(NASA-CR-175381) SCIENTIFIC PROGRAM IN PLANETARY ATMOSPHERIC STUDIES Final Technical Report, 1 May 1980 - 31 Dec. 1983 (California Univ.) 21 p HC A02/MF A01 CSCL 03B G3/91

N84-19263

Unclas 12400

Final Technical Report to the

National Aeronautics and Space Administration

SCIENTIFIC PROGRAM IN PLANETARY ATMOSPHERIC STUDIES

NASA Grant NAGW-62

May 1, 1980 through December 31, 1983

Submitted by

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I. INTRODUCTION

The Voyager encounters with Jupiter led to two main areas of investigation: 1) the definition of the structure and composition of the upper atmosphere and the interaction of the magnetoshpere and atmosphere, and 2) the study of the plasma torus using the EUV (Extreme Ultraviolet) data in conjunction with ground-based and in-situ measurements. In the course of these investigations, the atmosphere studies were extended to a comparative study with the bound atmospheres of Saturn and Titan; and the torus study expanded to include the extended atmospheres of Titan (the H torus) and the rings of Saturn. References listed in the appendix were partially supported by this grant.

II. IO'S PLASMA TORUS

1. Introduction

The discovery of Io's warm plasma torus by the Voyager Ultraviolet Spectrometer (UVS) has opened new fields of research in the topics of space plasmas and energization mechanisms. Interpretations of the EUV spectrum of the torus in terms of a plasma of singly and doubly ionized sulfur and oxygen atoms with an electron temperature near 8×10^4 K were largely verified by in situ measurements made during the Voyager encounter period. Since then, continuing interpretation of in situ and remote (EUV) measurements made by Voyager has been supplemented and extended by ground-based observers and using the International Ultraviolet Explorer satellite.

This program was initiated as a result of the Voyager encounters at Jupiter to support reduction, analysis, and interpretation of data acquired by the Voyager Ultraviolet Spectrometers and bearing on the questions of the plasma torus. The basic goal was to use our EUV observations of the torus emissions, combined when appropriate with information from ground based remote sensing and in situ measurements, to improve our understanding of the physics of the plasma torus. These data bear directly on such key questions as the composition and the energy and mass budgets of the torus.

At their Saturn encounters, the Voyager UVS instruments provided the first definitive evidence for the existence of an extensive cloud of atomic hydrogen predicted on theoretical grounds to be associated with Titan. The scope of this program was subsequently expanded to include an investigation of this phenomenon in collaboration with D.M. Hunten of the University of Arizona and a graduate student, D. Hilton, who intends to base his PhD thesis on his investigation of Titan's neutral hydrogen torus. This cloud of H extends between 8 and 25 R_S in the plane of Titan's orbit and about 7 R_S above and below the plane. The H density and the lifetime of neutral H against ionization are large enough that collisions probably play an important role in determining the distribution of the H. Collisional redistribution of H velocities takes on even greater importance if the H is accompanied by larger amounts of H_2, as expected on theoretical grounds.

The major thrust of the effort was directed toward an improved understanding of Io's plasma torus. In the following section, progress made so far is summarized.

2. Summary of Progress

Analysis of the spectra of the EUV emission of the torus have led to a fairly complete understanding of its ion composition and the temperature of the electron gas. The plasma consists primarily of a singly, doubly, and triply ionized sulfur (S II, S III, and S IV) and singly ionized oxygen atoms (O II) (Shemansky, 1980a). These atoms are collisionally excited by the ~8 x 10^4 K electron gas of the plasma and emit bright EUV radiation. About 2 x 10^{12} W is emitted in the EUV; this is the dominant mechanism for energy loss from the torus. The ion concentrations inferred from spectral analysis (Shemansky 1980a,b; Shemansky and Smith, 1981) and the spatial distributions of the ions inferred from the EUV morphology (Sandel and Broadfoot, 1982a) are in general, although not precise, agreement with in situ measurements. Indications are that including the details of the radial variation in the plasma electron temperature derived from the EUV observations in models of the excitation process removes an apparent discrepancy (Sandel and Broadfoot, 1982a) between in situ and remote (UVS) determinations of ion density near the outer edge of the torus.

The spectral analysis of torus emissions has been expanded to large-scale morphological studies of the torus. Building on information derived from spectral analysis, these morphological studies have led to new insight into the mechanisms that supply energy to the electrons of the plasma – a crucial link in our understanding of the physics of the torus. Although it is likely that the ultimate source is the rotational energy of Jupiter, the details of the energy transfer process are not well known. Sandel and Broadfoot (1982a) showed that the volume emission rate of the dominant S III 685 Å feature in the torus spectrum is 50% greater near the dusk meridian than near dawn. They demonstrated that the brightness difference was the result of a difference in the plasma electron temperature rather than ion density, and therefore tied directly to the energy budget of the torus.

