

# MHD & Dynamos



morning discussion

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# Magnetic fields - I.

- source of extra pressure (ie. support)

$$\frac{d\mathbf{v}}{dt} = -\frac{\nabla P}{\rho} + \frac{\mathbf{J} \times \mathbf{B}}{\mu_0 \rho}$$

$$\frac{d\mathbf{v}}{dt} = -\frac{1}{\rho} \nabla \cdot \left[ \left( P + \frac{1}{2} \frac{B^2}{\mu_0} \right) \mathbf{I} - \frac{\mathbf{B}\mathbf{B}}{\mu_0} \right]$$

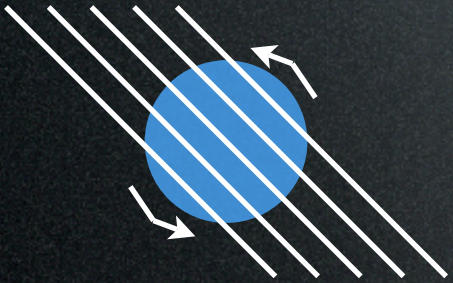
isotropic pressure  
(same in all directions)

anisotropic tension force  
(perpendicular to magnetic field)

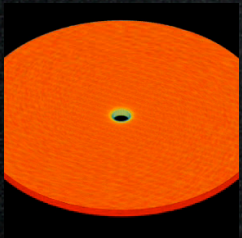


# Magnetic fields - II.

transport angular momentum:



- magnetic braking
- jets and outflows
- magneto-rotational instability in discs (Balbus/Hawley)





# Key parameters

$$\left(\frac{M}{\Phi}\right) / \left(\frac{M}{\Phi}\right)_{crit} \quad \text{magnetic field vs gravity}$$

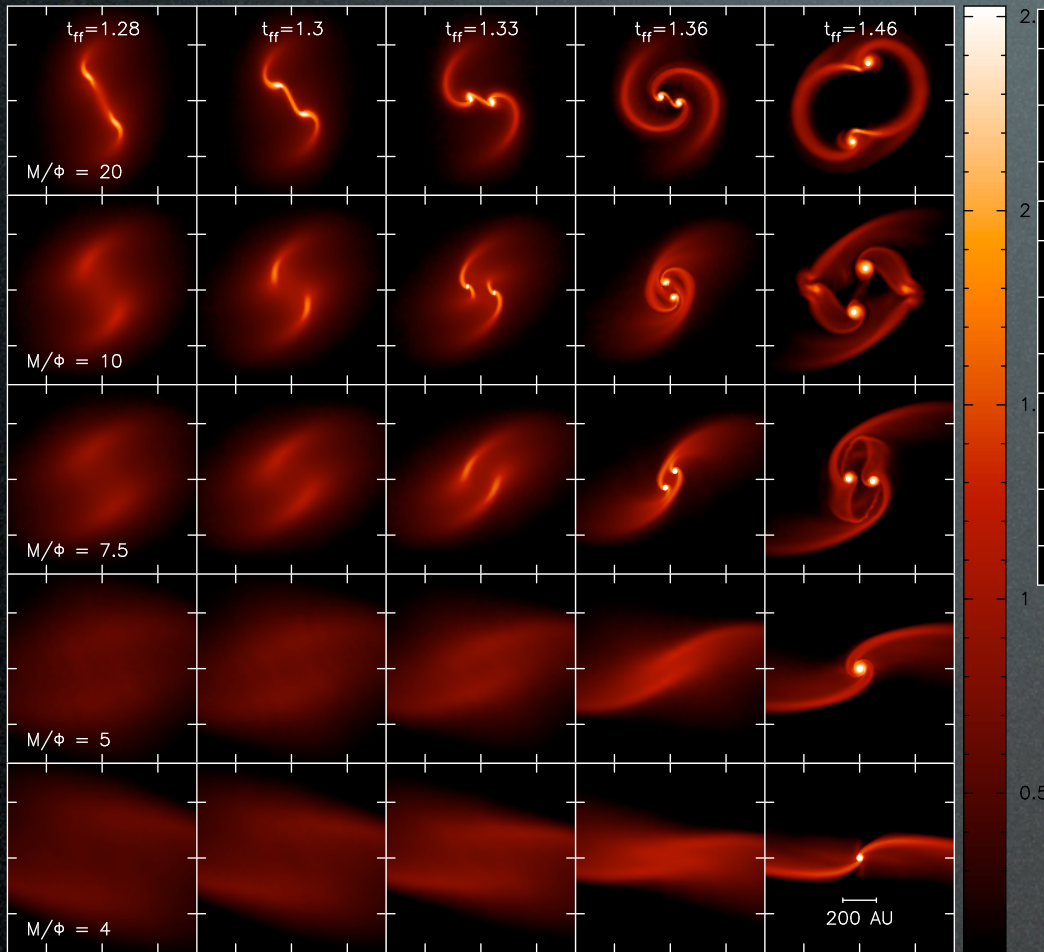
$$\beta = \frac{c_s^2 \rho}{\frac{1}{2} B^2 / \mu_0} \quad \text{magnetic fields vs pressure}$$

