Magnetic field structures & statistics:

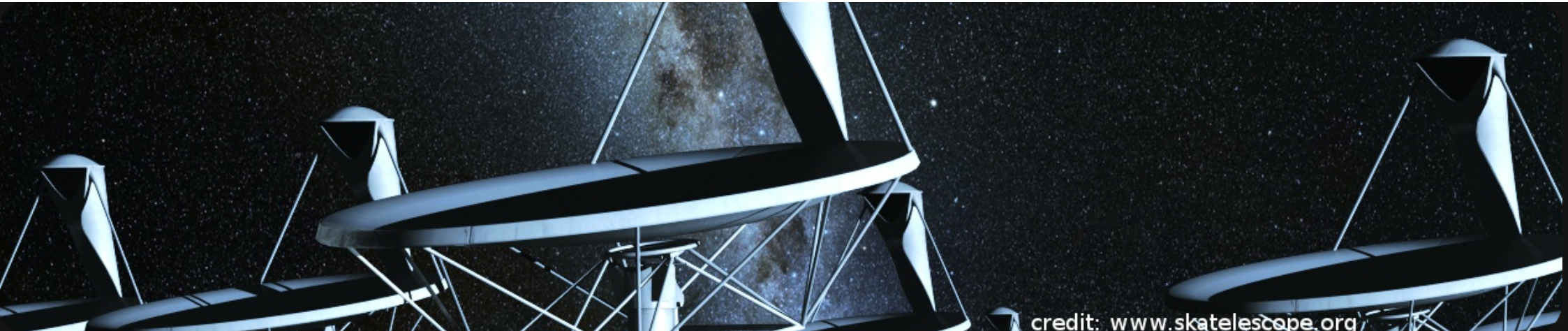
unraveling the inner workings of magnetic dynamos

Torsten Enßlin

A fresh view of the radio sky: science with LOFAR, SKA and its pathfinders

Annual meeting of the Astronomische Gesellschaft, September 19-23, 2011

"Surveys & Simulations - The Real and the Virtual Universe"



Magnetic field structures & statistics:

unraveling the inner workings of magnetic dynamos

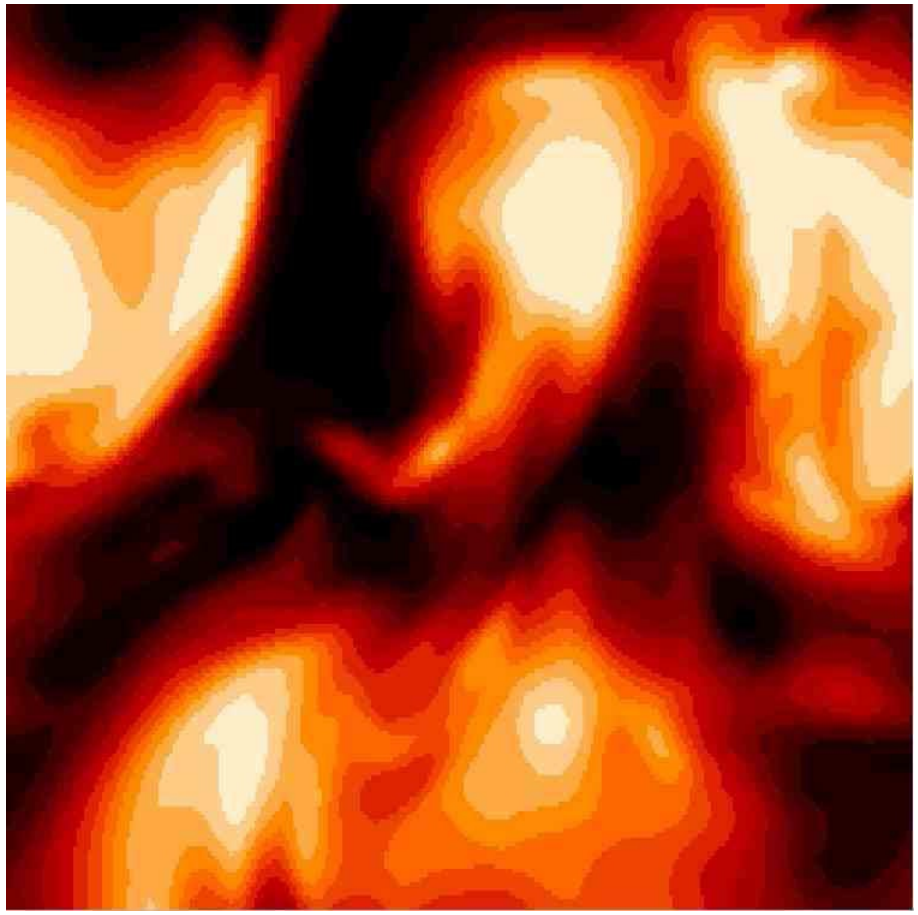
– outline –

Magnetic fields are ubiquitous in the Universe.
They control the transport of heat, momentum, cosmic rays, … .
They are wittnesses of dynamical processes.
How to study magnetic fields observationally?
Which processes generate, amplify, & shape magnetic fields?
How can fields & processes be probed with Lofar, SKA, … ?

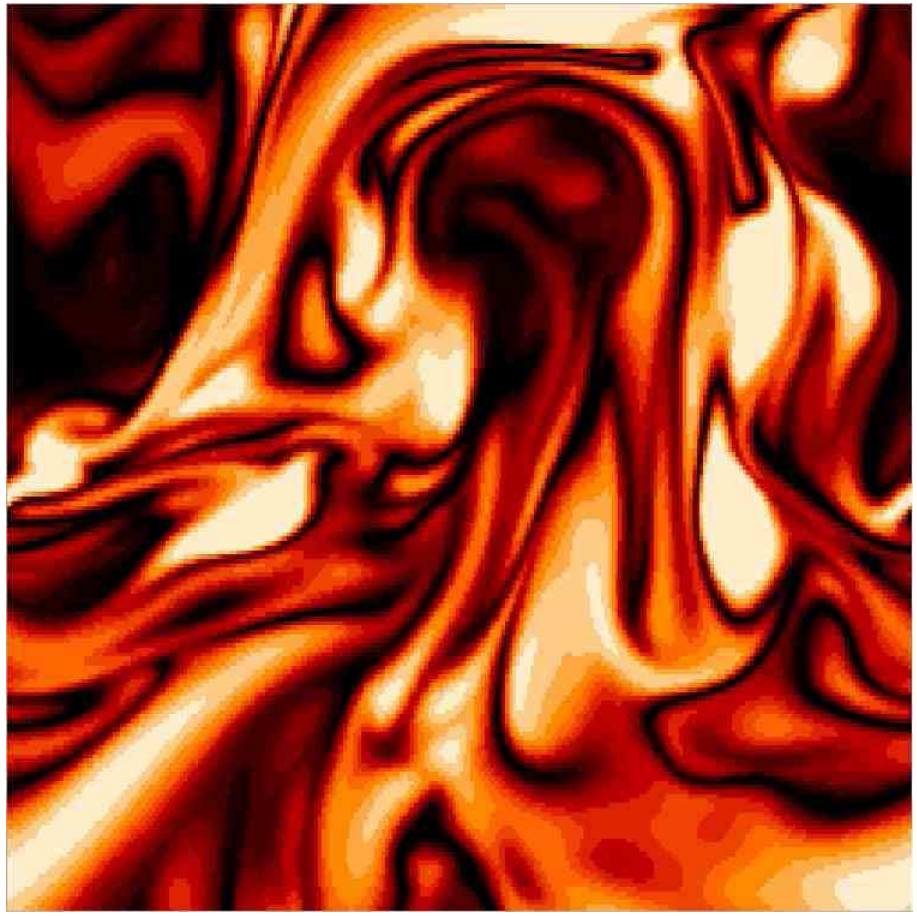
- small-scale dynamo:
  morphology – energy spectrum – tension force spectrum
- large-scale dynamo:
  large-scale topology – magnetic helicity – Faraday caustics

Small-scale dynamo

velocity field



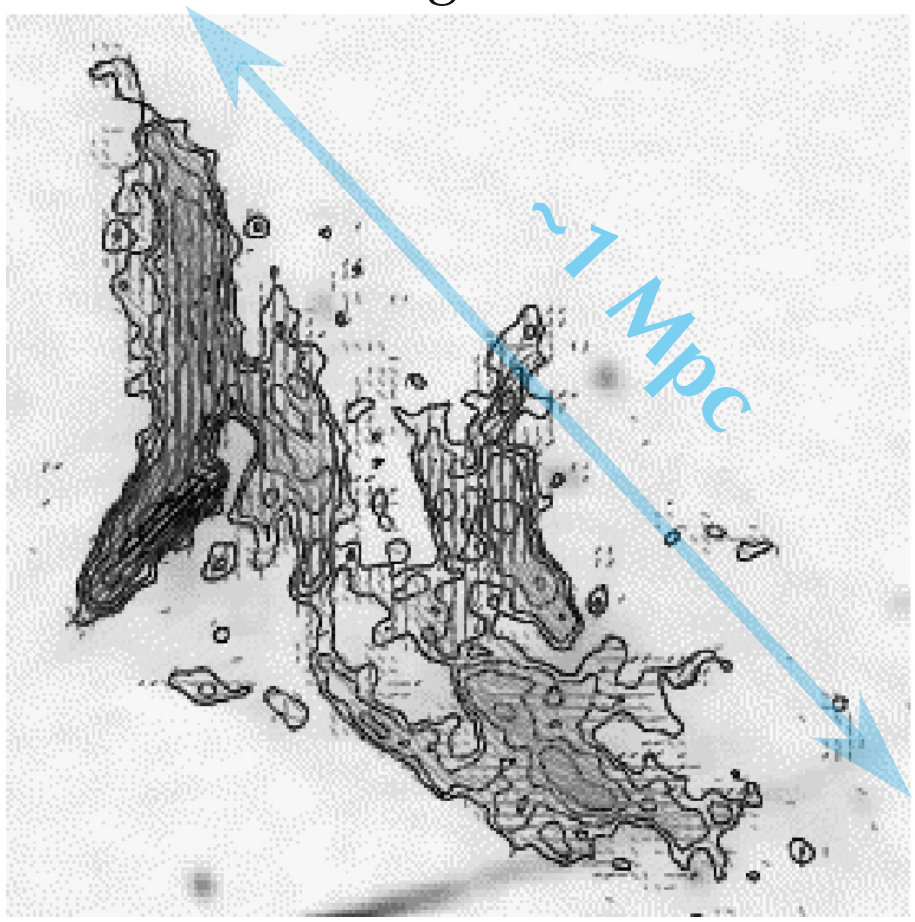
magnetic field



Schekochihin & Cowley (2007)

