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Aeronomic problems of molecular oxygen photodissociation

VI. Photodissociation frequency and transmittance in the spectral range of the Schumann-Runge bands

by

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FOREWORD

This article entitled "Photodissociation frequency and transmittance in the spectral range of the Schumann-Runge bands", Part VI of "Aeronomic problems of molecular oxygen photodissociation", provides the various numerical values to be used for a parameterization for 500 cm^{-1} intervals. It will be published in Planetary and Space Science.

AVANT-PROPOS

L'article intitulé "Photodissociation frequency and transmittance in the spectral range of the Schumann-Runge bands", Part VI of "Aeronomic problems of molecular oxygen photodissociation", fournit les différentes valeurs numériques à utiliser dans les formules paramétriques correspondant à des intervalles de 500 cm^{-1}. Il sera publié dans Planetary and Space Science.

VOORWOORD

Het artikel "Photodissociation frequency and transmittance in the spectral range of the Schumann-Runge bands", Deel VI van "Aeronomic problems of molecular oxygen photodissociation" geeft de verschillende numerieke waarden die gebruikt moeten worden voor de parametrische formules overeenstemmend met intervallen van 500 cm^{-1}. De tekst zal verschijnen in Planetary and Space Science.

VORWORT

Dieser Aufsatz "Photodissociation frequency and transmittance in the spectral range of the Schumann-Runge bands", Teil VI von "Aeronomic problems of molecular oxygen photodissociation" stellt die verschiedenen numerischen Werte vor, die gebraucht werden müssen in den parametrischen Formeln relativ zu Intervallen von 500 cm^{-1}. Dieser Text wird in Planetary and Space Science veröffentlicht.

AERONOMIC PROBLEMS OF MOLECULAR OXYGEN PHOTODISSOCIATION

VI.- Photodissociation frequency and transmittance in the spectral range of the Schumann-Runge bands

by

Marcel Nicolet and Robert Kennes

Abstract

The relative photodissociation frequency and direct transmittance of O_2 can be derived from parametric formulas for 500 cm^{-1} intervals in the 175-202 nm spectral region that corresponds to the domain of the bands of the Schumann-Runge system. The parameterization is obtained by comparison of detailed calculations (0.1 cm^{-1} intervals from 115 km to 15 km) from Nicolet et al. (1987, 1988 and 1989) with formulas that depend on the solar zenith angle and the O_2 column abundances. The overall similarity between the results of the detailed calculations and of the parameterization that incorporates the requisite constants implies that this new set of practical transmission functions and relative photodissociation rates for O_2 is appropriate for atmospheric modeling in the mesosphere and stratosphere.

Résumé

La fréquence relative de photodissociation de O_2 et sa transmittence directe sont déterminées à partir de formules paramétriques adaptées à des intervalles de 500 cm^{-1} dans le domaine des bandes du système de Schumann-Runge correspondant à la région spectrale 175-202 nm. Les divers paramètres sont obtenus après une comparaison des résultats de calculs détaillés (intervalles de 0.1 cm^{-1} de 115 km a 15 km, Nicolet et al., 1987, 1988 et 1989) et des formules qui dépendent à la fois de la distance zénithale du Soleil et du contenu total de la colonne correspondante de molécules O_2. La similitude réalisée entre les résultats des calculs détaillés et ceux obtenus par les formules avec les constantes adéquates permet de fournir des fonctions de transmission et de fréquence de photodissociation relative de O_2 applicables immédiatement à des modèles atmosphériques de la mésosphère et de la stratosphère.

Samenvatting

De relatieve fotodissociatiefrequentie en de rechtstreekse doorlating van O_2 worden bepaald aan de hand van parametrische formules, aangepast aan intervallen van 500 cm^{-1} in het bandengebied van het Schumann-Runge systeem, dat overeenstemt met het spectraal gebied van 175-202 nm. De verschillende parameters worden bekomen na vergelijking van de resultaten van gedetailleerde berekeningen (intervallen van 0.1 cm^{-1} van 115 km tot 15 km) van Nicolet et al. (1987, 1988 en 1989) met formules die afhankelijk zijn van de zenitafstand van de zon en de totale hoeveelheid O_2 molekulen in de overeenstemmende kolom. De goede overeenkomst tussen de resultaten van de gedetailleerde berekeningen en de berekeningen met behulp van de formules met de adequate constanten laat toe doorlatingsfuncties en functies van relatieve fotodissociatiefrequentie van O_2 te geven die onmiddellijk kunnen toegepast worden voor atmosferische modellen van de mesosfeer en de stratosfeer.

Zusammenfassung

Die relative Photodissoziationsfrequenz und die direkte Durchlässigkeit von O_2 werden durch parametrische Formeln bestimmt, angepasst an Intervallen von 500 cm^{-1} im Spektralgebiet (175-202 nm) des Schumann-Runge Systems. Die verschiedene Parameters werden erhalten nach einem Vergleich von den Ergebnissen von ausführlichen Rechnungen (0.1 cm^{-1} Intervallen, von 115 bis 15 km), Nicolet et al; (1987, 1988 und 1989) mit Formeln die gleichzeitig vom dem Zenitabstand der Sonne und von dem O_2 Inhalt der entsprechenden Säule abhängen. Die Übereinstimmung den Ergebnissen von den ausführlichen Rechnungen mit den Ergebnissen van der Anwendung der Formeln mit den angemessenen Konstanten erlaubt Übertragungsfunktionen und Funktionen von der relativen O_2 Photodissoziationsfrequenz zu bestimmen die sofort für atmosphärische Modellen der Mesosphäre und der Stratosphäre anwendbar sind.

1. *INTRODUCTION*

The photodissociation frequency of O_2 in the Schumann-Runge band region and, therefore, the photodissociation rate with its associated production of oxygen atoms, cannot be determined without direct introduction of the cross-section for the underlying continuum. Two different calculations are needed to arrive at a correct determination of the O_2 photodissociation frequency and of the O_2 transmittance in the spectral region of the Schumann-Runge bands.

The O_2 transmittance for a specific spectral domain, here 500 cm^{-1}, is

$$Tr(O_2) = \sum_{i=1}^{n} e^{-(\sigma_i + \sigma_c)N_1 \sec \chi} \qquad (1)$$

where σ_i is the Schumann-Runge band cross-section calculated for each 0.1 cm^{-1} interval ; it is a function of the temperature and of the total number of O_2 molecules, N ; N_1 is the number of O_2 molecules (cm^{-2}) for a vertical column and sec χ taken account of the effect of the solar zenith angle χ. σ_c is the underlying continuum cross-section and may be taken, to a good approximation, as constant over a 500 cm^{-1} interval.

Thus, (1) can be written

$$Tr(O_2) = e^{-\sigma_c N_1 \sec \chi} \sum_{i=1}^{n} e^{-\sigma_i N_1 \sec \chi} \qquad (2)$$

The photodissociation frequency (s^{-1}) under the same conditions, i.e. without including any effect from the absorptions by molecular scattering and by ozone is, (q_∞ = 1, number of photons cm^{-2} s^{-1}),

$$J(O_2) = \sum_{i=1}^{n} (\sigma_i + \sigma_c)\, e^{-(\sigma_i + \sigma_c)N_1 \sec \chi} \qquad (3)$$

and becomes

$$J(O_2) = \left[\sum_{i=1}^{n} \sigma_i e^{-\sigma_i N_1 \sec \chi} + \sigma_c \sum_{i=1}^{n} e^{-\sigma_i N_1 \sec \chi} \right] \left[Tr_c^1(O_2) \right]^{\sec \chi} \quad (4)$$

where the last term is the O_2 transmittance of the underlying continuum for a vertical column. Formulas (2) and (4) show that the transmittance can be computed with and without the introduction of the underlying continuum, and that the photodisociation always requires the introduction of the continuum.

With the introduction of the atmospheric transmittance the photodissociation frequency would be, instead of (4),

$$J(O_2) = \sigma_D(T, N)\ Tr(O_2) \quad (5)$$

where $\sigma_D(T, N)$ should be an equivalent photodissociation cross-section function of the temperature T and of the total number of absorbing O_2 molecules N. After a detailed analysis of the numerical results based on formula (5), it was deduced that the accuracy was not satisfactory when compared with the values deduced directly from (4). The results of the comparison will not be reproduced here.

2. *COMPARISONS OF SYNTHETIC AND EXPERIMENTAL CROSS-SECTIONS*

The experimental and theoretical data have been described by Nicolet et al. (1987, 1988 and 1989) and are used in the determination of the photodissociation frequency and of the transmittance of O_2.

A general view of the spectrum of the Schumann-Runge bands from (0-0) to (19-0) is given for wavenumber intervals of 50 cm^{-1} (corresponding to the averaged cross-section of 500 calculated values) in Fig. 1a, 2a, 3a, and 4a and in Fig. 1b, 2b, 3b and 4b at 300 K and 190 K, respectively. The calculated cross-section varies from less than 10^{-23} cm^2 to more than 10^{-19} cm^2. A 50 cm^{-1} interval corresponds to 0.175 $\pm$ 0.025 nm in the spectral region 200-175 nm.

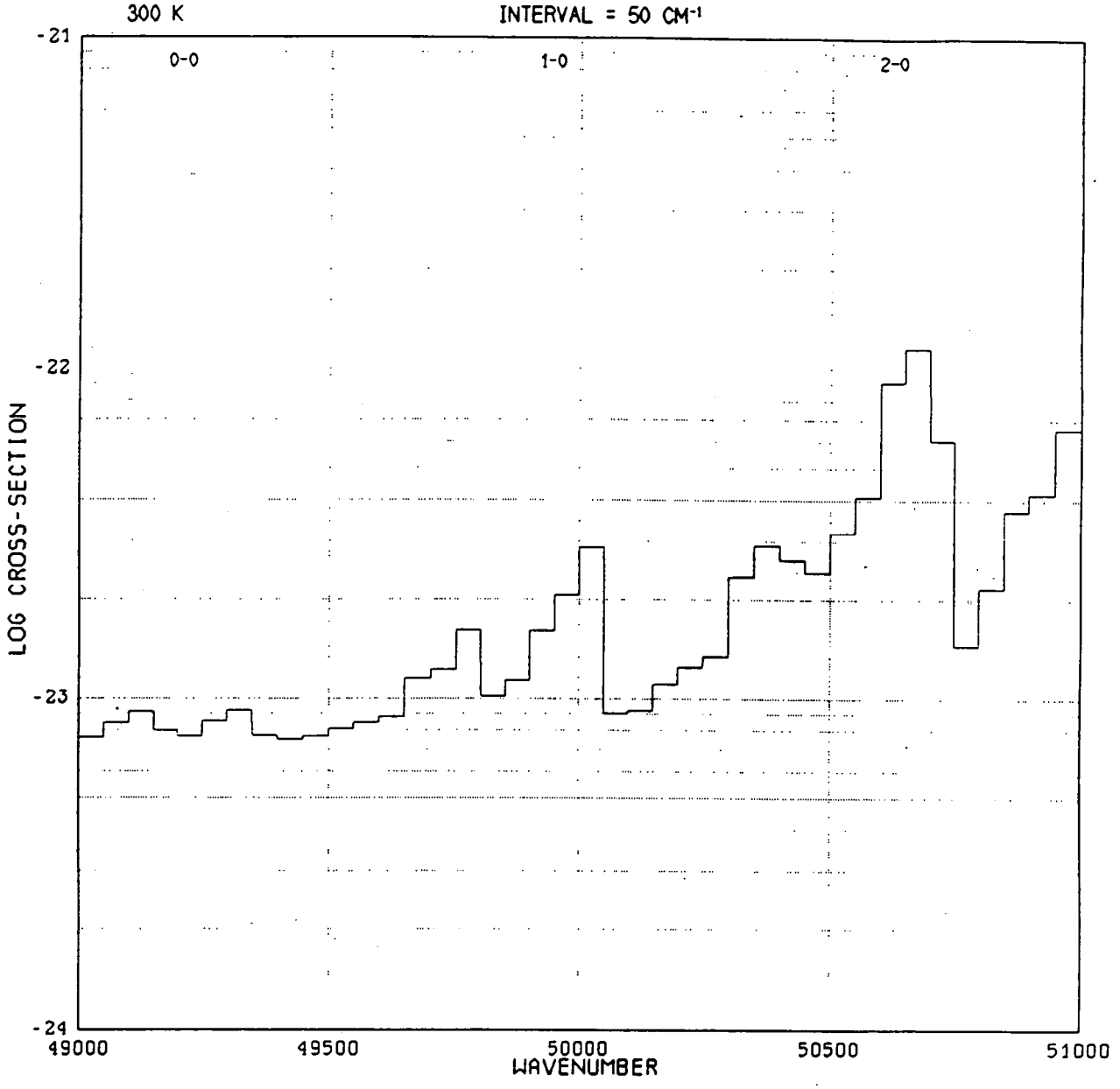

Fig.1a Structure of the O_2 absorption between 49000 and 51000 cm^{-1}; 50 cm^{-1} intervals and T = 300 K.

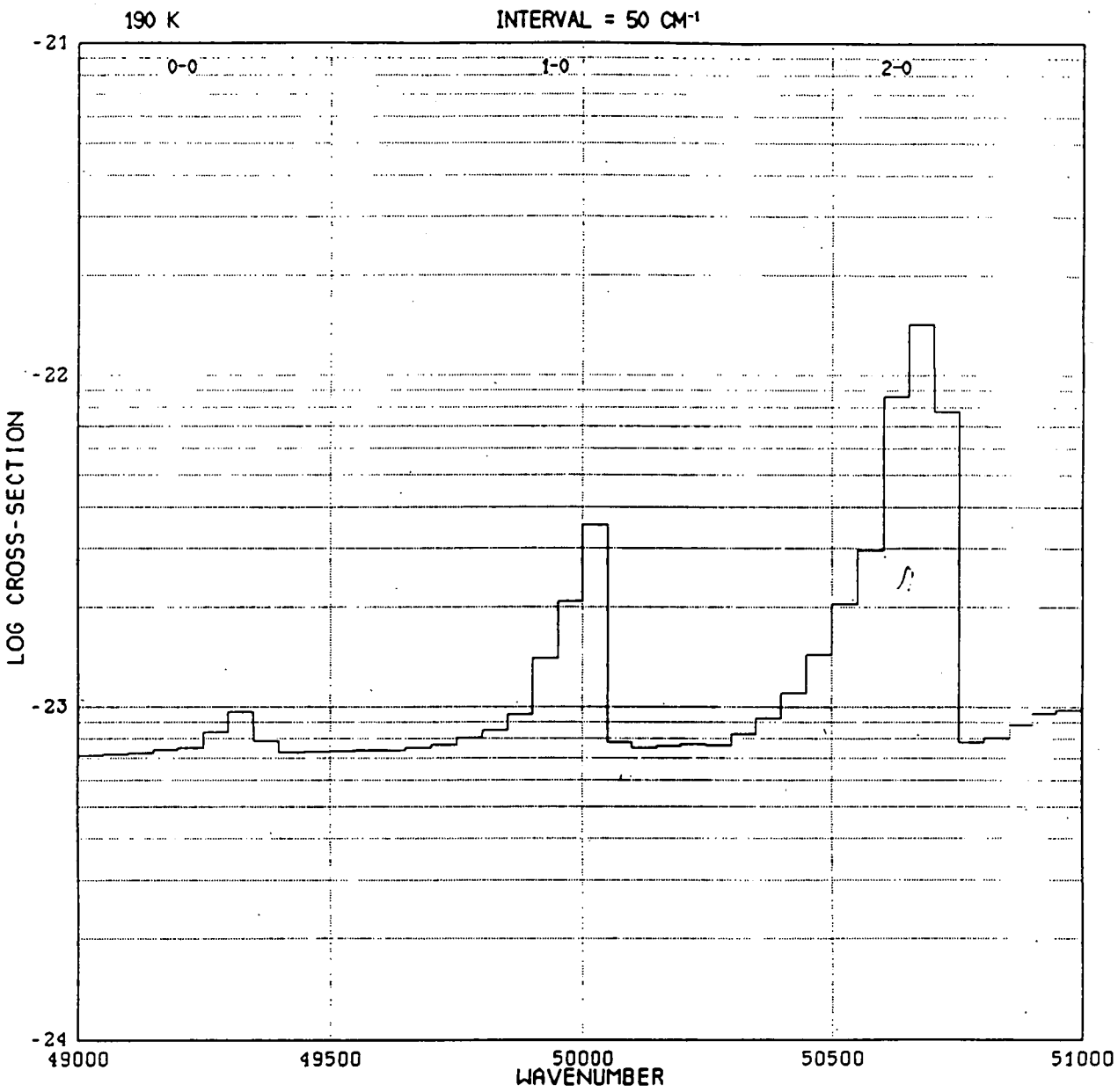

Fig.1b As in Fig. 1a, but T = 190 K.

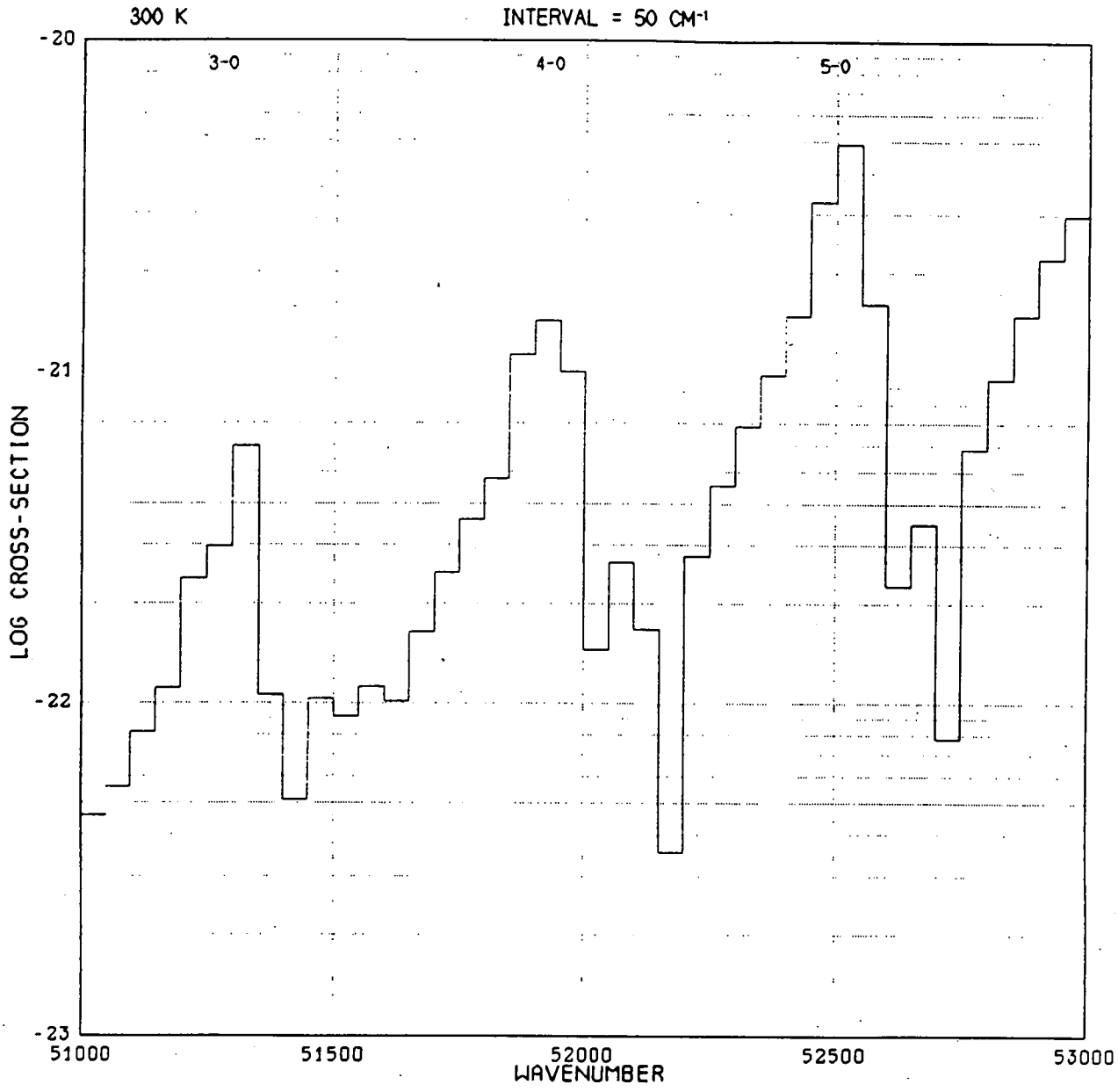

Fig.2a As in Fig. 1a, between 51000 and 53000 cm^{-1}.

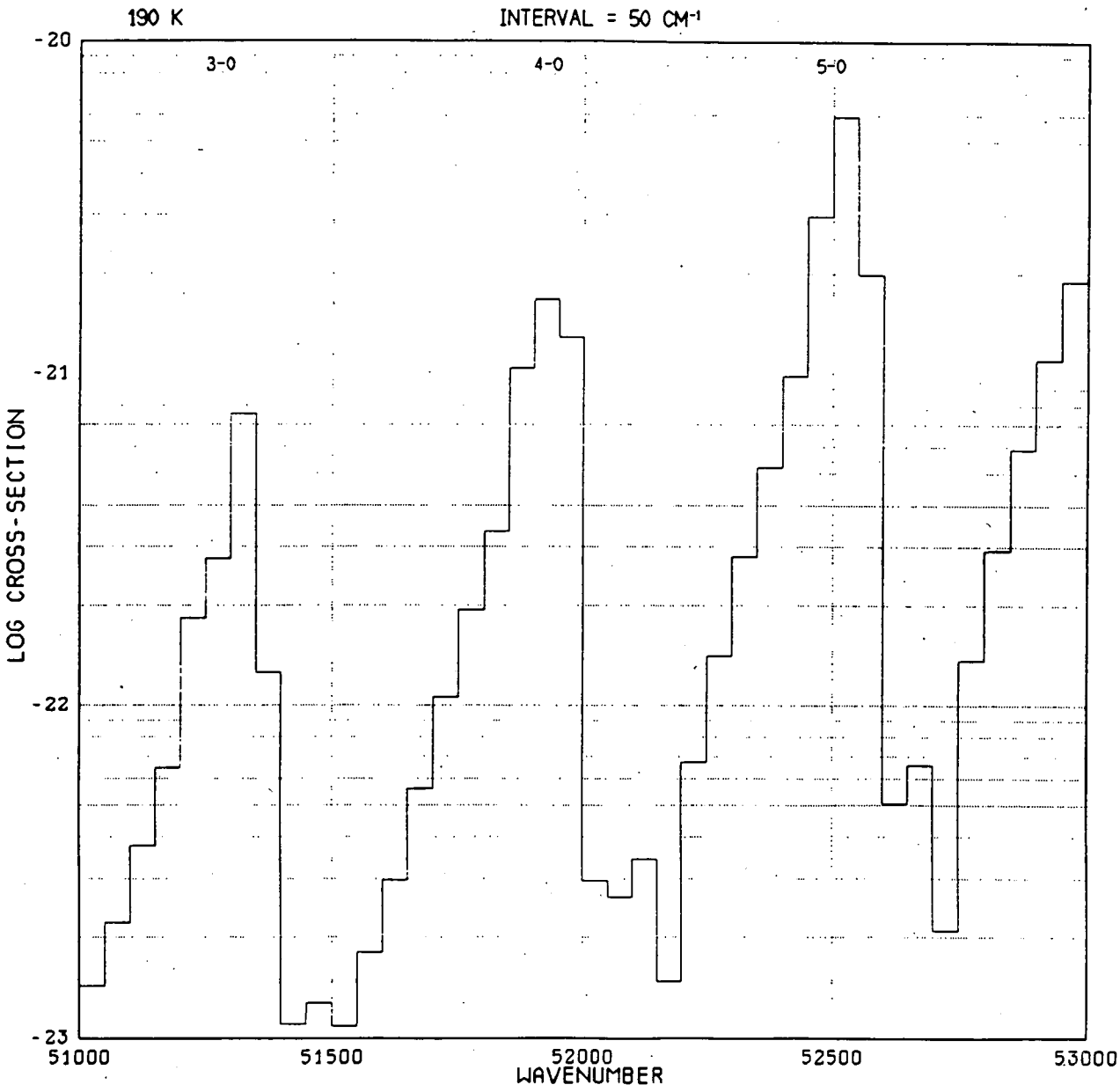

Fig.2b As in Fig. 1b, between 51000 and 53000 cm^{-1}.

