Combining Models of Coronal Mass Ejections and Solar Dynamos

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Abstract

Observations show that Coronal Mass Ejections (CMEs) are associated with twisted magnetic flux configurations. Conventionally, CMEs are modeled by shearing and twisting the footpoints. The surface velocities and magnetic field patterns should ultimately be obtained from realistic simulations of the solar convection zone where the field is generated by dynamo action. Therefore, a unified treatment of the convection zone and the CMEs is needed. Numerical simulations of turbulent dynamos show that the amplification of magnetic fields can be catastrophically quenched at magnetic Reynolds numbers typical of the interior of the Sun. A strong flux of magnetic helicity leaving the dynamo domain can alleviate this quenching. In this sense, a realistic (magnetic) boundary condition is an important ingredient of a successful solar dynamo model. We combine a dynamo-active region with a simplified corona. The simulations show magnetic fields that emerge at the surface of the dynamo region and are ejected into the coronal part of the domain. Their morphological form allows us to associate these events with CMEs. Our convection-driven dynamo model with a coronal envelope has a solar-like differential rotation with radial (spoke-like) contours of constant rotation rate, together with a solar-like meridional circulation and a near-surface shear layer.

The spoke-like rotation profile is due to latitudinal entropy gradient which violates the Taylor–Proudman balance through the baroclinic term. We find mean magnetic fields that migrate equatorward in models both with and without the coronal layer.

One remarkable result is that the dynamo action benefits substantially from the presence of a corona becoming stronger and more realistic.

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