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NASA Technical Memorandum 103957

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# A New Software Tool for Computing Earth's Atmospheric Transmission of Near- and Far-Infrared Radiation

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(NASA-TM-103957) A NEW SOFTWARE  
TOOL FOR COMPUTING EARTH'S  
ATMOSPHERIC TRANSMISSION OF NEAR-  
AND FAR-INFRARED RADIATION (NASA)  
194 p

N93-20066

Unclas

G3/46 0146073

December 1992

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# **A New Software Tool for Computing Earth's Atmospheric Transmission of Near- and Far-Infrared Radiation**

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Space Administration

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## SUMMARY

This report describes a new software tool, ATRAN, which computes the transmittance of Earth's atmosphere at near- and far-infrared wavelengths. We compare the capabilities of this program with others currently available and demonstrate its utility for observational data calibration and reduction. The program employs current water-vapor and ozone models to produce fast and accurate transmittance spectra for wavelengths ranging from 0.8  $\mu\text{m}$  to 10 mm.

## 1. INTRODUCTION

During the last year, through the acquisition of an augmented data base and the improvement of existing software algorithms, we have developed a software tool, "ATRAN," which accurately and efficiently models Earth's atmospheric transmission of radiation ranging from 0.8 to 10,000  $\mu\text{m}$  in wavelength, which includes the near-infrared (NIR), far-infrared (FIR), and microwave windows. This report describes the main features of this new software product, and gives instructions for its use.

The virtues of the new software over existing packages include its high accuracy and ability to model both high- and low-resolution ( $\Delta\lambda/\lambda = 0.0001$  to 0.1) spectral profiles. The program achieves high accuracy by modeling Earth's atmosphere in detail, using ozone and water-vapor models derived from detailed observations. The program performs its calculation efficiently, making it especially useful for real-time applications.

Since the software identifies spectral lines present in high-resolution NIR, FIR, and microwave spectral-line observations, it is useful in the routine wavelength calibration of the spectrometers used to make such observations. The software is also particularly useful for determining the extinction toward astronomical sources as a function of wavelength, observational altitude, and zenith angle, and for correcting the observed flux. The program output consists of numerical data files, and screen and hardcopy graphical displays.

Our work relies largely on previous NIR and FIR studies of Earth's atmospheric absorption properties, including studies of the atmospheric absorption of the emission lines from astronomical objects. In the following section we trace the development of this software from such studies.

We would like to acknowledge the help of Richard Freedman in supplying us with the HITRAN data base, as well as invaluable advice regarding its use. We thank David Goorvitch for encouraging us to expand the scope of the software and the domain of its use, and for providing the necessary support to make this project possible. We also thank Jason Craig for his help with the broad line search, and in preparing this document using TeX.

## 2. COMPARING THIS PRODUCT WITH OTHERS

Currently, there are several computer programs available for modeling atmospheric transmittance. Here we describe some of those programs, and trace their evolution as software tools used within the Space Science Division at Ames Research Center. Attributes of the various programs are listed and compared with those of ATRAN. Another product, available from the Jet Propulsion Laboratory, is also mentioned.

The program DEGRADE (ref. 1) provided the basis for the programs ATMOS and CDG21 (refs. 2 and 3), which were implemented on a CDC 7600 and an HP 2100 computer at Ames. The authors of references 2 and 3 also utilized some of first spectral-line lists compiled by the Air Force Geophysical Laboratories (AFGL, now Phillips Research Laboratories, PL). These programs are now obsolete, but they formed the basis of further work, and references 1-3 contain very concise and useful descriptions of the process of modeling atmospheric absorption lines.

As an improvement to this software, the program NWATR was modified from DEGRADE in 1976, by J. Simpson at Ames, for use on an HP 1000 computer. NWATR was moved to the Ames CRAY YMP computer and was extended to handle shorter wavelengths (to 3  $\mu\text{m}$ ) in 1988. This CRAY NWATR version is also called DEGRADE.

In 1989 a new program, ATRAN, (the product described herein) was written at Ames to run on a VAX 8600. In 1991 a second version of ATRAN was produced to run on UNIX machines (Sun workstations, and a DEC Ultrix system). The spectral-line list for all versions of ATRAN, as well as for the CRAY version of NWATR, is the newest 1991 HITRAN data base (ref. 4) provided by PL.

Independent of these efforts, PL, in an ongoing large-scale project of the USAF Systems Command,

has produced a series of atmospheric modeling programs. The most recent versions are called LOWTRAN7 (ref. 5) and FASCOD3 (refs. 6 and 7). This same group has continually refined and expanded their data base of atmospheric lines, which was formerly called the AFGL data base; it is now called the HITRAN data base. HITRAN is the data base that all of the programs—FASCOD3, NWATR (the CRAY version), and ATRAN—currently use.

The source code for FASCOD3 and the object code for LOWTRAN7 (a PC version) are available in the Space Science Division (from R. Freedman and the author, respectively), although owing to their size, neither program has ever been compiled and run. Portions of FASCOD2 have been extracted and used in programs written by R. Freedman on the CRAY YMP to model planetary atmospheres such as those of Venus and Mars. FASCOD2 for the PC (in a version called PCLnTRAN) is available from the ONTAR Corporation of Brookline, Massachusetts.

The programs NWATR, ATRAN, and FASCOD are described and compared below.

## NWATR

The acronym NWATR begins with N as a tag for spectroscopy software, and WATR stands for water vapor absorption, etc. The great virtue of this program is its simplicity. Although other programs may give results that are more accurate than those of HP 1000 NWATR (by several percent in some cases), NWATR is relatively short and simple. The program ATRAN is about an order of magnitude longer and more complex than NWATR, and FASCOD is yet another order of magnitude more complex than ATRAN. NWATR is primarily set up to model the atmosphere above 41,000 ft. Its model divides the atmosphere into 1, 10, or 20 layers, assigning to the layers characteristic pressures above 41,000 ft; the pressures may be linearly scaled. The atmosphere is described by a single temperature, which also may be reset. The program searches for lines residing a fixed number of wave numbers outside the range of interest for deep lines, looking for line wings which may cause absorption in the range. This procedure is sufficient at high altitudes for most FIR wavelengths with  $\lambda > 9 \mu\text{m}$ .

The CRAY version of NWATR has recently been augmented to access the latest PL data base, HITRAN. The program has also been equipped with a 10-layer

atmospheric ozone model, pressures to sea level pressure, and a temperature function with altitude, and has been extended to calculate emission lines in addition to absorption lines. Access is only possible through the CRAY, or to the older version residing on an HP 1000 (soon to be discarded). Detailed comparisons of the CRAY NWATR and the ATRAN have not been conducted; each program has undergone recent improvements.

## ATRAN

ATRAN (Atmospheric TRANsmission) was written to accomplish several goals. These goals, in general, involve an increase in accuracy over existing software without a loss in execution speed.

One goal is to model the atmosphere in more detail so as to accurately calculate atmospheric transmittance from altitudes ranging from 0 to 30 km. For this purpose, we use several detailed atmospheric models from the literature. These include models for the mixed gases, water vapor, and ozone (all these input models are described in sec. 4). The program is versatile in using the models, dividing the gas distributions into an arbitrary number of layers of equal mass, and raising or lowering the water and ozone distribution with altitude to match conditions observed. A useful approximation, the "Curtis-Godson" approximation, is also used to model the uppermost layer in the calculations.

The program covers a wide range of wavelengths, from 0.8 to 10,000  $\mu\text{m}$  (8000 Å to 10 mm), thereby including the near-infrared, the far-infrared, and the microwave windows. To handle this wide range, the program performs its calculations specially for the particular wavelength range selected. For example, to compute the integration step in wave number, the program considers the pressure at the highest atmospheric layer (which determines the width of the narrowest lines), the typical line width at the given wavelength, and the resolution degradation caused by the user-selected smoothing function. Likewise, the program knows the location of very deep lines within these windows, lines that have wings extending several hundred wave numbers. When attempting to compute transmittance spectra near these lines, the program will extend its integration range to take into effect the wings from these lines. The cutoff criterion for weak lines (lines with wings that are sufficiently shallow to constitute a negligible opacity) is determined in part by a knowledge of

the number of contributing lines at a particular wavelength. The program keeps track of the number of absorption lines present per wave number as a function of wave number. The program can also handle a large wavelength range, computing transmittance spectra spanning up to 800 wave numbers. The user is given a choice of smoothing functions, or an additional "no-smoothing" option, which will produce a quick look at the true transmittance, independent of measuring instruments. The Lorentz line shape is used at wavelengths below 100  $\mu\text{m}$ , whereas the more precise kinetic (Van Vleck) line shape is used at longer wavelengths.

To assist in laboratory settings, the program has a "tank" mode, in which a single gas, such as water vapor, or  $\text{D}_2\text{O}$ , is modeled on the basis of the pressure, gas column density, and temperature within the tank, that is, one layer.

An important feature of the program is the production of presentable, self-documented plots, which contain a legend describing all the input information that went into the production of the particular transmittance profile. This is accomplished by means of a MONGO interactive plot command file produced by the program. The plot axes may be configured variously for wave number, wavelength, or velocity. Additionally, in plots showing significant atmospheric absorption, the deepest 40 lines in the profile are marked, and the absorbing species are identified at the bottom of the plot. The plotting capability extends to various graphic screens, X and SunView windows, and laser printers. Also, the user is given a file containing the plot commands, and another file containing the sampled function.

A final important attribute of the program is its portability. Currently, versions of the code are running identically under UNIX and VMS environments. Along with the program, the HITRAN data base (in a condensed form) is supplied, as well as programs that will read and write the data base in ASCII and binary.

NWATR and ATRAN are found to run comparably fast on the same machine, producing a transmittance profile typically in less than a minute.

Appendixes A-C list ATRAN and give instructions for its installation and operation.

## FASCOD

Most of the attributes of ATRAN described above are also present in the Fast Atmospheric Signature

Code (FASCOD). Earth's atmosphere is modeled here in many *spherical* layers and emphasis is placed on the program's ability to efficiently sample (sort through) the spectral-line list in preparing a transmittance profile. The program will compute radiance (emission) in addition to atmospheric absorption. FASCOD models the same large range of wavelengths spanned by ATRAN, since both programs use the same Phillips Research Laboratories (PL) HITRAN data base.

FASCOD contains many refinements for computing transmittance and radiance profiles. These include computing the effect of line coupling (below two wave numbers), continuum emission, and continuum absorption of line emission. Continuum functions within the program are also used to correct line shapes for impact broadening. The program will treat Earth atmospheres that are out of local thermodynamic equilibrium, and will also accept a foreign atmosphere of the user's construction. Upper atmosphere gases at altitudes up to 120 km are included in the models, which contain a variety of aerosols. FASCOD has also been equipped with routines from the associated PL product LOWTRAN (which computes transmission at low resolution). These routines take into account Earth atmospheric changes with climate, latitude, season, and weather. FASCOD is a much larger and more general product than NWATR or ATRAN. We do not have specific information about its total size and speed. It clearly has attributes that are beyond the needs of many of the current users of ATRAN and NWATR, and it presumably runs significantly more slowly. We note that the information we report here on FASCOD is gathered from reference 7, and not from experience with the program.

## JPL Data Base

There exists another atmospheric data base (ref. 8), concentrated at wavelengths longward of 30  $\mu\text{m}$ , extending into the millimeter range. This effort is conducted at the California Institute of Technology and at the Jet Propulsion Laboratory. The authors have collected a large catalog of line transitions for 130 atomic and molecular species. (The products above model fewer species. FASCOD models about 28 species, and ATRAN and NWATR select the most abundant 7 of these. The CRAY NWATR program, in one version, now also models the additional "trace species.")

We have recently learned of two other codes. The first, GENLN, is very similar to FASCOD, and was developed at Oxford University, transported to NCAR by David Edwards, and developed further there. The second, IRTAN, is used at Goddard Space Flight Center. We have no further information on these codes.

### 3. BASIC MATHEMATICS

We now discuss the fundamental calculations performed by ATRAN. Our discussion follows the treatment of Augason and Burnes (ref. 2). The transmittance,  $t$ , is defined as the fraction of radiative intensity that passes through the atmosphere unabsorbed,  $t = I/I_0$ . Transmittance within a wavelength band (or wave-number band, where wave number  $\sigma$  cm<sup>-1</sup> is given by  $\sigma = 10000/\lambda$ ), with  $\lambda$  in microns, is calculated at finely spaced wave-number intervals. At each wave number  $\sigma$ , the absorption due to the relevant molecular transition is computed. The absorption depends on the ambient temperature, pressure, and gas density, and in order to correctly characterize these atmospheric parameters with altitude, we divide the atmosphere into multiple layers. At a specific wave number  $\sigma$ , for each molecular transition and each atmospheric layer, a column density  $\omega$  and an absorption coefficient  $\kappa$  are determined. At a particular wave number  $\sigma$ , the  $\kappa\omega$  values are summed for all the contributing transitions (indexed  $i$ ), and layers (indexed  $l$ ). The exponentiation of  $-\kappa\omega$  gives the transmittance:

$$t(\sigma) = \exp\left(-\sum_{i,l} \kappa_{i,l}(\sigma)\omega_{i,l}\right)$$

The number of significantly contributing transitions  $I$ , where  $i = 1$  to  $I$ , depends on the wave number, and may range from zero to thousands. In the above expression, the absorption coefficient  $\kappa$  for the  $i$ th transition is given by

$$\kappa_i(\sigma) = S_i L(\gamma_i, \sigma)$$

where  $S_i$  is the line strength for the  $i$ th transition, and  $L$  is the line-shape function centered at wave number  $\sigma_i$  with a half width at half maximum (HWHM) given by  $\gamma_i$ . For wavelengths less than 100  $\mu$ m, a Lorentzian line shape accurately describes the (pressure-broadened) lines:

$$L(\gamma_i, \sigma) = \frac{1}{\pi} \frac{\gamma_i}{(\sigma - \sigma_i)^2 + \gamma_i^2}$$

At longer wavelengths, an approximation to the classical line shape (refs. 9–11), sometimes called the “kinetic” line shape, is appropriate:

$$L(\gamma_i, \sigma) = \frac{1}{\pi} \frac{\sigma \sigma_i 4\gamma_i}{(\sigma^2 - \sigma_i^2)^2 + 4\gamma_i^2 \sigma^2}$$

In each case, the function  $L$  is normalized to have unity area over the interval  $-\infty \leq \sigma \leq \infty$ . The half width at half maximum  $\gamma_i$  scales with pressure  $P$ (atm) and temperature  $T$  as

$$\gamma_i = \gamma_i^0 P \left(\frac{296}{T}\right)^{n_i}$$

where  $n_i$  varies for each transition (indexed by  $i$ , the transition index), and averages between 0.5 and 0.62. We note that the extreme wings of some lines, (e.g., H<sub>2</sub>O lines in the microwave window), may not be well represented by these functions, as is discussed in reference 12. Also, reference 13 discusses in some detail the temperature dependence of absorption coefficients.

The line strength is corrected for stimulated emission at temperature  $T$  by

$$S_i = S_i^0 \left(\frac{T_0}{T}\right)^{m_j} \exp\left(-\frac{E(T_0 - T)}{0.695 T_0 T}\right) \times \left[ \frac{1 - \exp\left(\frac{-\sigma_i}{0.695 T}\right)}{1 - \exp\left(\frac{-\sigma}{0.695 T_0}\right)} \right]$$

where  $T_0 = 296$  K is the reference temperature for the transition parameters. The value  $m_j$  for species  $j$  describes the temperature dependence of the partition function, and depends on the species. Table 1 gives  $m_j$ , a typical value for  $n_i$ , the abundance in parts per million (ppm), and species index  $j$  for the seven most important atmospheric species. These are the seven species followed by the program.

Note that the exact value for  $n_i$  is available for each transition from the HITRAN data base, and ATRAN uses the data base value for each transition. (For some species,  $n_i$  is dependent on the rotation quantum number  $J$ .)

The HITRAN data base (expanded from the former 1986 data base to include parameter corrections, additional weaker lines, a broader wavelength coverage, and more species, gives the following data for each transition:  $\sigma_i$ ,  $S_i^0$ ,  $\gamma_i^0$ ,  $E$ ,  $j$ , and  $n_i$ . Note that for isotopic transitions, the line-strength parameter in

Table 1. Specie parameters

| Molecule         | $m_j$ | $n_i$ | Abundance, ppm | Index = j |
|------------------|-------|-------|----------------|-----------|
| H <sub>2</sub> O | 1.5   | 0.62  | -              | 1         |
| CO <sub>2</sub>  | 1.0   | 0.5   | 330            | 2         |
| O <sub>3</sub>   | 1.5   | 0.5   | -              | 3         |
| N <sub>2</sub> O | 1.0   | 0.5   | 0.28           | 4         |
| CO               | 1.0   | 0.5   | 0.75           | 5         |
| CH <sub>4</sub>  | 1.5   | 0.5   | 1.6            | 6         |
| O <sub>2</sub>   | 1.0   | 0.5   | 2.1            | 7         |

the data base has been weighted downward by the isotopic ratio, so that the column density  $\omega$  of the most common isotope may still be used to compute the line strength.

The atmospheric line data from HITRAN, in combination with model atmospheric physical parameters  $\omega$ , T, and P, provide the information necessary to compute a transmittance spectrum.

#### 4. DETAILS OF THE CODE

A sequential flowchart of the program is given below. The flow is controlled by a main program, which calls a succession of subroutines. The subroutines perform the functions necessary to compute one transmittance function. If additional functions are required, control returns to the beginning of the main program. The subroutines are as follows:

|        |   |
|--------|---|
| GETPRT | Sets up the parts per million of atmospheric gases  |
| GETLEV | Reads in the standard atmospheric model table giving temperature, pressure, etc., at 0.1-km intervals |
| GETATM | Shifts water vapor and ozone content of atmosphere in altitude if necessary                           |
| SCALGS | Sets up the scaling coefficients for the line parameters $S_i$ and $\gamma_i$                         |
| LEVELS | Divides atmospheric model into layers   |
| GETLAM | Establishes wavelength range and resolution   |
| GETPLO | Sets up instrumental smoothing function for plot  |
| GETSET | Reads through spectral line data base to records of relevance   |
| INTEG  | Integrates absorption line profiles at each layer   |

EXPO Exponentiates  $-k\omega$  to determine transmittance

PLOT Writes out the data array and a MONGO control file for plotting

Below we discuss key portions of the code which establish the atmospheric model, carry out the integration, and simulate the instrumental smoothing functions.

#### Earth Atmosphere Model

The atmospheric model is set up in three stages. In the first stage, the user chooses fundamental parameters for the atmosphere: observational altitude, zenith angle, overhead water-vapor content (if available), and total ozone content (if available). The program also reads in a standard atmosphere parameter table (appendix D) which gives the temperature, pressure, and overhead column density for the mixed gases and the water vapor and ozone separately (figs. 1-4). The ozone data include a selection of four distributions in altitude that are typical for the latitudes 9°, 30°, 43°, and 59° north or south. These have been taken from figure 5.7 of reference 14.

At an arbitrary latitude, it is observed that when the total ozone column density changes, the shape of the density profile also changes, and the profile is likely to resemble one of the four profiles we have tabulated. The total column densities (in molecules  $\text{cm}^{-2}$ ) of the profiles are  $6.86 \times 10^{18}$  (lat. 9°),  $8.41 \times 10^{18}$  (lat. 30°),  $1.03 \times 10^{19}$  (lat. 43°),  $1.21 \times 10^{19}$  (lat. 59°). The program selects the profile most closely matching the observed total column of ozone (a value that may come from satellite observations). If no ozone value is supplied, the program assumes a value of  $9.13 \times 10^{18}$ , which is typical for the latitude of 39° north or south (ref. 14). After selecting the best profile, the density

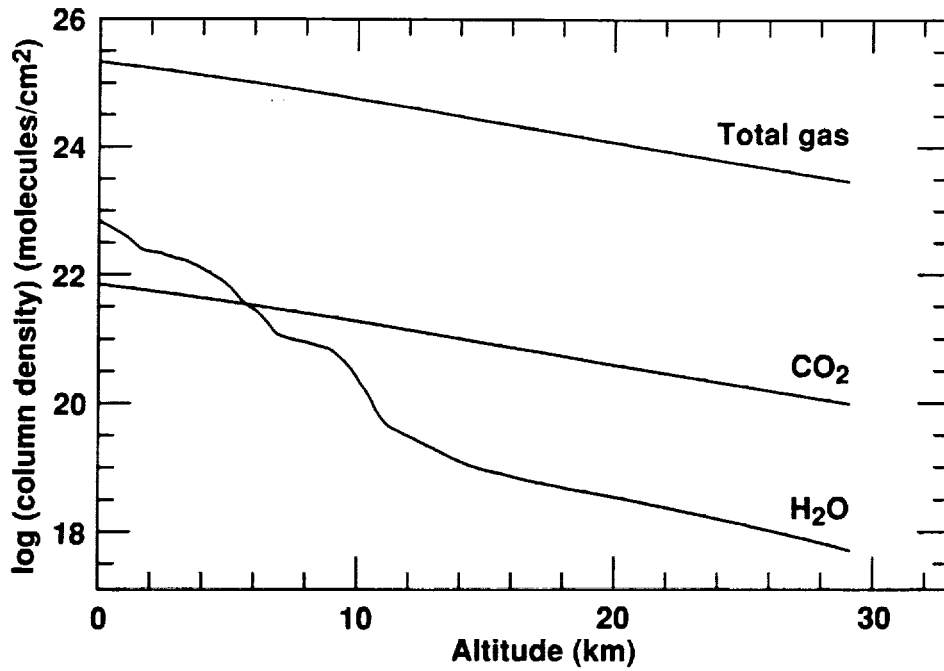


Figure 1. Atmospheric gas overhead column density falls exponentially with altitude (ref. 16); water vapor column density falls off more rapidly, as traced by balloon soundings (ref. 15).

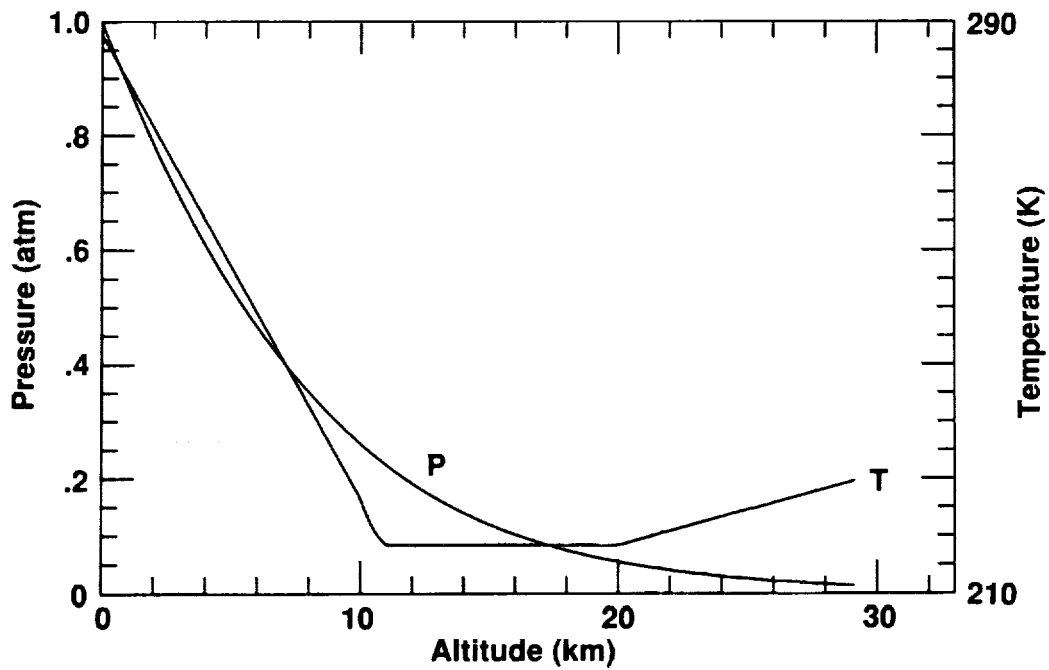


Figure 2. Temperature and pressure of atmosphere (from ref. 16).



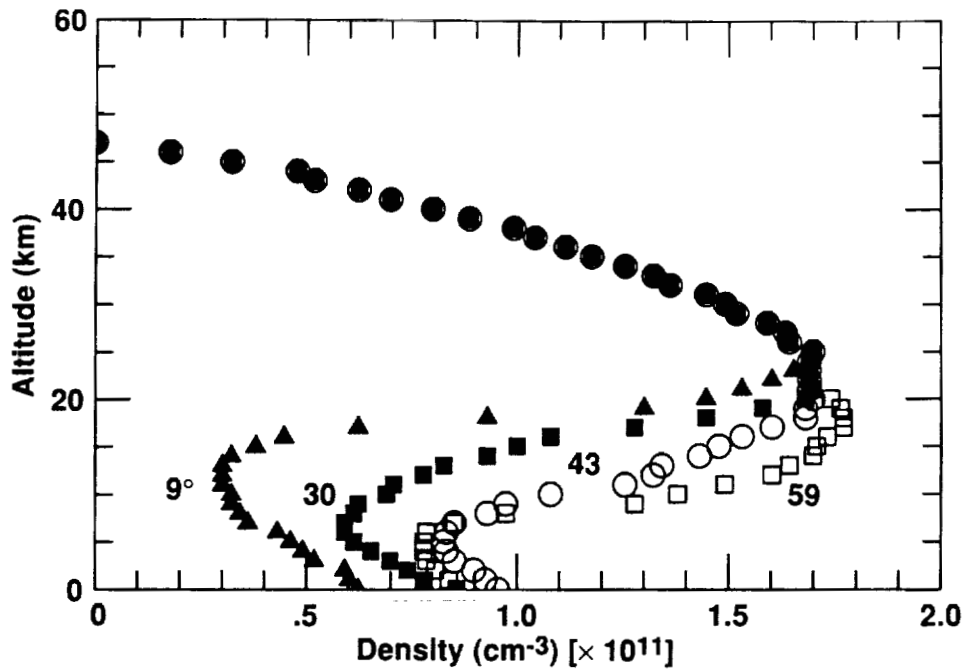


Figure 3. Ozone density profile at four latitudes (from ref. 14).

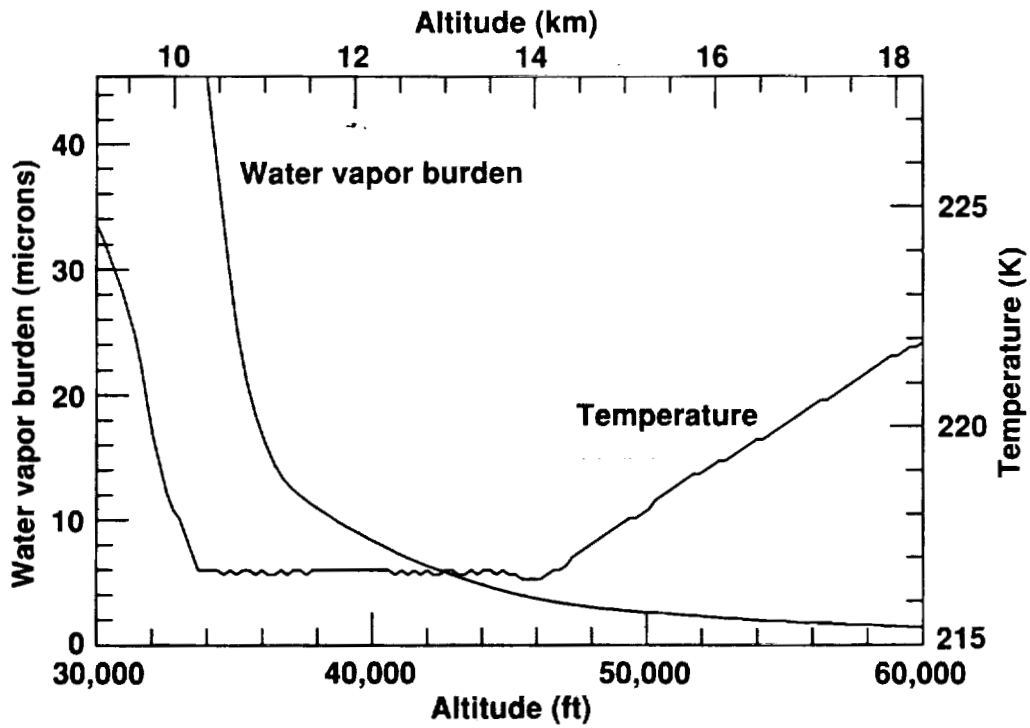


Figure 4. A detailed look at the water-vapor burden through the tropopause, where the overhead burden may drop to half, from altitude 41,000 ft to altitude 45,000 ft, for example.

values at each layer are linearly scaled to match the observed total column density.

The density values for the atmospheric water-vapor content are taken from reference 15. Especially important to airborne astronomy is the altitude gradient in the water-vapor burden through the tropopause. (By burden, we mean the overhead column density, toward the zenith. This quantity is sometime expressed as the height of an equivalent column of liquid water.) A typical water-vapor profile is shown in figure 1, representing balloon flights at a latitude of  $39^\circ$ . As the altitude of the tropopause rises and falls, the ambient pressure and density profile of the water-vapor component will do likewise. So, when the observed overhead water-vapor column density differs from the average profile tabulated in the model, the program moves the atmospheric profile (including the temperature and pressure profile) up or down in altitude (within reasonable limits) to best match the reported water-vapor column density. After an integer number of 0.1-km steps, to achieve the closest match, the profile is then linearly scaled in density to exactly match the observed value. If the user supplies no information of the overhead water content, the standard model is used, which gives, for example, a overhead burden of  $7 \mu\text{m}$  of (precipitable) water at 41,000 ft (12.5 km) (fig. 4).

The mixed gases (indexed 2, 4-7 in table 1) are also modeled at 0.1-km steps, using a constant term for their concentration in parts per million as given in table 1 (from ref. 5). The gas densities, pressures, and temperatures are from the U.S. Standard Atmosphere (ref. 16), tabulated up to 30 km, as given in appendix D.

The second stage of setting up the atmosphere is to divide the atmosphere into several equal mass layers (excluding the gases above 30 km, which are treated separately). We find the altitudes that divide the mixed gases, water vapor, and ozone into equal mass layers separately, through the use of interpolation routines operating on the tabulated column densities with altitude. We then find the altitude that divides each layer into two equal masses, and save the temperature and pressure at this altitude to characterize the layer. A typical number of such layers might be five, that is,  $L = 5$ . The three atmospheric components, ozone, water vapor, and the mixed gases, have very different distributions with altitude. By establishing a model with equal mass layers for each component separately, the temperature and pressure variations within each of these components are accurately tracked.

An additional feature of the program is the use of the Curtis-Godson approximation (e.g., ref. 2). This is considered the best way to model the overhead parameters if only a single layer is used, and also, for multiple-layer models, to parameterize the topmost layer (here comprising the gases above 30 km). In this method, the average conditions above a ceiling altitude are set to the temperature and pressure of a specific (higher) altitude. For the mixed gases and ozone, this specific altitude is given by the altitude where the pressure is half that at the ceiling altitude. For water vapor, the approximation follows a different rule. For water vapor, the temperature and pressure are used from the specific altitude at which the water vapor is at a density that is half that at the ceiling altitude. For each ceiling altitude, the temperature and pressure values at half-pressure and half-density altitudes are tabulated.

In this way, the atmosphere is completely characterized by three sets of layers, where one set is for the mixed gases, one is for water vapor, and one is for ozone. Each set contains the temperature and pressure at the center of the layer, and the total column density of each layer. In each set, the layer column densities are equal except for the topmost layer.

The final stage of the atmospheric model setup is to predetermine the temperature-dependent coefficient  $(296/T)^m$  (sec. 3). This term affects the line strength for each species. We tabulate these terms once for each of the possible exponents  $m$  listed in table 1, so as to integrate lines more efficiently.

## Integrating Absorption Lines

Computing a transmittance spectrum requires the integration of a few to thousands of absorption lines over many layers. An efficient integration algorithm depends on integrating only the relevant lines and only the relevant portions of those lines. By relevant, we mean *significant*, such that all excluded lines, or line portions, if included, would produce an additional loss of less than 0.001 in the reported transmittance. This value,  $\epsilon = 0.001$ , is our error specification.

There are four steps in making the selections of relevant line portions:

1. Determine how far beyond the specified wavelength range to search for broad contributing lines.
2. Determine, for each line within the search range, what, if any, is the relevant extent of the line wings.
3. Integrate accurately narrow lines.

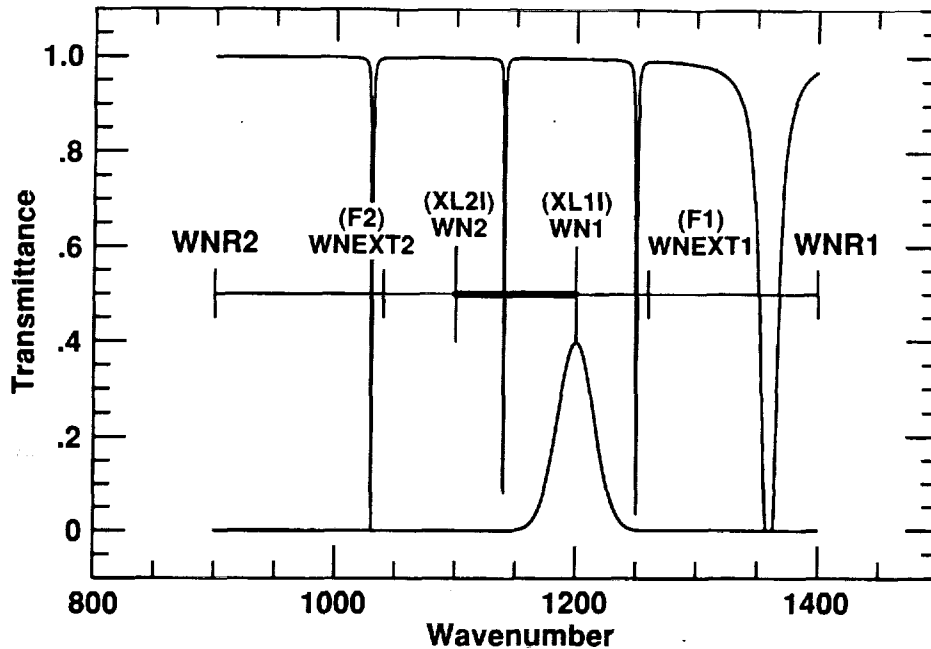


Figure 5. Hypothetical example showing three wave-number ranges used by the program. All absorption lines, such as the four shown, centered within the outermost range, WNR, are considered, but only the portions of these lines within the WNEXT range are added into the fine array. The fine array runs from WNEXT1 to WNEXT2. The fine array is smoothed (a Gaussian smoothing function is shown at the bottom of the plot) to produce the transmittance spectrum between WN2 and WN1. In this hypothetical spectrum, a deep line at 1360 wave numbers has significant absorption in its wings at 1260. The smoothing function, centered at WN1, will include the absorption at 1260 to produce the smoothed absorption at WN1.

4. Determine the best sampling interval ( $\Delta\sigma$ ) for the integration.

Steps (1) and (2) are very much related, and present some difficulties. One difficulty is that the absorption contribution of an extended line wing may be small, but may be significant if many such wings overlap at a single wavelength. The absorption at some wavelengths is dominated by the summation of thousands of faint overlapping absorption line wings. Determining where this occurs is difficult, and can lead to a bit of a vicious circle. The circle goes like this: the extent of a line that we should consider is determined by what we consider to be a significant level of absorption. A significant absorption level is fixed by our maximum tolerance ( $\epsilon = 0.001$ ) and by how many such line wings could possibly overlap at a point. But the number of such line wings depends on the width of the relevant portion of each line, thus completing the circle.

We have completed step(1) empirically for two altitude ranges: a ground-based, mountain-based, and

low-altitude airborne range ( $0 \leq \text{altitude} \leq 39,000$  ft); and, an airborne observation range (altitude  $\geq 39,000$  ft). The method of finding the maximum wave-number range in which to search for deep lines was to frame the search in the most extreme situations. We chose an extreme zenith angle of  $80^\circ$  and a single-layer atmosphere (thus maximizing pressure and temperature broadening effects).

We considered all deep absorption line features and determined how far away, in wave number, from the line center the absorption becomes insignificant. This was computed for the ground-based and airborne cases, from 0.8 to  $10,000 \mu\text{m}$ . We encoded the results into tables within the program (see subroutine SEARCH), and used these tables to conduct efficient line integrations. The variable IWINGS holds the distance expressed in wave numbers.

As shown in figure 5, the range of wavelengths for which the user would like transmittance information is given by the variables (WL1I, WL2I), which stand for wavelength 1 (input), wavelength 2 (input). These are

equated to the wave numbers (WN1, WN2). The instrumental resolution is given by DWNI which stands for the delta-wave-number inputted. The program prepares a spectrum beyond the (WN1, WN2) range. The extended range, given by (WNEXT1, WNEXT2), is an integer number of instrumental FWHM widths, so that the effects of lines beyond the edge of the spectrum are included. The integer is called ISLITS in the program, and ISLITS = 2. Thus, WNEXT2 = WN2 + ISLITS × DWLI. In the program, this range is also called (F1, F2), which stands for the first and last wave numbers of the "fine" array, where fine refers to the high-resolution integration array. However, lines that contribute to the range (WNEXT1, WNEXT2) may have centers outside this range. The search range for (WNEXT1, WNEXT2) is (WNR1, WNR2) where WNR2 = WNEXT2 + IWINGS, as explained above. Figure 5 show the three ranges. (WN1, WN2) is requested of the user. The program prepares a spectrum for the range (WNEXT1, WNEXT2) drawing on lines that originate within (WNR1, WNR2). In this hypothetical example, the smoothing function is shown at the bottom of the plot, at the far edge of the requested range. Its wings are considered out to WNEXT1, where a deep line, centered within WNR1 affects the transmittance.

The second step, regarding how far out to integrate a line's wings for lines within (WNR1, WNR2) is accomplished as follows:

Suppose there are  $N$  absorption lines which have an absorption coefficient  $\kappa$  in each of  $L$  layers at a particular wave number. Then the transmittance is

$$t = e^{-NL\omega'\kappa}$$

where  $\omega' = \omega/\mu$ , with  $\mu$  being the cosine of the zenith angle, so as to account for the number of air masses along a line of sight.

To calculate an absorption cutoff, we assume there are  $N$  lines exactly at the cutoff absorption level at a particular wavelength. (Assuming all excluded absorptions are at a level equal to the cutoff is a worst-case scenario which allows us to calculate the cutoff.) We have

$$(1 - \epsilon) = e^{-NL\omega'\kappa}$$

With  $\epsilon = 0.001$ , all the excluded absorption lines together could contribute at worst a 0.1% loss in transmission. Solving for  $\kappa$  and then  $S$ ,

$$\ln(1 - \epsilon) < -NL\omega'\kappa$$

with

$$\begin{aligned} \kappa &= \frac{S\gamma}{\pi(\Delta\sigma^2 + \gamma^2)} \\ \frac{-\pi \ln(1 - \epsilon)}{LN} &= \omega' \frac{S\gamma}{\Delta\sigma^2 + \gamma^2} \\ \text{CONST} &= \frac{-\pi \ln(1 - \epsilon)}{L} \end{aligned}$$

At this point we wish to know  $N$ , the maximum number of lines that could have a contribution at the wave number in question. To do so, we have made a table of the number of line centers per wave number extending from 0.8 to 10,000  $\mu\text{m}$  (in the file SKIPA.DAT). (This table is also used to efficiently advance the HITRAN data base to the relevant records.) We use the table and an extreme line width of 6 wave numbers (set by the variable JWINGS), and find the total number of lines centered within  $\pm 3$  wave numbers of each  $\sigma$  within the range. The maximum value so obtained is called MAXLPN (maximum overlaps per wave number), and is tabulated in subroutine GETSET. We then have:

MAXLPN (Maximum number of overlapping lines per wave number) =  $N$

So now,

$$\frac{\text{CONST}}{\text{MAXLPN}} = \frac{\omega'S\gamma}{\Delta\sigma^2 + \gamma^2}$$

and

$$\Delta\sigma_{max} = \left( \omega'S\gamma \frac{\text{MAXLPN}}{\text{CONST}} - \gamma^2 \right)^{\frac{1}{2}}$$

This last expression tells us how far to integrate a line. Various cases are handled in subroutine INTEG. For a line centered at  $\sigma_i$ , the significant range is  $\sigma_i \pm \Delta\sigma_{max}$ . If the term within the square root is negative, the line is everywhere too weak, and it is rejected. If the entire range  $\sigma_i - \Delta\sigma_{max}$  to  $\sigma_i + \Delta\sigma_{max}$  lies outside of (WNEXT1, WNEXT2), again, we reject the line. If part or all of a line is within the range, the entire line is integrated or at least the part of the line extending to the fine array edge. Finally, if  $2 \times \Delta\sigma_{max}$  is less than the resolution of the fine array, a special integration technique is used. We model such narrow lines with a triangle function to determine the mean absorption within the interval and integrate this value into the fine array. A comparison of a triangle function and a Lorentzian is shown in figure 6. It may be

seen here that for the region within  $|\sigma| < 0.5$  FWHM, the triangle function provides a good approximation to the Lorentzian. The occurrence of such under-resolved lines is counted by the variable IDELIN (delta functions inside the range), and is rather infrequent. (This therefore accomplishes step (3) above.)

Finally, we discuss the resolution (step (4)). The fine array, dimensioned F(1000000), is used to sum the absorption from each line and each layer. This is done by INTEG. The wave-number resolution of this array, FD, is determined by  $FD = RESRB \times P(L-1)$ , where RESRB is the resolution "rock-bottom," the resolution required to handle sea-level line widths, (i.e., lines at 1 atm). We are scaling this value by the pressure to correctly model the line shapes of narrow lines from regions of low pressure. From examining a histogram of line widths ( $\gamma_i$ ) over the entire wave-number range (fig. 7), we have determined that RESRB be set to 0.01 wave numbers.  $P(L-1)$  is the pressure characterizing the top of the atmosphere model, just below the  $L$ th layer, whereas the  $L$ th layer includes only the

gas above 30 km. In a multiple-layer atmosphere, each layer will typically hold much more mass than the  $L$ th. In a one-layer atmosphere, we use the Curtis-Godson pressure for  $P(L-1)$ . For one layer and an altitude of 41,000 ft, the resolution of the fine array is typically a little less than 0.001 wave numbers. When we divide the atmosphere into  $L$  layers, then the larger the value of  $L$ , the closer the center of the  $L-1$ th layer will be to the 30 km, and therefore the smaller the pressure of the  $L-1$ th layer will be. For a given observing altitude, as  $L$  goes up,  $P(L-1)$  will go down, and DF will go down.

It is important to note that since the number of resolution elements, NF, given by  $NF = (NWEXT2 - WNEXT1)/DF$ , goes as  $L$ , and the number of layers goes as  $L$ , the length of time required to compute a transmittance spectrum goes as  $L^2$ . When high accuracy is not required, for example, if  $\sim 3\%$  errors are acceptable at the centers of lines, then a single layer,  $L = 1$ , will usually suffice, depending on the instrumental resolution.

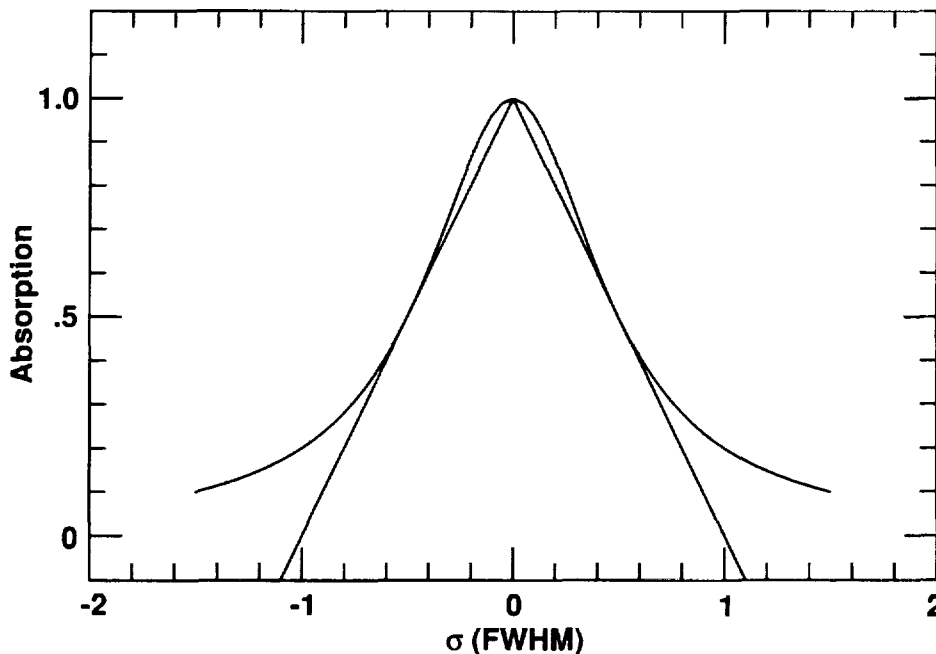


Figure 6. Lines significantly narrower than the fine array step are estimated with a triangle function, which provides a good estimate of the Lorentzian line shape within the central 0.5 FWHM (full width at half maximum) as seen here.

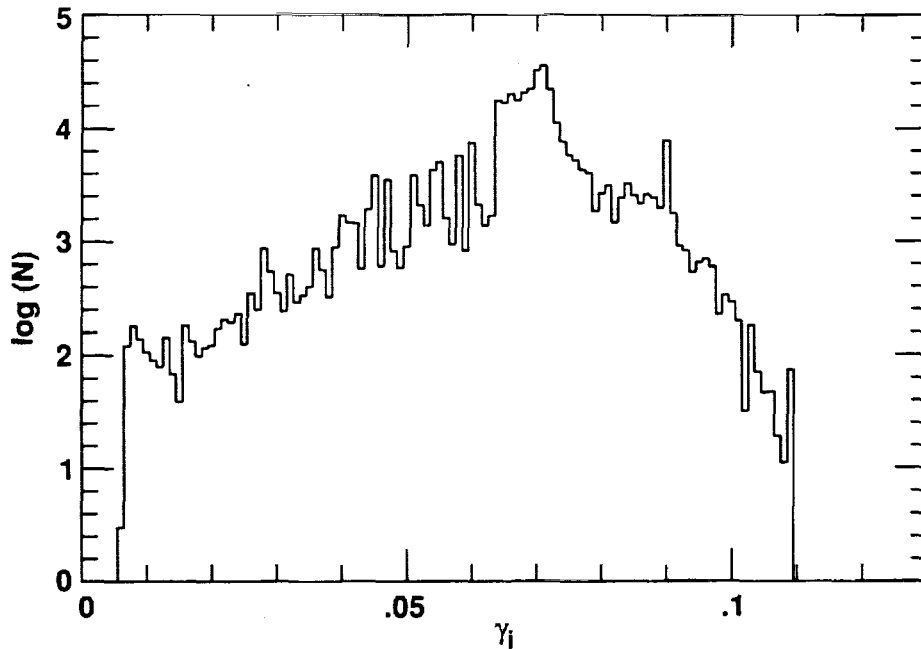


Figure 7. A histogram of  $\gamma_i$  is shown for the wavelength range between 0.8 and 10,000  $\mu\text{m}$ ; a very small fraction of the lines have widths narrower than 0.01 wave numbers, the largest resolution that the program will use for the fine array.

### Instrumental Profiles

The ATRAN program will compute any one of four instrumental profiles, a triangle, a Gaussian, a sinc function, and a rectangle. These are shown in figure 8, all on the same axes, with the x-axis in FWHM units and the y-axis with normalized maxima. The rectangular function, with its sharp falloff, will tend to retain the high frequencies present in an unsmoothed profile, unlike the other functions. Smoothing occurs in a very straightforward manner. To compute a smoothed value at a particular wave number, the smoothing function is aligned with that point, and the fine array is averaged over a  $2 \times \text{FWHM}$  span of the smoothing function.

A "no-smoothing" option is also available. Here the fine array will be written out just as it appears, if space allows (the limit is currently set to 20,000 elements, the data-point limitation of a MONGO (x,y) plot). This represents the atmospheric transmittance as seen without any instrumental degradation in resolution. If the fine array contains more than 20,000 elements, the program will select the lowest integral sampling interval for the data points (e.g., each second, each third) and output these as the output data file. The no-smoothing option is the fastest, because the data are simply copied-out.

Plots of transmittance from flight and sea-level altitude are displayed for the entire wavelength range in appendixes E-G.

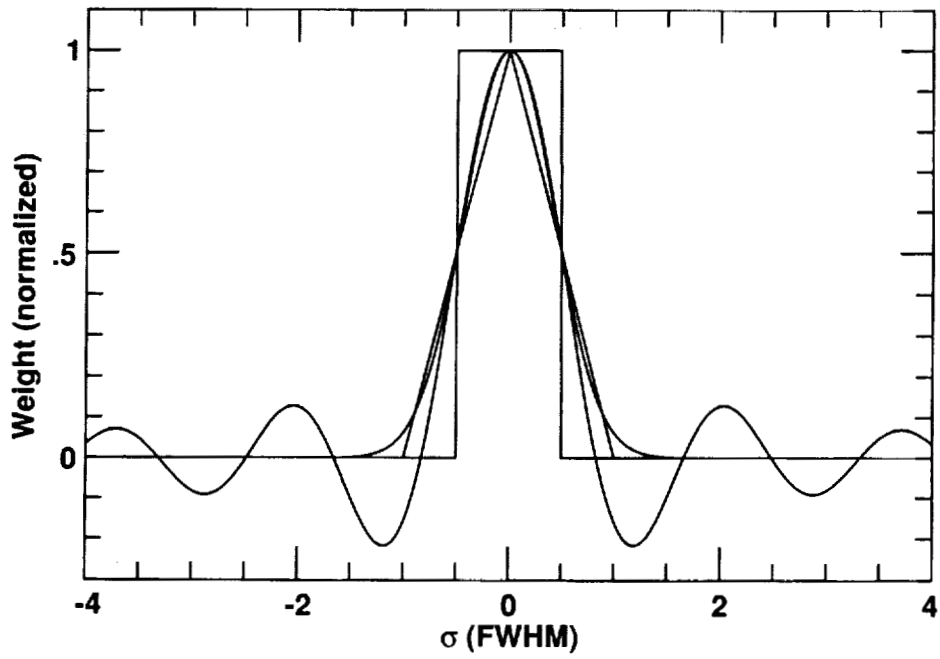


Figure 8. The four instrumental profiles, triangle, Gaussian, rectangle, and sinc, are plotted as a function of the FWHM (full width at half maximum).

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# APPENDICES

**APPENDIX A**

**SOFTWARE LISTING OF ATRAN**

We list the UNIX implementation of the program. The VMS implementation differs only slightly.

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16  
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PROGRAM ATRAN

C \*\*\*\*\*  
 C Calculates IR atmospheric absorption  
 C S. Lord - May 1988, Rev. July 1991  
 C \*\*\*\*\*  
 C

```

CHARACTER*1 A
COMMON /RANGE/WL1I,WL2I,DWLI,WNEXT1,WNEXT2,WNR1,WNR2,WLEXT1
1 , WLEXT2,WLLINE,IZSKIP
COMMON /LIMIT/NFMAX,NRES,BOTL,TOPL,ISLITS,IWINGS,IPLTN
1 ,RESRB,AC,JWINGS
COMMON /WGAS/ WGASES(7,2),PALL(3,300),TALL(3,300)
1 ,ITANK,LAYER
COMMON /FARRA/F(1000000)
COMMON /FVECT/F1,F2,FD,NF
COMMON /PVECT/P1,P2,PD,NP,NINST,IPLTCNT
COMMON /SKIPS/ISKIPWN(12500),ISKIPSUM(12500),ISKIPMAX(12500)
COMMON /PARRA/P(20000),IPTYPE
COMMON /TERM/ITERM
COMMON /STRONG/SLINES(80),ISPEC(80),SEW(80),ISTRONG
1 ,IPOINT,STRENGTH
  
```

C  
 C (THE DIMENSION 12500 MAY CHANGE WITH THE SIZE OF THE AFGL FILE...)  
 C

C Define Global limits

C Dimension of the "Fine" array (too big for an HP1000)  
 NFMAX=1000000

C Fractional accuracy spec. on final trans. spectrum  
 AC=0.01

C resolution Rock Bottom  
 RESRB=0.01

C Fine array resolution is at max RESRB wave numbers  
 C times the top layer atmospheric pressure, in atm.s,  
 C which is typically less than 0.1 atm, and so  
 C the resolution of the fine array is typically a  
 C little less than 0.001 wave numbers.  
 C The fine array resolution can be set as small as the  
 NRES=10

C user requires. It is always set to less than  
 C 1/NRES times the instrumental resolution to obtain  
 C accurate results.

C Lowest wavelength currently available (micrometers).  
 BOTL=0.8

C Highest wavelength currently available (micrometers).  
 TOPL= 10000

C Look for wings from lines ISLITS instrumental  
 C slit widths beyond plot range.  
 ISLITS=2

C lines may overlap from the surrounding JWINGS WN's  
 JWINGS=3

C Maximum number of points allowed in plot.

```

        IPLOTN=20000
C Counts the number of diff. functions on 1 plot (1-9).
        IPLTCNT=0
C Number of strong lines that will appear at the bottom
        ISTRONG=80
C of the plot, STRENGTH is the minimum values of
        STRENGTH=-ALOG(1-.05)
C - ln(equivalent width) required to get on the list
C*****
C** Main Entry Point
C*****
        PRINT*
        PRINT*
C
        PRINT*,' Welcome to atmospheric modeling program!'
        PRINT*
        PRINT*,' If you don''t know what to answer to a question'
1      ', try' the answer given in parentheses.'
        PRINT*
1007   WRITE(*,'('' Input Terminal type. '')')
        WRITE(*,'('' 1 for Tektronics, 2 for X window, 3 for Sunview'
1      ', window',/, ' 4 for GraphOn (1): ',,$)')
        READ(*,*,ERR=1007)ITERM
        PRINT*,'{'',ITERM,'}'
        IF(ITERM.LT.1.OR.ITERM.GT.4)GO TO 1007
1008   WRITE(*,'('' Plot x-axis units in wavelength (um) [1], ''
1      ', ''or wavenumbers (cm^-1) [2] (1): ',,$)')
        READ(*,*,ERR=1008)IPTYPE
        PRINT*,'{'',IPTYPE,'}'
        IF(IPTYPE.NE.1.AND.IPTYPE.NE.2)GO TO 1008
1      CONTINUE
C      WRITE(*,'('' Input nominal max line width in wavenumbers ''',
C      1      /, '' and deep line search in wavenumbers (temporary'',
C      1      '' parameters)(3,20): ',,$)')
C
C      READ*,JJWINGS,IIWINGS
C      PRINT*,'{'',JJWINGS,IIWINGS,'}'
C
C      IF(JJWINGS.LT.1.OR.JJWINGS.GT.20
C      1      .OR.IIWINGS.LT.1.OR.IIWINGS.GE.100)THEN
C          PRINT*,' Range is 1 to 20 and 1 to 100. Try again'
C          GOTO 1
C      ENDIF
C      IWINGS=IIWINGS
C      JWINGS=JJWINGS
C      JWINGS=3
C
C Establish the parts per million of atm gases
        CALL GETPRT
C Read in model atmosphere parameters
        IF(ITANK.NE.1)CALL GETLEV
C Set-up the atmospheric or slab model
        CALL GETATM

```

```

C Establish the wavelength range
2   CALL GETLAM
C Set-up the plot x-axis
   CALL GETPLO
C Find section of atm. line data file of relevance
   CALL GETSET(IER)
   IF(IER.EQ.1)GO TO 2
C Integrate all lines & levels into the fine array
   CALL INTEG
C Convert opacity to transmission by exponentiating
   CALL EXPO
C Smooth the fine array into the plot array
   CALL SMEAR
C Output the plot
   CALL PLOT
3   PRINT 4
4   FORMAT(' Another function on this plot (Y or N) (N): ', $)
   READ 5, A
   PRINT*, '{', A, '}'
5   FORMAT(A1)
      IF(A.EQ.'Y'.OR.A.EQ.'y')THEN
          IF(IPLTCNT.EQ.10)THEN
              PRINT*, ' Maximum (9) exceeded'
              STOP
          ENDIF
      GO TO 1
      ELSE IF (A.NE.'N'.AND.A.NE.'n')THEN
          GO TO 3
      ENDIF
   PRINT*, ' p.plo, a MONGO control file has been made.'
   PRINT*, ' parray.dat1, the output data has been written.'
   CLOSE(20)
   END

```

SUBROUTINE GETPRT

```

C *****
C Finds the atmospheric constituents
C *****
   REAL PPM(2:7)
   COMMON /WGAS/ WGASES(7,2), PALL(3,300), TALL(3,300)
1   , ITANK, LAYER
   COMMON /PART/PARTS(2:7), CDOZ, IDISTO3
   COMMON /ATMJNK/AWV, AZ, AWVL, IATYPE, IALAY, IALT, TORR
   DATA PARTS/330E-6, 0., .28E-6, .075E-6, 1.6E-6, 2.1E-1/,
C Gordon's Value   Ozone Ozone Ozone Ozone
C   1   CDOZ/1.31E19/
C Jan's Value   Ozone Ozone Ozone Ozone [Pick one!]
C   1   CDOZ/6.68E18/
C Steve's value for lat 39 (TOMS data average) also
C   1   CDOZ/9.13E18/
C Brasseur & Solomon, Fig .7 give the following

```

```

C      totals for various latitudes....
C      lat   9   30   43   59
C      6.86E18 8.41E18 1.03E19 1.21E19
C
      ITANK=0
      IDISTO3=3
2221  PRINT*, ' Enter: '
      PRINT*, ' 0 for a standard atmosphere of mixed gases, '
      PRINT*, ' 1 for a single H2O layer (a tank), '
      PRINT 22
22    FORMAT(' 2 for a special atmosphere, or -1 to exit (0): ', $)
      READ(*, *, ERR=2221) I
      PRINT*, '{', I, '}'
      IATYPE=I
      IF(I.EQ.-1) STOP
      IF(I.EQ.0) THEN
      RETURN
      ELSEIF (I.EQ.1) THEN
      ITANK=1
      RETURN
      ENDIF
      IF(I.NE.2) GO TO 2221
      DO L=2, 7
      PPM(L)=PARTS(L)*1E6
      ENDDO
15    WRITE(*, 10) PPM(2), CDOZ, (PPM(J), J=4, 7)
10    FORMAT(' Molecule: CO2      O3(tot/cm2)  N2O  ',
1      ' CO      CH4      O2  ', /,
1      ' Index:      2      3      4      ',
1      ' 5      6      7  ', /,
2      ' PPM:      ', F5.0, '      ', 1PE8.2, '      ',
3      ' OPF6.2, 1X, OPF6.3, 1X, OPF4.1, 3X, 1PE7.1)
      PRINT*, ' Enter 0 to continue or the gas index number '
1      ' to change the ppm of that gas: '
      READ(*, *, ERR=15) I
      PRINT*, '{', I, '}'
      IF(I.EQ.3) THEN
1033  PRINT*, ' Ozone layer has total column density of ', CDOZ
      PRINT*, ' (this is looking through the entire atmosphere) '
      PRINT*, ' (in molecules per cm^2). New value (use a negative '
      PRINT*, ' number to input in Dobson units): '
      READ(*, *, ERR=1033) CDOZ
      PRINT*, '{', CDOZ, '}'
      IF(CDOZ.LT.0) CDOZ=ABS(CDOZ)*2.69E16

```

```

C
C use the appropriate atmospheric ozone curve
C we have a selection of 4 distribution for the
C latitudes: 9, 30, 43, and 59,
C taken from Fig 5.7 B&S, op cit.
C We choose the closest, based on the total
C column density. If the
C default O3 value is used (no adjustment), then
C the distribution defaults to the 59 lat. (IDISTO3=1).

```

```

C
C at the various lat.s we have: 6.86E18 8.41E18 1.03E19 1.21E19
C
      IF(CDOZ.LT.3E18)THEN
      TYP=6.86E18/2.6E16
PRINT*, ' That''s VERY little O3! Typical min is 6.86E18/cm^2'
PRINT*, ' which is ',TYP,' Dobson units'
ENDIF
      IF(CDOZ.LT.7.635E18) IDISTO3=1
      IF(CDOZ.GT.7.635E18.AND.CDOZ.LT.9.355E18) IDISTO3=2
      IF(CDOZ.GT.9.355E18.AND.CDOZ.LT.1.12E19) IDISTO3=3
      IF(CDOZ.GE.1.12E19) IDISTO3=4
      IF(CDOZ.GT.2.4E19)THEN
      TYP=1.12E19/2.6E16
PRINT*, ' That''s a LOT of O3! Typical max is 1.12E19/cm^3'
PRINT*, ' which is ',TYP,' Dobson units'
ENDIF
      ELSEIF(I.GE.2.AND.I.LE.7)THEN
6861 PRINT*, ' Old value = ',PPM(I)
PRINT*, ' Enter new value: '
READ(*,*,ERR=6861) PPM(I)
PRINT*, ' {',PPM,'}'
PARTS(I)=PPM(I)/1E6
      ELSEIF (I.EQ.0)THEN
      RETURN
      ENDIF
GO TO 15
END

      SUBROUTINE GETLEV
C *****
C Reads in the atmospheric model
C compiled by Gordon Augason NASA/Ames, and
C Described in the Documentation
C for program "CDG21" by Augason and Burnes
C *****
      COMMON /MODEL/ ALT(292),ST(292),SP(292),CH2O(292),SC(292)
1      ,TH2O(292),TMIX(292),PH2O(292),PMIX(292),CO3(4,292),IH2OTOP
      CHARACTER*1 A1
C
      OPEN(1,FILE='/work/cgs/atran/model.dat',STATUS='OLD',ERR=123)
C
C 1 READONLY)
C
C Advance past the header, ("/" in a FORMAT statement here is unsafe)
C
      READ(1,100,ERR=30)A1,A1,A1,A1
100      FORMAT(A1)
      DO 1 I=1,292
1      READ(1,*,END=30,ERR=30)ALT(I),ST(I),SP(I),CH2O(I),SC(I),
1      TH2O(I),TMIX(I),PH2O(I),PMIX(I),(CO3(J,I),J=1,4)
      CLOSE (1)
      RETURN
30      PRINT*, ' Error reading model.dat'

```

```

        STOP
123     PRINT*, ' Can''t find model.dat'
        STOP
        END
        SUBROUTINE GETATM
C *****
C Establishes the T, P, and Column Densities of water vapor,
C ozone, and mixed gases in a n-layer model atmosphere
C *****
        COMMON/D2O/D2OG
        COMMON /PART/PARTS(2:7),CDOZ, IDISTO3
        COMMON /ATMJNK/AWV,AZ,AWVL,IATYPE,IALAY,IALT,TORR
        CHARACTER*11 MILMIC
        COMMON /MODEL/ ALT(292),ST(292),SP(292),CH2O(292),SC(292)
1       ,TH2O(292),TMIX(292),PH2O(292),PMIX(292),CO3(4,292),IH2OTOP
        COMMON /WGAS/ WGASES(7,2),PALL(3,300),TALL(3,300)
1       ,ITANK,LAYER
        IF(ITANK.EQ.1) THEN
5010    PRINT 501
501     FORMAT(' Enter pressure in Torr (millimeters of Hg,'
1       ' 1/760 Atm) (15): ', $)
        READ(*,*,ERR=5010)TORR
        PRINT*, '{', TORR, '}'
        PALL(1,1)=TORR/760.

C
C     Let's assume a room temperature. Labs are typically about 68 F.
C
        TALL(1,1)=293.15
5020    PRINT 502
502     FORMAT(' Enter water column density in micron (10): ', $)
        READ(*,*,ERR=5020)WVMIC
        PRINT*, '{', WVMIC, '}'
        AWV=WVMIC
        AWVL=WVMIC
        WGASES(1,1)=(WVMIC/2.994E-19)*1.E-20
5030    PRINT 503
503     FORMAT(' Enter D2O column density in microns (0): ', $)
        READ(*,*,ERR=5030)D2OC
        D2OG=(D2OC/2.994E-19)*1.E-20

        LAYER=1
        IALAY=1
        CALL SCALGS
        RETURN
        ENDIF

C
C Start here for non-tank case, ie - an atmosphere
C
C We've read in the model already.
C (This will happen for each function plotted
C which is useful,
C because we rescale standard atmospheric density, P and T
C distributions.

```



```

C
C
C the overhead H2O column density in the atmosphere can be shifted,
C by which we mean we reset
C the distribution to reside at at higher or lower
C altitudes. The distribution can also
C be scaled (multiplied by a constant).
C Nominally, our lookup table of
C density, etc, stops at array elt 292.(29.1 km)
C This may be lowered
C for situations with less water than the standard model.
C
      IH2OTOP=292
1      PRINT 11
11     FORMAT(' Enter altitude (feet) (41000): ', $)
      READ(*,*,ERR=1)ALTFT
      PRINT*,' {' ,ALTFT, '}'
      IALT=ALTFT
2      ALTKM=ALTFT*.0003048
C
C Get overhead burden in molecules cm^-2 of H2O at this altitude
C WVMOD is the wv in precipitable microns
C WCOL is the WV in molecules / cm^3
C
      WCOL=A1ATB1(CH2O,ALT,292,ALTKM,IERR)
      IF(IERR.NE.0)THEN
      PRINT*,' Altitude out of range 0 to 95,470 ft. try again.'
      GO TO 1
      ENDIF
      WVMOD=WCOL*2.9940E-19
      WVMOD1=WVMOD
      AWV=WVMOD
      MILMIC='Microns'
C
C Speak in the optimal units
C
      IF(WVMOD.LT.1.OR.WVMOD.GT.1E6)THEN
15     WRITE(*,15)WVMOD
1      FORMAT('The atmospheric model gives ',1PE9.3,
1      ' microns of water toward the zenith.')
      ELSE
      IF(WVMOD.GE.1E3.AND.WVMOD.LT.1E6)THEN
      MILMIC='Millimeters'
      WVMOD1=WVMOD*1E-3
      ENDIF
      WRITE(*,20)WVMOD1,MILMIC
20     FORMAT(' The atmospheric model gives
1      ',F5.1,' ',A11,' of water,'
1      ' toward the zenith.')
      ENDIF
C
C Scale water vapor column density array if so desired
C

```

```

2510 PRINT 25
25   FORMAT(' Enter preferred value at this altitude in MICRONS,',
1     /, ' or 0 for no adjustment of the model (0): ', $)
    READ(*,*,ERR=2510)WV
    PRINT*,' {' ,WV, '}'

C
C Now, if the overhead H2O is different than the standard model, we
C move the atmospheric H2O,
C along with its Temp and Pressure up or down
C in Altitude. We do this at most 10 km, 35,000 ft.
C We then mult the density at each layer by a scale factor to get the
C overhead burden to exactly the value desired.
C
    IF(WV.GT.0)THEN
C
C find the altitude at which this burden occurs
C
    TARGET=WV/2.994E-19
    ALTNEW=A1ATB1(ALT,CH20,292,TARGET,IERR)
    IF(IERR.EQ.1)THEN
    PRINT*,' The overhead burden of the model does not include'
    PRINT*,' this value in its range, we'll scale std. profile.'
    GO TO 1010
    ENDIF
    ALTINFT=ALTNEW/.0003048
C PRINT*,' This burden is found above ',ALTINFT,' ft in the model'
    ALTDIF=ALTNEW-ALTKM
    IF(ABS(ALTDIF).GT.35)THEN
    PRINT*,' This is too far to shift the water vapor,
1 we'll just scale it...'
    GOTO 1010
    ENDIF
C
C Shift atmospheric H2O distribution up or down.
C
    ITENTHS=NINT(10*ALTDIF)
C
C If the appropriate altitude is within
C 0.1 km of the altitude being used
C (ALTKM) no shifting is necessary, just scaling
C
    IF(ITENTHS.EQ.0)GO TO 1010
C
C If ITENTHS<0 then the user wants
C more overhead H2O. We shift the overhead
C column density found at each layer
C to a higher layer.
C Since CH20(292) holds
C the total H2O above 29.1 km,
C we deposit into this array element those layers
C shifted to altitudes above 29.1 km.
C The Curtis-Godson approx. will be slightly
C less accurate when N=1, since

```

C we are not rederiving the alt.  
 C at 1/2 density for T and P.  
 C This will not be very different, nor important - if high accuracy  
 C is desired, then N should be greater than 1 anyway.

```

C
      ITEN=IABS(ITENTHS)
      IF(ITENTHS.LT.0) THEN
        DO I=1,ITEN
          CH20(292)=CH20(292)+CH20(292-I)
        ENDDO
  
```

C  
 C shift atm H2O up  
 C

```

      DO I=291,2,-1
        IF(I.LE.ITEN) THEN
          CH20(I)=CH20(1)
        ELSE
          CH20(I)=CH20(I-ITEN)
        ENDIF
      ENDDO
      ELSEIF(ITENTHS.GT.0) THEN
  
```

C  
 C If ITENTHS<0 then the user wants less overhead H2O.  
 C We shift the overhead  
 C column density found at each layer down  
 C to a lower layer. CH20(292) formerly  
 C held the total H2O above 29.1 km.  
 C Now we lower the altitude of the top layer  
 C by moving this element to a lower  
 C array location. I.e. the model for H2O  
 C now terminates lower than 29.1 km. Again,  
 C the Curtis Godson approx. will  
 C be slightly less accurate. (see above)

```

      DO I=1,292-ITEN
        CH20(I)=CH20(I+ITEN)
      ENDDO
      IH2OTOP=292-ITEN
    ENDIF
  
```

C  
 C see how we did ... recompute overhead H2O  
 C

```

      WCOL=A1ATB1(CH20,ALT,IH2OTOP,ALTKM,IERR)
      WVMOD1=WCOL*2.9940E-19
      PRINT*,' New Atm model gives ',WVMOD1,' microns'
      IF(ABS(WV-WVMOD1)/WVMOD1.gt..2) then
        PRINT*,' Atm. shift failed!'
        STOP
      ENDIF
  
```

C  
 1010 CONTINUE  
 C PRINT\*,' SCALING H2O model'  
 SCALE=WV/WVMOD1

```

C          PRINT*, ' scale factor = ',scale
          AWV=WV
          IF (IATYPE.EQ.0) IATYPE=3
            DO I=1,IH2OTOP
              CH2O(I)=SCALE*CH2O(I)
            ENDDO
          ENDIF

C
C Now that we have our input model atmosphere, we break it into
C N levels, (N can be 1)
C
31        PRINT 311
311       FORMAT(' Number of atmospheric layers (2 recommended) (2): ', $)
          READ(*,*,ERR=31)LAYERS
          PRINT*, '{',LAYERS,'}'
          IF (LAYERS.LT.1.OR.LAYERS.GT.300) THEN
            PRINT*, ' Number of layers must be between 1 and 300'
            GO TO 31
          ENDIF
          LAYER=LAYERS
          IALAY=LAYERS
331       PRINT 3311
3311      FORMAT(' Zenith angle through atmosphere (0=UP) (0): ', $)
          READ(*,*,ERR=331)Z
          PRINT*, '{',Z,'}'
          IF (MOD(Z,180.).EQ.90) THEN
            PRINT*, ' Not allowed for this slab atmosphere.'
            GO TO 331
          ENDIF
          AZ=Z
          XMU=COSD(Z)
          AWVL=AWV/XMU
          CALL LEVELS(LAYERS,ALTKM,XMU)
          CALL SCALGS
C          PRINT*, 'Got through'
          RETURN
          END

```

```

          SUBROUTINE LEVELS(N,ALTKM,ZMU)
C *****
C Divides up the atmosphere into layers of equal mass
C *****
          COMMON /PART/PARTS(2:7),CDOZ,IDISTO3
          COMMON /MODEL/ ALT(292),ST(292),SP(292),CH2O(292),SC(292)
1          ,TH2O(292),TMIX(292),PH2O(292),PMIX(292),CO3(4,292),IH2OTOP
          COMMON /WGAS/ WGASES(7,2),PALL(3,300),TALL(3,300)
1          ,ITANK,LAYER
          REAL CDO3(292),CO3CONS(4)
          DATA CO3CONS/6.86E18,8.41E18,1.03E19,1.21E19/
          ITP=IH2OTOP
          IALT=ALTKM*10+1

```

C

```

C
C In the model atmosphere there are 5 mixed gas components,
C and then there is water vapor and ozone. Ozone occupies its own
C special distribution as does H2O. We treat these components
C separately in the multi-layer integration.
C
C O3 and Water vapor share the T and P of the 5
C mixed components, w/a separate
C column density fn. with alt.. If more
C than one layer is requested ( N > 1 ),
C we divide the mixed gas and water
C vapor each into N-1 layers between the
C observer's altitude and 29.1 km, such that
C each layer contains equal mass.
C We find the T and P at
C the midpoint of each layer, and record these
C data in WGASES, TALL, PALL for use
C in the integration. For the Nth layer
C (also, when N is 1), we use
C the Curtis-Godson approximation.
C When N>1 the Nth layer is the
C gas above 29.1 km. When N=1, the
C approximation is used to the gas above
C the altitude of observation.
C The C.G. approximation approximates the average conditions
C above a
C given altitude by using C the atmospheric
C parameters T and P for the mixed
C gases which reside at a higher altitude,
C namely where the pressure is half
C the pressure at the given altitude. For
C water vapor the approximation uses
C a different rule. For water vapor, the
C T and P are used from an altitude
C at which the water vapor is at
C half the density as that at the altitude of
C observation.
C
C We load the best O3 distribution
C (determined in GETPRTS) into a local array,
C scaling to get the total to match the requested value.
C
      DO I=1,292
      CD03(I)=CO3(IDISTO3,I)*CDOZ/CO3CONS(IDISTO3)
      ENDDO
C
C The routine loads up three
C arrays... WGASES( 7 species , 2 index)
C where index=1 is for the column density
C for N-1 layers of equal column density
C and index = 2 is for the
C Nth layer, it is the column density of all the
C gas above the N-1th layer (to infinity)

```

```

C When N=1, the index=1 term is used only,
C and it is the column density above
C the observation altitude.
C the other 2 arrays that
C are loaded are the pressure and
C temperature arrays, PALL( 3 = H2O, mixed,
C and O3, 300 = max num of levels)
C and TALL likewise.
C The routine checks first to see if
C it is loading up a multi-layer atm
C and fills the arrays if this is
C so, else it loads a single layer atm (N=1)
C
      IF(N.NE.1) THEN
C
C This is a multi-layered atm.
C Do mixed gases, O3, and water vapor in tandem
C
      CDBOT= A1ATB1(SC ,ALT,292,ALTKM,IERR )
      CDBOTW=A1ATB1(CH2O,ALT,ITP,ALTKM,IERRW)
      CDBOTO=A1ATB1(CDO3,ALT,292,ALTKM,IERRO)
      IF(IERR.NE.0.OR.IERRW.NE.0.OR.IERRO.NE.0) THEN
        PRINT*,'Alt. = ',ALTKM,' out of range in sub. LEVELS'
        STOP
      ENDIF
C
C Get total column density between input alt and 29.1 km
C H2O may have been scaled. Use new value.
C
      TOTLTC= CDBOT - 2.930E23
      TOTLCW=CDBOTW - CH2O(ITP)
      TOTLCO=CDBOTO - CDO3(292)
C
C We are interested in
C the layer centers. Find the column density at each
C
      IDIVS=(N-1)*2
      DELC =TOTLTC /IDIVS
      DELCW=TOTLCW/IDIVS
      DELCO=TOTLCO/IDIVS
      LEVEL=0
      DO 300 I=1,IDIVS-1,2
C
      LEVEL=LEVEL+1
      XLAYC =CDBOT -I*DELC
      XLAYCW=CDBOTW-I*DELCW
      XLAYCO=CDBOTO-I*DELCO
C
C To find the T's and P's, we interpolate from the column density
C We only look at the arrays over the range between the altitude of
C Observation and the top of the array
C
      NUM=292-IALT+1

```

```

NWV=ITP-IALT+1
PALL (1,LEVEL)=A1ATB1(SP(IALT),CH2O(IALT),NWV,XLAYCW,IE1)
PALL (2,LEVEL)=A1ATB1(SP(IALT),SC(IALT),NUM,XLAYC,IE2)
PALL (3,LEVEL)=A1ATB1(SP(IALT),CDO3(IALT),NUM,XLAYCO,IE3)
TALL (1,LEVEL)=A1ATB1(ST(IALT),CH2O(IALT),NWV,XLAYCW,IE4)
TALL (2,LEVEL)=A1ATB1(ST(IALT),SC(IALT),NUM,XLAYC,IE5)
TALL (3,LEVEL)=A1ATB1(ST(IALT),CDO3(IALT),NUM,XLAYCO,IE6)
C
      IF(IE1.NE.0.OR.IE2.NE.0.OR.IE3.NE.0
1      .OR.IE4.NE.0.OR.IE5.NE.0.OR.IE6.NE.0)THEN
      PRINT*,' Column density(s) out of range in '
1      ,'Sub. LEVEL, error flags are: '
1      ,'IE1,IE2,IE3,IE4,IE5,IE6
      STOP
      ENDIF
300      CONTINUE
C
C Finally load up the WGASES-array that holds in W(IS,1) the column
C density at each level
C - and treating ozone (IS=3) and H2O (IS=1) with
C their own function. We remove a factor
C of 1.0E20, which we will add into the
C line strengths, in order to easily prevent under and over-flow.
C Recall that all N-1 levels of the atmosphere
C have the same column density
C WGASES(1, ...), and the top of the
C atm has column density WGASES(2, ...)
C
      DO 250 IS=1,7
          IF (IS.EQ.1)THEN
C
C Water
C
          WGASES(IS,1)=(2.*DELWCW/ZMU)*1.E-20
          WGASES(IS,2)=(CH2O(ITP)/ZMU)*1.E-20
C
          ELSEIF (IS.EQ.3) THEN
C
C Ozone
C
          WGASES(IS,1)=(2.*DELCO/ZMU)*1.E-20
          WGASES(IS,2)=(CDO3(292)/ZMU)*1.E-20
          ELSE
C
C Mixed gases
C
          WGASES(IS,1)=(2.*DELC/ZMU)*PARTS(IS)*1.E-20
          WGASES(IS,2)=(SC(292)/ZMU)*PARTS(IS)*1.E-20
          ENDIF
250      CONTINUE
C
C Now we treat the top
C Nth level of the atmosphere using 29.1 km values

```

C

```
TALL(1,N) = TH2O(ITP)
TALL(2,N) = TMIX(292)
TALL(3,N) = TMIX(292)
PALL(1,N) = PH2O(ITP)
PALL(2,N) = PMIX(292)
PALL(3,N) = PMIX(292)
```

C

C If the user has requested a  
C 1 layer atmosphere (N=1) then load this up instead

C-----

C

```
ELSE
```

C

C H2O Layer, use T and P at 1/2 density

C

```
TALL (1,N)=A1ATB1(TH2O,ALT,ITP,ALTKM,IE1)
PALL (1,N)=A1ATB1(PH2O,ALT,ITP,ALTKM,IE2)
```

C

C Mixed gases, use T and P at 1/2 pressure

C

```
TALL (2,N)=A1ATB1(TMIX,ALT,292,ALTKM,IE3)
PALL (2,N)=A1ATB1(PMIX,ALT,292,ALTKM,IE4)
```

C

C Ozone if we are under 22 km (ie, we are not in a balloon or rocket)  
C then we are under the  
C bulk of the Ozone Layer - use T P parameters of  
C 22 km, else, use the T and P at altitude

C

```
IF(ALTKM.LT.22) THEN
  TALL (3,N)=A1ATB1(ST,ALT,292,22.,IE5)
  PALL (3,N)=A1ATB1(SP,ALT,292,22.,IE6)
ELSE
  TALL (3,N)=A1ATB1(ST,ALT,292,ALTKM,IE7)
  PALL (3,N)=A1ATB1(SP,ALT,292,ALTKM,IE8)
ENDIF
```

```
DO 600 IS=1,7
```

C

C H2O

C

```
IF(IS.EQ.1) THEN
  WGASES(IS,N)=A1ATB1(CH2O,ALT,ITP,ALTKM,IE9)
  /ZMU*1E-20
```

1

C

C Ozone

C

```
ELSEIF (IS.EQ.3) THEN
  WGASES(IS,N)=A1ATB1(CDO3,ALT,292,ALTKM,IE10)
  /ZMU*1E-20
```

1

C

C Mixed gases

C



```

ELSE
WGASES (IS, N) = A1ATB1 (SC , ALT, 292, ALTKM, IE11)
1 /ZMU*PARTS (IS) *1E-20
C
ENDIF
IF (IE1.NE.0.OR.IE2.NE.0.OR.IE3.NE.0.OR.IE4.NE.0
1 .OR.IE5.NE.0.OR.IE6.NE.0.OR.IE7.NE.0.OR.IE8.NE.0
2 .OR.IE9.NE.0.OR.IE0.NE.0.OR.IE10.NE.0.OR.IE11.NE.0)
3 THEN
PRINT*, ' Column density(s) out of range in '
1 , 'sub. LEVEL, error FLAG 1,2,... are: ',
2 IE1, IE2, IE3, IE4, IE5, IE6, IE7, IE8, IE9, IE10, IE11
STOP
ENDIF

```

```

600 CONTINUE
ENDIF
Cd IF (N.NE.1) PRINT*, ' T P TW, PW ', TALL(2, N), PALL(2, N), TALL(1, N)
Cd 1 , PALL(1, N)
c OPEN(7, FILE='le.', STATUS='NEW')
c DO I=1, 2
c WRITE(7, 777) I, (WGASES (II, I), II=1, 7)
c777 FORMAT(1X, I1, 1X, 7(E8.3, 1X), /)
c ENDDO
c DO J=1, N
c WRITE(7, 888) J, (PALL(K, J), K=1, 3), (TALL(KK, J), KK=1, 3)
c888 FORMAT(1X, I2, 1X, 6(E8.3, 1X))
c ENDDO
c CLOSE(7)
c RETURN
c END

```

SUBROUTINE SCALGS

```

C *****
C Provides Gamma and S scale factors for line shapes
C for all N species T(1,) is H2O, T(2,) is mixed gas, T(3,) is O3,
C & likewise for P, and the S and Gamma scale factors, SSCALE, GSCALE
C (As usual, hundreds of memory locations (eg, T(3,2:300) )
C are unused, because
C O3 is treated currently as a monolayer. Perhaps this will change.
C *****
REAL EXPM(3), EXPN(3)
COMMON /WGAS/ WGASES(7, 2), PALL(3, 300), TALL(3, 300)
1 , ITANK, LAYER
COMMON /SCALE/ SSCALE(3, 300), GSCALE(3, 300)
DATA EXPM/1.5, 1.0, 1.5/, EXPN/0.62, 0.5, 0.5/
ITYPES=3
IF (ITANK.EQ.1) ITYPES=1
DO K=1, ITYPES
NLEV=LAYER
DO I=1, NLEV
SSCALE(K, I) = (296./TALL(K, I)) ** EXPM(K)
GSCALE(K, I) = PALL(K, I) * (296./TALL(K, I)) ** EXPN(K)

```

```

C          PRINT*, ' IN SUB SS,GS, K LEV ',SSCALE(K,I),
C      1      GSCALE(K,I),K,I
          ENDDO
          ENDDO
          RETURN
          END

```

SUBROUTINE GETLAM

```

C *****
C Get the wavelength range and resolution
C *****
      REAL ASPN(19)
      CHARACTER*3 MOLE(7),ASP(19)*5,ASPECIES*5
      COMMON /ATMJNK/AWV,AZ,AWVL,IATYPE,IALAY,IALT,TORR
      COMMON /LIMIT/NFMAX,NRES,BOTL,TOPL,ISLITS,IWINGS,IPLLOTN
1      ,RESRB,AC,JWINGS
      COMMON /FVECT/F1,F2,FD,NF
      COMMON /RANGE/WL1I,WL2I,DWLI,WNEXT1,WNEXT2,WNR1,WNR2,WLEXT1
1      ,WLEXT2,WLLINE,IZSKIP
      COMMON /WGAS/ WGASES(7,2),PALL(3,300),TALL(3,300)
1      ,ITANK,LAYER
      DATA ASP/'SIII','SIII2','OIII','OIII2','OI',
1      'OI2','CII','NIII','SiII','NeIII','NII',
2      'SI','FeII','OIV','NeV','FeIII','NII2','SII','SII2'/
      DATA ASPN/ 18.713, 33.480, 51.815, 88.356, 63.18372,
1      145.52548, 157.741, 57.330, 34.814, 36.010,121.897,
2      25.249,25.9882,25.87,24.28,22.93,205.25,68.49,129.7/
      DATA MOLE/'H2O','CO2',' O3',' N2O',' CO','CH4',' O2'/
2010 PRINT 2011
2011 FORMAT(' Enter wavelength of spectral line of interest',/,
1      ' (this is used to make the velocity scale), or...','/,
2      ' -1 for species specification, ',/,
2      ' or else 0 for don't care (0): ',,$)
      READ(*,*,ERR=2010)WLLINE
      PRINT*, '{',WLLINE,'}'
      IF (WLLINE.EQ.-1) THEN
20121 PRINT 2012
2012 FORMAT(' Enter species (with no trailing tabs), eg. OI',
1      /,,' (enter ''NO'' to get out,',
1      ' enter ''LI'' to print the list) (NO): ',,$)
          READ(*,2013,ERR=20121)ASPECIES
          WRITE(*,20132)ASPECIES
2013 FORMAT(A5)
20132 FORMAT('{',A5,'}')
          IF(ASPECIES.EQ.'LI'.OR.ASPECIES.EQ.'LI') THEN
              DO II=1,19
                  WRITE(*,4013)ASP(II),ASPN(II)
4013 FORMAT(1X,A5,' at wavelength ',F9.5)
              ENDDO
              GO TO 20121
          ENDIF
          IF(ASPECIES.EQ.'NO')GO TO 2010
          DO II=1,16

```

```

                IF (ASPECIES.EQ.ASP(II)) THEN
                    WLLINE=ASPN(II)
                    PRINT 20131,ASPECIES,WLLINE
20131          FORMAT(1X,A5,' Wavelength = ',F8.4)
                    GOTO 100
                    ENDIF
                ENDDO
                PRINT2014,ASPECIES
2014          FORMAT(1X,A5,' Not found, try again. (Get out with ''NO'') ')
                GO TO 20121
            ENDIF
100          PRINT 1011
1011          FORMAT(' You may enter the limits of the x-axis in either',/,
1          ' wavelength or velocity; each unit will be printed.',/,
2          ' Enter wavelength range of interest; Lambda 1 and Lambda 2'
3          ', ' in microns.',/,
4          ' (''0 0'' for velocities instead) (10 10.1): ', $)
            READ(*,*,ERR=100)WL1I,WL2I
            PRINT*,' {' ,WL1I,WL2I, '}'
                IF(WL1I.LT.0)THEN
                    DUM=WL2I
                    WL2I=-10000/WL1I
                    WL1I=-10000/DUM
                    PRINT*,' Wavelengths ',WL1I,' to ', WL2I
                ENDIF
            IF(WL1I.EQ.0)THEN
                IF(WLLINE.EQ.0)GO TO 2010
10110          PRINT 10111
10111          FORMAT(' Enter beginning and ending velocity (km/s) ',
1          ' for plot (-1000 1000): ', $)
                READ(*,*,ERR=10110)V1,V2
                PRINT*,' {' ,V1,V2, '}'
                WL1I=(1+V1/2.9979E5)*WLLINE
                WL2I=(1+V2/2.9979E5)*WLLINE
                PRINT 10112,WL1I,WL2I
10112          FORMAT(' The wavelength range is then ',F9.5,1X,F9.5)
            ENDIF
            WL1=WL1I
            WL2=WL2I
            IF(WLLINE.EQ.0)WLLINE=0.5*(WL1I+WL2I)
            IF(WL1.LT.BOTL.OR.WL2.GT.TOPL.OR.WL1.GT.WL2)THEN
                PRINT*,' Invalid
1          range. Min, Max are: ',BOTL,TOPL,' microns'
                PRINT*,' Try again...'
                GO TO 100
            ENDIF

```

C  
C We set the variable IWINGS which tells how far out of the requested  
C wavelength range deep lines could reside which might influence the  
C spectrum. We consider  
C two cases, at or above flight altitude (Alt=41000 ft)  
C IDEEP=1, and below flight altitude, or a tank IDEEP=2  
C

```

IDEEP=1
IF(IALT.LT.41000.OR.ITANK.EQ.1)IDEEP=2
CALL SEARCH(WL1I,WL2I,IDEEP,IWINGS)
111 PRINT 1111
1111 FORMAT(' Enter instrumental resolution in microns ',/,
1 ' (0 for the CGS high resolution system',
1 ' resolution = 60 km/s),',/,
1 ' or -1 for no smoothing. (0): ',,$)
READ(*,*,ERR=111)DWLI
PRINT*,' {' ,DWLI, '}'
IF (DWLI.EQ.0)DWLI=RES(WLLINE)
IF (DWLI.EQ.-1)DWLI=0
IF(DWLI.LT.0)GO TO 111
WLCENTER=.5*(WL1I+WL2I)
WNCENTER=WLORWN(WLCENTER)
DWN1=DLORDN(DWLI,WLCENTER)
DWNIN=DWN1/NRES
WN1=WLORWN(WL1)
WN2=WLORWN(WL2)
IF(ITANK.NE.1)THEN
IF(LAYER.EQ.1)THEN
DWN=PALL(2,1)*RESRB
C PRINT*,' RESRB, PALL(2,1) ,DWN ',RESRB,PALL(2,1),DWN
ELSE
DWN=PALL(2,LAYER-1)*RESRB
ENDIF
ELSE
DWN=PALL(1,1)*RESRB
ENDIF
C PRINT*,' DWN, DWNIN ',DWN, DWNIN
IF(DWLI.NE.0.AND.DWNIN.LT.DWN)DWN=DWNIN

C
C Check that the range & resolution
C requested will fit into the fine array, characterized by FVECT
C

WNEXT2=WN2-ISLITS*DWN1
WLEXT2=WLORWN(WNEXT2)
IF(WLEXT2.GT.TOPL)THEN
PRINT*,' Warning, the instrumental slit',
1 ' will encompass no lines ',
1 ' longward of ',TOPL,' um - these are not in the database.'
WLEXT2=TOPL
WNEXT2=WLORWN(TOPL)
ENDIF
WNEXT1=WN1+ISLITS*DWN1
WLEXT1=WLORWN(WNEXT1)
IF(WLEXT1.LT.BOTL)THEN
PRINT*,' Warning, the instrumental slit'
1 ' will encompass no lines ',
1 ' shortward of ',BOTL,
1 ' um - these are not in the database.'

