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PLANETARY AERONOMY

VII: THE SOLAR FLUX INCIDENT AT THE TOP OF THE ATMOSPHERES OF EARTH AND NEIGHBORING PLANETS FOR THE SPECTRAL REGION 50 Å TO 3000 Å

by E. D. Schultz and A. C. Holland

Prepared under Contract No. NASw-395 *by*
GEOPHYSICS CORPORATION OF AMERICA
Bedford, Massachusetts
for

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Geophysics Corporation of America
GCA Technical Report No. 62-14-N

ABSTRACT

The distribution and absolute intensity of the solar flux for wavelengths below 3000 A is an important aeronomic parameter for systematic studies of planetary aeronomy. A compilation of the solar flux incident at the top of the Earth's atmosphere is presented to serve as a basis for calculating similar data for other planets. For convenient reference, the flux data for Mercury, Venus, Mars, and Jupiter have been computed. The tabulated data for Earth were used to generate the entire model of the solar photon flux from 50 A to 3000 A for the top of the atmospheres of Venus and Mars.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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THE SOLAR FLUX INCIDENT AT THE TOP OF THE ATMOSPHERES OF EARTH AND NEIGHBORING PLANETS FOR THE SPECTRAL REGION 50 A TO 3000 A

E. D. Schultz and A. C. Holland

Most planetary atmospheric gases strongly absorb radiation below 3000 A. These absorptions often result in photoionization and/or photodissociation; so although the total flux below 3000 A is small, its effect on the aeronomic properties of the upper atmosphere such as chemical composition, atmospheric thermodynamics, atmospheric dynamics, terrestrial gas reflectivities, etc. is large. Accordingly, the distribution and absolute intensity of the solar flux for wavelengths below 3000 A is an important aeronomic parameter for systematic studies of planetary aeronomy such as are being performed at GCA under the present contract.

As a first step, the solar flux incident at the top of the Earth's atmosphere has been compiled for the spectral region 50 A to 3000 A.[(1)*] The compilation was based essentially on the work of K. Watanabe,[(2)] H. E. Hinteregger,[(3)] C. R. Detwiler *et al.*,[(4)] and F. S. Johnson.[(5)]

Between 50 A and 1850 A, the major emission lines were distinguished from the continuum and are presented separately. The continuum and weak lines are lumped together. The emission lines published by Watanabe[(2)]

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and by Detwiler et al.[4] were modified to reflect the most recent measurements by Hinteregger.[3] Beyond 1850 A, emission lines could not be resolved from the continuum. Below 283 A, the absence of emission lines merely reflects the lack of experimental data.

In the near ultraviolet, the data published by Johnson[5] and by Detwiler and co-workers[4] agree down to 2400 A; but at shorter wavelengths, they differ by a factor that reaches 2.0 at 2200 A. The two sets were joined at 2600 A using the method outlined in Table 1. In the far ultraviolet, the discrepancy between Detwiler and Watanabe was not consistent, and the two sets of data were arbitrarily joined at 1600 A. The top of Earth atmosphere solar photon flux from 50 A to 3000 A are reproduced from the original work[1] in Figures 1 through 5 to serve as a basis for calculating similar data for other planets. Tabulated values of how the tables and graphs were generated are given in Tables 1 and 2.

In all of the figures, the pure experimental data are plotted in two clear and unambiguous presentations of the tabulation to provide a convenient comparison of the contribution of major emission lines with the contribution of the continuum and weak lines. As indicated in the tabulation, some of the individual emission lines contain contributions from the same and/or other elements or unresolved multiplets.

To obtain the flux values at the top of the atmospheres of neighboring planets, intensity dilution factors are easily determined using an

TABLE 1

SOLAR PHOTON FLUX - CONTINUUM TO 3000Å
AT THE TOP OF EARTH ATMOSPHERE

Ref.: (a) 0-1625Å; K.Watanabe (see Atmospheric Processes, P.Nawrocki and R.Papa, Pergamon Press, 1962).

(b) 1525-2625Å; C.R.Detwiler et al., Ann. de Géophysique, 17, 263 (1961).

(c) 2525-3025Å; F.S.Johnson, J. Meteorol., 11, 431 (1954).

$\lambda \pm 25$Å	E/Photon$_\lambda$	Total Flux	Photon Flux
Å	ergs photon^{-1} (x 10^{-11})	ergs cm^{-2}sec^{-1}(50Å)$^{-1}$	photon cm^{-2}sec^{-1}(50Å)$^{-1}$ (x 10^{10})
(a) 50	52.963	0.056	0.0106
100	21.185	0.075	0.0354
150	13.619	0.085	0.0624
200	10.088	0.130	0.129
250	8.0246	0.135	0.168
300	6.6666	0.072	0.108
350	5.7037	0.025	0.0438
400	4.9847	0.025	0.0502
450	4.4272	0.025	0.0565
500	3.9822	0.028	0.0703
550	3.6186	0.030	0.0829
600	3.3159	0.030	0.0905
650	3.0601	0.030	0.0980
700	2.8409	0.030	0.106
750	2.6511	0.030	0.113
800	2.4850	0.040	0.161
850	2.3386	0.150	0.641
900	2.2085	0.167	0.756
950	2.0921	0.047	0.225
1000	1.9873	0.012	0.0604
1050	1.8926	0.028	0.148
1100	1.8065	0.079	0.437
1150	1.7278	0.144	0.833
1200	1.6558	0.185	1.12
1250	1.5895	0.150	0.943
1300	1.5283	0.125	0.818
1350	1.4717	0.150	1.02
1400	1.4191	0.175	1.23
1450	1.3701	0.250	1.82
1500	1.3244	0.350	2.64
1550	1.2817	0.450	3.51
1600	1.2414	0.580	4.67
(b) 1550	1.2817	1.36	10.6
1600	1.2414	3.20	25.8
1650	1.2038	4.69	39.0
1700	1.1684	8.20	70.2

TABLE 1 (continued)

SOLAR PHOTON FLUX - CONTINUUM TO 3000Å AT THE TOP OF EARTH ATMOSPHERE

$\lambda \pm 25$Å	E/Photon$_\lambda$	Total Flux	Photon Flux
Å	ergs photon^{-1} (x 10^{-11})	ergs cm^{-2}sec^{-1}(50Å)$^{-1}$	photon cm^{-2}sec^{-1}(50Å)$^{-1}$ (x 10^{13})
*1750	1.1350	12.0	0.106
1800	1.1034	18.4	0.167
1850	1.0736	28.0	0.261
1900	1.0454	40.9	0.391
1950	1.0186	55.0	0.540
2000	0.99310	70.0	0.705
2050	0.96888	90.0	0.929
2100	0.94581	145	1.53
2150	0.92381	240	2.60
2200	0.90282	310	3.43
2250	0.88276	350	3.96
2300	0.86357	360	4.17
2350	0.84519	320	3.79
2400	0.82758	340	4.11
2450	0.81069	390	4.81
2500	0.79448	380	4.78
2550	0.77890	560	7.19
2600	0.76392	700	9.16
(c)2550	0.77890	490	6.29
2600	0.76392	765	10.0
2650	0.74951	975	13.0
2700	0.73563	1115	15.2
2750	0.72225	1185	16.4
2800	0.70936	1325	18.7
2850	0.69691	1815	26.0
2900	0.68490	2510	36.6
2950	0.67329	3210	47.7
3000	0.66207	3140	47.4

*Reference (b) continued [note that at λ=1750Å, photon flux changes from (x10^{10}) to (x 10^{13})].

Total Flux $I_o = \int_{\lambda-25}^{\lambda+25} I_o(\lambda)d\lambda$; Photon Flux $Q = \dfrac{I_o}{\text{E/Photon}_\lambda}$;

$$\text{E/Photon}_\lambda\Big|_{\text{Ref.(a)}} = \overline{\text{E/Photon}_{\lambda\pm25}} = \frac{hc}{2}\left(\nu_{\lambda-25} + \nu_{\lambda+25}\right)\Big/\text{Photon}_\lambda \;;$$

$$\text{E/Photon}_\lambda\Big|_{\text{Ref.(b),(c)}} = \frac{hc}{\lambda}\Big/\text{Photon}_\lambda \;;\; hc = 1.9862\text{x}10^{-16} \text{ erg cm}$$

Where data overlaps, photon flux was determined as per example at 1600Å:

$$Q\Big|_{1550} = \left(2Q_{(a)1550} + Q_{(b)1550}\right)\Big/3$$

$$Q\Big|_{1600} = \left(Q_{(a)1600} + 2Q_{(b)1600}\right)\Big/3$$

$$Q\Big|_{1650} = Q_{(b)1600}\text{, etc.}$$

TABLE 2

SOLAR PHOTON FLUX - EMISSION LINES TO 1850Å AT THE TOP OF EARTH ATMOSPHERE

Ref.: (a) 520-1600Å; K Watanabe (see Atmospheric Processes, P.Nawrocki and R.Papa, Pergamon Press, 1962).

(b) 1600-1850Å; C.R.Detwiler *et al.*, Ann. de Géophysique, 17, 263 (1961).

†(c) 283-1215.7Å; H.E.Hinteregger *et al.*, Private Communication (flux measurements performed August 1961).

	λ	Identification	Mean λ in Group	E/Photon$_\lambda$	Flux	Photon Flux
	Å		Å	ergs photon^{-1} (x 10^{-11})	ergs cm^{-2} sec^{-1}	photon cm^{-2} sec^{-1} (x 10^{9})
†	283			7.0184	0.04	0.62
†	303.8	He II		6.5378	0.3	3.8
†	335			5.9290	0.03	0.48
†	368.1			5.3958	0.03	0.60
†	465.2			4.2696	0.01	0.30
†	500			3.9724	0.02	0.44
(a)	520	Si XII		3.8197	0.02	0.52
	537	He I		3.6988	0.01	0.27
†	554	O IV		3.5853	0.02	0.53
†	584.3	He I		3.3993	0.05	1.6
†	610	Mg X		3.2561	0.03	0.80
	625	Mg X		3.1780	0.01	0.31
†	629.7	O V		3.1542	0.04	1.4
	770,80	Ne VIII	775	2.5628	0.015	0.58
†	788,90	O IV	789	2.5174	0.01	0.37
†	833,35	O II, O III	834	2.3816	0.01	0.46
†	865,85*		875	2.2699	0.05	2.3
	935,45	S VI	940	2.1130	0.0004	0.019
	938	Ly ε		2.1175	0.005	0.24
†	949.7	Ly δ		2.0914	0.007	0.35
†	972.5	Ly γ		2.0423	0.01	0.47
†	977.0	C III		2.0330	0.08	4.0
	990*	N III	990	2.0063	0.02	1.0
	1011*	C II, etc.	1011	1.9646	0.005	0.25
†	1025.7	Ly β		1.9363	0.05	2.5
	1032,38	O VI	1035	1.9191	0.07	3.6
	1064,75*	S IV	1069.5	1.8570	0.02	1.1
	1085	N II		1.8306	0.06	3.3
	1110*	Si III, etc.	1112	1.7862	0.03	1.7
	1127*	Si III, etc.	1127	1.7624	0.02	1.1
	1134	N I		1.7515	0.01	0.57
	1140	C I		1.7423	0.02	1.1
	1152*	O I, etc.	1157	1.7167	0.04	2.3

*Indicates a blend of lines of the same and/or other elements or an unresolved multiplet.

