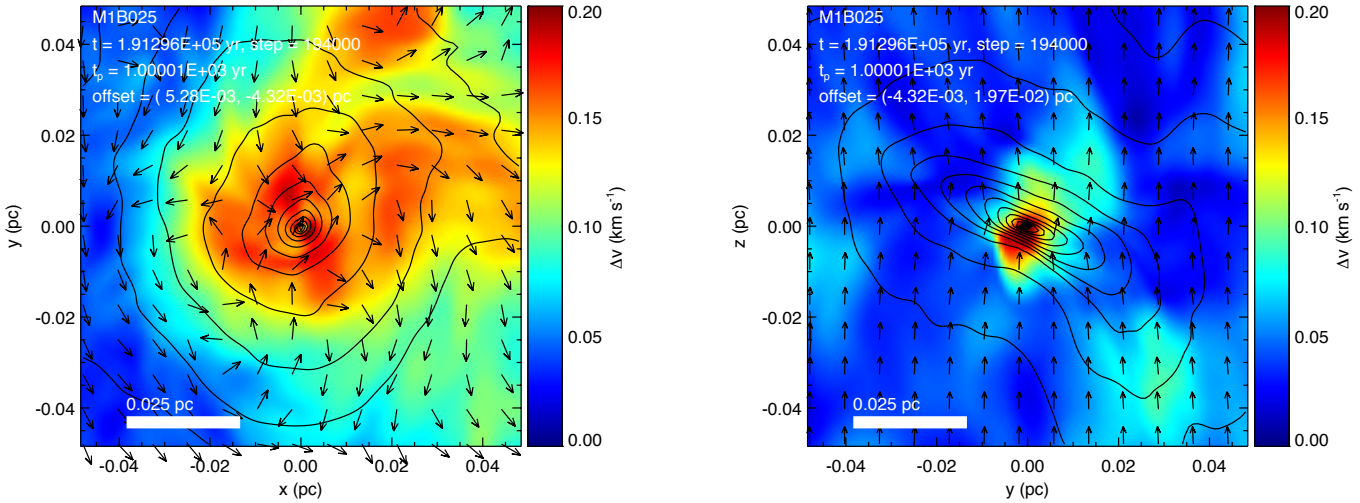
Reference Matsumoto+ 17 ApJ

磁場と乱流を考慮した分子雲コアから原始星・星周円盤・アウトフローの形成

Tomoaki Matsumoto (Hosei univ)
Masahiro Machida (Kyushu univ),
Shu-ichiro, Inutsuka (Nagoya univ)

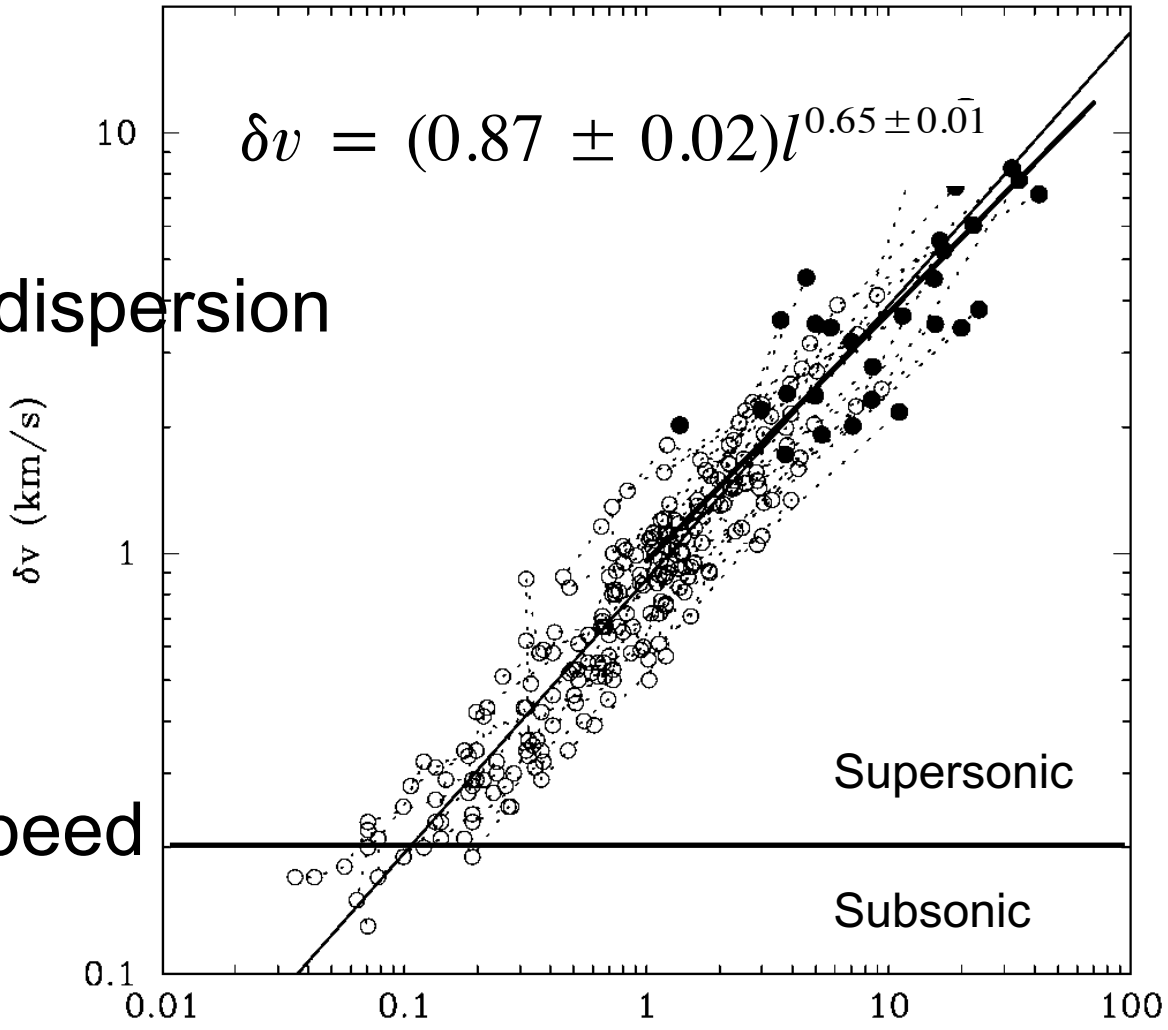
MHD turbulent simulation



Turbulence and magnetic field in SF

- Strong turbulence in ISM.
  - Size-linewidth relation (e.g., Larson 81)
- Strong magnetic field in ISM
  - Mass-to-flux ratio is roughly critical value.

