Nov. 18, 2005: MHD workshop (Chiba Univ.)

3D MHD simulation of cloud fragmentation

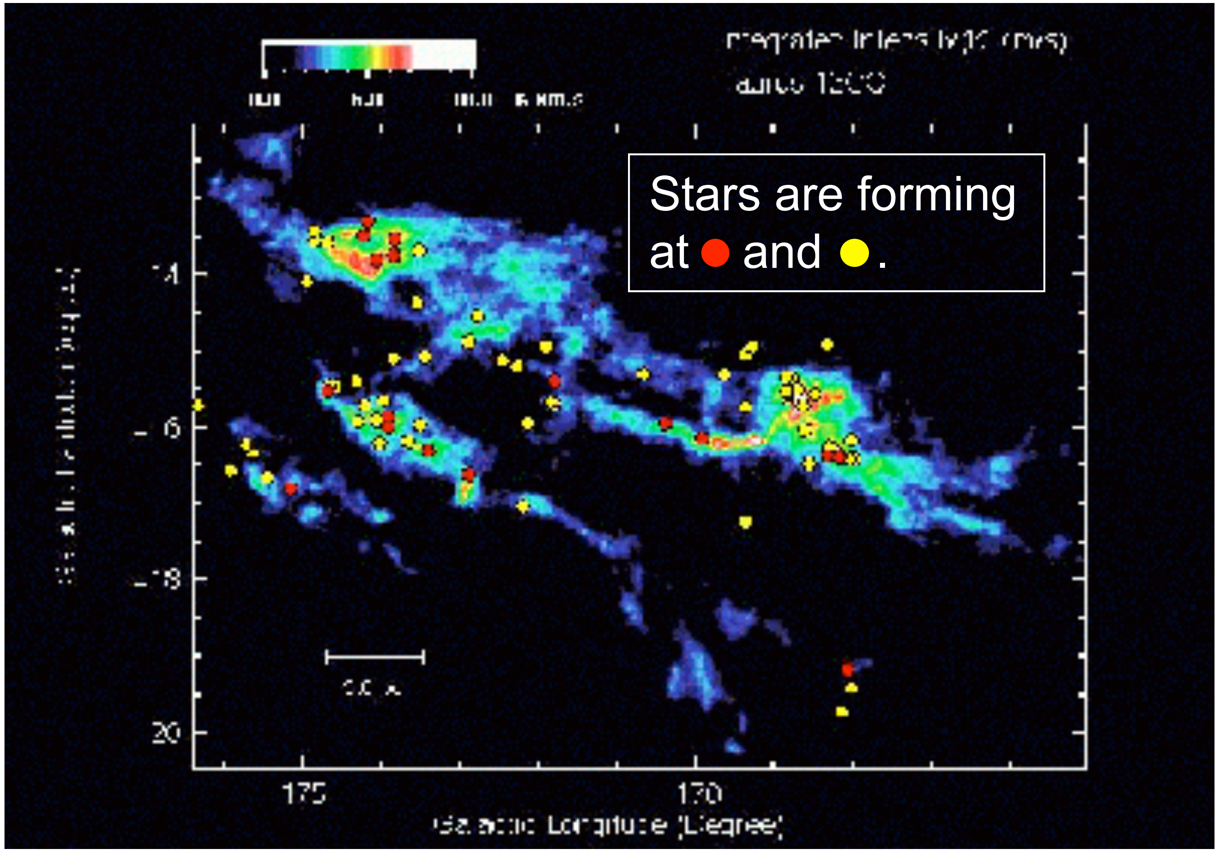
(a short comment)

Takahiro Kudoh (NAOJ)

Collaborators: **Shantanu Basu (UWO), Yoichi Ogata (TIT), Takashi Yabe (TIT)**

Interstellar molecular clouds are the sites of star formation.

Taurus (Nagoya 4m) radio (^{13}CO)



~10pc

A simple model: They are self-gravitating gas clouds with magnetic field and turbulence.

Cloud contraction with magnetic field

There is an evidence of large-scale magnetic fields in the cloud.

Magnetic force prevent the gas moving across the magnetic field.