```

```

WLEXT1=BOTL
WNEXT1=WLORWN (BOTL)
ENDIF

```

```

XNTEST= (WNEXT1 - WNEXT2) / DWN
COMPARE=NFMAX
IF (XNTEST+1 .LT. COMPARE) THEN
NF=XNTEST+1
F2=WNEXT2
FD=DWN
F1=WNEXT2+FD*NF
WNR1=WNEXT1+IWINGS
WLR1=WLORWN (WNR1)
IF (WLR1 .LT. BOTL) THEN
WLR1=BOTL
WNR1=WLORWN (BOTL)
ENDIF
WNR2=WNEXT2 - IWINGS
IF (WNR2 .LE. 0) WNR2=1E-3
WLR2=WLORWN (WNR2)
IF (WLR2 .GT. TOPL .OR. WLR2 .LT. 0) THEN
WLR2=TOPL
WNR2=WLORWN (TOPL)
ENDIF

```

```

C
C COMMON /FVECT/ is now set up for the fine array,
C

```

```

ELSE

```

```

DO IDECEXP=4, -5, -1
DO ICOEF=9, 0, -1
DELWL=ICOEF*10.** (IDECEXP-1)+10.**IDECEXP
WLTEST1=WLCENTER-DELWL-ISLITS*DWLI
IF (WLTEST1 .LT. BOTL) GOTO 8500
WNTTEST1=WLORWN (WLTEST1)
WLTEST2=WLCENTER+DELWL+ISLITS*DWLI
IF (WLTEST2 .GT. TOPL) GOTO 8500
WNTTEST2=WLORWN (WLTEST2)
XNTEST= (WNTTEST1 - WNTTEST2) / DWN
PRINT*, ' DEL WL1, WL2, XN ', DELWL, WLTEST1, WLTEST2, XNTEST
IF (XNTEST+1 .LT. COMPARE) GO TO 9000
CONTINUE
ENDDO

```

```

c
8500
ENDDO
PRINT*, ' Wavelength range too large, '
PRINT*, ' Trouble finding acceptable range...'
GO TO 100

```

```

9000
WL1=AMAX1 (BOTL, WLTEST1)
WL2=AMIN1 (TOPL, WLTEST2)

```

```

1001
PRINT 1001, WL1, WL2
FORMAT(' Range too large. Try something like ',/,
1 F13.7, ' - ', F13.7)

```

```

PRINT*, ' Enter new Lambda 1, Lambda 2'

```

```

1          ,', and/or resolution.'
PRINT*, ' Wavelength range too large. Try a smaller range.'
      GO TO 100
      ENDIF
      RETURN
      END

```

```

SUBROUTINE SEARCH(WWL1,WWL2, IDEEP, IWINGS)

```

```

C *****
C Determines how far to search for deep lines
C *****

```

```

      REAL WNLST(8), SEARCHLST(8,2)
      DATA WNLST/1,280,600,740,1600,3200,3800,12500/
      DATA SEARCHLST/30, 10, 80, 10,800, 30, 10,0,
1          200,200,200,200,800,200,200,0/
      WN1=10000./WWL2
      WN2=10000./WWL1
      DO I=1,7
          IF(WN1.GE.WNLST(I) .AND.WN1.LE.WNLST(I+1)) THEN
              INDEX1=I
          ENDIF
          IF(WN2.GE.WNLST(I) .AND.WN2.LE.WNLST(I+1)) THEN
              INDEX2=I
          ENDIF
      ENDDO
      IWINGS=0
      DO I=INDEX1,INDEX2
          IF(SEARCHLST(I, IDEEP) .GT. IWINGS) IWINGS=SEARCHLST(I, IDEEP)
      ENDDO

      IF(IWINGS.EQ.0) THEN
          PRINT*, ' ERROR SETING IWINGS'
          STOP
      ENDIF

      RETURN
      END

```

```

FUNCTION RES(WL)

```

```

C
C Give the resolution of the CGS "High Resolution System" for a
C specified wavelength
C
C for now...
      res=wl*60./3e5
      RETURN
      END

```

```

SUBROUTINE GETPLO

```

```

C *****
C Get the plot parameters
C *****

```

```

COMMON /LIMIT/NFMAX,NRES,BOTL,TOPL,ISLITS,IWINGS,IPLOTN
1  ,RESRB,AC,JWINGS
COMMON /FVECT/ F1,F2,FD,NF
COMMON /PVECT/P1,P2,PD,NP,NINST,IPLTCNT
COMMON /RANGE/ WL1I,WL2I,DWLI,WNEXT1,WNEXT2,WNR1,WNR2,WLEXT1
1  , WLEXT2,WLLINE,IZSKIP

C
C now for /PVECT/ which controls the plotting array
C
C Take care of case where there is now smoothing, instrumental res=0
C
      IF(DWLI.EQ.0) THEN
      IHOP=NF/IPLOTN+1
      PRINT*, ' NF,IPLOTN,IHOP ',NF,IPLOTN,IHOP
499    PRINT 500,IHOP
500    FORMAT(' The ''fine array'' will be plotted, by sampling ',
1' each ',I3,' elements. Input 0 if',/,
2' this is OK, or else a larger integer element interval: ', $)
      READ(*,*,ERR=499) IHOP1
      PRINT*, '{',IHOP1,'}'
      IF(IHOP1.EQ.0) IHOP1=IHOP
      IF(IHOP.GT.IHOP1) GO TO 499
      IZSKIP=IHOP1
      P1=WL1I
      P2=WL2I
      NP=(1.*NF)/IZSKIP
      PD=(P2-P1)/NP
      GOTO 100
      ENDIF

C
      PRINT*, ' Setting the data point spacing ',
1' (sampling) to 1/5 instrument resolution...'
      RESI=0.2*DWLI
      NIND=(WL2I-WL1I)/RESI
501    WRITE(*,5011)NIND
5011   FORMAT(' There will be',I7,' points plotted.')
      IF(NIND.LT.3.OR.NIND.GT.IPLOTN) THEN
          PRINT*, ' Number of points must be greater than 2'
1          , ' and less than ',IPLOTN
          GOTO 599
      ENDIF
      IF(RESI.GE..0001.AND.RESI.LT.10.) THEN
          WRITE(*,502)RESI
502    FORMAT(' Their spacing will be ',F7.4,' microns.')
      ELSE
          WRITE(*,503)RESI
503    FORMAT(' Their spacing will be ',1PE9.3,' microns.')
      ENDIF
599    PRINT 999
999    FORMAT(' Enter a new number of points, or 0 to keep these '
1      , 'values, or ',/, ' -1 to change the spacing (0): ', $)
      READ(*,*,ERR=599)L
      PRINT*, '{',L,'}'

```

```

C
C
C
      IF(L.GT.0) THEN
          New # of points
              IF(L.GE.2.AND.L.LE.IPLOTN) THEN
                  P1=WL1I
                  P2=WL2I
                  PD=(WL2I-WL1I)/L
                  NP=L
              ELSE
1          PRINT*, ' Number of points must be greater than 2'
              , ' and less than ',IPLOTN
                  GO TO 501
                  ENDIF
          ELSEIF (L.EQ.-1) THEN
C
C
C
          New # of points for new spacing
8880      PRINT 888
888      FORMAT(' Enter new spacing in microns (.005): ', $)
          READ(*,*,ERR=8880)RESNEW
          PRINT*, '{', RESNEW, '}'
          L=(WL2I-WL1I)/RESNEW
              IF(L.GE.2.AND.L.LE.IPLOTN) THEN
                  P1=WL1I
                  P2=WL2I
                  PD=RESNEW
                  NP=L
                  PRINT*, ' ', NP, ' points will be plotted.'
              ELSE
                  PRINT*, ' ', L, ' points result....'
1          PRINT*, ' Number of points must be greater than 2'
              , ' and less than ',IPLOTN, ', (Mongo can''t handle'
          PRINT*, ' many more). Try again...'
              GO TO 501
              ENDIF
          ELSE
C
C
C
          Use existing number of points
              IF(NIND.GE.2.AND.NIND.LE.IPLOTN) THEN
                  P1=WL1I
                  P2=WL2I
                  PD=RESI
                  NP=NIND
              ELSE
1          PRINT*, ' Number of points must be greater than 2'
              , ' and less than ',IPLOTN, ', (Mongo can''t handle'
          PRINT*, ' many more). Try again...'
              GO TO 501
              ENDIF
          ENDIF
100      NINST=5

```



```

      IF(DWLI.GT.0)THEN
2      PRINT*,' Select instrument profile function: '
      PRINT 3
3      FORMAT(' [1] Triangle, [2] Gaussian, [3] Sinc,',
1      ' [4] Rectangle (2): ', '$)
      READ(*,*,ERR=2)NINST
      PRINT*,' {', NINST, '}'
      IF(NINST.LT.1.OR.NINST.GT.4)GO TO 2
      IF(NINST.EQ.3)CALL SINCO(DWLI)
      ENDIF
      RETURN
      END

      FUNCTION A1ATB1(A,B,N,B1,IERR)

C      A general interpolation function - S.Lord 12 MAY 88
C      Interpolates to find
C      A1(B1), given absissa B and ordinate values B-array
C      B array (the absissa) must be
C      monotonically increasing or decreasing
C      Error Flag:      IERR=0    No error
C                      =-1    B1 less than entire B-array range
C                      +1      greater
C                      +2    B array contains adjacent equal elements
C                      +3    B array is not monotonic

      REAL A(N),B(N)
      IERR=0

C      IF(B(1).LE.B(N))THEN
C      Treat ascending B-array case first:
C
      IF(B1.LT.B(1))THEN
      IERR=-1
      RETURN
      ENDIF
      IF(B1.GT.B(N))THEN
      IERR=1
      RETURN
      ENDIF

C
      DO 10 J=2,N
      I=J-1
      IF(B(I).EQ.B(J))THEN
      IERR=2
      RETURN
      ENDIF
      IF(B(I).GT.B(J))THEN
      IERR=3
      RETURN
      ENDIF
      IF(B(J).GE.B1)THEN

```

```

                A1ATB1=A(I)+(A(J)-A(I))*(B1-B(I))/(B(J)-B(I))
                RETURN
            ENDIF
10             CONTINUE
                PRINT*,' A1TOB1 1'
                STOP

C
C Treat decending B-array case second:
C
            ELSE
                IF(B1.LT.B(N)) THEN
                    IERR=-1
                    RETURN
                ENDIF
                IF(B1.GT.B(1)) THEN
                    IERR=1
                    RETURN
                ENDIF

C
                DO 20 J=2,N
                    I=J-1
                        IF(B(I).EQ.B(J)) THEN
                            IERR=2
                            RETURN
                        ENDIF
                        IF(B(I).LT.B(J)) THEN
                            IERR=3
                            RETURN
                        ENDIF
                        IF(B(J).LE.B1) THEN
                            A1ATB1=A(I)+(A(J)-A(I))*(B1-B(I))/(B(J)-B(I))
                            RETURN
                        ENDIF
20             CONTINUE
                PRINT*,' A1TOB1 2'
                STOP

            ENDIF
        END

        FUNCTION WLORWN(ARG)
C *****
C WL - wavelength, WN - wave number. Converts one to the other.
C *****
C This calculates wavelength (lambda
C in microns) at a wave number (cm^-1).
C Conversely it calculates a wave number (cm^-1)
C at a wave length (microns)
C It's a little silly to do in
C a function, but it trades speed for clarity.
C
                WLORWN=1E4/ARG
                RETURN

```

END

FUNCTION DLORDN(DELARG,ARG)

```
C *****
C DL - delta lambda, DN - C delta wave number.
C Converts one to the other.
C Note: DELARG and ARG are the input
C and are the same type unit.
C *****
C This calculates delta lambda (microns) at delta sigma (cm^-1).
C Conversely it calculates delta sigma
C (cm^-1) at delta lambda (microns)
C Formally, the sign should be reversed, but
C this is not usually desired.
C
      DLORDN=1E4*DELARG/(ARG*ARG)
      RETURN
      END
```

FUNCTION IFATWN(WN,IE)

```
C *****
C Finds the index in the F = Fine array
C that represents the largest wave number
C that is less than WN.
C If WN is less than the first wave number F1, IE=-1
C *****
C If WN is greater than the last WN, IE = 1. Else, IE=0. N.B. we have
C set up the fine array in decreasing wave number, FD is negative.
C
      COMMON /FVECT/ F1,F2,FD,NF
      IFATWN=NINT((WN-F1)/FD)+1
      IE=0
      IF(IFATWN.LT.1) IE=-1
      IF(IFATWN.GT.NF) IE=1
      RETURN
      END
```

SUBROUTINE GETSET(IER)

```
C *****
C Uses a file listing the number of lines per integer wavenumber,
C *****
C The AFCRL database provides the input.
C Also SKIPA records the number of lines
C( = records) of the AFCRL database
C that must be read to arrive at a wavenumber's first line, all listed
C in two columns from the shortest to longest wavenumber.
C
      COMMON /LIMIT/NFMAX,NRES,BOTL,TOPL,ISLITS,IWINGS,IPLTN
1      ,RESRB,AC,JWINGS
      COMMON /FVECT/ F1,F2,FD,NF
      COMMON /RANGE/ WL1I,WL2I,DWLI,WNEXT1,WNEXT2,WNR1,WNR2,WLEXT1
1      ,WLEXT2,WLLINE,IZSKIP
      COMMON /WREAD/ IRECA,IRECZ
```

```

COMMON /SKIPS/ISKIPWN(12500),ISKIPSUM(12500),ISKIPMAX(12500)
C
Cd  print*, 'ext21 read21 ', wnext2, wnext1, wnr2, wnr1
   IER=0
   OPEN(1, FILE='/work/cgs/atran/skipa.dat', STATUS='OLD', ERR=1232)
C, READONLY)
   IBEG=10000./TOPL+.0001
   IEND=10000./BOTL+.0001
c    PRINT*, ' WNR1 WNR2 ', WNR1, WNR2
C    PRINT*, ' TOPL, BOTL, IBEG, IEND ', TOPL, BOTL, IBEG, IEND

      IF (IBEG.GT.WNR2.OR.IEND.LT.WNR1) THEN
      WLR1=WLORWN(WNR1)
      WLR2=WLORWN(WNR2)
      PRINT*, ' AFCRL file''s available wavelength range:'
      PRINT10, BOTL, TOPL, WLR1, WLR2
10   FORMAT(' ', F7.2, ' - ', F7.2, /
1     , ' does not include desired span:'
2     , F7.2, ' - ', F7.2, ' which is the span, ', /,
3     ' extended to include nearby line wings')
      CLOSE(1)
      IER=1
      RETURN
      ENDIF

IFLAG=0
C    PRINT*, ' BEFORE LOOP WNR2, 1 ', WNR2, WNR1
DO 1 I=IBEG, IEND
READ(1, *, END=21, ERR=20) LPN, NTOT
C    PRINT*, ' IN LOOP, WN, LPN, NTOT= ', I, LPN, NTOT
ISKIPWN(I)=LPN
IF (IFLAG.EQ.0) THEN
      IF (I+1.GT.WNR2) THEN
      IFLAG=1
C    PRINT*, ' Flags up, we''re rolling! '
      IRECA=NTOT
      ENDIF
ELSEIF (IFLAG.EQ.1) THEN
      IF (I.GT.WNR1) THEN
      IRECA=NTOT
      IFLAG=2
      ENDIF
ELSEIF (IFLAG.EQ.2) THEN
      IF (I.GT.WNR1+IWINGS) GO TO 15
ENDIF
1   CONTINUE
   PRINT*, ' Warning, '
   1 , 'lacking information for line wings shortward of ',
   1 IBOTL, ' micrometers'
   GOTO15
20  CONTINUE
   PRINT*, ' Error in skipa.dat, WN, LPN, NTOT= ', I, LPN, NTOT
   IER=1
   RETURN

```

```

21 PRINT*, ' Premature end of file in SKIPA File.'
   IER=1
   RETURN
15 CONTINUE
   IF(IRECZ.EQ.IRECA)GOTO21
C PRINT*, ' IRECA, IRECZ ', IRECA, IRECZ
C CLOSE (1)
C
C The arrays ISKIPSUM and ISKIPMAX count
C the max possible line with wings
C IWINGS wave numbers out from the center
C that may overlap at a wavenumber
C
   IWNBEG=WNR2
   IWNEND=WNR1
c PRINT*, ' start and stop wn on getset... ', IWNBEG, IWNEND
   DO I=IWNBEG, IWNEND
     J=MAX(I-JWINGS, 1)
     K=MIN(I+JWINGS, 12500)
     ISKIPSUM(I)=0
     DO L=J, K
       ISKIPSUM(I)=ISKIPSUM(I)+ISKIPWN(L)
     ENDDO
   ENDDO
   DO I=IWNBEG, IWNEND
     J=MAX(I-JWINGS, 1)
     K=MIN(I+JWINGS, 12500)
     ISKIPMAX(I)=1
     DO L=J, K
       IF(ISKIPSUM(L).GT.ISKIPMAX(I))ISKIPMAX(I)=ISKIPSUM(L)
     ENDDO
   ENDDO
   JBEG=MAX(IWNBEG-IWINGS, 1)
   KEND=MIN(IWNEND+IWINGS, 12500)
c PRINT*, ' WN WAVELENGTH ISKIPWN ISKIPSUM SKIPMAK '
c PRINT*, '-----'
c DO I=JBEG, KEND
c WAVELEN=10000./I
c WRITE(*, 4444) I, WAVELEN, ISKIPWN(I), ISKIPSUM(I), ISKIPMAX(I)
c4444 FORMAT(1X, I7, 1X, F10.3, 1X, 3(I6, 2X))
c ENDDO
OPEN(1, FILE='/work/cgs/atran/afgl.bin', STATUS='OLD',
1 FORM='UNFORMATTED',
2 iostat=ierrs)
if(ierrs.ne.0)goto1234
WRITE(*, (' 'Reading through database'
1 , ' to this wavelength.....'))
DO I=1, IRECA
READ(1)
ENDDO
PRINT*, ' '
C PRINT*, ' Data file advanced'
C READ(1)wn, st, wd, ep, n

```

```

C      WL=10000./WN
C      PRINT*,' WL WN ',WL,WN
      RETURN
1232   PRINT*,' Can't fine skipa.dat'
      STOP
1234   PRINT*,' Can't find afgl.bin'
      print*,'ierrs= ',ierrs
      STOP
      END

```

SUBROUTINE INTEG

```

C *****
C Integrates Lorentz line shapes into the fine array
C *****
C Reads the lines from the AFCRL database one by one, and, for each
C level of the atmosphere, add the lines into the Fine array. The
C lines are all Lorentzian.
C
C statistical counters.... IWEAK
C
C IWEAK          The line at line cntr
C                (for gamma etc. in this layer) is too weak
C IDELIN        delta fn. in range
C                (fn. has FWHP less than .5 FD; is integrated)
C IDELOUT       delta fn. out of range (rejected)
C IWIDEIN       broad line, in range, (integrated)
C IWIDEOUT      broad line, out of range, (rejected)
C
      CHARACTER*3 MOLE(7)
      INTEGER IN(7), INN(7), IWEAK(7,300), IDELIN(7,300),
      1 IDELOUT(7,300), IWIDEOUT(7,300), IWIDEIN(7,300)
      REAL*8 E
      COMMON/D2O/D2OG
      COMMON /LIMIT/NFMAX, NRES, BOTL, TOPL, ISLITS, IWINGS, IPLOTN
      1 , RESRB, AC, JWINGS
      COMMON /FARRA/F(1000000)
      COMMON /PVECT/P1, P2, PD, NP, NINST, IPLTCNT
      COMMON /FVECT/F1, F2, FD, NF
      COMMON /WREAD/ IRECA, IRECZ
      COMMON /RANGE/WL1I, WL2I, DWLI, WNEXT1, WNEXT2, WNR1, WNR2, WLEXT1
      1 , WLEXT2, WLLINE, IZSKIP
      COMMON /WGAS/ WGASES(7,2), PALL(3,300), TALL(3,300)
      1 , ITANK, LAYER
      COMMON /SCALE/SSCALE(3,300), GSCALE(3,300)
      COMMON /SKIPS/ISKIPWN(12500), ISKIPSUM(12500), ISKIPMAX(12500)
      COMMON /STRONG/SLINES(80), ISPEC(80), SEW(80), ISTRONG
      1 , IPOINT, STRENGTH
      DATA MOLE/'H2O', 'CO2', ' O3', ' N2O', ' CO', 'CH4', ' O2'/
      DATA IN/1,2,3,4*2/,
      1 INN/1,2,3,2,2,3,2/, PI/3.14159265/, PII/0.318309886/
      c      open(81,file='deb.',status='new')
C
C Clear statistics counters

```

```

C
C      IZIP=0
C      IZAP=0
C      WN1I=10000./WL1I
C      WN2I=10000./WL2I
C      IF(DWLI.GT.0)WNINST=DLORDN(DWLI,WLEXT1)
C      IF(DWLI.EQ.0)WNINST=NRES*FD
C      IF(IPLTCNT.NE.0)THEN
C      PRINT*,' CLEARING STAT COUNTERS...'
C          DO I=1,300
C              DO J=1,7
C                  IWEAK(J,I)=0
C                  IDELIN(J,I)=0
C                  IWIDEOUT(J,I)=0
C                  IWIDEIN(J,I)=0
C                  IDELOUT(J,I)=0
C              ENDDO
C          ENDDO
C      PRINT*,' STAT COUNTERS CLEAR'
C
C      PRINT*,' Reinitializing Arrays...'
C          DO I=1,NF
C              F(I)=0
C          ENDDO
C      PRINT*,' FINE ARRAY CLEAR'
C      ENDIF
C
C      IATMOK=0
C      IACCEPT=0
C      IREJECT=0
C      HALFF=FD/2.
C      CONST=-LOG(1-AC)*PI/LAYER
C
C      Outermost loop for the lines
C
C      PRINT*,' Beginning read-in loop...'
C
C          ITOTL=IRECZ-IRECA+1
C          DO 1 I=IRECA,IRECZ
C              ITELL=I-IRECA+1
C              IF(MOD(ITELL,500).EQ.0)THEN
5555          WRITE(*,5555)ITELL,ITOTL
C              FORMAT(1X,I8,' out of ',I8,' lines processed.')
C              ENDIF
C          READ(1)WNO,S0,GAMMA0,E,ISP,XN
C              if (iii.eq.141685)then
C                  print*,' got it '
C                  go to 1
C              endif
C          IF(WNO.GT.1003.6)PRINT*,' IN INTEG WNO= ', WNO
C              S0=S0*1E+20
C
C      Check to see if we are

```

```

C starting or stopping our read within the range
C
      IF(I.EQ.IRECA.AND.WN0.GT.WNEXT2)THEN
        PRINT*, ' WARNING '
1      ,'- Starting read inside range, WN0, WNEXT2 ',
1      WN0,WNEXT2
      ENDIF
      IF(I.EQ.IRECZ.AND.WN0.LT.WNEXT1)THEN
1      PRINT*, ' WARNING - Ending read inside range, WN0, WNEXT1 ',
      WN0,WNEXT1
      ENDIF
C
C Lines not in the
C F array interval are easily dismissed if they are too
C narrow, set a flag. Remember WNEXT1 > WNEXT2
C
      IF(WN0.LE.WNEXT1.AND.WN0.GE.WNEXT2)THEN
        INTERV=1
      ELSE
        INTERV=0
      ENDIF
Cd      WRITE(*,1111)INTERV
1111    FORMAT(' INTERV#####',2X,I1)
C
C Check to see if we are out of the range
C of WNR1 WNR2 necessary for the integ.
C
      IF(WN0.LT.WNR2)THEN
        IREJECT=IREJECT+1
        GOTO1
      ENDIF
C
C Check to see if we have passed the necessary range
C
      IF(WN0.GT.WNR1)GOTO 9999
C
C Check if it is not H2O and we
C are modeling the "tank." (if so, reject)
C
      IF (ITANK.EQ.1)THEN
        IF(ISP.NE.1) THEN
          IREJECT=IREJECT+1
          GO TO 1
        ENDIF
      ENDIF
C
      IACCEPT=IACCEPT+1
Cd      PRINT*, ' '
Cd      PRINT*, ' '
Cd      PRINT*, ' Accepting No. ', IACCEPT
      LEVS=LAYER
      K=IN(ISP)
      KK=INN(ISP)

```



```

C
C MAXLPN is the maximum
C number of lines that can overlap at this wave number
C XLIM is a constant to use in
C comparison with line center strengths, to
C determine if a line is significant.
C
      IND=WNO
      MAXLPN=ISKIPMAX(IND)
      IF(MAXLPN.EQ.0) THEN
      PRINT*, ' ???? IND, ISKIPMAX(IND) ', IND, ISKIPMAX(IND)
      MAXLPN=1
      ENDIF
      XLIM=CONST/MAXLPN
C
C Middle loop for the atmospheric levels
C
      DO 100 LEV=1,LEVS
      IF(LEV.EQ.LEVS) INDEX=2
      IF(LEV.LT.LEVS.OR.LEVS.EQ.1) INDEX=1
      W=WGASES(ISP,INDEX)
      S=SSCALE(K,LEV)*SSCAL1(WNO,E,TALL(K,LEV))*S0
      IF(ITANK.EQ.1) THEN
      IF(D2OG.GT.0.AND.ABS(WNO-48.75267).LT..0003) THEN
      W=D2OG
      S=S*1E7
      PRINT*, ' (Picked up the D2O line!) '
      ENDIF
      ENDIF
      ENDIF
C
C
C      X=SSCAL1(WNO,E,TALL(K,LEV))
C WRITE(81,*) ' K LEV TALL(K,LEV) P', K, LEV, TALL(K,LEV), PALL(K,LEV)
C WRITE(81,*) ' X, SS, SG, S0, S', X, SSCALE(K,LEV), GSCALE(K,LEV), S0, S
C WRITE(81,*) ' ISP, LEV, WG, LEVS ', ISP, LEV, WGASES(ISP,INDEX), LEVS
C
      GAMMA=GAMMA0 * PALL(K,LEV) * (296./TALL(K,LEV))**XN
      TERM=S*W*GAMMA/XLIM-GAMMA*GAMMA
      TERM1=S*W*GAMMA-GAMMA*GAMMA
C
C IF TERM < 0 it means the line
C center is below the threshold for significance
C
      IF(TERM.LT.0) THEN
      IWEAK(ISP,LEV)=IWEAK(ISP,LEV)+1
      GOTO 100
      ENDIF
C
C Determine if the equivalent width is sufficient to include the line
C in the list to mark.
C
      IF(LEV.EQ.1.AND.WNO.GE.WN2I.AND.WNO.LE.

```

```

1 WN1I) THEN
    EW=S*W*LAYER/WNINST
    IF (EW.GT.STRENGTH) THEN
        IF (IPOINT.GE.ISTRONG) THEN
C
C List is full... we see if we can bump one of lesser lines
C
            DO IS=1, ISTRONG
                IF (SEW(IS) .LT. EW) THEN
                    SLINES (IS) =WN0
                    SEW (IS) =EW
                    ISPEC (IS) =ISP
                    GO TO 1777
                ENDIF
            ENDDO
        ELSE
            IPOINT=IPOINT+1
            SLINES (IPOINT) =WN0
            SEW (IPOINT) =EW
            ISPEC (IPOINT) =ISP
        ENDIF
    ENDIF
ENDIF
ENDIF
C
C DELSIG is the number
C of wavenumbers beyond which the line becomes weak
C enough to ignore.
C
1777         DELSIG=SQRT (TERM)
C           IF (TERM1.LE.0) GO TO 1778
C           DELSIG1=SQRT (TERM1)
C
C Reality check #1... If this bell rings,
C we need to increase the value of
C IWINGS
C
C           IF (DELSIG1.GT.1) WRITE (55, 1755) WN0, MOLE (ISP) , DELSIG1
1755         FORMAT (1X, F11.5, 3X, A3, 3X, F8.2)
Cd         WL0=WLORWN (WN0)
Cd         if (iaccept.eq.15) then
Cd         print *, ' s0, gamma0 e s gamma w ', s0, gamma0, e, s, gamma, w
Cd         endif
Cd         write (*, 156) WLEXT1, WLEXT2, WL0, WN0, F1, FD, TERM, NF
156         format (' WLEXT1      WLEXT2          WLO          WN0          F1'
1           1 , '          FD '
1           1 , '          TERM          NF' , /, 7 (F9.4, 1X) I6)
C
C See if it's a delta fn. within the WN range...
C
1778         IF (2*DELSIG.LT.FD.AND.INTERV.EQ.1) THEN
            INF=NINT (( F1-WN0) /FD) +1

```

```

                IF (INF .GE. 1 .AND. INF .LE. NF) THEN
C                IF (2 * GAMMA .GT. FD) THEN
C                PRINT *, ' RATHER BROAD DEL FN, 2 * G, 2 * DEL, FD ',
C                1                2 * GAMMA, 2 * DELSIG, FD
C                ENDIF
                CEN = S * W / GAMMA
                IF (CEN .LT. XLIM) THEN
1                PRINT *, ' Reality check 2 failed... center is less than limit',
                ' Center, limit ', cen, xlim
                ENDIF
                YMEAN = .5 / PI * (CEN + XLIM)
                YAVE = YMEAN * 2 * DELSIG / FD
Cd                PRINT *, ' MIN DEL INT INTO ', INF
                F (INF) = F (INF) + YAVE
                ELSE
Cd                WRITE (*, 157) INF
157                FORMAT (1X, ' IDELIN TROUBLE, INF' , /, 1X, I6)
                ENDIF
Cd                PRINT *, ' TAKEN IDELIN'
                IDELIN (ISP, LEV) = IDELIN (ISP, LEV) + 1
                GO TO 100
Cd                ELSEIF (2 * DELSIG .LT. FD .AND. INTERV .EQ. 0) THEN
                PRINT *, ' TOO FAR MINIDEL'
                IDELOUT (ISP, LEV) = IDELOUT (ISP, LEV) + 1
                GO TO 100
                ENDIF
Cd                PRINT *, ' IDELOUT NOT THE CASE'
Cd                WRITE (*, 1599) FD, ZD, AWAY1, FDTOT
1599                FORMAT ('      FD      ZD      AWAY1      FDTOT      ', /,
1                4 (F9.4, 1X))
C
C We set up our F array integration
C range, and make sure the ends don't
C exceed the F array extent.
C
                Z1 = WN0 + DELSIG
                Z2 = WN0 - DELSIG
C
C I1 and I2 are the indices of the F array between which the line has
C significant extinction.
C
                I1 = NINT ((F1 - Z1) / FD) + 1
                I2 = NINT ((F1 - Z2) / FD) + 1
C
                IF (I1 .GT. NF .OR. I2 .LT. 1) THEN
                IWIDEOUT (ISP, LEV) = IWIDEOUT (ISP, LEV) + 1
                GO TO 100
                ENDIF
                IWIDEIN (ISP, LEV) = IWIDEIN (ISP, LEV) + 1
                IF (I1 .LT. 1) I1 = 1
                IF (I2 .GT. NF) I2 = NF
Cd                PRINT *, ' GAMMA ', GAMMA

```

```

C          IF (WLEXT2.LT.100) THEN
C              IF (IZAP.EQ.0) PRINT*, ' LORENTZ'
C                  IZAP=1
C                  CON=S*W*GAMMA/PI
C                  GAMMA2=GAMMA**2
C                  WN0F1FD=WN0-F1-FD
C                  DO INOW=I1,I2
C                      DEL=WN0F1FD+INOW*FD
C                      F (INOW) =F (INOW) +CON/ (GAMMA2+DEL*DEL)
C                  ENDDO
C          ELSE
C              IF (IZIP.EQ.0) PRINT*, ' KINETIC'
C                  IZIP=1
C                  CON=S*W*4*WN0*GAMMA/PI
C                  GAMMA42=4*GAMMA**2
C                  WN02=WN0*WN0
C                  F1FD=F1+FD
C                  DO INOW=I1,I2
C                      SIG=F1FD-INOW*FD
C                      SIG2=SIG*SIG
C                      DIF=WN02-SIG2
C                      F (INOW) =F (INOW) +SIG*CON/ (DIF*DIF+GAMMA42*SIG2)
C                  ENDDO
C          ENDIF

Cd          DO 109 II= IFBEG-1,IFEND+1
Cd109      PRINT*,II,F(II)
100          CONTINUE
1          CONTINUE
9999      PRINT*,IACCEPT,' CONSIDERED, ',IREJECT,' REJECTED'
          PRINT*, ' OF THOSE CONSIDERED..... '
          PRINT*, ' '
          PRINT*, ' IWEAK '
          1 , '1(H2O)2(CO2)3(O3) 4(N2O) 5(CO) 6(CH4)7(O2) '
          PRINT*, ' Weak line, reject'
          PRINT 994
994      FORMAT(1X,70('-'))
          DO 1042 J=1,LAYER
1042      PRINT 77, J, (IWEAK(ISP,J),ISP=1,7)
          PRINT*, ' '
          PRINT*, ' IDELIN 1(H2O)2(CO2)3(O3) 4(N2O) 5(CO) 6(CH4)7(O2) '
          PRINT*, ' Narrow line in range, accept'
          PRINT 99
99      FORMAT(1X,70('-'))
          DO 1002 J=1,LAYER
1002      PRINT 77, J, (IDELIN(ISP,J),ISP=1,7)
          PRINT*, ' '
          PRINT*, '
          1 ' IDELOUT 1(H2O)2(CO2)3(O3) 4(N2O) 5(CO) 6(CH4)7(O2) '
          PRINT*, ' Narrow line out range, reject'
          PRINT 99
          DO 1003 J=1,LAYER
1003      PRINT 77, J, (IDELOUT(ISP,J),ISP=1,7)

```

```

PRINT*, ' '
PRINT*,
1 ' IWIDEOUT 1(H2O)2(CO2)3(O3) 4(N2O) 5(CO) 6(CH4)7(O2) '
PRINT*, ' Broad line out range, reject'
PRINT 99
DO 1004 J=1,LAYER
1004 PRINT 77, J, (IWIDEOUT(ISP,J),ISP=1,7)
PRINT*, ' '
PRINT*,
1 ' IWIDEIN 1(H2O)2(CO2)3(O3) 4(N2O) 5(CO) 6(CH4)7(O2) '
PRINT*, ' Broad line in range, accept'
PRINT 99
DO 1005 J=1,LAYER
1005 PRINT 77, J, (IWIDEIN(ISP,J),ISP=1,7)
77 FORMAT(' Lyr.',I2,7(I6))
CLOSE (1)
RETURN
END

```

```

FUNCTION SSCAL1(WN0,E,T)
C *****
C Finds the S (line strength) scaling parameter that is
C wave number, energy, and Temperature dependent
C *****
REAL*8 E
WN695=WN0/0.695
TERM1=EXP(-E*(296-T)/(0.694927*296*T))
TERM2=(1-EXP(-WN695/T))
TERM3=(1-EXP(-WN695/296))
SSCAL1=TERM1*TERM2/TERM3
RETURN
END

```

```

SUBROUTINE EXPO
C *****
C Converts Opacities to Transmissions en situ by exponentiating
C *****
COMMON /FARRA/F(1000000)
COMMON /FVECT/F1,F2,FD,NF
PRINT*, ' Converting opacity to transmittance...'
DO I=1,NF
IF(F(I).LT.0)THEN
PRINT*, ' NEGATIVE OPACITY! F(I), I ',F(I),I
STOP
ELSEIF (F(I).LT.10)THEN
F(I)=EXP(-F(I))
ELSE
F(I)=0
ENDIF
ENDDO

```

```
: RETURN
END
```

```
SUBROUTINE SMEAR
```

```
C*****
C Smooths the "fine" array by the selected instrument
C function, and puts it into the plot array
C*****
```

```
REAL HWHMS(4)
COMMON /PARRA/P(20000),IPTYPE,
1 /PVECT/P1,P2,PD,NP,NINST,IPLTCNT
COMMON /FARRA/F(1000000), /FVECT/F1,F2,FD,NF
COMMON /RANGE/WL1I,WL2I,DWLI,WNEXT1,WNEXT2,WNR1,WNR2,WLEXT1
1, WLEXT2,WLLINE,IZSKIP
```

```
C
C HWHMS are the number of half
C widths at half powers from the center of a
C particular weighting function which need computing. The
C functions are indexed
C 1=Triangle, 2=Gaussian, 3=Sinc, 4=Box. The Sinc function
C is the broadest.
```

```
C
DATA HWHMS/2.1,3.,8.1,1.1/
```

```
C
C We determine the range of indices in
C the fine array over which to apply
C the smoothing function. Variables are defined:
```

```
C
C DWLI          the instrumental resolution
C FWHM          " " "
C              (full width at half maximum)
C HWHM          half width at half maximum
C DLAM1         the spacing of the F array IN WVLGTH (micr)
C              at the low wl end
C N             the number of indices in the F
C              array needed to contain half
C              of the extent of the selected weighting function
C I             indexes the element of the P array being computed
C PL           the wavelength of this element (microns)
C ICENTF        the index of
C              the nearest F array element corresponding to PL
C IF1 to IF2    the index range to smooth the F array to get P(I)
C IFS           the index of an F array value
C WL           the wavelength of this F array element
C DWL           how far in wavelength this
C              element is from the P(I)'s wl
C PINT          the integrated weighted P array value
```

```
C
IF (DWLI.EQ.0) RETURN
FWHM=DWLI
HWHM=0.5*DWLI
DLAM1=DLORDN(FD,F1)
```

```

N=HWHMS (NINST) *HWHM/DLAM1+.5
  IF (N.LT.2) THEN
PRINT*, ' Only one fine array point for each plotted point!'
  ENDIF

```

C

```

PRINT*, ' Smoothing the Fine array.....'
ITASK=2*N*NP/1000
ITCNT=0
  DO I=1, NP
    PL=P1+(I-1)*PD
    ICENTF=(F1-WLORWN(PL))/FD+1.5
    IF1=ICENTF-N
    IF2=ICENTF+N
    IF(IF1.LT.1) IF1=1
    IF(IF2.GT.NF) IF2=NF
    IF(IF2.GT.NF.OR.IF1.LT.1) THEN
      PRINT*, ' CAN'T SMOOTH TO OBTAIN PLOT INDEX ', I,
        ' AT WAVELENGTH ', PL
1      STOP
    ENDIF
    PINT=0
    WT=0
    DO IFS=IF1, IF2
      ITCNT=ITCNT+1
      IF (ITASK.GT.50..AND.MOD(ITCNT, 50000).EQ.0) THEN
        ITA=ITCNT/1000
        WRITE(*, 3535) ITA, ITASK
3535      FORMAT(1X, I7, ' K out of ', I7, ' K smoothing',
1        ' operations done.')
      ENDIF
      WL=WLORWN(F1-(IFS-1)*FD)
      DWL=PL-WL
      WTI=DINST(DWL, FWHM, NINST)
      WT=WT+WTI
      PINT=PINT+WTI*F(IFS)
    ENDDO
    IF (WT.NE.0) THEN
      P(I)=PINT/WT
    ELSE
      P(I)=0
    ENDIF
900    CONTINUE
  ENDDO

```

C

C Compute the total transmission through the band for both arrays

C

```

SUMP=0
  DO IP=1, NP
    SUMP=SUMP+P(IP)
  ENDDO
SUMP=SUMP/NP
SUMF=0
  DO IF=1, NF

```

```

                SUMF=SUMF+F(IF)
                ENDDO
SUMF=SUMF/NF
PRINT*, 'F TRANS, P TRANS: ',SUMF,SUMP
RETURN
END

```

```

SUBROUTINE SINCO(FWHM)

```

```

C*****
C This determines
C a constant C so that we may smooth the data with a SINC
C function possessing the correct full width at half maximum (FWHM)
C I.E.,  $\text{SIN}(C * \text{HWHM}) / (C * \text{HWHM}) = 0.5$ , where  $\text{HWHM} = 0.5 \text{ FWHM}$ .
C To find C we use the method of Successive Approximations.
C*****

```

```

COMMON /SINCC/C

```

```

HWHM=0.5*FWHM
C=HWHM

```

```

DO I=1,200
C=2./HWHM * SIN (C*HWHM)
ENDDO

```

```

HALF=SIN(C*HWHM)/(C*HWHM)
IF(ABS(0.5-HALF).GT..01)THEN
PRINT*, ' SINC INITIALIZATION FAILED, HALF= ',HALF
STOP

```

```

ENDIF
RETURN
END

```

```

FUNCTION DINST(DELWL,FWHM,NINST)

```

```

C*****
C Evaluates one of four (NINST=1 to 4) instrumental functions at
C a wavelength displacement DELWL from the function center, with the
C instrument function completely defined by NINST and FWHM
C If a SINC function is used (NINST=3) then SINCO must be call prior
C to using this function.

```

```

C NINST=1 Triangle, 2 Gaussian, 3 Sinc, 4 Rectangle

```

```

C*****
COMMON /SINCC/C
GO TO (10,20,30,40)NINST
PRINT*, ' INSTRUMENT FUNCTION UNDEFINED', NINST
STOP

```

```

C
C TRIANGLE (NINST=1)
C
10    DINST=-ABS(DELWL)/FWHM+1
      IF(DINST.LT.0)DINST=0
      RETURN

```

```

C

```



```
C GAUSSIAN (NINST=2)
```

```
C  
20     EXPON=0.693*(DELWL*2/FWHM)**2  
       IF(EXPON.LT.10) THEN  
         DINST=EXP(-EXPON)  
       ELSE  
         DINST=0  
       ENDIF  
       RETURN
```

```
C  
C SINC (NINST=3)
```

```
C  
30     IF(DELWL.NE.0) THEN  
       DINST=SIN(C*DELWL)/(C*DELWL)  
     ELSE  
       DINST=1  
     ENDIF  
     RETURN
```

```
C  
C RECTANGLE (NINST=4)
```

```
C  
40     IF(ABS(DELWL).LT.FWHM/2.) THEN  
       DINST=1  
     ELSE  
       DINST=0  
     ENDIF  
     RETURN  
     END
```

```
      SUBROUTINE PLOT
```

```
C  
C*****  
C Sends P array to Mongo  
C*****  
C
```

```
      CHARACTER*35 UNIT(2),AUNIT,PNAME(9)*11,TEN(3)*10  
      INTEGER MTERM(4),MPLOC(4,4),IDOTS(3,7)  
      REAL DOTLOC(3)  
      COMMON /TERM/ITERM  
      COMMON /PARRA/P(20000),IPTYPE  
      COMMON /PVECT/P1,P2,PD,NP,NINST,IPLTCNT  
      COMMON /FARRA/F(1000000)  
      COMMON /FVECT/F1,F2,FD,NF  
      COMMON /RANGE/WL1I,WL2I,DWLI,WNEXT1,WNEXT2,WNR1,WNR2,WLEXT1  
1     , WLEXT2,WLLINE,IZSKIP  
      COMMON /STRONG/SLINES(80),ISPEC(80),SEW(80),ISTRONG  
1     , IPOINT,STRENGTH  
      LOGICAL EX  
      DATA MTERM/3,11,7,14/,MPLOC/100,750,100,700, 40,375,60,350,  
1     48,453,78,379, 40,375,40,350/  
      DATA PNAME/'parray.dat1',  
1     'parray.dat2','parray.dat3','parray.dat4',  
1     'parray.dat5','parray.dat6','parray.dat7','parray.dat8',
```

```

2 'parray.dat9' /
DATA UNIT/'\\rWavelength ( \\gmm )',
1 '\\rWavenumber ( cm\\u-\\u1 )' /
DATA DOTLOC/-.08,-.06,-.04/
DATA IDOTS/0,0,1, 0,1,0, 0,1,1, 1,0,0, 1,0,1, 1,1,0, 1,1,1/
IPLTCNT=IPLTCNT+1
IF(IPLTCNT.EQ.1) THEN
    DO II=1,9
        INQUIRE (FILE=PNAME (II) , EXIST=EX)
        IF (EX.EQ..TRUE.) THEN
            OPEN (11, FILE=PNAME (II) , STATUS='OLD' )
            CLOSE (11, STATUS='DELETE' )
        ENDIF
    ENDDO
ENDIF
OPEN (10, FILE=PNAME (IPLTCNT) , STATUS='NEW' )
IF (DWLI.EQ.0) THEN
    DO JJ=1,NF, IZSKIP
        WL=F1- (JJ-1) *FD
            IF (IPTYPE.EQ.1) WL=10000./WL
        WRITE (10, *) II, WL, F (JJ)
    ENDDO
ELSE
    DO II=1, NP
        WL=P1+ (II-1) *PD
            IF (IPTYPE.EQ.2) WL=10000./WL
        WRITE (10, *) II, WL, P (II)
    ENDDO
ENDIF
CLOSE (10)
IF (IPLTCNT.EQ.1) THEN
    INQUIRE (FILE='p.plo' , EXIST=EX)
    IF (EX.EQ..TRUE.) THEN
        OPEN (11, FILE='p.plo' , STATUS='OLD' )
        CLOSE (11, STATUS='DELETE' )
    ENDIF
    OPEN (20, FILE='p.plo' , STATUS='NEW' )
    AUNIT=UNIT (IPTYPE)
    YUP=1.2
    IF (IPTYPE.EQ.2) THEN
        P1=10000/WL2I
        P2=10000/WL1I
        P11=P1-.1* (P2-P1)
        P22=P2+.1* (P2-P1)
        STARTWL=WL2I
        WRITE (TEN (1) , 1011) STARTWL
        FORMAT (F10.4)
        STOPWL=WL1I
        WRITE (TEN (3) , 1011) STOPWL
        CENTERWN=.5* (P11+P22)
        CENTERWL=10000/CENTERWN
        WRITE (TEN (2) , 1011) CENTERWL
        WRITE (20, 131) MTERM (ITERM) , (MPLOC (I, ITERM) , I=1, 4) ,

```

1011

```

1          P11, P22, CENTERWN, P11, P22,
1          P1, P1, CENTERWN, CENTERWN, P2, P2,
1          P1, TEN(1), CENTERWN, TEN(2), P2, TEN(3)
131       FORMAT(          'TERM ', I2          ,/,
1          'ERA'          ,/,
1          'EXP 1.'      ,/,
1          'LOC ', 4(I4, 1X) ,/,
2          'LIM ', F13.7, 1X, F13.7, ' -.1 1.1' ,/,
1          'RELOC ', F13.7, ' 1.2' ,/,
9          'PUTL 8 \\\rWavelength ( \gmm )' ,/,
8          'RELOC ', F13.7, ' 1.1' ,/,
C Top y line
8          'DRAW ', F13.7, ' 1.1' ,/,
8          'RELOC ', F13.7, ' 1.1' ,/,
C left top tick
8          'DRAW ', F13.7, ' 1.05' ,/,
8          'RELOC ', F13.7, ' 1.1' ,/,
C middle top tick
8          'DRAW ', F13.7, ' 1.05' ,/,
8          'RELOC ', F13.7, ' 1.1' ,/,
C right top tick
8          'DRAW ', F13.7, ' 1.05' ,/,
8          'RELOC ', F13.7, ' 1.15' ,/,
C Left top Number
8          'PUTL 6 \\\r', A10 ,/,
8          'RELOC ', F13.7, ' 1.15' ,/,
C Middle top Number
8          'PUTL 5 \\\r', A10 ,/,
8          'RELOC ', F13.7, ' 1.15' ,/,
C Right top Number
8          'PUTL 4 \\\r', A10          )
          ELSE
          P11=P1-.1*(P2-P1)
          P22=P2+.1*(P2-P1)
          XMID=0.5*(P22+P11)
          VMID=2.9979E5*(XMID-WLLINE)/WLLINE
          V1=2.9979E5*(P11-WLLINE)/WLLINE
          V2=2.9979E5*(P22-WLLINE)/WLLINE
          WRITE(20, 132) MTERM(ITERM), (MPLOC(I, ITERM), I=1, 4),
          V1, V2, VMID, YUP
132       FORMAT(          'TERM ', I2          ,/,
1          'ERA'          ,/,
1          'EXP 1.'      ,/,
1          'LOC ', 4(I4, 1X) ,/,
2          'LIM ', 2(F15.5, 1X), ' -.1 1.1' ,/,
8          'RELOC ', F15.5, 1X, F4.2 ,/,
9          'PUTL 8 \\\rVelocity (km s\\u-\u1 )' ,/,
2          'BOX -1 -1 +1 -1' )
          ENDIF
          WRITE(20, 133) P11, P22, AUNIT
133       FORMAT(
4          'LIM ', 2(F13.7, 1X), ' -.1 1.1' ,/,
5          'BOX 1 2 -1 0' ,/,

```

```

6      'YLAB \\\rTransmittance'
7      'XLAB ',A35
8      'DATA parray.dat1'
9      'YCOL 3'
1     'XCOL 2'
2     'CONN')
C
C mark strong lines
C
      IF(IPOINT.GE.1)WRITE(20,155)
155    FORMAT('EXP 0.3',/, 'PTY 10 3 ')
      DO I=1,IPOINT
      IF(IPTYPE.EQ.1)SLINES(I)=10000./SLINES(I)
      WRITE(20,156)SLINES(I),SLINES(I)
156    FORMAT('RELOC ',F13.7,' -0.02', 'DRAW ',F13.7,' -.1')
      DO J=1,3
      IF (IDOTS(J,ISPEC(I)).EQ.1)THEN
      WRITE(20,157)SLINES(I),DOTLOC(J)
157    FORMAT('RELOC ',F13.7,' ',F6.3,/, 'DOT')
      ENDIF
      ENDDO
      ENDDO
      CALL KEY(P11,P22)
      ELSE
C      PRINT*,
C      1' IPTYPE, IPLTCNT, P11, P22 ',IPTYPE,PNAME(IPLTCNT),P11,P22
      WRITE(20,134)(MPLOC(I,ITERM),I=1,4),P11,P22,PNAME(IPLTCNT)
134    FORMAT(
1      'LOC ',4(I4,1X)
2      'LIM ',2(F13.7,1X), ' -.1 1.1'
8      'DATA ',A11
9      'YCOL 3'
1     'XCOL 2'
2     'CONN')
      ENDIF
      RETURN
C
      END
      SUBROUTINE KEY(P11,P22)
C*****
C Writes a key on the right side of the plot
C*****
      INTEGER MTERM(4),MKLOC(4,4),MPLOC(4,4),IDOTS(3,7)
      REAL POSY(20),DOTLOC(3),KEYLOC(7)
      CHARACTER COMMT*20, LAB(17)*20, TYPES(4)*15, TYPEI*15,
1     FNS(5)*10, FNI*15, DATER*24, LINENAM(7)*5, DATERI(24)*1, DATERF*30
      COMMON /PART/PARTS(2:7),CDOZ, IDISTO3
      COMMON /TERM/ITERM
      COMMON /STRONG/SLINES(80), ISPEC(80), SEW(80), ISTRONG
1     , IPOINT, STRENGTH
      COMMON /ATMJNK/AWV, AZ, AWVL, IATYPE, IALAY, IALT, TORR
      COMMON /PVECT/ P1, P2, PD, NP, NINST, IPLTCNT
      COMMON /RANGE/WL1I, WL2I, DWLI, WNEXT1, WNEXT2, WNR1, WNR2, WLEXT1

```

```

1 , WLEXT2,WLLINE,IZSKIP
DATA MTERM/3,11,7,14/,MPLOC/100,750,100,700, 40,375,60,350,
1 48,453,78,379, 40,375,40,350/
DATA DOTLOC/11.7,12,12.3/,UP/12.5/,DOWN/11.5/,YLET/10.9/
DATA IDOTS/0,0,1, 0,1,0, 0,1,1, 1,0,0, 1,0,1, 1,1,0, 1,1,1/
DATA LINENAM
1 /'H\\d20','CO\\d2','O\\d3','N\\d20','CO','CH\\d4',' O\\d2'/
DATA KEYLOC/.1,.4,.7,1.0,1.3,1.6,1.9/
DATA MKLOC/760,1000,100,760, 380,600,50,375,
1 459,604,99,452, 380,500,10,375/

DATA TYPES/'Standard','Tank','Special','Std.&H\\d20 Adj.'/
DATA FNS/'Triangle','Gaussian','Sinc','Rectangle','None'/
DATA POSY/20,18,17,16,15,14,13,10,9,8,7,6,5,4,3,5*0/
DATA LAB/' ','Zenith WV','Zenith Ang','L.O.S. WV',
1 'Atm. Type','Layers','Altitude','Lambda 1','Lambda 2',
2 'Sampling','Res(FWHM) ','Instr. Fn.','Line Ctr','Num. Pts.',
3 'Ozone','Time','P(mm Hg)'/
PRINT 11
11 FORMAT(' Comment for plot (A20)',
1 ' (you may use mongo '\\u', etc.) (Test): ')
READ 12,COMMT
12 FORMAT(A20)
PRINT 121,COMMT
121 FORMAT('{',A20,}')
CALL FDATE(DATER)
WRITE(DATERF,1212)DATER
1212 FORMAT(A24)
READ(DATERF,1213)DATERI
1213 FORMAT(24A1)
C IF((DATERI(5).eq.'A'.or.DATERI(5).eq.'M').and.
C 1 (DATERI(6).eq.'p'.or.DATERI(6).eq.'a').and.
C 2 (DATERI(7).eq.'r'.or.DATERI(7).eq.'y').and.
C 3 DATERI(24).eq.'2')then
C PRINT*,' '
C ELSE
C PRINT*,' Sorry, software has expired.'
C STOP
C ENDIF

CALL TIME(TIMER)
TYPEI=TYPES(IATYPE+1)
FNI=FNS(NINST)

WRITE (20,20) (MKLOC(I,ITERM),I=1,4)

20 FORMAT( 'LOC ',4(I4,1X) ,/,
1 'LIMIT 0 2 0 22' ,/,
2 'EXP .8' )
DO I=1,15
30 WRITE(20,30) POSY(I),LAB(I)
FORMAT('RELOC 0 ',F4.1,/, 'PUTL 6 \\\\r',A15)
ENDDO

```

```

        WRITE(20,40)
    1   POSY(1),COMMT,    POSY(2),AWV,  POSY(3),AZ,          POSY(4),AWVL,
    2   POSY(5),TYPEI,   POSY(6),IALAY, POSY(7),IALT,       POSY(8),P1,
    3   POSY(9),P2,      POSY(10),PD,   POSY(11),DWLI,     POSY(12),FNI,
    4   POSY(13),WLLINE, POSY(14),NP, POSY(15),CDOZ

```

```

40   FORMAT(
C   COMMT
    1   'RELOC 0 ',F4.1,/, 'PUTL 6 \\\r',A20  ,/,
C   AWV
    2   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',F8.1  ,/,
C   AZ
    3   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',F5.1  ,/,
C   AWVL
    4   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',F8.1  ,/,
C   TYPEI
    5   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',A15   ,/,
C   IALAY
    6   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',I3    ,/,
C   IALT
    7   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',I5    ,/,
C   P1
    8   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',F9.3  ,/,
C   P2
    9   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',F9.3  ,/,
C   PD
    9   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',F9.6  ,/,
C   NP
    1   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',F9.6  ,/,
C   FNI
    2   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',A9    ,/,
C   WLLINE
    3   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',F9.3  ,/,
C   NP
    4   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',I7    ,/,
C   OZONE
    5   'RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',1PE8.2)

```

```

C TIME and date

```

```

        WRITE(20,898)DATER

```

```

898   FORMAT('RELOC -1 -3',/, 'PUTL 6 \\\r ',A24)

```

```

C
C Write Line Key, after determining if line was seen.
C

```

```

        IF(IATYPE.NE.1.AND.IPOINT.GT.0)THEN
            WRITE(20,*)'PTYPE 10 3'
            ILI=0
            DO 2000 I=1,7
                DO J=1,IPOINT
                    IF(ISPEC(J).EQ.I)GO TO 1000
                ENDDO

```

```

GO TO 2000
1000  ILI=ILI+1
      WRITE(20,100) KEYLOC(ILI),UP,KEYLOC(ILI),DOWN
100   FORMAT('RELOC ',F7.3,' ',F7.3,/, 'DRAW ',F7.3,' ',F7.3)
      WRITE(20,*) 'EXP .3'
      DO K=1,3
        IF(IDOTS(K,I).EQ.1) THEN
200   WRITE(20,200) KEYLOC(ILI),DOTLOC(K)
        FORMAT('RELOC ',F7.3,' ',F7.3,/, 'DOT')
        ENDIF
      ENDDO
      WRITE(20,300) KEYLOC(ILI),YLET,LINENAM(I)
300   FORMAT('EXP .8',/, 'RELOC ',F7.3,' ',F7.3,/, 'PUTL 5 \\\r',A5)
2000  CONTINUE
      ELSEIF(IATYPE.EQ.1) THEN
        WRITE(20,50) POSY(17),LAB(17)
50    FORMAT('RELOC 0 ',F4.1,/, 'PUTL 6 \\\r',A15)
        WRITE(20,60) POSY(17),TORR
C PRESSURE
60    FORMAT('RELOC 1 ',F4.1,/, 'PUTL 6 \\\r',F7.3 )
      ENDIF
      WRITE(20,134) (MPLOC(I,ITERM),I=1,4),P11,P22
134   FORMAT(
1     'LOC ',4(I4,1X),/,
2     'LIM ',2(F13.7,1X), ' -.1 1.1')
      RETURN
      END

```

## APPENDIX B

### INSTALLING THE PROGRAMS

Instructions for installing the ATRAN software on UNIX and VMS machines are given. Additionally, three supporting programs are listed. WR.F reads the ASCII HITRAN data base. SKIP.A.F determines the number of absorption lines per wave number. GTOLA.F converts MONGO screen display code to hardcopy printing code.



## APPENDIX B      INSTALLING THE      PROGRAMS

Note, this software is already installed on some of the NASA/Ames SS Division computers. If you are using GAL, see STARCAT\$DISK:[catalog]HELP ATMOSPHERE for instructions. If you are using CYGNUS, use /work/doc/atran.doc. The software is also already installed on PAN and CMA.

Installing this software on other UNIX and VMS systems is quite straight forward. It involves 3 steps:

First the user must acquire 6 files: afgl.dat, wr.f, skipa.dat, model.dat, atran.f and laseatran.f. The three programs with the .f extension are UNIX versions. For a VMS system, instead acquire WR.FOR, ATRAN.FOR and LASEATRAN.FOR. Contact the author to acquire these files.

Of these files, only AFGL.DAT is very large. Below is a directory listing. (AFGL.BIN is discussed below.)

| BYTES    | DATE         | FILE        | Listed |
|----------|--------------|-------------|--------|
| 12569616 | Aug 5 23:01  | afgl.bin    |        |
| 23044296 | Aug 5 21:59  | afgl.dat    |        |
| 29744    | Aug 5 21:55  | model.dat   | App. D |
| 575000   | Aug 5 21:55  | skipa.dat   |        |
| 152660   | Aug 5 22:44  | wr          |        |
| 1035     | Dec 16 14:58 | wr.f        |        |
| 64127    | Dec 16 14:58 | atran.f     | App. A |
| 2556     | Dec 16 14:59 | laseatran.f |        |

The second step is to make the database, afgl.bin. To do this, edit the file wr.f. The directory areas in the two OPEN statements must be modified to reflect where afgl.dat is, and where you would like afgl.bin to reside. Select the appropriate directories in wr.f, compile and run it. This routine will generate afgl.bin in a few minutes. (afgl.dat is not used by the software after afgl.bin has been created. The .bin file is about half the size of the .dat file.)

The last step is different for VMS systems and UNIX systems.

For VMS systems:

Before program atran.for may be compiled, one change must be made. Locate the OPEN statement, which opens the AFGL.DAT file (this is the HITRAN database). Modify the directory to correspond to where AFGL.BIN resides on your system. ATRAN.FOR may then be compiled and linked. The other directory areas used by the program are defined as logical symbols. Some of these must be defined by each user. The following gives commands that may be entered into the users login.com file:

```

$!
$! Where ATRAN.EXE, MODEL.DAT, and SKIP.A.DAT reside:
$!
$      DEFINE/NOLOG      ATRANDIR      USER$DISK7: [LORD.WV]
$!      (for example)
$!
$! Next is the user's directory.
$! This is where the newly created MONGO
$! plotting control files are put.
$!
$      DEFINE/NOLOG      ATRANUSERDIR      USER$DISK$yours: [yourdir]
$!
$! Next is user's area for the array of up to
$! 20000 ASCII X,Y data points.
$! The program will delete all old versions,
$! so these files normally do not
$! pile-up.
$!
$      DEFINE/NOLOG      ATRANSCRATCHDIR SCRATCH$DISK: [yourdir]
$! (for example)
$!
$! To run ATRAN type "RUN ATRANDIR:Z"
$!
$! ATRAN will make two files: ATRANUSERDIR:P.PLO and
$! ATRANSCRATCH$DISK:PARRAY.DAT
$! P.PLO in turn, will use PARRAY.DAT to make a plot.
$!

```

For UNIX Systems:

Check all occurrences within OPEN statements within atran.f for the files afgl.bin, model.dat, and skipa.dat. Edit these to refer to the particular directory where you wish these files to reside. Then compile atran.f. Users may run the program with their pwd (present working directory) set arbitrarily. The data files parray.dat\* and the plot file p.plo will be written into that directory. (All previous versions of p.plo and parray.dat\* will first be removed by the program.

This completes the installation notes for UNIX and VMS systems.

Another useful program is laseatran.f (or laseatran.for). It will quickly edit a p.plo file to change the MONGO LOCATION commands and MONGO TERM commands to values appropriate for make a hard copy of the plot.

Finally, if the user ever wishes to go to the source, to the unabridged HITRAN database, we show how this is done at the SS Division at NASA/Ames. HITRAN resides on a tape which may be read off the CRAY-YMP computer. The following procedure is used to select a subset of that tape, and output it in ASCII, to provide a database, as we have done. The database we selected is all occurrences of the 7 species indicated in Table~1. The user is

able to select a customized database with the following procedure. One must have a CRAY account to accomplish this.

```
#
# Procedure to read out a portion of the HITRAN database. Written
# By R. Freedman, 1991.
# The procedure accesses accounts on the computer
# columbia, for which passwords are required.
#
# This procedure assumes that you have already created a
# temporary [scratch]
# directory $TMP on your CRAY account. Such a directory holds database
# changes temporarily.
#
cd $TMP
#
# The following version makes line files for FASCODE2.
# It uses the new partition
# functions, the IDs for line lists, and a new binary format.
#
# To transfer the output of the procedure to another computer,
# use ftp.
#
# We assume that user has a .netrc file active on their account.
#
ftp columbia << END
cd /csf/ss/sst/freedman/hitran_91
get ../exe/select_newf2 select.e
get ../binary/hitran_91_new_format h91
#
# We are getting a table of block-line IDs.
#
quit
END
cp /u2/sst/freedman/hitran_91/notes/header_102 102
#
# Finally, the user must run "select.e"
# and answer questions that appear on the screen.
# These questions will pertain to the subset of the HITRAN lines to be
# written into the output file.
#
# REMEMBER that the file name for the database is h91
# - use this name when
# answering the questions.
#
```

PROGRAM WR

```

C
C This program will read the afgl.dat file and produce the
C afgl.bin file.
C commented lines may be uncommented to check for IEEE violations
C
c      integer oldstatus,fpstatus
      REAL*8 E
      OPEN(1,FILE='afgl.bin',STATUS='NEW',
1      FORM='UNFORMATTED',IOSTAT=IERRS)
      IF(IERRS.NE.0)GOTO10
      OPEN(2,FILE='afgl.dat',STATUS='OLD')
      I=1
1      READ(2,22,END=20,ERR=11),I,WNO,S0,GAMMA0,E,ISP,XN
22     FORMAT
      1(1X,I7,F13.5,2X,1PE12.6,2X,0PF5.3,2X,0PF10.4,2X,I2,2X,0PF5.3)
      WRITE(1)WNO,S0,GAMMA0,E,ISP,XN
c      oldstatus = fpstatus(0)
c      IF(and(oldstatus,8).ne.0)THEN
c      print*, ' inexact occured'
c      PRINT*,I,WNO,S0,GAMMA0,E,ISP,XN
c      endif
c      IF(and(oldstatus,32).ne.0)then
c      print*, 'underflow occured'
c      PRINT*,I,WNO,S0,GAMMA0,E,ISP,XN
c      endif
c      I=I+1
      IF((I/1000)*1000.EQ.I)THEN
          J=I/1000
          PRINT*,J,' K out of 349 K'
C
C Actually, total number of lines from .8 to 100000 microns is 349156
C
      ENDIF
      IF(1.EQ.1)GO TO 1
10     PRINT*, ' OPEN ERROR'
      STOP
11     PRINT*, ' READ ERROR'
      STOP
20     PRINT*, ' Normal end... afgl.bin written'
      end

```

PROGRAM SKIPA

C  
 C This program reads the hitran database (afgl.bin) file, and  
 C counts how many lines there are per wavenumber. It Outputs this  
 C information in a file called LISTA.DAT  
 C  
 C The current version assumes that the span of wavenumbers in aagl.bin  
 C runs from 1 to 125000  
 C

```

      INTEGER A(12500),B(12500)
      DATA A/12500*0/,B/12500*0/
      REAL*8 E
      OPEN(1,FILE='AFGL.BIN',STATUS='OLD',
      1 RECORDTYPE='FIXED',RECL=7,FORM='UNFORMATTED',
      2 IOSTAT=IERRS)
      OPEN(2,FILE='SKIPA.DAT',STATUS='NEW')
      I=0
1     READ(1,ERR=10,END=20)WN0,S0,GAMMA0,E,ISP,XN
      J=WN0
      A(J)=A(J)+1
      I=I+1
      IF((I/1000)*1000.EQ.I)PRINT*,I
      IF(1.EQ.1)GO TO 1
10    PRINT*,' ERROR'
20    PRINT*,' ENDING, LINE ',I
      B(1)=0
      DO I=2,12500
      B(I)=A(I-1)+B(I-1)
      ENDDO
      DO I=1,12500
      WL=10000./I
      WRITE(2,23)A(I),B(I),I,I+1,WL
23    FORMAT(2X,I7,2X,I7,4X,I5,'-',I5,2X,F10.4)
      ENDDO
      END
  
```

PROGRAM GOTOLA

```

C
c The purpose of this program is to quickly translate Mongo
c plot files intended for a graphics terminal to a Mongo plot
c file for the laser printer (device imp). THUS: GO to LA(ser).
C
C We do only 5 things to the file :
C
c 1) DEL all occurances of "TER" commands
c 2) DEL all occurances of "ERA" commands (ERASE)
c 3) Start the new .IMP file with "psland
c 4) End the new .IMP file with "hard"
c 5) Change 1st "LOC ..." to "LOC 80 570 100 500"
c 6) Change 2nd "loc ..." to "loc 585 750 100 560"
c - S. Lord 1-May-1988.
C
      LOGICAL EX
      CHARACTER*3 TROI
      CHARACTER*77 REST
C
C Delete any old p.imp files
C
      INQUIRE(FILE='p.imp',EXIST=EX)
      IF(EX.EQ..TRUE.)THEN
      OPEN(11,FILE='p.imp',STATUS='OLD')
      CLOSE(11,STATUS='DELETE')
      ENDIF
      LOCFLG=0
C
10      CONTINUE
      OPEN(1,FILE='p.plo',STATUS='OLD')
      OPEN(2,FILE='p.imp',STATUS='NEW')
      WRITE(2,111)
111     FORMAT(' psland')
      DO 1100 I=1,3000
      READ(1,33,END=44)TROI,REST
33      FORMAT(A3,A77)
      IF(TROI.EQ.'TER'.OR.TROI.EQ.'ERA'.OR.
1      TROI.EQ.'ter'.OR.TROI.EQ.'era')GO TO 1100
      IF (TROI.EQ.'LOC'.OR.TROI.EQ.'loc')THEN
      IF(LOCFLG.NE.1)THEN
      REST=' 80 570 100 500'
      ELSE
      REST=' 585 750 100 560'
      ENDIF
      LOCFLG=LOCFLG+1
      ENDIF
      WRITE(2,33)TROI,REST
1100    CONTINUE
      PRINT*,' A length problem??'
      STOP
44     WRITE(2,45)

```

```
45     FORMAT('hard',/, 'end')
      print 46, 'P'
46     FORMAT('... Success! "', A1, '.IMP"      Created')
      STOP
20     PRINT*, ' Try again....'
      GO TO 10
      END
```

## **APPENDIX C**

### **OPERATING INSTRUCTIONS AND SAMPLE RUNS**

Example ATRAN runs on UNIX and VMS systems are shown.



Instructions to run the program atran.f and ATRAN.FOR

UNIX instructions: atran.f

-----

We compile atran.f with:  
f77 -o atran atran.f

To run atran, type " /dir/atran "  
where dir is the directory path to atran.

The program will ask you your terminal type for plotting.  
If you are on a HDS, GraphOn, or other Tektronics Emulating Terminal,  
select Tektronics; menu item 1. If you are on an X terminal,  
select 2.

After running the program, you may wish to see the plot on the  
screen. type:

```
mongo
*term 11 (if your are on an X Terminal,
"term 3" if you are on a Tektronix emulator)
*inp p.plo
(Where mongo has typed the "*" .) Type
*end
to exit MONGO.
```

compile the program laseatran.f:  
f77 -o laseatran laseatran.f  
To get a laser hardcopy, type:

```
laseatran
mongo
* inp p.imp
(Where mongo has typed the "*" .) Type
*end
to exit MONGO.
```

VMS instructions (ATLAN.FOR)

-----

ATLAN has been compiled with  
fortran atran.for  
link atran

then run atran.exe from any area with  
r atrandir:atran  
the program will ask a series of questions, shown in the example  
below.

To get a plot on a graphics screen type:  
MONGO

```
* inp p.plo
* end
```

Also, compile the program LASEATRAN.FOR:  
FOR LASEATRAN  
LIN LASEATRAN

To get a laser hardcopy, type:

```
LASEATRAN
```

```
MONGO
```

```
* INP P.IMP
```

(Where MONGO has typed the "\*" .) Type ^Z to exit MONGO.

The following is a sample run of the program atran on a UNIX machine.  
(A run on a VMS system would proceed identically,  
except that the initial command would be "r atrandir:atran"  
rather than "atran")

Our helpful comments below begin with ">". User input appears after  
queries ending with a colon.

```
-----
cygnus/work/lord>atran
```

```
> user selects program atran
```

```
Welcome to atmospheric modeling program!
```

```
If you don't know what to answer to a question, try
the answer given in parentheses.
```

```
Input Terminal type.
```

```
1 for Tektronics, 2 for X window, 3 for Sunview window
```

```
4 for GraphOn (1): 1
```

```
{ 1}
```

```
> user selects a Tek screen for graphics. Note: GraphOn 230's
> support either Tek or GraphOn graphics type MONGO output
> (term 3 and 11 in 1989 VMS MONGO), HDS terminals support at least
> Tek (term 3) output. So if you have a GraphOn, an HDS, or a
> Tek 4010 etc. emulating terminal, option 1 above may
> be best.
```

```
Plot x-axis units in wavelength (um) [1],
or wavenumbers (cm^-1) [2] (1): 1 { 1}
```

```
> With option 1, a wavelength scale (in micrometers)
> will appear on the bottom of the plot, and a velocity
> scale will appear on the top.
> With option 2, a wave number (10000/wavelength)
> scale will appear at the
> bottom and a wavelength scale will appear at the top.
```

```

Enter:
  0 for a standard atmosphere of mixed gases,
  1 for a single H2O layer (a tank),
  2 for a special atmosphere, or -1 to exit (0): 0
{ 0}

> user selects standard earth atmosphere model,
> the "U.S. Standard Atmosphere" (Ref. 16)

Enter altitude (feet) (41000): 41000
{ 41000.0}

> user selects typical flight altitude of the
> Kuiper Airborne Observatory.

The atmospheric model gives 7.3 Microns of water,
toward the zenith.
Enter preferred value at this altitude in MICRONS,
or 0 for no adjustment of the model (0): 0
{ 0.}

> The program has integrated all the
> water vapor in its model (Ref. 15) above
> the airplane to be 7.3 precipitable microns.
> The user accepts this value.

Number of atmospheric layers (2 recommended) (2): 5
{ 5}

> A 5 layer atmosphere
> (modeling mixing ratio, density, pressure and temperature
> at 5 overhead points), is selected.

Zenith angle through atmosphere (0=UP) (0): 0
{ 0.}

> the user has selected absorption along
> a line of sight directly overhead.

Enter wavelength of spectral line of interest
  (this is used to make the velocity scale), or...,
-1 for species specification,
or else 0 for don't care (0): 0
{ 0.}

> the user does not care
> if the doppler velocity scale for
> the top abscissa
> is centered on a specific rest (v=0) wavelength.
> So, v=0 will be centered at
> the midpoint of the wavelength range, selected next.