The dawn-dusk brightness asymmetry was interpreted by Shemansky and Sandel (1982) as evidence for localization of torus energy input. In this interpretation, most of the energy was supplied to the sunward half of the torus, centered near local noon, and cooling of the electron gas was by radiation only. Later Barbosa and Kivelson (1983) and Ip and Goertz (1983) independently proposed an alternative explanation based on the possibility of a dawn-dusk electric field shifting the drift orbits of charged particles by about 0.2 R_J (Barbosa and Kivelson) toward dawn. Adiabatic compression of the electron gas in the dawn-to-dusk half of the orbit would then provide the observed increase in temperature from dawn to dusk. Thus the heating is of much the same form as described by Shemansky and Sandel. However, in the alternative models, adiabatic cooling of the plasma in the dusk-to-dawn portion of the orbit relieves the requirement imposed by assuming only radiative cooling, and permits the distribution of energy supply to be more uniform in azimuth than demanded by Shemansky and Sandel. In Barbosa and Kivelson's view, the electric field is attributed to the escape of plasma down the tail of Jupiter's magnetosphere. Through this theory, the UVS observations are related to large-scale magnetospheric phenomena, and may serve as a useful diagnostic in this field of research, if the relationship can be verified.

A correlation between the EUV brightness of the torus and the position of Io has led to a direct observation of energy flow into the torus electron gas (Sandel and Broadfoot, 1982b). The plasma downstream from Io is brighter in S III 685 Å emission, reflecting a higher electron temperature there. The electron temperature is raised by a mechanism operating with 45° of the azimuthal position of Io in its orbit; the interaction region may extend over a much smaller range of azimuth. Differences in electron temperature inferred from spectral analysis account for the observed difference in brightness, implying that no change in the composition or density of the warm plasma occur. The Io-correlated source provides a time-averaged power of 8×10^{-14} erg cm^{-3} sec^{-1} (4×10^{11} W) or about 20% of the power radiated by the torus.

A persistent puzzle has been the difficulty in reconciling ground-based measurements of azimuthal variations in ion concentrations with the picture of near-uniform distribution of S III in azimuth implied by the EUV observations (Sandel and Broadfoot, 1982a). In contrast ground based measurements of S II (e.g., Pilcher and Strobel, 1981) and more recently S III (Morgan et al., 1983) show strong azimuthal variations in the concentrations of both ions with a peak near $\lambda_{III} \sim 180^{\circ}$. Recently Hill (1983) has suggested a resolution based on the fact that the ion velocity falls slightly below co-rotation velocity. With the proper relationship among the ionization lifetimes and the System III drift period, a strongly asymmetrical distribution of S II would not be carried over to the S III distribution. However, Shemansky (private communication, 1984) has pointed out that certain critical ionization rates used by Hill are probably incorrect; using better estimates of these values destroys the relationships necessary for the theory to work. The resolution of this dilemma is not yet known; it therefore seems likely that it is related to a fundamental property of the plasma torus not yet understood.

Analysis of the EUV observations has recently revealed a weak periodicity of $10^{h}\ 14^{m}$ in the brightness of the eastern and western ansae of the torus (Sandel, 1983). This period (see Figure 1) exceeds the System III rotation period by about 3%, and is generally consistent with brightness variations in visible wavelengths observed by Roesler et al. 1984 and with ion velocity measurements reported by Brown (1983). These latter measurements were interpreted in terms of corotation lag near 6 R_J, but this is probably not the proper interpretation of the EUV observations. This is because spectral analysis indicates that the EUV brightness variations are driven by a difference in electron temperature, rather than an azimuthal variation in ion concentration. This periodicity may be another direct manifestation of energy flowing into the torus. A particularly notable aspect of this discovery is the fact that the presence of the modulation at the eastern ansa depends on the position of Io, as shown in Figure 2, but the modulation is always present in the west. The picture is complicated by a period very near that of System III that appears in the east, but not in the west. We are left with a complex set of related signatures, as yet only partly understood and certainly not within the capability of current theories and models of the physics of the plasma torus.