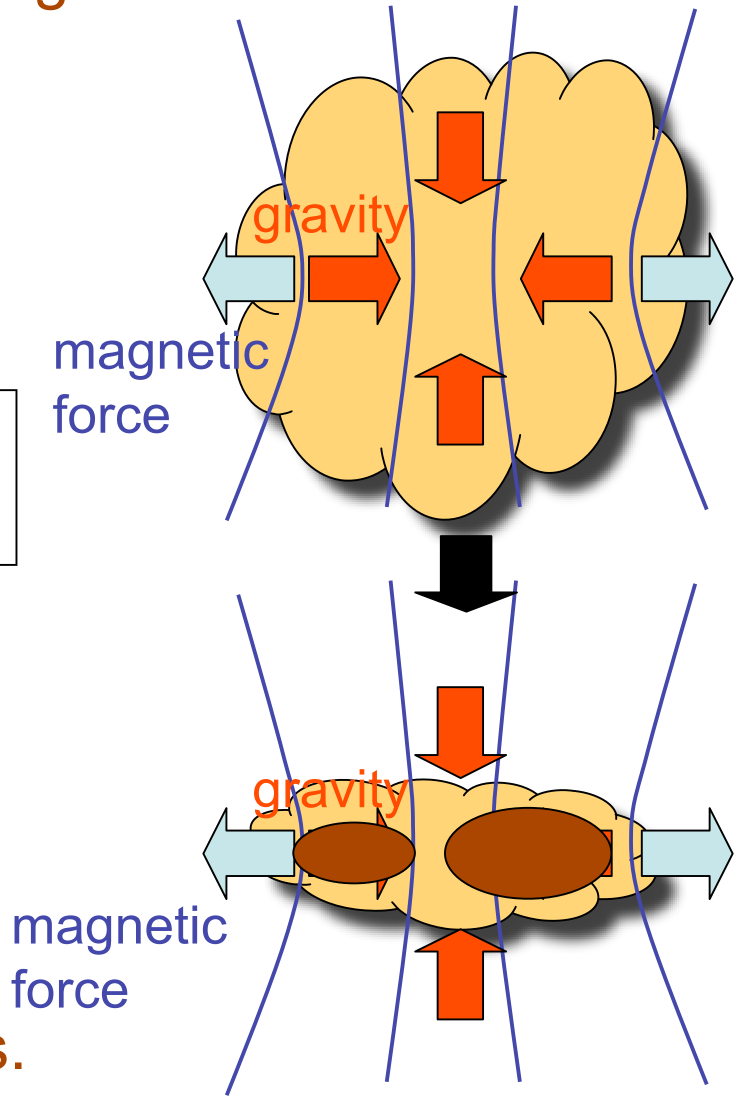
↓

The cloud is expected to be flat perpendicular to the magnetic field.

↓

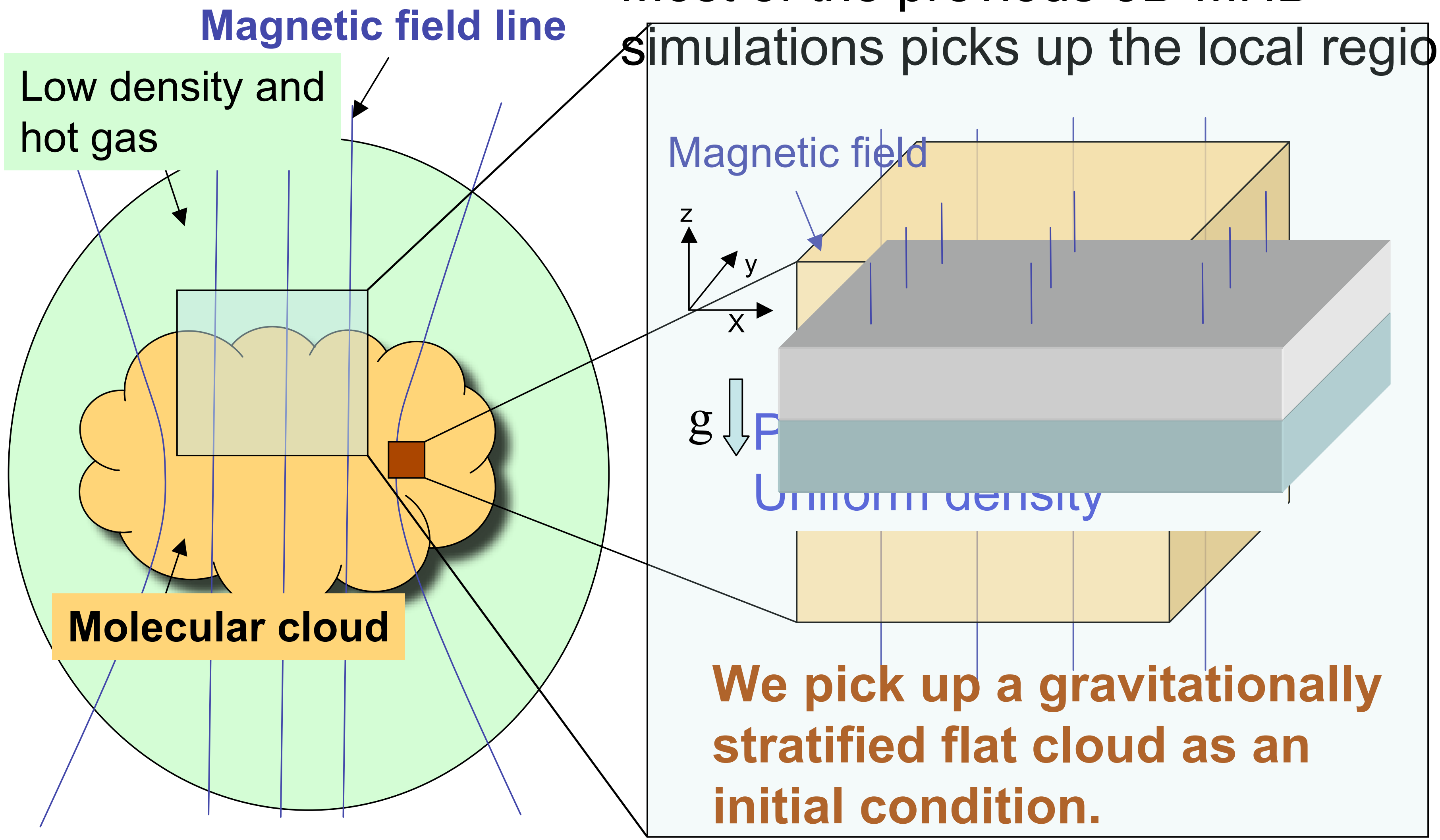
The flat cloud is fragmented and cores are formed in the cloud.

