When these values are plotted they give curves which represent the general character of the observed distribution of density. For a good agreement a large value of n seems necessary. As n increases the curves tend to similarity, and the uncertainty in the radius of the cluster makes it impossible to attach any great weight to the determination of n. With the diameter already mentioned a fair representation is obtained by assuming $n = 11$. Unfortunately it is not easy to show the comparison graphically except on a very large scale, as the variation from straight line is small in the greater part of the curve, and the various curves have a tendency to coalesce. But assuming a central density of sixty-five stars in a unit of space, the number of stars read from the curves can be compared numerically with the values computed from the above table.

Distance from Centre.	No. of Stars Observed.	No. of Stars $n=8$.	No. of Stars $n=9$.	No. of Stars $n=10$.	No. of Stars $n=11$.
0″	65·0	65·0	65·0	65·0	65·0
45	33·4	41·4	38·5	35·7	33·1
93	12·7	19·0	15·8	13·1	10·9
136	5·0	7·1	5·2	3·8	2·7
188	2·3	2·2	1·4	0·8	0·5
258	1·1	0·5	0·1		

The agreement is not very satisfactory in any case, but it seems safe to say that while n may be as high as 11, it is not less than 8. Professor Geo. E. Hale has offered me a plate on which the number of images recorded is much larger than on the plate here discussed, and I hope to return to this question again.

The discussion as far as it goes affords an example of the spirit of devolution of which we have heard something of late, and I acknowledge my indebtedness to the Directors of the Yerkes and Oxford Observatories, and to others, who have enabled me to carry out this investigation.

1905 *June* 5.

The Solar Rotation Period from Greenwich Sun-spot Measures, 1879–1901. By E. Walter Maunder and A. S. D. Maunder.

1. *Material Employed.*

The material employed in the following paper is much more ample than has been used in any previous discussion of the solar rotation. It is drawn from the Photoheliographic Results published in the annual volumes of the *Greenwich Observations*, and especially from the ledgers of sun-spots. From the 4700 spot-groups catalogued in these results for the twenty-three years (1879–1901) we have taken every group which persisted for six or more days—1872 in number. A very few groups of this duration were excluded, because the record was in some way defective. For the sake of symmetry the last groups of the cycle, which expired in 1879, and the first groups of the cycle, which began in 1901, have been left out of the discussion, which is thus limited to the two complete cycles. These two cycles will be referred to hereafter as cycle 1 and cycle 2—cycle 1 attaining its maximum in 1883, and cycle 2 in 1893. It may be noted here that when sun-spots are treated, as in this discussion, in narrow zones of latitude, there is (broadly speaking) not the slightest possibility of ambiguity as to which of the two cycles a given group belongs. The break between the two cycles in any particular latitude generally lasts for something like three full years during which no spots whatsoever, not even the most minute, appear in that particular zone. The time when this break takes place differs for different zones; but for any particular zone this entire cessation of activity is one of the most unmistakable characteristics of solar variation.

The material has been used in two ways. First, each apparition of a spot-group has been used independently of any other apparition of the same. Second, the spot-groups have been carefully examined for cases of return, and where it appeared clear that the same group has returned a second time or more frequently, without any temporary disappearance or subsidence, such a long-continued group has been treated as an entity throughout. But in both methods the entire spot group has been taken as a whole on each day of observation, the centre of gravity of the entire group being taken as the position of the group on that particular day. There has been no selection of spots because they seemed to be steady in motion or regular in shape, no rejection because of unsteadiness or irregularity. The only criterion for the inclusion of a group in the discussion has been that it lasted for six consecutive days; subject to the caution that when a group on a certain day was close to the limb, and there was reason to fear from a marked and sudden change of area or position that the entire group was not in view, that day was not used. If on the first or last day of observation the group was within 70° of the central meridian, then the group was retained, no matter whether the measures appeared accordant or not. If the distance from the central meridian was much greater than 70° on any day, then that day's measures were only retained if there was clear indication that the whole of the group was still within the visible hemisphere.

