NATIONAL BUREAU OF STANDARDS REPORT

9034

Photoelectric Filter Measurements of
Solar Ultraviolet Irradiances at
Los Angeles, California, October 1965

by

Ralph Stair
William R. Waters
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Metrology Division
National Bureau of Standards
Washington, D.C.

Report of Solar Radiation Project

Sponsored by
Department of Health, Education, and Welfare
Public Health Service

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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I. INTRODUCTION

The literature of the past fifty years contains much data on the total solar irradiances at various locations and for the different seasons of the year. These data have usually been obtained with some type of pyrheliometer in the form of a blackened horizontal receiver housed in a glass envelope. As a result, the short-wave ultraviolet and long-wave infrared are not included in the measurements.[1] Furthermore, the uncertainty in the measurements has been of the order of a few percent -- a magnitude approximating that of the total ultraviolet irradiance. Hence, the great amount of available data gives little information concerning the solar ultraviolet irradiance present in any locality. Only in those researches wherein special equipment has been employed are any quantitative ultraviolet data available. Measurements of this type have usually been made at high altitudes or in locations having relatively unpolluted atmospheres. Since the primary purpose of the present investigation was to evaluate the available solar ultraviolet in both a polluted area and a nearby area relatively free of polution, special instrumentation and techniques were required.

II. INSTRUMENTATION AND METHOD

HEW-PHS is interested primarily in photochemical processes to which suspended material in the atmosphere are subjected. Although these processes are directly related to absorption of radiation incident from any direction (a volume effect), it is to be noted that our instrumentation set up in down-town Los Angeles and on Mt. Wilson measures the solar ultraviolet irradiance (at selected wavelengths) on a horizontal surface. For best results, this requires the use of a detector having sensitivity over its surface in accordance with the cosine law for all angles from 0° (the horizon) to 90° (the zenith). No such commercial ultraviolet detector exists. If it did, a further difficulty would be encountered in devising spectral filters which would separate narrow spectral bands and at the same time not upset the cosine law response for angular elevation of source (the sun and sky). Hence, equipment of special design was required and was built.

In figure 1 is shown a layout diagram of the photoelectric equipment as assembled for this work. The solar irradiance (sun and sky) was collected in the integrating sphere[2] which was coated with a thick layer of $BaSO_4$. The entrance and exit ports were each 1/2 inch in diameter, the sphere diameter being 4 inches. The entrance port was fashioned with a "knife-edge" opening, which was in the plane of the topmost section of the box, and was adjusted precisely to a horizontal position. The exit opening was placed to the East or West, (so that at no time did the sun or its primary reflection, fall directly into its view) and was covered by a shield and Corning filter 9863 having high opacity within the visible spectral region.

A filter wheel carrying 9 narrow-and 1 wide-band interference filters and 2 blanks (zero transmittance) was set at about 6 inches from the sphere exit port so that a narrow beam of ultraviolet flux passed (near perpendicularly) through each of the filters onto a type RCA-935 photoelectric cell as the filter-wheel was step-rotated by a synchronous motor and geneva-drive mechanism. In this manner each filter and each blank (zero transmittance) was set in position for a period of about 10 seconds (sufficient time for the pico-ammeter and recorder to register on a strip chart a definite value). Thus the magnitude of each spectral irradiance was registered once in each interval of approximately two minutes (about 30 times per hour). For purposes of calibration at intervals during each day a 1000-watt quartz iodine lamp standard of spectral irradiance mounted in a special carriage to eliminate all sun and sky irradiance was placed above the integrating sphere (at a measured distance) and the output through the 10 filters was recorded over a period of several minutes (2 to 3 rotations of the filter disk.).

The spectral transmittance of each of the 9 narrow-band interference filters employed at Mt. Wilson is depicted in figure 2. Each filter has a half-band width of approximately 10 nm, and its centroid is situated near even 10-nm intervals from 310 nm to 390 nm.

In table I are tabulated (in column 2) the relative response of our RCA type 935 phototube (#5) when irradiated by a 1000-watt quartz-iodine lamp standard of spectral irradiance #131 through Corning filter 9863 and each interference filter in turn, (in column 3) the wavelength centroid under these same conditions and (in column 4), as an example, the correction that should be applied when the spectral energy distribution of the irradiating source is that of the sun as determined at Sacramento Peak, New Mexico [3/], for air mass 1.0 rather than that of lamp standard #131. The spectral data on these sources, this detector, and Corning filter 9863 are also included in Figure 2. Because corrections as listed in column 4 of table I are smaller than the uncertainties in this type of measurement they were not made in computing the values reported in Section III of this Report. Other small corrections that are worthy of note, but which have been neglected in this Report arise from the following considerations: (1) the data herein reported in detail apply to the Mt. Wilson instrumentation, a "duplicate" of which with filters cut from the same stock was set up and operated in down-town Los Angeles (at 300 South Pedro Street); the differences between the instruments are considered to be minor, and (2) an additional correction of approximately one percent could be applied to cover loss of sky irradiance passing directly through the two sphere openings and missing the detector entirely (see fig. 1); however, a nearly equal but opposite error occurs for sky irradiance reflected on first reflection from the sphere wall directly onto detector (it is to be noted that all of the flux from the quartz-iodine standard and nearly all of the sky flux is multiply reflected in the sphere before it is incident on the detector).

The instrumentation required little attention since all operations, except for setting up and operating the standard lamp for calibration, were automated. The usual service consisted of keeping the quartz hemisphere cover clean, the recorder pen cleaned and filled, and time indications and other pertinent weather and air pollution information noted on the recorder strip chart or associated notebook.

An examination of column 2 of table I discloses that there is a factor of more than 10 between the highest and lowest integrated instrumental reading at one total irradiance. A further variation of nearly 10 occurred between the early morning (or late afternoon) readings and those obtained near the noon hour. Since it is impractical to change instrumental sensitivity either between the interposition of filters or during the day, another method was employed to keep all data on a reasonable chart scale. This consisted of placing (permanently) perforated metal screens (of various transmittances) over most of the filters so that in all cases the short-wave spectral regions produced readable deflections while the other spectral regions produced deflections not exceeding the chart limits or the fatique level for the phototube. The transmittance values for these screens were not required and have not been obtained in the reduction of the data.

III. Results.

Ultraviolet spectral solar and sky irradiances on a horizontal surface were made daily over a period of about one month between about September 20 and October 20, 1965, at Mt. Wilson (altitude 5710 feet) and down-town Los Angeles (altitude about 500 feet). During this time supplementary aeroplane flights were made on 6 days in which other ultraviolet instrumentation was employed. During 5 of these days data were obtained employing the herein described instrumentation. Some of the data obtained with the narrow-band interference filters is plotted on charts Nos. 3 to 12. These data as well as some obtained for the wide-band spectral region of 300 to 380 nanometers are summarized in tables II and III. It is to be noted that precise values of spectral response of the particular phototube (set up at Mt. Wilson) as well as of the spectral irradiance of the NBS standard lamp and of the spectral transmittance of the wide-band filters used at that station were employed in the reduction of the measurements on Mt. Wilson made with the wide-band filters. Under these conditions the two sets of data for the spectral region of 300 to 380 nm are in agreement to about 1 percent which may be considered unexpectedly good considering the fact that a solar curve for M = 1 for Sacramento Peak, New Mexico (rather than the true curve) was employed as a basis for the reduction of the measurements with the wide-band filter.

A wider disagreement (2.5 to 3.0 percent) occurs in the case of the down-town Los Angeles measurements for the wide-band spectral region of 300 to 380 nanometers. Possibly wider divergencies exist between the true and the solar curve (M = 1.0 for Sacramento Peak) employed. Or the greater discrepancy results because of our assumption that the two phototubes had the same relative spectral responses. A difference of 2.5 to 3.0 percent is small--but since all measurements fall within the range of 2.5 to 3.0 percent, the indication is that the error is contained in some of the basic factors common to all the measurements. Possibly the wide-band filter transmittance was significantly different at Los Angeles from what it was when measured following the work in the field. As a matter of fact, all the interference filters employed in this work solarized significantly during the course of the investigation, but since lamp calibrations were made at least twice daily any error resulting because of filter solarization is considered insignificant except possibly for the wide-band unit.

The development of the instrumentation employed in this investigation was sponsored jointly by the United States Public Health Service and the National Aeronautics and Space Administration.

The authors acknowledge with appreciation the aid and cooperation furnished at the Mt. Wilson Station during the course of these measurements. Special thanks are due Mr. Edward Swanson of the Mt. Wilson Resort for making a protected area on that property available for the work; and to Television station KCET T-V for the use of their facilities during the course of the investigation. Mr. James Mead and other members of the station staff spared no effort in giving us assistance in many ways.

IV. Miscellaneous Notes on Weather & Smog

October 6 -

Sky clear on Mt. Wilson during most of the day but with a very slight haze. Little or no wind at both stations. Smog layer appearing early over basin. Overcast and smoggy in down-town Los Angeles all day. Some clouds on Mt. Wilson after 2:00 p.m. A very smoggy day.

October 12 -

Sky very clear on Mt. Wilson in early morning. Thin layer of reddish-brown smog present at about 1000 feet below Mt. Wilson station. No wind. By 2:30 p.m. smog layer reached Mt. Wilson station. Ozone meter responds to incoming oxidants. Down-town overcast all day. Intermediate smog.

October 16 -

Sky clear on Mt.Wilson all day. Good visibility down-town. Northwest wind at both stations-about 30 mph. on Mt. Wilson. A clear and windy day. Little smog.

October 18 -

Sky clear on Mt. Wilson all day. Light haze and smog over basin. Little or no wind at both stations. A relatively clear and calm day.

