# XMS3GU050 - EARTH AND PLANETARY INTERIORS
# GEOMAGNETISM PRACTICAL

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**CODES** *https://github.com/filipecros/Geomag_TP*

**GEOMAGNETIC FIELD REPRESENTATION** The radial component of Earth's magnetic field can be written:

$$B_r(r,\theta,\phi) = \sum_{\ell=1}^{\ell_{max}} \left(\frac{a}{r}\right)^{\ell+2} \sum_{m=0}^{l} (g_\ell^m \cos m\phi + h_l^m \sin m\phi) P_\ell^m$$

**SYNTHETIC** Manipulate the spherical harmonic coefficients (Gauss coefficients) to produce fields that are purely dipolar ($\ell = 1$), quadrupolar ($\ell = 2$), octopolar ($\ell = 3$), zonal ($m = 0$), non-zonal ($\ell \neq 0$), sectoral ($\ell = m$) or tesseral ($\ell \neq m$) can be produced.

- What $g_2^0/g_1^0$ ratio gives $B_r = 0$ at the CMB at latitude 30°N?
- For $h_1^1$, what $g_1^1/g_1^0$ ratio gives dipole tilt of 10°? Does the radial distance matter?

**REAL** Using a model based on observations of Earth's magnetic field model (COV-OBS.x2, Huder et al., (2020)) for the historical and modern era:

- Plot $B_r$ at the CMB for different $\ell_{max}$ and calculate max($|B_r|$) vs. $\ell_{max}$ for $\ell_{max} = 5$–$14$.
- Plot $B_{r_{dip}}$ ($\ell = 1$) and $B_{r_{ndip}}$ ($\ell > 1$). Where are the largest non-dipole contributions?
- Plot $B_{r_{zon}}$ ($m = 0$) and $B_{r_{nzon}}$ ($m \neq 0$). Where are the largest non-zonal contributions?
- Plot $B_{r_{sym}}$ ($\ell+m$ even) and $B_{r_{nsym}}$ ($\ell+m$ odd). Is the field more equatorially symmetric or anti-symmetric?

**SPECTRUM** The magnetic field spectrum $R_\ell$ at the CMB can be expressed as a function of spherical harmonic degree $\ell$ in terms of the Gauss coefficients of the core field as (Lowes, 1974):

$$R_\ell = (\ell + 1)\left(\frac{a}{c}\right)^{2\ell+4} \sum_{m=0}^{l} \left((g_\ell^m)^2 + (h_l^m)^2\right)$$

where c is the radius of Earth's outer core.

- Plot $R_\ell$ as a function of $\ell$ at the core-mantle boundary. How would you describe Earth's magnetic field based on its spectral analysis?

**TIMESERIES**: Studying the time-dependence of the strength of the axial dipolar component of Earth's magnetic field.

- Plot the axial dipolar component of the field as a function of time. What is the average decrease rate? If it continues to decrease at the current rate, when will the field reverse?
- Plot the dipole tilt $\theta_{dip} = atan\left(\frac{\sqrt{(g_1^1)^2+(h_1^1)^2}}{g_1^0}\right)$ as a function of time. Does the present day dipole tilt behave like a beginning of a reversal?