Numerical simulation of filamentary molecular cloud in magnetic field
(磁場に貫かれた フィラメント状分子雲の 安定性)

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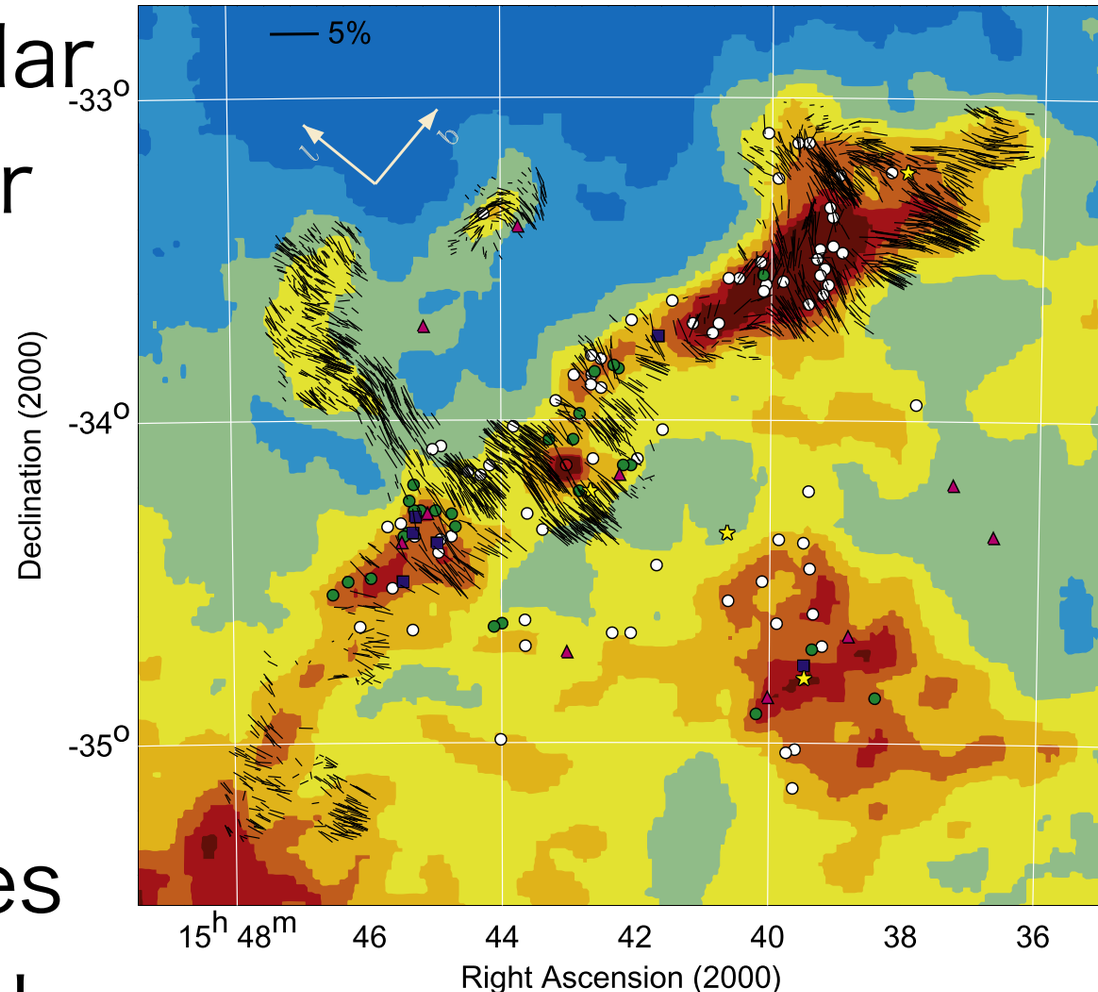
Introduction

- Many molecular clouds show filamentary structures. Interstellar magnetic field are perpendicular to the filamentary axis.

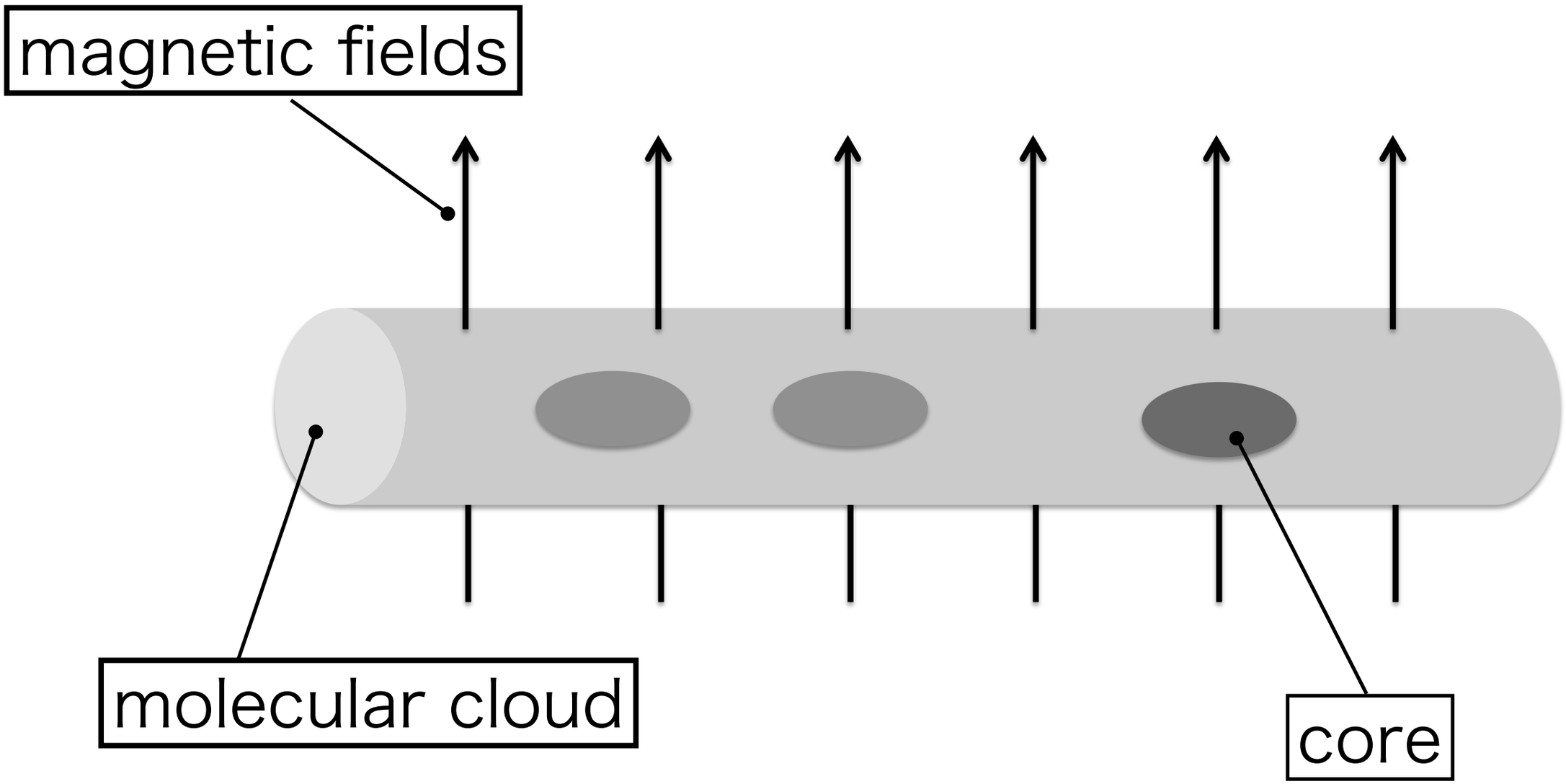
- However, the stability of these clouds are not well known.

