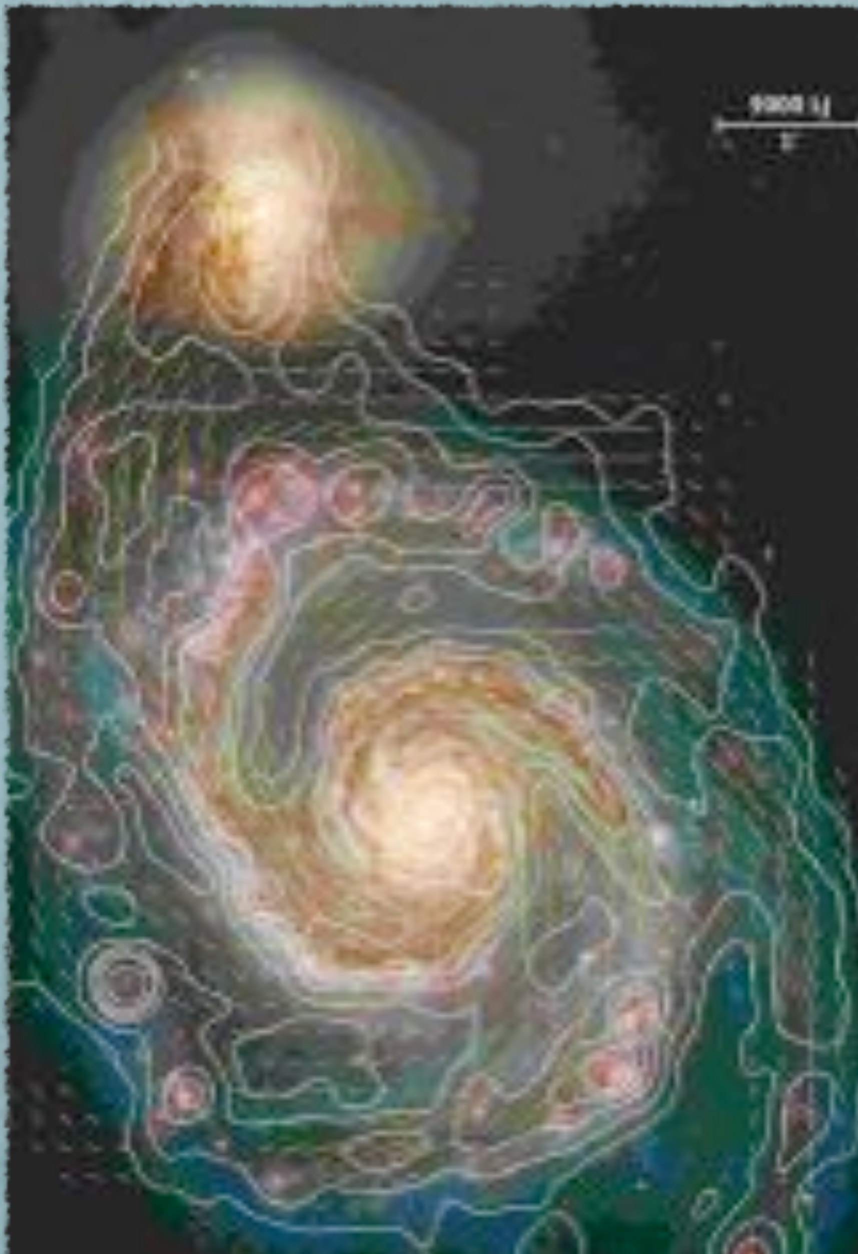
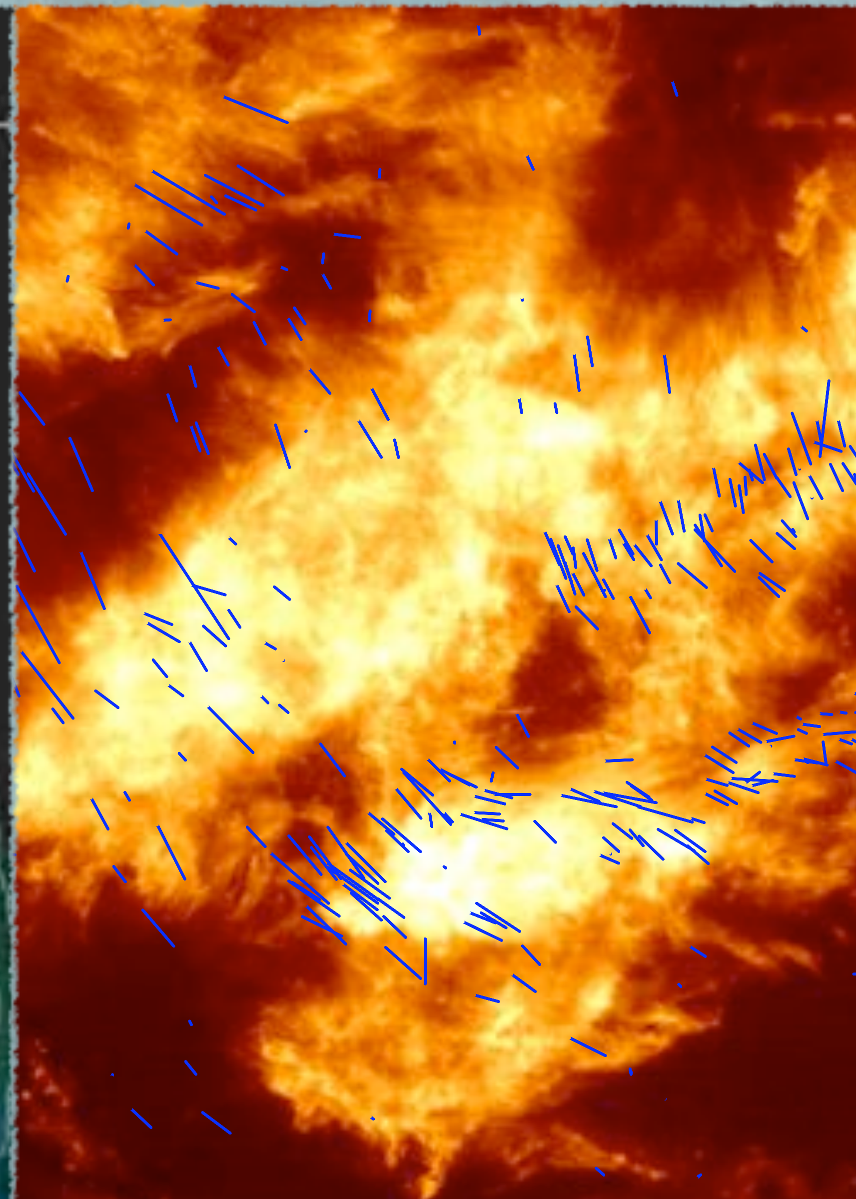
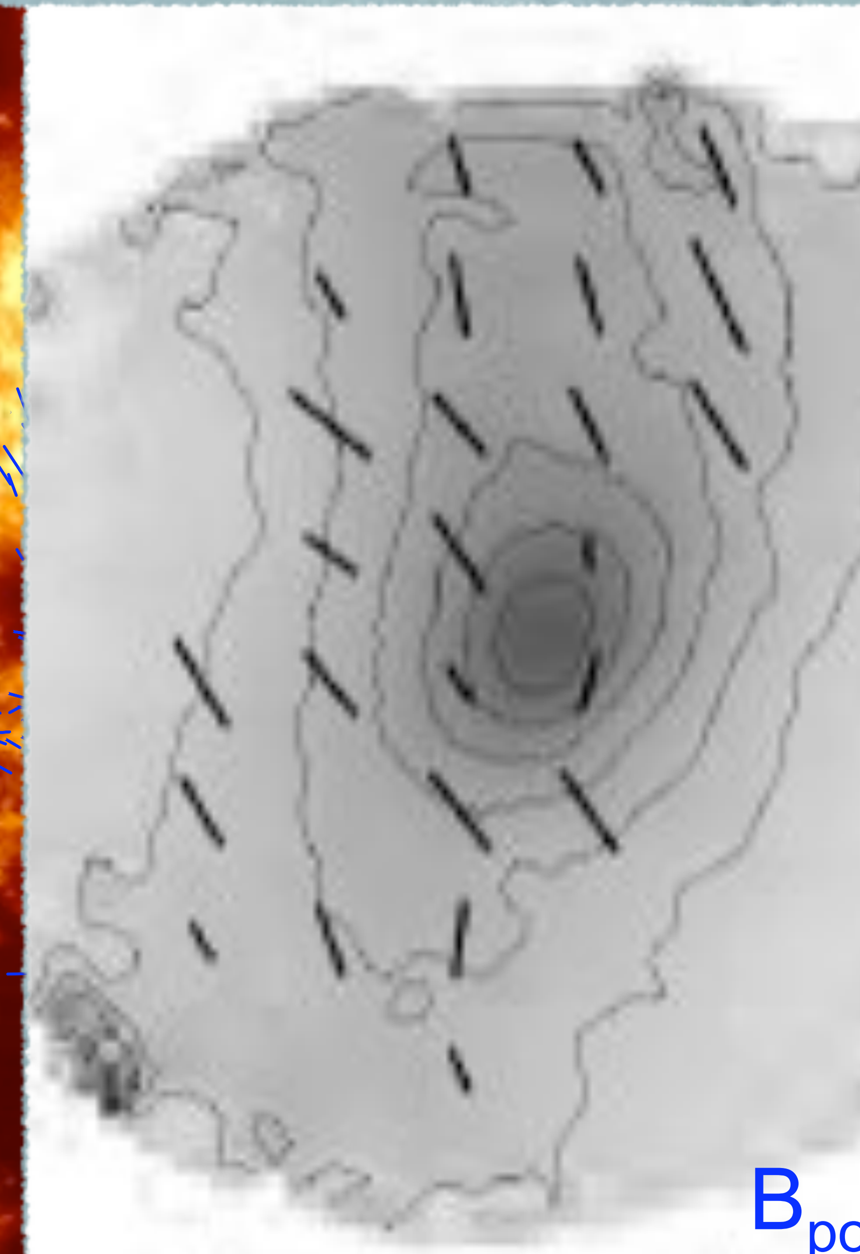




Goldsmith, Heyer, Brunt et al. (2007)



Magnetic fields in the ISM:

from galaxies to stars

Daniel Price
(MoCA)

Are magnetic fields important?

$$\left(\frac{M}{\Phi}\right) / \left(\frac{M}{\Phi}\right)_{crit}$$

Magnetic fields vs. gravity

$$\beta = \frac{c_s^2 \rho}{\frac{1}{2} B^2 / \mu_0}$$

Magnetic fields vs. pressure

$$\frac{v_{turb}}{v_{Alfven}}$$

Magnetic fields vs. turbulence

Are magnetic fields important in the ISM?

