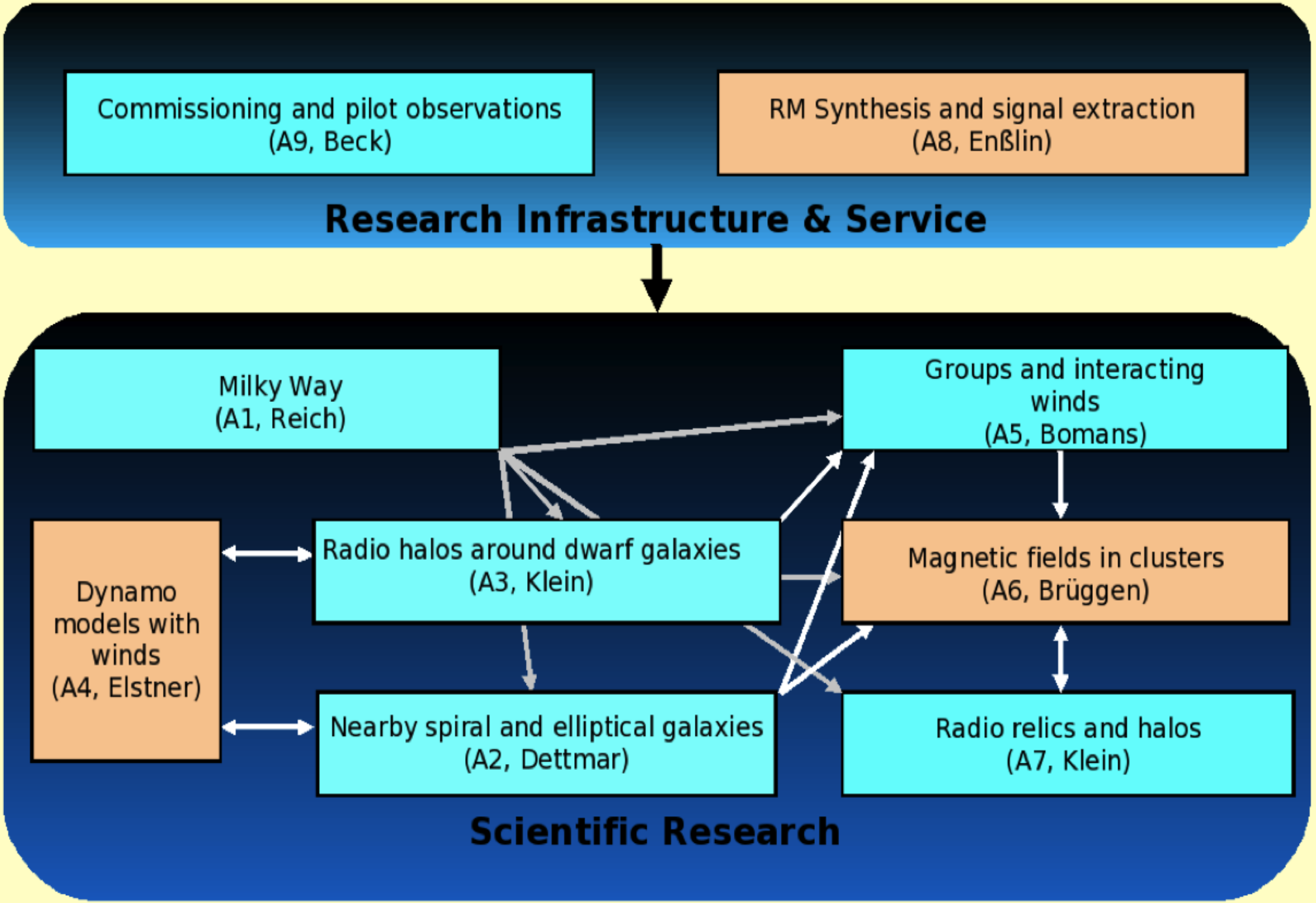
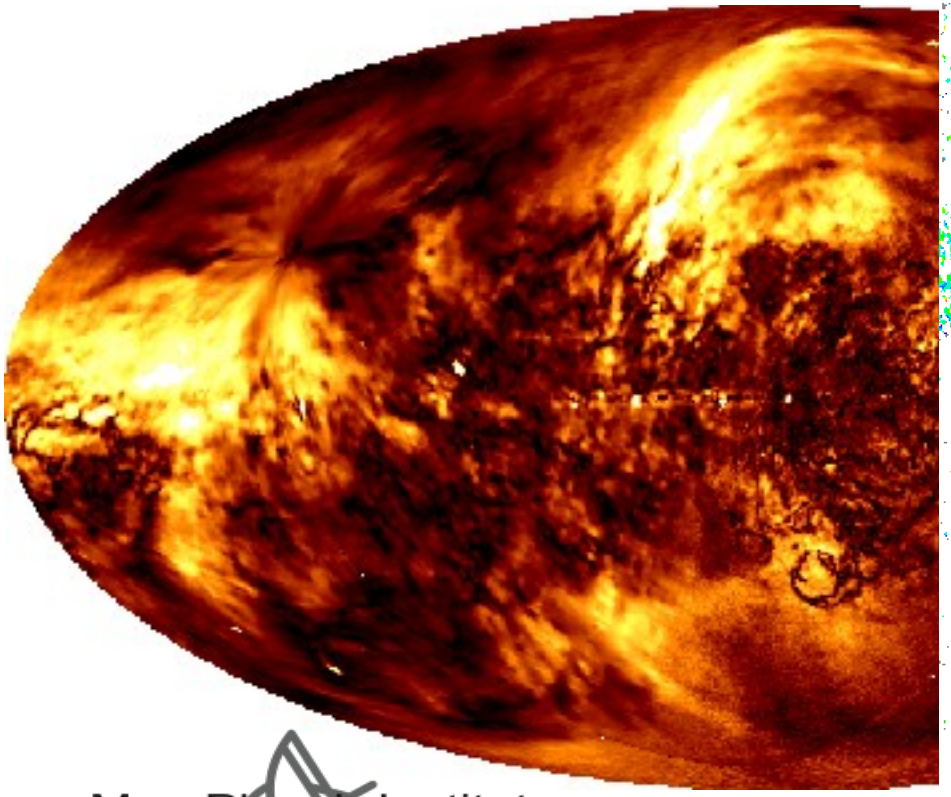
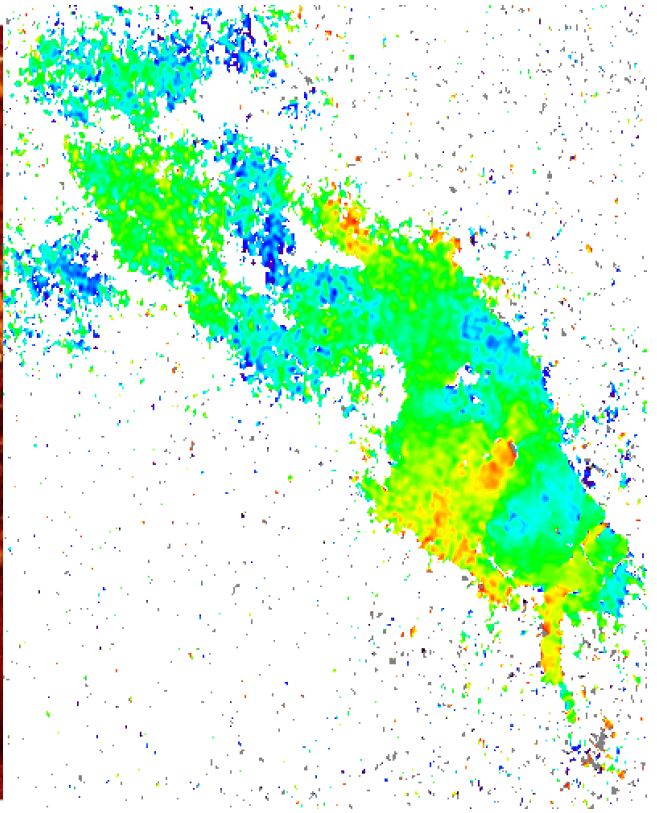
DFG-Forschergruppe: Magnetisation of interstellar and intergalactic media

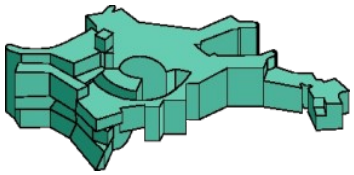


A8 RM Synthesis
& magnetic field statistics

Torsten Enßlin, Rainer Beck, Marcus Brüggen
Michael Bell, Thomas Riller, Henrik Junklewitz
[Andre Waelkens, Petr Kuchar, Niels Oppermann, ...]





