Main outlines

1. Introduction
Speaker: **P. Barrère**

2. Some theory
Speaker: **R. Raynaud**

3. Numerical methods
Speaker: **L. Petitdemange**

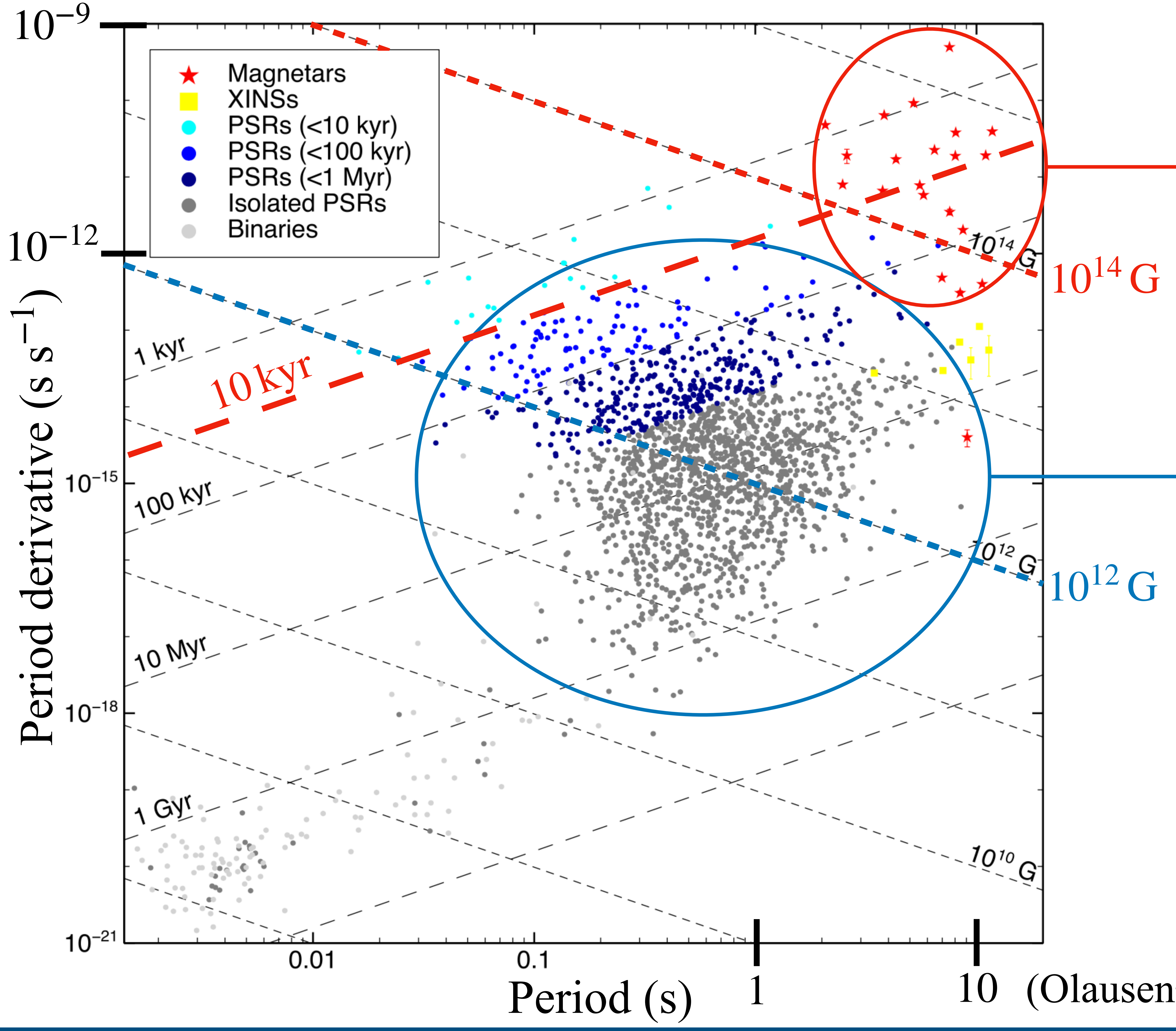
Coffee break

4. Applications and results
Speakers: **L. Petitdemange, F. Daniel, P. Barrère** →

Work in progress:
- Context: **Magnetar formation**
- Simulations: **Tayler instability/ Tayler-Spruit dynamo**

5. Presentation of the practical training
Speaker: **P. Barrère**

A bit of context: magnetar formation



(Olausen+14)

Magnetars

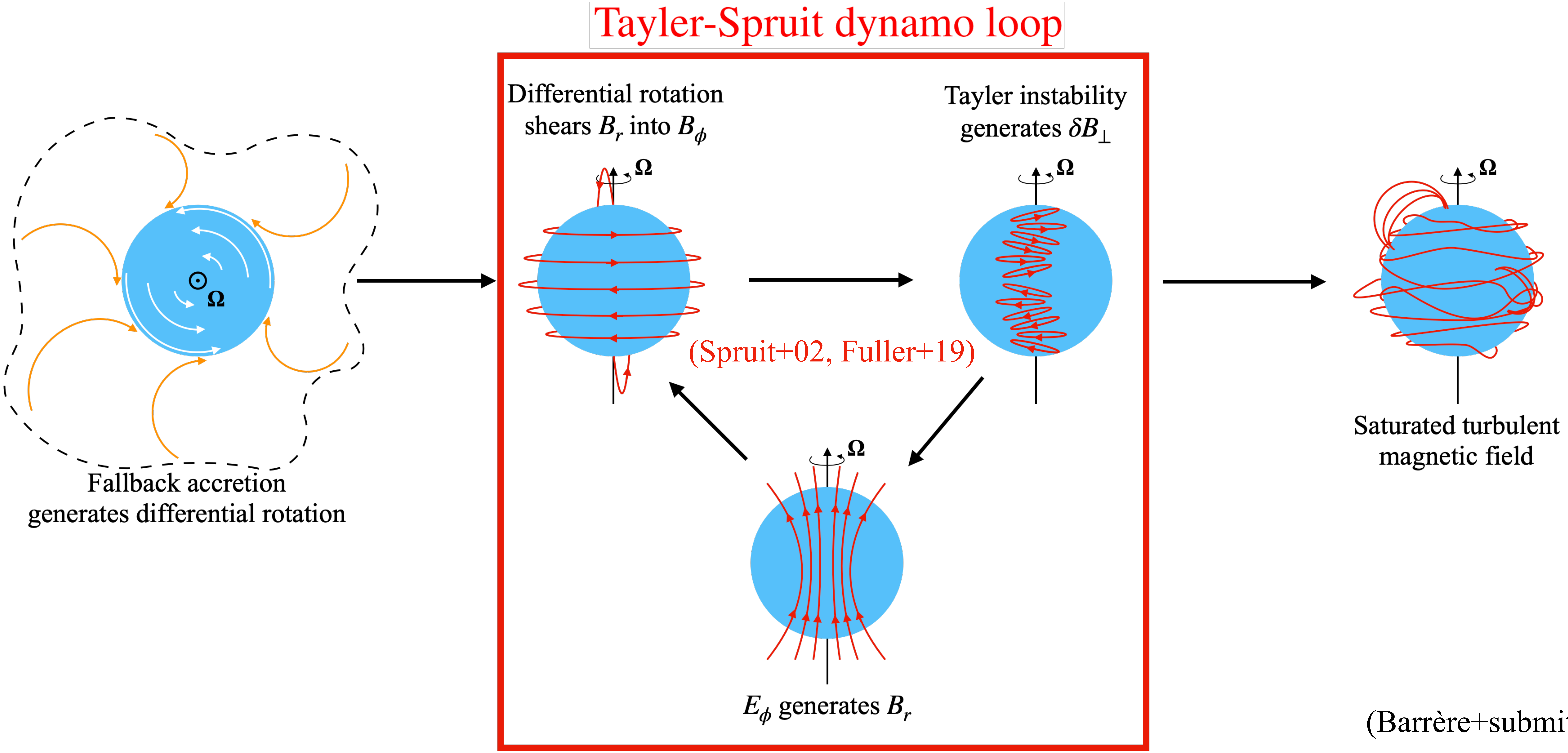
$B_{\rm dip} \sim 10^{14} - 10^{15}$ G

Pulsars

$B_{\rm dip} \sim 10^{12} - 10^{13}$ G

$$B_{\rm dip} = 3.2 \times 10^{19} \left(\frac{P}{1\ \rm s} \right)^{1/2} \left(\frac{\dot{P}}{1\ \rm s\ s^{-1}} \right)^{1/2} \rm G$$

A bit of context: new formation scenario



(Barrère+submitted)

Tayler instability: numerical setup

Magnetic field

- Initial quadrupolar axisymetric field
- Insulating conditions on both boundaries

Velocity field

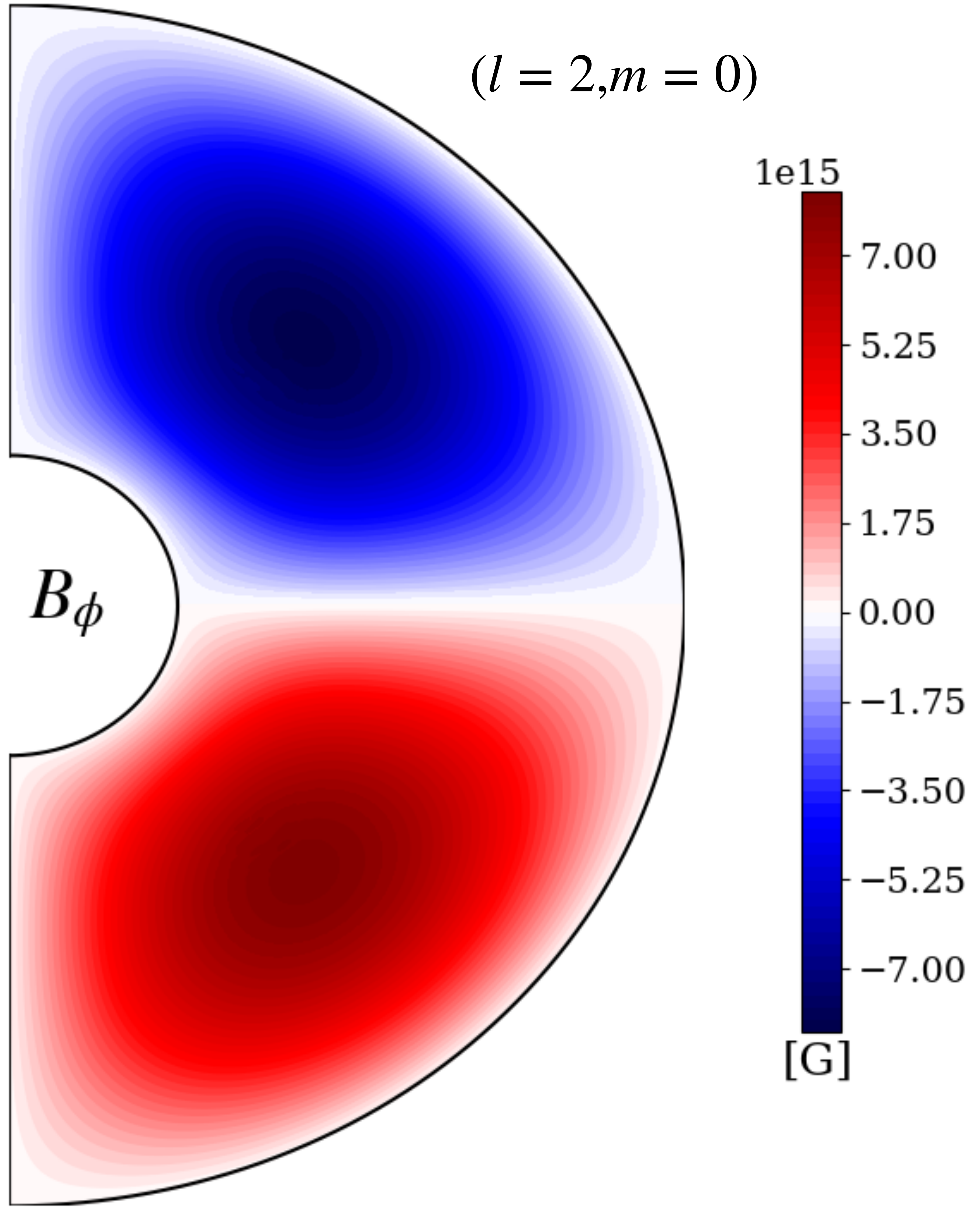
- Random weak amplitude perturbations
- No-slip conditions on both boundaries

