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地磁気スペクトルを用いた外核乱流の推定
Time spectra of the geomagnetic field at the CMB and MHD flow in the core

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The flow of electrically conducting fluid in the outer core is responsible to generate and sustain the geomagnetic field. The flow in the core is expected to contain wide range of spatial spectrum, from planetary to turbulent scale. In this study, we made an attempt to extract information of the turbulence in the core from the geomagnetic field time spectra of decadal time scale.

The kinetic energy density of turbulence depends on power law with respect to the wave number in the inertial range and the power law also holds for certain frequency range according to Taylor's hypothesis. The exponent or the slope of the power spectral density (psd) in log space depends on the characteristics of the flow. Theoretical and numerical studies of MHD turbulence suggest that the exponents of the kinetic and magnetic energy are related with each other by magnetic induction. Therefore, if the exponent of the magnetic energy is obtained, it is possible to discuss the turbulent flow in the core by using the relationship between the two exponents.

Previous studies of the geomagnetic field spectra of decadal time scales employed magnetic field variation at the Earth's surface (Consolini et al., 2002) or the dipole moment (Sakuraba and Hamano, 2007). However, it would be more appropriate to analyze the magnetic field variation closer to the core for the discussion of the turbulent flow in the core. In this study, we used global geomagnetic main field model ufm1 (Bloxham and Jackson, 1992) to calculate the magnetic field time series and the psd of magnetic energy at the CMB. Average exponent of the psd is obtained as -5.8 when the spherical harmonic expansion is truncated at degree 10. It is confirmed that the exponent converges by increasing the truncation degree. The obtained value of exponent is significantly different from -11/3, which was obtained by previous studies of the surface magnetic field or the dipole moment.

The magnetic field calculated by a recent geodynamo (Sakuraba and Roberts, 2009) is also analyzed to compare the characteristics of the exponents. The obtained exponent is -5.3 and its variation with respect to increasing truncation degree is similar to that of ufm1. Similarity of the exponent value and the truncation behavior imply that the MHD dynamo model may reflect the dynamics of the Earth's core well.

In addition to the magnetic field, calculated flow by the geodynamo model was analyzed to compare the slopes of the magnetic and kinetic energy. The obtained exponent near the CMB was -3.1. The difference of the magnetic and kinetic energy exponents, about two, is consistent with the result of order estimate using the induction equation by assuming quantities expected in the core. The kinetic energy exponent in the core is estimated as about -3.3 when the same relationship between the magnetic and kinetic energy exponents holds. The value is smaller than the Kolmogorov exponent of -5/3. The strong magnetic field in the core, coordinate rotation and vigorous convection by high Rayleigh number are the possible causes of the steeper slope.