- We study the nonlinear stabilities of the clouds by MHD numerical simulation.



black line:
direction of magnetic field

Schematic picture of the filamentary molecular cloud



Method

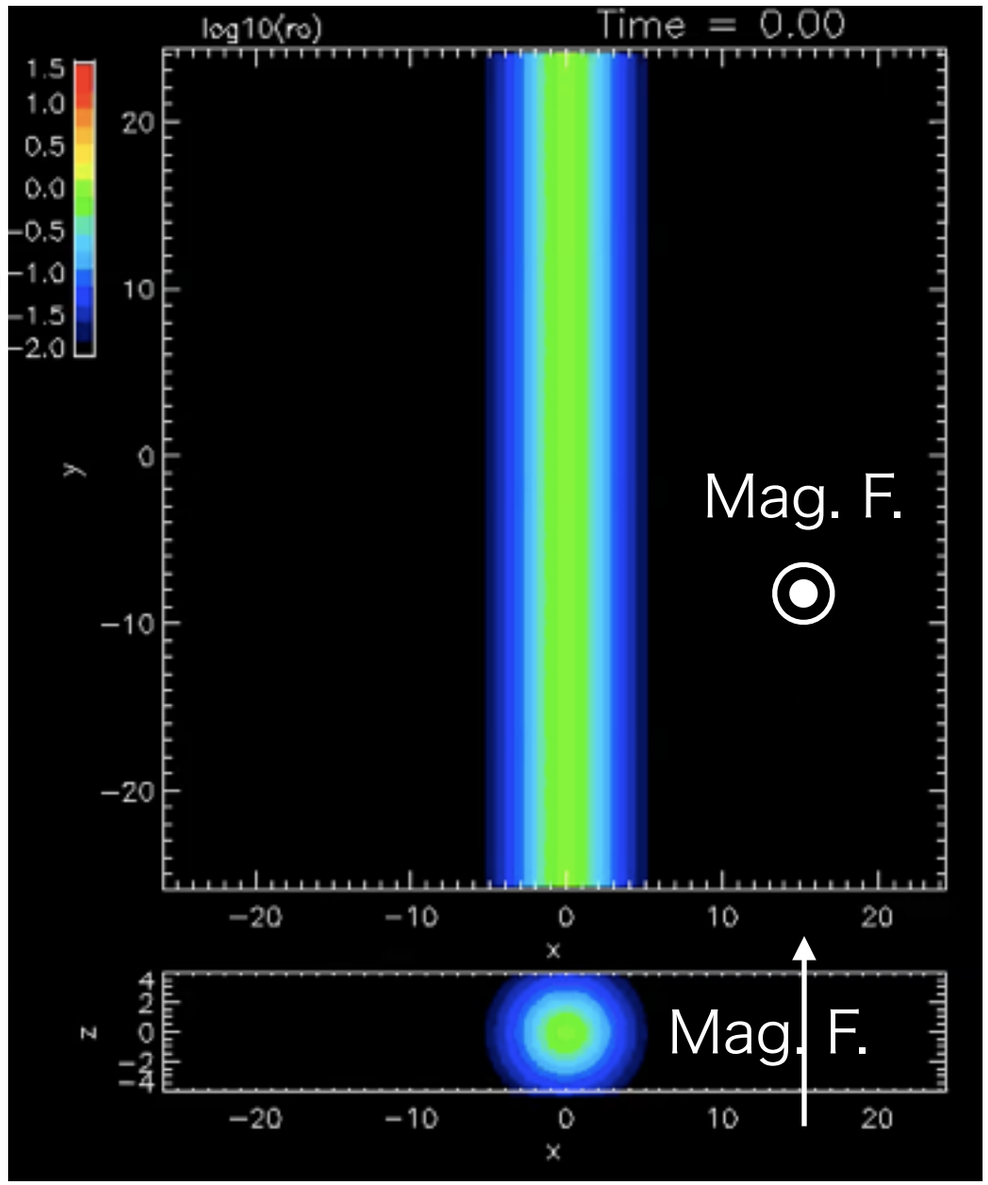
- The initial filamentary cloud is dynamically equilibrium (Stodolkiewicz 1963, Ostriker 1964)

- Magnetic fields are uniform and perpendicular to the filamentary axis.

- Input rondom noise.