Rotation

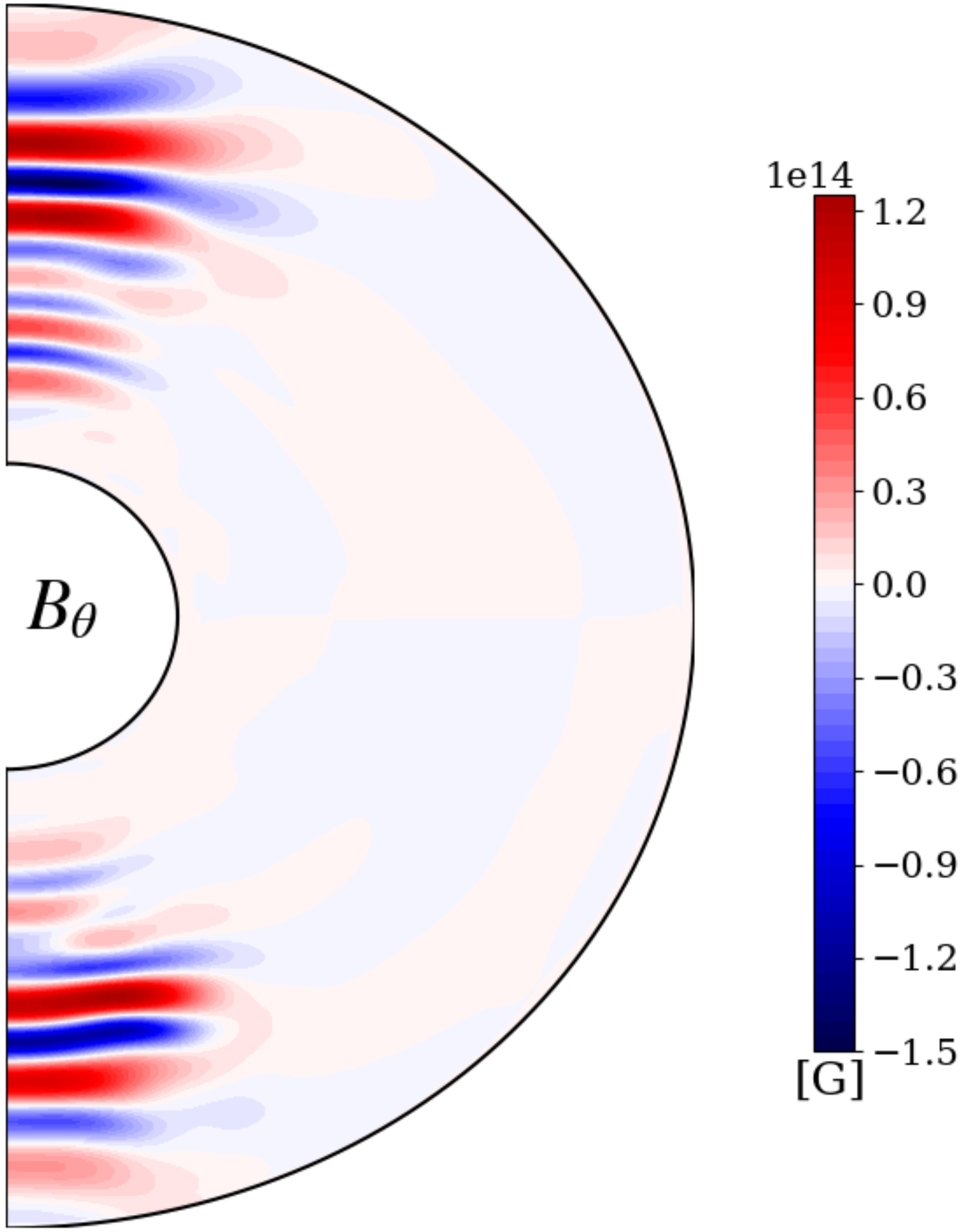
- Solid-body rotation
- Imposed rotation rate on both boundaries

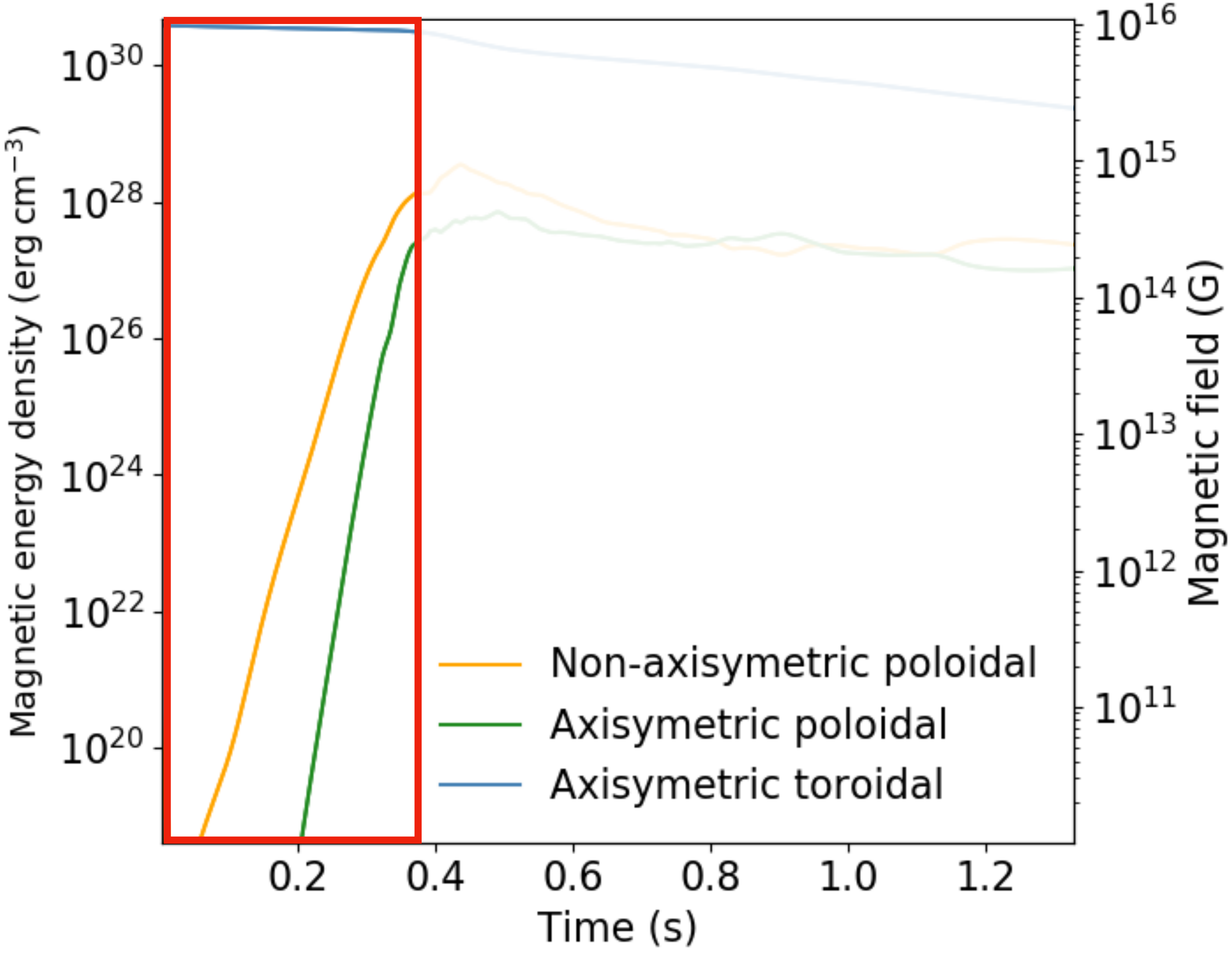
Parameters

- $(n_r, n_\theta, n_\phi) = (256{,}256{,}512)$
- $\mathrm{Pr} = \nu/\kappa = 10^{-3}$
- $\mathrm{Pm} = \nu/\eta = 1$
- $N/\Omega \in [8{,}47]$

