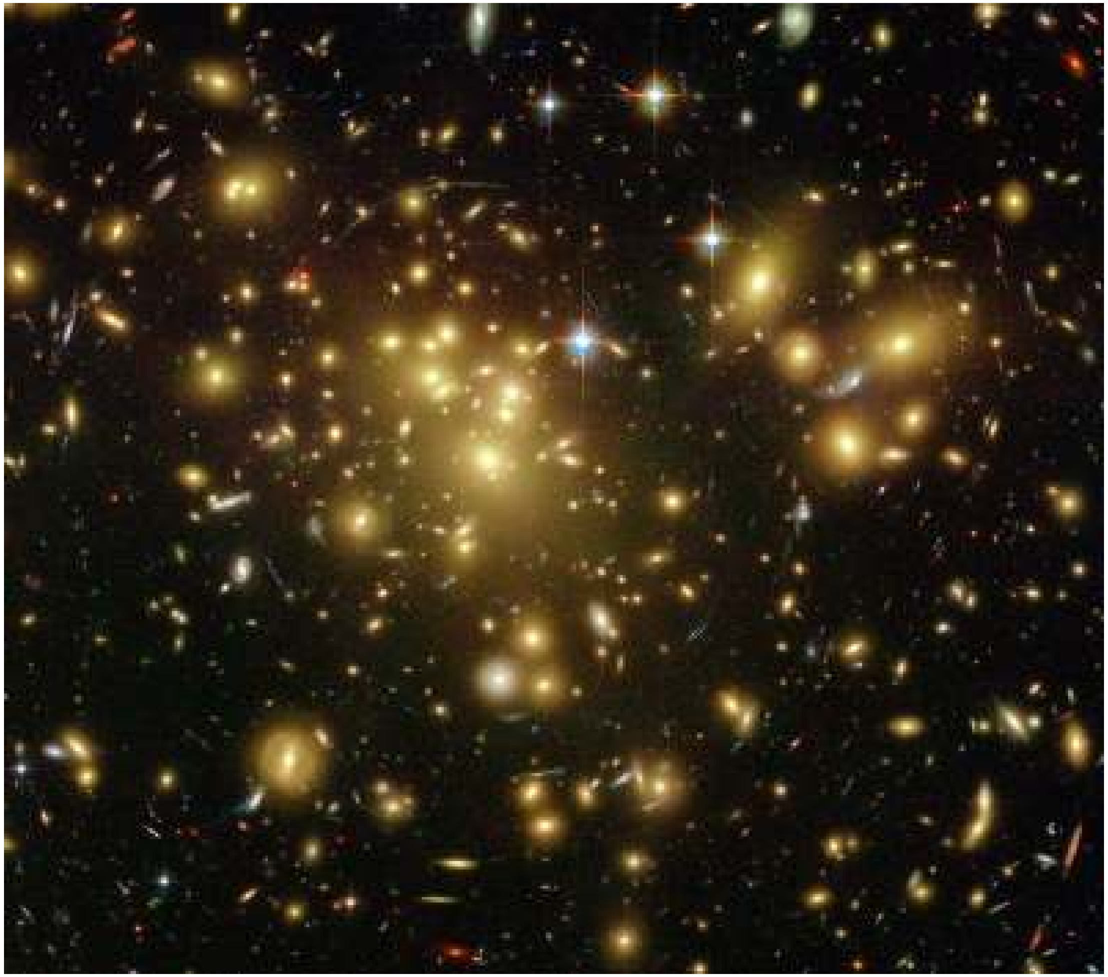
Overview cosmic magnetism issues: towards the study of cosmic magnetic fields with semi-analytic methods

Federico Stasyszyn

Collaborators: many…….

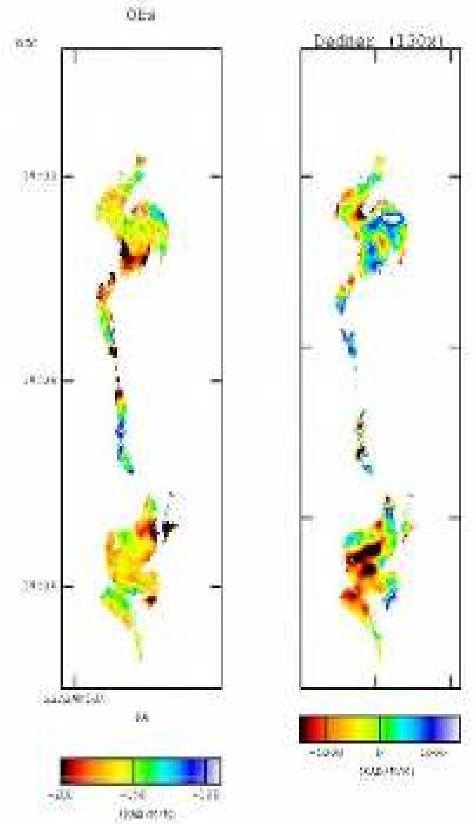
Outline

- Magnetic fields?
- Different environments
- Voids
- Filaments
- Galaxy Clusters
- SAMs?
- Conclusions

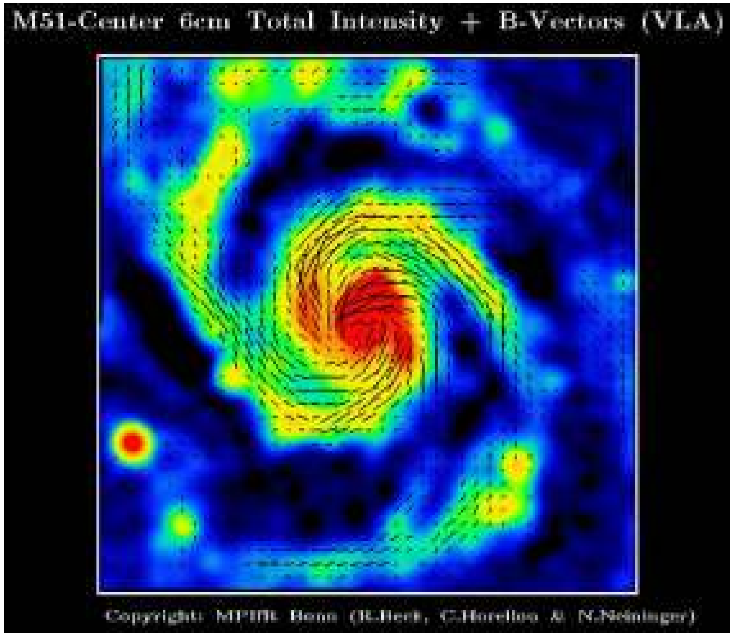


Abell 1689, NASA, ESA, L. Bradley (JHU), R. Bouwens (UCSC), H. Ford (JHU), and G. Illingworth (UCSC)

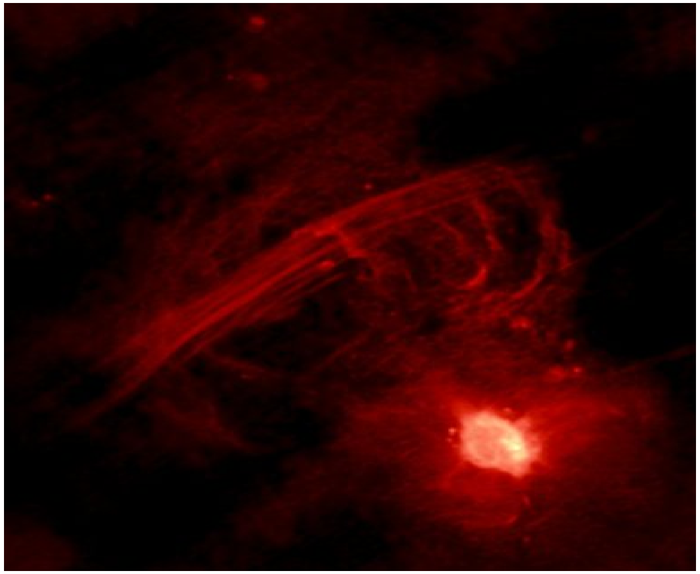
Magnetic Universe



3C449
(Feretti et al 1999)

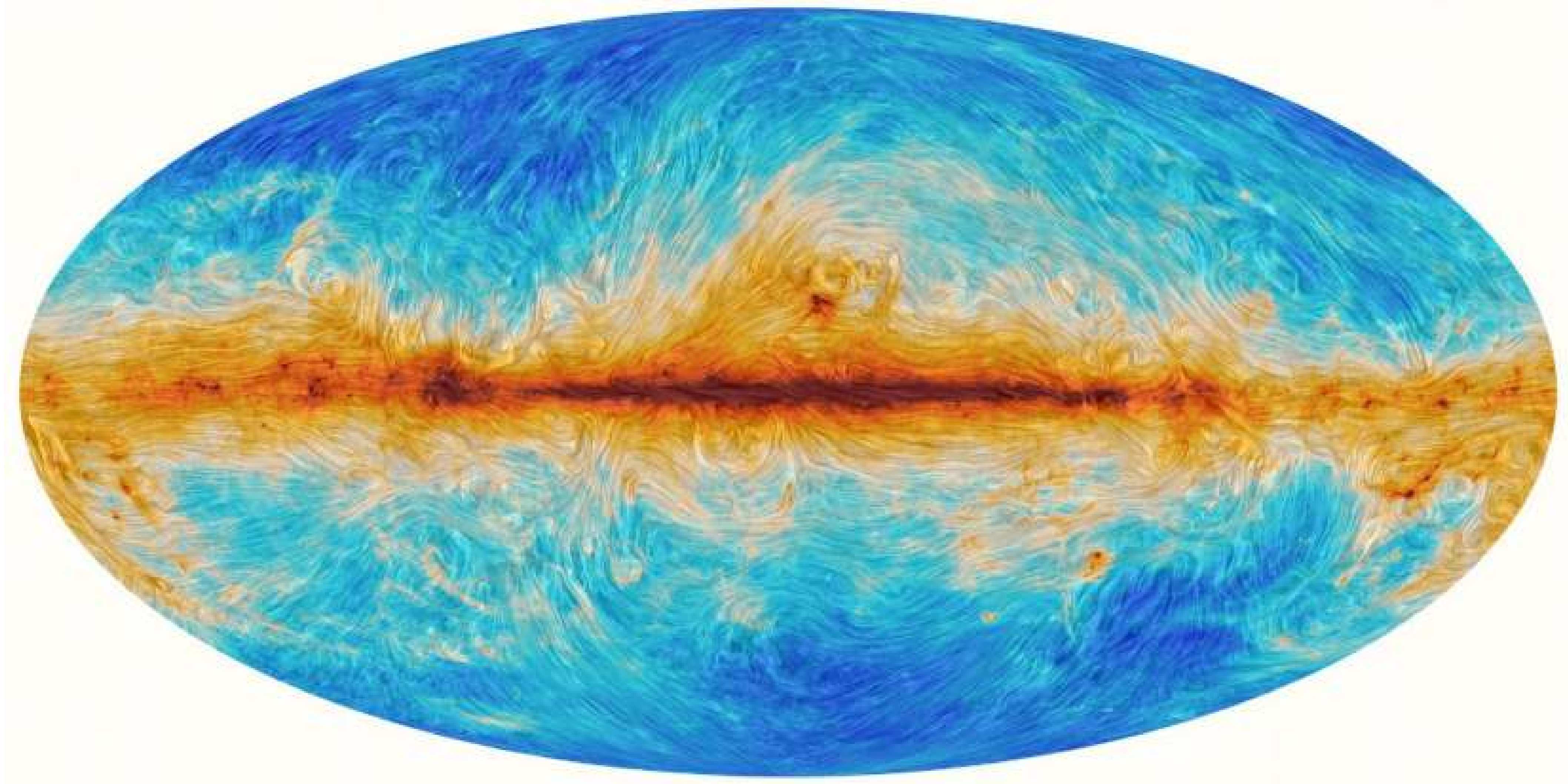


Galaxies
(Beck, R. 2009)



