AD-A091 327   AIR FORCE GEOPHYSICS LAB HANSCOM AFB MA   F/G 3/2

THE LIFETIMES OF SUNSPOT MOATS,(U)

APR 79   L PARDON, S P WORDEN, T J SCHNEEBERGER

UNCLASSIFIED   AFGL-TR-80-0298   NL

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFGL-TR-80-0298
2. GOVT ACCESSION NO.: AD-A091 327
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): THE LIFETIMES OF SUNSPOT MOATS
5. TYPE OF REPORT & PERIOD COVERED: Scientific. Interim.
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s):

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8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Air Force Geophysics Laboratory (PHS), Hanscom AFB, Massachusetts 01731
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 2311G312
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Geophysics Laboratory (PHS), Hanscom AFB, Massachusetts 01731
12. REPORT DATE: 2 October 1980
13. NUMBER OF PAGES: 4
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): [redacted]

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:

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Reprinted from Solar Physics 63 (1979) 247-250, September 1979

19. KEY WORDS (Continue on reverse side if necessary and identify by block number):

Sunspots
Solar magnetic fields
Sunspot moats

20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

Daily full disk magnetograms observed with the Kitt Peak 40 channel magnetograph have been examined for the rise time, decay time and lifetime of sunspot moats. Eighteen well defined moats result in rise and decay times of 0.5 ± 1d, with a lifetime at maximum development of 6d ± 3d. The moat appears approximately 3 days after the spot is observed in our data.

AFGL-TR-80-0298

THE LIFETIMES OF SUNSPOT MOATS

(*Research Note*)

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(Received 9 April, 1979)

Abstract. Daily full disk magnetograms observed with the Kitt Peak 40 channel magnetograph have been examined for the rise time, decay time and lifetime of sunspot moats. Eighteen well defined moats result in rise and decay times of 0.5d ± 1d, with a lifetime at maximum development of 6d ± 3d. The moat appears approximately 3 days after the spot is observed in our data.

1. Introduction

The term sunspot 'moat' was coined by Harvey and Harvey (1973) to describe the doughnut shaped field free region between a sunspot and a surrounding network field. Harvey and Harvey (1973) have shown that moats are associated with the decay of sunspots. Moving magnetic features (MMF) move nearly radially outward from spots to the network field at velocities of 1 km s^{-1}. These features have been observed in a sequence of Zeeman spectroheliograms in the Ca I λ6103 Å line by Vrabec (1971), and in a time series of magnetograms observed by Harvey and Harvey (1973) in the Fe I λ5233 Å and Mg I 5173 Å lines. These features appear to be indentical to the moving bright points observed in CN by Sheeley (1969) and the $K2_v$ emission features observed by Liu (1973). Harvey and Harvey (1973) also detected faint Hα emission 'clouds' in association with the MMF. The photospheric velocity in the moat region is outward, away from the spot at 0.5–1 km s^{-1} (Sheeley, 1972).

These observations have led to models of the moat region by Harvey and Harvey (1973) and by Meyer *et al.* (1974), which depict the sunspot moat region as a supergranular cell with the spot at the center. The horizontal velocities push twisted flux tubes (MMF) through the moat to the network, thus destroying the spot.

In this note we examine the lifetimes of moats, the rise and decay of moats, and the time behavior of sunspots as moats decay. The lifetimes are much greater than typical

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† Operated by the Association of Universities for Research in Astronomy, Inc., under contract to the National Science Foundation.

Solar Physics **63** (1979) 247–250. 0038-0938/79/0632-0247 $00.60.

supergranular lifetimes, and thus moat cells must be particularly stable. This observational information is important to a further understanding of the decay of sunspots.

2. Observations

Daily magnetograms were observed with the 40-channel magnetograph at the McMath Solar Telescope on Kitt Peak (Livingston *et al.*, 1971) in support of the Skylab mission. These observations were made using the Fe I 5233 Å line. The data observed from April 1, 1973 through June 30, 1973, and from November 4, 1973 through April 13, 1974 were kindly lent to us by J. Harvey. The data has a typical

