DTS: Results of an MHD spherical Couette flow experiment

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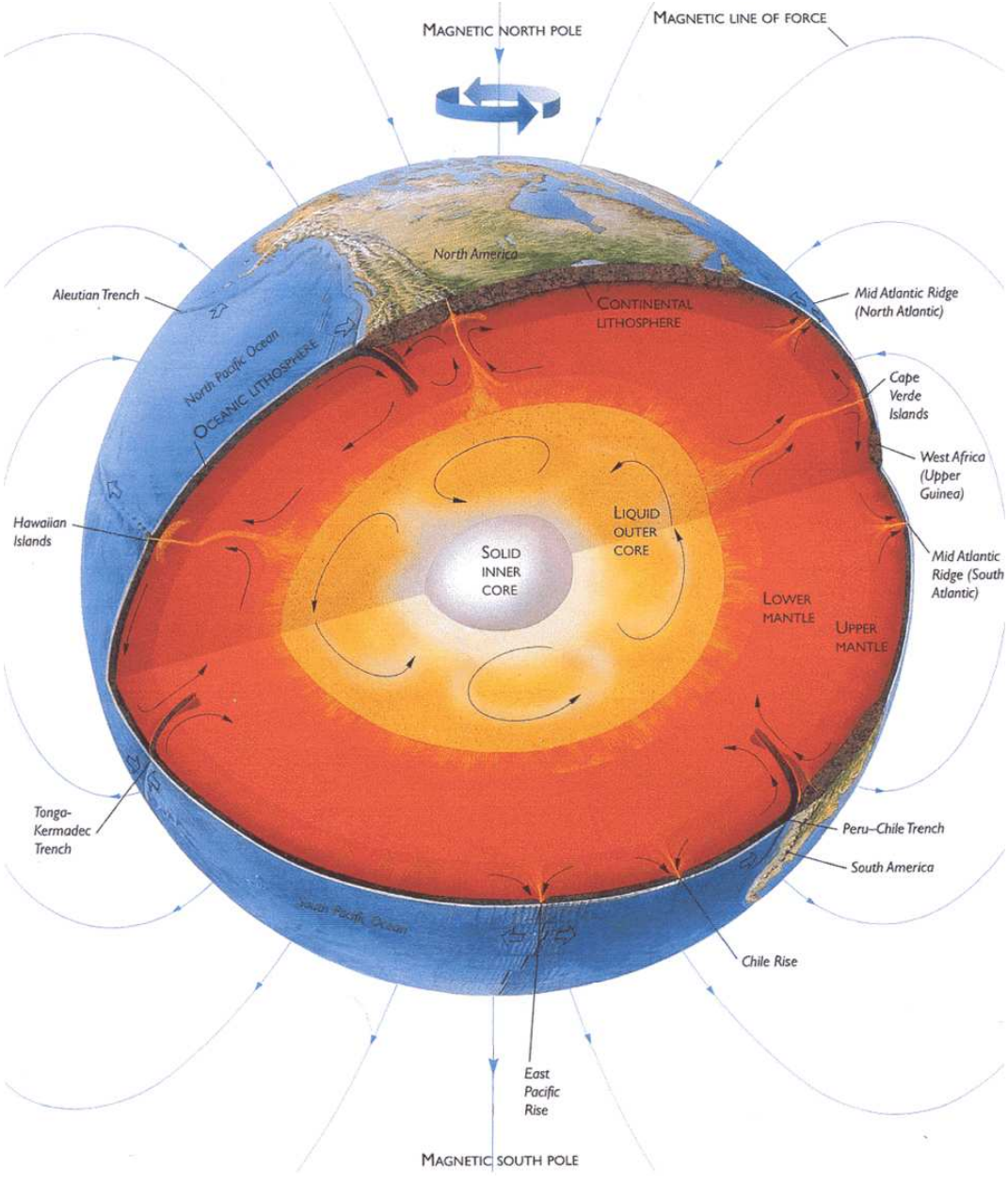
Warwick Turbulence Symposium
Instabilities and Turbulence in MHD flows

The Geodynamo



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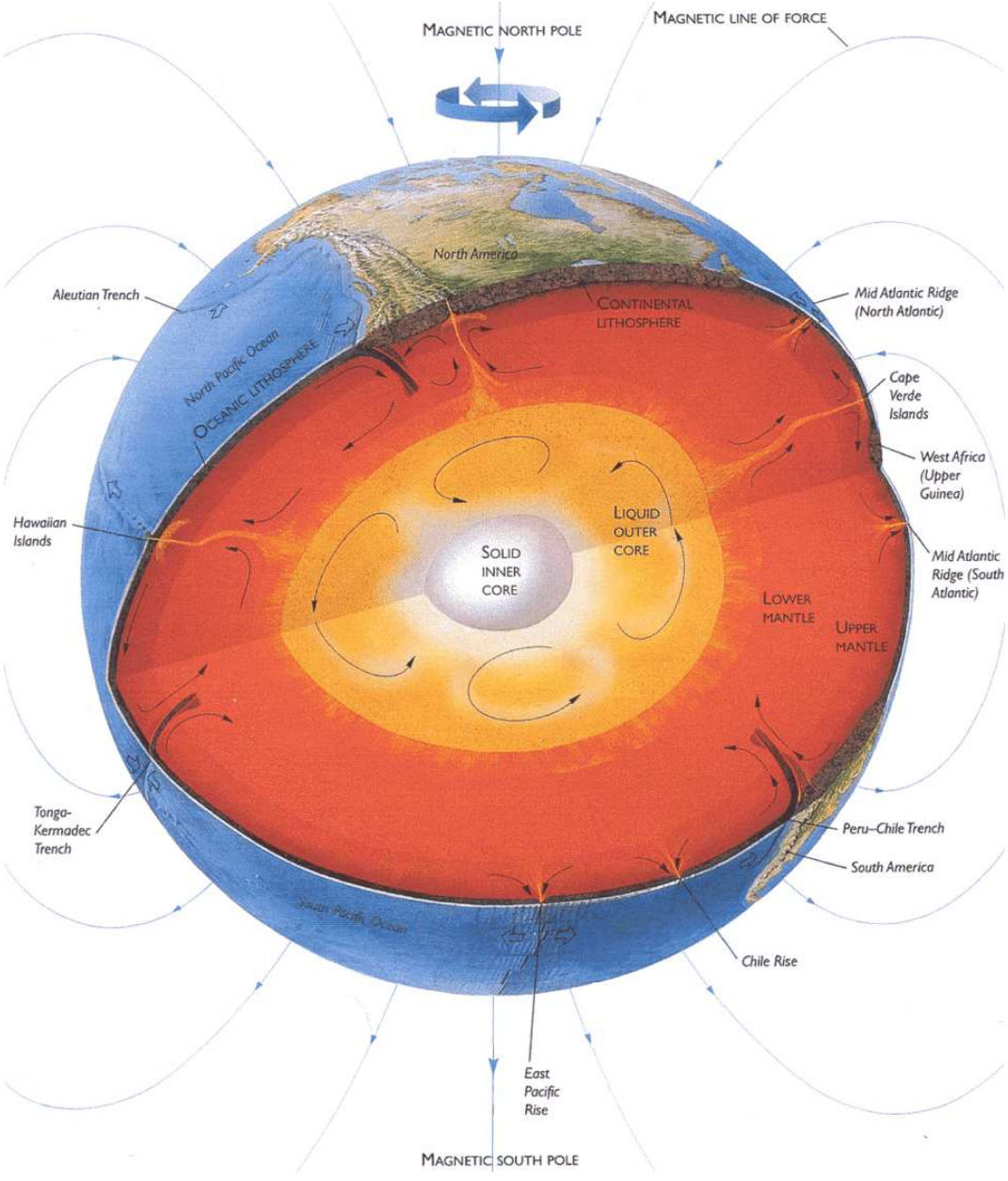
The Geodynamo



- Self-sustained dynamo
- Strong Lorentz forces
- Strong Coriolis forces
- Small viscosity

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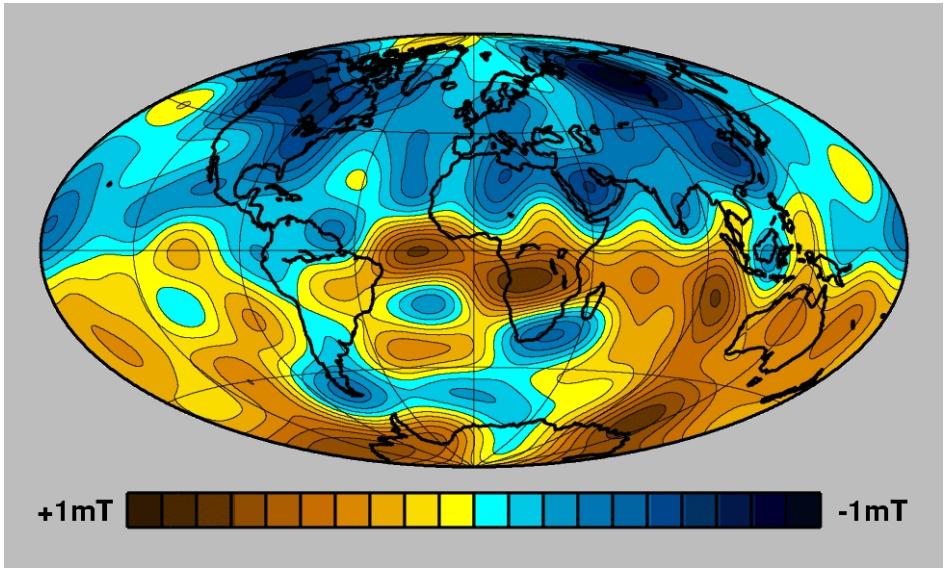
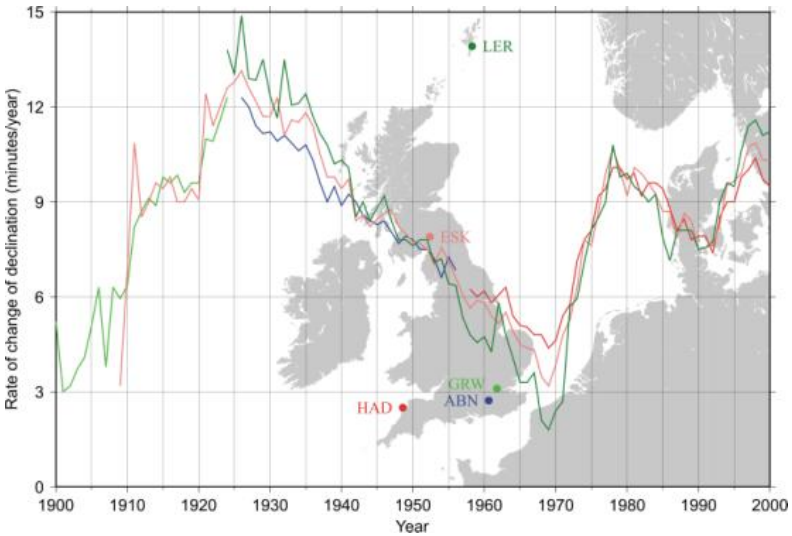
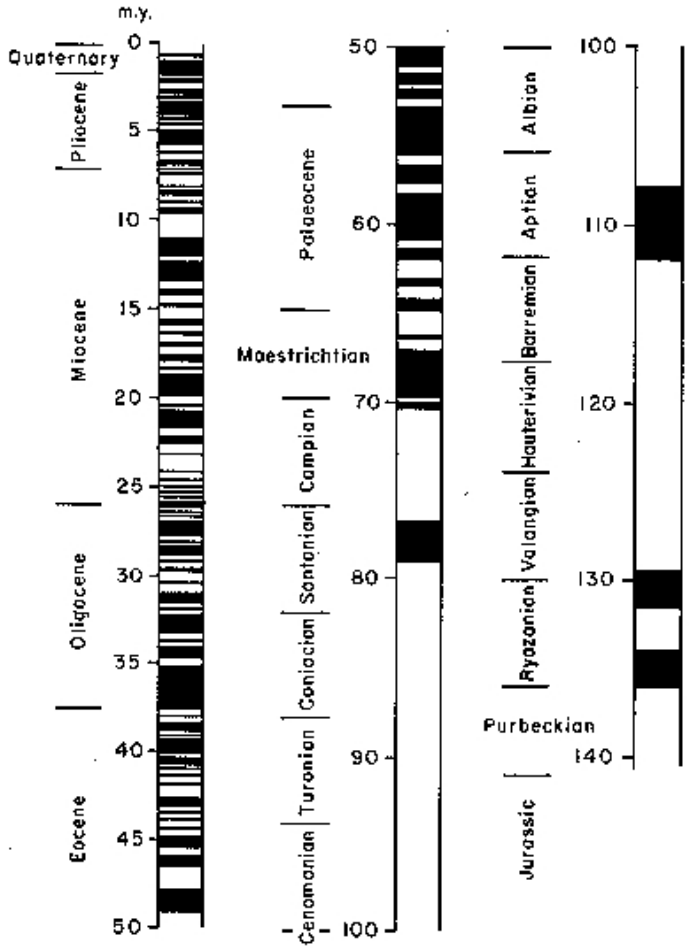
Observations







