No. 165 ARIZONA-NASA ATLAS OF THE INFRARED SOLAR SPECTRUM, REPORT IX

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ABSTRACT

In this paper we give the solar spectrum λλ 25583–30920 Å as obtained from the NASA CV-990 Jet. A laboratory spectrum of the 2.7 μ H_2O bands is included; Courtoy's laboratory spectrum of the 2.7 μ CO_2 bands is given.

In the summer of 1968 two LPL spectrometers recorded the solar spectrum from the NASA CV 990 Jet at high altitude. This paper concludes the preliminary reports on the solar spectrum as obtained with the LPL 4-m spectrometer. Previous reports were published as *Comm. LPL* Nos. 123, 124, 160, 161, 163, 164. The present report gives the solar spectrum λλ 25583-30920 Å; in a great part of the interval duplicate runs were available. The observing data are listed in Table I, pp. 142–43.

The wavelength scale is based on the wavelengths of water vapor lines as given by Plyler and Tidwell (1957) and by Gates *et al.* (1964); the wavelengths of CO_2 lines as given by Courtoy (1959); the wavelengths of N_2O as given by Tidwell, Plyler and Benedict (1960). For the conversion of wavenumbers to wavelengths, Coleman's *Table of Wavenumbers* (NBS 1960) was used. Inaccuracy in the wavelength scale is caused by a periodic and a small random error in the dispersion, and by small inconsistencies in the above mentioned sources of wavelengths. The wavelength scale of Figs. 18–20 (Charts 67–69) had to be interpolated between the few water vapor absorptions, of which the wavelengths were taken from Gates *et al.* (1964).* The positions of solar CO lines were calculated from the constants given by Goldberg and Müller (1953). The CO lines are indicated with an asterisk above the spectral traces. Atmospheric absorptions by H_2O, N_2O, and CO_2 are indicated by a dot, the symbol ⊹, and a vertical line, respectively, all above the spectral trace. We tried to separate the several CO_2 bands in this region by placing the vertical lines at different levels and giving them a different appearance. In doing this we consulted Courtoy's spectrum of CO_2, herein reproduced in Figs. 29 and 30.

Several runs of the water vapor spectrum at 2.7 μ were made, with different amounts of gas. In Figs. 21–28 we reproduce a spectrum with medium-strong absorptions. It shows the weak lines while the strong lines are saturated and their fine structure is not visible, contrary to the solar spectra. Some unidentified lines in the solar spectra may still be telluric.

*Identification of solar lines on these charts were obtained from Migeotte, *et al* (1956).

The solar spectra were obtained in the NASA CV-990 by Messrs. Kuiper and Cruikshank. The derivation of the wavelength scale and the identifications were all performed by Mr. Bijl, who also obtained the laboratory spectra of the 2.7 μ H_2O bands and prepared the charts for publication.

Acknowledgments — We wish to thank Messrs. J. Percy, B. McClendon, A. Thomson and Rev. G. Sill of LPL and Mr. D. Olsen of NASA-Ames for their assistance during the flights. Mr. D. C. Benner constructed the wavelength scales for the laboratory spectra and assisted in the calculation of the CO line positions. Mrs. A. P. Agnieray and Mr. S. M. Larson assisted in the preparation of the figures. This research was supported by NASA through Grant NsG 161-61 and the University of Arizona Institutional Grant NGR-03-002-091.

REFERENCES

Coleman, C. D., Bozman, W. R., and Meggers, W. F. 1960, *Table of Wavenumbers, Vol. II, 7000 Å to 1000 μ*, NBS Mono. 3 (Washington, D.C.: NBS).

Courtoy, C. P. 1959, "Spectre Infrarouge à Grande Dispersion et Constantes Moleculaires du CO_2," *Ann. Soc. Sci. Bruxelles,* Séries I, Tome **73**, pp. 5–230.

Gates, D. M., Calfee, R. F., Hansen, D. W., and Benedict, W. S. 1964, *Line Parameters and Computed Spectra for Water Vapor Bands at 2.7 μ*, NBS Mono. 71 (Washington, D.C.: NBS).

Goldberg, L., and Müller, E. A. 1953, "Carbon Monoxide in the Sun," *Ap. J.*, **118**, pp. 397–411.

Migeotte, M., Neven, L., and Swensson, J. 1956, "The Solar Spectrum from 2.8 to 23.7 Microns, Part I, Photometric Atlas," *Mem. Soc. Roy. Sci. Liège,* Special Vol. 1.

Migeotte, M., Neven, L. and Swensson, J. 1957, "The Solar Spectrum from 2.8 to 23.7 Microns, Part II, Measures and Identifications," *Mem. Soc. Roy. Sci. Liège,* Special Vol. 2.

Plyler, E. K. and Tidwell, E. D. 1957, "The Precise Measurement of the Infrared Spectra of Molecules of the Atmosphere," *Mém. Soc. Roy. Sci. Liège,* 4th Series, **18**, pp. 426–449.

Tidwell, E. D., Plyler, E. K., and Benedict, W. S. 1960, "Vibration-Rotation Bands of N_2O," *J. Opt. Soc. Am.,* **50**, pp. 1243–1263.

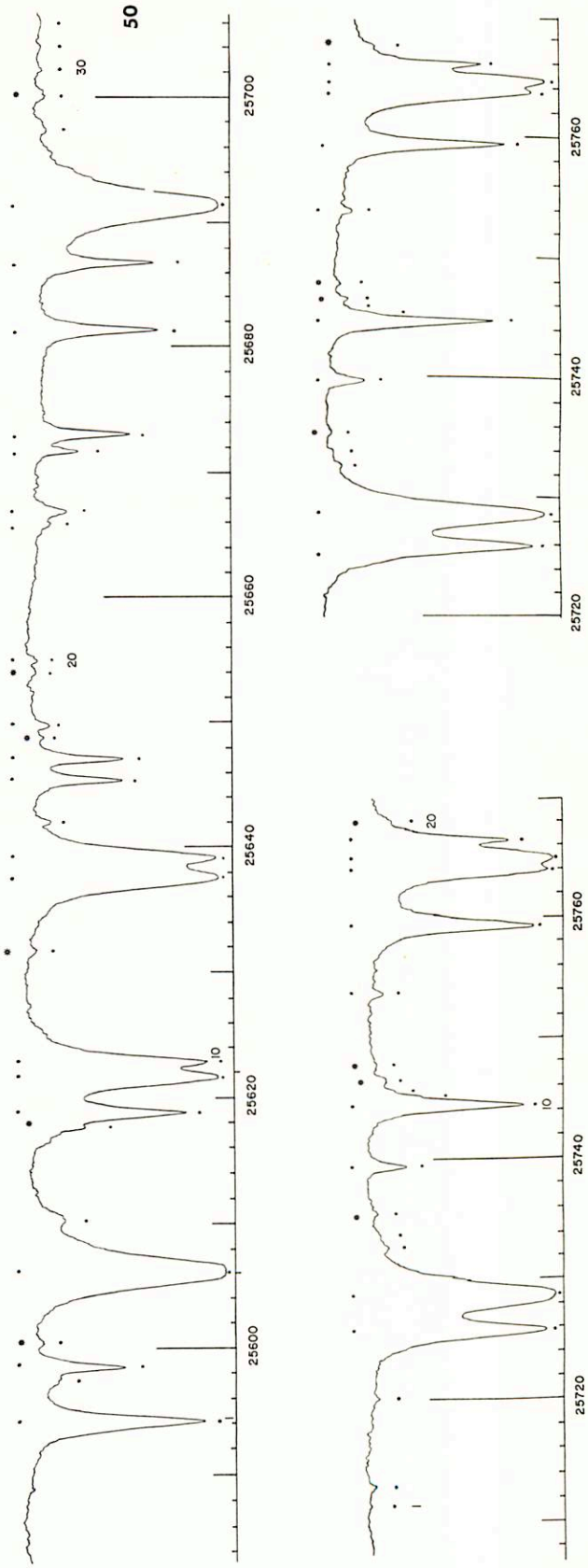

Fig. 1 Solar Spectrum λλ 25583–25770, in two strips (cf. Table 1).

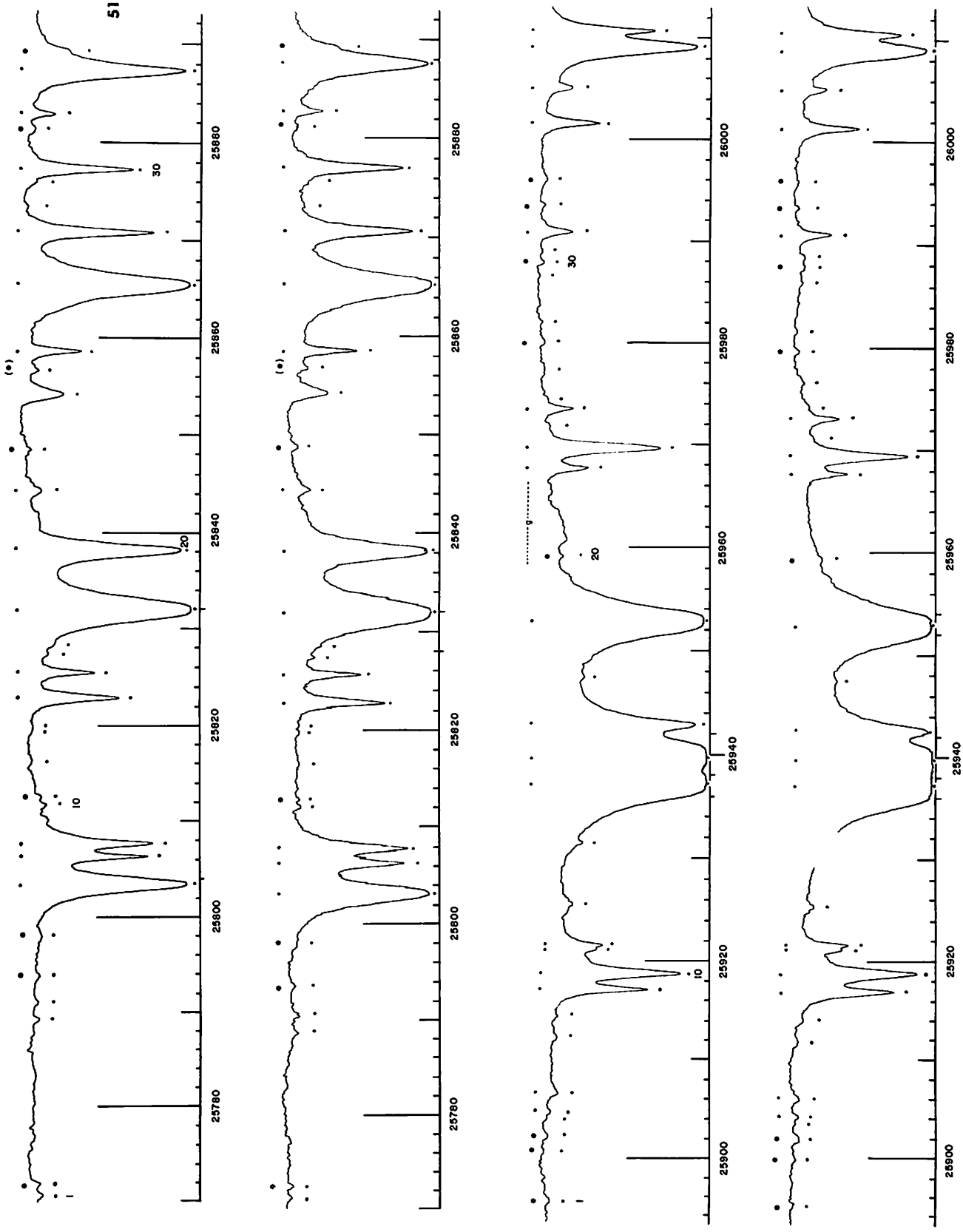

Fig. 2 Solar Spectrum λλ 25770–26013, in four strips (cf. Table 1).

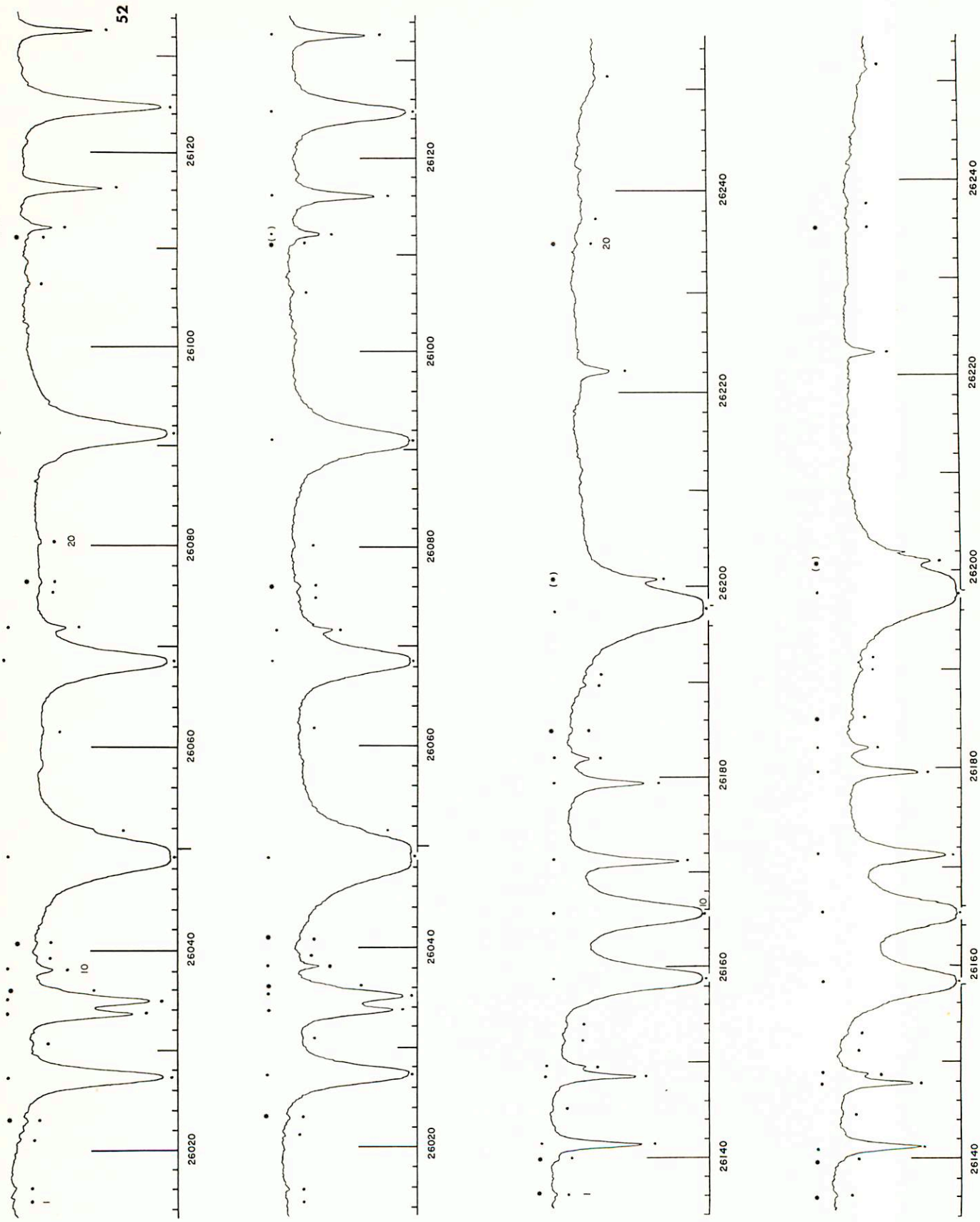

Fig. 3 Solar Spectrum λλ 26013–26255, in four strips (cf. Table 1).

