INTERIOR STRUCTURE OF WATER PLANETS: IMPLICATIONS FOR THEIR DYNAMO SOURCE REGIONS. B. Y. Tian[1] and S. Stanley[2], Department of Physics, Univ. of Toronto, McLennan Physical Laboratory, 60 St. George St., Toronto, ON, CAN M5S 1A7 ([1]ytian@physics.utoronto.ca, [2]stanley@physics.utoronto.ca,)

Introduction: With the growing number of extrasolar planets being discovered, a new population has emerged, bridging the gap between Earth-massed terrestrial planets and Neptune-massed giant planets.

Compositional modeling of some of these planets based on their mass-radius relationship suggests an enrichment of heavy elements (C, N, O) [1], with metallicity more similar to Uranus and Neptune rather than to Jupiter or Saturn. Thus, like Uranus and Neptune, the interior of these bodies are thought to consist of a mixture of water (H_2O), ammonia (NH3) and methane (CH4) `ices' (the term `ices' is intended to specify the composition rather than a specific phase of the material). The class of water-rich, sub-Neptunian to Neptunian-massed `ice' giants with short-period orbits represents a new parameter space for many aspects of planetary science, including the study of planetary dynamos.

In this study, we explore the geometry of the dynamo source region within this parameter space using 1-D interior structure models.

Methods: We model planets with 4 chemically distinct layers that consist of (1) an iron core, (2) a silicate layer, (3) an H_2O layer, and (4) an H/He envelope. The calculations to generate the 1D interior structure models are similar to that of Rogers et al. (2011) [2]. This was done by integrating the equations of hydrostatic equilibrium, mass conservation, and equations of state for each material layer from the surface of the planet down to its center in mass coordinates.

We use the SCvH equation of state [3] to calculate the density of the H/He layer. We use the first-principle equation of state of water from French et al. (2009) [4]. For the iron and silicate core, we use a polytropic equation of state from Seager et al. (2008) [5] as an approximation.

By varying the total planetary mass (M) in the range of 1 - 19M_{Earth}, the mass fraction of the H/He envelope (χ) between 0.1 - 5.1%, and the equilibrium temperature (T_{eq}) between 100 - 1000 K, a survey of the parameter space is conducted for potential dynamo source region geometries (determined by the location of electrically conductive fluid phases of H_2O [4]).

Results:

Temperature Profiles: We find that varying the equilibrium temperature has little effect on the temperature profiles in the deep interiors of the planet. Also, increasing the mass of the H/He envelope heats the interior of the planet at a particular pressure, while increasing the total planet mass cools it. These are illustrated in Figure 1.

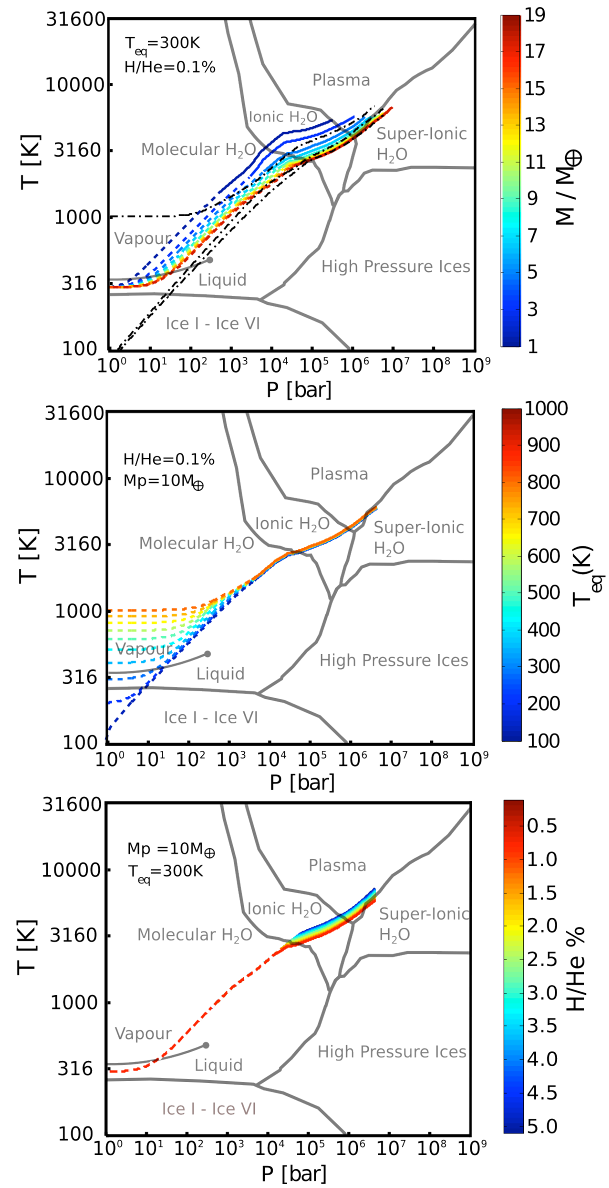

Figure 1. The temperature profiles in T-P space for planets with varying mass (top), Teq (middle), and H/He mass fraction (bottom). Dashed parts of the temperature profiles correspond to the hydrogen layer, and all of the profiles end at the outer boundary of the rocky cores.

Dynamo Source Fraction: Assuming that the dynamo source region is the combination of ionic and plasma layers, we define a quantity *f* as the ratio of the total thickness of dynamo generating layers to the outer radius of the dynamo source region. This gives us a proxy for whether the dynamo is operating in a thick-shelled or a thin-shelled regime.

