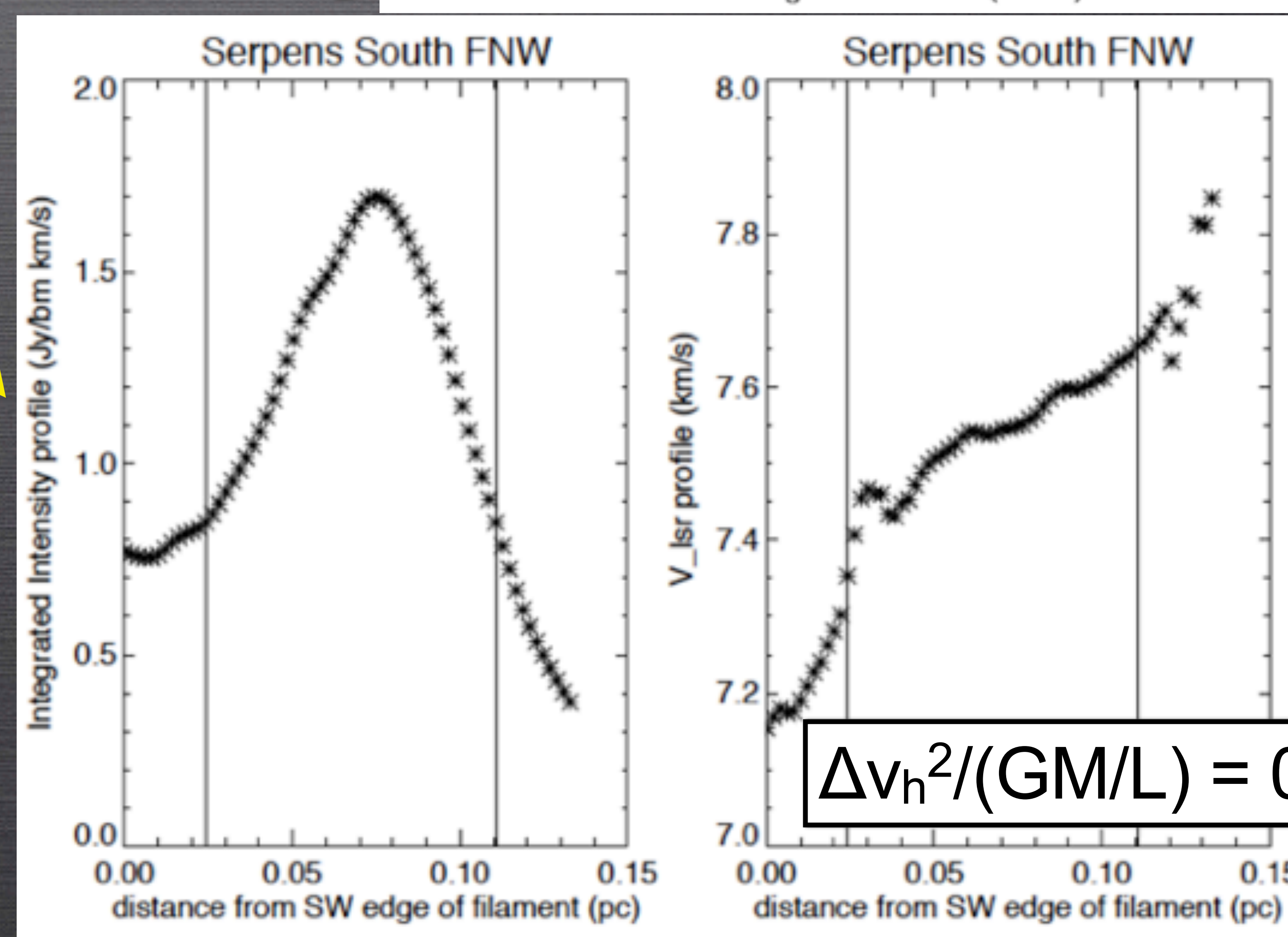
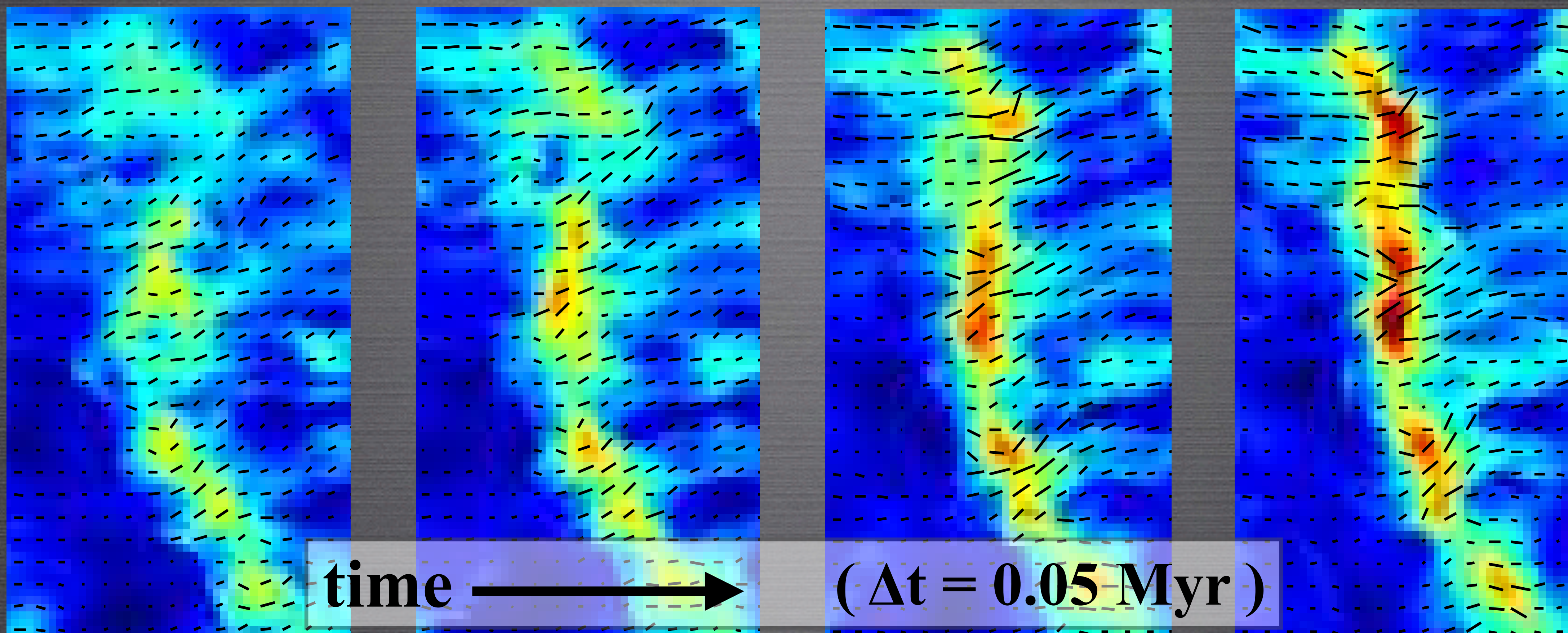