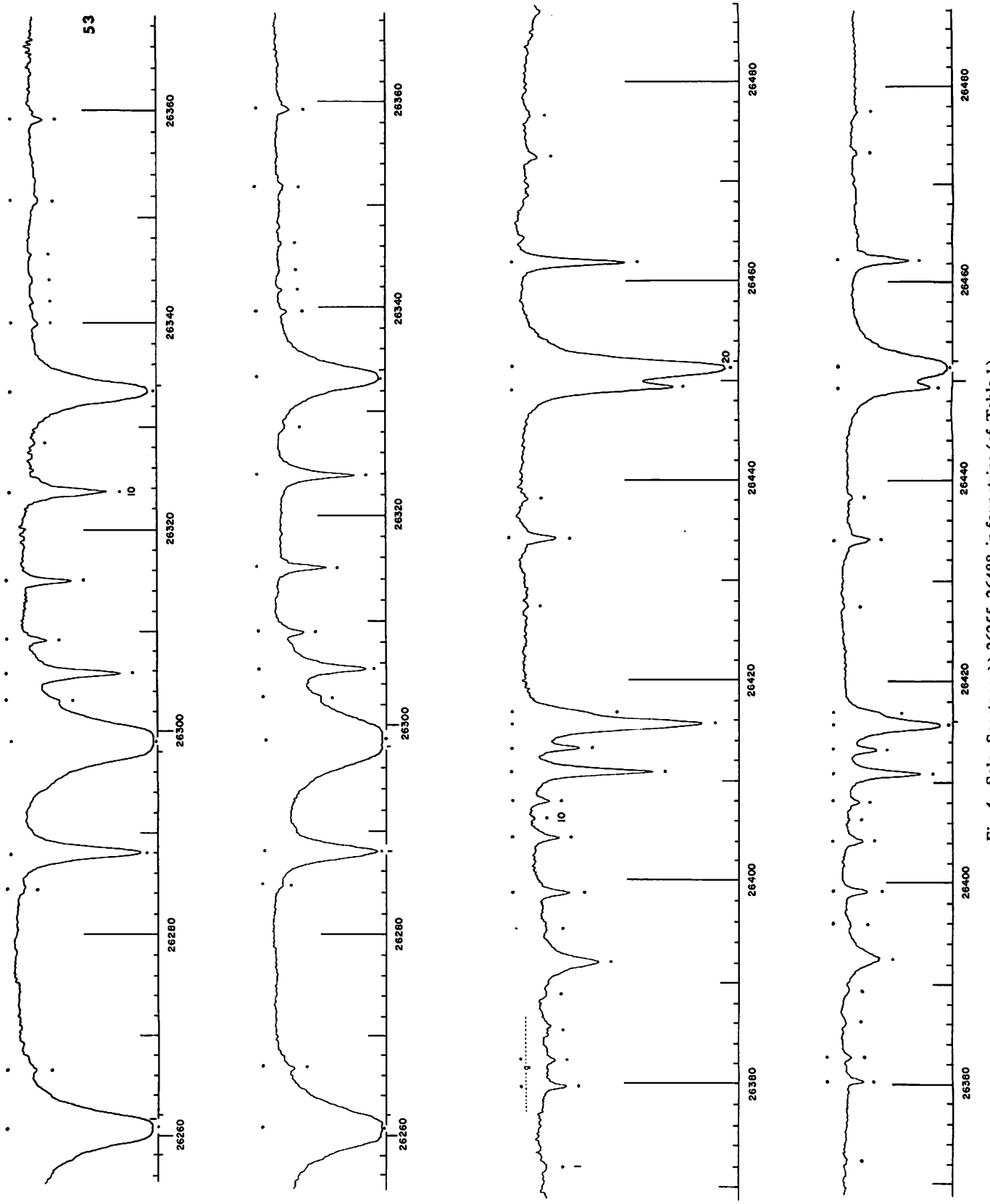

Fig. 4 Solar Spectrum λλ 26255–26488, in four strips (cf. Table 1).

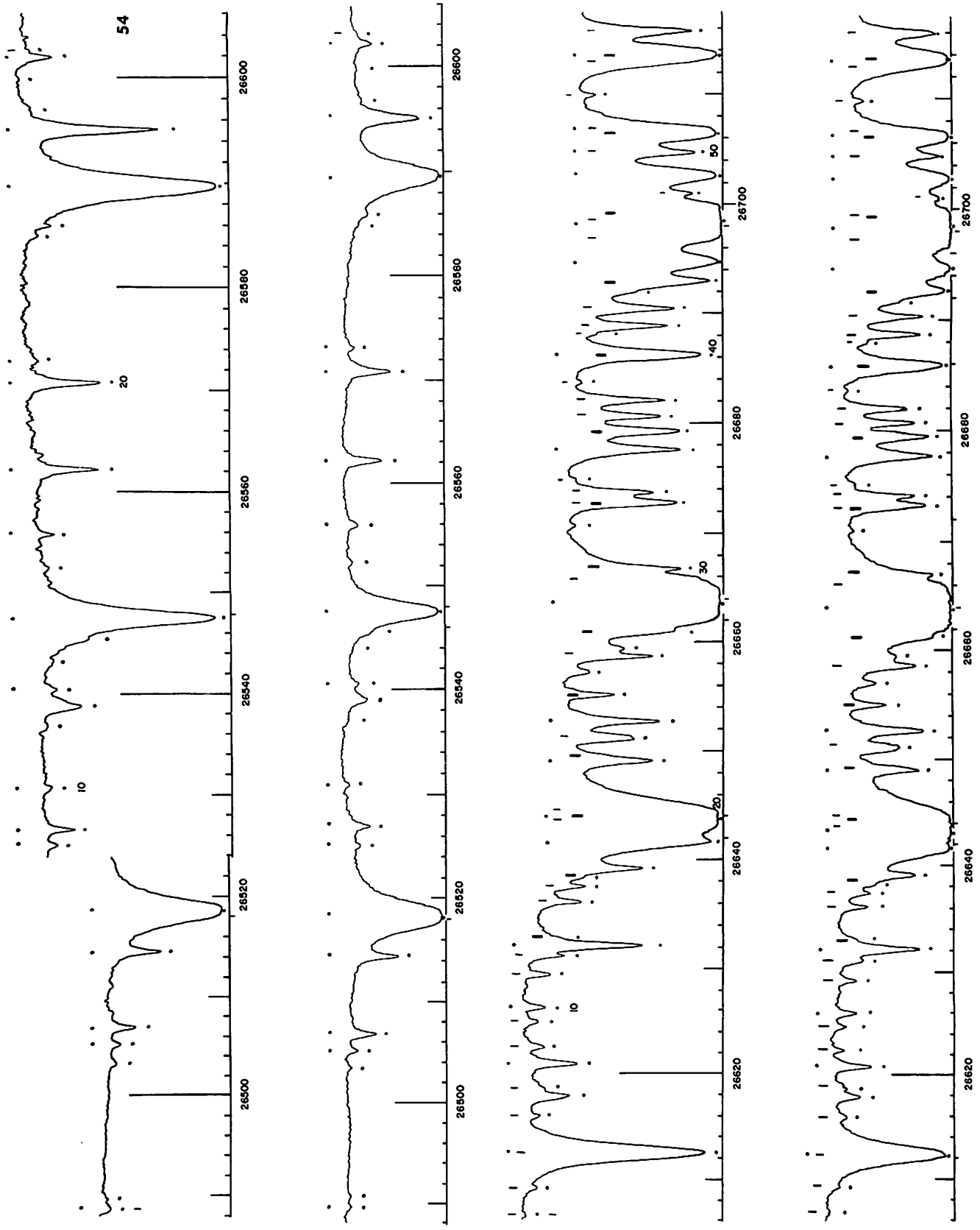

Fig. 5 Solar Spectrum λλ 26488–26718, in four strips (cf. Table 1).

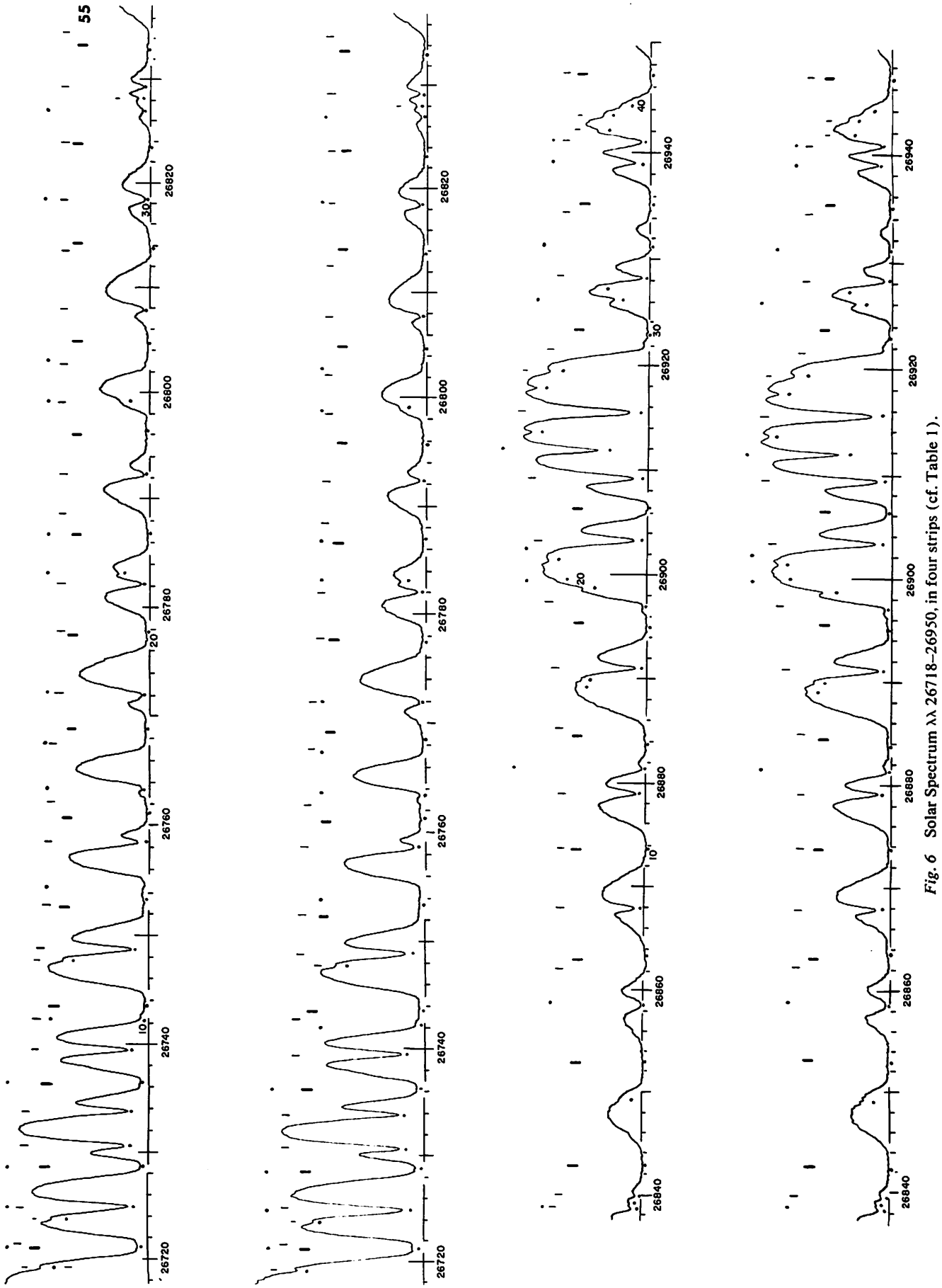

Fig. 6 Solar Spectrum λλ 26718–26950, in four strips (cf. Table 1).

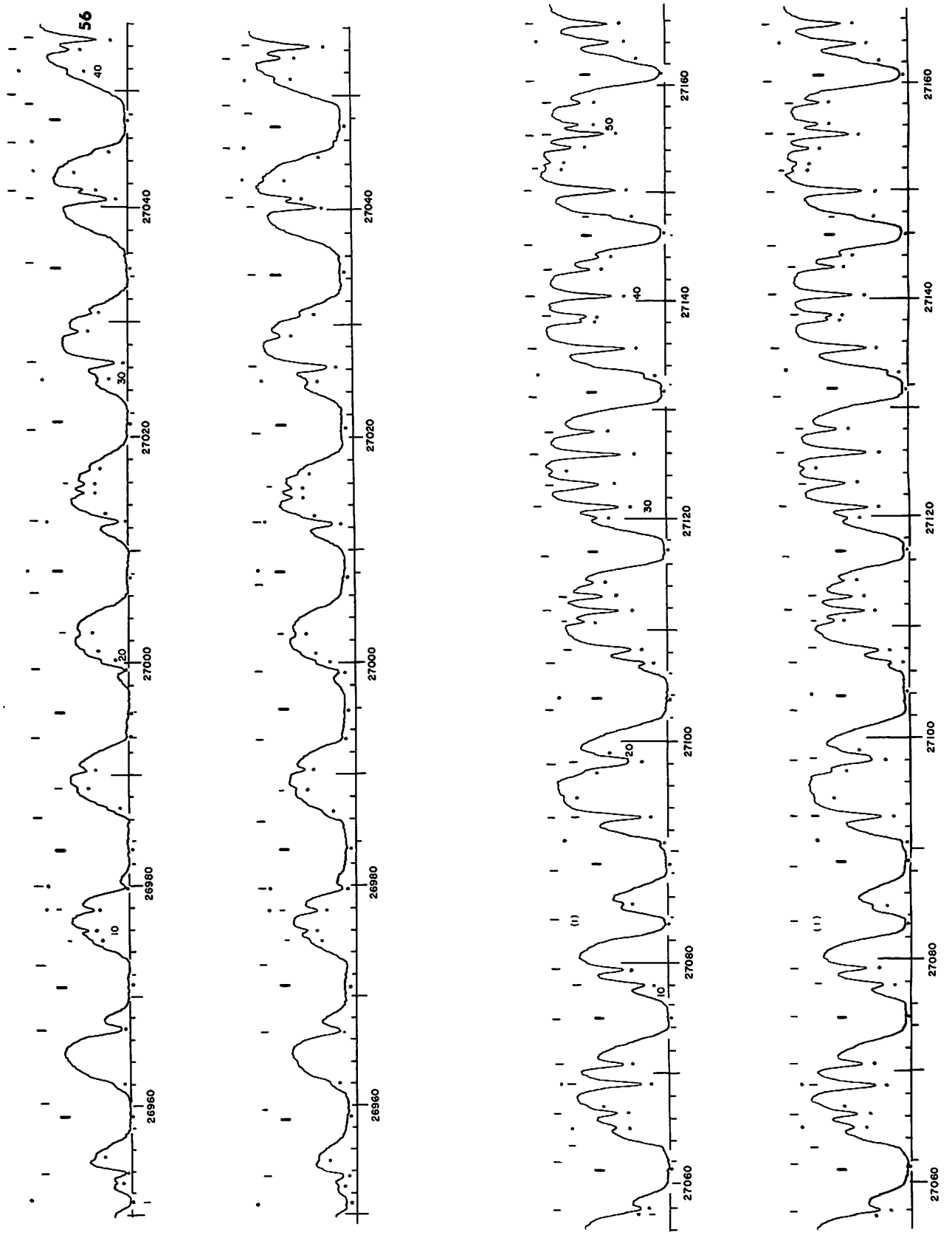

Fig. 7 Solar Spectrum λλ 26950–27167, in four strips (cf. Table 1).

