OUTER SATELLITE ATMOSPHERES: THEIR

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2 Government Accession No.	3. Recipient's Catalog No.
4 Title and Subtitle Outer Satellite Atmospheres: Their Extended Nature and Planetary Interactions		5. Report Date December 1983
		6 Performing Organization Code
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9. Performing Organization Name and Address Atmospheric and Environmental Research, Inc. 840 Memorial Drive Cambrdige, Massachusetts 02139		10. Work Unit No.
		11. Contract or Grant No. NASW-3387
12. Sponsoring Agency Name and Address NASA Headquarters Headquarters Contract Division Washington, DC 20546		13. Type of Report and Period Covered Interim Report September-November 1983
		14. Sponsoring Agency Code HW-2
15. Supplementary Notes		

16. Abstract

Model calculations for the spatial morphology of the Region B sodium cloud are presented that include both the oscillating plasma torus sink and solar radiation pressure in the D-lines. These calculations exhibit the qualitative behavior observed in the sodium cloud and have diagnostic capabilities to probe more deeply the atom ejection characteristics of the sodium source. Significant progress in specifying the plasma properties of Saturn's magnetosphere for use in the Titan hydrogen torus model is reported. Efforts to apply the AER comet model to calculations of the spatial distribution of the H atoms in cometary atmospheres are also discussed.

17. Key Words (Selected by Author(s)) satellite atmospheres planetary magnetospheres comets	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	12	

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

I. SUMMARY OF RESEARCH PERFORMED IN THE SECOND QUARTER

Research activities in the past quarter have been primarily focused upon (1) further modeling studies of the spatial morphology of the region B sodium cloud, (2) implementation of the Saturn magnetospheric plasma data in our Titan hydrogen torus model, and (3) application of our earlier comet model to analyze the spatial distribution of cometary hydrogen.

1. Spatial Morphology of the Sodium Cloud

Model calculations for the spatial morphology of the Region B sodium cloud have been performed this quarter where effects of both the oscillating plasma torus sink and the acceleration of cloud atoms by solar radiation pressure in the D-lines have been included. Model calculations illustrating these effects for Io at both eastern and western elongation are shown projected onto the sky plane in Figure 1 and projected normal to the satellite plane in Figure 2. These calculations assume radial and isotropic ejection of sodium from Io. The more elongated sodium cloud at western elongation results directly from the combined effects of orbit perburtions by solar radiation pressure and the spatially non-uniform lifetime of sodium in the plasma torus. This preferential elongation was anticipated by Smyth (1983) and has been observed for the sodium cloud (Goldberg et al., 1980; Goldberg, 1983).

The preferential elongation of the sodium cloud in the west may be enhanced, however, by suitably modifying the ejection conditions of sodium from Io. This is illustrated in Figure 3, where sodium is ejected radially and uniformly only from the band region (defined in the Figure caption). This band ejection region is geometrically very similar to that shown by Pilcher et al. (1983) as the source of high-velocity sodium (20 km sec^{-1}) which can explain the space-time variations of the sodium directional features. The initial directions and speeds of sodium escaping Io that form the directional features were noted (Pilcher et al. 1983) to be understood in terms of a magnetospheric-wind-driven escape mechanism. Careful modeling of data describing this east-west orbital asymmetry in the sodium cloud will allow a more refined description of the ejection conditions to be deduced. This information will then allow us to understand better the gas escape mechanism at Io as well as the properties of the local satellite atmosphere.