We are going to study this process.



Model: Gravitationally Stratified Cloud

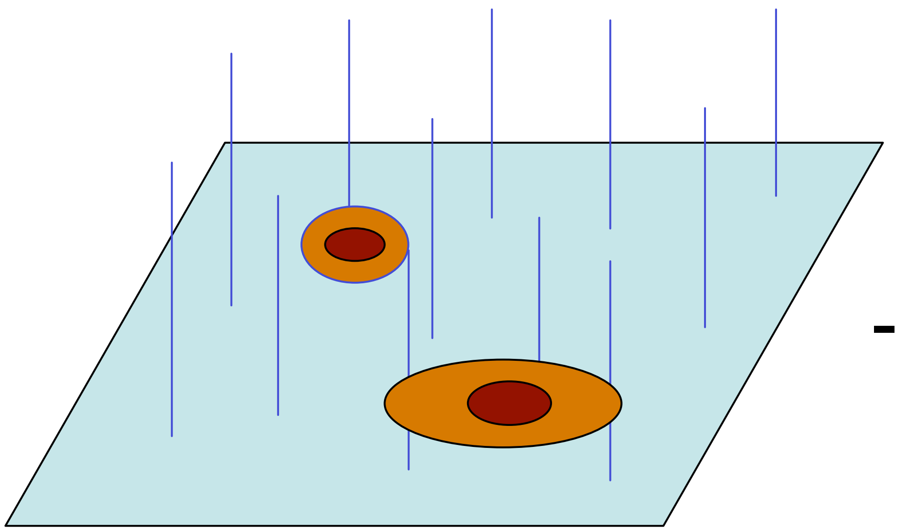
Most of the previous 3D MHD simulations picks up the local region.



We pick up a gravitationally stratified flat cloud as an initial condition.

Gravitational instability of plate-shaped gas.