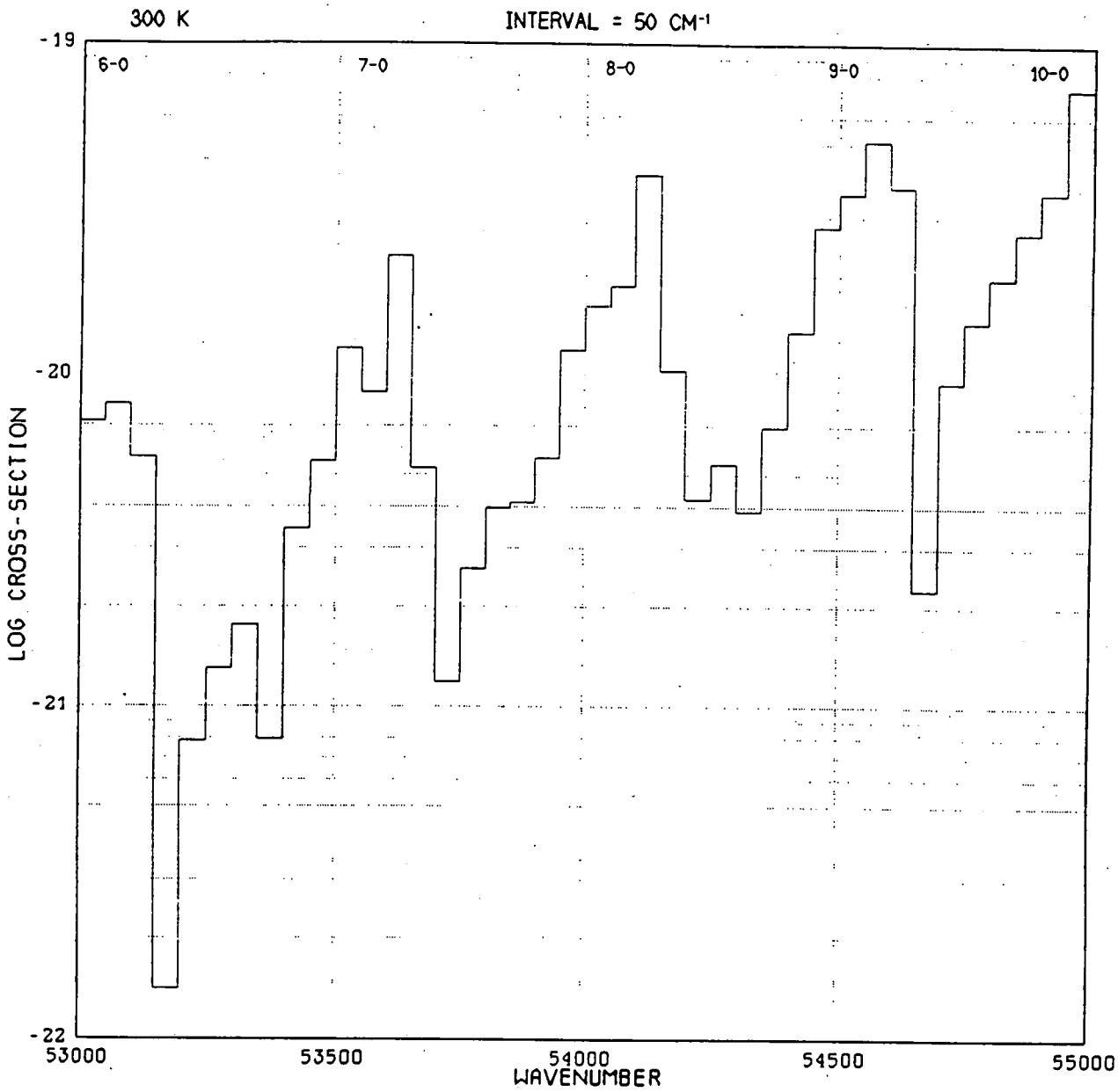

Fig.3a As in Fig. 1a and 2a, between 53000 and 55000 cm^{-1}.

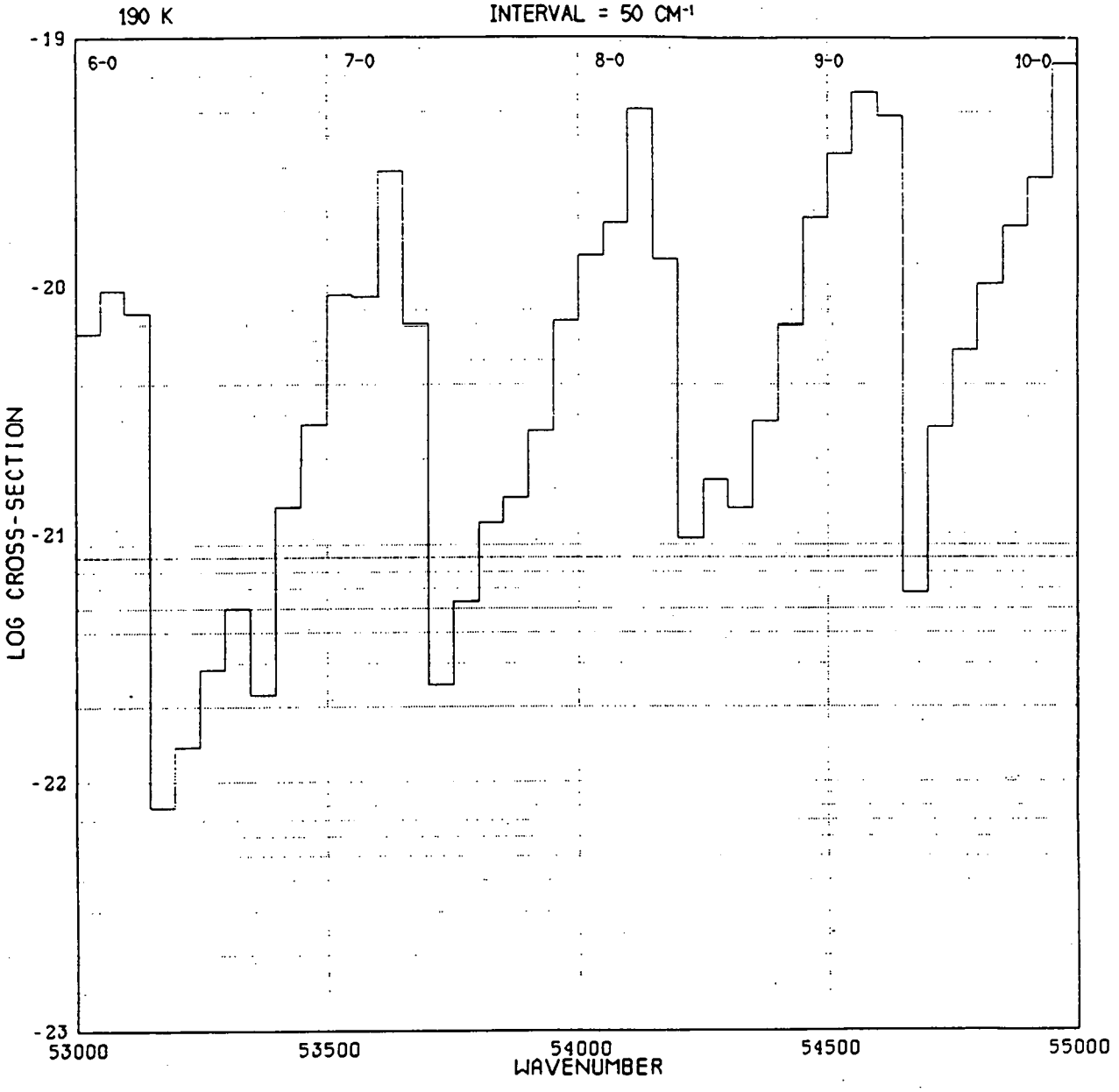

Fig.3b As in Fig. 1b and 2b, between 53000 and 55000 cm^{-1}.

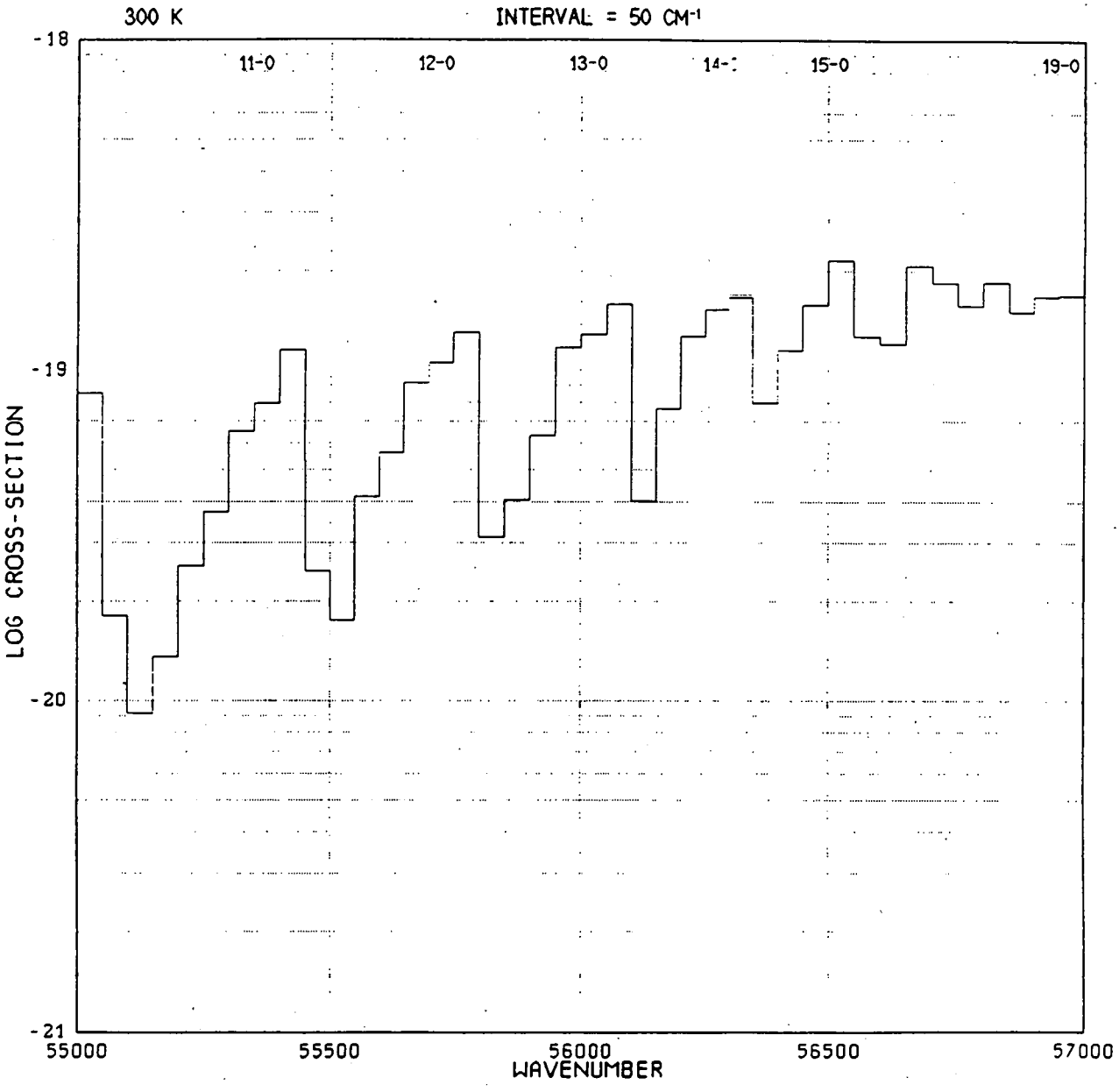

Fig.4a As in Fig. 1a - 3a, between 55000 and 57000 cm^{-1}.

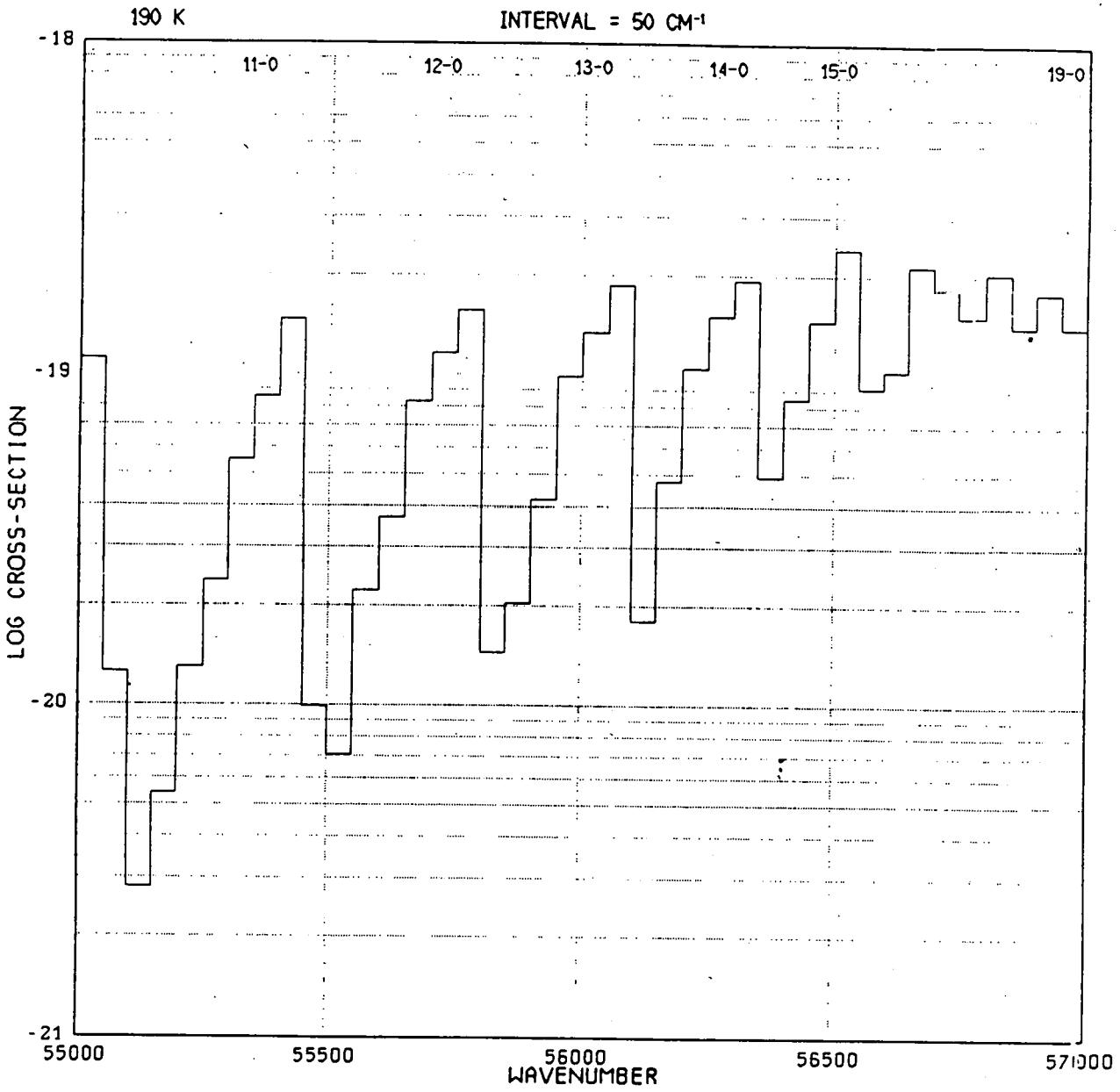

Fig.4b As in Fig. 1b - 3b, between 55000 and 57000 cm^{-1}.

Other examples are presented in Fig.5a and 5b and in Fig.6a and 6b at 300 and 190 K, respectively, for spectral intervals of 20 cm^{-1} (mean of 200 values in about 0.08 nm) and of 1 cm^{-1} (mean of 10 values in about 0.004 nm), in the spectral region of the 3-0 to 6-0 bands.

As an example, the line positions used in the calculations for the 52500-52000 cm^{-1} interval associated mainly with the 5-0 band are presented in Table 1a and 1b, and Fig.7 illustrates the differences at 300 K and at 79 K between the cross-sections of the 5-0 band up to P15-R17 obtained with a resolution of 0.1 cm^{-1}. The final comparison between the theoretical and experimental cross-sections at 300 K with the corresponding identification of the various rotational lines is depicted in Fig.8a and 8b between 52500 and 52000 cm^{-1}. The corresponding figures 9a and 9b show that differences of $\pm$ 20 or $\pm$ 10 % in the cross-section of the Herzberg continuum are practically negligible. However, the presence or the absence of an underlying continuum cannot be neglected, as is clearly indicated in Fig. 10a and 10b and Fig.11a and 11b for temperatures between 300 K and 190 K, respectively ; the effect is especially important in the spectral region of the 7-1 band and of the rotational lines of the highest levels of the 5-0 band at 190 K.

Finally, two figures (Fig.12a and 12b) represent the variation of the rotational structure in the 52500-52000 cm^{-1} region associated with the variation of the temperature : 300, 270, 230 and 190 K. They demonstrate that it is possible to apply the O_2 absorption cross-sections in the region of the Schumann-Runge bands to the calculation of the transmission of the solar spectral irradiance in the mesosphere and stratosphere when all the aeronomic parameters are considered along with their intimate interactions.

3. *CONCLUSIONS AND GENERAL CONSIDERATIONS ON THE RESULTS*

When all direct photodissociations processes are considered (see Nicolet and Kennes, 1986; Nicolet et al., 1987; Nicolet and Kennes, 1988a; Nicolet et al., 1988; Nicolet and Kennes, 1988b; Nicolet, 1989;

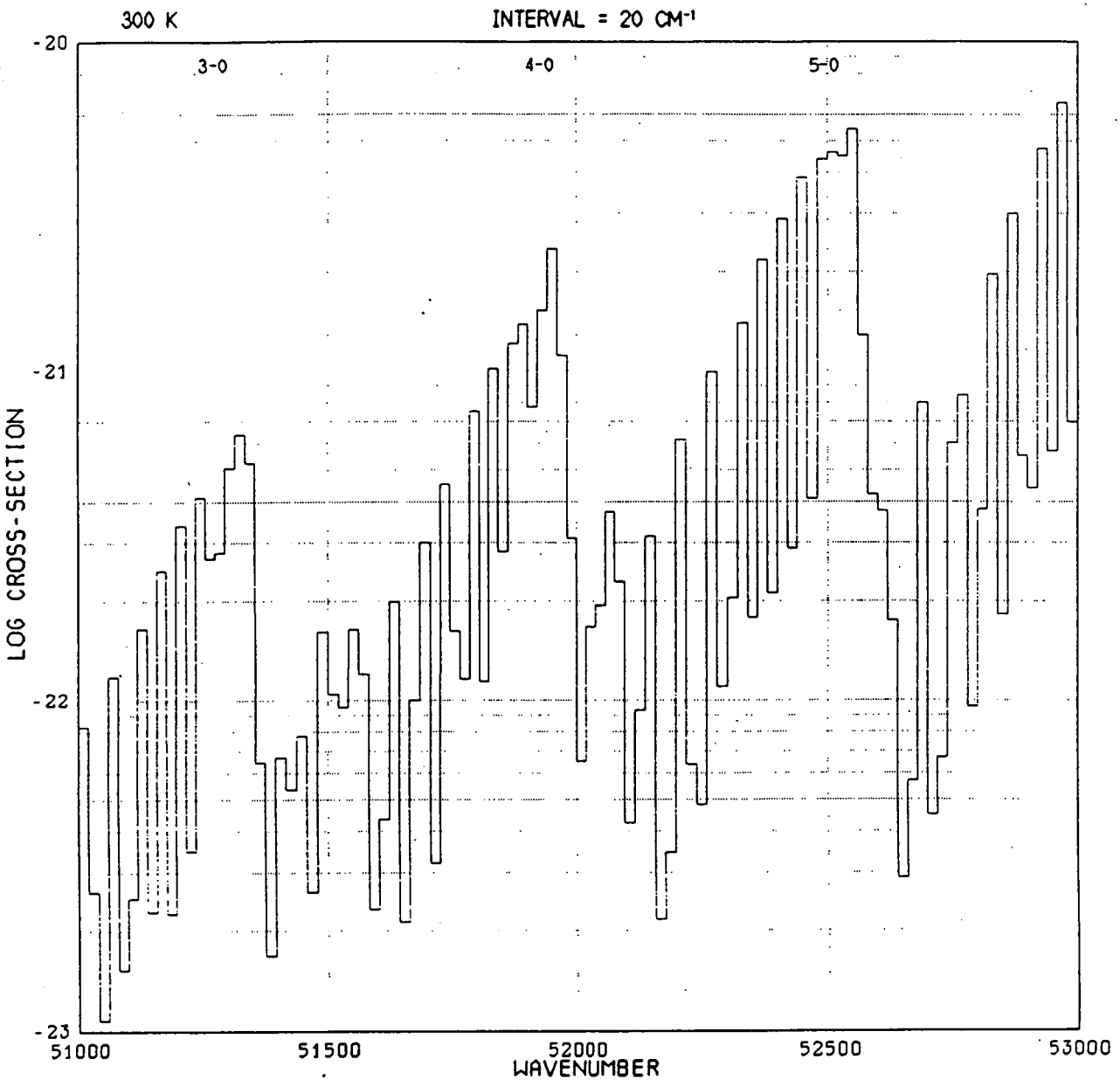

Fig.5a Structure of the O_2 absorption between 51000 and 53000 cm^{-1} ; 20 cm^{-1} intervals and T = 300 K. See Fig.2a.

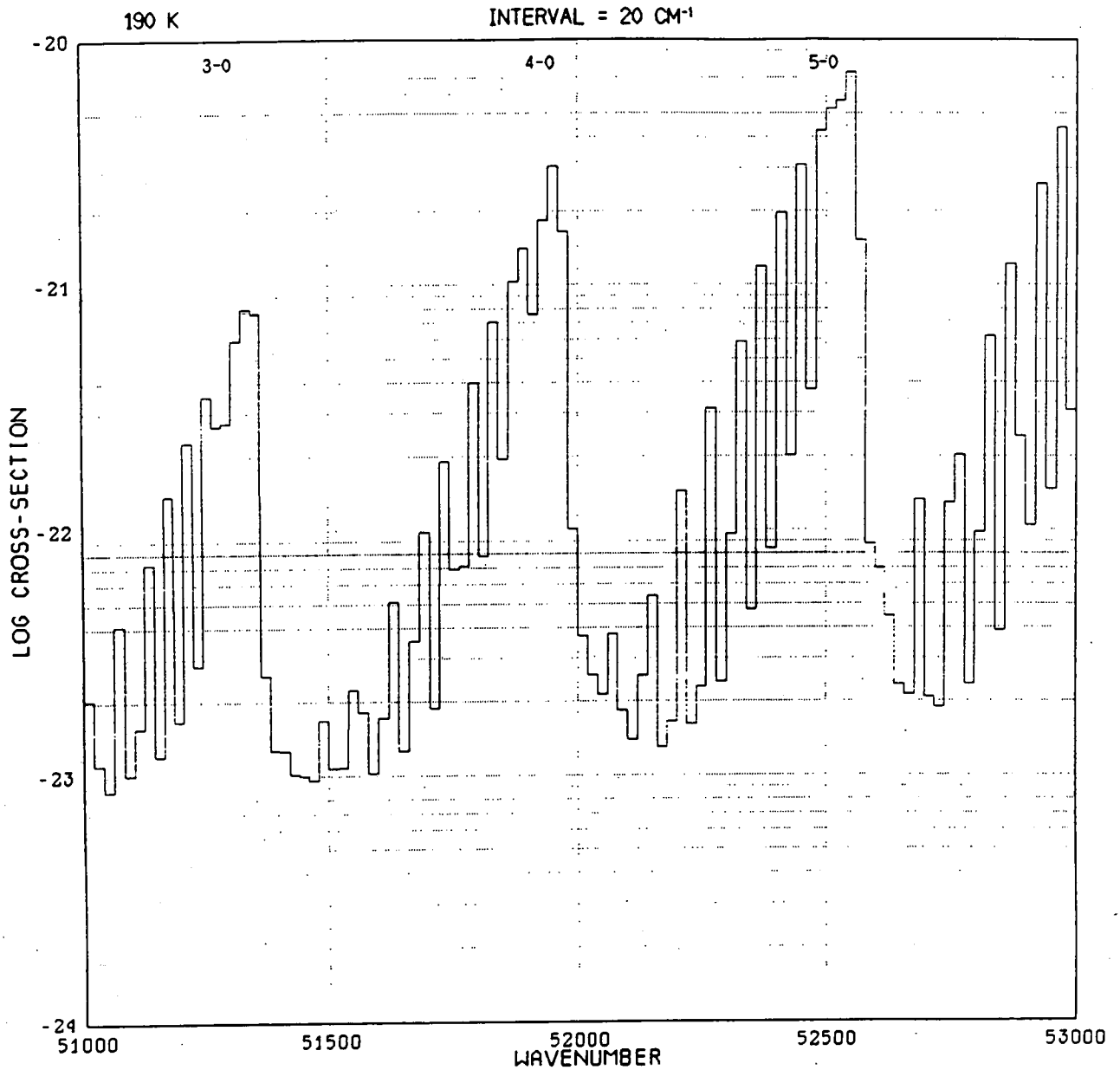

Fig.5b As in Fig. 5a, but T = 190 K. See Fig. 2b.

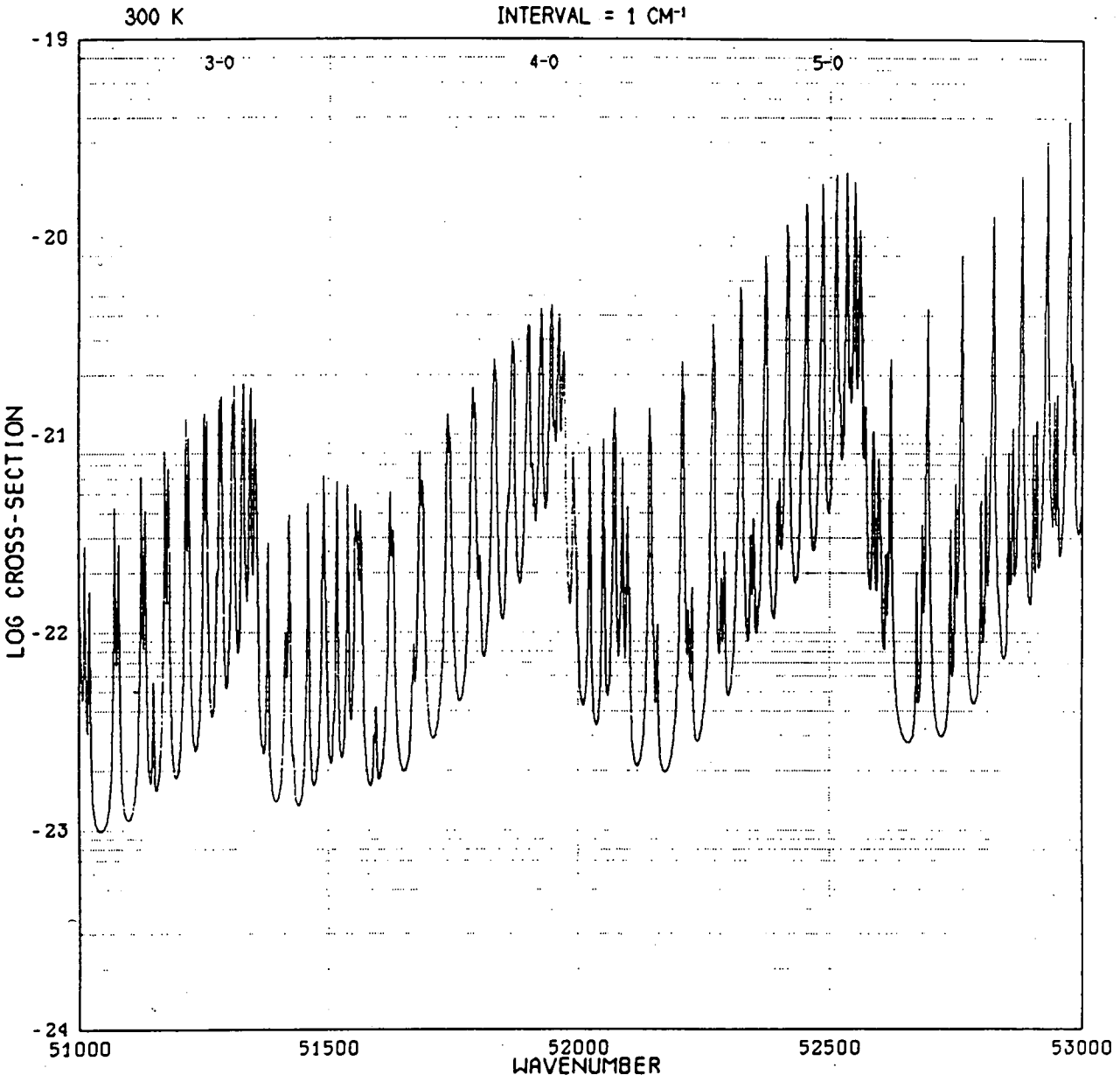

Fig.6a Structure of the O_2 absorption between 51000 and 53000 cm^{-1} ; 1 cm^{-1} intervals and T = 300 K. See Fig. 2a and 5a.

