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Spectroscopic Investigations of the Sun

PART I

GENERAL OUTLINE OF OBSERVATIONS, INSTRUMENTS, AND
METHODS—SECTION 7

BY

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GENERAL OUTLINE OF OBSERVATIONS, INSTRUMENTS AND METHODS

SECTION 7.—A DEVICE AND TABLES FOR COMPUTING THE COMPONENTS OF THE ORBITAL VELOCITY OF THE EARTH TO POINTS ON THE SUN

BY

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In spectroscopic determinations of the rotational velocity of the sun, the correction to be applied to the observations due to the components of the earth's orbital velocity may be obtained with the aid of the table¹ given by Dunér for points on the solar limb relatively to the centre. The Ottawa observations made from 1913 on, however, include not only spectra from pairs of points within the limb, but also from the centre and intermediate positions, and from laboratory sources for determining spectrum wave-lengths and their variations for individual solar points. Consequently, the need arose for computing the component of the earth's orbital velocity to any point on the sun. For this purpose, and of course also for the determination of the difference between the components to any pair of points on the solar disc, the device described herein possesses advantages, especially for a considerable number of points on the sun observed at one time.

Using Chauvenet's notation, the angle i between the normal to the direction of the orbital motion of the earth and the radius vector is related to the eccentricity of the earth's orbit, e , and the true anomaly, u , by the equation:—

$$\tan i = \frac{e \sin u}{1 + e \cos u}$$

and since e is 0.01674, this becomes, in a form convenient for computation,

$$\cot i = 59.737 \operatorname{cosec} u + \cot u,$$

and u is, for year Y , $\odot - 281^\circ 39' - 1' . 03$ ($Y - 1925.0$). In Table XII are given the values of i corresponding to each degree in the range of values of u , from 0° to 180° when the normal to the earth's orbital motion is west of the radius vector, and from 180° to 360° when the normal is east of the radius vector.

The greatest value of i is $57' . 56$ when $\cos u$ is $-e$, or when u is $180^\circ \mp 89^\circ 2' . 45$, at which times the semi-diameter of the sun, s , is $16' . 03$; so that a point on the sun is at most about $73' . 6$ from the normal to the direction of the orbital motion of the earth. Sines of angles smaller than this are very closely proportional to the angles, and hence the computation of the components of the orbital velocity of the earth to points on the

¹ N. C. Dunér, Nova Acta Regiae Societatis Scientiarum Upsaliensis, Ser. IV, Vol. I, N. 6, p. 24, 1907.

sun may be reduced to linear graphical measurement when the value of i and the difference between the components of velocity to two points on the ecliptic near the radius vector have been determined. This difference follows readily from the zero velocity along the normal and the velocity along the radius vector determined from the change dR in the length of the radius vector in one day. However, for the smaller values of i and dR the scale of velocity-differences along the line of the ecliptic cannot be found with sufficient accuracy, so that in general the scale is derived from the difference between the components of the orbital velocity, $R \cdot \sec i \cdot d\odot : dt$, to the centre of the solar disc and to a limb point on the ecliptic, namely, $R \cdot \sec i \{ \sin(i+s) - \sin i \} \cdot d\odot : dt$, or very closely, $R \cdot \sin s \cdot d\odot : dt$, or $r \cdot d\odot : dt$, where r the radius of the sun is 695,553 km. Hence,

$$\begin{aligned} r \cdot d\odot : dt &= 0.002342 \cdot d\odot \text{ km. per sec. } (d\odot \text{ in minutes per day}) \\ &= 0.000937 \cdot d\odot \text{ km. per sec. } (d\odot \text{ in seconds per hour}). \end{aligned}$$

In this way the values of $r \cdot d\odot : dt$ of Table XIII were computed for the range in values of $d\odot$ per day and per hour.

In Table XIV are given the differences between the components of the earth's orbital velocity to the centre of the sun and to a point on the limb β° from the ecliptic, for the range of values of $d\odot$ per hour from $143''$ to $153''$, computed from the formula $r \cdot \cos \beta \cdot d\odot : dt$, to four figures, to insure an accuracy of interpolation to 0.001 km. per sec.

The angle p between the diameters of the solar disc lying in the planes of the ecliptic and the solar equator, with reference to which latter the observations are made, is readily computed from the heliographic latitude of the centre of the sun's disc, B_0 , as tabulated in the ephemerides, the relationship being derived as follows: in figure 22 the circle represents the limb of the sun, E the pole of the ecliptic and S the pole of the sun, C the point where the surface of the sun cuts the radius vector, and D the point where the equator of the sun is cut by the great circle through S and C . Then, p being equal to the angle ECS , it follows that,

$$\begin{aligned} \cos p &= \cos ES \cdot \sec DC \\ &= \cos 7^\circ 15' \cdot \sec B_0. \end{aligned}$$

Using this equation the values of p given in Table XV were computed for the range of values of the heliographic latitude of the centre of the solar disc, B_0 .