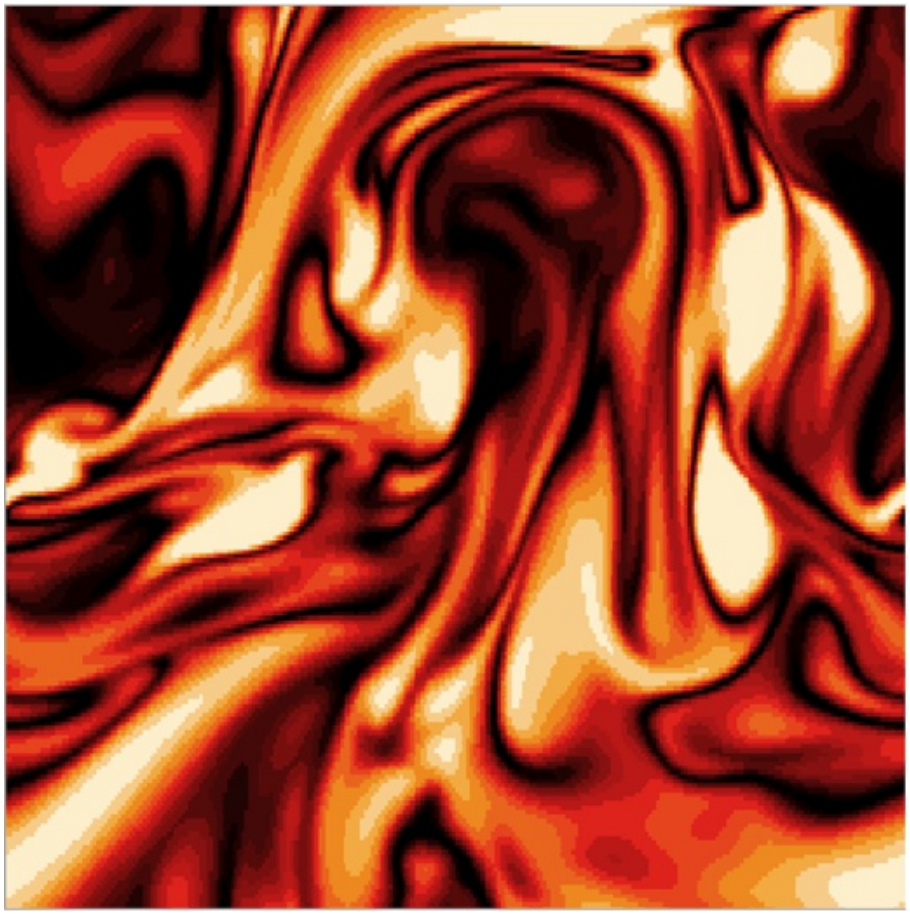
Small-scale dynamo

real magnetic field



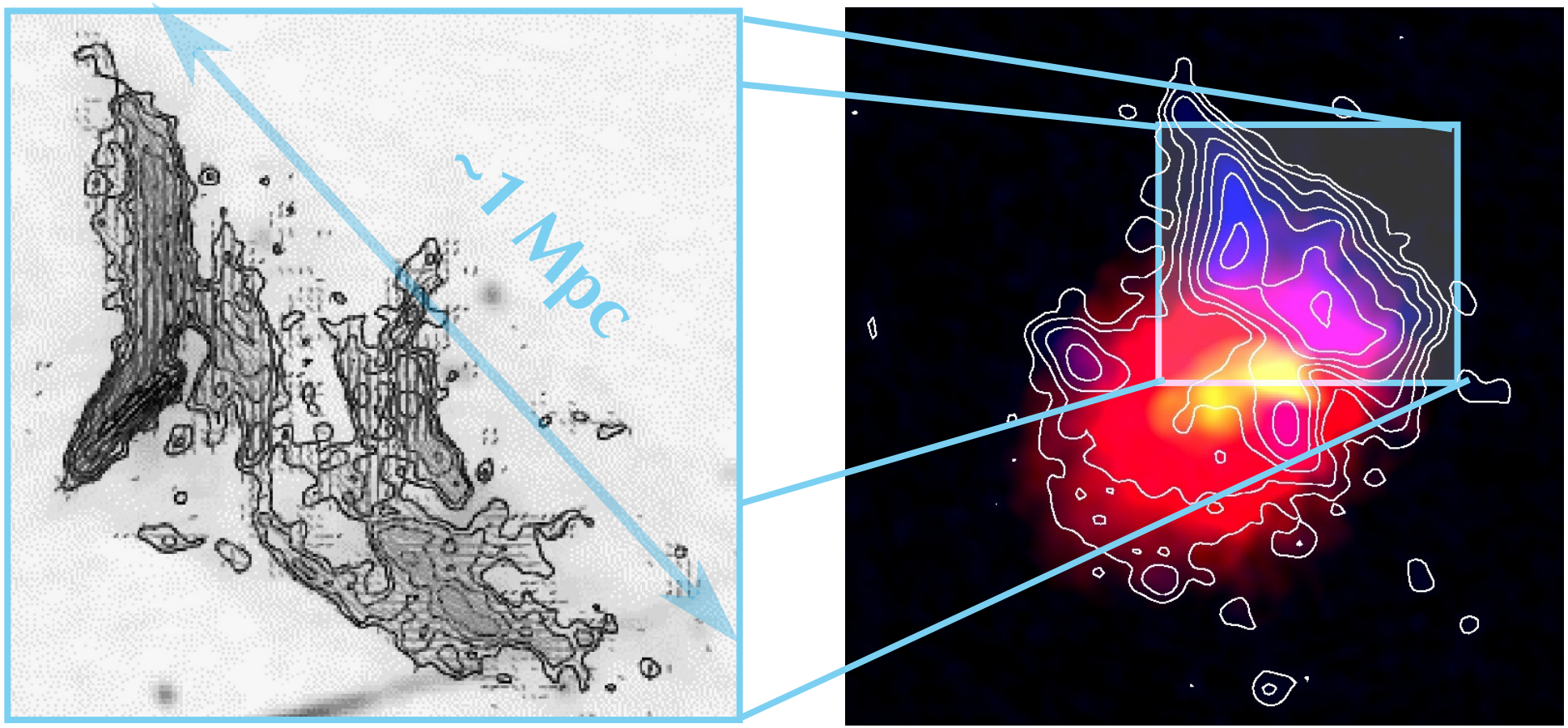
A2256 @ 1.4 GHz; Clarke & Enßlin

magnetic field



Schekochihin & Cowley (2007)

Small-scale dynamo

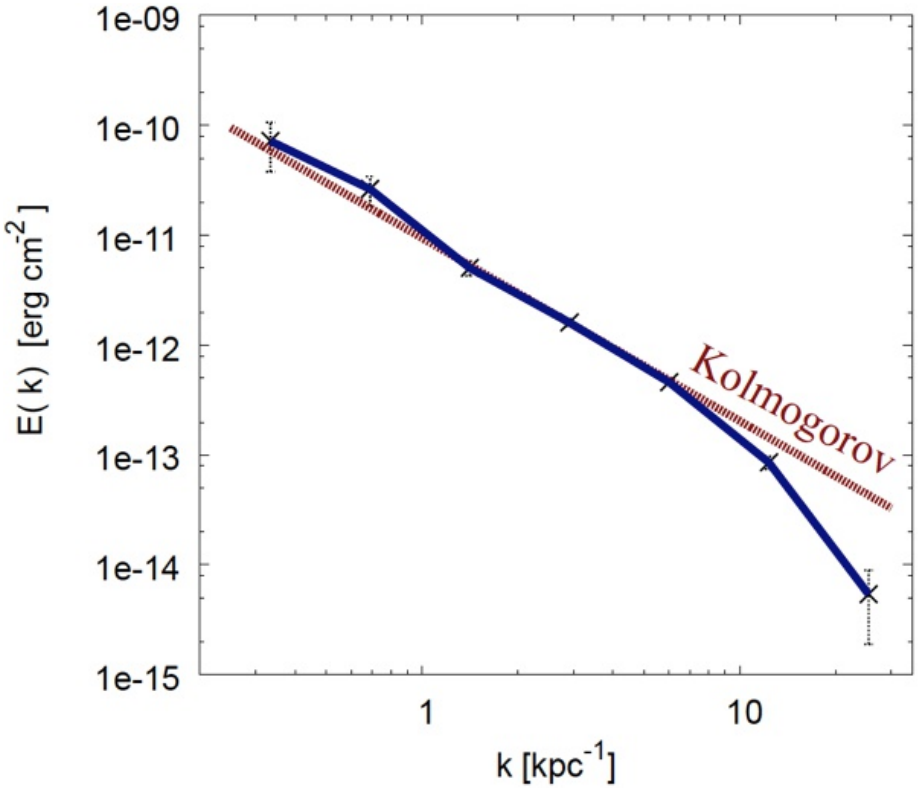


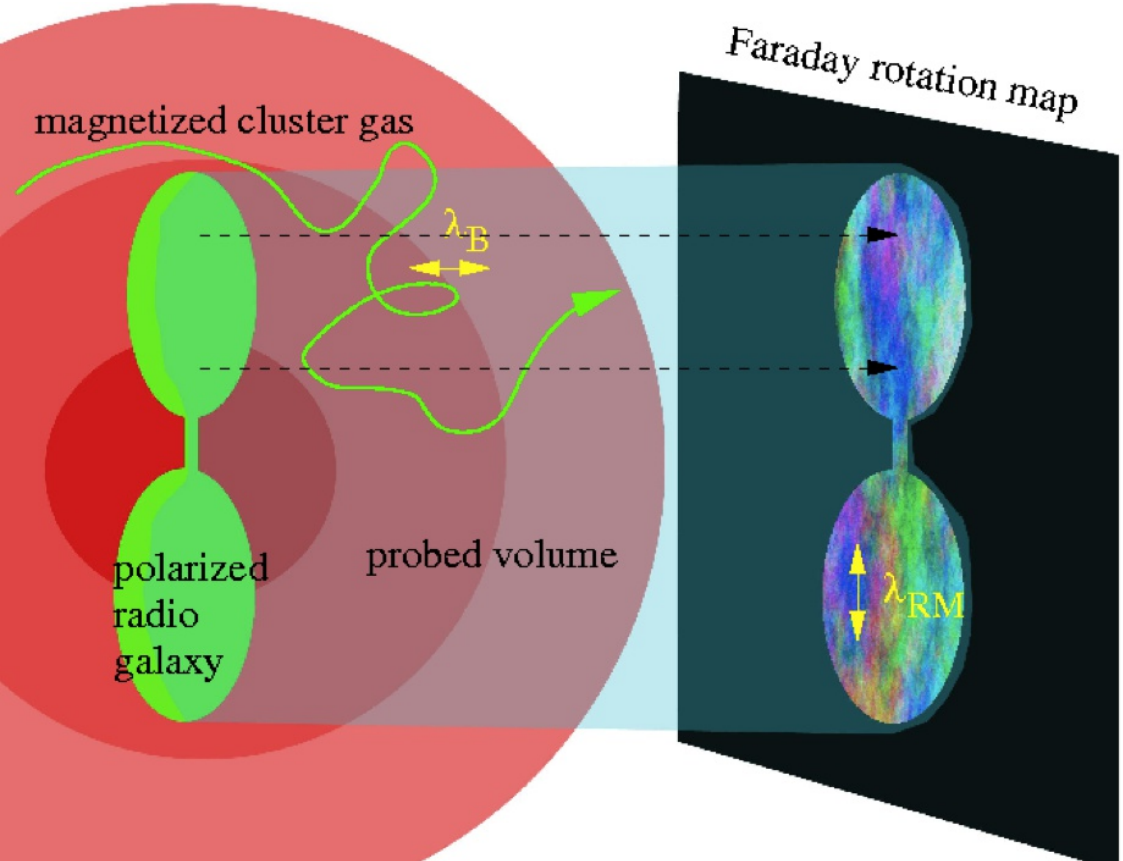
A2256 @ 1.4 GHz: Clarke & Enßlin

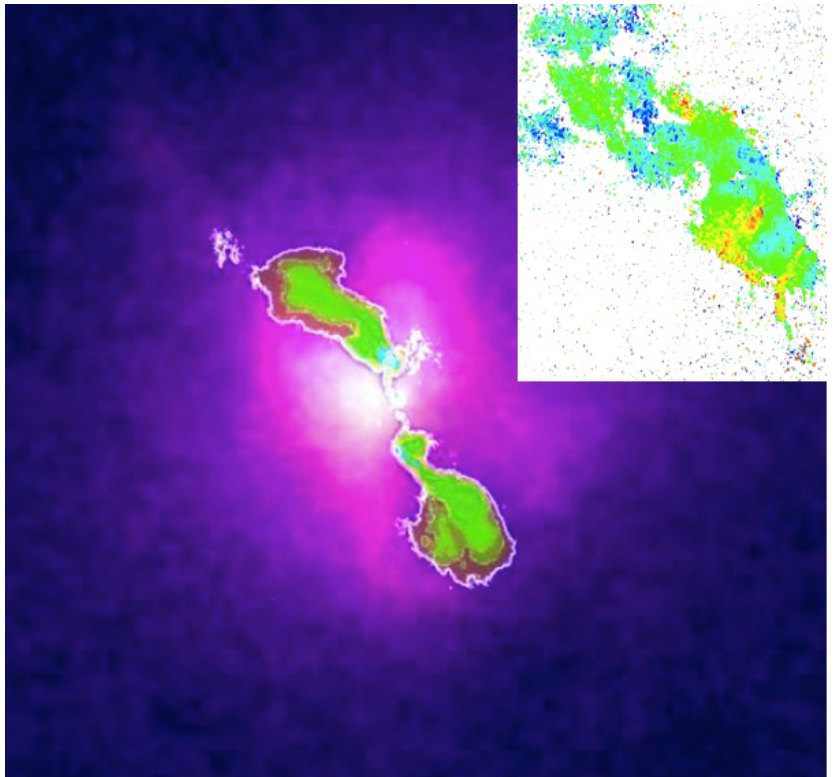
Small-scale dynamo

magnetic turbulence in Hydra A cluster

Enßlin & Vogt (2003), Vogt & Enßlin (2005),
Enßlin & Vogt (2006), Kuchar & Enßlin (2009)



