SPH-MHD - a call for additional Physics

Kloster Irsee – October .2010

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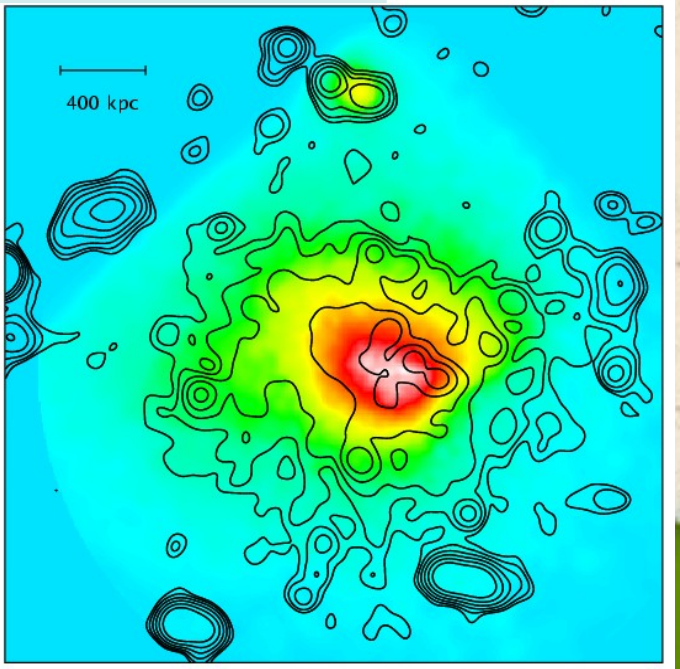
Astrophysical Motivation

- Looking for: Magnetic Field in Galaxy Clusters
- Prefered tool: Faraday RM maps

Galaxy Clusters: Galaxies (~5% Mtot) + DarkMatter (~80% Mtot) + Intra Cluster Medium (~15% Mtot)

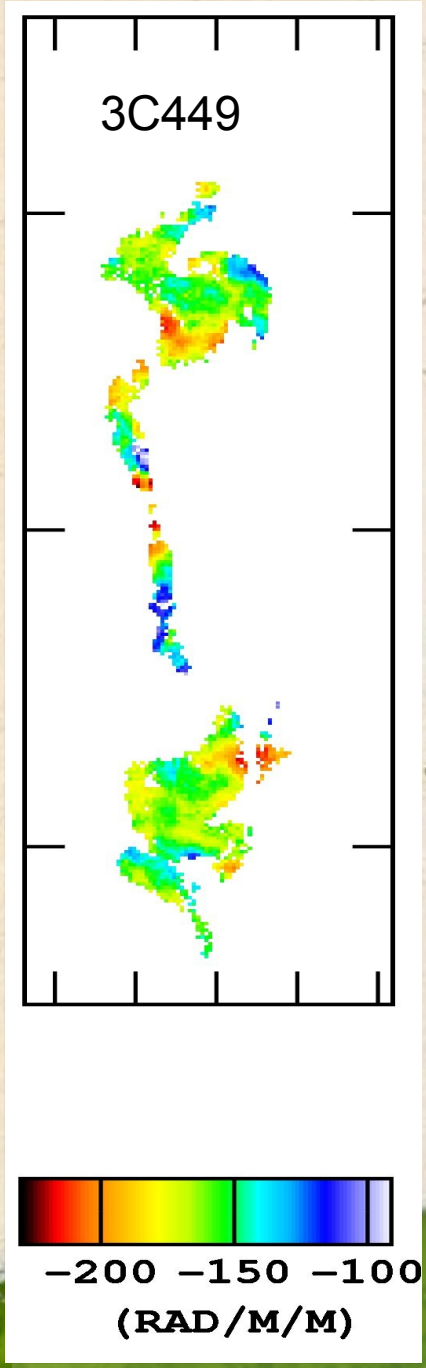
Abell 2163



Feretti et al. 2001/ Govoni et al 2004

$$RM = 0.81 . \int n_e B . dl \; rad \, m^{-1}$$

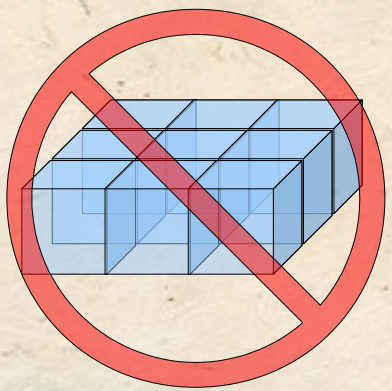
Non thermal component → magnetic field +relativistic particles

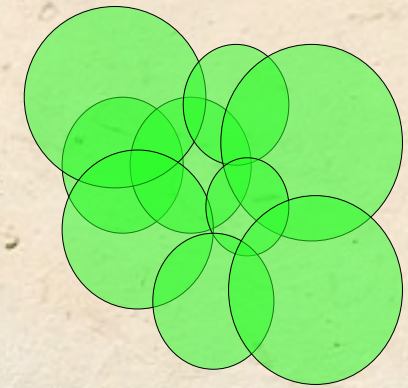


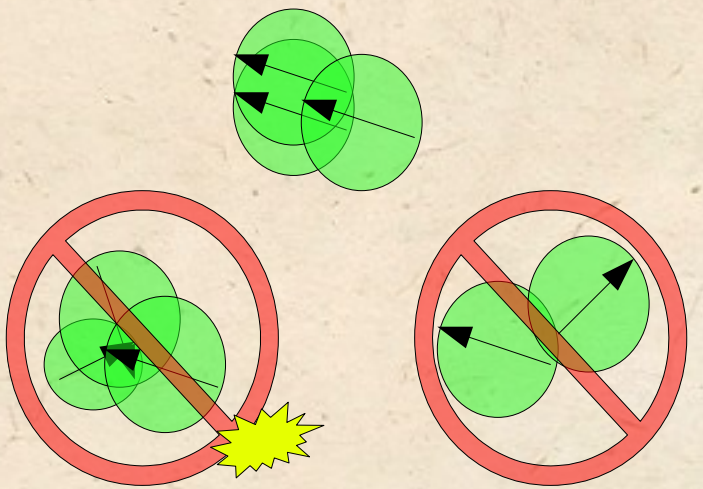
Feretti et al. 1999

Numerical MHD

- Smoothed Particles Hydrodinamics:
  - Natural Adaptativity and Huge Dynamical Range
  - Easy Gravity Calculation
  - Scalability
  - Galilean Invariant
  - ...





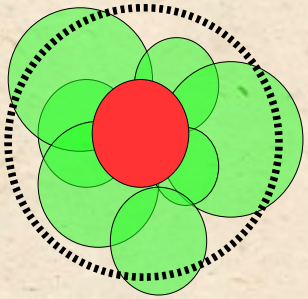


Approaches

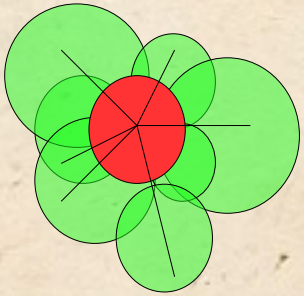
- Suppresion instabilities
  - Cleaning Schemes
  - Smoothing of the Field
  - Art. Dissipation
- Euler Potentials
- Vector Potential (?)