Early in June when the earth is ascending through the sun's equatorial plane, at which time \odot is N , say, the pole of the sun reaches its maximum separation of $7^\circ 25'$ westerly from the pole of the ecliptic. The solar pole appears west of the pole of the ecliptic during the interval when \odot varies from $N - 90^\circ$ to $N + 90^\circ$, and east of the pole of the ecliptic while \odot progresses from $N + 90^\circ$ to $N + 270^\circ$, N being, in accordance with Carrington's deductions, $74^\circ 42' 48'' \cdot 75 + 50'' \cdot 25$ ($Y - 1925 \cdot 0$), where Y is the year; or, in other words, p is measured west from the pole of the ecliptic while the heliographic latitude of the centre of the sun's disc, B_0 , varies from $-7^\circ 25'$ to $+7^\circ 25'$, and east from the pole of the ecliptic while B_0 varies from $+7^\circ 25'$ to $-7^\circ 25'$.

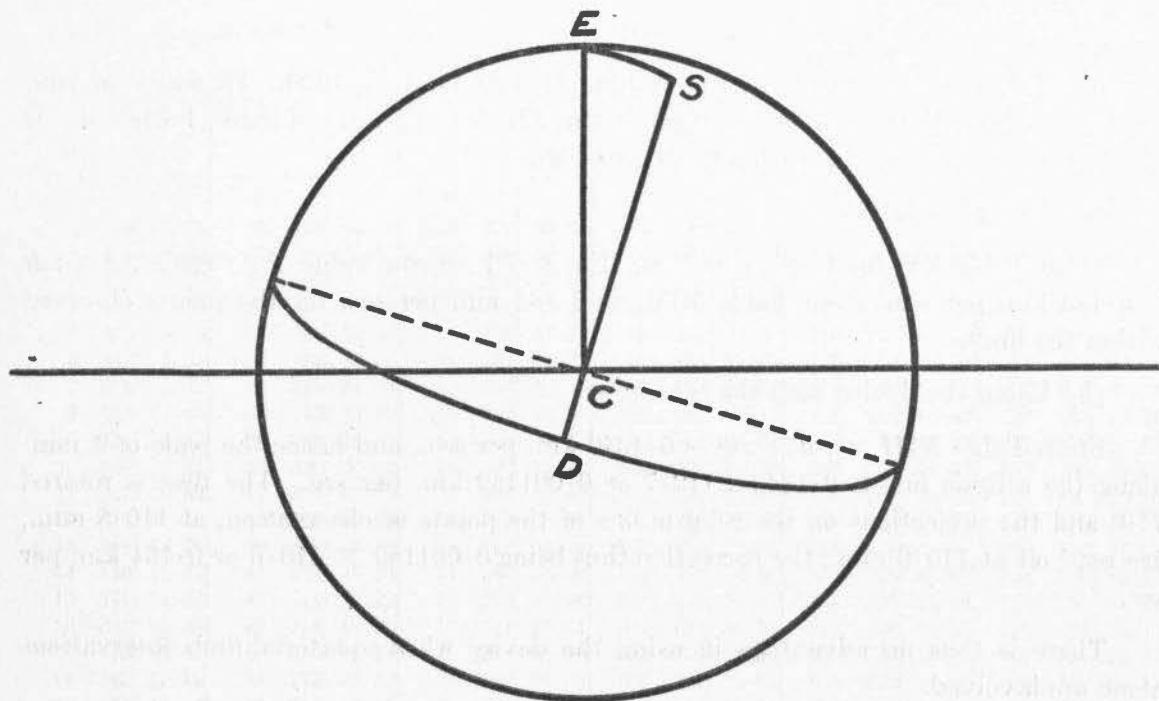


FIG. 22.

To facilitate the application of the tables to the computation of the several components of the orbital motion involved in a single observation, a device was constructed as follows:—

Three concentric circles of 110, 115, and 120 mm. radii were scratched on a strip of white celluloid—the radius of the solar image observed always lying within this range. Along the middle of the strip a straight line was scratched through the centre of the circles to represent the line of the ecliptic. This line was graduated in mm. and numbered at every cm. out to 430 mm. on each side of the centre. A sliding-scale, graduated in mm. and numbered at every 10 in both directions from 0 to 550 mm., was inset in the strip of film parallel and adjacent to the fixed scale. At intervals of 5 mm. out to 120 mm. on each side of the centre, lines were scratched perpendicular to the line representing the ecliptic and terminating at the circumference of the outer circle. Concentric with the circles is mounted, by external clamp-screws, a brass ring of 130 mm. external radius, graduated in degrees numbered at every ten from 0 to 360. The inner edge of the ring is bevelled to hold a disc of stiff transparent film, held also at the centre by a small bolt clamping it to the celluloid strip. Two diameters are scratched at right angles to one another on this transparent disc. The device is used to read the projected positions of the points of observation on the scale of the ecliptic, after first setting the brass ring p° from the ecliptic, pole from pole, and then rotating the transparent disc to the position angle of the observation measured around the brass ring. The following representative computations illustrate the methods employed, and fig. 23 shows the central part of the apparatus with the settings those of Example 3.

Example 1. Limbs at the solar equator.

Plate L 315, June 21, 11.34 a.m., or June 22, 4.34 G.M.T., 1909. Diameter of sun, 225.4 mm.; separation of points of observation, 221.5 mm.; ratio of these, 1.018. $d\odot$ is 57'.15 per day or 143''.13 per hour. B_\odot is 1°.89.

(a) Using the tables:—

From Table XV, for 1°.89, p is 7°.0. For $\beta = 7^\circ.0$, the value of $r \cdot \cos \beta \cdot d\odot : dt$ is 0.133 km. per sec., from Table XIV, or 0.131 km. per sec. for the points observed within the limb.