$\Delta v_h^2/(GM/L) = 0.3$

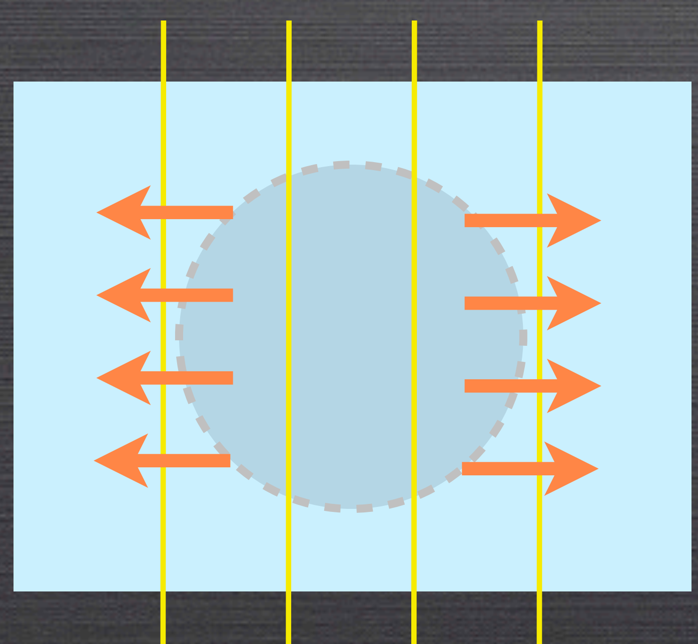
see also S. Storm's poster
K. Lee's poster