Orzang-Tang Vortex

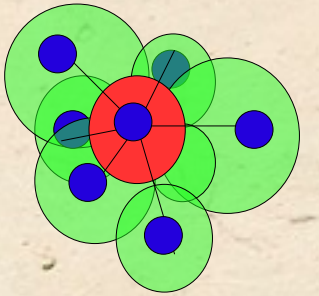
Smoothing:



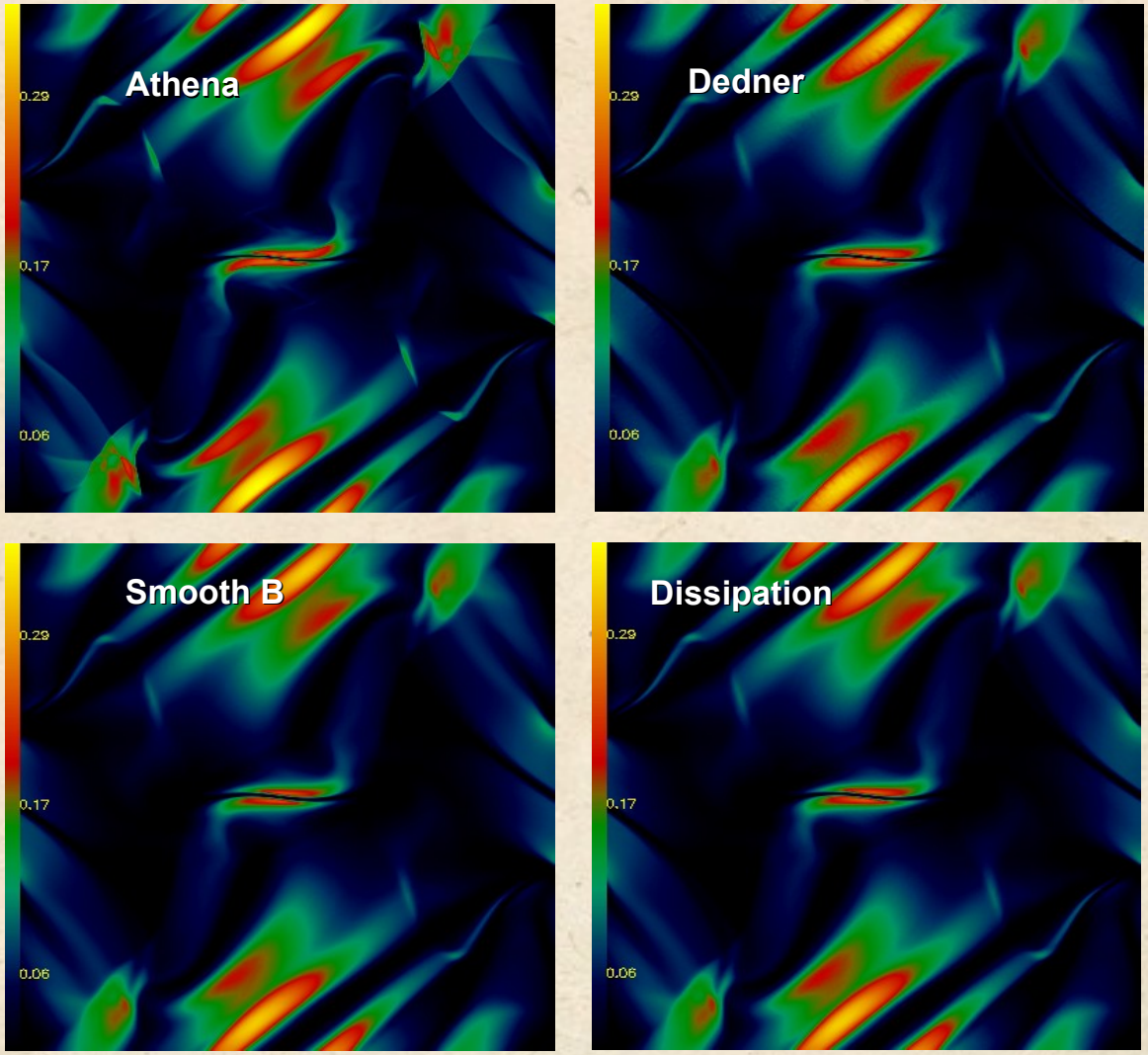
Art. Dissipation:



Cleaning Scheme (Dedner):



Magnetic Pressure



To a code or scheme be reliable has to complete resolution convergence and pass the full 1D/2D/3D test suite.

Orzang-Tang Vortex

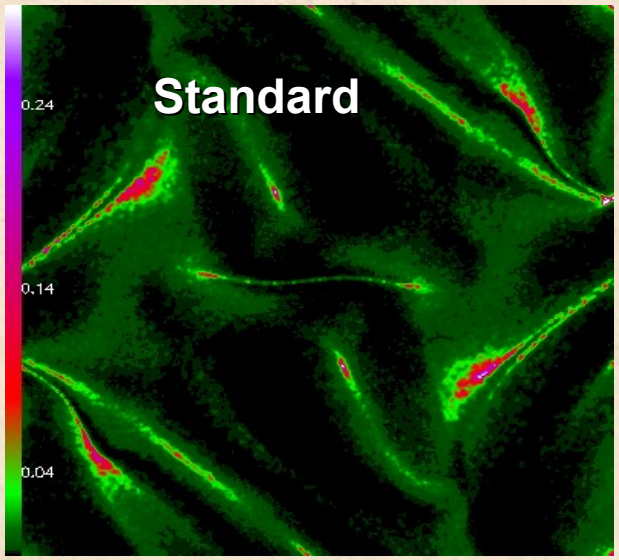
Div(B) errors

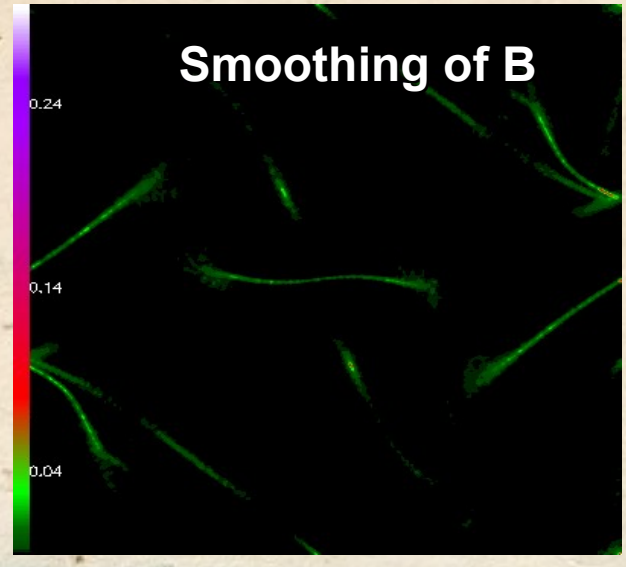
The div(B) is globally suppressed

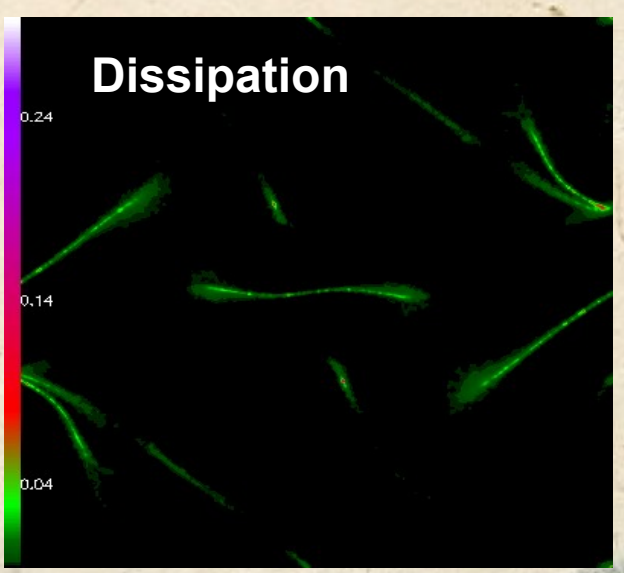
The front Shocks are a problem, in particular Dissipation and Smoothing still Oversmooth them.