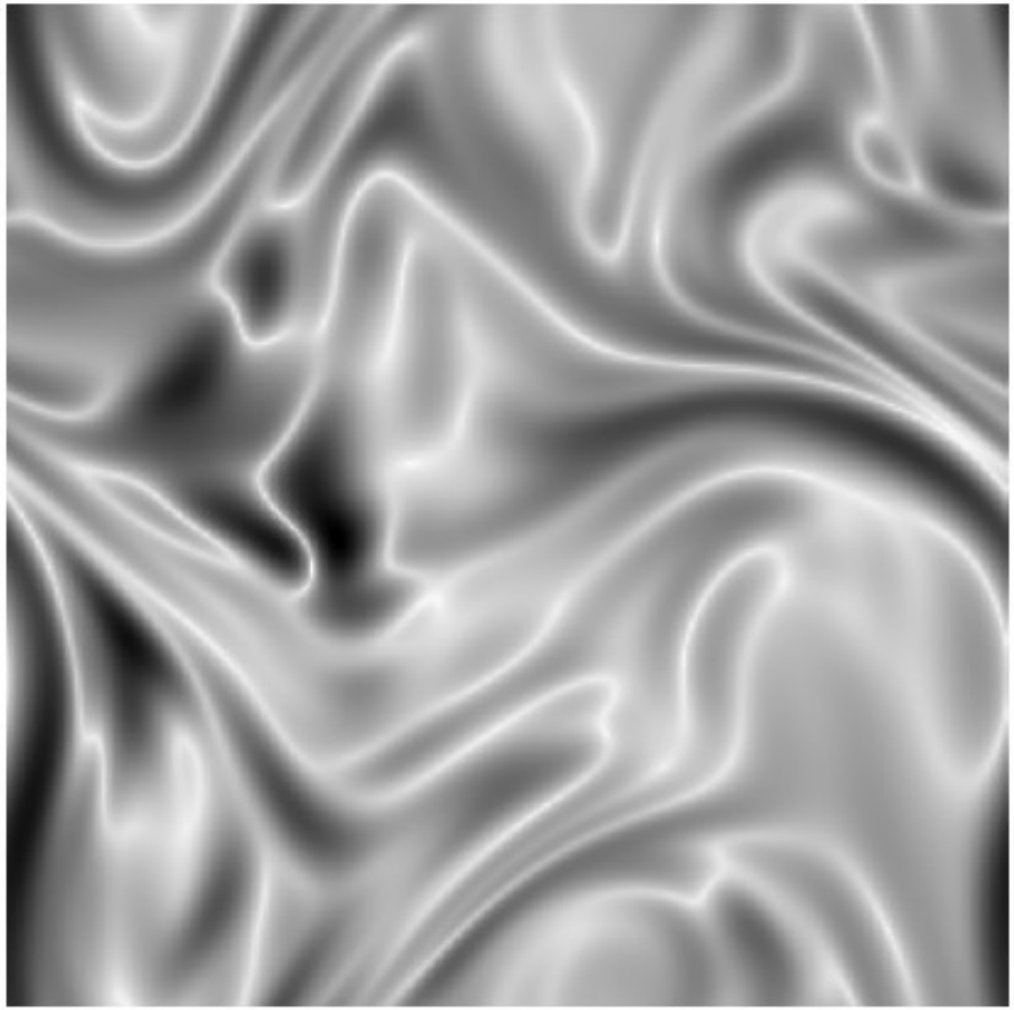




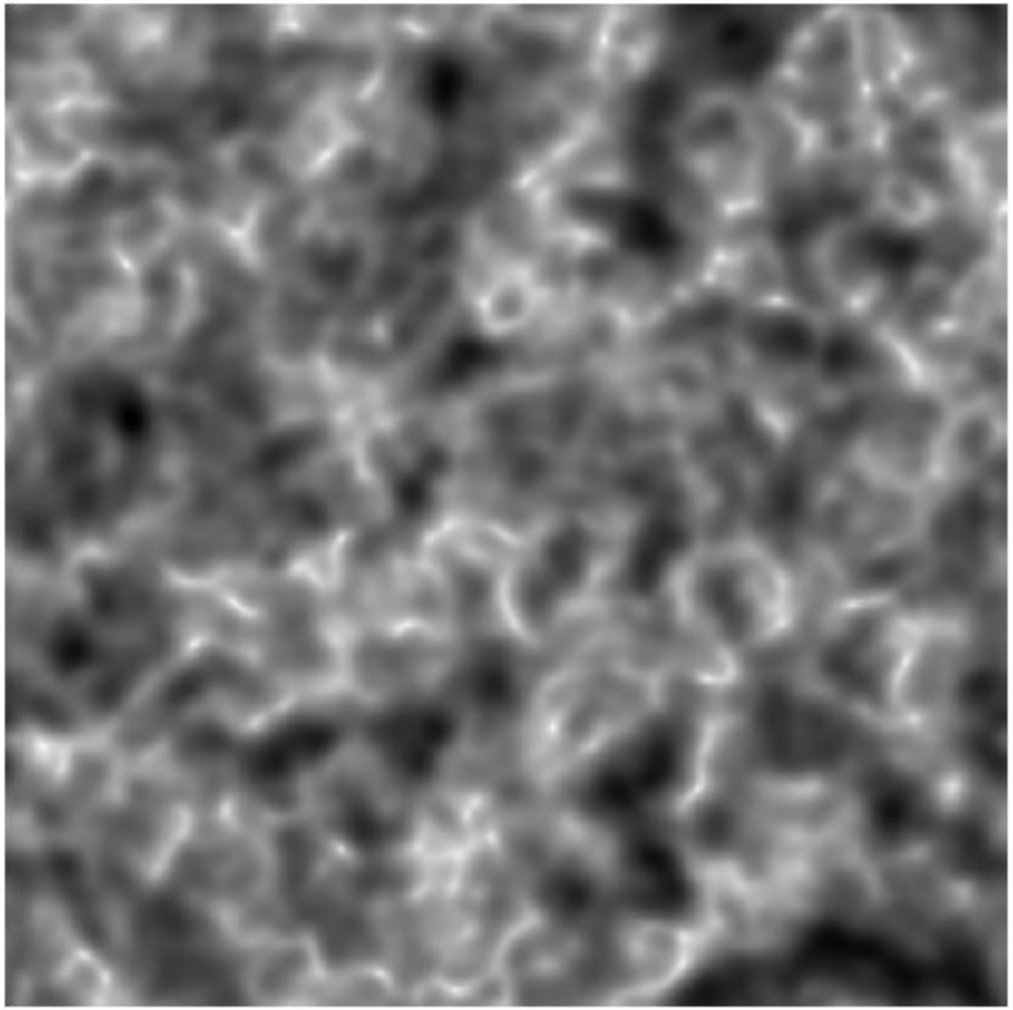
Small-scale dynamo

testing the field fluctuations: magnetic energy

MHD simulation



Gaussian random field

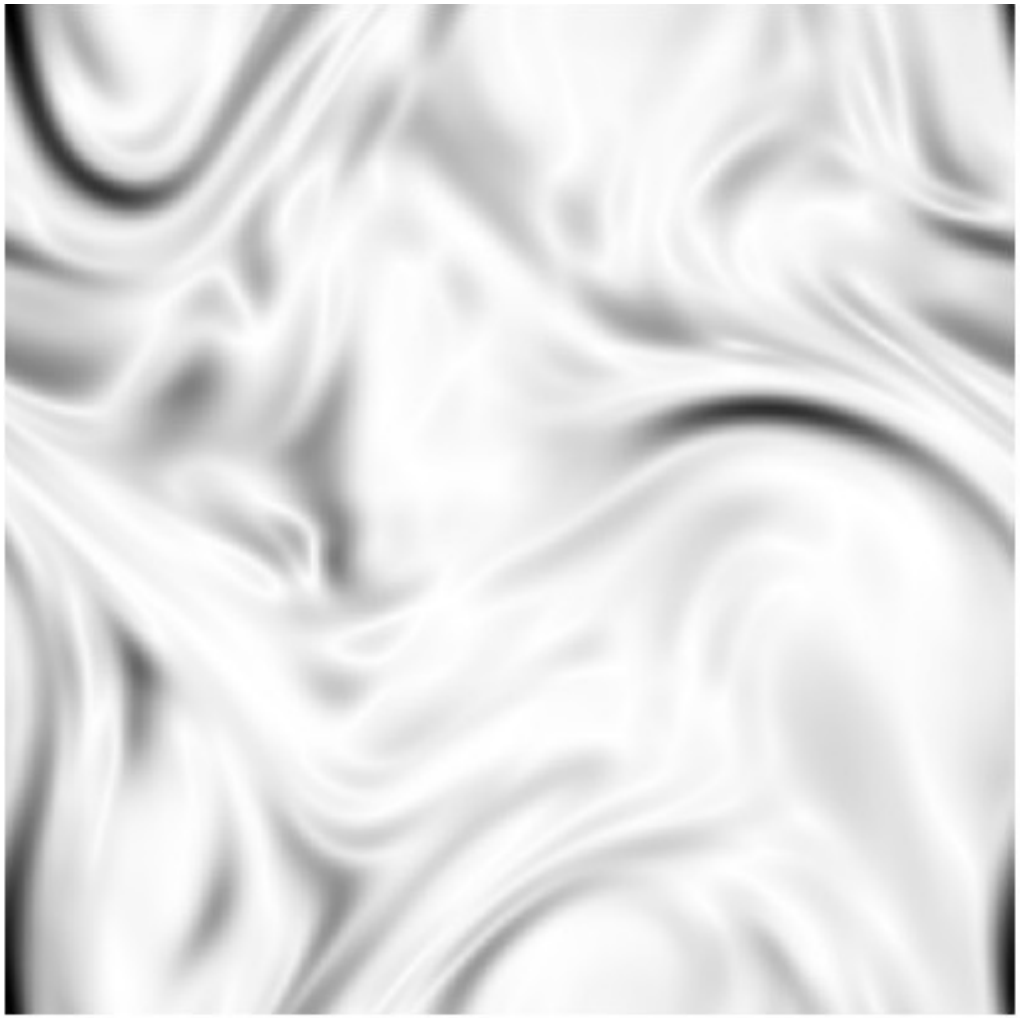


Waelkens, Schekochihin, Enßlin (2007)