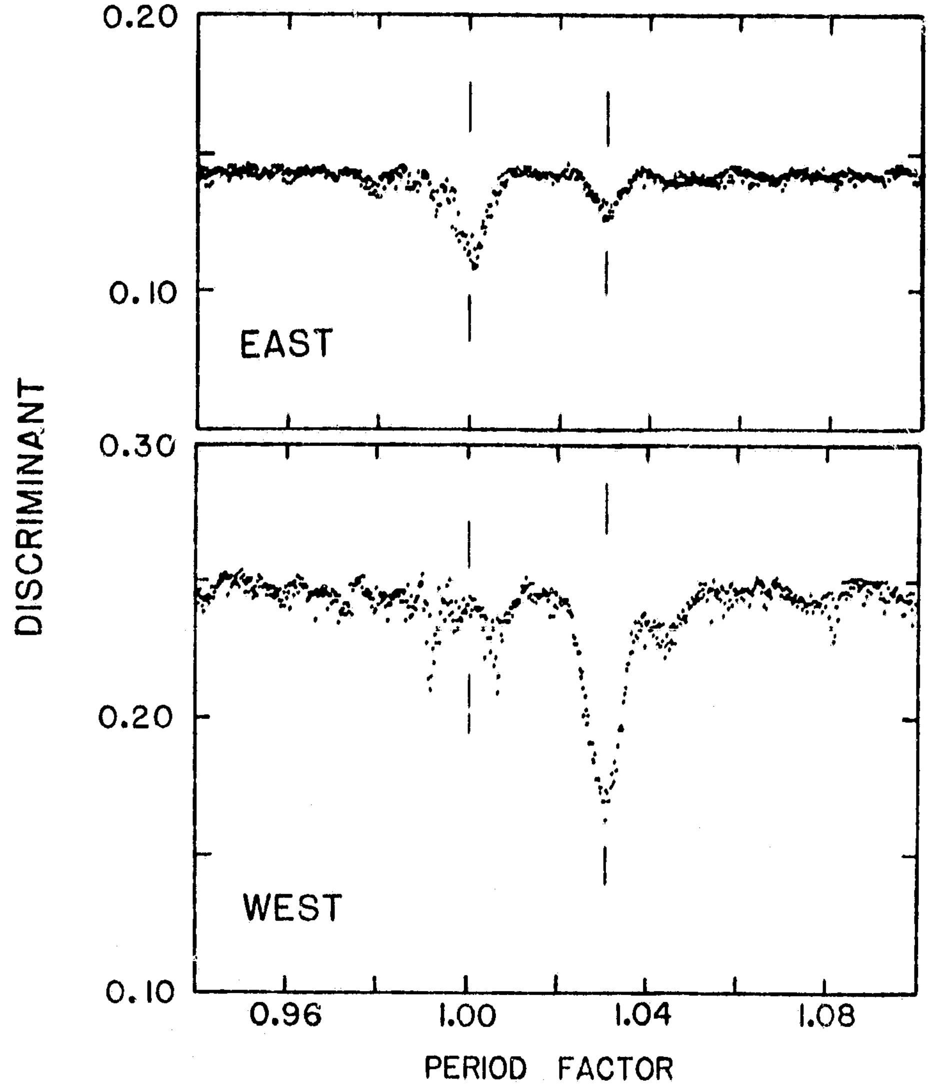

Figure 1

The discriminant is a measure of local scatter of the brightness vs. phase curve, with smaller values representing less scatter. This quantity is plotted in terms of the assumed period, expressed as a ratio to the System III rotation period. The pronounced dip at 1.031 at both east and west ansae indicates that the EUV brightness have components that vary with a period of 1.031 x (System III period) = $10^h\ 14^m$. In the east, the modulation at this period is much weaker than in the west, and the east also shows modulation very near the System III period.