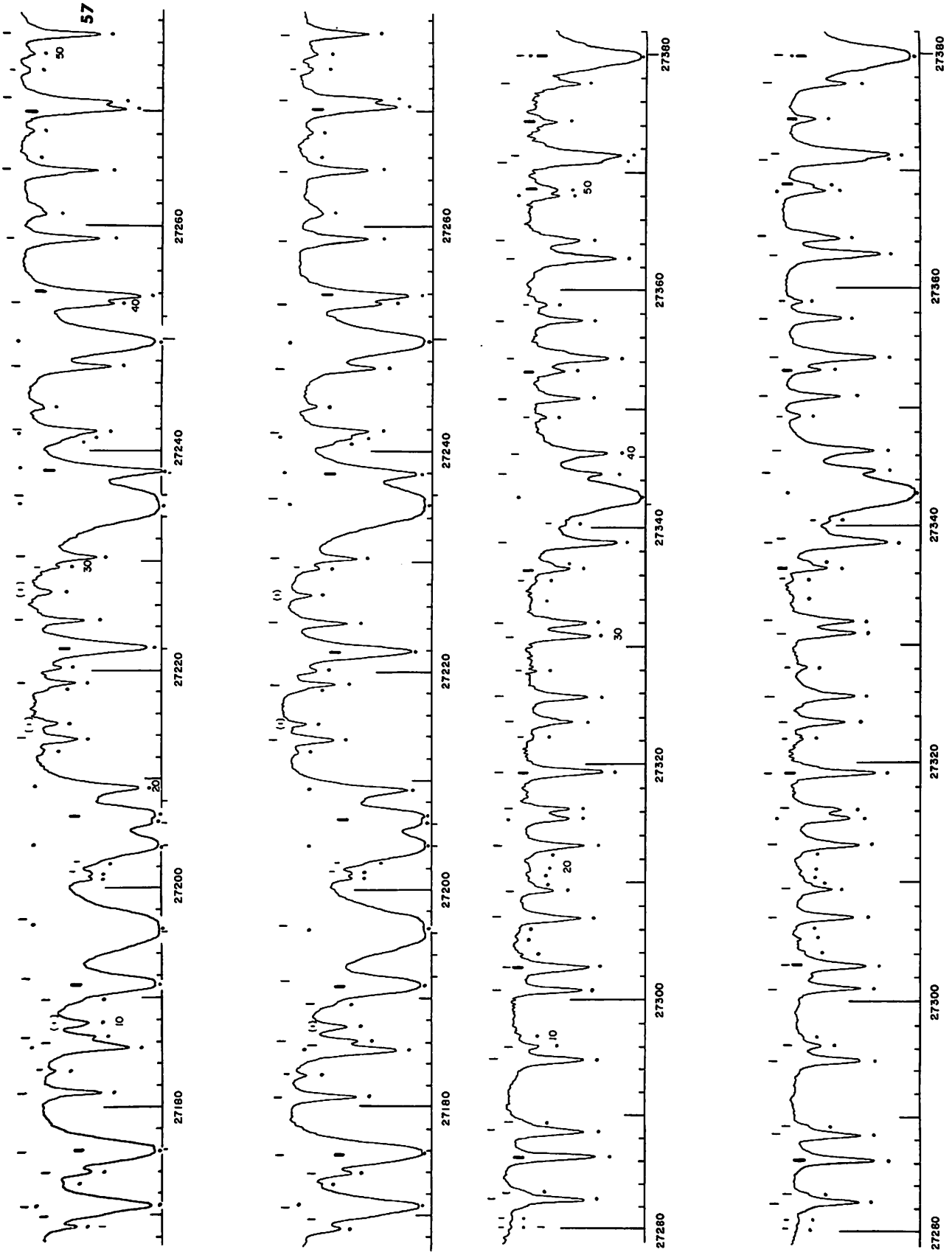

Fig. 8 Solar Spectrum λλ 27167–27382, in four strips (cf. Table 1).

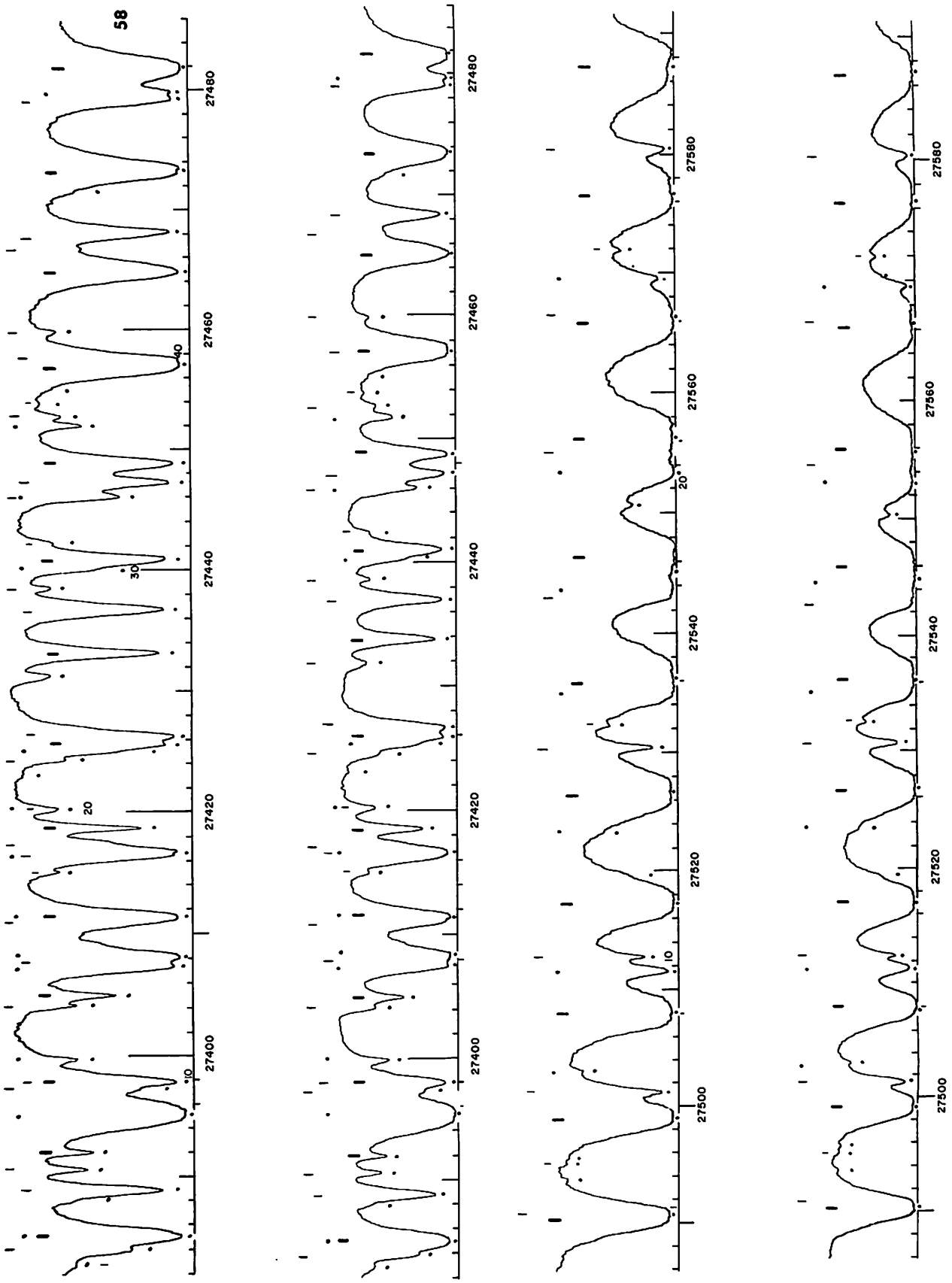

Fig. 9 Solar Spectrum λλ 27382–27592, in four strips (cf. Table 1).

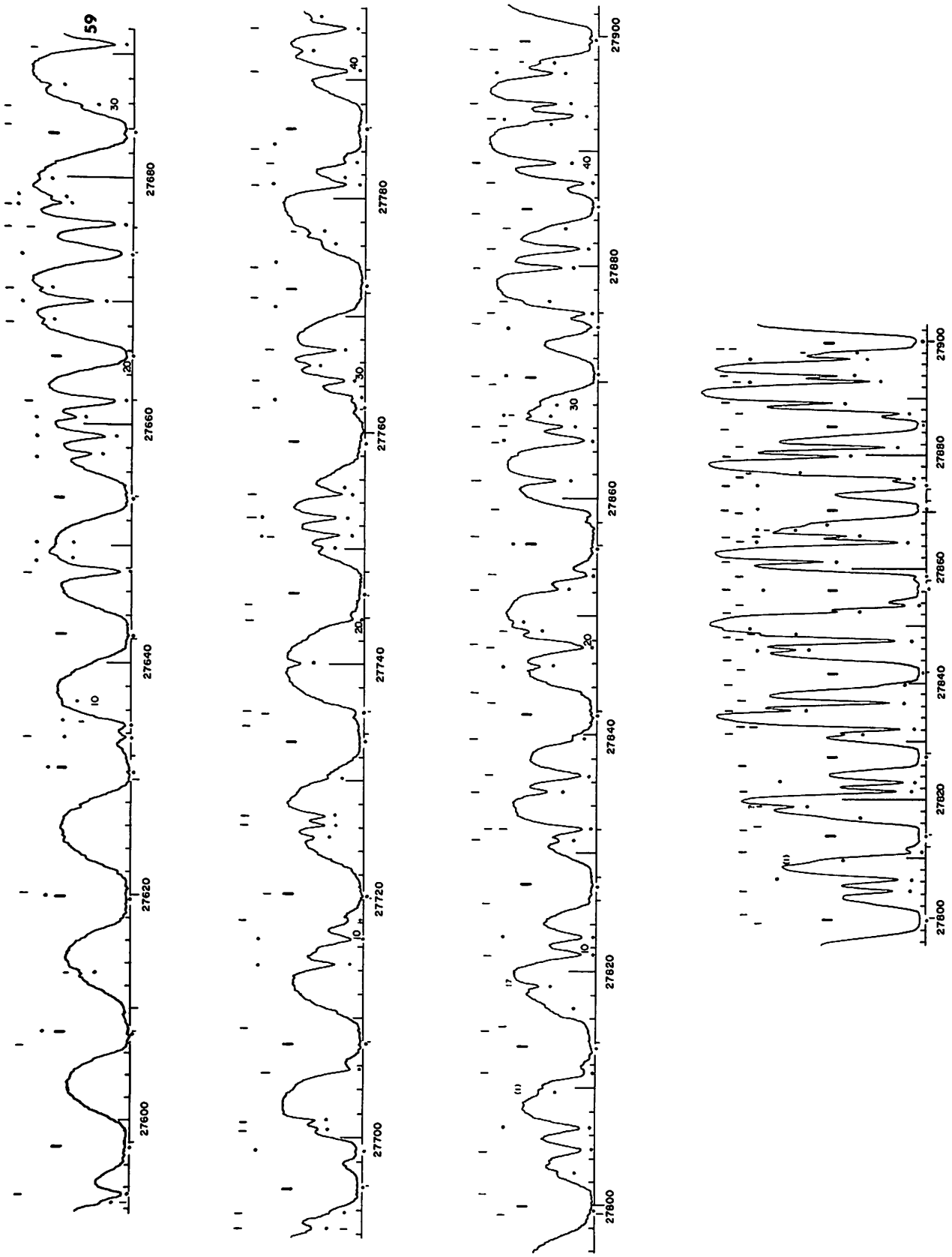

Fig. 10 Solar Spectrum λλ 27592–27903, in four strips (cf. Table 1).

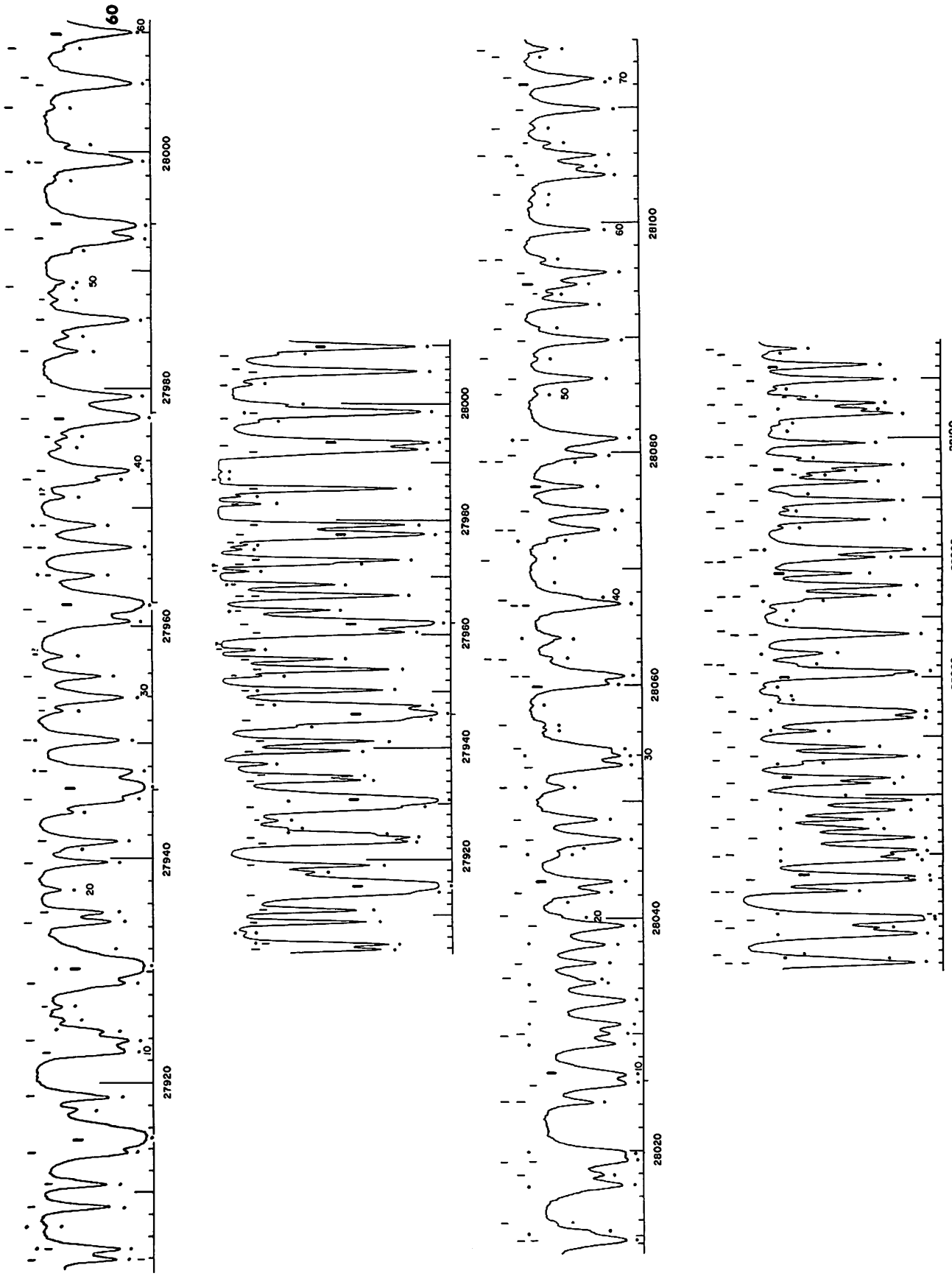

Fig. 11 Solar Spectrum λλ 27903–28116, in four strips (cf. Table 1).

