The Ultraviolet Albedo of Titan

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INTRODUCTION

Ultraviolet spectra of Titan obtained with the Faint Object Spectrograph of the Hubble Space Telescope in October 1991 and August 1992 have yielded a disk-average geometric albedo of 0.02–0.044 from 1800–3300 Å. These results are in excellent agreement with previous UV measurements from 2200–3300 Å spanning two decades, but have a significantly higher signal to noise ratio and spectral resolution. We add ~400 Å of new spectral information from 1800–2200 Å, a wavelength region in which Titan has not been detected previously. The albedo above 2200 Å is a factor of 1.18 higher in August 1992 than October 1991, which is most likely due to the 4.3° difference in Titan’s phase angle between the two dates. Below 2200 Å the albedo decreases only modestly with decreasing wavelength and does not show unambiguous evidence for discrete spectral features characteristic of several of the known hydrocarbons, particularly acetylene (C₂H₂). Comparison of the albedo with best-fit models provides constraints on the optical properties and distribution of the small particle component of Titan’s haze and on the C₂H₂ mole fraction. The small particle haze seems to be darker in the UV than the “Titan” tholins analog produced in the laboratory, and the vertical extent limited to altitudes above ~120–150 km. The acetylene distribution is consistent with the Voyager IRIS determination in the 130- to 180-km altitude range, where the mole fraction is of order 2 × 10⁻⁶.

Key Words: atmospheres, structure; abundances, atmospheres; Titan; satellites of Saturn.
Rannou et al. (1995) suggests that this bimodal population of particles may in fact be the apparent consequence of the fractal structure of fluffy aggregates. UV measurements also provide complementary information on atmospheric composition and structure, particularly for minor constituents. Composed primarily of molecular nitrogen, the Titan atmosphere contains many trace constituents identified primarily by the Voyager Infrared Interferometric Spectrometer (IRIS) experiment (Hanel et al. 1981, Kunde et al. 1981, Maguire et al. 1981), the most abundant of these being methane (CH₄) and acetylene (C₂H₂). Among the trace constituents, many are UV absorbers. Based on the Voyager IRIS abundance determinations, acetylene should play a dominant role in determining Titan's reflectivity below 2200 Å, and predicted but as yet undetected hydrocarbons such as C₆H₂ and nitriles such as acetonitrile and cyanopropylene may also contribute significantly to the total gaseous opacity. In fact, the total absorption cross section of the trace constituents weighted by the IRIS mixing ratios appropriate for the equatorial/mid-latitude range increases by almost five orders of magnitude between 3000 and 1600 Å. The reflectivity of Titan is thus expected to exhibit an even more pronounced decrease toward shorter UV wavelengths than that determined from haze properties alone.

However, to date no molecular absorber has been detected from spectral reflectivity measurements of Titan in the UV. Previous instruments were not capable of achieving sufficient signal to noise ratio (S/N) to detect Titan below 2200 Å, where the satellite is very dark. The increased sensitivity of the UV spectrographs on the Hubble Space Telescope (HST) was expected to provide substantial progress in detecting Titan below 2200 Å, with the possibility of providing direct evidence for gaseous molecular absorbers. We present here results from the first sets of UV observations of Titan made with HST in 1991 and 1992.

**OBSERVATIONS AND DATA REDUCTION**

Our data set consists of observations of Titan made on 9 October 1991 and 25 August 1992 with the Faint Object Spectrograph (FOS) of the HST using the 4'3' x 1'4' aperture and the blue digicon detector with gratings G190H (~1600–2300 Å) and G270H (~2200–3300 Å). The G190H grating provides a dispersion of 1.47 Å/diode, and the G270H grating provides a dispersion of 2.09 Å/diode. The observations are summarized in Table I. Note that the October 1991 observations consist of G270H measurements only, while the August 1992 observations obtained both G190H and G270H spectra.

The two sets of observations use different acquisition strategies to center Titan in the aperture. The October 1991 observations use the FOS firmware acquisition mode. This mode first performs a coarse map of the mirror image of the aperture in selectable X (parallel to dispersion) and Y (perpendicular to dispersion) increments. The aperture illuminates only the central 12 diodes of the 512 diode array and only 20 diodes are read out. A coarse map of 96 x 16 was created using Y steps of 0.3 and the standard quarter stepping strategy in X (i.e., each diode is sampled four times in the dispersion direction). The centroid in X and the edge of the broad peak in Y of the smoothed coarse map image are determined by the onboard software, and an offset slew is performed to achieve coarse centering. This is followed by a fine map using Y steps of 0.1, which is again centroided and used to determine a final offset centering slew. Confirmation acquisition images taken after the onboard acquisition but before the science observations show that Titan is very well centered in the aperture.