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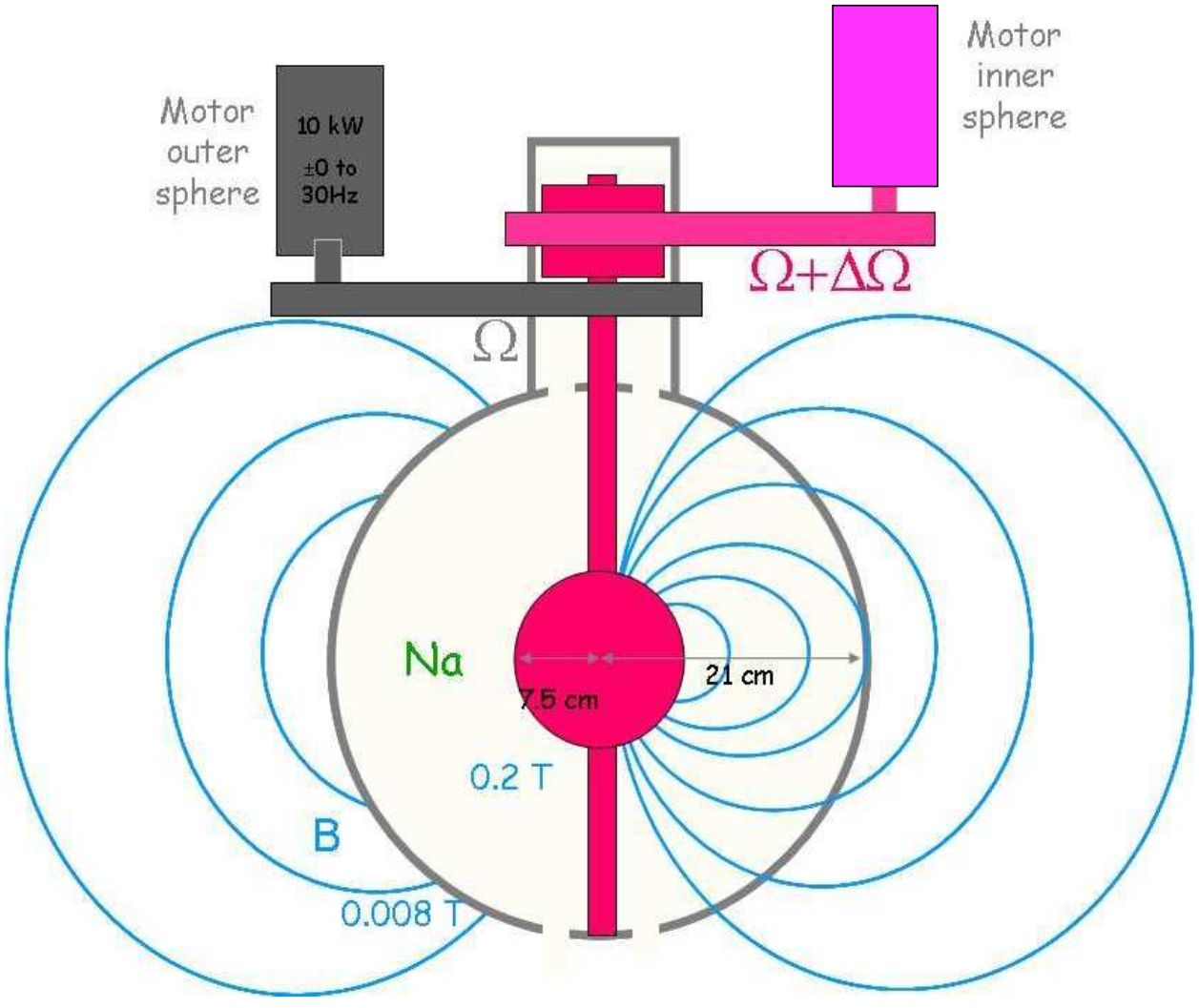
DTS: experimental configuration



- $\sim$ 50 liters Na
- 2×11 kW
- 2000 rpm (33 Hz)
- 130°C
- Stainless steel
- Copper

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Objectives

- Demonstration of dynamo action is not an objective

$$Rm = \frac{\Delta\Omega b a}{\eta} \leq 30 \qquad (10^3)$$

- Magnetostrophic regime

$$\Lambda = \frac{\sigma B^2}{\rho\Omega} \in [10^{-2}; 10^2] \qquad (10^{-1})$$

with very small viscosity

$Re \sim 10^6$ (10^9), $E \sim 10^{-7}$ (10^{-15}), $Ha \in [10^2; 10^3]$ (10^7)

- Waves : inertial, Rossby, and Alfvén

$$S \in [0.3; 10] \qquad (10^5)$$

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The lab, the team

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The lab, the team

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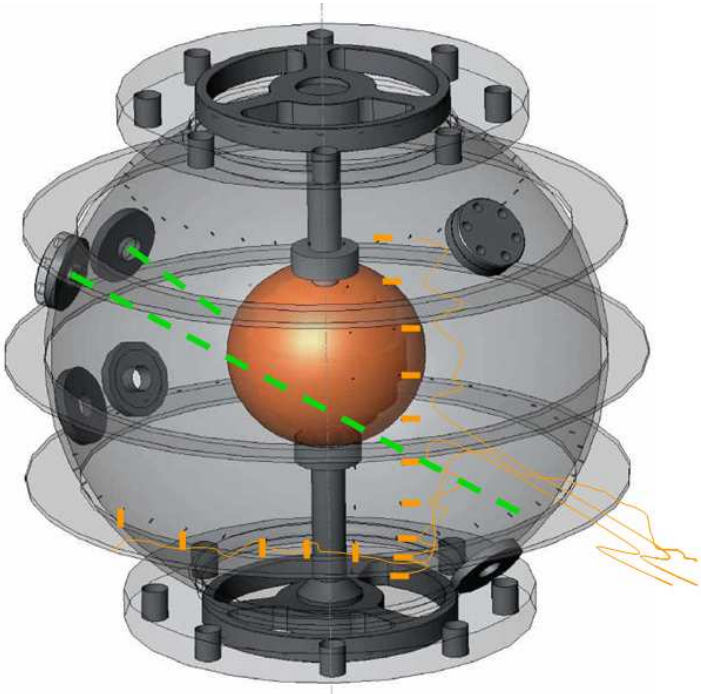
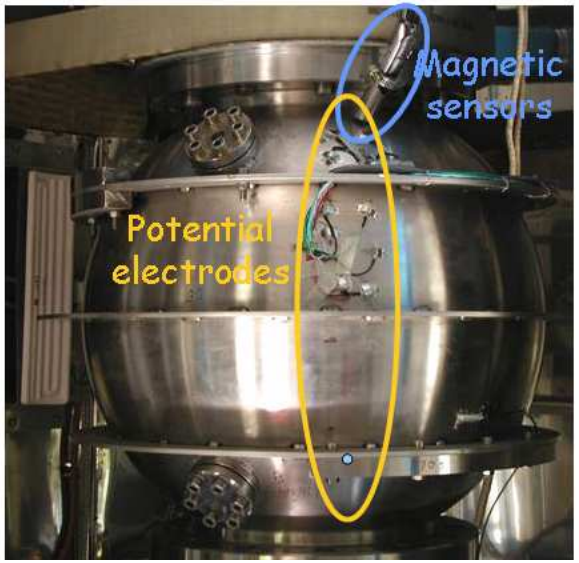
Measurements