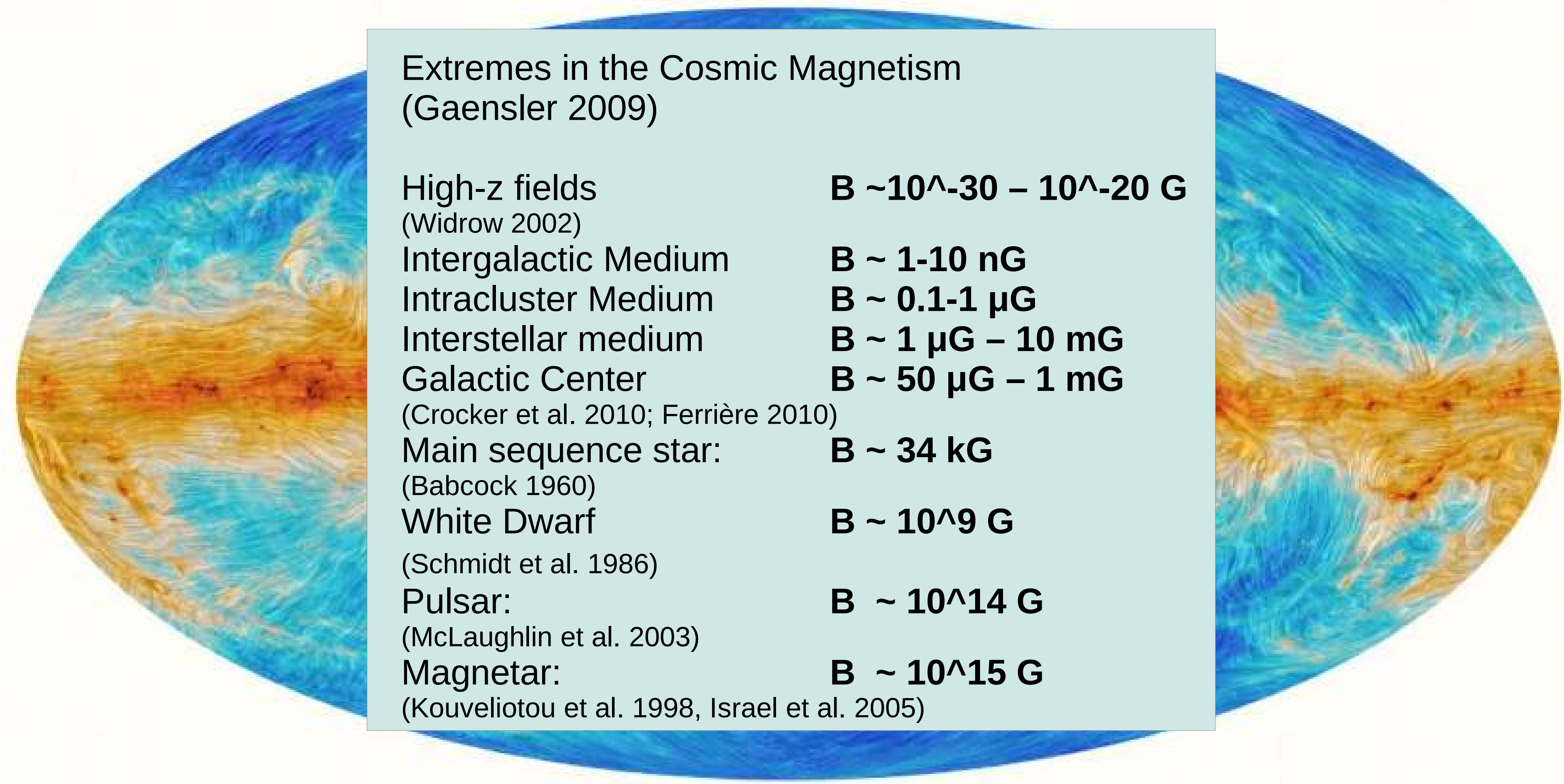
Galactic center
(Crocker 2010)

Magnetic Universe



Via Lactea
ESA & Planck (2015)

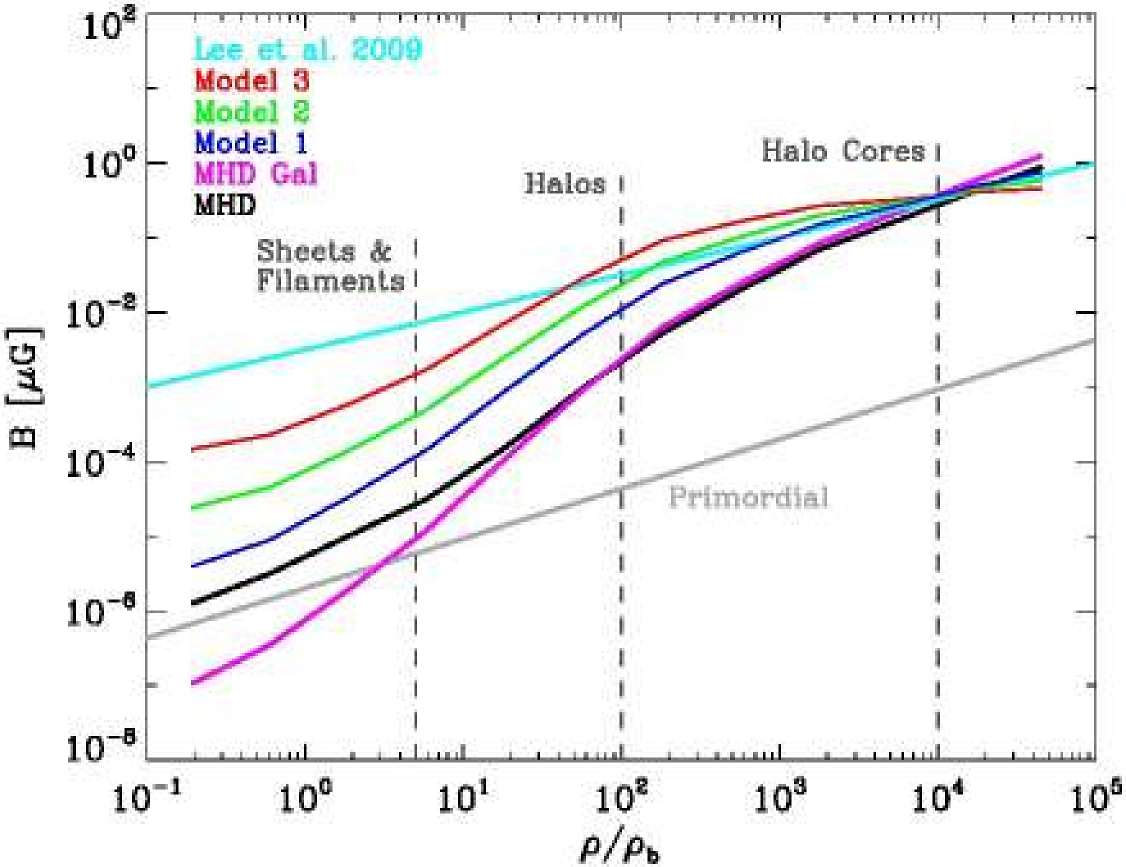
Magnetic Universe



Extremes in the Cosmic Magnetism
(Gaensler 2009)

High-z fields (Widrow 2002)	**B ~10^-30 – 10^-20 G**
Intergalactic Medium	**B ~ 1-10 nG**
Intracluster Medium	**B ~ 0.1-1 μG**
Interstellar medium	**B ~ 1 μG – 10 mG**
Galactic Center (Crocker et al. 2010; Ferrière 2010)	**B ~ 50 μG – 1 mG**
Main sequence star: (Babcock 1960)	**B ~ 34 kG**
White Dwarf (Schmidt et al. 1986)	**B ~ 10^9 G**
Pulsar: (McLaughlin et al. 2003)	**B ~ 10^14 G**
Magnetar: (Kouveliotou et al. 1998, Israel et al. 2005)	**B ~ 10^15 G**

Via Lactea
ESA & Planck (2015)



Need Non-Ideal MHD

$$\frac{\partial \vec{B}}{\partial t} = \nabla \times (\vec{V} \times \vec{B} + \alpha \vec{B}) + \eta \nabla^2 \vec{B}$$

Induction: $\nabla \times (\vec{V} \times \vec{B})$

Diffusion: $\eta \nabla^2 \vec{B}$

$$\eta = \frac{1}{\mu \sigma} = [\Omega m] = [\frac{m^2}{sec}]$$

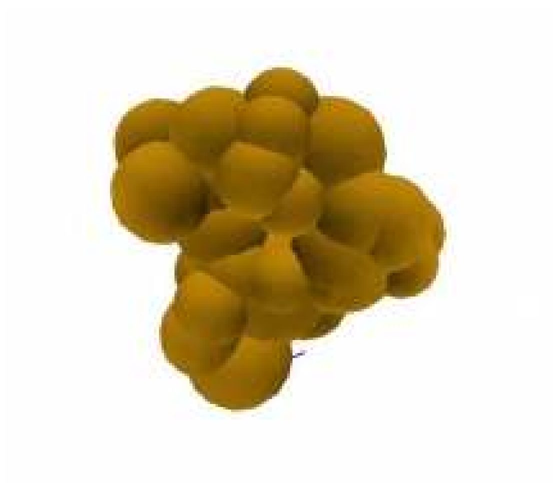
Dynamo: $\nabla \times (\alpha \vec{B})$