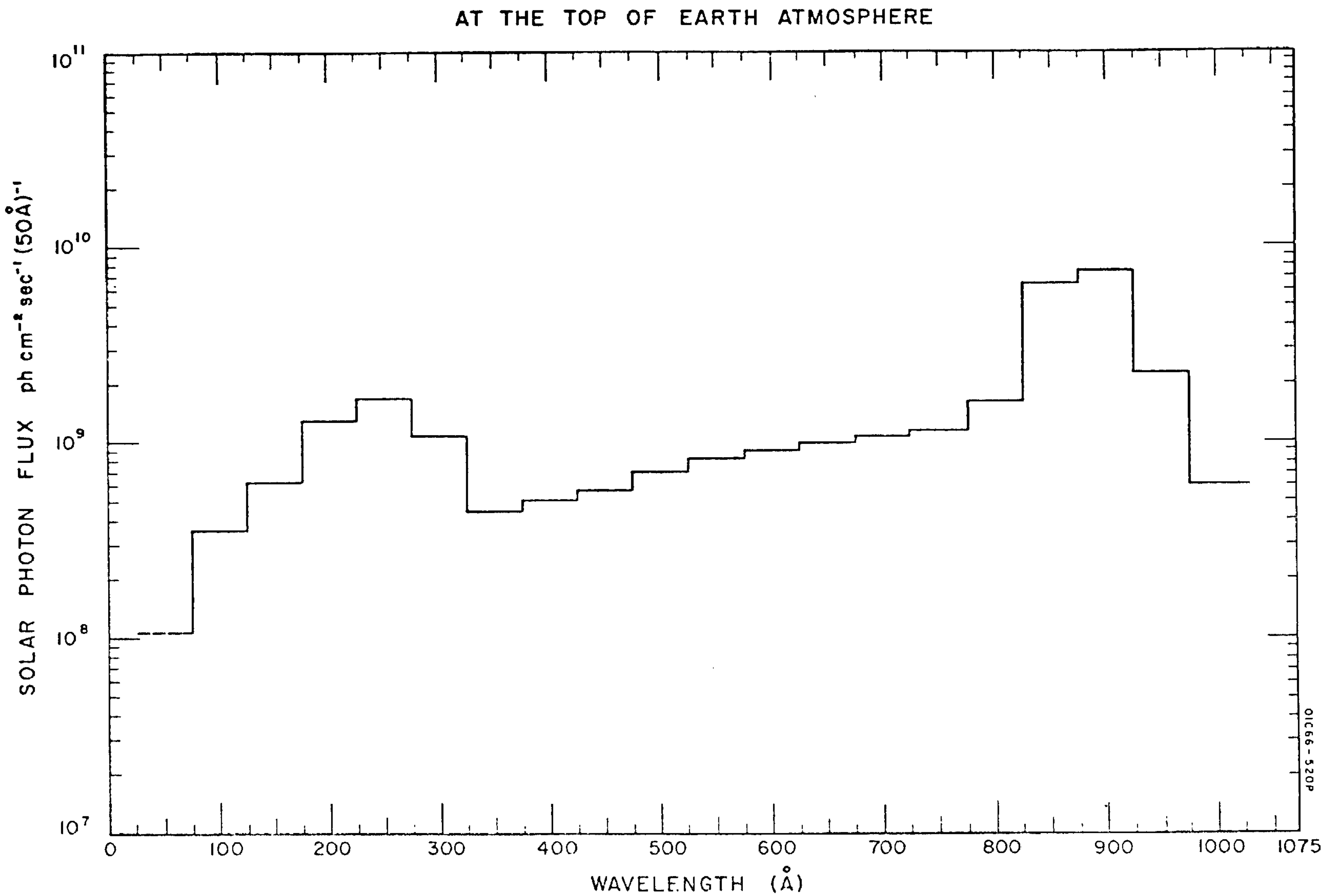
TABLE 2 (continued)

SOLAR PHOTON FLUX - EMISSION LINES TO 1850Å AT THE TOP OF EARTH ATMOSPHERE

λ	Identification	Mean λ in Group	E/Photon$_\lambda$	Flux	Photon Flux
Å		Å	ergs photon^{-1} (x 10^{-11})	ergs cm^{-2} sec^{-1}	photon cm^{-2} sec^{-1} (x 10^{9})
1170*		1170	1.6976	0.03	1.8
1175	C III		1.6904	0.15	8.8
1190*		1191	1.6677	0.02	1.2
1200	N I		1.6552	0.02	1.2
† 1206.5	Si III		1.6462	0.08	5.1
† 1215.7	Ly α		1.6338	5.0	310
1239	N V		1.6031	0.03	1.9
1243*	N V	1245	1.5954	0.03	1.9
1260*	S II	1258	1.5789	0.03	1.9
1263*	Si II	1265	1.5702	0.04	2.5
1277*		1277	1.5554	0.03	1.9
1294*		1294	1.5350	0.04	2.6
1302,05,06	O 1	1304.5	1.5225	0.18	12
1320*		1320	1.5047	0.06	4.0
1335,36	C II	1335.5	1.4872	0.30	20
1335*	O I, etc.	1335	1.4659	0.05	3.4
1394	Si IV		1.4249	0.12	8.4
1403	Si IV		1.4157	0.08	5.6
1430*	S I, etc.	1430	1.3890	0.03	2.2
1462*		1462	1.3586	0.03	2.2
1480*	S I, etc.	1482	1.3403	0.05	3.7
1527,33	Si II	1530	1.2982	0.07	5.4
1548	C IV		1.2831	0.17	13
1551	C IV		1.2806	0.12	9.3
1560*	C I, etc.	1559	1.2741	0.10	7.8
(b)1640.5	He II		1.2108	0.07	5.8
1657.0	C I		1.1987	0.16	13
1670.8	Al II		1.1888	0.08	6.7
1808.0	Si II		1.0986	0.15	14
1817.4	Si II		1.0929	0.45	41

*Indicates a blend of lines of the same and/or other elements or an unresolved multiplet.

For definitions and equations, refer to the discussion following the continuum tabulation (see page 5).

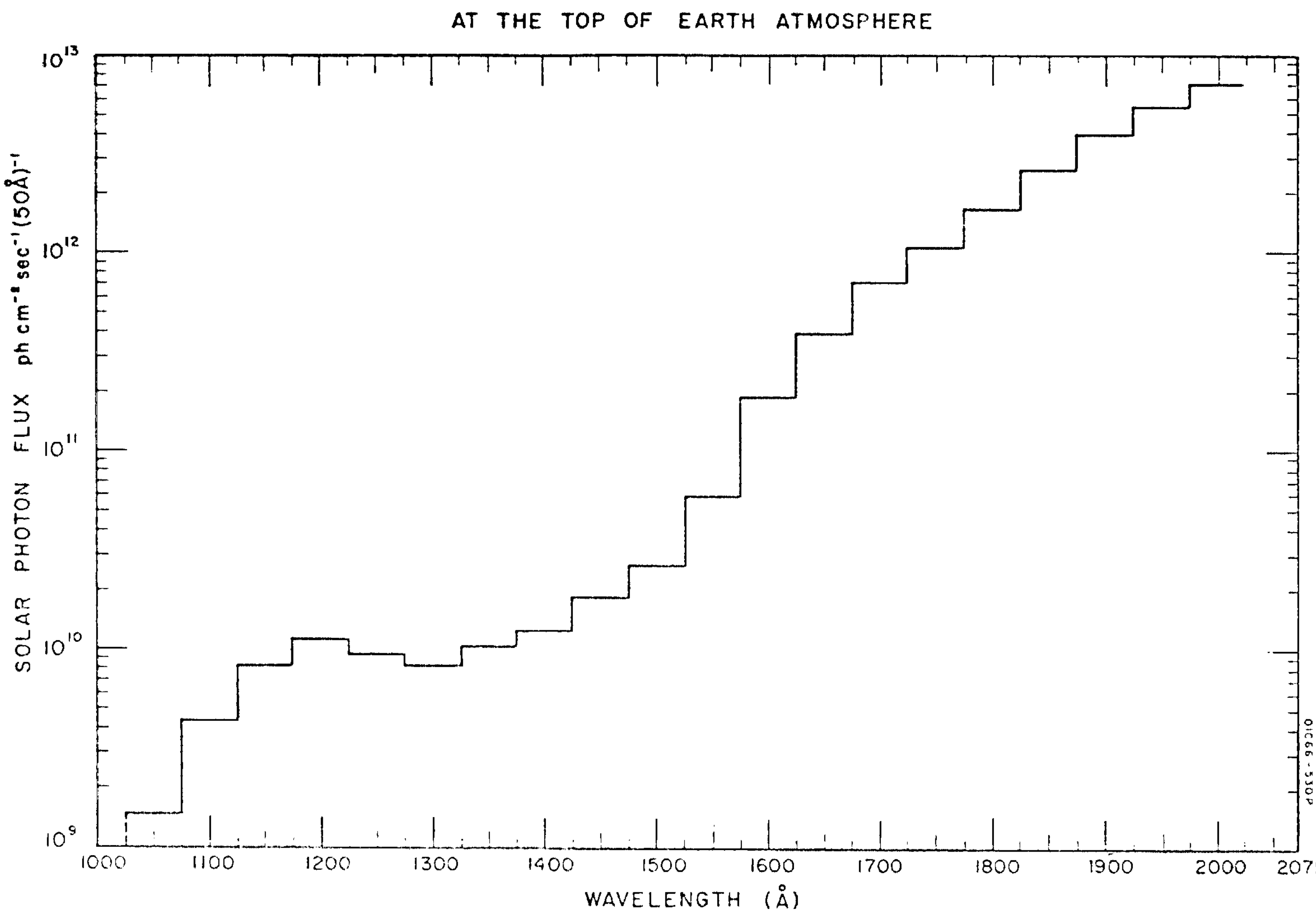


SOLAR PHOTON FLUX – CONTINUUM TO 1000 Å

REF.: SEE TABULATION

ACCURACY: 25 – 1025 Å, K. WATANABE, ± x3

Figure 1.



