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THE RADIO SPECTRUM OF CORONAL HOLE 1,(U)
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THE RADIO SPECTRUM OF CORONAL HOLE 1

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Scientific Report No. 1

DECEMBER, 1977

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AIR FORCE GEOPHYSICS LABORATORY
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19 REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
18 1. REPORT NUMBER AFGL-TR-77-0292	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 THE RADIO SPECTRUM OF CORONAL HOLE 1,		5. TYPE OF REPORT & PERIOD COVERED Scientific Report No. 1
		6. PERFORMING ORG. REPORT NUMBER A.C.B.U., Ser III No 65
7. AUTHOR(s) 10 Fred L. Wefer, Michael D. Papagiannis		8. CONTRACT OR GRANT NUMBER(s) 15 F-19628-77-C-0189 nc
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Astronomy, Boston University, 725 Commonwealth Ave., Boston, MA 02215		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62101F 16 464303AW 17 ø3
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory, Hanscom AFB, MA 01731, Contract Monitor: D. Guidice/PHP		12. REPORT DATE 11 Dece[redacted]77
		13. NUMBER OF PAGES 22 12 24p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 14 SER-III-NO-65, SCIENTIFIC-1		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

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

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B

18. SUPPLEMENTARY NOTES

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

Coronal Holes; Solar Radio Maps; Radio Spectrum

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

In an effort to determine the spectral characteristics of radio features associated with coronal holes, ~~we have analyzed~~, radioheliograms obtained at five different wavelengths during the period 25 June through 02 July 1973 were analyzed. X-ray pictures of the Sun, provided by American Science and Engineering, give the position of Coronal Hole 1 (CH1) on the solar disk during this period. The sources of the radio data and the corresponding

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wavelengths were: La Posta Astrogeophysical Observatory (0.86 and 2.0 cm), NEROC Haystack Observatory (3.8 cm), Stanford Radio Astronomy Institute (9.1 cm), University of Sydney, Australia (21 cm). On 28 June 1973 radio maps were available at all five wavelengths. Scans at the same solar latitude (40°N) of the maps were used to reduce the radio spectrum of CH1. These scans showed also a westward dispacement of the "radio hole" relative to the "X-ray hole" which is a not-well-understood effect that requires further study. It should be mentioned also that this was the first time that an attempt was made to put together the radio spectrum of a coronal hole. The analysis of the radio data for CH1 showed the following. The coronal hole cannot be identified in the 8.6 mm maps, hence the radio emission from the coronal hole region at 8.6 mm must be practically identical to the background radio emission of the solar disk at this wavelength. At 2.0 cm the radio maps showed an enhancement relative to the radio background of the solar disk. It is shown in this report that though small, this enhancement is genuine and not an artifact produced by the computer processing of the radio maps. At 3.8, 9.1, and 21 cm, the radio maps showed a depression relative to the radio background of the solar disk, which tended to become more pronounced with increasing wavelength. Radio data at wavelengths ranging from 2.8 cm to 3.75 m obtained by other observers on subsequent disk passages of CH1 seem to fit reasonably well into the radio spectrum of CH1 deduced from the 28 June 1973 radio maps analyzed in this report.

THE RADIO SPECTRUM OF CORONAL HOLE 1

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1. Introduction

Reports of radio observations of coronal holes have been made by a number of investigators. Dulk and Sheridan (1974) have reported observations at 80 MHz (3.75 m-λ) and 160 MHz (1.8 m-λ) using the Culgoora radioheliograph. When compared with the NASA GSFC OSO-7 284 Å heliograms, depressions in the radio emission (amounting to 10-30% of the normal values) were found to correspond in location and to rotate with the coronal holes. They concluded that the radio manifestation of coronal holes must be due to a decrease in both the temperature and electron density within the coronal hole.

Fürst and Hirth (1975) have reported an observation at 10.7 GHz (2.8 cm-λ) using the Bonn 100-m telescope. They found a depression in the radio emission (amounting to 3-4% of the normal values) which "at least partly corresponds to a coronal hole".

Wefer et al. (1976) and Wefer and Bleiweiss (1976) have reported observations at 15.3 GHz (2.0 cm-λ) and 35.0 GHz (8.6 mm-λ) using the 18.3-m telescope of the La Posta Astrogeophysical Observatory. In comparisons with the NASA GSFC OSO-7 284 Å heliograms, they found areas of enhanced radio emissions (amounting to 1-3% of the central disk quiet sun brightness temperature). These areas were shown to correspond in location and shape with, and to rotate with coronal holes.

Kundu and Liu (1976) have reported an observation at 85 GHz (3.5 mm-λ) using the NRAO 36 ft. telescope. They found an area of depressed radio brightness (amounting to 1-8% of normal values) which coincided with a coronal hole apparent on an X-Ray photograph obtained by a sounding rocket (Krieger et al., 1973). Unfortunately, this depression also coincides in position with, and has a shape strikingly similar to a very large Hα filament (Solar-Geophysical Data 1971).