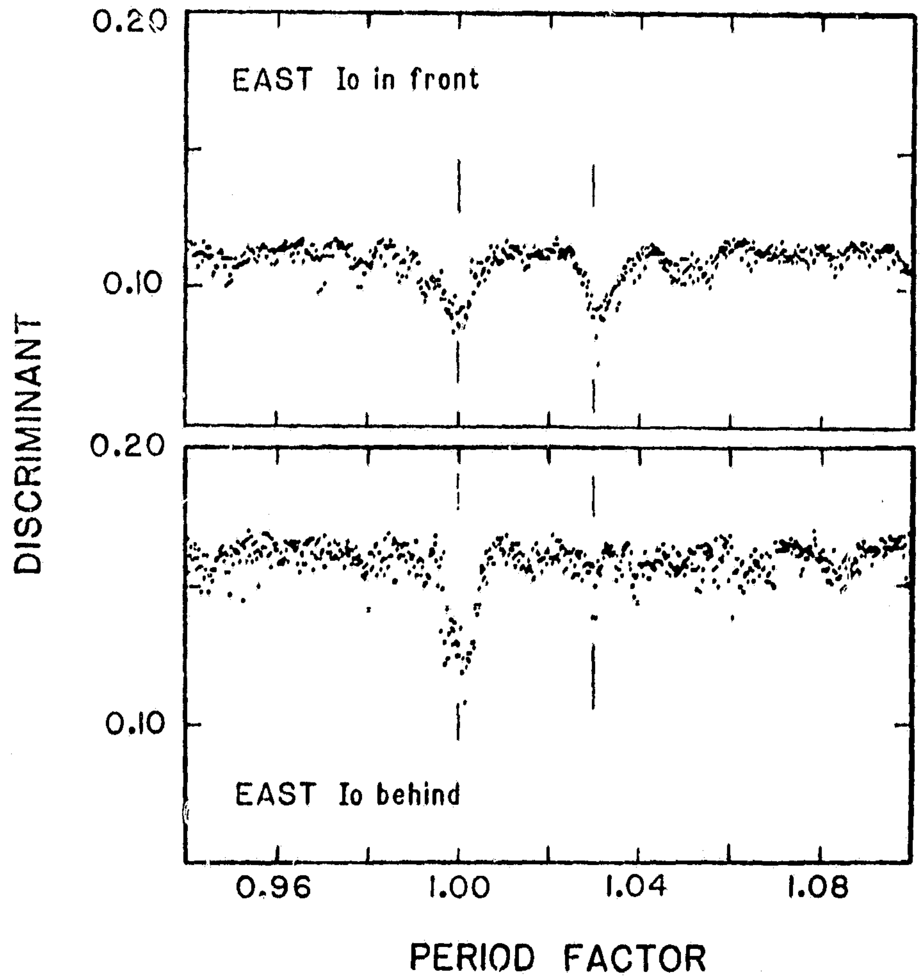

Figure 2

Data from the eastern ansa divided into two categories - those for which Io was "in the front half of its orbit" of Jupiter ($90 < \phi_{Io} < 270$), where ϕ_{Io} is the orbital phase of Io, and those for which it was in the "back half" ($\phi_{Io} < 90$ or $\phi_{Io} > 270$). The feature at 1.03 is present only when Io is in the front half of its orbit. This clearly demonstrates that Io exercises some kind of influence over the production of this modulation.

III. THE RINGS OF SATURN: THEIR ATMOSPHERE AND STRUCTURE

1. The Nature of the Ring Observations and Progress to Date

During the Voyager 1 and 2 encounters with Saturn the ultraviolet spectrometers made fundamental observations of Saturn's rings which can be grouped into three broad categories. First were the occultations of bright stars by the rings; three such occultations were observed. Second was a remarkable, long integration, spectrum of the rings in reflected sunlight obtained by Voyager 2. Third was the extensive set of observations of the rings in HI Lyman α (Lα, 1216 Å) obtained by both spacecraft. This latter set of observations was obtained over a wide range of observing geometries and constitutes the best available data base on the ring atmosphere. The primary focus of the study was the analysis of the ring atmosphere observations. As will be seen, however, both the occultation and reflectance observations are closely related to the analysis of the ring atmosphere data. In the following sections the progress which has been made in each of the areas is reviewed.

2. Stellar Occultations

Since the Saturn encounters a great deal of effort has gone into the reduction and interpretation of the stellar occultation data. As mentioned previously, three separate such events were observed; two extending from inner to mid C ring and one providing a continuous record of ring opacity across the entire ring system at ~ 3 km resolution. In all of these observations the UVS was effectively converted into a single channel photometer, since at UVS wavelengths the attenuation of light by the rings appears to have no spectral dependence (Sandel, et al., 1982). A large number of important results has come from the UVS occultations, mainly in the area of ring dynamics. Numerous features associated with satellite resonances have been identified (Holberg, Forrester and Lissauer, 1982; Holberg, 1982). Analysis of density waves associated with strong resonances in the A ring (Holberg, Forrester and Lissauer, 1982) provided the first surface mass densities in the A ring and the first reliable determination of the total mass of the ring system. Other features found to be associated with resonance phenomena in the rings include the outer edge of the A ring which was discovered to be coincident with the strong 7:6 resonance with Janus (Holberg, Forrester and Lissauer, 1982) and singular sharp edged features associated with the five strongest resonances in the C ring (Holberg and Forrester, 1983).

This phase of the analysis of the UVS ring occultation data is now complete and a review of the results will apear in Esposito et al. (1983a) along with other Voyager related results on ring dynamics. Work in this area is now primarily in the area of collaborative studies involving other Voyager experimenters and instruments. A multi-disciplinary study of the eccentric ringlet in the Maxwell Gap (1.45 R_S) involving UVS radio, photomultiplier and imaging data has recently been published (Esposito et al., 1983b). Two extensive collaborative studies of additional eccentric ringlets (Porco et al., 1983a) and the eccentric outer edges of the A and B rings (Porco et al., 1983b) have recently been completed and submitted for publication. Finally, a novel joint analysis of UVS and radio occultation data has led to a substantial improvement in the location of Saturn's rotational pole (Simpson, Tyler and Holberg, 1983). Such collaborative efforts continue.

3. Reflectance Spectrum

Several days prior to the Voyager 2 encounter with Saturn a considerable amount of time was devoted to imaging 'spoke' activity in the B ring. This provided the UVS with a unique opportunity to obtain a very long (~40,000 s) integration spectrum of the rings in reflected sunlight. This ring spectrum is shown in Figure 3 along with a comparison spectrum of the sun obtained through the UVS occultation port. Far from being merely a curiosity, the ring spectrum contains information on the reflectivity of the ring particles at wavelengths well shortward of any previous observation. A preliminary analysis of this spectrum (Sandel et al., 1982) indicates a relatively flat reflectance spectrum between 600 and 1100 Å and reflectances on the order of 5% between 1300 and 1400 Å. The later result is consistent with measurements of ring reflectivity at 1650 and 1700 Å obtained by Wieser and Moos (1978) from a rocket flight.

