

Dynamo action in the ISM

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Introduction

- Dynamo by SN driven turbulence,
- Disk setup (density, temperature, cooling, heating, gravitational potential)
- SN injection of thermal energy, clustered
- Rotation and shear is included
- Initial magnetic field
- with radial and azimuthal seed fields

Now vertical field seed fields

- Is there a magnetic net flux through the galaxy?
- Would that have implications for the dynamo?
- How would be the influence of the MRI ?
- IGM magnetic field $< 10^{-8} \text{G}$
- Galaxies in clusters with μG magnetic fields

vertical fields with and without net flux

Physics

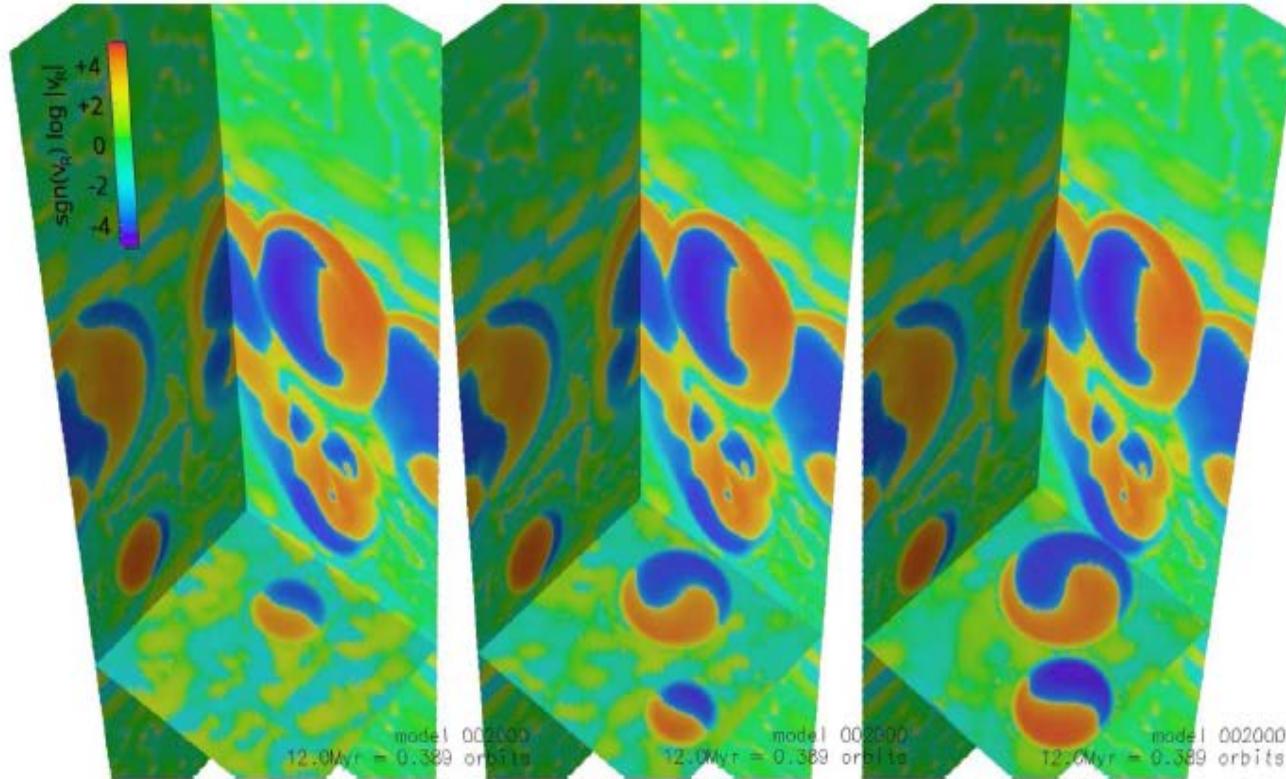
Model includes

viscosity, diffusivity, resistivity, thermal conductivity, optically thin heating and cooling.

Not considered

- Anisotropy of heat conduction
- Effects due to cosmic rays

Simulation box

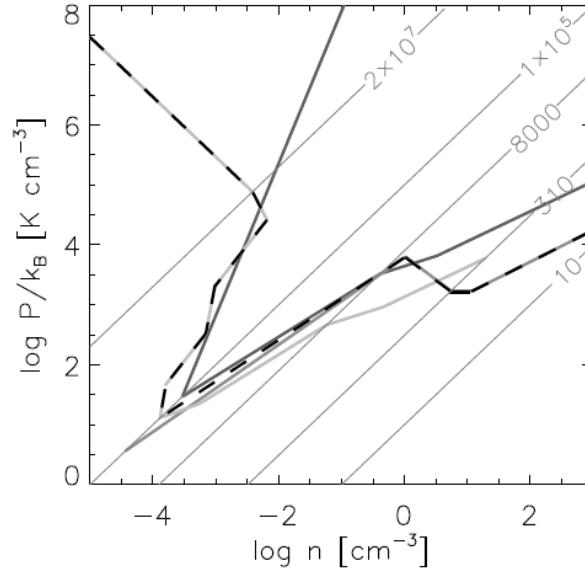
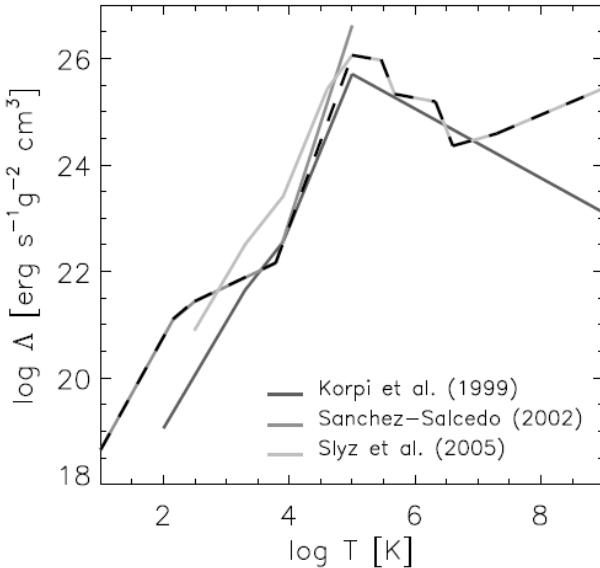


xy plane: 0.8 kpc x 0.8 kpc (96x96 grid cells)

Vertical size z: -2 kpc to 2 kpc (512 grid cells)

Heating and cooling

- SN, thermal energy injection
- Radiative cooling function
- Thermally unstable range
- Photo electric heating term