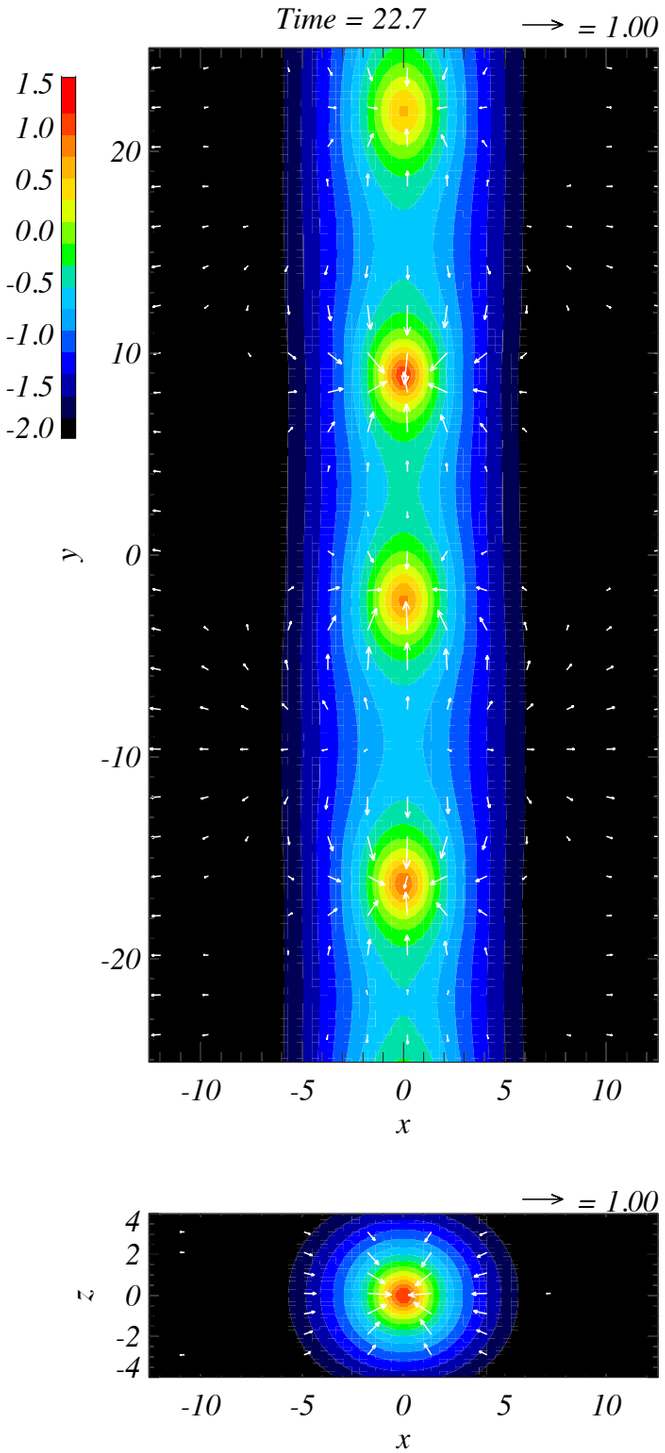
- Ideal MHD, self-gravity, isothermal.