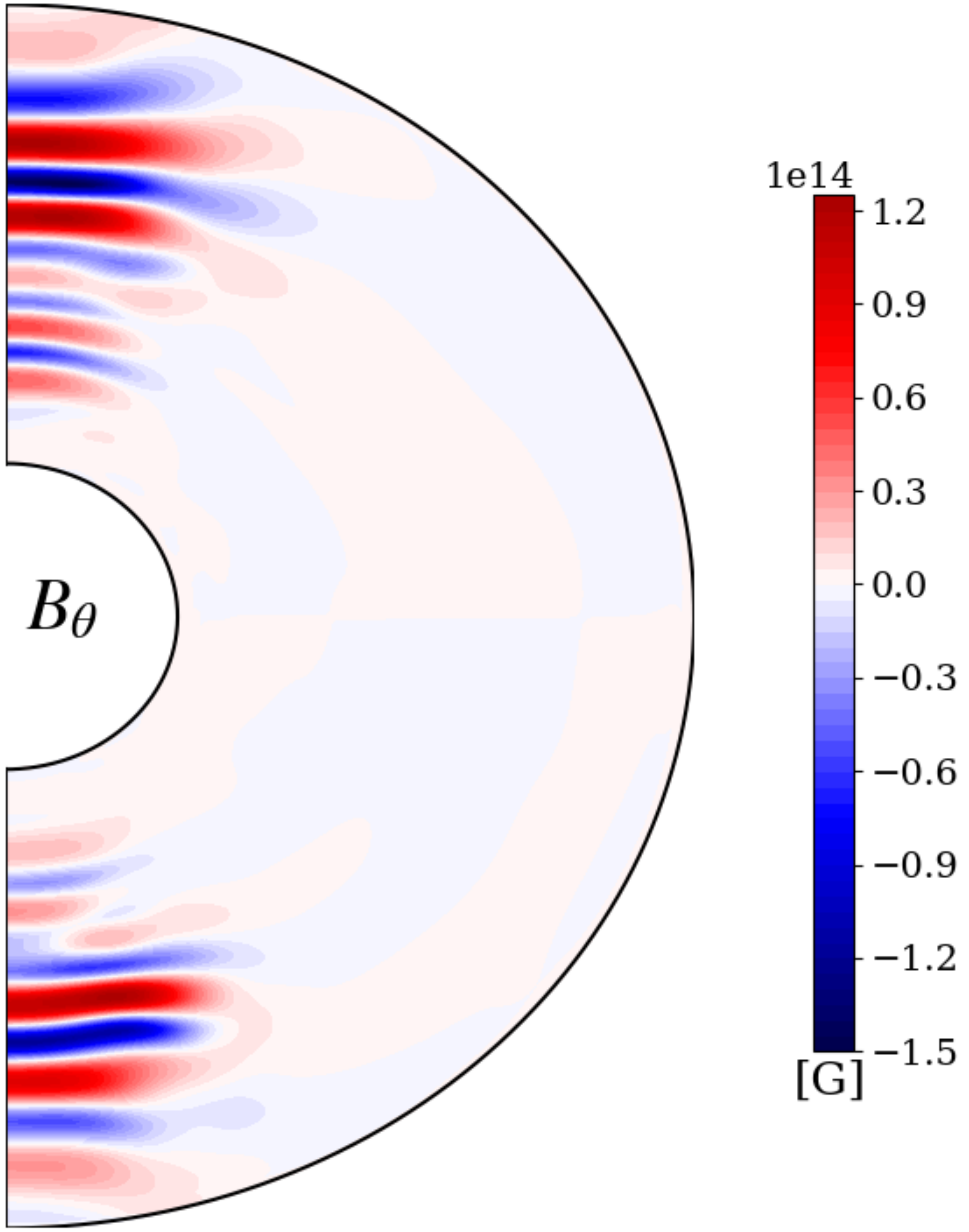


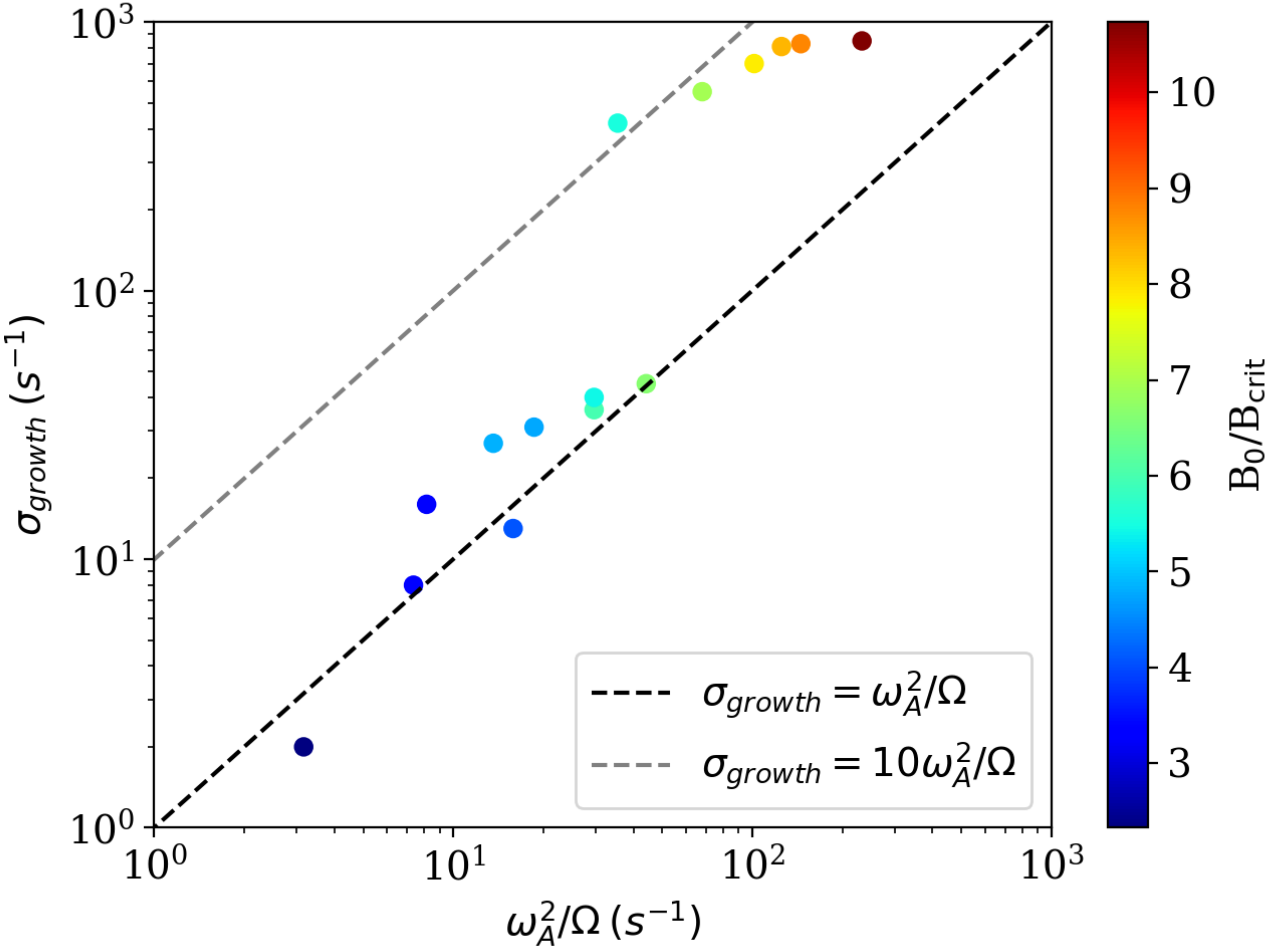
Tayler instability: linear phase



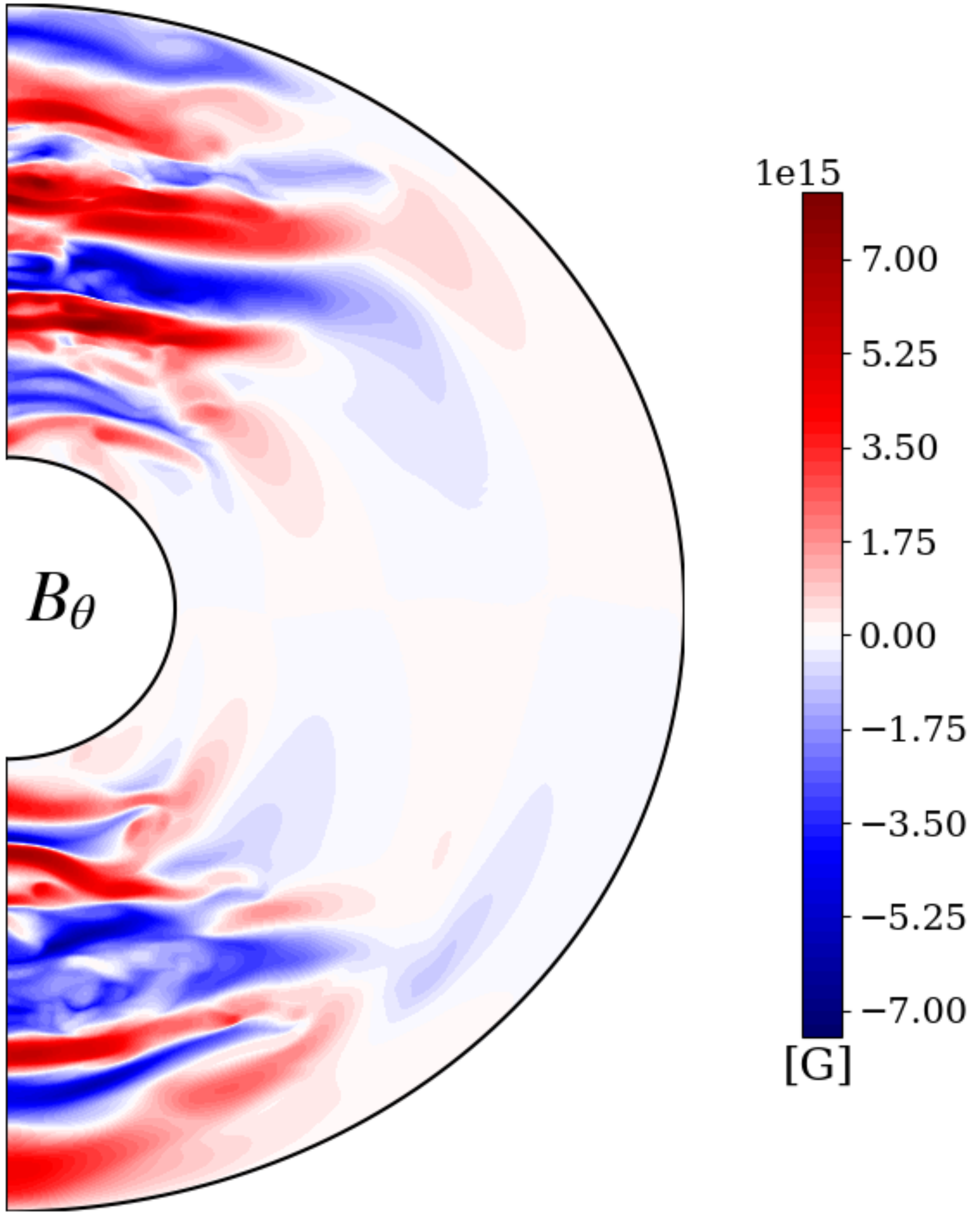


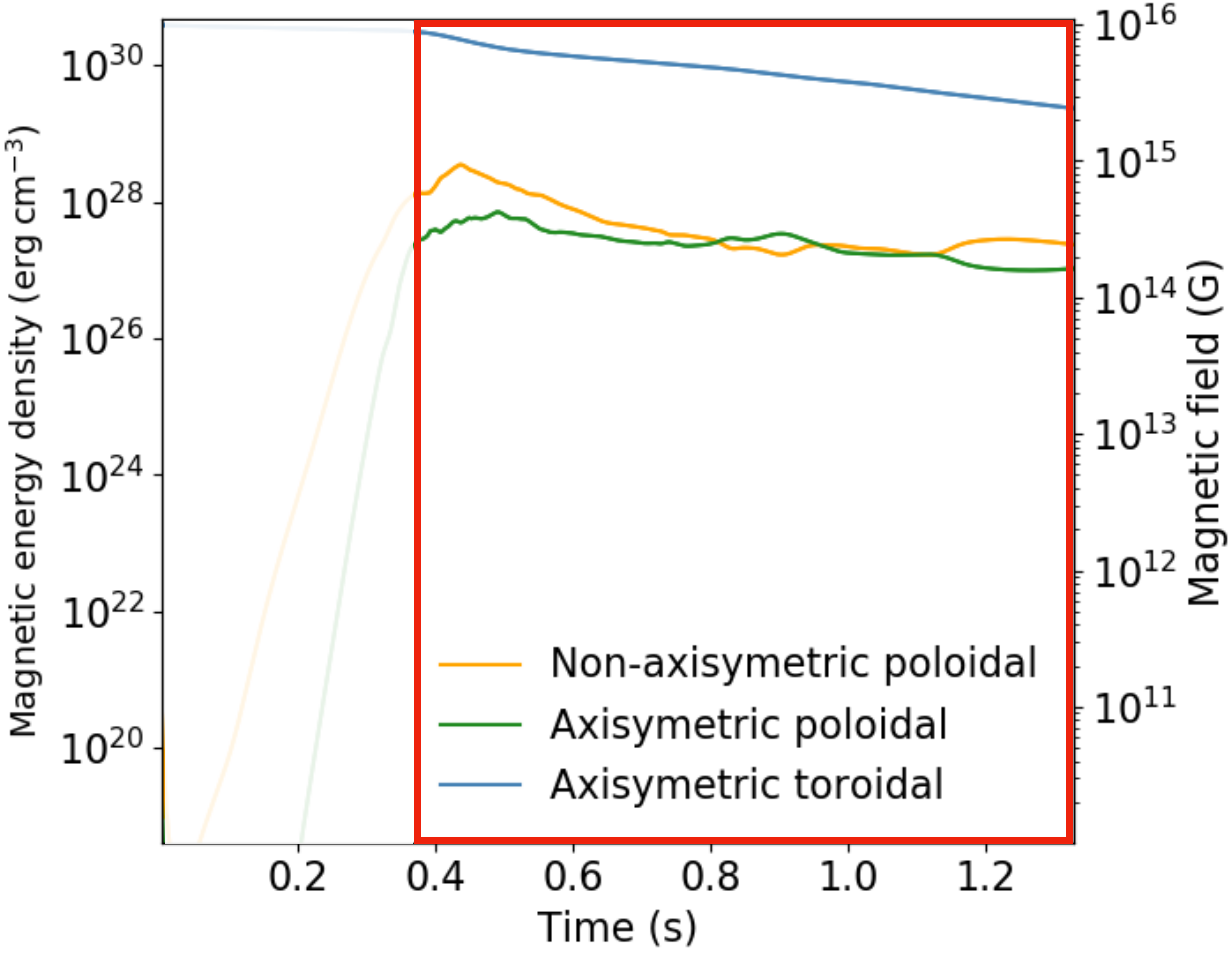
Tayler instability: linear phase





Tayler instability: non-linear saturation phase