(b) Using the device with the tables:—

From Table XIII, $r \cdot d\odot : dt$ is 0.1340 km. per sec., and hence the scale of 1 mm. along the ecliptic line is 0.1340 : 112.7 or 0.001189 km. per sec. The disc is rotated 7°.0 and the projections on the ecliptic line of the points of observation, at 110.8 mm., are read off at 110.0 mm., the correction thus being 0.001189 × 110.0 or 0.131 km. per sec.

There is thus no advantage in using the device when equatorial limb observations alone are involved.

Example 2. Limbs at various position angles.

Plate L 889, June 8, 9.20 a.m., or June 9, 2.20 G.M.T., 1912. Positions, W 0° E, WN 15° ES, also 30°, 45°, 60°, 75°, 80°, 85°, and 90°. Diameter of Sun, 226.0 mm.; separation of the points of observation at the same focal plane, 219.6 + 1.4 or 221.0 mm.; ratio, 1.023. $d\odot$ is 143''.43 per hour, and B_\odot is 0°.35.

(a) Using the tables:—

The value of P , Table XV, is 7°.24, the north pole of the sun being west of the north pole of the ecliptic. By subtracting this angle from the position angles, the values of β are found; from Table XIV the corresponding values of $r \cdot \cos \beta \cdot d\odot : dt$ are read off, thus:—

Position	0°	15°	30°	45°	60°	75°	80°	85°	90°
β	-7°.24	7°.76	22°.76	37°.76	52°.76	67°.76	72°.76	77°.76	82°.76
km./sec.	0.133	0.133	0.124	0.106	0.081	0.051	0.040	0.028	0.017

These components to the limb points are reduced to the points of observation by dividing by 1.023.

TABLE XII.—ANGLE BETWEEN RADIUS VECTOR AND NORMAL TO THE EARTH'S ORBITAL MOTION

<i>u</i>	<i>i</i>	u	i	u	i	u	i	u	i	u	i	u	i
0 0	/	0 0	/	0 0	/	0 0	/	0 0	/	0 0	/	0 0	/
1 359	0.98	31 329	29.23	61 299	49.92	91 269	57.55	121 239	49.76	151 209	28.32		
2 358	1.99	32 328	30.07	62 298	50.42	92 268	57.55	122 238	49.24	152 208	27.43		
3 357	2.97	33 327	30.91	63 297	50.89	93 267	57.52	123 237	48.71	153 207	26.53		
4 356	3.96	34 326	31.74	64 296	51.35	94 266	57.48	124 236	48.16	154 206	25.62		
5 355	4.95	35 325	32.55	65 295	51.79	95 265	57.41	125 235	47.60	155 205	24.70		
6 354	5.93	36 324	33.38	66 294	52.22	96 264	57.32	126 234	47.02	156 204	23.78		
7 353	6.91	37 323	34.18	67 293	52.63	97 263	57.23	127 233	46.43	157 203	22.84		
8 352	7.89	38 322	34.97	68 292	53.02	98 262	57.12	128 232	45.82	158 202	21.90		
9 351	8.87	39 321	35.76	69 291	53.41	99 261	56.98	129 231	45.20	159 201	20.95		
10 350	9.85	40 320	36.52	70 290	53.77	100 260	56.84	130 230	44.57	160 200	20.00		
11 349	10.82	41 319	37.29	71 289	54.12	101 259	56.67	131 229	43.91	161 199	19.04		
12 348	11.79	42 318	38.03	72 288	54.45	102 258	56.49	132 228	43.25	162 198	18.07		
13 347	12.75	43 317	38.78	73 287	54.76	103 257	56.28	133 227	42.58	163 197	17.10		
14 346	13.71	44 316	39.50	74 286	55.06	104 256	56.06	134 226	41.88	164 196	16.13		
15 345	14.67	45 315	40.22	75 285	55.34	105 255	55.83	135 225	41.18	165 195	15.15		
16 344	15.63	46 314	40.92	76 284	55.61	106 254	55.58	136 224	40.47	166 194	14.16		
17 343	16.58	47 313	41.62	77 283	55.86	107 253	55.30	137 223	39.74	167 193	13.17		
18 342	17.52	48 312	42.30	78 282	56.09	108 252	55.01	138 222	38.99	168 192	12.18		
19 341	18.46	49 311	42.96	79 281	56.31	109 251	54.71	139 221	38.24	169 191	11.18		
20 340	19.39	50 310	43.62	80 280	56.51	110 250	54.39	140 220	37.48	170 190	10.17		
21 339	20.32	51 309	44.26	81 279	56.69	111 249	54.05	141 219	36.70	171 189	9.17		
22 338	21.24	52 308	44.89	82 278	56.86	112 248	53.70	142 218	35.91	172 188	8.16		
23 337	22.15	53 307	45.50	83 277	57.00	113 247	53.32	143 217	35.10	173 187	7.15		
24 336	23.06	54 306	46.11	84 276	57.13	114 246	52.93	144 216	34.30	174 186	6.13		
25 335	23.96	55 305	46.69	85 275	57.24	115 245	52.53	145 215	33.47	175 185	5.12		
26 334	24.86	56 304	47.27	86 274	57.34	116 244	52.14	146 214	32.64	176 184	4.10		
27 333	25.75	57 303	47.83	87 273	57.42	117 243	51.67	147 213	31.79	177 183	3.08		
28 332	26.63	58 302	48.37	88 272	57.48	118 242	51.21	148 212	30.94	178 182	2.06		
29 331	27.51	59 301	48.91	89 271	57.52	119 241	50.74	149 211	30.07	179 181	1.04		
30 330	28.37	60 300	49.43	90 270	57.54	120 240	50.26	150 210	29.20	180 180	0.00		