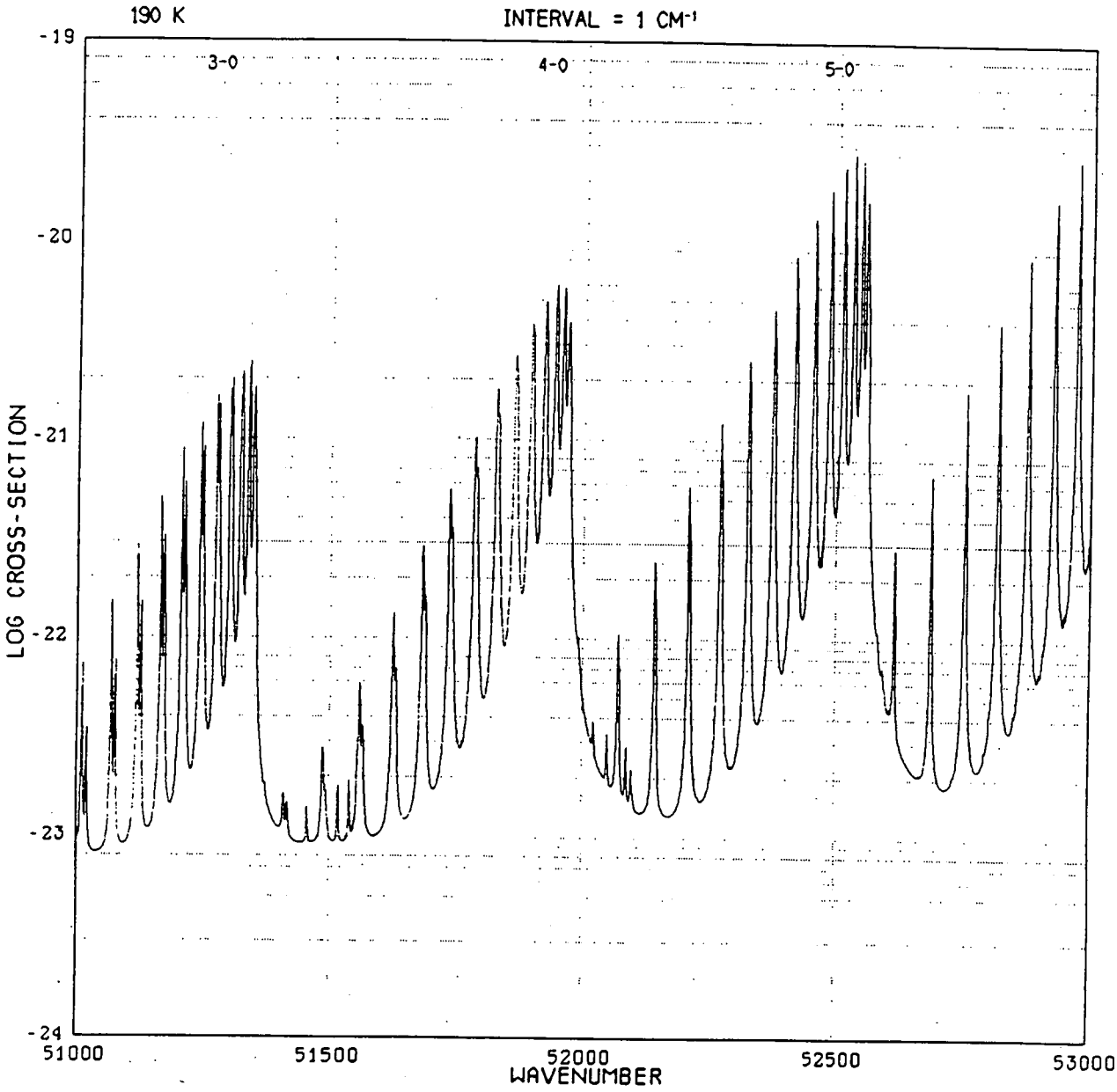

Fig.6b As inFig. 6a, but T = 190 K. See Fig. 2b and 5b.

TABLE 1a.-

IDENTIFICATION OF O_2 SCHUMANN-RUNGE ROTATIONNAL LINES
52250 - 52500 cm^{-1}

ν	λ	band	ν	λ	band
52250					
52266.9	1913.26	5-0 P19	52416.4	1907.80	5-0 R15
52267.0	1913.26	5-0 P19	52416.9	1907.78	5-0 R15
52267.4	1913.24	5-0 P19	52432.5	1907.21	9-1 R29
52269.4	1913.16	5-0 R21	52433.2	1907.19	9-1 R29
52269.6	1913.16	5-0 R21	52433.8	1907.17	9-1 R29
52270.2	1913.14	5-0 R21	52442.4	1906.85	8-1 R15
52284.5	1912.61	8-1 R21	52442.7	1906.84	8-1 R15
52284.9	1912.60	8-1 R21	52443.1	1906.83	8-1 R15
52285.5	1912.58	8-1 R21	52446.7	1906.70	8-1 P13
52290.9	1912.38	8-1 P19	52446.8	1906.69	8-1 P13
52291.1	1912.37	8-1 P19	52447.1	1906.68	8-1 P13
52291.5	1912.36	8-1 P19	52447.8	1906.66	9-1 P27
52300			52448.2	1906.64	9-1 P27
52321.7	1911.25	5-0 P17	52448.6	1906.63	9-1 P27
52321.7	1911.25	5-0 P17	52450		
52322.2	1911.24	5-0 P17	52452.3	1906.49	5-0 P11
52324.0	1911.17	5-0 R19	52452.4	1906.49	5-0 P11
52324.1	1911.16	5-0 R19	52452.7	1906.48	5-0 P11
52324.7	1911.14	5-0 R19	52454.1	1906.43	5-0 R13
52343.2	1910.47	8-1 R19	52454.1	1906.43	5-0 R13
52343.5	1910.46	8-1 R19	52454.6	1906.41	5-0 R13
52344.0	1910.44	8-1 R19	52455.7	1906.37	6-0 P29
52348.8	1910.26	8-1 P17	52455.9	1906.36	6-0 P29
52349.0	1910.26	8-1 P17	52456.4	1906.35	6-0 P29
52349.4	1910.24	8-1 P17	52483.0	1905.38	8-1 R13
52350			52483.3	1905.37	8-1 R13
52357.1	1909.96	9-1 P29	52483.6	1905.36	8-1 R13
52357.6	1909.94	9-1 P29	52484.7	1905.32	5-0 P 9
52358.0	1909.93	9-1 P29	52484.8	1905.32	5-0 P 9
52370.8	1909.46	5-0 P15	52485.1	1905.30	5-0 P 9
52370.9	1909.46	5-0 P15	52486.2	1905.26	5-0 R11
52371.3	1909.44	5-0 P15	52486.2	1905.26	5-0 R11
52373.0	1909.38	5-0 R17	52486.6	1905.25	8-1 P11
52373.1	1909.38	5-0 R17	52486.6	1905.25	5-0 R11
52373.6	1909.36	5-0 R17	52486.8	1905.24	8-1 P11
52395.8	1908.55	8-1 R17	52487.1	1905.23	8-1 P11
52396.1	1908.54	8-1 R17			
52396.5	1908.52	8-1 R17			
52400					
52400.7	1908.37	8-1 P15			
52400.9	1908.37	8-1 P15			
52401.2	1908.35	8-1 P15			
52414.4	1907.87	5-0 P13			
52414.4	1907.87	5-0 P13			
52414.8	1907.86	5-0 P13			
52416.3	1907.80	5-0 R15			

TABLE 1b.-

IDENTIFICATION OF O_2 SCHUMANN-RUNGE ROTATIONNAL LINES
52000 - 52250 cm^{-1}

ν	λ	band	ν	λ	band
52000					
52000.3	1923.07	8-1 P27	52140.5	1917.89	5-0 P23
52021.2	1922.29	7-1 R11	52140.6	1917.89	5-0 P23
52021.3	1922.29	7-1 R11	52141.2	1917.87	5-0 P23
52021.7	1922.27	7-1 R11	52143.3	1917.79	5-0 R25
52022.2	1922.26	7-1 P 9	52143.5	1917.78	5-0 R25
52022.2	1922.26	7-1 P 9	52144.3	1917.76	5-0 R25
52022.6	1922.24	7-1 P 9	52149.2	1917.57	8-1 R25
52048.8	1921.28	7-1 R 9	52149.7	1917.55	8-1 R25
52048.8	1921.27	7-1 R 9	52150		
52049.2	1921.26	7-1 R 9	52150.4	1917.53	8-1 R25
52049.5	1921.25	7-1 P 7	52157.1	1917.29	8-1 P23
52049.6	1921.25	7-1 P 7	52157.4	1917.27	8-1 P23
52049.9	1921.23	7-1 P 7	52157.9	1917.26	8-1 P23
52050			52200		
52068.9	1920.53	5-0 P25	52206.5	1915.47	5-0 P21
52069.1	1920.53	5-0 P25	52206.6	1915.47	5-0 P21
52069.6	1920.51	5-0 P25	52207.1	1915.45	5-0 P21
52070.5	1920.47	7-1 R 7	52209.1	1915.37	5-0 R23
52070.5	1920.47	7-1 R 7	52209.4	1915.37	5-0 R23
52070.9	1920.46	7-1 R 7	52210.0	1915.34	5-0 R23
52071.1	1920.45	7-1 P 5	52219.9	1914.98	8-1 R23
52071.1	1920.45	7-1 P 5	52220.4	1914.96	8-1 R23
52071.5	1920.44	7-1 P 5	52221.0	1914.94	8-1 R23
52071.7	1920.43	5-0 R27	52227.0	1914.72	8-1 P21
52072.0	1920.42	5-0 R27	52227.3	1914.71	8-1 P21
52072.5	1920.40	8-1 R27	52227.7	1914.69	8-1 P21
52072.8	1920.39	5-0 R27			
52073.1	1920.38	8-1 R27			
52073.8	1920.35	8-1 R27			
52081.2	1920.08	8-1 P25			
52081.6	1920.07	8-1 P25			
52082.1	1920.05	8-1 P25			
52086.5	1919.88	7-1 R 5			
52086.5	1919.88	7-1 R 5			
52086.9	1919.87	7-1 P 3			
52086.9	1919.87	7-1 P 3			
52086.9	1919.87	7-1 R 5			
52087.4	1919.85	7-1 P 3			
52096.7	1919.51	7-1 R 3			
52096.7	1919.51	7-1 R 3			
52096.8	1919.51	7-1 P 1			
52097.1	1919.49	7-1 R 3			
52099.5	1919.40	7-1 Q 1			
52100					
52101.0	1919.35	7-1 R 1			
52101.1	1919.35	7-1 R 1			

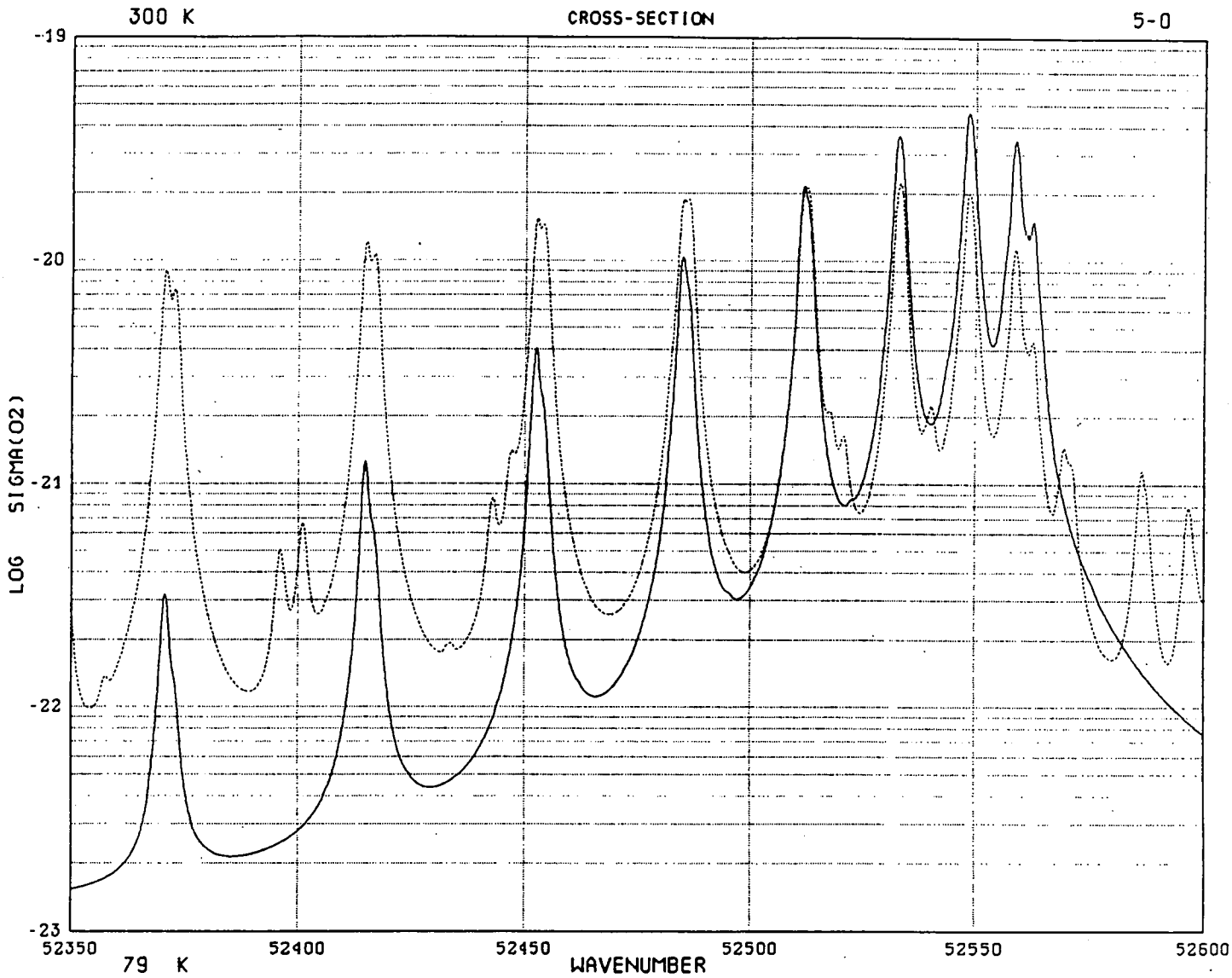

Fig.7 Comparison of the absorption cross-sections at 300 K and 79 K, respectively. 5-0 band between 52600 and 52350 cm^{-1}.

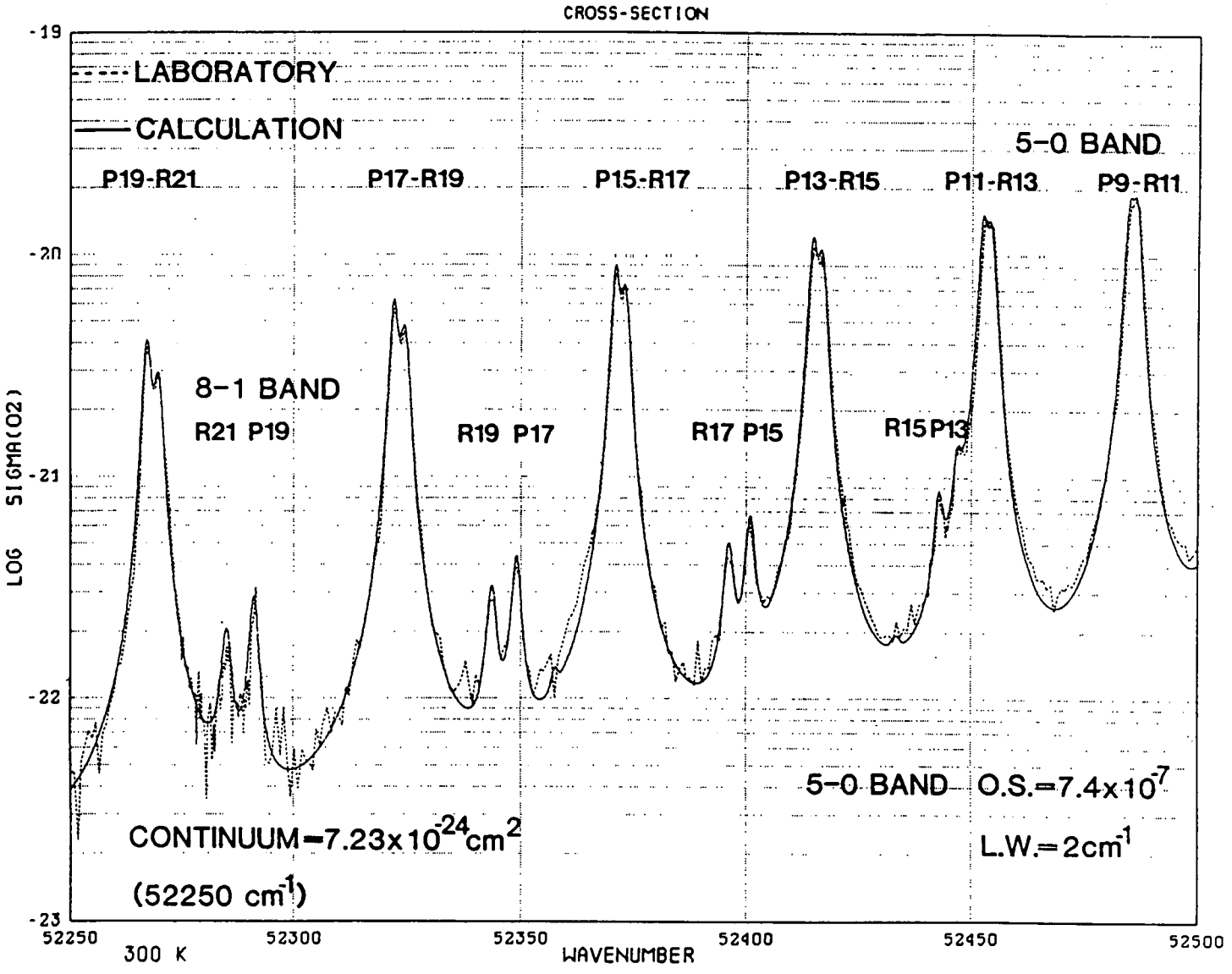

Fig.8a Experimental and theoretical absorption cross-sections at 300 K, between 52500 and 52250 cm^{-1}. 5-0 band and 8-1 band.

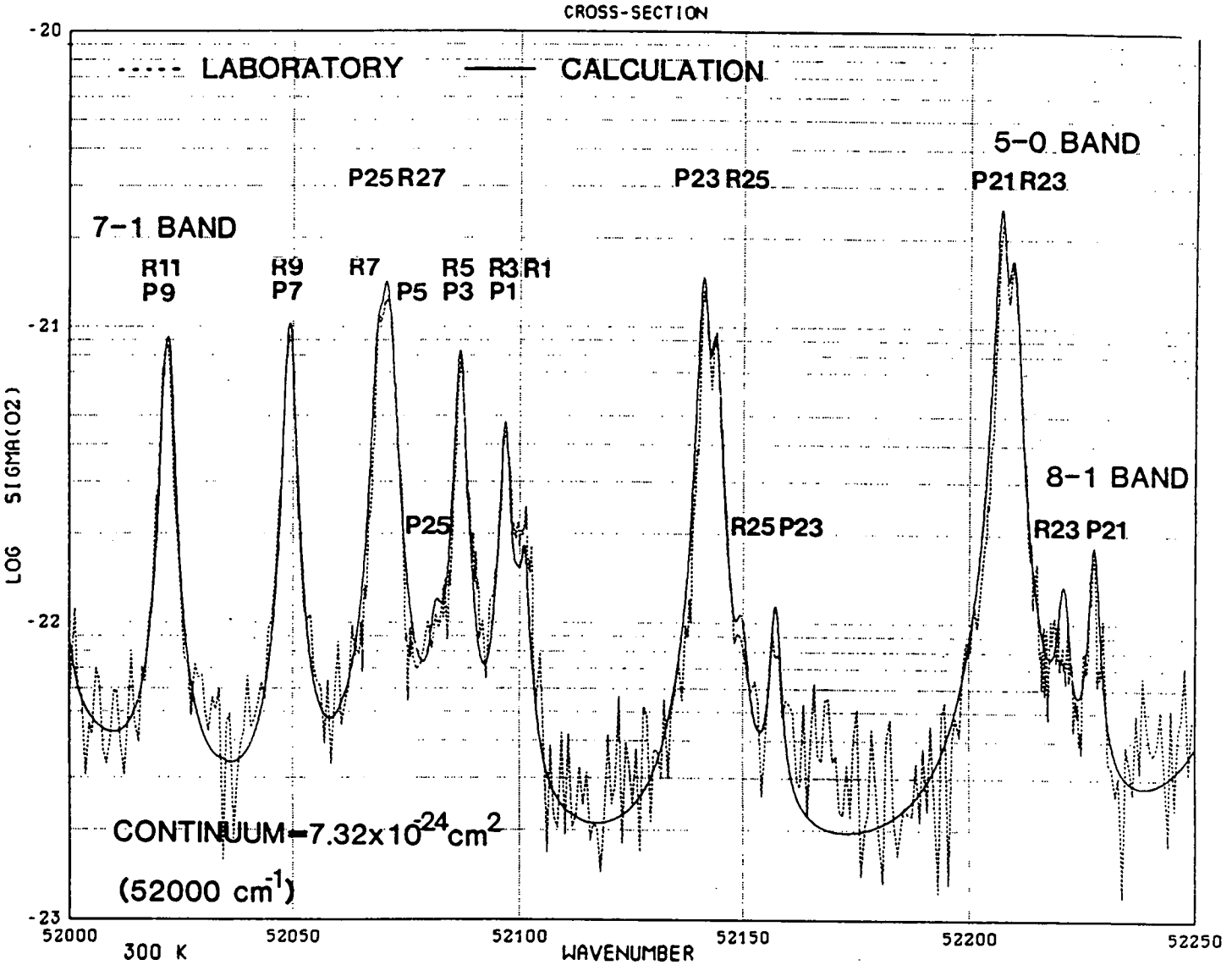

Fig.8b As in Fig. 8a, between 52250 and 52000 cm^{-1}. 5-0 band and 7-1 band.

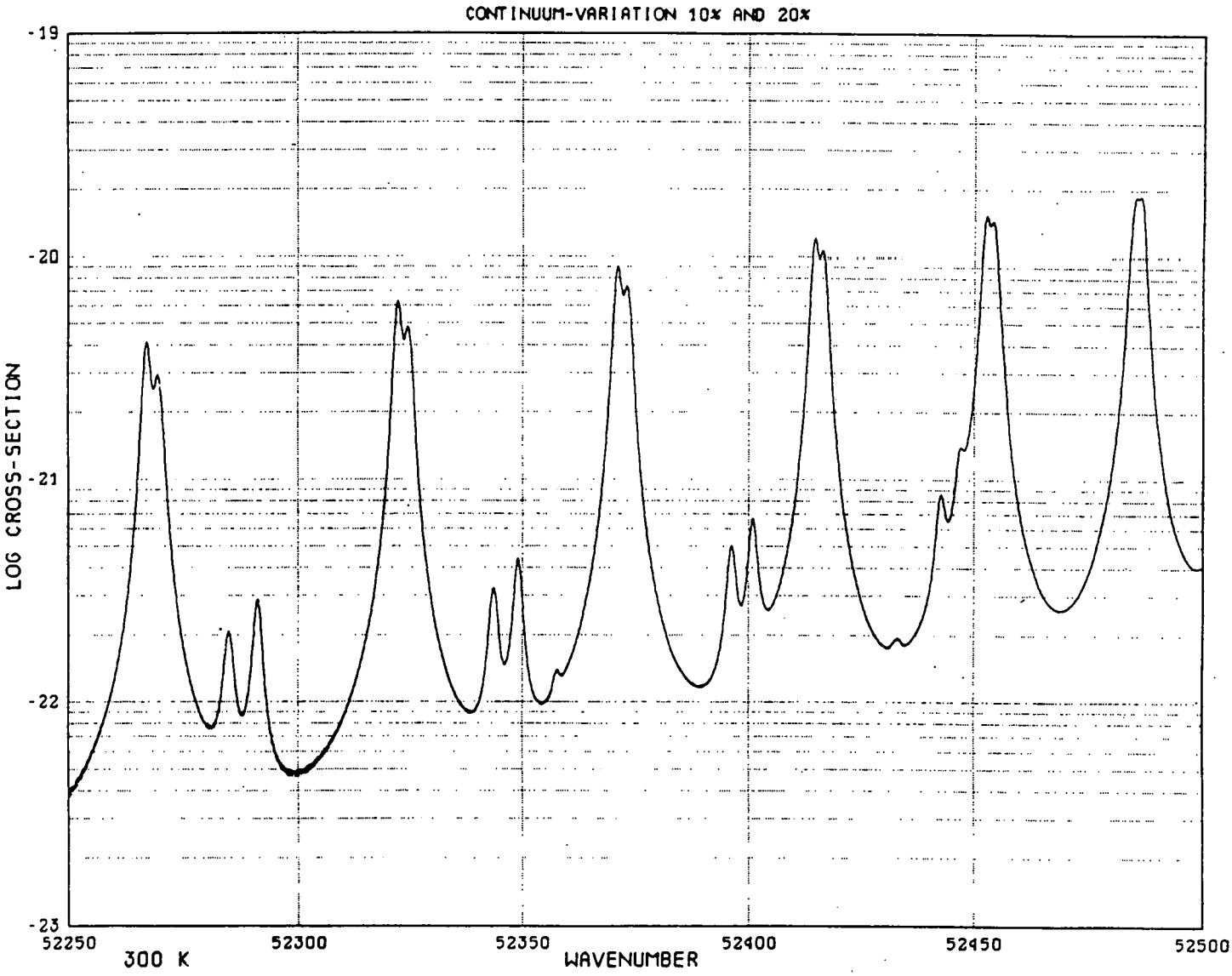

Fig.9a As in Fig. 8a, with variation of ± 10 and ± 20 % of the continuum absorption ; no effect.

