3.5 TITAN PHOTOMETRIC PARAMETERS*

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Measurements of the irradiance of Titan from 0.50 to 1.08 μm were carried out January 2 and 3, 1972, using the Mount Wilson 60-inch reflector, Fastie-Ebert spectrometer, and pulse counting electronics. An S-20 photomultiplier was used to obtain measurements from 0.50 to 0.795 μm, and an S-1 photomultiplier for measurements from 0.807 to 1.08 μm. A 30 Å exit bandpass was used both nights.

Selection of particular wavelengths of measurement was based upon previous continuous wavelengths energy scans of Jupiter made by the author. With the assumptions that CH_4 is the principal source of absorption in the spectrum of Titan and that the strengths of the absorptions are similar for Titan and Jupiter, the wavelengths were chosen first to show the apparent maxima and minima (absorption band centers), and second to obtain values every 100-200 Å.

The comparison standard stars were ξ^2 Ceti, α Leonis, ε Orionis, and γ Geminorum. The values used for the irradiances of these stars as well as the solar irradiances have been given previously by Younkin (1970). The former were based upon relative measurements of Hayes (1967) converted to an absolute scale by the measurements of Willstrop (1960). The latter were based upon measurements of the solar intensity by Labs and Neckel (1967).

The results of reduction of the measurements are given in Table 3-2. A correction to zero solar phase angle of Titan has been made according to the phase law of Blanco and Catalano (1971). The correction increased the brightness of Titan measured here by 0.03 mag.

The irradiances of Titan at the position of the Earth, H, are given in ergs/cm^2/sec/Å and are reduced to mean opposition distances of the Earth and Saturn. The mean surface radiances over the disk of Titan, N, are in ergs/cm^2/steradian/A, corrected to mean opposition distance. For the computation of N and the geometric albedo p_λ (0), Dollfus's (1970) value was used for the angular subtense of Titan at 9.539 AU, 0.700 arc seconds.

The 30 Å bandpass values of the geometric albedo at the measured wavelengths, given in Table 3-2, are plotted in Figure 3-4. An approximate contour has been drawn between the points, with some weight given to the shape of the methane bands of Jupiter, based upon unpublished continuous scans of the center of the disk by the author. This contour thus assumes methane is the principal absorber in this spectral range.

It is seen from Figure 3-4 that the geometric albedo of Titan reaches a maximum value of 0.37 at 0.68, 0.753, and 0.83 μm, while in the center of the strongest absorption features, at 0.89 and 1.01 μm, it falls to 0.10. Comparison with the methane bands of Jupiter and Saturn given below indicates the

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Table 3-2. Photometric Parameters for Titan

λ	H x 10^{12}	N	p_λ (0)
0.5000	1.54	0.133	0.209
0.5124	1.65	0.143	0.223
0.5264	1.74	0.150	0.242
0.5370	1.90	0.164	0.260
0.5490	1.97	0.170	0.270
0.5556	2.00	0.172	0.278
0.5652	2.07	0.179	0.290
0.5840	2.17	0.188	0.302
0.5914	2.15	0.185	0.311
0.6024	2.15	0.186	0.317
0.6100	2.15	0.186	0.318
0.6140	1.97	0.170	0.296
0.6190	1.85	0.160	0.279
0.6240	1.98	0.171	0.299
0.6280	2.20	0.190	0.342
0.6370	2.22	0.191	0.343
0.6424	2.19	0.189	0.347
0.6500	2.17	0.187	0.351
0.6630	2.03	0.175	0.331
0.6730	2.07	0.179	0.352
0.6800	2.11	0.182	0.368
0.7020	1.66	0.143	0.305
0.7124	1.88	0.162	0.351
0.7274	1.07	0.093	0.206
0.7364	1.44	0.124	0.280
0.7450	1.81	0.156	0.360
0.7500	1.81	0.156	0.364
0.7530	1.81	0.156	0.368
0.7724	1.53	0.132	0.324
0.7834	1.22	0.104	0.263
0.7890	1.23	0.108	0.263
0.7950	1.12	0.096	0.248
0.8070	1.20	0.104	0.274

Table 3-2. Photometric Parameters for Titan (Contd)

λ	$H \times 10^{12}$	N	$p_\lambda(0)$
0.8172	1.51	0.130	0.353
0.8300	1.55	0.133	0.372
0.8400	0.95	0.082	0.234
0.8470	1.10	0.095	0.276
0.8600	0.69	0.060	0.176
0.8640	0.67	0.058	0.170
0.8670	0.59	0.050	0.150
0.8700	0.69	0.060	0.178
0.8804	0.56	0.048	0.147
0.8872	0.38	0.032	0.101
0.8926	0.38	0.033	0.104
0.9100	0.76	0.066	0.220
0.9358	1.07	0.092	0.317
0.9700	0.43	0.037	0.139
0.9880	0.35	0.030	0.116
1.0120	0.30	0.026	0.105
1.0200	0.36	0.031	0.128
1.0400	0.46	0.040	0.169
1.0600	0.62	0.054	0.246
1.0800	0.78	0.068	0.320