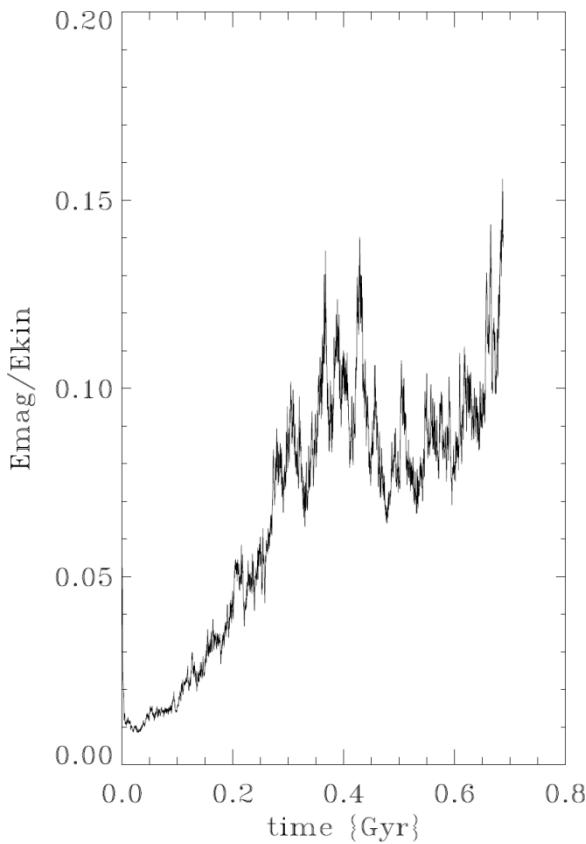
Thermally unstable range
141K to 6102K

Models

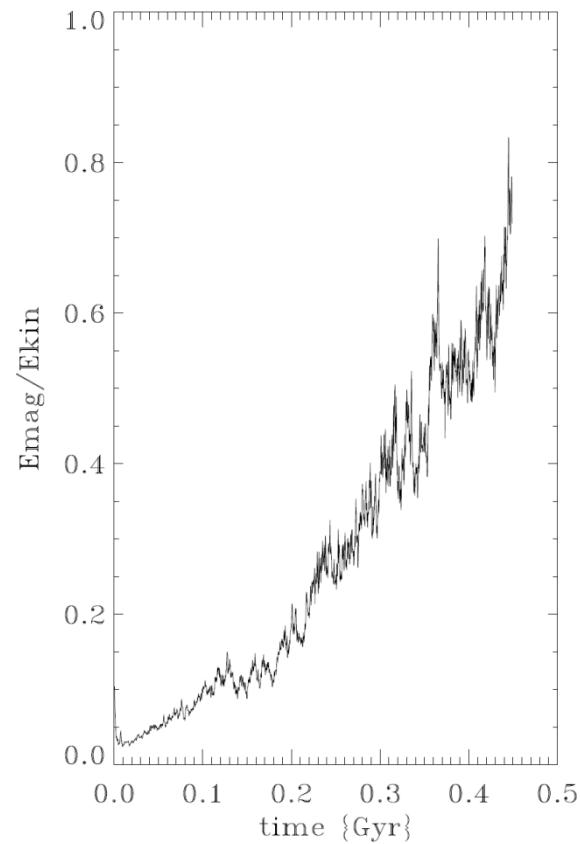
	M1	M2	M4	M5	M6
Time (Myr)	750	3300	620	450	550
Flux (μGcm^2)	0	0	10^{41}	10^{41}	10^{41}
SN rate (%)	25	0	0	25	50
B_{seed} (μG)	0.1	0.1	0.1	0.1	0.1
Growth time (Myr)	180	100	71	200	240
$E_{\text{mag}} : E_{\text{kin}}$	0.1	100	100 +	1+	1+
$\langle B \rangle_U$ (μG)	-0.05	-0.1	-1	0.3	0.3
$\langle B \rangle_L$ (μG)	0.01	-0.02	2.7	-0.3	-0.5
$B_{\text{mean}} : B_{\text{rms}}$	0.8	1	1	0.9	0.8

Evolution of magnetic field

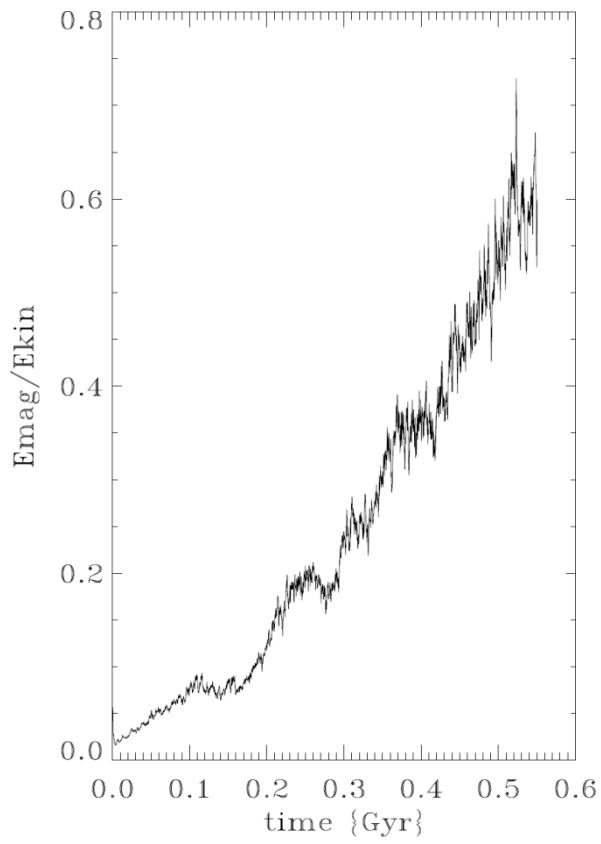
m1



m5



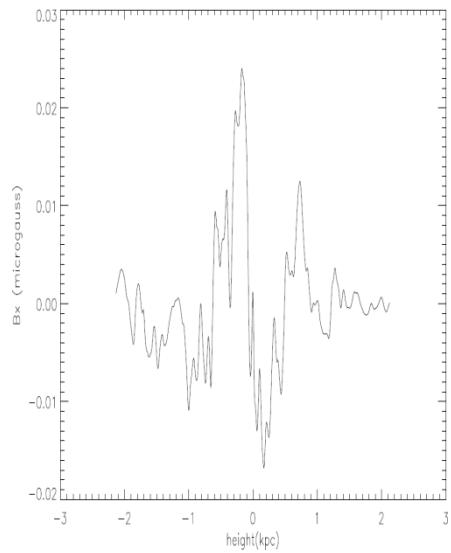
m6



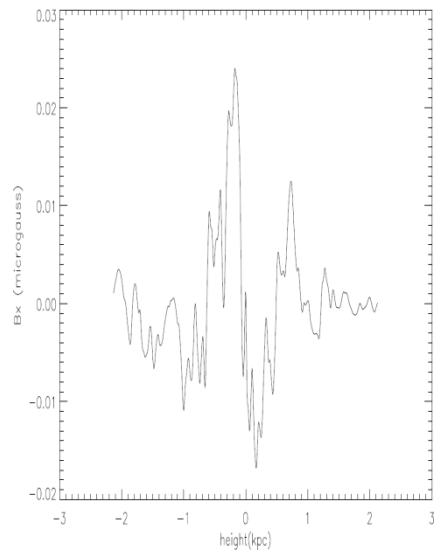
m1

<B_x>

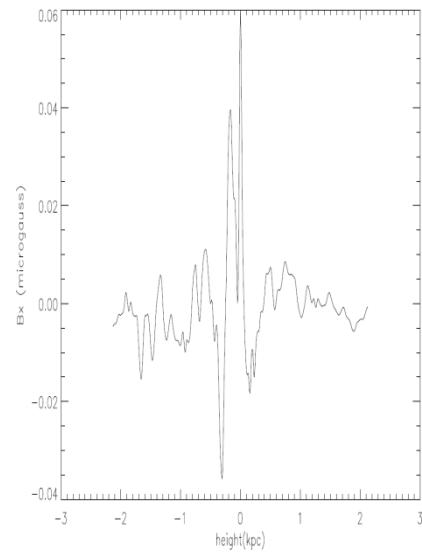
150



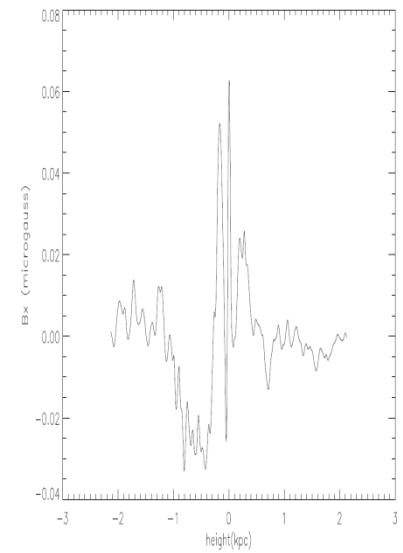
300



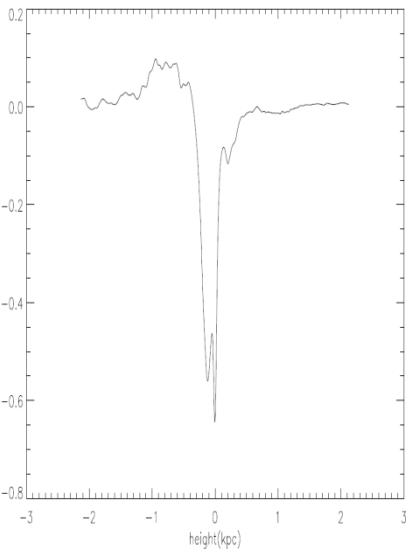
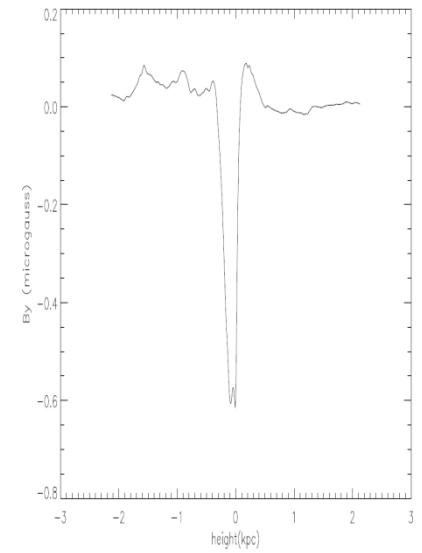
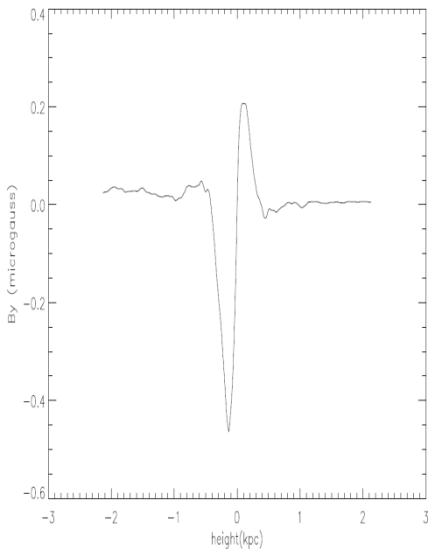
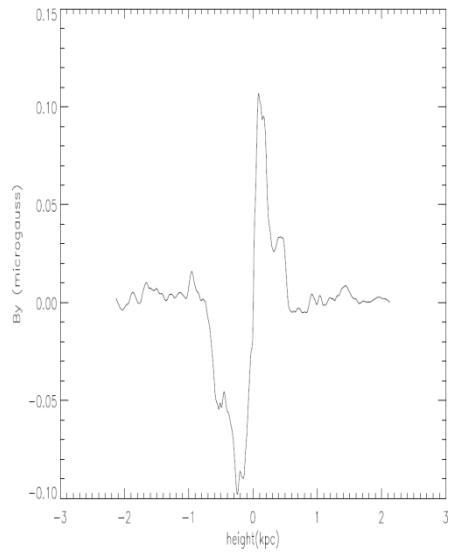
450