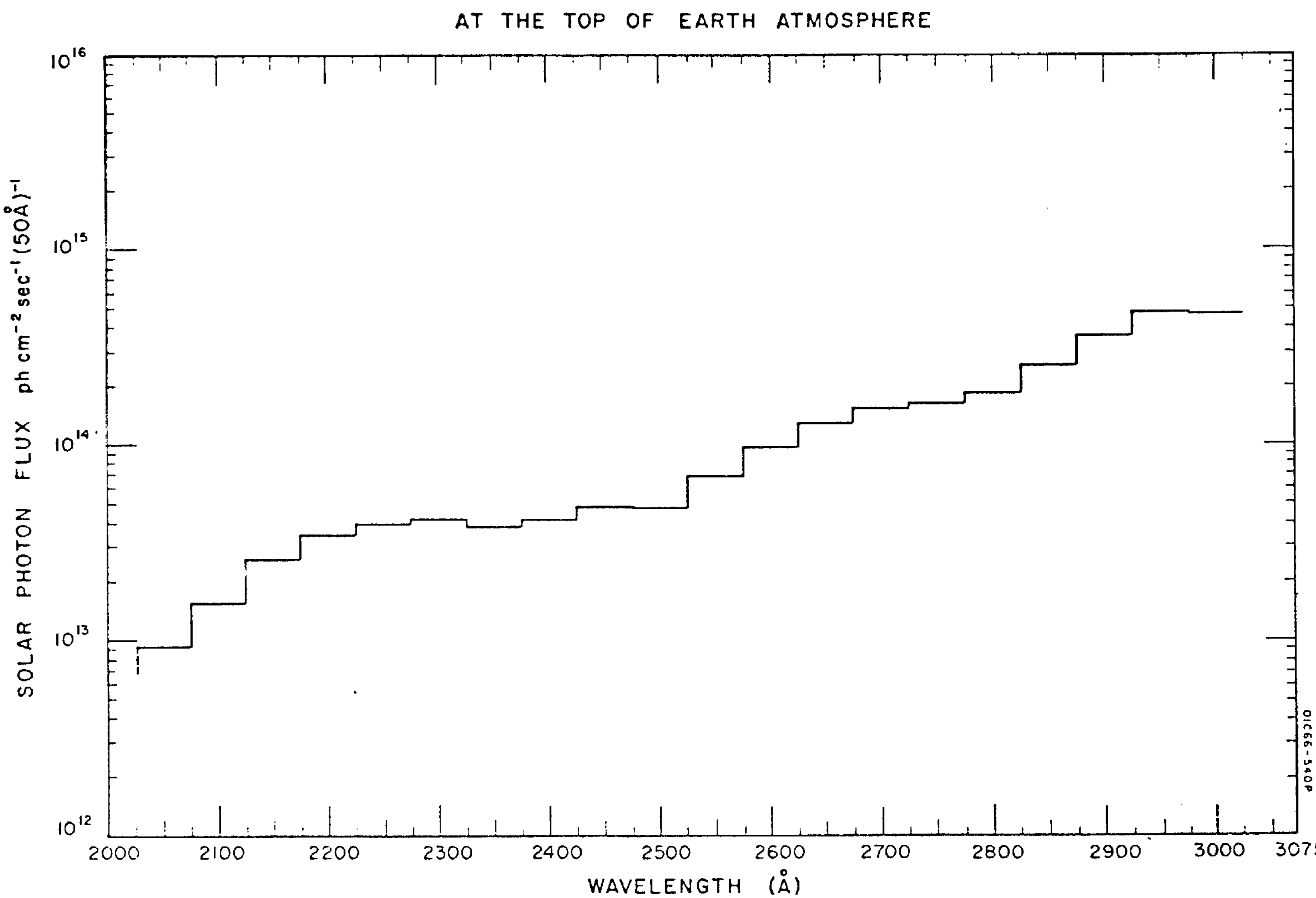
SOLAR PHOTON FLUX – CONTINUUM 1000 – 2000 Å

REF.: SEE TABULATION

ACCURACY: 1025 – 1625 Å, K. WATANABE, ±3

1525 – 2025 Å, C. R. DETWILER et al., ± ×1.2 – ± ×2

Figure 2.

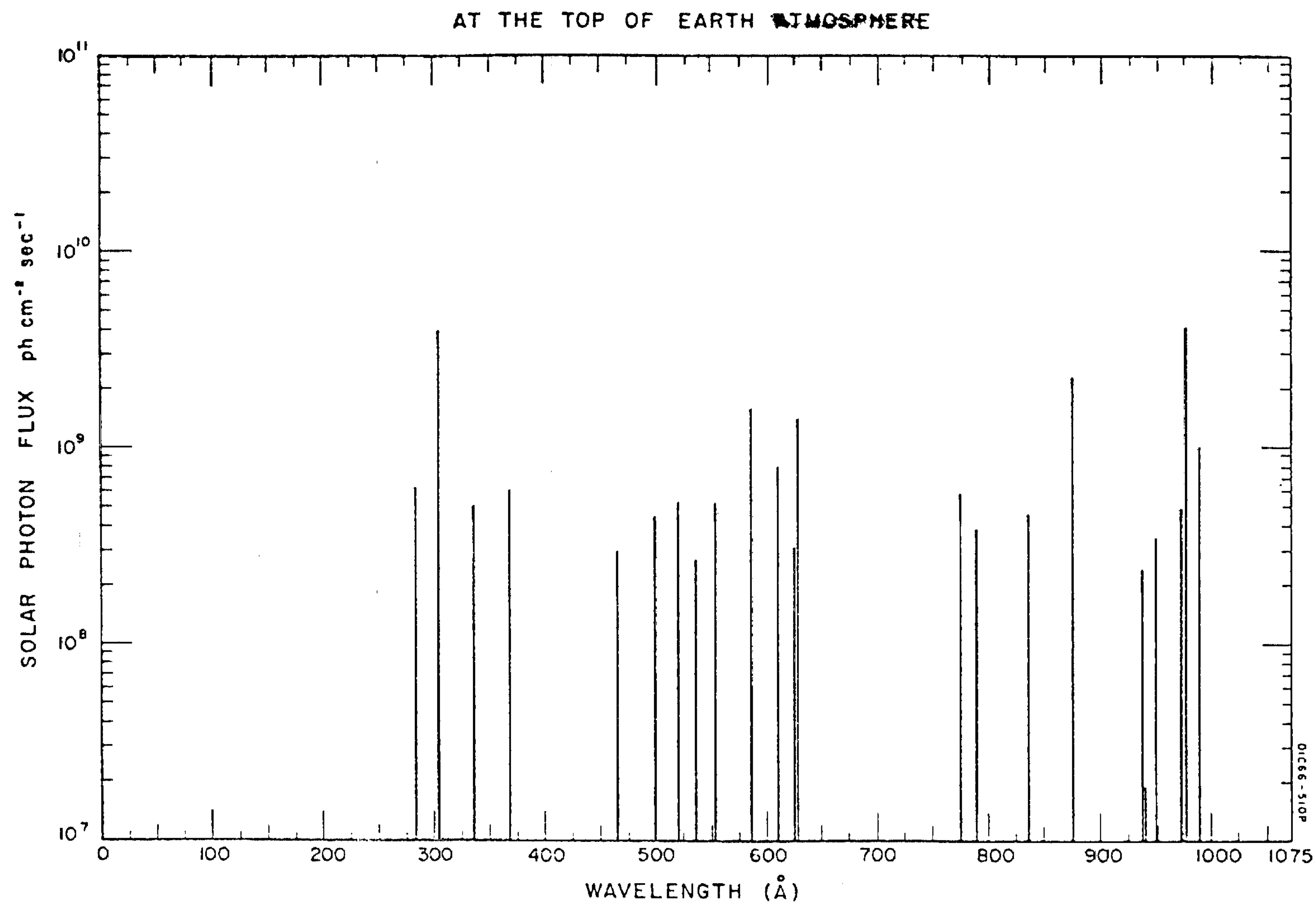


SOLAR PHOTON FLUX - CONTINUUM 2000-3000 Å

REF.: SEE TABULATION

ACCURACY: 2025 - 2625A, C.R. DETWILER et al., ± 1.2 - ± 1.5
2525 - 3025A, F.S. JOHNSON, ± 10 %

Figure 3.

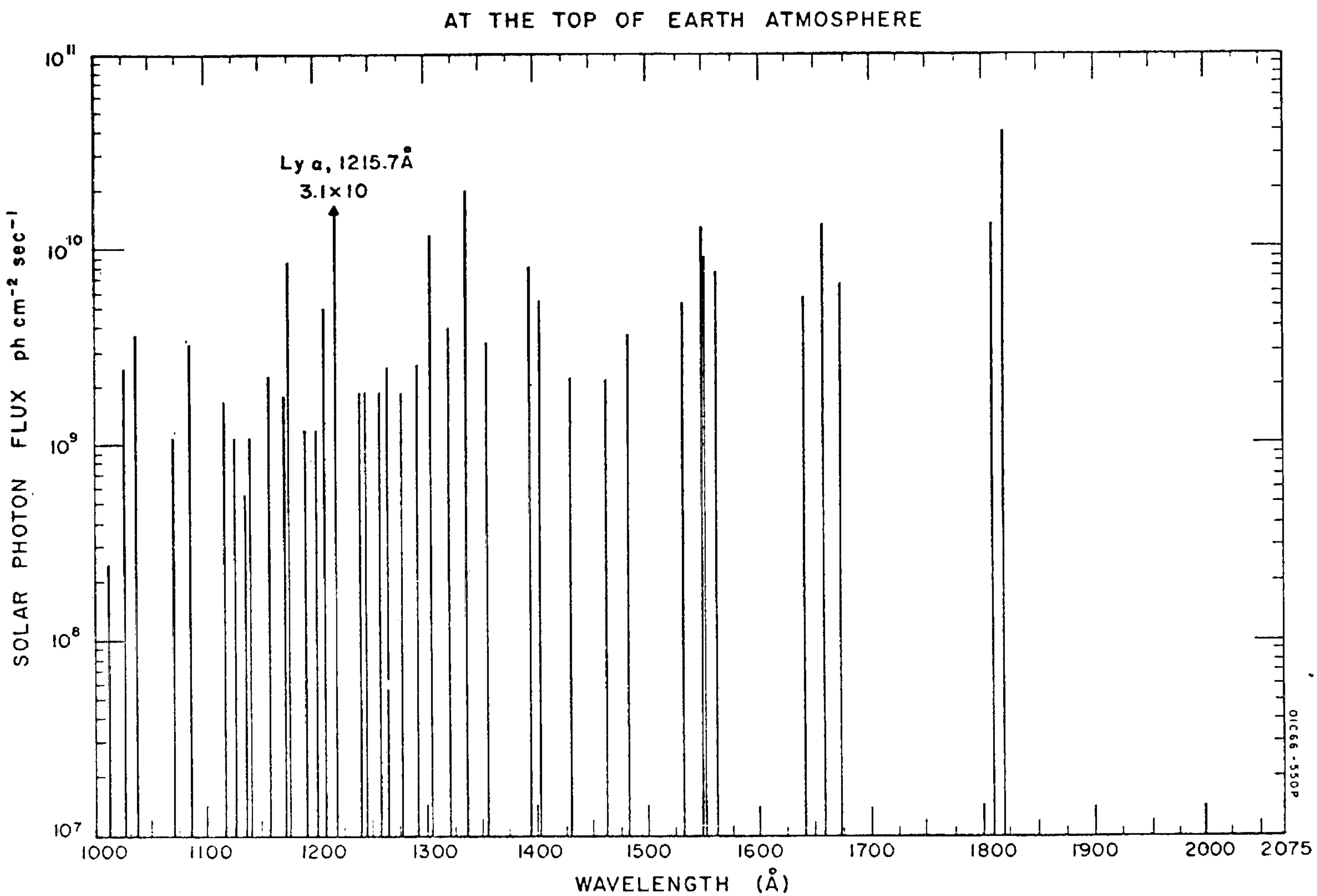


SOLAR PHOTON FLUX - EMISSION LINES TO 1000 Å

REF.: SEE TABULATION

ACCURACY: 283 - 1000 Å, H.E. HINTEREGGER et al.; ±10 - ±25%
520 - 1000 Å, K. WATANABE, ±×2 - ±×5

Figure 4.



SOLAR PHOTON FLUX – EMISSION LINES 1000-1850Å

REF.: SEE TABULATION

ACCURACY: 1000 – 1215.7Å, H.E. HINTEREGGER et al., ± 10 %
1000 – 1600Å, K. WATANABE, ± ×2 – ± ×5
1600 – 1850Å, C.R. DETWILER et al., ± ×1.2 – ± ×2

Figure 5.

inverse square relation based on mean radius vector magnitudes. These data appear in Table 3. For convenient reference the flux data for Mercury, Venus, Mars and Jupiter have been computed and are included with values for Earth in Tables 4 and 5. The previously discussed tabulated data for Earth were used as a base to generate the entire model of the solar photon flux from 50 A to 3000 A for the top of the atmospheres of Venus and Mars.

It should be emphasized that the intensity dilution factors are average values. Variation in these factors due to orbital eccentricities alone are shown in Table 6 for the cases of Venus, Earth and Mars. Furthermore, the variation in the factor for Earth reflects itself in additional variance in the factors for other planets, since the original intensity data were obtained at Earth for an assumed radius vector of 1 A.U. However, for present purposes, the simplifying assumption of zero eccentricity of Earth's orbit is justified since the experimental errors and/or the real time variation of flux may exceed variations due to the Earth's orbit eccentricity.