initial setup

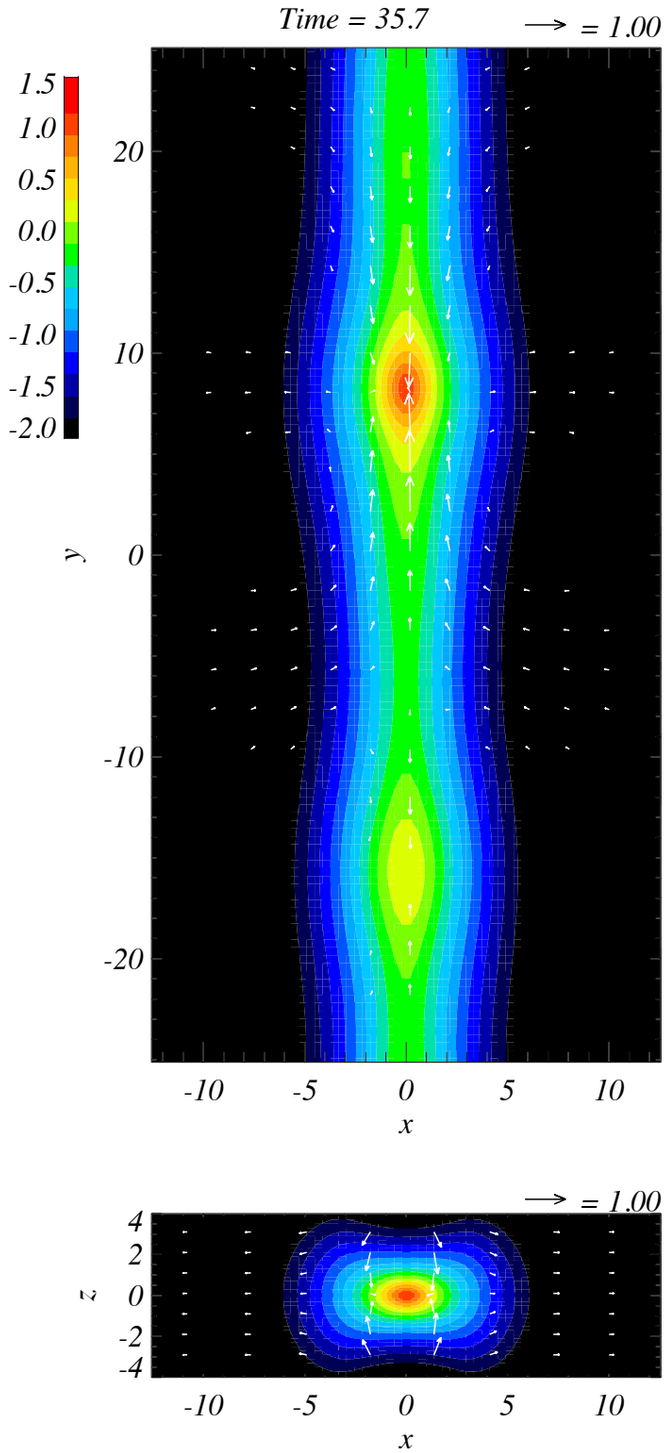


Results

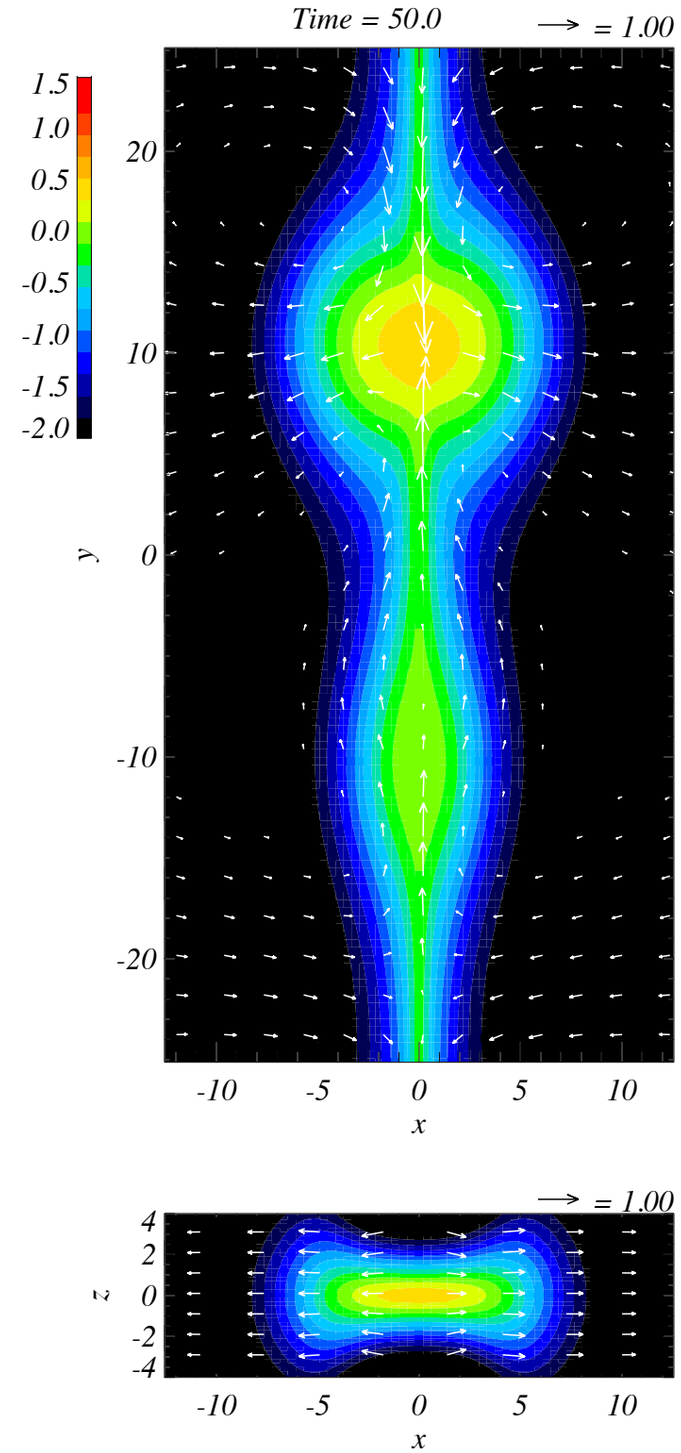
no mag. F



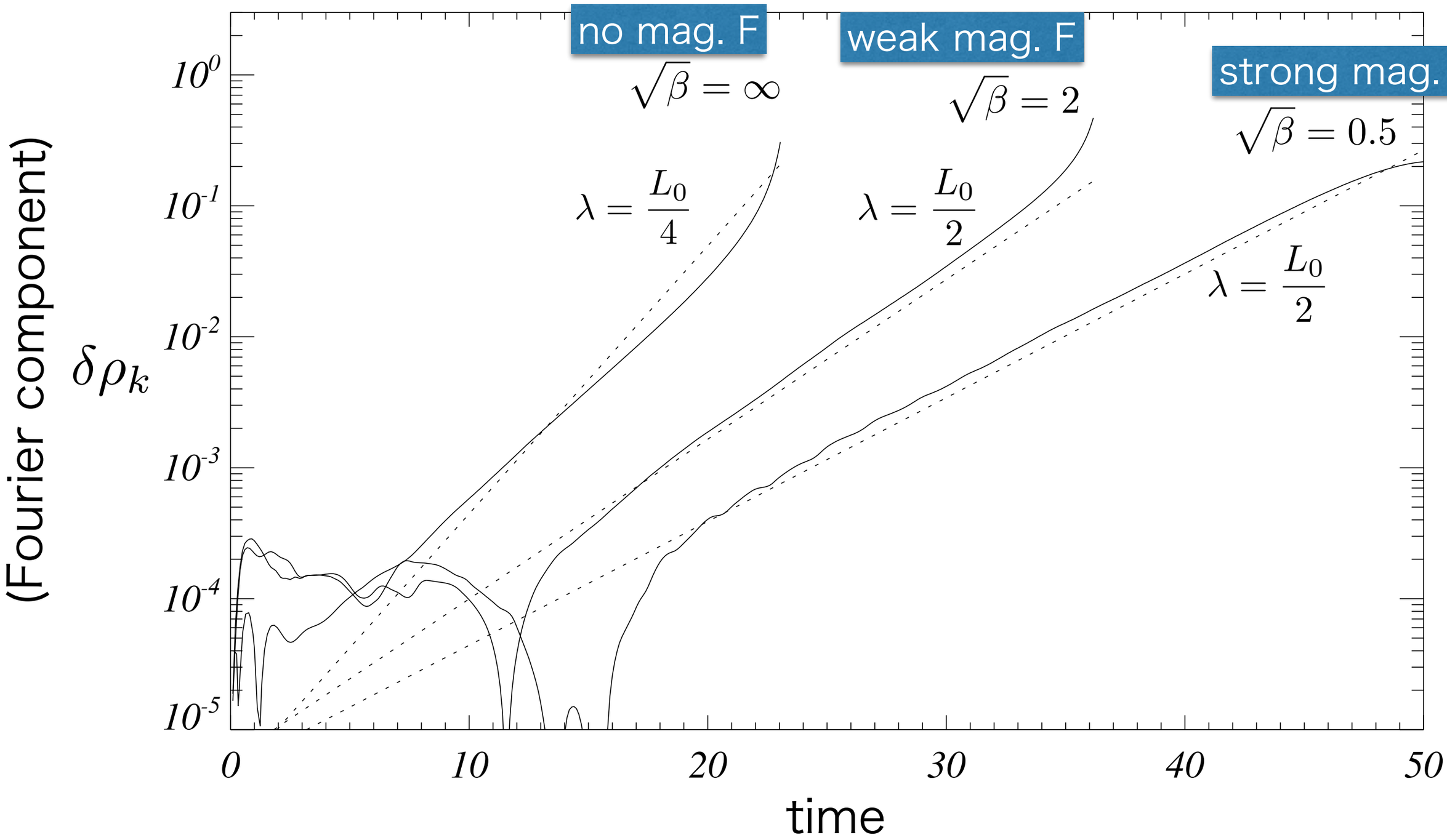
weak mag. F



strong mag. F



Comparison to linear analysis (Hanawa)

