

# Laboratory Planetary Physics Using Intense Heavy Ion Beams

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The Giant planets in our solar system are fascinating objects and investigation of their structure is a problem of fundamental scientific interest. Using the improved set of gravitational moments provided by the Voyager, new models have been developed for the distant planets Uranus and Neptune [1]. The two planets are believed to have very similar structure. Fig.1 shows a cross-sectional view of Neptune based on such models and it is seen that it has an atmosphere of hydrogen and helium while its surface consists of a thick layer of ice which has a temperature of 5000 K, a pressure of 3 Mbar and a density of about 4 g/cm<sup>3</sup>

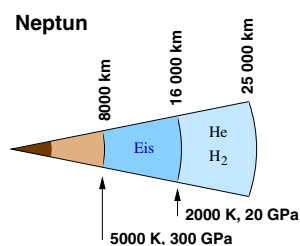


Figure 1: A Model Picture of Neptune.

Figure 2 shows a phase diagram of water under those planetary conditions which is obtained by ab initio Car-Purinello molecular dynamics simulation [2].

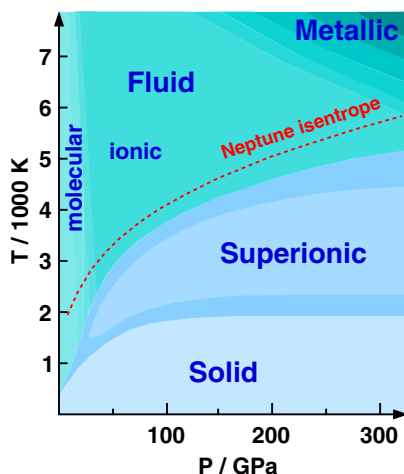


Figure 2: A Phase Diagram of Water

In a previous publication [3] we showed that one may use an intense heavy ion beam to implode a hydrogen sample that is enclosed in a multi-layered cylindrical target to extreme physical conditions that are found in the interior of Jupiter. In this contribution we have used the same target design that consists of a solid cylindrical lead shell that is filled with water. One face of the cylinder is irradiated with an intense heavy ion beam which has an annular focal spot. This avoids direct heating of the sample material by the beam. The lead material around the sample material is heated and the high pressure generated in the heated

region implodes the sample material quasi-isentropically.

Using a two-dimensional hydrodynamic computer code we have carried out simulations of implosion of the above target using a high intensity uranium beam with a particle energy of 1 GeV/u and a pulse duration of 50 ns. For the beam intensity,  $N$ , we use three different values, namely,  $5 \times 10^{11}$ ,  $10^{12}$  and  $2 \times 10^{12}$  respectively. These beam parameters correspond to the future SIS-100 beam. The results are plotted in Figs.3 and 4. where we plot the density and pressure at the time of maximum compression vs radius at the middle of the cylinder in the sample region (ice). It is seen that using the above beam intensity range one can achieve a density of 4 - 6.5 g/cm<sup>3</sup>, a pressure of 2 - 12 Mbar while the corresponding temperature range is 2000 - 10000 K. Using the future SIS-100 beam one can therefore access the entire phase diagram of water shown in Fig.2.

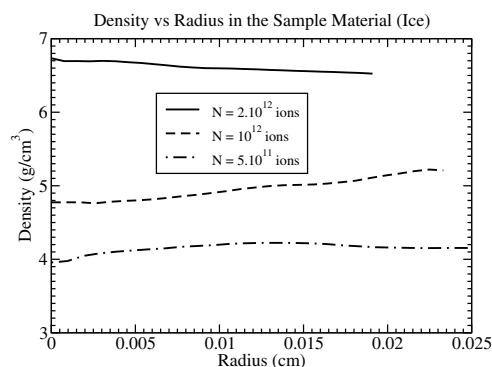


Figure 3: Density vs Cylinder Radius at the Time of Maximum Compression Using Different Beam Intensities,  $\tau=50$  ns.

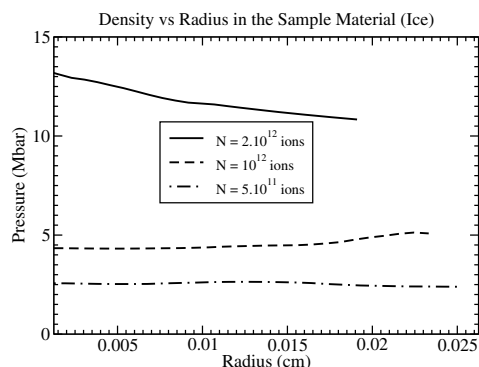


Figure 4: Pressure Profiles Corresponding to Fig.3

## References

- [1] M. Podlak et al., Planet. Space Science 43 (1995) 1517.
- [2] Carlo Cavazzoni, PhD Thesis, Int. School for Adv. Studies, Rome (1998)
- [3] N.A. Tahir et al., Phys. Rev. E 63 (2001) 016402.