Filament ⇨ Core Formation



- Classical picture of magnetized cores

quasi-static ambipolar diffusion



$t \sim 10^7$ yr

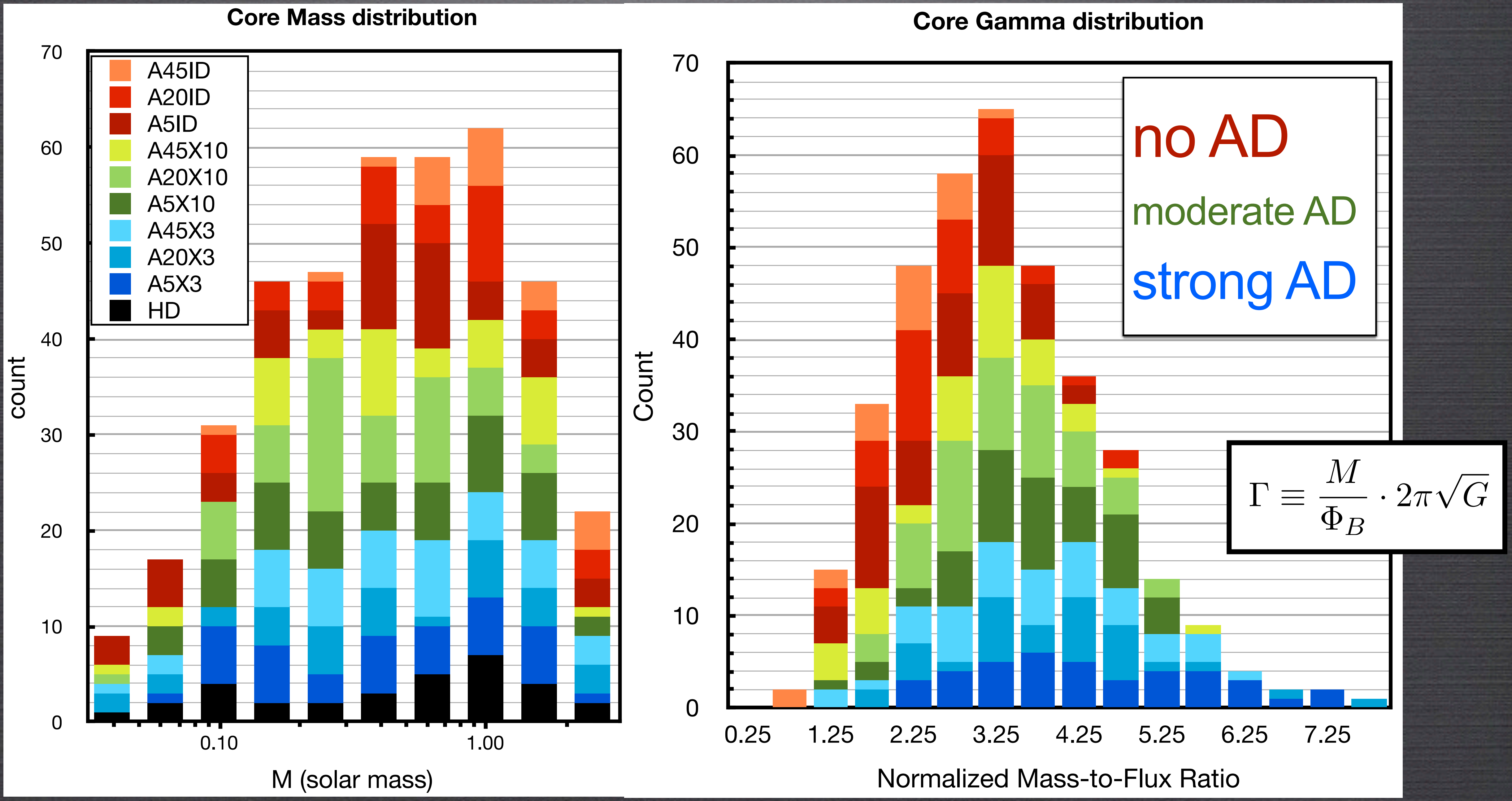
self-gravitating core

