The role of Magnetic Fields in Star (Cluster) Formation

Nakamura & Li, 2010
arXiv:1008.0959v2

Motivation

Most stars form in clusters

Protocluster clumps highly turbulent and magnetized

Need to understand relative importance of these processes

Protocluster Size Scales

1 pc across

10^2-10^3 solar mass

Magnetic Stability

Critical Mass-Flux Ratio = 1/(2 Pi SQRT(G))

If Mass-Flux Ratio > Critical Value ->

COLLAPSE ensues

Idealized Simulation Setup

-Parsec scale dense clump as initial condition
-Realistic radial density profile:

*Peak density, 5e-20 g/cc (tff=.30 Myr)
*Average density, 7.5e-21 g/cc (tff=.77 Myr)

-Mtot =884 Solar Masses
-T=15 K

Idealized Simulation Setup

-Initial field is uniform in x
-Beta=Ptherm/Pmag at cloud center
-3 runs,

1. Weak field (B=10e6)
2. Stronger field (B=2)
3. Really strong field (B=.2)

-All runs are magnetically supercritical

Idealized Simulation Setup

-Initialize turbulent velocity field with RMS Mach=5

-Protostellar feedback

Results

Magnetic fields impede Star Formation

Field topology and resultant gas dynamics depends on strength of initial field

Synthetic Polarization Maps elucidate field strength

Morphological differences

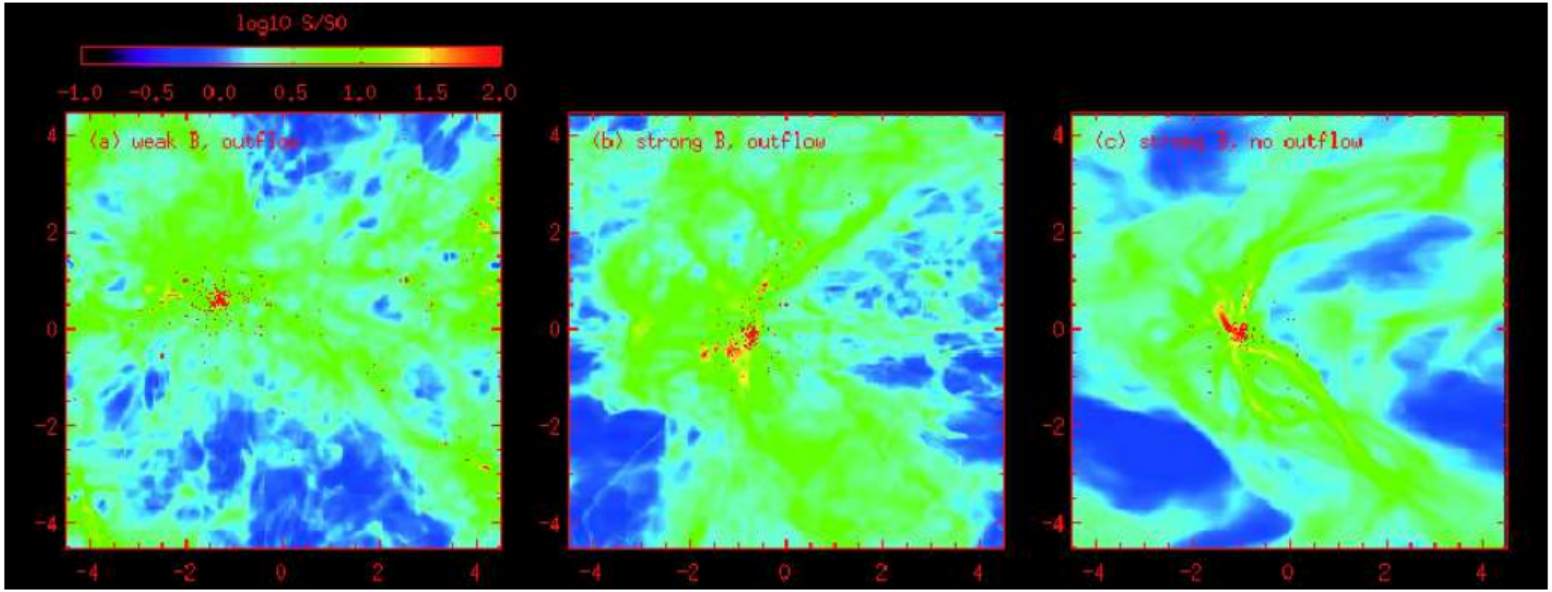

Figure 1. Snapshots of the column density distribution for (a) the weakly-magnetized model with the outflow feedback [$\Gamma = 4.3$ ($\beta = 2.0$) and $t = 2.8t_{\rm ff}$], (b) strongly-magnetized model with the outflow feedback, [$\Gamma = 1.4$ ($\beta = 0.2$) and $t = 4.0t_{\rm ff}$] and (c) strongly-magnetized model without the outflow feedback [$\Gamma = 1.4$ ($\beta = 0.2$) and $t = 1.3t_{\rm ff}$], at the stage when the star formation efficiency has reached 15 %. The initial magnetic field direction is parallel to the horizontal axis. The small red dots indicate the positions of stars. The units of length is the Jeans length of the initial cloud $L_J = 0.22$ pc and the global free-fall time is $t_{\rm ff} = 0.77$ Myr.