600



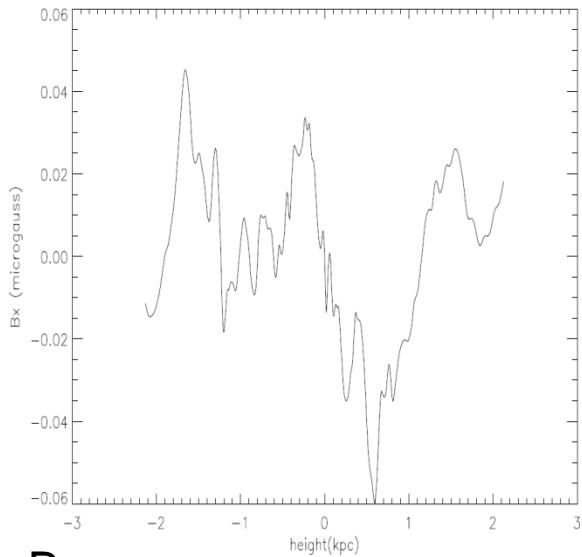
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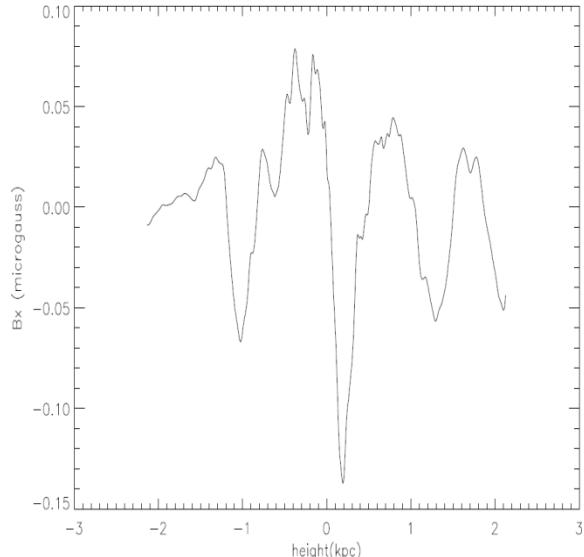
m5

Bx

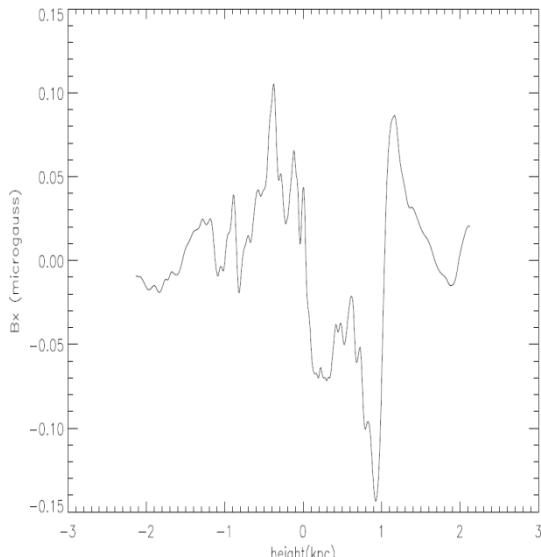
150



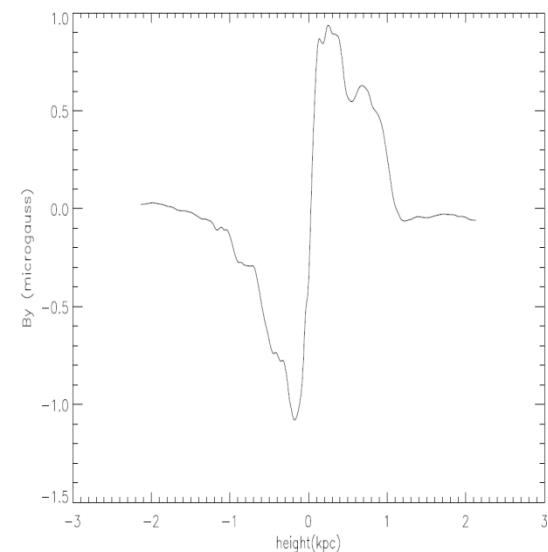
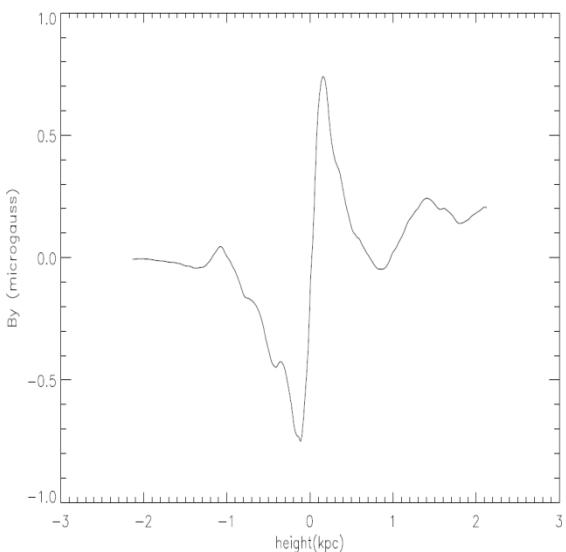
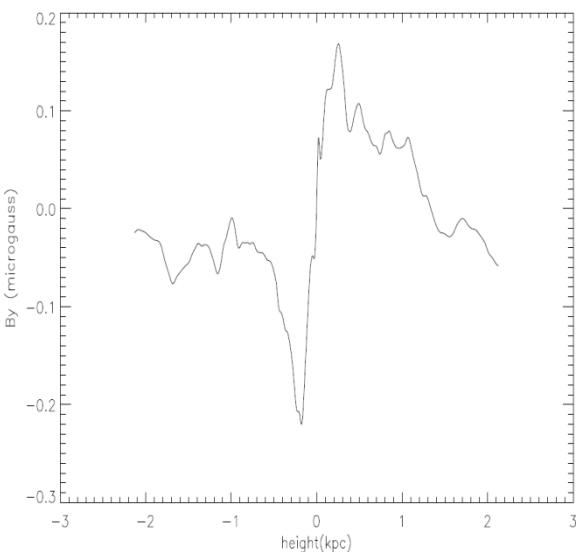
300



