NEW INSIGHT INTO THE PHYSICAL STATE OF SOLAR SYSTEM OBJECTS*

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ABSTRACT

The application of IUE to observations of solar system objects is summarized and a brief survey of new discoveries made during the first two years of IUE operation is given.

INTRODUCTION

The successful launch and operation of an earth-orbiting ultraviolet telescope facility such as IUE provides a new tool to the planetary astronomer with many features not available in earlier satellite observatories. The use of IUE for solar system observations in the first two years of operation has been directed at a wide variety of problems concerning planets, satellites, asteroids and comets. We present here a brief overview of some of the discoveries in this area made to date, with particular emphasis on the utilization of some of the unique capabilities of IUE. More detailed discussion of some recent results can be found elsewhere in the symposium proceedings.

There are several advantages to using IUE for solar system observations. Perhaps the most important is the ability to make synoptic observations over a rather long baseline in time in order to determine the response of a planetary atmosphere to the variability in the solar ultraviolet or particle output or to study the large-scale weather pattern in the lower atmosphere of a planet. This type of information is not obtained from the ultraviolet "snapshot" taken by rocket experiments or planetary flybys, and in the case of HI Lα observations of Jupiter, discrepant brightness values obtained by a variety of rocket and flyby experiments during a 10-year period were only recently recognized as being indicative of a true temporal variability (ref. 1). IUE also allows for spatial imaging in the ultraviolet with $\approx$5" resolution using the large spectrograph apertures, and larger scale spatial features can be mapped by offsets of the apertures. The wide spectral range of the IUE spectrographs and the dual dispersion capability allows for comprehensive, simultaneous observations of a large number of related species in a planetary atmosphere, and provide vital, correlative information to complement ultraviolet instruments on planetary flybys and probes such as Voyager or Pioneer Venus Orbiter. Finally, we note the opportunity to increase our knowledge of the ultraviolet spectra of comets many-fold and in a systematic manner to study their time evolution over a large range of

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heliocentric distance. Two moderately active comets have been observed to date (Seargent, 1978m and Bradfield, 1979ℓ) and it is to be hoped that a giant comet like Bennett (1970II) or West (1976VI) might make an apparition during the lifetime of IUE.

There are observing difficulties encountered when using IUE for solar system objects due to the original design of the satellite to allow for observations of the entire range of astronomical objects and these will be mentioned briefly to indicate the problems faced in observing these targets. These include saturation of the Fine Error Sensor (FES) on nearly all of the planets; the need for an accurate spacecraft-centered ephemeris for moving targets; long-wavelength scattered light in the short wavelength spectrograph camera due to the use of a non-solar blind photocathode; and the 45° solar avoidance cone which constrains observations of Venus and comets. Despite these difficulties, the first two years of IUE have witnessed many new discoveries that have made IUE a primary tool in solar system research.

BRIEF SURVEY OF RESULTS TO DATE

The results presented here are not meant to be a complete summary of all solar system observations but rather a sampling of highlights which illustrate the utility of IUE for these studies. Reference is made only to work that has been published or submitted for publication or is included in this symposium.

Saturn

The traditional method of determining the composition of a planetary atmosphere is illustrated by the detection of acetylene (C_2H_2) in absorption in the spectrum of reflected sunlight near 1750 Å from Saturn (ref. 2). Acetylene was previously identified in the far-infrared spectrum of Jupiter and also appears in IUE spectra of Jupiter (ref. 3). For both planets, the relative abundance of C_2H_2 is determined and found to be consistent with recent photochemical models. Saturn also has been found to exhibit an asymmetrical distribution of HI Lα emission similar to what is observed for Jupiter (ref. 4).

Jupiter

The spatial imaging capability of IUE is beautifully illustrated by the photowrite images of aurora in the north and south polar regions of Jupiter given by Clarke et al. in this volume (ref. 5). In this case three exposures were taken with the large aperture of the short-wavelength spectrograph on the center of the planet and offset by ≈20" towards each of the poles. Enhanced emission of HI Lα and strong emission in the Lyman bands of H_2 near 1600 Å is seen in the polar regions but not near the equator or at mid-latitudes. The spectrum of the Jovian aurora is very similar to that observed by Voyager (ref. 6), and provides a means of remotely monitoring the magnetospheric activity of Jupiter with time. Jupiter also exhibits an asymmetry in HI Lα emission near the equator which has also been observed by Voyager and by a rocket experiment (ref. 1). The longitudinal variation and temporal behavior of this bulge has been studied by IUE (ref. 4).

