THE ASYMMETRY OF SOLAR ACTIVITY IN THE YEARS 1959–1969*

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Abstract. One of the most outstanding feature of solar activity in the decade 1959–1969 was a very strong asymmetry on the two hemispheres. On the northern hemisphere spots, faculae and prominences were more numerous and the white light corona was brighter than on the southern hemisphere. This happened as well in the main zone as in the polar zone. The green coronal line too was brighter on the northern hemisphere, but the intensity of the red line was asymmetric in the opposite sense. From this behaviour it follows that over the more active hemisphere the corona is denser and hotter. Between density N_e and temperature T holds the relation: $N_e = 10^{-10}\,T^3$. The real asymmetry was strengthened by a phase difference of the two hemispheres. This phase shift is subject to a long period that contains 8 eleven-year cycles. The intensity of the individual cycles follows the same long period. With low maxima of solar activity the northern hemisphere precedes, with high maxima the southern hemisphere (Figure 3).

1. Introduction

It hardly happens that solar activity is equal on both hemispheres. Normally we have asymmetry. This is of no importance for a single day, because it is due to the more or less random distribution of the centers of activity. But even during longer intervals, months or years, the solar activity remains asymmetrical. Since 1949 the activity on the northern hemisphere has been larger than on the southern one with the only exception of 1957 that shows a southern excess. Thus, the asymmetry is not or not directly connected with the 11-year cycle, but seems to be ruled by the 'long' period of 80 to 100 years (Waldmeier, 1957). The present investigation analyses the solar activity during the decade 1959–1969 when the asymmetry reached a far higher extent than ever before in times of which we have the corresponding data.

2. The Asymmetry of the Main Zone

The material used in this paper is derived from observations made at the Swiss Federal Observatory. Some data have not yet been published, however, most of the material can be drawn from the 'Sonnenaktivität' published annually in the series of the 'Astronomische Mitteilungen der Eidgenössischen Sternwarte' (Waldmeier, 1958–1971).

Table I gives the annual number of the northern (N) and the southern (S) spot groups, and the asymmetry defined by (N − S)/(N + S) for the years 1957–1969. Figure 1 in which the annual values for N and S are plotted separately for cycles

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TABLE I

The asymmetry of spots, faculae and prominences (main zone)

Year	Spots			Faculae			Prominences		
	N	S	(N − S)/(N + S)	N	S	(N − S)/(N + S)	N	S	(N − S)/(N + S)
1957	417	484	−0.074	17.4	21.4	−0.103	2257	2294	−0.008
1958	577	483	+0.089	23.7	20.5	+0.072	2523	2142	+0.082
1959	624	296	0.356	27.1	12.7	0.362	2606	2520	0.017
1960	427	255	0.252	13.9	8.5	0.241	2033	1532	0.140
1961	205	131	0.220	8.3	5.0	0.248	1811	1611	0.058
1962	157	71	0.377	5.5	2.5	0.375	1777	1165	0.208
1963	138	58	0.408	3.6	1.2	0.500	1610	853	0.307
1964	84	32	0.448	1.8	0.4	0.637	1184	652	0.290
1965	107	27	0.596	2.3	0.4	0.704	1365	741	0.296
1966	271	57	0.653	5.3	0.8	0.738	1681	777	0.368
1967	353	209	0.256	6.7	3.4	0.327	2093	1814	0.071
1968	332	290	0.068	6.3	5.0	0.115	2577	2206	0.078
1969	322	233	0.160	8.7	5.9	0.192	2320	2191	0.029

nos. 19 and 20 shows that two different motives take part in the strong asymmetry during 1958–1969. Once the northern hemisphere effectively contains more spots: in cycle no. 19 (1954–1964) 3134 spot groups appeared on the northern hemisphere, 2229 on the southern one; cycle no. 20 showed 1403 northern and 805 southern spot groups from 1964 until the end of 1969. This asymmetry already important in itself is increased by a second cause, a phase shift of activity between the two hemispheres. In cycle no. 19 the southern maximum occurs in the years 1957/58, the northern one