Nakano & Nakamura 1978



- Weak magnetic field

$$E_{\mathrm{mag}} < E_{\mathrm{grav}} \quad \text{(supercritical)}$$

→ gravitationally unstable

$$\lambda_{\text{most unstable}} \approx 4\pi H \quad (B \approx 0)$$

- Strong magnetic field

$$E_{\mathrm{mag}} > E_{\mathrm{grav}} \quad \text{(subcritical)}$$

→ gravitationally stable

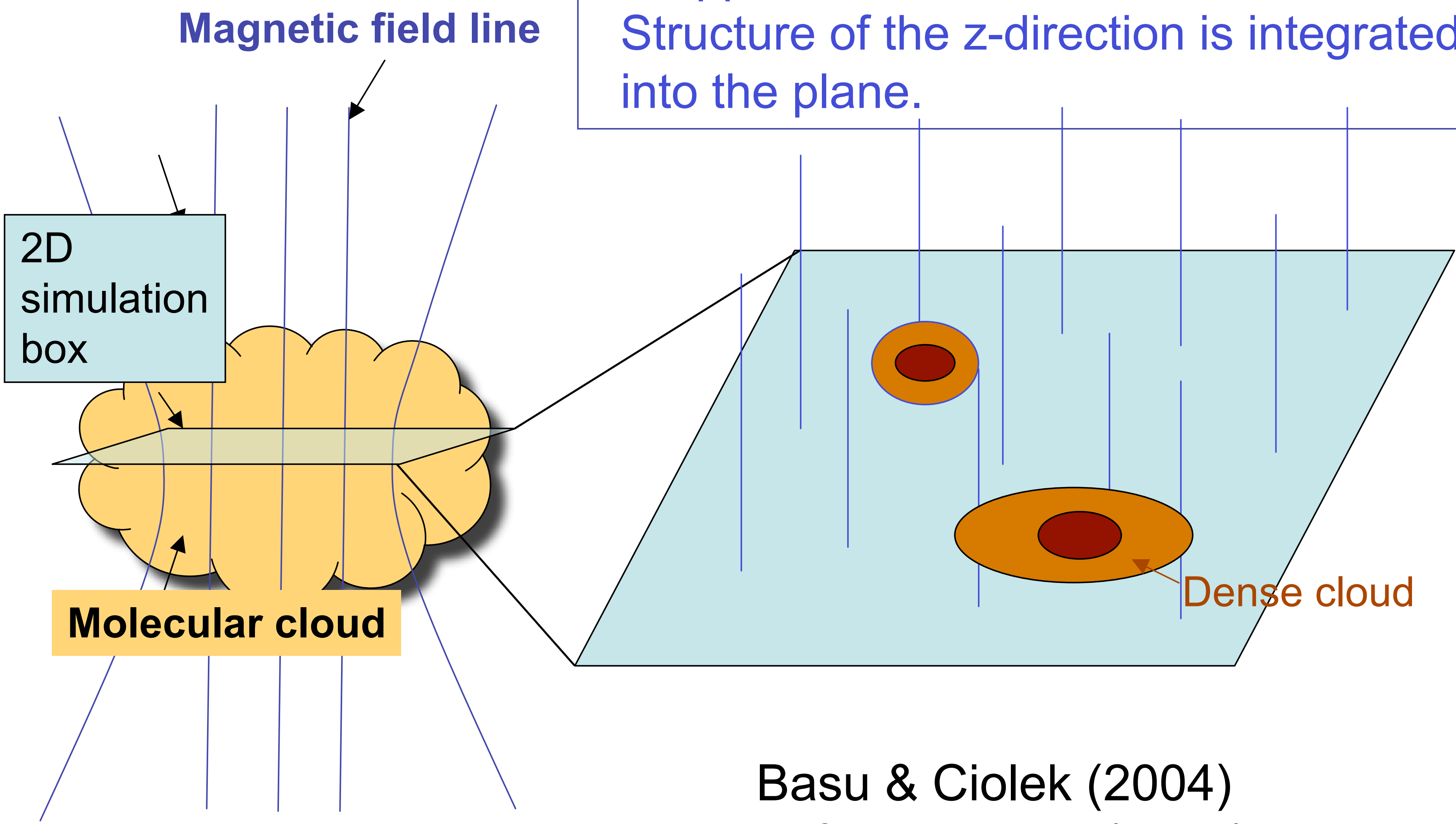
ambipolar diffusion (magnetic diffusion)

→ gravitationally unstable

(Mouschovias 1978)