$$\frac{v_{turb}}{v_{Alfven}} \quad \text{magnetic fields vs turbulence}$$

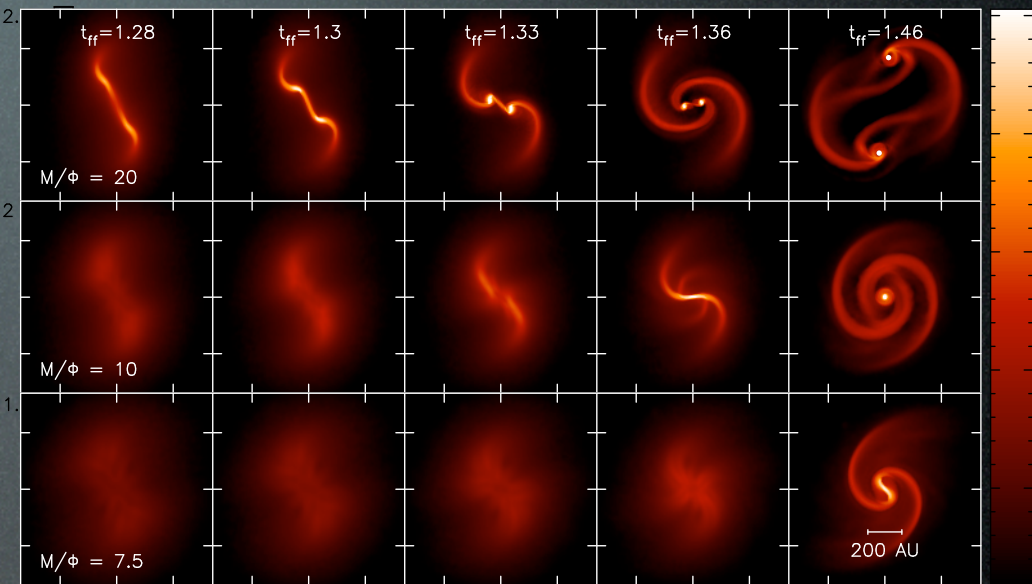


# Pressure vs tension

full MHD ( $B_x$  field)