1. Velocity, torque
2. Ultrasound Doppler velocimetry
3. Pressure
4. Electric potential
5. Magnetic field

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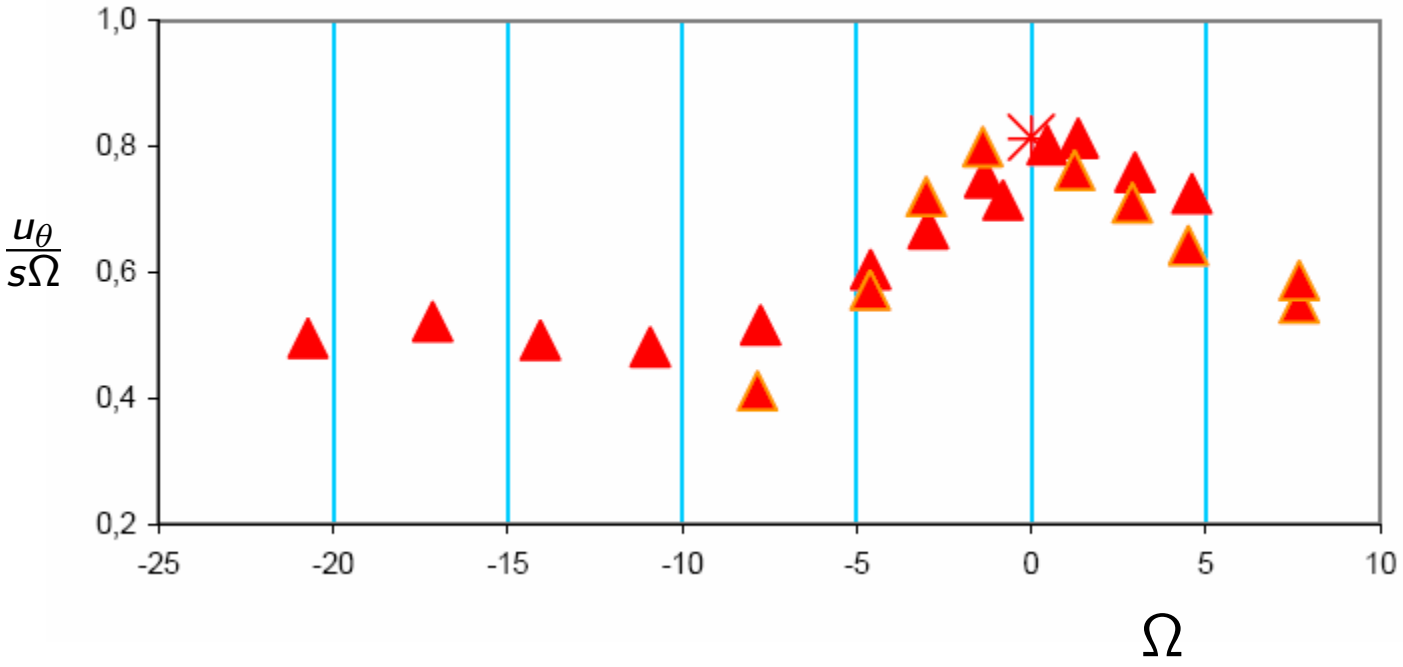
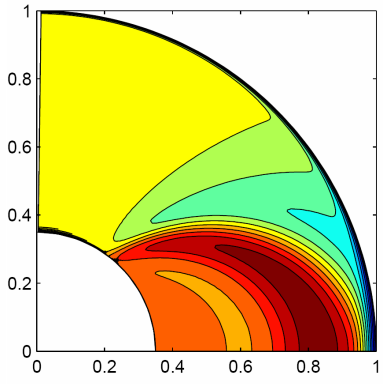
The mean flow (outer sphere steady)

as indicate by potential differences $u_\theta B_r R\delta\theta \simeq \delta\phi$





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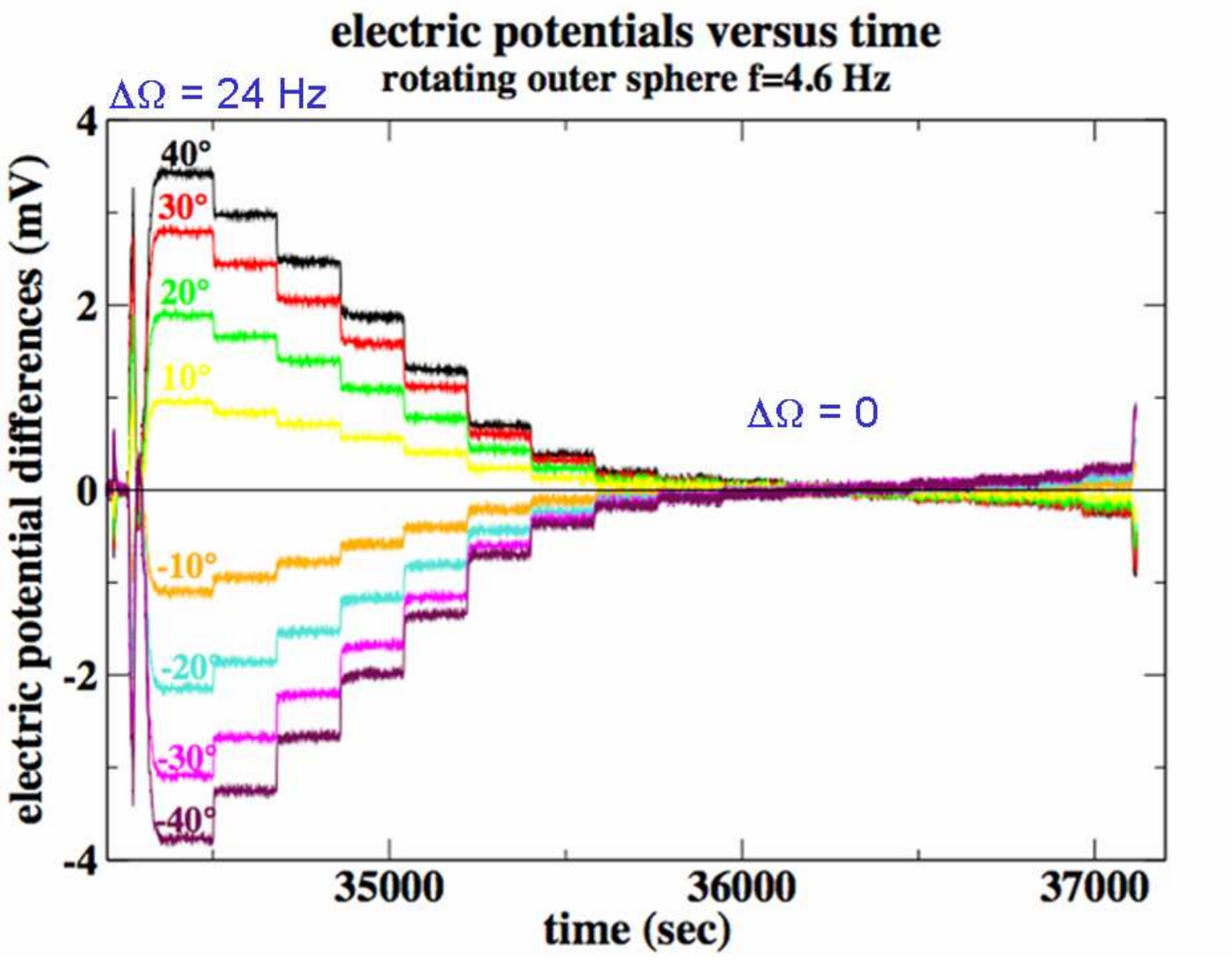
Variation of electric potential differences



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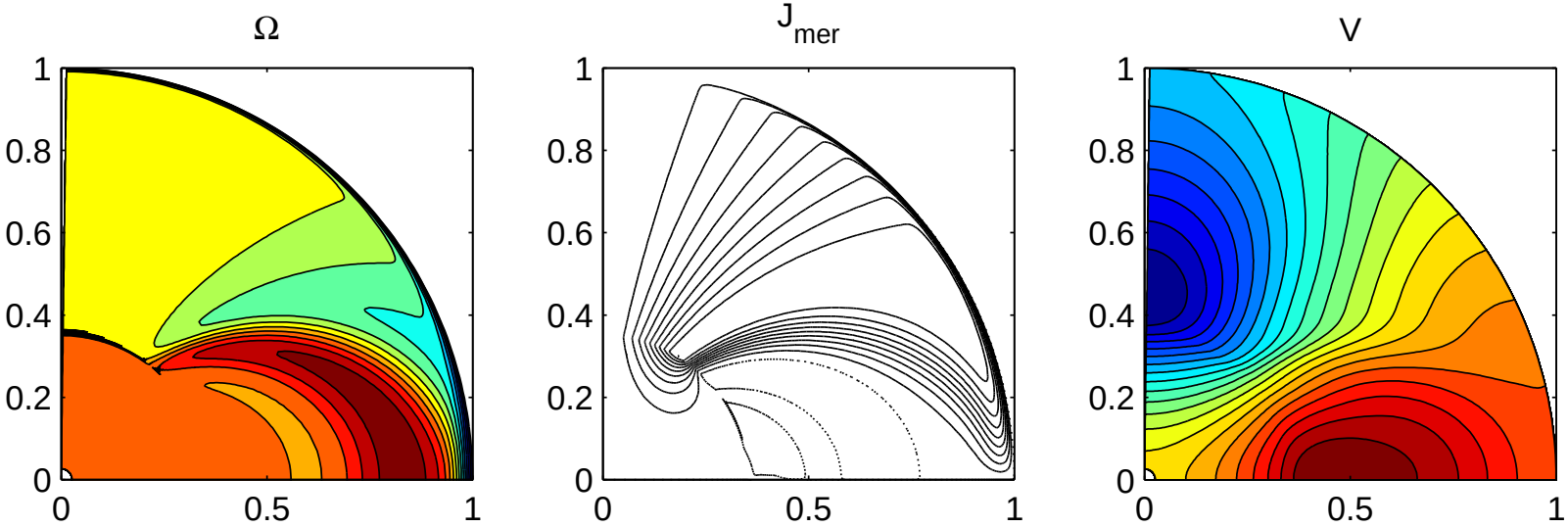
Numerical simulations

PARODY numerical code (Dormy, Aubert, Cardin)