```

You may enter the limits of the x-axis in either wavelength or velocity; each unit will be printed. Enter wavelength range of interest; Lambda 1 and Lambda 2 in microns. ('0 0' for velocities instead) (10 10.1): 13.9 14.1  
{ 13.9000 14.1000 }

- > The program will determine the transmission between 13.9 and 14.1 micrometers. This will be the functions range on the x-axis.
- > The plot box boundaries will frame a region slightly (10%) larger.

Enter instrumental resolution in microns (0 for the CGS high resolution system resolution = 60 km/s), or -1 for no smoothing. (0): .001  
{ 1.00000E-03 }

- > the transmission spectrum will be smoothed by an "instrument" point spread function with full width at half power = 0.001 micrometers.

Setting the data point spacing (sampling) to 1/5 instrument resolution... There will be 1000 points plotted. Their spacing will be 0.0002 microns.

Enter a new number of points, or 0 to keep these values, or -1 to change the spacing (0): 0  
{ 0 }

- > the output file and the plot will record data at 1/5 \* 0.001 micrometer spacing, and over the range, this will amount to 1000 points. User accepts this.

Select instrument profile function:  
[1] Triangle, [2] Gaussian, [3] Sinc, [4] Rectangle (2): 2  
{ 2 }

- > the instrument function will be a Gaussian. We note that the FWHM of a rectangle function equals the FWZP of a rectangle - a rectangle function has vertical fall-off which preserves high frequencies present in the unsmoothed transmission spectra. The choice of this function can yield a more rapidly varying spectrum than will the others.

Reading through database to this wavelength regime.....

34125 CONSIDERED, 24 REJECTED  
OF THOSE CONSIDERED.....

500 out of 34173 lines processed.

|       |        |       |                  |
|-------|--------|-------|------------------|
| 1000  | out of | 34173 | lines processed. |
| 1500  | out of | 34173 | lines processed. |
| 2000  | out of | 34173 | lines processed. |
| 2500  | out of | 34173 | lines processed. |
| 3000  | out of | 34173 | lines processed. |
| 3500  | out of | 34173 | lines processed. |
| 4000  | out of | 34173 | lines processed. |
| 4500  | out of | 34173 | lines processed. |
| 5000  | out of | 34173 | lines processed. |
| 5500  | out of | 34173 | lines processed. |
| 6000  | out of | 34173 | lines processed. |
| 6500  | out of | 34173 | lines processed. |
| 7000  | out of | 34173 | lines processed. |
| 7500  | out of | 34173 | lines processed. |
| 8000  | out of | 34173 | lines processed. |
| 8500  | out of | 34173 | lines processed. |
| 9000  | out of | 34173 | lines processed. |
| 9500  | out of | 34173 | lines processed. |
| 10000 | out of | 34173 | lines processed. |
| 10500 | out of | 34173 | lines processed. |
| 11000 | out of | 34173 | lines processed. |
| 11500 | out of | 34173 | lines processed. |
| 12000 | out of | 34173 | lines processed. |
| 12500 | out of | 34173 | lines processed. |
| 13000 | out of | 34173 | lines processed. |
| 13500 | out of | 34173 | lines processed. |
| 14000 | out of | 34173 | lines processed. |
| 14500 | out of | 34173 | lines processed. |
| 15000 | out of | 34173 | lines processed. |
| 15500 | out of | 34173 | lines processed. |
| 16000 | out of | 34173 | lines processed. |
| 16500 | out of | 34173 | lines processed. |
| 17000 | out of | 34173 | lines processed. |
| 17500 | out of | 34173 | lines processed. |
| 18000 | out of | 34173 | lines processed. |
| 18500 | out of | 34173 | lines processed. |
| 19000 | out of | 34173 | lines processed. |
| 19500 | out of | 34173 | lines processed. |
| 20000 | out of | 34173 | lines processed. |
| 20500 | out of | 34173 | lines processed. |
| 21000 | out of | 34173 | lines processed. |
| 21500 | out of | 34173 | lines processed. |
| 22000 | out of | 34173 | lines processed. |
| 22500 | out of | 34173 | lines processed. |
| 23000 | out of | 34173 | lines processed. |
| 23500 | out of | 34173 | lines processed. |
| 24000 | out of | 34173 | lines processed. |
| 24500 | out of | 34173 | lines processed. |
| 25000 | out of | 34173 | lines processed. |
| 25500 | out of | 34173 | lines processed. |
| 26000 | out of | 34173 | lines processed. |
| 26500 | out of | 34173 | lines processed. |
| 27000 | out of | 34173 | lines processed. |

27500 out of 34173 lines processed.  
 28000 out of 34173 lines processed.  
 28500 out of 34173 lines processed.  
 29000 out of 34173 lines processed.  
 29500 out of 34173 lines processed.  
 30000 out of 34173 lines processed.  
 30500 out of 34173 lines processed.  
 31000 out of 34173 lines processed.  
 31500 out of 34173 lines processed.  
 32000 out of 34173 lines processed.  
 32500 out of 34173 lines processed.  
 33000 out of 34173 lines processed.  
 33500 out of 34173 lines processed.  
 34000 out of 34173 lines processed.

- > This takes a few minutes.
- > The seven species are indexed in the table
- > below. The number of line accepted
- > and rejected in each layer (abbreviated
- > LYR is given, along with an explanation
- > as to why the line was accepted or
- > rejected.
- >
- > The lines are broken up into 5 categories...
- > IWEAK The line, even at line center is too weak to consider
- > IDELIN delta fn. in range
- > (fn. has FWHP less than .5 FD; is integrated)
- > IDELOUT delta fn. out of range (rejected)
- > IWIDEOUT broad line, out of range, (rejected)
- > IWIDEIN broad line, in range, (integrated)

OF THOSE CONSIDERED.....

IWEAK 1(H2O) 2(CO2) 3(O3) 4(N2O) 5(CO) 6(CH4) 7(O2)  
 Weak line, reject

---

|        |     |      |      |    |   |   |   |
|--------|-----|------|------|----|---|---|---|
| LYR. 1 | 158 | 3078 | 3782 | 50 | 0 | 0 | 0 |
| LYR. 2 | 155 | 2645 | 2457 | 46 | 0 | 0 | 0 |
| LYR. 3 | 150 | 2124 | 998  | 41 | 0 | 0 | 0 |
| LYR. 4 | 127 | 1142 | 196  | 20 | 0 | 0 | 0 |
| LYR. 5 | 131 | 57   | 0    | 4  | 0 | 0 | 0 |

IDELIN 1(H2O) 2(CO2) 3(O3) 4(N2O) 5(CO) 6(CH4) 7(O2)

Very narrow lines, within range, integrate with triangular approx.

---

|        |   |    |   |   |   |   |   |
|--------|---|----|---|---|---|---|---|
| LYR. 1 | 0 | 0  | 1 | 0 | 0 | 0 | 0 |
| LYR. 2 | 0 | 0  | 4 | 0 | 0 | 0 | 0 |
| LYR. 3 | 0 | 2  | 4 | 0 | 0 | 0 | 0 |
| LYR. 4 | 0 | 2  | 5 | 0 | 0 | 0 | 0 |
| LYR. 5 | 3 | 28 | 0 | 0 | 0 | 0 | 0 |

IDELOUT 1(H2O) 2(CO2) 3(O3) 4(N2O) 5(CO) 6(CH4) 7(O2)

Narrow line out range, reject

---

|        |   |    |   |   |   |   |   |
|--------|---|----|---|---|---|---|---|
| LYR. 1 | 0 | 0  | 1 | 0 | 0 | 0 | 0 |
| LYR. 2 | 0 | 0  | 4 | 0 | 0 | 0 | 0 |
| LYR. 3 | 0 | 2  | 4 | 0 | 0 | 0 | 0 |
| LYR. 4 | 0 | 2  | 5 | 0 | 0 | 0 | 0 |
| LYR. 5 | 3 | 28 | 0 | 0 | 0 | 0 | 0 |

IWIDEOUT 1(H2O)2(CO2)3(O3) 4(N2O) 5(CO) 6(CH4)7(O2)  
 Broad line out range, reject

|        |     |       |       |     |   |   |   |
|--------|-----|-------|-------|-----|---|---|---|
| LYR. 1 | 171 | 9571  | 14981 | 152 | 0 | 0 | 0 |
| LYR. 2 | 173 | 9991  | 16224 | 156 | 0 | 0 | 0 |
| LYR. 3 | 178 | 10506 | 17545 | 162 | 0 | 0 | 0 |
| LYR. 4 | 199 | 11502 | 18286 | 183 | 0 | 0 | 0 |
| LYR. 5 | 194 | 12574 | 18484 | 199 | 0 | 0 | 0 |

IWIDEIN 1(H2O)2(CO2)3(O3) 4(N2O) 5(CO) 6(CH4)7(O2)  
 Broad line in range, accept

|        |    |     |      |    |   |   |   |
|--------|----|-----|------|----|---|---|---|
| LYR. 1 | 9  | 842 | 1315 | 15 | 0 | 0 | 0 |
| LYR. 2 | 10 | 855 | 1394 | 15 | 0 | 0 | 0 |
| LYR. 3 | 10 | 859 | 1532 | 14 | 0 | 0 | 0 |
| LYR. 4 | 12 | 845 | 1592 | 14 | 0 | 0 | 0 |
| LYR. 5 | 10 | 832 | 1595 | 14 | 0 | 0 | 0 |

Converting opacity to transmittance...

Smoothing the Fine array.....

50 K out of 458 K smoothing operations done.  
 100 K out of 458 K smoothing operations done.  
 150 K out of 458 K smoothing operations done.  
 200 K out of 458 K smoothing operations done.  
 250 K out of 458 K smoothing operations done.  
 300 K out of 458 K smoothing operations done.  
 350 K out of 458 K smoothing operations done.  
 400 K out of 458 K smoothing operations done.  
 450 K out of 458 K smoothing operations done.

F TRANS, P TRANS: 0.689112 0.691854

Comment for plot (A20) (you may use mongo '\u', etc.) (Test):

```
demo
{demo }
```

> The transmission of the atmosphere  
 > is first calculated at very high  
 > resolution, typically at 0.001  
 > delta-wavenumber resolution. (recall that  
 > delta-wavelength=delta-wavenumber  
 > x wavelength^2/10000, with units of  
 > microns and cm^-1.) The number of  
 > operations (mults and adds) necessary for  
 > smoothing equals the number of resolution  
 > elements (each .001 cm-1)  
 > across the smoothing function times  
 > the number of points in the final plot  
 > (1000 here). There are about 450 resolution  
 > elements across a .001 micrometer

```

> FWHM Gaussian instrumental function
> here, so about 1/2 million multiplies
> must be done. Decreasing the number
> of points to plot, or the resolution,
> each decreases the number of smoothing
> operations linearly.

```

```
F TRANS, P TRANS:    0.6967122      0.7027934
```

```

> these quantities are the average atmospheric transition
> before and after smoothing

```

```
Comment for plot (A20) (you may use mongo '\u', etc.) (Test): demo
```

```
> There is a comment line in the plot. The comment here is "demo"
```

```

Another function on this plot (Y or N) (N): n
p.plo, a MONGO control file has been made.
parray.dat1, the output data has been written.

```

```

> the x,y data pairs (wavelength, transmission)
> have been written to a
> parray.dat1. A mongo style plotting file has been written to
> the users area, and is called p.plo

```

```

mongo          ! (This is LICKMONGO)
* input p.plo

```

```
> this will produce a plot on the screen shown in figure C1
```

```
> to get a hard copy, follow this example...
```

```

cygnus/work/lord> laseatran
... Success! "P.IMP"      Created
cygnus/work/lord> mongo
* inp p.imp
using paper size letter
-17 vectors plotted.
* end

```

```

For users wishing to automate the running of this program,
we list below the input.

```

```

*****
*****          Input Alone          *****
*****

```

```

1          ! Tektronics terminal
1          ! wavelength is on the x-axis
0          ! a standard atmosphere
41000     ! altitude in feet
0          ! use model overhead water vapor
1          ! number of layers

```



```

0          ! zenith angle
0          ! wavelength of velocity=0
13.9 14.1  ! the range of the x-axis
.001      ! resolution in microns
0          ! use default plot spacing
2          ! select Gaussian function
demo\\e    ! plot label, \\e is end of string
no         ! no more plots on this axis
-----

```

Next we list a run that uses some of the other features of the program...

```
cygnus/work/lord> atran
```

Welcome to EXPERIMENTAL atmospheric modeling program!

If you don't know what to answer to a question, try the answer given in parentheses.

Input Terminal type.

1 for Tektronics, 2 for X window, 3 for Sunview window

4 for GraphOn (1): 1

```
{ 1 }
```

Plot x-axis units in wavelength (um) [1],

or wavenumbers (cm<sup>-1</sup>) [2] (1): 2

```
{ 2 }
```

> user selects wavenumbers for bottom x-axis,  
top x-axis will be wavelength

Enter:

0 for a standard atmosphere of mixed gases,

1 for a single H2O layer (a tank),

2 for a special atmosphere, or -1 to exit (0): 2

```
{ 2 }
```

> by answering with option 2 here, the user may adjust the quantity of  
> gases (other than H2O) in the atmosphere

| Molecule: | CO2  | O3 (tot/cm2) | N2O  | CO    | CH4 | O2      |
|-----------|------|--------------|------|-------|-----|---------|
| Index:    | 2    | 3            | 4    | 5     | 6   | 7       |
| PPM:      | 330. | 9.13E+18     | 0.28 | 0.075 | 1.6 | 2.1E+05 |

Enter 0 to continue or the gas index number to  
change the ppm of that gas: 3

```
{ 3. }
```

> user will modify ozone content

Ozone layer has total column density of 9.1299999E+18  
(this is looking through the entire atmosphere)  
(in molecules per cm<sup>2</sup>). New value (use a negative  
number to input in Dobson units):

```
1.3e19
{ 1.30000E+19}
```

> there will be a little more ozone than the standard model

```
Molecule: CO2      O3(tot/cm2)  N2O      CO      CH4      O2
Index:      2        3            4        5        6        7
PPM:        330.     1.30E+19    0.28    0.075   1.6     2.1E+05
Enter 0 to continue or the gas index number
to change the ppm of that gas: 0
{ 0}
```

> user is happy with other gas parts per million (ppm).

```
Enter altitude (feet) (41000): 13500
{ 13500.0}
```

> user has selected an altitude characteristic of  
> a mountain top observatory.

The atmospheric model gives 3.5 Millimeters of water,  
toward the zenith.

```
Enter preferred value at this altitude in MICRONS,
or 0 for no adjustment of the model (0): 2000
{ 2000.00}
```

> user has forced the overhead water vapor to be 2 mm.

```
Number of atmospheric layers (2 recommended)(2): 1
{ 1}
```

> a single layer atmosphere will  
> provide the model. The calculations will  
> be rapid, although the line shapes may  
> be slightly broader than in the  
> more accurate multi-layer runs.

```
Zenith angle through atmosphere (0=UP)(0): 45
{ 45.0000}
```

> The source will be at an angle 45 deg. from  
> the zenith, so we will  
> look through root 2 airmasses, increasing  
> the column density of all gases  
> by this amount.

```
Enter wavelength of spectral line of interest
(this is used to make the velocity scale), or...,
-1 for species specification,
or else 0 for don't care (0): -1
{ -1.00000}
```

> user has chosen to select a spectral line from the internal list

```
Enter species, eg. OI,  
(enter 'NO' to get out, enter 'LI' to print the list) (NO): LI  
{LI }
```

```
> user has asked to see the list
```

```
SIII at wavelength 18.71300  
SIII2 at wavelength 33.48000  
OIII at wavelength 51.81500  
OIII2 at wavelength 88.35600  
OI at wavelength 63.18372  
OI2 at wavelength 145.52548  
CII at wavelength 157.74100  
NIII at wavelength 57.33000  
SiIII at wavelength 34.81400  
NeIII at wavelength 36.01000  
NII at wavelength 121.89700  
SI at wavelength 25.24900  
FeII at wavelength 25.98820  
OIV at wavelength 25.87000  
NeV at wavelength 24.28000  
FeIII at wavelength 22.93000
```

```
Enter species, eg. OI,  
(enter 'NO' to get out, enter 'LI' to print the list) (NO): SIII  
{SIII }
```

```
> user picks Sulfur++
```

```
SIII Wavelength = 18.7130
```

```
You may enter the limits of the x-axis in either  
wavelength or velocity; each unit will be printed.
```

```
Enter wavelength range of interest; Lambda 1 and Lambda 2 in microns.  
( '0 0' for velocities instead) (10 10.1): 0 0  
{0 0 }
```

```
> user chooses to specify wavelength  
> range using velocities from line center.  
> Note, wavenumbers could have been  
> entered, by using negative numbers here.  
> if the user had answered -530,-540, the  
> plot range would be from  
> 530 cm-1 to 540 cm-1.
```

```
Enter beginning and ending velocity (km/s)  
for plot (-1000 1000): -3000 3000  
{ -3000.00 3000.00}  
> the velocity range will run  
> from -3000 km/s to +3000 km/s around the rest  
> wavelength.  
{ 0. }
```

```
The wavelength range is then 18.52574 18.90026
```

Enter instrumental resolution in microns  
(0 for the CGS high resolution system resolution = 60 km/s),  
or -1 for no smoothing. (0): 0  
{ 0.}

> the resolution is set to 60 km/s (about .0035 microns)

Setting the data point spacing  
> (sampling) to 1/5 instrument resolution...  
There will be 500 points plotted.

Their spacing will be 0.0007 microns.  
Enter a new number of points, or 0 to keep these values, or  
-1 to change the spacing (0): 300  
{ 300}

> user has chosen to have fewer points plotted.  
> There will be 3 points per  
> FWHP of the instrument function plotted.

Select instrument profile function:  
[1] Triangle, [2] Gaussian, [3] Sinc, [4] Rectangle (2): 4  
{ 4}

> the instrument function is rectangular

Reading through database to this wavelength regime.....

|              |                        |
|--------------|------------------------|
| 500 out of   | 40581 lines processed. |
| 1000 out of  | 40581 lines processed. |
| 1500 out of  | 40581 lines processed. |
| 2000 out of  | 40581 lines processed. |
| 2500 out of  | 40581 lines processed. |
| 3000 out of  | 40581 lines processed. |
| 3500 out of  | 40581 lines processed. |
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| 4500 out of  | 40581 lines processed. |
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| 7500 out of  | 40581 lines processed. |
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| 8500 out of  | 40581 lines processed. |
| 9000 out of  | 40581 lines processed. |
| 9500 out of  | 40581 lines processed. |
| 10000 out of | 40581 lines processed. |
| 10500 out of | 40581 lines processed. |
| 11000 out of | 40581 lines processed. |
| 11500 out of | 40581 lines processed. |
| 12000 out of | 40581 lines processed. |
| 12500 out of | 40581 lines processed. |
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38500 out of 40581 lines processed.  
39000 out of 40581 lines processed.  
39500 out of 40581 lines processed.

40000 out of 40581 lines processed.  
 40354 CONSIDERED, 32 REJECTED  
 OF THOSE CONSIDERED.....

IWEAK 1(H2O)2(CO2)3(O3)4(N2O)5(CO)6(CH4)7(O2)  
 Weak line, reject

-----  
 LYR. 1 94 1584 367 204 0 572 0

IDELOUT 1(H2O)2(CO2)3(O3)4(N2O)5(CO)6(CH4)7(O2)  
 Narrow line in range, accept

-----  
 LYR. 1 1 2 182 0 0 0 0

IDELOUT 1(H2O)2(CO2)3(O3)4(N2O)5(CO)6(CH4)7(O2)  
 Narrow line out range, reject

-----  
 LYR. 1 1 2 182 0 0 0 0

IWIDEOUT 1(H2O)2(CO2)3(O3)4(N2O)5(CO)6(CH4)7(O2)  
 Broad line out range, reject

-----  
 LYR. 1 1201 14971 18773 1990 0 0 0

IWIDEIN 1(H2O)2(CO2)3(O3)4(N2O)5(CO)6(CH4)7(O2)  
 Broad line in range, accept

-----  
 LYR. 1 99 302 0 12 0 0 0

Converting opacity to transmittance...

Smoothing the Fine array.....

F TRANS, P TRANS: 0.792826 0.790070

Comment for plot (A20) (you may use mongo '\u', etc.) (Test):

demo2

{demo2 }

Another function on this plot (Y or N) (N): y

{y}

- > the user has selected to display
- > another transmission function on this plot.
- > we skip the identical dialog that
- > transpires, and show just the places
- > where the users response differed.

Ozone layer has total column density of 1.3000000E+19  
 (this is looking through the entire atmosphere)  
 (in molecules per cm<sup>2</sup>). New value (use a negative  
 number to input in Dobson units):

.5e18

{ .5000E18 }

That's VERY little O3! Typical min is 6.86E18/cm<sup>3</sup>  
 which is 263.8462 Dobson units

Molecule: CO2 O3(tot/cm2) N2O CO CH4 O2

```
Index:      2      3      4      5      6      7
PPM:      330.    5.00E+17  0.28  0.075  1.6   2.1E+05
Enter 0 to continue or the gas
index number to change the ppm of that gas: 0
{ 0 }
```

```
Enter altitude (feet) (41000): 13500
{ 13500 }
```

The atmospheric model gives 3.5 Millimeters of water,  
toward the zenith.

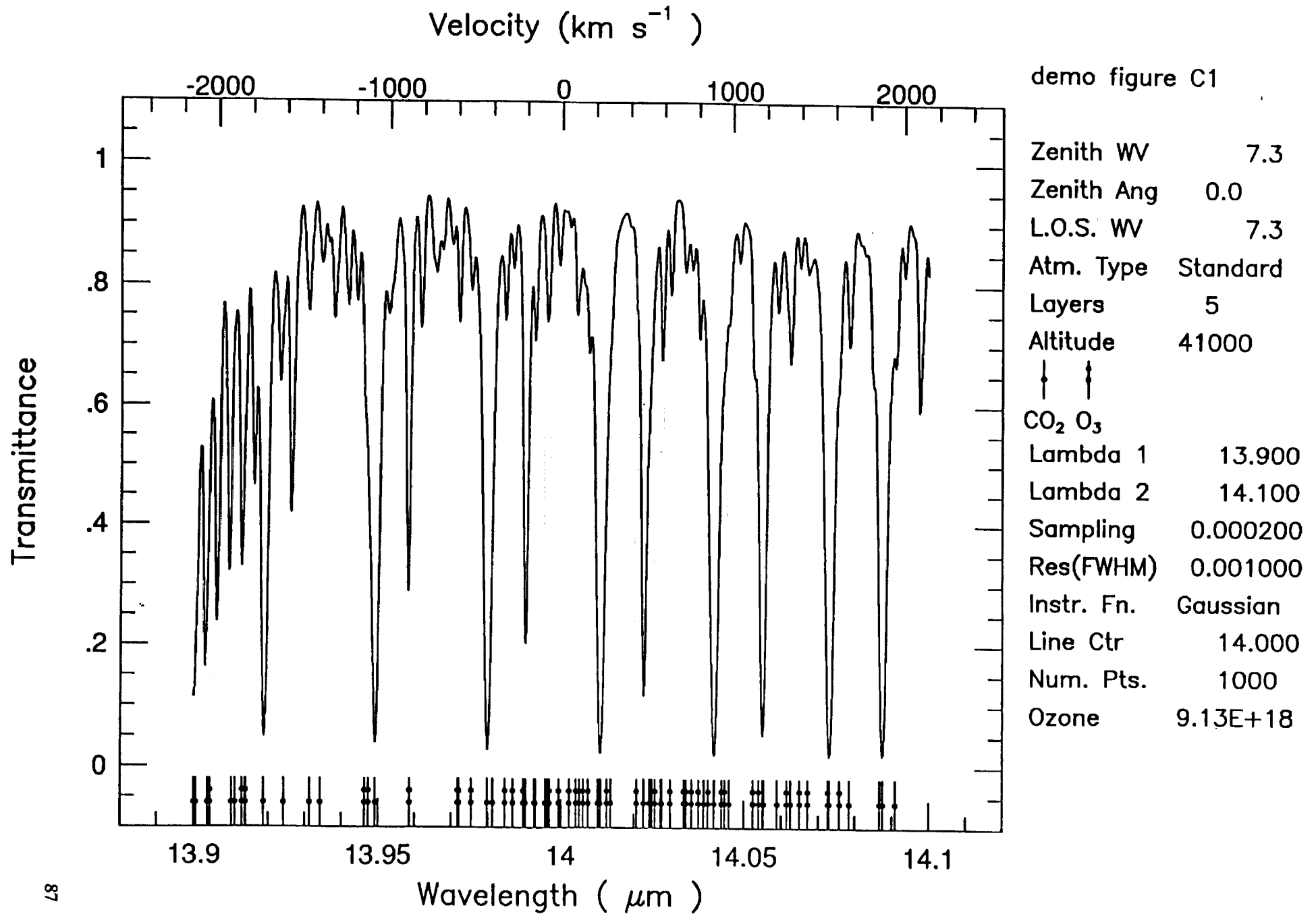
```
Enter preferred value at this altitude in MICRONS,
or 0 for no adjustment of the model (0): 1000
```

```
> this second function will have only 1mm H2O and also less ozone
..... (some dialog skipped)
```

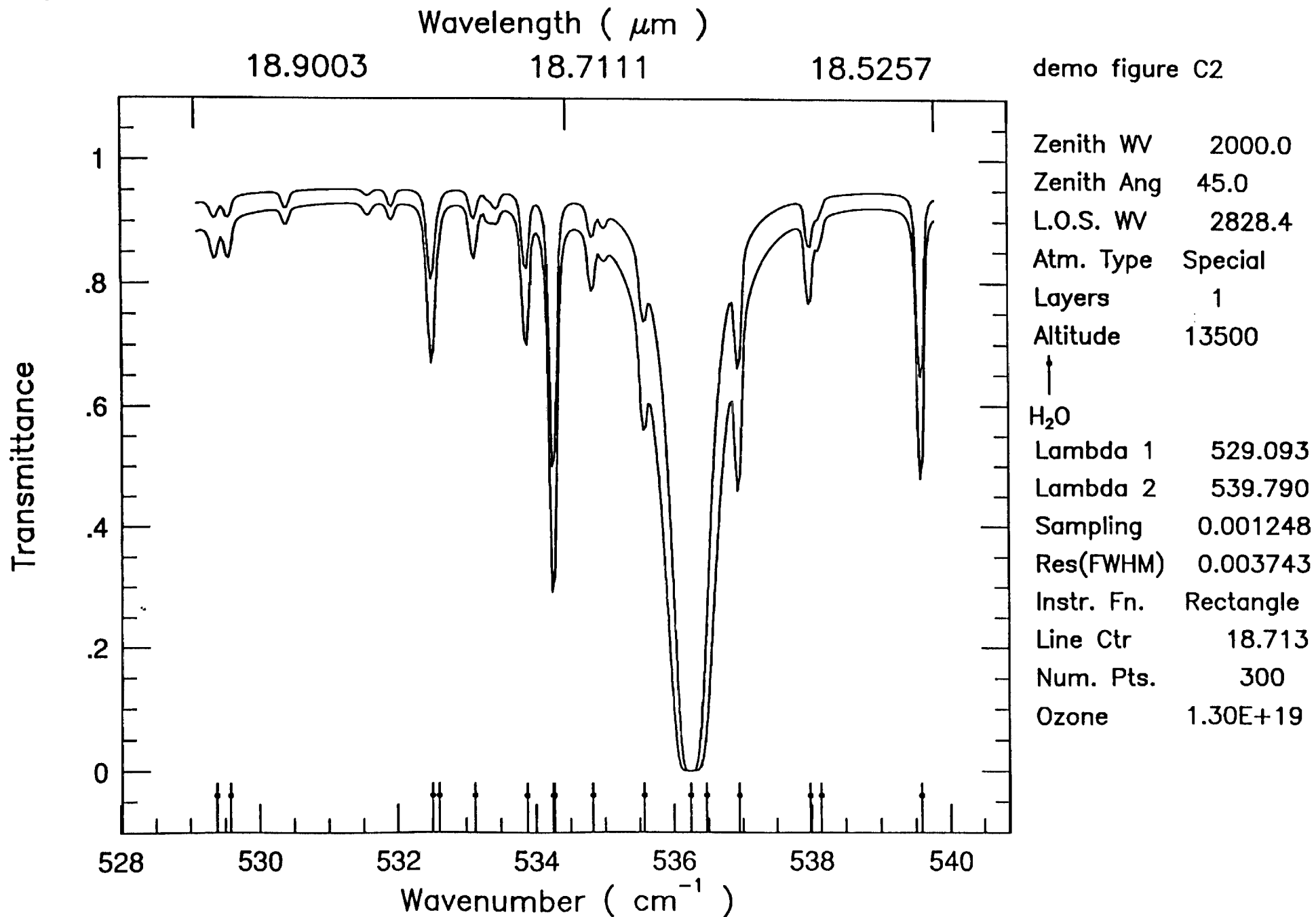
```
F TRANS, P TRANS:    0.854487    0.852218
Another function on this plot (Y or N) (N): N
P.PLO, a MONGO control file has been made.
PARRAY.DAT, the output data has been written.
mongo
* term 3
* input p.plo
```

This will yield a plot like the one shown in Figure C2.

```
-----
to make a hard copy
/work/lord/laseatran
then start mongo again....
mongo
* input p.imp
* end
and you will get a hardcopy.
```







Thu Dec 19 14:08:52 1991

## APPENDIX D

### MODEL ATMOSPHERE TABLE

The standard atmosphere model is given showing pressure, temperature, and column density as a function of altitude. The median pressure and temperature overhead is also given, and four ozone profiles for different latitudes.

| ALT<br>(KM) | T<br>(K) | P<br>(ATM) | COL. DEN.         |                       | T(.5)      |            | P(.5)        |              | COL. DEN. (4 Profiles) |                      |           |           |
|-------------|----------|------------|-------------------|-----------------------|------------|------------|--------------|--------------|------------------------|----------------------|-----------|-----------|
|             |          |            | H2O<br>(MOL/CM^2) | MIX GAS<br>(MOL/CM^2) | H2O<br>(K) | MIX<br>(K) | H2O<br>(ATM) | MIX<br>(ATM) | 9 LAT<br>03            | 36 LAT<br>(MOL/CM^2) | 43 LAT    | 56 LAT    |
| 0.0         | 288.2    | 1.0000     | 7.410E22          | 2.148E25              | 280.6      | 252.6      | .8692        | .5000        | 6.8581E18              | 8.4126E18            | 1.0325E19 | 1.2119E19 |
| 0.1         | 287.5    | 0.9881     | 6.705E22          | 2.123E25              | 279.8      | 252.0      | .8561        | .4941        | 6.8539E18              | 8.4054E18            | 1.0316E19 | 1.2111E19 |
| 0.2         | 286.9    | 0.9764     | 6.341E22          | 2.098E25              | 279.3      | 251.4      | .8489        | .4882        | 6.8497E18              | 8.3983E18            | 1.0308E19 | 1.2104E19 |
| 0.3         | 286.2    | 0.9645     | 6.055E22          | 2.072E25              | 278.9      | 250.8      | .8430        | .4822        | 6.8456E18              | 8.3914E18            | 1.0299E19 | 1.2097E19 |
| 0.4         | 285.6    | 0.9535     | 5.777E22          | 2.049E25              | 278.6      | 250.3      | .8372        | .4767        | 6.8414E18              | 8.3845E18            | 1.0290E19 | 1.2090E19 |
| 0.5         | 284.9    | 0.9415     | 5.473E22          | 2.023E25              | 278.2      | 249.7      | .8307        | .4708        | 6.8373E18              | 8.3778E18            | 1.0281E19 | 1.2083E19 |
| 0.6         | 284.3    | 0.9308     | 5.201E22          | 2.000E25              | 277.7      | 249.1      | .8240        | .4654        | 6.8332E18              | 8.3712E18            | 1.0272E19 | 1.2076E19 |
| 0.7         | 283.6    | 0.9194     | 4.926E22          | 1.975E25              | 277.0      | 248.5      | .8133        | .4597        | 6.8291E18              | 8.3647E18            | 1.0264E19 | 1.2069E19 |
| 0.8         | 282.9    | 0.9084     | 4.666E22          | 1.952E25              | 275.6      | 248.0      | .7906        | .4542        | 6.8251E18              | 8.3584E18            | 1.0255E19 | 1.2062E19 |
| 0.9         | 282.3    | 0.8978     | 4.400E22          | 1.929E25              | 272.8      | 247.4      | .7497        | .4489        | 6.8210E18              | 8.3521E18            | 1.0247E19 | 1.2055E19 |
| 1.0         | 281.7    | 0.8872     | 4.152E22          | 1.906E25              | 271.7      | 246.9      | .7342        | .4436        | 6.8170E18              | 8.3460E18            | 1.0238E19 | 1.2048E19 |
| 1.1         | 281.0    | 0.8765     | 3.898E22          | 1.884E25              | 270.5      | 246.3      | .7176        | .4383        | 6.8130E18              | 8.3400E18            | 1.0230E19 | 1.2041E19 |
| 1.2         | 280.4    | 0.8660     | 3.617E22          | 1.861E25              | 268.7      | 245.7      | .6928        | .4330        | 6.8090E18              | 8.3340E18            | 1.0221E19 | 1.2034E19 |
| 1.3         | 279.7    | 0.8553     | 3.332E22          | 1.838E25              | 266.5      | 245.2      | .6634        | .4277        | 6.8050E18              | 8.3281E18            | 1.0213E19 | 1.2027E19 |
| 1.4         | 279.0    | 0.8443     | 3.059E22          | 1.815E25              | 265.1      | 244.5      | .6454        | .4222        | 6.8011E18              | 8.3223E18            | 1.0205E19 | 1.2021E19 |
| 1.5         | 278.4    | 0.8344     | 2.824E22          | 1.793E25              | 263.9      | 244.0      | .6299        | .4172        | 6.7971E18              | 8.3165E18            | 1.0197E19 | 1.2014E19 |
| 1.6         | 277.8    | 0.8242     | 2.605E22          | 1.771E25              | 262.6      | 243.4      | .6157        | .4121        | 6.7932E18              | 8.3107E18            | 1.0189E19 | 1.2007E19 |
| 1.7         | 277.1    | 0.8138     | 2.468E22          | 1.749E25              | 262.1      | 242.8      | .6074        | .4069        | 6.7892E18              | 8.3050E18            | 1.0180E19 | 1.2001E19 |
| 1.8         | 276.5    | 0.8043     | 2.402E22          | 1.729E25              | 261.7      | 242.3      | .6032        | .4021        | 6.7853E18              | 8.2994E18            | 1.0172E19 | 1.1994E19 |
| 1.9         | 275.8    | 0.7945     | 2.352E22          | 1.708E25              | 261.4      | 241.7      | .5998        | .3972        | 6.7814E18              | 8.2938E18            | 1.0164E19 | 1.1988E19 |
| 2.0         | 275.2    | 0.7846     | 2.307E22          | 1.687E25              | 261.2      | 241.2      | .5967        | .3923        | 6.7775E18              | 8.2882E18            | 1.0156E19 | 1.1981E19 |
| 2.1         | 274.5    | 0.7747     | 2.271E22          | 1.665E25              | 261.0      | 240.6      | .5943        | .3874        | 6.7736E18              | 8.2827E18            | 1.0149E19 | 1.1975E19 |
| 2.2         | 273.8    | 0.7649     | 2.236E22          | 1.644E25              | 260.8      | 240.0      | .5919        | .3824        | 6.7697E18              | 8.2773E18            | 1.0141E19 | 1.1968E19 |
| 2.3         | 273.2    | 0.7556     | 2.212E22          | 1.624E25              | 260.7      | 239.4      | .5903        | .3778        | 6.7659E18              | 8.2719E18            | 1.0133E19 | 1.1962E19 |
| 2.4         | 272.6    | 0.7464     | 2.188E22          | 1.605E25              | 260.5      | 238.9      | .5887        | .3732        | 6.7622E18              | 8.2665E18            | 1.0125E19 | 1.1956E19 |
| 2.5         | 271.9    | 0.7372     | 2.110E22          | 1.585E25              | 260.1      | 238.3      | .5836        | .3686        | 6.7586E18              | 8.2612E18            | 1.0118E19 | 1.1949E19 |
| 2.6         | 271.3    | 0.7280     | 2.012E22          | 1.565E25              | 259.6      | 237.7      | .5774        | .3640        | 6.7550E18              | 8.2560E18            | 1.0110E19 | 1.1943E19 |
| 2.7         | 270.6    | 0.7187     | 1.954E22          | 1.545E25              | 259.2      | 237.2      | .5736        | .3594        | 6.7514E18              | 8.2508E18            | 1.0103E19 | 1.1937E19 |
| 2.8         | 269.9    | 0.7095     | 1.907E22          | 1.526E25              | 258.9      | 236.6      | .5703        | .3548        | 6.7479E18              | 8.2456E18            | 1.0095E19 | 1.1931E19 |
| 2.9         | 269.3    | 0.7008     | 1.854E22          | 1.507E25              | 258.6      | 236.0      | .5664        | .3504        | 6.7445E18              | 8.2405E18            | 1.0088E19 | 1.1925E19 |
| 3.0         | 268.7    | 0.6922     | 1.806E22          | 1.488E25              | 258.3      | 235.5      | .5627        | .3461        | 6.7412E18              | 8.2355E18            | 1.0081E19 | 1.1919E19 |
| 3.1         | 268.0    | 0.6836     | 1.762E22          | 1.470E25              | 258.0      | 234.9      | .5594        | .3418        | 6.7379E18              | 8.2305E18            | 1.0074E19 | 1.1912E19 |
| 3.2         | 267.4    | 0.6749     | 1.723E22          | 1.451E25              | 257.7      | 234.4      | .5564        | .3375        | 6.7346E18              | 8.2255E18            | 1.0067E19 | 1.1906E19 |
| 3.3         | 266.7    | 0.6663     | 1.682E22          | 1.433E25              | 257.5      | 233.8      | .5535        | .3331        | 6.7313E18              | 8.2206E18            | 1.0060E19 | 1.1900E19 |
| 3.4         | 266.1    | 0.6577     | 1.628E22          | 1.414E25              | 257.2      | 233.2      | .5498        | .3288        | 6.7281E18              | 8.2158E18            | 1.0053E19 | 1.1894E19 |
| 3.5         | 265.4    | 0.6491     | 1.560E22          | 1.396E25              | 256.8      | 232.6      | .5454        | .3245        | 6.7249E18              | 8.2110E18            | 1.0046E19 | 1.1888E19 |
| 3.6         | 264.7    | 0.6405     | 1.491E22          | 1.378E25              | 256.4      | 232.0      | .5412        | .3203        | 6.7217E18              | 8.2062E18            | 1.0039E19 | 1.1882E19 |
| 3.7         | 264.1    | 0.6325     | 1.431E22          | 1.360E25              | 256.0      | 231.5      | .5376        | .3162        | 6.7185E18              | 8.2015E18            | 1.0032E19 | 1.1876E19 |
| 3.8         | 263.5    | 0.6244     | 1.372E22          | 1.343E25              | 255.7      | 230.9      | .5340        | .3122        | 6.7153E18              | 8.1969E18            | 1.0025E19 | 1.1870E19 |
| 3.9         | 262.8    | 0.6163     | 1.307E22          | 1.326E25              | 255.4      | 230.3      | .5301        | .3082        | 6.7122E18              | 8.1923E18            | 1.0018E19 | 1.1864E19 |
| 4.0         | 262.1    | 0.6083     | 1.241E22          | 1.308E25              | 255.0      | 229.8      | .5260        | .3041        | 6.7091E18              | 8.1877E18            | 1.0011E19 | 1.1858E19 |
| 4.1         | 261.5    | 0.6003     | 1.180E22          | 1.291E25              | 254.7      | 229.2      | .5223        | .3001        | 6.7060E18              | 8.1832E18            | 1.0005E19 | 1.1852E19 |
| 4.2         | 260.9    | 0.5929     | 1.125E22          | 1.275E25              | 254.3      | 228.6      | .5190        | .2964        | 6.7029E18              | 8.1788E18            | 9.9978E18 | 1.1846E19 |
| 4.3         | 260.2    | 0.5852     | 1.067E22          | 1.259E25              | 254.0      | 228.1      | .5154        | .2926        | 6.6998E18              | 8.1744E18            | 9.9910E18 | 1.1840E19 |
| 4.4         | 259.6    | 0.5774     | 1.006E22          | 1.242E25              | 253.7      | 227.5      | .5116        | .2887        | 6.6968E18              | 8.1700E18            | 9.9843E18 | 1.1834E19 |

| ALT<br>(KM) | T<br>(K) | P<br>(ATM) | COL. DEN.         |                       | T(.5)      |            | P(.5)        |              | COL. DEN. (4 Profiles) |                      |           |           |
|-------------|----------|------------|-------------------|-----------------------|------------|------------|--------------|--------------|------------------------|----------------------|-----------|-----------|
|             |          |            | H2O<br>(MOL/CM^2) | MIX GAS<br>(MOL/CM^2) | H2O<br>(K) | MIX<br>(K) | H2O<br>(ATM) | MIX<br>(ATM) | 9 LAT<br>O3            | 36 LAT<br>(MOL/CM^2) | 43 LAT    | 56 LAT    |
| 4.5         | 258.9    | 0.5696     | 9.489E21          | 1.225E25              | 253.3      | 226.9      | .5083        | .2848        | 6.6938E18              | 8.1656E18            | 9.9775E18 | 1.1828E19 |
| 4.6         | 258.3    | 0.5622     | 8.997E21          | 1.209E25              | 253.0      | 226.4      | .5048        | .2811        | 6.6908E18              | 8.1613E18            | 9.9707E18 | 1.1822E19 |
| 4.7         | 257.6    | 0.5552     | 8.529E21          | 1.194E25              | 252.7      | 225.8      | .5016        | .2776        | 6.6878E18              | 8.1571E18            | 9.9640E18 | 1.1816E19 |
| 4.8         | 257.0    | 0.5480     | 7.999E21          | 1.179E25              | 252.3      | 225.3      | .4973        | .2740        | 6.6848E18              | 8.1529E18            | 9.9573E18 | 1.1810E19 |
| 4.9         | 256.3    | 0.5406     | 7.406E21          | 1.163E25              | 251.7      | 224.7      | .4910        | .2703        | 6.6819E18              | 8.1487E18            | 9.9506E18 | 1.1804E19 |
| 5.0         | 255.7    | 0.5336     | 6.824E21          | 1.148E25              | 250.9      | 224.1      | .4832        | .2668        | 6.6790E18              | 8.1445E18            | 9.9438E18 | 1.1798E19 |
| 5.1         | 255.1    | 0.5266     | 6.248E21          | 1.133E25              | 250.1      | 223.6      | .4747        | .2633        | 6.6761E18              | 8.1404E18            | 9.9371E18 | 1.1792E19 |
| 5.2         | 254.4    | 0.5195     | 5.667E21          | 1.118E25              | 249.1      | 222.8      | .4649        | .2597        | 6.6732E18              | 8.1364E18            | 9.9304E18 | 1.1786E19 |
| 5.3         | 253.7    | 0.5124     | 5.093E21          | 1.103E25              | 248.1      | 221.9      | .4549        | .2562        | 6.6703E18              | 8.1323E18            | 9.9237E18 | 1.1780E19 |
| 5.4         | 253.1    | 0.5054     | 4.542E21          | 1.088E25              | 247.2      | 221.1      | .4471        | .2527        | 6.6675E18              | 8.1283E18            | 9.9170E18 | 1.1774E19 |
| 5.5         | 252.4    | 0.4986     | 4.076E21          | 1.073E25              | 246.6      | 220.4      | .4407        | .2493        | 6.6647E18              | 8.1242E18            | 9.9102E18 | 1.1768E19 |
| 5.6         | 251.8    | 0.4918     | 3.738E21          | 1.058E25              | 246.0      | 219.7      | .4355        | .2459        | 6.6619E18              | 8.1202E18            | 9.9035E18 | 1.1762E19 |
| 5.7         | 251.2    | 0.4855     | 3.497E21          | 1.045E25              | 245.6      | 219.2      | .4318        | .2428        | 6.6591E18              | 8.1163E18            | 9.8967E18 | 1.1756E19 |
| 5.8         | 250.5    | 0.4791     | 3.270E21          | 1.031E25              | 245.2      | 218.6      | .4284        | .2396        | 6.6563E18              | 8.1123E18            | 9.8900E18 | 1.1750E19 |
| 5.9         | 249.8    | 0.4724     | 3.052E21          | 1.017E25              | 244.9      | 218.1      | .4252        | .2362        | 6.6536E18              | 8.1084E18            | 9.8832E18 | 1.1744E19 |
| 6.0         | 249.2    | 0.4661     | 2.866E21          | 1.003E25              | 244.6      | 217.7      | .4222        | .2330        | 6.6509E18              | 8.1044E18            | 9.8764E18 | 1.1738E19 |
| 6.1         | 248.6    | 0.4599     | 2.695E21          | 9.898E24              | 244.2      | 217.3      | .4191        | .2299        | 6.6482E18              | 8.1005E18            | 9.8696E18 | 1.1731E19 |
| 6.2         | 247.9    | 0.4534     | 2.498E21          | 9.759E24              | 243.7      | 217.0      | .4144        | .2267        | 6.6455E18              | 8.0966E18            | 9.8628E18 | 1.1725E19 |
| 6.3         | 247.2    | 0.4470     | 2.265E21          | 9.621E24              | 242.8      | 216.8      | .4024        | .2235        | 6.6429E18              | 8.0927E18            | 9.8559E18 | 1.1719E19 |
| 6.4         | 246.6    | 0.4411     | 2.052E21          | 9.495E24              | 240.2      | 216.7      | .3842        | .2206        | 6.6403E18              | 8.0888E18            | 9.8490E18 | 1.1713E19 |
| 6.5         | 246.0    | 0.4352     | 1.860E21          | 9.368E24              | 237.3      | 216.7      | .3601        | .2176        | 6.6378E18              | 8.0849E18            | 9.8421E18 | 1.1706E19 |
| 6.6         | 245.3    | 0.4292     | 1.662E21          | 9.239E24              | 234.2      | 216.7      | .3364        | .2146        | 6.6353E18              | 8.0810E18            | 9.8351E18 | 1.1699E19 |
| 6.7         | 244.7    | 0.4231     | 1.460E21          | 9.109E24              | 231.1      | 216.7      | .3133        | .2116        | 6.6328E18              | 8.0771E18            | 9.8282E18 | 1.1693E19 |
| 6.8         | 244.0    | 0.4171     | 1.300E21          | 8.979E24              | 229.4      | 216.7      | .3014        | .2085        | 6.6304E18              | 8.0732E18            | 9.8212E18 | 1.1686E19 |
| 6.9         | 243.3    | 0.4114     | 1.205E21          | 8.857E24              | 228.7      | 216.7      | .2969        | .2057        | 6.6280E18              | 8.0693E18            | 9.8141E18 | 1.1679E19 |
| 7.0         | 242.7    | 0.4057     | 1.153E21          | 8.735E24              | 228.4      | 216.7      | .2945        | .2029        | 6.6257E18              | 8.0654E18            | 9.8070E18 | 1.1672E19 |
| 7.1         | 242.0    | 0.3999     | 1.118E21          | 8.609E24              | 228.1      | 216.7      | .2928        | .1999        | 6.6234E18              | 8.0615E18            | 9.7999E18 | 1.1665E19 |
| 7.2         | 241.4    | 0.3941     | 1.085E21          | 8.486E24              | 227.9      | 216.7      | .2912        | .1971        | 6.6211E18              | 8.0576E18            | 9.7927E18 | 1.1658E19 |
| 7.3         | 240.7    | 0.3886     | 1.051E21          | 8.367E24              | 227.6      | 216.7      | .2895        | .1943        | 6.6188E18              | 8.0537E18            | 9.7853E18 | 1.1650E19 |
| 7.4         | 240.1    | 0.3833     | 1.021E21          | 8.254E24              | 227.4      | 216.7      | .2880        | .1917        | 6.6165E18              | 8.0497E18            | 9.7778E18 | 1.1642E19 |
| 7.5         | 239.4    | 0.3778     | 9.901E20          | 8.134E24              | 227.2      | 216.6      | .2864        | .1889        | 6.6143E18              | 8.0457E18            | 9.7701E18 | 1.1634E19 |
| 7.6         | 238.8    | 0.3727     | 9.671E20          | 8.025E24              | 227.0      | 216.6      | .2852        | .1863        | 6.6120E18              | 8.0417E18            | 9.7623E18 | 1.1626E19 |
| 7.7         | 238.2    | 0.3674     | 9.508E20          | 7.912E24              | 226.8      | 216.7      | .2843        | .1837        | 6.6098E18              | 8.0377E18            | 9.7544E18 | 1.1618E19 |
| 7.8         | 237.5    | 0.3618     | 9.350E20          | 7.791E24              | 226.7      | 216.6      | .2835        | .1809        | 6.6075E18              | 8.0337E18            | 9.7463E18 | 1.1609E19 |
| 7.9         | 236.8    | 0.3568     | 9.188E20          | 7.683E24              | 226.6      | 216.6      | .2827        | .1784        | 6.6053E18              | 8.0296E18            | 9.7381E18 | 1.1600E19 |
| 8.0         | 236.2    | 0.3520     | 9.013E20          | 7.580E24              | 226.5      | 216.7      | .2818        | .1760        | 6.6031E18              | 8.0255E18            | 9.7297E18 | 1.1591E19 |
| 8.1         | 235.6    | 0.3468     | 8.802E20          | 7.469E24              | 226.3      | 216.6      | .2808        | .1734        | 6.6009E18              | 8.0214E18            | 9.7212E18 | 1.1581E19 |
| 8.2         | 234.9    | 0.3417     | 8.566E20          | 7.360E24              | 226.1      | 216.6      | .2796        | .1709        | 6.5987E18              | 8.0173E18            | 9.7127E18 | 1.1571E19 |
| 8.3         | 234.3    | 0.3368     | 8.327E20          | 7.254E24              | 225.9      | 216.7      | .2784        | .1684        | 6.5965E18              | 8.0132E18            | 9.7040E18 | 1.1560E19 |
| 8.4         | 233.6    | 0.3319     | 8.081E20          | 7.148E24              | 225.7      | 216.6      | .2772        | .1659        | 6.5944E18              | 8.0091E18            | 9.6952E18 | 1.1547E19 |
| 8.5         | 233.0    | 0.3270     | 7.831E20          | 7.043E24              | 225.6      | 216.6      | .2759        | .1635        | 6.5922E18              | 8.0049E18            | 9.6863E18 | 1.1534E19 |
| 8.6         | 232.2    | 0.3223     | 7.638E20          | 6.943E24              | 225.4      | 216.7      | .2749        | .1611        | 6.5901E18              | 8.0008E18            | 9.6774E18 | 1.1520E19 |
| 8.7         | 231.7    | 0.3176     | 7.470E20          | 6.842E24              | 225.2      | 216.6      | .2741        | .1588        | 6.5879E18              | 7.9966E18            | 9.6684E18 | 1.1505E19 |
| 8.8         | 231.0    | 0.3131     | 7.291E20          | 6.745E24              | 225.1      | 216.6      | .2731        | .1566        | 6.5858E18              | 7.9925E18            | 9.6592E18 | 1.1489E19 |
| 8.9         | 230.4    | 0.3085     | 7.064E20          | 6.646E24              | 224.9      | 216.7      | .2720        | .1542        | 6.5837E18              | 7.9883E18            | 9.6500E18 | 1.1472E19 |

| ALT<br>(KM) | T<br>(K) | P<br>(ATM) | COL. DEN.         |                       | T(.5)      |            | P(.5)        |              | COL. DEN. (4 Profiles) |           |           |           |
|-------------|----------|------------|-------------------|-----------------------|------------|------------|--------------|--------------|------------------------|-----------|-----------|-----------|
|             |          |            | H2O<br>(MOL/CM^2) | MIX GAS<br>(MOL/CM^2) | H2O<br>(K) | MIX<br>(K) | H2O<br>(ATM) | MIX<br>(ATM) | 9 LAT                  | 36 LAT    | 43 LAT    | 56 LAT    |
| 9.0         | 229.7    | 0.3040     | 6.744E20          | 6.549E24              | 224.6      | 216.6      | .2704        | .1520        | 6.5816E18              | 7.9841E18 | 9.6407E18 | 1.1453E19 |
| 9.1         | 229.1    | 0.2994     | 6.292E20          | 6.450E24              | 224.3      | 216.7      | .2681        | .1497        | 6.5795E18              | 7.9799E18 | 9.6313E18 | 1.1434E19 |
| 9.2         | 228.4    | 0.2950     | 5.818E20          | 6.355E24              | 223.9      | 216.7      | .2657        | .1475        | 6.5774E18              | 7.9756E18 | 9.6216E18 | 1.1415E19 |
| 9.3         | 227.8    | 0.2907     | 5.374E20          | 6.263E24              | 223.5      | 216.6      | .2636        | .1453        | 6.5753E18              | 7.9713E18 | 9.6117E18 | 1.1395E19 |
| 9.4         | 227.1    | 0.2861     | 4.922E20          | 6.164E24              | 223.1      | 216.7      | .2613        | .1431        | 6.5732E18              | 7.9669E18 | 9.6015E18 | 1.1374E19 |
| 9.5         | 226.5    | 0.2819     | 4.511E20          | 6.074E24              | 222.6      | 216.7      | .2591        | .1409        | 6.5711E18              | 7.9624E18 | 9.5911E18 | 1.1353E19 |
| 9.6         | 225.8    | 0.2778     | 4.105E20          | 5.987E24              | 222.1      | 216.7      | .2568        | .1389        | 6.5690E18              | 7.9578E18 | 9.5804E18 | 1.1332E19 |
| 9.7         | 225.2    | 0.2738     | 3.710E20          | 5.900E24              | 221.4      | 216.7      | .2537        | .1369        | 6.5669E18              | 7.9532E18 | 9.5694E18 | 1.1310E19 |
| 9.8         | 224.5    | 0.2696     | 3.298E20          | 5.810E24              | 220.5      | 216.7      | .2495        | .1348        | 6.5648E18              | 7.9485E18 | 9.5582E18 | 1.1287E19 |
| 9.9         | 223.9    | 0.2655     | 2.886E20          | 5.722E24              | 219.7      | 216.7      | .2460        | .1328        | 6.5627E18              | 7.9438E18 | 9.5467E18 | 1.1264E19 |
| 10.0        | 223.2    | 0.2617     | 2.498E20          | 5.639E24              | 219.1      | 216.7      | .2425        | .1309        | 6.5606E18              | 7.9389E18 | 9.5350E18 | 1.1241E19 |
| 10.1        | 222.2    | 0.2574     | 2.091E20          | 5.547E24              | 218.5      | 216.7      | .2388        | .1287        | 6.5585E18              | 7.9340E18 | 9.5230E18 | 1.1217E19 |
| 10.2        | 221.3    | 0.2534     | 1.839E20          | 5.462E24              | 218.1      | 216.7      | .2363        | .1267        | 6.5564E18              | 7.9291E18 | 9.5104E18 | 1.1192E19 |
| 10.3        | 220.5    | 0.2497     | 1.659E20          | 5.382E24              | 217.9      | 216.7      | .2345        | .1248        | 6.5543E18              | 7.9242E18 | 9.4972E18 | 1.1167E19 |
| 10.4        | 219.7    | 0.2458     | 1.431E20          | 5.298E24              | 217.5      | 216.7      | .2313        | .1229        | 6.5522E18              | 7.9192E18 | 9.4834E18 | 1.1141E19 |
| 10.5        | 219.0    | 0.2420     | 1.224E20          | 5.217E24              | 217.1      | 216.7      | .2274        | .1210        | 6.5502E18              | 7.9142E18 | 9.4690E18 | 1.1114E19 |
| 10.6        | 218.4    | 0.2383     | 1.018E20          | 5.136E24              | 216.7      | 216.7      | .2218        | .1191        | 6.5481E18              | 7.9092E18 | 9.4540E18 | 1.1086E19 |
| 10.7        | 217.9    | 0.2346     | 8.345E19          | 5.056E24              | 216.7      | 216.7      | .2131        | .1173        | 6.5461E18              | 7.9042E18 | 9.4384E18 | 1.1058E19 |
| 10.8        | 217.5    | 0.2311     | 7.074E19          | 4.981E24              | 216.7      | 216.7      | .2016        | .1155        | 6.5440E18              | 7.8992E18 | 9.4222E18 | 1.1029E19 |
| 10.9        | 217.1    | 0.2276     | 6.168E19          | 4.905E24              | 216.7      | 216.7      | .1922        | .1138        | 6.5420E18              | 7.8941E18 | 9.4054E18 | 1.1000E19 |
| 11.0        | 216.8    | 0.2241     | 5.464E19          | 4.830E24              | 216.6      | 216.7      | .1841        | .1120        | 6.5400E18              | 7.8890E18 | 9.3880E18 | 1.0969E19 |
| 11.1        | 216.7    | 0.2206     | 4.892E19          | 4.755E24              | 216.7      | 216.7      | .1773        | .1103        | 6.5380E18              | 7.8839E18 | 9.3700E18 | 1.0938E19 |
| 11.2        | 216.7    | 0.2171     | 4.472E19          | 4.680E24              | 216.6      | 216.7      | .1720        | .1085        | 6.5360E18              | 7.8788E18 | 9.3517E18 | 1.0907E19 |
| 11.3        | 216.7    | 0.2136     | 4.202E19          | 4.605E24              | 216.7      | 216.7      | .1683        | .1068        | 6.5340E18              | 7.8735E18 | 9.3331E18 | 1.0874E19 |
| 11.4        | 216.7    | 0.2103     | 3.997E19          | 4.533E24              | 216.7      | 216.7      | .1653        | .1051        | 6.5320E18              | 7.8681E18 | 9.3142E18 | 1.0840E19 |
| 11.5        | 216.7    | 0.2070     | 3.810E19          | 4.462E24              | 216.6      | 216.7      | .1625        | .1035        | 6.5300E18              | 7.8626E18 | 9.2950E18 | 1.0805E19 |
| 11.6        | 216.7    | 0.2038     | 3.648E19          | 4.394E24              | 216.7      | 216.7      | .1601        | .1019        | 6.5280E18              | 7.8571E18 | 9.2755E18 | 1.0770E19 |
| 11.7        | 216.7    | 0.2007     | 3.492E19          | 4.327E24              | 216.6      | 216.7      | .1577        | .1003        | 6.5260E18              | 7.8515E18 | 9.2557E18 | 1.0734E19 |
| 11.8        | 216.7    | 0.1974     | 3.328E19          | 4.257E24              | 216.6      | 216.6      | .1552        | .0987        | 6.5240E18              | 7.8457E18 | 9.2356E18 | 1.0696E19 |
| 11.9        | 216.7    | 0.1945     | 3.186E19          | 4.194E24              | 216.7      | 216.7      | .1530        | .0972        | 6.5220E18              | 7.8399E18 | 9.2152E18 | 1.0658E19 |
| 12.0        | 216.7    | 0.1915     | 3.053E19          | 4.130E24              | 216.6      | 216.7      | .1507        | .0957        | 6.5200E18              | 7.8340E18 | 9.1945E18 | 1.0619E19 |
| 12.1        | 216.6    | 0.1885     | 2.922E19          | 4.065E24              | 216.7      | 216.6      | .1485        | .0943        | 6.5180E18              | 7.8280E18 | 9.1735E18 | 1.0579E19 |
| 12.2        | 216.6    | 0.1855     | 2.792E19          | 3.999E24              | 216.7      | 216.7      | .1463        | .0927        | 6.5160E18              | 7.8219E18 | 9.1524E18 | 1.0539E19 |
| 12.3        | 216.7    | 0.1826     | 2.672E19          | 3.938E24              | 216.6      | 216.7      | .1440        | .0913        | 6.5140E18              | 7.8158E18 | 9.1312E18 | 1.0498E19 |
| 12.4        | 216.6    | 0.1797     | 2.549E19          | 3.876E24              | 216.7      | 216.6      | .1414        | .0899        | 6.5120E18              | 7.8096E18 | 9.1099E18 | 1.0457E19 |
| 12.5        | 216.7    | 0.1768     | 2.427E19          | 3.813E24              | 216.7      | 216.6      | .1386        | .0884        | 6.5100E18              | 7.8033E18 | 9.0885E18 | 1.0415E19 |
| 12.6        | 216.7    | 0.1741     | 2.317E19          | 3.754E24              | 216.7      | 216.7      | .1359        | .0870        | 6.5080E18              | 7.7969E18 | 9.0670E18 | 1.0373E19 |
| 12.7        | 216.6    | 0.1714     | 2.214E19          | 3.696E24              | 216.7      | 216.7      | .1331        | .0857        | 6.5060E18              | 7.7905E18 | 9.0454E18 | 1.0331E19 |
| 12.8        | 216.7    | 0.1688     | 2.118E19          | 3.640E24              | 216.7      | 216.6      | .1303        | .0844        | 6.5040E18              | 7.7840E18 | 9.0237E18 | 1.0288E19 |
| 12.9        | 216.7    | 0.1663     | 2.031E19          | 3.586E24              | 216.7      | 216.6      | .1277        | .0831        | 6.5020E18              | 7.7775E18 | 9.0019E18 | 1.0245E19 |
| 13.0        | 216.6    | 0.1637     | 1.944E19          | 3.530E24              | 216.7      | 216.7      | .1248        | .0818        | 6.5000E18              | 7.7708E18 | 8.9800E18 | 1.0201E19 |
| 13.1        | 216.7    | 0.1611     | 1.858E19          | 3.475E24              | 216.7      | 216.6      | .1214        | .0806        | 6.4980E18              | 7.7641E18 | 8.9580E18 | 1.0157E19 |
| 13.2        | 216.6    | 0.1586     | 1.775E19          | 3.421E24              | 216.7      | 216.6      | .1177        | .0793        | 6.4960E18              | 7.7573E18 | 8.9355E18 | 1.0112E19 |
| 13.3        | 216.6    | 0.1561     | 1.693E19          | 3.368E24              | 216.7      | 216.7      | .1136        | .0781        | 6.4940E18              | 7.7502E18 | 8.9125E18 | 1.0067E19 |
| 13.4        | 216.7    | 0.1537     | 1.614E19          | 3.315E24              | 216.7      | 216.7      | .1092        | .0768        | 6.4919E18              | 7.7430E18 | 8.8890E18 | 1.0021E19 |

| ALT  | T     | P      | COL. DEN.<br>H2O | COL. DEN.<br>MIX GAS | T(.5)<br>H2O | T(.5)<br>MIX | P(.5)<br>H2O | P(.5)<br>MIX | COL. DEN. (4 Profiles) |            |           |           |
|------|-------|--------|------------------|----------------------|--------------|--------------|--------------|--------------|------------------------|------------|-----------|-----------|
| (KM) | (K)   | (ATM)  | (MOL/CM^2)       | (MOL/CM^2)           | (K)          | (K)          | (ATM)        | (ATM)        | 9 LAT                  | 36 LAT     | 43 LAT    | 56 LAT    |
|      |       |        |                  |                      |              |              |              |              | O3                     | (MOL/CM^2) |           |           |
| 13.5 | 216.6 | 0.1512 | 1.542E19         | 3.262E24             | 216.7        | 216.6        | .1059        | .0756        | 6.4899E18              | 7.7355E18  | 8.8650E18 | 9.9750E18 |
| 13.6 | 216.7 | 0.1488 | 1.470E19         | 3.211E24             | 216.7        | 216.6        | .1027        | .0744        | 6.4879E18              | 7.7279E18  | 8.8405E18 | 9.9280E18 |
| 13.7 | 216.7 | 0.1466 | 1.405E19         | 3.163E24             | 216.6        | 216.6        | .0997        | .0733        | 6.4858E18              | 7.7202E18  | 8.8155E18 | 9.8804E18 |
| 13.8 | 216.6 | 0.1444 | 1.345E19         | 3.114E24             | 216.7        | 216.7        | .0970        | .0722        | 6.4837E18              | 7.7122E18  | 8.7900E18 | 9.8322E18 |
| 13.9 | 216.7 | 0.1421 | 1.289E19         | 3.065E24             | 216.6        | 216.6        | .0941        | .0711        | 6.4816E18              | 7.7041E18  | 8.7640E18 | 9.7834E18 |
| 14.0 | 216.7 | 0.1399 | 1.241E19         | 3.018E24             | 216.7        | 216.6        | .0915        | .0699        | 6.4796E18              | 7.6957E18  | 8.7375E18 | 9.7340E18 |
| 14.1 | 216.7 | 0.1377 | 1.195E19         | 2.972E24             | 216.6        | 216.7        | .0888        | .0689        | 6.4775E18              | 7.6872E18  | 8.7105E18 | 9.6840E18 |
| 14.2 | 216.7 | 0.1355 | 1.150E19         | 2.923E24             | 216.7        | 216.7        | .0862        | .0677        | 6.4753E18              | 7.6786E18  | 8.6832E18 | 9.6339E18 |
| 14.3 | 216.7 | 0.1333 | 1.110E19         | 2.877E24             | 216.6        | 216.6        | .0833        | .0667        | 6.4732E18              | 7.6698E18  | 8.6556E18 | 9.5837E18 |
| 14.4 | 216.7 | 0.1312 | 1.074E19         | 2.832E24             | 216.6        | 216.6        | .0808        | .0656        | 6.4710E18              | 7.6608E18  | 8.6277E18 | 9.5334E18 |
| 14.5 | 216.7 | 0.1292 | 1.040E19         | 2.788E24             | 216.7        | 216.7        | .0786        | .0646        | 6.4688E18              | 7.6517E18  | 8.5995E18 | 9.4830E18 |
| 14.6 | 216.7 | 0.1272 | 1.007E19         | 2.744E24             | 216.7        | 216.6        | .0766        | .0636        | 6.4665E18              | 7.6425E18  | 8.5710E18 | 9.4325E18 |
| 14.7 | 216.7 | 0.1252 | 9.775E18         | 2.702E24             | 216.6        | 216.6        | .0749        | .0626        | 6.4642E18              | 7.6331E18  | 8.5422E18 | 9.3819E18 |
| 14.8 | 216.7 | 0.1233 | 9.520E18         | 2.662E24             | 216.6        | 216.6        | .0734        | .0617        | 6.4619E18              | 7.6235E18  | 8.5131E18 | 9.3312E18 |
| 14.9 | 216.7 | 0.1214 | 9.287E18         | 2.621E24             | 216.7        | 216.5        | .0720        | .0607        | 6.4596E18              | 7.6138E18  | 8.4837E18 | 9.2804E18 |
| 15.0 | 216.7 | 0.1195 | 9.077E18         | 2.580E24             | 216.6        | 216.5        | .0706        | .0597        | 6.4572E18              | 7.6040E18  | 8.4540E18 | 9.2295E18 |
| 15.1 | 216.7 | 0.1176 | 8.866E18         | 2.539E24             | 216.7        | 216.5        | .0690        | .0588        | 6.4548E18              | 7.5940E18  | 8.4240E18 | 9.1785E18 |
| 15.2 | 216.7 | 0.1158 | 8.670E18         | 2.500E24             | 216.7        | 216.5        | .0675        | .0579        | 6.4524E18              | 7.5838E18  | 8.3936E18 | 9.1272E18 |
| 15.3 | 216.7 | 0.1140 | 8.500E18         | 2.461E24             | 216.6        | 216.5        | .0660        | .0570        | 6.4499E18              | 7.5734E18  | 8.3628E18 | 9.0756E18 |
| 15.4 | 216.7 | 0.1122 | 8.343E18         | 2.422E24             | 216.7        | 216.6        | .0646        | .0561        | 6.4474E18              | 7.5628E18  | 8.3316E18 | 9.0237E18 |
| 15.5 | 216.7 | 0.1104 | 8.188E18         | 2.383E24             | 216.6        | 216.6        | .0634        | .0552        | 6.4448E18              | 7.5520E18  | 8.3000E18 | 8.9715E18 |
| 15.6 | 216.7 | 0.1087 | 8.021E18         | 2.346E24             | 216.6        | 216.7        | .0622        | .0543        | 6.4422E18              | 7.5410E18  | 8.2680E18 | 8.9190E18 |
| 15.7 | 216.7 | 0.1070 | 7.837E18         | 2.309E24             | 216.5        | 216.7        | .0609        | .0535        | 6.4396E18              | 7.5298E18  | 8.2356E18 | 8.8662E18 |
| 15.8 | 216.7 | 0.1054 | 7.654E18         | 2.275E24             | 216.5        | 216.8        | .0596        | .0527        | 6.4369E18              | 7.5184E18  | 8.2028E18 | 8.8131E18 |
| 15.9 | 216.7 | 0.1038 | 7.472E18         | 2.240E24             | 216.5        | 216.9        | .0583        | .0519        | 6.4342E18              | 7.5068E18  | 8.1696E18 | 8.7597E18 |
| 16.0 | 216.7 | 0.1021 | 7.290E18         | 2.205E24             | 216.5        | 217.0        | .0571        | .0510        | 6.4314E18              | 7.4950E18  | 8.1360E18 | 8.7060E18 |
| 16.1 | 216.7 | 0.1005 | 7.111E18         | 2.170E24             | 216.6        | 217.1        | .0560        | .0503        | 6.4286E18              | 7.4830E18  | 8.1020E18 | 8.6520E18 |
| 16.2 | 216.6 | 0.0990 | 6.943E18         | 2.138E24             | 216.7        | 217.2        | .0549        | .0495        | 6.4257E18              | 7.4703E18  | 8.0674E18 | 8.5975E18 |
| 16.3 | 216.7 | 0.0975 | 6.773E18         | 2.104E24             | 216.7        | 217.3        | .0537        | .0487        | 6.4226E18              | 7.4569E18  | 8.0322E18 | 8.5425E18 |
| 16.4 | 216.7 | 0.0959 | 6.611E18         | 2.070E24             | 216.8        | 217.4        | .0526        | .0479        | 6.4194E18              | 7.4428E18  | 7.9964E18 | 8.4870E18 |
| 16.5 | 216.6 | 0.0944 | 6.473E18         | 2.038E24             | 217.0        | 217.5        | .0517        | .0472        | 6.4160E18              | 7.4280E18  | 7.9600E18 | 8.4310E18 |
| 16.6 | 216.7 | 0.0929 | 6.337E18         | 2.007E24             | 217.1        | 217.6        | .0507        | .0465        | 6.4125E18              | 7.4125E18  | 7.9230E18 | 8.3745E18 |
| 16.7 | 216.7 | 0.0915 | 6.207E18         | 1.975E24             | 217.2        | 217.7        | .0498        | .0457        | 6.4089E18              | 7.3963E18  | 7.8854E18 | 8.3175E18 |
| 16.8 | 216.6 | 0.0900 | 6.084E18         | 1.945E24             | 217.3        | 217.8        | .0490        | .0450        | 6.4051E18              | 7.3794E18  | 7.8472E18 | 8.2600E18 |
| 16.9 | 216.6 | 0.0886 | 5.958E18         | 1.915E24             | 217.4        | 217.9        | .0481        | .0443        | 6.4012E18              | 7.3618E18  | 7.8084E18 | 8.2020E18 |
| 17.0 | 216.7 | 0.0873 | 5.834E18         | 1.885E24             | 217.5        | 218.0        | .0473        | .0437        | 6.3971E18              | 7.3435E18  | 7.7690E18 | 8.1435E18 |
| 17.1 | 216.7 | 0.0859 | 5.730E18         | 1.856E24             | 217.6        | 218.1        | .0466        | .0430        | 6.3929E18              | 7.3245E18  | 7.7290E18 | 8.0845E18 |
| 17.2 | 216.6 | 0.0846 | 5.640E18         | 1.827E24             | 217.7        | 218.3        | .0459        | .0423        | 6.3883E18              | 7.3046E18  | 7.6882E18 | 8.0255E18 |
| 17.3 | 216.6 | 0.0832 | 5.545E18         | 1.798E24             | 217.8        | 218.4        | .0453        | .0416        | 6.3832E18              | 7.2838E18  | 7.6466E18 | 7.9665E18 |
| 17.4 | 216.7 | 0.0819 | 5.450E18         | 1.770E24             | 217.9        | 218.4        | .0447        | .0410        | 6.3777E18              | 7.2621E18  | 7.6042E18 | 7.9075E18 |
| 17.5 | 216.6 | 0.0807 | 5.359E18         | 1.743E24             | 217.9        | 218.5        | .0442        | .0404        | 6.3718E18              | 7.2395E18  | 7.5610E18 | 7.8485E18 |
| 17.6 | 216.6 | 0.0795 | 5.273E18         | 1.717E24             | 218.0        | 218.6        | .0436        | .0397        | 6.3655E18              | 7.2160E18  | 7.5170E18 | 7.7895E18 |
| 17.7 | 216.7 | 0.0783 | 5.180E18         | 1.691E24             | 218.1        | 218.7        | .0430        | .0391        | 6.3587E18              | 7.1916E18  | 7.4722E18 | 7.7305E18 |
| 17.8 | 216.7 | 0.0770 | 5.074E18         | 1.663E24             | 218.3        | 218.8        | .0422        | .0385        | 6.3515E18              | 7.1663E18  | 7.4266E18 | 7.6715E18 |
| 17.9 | 216.6 | 0.0758 | 4.967E18         | 1.637E24             | 218.4        | 218.9        | .0414        | .0379        | 6.3438E18              | 7.1401E18  | 7.3802E18 | 7.6125E18 |

| ALT<br>(KM) | T<br>(K) | P<br>(ATM) | COL. DEN.         |                       | T(.5)      |            | P(.5)        |              | COL. DEN. (4 Profiles) |                      |           |           |
|-------------|----------|------------|-------------------|-----------------------|------------|------------|--------------|--------------|------------------------|----------------------|-----------|-----------|
|             |          |            | H2O<br>(MOL/CM^2) | MIX GAS<br>(MOL/CM^2) | H2O<br>(K) | MIX<br>(K) | H2O<br>(ATM) | MIX<br>(ATM) | 9 LAT<br>03            | 36 LAT<br>(MOL/CM^2) | 43 LAT    | 56 LAT    |
| 18.0        | 216.6    | 0.0746     | 4.862E18          | 1.612E24              | 218.5      | 219.0      | .0408        | .0373        | 6.3358E18              | 7.1130E18            | 7.3330E18 | 7.5535E18 |
| 18.1        | 216.6    | 0.0734     | 4.762E18          | 1.587E24              | 218.6      | 219.1      | .0401        | .0367        | 6.3273E18              | 7.0850E18            | 7.2850E18 | 7.4945E18 |
| 18.2        | 216.7    | 0.0723     | 4.668E18          | 1.562E24              | 218.7      | 219.2      | .0394        | .0362        | 6.3176E18              | 7.0560E18            | 7.2370E18 | 7.4356E18 |
| 18.3        | 216.6    | 0.0712     | 4.584E18          | 1.538E24              | 218.8      | 219.3      | .0388        | .0356        | 6.3068E18              | 7.0260E18            | 7.1890E18 | 7.3768E18 |
| 18.4        | 216.6    | 0.0701     | 4.506E18          | 1.515E24              | 218.9      | 219.4      | .0383        | .0351        | 6.2949E18              | 6.9950E18            | 7.1410E18 | 7.3181E18 |
| 18.5        | 216.7    | 0.0690     | 4.432E18          | 1.491E24              | 218.9      | 219.5      | .0379        | .0345        | 6.2818E18              | 6.9630E18            | 7.0930E18 | 7.2595E18 |
| 18.6        | 216.7    | 0.0679     | 4.362E18          | 1.468E24              | 219.0      | 219.7      | .0374        | .0340        | 6.2675E18              | 6.9300E18            | 7.0450E18 | 7.2010E18 |
| 18.7        | 216.6    | 0.0669     | 4.297E18          | 1.445E24              | 219.1      | 219.8      | .0370        | .0334        | 6.2521E18              | 6.8960E18            | 6.9970E18 | 7.1426E18 |
| 18.8        | 216.6    | 0.0658     | 4.238E18          | 1.423E24              | 219.2      | 219.9      | .0366        | .0329        | 6.2356E18              | 6.8610E18            | 6.9490E18 | 7.0843E18 |
| 18.9        | 216.7    | 0.0648     | 4.182E18          | 1.401E24              | 219.2      | 220.0      | .0363        | .0324        | 6.2179E18              | 6.8250E18            | 6.9010E18 | 7.0261E18 |
| 19.0        | 216.6    | 0.0639     | 4.123E18          | 1.380E24              | 219.3      | 220.1      | .0358        | .0320        | 6.1990E18              | 6.7880E18            | 6.8530E18 | 6.9680E18 |
| 19.1        | 216.6    | 0.0628     | 4.055E18          | 1.358E24              | 219.4      | 220.2      | .0354        | .0314        | 6.1790E18              | 6.7500E18            | 6.8050E18 | 6.9100E18 |
| 19.2        | 216.6    | 0.0618     | 3.983E18          | 1.335E24              | 219.5      | 220.3      | .0348        | .0309        | 6.1582E18              | 6.7110E18            | 6.7568E18 | 6.8523E18 |
| 19.3        | 216.5    | 0.0608     | 3.915E18          | 1.315E24              | 219.6      | 220.4      | .0343        | .0304        | 6.1366E18              | 6.6710E18            | 6.7084E18 | 6.7949E18 |
| 19.4        | 216.5    | 0.0599     | 3.850E18          | 1.295E24              | 219.7      | 220.5      | .0339        | .0300        | 6.1142E18              | 6.6300E18            | 6.6598E18 | 6.7378E18 |
| 19.5        | 216.5    | 0.0590     | 3.788E18          | 1.275E24              | 219.7      | 220.6      | .0335        | .0295        | 6.0910E18              | 6.5880E18            | 6.6110E18 | 6.6810E18 |
| 19.6        | 216.5    | 0.0581     | 3.724E18          | 1.256E24              | 219.8      | 220.7      | .0330        | .0291        | 6.0670E18              | 6.5450E18            | 6.5620E18 | 6.6245E18 |
| 19.7        | 216.5    | 0.0572     | 3.655E18          | 1.236E24              | 219.9      | 220.8      | .0325        | .0286        | 6.0422E18              | 6.5010E18            | 6.5128E18 | 6.5683E18 |
| 19.8        | 216.6    | 0.0563     | 3.584E18          | 1.217E24              | 220.0      | 220.9      | .0320        | .0281        | 6.0166E18              | 6.4560E18            | 6.4634E18 | 6.5124E18 |
| 19.9        | 216.6    | 0.0555     | 3.515E18          | 1.198E24              | 220.1      | 221.0      | .0316        | .0278        | 5.9902E18              | 6.4100E18            | 6.4138E18 | 6.4568E18 |
| 20.0        | 216.7    | 0.0546     | 3.450E18          | 1.180E24              | 220.2      | 221.1      | .0311        | .0273        | 5.9630E18              | 6.3630E18            | 6.3640E18 | 6.4015E18 |
| 20.1        | 216.7    | 0.0537     | 3.387E18          | 1.162E24              | 220.3      | 221.2      | .0307        | .0269        | 5.9350E18              | 6.3150E18            | 6.3140E18 | 6.3465E18 |
| 20.2        | 216.8    | 0.0529     | 3.326E18          | 1.144E24              | 220.4      | 221.3      | .0303        | .0265        | 5.9064E18              | 6.2668E18            | 6.2641E18 | 6.2920E18 |
| 20.3        | 216.9    | 0.0521     | 3.267E18          | 1.126E24              | 220.5      | 221.4      | .0299        | .0260        | 5.8772E18              | 6.2184E18            | 6.2143E18 | 6.2380E18 |
| 20.4        | 217.0    | 0.0513     | 3.210E18          | 1.108E24              | 220.6      | 221.5      | .0295        | .0257        | 5.8474E18              | 6.1698E18            | 6.1646E18 | 6.1845E18 |
| 20.5        | 217.1    | 0.0505     | 3.154E18          | 1.091E24              | 220.6      | 221.6      | .0291        | .0253        | 5.8170E18              | 6.1210E18            | 6.1150E18 | 6.1315E18 |
| 20.6        | 217.2    | 0.0497     | 3.096E18          | 1.074E24              | 220.7      | 221.7      | .0287        | .0248        | 5.7860E18              | 6.0720E18            | 6.0655E18 | 6.0790E18 |
| 20.7        | 217.3    | 0.0489     | 3.035E18          | 1.057E24              | 220.8      | 221.8      | .0282        | .0245        | 5.7544E18              | 6.0228E18            | 6.0161E18 | 6.0270E18 |
| 20.8        | 217.4    | 0.0481     | 2.978E18          | 1.041E24              | 220.9      | 221.8      | .0279        | .0240        | 5.7222E18              | 5.9734E18            | 5.9668E18 | 5.9755E18 |
| 20.9        | 217.5    | 0.0474     | 2.924E18          | 1.024E24              | 221.0      | 221.9      | .0275        | .0237        | 5.6894E18              | 5.9238E18            | 5.9176E18 | 5.9245E18 |
| 21.0        | 217.6    | 0.0467     | 2.875E18          | 1.009E24              | 221.1      | 222.0      | .0270        | .0234        | 5.6560E18              | 5.8740E18            | 5.8685E18 | 5.8740E18 |
| 21.1        | 217.7    | 0.0460     | 2.825E18          | 9.939E23              | 221.2      | 222.1      | .0267        | .0230        | 5.6220E18              | 5.8240E18            | 5.8195E18 | 5.8240E18 |
| 21.2        | 217.8    | 0.0452     | 2.767E18          | 9.780E23              | 221.3      | 222.2      | .0263        | .0226        | 5.5874E18              | 5.7741E18            | 5.7705E18 | 5.7741E18 |
| 21.3        | 217.9    | 0.0445     | 2.704E18          | 9.621E23              | 221.4      | 222.3      | .0259        | .0223        | 5.5522E18              | 5.7243E18            | 5.7215E18 | 5.7243E18 |
| 21.4        | 218.0    | 0.0438     | 2.648E18          | 9.473E23              | 221.5      | 222.4      | .0255        | .0219        | 5.5164E18              | 5.6746E18            | 5.6725E18 | 5.6746E18 |
| 21.5        | 218.1    | 0.0431     | 2.600E18          | 9.328E23              | 221.6      | 222.5      | .0252        | .0215        | 5.4800E18              | 5.6250E18            | 5.6235E18 | 5.6250E18 |
| 21.6        | 218.2    | 0.0425     | 2.557E18          | 9.189E23              | 221.6      | 222.6      | .0250        | .0213        | 5.4430E18              | 5.5755E18            | 5.5745E18 | 5.5755E18 |
| 21.7        | 218.4    | 0.0418     | 2.514E18          | 9.050E23              | 221.7      | 222.7      | .0247        | .0209        | 5.4054E18              | 5.5261E18            | 5.5255E18 | 5.5261E18 |
| 21.8        | 218.4    | 0.0412     | 2.466E18          | 8.909E23              | 221.8      | 222.8      | .0244        | .0206        | 5.3672E18              | 5.4768E18            | 5.4765E18 | 5.4768E18 |
| 21.9        | 218.5    | 0.0406     | 2.419E18          | 8.775E23              | 221.8      | 222.9      | .0241        | .0203        | 5.3284E18              | 5.4276E18            | 5.4275E18 | 5.4276E18 |
| 22.0        | 218.6    | 0.0400     | 2.373E18          | 8.643E23              | 221.9      | 223.0      | .0238        | .0200        | 5.2890E18              | 5.3785E18            | 5.3785E18 | 5.3785E18 |
| 22.1        | 218.7    | 0.0393     | 2.327E18          | 8.511E23              | 222.0      | 223.1      | .0234        | .0196        | 5.2490E18              | 5.3295E18            | 5.3295E18 | 5.3295E18 |
| 22.2        | 218.8    | 0.0387     | 2.281E18          | 8.379E23              | 222.1      | 223.2      | .0231        | .0193        | 5.2085E18              | 5.2805E18            | 5.2805E18 | 5.2805E18 |
| 22.3        | 218.9    | 0.0381     | 2.234E18          | 8.247E23              | 222.2      | 223.3      | .0227        | .0191        | 5.1675E18              | 5.2315E18            | 5.2315E18 | 5.2315E18 |
| 22.4        | 219.0    | 0.0375     | 2.186E18          | 8.115E23              | 222.3      | 223.4      | .0223        | .0188        | 5.1260E18              | 5.1825E18            | 5.1825E18 | 5.1825E18 |