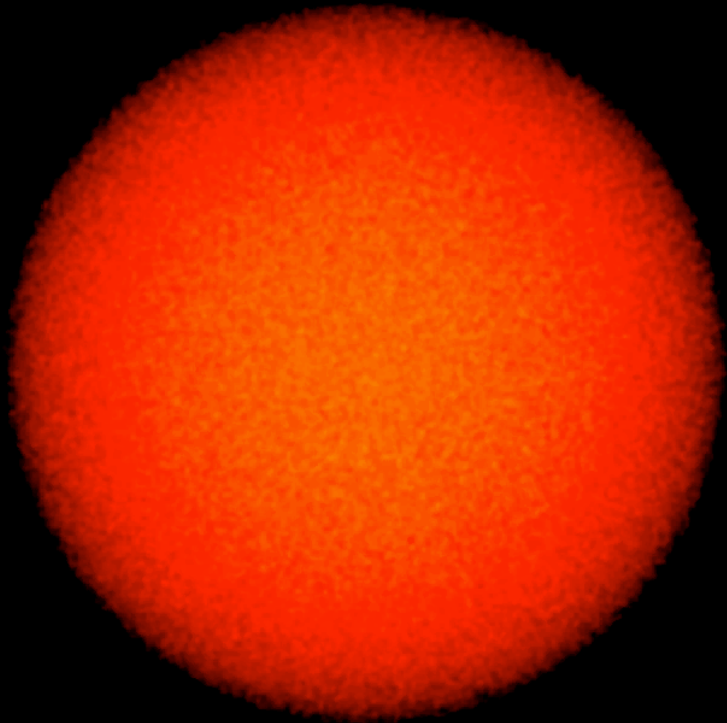
mag pressure only





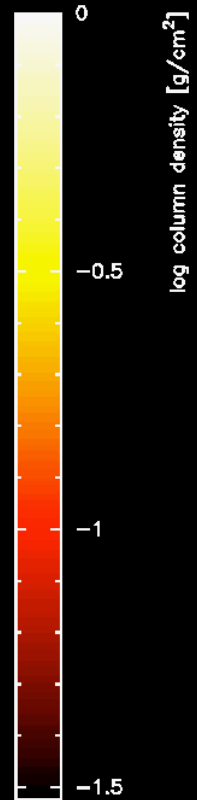
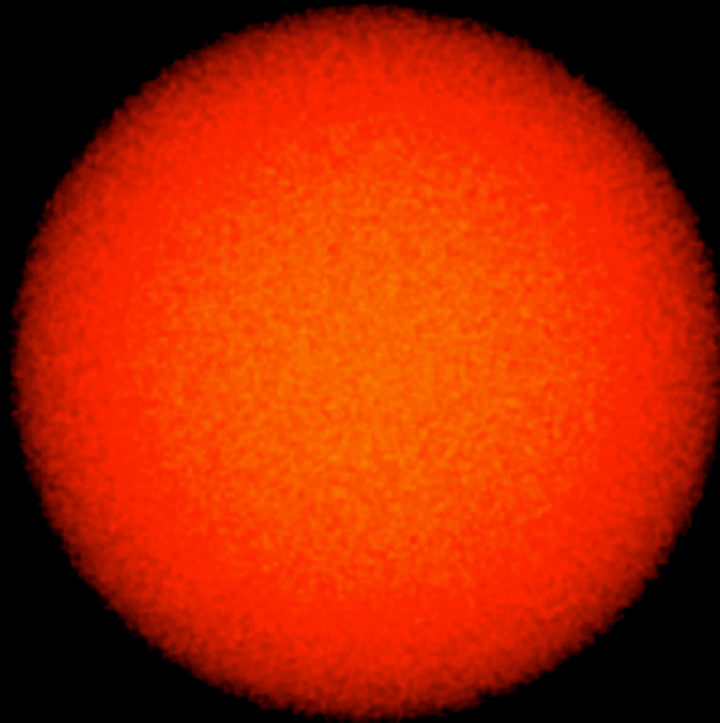
t=0 yr