Inasmuch as the eccentricity of Venus' orbit is less than that for Earth, we may also consider that variance as negligible. In the case of Mars, however, such an approximation cannot be made. When the eccentricities for Earth and Mars are coupled, the resulting variation in the dilution factor for the latter can reach as high as 45 percent.

TABLE 3

INTENSITY DILUTION FACTORS (μ) FOR PLANETS

*Ref.: "Space Technology" (H.S. Seifert, ed.) pp.8-08,09, John Wiley and Sons, Inc., London (1959).

Planet	*Eccentricity	*Mean Distance (a) from Sun (A.U.)	a^2	μ
Mercury	0.2056259	0.387099	0.149846	6.6735
Venus	0 0067935	0.723332	0.523209	1.9113
Earth	0.0167272	1.000000	1.000000	1.0000
Mars	0.0933654	1.523691	2.321634	0.43073
Jupiter	0.0484305	5.202803	27.069159	0.03694
Saturn	0.0556922	9.538843	90.989526	0.01099
Uranus	0.0472012	19.181973	367.948088	0.002718
Neptune	0.0085724	30.057707	903.465750	0.001107
Pluto	0.2486438	39.517740	1561.651770	0.000640

I = Intensity of Solar Radiation incident at top of planetary atmosphere.

μ is defined as follows:

$$I_E = ka_E^{-2} \,, \quad I_p = ka_p^{-2}$$

$$\frac{I_p}{I_E} = \frac{a_p^{-2}}{a_E^{-2}} = \left(\frac{a_E}{a_p}\right)^2 , \text{ where } \quad a_E^2 \approx$$

$$\frac{I_p}{I_E} = \mu_p = \frac{1}{a_p^2}$$

TABLE 4

SOLAR PHOTON FLUX - CONTINUUM TO 3000Å

AT THE TOP OF THE ATMOSPHERES OF SOME PLANETS

Equations, definitions, references and additional data are included in the separate tabulation for the case of earth.

$\lambda \pm 25$Å	PHOTON FLUX				
Å	photons cm^{-2} sec^{-1} $(50Å)^{-1}$				
$(a_o^2/a_p^2) =$	Mercury 6 6735	Venus 1.9113	Earth 1.0000	Mars 0.43073	Jupiter 0.03694
50	0.0707×10^{10}	0.0202×10^{10}	0.0106×10^{10}	0.00456×10^{10}	0.0392×10^{8}
100	0.236	0.0677	0.0354	0.0152	0.131
150	0.416	0.119	0.0624	0.0269	0.230
200	0.861	0.246	0.129	0.0556	0.476
250	1.12	0.321	0.168	0.0724	0.620
300	0.721	0.206	0.108	0.0465	0.399
350	0.292	0.0837	0.0438	0.0189	0.162
400	0.335	0.0959	0.0502	0.0216	0.185
450	0.377	0.108	0.0565	0.0243	0.209
500	0.469	0.134	0.0703	0.0303	0.260
550	0.553	0.158	0.0829	0.0357	0.306
600	0.604	0.173	0.0905	0.0390	0.334
650	0.654	0.187	0.0980	0.0422	0.362
700	0.707	0.202	0.106	0.0456	0.392
750	0.754	0.216	0.113	0.0487	0.417
800	1.07	0.308	0.161	0.0693	0.595
850	4.28	1.22	0.641	0.276	2.37
900	5.04	1.44	0.756	0.326	2.79
950	1.50	0.430	0.225	0.0969	0.831
1000	0.403	0.115	0.0604	0.0260	0.223
1050	0.988	0.283	0.148	0.0637	0.547
1100	2.92	0.835	0.437	0.188	1.61

TABLE 4 (continued)

SOLAR PHOTON FLUX - CONTINUUM TO 3000Å

AT THE TOP OF THE ATMOSPHERES OF SOME PLANETS

Equations, definitions, references and additional data are included in the separate tabulation for the case of earth.

$\lambda \pm 25$Å	PHOTON FLUX				
Å	photons cm^{-2} sec^{-1} $(50Å)^{-1}$				
	Mercury	Venus	Earth	Mars	Jupiter
1150	5.56×10^{10}	1.59×10^{10}	0.833×10^{10}	0.359×10^{10}	3.08×10^{8}
1200	7.47	2.14	1.12	0.482	4.14
1250	6.29	1.80	0.943	0.406	3.48
1300	5.46	1.56	0.818	0.352	3.02
1350	6.81	1.95	1.02	0.439	3.77
1400	8.21	2.35	1.23	0.530	4.54
1450	12.1	3.48	1.82	0.784	6.72
1500	17.6	5.04	2.64	1.14	9.75
1550	39.2	11.2	5.87	2.53	21.7
1600	0.0125×10^{14}	35.8	18.76	8.08	69.3
1650	0.0260	74.5	39.0	16.8	0.0144×10^{12}
1700	0.0468	0.134×10^{13}	70.2	30.2	0.0259
1750	0.0707	0.202	0.106×10^{13}	45.6	0.0392
1800	0.111	0.319	0.167	71.9	0.0617
1850	0.174	0.499	0.261	0.112×10^{13}	0.0964
1900	0.261	0.747	0.391	0.168	0.144
1950	0.360	1.03	0.540	0.232	0.199
2000	0.470	1.35	0.705	0.304	0.260
2050	0.620	1.78	0.929	0.400	0.343
2100	1.02	2.92	1.53	0.659	0.565
2150	1.74	4.97	2.60	1.12	0.960
2200	2.29	6.56	3.43	1.48	1.27
2250	2.64	7.57	3.96	1.70	1.46

TABLE 4 (continued)

SOLAR PHOTON FLUX - CONTINUUM TO 3000Å

AT THE TOP OF THE ATMOSPHERES OF SOME PLANETS

Equations, definitions, references and additional data are included in the separate tabulation for the case of earth.

$\lambda \pm 25$Å	PHOTON FLUX				
Å	photons cm^{-2} sec^{-1} $(50Å)^{-1}$				
	Mercury	Venus	Earth	Mars	Jupiter
2300	2.78×10^{14}	7.97×10^{13}	4.17×10^{13}	1.80×10^{13}	1.54×10^{12}
2350	2.53	7.24	3.79	1.63	1.46
2400	2.74	7.86	4.11	1.77	1.52
2450	3.21	9.19	4.81	2.07	1.78
2500	3.19	9.14	4.78	2.06	1.76
2550	4.80	13.2	6.89	2.97	2.54
2600	4.60	18.6	9.72	4.19	3.59
2650	6.49	24.8	13.0	5.60	4.80
2700	10.1	29.0	15.2	6.55	5.61
2750	10.9	31.3	16.4	7.06	6.06
2800	12.5	35.7	18.7	8.05	6.91
2850	17.4	49.7	26.0	11.2	9.60
2900	24.4	70.0	36.6	15.8	13.5
2950	31.8	91.2	47.7	20.5	17.6
3000	31.6	90.6	47.4	20.4	17.5

For each planet, the incident photon flux, I_p, was calculated for the planet's mean distance from the sun, a_p, by the relation

$$I_p = \left(\frac{a_o}{a_p}\right)^2 I_o$$

where subscript o refers to earth and $a_o = 1.000\ 000$

TABLE 5

SOLAR PHOTON FLUX - EMISSION LINES TO 1850Å

AT THE TOP OF THE ATMOSPHERES OF SOME PLANETS

Equations, definitions, references and additional data are included in the continuum discussion and in the separate tabulation for the case of earth.

λ	Identification	Photon Flux				
Å		photons cm^{-2} sec^{-1}				
		Mercury ($\times 10^{10}$)	Venus ($\times 10^{9}$)	Earth ($\times 10^{9}$)	Mars ($\times 10^{9}$)	Jupiter ($\times 10^{8}$)
283		0.41	1.2	0.62	0.27	0.23
303.8	He II	2.5	7.3	3.8	1.6	1.4
335		0.32	0.92	0.48	0.21	0.18
368.1		0.40	1.1	0.60	0.26	0.22
465.2		0.20	0.57	0.30	0.13	0.11
500		0.29	0.84	0.44	0.19	0.16
520	Si XII	0.35	0.99	0.52	0.22	0.19
537	He I	0.18	0.52	0.27	0.12	0.10
554	O IV	0.35	1.0	0.53	0.23	0.20
584	He I	1.1	3.0	1.6	0.69	0.59
610	Mg X	0.53	1.5	0.80	0.34	0.30
625	Mg X	0.21	0.59	0.31	0.13	0.11
629.7	O V	0.93	2.7	1.4	0.60	0.52
770, 80	Ne VIII	0.39	1.1	0.58	0.25	0.21
788, 90	O IV	0.25	0.71	0.37	0.16	0.14
833, 35	O II, O III	0.31	0.88	0.46	0.20	0.17
865, 85		1.5	4.4	2.3	0.99	0.85
935, 45	S VI	0.013	0.036	0.019	0.0082	0.0070
938	Ly ε	0.16	0.46	0.24	0.10	0.089
949.7	Ly δ	0.23	0.67	0.35	0.15	0.13
972.5	Ly γ	0.31	0.90	0.47	0.20	0.17
977.0	C III	2.7	7.6	4.0	1.7	1.5
990	N III	0.67	1.9	1.0	0.43	0.37
1011	C II, etc.	0.17	0.48	0.25	0.11	0.092
1025.7	Ly β	1.7	4.8	2.5	1.1	0.92
1032, 38	O VI	2.4	6.9	3.6	1.6	1.3
1064, 75	S IV	0.73	2.1	1.1	0.47	0.41
1085	N II	2.2	6.3	3.3	1.4	1.2
1110	Si III, etc.	1.1	3.2	1.7	0.73	0.63
1127	Si III, etc.	0.73	2.1	1.1	0.47	0.41
1134	N I	0.38	1.1	0.57	0.24	0.21
1140	C I	0.73	2.1	1.1	0.47	0.41
1152	O I, etc.	1.5	4.4	2.3	0.99	0.85

TABLE 5 (continued)

SOLAR PHOTON FLUX-EMISSION LINES TO 1850Å

AT THE TOP OF THE ATMOSPHERES OF SOME PLANETS

λ	Identification	Photon Flux				
Å		photons cm^{-2} sec^{-1}				
		Mercury ($\times 10^{10}$)	Venus ($\times 10^{9}$)	Earth ($\times 10^{9}$)	Mars ($\times 10^{9}$)	Jupiter ($\times 10^{8}$)
1170	•	1.2	3.4	1.8	0.78	0.66
1175	C III	5.9	17	8.8	3.8	3.2
1190		0.80	2.3	1.2	0.52	0.44
1200	N I	0.80	2.3	1.2	0.52	0.44
1206.5	Si III	3.4	9.7	5.1	2.2	1.9
1215.7	Ly α	207	592	310	134	114
1239	N V	1.3	3.6	1.9	0.82	0.70
1243	N V	1.3	3.6	1.9	0.82	0.70
1260	S II	1.3	3.6	1.9	0.82	0.70
1263	Si II	1.7	4.8	2.5	1.1	0.92
1277		1.3	3.6	1.9	0.82	0.70
1294		1.7	5.0	2.6	1.1	0.96
1302, 05, 06	O I	8.0	23	12	5.2	4.4
1320		2.7	7.6	4.0	1.7	1.5
1335, 36	C II	13	38	20	8.6	7.4
1355	O I, etc.	2.3	6.5	3.4	1.5	1.2
1394	Si IV	5.6	16	8.4	3.6	3.1
1403	Si IV	3.7	11	5.6	2.4	2.1
1430	SI, etc.	1.5	4.2	2.2	0.95	0.81
1462		1.5	4.2	2.2	0.95	0.81
1480	SI, etc.	2.5	7.1	3.7	1.6	1.4
1527, 33	Si II	3.6	10	5.4	2.3	2.0
1548	C IV	8.7	25	13	5.6	4.8
1551	C IV	6.2	18	9.3	4.0	3.4
1560	C I, etc.	5.2	15	7.8	3.4	2.9
1640.5	He II	3.9	11	5.8	2.5	2.1
1657.0	C I	8.7	25	13	5.6	4.8
1670.8	Al II	4.5	13	6.7	2.9	2.5
1808.0	Si II	9.3	27	14	6.0	5.2
1817.4	Si II	27	78	41	18	15