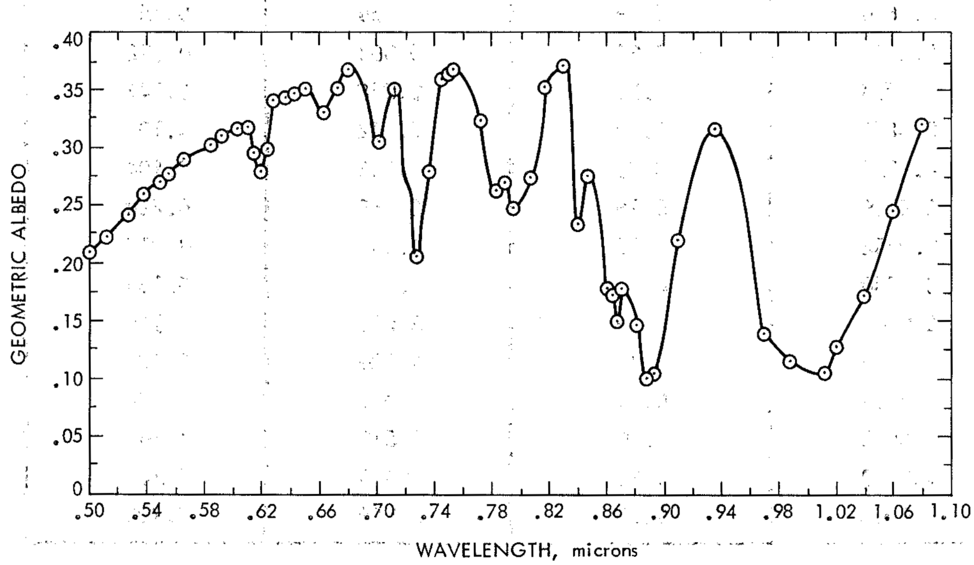

Figure 3-4. Narrow band geometric albedo of Titan, adjusted to zero planetary phase angle. The circles represent measured points, the curve, the estimated albedo between the points.

maxima at 0.936 and 1.08 μm clearly do not represent the continuum. The points at 0.753 and 0.83 μm may well also be depressed from continuum values by the wings of the methane bands adjacent to them. It is not clear from these measurements whether the "red" continuum short of 0.68 μm flattens out at longer wavelengths.

The bolometric albedo, A*, of a planet or satellite is defined as the ratio of the total reflected flux at all wavelengths to the total solar flux intercepted by the surface. This may be reduced to the well-known expression,

$$A^* = \int p_\lambda \, q_\lambda \, H_\lambda \, d\lambda / \int H_\lambda \, d\lambda \qquad (1)$$

where p_λ is the geometric albedo, q_λ the planetary phase function, and H_λ the solar irradiance at one AU.

To compute a value for A*, the wavelength range of p_λ must be extended. For 0.3 to 0.5 μm, the medium band measurements of McCord et al. (1971) have been fitted to the present results. The long wavelength limit for p_λ has been extended to 4.0 μm to include 98% of the incident solar flux. A hypothetical curve from 1.0 to 4.0 μm has been computed, based upon measurements of the energy from Jupiter and Saturn in this region by Moroz (1966), Danielson (1966), Gillett et al. (1969), and Johnson (1970). It assumes that methane is the principal absorber in this region. The curve adopted for the geometric albedo from 0.30 to 4.0 μm is shown in Figure 3-5.

Assuming a constant value of q_λ so it can be removed from the integral of Equation 1, evaluation of the integral gives

$$A^*/\bar{q} = 0.21 \qquad (2)$$

In the region beyond 1.1 μm where the values of p_λ have been estimated, the solar irradiance is falling rapidly from its maximum near 0.50 μm, so the values adopted for p_λ are not critical. It is believed therefore the value of $A^*/\bar{q}$ given above should be correct to ±10%, subject only to possible changes in the radius of Titan.

From measured values of q for the Earth, Venus, and Mars, as well as calculated values for various particle scattering functions and single scattering albedos, it is suggested the value of $\bar{q}$ for Titan is in the range 1.1 to 1.5, with a most plausible value of 1.3. Admittedly this represents merely an educated guess, but it is believed to be the best that can be made at this time. These values give 0.23, 0.27, and 0.31 for A*. Then the effective radiative temperature of Titan may be computed by the equation

$$T_e^4 = S_o \, (1 - A^*)/D^2\sigma \qquad (3)$$

where S_o is the solar constant, D, the Sun-Saturn distance, and σ, the Stefan-Boltzmann constant. With the values of A* above, T_e = 84 ± 2°K.

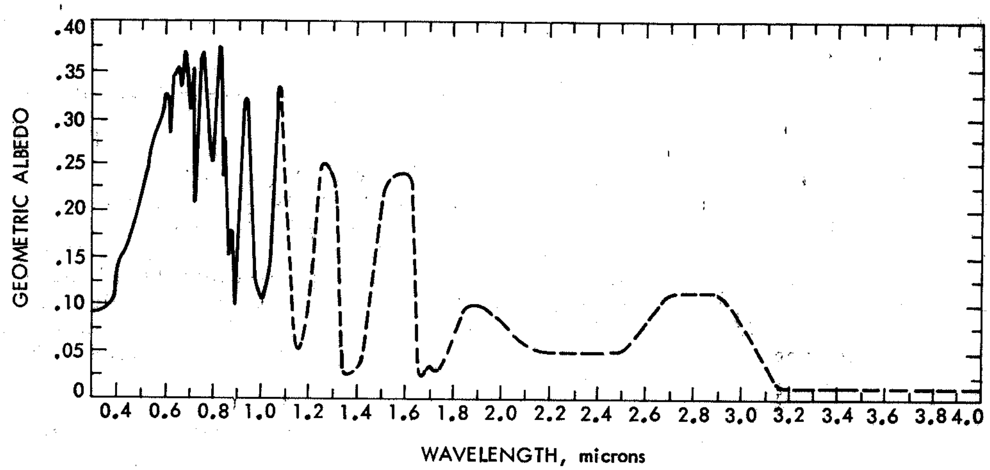

Figure 3-5. Geometric albedo of Titan from 0.3 to 4.0 μm. The solid line represents measured values, the dashed line estimated values.

Acknowledgements

This paper presents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under Contract Number NAS7-100, sponsored by the National Aeronautics and Space Administration.