We find that equilibrium temperature again has very little effect on the interior structure. On the other hand, increasing the total mass can cool the planet's temperature profile below the plasma-ionic-superionic triple-point (this can be seen in Figure 1). This causes the bulk interior of the planet to sit in the superionic phase. Since superionic water was not defined to be a dynamo generating source (see [6] for reasoning), the planet's *f* value decreases drastically during this regime shift.

The regime shift from thick-shell (high *f*) to thin-shell (low *f*) dynamo source geometry also occurs when the H/He mass fraction decreases. A summary of these results is shown in Figure 2.

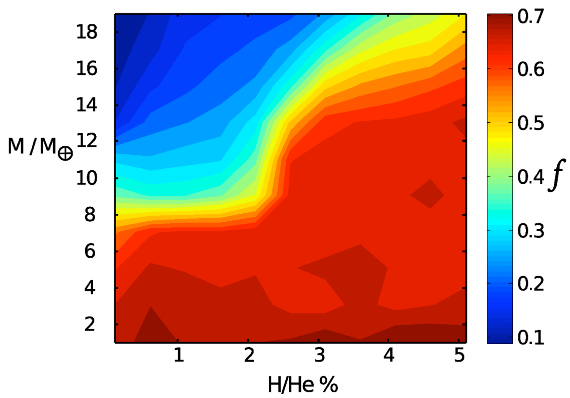

Figure 2. Relative thickness of the dynamo generating layer to the total radius of the dynamo source region *f* contoured over mass and H/He %.

Interior Structure: A summary of the interior structure as we vary the total mass, equilibrium temperature and H/He envelope mass fraction is displayed in Figure 3.

Discussion: In our solar system, water-rich giant planets Uranus and Neptune exhibit a non-axisymmetric, non-dipolar magnetic field, in contrast to the axial-dipole dominated fields produced by other solar system dynamos. The geometry of the dynamo-generating layer of Uranus and Neptune likely explains this difference. Specifically, numerical simulations have demonstrated that a dynamo generated in a thin convecting shell of ionically conductive water phase, surrounding a stably stratified layer can reproduce the unique magnetic field morphologies of the ice giants [7]. In contrast, the thick-shell geometries for the dynamo regions of Earth, Jupiter and Saturn appear to promote more axial-dipolar magnetic fields in these planets.

The models in this study suggest that small planets ($M < 5M_{Earth}$) and planets with a high abundance of H/He ($\chi > 2.5\%$) are likely in the regime of a thick-shelled dynamo. Massive planets ($M > 10M_{Earth}$) and planets with a low abundance of H/He ($0.1\% < \chi < 2.5\%$) are likely to be in the regime of a thin-shelled dynamo.

This is important for potential observations of exoplanetary magnetic fields and their properties through the detection of radio emissions from these bodies. Such observations will also be a factor in the assessment of a planet's habitability.

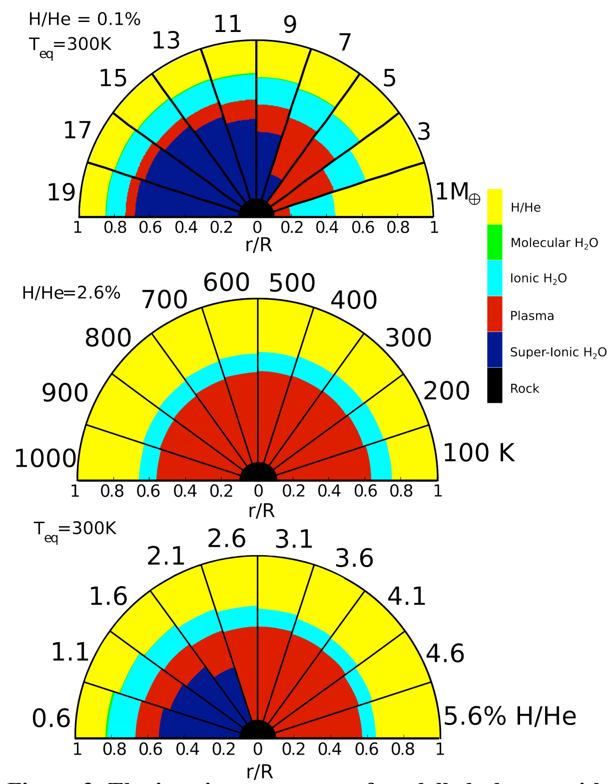

Figure 3. The interior structures of modelled planets with varying mass (top), equilibrium temperature (middle), and H/He mass fraction (bottom), while holding the other two parameters constant. When mass is held constant, it is at 10 M_{Earth}. Each wedge is normalized to its own radius. The actual planet radius varies between the models but is not represented in this figure.

References: [1] Adams E. R. et al. (2008) *ApJ, 673,* 1160. [2] Rogers L. A. et al. (2011) *ApJ, 738, 59*. [3] Saumon D. et al. (1995) *ApJ,* 99, 29. [4] French. M. (2009) *Phys. Rev. B., 79, 054107*. [5] Seager. S. et al. (2007) *ApJS, 669, 1279*. [6] Redmer. R. et al. (2011) *Icarus, 211, 6*. [7] Stanley. S. and Bloxham J. (2004) *Nature, 428, 151*.