TABLE XIII.—DIFFERENCE BETWEEN COMPONENTS OF THE EARTH'S ORBITAL VELOCITY TO SOLAR CENTRE AND LIMB POINTS ON THE ECLIPTIC

$d\odot$ per day	$d\odot$ per hour	$r \frac{d\odot}{dt}$	$d\odot$ per day	$d\odot$ per hour	$r \frac{d\odot}{dt}$	$d\odot$ per day	$d\odot$ per hour	$r \frac{d\odot}{dt}$	$d\odot$ per day	$d\odot$ per hour	$r \frac{d\odot}{dt}$
'	"	km./sec.	'	"	km./sec.	'	"	km./sec.	'	"	km./sec.
.....	143.0	0.1339	58.2	145.5	0.1363	59.2	148.0	0.1386	60.2	150.5	0.1410
57.2	.1	.1340	.....	.6	.1364	.....	.1	.1387	.....	.6	.1411
.....	.2	.1341	58.3	.7	.1365	.....	.2	.1388	60.3	.7	.1412
57.3	.3	.1342	.....	.8	.1366	59.3	.3	.1389	.....	.8	.1413
.....	.4	.1343	.....	.9	.1367	.....	.4	.1390	.....	.9	.1413
57.4	.5	.1344	58.4	146.0	.1368	59.4	.5	.1391	.....	151.0	.1414
.....	.6	.1345	.....	.1	.1368	.....	.6	.1392	60.4	.1	.1415
.....	.7	.1346	.....	.2	.1369	59.5	.7	.1393	.....	.2	.1416
57.5	.8	.1347	58.5	.3	.1370	.....	.8	.1394	60.5	.3	.1417
.....	.9	.1348	.....	.4	.1371	.....	.9	.1395	.....	.4	.1418
57.6	144.0	.1349	58.6	.5	.1372	59.6	149.0	.1396	60.6	.5	.1419
.....	.1	.1350	.....	.6	.1373	.....	.1	.1397	.....	.6	.1420
57.7	.2	.1351	.....	.7	.1374	.....	.2	.1398	.....	.7	.1421
.....	.3	.1352	58.7	.8	.1375	59.7	.3	.1398	60.7	.8	.1422
.....	.4	.1353	.....	.9	.1376	.....	.4	.1399	.....	.9	.1423
57.8	.5	.1354	58.8	147.0	.1377	.....	.5	.1400	60.8	152.0	.1424
.....	.6	.1354	.....	.1	.1278	59.8	.6	.1401	.....	.1	.1425
.....	.7	.1355	58.9	.2	.1379	.....	.7	.1402	60.9	.2	.1426
57.9	.8	.1356	.....	.3	.1380	59.9	.8	.1403	.....	.3	.1427
.....	.9	.1357	.....	.4	.1381	.....	.9	.1404	.....	.4	.1428
58.0	145.0	.1358	59.0	.5	.1382	60.0	150.0	.1405	.....	.5	.1428
.....	.1	.1359	.....	.6	.1383	.....	.1	.1406	61.0	.6	.1429
.....	.2	.1360	59.1	.7	.1384	.....	.2	.1407	.....	.7	.1430
58.1	.3	.1361	.....	.8	.1384	60.1	.3	.1408	61.1	.8	.1431
.....	.4	.1362	.....	.9	.1385	.....	.4	.1409	.....	.9	.1432