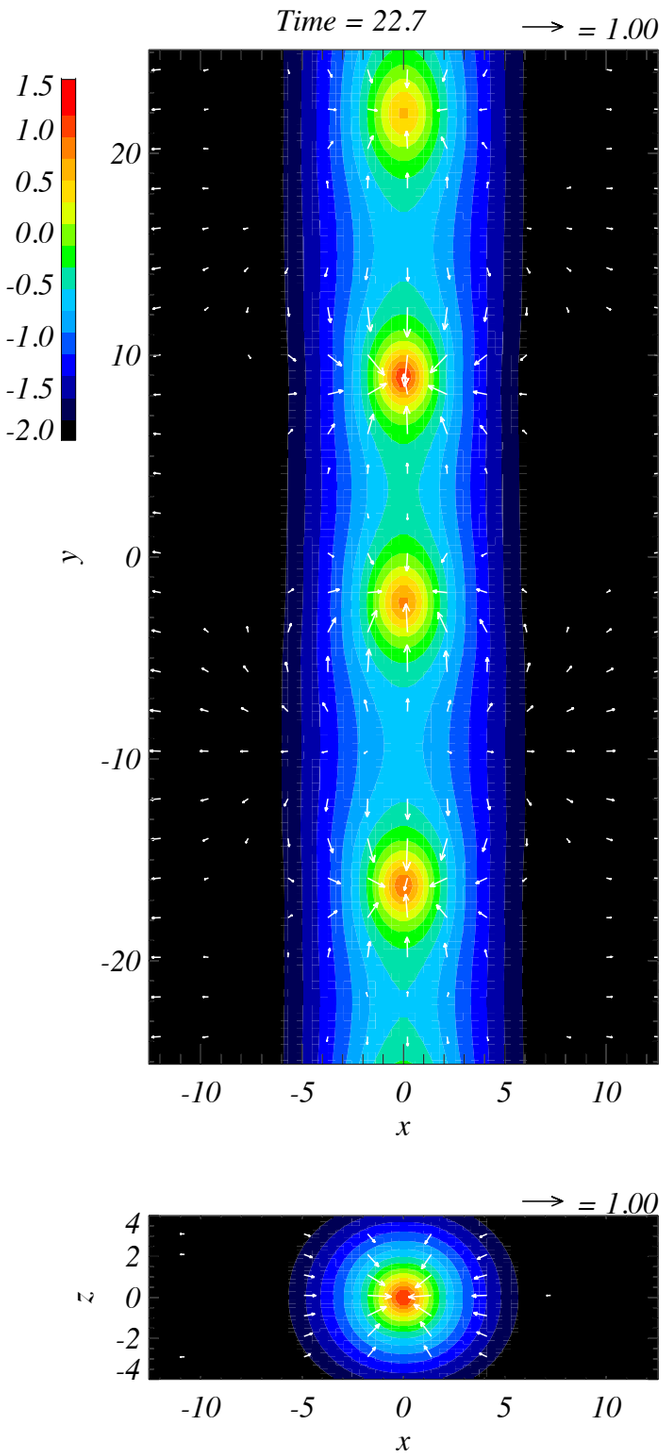


solid lines: numerical simulations
dashed lines: linear analysis

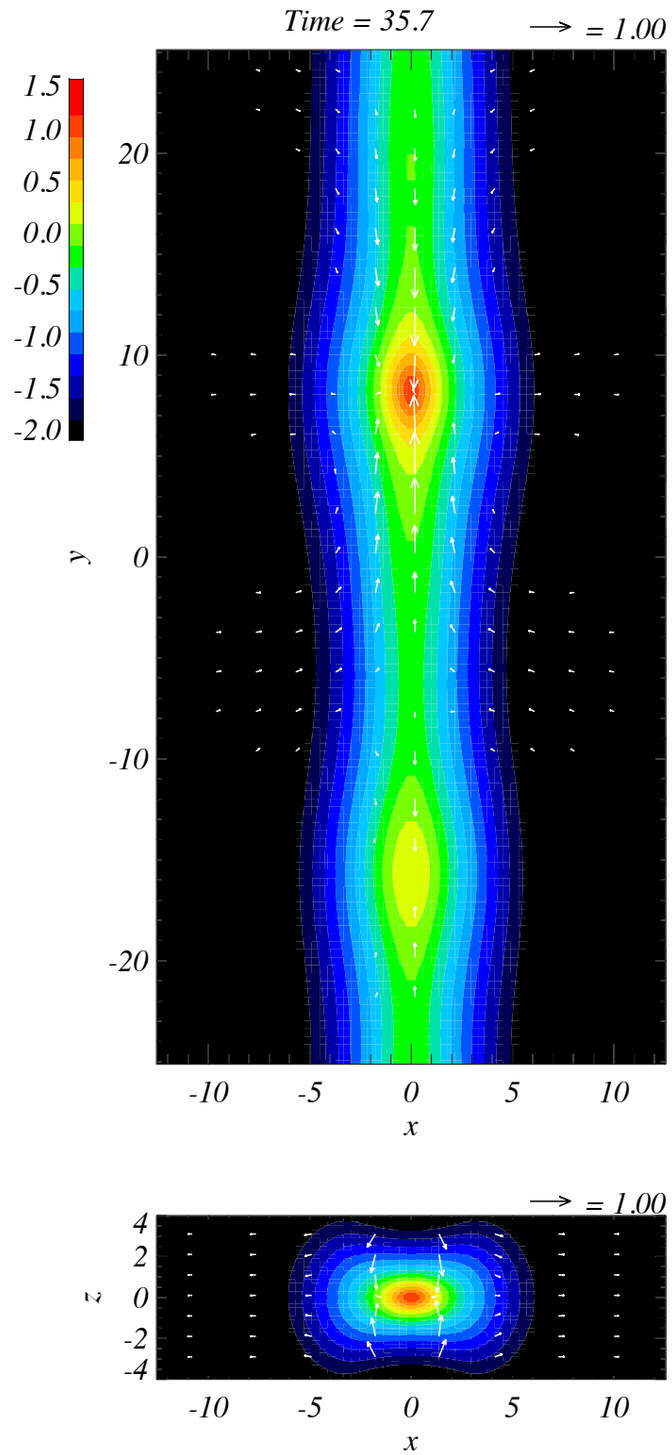
Results : Nonlinear evolution

runaway collapse

no mag. F

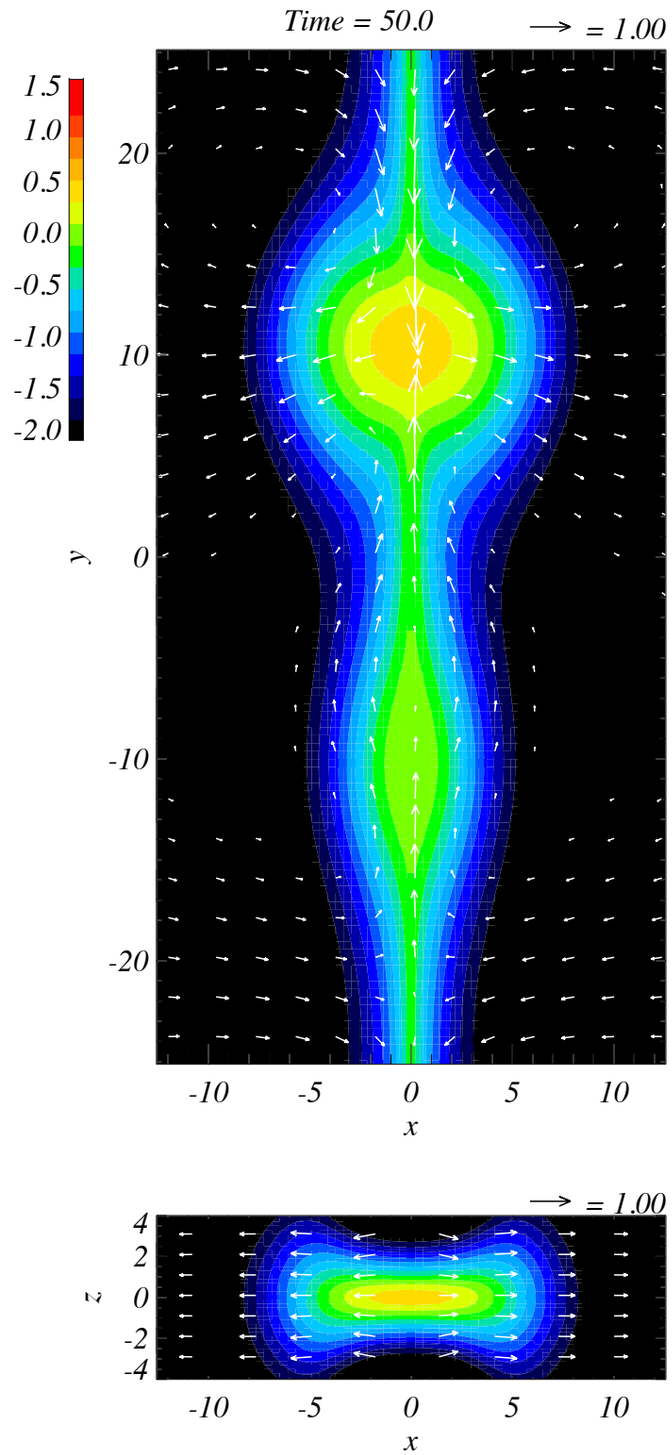


weak mag. F



no runaway collapse

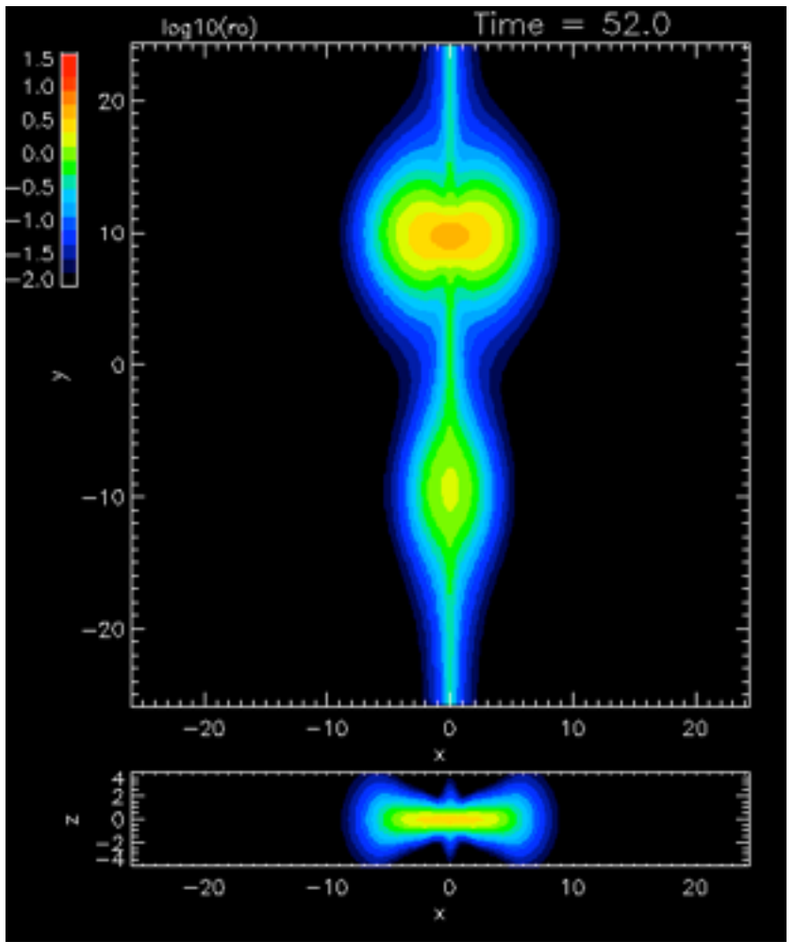