In August 1992, accurate centering was accomplished by mapping the 4'3' x 4'3' acquisition aperture in a series of 5 Y steps by taking a 30 s G270H spectrum at each Y step. Location in the Y direction is determined by comparing the brightness of the spectra in the 5 Y steps and in the X (dispersion) direction by comparing the measured wavelengths of features in the brightest acquisition spectrum with the known wavelengths of strong reflected solar Fraunhofer absorption lines in Titan's spectrum. The measured pointing error was then corrected in real time to achieve centering in the aperture. Corrections of 0.72, with an accuracy of about half a step (0.36), in the Y direction and −0.5 (3 Å) in the X direction were required. A short set of measurements similar to those just described confirmed pointing accuracy after the pointing correction uplink and prior to the science observations.

Both sets of science observations use the standard FOS quarter-stepping strategy, which results in four spectral samples per diode. Given the detector diode width of 0.35 and the Titan disk size of ~0.09 (see Table I), the quarter-stepping results in significant oversampling of ~10 times per resolution element. Because no discrete spectral features have been identified with greater than 2σ significance, the data have been rebinned for analysis by a factor of 6 for the G270H spectra and a factor of 12 for the G190H spectra, sacrificing resolution for S/N. The three G190H spectra have been averaged to improve the S/N ratio. We use the brightest of the five G270H acquisition spectra from August 1992 and combine it with the October 1991 G270H spectrum. The October 1991 flux level is a factor of 1.18 lower than in August 1992, of which a factor of 1.09 can be accounted for by the difference in geocentric distance, Δ (see Table I). To maintain the continuity between the G190H and G270H data we scale the October 1991 G270H data to match the August 1992 flux level before averaging. We discuss below the possibility that there is a real difference in the Titan albedo between the two observing dates.
We scope's spherical aberration. The second correction ac-

Identification of any Titan atmospheric contributions to

Precise determination of the geometric albedo depends

We make three significant corrections to the STScI pipe-

The third correction we make is for grating scattered

TABLE I

<table>
<thead>
<tr>
<th>Exposure number</th>
<th>Date</th>
<th>Grating</th>
<th>Exposure length</th>
<th>$d_{\text{p}}$ (AU)</th>
<th>$\Delta^p$ (AU)</th>
<th>Phase angle</th>
<th>Orbital longitude</th>
<th>Solid angle$^c$ (arcsec)</th>
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<tr>
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<td>9 Oct 1991</td>
<td>G270H</td>
<td>5 min</td>
<td>9.518</td>
<td>9.645</td>
<td>5.5$^a$</td>
<td>2$^a$</td>
<td>0.832</td>
</tr>
<tr>
<td>y11r0101</td>
<td>25 Aug 1992</td>
<td>G270H</td>
<td>2 min</td>
<td>9.898</td>
<td>8.934</td>
<td>1.2$^a$</td>
<td>35$^a$</td>
<td>0.899</td>
</tr>
<tr>
<td>y11r0201-3</td>
<td>25 Aug 1992</td>
<td>G190H</td>
<td>24 min</td>
<td>9.898</td>
<td>8.934</td>
<td>1.2$^a$</td>
<td>35$^a$</td>
<td>0.899</td>
</tr>
</tbody>
</table>

$^a$ Titan–Sun distance.

$^b$ Titan–Earth distance.

$^c$ Assumes Titan radius of 2900 km.

tion, which fits Titan’s full disk inside the aperture but
results in ~5% loss of light in the wings due to the tele-
scope’s spherical aberration. The second correction ac-
counts for the time-variability of the detector sensitivity,
which is not included in the pipeline calibration. These
two corrections result in a factor of 1.09 increase to the
pipeline flux calibration.

