A LONG-LIVED ACTIVE AREA ON THE SUN

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Abstract

The development and major energetic phenomena associated with a long-lived solar active area with a mean heliographic position of $l = 27\overset{\circ}{.}2$, $b = +16\overset{\circ}{.}5$ are examined.

For a number of years it has been realized that new sunspot groups are more likely to emerge near the scene of previous activity (Bumba and Howard 1965), and that this is not a chance occurrence (Gaizauskas *et al.* 1983). Consequently, the study of regions which repeatedly produce active phenomena (flares, sunspots, or plages) can add to the knowledge of the Sun's interior and magnetic dynamo. Occasionally one of these locations will produce great activity for a few months and then fall dormant for months or even years before spawning a new burst of comparable activity. Other areas, such as the one we describe, continue to yield new and recurrent spot-groups during a number of consecutive rotations.

According to the visual observations by one of us (Alexescu), an active area with a very long life first appeared during Carrington Rotation Number (CRN) 1830, more specifically on June 28, 1990. When the area made its initial appearance on the Sun's northeastern limb it was classed as a type HAX sunspot group according to the McIntosh system (McIntosh 1981). Subsequent observations showed the cluster to be a moderate-sized EKI group, and was named Region 6133 in accordance with the NOAA/USAF numbering system for solar active areas.

During each of the following nine rotations, other spot-groups, some of which were recurrent, were located close to the position of old Region 6133. Spot activity continued at this location until the final sunspot group of the sequence (Region 6539) died on March 10, 1991, one day past its Central Meridian Passage (CMP). However, plages associated with this active area were apparent until it passed over the Sun's western limb on March 15th.

The daily evolution of these complexes by McIntosh class is given in Table 1, and is shown according to area in millionths of the solar hemisphere in Figure 1 (*Solar-Geophysical Data,* 1990-91). Regions 6412 and 6444 are known to be return appearances of Region 6368, one of the larger clusters to emerge during solar cycle twenty-two.

For each of the nine succeeding solar rotations after CRN 1830, the mean longitude of these groups (measured at CMP) gradually changed. This variation can be described by an equally-weighted linear regression:

$$l = 35\overset{\circ}{.}87 - 1\overset{\circ}{.}93\,R \qquad \pm\, 2\overset{\circ}{.}2 \qquad (1)$$

with R = CRN-1830. The correlation coefficient, r, which emerges from this reduction is 0.88. If these data are characterized by a second-order regression, r rises to 0.94 and the generally dwindling longitude is portrayed by:

$$l = 39.^{\circ}92 - 4.^{\circ}96\ R + 0.^{\circ}34\ R^2 \qquad \pm 0.^{\circ}1 \qquad (2)$$

Figure 2 is a plot of these data along with the regression lines given by equations (1) and (2). It is possible that the measured longitude for Region 6484 at CMP (CRN 1838) reflects a resurgence of spot activity near the location of old Region 6444's principal preceding (more westerly) spot. This could account for the systematically varying longitude. Note that the slightly lower latitude of this group could confirm this scenario in accordance with Joy's law (Hale *et al.* 1919).