The effect on star formation

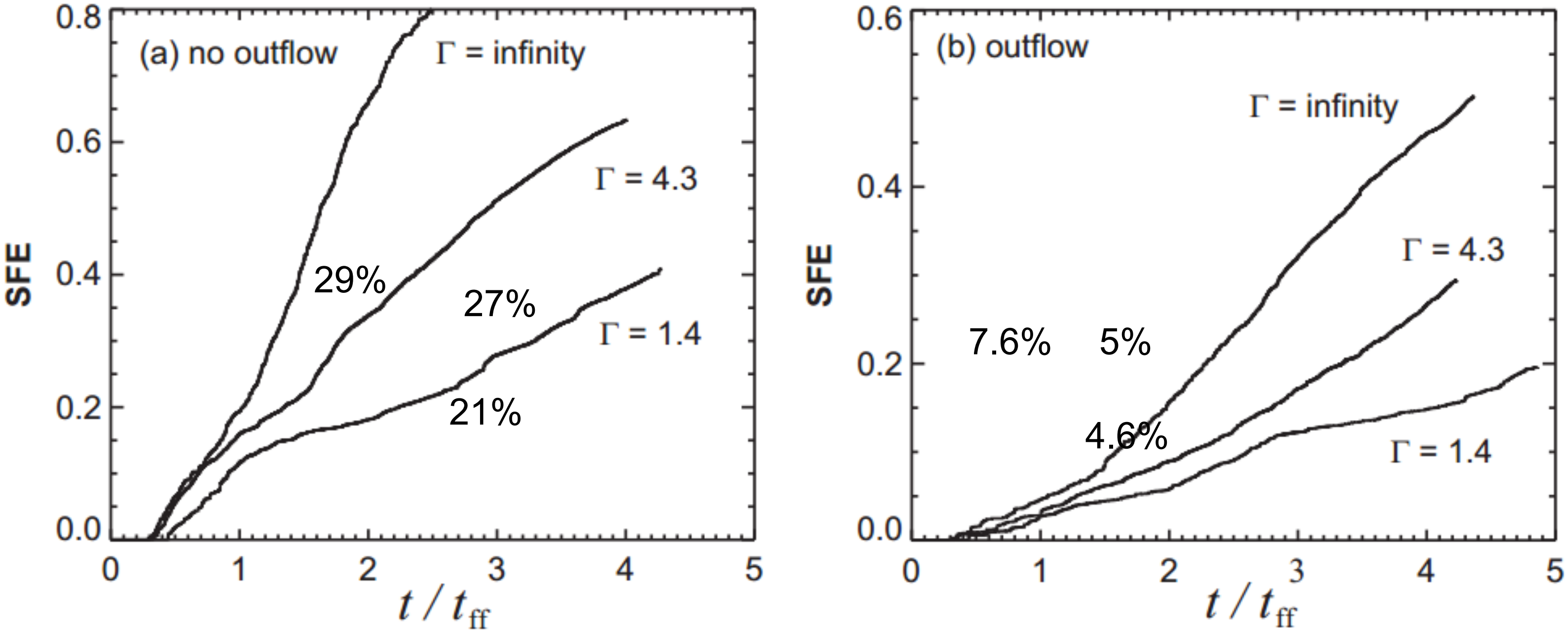

Figure 2. (a) Star formation efficiencies for three models with no outflow feedback against evolution time that is normalized to the global clump free-fall time, (1) $\Gamma = 3.0 \times 10^3$, (2) $\Gamma = 4.3$ (weak magnetic field), and (3) $\Gamma = 1.4$ (moderately-strong magnetic field). Protostellar outflow feedback is not taken into account for these models. (b) Same as panel (a) but for models with outflow feedback.