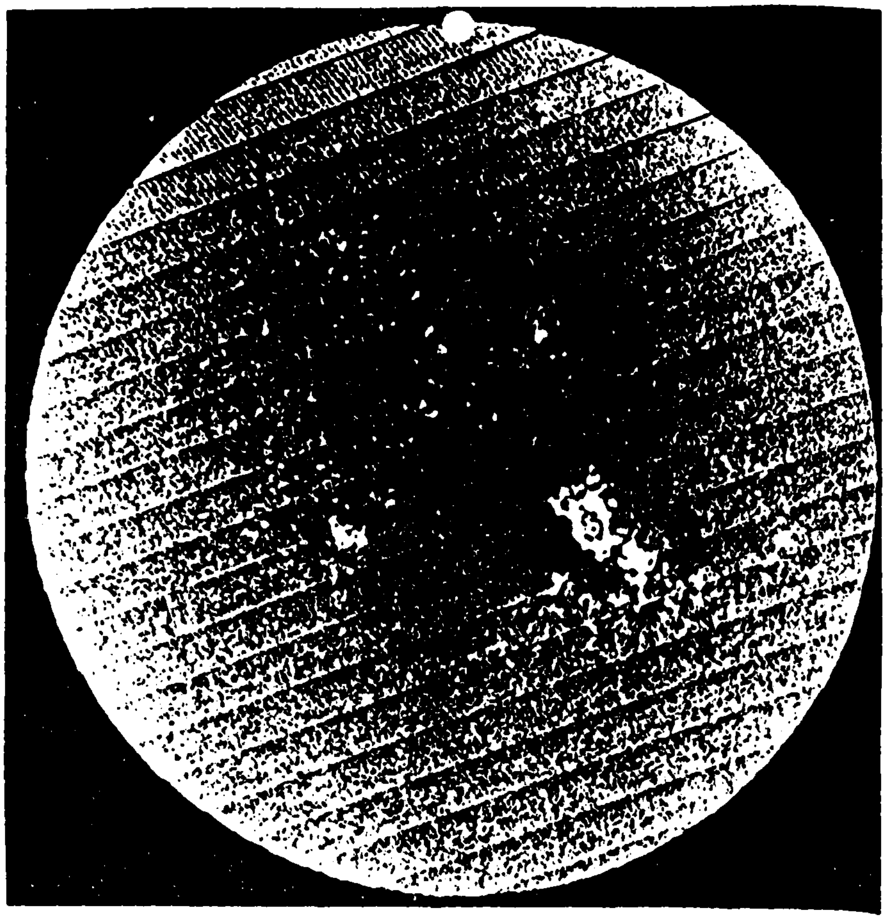

Fig. 1. A portion of a Kitt Peak magnetogram, taken at 17:47 UT on May 8, 1973, showing a well developed sunspot moat. North is up.

resolution of 2″. Figure 1 shows an example of a well developed sunspot moat observed in this data. We examined the lifetimes of eighteen such moats. Eight additional moats with less than a 240° arc of surrounding network field were also studied.

After finding a moat in the data set, the data from preceding and following days were examined to determine lifetimes.

3. Results and Discussion

Table I lists our compiled data for the eighteen well developed moats studied. The number of days to maximum moat development, days at maximum and number of days to moat disappearance are given along with data on the sunspot region. Moats develop very quickly, with a mean rise time of 0.5d, but with a considerable standard deviation of 1d. Upon reaching maximum development, the moat remains stable for an average of 6d ± 3d, or a factor of 7 longer than typical supergranular lifetimes. Decay times are very similar to the rise times, 0.5d. In two of the regions, the moat persisted for two days after the spot had disappeared, but the other moats break up as

TABLE I

Properties of sunspot moats

McMath region number	UT date at max.	Rise time (days)	Days at maximum	Decay time (days)	Spot development[a]		
					Rise	Max	Decay
336a	May 06, 73	3	5	Limb	F	F–H	–
357	May 25, 73	1	1	1	D	D	C
322	Apr 24, 73	1	2	1	D	D	D
352a	May 16, 73	Limb	7	1	–	D	C
352b	May 15, 73	0	4	0	–	D	—
352c	May 15, 73	0	2	0	–	D	–
387a	Jun 11, 73	0	5	0	—	C	—
387b	Jun 11, 73	0	5	0	–	C–B	– –
349	May 14, 73	0	3	1	—	C	A
379	Jun 09, 73	3	5	1	D	H–A	A
694	Jan 12, 74	1	3	4	C	C	C–B
628	Nov 24, 73	0	8	0	–	D→E →C	—
662	Dec 15, 73	0	12	0		H→C →H	—
651	Dec 08, 73	0	9	0	–	H	—
703	Jan 12, 74	0	9	0	–	C–B	—
742	Feb 08, 74	0	7	0	—	D→C	—
702	Jan 11, 74	0	7	0	–	H→C → H→A	—
706a	Jan 15, 74	0	6	0	–	D–C	– –

[a] Modified Zurich class

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the spot disappears. No spots outlasted the moat feature. This clearly confirms Harvey and Harvey's (1973) result that moats are associated with decaying spots. The rapid onset of a moat indicate that the change from stable spot to decaying spot occurs in an average of 0.5d. From the data it is clear that the dynamics of the last stages of sunspot evolution are dominated by a very stable (6d) cell or moat which becomes unstable and collapses in 0.5d, once the spot itself is gone.

For 13 of the observed sunspot regions we are able to estimate the time from sunspot appearance to moat formation. For these spots, moats form in 3 ± 1 days after the spot is first observed.

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