Table 1. Daily Region Evolution

	Mean		*Disk Appearance*			
Region	*l°*	*b°*	*First Day*	*Last Day*	*CMP*	*Source*
6133	41.4	17	6/28/90	7/11/90	7/5	*SGD* 553
Evolution:	HAX,CKO,EKI,EKI,EKI,EKI,EKI,EKI,DKI,DKO,DKI,DKO,DKO,DKO					
6180	34.2	18	7/27	8/7	8/2	" 554
	DAO,CSO,CAO,CAO,CAO,CAO,CAO,CAO,HSX,HRX,HRX,AXX					
6233	31.2	13	8/23	9/5	8/29	" 554
	DAO,DSO,EAO,EHI,FKI,FKC,FKC,FKC,EKC,EKI,EKO,EKO,EAO,HSX					
6280	28.0	13	9/19	10/2	9/26	" 555
	HSX,DAO,EAO,EAO,ESO,EAO,EAO,EAO,EAO,EAO,DAO,DAO,CAO,BXO					
6327	25.9	19	10/16	10/31	10/23	" 556
	BXO,EAO,FAO,FAO,FKO,FAO,FSO,FSO,FSO,FSI,FAO,FAO,FAO,CRO,BXO,AX					
6368	25.4	17	11/12	11/27	11/19	" 557
	HSX,DHO,FKI,FKI,FKI,FKI,FKI,FKI,FKI,FKI,FKI,FKI,FKI,FKI,DKI,CKO					
6412	20.1	18	12/10	12/24	12/17	" 558
	HHX,HHX,FKO,FKO,FKO,FKO,FKI,FKI,FKI,FKO,FKI,FKI,FKI,FKI,DHO					
6444	20.3	17	1/7/91	1/21/91	1/14/91	" 559
	HK,FKO,FKO,FKO,FKO,FKO,FKO,FKO,FKO,FKO,FKO,FKO,FKO,CKO,CKO					
6484	27.3	14	2/3	2/15	2/9	" 560
	HAX,HAX,HSX,CAO,CSO,CSO,CSO,CSO,DSO,DSO,DSO,DAO,DAO					
6539	20.3	19	3/5	3/10	3/9	" 561
	AXX,BXO,BXO,CAO,BXO,AXX					

Note: First and last days of an evolutionary series reflect limb observations when a portion of the group may not be visible.

The Sun's sidereal rotation rate for any latitude can be approximated by the equation of Newton and Nunn (1951), which was derived from recurrent sunspot measurements:

$$\Omega = 14.^{\circ}38 - 2.^{\circ}96 \sin^2 b \ /\text{day} \quad (3)$$

In this case, the mean latitude (b) of the spot-groups in this series which are known to be recurrent (Regions 6368, 6412, and 6444) is 17.3 degrees/day. Application of equation (3) gives a rotation rate of about 14.12 degrees/day (leading to a period of ≈25.5 days), which is reasonably close to that given by more complex methods (e.g. Zirin 1988). The Sun must rotate a little farther to match the Earth's new position, so the corresponding synodic period is longer (≈27.4 days), reflecting the Earth's mean motion of $0.^{\circ}9856$ /day. In spite of the slowly diminishing heliographic longitudes of each cluster, the average (observed) interval between CMP passages for all groups in Table 1 is ≈27.5 days.

Some limited sunspot activity also took place near the location of Region 6133 during the two rotations prior to CRN 1830. During CRN 1828, Region 6061 ($l = 42^{\circ}$, $b = 17^{\circ}$) made a brief appearance as a small BXO group, then died several days later. Region 6092 behaved similarly during rotation 1829, but emerged at a more easterly location ($l = 21^{\circ}$), which may indicate that its appearance was unrelated to later developments.

The solar flare activity in each of these regions is compiled in Table 2 from data which originally appeared in the *PRF* (1990-91). Inasmuch as the spot-groups which emerged at this location rotated at nearly the same rate as that due to differential rotation, local shear was probably minimal. This condition may have contributed to the relatively poor flare production of these clusters.

Table 2. Solar Flare Activity by Active Region

	X-ray			*Optical*				
Region	*C*	*M*	*X*	*S*	*1*	*2*	*3*	*Source*
6133	15	4	0	54	3	1	0	PRF 776
6180	2	1	0	5	0	3	0	780
6233	32	16	1	100	10	2	0	784
6280	11	1	0	26	5	0	0	788
6327	21	1	0	56	1	0	0	792
6368	96	14	0	189	21	2	0	796
6412	46	6	2	99	14	2	0	800
6444	32	2	0	82	3	1	0	803
6484	6	0	0	24	2	0	0	807
6539	0	0	0	6	0	0	0	811
Totals:	261	45	3	641	59	11	0	