$$\alpha = -1/3 \langle \vec{V}_t \cdot \nabla \times \vec{V}_t \rangle$$

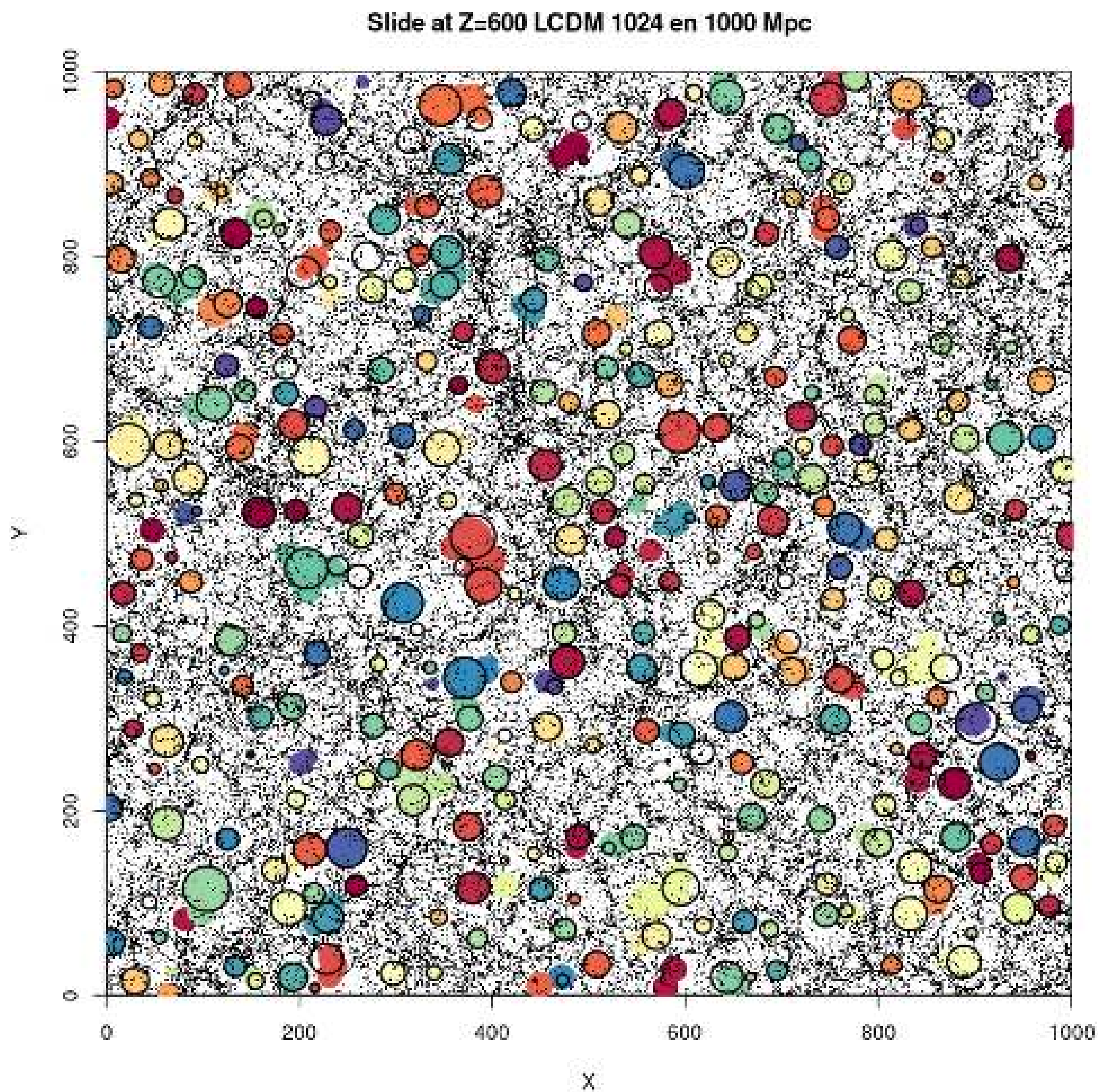
Brief Cosmic Magnetic problems:
- Galaxies: the actual MF should be vanished at 10^8 years.
-Galaxy Clusters: Only Gravitational Collapse does not explain their fields
-Stars/Sun: understanding the activity cycle, MF reversals
-Magnetic seeds….

continue.....

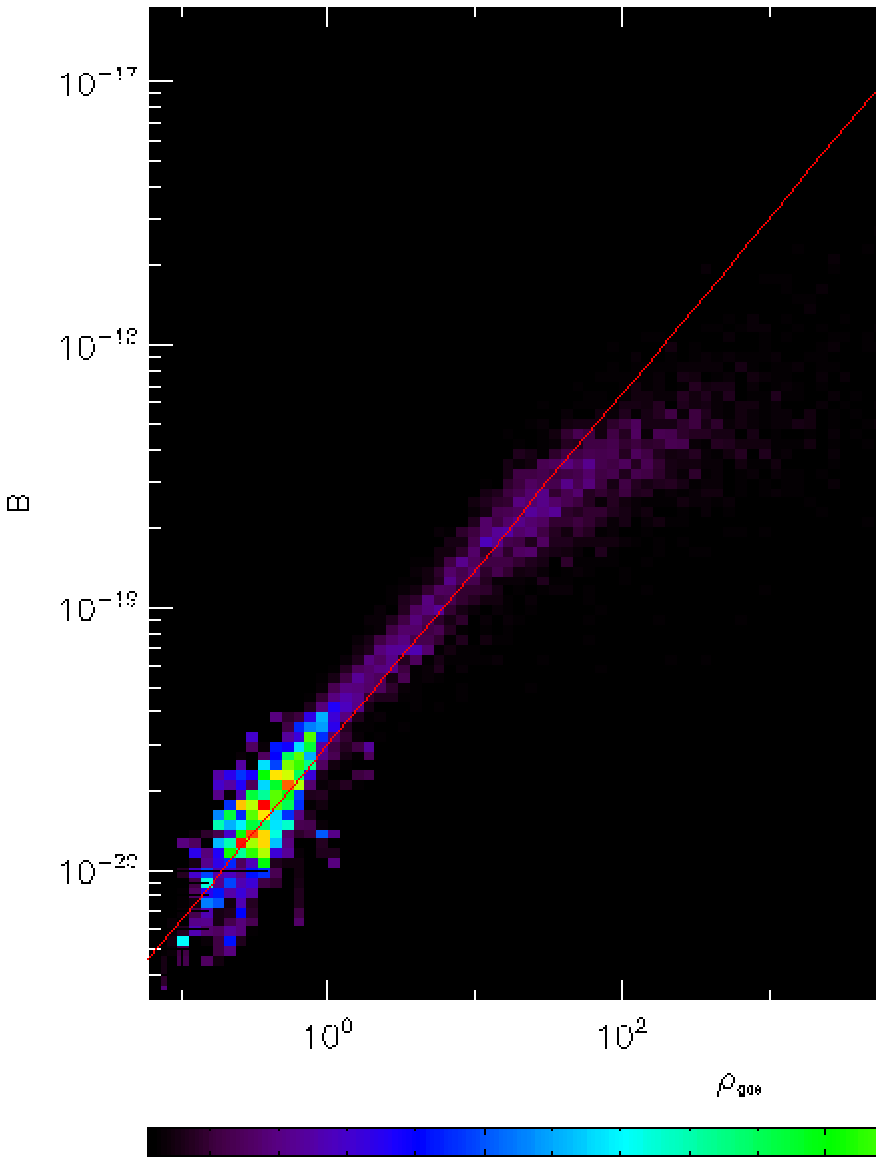
Voids….

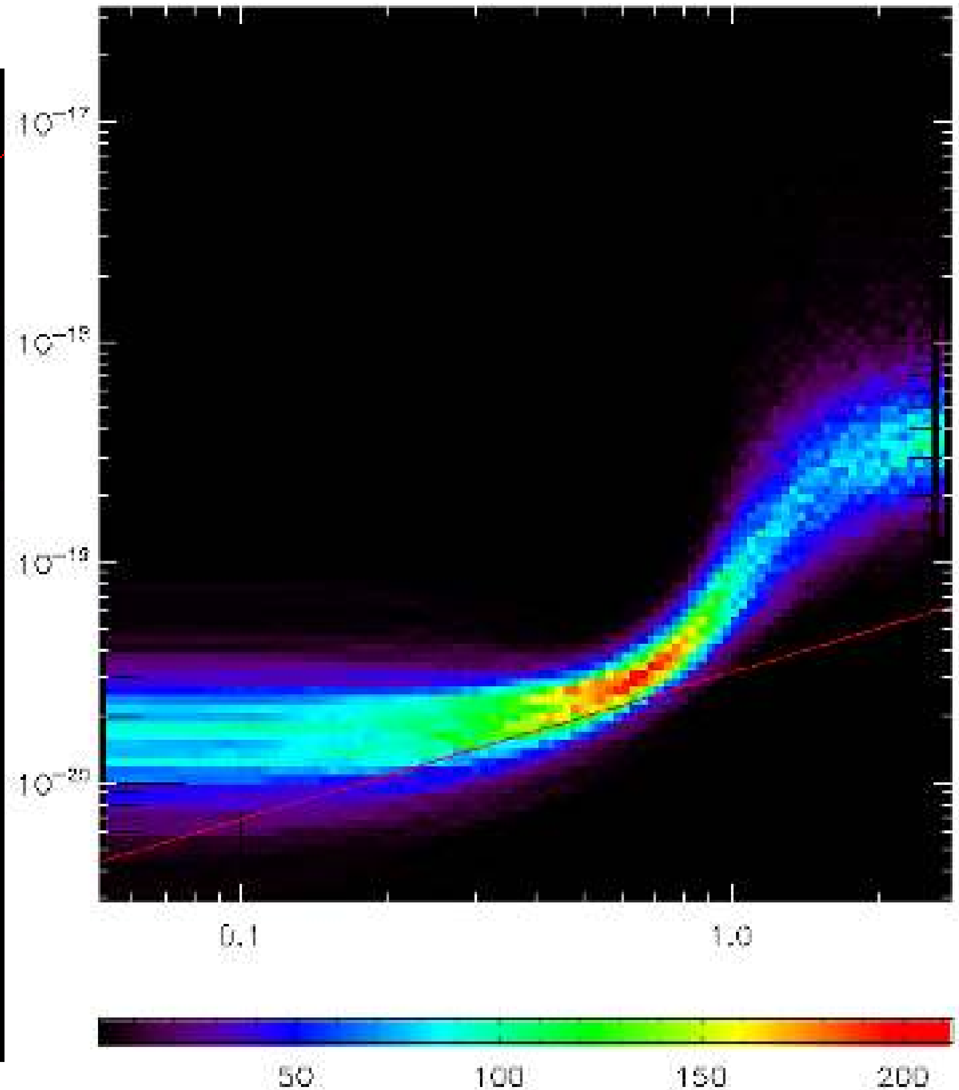


Pop Corn properties
- Dynamics
  - Internal
  - Between them
- Evolution
- Shapes