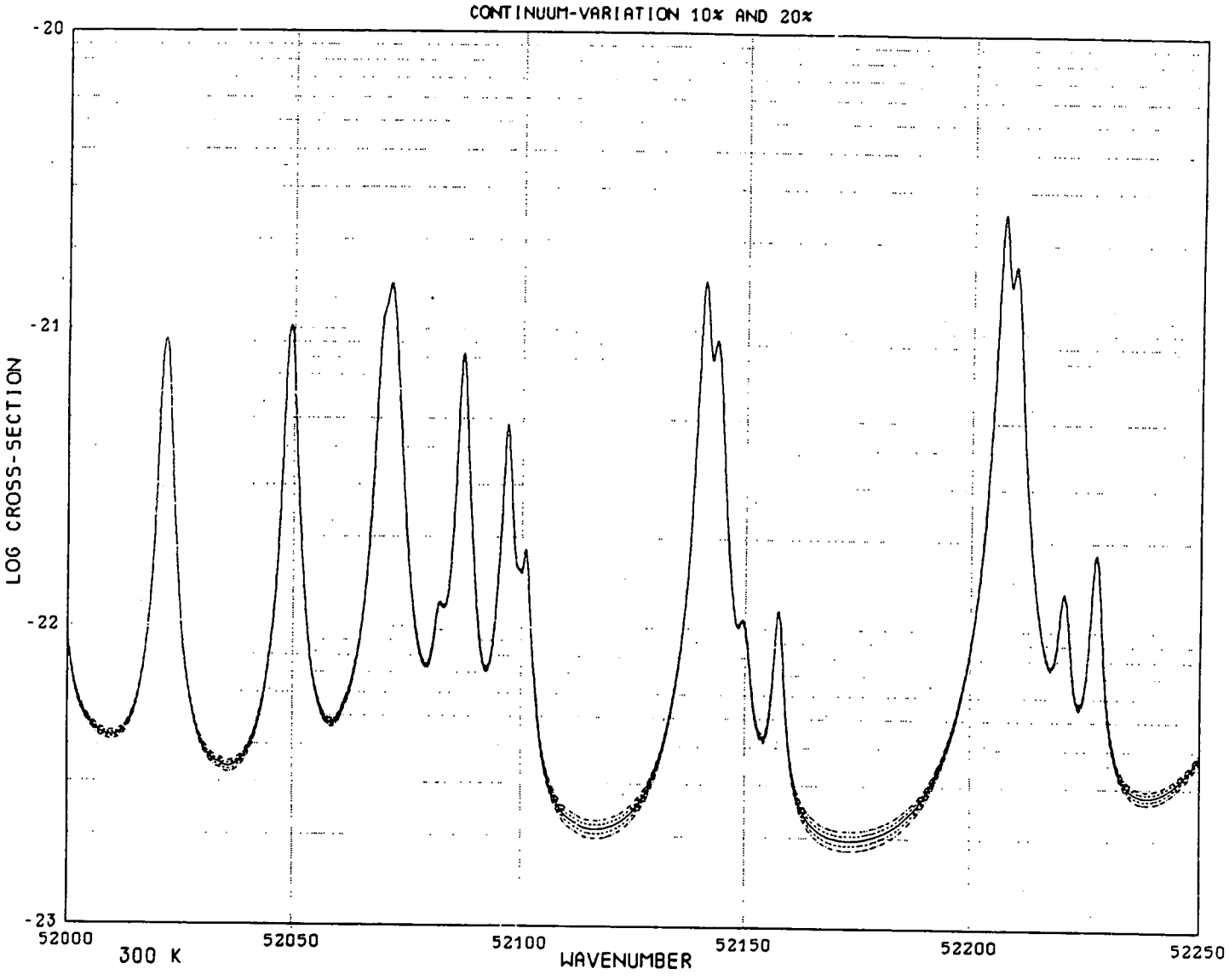

Fig.9b As in Fig. 8b and equivalent to Fig. 8a ; very small effect.

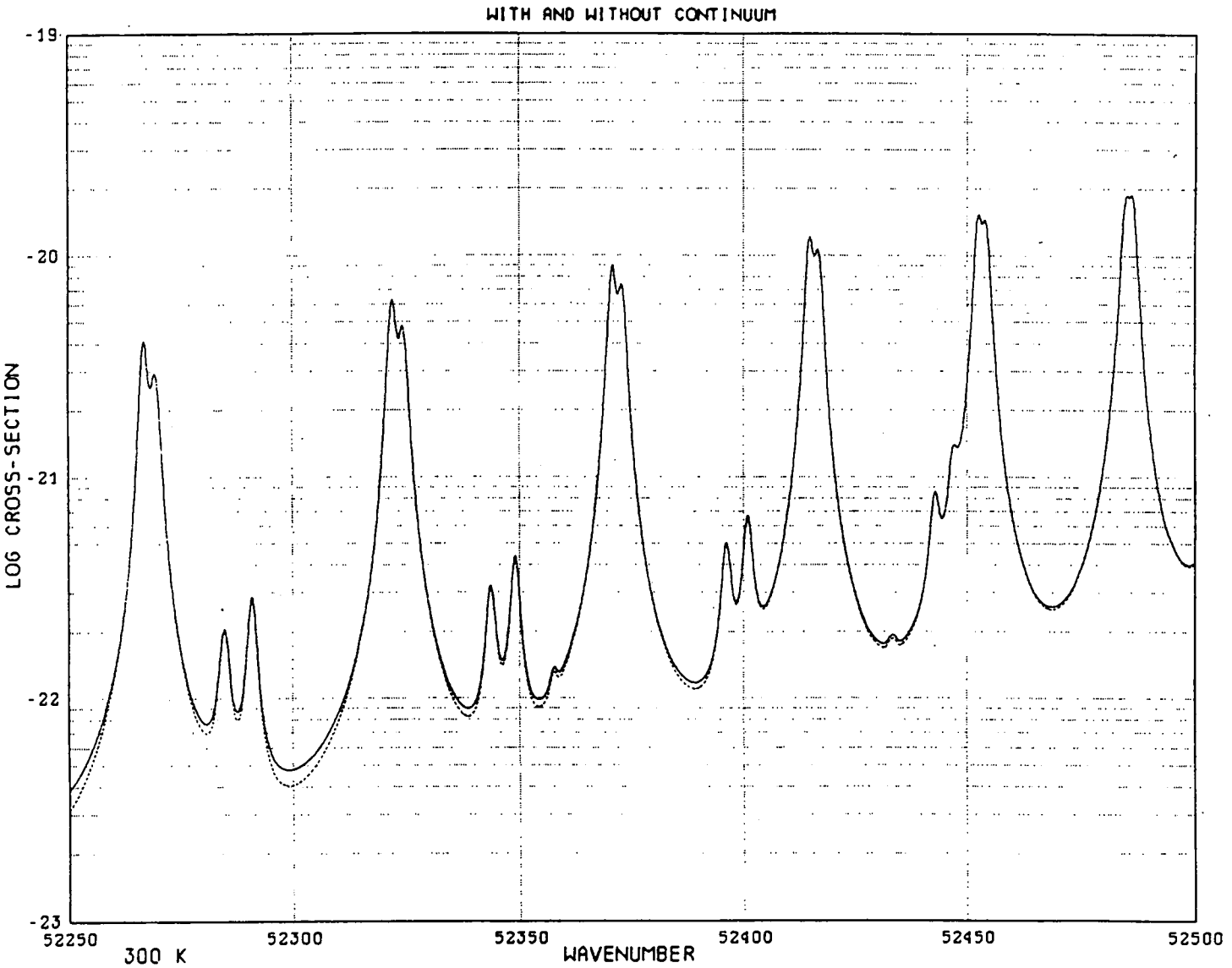

Fig.10a As in Fig. 8a, with and without continuum, negligible effect at 300 K.

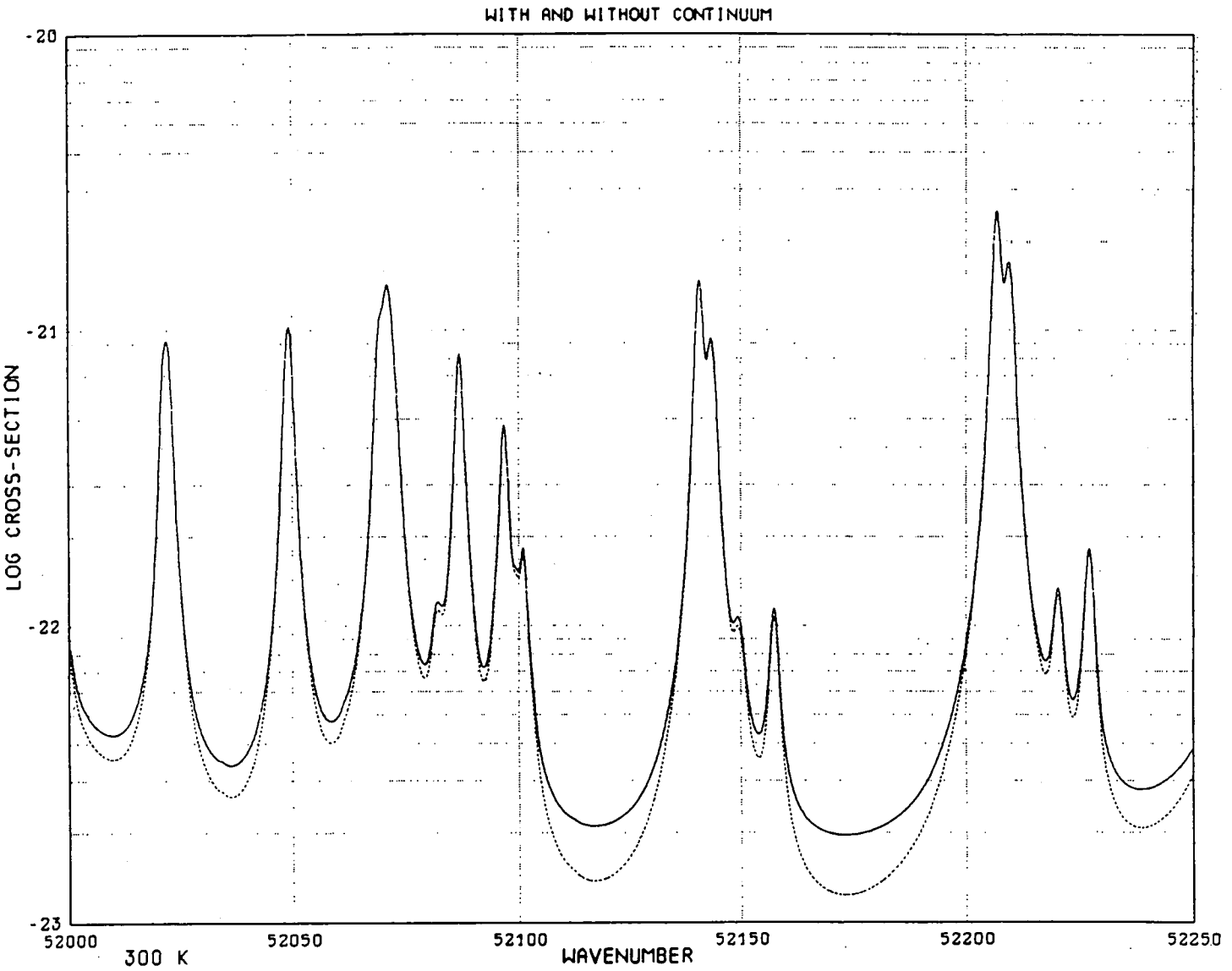

Fig.10b As in Fig. 10a; equivalent to Fig. 10a ; effect of underlyng continuum between certain rotational lines, even at 300 K.

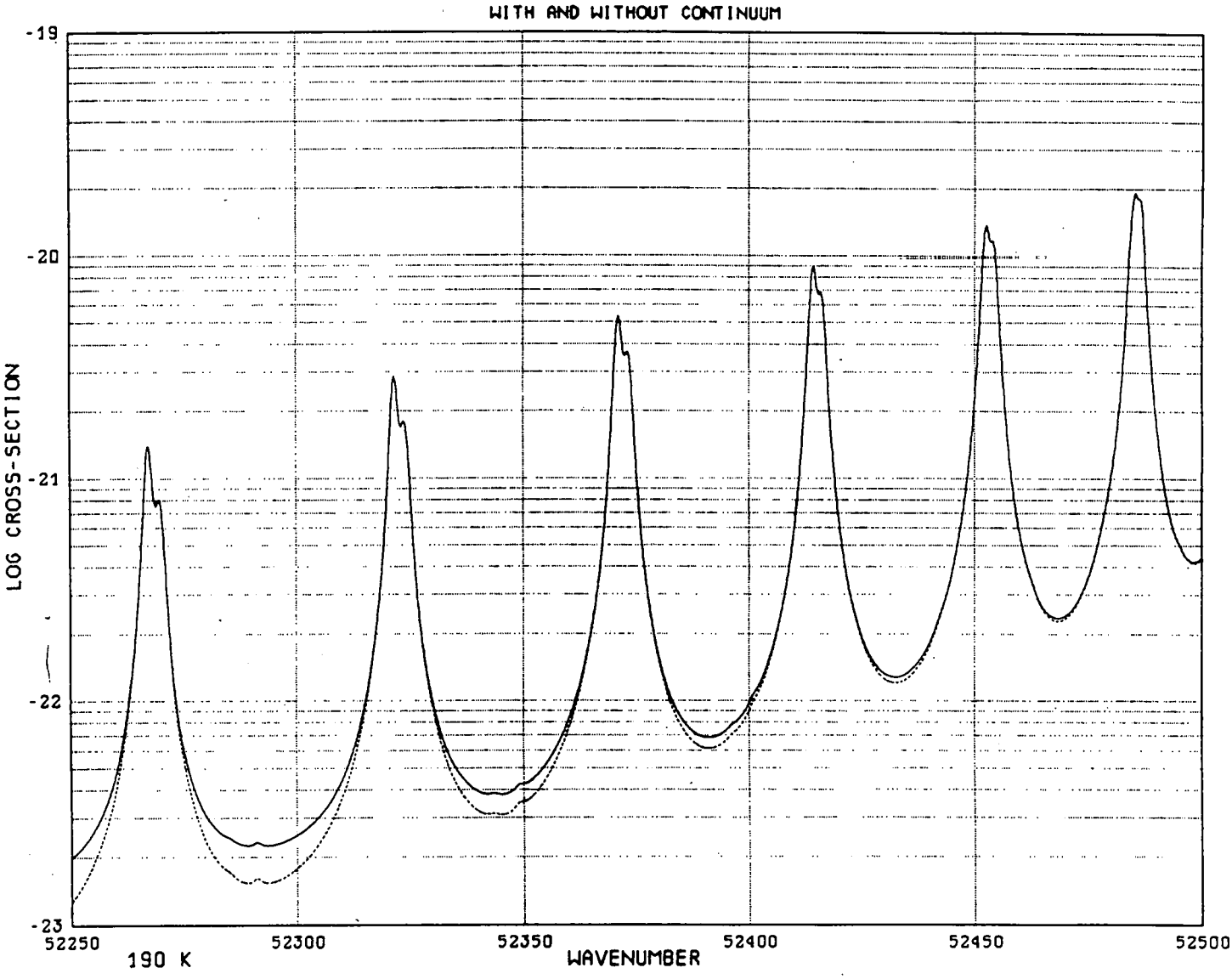

Fig.11a As in Fig.10a, at 190 K ; small effect of the underlying continuum.

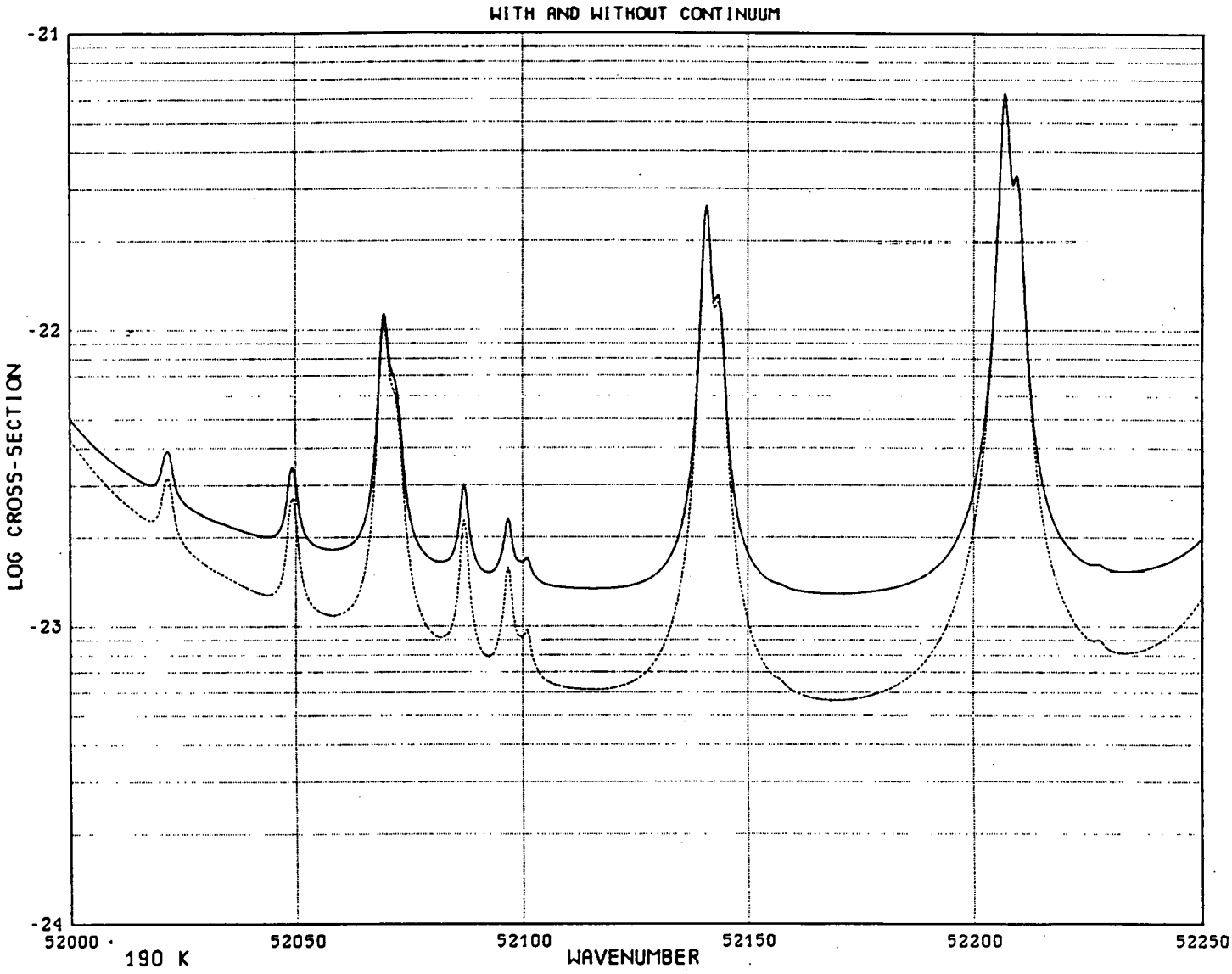

Fig.11b As in Fig. 10b, at 190 K, strong effect of the underlying continuum.

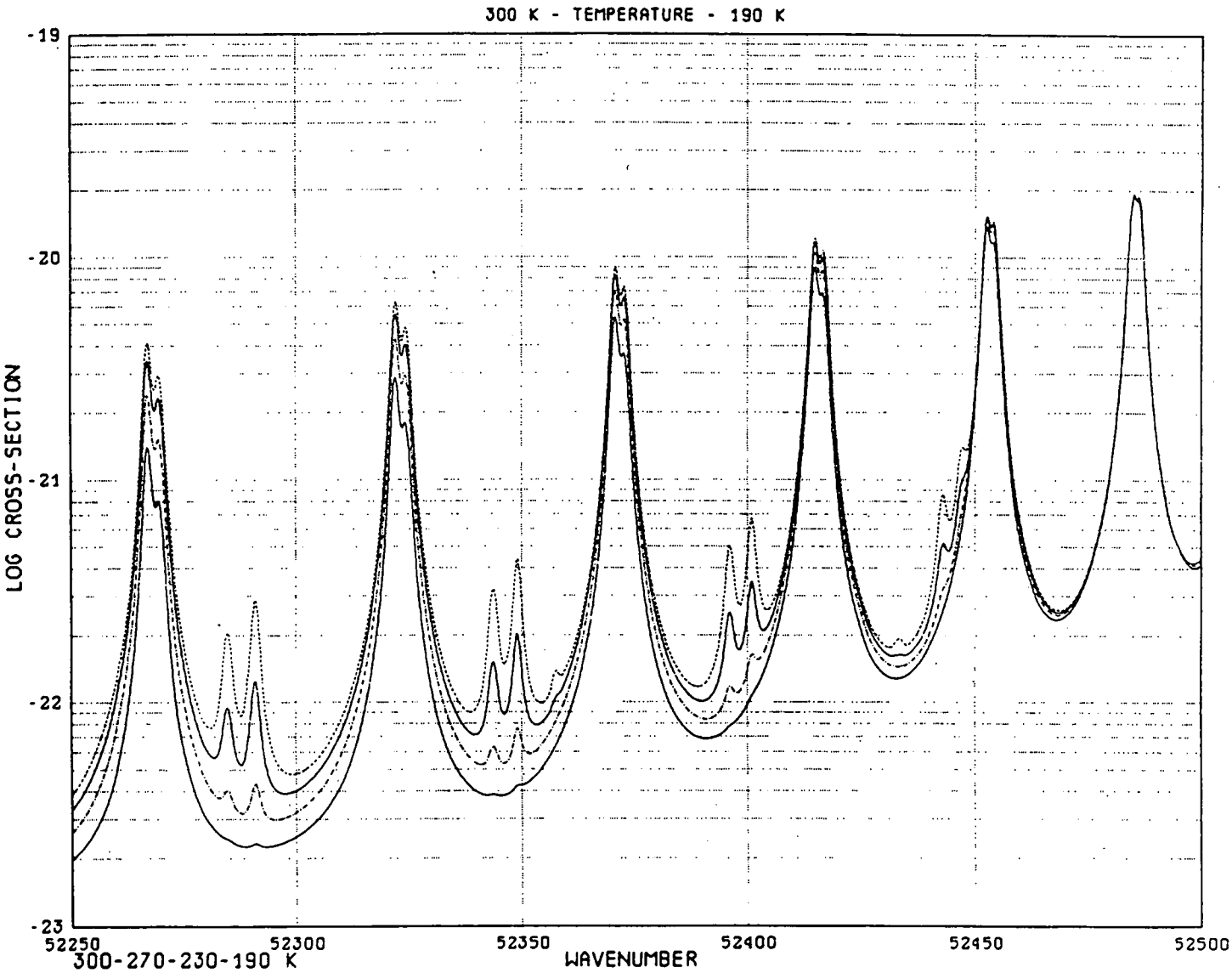

Fig.12a As in Fig. 8a ; variation of the absorption cross-sections for temperatures from 300 K to 190 K, between 52500 and 52250 cm^{-1}.