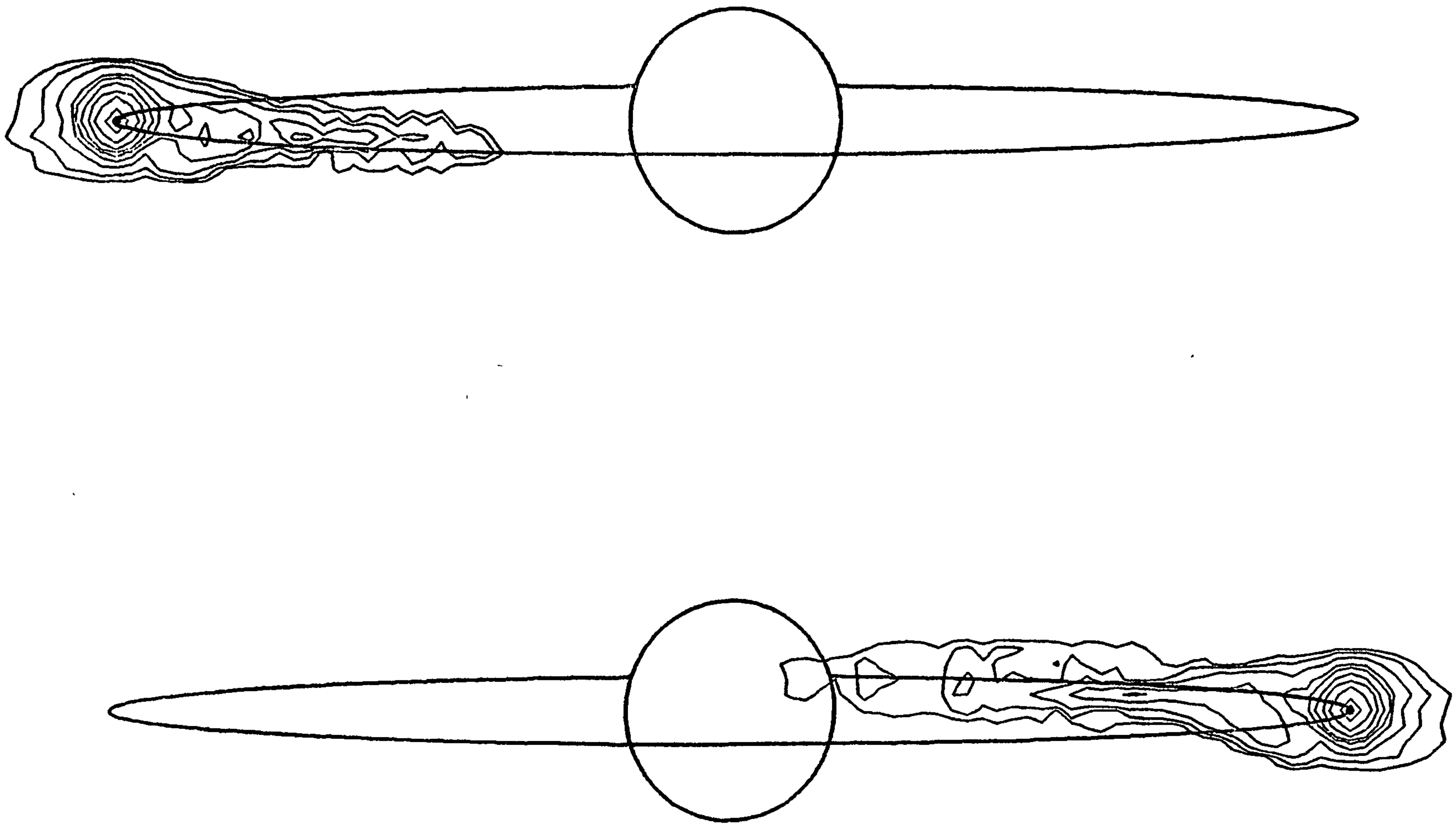

Figure 1. Model Calculation for the Io Sodium Cloud. The calculation using the new AER model illustrates the D_2 emission line brightness on the sky plane produced when the oscillating plasma torus sink and solar radiation pressure are both included. The two calculations, for Io at orbital elongation and at a System III magnetic longitude of 200°, assume radial and isotropic ejection of sodium at 2.6 km sec^{-1} with a total source rate of 1.8×10^{26} atoms sec^{-1}. Contour values are, from outside to inside, 0.25, 0.5, 1, 2, 3, 5, 10, 20 and 50 kiloRayleighs.