E=1 Re=0.0422 Ha=210 Pm=1e−05



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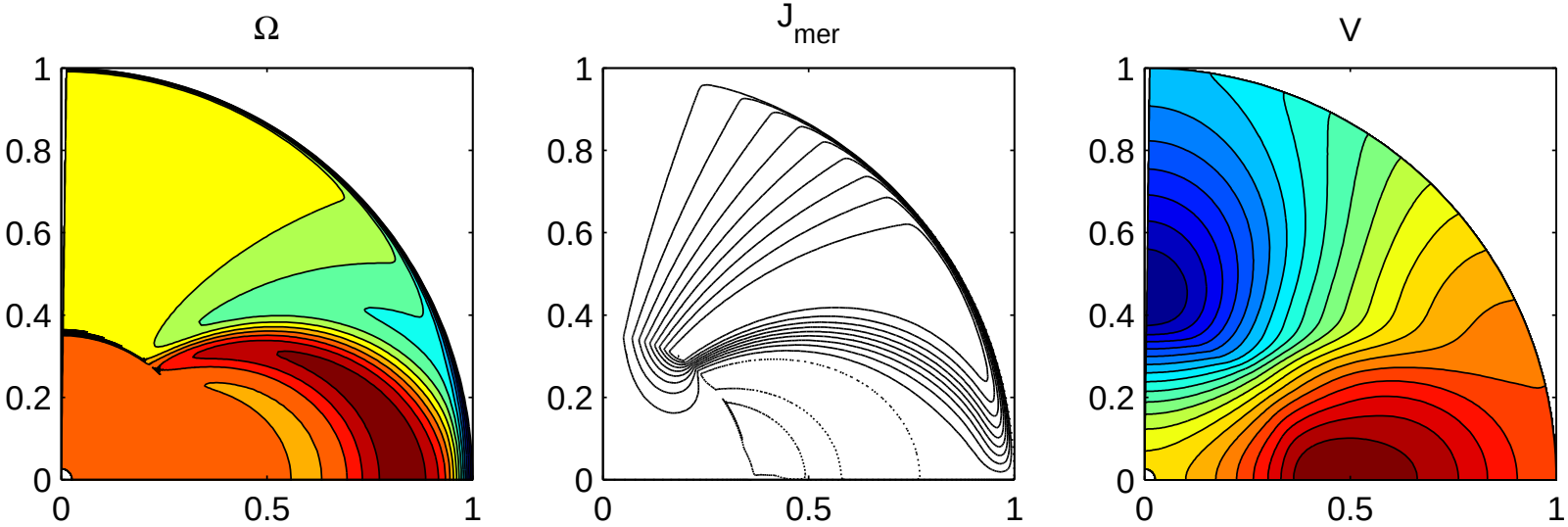
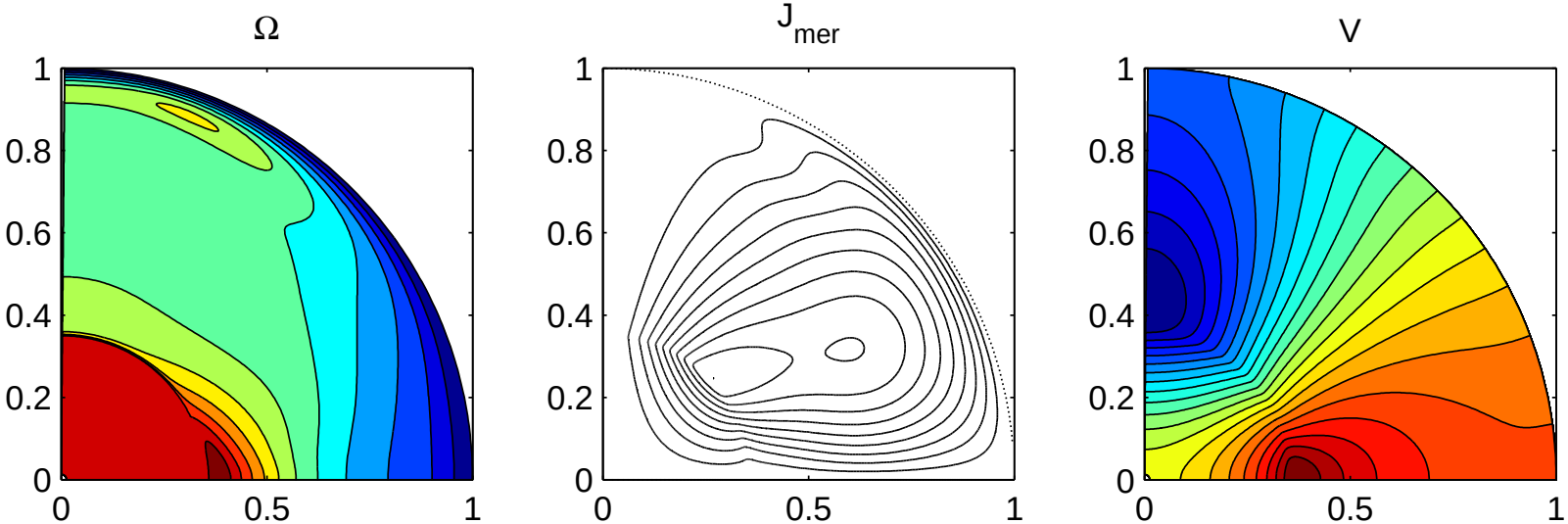


E=0.001 Re=1.06e+03 Ha=10 Pm=0.001



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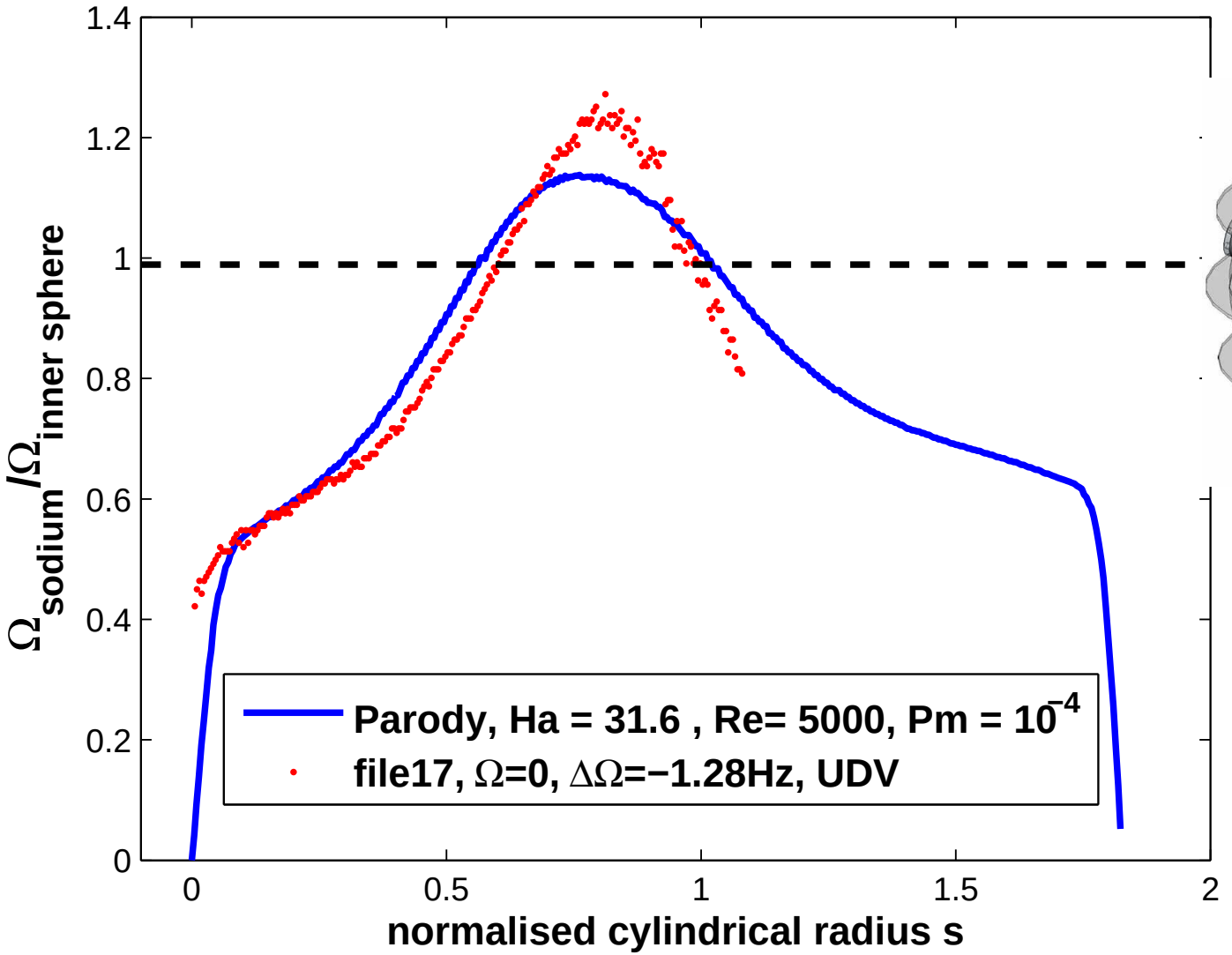
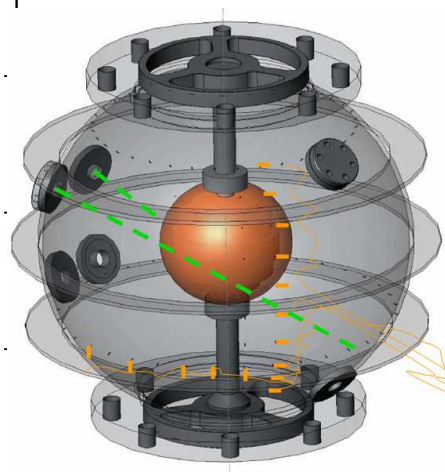
Experimental evidence of super-rotation