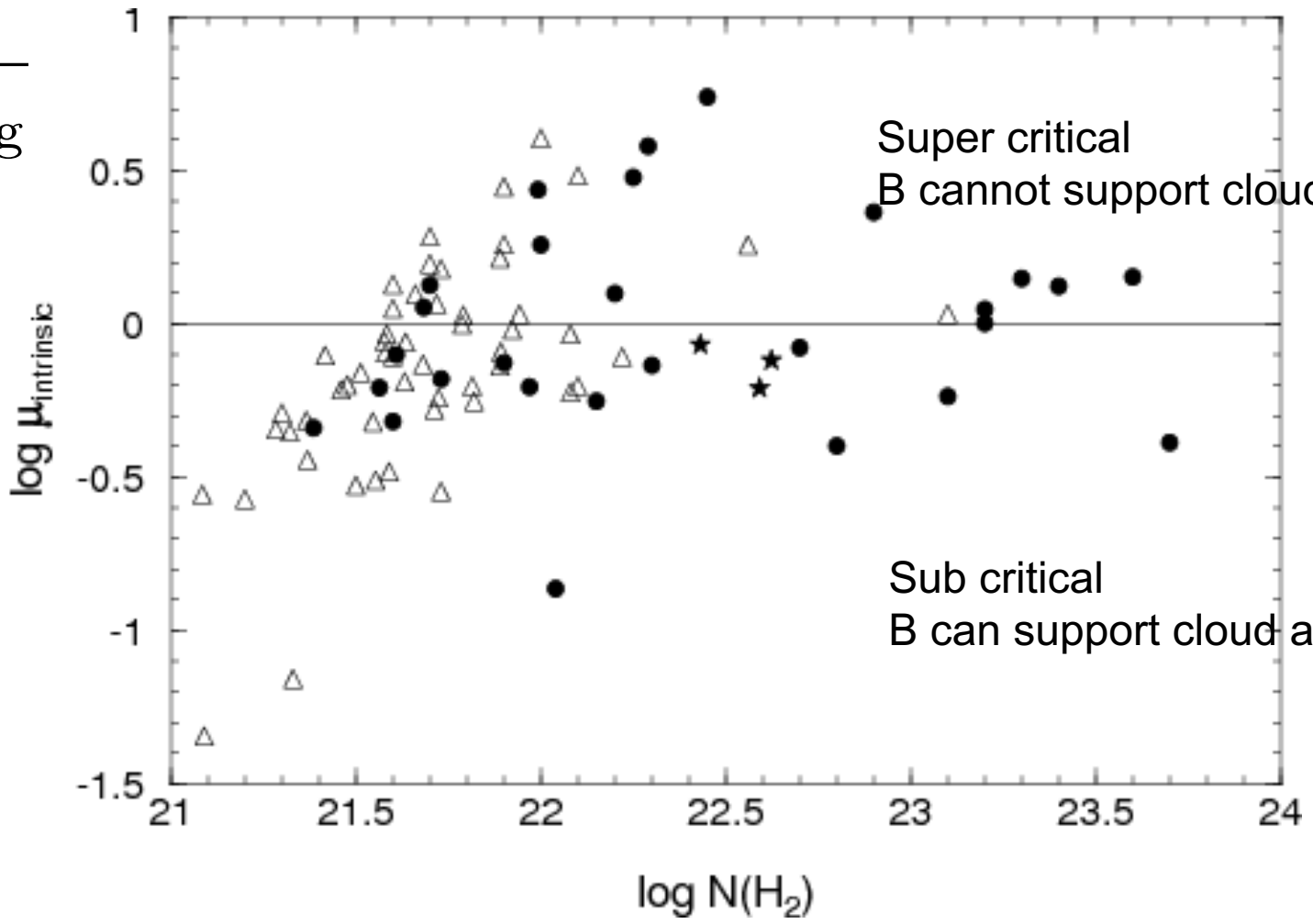
Size-linewidth relation



Heyer+04
c.f., Larson 81

Strong magnetic field
Supercritical vs subcritical

$$\frac{M}{\Phi_{\mathrm{mag}}}$$



Heiles & Crutcher 05

Model

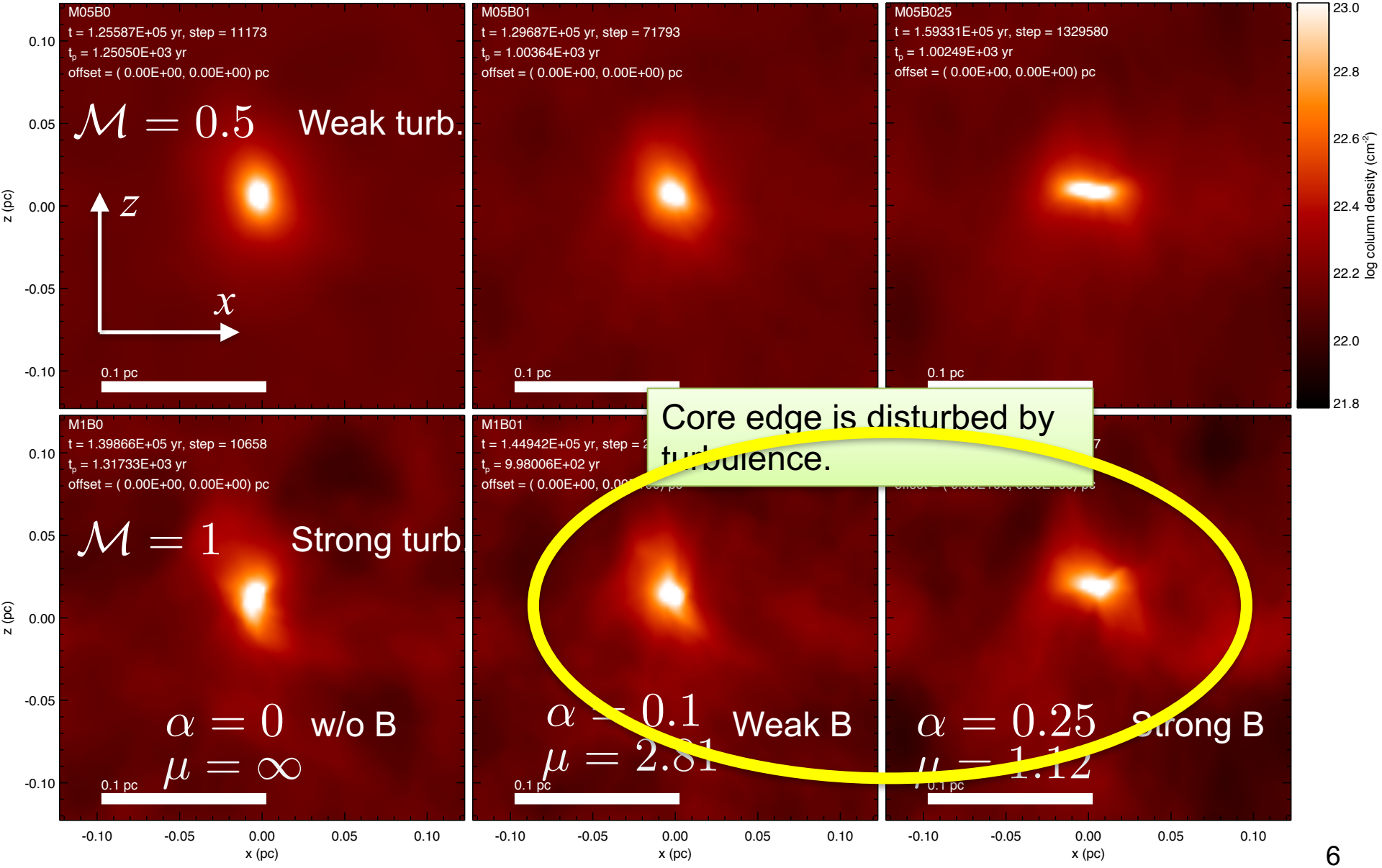
- Initial condition
  - Critical Bonner-Ebert sphere＋uniform envelope
    - Critical BE x 2 to be unstable against gravitational collapse
  - Turbulence $R_c = 0.06$ pc
    - Uniform turbulence with scaling law of Larson (1981)
    - Mean Mach number $\mathcal{M} = \frac{1}{c_s V}\int_V |\boldsymbol{v}| dV$
  - Magnetic field
    - Uniform B_z
    - The strength（$B_z/B_{\rm cr}$） $\alpha = \frac{B_z}{B_{\rm cr}}$
  - Model parameters $\mathcal{M}, \alpha$
    - Turbulence（Mach 0.5, Mach 1）, B-field (25μG, 64μG)

