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On the relation between magnetic field strength and Wilson depression in sunspots

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Abstract. At the Solar Tower Telescope of Kodaikanal Observatory, we obtained Zeeman spectra of sunspots on their disk passage during 1979-84 (Solar max. 21). Using this data and full disk white light pictures obtained at the observatory, we are examining the possible relation between Wilson Effect (WE) and longitudinal magnetic field strength (B_l) of selected spots. Preliminary results indicate that WE does not depend upon B_l. Further, a large number of spots do not exhibit WE. It appears that the magnetic field configuration, rather than field strength, plays the key role in the occurrence or absence of WE.

Key words: sunspot magnetic fields, Wilson effect, Wilson depression

1. Introduction

Sunspots close to solar limb exhibit much wider penumbrae on the limbward side than on the disk-side. This classical picture known as the 'Wilson effect' had exceptions reported in 1960s but the changes observed in proportions of penumbral widths remained unexplained (McIntosh 1981). However, a Wilson Depression (WD) in the range of 400 to 1000 km, which is explained as the cause of this effect, has been taken more or less as the standard picture of sunspots (Durrant 1988 ; Stix 1989).

At Kodaikanal Observatory, we obtained high dispersion Zeeman spectra in 6302.5Å with the Solar Tower Telescope for over 800 spot groups to derive the longitudinal magnetic fields (B_l) of the spots and large pores. The almost daily observations of 20 cm white light pictures obtained at the observatory (see Bappu 1967) provided morphological details of the spots. We have used these data for selected spots to study the possible relation between B_l and WD in sunspots.

2. Observation and results

We selected representative cases of spots exhibiting clearly the Wilson Effect (WE) or the Reverse Wilson Effect (RWE) and estimated their field strengths (B_{kkl}) in Gauss ($\pm$80) for

positions closest to central meridian passage as shown in Table 1. B_{max} is maximum value for spot on disk and B_{obs} is for nearest day to observation, both from Solar Geophysical Data.

Table 1. Magnetic field data and areas of spots for studying the Wilson effect.

Date	Position	B_{max}	B_{obs}	B_{kkl}	Spot area	WE/RWE	Polarity
01/13/79	71W08*N*	2300	1800	-	160/850	*RWE*	1**N**1*S*
05/16/79	65W08*N*	2800	2300	-	280/430	*RWE*	1**N**1*S*
06/12/79	65W22*S*	2300	1300	-	390/600	*RWE*	2*S*1**N**
10/14/79	70W25*N*	2800	1800	1775	260/560	*WE*	1**N**
11/24/79	70E20*N*	-	-	1500	940/1130	*WE*	1**N**
04/30/80	80W12*S*	2300	-	1275	690/1130	*RWE*	1*S*1**N**
05/22/80	60W08*S*	1800	-	1725	90/270	*WE*	1**N**
09/19/80	65W15*N*	2800	-	1750	380/500	*RWE*	1*N*1**S**
11/02/80	60W17*S*	2300	2300	1700	370/370	*RWE*	1*S*1*N*
11/25/80	70W17*S*	2300	1800	-	100/240	*WE*	1**S**
12/03/80	75W18*N*	2300	1800	1500	500/620	*RWE*	1**N**1**S**
08/03/81	65W12*S*	2300	1300	-	440/2750	*RWE*	1*S*1**N**
11/19/81	60W18*N*	-	-	2025	-	*WE*	1**N**
12/03/81	80W12*N*	-	-	1750	-	*WE*	1**N**
01/14/82	70W15*S*	2800	1800	1750	180/270	*WE*	1**S**
03/20/82	65E13*S*	2300	1800	1525	100/140	*WE*	1**S**
03/21/82	65W15*N*	2300	1800	1700	250/550	*WE*	1**N**
12/28/82	75W05*N*	-	-	-	-	*RWE*	1**N**1*S*
03/25/82	75W10*S*	2300	1800	-	100/140	*RWE*	1**S**1*N*
01/14/83	65E03*N*	2800	2300	1475	220/370	*WE*	1**N**

Spot area is (area on day of observation)/(maximum area on disk), in millionths of solar hemisphere. Polarity of the observed spot is shown in bold N/S. The number of cases studied is limited as RWE spots are rare. Our preliminary results indicate that WE does not appear to be related to B_t. WE does not either show a dependance on the area of the spots. However, the following interesting conclusion emerges from our study : (a) Most of the spots exhibiting WE are single isolated spots in predominantly unipolar regions, (b) Spots exhibiting RWE are seen essentially in bipolar regions, and (c) There is a significant number of spots which neither show WE or RWE.

3. Conclusions

A large proportion of spots do not exhibit Wilson effect but instead show reverse or no Wilson effect at all. In this new scanario, Wilson depression is probably not a common fundamental property of sunspots at all times! Appearance of WE (a depression) or RWE (a cusp) seems to be related to magnetic field configuration of the active region and not to field strength. We are studying a large number of cases to confirm our finding and to look for quantitative details of the phenomenon.

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