The method of reduction employed was very simple, but seemed sufficiently effective for the purpose in view. The mean of the positions of the group on the first three days was taken as the first position of the group; the mean of the positions on the last three days as the second position; the difference between the two longitudes thus given divided by the number of days and parts of a day gave the mean daily drift, eastward or westward according to its sign. Thus a group observed on six consecutive days would have its mean position determined for the second and fifth days, giving an interval of three days. The longest period during which a group can be observed during a single apparition is fourteen days, and it was of course extremely rare under these circumstances that both the first and the last observations could be regarded as complete. A fourteen-day group, where all the fourteen days could be used, would thus give an interval of eleven days.

In the case of the long-continued spots, that is to say, of spots that have been seen during more than one apparition, the mean of the first five days of the first apparition has been compared with the mean of the last five days of the last apparition, wherever this was possible. As in the former case, days of observation when the group was imperfectly seen at either limb have not been included.

The term "solar rotation period" is not used in this paper in a rigid sense. Strictly speaking, the Sun can have but one rotation period, but an inquiry like the present, confined entirely to the apparent movements of spot-groups, necessarily deals with the resultant effect of such solar rotation period and of the motions of the groups, whether such motions are systematic, or irregular, or both. To speak, for example, of the solar rotation period as derived from a single group, possibly short-lived, and moving at an unusual speed, would be quite inexcusable if it were not clearly pointed out that the expression was used partly for brevity and convenience, and partly because the solar rotation period is, after all, much the most considerable factor, as well as the most permanent in the apparent movements of the spots upon the solar disc.

2. *Each Apparition treated separately.*

In the reduction of the measures of the solar photographs at Greenwich Carrington's value for the mean sidereal rotation period of the Sun has been adopted throughout. This period is 25·38 days, corresponding to a daily sidereal angular motion of 851′·06. The first operation in the discussion of the observations was to ascertain for each group the amount of its apparent daily drift in longitude as computed with this constant. The "drifts" thus obtained have been combined in various ways, the first attempt being to find an expression for the variation of the rotation rate in different solar latitudes. Table I. exhibits the result of treating the spots in zones of latitude each 5° wide. The centres of these zones have been taken $2\frac{1}{2}°$ apart, starting from the equator and proceeding in either direction. Thus every group has been used twice, except the groups in the two exterior half-zones. This is the only smoothing that has been used. The weighting has been strictly in proportion to the number of days' interval given by each group; that is to say, a

3 L

group lasting six days would have its mean positions taken for the second and fifth days; the interval would be three days and the weight would be 3.

TABLE I.

Rotation Period for Different Zones of Latitude each Five Degrees wide.

Latitude.	Number of Groups.	Weight. Groups × Days.	Apparent Mean Daily Drift in Longitude.	Mean Synodic Rotation Period.	Daily Sidereal Motion.	Mean Sidereal Rotation Period.	Daily Sidereal Motion computed.	O−C.
°			′	d	′	d	′	′
+35	2	12	−46·3	28·97	804·8	26·84	821·7	−16·9
32½	3	21	23·6	28·11	827·4	26·11	828·4	− 1·0
30	11	71	18·7	27·94	832·3	25·95	834·7	− 2·4
27½	36	212	11·6	27·68	839·4	25·73	840·2	− 0·8
25	66	400	7·4	27·53	843·6	25·61	846·4	− 2·8
22½	115	703	− 0·4	27·29	850·7	25·39	851·7	− 1·0
20	167	1018	+ 7·6	27·02	858·6	25·16	856·5	+ 2·1
17½	188	1174	13·6	26·82	864·6	24·98	860·9	+ 3·7
15	241	1587	14·3	26·79	865·4	24·96	864·7	+ 0·7
12½	291	1934	15·8	26·74	866·9	24·92	868·0	− 1·1
10	246	1592	19·7	26·61	870·8	24·81	870·7	+ 0·1
7½	154	987	23·0	26·50	874·1	24·71	872·9	+ 1·2
5	99	629	26·0	26·41	877·0	24·63	874·4	+ 2·6
+ 2½	63	392	28·1	26·34	879·1	24·57	875·4	+ 3·7
0	41	256	25·2	26·43	876·2	24·65	875·7	+ 0·5
− 2½	70	453	23·3	26·49	874·4	24·70	875·4	− 1·0
5	148	957	20·6	26·58	871·7	24·78	874·4	− 2·7
7½	240	1570	18·2	26·66	869·3	24·85	872·9	− 3·6
10	289	1874	17·4	26·69	868·4	24·87	870·7	− 2·3
12½	294	1867	15·8	26·74	866·8	24·92	868·0	− 1·2
15	277	1740	12·8	26·84	863·8	25·00	864·7	− 0·9
17½	252	1573	8·6	26·98	859·6	25·13	860·9	− 1·3
20	188	1195	5·4	27·09	856·4	25·22	856·5	− 0·1
22½	110	696	+ 1·4	27·23	852·5	25·34	851·7	+ 0·8
25	69	422	− 5·6	27·47	845·5	23·55	846·4	− 0·9
27½	44	273	7·7	27·56	843·3	25·63	840·2	+ 3·1
30	24	150	11·8	27·69	839·2	25·74	834·7	+ 4·5
32½	9	50	26·8	28·23	824·3	26·21	828·4	− 4·1
−35	3	12	−33·7	28·49	817·4	26·43	821·7	− 4·3
All Spots*	1871	11915	+13·1	26·83	864·17	25·00	...	...
Carrington ...	...	...	...	27·275	851·06	25·38	...	...