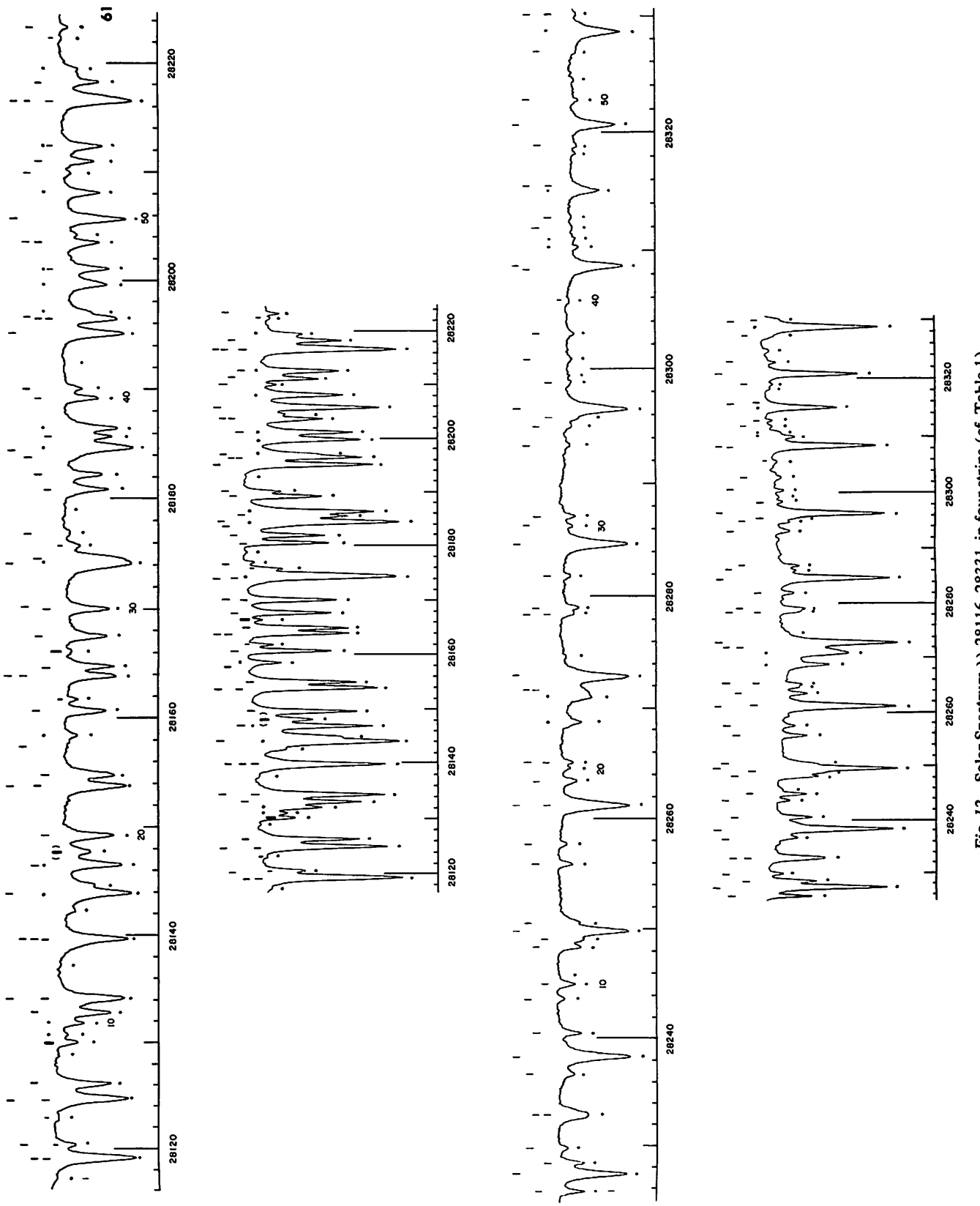

Fig. 12 Solar Spectrum λλ 28116–28331, in four strips (cf. Table 1).

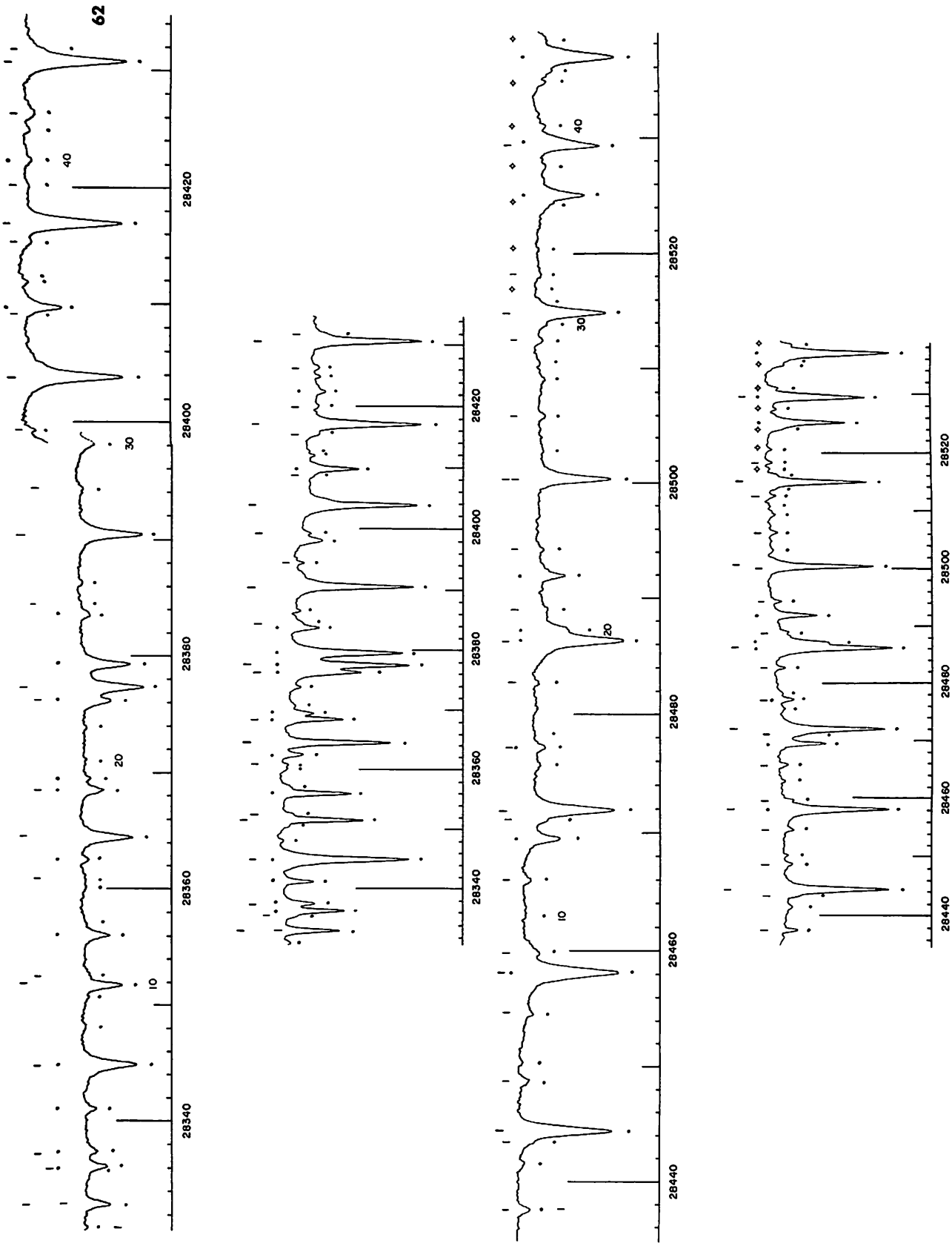

Fig. 13 Solar Spectrum λλ 28331–28539, in four strips (cf. Table 1).

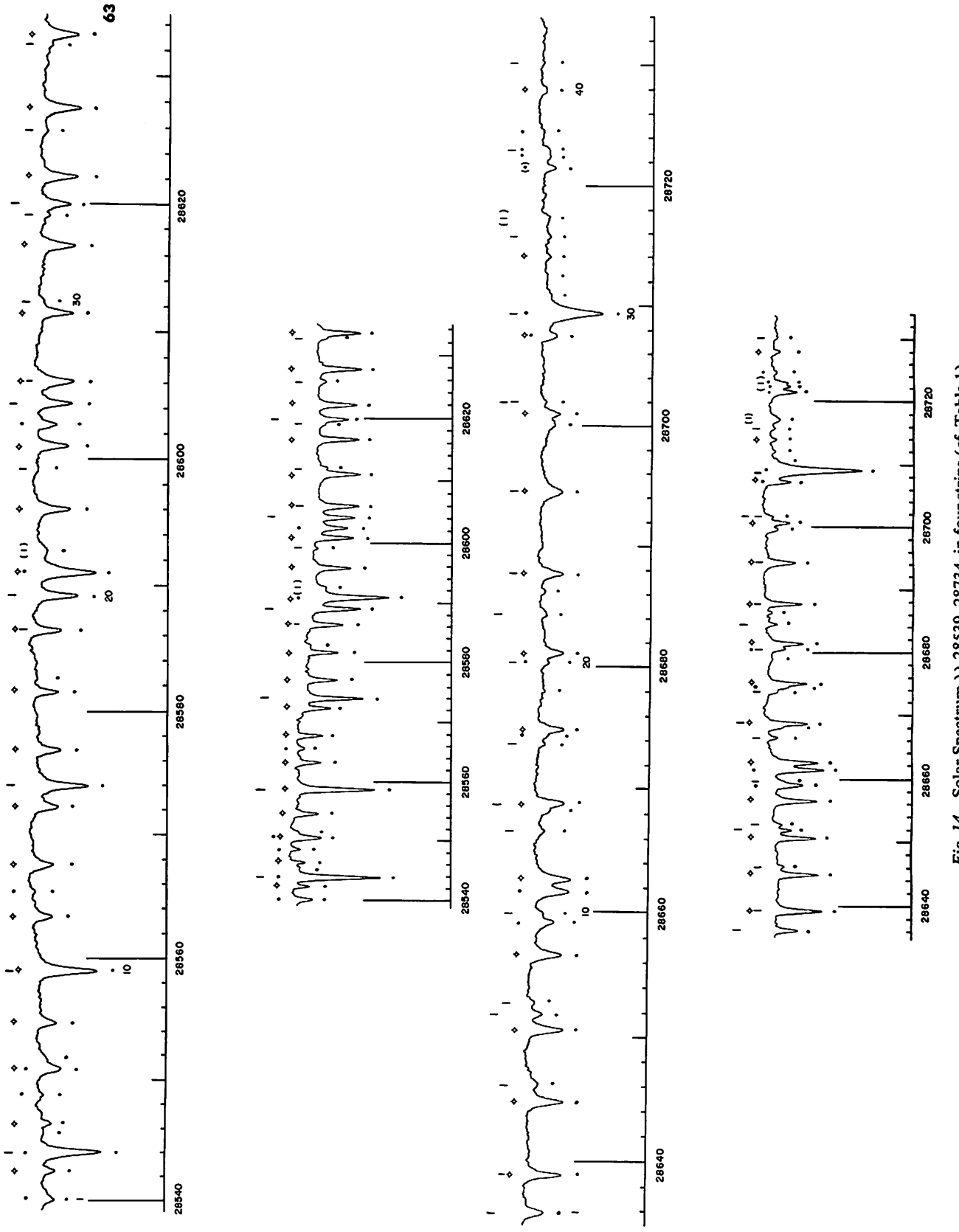

Fig. 14 Solar Spectrum λλ 28539–28734, in four strips (cf. Table 1).

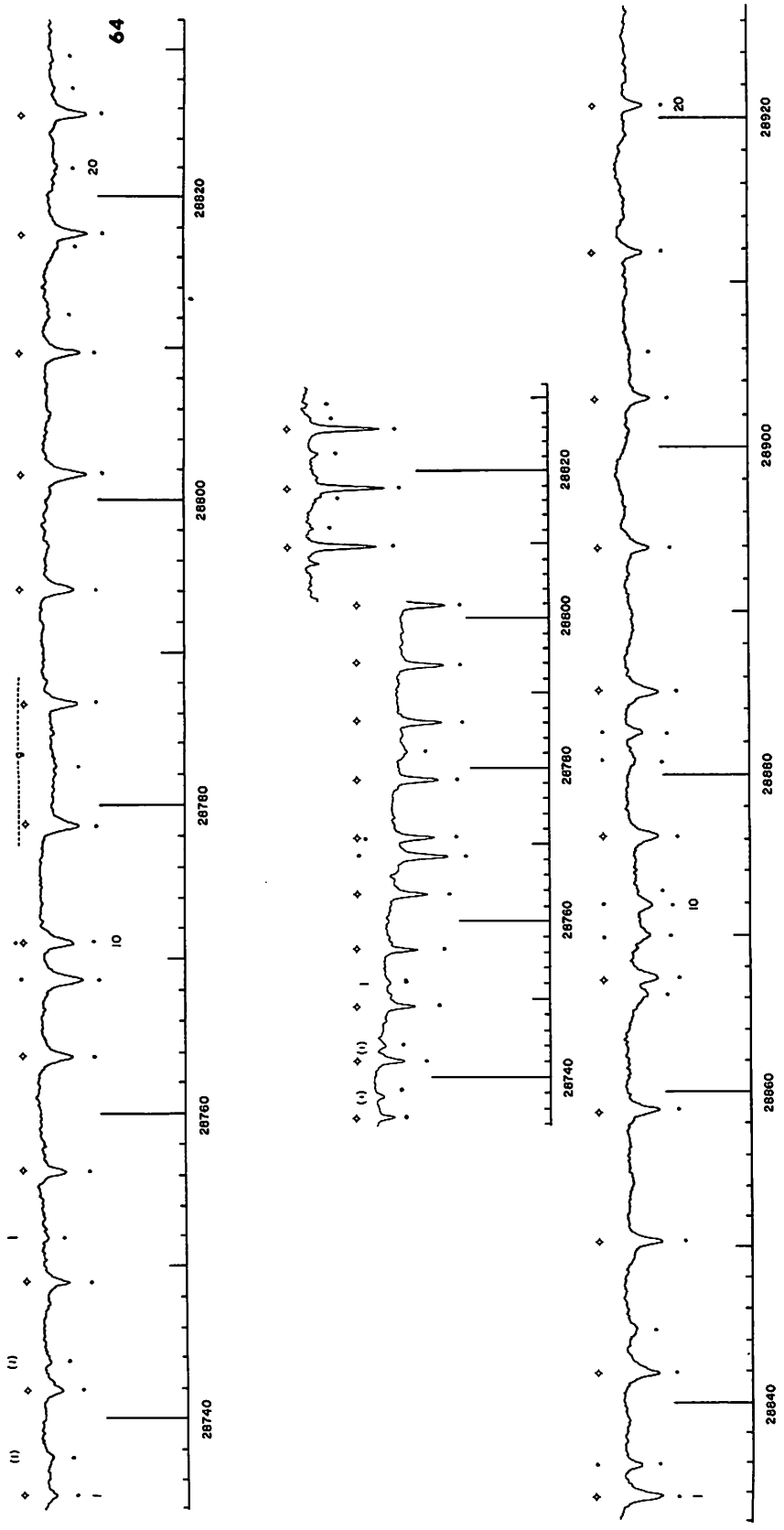

Fig. 15 Solar Spectrum λλ 28734–28927, in four strips (cf. Table 1).

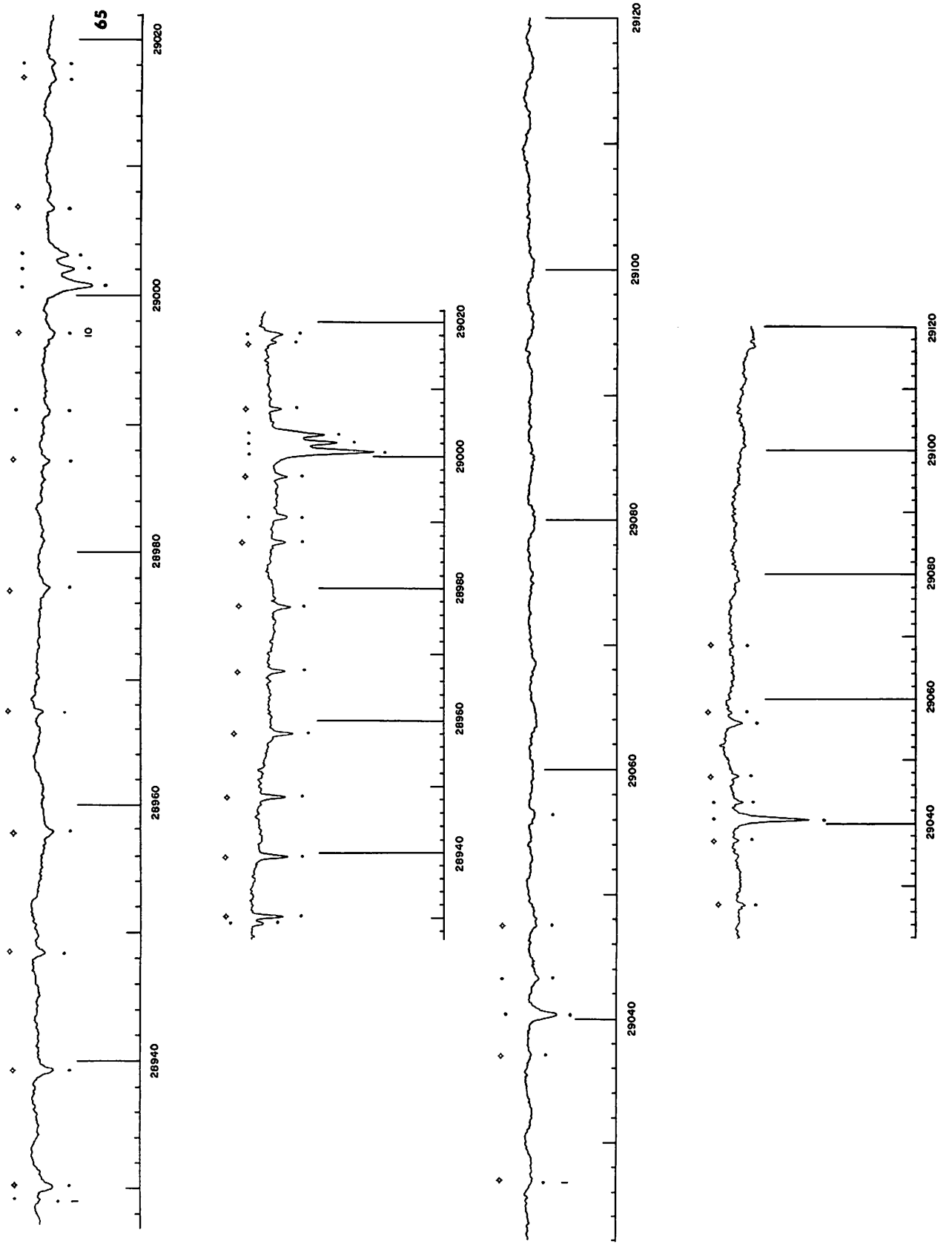

Fig. 16 Solar Spectrum λλ 28927–29120, in four strips (cf. Table 1).

