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SEMINAR SERIES

Planetary Dynamos: The Curious Case of Saturn

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Magnetic field measurements by the Cassini mission have confirmed the earlier Pioneer 11 and Voyager missions' results that Saturn's observed magnetic field is extremely axisymmetric. For example, Saturn's dipole tilt is less than 0.06 degrees. The near-perfect axisymmetry of Saturn's dipole is troubling because of Cowling's Theorem which states that an axisymmetric magnetic field cannot be maintained by a dynamo. However, Cowling's Theorem applies to the magnetic field generated inside the dynamo source region and we can avert any contradiction with the theorem if we can find reason for a non-axisymmetric field generated inside the dynamo region to have an axisymmetric potential field observed at satellite altitude. Stevenson (1980) proposed that the Helium Insolubility Layer (HIL), which forms at the top of the metallic hydrogen layer in Saturn, could provide such a mechanism. This layer is stably stratified and electrically conducting. Differential rotation in this layer, which surrounds the dynamo source region, could act to attenuate the non-axisymmetric features and hence produce an axisymmetric observed magnetic field.

Here we use numerical dynamo simulations to demonstrate that the HIL can produce a more axisymmetric field. We also demonstrate an important theoretical consequence of this axisymmetrization process: the secular variation of the axisymmetric field components must be extremely slow. Observational evidence suggests this may be the case for Saturn. In addition, we present numerical dynamo simulations that reproduce the observed axisymmetry of Saturn's field and confirm the extremely slow secular variation rates in highly axisymmetric models. A consequence of this result is that we can use time variation of the axisymmetric field to learn about the non-axisymmetric field components which are not observed in present data from Cassini.

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