* Each spot is, of course, only taken once in this summary.

TABLE II.

Numbers of Spot-groups, arranged in Zones of Latitude 5° wide, giving Different Rotation Periods.

Synodic Rotation Period. d	Above +35°.	+35° to +30°.	+30° to +25°.	+25° to +20°.	+20° to +15°.	+15° to +10°.	+10° to +5°.	+5° to 0°.	0° to −5°.	−5° to −10°.	−10° to −15°.	−15° to −20°.	−20° to −25°.	−25° to −30°.	−30° to −35°.	Below −35°.
3·4	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...
6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4·0	...	...	...	...	...	...	...	...	...	...	2	2	...	...	...	...
2	...	...	...	...	2	...	1	...	...	2	...	1	...	...	...	...
4	...	...	...	...	...	1	1	...	2	1	2	1	...	...	...	...
6	...	...	...	...	...	3	...	1	2	3	1	...	1	1	...	...
8	...	...	...	...	2	2	3	1	1	1	3	2	...	...	...	...
5·0	...	...	1	3	2	2	2	2	3	4	3	6	...	...	...	...
2	...	...	...	1	3	5	4	4	2	6	6	1	1	...	...	...
4	...	...	...	1	5	5	2	2	1	4	13	3	...	1	...	...
6	...	...	1	3	4	12	7	1	3	5	5	8	2	1	...	...
8	...	...	1	1	9	12	15	4	2	5	13	9	2	...	...	...
6·0	...	...	...	4	6	12	10	10	2	12	14	9	8	1	...	...
6·2	...	...	2	4	7	23	16	1	5	25	16	16	7	1	...	...
4	...	...	1	5	15	21	14	10	6	19	24	14	4	...	...	...
6	...	1	3	8	15	23	7	9	15	26	26	14	9	2	...	...
8	...	...	2	3	14	31	26	9	7	20	30	16	7	4	1	...
7·0	...	...	...	7	25	41	17	8	6	42	41	23	8	1	...	...
2	...	...	1	13	25	39	15	...	5	26	37	38	12	2	...	...
4	...	...	2	15	18	29	8	1	1	19	23	33	5	4	1	...
6	...	...	3	12	22	7	...	...	2	5	13	19	14	4	...	1
8	...	...	4	11	5	9	3	...	1	5	4	16	13	6	1	...
8·0	...	...	4	5	4	4	1	...	1	5	4	2	3	7	...	...
2	...	...	2	5	3	2	2	...	2	2	3	4	7	2	1	...
4	...	...	3	5	2	1	...	...	1	2	4	3	5	3	1	...
6	...	2	2	1	...	2	...	..	...	1	2	1	...	...	1	...
8	...	...	1	2	...	...	...	...	...	...	2	6	1	1	1	...
9·0	...	...	1	3	...	1	...	...	...	...	...	1	...	1	...	...
9·2	...	...	1	...	...	...	...	...	...	...	1	1	...	1	1	...
4	...	...	...	...	...	1	...	...	...	...	...	1	1	...	...	...
6	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	...	...	...	...	...	1	...	...	...	...	...	1	...	1	1	...
·0	...	...	...	1	...	1	...	...	...	...	1	1	...	...	...	...
2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	..	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
6	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...
8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...