$\mu = 2.81, 1.12$

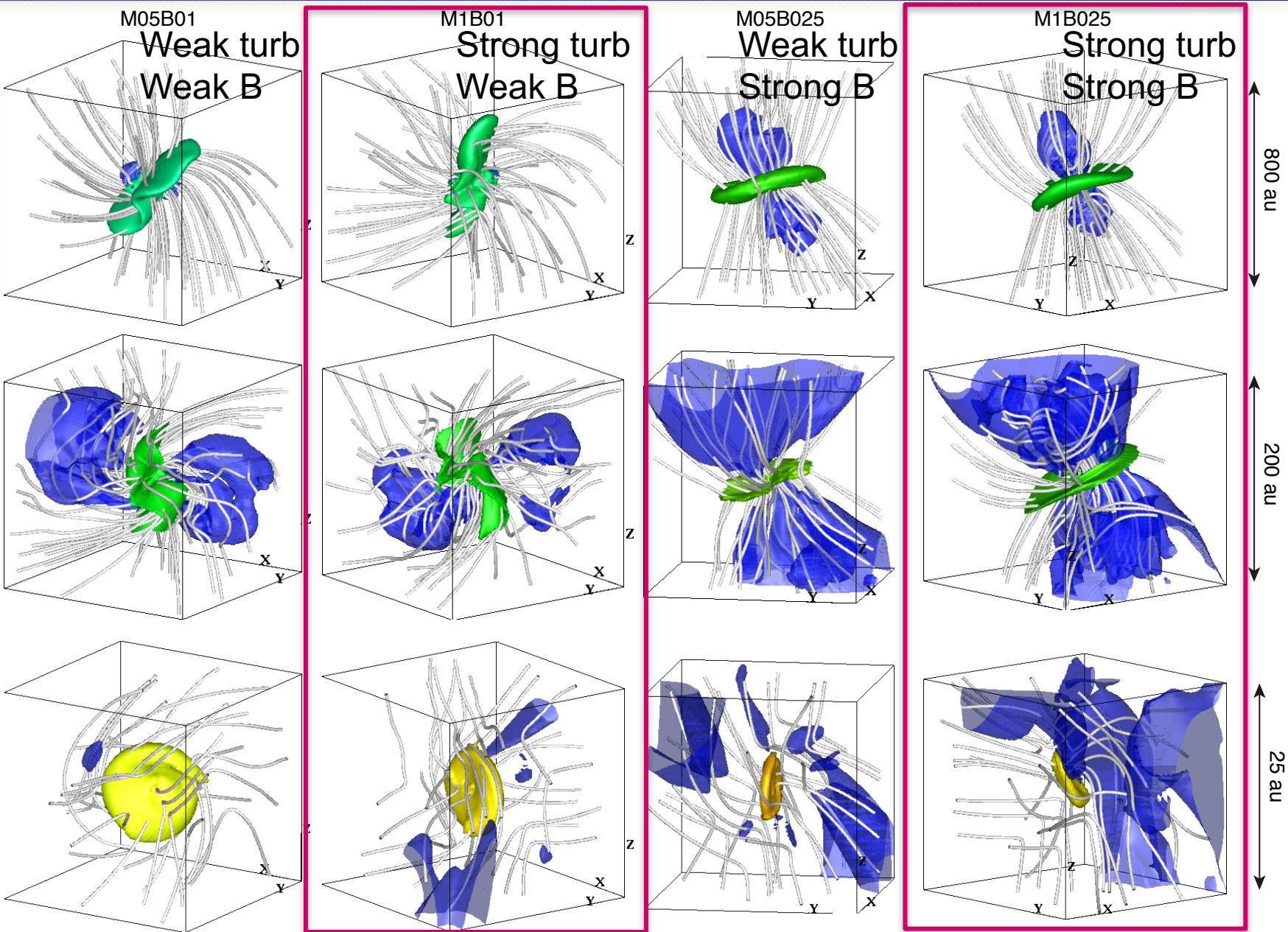
- Assumption
  - Barotropic EOS: $P(\rho) = c_s^2 + \kappa\rho^{7/5}, \quad n_{\rm cr} = 2.62 \times 10^{10}{\rm cm}^{-3}$
  - Ohmic dissipation: $Re_m < 1$ for $n > 2 \times 10^{12}{\rm cm}^{-3}$
  - Sink particle: $n_{\rm sink} = 2.62 \times 10^{13}{\rm cm}^{-3}$
  - Periodic boudary condition

On the cloud core scale

1000 yr after the protostar formation



Envelope(green), disk（yellow）, outflow(blue)



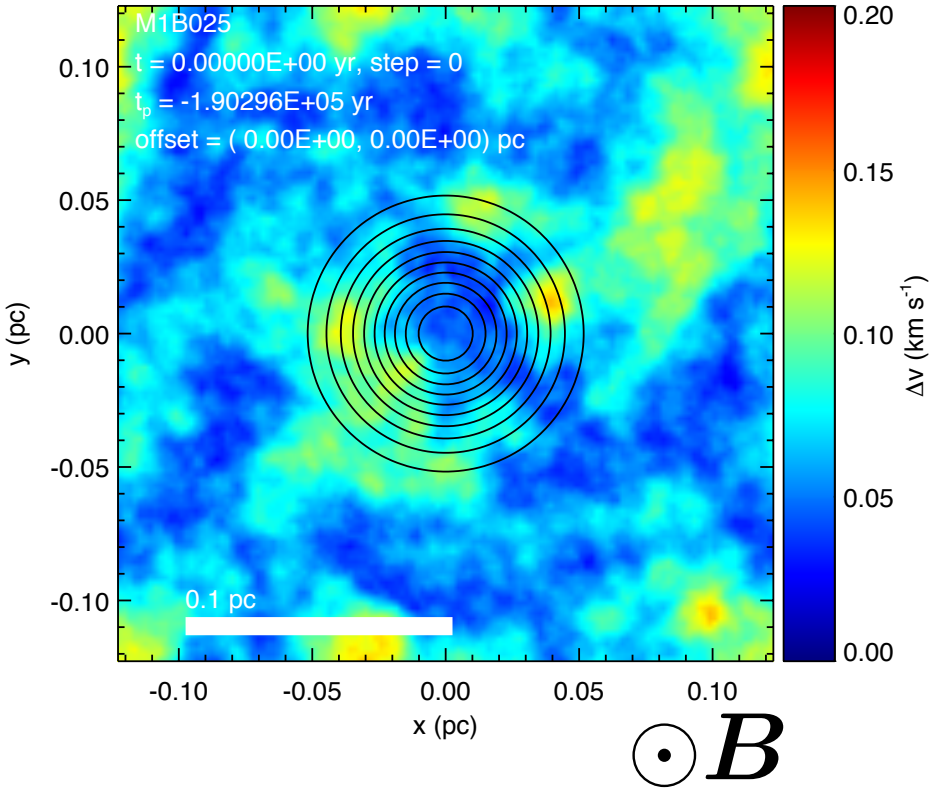
On cloud core scale

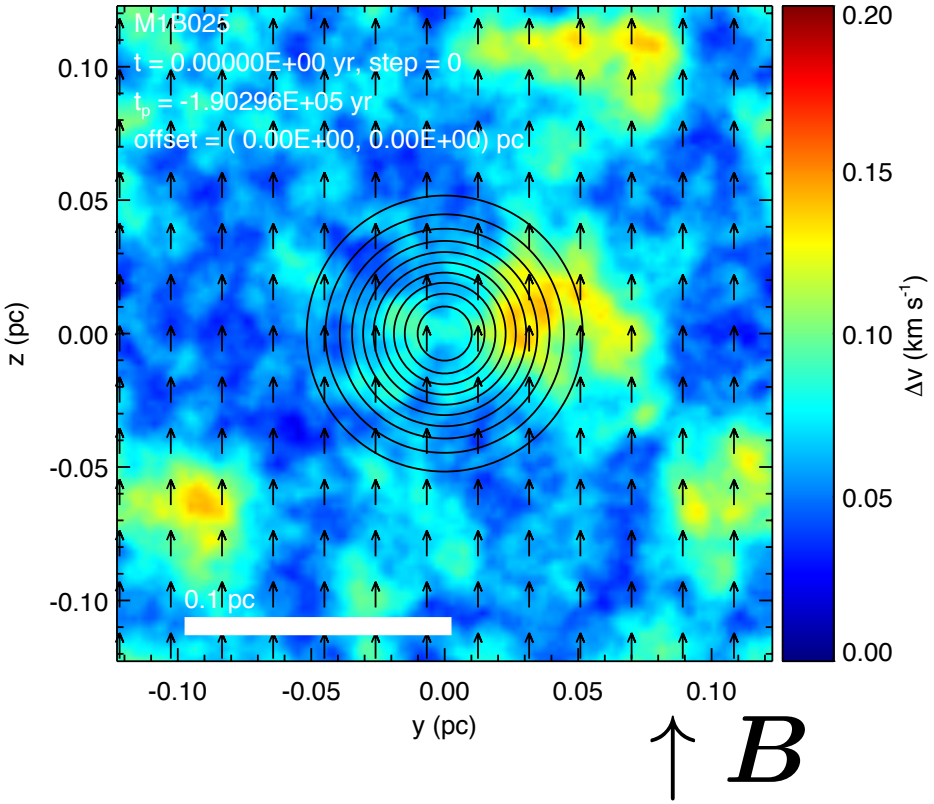
Initial condition (velocity dispersion)

Model

Strong magnetic field μ = 1.12

Moderate Mach number M = 1





Color : velocity dispersion (rms velocity along los)