| ALT<br>(KM) | T<br>(K) | P<br>(ATM) | COL. DEN.         |                       | T(.5)      |            | P(.5)        |              | COL. DEN. (4 Profiles) |                      |           |           |
|-------------|----------|------------|-------------------|-----------------------|------------|------------|--------------|--------------|------------------------|----------------------|-----------|-----------|
|             |          |            | H2O<br>(MOL/CM^2) | MIX GAS<br>(MOL/CM^2) | H2O<br>(K) | MIX<br>(K) | H2O<br>(ATM) | MIX<br>(ATM) | 9 LAT<br>O3            | 36 LAT<br>(MOL/CM^2) | 43 LAT    | 56 LAT    |
| 22.5        | 219.1    | 0.0369     | 2.141E18          | 7.989E23              | 222.4      | 223.6      | .0219        | .0184        | 5.0840E18              | 5.1335E18            | 5.1335E18 | 5.1335E18 |
| 22.6        | 219.2    | 0.0364     | 2.100E18          | 7.869E23              | 222.5      | 223.6      | .0216        | .0182        | 5.0415E18              | 5.0845E18            | 5.0845E18 | 5.0845E18 |
| 22.7        | 219.3    | 0.0358     | 2.060E18          | 7.749E23              | 222.6      | 223.7      | .0213        | .0179        | 4.9985E18              | 5.0355E18            | 5.0355E18 | 5.0355E18 |
| 22.8        | 219.4    | 0.0353     | 2.022E18          | 7.634E23              | 222.7      | 223.8      | .0210        | .0177        | 4.9550E18              | 4.9865E18            | 4.9865E18 | 4.9865E18 |
| 22.9        | 219.5    | 0.0347     | 1.984E18          | 7.518E23              | 222.8      | 223.9      | .0207        | .0173        | 4.9110E18              | 4.9375E18            | 4.9375E18 | 4.9375E18 |
| 23.0        | 219.6    | 0.0342     | 1.947E18          | 7.402E23              | 222.8      | 224.0      | .0205        | .0171        | 4.8665E18              | 4.8885E18            | 4.8885E18 | 4.8885E18 |
| 23.1        | 219.7    | 0.0337     | 1.910E18          | 7.286E23              | 222.9      | 224.1      | .0202        | .0169        | 4.8215E18              | 4.8395E18            | 4.8395E18 | 4.8395E18 |
| 23.2        | 219.8    | 0.0332     | 1.875E18          | 7.176E23              | 223.0      | 224.2      | .0200        | .0166        | 4.7761E18              | 4.7905E18            | 4.7905E18 | 4.7905E18 |
| 23.3        | 219.9    | 0.0327     | 1.840E18          | 7.069E23              | 223.1      | 224.3      | .0197        | .0163        | 4.7303E18              | 4.7415E18            | 4.7415E18 | 4.7415E18 |
| 23.4        | 220.0    | 0.0322     | 1.804E18          | 6.962E23              | 223.2      | 224.4      | .0195        | .0161        | 4.6841E18              | 4.6925E18            | 4.6925E18 | 4.6925E18 |
| 23.5        | 220.1    | 0.0317     | 1.767E18          | 6.856E23              | 223.3      | 224.5      | .0192        | .0159        | 4.6375E18              | 4.6435E18            | 4.6435E18 | 4.6435E18 |
| 23.6        | 220.2    | 0.0312     | 1.729E18          | 6.749E23              | 223.4      | 224.7      | .0189        | .0156        | 4.5905E18              | 4.5945E18            | 4.5945E18 | 4.5945E18 |
| 23.7        | 220.3    | 0.0307     | 1.693E18          | 6.645E23              | 223.5      | 224.8      | .0186        | .0154        | 4.5431E18              | 4.5455E18            | 4.5455E18 | 4.5455E18 |
| 23.8        | 220.4    | 0.0302     | 1.658E18          | 6.543E23              | 223.6      | 224.8      | .0184        | .0151        | 4.4953E18              | 4.4965E18            | 4.4965E18 | 4.4965E18 |
| 23.9        | 220.5    | 0.0298     | 1.624E18          | 6.441E23              | 223.7      | 224.9      | .0181        | .0149        | 4.4471E18              | 4.4475E18            | 4.4475E18 | 4.4475E18 |
| 24.0        | 220.6    | 0.0293     | 1.592E18          | 6.346E23              | 223.7      | 225.1      | .0179        | .0147        | 4.3985E18              | 4.3985E18            | 4.3985E18 | 4.3985E18 |
| 24.1        | 220.7    | 0.0289     | 1.560E18          | 6.250E23              | 223.8      | 225.2      | .0176        | .0144        | 4.3495E18              | 4.3495E18            | 4.3495E18 | 4.3495E18 |
| 24.2        | 220.8    | 0.0284     | 1.529E18          | 6.155E23              | 223.9      | 225.3      | .0174        | .0142        | 4.3004E18              | 4.3004E18            | 4.3004E18 | 4.3004E18 |
| 24.3        | 220.9    | 0.0280     | 1.499E18          | 6.060E23              | 224.0      | 225.3      | .0172        | .0140        | 4.2512E18              | 4.2512E18            | 4.2512E18 | 4.2512E18 |
| 24.4        | 221.0    | 0.0276     | 1.470E18          | 5.965E23              | 224.1      | 225.4      | .0169        | .0138        | 4.2019E18              | 4.2019E18            | 4.2019E18 | 4.2019E18 |
| 24.5        | 221.1    | 0.0271     | 1.441E18          | 5.878E23              | 224.2      | 225.6      | .0167        | .0136        | 4.1525E18              | 4.1525E18            | 4.1525E18 | 4.1525E18 |
| 24.6        | 221.2    | 0.0267     | 1.413E18          | 5.788E23              | 224.3      | 225.7      | .0165        | .0133        | 4.1030E18              | 4.1030E18            | 4.1030E18 | 4.1030E18 |
| 24.7        | 221.3    | 0.0263     | 1.384E18          | 5.701E23              | 224.3      | 225.8      | .0163        | .0132        | 4.0534E18              | 4.0534E18            | 4.0534E18 | 4.0534E18 |
| 24.8        | 221.4    | 0.0259     | 1.354E18          | 5.615E23              | 224.4      | 225.9      | .0161        | .0130        | 4.0037E18              | 4.0037E18            | 4.0037E18 | 4.0037E18 |
| 24.9        | 221.5    | 0.0255     | 1.323E18          | 5.530E23              | 224.5      | 226.0      | .0158        | .0127        | 3.9539E18              | 3.9539E18            | 3.9539E18 | 3.9539E18 |
| 25.0        | 221.6    | 0.0251     | 1.292E18          | 5.445E23              | 224.6      | 226.1      | .0156        | .0126        | 3.9040E18              | 3.9040E18            | 3.9040E18 | 3.9040E18 |
| 25.1        | 221.7    | 0.0248     | 1.261E18          | 5.361E23              | 224.7      | 226.2      | .0154        | .0124        | 3.8540E18              | 3.8540E18            | 3.8540E18 | 3.8540E18 |
| 25.2        | 221.8    | 0.0244     | 1.232E18          | 5.282E23              | 224.8      | 226.3      | .0151        | .0122        | 3.8046E18              | 3.8046E18            | 3.8046E18 | 3.8046E18 |
| 25.3        | 221.8    | 0.0240     | 1.204E18          | 5.203E23              | 224.9      | 226.4      | .0149        | .0120        | 3.7558E18              | 3.7558E18            | 3.7558E18 | 3.7558E18 |
| 25.4        | 221.9    | 0.0237     | 1.178E18          | 5.124E23              | 225.0      | 226.5      | .0147        | .0119        | 3.7076E18              | 3.7076E18            | 3.7076E18 | 3.7076E18 |
| 25.5        | 222.0    | 0.0233     | 1.155E18          | 5.048E23              | 225.1      | 226.6      | .0146        | .0116        | 3.6600E18              | 3.6600E18            | 3.6600E18 | 3.6600E18 |
| 25.6        | 222.1    | 0.0230     | 1.133E18          | 4.973E23              | 225.2      | 226.7      | .0143        | .0115        | 3.6130E18              | 3.6130E18            | 3.6130E18 | 3.6130E18 |
| 25.7        | 222.2    | 0.0226     | 1.113E18          | 4.898E23              | 225.3      | 226.8      | .0142        | .0113        | 3.5666E18              | 3.5666E18            | 3.5666E18 | 3.5666E18 |
| 25.8        | 222.3    | 0.0223     | 1.093E18          | 4.823E23              | 225.3      | 226.9      | .0141        | .0111        | 3.5208E18              | 3.5208E18            | 3.5208E18 | 3.5208E18 |
| 25.9        | 222.4    | 0.0219     | 1.073E18          | 4.748E23              | 225.4      | 227.0      | .0139        | .0110        | 3.4756E18              | 3.4756E18            | 3.4756E18 | 3.4756E18 |
| 26.0        | 222.5    | 0.0216     | 1.050E18          | 4.674E23              | 225.5      | 227.1      | .0137        | .0108        | 3.4310E18              | 3.4310E18            | 3.4310E18 | 3.4310E18 |
| 26.1        | 222.6    | 0.0213     | 1.028E18          | 4.606E23              | 225.6      | 227.2      | .0136        | .0106        | 3.3870E18              | 3.3870E18            | 3.3870E18 | 3.3870E18 |
| 26.2        | 222.7    | 0.0209     | 1.005E18          | 4.537E23              | 225.7      | 227.3      | .0134        | .0104        | 3.3431E18              | 3.3431E18            | 3.3431E18 | 3.3431E18 |
| 26.3        | 222.8    | 0.0206     | 9.824E17          | 4.469E23              | 225.7      | 227.4      | .0132        | .0103        | 3.2993E18              | 3.2993E18            | 3.2993E18 | 3.2993E18 |
| 26.4        | 222.9    | 0.0203     | 9.596E17          | 4.401E23              | 225.8      | 227.5      | .0131        | .0102        | 3.2556E18              | 3.2556E18            | 3.2556E18 | 3.2556E18 |
| 26.5        | 223.0    | 0.0200     | 9.372E17          | 4.332E23              | 225.9      | 227.5      | .0129        | .0100        | 3.2120E18              | 3.2120E18            | 3.2120E18 | 3.2120E18 |
| 26.6        | 223.1    | 0.0197     | 9.169E17          | 4.268E23              | 226.0      | 227.5      | .0127        | .0099        | 3.1685E18              | 3.1685E18            | 3.1685E18 | 3.1685E18 |
| 26.7        | 223.2    | 0.0194     | 8.975E17          | 4.205E23              | 226.1      | 227.6      | .0126        | .0097        | 3.1251E18              | 3.1251E18            | 3.1251E18 | 3.1251E18 |
| 26.8        | 223.3    | 0.0191     | 8.787E17          | 4.143E23              | 226.2      | 227.7      | .0124        | .0095        | 3.0818E18              | 3.0818E18            | 3.0818E18 | 3.0818E18 |
| 26.9        | 223.4    | 0.0188     | 8.603E17          | 4.081E23              | 226.3      | 227.8      | .0122        | .0094        | 3.0386E18              | 3.0386E18            | 3.0386E18 | 3.0386E18 |

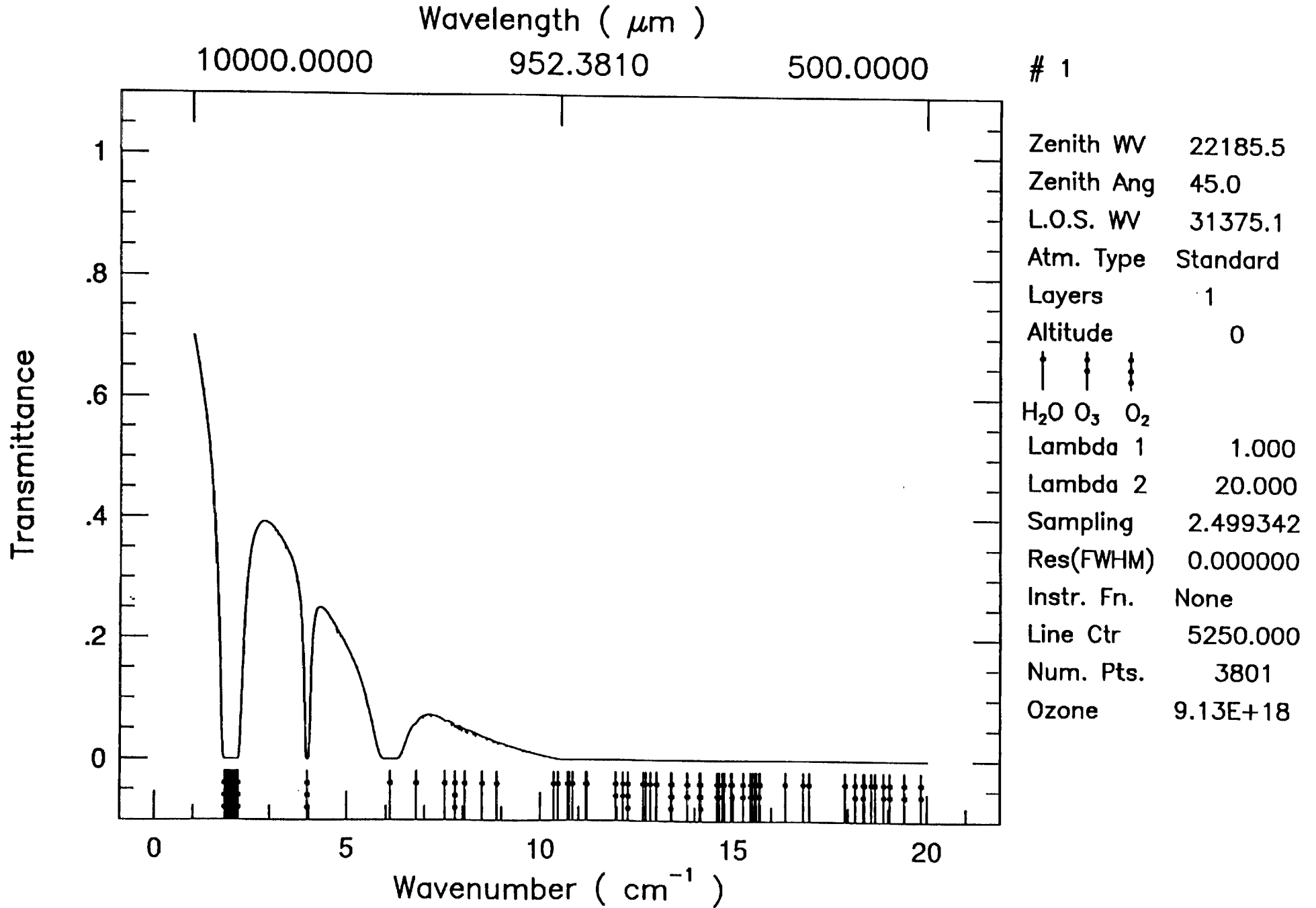


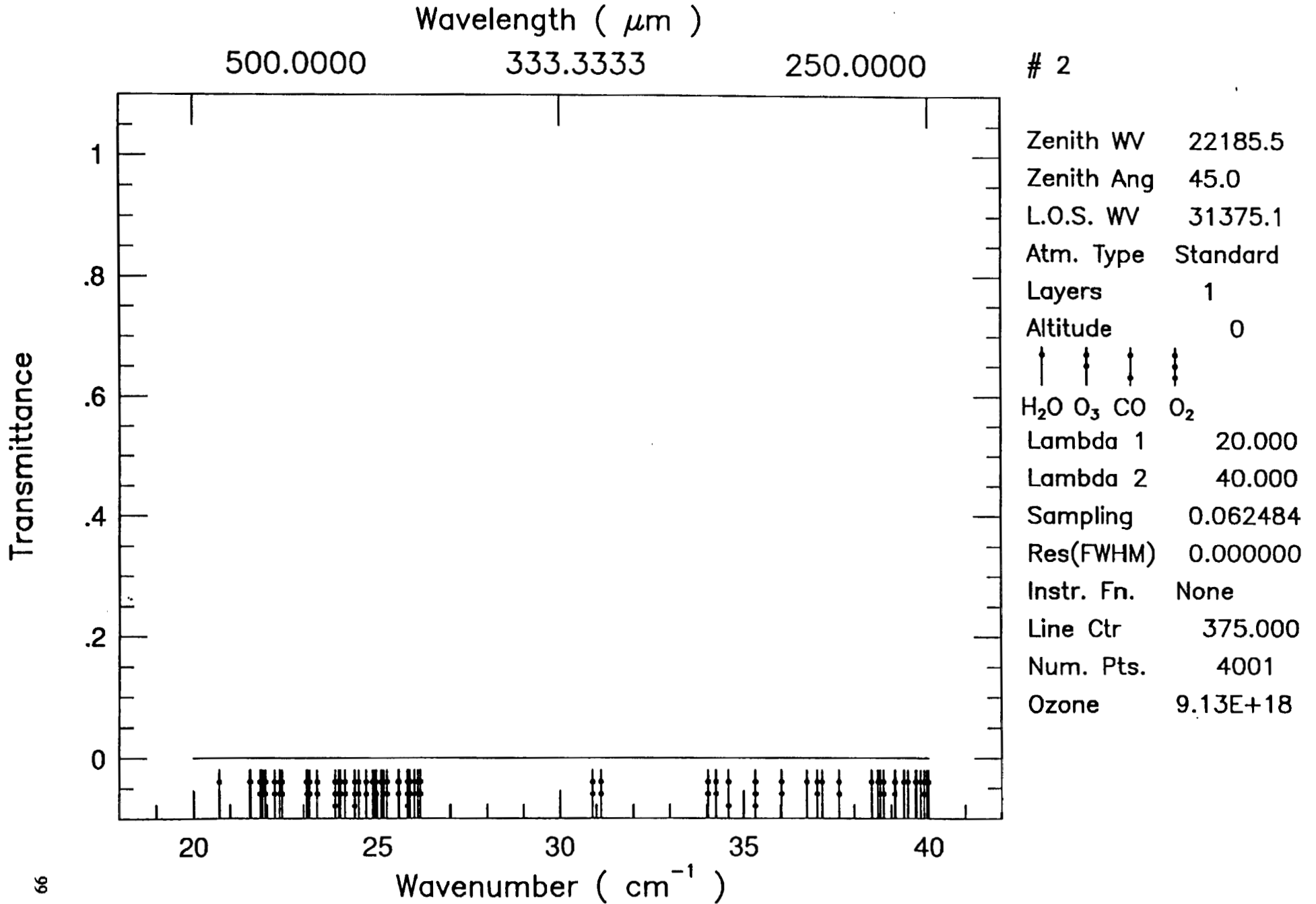
| ALT<br>(KM) | T<br>(K) | P<br>(ATM) | COL. DEN.         |                       | T(.5)      |            | P(.5)        |              | COL. DEN. (4 Profiles) |                      |           |           |
|-------------|----------|------------|-------------------|-----------------------|------------|------------|--------------|--------------|------------------------|----------------------|-----------|-----------|
|             |          |            | H2O<br>(MOL/CM^2) | MIX GAS<br>(MOL/CM^2) | H2O<br>(K) | MIX<br>(K) | H2O<br>(ATM) | MIX<br>(ATM) | 9 LAT<br>03            | 36 LAT<br>(MOL/CM^2) | 43 LAT    | 56 LAT    |
| 27.0        | 223.5    | 0.0186     | 8.420E17          | 4.020E23              | 226.4      | 227.9      | .0121        | .0093        | 2.9955E18              | 2.9955E18            | 2.9955E18 | 2.9955E18 |
| 27.1        | 223.6    | 0.0183     | 8.235E17          | 3.959E23              | 226.4      | 228.0      | .0119        | .0092        | 2.9525E18              | 2.9525E18            | 2.9525E18 | 2.9525E18 |
| 27.2        | 223.7    | 0.0180     | 8.046E17          | 3.898E23              | 226.5      | 228.2      | .0118        | .0090        | 2.9099E18              | 2.9099E18            | 2.9099E18 | 2.9099E18 |
| 27.3        | 223.8    | 0.0177     | 7.868E17          | 3.841E23              | 226.6      | 228.4      | .0117        | .0088        | 2.8677E18              | 2.8677E18            | 2.8677E18 | 2.8677E18 |
| 27.4        | 223.9    | 0.0175     | 7.691E17          | 3.784E23              | 226.7      | 228.6      | .0115        | .0088        | 2.8259E18              | 2.8259E18            | 2.8259E18 | 2.8259E18 |
| 27.5        | 224.0    | 0.0172     | 7.514E17          | 3.728E23              | 226.7      | 228.8      | .0114        | .0086        | 2.7845E18              | 2.7845E18            | 2.7845E18 | 2.7845E18 |
| 27.6        | 224.1    | 0.0169     | 7.341E17          | 3.672E23              | 226.8      | 229.0      | .0113        | .0084        | 2.7435E18              | 2.7435E18            | 2.7435E18 | 2.7435E18 |
| 27.7        | 224.2    | 0.0167     | 7.170E17          | 3.617E23              | 226.9      | 229.3      | .0112        | .0083        | 2.7029E18              | 2.7029E18            | 2.7029E18 | 2.7029E18 |
| 27.8        | 224.3    | 0.0164     | 6.998E17          | 3.562E23              | 227.0      | 229.5      | .0110        | .0082        | 2.6627E18              | 2.6627E18            | 2.6627E18 | 2.6627E18 |
| 27.9        | 224.4    | 0.0162     | 6.826E17          | 3.508E23              | 227.0      | 229.8      | .0109        | .0081        | 2.6229E18              | 2.6229E18            | 2.6229E18 | 2.6229E18 |
| 28.0        | 224.5    | 0.0159     | 6.668E17          | 3.456E23              | 227.1      | 230.1      | .0108        | .0080        | 2.5835E18              | 2.5835E18            | 2.5835E18 | 2.5835E18 |
| 28.1        | 224.6    | 0.0157     | 6.513E17          | 3.405E23              | 227.2      | 230.3      | .0106        | .0078        | 2.5445E18              | 2.5445E18            | 2.5445E18 | 2.5445E18 |
| 28.2        | 224.7    | 0.0155     | 6.363E17          | 3.353E23              | 227.4      | 230.6      | .0104        | .0077        | 2.5061E18              | 2.5061E18            | 2.5061E18 | 2.5061E18 |
| 28.3        | 224.8    | 0.0152     | 6.219E17          | 3.303E23              | 227.5      | 230.9      | .0102        | .0076        | 2.4683E18              | 2.4683E18            | 2.4683E18 | 2.4683E18 |
| 28.4        | 224.9    | 0.0150     | 6.076E17          | 3.254E23              | 227.5      | 231.2      | .0100        | .0075        | 2.4311E18              | 2.4311E18            | 2.4311E18 | 2.4311E18 |
| 28.5        | 225.0    | 0.0148     | 5.931E17          | 3.204E23              | 227.5      | 231.5      | .0099        | .0074        | 2.3945E18              | 2.3945E18            | 2.3945E18 | 2.3945E18 |
| 28.6        | 225.1    | 0.0146     | 5.788E17          | 3.157E23              | 227.5      | 231.8      | .0099        | .0073        | 2.3585E18              | 2.3585E18            | 2.3585E18 | 2.3585E18 |
| 28.7        | 225.2    | 0.0143     | 5.642E17          | 3.109E23              | 227.5      | 232.1      | .0099        | .0071        | 2.3231E18              | 2.3231E18            | 2.3231E18 | 2.3231E18 |
| 28.8        | 225.3    | 0.0141     | 5.496E17          | 3.063E23              | 227.5      | 232.3      | .0099        | .0071        | 2.2883E18              | 2.2883E18            | 2.2883E18 | 2.2883E18 |
| 28.9        | 225.4    | 0.0139     | 5.357E17          | 3.019E23              | 227.5      | 232.6      | .0099        | .0069        | 2.2541E18              | 2.2541E18            | 2.2541E18 | 2.2541E18 |
| 29.0        | 225.5    | 0.0137     | 5.221E17          | 2.975E23              | 227.5      | 232.9      | .0099        | .0069        | 2.2205E18              | 2.2205E18            | 2.2205E18 | 2.2205E18 |
| 29.1        | 225.6    | 0.0135     | 5.086E17          | 2.930E23              | 227.5      | 233.2      | .0099        | .0068        | 2.1875E18              | 2.1875E18            | 2.1875E18 | 2.1875E18 |

## APPENDIX E

### TRANSMITTANCE AT SEA LEVEL

We show the transmittance at sea-level. The plots are numbered from 1 to 45 covering 10,000  $\mu\text{m}$  to 0.8  $\mu\text{m}$ .





Transmittance

Wavelength (  $\mu\text{m}$  )

250.0000

200.0000

166.6667

# 3



40

45

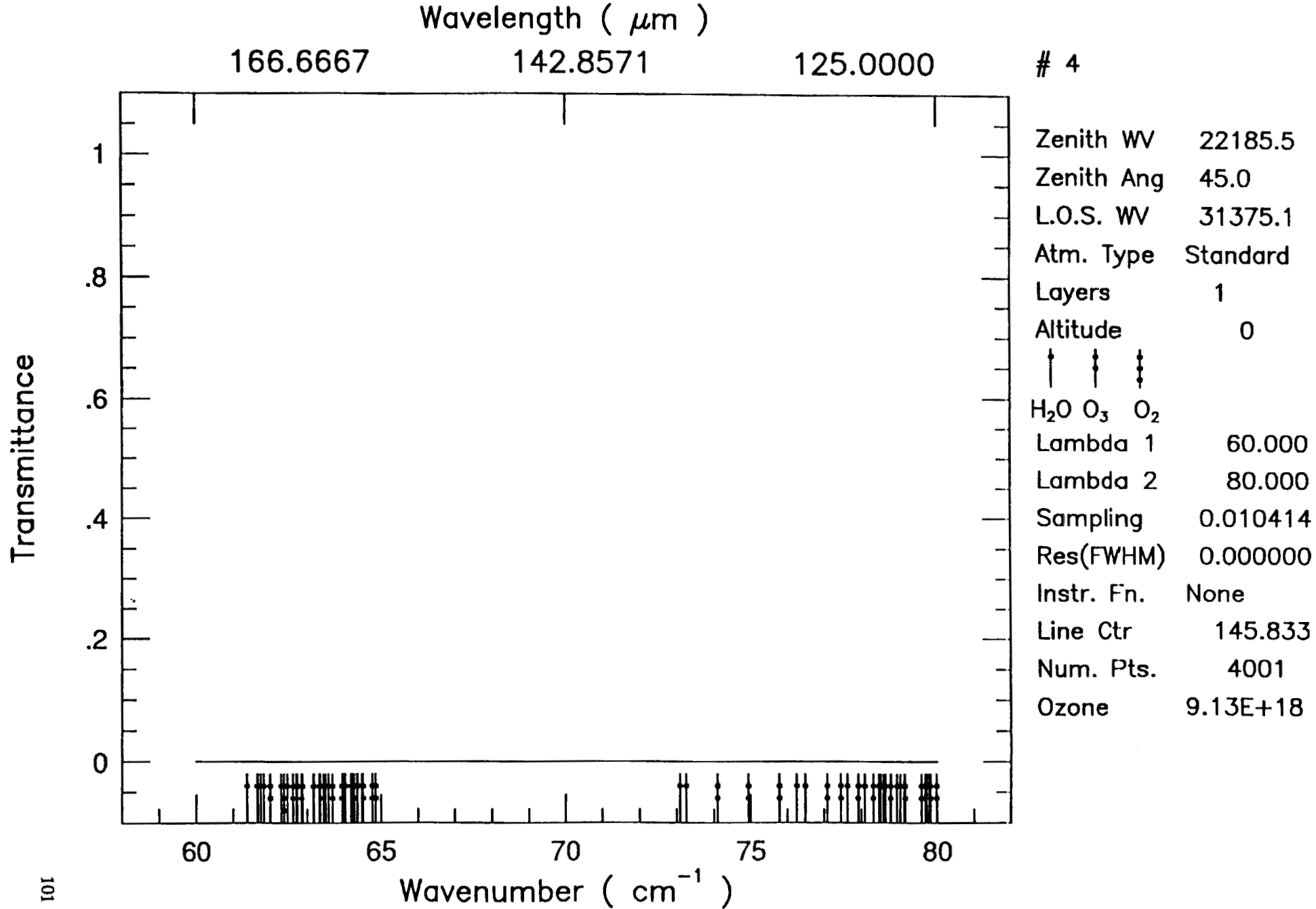
50

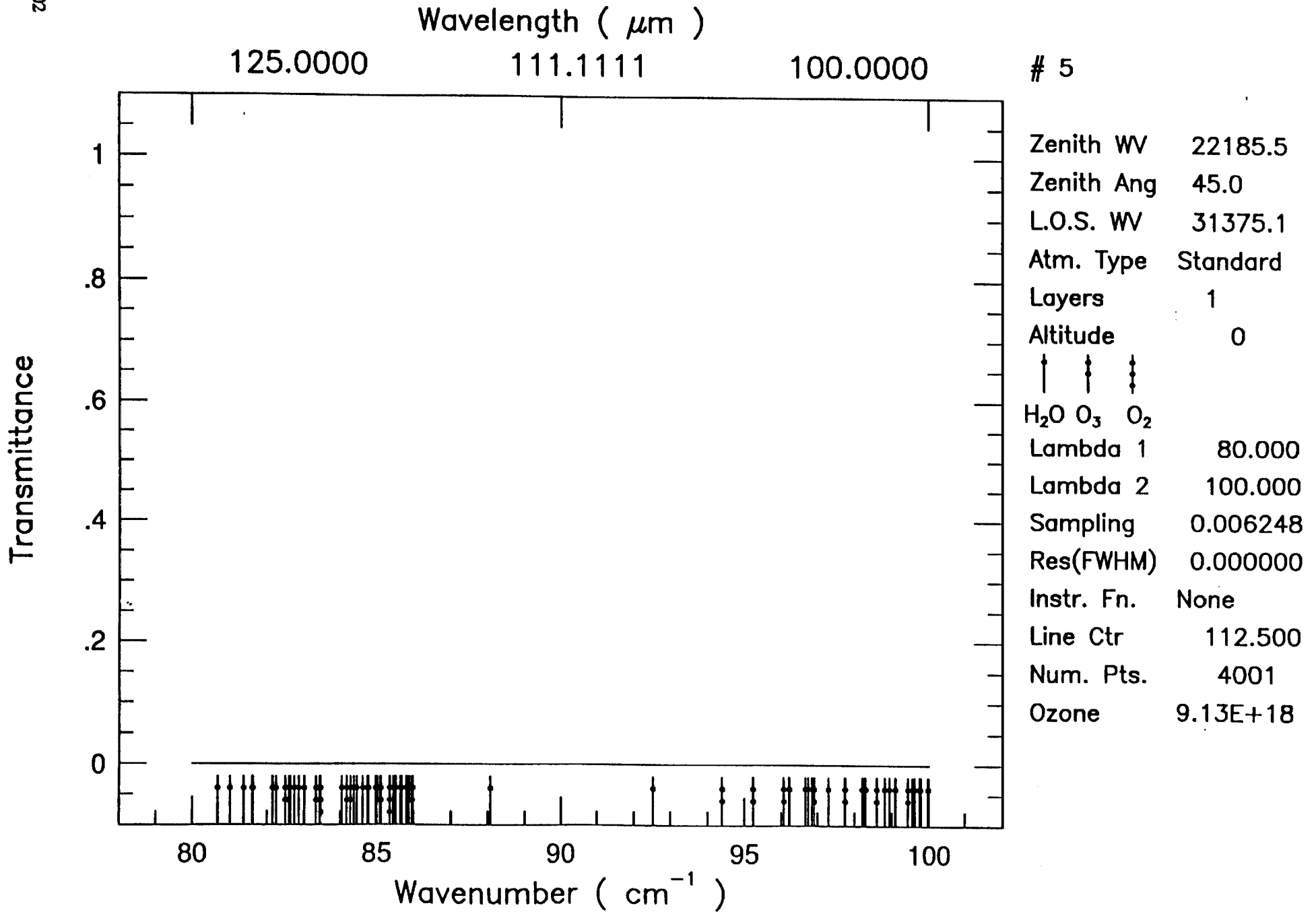
55

60

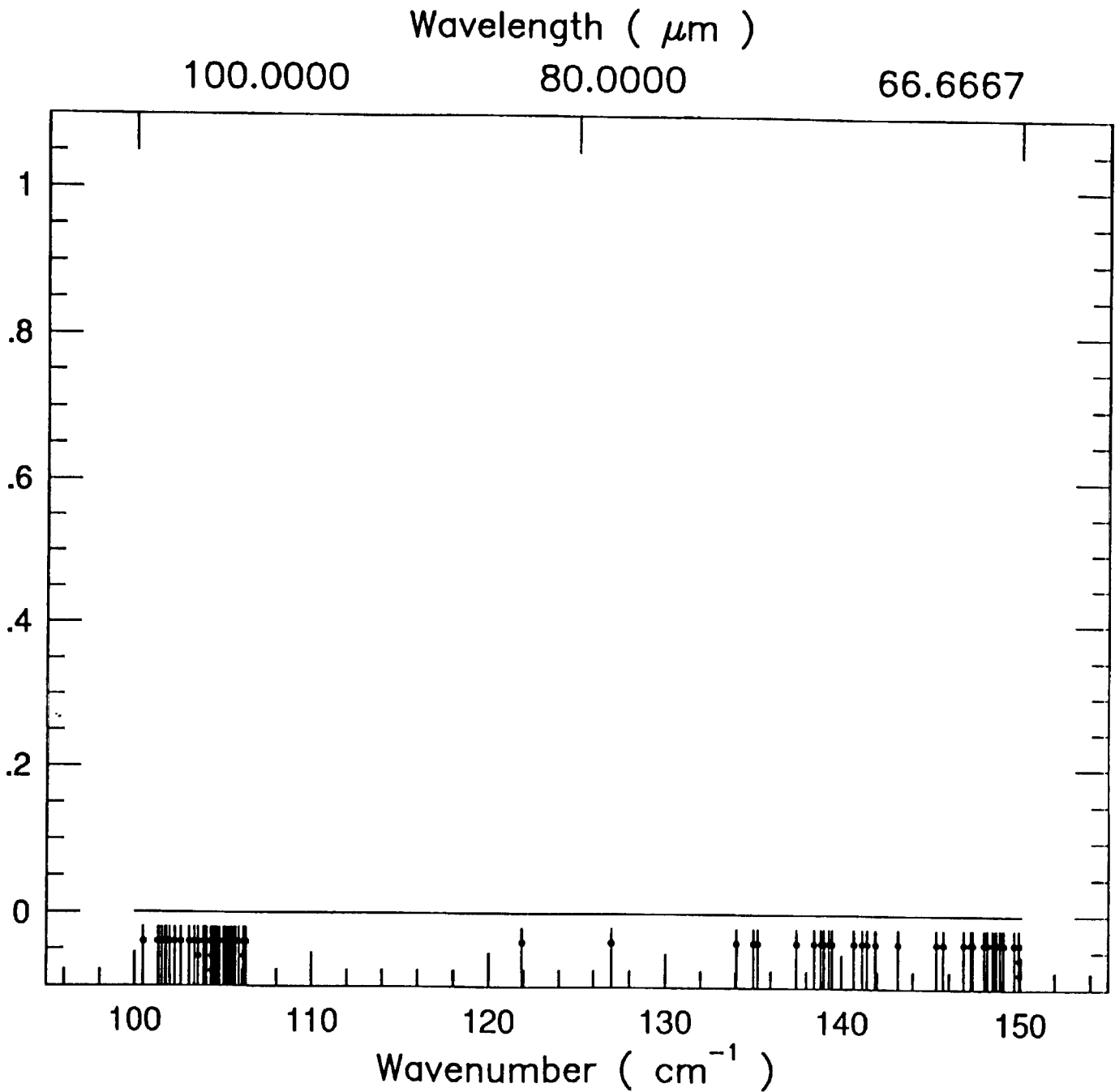
Wavenumber (  $\text{cm}^{-1}$  )

|  |          |
|--|----------|
| Zenith WV  | 22185.5  |
| Zenith Ang                                       | 45.0     |
| L.O.S. WV  | 31375.1  |
| Atm. Type  | Standard |
| Layers   | 1        |
| Altitude   | 0        |
| ↑   ↑   ↓  |          |
| H <sub>2</sub> O   O <sub>3</sub> O <sub>2</sub> |          |
| Lambda 1   | 40.000   |
| Lambda 2   | 60.000   |
| Sampling   | 0.020828 |
| Res(FWHM)  | 0.000000 |
| Instr. Fn.                                       | None     |
| Line Ctr   | 208.333  |
| Num. Pts.  | 4001     |
| Ozone  | 9.13E+18 |



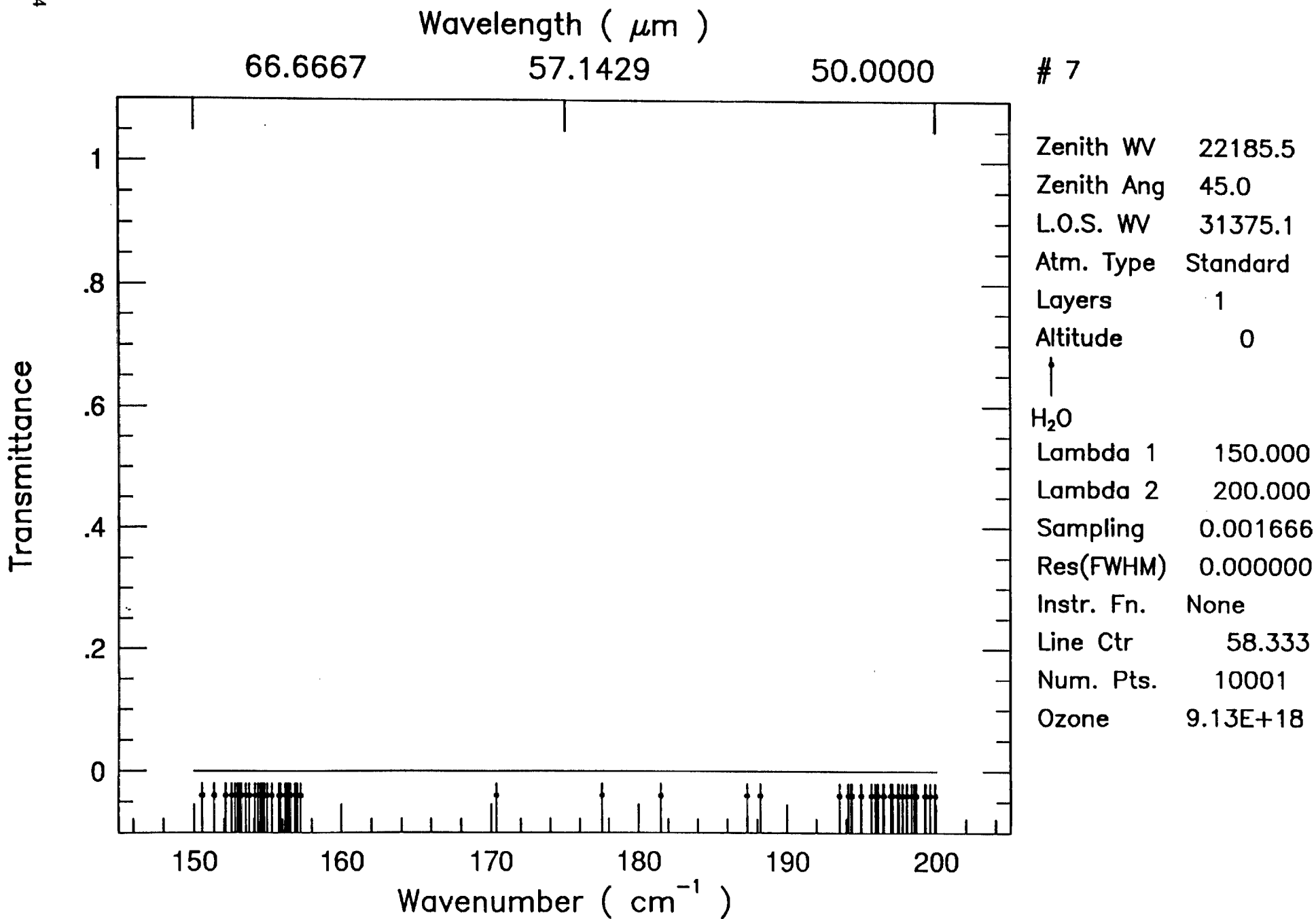


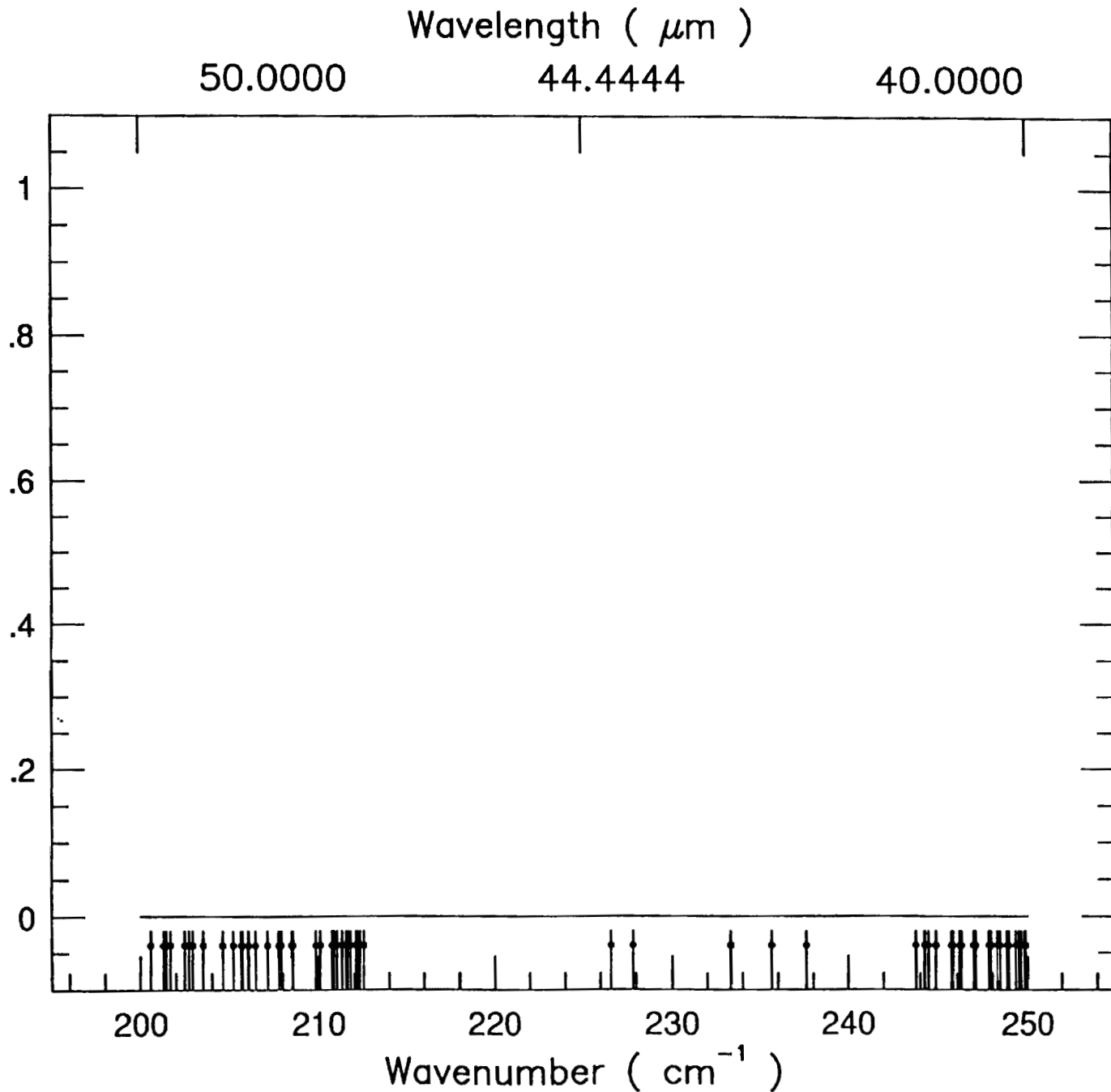
Wed Oct 23 15:57:17 1991



|  |          |
|--|----------|
| Zenith WV                                      | 22185.5  |
| Zenith Ang                                     | 45.0     |
| L.O.S. WV                                      | 31375.1  |
| Atm. Type                                      | Standard |
| Layers   | 1        |
| Altitude                                       | 0        |
| ↑    ↑    ↑                                    |          |
| H <sub>2</sub> O O <sub>3</sub> O <sub>2</sub> |          |
| Lambda 1                                       | 100.000  |
| Lambda 2                                       | 150.000  |
| Sampling                                       | 0.003333 |
| Res(FWHM)                                      | 0.000000 |
| Instr. Fr.                                     | None     |
| Line Ctr                                       | 83.333   |
| Num. Pts.                                      | 10001    |
| Ozone  | 9.13E+18 |

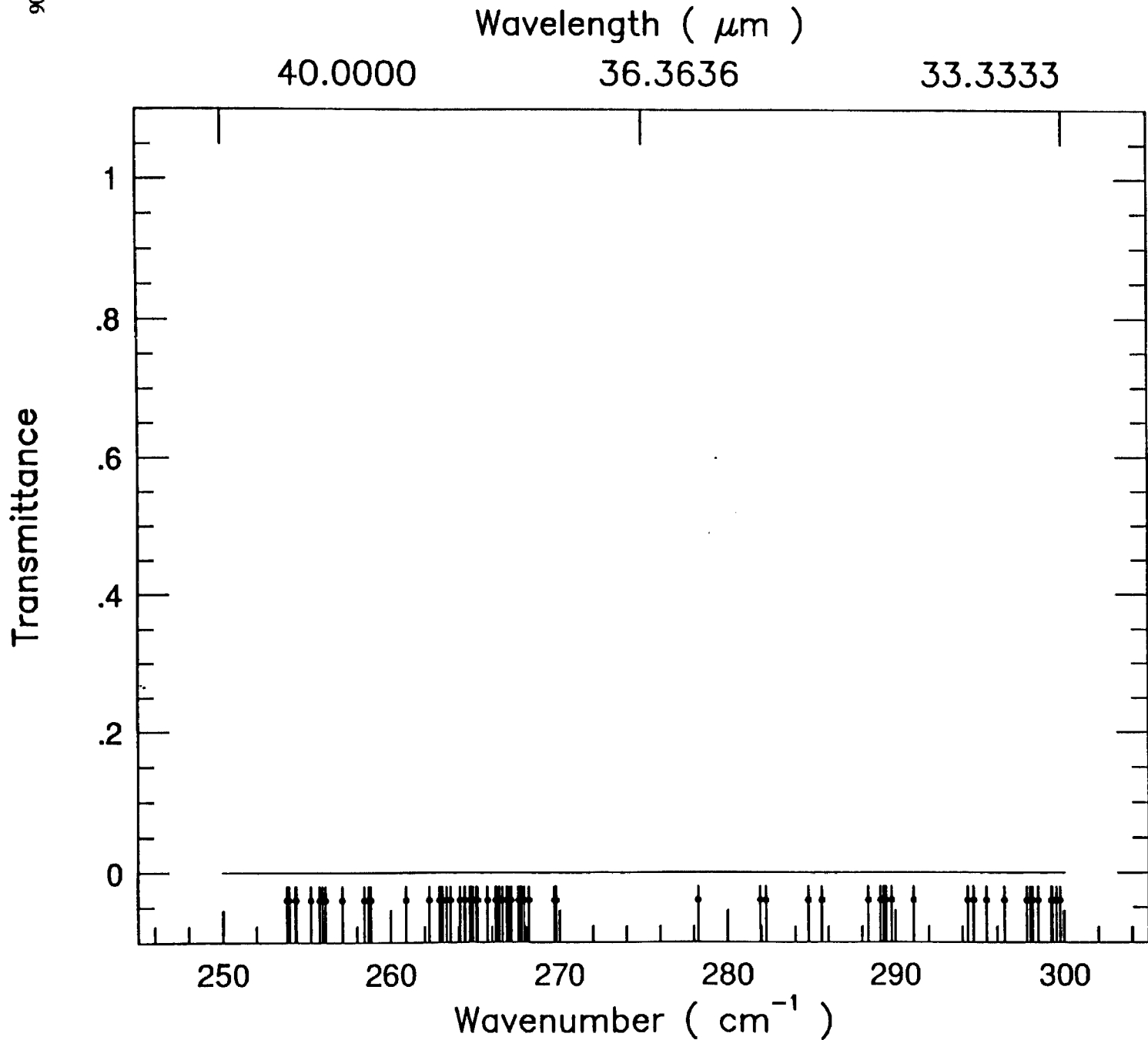






# 8

|                  |          |
|------------------|----------|
| Zenith WV        | 22185.5  |
| Zenith Ang       | 45.0     |
| L.O.S. WV        | 31375.1  |
| Atm. Type        | Standard |
| Layers           | 1        |
| Altitude         | 0        |
| ↑                |          |
| H <sub>2</sub> O |          |
| Lambda 1         | 200.000  |
| Lambda 2         | 250.000  |
| Sampling         | 0.001000 |
| Res(FWHM)        | 0.000000 |
| Instr. Fn.       | None     |
| Line Ctr         | 45.000   |
| Num. Pts.        | 10001    |
| Ozone            | 9.13E+18 |



# 9

|                  |          |
|------------------|----------|
| Zenith WV        | 22185.5  |
| Zenith Ang       | 45.0     |
| L.O.S. WV        | 31375.1  |
| Atm. Type        | Standard |
| Layers           | 1        |
| Altitude         | 0        |
| ↑                |          |
| H <sub>2</sub> O |          |
| Lambda 1         | 250.000  |
| Lambda 2         | 300.000  |
| Sampling         | 0.000667 |
| Res(FWHM)        | 0.000000 |
| Instr. Fn.       | None     |
| Line Ctr         | 36.667   |
| Num. Pts.        | 10001    |
| Ozone            | 9.13E+18 |

Wavelength (  $\mu\text{m}$  )

33.3333

30.7692

28.5714

#10



|                  |          |
|------------------|----------|
| Zenith WV        | 22185.5  |
| Zenith Ang       | 45.0     |
| L.O.S. WV        | 31375.1  |
| Atm. Type        | Standard |
| Layers           | 1        |
| Altitude         | 0        |
| ↑                |          |
| H <sub>2</sub> O |          |
| Lambda 1         | 300.000  |
| Lambda 2         | 350.000  |
| Sampling         | 0.000476 |
| Res(FWHM)        | 0.000000 |
| Instr. Fn.       | None     |
| Line Ctr         | 30.952   |
| Num. Pts.        | 10001    |
| Ozone            | 9.13E+18 |

300

310

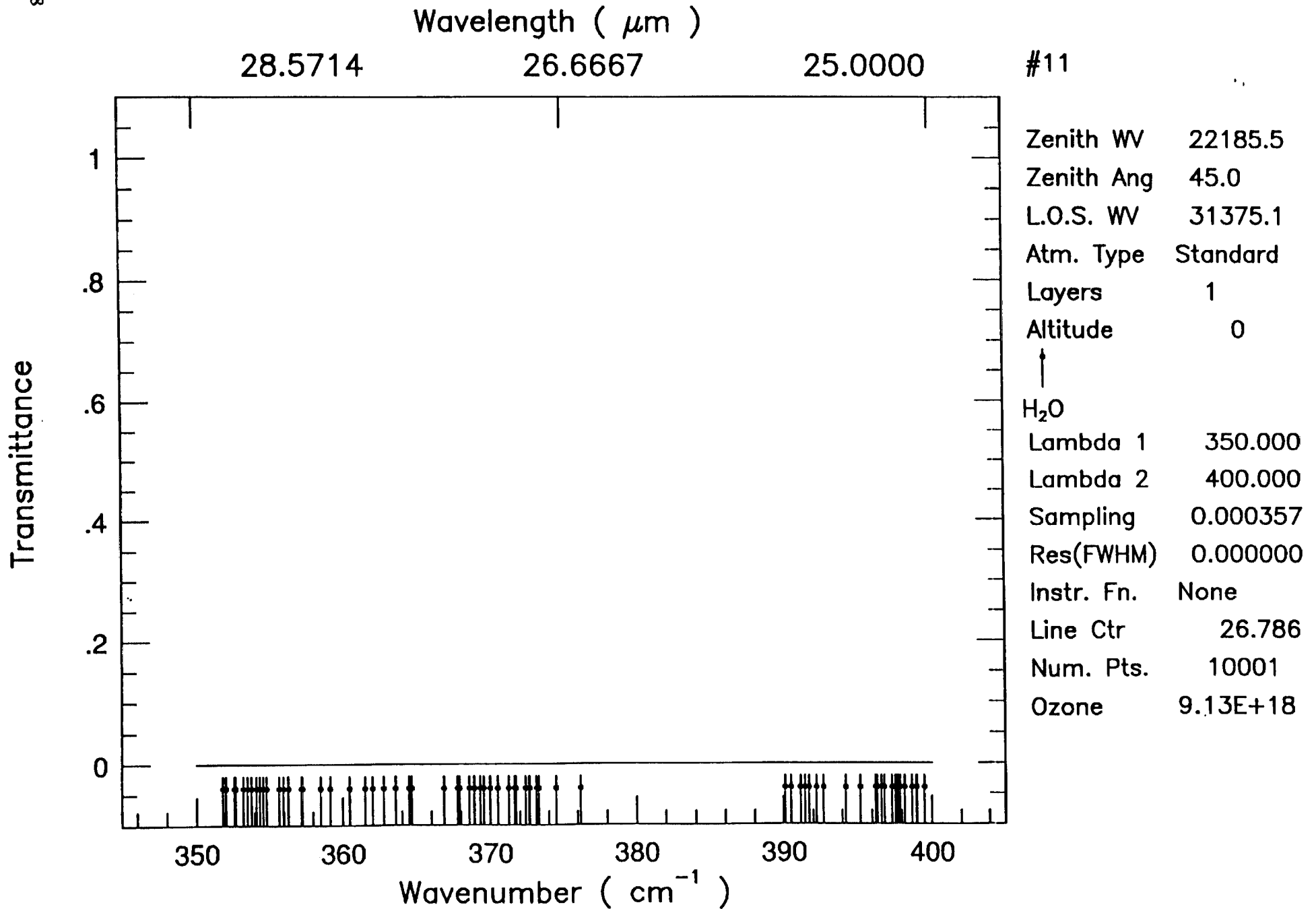
320

330

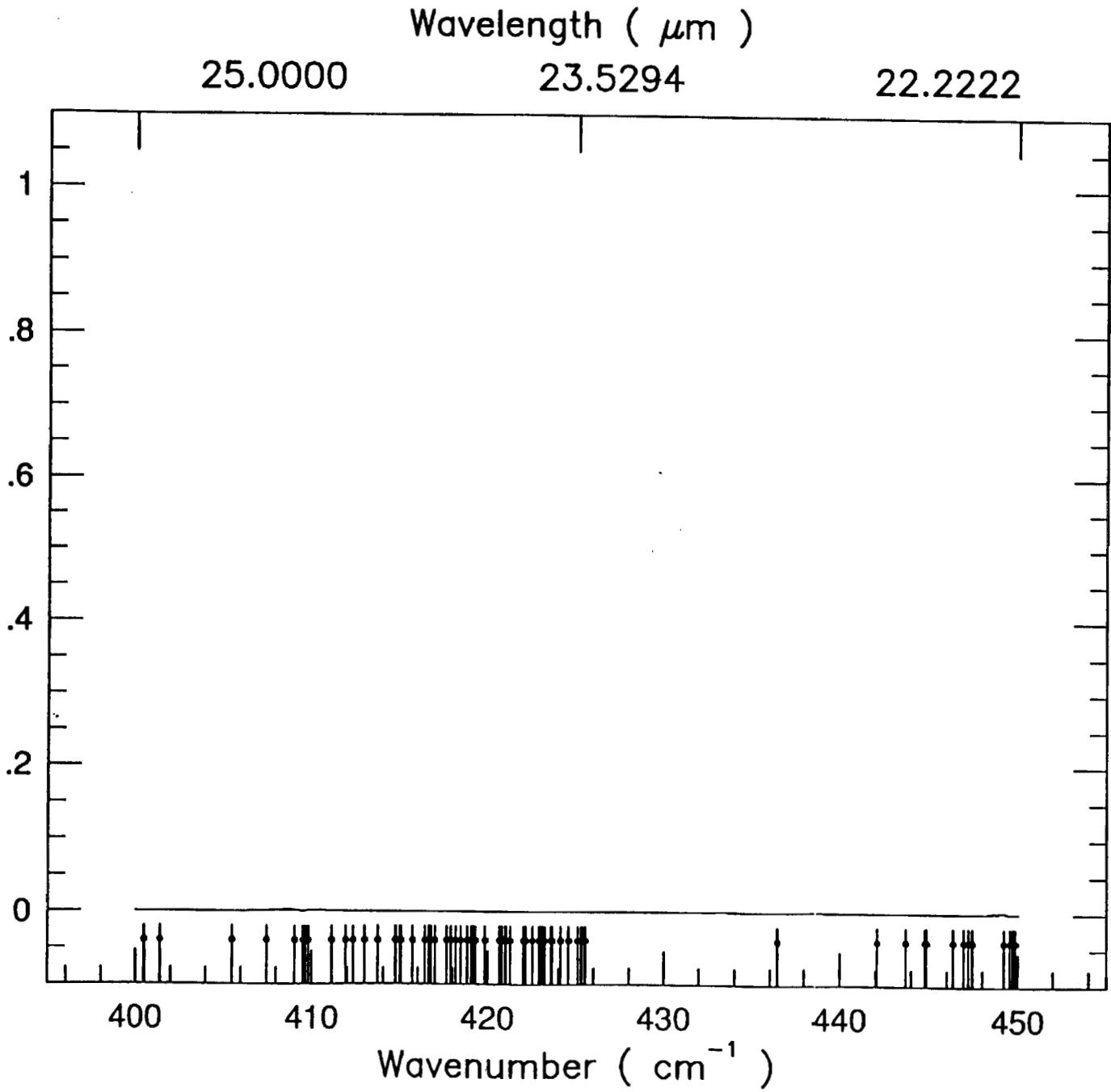
340

350

Wavenumber (  $\text{cm}^{-1}$  )

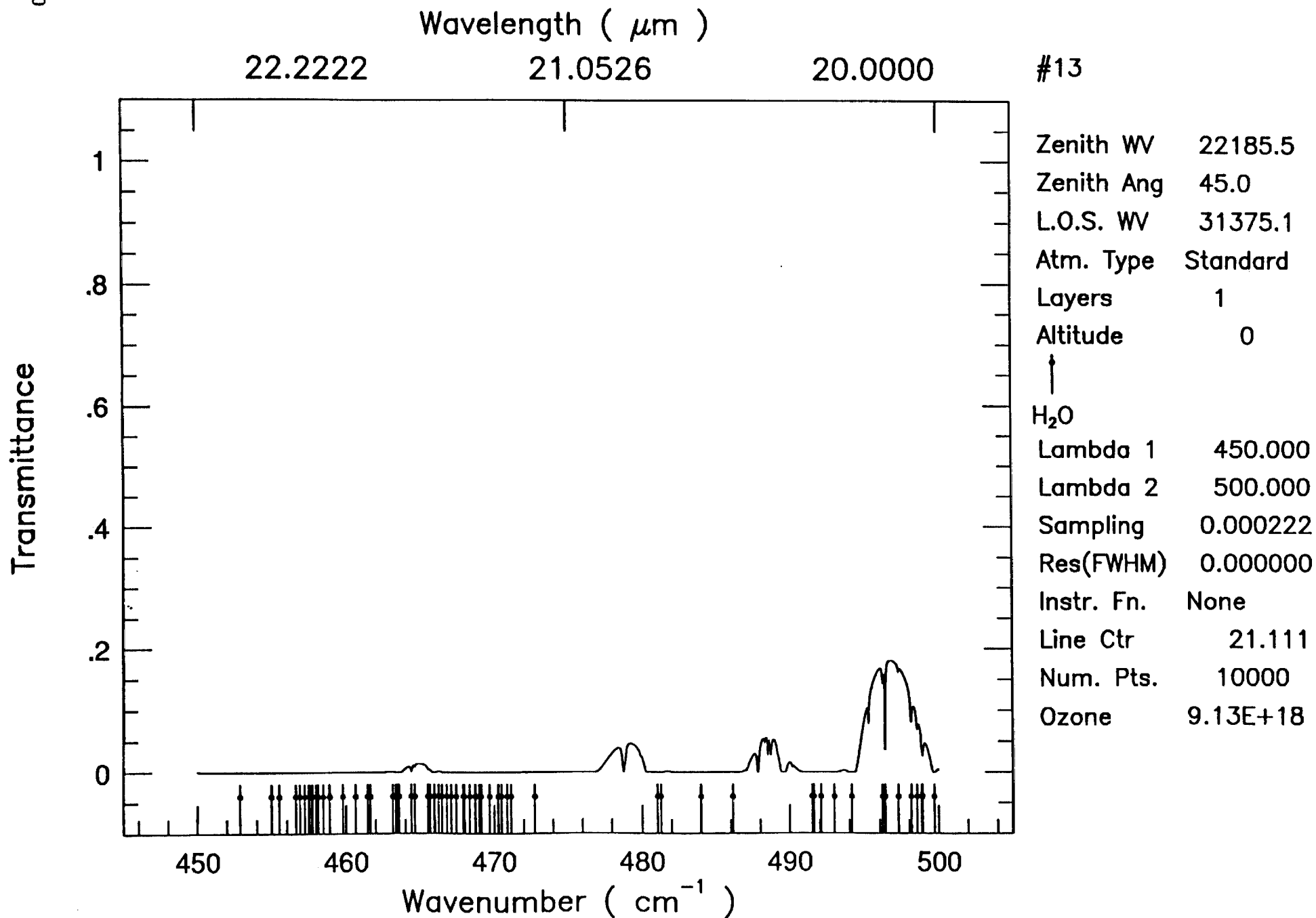


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#12

|                  |          |
|------------------|----------|
| Zenith WV        | 22185.5  |
| Zenith Ang       | 45.0     |
| L.O.S. WV        | 31375.1  |
| Atm. Type        | Standard |
| Layers           | 1        |
| Altitude         | 0        |
| ↑                |          |
| H <sub>2</sub> O |          |
| Lambda 1         | 400.000  |
| Lambda 2         | 450.000  |
| Sampling         | 0.000278 |
| Res(FWHM)        | 0.000000 |
| Instr. Fn.       | None     |
| Line Ctr         | 23.611   |
| Num. Pts.        | 10001    |
| Ozone            | 9.13E+18 |



Wed Oct 23 16:15:30 1991

Transmittance

Wavelength (  $\mu\text{m}$  )

20.0000

19.0476

18.1818

#14

Zenith WV 22185.5

Zenith Ang 45.0

L.O.S. WV 31375.1

Atm. Type Standard

Layers 1

Altitude 0

↑ ↓  
H<sub>2</sub>O CO<sub>2</sub>

Lambda 1 500.000

Lambda 2 550.000

Sampling 0.000182

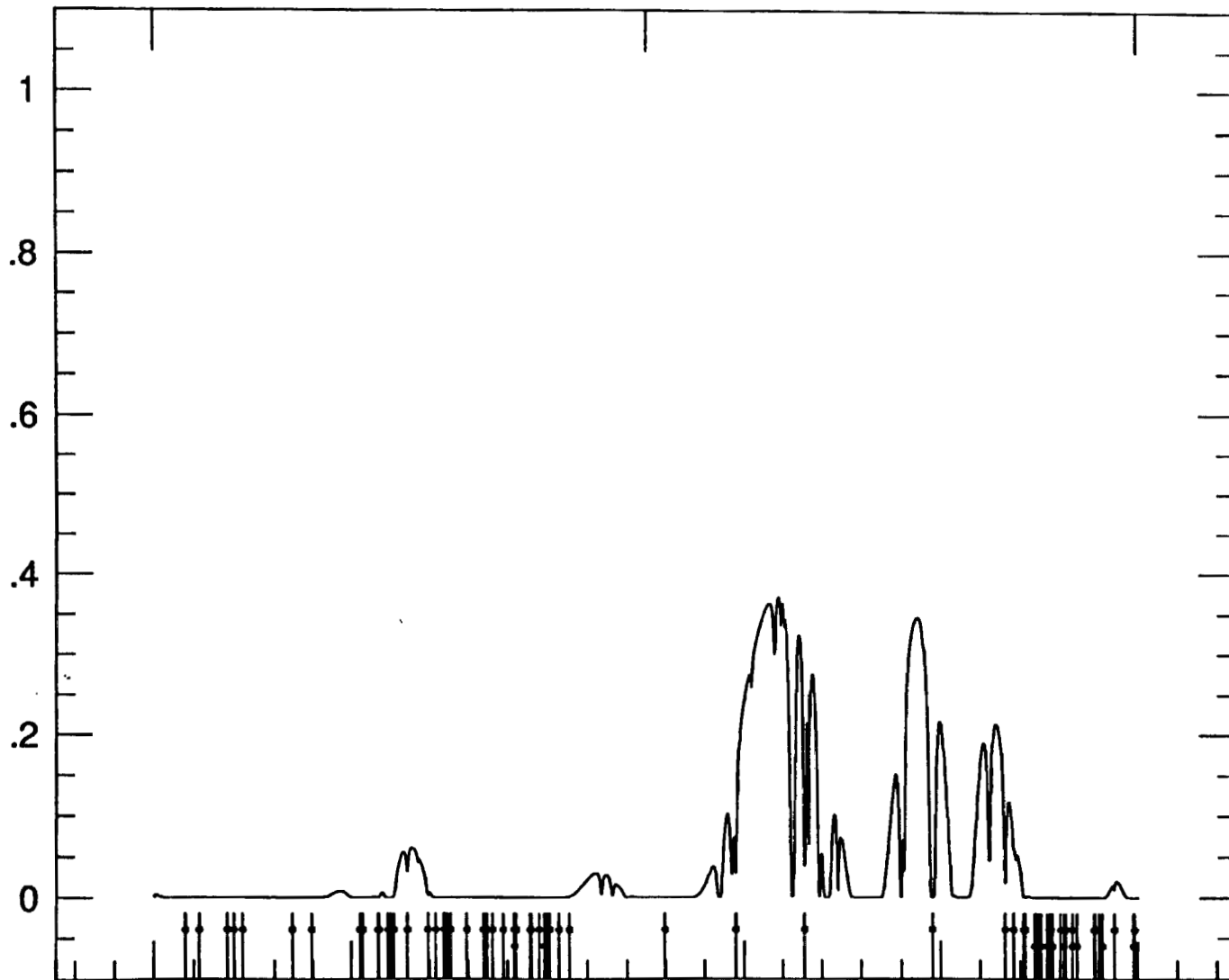
Res(FWHM) 0.000000

Instr. Fn. None

Line Ctr 19.091

Num. Pts. 10001

Ozone 9.13E+18



500

510

520

530

540

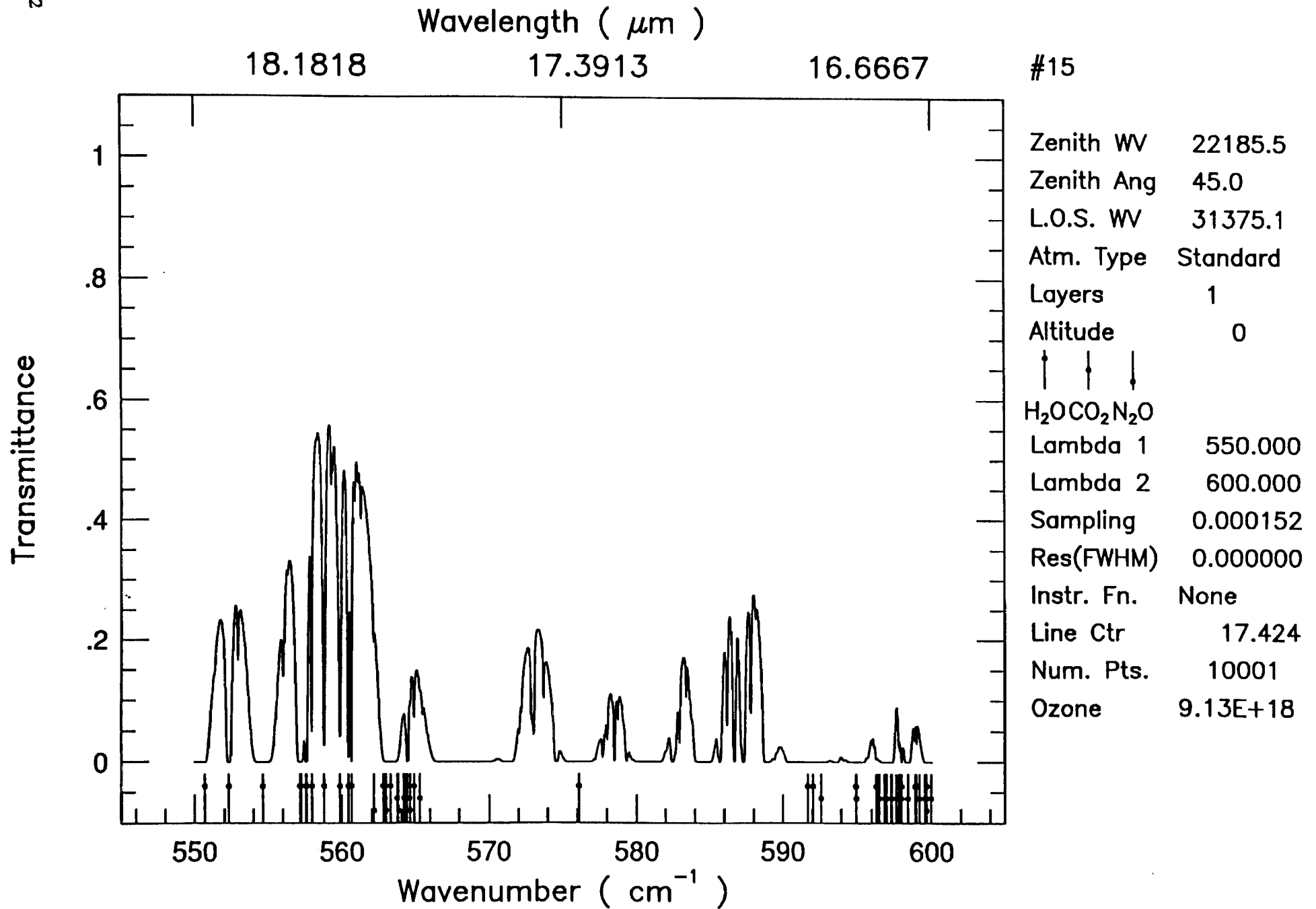
550

Wavenumber (  $\text{cm}^{-1}$  )

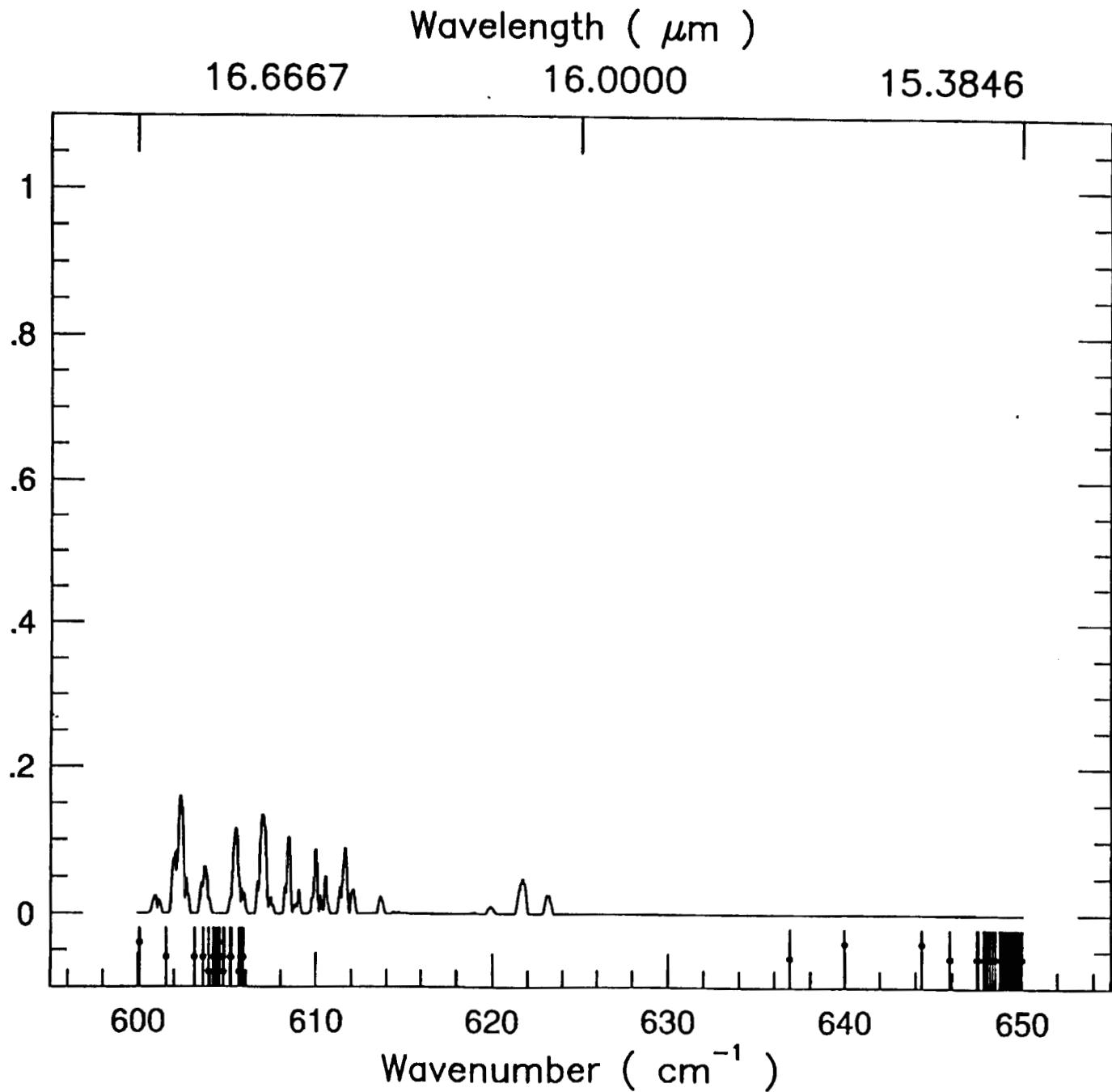
111

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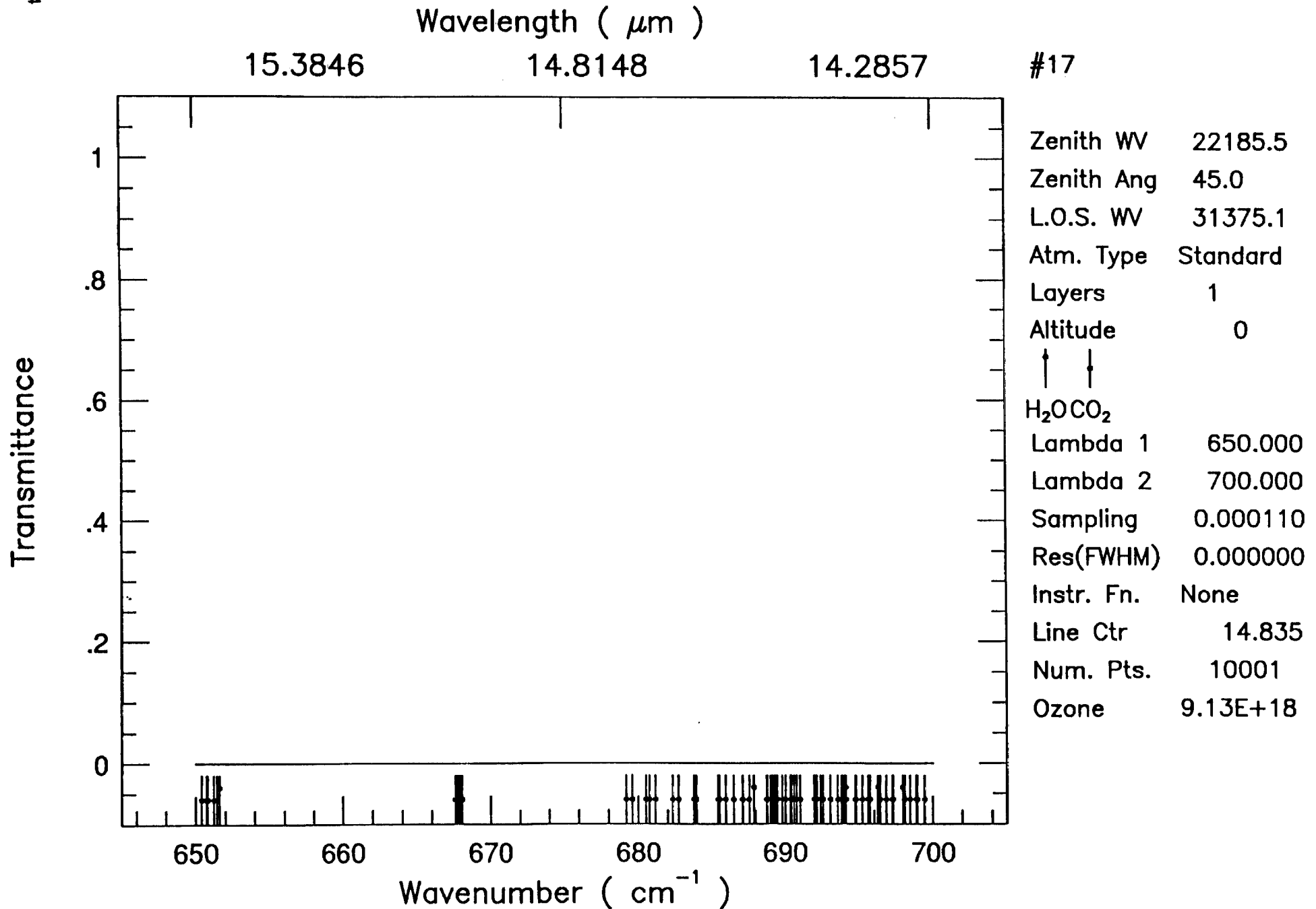


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#16

|   |          |
|---|----------|
| Zenith WV   | 22185.5  |
| Zenith Ang  | 45.0     |
| L.O.S. WV   | 31375.1  |
| Atm. Type   | Standard |
| Layers  | 1        |
| Altitude  | 0        |
| ↑     ↓     ↓                                     |          |
| H <sub>2</sub> O CO <sub>2</sub> N <sub>2</sub> O |          |
| Lambda 1  | 600.000  |
| Lambda 2  | 650.000  |
| Sampling  | 0.000128 |
| Res(FWHM)   | 0.000000 |
| Instr. Fn.  | None     |
| Line Ctr  | 16.026   |
| Num. Pts.   | 10001    |
| Ozone   | 9.13E+18 |