October 20 -

Sky clear on Mt. Wilson all day except for a few thin scattered clouds in afternoon. Some cloudiness and haze over basin all day. Little or no wind at either station. Light to moderate smog in down-town Los Angeles.

1. IGY Instruction Manual, Part VI, Radiation Instruments and Measurement, Pergamon Press, (1958). (The glass envelope of pyrheliometers is opaque to the infrared of wavelengths longer than about 4 microns and to some of the ultraviolet; new instruments have higher transmittances at 300 nm.)

2. Ralph Stair, William E. Schneider, William R. Waters, John K. Jackson, and Roger E. Brown, Some developments in improved methods for the measurement of the spectral irradiances of solar simulators, NASA Contractor Report, CR-201, (1965).

3. Ralph Stair and Russell G. Johnston, Preliminary spectroradiometric measurements of the solar constant, J. Res. NBS 57, 205 (1956).

Table I

Interference Filter nm	Filter Tr x lamp energy x Phototube Resp. x Corning 9863	Wavelength Centroid nm	Percent Correction when measuring solar irradiance (air mass 1.0)
310	1172	309.42	+2.9
320	3345	322.29	-3.0
330	4663	331.58	+1.4
340	5145	340.65	+0.8
350	9759	352.70	+3.2
360	12500	360.22	+0.2
370	10539	371.80	+2.5
380	8805	381.33	+1.9
390	7609	392.10	-2.7

Table IIa - Ultraviolet Spectral Irradiance of Sun and Sky on a Horizontal Surface at Mt. Wilson, California in $\mu W/cm^2$ for 10nm Wavelength Intervals on Selected Days at 30 Minute Intervals (P.D.S.T.); also total irradiance for spectral region of 300 to 380 nm evaluated as sum of narrow bands and as measured through the use of a wide-band filter.

		a.m. Time								
Wave-length (nm)	Date Oct. 1965	8:00	8:30	9:00	9:30	10:00	10:30	11:00	11:30	12:00
310	6	4.5	13.4	35.8	58.2	76.1	102.9	116	139	148
	12	5.8	17.5	26.3	43.8	64.2	78.8	105	117	131
320	6	49.7	90.6	139	189	234	278	316	345	364
	12	41.0	76.3	118	163	208	249	288	316	332
330	6	102	171	248	324	395	459	512	558	585
	12	84.2	146	213	283	350	411	467	508	534
340	6	114	182	261	338	401	468	521	563	588
	12	99.2	164	233	305	374	434	491	534	559
350	6	117	185	264	343	411	471	572	572	595
	12	102	168	238	311	379	443	498	540	566
360	6	114	182	263	342	408	474	526	573	598
	12	103	170	242	320	389	455	513	558	582
370	6	136	221	314	409	489	567	626	680	708
	12	118	197	279	368	447	517	588	635	664
380	6	131	215	307	399	474	548	609	663	689
	12	117	197	277	364	443	513	581	630	655
390	6	140	231	329	424	504	583	644	701	727
	12	121	207	289	378	457	529	600	650	674
300-380	6	704	1156	1485	2209	2660	3106	3449	3779	3951
	12	612	1040	1491	1981	2441	2854	3254	3538	3712
300-380 (W.B.F.)	6	717	1154	1658	2174	2611	3025	3384	3697	3877
	12	629	1060	1513	1996	2434	2844	3224	3487	3655

Table IIa - Ultraviolet Spectral Irradiance of Sun and Sky on a Horizontal Surface at Mt. Wilson, California in μW/cm^2 for 10nm Wavelength Intervals on Selected Days at 30 Minute Intervals (P.D.S.T.); also total irradiance for spectral region of 300 to 380 nm evaluated as sum of narrow bands and as measured through the use of a wide-band filter.

		p.m. Time									
Wave-length (nm)	Date Oct. 1965	12:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00
310	6	143	152	143	139	94.0	102.9	40.3	40.3	22.4	
	12	131	134	131	111	102	75.9	58.4	32.1	14.6	8.8
320	6	364	368	360	342	250	300	164	161	117	
	12	338	341	334	311	279	242	203	155	110	63
330	6	584	590	581	552	419	495	221	284	213	
	12	540	545	536	503	456	398	346	271	201	125
340	6	590	595	585	558	418	510	219	294	222	
	12	565	572	560	528	483	424	367	292	218	140
350	6	592	603	594	568	423	527	204	302	226	
	12	567	577	567	536	489	433	375	301	223	143
360	6	592	602	598	571	474	534	199	304	228	
	12	585	594	585	549	500	441	383	304	224	143
370	6	703	718	706	672	541	636	232	363	270	
	12	665	677	665	628	575	509	437	348	259	163
380	6	681	694	684	658	466	625	228	356	264	
	12	656	671	661	623	571	504	433	344	257	162
390	6	720	731	723	697	447	671	254	375	280	
	12	674	694	684	637	588	519	447	351	264	165
Σ300-380	6	3929	3995	3926	3747	2864	3429	1387	1932	1435	
	12	3735	3792	3725	3491	3182	2784	2393	1879	1380	868
300-380 (W.B.F.)	6	3843	3888	3821	3664	2633	3361	1647	1905	1434	
	12	3677	3750	3684	3436	3114	2749	2361	1857	1367	855

Table IIb - Ultraviolet Spectral Irradiance of Sun and Sky on a Horizontal Surface at Mt. Wilson California in μW/cm^2 for 10nm Wavelength Intervals on Selected Days at 30 Minute Intervals (P.D.S.T.); also Total irradiance for spectral regions of 300 to 380 nm evaluated as sum of narrow bands and as measured through the use of a wide-band filter.

		a.m. Time							
Wave-length (nm)	Date Oct. 1965	8:15	8:45	9:15	9:45	10:15	10:45	11.15	11:45
310	16	5.8	17.5	35.0	56.0	73.2	93.4	105	120
	18	5.8	17.5	32.1	46.7	73.0	88	102	114
	20	5.8	20.4	32.1	49.6	73.0	87.6	108	114
320	16	51.5	91.6	135	178	222	259	286	310
	18	50.6	89.7	133	176	219	255	282	298
	20	49.6	87.8	130	174	216	252	280	303
330	16	107	171	239	307	370	423	464	499
	18	105	168	237	306	370	422	461	485
	20	102	165	231	300	361	415	461	492
340	16	129	199	274	343	411	469	512	548
	18	122	194	265	336	402	455	493	514
	20	119	186	256	327	391	446	493	524
350	16	129	199	268	342	407	464	510	545
	18	124	193	267	338	403	455	495	518
	20	120	189	260	332	397	451	497	529
360	16	131	207	282	356	428	486	531	571
	18	127	200	274	351	419	473	516	539
	20	124	196	270	344	413	471	518	552
370	16	148	234	319	405	484	544	598	638
	18	143	225	312	398	472	536	580	608
	20	138	220	304	390	464	529	581	618
380	16	147	229	314	399	476	538	590	630
	18	142	224	311	394	468	531	574	601
	20	135	220	300	384	461	524	578	615
390	16	151	242	331	420	504	561	618	657
	18	121	235	324	410	489	546	590	620
	20	141	227	311	400	474	538	593	630
Σ 300-380	16	776	1236	1713	2194	2642	3019	3314	3561
	18	749	1201	1680	2155	2601	2961	3229	3391
	20	727	1177	1637	2115	2555	2905	3241	3454
300-380 (W.B.F)	16	789	1213	1696	2171	2610	2968	3275	3494
	18	760	1206	1689	2142	2580	2924	3180	3341
	20	738	1184	1637	2105	2529	2902	3202	3421

Table IIb- Ultraviolet Spectral Irradiance of Sun and Sky on a Horizontal Surface at Mt. Wilson California in μW/cm^2 for 10nm Wavelength Intervals on Selected Days at 30 Minute Intervals (P.D.S.T.); also Total irradiance for spectral regions of 300 to 380 nm evaluated as sum of narrow bands and as measured through the use of a wide-band filter.

Wave-length (nm)	Date Oct. 1965	P.M. Time 12.15	12:45	1:15	1:45	2:15	2:45	3:15	3:45	4:15	4:45
310	16	123	120	120	114	99.3	84.7	61.3	40.9	26.3	8.8
	18	120	120	114	108	88.2	73.0	58.0	35.1	23.0	5.8
	20	117	114	111	96.0	85.0	64.1	43.8	32.1	17.5	8.8
320	16	320	318	317	304	281	249	206	162	115	72.5
	18	312	313	308	290	266	235	196	155	111	65.0
	20	309	303	297	277	254	205	172	135	93.5	57.2
330	16	513	509	507	490	456	411	350	283	213	145
	18	504	505	498	474	440	392	336	274	204	129
	20	501	490	483	455	420	345	299	241	172	112
340	16	561	558	557	536	500	448	383	315	242	166
	18	536	536	530	506	470	421	364	299	226	148
	20	533	518	513	482	446	371	326	263	191	125
350	16	558	552	554	534	500	447	382	311	245	169
	18	535	538	532	510	476	428	369	305	229	152
	20	541	526	524	488	455	376	334	271	200	129
360	16	578	576	578	556	521	473	404	327	252	173
	18	560	559	552	529	494	444	381	313	236	154
	20	560	543	543	509	475	393	343	281	207	130
370	16	647	643	647	623	585	531	455	371	289	198
	18	630	628	620	598	551	504	435	354	269	176
	20	633	610	610	571	536	444	386	316	237	144
380	16	638	636	640	616	578	523	449	367	284	195
	18	621	620	613	596	553	501	431	352	267	175
	20	630	606	605	568	534	443	382	317	237	142
390	16	664	664	667	645	600	543	467	385	299	203
	18	637	640	630	613	566	516	444	366	272	183
	20	635	618	618	578	546	452	393	324	247	143
Σ300-380	16	3634	3609	3615	3479	3243	2916	2474	1999	1528	1031
	18	3522	3524	3475	3327	3073	2757	2362	1916	1443	918
	20	3524	3421	3397	3174	2949	2428	2200	1702	1239	778
300-380 (W.B.F.)	16	3582	3575	3567	3436	3202	2880	2442	1988	1528	1045
	18	3472	3487	3428	3290	3056	2756	2354	1923	1418	936
	20	3465	3392	3370	3136	2953	2456	2083	1689	1257	789