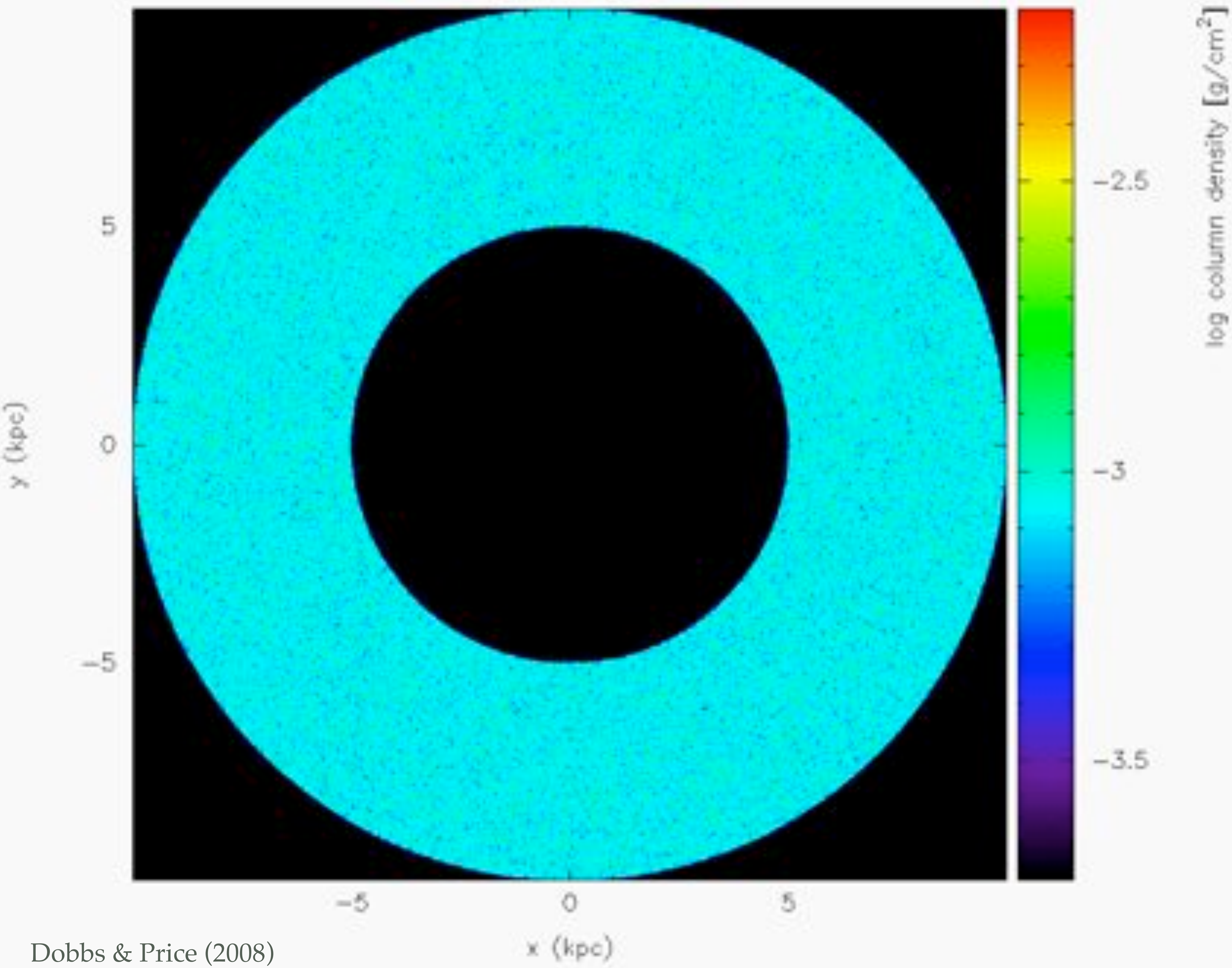
SUBCRITICAL

	super-Alfvenic	sub-Alfvenic
beta < 1	CNM, Warm ISM	
beta > 1		

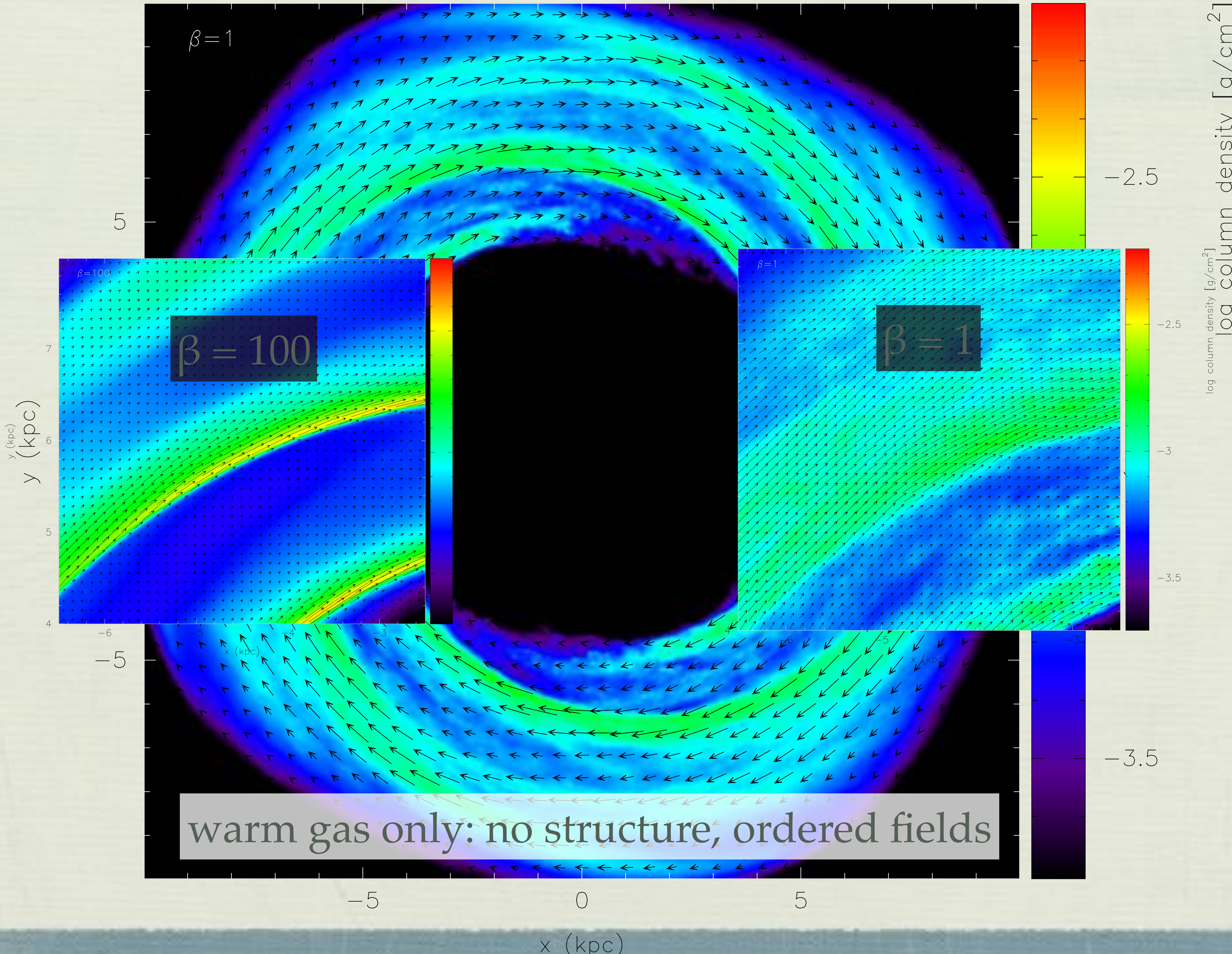
SUPERCRITICAL

	super-Alfvenic	sub-Alfvenic
beta < 1	cores GMCs?	
beta > 1		

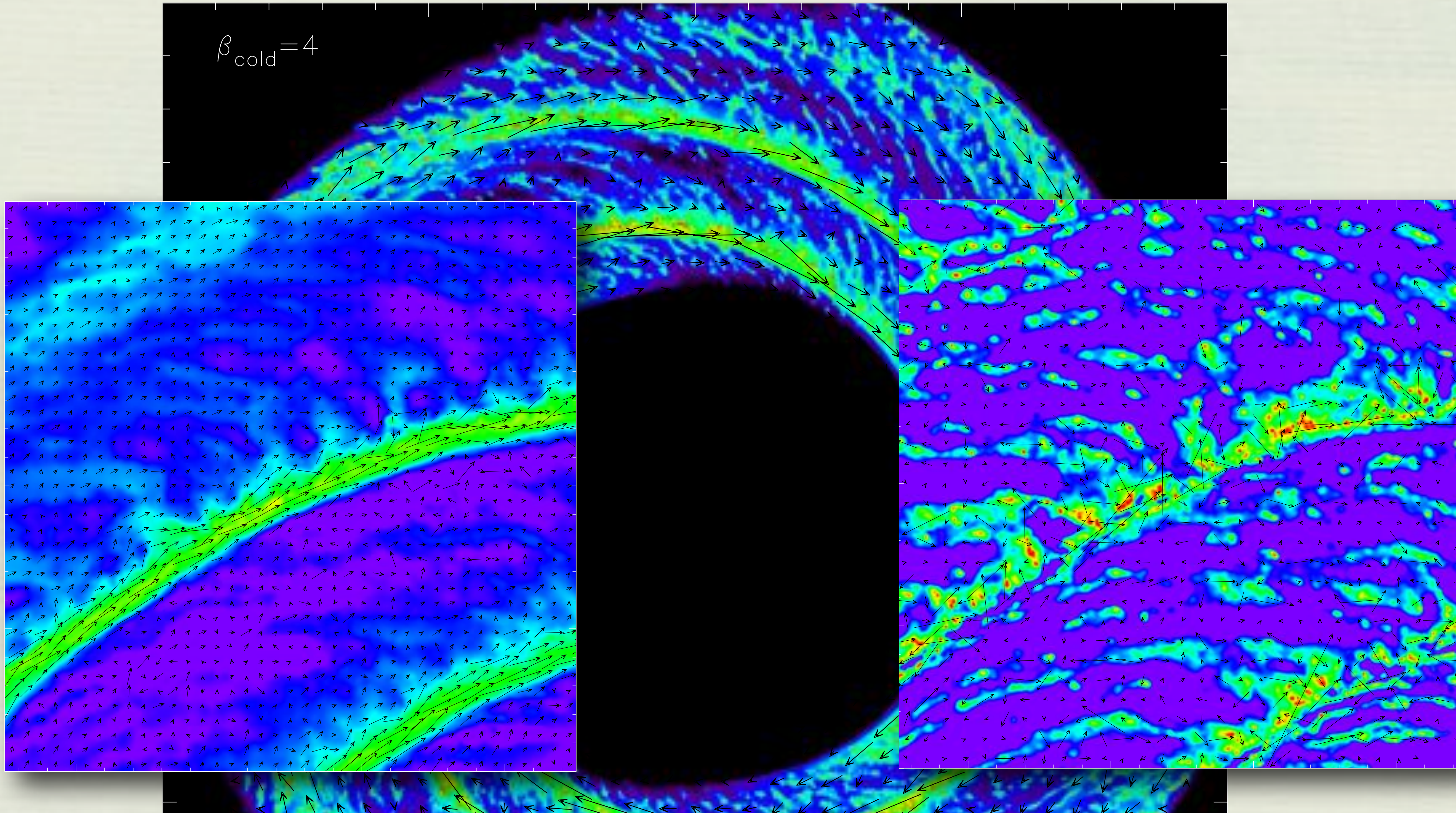
refs: Crutcher (1999), Bourke et al. (2001), Heiles & Troland (2004)



Dobbs & Price (2008)



warm gas only: no structure, ordered fields



Presence of both cold and warm gas key to producing relative amounts of ordered / disordered field

Provided cold gas is present, get random field of similar magnitude to ordered component