TABLE 6

VARIATION OF INTENSITY DILUTION FACTORS

Planet	R (perihelion) (A.U.)	R (aphelion) (A.U.)	Variation of R	μ_{min}	μ_{max}	Variation of μ
Venus	0.718	0.728	± 0.7%	1.886	1.938	2.7%
Earth	0.983	1.017	± 1.7%	0.967	1.034	6.8%
Mars	1.381	1.666	± 9.3%	0.360	0.524	38.1%

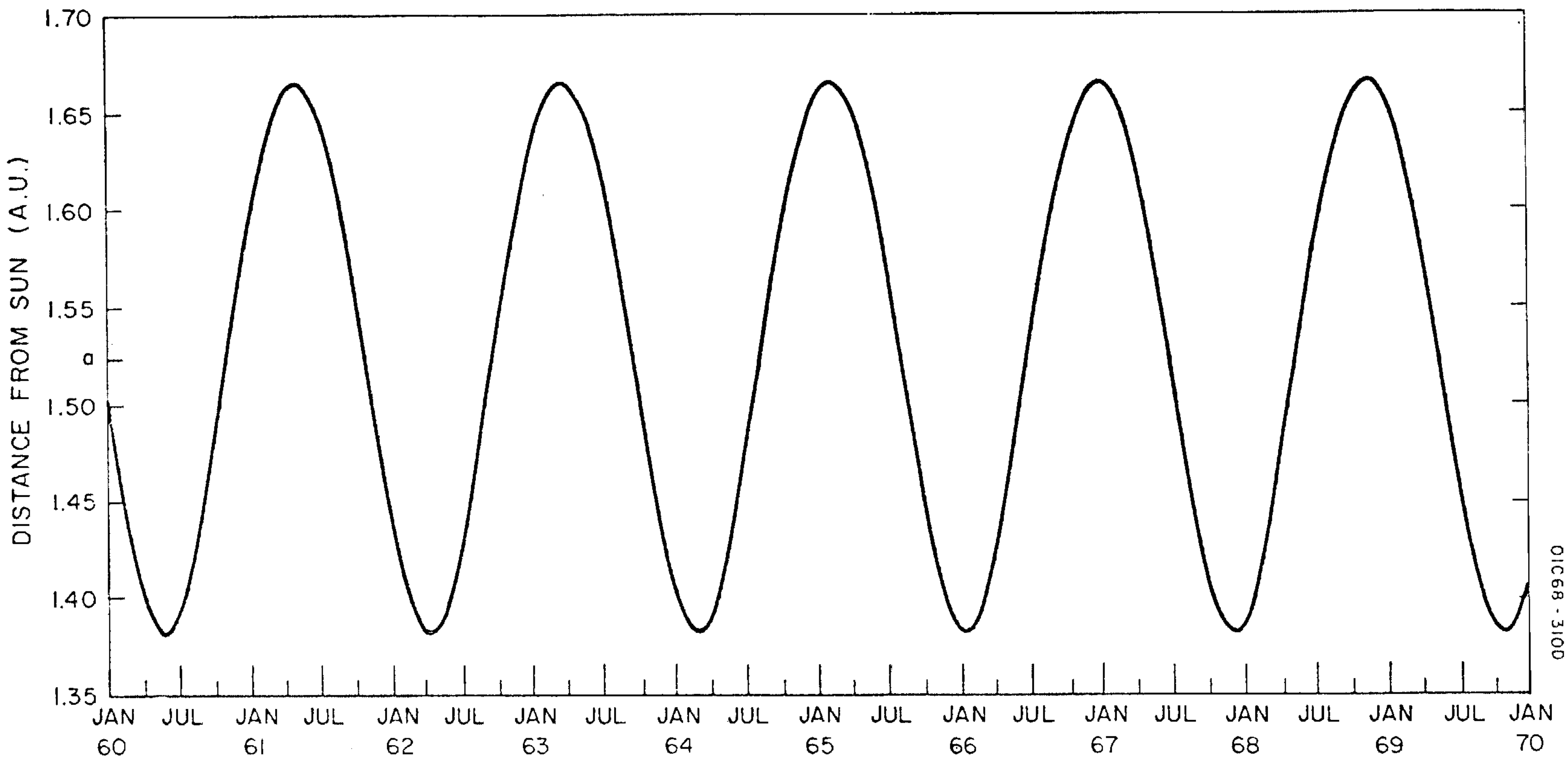
R = magnitude of radius vector

Figure 6 is a plot of the magnitude of the radius vector of Mars for the decade 1960 - 1970. Figures 7 through 16 can be conveniently employed for the solar flux incident in the top of the atmospheres of Venus and Mars.

Additional variations due to other factors such as the variance of solar activity throughout the eleven-year cycle and the solar flares and prominences are present during which strong UV and X radiation have been observed. However, at present these factors cannot be taken into account in any meaningful manner.

Finally, a comparison of the different sources of data was not attempted here; discussions of individual methods and experimental errors can be obtained at the sources. It is important to emphasize the limitations of this presentation, but at the same time recognize its value for certain investigations. While the numerical values in the model may change as more experimental measurements are made, the essential format of the model should remain.

Geophysics Corporation of America
Bedford, Massachusetts
November 1962



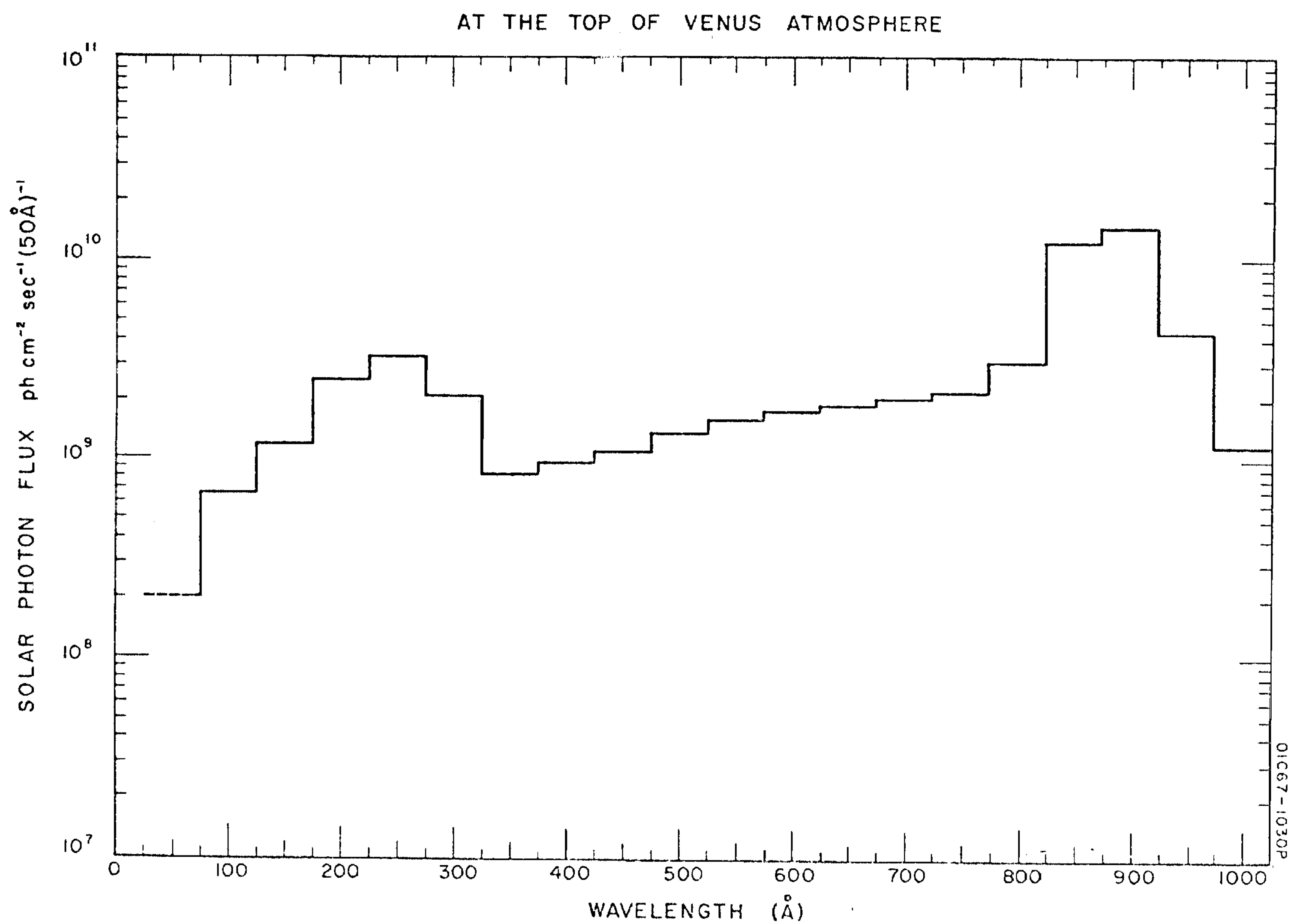
TIME VARIATION OF THE RADIUS VECTOR OF MARS

0^h 1 JAN 60 to 0^h 1 JAN 70 U.T.