☹ core lifetime too long

⁇ core mass ↔ AD

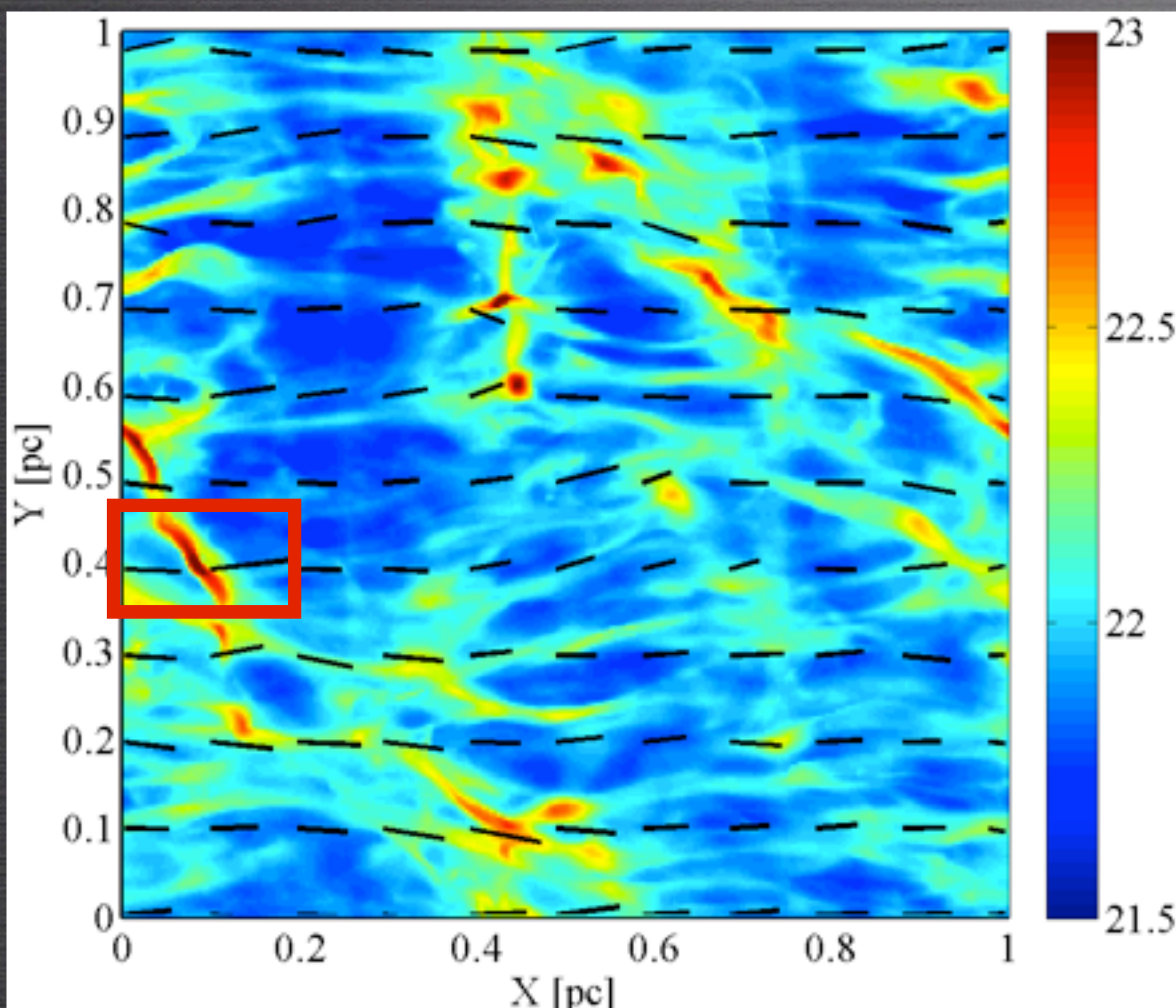
Simulation Results

- Models with same pre-shock pressure
  $\Rightarrow$ similar core masses, with or without AD