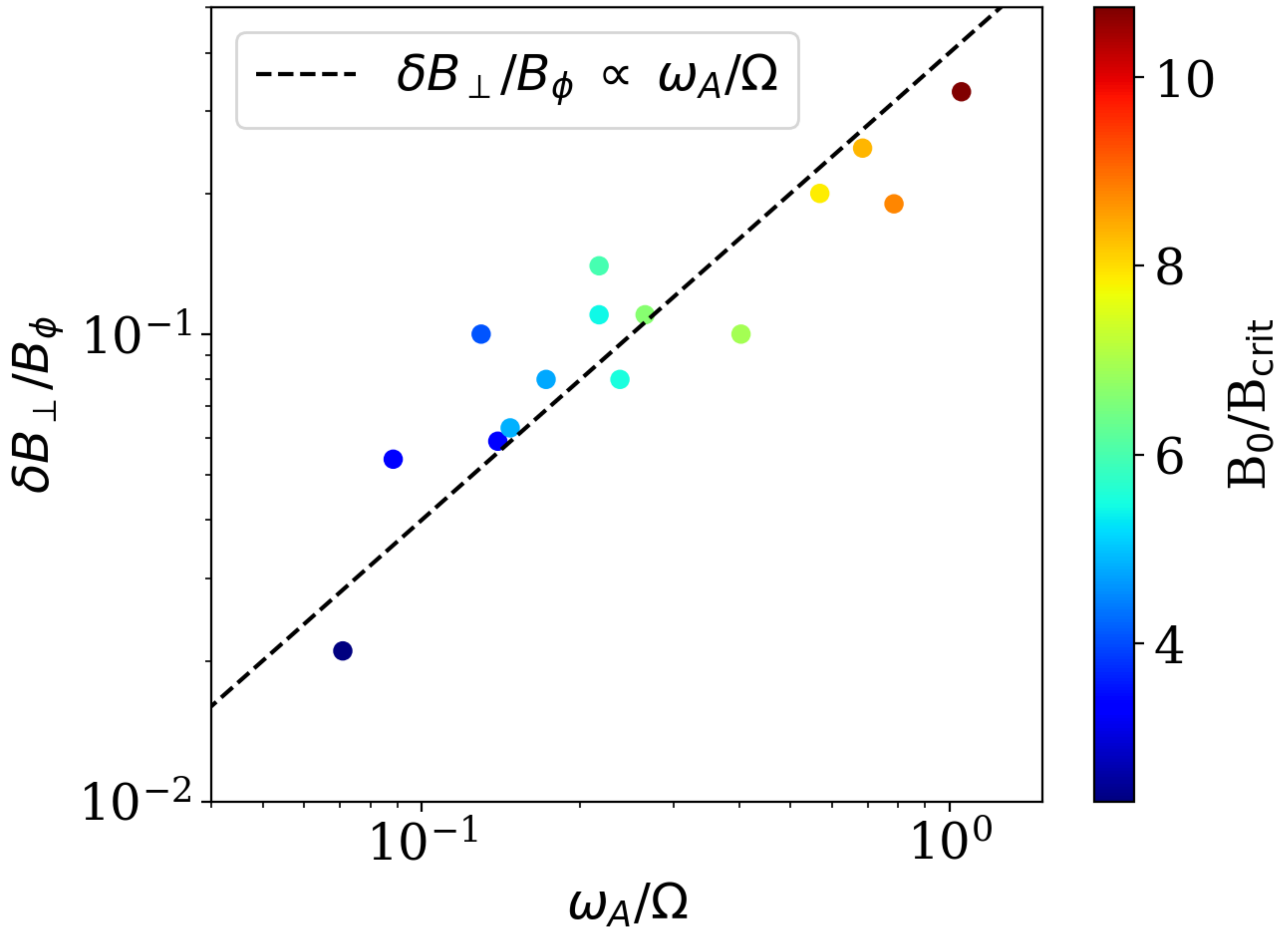




Tayler instability: non-linear saturation phase

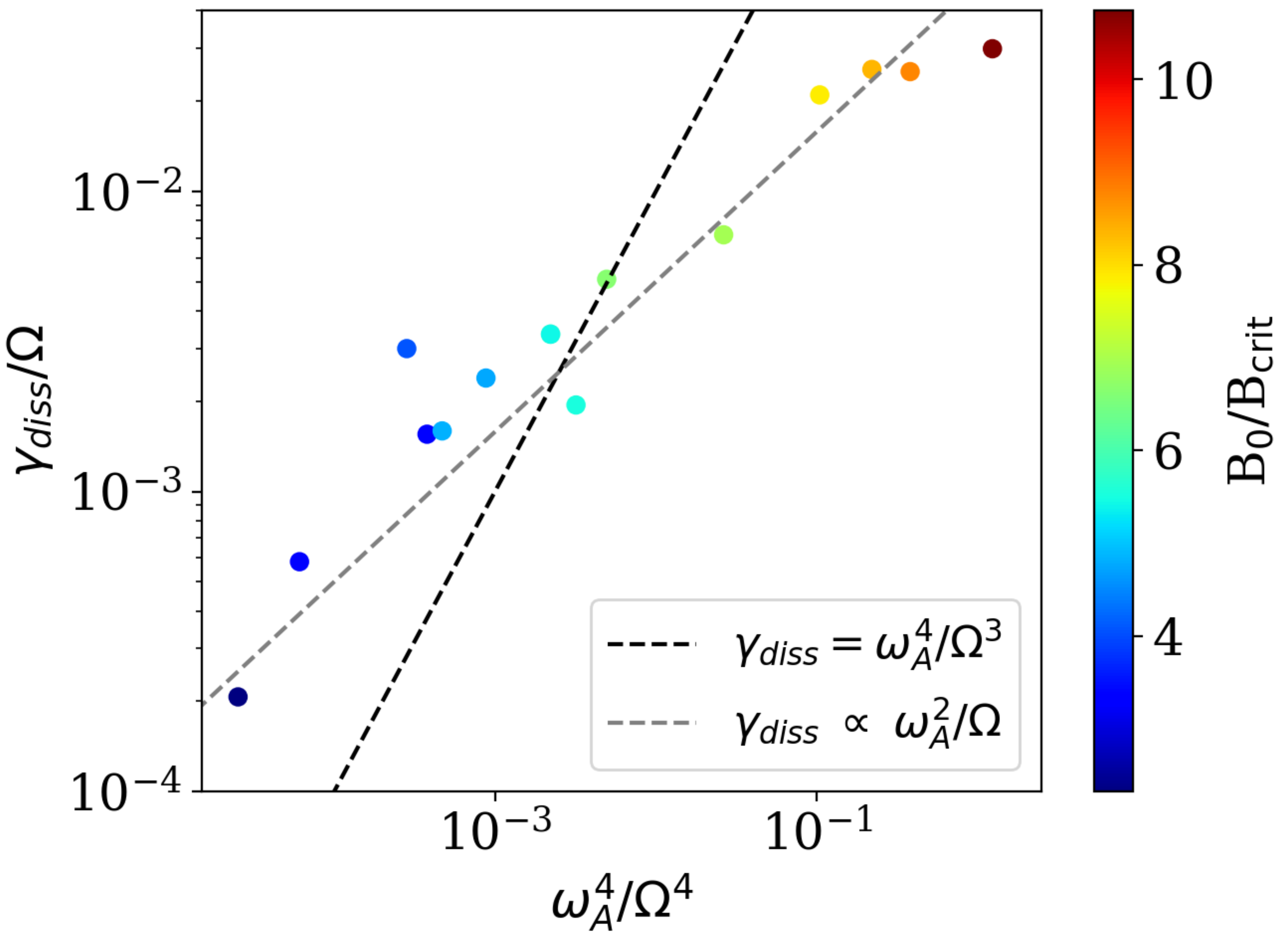
Analytical prediction:

- $\frac{\delta B_\perp}{B_\phi} \sim \frac{\omega_A}{\Omega}$ (Fuller+19)



Analytical predictions:

