Interior models of Jupiter, Saturn and Neptune

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Interior model calculations of Jupiter, Saturn and Neptune require EOS-data of hydrogen, helium and water in the regime of *warm dense matter*. In case of Saturn, the pressure in the deep interior rises up to 15 Mbar at 6000-10000 K and a hydrogen mass fraction of at least 40%. In Jupiter, due to his larger total mass compared to Saturn, the high-pressure region is more extended with pressures up to 40 Mbar at 15000-22000 K and a hydrogen mass fraction of at least 60%. In Neptune, icy condensates from the protosolar cloud provide the main component with pressures up to 8 Mbar at 5000-6000 K. Precise values depend on error bars of observational contstraints and on the equation of state (EOS) used for modeling. The lack of consistency of models of Jupiter with these constraints has been a longstanding problem which imposes strong conditions on the H-EOS [1, 2]; the only successfully applied so far is that of [3].

We have developed an alternative H-EOS based on QMD-simulations [4]. First preliminary results are promising, but the temperature profiles of Jupiter and Saturn turn out to be several thousand degrees colder than previous results [5]. Most of the models require a core of heavy elements like rocks or ices. Since the true composition and size of the core is unconstraint by observations, we have applied QMD-data for water to the cores of Jupiter and Saturn. Under typical conditions for the deep interior as described above, water in the core region of Jupiter would form a plasma that probably dissolves in the fluid envelope. With water being the least volatile condensate compared with methane and ammonia, we predict Jupiter's core to consist purely of rocks in contrast to previous estimates [1, 5]. On the other hand, water in the core region of Saturn would form a superionic lattice of oxygen atoms with protonic conductivity [6]. Assuming the standard three layer structure of Giant Planets [5], i.e. two fluid convective envelopes of different composition above a solid core, the size of the core depends on the choice of the transition pressure between the envelopes, see fig. 1. Choosing the experimentally identified transition from an isolating to a conductive metallic fluid at about 1.4 Mbar [7], the uncertainty in our calculations reduces to 1-4 M_E depending on the precise value of the gravitational moment J_4 and the composition of the core material. Using old data from the Pioneer and Voyager missions, a transition pressure as high as 1.4 Mbar is not possible because of the strongly decreasing core mass with transition pressure.

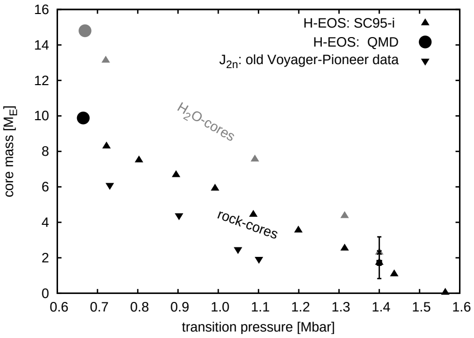

Figure 1: Core mass of Saturn using different H-EOS, transition pressures and J_4 values.

For the model of Neptune shown in fig. 2 we reduced the number of components to the main constituents H_2O, H, He and a rocky core. For the outermost region below 1000 K we used experimentally well proven data of H_2O [8]. Between 1000 and 2000 K we applied Sesame data table 7150. In the warm dense matter regime for temperatures higher than 2000 K we applied QMD data of H_2O. In this regime, water undergoes a transtion from ionic dissociated molecules to the superionic phase at about 2 Mbar and 3500 K [6].

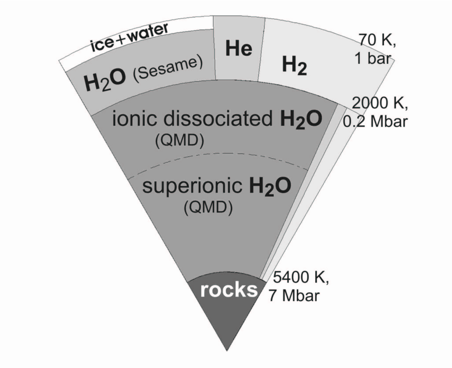

Figure 2: Interior model of Neptune.

We conclude that the deep interior of Saturn and most of the interior of Neptune contains superionic water. QMD simulations of hydrogen and helium [9] may start up the next generation of interior models of Jupiter and Saturn.

References

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