Mass/flux ratio =  $\infty$



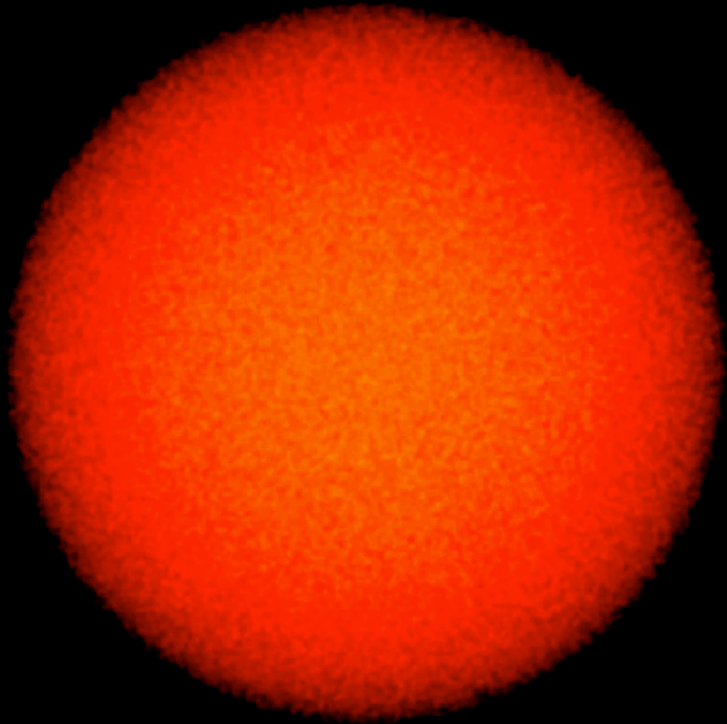
t=0 yr

Mass/flux ratio = 20



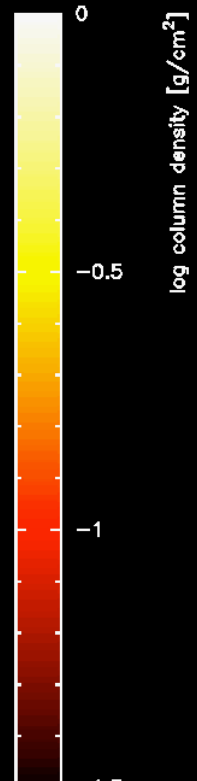
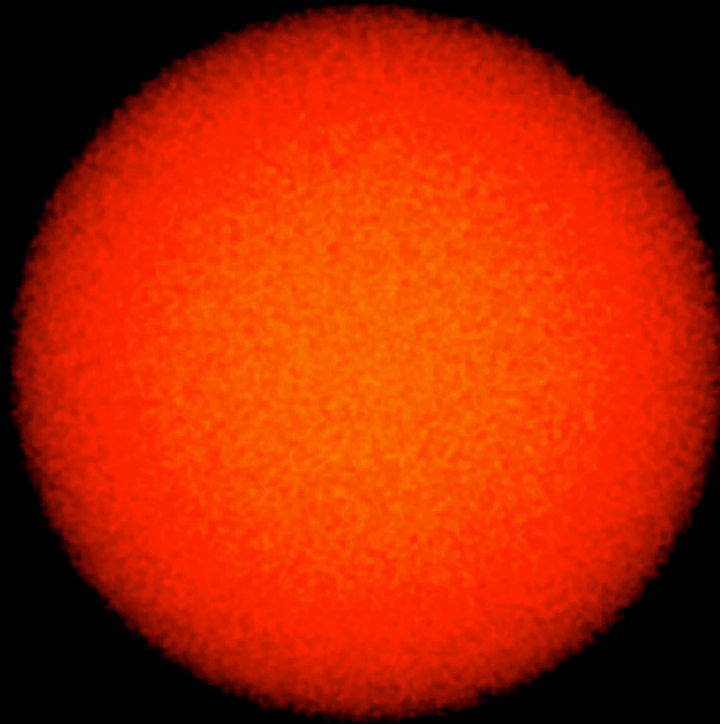
t=0 yr

Mass/flux ratio = 10



t=0 yr

Mass/flux ratio = 5





# Theoretical questions

1) What is the effect of magnetic fields on fragmentation? suppress or enhance? effect on IMF?

2) Role of magnetic pressure vs magnetic tension? extra support, magnetic braking, magnetic cushioning.

3) Magnetic fields -> outflow connection? what are the necessary ingredients for outflow production?

4) What are the effects of magnetic fields on the star formation rate/efficiency? support of low density regions, suppression of accretion, generation of outflows.

5) What are the important numerical issues to get right? resolution criterion for MHD?

6) Importance of non-ideal effects? ambipolar...hall...resistive. In what order?



# Observational questions

1) In which magnetic regime are local molecular clouds? super/sub critical, super/sub Alfvénic,  $\beta < 1$  or  $\beta > 1$ ?  
e.g. Crutcher, Bourke, Heiles etc.

2) Do magnetic fields have an observable effect on molecular cloud morphology and/or kinematics?  
magnetically supported voids? anisotropic turbulent motions?  
column density striations? e.g. Taurus

3) What is the origin of magnetic fields in molecular clouds? turbulent dynamo or drop-out from galactic magnetic field?  
e.g. observations of Han & Zhang 2007



1) In which magnetic regime are local molecular clouds? super/sub critical, super/sub Alfvénic,  $\beta < 1$  or  $\beta > 1$ ?  
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## SUBCRITICAL

|             | super-Alfvénic | sub-Alfvénic |
|-------------|----------------|--------------|
| $\beta < 1$ | CNM            |              |
| $\beta > 1$ |                |              |

## SUPERCRITICAL

|             | super-Alfvénic | sub-Alfvénic |
|-------------|----------------|--------------|
| $\beta < 1$ | cores<br>GMCs? |              |
| $\beta > 1$ |                |              |