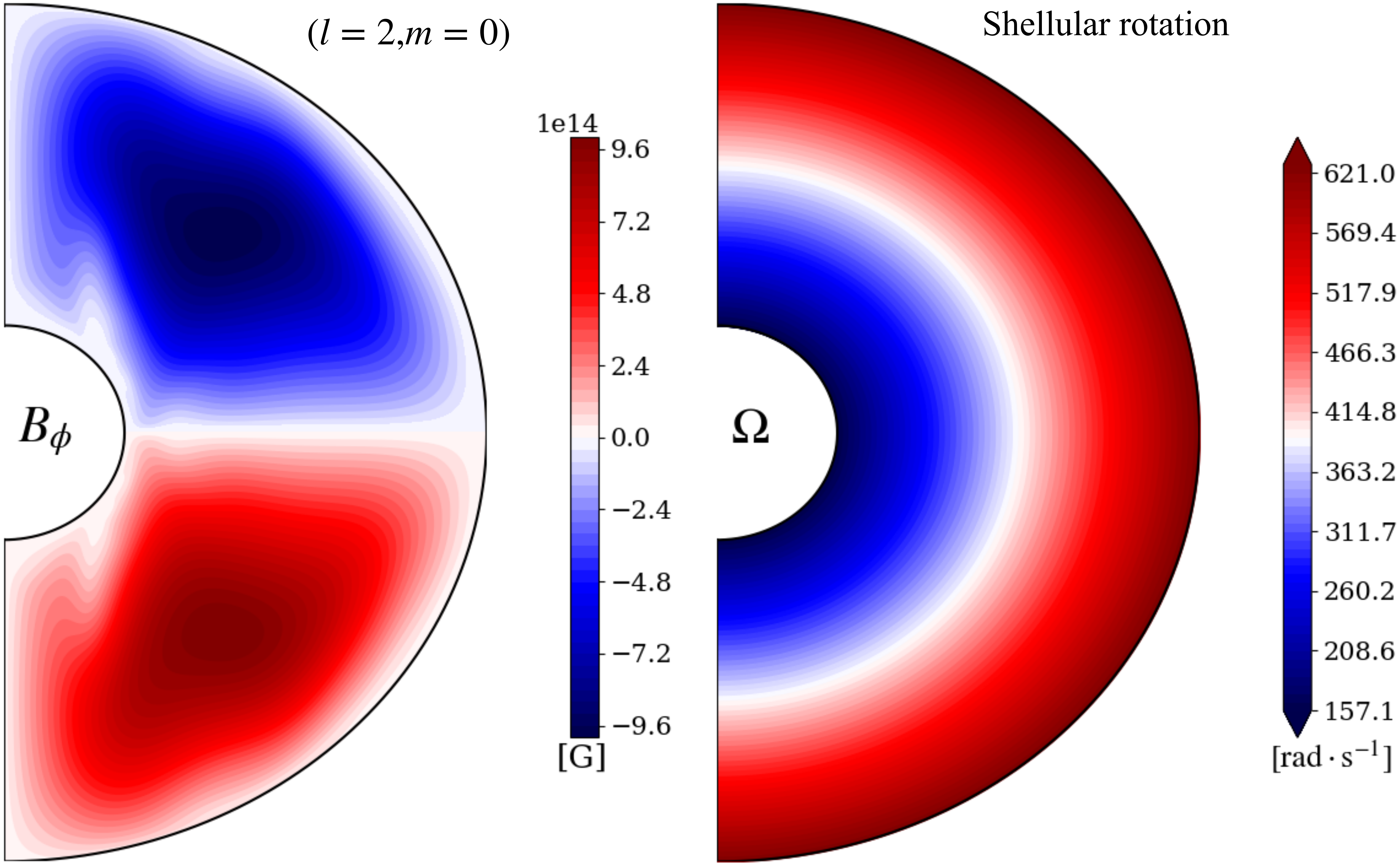
- $\gamma_{diss} \sim \frac{\omega_A^4}{\Omega^3}$ (Fuller+19)
- $\gamma_{diss} \sim \frac{\omega_A^2}{\Omega}$ (Spruit+02)



Differential rotation: numerical setup

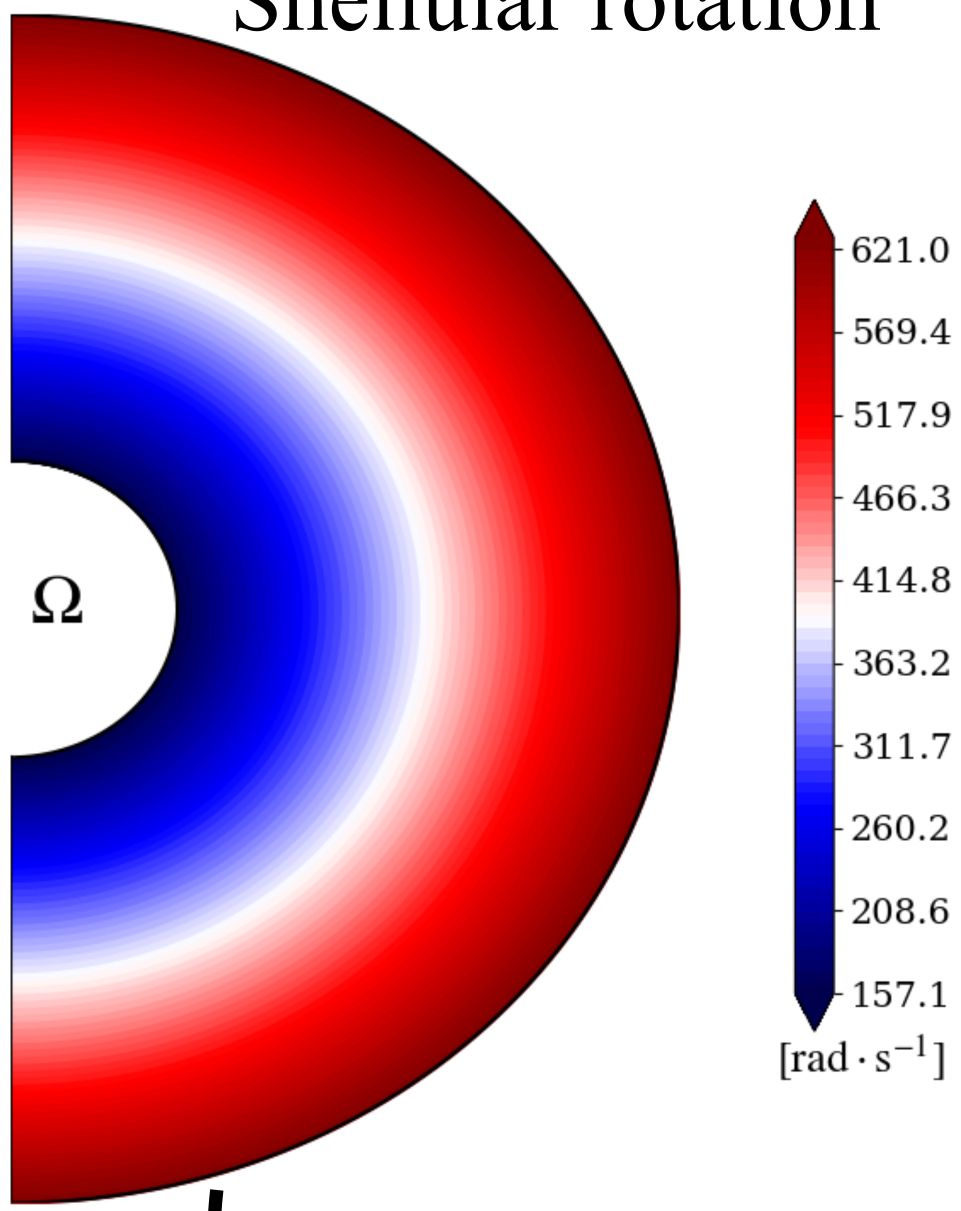
Parameters

- $(n_r, n_\theta, n_\phi) = (480{,}512{,}1024)$
- $\mathrm{Pr} = \nu/\kappa = 10^{-1}$
- $\mathrm{Pm} = \nu/\eta = 1$
- $N/\Omega = 10^{-1}$
- $Ro \equiv \Delta\Omega/\Omega = 0.75$



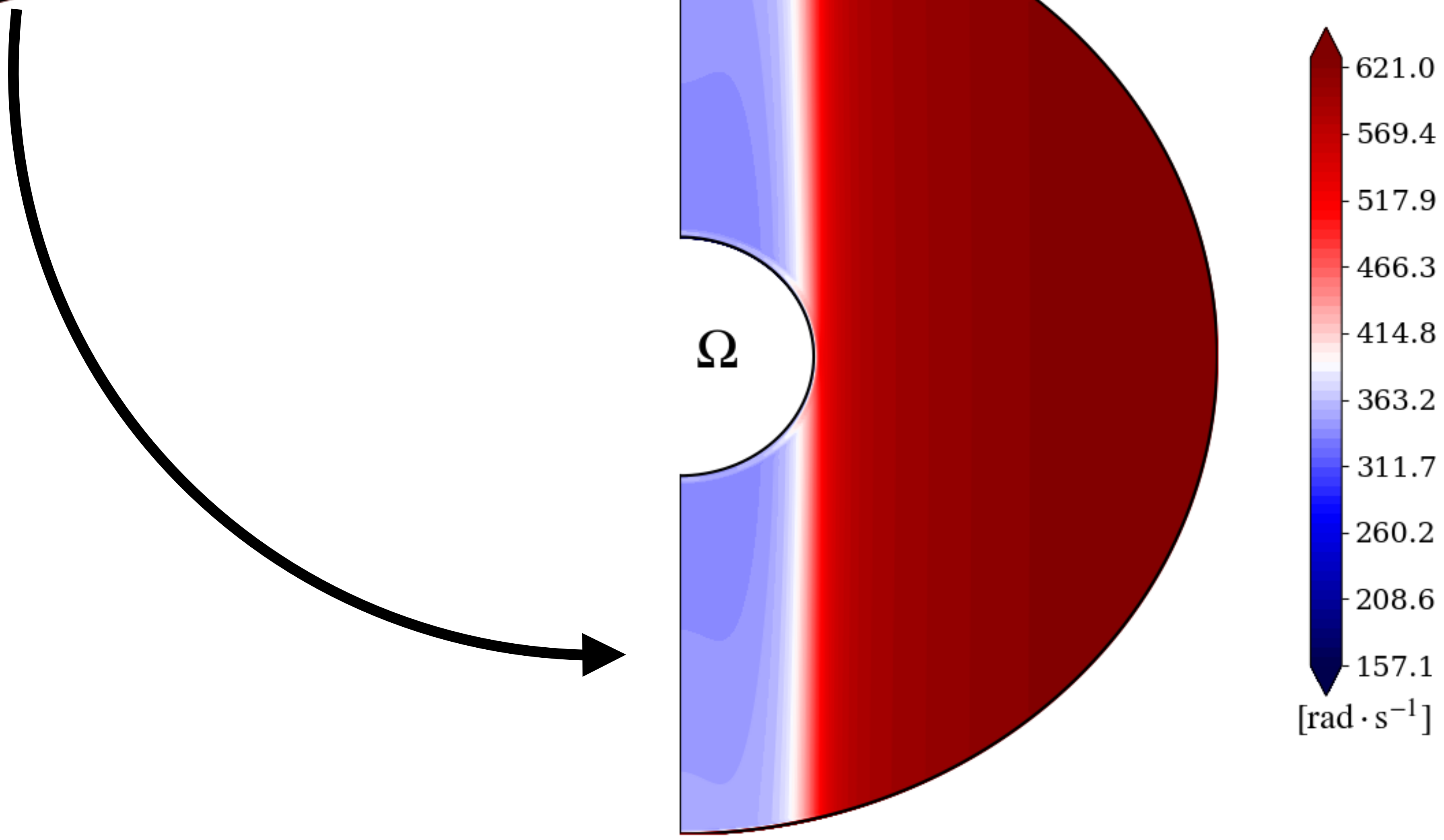
Differential rotation: preliminary results