The third correction we make is for grating scattered
light. Ultraviolet FOS spectra contain a background (“red
leak”) component consisting of near-UV and visible light
instrumentally scattered to shorter wavelengths. This prob-
lem is particularly severe for late-type spectra such as those
of solar system objects. The severity of the grating-scatter-
ed light scales with the flux of longer-wavelength pho-
tons. Two independent techniques have been used to deter-
mine the magnitude of the scattered light as a function of
wavelength. Preflight measurements with the blue detector
and G190H grating (Blair et al. 1989, Sirk and Bohlin 1985)
show the scattered light to be relatively smooth, increasing
linearly toward longer wavelength. Scaling the measure-
ments of Blair et al. to the level of counts in the Titan
G190H data results in a shape for the scattered light that
is essentially constant with wavelength. Based on inflight
measurements of the solar analog star 16 Cygni B with
both the FOS and the solar blind Goddard High Resolution
Spectrograph, Cunningham and Caldwell (1993) have de-
termined a scattering function that is constant with wave-
length except for a broad feature at ~1700 Å. We have
tested scattered light corrections using both of these func-
tions, with results shown in Fig. 1. The ambiguity involves
how and where to match the scattering function to the
data, and the resulting albedo at the bluest wavelengths
is very sensitive to this. The Caldwell function is matched
at the shortest detected wavelengths, while the Blair et al.
function has been matched at both the shortest wave-
lengths (resulting in a scaling factor of 0.021) and at ~1700
Å (resulting in a scaling factor of 0.019), which results in
a flux that matches a solar type spectrum to the shortest
possible wavelengths and represents our best estimate of
the scaling. The sensitivity of the derived geometric albedo
to the scattering correction is illustrated in Fig. 1b. There
is good agreement among the three techniques to wavelengths as short as \( \sim 1800 \text{ Å} \). At wavelengths shorter than this, the albedo diverges and is not reliable. Uncertainty in the data are also very large below 1800 Å in any case due to the rapidly decreasing sensitivity of the grating, which would limit the usefulness of the data in this region even if there were no scattered light problem. We therefore limit our analysis to include only data longer than 1800 Å. We use the Blair \( \times 0.019 \) scattering function in producing the final albedo used for analysis. The flux spectrum corrected with this same scattering function is shown in Fig. 1a.

There is \( \sim 100 \text{ Å} \) (2220–2320 Å) of overlap between the G190H and G270H grating coverage. The fluxes in the overlap region for the August 1992 data match to within a few percent before the scattered light correction is applied to the G190H data. There is no evidence for scattered light in the G270H data, based on comparison with a scaled solar spectrum. Therefore, after the scattered light correc-

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**FIG. 1.** (a) G190H flux spectrum of Titan with and without a scattered light correction compared with a scaled solar spectrum, illustrating the scattered light present at short wavelengths. (b) Geometric albedo of Titan for the G190H spectral range showing the effect on the albedo of various scattered light corrections. The correction is not reliable shortward of \( \sim 1800 \text{ Å} \), and we do not consider this wavelength region in our modeling. The final HST albedo longward of 1800 Å presented in this paper uses the Blair function scaled by a factor of 0.019.
tion to the G190H data, the flux in the overlap region is \( \sim 10\% \) lower for the G190H data, consistent with previous results obtained for FOS observations of extended objects (Cunningham et al. 1993). Since the G270H data do not suffer seriously from scattered light, they are considered the more reliable of the two. To force self-consistency, we scale the G190H data by a linear function equal to 1.0 at 1700 Å and the ratio of G270H to G190H flux in the region of overlap centered at \( \sim 2280 \) Å, as recommended by Cunningham et al. (1993).

Error bars for the Titan albedo are produced by adding quadratically the statistical photon counting error with an error for the scattered light correction. The latter is based on the standard deviation of the data in the regions used to determine the magnitude of the scattered light correction. Figure 2 includes only these relative error bars, which are dominated by the photon counting statistics. Because of the variation in the sensitivities of the gratings, the photon counting error decreases from \( \sim 18\% \) to \( \sim 2\% - 3\% \) between the short and long wavelength ends of the spectral regions of both gratings. The error bars therefore increase near 2300 Å since this is the short wavelength end of the G270H spectrum, which has a lower S/N ratio due to the much shorter integration time compared with the G190H data (7.5 min total compared with 72 min total). We use the G270H data in the region of overlap. The absolute error in the Titan albedo is estimated to be \( \sim 11\% \), with \( \sim 10\% \) due to the uncertainty in the FOS calibration and \( \sim 5\% \) due to the uncertainty in the solar spectrum calibration. We add the three sources of error quadratically to produce the absolute error bars shown in Fig. 3b for the final disk-average albedo used in comparison with other data and models, discussed below.