Overall good performance of Dedner Method

In general at most still 10% errors in Front shocks

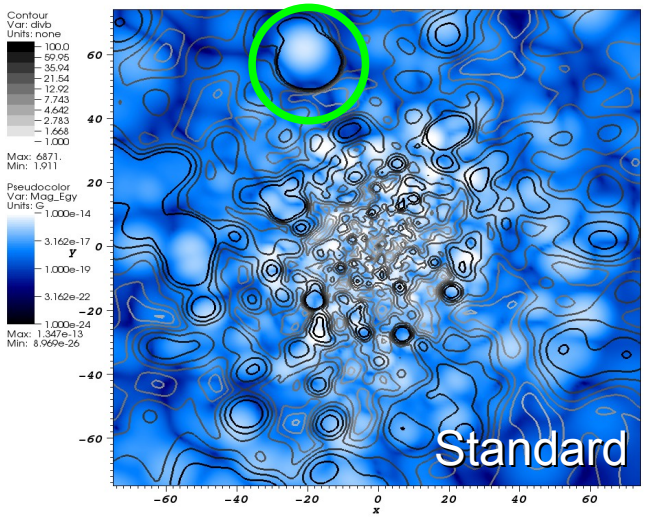




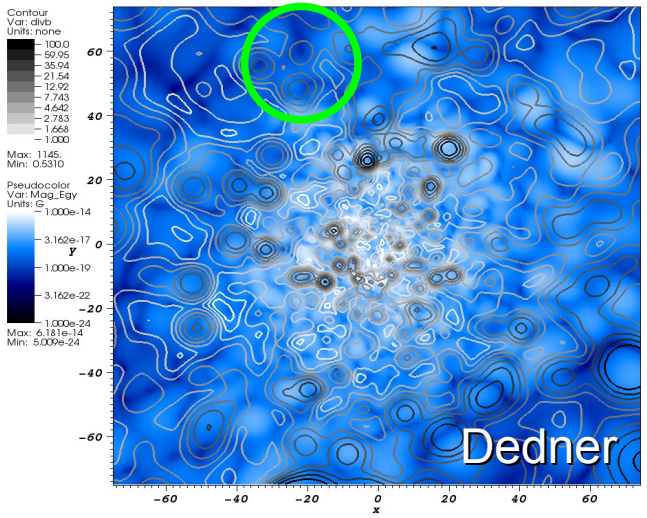


Galaxy Clusters

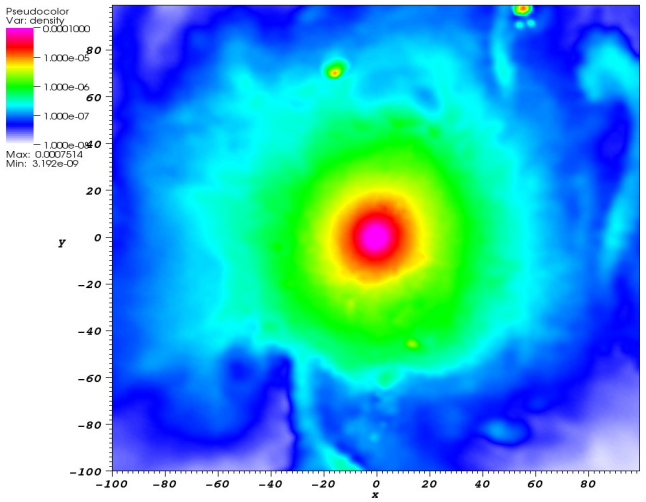
Low Resolution (1x)



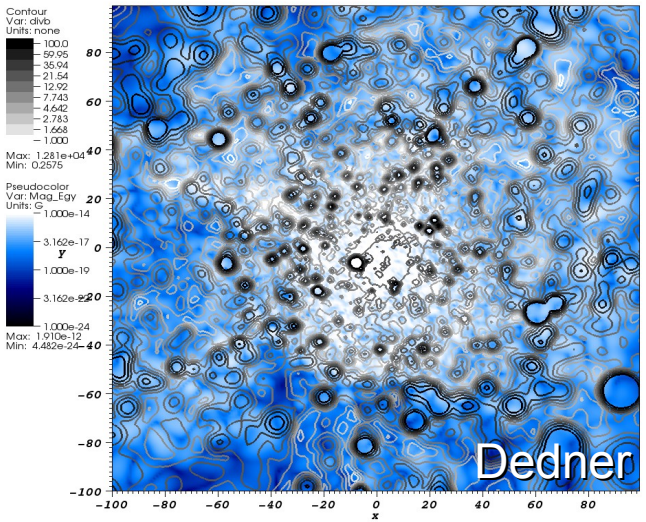
Magnetic Field



Magnetic Field



Density

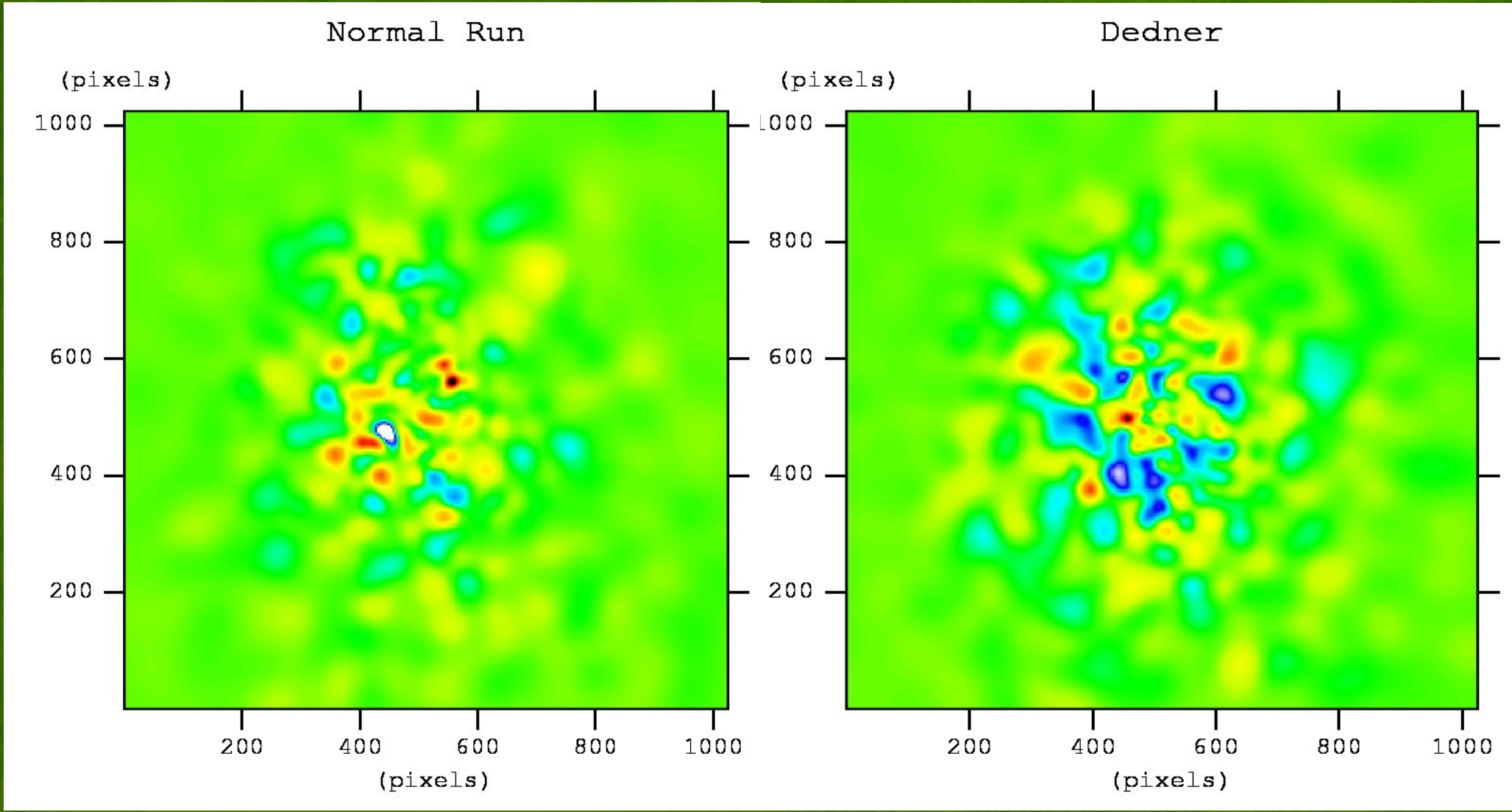


Magnetic Field

High Resolution (10x)