Wed Oct 23 16:29:37 1991

Transmittance

Wavelength (  $\mu\text{m}$  )

14.2857

13.7931

13.3333

#18

Zenith WV 22185.5

Zenith Ang 45.0

L.O.S. WV 31375.1

Atm. Type Standard

Layers 1

Altitude 0

H<sub>2</sub>O CO<sub>2</sub> O<sub>3</sub>

Lambda 1 700.000

Lambda 2 750.000

Sampling 0.000095

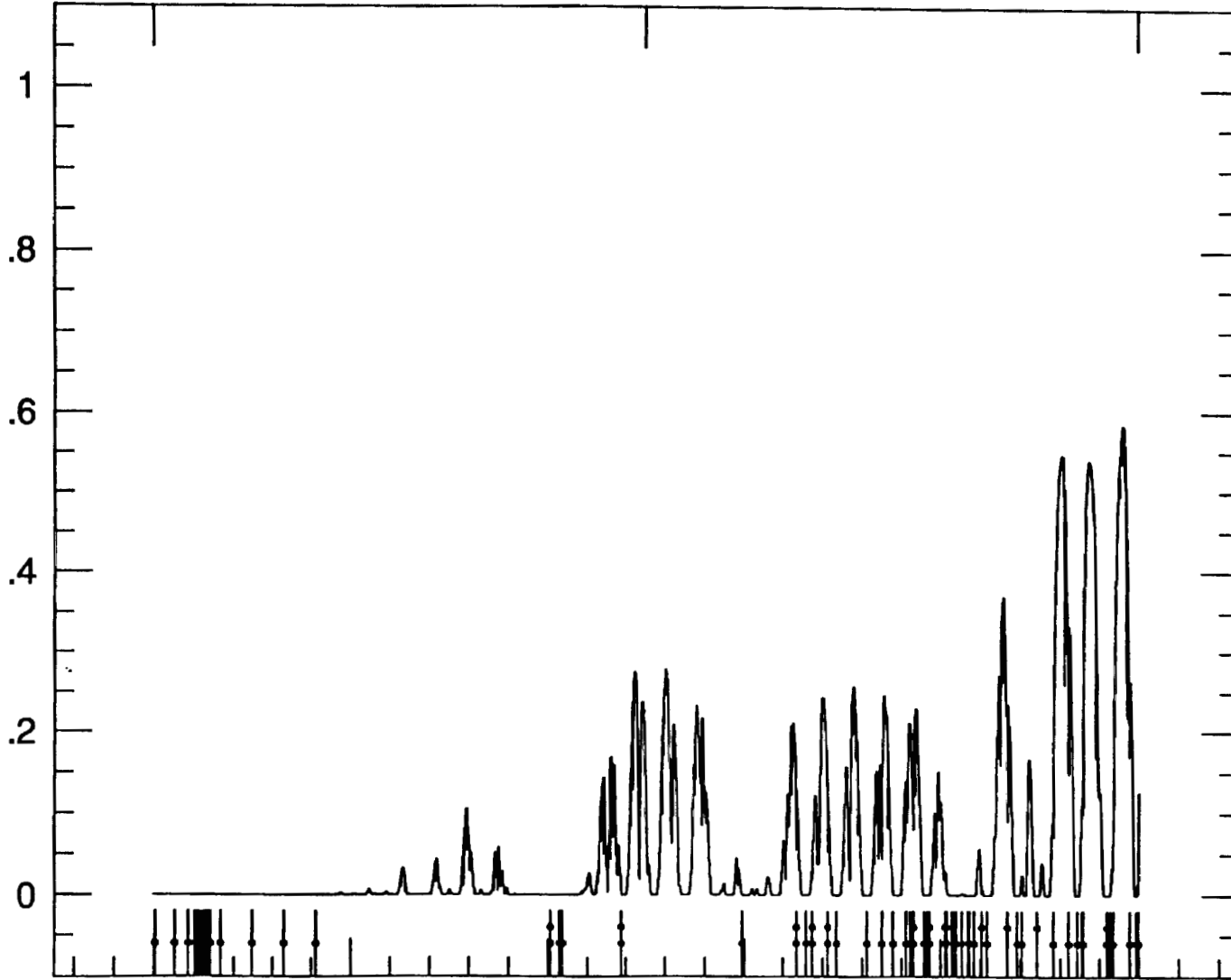
Res(FWHM) 0.000000

Instr. Fn. None

Line Ctr 13.810

Num. Pts. 10001

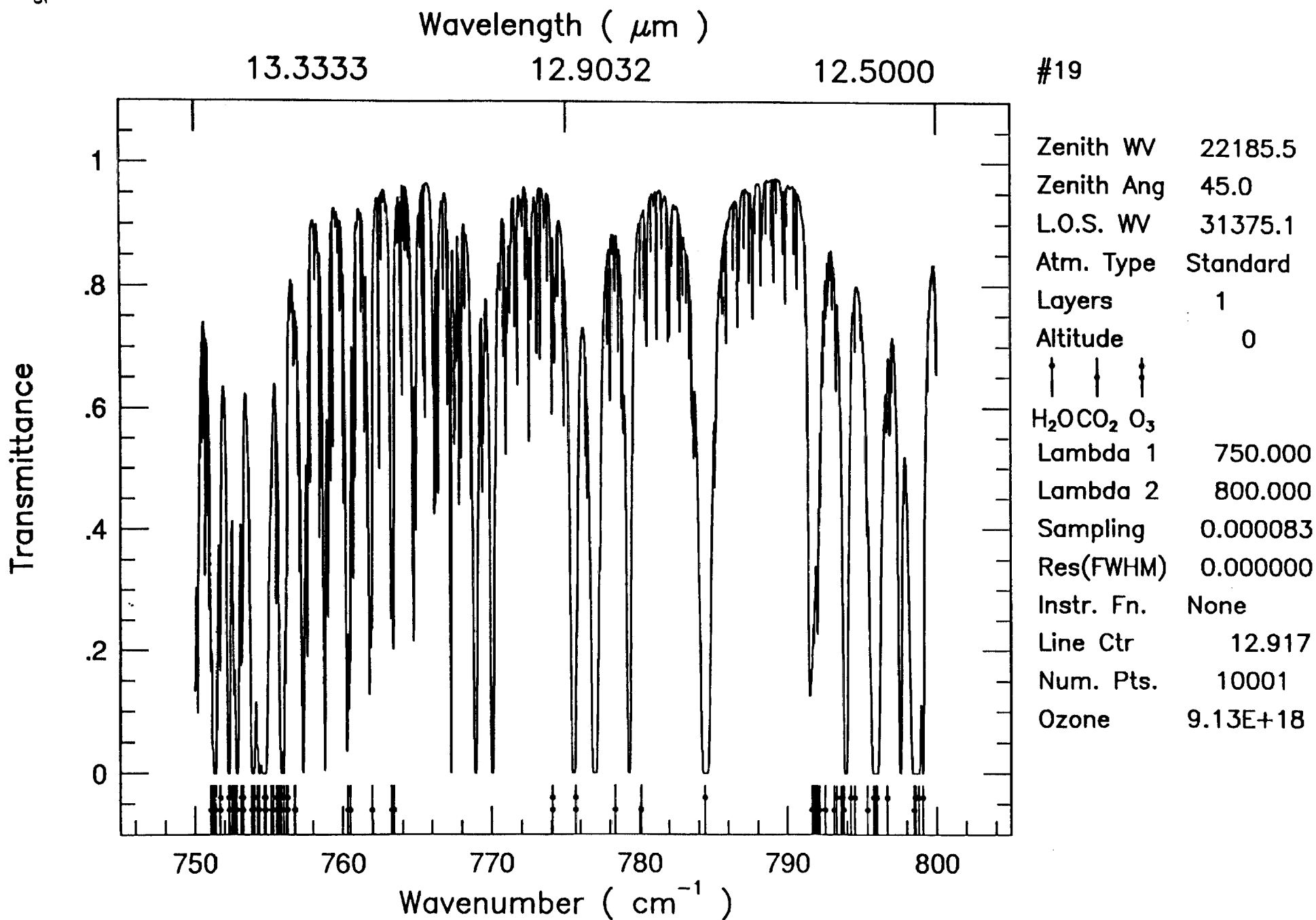
Ozone 9.13E+18



700 710 720 730 740 750

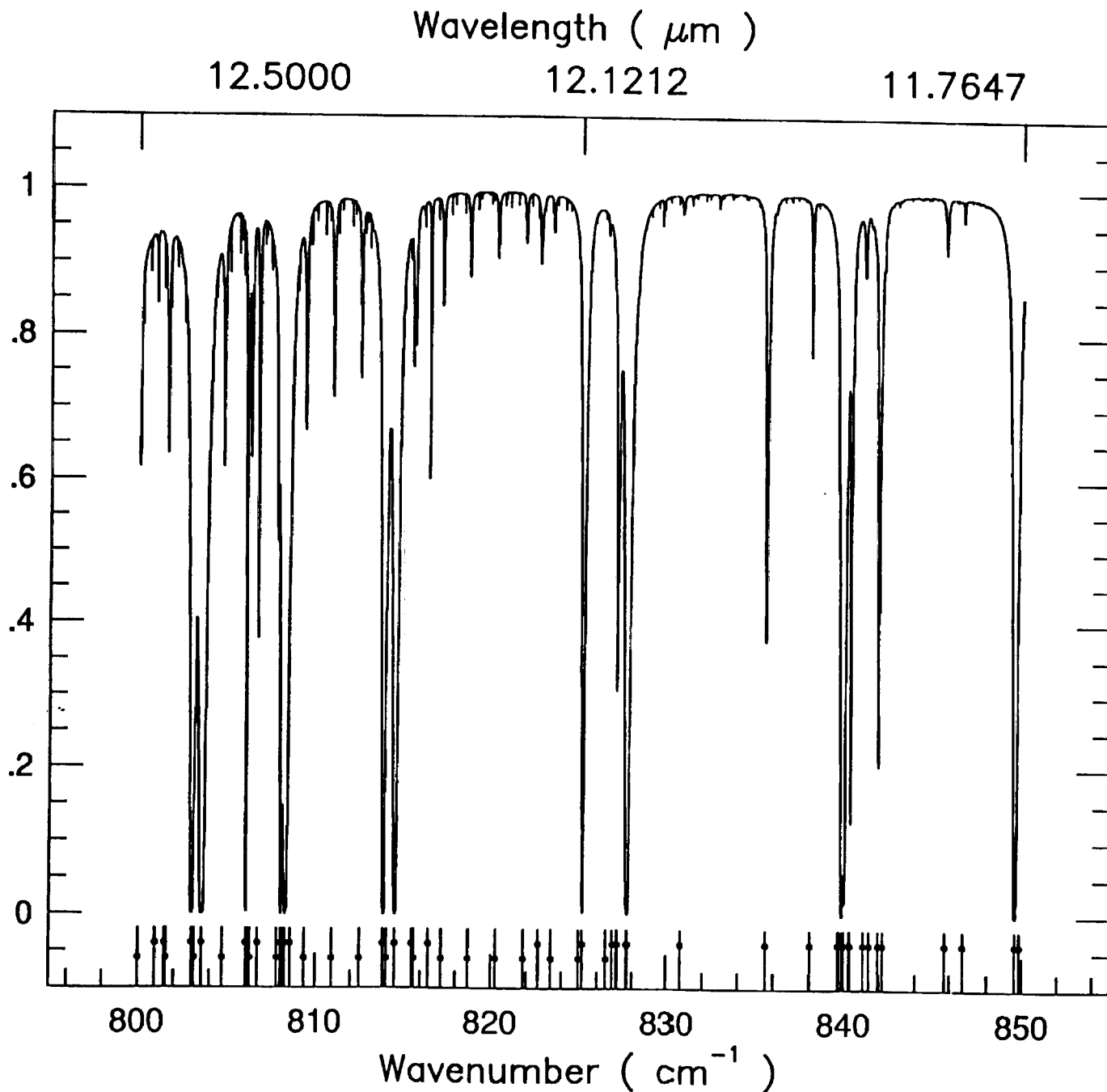
Wavenumber (  $\text{cm}^{-1}$  )

115



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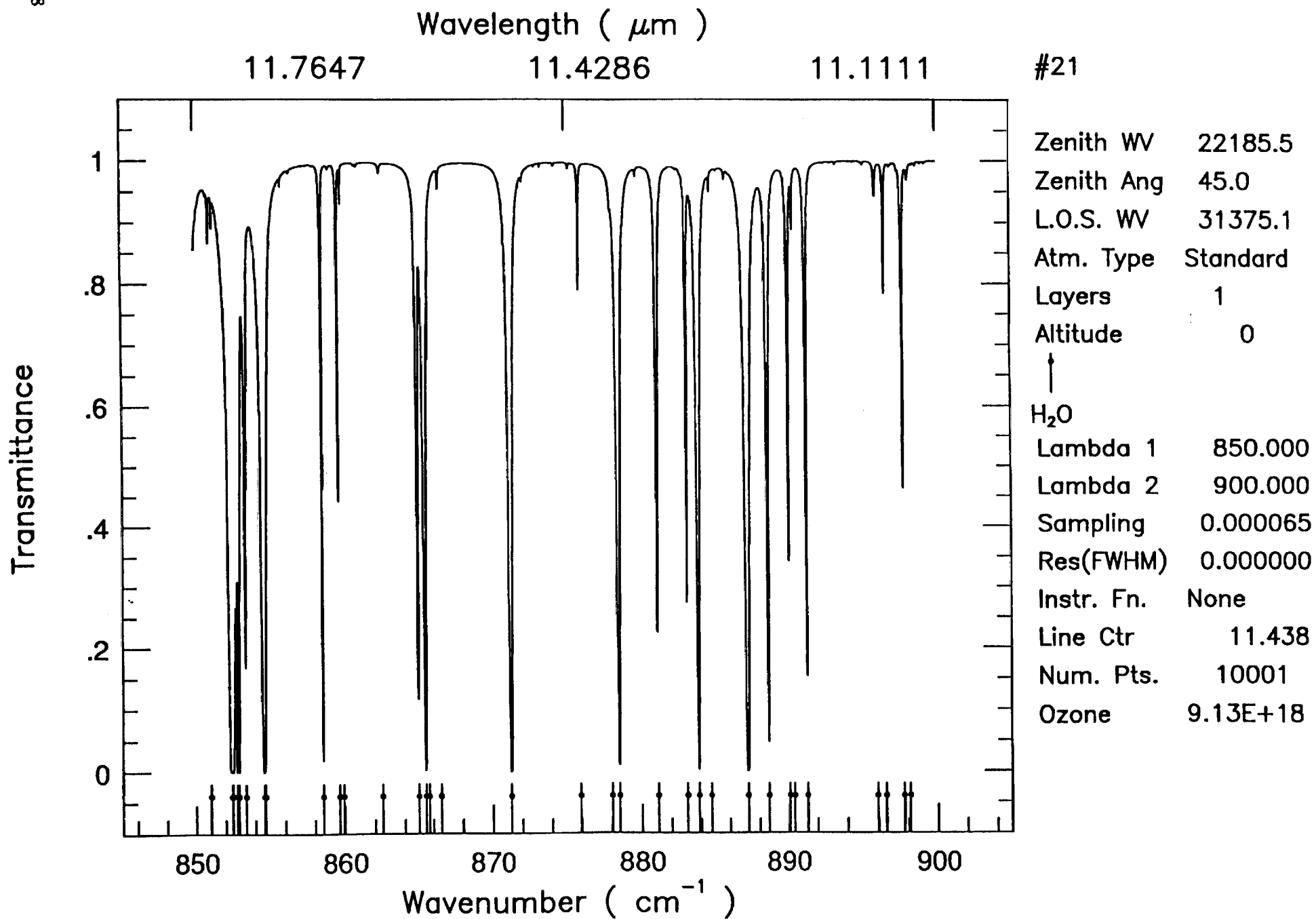
Transmittance



#20

|                  |          |
|------------------|----------|
| Zenith WV        | 22185.5  |
| Zenith Ang       | 45.0     |
| L.O.S. WV        | 31375.1  |
| Atm. Type        | Standard |
| Layers           | 1        |
| Altitude         | 0        |
| H <sub>2</sub> O | ↑        |
| CO <sub>2</sub>  | ↓        |
| Lambda 1         | 800.000  |
| Lambda 2         | 850.000  |
| Sampling         | 0.000074 |
| Res(FWHM)        | 0.000000 |
| Instr. Fn.       | None     |
| Line Ctr         | 12.132   |
| Num. Pts.        | 10001    |
| Ozone            | 9.13E+18 |

117



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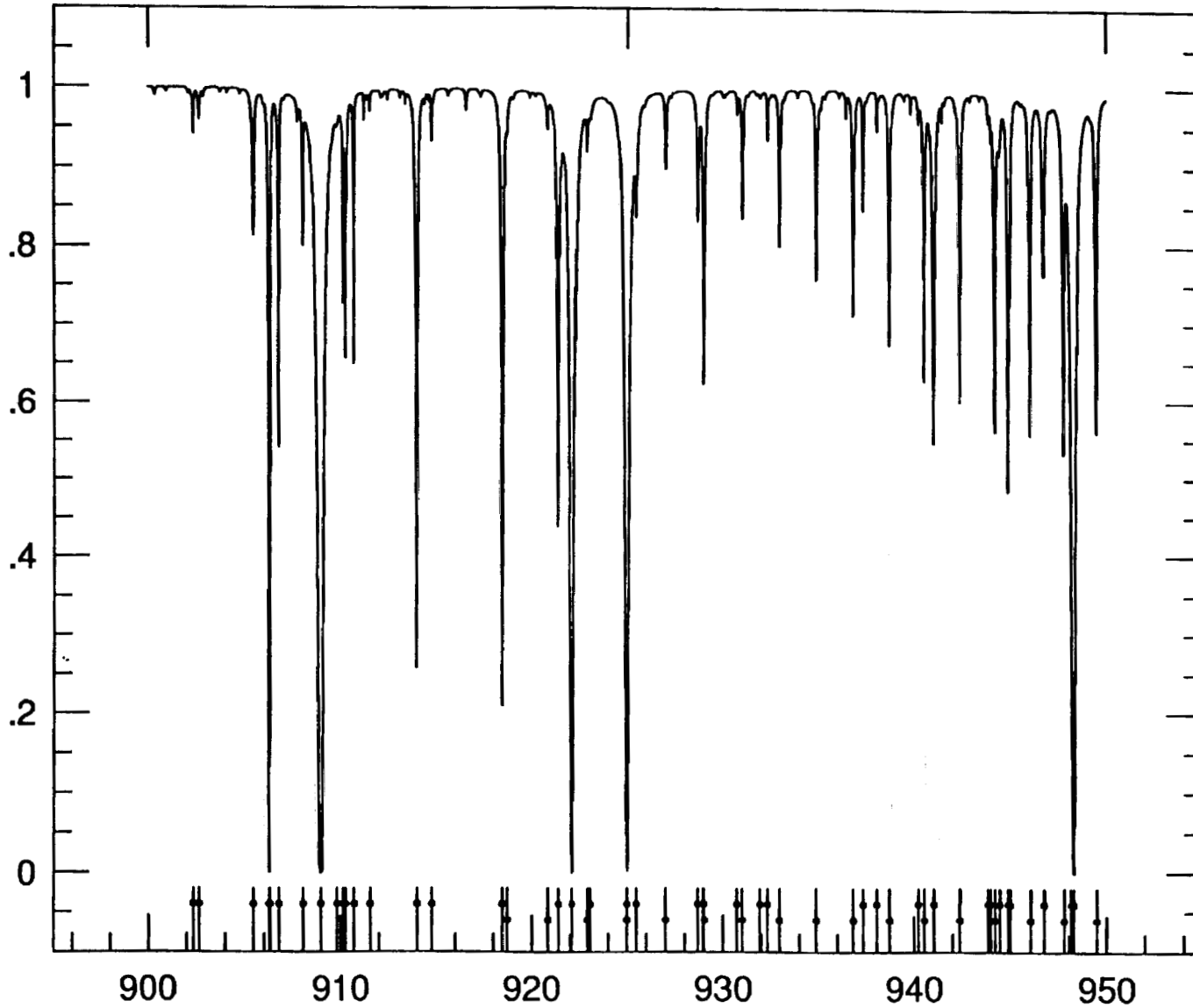
Wavelength (  $\mu\text{m}$  )

11.1111

10.8108

10.5263

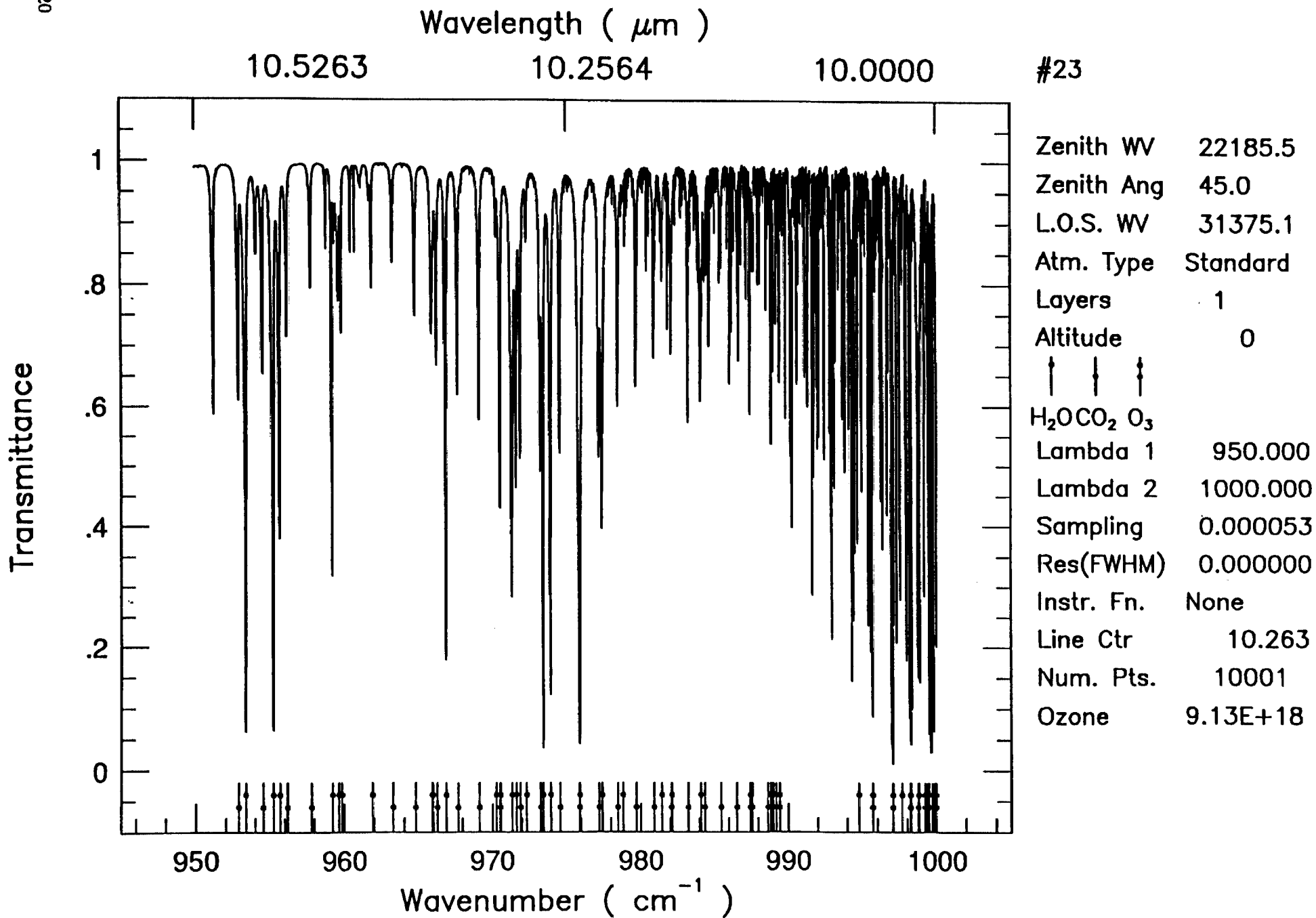
#22



|                  |          |
|------------------|----------|
| Zenith WV        | 22185.5  |
| Zenith Ang       | 45.0     |
| L.O.S. WV        | 31375.1  |
| Atm. Type        | Standard |
| Layers           | 1        |
| Altitude         | 0        |
| ↑ ↓              |          |
| H <sub>2</sub> O |          |
| CO <sub>2</sub>  |          |
| Lambda 1         | 900.000  |
| Lambda 2         | 950.000  |
| Sampling         | 0.000058 |
| Res(FWHM)        | 0.000000 |
| Instr. Fn.       | None     |
| Line Ctr         | 10.819   |
| Num. Pts.        | 10000    |
| Ozone            | 9.13E+18 |

Wavenumber (  $\text{cm}^{-1}$  )





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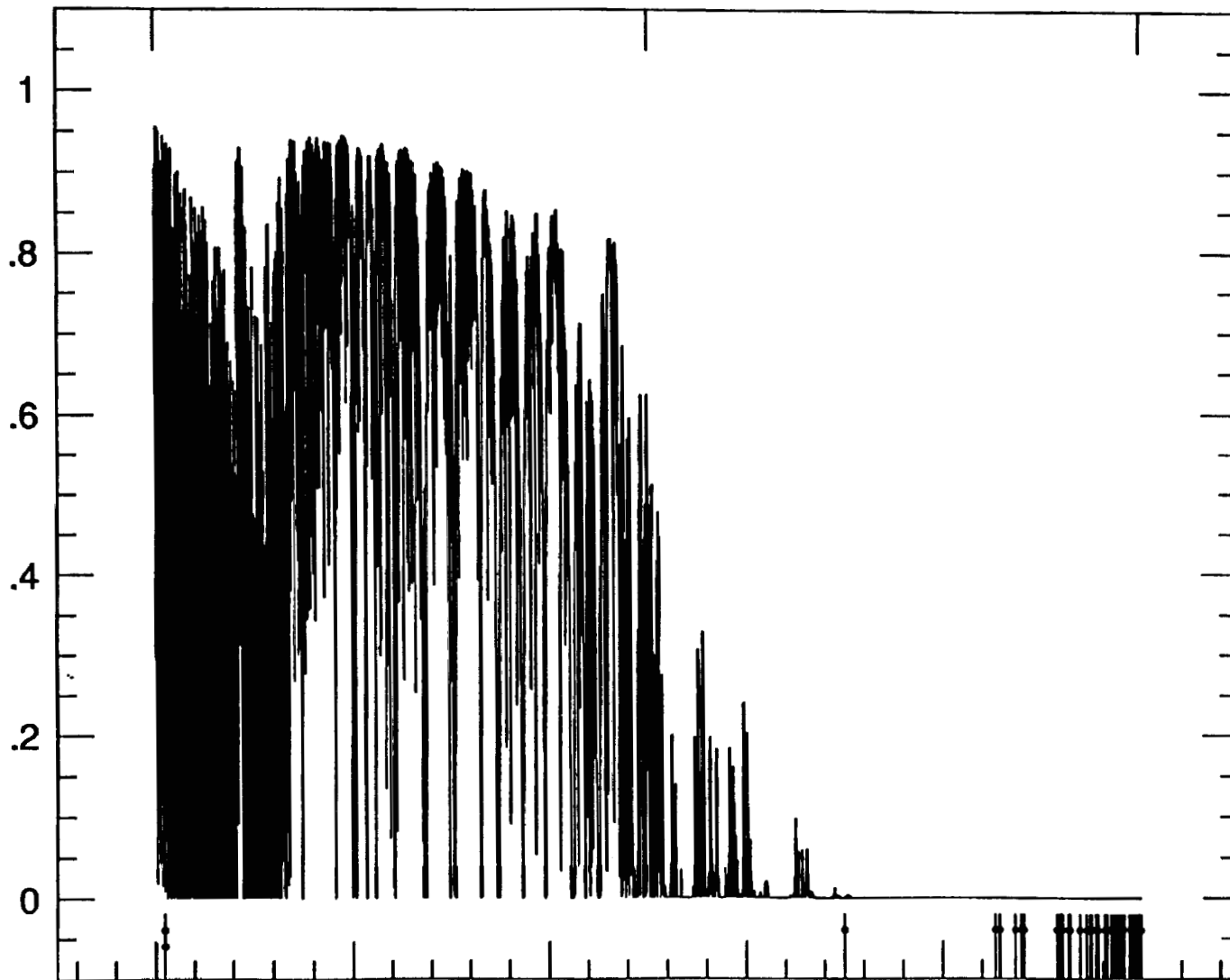
Wavelength (  $\mu\text{m}$  )

10.0000

8.0000

6.6667

#24



1000

1100

1200

1300

1400

1500

Wavenumber (  $\text{cm}^{-1}$  )

Zenith WV 22185.5

Zenith Ang 45.0

L.O.S. WV 31375.1

Atm. Type Standard

Layers 1

Altitude 0

H<sub>2</sub>O O<sub>3</sub>

Lambda 1 1000.000

Lambda 2 1500.000

Sampling 0.000200

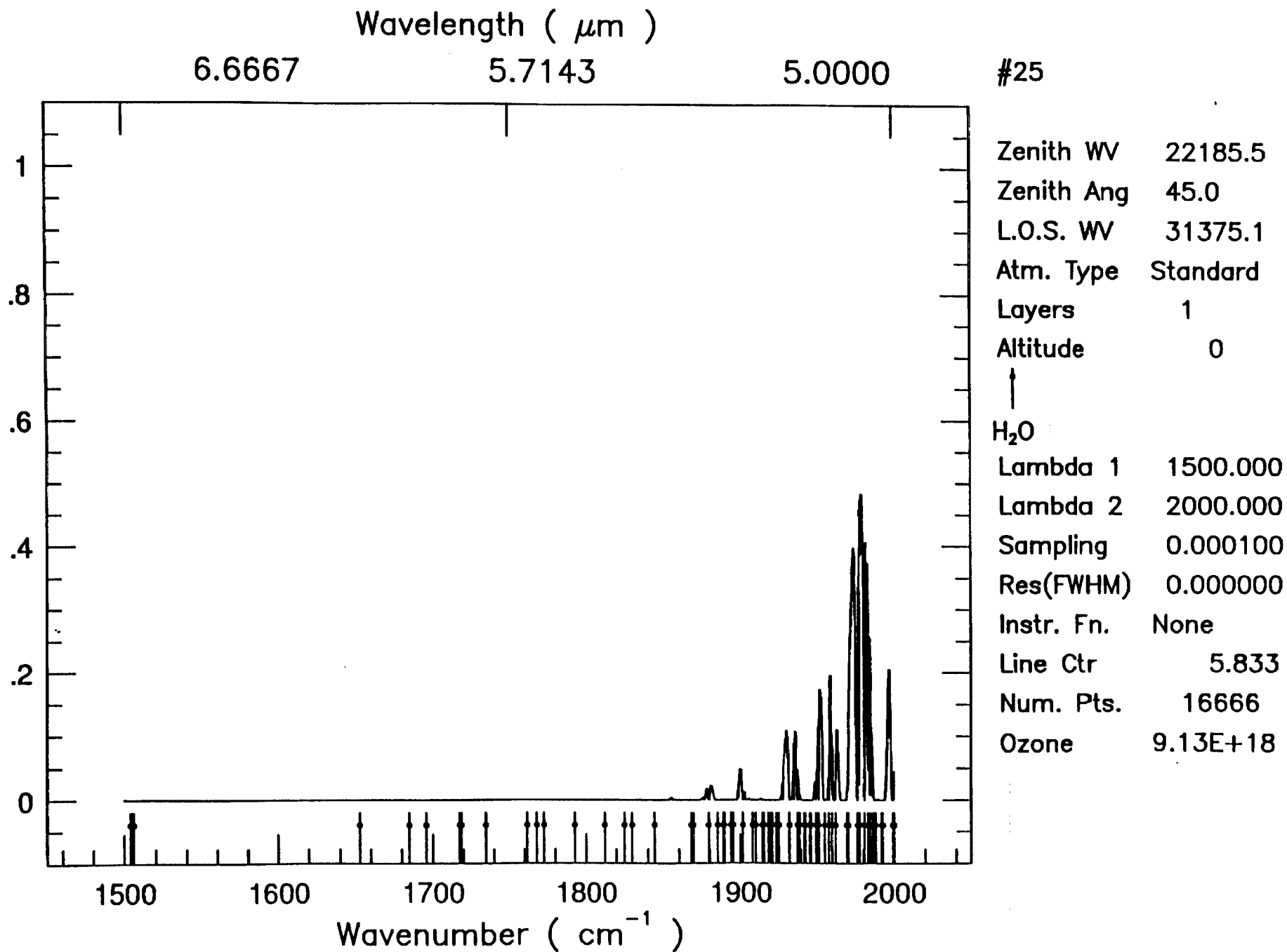
Res(FWHM) 0.000000

Instr. Fn. None

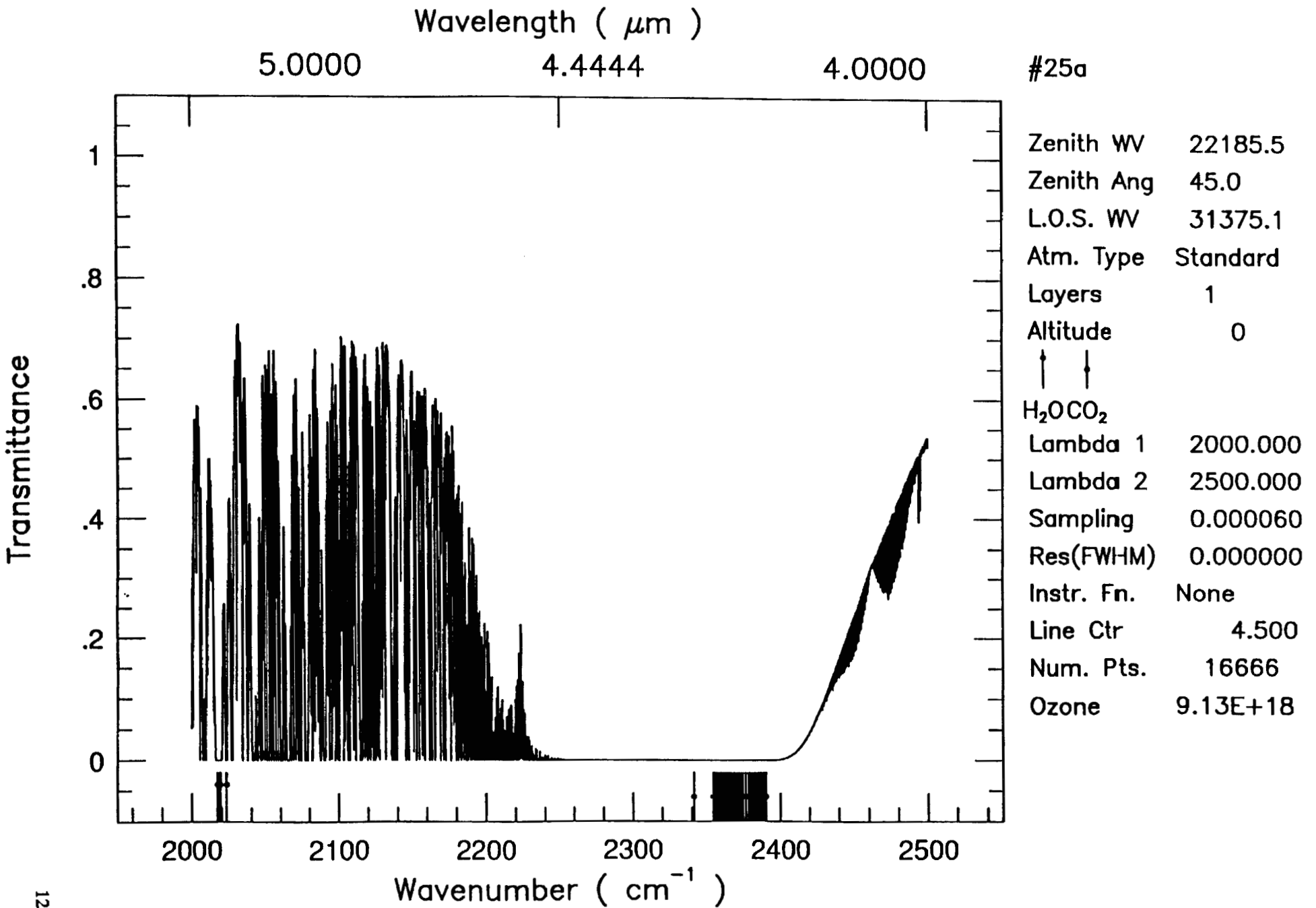
Line Ctr 8.333

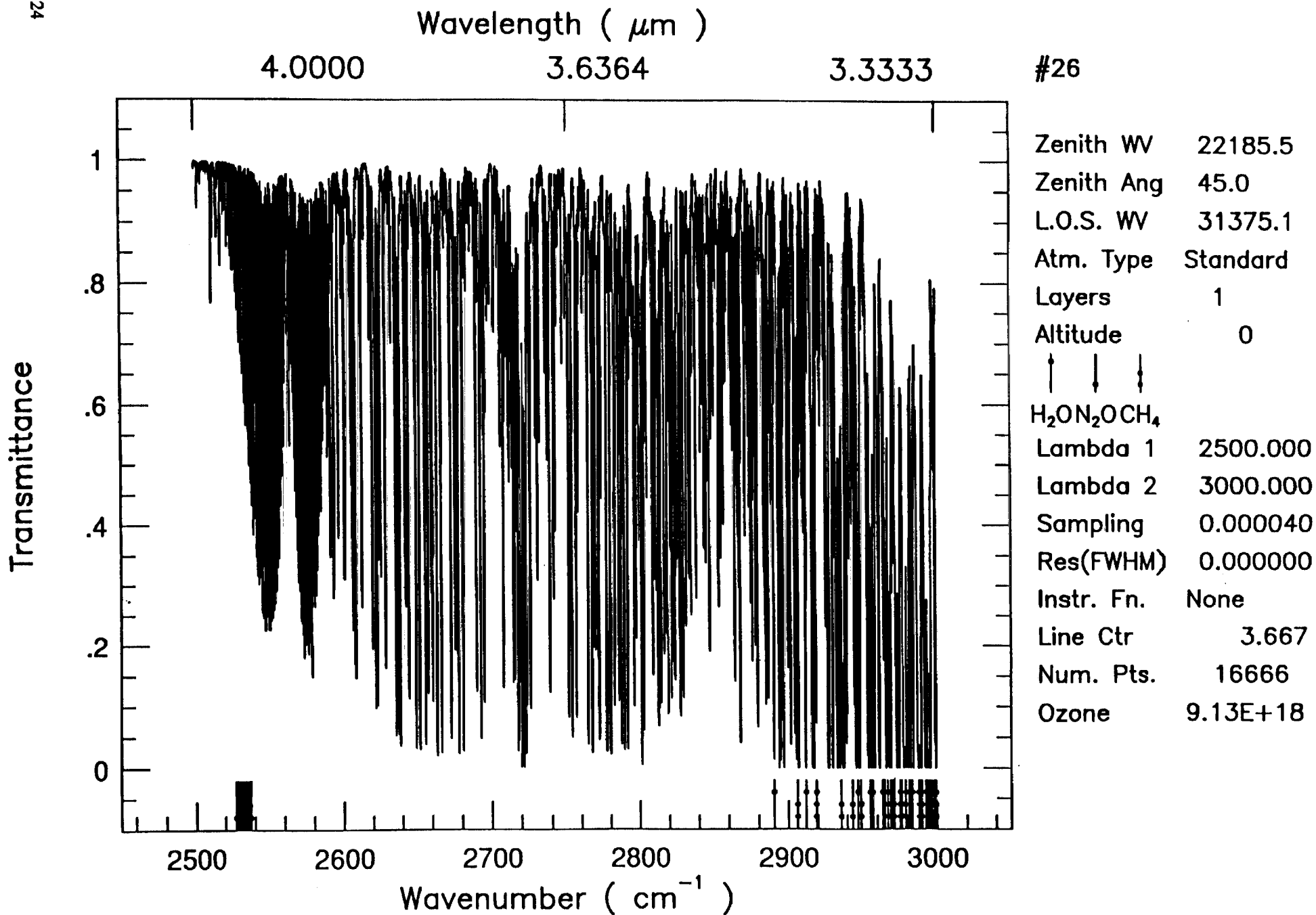
Num. Pts. 16666

Ozone 9.13E+18



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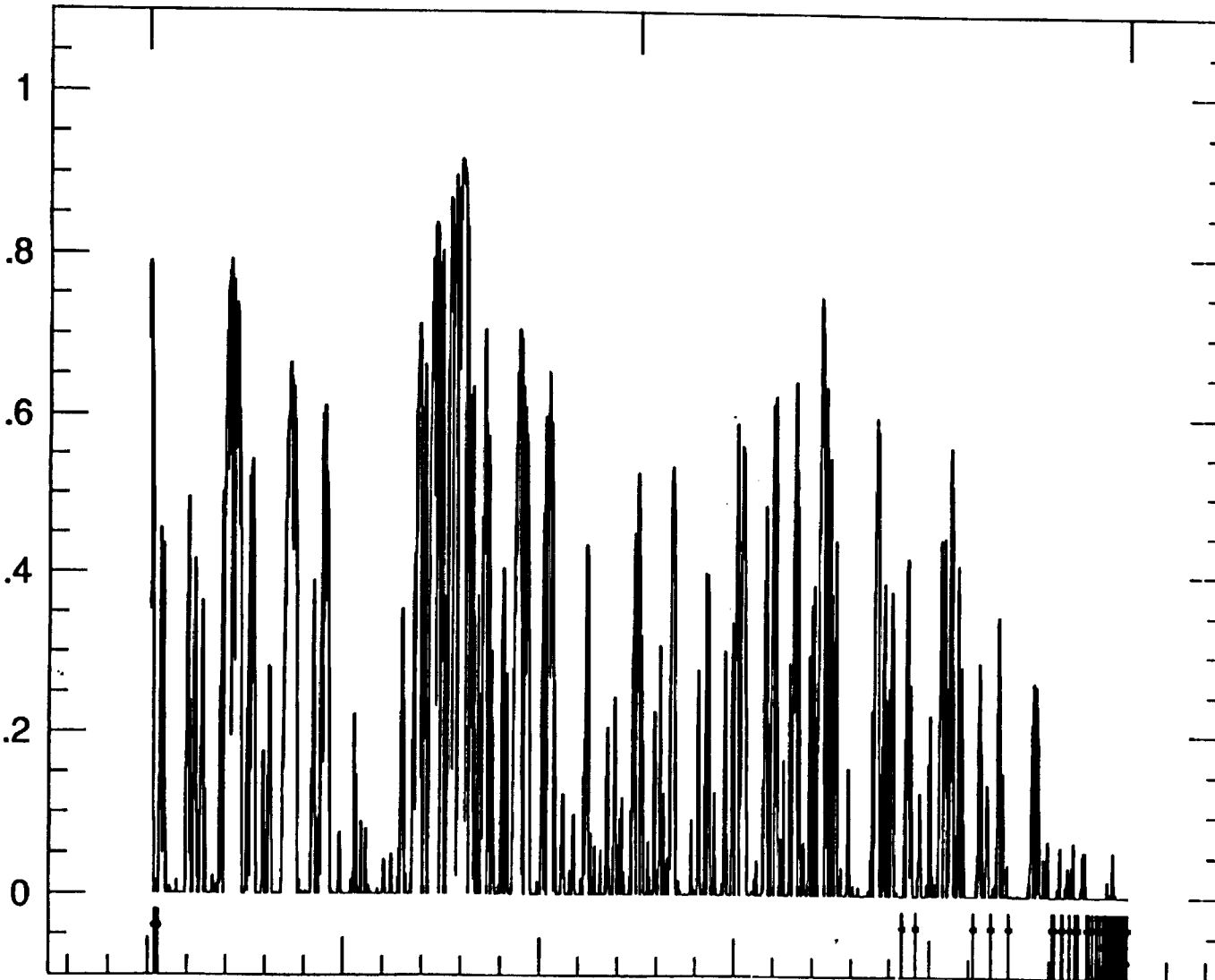
Wavelength (  $\mu\text{m}$  )

3.3333

3.0769

2.8571

#27



|                  |          |
|------------------|----------|
| Zenith WV        | 22185.5  |
| Zenith Ang       | 45.0     |
| L.O.S. WV        | 31375.1  |
| Atm. Type        | Standard |
| Layers           | 1        |
| Altitude         | 0        |
| ↑ ↓ ↓            |          |
| H <sub>2</sub> O |          |
| CO <sub>2</sub>  |          |
| N <sub>2</sub>   |          |
| O                |          |
| Lambda 1         | 3000.000 |
| Lambda 2         | 3500.000 |
| Sampling         | 0.000029 |
| Res(FWHM)        | 0.000000 |
| Instr. Fn.       | None     |
| Line Ctr         | 3.095    |
| Num. Pts.        | 16666    |
| Ozone            | 9.13E+18 |

3000

3100

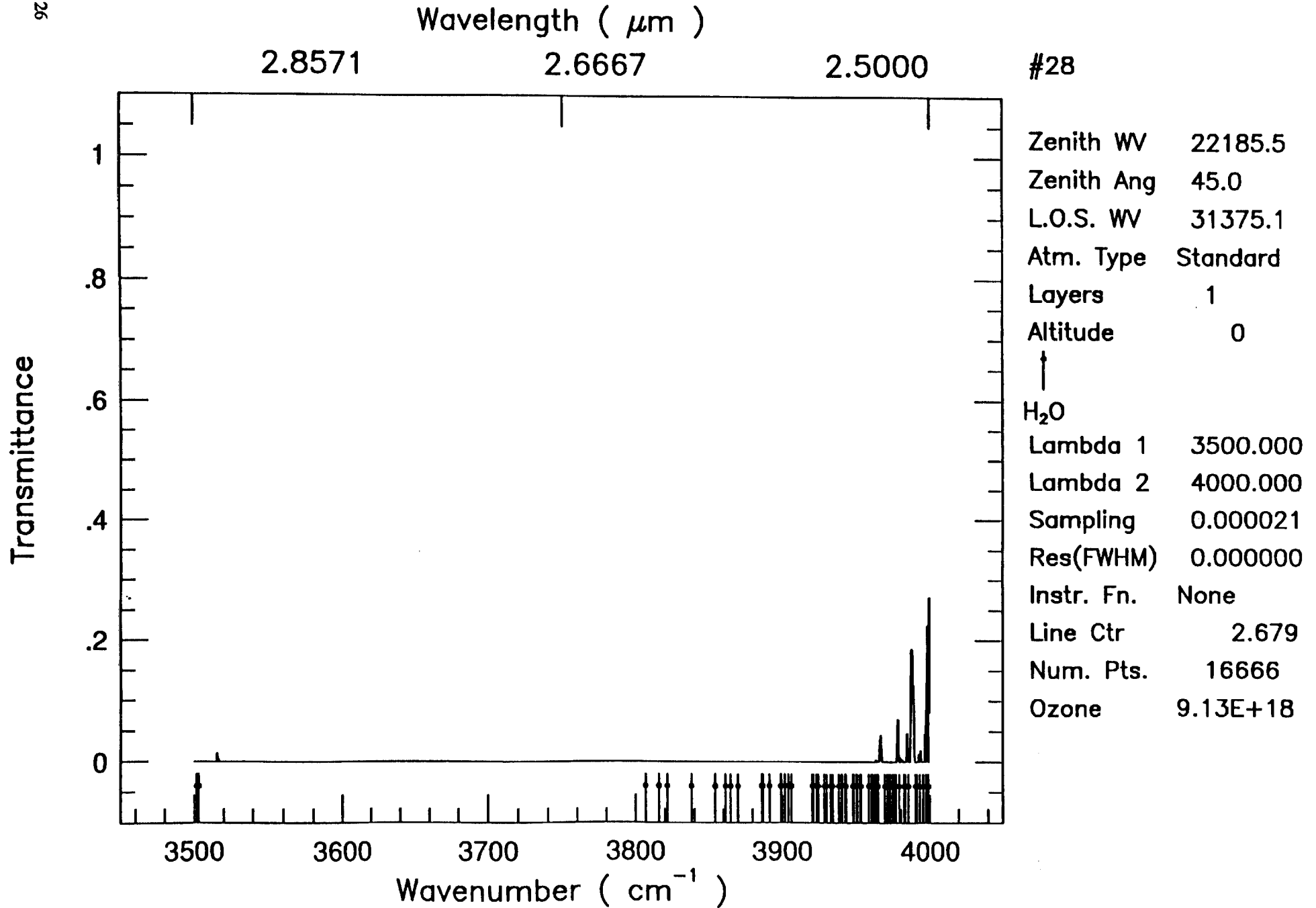
3200

3300

3400

3500

Wavenumber (  $\text{cm}^{-1}$  )



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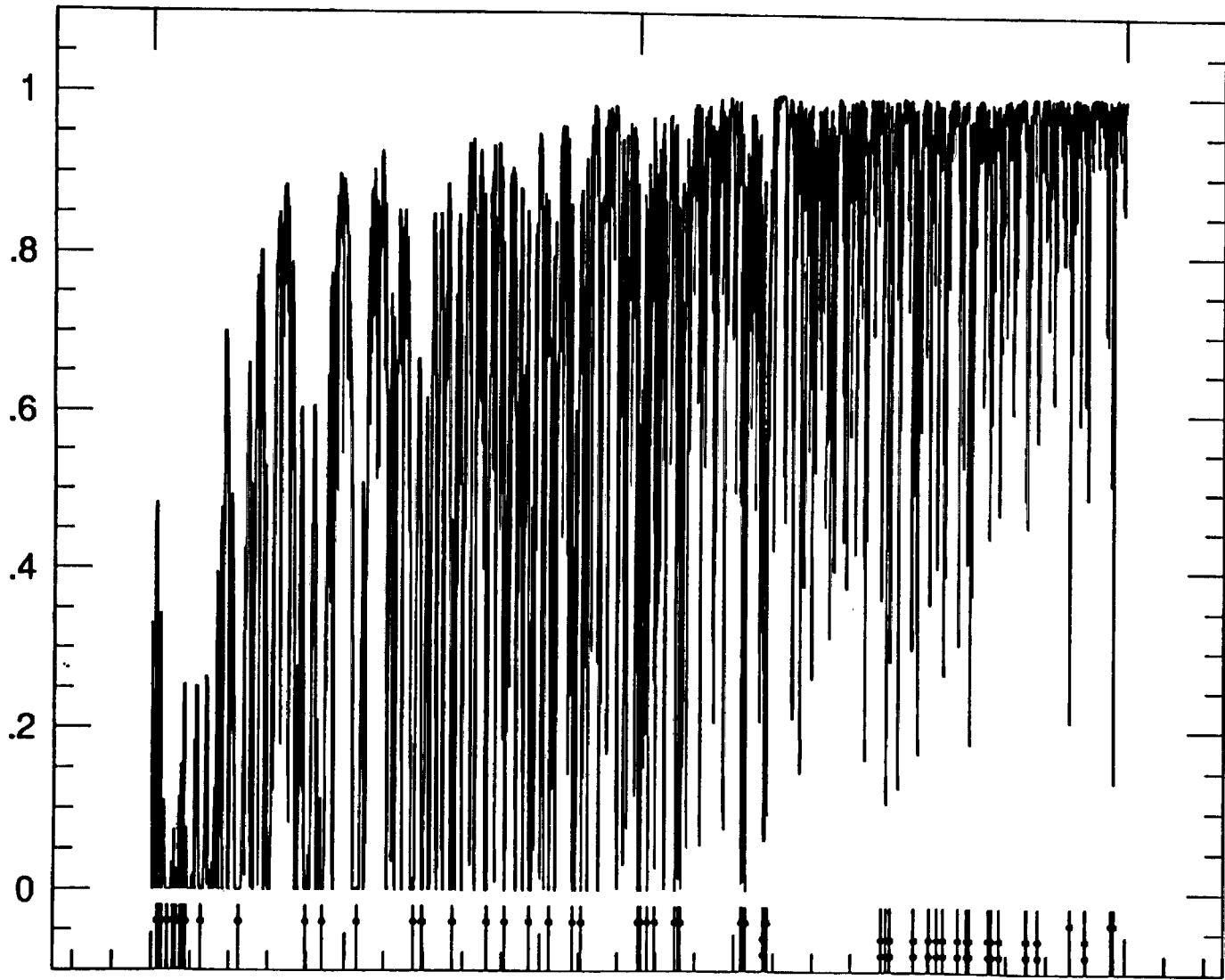
Wavelength (  $\mu\text{m}$  )

2.5000

2.3529

2.2222

#29

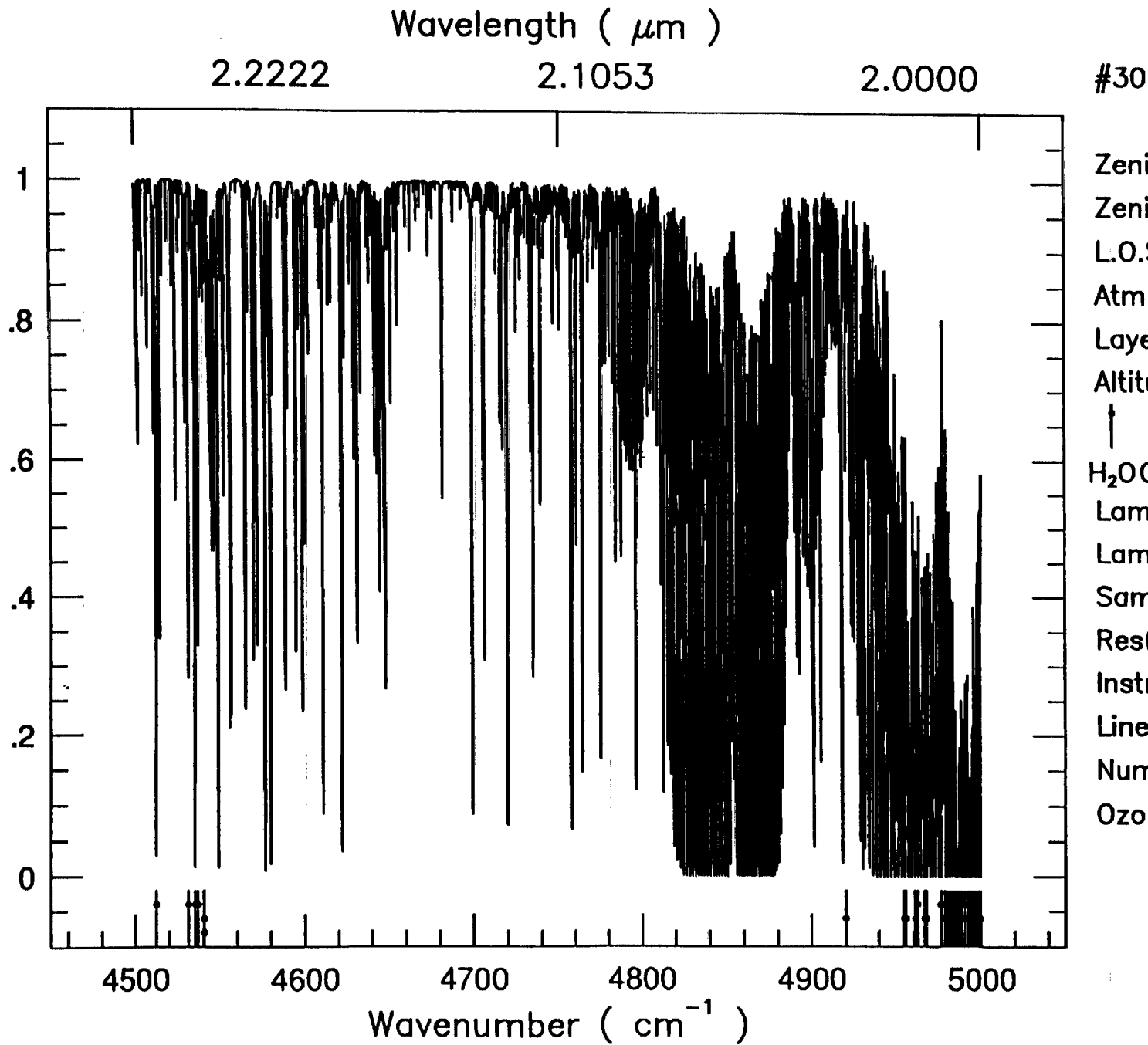


|                                 |          |
|---------------------------------|----------|
| Zenith WV                       | 22185.5  |
| Zenith Ang                      | 45.0     |
| L.O.S. WV                       | 31375.1  |
| Atm. Type                       | Standard |
| Layers                          | 1        |
| Altitude                        | 0        |
| ↑ ↓                             |          |
| H <sub>2</sub> OCH <sub>4</sub> |          |
| Lambda 1                        | 4000.000 |
| Lambda 2                        | 4500.000 |
| Sampling                        | 0.000017 |
| Res(FWHM)                       | 0.000000 |
| Instr. Fn.                      | None     |
| Line Ctr                        | 2.361    |
| Num. Pts.                       | 16666    |
| Ozone                           | 9.13E+18 |

4000      4100      4200      4300      4400      4500

Wavenumber (  $\text{cm}^{-1}$  )





|  |          |
|--|----------|
| Zenith WV  | 22185.5  |
| Zenith Ang                                       | 45.0     |
| L.O.S. WV  | 31375.1  |
| Atm. Type  | Standard |
| Layers   | 1        |
| Altitude   | 0        |
| ↑   ↓   ↓  |          |
| H <sub>2</sub> O CO <sub>2</sub> CH <sub>4</sub> |          |
| Lambda 1   | 4500.000 |
| Lambda 2   | 5000.000 |
| Sampling   | 0.000013 |
| Res(FWHM)  | 0.000000 |
| Instr. Fn.                                       | None     |
| Line Ctr   | 2.111    |
| Num. Pts.  | 16666    |
| Ozone  | 9.13E+18 |

Wed Oct 23 17:39:08 1991

Transmittance

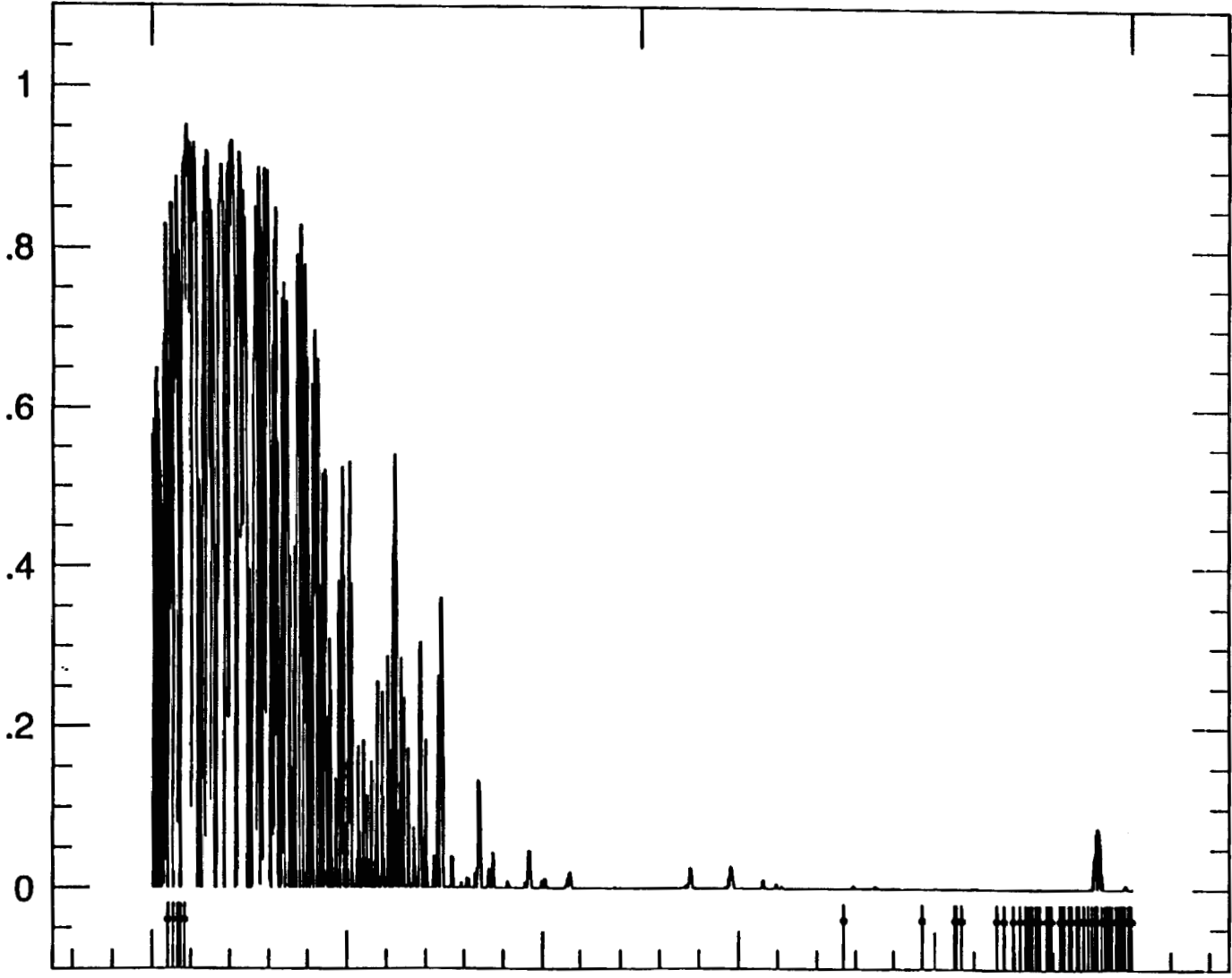
Wavelength (  $\mu\text{m}$  )

2.0000

1.9048

1.8182

#31



5000

5100

5200

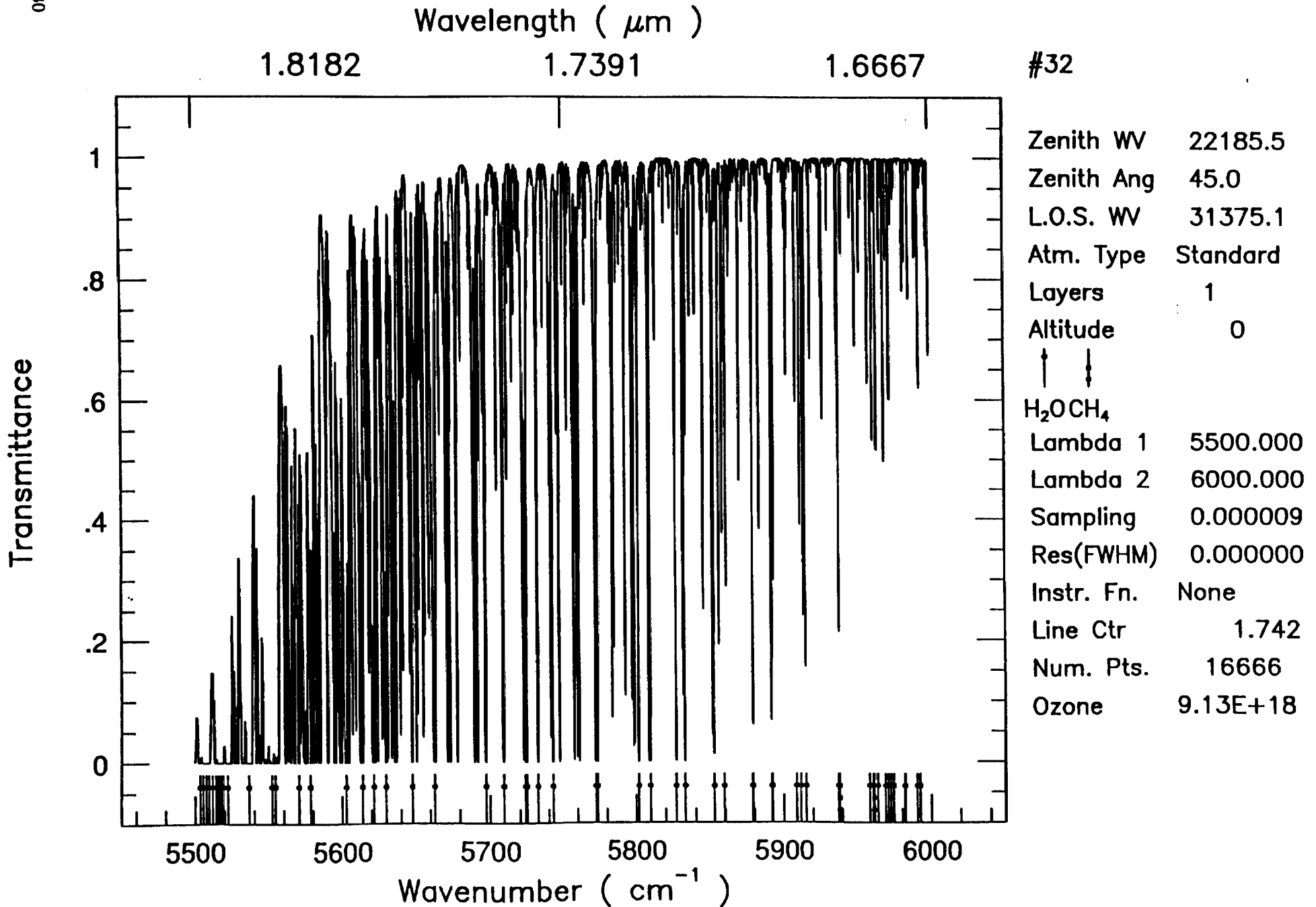
5300

5400

5500

Wavenumber (  $\text{cm}^{-1}$  )

|                  |          |
|------------------|----------|
| Zenith WV        | 22185.5  |
| Zenith Ang       | 45.0     |
| L.O.S. WV        | 31375.1  |
| Atm. Type        | Standard |
| Layers           | 1        |
| Altitude         | 0        |
| H <sub>2</sub> O |          |
| Lambda 1         | 5000.000 |
| Lambda 2         | 5500.000 |
| Sampling         | 0.000011 |
| Res(FWHM)        | 0.000000 |
| Instr. Fn.       | None     |
| Line Ctr         | 1.909    |
| Num. Pts.        | 16666    |
| Ozone            | 9.13E+18 |



Wed Oct 23 17:46:31 1991

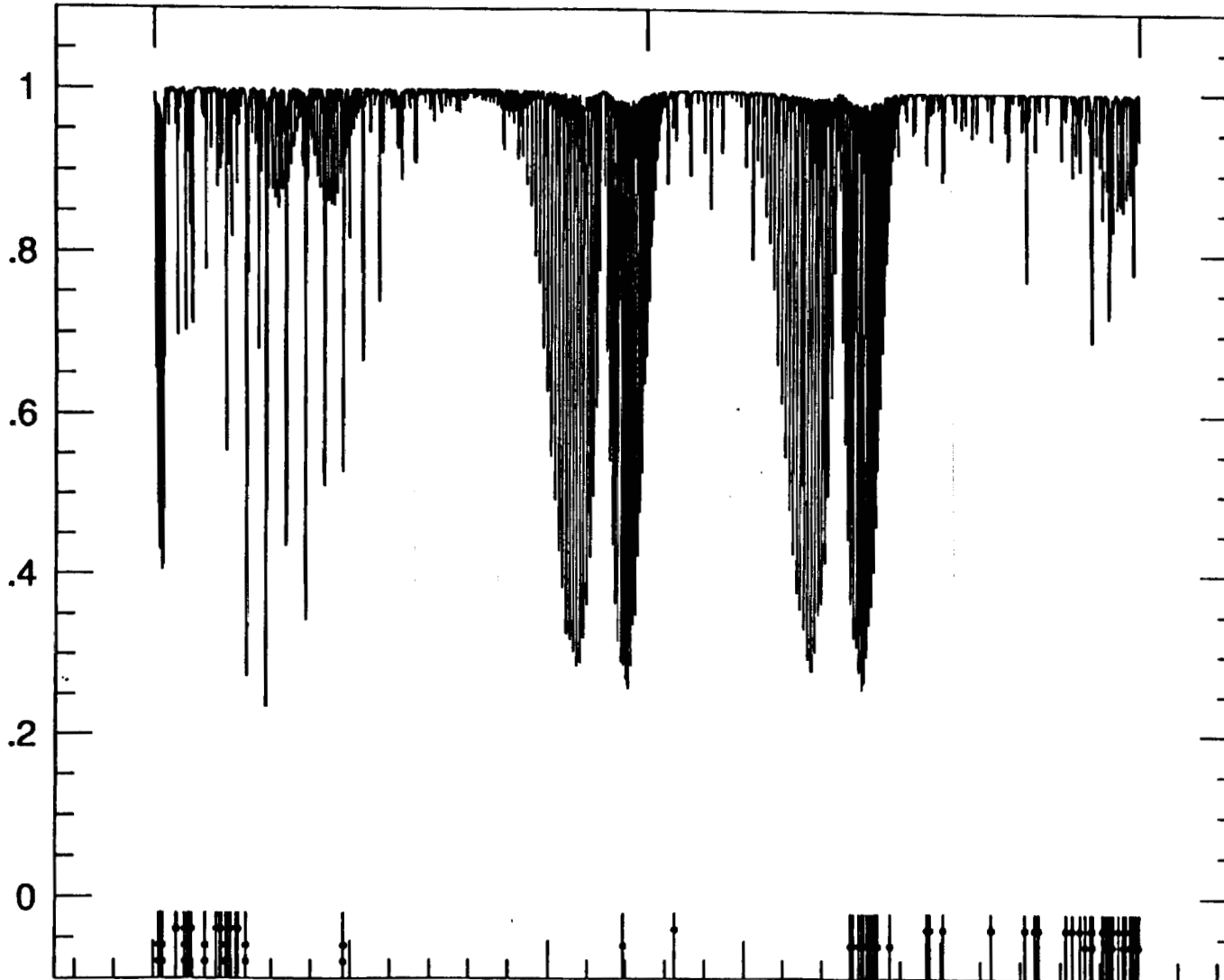
Wavelength (  $\mu\text{m}$  )

1.6667

1.6000

1.5385

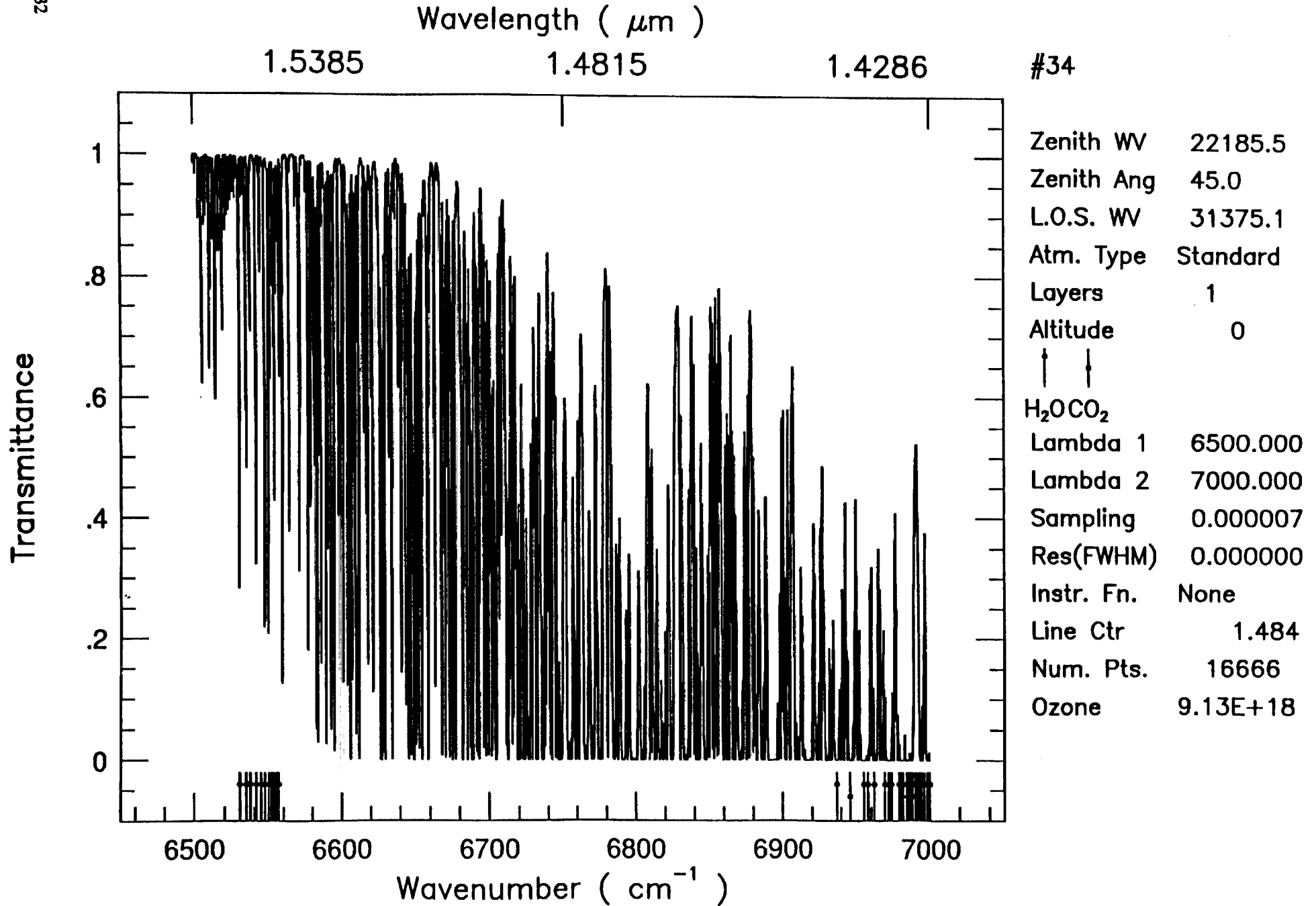
#33



|                  |                 |
|------------------|-----------------|
| Zenith WV        | 22185.5         |
| Zenith Ang       | 45.0            |
| L.O.S. WV        | 31375.1         |
| Atm. Type        | Standard        |
| Layers           | 1               |
| Altitude         | 0               |
| ↑ ↓ ↓            |                 |
| H <sub>2</sub> O | CO <sub>2</sub> |
| CH <sub>4</sub>  |                 |
| Lambda 1         | 6000.000        |
| Lambda 2         | 6500.000        |
| Sampling         | 0.000008        |
| Res(FWHM)        | 0.000000        |
| Instr. Fn.       | None            |
| Line Ctr         | 1.603           |
| Num. Pts.        | 16666           |
| Ozone            | 9.13E+18        |

6000      6100      6200      6300      6400      6500

Wavenumber (  $\text{cm}^{-1}$  )



Wed Oct 23 17:52:13 1991

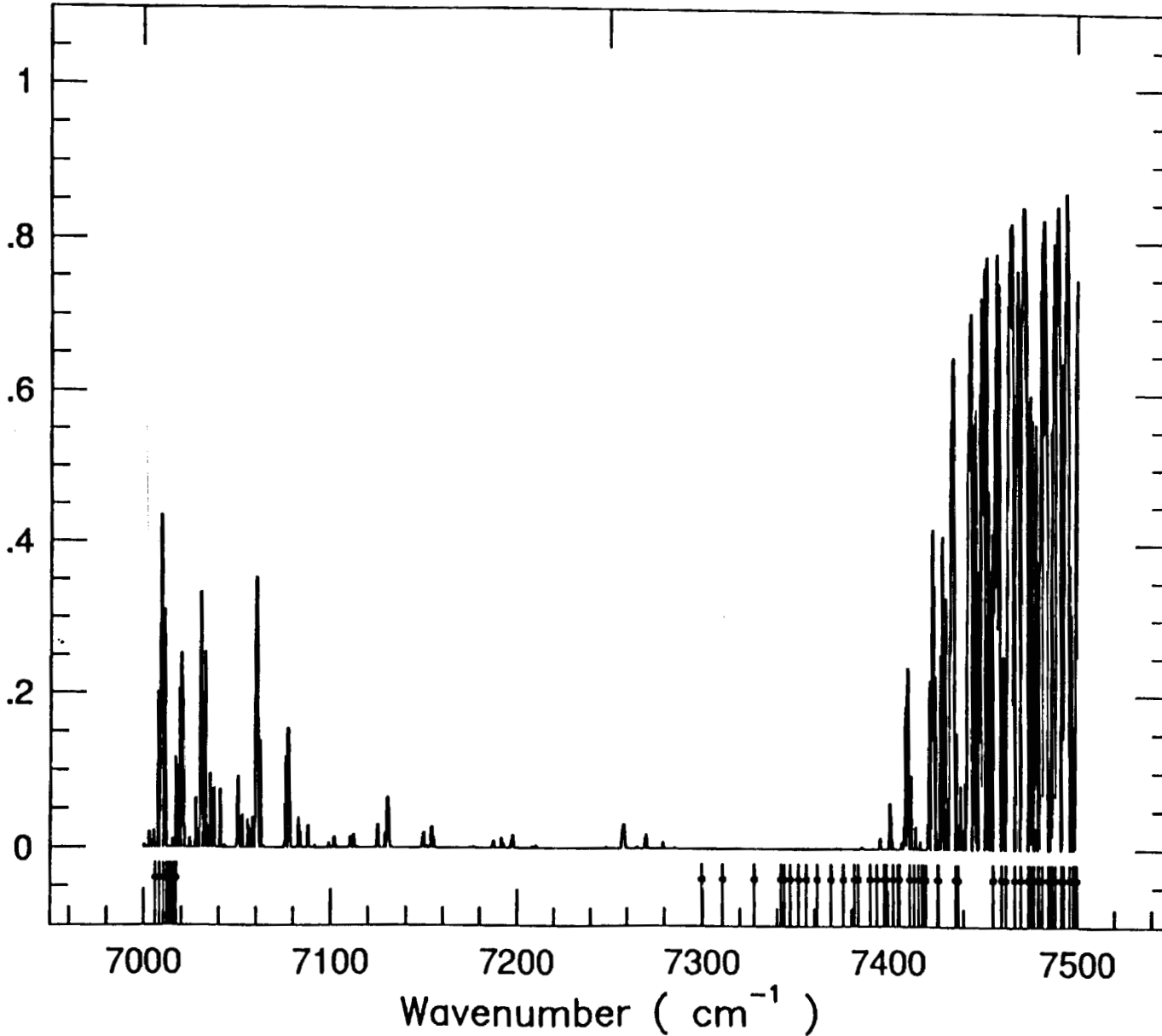
Wavelength (  $\mu\text{m}$  )

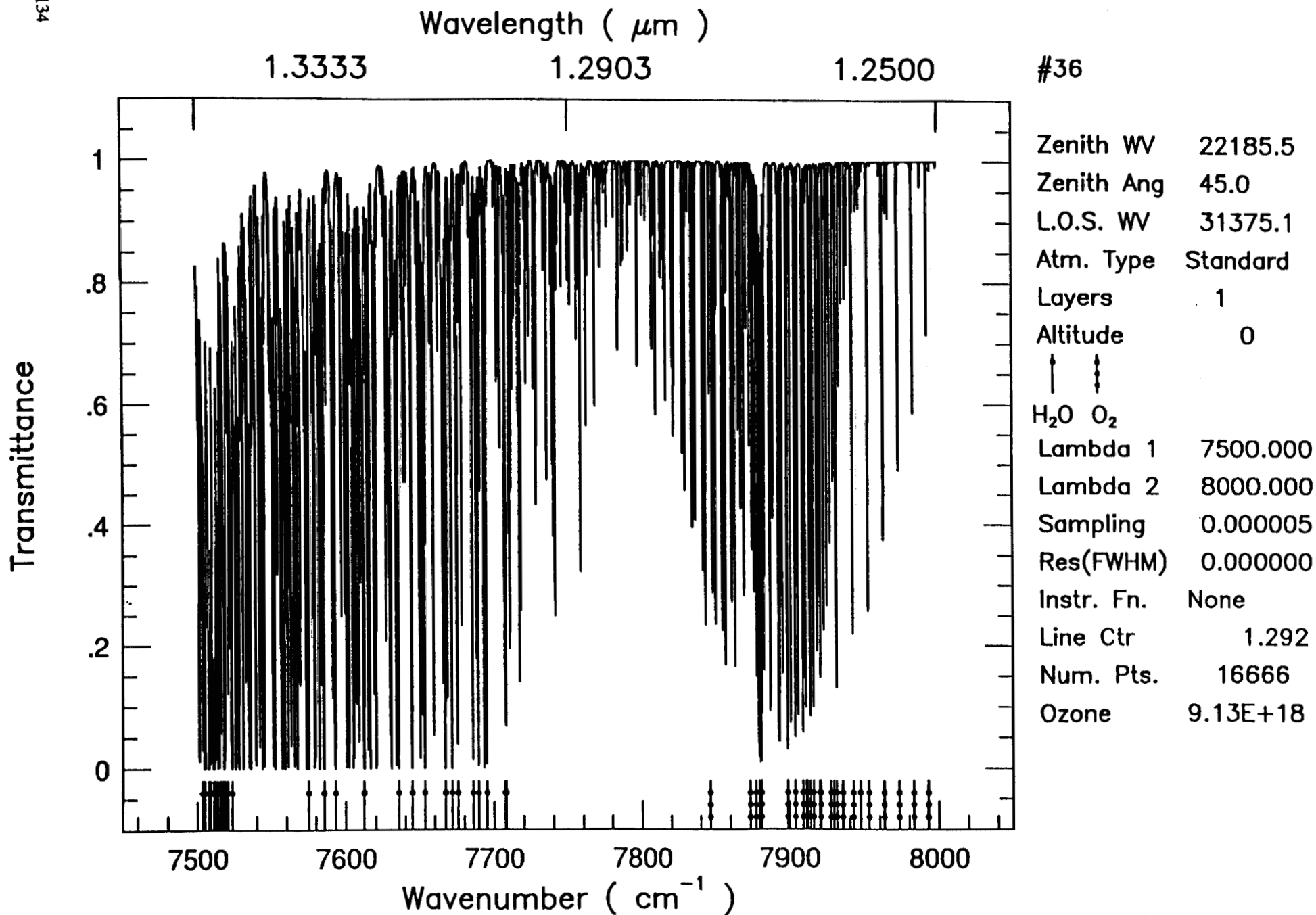
1.4286                      1.3793                      1.3333

