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Axisymmetric and non-axisymmetric MagnetoStrophic MRI modes

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We have shown that a simple, modified version of the Magnetorotational Instability (MRI) can develop in the outer liquid core of the Earth, in the presence of a background shear (Petitdemange, Dormy, Balbus, GRL,35, 2008). It requires either a thermal wind, or a primary instability, such as convection, to drive a weak differential rotation within the core. The force balance in the Earth's core is unlike classical astrophysical applications of the MRI (such as gaseous disks around stars). Here, the weak differential rotation in the Earth core yields an instability by its constructive interaction with the planet's much larger rotation rate. The resulting destabilising mechanism is just strong enough to counteract stabilizing resistive effects, and produce growth on geophysically interesting timescales. We refer to this instability as the Magnetostrophic MRI (MS-MRI). Hollerbach and Rüdiger have reported a new type of MRI (so-called HMRI) in the presence of combined axial and azimuthal magnetic fields. HMRI is weakly destabilized inertial oscillations propagating along the vertical axis and it is known to act at arbitrarily low magnetic Reynolds number. This Helical version could generate oscillations in planetary interiors where the magnetic Prandt number is $\approx 10^{-6}$. We investigate analitically and numerically the influence of an additional toroidal magnetic field on the MS-MRI i.e. in rapid rotating systems. We investigate linear and nonlinear developments of the MS-MRI. We present global numerical simulations both axisymmetric and three-dimensional. We identify the 3D mechanism of this instability, and the role of a helical applied magnetic field. We discuss the possible signature of MS-MRI in recent geomagnetic simulations and address the connection between the MS-MRI and the planetary dynamos. —-