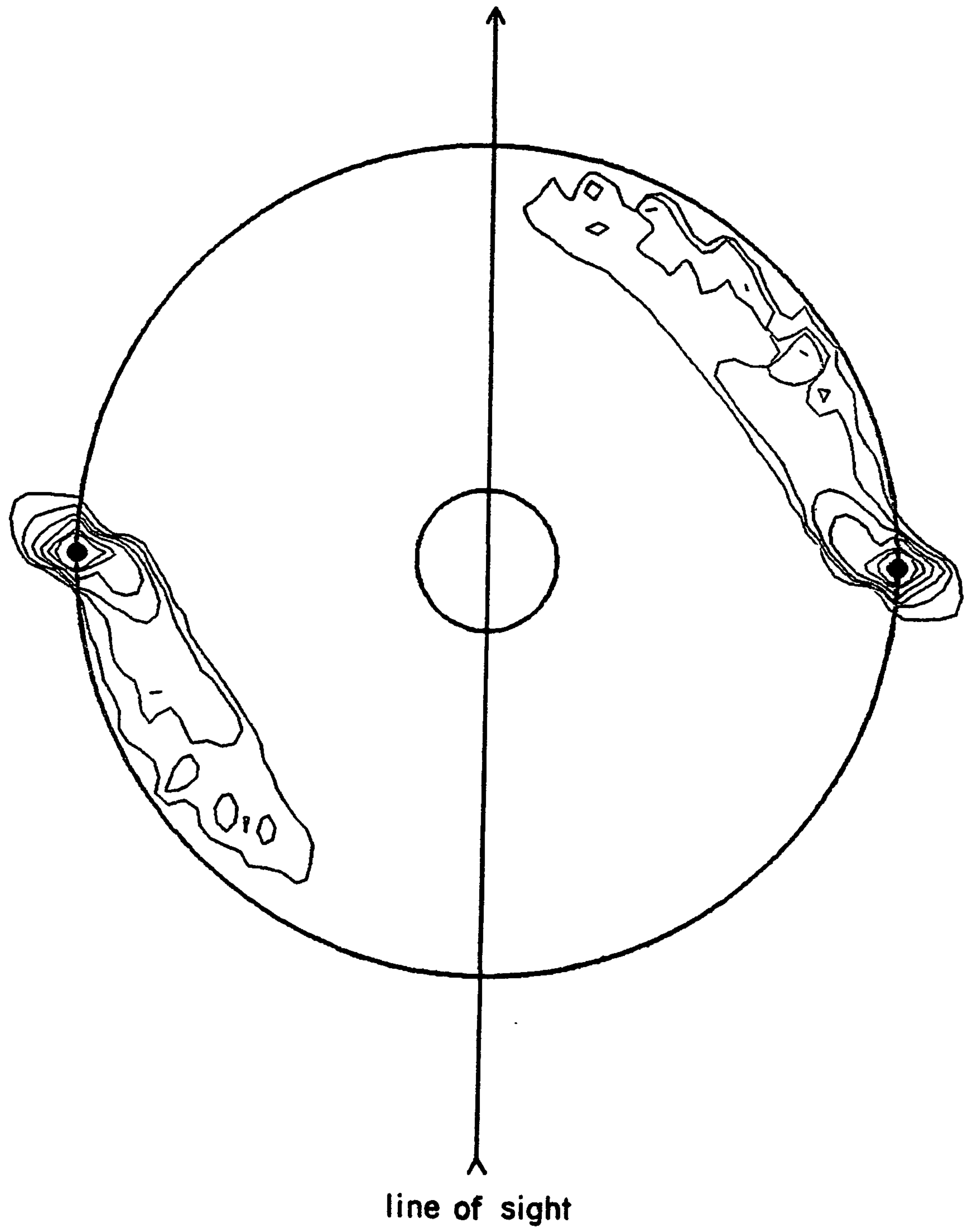

Figure 2. Model Calculation for the Io Sodium Cloud. The calculations are the same two described in Fig. 1, but here show the D_2 emission intensity projected normal to the satellite plane. Contour values are, from the outside to inside, 0.1, 0.25, 0.5, 1, 2, 3 and 5 kiloRayleighs.