Table IIIa - Ultraviolet Spectral Irradiance of Sun and Sky on a Horizontal Surface in Down-Town Los Angeles, California in $\mu W/cm^2$ for 10nm Wavelength Intervals on Selected Days at 30 Minute Intervals (P.D.S.T.); also total irradiance for spectral region of 300 to 380 nm evaluated as sum of narrow bands and as measured through the use of a wide-band filter.

		a.m. Time								
Wave-length (nm)	Date Oct. 1965	8:00	8:30	9:00	9:30	10:00	10:30	11:00	11:30	12:00
310	6	4.8	11.3	20.9	29.0	40.3	46.7	48.3	51.5	74.1
	12	4.8	8.1	12.9	16.1	25.8	33.8	45.1	56.4	62.8
320	6	31.1	52.8	77.6	97.5	128	137	131	140	197
	12	22.4	39.1	52.8	65.2	91.9	103	133	158	172
330	6	60.1	94.4	133	163	209	224	210	223	314
	12	44.6	70.9	92.1	110	141	167	211	251	270
340	6	68.9	107	146	176	224	238	225	238	338
	12	53.4	81.5	104	122	154	181	228	272	293
350	6	67.5	113	154	186	237	249	240	256	364
	12	56.8	86.8	110	129	162	190	243	287	311
360	6	75.3	115	156	190	242	255	247	273	384
	12	59.5	90.2	114	133	167	197	251	300	325
370	6	87.7	135	184	221	285	298	291	331	450
	12	69.1	105	132	156	193	229	292	348	380
380	6	86.1	132	179	217	279	290	288	328	448
	12	67.2	103	130	153	189	223	286	342	371
390	6	88.6	134	184	221	285	296	285	332	449
	12	69.2	105	134	156	192	225	290	348	380
Σ300-380	6	434	696	964	1175	1610	1599	1542	1683	2354
	12	340	534	684	811	1032	1220	1558	1851	2007
300-380 (W.B.F.)	6	473	731	988	1211	1552	1629	1538	1608	2359
	12	362	564	710	842	1044	1246	1594	1886	2053

Table IIIa - Ultraviolet Spectral Irradiance of Sun and Sky on a Horizontal Surface in Down-Town Los Angeles, California in $\mu W/cm^2$ for 10nm Wavelength Intervals on Selected Days at 30 Minute Intervals (P.D.S.T.); also total irradiance for spectral region of 300 to 380 nm evaluated as sum of narrow bands and as measured through the use of a wide-band filter.

Wave-length (nm)	Date Oct. 1965	p.m. Time 12:30	1.00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00
310	6	82.1	86.9	88.6	80.5	70.8	56.4	43.5	24.2	17.7	6.4
	12	64.4	72.5	75.7	70.8	66.0	51.5	40.3	27.4	12.9	4.8
320	6	212	230	231	221	200	158	142	95.6	77.0	46.0
	12	175	193	209	197	193	163	132	103	72.0	42.2
330	6	335	367	368	351	321	272	235	142	133	85.8
	12	276	303	330	312	309	265	217	173	126	78.9
340	6	355	393	391	374	346	315	265	153	148	96[illegible]
	12	298	328	357	337	338	290	237	191	141	91.1
350	6	377	421	416	395	369	337	284	170	156	103
	12	316	349	380	359	360	308	253	204	150	104
360	6	395	433	427	402	380	334	301	164	163	105
	12	331	377	395	366	370	319	261	211	154	99.5
370	6	467	513	503	475	450	387	364	187	192	124
	12	382	429	460	430	428	370	304	247	180	117
380	6	460	505	495	466	444	380	362	176	188	122
	12	376	422	454	419	418	362	298	241	175	113
390	6	469	515	504	480	454	383	357	172	195	122
	12	382	428	461	430	420	364	303	245	176	111
Σ300-380	6	2463	2707	2683	2542	2368	2061	1821	1027	983	628
	12	2039	2272	2243	2290	2281	1954	1598	1280	925	595
300-380	6	2506	2749	2735	2575	2408	2123	1970	1281	1030	654
(W.B.F.)	12	2060	2311	2520	2346	2290	1977	1643	1329	954	606

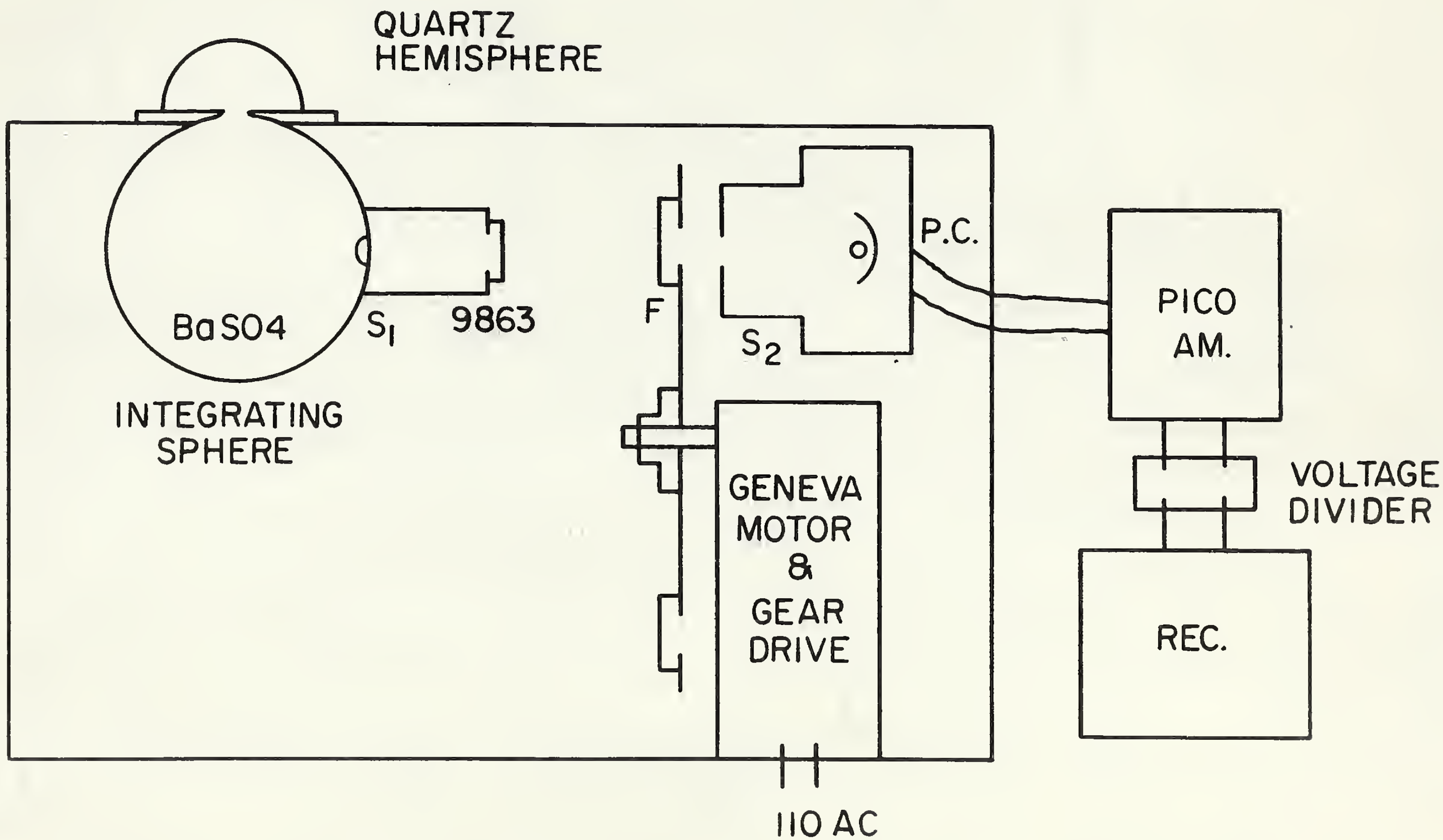
Table IIIb - Ultraviolet Spectral Irradiance of Sun and Sky on a Horizontal Surface in Down-town Los Angeles, California in μW/cm² for 10nm Wavelength Intervals on Selected Days at 30 Minute Intervals (P.D.S.T.); also total irradiance for spectral region of 300 to 380 nm evaluated as sum of narrow bands and as measured through the use of a wide-band filter.