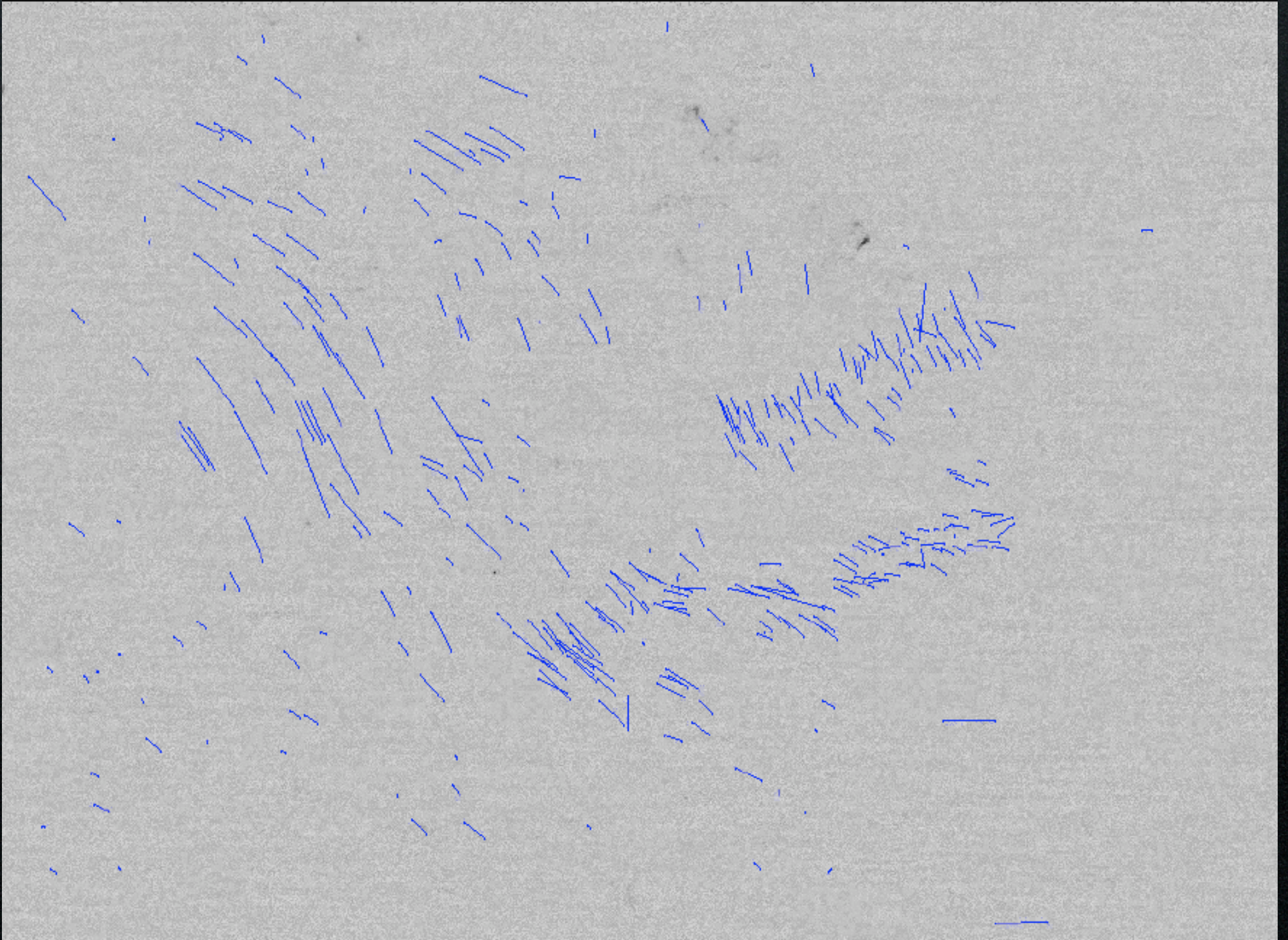


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# Taurus Molecular Cloud (Brunt/Heyer)