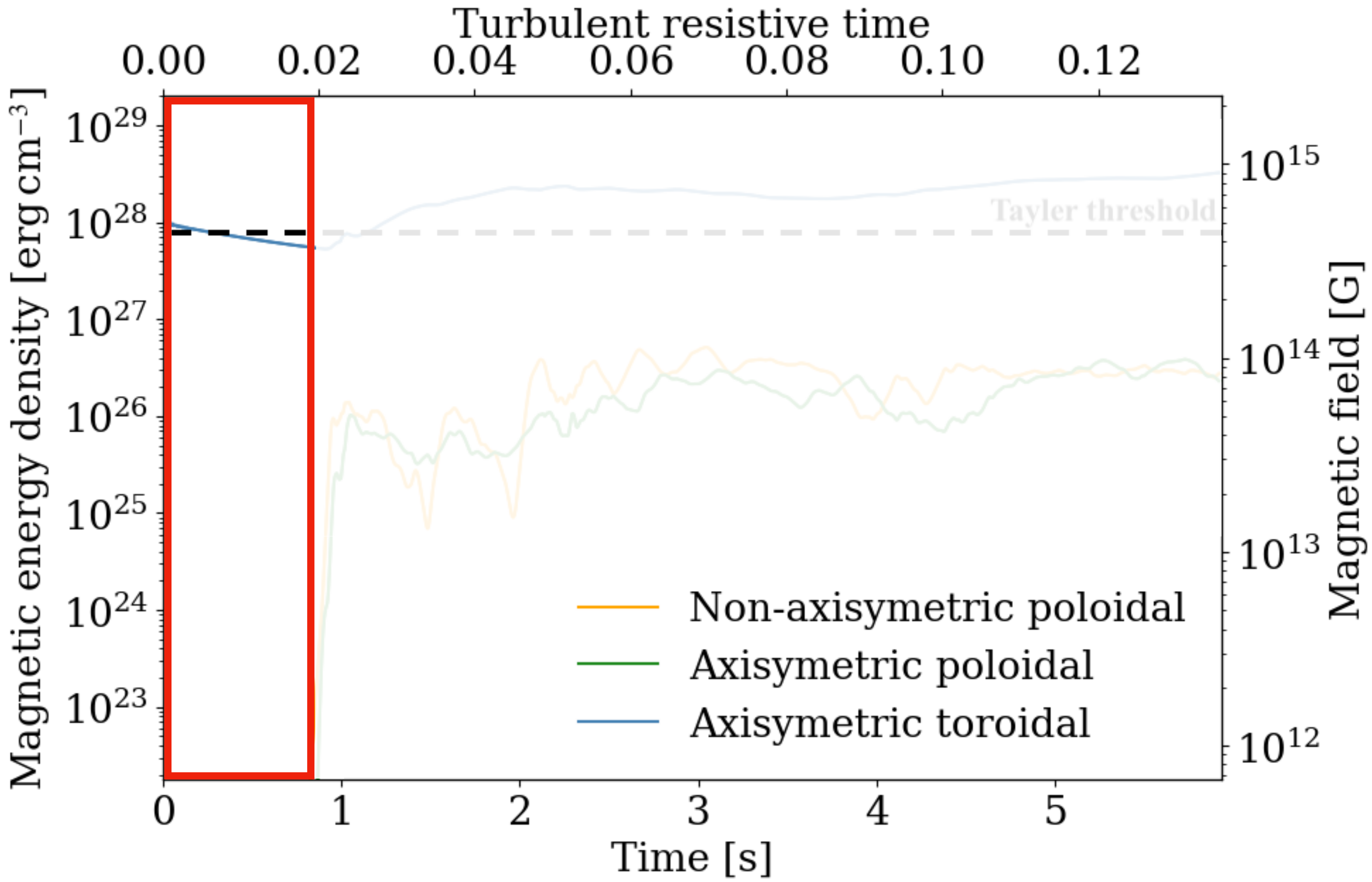
Shellular rotation



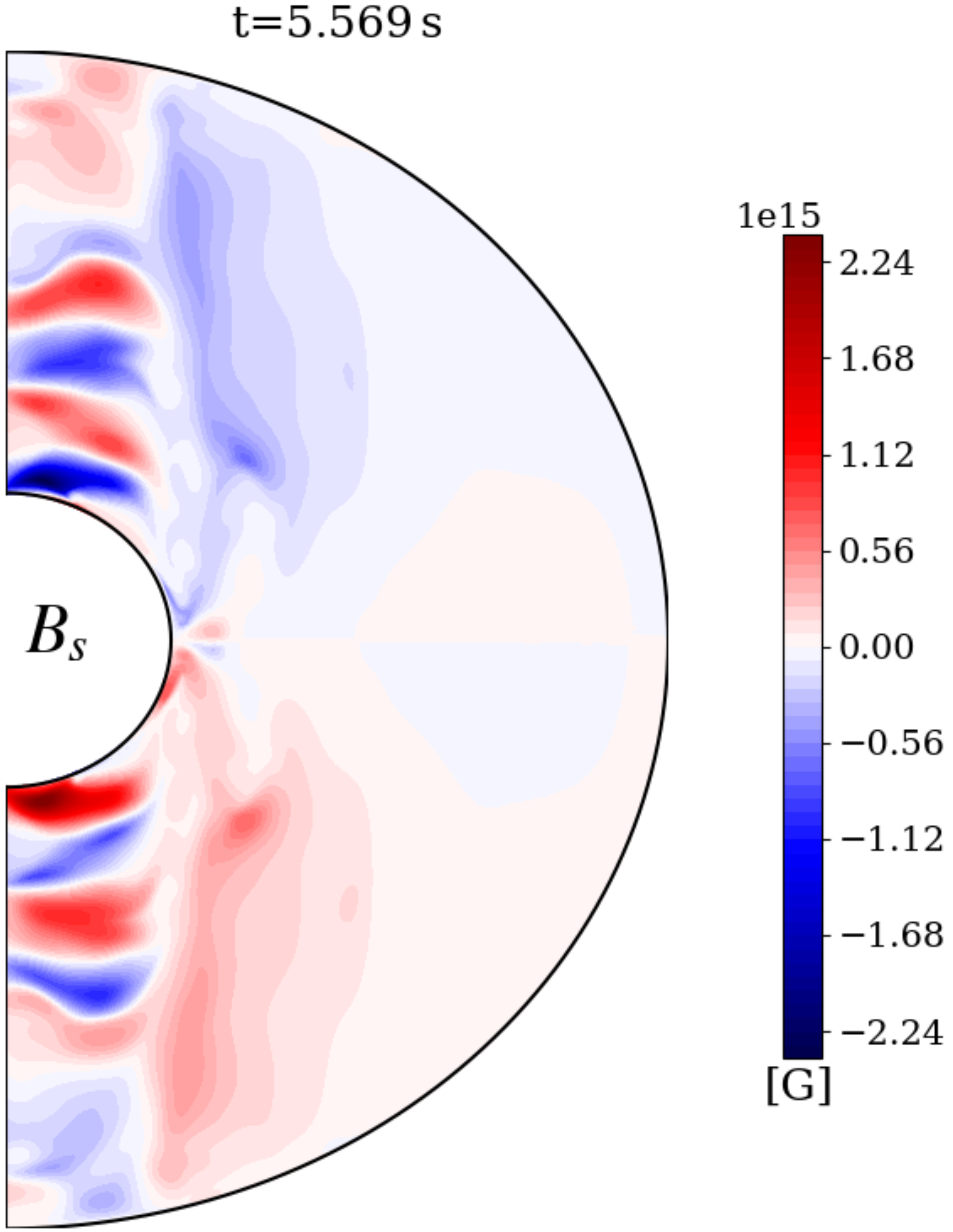
$$\mathrm{Pr}\left(\frac{N}{\Omega}\right)^2 \ll 1$$