Contour: column density

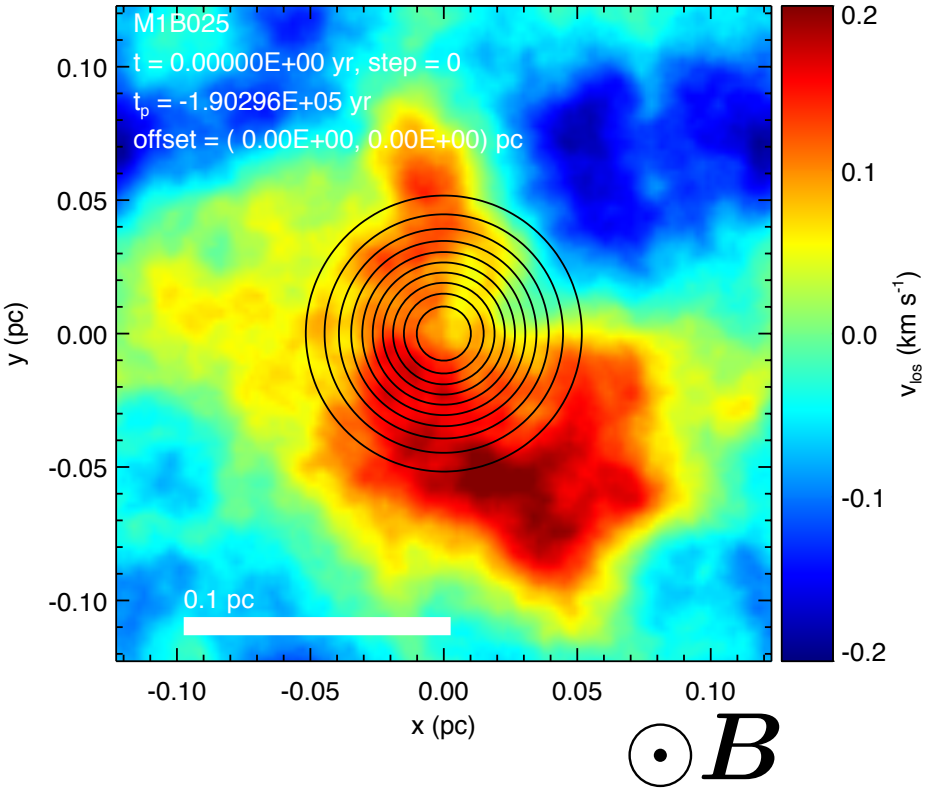
Arrows: magnetic field (normalized)

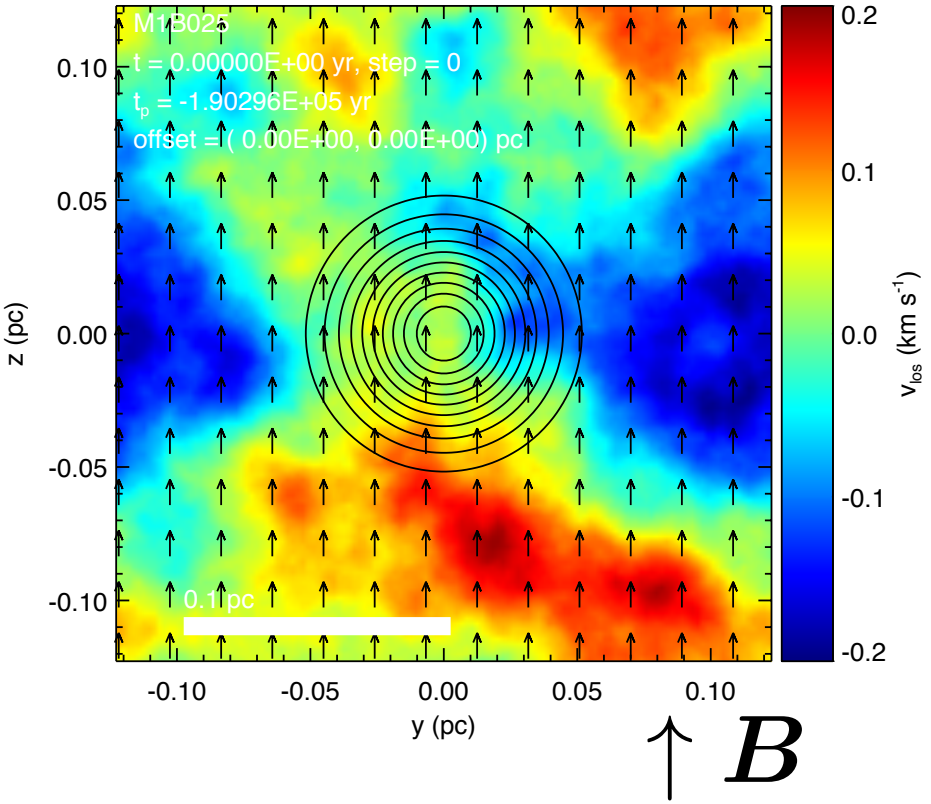
Initial condition (centroid velocity)

Model

Strong magnetic field μ = 1.12

Moderate Mach number M = 1





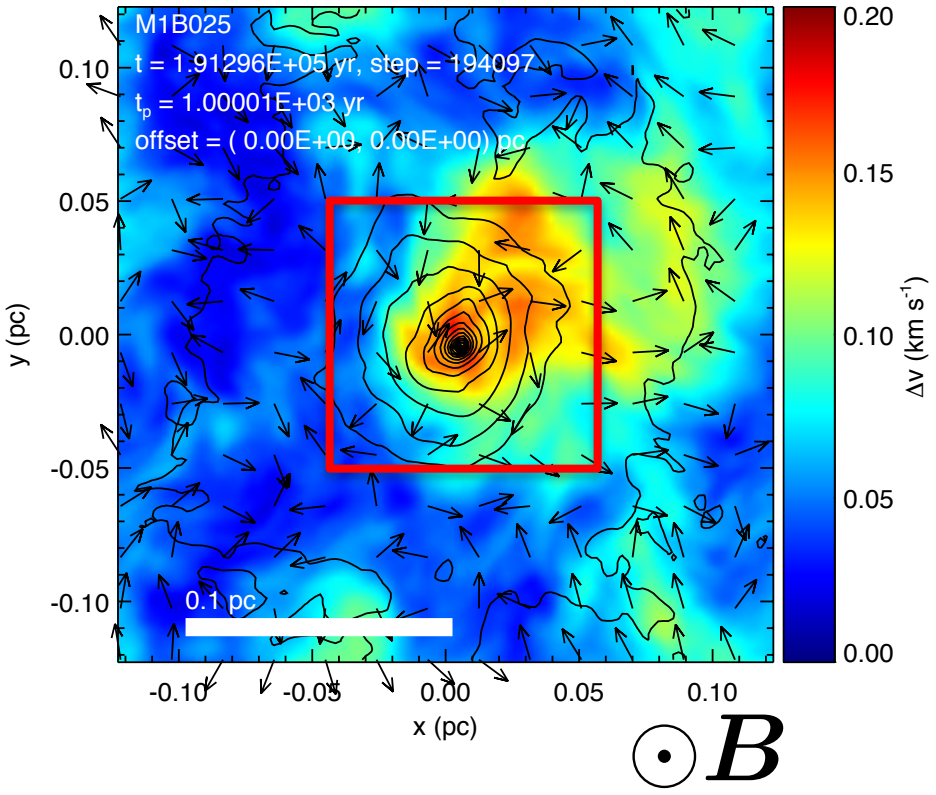
Color : density weighted velocity along los

Contour: column density

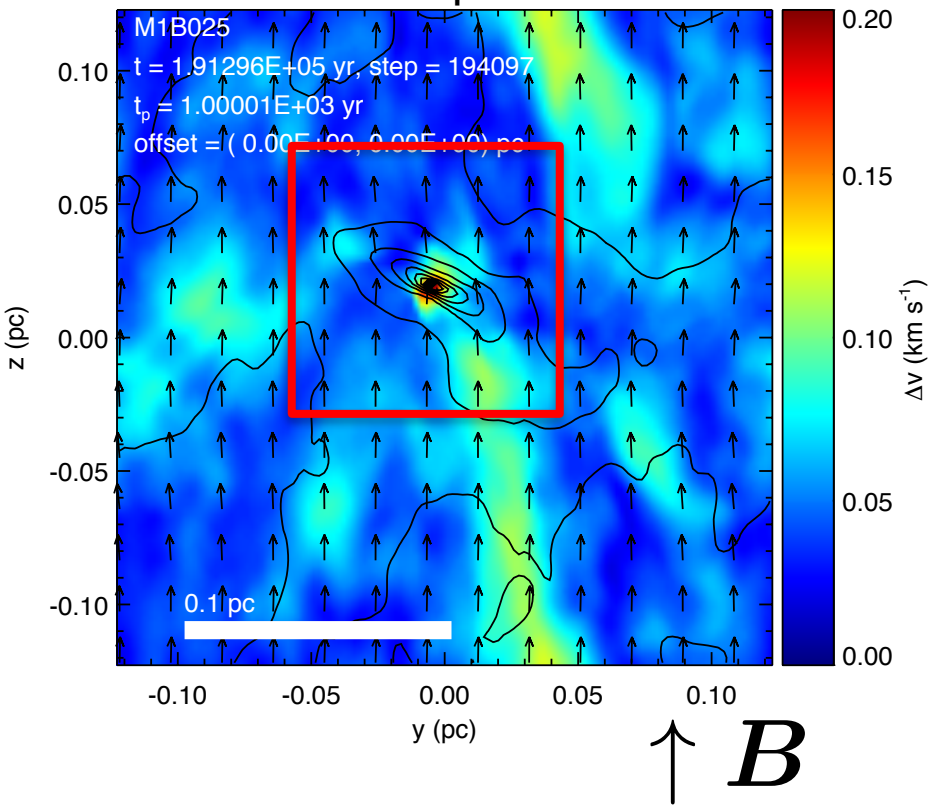
Arrows: magnetic field (normalized)