REF: "PLANETARY CO-ORDINATES...1960-1980", H.M. NAUTICAL ALMANAC OFFICE, 1958. REFERRED TO THE EQUINOX OF 1950-0

a = 1.523691 A.U., MEAN DISTANCE
1 A.U. = 1.495×10^6 km = 92.9×10^6 miles
e = 0.093371, ECCENTRICITY

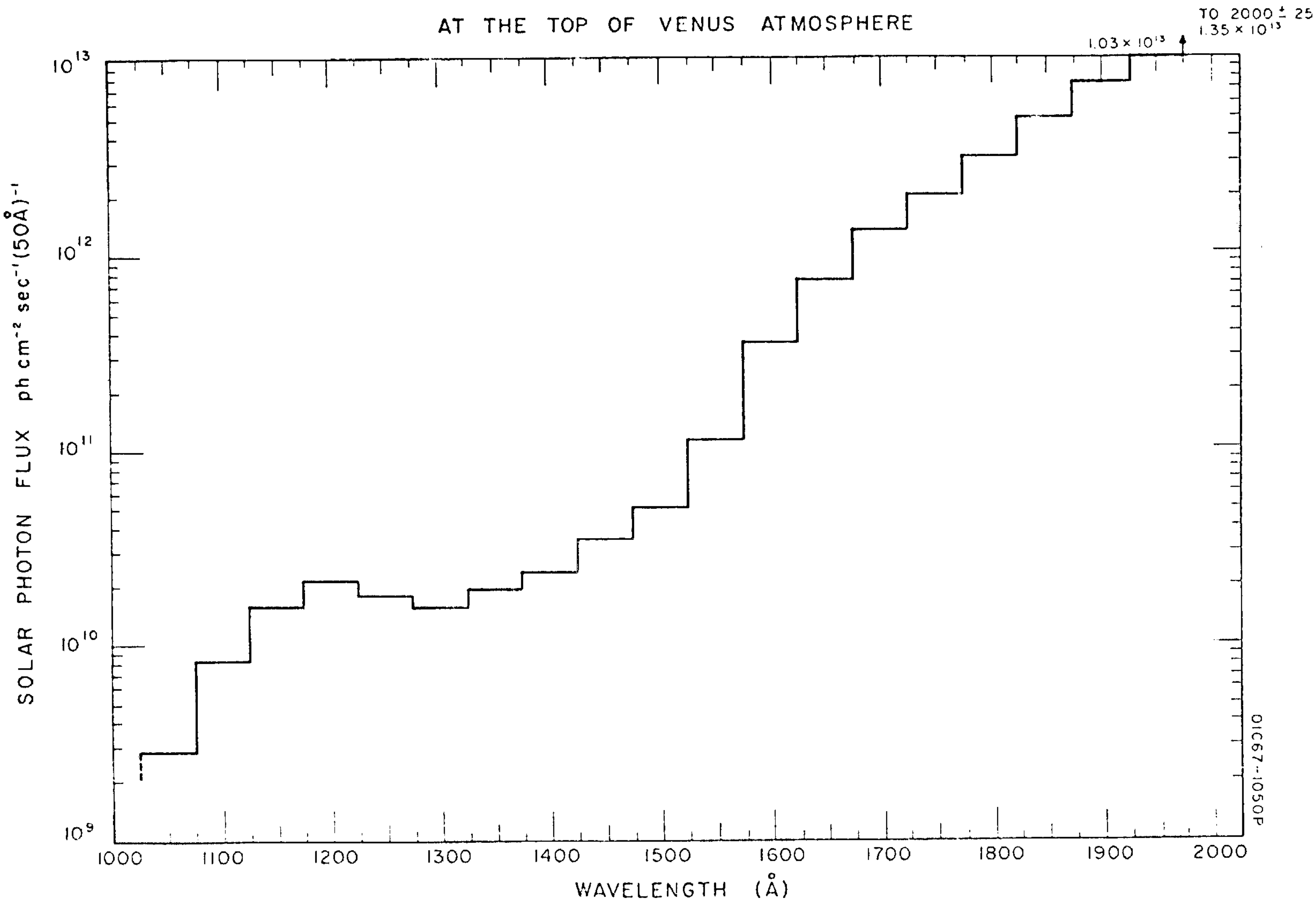
Figure 6.



SOLAR PHOTON FLUX - CONTINUUM TO 1000 Å

REF. AND ACCURACY: SEE SEPARATE STUDY FOR EARTH

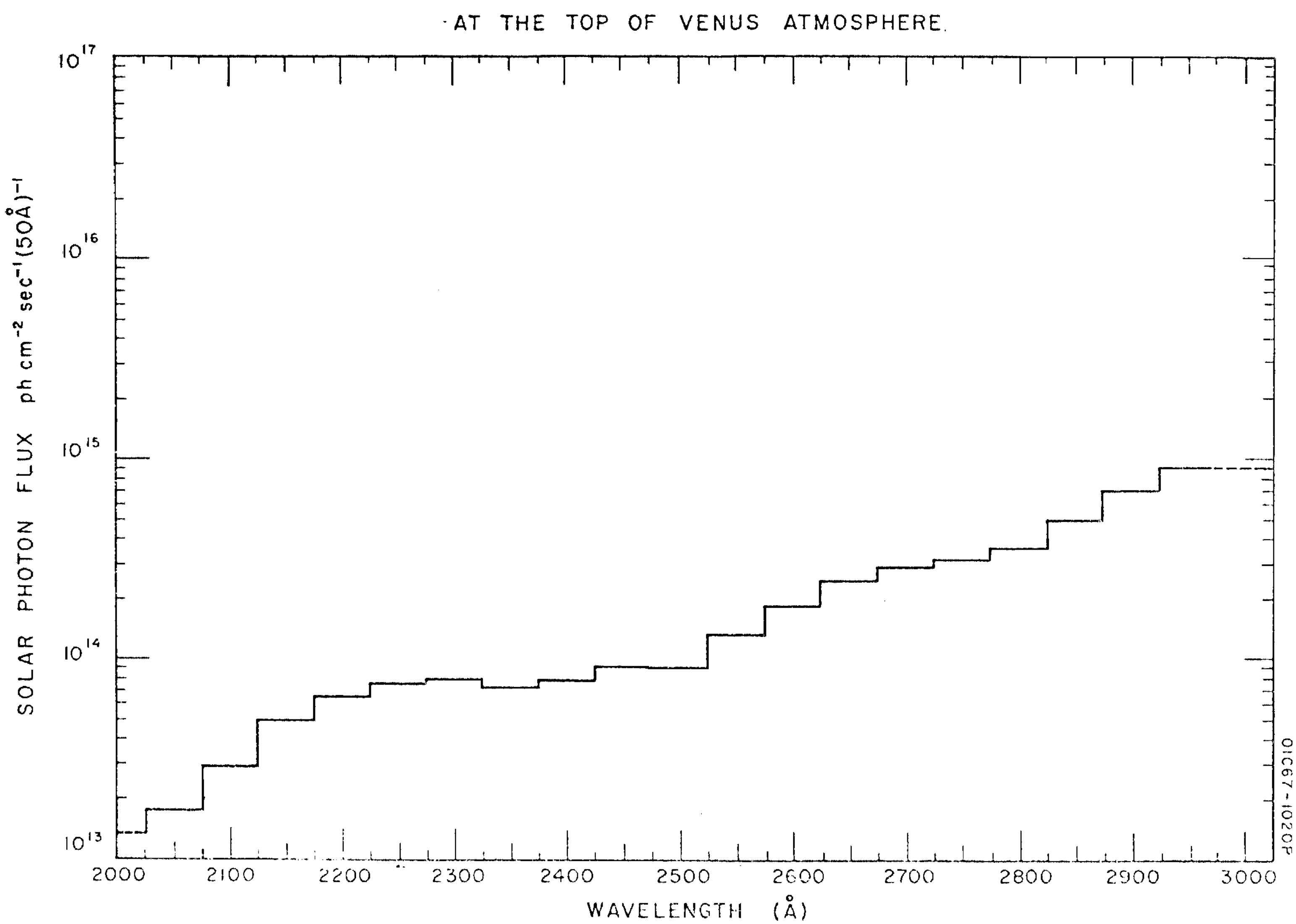
Figure 7.



SOLAR PHOTON FLUX – CONTINUUM 1000 – 2000 Å

REF. AND ACCURACY: SEE SEPARATE STUDY FOR EARTH

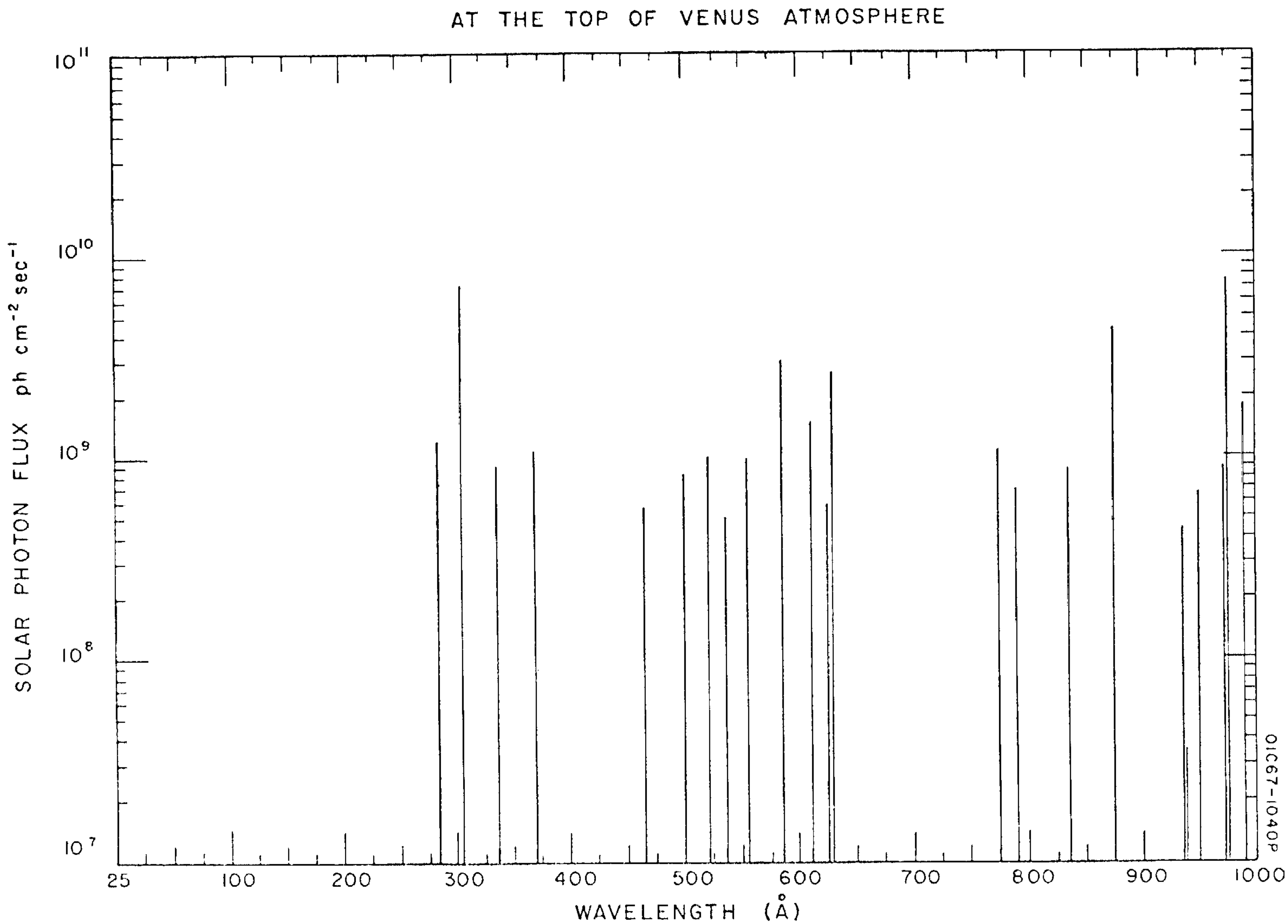
Figure 8.