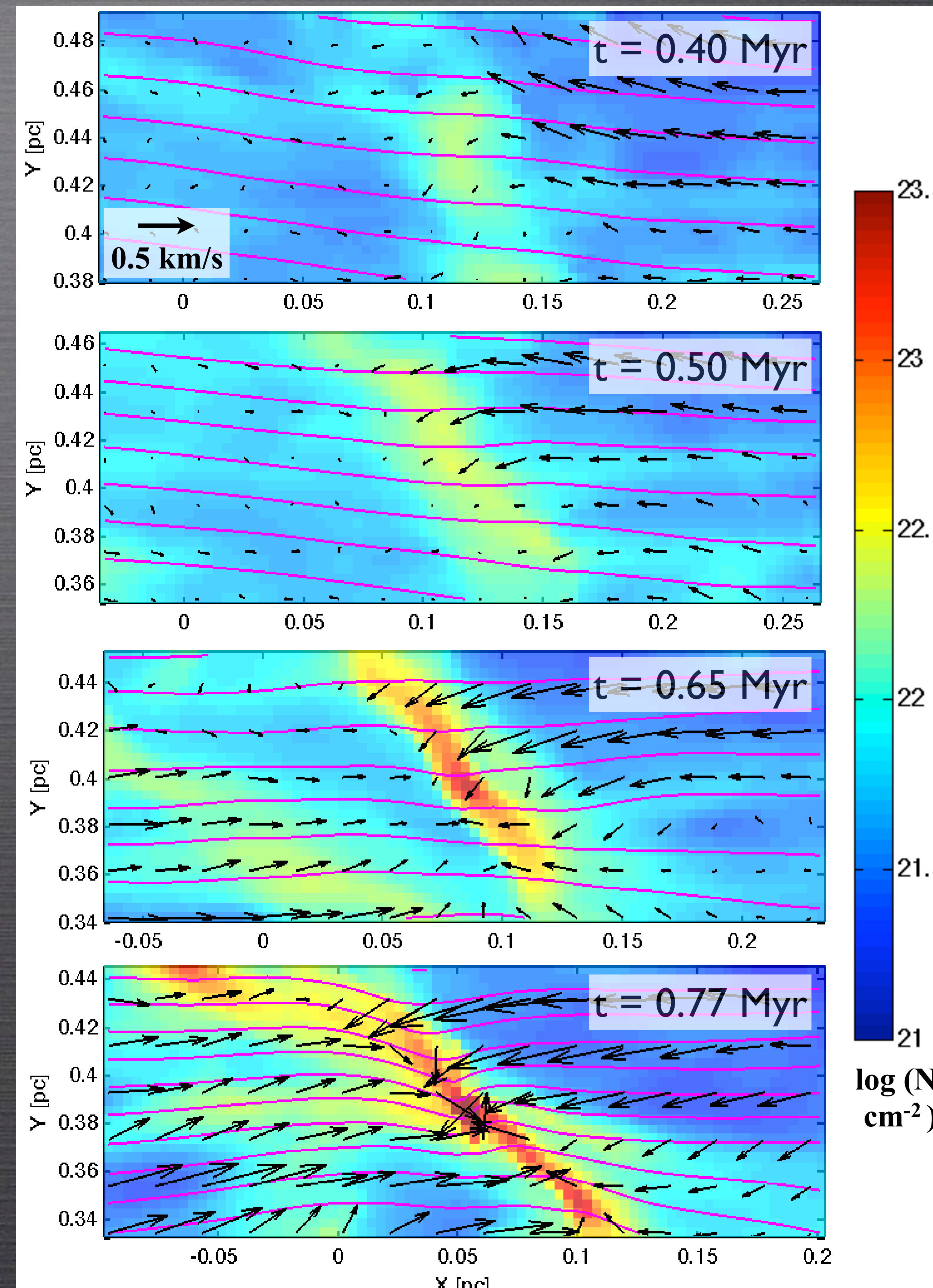


(Chen & Ostriker 2014)