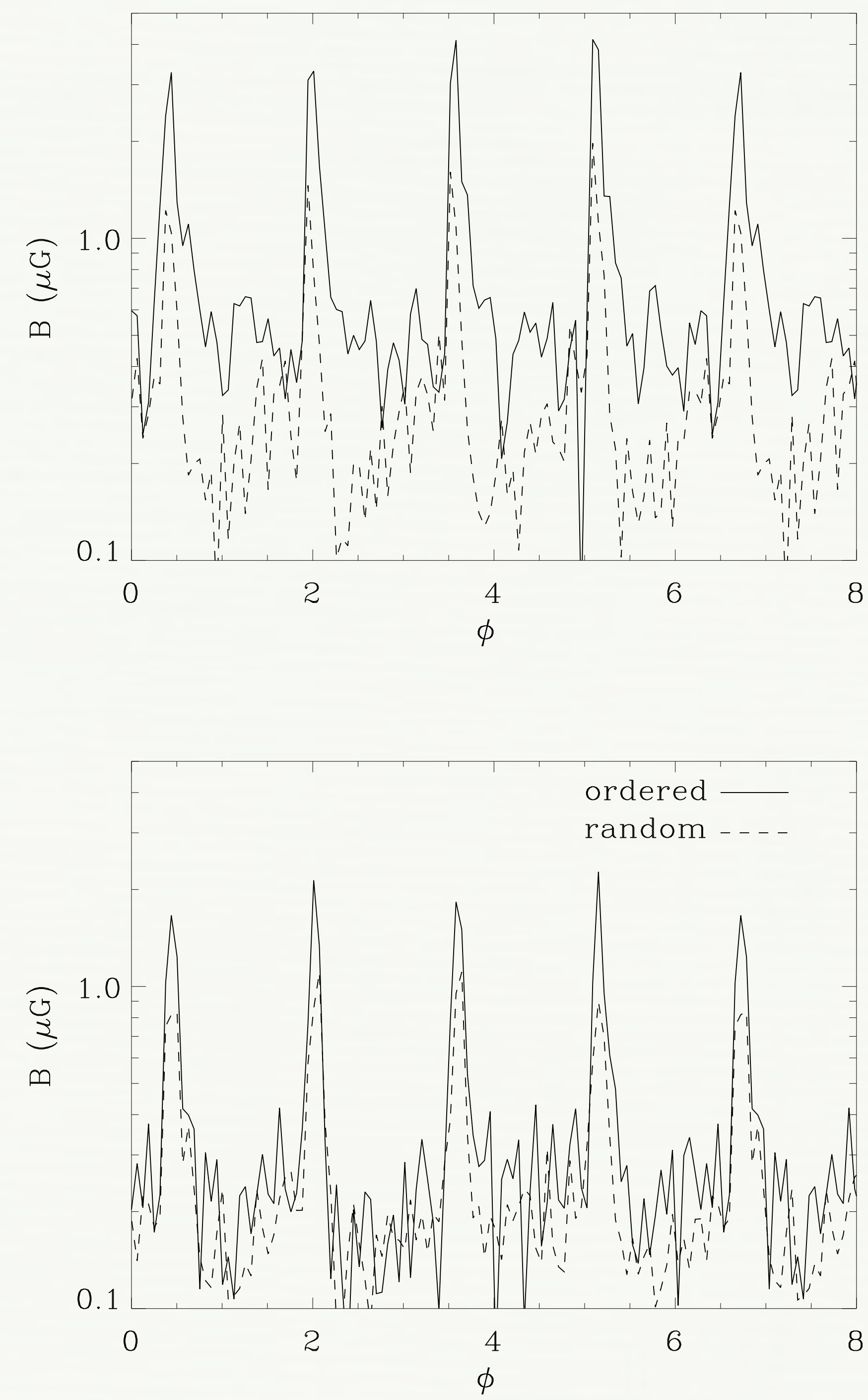


Figure 6. The volume averaged random and ordered components of the magnetic field are plotted against azimuth for the models with cold gas for the strongest magnetic field ($\beta = 0.1$, top) and when the magnetic and thermal pressure are equal ($\beta = 1$, lower). The corresponding time is 200 Myr. The magnetic field has a comparatively more ordered field when the field is stronger.

SIMULATING MAGNETIC FIELDS IN THE ANTENNAE GALAXIES

H. Kotarba[1,2], S. J. Karl[1], T. Naab[1,3], P. H. Johansson[1], K. Dolag[3], H. Lesch[1] & F. A. Stasyszyn[3]
[1] University Observatory Munich, Scheinerstr.1, D-81679 Munich, Germany
[2] Max Planck Institute for Extraterrestrial Physics, Giessenbachstrasse, D-85748 Garching, Germany and
[3] Max Planck Institute for Astrophysics, Karl-Schwarzschild-Str. 1, D-85741 Garching, Germany

Draft version May 17, 2010

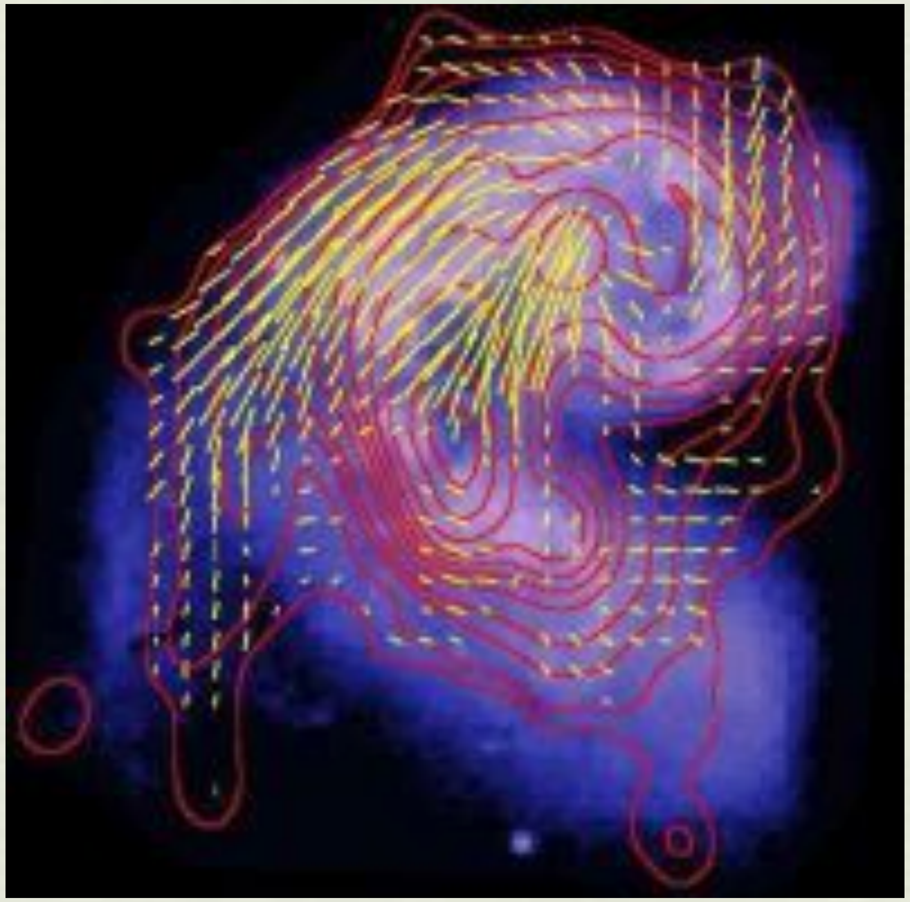


Fig. 1.— Total synchrotron emission (contours) and magnetic field vectors of polarized intensity at 4.86 GHz based on VLA data (yellow), overlaid on a DSS image (blue - white background) (Digitized Sky Survey, Palomar and UK Schmidt telescopes). The contour levels are 0.005, 0.12, 0.30, 0.53, 1.2, 2.1, 3.3, 5.3, 9.0, 17 and 24 mJy/beam-area. The resolution is 17"×14". Credit: Chyzy (2005)

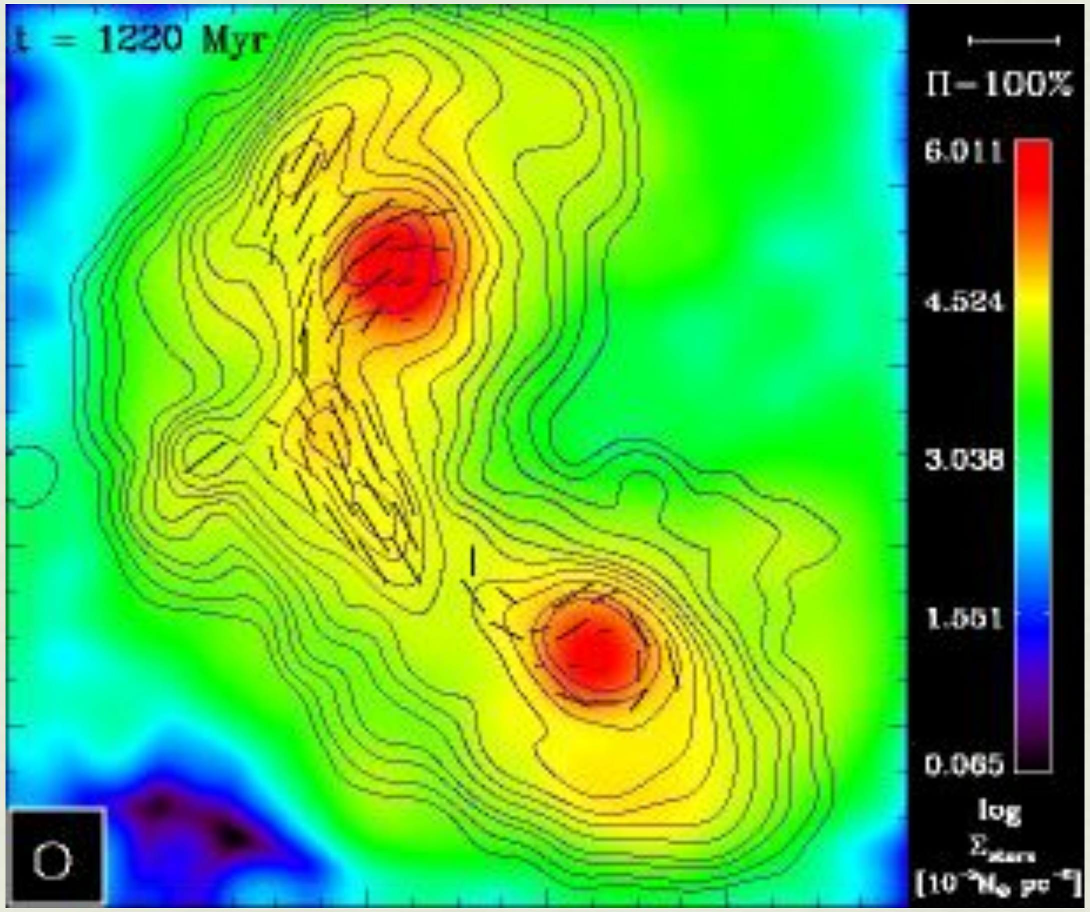


Fig. 14.— Inner region (innermost 28 kpc) of the simulated Antennae system. Colors correspond to the stellar surface density (in units of 10^{-5} $M_{\odot}$ pc^{-2}), overlaid with contours of total synchrotron power. The contour levels are 0.005, 0.12, 0.30, 0.53, 1.2, 2.1, 3.3, 5.3, 9.0, 17 and 24 mJy. Magnetic field lines derived from calculations of polarization are shown in black. The simulated systems compares very well to the observed system (Fig. 1).