The two albedos resulting from the October 1991 and August 1992 observations are shown in Fig. 2a. The shape of the spectrum does not change between the two dates, as indicated by a flux ratio (August/October) that is flat with wavelength at a value of 1.18. The differences in the heliocentric (\( d \)) and geocentric (\( D \)) distances of Saturn between the two dates (see Table I) reduce the difference in the albedos to a factor of 1.09, since the albedo scales as \((d/D)^2\). The two observations are made at phase angles of 1.2° and 5.5°. Correction for phase angle in the UV is unknown because observations covering a wide range of phase angles with adequate S/N ratio do not exist in this spectral range. We therefore estimate the magnitude of this effect using the formula based on visible observations from Lockwood et al. (1986), \( F(\alpha^o) = F(\alpha)p^{-\alpha} \), where \( \alpha \) is the phase angle and \( p(\lambda) = 1.0045633 + 0.0155986 \ln \lambda \). The albedos on the two dates corrected for phase angle are shown in Fig. 2b, and the ratio of the two corrected for phase angle is shown in Fig. 2c. This correction results in albedos that match to within less than a factor of 1.025 over the entire wavelength range. If this phase angle correction is reasonably accurate, there is not a significant difference in the Titan albedos between the two dates. This result would be consistent with searches for variations at visible wavelengths on short time scales such as Titan’s 16-day orbital period that has revealed no variations larger than 1% (Lockwood 1975). Since we do not believe there is a statistically significant difference between the two sets of data, we scale the October 1991 data to that of August 1992 and average the two to produce the final UV albedo shown in Fig. 3.

**RESULTS AND DISCUSSION**

The Titan reflection spectrum has not been detected previously in the spectral region below about 2250 Å (see Fig. 3b), so we add \( \sim 400 \) Å of new spectral information. Generally speaking, the UV reflectivity measured by HST decreases gradually from about 0.04 to 0.02 between 3300 and 1800 Å. There are no abrupt changes in the slope of the albedo and no unambiguous discrete spectral absorption features (especially from \( \text{C}_2\text{H}_2 \)) of Titan's albedo. There are several marginally significant emission features in the albedo near the strongest solar Fraunhofer lines of \( \text{MgII} \) (\( \sim 2800 \) Å) and \( \text{MgI} \) (\( \sim 2850 \) Å). We attribute these features to nonconservative Raman scattering that occurs in addition to the Rayleigh and particulate scattering and particulate and gaseous absorption (Caldwell et al. 1994). We note that these features are weaker in the August 1992 albedo than the October 1991 one shown in Fig. 2b, which we attribute at least in part to the shorter integration time for the August observation.

We compare this average HST albedo with the visible-wavelength albedo of Karkoschka (1994) in Fig. 3a. These data are also used to check the consistency of the FOS absolute calibration. The geometric albedo for the ground-based data was derived with a Titan radius of 2575 km, which is not appropriate for the visible wavelength. We have rescaled the ground-based data using the wavelength-dependent radius given by Toon et al. (1992) as

\[
R(\lambda) = 2965.1 - \frac{226.288 A}{10^4} + \frac{35.03 A^2}{10^8},
\]

where the radius is in km and the wavelength in Å. For consistency we also scale the FOS data, although it represents a minor correction (1.0–1.7% in G190H, 0.4–1.1% in G270H). The FOS average albedo matches the Karkoschka data extremely well in the region of overlap. We do not believe the downturn in the UV albedo near 3300 Å is real and attribute it to an edge effect, possibly due to the tilt of the spectrum near the edge of the diode array. The HST albedo is also compared with previous UV measurements at \( \lambda \approx 2250 \) Å spanning two decades in Fig. 3b. The IUE (phase angle 3.5°) and OAO-2 (phase angle
6.3°) data have also been corrected to zero phase angle using the formula given above. The agreement among the UV data sets is also remarkably good; they match to within the error bars over the entire range of overlap. The HST albedo is somewhat higher from 2600–3300 Å but this difference at best only marginally statistically significant. Since the error bars for the HST albedo are dominated by the absolute calibration uncertainty, averaging over larger spectral regions to improve the photon counting statistics will not change this result. Titan is known to exhibit seasonal variability of as much as 10% in the visible wavelength region. The apparent difference in slopes of the
IUE and HST albedos toward longer (visible) wavelengths may be due to such seasonal variability that manifests itself at visible, but not at UV, wavelengths. A stronger conclusion than this regarding the lack of evidence for seasonal variability in the UV requires higher quality UV data. Other than the difference between October 1991 and August 1992 discussed above, there is no evidence for variability at wavelengths below 2600 Å in the UV.

