Magnetic Signatures from the Interiors of Jupiter and Saturn. H. Cao[1,2], C. T. Russell[1,2], and M. K. Dougherty[3], [1]Department of Earth, Planetary and Space Sciences, University of California, Los Angeles, CA 90095, USA, (haocao@ucla.edu), [2]Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095, USA, [3]Blackett Laboratory, Imperial College London, SW72AZ, UK.

Introduction: The gas giant planets, Jupiter and Saturn, not only played important roles in the evolution of our solar system but also are representative of many exoplanets of this type. Many similarities are shared by these two planets. The major composition of both planets are hydrogen and helium. In the atmosphere of both planets, helium mass ratios are found to be smaller than proto-solar value [1-3]; most of the measured heavy elements, other than neon, are found to be enhanced compared to the proto-solar value [4, 5]. Both planets emit as much as twice the power they receive from the Sun respectively [6]. Whether these two planets possess a central core and what is the mass and size of the core is still under debate given all the observational data [7-10].

Both Jupiter and Saturn possess global-scale magnetic fields. Dynamo actions in the convecting metallic hydrogen layers are believed to be responsible for these observed magnetic fields. Measuring and characterizing magnetic fields can enhance our understandings of the interior structures and dynamics of the host planets. Strength and morphology are two observable quantities to be used to characterize planetary magnetic fields.

Magnetic Field Observations: We will present our characterization of the intrinsic magnetic fields of both planets in terms of field strength, non-axisymmetry, secular variation, high-degree moments based on in-situ magnetic field measurements made by space missions (Pioneer 11, Voyager 1 and Galileo for Jupiter and Pioneer 11, Voyager 1 & 2 and Cassini for Saturn), traceable "ground" features – Auroral footprints of Io and Enceladus will also be considered. For Saturn, we find not only no evidence for any departure from axisymmetry [11] but also that the magnetic flux inside Saturn is strongly concentrated near the spin-poles [12], in contrast to the well-defined polar field minima observed at the surface of the Earth's core [13] and in geodynamo models. For Jupiter, the departure from axisymmetry is evident but currently available measurements cannot discern whether the magnetic fields at the polar regions of the dynamo surface are at maxima or minima. We postulated the effects of the geometry of the dynamo region, controlled by the size of a central core as well as the mode of buoyancy forcing, on the existence or absence of polar field minima regions and carried out numerical dynamo tests.

Solid-body rotation of the dynamo region can be monitored by the tracing the non-axisymmetric magnetic fields and radio emissions of Jupiter. A similar procedure has not yielded unambiguous results for Saturn due to the extreme axisymmetry of the magnetic field. Large-scale circulation (e.g. differential rotation) at the surface of the dynamo region of Jupiter will produce magnetic signals expressed as secular variations. We seek to put upper-bonds on the velocity of large-scale circulation at the surface of the dynamo region of Jupiter by comparing magnetic measurements made in the inner Jovian magnetosphere from different epochs.

Implications for the Interior Structures and Dynamics of Jupiter and Saturn:

Helium re-distribution likely has occurred inside both Jupiter and Saturn, as a result of the crossing of the adiabats and hydrogen-helium immiscibility curve. There exist two end-member scenarios of helium re-distribution inside Jupiter and Saturn: the first is a stably stratified layer atop the convecting metallic hydrogen layer while the second is a helium ocean at the bottom of the convecting metallic hydrogen layer (Fig. 1).

Jupiter's non-dipolar power likely becomes flat at 0.85 Rj. This coincides with the estimated molecular-metallic transition depth. Saturn's magnetic power spectrum, up to degree 5, only becomes flat near 0.4 Rs [12]. This is much deeper than the estimated molecular-metallic transition depth at 0.65 Rs.

Saturn's magnetic field properties, the weak strength of the field given the excess heat output, the extreme axisymetry, and the flatness of the spectrum at 0.4 Rs, can be reconciled with a stable conducting layer from 0.4 Rs to 0.65 Rs. Thus the scenario of helium re-distribution with a stably stratified layer atop the convecting metallic hydrogen layer is favored. However, heat transfer through such a thick layer needs to work out in a novel way.

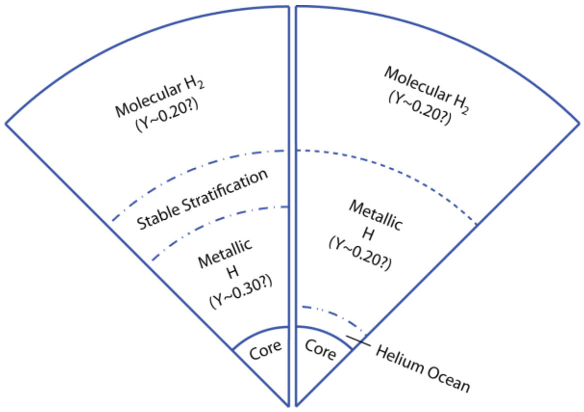

Figure 1. Two end-member scenarios of helium redistribution inside Jupiter and Saturn: a stably stratified layer atop the convecting metallic hydrogen layer and a helium ocean at the bottom of the convecting metallic hydrogen layer.

The absence of polar magnetic minima inside Saturn can be explained by a relatively small central core inside Saturn. The magnetically cleared equatorial region inside Saturn could result from "strong" equatorial zonal winds near the surface of the dynamo region.

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