1000 years after protostar formation

Broad linewidth



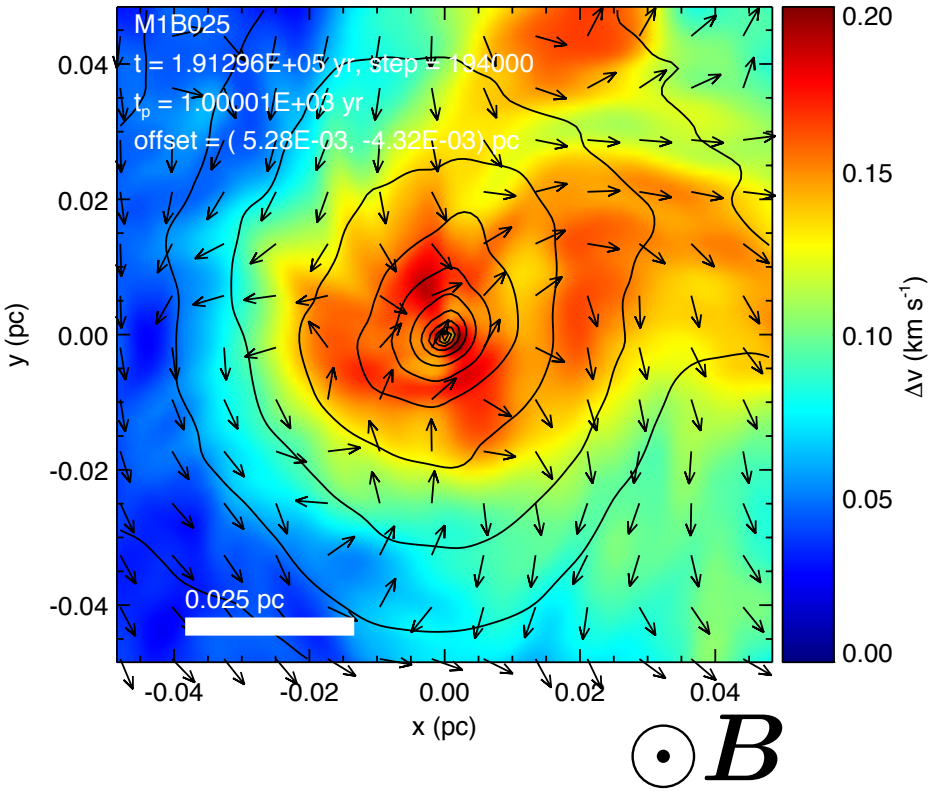
Narrow linewidth
Flat shape



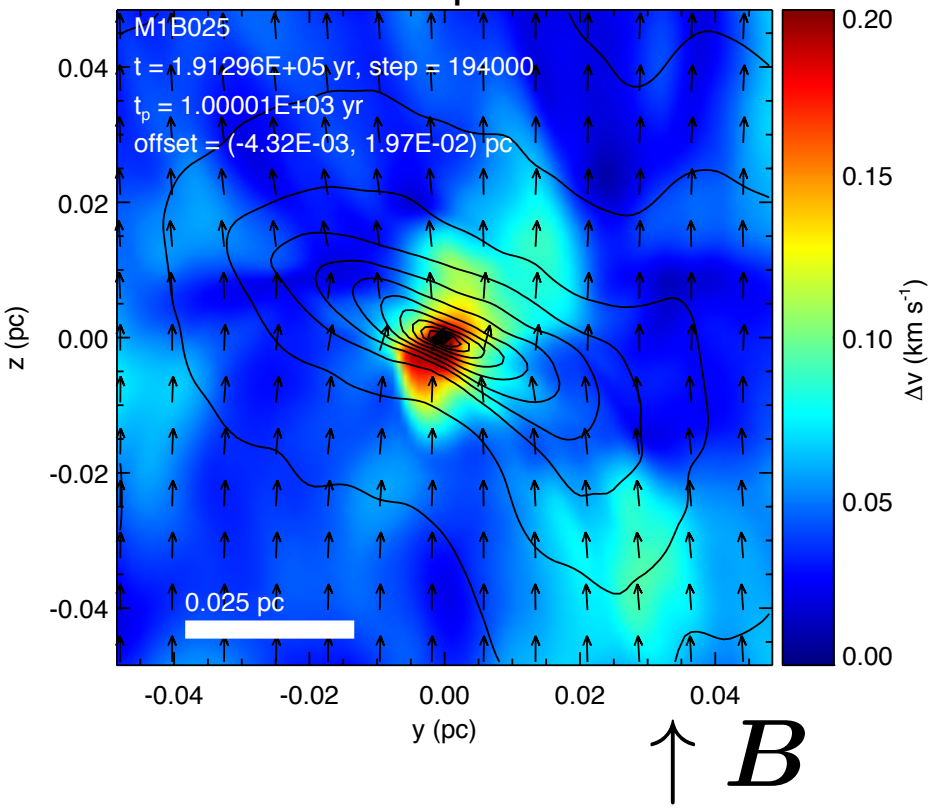
Color : velocity dispersion (rms velocity along los)
Contour: column density
Arrows: magnetic field (normalized)