4. The Ring Atmosphere

The realization that the ring particles are composed largely of water ice naturally leads to the expected presence, at some level, of a ring 'atmosphere' of H_2O and its dissociation products. Such an atmosphere would represent an equilibrium between those processes (sources) which produce or free molecules from ice surfaces in the rings, and those processes which lead to either the re-adsorption of gas molecules or their final loss from the rings due to ionization or neutral escape. Initial source estimates (Dennefeld, 1974 and Blamont, 1974) involving such mechanisms as thermal sublimation, meteoritic impact, and solar and interstellar wind bombardments all lead to low production rates and atmospheres so tenuous as to be undetectable.

The most sensitive method for detecting a ring atmosphere is through observation of solar scattered Lyman α (Lα) emission from neutral hydrogen. Such hydrogen, presumably formed by photodissociation of H_2O, OH and H_2, would form a bright Lα cloud similar in some respects to those observed to develop around comets. The first detection of Lα emission from Saturn's rings came from a sounding rocket observation by Weiser et al. (1977) who measured 200 ± 100 Rayleighs (R) of Lα emission from the general vicinity of Saturn's rings. This measurement was followed by observations of higher spatial resolution with Copernicus (Barker et al., 1980), and IUE (Clarke et al., 1981) both of which produced upper limits to the Lα brightness of the rings less than that of Weiser et al. During the Pioneer 11 encounter with Saturn the long wavelength UV photometer observed an enhanced UV emission (presumably Lα) while the spacecraft was beneath the B ring (Judge et al., 1980). The current observational and theoretical status of the ring atmosphere has been reviewed by Holberg in Cuzzi et al. (1983).

The most extensive UV observations of the rings are those of the Voyager 1 and 2 UVS, which made numerous scans of the rings from widely differing observing geometries (Broadfoot et al., 1981b). The preliminary picture of ring associated Lα emission which emerged from these observations contains significant differences from those discussed previously. Most significantly Voyager found the optically thick B ring to be the weakest source of Lα

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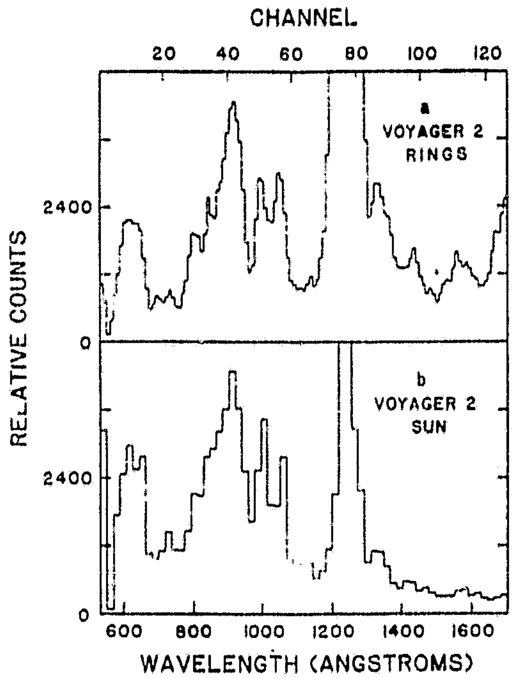

Figure 3

The spectrum of the rings observed with the Voyager 2 UVS (a) compared with the solar spectrum (b) observed through the Voyager 2 occultation port. The ring spectrum, with the exception of Lα is entirely due to reflected sunlight. Prominent features include the Lyman continuum peaking at 912 Å and a blend of He I 584 Å, Mg V and O V at 600 Å.

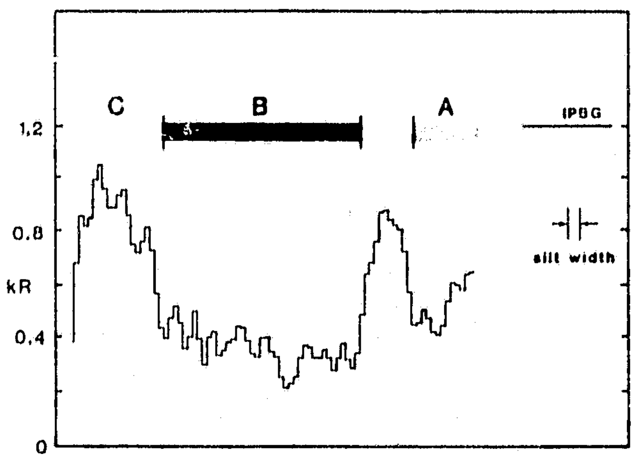

Figure 4

Lα brightness across the illuminated side of the rings observed by the Voyager 1 UVS. The rings were scanned from mid-C ring to mid-A ring with the UVS slit (0.1 R_S, radial resolution) oriented approximately perpendicular to the radial dimension of the rings. The signal is composed primarily of interplanetary background (IPBG) Lα transmitted through the rings and the ring atmosphere. Since the signal is anti-correlated with the visual brightness of the rings, it is concluded that Lα reflected from the rings contributes only marginally to the observed brightness. The minimum signal, ~360 R, in the B ring is assumed to be primarily due to the foreground ring atmosphere since the B ring is opaque. Similar brightnesses were observed from the unilluminated side of the rings.