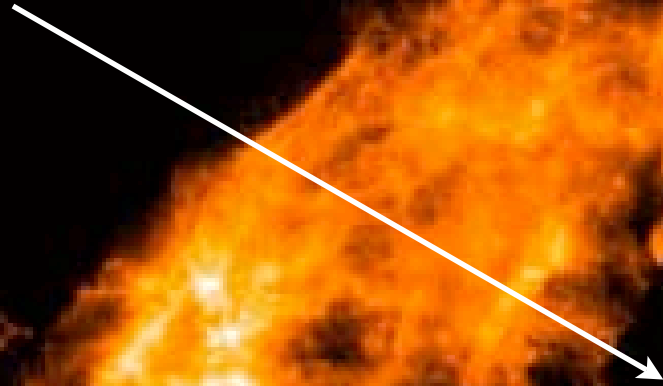


$^{12}\text{CO}$

Goldsmith, Heyer, Brunt et al. (2007)



“A hole...[where] it appears  
that some agent has been  
responsible for dispersing  
the molecular gas”

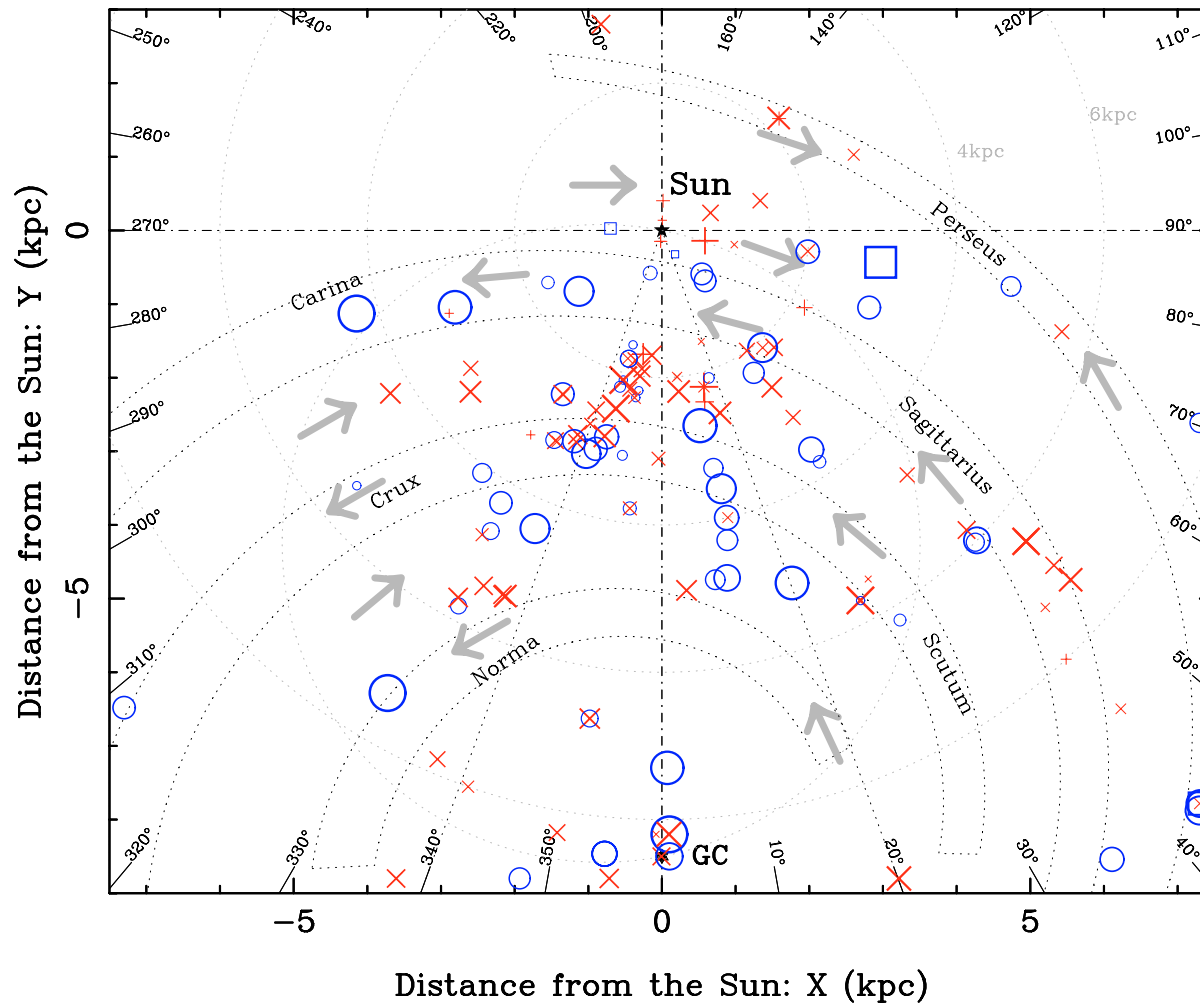