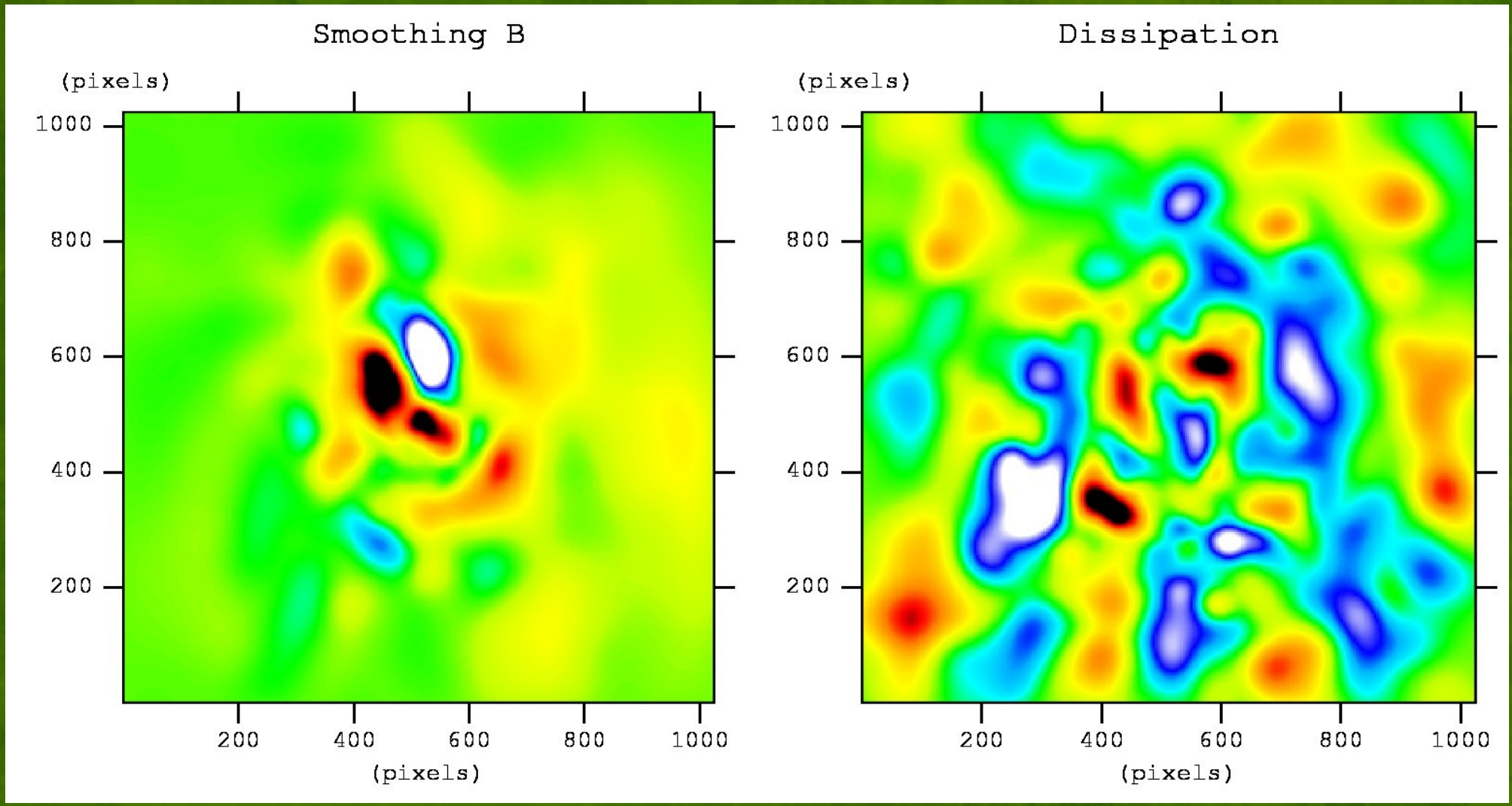
Cleaning scheme confines the DivB errors in smaller volumes, and diffuse them quickly.