450

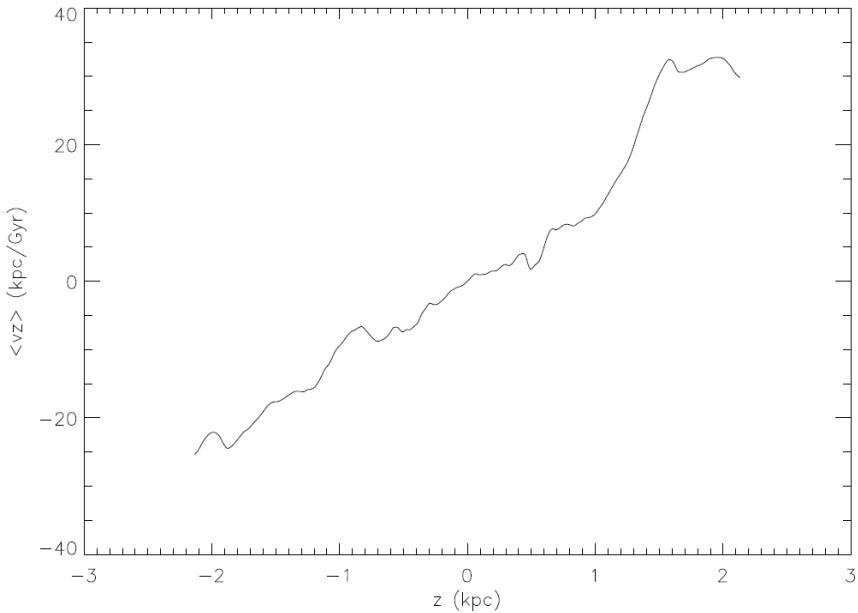


By

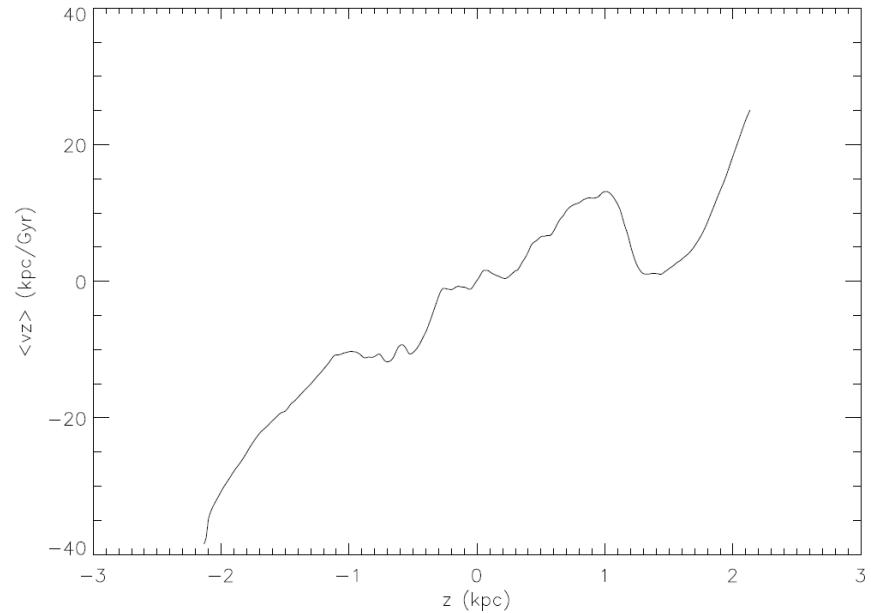


Galactic Wind

m1 (25% SN, zero net flux)

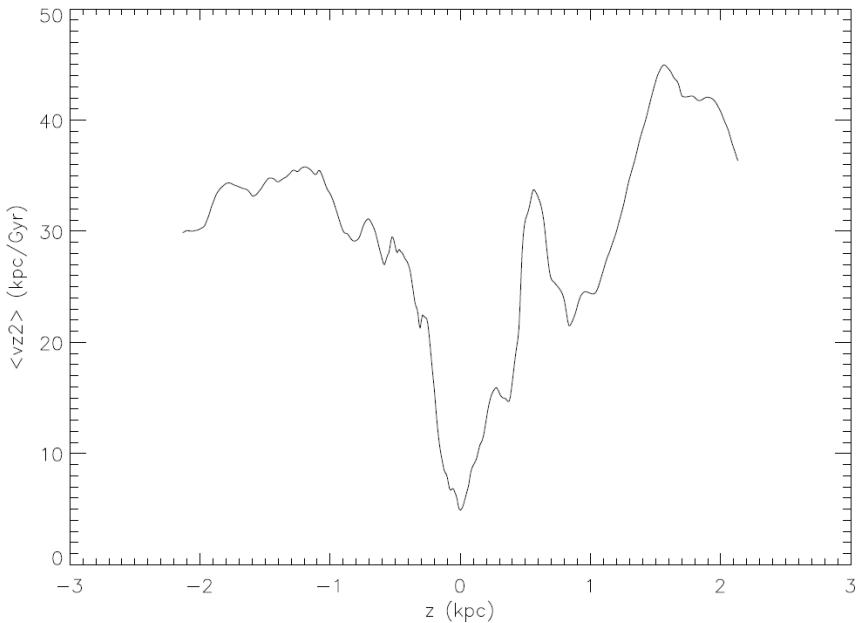


m5 (25% SN, net vertical flux)

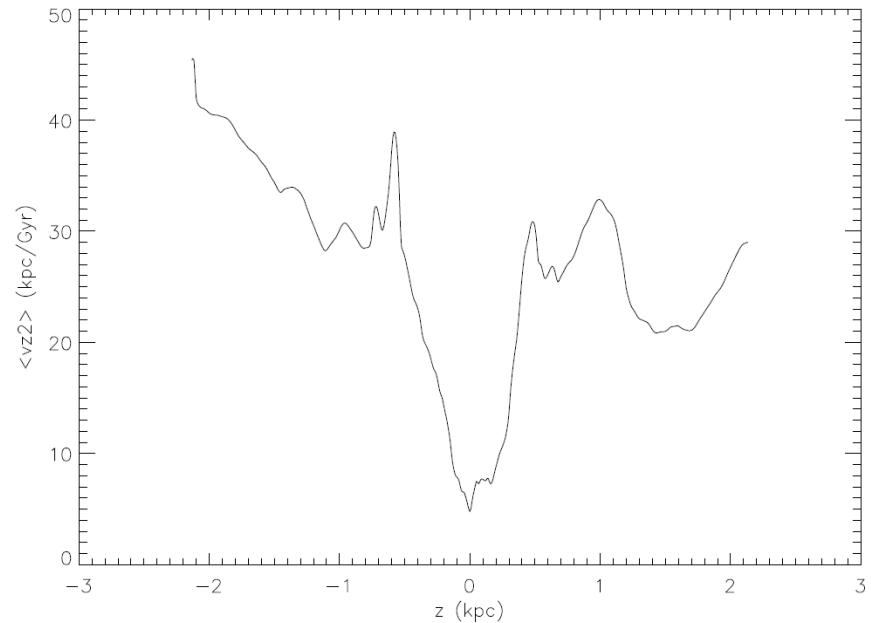


Turbulent velocity

my1 (25 % SN, no vertical flux)

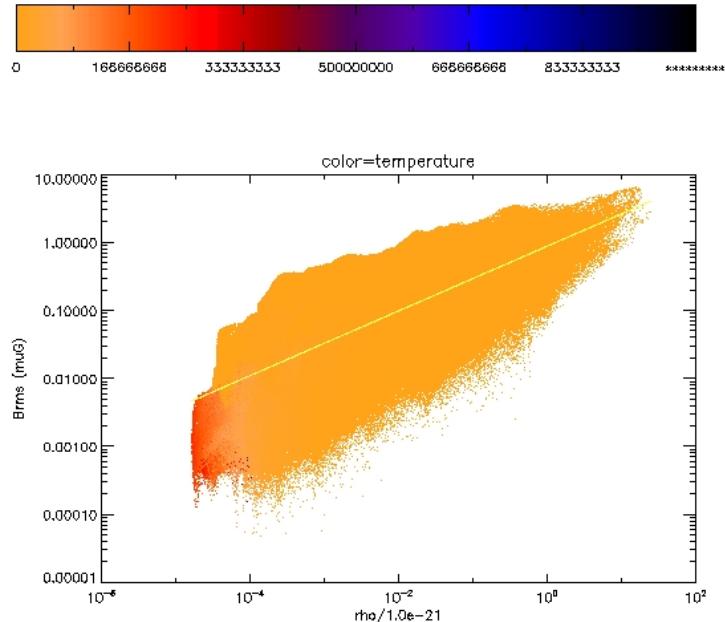


my5 (25% SN, net vertical flux)



