Highly Variable and Hemispherical Dynamo Simulations Pertinent to Uranus and Neptune

Voyager 2 measurements at Uranus and Neptune revealed that Uranus and Neptune have multipolar magnetic fields. This is often considered to be the result of vigorous convection in a thin, electrically conducting fluid shell (called the dynamo) close beneath the planetary surface. Recent high pressure and temperature experiments, molecular dynamics simulations, and ab-initio simulations suggest that the dynamo is likely composed of an ionic, volatile-rich fluid that lies above a thicker region of superionic material. Superionic volatiles have been shown to reach up to two orders of magnitude higher electrical conductivity than their ionic counterparts. We use this new constraint to run three-dimensional dynamo simulations representing Uranus and Neptune with thin, electrically and thermally-conducting fluid shells surrounding a solid inner core that ranges from equally to 100 times as electrically conductive as the fluid shell. We varied the fluid shell thickness and the ratio between electrical conductivities of the inner and outer core. Our simulations produce hemispherical dynamos that vary dramatically across time. We upward continued the simulated fields from various dynamo depths - this reveals that the magnetic field produced by a shallower(deeper) thin-shell dynamo does(doesn't) look hemispherical at the planetary surface, despite being hemispherical above the dynamo. The field morphology inferred from future Uranus orbiter data may thus be used to confirm whether Uranus holds a deep or shallow thin-shell dynamo. Also, time series of spherical harmonic modes in the spatial power spectra reveal that the simulated magnetic fields resemble Uranus' and Neptune's fields at short-lived time intervals but not stably across time. This indicates that we must develop a careful definition in order to evaluate when numerical simulations are indeed "ice giant - like".