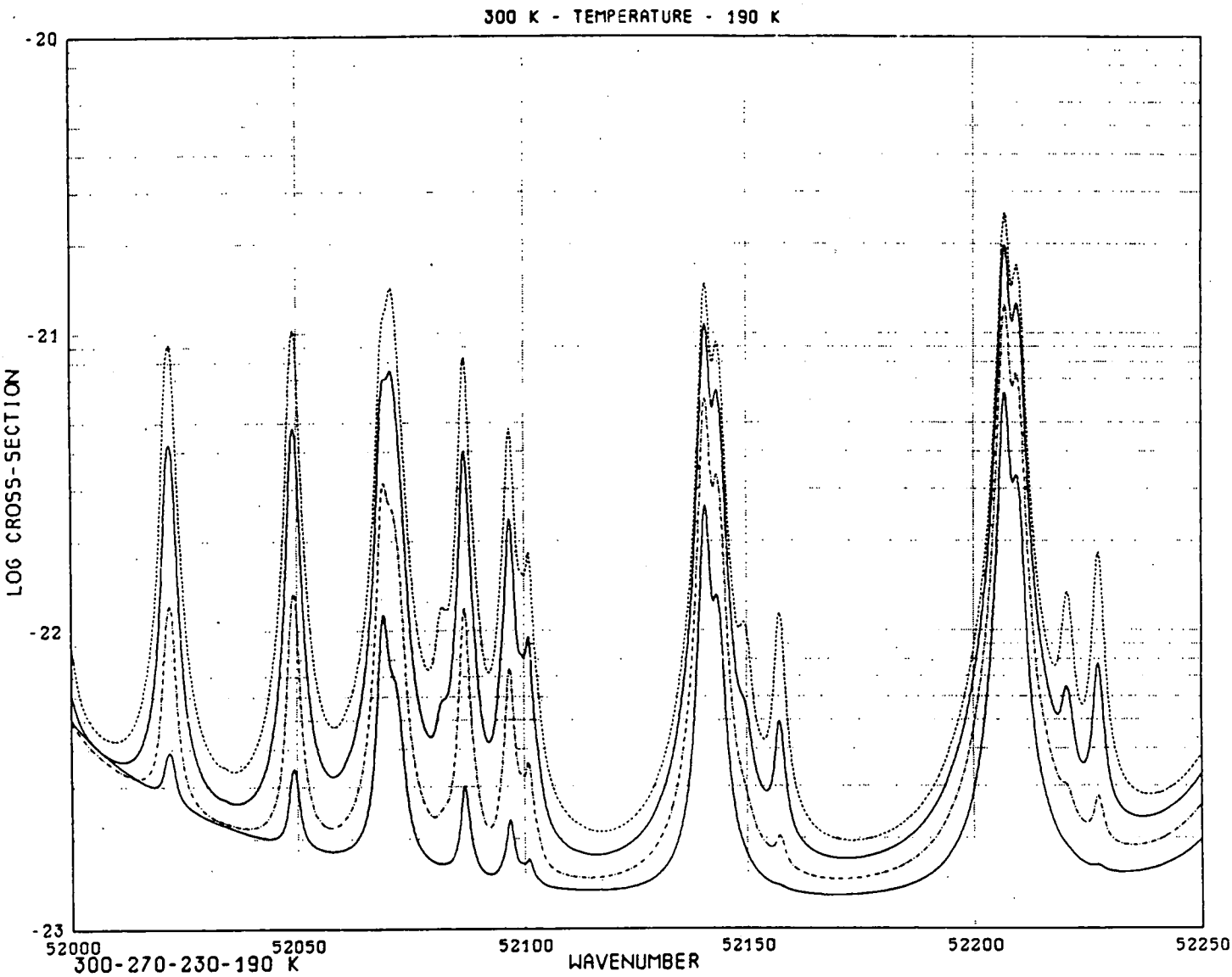

Fig.12b As in Fig. 12a ; between 52250 and 52000 cm^{-1}.

Nicolet et al., 1989 and this paper) it is possible to formulate a few conclusions on the production rate of oxygen atoms (Table 2).

Upon adoption of the solar irradiances deduced from Spacelab 2 observations (SUSIM), it can be said that the O_2 photodissociation frequency is of the order of 10^{-8} s^{-1} near the mesopause with a mean contribution effect from the Herzberg region ($\lambda > 202$ nm) of the order of only 5%. However, near 60-65 km where $N(O_2)$ reaches 2×10^{21} cm^{-2}, the ratio $J(O_2)_{HER}/ J(O_2)_{Total} > 50\%$. For the standard atmosphere the results are reproduced in Table 3.

4. *PARAMETERIZATION OF THE PHOTODISSOCIATION FREQUENCY AND OF THE TRANSMITTANCE IN THE SPECTRAL RANGE OF THE SCHUMANN-RUNGE BANDS*

Detailed calculations based on the Tchebychev approximation method were made to provide the possibility of determining the O_2 photodissociation frequency and the atmospheric transmittance by simple formulas. A final application was made with a formula of the following type :

$$\ln J/J_\infty \text{ (or } \ln \tau\text{) (or } \ln q/q_\alpha) =$$

$$a_0 + a_1 \sec \chi + a_2(\sec \chi)^2 + a_3(\sec \chi)^3$$

$$+ [b_0 + b_1 \sec \chi + b_2(\sec \chi)^2 + b_3(\sec \chi)^3]\ln N(O_2)$$

$$+ [c_0 + c_1 \sec \chi + c_2(\sec \chi)^2 + c_3(\sec \chi)^3]\ln N(O_2)^2$$

$$+ [d_0 + d_1 \sec \chi + d_2(\sec \chi)^2 + d_3(\sec \chi)^3]\ln N(O_2)^3$$

This practical formula was applied to the 500 cm^{-1} intervals from 57000 - 56500 cm^{-1} to 50000 - 49500 cm^{-1} that correspond to the 16-0 to 19-0 bands, and mainly to the 1-0 band, respectively.

The application was used to determine

(1) the photodissociation frequency : $J/J_\infty = e^{-\tau}$ by $\ln \tau_{PHO}$

Table 2 - Absorption cross-sections (cm^2) at zero optical depth for the O_2 Schumann-Runge band intervals (500 cm^{-1}) and for the Herzberg continuum, according to Nicolet and Kennes (1989a)

Wavenumber interval (cm^{-1})	Cross-section S-R-O_2 (cm^2)	Temperature range	Herzberg Continuum (cm^2)
49500-50000	$1.05 \pm 0.07 \times 10^{-23}$	$170 \leq T \leq 270$	7.4×10^{-24}
50000-50500	1.34 ± 0.15	$200 \leq T \leq 270$	7.5
50500-51000	4.22 ± 0.25	$170 \leq T \leq 270$	7.5
51000-51500	$1.55 \pm 0.05 \times 10^{-22}$	$170 \leq T \leq 270$	7.5
51500-52000	4.83 ± 0.07	$210 \leq T \leq 270$	7.4
52000-52500	6.33 ± 0.33	$210 \leq T \leq 270$	7.2
52500-53000	$1.34 \pm 0.07 \times 10^{-21}$	$210 \leq T \leq 270$	7.0
53000-53500	3.06 ± 0.15	$180 \leq T \leq 270$	6.7
53500-54000	7.04 ± 0.40	$180 \leq T \leq 270$	6.4
54000-54500	$1.34 \pm 0.07 \times 10^{-20}$	$180 \leq T \leq 270$	6.0
54500-55000	2.92 ± 0.10	$170 \leq T \leq 290$	5.6
55000-55500	4.63 ± 0.03	$180 \leq T \leq 270$	
55500-56000	6.24 ± 0.25	$180 \leq T \leq 250$	
56000-56500	$1.12 \pm 0.02 \times 10^{-19}$	$180 \leq T \leq 230$	
56500-57000	1.65 ± 0.01	$170 \leq T \leq 250$	

Table 3 - O_2 photodissociation frequency for a solar zenith angle of 60°

Altitude (km)	$N(O_2)$ (cm^{-2})	$J(O_2)$ (s^{-1})	% Herzberg
85	3.56×10^{19}	1.11×10^{-8}	5
80	9.28×10^{19}	5.54×10^{-9}	10
75	2.24×10^{20}	3.31	17
70	5.00×10^{20}	2.09	28
65	1.04×10^{21}	1.43	40
60	2.02×10^{21}	1.05	54
55	3.86×10^{21}	8.23×10^{-10}	65
50	7.22×10^{21}	6.50	74
45	1.35×10^{22}	4.42	80
40	2.58×10^{22}	2.26	80
35	5.18×10^{22}	5.87×10^{-11}	78
30	1.08×10^{23}	1.49	74
25	2.28×10^{23}	1.08×10^{-12}	70
20	4.96×10^{23}	1.57×10^{-14}	70
15	1.08×10^{24}	2.21×10^{-17}	76
10	2.36×10^{24}	1.67×10^{-22}	90

Nicolet et al., 1989 and this paper) it is possible to formulate a few conclusions on the production rate of oxygen atoms (Table 2).

Upon adoption of the solar irradiances deduced from Spacelab 2 observations (SUSIM), it can be said that the O_2 photodissociation frequency is of the order of 10^{-8} s^{-1} near the mesopause with a mean contribution effect from the Herzberg region ($\lambda > 202$ nm) of the order of only 5%. However, near 60-65 km where $N(O_2)$ reaches 2×10^{21} cm^{-2}, the ratio $J(O_2)_{HER}/ J(O_2)_{Total} > 50\%$. For the standard atmosphere the results are reproduced in Table 3.

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Detailed calculations based on the Tchebychev approximation method were made to provide the possibility of determining the O_2 photodissociation frequency and the atmospheric transmittance by simple formulas. A final application was made with a formula of the following type :

$$\ln J/J_\infty \text{ (or } \ln \tau\text{) (or } \ln q/q_\alpha) =$$

$$a_0 + a_1 \sec \chi + a_2(\sec \chi)^2 + a_3(\sec \chi)^3$$

$$+ [b_0 + b_1 \sec \chi + b_2(\sec \chi)^2 + b_3(\sec \chi)^3]\ln N(O_2)$$

$$+ [c_0 + c_1 \sec \chi + c_2(\sec \chi)^2 + c_3(\sec \chi)^3][\ln N(O_2)]^2$$

$$+ [d_0 + d_1 \sec \chi + d_2(\sec \chi)^2 + d_3(\sec \chi)^3][\ln N(O_2)]^3$$

This practical formula was applied to the 500 cm^{-1} intervals from 57000 - 56500 cm^{-1} to 50000 - 49500 cm^{-1} that correspond to the 16-0 to 19-0 bands, and mainly to the 1-0 band, respectively.

The application was used to determine

(1) the photodissociation frequency : $J/J_\infty = e^{-\tau}$ by $\ln \tau_{PHO}$

(2) the transmittance : $q/q_\infty = e^{-\tau_{SRB_{bc}}}$ by $\ln\tau_{SRB_{bc}}$ with continuum

(3) the transmittance : $q/q_\infty = e^{-\tau_{SRB_b}}$ by $\ln\tau_{SRB_b}$ without continuum.

Table I provides all the coefficients $a_o \ldots d_3$ for the 15 intervals of 500 cm^{-1} between 57000 and 49500 cm^{-1} for an equivalent optical depth with the reduction factor $J(N,\chi)/J_\infty$ that corresponds to the O_2 photodissociation frequency (s^{-1}) at zero optical depth from numerical data given in Table 2. For each 500 cm^{-1} interval, the various limits for the application of the formula are determined : the minimum altitude, the maximum number of the O_2 column ($N < x\ cm^{-2}$) the upper limit for the equivalent optical depth that corresponds to a reduction factor of at least 10^{-3}, and the maximum difference between the values obtained by direct calculation and by use of the parametric formula.

For the same spectral intervals, Table II also provides the coefficients $a_o \ldots d_3$ for the O_2 transmittance with their various limits for the application of the formula. Such values of transmittance given by $\tau_{SRB(b+c)}$ correspond to the combined absorption of the Schumann-Runge bands and their underlying continua. However, the optical depth without underlying continuum, $\ln \tau_{SRBb}$, has also been determined; the various parameters a_o to d_3 are given in Table III. Comparison between the numerical results deduced from Tables II and III opens the possibility of determining the relative effects of the Schumann-Runge bands and of the underlying continuum on the atmospheric transmittance of O_2.

Tables IVa and IVb make clear in two examples, for almost equivalent total numbers of oxygen molecules, $N(O_2)\ cm^{-2}$, the importance of the various terms adopted in the parameterization of the photodissociation frequency and of the transmittance in the various 500 cm^{-1} intervals from 57000 - 56500 cm^{-1} to 50000 - 49500 cm^{-1}. In table IVa the values obtained from detailed calculation and then from numerical application of the formula are compared for the transmission factors with their equivalent optical depths τ and $\ln \tau$ used for the parameterization. In Table IVb, all terms based on $a_o, \ldots$ to d_3 are given ($\pm$ %) for the

examples adopted in Table IVa, and differences occurring in the relative importance of the 16 terms are pointed out.

Thus, it is possible to determine the aeronomic parameters of the Schumann-Runge bands of O_2 with good accuracy.

ACKNOWLEDGEMENTS

Support for the preparation of this paper has been provided by the Chemical Manufacturers Association, Contract FC-86-621 with the Institut d'Aéronomie Spatiale de Belgique.

TABLE I.- Equivalent optical depth (τ_φ) for the reduction factor $J(N,\chi)/J_\infty$ corresponding to the O_2 photodissociation frequency (J) for 500 cm^{-1} intervals.

ln τ_φ

57000 - 56500 cm^{-1} ($z \geq 75$ km; $N \leq 2 \times 10^{20}$ cm^{-2}; $\tau_\varphi \leq 8$; Dif $\leq 5\%$)			
$a_0 = -2.599300 \times 10^3$	$b_0 = +1.741902 \times 10^2$	$c_0 = -3.897873$	$d_0 = +2.913743 \times 10^{-2}$
$a_1 = +2.655023 \times 10^3$	$b_1 = -1.802813 \times 10^2$	$c_1 = +4.077368$	$d_1 = -3.071576 \times 10^{-2}$
$a_2 = -1.266375 \times 10^3$	$b_2 = +8.569908 \times 10^1$	$c_2 = -1.931968$	$d_2 = +1.450898 \times 10^{-2}$
$a_3 = +1.773584 \times 10^2$	$b_3 = -1.197953 \times 10^1$	$c_3 = +2.695691 \times 10^{-1}$	$d_3 = -2.020902 \times 10^{-3}$
56500 - 56000 cm^{-1} ($z \geq 65$ km; $N \leq 7.5 \times 10^{20}$ cm^{-2}; $\tau_\varphi \leq 8$; Dif $\leq 5\%$)			
$a_0 = -9.514357 \times 10^2$	$b_0 = +6.235309 \times 10^1$	$c_0 = -1.366381$	$d_0 = +1.002556 \times 10^{-2}$
$a_1 = -1.135892 \times 10^2$	$b_1 = +6.548604$	$c_1 = -1.235963 \times 10^{-1}$	$d_1 = +7.593053 \times 10^{-4}$
$a_2 = -2.787569 \times 10^1$	$b_2 = +2.118148$	$c_2 = -5.249648 \times 10^{-2}$	$d_2 = +4.265425 \times 10^{-4}$
$a_3 = +1.274037 \times 10^1$	$b_3 = -8.705251 \times 10^{-1}$	$c_3 = +1.976787 \times 10^{-2}$	$d_3 = -1.492192 \times 10^{-4}$
56000 - 55500 cm^{-1} ($z \geq 60$ km; $N \leq 2.5 \times 10^{21}$ cm^{-2}; $\tau_\varphi \leq 9$; Dif $\leq 5\%$)			
$a_0 = -3.642895 \times 10^2$	$b_0 = +2.343907 \times 10^1$	$c_0 = -5.072168 \times 10^{-1}$	$d_0 = +3.704249 \times 10^{-3}$
$a_1 = -1.297202 \times 10^3$	$b_1 = +8.426122 \times 10^1$	$c_1 = -1.822141$	$d_1 = +1.311846 \times 10^{-2}$
$a_2 = +5.684750 \times 10^2$	$b_2 = -3.704713 \times 10^1$	$c_2 = +8.038520 \times 10^{-1}$	$d_2 = -5.807468 \times 10^{-3}$
$a_3 = -7.540241 \times 10^1$	$b_3 = +4.920337$	$c_3 = -1.069057 \times 10^{-1}$	$d_3 = +7.734156 \times 10^{-4}$

ln τ_φ (continued)

55500 - 55000 cm^{-1} ($z \geq 55$ km; $N \leq 2 \times 10^{21} cm^{-2}$; $\tau_\varphi \leq 8$; Dif ≤ 5 %)

$a_0 = -1.237226 \times 10^3$	$b_0 = +7.913107 \times 10^1$	$c_0 = -1.590634$	$d_0 = +1.207925 \times 10^{-2}$
$a_1 = +4.266927 \times 10^2$	$b_1 = -2.769459 \times 10^1$	$c_1 = +5.992954 \times 10^{-1}$	$d_1 = -4.323512 \times 10^{-3}$
$a_2 = -2.614080 \times 10^2$	$b_2 = +1.686899 \times 10^1$	$c_2 = -3.627784 \times 10^{-1}$	$d_2 = +2.599991 \times 10^{-3}$
$a_3 = +4.228534 \times 10^1$	$b_3 = -2.728290$	$c_3 = +5.865426 \times 10^{-2}$	$d_3 = -4.201589 \times 10^{-4}$

55000 - 54500 cm^{-1} ($z \geq 50$ km; $N \leq 5 \times 10^{21}$ cm^{-2}; $\tau_\varphi \leq 8$; Dif ≤ 5%)

$a_0 = -1.032701 \times 10^3$	$b_0 = +6.488547 \times 10^1$	$c_0 = -1.361884$	$d_0 = +9.562723 \times 10^{-3}$
$a_1 = +2.864989 \times 10^2$	$b_1 = -1.789081 \times 10^1$	$c_1 = +3.724736 \times 10^{-1}$	$d_1 = -2.585671 \times 10^{-3}$
$a_2 = -1.569776 \times 10^2$	$b_2 = +9.810541$	$c_2 = -2.043335 \times 10^{-1}$	$d_2 = +1.418441 \times 10^{-3}$
$a_3 = +2.462586 \times 10^1$	$b_3 = -1.544991$	$c_3 = +3.230393 \times 10^{-2}$	$d_3 = -2.251124 \times 10^{-4}$

54500 - 54000 cm^{-1} ($z \geq 50$ km; $N \leq 7.5 \times 10^{21}$ cm^{-2}; $\tau_\varphi \leq 7.5$; Dif ≤ 7.5 %)

$a_0 = -1.087474 \times 10^3$	$b_0 = +6.747286 \times 10^1$	$c_0 = -1.399023$	$d_0 = 9.706777 \times 10^{-3}$
$a_1 = +6.073534 \times 10^2$	$b_1 = -3.763451 \times 10^1$	$c_1 = +7.771822 \times 10^{-1}$	$d_1 = -5.349041 \times 10^{-3}$
$a_3 = -3.760877 \times 10^2$	$b_2 = +2.335690 \times 10^1$	$c_2 = -4.831703 \times 10^{-1}$	$d_2 = +3.329411 \times 10^{-3}$
$a_3 = +5.739547 \times 10^1$	$b_3 = -3.570293$	$c_3 = +7.396226 \times 10^{-2}$	$d_3 = -5.102941 \times 10^{-4}$

ln τ_φ (continued)

54000 - 53500 cm^{-1} ($z \geq 45$ km; $N \leq 7.5 \times 10^{21}$ cm^{-2}; $\tau_\varphi < 7$; Dif ≤ 7.5 %)

$a_0 = -1.632616 \times 10^3$	$b_0 = +1.019881 \times 10^2$	$c_0 = -2.127676$	$d_0 = +1.483371 \times 10^{-2}$
$a_1 = +5.931252 \times 10^2$	$b_1 = -3.719961 \times 10^1$	$c_1 = +7.780204 \times 10^{-1}$	$d_1 = -5.426164 \times 10^{-3}$
$a_2 = -2.310579 \times 10^2$	$b_2 = +1.440162 \times 10^1$	$c_2 = -2.992668 \times 10^{-1}$	$d_2 = +2.073311 \times 10^{-3}$
$a_3 = +2.457513 \times 10^1$	$b_3 = -1.525605$	$c_3 = +3.157678 \times 10^{-2}$	$d_3 = -2.179103 \times 10^{-4}$

53500 - 53000 cm^{-1} ($z \geq 35$ km; $N \leq 5 \times 10^{22}$ cm^{-2}; $\tau_\varphi \leq 8$; Dif ≤ 10 %)

$a_0 = +6.609790 \times 10^2$	$b_0 = -4.201220 \times 10^1$	$c_0 = +8.824878 \times 10^{-1}$	$d_0 = -6.120329 \times 10^{-3}$
$a_1 = -1.199910 \times 10^3$	$b_1 = +7.429151 \times 10^1$	$c_1 = -1.530417$	$d_1 = +1.049059 \times 10^{-2}$
$a_2 = +3.416500 \times 10^2$	$b_2 = -2.123104 \times 10^1$	$c_2 = +4.388857 \times 10^{-1}$	$d_2 = -3.018357 \times 10^{-3}$
$a_3 = -3.021659 \times 10^1$	$b_3 = +1.892274$	$c_3 = -3.939891 \times 10^{-2}$	$d_3 = +2.727834 \times 10^{-4}$

53000 - 52500 cm^{-1} ($z \geq 35$ km; $N \leq 5 \times 10^{22}$ cm^{-2}; $\tau_\varphi \leq 7$; Dif ≤ 10 %)

$a_0 = +3.572609 \times 10^2$	$b_0 = -2.330176 \times 10^1$	$c_0 = +4.984390 \times 10^{-1}$	$d_0 = -3.495637 \times 10^{-3}$
$a_1 = -9.750822 \times 10^2$	$b_1 = +6.005544 \times 10^1$	$c_1 = -1.230972$	$d_1 = +8.397393 \times 10^{-3}$
$a_2 = +3.073666 \times 10^2$	$b_2 = -1.890982 \times 10^1$	$c_2 = +3.872599 \times 10^{-1}$	$d_2 = -2.639991 \times 10^{-3}$
$a_3 = -3.277112 \times 10^1$	$b_3 = +2.014140$	$c_3 = -4.121550 \times 10^{-2}$	$d_3 = +2.807962 \times 10^{-4}$

ln τ_φ (continued)

52500 - 52000 cm^{-1} ($z \geq 25$ km; $N \leq 2 \times 10^{23}$ cm^{-2}; $\tau_\varphi \leq 9$; Dif ≤ 7.5 %)

$a_0 = -3.814297$	$b_0 = -8.248373 \times 10^{-1}$	$c_0 = +3.337598 \times 10^{-2}$	$d_0 = -2.981130 \times 10^{-4}$
$a_1 = -1.206385 \times 10^{2}$	$b_1 = +7.590959$	$c_1 = -1.597914 \times 10^{-1}$	$d_1 = +1.123481 \times 10^{-3}$
$a_2 = -4.376900$	$b_2 = +2.089978 \times 10^{-1}$	$c_2 = -2.572183 \times 10^{-3}$	$d_2 = +3.335859 \times 10^{-6}$
$a_3 = +1.246409$	$b_3 = -7.030542 \times 10^{-2}$	$c_3 = +1.246057 \times 10^{-3}$	$d_3 = -6.832791 \times 10^{-6}$

52000 - 51500 cm^{-1} ($z \geq 25$ km; $N \leq 2 \times 10^{23}$ cm^{-2}; $\tau_\varphi \leq 8$; Dif ≤ 7.5 %)

$a_0 = -1.430552 \times 10^{3}$	$b_0 = +8.192095 \times 10^{1}$	$c_0 = -1.566536$	$d_0 = +1.001490 \times 10^{-2}$
$a_1 = +7.436258 \times 10^{2}$	$b_1 = -4.333269 \times 10^{1}$	$c_1 = +8.409682 \times 10^{-1}$	$d_1 = -5.435765 \times 10^{-3}$
$a_2 = -1.525438 \times 10^{2}$	$b_2 = +8.933776$	$c_2 = -1.742635 \times 10^{-1}$	$d_2 = +1.132201 \times 10^{-3}$
$a_3 = 0$	$b_3 = 0$	$c_3 = 0$	$d_3 = 0$

51500 - 51000 cm^{-1} ($z \geq 20$ km; $N \leq 5 \times 10^{23}$ cm^{-2}; $\tau_\varphi \leq 9$; Dif ≤ 7.5 %)

$a_0 = -4.220338 \times 10^{2}$	$b_0 = +2.289616 \times 10^{1}$	$c_0 = -4.172389 \times 10^{-1}$	$d_0 = +2.566495 \times 10^{-3}$
$a_1 = -1.445513 \times 10^{3}$	$b_1 = +8.469511 \times 10^{1}$	$c_1 = -1.653274$	$d_1 = +1.075184 \times 10^{-2}$
$a_2 = +6.930887 \times 10^{2}$	$b_2 = -4.046925 \times 10^{1}$	$c_2 = +7.872386 \times 10^{-1}$	$d_2 = -5.101953 \times 10^{-3}$
$a_3 = -9.035258 \times 10^{1}$	$b_3 = +5.271651$	$c_3 = -1.024676 \times 10^{-1}$	$d_3 = +6.635387 \times 10^{-4}$

$\ln \tau_\varphi$ (continued)

51000 - 50500 cm^{-1} ($z \geq 15$ km; $N \leq 7.5 \times 10^{23}$ cm^{-2}; $\tau_\varphi \leq 9$; Dif ≤ 7.5 %)

$a_0 = -3.866259 \times 10^3$	$b_0 = +2.222383 \times 10^2$	$c_0 = -4.262894$	$d_0 = +2.729168 \times 10^{-2}$
$a_1 = +2.342889 \times 10^3$	$b_1 = -1.352420 \times 10^2$	$c_1 = +2.600128$	$d_1 = -1.664979 \times 10^{-2}$
$a_2 = -6.612285 \times 10^2$	$b_2 = +3.841536 \times 10^1$	$c_2 = -7.432431 \times 10^{-1}$	$d_2 = +4.788924 \times 10^{-3}$
$a_3 = +6.641651 \times 10^1$	$b_3 = -3.881261$	$c_3 = +7.552242 \times 10^{-2}$	$d_3 = -4.893218 \times 10^{-4}$

50500 - 50000 cm^{-1} ($z \geq 15$ km; $N \leq 7.5 \times 10^{23}$ cm^{-2}; $\tau_\varphi \leq 7$; Dif ≤ 5 %)

$a_0 = -1.190686 \times 10^3$	$b_0 = +6.825466 \times 10^1$	$c_0 = -1.315837$	$d_0 = +8.528854 \times 10^{-3}$
$a_1 = +3.342954 \times 10^2$	$b_1 = -1.895472 \times 10^1$	$c_1 = +3.578694 \times 10^{-1}$	$d_1 = -2.249793 \times 10^{-3}$
$a_2 = -8.070679 \times 10^2$	$b_2 = +4.523051 \times 10^1$	$c_2 = -8.447909 \times 10^{-1}$	$d_2 = +5.258491 \times 10^{-3}$
$a_3 = +1.912777 \times 10^2$	$b_3 = -1.072756 \times 10^1$	$c_3 = +2.005172 \times 10^{-1}$	$d_3 = -1.249155 \times 10^{-3}$