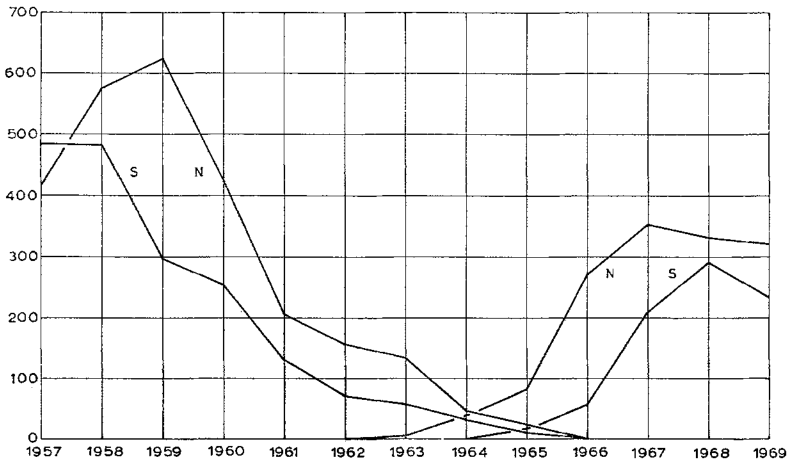

Fig. 1. The annual numbers of northern (N) and southern (S) spot-groups for cycles No. 19 and 20.

follows but in 1959 (Figure 1). Even if both hemispheres were of equal activity this phase shift alone would cause a N-excess on the descending branch of cycle no. 19 (and, correspondingly a S-excess on the ascending branch). Cycle no. 20 too shows a phase difference between the two hemispheres, however, opposite to the preceding cycle, as now the northern activity precedes the southern one. Following Figure 1 the maximum on the northern hemisphere happened to be already in 1967, on the southern one but only in 1968. This phase difference causes a N-excess on the ascending branch for cycle no. 20 (and, correspondingly a S-excess on the descending one) even if the two hemispheres were equally active. Thus the already existing N–S-asymmetry is strengthened by the 'correct' phase difference and the change of its sign at the time of solar minimum.

In addition to the spot groups also the areas of faculae were investigated upon their asymmetry (Table I). It is about the photospheric faculae that are in the main zone, but sometimes may advance up to 50° from the solar equator. The asymmetry of the faculae runs similar to that of the spots, but is even more pronounced than the latter.

Finally Table I gives the areas of the prominences. Restricting upon the main zone, only prominences within heliographic latitude of $\pm 50°$ were considered. Prominences show a smaller asymmetry than the spots and faculae, but it increases with the years and assumes its highest value in 1966 like spots and faculae.

3. The Asymmetry of the Polar Regions

The activity is fainter at heliographic latitudes $|b| > 50°$. Spots are completely absent, faculae occur only as isolated points, only the prominences form the polar zones, extending from mid-latitudes up to the poles.

Table II gives the areas of the prominences for heliographic latitudes from 50° to 90° and the number of polar faculae. Generally the polar prominences too show an excess of northern activity in the period of 1958 to 1967: only 1960 and 1961 have an excess of southern activity. In these years the N-excess of either spot groups, faculae and prominences of the main zone is smaller than during the adjacent years 1959 and 1962.

TABLE II

The asymmetry of polar prominences and faculae

Year	Prominences			Faculae		
	N	S	(N − S)/(N + S)	N	S	(N − S)/(N + S)
1957	822	360	0.391			
1958	1645	593	0.471			
1959	792	324	0.420			
1960	130	331	−0.436	699	49	0.869
1961	105	291	−0.470	1139	70	0.885
1962	269	223	0.094	542	72	0.766
1963	88	75	0.080	484	78	0.722
1964	504	94	0.685	405	127	0.523
1965	443	66	0.741	197	136	0.183
1966	906	100	0.801	105	93	0.061
1967	941	768	0.101	25	41	0.242
1968	802	962	−0.091			
1969	549	1008	−0.294			

Polar faculae were observed only from 1960 to 1967. During all these years they were more frequent in the northern polar zone than in the southern one. On the northern hemisphere polar faculae occurred extremely numerous in 1960 and 1961. It is remarkable to notice that exactly these two years show an S-excess of polar prominences. After 1961 the number of northern polar faculae decreases gradually whereas that of the southern ones increases assuming its maximum in 1964/65, when, however, the number of southern points of faculae is still smaller than that on the northern hemisphere.

Thus the polar activity shows the same N–S-asymmetry as the main zone.

