The Non-Axisymmetric Solar Dynamo

Abstract of the talk that will be presented at the Workshop "Mathematical Aspects of Natural Dynamos", Caramulo, Portugal, August 31 – September 6, 2003

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We investigate the dynamo generation and coupling of axisymmetric and non-axisymmetric modes of the mean solar magnetic field. The work is motivated by the fact that solar magnetic activity tends to cluster at ``preferred" longitudes, which indicates the involvement of non-axisymmetric large-scale (mean) magnetic fields in the process of the activity formation. Spacecraft data collected over three solar cycles indicate a persistent dependence of the solar wind speed and the radial component of the interplanetary magnetic field on solar longitude rotating with a fixed period, which is also seen in solar magnetograms.

Our kinematic dynamo model incorporates the solar rotation reconstructed by inversion of helioseismic data in the convection zone and simulated distributions of the turbulent resistivity and the mean kinetic helicity. We demonstrate first that the dynamo breaks the axial symmetry by exciting non-axisymmetric modes even when all sources of generation (differential rotation, helicity, diffusivity and meridional circulation) are axisymmetric. Then we couple axisymmetric and non-axisymmetric modes using a non-axisymmetric addition to the mean helicity. Mathematically, it is done in the kinematic approximation without the standard use of a non-linear quenching.

We find that this coupling of non-axisymmetric and axisymmetric modes (1) reproduces the phase relation between these modes observed in the solar cycle; (2) the non-axisymmetric modes are localized near the base of the convection zone thus influencing the formation of active regions.

This research was conducted in part at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautic and Space Administration.