N92-10838

CHARGED-PARTICLE INDUCED ALTERATIONS OF SURFACES IN THE OUTER SOLAR SYSTEM

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Solar system surfaces unprotected by an atmosphere can be modified by plasma bombardment. This is one aspect of planetary surface weathering. This knowledge can be used to establish the age of the surface layer and the rates for geologic processes. The list of possible irradiation effects is long and, indeed, the list is likely to be increased as the data on Uranus, Halley, and Pluto are further analyzed. In addition there is the renewed interest in the lunar surface for which plasma effects are well documented but only partially understood. In this work we make accurate assessments of surface of objects for which relevant laboratory information on irradiation effects is available or can be successfully extrapolated. Until sample return missions are possible, the limitations of observations to the outer layers of solid objects requires careful evaluation of the surface modifications which can affect interpretations of remote sensing data. Irradiation effects have been used to account for many initially uncertain observations, and often these initial guesses have been wrong. Our modelling, therefore, provides an important constraint and much of the recent work has been summarized in a monograph Energetic Charged-Particle Interaction.

In the previous we have placed strong emphasis on describing the plasma interaction with possible Io surface constituents SO_2, sulfur, and Na_2S in order to interpret polar darkening by radiation and ejection of species into the atmosphere and torus. More recently we have calculated the plasma bombardment profiles of the surfaces of the icy Saturnian satellites to interpret reflection spectra and the effect of charged particles on the surfaces (mantles) of Pluto and of comets in the Oort cloud.

Pluto's exposure to cosmic rays results in a slow alteration of the reflectance of the methane condensed on its surface and the UV absorbed in the atmosphere can produce precipitates. We showed that, depending on the rates of the competing regolith processes and the rates for replenishment of the methane, the surface can appear bright, 'red', or 'dark'. Using laboratory data we showed that the amount of darkening occurring in one orbit is small. Therefore, transport, burial and re-exposure of organic 'sediments' must control the reflectance, and the average reflectance is established by the radiation altered species accumulated over many orbits with the observed spatial, and possibly temporal, differences in albedo due to transport. The cosmic rays although producing changes in reflectance slowly, do so inevitably. Therefore, the fact that the surface is not dark everywhere implies that it is active and the exposure rates vs. depth into the surface given in the paper on Pluto can be used to constrain turnover rates.

Comets in the Oort cloud experience similar effects. This irradiation processing occurs in competition with a number of surface alteration processes evaluated by Stern. We have corrected the many different estimates of cosmic ray dose that have led to 'primordial' mantles varying from 50 m to a few cm. These discussions are summarized in a review chapter in the Bamburg proceedings and in an article in the proceedings of the Milipitas conference on the Rossetta mission. Because a sample return is being proposed and because CRAF was to have a penetrator the thickness of the primordial crust is important. Recently we have used experimental data to show that this crust should survive the thermal shock of the comet's entrance into the inner solar system.

Our most recent efforts has been to develop analysis for determination of satellite surface composition from local plasma measurement by Cassini and the proposed Lunar orbiter. The coupling between the ions in lunar corona with the composition of the local surface indicates unique surficial information is available from the plasma measurements. Directly sputtered species or species ejected by micrometeorites were shown to give a corona indicative of the average composition of the moon's surface. Similarly, at Saturn the plasma instrument may be the most hopeful for determining trace species in the surfaces of the icy moons.

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