Table II. exhibits the distribution of the spot-groups in a table of double entry, the horizontal lines showing the numbers of groups yielding different synodic rotation periods, the vertical columns, the numbers of groups in each zone of latitude 5° wide.

This table brings out a most important point which has hitherto been practically entirely neglected, namely, the way in which the apparent spot movements in any particular zone of latitude differ among themselves. It will be seen that the differences of rotation period of the various groups in any particular zone of latitude are much greater than the differences of mean rotation between the different zones. The extreme differences shown in Table I. lie between 26·3 days and 29·0 days (synodic rotation periods); that is to say, within an extreme range of 2·7 days. The groups with periods between these limits have been printed in heavier type in Table II. If we turn to this latter table we see that in one particular zone of latitude, +10° to +15°, the extreme range is from 24·4 days to 31·2 days. In other words, if these spots persisted for nine consecutive rotations and travelled continuously at the same rate, the most quickly moving spot would make ten rotations and the most slowly moving only eight rotations, whilst the spots with mean period would be completing nine. The bearing of this fact upon the inquiry into the connexion between sun-spots and magnetic disturbances is obvious. It is not in the least necessary to presume that a disturbance indicating a long rotation period is due to a spot in high latitude. It is perfectly true that when we are dealing with the *mean* motions in any zone we find that the rotation period generally lengthens with the distance from the equator; but, as Table II. also shows, the individual spot-groups giving the longest periods are by no means situated in the highest latitudes.

A more detailed examination of the table shows that above 25° latitude, north or south, there is scarcely any tendency in the spot-groups to concentrate upon one particular period. The higher the latitude the more evenly are the groups scattered amongst the different rotation periods; a fact which has an important bearing upon the law of the variation of rotation rate with latitude. Carrington's expression for the rotation period involves the term $\sin^{\frac{7}{4}} \lambda$, and Spoerer's the term $\sin(41° 13' + \lambda)$. The fractional exponent in the one case and the auxiliary angle in the other are refinements which have no warrant in the observations. It is perfectly clear that beyond 25° from the equator we can attach no great precision to the rotation period derived from spot-groups, since groups in higher latitudes are not only few in number, but appear almost accidental in the rotation periods which they yield; so that there is no justification for departing from a simple expression of the form $a - b \sin^2 \lambda$. The formula $875'{\cdot}7 \mp 164' \sin^2 \lambda$ satisfies the observation sufficiently well for all but the extreme latitudes, as will be seen by the eighth and ninth columns of Table I., which give respectively the values of the daily angular movement as computed by this formula, and the differences of the observations from them.

The important discovery of Carrington of what has been described as "the systematic variation of rotation rate from equator to poles" has generally obscured this striking and remarkable variety in the motions of spots in any given latitude. It has been forgotten that, whatever the cause which produces this variation of rotation rate with latitude, the causes producing difference of rate within any given latitude are more effective still.

The question has been raised as to whether the mean rotation period of the Sun as derived from the spots varies from cycle to cycle, or in different parts of the progress of any one cycle. Table III. exhibits the daily sidereal movement for the different zones of latitude for the two cycles treated separately; it thus corresponds to Table I.; but to save space the two columns of mean synodic and mean sidereal rotation periods have been omitted. The comparison of the table emphasises the remark just made that there is no sufficient warrant for seeking a more complicated expression than one of the form $a - b \sin^2 \lambda$, the differences between the results given by the two cycles being often so considerable.

TABLE III.

Comparison of the Two Cycles.