In addition to these two-dimensional observations, a number of researchers have reported one-dimensional (interferometer) observations of coronal holes. Chiuderi-Drago (1974) made observations at 408 MHz (73 cm-λ) and 169 MHz (1.8 m-λ) with the Nancay interferometer. At the higher frequency the coronal hole showed up as a depression in the radio emission amounting to approximately 20% of normal coronal values.

Lantos and Avingnon (1975) have concluded, from observations made also at 169 MHz with the Nancay interferometer, that the radio quiet sun determined from the lower envelope of the daily drift scans corresponds to the level of emission from coronal holes.

Covington (1976) has reported observations at 2.8 GHz (10.7 cm-λ) made with the Algonquin interferometer. From a comparison of drift scans of a coronal hole (which extended nearly from pole to pole at central meridan) with drift scans made during 1975 (when solar activity reached extremely low levels) he concluded also that the radio emission from coronal holes coincided with the level of the quiet sun.

Dulk et al. (1977) have recently compared EUV and radio data at three wavelengths for coronal hole 1 (CH1) during its July and August disk passages. They point to a discrepancy in the observations since they found no reasonable choice of the three parameters of their solar model which gave agreement between the radio and EUV data. Their study suggests the possibility that the radio brightness temperatures obtained for coronal holes are too small.

2. Observations

In an effort to determine the spectral characteristics of radio features associated with coronal holes, we have collected radioheliograms at five wavelengths for the period 25 June through 02 July 1973 when CH1 was on the solar disk. During this eight day period, only on 28 June 1973 are radio maps available at all five wavelengths. The maps for this date are shown in Figure 1. Figure 1a shows the 8.6 mm radio map (beamwidth = 2.8 arc min FWHM) from the La Posta Astrogeophysical Observatory on 28 June 1973. The boundary of CH1 (Nolte et al. 1976), rotated to its position at the time of the map, is delineated with a dashed line. Filaments are shown with dark wiggly lines.

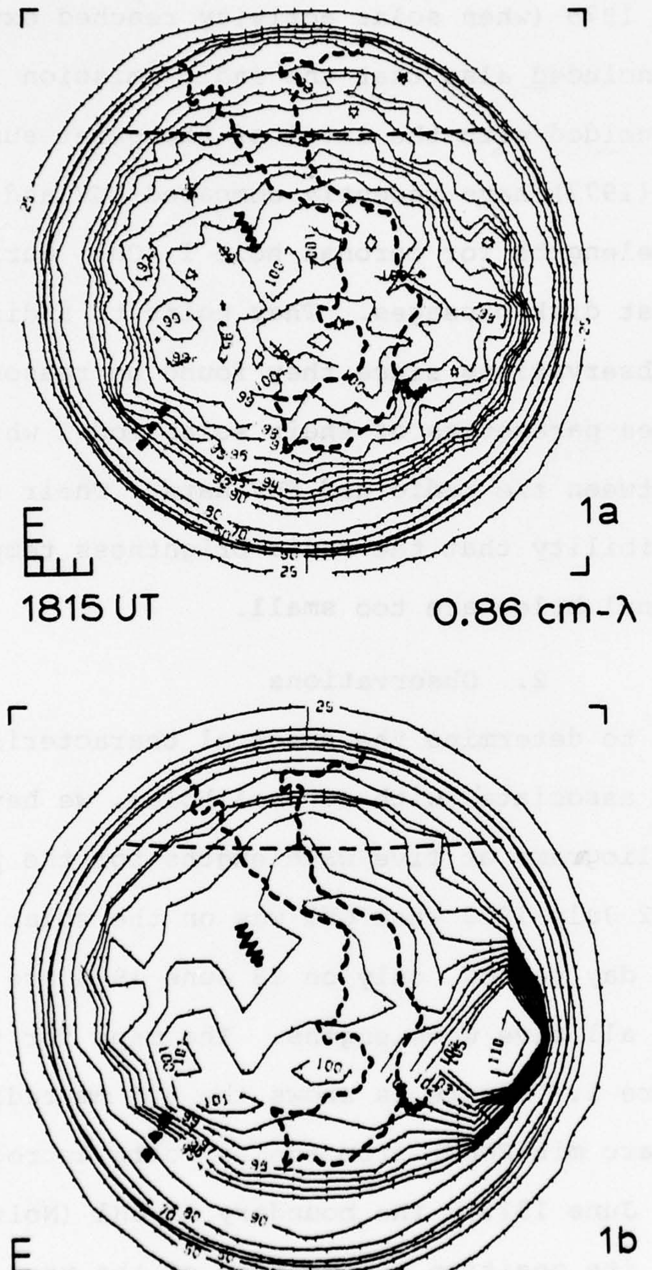
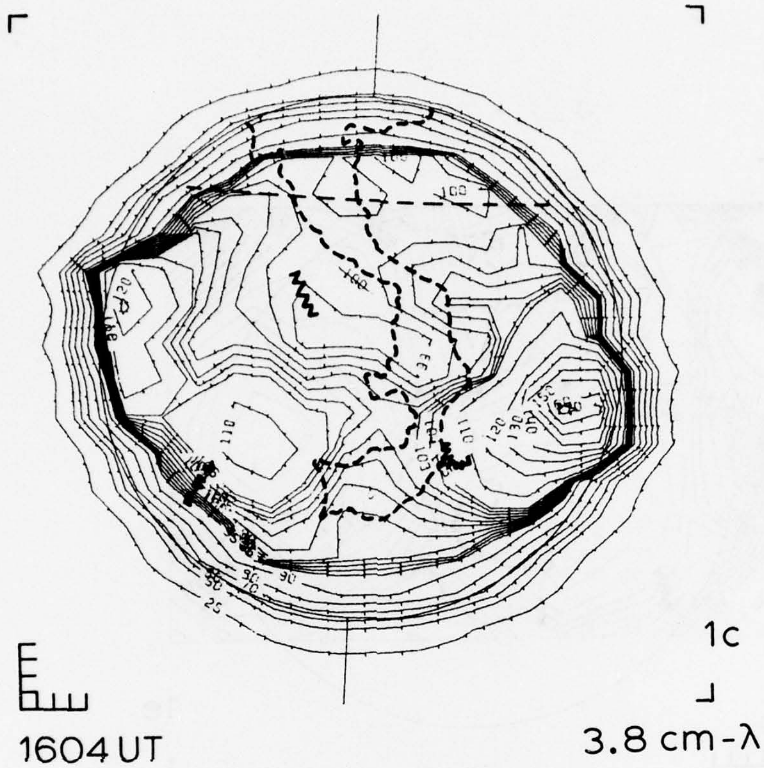