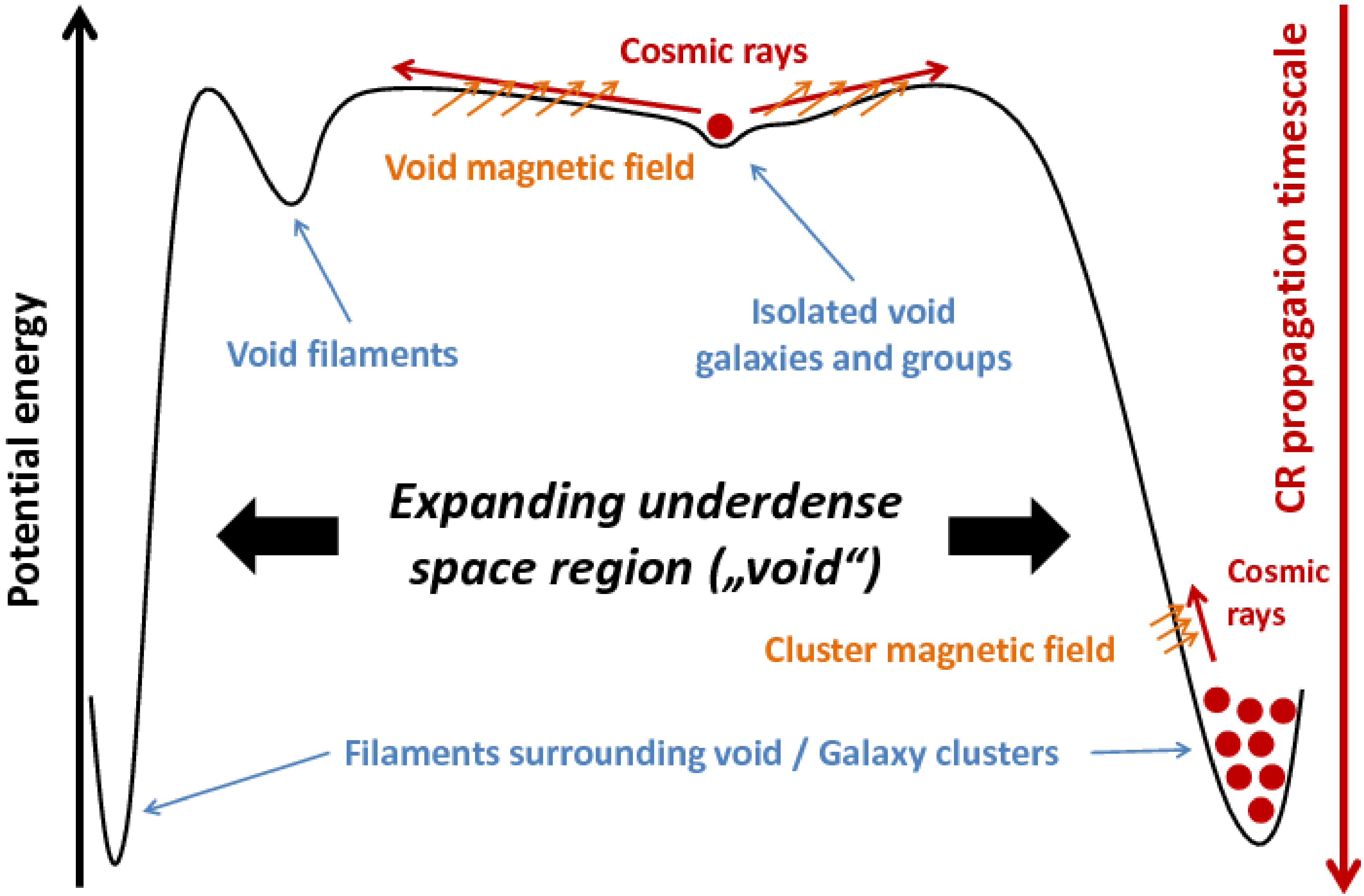


Paz, Ruiz, Lares, Luparello…. IATE-Group

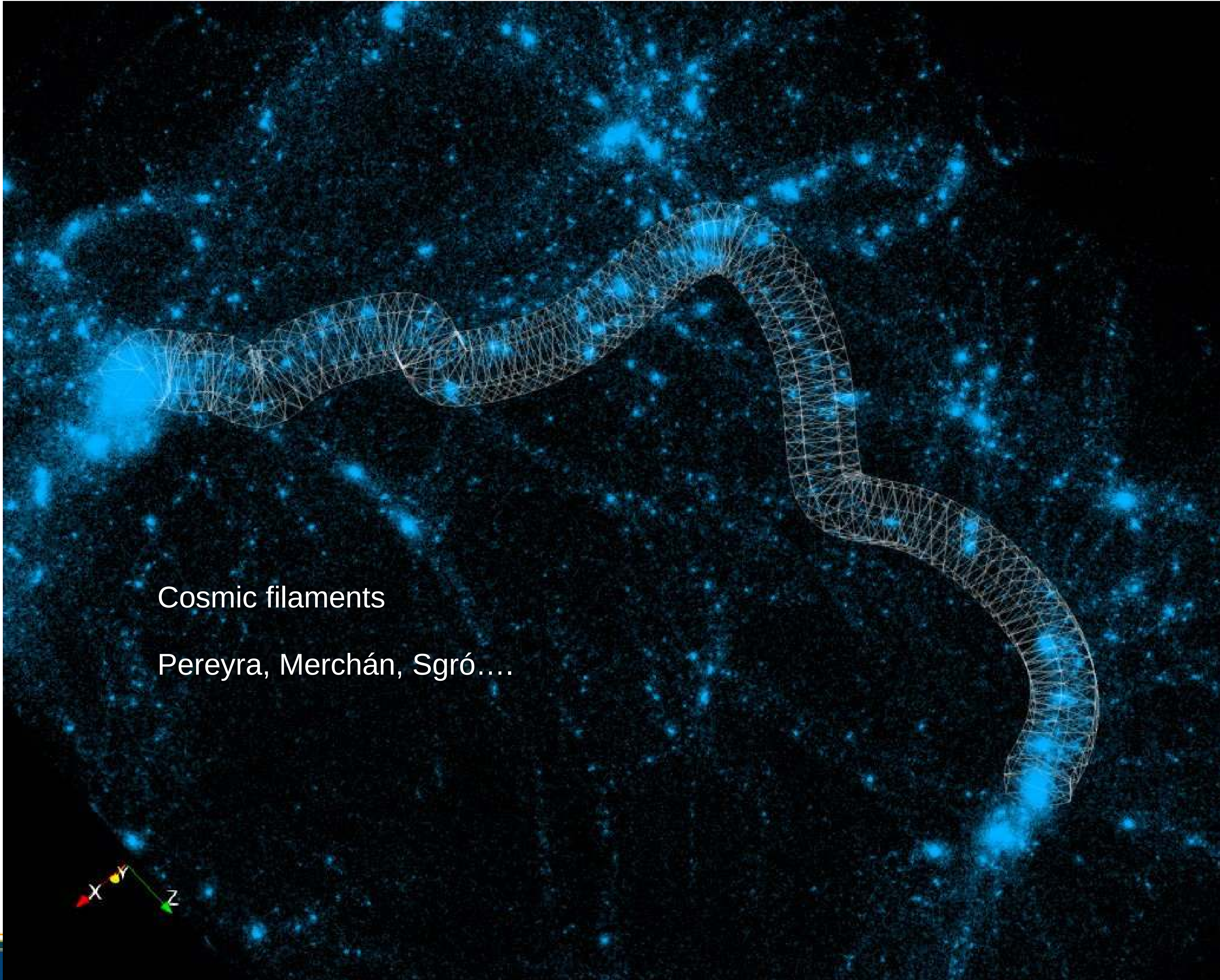


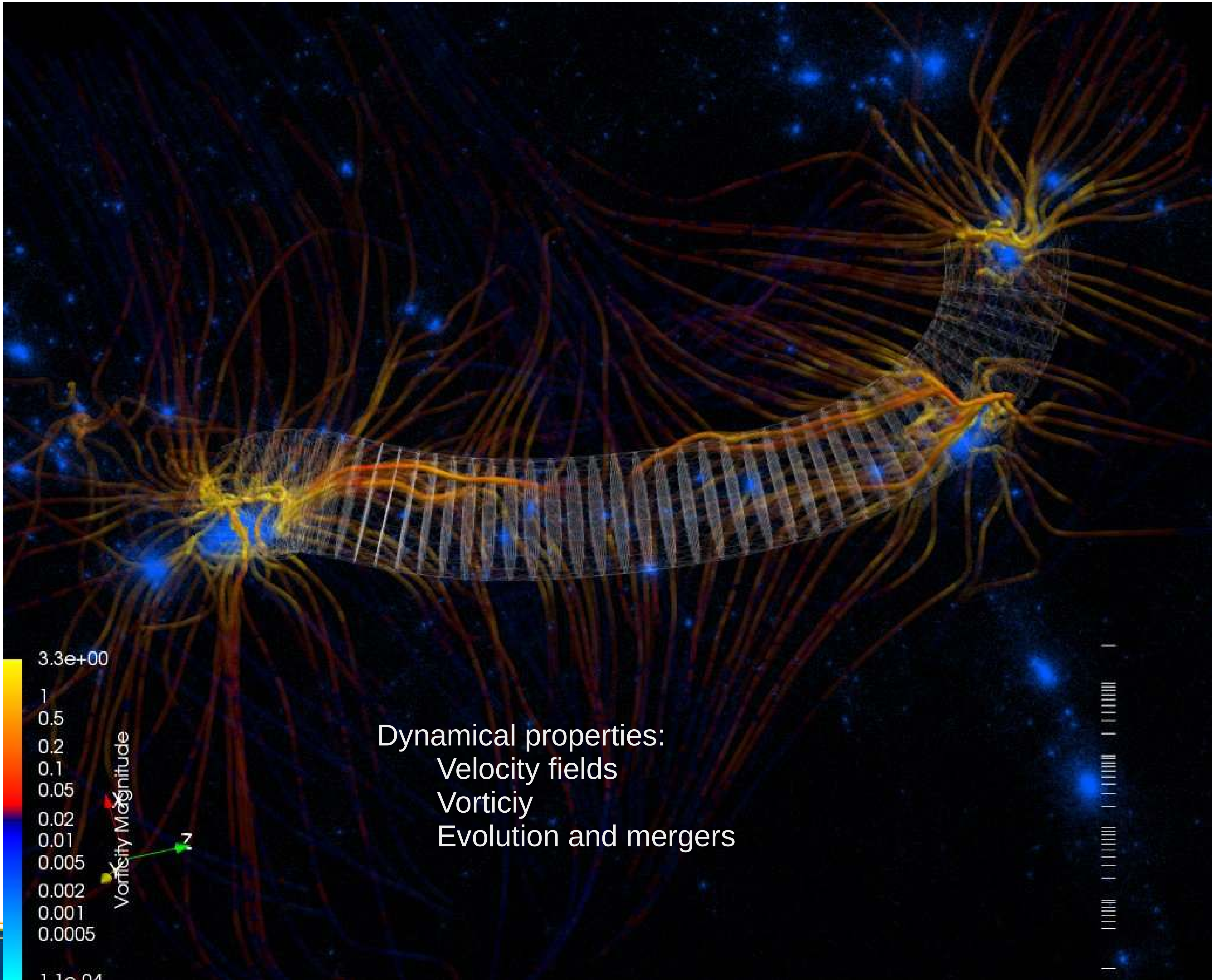


Void Profiles:
If primordial magnetic fields the void environment follows an adiabatic growth of magnetic fields



Voids are places, where the cosmic rays propagation can help to fill the space with magnetic fields enough to match the measured filling factors form Gamma Ray Bursts. (Beck et al 2015)