Galactic ménage à trois: Simulating magnetic fields in colliding galaxies

H. Kotarba[1,2⋆], H. Lesch[1], K. Dolag[1,3], T. Naab[3,1], P. H. Johansson[4,5,1], J. Donnert[3] & F. A. Stasyszyn[1,3]
[1] *University Observatory Munich, Scheinerstr.1, D-81679 Munich, Germany*
[2] *Max Planck Institute for Extraterrestrial Physics, Giessenbachstrasse, D-85748 Garching, Germany*
[3] *Max Planck Institute for Astrophysics, Karl-Schwarzschild-Str. 1, D-85741 Garching, Germany*
[4] *Finnish Centre for Astronomy with ESO, University of Turku, Väisäläntie 20, FI-21500 Piikkiö, Finland*
[5] *Department of Physics, University of Helsinki, Gustaf Hällströmin katu 2a, FI-00014 Helsinki, Finland*

"The magnetic field in the system saturates rapidly after the mergers at ~ 10^{-6} G within the galaxies"

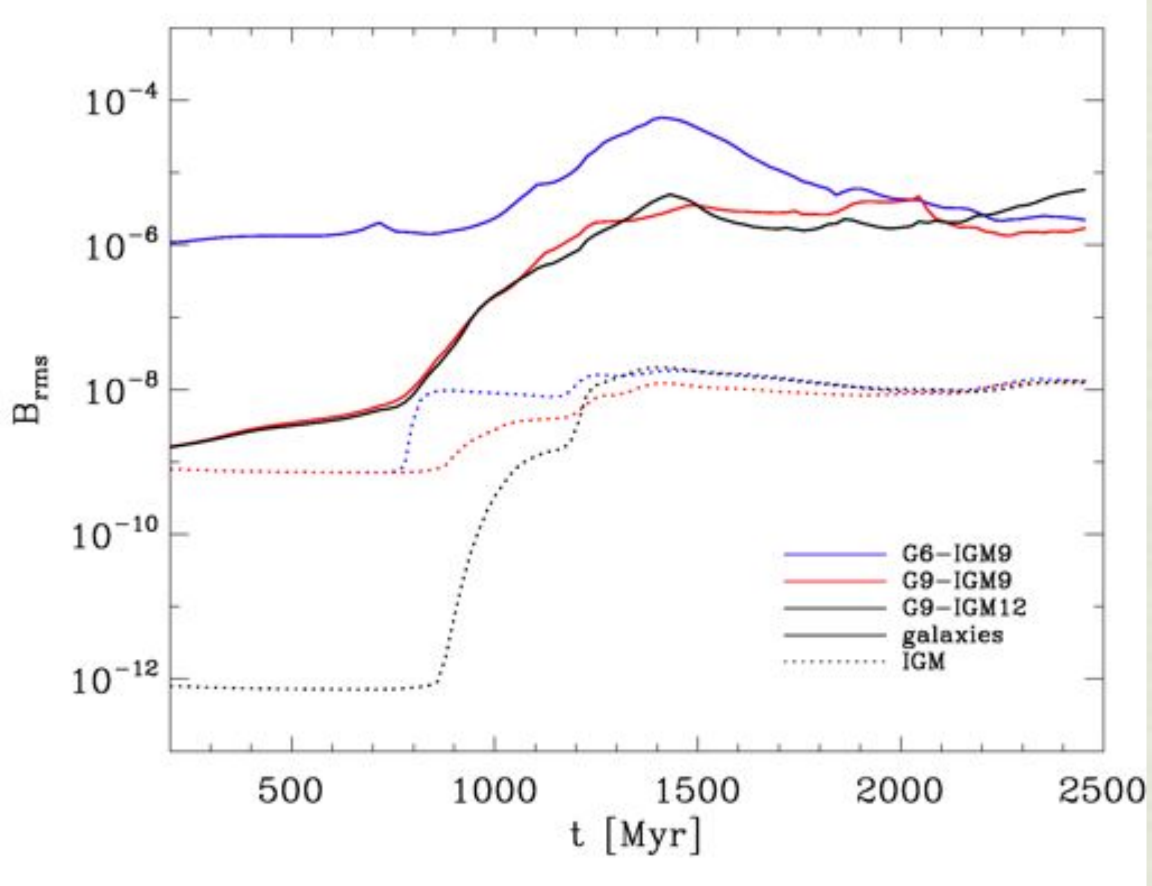
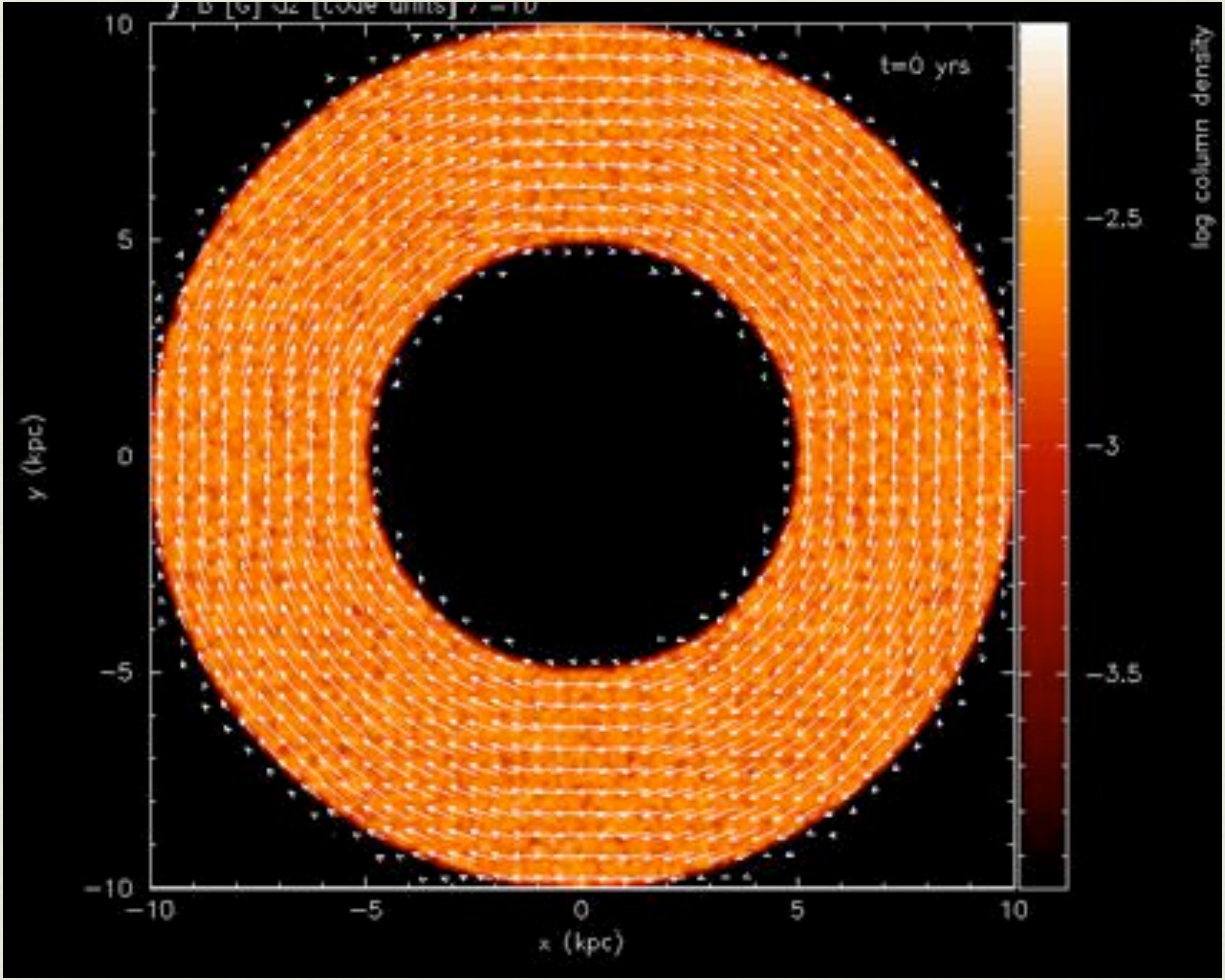
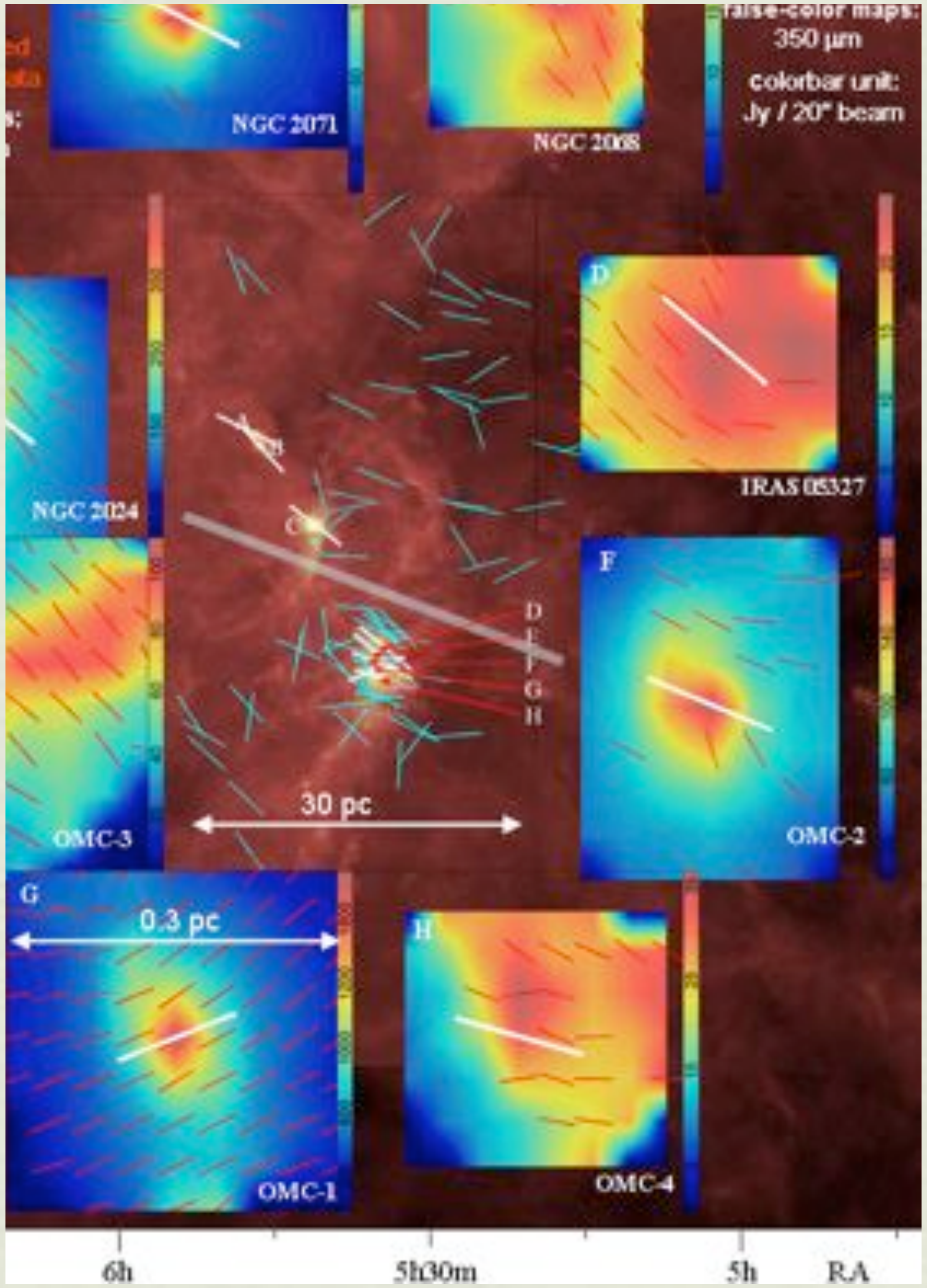


Figure 11. $B_{\rm rms} = \sqrt{\langle B^2 \rangle}$ as a function of time for the G6-IGM9 scenario (blue lines), the G9-IGM9 scenario (red lines), and the G9-IGM12 scenario (black lines). We separately show the IGM values (dotted lines) and the values inside the galaxies (solid lines). We distinguish between the IGM and the galaxies applying a density threshold of 10^{-29} g cm^{-3}. The final values for the galactic and the IGM magnetic field, respectively, are the same within all scenarios.