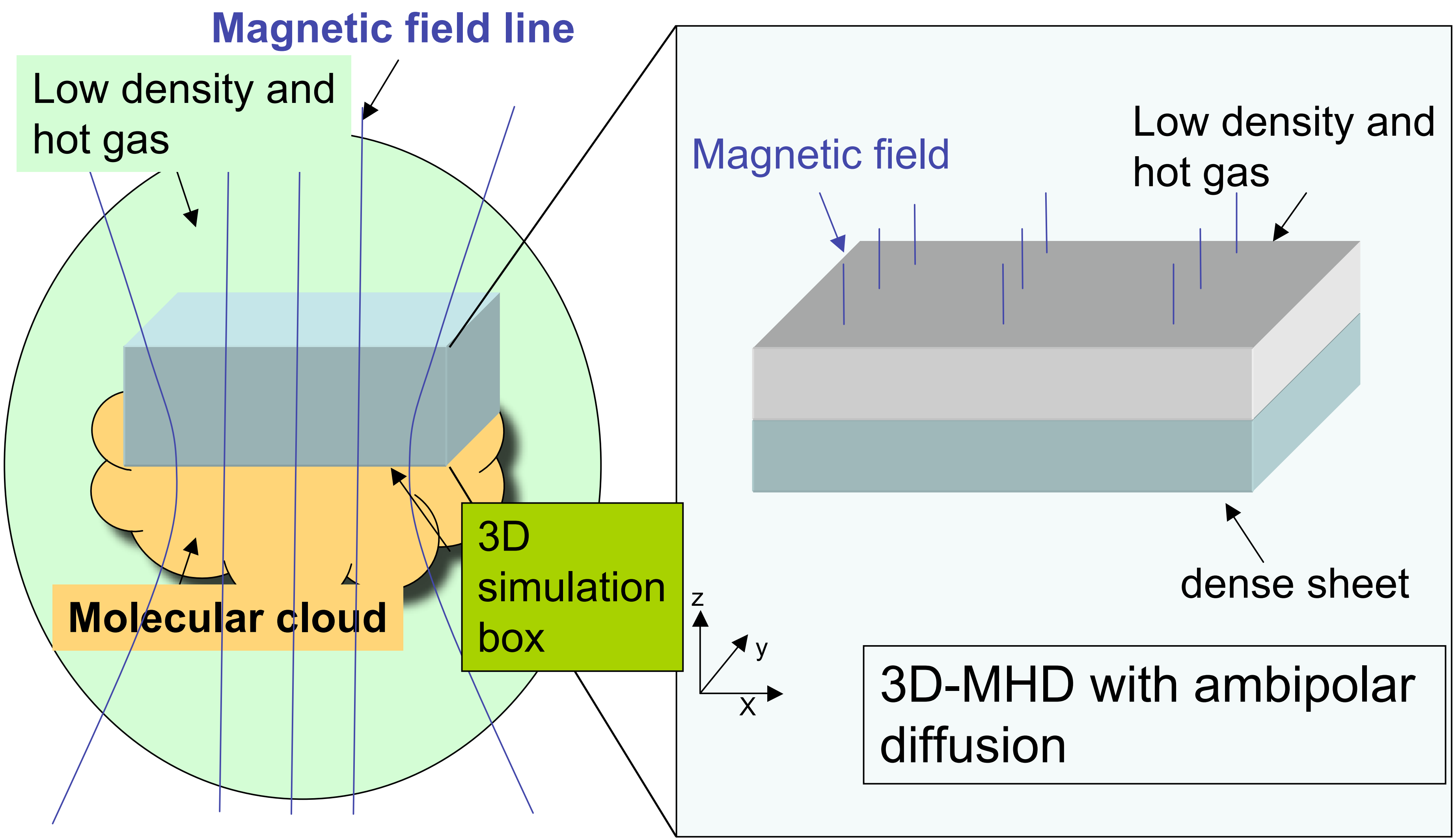
2D-MHD simulation with ambipolar diffusion

2D approximation :
Structure of the z-direction is integrated into the plane.



Basu & Ciolek (2004)
Li & Nakamura (2004)

3D-MHD simulation with ambipolar diffusion (this study)