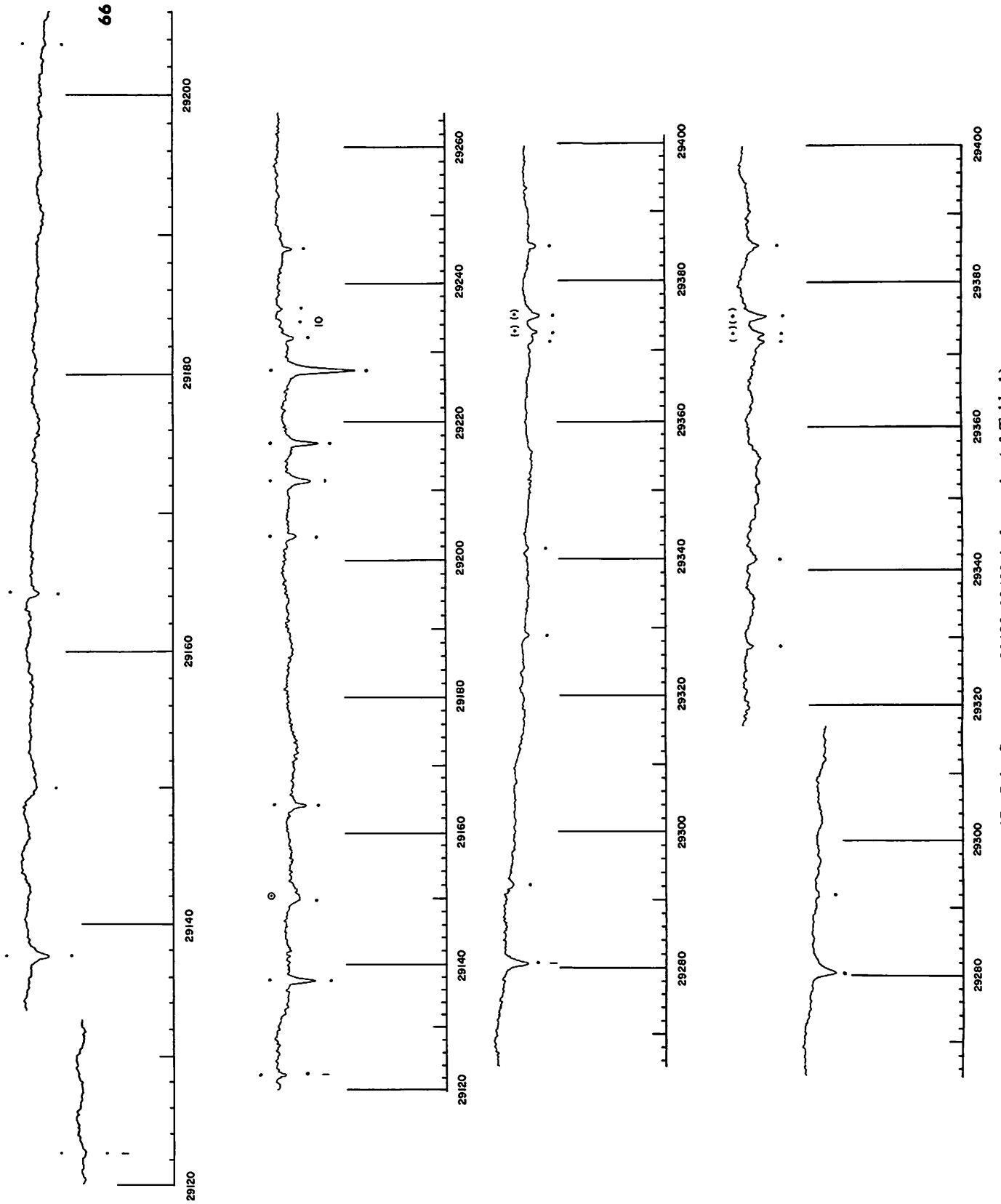

Fig. 17 Solar Spectrum λλ 29120–29400, in four strips (cf. Table 1).

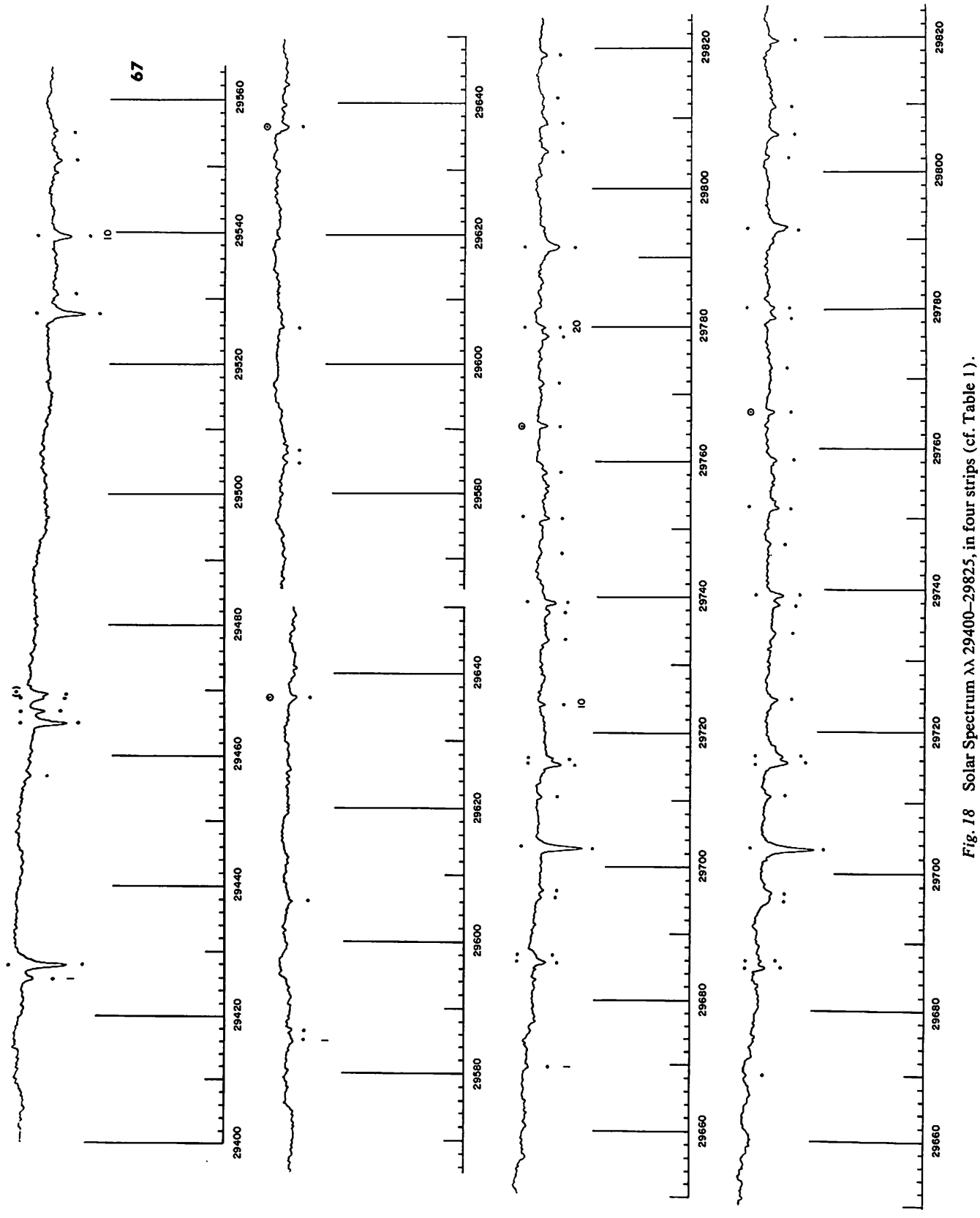

Fig. 18 Solar Spectrum λλ 29400–29825, in four strips (cf. Table 1).

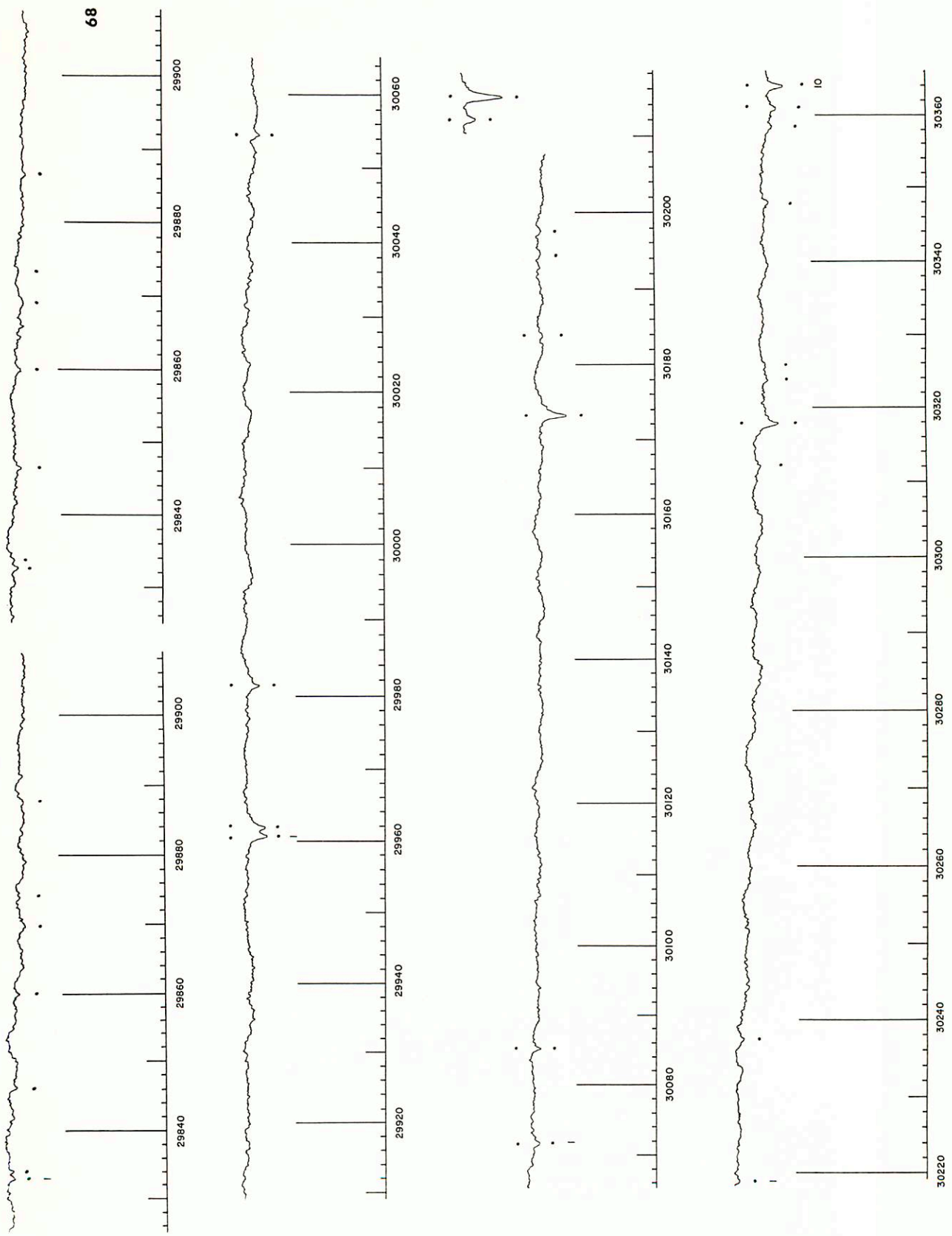

Fig. 19 Solar Spectrum λλ 29825–30366, in four strips (cf. Table 1).

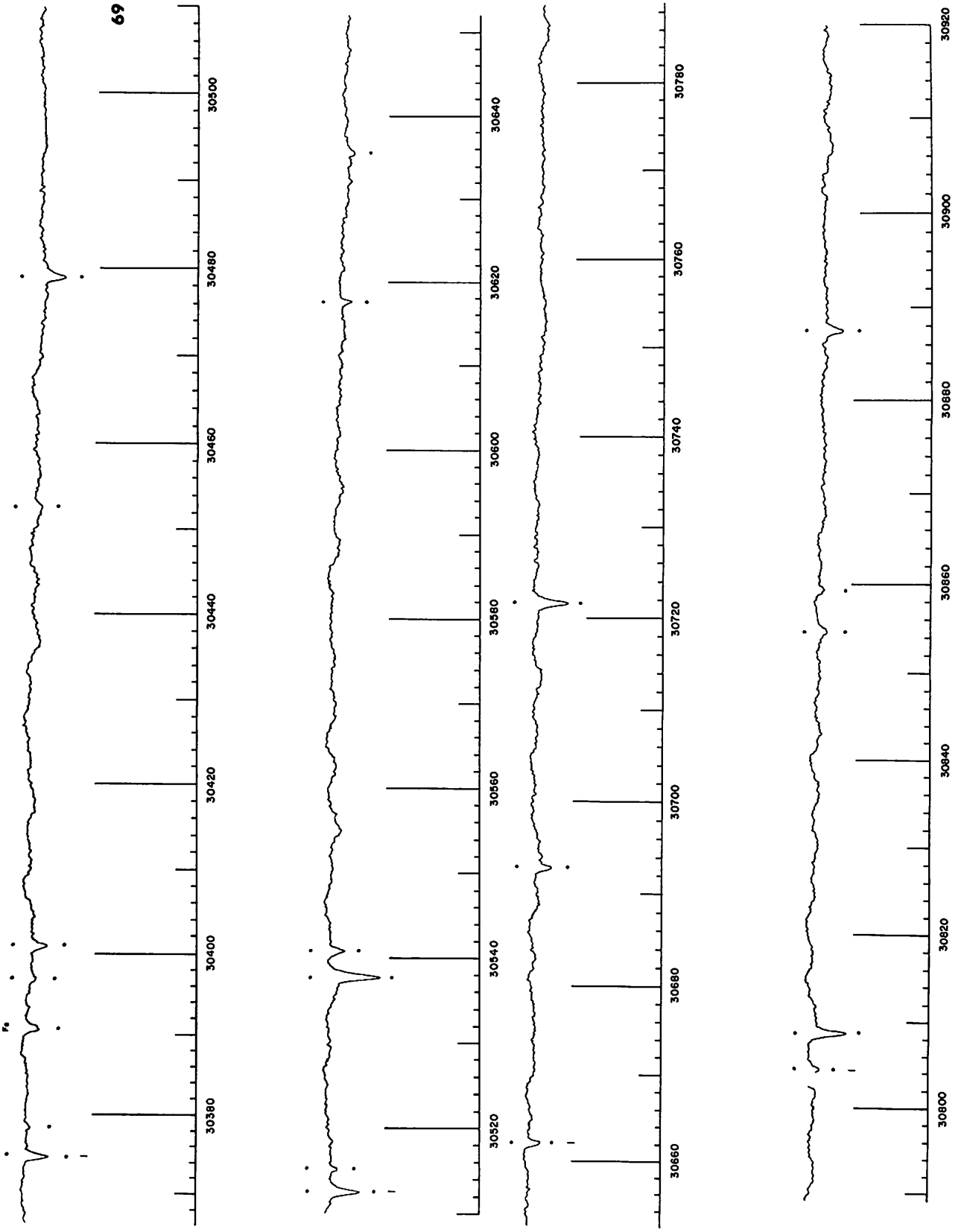

Fig. 20 Solar Spectrum λλ 30366–30920, in four strips (cf. Table 1).