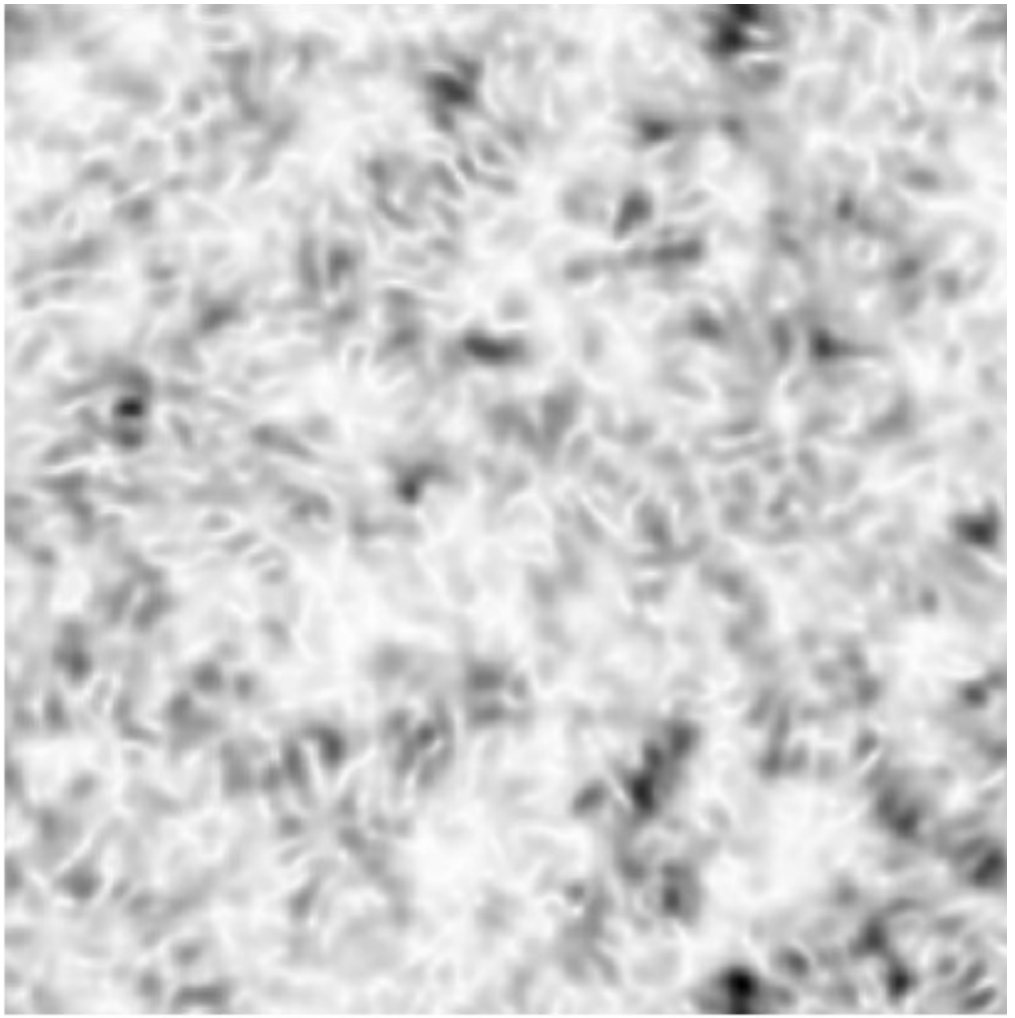
Small-scale dynamo

testing the field fluctuations: magnetic tension

MHD simulation



Gaussian random field



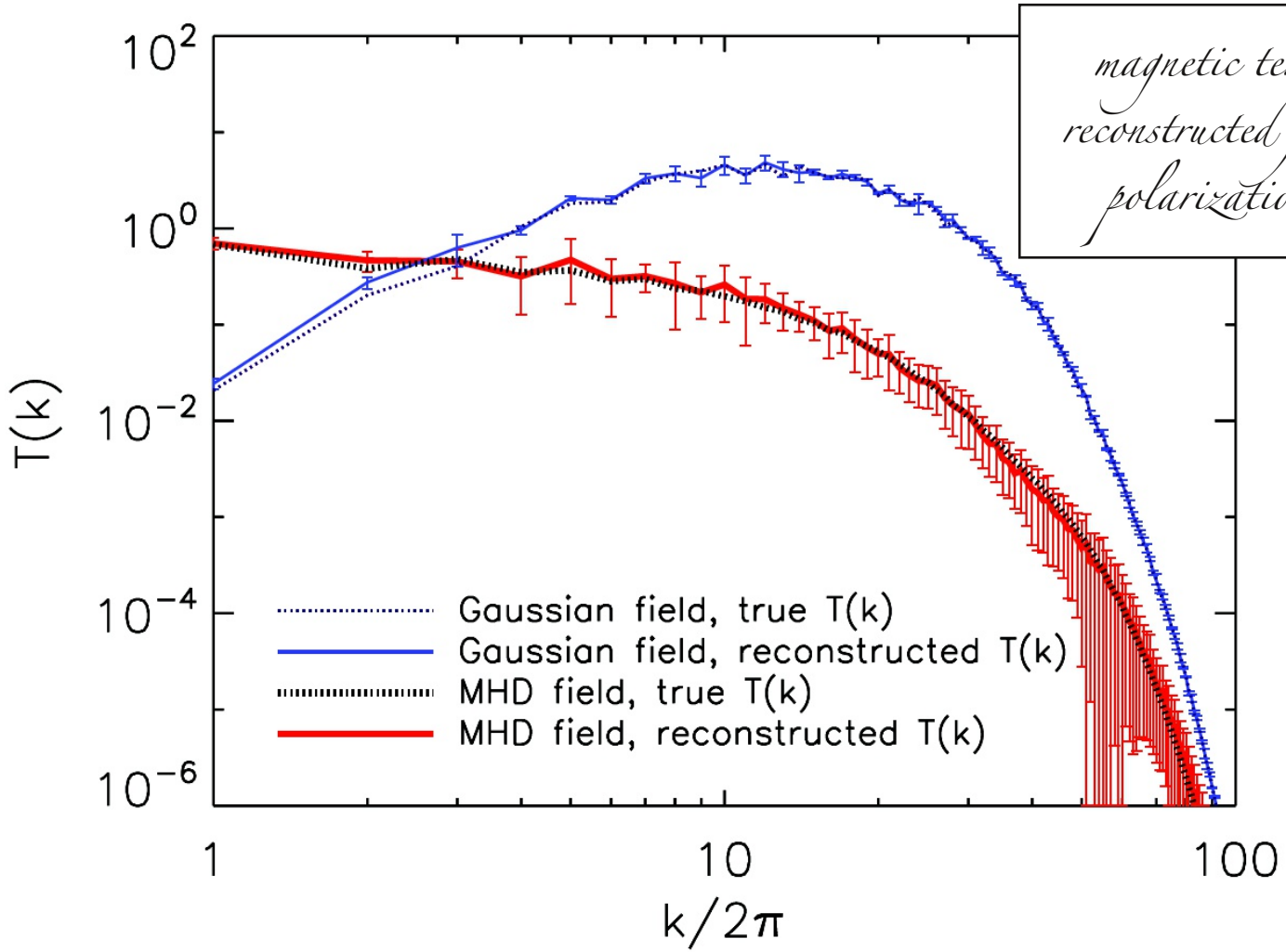
Waelkens, Schekochihin, Enßlin (2007)

Small-scale dynamo

testing the field fluctuations: magnetic tension power spectra

MHD simulation

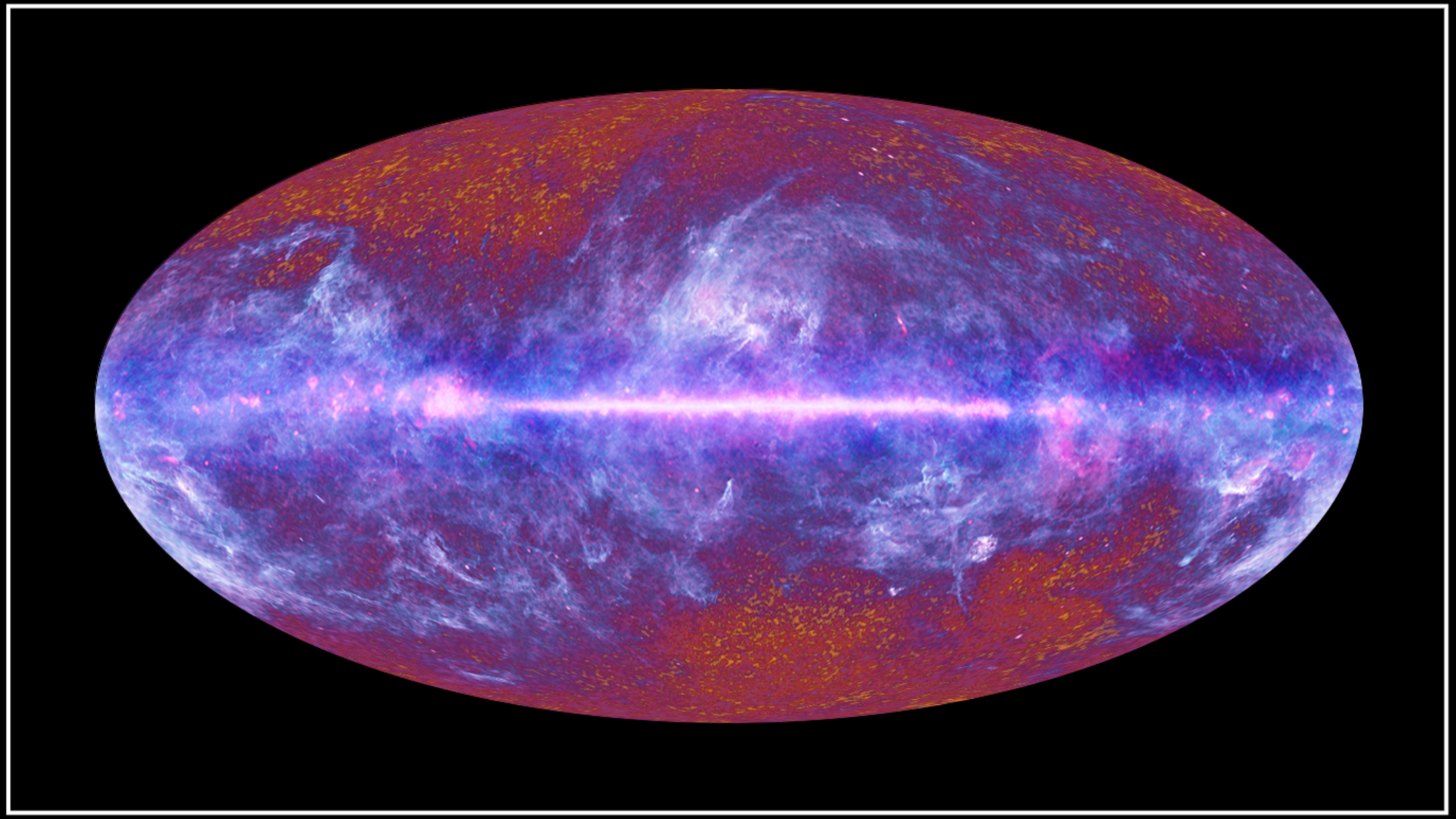
Gaussian random field



magnetic tension spectrum reconstructed from synchrotron polarization correlations

Waelkens, Schekochihin, Enßlin (2007)