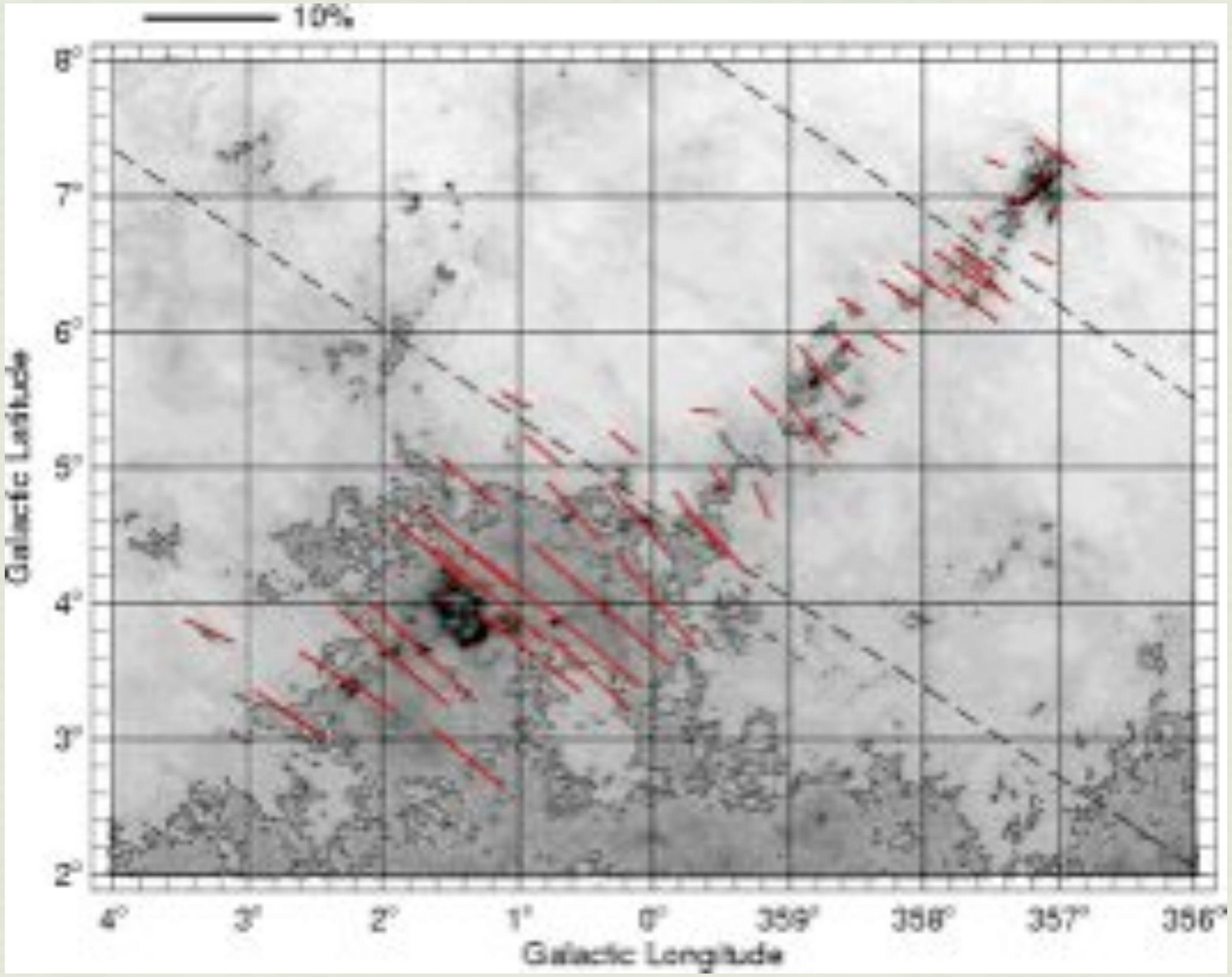

t=0 yrs
log column density
−2.5
−3
−3.5
y (kpc)
10
5
0
−5
−10
x (kpc)
−10
−5
0
5
10

Orion

Pipe Nebula



Li et al. (2009)

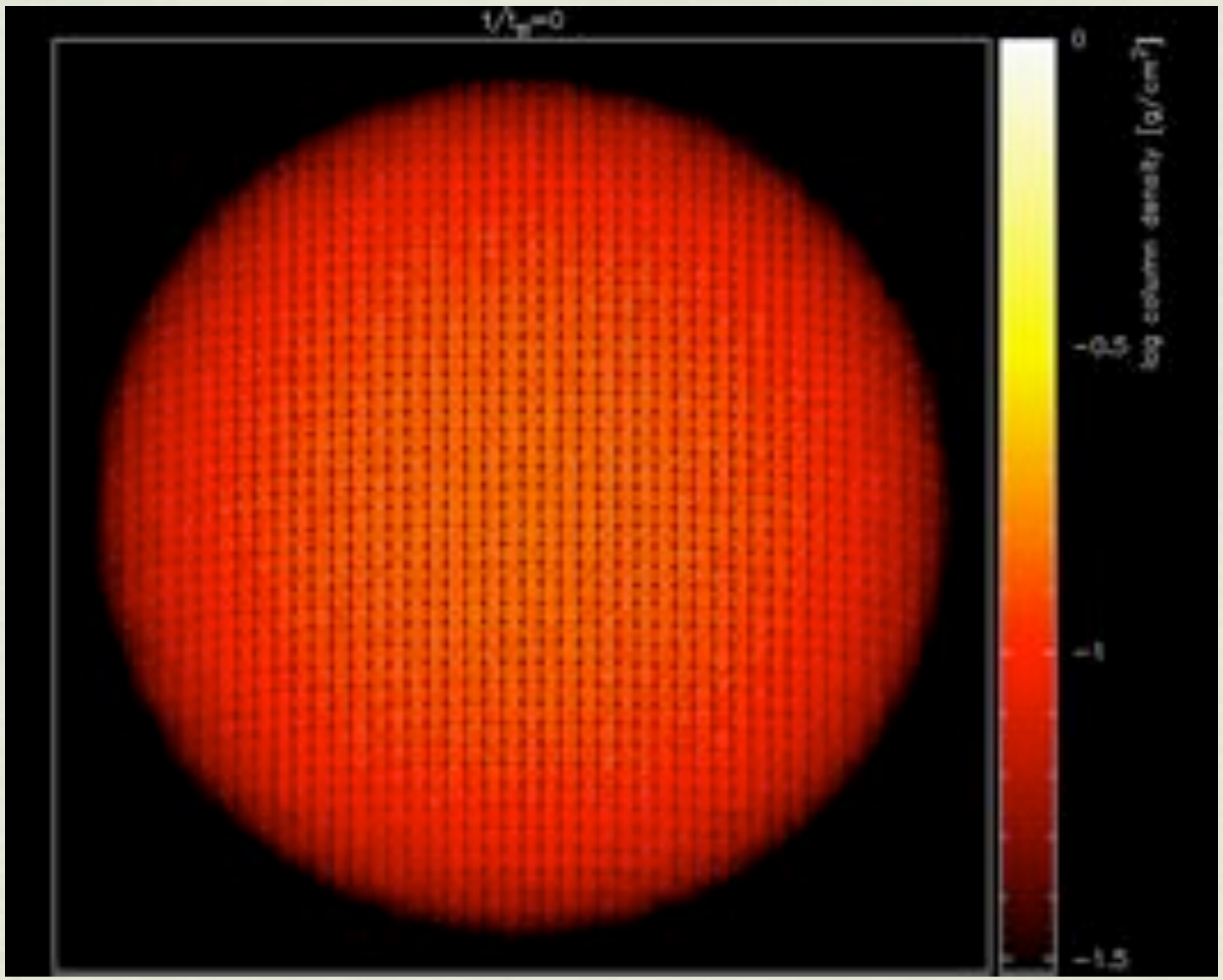


Alves et al. (2008)

what do magnetic fields change about the star formation process?

Magnetic fields in star cluster formation

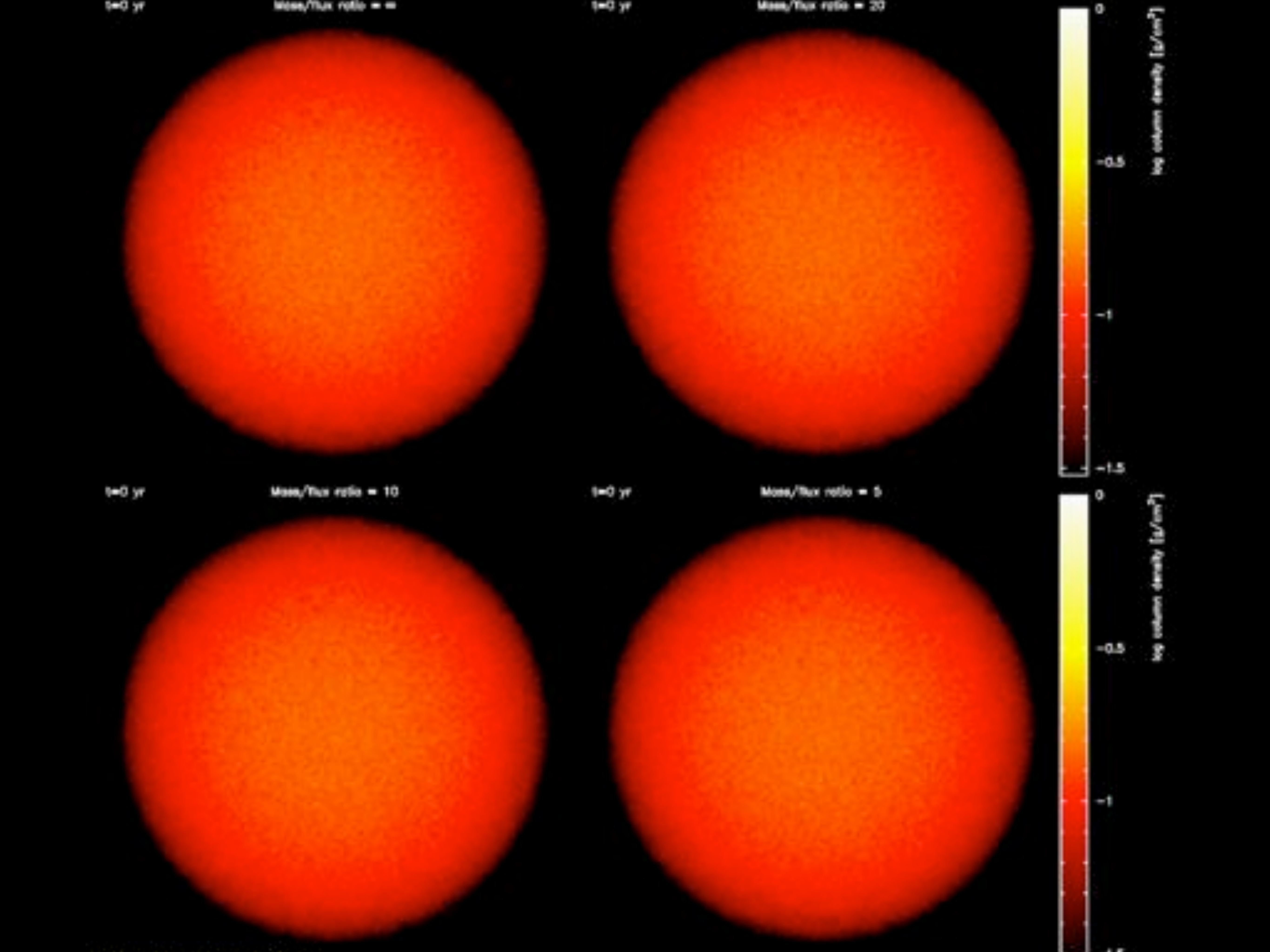
Price & Bate (2008)