50000 - 49500 cm^{-1} ($z \geq 15$ km; $N \leq 7.5 \times 10^{23}$ cm^{-2}; $\tau_\varphi \leq 8$; Dif ≤ 5 %)

$a_0 = +4.777535 \times 10^2$	$b_0 = -2.477171 \times 10^1$	$c_0 = +4.100240 \times 10^{-1}$	$d_0 = -2.125721 \times 10^{-3}$
$a_1 = -4.739592 \times 10^3$	$b_1 = +2.639995 \times 10^2$	$c_1 = -4.899641$	$d_1 = +3.029842 \times 10^{-2}$
$a_2 = +2.535504 \times 10^3$	$b_2 = -1.418042 \times 10^2$	$c_2 = +2.642615$	$d_2 = -1.640950 \times 10^{-2}$
$a_3 = -3.613387 \times 10^2$	$b_3 = +2.024602 \times 10^1$	$c_3 = -3.779983 \times 10^{-1}$	$d_3 = +2.351591 \times 10^{-3}$

Table II Optical depth $\tau_{SRB(b+c)}$ corresponding to the transmittance of O_2 related to the absorption associated with the rotational lines of the Schumann-Runge bands and their underlying continuum

$$\ln \tau_{SRB(b+c)}$$

57000 - 56500 cm^{-1} ($z \geq 70$ km) ; $N \leq 3 \times 10^{20}$ cm^{-2} ; $\tau_{SRB} \leq 8$; Dif $\leq 5\%$)

$a_0 = -5.677451 \times 10^{1}$	$b_0 = +4.023481$	$c_0 = -1.082140 \times 10^{-1}$	$d_0 = +1.047532 \times 10^{-3}$
$a_1 = -1.542575 \times 10^{3}$	$b_1 = +1.000228 \times 10^{2}$	$c_1 = -2.158563$	$d_1 = +1.550289 \times 10^{-2}$
$a_2 = +9.107228 \times 10^{2}$	$b_2 = -5.955032 \times 10^{1}$	$c_2 = +1.296826$	$d_2 = -9.405240 \times 10^{-3}$
$a_3 = -1.448050 \times 10^{2}$	$b_3 = +9.504656$	$c_3 = -2.078151 \times 10^{-1}$	$d_3 = +1.513569 \times 10^{-3}$

56500 - 56000 cm^{-1} ($z \geq 60$ km ; $N \leq 2 \times 10^{21}$ cm^{-2} ; $\tau_{SRB} \leq 9$; Dif $\leq 5\%$)

$a_0 = -7.029478 \times 10^{2}$	$b_0 = +4.527896 \times 10^{1}$	$c_0 = -9.837196 \times 10^{-1}$	$d_0 = +7.213790 \times 10^{-3}$
$a_1 = +2.373070 \times 10^{2}$	$b_1 = -1.494671 \times 10^{1}$	$c_1 = +3.142520 \times 10^{-1}$	$d_1 = -2.207088 \times 10^{-3}$
$a_2 = -1.577500 \times 10^{2}$	$b_2 = +1.009023 \times 10^{1}$	$c_2 = -2.150946 \times 10^{-1}$	$d_2 = +1.528517 \times 10^{-3}$
$a_3 = +2.352943 \times 10^{1}$	$b_3 = -1.514461$	$c_3 = +3.247858 \times 10^{-2}$	$d_3 = -2.321164 \times 10^{-4}$

56000 - 55500 cm^{-1} ($z \geq 50$ km ; $N \leq 4 \times 10^{21}$ cm^{-2} ; $\tau_{SRB} \leq 9$; Dif $\leq 5\%$)

$a_0 = -5.256423 \times 10^{2}$	$b_0 = +3.327881 \times 10^{1}$	$c_0 = -7.145414 \times 10^{-1}$	$d_0 = +5.205542 \times 10^{-3}$
$a_1 = +7.691021 \times 10^{2}$	$b_1 = -4.850722 \times 10^{1}$	$c_1 = +1.018562$	$d_1 = -7.122706 \times 10^{-3}$
$a_2 = -4.376229 \times 10^{2}$	$b_2 = +2.775216 \times 10^{1}$	$c_2 = -5.858552 \times 10^{-1}$	$d_2 = +4.117691 \times 10^{-3}$
$a_3 = +6.324255 \times 10^{1}$	$b_3 = -4.011222$	$c_3 = +8.469823 \times 10^{-2}$	$d_3 = -5.954719 \times 10^{-4}$

$\ln \tau_{SRB(b+c)}$ (continued)

55500 - 55000 cm^{-1} ($z \geq 50$ km ; $N \leq 7.5 \times 10^{21}$ cm^{-2} ; $\tau_{SRB} \leq 8$; Dif $\leq 5\%$)

$a_0 = 1.513649 \times 10^{2}$	$b_0 = -1.136678 \times 10^{1}$	$c_0 = +2.656287 \times 10^{-1}$	$d_0 = -1.960843 \times 10^{-3}$
$a_1 = -4.451828 \times 10^{2}$	$b_1 = +2.943279 \times 10^{1}$	$c_1 = -6.468379 \times 10^{-1}$	$d_1 = +4.724945 \times 10^{-3}$
$a_2 = +1.563519 \times 10^{2}$	$b_2 = -1.019193 \times 10^{1}$	$c_2 = +2.214479 \times 10^{-1}$	$d_2 = -1.603107 \times 10^{-3}$
$a_3 = -2.016080 \times 10^{1}$	$b_3 = +1.299175$	$c_3 = -2.794919 \times 10^{-2}$	$d_3 = +2.006206 \times 10^{-4}$

55000 - 54500 cm^{-1} ($z \geq 45$ km ; $N \leq 1 \times 10^{22}$ cm^{-2} ; $\tau_{SRB} \leq 8$; Dif $\leq 2\%$)

$a_0 = +1.091262 \times 10^{2}$	$b_0 = -8.108570$	$c_0 = +1.847644 \times 10^{-1}$	$d_0 = -1.312435 \times 10^{-3}$
$a_1 = -3.676559 \times 10^{2}$	$b_1 = +2.420565 \times 10^{1}$	$c_1 = -5.292890 \times 10^{-1}$	$d_1 = +3.844314 \times 10^{-3}$
$a_2 = +6.483679 \times 10^{1}$	$b_2 = -4.438580$	$c_2 = +1.004077 \times 10^{-1}$	$d_2 = -7.513844 \times 10^{-4}$
$a_3 = -2.071426$	$b_3 = +1.736988 \times 10^{-1}$	$c_3 = -4.530374 \times 10^{-3}$	$d_3 = +3.769981 \times 10^{-5}$

54500 - 54000 cm^{-1} ($z \geq 40$ km ; $N \leq 2.5 \times 10^{22}$ cm^{-2} ; $\tau_{SRB} \leq 8$; Dif $\leq 3\%$)

$a_0 = +3.694147 \times 10^{2}$	$b_0 = -2.389680 \times 10^{1}$	$c_0 = +5.043392 \times 10^{-1}$	$d_0 = -3.474075 \times 10^{-3}$
$a_1 = -4.385371 \times 10^{2}$	$b_1 = +2.697252 \times 10^{1}$	$c_1 = -5.542959 \times 10^{-1}$	$d_1 = +3.804916 \times 10^{-3}$
$a_2 = +2.161684 \times 10^{2}$	$b_2 = -1.312210 \times 10^{1}$	$c_2 = +2.659376 \times 10^{-1}$	$d_2 = -1.799240 \times 10^{-3}$
$a_3 = -3.651598 \times 10^{1}$	$b_3 = +2.215929$	$c_3 = -4.486555 \times 10^{-2}$	$d_3 = +3.030657 \times 10^{-4}$

$\ln \tau_{SRB(b+c)}$ (continued)

54000 - 53500 cm^{-1} ($z \geq 35$ km ; $N \leq 2.5 \times 10^{22}$ cm^{-2} ; $\tau_{SRB} \leq 8$; Dif $\leq 5\%$)

$a_0 = +5.693931 \times 10^{2}$	$b_0 = -3.649096 \times 10^{1}$	$c_0 = +7.677198 \times 10^{-1}$	$d_0 = -5.305310 \times 10^{-3}$
$a_1 = -6.277182 \times 10^{2}$	$b_1 = +3.854031 \times 10^{1}$	$c_1 = -7.902587 \times 10^{-1}$	$d_1 = +5.410173 \times 10^{-3}$
$a_2 = +3.832032 \times 10^{2}$	$b_2 = -2.337004 \times 10^{1}$	$c_2 = +4.754281 \times 10^{-1}$	$d_2 = -3.225998 \times 10^{-3}$
$a_3 = -6.433339 \times 10^{1}$	$b_3 = +3.923910$	$c_3 = -7.979622 \times 10^{-2}$	$d_3 = +5.410026 \times 10^{-4}$

53500 - 53000 cm^{-1} ($z \geq 30$ km ; $N \leq 1 \times 10^{23}$ cm^{-2} ; $\tau_{SRB} \leq 8$; Dif $\leq 5\%$

$a_0 = -4.142061 \times 10^{2}$	$b_0 = +2.366384 \times 10^{1}$	$c_0 = -4.595400 \times 10^{-1}$	$d_0 = +3.041165 \times 10^{-3}$
$a_1 = -6.649624 \times 10^{2}$	$b_1 = +4.031858 \times 10^{1}$	$c_1 = -8.130492 \times 10^{-1}$	$d_1 = +5.454250 \times 10^{-3}$
$a_2 = +2.848387 \times 10^{2}$	$b_2 = -1.741799 \times 10^{1}$	$c_2 = +3.537976 \times 10^{-1}$	$d_2 = -2.388030 \times 10^{-3}$
$a_3 = -2.921080 \times 10^{1}$	$b_3 = +1.814843$	$c_3 = -3.737692 \times 10^{-2}$	$d_3 = +2.553641 \times 10^{-4}$

53000 - 52500 cm^{-1} ($z \geq 25$ km ; $N \leq 2.5 \times 10^{23}$ cm^{-2} ; $\tau_{SRB} \leq 8$; Dif $\leq 5\%$)

$a_0 = +1.733730 \times 10^{3}$	$b_0 = -9.922330 \times 10^{1}$	$c_0 = +1.883033$	$d_0 = -1.184142 \times 10^{-2}$
$a_1 = -3.916607 \times 10^{3}$	$b_1 = +2.251326 \times 10^{2}$	$c_1 = -4.312744$	$d_1 = +2.753334 \times 10^{-2}$
$a_2 = +1.488781 \times 10^{3}$	$b_2 = -8.545866 \times 10^{1}$	$c_2 = +1.634815$	$d_2 = -1.042243 \times 10^{-2}$
$a_3 = -1.690488 \times 10^{2}$	$b_3 = +9.678694$	$c_3 = -1.846797 \times 10^{-1}$	$d_3 = +1.174409 \times 10^{-3}$

$\ln \tau_{SRB(b+c)}$ (continued)

52500 - 52000 cm^{-1} ($z \geq 20$ km ; $N \leq 4 \times 10^{23}$ cm^{-2} ; $\tau_{SRB} \leq 9$; Dif $\leq 5\%$)

$a_0 = -2.240335 \times 10^{3}$	$b_0 = +1.308706 \times 10^{2}$	$c_0 = -2.556448$	$d_0 = +1.670035 \times 10^{-2}$
$a_1 = +1.594733 \times 10^{3}$	$b_1 = -9.461007 \times 10^{1}$	$c_1 = +1.867587$	$d_1 = -1.226721 \times 10^{-2}$
$a_2 = -7.612868 \times 10^{2}$	$b_2 = +4.503031 \times 10^{1}$	$c_2 = -8.864307 \times 10^{-1}$	$d_2 = +5.807601 \times 10^{-3}$
$a_3 = +1.168341 \times 10^{2}$	$b_3 = -6.900356$	$c_3 = +1.356423 \times 10^{-1}$	$d_3 = -8.875040 \times 10^{-4}$

52000 - 51500 cm^{-1} ($z \geq 20$ km ; $N \leq 5 \times 10^{23}$ cm^{-2} ; $\tau_{SRB} \leq 8$; Dif $\leq 2.5\%$)

$a_0 = -1.353959 \times 10^{3}$	$b_0 = +7.878909 \times 10^{1}$	$c_0 = -1.535936$	$d_0 = +1.003217 \times 10^{-2}$
$a_1 = +6.048852$	$b_1 = -1.121316$	$c_1 = +3.602221 \times 10^{-2}$	$d_1 = -3.205156 \times 10^{-4}$
$a_2 = -1.272266 \times 10^{2}$	$b_2 = +7.458374$	$c_2 = -1.456247 \times 10^{-1}$	$d_2 = +9.469016 \times 10^{-4}$
$a_3 = +3.067257 \times 10^{1}$	$b_3 = -1.769713$	$c_3 = +3.402297 \times 10^{-2}$	$d_3 = -2.179414 \times 10^{-4}$

51500 - 51000 cm^{-1} ($z \geq 15$ km ; $N \leq 7.5 \times 10^{23}$ cm^{-2} ; $\tau_{SRB} \leq 9$; Dif $\leq 2.5\%$)

$a_0 = -9.229843 \times 10^{2}$	$b_0 = +5.318720 \times 10^{1}$	$c_0 = -1.032775$	$d_0 = +6.755804 \times 10^{-3}$
$a_1 = +3.111203 \times 10^{1}$	$b_1 = -1.848330$	$c_1 = +3.705178 \times 10^{-2}$	$d_1 = -2.495782 \times 10^{-4}$
$a_2 = -4.503448 \times 10^{1}$	$b_2 = +2.419667$	$c_2 = -4.348491 \times 10^{-2}$	$d_2 = +2.614217 \times 10^{-4}$
$a_3 = +9.410113$	$b_3 = -5.038890 \times 10^{-1}$	$c_3 = +9.004122 \times 10^{-3}$	$d_3 = -5.369612 \times 10^{-5}$

$\ln \tau_{SBR(b+c)}$ (continued)

51000 - 50500 cm^{-1} ($z \geq 15$ km ; $N \leq 7.5 \times 10^{23}$ cm^{-2} ; $\tau_{SRB} \leq 9$; Dif $\leq 2.5\%$)

$a_0 = -7.142870 \times 10^{2}$	$b_0 = +4.050765 \times 10^{1}$	$c_0 = -7.802260 \times 10^{-1}$	$d_0 = +5.099838 \times 10^{-3}$
$a_1 = +1.339472 \times 10^{2}$	$b_1 = -8.005738$	$c_1 = +1.592838 \times 10^{-1}$	$d_1 = -1.054600 \times 10^{-3}$
$a_2 = -1.922391 \times 10^{2}$	$b_2 = +1.103898 \times 10^{1}$	$c_2 = -2.112382 \times 10^{-1}$	$d_2 = +1.346930 \times 10^{-3}$
$a_3 = +3.903214 \times 10^{1}$	$b_3 = -2.237085$	$c_3 = +4.271748 \times 10^{-2}$	$d_3 = -2.717605 \times 10^{-4}$

50500 - 50000 cm^{-1} ($z \geq 15$ km ; $N \leq 1 \times 10^{24}$ cm^{-2} ; $\tau_{SRB} \leq 9$; Dif $\leq 2.5\%$)

$a_0 = -1.354127 \times 10^{3}$	$b_0 = +7.552211 \times 10^{1}$	$c_0 = -1.420512$	$d_0 = +9.011688 \times 10^{-3}$
$a_1 = +1.418853 \times 10^{3}$	$b_1 = -8.011893 \times 10^{1}$	$c_1 = +1.508299$	$d_1 = -9.466235 \times 10^{-3}$
$a_2 = -6.556115 \times 10^{2}$	$b_2 = +3.693544 \times 10^{1}$	$c_2 = -6.936703 \times 10^{-1}$	$d_2 = +4.342776 \times 10^{-3}$
$a_3 = +8.473063 \times 10^{1}$	$b_3 = -4.771368$	$c_3 = +8.956634 \times 10^{-2}$	$d_3 = -5.604537 \times 10^{-4}$

50000 - 49500 cm^{-1} ($z \geq 15$ km ; $N \leq 1 \times 10^{24}$ cm^{-2} ; $\tau_{SRB} \leq 9$; Dif $\leq 0.5\%$)

$a_0 = -3.885481 \times 10^{2}$	$b_0 = +2.116285 \times 10^{1}$	$c_0 = -4.009890 \times 10^{-1}$	$d_0 = +2.641052 \times 10^{-3}$
$a_1 = +2.194520 \times 10^{2}$	$b_1 = -1.328896 \times 10^{1}$	$c_1 = +2.567435 \times 10^{-1}$	$d_1 = -1.775971 \times 10^{-3}$
$a_2 = -8.320608 \times 10^{1}$	$b_2 = +5.052619$	$c_2 = -1.016341 \times 10^{-1}$	$d_2 = +6.777717 \times 10^{-4}$
$a_3 = +7.197340$	$b_3 = -4.532467 \times 10^{-1}$	$c_3 = +9.394015 \times 10^{-3}$	$d_3 = -6.423345 \times 10^{-5}$

TABLE III.- Optical depth τ_{SRBb} corresponding to the transmittance of O_2 related to the absorption associated with the rotation lines of the Schumann-Runge bands but without the underlying continuum.

$\ln \tau_{SRBb}$

57000 - 56500 cm^{-1} ($z \geq 65$ km; $N \leq 7.5 \times 10^{20}$ cm^{-2}; $\tau \leq 8$; dif $\leq 2\%$)			
$a_0 = -4.765373 \times 10^{2}$	$b_0 = +3.007256 \times 10^{1}$	$c_0 = -6.415873 \times 10^{-1}$	$d_0 = +4.639339 \times 10^{-3}$
$a_1 = -2.185491 \times 10^{2}$	$b_1 = +1.447762 \times 10^{1}$	$c_1 = -3.195355 \times 10^{-1}$	$d_1 = +2.349749 \times 10^{-3}$
$a_2 = +7.725891 \times 10^{1}$	$b_2 = -5.108804$	$c_2 = +1.125623 \times 10^{-1}$	$d_2 = -8.263548 \times 10^{-4}$
$a_3 = -9.585645$	$b_3 = +6.329458 \times 10^{-1}$	$c_3 = -1.392559 \times 10^{-2}$	$d_3 = +1.020838 \times 10^{-4}$
56500 - 56000 cm^{-1} ($z \geq 55$ km; $N \leq 2.5 \times 10^{21}$ cm^{-2}; $\tau \leq 9$; dif $\leq 1.5\%$)			
$a_0 = -1.480071 \times 10^{2}$	$b_0 = +8.366320$	$c_0 = -1.650802 \times 10^{-1}$	$d_0 = +1.159537 \times 10^{-3}$
$a_1 = -3.228105 \times 10^{2}$	$b_1 = +2.172804 \times 10^{1}$	$c_1 = -4.856765 \times 10^{-1}$	$d_1 = +3.605628 \times 10^{-3}$
$a_2 = +8.196895 \times 10^{1}$	$b_2 = -5.585825$	$c_2 = +1.262790 \times 10^{-1}$	$d_2 = -9.473543 \times 10^{-4}$
$a_3 = -9.148820$	$b_3 = +6.227918 \times 10^{-1}$	$c_3 = -1.406539 \times 10^{-2}$	$d_3 = +1.054236 \times 10^{-4}$
56000 - 55500 cm^{-1} ($z \geq 50$ km; $N \leq 5 \times 10^{21}$ cm^{-2}; $\tau \leq 9$; dif $\leq 4\%$)			
$a_0 = -1.177132 \times 10^{3}$	$b_0 = +7.472188 \times 10^{1}$	$c_0 = -1.591780$	$d_0 = +1.138306 \times 10^{-2}$
$a_1 = +1.540400 \times 10^{3}$	$b_1 = -9.818995 \times 10^{1}$	$c_1 = +2.084493$	$d_1 = -1.473895 \times 10^{-2}$
$a_2 = -6.903485 \times 10^{2}$	$b_2 = +4.416978 \times 10^{1}$	$c_2 = -9.411011 \times 10^{-1}$	$d_2 = +6.677640 \times 10^{-3}$
$a_3 = +8.694671 \times 10^{1}$	$b_3 = -5.573158$	$c_3 = +1.189621 \times 10^{-1}$	$d_3 = -8.456493 \times 10^{-4}$

$\ln \tau_{SRBb}$ (continued)

55500 - 55000 cm^{-1} ($z \geq 45$ km; $N \leq 7.5 \times 10^{21}$ cm^{-2}; $\tau \leq 8$; dif. $\leq 5\%$)

$a_0 = +2.643531 \times 10^{2}$	$b_0 = -1.660525 \times 10^{1}$	$c_0 = +3.390146 \times 10^{-1}$	$d_0 = -2.237537 \times 10^{-3}$
$a_1 = -3.390744 \times 10^{2}$	$b_1 = +2.038277 \times 10^{1}$	$c_1 = -4.106919 \times 10^{-1}$	$d_1 = +2.773228 \times 10^{-3}$
$a_2 = +3.588229 \times 10^{1}$	$b_2 = -1.763041$	$c_2 = +2.814642 \times 10^{-2}$	$d_2 = -1.448584 \times 10^{-4}$
$a_3 = +2.267497$	$b_3 = -2.049257 \times 10^{-1}$	$c_3 = +5.399946 \times 10^{-3}$	$d_3 = -4.415489 \times 10^{-5}$

55000 - 54500 cm^{-1} ($z \geq 45$ km; $N \leq 1 \times 10^{22}$ cm^{-2}; $\tau \leq 8$; dif. $\leq 2\%$)

$a_0 = +1.811937 \times 10^{2}$	$b_0 = -1.261006 \times 10^{1}$	$c_0 = +2.784380 \times 10^{-1}$	$d_0 = -1.961896 \times 10^{-3}$
$a_1 = -4.922739 \times 10^{2}$	$b_1 = +3.196948 \times 10^{1}$	$c_1 = -6.303920 \times 10^{-1}$	$d_1 = +4.957777 \times 10^{-3}$
$a_2 = +1.330347 \times 10^{2}$	$b_2 = -8.685634$	$c_2 = +1.385009 \times 10^{-1}$	$d_2 = -1.360005 \times 10^{-3}$
$a_3 = -1.379337 \times 10^{1}$	$b_3 = +9.035590 \times 10^{-1}$	$c_3 = -1.966656 \times 10^{-2}$	$d_3 = +1.422542 \times 10^{-4}$

54500 - 54000 cm^{-1} ($z \geq 35$ km; $N \leq 2.5 \times 10^{22}$ cm^{-2}; $\tau \leq 8$; dif. $\leq 4\%$)

$a_0 = -6.757764 \times 10^{2}$	$b_0 = +4.128405 \times 10^{1}$	$c_0 = -8.483824 \times 10^{-1}$	$d_0 = +5.869175 \times 10^{-3}$
$a_1 = +8.699923 \times 10^{2}$	$b_1 = -5.462827 \times 10^{1}$	$c_1 = +1.139265$	$d_1 = -7.893820 \times 10^{-3}$
$a_2 = -3.774244 \times 10^{2}$	$b_2 = +2.380272 \times 10^{1}$	$c_2 = -4.986839 \times 10^{-1}$	$d_2 = +3.471818 \times 10^{-3}$
$a_3 = +5.024470 \times 10^{1}$	$b_3 = -3.166560$	$c_3 = +6.631875 \times 10^{-2}$	$d_3 = -4.616835 \times 10^{-4}$

$\ln \tau_{SRBb}$ (continued)

54000 - 53500 cm^{-1} ($z \geq 35$ km; $N \leq 2.5 \times 10^{22}$ cm^{-2}; $\tau \leq 7$; dif $\leq 4\%$)

$a_0 = +\ 4.893557 \times 10^{2}$	$b_0 = -\ 3.032855 \times 10^{1}$	$c_0 = +\ 6.173270 \times 10^{-1}$	$d_0 = -\ 4.122500 \times 10^{-3}$
$a_1 = -\ 3.938809 \times 10^{2}$	$b_1 = +\ 2.172470 \times 10^{1}$	$c_1 = -\ 3.981428 \times 10^{-1}$	$d_1 = +\ 2.423969 \times 10^{-3}$
$a_2 = +\ 2.691657 \times 10^{2}$	$b_2 = -\ 1.514039 \times 10^{1}$	$c_2 = +\ 2.830358 \times 10^{-1}$	$d_2 = -\ 1.757998 \times 10^{-3}$
$a_3 = -\ 4.838315 \times 10^{1}$	$b_3 = +\ 2.769397$	$c_3 = -\ 5.274846 \times 10^{-2}$	$d_3 = +\ 3.342914 \times 10^{-4}$

53500 - 53000 cm^{-1} ($z \geq 25$ km; $N \leq 2 \times 10^{23}$ cm^{-2}; $\tau \leq 9$; dif. $\leq 5\%$)

$a_0 = -\ 2.585329 \times 10^{2}$	$b_0 = +\ 1.410357 \times 10^{1}$	$c_0 = -\ 2.638341 \times 10^{-1}$	$d_0 = +\ 1.705537 \times 10^{-3}$
$a_1 = -\ 8.865887 \times 10^{2}$	$b_1 = +\ 5.377095 \times 10^{1}$	$c_1 = -\ 1.084966$	$d_1 = +\ 7.284720 \times 10^{-3}$
$a_2 = +\ 3.872125 \times 10^{2}$	$b_2 = -\ 2.363421 \times 10^{1}$	$c_2 = +\ 4.794904 \times 10^{-1}$	$d_2 = -\ 3.234420 \times 10^{-3}$
$a_3 = -\ 4.323445 \times 10^{1}$	$b_3 = +\ 2.666883$	$c_3 = -\ 5.461523 \times 10^{-2}$	$d_3 = +\ 3.715083 \times 10^{-4}$

53000 - 52500 cm^{-1} ($z \geq 20$ km; $N \leq 2.5 \times 10^{23}$ cm^{-2}; $\tau \leq 7$; dif. $\leq 5\%$)