$^{13}\text{CO}$

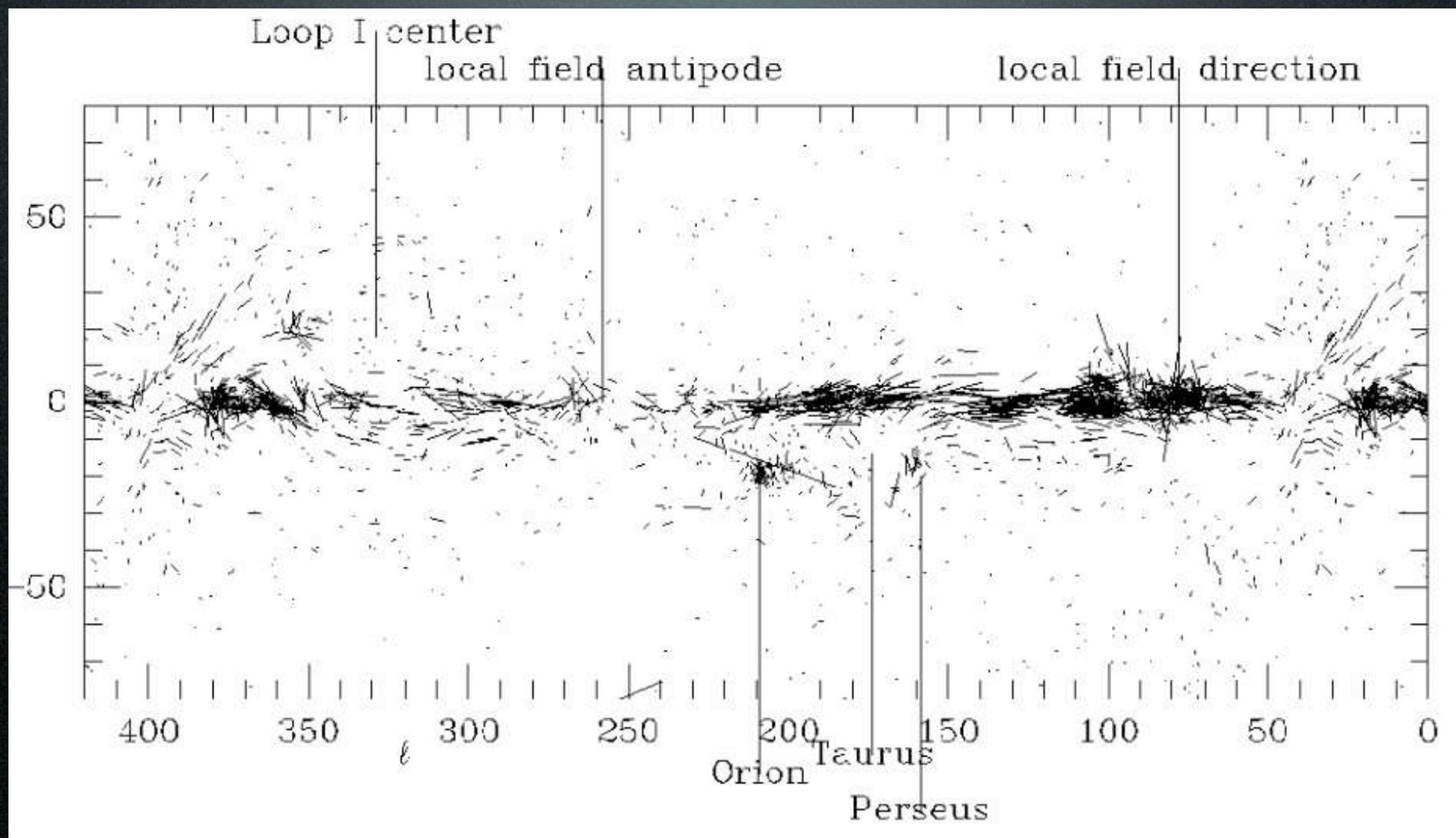


3) What is the origin of magnetic fields in molecular clouds? turbulent dynamo or drop-out from galactic magnetic field? e.g. observations of Han & Zhang 2007