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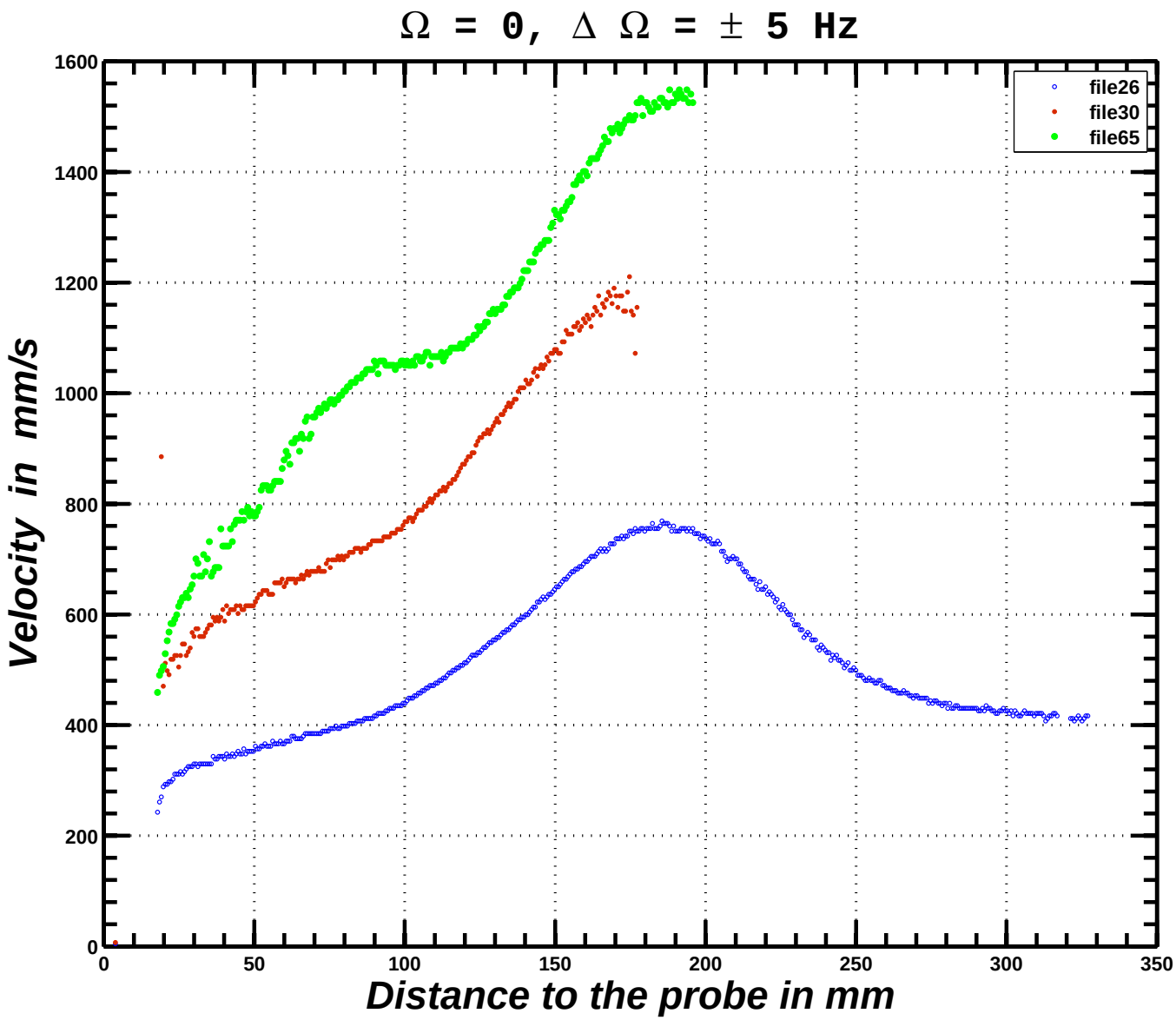
Multiple mean solutions (ultrasonic Doppler)



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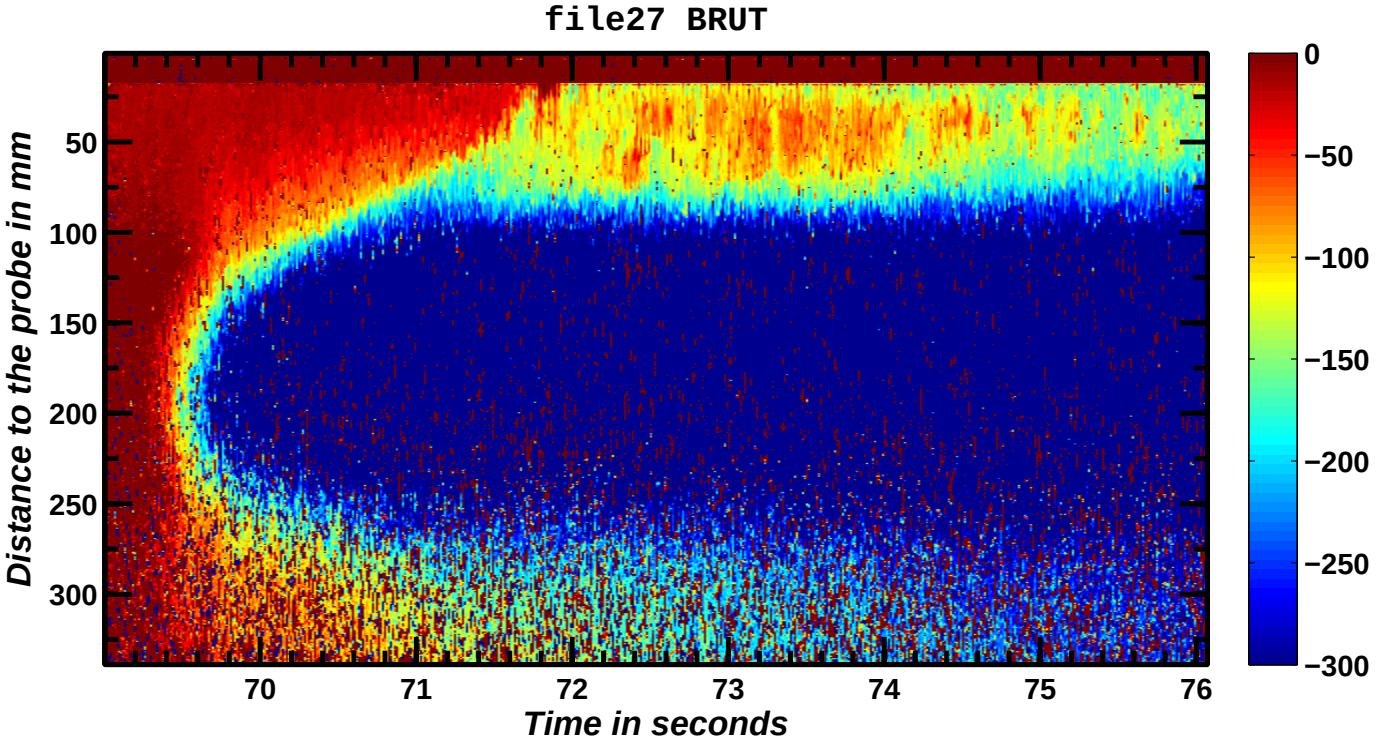
Weak fluctuations (ultrasonic Doppler)



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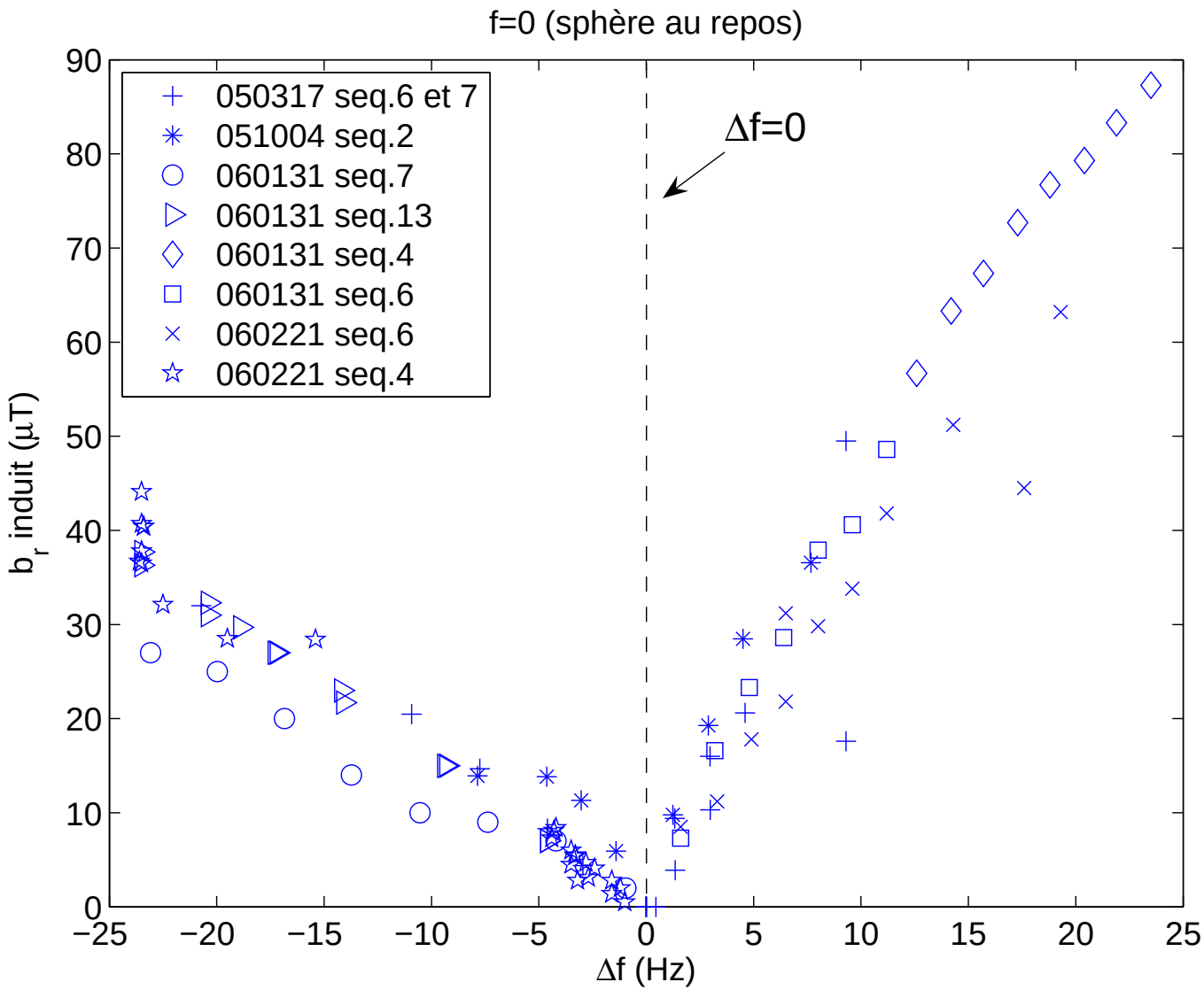
Mean induced magnetic field