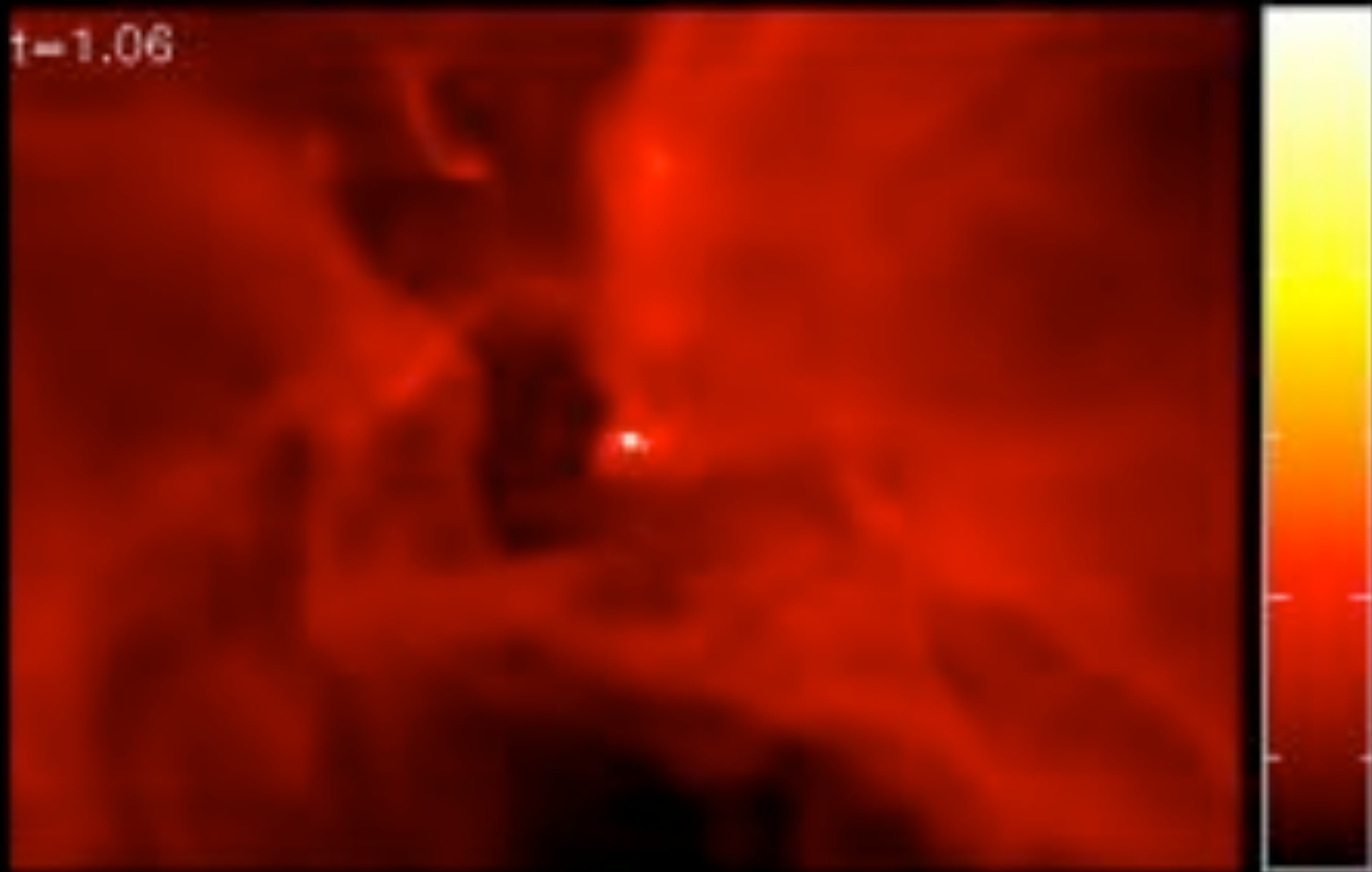
- 50 solar mass cloud
- diameter 0.375 pc, $n_{H2} = 3.7 \times 10^4$
- initial uniform B field
- T=10K
- turbulent velocity field $P(k) \propto k^{-4}$
- RMS Mach number 6.7
- barotropic equation of state

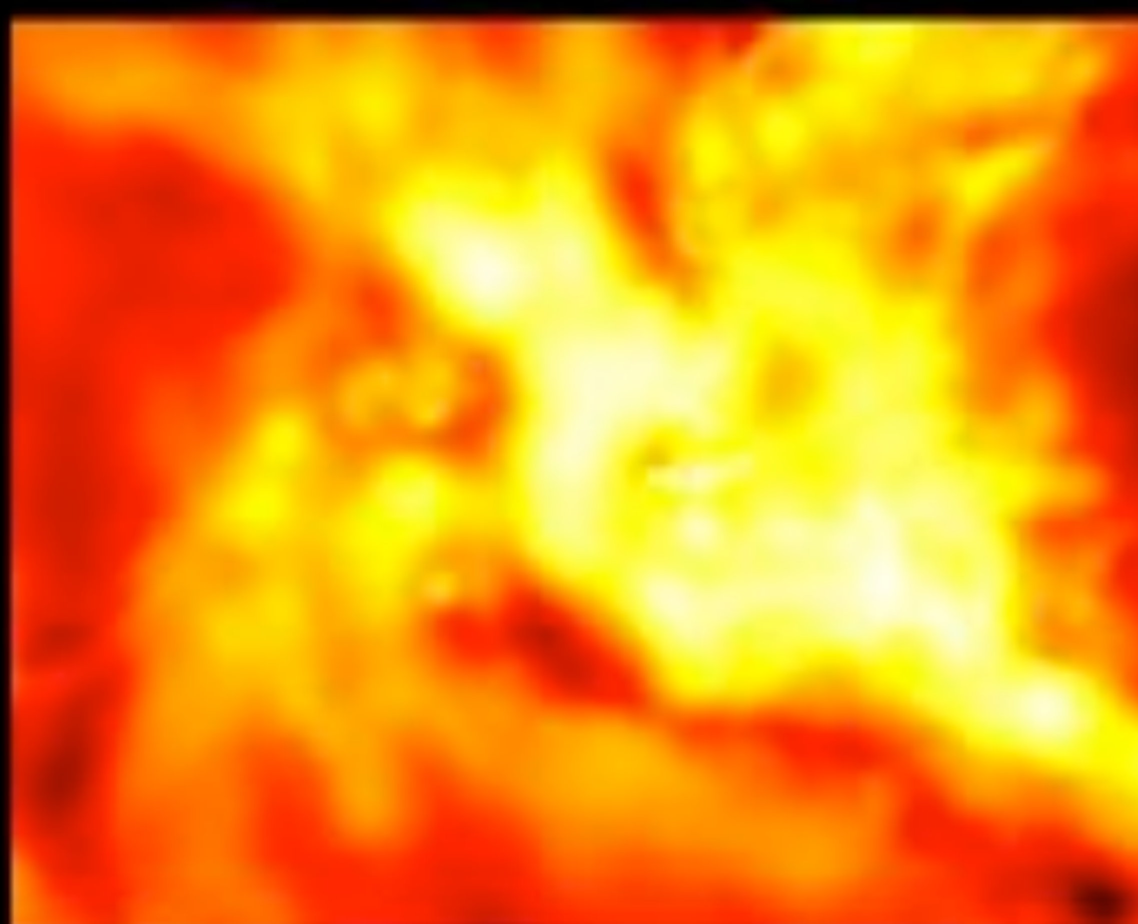
Magnetised version of Bate, Bonnell & Bromm (2003)

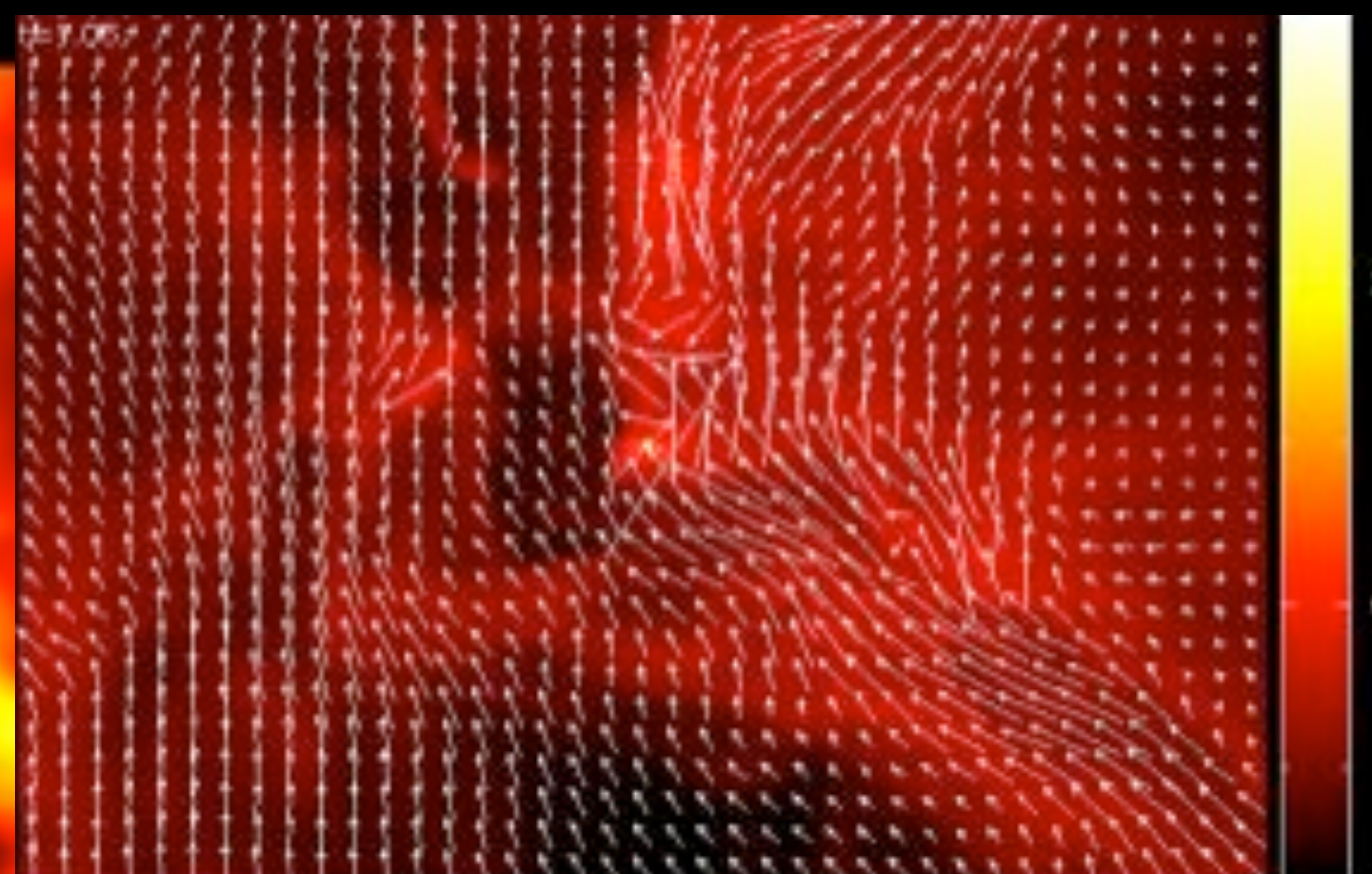
vary magnetic field strength...