FIGURE 1



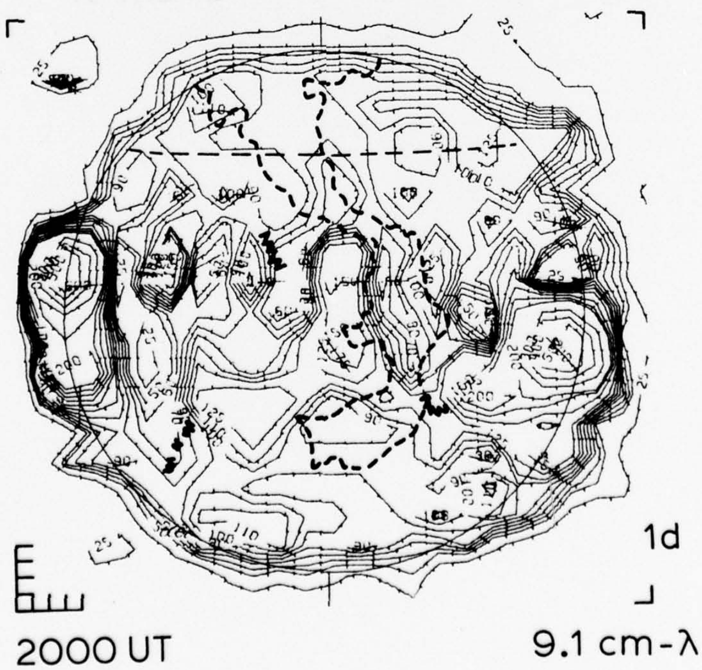


FIGURE 1 (continued)

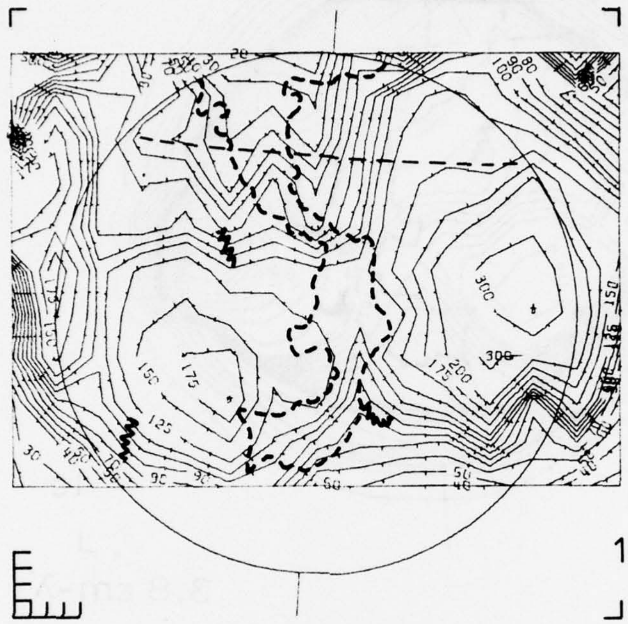


FIGURE 1 (continued)

Tic marks on the contour lines indicate the low side, and each contour is labelled in percent of the central disk quiet area temperature. The scale of the plot is indicated by one arc min tic marks on the lower left-hand corner of the map. The thin dashed line running nearly horizontally across the disk is the latitude line for 40°N. We have found no clear evidence for CH1 on the 8.6 mm radio maps.