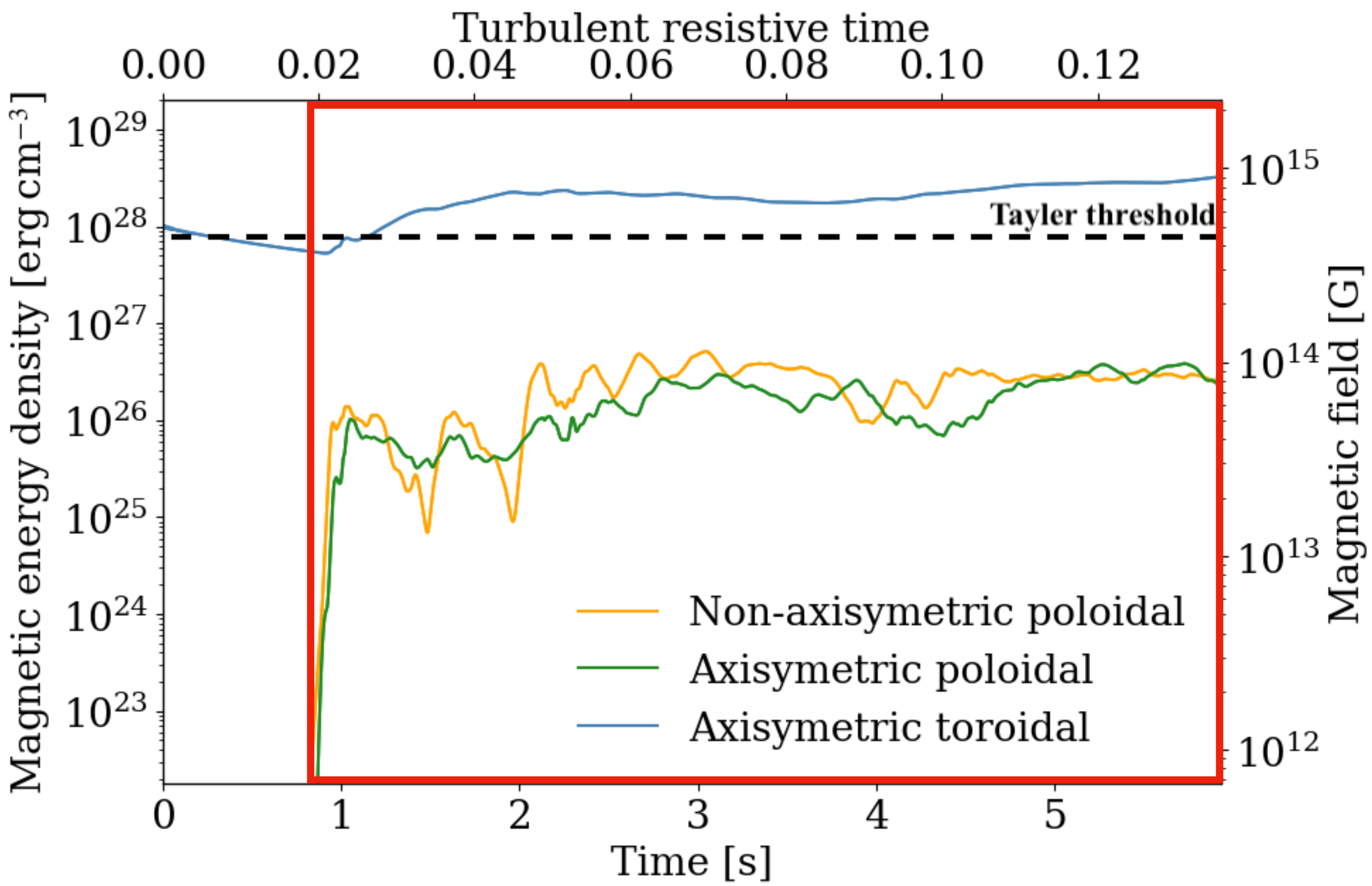
Cylindrical rotation





Differential rotation: preliminary results





Differential rotation: start from a poloidal field

Parameters

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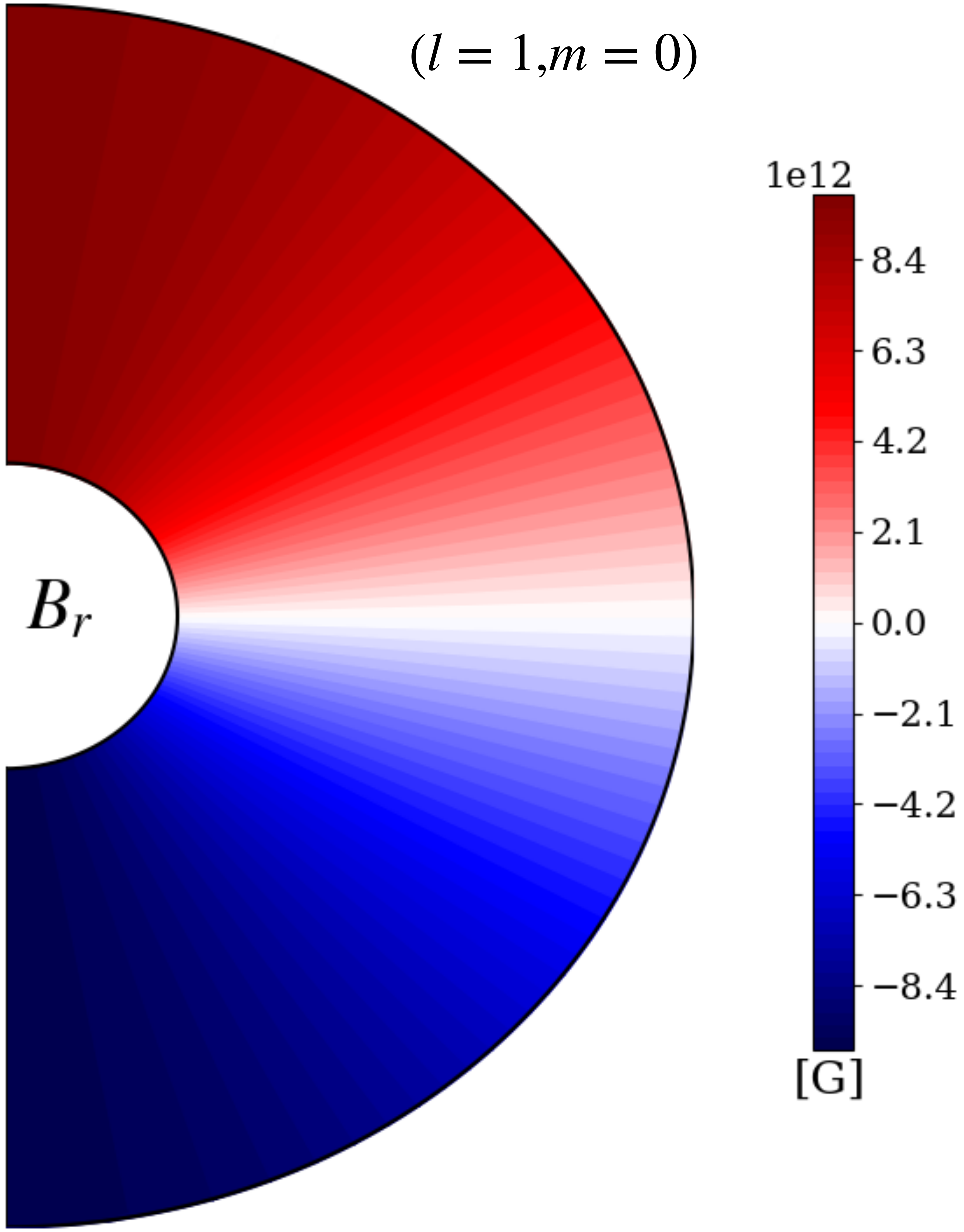
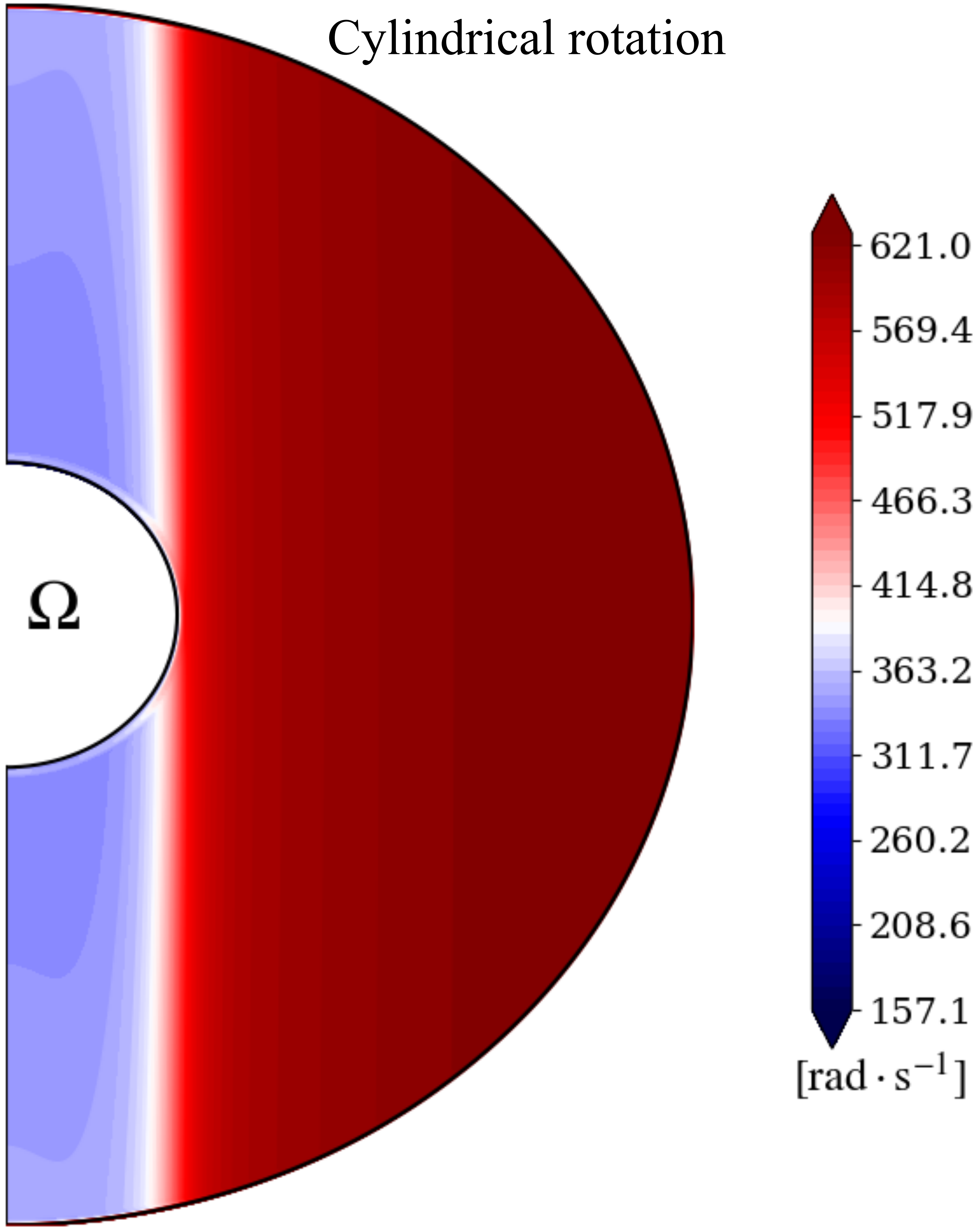
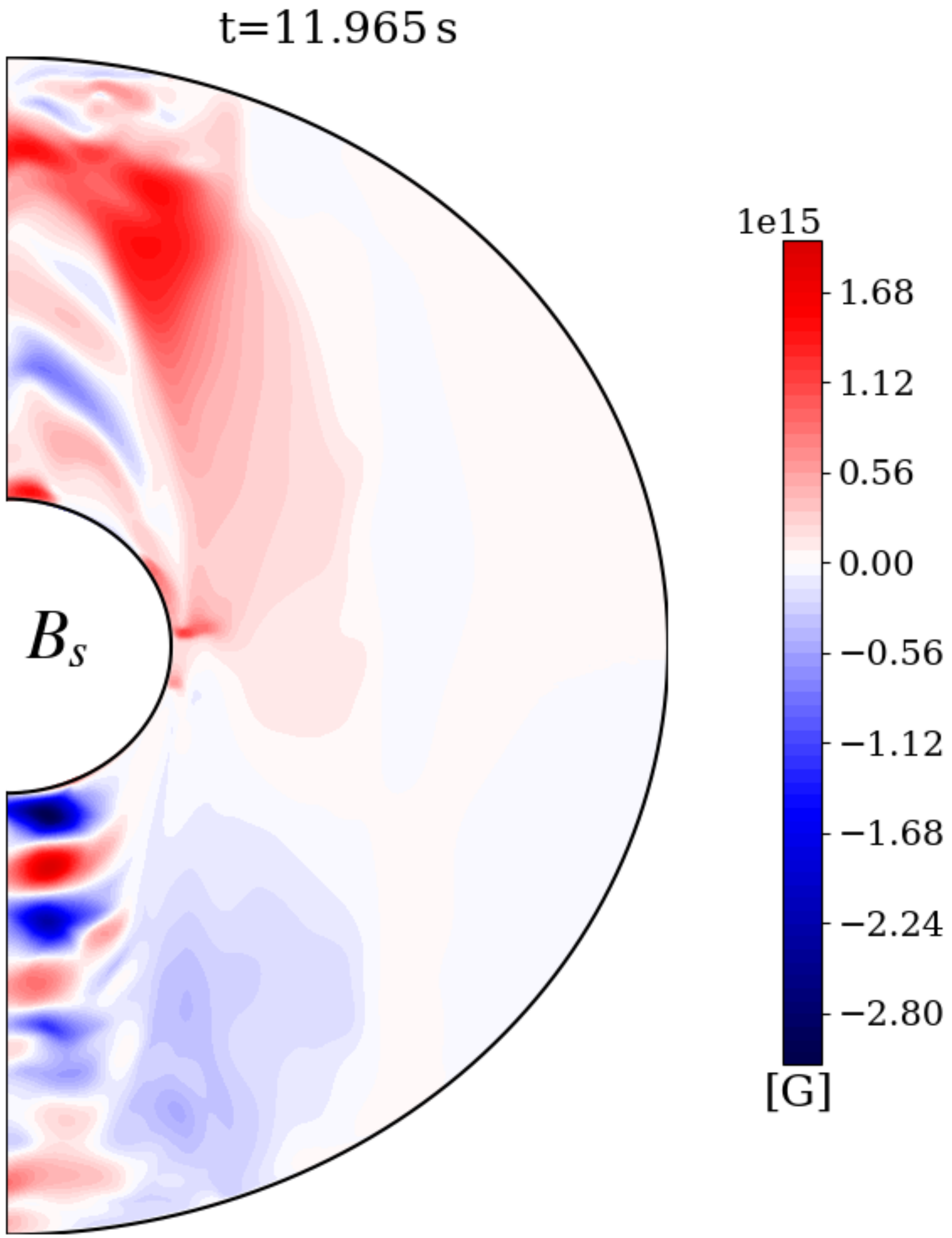
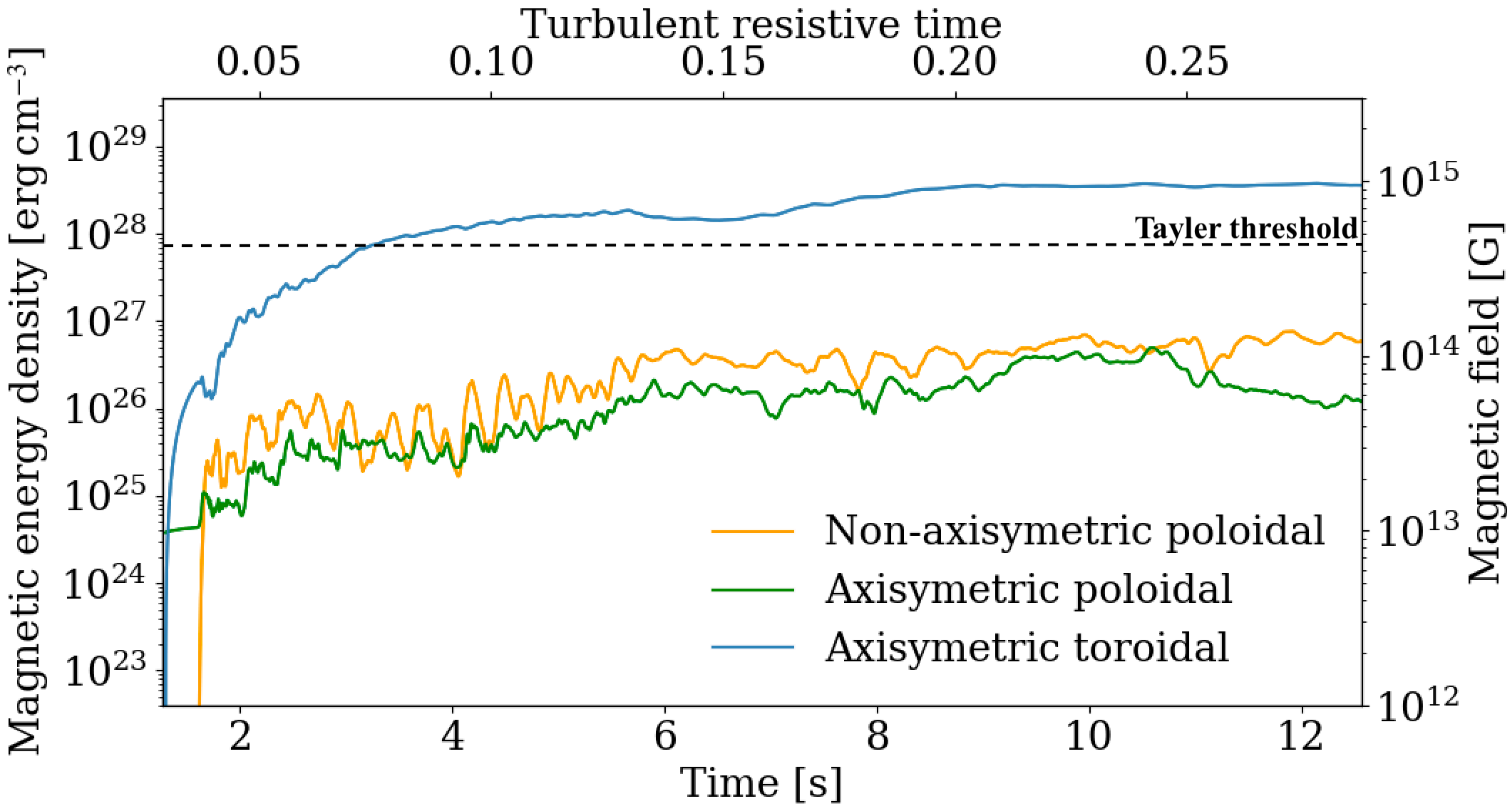