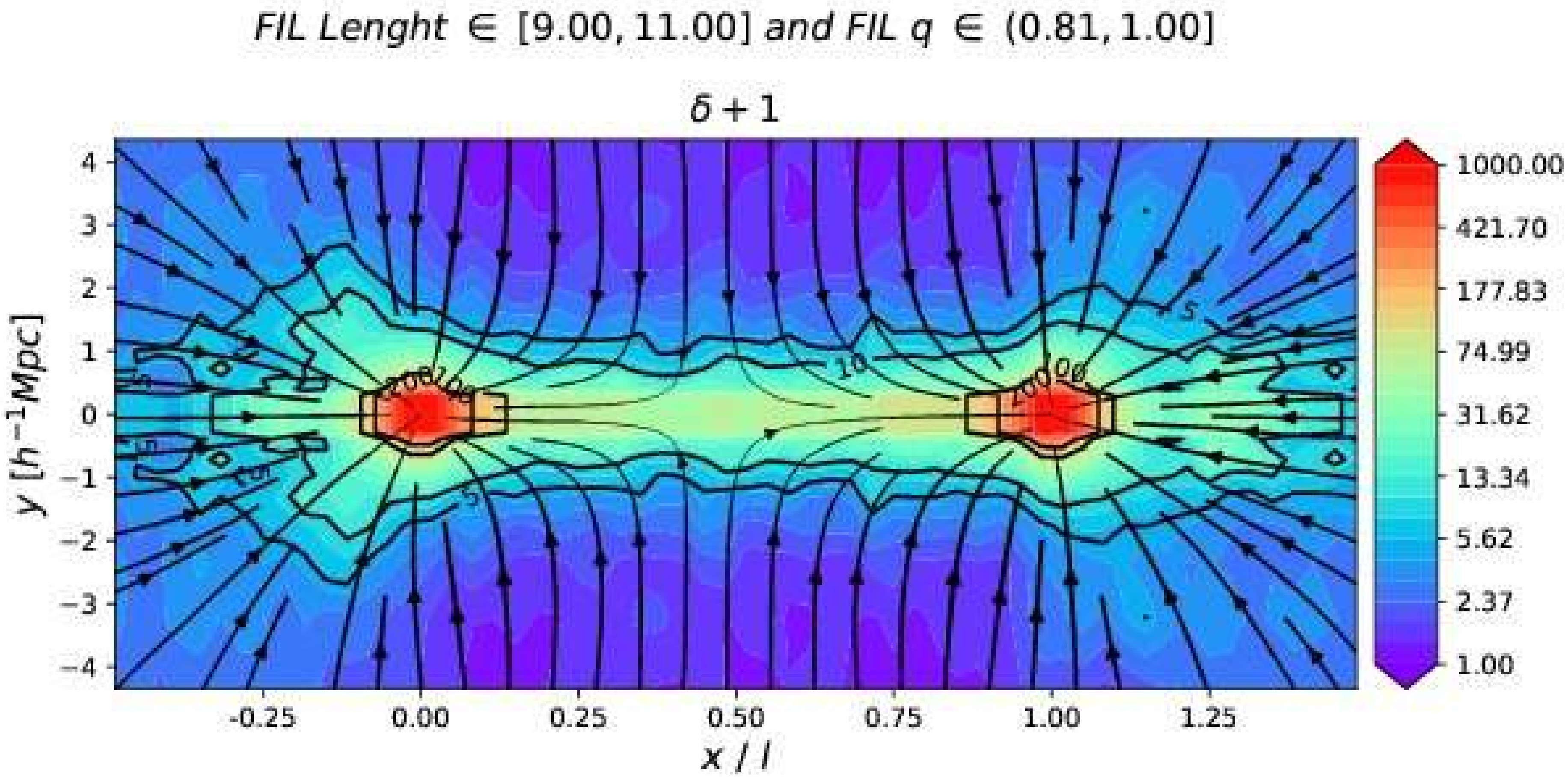

Cosmic filaments
Pereyra, Merchán, Sgró….
X
Y
Z



Dynamical properties:

- Velocity fields
- Vorticiy
- Evolution and mergers

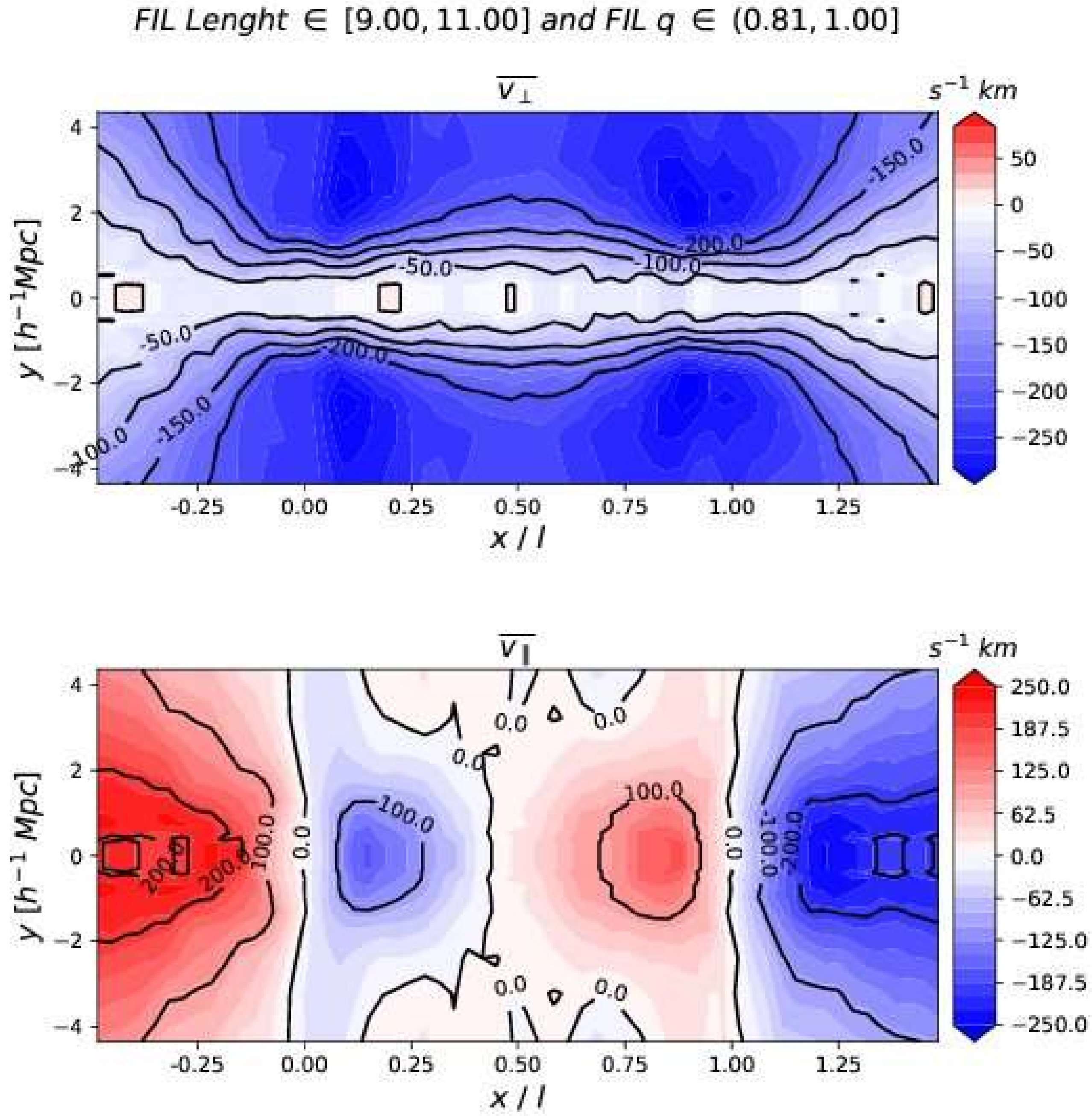
Environment: Filaments



General properties:

- Density fields
- Highway to halos
- 3D velocity field

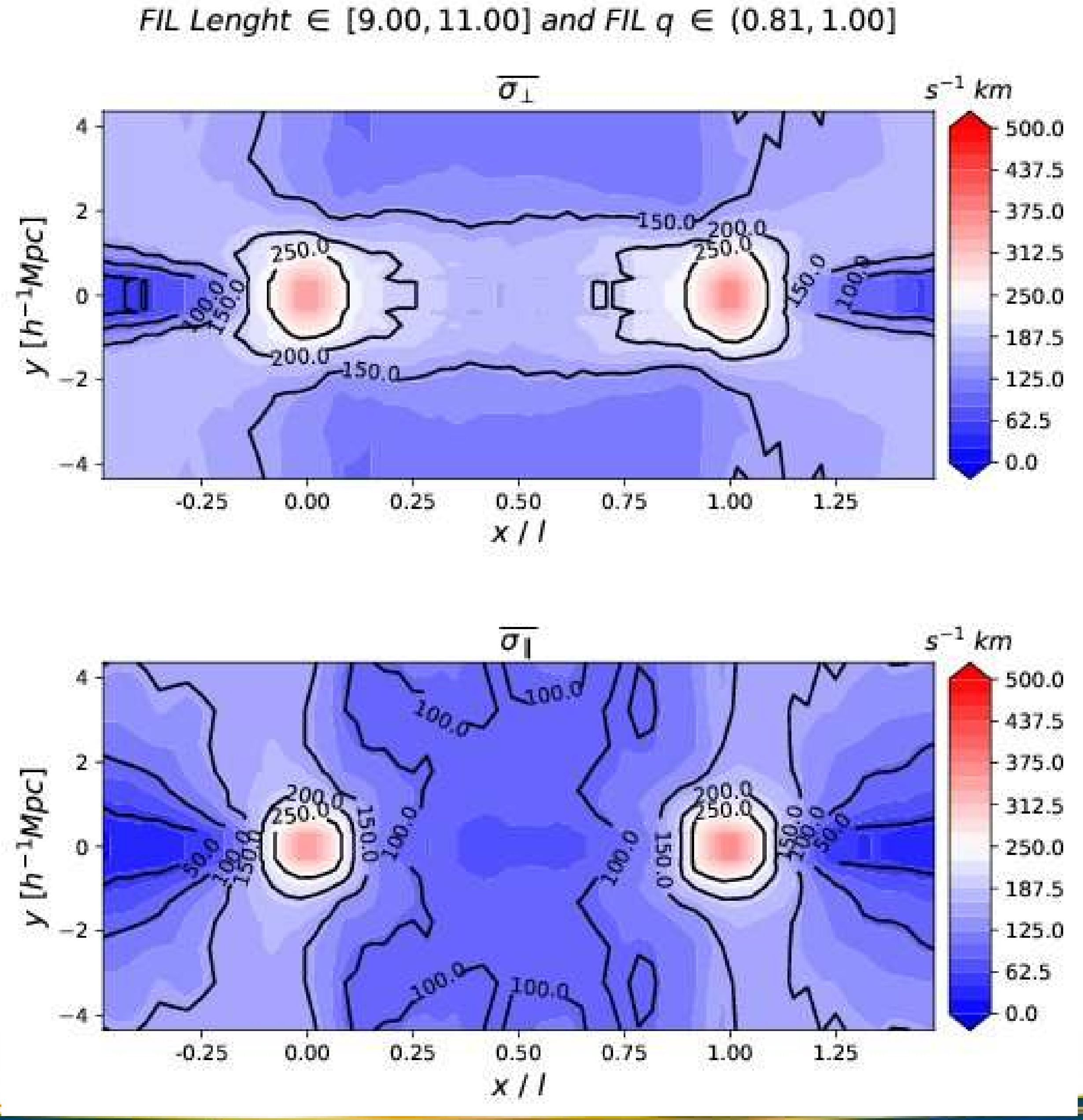
Environment: Filaments



We can follow the infall and follow the astrophysical properties!

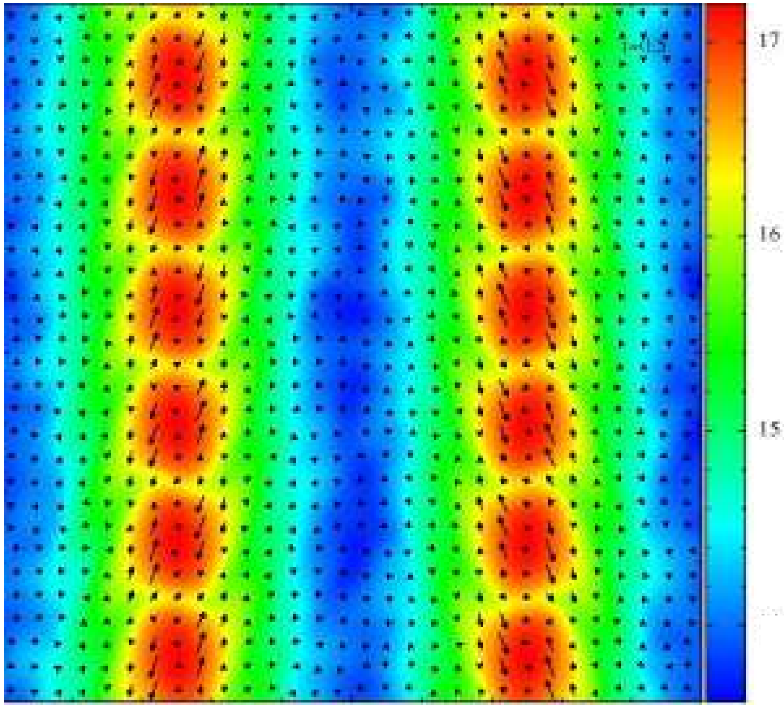
And do statistics for lenghts, mass….