		a.m. Time							
Wave-length (nm)	Date Oct. 1965	8:15	8:45	9:15	9:45	10:15	10:45	11:15	11:45
310	16	6.4	17.7	25.8	40.3	54.7	69.2	80.5	93.4
	18	6.4	12.9	24.2	35.4	49.9	61.2	74.1	78.9
	20	6.4	14.5	25.8	38.6	51.5	66.0	72.5	82.1
320	16	42.2	68.3	110	145	183	212	238	259
	18	38.5	64.6	91.9	120	157	186	212	221
	20	39.1	69.6	103	136	163	192	202	224
330	16	83.5	136	191	246	302	345	383	411
	18	74.9	116	157	197	255	298	334	347
	20	75.5	124	175	222	263	305	324	349
340	16	100	156	216	276	337	382	421	451
	18	88.9	134	178	219	282	330	365	376
	20	89.7	143	196	245	292	333	351	375
350	16	106	167	232	296	359	406	448	481
	18	95.5	142	190	234	304	353	387	402
	20	95.5	154	212	261	313	357	383	406
360	16	110	174	242	308	376	424	467	503
	18	99.5	150	199	247	323	368	410	425
	20	100	161	222	286	331	379	402	441
370	16	127	203	281	357	437	489	539	581
	18	115	170	229	283	372	421	470	487
	20	115	185	254	324	377	429	455	503
380	16	122	197	275	351	425	476	524	566
	18	110	167	223	276	362	411	457	475
	20	113	184	254	320	372	422	451	489
390	16	122	200	279	356	428	483	528	573
	18	108	169	229	280	370	419	467	481
	20	113	184	254	320	372	422	451	489
Σ300-380	16	637	1023	1439	1849	2268	2574	2849	3074
	18	575	855	1184	1478	1930	2230	2481	2584
	20	579	945	1318	1677	1983	2280	2422	2615
300-380 (W.B.F.)	16	668	1072	1489	1907	2325	2659	2916	3167
	18	599	919	1232	1524	1984	2283	2596	2666
	20	612	981	1364	1754	2032	2318	2464	2652

Table IIIb - Ultraviolet Spectral Irradiance of Sun and Sky on a Horizontal Surface in Down-town Los Angeles, California in μW/cm^2 for 10nm Wavelength Intervals on Selected Days at 30 Minute Intervals (P.D.S.T.); also total irradiance for spectral region of 300 to 380 nm evaluated as sum of narrow bands and as measured through the use of a wide-band filter.

Wave-length (nm)	Date Oct. 1965	p.m. Time 12:15	12:45	1:15	1:45	2:15	2:45	3:15	3:45	4:15	4:45
310	16	95.0	93.4	91.8	90.2	77.3	64.4	49.9	35.4	17.7	8.1
	18	77.3	67.6	53.1	49.9	46.7	38.6	33.8	25.8	14.5	6.4
	20	91.8	93.4	83.7	72.5	59.6	46.7	40.3	25.8	12.9	4.8
320	16	267	255	255	253	229	199	165	130	88.8	57.8
	18	215	191	157	151	145	129	119	102	73.9	46.6
	20	250	253	235	209	184	152	139	103	75.1	46.6
330	16	423	405	405	407	367	322	270	219	154	108
	18	336	303	249	243	235	209	197	172	131	88.1
	20	386	392	366	330	292	246	226	172	130	85.8
340	16	463	443	442	446	403	355	300	245	173	123
	18	367	329	273	270	258	231	219	191	149	101
	20	415	422	394	358	317	268	248	187	145	97.8
350	16	492	470	468	474	430	378	320	261	184	131
	18	389	355	297	295	279	247	238	207	160	109
	20	448	455	426	389	344	293	268	201	157	106
360	16	512	489	490	495	451	395	333	272	191	135
	18	409	375	313	313	294	260	250	217	167	114
	20	487	478	451	412	366	312	284	212	166	111
370	16	590	562	561	569	520	455	375	313	220	157
	18	475	427	363	363	339	300	290	250	192	129
	20	553	544	515	469	417	357	324	237	188	125
380	16	575	550	542	553	507	445	376	304	214	151
	18	460	424	361	357	333	293	284	244	188	126
	20	543	536	506	465	414	356	324	234	184	122
390	16	580	557	544	557	510	452	383	309	217	153
	18	467	432	370	364	341	300	291	251	190	127
	20	543	536	506	465	414	356	324	234	184	122
Σ300-380	16	3136	3004	2995	3022	2741	2399	2007	1632	1138	796
	18	2508	2268	1892	1870	1769	1566	1493	1290	983	658
	20	2914	2917	2734	2481	2194	1859	1696	1258	968	639
300-380 (W.B.F.)	16	3209	3083	3076	3069	2805	2464	2081	1691	1176	828
	18	2554	2276	1928	1900	1817	1594	1531	1336	1030	689
	20	3014	3000	2777	2533	2255	1907	1740	1308	1009	668

Fig. 1. Block diagram showing the instrumental layout. All optical components were placed inside a light-tight box, painted white on the outside and black inside. The phototube and 45 volt battery source were connected through a special shielded coaxial cable to the pico-ammeter whose output was fed through a special voltage divider for proper match at selected voltage steps with a standard 10 millivolt strip-chart recorder.



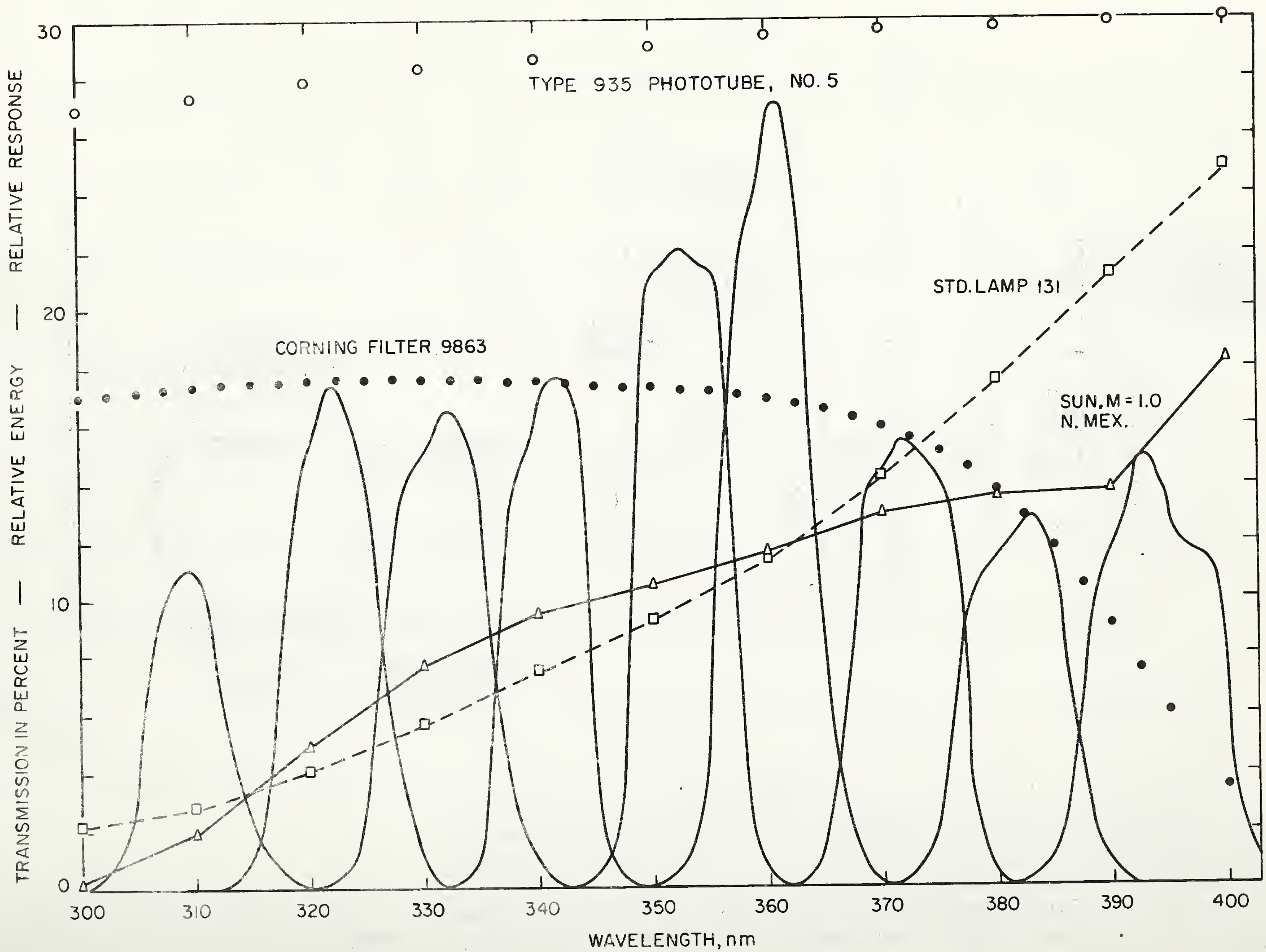


Fig. 2. Spectral characteristics of the filters, phototube, 1000-watt quartz-iodine lamp standard of spectral irradiance, and the sun. The ordinates are exact for the nine interference filters, divided by 5 for Corning glass No. 9863, and relative only for the phototube, standard lamp and the sun.