TABLE XIV.—DIFFERENCE BETWEEN COMPONENTS OF THE EARTH'S ORBITAL VELOCITY
TO SOLAR CENTRE AND POINTS ON THE LIMB

β	$d \odot$ per hour										
	143''	144''	145''	146''	147''	148''	149''	150''	151''	152''	153''
°	km./sec.	km./sec.	km./sec.	km./sec.	km./sec.	km./sec.	km./sec.	km./sec.	km./sec.	km./sec.	km./sec.
0	0.1339	0.1349	0.1358	0.1368	0.1377	0.1386	0.1396	0.1405	0.1414	0.1424	0.1433
2	.1338	.1348	.1357	.1367	.1376	.1385	.1395	.1404	.1413	.1423	.1432
4	.1336	.1346	.1355	.1365	.1374	.1383	.1393	.1402	.1411	.1421	.1430
6	.1332	.1342	.1351	.1361	.1369	.1378	.1388	.1397	.1406	.1416	.1425
8	.1326	.1336	.1345	.1355	.1364	.1373	.1382	.1391	.1400	.1410	.1419
10	.1319	.1329	.1337	.1347	.1356	.1365	.1375	.1384	.1393	.1402	.1411
12	.1310	.1320	.1328	.1338	.1347	.1356	.1365	.1374	.1383	.1393	.1402
14	.1299	.1309	.1318	.1327	.1336	.1345	.1355	.1363	.1372	.1382	.1390
16	.1287	.1297	.1305	.1315	.1324	.1332	.1342	.1351	.1359	.1369	.1377
18	.1273	.1283	.1292	.1301	.1310	.1318	.1328	.1336	.1345	.1354	.1363
20	.1258	.1268	.1276	.1286	.1294	.1302	.1312	.1320	.1329	.1338	.1347
22	.1241	.1251	.1259	.1268	.1277	.1285	.1294	.1303	.1311	.1320	.1329
24	.1223	.1232	.1241	.1250	.1258	.1266	.1275	.1284	.1292	.1301	.1309
26	.1203	.1212	.1221	.1230	.1238	.1246	.1255	.1263	.1271	.1280	.1288
28	.1182	.1191	.1199	.1208	.1216	.1224	.1233	.1241	.1248	.1257	.1265
30	.1160	.1168	.1176	.1185	.1193	.1200	.1209	.1217	.1225	.1233	.1241
32	.1136	.1144	.1152	.1160	.1168	.1175	.1184	.1192	.1199	.1208	.1215
34	.1110	.1118	.1126	.1134	.1142	.1149	.1157	.1165	.1172	.1181	.1188
36	.1083	.1091	.1099	.1107	.1114	.1121	.1129	.1137	.1144	.1152	.1159
38	.1055	.1063	.1070	.1078	.1085	.1092	.1100	.1107	.1114	.1122	.1129
40	.1026	.1033	.1040	.1048	.1055	.1062	.1069	.1076	.1083	.1091	.1098
42	.0995	.1003	.1009	.1017	.1023	.1030	.1037	.1044	.1051	.1058	.1065
44	.0963	.0970	.0977	.0984	.0991	.0997	.1004	.1011	.1017	.1024	.1031
46	.0930	.0937	.0943	.0950	.0957	.0963	.0970	.0976	.0982	.0989	.0995
48	.0896	.0903	.0909	.0915	.0921	.0927	.0934	.0940	.0946	.0953	.0959
50	.0861	.0867	.0873	.0879	.0885	.0891	.0897	.0903	.0909	.0915	.0921
52	.0824	.0831	.0836	.0842	.0848	.0853	.0859	.0865	.0871	.0877	.0882
54	.0787	.0793	.0798	.0804	.0809	.0815	.0821	.0826	.0831	.0837	.0842
56	.0749	.0754	.0759	.0765	.0770	.0775	.0781	.0786	.0791	.0796	.0801
58	.0710	.0715	.0720	.0725	.0730	.0734	.0740	.0745	.0749	.0755	.0759
60	.0670	.0675	.0679	.0684	.0689	.0693	.0698	.0703	.0707	.0712	.0717
62	.0629	.0633	.0638	.0642	.0646	.0651	.0655	.0660	.0664	.0669	.0673
64	.0587	.0591	.0595	.0600	.0604	.0608	.0612	.0616	.0620	.0624	.0628
66	.0545	.0549	.0552	.0556	.0560	.0564	.0568	.0571	.0575	.0579	.0583
68	.0502	.0505	.0509	.0512	.0516	.0519	.0523	.0526	.0530	.0533	.0537
70	.0458	.0461	.0464	.0468	.0471	.0474	.0477	.0481	.0484	.0487	.0490
72	.0414	.0417	.0420	.0423	.0426	.0428	.0431	.0434	.0437	.0440	.0443
74	.0369	.0372	.0374	.0377	.0380	.0382	.0385	.0387	.0390	.0393	.0395
76	.0324	.0326	.0329	.0331	.0333	.0335	.0338	.0340	.0342	.0344	.0347
78	.0278	.0280	.0282	.0284	.0286	.0288	.0290	.0292	.0294	.0296	.0298
80	.0233	.0234	.0236	.0238	.0241	.0241	.0242	.0244	.0246	.0247	.0249
82	.0186	.0188	.0189	.0190	.0192	.0193	.0194	.0196	.0197	.0198	.0199
84	.0140	.0141	.0142	.0143	.0144	.0145	.0146	.0147	.0148	.0149	.0150
86	.0093	.0094	.0095	.0095	.0096	.0097	.0097	.0098	.0099	.0099	.0100
88	.0047	.0047	.0047	.0048	.0048	.0048	.0049	.0049	.0049	.0050	.0050