the B ring. The UVS observations also found that Lα emission apparently does not extend significantly beyond the outer edge of the A ring in contrast to Pioneer 11 which indicated an emission component several Saturn radii (R_S) beyond the A ring. As previously mentioned Weiser et al. observed excess Lα emission from the 'vicinity' of the rings while Copernicus and IUE observed only upper limits, at a lower level. The Copernicus and IUE upper limits are relatively easy to reconcile with the Voyager observations since they were obtained either when the rings were viewed edge-on (IUE) or at an orientation such that the outer A rings only filled a small fraction of the field of view (Copernicus). As such both the existing IUE and Copernicus observations refer mainly to emission extending above the ring plane (IUE) or beyond the edge of the A ring (Copernicus). The Weiser et al. results were obtained when the rings were relatively open and are more difficult to interpret. The reason for this is that as viewed from Voyager the rings actually appear dark in Lα when seen against the bright background of the sky. This sky background is due to resonantly scattered solar Lα from interstellar neutral hydrogen entering the solar system and constitutes an important complicating factor in the interpretation of Lα emission from the rings. A Voyager based prediction for the Weiser et al. observation would therefore be a deficit of Lα from the vicinity of the rings.

The observed distribution of Lα emission across the rings is illustrated in Figure 4 which shows a Voyager 1 UVS radial scan over the illuminated rings. Several significant features are present in Figure 4. First, the Lα brightness of the rings is anti-correlated with optical depth; most of this effect can be explained by Lα sky background transmitted through the optically thinner portions of the rings. The unattenuated sky background level is indicated at the left of Figure 4. Second, the minimum brightness (~360 R) is seen in mid B ring. This residual B ring brightness cannot be due to transmitted Lα sky background since measured B ring optical depths are too high to permit any significant transmission and the bulk of the Lα must originate on the sunlit side of the rings. Surprisingly, corresponding views of the unilluminated side of the rings show similar brightnesses. The simplest, least contrived, explanation for these observations is that the bulk of the 360 R minimum observed on both sides of the B ring is due to H associated with the rings. Since the sun was at very low elevation angles during both Voyager encounters, any ring atmosphere having an appreciable scale height (>0.1 R_S) would display approximately equal illuminated columns on both sides of the rings.

In characterizing the ring atmosphere Broadfoot et al. (1981b) assumed all 360 R of Lα observed by Voyager 1 from the B ring was due to the ring atmosphere. This then led to an H column of 10^{13} cm^{-2}. If this H were distributed in a spherical shell having the radial extent of the rings, the corresponding cloud would contain 5 x 10^{32} atoms with a density of 600 cm^{-3} and an implied production rate of 1 x 10^{28} s^{-1}. These are surprisingly large numbers in view of the initial investigations of source mechanisms (Dennefeld, 1974; Blamont, 1974). More recent work has led to a significant revision of the expected production rate due to meteroid impact. Morfill et al. (1983), using improved meteroid fluxes and neutral vapor production rates, obtain estimates of the neutral hydrogen within ± 1 R_S of the ring plane of 200 - 1800 cm^{-3}. While the production of H due to micrometeroid impact is undoubtably larger than previously realized, the implied erosion rates of ring undoubtably larger than previously realized, the implied erosion rates of ring particles due to this mechanism are also very large. A mechanism which relies on a source of H external to the rings is suggested by UVS observations of excited H_2 in Saturn's atmosphere. Shemansky and Smith (1982) propose that the dissociation of H_2 by electrons (Shemansky and Ajello, 1983) at the exobase of Saturn's atmosphere would provide a source of 'hot' H with sufficient energy (>3 eV) to escape from the planet's exosphere. The rings in this view would then constitute a 'cold trap' for a fraction of the escaping H. This source, which is estimated to produce a total of 10^{29} H s^{-1} (Shemansky and Smith, 1982) from Saturn's atmosphere, must also be considered as a potential, or even major, contributor to the observed H in the Titan torus at 8 to 25 R_S.

One major current uncertainty is the extent of the ring atmosphere. Voyager observations indicate that it does not appear to extend beyond the outer edge of the A ring. Beyond this, little can be said at present. The ring atmosphere could be confined relatively closely to the ring plane. This would decrease the total content of the assumed cloud but would also increase the density since the observed column of H does not depend critically on the assumed geometry.