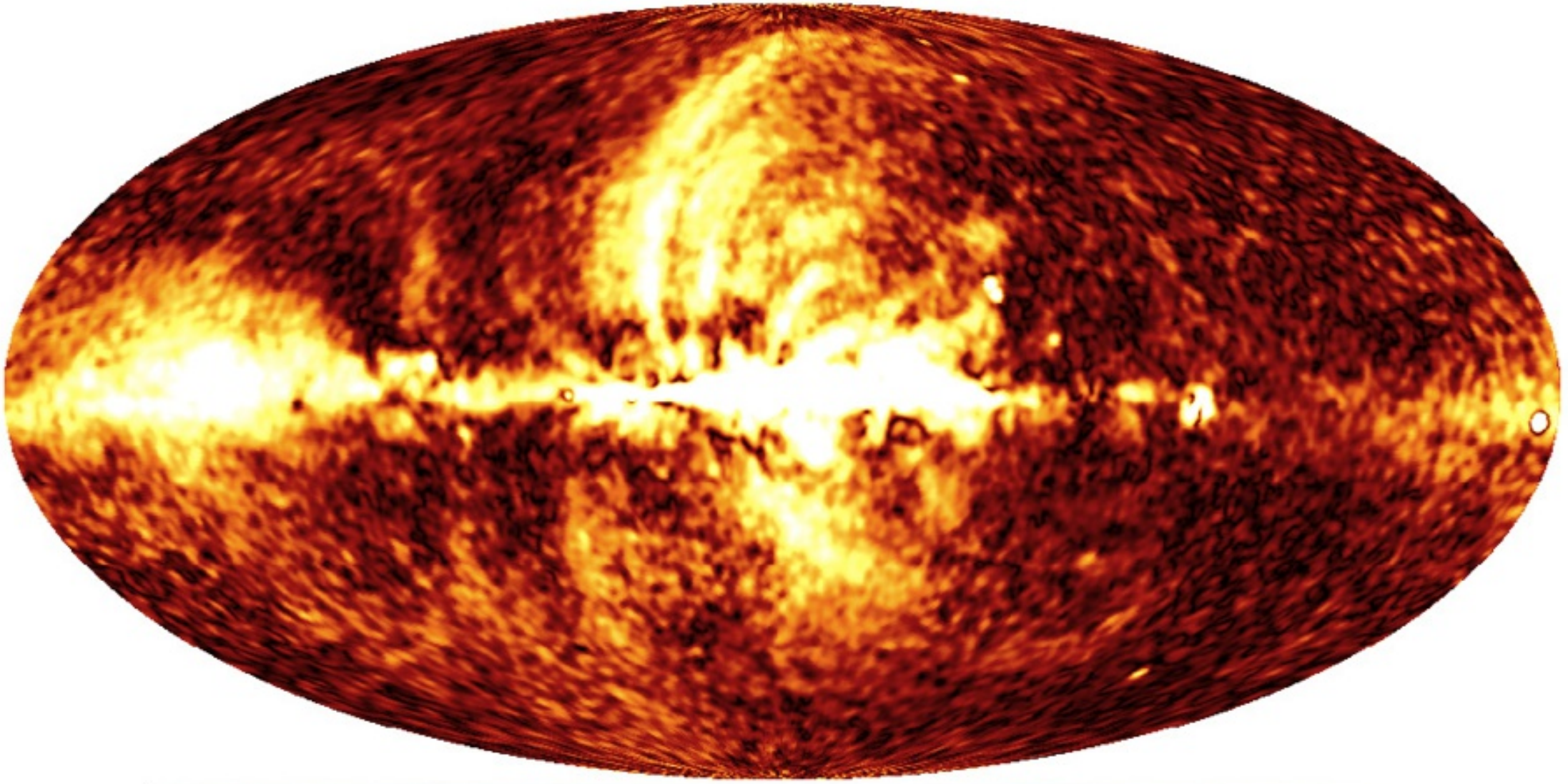
Large-scale dynamo



The Planck one-year all-sky survey

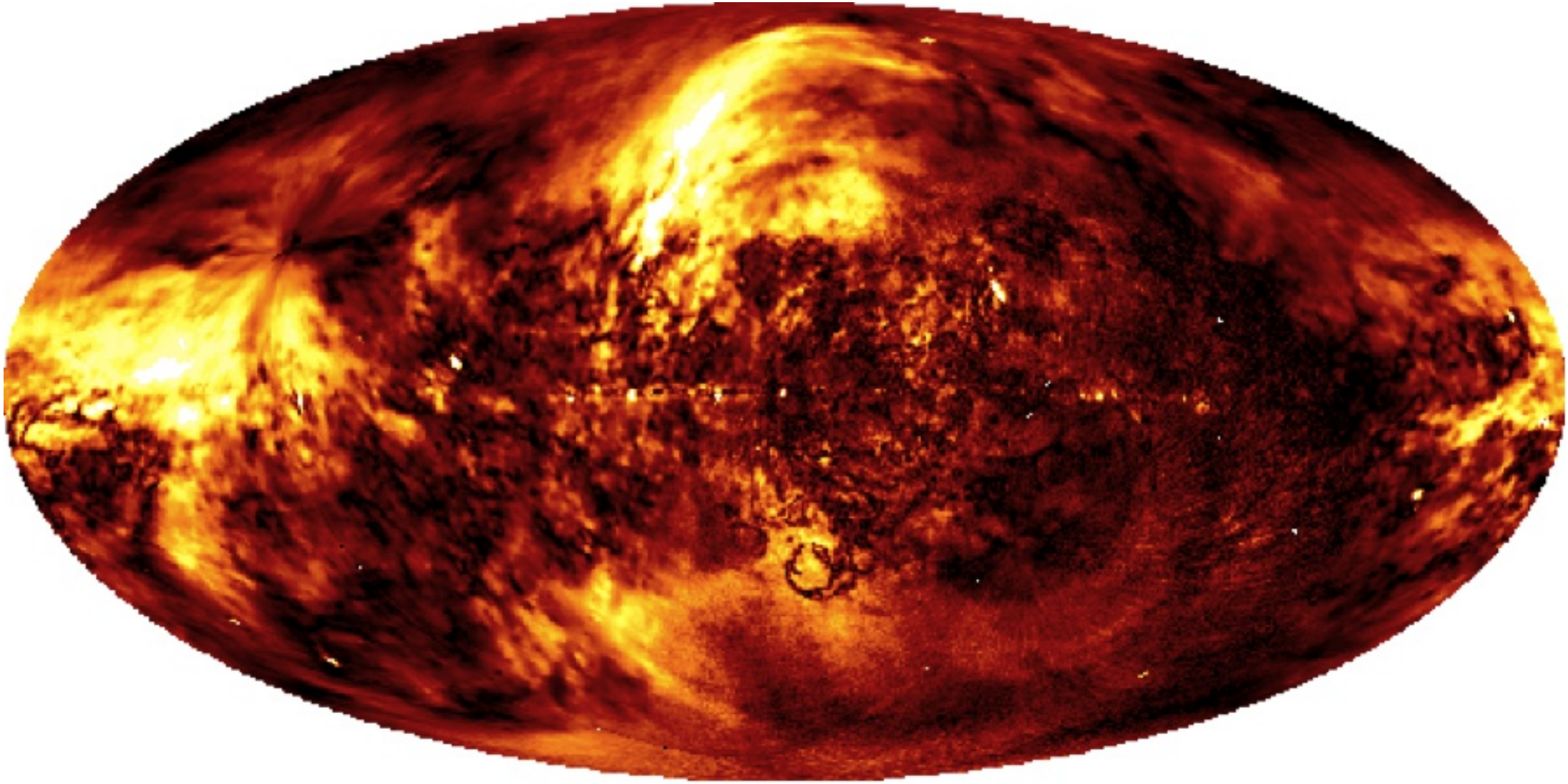
esa

Polarized radio sky



22 GHz: WMAP team

Polarized radio sky

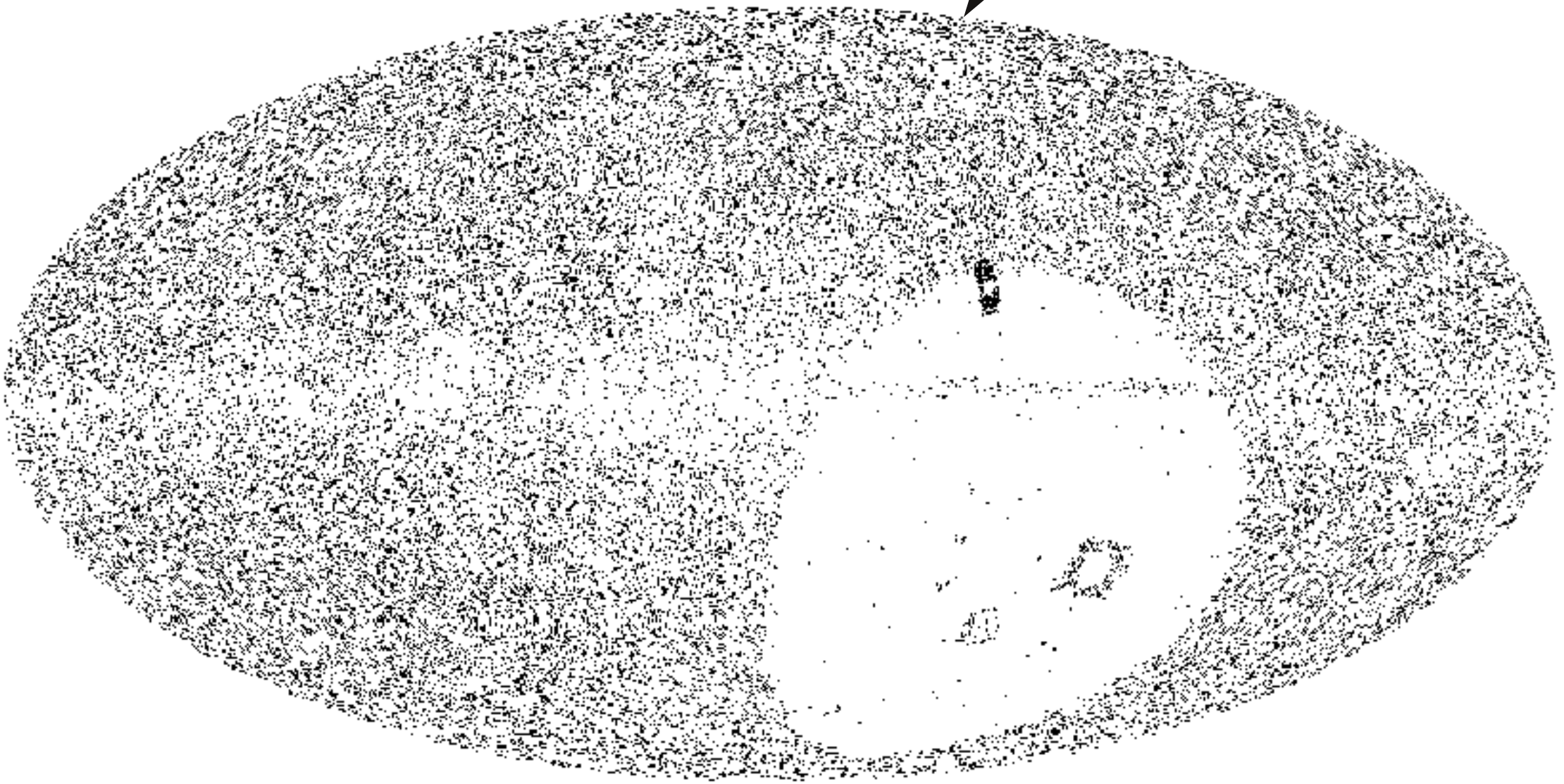


1.4 GHz: Reich & Wolleben

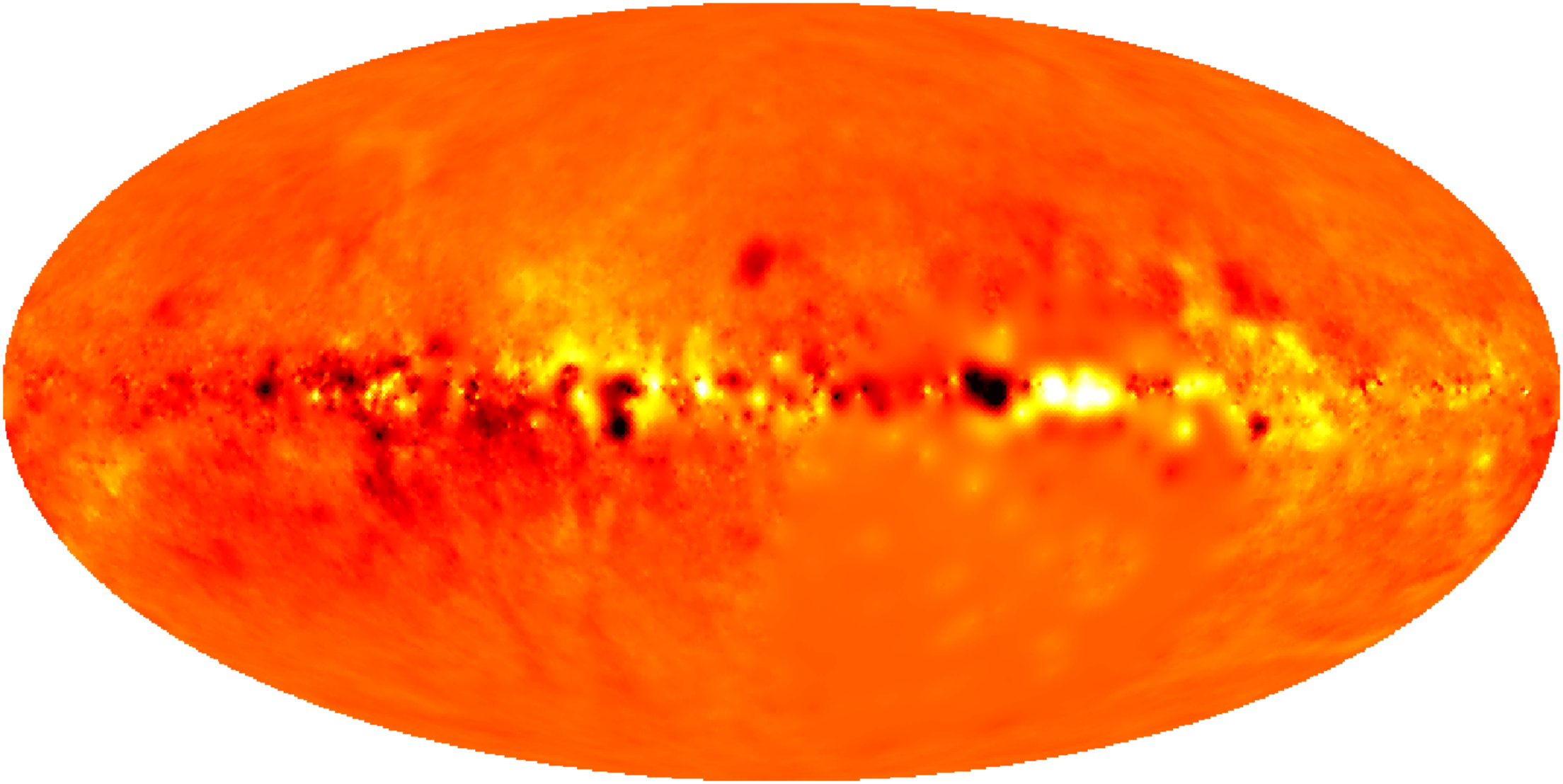
