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# Can We Tell the Inner Core Size and the Heat Flow Pattern inside a Planet from the Observed Magnetic Field?

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## 1. Introduction

Several distinct features of Saturn's magnetic field have been revealed in a recent study based on in-situ magnetic field measurements made by the Cassini spacecraft [1]. The field at the dynamo surface is found to be strongly concentrated near the spin-poles with little hemispherical asymmetry. This field geometry corresponds to a zig-zag shape magnetic spectrum with pronounced odd degree terms and all odd degree magnetic moments possess the same sign ($g_1^0$, $g_3^0$ and $g_5^0$ all be positive in this case). This is in contrast to the field properties at the outer core surface of the Earth, where the field near the spin-poles is at a relative minimum compared to field at mid-latitude (see Fig. 1). An anticyclonic polar vortex with upwelling flow inside the tangent cylinder (the tangent cylinder is an imaginary cylinder parallel to the spin axis and tangent to the inner core surface at the equator) has been inferred at the Earth's core surface from geomagnetic secular variation analyses [2]. The associated advective transport of magnetic field is like responsible for the typical minimum or inverse geomagnetic field at high latitudes and the pronounced flux patches at mid-latitudes. This feature is also frequently found in convectively driven geodynamo models [3].

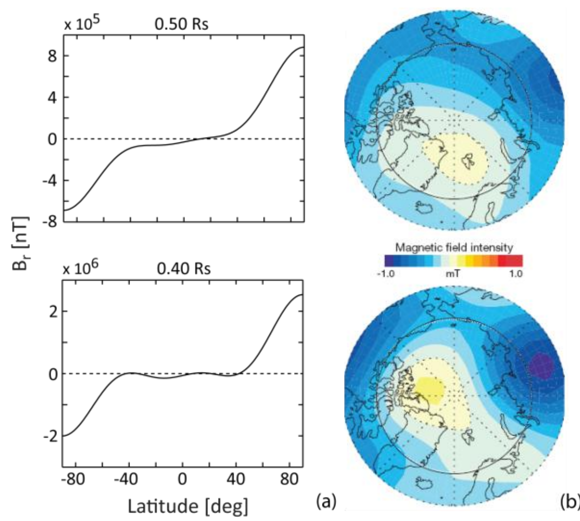


Figure 1: (a) The magnetic field morphologies at two possible Saturnian dynamo surfaces, with radial component plotted as a function of planetocentric latitude, show strong poleward flux concentration; (b) The morphologies of the geomagnetic field at epochs 1870 (upper panel) and 1990 (lower panel) at the northern hemisphere of the Earth's core, with radial component plotted on a polar projection, clearly show weak field regions at the spin poles [2]

## 2. Model Set-up

What roles do the inner core size and outer boundary heat flow pattern play in the dynamo process? Could the magnetic field properties observed at Saturn be used to reveal the inner core size and the heat flow pattern inside this planet? To answer these questions, we performed a series of numerical dynamo simulations. In all our dynamo models, the only energy source is the secular cooling of the planet.

Four inner core sizes, $\chi = 0.20, 0.50, 0.75, 0.90$ (here $\chi$ is the inner core to outer core radius ratio), and four outer boundary heat flux patterns, $-Y_0^0 - 0.00Y_2^0$, $-Y_0^0 - 0.23Y_2^0$, $-Y_0^0 - 0.50Y_2^0$, $-Y_0^0 - 0.89Y_2^0$ (here $Y_0^0$ and $Y_2^0$ are totally normalized spherical harmonics) are tested (see Fig. 2). A proportional uniform outward heat flow is applied at the inner boundary in each case.

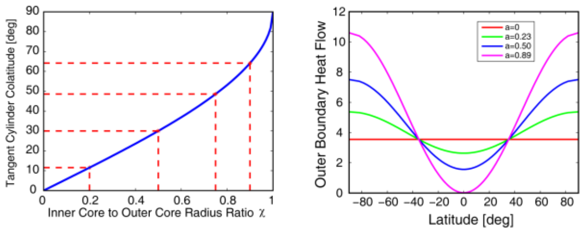


Figure 2: Tangent cylinder colatitude at the outer core surface as a function of inner core to outer core radius ratio $\chi$, and outer boundary heat flow patterns tested in this study

## 3. Results

Our numerical studies suggest that within the thick shell geometry ($\chi \leq 0.50$), both the inner core size and the outer boundary heat flow pattern contribute to determining the field geometry at the dynamo surface. With uniform outer boundary heat flux, the inner core size determines the size of the convective upwelling flow region and thus the polar magnetic field minima region. With a $Y_2^0$ type outer boundary heat flux pattern, zonal flow in the equatorial region is enhanced. The enhanced zonal flow removes the radial magnetic field in the equatorial region, to minimize the magnetic shear (Ferraro's law of corotation). As the amplitude of the $Y_2^0$ heat flux increases relative to the average heat flow, the dipole tilt also becomes smaller statistically.

## References

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