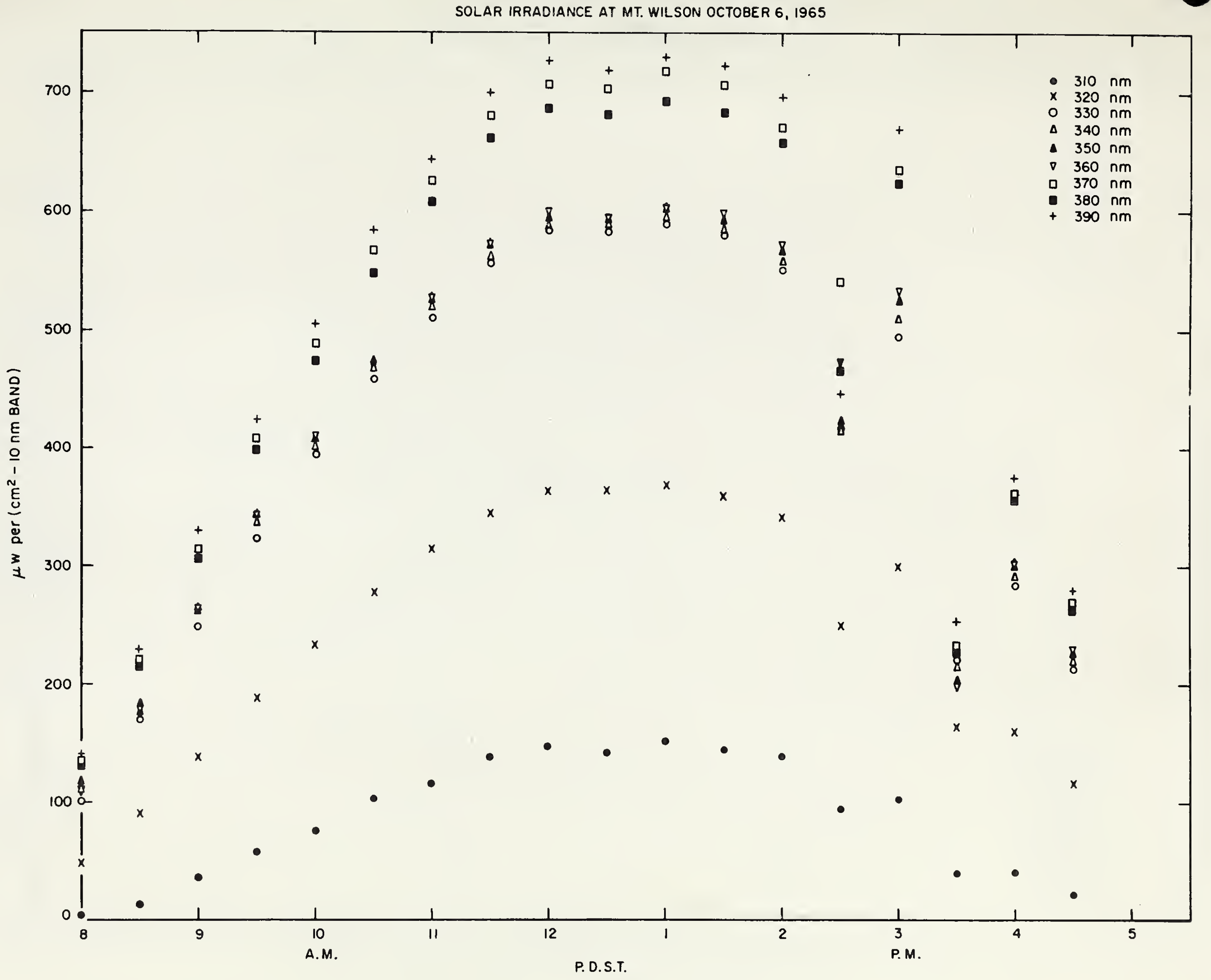


Fig. 3. Spectral solar and sky irradiances for 10-nm bands at Mt. Wilson, October 6, 1965.

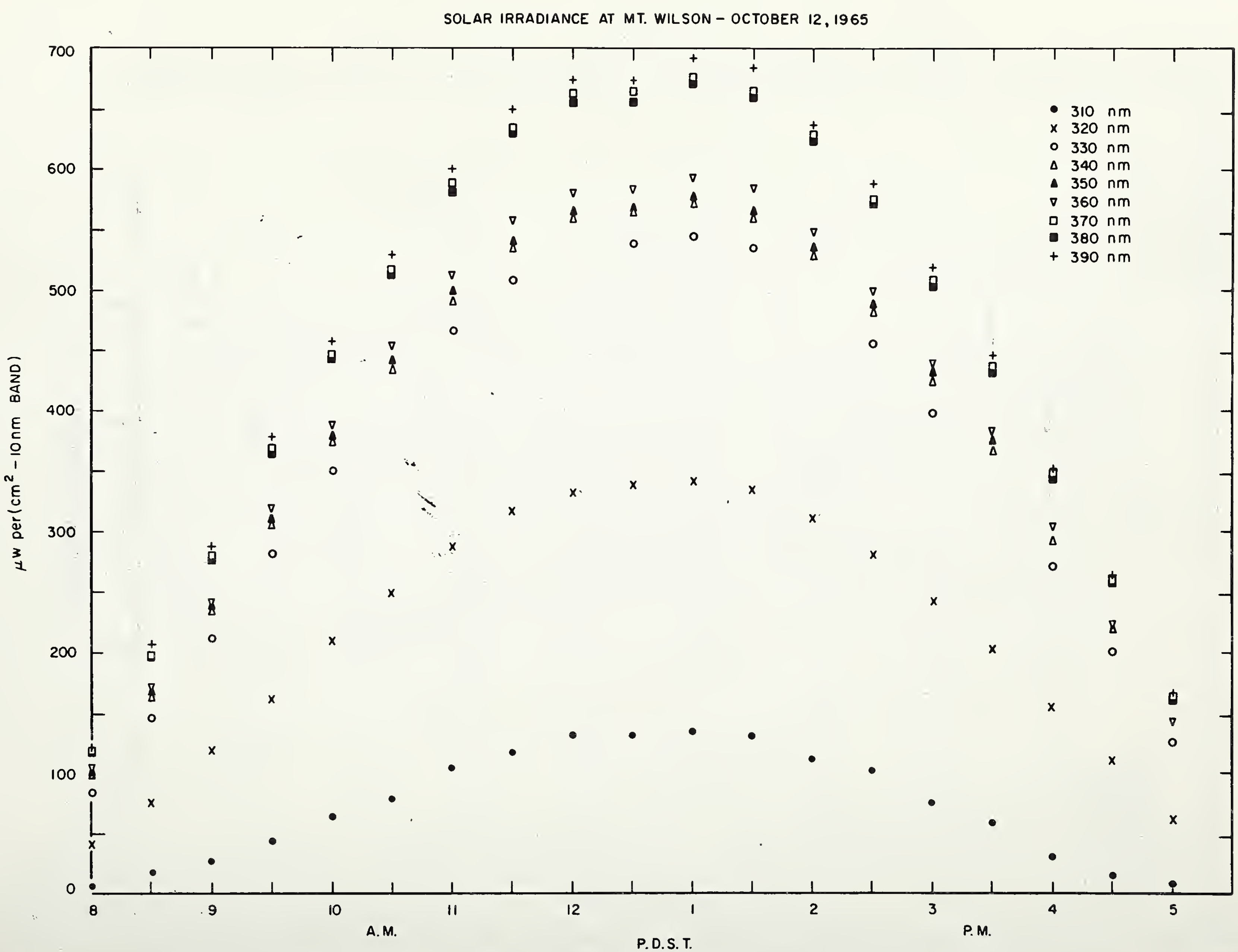


Fig. 4. Spectral solar and sky irradiances for 10-nm bands at Mt. Wilson, Octo[illegible] 12, 1965.

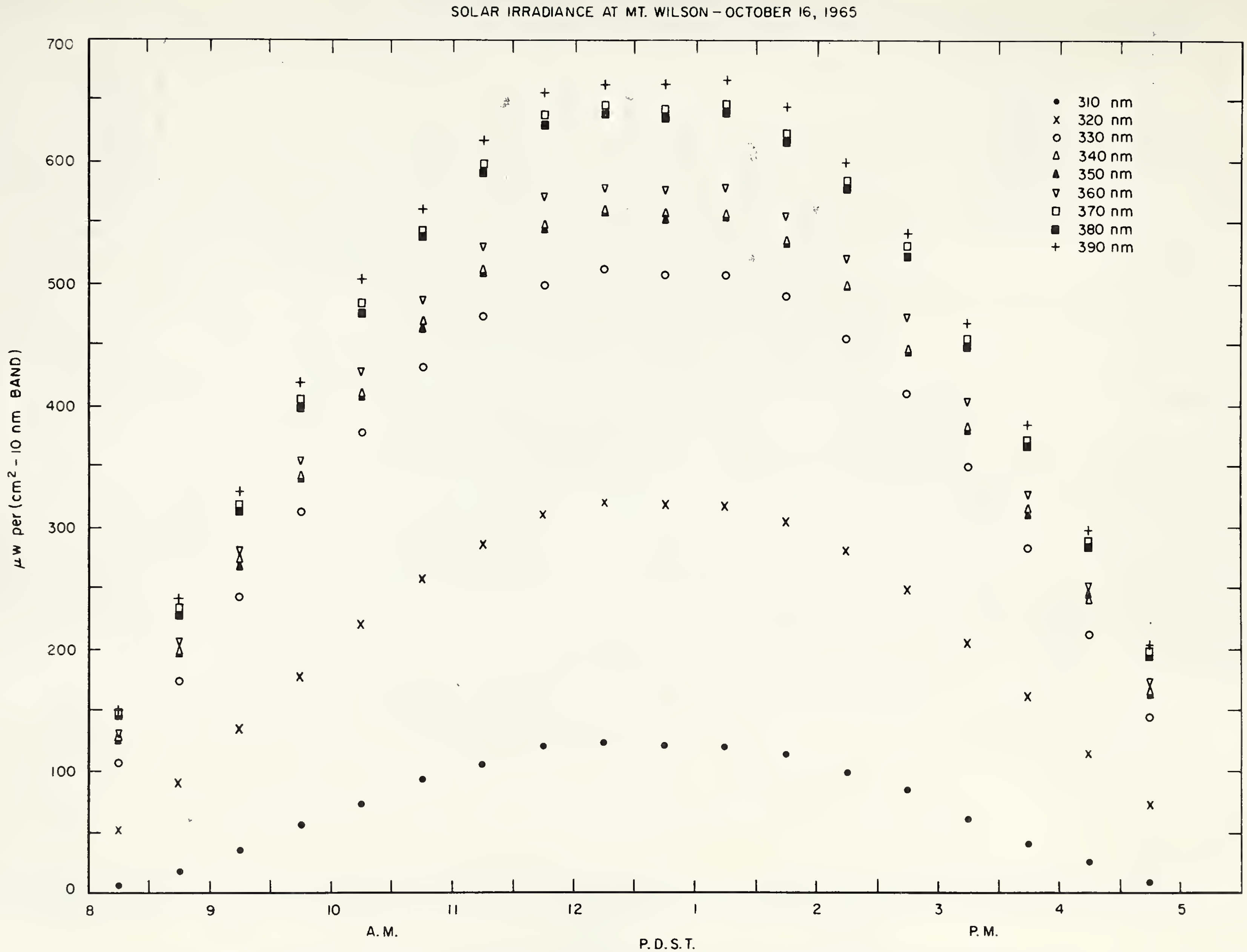


Fig. 5. Spectral solar and sky irradiances for 10-nm bands at Mt. Wilson, October 16, 1965.