Anisotropic Gas Flows



(Chen & Ostriker 2014)



Anisotropic Core Formation

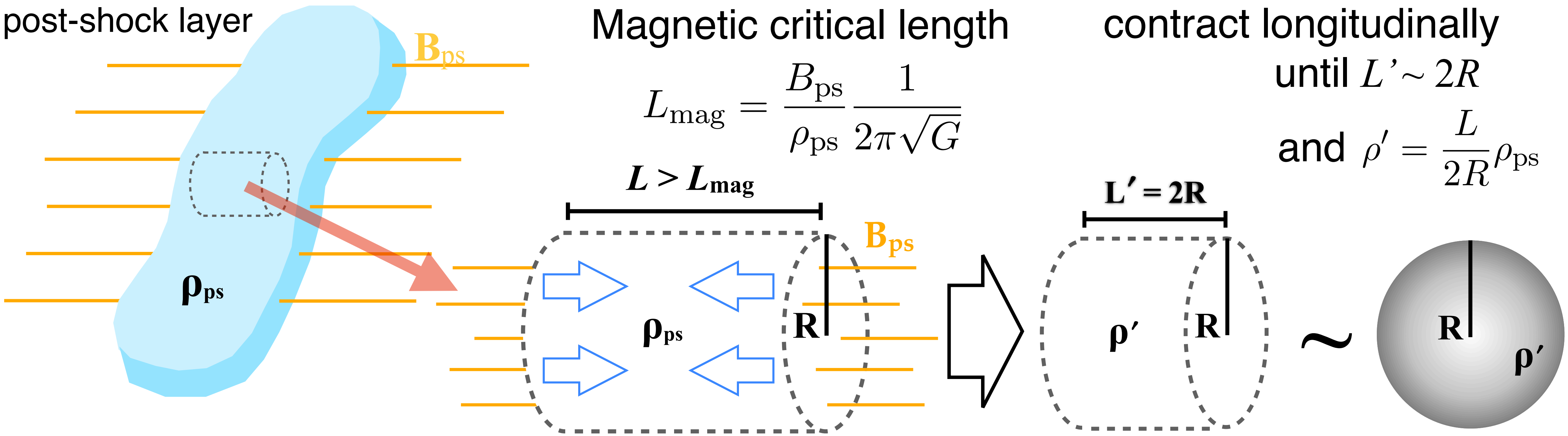
filament formed in post-shock layer

Magnetic critical length

$$L_{\rm mag} = \frac{B_{\rm ps}}{\rho_{\rm ps}} \frac{1}{2\pi\sqrt{G}}$$

contract longitudinally until $L' \sim 2R$

and $\rho' = \frac{L}{2R}\rho_{\rm ps}$



Thermally supercritical: $R \sim R_{\rm BE}\left(\rho'\right) = 0.65\frac{c_s}{\sqrt{G\rho'}}$ ➡ $R = 0.84\frac{{c_s}^2}{G\rho_{\rm ps}L},$

$$M = \pi R^2 L\rho_{\rm ps} = 2.2\frac{{c_s}^4}{G^2\rho_{\rm ps}L}$$

Magnetically critical, Anisotropic

$$L = L_{\rm mag} \;➡\; \rho_{\rm ps}L = \frac{B_{\rm ps}}{2\pi\sqrt{G}}$$

$$M_{\rm crit,cyl} = 14\frac{{c_s}^4}{\sqrt{G^3}B_{\rm ps}}$$

$$= 1.3\ {\rm M}_\odot \left(\frac{B_{\rm ps}}{50\ \mu{\rm G}}\right)^{-1}\left(\frac{T}{10\ {\rm K}}\right)^2$$

$$= 2.8\frac{c_s}{\sqrt{G^3\rho_0{v_0}^2}} \propto \mathcal{M}^{-1}$$

Magnetically critical, Isotropic

Spherical core with $R = \frac{L_{\rm mag}}{2} = \frac{B_{\rm ps}}{4\pi\sqrt{G}\rho_{\rm ps}}$

$$M_{\rm crit,sph} = \frac{4\pi R^3}{3}\rho_{\rm ps} = \frac{1}{48\pi^2 G^{3/2}}\frac{{B_{\rm ps}}^3}{{\rho_{\rm ps}}^2}$$