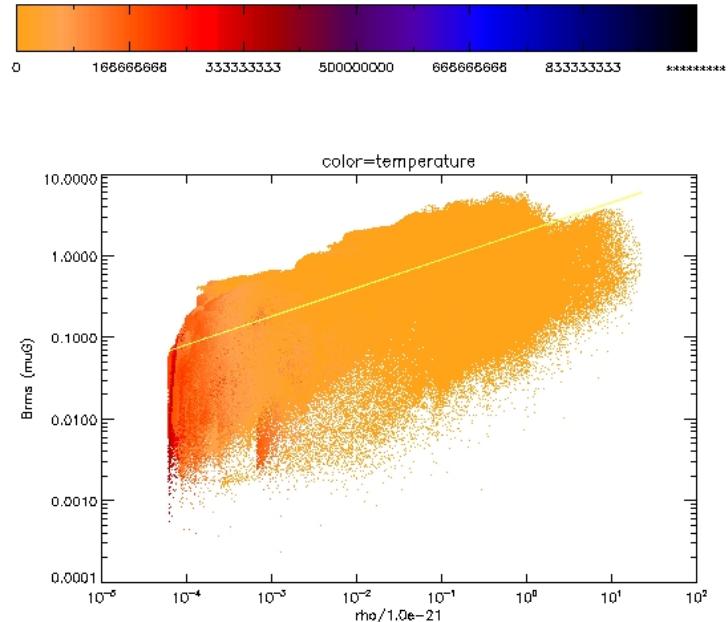
B_{rms} Vs. rho

m1 (25% SN, zero net flux)



$$B_{rms} \sim \rho^{0.48}$$

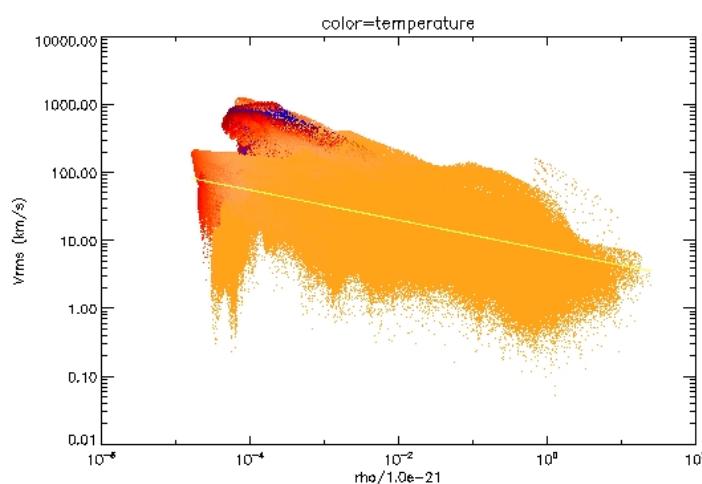
m5 (25% SN, non zero flux)



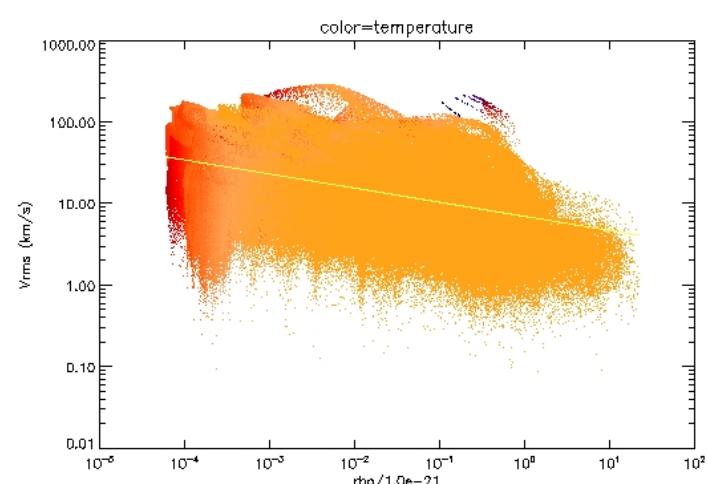
$$B_{rms} \sim \rho^{0.35}$$

V_{rms} Vs. rho

m1 (25% SN, zero net flux)



m5 (25% SN, net flux)



$$V_{rms} \sim \rho^{-0.26}$$

$$V_{rms} \sim \rho^{-0.2}$$

Summary

- $B_{rms} \sim \rho^{0.48}$
- $B_{mean}/B_{rms} = 0.8$
- $\langle KE \rangle \sim \rho^{0.6}$ for both models
- Wind velocities are higher for non zero flux model,
- Wind velocities & turbulent velocities are higher compared to Gressel's models
- Magnetic energy may become greater than kin. Energy for models with flux (may be by the help of MRI)

Outlook

Determination of mean field coefficients

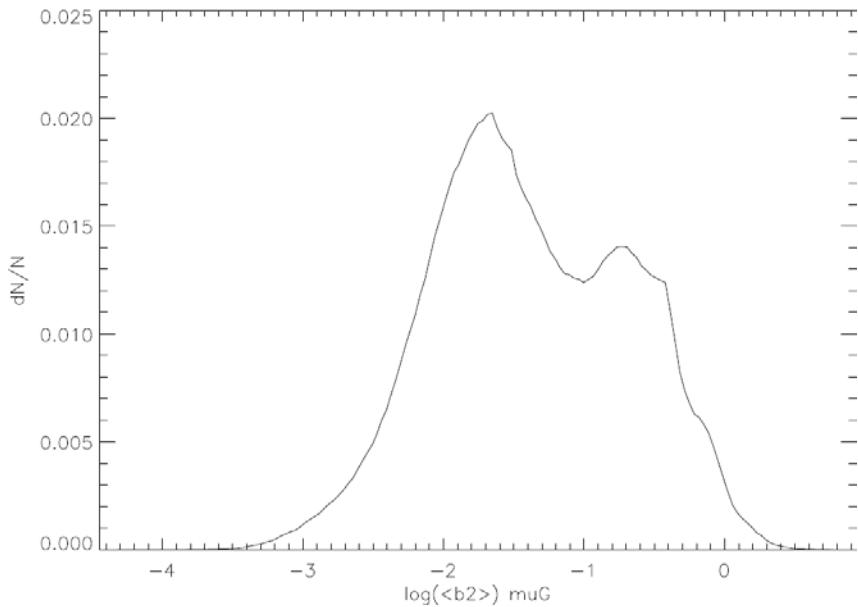
More models with weaker fields, other SN rates

Inclusion of cosmic ray physics

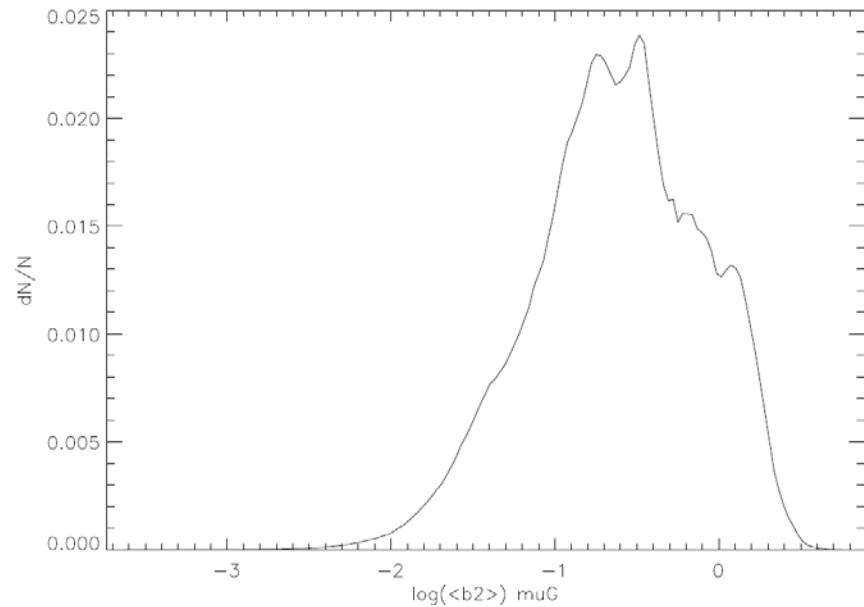
Non-linear saturation

dN/N (Brms)

my1 (25% SN, zero net flux)

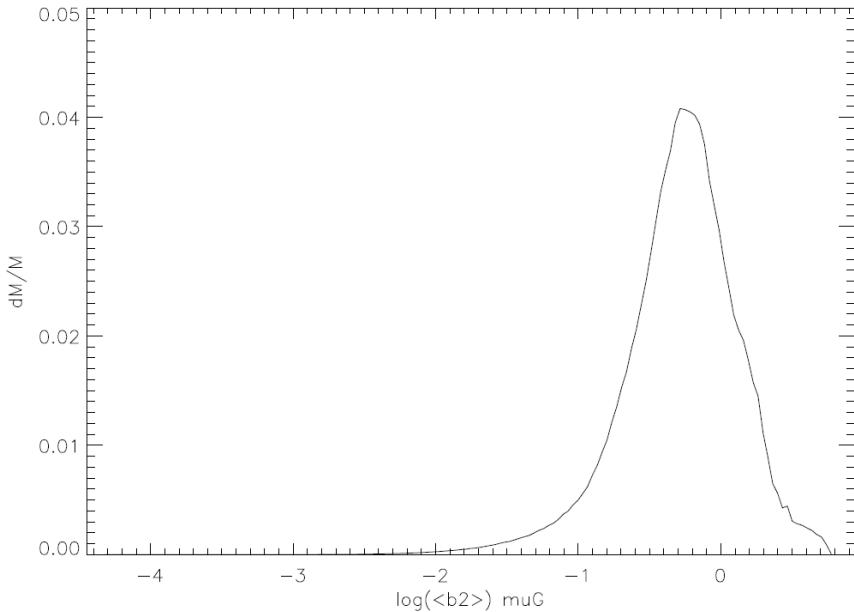


my5 (25% SN, net vertical flux)