TABLE XV.—ANGLE BETWEEN ECLIPTIC AND EQUATORIAL DIAMETERS OF THE SOLAR DISC

$B_o$	$p$	$B_o$	$p$	$B_o$	$p$	$B_o$	$p$	$B_o$	$p$	B_o	p
°	°	°	°	°	°	°	°	°	°	°	°
7.25	0.00	7.05	1.70	6.70	2.78	6.00	4.03	4.90	5.35	2.90	6.65
7.24	0.38	7.04	1.74	6.68	2.82	5.95	4.15	4.80	5.44	2.80	6.69
7.23	0.54	7.03	1.78	6.66	2.87	5.90	4.22	4.70	5.53	2.70	6.73
7.22	0.67	7.02	1.82	6.64	2.92	5.85	4.29	4.60	5.61	2.60	6.78
7.21	0.76	7.01	1.86	6.62	2.96	5.80	4.36	4.50	5.69	2.50	6.81
7.20	0.85	7.00	1.89	6.60	3.01	5.75	4.42	4.40	5.77	2.40	6.84
7.19	0.93	6.98	1.97	6.58	3.05	5.70	4.49	4.30	5.84	2.30	6.88
7.18	1.01	6.96	2.04	6.56	3.09	5.65	4.55	4.20	5.92	2.20	6.91
7.17	1.08	6.94	2.10	6.54	3.14	5.60	4.61	4.10	5.98	2.10	6.94
7.16	1.14	6.92	2.17	6.52	3.18	5.55	4.67	4.00	6.05	2.00	6.97
7.15	1.20	6.90	2.23	6.50	3.22	5.50	4.73	3.90	6.12	1.80	7.02
7.14	1.26	6.88	2.29	6.45	3.32	5.45	4.78	3.80	6.18	1.60	7.07
7.13	1.32	6.86	2.35	6.40	3.42	5.40	4.84	3.70	6.24	1.40	7.11
7.12	1.37	6.84	2.41	6.35	3.51	5.35	4.90	3.60	6.30	1.20	7.15
7.11	1.42	6.82	2.47	6.30	5.60	5.30	4.95	3.50	6.35	1.00	7.18
7.10	1.47	6.80	2.52	6.25	3.68	5.25	5.01	3.40	6.41	0.80	7.21
7.09	1.52	6.78	2.57	6.20	3.77	5.20	5.06	3.30	6.46	0.60	7.23
7.08	1.57	6.76	2.63	6.15	3.85	5.15	5.11	3.20	6.51	0.40	7.24
7.07	1.61	6.74	2.68	6.10	3.93	5.10	5.16	3.10	6.56	0.20	7.25
7.06	1.65	6.72	2.73	6.05	4.00	5.00	5.26	3.00	6.60	0.00	7.25

TABLE XVI.—COMPONENTS OF THE EARTH'S ROTATIONAL VELOCITY TO THE CENTRE OF THE SUN FOR OTTAWA

 $0.3263 \cos \delta \sin t \text{ km./sec.}$

$t \backslash \delta$	0°	5°	10°	15°	20°	25°	$t \backslash \delta$	0°	5°	10°	15°	20°	25°
h m							h m						
0 5	0.0071	0.0071	0.0070	0.0068	0.0067	0.0064	3 5	0.2357	0.2348	0.2321	0.2277	0.2215	0.2136
10	.0143	.0142	.0140	.0138	.0134	.0129	10	.2406	.2396	.2369	.2323	.2261	.2180
15	.0213	.0213	.0210	.0206	.0200	.0193	15	.2453	.2444	.2417	.2369	.2305	.2224
20	.0284	.0283	.0280	.0274	.0267	.0256	20	.2500	.2490	.2462	.2415	.2348	.2266
25	.0355	.0354	.0350	.0343	.0334	.0322	25	.2536	.2527	.2506	.2458	.2391	.2306
30	.0426	.0424	.0419	.0411	.0400	.0386	30	.2581	.2572	.2541	.2500	.2433	.2351
35	.0497	.0495	.0489	.0479	.0466	.0450	35	.2632	.2622	.2592	.2541	.2473	.2385
40	.0567	.0565	.0558	.0547	.0533	.0514	40	.2673	.2663	.2633	.2581	.2511	.2423
45	.0636	.0634	.0627	.0615	.0598	.0577	45	.2713	.2703	.2672	.2621	.2549	.2459
50	.0707	.0704	.0696	.0680	.0663	.0640	50	.2752	.2742	.2710	.2658	.2585	.2494
55	.0776	.0773	.0764	.0749	.0729	.0704	55	.2790	.2779	.2747	.2694	.2621	.2528
1 0	.0844	.0841	.0831	.0815	.0793	.0765	4 0	.2826	.2816	.2784	.2729	.2655	.2561
5	.0913	.0910	.0900	.0882	.0857	.0827	5	.2861	.2850	.2818	.2763	.2688	.2593
10	.0981	.0977	.0966	.0948	.0924	.0890	10	.2894	.2884	.2851	.2796	.2719	.2624
15	.1048	.1045	.1033	.1015	.0985	.0951	15	.2926	.2915	.2882	.2827	.2749	.2653
20	.1116	.1112	.1105	.1078	.1048	.1011	20	.2957	.2946	.2913	.2856	.2778	.2680
25	.1182	.1178	.1165	.1142	.1111	.1072	25	.2987	.2976	.2941	.2884	.2807	.2707
30	.1249	.1244	.1229	.1206	.1173	.1132	30	.3015	.3004	.2969	.2911	.2833	.2732
35	.1314	.1309	.1295	.1270	.1234	.1191	35	.3041	.3030	.2996	.2937	.2858	.2756
40	.1379	.1374	.1358	.1332	.1296	.1250	40	.3066	.3055	.3020	.2961	.2881	.2779
45	.1444	.1437	.1421	.1394	.1356	.1308	45	.3090	.3078	.3043	.2985	.2903	.2801
50	.1507	.1501	.1484	.1456	.1415	.1365	50	.3112	.3100	.3065	.3006	.2914	.2821
55	.1569	.1564	.1546	.1516	.1475	.1422	55	.3132	.3121	.3085	.3026	.2943	.2839
2 0	.1632	.1625	.1607	.1576	.1533	.1479	5 0	.3151	.3140	.3104	.3044	.2961	.2857
5	.1693	.1687	.1668	.1635	.1590	.1534	5	.3170	.3157	.3121	.3061	.2979	.2873
10	.1753	.1747	.1727	.1693	.1648	.1589	10	.3186	.3174	.3137	.3077	.2994	.2887
15	.1812	.1806	.1785	.1751	.1703	.1643	15	.3201	.3189	.3151	.3091	.3007	.2900
20	.1872	.1865	.1844	.1807	.1758	.1696	20	.3214	.3202	.3163	.3104	.3020	.2912
25	.1929	.1922	.1900	.1864	.1812	.1749	25	.3225	.3213	.3176	.3115	.3030	.2923
30	.1986	.1979	.1956	.1918	.1867	.1800	30	.3235	.3223	.3186	.3124	.3040	.2932
35	.2043	.2035	.2011	.1972	.1919	.1851	35	.3244	.3232	.3194	.3132	.3048	.2940
40	.2097	.2090	.2066	.2026	.1971	.1901	40	.3251	.3239	.3201	.3139	.3054	.2946
45	.2151	.2144	.2119	.2078	.2022	.1950	45	.3256	.3244	.3207	.3144	.3059	.2951
50	.2204	.2196	.2171	.2129	.2072	.1998	50	.3260	.3248	.3211	.3148	.3063	.2954
55	.2257	.2248	.2223	.2179	.2120	.2045	55	.3262	.3250	.3213	.3150	.3065	.2956
3 0	.2307	.2299	.2273	.2229	.2168	.2091	6 0	.3263	.3251	.3214	.3151	.3066	.2957