Field strength

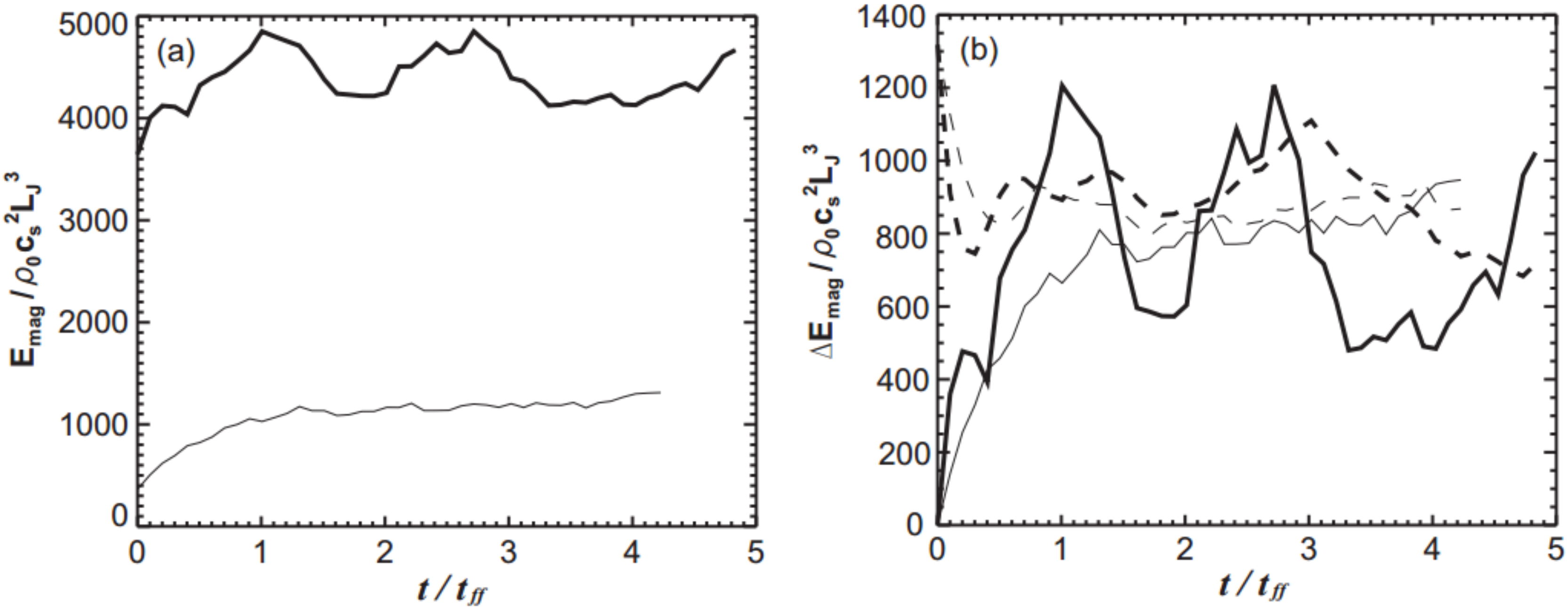

Figure 3. (a) Time evolution of total magnetic energy for two magnetized models. Thick and thin lines are for the models with moderately-strong ($\Gamma = 1.4$) and weak magnetic fields ($\Gamma = 4.3$), respectively. (b) Time evolution of magnetic energy of amplified component (*solid lines*) and kinetic energy of turbulence (*dashed lines*). The magnetic energy of the amplified component tends to approaches the kinetic energy for each model.