TABLE I

SOLAR SPECTRUM RECORDS, 4-m SPECTROMETER, NASA CV-900 JET
GRATING 600 l/mm: GRATING BLAZE, JULY 19: 1.6 μ, JULY 30, AUG. 1: 2.5 μ
FILTER 1.8 μ; DETECTOR 0.10 mm

FIG.	CHART		1968 DATE	UT	ALT. (FT.)	OUTSIDE TEMP. (°C)	CABIN ALT. (FT.)	GAIN	SLIT (mm)	τ (SEC.)
1	50 c	25583-25707	July 19	19:04	39,000	−52	8500	5-6	0.18	0.12
	d	25707-25770	July 19/30	19:07/18:26	39,000/40,800	−52/−55	8500/8900	5-5	0.18/0.15	0.12
2	51 a	25770-25893	July 30	18:29	41,000	−55	8900	5-5	0.15	0.12
	b	25770-25893	July 19	19:09	39,000	−52	8500	5-6	0.18	0.12
	c	25893-26013	July 30	18:32	41,100	−55	8900	5-5	0.15	0.12
	d	25893-26013	July 19	19:12	39,000	−52	8500	5-6	0.18	0.12
3	52 a	26013-26134	July 30	18:35	41,200	−55	8900	5-5	0.15	0.12
	b	26013-26134	July 19	19:16	39,000	−52	8500	5-6	0.18	0.12
	c	26134-26255	July 30	18:38	41,300	−55	8900	5-5	0.15	0.12
	d	26134-26255	July 19	19:19	39,000	−52	8500	5-6	0.18	0.12
4	53 a	26255-26369	July 30	18:41	41,400	−55	8900	5-5	0.15	0.12
	b	26255-26369	July 19	19:22	39,000	−52	8500	5-6	0.18	0.12
	c	26369-26488	July 30	19:25	41,500	−59	8900	5-6	0.15	0.12
	d	26369-26488	July 19	19:25	39,000	−52	8500	5-6	0.18	0.12
5	54 a	26488-26606	July 30	18:47/19:28	41,500	−55/−59	8900	5-5/5-6	0.15	0.12
	b	26488-26606	July 19	19:29	39,000	−52	8500	5-6	0.18	0.12
	c	26606-26718	July 30	19:31	41,500	−59	8900	5-6	0.15	0.12
	d	26606-26718	July 19	19:37	39,000	−52	8500	6-2	0.18	0.12
6	55 a	26718-26837	July 30	19:34	61,500	−59	8900	5-6	0.15	0.12
	b	26718-26837	July 30	18:55	41,700	−55	8900	5-6	0.15	0.12
	c	26837-26950	July 30	19:38	41,500	−59	8900	5-6	0.15	0.12
	d	26837-26950	July 30	18:58	41,600	−56	8900	5-6	0.15	0.12
7	56 a	26950-27056	July 30	19:42	41,500	−60	8900	5-6	0.15	0.12
	b	26950-27056	July 30	19:01	41,600	−57	8900	5-6	0.15	0.12
	c	27056-27167	July 30	19:45	41,500	−60	8900	5-6	0.15	0.12
	d	27056-27167	July 30	19:05	41,500	−58	8900	5-6	0.15	0.12
8	57 a	27167-27279	July 30	19:48	41,500	−60	8900	5-6	0.15	0.12
	b	27167-27279	July 30	19:08	41,500	−58	8900	5-6	0.15	0.12
	c	27279-27382	July 30	19:51	41,500	−60	8900	5-6	0.15	0.12
	d	27279-27382	July 30	19:11	41,500	−59	8900	5-6	0.15	0.12
9	58 a	27382-27486	July 30	19:57	41,500	−60	8900	6-2	0.15	0.12
	b	27382-27486	July 30	19:14	41,500	−59	8900	5-6	0.15	0.12
	c	27486-27592	July 30	20:00	41,500	−59	8900	6-2	0.15	0.12
	d	27486-27592	July 30	19:17	41,500	−59	8900	5-6	0.15	0.12

10	59 a	27592-27692	July 30	20:03	41,500	−59	8900	6-2	0.15	0.12
	b	27692-27796	July 30	20:06	41,500	−59	8900	6-2	0.15	0.12
	c	27796-27903	July 30	20:10	41,500	−59	8900	6-2	0.14	0.12
	d*	27796-27903	Aug. 1	18:19	39,000	−54	9300	6-1	0.30	0.12
11	60 a	27903-28011	July 30	20:13	41,500	−59	8900	6-2	0.14	0.12
	b*	27903-28011	Aug. 1	18:20	39,000	−54	9300	6-1	0.30/0.24	0.12
	c	28011-28116	July 30	20:16	41,500	−58	8900	6-2	0.14	0.12
	d*	28011-28116	Aug. 1	18:22	39,200	−54	9300	6-1	0.24	0.12
12	61 a	28116-28225	July 30	20:20	41,500	−58	8900	6-2	0.14	0.12
	b*	28116-28225	Aug. 1	18:24	39,400	−56	9300	6-1	0.24	0.12
	c	28225-28331	July 30	20:23	41,500	−58	8900	6-2	0.14	0.12
	d*	28225-28331	Aug. 1	18:26	39,600	−54	9300	6-1	0.24	0.12
13	62 a	28331-28435	July 30	20:26	41,500	−58	8900	6-2/6-3	0.14	0.12/0.24
	b*	28331-28435	Aug. 1	18:27	39,800	−54	9300	6-1	0.24	0.12
	c	28435-28539	July 30	20:30	41,500	−58	8900	6-3	0.14	0.24
	d*	28435-28539	Aug. 1	18:29	40,000	−54	9300	6-1	0.24	0.12
14	63 a	28539-28635	July 30	20:33	41,500	−58	8900	6-3	0.14	0.24
	b*	28539-28635	Aug. 1	18:31	40,200	−53	9300	6-1	0.24	0.12
	c	28635-28734	July 30	20:37	41,500	−58	8900	6-3	0.14	0.24
	d*	28635-28734	Aug. 1	18:32	40,400	−53	9300	6-1	0.24	0.12
15	64 a	28734-28832	July 30	20:40	41,500	−58	8900	6-3	0.24	0.24
	b*	28734-28832	Aug. 1	18:34	40,500	−53	9300	6-1/6-2	0.24	0.12
	c	28832-28927	July 30	20:43	41,500	−58	8900	6-3	0.14	0.24
	d*	28832-28927	Aug. 1	18:36	40,500	−53	9300	6-2	0.24	0.12
16	65 a	28927-29022	July 30	20:46	41,500	−58	8900	6-3	0.14	0.24
	b*	28927-29022	Aug. 1	18:37	40,500	−53	9300	6-2	0.24	0.12
	c	29022-29120	July 30	20:49	41,500	−58	8900	6-3	0.14	0.24
	d*	29022-29120	Aug. 1	18:39	40,500	−53	9300	6-2	0.24	0.12
17	66 a	29120-29206	July 30	20:52	41,500	−58	8900	6-3	0.14/0.20	0.24
	b*	29120-29265	Aug. 1	18:41	40,500	−53	9300	6-2	0.24	0.12
	c*	29265-29400	Aug. 1	18:44	40,300	−53	9300	6-2	0.24	0.12/0.24
	d*	29265-29400	Aug. 1	18:48	40,500	−53	9300	6-2/6-3	0.24	0.24
18	67 a*	29400-29565	Aug. 1	18:50	40,500	−53	9300	6-3	0.24	0.24
	b*	29565-29650	Aug. 1	18:53/19:21	40,800/41,500	−55/−58	9300	6-3	0.24	0.24
	c*	29650-29825	Aug. 1	18:55	41,200	−58	9300	6-3	0.24	0.24
	d*	29650-29825	Aug. 1	19:23	41,500	−58	9300	6-3	0.24	0.24
19	68 a*	29825-29909	Aug. 1	18:58/19:26	41,800/41,500	−59/−60	9300	6-3	0.24	0.24
	b*	29909-30065	Aug. 1	19:28	41,500	−60	9300	6-3	0.24	0.24
	c*	30065-30218	Aug. 1	19:31	41,500	−60	9300	6-3	0.24/0.38	0.24
	d*	30218-30366	Aug. 1	19:34	41,500	−60	9300	6-3	0.38	0.24
20	69 a*	30366-30510	Aug. 1	19:37	41,500	−60	9300	6-3	0.38	0.24
	b*	20510-30652	Aug. 1	19:40	41,500	−60	9300	6-3	0.38	0.24
	c*	30652-30789	Aug. 1	19:43	41,500	−60	9300	6-3	0.38	0.24
	d*	30789-30920	Aug. 1	19:47	41,500	−60	9300	6-3	0.38	0.24

*Grating turned at double rate.

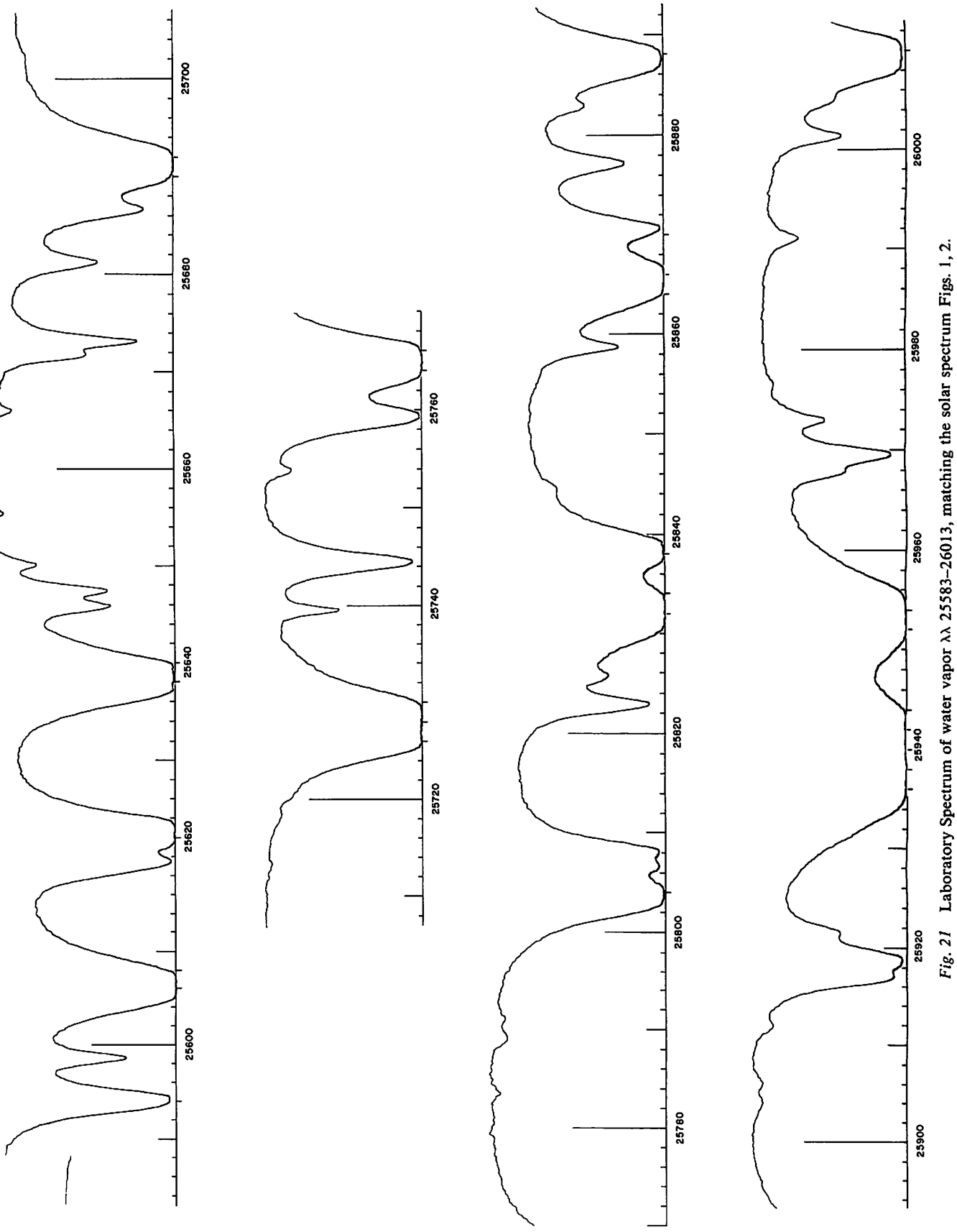

Fig. 21 Laboratory Spectrum of water vapor λλ 25583–26013, matching the solar spectrum Figs. 1, 2.

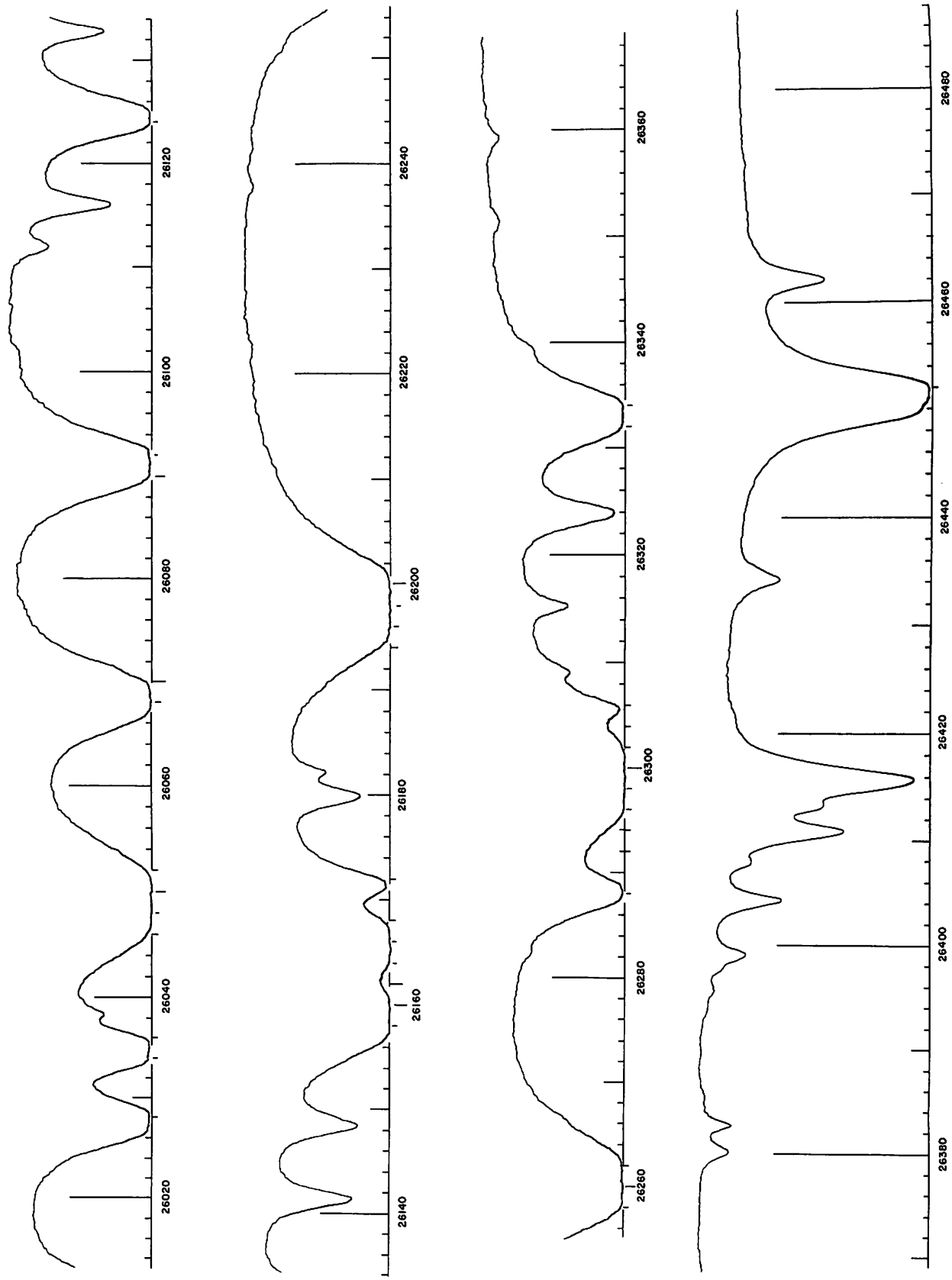

Fig. 22 Laboratory Spectrum of water vapor λλ 26013–26488, matching the solar spectrum Figs. 3, 4.