Faraday grid

extragalactic radio sources

mostly from NVSS



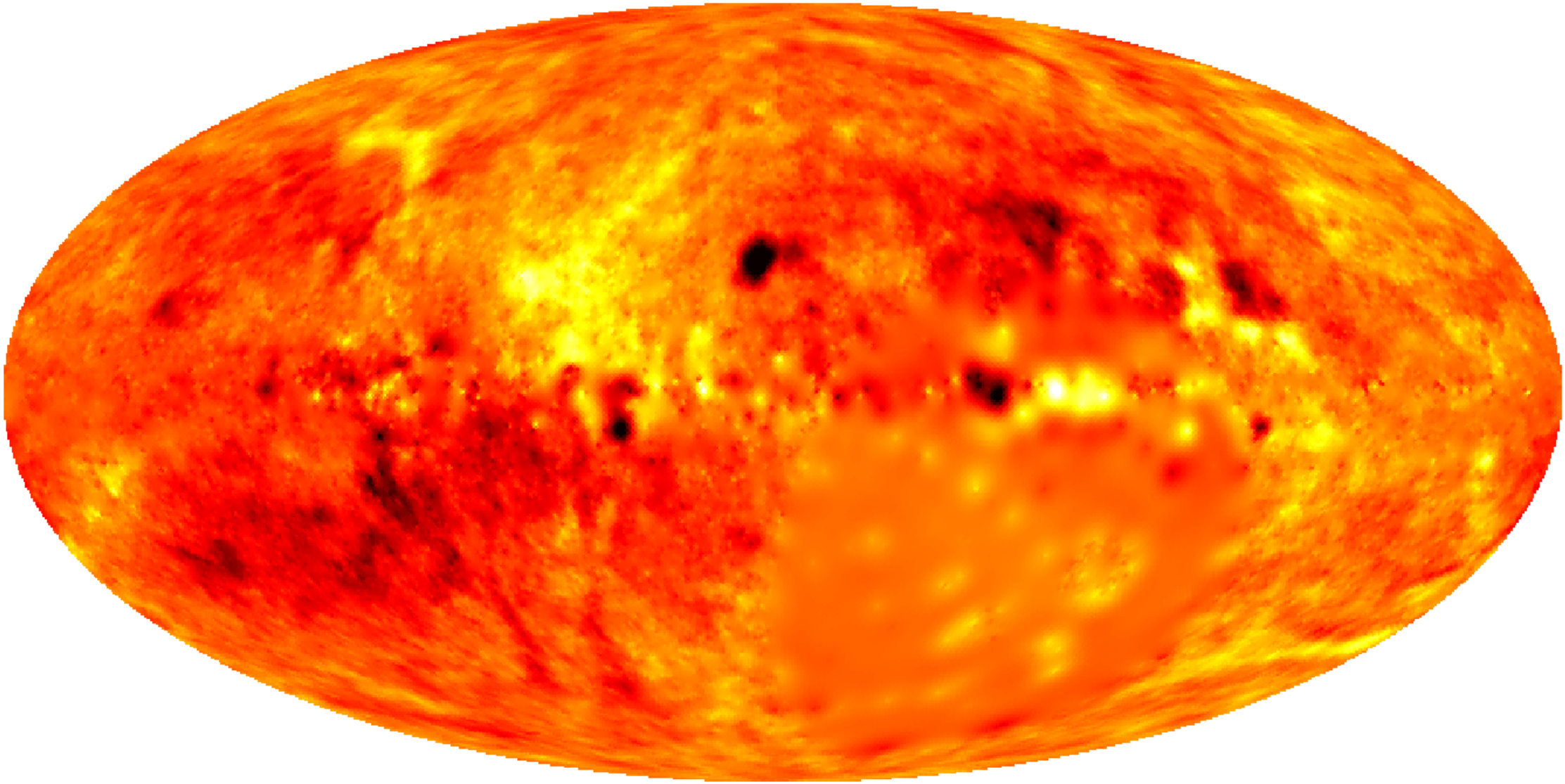
Faraday sky



-500 500

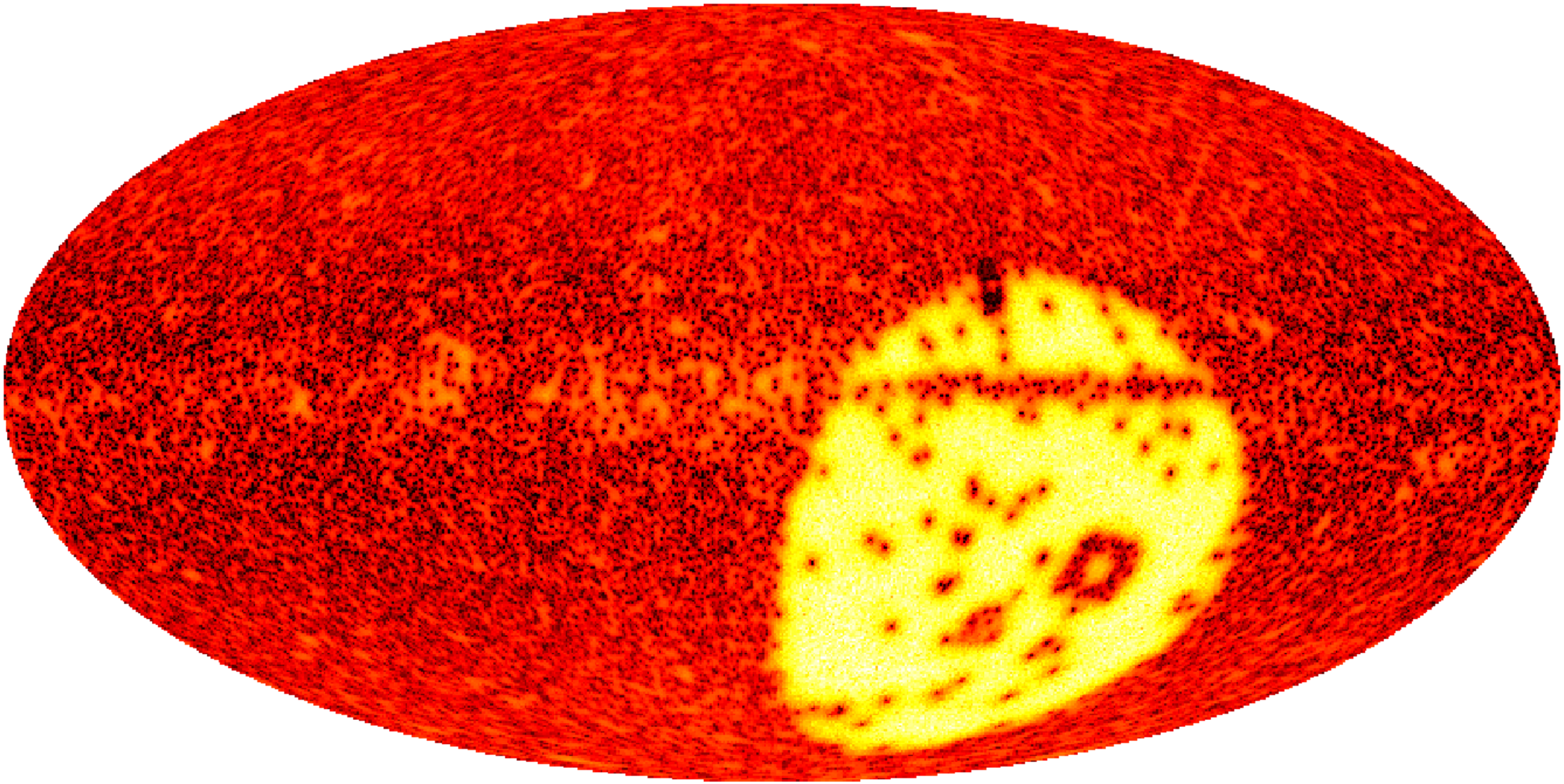
Oppermann et al. (in prep.)

Faraday sky - without profile



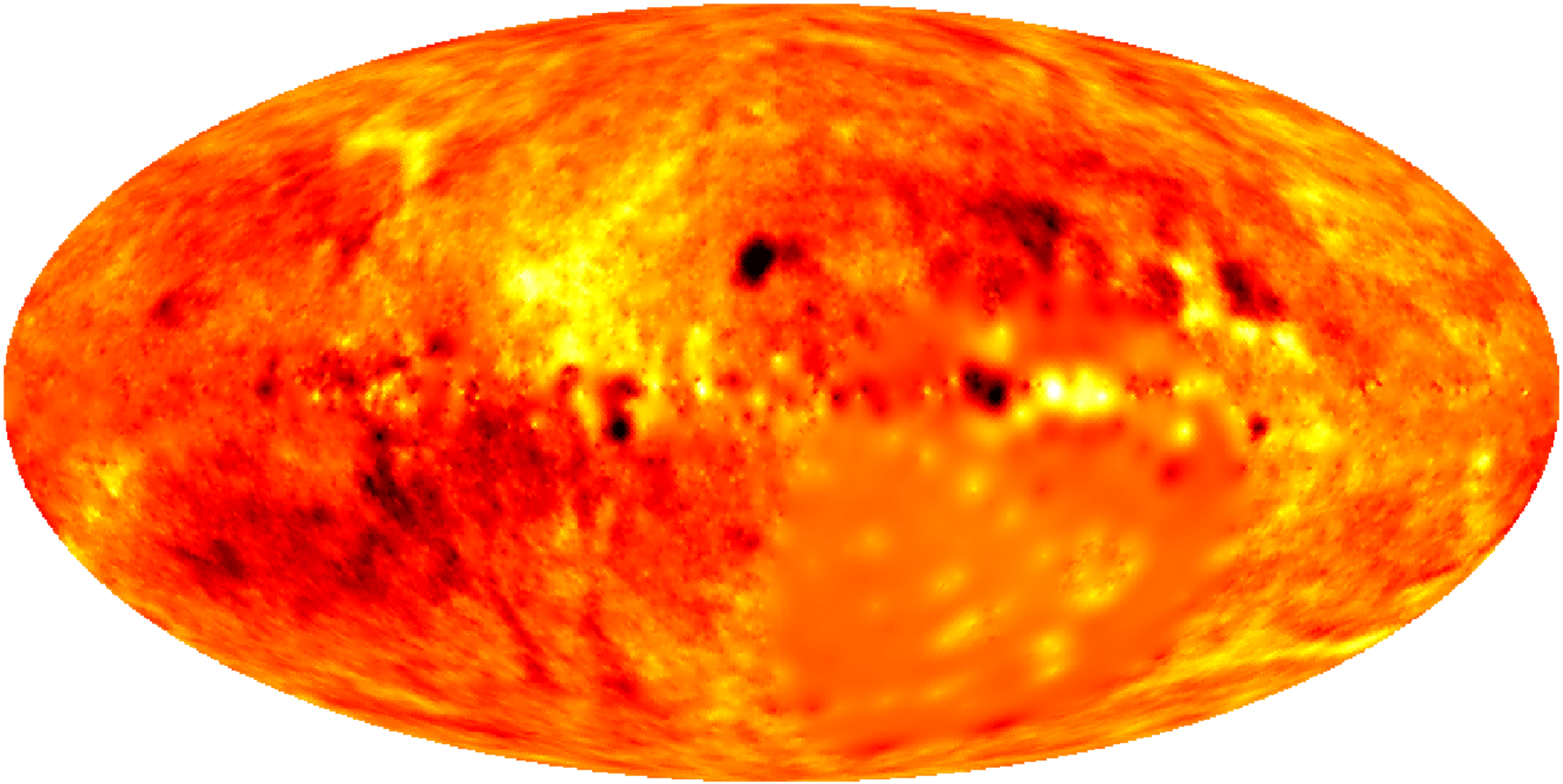
Oppermann et al. (in prep.)