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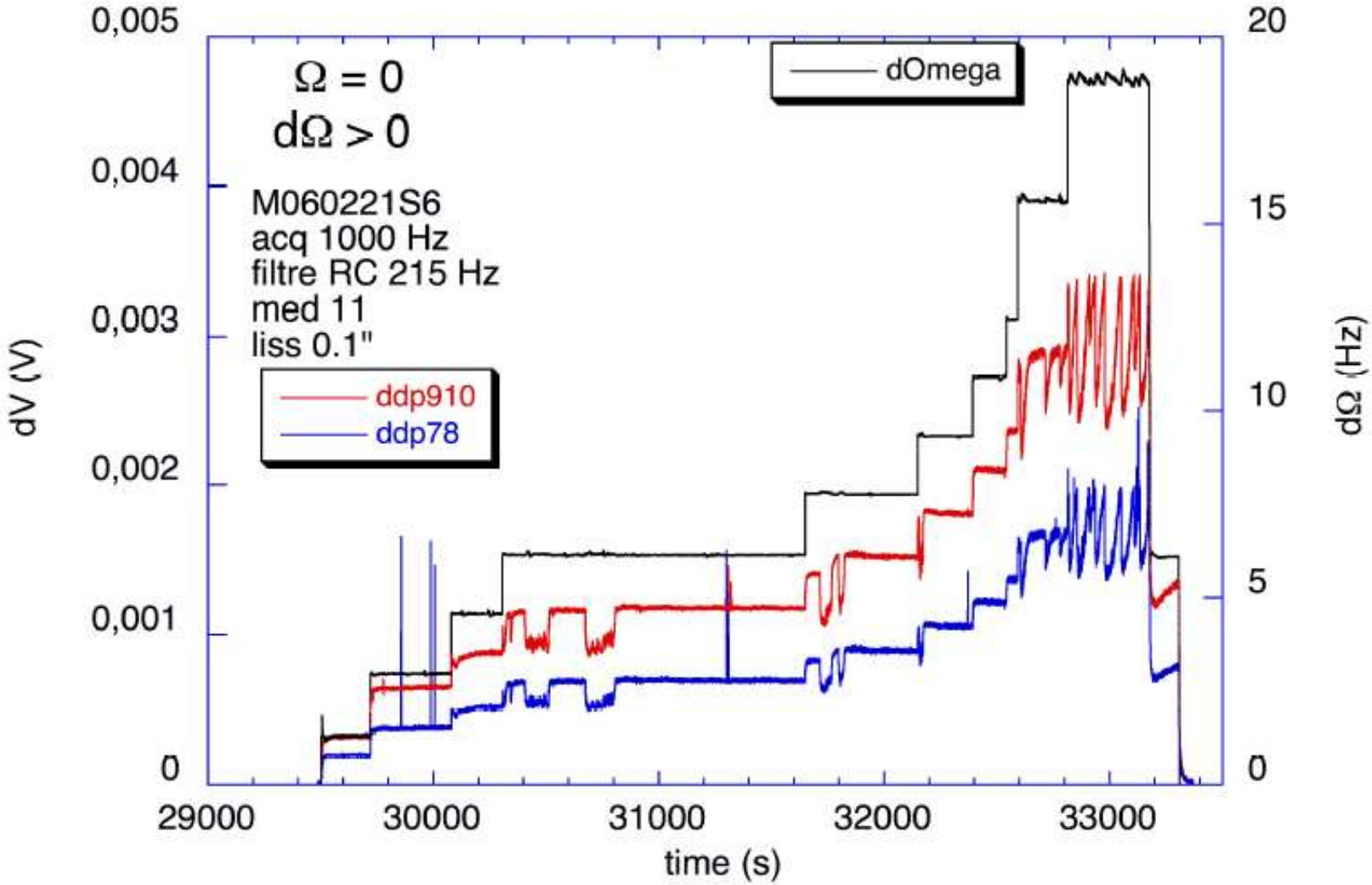
Spontaneous jumps (electrical potentials)



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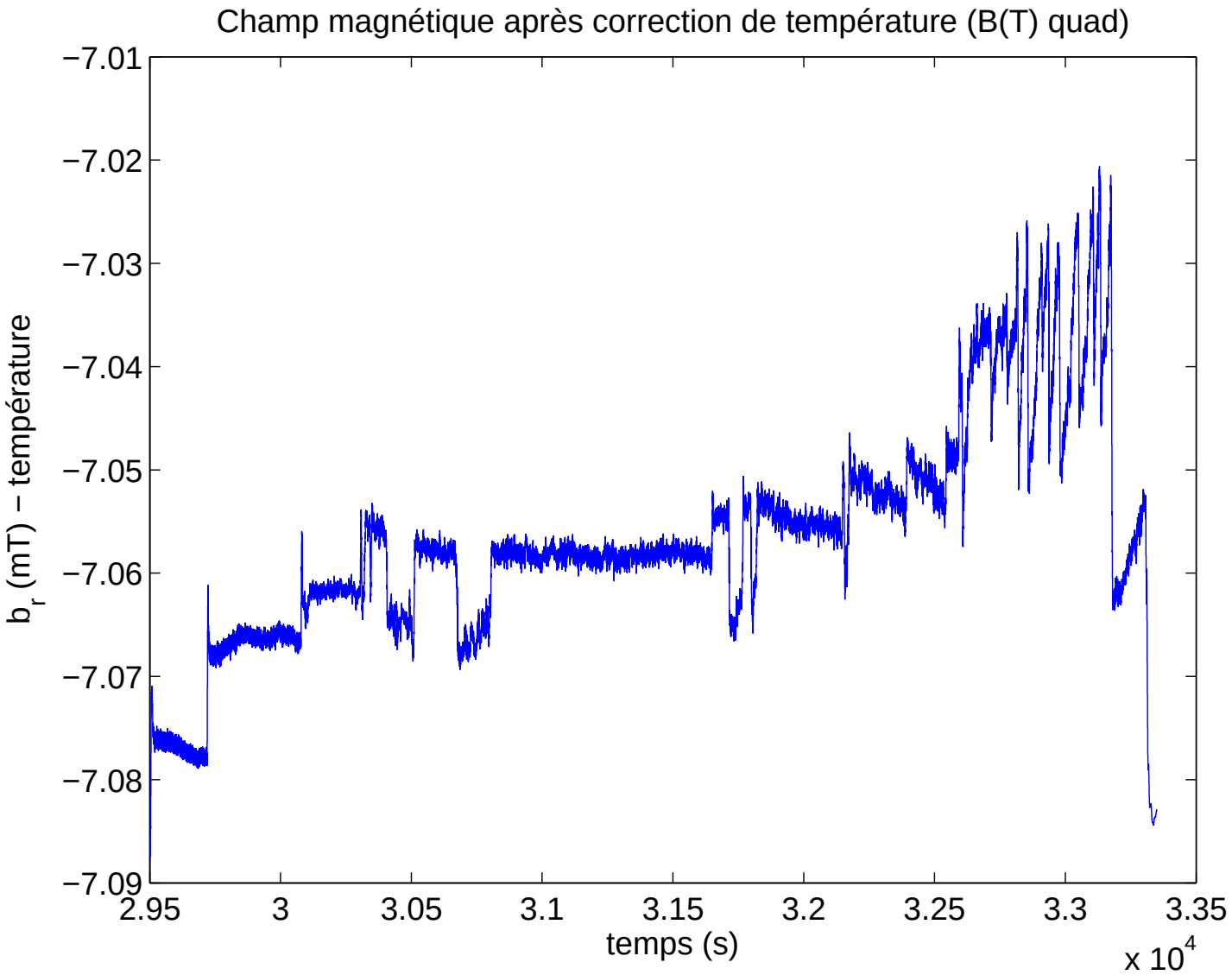
Spontaneous jumps (induced magnetic field)



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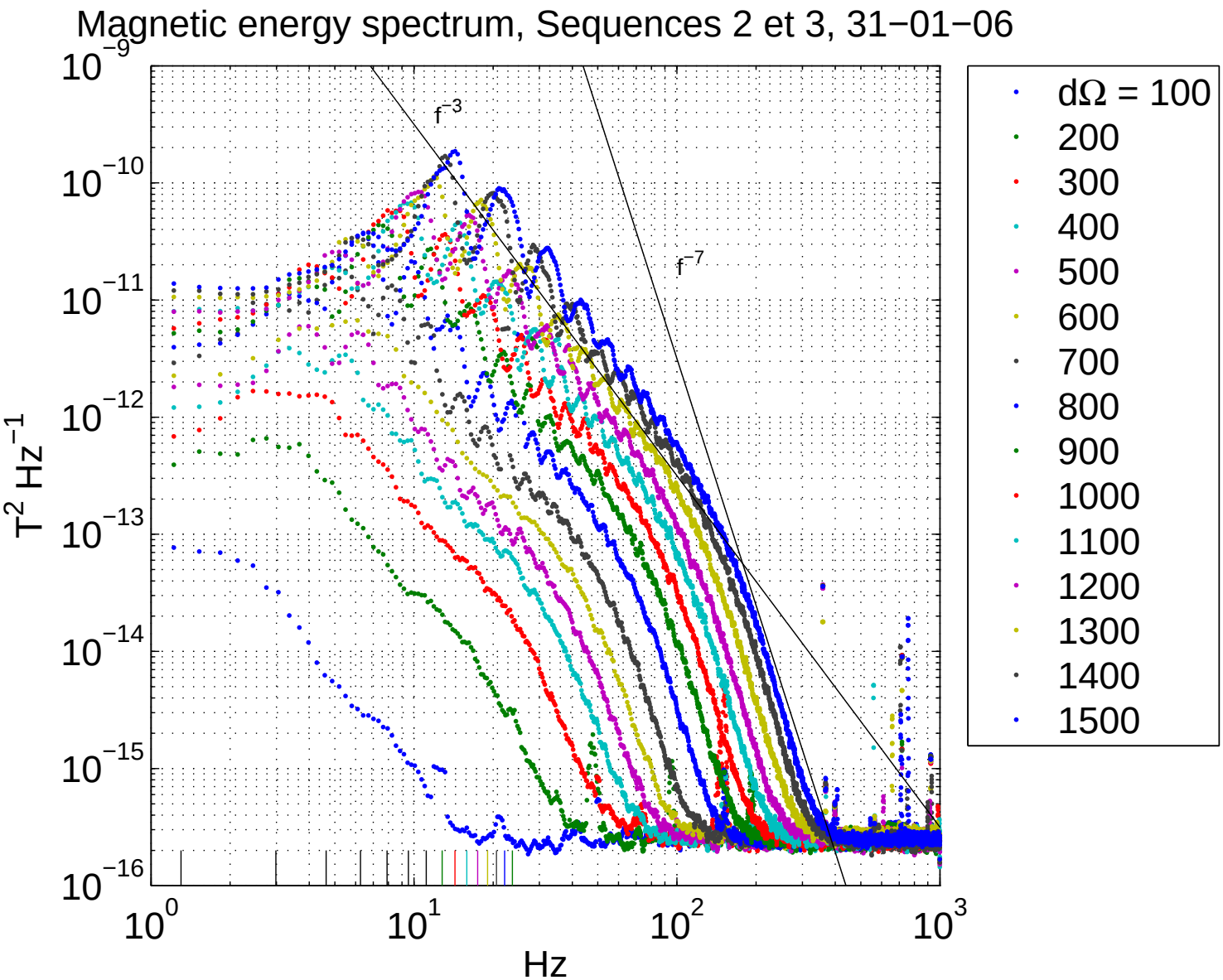
Magnetic energy spectra