(NOTE.—When using this table at another observatory, multiply the value derived from a given δ and t by the necessary factor).

(b) Using the device:—

The *N* pole of the graduated ring is rotated $7^{\circ}24' W$ of the *N* pole of the ecliptic. The observed point, 110.5 mm. from the centre, is marked on a diameter of the transparent disc measured on the mm. scale of the ecliptic. The disc is rotated so that its *N* pole coincides with the *N* pole of the ring, and the projection of the observed point on the ecliptic is read, corresponding to position 0° . The disc is rotated back 15° , 30° , and so on to 90° , and the projections of the marked point read on the ecliptic line. Since $d\odot$ is $143''43$, the scale per mm. along the ecliptic is $0.1343 : 113.0$ or 0.001189 km. per sec., and the projections are converted into km. per sec. values, thus:—

Position	0°	15°	30°	45°	60°	75°	80°	85°	90°
mm.	109.5	109.5	102.0	87.5	66.7	41.7	32.5	23.0	14.0
km./sec.	0.130	0.130	0.121	0.104	0.079	0.050	0.039	0.027	0.017

It is advantageous to use the device in such cases where there are many observed points at various position angles for the one setting of the graduated ring.

Example 3. Centre, intermediate, and limb points.

Plate L 2320, August 12, 3:13 - 18 (8:15 G.M.T.), 1917. Centre; a pair of points 57.0 mm. from centre, and a pair 111.0 mm. from centre at 15° (*WN - ES*); a pair at 111.0 mm. from centre at 75° (*NE - SW*). Diameter of sun, 226.0 mm.; $d\odot = 144''07$ per hour, so from Table XIII, $r : d\odot : dt$ is 0.1355 km. per sec.; and scale is $0.1355 : 113.0$ or 0.001199 km. per sec. for 1 mm. along the ecliptic line. B_0 is $+6^{\circ}55'$, and from Table XV, therefore, p is $3^{\circ}12'$; also $dR : dt$ is -0.299 km. per sec.

The device is advantageously used for such observations, thus: The *N* pole of the graduated ring is rotated $3^{\circ}12' W$ of the *N* pole of the ecliptic, and the *N* pole of the disc is placed $15^{\circ} E$ of the pole of the ring. All the observed points at 57.0 mm. and 111.0 mm. from the centre are marked permanently on the film as they are used in many observations. The projections of the points on the fixed mm. scale of the ecliptic are read and by multiplying these by 0.001199 the components relative to the centre are obtained, and from these the orbital components are found by adding -0.299 km. per sec., as follows:—

	<i>ES</i>	<i>ME</i>	<i>NE</i>	<i>C</i>	<i>SW</i>	<i>MW</i>	<i>WN</i>
mm.....	108.7	55.4	22.9	0	23.0	55.3	108.8
km./sec.....	0.130	0.066	0.027	0.000	-0.027	-0.066	-0.130
km./sec. -0.299.....	-0.169	-0.233	-0.272	-0.299	-0.326	-0.365	-0.429

Corresponding to the value of u for this plate, namely, $\odot - 281^{\circ}39' - 1'03$ (1917.6 - 1925.0) or $217^{\circ}99'$, the value of i from Table XII is $35'90$. The radius of the sun is $15'82$, which corresponds to 0.1355 km. per sec. along the ecliptic line, and consequently $35'90$ corresponds to -0.307 km. per sec. The disagreement of this value, involving $d\odot : dt$, with the value of $dR : dt$, -0.299 km. per sec., is attributable to the moon, Jupiter, and other planets. The value, -0.299 km. per sec., measured along the ecliptic

is 250·0 mm., and by setting the sliding-scale with its zero 250·0 mm. *E* of the centre, the components to the various points are read off directly:

mm.	141·4	194·6	227·3	250·0	273·0	305·2	358·8
km./sec.	-0·169	-0·233	-0·272	-0·299	-0·326	-0·365	-0·429

It may be noted here that while the effect of Jupiter is included in $dR : dt$, a rotational term, approximately $0\cdot012 \cdot \cos \beta$, remains.