#35

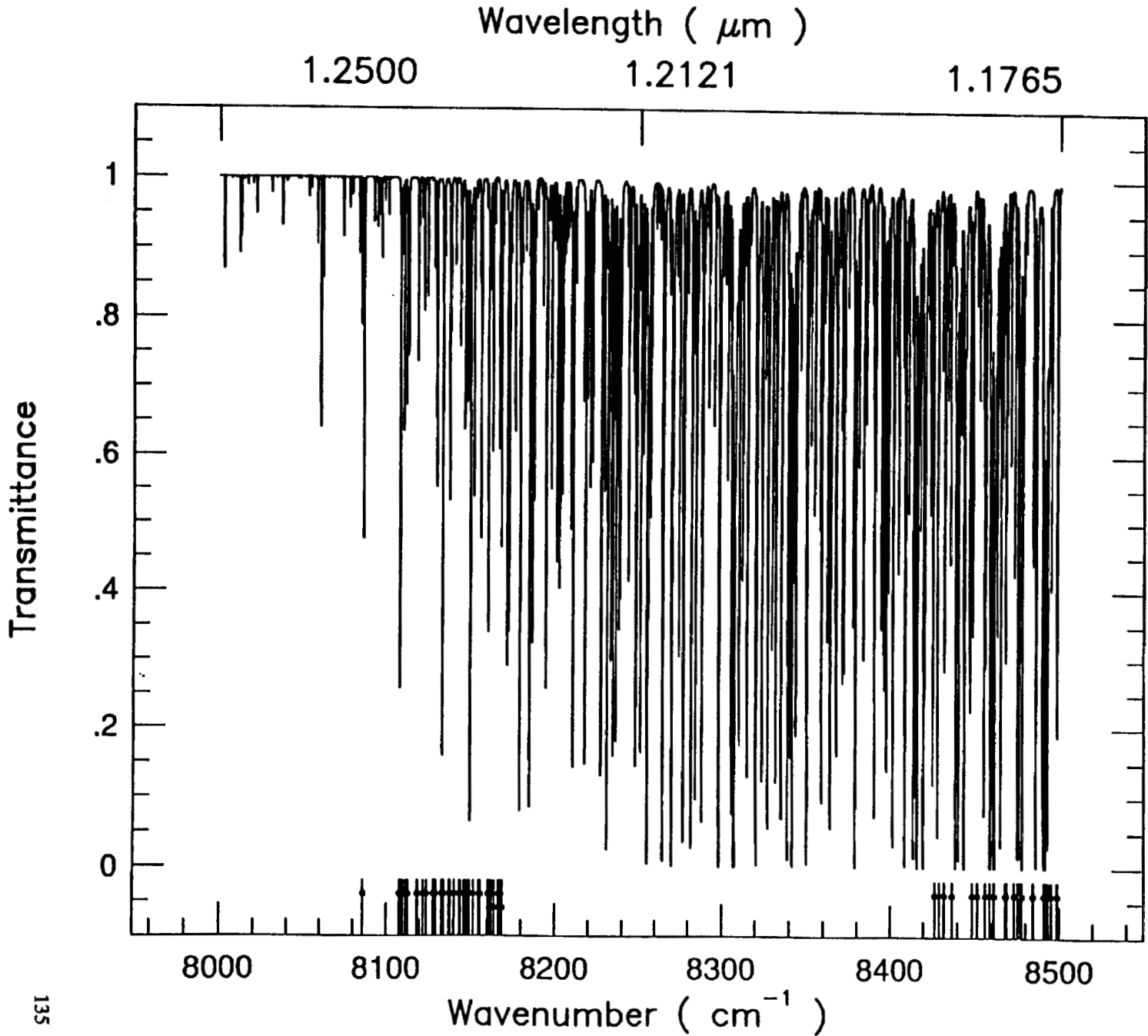
Transmittance

Zenith WV    22185.5  
 Zenith Ang    45.0  
 L.O.S. WV    31375.1  
 Atm. Type    Standard  
 Layers        1  
 Altitude      0  
 ↑  
 H<sub>2</sub>O  
 Lambda 1    7000.000  
 Lambda 2    7500.000  
 Sampling     0.000006  
 Res(FWHM)   0.000000  
 Instr. Fn.    None  
 Line Ctr      1.381  
 Num. Pts.    16666  
 Ozone        9.13E+18





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|                  |          |
|------------------|----------|
| Zenith WV        | 22185.5  |
| Zenith Ang       | 45.0     |
| L.O.S. WV        | 31375.1  |
| Atm. Type        | Standard |
| Layers           | 1        |
| Altitude         | 0        |
| ↑ ↓              |          |
| H <sub>2</sub> O |          |
| CO <sub>2</sub>  |          |
| Lambda 1         | 8000.000 |
| Lambda 2         | 8500.000 |
| Sampling         | 0.000004 |
| Res(FWHM)        | 0.000000 |
| Instr. Fn.       | None     |
| Line Ctr         | 1.213    |
| Num. Pts.        | 16666    |
| Ozone            | 9.13E+18 |



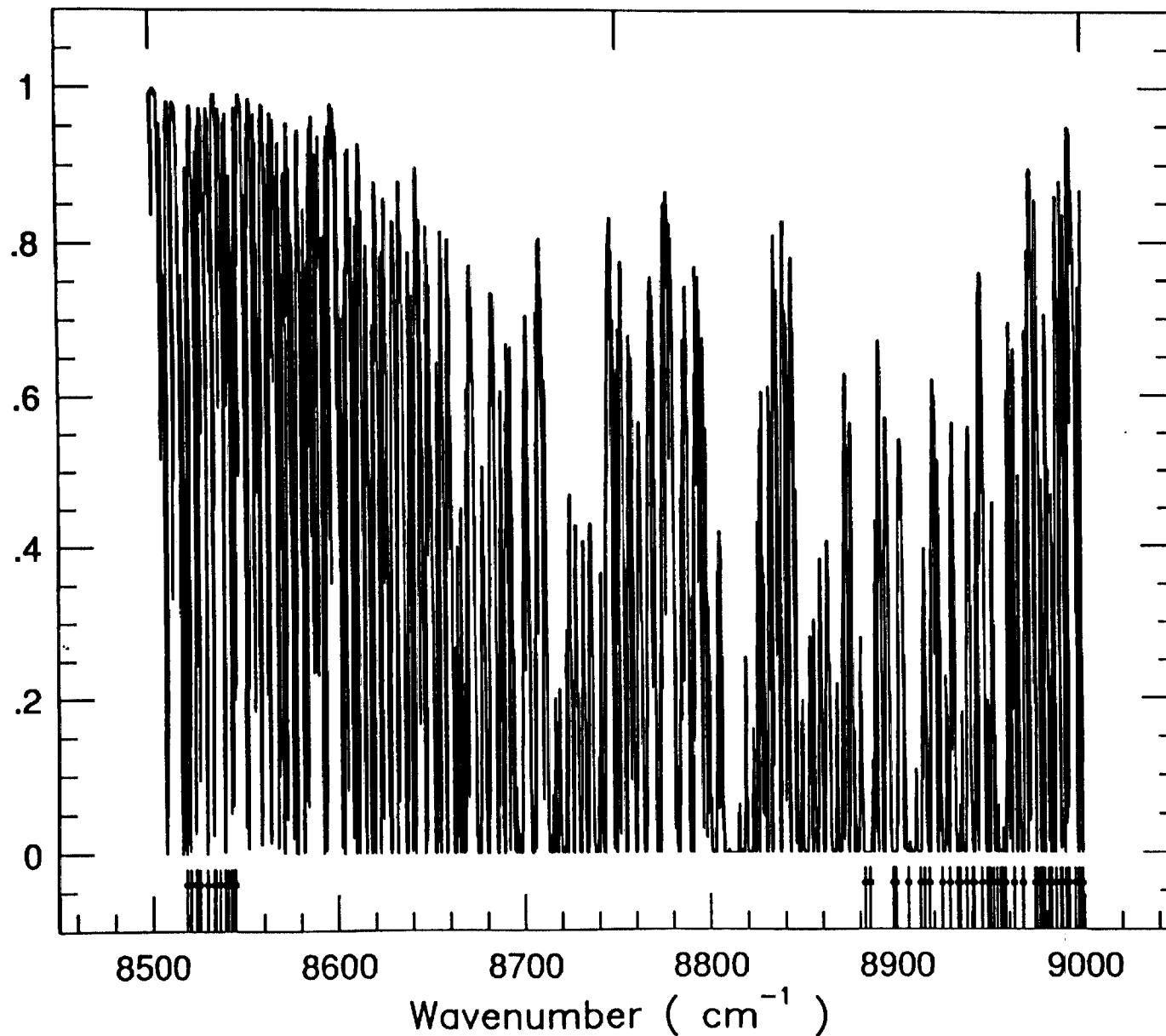
Wavelength (  $\mu\text{m}$  )

1.1765

1.1429

1.1111

#38



|                  |          |
|------------------|----------|
| Zenith WV        | 22185.5  |
| Zenith Ang       | 45.0     |
| L.O.S. WV        | 31375.1  |
| Atm. Type        | Standard |
| Layers           | 1        |
| Altitude         | 0        |
| ↑                |          |
| H <sub>2</sub> O |          |
| Lambda 1         | 8500.000 |
| Lambda 2         | 9000.000 |
| Sampling         | 0.000004 |
| Res(FWHM)        | 0.000000 |
| Instr. Fn.       | None     |
| Line Ctr         | 1.144    |
| Num. Pts.        | 16666    |
| Ozone            | 9.13E+18 |

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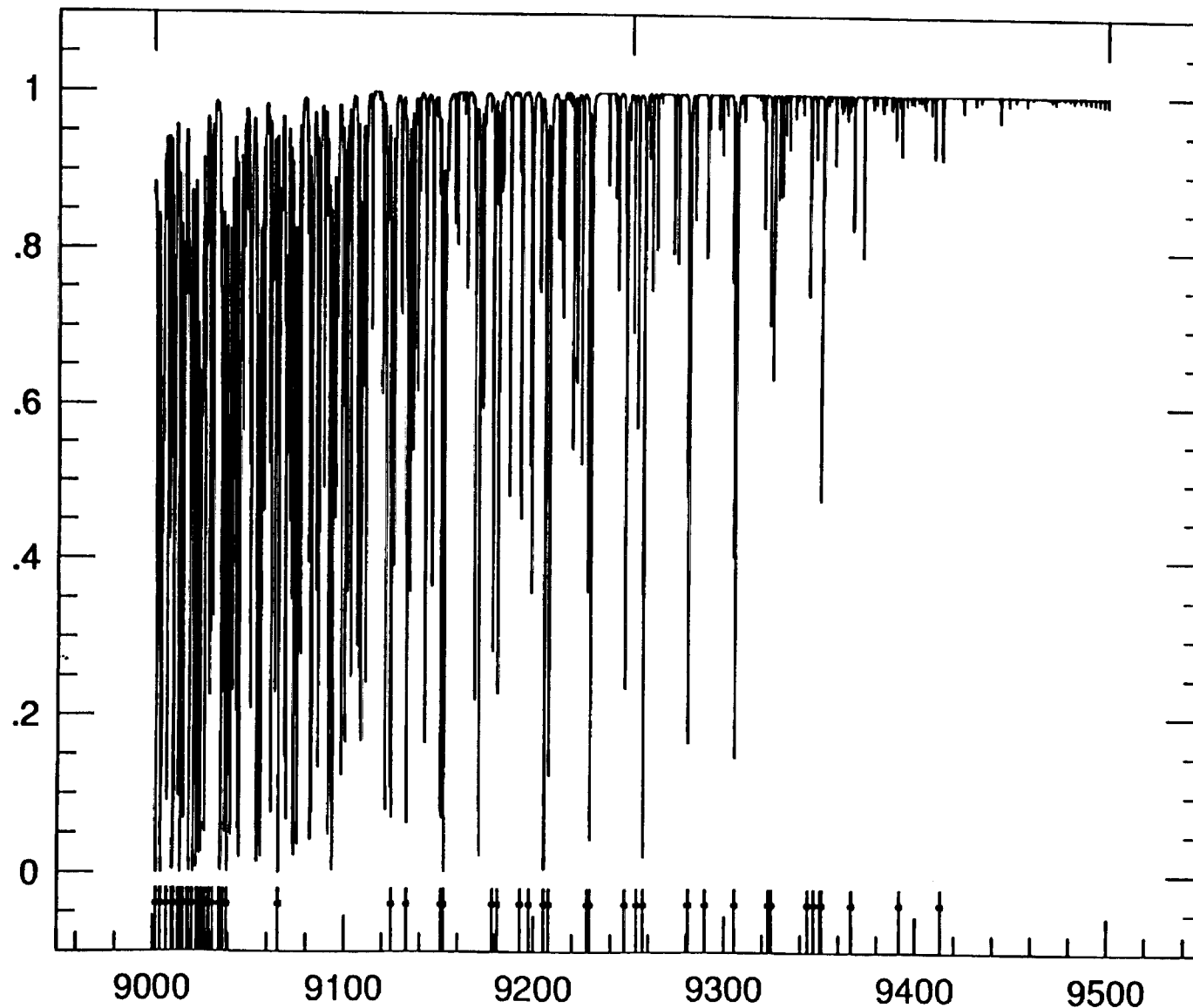
Wavelength (  $\mu\text{m}$  )

1.1111

1.0811

1.0526

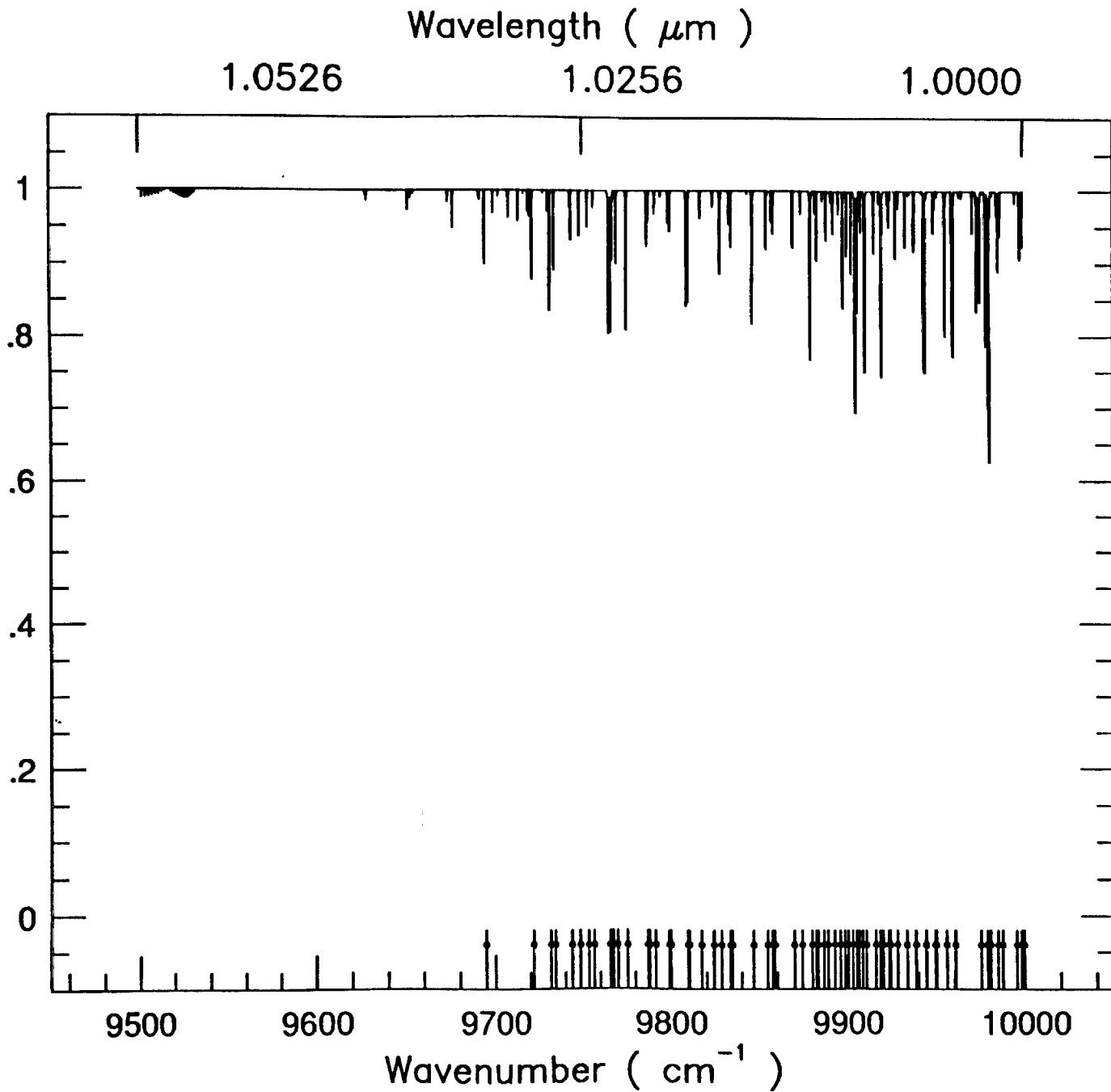
#39



|                  |          |
|------------------|----------|
| Zenith WV        | 22185.5  |
| Zenith Ang       | 45.0     |
| L.O.S. WV        | 31375.1  |
| Atm. Type        | Standard |
| Layers           | 1        |
| Altitude         | 0        |
| ↑                |          |
| H <sub>2</sub> O |          |
| Lambda 1         | 9000.000 |
| Lambda 2         | 9500.000 |
| Sampling         | 0.000004 |
| Res(FWHM)        | 0.000000 |
| Instr. Fn.       | None     |
| Line Ctr         | 1.082    |
| Num. Pts.        | 16666    |
| Ozone            | 9.13E+18 |

Wavenumber (  $\text{cm}^{-1}$  )

Transmittance



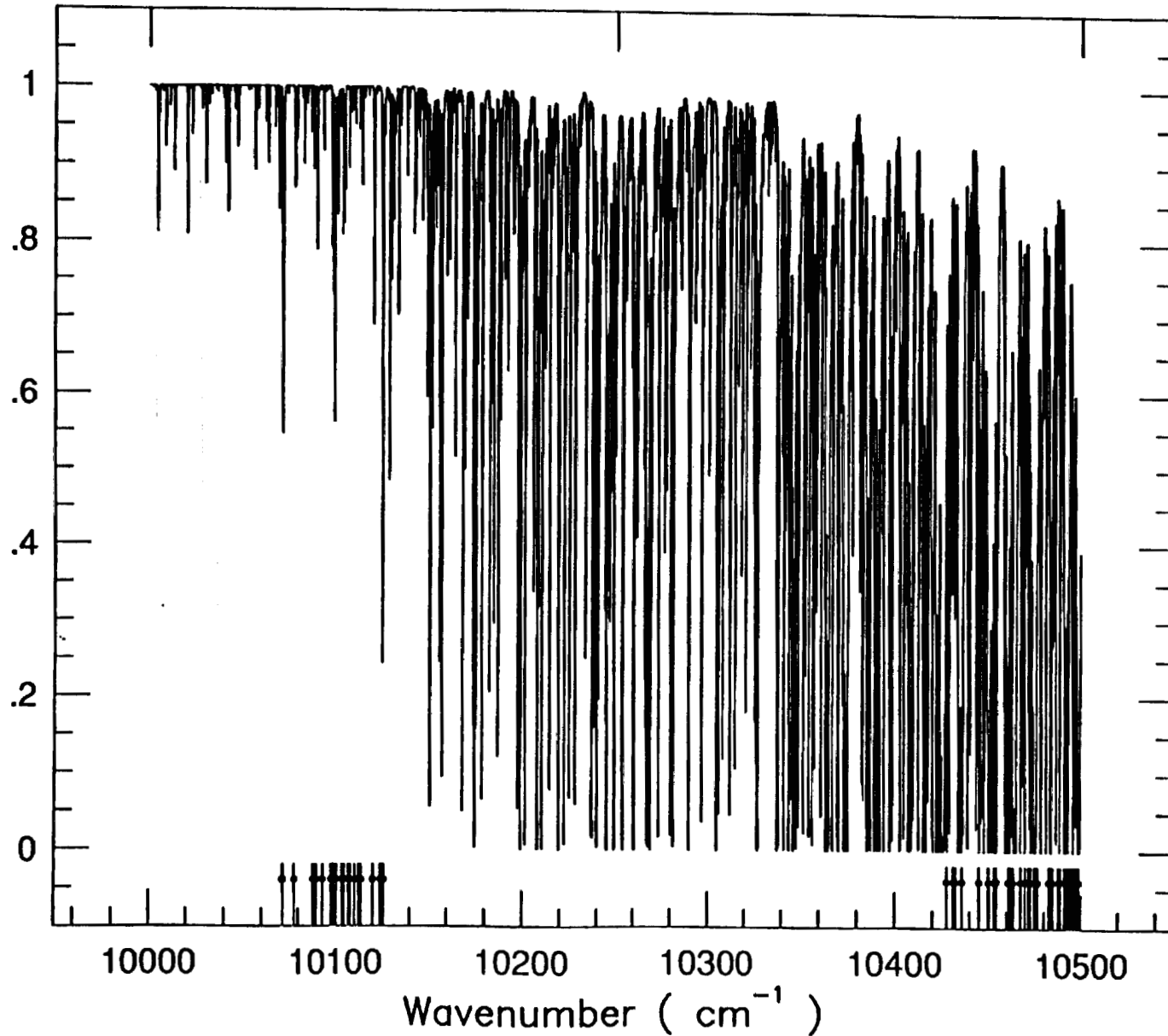
Wavelength (  $\mu\text{m}$  )

1.0000

0.9756

0.9524

#41



|                  |           |
|------------------|-----------|
| Zenith WV        | 22185.5   |
| Zenith Ang       | 45.0      |
| L.O.S. WV        | 31375.1   |
| Atm. Type        | Standard  |
| Layers           | 1         |
| Altitude         | 0         |
| ↑                |           |
| H <sub>2</sub> O |           |
| Lambda 1         | 10000.000 |
| Lambda 2         | 10500.000 |
| Sampling         | 0.000003  |
| Res(FWHM)        | 0.000000  |
| Instr. Fn.       | None      |
| Line Ctr         | 0.976     |
| Num. Pts.        | 16666     |
| Ozone            | 9.13E+18  |

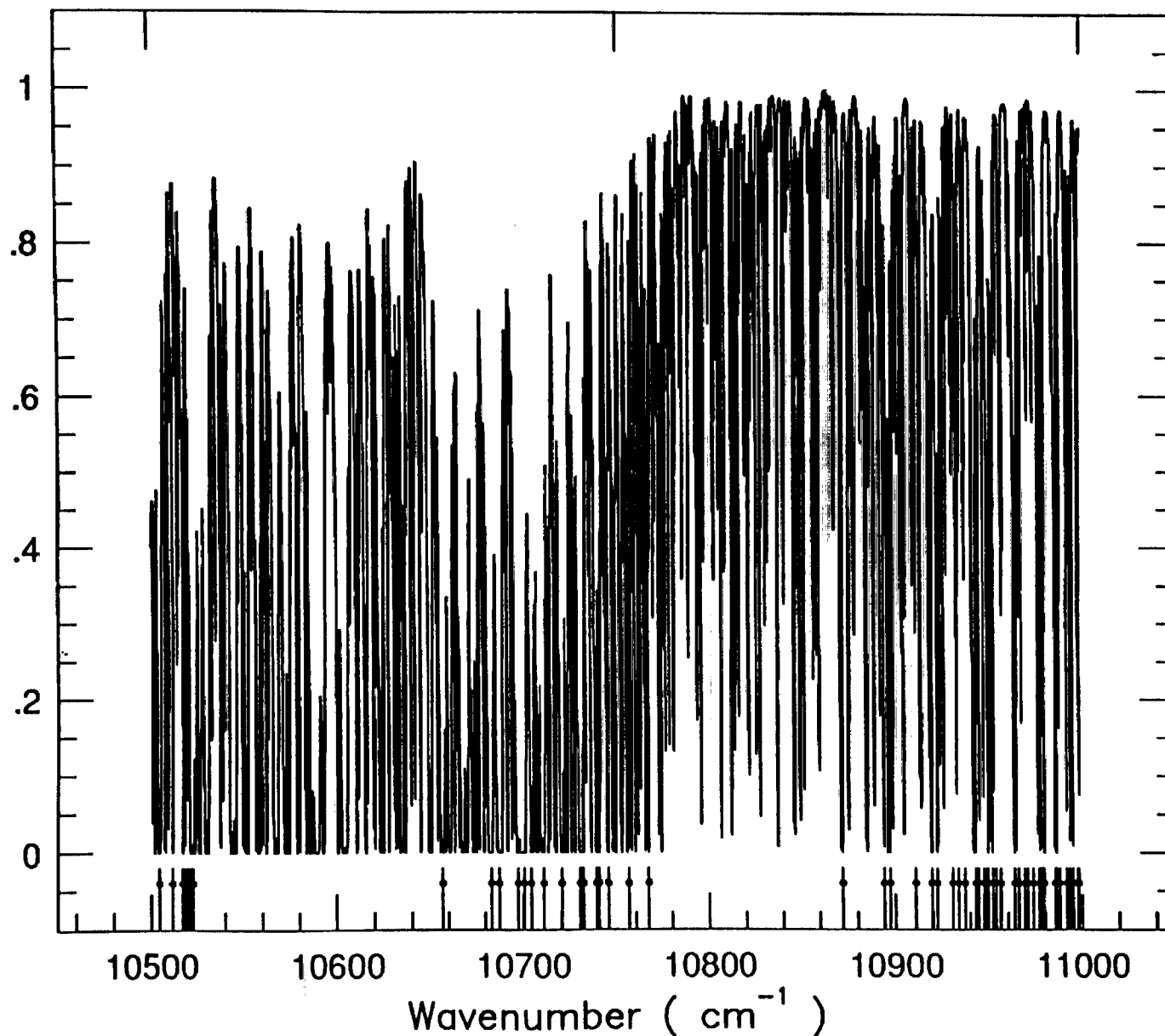
Wavelength (  $\mu\text{m}$  )

0.9524

0.9302

0.9091

#42



Zenith WV 22185.5

Zenith Ang 45.0

L.O.S. WV 31375.1

Atm. Type Standard

Layers 1

Altitude 0

↑

H<sub>2</sub>O

Lambda 1 10500.000

Lambda 2 11000.000

Sampling 0.000003

Res(FWHM) 0.000000

Instr. Fn. None

Line Ctr 0.931

Num. Pts. 16666

Ozone 9.13E+18

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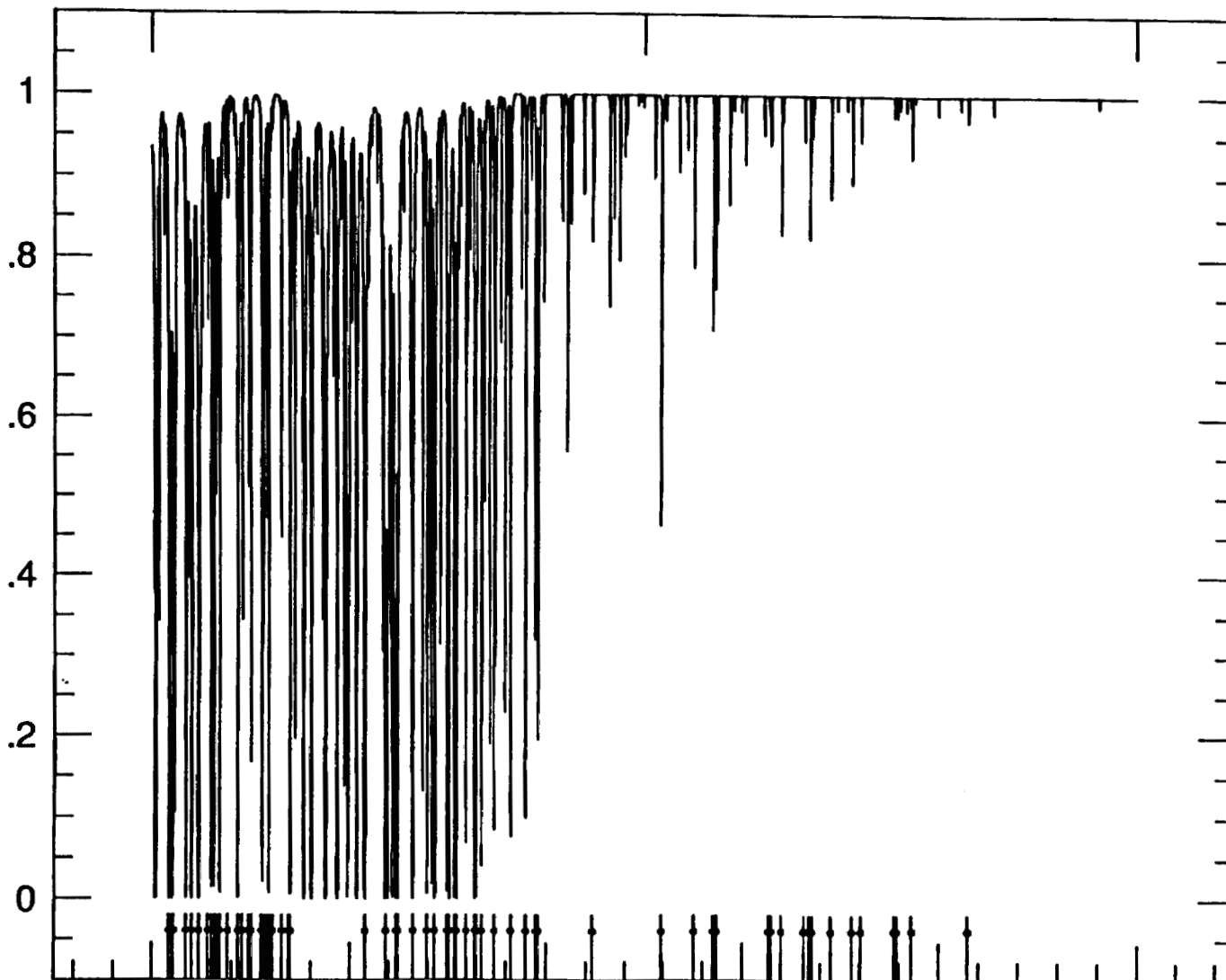
Wavelength (  $\mu\text{m}$  )

0.9091

0.8889

0.8696

#43



Zenith WV 22185.5

Zenith Ang 45.0

L.O.S. WV 31375.1

Atm. Type Standard

Layers 1

Altitude 0

↑

H<sub>2</sub>O

Lambda 1 11000.000

Lambda 2 11500.000

Sampling 0.000002

Res(FWHM) 0.000000

Instr. Fn. None

Line Ctr 0.889

Num. Pts. 16666

Ozone 9.13E+18

11000

11100

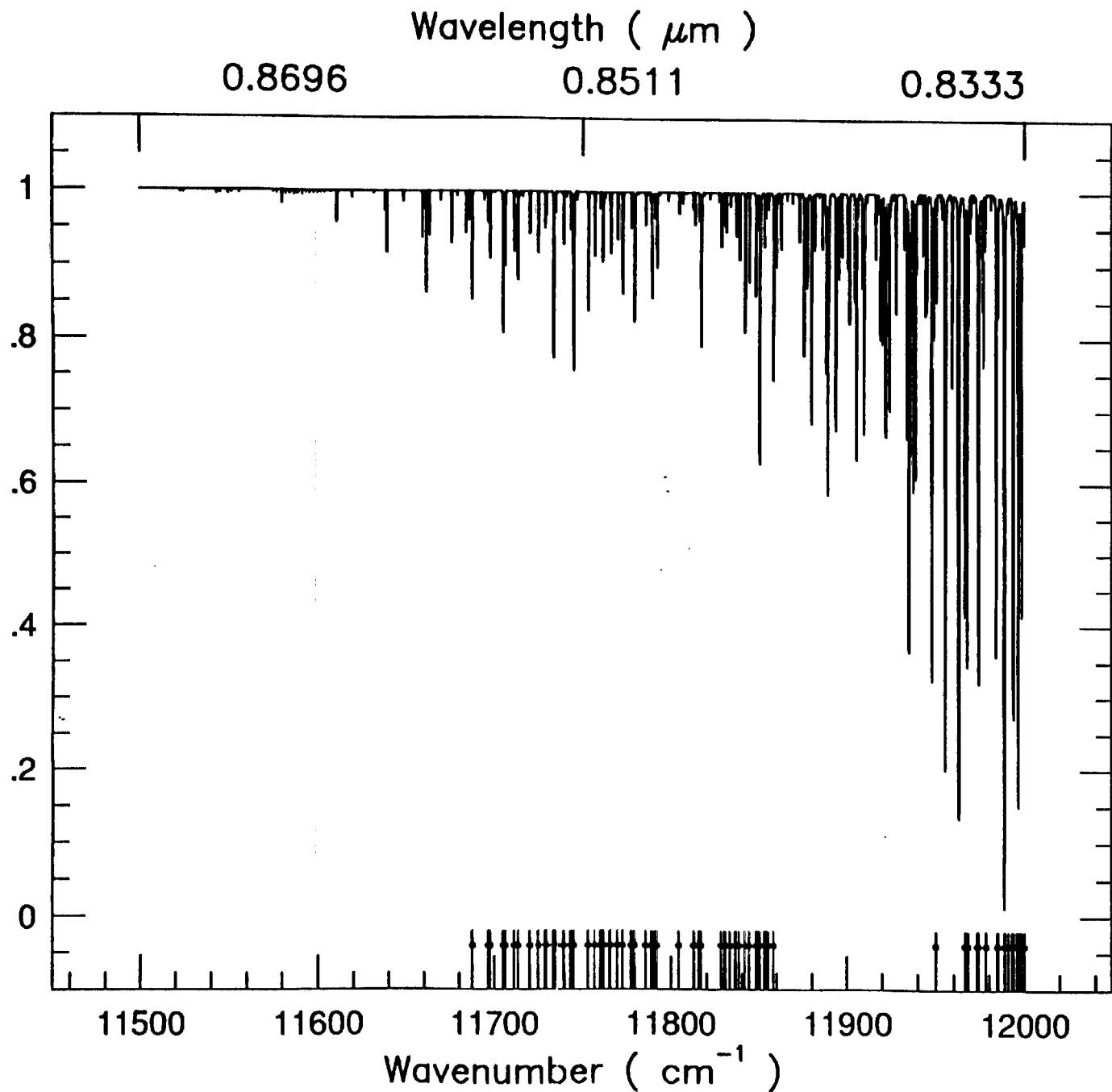
11200

11300

11400

11500

Wavenumber (  $\text{cm}^{-1}$  )



#44

Zenith WV 22185.5

Zenith Ang 45.0

L.O.S. WV 31375.1

Atm. Type Standard

Layers 1

Altitude 0

H<sub>2</sub>O

Lambda 1 11500.000

Lambda 2 12000.000

Sampling 0.000002

Res(FWHM) 0.000000

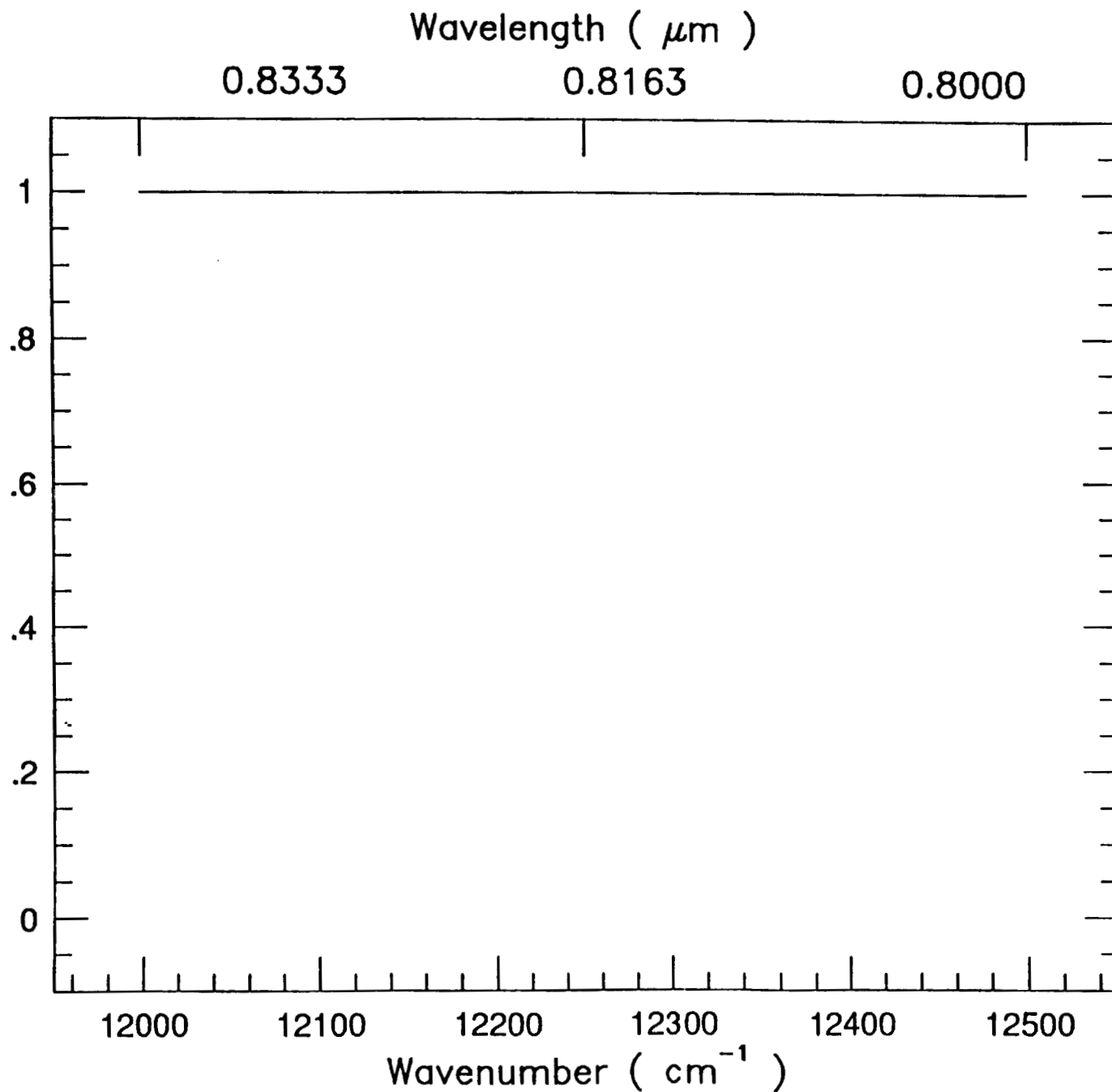
Instr. Fn. None

Line Ctr 0.851

Num. Pts. 16666

Ozone 9.13E+18

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## APPENDIX F

### TRANSMITTANCE AT FLIGHT ALTITUDE

We show the transmittance at 41,000 ft. The plots are numbered from 1 to 45 covering 10,000  $\mu\text{m}$  to 0.8  $\mu\text{m}$ .

PRECEDING PAGE BLANK NOT FILMED

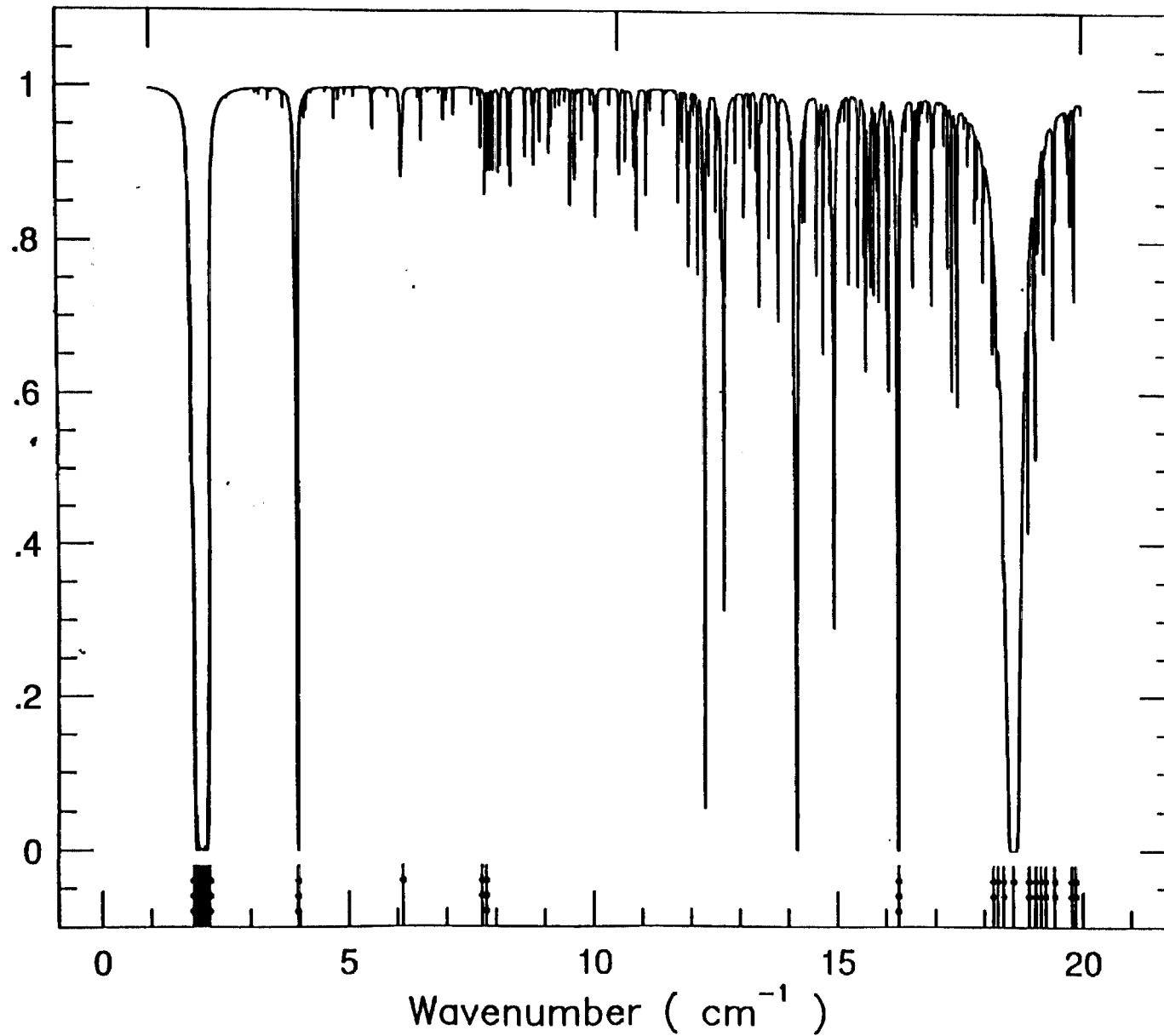
Wavelength (  $\mu\text{m}$  )

10000.0000

952.3810

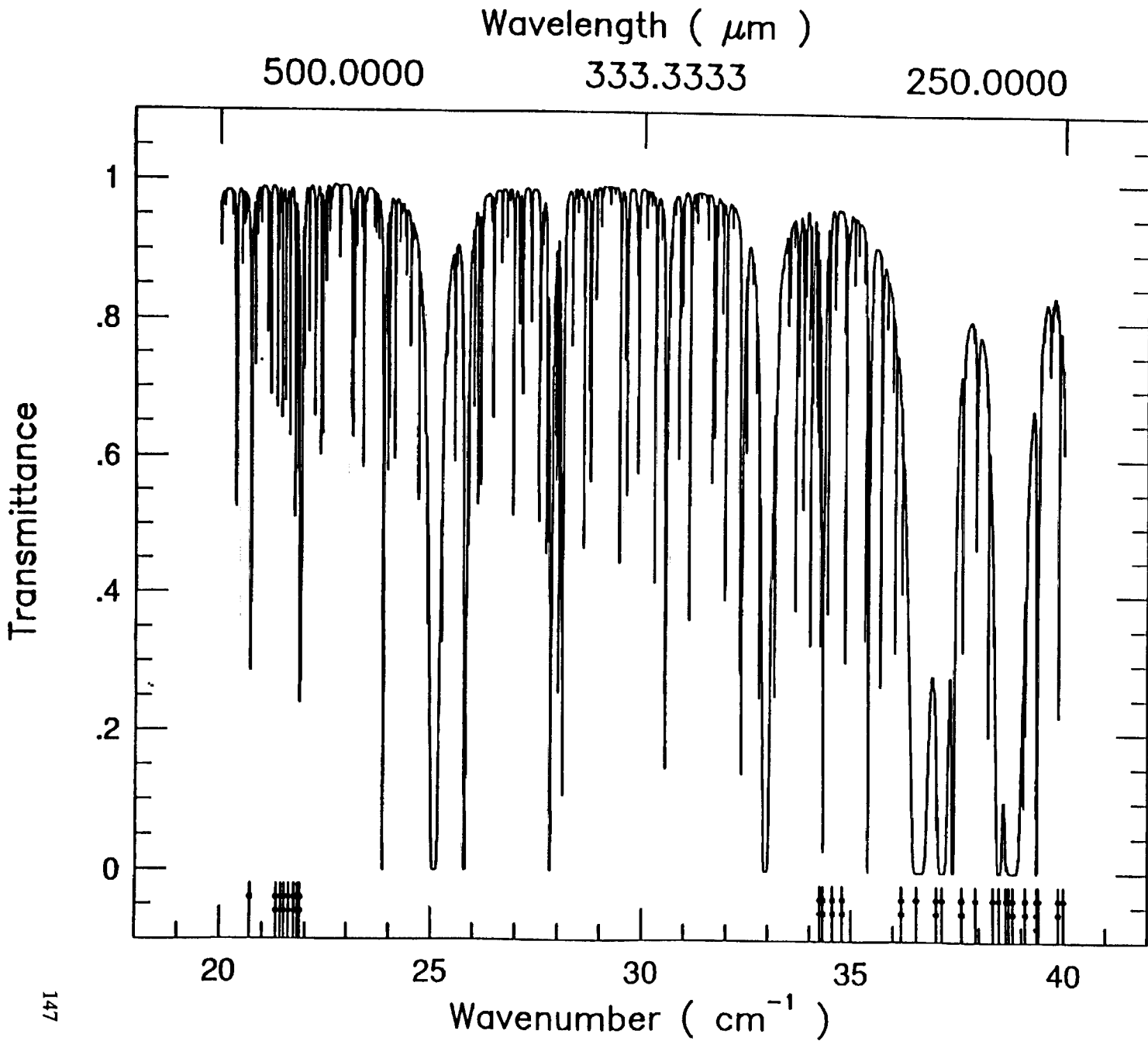
500.0000

# 1



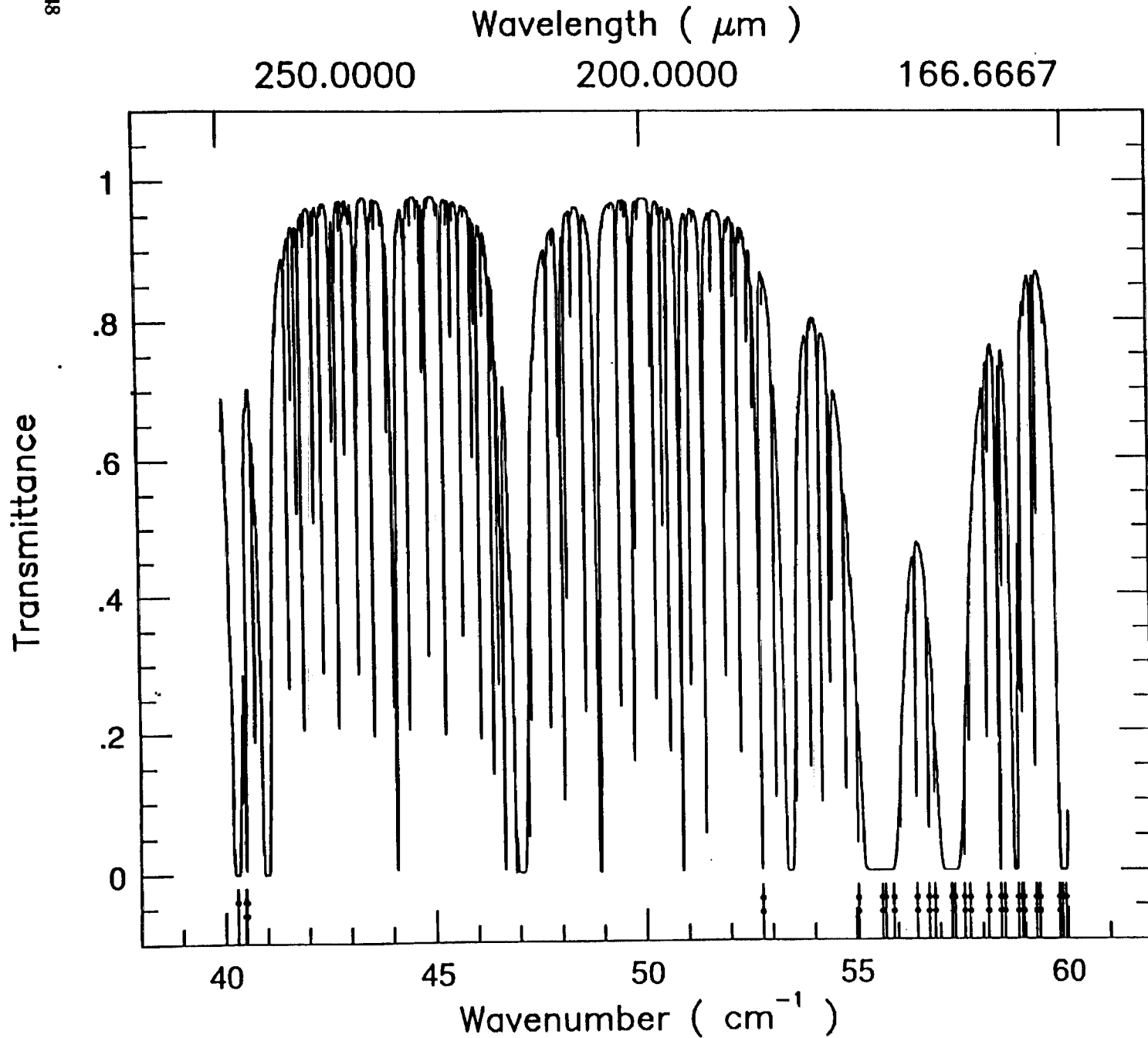
|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑                | ↑                          |
| H <sub>2</sub> O | O <sub>3</sub>             |
|                  | O <sub>2</sub>             |
| Lambda 1         | 1.000                      |
| Lambda 2         | 20.000                     |
| Sampling         | 0.884461                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 5250.000                   |
| Num. Pts.        | 10741                      |
| Ozone            | 9.13E+18                   |

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# 2

|                  |                |                |
|------------------|----------------|----------------|
| Zenith WV        | 10.0           |                |
| Zenith Ang       | 45.0           |                |
| L.O.S. WV        | 14.1           |                |
| Atm. Type        | Std.&H2O Adj.  |                |
| Layers           | 1              |                |
| Altitude         | 41000          |                |
| ↑                | ↑              | ↑              |
| H <sub>2</sub> O | O <sub>3</sub> | O <sub>2</sub> |
| Lambda 1         | 20.000         |                |
| Lambda 2         | 40.000         |                |
| Sampling         | 0.022112       |                |
| Res(FWHM)        | 0.000000       |                |
| Instr. Fn.       | None           |                |
| Line Ctr         | 375.000        |                |
| Num. Pts.        | 11306          |                |
| Ozone            | 9.13E+18       |                |



|                                 |                            |
|---------------------------------|----------------------------|
| Zenith WV                       | 10.0                       |
| Zenith Ang                      | 45.0                       |
| L.O.S. WV                       | 14.1                       |
| Atm. Type                       | Std.&H <sub>2</sub> O Adj. |
| Layers                          | 1                          |
| Altitude                        | 41000                      |
| ↑    ↓                          |                            |
| H <sub>2</sub> O O <sub>3</sub> |                            |
| Lambda 1                        | 40.000                     |
| Lambda 2                        | 60.000                     |
| Sampling                        | 0.007371                   |
| Res(FWHM)                       | 0.000000                   |
| Instr. Fn.                      | None                       |
| Line Ctr                        | 208.333                    |
| Num. Pts.                       | 11306                      |
| Ozone                           | 9.13E+18                   |

Transmittance

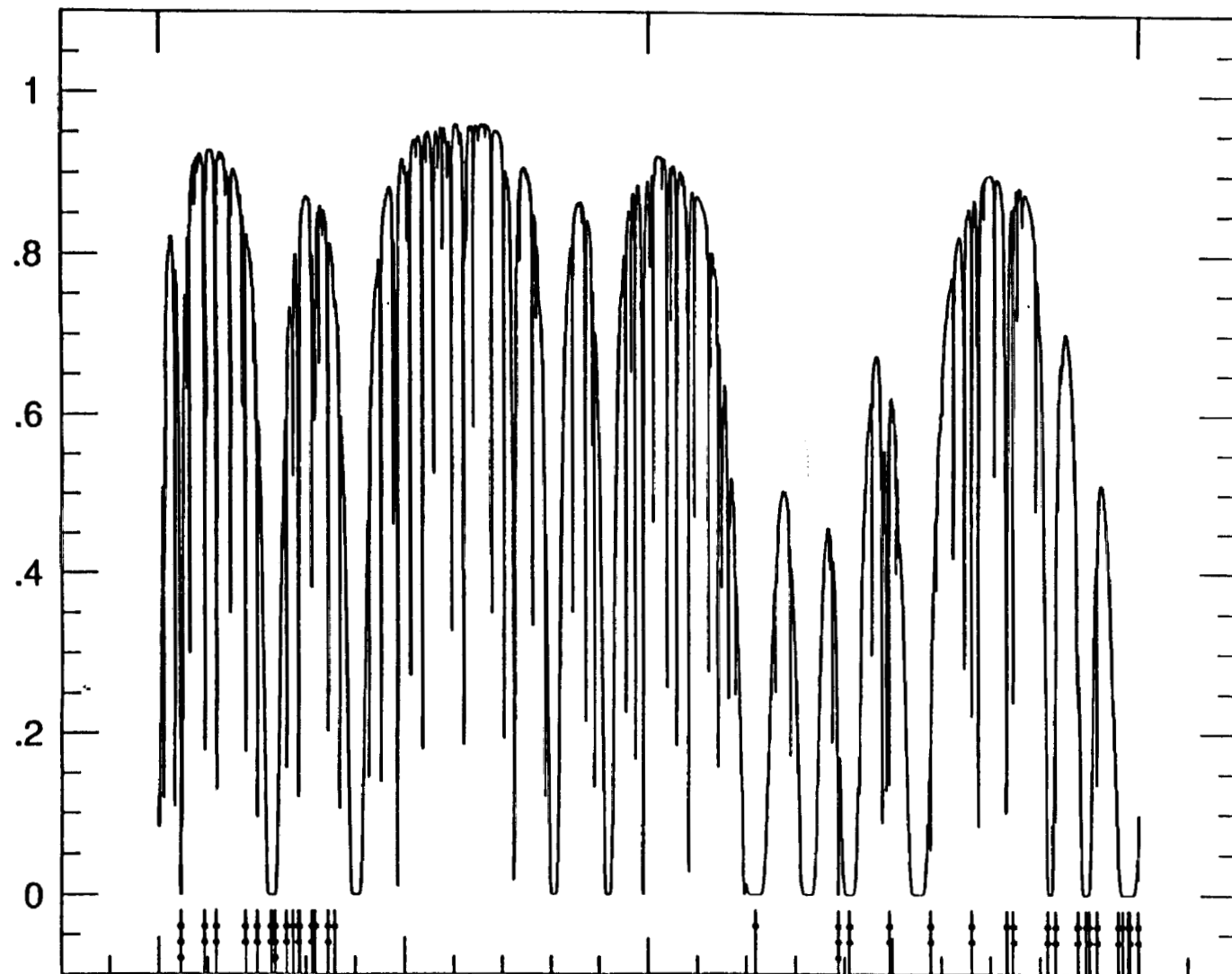
Wavelength (  $\mu\text{m}$  )

166.6667

142.8571

125.0000

# 4



|  |                            |
|--|----------------------------|
| Zenith WV                                      | 10.0                       |
| Zenith Ang                                     | 45.0                       |
| L.O.S. WV                                      | 14.1                       |
| Atm. Type                                      | Std.&H <sub>2</sub> O Adj. |
| Layers   | 1                          |
| Altitude                                       | 41000                      |
| ↑ ↑ ↓  |                            |
| H <sub>2</sub> O O <sub>3</sub> O <sub>2</sub> |                            |
| Lambda 1                                       | 60.000                     |
| Lambda 2                                       | 80.000                     |
| Sampling                                       | 0.003685                   |
| Res(FWHM)                                      | 0.000000                   |
| Instr. Fn.                                     | None                       |
| Line Ctr                                       | 145.833                    |
| Num. Pts.                                      | 11306                      |
| Ozone  | 9.13E+18                   |

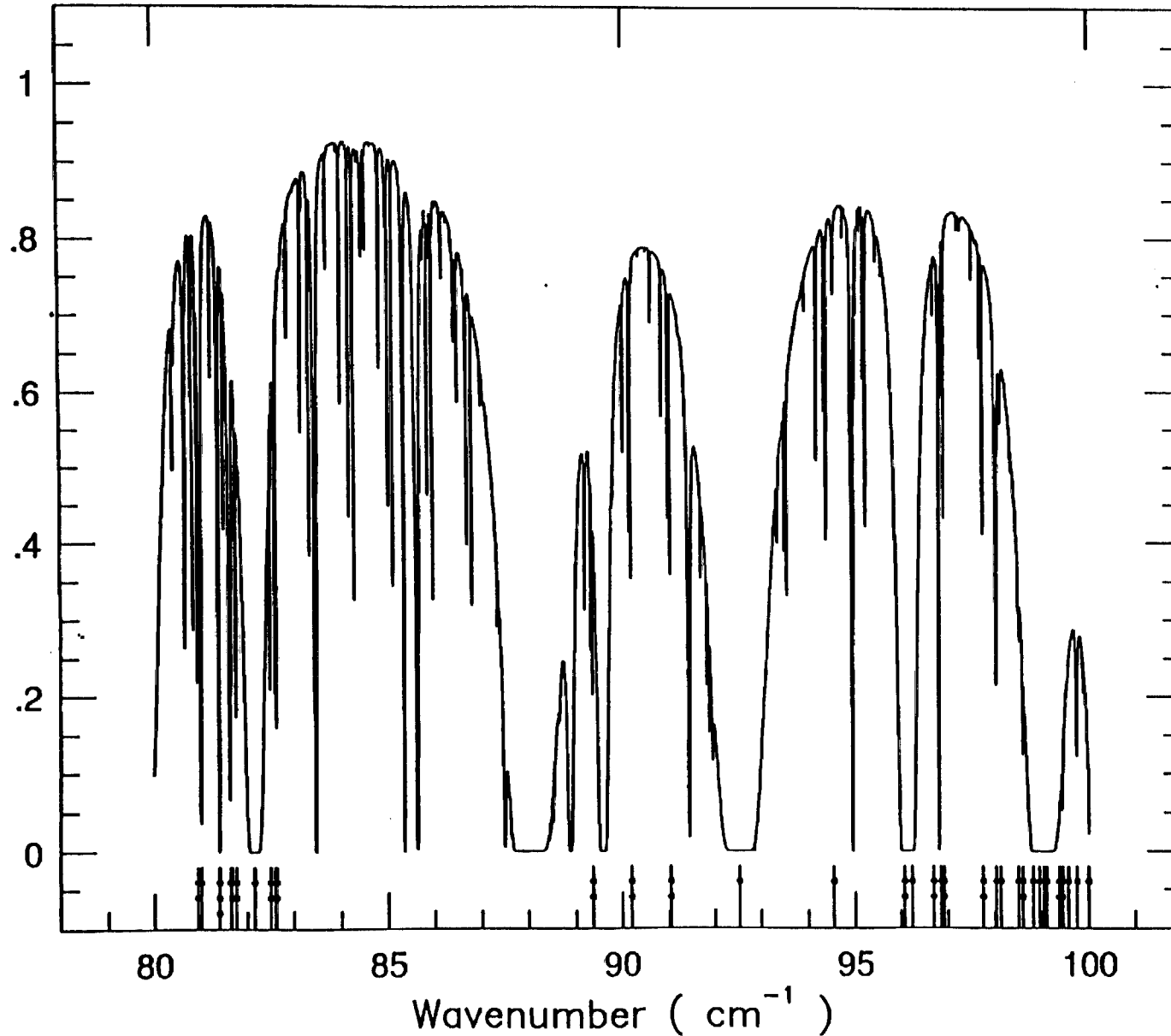
Wavelength (  $\mu\text{m}$  )

125.0000

111.1111

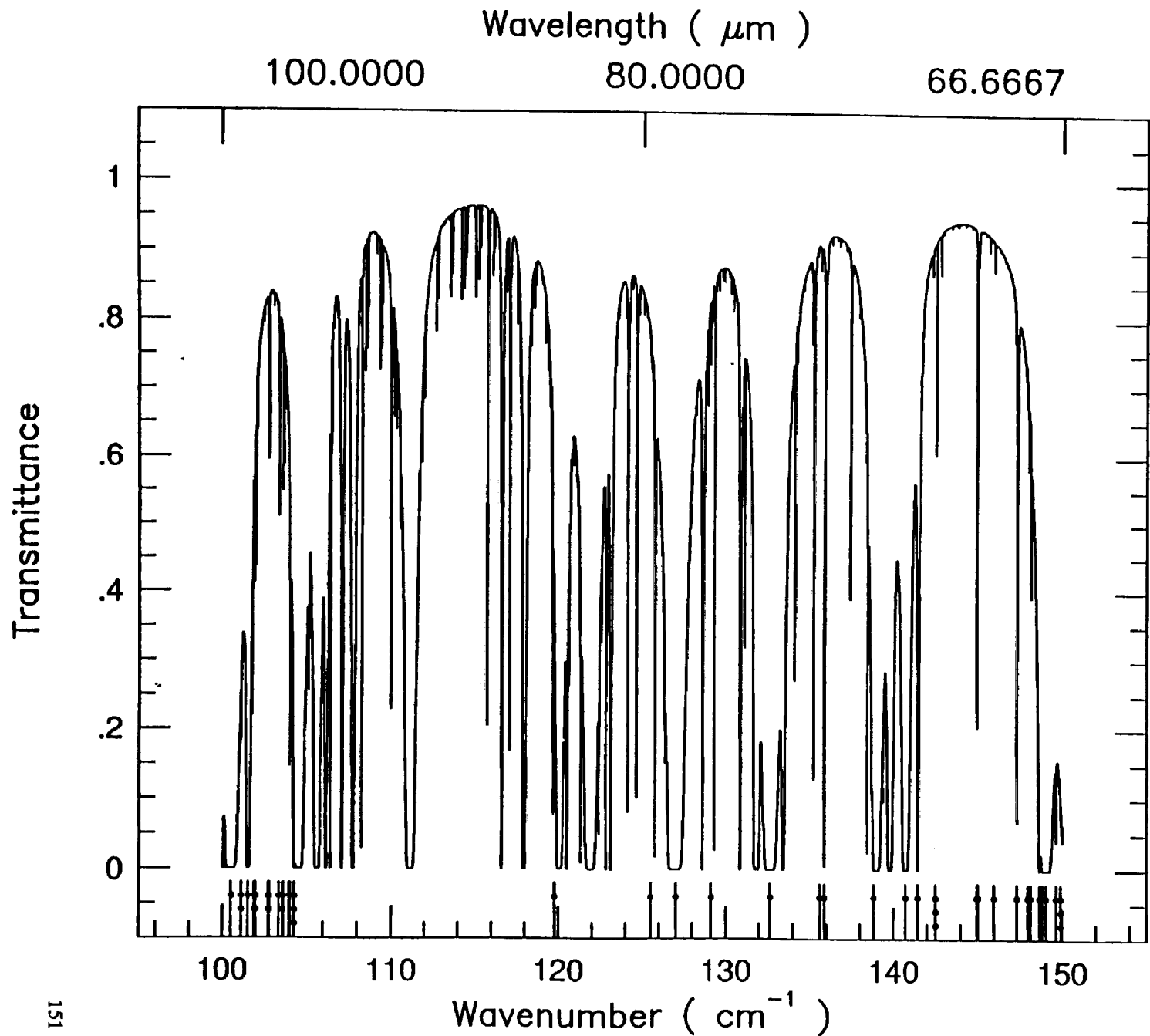
100.0000

# 5



|  |                            |
|--|----------------------------|
| Zenith WV                                      | 10.0                       |
| Zenith Ang                                     | 45.0                       |
| L.O.S. WV                                      | 14.1                       |
| Atm. Type                                      | Std.&H <sub>2</sub> O Adj. |
| Layers   | 1                          |
| Altitude                                       | 41000                      |
| ↑    ↑    ↓                                    |                            |
| H <sub>2</sub> O O <sub>3</sub> O <sub>2</sub> |                            |
| Lambda 1                                       | 80.000                     |
| Lambda 2                                       | 100.000                    |
| Sampling                                       | 0.002211                   |
| Res(FWHM)                                      | 0.000000                   |
| Instr. Fn.                                     | None                       |
| Line Ctr                                       | 112.500                    |
| Num. Pts.                                      | 11306                      |
| Ozone  | 9.13E+18                   |

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# 6

|  |                            |
|--|----------------------------|
| Zenith WV                                      | 10.0                       |
| Zenith Ang                                     | 45.0                       |
| L.O.S. WV                                      | 14.1                       |
| Atm. Type                                      | Std.&H <sub>2</sub> O Adj. |
| Layers   | 1                          |
| Altitude                                       | 41000                      |
| ↑    ↑    ↑                                    |                            |
| H <sub>2</sub> O O <sub>3</sub> O <sub>2</sub> |                            |
| Lambda 1                                       | 100.000                    |
| Lambda 2                                       | 150.000                    |
| Sampling                                       | 0.001769                   |
| Res(FWHM)                                      | 0.000000                   |
| Instr. Fn.                                     | None                       |
| Line Ctr                                       | 83.333                     |
| Num. Pts.                                      | 18843                      |
| Ozone  | 9.13E+18                   |

Wavelength (  $\mu\text{m}$  )

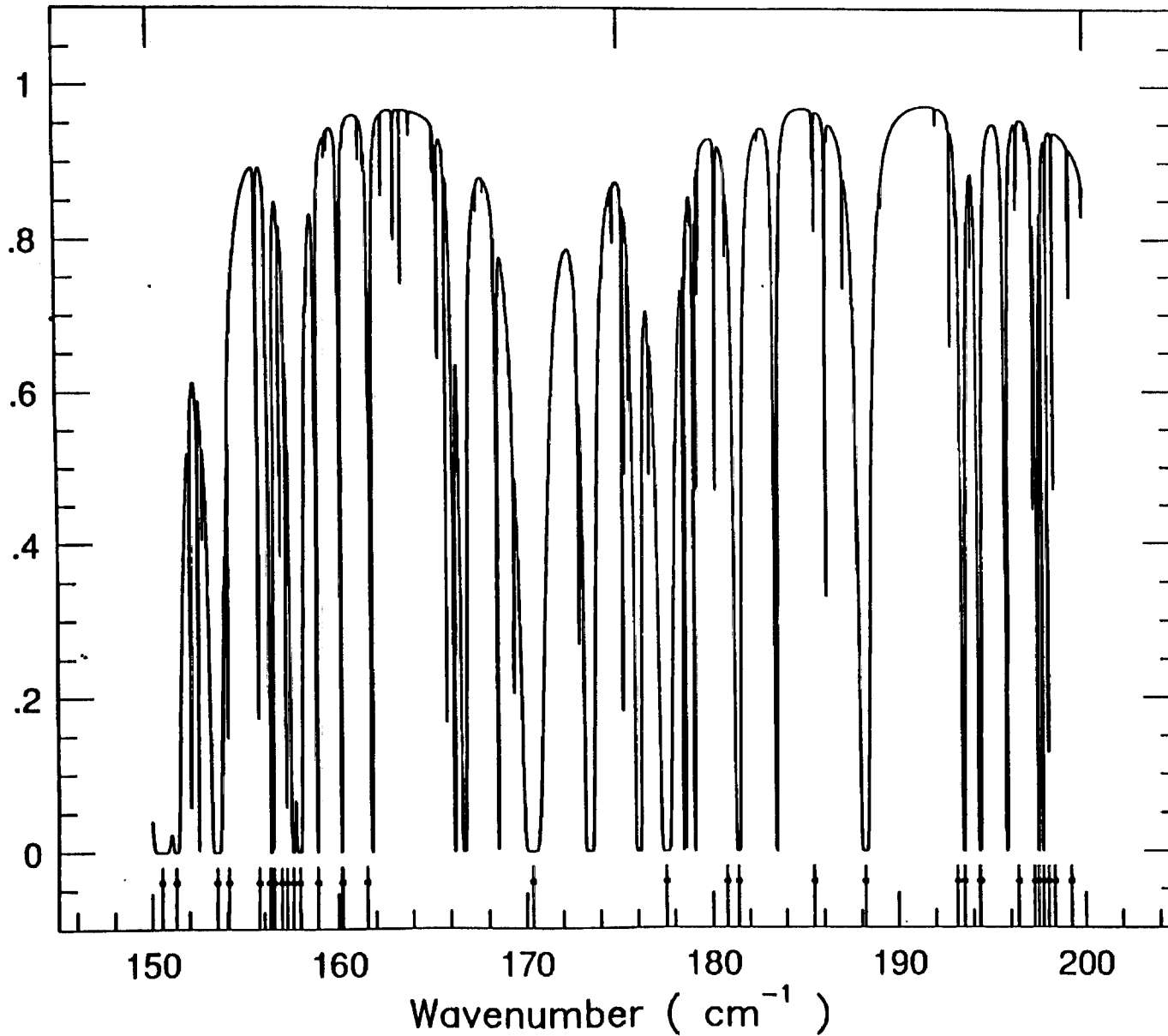
66.6667

57.1429

50.0000

# 7

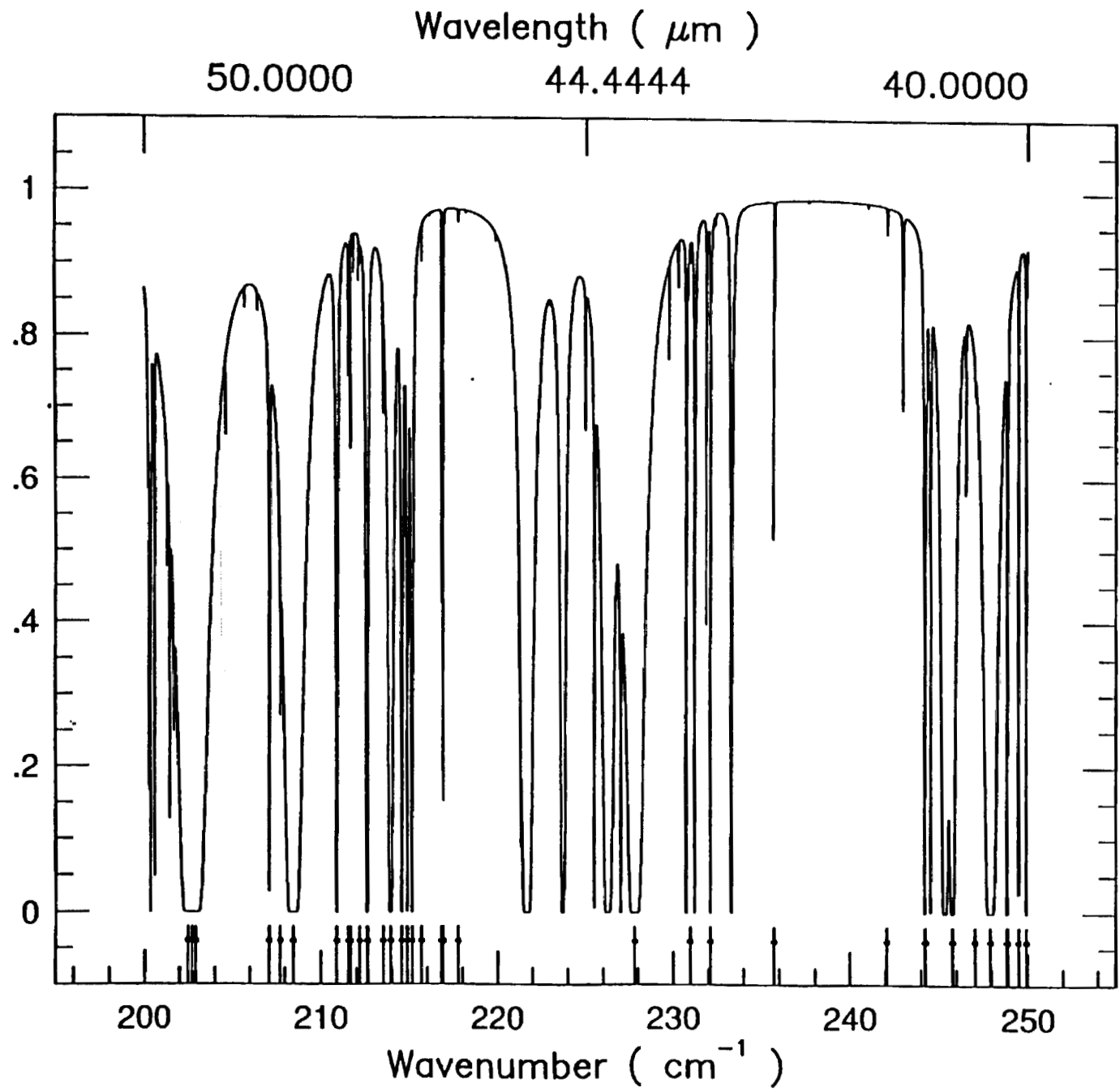
Transmittance



|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑                |                            |
| H <sub>2</sub> O |                            |
| Lambda 1         | 150.000                    |
| Lambda 2         | 200.000                    |
| Sampling         | 0.000885                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 58.333                     |
| Num. Pts.        | 18843                      |
| Ozone            | 9.13E+18                   |

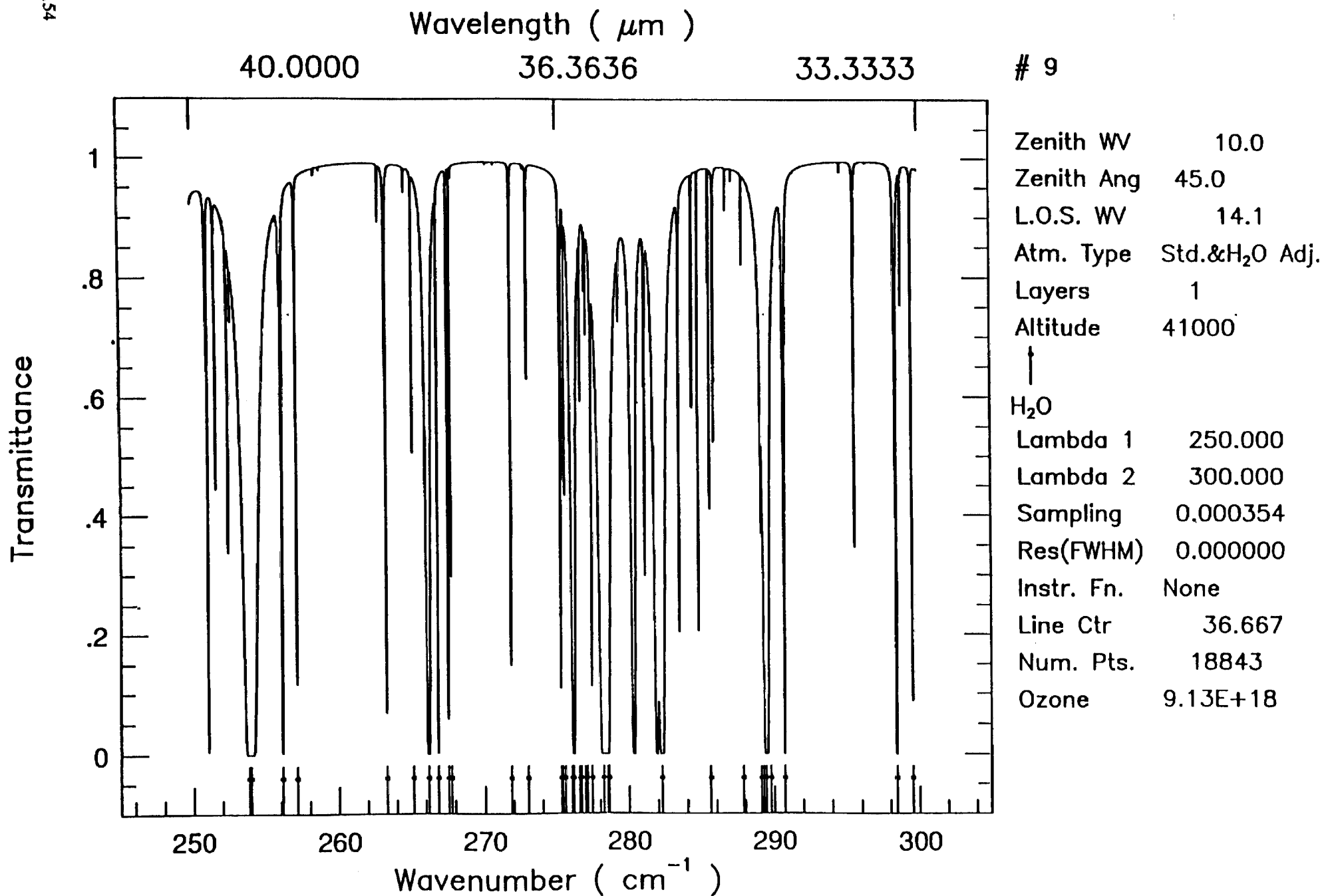
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# 8

|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑                |                            |
| H <sub>2</sub> O |                            |
| Lambda 1         | 200.000                    |
| Lambda 2         | 250.000                    |
| Sampling         | 0.000531                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 45.000                     |
| Num. Pts.        | 18843                      |
| Ozone            | 9.13E+18                   |



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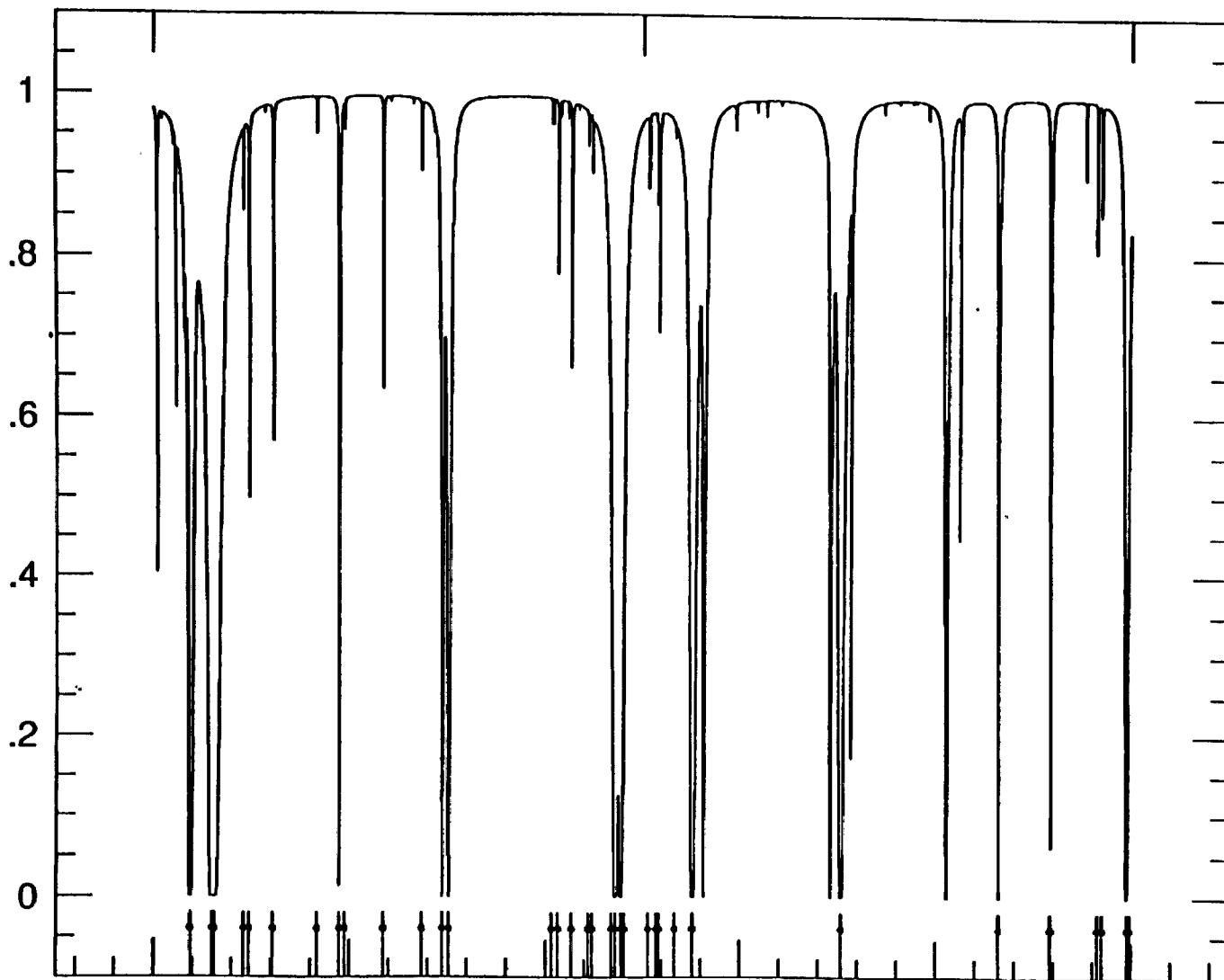
Wavelength (  $\mu\text{m}$  )