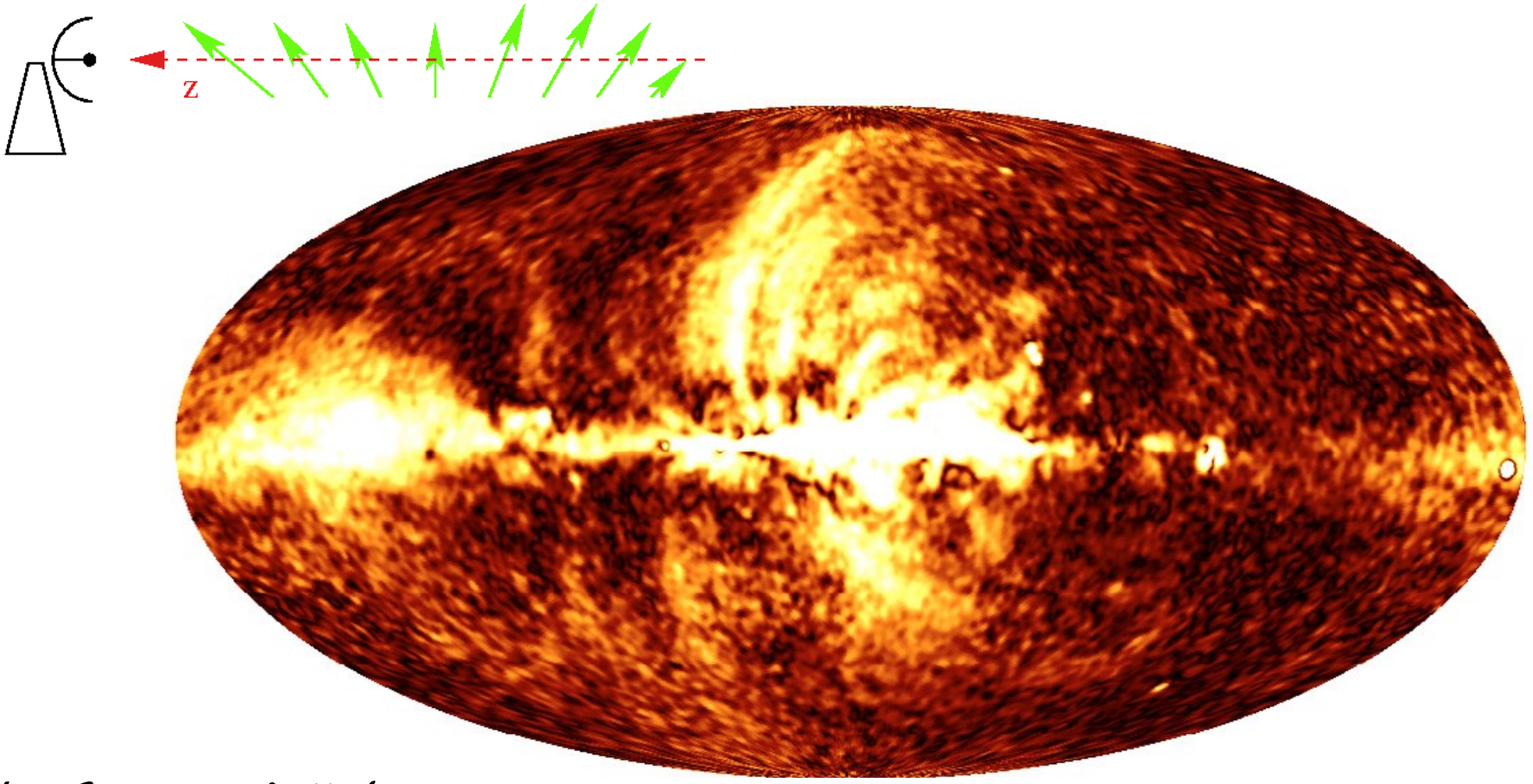


Max-Planck-Institut
für Astrophysik

JACOBS
UNIVERSITY

Max-Planck-Institut
für
Radioastronomie

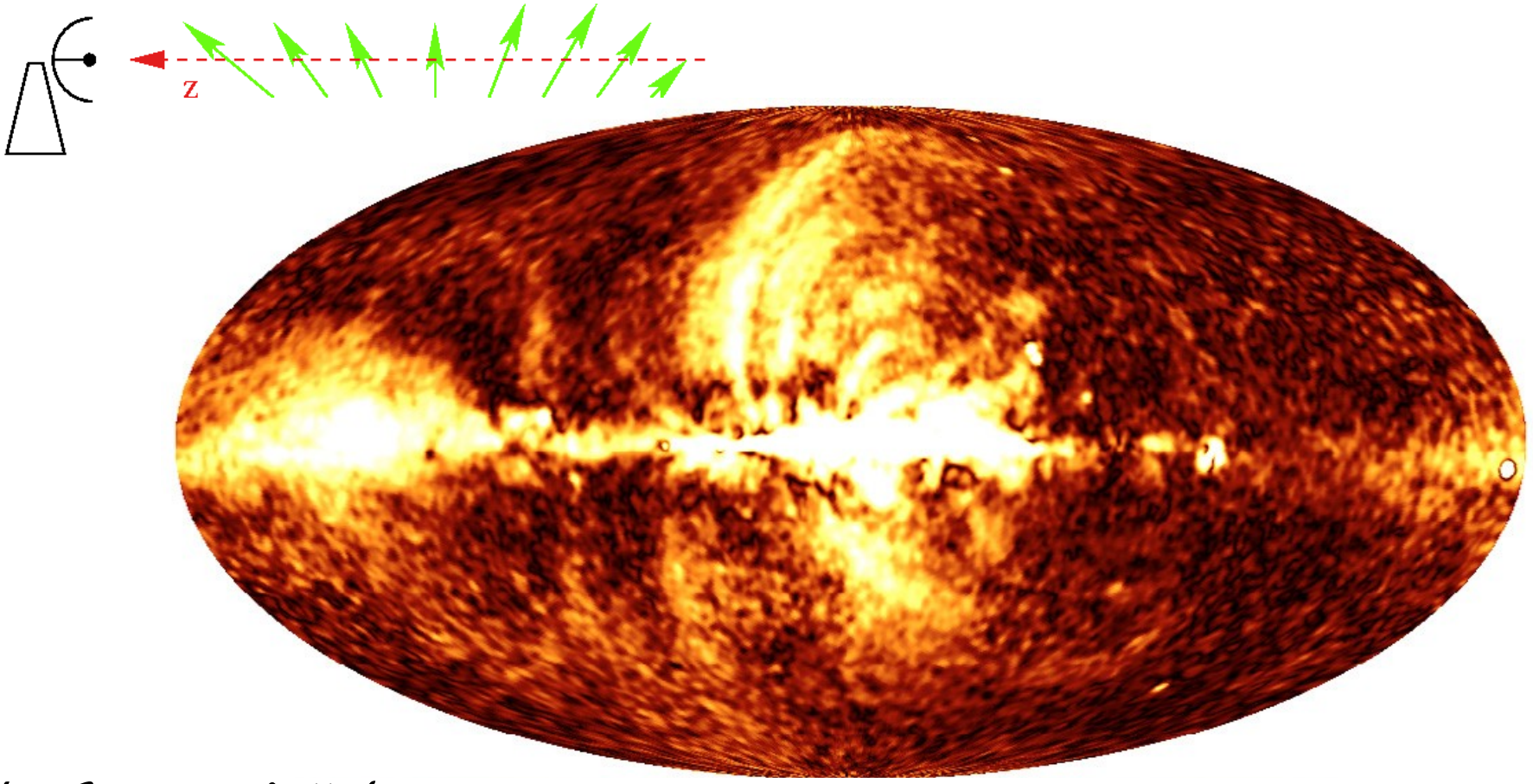
Galactic Magnetic Fields



1.4 GHz: Reich & Wolleben

22 GHz: WMAP team

Galactic Magnetic Fields

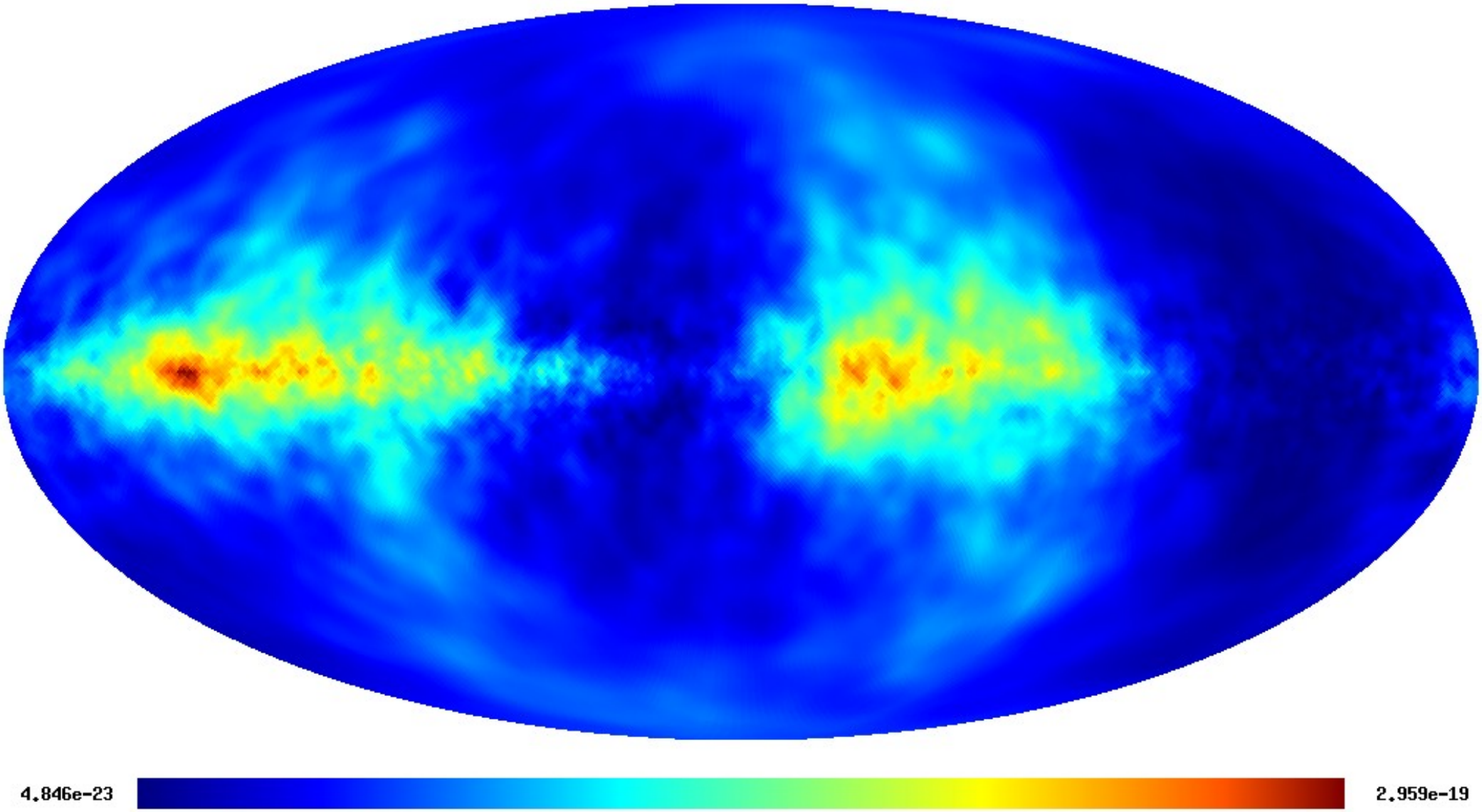


1.4 GHz: Reich & Wolleben

22 GHz: WMAP team

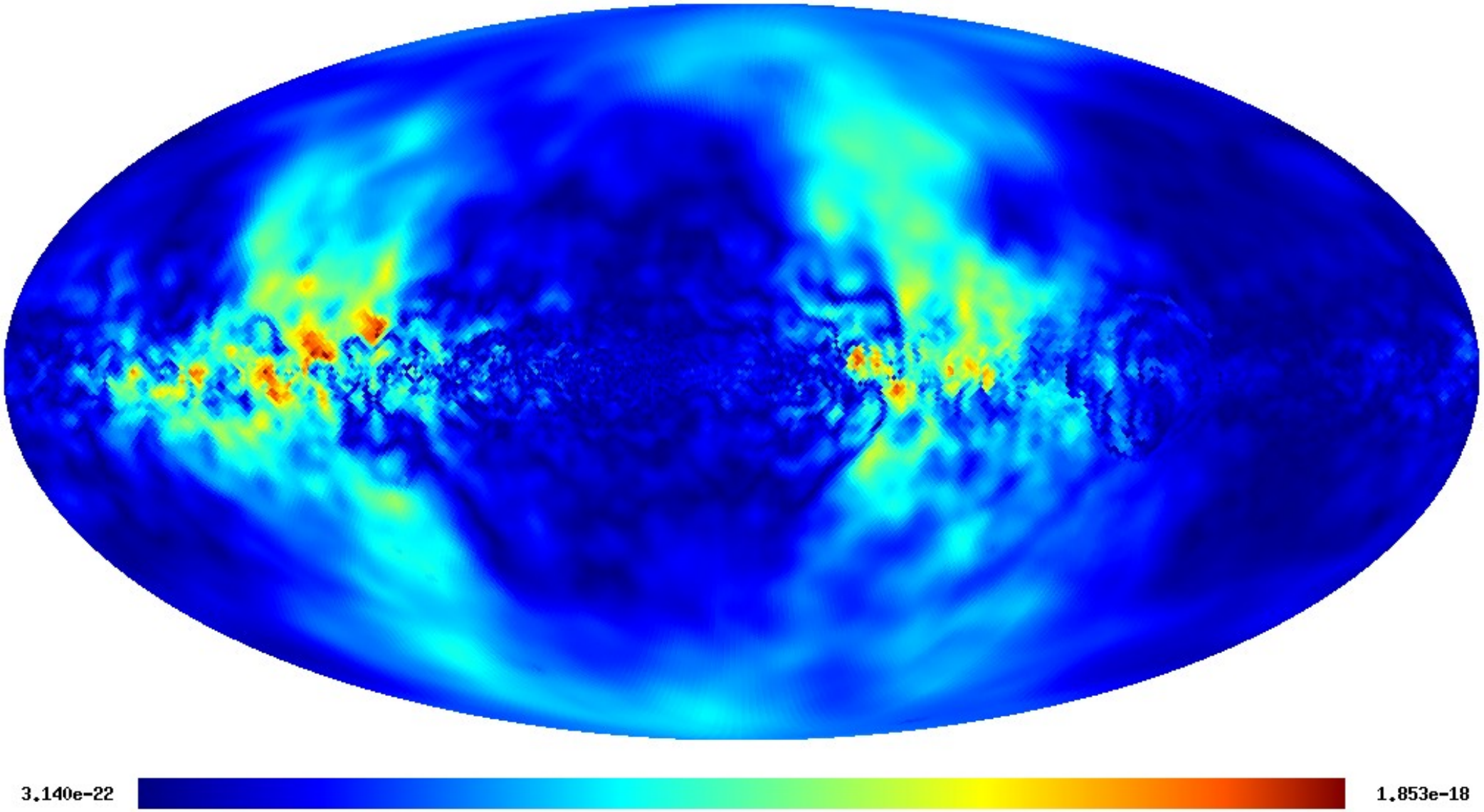
22 GHz

Hammurabi-Simulation



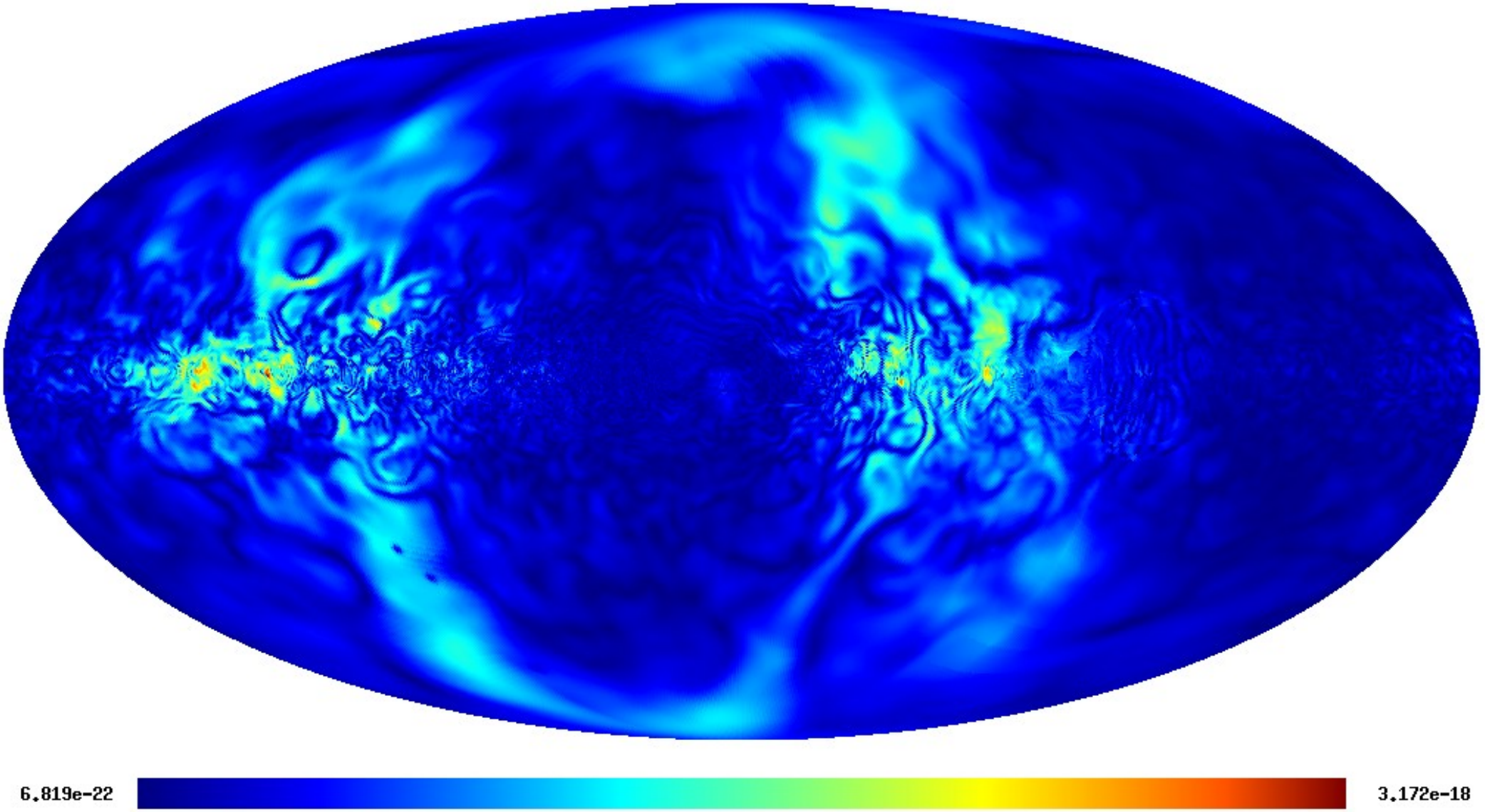
2.4 GHz