In Table XVI are given the components to the sun of the earth's rotational velocity at Ottawa, $0\cdot3263 \cdot \cos \delta \cdot \sin t$ km. per sec. for every 5° declination of the sun, δ , and every 5 minutes of hour angle of the sun, t , to 6 hours. This value is derived from the distance, 4486·8 km., of the coelostat from the axis of rotation of the earth, computed from the expression $a^2 (a^2 + b^2 \tan^2 \phi)^{-0\cdot5} + 0\cdot084 \cos \phi$, using the values of Hayford's spheroid of 1909, the position of the coelostat being, latitude, ϕ , $45^\circ 23' 39''\cdot0$, longitude, 5h. 2 m. 51·9s., and elevation 275·4 feet or 0·084 km.

In employing Table XVI at other observatories it will be necessary only to multiply the interpolated readings by a factor.

DOMINION OBSERVATORY,

OTTAWA, CANADA,

June, 1928.

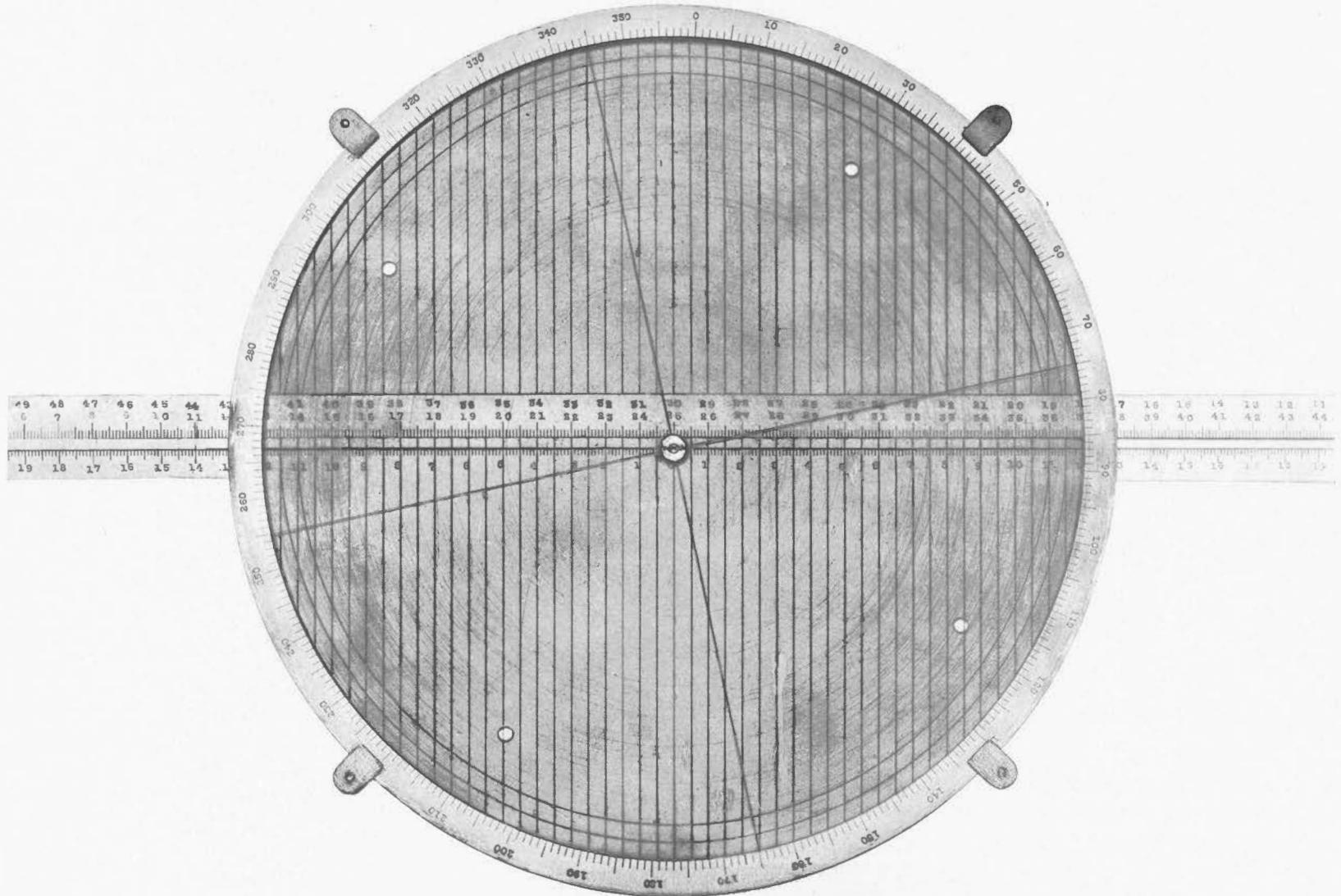


FIG. 23.—Device for Computing the Components of the Orbital Velocity of the Earth to Points on the Sun.