Synthetic RM



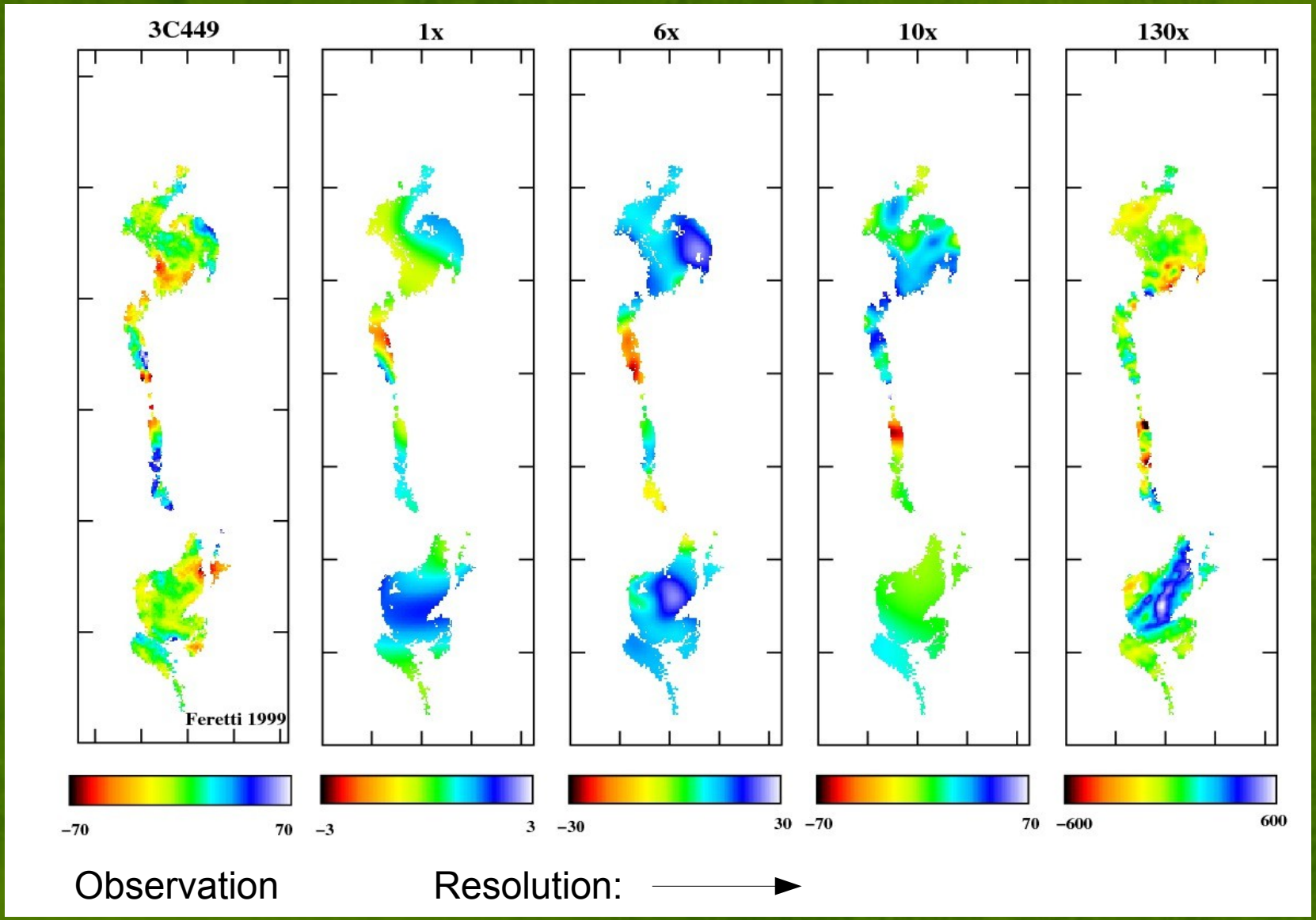
Internal Structure Conserved

Synthetic RM



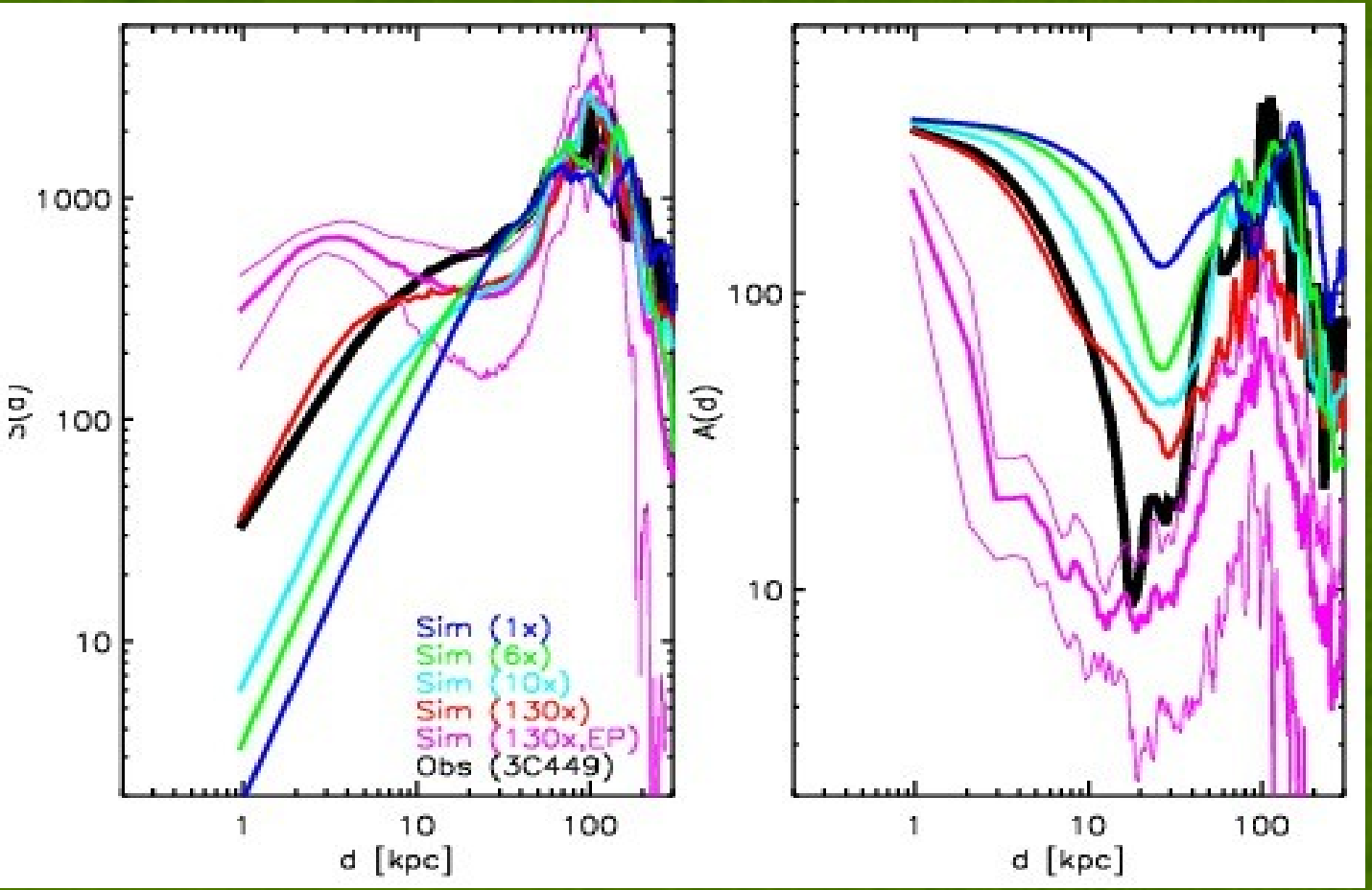
Less structure
Art. Dissipation Shows Transport of MF outside the core region

Synthetic RM



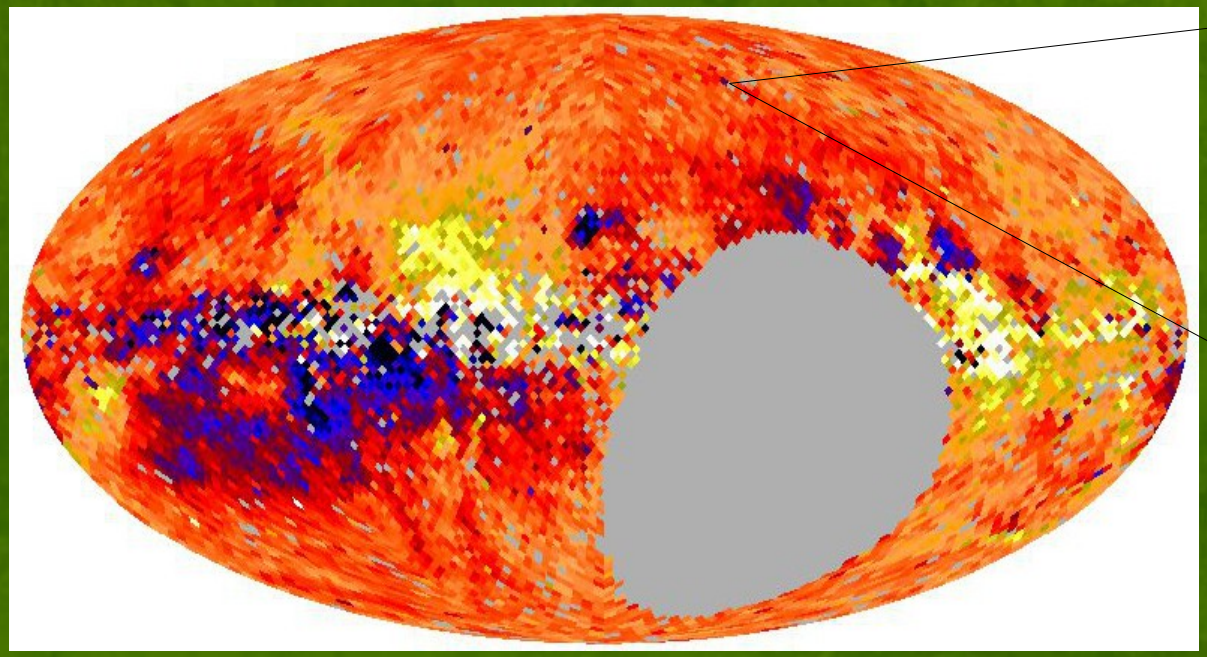
Currently we can compare with direct obervations.

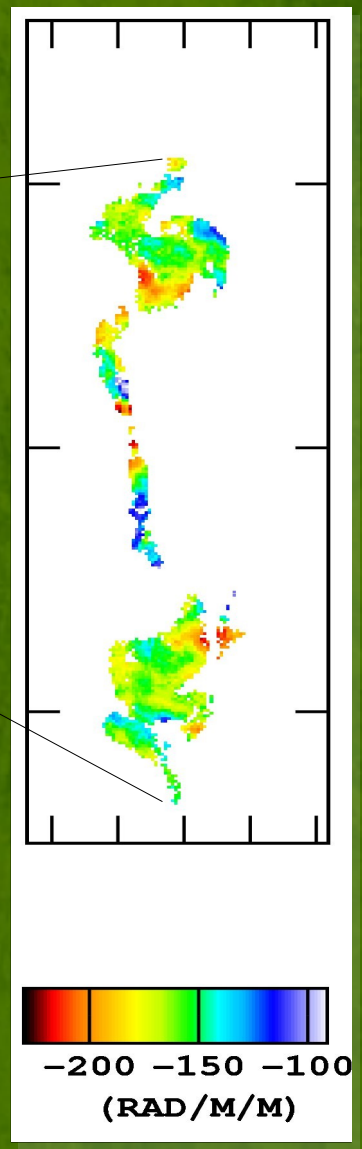
Synthetic RM



Structure and Correlation functions, show good agreement at low resolution but when we increase the resolution additional features raise.