Faraday sky - uncertainty



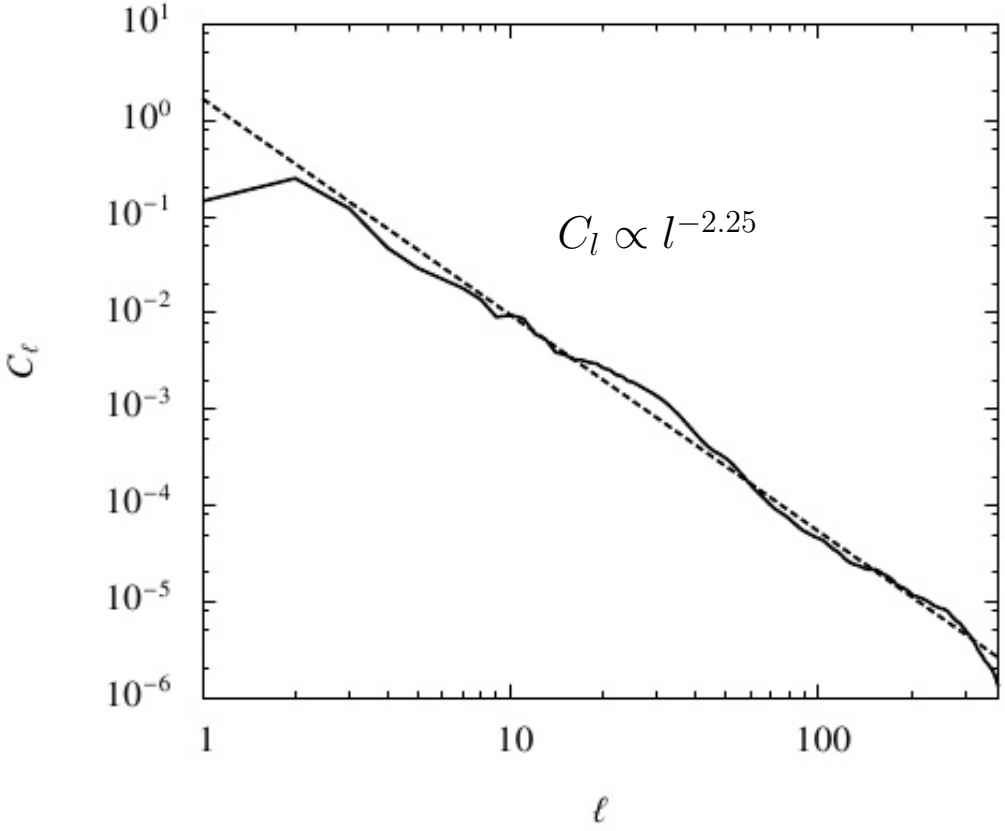
Oppermann et al. (in prep.)

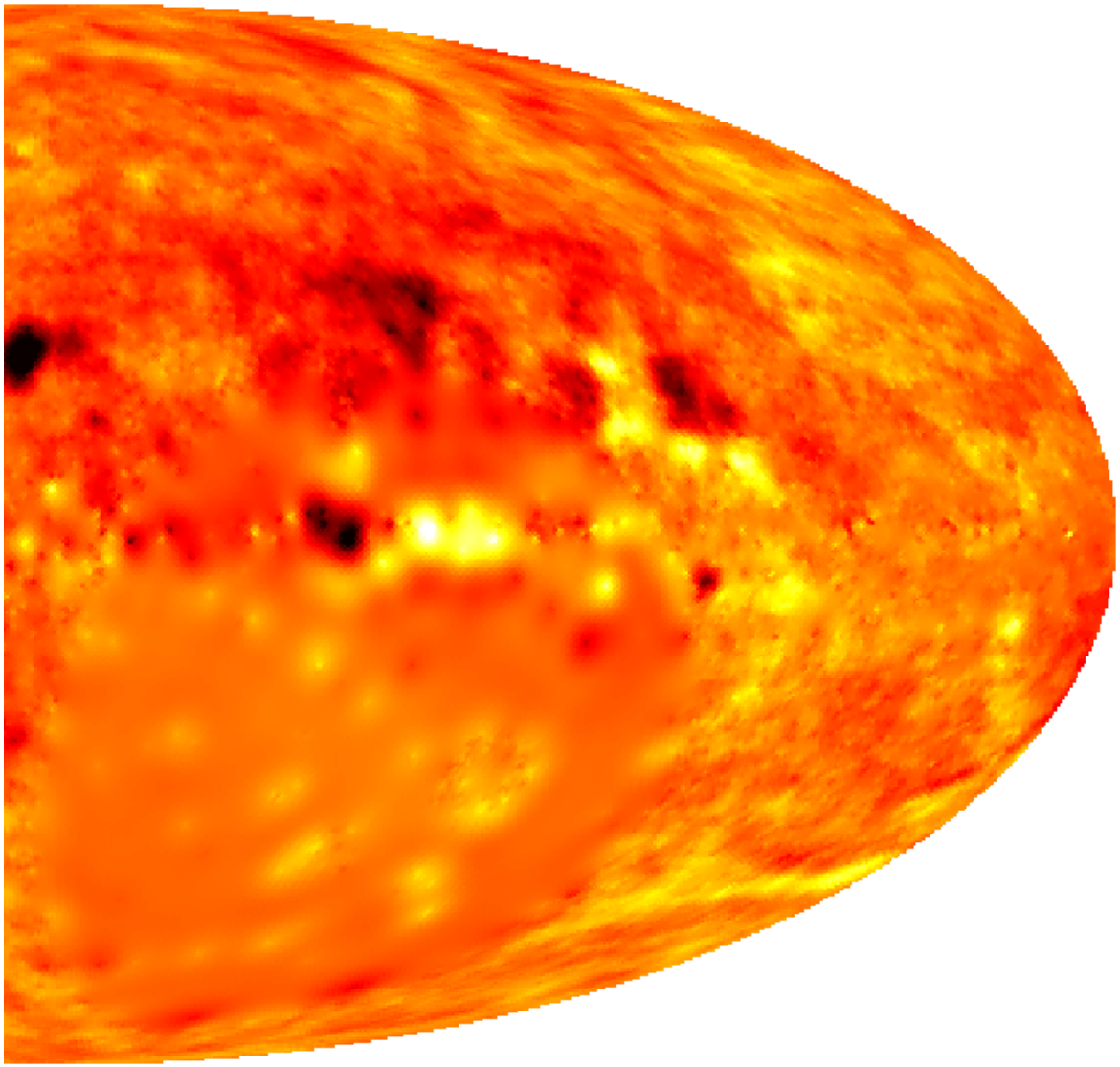
Faraday sky - without profile



Oppermann et al. (in prep.)

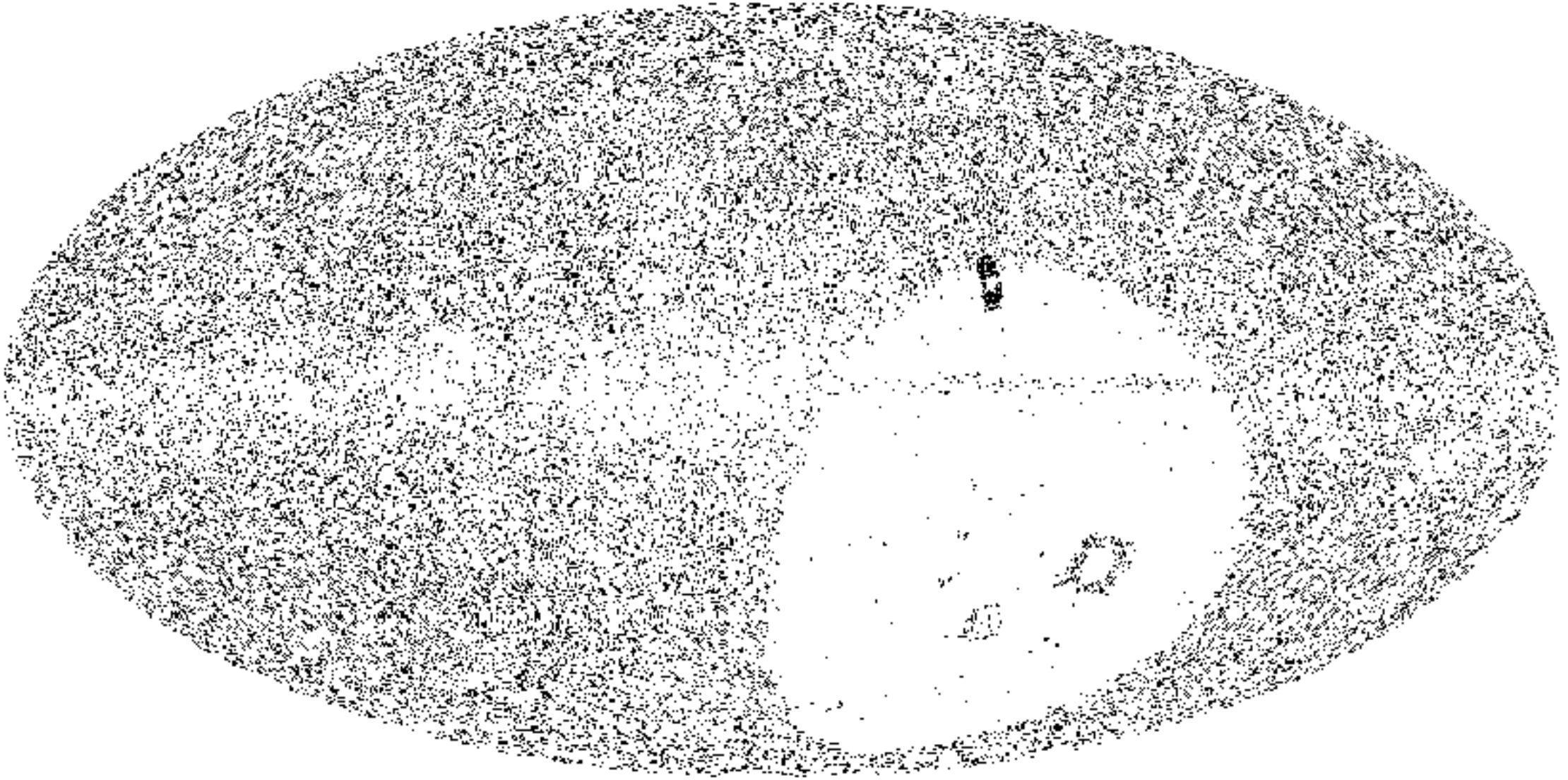
Faraday sky - power spectrum





Oppermann et al. (in prep.)

