Far Ultraviolet Spectroscopy of Rhea

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Introduction
Rhea is Saturn’s second largest moon and has been subject of several flybys in the Cassini-Huygens mission. Rhea is an ice covered moon that orbits Saturn with a velocity that is slower relative to the co-orbiting plasma generated in Saturn’s magnetosphere. Thus, the moon’s trailing hemisphere is preferentially irradiated by plasma and cold ions while the leading hemisphere is irradiated with neutral particles and possible E-ring material.

Rhea is an Exogenic Environment

Experimental Results
Vacuum-UV spectra of ice films were recorded at a temperature of ~70K under ultra high vacuum conditions under a joint agreement between the PRl (India), NSRRG (Taiwan) and The Open University (UK). The laboratory vacuum-UV spectra were measured in transmittance mode and subsequently converted to absorbance spectra. Data were deposited into the AstroChemical Ices Database (ACID) at https://www.ptf.res.in/~dinesh/acid/

The derived absorbance measurements were then used to calculate the absorption cross-section and, using the optical constants for chemical species, model spectra were generated. The modelled spectra of water-ice, various organics, halogens, and alcohols suspected to exist on the surface of icy satellites in the outer solar system were then compared to the observed UVIS spectra.

The UVIS/FUV spectra were calibrated to radiance units, followed by division by the solar irradiance, scaled to the distance of Rhea from the Sun. The final UVIS spectra are in units of I/F: I/F is the ratio of measured radiance to solar irradiance scaled by a factor of pi, and is unitless. It is the reflectance measured by the instrument.

The UVIS far-UV spectra on both hemispheres on Rhea can be modelled using both hydrazine monohydrate and a layer of tetrachloromethane below water-ice. Hydrazine monohydrate (H$_2$N$\cdot$H$_2$O) can be produced from reactions among water-ice and ammonia:

H$_2$O$_{\text{cellular ice}}$ + NH$_3$ → H$_2$N$\cdot$H$_2$O

An alternative possibility is that hydrazine could be produced in the atmosphere of Titan (rich in nitrile compounds), and is then transferred inward towards Rhea.

Tetrachloromethane (CCl$_4$) can be produced from the following chemical reactions:

CCl$_4$ $+$ O$\cdot$ $\rightarrow$ CH$_2$Cl$_2$ $+$ HCl

The source of Cl$_4$, could originate from a deep subsurface ocean layer inside Rhea, where migration of the chlorine occurs through cracks in the ice. An alternative explanation is an exogenic source of chlorine from impacts of chondritic bodies over the history of Rhea. However, the presence of chlorine on Rhea is more difficult to explain, since no evidence of current endogenic activity exists on Rhea. Evidence for past endogenic activity on Rhea does exist in the form of geomorphological evidence. If minor amounts of ammonia exist on Rhea, then it is far easier to explain the presence of hydrazine monohydrate on Rhea than chlorine compounds.

Conclusions
The first detailed geochemical survey of Rhea’s icy surface in the far-UV region indicates the possible presence of chlorine compounds or hydrazine monohydrate, or possibly both chemical species.