Field Structure in Simulation

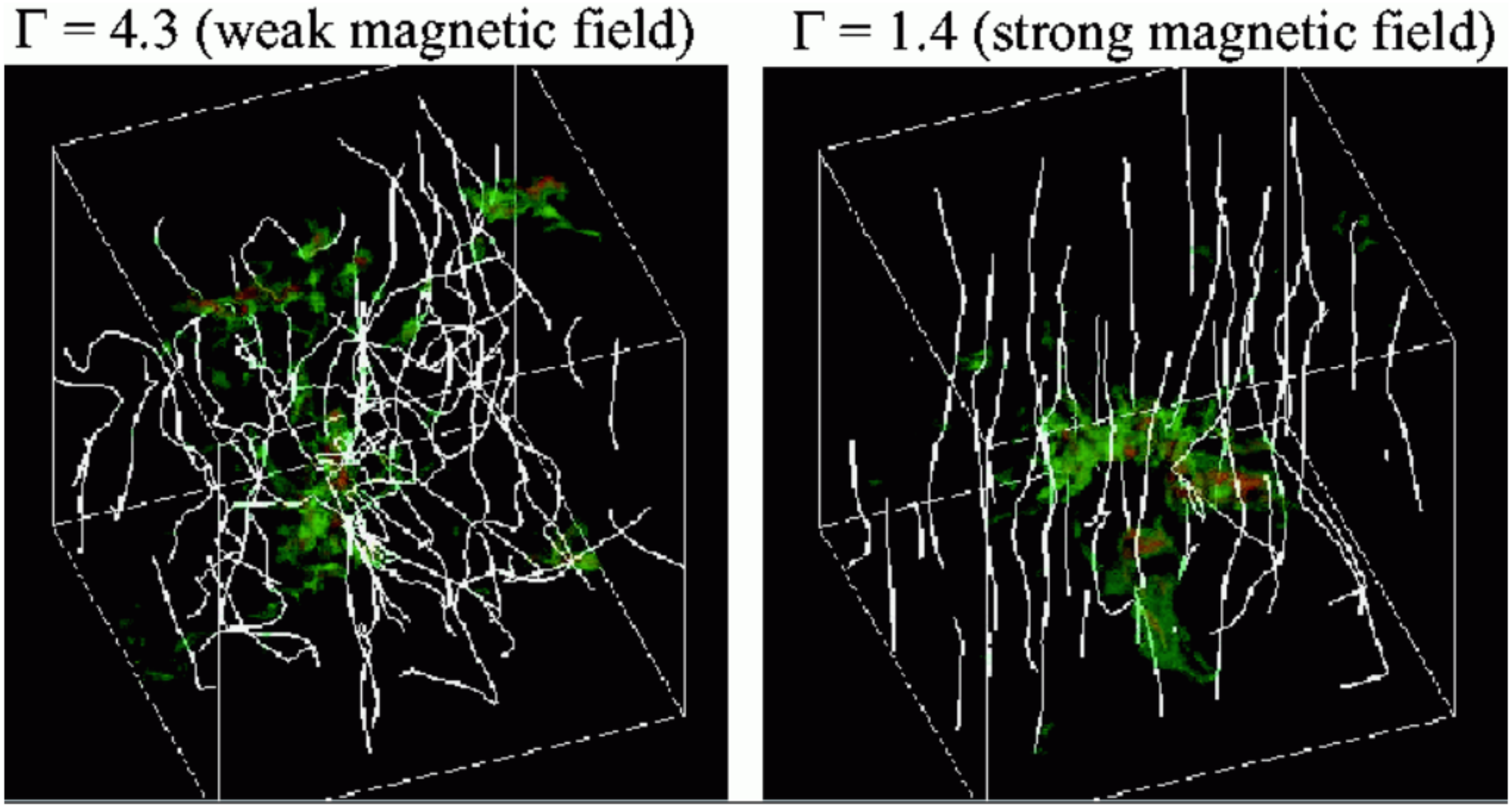

Figure 4. 3D view of the density and magnetic field distributions for the weakly-magnetized model with $\Gamma = 4.3$ (*left*) and the strongly-magnetized model with $\Gamma = 1.4$ (*right*).