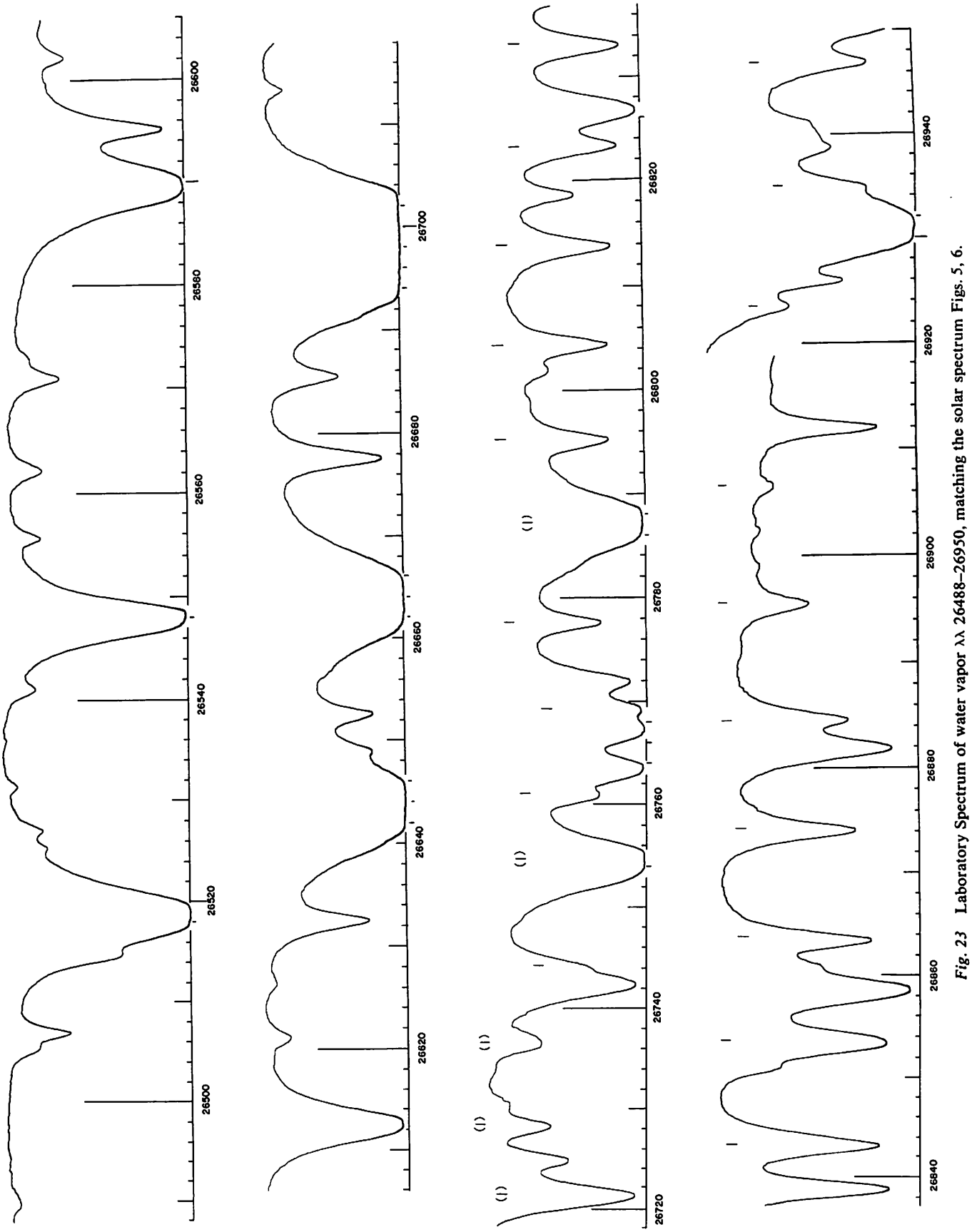

Fig. 23 Laboratory Spectrum of water vapor λλ 26488–26950, matching the solar spectrum Figs. 5, 6.

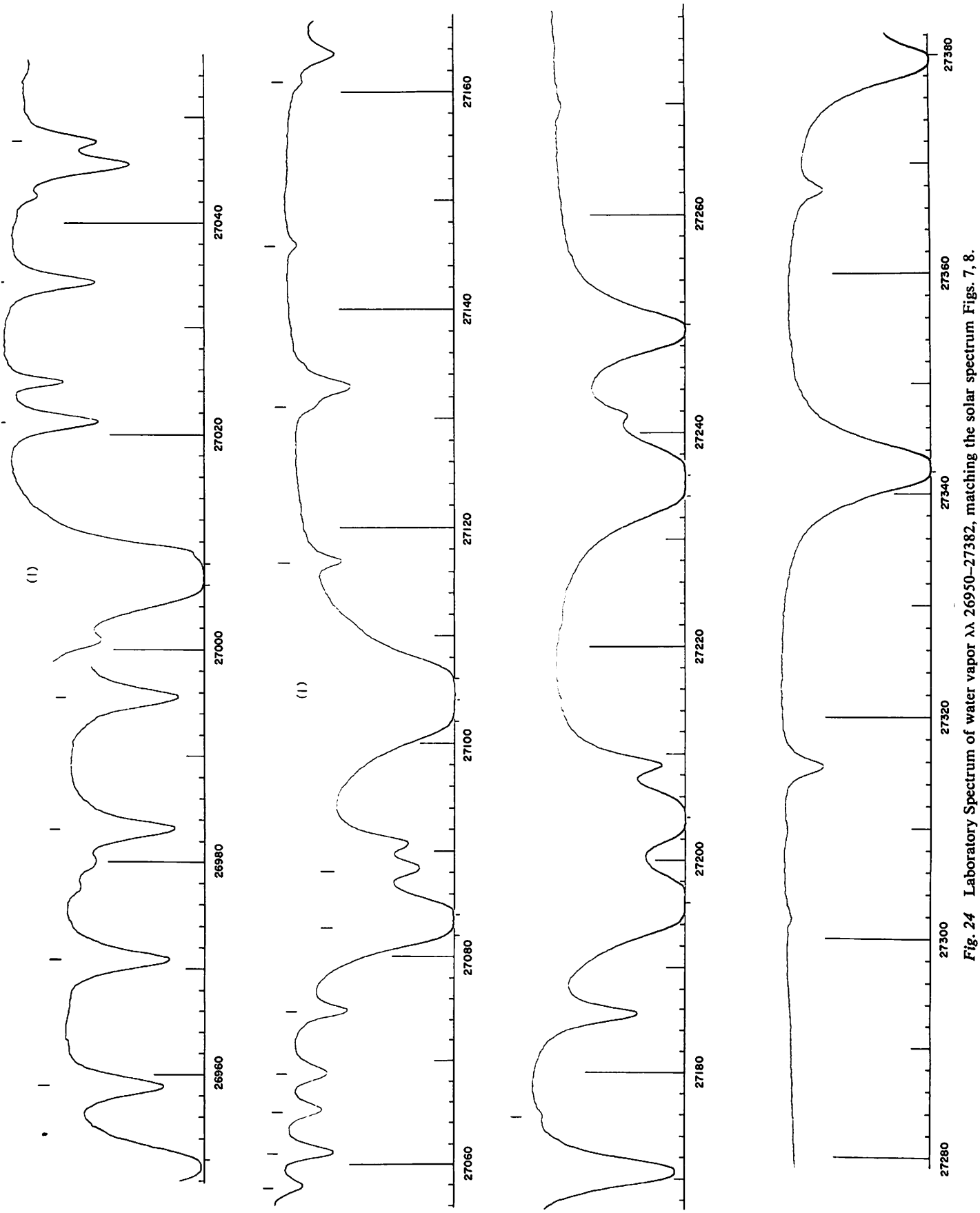

Fig. 24 Laboratory Spectrum of water vapor λλ 26950–27382, matching the solar spectrum Figs. 7, 8.

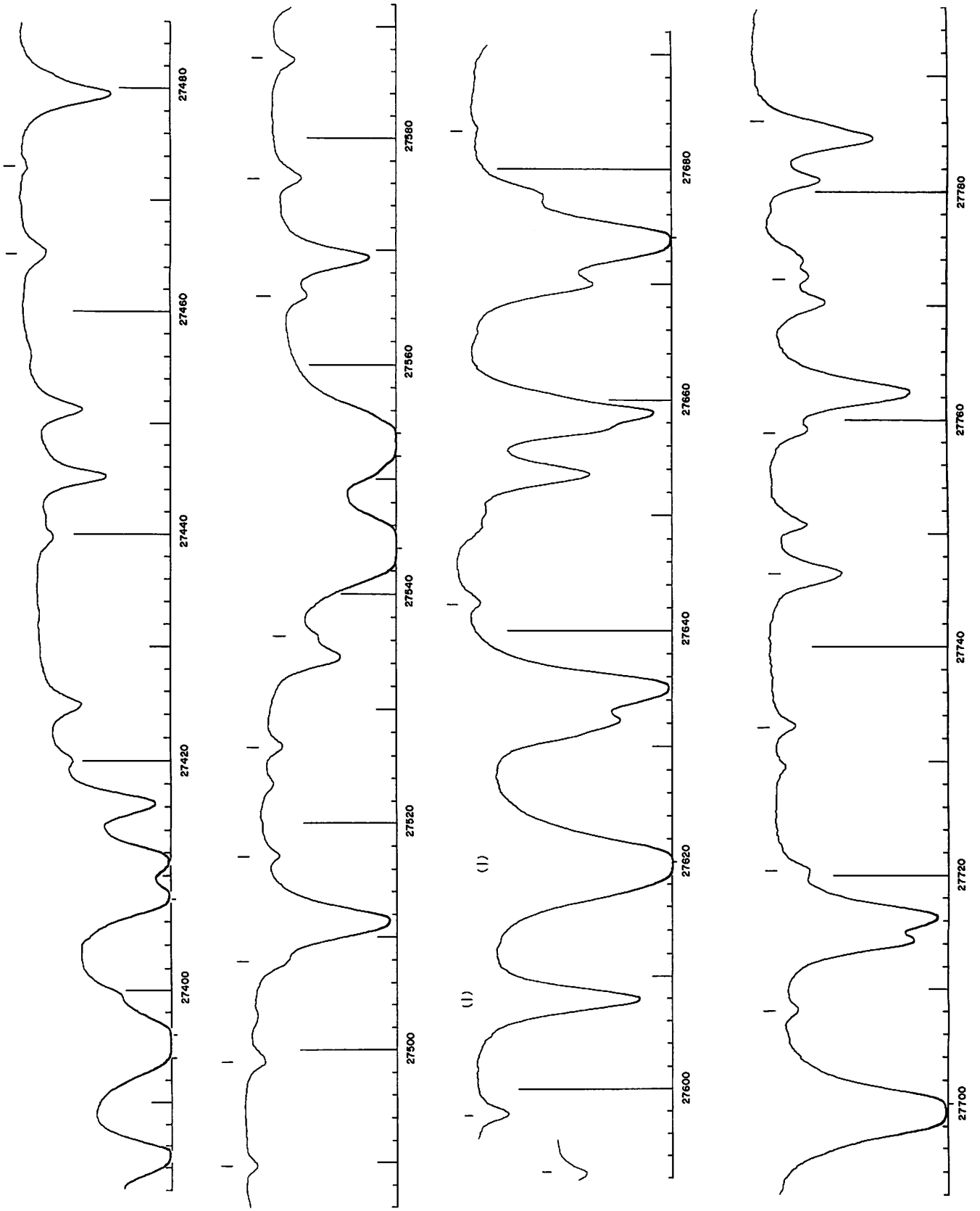

Fig. 25 Laboratory Spectrum of water vapor λλ 27382–27796, matching the solar spectrum Figs. 9, 10*a*, *b*.

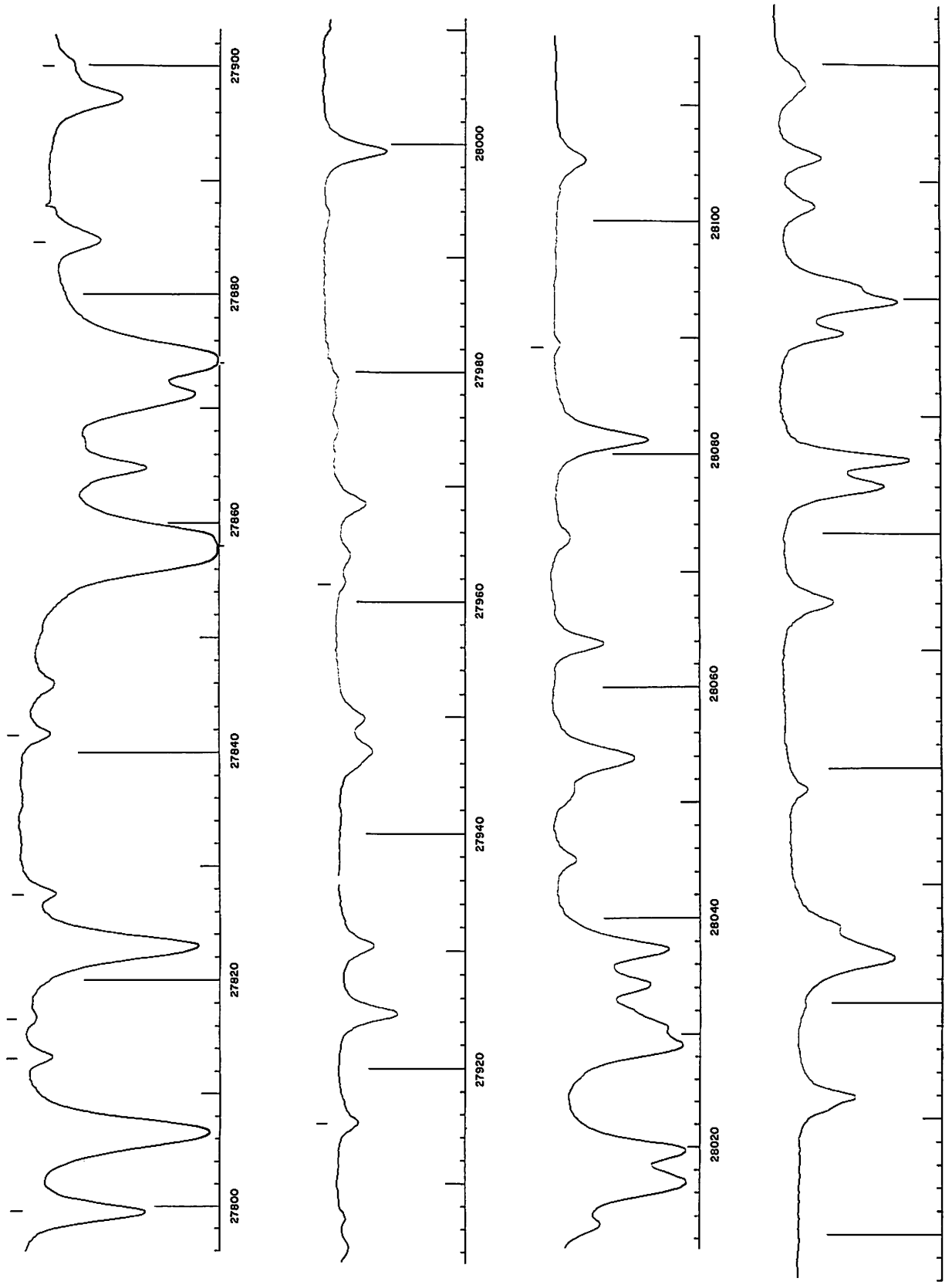

Fig. 26 Laboratory Spectrum of water vapor λλ 27796–28225, matching the solar spectrum Figs. 10*c*/*d*, 11, 12*a*/*b*.