Hammurabi-Simulation



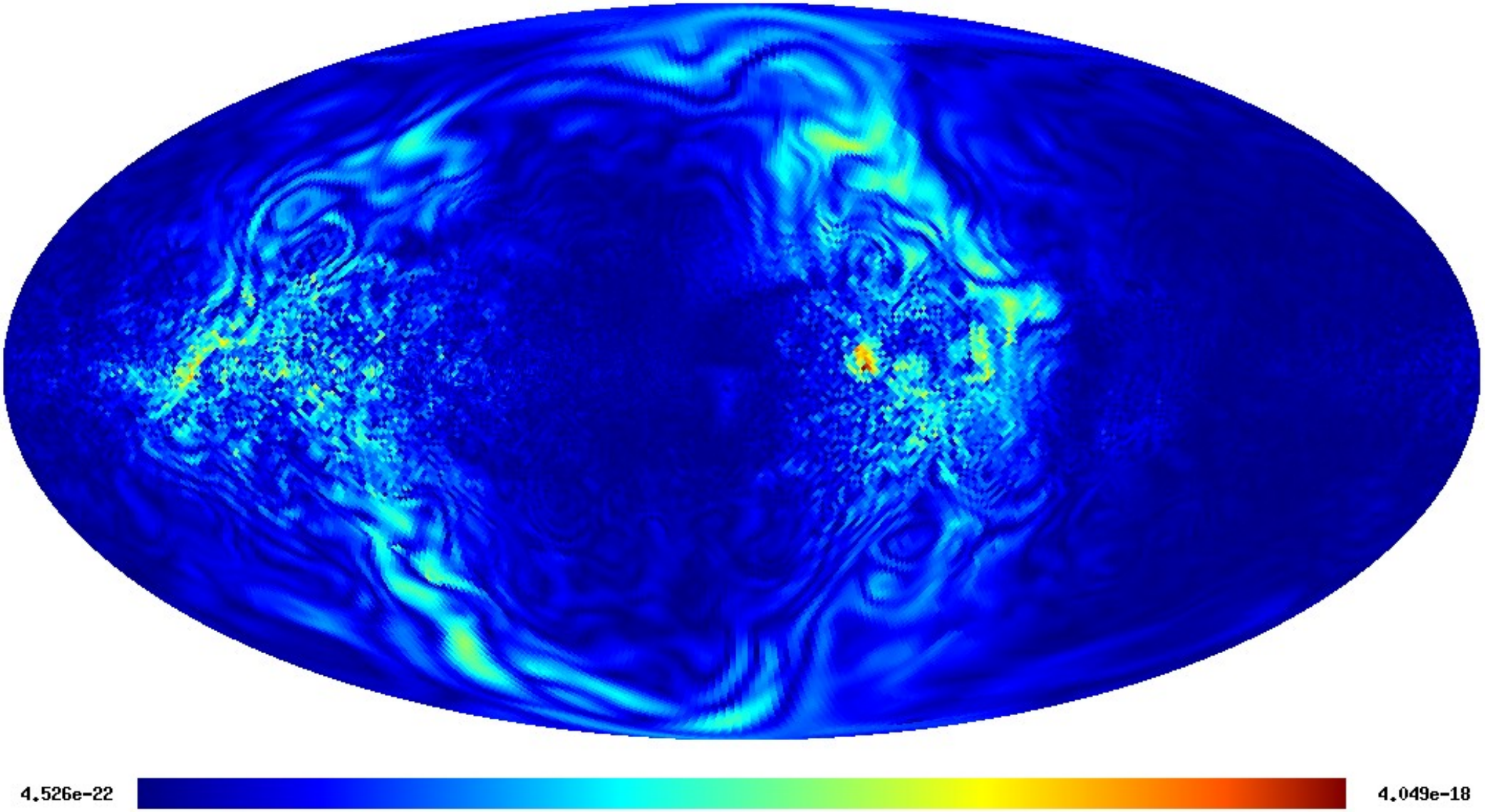
1.4 GHz

Hammurabi-Simulation



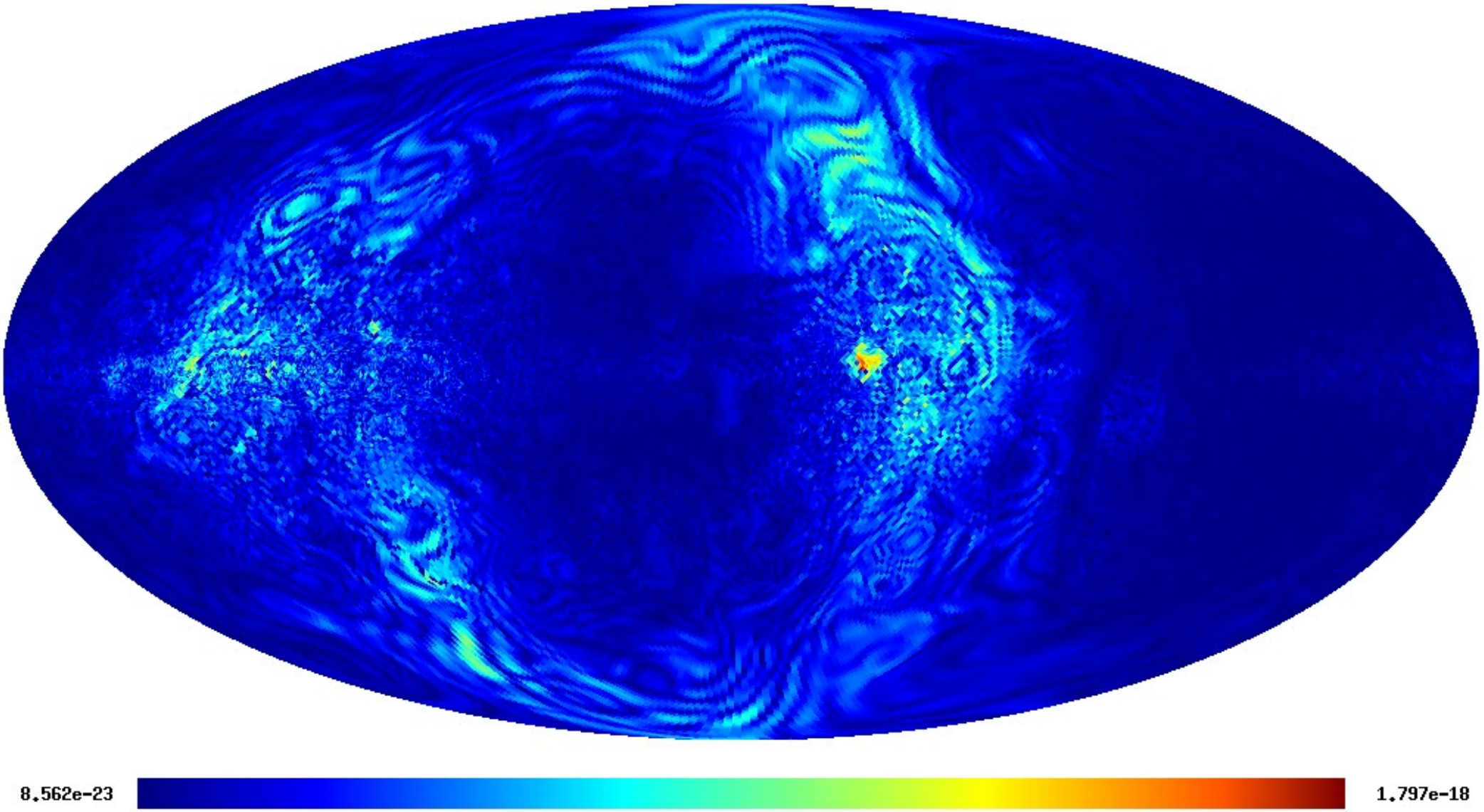
0.8 GHz

Hammurabi-Simulation



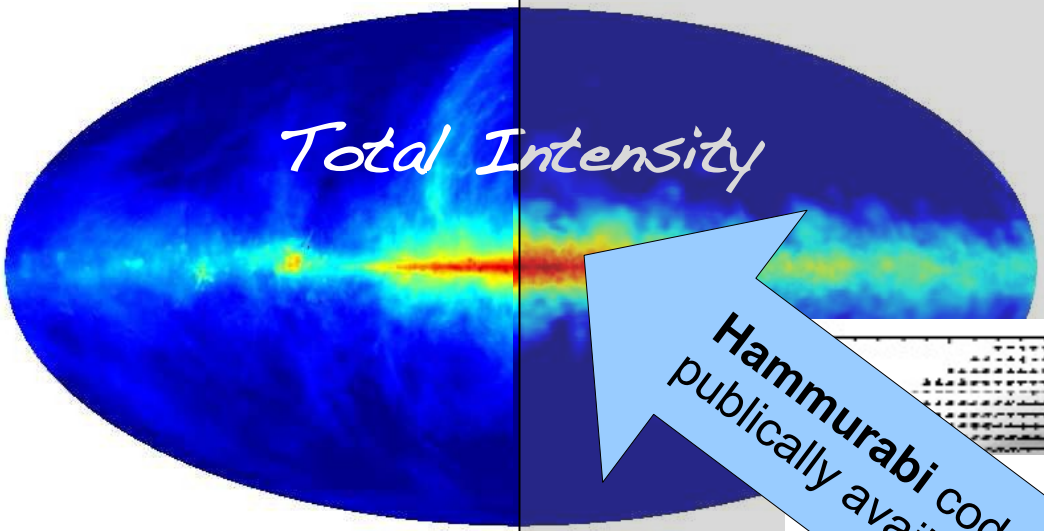
0.4 GHz

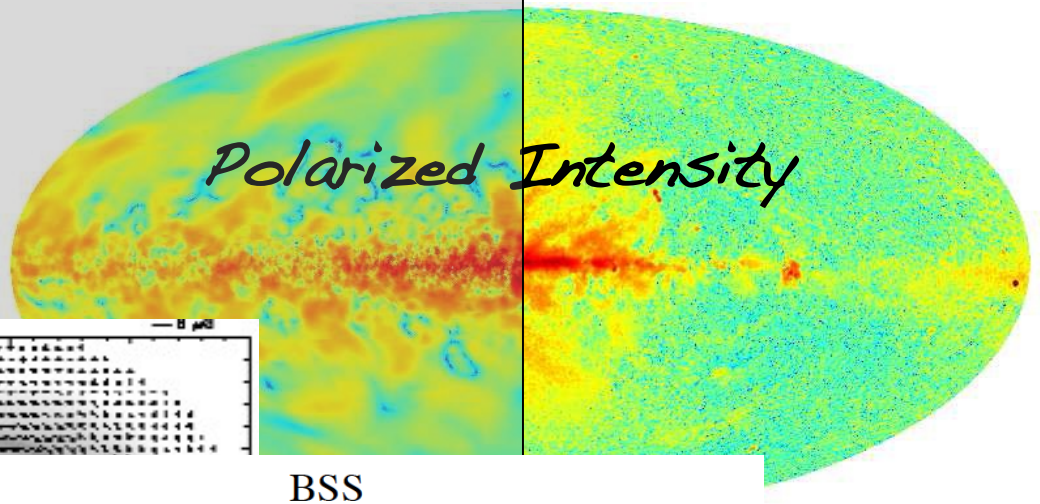
Hammurabi-Simulation



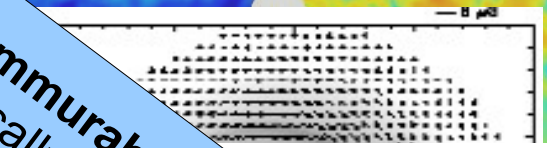
Hammurabi simulation of galactic magnetic field observables

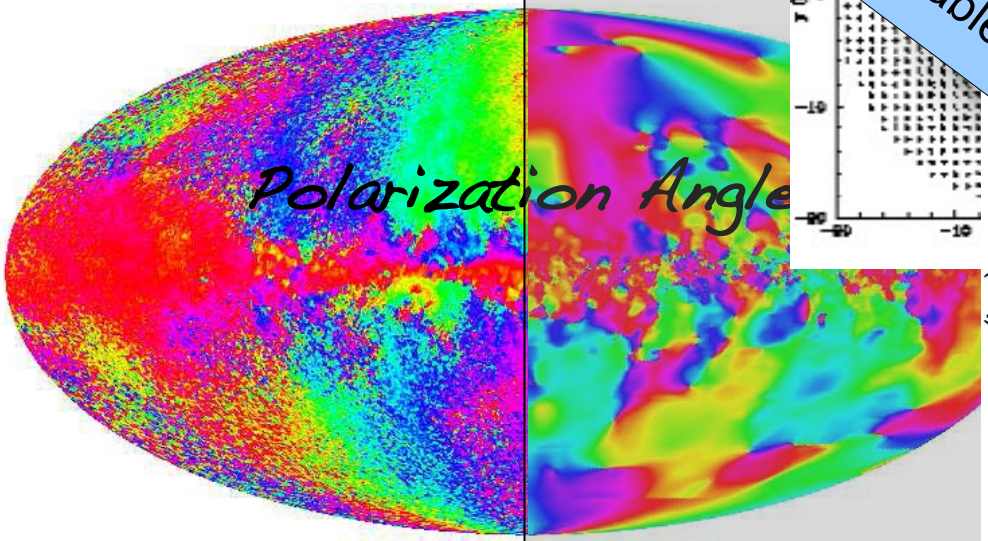
Waelkens et al. (2009)
Sun et al. (2008)
Janson et al. (2008)