t=0 yr
Mass/flux ratio = ∞
t=0 yr
Mass/flux ratio = 20
t=0 yr
Mass/flux ratio = 10
t=0 yr
Mass/flux ratio = 5
log column density [g/cm^2]
0
−0.5
−1
−1.5

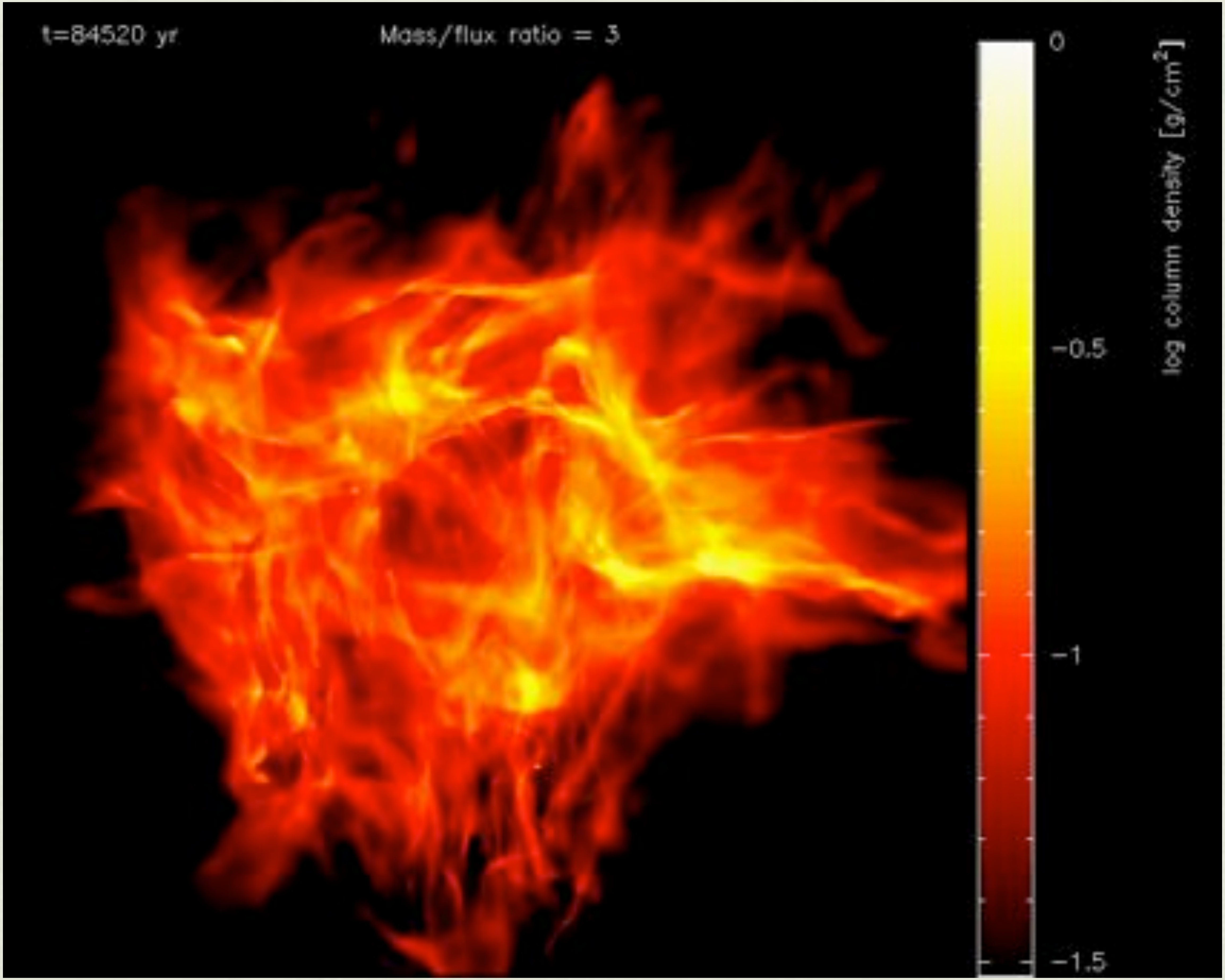
Magnetic cushioning in voids

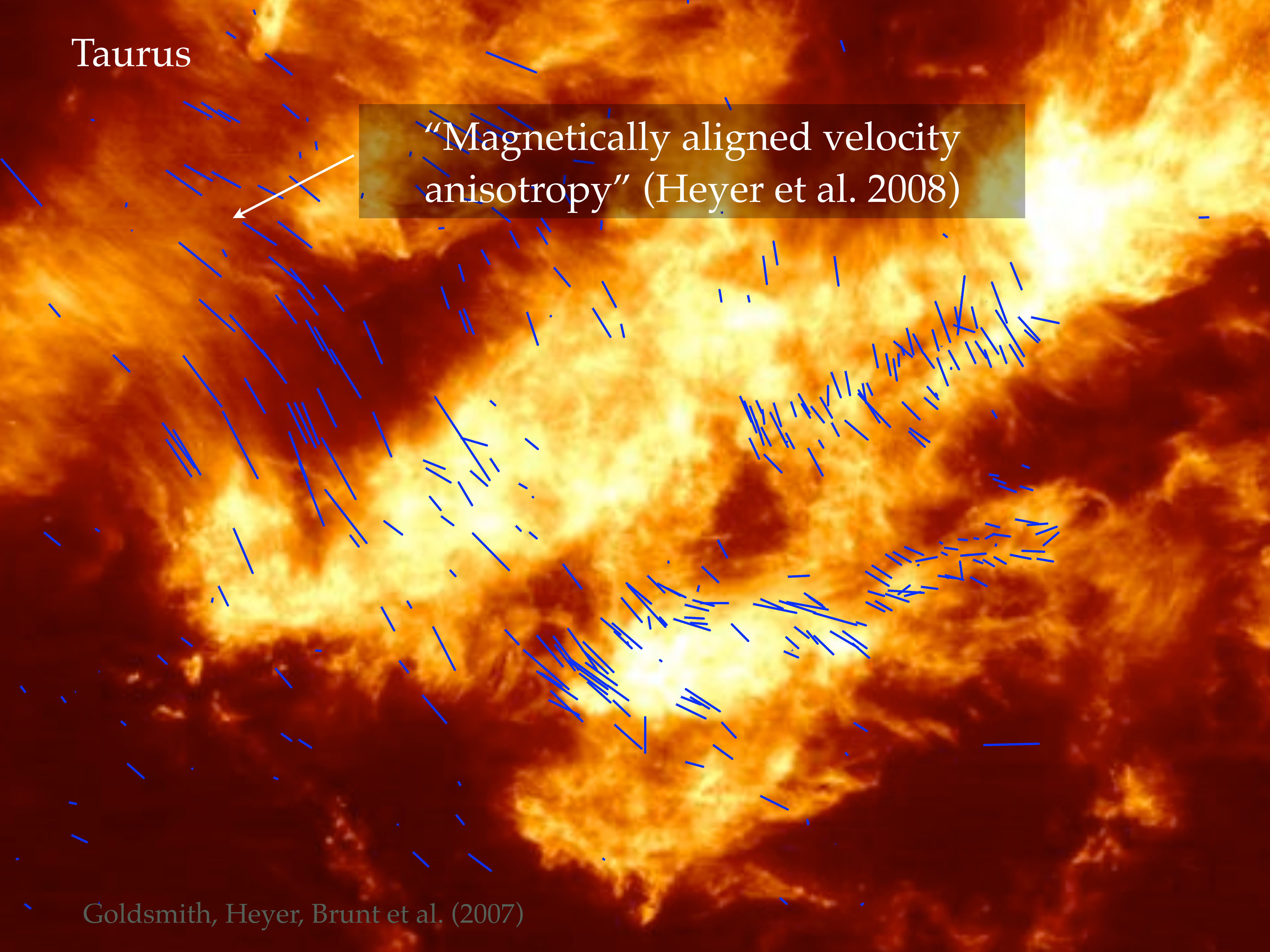






even stronger field...




Taurus
“Magnetically aligned velocity anisotropy” (Heyer et al. 2008)
Goldsmith, Heyer, Brunt et al. (2007)

Riegel-Crutcher Cloud (McClure-Griffiths et al. 2006)

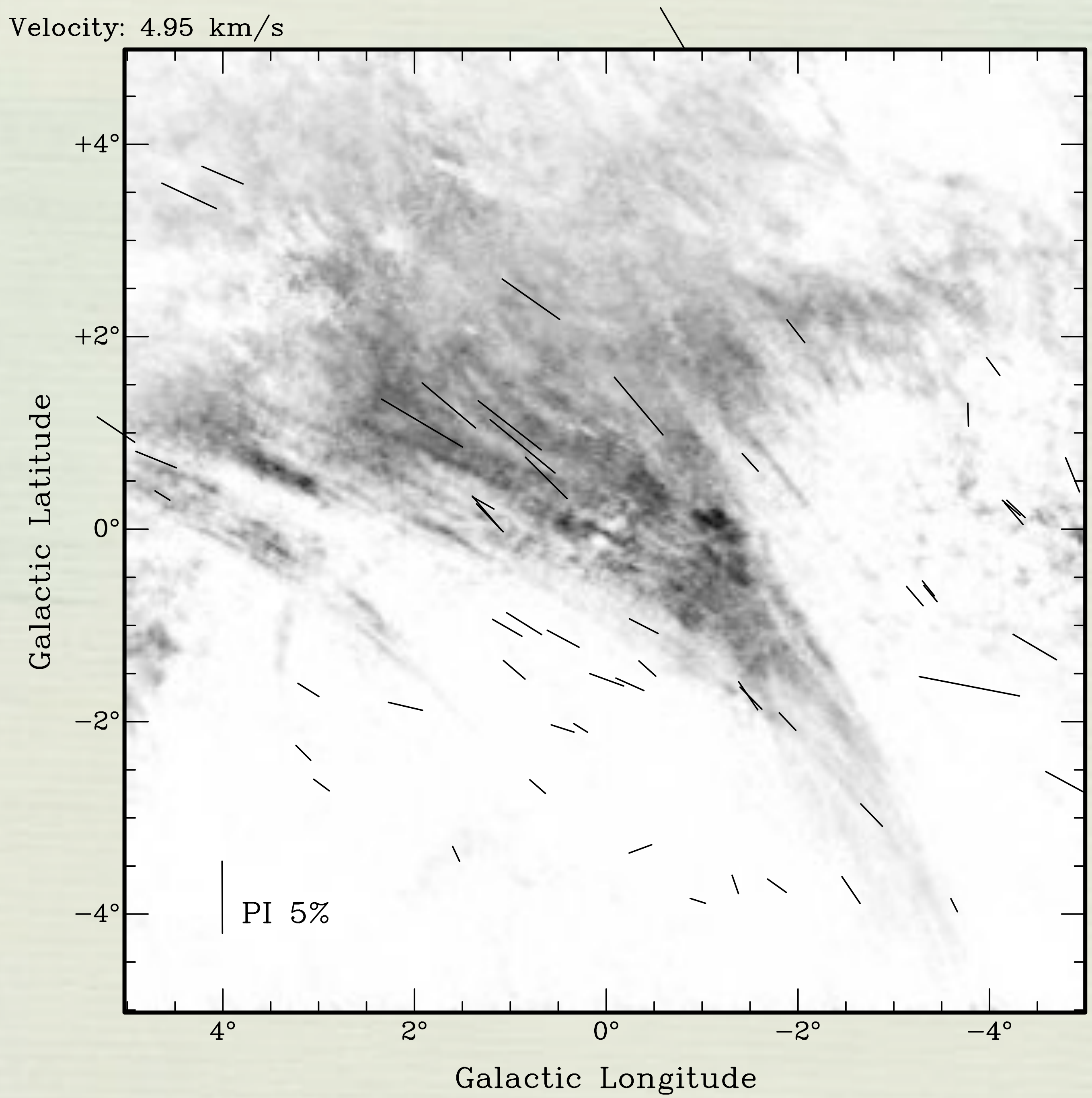


FIG. 6.—H I image of the R-C cloud at $v = 4.95$ km s^{-1} overlaid with vectors of stellar polarization from Heiles (2000). The measured polarization vectors are aligned with the magnetic field direction. The length of the vectors is proportional to the measured fractional polarized intensity, with the scale given by the 5% fractional polarized intensity vector shown by the scale of the vector in the bottom left corner.