Latitude.	Cycle I.			Cycle II.			I.–II.
	No. of Groups.	Weight.	Daily Sidereal Motion.	No. of Groups.	Weight.	Daily Sidereal Motion.	
+ 35°	1	4	789′·3	1	8	812′·8	−23′·5
32½	0	0	...	3	21	827·5	...
30	2	9	818·2	9	62	834·4	−16·2
27½	13	78	821·9	23	134	849·6	−27·7
25	24	147	822·8	42	253	848·3	−25·5
22½	50	295	844·3	65	408	854·3	−10·0
20	61	358	853·1	106	660	861·7	− 8·6
17½	58	335	864·0	130	839	864·9	− 0·9
15	101	634	861·7	140	953	867·9	− 6·2
12½	124	796	865·1	167	1138	868·1	− 3·0
10	93	580	871·5	153	1012	870·5	+ 1·0
7½	58	360	874·6	96	627	873·8	+ 0·8
5	36	228	880·1	63	401	875·3	+ 4·8
+ 2½	21	136	880·6	42	256	878·4	+ 2·2
0	19	113	868·9	22	143	880·5	−11·6
− 2½	35	224	874·1	35	229	874·7	− 0·6
5	65	413	870·1	83	544	872·9	− 2·8

Latitude.	Cycle I. No. of Groups.	Cycle I. Weight.	Cycle I. Daily Sidereal Motion.	Cycle II. No. of Groups.	Cycle II. Weight.	Cycle II. Daily Sidereal Motion.	I.–II.
$-7\frac{1}{2}$°	110	708	867′·8	130	862	870·7	− 2′·9
10	126	804	867·9	163	1070	868·9	− 1·0
$12\frac{1}{2}$	110	671	868·2	184	1196	866·1	+ 2·1
15	114	713	865·5	163	1027	862·7	+ 2·8
$17\frac{1}{2}$	104	662	862·0	148	911	860·2	+ 1·8
20	66	424	854·0	122	771	857·8	− 3·8
$22\frac{1}{2}$	38	239	854·0	72	457	851·8	+ 2·2
25	21	117	849·6	48	305	844·0	+ 5·6
$27\frac{1}{2}$	12	71	832·5	32	202	847·1	− 14·6
30	7	46	829·9	17	104	843·4	− 13·5
$32\frac{1}{2}$	2	11	844·2	7	39	818·6	+ 25·6
−35	1	6	843·4	2	6	791·8	+ 51·6

One most remarkable peculiarity is common to both cycles; and since it was brought out by Carrington's inquiry two cycles earlier than the first of these it is probable that it expresses a real peculiarity of the solar rotation. In spite of the great irregularity in the rotation periods given by the spots in any particular zone, there does appear to be a distinct tendency for the shortest mean period to be given, not at the equator, but slightly to the north of it. The curve given by the different rotation periods is not precisely symmetrical with respect to the equator, and, *on the whole*, there appears to be a tendency for the periods in the northern latitudes to lengthen more rapidly with distance from the equator than with those of the southern. The question as to any variation in the rotation period during the progress of a cycle is a particularly difficult one to answer satisfactorily, since there is a well-defined tendency for the spots to seek special latitudes at different parts of the cycle; and consequently, as at the beginning of a cycle most of the spots are in high latitudes, and at the end in low, the mean rotation periods tend to shorten as the cycle progresses, and it is difficult to ascertain whether this effect is wholly a function of Spoerer's "Law of Zones," or whether some further cause is also at work.

In Table IV. the two cycles under discussion have been divided into three portions; three years in each cycle have been considered as years of maximum, viz. 1882–4 in the first cycle, 1892–4 in the second cycle, and have been taken as the centre periods. The years preceding these are the years of increasing, those succeeding them of decreasing activity. The examination has been confined to the zone 10° to $22\frac{1}{2}$° in each hemisphere, since the latitudes higher than this belt are scarcely represented at all during decrease, and the latitudes lower than it are in like manner scarcely represented during increase. The comparison shows that there is no clear evidence of anything like a systematic change in the rotation period during the progress of any particular cycle, and very little evidence, if any, of a change from one cycle to another.

TABLE IV.

Comparison of the Rotation Periods given by Different Cycles and Different Parts of a Cycle.