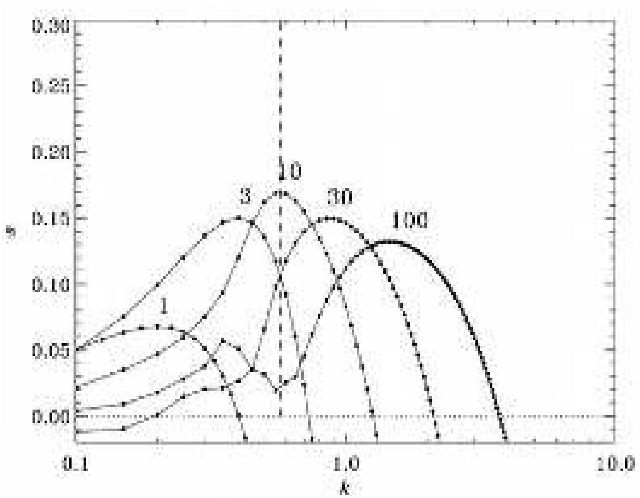
Environment: Filaments



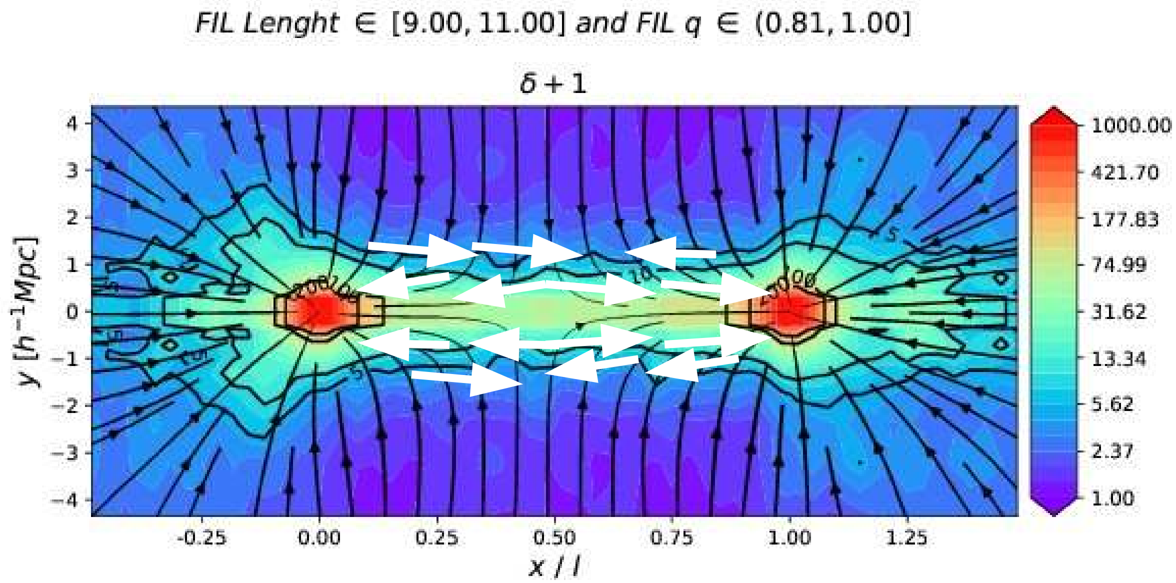
The filaments are not turbulent. Therefore the 3D velocity field can be parametrized and we can identify which dynamo can be acting.

Environment: Filaments

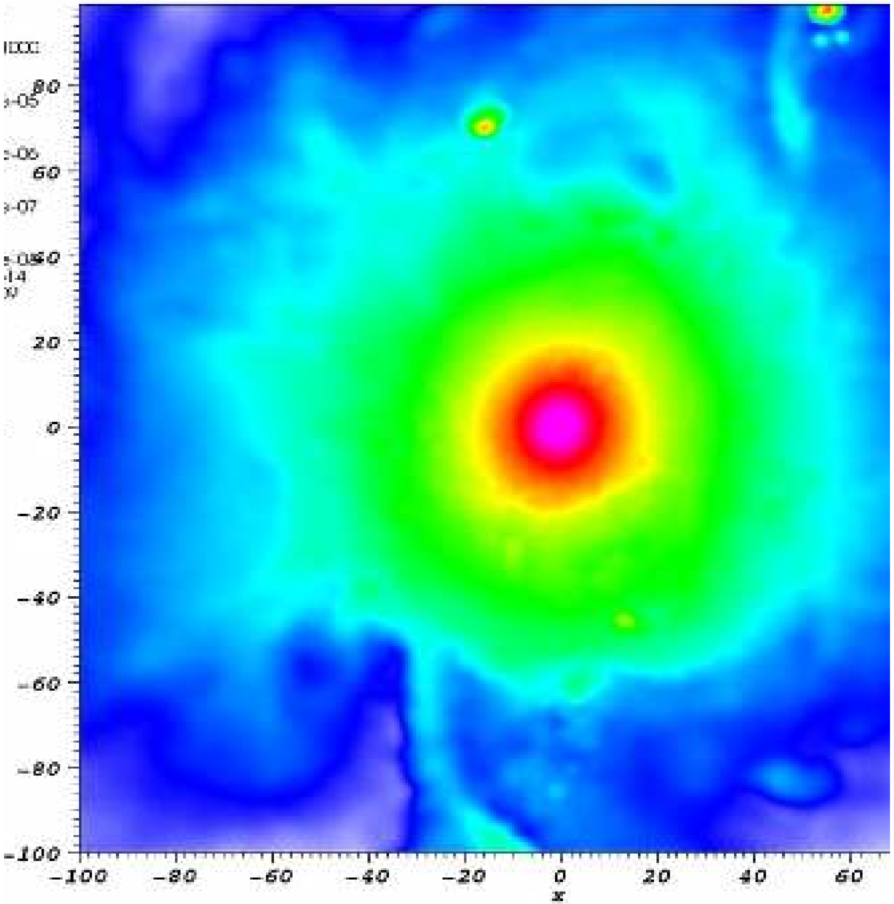


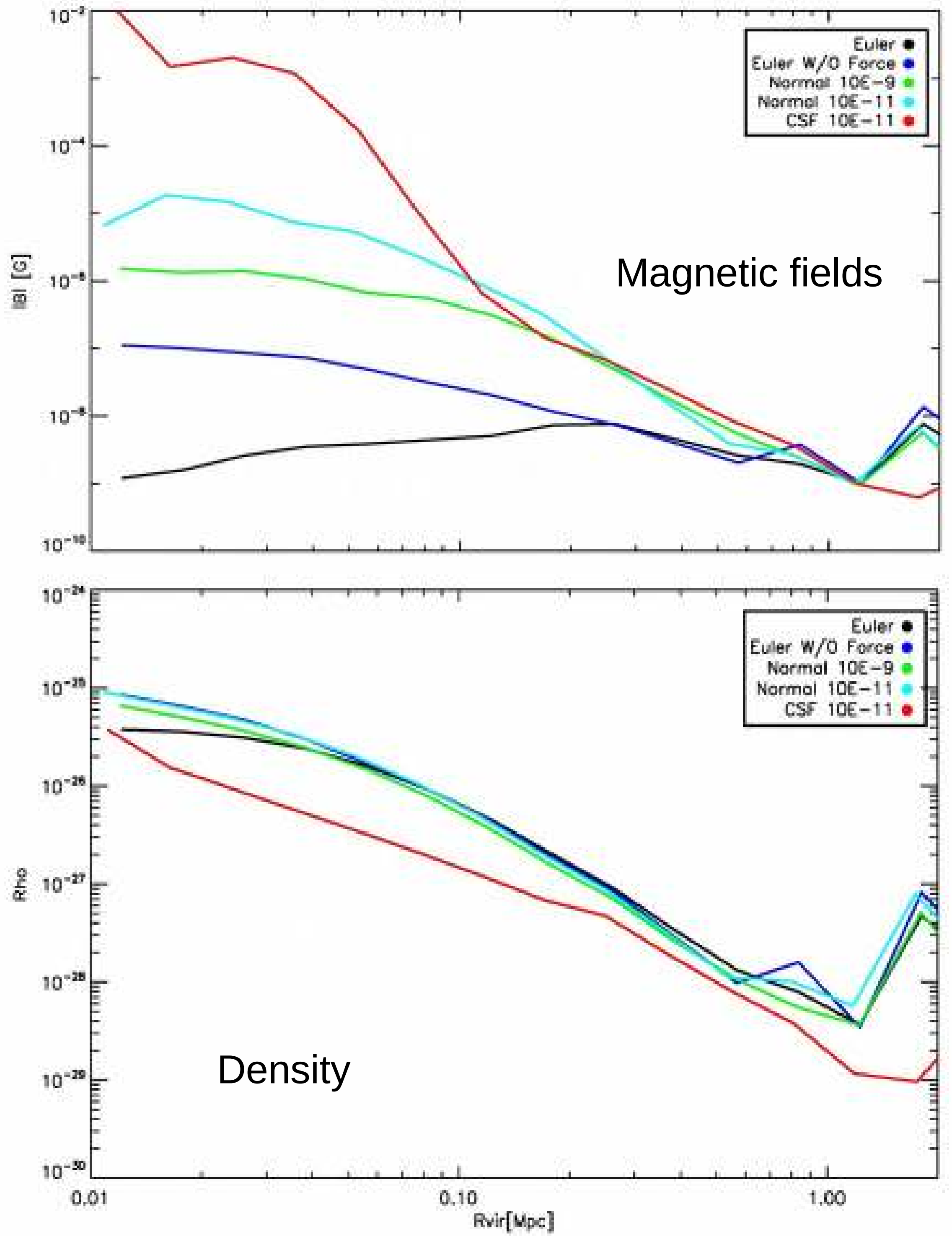


- Assuming the characteristic velocities and lengths from DM and using a standard dynamo as the Roberts Flow, we show that the dynamo action can effective in much less than the age of the universe (100 Myears)
- This is not recovered yet in MHD Simulations!
- Re-simulations of cosmic filaments needed!