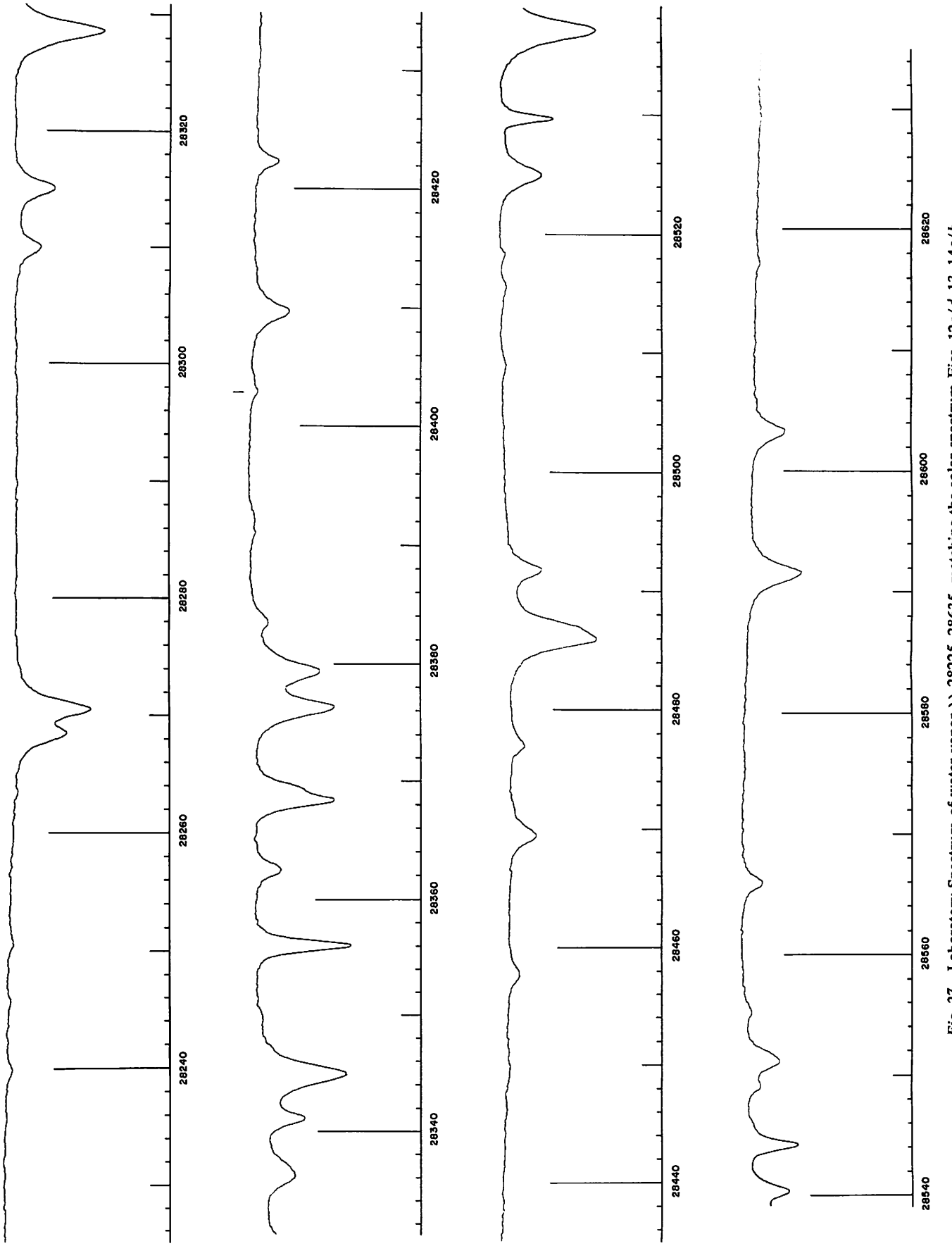

Fig. 27 Laboratory Spectrum of water vapor λλ 28225–28635, matching the solar spectrum Figs. 12*c*/*d*, 13, 14*a*/*b*.

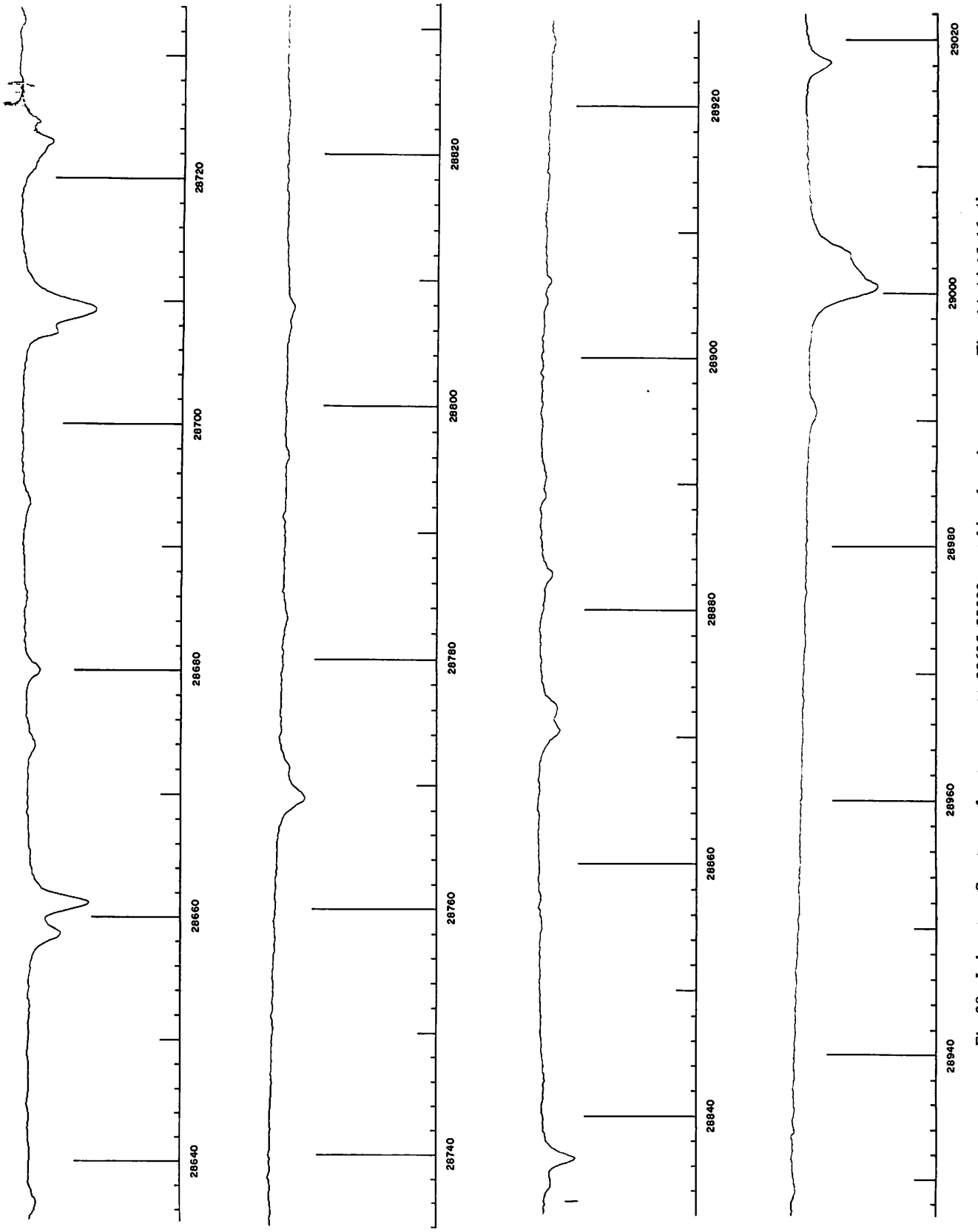

Fig. 28 Laboratory Spectrum of water vapor λλ 28635–29022, matching the solar spectrum Figs. 14*c*/*d*, 15, 16*a*/*b*.

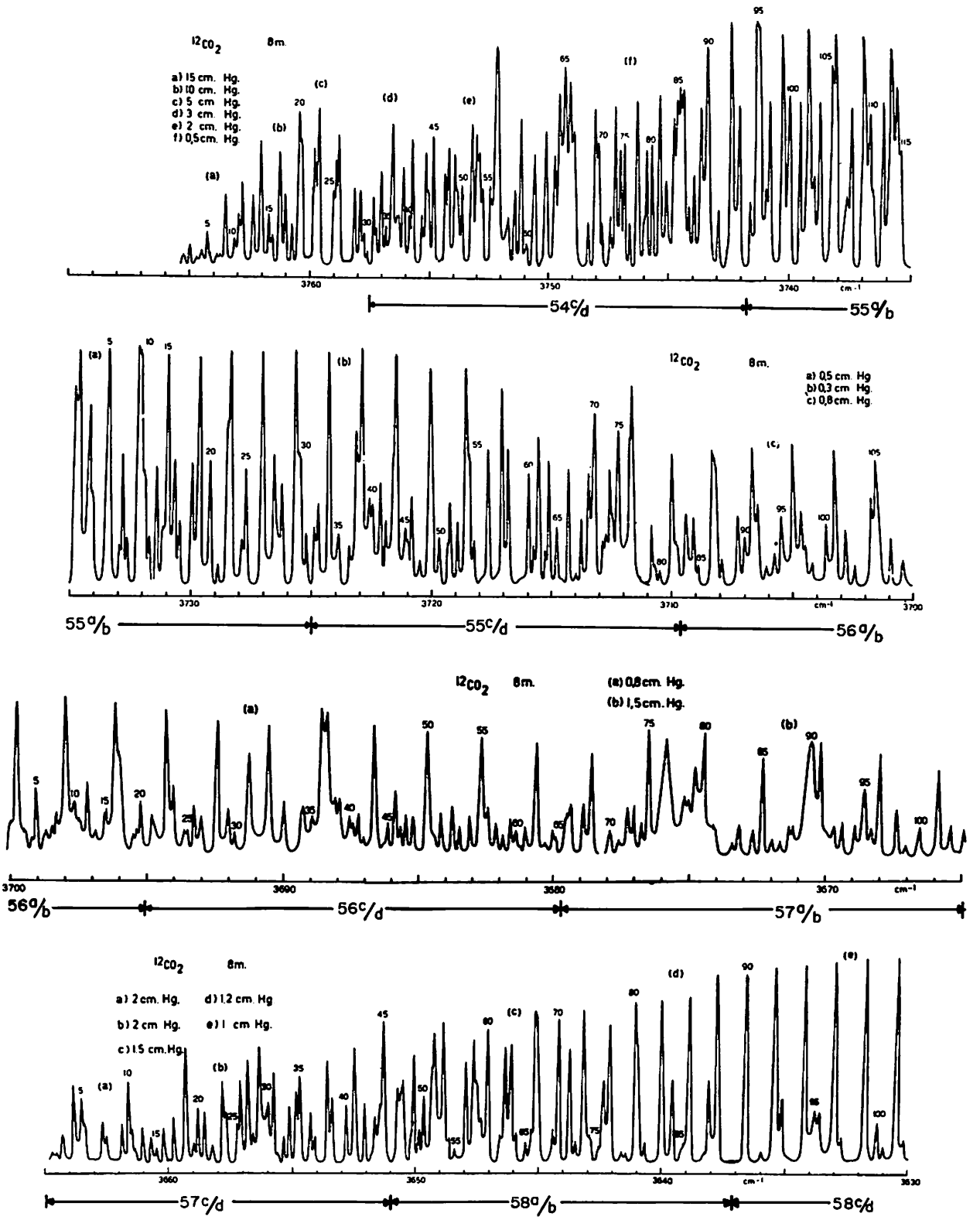

Fig. 29 Laboratory spectrum of CO_2 by C. P. Courtoy. Scales in wavenumbers. Arrows indicate corresponding parts of solar records. (Reproduced with permission).

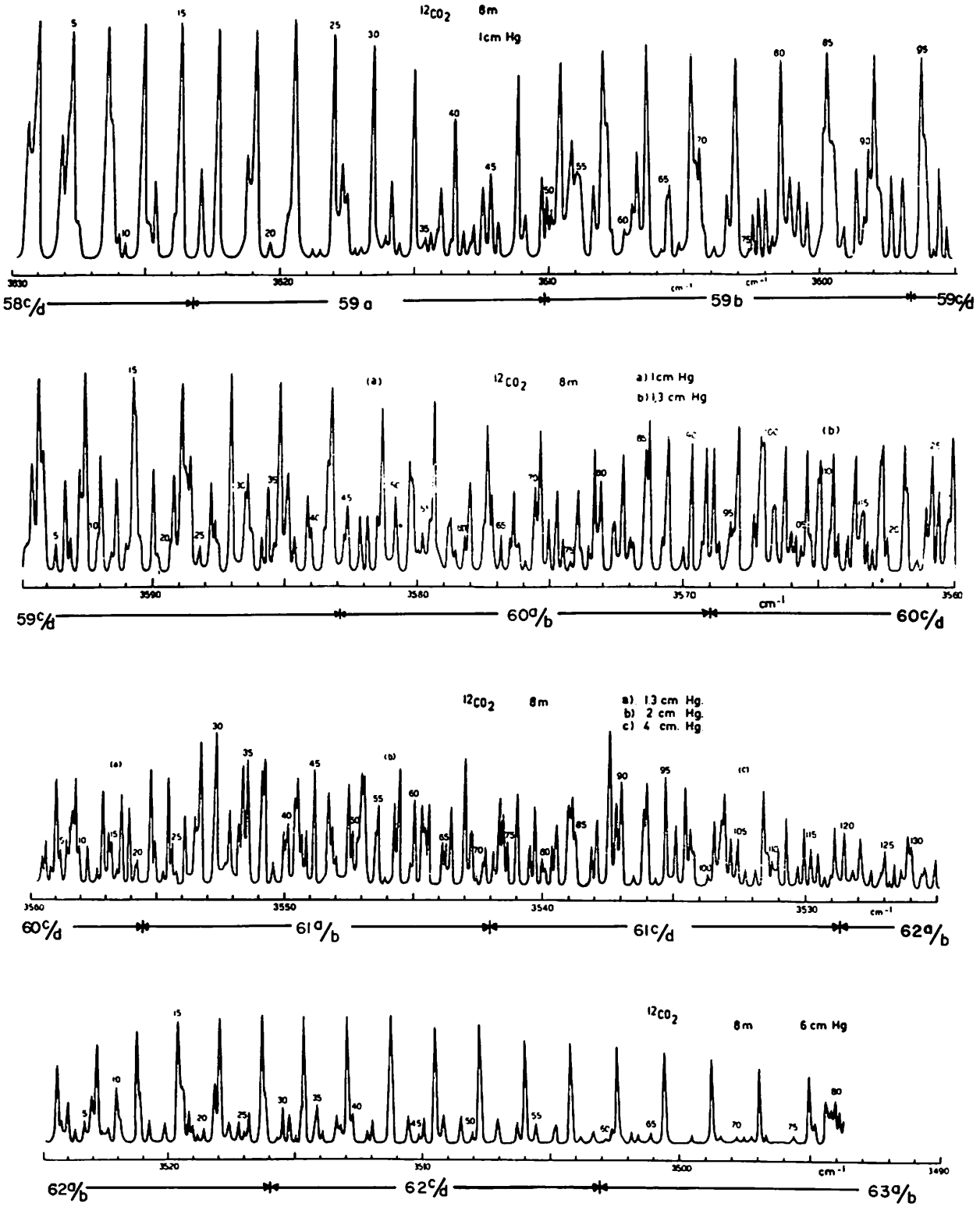

Fig. 30 Laboratory spectrum of CO_2 by C. P. Courtoy. Scales in wavenumbers. Arrows indicate corresponding parts of solar records. (Reproduced with permission).

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