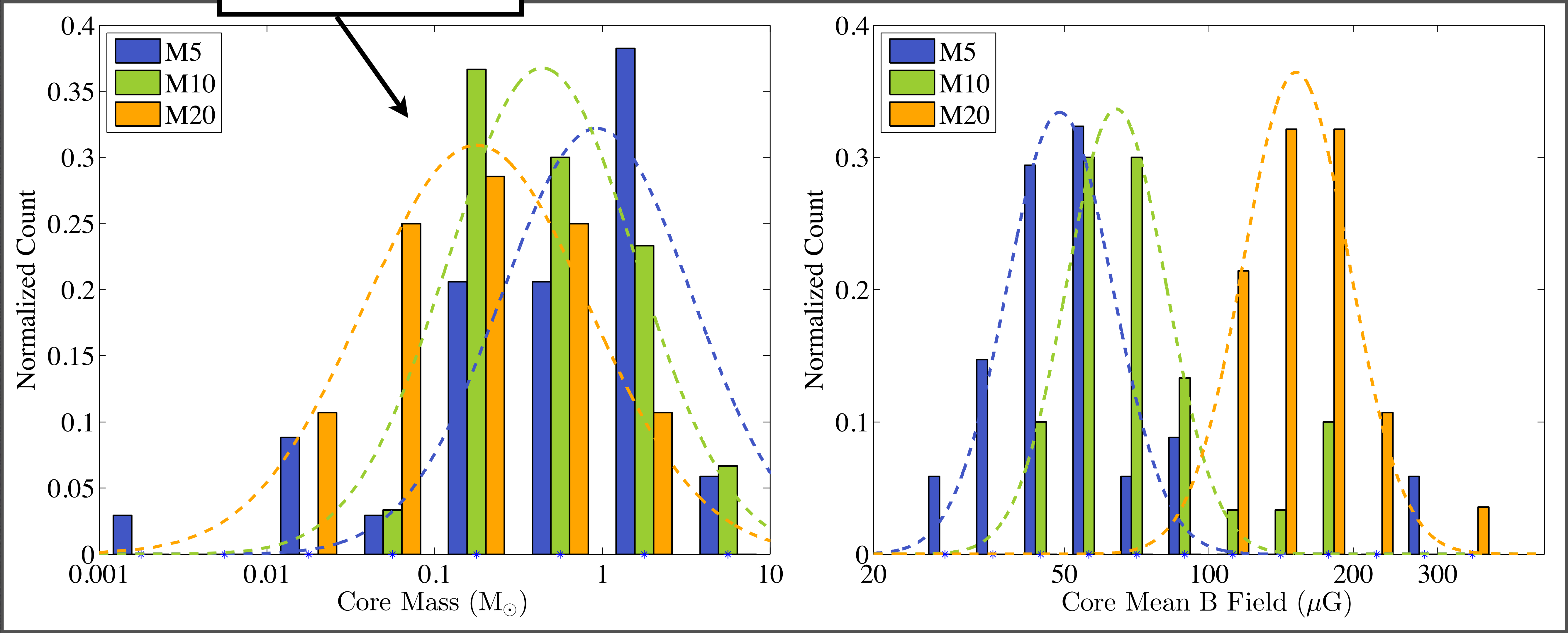
$$= 5.21\ {\rm M}_\odot \left(\frac{B_{\rm ps}}{50\ \mu{\rm G}}\right)^3\left(\frac{n_{\rm ps}}{10^4\ {\rm cm}^{-3}}\right)^{-2}$$

Core Properties

- Core mass varies with inflow Mach number

$M_{\rm core} \propto \mathcal{M}^{-0.9}$

(Chen & Ostriker *in prep.*)



- $B_{\rm core}$ is within a factor of 2 of $B_{\rm post\text{-}shock}$

Summary

- Filament network and core properties found in our simulations are comparable to observations

- Filament transverse velocity gradients provide evidence of condensation in flattened structures

- Magnetically-supercritical, low-mass cores form anisotropically via contraction along $\vec{B}$

- These cores have masses and magnetic fields that depend on pre-shock ρv^2 in cloud