SOLAR PHOTON FLUX -- CONTINUUM 2000 - 3000 Å

REF. AND ACCURACY: SEE SEPARATE STUDY FOR EARTH

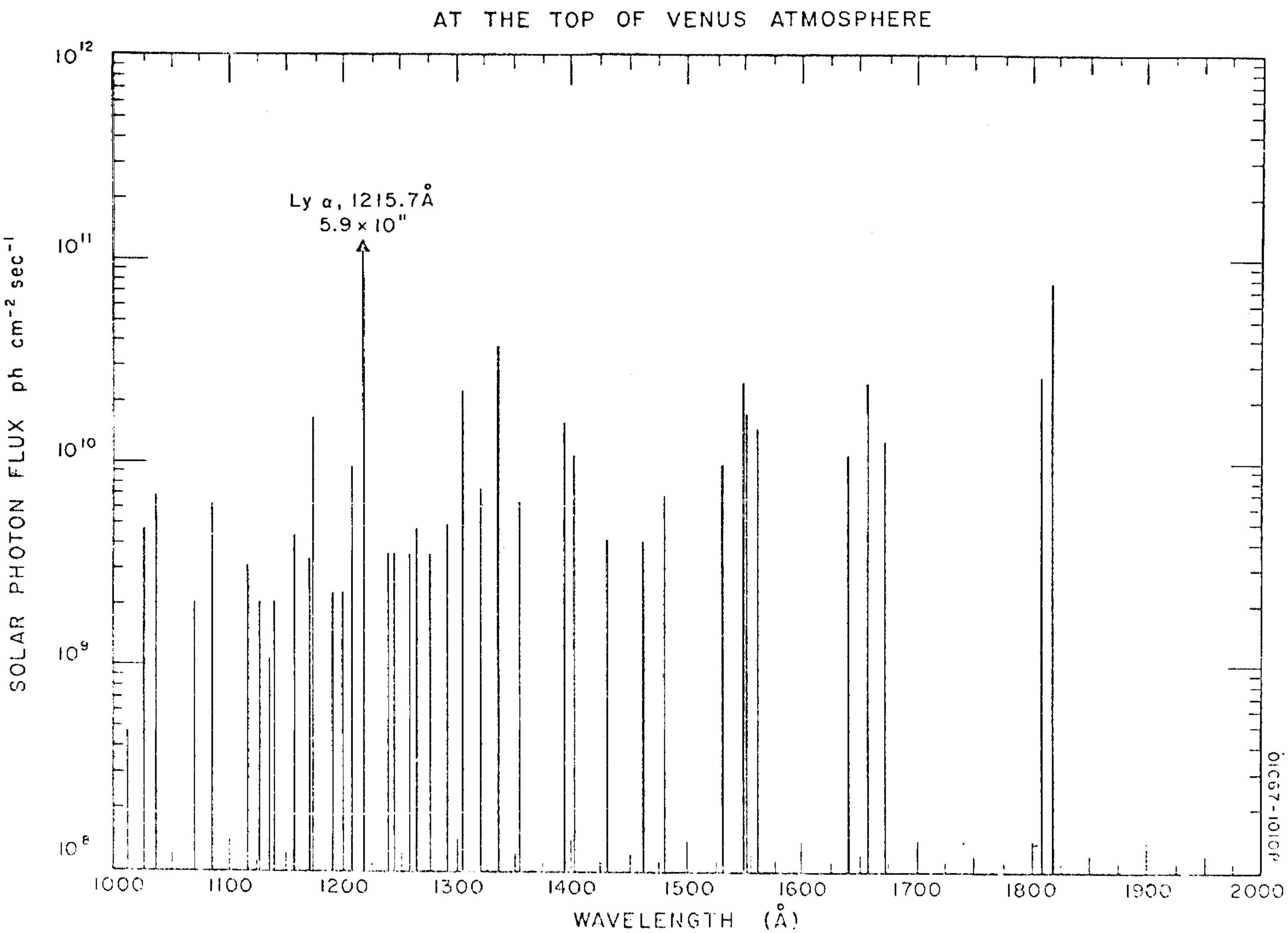
Figure 9.



SOLAR PHOTON FLUX -- EMISSION LINES TO 1000 Å

REF. AND ACCURACY: SEE SEPARATE STUDY FOR EARTH

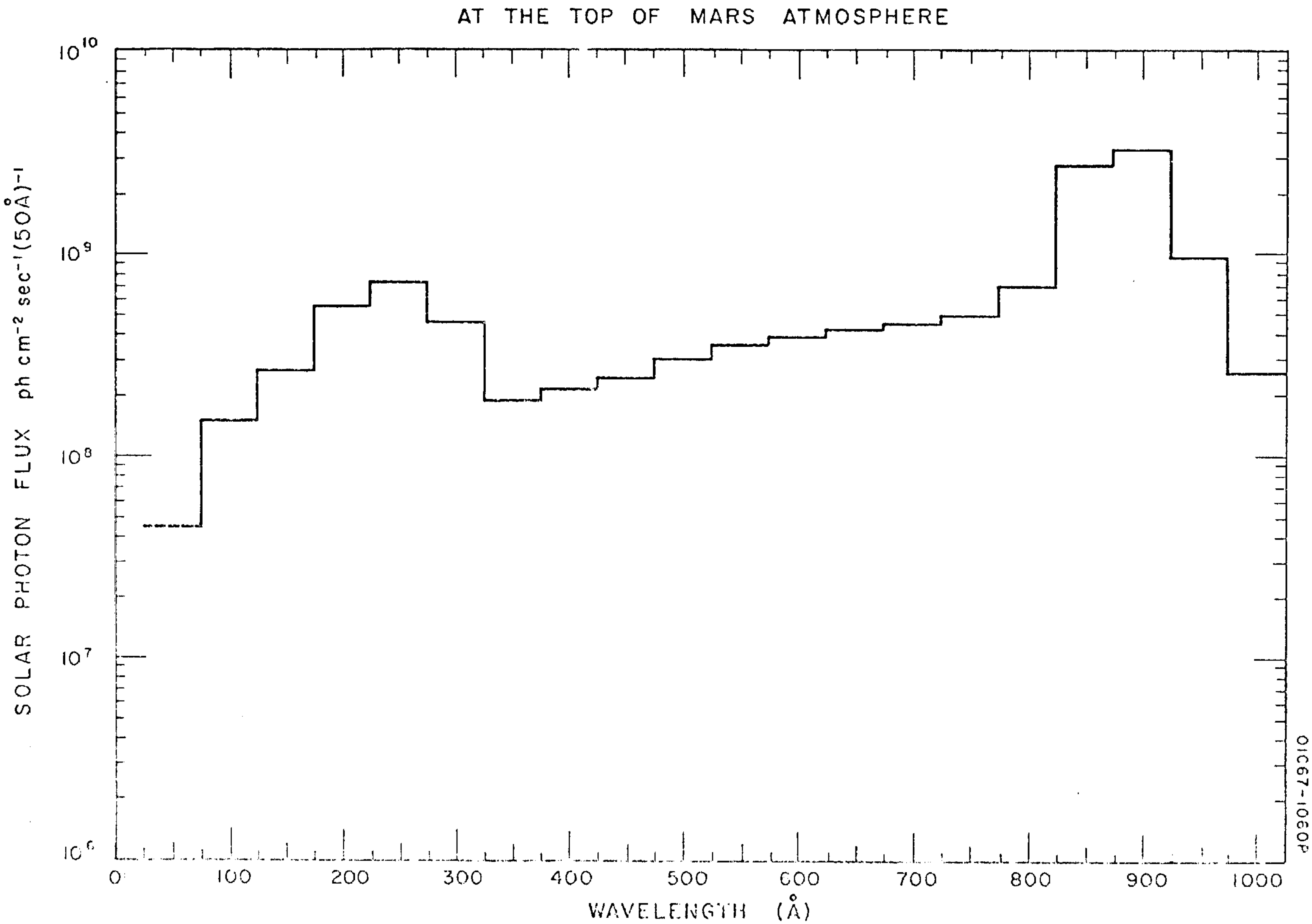
Figure 10.



SOLAR PHOTON FLUX – EMISSION LINES 1000 – 1850 Å

REF. AND ACCURACY: SEE SEPARATE STUDY FOR EARTH

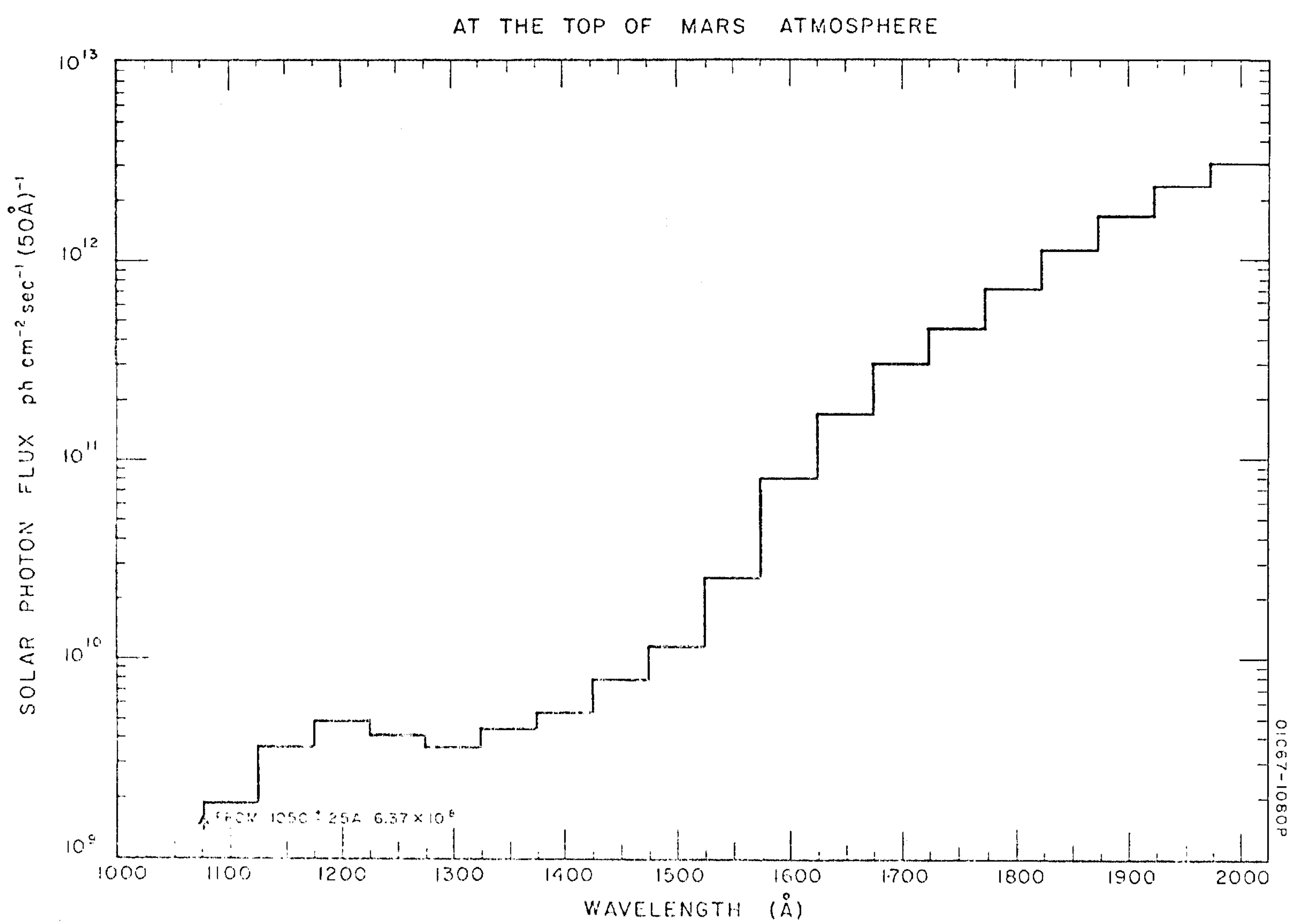
Figure 11.



