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Orbits of the Small Satellites of Saturn

Abstract. *Orbital parameter values and associated uncertainties determined from Voyager 1 imaging data for the satellites 1980S1, 1980S3, 1980S6, 1980S26, 1980S27, and 1980S28 are presented.*

Six small satellites were observed during the approach of Voyager 1 to Saturn; three were known from ground-based observations (*1–4*) and three were discovered in the Voyager images (*5*). The "co-orbital" satellites 1980S1 and 1980S3 (*6*) were observed first approximately 75 days before encounter on the basis of predictions by B. A. Smith, H. J. Reitsema, and J. Fountain (*7*). The intervals for the remaining four are considerably shorter, ranging from about 20 days for 1980S6 and 1980S27 to approximately 8 days for 1980S28.

In order to refer their positions to the center of Saturn, 1980S1, 1980S3, and 1980S6 were recorded over the entire observing interval in frames in which at least one pointing reference, either a star or one or more of the satellites Mimas, Enceladus, Tethys, Dione, and Rhea, also appeared. The orbital parameter values of these large satellites were also improved during approach by using hundreds of satellite-star frames taken primarily for spacecraft navigational purposes. Observations of 1980S26, 1980-S27, and 1980S28 were then referred to the center of Saturn by using stars and/or the orbits of the large satellites as well as 1980S1 and 1980S3.

Since orbits were nearly singular, some of the parameters actually estimated were combinations of the usual classic set. In particular, the parameters h, k, p, and q (*8*) were estimated:

$$h = e \sin \tilde{\omega}$$
$$k = e \cos \tilde{\omega}$$
$$p = \tan i/2 \sin \Omega$$
$$q = \tan i/2 \cos \Omega$$

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Table 1. Orbital elements for six small satellites of Saturn; epoch 244 4513.5 (1 October 1980, 0 hours Ephemeris Time).

Parameter*	1980S1		1980S3		1980S6		1980S26		1980S27		1980S28	
a†	1.51472	$\times 10^5$	1.51422	$\times 10^5$	3.7806	$\times 10^5$	1.41700	$\times 10^5$	1.39353	$\times 10^5$	1.37670	$\times 10^5$
e	.007	± .002	.009	± .002	.005	± .003	.004	± .003	.003	± .003	.002	± .003
i	0.14°	± 0.05°	0.34°	± 0.05°	0.15°	± 0.2°	0.05°	± 0.15°	0.0°	± 0.15°	0.3°	± 0.2°
$\tilde{\omega}$‡	82°	± 12°	193°	± 10°								
Ω‡	87°	± 30°	134°	± 10°								
λ	138.24°	± 0.2°	21.2°	± 0.2°	150.75°	± 0.1°	52.1°	± 0.5°	109.0°	± 0.5°	252.0°	± 1.5°
n	518.236	± 0.01	518.490	± 0.01	131.43	± 0.02	572.77	± 0.02	587.28	± 0.02	598.08	± 0.05

* Symbols: a, semimajor axis; e, eccentricity; λ, longitude at epoch; n, mean motion (degrees per day). Other symbols are defined in the text. † Computed by using n and J_2 (*9*); uncertainties in a are essentially represented by the error in n. ‡ The errors in these parameters for 1980S6, 1980S26, 1980S27, and 1980S28 are currently so large as to make the values essentially meaningless.

where Ω is the angle (at epoch) to the orbit's ascending node on Saturn's equator and $\tilde{\omega}$ is the longitude of periapse (also at epoch), both measured from Saturn's autumnal equinox, and i is the inclination. The longitude at epoch is also referred to the autumnal equinox.

The dynamic model for all satellites is a Keplerian ellipse whose apse and node precess under the influences of the central-body harmonics. No attempt was made to model resonance libration terms. The pole and the gravitational harmonics J_2 and J_4 of Saturn are from (*9*). In computing the nodal and apsidal rates it was assumed that the dominant effects were due to J_2 and J_4.

The uncertainty associated with each parameter is an estimate of the real error, not merely a formal statistic. Over the observing interval, the camera resolution increased from ~ 900 km per pixel (*10*) 75 days from Saturn to ~ 50 km per pixel in the last pictures taken 3 days before encounter. In general, the root-mean-square (RMS) fit was ~ 0.5 pixel over each satellite's recorded interval, except for 1980S28, for which the eight observations over 6 days were fit to ~ 1 pixel RMS. Approximately 20 observations were used for both 1980S26 and 1980S27, and 40 for both 1980S1 and 1980S3.

In evaluating eccentricity and inclination, the largest source of error is the difficulty of making useful measurements when the satellites are in transit or approaching transit. At these times, particularly for 1980S26, 1980S27, and 1980S28, it is difficult to separate the image of the satellite from the heavily exposed image of the bright rings; with further processing, we hope to be able to include such data in future analyses.

The orbital elements for the six satellites are given in Table 1. It should be noted that these elements are for osculating orbits at the epoch of the observations. This is especially important when considering 1980S1 and 1980S3, which periodically exchange orbits (*11*), and 1980S6, which moves about the leading triangular libration point of Dione.

Satellites 1980S26 and 1980S27 are the outer and inner "shepherding" satellites that stabilize Saturn's F ring (*3*). We call attention to the fact that 1980S26 is itself stabilized by a 3:2 resonance with Mimas, which prevents the satellite–ring particle interaction from forcing 1980S26 outward.

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Infrared Observations of the Saturnian System from Voyager 1

Abstract. *During the passage of Voyager 1 through the Saturn system, the infrared instrument acquired spectral and radiometric data on Saturn, the rings, and Titan and other satellites. Infrared spectra of Saturn indicate the presence of H_2, CH_4, NH_3, PH_3, C_2H_2, C_2H_6, and possibly C_3H_4 and C_3H_8. A hydrogen mole fraction of 0.94 is inferred with an uncertainty of a few percent, implying a depletion of helium in the atmosphere of Saturn relative to that of Jupiter. The atmospheric thermal structure of Saturn shows hemisphere asymmetries that are consistent with a response to the seasonally varying insolation. Extensive small-scale latitudinal structure is also observed. On Titan, positive identifications of infrared spectral features are made for CH_4, C_2H_2, C_2H_4, C_2H_6, and HCN; tentative identifications are made for C_3H_4 and C_3H_8. The infrared continuum opacity on Titan appears to be quite small between 500 and 600 cm^{-1}, implying that the solid surface is a major contributor to the observed emission over this spectral range; between 500 and 200 cm^{-1} the opacity increases with decreasing wave number, attaining an optical thickness in excess of 2 at 200 cm^{-1}. Temperatures near the 1-millibar level are independent of longitude and local time but show a decrease of ~ 20 K between the equator and north pole, which suggests a seasonally dependent cyclostrophic zonal flow in the stratosphere of ~ 100 meters per second. Measurements of the C ring of Saturn yield a temperature of 85 ± 1 K and an infrared optical depth of 0.09 ± 0.01. Radiometer observations of sunlight transmitted through the ring system indicate an optical depth of $10^{-1.3 \pm 0.3}$ for the Cassini division. A phase integral of 1.02 ± 0.06 is inferred for Rhea, which agrees with values for other icy bodies in the solar system. Rhea eclipse observations indicate the presence of surface materials with both high and low thermal inertias, the former most likely a blocky component and the latter a frost.*

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