Hemisphere.	Cycle.	Phase of Cycle.	No. of Groups.	Apparent Mean Daily Drift.	Mean Synodic Rotation Period.	Daily Sidereal Motion.	Mean Sidereal Rotation Period.
				′	d	′	d
North	I.	Increase	73	+ 4·4	27·12	855·4	25·25
		Maximum	112	+ 13·7	26·81	864·8	24·97
		Decrease	34	+ 12·8	26·84	863·8	25·00
		Entire cycle	219	+ 10·6	26·92	861·7	25·07
	II.	Increase	51	+ 17·0	26·70	868·1	24·88
		Maximum	187	+ 15·2	26·76	866·2	24·93
		Decrease	98	+ 14·3	26·79	865·3	24·96
		Entire cycle	336	+ 15·2	26·76	866·2	24·93
South	I.	Increase	36	+ 13·1	26·83	864·1	24·99
		Maximum	126	+ 11·9	26·87	863·0	25·03
		Decrease	76	+ 10·2	26·93	861·3	25·08
		Entire cycle	238	+ 11·5	26·88	862·6	25·04
	II.	Increase	23	+ 11·5	26·89	862·5	25·04
		Maximum	204	+ 9·5	26·95	860·5	25·10
		Decrease	149	+ 14·7	26·78	865·8	24·95
		Entire cycle	376	+ 11·6	26·88	862·7	25·04
All spots	I.	Increase	109	+ 7·2	27·03	858·3	25·17
		Maximum	238	+ 12·8	26·84	863·8	25·00
		Decrease	110	+ 11·0	26·90	862·0	25·05
		Entire cycle	457	+ 11·0	26·90	862·0	25·05
	II.	Increase	74	+ 15·2	26·76	866·3	24· 3
		Maximum	391	+ 12·2	26·86	863·3	25·02
		Decrease	247	+ 14·5	26·78	865·5	24·95
		Entire cycle	712	+ 13·3	26·82	864·4	24·98
All spots	Both cycles	Increase	183	+ 10·6	26·92	861·7	25·07
		Maximum	629	+ 12·4	26·85	863·5	25·01
		Decrease	357	+ 13·4	26·82	864·5	24·98
		Entire cycle	1169	+ 12·5	26·85	863·6	25·01

The very slight diminution of the period with the progress of the cycle shown by the last section of Table IV. may be looked upon as purely accidental, for it will be observed that the northern spots in the second cycle and the southern spots in the first cycle showed quite as distinct a progression in the other direction. We may conclude, therefore, that there is no evidence of a change in the rotation period during the progress of the cycle other than that which results from the change in the distribution of the spots in latitude.

But if we compare together spots of different durations there does seem some distinct evidence of a systematic difference. Table V. brings this out. The spots are divided into three classes: those observed on six or seven days are regarded as short-lived spots; those on eight, nine, or ten, as spots of medium duration; and those of eleven, twelve, thirteen, and fourteen days, as long-lived. In order to complete the comparison we have added the recurring spots, and it will be noted that there is on the whole a distinct tendency for the short-lived spots to give a shorter rotation period than those of longer duration.

TABLE V.

Comparison of the Rotation Periods given by Spots of Different Durations.

Hemi-sphere.	Cycle.	Duration of Group.	No. of Groups.	Weight.	Apparent Mean Daily Drift.	Mean Synodic Rotation Period.	Daily Sidereal Motion.	Mean Sidereal Rotation Period.
					′	d	′	d
North	I.	Short	79	275	+ 9·5	26·95	860·5	25·10
		Medium	141	853	+ 15·4	26·75	866·5	24·93
		Long	105	876	+ 9·2	26·96	860·3	25·11
		Recurrent	99	3449	+ 7·8	27·01	858·8	25·15
	II.	Short	127	445	+ 23·0	26·50	874·0	24·71
		Medium	175	1061	+ 19·8	26·61	870·9	24·80
		Long	224	1917	+ 11·3	26·89	862·3	25·05
		Recurrent	133	4980	+ 5·8	27·07	856·9	25·21
South	I.	Short	107	376	+ 17·9	26·67	868·9	24·85
		Medium	156	944	+ 20·2	26·60	871·3	24·79
		Long	149	1272	+ 5·6	27·08	856·6	25·21
		Recurrent	125	8572	+ 6·6	27·05	875·7	25·18
	II.	Short	157	545	+ 21·5	26·55	872·6	24·75
		Medium	209	1260	+ 15·7	26·74	866·8	24·92
		Long	242	2091	+ 7·3	27·03	858·3	25·16
		Recurrent	167	11150	+ 5·1	27·10	856·1	25·23
Both	Both	Short	470	1641	+ 19·0	26·63	870·1	24·82
		Medium	681	4118	+ 17·8	26·67	868·8	24·85
		Long	720	6156	+ 8·5	26·98	859·5	25·13
		Recurrent	524	19722	+ 6·1	27·07	857·2	25·20