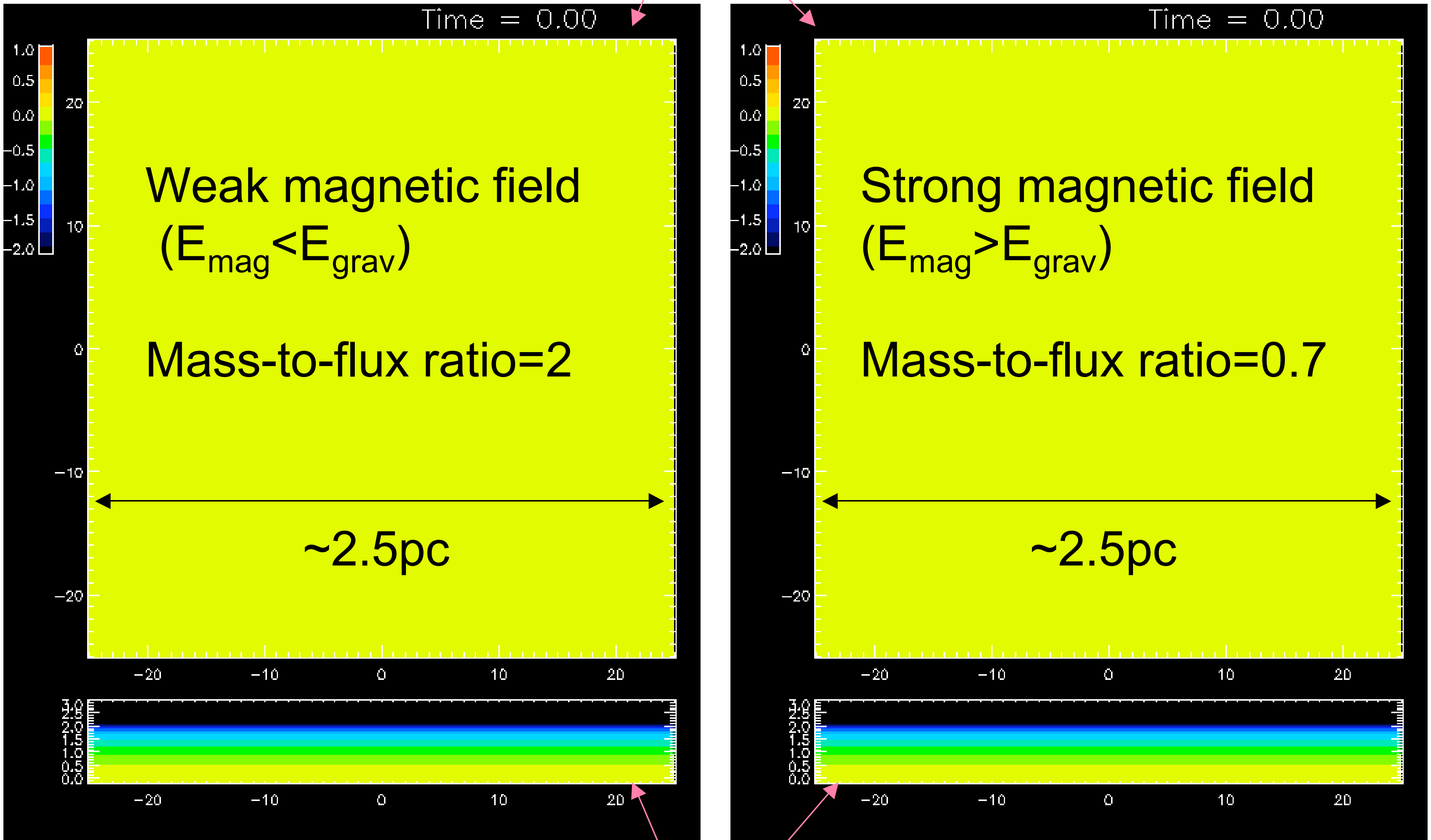


Isothermal

We input large random perturbation (V_{max}=10C_s) perpendicular to magnetic field at *t=0.*