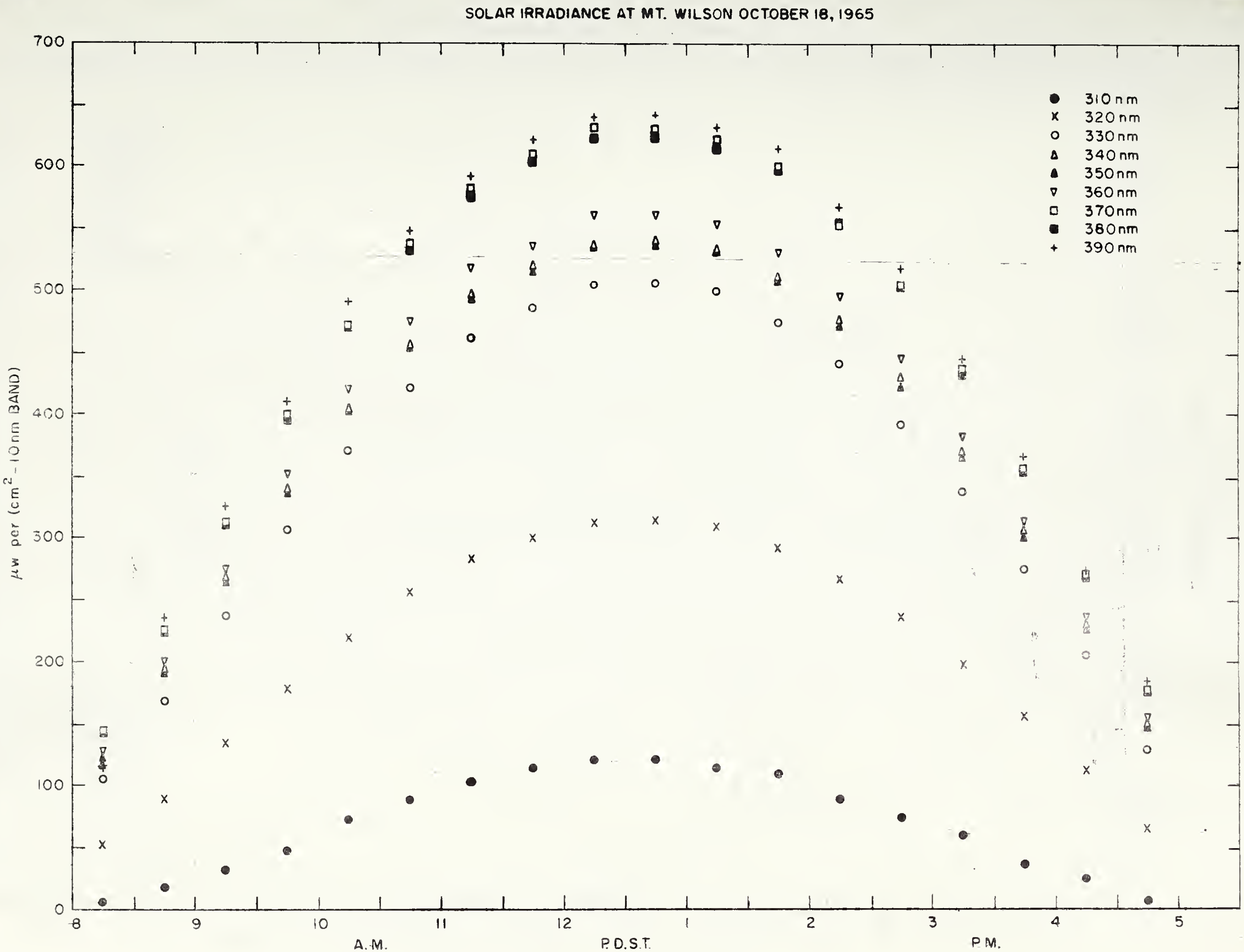


Fig. 6. Spectral solar and sky irradiances for 10-nm bands at Mt. Wilson, October 18, 1965.

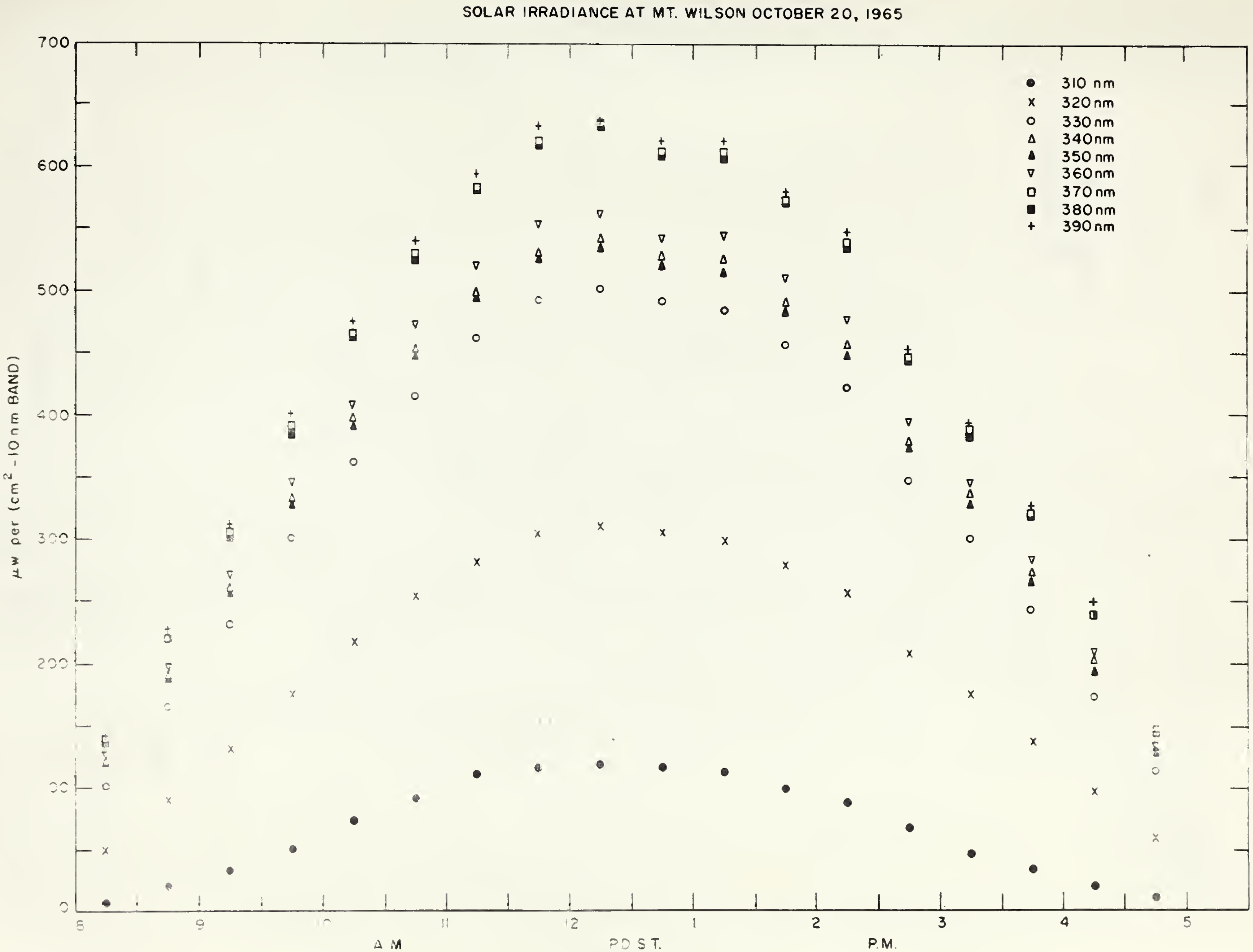


Fig. 7. Spectral solar and sky irradiances for 10-nm bands at Mt. Wilson, October 20, 1965.