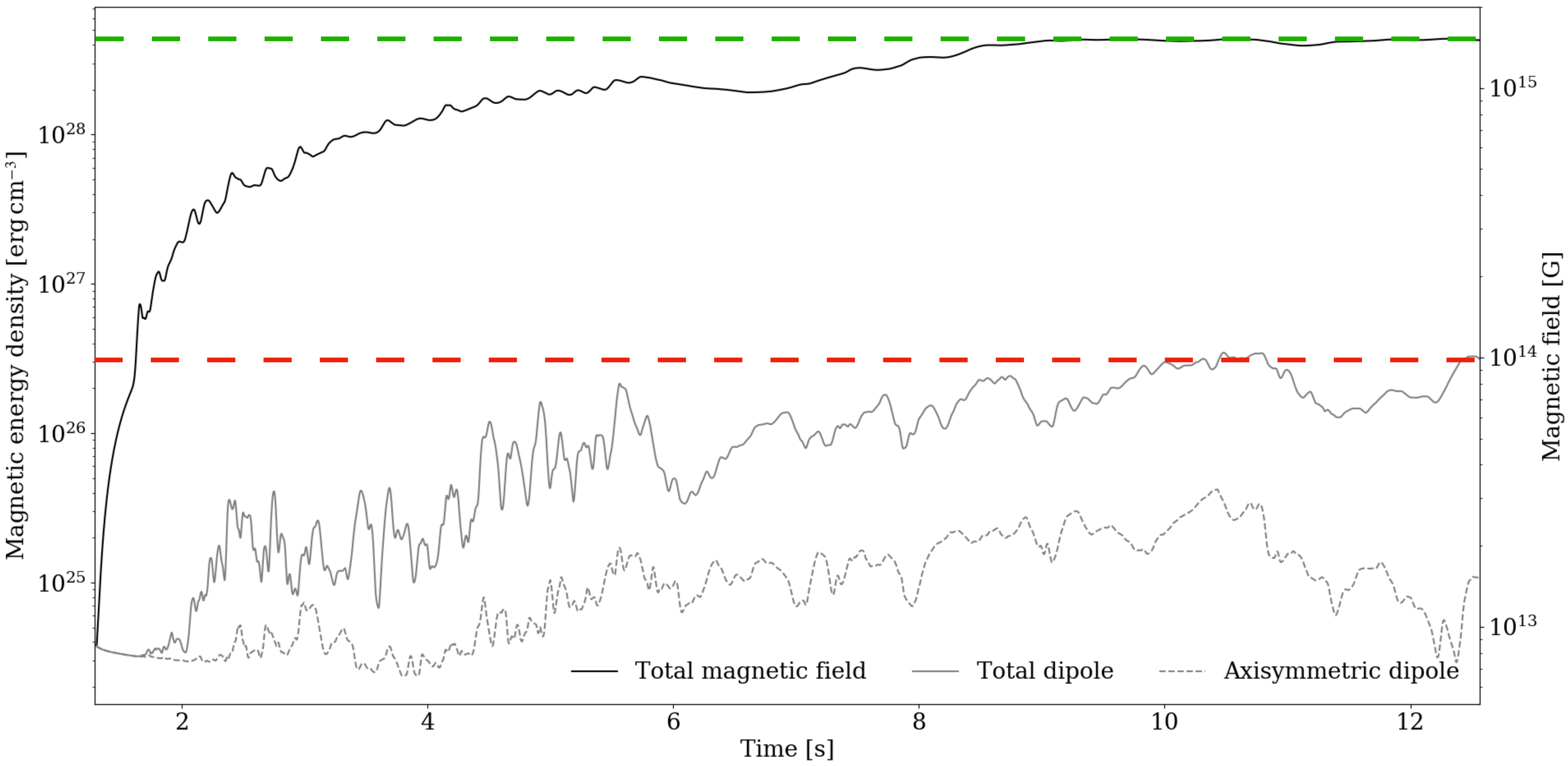


Differential rotation: start from a poloidal field





Differential rotation: dipolar magnetic field



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   Speakers: **L. Petitdemange, F. Daniel, P. Barrère**

5. Presentation of the practical training
   Speaker: **P. Barrère**

Before practice: practical training with MagIC

Open source code & version management:

- Code: https://github.com/magic-sph/magic
- Documentation: https://magic-sph.github.io

Community:

- $\gtrsim$ 30 users
- $\gtrsim$ 100 published scientific articles

(Wicht 02, Gastine & Wicht 12)

Several national programs (PNs):

- IRAP $\longrightarrow$ PNPS
- IPGP $\longrightarrow$ Geophysics
- CEA/AIM $\longrightarrow$ PNHE

Testable code:

- Reproduces international benchmarks
- Series of unit tests

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Objectives of the PT:
- Download and compile the code
- Set up and launch a run
- Outputs and post-processing

(Wicht 02, Gastine & Wicht 12)

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Testable code:
- Reproduces international benchmarks
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Before practice: namelist file `Namelist.f90`

`&grid` : Parameters for the grid

⟶ resolution in the radial and the perpendicular directions (outer and inner core)

`&control` : Parameters controlling the run

⟶ simulation mode (dynamo, hydro, etc)

⟶ number of steps, duration of the simulation, time scheme

`&phys_param` : Physical parameters

⟶ Dimensionless numbers (Rayleigh, Ekman, etc)

⟶ Boundary conditions

`&start_field` : Initial field parameters

⟶ Restart from the checkfile ?

⟶ Initial field modes and amplitudes

`&output_control` : Parameters for the output files

⟶ Number of files (3D graphics, spectra, movies, etc)

`&mantle` and `&inner_core` : Parameters for both shells

⟶ Rotation rates of the shells

Before practice: launch a parallelized run

Cluster: `astro_thin` ⟶ **24 cores per nodes $\Longleftrightarrow$ 4 MPI/nodes $\times$ 6 OpenMP/MPI**
Partition: `def`
QoS: `astro_thin_def_long`

Number of radial grid points: N_r

↓

Total number of tasks (i.e. of MPI): $N_{\mathrm{MPI}} = N_r/4$

↓

$$\textbf{Number of nodes} = \frac{\text{Total number of MPI}}{\text{MPI per node}}$$

Exemple: $N_r = 32 \Longrightarrow N_{\mathrm{MPI}} = 8 \Longrightarrow 2$ nodes

Attention:

- $N_r = 4 \times n$ **(where** n **is an integer)**
- N_r **must only contain multiple of 3, 4 and 5 if Chebyshev polynomials are used**