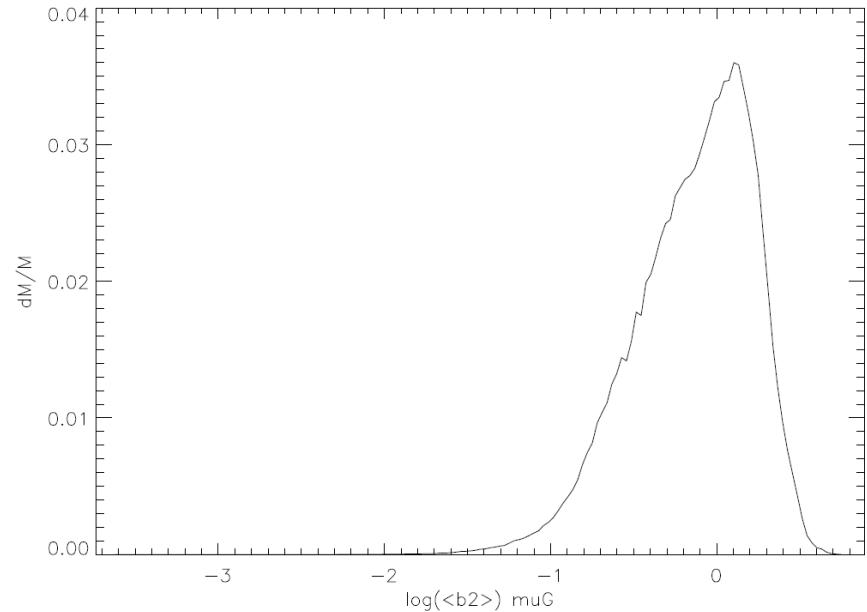


dM/M (Brms)

my1 (25% SN, zero net flux)

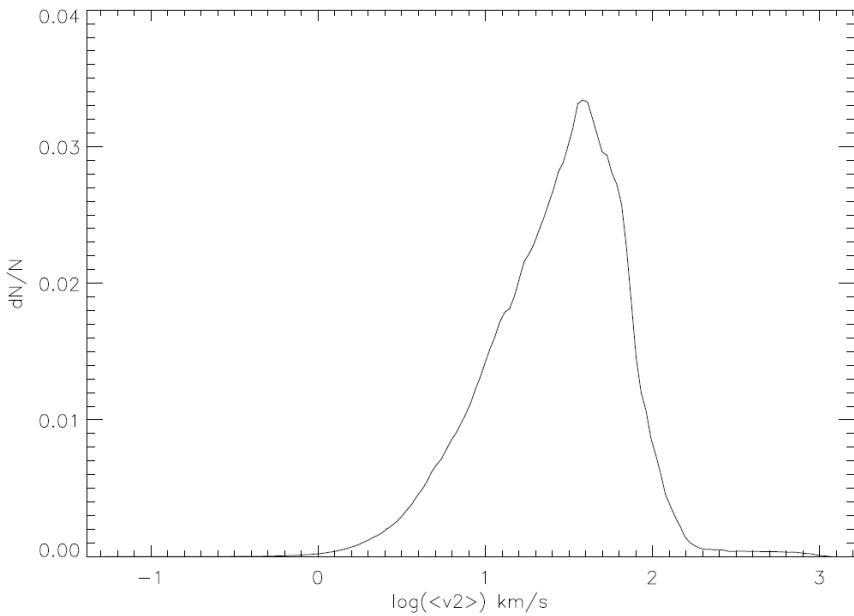


my5 (25% SN, net vertical flux)

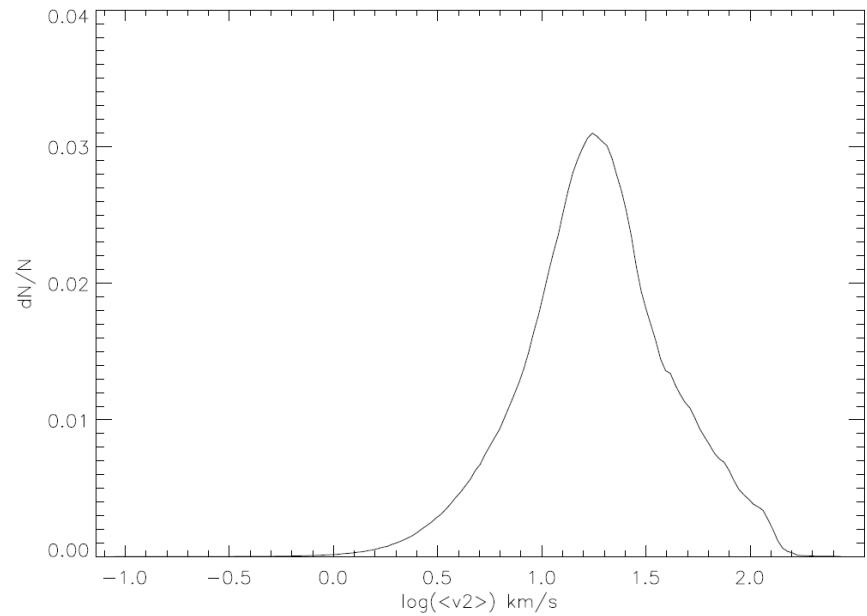


dN/N (Vrms)

my1 (25% SN, zero net flux)

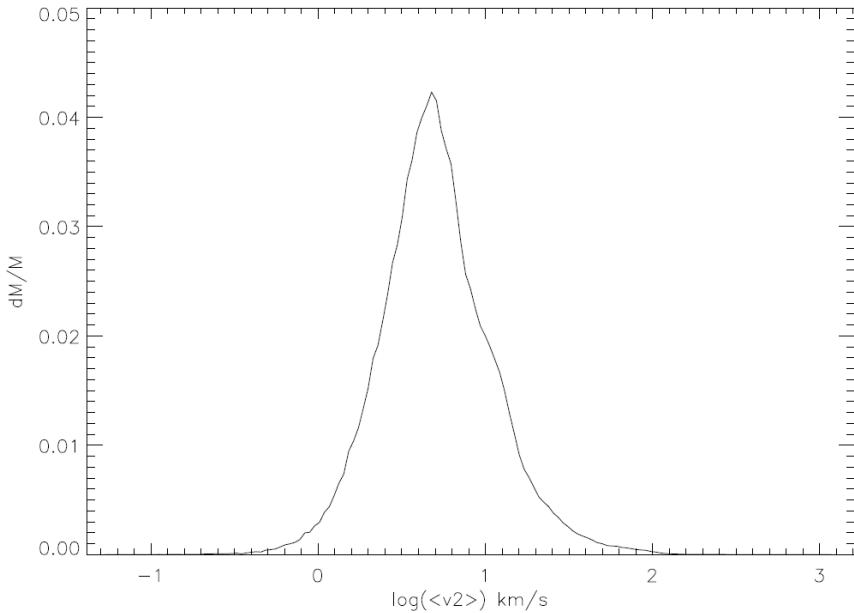


my5 (25% SN, net vertical flux)

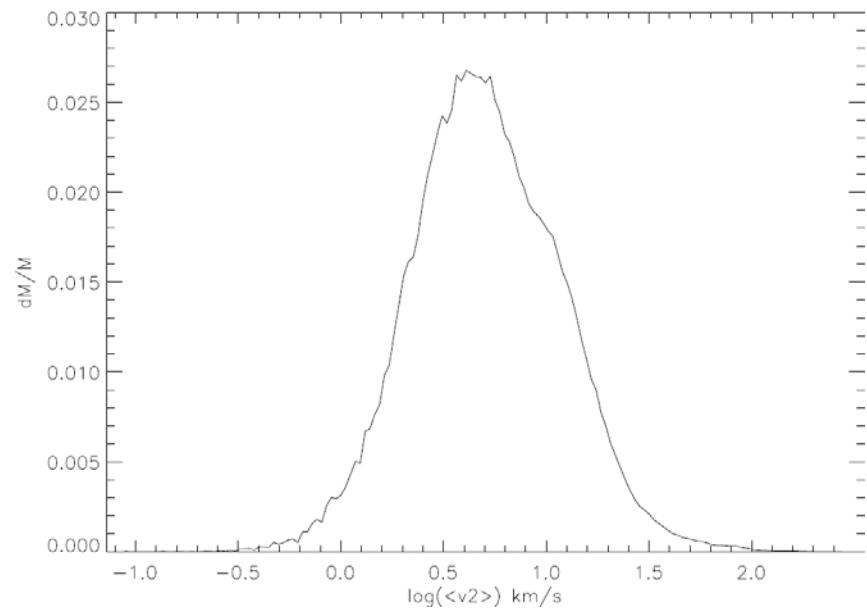


dM/M (V_{rms})

my1 (25% SN, zero net flux)



my5 (25% SN, net vertical flux)