strong mag. F



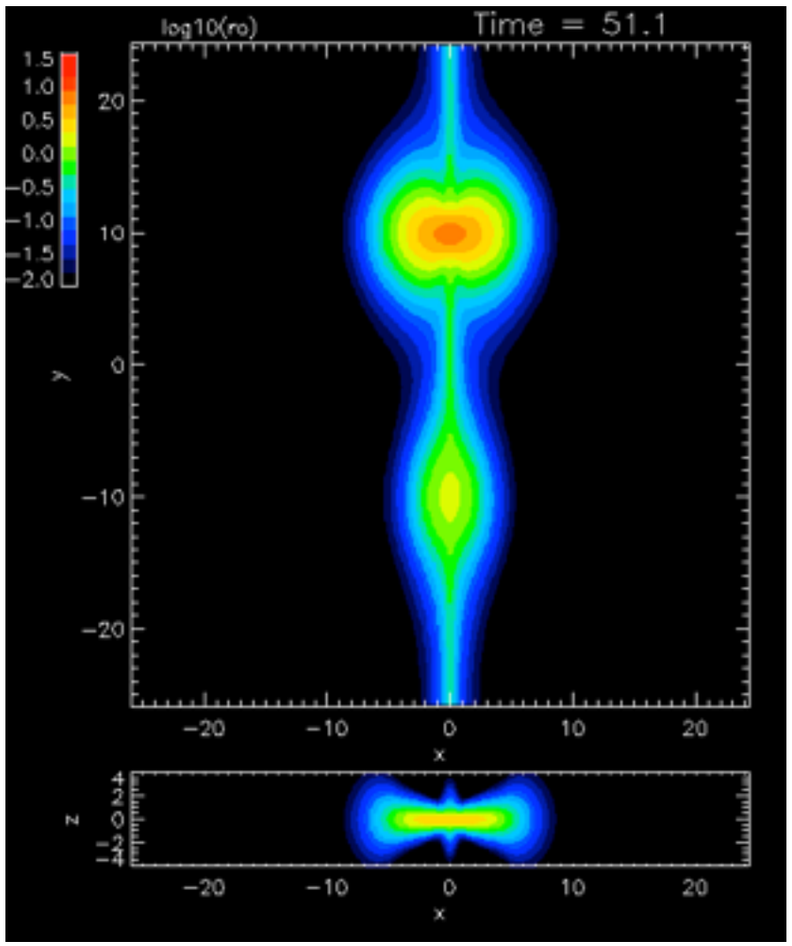
strong magnetic field

initial plasma β on the axis.

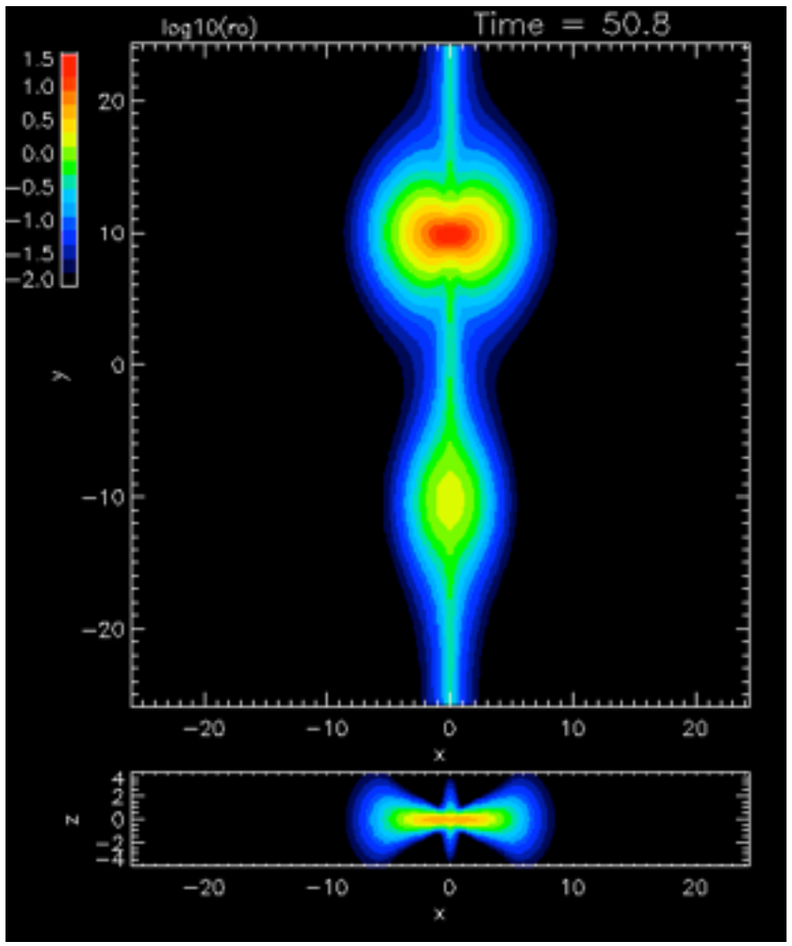
$\beta = 0.36$



$\beta = 0.49$



$\beta = 0.64$



no runaway collapse

runaway collapse

Theoretical estimation

$$B_{\rm cr} \equiv 2\pi\sqrt{G}\Sigma(0)$$