RM Statistics



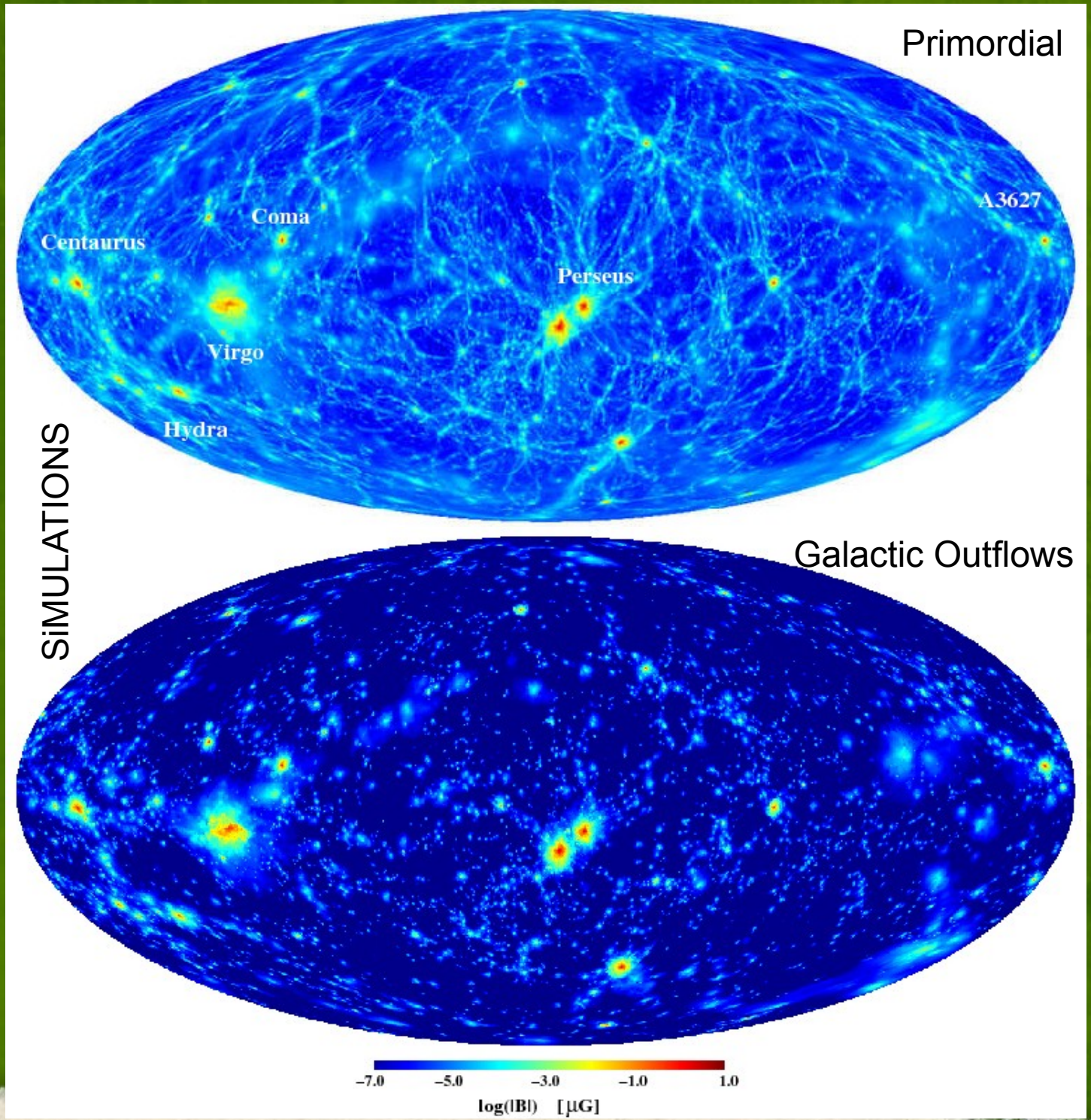


Structure Functions $S(r) := \langle (a(s) - a(s+r))^2 \rangle$

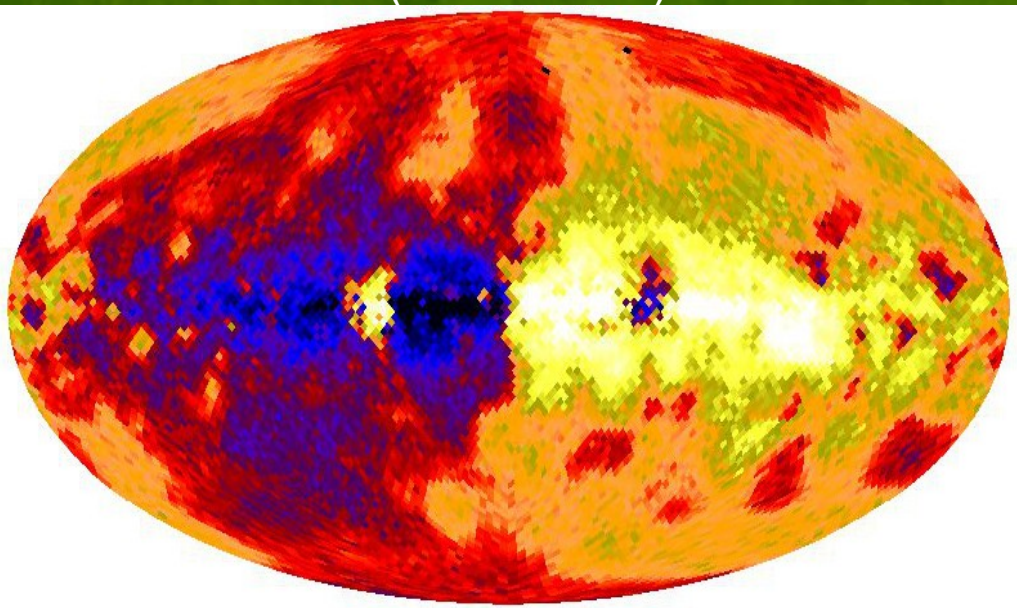
Autocorrelation Functions $A(r) := \langle a(s) * a(s+r) \rangle$

Marc Correlation Functions $M(r) := \langle a(s) * b(s+r) \rangle / (\bar{a}\,\bar{b}\,n(r))$

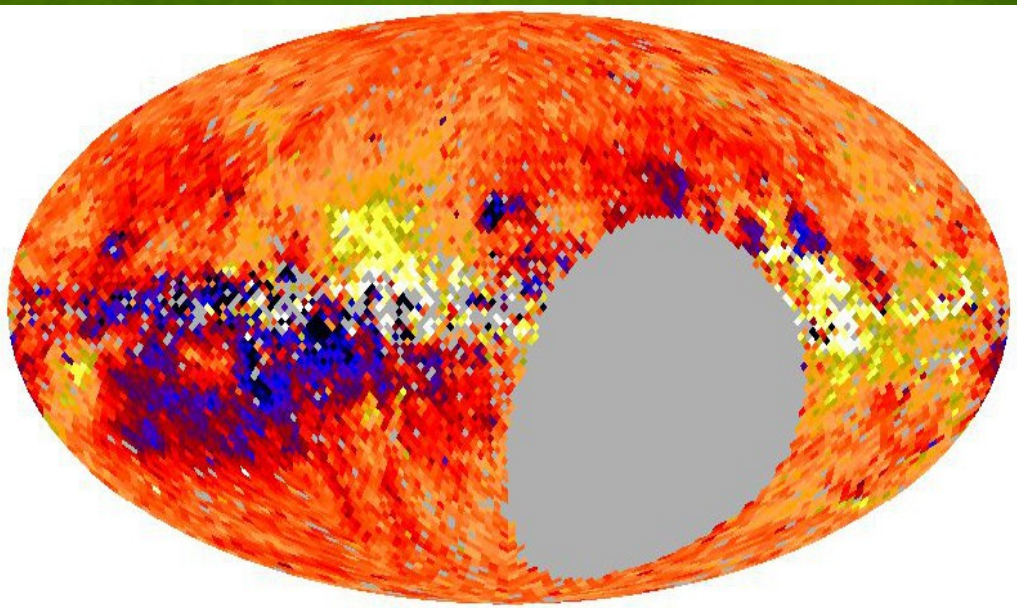
$omega(r) := \langle Del_n(r) * B \rangle / (\bar{n}\,\bar{B})$


Primordial
Coma
Centaurus
A3627
Perseus
Virgo
Hydra
SiMULATIONS
Galactic Outflows
−7.0
−5.0
−3.0
−1.0
1.0
log(|B|) [μG]

