ULTRAVIOLET SPECTROSCOPY OF THE OUTER SOLAR SYSTEM

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This talk will focus on the information to be gained through UV reflectance spectroscopy of atmospheres in the outer solar system. Here, we are concerned with the spectral region below 3000 Å, where many interesting molecular species have significant absorption cross sections, and observations must be made from sounding rockets or space-based observatories. With the exception of a few important rocket measurements the bulk of the observations in this region to dat have been made with the Voyager spacecraft and IUE observatories. The Voyager Ultraviolet Spectrometer (UVS) measurements offer the advantage of relatively high spatial resolution while IUE permits repeated measurements over a long time base. HST will combine both features and should led to a significant advancement in our understanding of outer solar system atmospheres.

Figure 1 shows the pressure of optical depths 1 and 3 in a H_2/He Rayleigh scattering atmosphere as a function of wavelength for the planet Uranus. Inspection of the figure reveals that UV radiation is scattered between 1 and 100 mbar, essentially the entire stratosphere. Similar curves apply to Saturn and Neptune while the figure can be adapted easily to Jupiter by scaling the pressures upward by a factor of 2.5. Impressed upon the Rayleigh scattering background are the absorption signatures of minor species, which in the outer solar system atmospheres are hydrocarbons of various sorts. Absorption processes in the UV typically lead to dissociation of the molecule consequently the UV spectra of a planet provides a window into photochemical processes in the stratosphere. Through analysis of the UV spectra it is possible to infer the abundance of absorbing constituents at one or more pressure levels in the atmosphere and thereby constrain models for the production and distribution of these species. Adequate data for cross sections is essential for this activity.

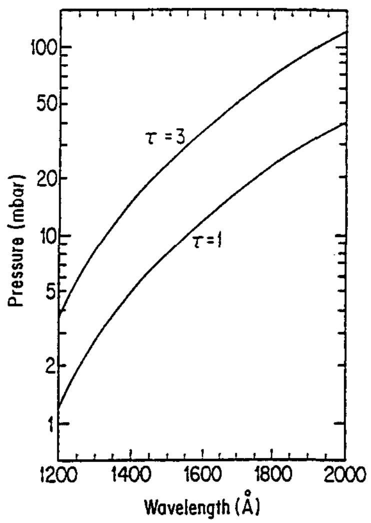

FIG. 1. The variation with wavelength of the $\tau = 1$ and $\tau = 3$ pressure levels for Rayleigh–Raman scattering. The calculations use a gravitational acceleration of 900 cm sec^{-1} and a H_2 mixing ratio of 0.85 to convert from column density to atmospheric pressure. The pressure levels between 1 and 30 mbar are most important in the UVS wavelength region.

A problem common in many aspects of outer solary system aeronomy is that the atmospheres tend to be colder than a typical terrestrial laboratory. For this reason, important

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data on atomic and molecular processes is often available at room temperature but not at the more relevant low temperatures. Some recent progress on this problem has been made by Smith *et al.* (1991) and Wu *et al.* (1989), who measured the C_2H_2 absorption cross sections from 1470 Å to 2010 Å. Differences on the order of 50 to 100 % are found at wavelengths below 1550 Å and above 1900 Å. Similar effects might be expected for several other molecules, including C_2H_4, and C_4H_2, but data at low temperatures are lacking.

Titan possesses by far the most complex atmosphere in the outer solar system. Inspection of Table V in Thompson *et al.* (1991) reveals the large number and variety of minor species detected to date and others which are expected to be present. The only analysis of the UV albedo of Titan is the work of Courtin *et al.* (1991), which is based on IUE observations. According to Courtin *et al.* most of the absorption in the FUV is due to small, sub-micron particles which they call polymers. Courtin *et al.* do place useful upper limits on the abundance of various gaseous species. Courtin *et al.* had to degrade the spectral resolution of their observations to enhance the signal-to-noise ratio and it is possible (and perhaps likely) that higher quality data would reveal the presence of gaseous absorbers. In my opinion there are hints of such absorption in the IUE spectra. On Titan, more so than the Jovain planets, analysis of the UV spectra is hampered by the lack of adequate data on absorption cross sections. Progress is being made in this area (Bruston *et al.* 1991) but several important cross sections are poorly known. For example, although the spectral shape of C_6H_2 and C_8H_2 have been measured (Kloster-Jensen *et al.* 1974), absolute values for the absorption coefficient are unavailable.

In summary, analysis of the ultraviolet reflection spectra of the atmospheres in the outer solar system is an important techniques for the study of the stratospheres of these planets. In many ways UV spectroscopy is complementary to IR emission spectroscopy, which is sensitive to many of the same molecules but generally at modestly different pressure regimes. Adequate cross section data is available for some, but not all, of the important constituents. Low temperature measurements are particularly useful.

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