

Differential rotation and inherent movement in NOAA 0918 & 0933

From the end of October 2006 till the beginning of March 2007, solar activity was mainly determined by NOAA 0918. Eventually, this group would transit the solar disc 6 times, and from the end of December, get the company of NOAA 0933.

Solar observers will certainly remember NOAA 0918 from its third passage as NOAA 0930, spawning 4 energetic X-flares. Two of those were White-Light Flares (WLF), and the two other powerful protonflares. From its fourth appearance onwards, it teamed with NOAA 0933 to form an impressive pair of dark dots on the otherwise featureless solar disc.

Table underneath contains the most prominent characteristics of these two groups during their appearances (source: NOAA's The Weekly). The positions and period of visibility are mainly based on the drawings from Kanzelhöhe Observatory¹.

NOAA	Observation		Heliographic		Maximum	McIntosh	Magnetic	Flares		
	First	Last	Longitude	Latitude	Area (MH)	Class	Class	C	M	X
0918	23 Oct 06	24 Oct 06	0,3°	-3,6°	50	Cro	B	0	0	0
0923	08 Nov 06	20 Nov 06	5,9°	-4,6°	660	Cko	B	3	0	0
0930	04 Dec 06	17 Dec 06	10,0°	-4,9°	680	Dki	BGD	42	5	4
0935	01 Jan 07	14 Jan 07	9,0°	-6,8°	270	Hhx	A	0	0	0
0941	29 Jan 07	10 Feb 07	8,0°	-7,4°	190	Hsx	A	0	0	0
0945	26 Feb 07	06 Mar 07	6,1°	-6,7°	70	Hsx	A	0	0	0
0933	30 Dec 06	12 Jan 07	36,9°	-4,8°	310	Dhi	B	4	0	0
0940	26 Jan 07	08 Feb 07	42,2°	-4,9°	290	Dsi	B	4	0	0
0944	22 Feb 07	06 Mar 07	45,9°	-6,0°	120	Hsx	A	0	0	0

Groups with such a long lifetime are quite rare. According to the IPS-statistics, only 10% of all sunspot groups live for 11 days or longer. NOAA 0933 and 0918 truly are the exceptions to this rule. With a lifetime of 135 days, NOAA 0918 belongs to a select few of only 4 SC23-groups who managed to appear 6 times.

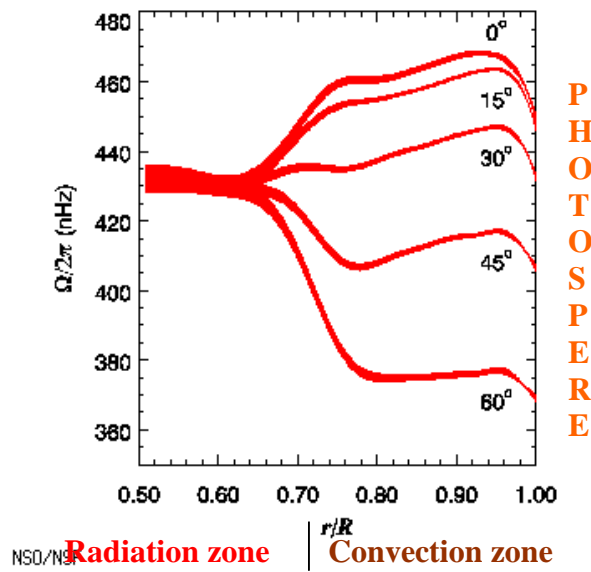
With 67 days, NOAA 0933 had obviously also more than an average lifetime. Thus, this group is well suited to determine the differential rotation of the sun for that latitude. Because the Sun has no fixed surface like the earth, but instead consists of plasma, its upper layers ($r/R > 0,71$) rotate with different speeds. The layers closest to the solar equator rotate the fastest, those at the poles the slowest².

According to SOHO-observations, the solar rotation averages 25,38 days (456 nHz) in the area 15° on both sides of the solar-equator, and 28,58 days (405 nHz) at 45° latitude. At the poles, there are indications this rotation period is around 33 days. Different speeds are obtained when different solar phenomena like filaments, coronal bright points,... are used to determine the solar differential rotation. This study uses as a reference the result obtained by F. Tang³: $\omega = A + B \sin^2(\beta)$, with ω the rotational speed (°/day), β the latitude of the group, $A = 14,37 \pm 0,05$ and $B = -2,60$. The normal rotation time of 25,38 days corresponds to a solar latitude of $\pm 16^\circ$.