Figure 1b shows the 2.0 cm radio map (beamwidth = 4.0 arc min FWHM) from the La Posta Astrogeophysical Observatory on 28 June 1973. The format is the same for all the maps as discussed above. Here we find a ridge of enhanced radio emission corresponding in location and shape with CH1. The contour interval near the center of the map is 1%, hence we are seeing a brightness temperature enhancement of about 200 K.

Figure 1c shows the 3.8 cm radio map (beamwidth = 4.4 arc min FWHM) from the NEROC Haystack Observatory. The only clear indication of CH1 is the small area of reduced radio emission (≃ -2%) near the north pole. The ridge of emission extending from the west limb active region appears to be associated with a weak H-alpha plage region, and does not coincide in position with either CH1 or the ridge of emission at 2.0 cm.

Figure 1d shows the 9.1 cm radio map (beamwidth = 3.0 arc min FWHM) from the Stanford Radio Astronomy Institute as published in Solar-Geophysical Data. On this map we see a region of reduced emission running from the north pole towards the equator where it disappears in the side lobe pattern from the active regions. This area corresponds in location with CH1.

Figure 1e shows the 21 cm radio map (beamwidth = 3x6 arc min FWHM) from the University of Sydney Fleurs Radio Astronomy Field Station. Here again we see reduced emission corresponding in position with CH1. Because of severe side lobe problems and a likely declination error in the maps (21 cm active regions are ≈5 arc min north of the 9.1 cm active regions), it is unclear that this region of reduced emission rotates with CH1.

To get an idea of what a drift scan through a coronal hole would look like, we have plotted in Figure 2 the distances from central meridan at which the contour lines cross the N 40° latitude line, versus the levels of those contours. The N 40° latitude line was chosen because four of the five wavelengths give a clear indication of CH1 along this line. The scans were then displaced in central meridian distance so that the boundaries of CH1 would line up. We see here that the radio manifestation of CH1 appears to be about ½ day west of the X-Ray hole. We have carefully checked our rotation of the boundary of CH1 from the atlas by Nolte et al. (1976). The effect appears to be real.

Figure 3 shows the radio spectrum of CH1. The filled circles are from this study, the data being taken at N 40° latitude. The triangles represent observations of CH1 on its next disk passage. The 2.8 cm observation is that of Fürst and Hirth (1975). The other three triangles are from Dulk et al. (1977), the two longest wavelengths being 1.87 m (160 MHz) and 3.75 m (80 MHz). The open circle is the interferometer observation of Chiuderi-Drago (1974)