1000 years after protostar formation on cloud core scale

Broad linewidth



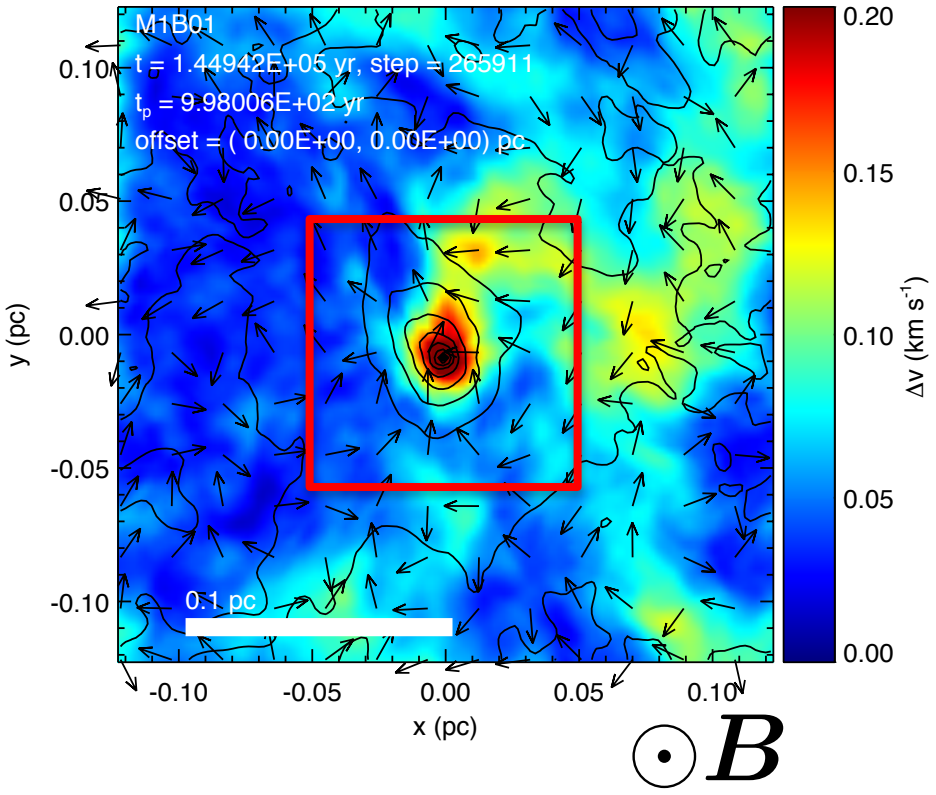
Narrow linewidth
Flat shape



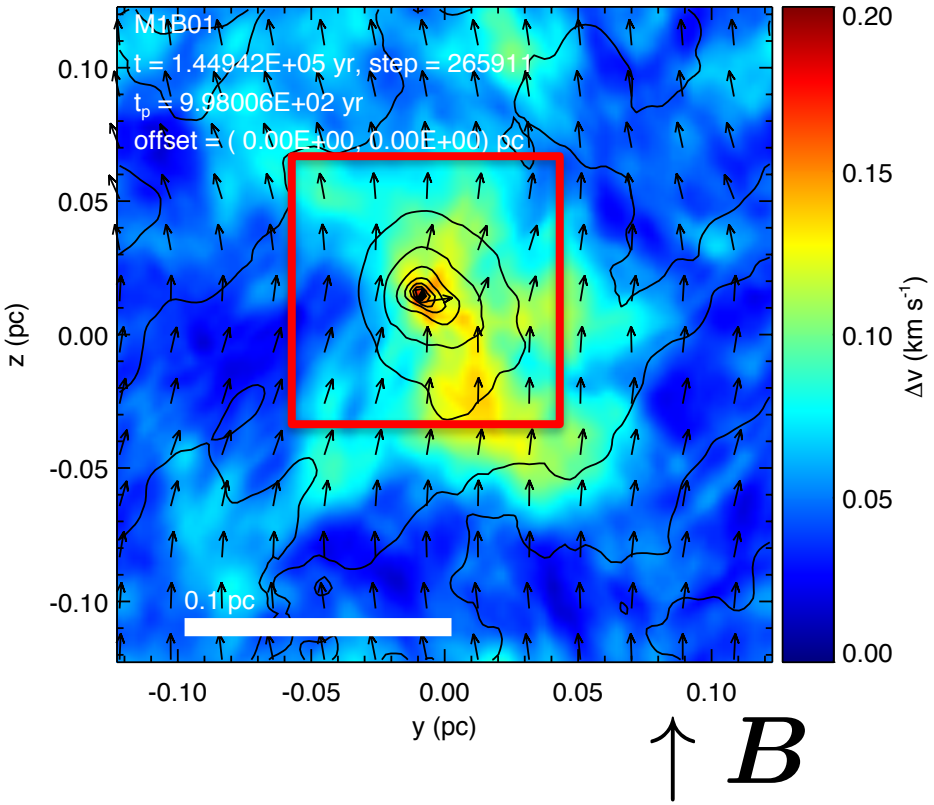
Color : velocity dispersion (rms velocity along los)
Contour: column density
Arrows: magnetic field (normalized)

Weak field case μ = 2.81

Broad linewidth



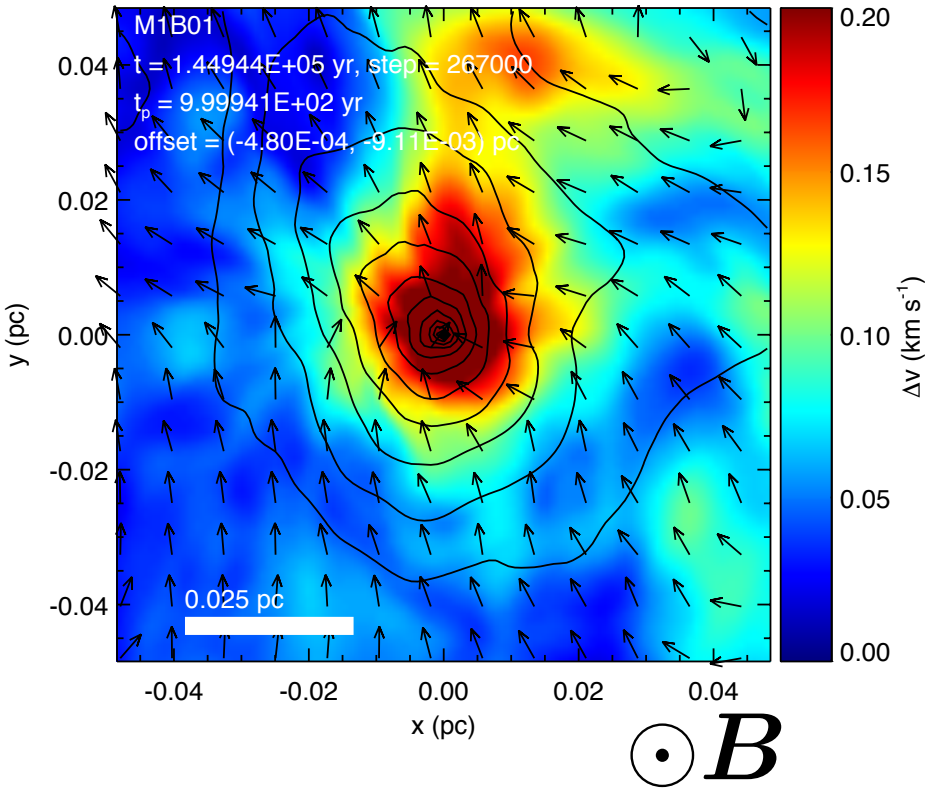
Narrow linewidth



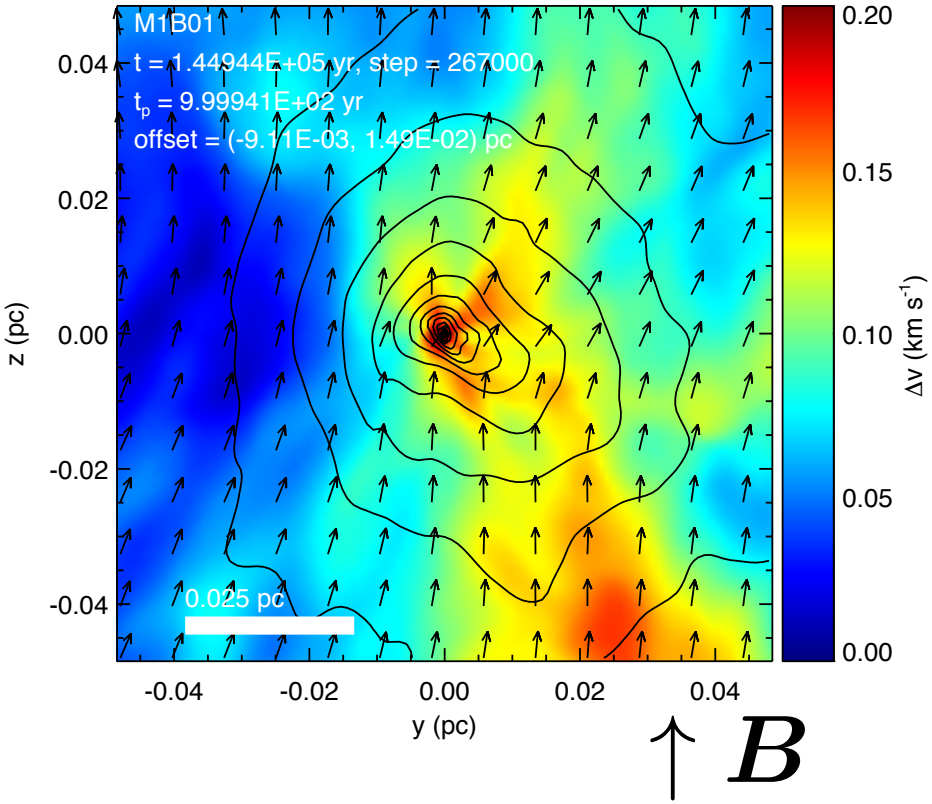
Color : velocity dispersion (rms velocity along los)
Contour: column density
Arrows: magnetic field (normalized)