Faraday grid

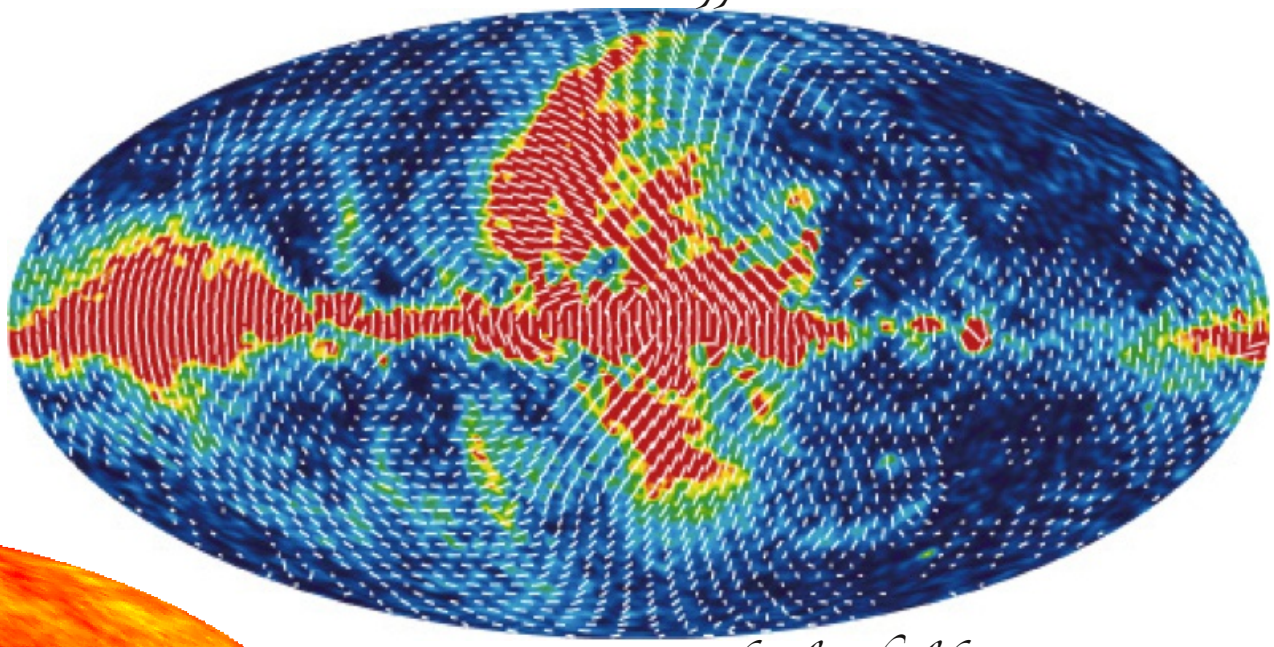


Magnetic helicity

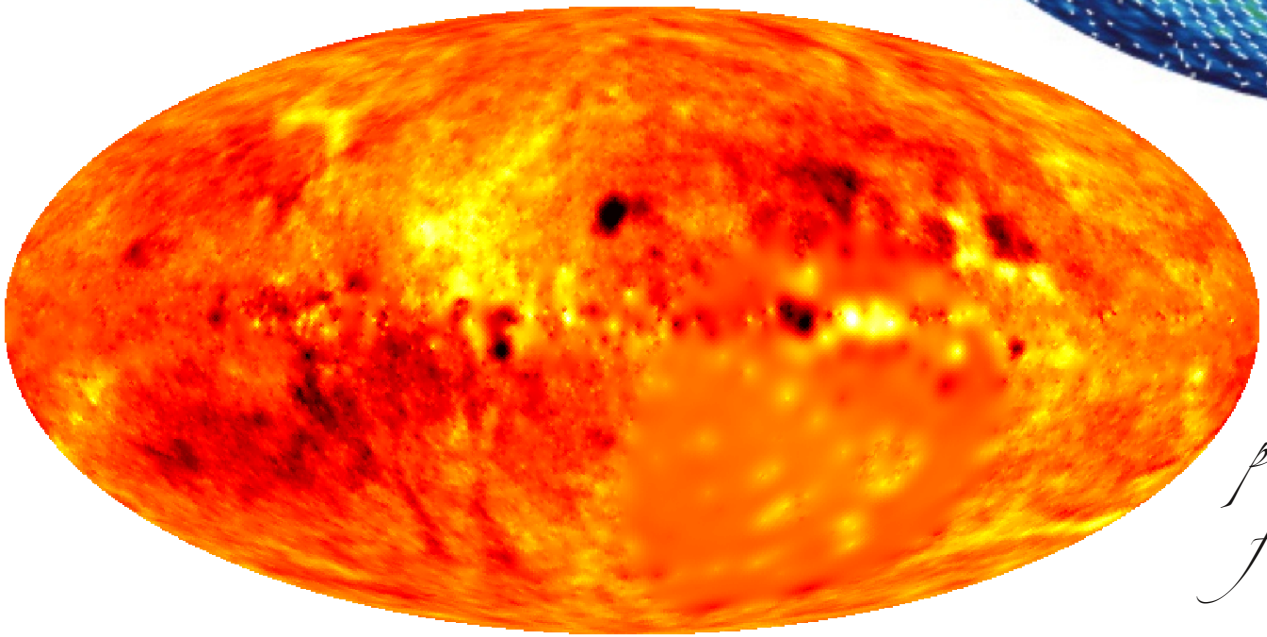
helicity is a 3-d structure

Junklewitz & Enßlin (2011)

Oppermann et al. (2011)



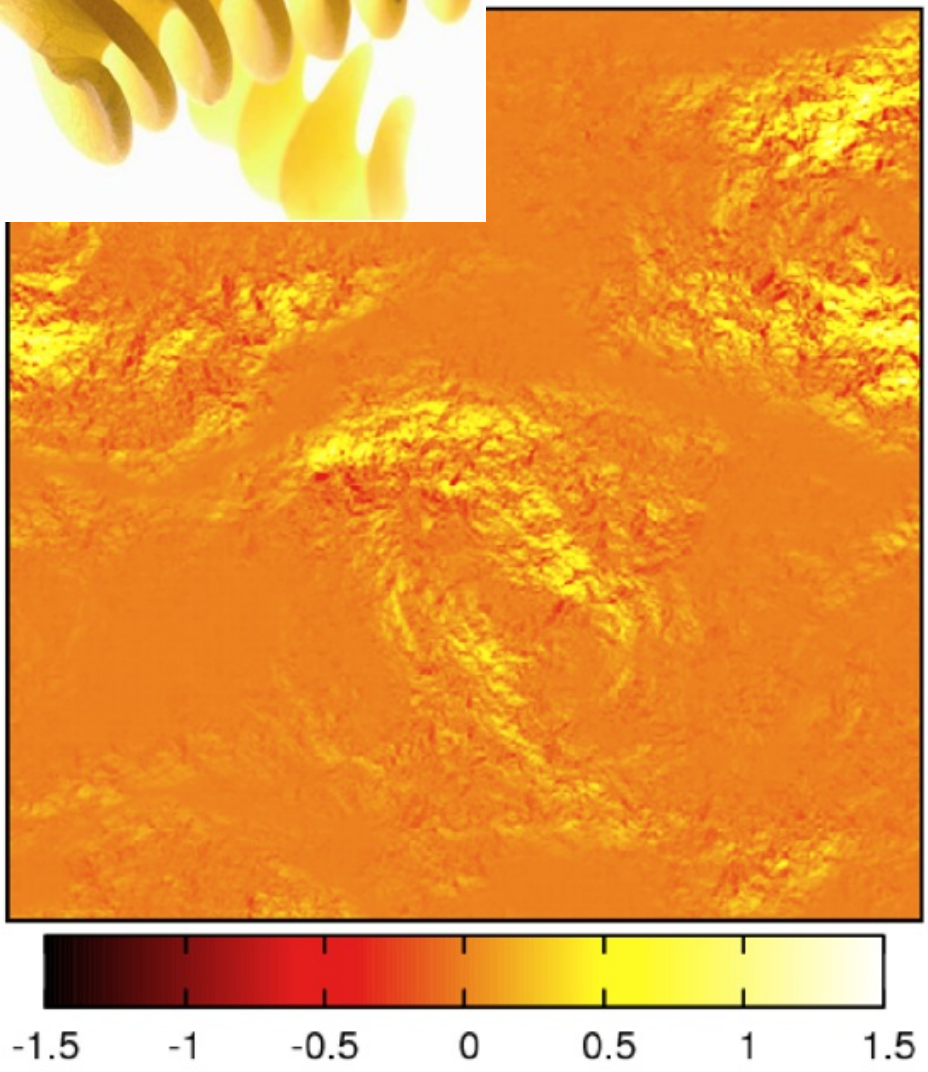
perpendicular field component from synchrotron polarization



parallel field component from Faraday rotation

Magnetic helicity

LITMUS test using Faraday & polarization



Optical caustics – Faraday caustics

Optical caustics:

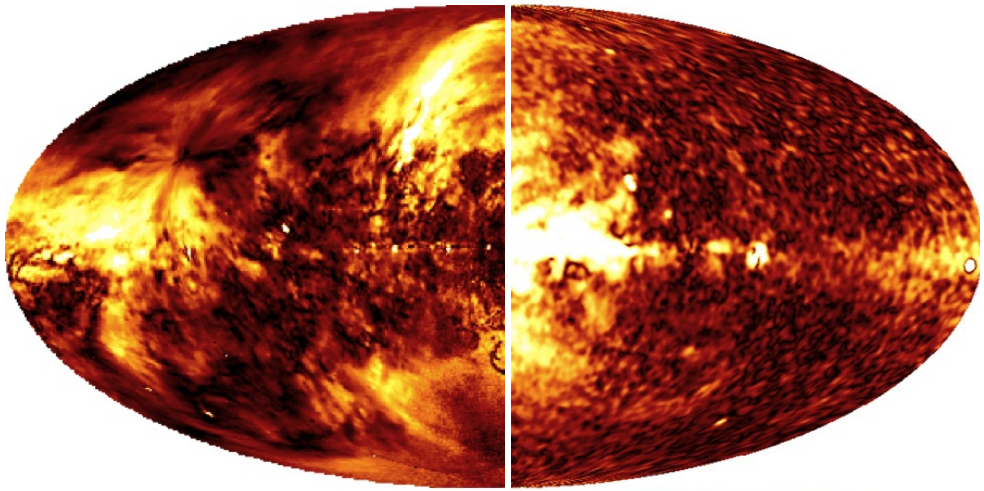
foldings in mapping from surface to bottom

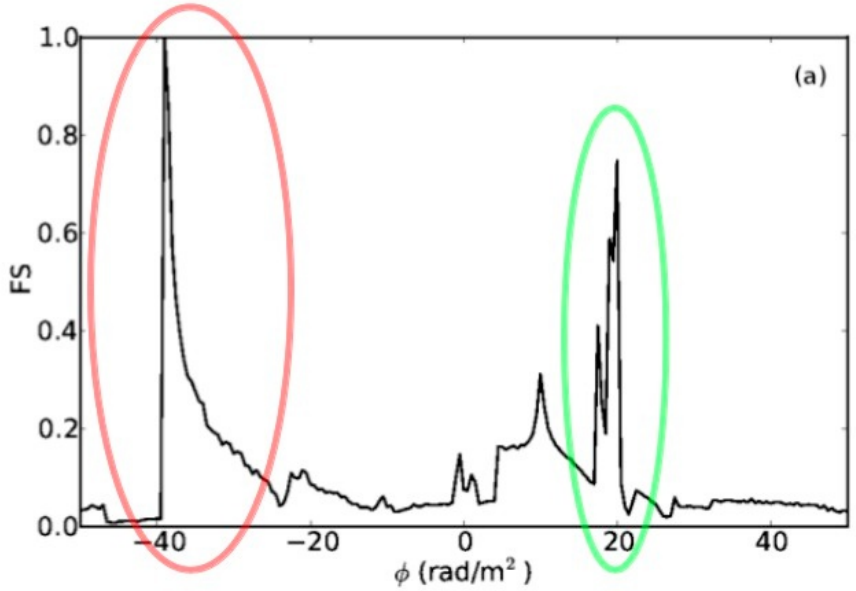
Faraday caustic:

foldings in mapping from real to Faraday space

– sheets separating domains of magnetic polarity

Bell et al. (in press)





Magnetic field structures & statistics:

unraveling the inner workings of magnetic dynamos

Conclusions

How to study magnetic fields observationally?
Sensitive radio polarimetry with high spatial & spectral resolution.
Which processes generate, amplify, & shape magnetic fields?
Turbulence, shock waves, small- & large-scale dynamos.
How can fields & processes be probed with Lofar, SKA, … ?
Statistical correlation functions of magnetic field and plasma probes.

- small-scale dynamo:
  morphology – energy spectrum – tension force spectrum
- large-scale dynamo:
  large-scale topology – magnetic helicity – Faraday caustics