33.3333

30.7692

28.5714

#10



300

310

320

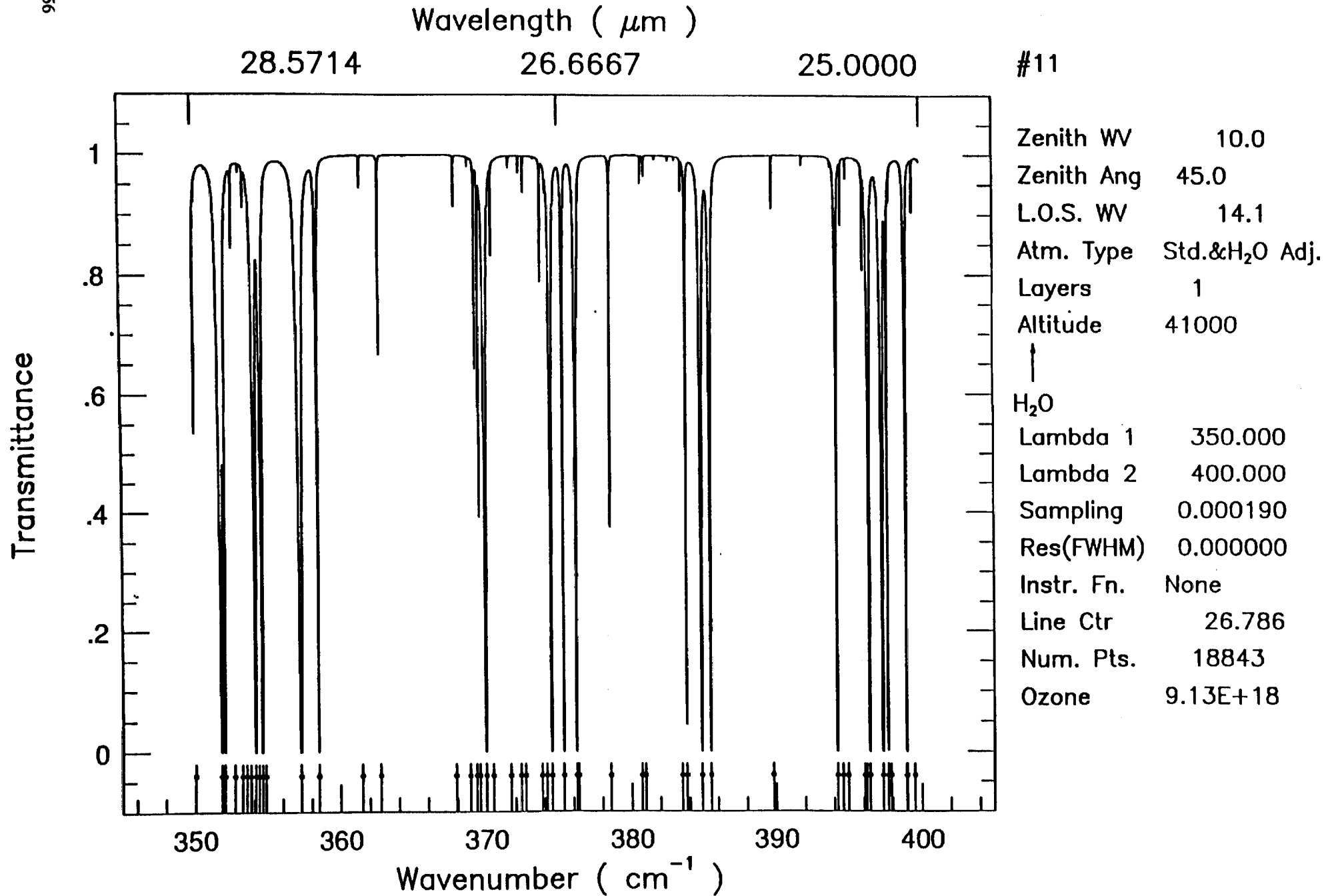
Wavenumber (  $\text{cm}^{-1}$  )

330

340

350

|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑                |                            |
| H <sub>2</sub> O |                            |
| Lambda 1         | 300.000                    |
| Lambda 2         | 350.000                    |
| Sampling         | 0.000253                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 30.952                     |
| Num. Pts.        | 18843                      |
| Ozone            | 9.13E+18                   |



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Transmittance

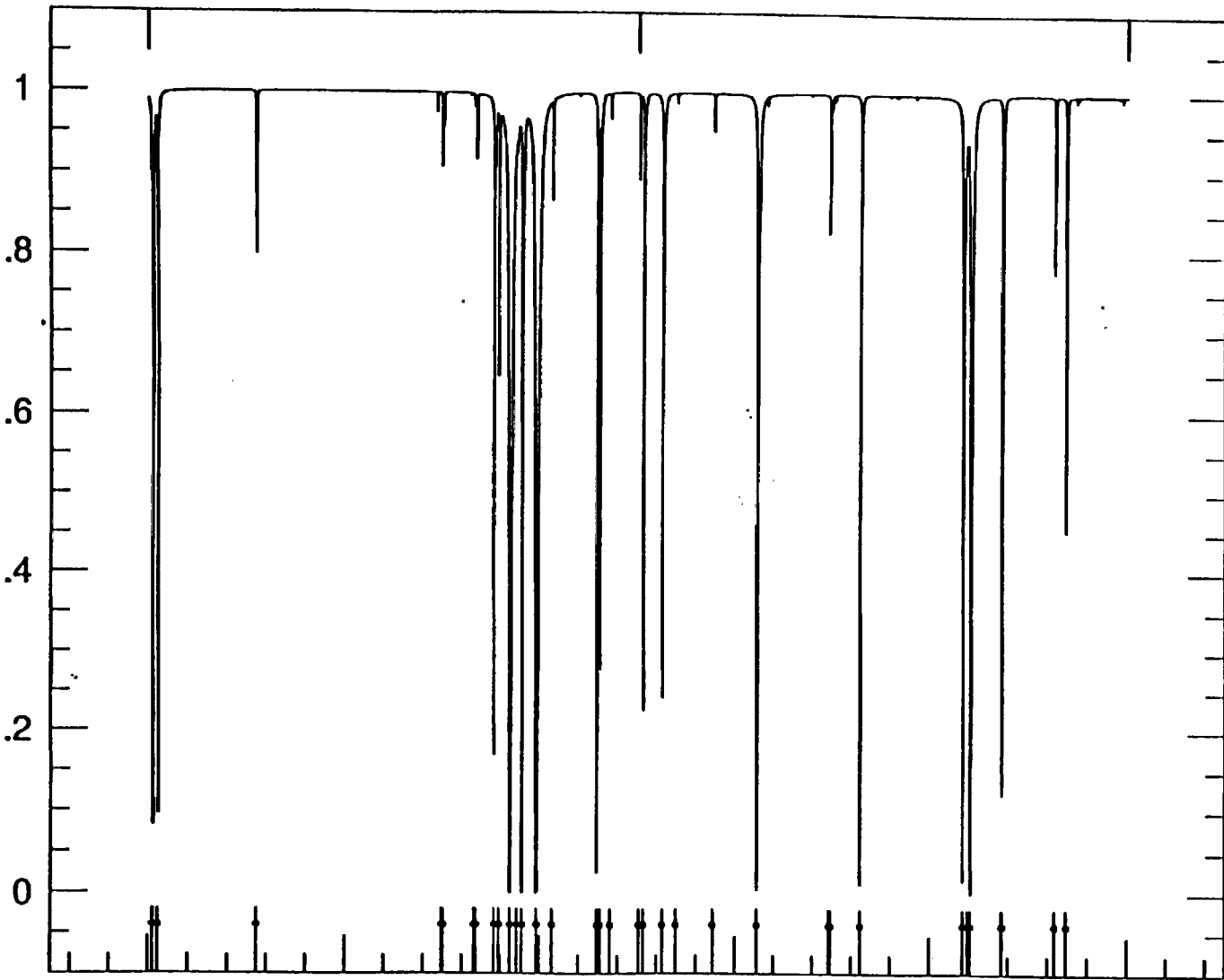
Wavelength (  $\mu\text{m}$  )

25.0000

23.5294

22.2222

#12

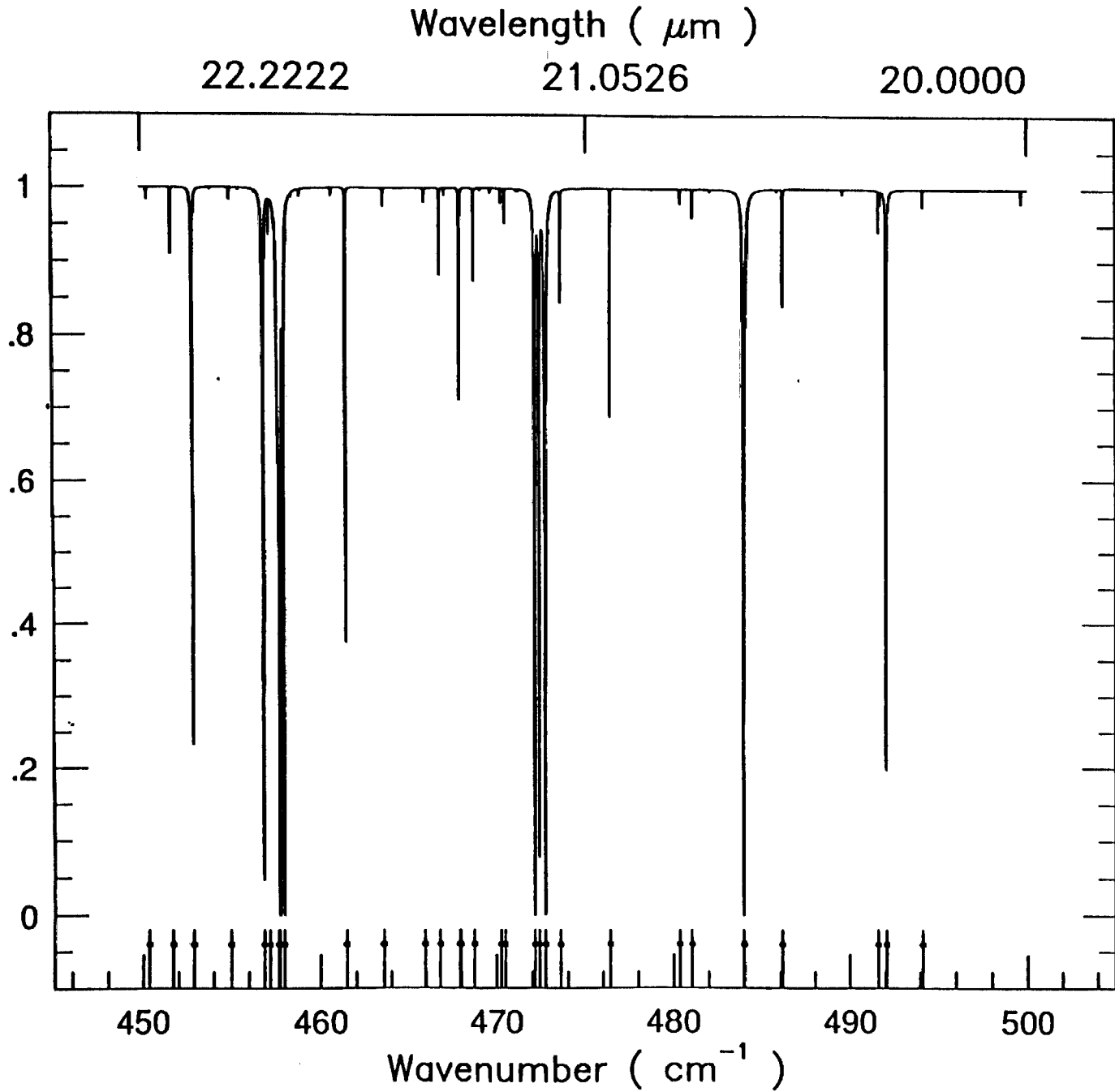


Zenith WV 10.0  
 Zenith Ang 45.0  
 L.O.S. WV 14.1  
 Atm. Type Std.&H<sub>2</sub>O Adj.  
 Layers 1  
 Altitude 41000  
 ↑  
 H<sub>2</sub>O  
 Lambda 1 400.000  
 Lambda 2 450.000  
 Sampling 0.000147  
 Res(FWHM) 0.000000  
 Instr. Fn. None  
 Line Ctr 23.611  
 Num. Pts. 18843  
 Ozone 9.13E+18

400 410 420 430 440 450

Wavenumber (  $\text{cm}^{-1}$  )

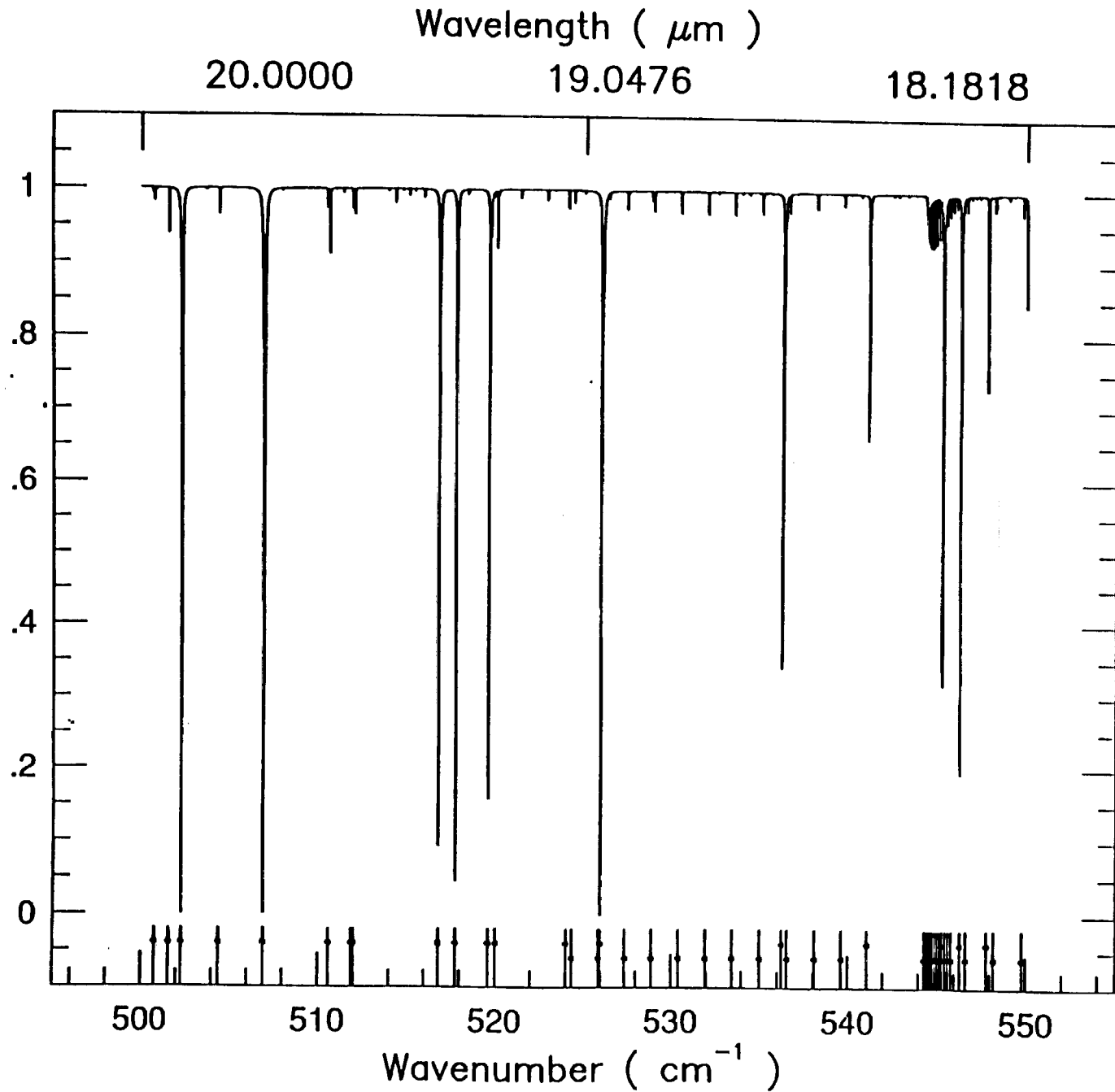
Transmittance



#13

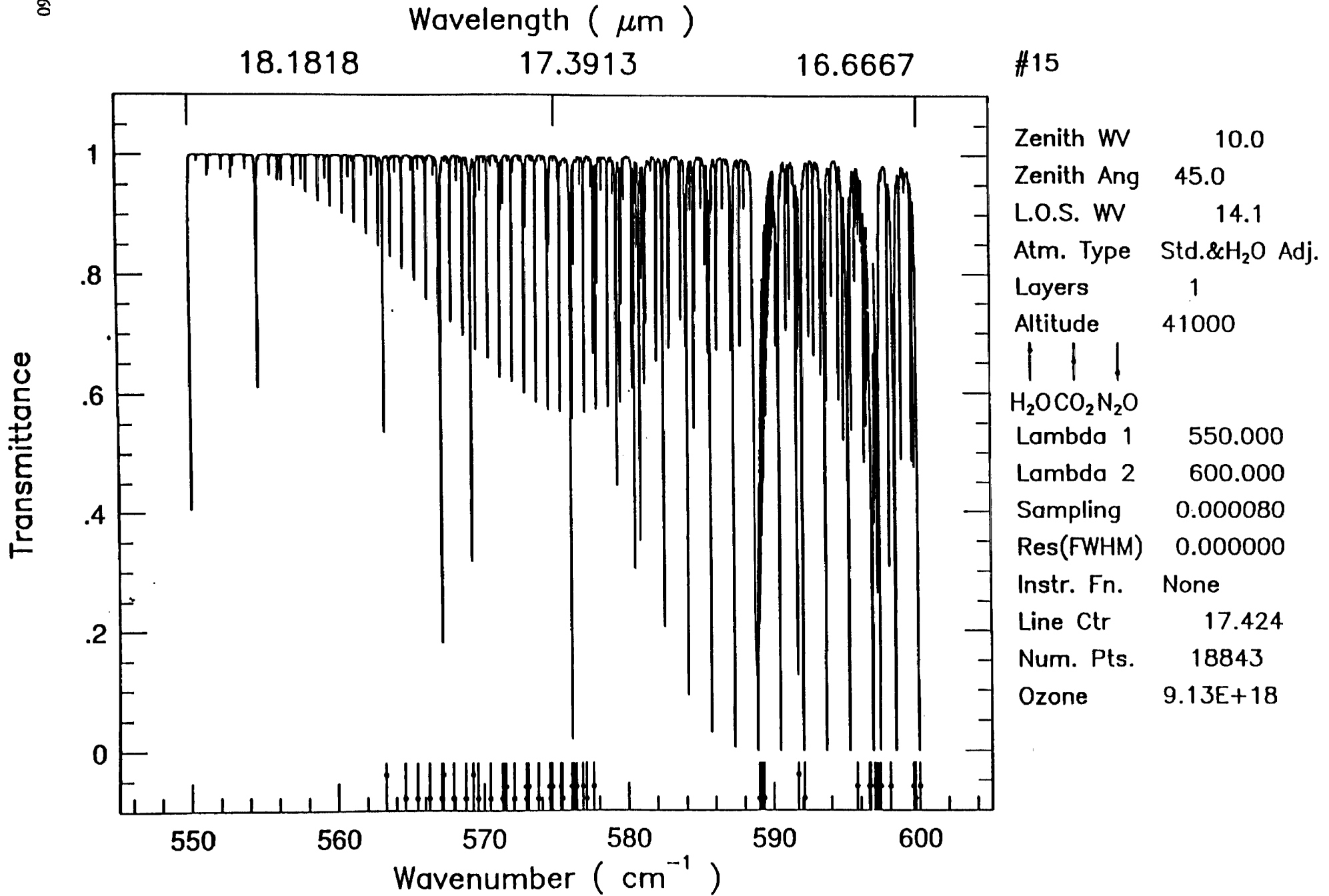
|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑                |                            |
| H <sub>2</sub> O |                            |
| Lambda 1         | 450.000                    |
| Lambda 2         | 500.000                    |
| Sampling         | 0.000118                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 21.111                     |
| Num. Pts.        | 18843                      |
| Ozone            | 9.13E+18                   |

Transmittance



#14

|                                 |                            |
|---------------------------------|----------------------------|
| Zenith WV                       | 10.0                       |
| Zenith Ang                      | 45.0                       |
| L.O.S. WV                       | 14.1                       |
| Atm. Type                       | Std.&H <sub>2</sub> O Adj. |
| Layers                          | 1                          |
| Altitude                        | 41000                      |
| ↑ ↓                             |                            |
| H <sub>2</sub> OCO <sub>2</sub> |                            |
| Lambda 1                        | 500.000                    |
| Lambda 2                        | 550.000                    |
| Sampling                        | 0.000096                   |
| Res(FWHM)                       | 0.000000                   |
| Instr. Fn.                      | None                       |
| Line Ctr                        | 19.091                     |
| Num. Pts.                       | 18843                      |
| Ozone                           | 9.13E+18                   |



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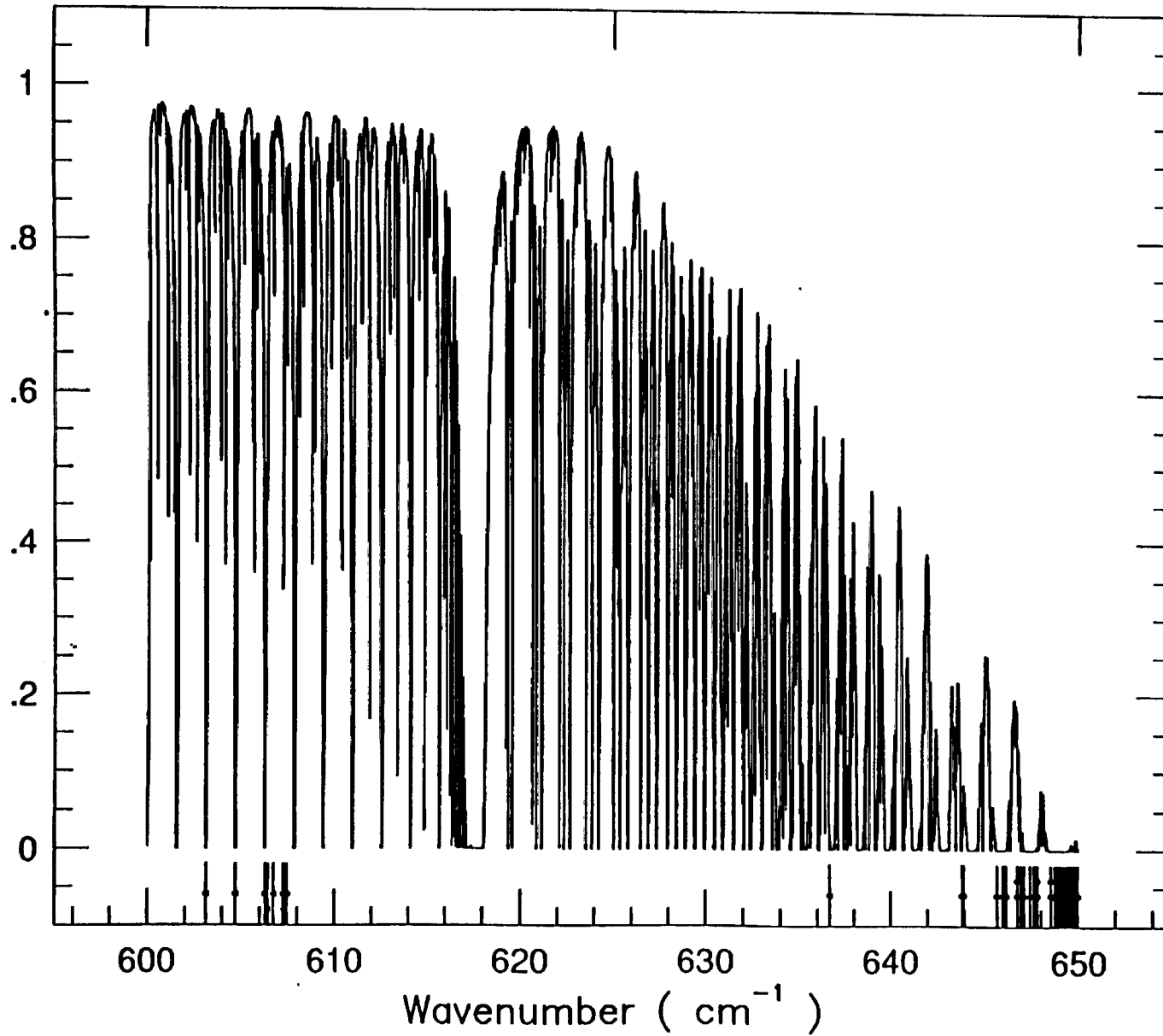
Wavelength (  $\mu\text{m}$  )

16.6667

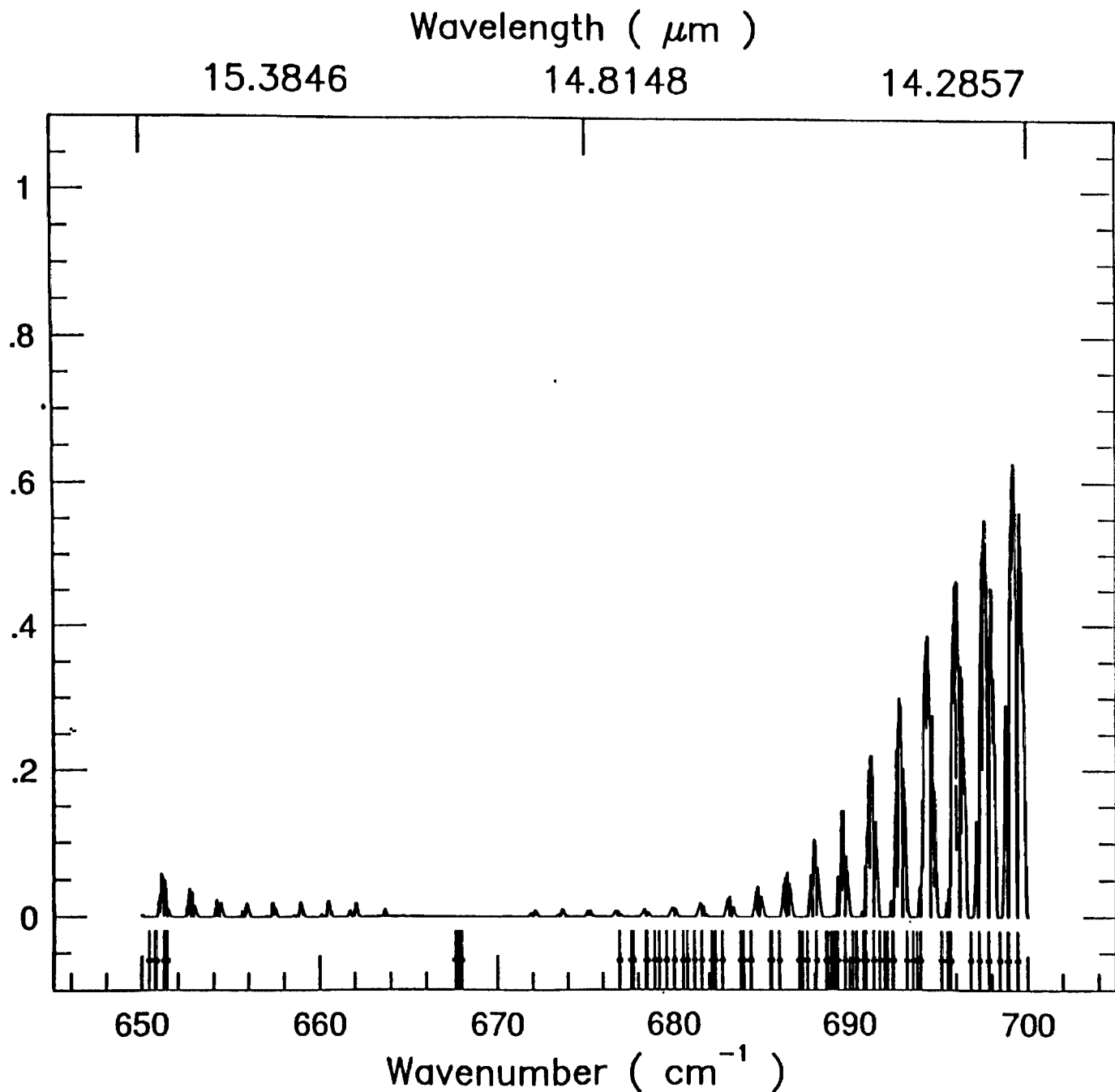
16.0000

15.3846

#16



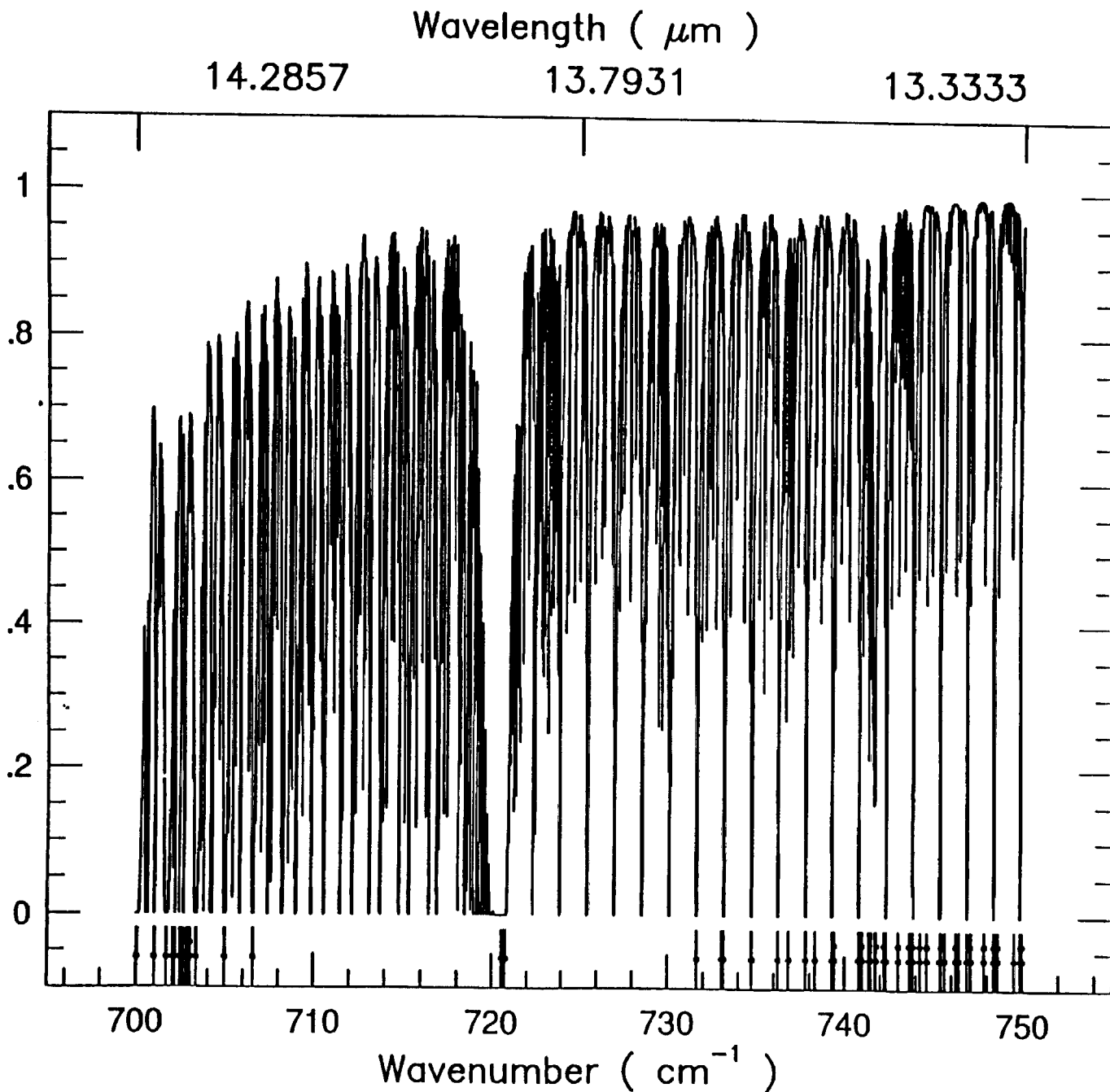
|   |                            |
|---|----------------------------|
| Zenith WV                                       | 10.0                       |
| Zenith Ang                                      | 45.0                       |
| L.O.S. WV                                       | 14.1                       |
| Atm. Type                                       | Std.&H <sub>2</sub> O Adj. |
| Layers  | 1                          |
| Altitude  | 41000                      |
|   | ↓ ↓ ↓                      |
| CO <sub>2</sub> O <sub>3</sub> N <sub>2</sub> O |                            |
| Lambda 1  | 600.000                    |
| Lambda 2  | 650.000                    |
| Sampling  | 0.000068                   |
| Res(FWHM)                                       | 0.000000                   |
| Instr. Fn.                                      | None                       |
| Line Ctr  | 16.026                     |
| Num. Pts.                                       | 18843                      |
| Ozone   | 9.13E+18                   |



#17

|                 |                            |
|-----------------|----------------------------|
| Zenith WV       | 10.0                       |
| Zenith Ang      | 45.0                       |
| L.O.S. WV       | 14.1                       |
| Atm. Type       | Std.&H <sub>2</sub> O Adj. |
| Layers          | 1                          |
| Altitude        | 41000                      |
| ↓               |                            |
| CO <sub>2</sub> |                            |
| Lambda 1        | 650.000                    |
| Lambda 2        | 700.000                    |
| Sampling        | 0.000058                   |
| Res(FWHM)       | 0.000000                   |
| Instr. Fn.      | None                       |
| Line Ctr        | 14.835                     |
| Num. Pts.       | 18843                      |
| Ozone           | 9.13E+18                   |

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#18

|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| H <sub>2</sub> O | ↑                          |
| CO <sub>2</sub>  | ↑                          |
| O <sub>3</sub>   | ↑                          |
| Lambda 1         | 700.000                    |
| Lambda 2         | 750.000                    |
| Sampling         | 0.000051                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 13.810                     |
| Num. Pts.        | 18843                      |
| Ozone            | 9.13E+18                   |

Wavelength (  $\mu\text{m}$  )

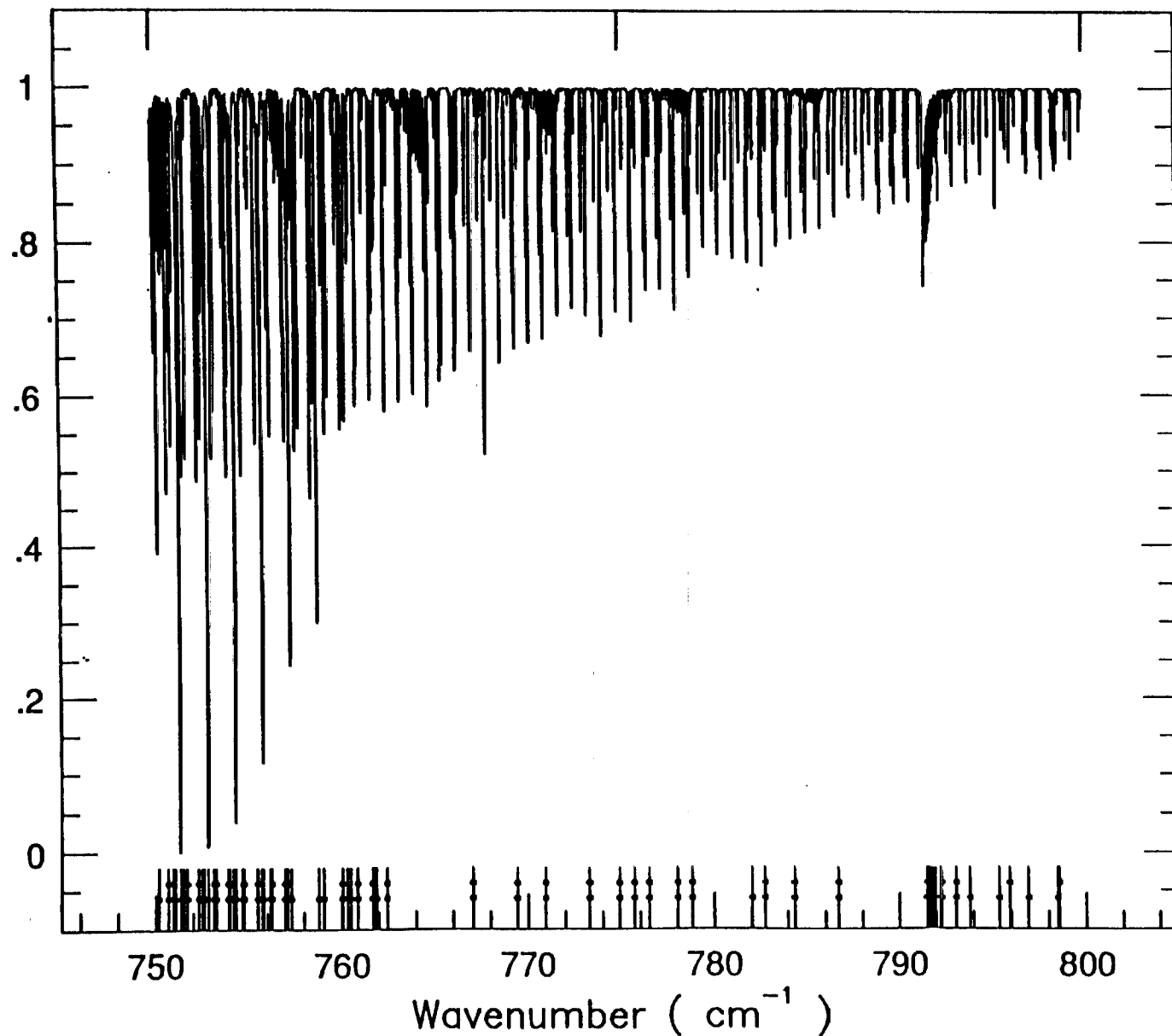
13.3333

12.9032

12.5000

#19

Transmittance



|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑   ↓   ↓        |                            |
| H <sub>2</sub> O | CO <sub>2</sub>            |
| O <sub>3</sub>   |                            |
| Lambda 1         | 750.000                    |
| Lambda 2         | 800.000                    |
| Sampling         | 0.000044                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 12.917                     |
| Num. Pts.        | 18843                      |
| Ozone            | 9.13E+18                   |

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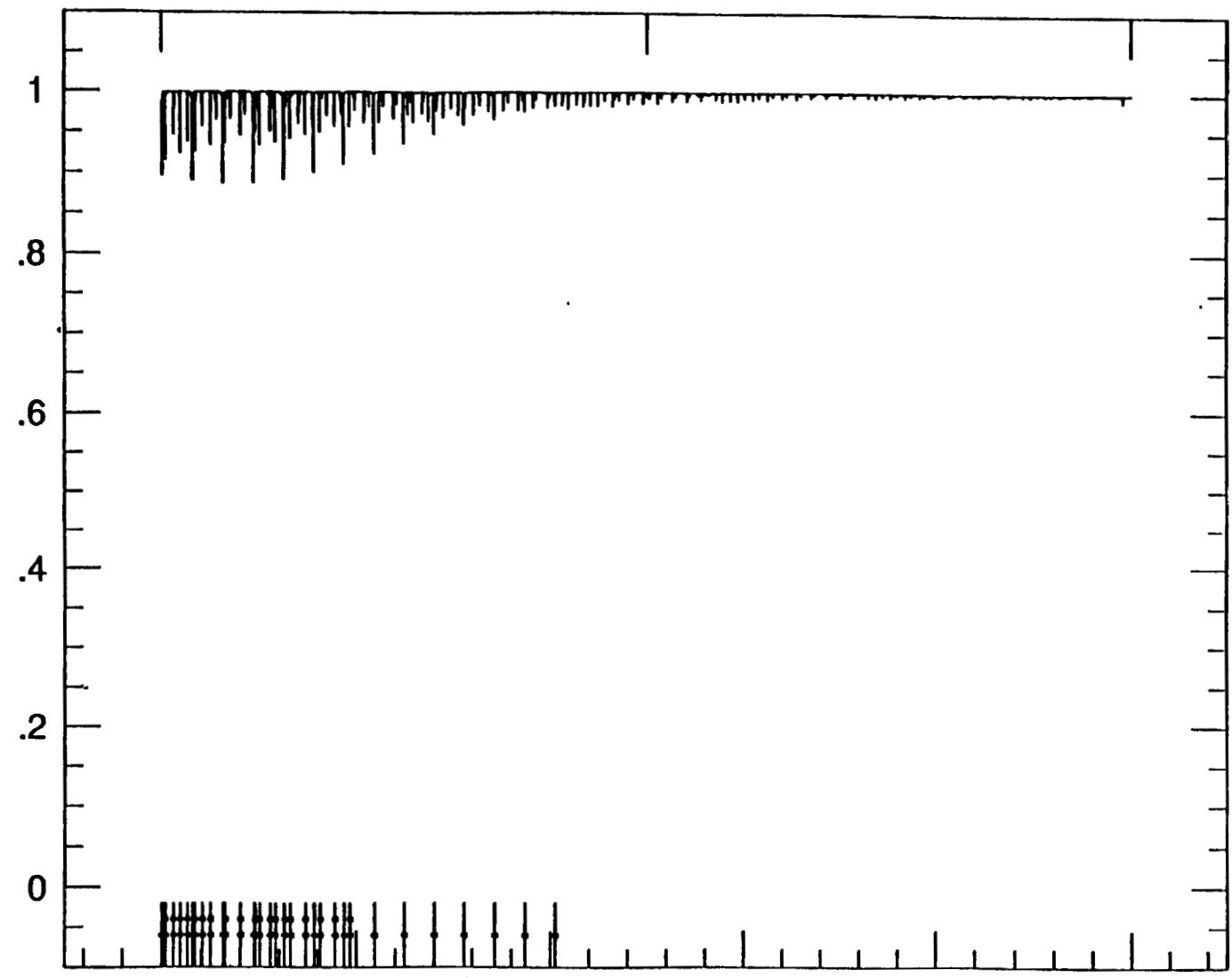
Wavelength (  $\mu\text{m}$  )

12.5000

12.1212

11.7647

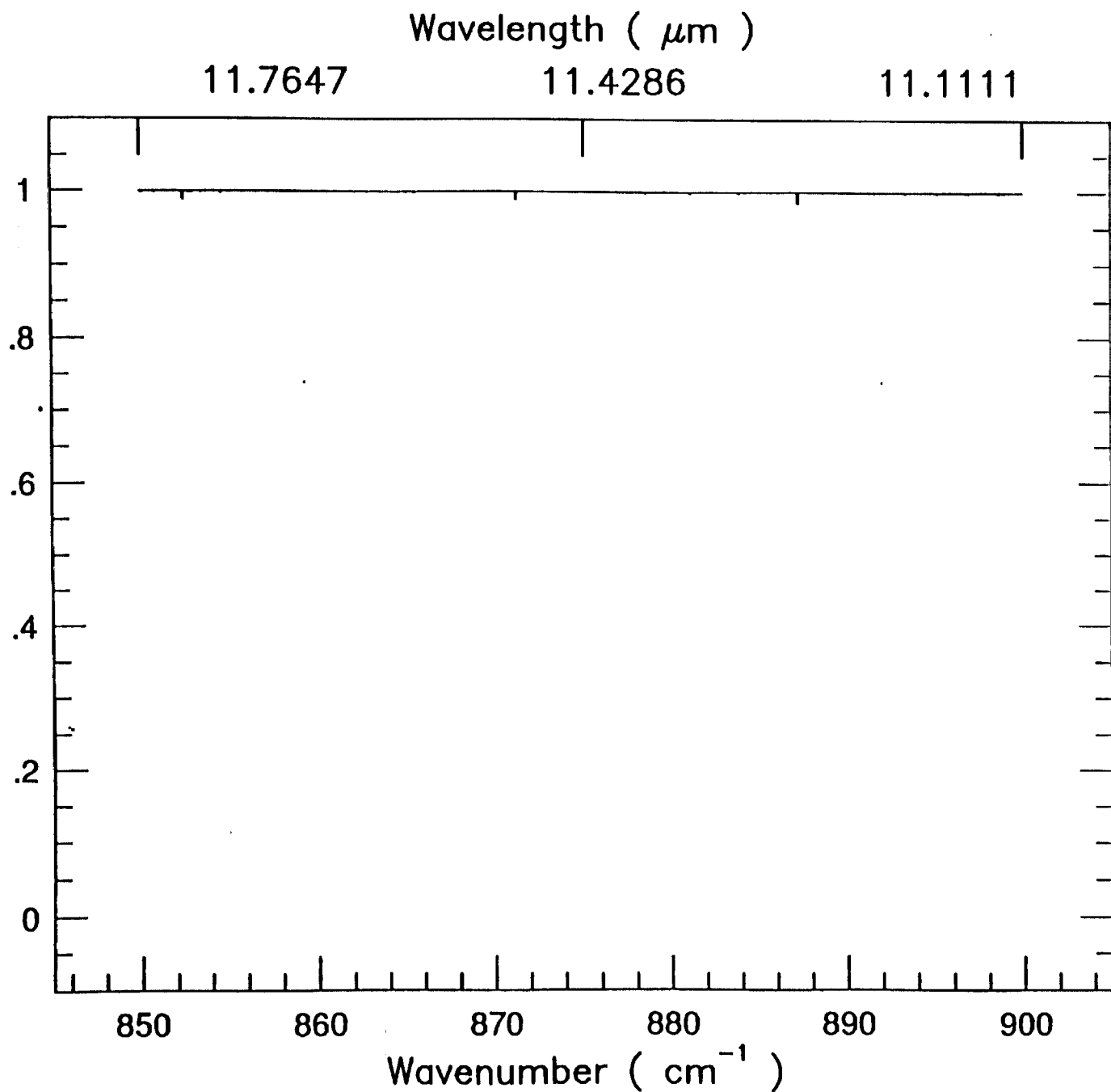
#20



800 810 820 830 840 850

Wavenumber (  $\text{cm}^{-1}$  )

|                                |                            |
|--------------------------------|----------------------------|
| Zenith WV                      | 10.0                       |
| Zenith Ang                     | 45.0                       |
| L.O.S. WV                      | 14.1                       |
| Atm. Type                      | Std.&H <sub>2</sub> O Adj. |
| Layers                         | 1                          |
| Altitude                       | 41000                      |
| CO <sub>2</sub> O <sub>3</sub> |                            |
| Lambda 1                       | 800.000                    |
| Lambda 2                       | 850.000                    |
| Sampling                       | 0.000039                   |
| Res(FWHM)                      | 0.000000                   |
| Instr. Fn.                     | None                       |
| Line Ctr                       | 12.132                     |
| Num. Pts.                      | 18843                      |
| Ozone                          | 9.13E+18                   |



#21

|            |                            |
|------------|----------------------------|
| Zenith WV  | 10.0                       |
| Zenith Ang | 45.0                       |
| L.O.S. WV  | 14.1                       |
| Atm. Type  | Std.&H <sub>2</sub> O Adj. |
| Layers     | 1                          |
| Altitude   | 41000                      |
| Lambda 1   | 850.000                    |
| Lambda 2   | 900.000                    |
| Sampling   | 0.000035                   |
| Res(FWHM)  | 0.000000                   |
| Instr. Fn. | None                       |
| Line Ctr   | 11.438                     |
| Num. Pts.  | 18843                      |
| Ozone      | 9.13E+18                   |

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Transmittance

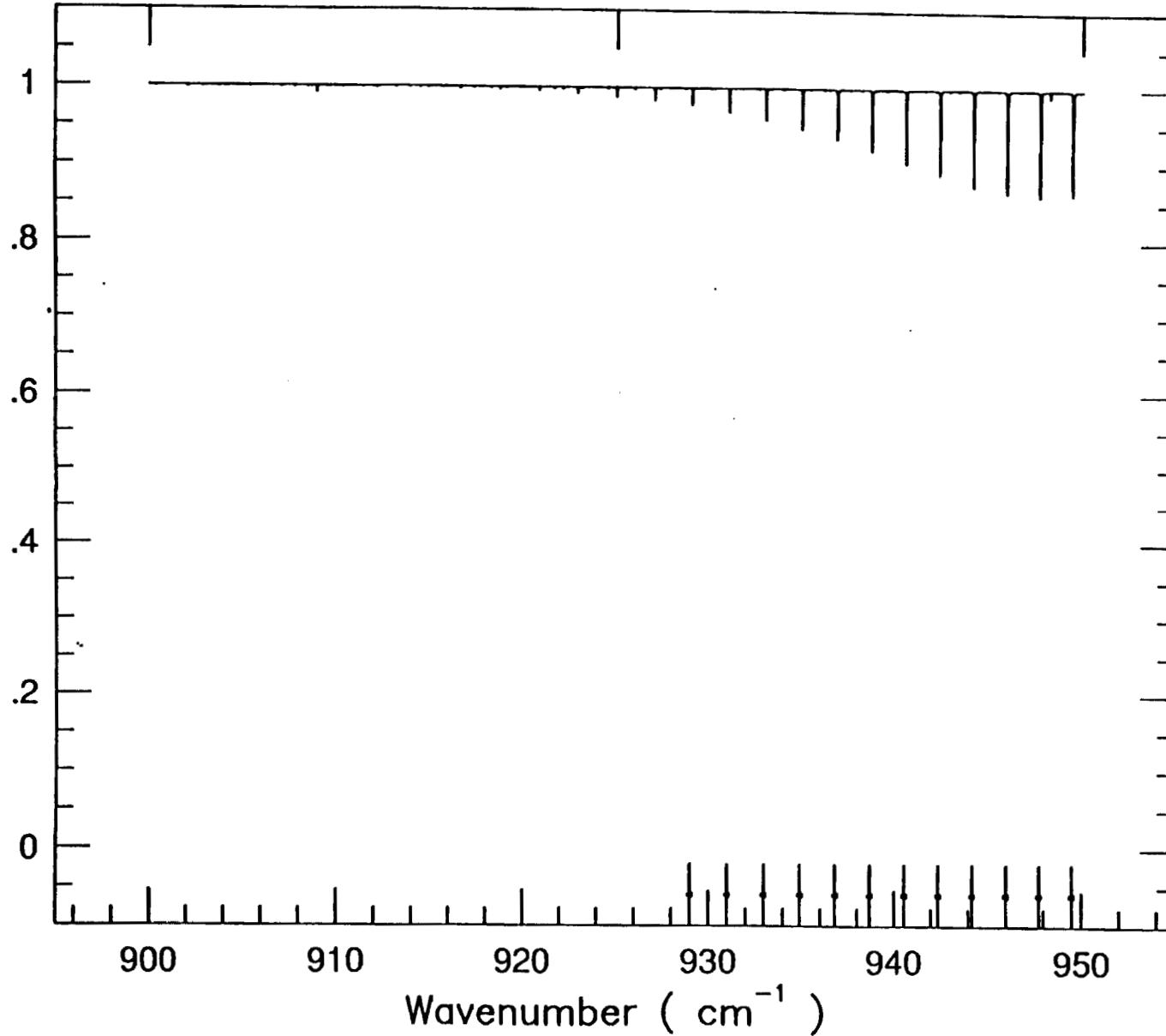
Wavelength (  $\mu\text{m}$  )

11.1111

10.8108

10.5263

#22



|                 |                            |
|-----------------|----------------------------|
| Zenith WV       | 10.0                       |
| Zenith Ang      | 45.0                       |
| L.O.S. WV       | 14.1                       |
| Atm. Type       | Std.&H <sub>2</sub> O Adj. |
| Layers          | 1                          |
| Altitude        | 41000                      |
| ↓               |                            |
| CO <sub>2</sub> |                            |
| Lambda 1        | 900.000                    |
| Lambda 2        | 950.000                    |
| Sampling        | 0.000031                   |
| Res(FWHM)       | 0.000000                   |
| Instr. Fn.      | None                       |
| Line Ctr        | 10.819                     |
| Num. Pts.       | 18843                      |
| Ozone           | 9.13E+18                   |

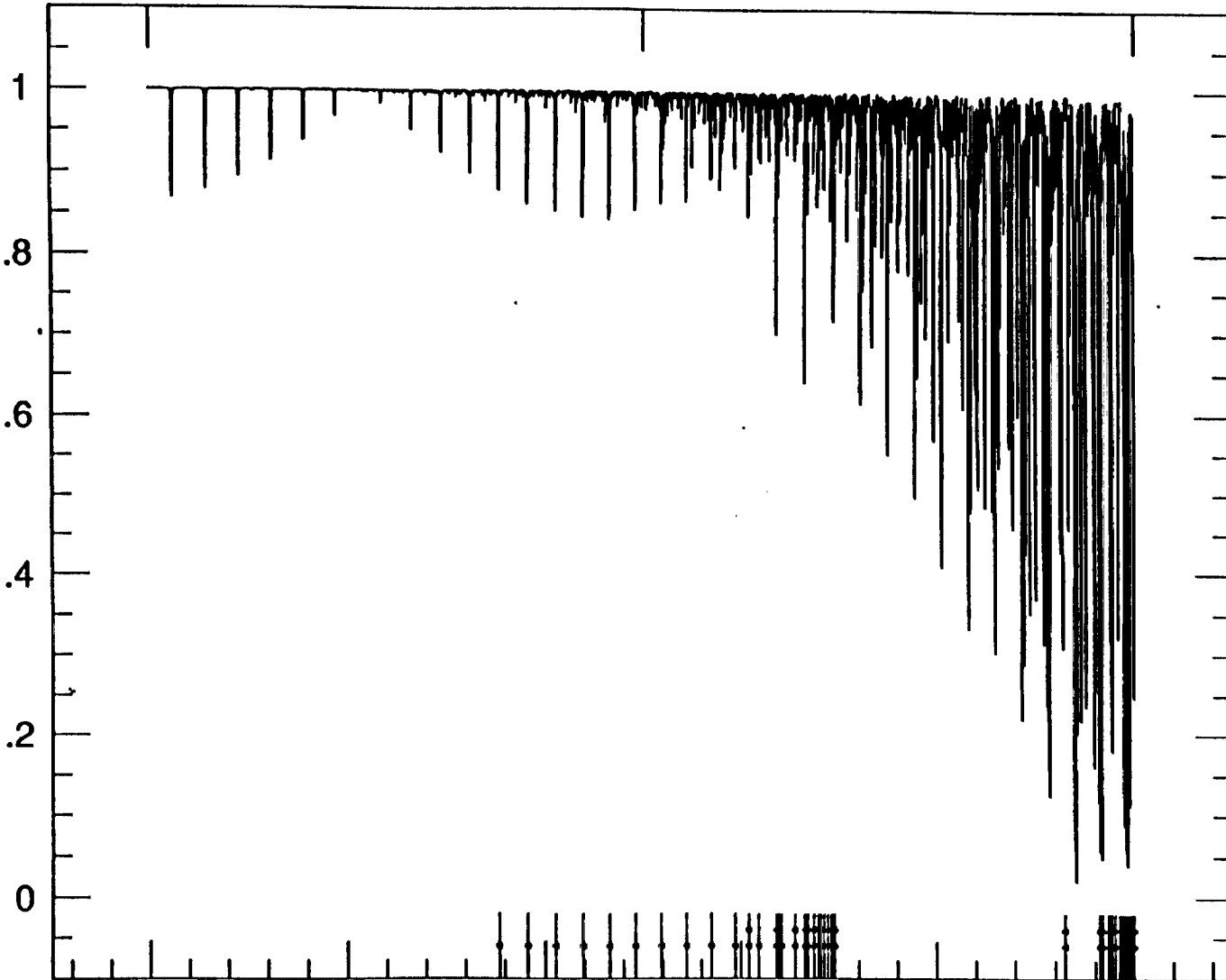
Wavelength (  $\mu\text{m}$  )

10.5263

10.2564

10.0000

#23

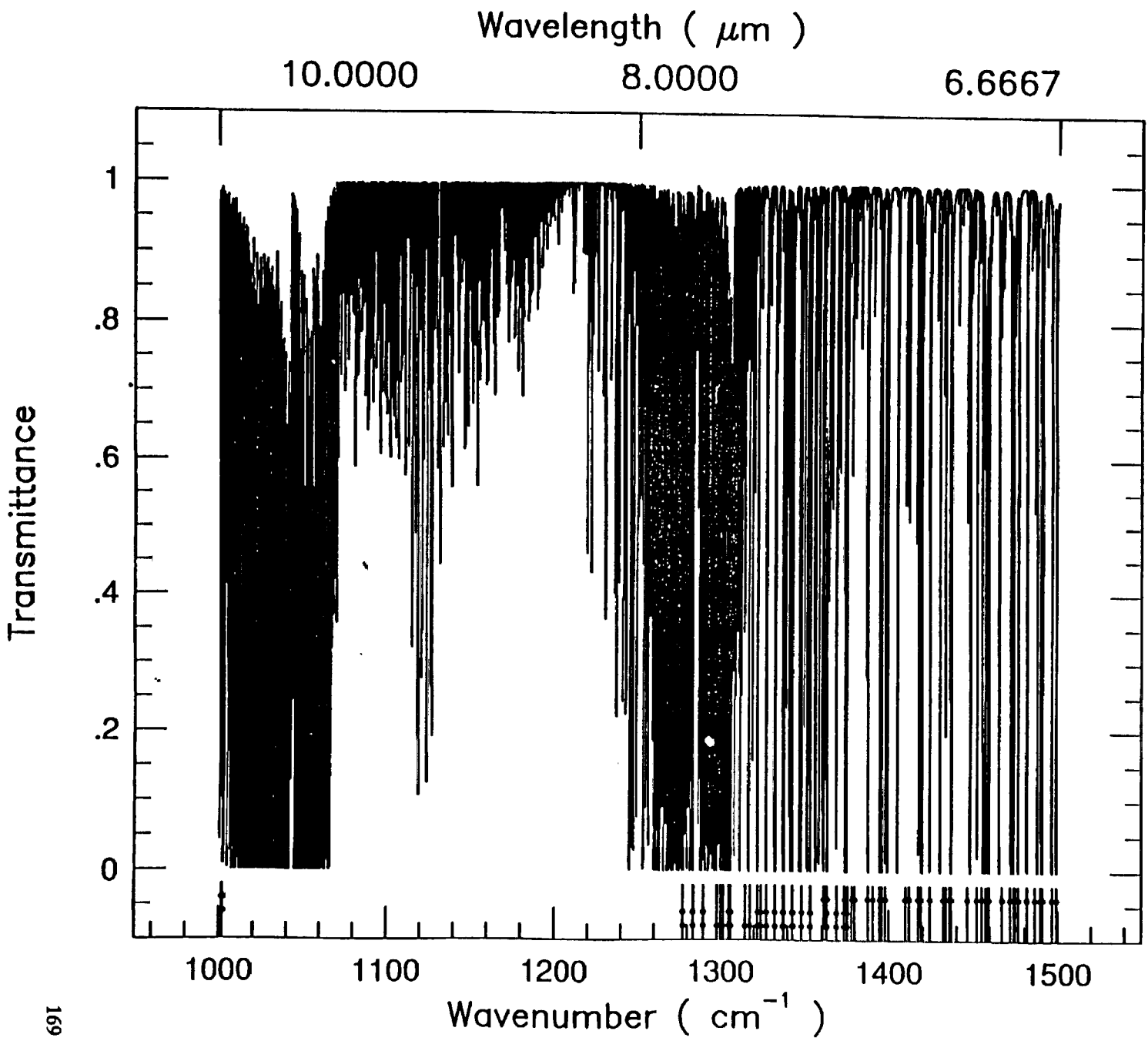


|                                |                            |
|--------------------------------|----------------------------|
| Zenith WV                      | 10.0                       |
| Zenith Ang                     | 45.0                       |
| L.O.S. WV                      | 14.1                       |
| Atm. Type                      | Std.&H <sub>2</sub> O Adj. |
| Layers                         | 1                          |
| Altitude                       | 41000                      |
| CO <sub>2</sub> O <sub>3</sub> |                            |
| Lambda 1                       | 950.000                    |
| Lambda 2                       | 1000.000                   |
| Sampling                       | 0.000028                   |
| Res(FWHM)                      | 0.000000                   |
| Instr. Fn.                     | None                       |
| Line Ctr                       | 10.263                     |
| Num. Pts.                      | 18843                      |
| Ozone                          | 9.13E+18                   |

950      960      970      980      990      1000

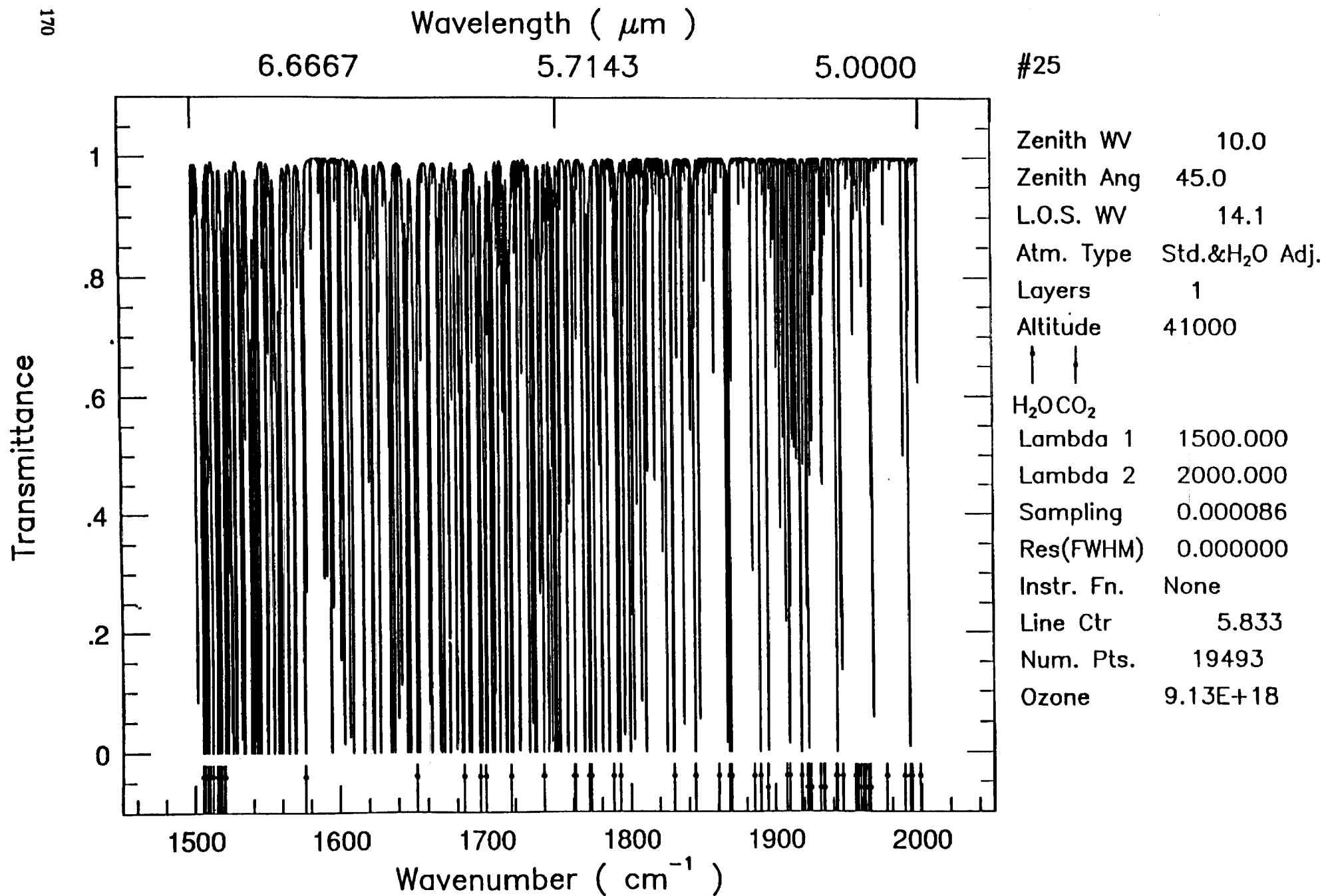
Wavenumber (  $\text{cm}^{-1}$  )



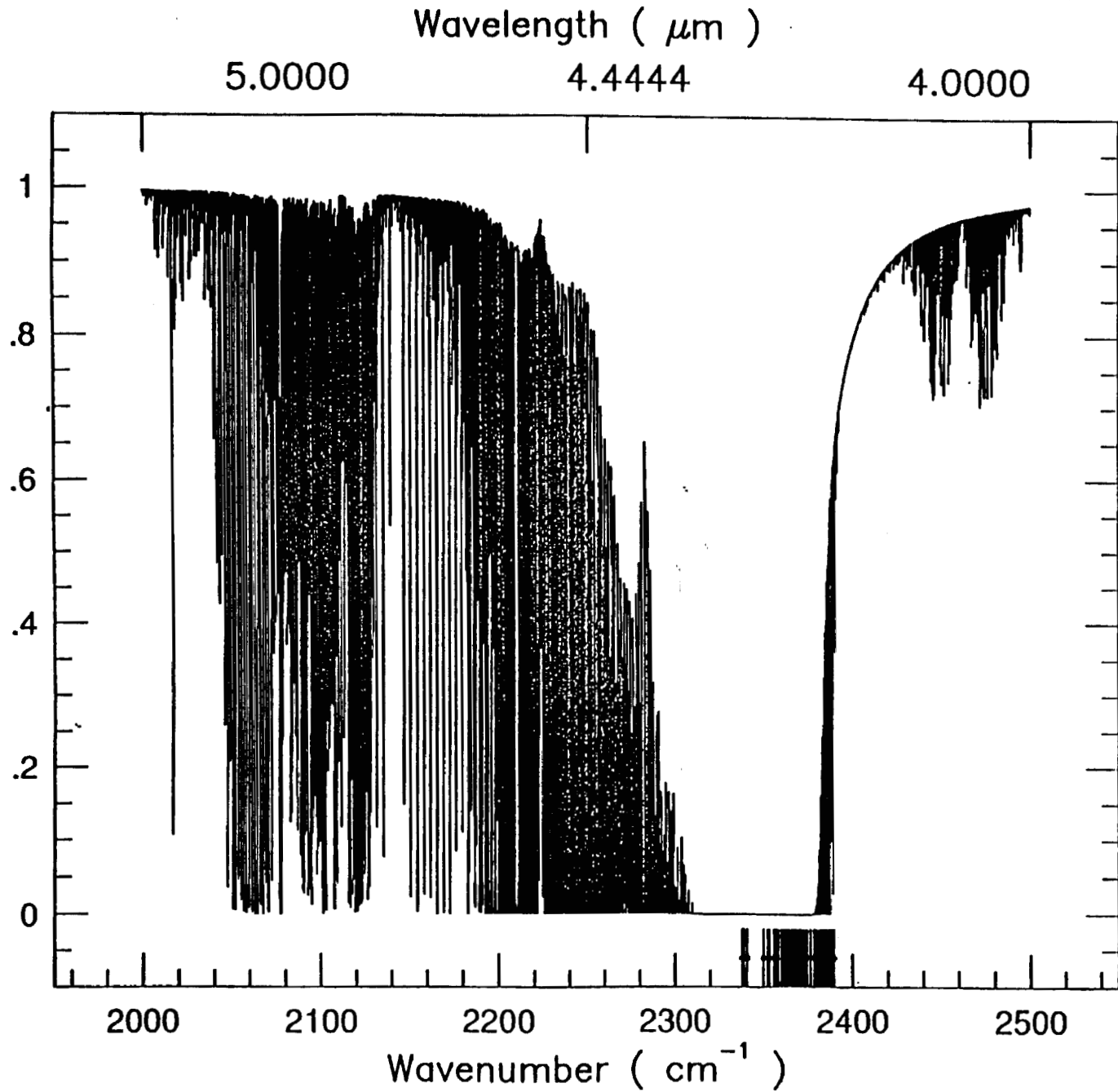


#24

|   |                            |
|---|----------------------------|
| Zenith WV   | 10.0                       |
| Zenith Ang  | 45.0                       |
| L.O.S. WV   | 14.1                       |
| Atm. Type   | Std.&H <sub>2</sub> O Adj. |
| Layers  | 1                          |
| Altitude  | 41000                      |
| ↑ ↓ ↓ ↓   |                            |
| H <sub>2</sub> O O <sub>3</sub> N <sub>2</sub> OCH <sub>4</sub> |                            |
| Lambda 1  | 1000.000                   |
| Lambda 2  | 1500.000                   |
| Sampling  | 0.000171                   |
| Res(FWHM)   | 0.000000                   |
| Instr. Fn.  | None                       |
| Line Ctr  | 8.333                      |
| Num. Pts.   | 19493                      |
| Ozone   | 9.13E+18                   |

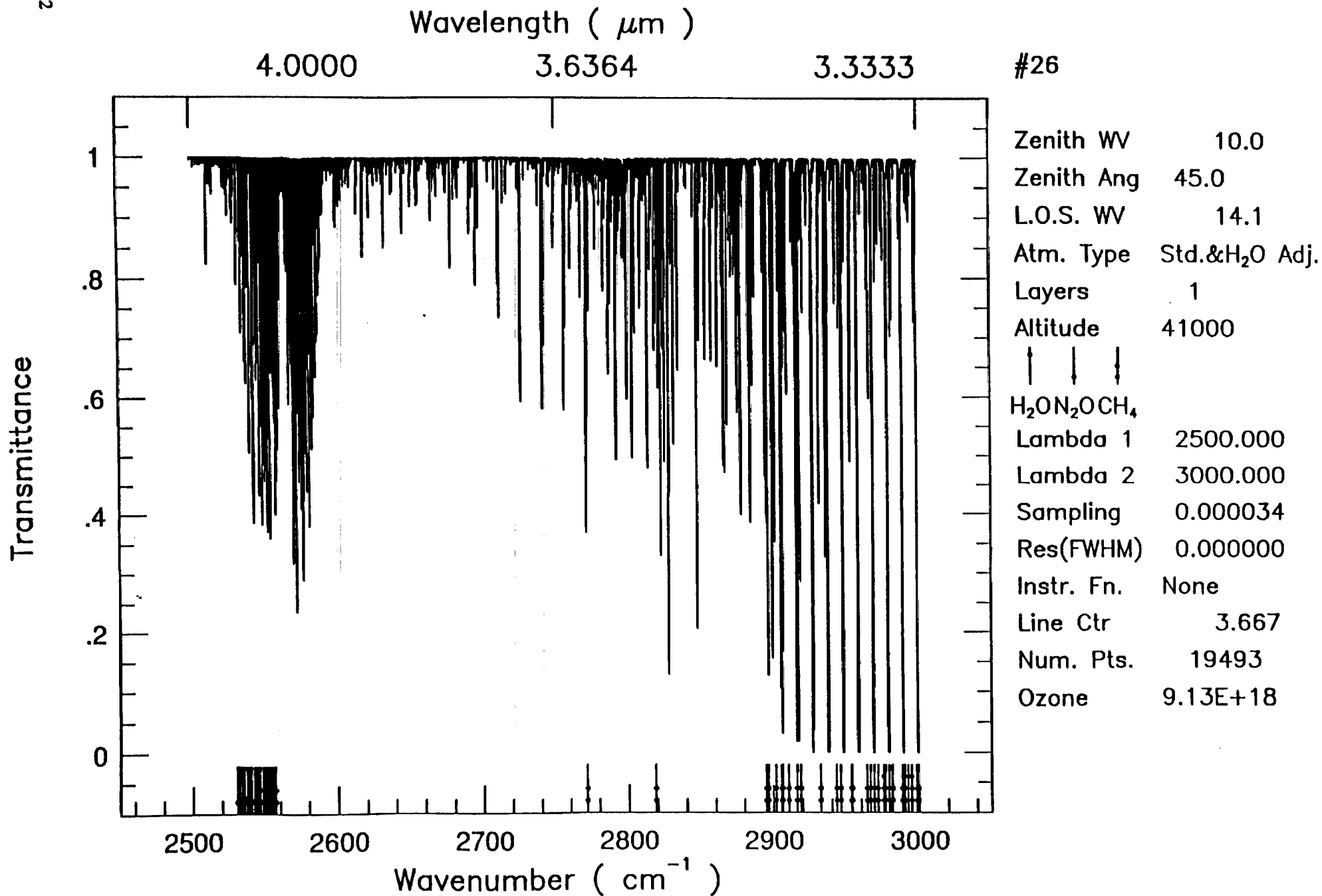


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#25a

|                 |                            |
|-----------------|----------------------------|
| Zenith WV       | 10.0                       |
| Zenith Ang      | 45.0                       |
| L.O.S. WV       | 14.1                       |
| Atm. Type       | Std.&H <sub>2</sub> O Adj. |
| Layers          | 1                          |
| Altitude        | 41000                      |
| ↓               |                            |
| CO <sub>2</sub> |                            |
| Lambda 1        | 2000.000                   |
| Lambda 2        | 2500.000                   |
| Sampling        | 0.000051                   |
| Res(FWHM)       | 0.000000                   |
| Instr. Fn.      | None                       |
| Line Ctr        | 4.500                      |
| Num. Pts.       | 19493                      |
| Ozone           | 9.13E+18                   |



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Wavelength (  $\mu\text{m}$  )

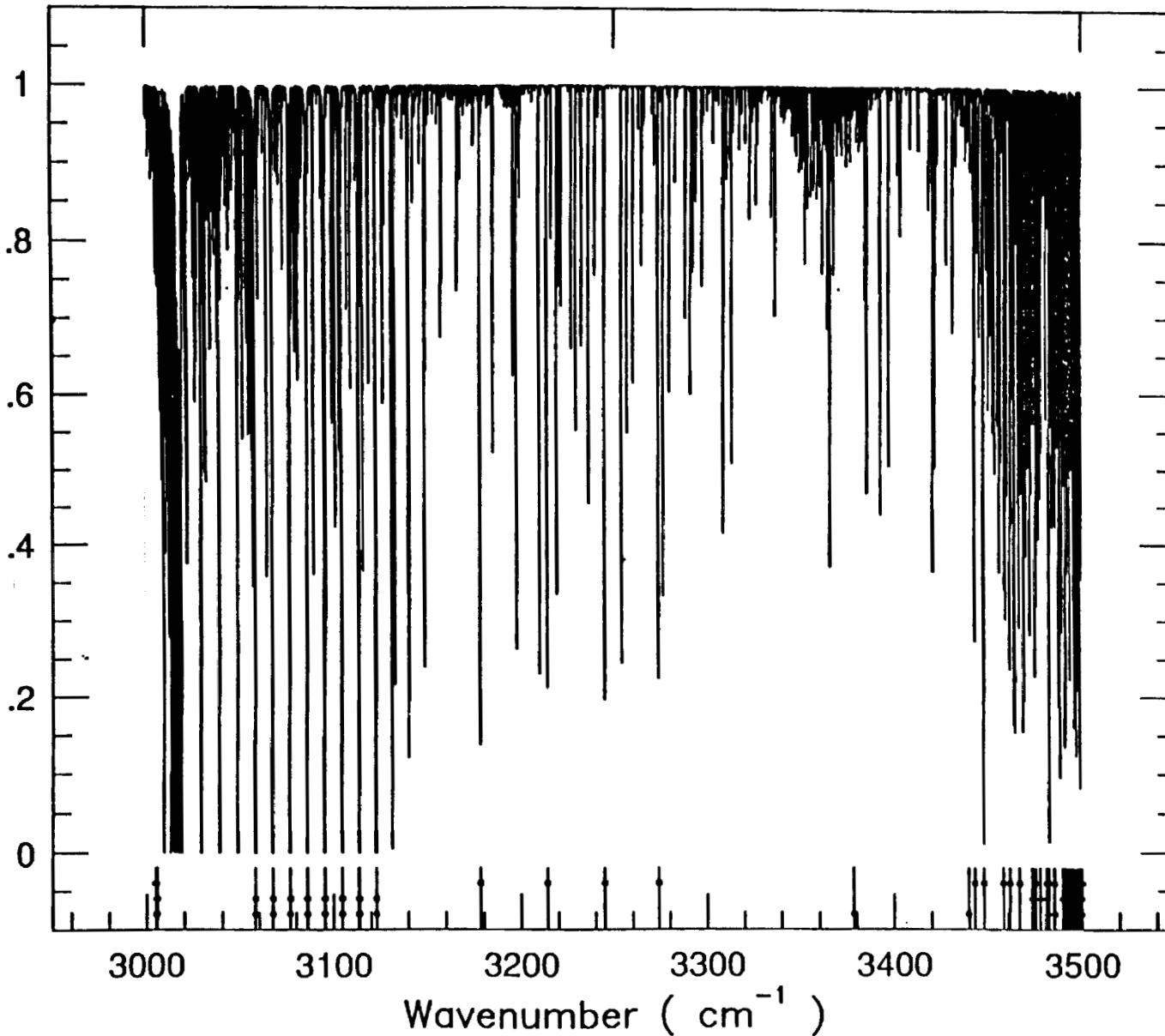
3.3333

3.0769

2.8571

#27

Transmittance



|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑ ↓ ↓ ↓          |                            |
| H <sub>2</sub> O | CO <sub>2</sub>            |
| N <sub>2</sub>   | O                          |
| CH <sub>4</sub>  |                            |
| Lambda 1         | 3000.000                   |
| Lambda 2         | 3500.000                   |
| Sampling         | 0.000024                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 3.095                      |
| Num. Pts.        | 19493                      |
| Ozone            | 9.13E+18                   |

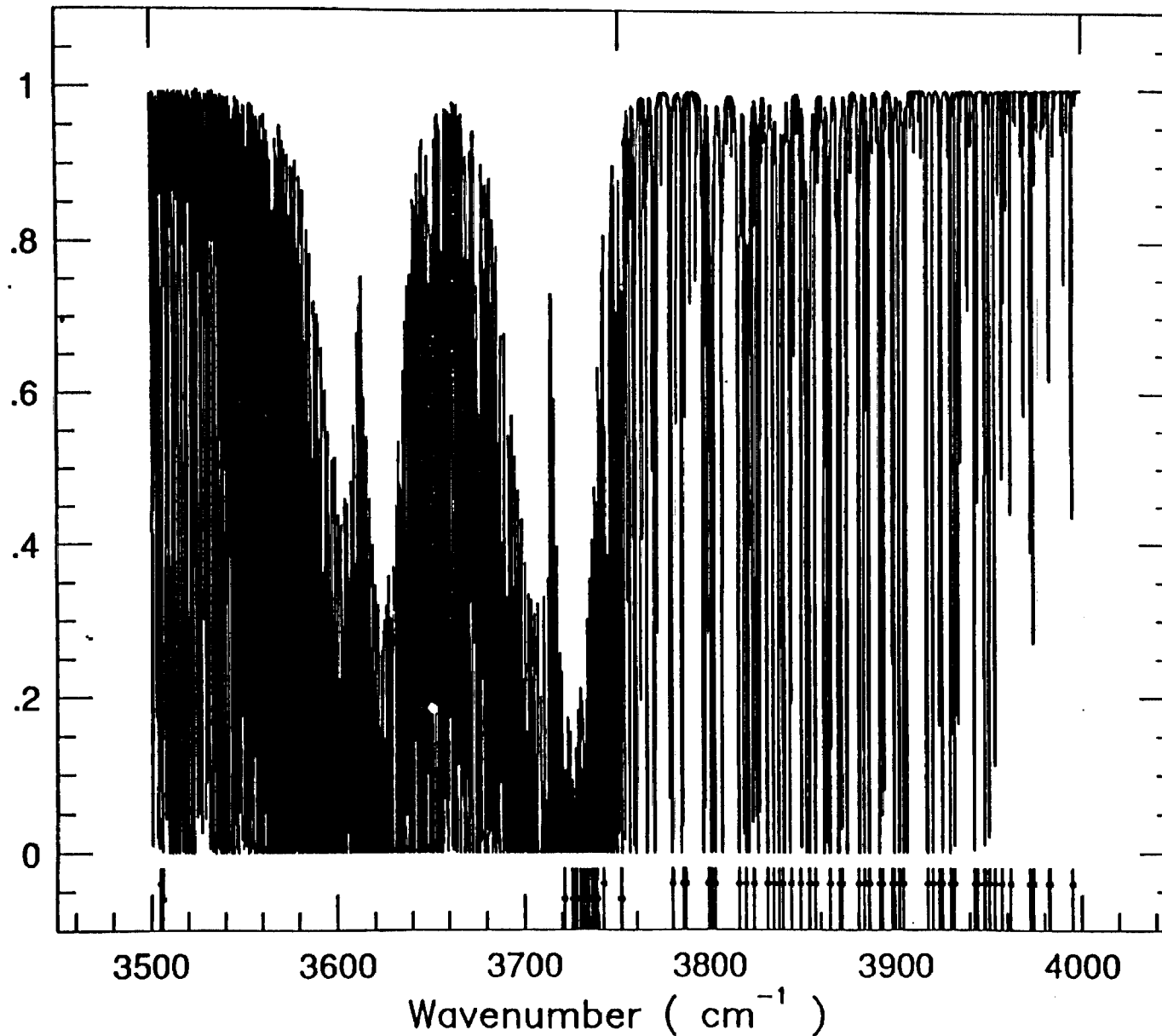
Wavelength (  $\mu\text{m}$  )