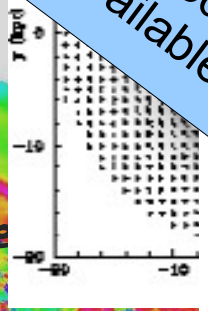




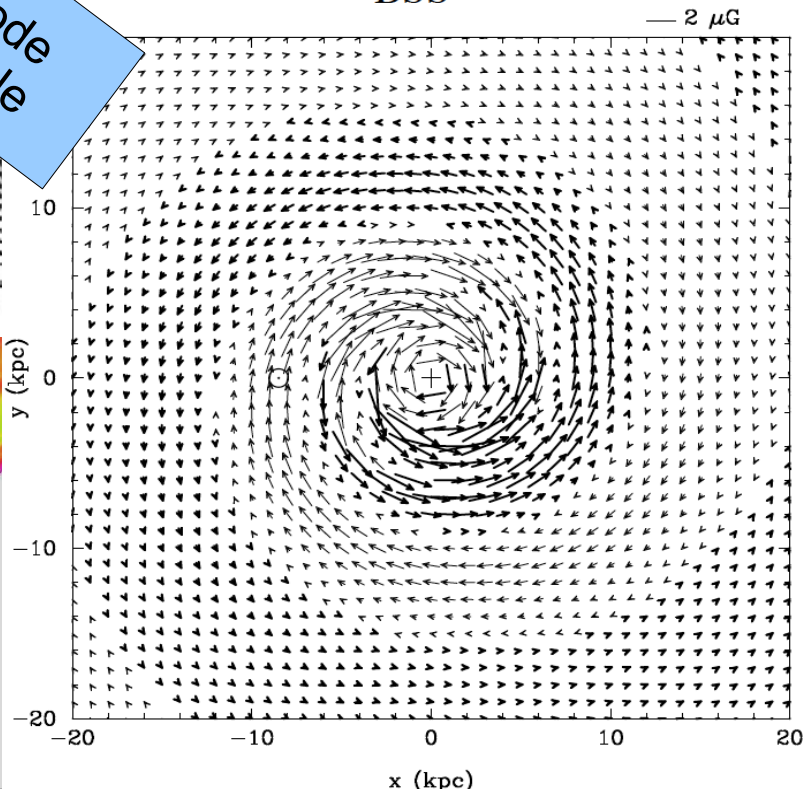
Hammurabi code publically available

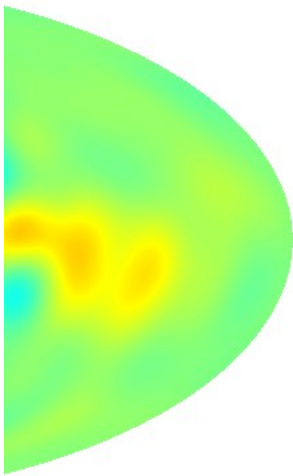


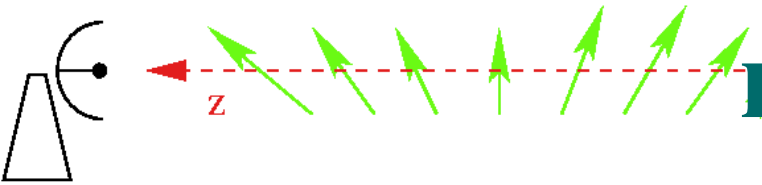




BSS







model fitting

realities

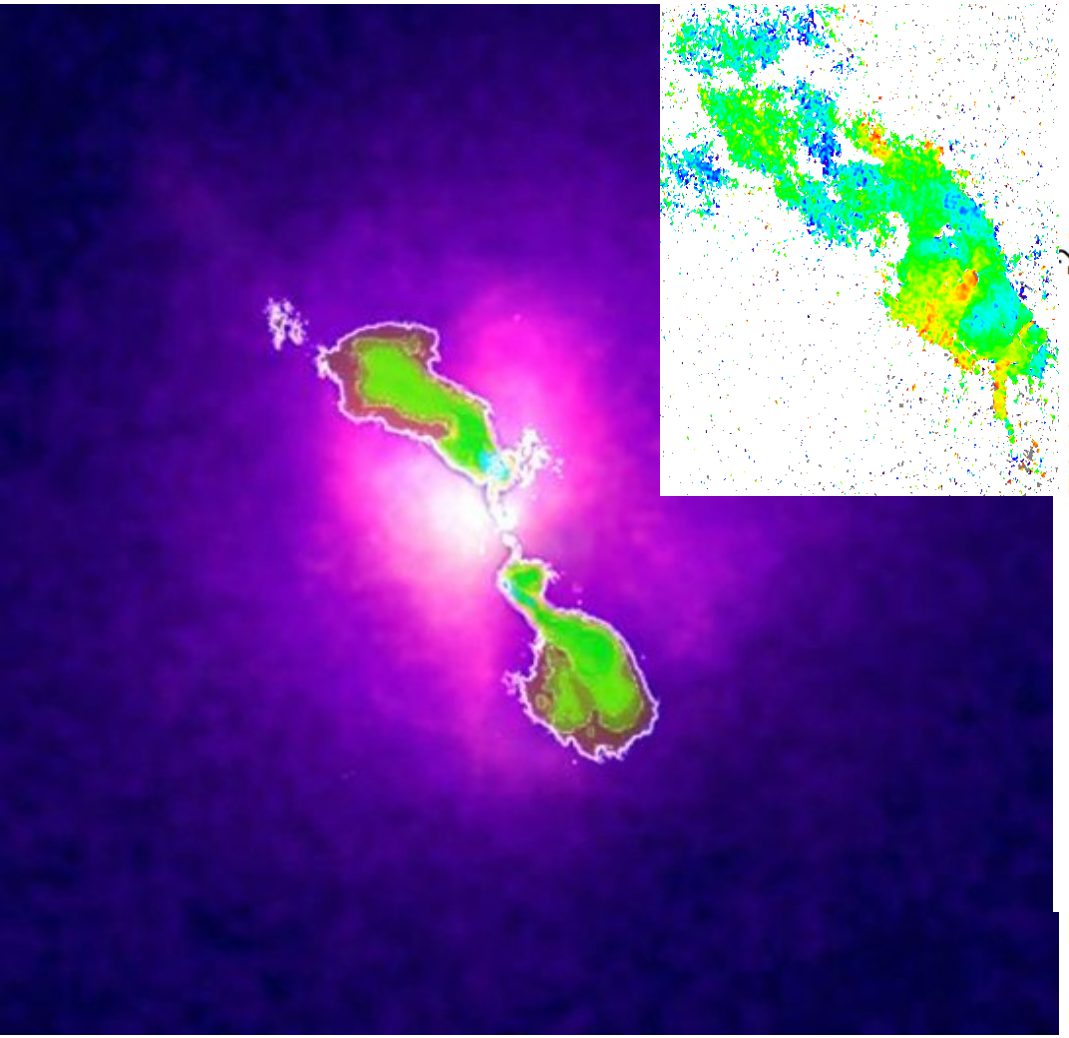
data space

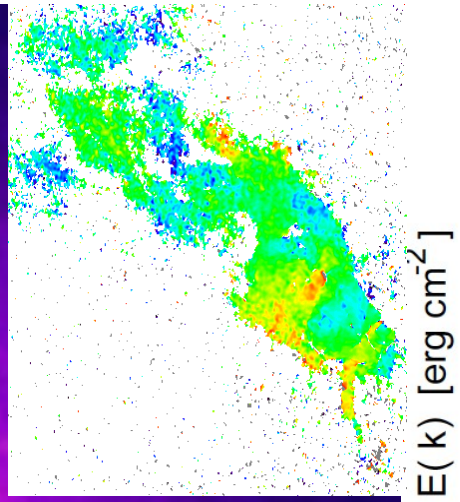
i.e. Hammurabi code

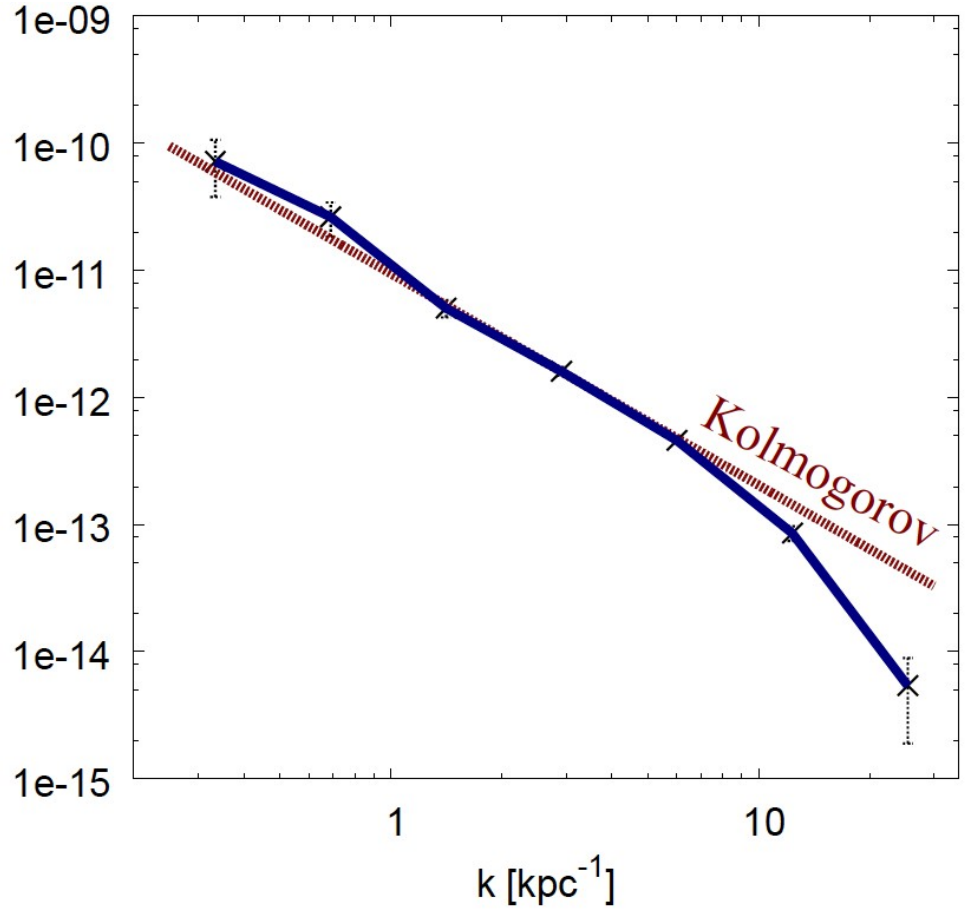
model space

Magnetic power spectrum in Hydra A cool core cluster

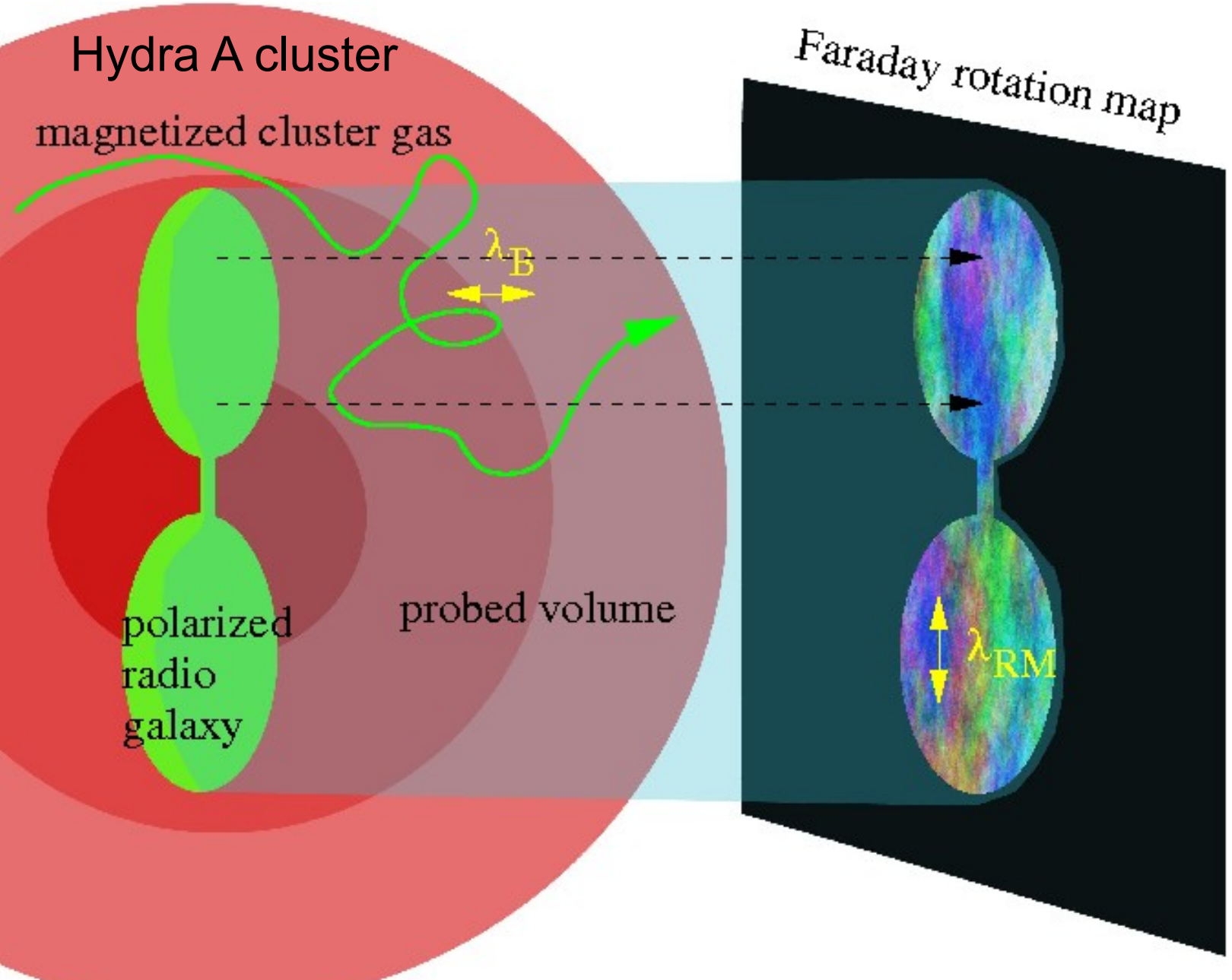
Kuchar & EnBlin (2009)



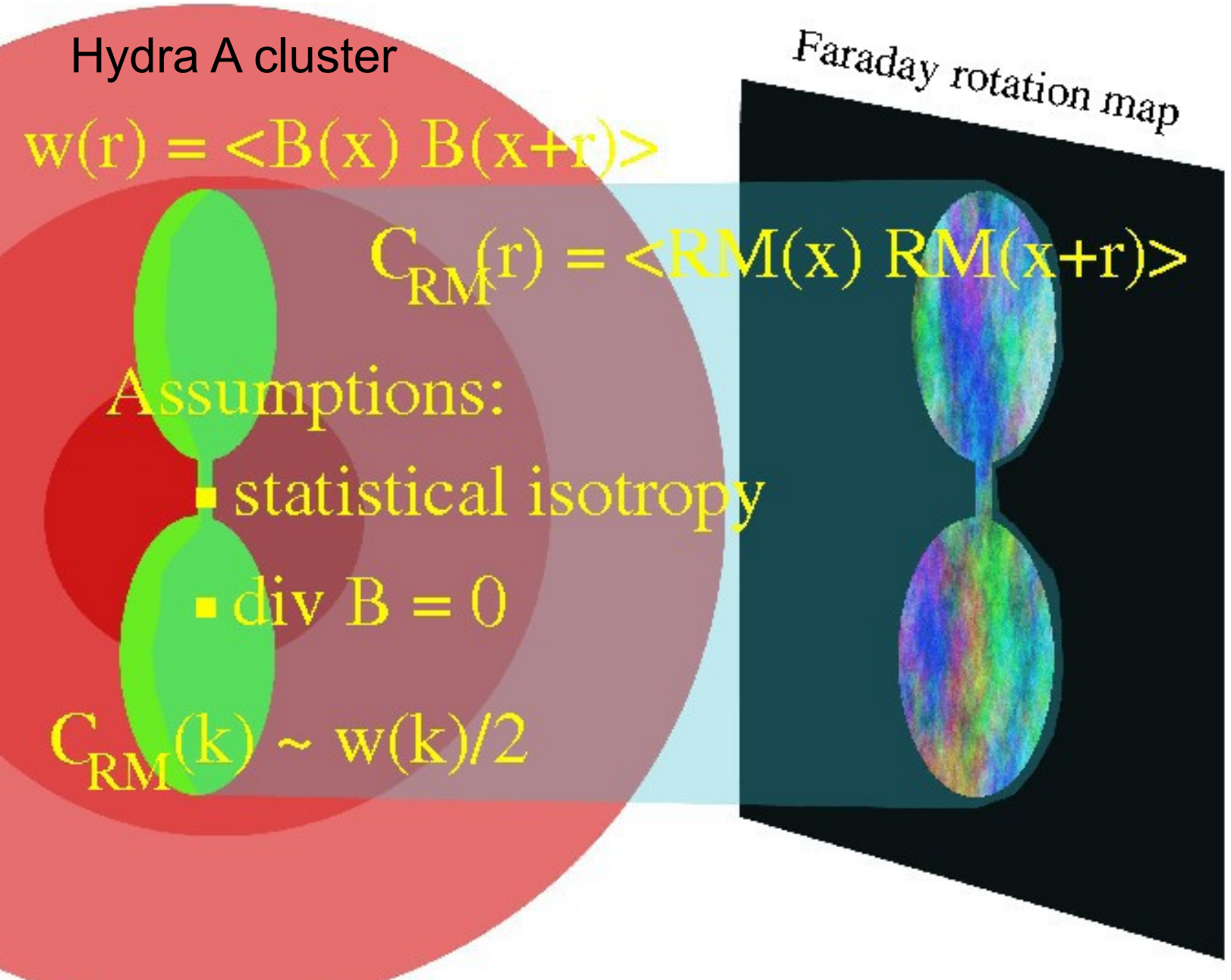




Observational Setup

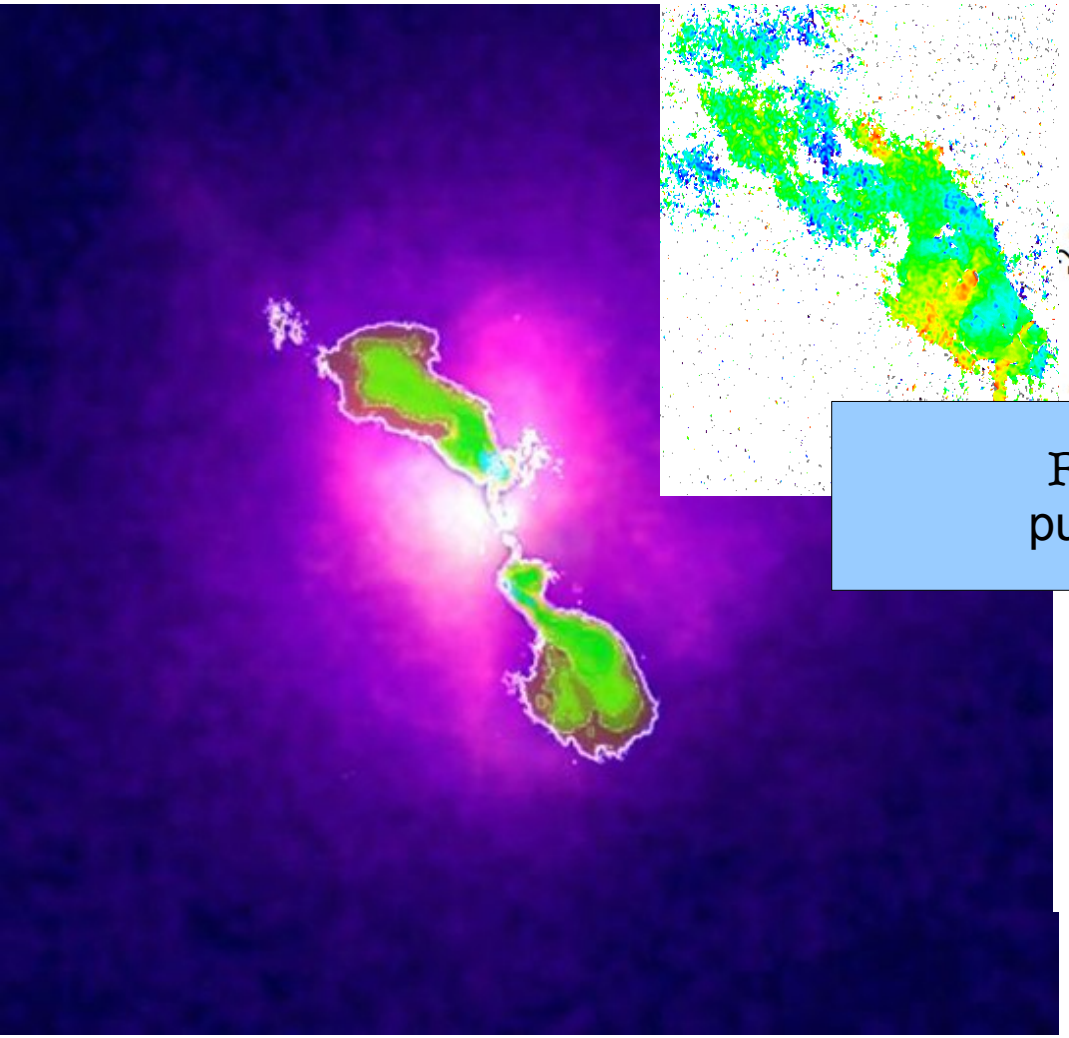


Observational Setup

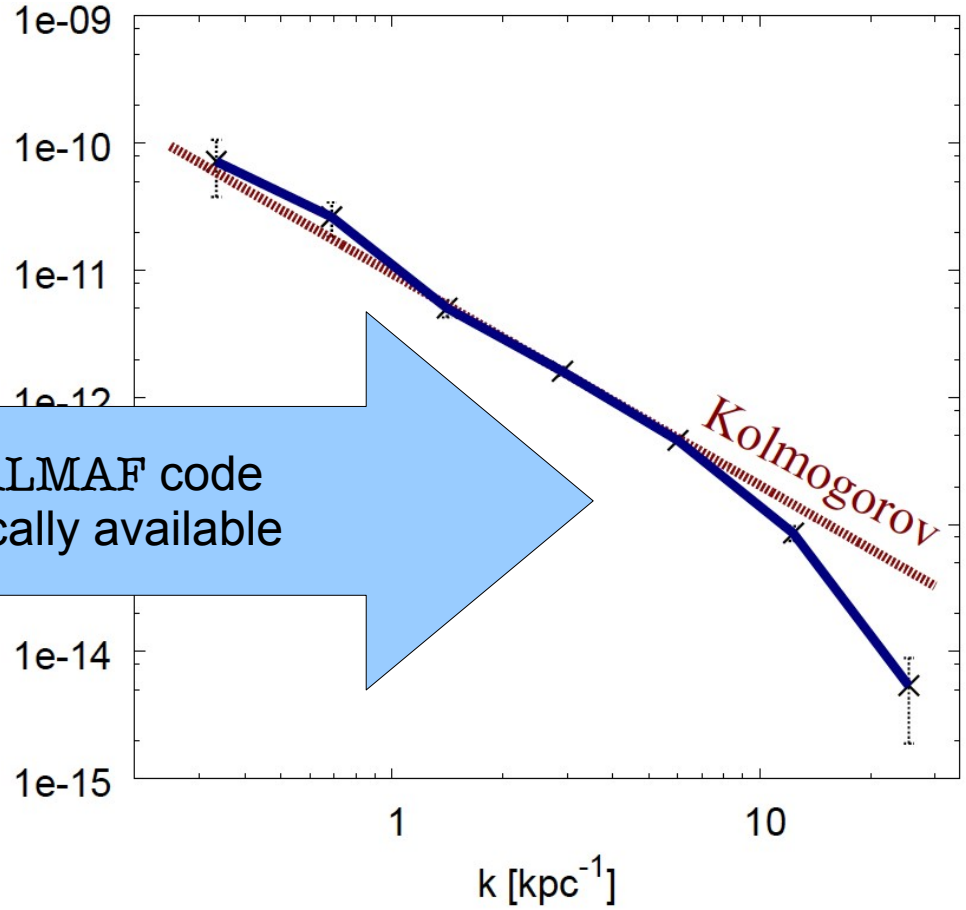


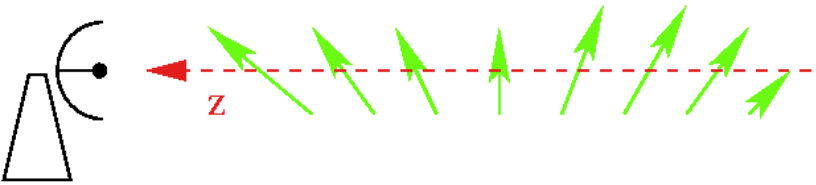
Magnetic power spectrum in Hydra A cool core cluster

Kuchar & EnBlin (2009)