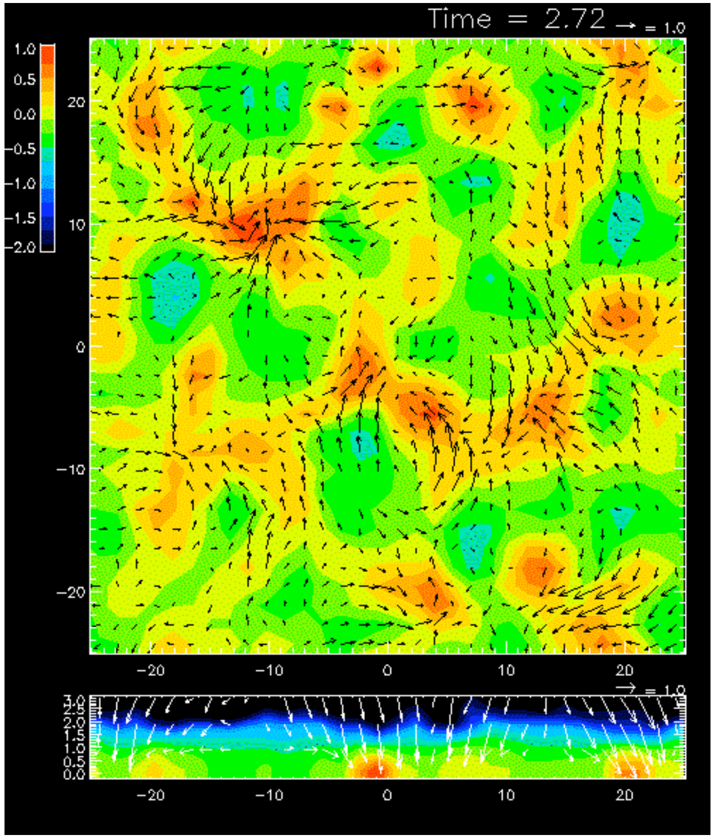
Density

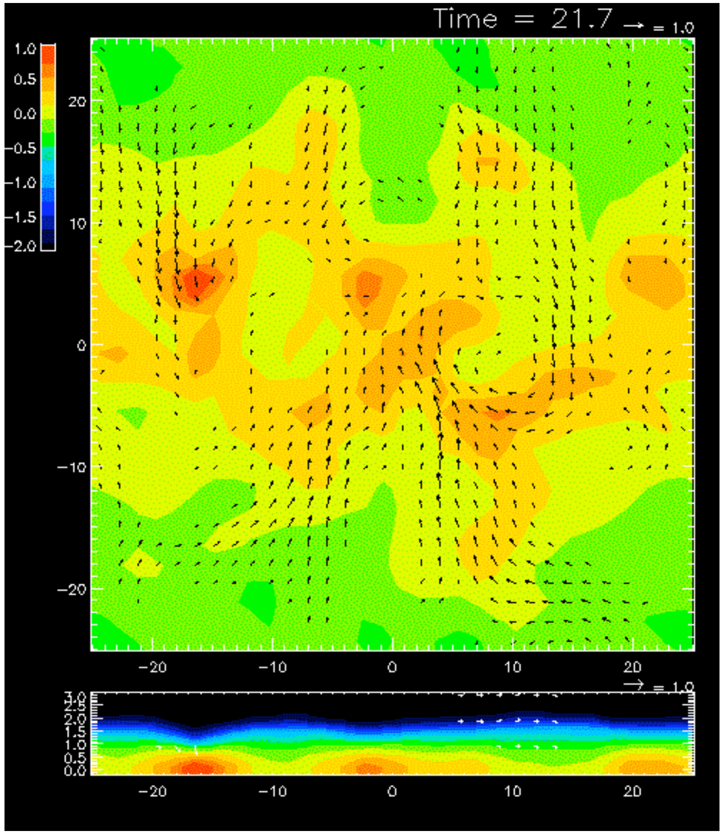
top view slice



side view slice

Weak magnetic field ($E_{mag}<E_{grav}$) Strong magnetic field ($E_{mag}>E_{grav}$)





- Fast gravitational collapse ~ 7 x10^5 year
- Infall velocity is nearly super-sonic.
- V_z is also nearly supersonic.

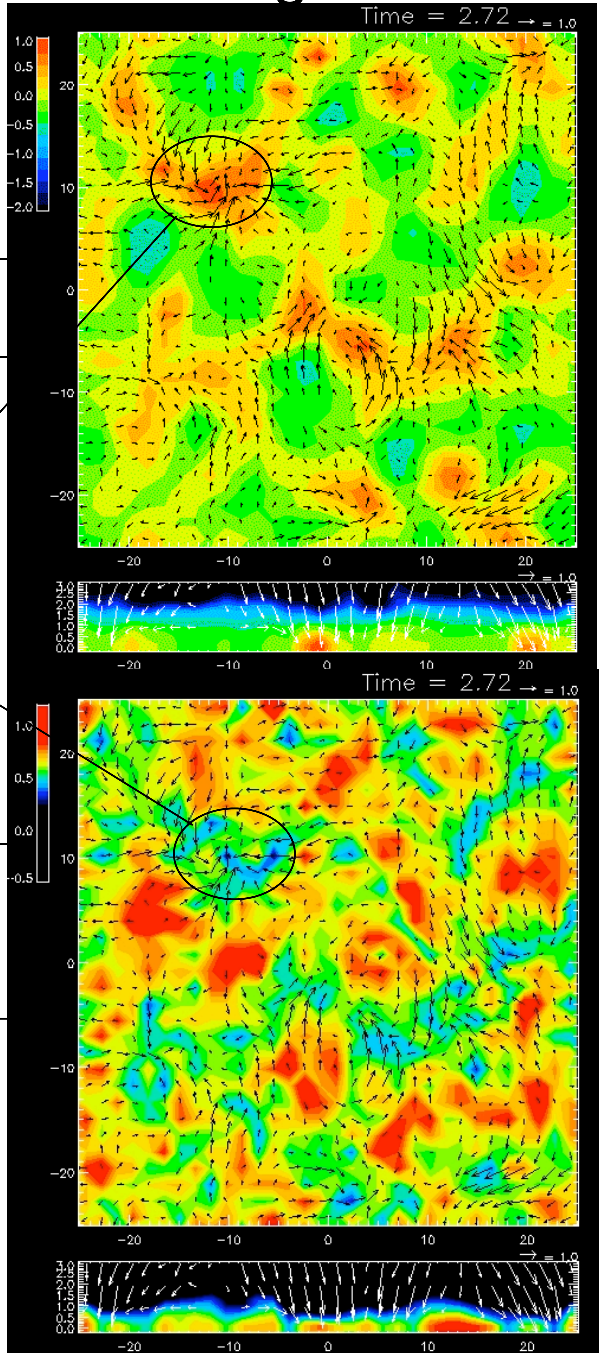
- Slow gravitational collapse ~ 5 x10^6 year
- Infall velocity is subsonic.
- V_z is also subsonic.