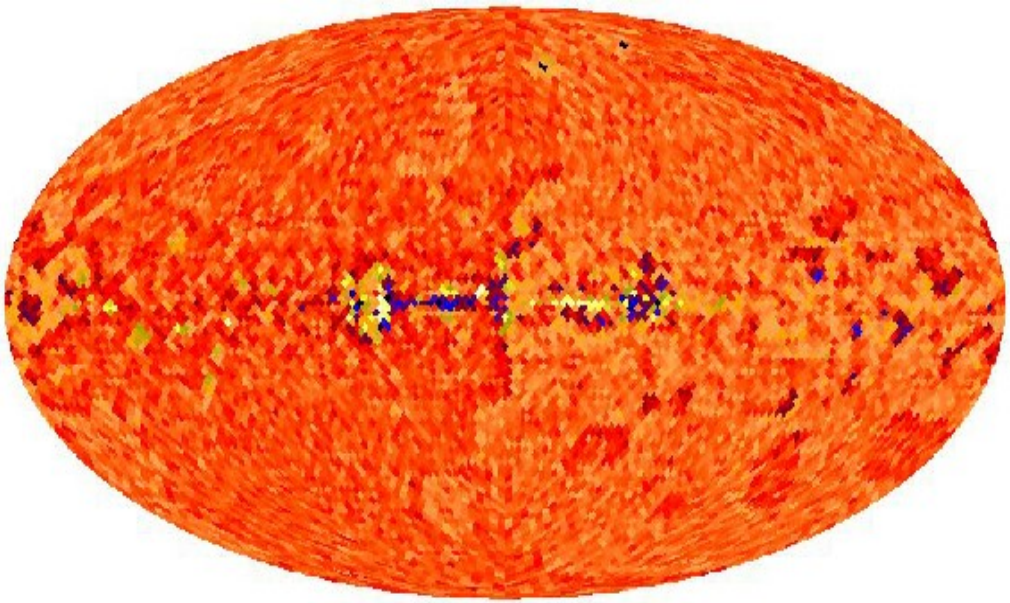
Simulation + Galactic Foreground
(Hammurabi)



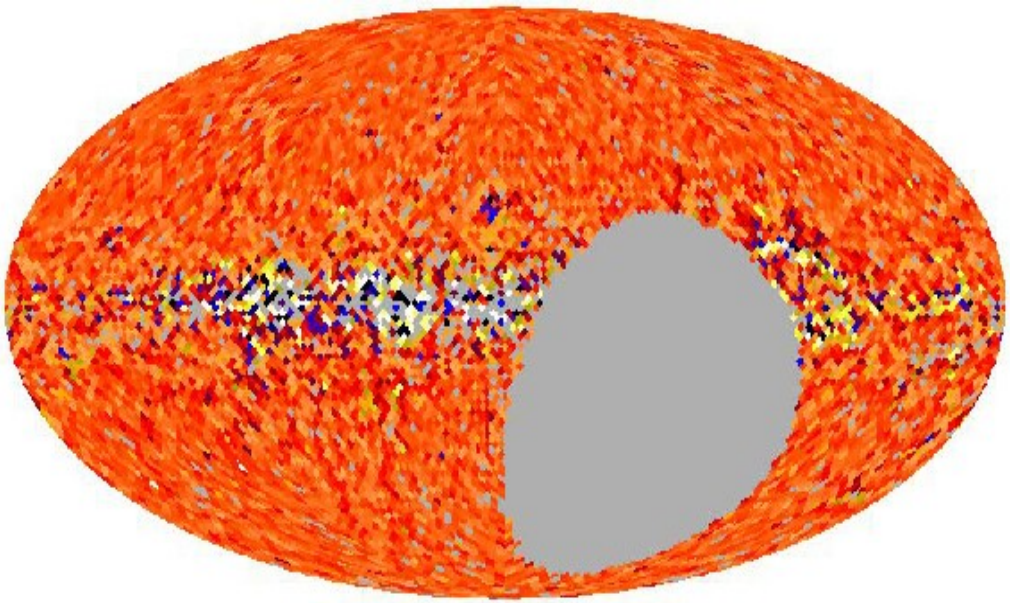
Observation (Taylor 2009)

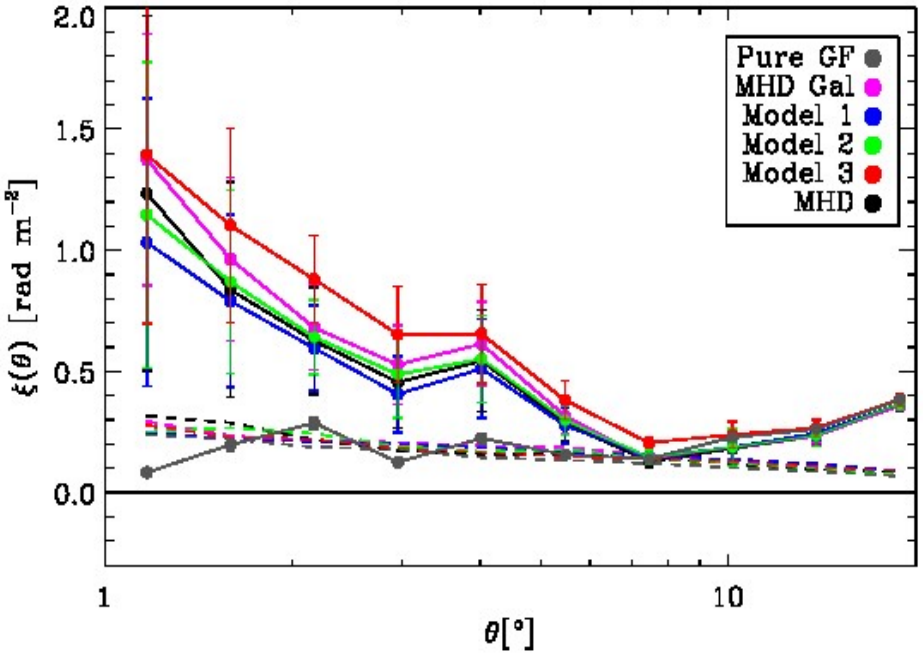


Simulation + Galactic Foreground – Substraction + Noise



Observation – Substraction





Future Predictions

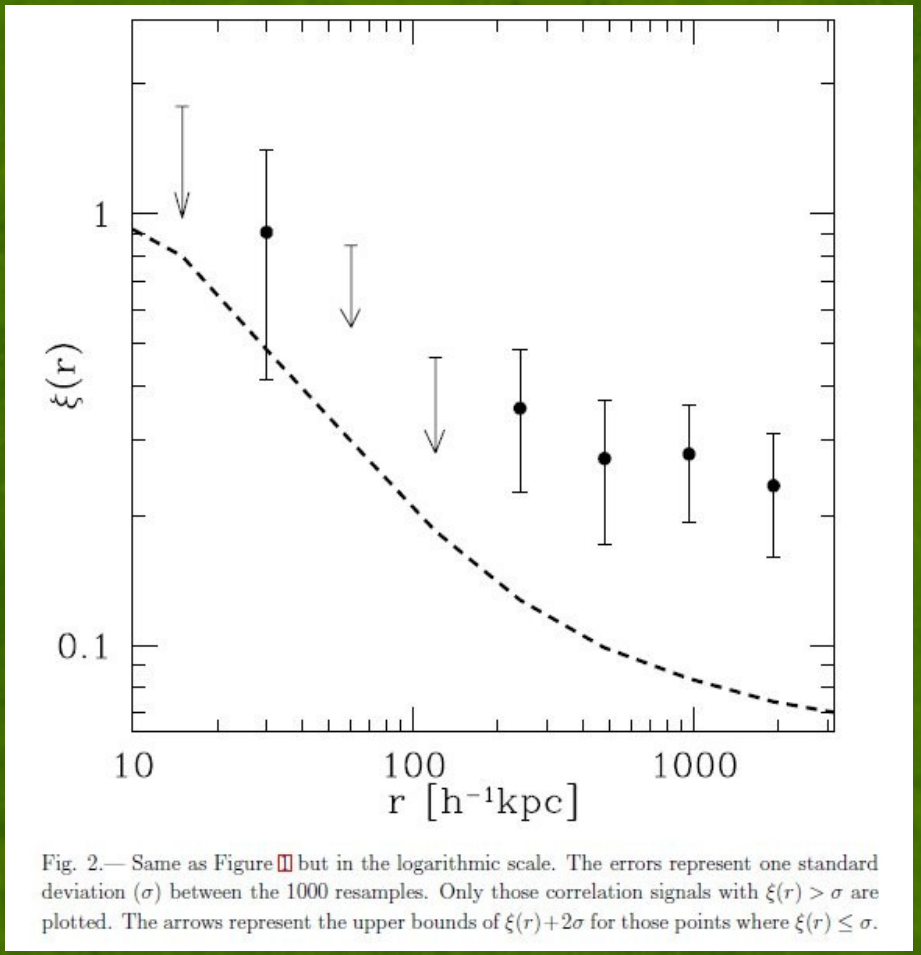
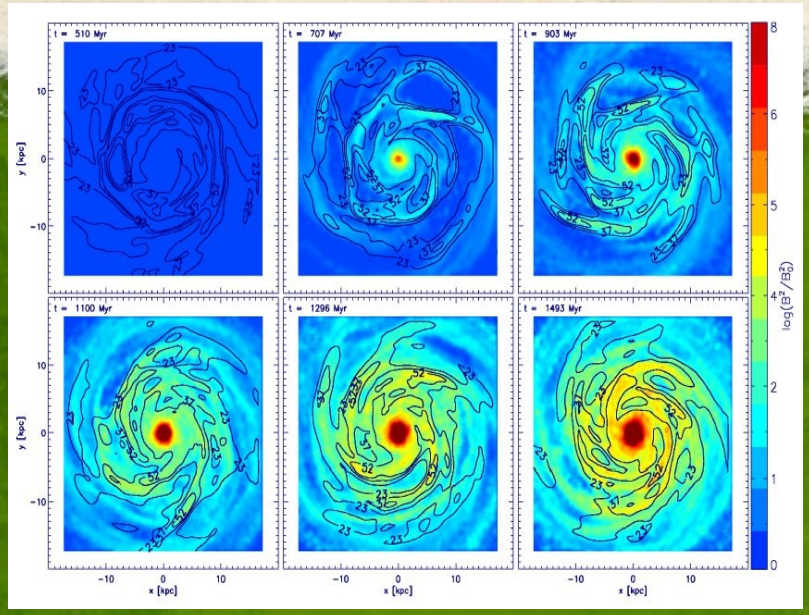