REALMAF code
publically available





inference

realities

data space

i.e. REALMAF code

model space

RM Synthesis

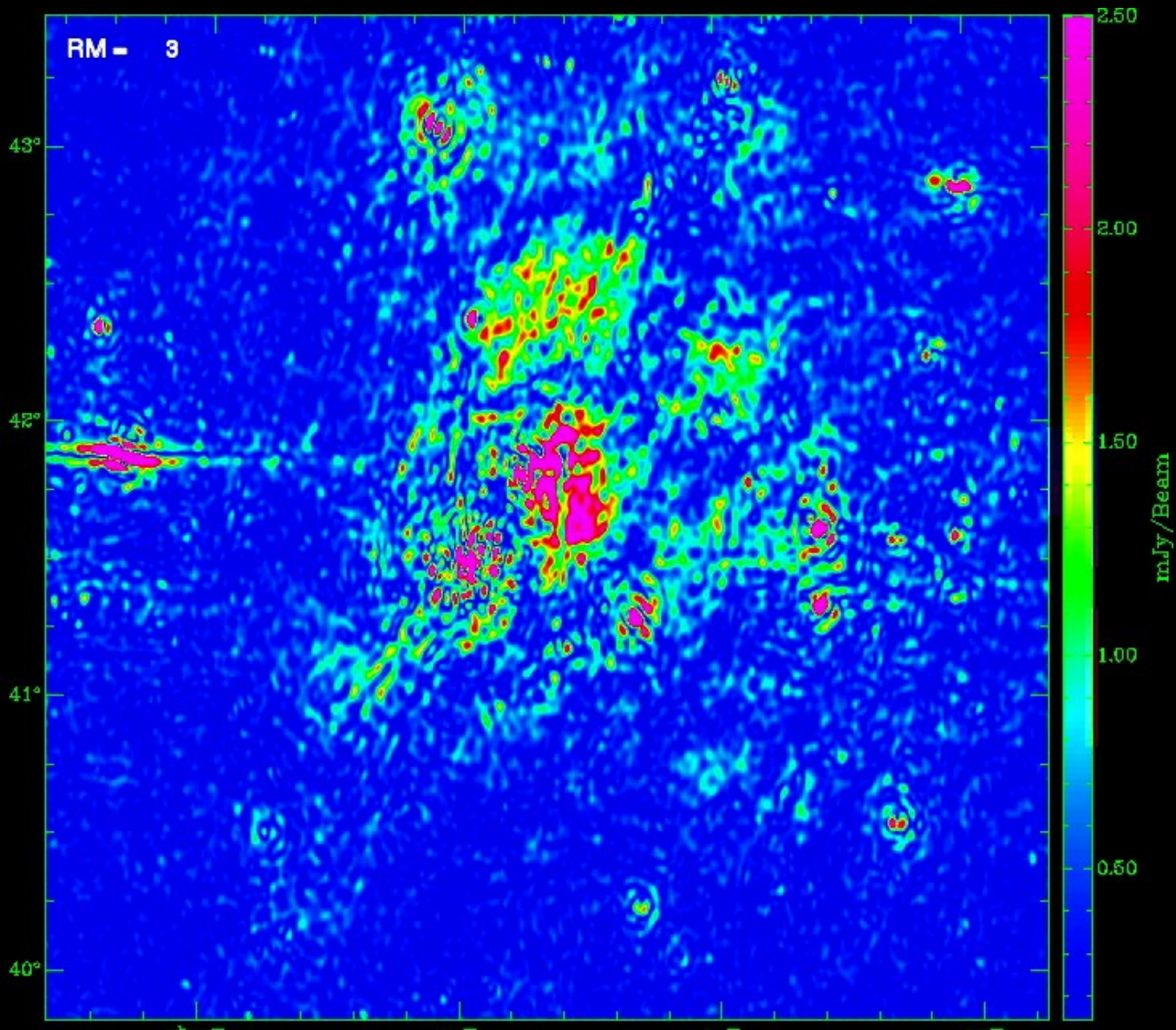
de Bruyn & Brentjens (2005)

RM Synthesis

de Bruyn & Brentjens (2005)

RM Synthesis

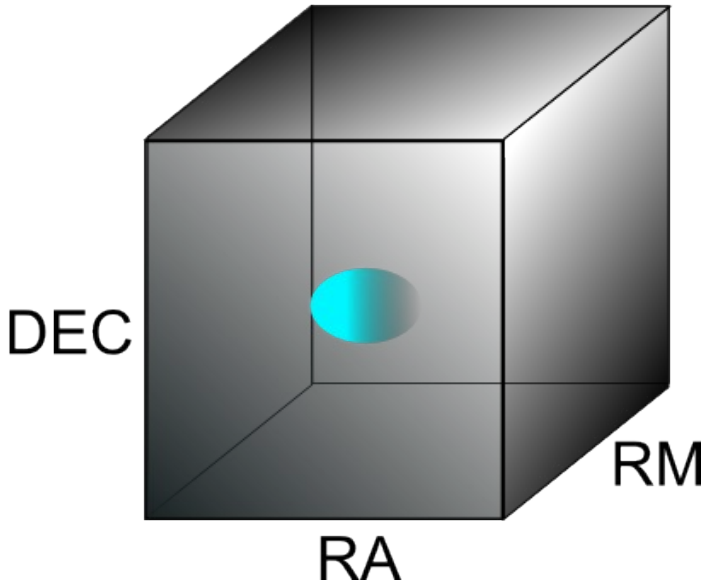
de Bruyn & Brentjens (2005)