3. *Recurring Sun-spots.*

Table VI. presents for the recurring spot-groups the same statistics as were given in Table I. for the several groups considered independently at each apparition. It has not been thought worth while to give a table for these long-lived groups similar to Table II., but Table VII., corresponding to Table III., gives a comparison of the two cycles for these recurring groups. There is no doubt that these groups are much more free from the effect of accidental motions than the groups when considered separately in each apparition. The mean sidereal period given by them is exactly

$$25^{\cdot}2 \text{ days}$$

and the formula which satisfies the variation of rotation period with latitude, and has been adopted in Table VI., is

$$866'{\cdot}6 \mp 128' \sin^2 \lambda$$

Table VI.

Rotation Periods from Recurrent Spots for Different Zones of Latitude.

Latitude.	No. of Groups.	Weight.	Apparent Mean Daily Drift.	Mean Synodic Rotation Period.	Daily Sidereal Motion.	Mean Sidereal Rotation Period.	Daily Sidereal Motion computed.	O−C.
°			′	d	′	d	′	′
+30	3	92	−23·9	28·12	827·1	26·12	834·6	−7·5
27½	10	364	−12·8	27·72	838·2	25·69	839·3	−1·1
25	19	704	− 6·8	27·51	844·2	25·59	843·7	+0·5
22½	38	1401	− 1·8	27·34	849·3	25·42	847·9	+1·4
20	54	1909	+ 3·3	27·16	854·4	25·28	851·6	+2·8
17½	57	1985	+ 7·0	27·04	858·0	25·18	855·0	+3·0
15	62	2143	+ 8·4	26·99	859·5	25·13	858·0	+1·5
12½	76	2904	+10·0	26·94	861·0	25·09	860·4	+0·6
10	65	2552	+11·0	26·90	862·1	25·06	862·9	−0·8
7½	32	1203	+14·8	26·78	865·8	24·95	864·4	+1·4
5	25	870	+18·2	26·66	869·2	24·86	865·6	+3·6
+ 2½	19	572	+17·0	26·70	868·1	24·88	866·4	+1·7
0	11	398	+15·1	26·76	866·2	24·94	866·6	−0·4
− 2½	21	693	+16·5	26·72	867·6	24·90	866·4	+1·2
5	38	1356	+13·1	26·83	864·2	24·99	865·6	−1·4
7½	65	2742	+10·7	26·91	861·7	25·06	864·4	−2·7
10	75	3249	+ 9·7	26·94	860·8	25·10	862·9	−2·1
12½	80	3198	+ 9·5	26·95	860·6	25·11	860·4	+0·2
15	79	3021	+ 8·5	26·98	859·6	25·13	858·0	+1·6
17½	68	2395	+ 4·5	27·12	855·6	25·24	855·0	+0·6

Latitude.	No. of Groups.	Weight.	Apparent Mean Daily Drift.	Mean Synodic Rotation Period.	Daily Sidereal Motion.	Mean Sidereal Rotation Period.	Daily Sidereal Motion computed.	O−C.
°			′	d	′	d	′	′
−20	58	2176	+ 0·5	27·26	851·6	25·37	851·6	0·0
22½	38	1664	− 4·8	27·44	846·3	25·53	847·9	−1·6
25	22	911	− 9·2	27·57	841·9	25·66	843·7	−1·8
27½	18	516	−10·4	27·64	840·6	25·70	839·3	+1·3
30	11	340	−15·7	27·84	835·4	25·86	834·6	+0·8
−32½	2	84	−24·4	28·13	826·7	26·13	829·7	−3·0
All spots ...		...	+ 6·1	27·07	857·2	25·20	...	...
Carrington		...	...	27·275	851·06	25·38	...	...