in the case of filaments,

$$\rho(x,y) = \rho_0 \left(1 + \frac{x^2+z^2}{8\pi H^2}\right)^{-2} \qquad \left(H = \frac{c_s}{\sqrt{4\pi G\rho_0}}\right)$$

$$\Sigma(0) = \sqrt{2}\pi\rho_0 H$$

therefore,

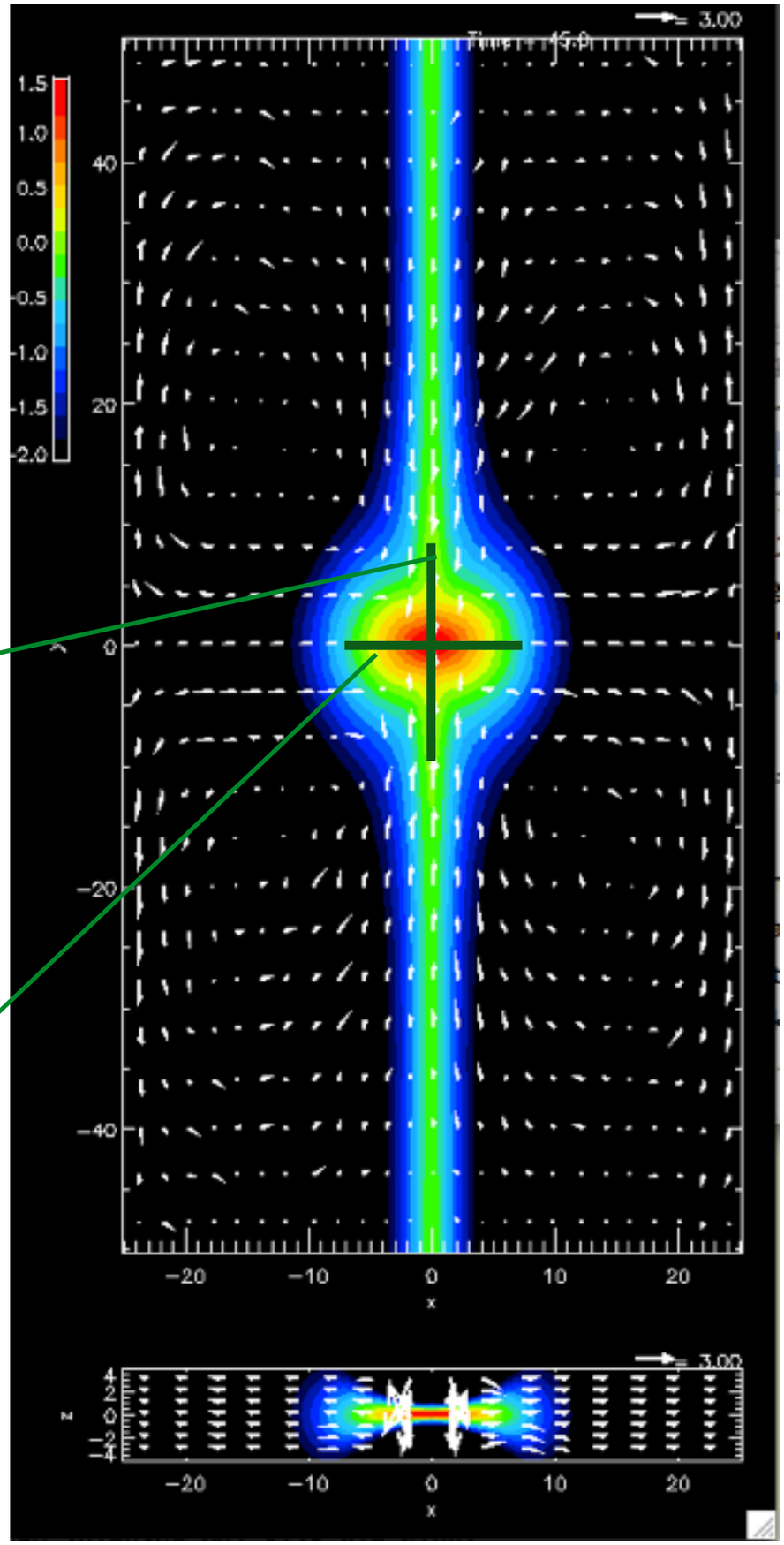
$$B_{\rm cr} = 2\sqrt{2}\pi^2\rho_0\sqrt{G}H$$