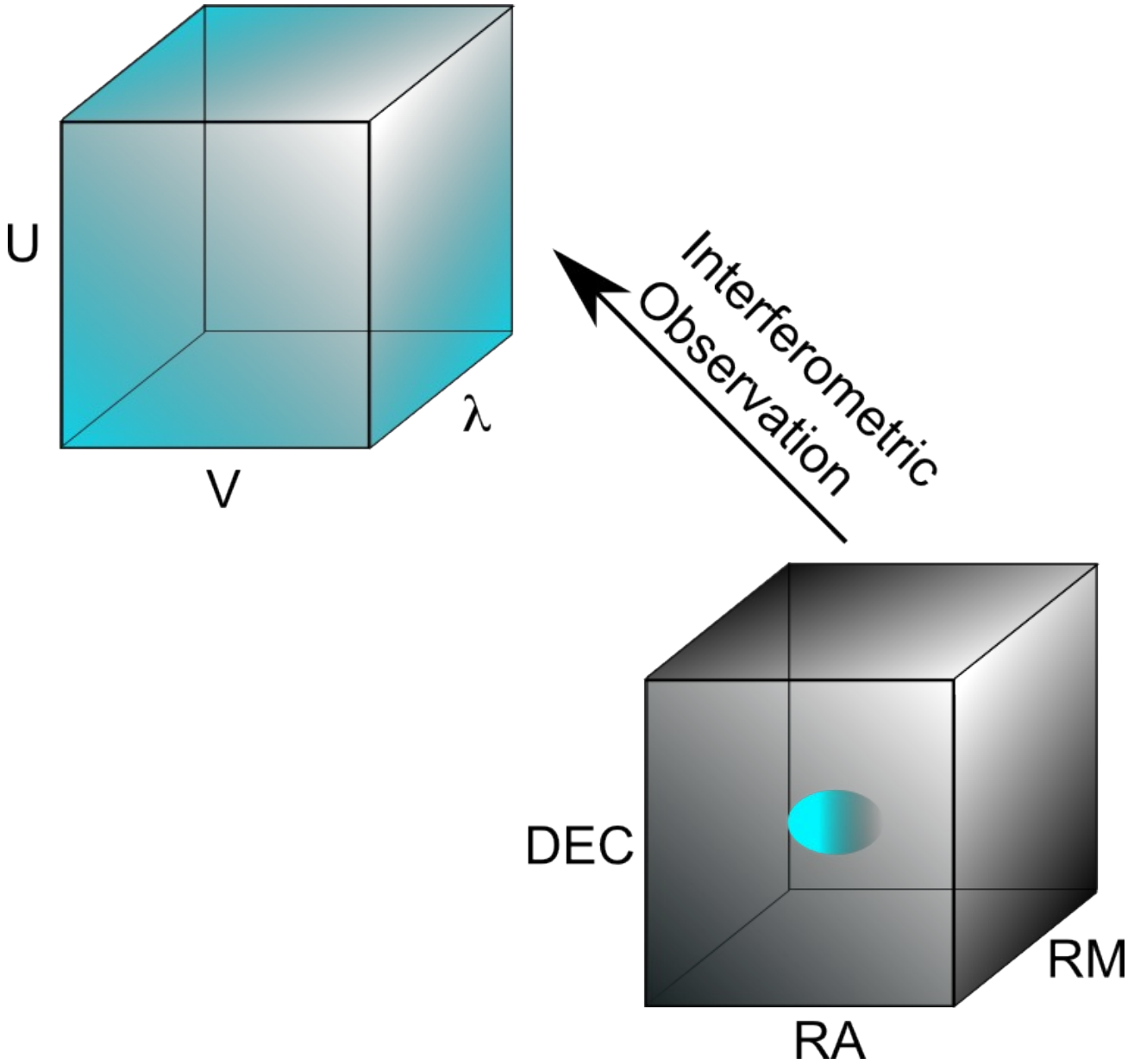
RM Synthesis

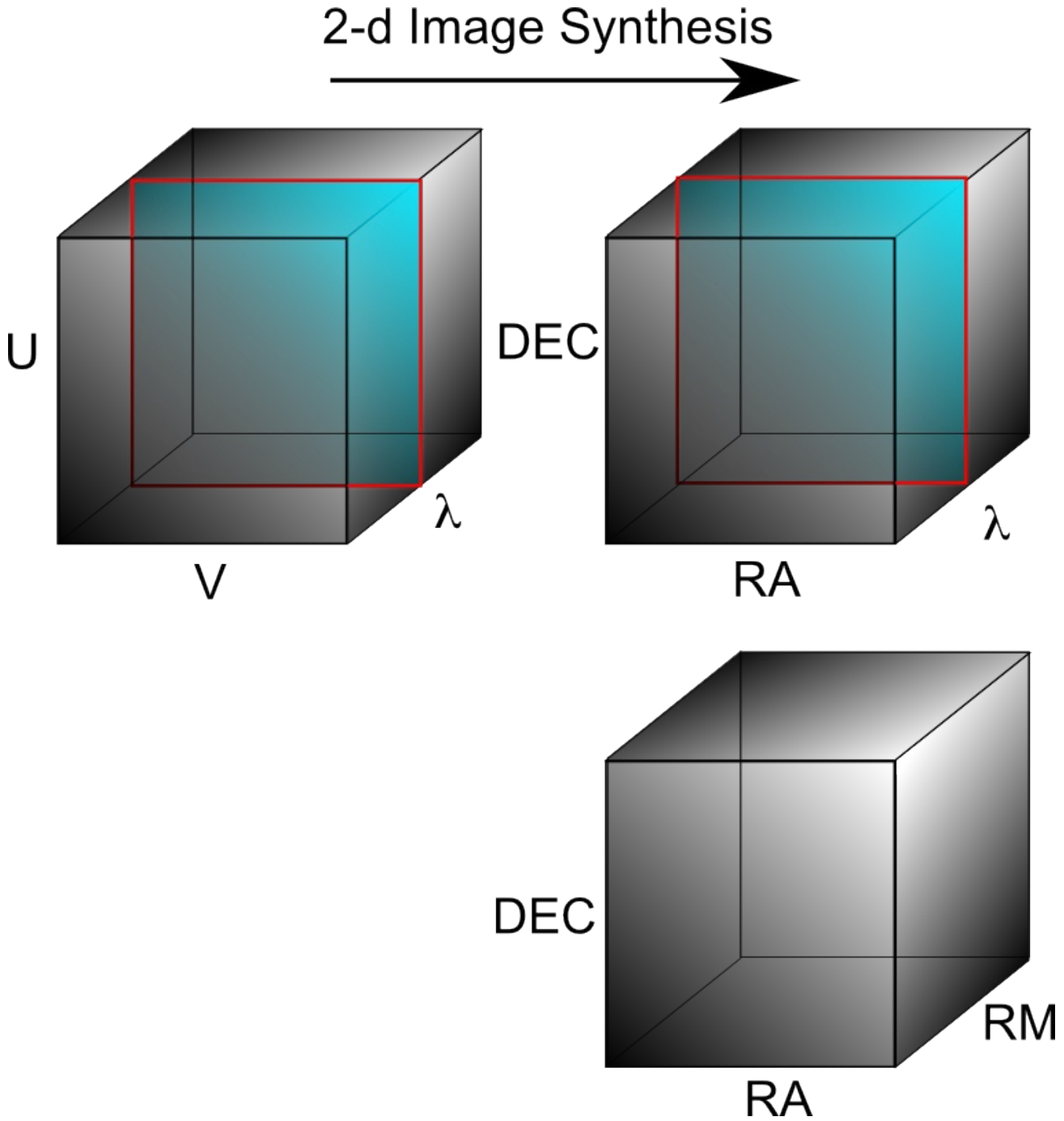
3d RM Synthesis

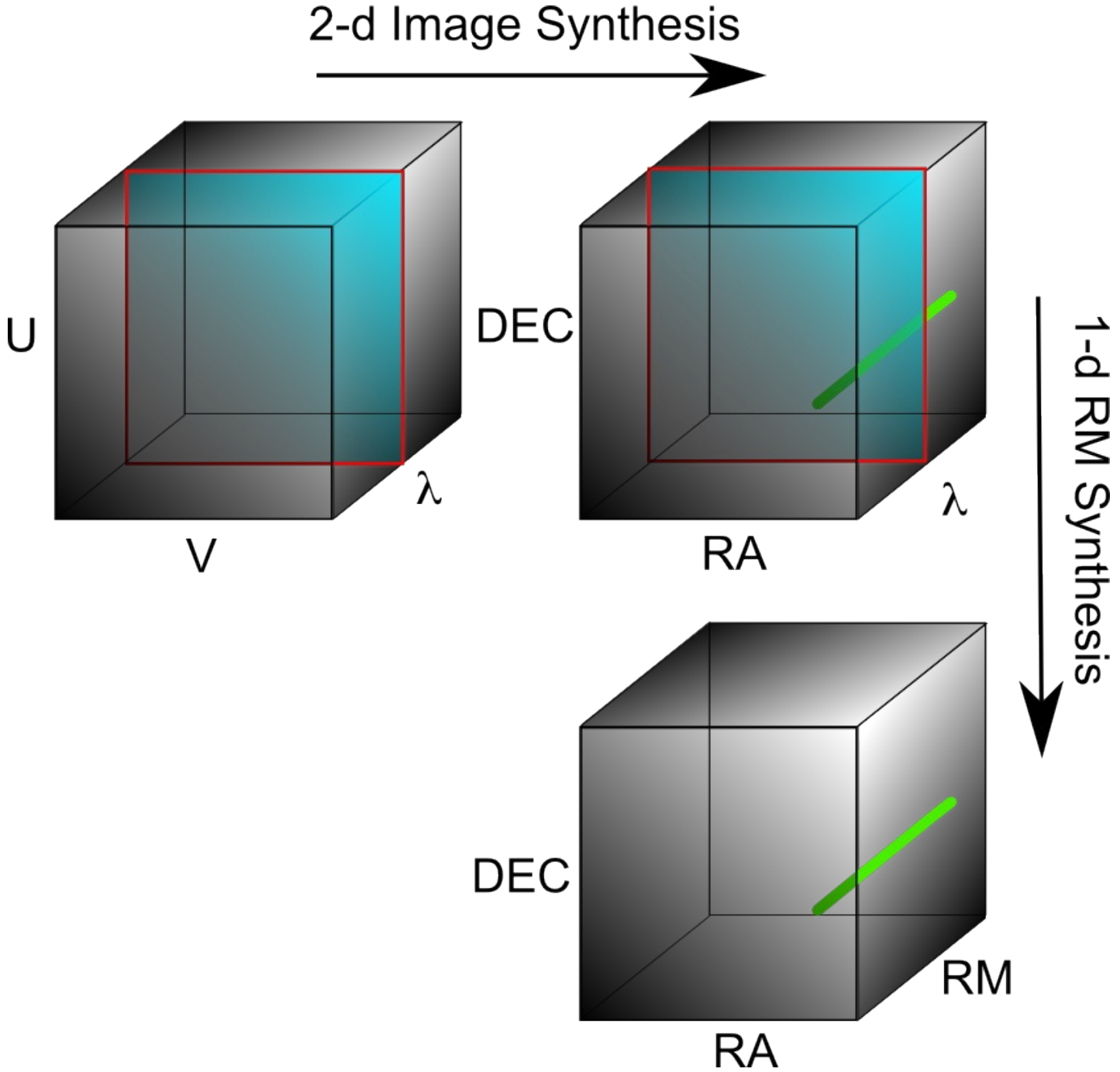
3d RM Synthesis

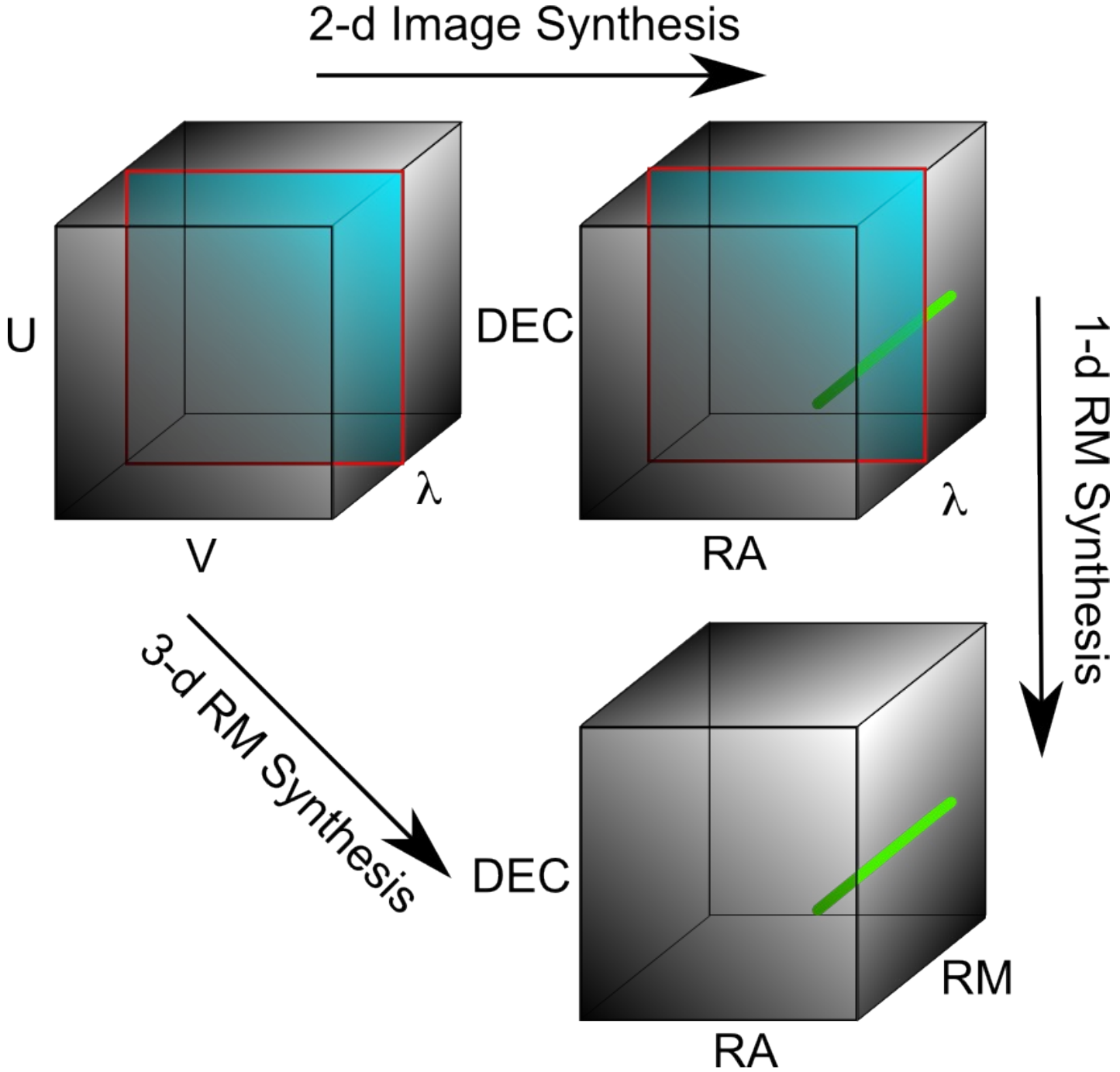


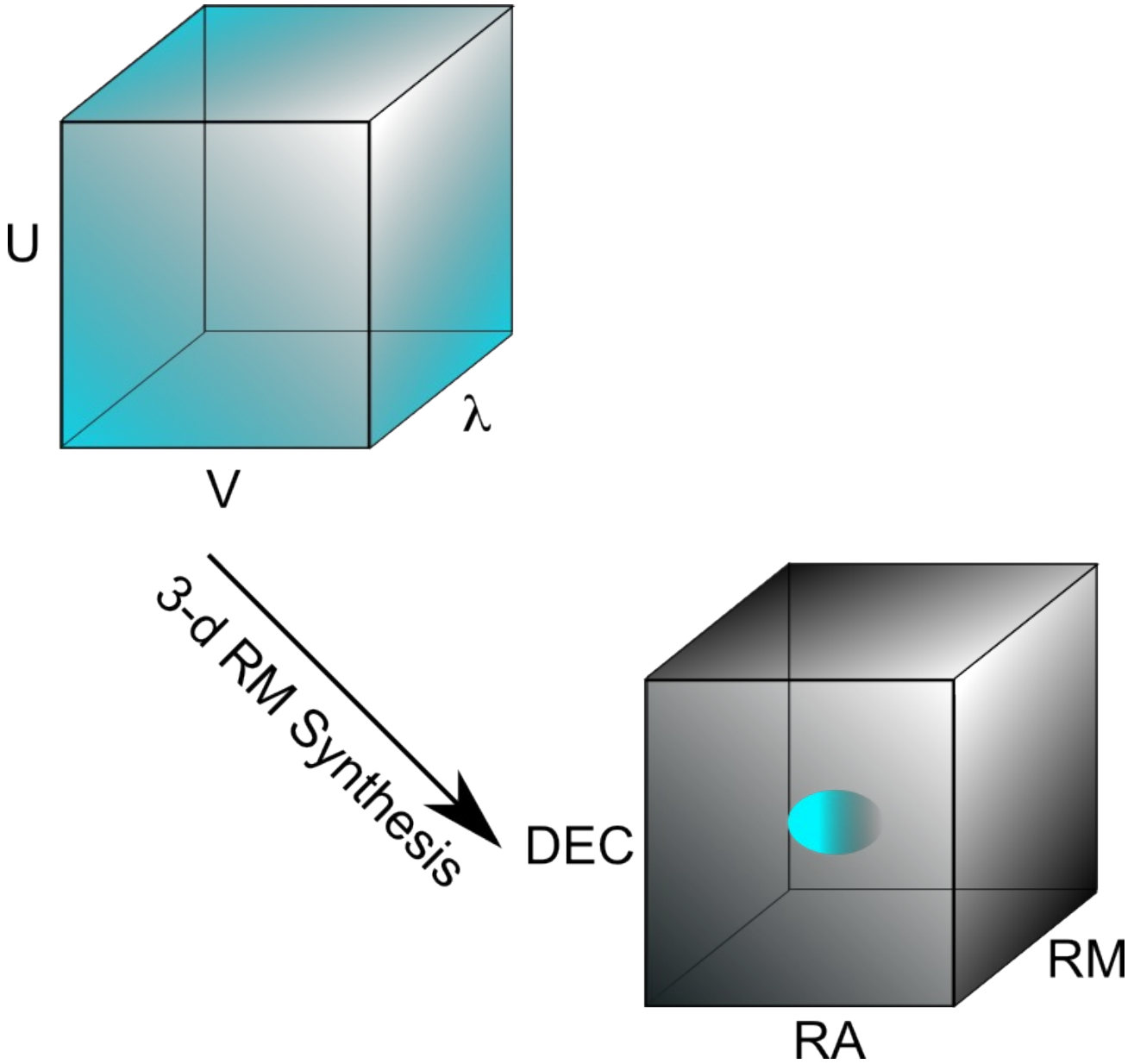
3d RM Synthesis

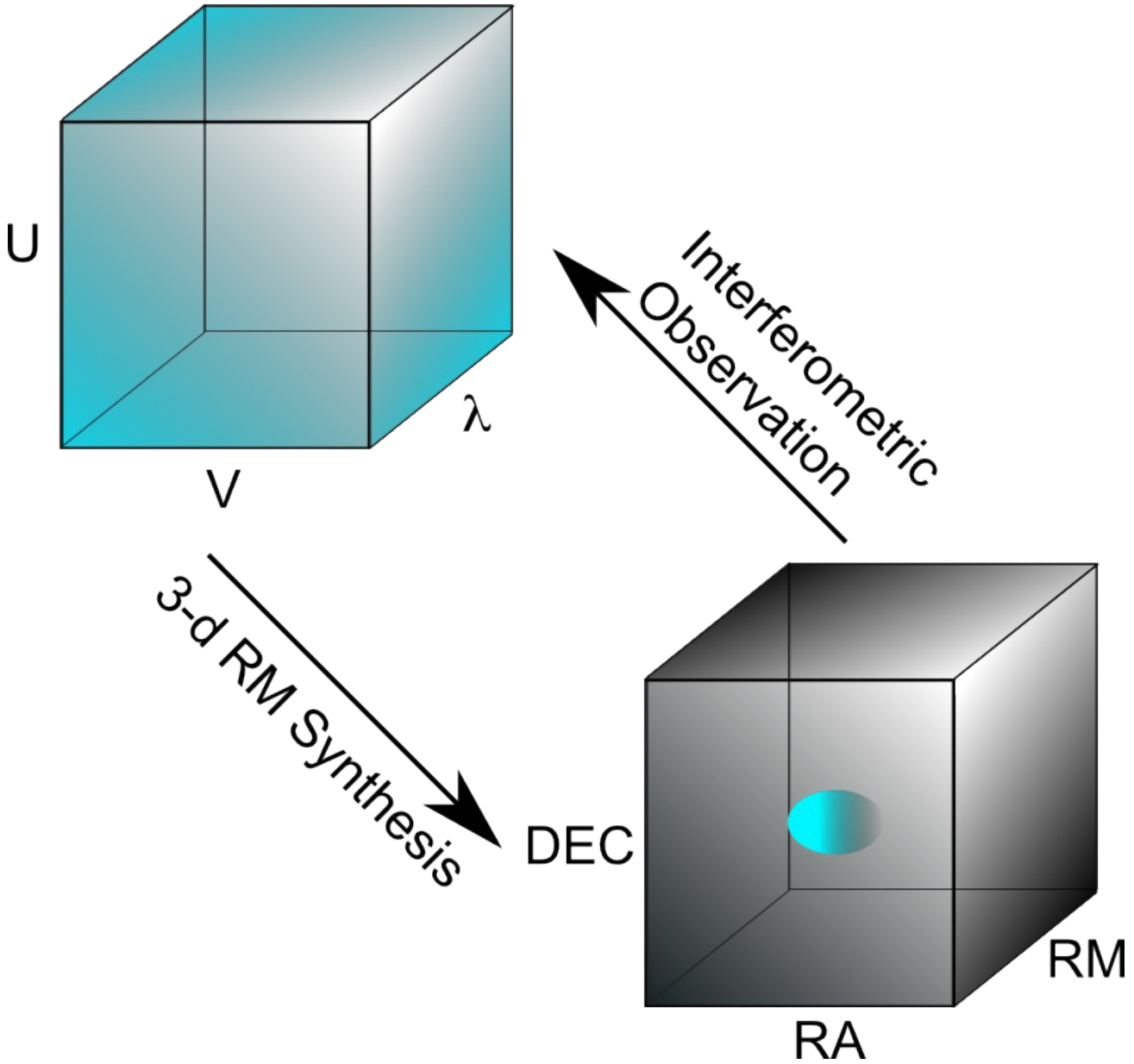



2-d Image Synthesis
U
V
λ
DEC
RA
λ
DEC
RA
RM

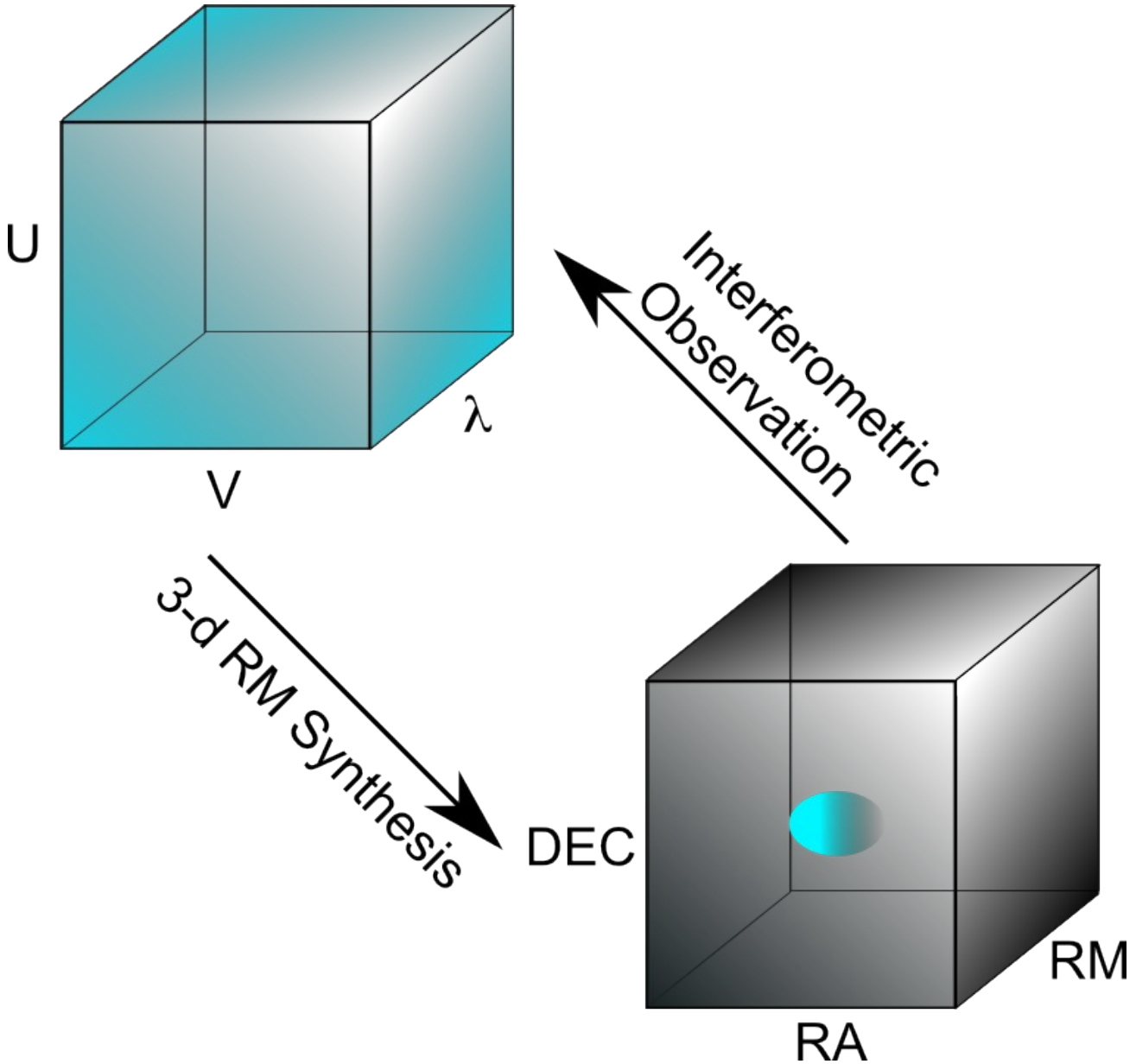

2-d Image Synthesis
U
V
λ
DEC
RA
λ
1-d RM Synthesis
DEC
RA
RM


2-d Image Synthesis
U
V
λ
DEC
RA
λ
1-d RM Synthesis
3-d RM Synthesis
DEC
RA
RM


U
V
λ
3-d RM Synthesis
DEC
RA
RM


U
V
λ
Interferometric
Observation
3-d RM Synthesis
DEC
RA
RM

information

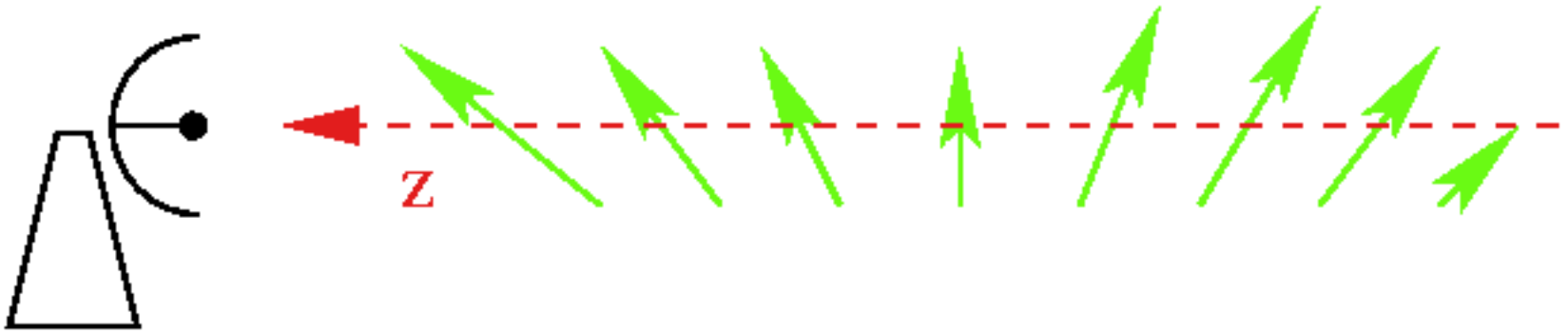


How to obtain information ?

physical signal s

1) prior knowledge: P(s)

2) measurement: d = R(s) + n, P(d|s)



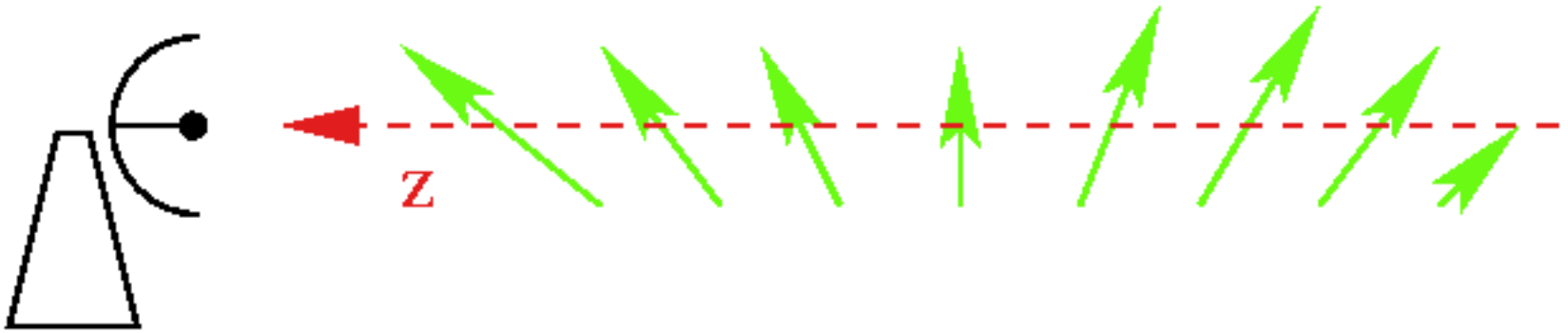
3) inference: P(s|d) = P(d|s) P(s) / P(d), d → s

Wiener filter

physical signal s

1) prior knowledge: P(s) = G(s,S) Gaussian

2) linear measurement: d = R s + n, P(n) = G(n,N)



3) inference: P(s|d) = G(s-m,D)

$$m = (S^{-1}+R^{\dagger} N^{-1} R)^{-1} R^{\dagger} N^{-1} d$$

$$D = (S^{-1}+R^{\dagger} N^{-1} R)^{-1}$$

Prior information ?