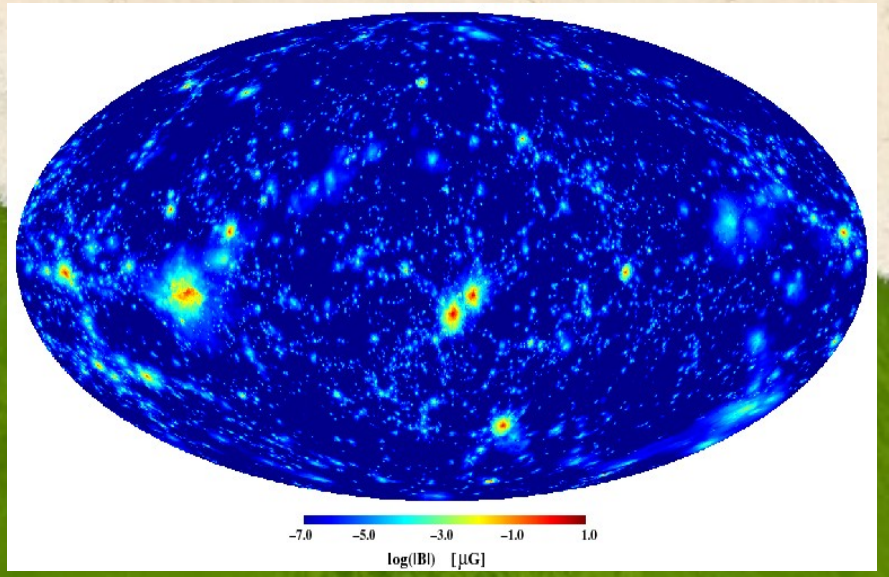
Fig. 2.— Same as Figure but in the logarithmic scale. The errors represent one standard deviation (σ) between the 1000 resamples. Only those correlation signals with $\xi(r) > \sigma$ are plotted. The arrows represent the upper bounds of $\xi(r)+2\sigma$ for those points where $\xi(r) \leq \sigma$.

Lee et al. 2009 (?)

The Observational Data is close to be Statistically important (if not already).
The Numerical simulations are able to help to understand theses new sets of data and improve predictions for the new gereneration of telescopes

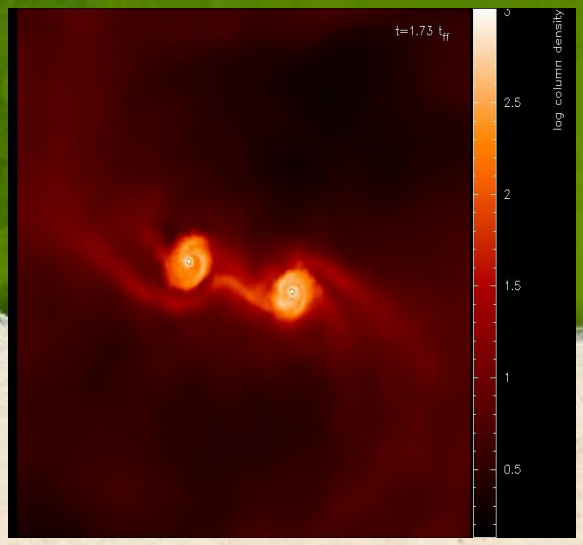


Hanna Kotarba – USM
Harald Lesch - USM
Detlef Elsner – AIP

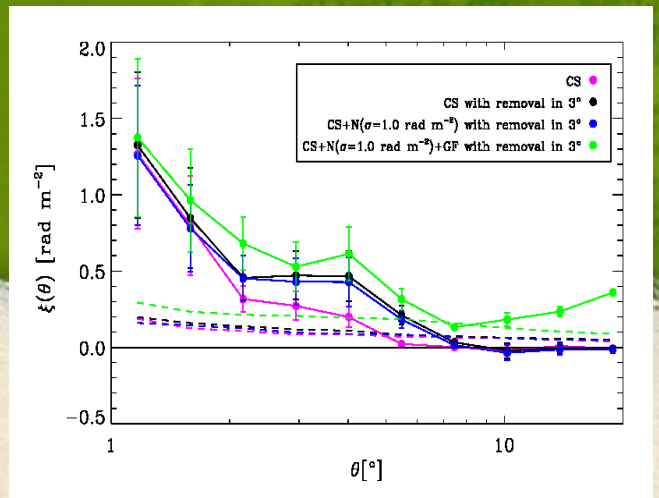


Julius Donnert - MPA

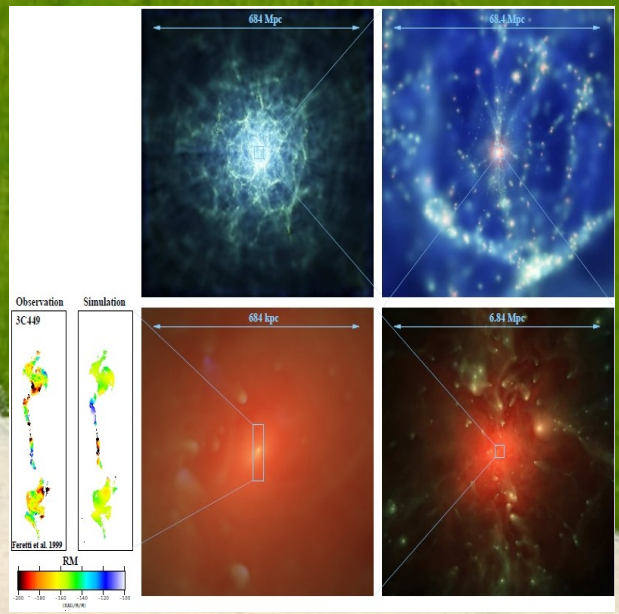
Florian Bruenzl – Uni. Konstanz



Sebastian Nuza – AIP



Klaus Dolag - USM



Open problems, room for " new" physics...

We need to improve our Methods and add additional Physics in the Sub-grid models

- **Divergence Cleaning**
- **Euler Potentials**
- **Vector Potential (?)**
- **Alfa-Omega Dynamo (?)**
- **Multi-face SF (?)**
- **Feedback MF Seeding (?)**
- **.....**