Field Structure - Polarization Maps

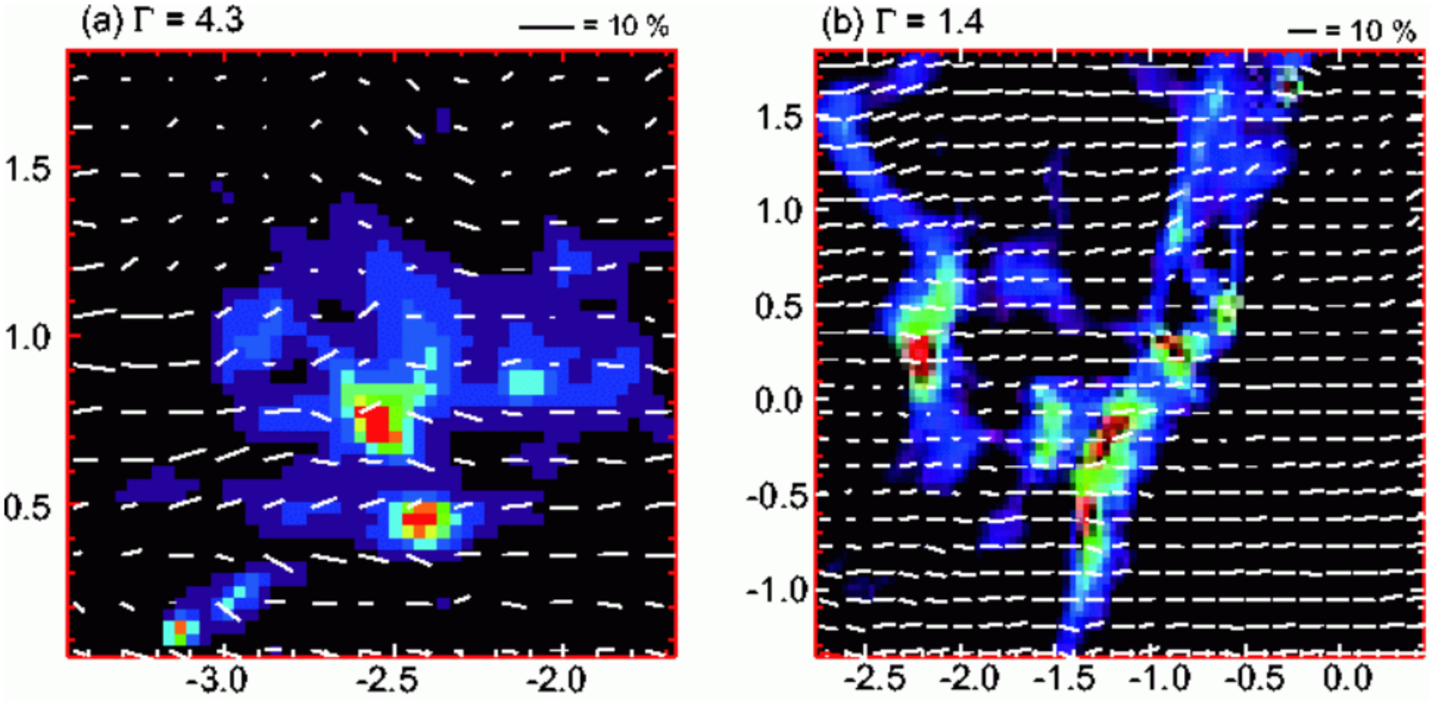

Figure 6. (a) Polarization maps of the models with $\Gamma = 4.3$ (weak magnetic field) and (b) $\Gamma = 1.4$ (moderately-strong magnetic field). The length of the polarization vectors is proportional to the degree of polarization, with the longest vector corresponding to $P = 10\%$. Only one polarization vector is plotted for every four computational cells. The color contour shows the column density distribution. The initial magnetic field lines are parallel to the horizontal line.

Results

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