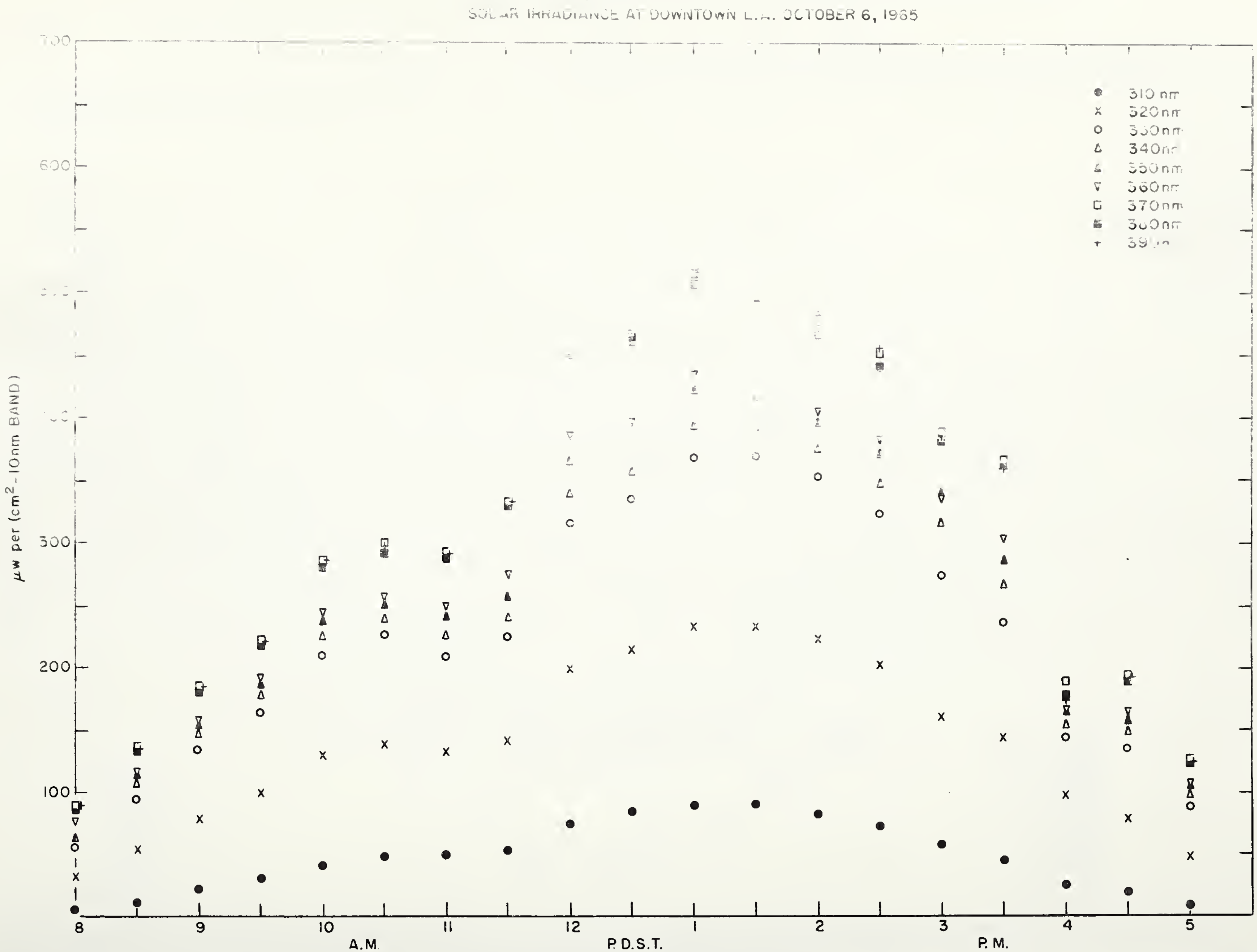


Fig. 8. Spectral solar and sky irradiances for 10-nm bands in down-town Los Angeles, October 6, 1965

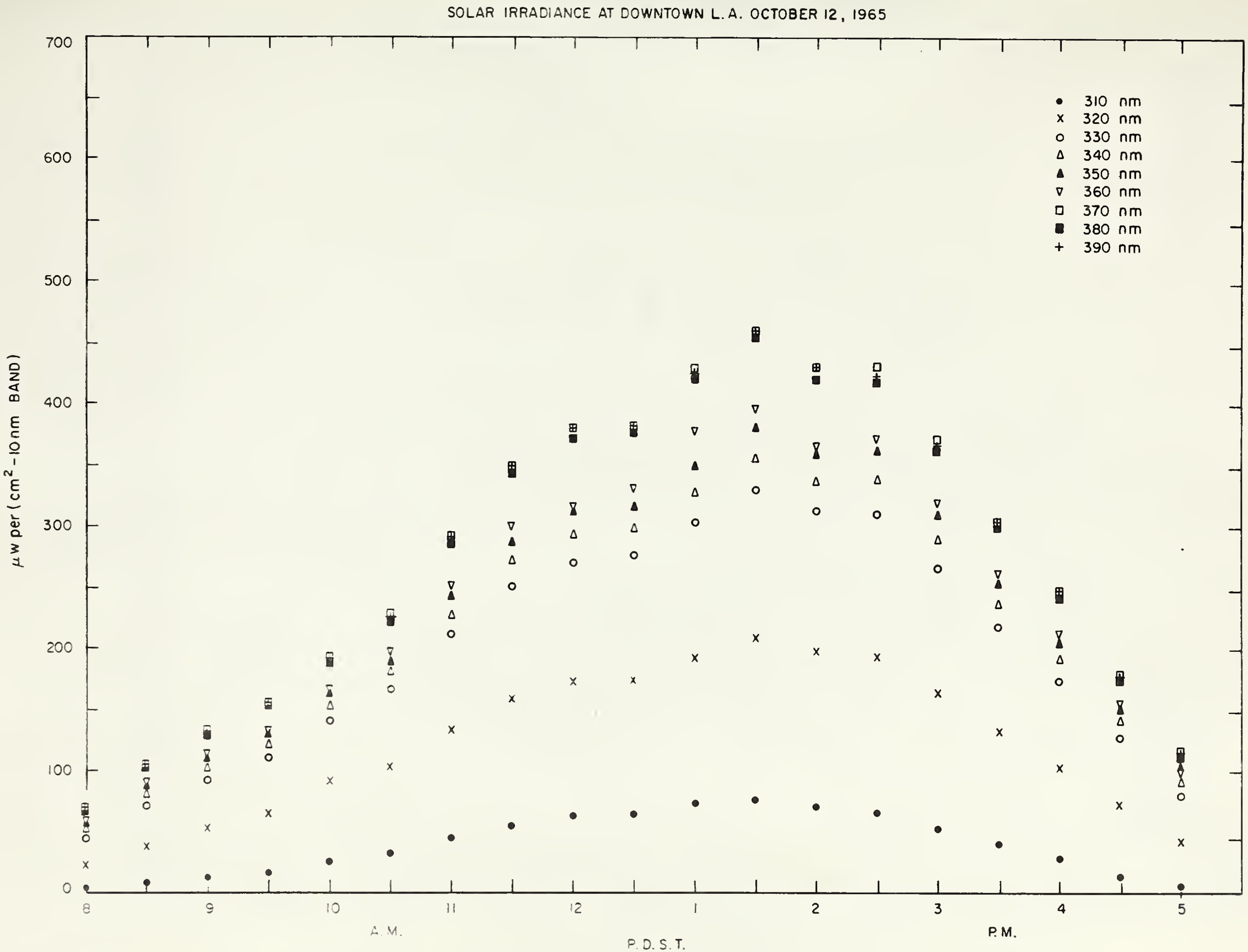


Fig. 9. Spectral solar and sky irradiances for 10-nm bands in down-town Los Angeles, October 12, 1965.