Distribution

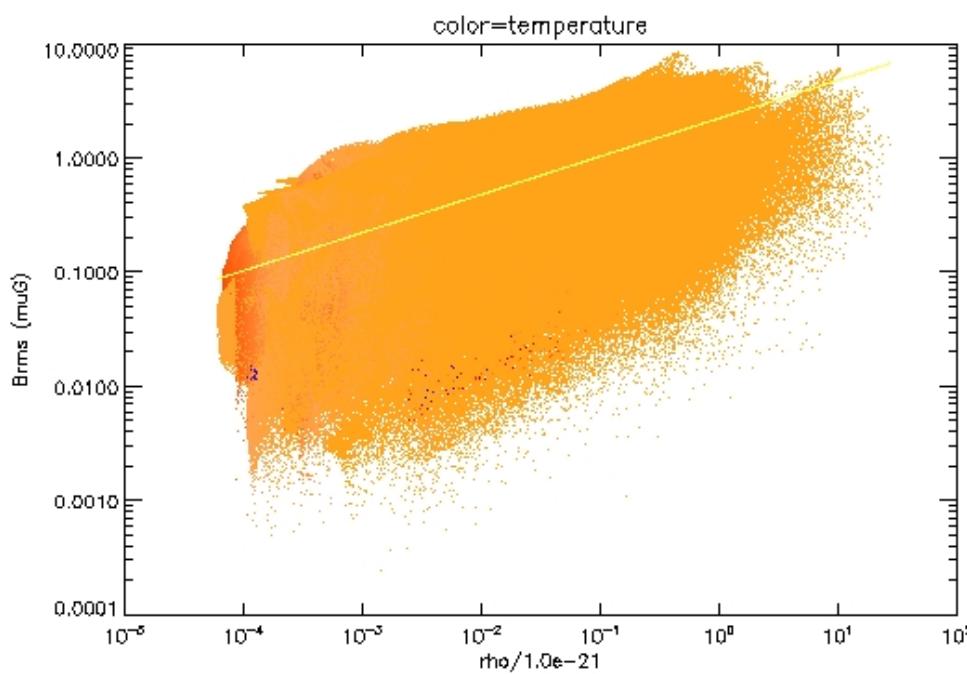
% dN/N

Temp.	M1	M2	M4	M5	M6
< 200	< 1	< 1	< 1	< 1	< 1
200 – 4400	1.1	1	9	1	1
4400 – 1e5	46	98	66	54	57
1e5 <	53	<1	33	44	42

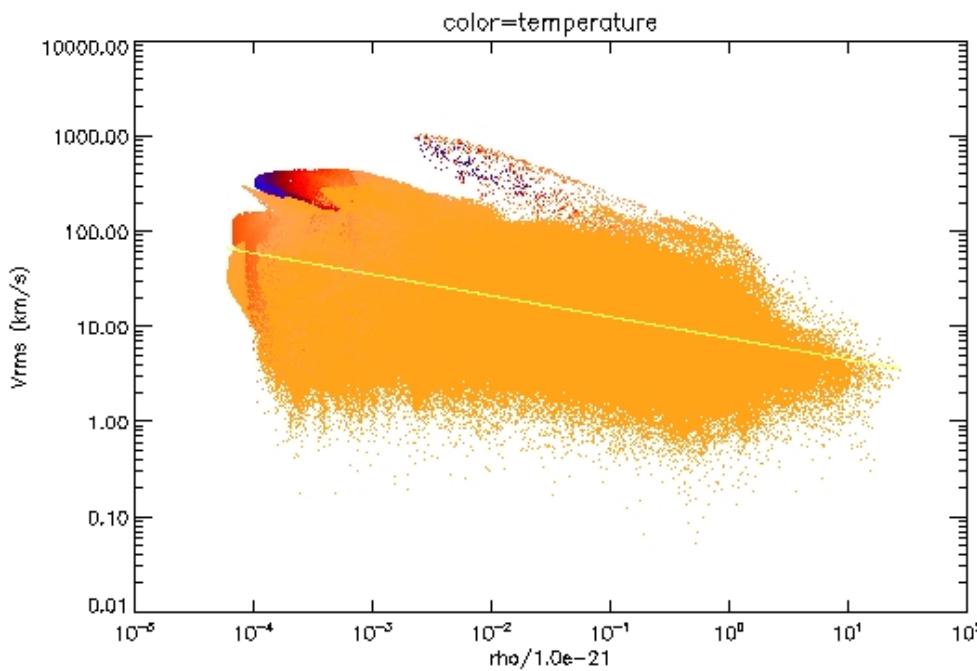
% dM/M

Temp.	M1	M2	M4	M5	M6
< 200	1	40	29	2	1
200 – 4400	21	58	67	26	18
4400 – 1e5	77	<1	4	72	79
1e5 <	1	2	<1	<1	2

Comparison (my6)



Comparison (my6)



Scaling

$$B_{rms} \sim \rho^a$$

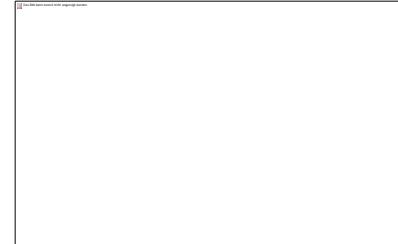
	M1	M5	M6
< 200	-0.05 (+- 0.1)	-0.48 (+- 0.2)	-0.75 (+- 0.2)
200 – 4400	0.6 (1e-3)	0.2 (3e-3)	0.3 (3e-3)
4400 – 1.e5	0.3 (1e-4)	0.3 (2e-4)	0.3 (2e-4)
1.e5 <	0.3 (1e-4)	0.4 (4e-4)	0.2 (2e-4)
total	0.48 (2e-4)	0.35 (1e-4)	0.33 (1e-3)

$$V_{rms} \sim \rho^a$$

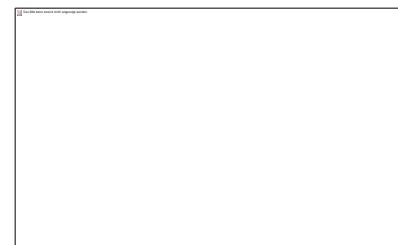
	M1	M5	M6
< 200	-0.19 (+0.14)	-0.5 (+0.1)	-0.13 (+0.14)
200 – 4400	-0.3 (1e-3)	-0.3 (3e-3)	-0.26 (3e-3)
4400 – 1.e5	-0.26 (2e-4)	-0.24 (6e-4)	-0.17 (2e-3)
1.e5 <	0.17 (4e-4)	0.09 (6e-4)	0.01 (4e-4)
total	-0.22 (1e-4)	-0.17 (1e-4)	-0.22 (1e-4)