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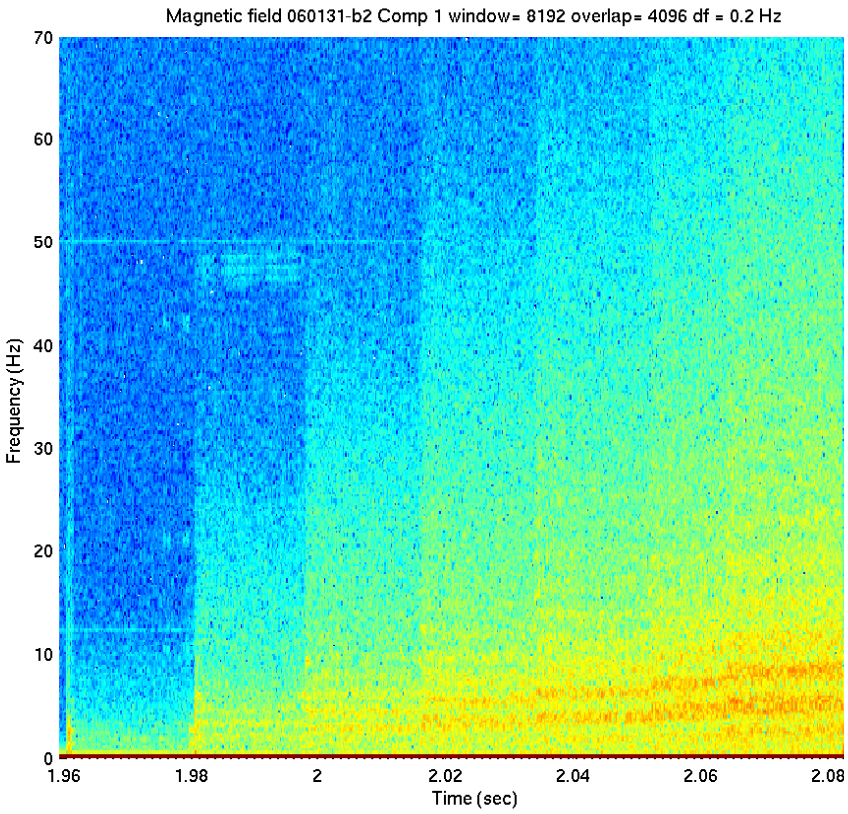
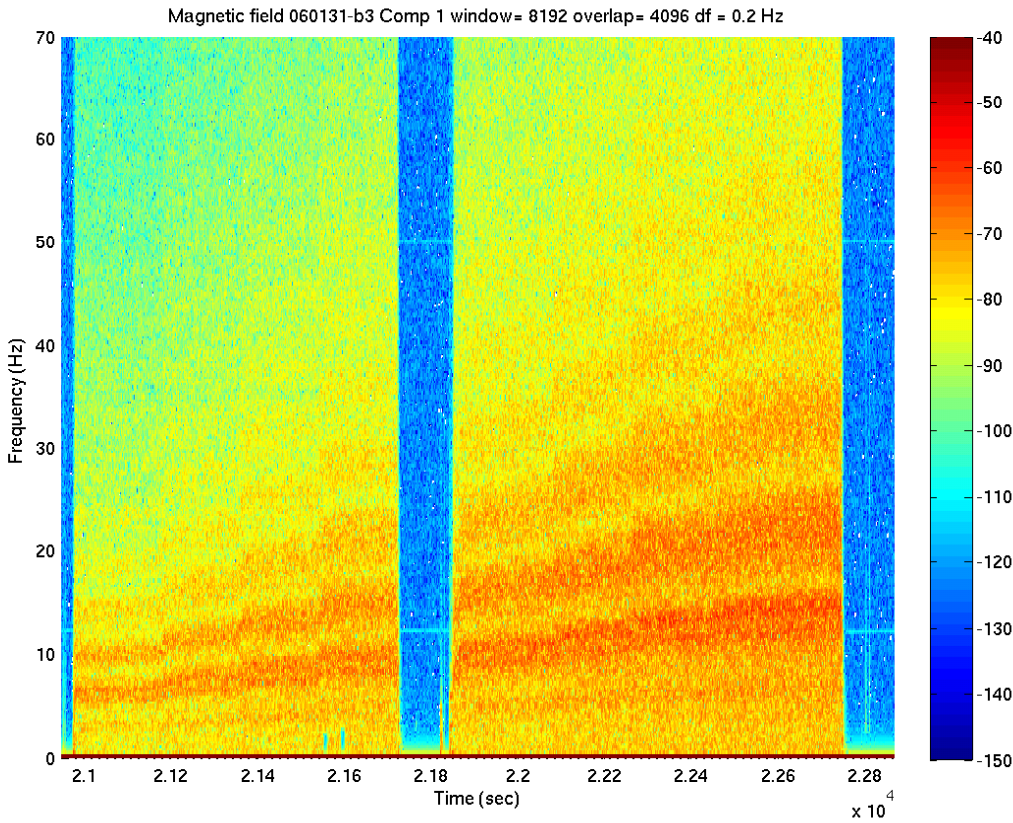
Time-frequency analysis of magnetic signals





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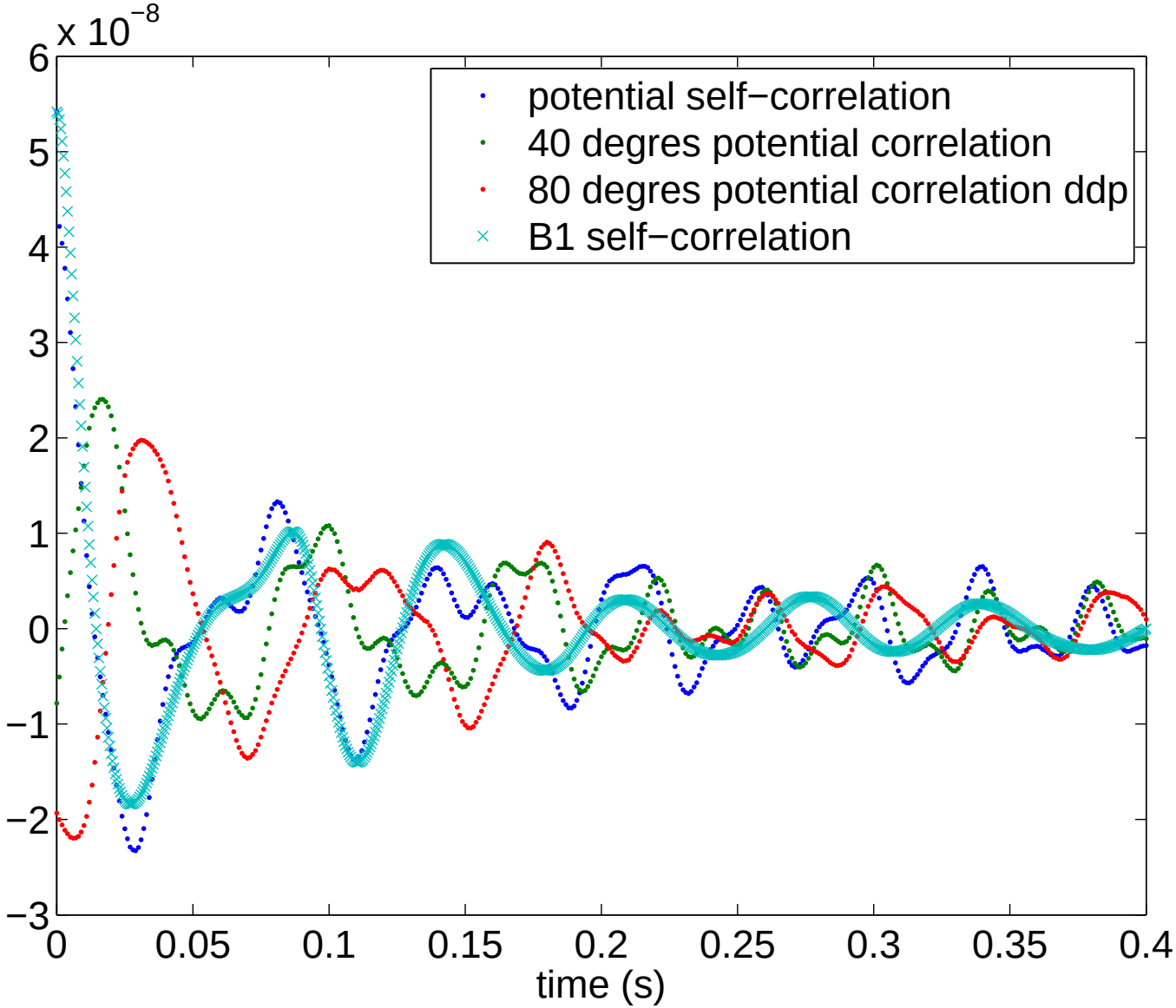
Correlations



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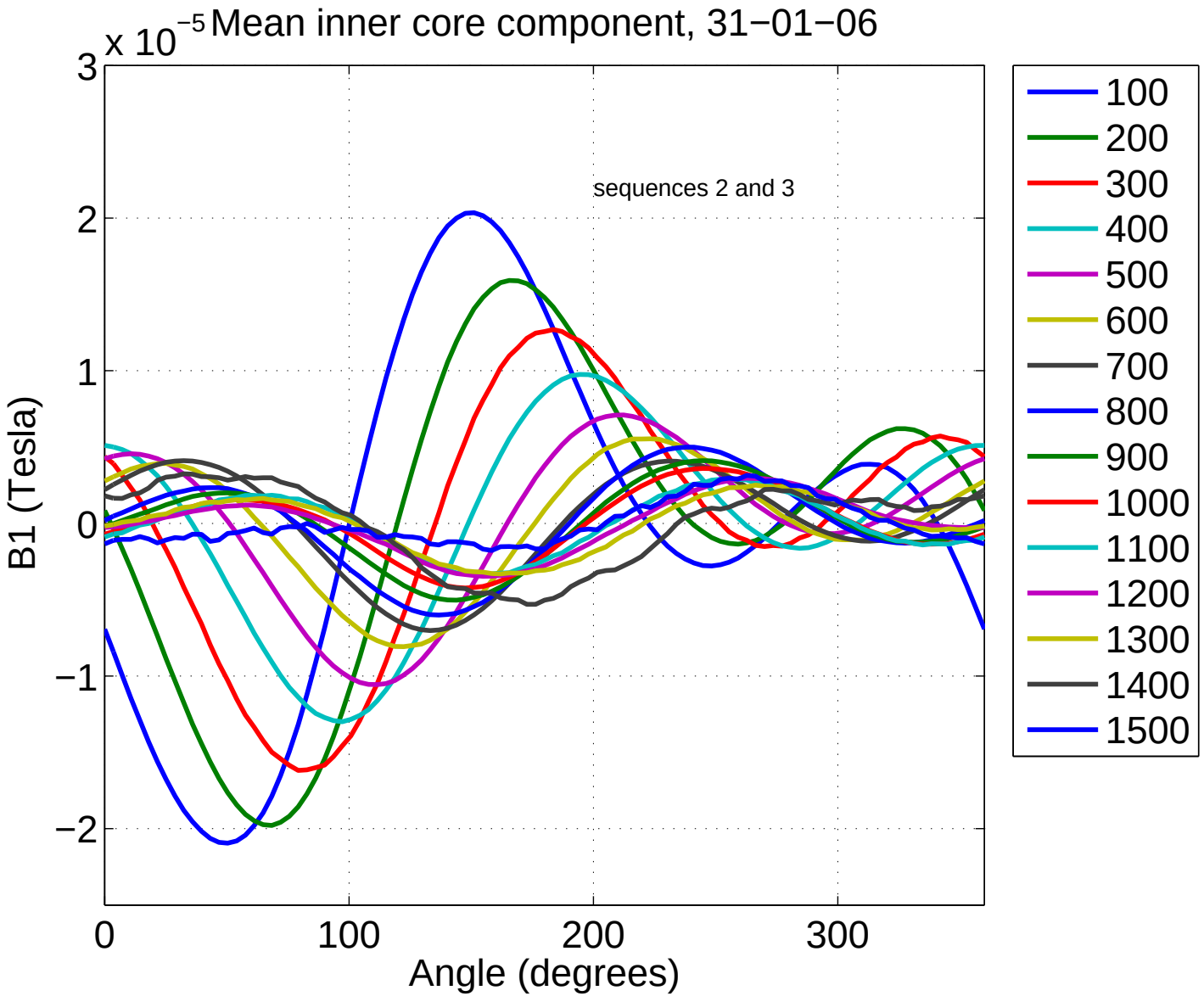
Magnetic expulsion (good use of defects)



