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Recent Progress in Planetary Exploration

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Jupiter After the Galileo Probe

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The Galileo Mission to Jupiter, which arrived in December of 1995, provided the first study by an orbiter, and the first in-situ sampling via an entry probe, of an outer planet atmosphere. The rationale for an entry probe is that, even from an orbiter, remote sensing of the Jovian atmosphere could not adequately retrieve the information desired. This talk provides a current summary of the most significant aspects of the data returned from the Galileo entry probe. As a result of the probe measurements, there has been a reassessment of our understanding of outer planet formation and evolution of the solar system. The primary scientific objective of the Galileo probe was to determine the composition of the Jovian atmosphere, which from remote sensing remained either very uncertain, or completely unknown, with respect to several key elements. For example, the O abundance, in the form H_2O, was uncertain by two orders of magnitude. Only a highly depleted upper abundance limit obtained near the 1 bar pressure level was known for S, and abundances of noble gases heavier than He were unknown. The probe found that the global He mass fraction is significantly above the value reported from the Voyager Jupiter flybys but is slightly below the protosolar value, implying that there has been some settling of He to the deep Jovian interior. The probe He measurements have also led to a reevaluation of the Voyager He mass fraction for Saturn, which is now determined to be much closer to that of Jupiter. The elements C, N, S, Ar, Kr, Xe were all found to have global abundances approximately 3 times their respective solar abundances. This result has raised a number of fundamental issues with regard to properties of planetesimals and the solar nebula at the time of giant planet formation. The global abundance of O was not obtained by the probe because of the influence of local processes at the probe entry site (PES), processes which depleted condensible species, in this case H_2O, well below condensation levels. Other condensible species, namely NH_3 and H_2S, were similarly affected but attained their deep equilibrium mixing ratios before the maximum depth sampled by the probe. Processes that might be capable of producing such effects on the condensibles are still under investigation. Measured isotopic ratios of noble gases and other heavy elements are solar, and (D + 3He)/H is the same to within measurement uncertainties as in the local interstellar medium. No thick clouds were detected, and in particular no significant water cloud, but the PES location clearly affected the probe measurements of clouds. In fact, the probe data must be understood in the context of the location of the PES, which was

within what is termed a 5 μm hot spot, a local clearing in the clouds that is bright near the 5 μm spectral region. The thermal structure at the PES was determined from approximately 1000 km above the 1 bar pressure level (10^{-9} bars) to 132 km below 1 bar (22 bars). Probe measurements showed the atmosphere to be generally stably stratified as deep as the probe made measurements, with a typical static stability of $\sim$0.1 K km^{-1} at and below visible cloud levels. In the upper atmosphere the probe derived a maximum positive vertical temperature gradient of approximately 5 K km^{-1}, and maximum temperature of $\sim$900 K. The energy sources producing the warm upper atmosphere have yet to be completely identified. At first glance, Doppler tracking of the probe indicates that the long observed cloud level zonal winds extend to levels at least as deep as the probe made measurements. Zonal wind increases from $\sim$80 m s^{-1} at pressures less than a bar to about 180 m s^{-1} near 5 bars, and remains approximately constant with depth thereafter. However, there is a question as to whether the winds measured from probe tracking are representative of the general wind field, or are considerably influenced by localized winds associated with the PES.