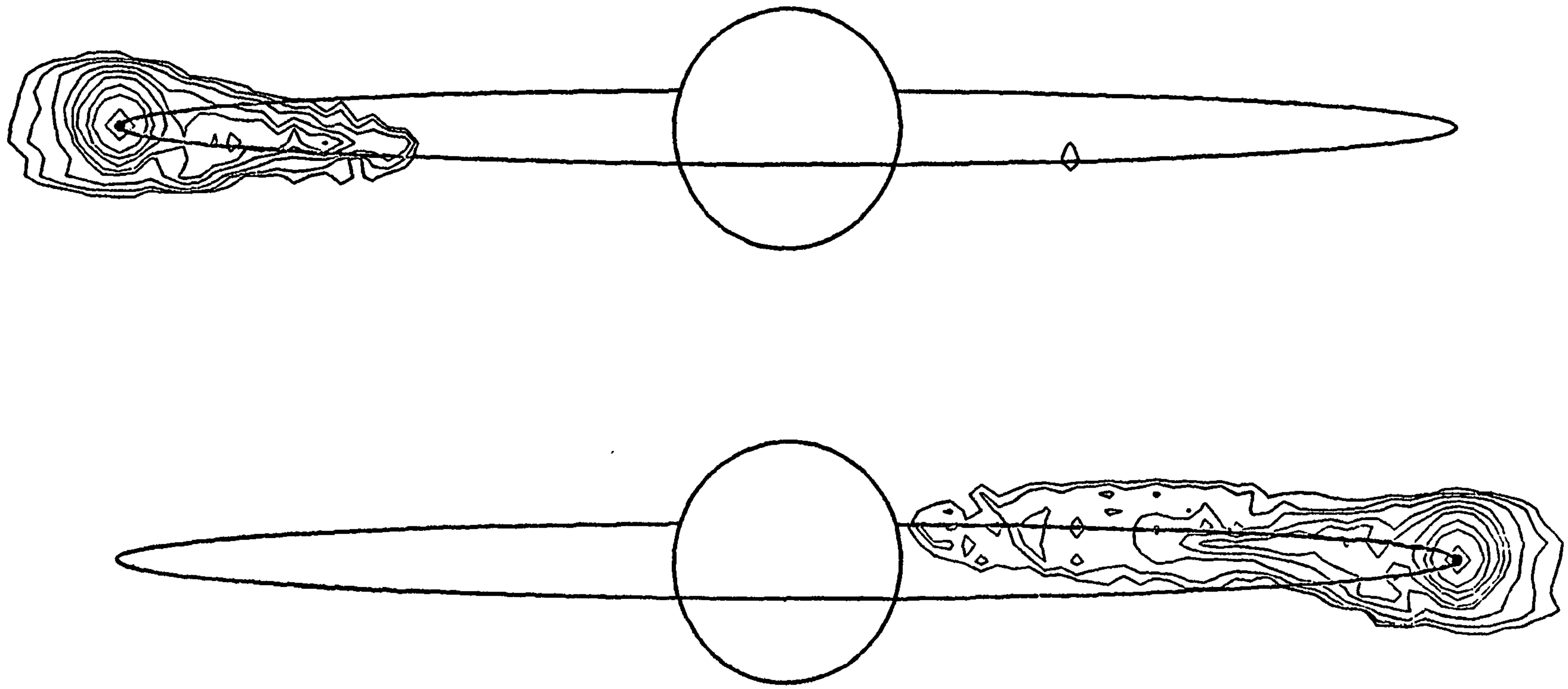

Figure 3. Model Calculation for the Io Sodium Cloud. The calculation using the new AER model illustrates the D_2 emission line brightness on the sky plane produced when the oscillating plasma torus sink and solar radiation pressure are both included. The two calculations, for Io at orbital elongation and at a System III magnetic longitude of 200°, assume uniform and radial atom ejection at 2.6 km sec^{-1} from a symmetric band centered on the great circle normal to Io's orbital motion and having an angular width of ±40° and a total source rate of about 1.4×10^{26} atoms sec^{-1}. Contour values are, from outside to inside, 0.2, 0.5, 1, 2, 5, 10, 20, 50, and 100 kiloRayleighs.

2. Titan's Hydrogen Torus

Information describing in two-dimensions (radial and vertical) the density and temperature of the ions and electrons in Saturn's magnetosphere was obtained this quarter from Sittler (1983). This information, derived from the Voyager PLS data, is currently being studied. It will later be used to calculate the spatially non-uniform lifetime of H atoms in the Saturn environment, which is required as input information in our Titan torus model. Calculations using this model are to be compared with the spatial distribution of H atoms deduced from data recorded by the UVS instrument of Voyager 1 and Voyager 2, in order to understand better the role of Titan in the production of hydrogen in the Saturn system.

3. Comet Modeling

Cometary research at AER represents a broadening and natural extension of our previous modeling of extended satellite atmospheres, that was initially undertaken for NASA in 1979 and 1980. A continuation of this effort was scheduled and consolidated within this, the third year of our current program. Because of the expertise developed at AER in modeling extended satellite atmospheres, which are in a collisionless regime but remain in a complex gravitation field, we have addressed that area of cometary atmospheres where similar conditions are present. The three dimensional particle trajectory model developed at AER earlier is being applied to the extended neutral atomic gas clouds observed in comets (e.g. H, C and O). In particular we have begun a modeling effort to understand the observed spatial distribution of cometary hydrogen. The AER three dimensional particle trajectory model is ideally suited to modeling cometary H atoms which travel under the influence of the solar gravitation field and a variable solar radiation pressure field owing to resonance scattering of solar Lyman α photons.