Furthermore, the polar zone of prominences also shows the phase shift that was observed in the zone of spots and faculae. On the southern hemisphere it reached the pole by the middle of 1958, whereas on the northern side it took 1.5 years more to arrive at the pole. But in cycle no. 20 the northern polar zone precedes the southern one, as show the heliographic latitudes of these two zones: 1965: +47°, −41°; 1966: +55°, −42°; 1967: +65°, −52°; 1968: +72°, −58°; 1969: +78°, −68°.

4. The Asymmetry of the White Corona

The solar eclipses of 15 February 1961, 5 February 1962, 20 July 1963, 30 May 1965, 12 November 1966 and 22 September 1968 fall within the scope of strongest asymmetry of solar activity. All these eclipses were successfully observed by the author, and for each one the distribution of the brightness has been published (Waldmeier, 1962–1969).

Let $v = I_{b,r}/I_{-b,r}$ be the ratio of brightness of the white corona in two conjugated points, i. e. points with the same distance from the center of the sun and positions symmetrical to the equator. Both on the east side and on the west side two conjugate points with distances of $r = 1.1$, 1.2 and 1.3 for $b = \pm 10°$, $\pm 20°, \ldots \pm 90°$ each were taken in order to form a mean value out of 6 single values. They are presented in Table III.

TABLE III
The asymmetry of the white light corona

Year	1961	1962	1963	1965	1966	1968	mean
b							
10°	1.20	2.04	1.17	1.23	1.29	1.00	1.39
20°	1.41	1.71	1.12	1.27	1.66	1.00	1.43
30°	1.81	1.32	1.11	1.97	1.36	0.92	1.52
40°	1.98	1.26	1.30	2.95	1.41	1.00	1.78
50°	1.52	1.41	1.67	3.11	1.35	1.04	1.81
60°	1.10	1.62	1.94	2.78	2.08	0.65	1.90
70°	0.82	1.70	1.50	1.76	2.09	0.70	1.57
80°	0.81	1.86	1.19	1.14	1.96	1.10	1.39
90°	0.72	1.89	1.21	1.14	1.76	1.24	1.34
mean	1.26	1.65	1.36	1.93	1.66	0.96	1.57

For the eclipses 1962 to 1966 the northern corona is brighter than the southern for all heliographic latitudes. The corona of 1961 and that of 1968 show S-excesses of brightness at 3 different heliographic latitudes each. Averaged over all heliographic latitudes the eclipses of 1961–1966 give considerable N-excesses; only the eclipse of 1968 has a southern corona being a bit brighter than the northern one. As after 1966 the asymmetry of spots, faculae and prominences rapidly decreased and nearly vanished in 1968, we exclude the results of the corona of 1968 for the following investigation.

The values v_b averaged over the remaining 5 eclipses grow with increasing b, for $b = 60°$ they assume their highest value and then decrease again towards the pole. Averaged over all heliographic latitudes the individual eclipses give values for $\bar{v}$ of 1.26 to 1.93. Averaged over all eclipses and over all heliographic latitudes one gets $\bar{\bar{v}} = 1.57$. As we consider here only the inner corona for which we know the brightness to be proportional to the electron density, the asymmetry observed during 1961–1966 leads to an electron density on the northern corona that exceeds the southern one by a factor of 1.57.

TABLE IV

The asymmetry of the corona's emission in the lines 5303 and 6374 Å

Year	5303 total			5303 polar			6374 total			6374 polar		
	N	S	(N − S)/(N + S)	N	S	(N − S)/(N + S)	N	S	(N − S)/(N + S)	N	S	(N − S)/(N + S)
1957	589	741	−0.114	62	118	−0.311	548	596	−0.042	91	102	−0.057
1958	677	613	0.050	69	75	−0.042	623	581	−0.035	104	111	−0.033
1959	646	503	0.125	60	55	0.043	629	565	0.054	114	103	0.051
1960	486	358	0.152	38	32	0.086	460	583	−0.118	78	110	−0.170
1961	424	297	0.176	42	25	0.254	469	566	−0.094	80	102	−0.121
1962	303	145	0.353	26	1	0.925	508	601	−0.084	76	102	−0.146
1963	205	56	0.572	16	0	1.000	463	618	−0.143	62	94	−0.205
1964	135	20	0.743	15	0	1.000	566	699	−0.105	71	89	−0.112
1965	130	21	0.723	7	1	0.750	437	536	−0.102	54	61	−0.061
1966	312	46	0.742	37	2	0.899	444	520	−0.079	65	67	−0.015
1967	368	264	0.165	34	13	0.447	440	390	0.060	70	53	0.138
1968	410	482	−0.081	26	55	−0.358	552	478	0.072	117	80	0.188
1969	360	378	−0.024	17	34	−0.333	–	–	–	–	–	–