Since previous UV data only go to 2200 Å, there are few existing models of the Titan albedo which cover the wavelength range 1750–2200 Å where we have new spectral information. Courtin (1992) has presented synthetic models of the Titan albedo down to 1600 Å that match the previous UV data using Voyager IRIS derived values of hydrocarbon abundances. We adopt a similar model (described more fully in Courtin et al. 1991) for comparison with the new data and use the model to provide information about the haze index of refraction, the distribution of Rayleigh scatterers, and the limits on the acetylene abundance compared to the Voyager IRIS results.

The radiative transfer method is that described by Courtin et al. (1991), modified slightly by the incorporation of Raman scattering, which was modeled using the approximation proposed by Pollack et al. (1986). The Raman scattering cross-section for the N₂ fundamental vibrational transition was adopted from Burris et al. (1992), and measurements from the UARS/SOLSTICE experiment (Rottman et al. 1993, Woods et al. 1993) were used for the detailed spectral characteristics of the solar irradiance. Convolution with a Gaussian slit function of width 3.7 Å has been used to approximate the FOS LSF.

The baseline haze model is that of Courtin et al. (1991). It is characterized by a bimodal size distribution for the haze particles (Mie-type and Rayleigh-type scatterers). The same index of refraction is used for both types of particles. We use the combined HST + ground-based albedo to constrain the imaginary index of refraction of atmospheric aerosols at several wavelengths (indicated in Fig. 3a) down to 2070 Å. As noted by Courtin et al. (1991),
the only derivable constraint for the Rayleigh-type scatterers is the product of their mass-column density $M_o$ by their imaginary index of refraction $k_{im}$. The density distribution of these aerosols is assumed to be proportional to the atmospheric pressure scale above a given altitude $Z_o$. Below that level the distribution decreases rapidly to zero. For a given value of $M_o$, we find a solution $k_{im}(\lambda)$ that fits the combined HST + ground-based albedo. These solutions are slightly dependent on the parameter $Z_o$ as well. The lower the cut-off altitude, the darker these small particles need to be, especially at wavelengths below 2500 Å. This has some implications for the fit to the HST data in that spectral range.

Figure 4 shows the inferred values of the imaginary index for three sets of the parameters $M_o$ and $Z_o$ and compares them to the measured values for "Titan" tholins (Khare et al. 1984) and for HCN polymers (Khare et al. 1994). None of these solutions match the optical properties of the "Titan" tholins exactly. The aerosols in our model are either brighter than the tholins in the blue-violet or darker in the UV. On the other hand, they do not resemble HCN polymers either. However, we note that a 75–25% mixture of "Titan" tholins and poly-HCN does approximate quite closely one of our solutions (corresponding to $M_o = 9.5 \times 10^{-6} \text{g/cm}^2$ and $Z_o = 150 \text{km}$). An alternative explanation is that the stochiometry of the "Titan" tholins produced by Khare et al.—mainly characterized by their C/N ratio—differs significantly from that of Titan’s aerosols. McKay (1996) has shown that the UV and violet absorptivity is a critical function of the CH$_4$ to N$_2$ ratio in the original gas mixture used to produce the tholins.

Information on the haze and acetylene distributions is derived from model fits to the HST data. As a nominal case, we used the $k_{im}$ values corresponding to the median curve ($M_o = 9.5 \times 10^{-6} \text{g/cm}^2$, $Z_o = 150 \text{km}$). The solution is of course not unique, but it seems logical to use a model which is closest to the tholins case, since there is already a close match in the visible (McKay et al. 1989). Solutions with significantly lower values of $Z_o$, e.g., $Z_o = 90 \text{ km}$, give very poor fits to the data. Below 2070 Å, the refractive index is extrapolated at a constant value. The manner in which the extrapolation is done will influence the determination of the C$_2$H$_2$ distribution. This point is discussed below.

For the acetylene photoabsorption cross-sections, we relied on the recent low temperature ($T = 155 \text{ K}$) measurements of Bénilan et al. (1995). However, these measurements only cover the spectral interval from 1890 to 2030 Å. We therefore combined them with previous room-temperature data from Nakayama and Watanabe (1964). The effect of a lower temperature is to decrease the pseudo-continuum and increase the peak absorption by about 40%. At the resolution of a few Å, this effect is considerably smoothed out, so it is justified to combine the two data sets.