2.8571

2.6667

2.5000

#28



|                                  |                            |
|----------------------------------|----------------------------|
| Zenith WV                        | 10.0                       |
| Zenith Ang                       | 45.0                       |
| L.O.S. WV                        | 14.1                       |
| Atm. Type                        | Std.&H <sub>2</sub> O Adj. |
| Layers                           | 1                          |
| Altitude                         | 41000                      |
| ↑ ↓                              |                            |
| H <sub>2</sub> O/CO <sub>2</sub> |                            |
| Lambda 1                         | 3500.000                   |
| Lambda 2                         | 4000.000                   |
| Sampling                         | 0.000018                   |
| Res(FWHM)                        | 0.000000                   |
| Instr. Fn.                       | None                       |
| Line Ctr                         | 2.679                      |
| Num. Pts.                        | 19493                      |
| Ozone                            | 9.13E+18                   |

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Wavelength (  $\mu\text{m}$  )

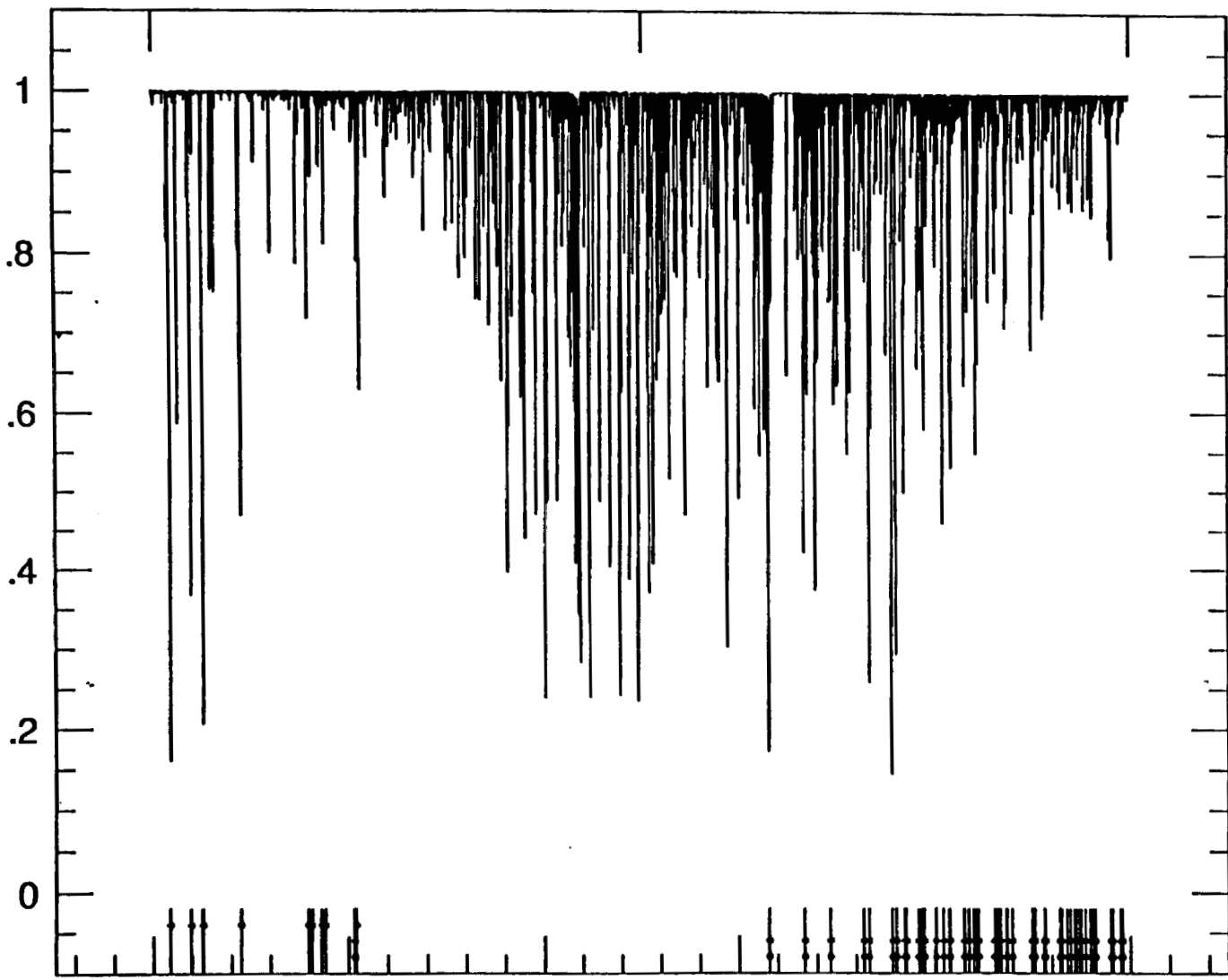
2.5000

2.3529

2.2222

#29

Transmittance



|                                 |                            |
|---------------------------------|----------------------------|
| Zenith WV                       | 10.0                       |
| Zenith Ang                      | 45.0                       |
| L.O.S. WV                       | 14.1                       |
| Atm. Type                       | Std.&H <sub>2</sub> O Adj. |
| Layers                          | 1                          |
| Altitude                        | 41000                      |
| H <sub>2</sub> OCH <sub>4</sub> |                            |
| Lambda 1                        | 4000.000                   |
| Lambda 2                        | 4500.000                   |
| Sampling                        | 0.000014                   |
| Res(FWHM)                       | 0.000000                   |
| Instr. Fn.                      | None                       |
| Line Ctr                        | 2.361                      |
| Num. Pts.                       | 19493                      |
| Ozone                           | 9.13E+18                   |

4000 4100 4200 4300 4400 4500

Wavenumber (  $\text{cm}^{-1}$  )

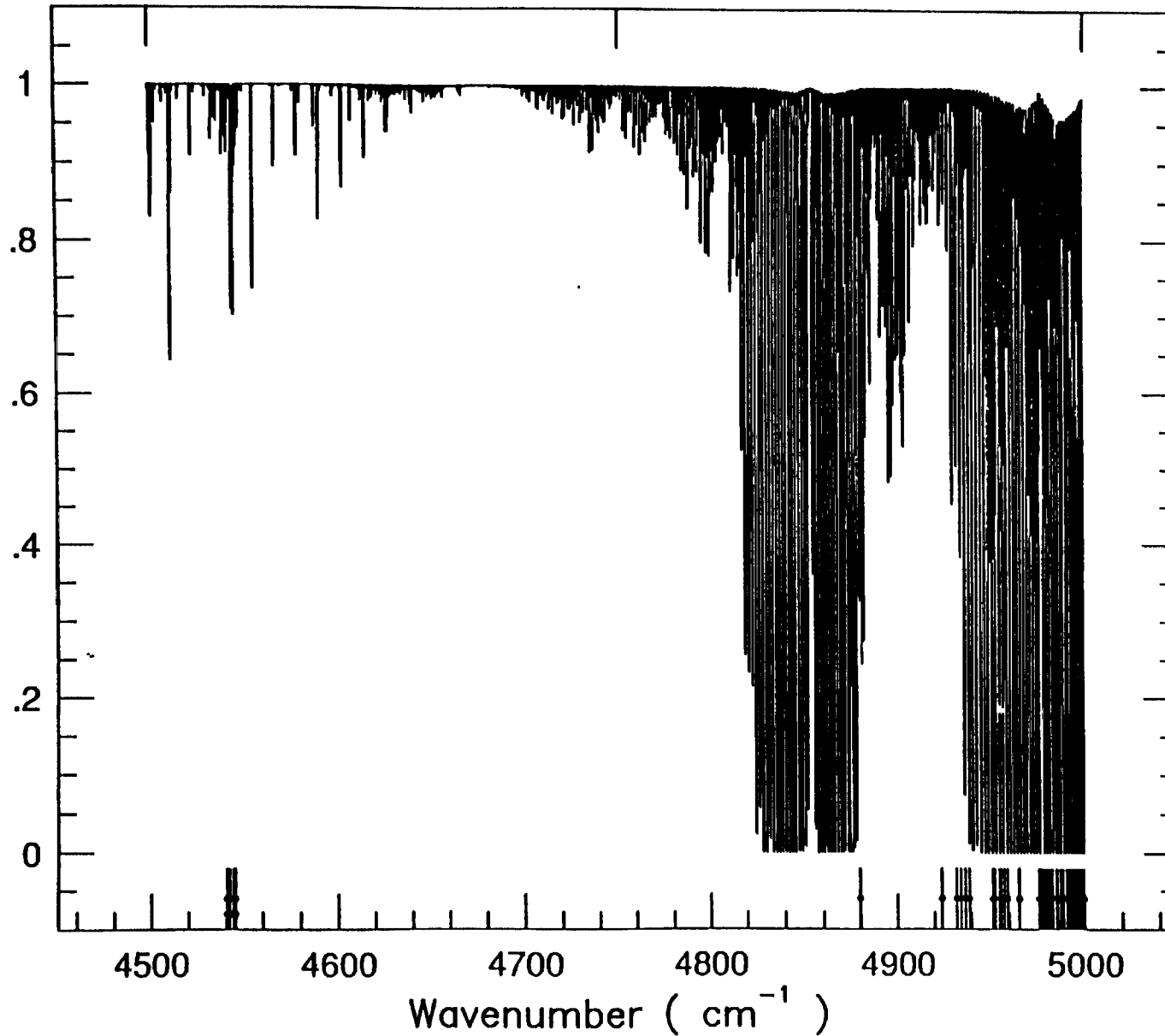
Wavelength (  $\mu\text{m}$  )

2.2222

2.1053

2.0000

#30



|  |                            |
|--|----------------------------|
| Zenith WV  | 10.0                       |
| Zenith Ang                                       | 45.0                       |
| L.O.S. WV  | 14.1                       |
| Atm. Type  | Std.&H <sub>2</sub> O Adj. |
| Layers   | 1                          |
| Altitude   | 41000                      |
| ↑ ↓ ↓  |                            |
| H <sub>2</sub> O CO <sub>2</sub> CH <sub>4</sub> |                            |
| Lambda 1   | 4500.000                   |
| Lambda 2   | 5000.000                   |
| Sampling   | 0.000011                   |
| Res(FWHM)  | 0.000000                   |
| Instr. Fn.                                       | None                       |
| Line Ctr   | 2.111                      |
| Num. Pts.  | 19493                      |
| Ozone  | 9.13E+18                   |

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Wavelength (  $\mu\text{m}$  )

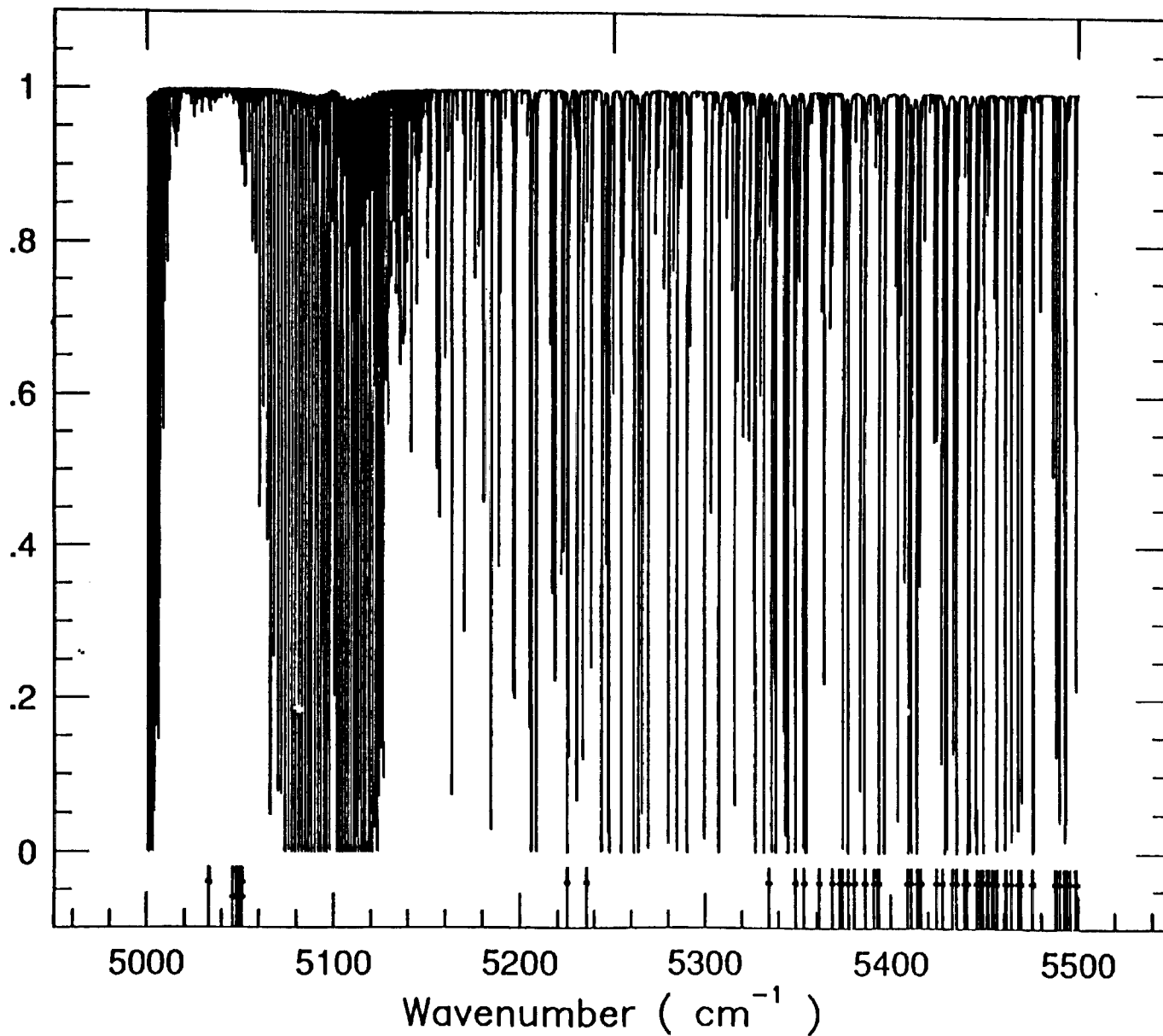
2.0000

1.9048

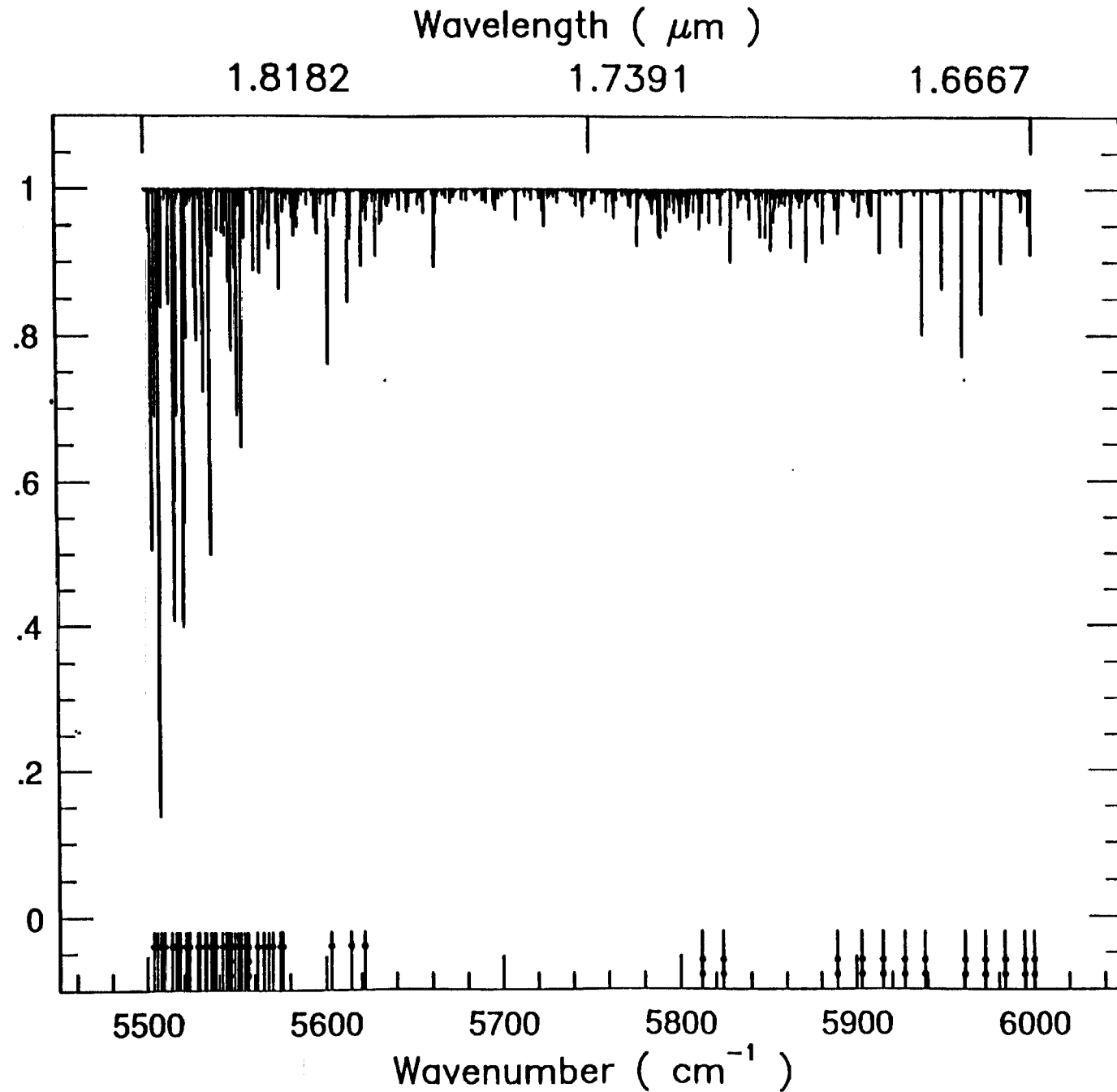
1.8182

#31

Transmittance



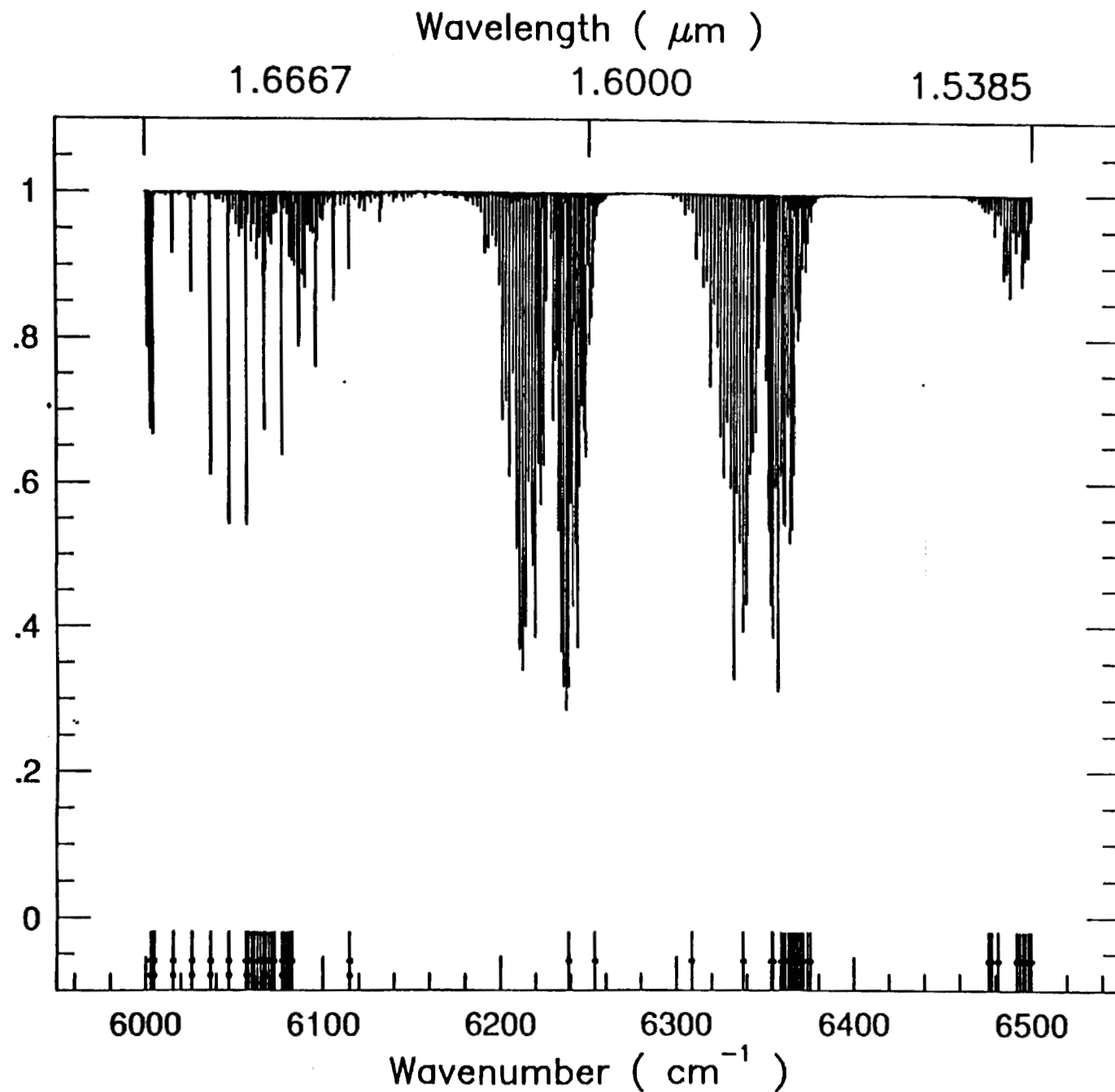
|                                 |                            |
|---------------------------------|----------------------------|
| Zenith WV                       | 10.0                       |
| Zenith Ang                      | 45.0                       |
| L.O.S. WV                       | 14.1                       |
| Atm. Type                       | Std.&H <sub>2</sub> O Adj. |
| Layers                          | 1                          |
| Altitude                        | 41000                      |
| H <sub>2</sub> OCO <sub>2</sub> |                            |
| Lambda 1                        | 5000.000                   |
| Lambda 2                        | 5500.000                   |
| Sampling                        | 0.000009                   |
| Res(FWHM)                       | 0.000000                   |
| Instr. Fn.                      | None                       |
| Line Ctr                        | 1.909                      |
| Num. Pts.                       | 19493                      |
| Ozone                           | 9.13E+18                   |



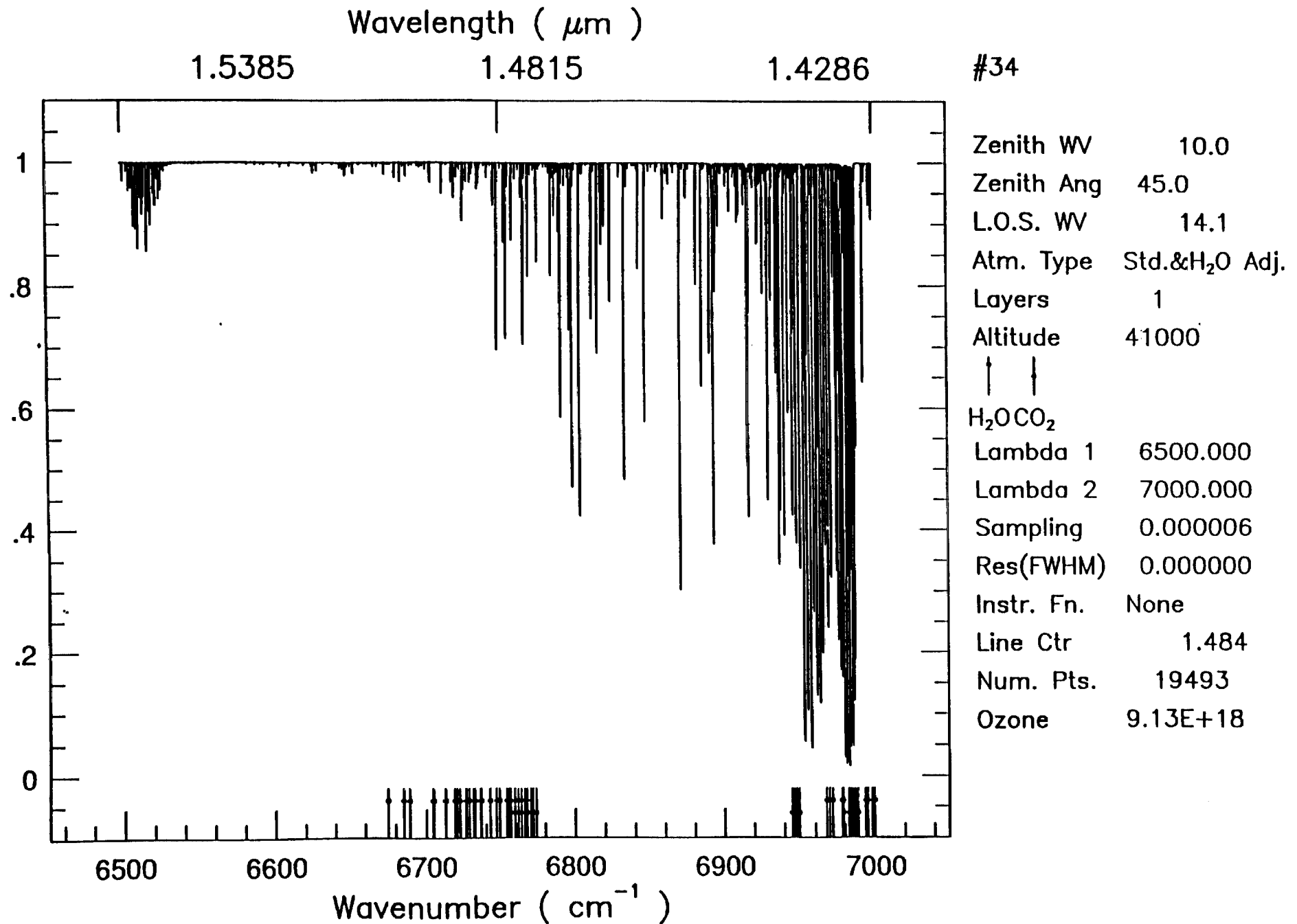
#32

|                                 |                            |
|---------------------------------|----------------------------|
| Zenith WV                       | 10.0                       |
| Zenith Ang                      | 45.0                       |
| L.O.S. WV                       | 14.1                       |
| Atm. Type                       | Std.&H <sub>2</sub> O Adj. |
| Layers                          | 1                          |
| Altitude                        | 41000                      |
| H <sub>2</sub> OCH <sub>4</sub> |                            |
| Lambda 1                        | 5500.000                   |
| Lambda 2                        | 6000.000                   |
| Sampling                        | 0.000008                   |
| Res(FWHM)                       | 0.000000                   |
| Instr. Fn.                      | None                       |
| Line Ctr                        | 1.742                      |
| Num. Pts.                       | 19493                      |
| Ozone                           | 9.13E+18                   |

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|                                 |                            |
|---------------------------------|----------------------------|
| Zenith WV                       | 10.0                       |
| Zenith Ang                      | 45.0                       |
| L.O.S. WV                       | 14.1                       |
| Atm. Type                       | Std.&H <sub>2</sub> O Adj. |
| Layers                          | 1                          |
| Altitude                        | 41000                      |
| ↓ ↓                             |                            |
| CO <sub>2</sub> CH <sub>4</sub> |                            |
| Lambda 1                        | 6000.000                   |
| Lambda 2                        | 6500.000                   |
| Sampling                        | 0.000007                   |
| Res(FWHM)                       | 0.000000                   |
| Instr. Fn.                      | None                       |
| Line Ctr                        | 1.603                      |
| Num. Pts.                       | 19493                      |
| Ozone                           | 9.13E+18                   |



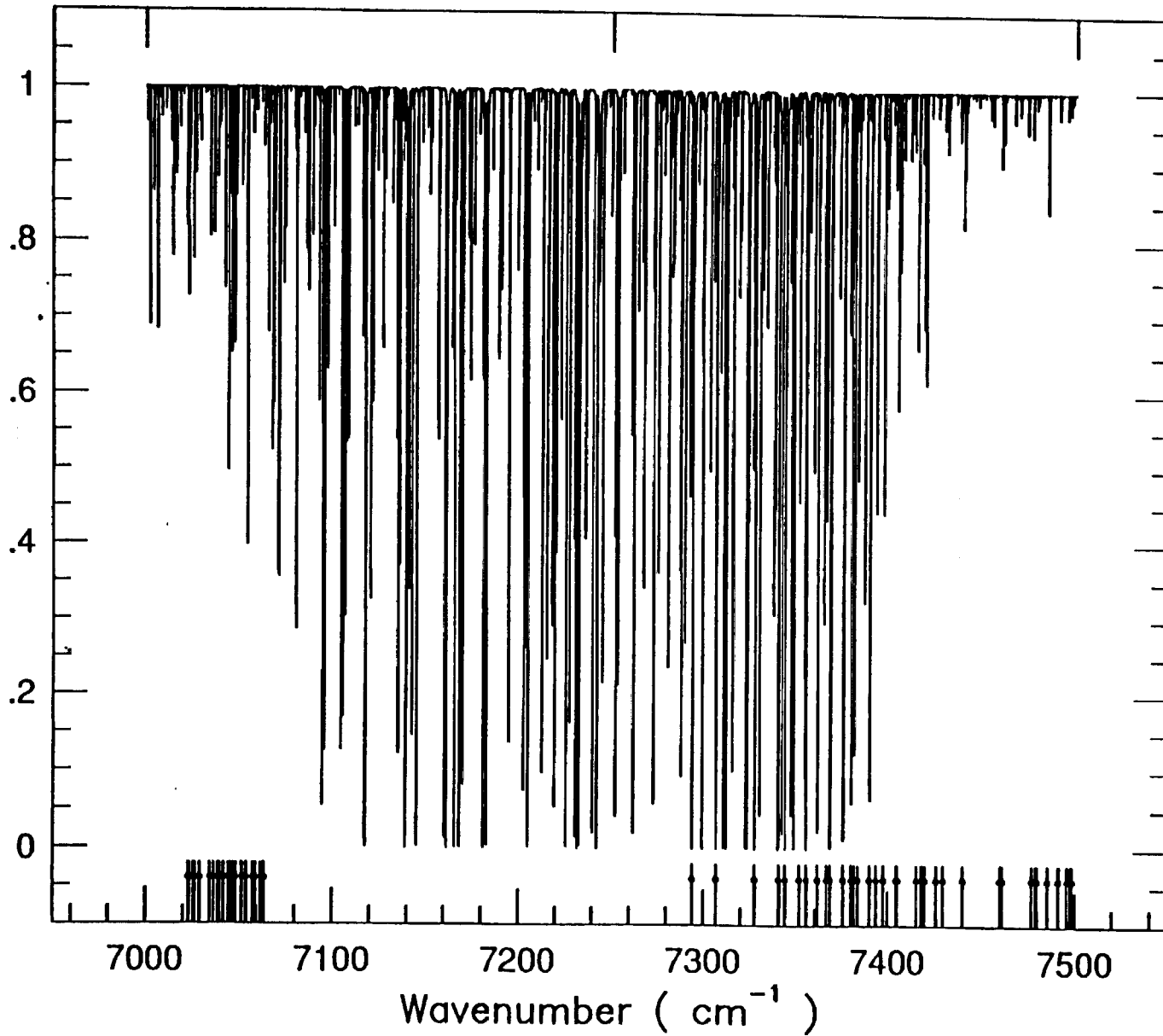
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Wavelength (  $\mu\text{m}$  )  
1.4286                      1.3793

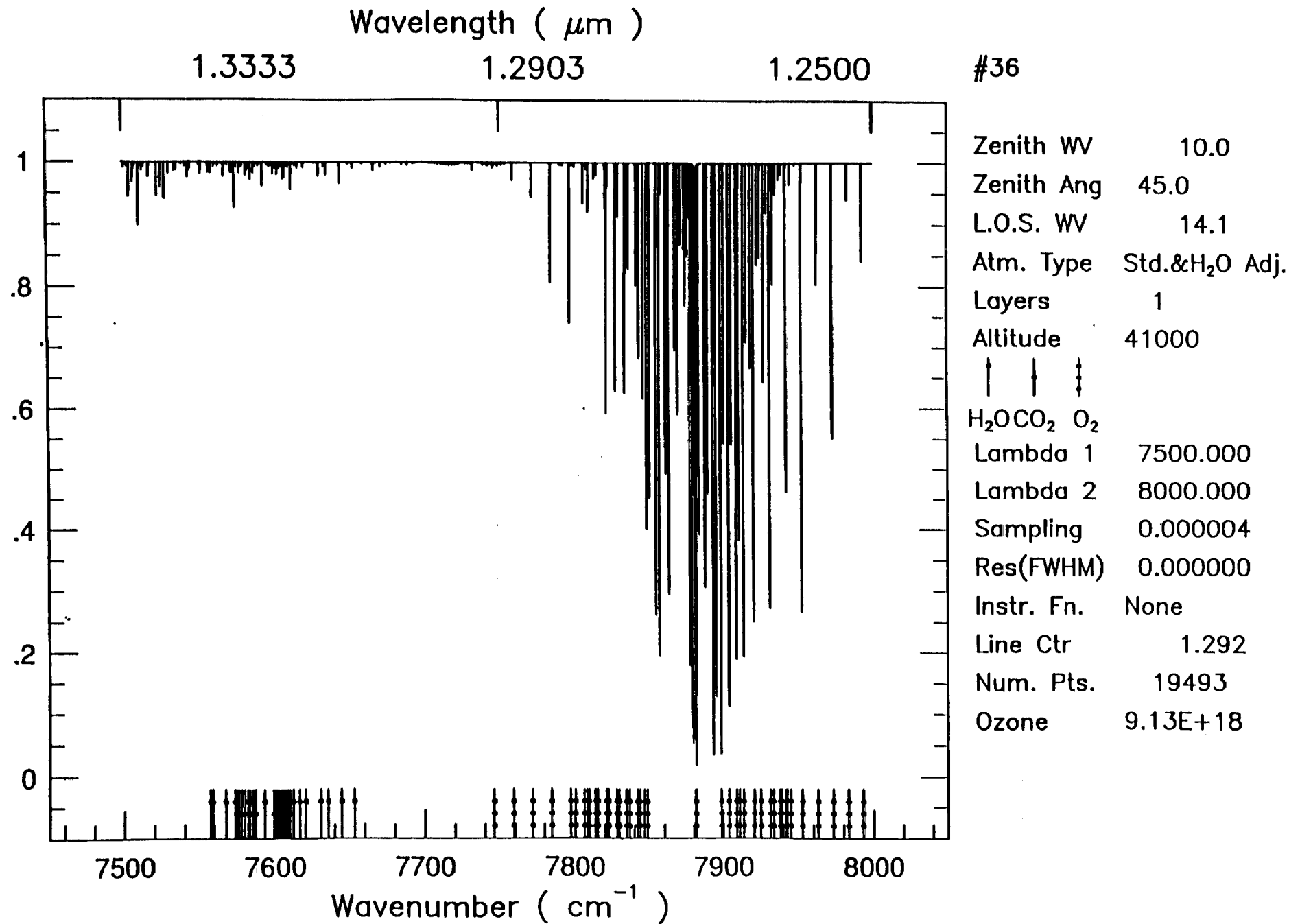
1.3333

#35

Transmittance



|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑                |                            |
| H <sub>2</sub> O |                            |
| Lambda 1         | 7000.000                   |
| Lambda 2         | 7500.000                   |
| Sampling         | 0.000005                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 1.381                      |
| Num. Pts.        | 19493                      |
| Ozone            | 9.13E+18                   |



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Wavelength (  $\mu\text{m}$  )

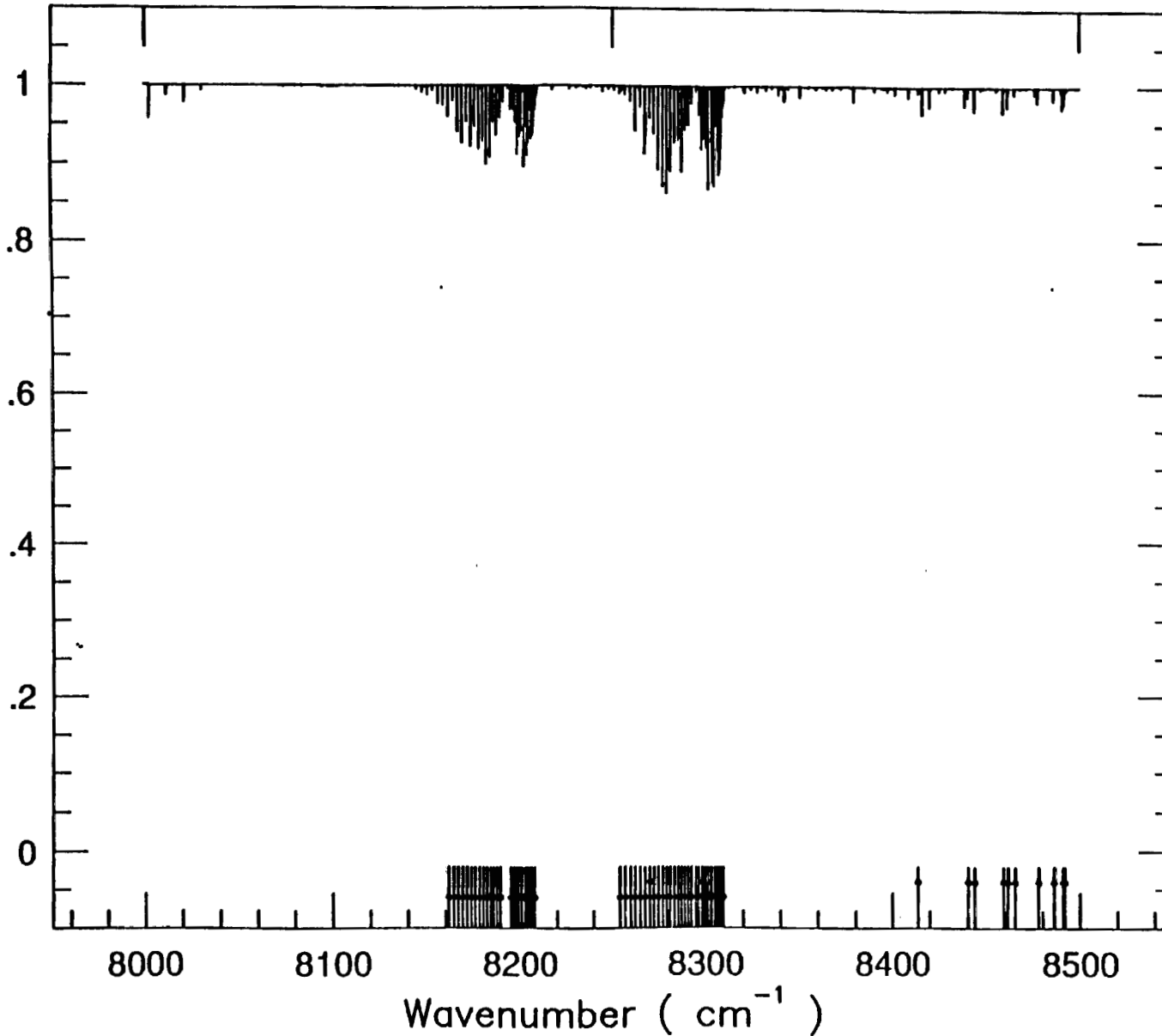
1.2500

1.2121

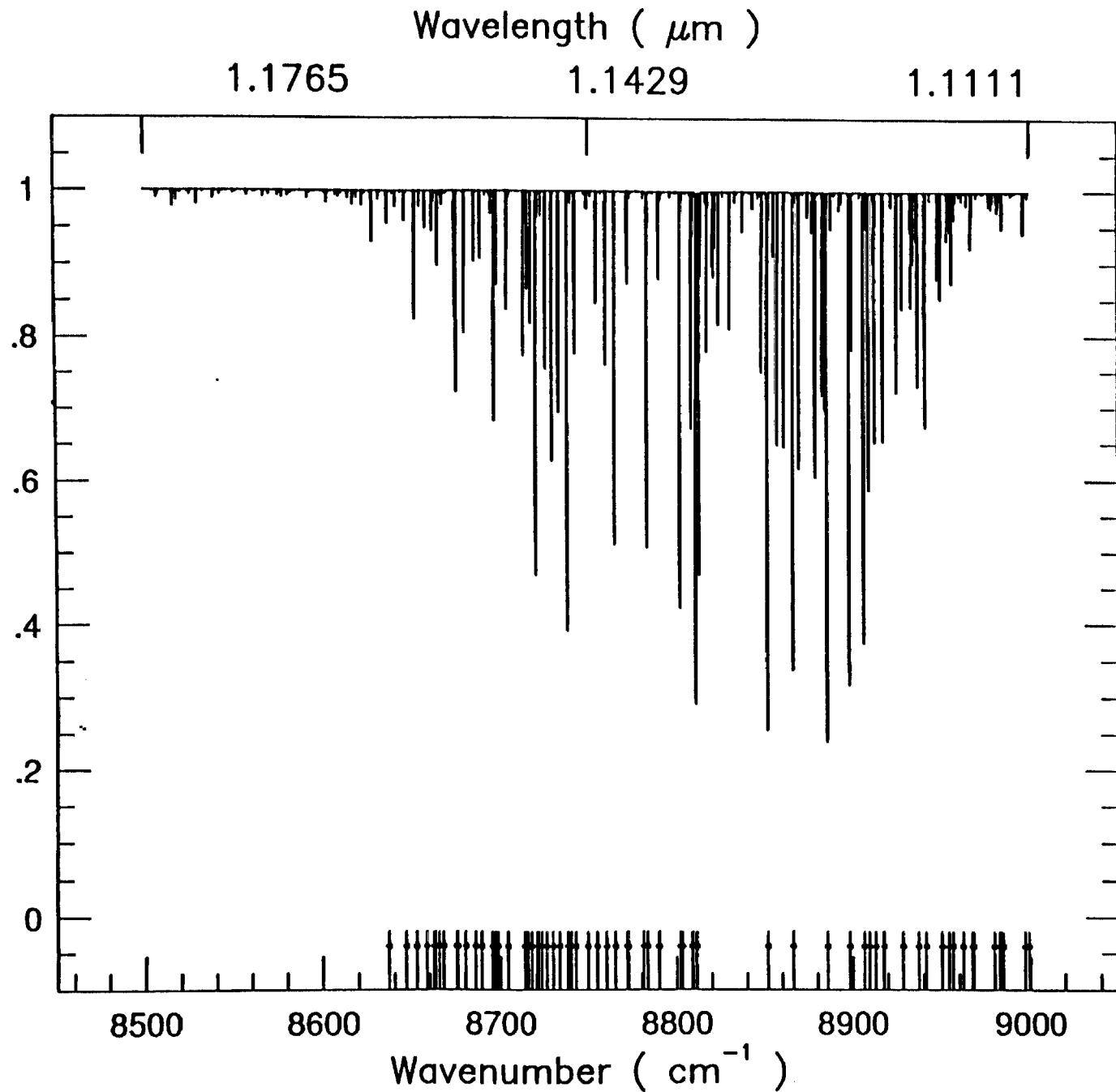
1.1765

#37

Transmittance



|                                 |                            |
|---------------------------------|----------------------------|
| Zenith WV                       | 10.0                       |
| Zenith Ang                      | 45.0                       |
| L.O.S. WV                       | 14.1                       |
| Atm. Type                       | Std.&H <sub>2</sub> O Adj. |
| Layers                          | 1                          |
| Altitude                        | 41000                      |
| H <sub>2</sub> OCO <sub>2</sub> |                            |
| Lambda 1                        | 8000.000                   |
| Lambda 2                        | 8500.000                   |
| Sampling                        | 0.000004                   |
| Res(FWHM)                       | 0.000000                   |
| Instr. Fn.                      | None                       |
| Line Ctr                        | 1.213                      |
| Num. Pts.                       | 19493                      |
| Ozone                           | 9.13E+18                   |



#38

|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑                |                            |
| H <sub>2</sub> O |                            |
| Lambda 1         | 8500.000                   |
| Lambda 2         | 9000.000                   |
| Sampling         | 0.000003                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 1.144                      |
| Num. Pts.        | 19493                      |
| Ozone            | 9.13E+18                   |

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Wavelength (  $\mu\text{m}$  )

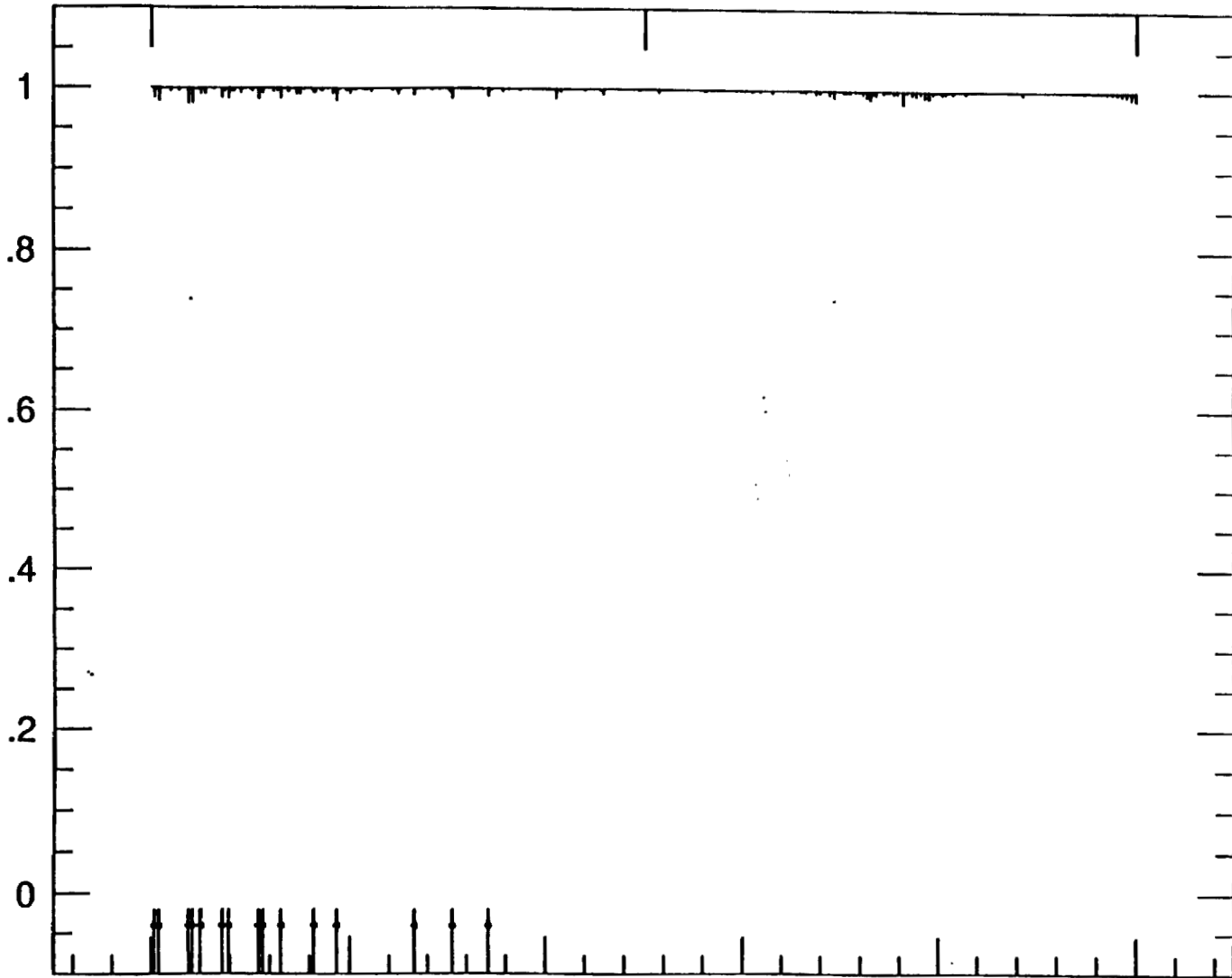
1.1111

1.0811

1.0526

#39

Transmittance



|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑                |                            |
| H <sub>2</sub> O |                            |
| Lambda 1         | 9000.000                   |
| Lambda 2         | 9500.000                   |
| Sampling         | 0.000003                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 1.082                      |
| Num. Pts.        | 19493                      |
| Ozone            | 9.13E+18                   |

9000      9100      9200      9300      9400      9500

Wavenumber (  $\text{cm}^{-1}$  )

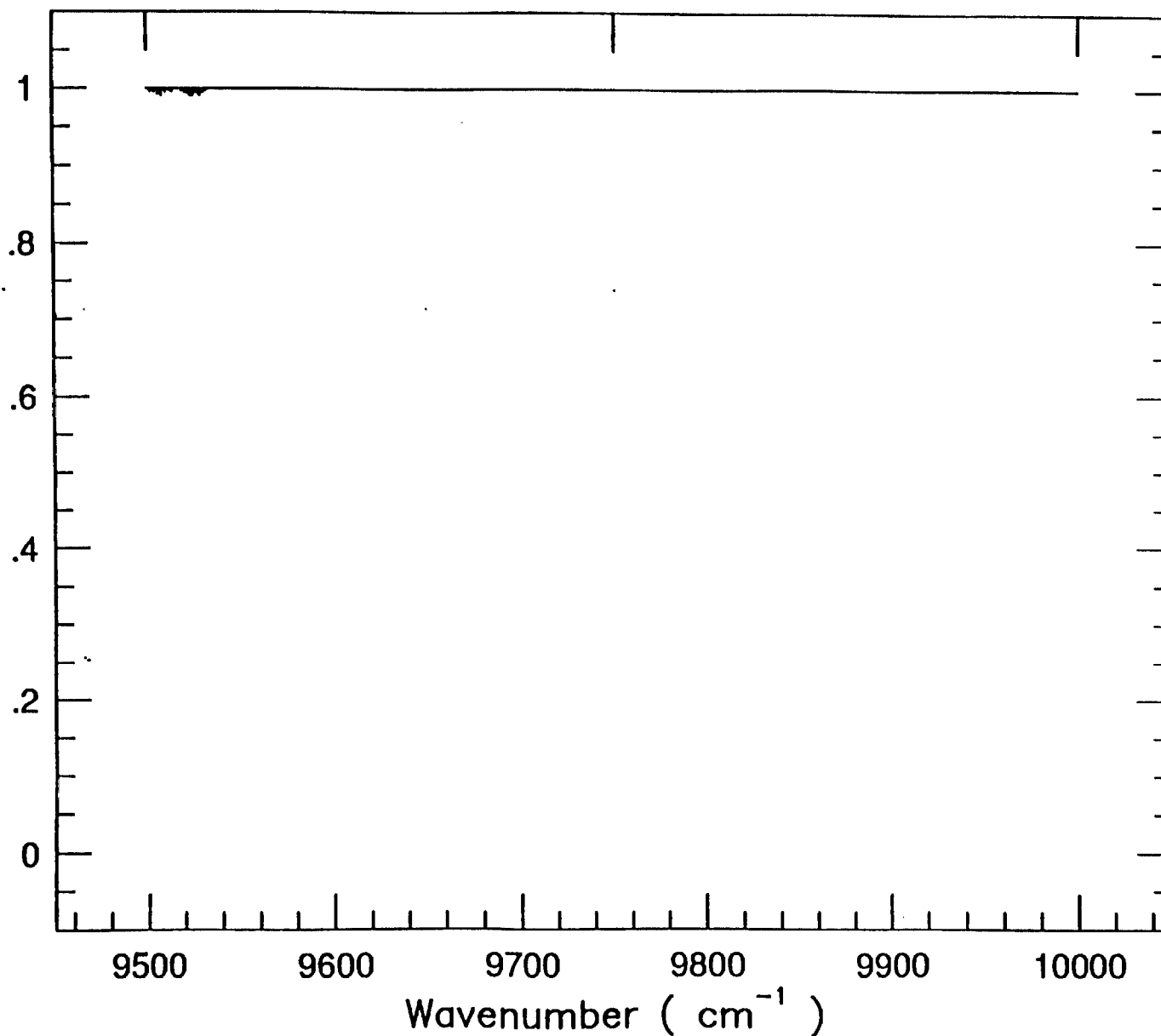
Wavelength (  $\mu\text{m}$  )

1.0526

1.0256

1.0000

#40



|            |                            |
|------------|----------------------------|
| Zenith WV  | 10.0                       |
| Zenith Ang | 45.0                       |
| L.O.S. WV  | 14.1                       |
| Atm. Type  | Std.&H <sub>2</sub> O Adj. |
| Layers     | 1                          |
| Altitude   | 41000                      |

|            |           |
|------------|-----------|
| Lambda 1   | 9500.000  |
| Lambda 2   | 10000.000 |
| Sampling   | 0.000003  |
| Res(FWHM)  | 0.000000  |
| Instr. Fn. | None      |
| Line Ctr   | 1.026     |
| Num. Pts.  | 19493     |
| Ozone      | 9.13E+18  |

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Wavelength (  $\mu\text{m}$  )

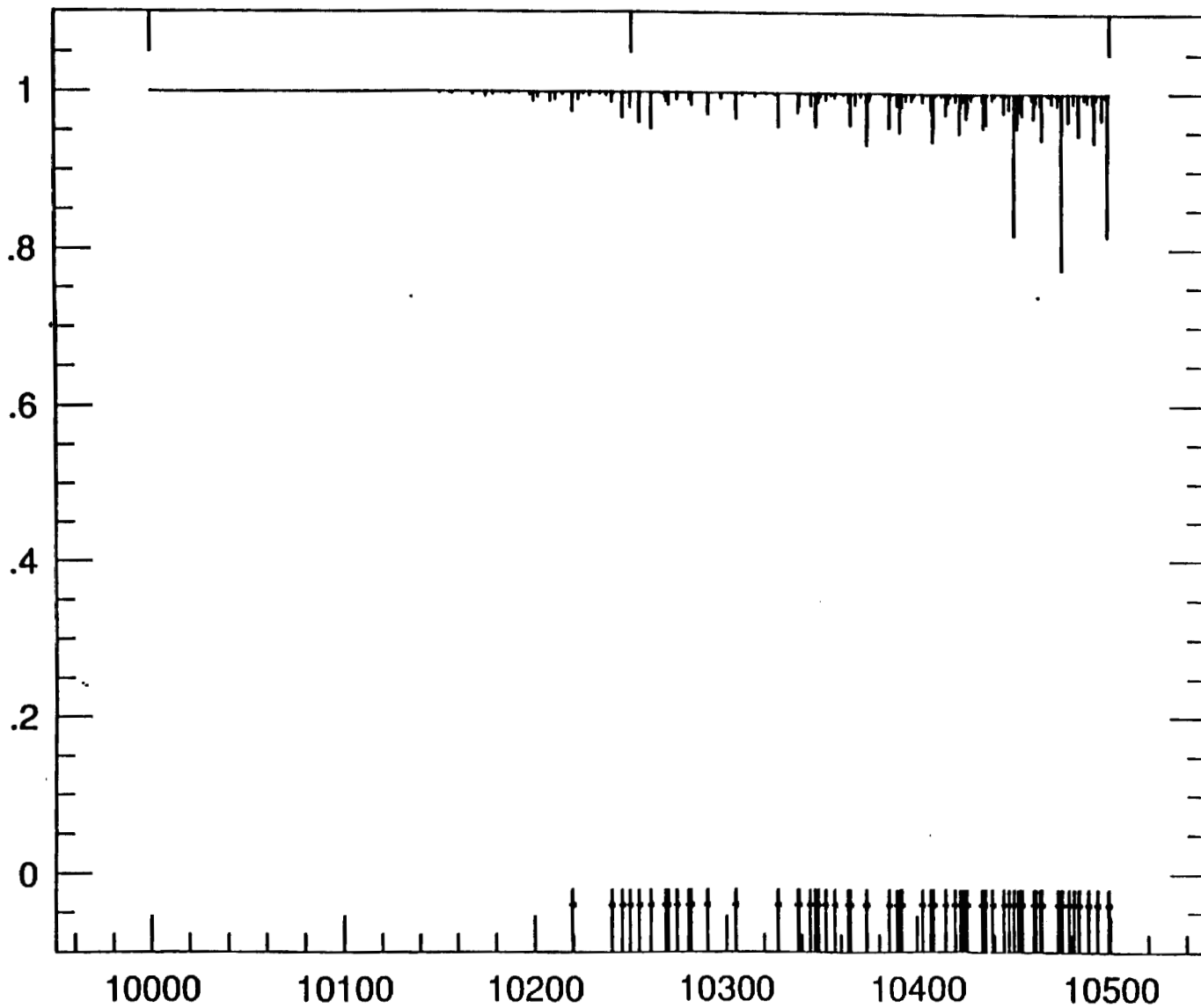
1.0000

0.9756

0.9524

#41

Transmittance



|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑                |                            |
| H <sub>2</sub> O |                            |
| Lambda 1         | 10000.000                  |
| Lambda 2         | 10500.000                  |
| Sampling         | 0.000002                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 0.976                      |
| Num. Pts.        | 19493                      |
| Ozone            | 9.13E+18                   |

Wavenumber (  $\text{cm}^{-1}$  )

Wavelength (  $\mu\text{m}$  )

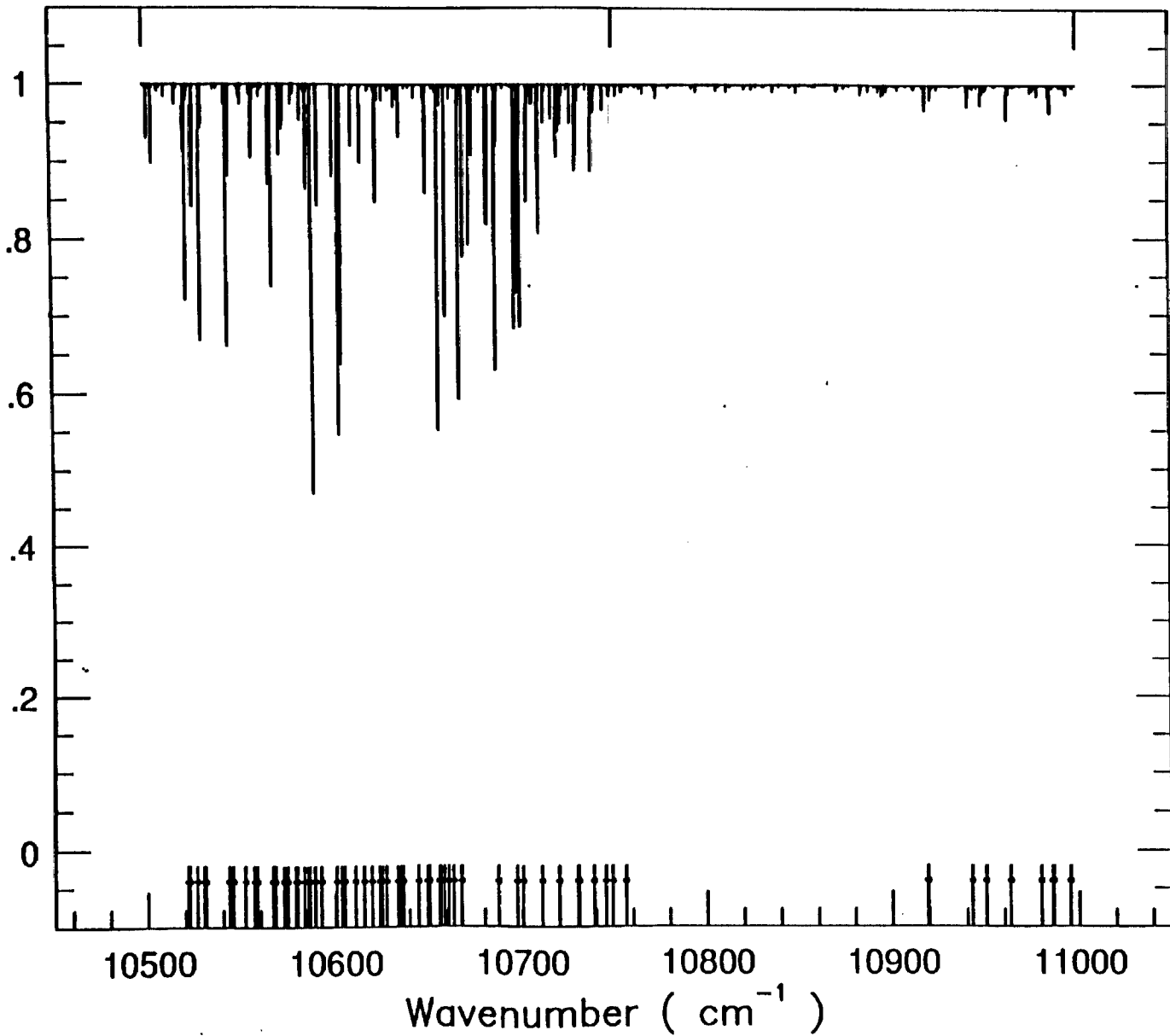
0.9524

0.9302

0.9091

#42

Transmittance



|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑                |                            |
| H <sub>2</sub> O |                            |
| Lambda 1         | 10500.000                  |
| Lambda 2         | 11000.000                  |
| Sampling         | 0.000002                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 0.931                      |
| Num. Pts.        | 19493                      |
| Ozone            | 9.13E+18                   |

Wavelength (  $\mu\text{m}$  )

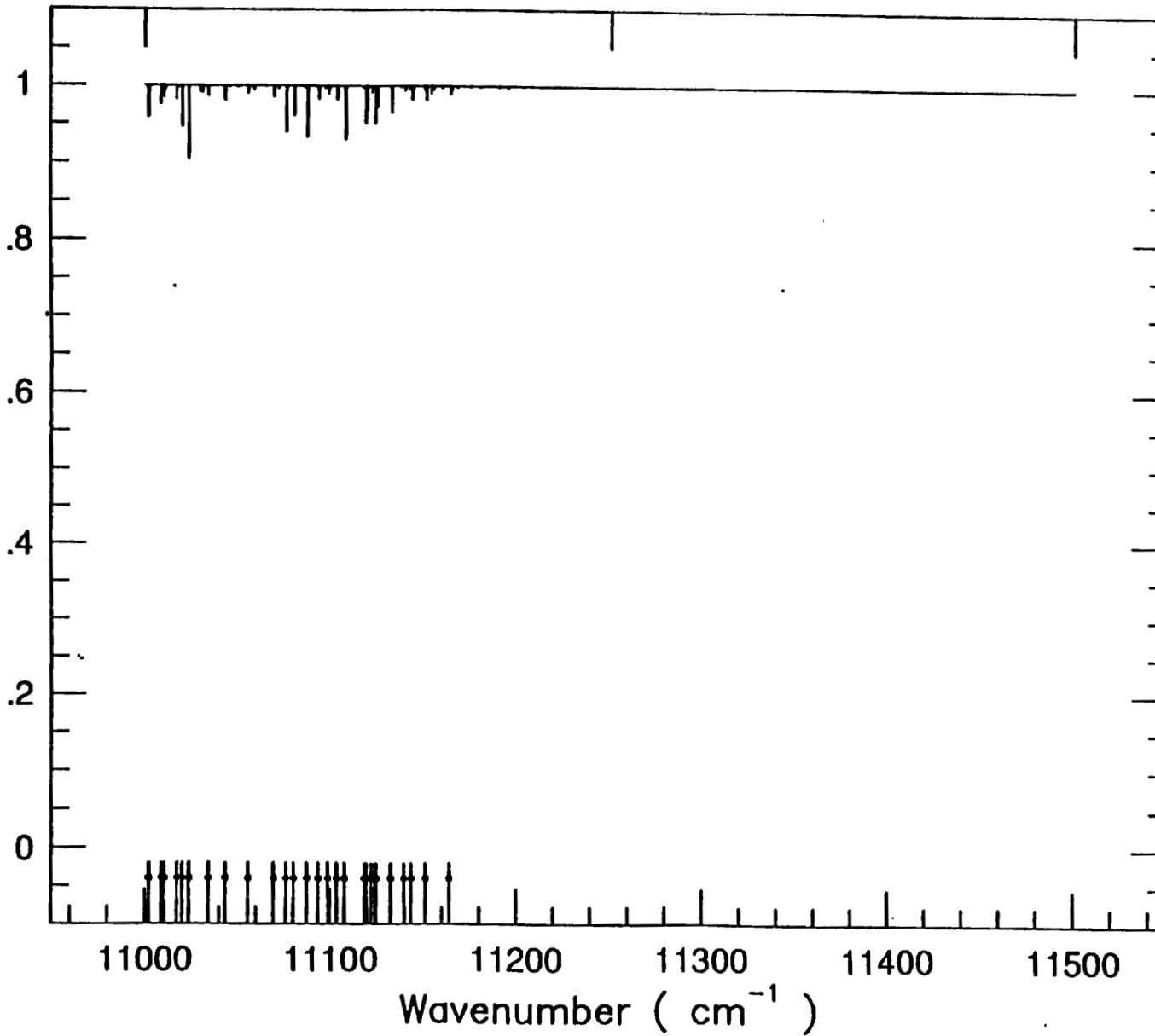
0.9091

0.8889

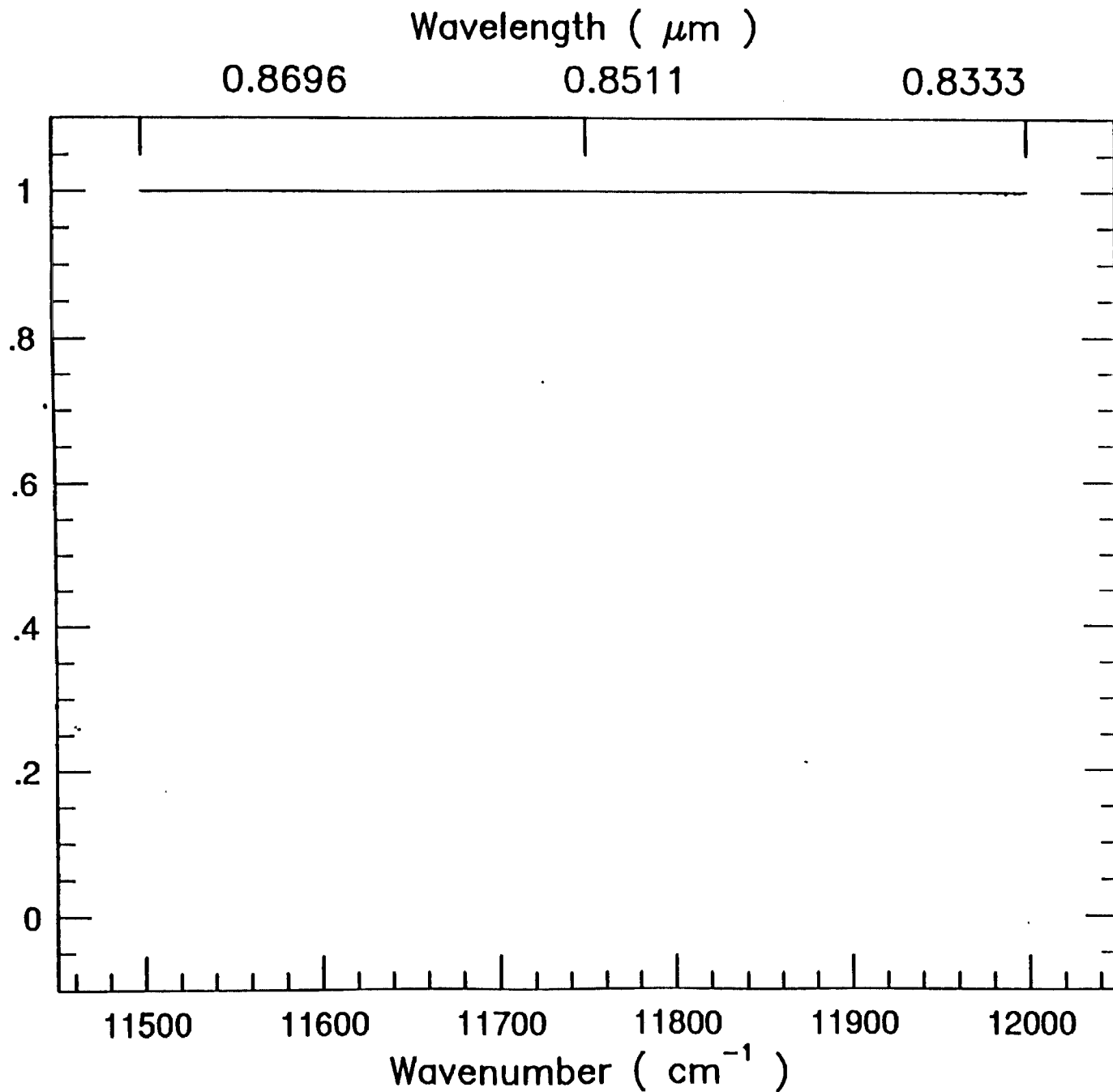
0.8696

#43

Transmittance



|                  |                            |
|------------------|----------------------------|
| Zenith WV        | 10.0                       |
| Zenith Ang       | 45.0                       |
| L.O.S. WV        | 14.1                       |
| Atm. Type        | Std.&H <sub>2</sub> O Adj. |
| Layers           | 1                          |
| Altitude         | 41000                      |
| ↑                |                            |
| H <sub>2</sub> O |                            |
| Lambda 1         | 11000.000                  |
| Lambda 2         | 11500.000                  |
| Sampling         | 0.000002                   |
| Res(FWHM)        | 0.000000                   |
| Instr. Fn.       | None                       |
| Line Ctr         | 0.889                      |
| Num. Pts.        | 19493                      |
| Ozone            | 9.13E+18                   |



#44

|            |                            |
|------------|----------------------------|
| Zenith WV  | 10.0                       |
| Zenith Ang | 45.0                       |
| L.O.S. WV  | 14.1                       |
| Atm. Type  | Std.&H <sub>2</sub> O Adj. |
| Layers     | 1                          |
| Altitude   | 41000                      |

|            |           |
|------------|-----------|
| Lambda 1   | 11500.000 |
| Lambda 2   | 12000.000 |
| Sampling   | 0.000002  |
| Res(FWHM)  | 0.000000  |
| Instr. Fn. | None      |
| Line Ctr   | 0.851     |
| Num. Pts.  | 19493     |
| Ozone      | 9.13E+18  |

Tue Oct 8 21:46:49 1991

Wavelength (  $\mu\text{m}$  )

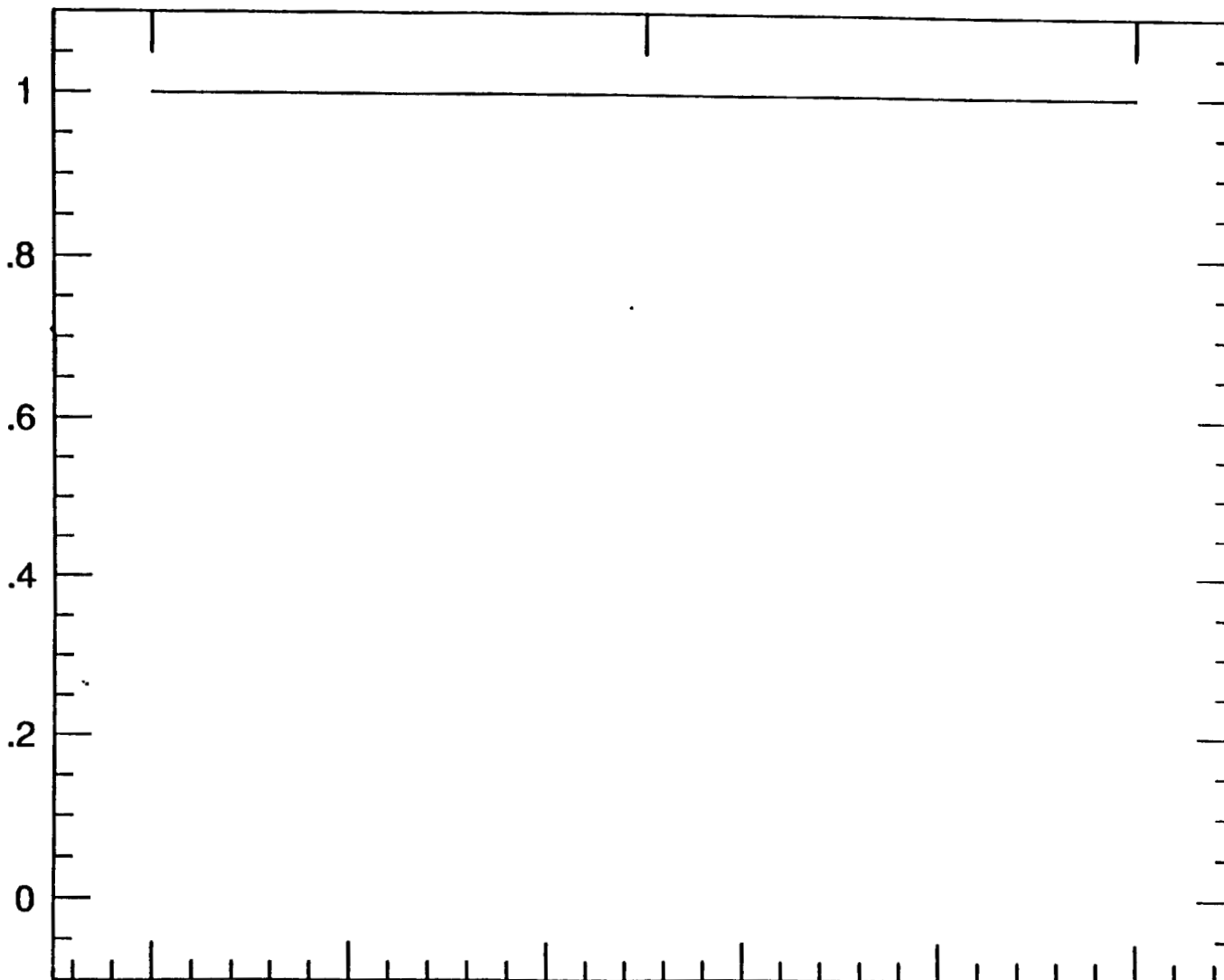
0.8333

0.8163

0.8000

#45

Transmittance



|            |                            |
|------------|----------------------------|
| Zenith WV  | 10.0                       |
| Zenith Ang | 45.0                       |
| L.O.S. WV  | 14.1                       |
| Atm. Type  | Std.&H <sub>2</sub> O Adj. |
| Layers     | 1                          |
| Altitude   | 41000                      |
| Lambda 1   | 12000.000                  |
| Lambda 2   | 12500.000                  |
| Sampling   | 0.000002                   |
| Res(FWHM)  | 0.000000                   |
| Instr. Fn. | None                       |
| Line Ctr   | 0.817                      |
| Num. Pts.  | 19493                      |
| Ozone      | 9.13E+18                   |

12000

12100

12200

12300

12400

12500

Wavenumber (  $\text{cm}^{-1}$  )

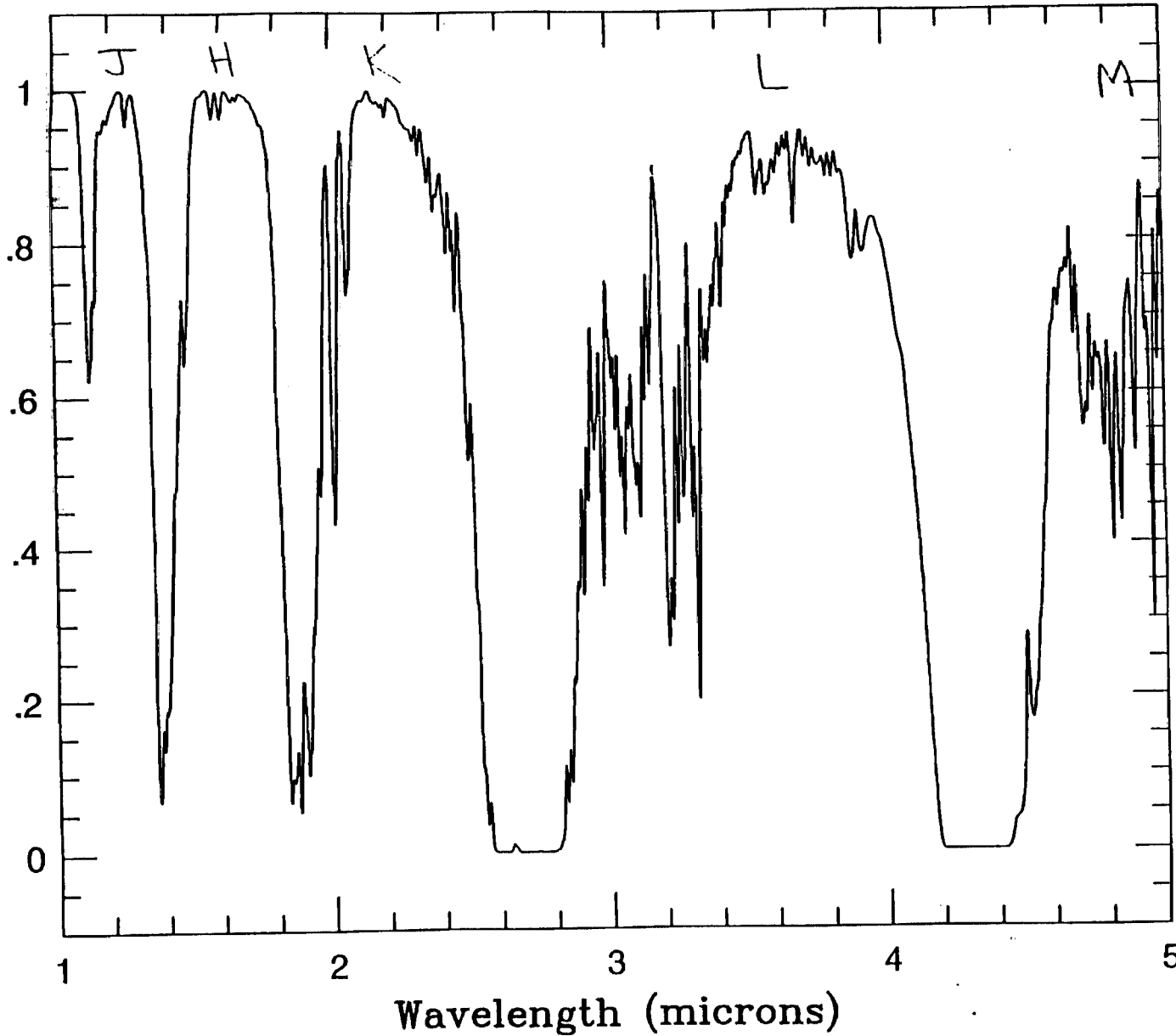
## APPENDIX G

### NEAR-IR BANDS AT MOUNTAINTOP ALTITUDE

The following spectrum was produced by running ATRAN 15 times, producing data files that encompass the near-IR band from 1 to 5  $\mu\text{m}$ . These files were appended to one file, and plotted as shown. The bands J, H, K, L, M are shown.

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Zenith WV 3508.5  
 Zenith Ang 45.0  
 L.O.S. WV 4961.8  
 Atm. Type Standard  
 Layers 1  
 Altitude 13500

Lambda 1 1.000  
 Lambda 2 5.000  
 Sampling 0.002000  
 Res(FWHM) 0.010000  
 Instr. Fn. Gaussian  
 Line Ctr 2.5  
 Num. Pts. 1990  
 Ozone 9.13E+18

Sat Dec 21 15:57:55 1991

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

|  |  |   |  |  |
|--|--|---|--|--|
| 1. AGENCY USE ONLY (Leave blank)   |  | 2. REPORT DATE<br>December 1992         | 3. REPORT TYPE AND DATES COVERED<br>Technical Memorandum         |  |
| 4. TITLE AND SUBTITLE<br>A New Software Tool for Computing Earth's Atmospheric Transmission of Near- and Far-Infrared Radiation  |  |   | 5. FUNDING NUMBERS<br>352-03-03-02                               |  |
| 6. AUTHOR(S)<br>Steven D. Lord   |  |   |  |  |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>Ames Research Center<br>Moffett Field, CA 94035-1000   |  |   | 8. PERFORMING ORGANIZATION REPORT NUMBER<br>A-92154              |  |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br>National Aeronautics and Space Administration<br>Washington, DC 20546-0001  |  |   | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER<br>NASA TM-103957 |  |
| 11. SUPPLEMENTARY NOTES<br>Point of Contact: Steven D. Lord, Ames Research Center, MS 245-6, Moffett Field, CA 94035-1000<br>(415) 604-5502  |  |   |  |  |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT<br>Unclassified-Unlimited<br>Subject Category - 46  |  |   | 12b. DISTRIBUTION CODE   |  |
| 13. ABSTRACT (Maximum 200 words)<br>This report describes a new software tool ATRAN which computes the transmittance of Earth's atmosphere at near- and far-infrared wavelengths. We compare the capabilities of this program with others currently available and demonstrate its utility for observational data calibration and reduction. The program employs current water-vapor and ozone models to produce fast and accurate transmittance spectra for wavelengths ranging from 0.8 $\mu\text{m}$ to 10 mm. |  |   |  |  |
| 14. SUBJECT TERMS<br>Atmospheric transmission, Radiative transfer, Atmospheric modeling  |  |   | 15. NUMBER OF PAGES<br>198                                       |  |
|  |  |   | 16. PRICE CODE<br>A09  |  |
| 17. SECURITY CLASSIFICATION OF REPORT<br>Unclassified  | 18. SECURITY CLASSIFICATION OF THIS PAGE<br>Unclassified | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT                                       |  |