One of the most exciting discoveries of the Voyager flybys is the intense volcanic activity of the satellite Io. Ultraviolet observations of the plasma torus associated with Io (ref. 6) show it to be composed of ions of sulfur and oxygen and the ion temperature and density can be deduced from the relative intensities of lines of different stages of ionization, such as SII and SIII which are observable with the IUE short-wavelength spectrograph (ref. 7). The surface of Io shows marked variation in ultraviolet albedo with phase, presumably due to differences in SO_2 frost on the surface in areas of recent volcanic activity.

Mars

IUE observations of Mars have focussed on the seasonal variability of atmospheric ozone first detected by the Mariner 9 orbiter (ref. 8).

Venus

Due to the constraint of a 45° solar avoidance cone, Venus can be observed only during a short period around the time of greatest elongation at which time the disk is roughly half illuminated. Because of its proximity to earth, tracking of Venus by the satellite is extremely difficult and the FES is hopelessly saturated. Orientation of the spectrograph slits on the illuminated half of the disk is accomplished by minimizing the extent of spill-over in the FES camera. High dispersion observations of the bright side have been used to determine the abundance of SO_2 in the Cytheran atmosphere (ref. 9) and to help identify $L\alpha$ induced fluorescence of CO fourth positive bands as an additional source of emission in low resolution spectra of the atomic oxygen multiplets at 1304 and 1356 Å (ref. 10).

By offsetting from the illuminated portion of the disk to the dark side, low dispersion spectra of the nightglow, first observed by photometers on Mariner 5 and more recently by the ultraviolet spectrometer on Pioneer Venus Orbiter, were obtained. Although severely contaminated by scattered light from the illuminated side of the disk, these spectra were used to identify the nightglow emissions as the δ-band system of nitric oxide produced by the radiative attachment of nitrogen and oxygen atoms (ref. 11). This identification was subsequently verified by the Pioneer Venus Orbiter UVS which was then able to use these emissions to study the transport of atomic nitrogen across the terminator to the night side (ref. 12).

Comets

Two moderately active comets, Seargent (1978m) (ref. 13) and Bradfield (1979ℓ) (ref. 14), have been observed by IUE, the latter over an extended 7 week period in January and February 1980 during which time the comet's heliocentric distance varied from 0.71 a.u. to 1.53 a.u. Spectra of Comet Bradfield taken over a period of several weeks are found to be very similar to the spectra of Comet Seargent (ref. 13) and earlier rocket spectra of Comet West (1976 VI) (ref. 15). This similarity suggests a common composition for these comets and although the sample of comets observed to date in the ultraviolet is quite small, future observations of comets by IUE and other orbiting observatories should provide a suitable statistical basis for understanding the composition and origin of these objects.

Several new discoveries have emerged from preliminary analyses of the Comet Bradfield spectra. These include the identification of CS as either a parent molecule or as the daughter of an extremely short-lived parent based on the point-like spatial distribution of the CS emission at 2576 Å (obtained at a resolution of ~1000 km) (ref. 16); the identification of the [OI] $^1S-^3P$ transition at 2972 Å, probably produced by direct photodissociation of H_2O; a still unexplained anomalous distribution of band intensities in the CO^+ first negative system; and a determination of the water production rate with heliocentric distance that strongly disagrees with earlier such determinations (ref. 17). High dispersion observations have been used to study the fluorescent pumping of the very strong OH bands near 3090 Å (ref. 18) and the spatial variation of various species observed at low dispersion provides a comparison for photochemical models of the coma.

CONCLUSION

The success of IUE for solar system observations illustrates the benefits obtained by complementing the direct exploration of the planets with earth-orbit observations in the ultraviolet and points the way for strong consideration of planetary and cometary spectroscopy in the requirements for the next generation of orbiting observatories.

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