5. The Asymmetry of the Monochromatic Corona

The intensities of the coronal lines 5303 and 6374 Å are measured along the solar limb, in a distance of about 30″ and in intervals of 5° of position angle. The sum of these 72 values of intensity is defined as the total intensity of the corona for the day in question. The annual mean values of the sums, separately for the northern (N) and the southern (S) hemisphere, are given in Table IV. For both lines the sums over all heliographic latitudes ('total') and for $b = 55°–90°$ only ('polar') are communicated.

For the line 5303 Å N-excess begins in 1958, assumes its highest values in 1964–1966 and vanishes in 1968. Similarly runs the asymmetry of the polar emission; it assumes extreme values in 1962–1966.

Line 6374 Å runs completely different. Spots, faculae and prominences were more frequent or more extended respectively on the northern hemisphere as well as the northern corona in white light and in the green line were more intensive. The red line, however, appears brighter on the southern hemisphere than on the northern one in years of strong asymmetry. This is true either for the 'total' as well as for the 'polar' emission. The intensity of the line 6374 Å grows with increasing density and with decreasing temperature. As the intensity of this line is stronger on the southern hemisphere, the density of the corona, however, larger on the northern hemisphere, the northern corona must have a higher temperature than the southern one.

6. The Asymmetry of Coronal Temperature

Approximately the ratio of the intensities of the green and the red coronal line I_g/I_r can be calculated – independent of electron density – by the abundance of their generating ions (Billings, 1966):

$$I_g/I_r = 2.4\, N_{XIV}/N_X$$

where N_X and N_{XIV} stand for the densities of the ions Fe X and Fe XIV respectively. This quotient, very strongly dependent on temperature, was calculated according to the theory of dielectric recombination (Burgess and Seaton, 1964). Table V gives the ratio of intensity I_g/I_r for the most frequent temperatures in the corona.

TABLE V

The intensity ratio I_g/I_r for different temperatures

$T \times 10^{-6}$	1.25	1.50	1.75	2.00	2.25	2.50
I_g/I_r	0.017	0.328	3.96	24.2	124.6	398.0

The intensities used in Section 5 rely on a scale based on visual estimations. Neither is this scale linear nor are the units equal for the lines 5303 and 6374 Å. But with the aid of a formerly computed calibration curve the estimated intensities were converted into absolute units. The ionisation temperatures derived from them, separately for the two hemispheres, are compiled in Table VI.