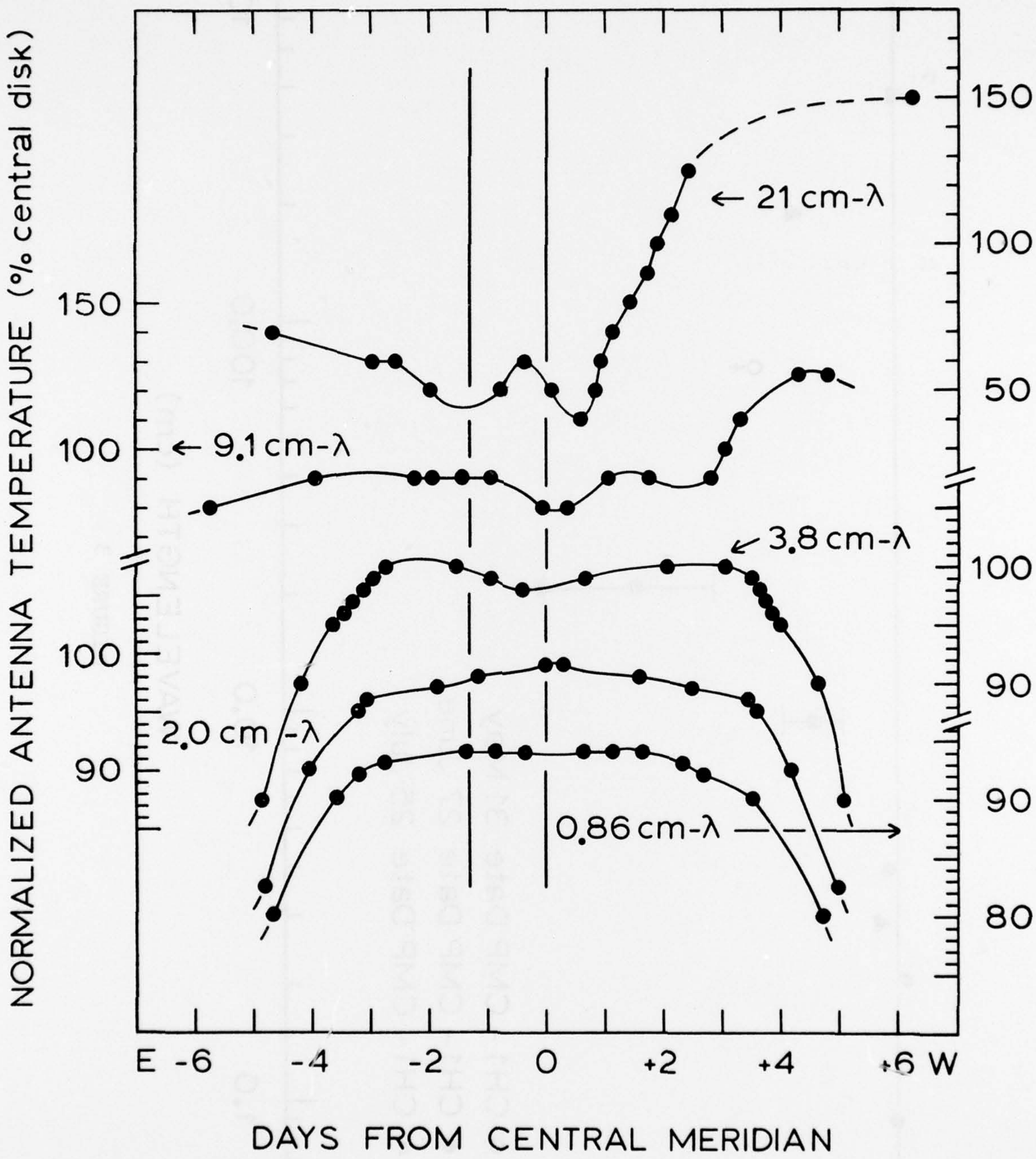

NORMALIZED ANTENNA TEMPERATURE (% central disk)
150
100
100
90
150
100
50
100
90
90
80
← 21 cm-λ
← 9.1 cm-λ
3.8 cm-λ
2.0 cm-λ
0.86 cm-λ
E -6
-4
-2
0
+2
+4
+6 W
DAYS FROM CENTRAL MERIDIAN

FIGURE 2

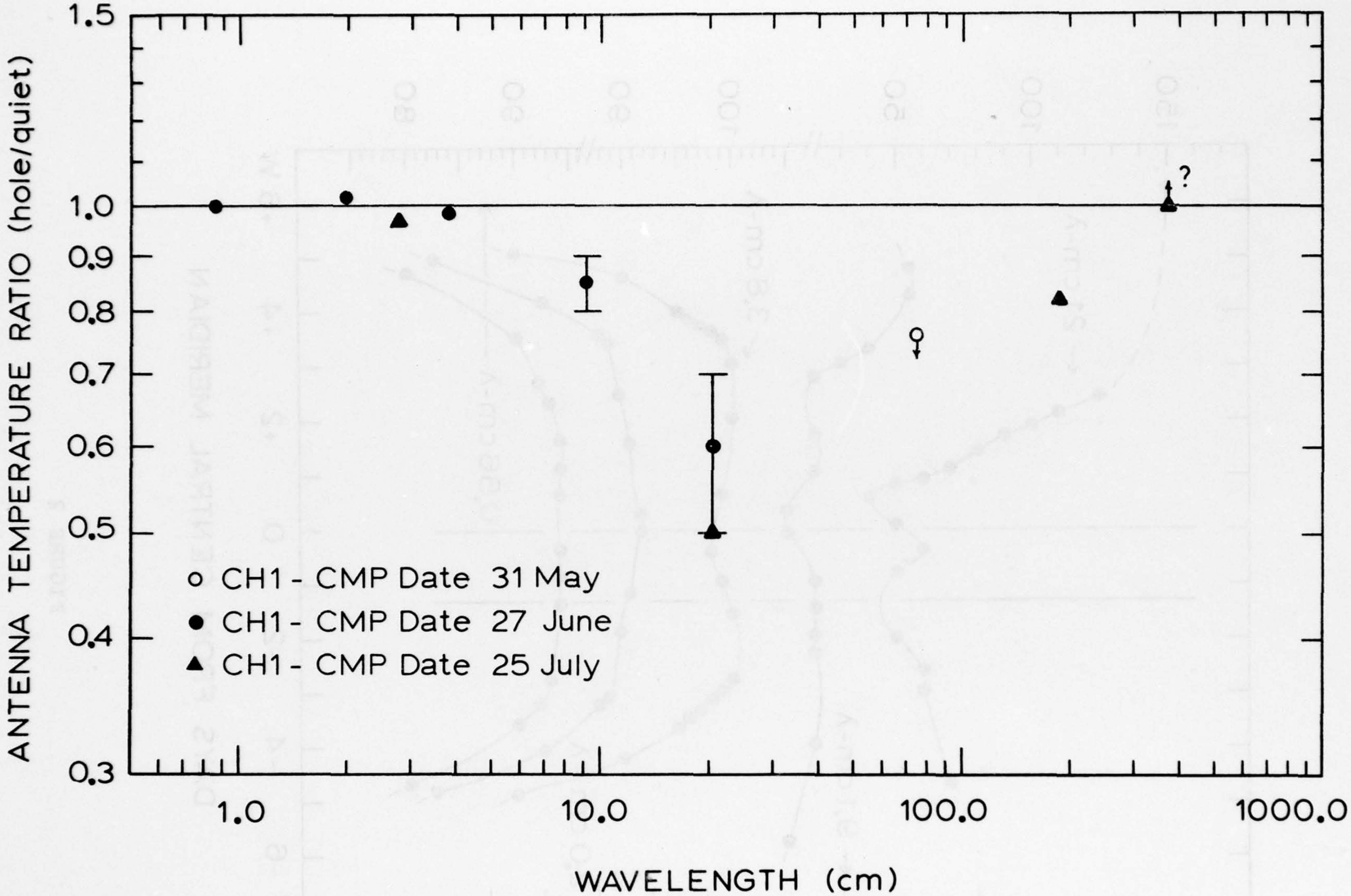

ANTENNA TEMPERATURE RATIO (hole/quiet)
1.5
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
?
○ CH1 - CMP Date 31 May
● CH1 - CMP Date 27 June
▲ CH1 - CMP Date 25 July
1.0
10.0
100.0
1000.0
WAVELENGTH (cm)