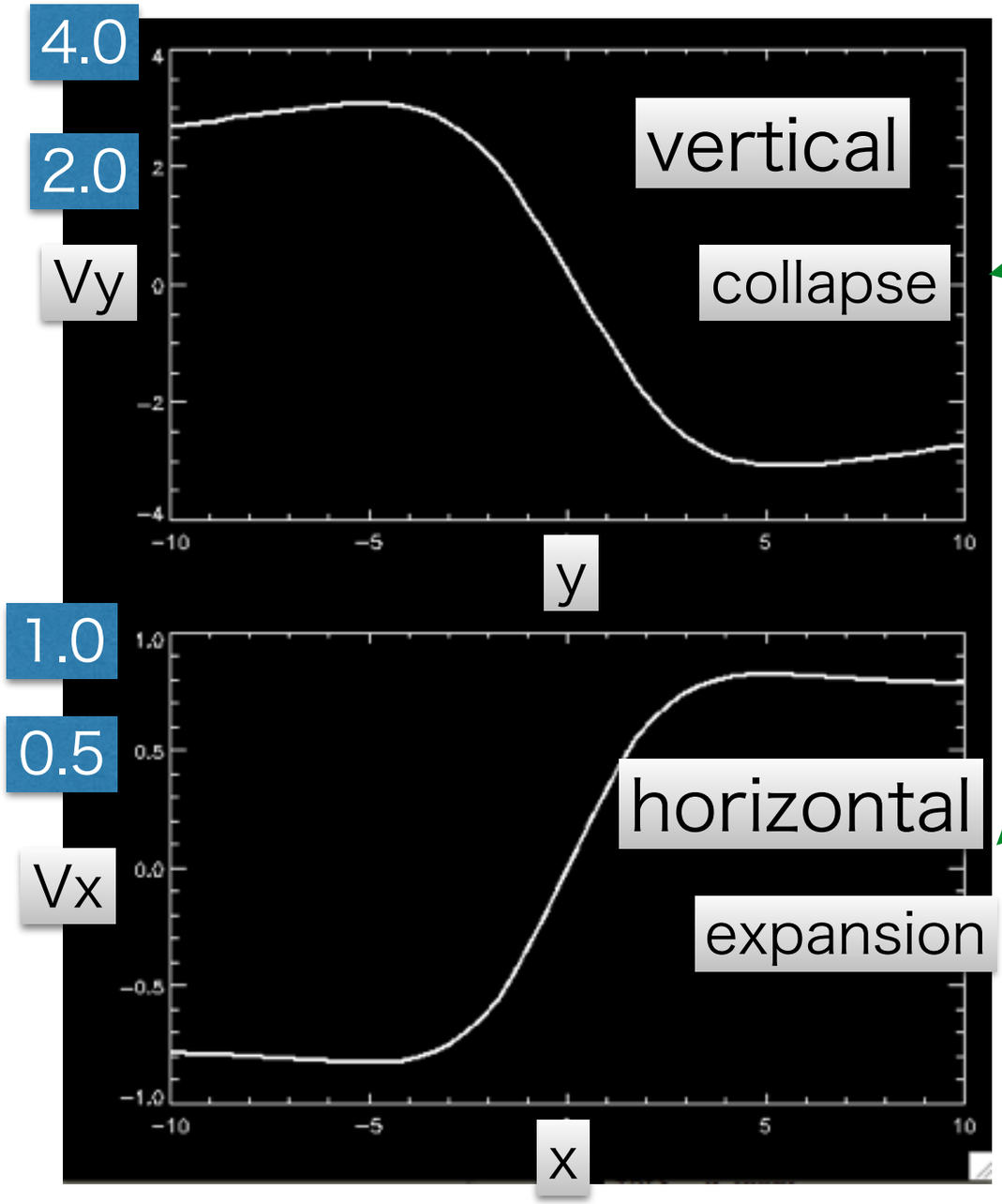
$$\rightarrow \quad \beta_{\rm cr} = \frac{8\pi\rho_0 c_s^2}{B_{\rm cr}} = \frac{4}{\pi^2} \simeq 0.405$$

$$\beta = 0.49$$

sinusoidal long wave perturb.

runaway collapse near critical





Summary

- Magnetic fields do not stabilize the self-gravitational instability of filamentary molecular clouds.

- When the magnetic field is not strong, the core shows runaway collapse. When the magnetic field is strong enough, the starless core is formed.

- Near the critical magnetic field, the core collapses along the filamentary axis but expands to the perpendicular direction.