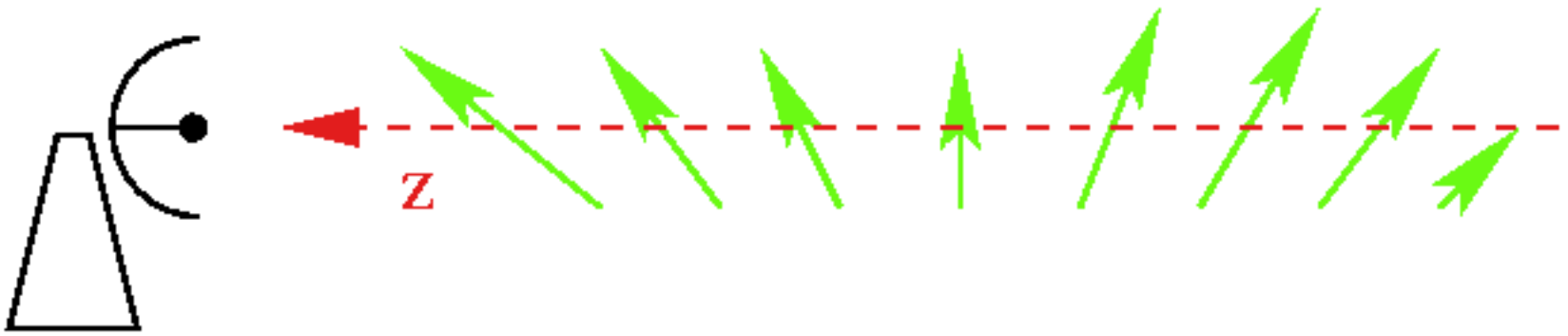
physical signal s

prior knowledge:

s sparse in pixel space
s sparse in wavelet space
s Gaussian random field
s non-Gaussian random field

optimal algorithm:

CLEAN
Compressed Sensing
Wiener Filtering
Information Field Theory

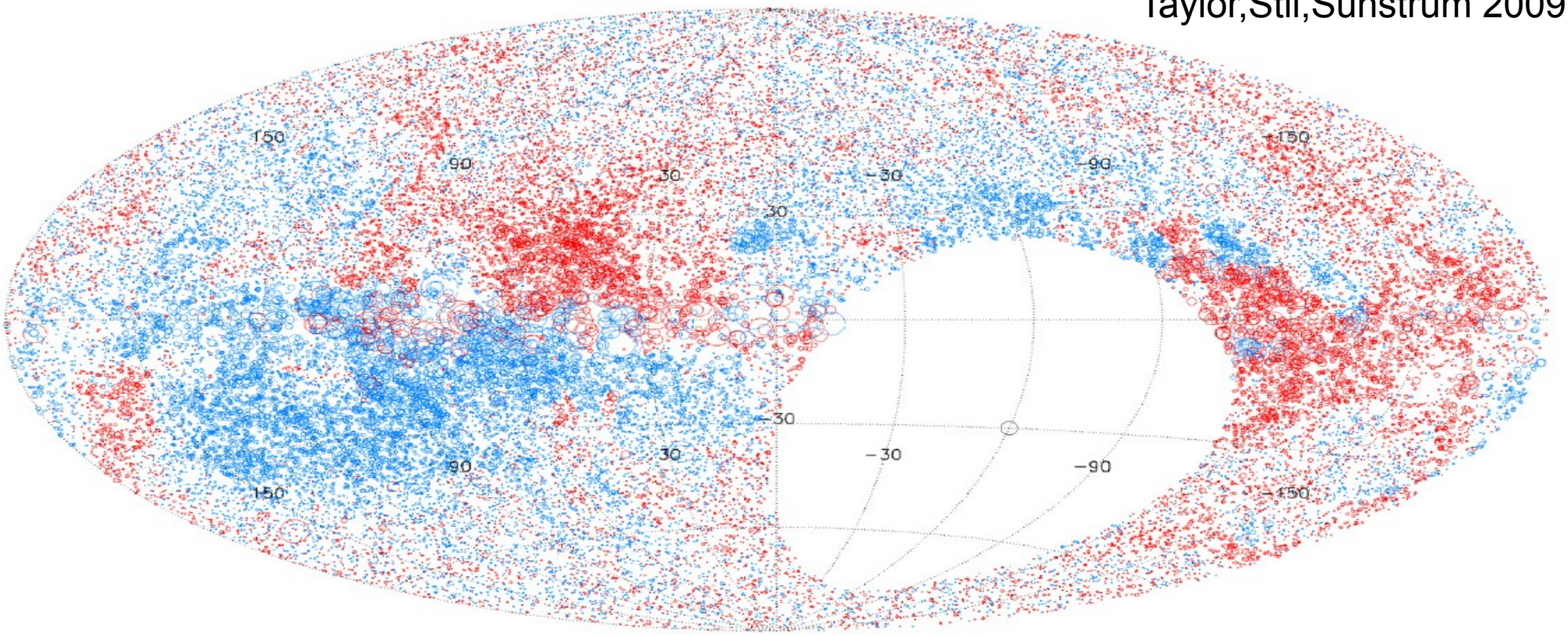


chicken & egg problem:

signal statistics & signal reconstruction
are interdependent

The RM Sky

Taylor,Stil,Sunstrum 2009



37,534 RM extragalactic RM-sources in the northern sky

The RM Sky

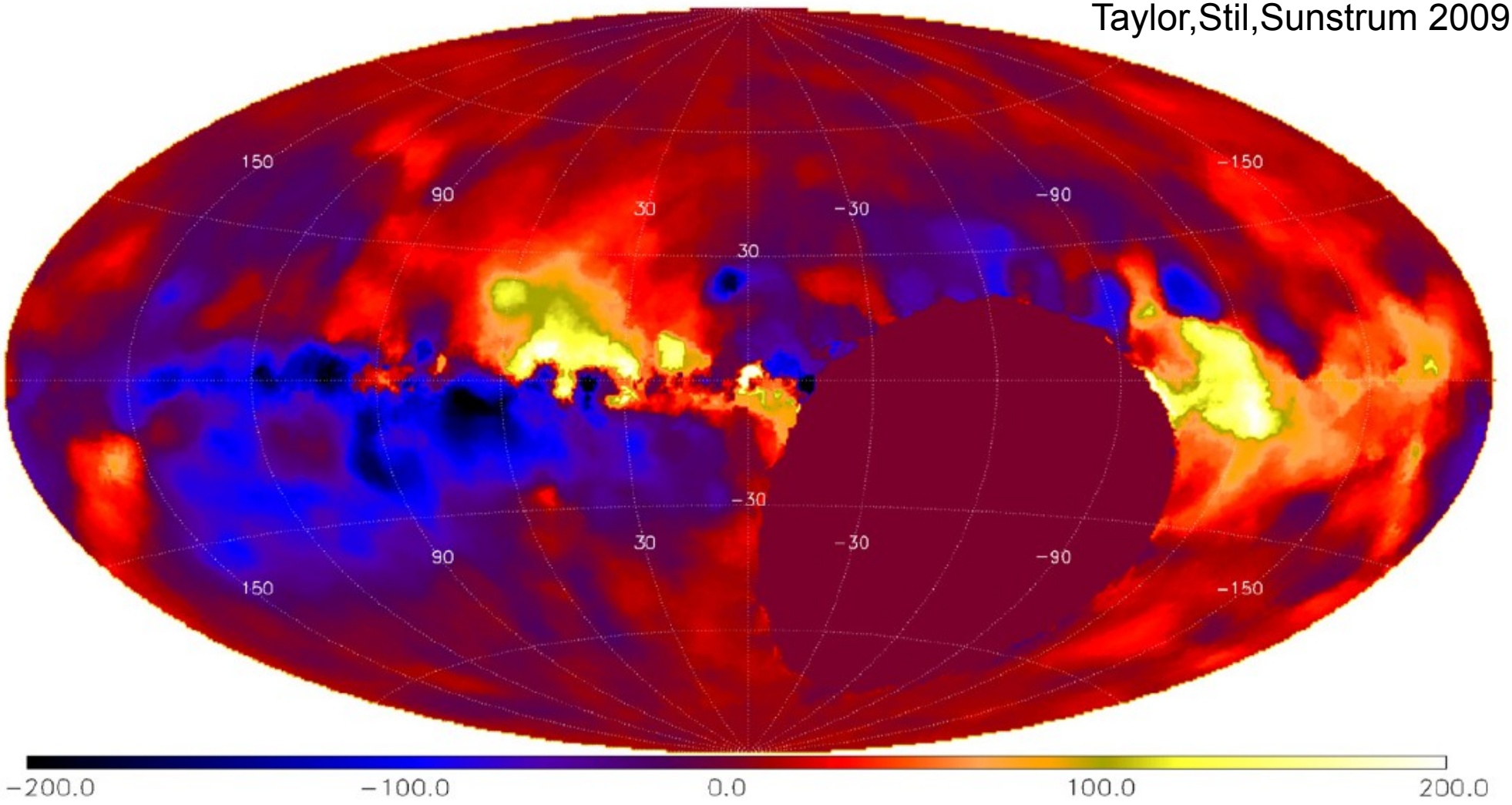
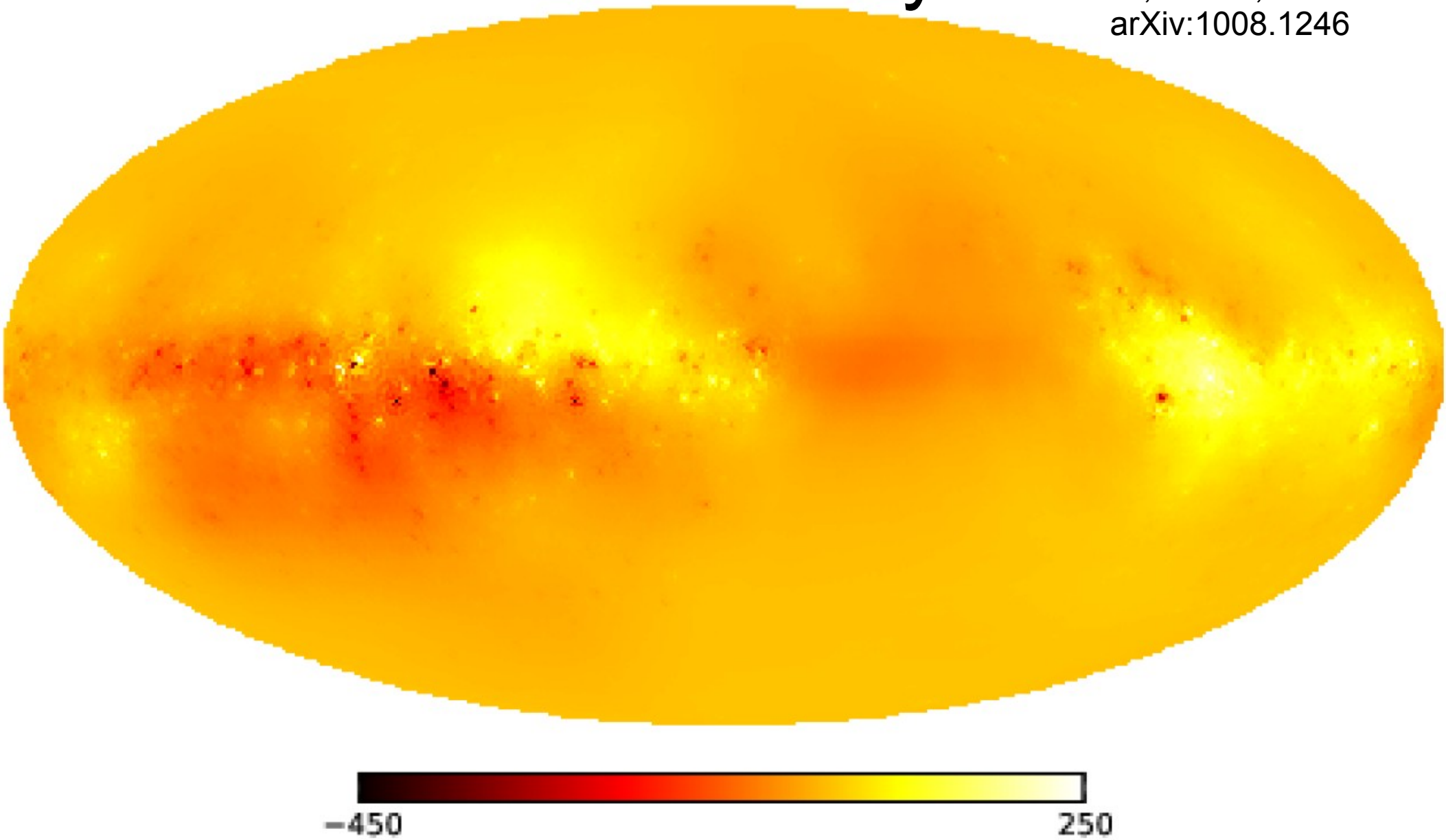


Image of the median value of RM

The RM Sky

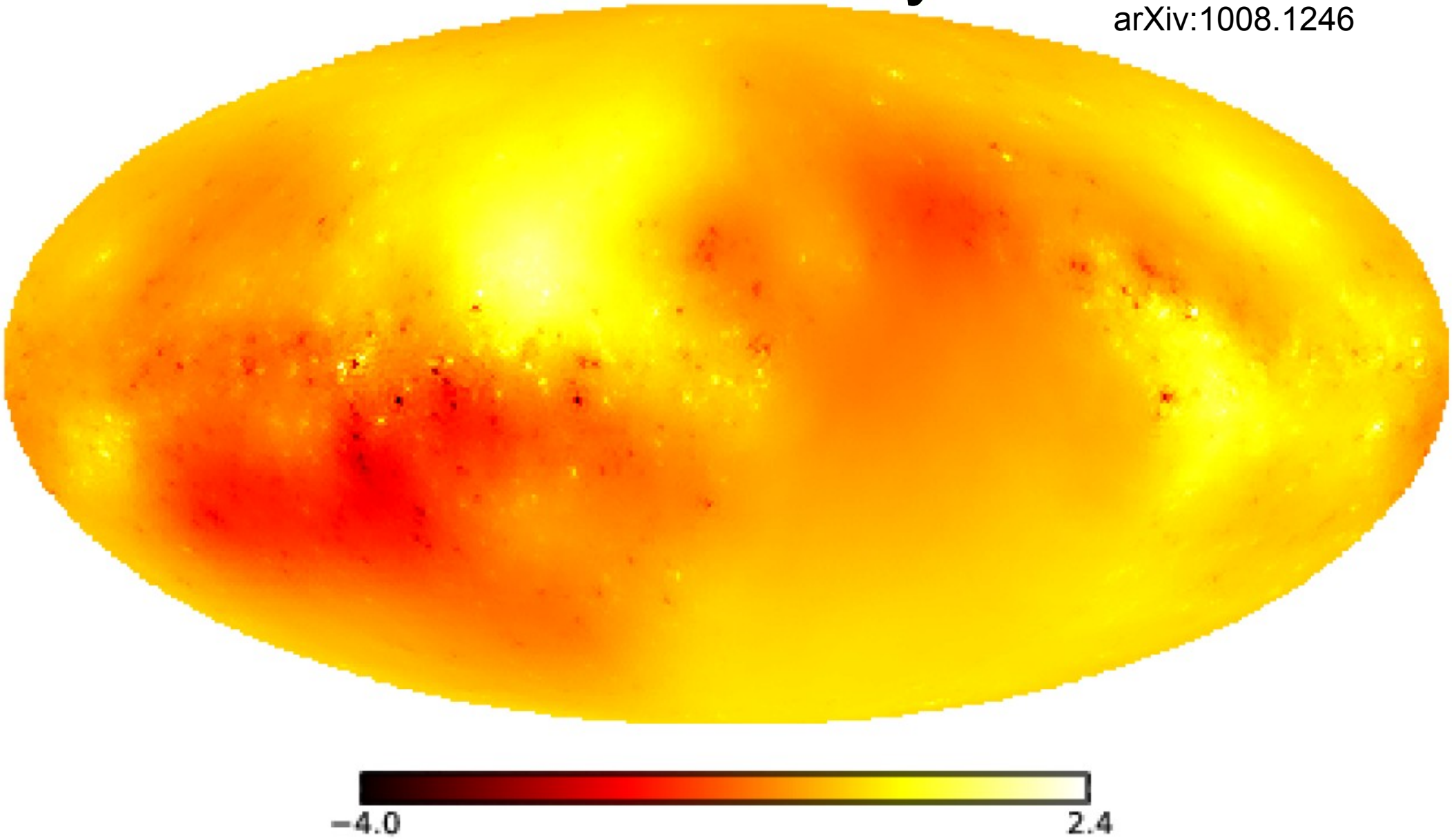
Oppermann, Junklewitz,
Robbers, Enßlin, 2010
arXiv:1008.1246