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**FIG. 5.** The distribution of C$_2$H$_2$ with altitude for various models. The distributions used to model the HST data are adapted from the photochemical production model of Toublanc et al. (1995), shown by the long dashed line. Our nominal solution is the minimum profile (short dashed line) shown here which uses $Z_o = 150 \text{ km}$ and $M_o = 9.5 \times 10^{-6} \text{ g cm}^{-2}$. It is compatible with the Voyager/IRIS determination in the 130- to 180-km altitude range. Also shown is the maximum profile (dash-dot line), with $Z_o = 120 \text{ km}$. The corresponding fits to the data are shown in Fig. 6a. Pseudo-weighting functions at 2000 Å are shown on the left for the three distributions.
Figure 5 shows two best-fit $C_2H_2$ distributions derived by fitting the HST data which we term the “minimum” and “maximum” distributions. Also shown is a distribution computed from photochemical modeling by Toublanc et al. (1995) and the Voyager–IRIS determination in the altitude range 80–180 km (Coustenis et al. 1989). In our model, we assumed the $C_2H_2$ distribution to follow the vertical profile calculated by Toublanc et al. (1995), but with an adjustable scaling factor. The corresponding albedos calculated using these distributions are compared with the data in Fig. 6a. The minimum distribution was obtained assuming a cut-off altitude $Z_o = 150$ km for the small scatterers and a constant value for the haze refractive index below 2070 Å; the maximum distribution corresponds to a cut-off altitude $Z_o = 120$ km. Pseudo-weighting functions, calculated at 2000 Å from the variation of the extinction optical depth with altitude, are also shown. Lowering the small scatterers cut-off level displaces the $\tau = 1$ level downward, hence, larger values of the $C_2H_2$ mole fractions are derived at a given altitude. For both distributions, the slope below 1900 Å is steeper than the observed one, but within the error bars associated with the albedo.

Models that agree better in the 1800 to 1900 Å interval have been achieved by assuming a sharp decrease of the imaginary index of the small particles below 2070 Å, which is illustrated by a third model fit shown in Fig. 6a. Very low values of $k_{im}$, of order $8 \times 10^{-2}$, would be needed in such a fit. This is about $\frac{1}{3}$ of the “Titan” tholins value, and...
we consider this case to be unlikely. Additionally, it is important to note that acetylene cannot account for the sharp downturn seen in the albedo below 1900 Å. Our nominal solution for the acetylene distribution is therefore the minimum profile shown in Fig. 5, while the maximum profile is indeed an upper limit with respect to fitting our data. The nominal solution is compatible with the IRIS determination in the upper part of the error box, between 130 and 180 km. In fact, the altitude range relevant to the IRIS acetylene measurements is itself a function of the assumed distribution. Using a distribution similar to that of Toublanc et al.—instead of a constant mole fraction as was assumed by Coustenis et al. (1989)—would raise the IRIS error box to slightly higher altitudes, thus bringing the IR and UV determinations into better agreement.

Figure 6b shows the nominal model fit to the HST/FOS albedo outside the region of C₂H₂ absorption. An excellent correlation is obtained between the more intense Raman signatures computed for N₂ and the observed features in this region. The intensities of these features are also consistent with the model predictions, given the relative uncertainties of the HST/FOS data. As a further test of the Raman scattering model, we compare our predictions with the ground-based data of Karkoschka (1994) in Fig. 6c, for a spectral resolution of 10 Å. The correlation is less satisfactory than with the HST/FOS data, although the residuals are at the 3% level, which is consistent with the 3-σ error bars for these data. The strongest signatures in the computed spectrum, around 3950 Å, would be well correlated with observed features but for a 7 Å shift that we have no explanation for at the present time. Figure 7 shows the fit to the full HST + ground-based albedo corresponding to the nominal model, i.e., a small haze particles cut-off at \( Z_o = 150 \) km, a constant imaginary index below 2070 Å, and the minimum C₂H₂ distribution shown in Fig. 5.

**CONCLUSIONS**

The HST/FOS measurements presented in this article allow us to place further constraints on the optical properties and distribution of the small particle component of Titan’s haze. The material constituting these particles seems to be darker in the UV than the “Titan” tholins analog produced in the laboratory. Indeed, its UV imaginary index of refraction could be approximated by that of a mixture of tholins and poly-HCN, with the former constituent in dominant proportion. The vertical extent of these small scatterers seems to be limited to altitudes above \( \sim 120–150 \) km, in agreement with stability arguments (Courtin et al. 1991). Furthermore, the acetylene distribution derived from these measurements is consistent with the Voyager/IRIS determination in the 130- to 180-km altitude range, where the mole fraction is on the order of \( 2 \times 10^{-6} \). We do not find evidence for other gaseous absorbers in the wavelength interval 1800–2200 Å, which is investigated for the first time by our measurements.
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