TABLE VI
The asymmetry of the corona's ionisation-temperature

Year	b	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	mean
1957	T_N	1.74	1.67	1.78	1.80	1.84	1.79	1.77	1.71	1.69	1.68	
	T_S	1.74	1.70	1.73	1.81	1.84	1.79	1.81	1.78	1.80	1.72	
	T_N/T_S	1	0.98	1.03	0.99	1.00	1.00	0.98	0.96	0.94	0.98	0.98
1958	T_N	1.75	1.75	1.74	1.78	1.80	1.80	1.80	1.71	1.64	1.62	
	T_S	1.75	1.74	1.73	1.77	1.81	1.84	1.79	1.70	1.63	1.62	
	T_N/T_S	1	1.01	1.01	1.01	0.99	0.98	1.01	1.01	1.01	1.00	1.00
1959	T_N	1.75	1.75	1.77	1.77	1.81	1.74	1.70	1.68	1.66	1.61	
	T_S	1.75	1.72	1.74	1.80	1.73	1.65	1.74	1.73	1.61	1.51	
	T_N/T_S	1	1.02	1.02	0.98	1.05	1.05	0.98	0.97	1.03	1.07	1.02
1960	T_N	1.76	1.76	1.77	1.78	1.83	1.85	1.83	1.65	1.51	1.31	
	T_S	1.76	1.72	1.67	1.67	1.66	1.60	1.59	1.65	1.60	1.57	
	T_N/T_S	1	1.02	1.06	1.07	1.10	1.16	1.15	1.00	0.95	0.84	1.04
1961	T_N	1.68	1.69	1.76	1.78	1.77	1.84	1.82	1.81	1.59	1.44	
	T_S	1.68	1.66	1.72	1.65	1.61	1.60	1.60	1.62	1.56	1.49	
	T_N/T_S	1	1.02	1.02	1.08	1.10	1.15	1.14	1.12	1.02	0.97	1.07
1962	T_N	1.72	1.66	1.72	1.67	1.60	1.65	1.76	1.70	1.55	1.46	
	T_S	1.72	1.64	1.61	1.58	1.48	1.37	1.31	1.20	1.20	1.20	
	T_N/T_S	1	1.01	1.07	1.06	1.08	1.20	1.34	1.42	1.29	1.22	1.19
1963	T_N	1.59	1.62	1.67	1.67	1.65	1.62	1.73	1.62	1.35	1.20	
	T_S	1.59	1.56	1.54	1.40	1.25	1.20	1.20	1.20	1.20	1.20	
	T_N/T_S	1	1.04	1.08	1.19	1.32	1.35	1.44	1.35	1.12	1.00	1.21
1964	T_N	1.50	1.55	1.55	1.58	1.58	1.63	1.69	1.59	1.43	1.20	
	T_S	1.50	1.47	1.31	1.20	1.20	1.20	1.20	1.20	1.20	1.20	
	T_N/T_S	1	1.06	1.18	1.32	1.32	1.36	1.41	1.33	1.19	1.00	1.24
1965	T_N	1.34	1.51	1.61	1.73	1.68	1.62	1.63	1.57	1.32	1.20	
	T_S	1.34	1.35	1.26	1.44	1.53	1.49	1.48	1.25	1.20	1.20	
	T_N/T_S	1	1.12	1.28	1.20	1.10	1.09	1.10	1.26	1.10	1.00	1.14
1966	T_N	1.51	1.61	1.65	1.77	1.78	1.79	1.75	1.72	1.71	1.62	
	T_S	1.51	1.39	1.53	1.53	1.51	1.41	1.53	1.39	1.31	1.20	
	T_N/T_S	1	1.16	1.08	1.16	1.18	1.27	1.14	1.24	1.31	1.35	1.21
1967	T_N	1.61	1.64	1.71	1.84	1.82	1.77	1.71	1.73	1.68	1.67	
	T_S	1.61	1.70	1.69	1.80	1.80	1.69	1.65	1.65	1.58	1.44	
	T_N/T_S	1	0.97	1.01	1.02	1.01	1.05	1.04	1.05	1.06	1.16	1.04
1968	T_N	1.75	1.70	1.78	1.82	1.80	1.67	1.58	1.61	1.58	1.57	
	T_S	1.75	1.71	1.78	1.82	1.81	1.75	1.75	1.77	1.73	1.69	
	T_N/T_S	1	0.99	1.00	1.00	0.99	0.96	0.90	0.91	0.92	0.93	0.96
1969	T_N	1.83	1.74	1.79	1.81	1.82	1.72	1.60	1.54	1.45	1.33	
	T_S	1.83	1.74	1.82	1.70	1.73	1.68	1.63	1.71	1.64	1.62	
	T_N/T_S	1	1.00	0.98	1.06	1.05	1.02	0.98	0.90	0.89	0.82	0.97
mean 1958–1967	T_N/T_S	1	1.04	1.08	1.11	1.12	1.17	1.18	1.18	1.11	1.06	–

For each year the mean value of the temperature-ratio T_N/T_S (averaged over the 9 values from $b=10°$ to $90°$) is given at the right edge of Table VI. 1957 still shows a small excess of temperature of the southern hemisphere. In the following years, however, the northern corona becomes hotter than the southern one; asymmetry slowly grows, assumes the highest amounts in 1962–1966 and vanishes after 1967.

The variation of the quotient T_N/T_S with heliographic latitudes runs somewhat different in the individual years. Generally T_N/T_S is larger in midlatitudes than in low ones or at the pole. The mean values at the bottom of Table VI are drawn from the years 1958–1967, during which the northern corona was hotter than the southern one. With increasing distance from the solar equator T_N/T_S grows continuously, assumes its highest value at $b = 50°$ till $70°$ and then strongly decreases towards the pole.

