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Anelastic dynamo models with radially varying conductivity: application to gas giants

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Observations of the two gas giants show that both planets have dipolar magnetic fields: Jupiter's is very similar to Earth's magnetic field and Saturn's is very axisymmetric. Our main goal is to construct realistic numerical models that explain these features.

While the small density jump across terrestrial iron cores allows to use the Boussinesq approximation, the picture is different for the gas giants. Here, the density decreases by a factor of around 5000 from the deep interior to the surface (1 bar level). Though most of this density jump is accommodated in the outer molecular envelopes, it may still be significant in the metallic dynamo region. Among other properties, the electrical conductivity also varies significantly with radius, being roughly constant in the metallic hydrogen region and decaying exponentially in the molecular envelope. We solve an anelastic numerical dynamo model (which differs from a fully compressible model by neglecting sound waves) to explore the effects of density stratification and electrical conductivity variation on magnetic field generation.

We use an anelastic version of the MHD code MagIC with density jumps up to 245 and an electrical conductivity that decays exponentially in the outer 10-20\% of the simulated shell. Previous simulations using constant conductivity showed that dipole dominated magnetic fields are only found up to a density jump of 6. An increasing stratification progressively confines the most active convective region close to the outer boundary equator. Mean field models have shown that such a configuration prefers non-axisymmetric modes. The exponential conductivity decrease helps by separating magnetic field generation from the dominant convective region.

For intermediate stratifications ($6 <$ density jump < 148), the dipole component clearly dominates during short periods. Stable strongly dipolar solutions are found when a large stratification (density jump > 148) more clearly separates the dynamo from the dominant convective region.