Weak field case μ = 2.81 on cloud core scale

Broad linewidth



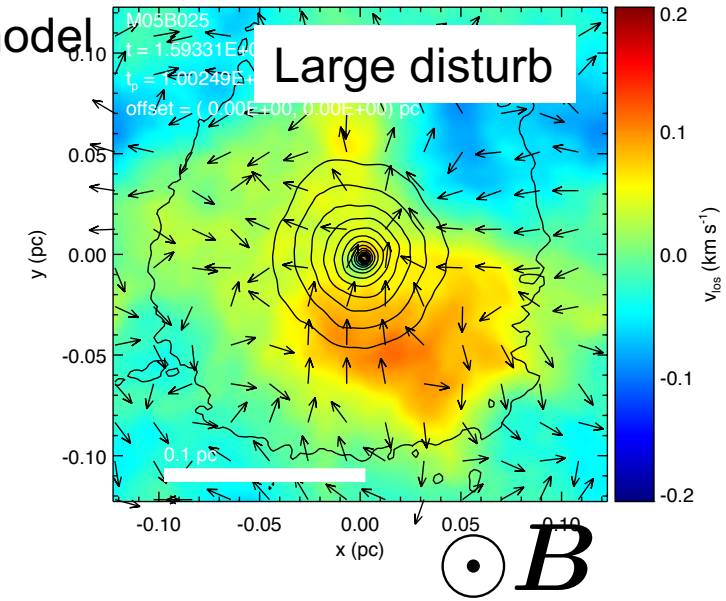
Narrow linewidth

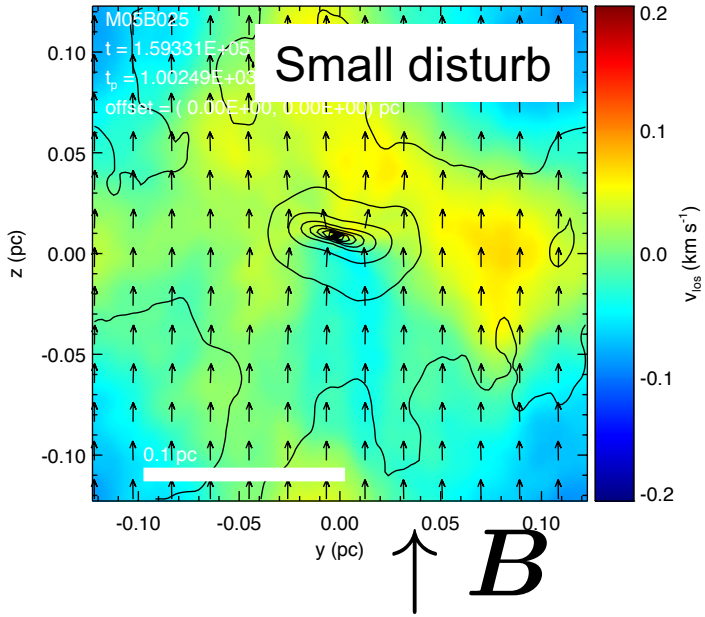


Color : velocity dispersion (rms velocity along los)
Contour: column density
Arrows: magnetic field (normalized)