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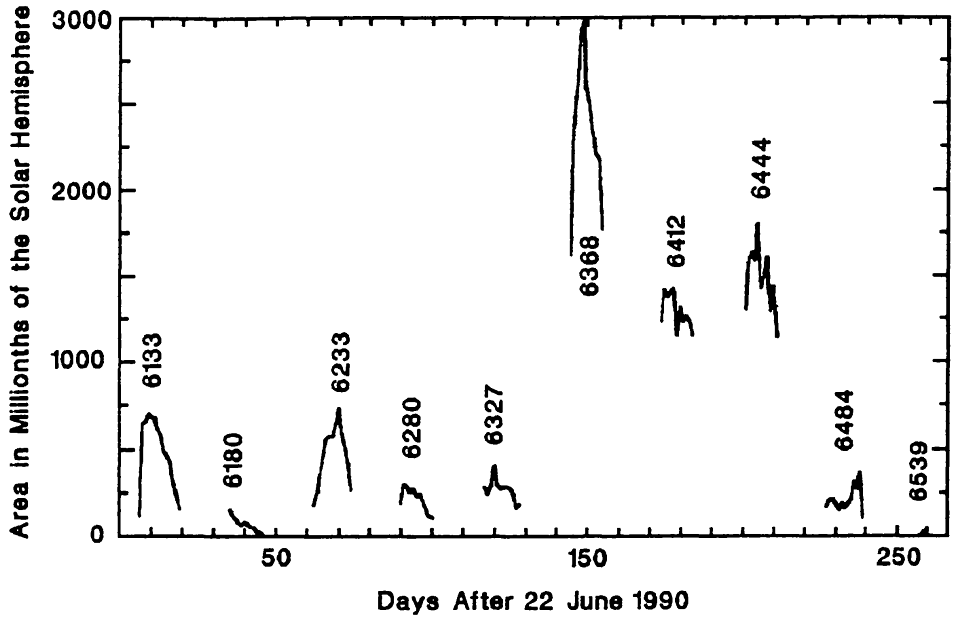

Figure 1. The growth and decay of each of the sunspot groups which are described in the text, according to their area in millionths of the solar hemisphere (MSH). (1000 MSH = 3036 million square kilometers.)

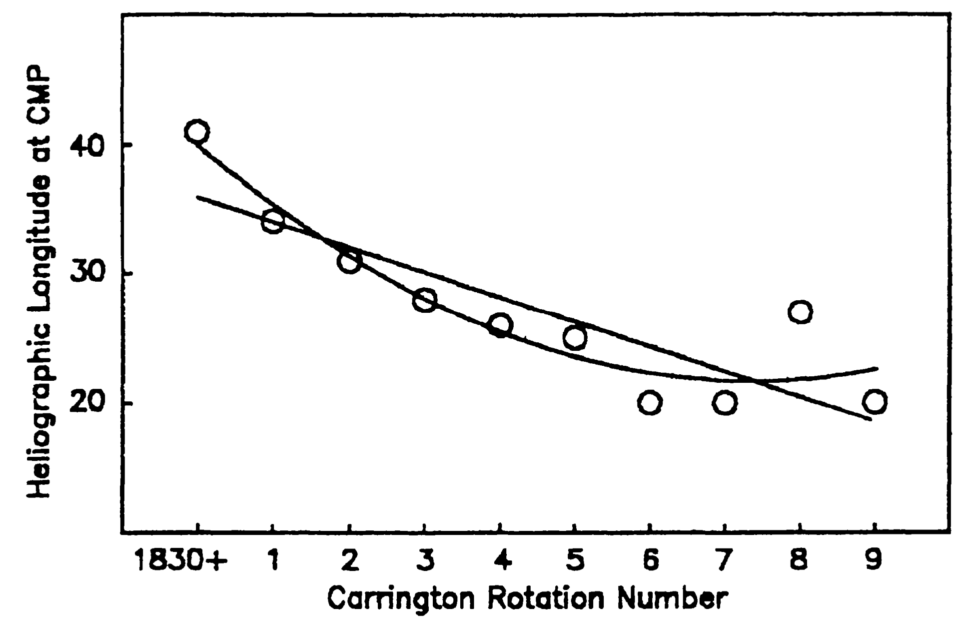

Figure 2. The changing mean-longitude of group location within the active area. The lines represent the regression solutions given by equations (1) and (2).