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The magnetic field and secular variation of Jupiter

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Planetary dynamos, resulting from fluid flow in electrically conductive parts of their interior, are thought to be highly time dependent. Currently, our understanding of temporal variation of these fields is limited because we only have observations for one example, the Earth. To overcome this, data acquired by 6 NASA space missions between 1973-2003 are used to investigate possible time variation (secular variation) of Jupiter's magnetic field.

Previous attempts to model jovimagnetic secular variation have been inconclusive or ineffective for a number of reasons, including limited data usage, inadequate consideration of the external current disk field and the modelling approach taken. We attempt to resolve these issues by using all data available within 12 Jovian radii, establishing and removing the current disk field for each individual orbit and taking a regularised minimum norm approach to modelling the internal planetary field. This approach allows construction of numerically stable models with constrained small-scale (high spherical harmonic degree) structure that directly fit the observations. Two models of Jupiter's magnetic field are presented: the first time-averaged over the whole dataset, whilst the second allows for linear time variation of the field. Comparison of these allow inferences to be made about jovimagnetic secular variation with our favoured model indicating a $\sim$0.042%yr^{-1} decrease in the dipole magnetic moment over the investigated time period; this value is comparable with Earth ($\sim$0.06%yr^{-1}). Simple models of jovian "core flow", while highly speculative, also show patterns not dissimilar from those of the Earth.

These models are calculated with reference to the Jovian System III 1965.0 reference frame, itself defined by the magnetic field. Thus, some of the secular variation could result from inaccuracies in this determination; however, such an effect cannot explain all the observed secular variation. The constraint on changes in planetary rotation rate allow a bound to be placed on angular momentum transfer between the atmosphere and deep interior, as seen for variations in Earth's observed length-of-day. Using changes in zonal atmospheric wind structure, if the winds were to extend to depths only 2% into the planet, observed atmospheric changes between 1979-1996 would translate to a $\sim 10^\circ$ rotation of the planetary interior via angular momentum exchange, inconsistent with the magnetic observations. We thus provide strong observational evidence against models linking surface winds to deep Jovian convection, particular deep convection on cylinders.