

Global MHD tachocline instabilities (Invited Reviewer)

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Abstract

Extensive studies of global instabilities in 2D and quasi-3D shallow-water and thin-shell models of solar/stellar tachocline indicate that the tachocline differential rotation can be hydrodynamically and magnetohydrodynamically unstable to nonaxisymmetric modes with low longitudinal wave numbers, $m=1$ as well as $m>1$. During nonlinear evolution of these instabilities, $m=1$ modes produce clam-shell pattern of broad toroidal fields and tipping of toroidal bands, whereas $m>1$ modes produce deformation of toroidal bands. Magnetized shear modes nonlinearly interact with high-frequency gravity waves. Radiative and overshoot tachoclines of the Sun and Sun-like stars are prone to this type of instabilities, due to which high latitude jet or polar spin-up occurs, and Reynolds, Maxwell and mixed stresses in the disturbances together with changing shell-thickness and meridional flow cause the evolution of differential rotation. After discussing the above results, we will present the importance of helical flow generated by shallow-water tachocline instabilities. We will demonstrate how the swelling and depression, created in the tachocline fluid due to such instability, can be responsible for producing "active-longitudes" on the solar/stellar surface. The interactions of oscillatory neutral modes and growing modes in a linear shallow-water system were demonstrated by Zaqarashvili et al. to explain the observed Rieger-type periodicity and quasi-biennial oscillations. During nonlinear evolution, an oscillatory exchange of energy occurs between the Rossby waves and differential rotation in the tachocline, and can explain the quasi-periodic, bursty "seasons" of solar activity. We will close by discussing the crucial role the tachocline dynamics play in influencing space-weather by shaping the spatio-temporal patterns of global magnetism manifested at the solar surface.