Joint Astronomy / EPS Colloquium
March 15, 2007
Tea: 3:30pm, Astronomy Lounge, 6th floor
Colloquium: 4:00pm, 1 Le Conte

BURKHARD MILITZER

GEOPHYSICAL LABORATORY
CARNEGIE INSTITUTION OF WASHINGTON

APPLICATION OF QUANTUM MECHANICS TO UNDERSTANDING THE INTERIORS AND EVOLUTION OF PLANETS

The discovery of the first extrasolar planet a decade ago opened a new chapter in planetary research, which has been characterized by great improvements in observational techniques and a rapidly expanding set of known extrasolar planets. Most of the over 200 discovered planets are gas giants that revolve around their parent star on much smaller orbits than are common in our solar system. The existence and properties of these so-called hot Jupiters have challenged our understanding of the formation process of solar systems. Also, in our solar system, a number of fundamental questions have remained unanswered. These include, e.g., whether Jupiter has a rocky core that served as a seed for the accretion of the gas envelop, or, alternatively, whether the planet was formed without a core by gravitational instability.

We report results from recent investigations of Jupiter's interior structure using state-of-the-art computer simulations of dense fluid hydrogen and helium that span the conditions in the planet's interior with a grid of temperature and density points. It will be explained how these simulation techniques are derived from the fundamentals of quantum mechanics and how they determine the planet's interior structure.

Our interior models update the suite of models that were based on the widely used Saumon-Chabrier-Van Horn (SCVH) equation of state (EOS) for hydrogen and helium. The calculated deviations from SCVH are approximately +/- 5% depending on the pressure. Our updated model predicts that Jupiter has a core of about 15 Earth masses, which is primarily a result of the pressure correction in the regime of metallic hydrogen. Using additional simulations, we demonstrate that planetary ices are not stable in metallic hydrogen and can therefore not contribute to Jovian cores.

Furthermore, we compare our EOS results with shock wave measurements, which are the primary experimental technique to study materials at megabar pressures and thousands of degrees Kelvin. We make predictions for future shock experiments and explain why hydrogen and helium behave very differently under shock compression. Our results will eventually aid in interpretation of data expected from the NASA's Juno orbiter mission.