ALMA

...seeing the first core a key target of ALMA

THE ASTROPHYSICAL JOURNAL, 742:1 (11pp), 2011 November 20 doi:10.1088/0004-637X/742/1/1

DETECTION OF A BIPOLAR MOLECULAR OUTFLOW DRIVEN BY A CANDIDATE FIRST HYDROSTATIC CORE

MICHAEL M. DUNHAM[1], XUEPENG CHEN[1], HÉCTOR G. ARCE[1], TYLER L. BOURKE[2], SCOTT SCHNEE[3], AND MELISSA L. ENOCH[4]
[1] Department of Astronomy, Yale University, P.O. Box 208101, New Haven, CT 06520, USA; michael.dunham@yale.edu
[2] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[3] National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903, USA
[4] Department of Astronomy, University of California at Berkeley, 601 Campbell Hall, Berkeley, CA 94720, USA
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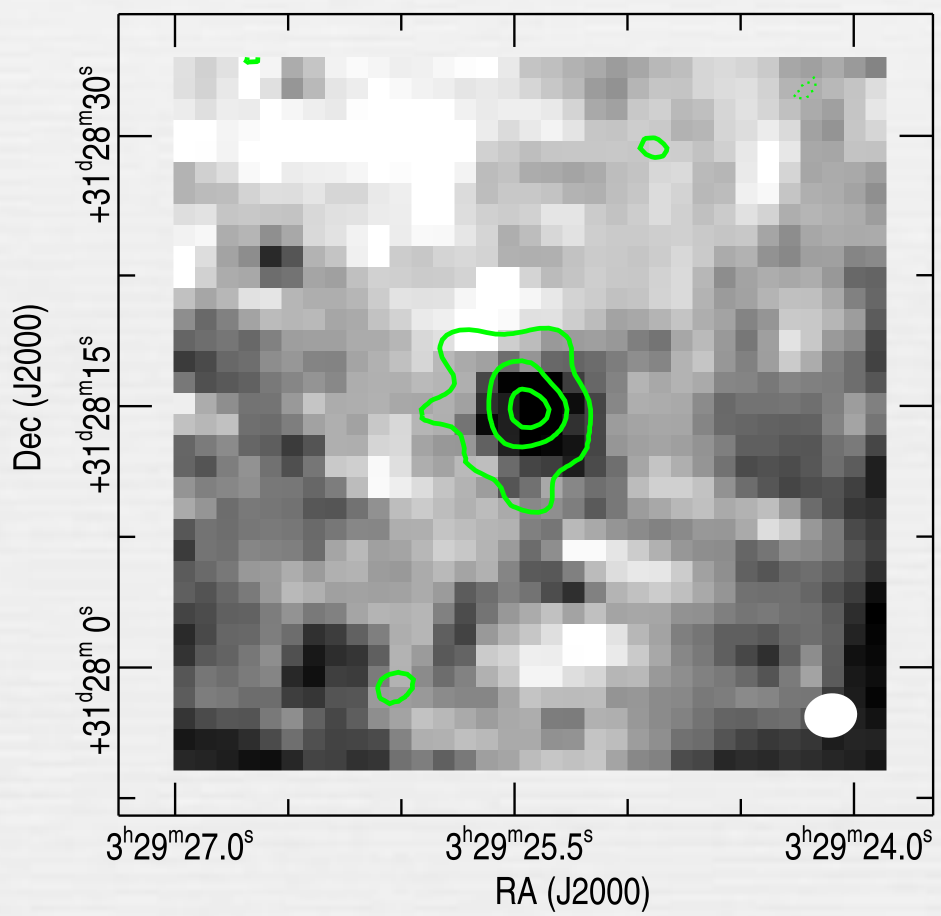
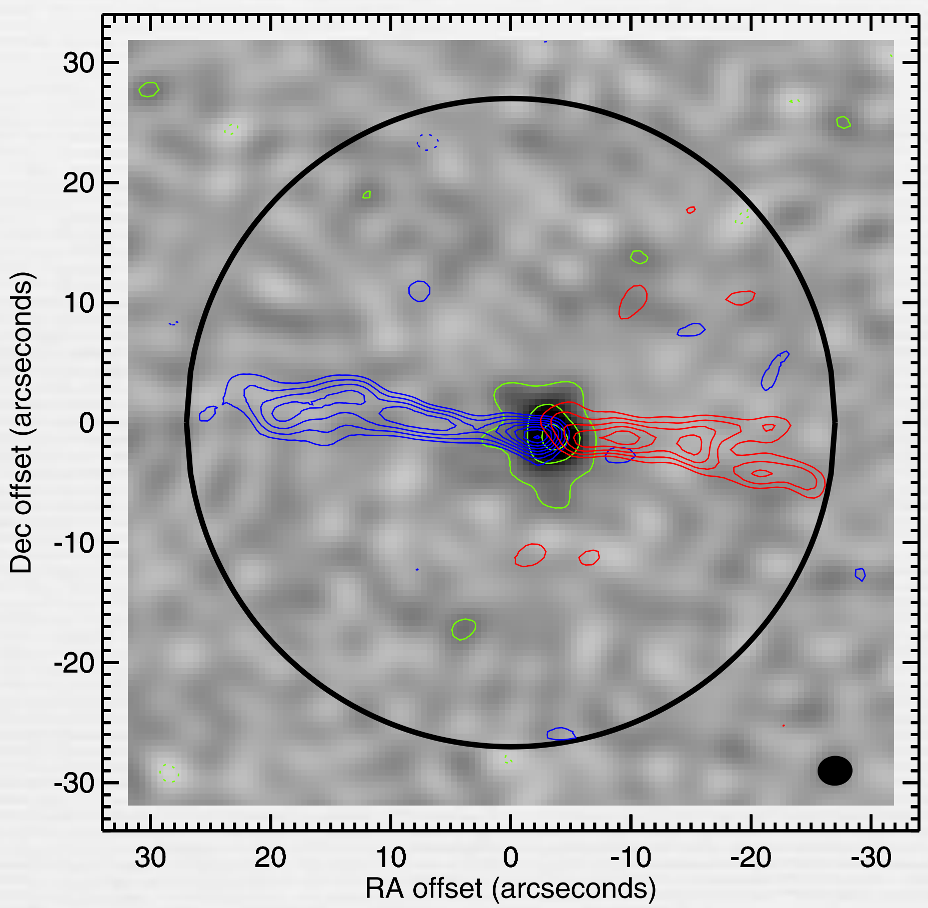




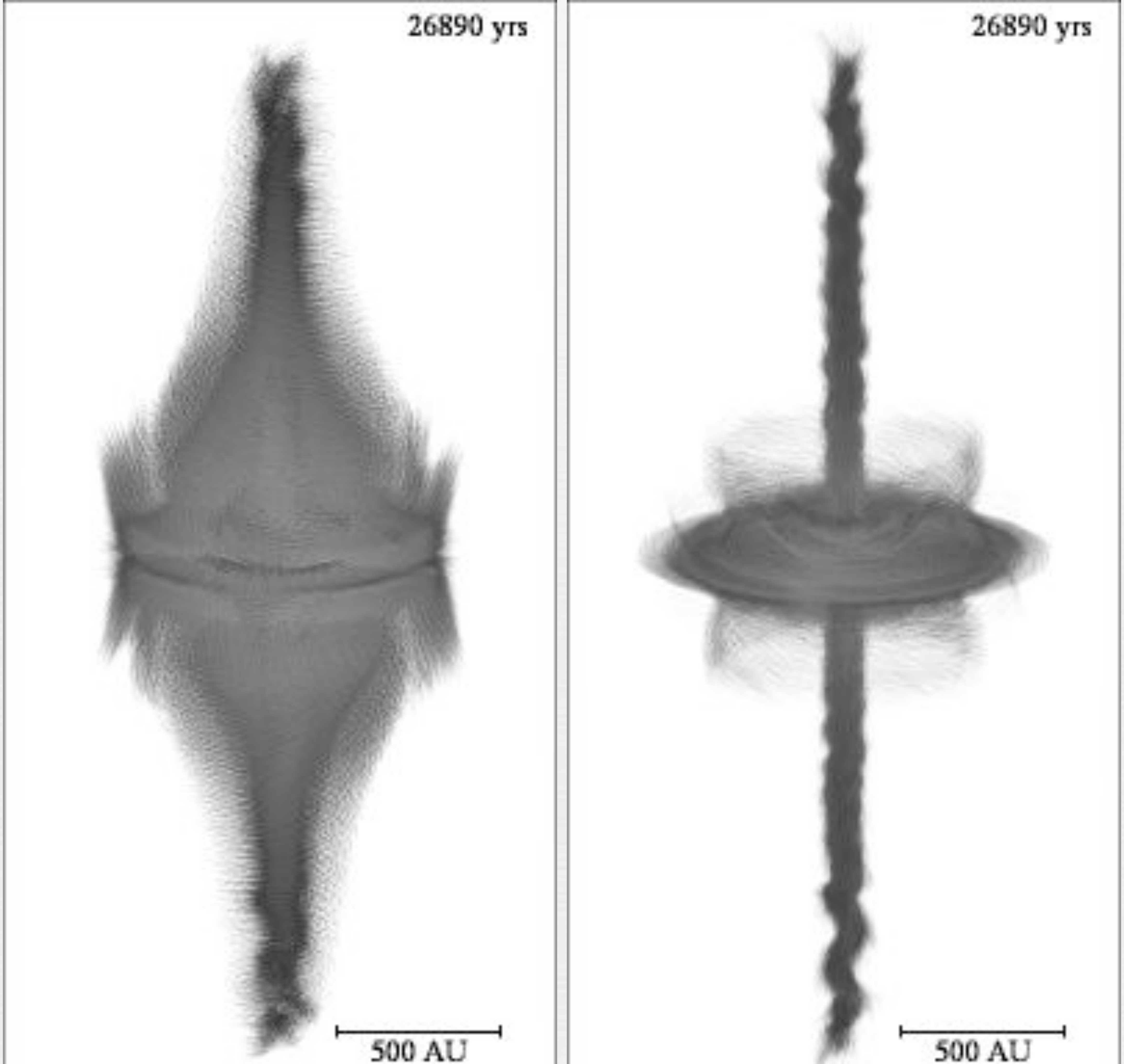
~1 solar mass core

The outflow is slow (characteristic velocity of 2.9 km s−1), shows a jet-like morphology (opening semi-angles ~8○ for both lobes), and extends to the edges of the primary beam.

^{12}CO J = 2–1 emission integrated from 0.3 to 7.3 km s^{-1}, while the red contours show redshifted emission integrated from 7.3 to 14.3 km s^{-1}. The solid blue

Price, Tricco & Bate (2012)


0 yrs
1
0
-1
log column density [g/cm


26890 yrs
500 AU
26890 yrs
500 AU

Summary

- can perhaps explain magnetic fields in galaxies by purely dynamical effects
- magnetic fields important as a source of pressure in ISM
- magnetic fields affect molecular cloud structure and dynamics, perhaps controlling star formation rate/efficiency even in turbulent clouds
- magnetic fields produce some of the most beautiful phenomena in astrophysics!