Galaxy Clusters



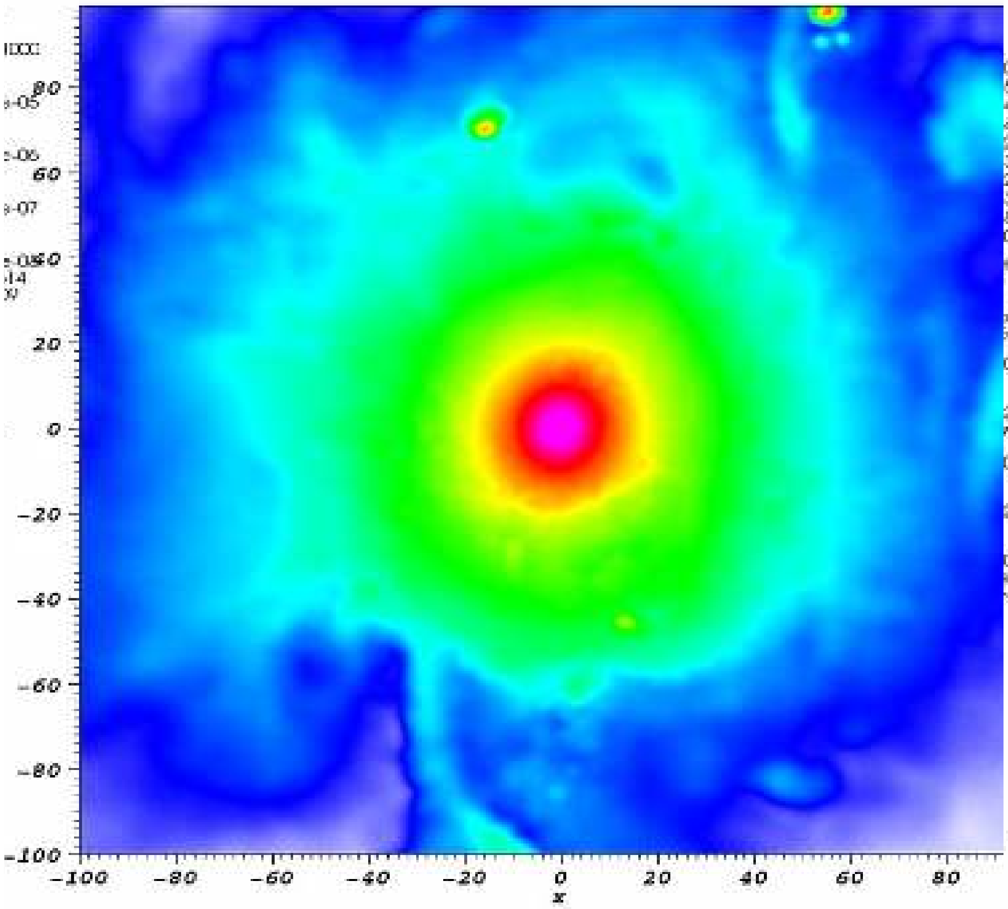


Re-simulation of Galaxy clusters

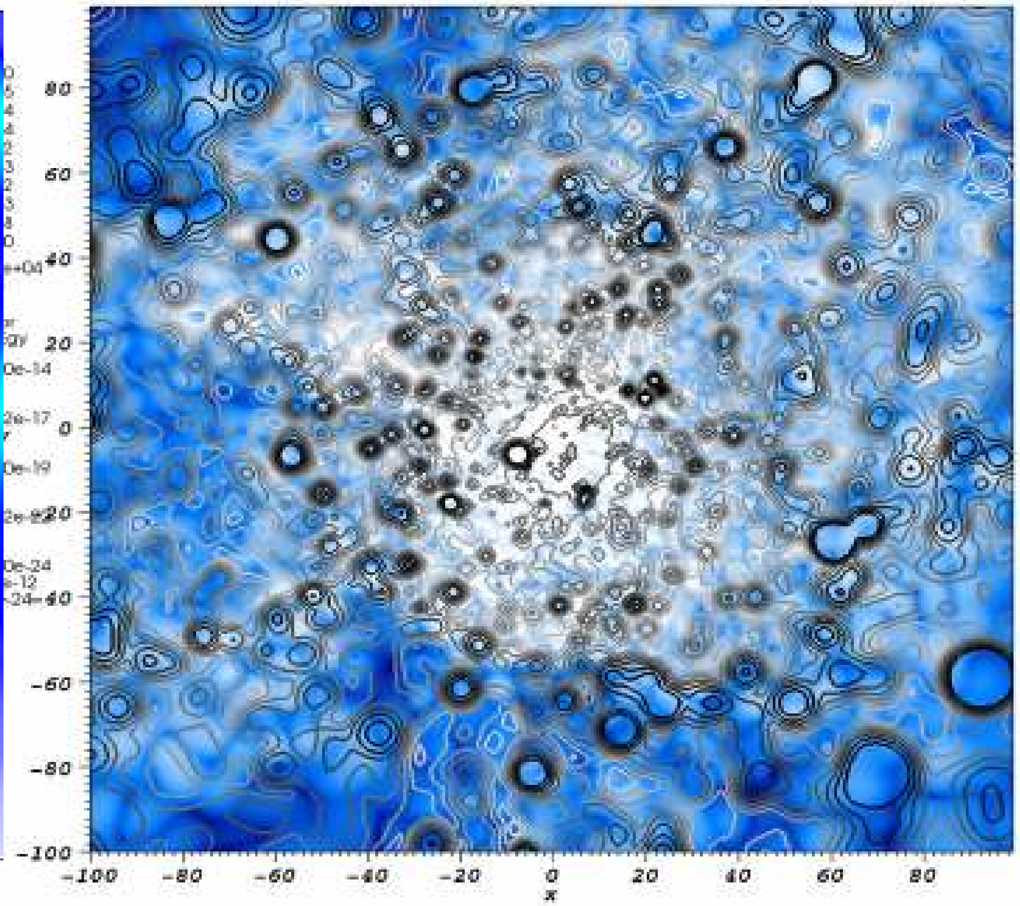
- MHD try to solve the Cool-core problem

Colaborators: Dolag K., Beck, Elstner D., Vazza F…..

Environment: Galaxy Clusters



Density



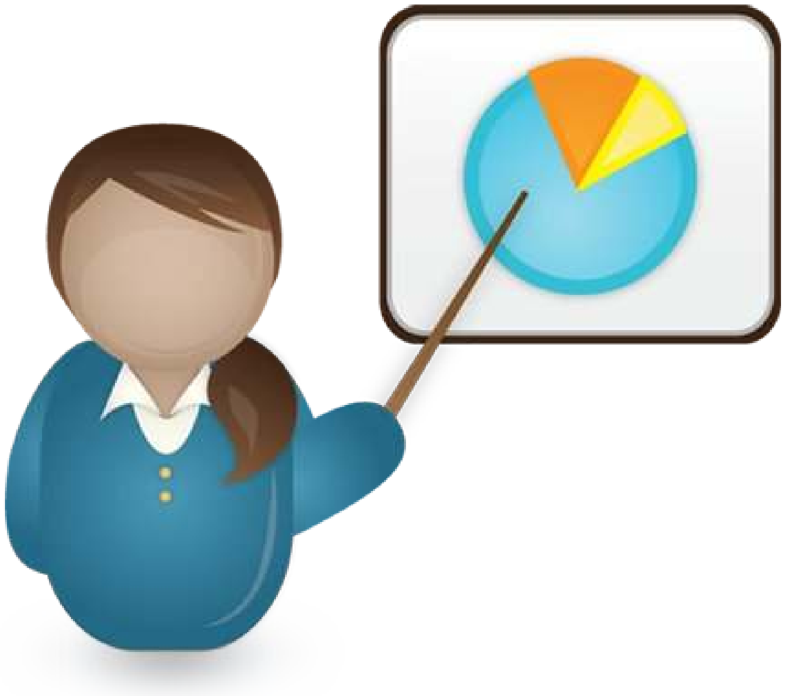
Magnetic Field

It turbulent dynamo woks, but it is the only proccess?

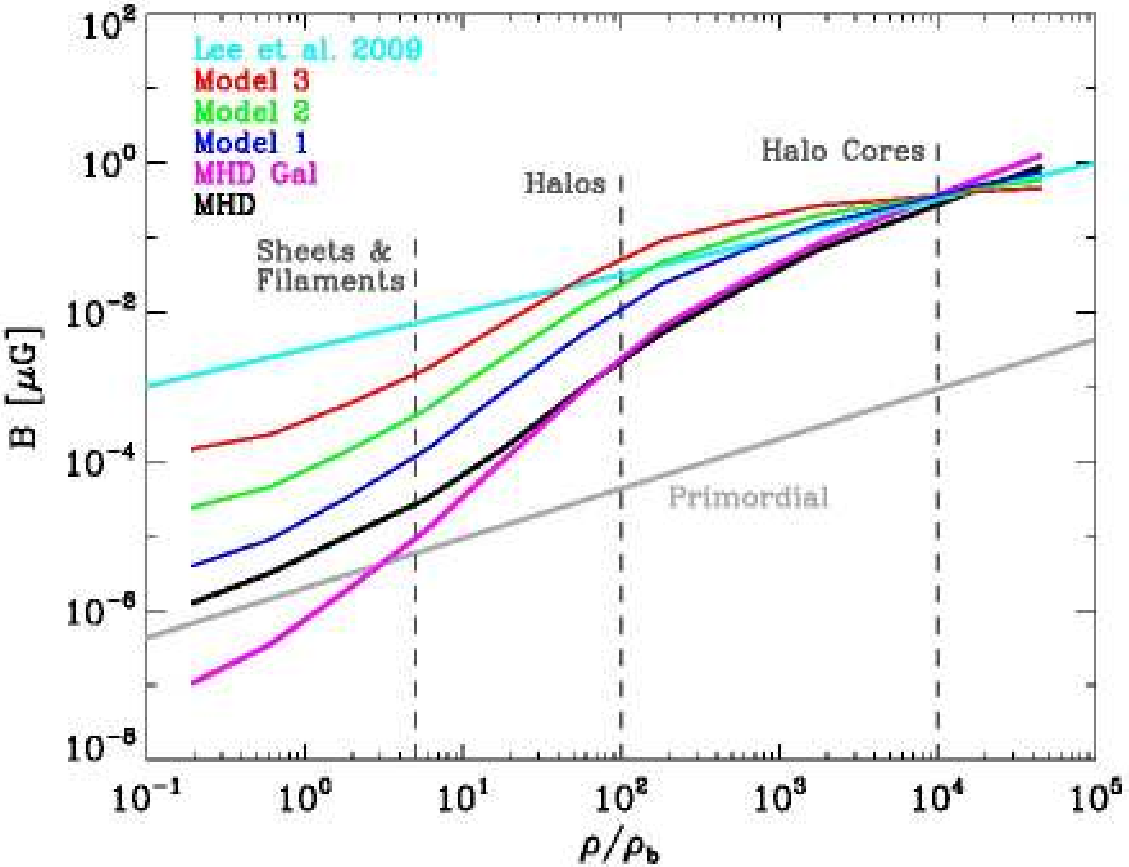
What we know?

What we want to know?

What is missing?



What we know?
What we want to know?
What is missing?



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We can use the recipes from what we know to constrain both sides of the ropes (the magnetic field and the galaxy formation Models) with observables...

Rodrigues et al. 2015, 2018.

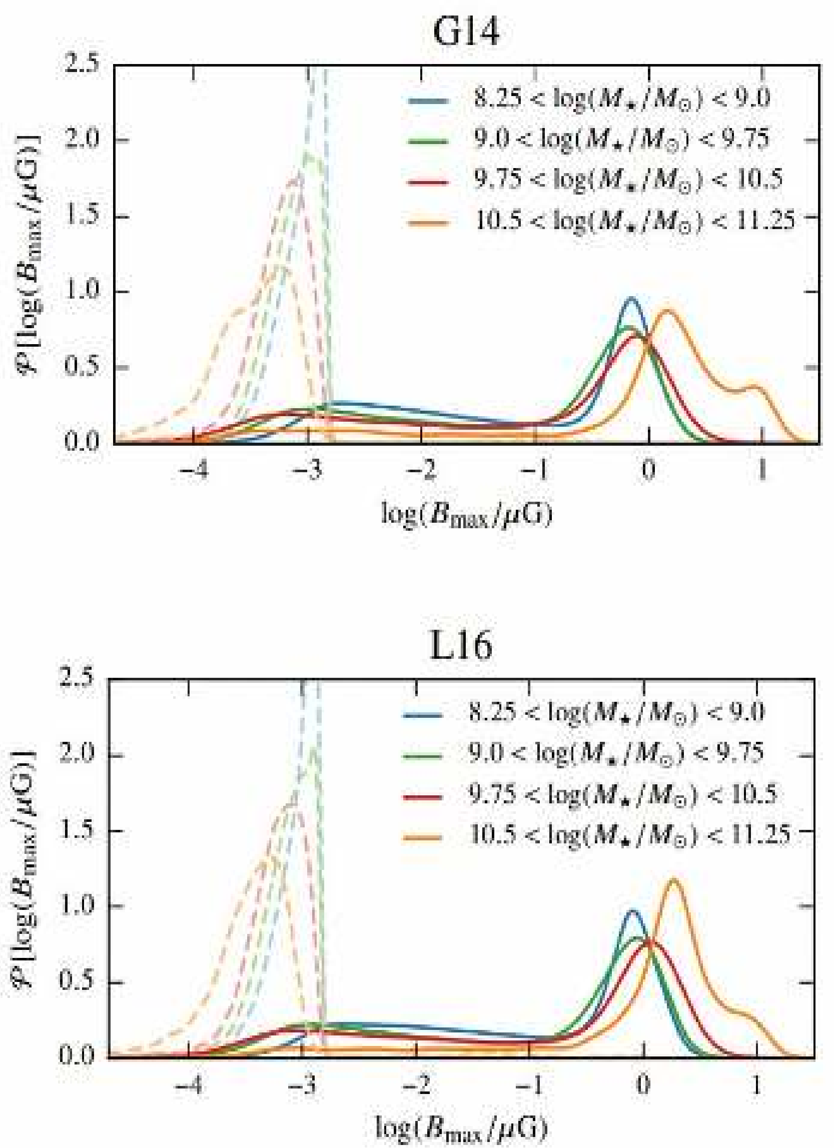
First attempt to use SAMs with magnetic field evolution

Table 1. Summary of the quantities used and notation.