The ionisation temperatures we have derived lie markedly below the kinetic temperatures. Here we will not enter into the particulars of this discrepancy as we are only engaged in the quotients T_N/T_S that are not affected by the scale value.

Thus the asymmetry of the intensity of the red line running in an opposite sense to that of the solar activity and of the brightness of the white and the green corona, is due to an asymmetry of the coronal temperature in such a way that on the more active hemisphere not only the density is increased but also the temperature of the corona.

7. The Relation between Density and Temperature in the Corona

At different times the author pointed on the fact that density and temperature of the corona are not independent of each other, but that temperature increases with density. "Temperature variations are closely connected with density variations. The regions of highest density are also the regions of highest temperature. This strong connection between density and temperature has to be taken into consideration by any theory of the heating mechanism of the corona." (Waldmeier, 1967.) On the occasion of the Summer School on the Solar Corona, Athens, September 1970, the author set up the relation $N_e = 10^{-10}\, T^3$ based on observed values of the electron density N_e and the temperature T (Waldmeier, 1971). In the meantime Reimers (1971) derived theoretically the relation $N_e \sim T^{5/2}$, only slightly different from the former relation.

From the asymmetry of the brightness and by it of the density of the corona as given in Table III, and from that of the temperature in Table VI, the exponent x of the density-temperature-relation $N_N/N_S = (T_N/T_S)^x$ can be computed. In Table VII the densities of the years mentioned refer to the day when a total solar eclipse occurred, the temperatures, however, are annual mean values. These need not to be represen-

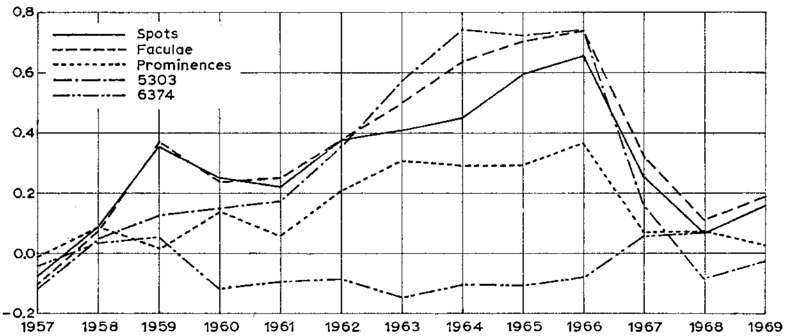

Fig. 2. The asymmetry (N − S)/(N + S) of spot-groups, faculae, prominences and the emission of the coronal lines 5303 and 6374 Å.

TABLE VII

The density-temperature-relation in the corona

Year	$\log(N_N/N_S)$	$\log(T_N/T_S)$	x
1961	0.100	0.029	3.45
1962	0.217	0.076	2.86
1963	0.134	0.083	1.62
1965	0.286	0.057	5.02
1966	0.220	0.083	2.65

tative for the eclipse day; that is why the x-values in Table VII scatter very much. Its mean value is $x=3.1$, closer to the empirical value mentioned above than to the theoretical one.

8. Asymmetry and Phase Difference

As the author showed, there is a relation between asymmetry and phase difference which both are subject to a long-period variation (Waldmeier, 1957). The phase difference has two consequences: first the hemisphere preceding in time is more active on the ascending branch of the spot curve whereas on the descending branch it is the hemisphere following in time; it is presumed that summed over the whole cycle both hemispheres are of equal activity. Second, the distance from the equator of the zone of activity is smaller during the whole cycle for the hemisphere preceding in time than for the hemisphere following in time.

The difference of the numbers of spot groups on the two hemispheres may be due to either a real asymmetry or to a phase difference. In order to separate the contribution produced only by the phase difference, the annual numbers N and S of the spot groups are transformed by the factors α_N and α_S to $N'=\alpha_N N$ and $S'=\alpha_S S$ respectively, so that $\sum N'=\sum S'$ summing over a whole cycle. If there is no phase shift this transformation causes the activity to proceed in the same way on both hemispheres; thus $q'=(N'-S')/(N'+S')=0$ for each year of the cycle. If the northern activity precedes the southern one, then $q'>0$ on the ascending branch, $q'<0$ on the descending one. Following the observations and apart from considerable fluctuations, the changes of q' are linear in time. The annual change $dq'/dt=a'$ is computed by the least-mean-squares method. It is a measure for the phase difference.