The current state of extended cometary gas cloud models is one in which sets of simplifying assumptions are made to tailor the models to one particular aspect of observational data. No completely general model yet exists. The two major and somewhat complementary modeling efforts to date have been put forth by Keller and his co-workers (Keller and Thomas, 1975, Keller and Meier, 1976) and Festou et al. (1979). Keller and co-workers have developed models for the extended H cloud ($>10^6$ km) that approximate the source region as a point. These models however use Maxwell-Boltzmann velocity distributions and various approximation schemes to calculate atom trajectories under the influence of the solar gravitational field and solar radiation pressure. Festou et al. (1979) have used the vectorial model (Festou 1981 a,b) to describe more realistically the source region of H in their analysis of the inner coma ($\sim 10^4$ km) Lyman α profiles from Comet Kobayashi-Berger-Milon (1975 IX). Their model assumed a steady state production rate and neglected (appropriately for this particular observation) the effects of the solar gravity field and solar radiation pressure.

The new hydrogen cloud model currently being developed at AER correctly characterizes both the time variation and velocity vector distribution of the source region, as well as the correct atom trajectories in three dimensions. Our first model application is to re-analyze the observed Lyman α distribution of Meier et al. (1976) in Comet Kohoutek (1973 XII). The basic physical features being incorporated into the model are as follows:

1) water production rate which varies according to the brightness curve compiled by Delsemme (1975) which indicated that some constituent (CO_2 was suggested) more volatile than H_2O at least influenced the vaporization of Comet Kohoutek;
2) production of hydrogen by the photodissociation of H_2O and OH (itself produced by H_2O);
3) a speed dispersion for hydrogen shown in Table 1 from the direct photodissociation of H_2O, as well as an 8 km sec^{-1} component from the photodissociation of OH;
4) a heliocentric velocity dependent lifetime for the OH source according to the recent calculations of Schleicher and A'Hearn (1983); and
5) radiation pressure acceleration on H atoms by resonance scattering of solar Lyman α photons as computed from the solar disk averaged Lyman α profile of Lemaire et al. (1978).

Activities during the past quarter have concentrated on data gathering for the basic physical source region description and implementing on the AER computer both the original particle trajectory code of 1979 and 1980 as well as the Monte Carlo particle trajectory model code of Combi and Delsemme (1980). This Monte Carlo code will be incorporated into the new AER model to generate a realistic source region for the distributions of H_2O and OH.

Table 1

Photoabsorption of Solar UV Radiation by H_2O Vapor

Wavelength Range	Reaction	Product Velocities (km sec^{-1}) H Atom	Product Velocities (km sec^{-1}) OH Molecule	References	Fraction of Total H_2O Photoabsorbed: Quiet Sun	Fraction of Total H_2O Photoabsorbed: Active Sun
1. 1357Å < λ < 1860Å	$H_2O + h\nu \longrightarrow H + OH(X^2\Pi)$	20	1.2	1, 2, 5, 10	.670	.534
	$\longrightarrow H_2 + O(^1D)$	--	--		.007	.005
2. λ = 1216Å	$H_2O + h\nu \longrightarrow H + OH(X^2\Pi)$	30	1.8	3, 4, 5, 6, 7, 10	.167	.269
	$\longrightarrow H_2 + O(^1D)$	--	--		.023	.036
	$\longrightarrow H + OH^*(A^2\Sigma^+) \longrightarrow H + O + H$	≤ 5.0;?	--		.027	.044
	$\longrightarrow H + OH(A^2\Sigma^+)$	5.0	0.3		.009	.015
3. 984Å < λ < 1357Å λ ≠ 1216Å	$H_2O + h\nu \longrightarrow H + OH(X^2\Pi)$	25-35	1.2-2.0	3, 4, 5, 6, 7, 10	.028	.021
	$\longrightarrow H_2 + O(^1D)$	--	--		.004	.003
	$\longrightarrow H + OH^*(A^2\Sigma^+) \longrightarrow H + O + H$	4.0-6.0;?	--		.004	.003
	$\longrightarrow H + OH(A^2\Sigma^+)$	0-17.0	0-1.0		.002	.001
4. λ < 984Å	$H_2O + h\nu \longrightarrow$ ionization products [H_2O^+, etc.]	--	--	8, 9	.059	.069

II. PROGRAM FOR THE NEXT QUARTER

Research activities in the next quarter will involve (1) further model studies of the spatial morphology of the sodium cloud, (2) continued efforts to implement the Saturn magnetospheric plasma data in our Titan torus model, and (3) incorporation of the Lyman α profile in the comet particle trajectory model for computing radiation pressure as well as additional efforts to properly generate the source region in our new hydrogen cometary cloud model.

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