TABLE VII.

Comparison of the Two Cycles for Recurrent Spots.

Latitude.	Cycle I.	Cycle II.	I.–II.	Latitude.	Cycle I.	Cycle II.	I.–II.
°	′	′	′	°	′	′	′
+30	823·9	832·5	− 8·6	− 7½	861·0	862·5	− 1·5
27½	828·5	841·3	−12·8	10	858·6	863·0	− 4·4
25	838·3	845·8	− 7·5	12½	859·5	861·6	− 2·1
22½	845·0	853·7	− 8·7	15	861·4	858·0	+ 3·4
20	850·0	858·0	− 8·0	17½	857·5	853·6	+ 3·9
17½	857·9	858·1	− 0·2	20	854·7	849·6	+ 5·1
15	860·2	858·9	+ 1·3	22½	845·3	846·6	− 1·3
12½	864·7	858·9	+ 5·8	25	842·4	841·5	+ 0·9
10	865·2	860·4	+ 4·8	27½	835·5	844·8	+ 9·3
7½	865·3	866·2	− 0·9	30	829·2	838·9	+ 9·7
5	871·4	867·3	+ 4·1	−32½	...	826·7	...
+ 2½	869·6	866·3	+ 3·3	North spots	858·8	856·9	+ 1·9
0	864·7	870·2	− 5·5	South spots	857·7	856·1	+ 1·6
− 2½	867·8	867·4	+ 0·4				
5	864·3	864·1	+ 0·2	All spots	858·1	856·4	+ 1·7

4. *Summary.*

The Greenwich sun-spot measures for the two complete cycles 1879–1901 give us, therefore, the following results :

(1) Carrington's period does not correspond to a latitude of between 10° and 15°, as he supposed, but is given by the separate spot-groups of latitude 22½° ; by the recurrent spots of latitude 20°.

(2) Carrington's period is not that of the mean of all spots, but is considerably longer than that mean.

(3) A different rotation period is given if the examination is restricted to the movements of each appearance of the groups considered separately and to those of the spots of long duration.

The latter—the recurrent spots—give a somewhat longer period in the mean, and are more accordant *inter se* than are the groups treated separately.

(4) The curve given by the different rotation periods is not precisely symmetrical with respect to the equator, the zone of shortest rotation being north of the equator.

(5) The rotation periods given by different spots in the same zone of latitude differ more widely than do the mean rotation periods for different zones of latitude.

(6) Spots of short duration tend to give a shorter rotation period than spots of long.

(7) There is no evidence of a progressive change in the mean rotation period during the progress of a sun-spot cycle other than that which follows from the gradual shift of sun-spot activity from higher to lower latitudes.

(8) A comparison of the rotation periods from the separate groups for the two cycles shows an apparent slight shortening of the period for the northern hemisphere whilst the southern is absolutely unchanged. It cannot be presumed that this apparent change in the northern hemisphere is anything but accidental.

(9) For when the recurrent spots are taken there is a slight retardation of the rotation period from the first cycle to the second, shown by both northern and southern hemispheres.

86 *Tyrwhitt Road, St. John's, S.E.:*
1905 *June* 9.

Observations of Mars, 1903. By Major P. B. Molesworth, R.E.

The apparition of 1902–3 was rather an unfavourable one, as the diameter of the planet at opposition was only 14″·57. The great tilt, however, of the axis presented the northern regions in most favourable position for observation, and the small diameter of the polar cap permitted the details to be followed up nearly to the pole. The southern regions of course were greatly foreshortened.

Vernal equinox, N. hemisphere	1902 August 12
Aphelion of *Mars*	1903 January 13
Summer solstice, N. hemisphere	February 27
Mars in opposition	March 29
Autumnal equinox, N. hemisphere	August 28

The north latitude of the centre of the disc decreased from +22°·6 on January 17, when the observations began, to +21°·09 on February 2, increasing again to +25°·9 on June 2, after