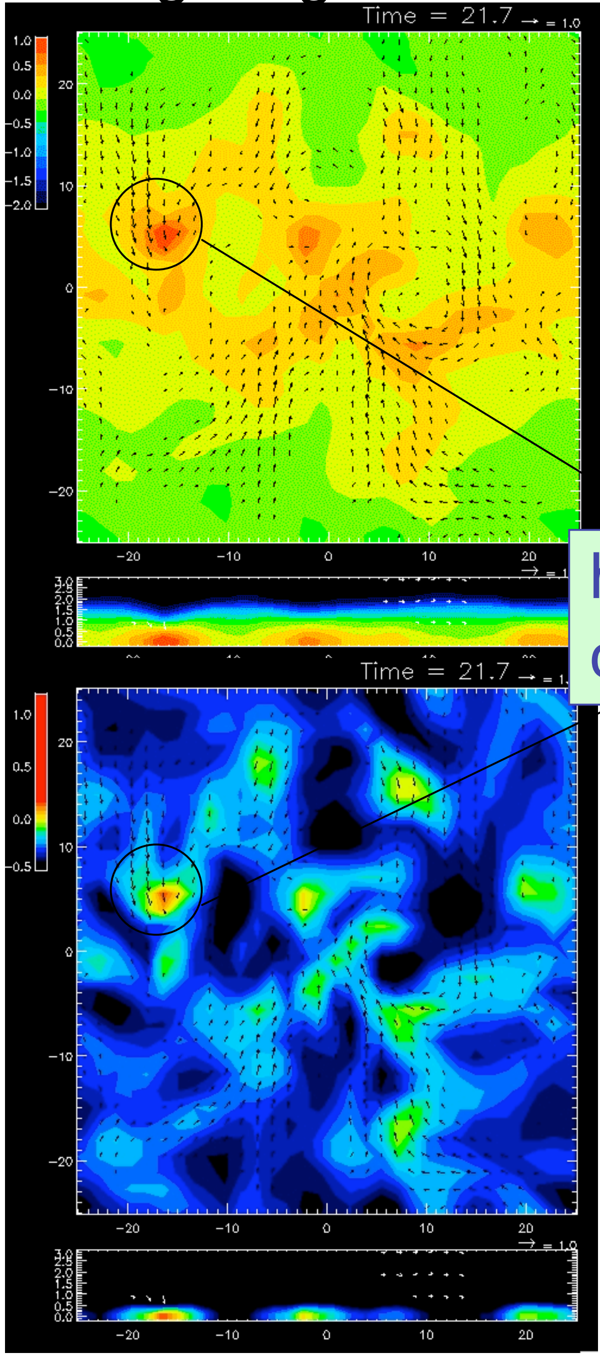
Magnetic flux

Weak magnetic field

Strong magnetic field

density





lower β core

$B \propto \rho^{0.6}$

higher β core

$B \propto \rho^{0.3}$

plasma β
=P_{gas}/P_{mag}

$B \propto \rho^{0.5}$
→ β const

Summary

- Time scale of the gravitational collapse

  Fast collapse ~ 7 x10^5 year : E_{mag}<E_{grav} (supercritical)

  Slow collapse ~ 5 x10^6 year : E_{mag}>E_{grav} (subcritical)

- Infall velocity

  supersonic: E_{mag}<E_{grav} (supercritical)

  subsonic: E_{mag}>E_{grav} (subcritical)

- Magnetic flux

  $B \propto \rho^{0.6}$(lower beta cores): E_{mag}<E_{grav} (supercritical)

  $B \propto \rho^{0.3}$(higher beta cores): E_{mag}>E_{grav} (subcritical)