$a_0 = -\ 3.662143 \times 10^{3}$	$b_0 = +\ 2.131356 \times 10^{2}$	$c_0 = -\ 4.141335$	$d_0 = +\ 2.686850 \times 10^{-2}$
$a_1 = +\ 3.641633 \times 10^{3}$	$b_1 = -\ 2.114422 \times 10^{2}$	$c_1 = +\ 4.090896$	$d_1 = -\ 2.637339 \times 10^{-2}$
$a_2 = -\ 1.676820 \times 10^{3}$	$b_2 = +\ 9.679716 \times 10^{1}$	$c_2 = -\ 1.862317$	$d_2 = +\ 1.194129 \times 10^{-2}$
$a_3 = +\ 2.333455 \times 10^{2}$	$n_3 = -\ 1.342686 \times 10^{1}$	$c_3 = +\ 2.575082 \times 10^{-1}$	$d_3 = -\ 1.646051 \times 10^{-3}$

$\ln \tau_{SRBb}$ (continued)

52500 - 52000 cm^{-1} ($z \geq 15$ km; $N \leq 8 \times 10^{23}$ cm^{-2}; $\tau \leq 9$; dif. $\leq 3\%$)

$a_0 = -1.225175 \times 10^{3}$	$b_0 = +7.143814 \times 10^{1}$	$c_0 = -1.395783$	$d_0 = +9.138289 \times 10^{-3}$
$a_1 = +9.160648 \times 10^{1}$	$b_1 = -7.169679$	$c_1 = +1.730722 \times 10^{-1}$	$d_1 = -1.327475 \times 10^{-3}$
$a_2 = -2.343339 \times 10^{1}$	$b_2 = +1.913029$	$c_2 = -4.731600 \times 10^{-2}$	$d_2 = +3.688818 \times 10^{-4}$
$a_3 = -2.650032$	$b_3 = +9.126765 \times 10^{-2}$	$c_3 = -5.956445 \times 10^{-4}$	$d_3 = -3.430417 \times 10^{-6}$

52000 - 51500 cm^{-1} ($z \geq 10$ km; $N \leq 2 \times 10^{24}$ cm^{-2}; $\tau \leq 8$; dif. $\leq 5\%$)

$a_0 = -1.613720 \times 10^{3}$	$b_0 = +9.330159 \times 10^{1}$	$c_0 = -1.802718$	$d_0 = +1.164180 \times 10^{-2}$
$a_1 = -2.789569 \times 10^{2}$	$b_1 = +1.383166 \times 10^{1}$	$c_1 = -2.243221 \times 10^{-1}$	$d_1 = +1.183002 \times 10^{-3}$
$a_2 = +3.264097 \times 10^{2}$	$b_2 = -1.785118 \times 10^{1}$	$c_2 = +3.250219 \times 10^{-1}$	$d_2 = -1.970140 \times 10^{-3}$
$a_3 = -5.651630 \times 10^{1}$	$b_3 = +3.128143$	$c_3 = -5.768276 \times 10^{-2}$	$d_3 = +3.543688 \times 10^{-4}$

51500 - 51000 cm^{-1} ($z \geq 10$ km; $N \leq 4 \times 10^{24}$ cm^{-2}; $\tau \leq 8$; dif. $\leq 2\%$)

$a_0 = -1.472295 \times 10^{3}$	$b_0 = +8.345967 \times 10^{1}$	$c_0 = -1.584305$	$d_0 = +1.007136 \times 10^{-2}$
$a_1 = +5.211158 \times 10^{2}$	$b_1 = -3.034976 \times 10^{1}$	$c_1 = +5.885583 \times 10^{-1}$	$d_1 = -3.800183 \times 10^{-3}$
$a_2 = -1.697419 \times 10^{2}$	$b_2 = +9.803754$	$c_2 = -1.886280 \times 10^{-1}$	$d_2 = +1.208967 \times 10^{-3}$
$a_3 = +1.685932 \times 10^{1}$	$b_3 = -9.742681 \times 10^{-1}$	$c_3 = +1.875247 \times 10^{-2}$	$d_3 = -1.202226 \times 10^{-4}$

$\ln \tau_{SRBb}$ (continued)

51000 - 50500 cm^{-1} ($z \geq 10$ km; $N \leq 5 \times 10^{24}$ cm^{-2}; $\tau \leq 3$; dif. $\leq 1.5\%$)

$a_0 = -9.560019 \times 10^{2}$	$b_0 = +5.392383 \times 10^{1}$	$c_0 = -1.022666$	$d_0 = +6.514690 \times 10^{-3}$
$a_1 = -5.296288 \times 10^{2}$	$b_1 = +2.818473 \times 10^{1}$	$c_1 = -4.973484 \times 10^{-1}$	$d_1 = +2.908988 \times 10^{-3}$
$a_2 = +1.940443 \times 10^{2}$	$b_2 = -1.050058 \times 10^{1}$	$c_2 = +1.887738 \times 10^{-1}$	$d_2 = -1.127272 \times 10^{-3}$
$a_3 = -2.717083 \times 10^{1}$	$b_3 = +1.481919$	$c_3 = -2.687878 \times 10^{-2}$	$d_3 = +1.621203 \times 10^{-4}$

50500 - 50000 cm^{-1} ($z \geq 10$ km; $N \leq 5 \times 10^{24}$ cm^{-2}; $\tau \leq 1.25$; dif. $\leq 1.5\%$)

$a_0 = -1.118200 \times 10^{3}$	$b_0 = +6.414120 \times 10^{1}$	$c_0 = -1.236103$	$d_0 = +7.987381 \times 10^{-3}$
$a_1 = -1.415924 \times 10^{3}$	$b_1 = +7.522780 \times 10^{1}$	$c_1 = -1.326520$	$d_1 = +7.760752 \times 10^{-3}$
$a_2 = +6.336393 \times 10^{2}$	$b_2 = -3.420757 \times 10^{1}$	$c_2 = +6.140398 \times 10^{-1}$	$d_2 = -3.664583 \times 10^{-3}$
$a_3 = -8.601704 \times 10^{1}$	$b_3 = +4.669416$	$c_3 = -8.453310 \times 10^{-2}$	$d_3 = +5.067235 \times 10^{-4}$

50000 - 49500 cm^{-1} ($z \geq 10$ km; $N \leq 5 \times 10^{24}$ cm^{-2}; $\tau \leq 0.9$; dif. $\leq 0.5\%$)

$a_0 = -2.025389 \times 10^{3}$	$b_0 = +1.132121 \times 10^{2}$	$c_0 = -2.120739$	$d_0 = +1.330079 \times 10^{-2}$
$a_1 = +2.152783 \times 10^{2}$	$b_1 = -1.434002 \times 10^{1}$	$c_1 = +3.112480 \times 10^{-1}$	$d_1 = -2.212285 \times 10^{-3}$
$a_2 = +6.739102$	$b_2 = +2.394632 \times 10^{-1}$	$c_2 = -1.633299 \times 10^{-2}$	$d_2 = +1.773461 \times 10^{-4}$
$a_3 = -6.771976$	$b_3 = +3.106584 \times 10^{-1}$	$c_3 = -4.484998 \times 10^{-3}$	$d_3 = +1.954261 \times 10^{-5}$

Table IVa - Comparison between detailed calculation and parametric formula

Ratios	Height (km)	Solar angle	$N(O_2)$ (cm^{-2})	$e^{-\tau}$ Calculation	$e^{-\tau}$ Formula	Diff. %	τ Calc.	τ Form.	Diff. %	$\ln\tau$ calc.	$\ln\tau$ Form.	Diff. %
57000 - 56500 cm^{-1}												
J/J_∞	80	75°	1.86×10^{20}	5.77×10^{-4}	5.79×10^{-4}	+ 0.5	7.46	7.45	0	2.009	2.009	0
	75	0°	1.12×10^{20}	2.68×10^{-3}	2.69×10^{-3}	+ 0.6	5.92	5.92	0	1.779	1.778	0
q/q_∞	with continuum			6.37×10^{-3}	5.74×10^{-3}	- 9.9	5.06	5.16	+ 2.1	1.621	1.641	+ 1.3
				2.09×10^{-2}	2.09×10^{-2}	0	3.87	3.87	0	1.352	1.353	0
q/q_∞	without continuum			4.69×10^{-2}	4.69×10^{-2}	0	3.06	3.06	0	1.119	1.119	0
				9.44×10^{-2}	9.43×10^{-2}	0	2.36	2.36	0	0.859	0.859	0
56500 - 56000 cm^{-1}												
J/J_∞	70	0°	2.5×10^{20}	4.19×10^{-3}	4.20×10^{-3}	+ 0.5	5.48	5.47	- 0.1	1.700	1.700	0
	70	75°	1.0×10^{21}	1.51×10^{-4}	1.53×10^{-4}	+ 1.2	8.80	8.79	- 0.1	2.175	2.173	- 0.1
q/q_∞	with continuum			7.57×10^{-2}	7.51×10^{-2}	- 0.8	2.58	2.59	+ 0.3	0.948	0.951	+ 0.3
				4.77×10^{-3}	4.95×10^{-3}	+ 3.8	5.35	5.31	- 0.7	1.676	1.669	- 0.4
q/q_∞	without continuum			9.94×10^{-2}	9.89×10^{-2}	- 0.6	2.31	2.31	0	0.837	0.839	+ 0.3
				1.19×10^{-2}	1.20×10^{-2}	+ 0.4	4.43	4.42	- 0.1	1.488	1.487	- 0.1
56000 - 55500 cm^{-1}												
J/J_∞	65	0°	5.19×10^{20}	5.16×10^{-3}	5.03×10^{-3}	- 2.2	5.27	5.29	+ 0.4	1.661	1.665	+ 0.3
	65	75°	2.08×10^{21}	1.96×10^{-4}	1.85×10^{-4}	- 5.6	8.54	8.60	+ 0.7	2.145	2.151	+ 0.3
q/q_∞	with continuum			1.12×10^{-1}	1.12×10^{-1}	0	2.19	2.19	0	0.783	0.783	0
				6.52×10^{-3}	6.92×10^{-3}	+ 6.1	5.03	4.97	- 1.2	1.616	1.604	- 0.7
q/q_∞	without continuum			1.35×10^{-1}	1.36×10^{-1}	+ 0.8	2.01	2.00	- 0.4	+ 0.696	+ 0.692	- 0.6
				1.24×10^{-2}	1.26×10^{-2}	+ 1.8	4.39	4.37	- 0.4	+ 1.480	+ 1.476	- 0.3

TABLE IVa (followed)

Ratios	Height (km)	Solar angle	$N(O_2)$ (cm^{-2})	$e^{-\tau}$ Calculation	$e^{-\tau}$ Formula	Diff. %	τ Calc.	τ Form.	Diff. %	$\ln\tau$ calc.	$\ln\tau$ Form.	Diff. %
55500 - 55000 cm^{-1}												
J/J_∞	60	0°	1×10^{21}	2.19×10^{-3}	2.26×10^{-3}	+ 3.3	6.12	6.09	- 0.5	1.812	1.807	- 0.3
		75°	4×10^{21}	7.72×10^{-5}	7.92×10^{-5}	+ 2.6	9.47	9.44	- 0.3	2.248	2.245	- 0.1
q/q_∞	with continuum			6.55×10^{-2}	6.69×10^{-2}	2.1	2.73	2.70	- 0.8	1.003	0.995	- 0.8
				4.26×10^{-3}	4.23×10^{-3}	- 0.6	5.46	5.47	+ 0.1	1.697	1.698	+ 0.1
q/q_∞	without continuum			6.98×10^{-2}	7.09×10^{-2}	+ 1.6	2.66	2.65	- 0.6	0.979	0.973	- 0.6
				5.01×10^{-3}	5.23×10^{-3}	+ 4.5	5.30	5.25	- 0.8	1.667	1.659	- 0.5
55000 - 54500 $^{-1}$												
J/J_∞	60	75°	4.04×10^{21}	5.76×10^{-4}	6.01×10^{-4}	+ 4.3	7.46	7.42	- 0.6	2.009	2.004	- 0.3
	55	60°	3.86×10^{21}	5.84×10^{-4}	5.25×10^{-4}	- 4.2	7.51	7.55	+ 0.6	2.016	2.022	- 0.3
q/q_∞	with continuum			3.18×10^{-2}	3.19×10^{-2}	+ 0.4	3.45	3.44	- 0.1	1.238	1.237	- 0.1
				2.83×10^{-2}	2.81×10^{-2}	- 0.8	3.56	3.57	+ 0.2	1.271	1.273	+ 0.2
q/q_∞	without continuum			3.25×10^{-2}	3.26×10^{-2}	+ 0.4	3.43	3.42	- 0.1	1.231	1.230	- 0.1
				2.89×10^{-2}	2.87×10^{-2}	- 0.9	3.54	3.55	+ 0.3	1.265	1.268	+ 0.2
54500 - 54000 cm^{-1}												
J/J_∞	55	75°	7.72×10^{21}	5.61×10^{-4}	5.48×10^{-4}	- 2.2	7.49	7.51	+ 0.3	2.013	2.016	+ 0.1
	50	60°	7.22×10^{21}	5.86×10^{-4}	5.68×10^{-4}	- 3.1	7.44	7.47	+ 0.4	2.007	2.011	+ 0.2
q/q_∞	with continuum			2.70×10^{-2}	2.71×10^{-2}	+ 0.3	3.61	3.61	0	1.284	1.283	- 0.1
				2.67×10^{-2}	2.66×10^{-2}	- 0.3	3.62	3.63	+ 0.1	1.287	1.288	+ 0.1
q/q_∞	without continuum			2.83×10^{-2}	2.81×10^{-2}	- 0.8	3.57	3.57	0	1.271	1.274	0.2
				2.79×10^{-2}	2.79×10^{-2}	+ 0.3	3.58	3.58	0	1.275	1.275	0

TABLE IVa (followed)

Ratios	Height (km)	Solar angle	$N(O_2)$ (cm^{-2})	$e^{-\tau}$ Calculation	$e^{-\tau}$ Formula	Diff. %	τ Calc.	τ Form.	Diff. %	$\ln\tau$ calc.	$\ln\tau$ Form.	Diff. %
54000 - 53500 cm^{-1}												
J/J_∞	55	75°	7.72×10^{21}	1.77×10^{-3}	1.63×10^{-3}	- 7.8	6.34	6.42	+ 1.3	1.847	1.859	+ 0.7
	50	60°	7.22×10^{21}	1.80×10^{-3}	1.66×10^{-3}	- 7.5	6.32	6.40	+ 1.2	1.844	1.856	+ 0.7
q/q_∞	with continuum			5.34×10^{-2}	5.53×10^{-2}	+ 3.5	2.93	2.90	- 1.2	1.075	1.063	- 1.1
				5.03×10^{-2}	5.20×10^{-2}	+ 3.3	2.99	2.96	- 1.1	1.095	1.084	- 1.0
q/q_∞	without continuum			$5.60 \times 10^{-}$	5.73×10^{-2}	+ 2.3	2.88	2.86	- 0.8	1.058	1.050	- 0.8
				5.26×10^{-2}	5.36×10^{-2}	+ 1.8	2.94	2.93	- 0.6	1.080	1.074	- 0.6
53500 - 53000 cm^{-1}												
J/J_∞	45	75°	2.70×10^{22}	8.52×10^{-4}	8.66×10^{-4}	+ 1.0	7.07	7.05	- 0.2	1.956	1.953	- 0.1
	40	60°	2.58×10^{22}	9.04×10^{-4}	9.04×10^{-4}	0	7.01	7.01	0	1.947	1.947	0
q/q_∞	with continuum			3.81×10^{-2}	3.86×10^{-2}	+ 1.2	3.27	3.26	- 0.4	1.184	1.180	- 0.3
				4.24×10^{-2}	4.20×10^{-2}	- 0.8	3.16	3.17	+ 0.3	1.151	1.154	+ 0.2
q/q_∞	without continuum			4.55×10^{-2}	4.49×10^{-2}	- 1.4	3.09	3.10	+ 0.5	1.128	1.133	+ 0.4
				5.02×10^{-2}	4.94×10^{-2}	- 1.6	2.99	3.01	+ 0.6	1.096	1.101	+ 0.5
53000 - 52500 cm^{-1}												
J/J_∞	40	60°	2.58×10^{22}	3.85×10^{-3}	4.13×10^{-3}	+ 7.0	5.56	5.49	- 1.3	1.716	1.703	- 0.7
	35	0°	2.59×10^{22}	3.85×10^{-3}	3.80×10^{-3}	- 1.2	5.56	5.57	+ 0.2	1.716	1.718	+ 0.1
q/q_∞	with continuum			1.36×10^{-1}	1.36×10^{-1}	0	2.00	2.00	0	0.690	0.690	0
				1.42×10^{-1}	1.42×10^{-1}	0	1.95	1.95	0	0.669	0.669	0
q/q_∞	without continuum			1.62×10^{-1}	1.63×10^{-1}	+ 0.6	1.82	1.81	- 0.3	0.599	0.596	- 0.5
				1.70×10^{-1}	1.69×10^{-1}	- 0.6	1.77	1.78	+ 0.3	0.572	0.575	- 0.6

Table IVa (followed)

Ratios	Height (km)	Solar angle	$N(O_2)$ (cm^{-2})	$e^{-\tau}$ Calculation	$e^{-\tau}$ Formula	Diff. %	τ Calc.	τ Form.	Diff. %	$\ln\tau$ calc.	$\ln\tau$ Form.	Diff. %
52500 - 52000 cm^{-1}												
J/J_∞	40	75°	5.16×10^{22}	4.14×10^{-3}	4.49×10^{-3}	+ 7.5	5.48	5.41	- 1.0	1.701	1.687	- 0.9
	35	60°	5.18×10^{22}	4.17×10^{-3}	4.12×10^{-3}	- 1.1	5.48	5.49	+ 0.2	1.701	1.703	+ 0.1
q/q_∞	with continuum			1.04×10^{-1}	1.03×10^{-1}	- 1.6	2.26	2.28	0.7	0.816	0.823	+ 0.8
				1.11×10^{-1}	1.11×10^{-1}	- 0.3	2.19	2.20	0.1	0.786	0.787	+ 0.1
q/q_∞	without continuum			1.50×10^{-1}	1.50×10^{-1}	0	1.89	1.90	+ 0.1	0.639	0.640	+ 0.1
				1.61×10^{-1}	1.60×10^{-1}	- 0.8	1.83	1.83	+ 0.4	0.602	0.606	+ 0.7
52000 - 51500 cm^{-1}												
J/J_∞	30	60°	1.08×10^{23}	1.51×10^{-3}	1.46×10^{-3}	- 3.7	6.49	6.53	+ 0.6	1.871	1.877	+ 0.3
	25	0°	1.14×10^{23}	1.45×10^{-3}	1.40×10^{-3}	- 3.5	6.54	6.57	+ 0.5	1.877	1.883	+ 0.3
q/q_∞	with continuum			4.94×10^{-2}	4.91×10^{-2}	- 0.6	3.01	3.01	+ 0.2	1.101	1.103	+ 0.2
				5.05×10^{-2}	5.04×10^{-2}	- 0.2	2.99	2.99	+ 0.1	1.094	1.095	+ 0.1
q/q_∞	without continuum			1.09×10^{-1}	1.09×10^{-1}	+ 0.3	2.22	2.22	- 0.1	0.798	0.796	- 0.2
				1.16×10^{-1}	1.19×10^{-1}	+ 2.3	2.15	2.13	- 1.1	0.766	0.756	- 1.4
51500 - 51000 cm^{-1}												
J/J_∞	25	70°	3.42×10^{23}	5.68×10^{-4}	5.92×10^{-4}	+ 4.2	7.47	7.43	- 0.6	2.011	2.006	- 0.3
	20	45°	3.51×10^{23}	5.70×10^{-4}	6.00×10^{-4}	+ 5.3	7.47	7.42	- 0.7	2.011	2.004	- 0.3
q/q_∞	with continuum			8.60×10^{-3}	8.65×10^{-3}	+ 0.7	4.76	4.75	- 0.1	1.559	1.558	- 0.1
				8.79×10^{-3}	8.87×10^{-3}	+ 0.9	4.73	4.73	- 0.2	1.555	1.553	- 0.1
q/q_∞	without continuum			1.10×10^{-1}	1.10×10^{-1}	0	2.21	2.21	0	0.791	0.791	0
				1.20×10^{-1}	1.21×10^{-1}	+ 0.6	2.12	2.11	- 0.3	0.751	0.748	- 0.4

TABLE IVa (followec)

Ratios	Height (km)	Solar angle	$N(O_2)$ (cm^{-2})	$e^{-\tau}$ Calculation	$e^{-\tau}$ Formula	Diff. %	τ Calc.	τ Form.	Diff. % 0.24	$\ln\tau$ calc.	$\ln\tau$ Form.	Diff. %
51000 - 50500 cm^{-1}												
J/J_∞	20	70°	7.44×10^{23}	2.02×10^{-4}	2.11×10^{-4}	+ 4.2	8.50	8.46	- 0.5	2.141	2.136	- 0.2
	15	45°	7.66×10^{23}	1.84×10^{-4}	1.96×10^{-4}	+ 6.6	8.60	8.54	- 0.7	2.152	2.144	- 0.3
q/q_∞	with continuum			1.05×10^{-3}	1.02×10^{-3}	- 2.9	6.86	6.89	+ 0.4	1.926	1.930	+ 0.2
				9.49×10^{-4}	9.10×10^{-4}	- 4.1	6.96	7.00	+ 0.6	1.940	1.946	+ 0.3
q/q_∞	without continuum			2.84×10^{-1}	2.86×10^{-1}	+ 0.7	1.26	1.25	- 0.5	0.231	0.225	- 2.4
				3.04×10^{-1}	3.03×10^{-1}	- 0.5	1.19	1.19	+ 0.4	0.174	0.178	+ 2.4
50500 - 50000 cm^{-1}												
J/J_∞	25	70°	3.42×10^{23}	2.14×10^{-2}	3.07×10^{-2}	+ 4.5	3.53	3.48	- 1.3	1.261	1.248	- 1.0
	20	45°	3.51×10^{23}	2.87×10^{-2}	2.91×10^{-2}	+ 1.4	3.55	3.54	- 0.4	1.267	1.263	- 0.3
q/q_∞	with continuum			4.92×10^{-2}	4.97×10^{-2}	+ 1.1	3.01	3.00	- 0.4	1.103	1.099	- 0.3
				4.85×10^{-2}	4.87×10^{-2}	+ 0.5	3.03	3.02	- 0.2	1.107	1.106	- 0.1
q/q_∞	without continuum			6.50×10^{-1}	6.50×10^{-1}	+ 0.8	0.44	0.43	- 1.7	-0.825	-0.843	+ 2.1
				6.80×10^{-1}	6.82×10^{-1}	+ 0.3	0.39	0.38	- 0.8	-0.951	-0.960	+ 0.9
50000 - 49500 cm^{-1}												
J/J_∞	30	75°	2.15×10^{23}	1.21×10^{-1}	1.24×10^{-1}	+ 2.8	2.11	2.09	- 1.3	0.749	0.735	- 1.8
	25	60°	2.28×10^{23}	1.10×10^{-1}	1.11×10^{-1}	+ 0.9	2.21	2.20	- 0.4	0.791	0.787	- 0.5
q/q_∞	with continuum			1.59×10^{-1}	1.59×10^{-1}	0	1.84	1.84	0	0.610	0.610	0
				1.46×10^{-1}	1.46×10^{-1}	0	1.92	1.92	0	0.654	0.654	0
q/q_∞	without continuum			7.89×10^{-1}	7.88×10^{-1}	0	0.24	0.24	0	-1.437	-1.437	0
				8.00×10^{-1}	8.00×10^{-1}	0	0.22	0.22	0	-1.498	-1.498	0

Table IVb - Distribution of the values (%) of the constants adopted in the formules