Positive values of a' signify a preceding of the southern, negative values a preceding of the northern hemisphere. Table VIII illustrates the a'-values to change sign every 4 cycles. Thus the variation of the phase shift is subject to a long period that contains eight 11-years cycles. The a'-value of cycle no. 20 is based on observations from 1963–1969 and therefore has to be considered as provisional. After closing of cycle no. 20 the definitive a'-value is expected to be somewhat smaller than the provisional one, but the sign will remain unchanged.

The second method to determine the phase difference is based on the heliographic latitude of the spot zone. The distance of the spots from the equator is known to decrease monotonously from the beginning of the cycle to its end and this diminution

TABLE VIII
The long term variations of the solar activity

Cycle No.	a'	D	Q	$\bar{R}_M$
10	+0.025	+0.45°	0.94	123
11	+0.018	+0.82	0.88	104
12	−0.111	−1.07	0.69	101
13	−0.065	−1.01	0.82	76
14	−0.072	−1.44	1.05	86
15	−0.015	−1.43	1.22	82
16	+0.006	+0.17	1.20	101
17	+0.101	+0.44	1.01	116
18	+0.075	+0.35	1.07	157
19	+0.057	+1.11	1.41	153
20	−0.235	−1.06	–	(125)

is dependent only on the time and not on the intensity of the cycle (Waldmeier, 1939). If activity leads on the northern hemisphere, the distance of the northern spots from the equator $|b_n|$ is smaller at any time than that of the southern ones $|b_s|$. For each year the difference $|b_n|-|b_s|$ is computed, and from them the average value D of the whole cycle. D is again a measure for the phase difference between the two hemispheres. Here again negative D-values signify an anticipation of northern activity. The D-values communicated in Table VIII have the same sign as a' for each cycle and so characterize once more the long period of 8 cycles. Again for cycle no. 20 the D-value is but provisional because it refers only to the years 1965–1969.

Furthermore the asymmetry Q is communicated for each cycle in Table VIII. For cycles nos. 12–18, Q is the quotient of the total area of northern spots divided by that of the southern spots. For the cycles nos. 10, 11 and 19 no measurements of the areas were available and therefore Q was derived from the sums of spot groups: $Q=\sum \text{N}/\sum \text{S}$. The Q-value for cycle no. 20 is not yet known; from the ascending branch a very high value results that, however, is due or at least partially due to the phase shift. During the descending branch it slowly will get smaller. For cycles nos. 10 to 13, Q is smaller than 1, for cycles nos. 14 to 19 and probably also for no. 20, Q is greater than 1. This demonstrates a long term variation for the asymmetry too; its relation to the variation of the phase shift (Figure 3), however, is not yet clear.

On the other hand the long term variation of the intensity of the solar activity seems to be connected with the phase shift. The intensity of a cycle is measured by the highest smoothed monthly relative number R_M. The $\bar{R}_M$-values communicated in Table VIII are the overlapping averages of 3 successive R_M-values. They are of regular running with a maximum in cycle no. 9 (Figure 3), a minimum in cycle no. 13 and another maximum in cycle no. 18. The $\bar{R}_M$-value given for cycle no. 20 is based on the assumption that no. 21 will be of low intensity ($R_M=70$). The $\bar{R}_M$-values run in phase with the a' and D-values respectively. a' and D are negative for small $\bar{R}_M$-values and positive for large ones. In other words: with low maxima the activity of the northern hemisphere precedes, with high maxima that of the southern hemisphere.

Fig. 3. Long-term-variations of the asymmetry (Q), the intensity of solar activity ($\bar{R}_M$) and the phase-shift (D, a') for cycles No. 8 through 20.

The phase shift changes its sign around the time when $\bar{R}_M$ reaches the value of 100. The last change happened with the beginning of cycle no. 20. However, the suspected $\bar{R}_M$-value for cycle no. 20 still lies markedly over 100 due to the extremely high R_M-value of 201 for cycle no. 19.

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