SOLAR PHOTON FLUX -- CONTINUUM TO 1000 Å

REF. AND ACCURACY: SEE SEPARATE STUDY FOR EARTH

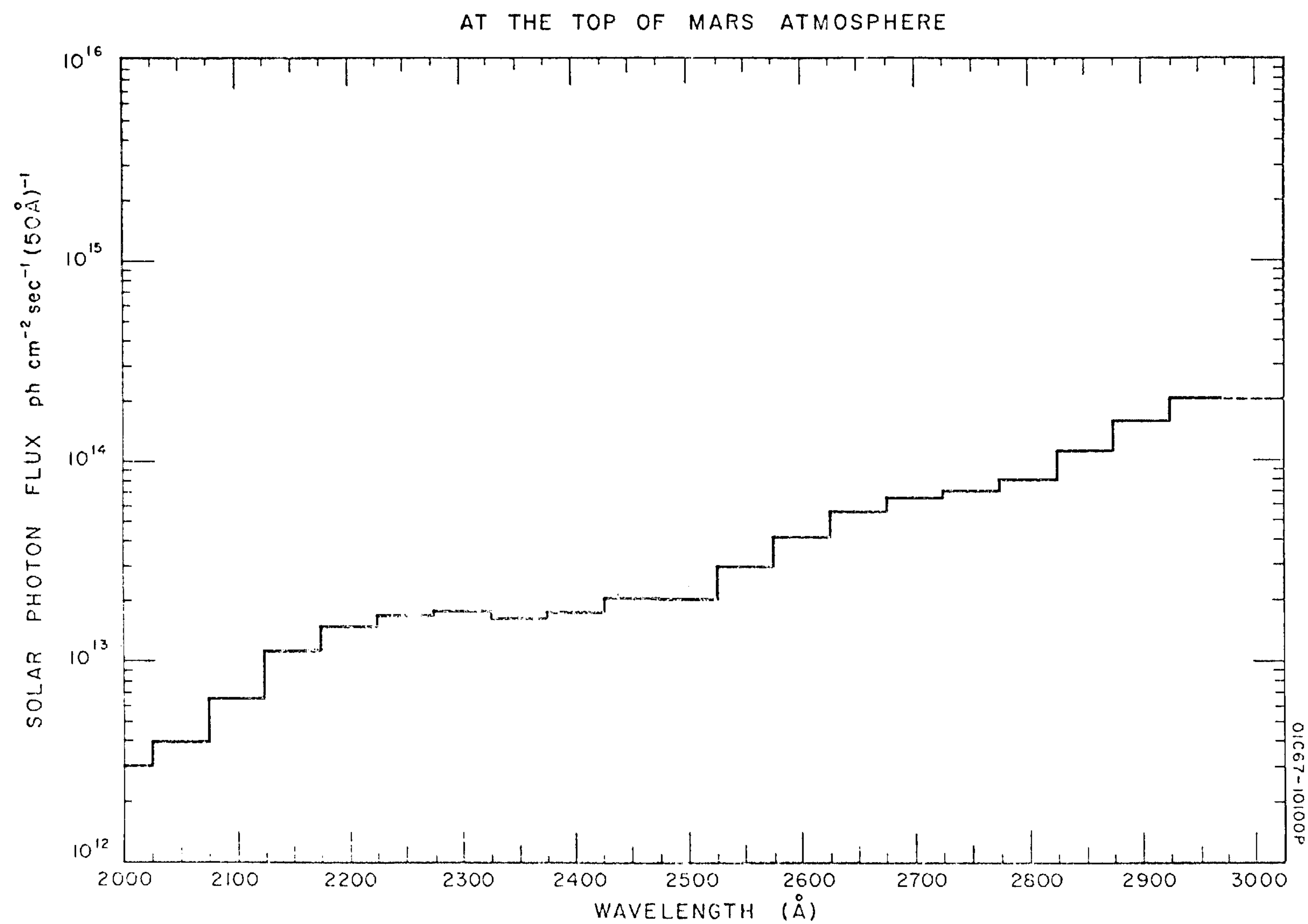
Figure 12.



SOLAR PHOTON FLUX – CONTINUUM 1000 – 2000 Å

REF. AND ACCURACY: SEE SEPARATE STUDY FOR EARTH

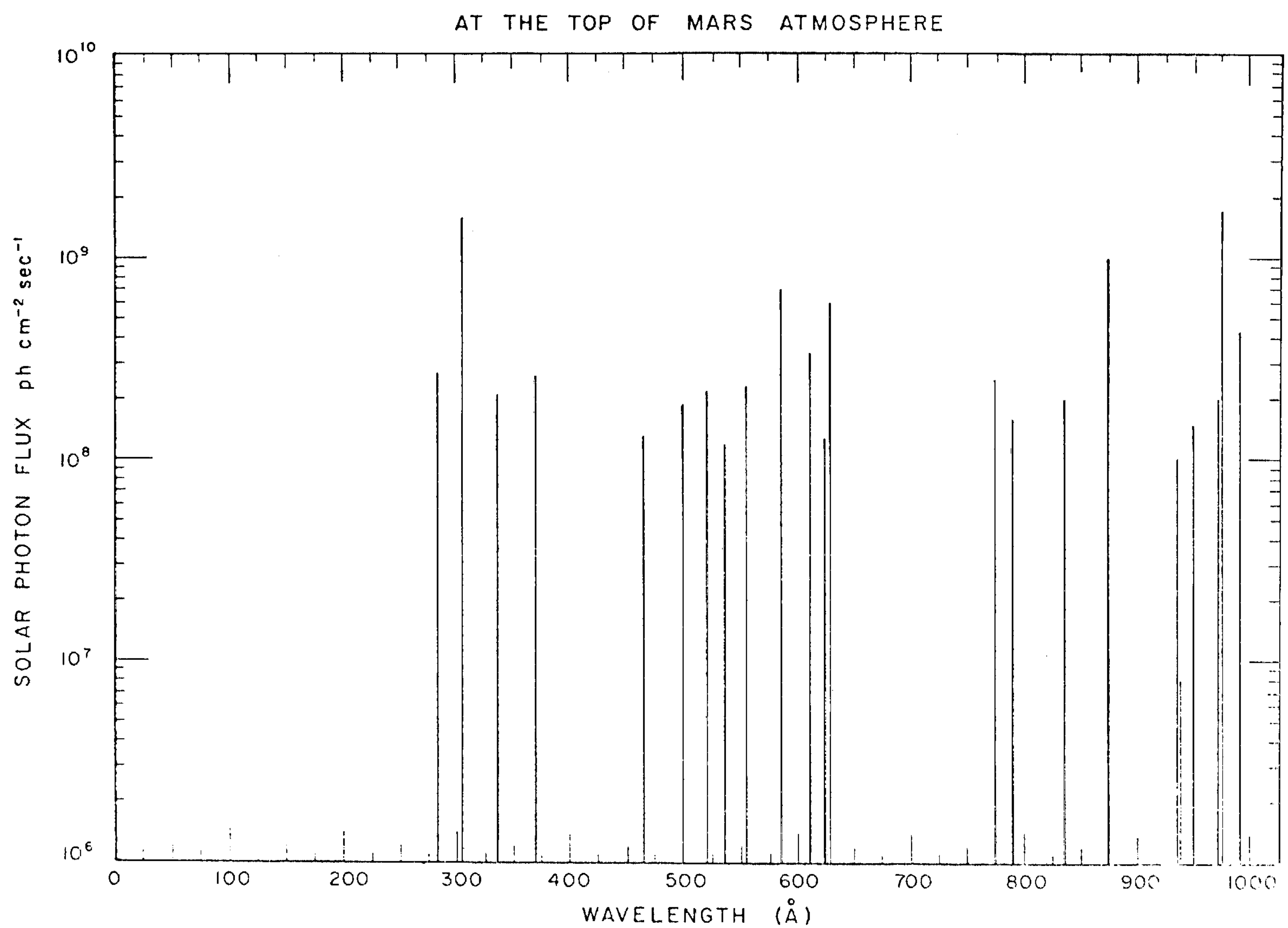
Figure 13.



SOLAR PHOTON FLUX — CONTINUUM 2000 – 3000 Å

REF. AND ACCURACY: SEE SEPARATE STUDY FOR EARTH

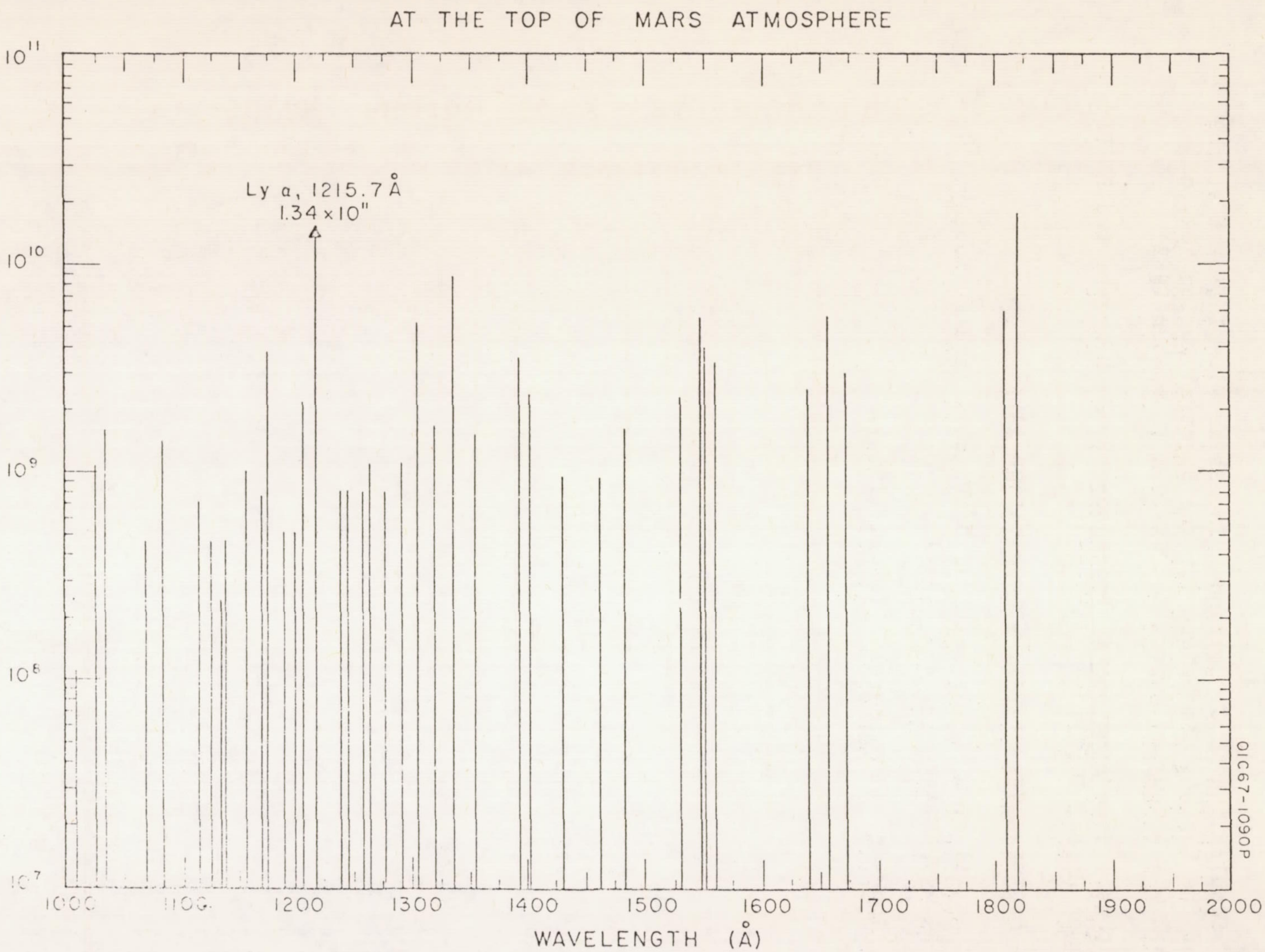
Figure 14.



SOLAR PHOTON FLUX – EMISSION LINES TO 1000 Å

REF. AND ACCURACY: SEE SEPARATE STUDY FOR EARTH

Figure 15.



SOLAR PHOTON FLUX – EMISSION LINES 1000 – 1850Å

REF. AND ACCURACY: SEE SEPARATE STUDY FOR EARTH

Figure 16.

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