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Differential Rotation Dynamos: An Application to Saturn

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Most planetary dynamo are thought to be driven be convection, and numerical simulations have confirmed that the associated chaotic flows can indeed account for many of the observed planetary magnetic field features. Saturn's dynamo, however, seems exceptional, producing a highly axisymmetric and relatively simple magnetic field. Its octupole is also much stronger and of opposite sign than typical for convectively driven dynamos. We have used numerical simulations to examine the dynamo action of the flow between two differentially rotating co-axial spheres, the so-called spherical-Couette system. When the differential rotation exceeds a critical value the stationary and axisymmetric Couette shear flow becomes instable. The non-axisymmetric instabilities can induce magnetic fields which are highly axisymmetric and concentrated in two flux bundles around both poles. Sub-rotation of the inner boundary preferentially results in an equatorially asymmetric field. Super-rotation of the inner boundary produces an equatorially antisymmetric magnetic field which shares many similarities with Saturn's magnetic field. It is not only highly axisymmetric but also produces a strong octupole component of the correct sign. We speculate that the super-rotation in Saturn's interior may be sustained by Helium precipitation. Extrapolation of our results indicates that vary small amount of differential rotation, or order one part in 10^7, could suffice to yield the respective dynamo action.