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The boundary mode of axially symmetric MAC waves can exist in the stratified layer at the top of the Earth's outer core

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Seismological observations (e.g. Helffrich & Kaneshima(2010), Kaneshima & Helffrich(2013)) and theoretical predictions show the existence of a layer stratified by the accumulation of light fluid at the top of the Earth's outer core. Helffrich(2014) suggested that its most probable origin is the vestige of primitive Earth. MAC waves, which arise from the balance among magnetic, Archimedes and Coriolis forces, can exist in the stratified layer. To explain the cause of the 60-year variations of the geomagnetic field, Braginsky(1993) examined axially symmetric approximate solutions of MAC waves theoretically. In his model, a boundary exists, where the fluid density is discontinuous between the layer and the bulk of outer core, and the buoyancy frequency is constant within the layer. (Recent seismological observations, however, indicate that the density jump is unlikely at the boundary.) The latitudinal phase velocity of the solution is equal to the Alfvén wave velocity multiplied by the buoyancy parameter ($c_{lat} = V_A \cdot B_u = V_A \cdot N / f$, where c_{lat} is the latitudinal phase velocity, V_A is the Alfvén wave velocity, B_u is the buoyancy parameter, N is the buoyancy frequency, and f is the Coriolis parameter), and the vertical structure is expressed as a superposition of sine waves. The decay rates of the wave are proportional to the magnetic diffusivity. Since the latitudinal phase velocity is proportional to buoyancy frequency, the stratification can be estimated if the phase velocity is determined observationally. If the 60-year variation of the geomagnetic field is identified as the fundamental mode with the latitudinal wavenumber l=2, the buoyancy frequency is estimated to be about twice the angular velocity of the Earth's rotation.

We have found that Braginsky's(1993) equations also have the solutions localized at the layer boundary, which we refer to as the boundary mode. This mode has a time scale smaller than the solution within the layer (Braginsky's(1993) solution), and spreads through magnetic diffusion. The phase propagates away from the layer boundary. The frequency of the boundary mode does not depend on the buoyancy frequency within the layer. The frequency and the vertical wavenumber depend on the magnitude of the density discontinuity, the latitudinal wavenumber, and several parameters. The wave amplitude decreases exponentially with the distance from the layer boundary. As the density jump or the latitudinal wavenumber increases, temporal and spatial decay rates increase. Therefore, small density jumps and small layer thicknesses are required to find the boundary mode observationally, and waves with smaller latitudinal wavenumbers are expected to be observed more easily. If the 60-year fluctuation of the geomagnetic field is identified as the boundary mode with the latitudinal wavenumber l = 2, the ratio of density discontinuity is estimated to be about 10^{-4}. Furthermore, the boundary in contrast to the MAC wave within the layer, the spatial and temporal decay rate of the boundary mode decreases as the magnetic diffusivity increases.

Keywords: MAC waves, the top of the Earth's outer core, H layer