FIGURE 3

at 408 MHz. It is considered an upper limit since the coronal hole did not extend from pole to pole. The ordinate of Figure 3 is the antenna temperature in the coronal hole normalized by the antenna temperature of the quiet sun. Plotting the spectrum in this way avoids the problem of the absolute calibration of solar brightness temperatures.

3. The 2.0 cm-λ Data

The observation of enhanced radio emission at 2.0 cm-λ associated with CH1 was previously reported by Wefer and Bleiweiss (1976). Because this discovery is somewhat controversial, we will take a closer look at the 2.0 cm data. Figure 4 shows the northern half of the radio maps at this wavelength. It is seen that the emission (which is only ≃ 2%) not only coincides in location and shape with CH1, but it also rotates with CH1.

It has been suggested (Kundu, 1977) that this enhanced emission is somehow produced in the considerable computer processing which has applied to these maps in order to: remove certain distortions, center the sun in the map grid, and normalize the antenna temperatures, as was discussed in some detail by Wefer et al. (1976). The unprocessed versions of the 2.0 cm radio maps for 27, 28, 29, and 30 June 1973 are shown in Figure 5. Because of the severe distortion, the 27 June map was never processed. The ridge of enhanced emission is clearly visible in these "raw data"

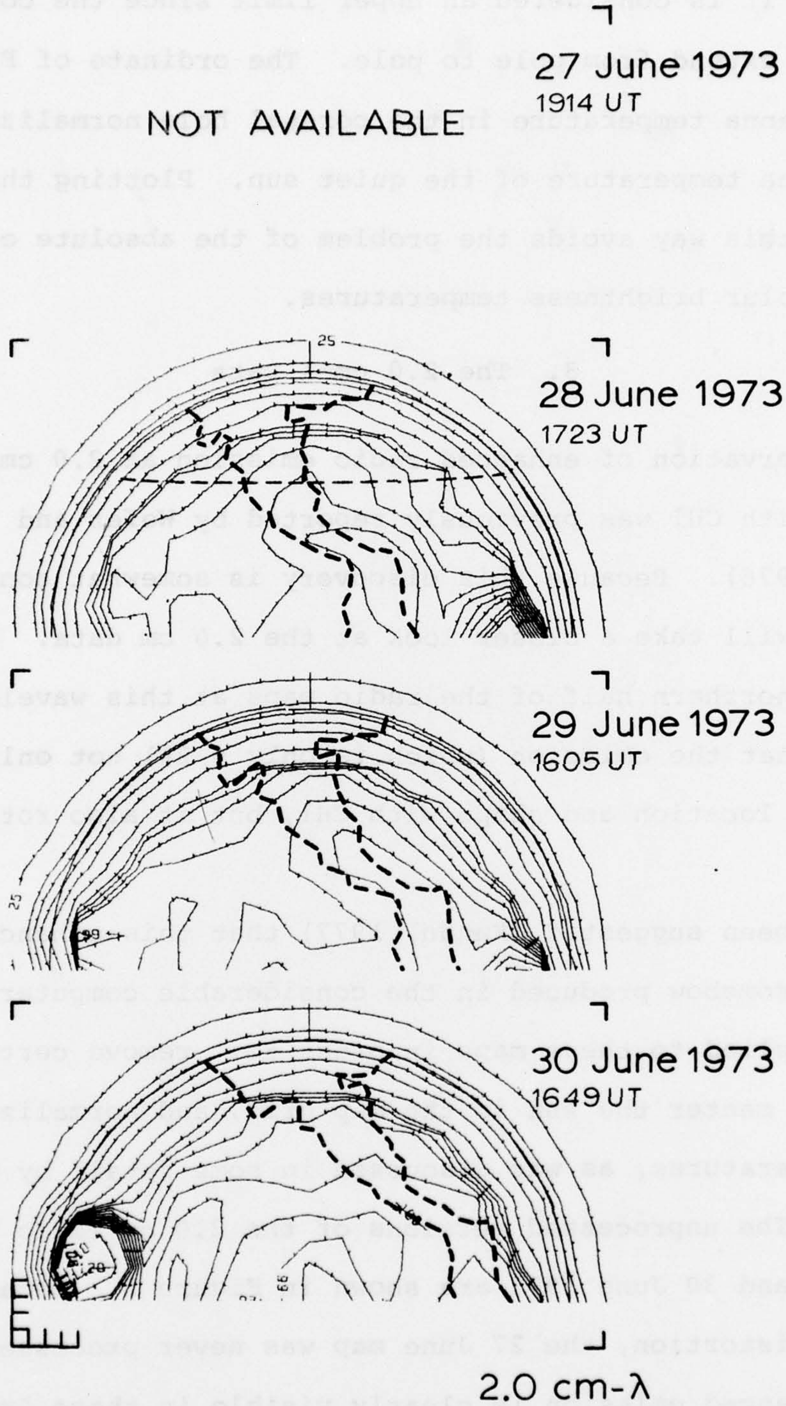

27 June 1973
1914 UT
NOT AVAILABLE
28 June 1973
1723 UT
29 June 1973
1605 UT
30 June 1973
1649 UT
2.0 cm-λ

FIGURE 4

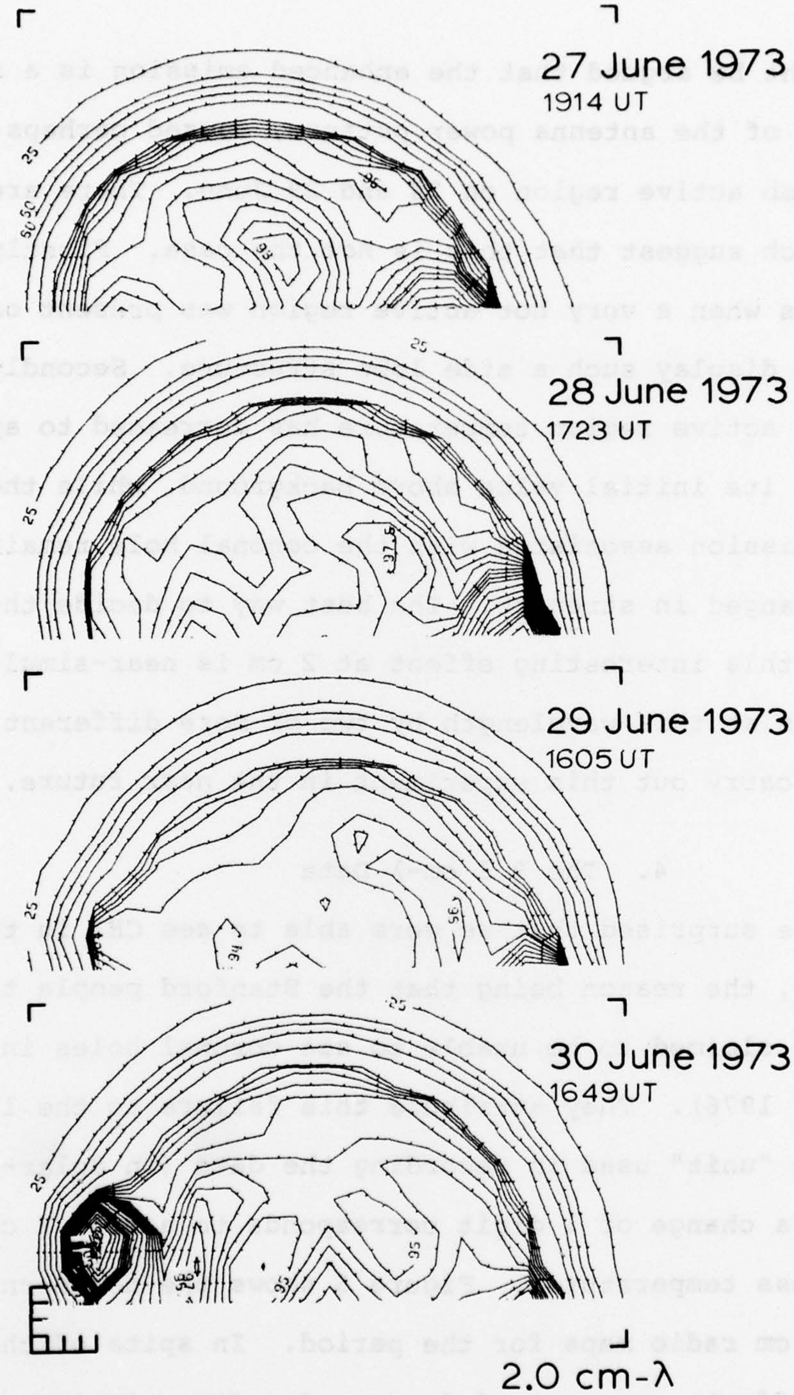

27 June 1973
1914 UT
28 June 1973
1723 UT
29 June 1973
1605 UT
30 June 1973
1649 UT
2.0 cm-λ

FIGURE 5

radioheliograms, hence cannot have been created in the computer processing.

It might be argued that the enhanced emission is a side lobe effect of the antenna power pattern, caused perhaps by the west limb active region on 28 and 29 June. There are two reasons which suggest that this is not the case. Firstly, maps made on days when a very hot active region was present on the disk do not display such a side lobe structure. Secondly, on 29 June the active region temperature has decreased to approximately half its initial value above background, while the enhanced emission associated with the coronal hole remained nearly unchanged in strength. The best way to decide the reality of this interesting effect at 2 cm is near-simultaneous observations at this wavelength by two or more different antennas. We hope to carry out this experiment in the near future.