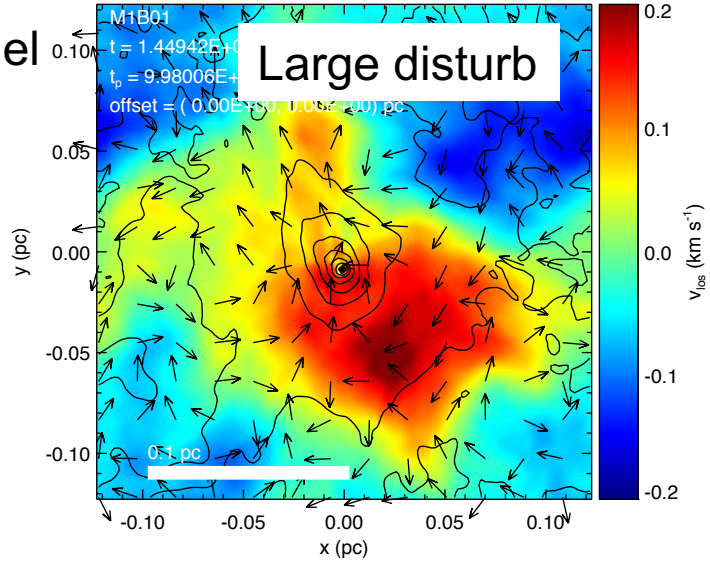
Centroid velocity

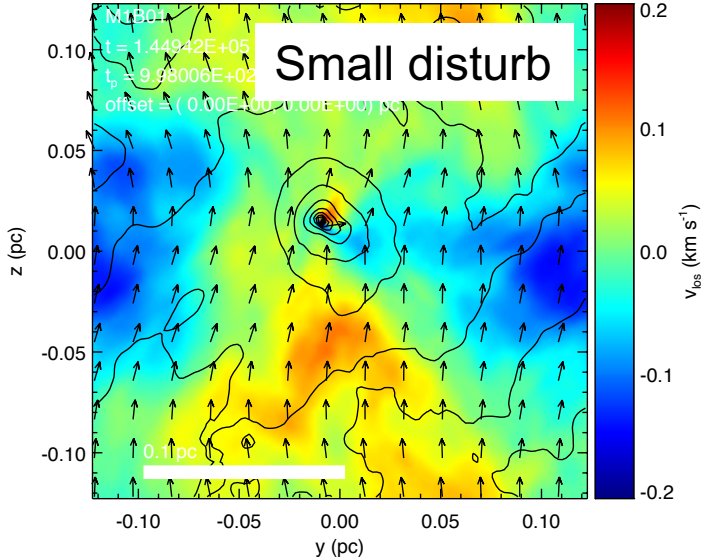
Strong B field model
μ = 1.12





Weak B field model
μ = 2.81

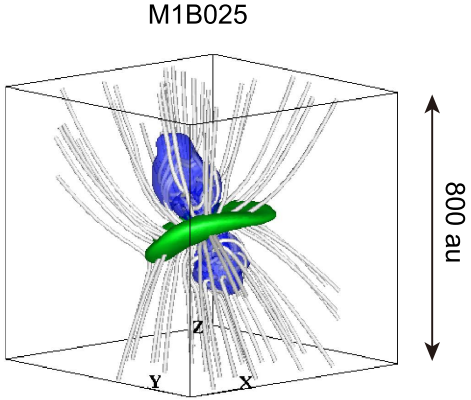


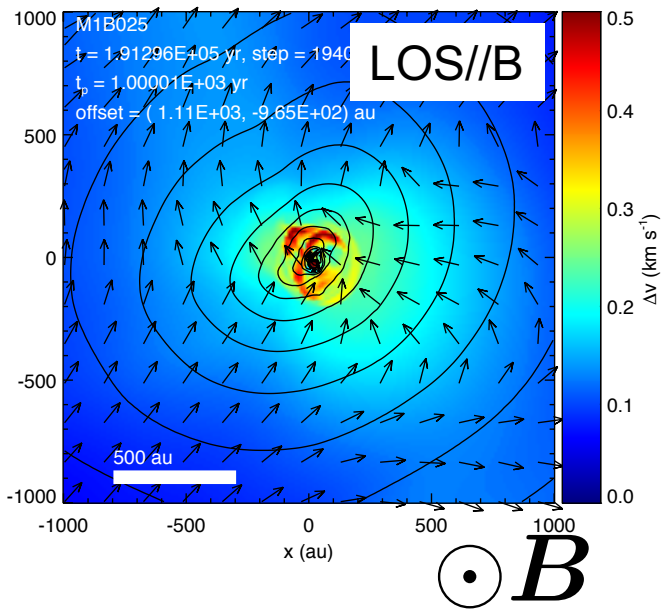


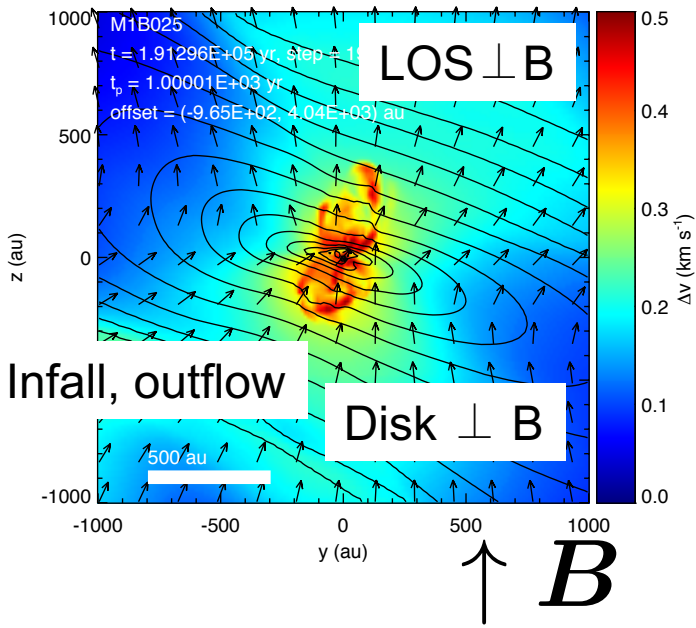
On envelope scale

On envelope scale

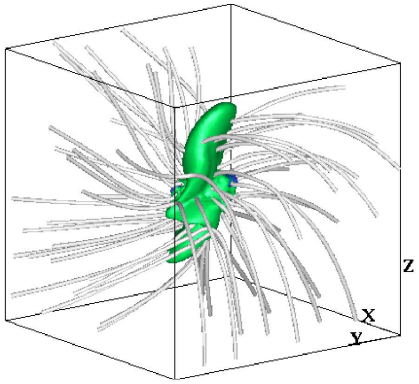
Strong B field model
μ = 1.12

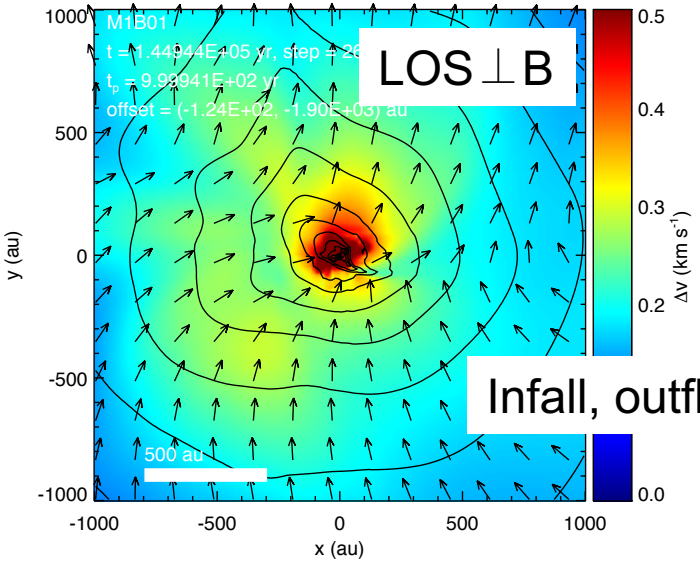


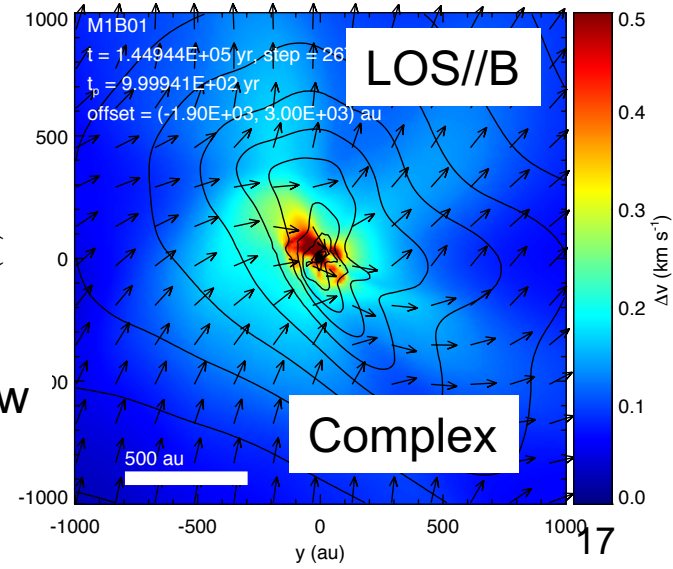




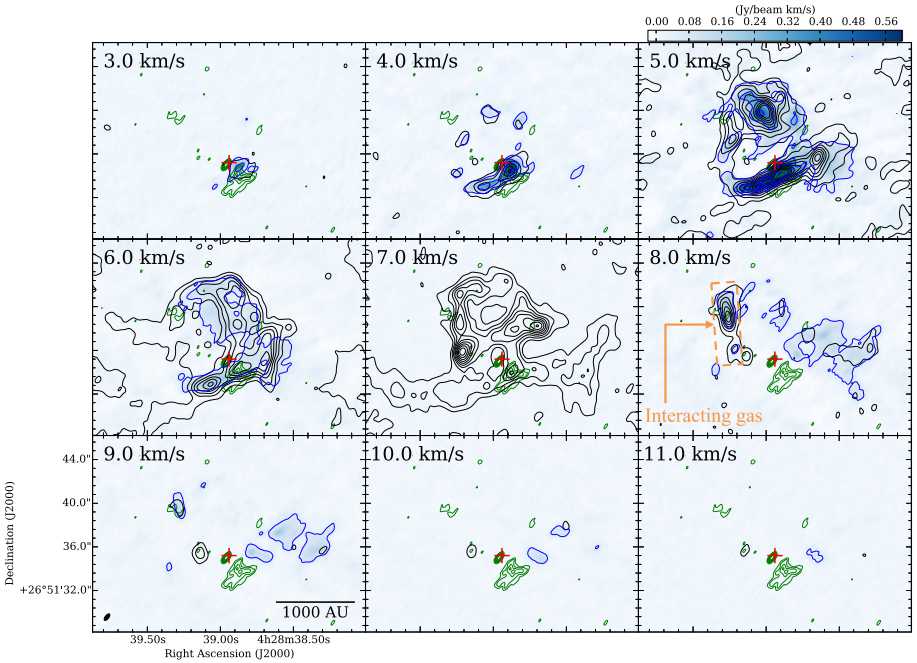
Weak B field model
μ = 2.81







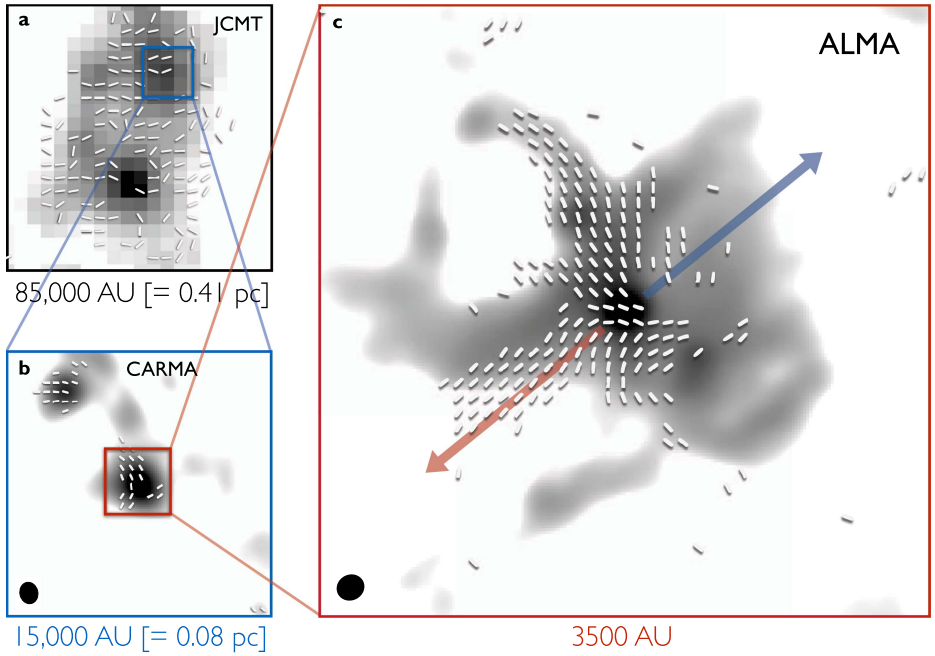
Complex structure at the center of cloud core



Tokuda+ 16
MC27 in Taurus

Class 0 protostar

12CO(J=3-2)
H13CO+(J=3-2)



Hull+ 17
Ser-emb 8

Class 0 protostar

Dust emission (stokes I)
B-vector

Internal, external, or inherited origin?

Summary

- Linewidth depends on direction of magnetic fields on star forming core scale.
  - Large Δv and disturbed vlos for LOS// B
  - Narrow Δv and smooth vlos for LOS ⊥ B
- Envelopes exhibit complex features
  - by turbulence, magnetic field, infall, outflow.
  - Simulations show smoother structure than observations do.
    - Open question
- Many realizations are necessary for statistical analysis.
  - Many models with low resolution are enough.