Type of parameter	Notation	Meaning	Defined in or the value adopted
Galactic properties obtained from the semi-analytic models of galaxy formation	M_g	Cold gas mass of a galaxy	
	M_*	Stellar mass of a galaxy	
	$r_{50,\mathrm{out}}$	Half-mass radius of the galactic disc	
	V_0	Circular velocity of the galactic disc at the half-mass radius	
	SFR	Star formation rate in the disc	
Quantities estimated in this paper	$\bar{h}$	Average scale height of the galactic disc	Eq. (5))
	$\bar{\rho}$	Average gas density in the galactic disc	Eq. (7)
	r_0	Corrected half-mass disc radius	Eq. (10)
	Ω	Angular velocity of the disc	Eq. (11)
	S	Maximum rotational shear	Eq. (12)
	v_{ad}	Local outflow speed	Eq. (19)
Adopted parameters	l_0	Characteristic length scale of the turbulence	0.1 kpc
	v_0	Root-mean-square gas velocity dispersion in the disc	$10\,\mathrm{km\,s^{-1}}$
	α	Number of contributions to the interstellar pressure	4 (Eq. A6)
	R_κ	Ratio of turbulent diffusivities of the mean helicity and large-scale magnetic field	0.3 (Eq. 28)
Computed quantities	R_u	Outflow magnetic Reynolds number	Eq. (27)
	D	Dynamo number	Eq. (25))
	D_c	Critical dynamo number	Eq. (29)
	$\overline{B}$	Steady-state large-scale magnetic fields strength	Eq. (30)
	b	Steady-state random magnetic field strength	Eq. (24)

Rodrigues et al. 2015, 2018.

First attempt to use SAMs with magnetic field evolution

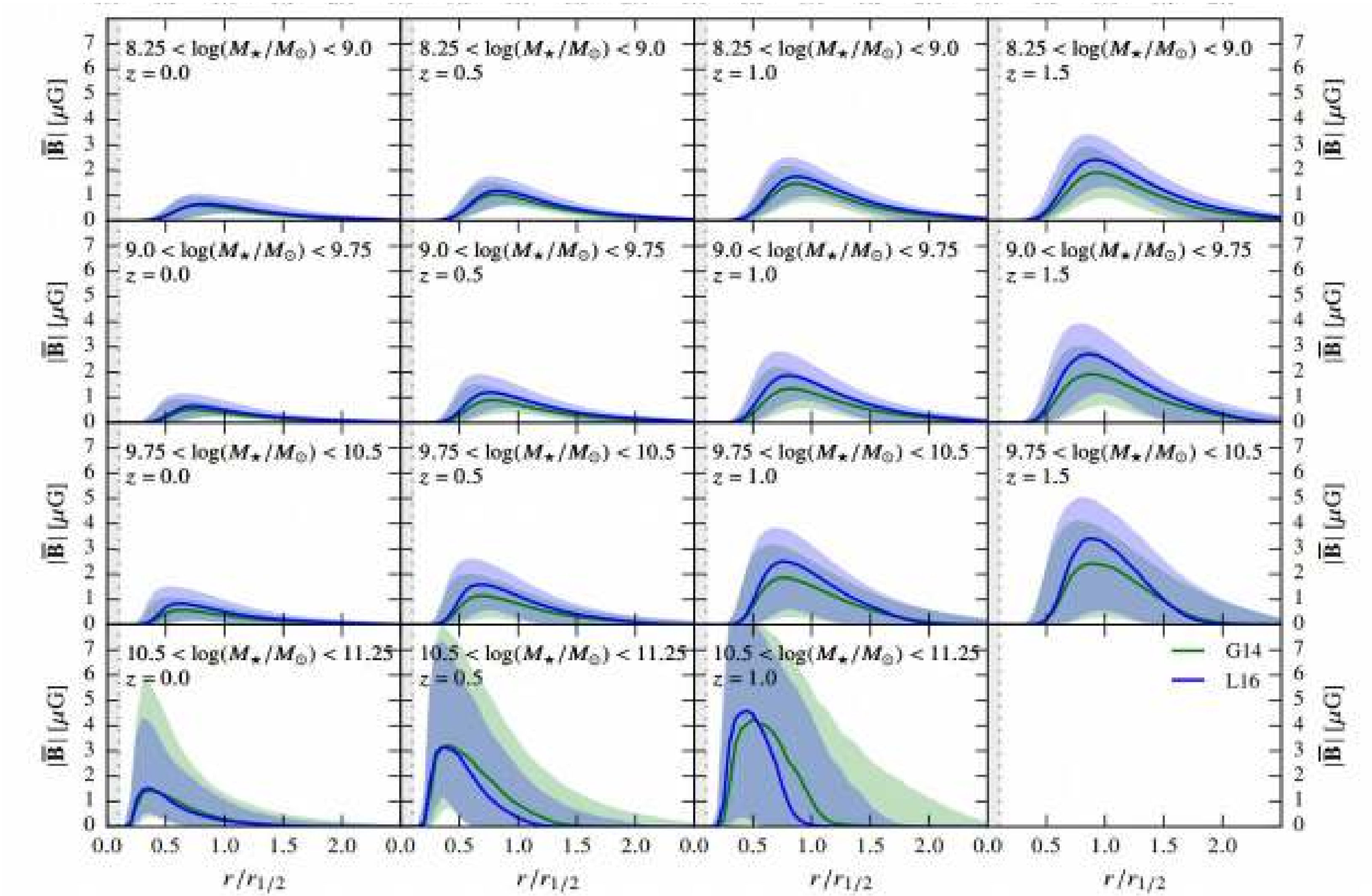


The magnetic field evolution is affected by the Galaxy formation model.

We also can derive parameters from the MF model:
-Turbulent / Large scale component of the MF
-Dynamo numbers (ask)
-MF radial distribution
-Pitch angles

Rodrigues et al. 2015, 2018.

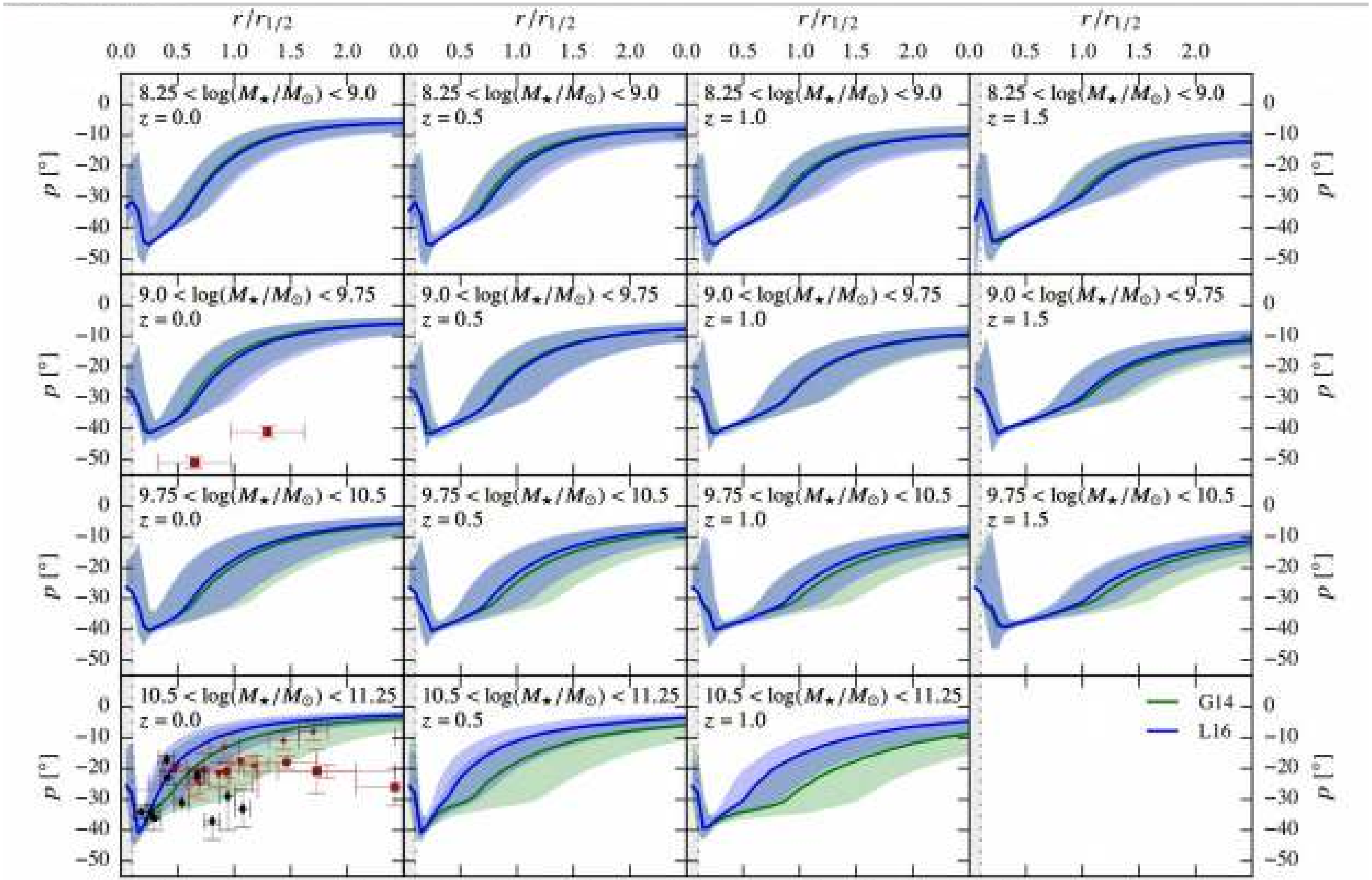
First attempt to use SAMs with magnetic field evolution



Magnetic field radial distribution

Rodrigues et al. 2015, 2018.

First attempt to use SAMs with magnetic field evolution



Pitch angles (warning we are biting our tail here)

Take home

- We have a lack of knowlegde about MF and Barions and Universe. From the seed, evolution, interplay…. We have done steps forewards…. But sill…
- We have information we can gather from different envirnoments and cosmological structures are complementary
- We need re-simulations with the „correct“ gastro-phisycs, for not resolved physics, now which??????
- We can use SAMs to infere which recipies work better.
- We still need to do a consistent star formation model.

Thank You !