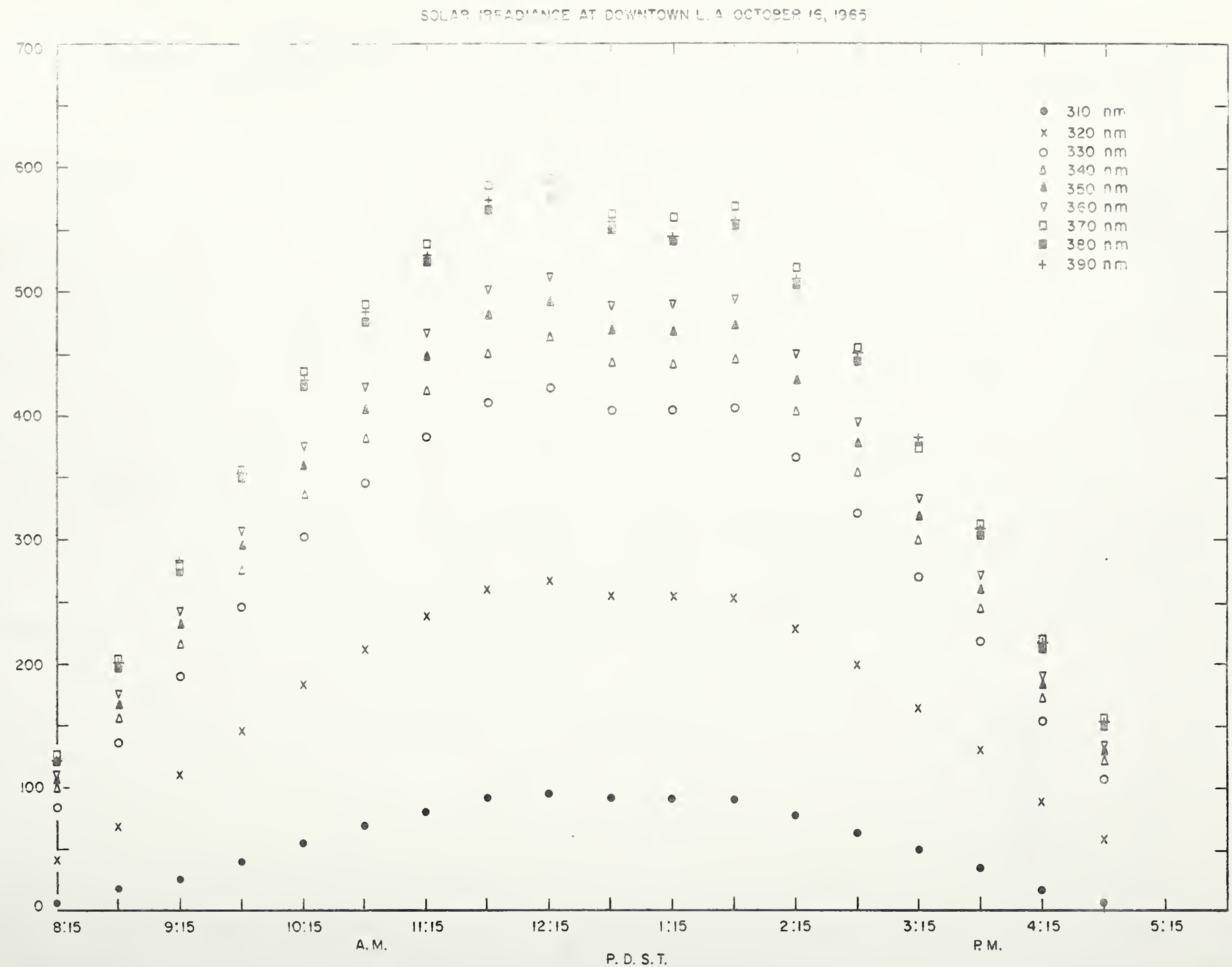


Fig. 10. Spectral solar and sky irradiances for 10-nm bands in down-town Los Angeles, October 16, 1965.

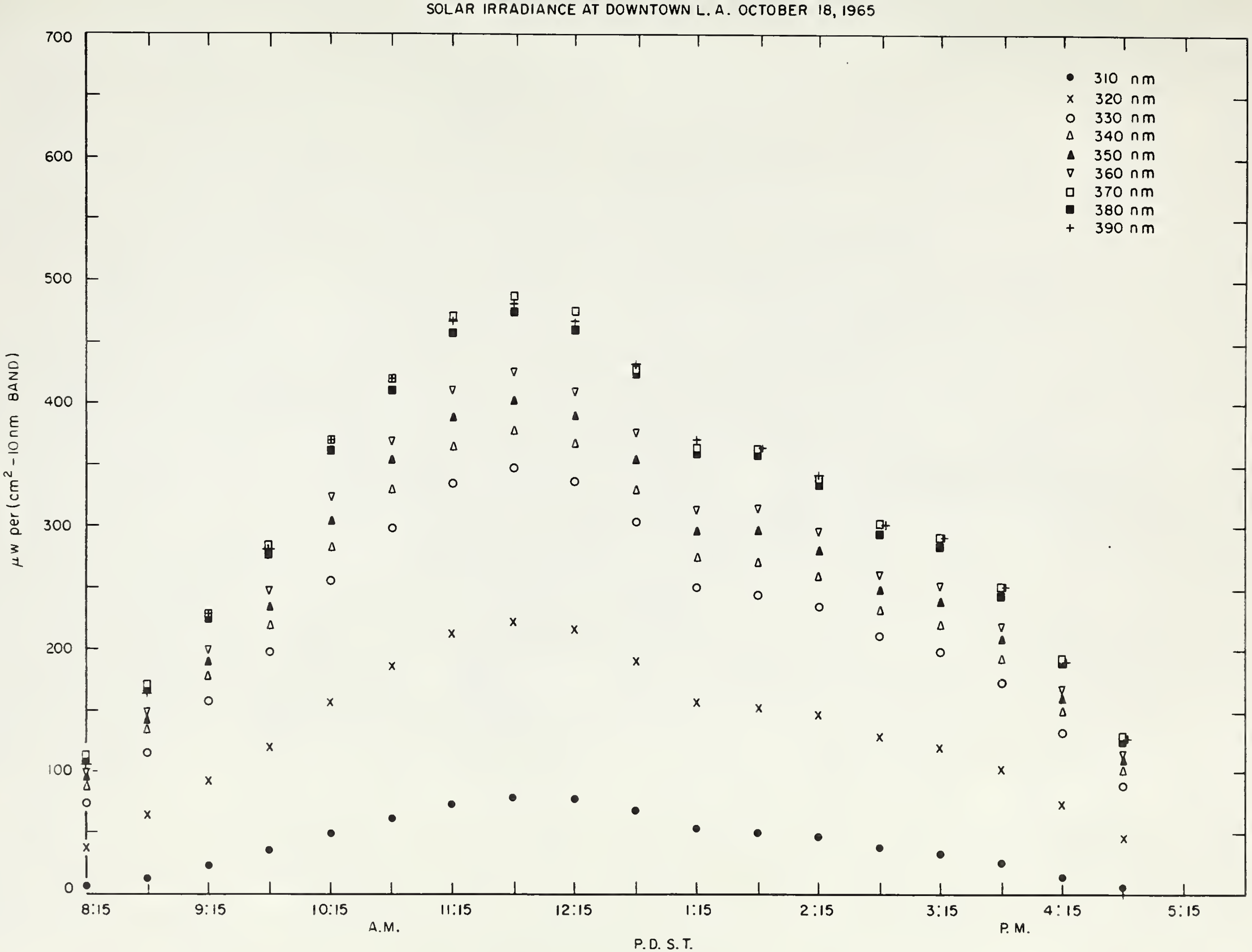


Fig. 11. Spectral solar and sky irradiances for 10-nm bands in down-town Los Angeles, October 18, 1965.

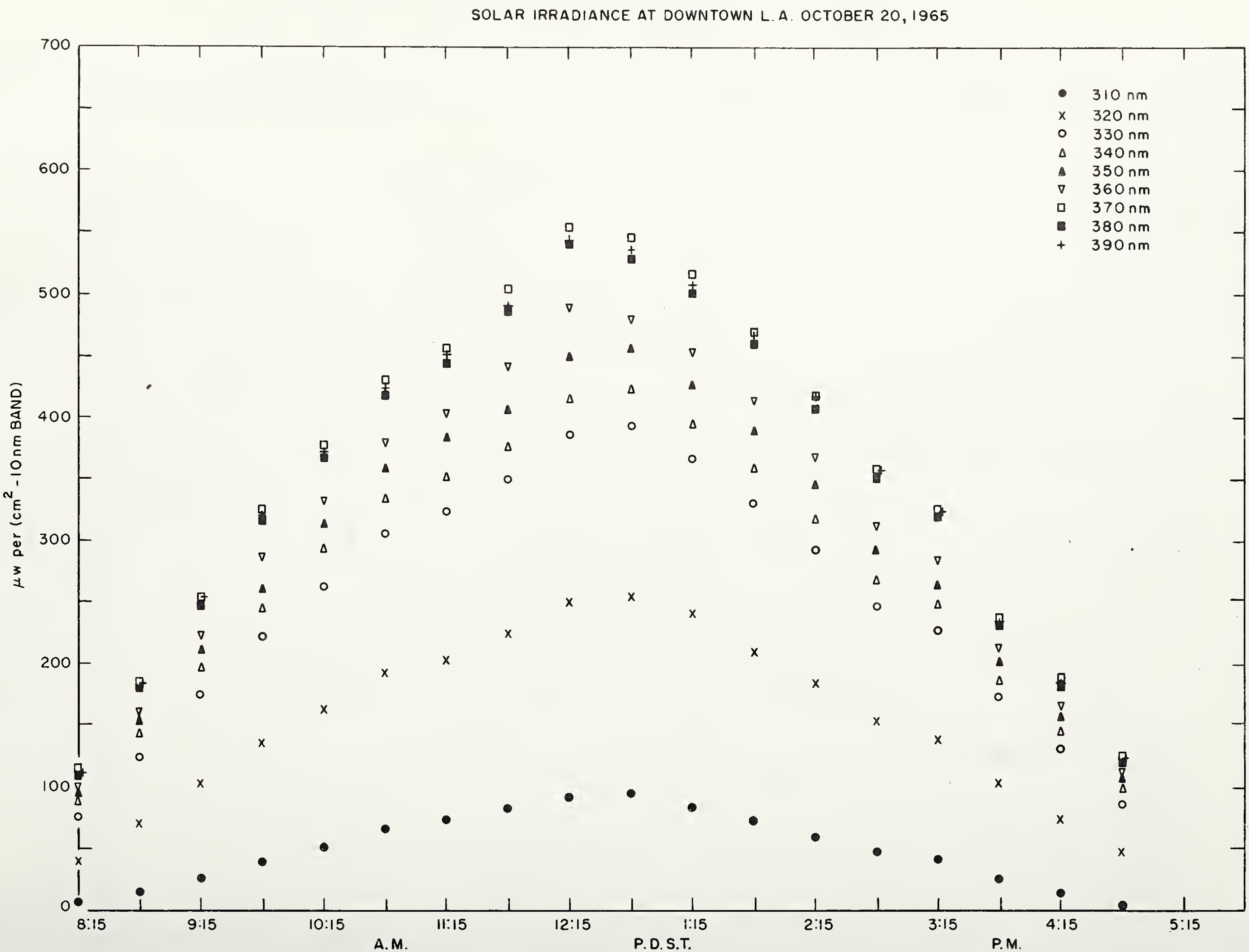


Fig. 12. Spectral solar and sky irradiances for 10-nm bands in down-town Los Angeles, October 20, 1965.

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