Discussion

- For zero flux case



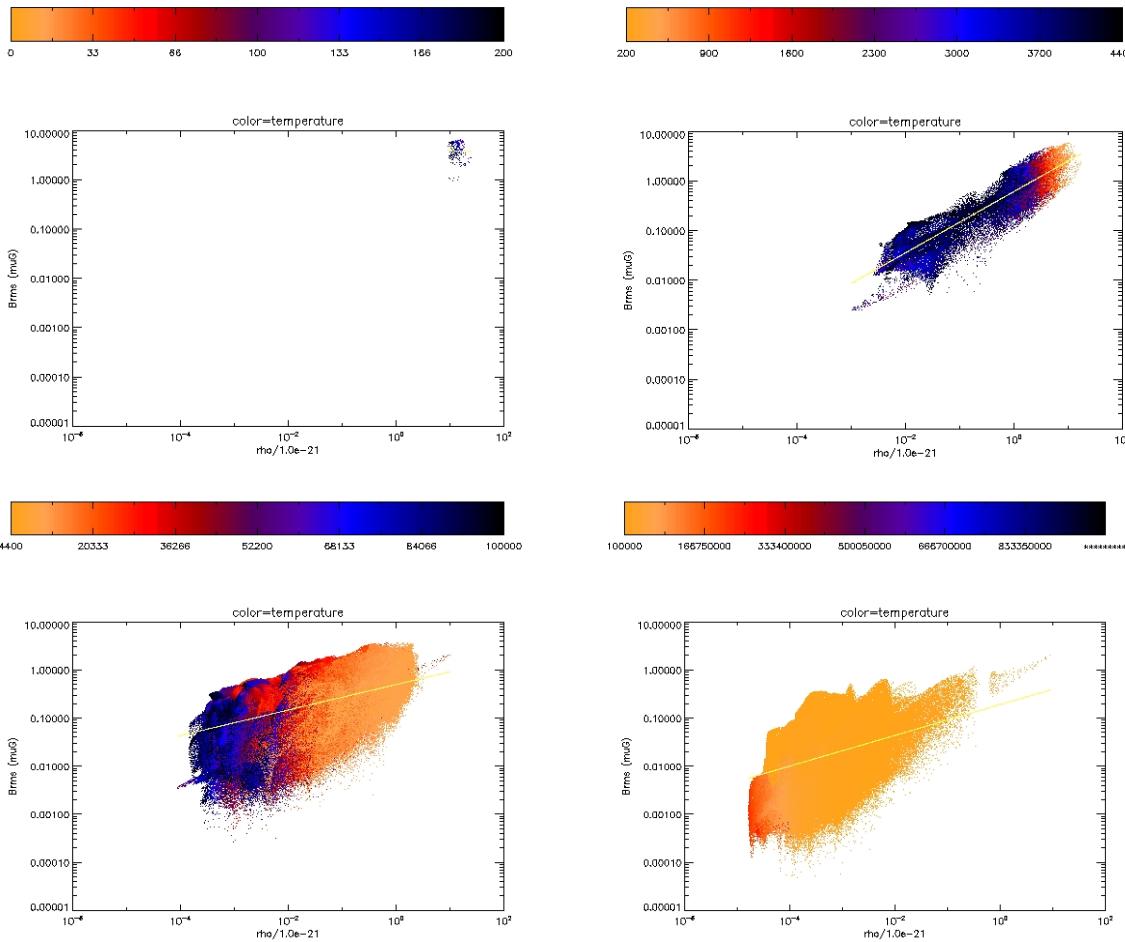
- For non zero flux



M1. Brms vs rho

Clockwise
from left

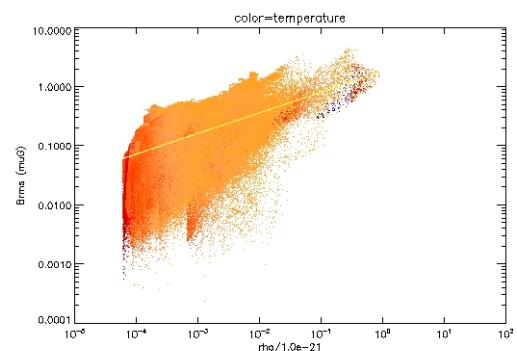
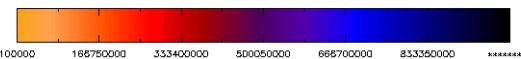
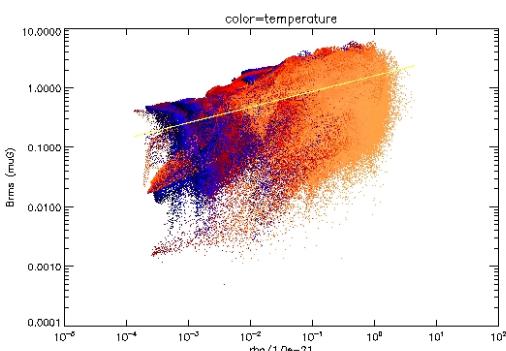
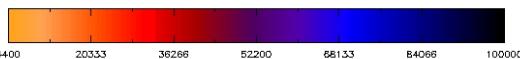
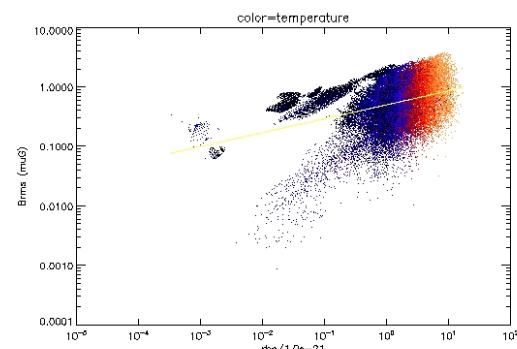
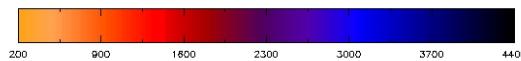
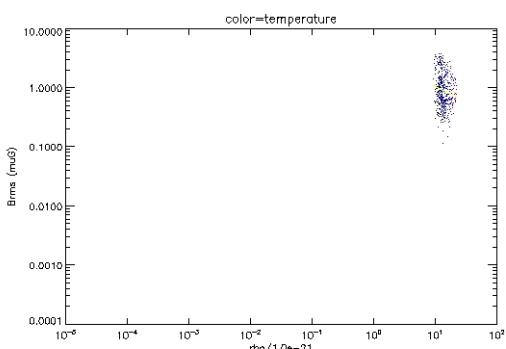
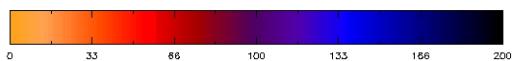
- 1) < 200
- 2) 200 -4400
- 3) 4400-1e5
- 4) 1e5<



M5. Brms vs rho

Clockwise
from left

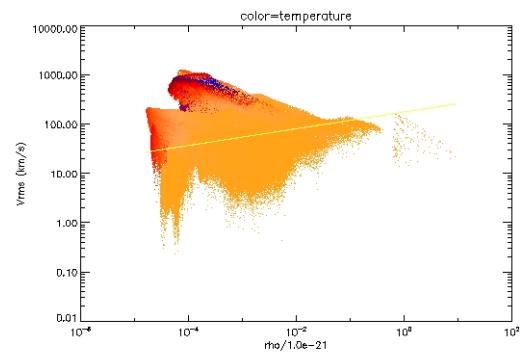
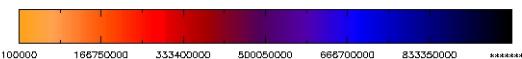
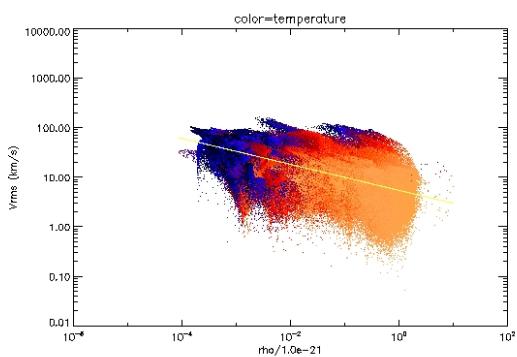
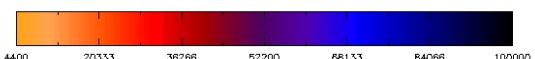
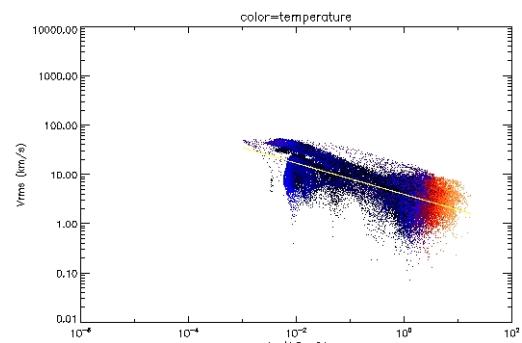
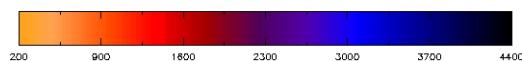
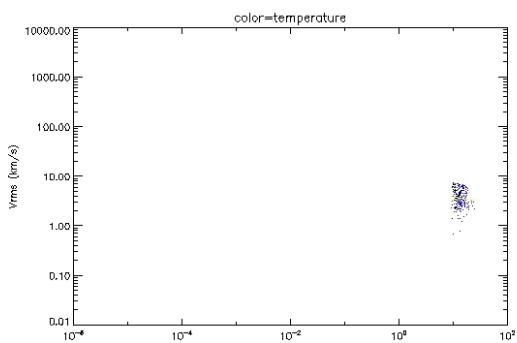
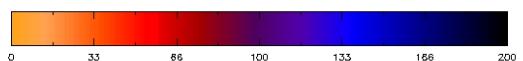
- 1) < 200
- 2) 200 -4400
- 3) 4400-1e5
- 4) 1e5<



M1. Vrms vs rho

Clockwise
from left

- 1) < 200
- 2) 200 -4400
- 3) 4400-1e5
- 4) 1e5<



M5. Vrms vs rho

Clockwise
from left

- 1) < 200
- 2) 200 -4400
- 3) 4400-1e5
- 4) 1e5<