IV. THE NEUTRAL ATMOSPHERE AND IONOSPHERE OF JUPITER, SATURN AND TITAN

The successful Voyager encounters with the Jovian and Saturnian systems have returned extensive data on the structure and composition of the atmospheres of Jupiter, Saturn and Titan. The UV solar occultation proved to be a very powerful new technique for probing the composition and temperature of the neutral upper atmospheres. The optical depth of the atmospheres was measured from the exospheric region down to the mesopause and somewhat lower in the case of Titan. Atmospheric models were used to infer the atmospheric structure, and exospheric constituents were measured through planet-wide UVS airglow measurements. Airglow observations were modeled to determine the nature of the exospheres. Below the exosphere the altitude distribution of chemical and photochemical reactions have been constrained by the optical depth measurements down to the mesopause. It has taken some time to define the analysis technique and demonstrate convincingly that the atmospheric models were in fact constrained by the optical depth determination. Much work remains to be done on the eight occultation measurements acquired to date on the Voyager mission.

Early analyses, which inferred the neutral upper atmospheric structure and temperature from the radio science electron density profiles, were in error. Voyager and Pioneer radio occultation experiments measured the electron density profiles for Jupiter and Saturn. On the Voyager mission to the outer planets, the neutral upper atmosphere was measured directly by the UVS solar and stellar occultation experiments. Figure 5 shows the situation at Jupiter. Curves 1, 2, 3, and 4 are the electron density profiles from the Radio Science experiment. The Atreya et al (1979) point indicates the concentration and altitude of the neutral atmosphere based on the measured electron density profiles. The curves H_2 and H were the measured neutral upper atmospheric constituent profiles from the UV solar occultation

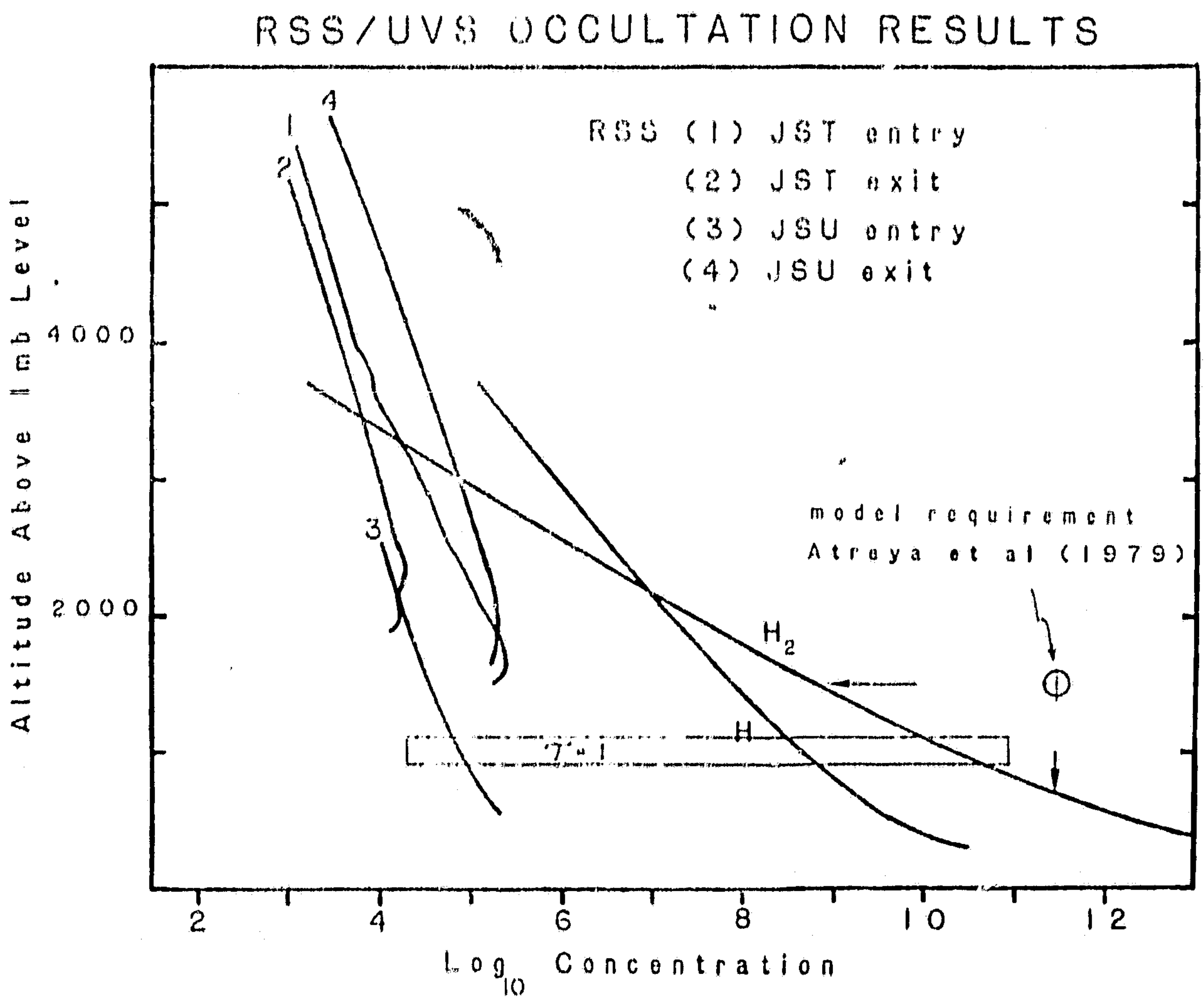
RSS/UVS OCCULTATION RESULTS
RSS (1) JST entry
(2) JST exit
(3) JSU entry
(4) JSU exit
model requirement
Atreya et al (1979)
H_2
H
Altitude Above 1mb Level
4000
2000
2
4
6
8
10
12
Log_{10} Concentration