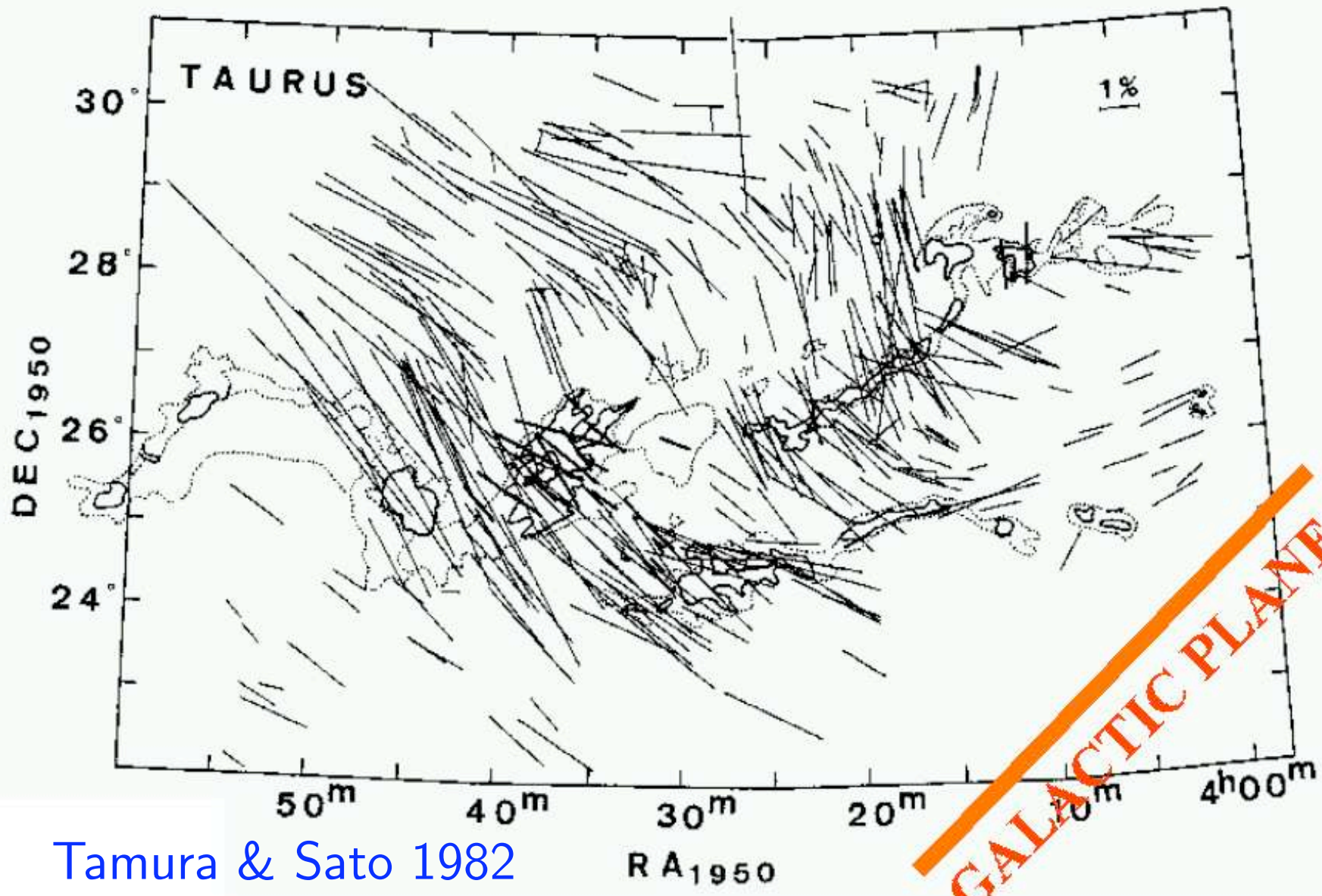
J. L. Han and J. S. Zhang: Magnetic fields in molecular clouds and HII regions











Tamura & Sato 1982