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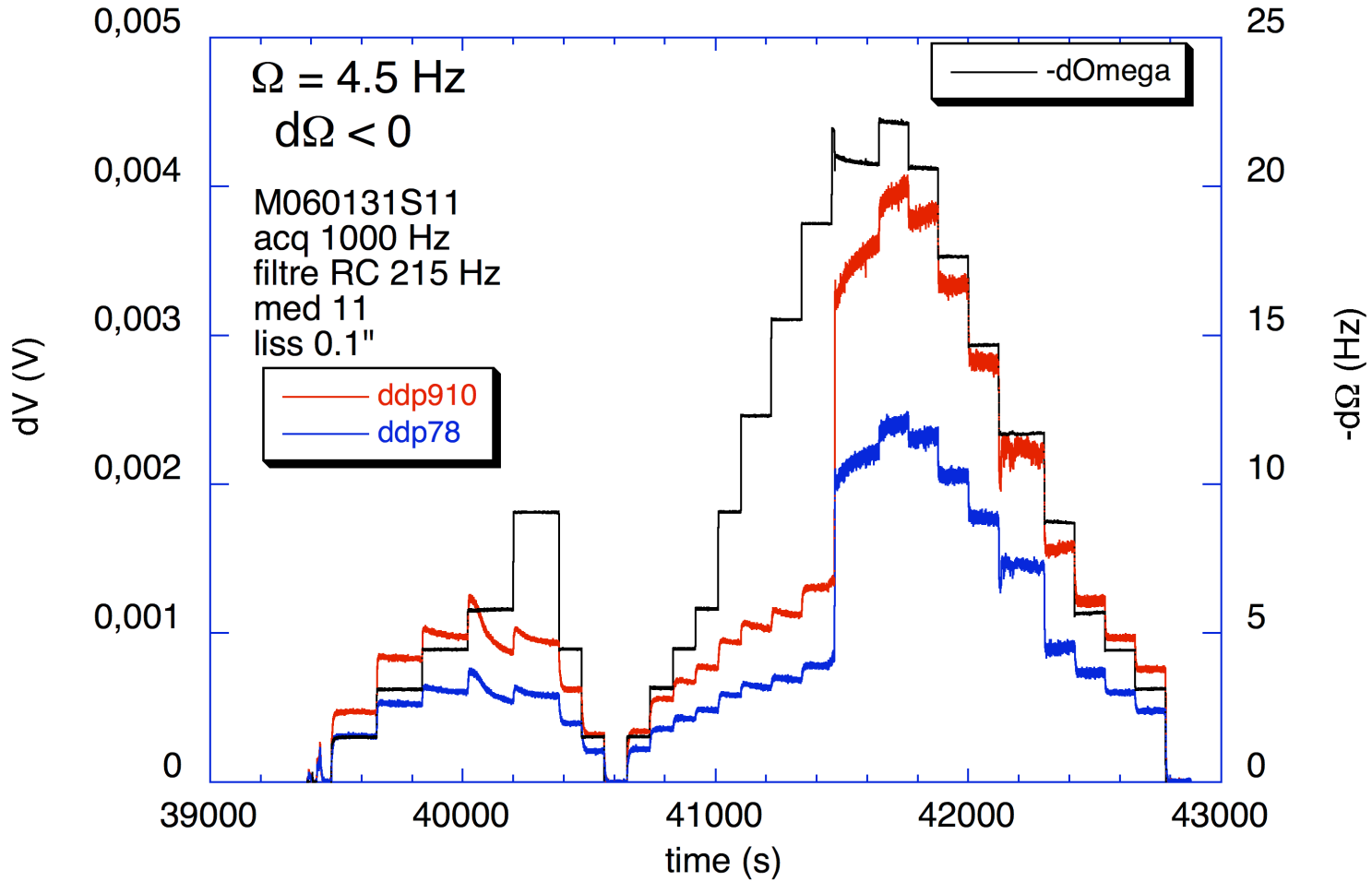
Jumps and fluctuations



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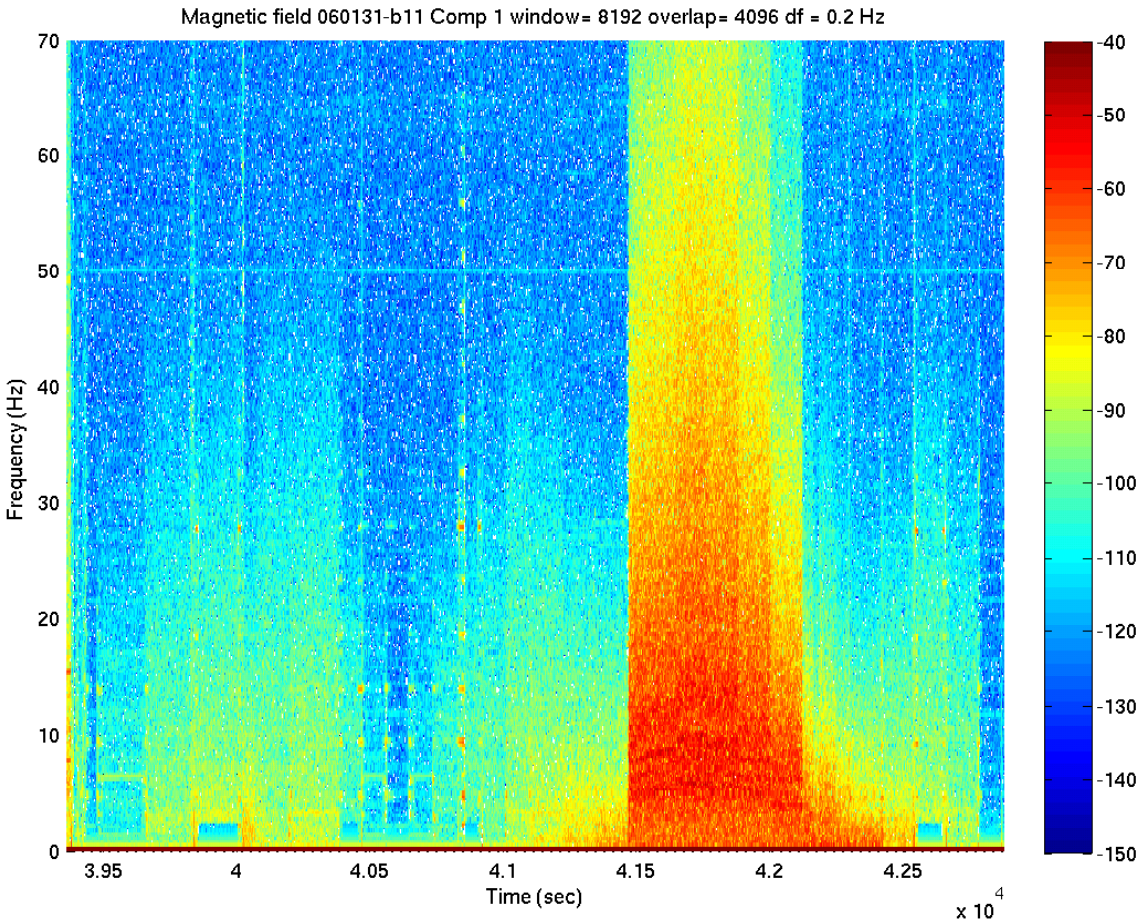
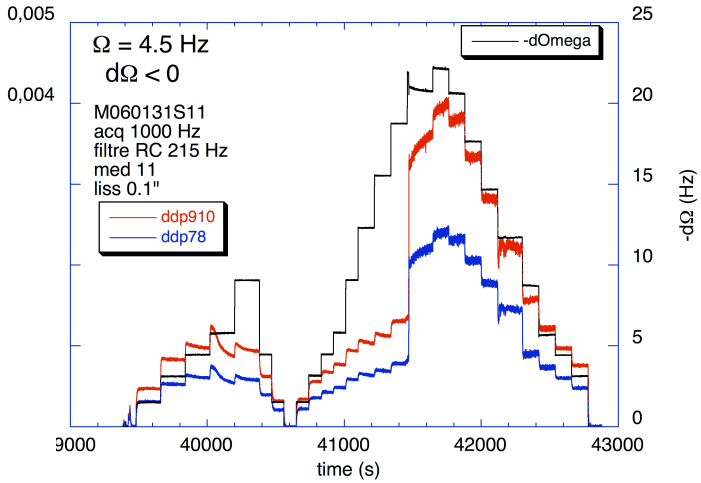
Jumps and fluctuations





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What are the findings?

- Super-rotation at low velocity, in agreement with numerical simulations
- Multiple steady states with small fluctuations (Rossby ?)
- asymmetry between positive and negative rotation
- Propagating waves with steady outer sphere

Perspectives

- Improve global measurements
  array of magnetic probes
  magnetic probe inside
  more ultrasonic paths
- then classify steady regimes
  have long runs
  devise of way of selecting a particular regime
- Identify wave motions
  waves on steady regimes
  runs with unsteady forcing

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