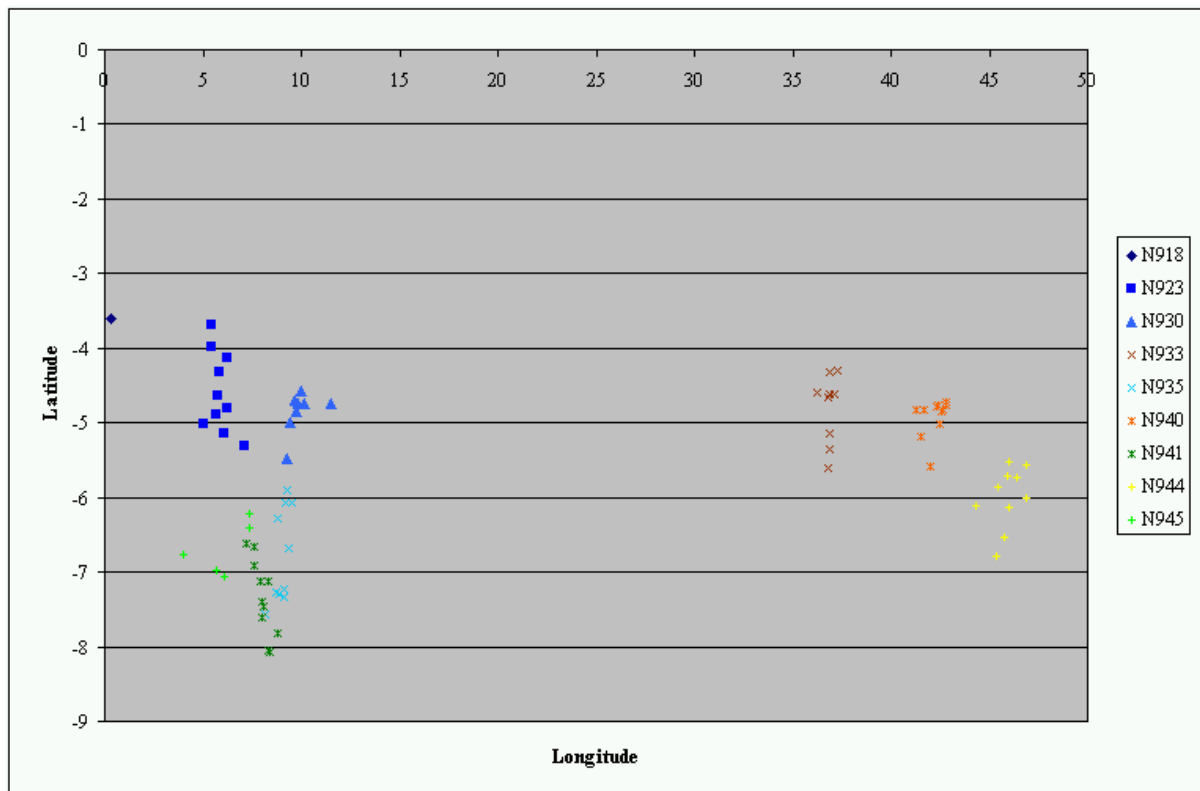
¹ Cesar: <http://cesar.kso.ac.at/>

² http://soi.stanford.edu/press/GONG_MDI_03-00/

³ Solar Physics **69** (1981) 399-404



For the entire visibility period and based on the Kanzelhöhe drawings, 85 positions were determined for the *main spot* of the 9 groups. From these series, all positions with a distance more than 75° from the central Meridian were removed. This was done to avoid too much influence from perspective (solar limb). The result for the different groups can be seen in the graph underneath.



From the time that elapses between two consecutive central meridian passages of the groups, the solar rotation speed for that latitude can be calculated. For NOAA 0933 and its two

reappearances, the rotation speed agrees very well with the results obtained by Wang. It is also clear that the group is moving away from the solar equator.

NOAA	Avg. Lat.	Lat.	CMD	Tsyn	fsyn	fcorr	fsid	Tsid	Rate	Tang
0933	-4,80°		5,692897 Jan 07							
0940	-4,92°	-4,86°	1,611772 Feb 07	26,918875	0,037149	0,002818	0,039966	25,02	14,39	14,35 +/-0,05
0944	-6,00°	-5,46°	28,699344 Feb 07	27,087572	0,036917	0,002818	0,039735	25,17	14,30	14,35 +/-0,05

A similar calculation was not performed for NOAA 0918 and its 5 reappearances. The reason for this is obvious from the graph with the positions for the main spot: Somewhere during the third passage (NOAA 0930), the spot changed from its southwestern course towards due south. This movement continued during the fourth transit. The spot reached a maximum southern latitude of -8° . During the subsequent appearance, the spot was moving back towards the equator, temporizing around $-6,5^\circ$ latitude where it dissolved during its final passage. Moreover, the region was moving slightly to the *east*, hence it was moving *slower* than the average solar rotation for that latitude.

This kind of movements prevents a reliable determination of the differential rotation. These “inherent motions” also contribute to larger uncertainties for the parameters used in the formulae.

In the Solar Astronomy Handbook⁴, 9 different causes for this kind of anomalous movements are discussed. However, none of them can explain the movement during the last three appearances of NOAA 0918. This is because in this case, it concerns a quiet, unipolar and dying sunspot type J/H, that is supposed to undergo –just like NOAA 0933- the differential rotation of the sun. A possible explanation for the observed inherent motions is that the powerful eruptions during the passage of NOAA 0930 have disturbed the underlying plasma movements so much that the spot started to deviate from its normal course. This supposition needs to be supported by additional helioseismological data.

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27 March 2007

⁴ Solar Astronomy Handbook pp. 257-259: B.3.3.5. Inherent Motion in sunspot groups (K. Reinsch)