Figure 5

which the solar energy deposition would generate the electron peak in the neutral atmosphere. Although this figure is 'dated', it describes the situation found at both Saturn and Jupiter. A common feature of all of the observed electron density profiles is that the altitudes of the peak electron densities occur at least several hundred kilometers above the region where photoionization is expected to produce peak electron densities. In addition peak electron densities are an order of magnitude less than expected. For Jupiter our ionospheric models indicate that strong meridional winds (or electric fields) are needed in order to move the plasma to high altitudes and that vibrationally excited H_2 reactions (McElroy, 1973) are needed to reduce the peak electron densities.

From the occultation data we have derived the following picture of the neutral atmosphere of these bodies. For Jupiter the thermospheric temperature is about 1000 K with an estimated column amount of H down to the homopause region of ~1.0×10^{17} cm^{-2}. For Saturn the temperature is ~420 K in the thermosphere (2500 km above 1 bar level) and decreases to ~120 K near the homopause at 1000 km (Smith et al, 1983). The density profiles of H_2 and CH_4 indicate an eddy diffusion coefficient near the CH_4 homopause of ~5×10^6 cm^{-2} s^{-1}. The H density profile implies a downward flux of ~1.8×10^9 cm^{-2} s^{-1} which indicates a considerable production of H in the upper regions of the atmosphere. The solar occultation experiment on Titan probed considerably deeper into the atmosphere than was possible on Jupiter or Saturn due to the smaller Chapman function for Titan. Due to this and a programed gain change, we were able to probe to several hundred kilometers below the homopause which resulted in the discovery of what we have interpreted as a severe mixing ratio change with altitude of acetylene. The thermospheric temperature for Titan is ~180 K. We have definitely determined CH_4 to be present with a mixing ratio of ~8% at 3700 km and C_2H_2 with ~1% down to ~.1% in the region 3500 km to 3300 km. A simple photochemical model indicates that the eddy diffusion coefficient is ~1×10^8 cm^{-2} s^{-1} near the homopause and decreases down to ~1×10^3 cm^{-2} s^{-1} in the lower stratosphere (Smith et al, 1982).

The airglow observations have yielded extensive information concerning the excited species in the upper atmospheres of these planets in addition to resonantly scattered Lyα and He 584 Å emissions. For Jupiter and Saturn the UVS spectra are dominated primarily by H_2 band emissions, Lyα and He 584 Å (Broadfoot et al, 1981a; Broadfoot et al, 1981b; Sandel et al, 1982). The H_2 band emissions are excited by electrons but appear only on the day side and very high in the atmosphere near the exobase (Broadfoot et al, 1981a; Sandel et al, 1982; Shemansky and Ajello, 1983). The Titan spectra are dominated entirely by excited N_2 and ionized N emissions (Strobel and Shemansky, 1982). The emission also appears to come only from the day side; however, for Titan part of the day side is facing into Saturn's co-rotating plasma (Bridge et al, 1981). Upper limits for the mixing ratios of NeI, ArI, CO, H_2, and HI at 3900 km have been set at 0.01, 0.06, 0.05, 0.06 and 0.1, respectively.

Analysis of the equatorial airglow emission data and the bright limb drifts (Broadfoot et al, 1981a; Broadfoot et al, 1981b; Shemansky and Ajello, 1983) have shown that the electron excited emissions originate near the exobase regions on Jupiter and Saturn and that the energy of the exciting electrons is on the order of ~30 eV (Smith et al, 1983; Shemansky and Ajello, 1983). In conjunction with this it definitely appears that solar photons act as a catalyst for this emission (see Broadfoot et al, 1981a) since the emission only appears on the day side and, in the case of Saturn, the emissions nearly disappear within the shadow of the rings. On Titan we have the emissions coming only from the day side; however, there is some question yet about the actual location of this emission in altitude (Strobel and Shemansky, 1982).

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