57000 - 56500cm^{-1}										
Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	80	75°	- 0.7	+ 2.7	- 5.2	+ 2.9	+ 2.1	- 8.7	+ 16.5	- 9.2
	75	0°	- 4.6	+ 4.7	- 2.2	+ 0.3	+ 14.2	- 14.7	+ 7.0	- 1.0
q/q_∞	with	cont.	+ 0.0	- 2.5	+ 5.9	- 3.8	+ 0.1	+ 7.6	- 18.0	+ 11.5
			- 0.3	- 7.2	+ 4.3	- 0.7	+ 0.9	+ 21.6	- 12.9	+ 2.1
q/q_∞	without	cont.	- 1.8	- 3.3	+ 4.7	- 2.3	+ 5.3	+ 10.2	- 14.4	+ 7.1
			- 7.7	- 3.5	+ 1.2	- 0.2	+ 22.3	+ 10.8	- 3.8	+ 0.5
Ratios	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	80	75°	- 2.2	+ 9.2	- 17.4	+ 9.7	+ 0.8	- 3.2	+ 6.1	- 3.4
	75	0°	- 14.6	+ 15.3	- 7.3	+ 1.0	+ 5.0	- 5.3	+ 2.5	- 0.4
q/q_∞	with	cont.	- 0.1	- 7.6	+-18.3	- 11.8	+ 0.0	+ 2.6	- 6.2	+ 4.0
			- 1.1	- 21.5	+ 12.9	- 2.1	+ 0.5	+ 7.1	- 4.3	- 0.7
q/q_∞	without	cont.	- 5.3	- 10.5	+ 14.8	- 7.3	+ 1.8	+ 3.6	- 5.1	+ 2.5
			- 22.1	- 11.0	- 3.9	- 0.5	+ 7.4	+ 3.7	- 1.3	+ 0.2
56500 - 56000cm^{-1}										
Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	70	0°	- 10.4	- 1.2	- 0.3	+ 0.1	+ 32.2	+ 3.4	+ 1.1	- 0.4
	70	75°	- 4.0	- 1.9	- 1.9	+ 3.4	+ 12.6	+ 5.3	+ 6.9	- 11.3
q/q_∞	with	cont.	- 7.8	+ 2.6	- 1.7	+ 0.3	+ 23.5	- 7.7	+ 5.2	- 0.8
			- 1.5	+ 2.0	- 5.3	+ 3.2	+ 4.6	- 6.1	+ 16.4	- 9.8
q/q_∞	without	cont.	- 3.2	- 7.0	- 1.8	- 0.2	+ 8.5	+ 22.1	- 5.7	+ 0.6
			- 0.5	- 4.3	+ 4.3	- 1.9	+ 1.3	+ 13.9	- 14.3	+ 6.4
	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	70	0°	- 33.1	- 3.0	- 1.3	+ 0.5	+ 11.4	+ 0.9	+ 0.5	- 0.2
	70	75°	- 13.4	- 4.8	- 8.2	+ 12.4	+ 4.7	+ 1.4	+ 3.2	- 4.5
q/q_∞	with	cont.	- 23.9	+ 7.6	- 5.2	+ 0.8	+ 8.2	- 2.5	+ 1.7	- 0.3
			- 4.8	+ 6.2	- 16.9	+ 10.2	+ 1.7	- 2.1	+ 5.8	- 3.5
q/q_∞	without	cont.	- 7.9	- 23.2	+ 6.0	- 0.7	+ 2.6	+ 8.1	- 2.1	+ 0.2
			- 1.3	- 15.0	+ 15.6	- 7.0	+ 0.4	+ 5.4	- 5.7	+ 2.5
56000 - 55500 cm^{-1}										
Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	65	0°	- 1.9	- 6.7	+ 2.9	- 0.4	+ 5.8	+ 20.8	- 9.1	+ 1.2
	65	75°	- 0.2	- 3.0	+ 5.3	- 2.8	+ 0.7	+ 9.6	- 17.0	+ 9.0
q/q_∞	with	cont.	- 3.6	+ 5.3	- 3.0	+ 0.4	+ 10.9	- 15.9	+ 9.1	- 1.3
			- 0.4	+ 2.5	- 5.7	+ 3.3	+ 1.3	- 7.7	+ 17.6	- 10.2
q/q_∞	without	cont.	- 4.1	+ 5.4	- 2.4	+ 0.3	+ 12.5	- 16.4	+ 7.4	- 0.9
			- 0.6	+ 3.0	- 5.4	+ 2.7	+ 1.8	- 9.4	+ 16.9	- 8.5
Ratios	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	65	0°	- 6.0	- 21.4	+ 9.4	- 1.3	+ 2.1	+ 7.4	- 3.3	+ 0.4
	65	75°	- 0.7	- 10.2	+ 18.1	- 9.6	+ 0.3	+ 3.6	- 6.4	+ 3.4
q/q_∞	with	cont.	- 11.2	+ 15.9	- 9.2	+ 1.3	+ 3.9	- 5.3	+ 3.1	- 0.4
			- 1.4	+ 7.9	- 18.3	+ 10.6	+ 0.5	- 2.7	+ 6.3	- 3.6
q/q_∞	without	cont.	- 12.7	+ 16.6	- 7.5	+ 0.9	+ 4.3	- 5.6	+ 2.5	- 0.3
			- 1.9	+ 9.8	- 17.7	+ 8.9	+ 0.7	- 3.4	+ 6.2	- 3.1

Table IVb (followed)

55500 - 55000 cm^{-1}										
Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	60	0°	- 7.4	+ 2.6	- 1.6	+ 0.3	+ 23.0	- 8.1	+ 4.9	- 0.8
		75°	- 1.4	+ 2.0	- 4.8	+ 3.1	+ 4.5	- 6.3	+ 15.4	- 10.0
q/q_∞	with	cont.	+ 2.2	- 6.4	+ 2.2	- 0.3	- 7.9	+ 20.4	- 7.1	+ 0.9
			+ 0.3	- 3.4	+ 4.8	- 2.5	- 1.1	+ 11.3	- 15.6	+ 8.0
q/q_∞	without	cont.	+ 5.3	- 6.9	+ 0.7	+ 0.0	- 16.2	+ 19.9	- 1.7	- 0.2
			+ 1.4	- 7.4	+ 3.1	+ 0.8	- 4.5	+ 22.0	- 7.6	- 3.5
Ratios	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	60	0°	- 23.8	+ 8.4	- 5.1	+ 0.8	+ 8.2	- 2.9	+ 1.8	- 0.3
		75°	- 4.8	+ 6.8	- 16.5	+ 10.7	+ 1.7	- 2.4	+ 5.9	- 3.8
q/q_∞	with	cont.	+ 8.9	- 21.7	+ 7.4	- 0.9	- 3.2	+ 7.7	- 2.6	+ 0.3
			+ 1.3	- 12.3	+ 16.9	- 8.5	- 0.5	+ 4.5	- 6.1	+ 3.0
q/q_∞	without	cont.	+ 16.0	- 19.4	+ 1.3	+ 0.3	- 5.1	+ 6.3	- 0.3	- 0.1
			+ 4.6	- 22.1	+ 6.0	+ 4.6	- 1.5	+ 7.4	- 1.5	- 1.9

55000 - 54500 cm^{-1}										
Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	60	75°	- 1.9	+ 2.2	- 4.7	+ 3.0	+ 6.1	- 6.7	+ 14.7	- 9.3
	55	60°	- 5.0	+ 2.8	- 3.0	+ 1.0	+ 15.7	- 8.6	+ 9.5	- 3.0
q/q_∞	with	cont.	+ 0.4	- 5.6	+ 3.9	- 0.5	- 1.5	+ 18.3	- 13.4	+ 2.1
			+ 1.0	- 7.0	+ 2.5	- 0.2	- 3.8	+ 22.8	- 8.4	+ 0.7
q/q_∞	without	cont.	+ 0.4	- 4.2	+ 4.6	- 1.9	- 1.3	+ 13.7	- 14.9	+ 6.2
			+ 1.1	- 6.0	+ 3.3	- 0.7	- 3.8	+ 19.5	- 10.6	+ 2.2
	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	60	75°	- 6.4	+ 6.9	- 15.2	+ 9.6	+ 2.2	- 2.4	+ 5.3	- 3.3
	55	60°	- 16.3	+ 8.9	- 9.8	+ 3.1	+ 5.7	- 3.1	+ 3.4	- 1.1
q/q_∞	with	cont.	+ 1.7	- 19.9	+ 15.1	- 2.7	- 0.6	+ 7.2	- 5.6	+ 1.1
			+ 4.3	- 24.8	+ 9.4	- 0.8	- 1.5	+ 9.0	- 3.5	+ 0.4
q/q_∞	without	cont.	+ 1.5	- 14.7	+ 16.0	- 6.7	- 0.5	+ 5.2	- 5.8	+ 2.4
			+ 4.2	- 20.9	+ 11.4	- 2.4	- 1.5	+ 7.5	- 4.1	+ 0.9

54500 - 54000 cm^{-1}										
Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	55	75°	- 1.0	+ 2.2	- 5.3	+ 3.3	+ 3.0	- 6.7	+ 16.7	- 10.2
	50	60°	- 3.0	+ 3.3	- 4.1	+ 1.3	+ 9.4	- 10.4	+ 13.0	- 4.0
q/q_∞	with	cont.	+ 0.6	- 2.7	+ 5.3	- 3.5	- 1.8	+ 8.3	- 16.1	+ 10.9
			+ 1.8	- 4.3	+ 4.3	- 1.4	- 6.0	+ 13.5	- 13.1	+ 4.4
q/q_∞	without	cont.	- 0.6	+ 3.0	- 5.2	+ 2.8	+ 1.8	- 9.5	+ 16.5	- 8.8
			- 1.8	+ 4.7	- 4.0	+ 1.1	+ 5.6	- 14.7	+ 12.8	- 3.4
Ratios	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	55	75°	- 3.2	+ 7.0	- 17.4	+ 10.7	+ 1.1	- 2.4	+ 6.1	- 3.7
	50	60°wi	- 9.8	+ 10.9	- 13.5	+ 4.1	+ 3.4	- 3.8	+ 4.7	- 1.4
q/q_∞	th	cont.	+ 1.9	- 8.6	+ 16.4	- 11.1	- 0.7	+ 3.0	- 5.6	+ 3.8
			+ 6.3	- 13.9	+ 13.4	- 4.5	- 2.2	+ 4.8	- 4.5	+ 1.5
q/q_∞	without	cont.	- 1.9	+ 9.9	- 17.4	+ 9.3	+ 0.6	- 3.5	+ 6.1	- 3.3
			- 5.8	+ 15.5	- 13.5	+ 3.6	+ 2.0	- 5.4	+ 4.7	- 0.7

Table IVb (followed)

Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
54000 - 53500 cm^{-1}										
J/J_∞	55	75°	- 2.0	+ 3.0	- 4.6	+ 2.0	+ 6.4	- 9.4	+ 14.6	- 6.2
	50	60°	- 4.8	+ 3.5	- 2.7	- 0.6	+ 15.1	- 11.0	+ 8.6	- 1.8
q/q_∞	with	cont.	+ 0.5	- 2.3	+ 5.5	- 3.7	- 1.7	+ 7.0	- 16.9	+ 11.4
			+ 1.8	- 3.9	+ 4.7	- 1.6	- 5.6	+ 11.9	- 14.5	+ 4.9
q/q_∞	without	cont.	+ 0.7	- 2.2	+ 6.1	- 4.4	- 2.2	+ 6.2	- 17.4	+ 12.7
			+ 2.4	- 3.8	+ 5.2	- 1.9	- 7.4	+ 10.7	- 14.9	+ 5.4
Ratios	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	55	75°	- 6.8	+ 9.9	- 15.2	+ 6.4	+ 2.4	- 3.5	+ 5.3	- 2.2
	50	60°	- 15.9	+ 11.6	- 8.9	+ 1.9	+ 5.6	- 4.1	+ 3.1	- 0.7
q/q_∞	with	cont.	+ 1.8	- 7.2	+ 17.4	- 11.7	- 0.6	+ 2.5	- 5.9	+ 4.0
			+ 6.0	- 12.3	+ 14.8	- 5.0	- 2.1	+ 4.2	- 5.1	+ 1.7
q/q_∞	without	cont.	+ 2.2	- 5.8	+ 16.4	- 12.2	- 0.8	+ 1.8	- 5.1	+ 3.9
			+ 7.6	- 9.8	+ 14.0	- 5.2	- 2.6	+ 3.0	- 4.4	+ 1.7
53500 - 53000 cm^{-1}										
Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	45	75°	+ 0.6	- 4.2	+ 4.8	- 1.7	- 1.9	+ 13.5	- 15.4	+ 5.5
	40	60°	+ 1.6	- 5.8	+ 3.3	- 0.6	- 5.2	+ 18.5	- 10.6	+ 1.9
q/q_∞	with	cont.	- 0.5	- 3.3	+ 5.6	- 2.3	+ 1.5	+ 10.2	- 17.6	+ 7.3
			- 1.6	- 5.0	+ 4.3	- 0.9	+ 4.6	+ 15.7	- 13.6	+ 2.8
q/q_∞	without	cont.	- 0.2	- 3.2	+ 5.6	- 2.5	+ 0.7	+ 10.1	- 17.8	+ 8.0
			- 0.8	- 5.3	+ 4.6	- 1.0	+ 2.2	+ 16.6	- 14.6	+ 3.3
	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	45	75°	+ 2.1	- 14.3	+ 16.4	- 5.9	- 0.7	+ 5.1	- 5.8	+ 2.1
	40	60°	+ 5.7	- 19.7	+ 11.3	- 2.0	- 2.0	+ 7.0	- 4.0	+ 0.7
q/q_∞	with	cont.	- 1.5	- 10.6	+ 18.5	- 7.8	+ 0.5	+ 3.7	- 6.4	+ 2.8
			- 4.6	- 16.4	+ 14.2	- 3.0	+ 1.6	+ 5.7	- 5.0	+ 1.1
q/q_∞	without	cont.	- 0.6	- 10.6	+ 18.7	- 8.5	+ 0.2	+ 3.7	- 6.5	+ 3.0
			- 2.1	- 17.3	+ 15.3	- 3.5	+ 0.7	+ 6.0	- 5.3	+ 1.2
53000 - 52500 cm^{-1}										
Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	40	60°	+ 1.1	- 5.8	+ 3.7	- 0.8	- 3.6	+ 18.6	- 11.7	+ 2.5
	35	0°	+ 2.4	- 6.6	+ 2.1	- 0.2	- 8.1	+ 20.9	- 6.6	+ 0.7
q/q_∞	with	cont.	+ 1.3	- 5.9	+ 4.5	- 1.0	- 3.9	+ 17.5	- 13.3	+ 3.0
			+ 3.0	- 6.8	+ 2.6	- 0.3	- 8.9	+ 20.3	- 7.7	+ 0.9
q/q_∞	without	cont.	- 2.4	+ 4.7	- 4.3	+ 1.2	+ 7.1	- 14.1	+ 12.9	- 3.6
			- 5.0	+ 4.9	- 2.3	- 0.3	+ 15.0	- 14.8	+ 6.8	- 0.9
Ratios	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	40	60°	+ 4.0	- 19.6	+ 12.4	- 2.6	- 1.4	+ 6.9	- 4.3	+ 0.9
	35	0°	+ 8.9	- 22.1	+ 7.0	- 0.7	- 3.2	+ 7.8	- 2.4	+ 0.3
q/q_∞	with	cont.	+ 3.8	- 17.3	+ 13.2	- 3.0	- 1.2	+ 5.7	- 4.3	+ 1.0
			+ 8.8	- 20.0	+ 7.6	- 0.9	- 2.8	+ 6.6	- 2.5	+ 0.3
q/q_∞	without	cont.	- 7.1	+ 14.0	- 12.8	+ 3.5	+ 2.4	- 4.7	+ 4.2	- 1.2
			- 15.0	+ 14.8	- 6.7	+ 0.9	+ 5.0	- 4.9	+ 2.2	- 0.3

Table IVb (followed)

52500 - 52000 cm^{-1}

Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	40	75°	- 0.1	- 8.6	- 1.2	+ 1.4	- 0.8	+ 28.3	+ 3.1	- 4.2
	35	60°	- 0.1	- 9.4	- 0.7	- 0.4	- 1.7	+ 30.8	+ 1.7	- 1.1
q/q_∞	with	cont.	- 0.9	+ 2.7	- 5.2	+ 3.2	+ 2.9	- 8.4	+ 15.9	- 9.8
			- 2.9	+ 4.1	- 3.9	+ 1.2	+ 8.7	- 12.6	+ 12.0	- 3.7
q/q_∞	without	cont.	- 6.1	+ 1.8	- 1.9	- 0.8	+ 18.6	- 7.5	+ 8.0	+ 1.5
			- 9.0	+ 1.3	- 0.7	- 0.2	+ 27.4	- 5.5	+ 2.9	- 0.3

Ratios	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	40	75°	+ 1.6	- 31.2	- 2.0	+ 3.9	- 0.8	+ 11.5	+ 0.1	- 1.1
	35	60°	+ 3.5	- 33.9	- 1.1	+ 1.1	- 1.7	+ 12.5	+ 0.1	- 0.3
q/q_∞	with	cont.	- 3.0	+ 8.6	- 16.4	+ 10.0	+ 1.0	- 3.0	+ 5.6	- 3.4
			- 8.9	+ 13.0	- 12.3	+ 3.8	+ 3.0	- 4.5	+ 4.2	- 1.3
q/q_∞	without	cont.	- 19.0	+ 9.4	- 10.3	- 0.5	+ 6.5	- 3.8	+ 4.2	- 0.2
			- 28.0	+ 6.9	- 3.8	- 0.1	+ 9.6	- 2.8	+ 1.5	0

52000 - 51500 cm^{-1}

Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	30	60°	- 4.9	+ 5.1	- 2.1	0	+ 14.9	- 15.7	+ 6.5	0
	25	0°	- 7.4	+ 3.9	- 0.8	0	+ 22.6	- 12.0	+ 2.5	0
q/q_∞	with	cont.	- 7.5	+ 0.1	- 2.8	+ 1.4	+ 23.1	- 0.7	+ 8.7	- 4.1
			- 10.5	0	- 1.0	+ 0.2	+ 32.4	- 0.5	+ 3.1	- 0.7
q/q_∞	without	cont.	- 5.3	- 1.8	+ 4.3	- 1.5	+ 16.3	+ 4.8	- 12.4	+ 4.4
			- 8.9	- 1.5	+ 1.8	- 0.3	+ 27.3	+ 4.0	- 5.2	+ 0.9

	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	30	60°	- 15.1	+ 16.2	- 6.7	0	+ 5.1	- 5.5	+ 2.3	0
	25	0°	- 23.0	+ 12.3	- 2.6	0	+ 7.8	- 4.2	+ 0.9	0
q/q_∞	with	cont.	- 23.9	+ 1.1	- 9.1	+ 4.2	+ 8.3	- 0.5	+ 3.1	- 1.4
			- 33.5	+ 0.8	- 3.2	+ 0.7	+ 11.6	- 0.4	+ 1.1	- 0.3
q/q_∞	without	cont.	- 16.7	- 4.1	+ 12.0	- 4.3	+ 5.7	+ 1.2	- 3.9	+ 1.4
			- 28.0	- 3.5	+ 5.1	- 0.9	+ 9.6	+ 1.0	- 1.6	+ 0.3

51500 - 51000 cm^{-1}

Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	25	70°	- 0.4	- 3.7	+ 5.4	- 2.1	+ 1.1	+ 11.8	- 17.0	+ 6.6
	20	45°	- 1.2	- 5.8	+ 3.9	- 0.7	+ 3.5	+ 18.4	- 12.4	+ 2.3
q/q_∞	with	cont.	- 6.7	+ 0.7	- 2.9	+ 1.8	+ 20.9	- 2.2	+ 8.6	- 5.3
			- 10.0	+ 0.5	- 1.0	+ 0.3	+ 31.3	- 1.5	+ 2.8	- 0.8
q/q_∞	without	cont.	- 3.5	+ 3.7	- 3.6	+ 1.1	+ 10.6	- 11.6	+ 11.2	- 3.3
			- 6.7	+ 3.4	- 1.5	+ 0.2	+ 20.6	- 10.6	+ 4.8	- 0.7

Ratios	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	25	70°	- 1.1	- 12.5	+ 17.9	- 7.0	+ 0.4	+ 4.4	- 6.3	+ 2.5
	20	45°	- 3.5	- 19.4	+ 13.1	- 2.4	+ 1.2	+ 6.8	- 4.6	+ 0.8
q/q_∞	with	cont.	- 22.0	+ 2.4	- 8.3	+ 5.2	+ 7.8	- 0.9	+ 2.7	- 1.7
			- 33.0	+ 1.7	- 2.8	+ 0.8	+ 11.7	- 0.6	+ 0.9	- 0.3
q/q_∞	without	cont.	- 10.9	+ 12.2	- 11.7	+ 3.5	+ 3.8	- 4.3	+ 4.1	- 1.2
			- 21.2	+ 11.2	- 5.1	+ 0.7	+ 7.3	- 3.9	+ 1.8	- 0.2

Table IVb(followed)

51000 - 50500 cm^{-1}										
Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	20	70°	- 2.4	+ 4.3	- 3.7	+ 1.1	+ 7.5	- 13.7	+ 11.7	- 3.5
	15	45°	- 5.1	+ 4.4	- 1.7	+ 0.2	+ 16.1	- 13.9	+ 5.6	- 0.8
q/q_∞	with	cont.	- 2.1	+ 1.2	- 5.1	+ 3.1	+ 6.6	- 3.9	+ 16.1	- 9.8
			- 5.9	+ 1.6	- 3.2	+ 0.9	+ 18.3	- 5.1	+ 10.0	- 2.9
q/q_∞	without	cont.	- 2.4	- 4.0	+ 4.4	- 1.8	+ 7.4	+ 11.6	- 13.0	+ 5.5
			- 5.5	- 4.3	+ 2.2	- 0.4	+ 16.9	+ 12.5	- 6.6	+ 1.3
Ratios	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	20	70°	- 7.9	+ 14.5	- 12.4	+ 3.8	+ 2.8	- 5.1	+ 4.4	- 1.3
	15	45°	- 17.0	+ 14.7	- 5.9	+ 0.9	+ 6.0	- 5.2	+ 2.1	- 0.3
q/q_∞	with	cont.	- 7.0	+ 4.3	- 17.0	+ 10.3	+ 2.5	- 1.6	+ 5.9	- 3.6
			- 19.4	+ 5.6	- 10.5	+ 3.0	+ 7.0	- 2.0	+ 3.7	- 1.1
q/q_∞	without	cont.	- 7.7	- 11.3	+ 12.9	- 5.5	+ 2.7	+ 3.6	- 4.2	+ 1.8
			- 17.7	- 12.1	+ 6.5	- 1.3	+ 6.2	+ 3.9	- 2.1	+ 0.4

50500 - 50000 cm^{-1}										
Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	25	70°	- 1.0	+ 0.8	- 6.1	+ 4.3	+ 3.1	- 2.6	+ 18.4	- 13.1
	20	45°	- 3.8	+ 1.5	- 5.1	+ 1.7	+ 11.7	- 4.6	+ 15.5	- 5.2
q/q_∞	with	cont.	- 1.2	+ 3.8	- 5.2	+ 2.0	+ 3.6	- 11.5	+ 15.9	- 6.2
			- 3.4	+ 5.0	- 3.2	+ 0.6	+ 10.1	- 15.2	+ 9.9	- 1.8
q/q_∞	without	cont.	- 1.1	- 4.1	+ 5.5	- 2.2	+ 3.4	+ 11.8	- 16.2	+ 6.6
			- 3.1	- 5.5	+ 3.5	- 0.7	+ 1.6	+ 15.9	- 10.3	+ 2.0
	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	25	70°	- 3.2	+ 2.6	- 18.6	+ 13.3	+ 1.1	- 0.9	+ 6.3	- 4.5
	20	45°	- 12.2	+ 4.7	- 15.7	+ 5.3	+ 4.3	- 1.6	+ 5.3	- 1.8
q/q_∞	with	cont.	- 3.7	+ 11.7	- 16.2	+ 6.3	+ 1.3	- 4.0	+ 5.5	- 2.1
			- 10.3	+ 15.5	- 10.1	+ 1.8	+ 3.6	- 5.3	+ 3.4	- 0.6
q/q_∞	without	cont.	- 3.5	- 11.3	+ 15.7	- 6.5	+ 1.2	+ 3.6	- 5.1	+ 2.1
			- 10.0	- 15.2	+ 10.0	- 1.9	+ 3.5	+ 4.8	- 3.2	- 0.6

50000 - 49500 cm^{-1}										
Ratios	Height (km)	Solar angle	a_0	a_1	a_2	a_3	b_0	b_1	b_2	b_3
J/J_∞	30	75°	+ 0.1	- 2.8	+ 6.1	- 3.5	- 0.2	+ 8.5	- 18.3	+ 10.5
	25	60°	+ 0.3	- 5.2	+ 5.5	- 1.6	- 0.7	+ 15.5	- 16.6	+ 4.7
q/q_∞	with	cont.	- 1.4	+ 3.2	- 4.8	+ 1.7	+ 4.1	- 10.4	+ 15.8	- 5.7
			- 3.7	+ 4.1	- 3.1	+ 0.5	+ 10.7	- 13.4	+ 10.2	- 1.8
q/q_∞	without	cont.	- 6.9	+ 2.9	+ 0.4	- 1.5	+ 20.8	- 10.5	+ 0.7	+ 3.7
			- 9.4	+ 2.0	+ 0.1	- 0.3	+ 28.4	- 7.2	+ 0.2	+ 0.6
Ratios	Height (km)	Solar angle	c_0	c_1	c_2	c_3	d_0	d_1	d_2	d_3
J/J_∞	30	75°	+ 0.2	- 8.5	+ 18.3	- 10.5	0	+ 2.8	- 6.1	+ 3.5
	25	60°	+ 0.6	- 15.4	+ 16.6	- 4.8	- 0.2	+ 5.1	- 5.6	+ 1.6
q/q_∞	with	cont.	- 4.2	+ 11.2	- 17.1	+ 6.3	+ 1.5	- 4.0	+ 6.1	- 2.3
			- 10.9	+ 14.5	- 11.1	+ 2.0	+ 3.9	- 5.2	+ 4.0	- 0.8
q/q_∞	without	cont.	- 20.9	+ 12.3	- 2.6	- 2.8	+ 7.1	- 4.7	+ 1.5	+ 0.7
			- 28.6	+ 8.4	- 0.9	- 0.5	+ 9.6	- 3.2	+ 0.5	+ 0.1

REFERENCES

Nicolet, M. (1989). Solar spectral irradiances with their diversity between 120 and 900 nm, *Space Sci. Rev.* **48**,

Nicolet, M. and Kennes, R. (1986). Aeronomic problems of molecular oxygen photodissociation I. The O_2 Herzberg continuum, *Planet. Space Sci.* **34**, 1043.

Nicolet, M. and Kennes, R. (1988a). Aeronomic problems of molecular oxygen photodissociation. III. Solar spectral irradiances in the region of the O_2 Herzberg continuum, Schumann-Runge bands and continuum, *Planet. Space Sci.* **36**, 1059.

Nicolet, M. and Kennes, R. (1988b). Aeronomic problems of molecular oxygen photodissociation IV. The various parameters for the Herzberg continuum, *Planet. Space Sci.*, **36**, 1069.

Nicolet, M. Cieslik, S. and Kennes, R. (1987). Rotational structures and absorption cross-sections from 300 K to 190 K of the Schumann-Runge bands, Inst. d'Aéronomie Spatiale de Belgique, Aeronomica Acta A, n° 318, 340 pages.

Nicolet, M., Cieslik, S. and Kennes, R. (1988). Aeronomic problems of molecular oxygen photodissociation II. Theoretical absorption cross-sections of the Schumann-Runge bands at 79 K, *Planet. Space Sci.* **36**, 1039.

Nicolet, M., Cieslik, S. and Kennes, R. (1989). Aeronomic problems of molecular oxygen photodissociation - V. The predissociation in the Schumann-Runge bands of oxygen, *Plant. Space Sci.* **37**, .