Wiener filtered RM-map with inferred power spectrum

The RM Sky

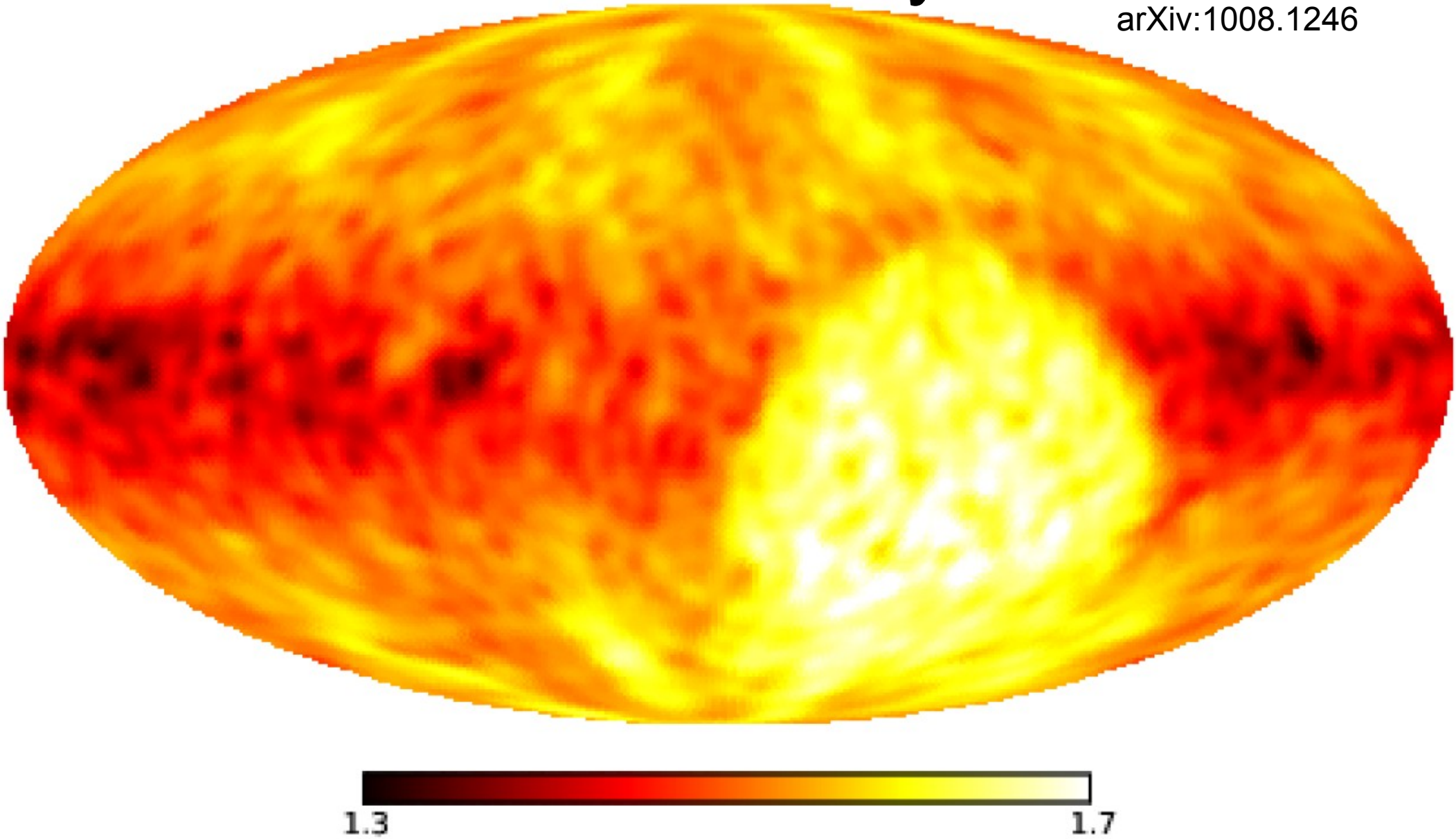
Oppermann, Junklewitz,
Robbers, Enßlin, 2010
arXiv:1008.1246



Wiener filtered RM-map with latitude profile removed

The RM Sky

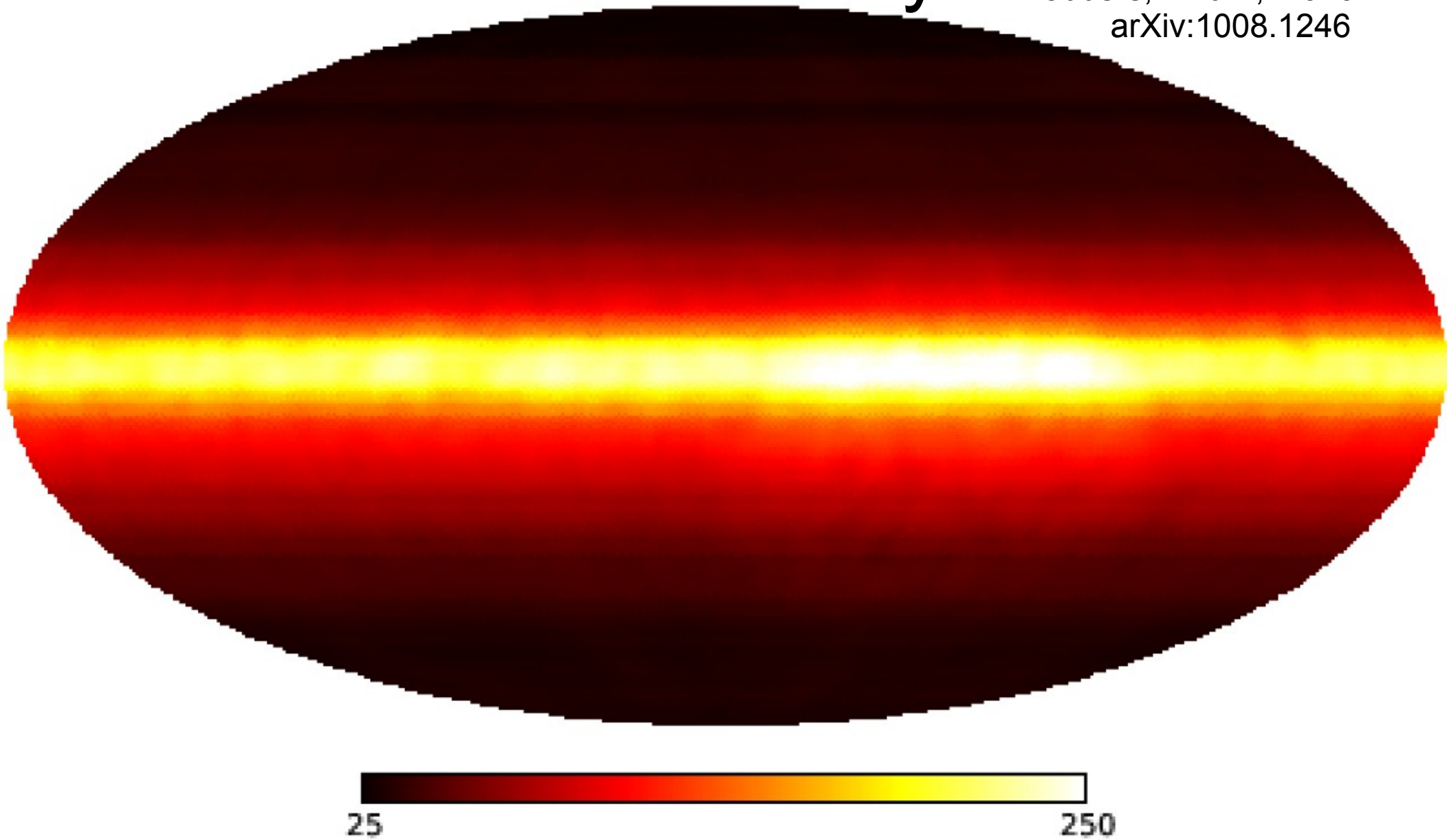
Oppermann, Junklewitz,
Robbers, Enßlin, 2010
arXiv:1008.1246



RM uncertainty map with latitude profile removed

The RM Sky

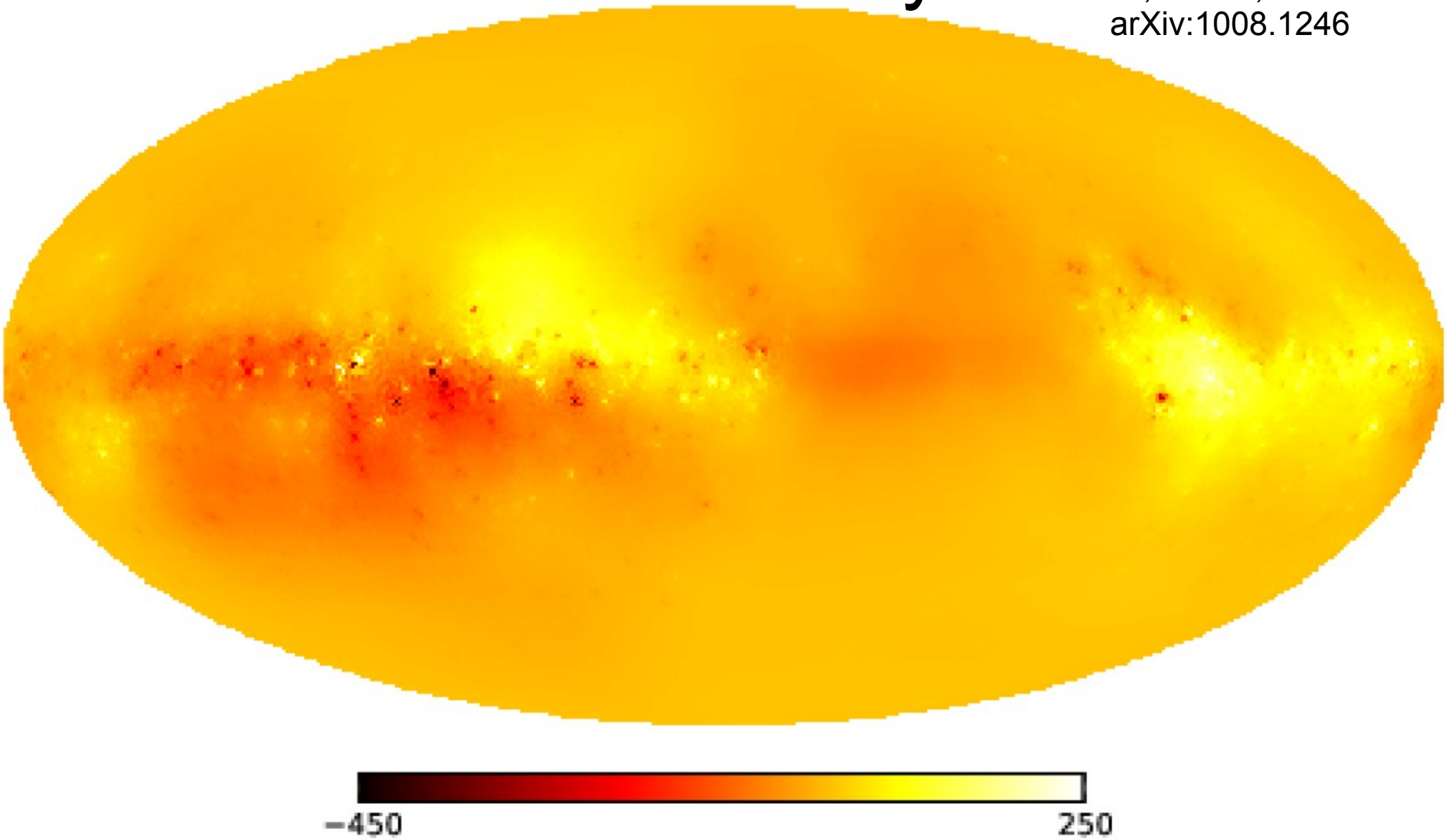
Oppermann, Junklewitz,
Robbers, Enßlin, 2010
arXiv:1008.1246



RM uncertainty map

The RM Sky

Oppermann, Junklewitz,
Robbers, Enßlin, 2010
arXiv:1008.1246



Wiener filtered RM-map with inferred power spectrum

Summary

A8: research tools for the research unit

magnetic field statistics:

`Hammurabi` – simulation of galactic observables

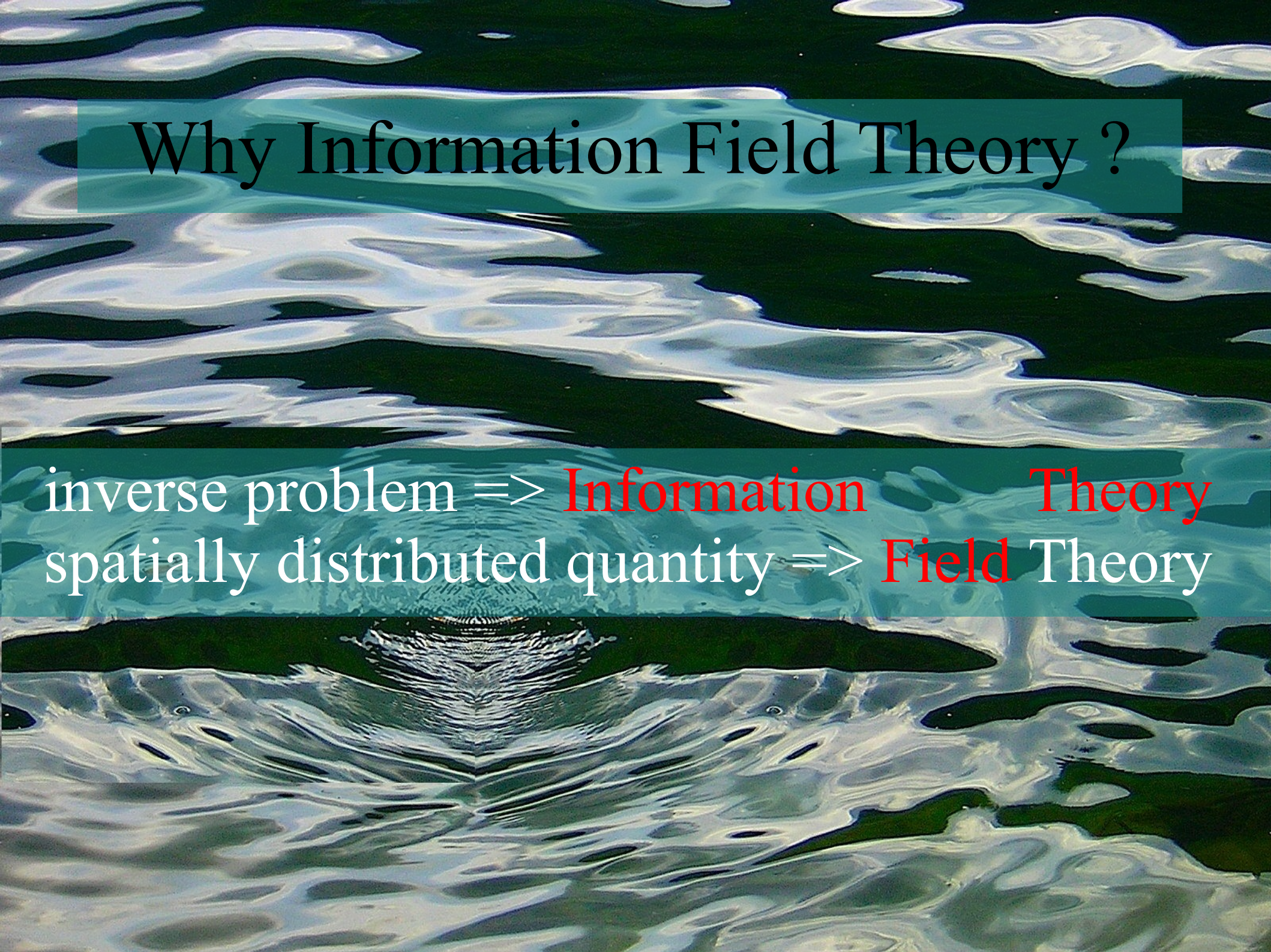
`REALMAF` – magnetic power spectrum inference

`Litmus Test` – magnetic helicity detection

Faraday tomography:

`1d & 3d RM Synthesis –` in development

[implementing CLEAN, Wiener Filter, ...]


Why Information Field Theory ?
inverse problem => Information Theory
spatially distributed quantity => Field Theory

Information Field Theory

EnBlin et al.(2009)
EnBlin & Frommert
EnBlin & Weig

Translation:

inference problem → statistical field theory

$$P(s|d) = \frac{P(d|s)\,P(s)}{P(d)} \equiv \frac{1}{Z}\,e^{-H[s]}$$

Dictionary:

log-Posterior	=	negative Hamiltonian
Evidence	=	partition function Z
Wiener variance	=	information propagator
noise weighted data	→	information source
inference algorithms	←	Feynman diagrams
maximum a Posteriori	=	classical solution
uncertainty correct.	=	loop corrections
Shannon information	=	negative entropy