4. The 9.1 cm-λ Data

We were surprised that we were able to see CH1 in the 9.1 cm maps, the reason being that the Stanford people themselves have claimed to be unable to see coronal holes in their data (Graf, 1976). They attribute this failure to the large temperature "unit" used in recording the data (in Solar-Geophysical Data a change of 1 digit corresponds to a 5000 K change in brightness temperature). Figure 6 shows the northern half of the 9.1 cm radio maps for the period. In spite of the strong side lobe effects, an area of depressed radio emission can be seen which coincides in location and rotates with CH1.

Figure 7 shows simulated drift scans again at N 40° latitude for the 9.1 cm data. We see that until 30 June when CH1 was well to the west of the central meridian, the radio depression was always to the west of the X-Ray hole, their centers differing by about ½ day.

5. Summary and Discussion

The radio spectrum of CH1, assembled from data obtained on three separate disk passages with several different radiotelescopes, hence with considerable variation in resolving power, is shown in Figure 3. Considering the difference in the beamwidths of the antennas used at 3.8 cm and 2.8 cm (4.4 arc min and 1.25 arc min FWHM, respectively), and considering that the observations were made on different disk passages, the two observations are in reasonable agreement. The enhanced emission at 2.0 cm-λ seen on two of the disk passages remains enigmatic.

The wavelength of the minimum in the spectrum probably lies between 21 cm and approximately 1.0 m; however, its exact value remains undetermined because of the quality of the 21 cm data and the lack of 2-dimensional data at longer wavelengths. The westward displacement of the "radio hole" relative to the X-Ray hole requires more study. The initial thought is to attribute it to a projection effect. Note, however, that the displacement is also present near the central meridian. It also appears to be nearly wavelength independent, i.e., the displacements at 2.0 cm,

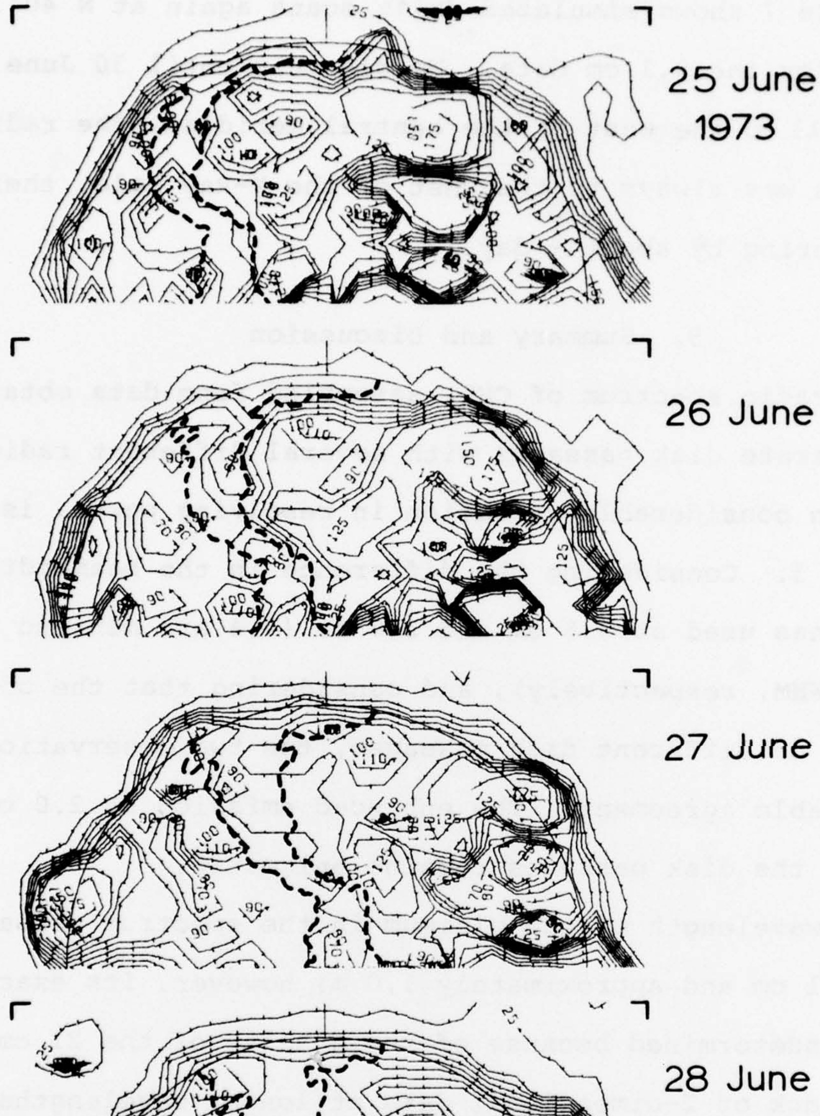


FIGURE 6

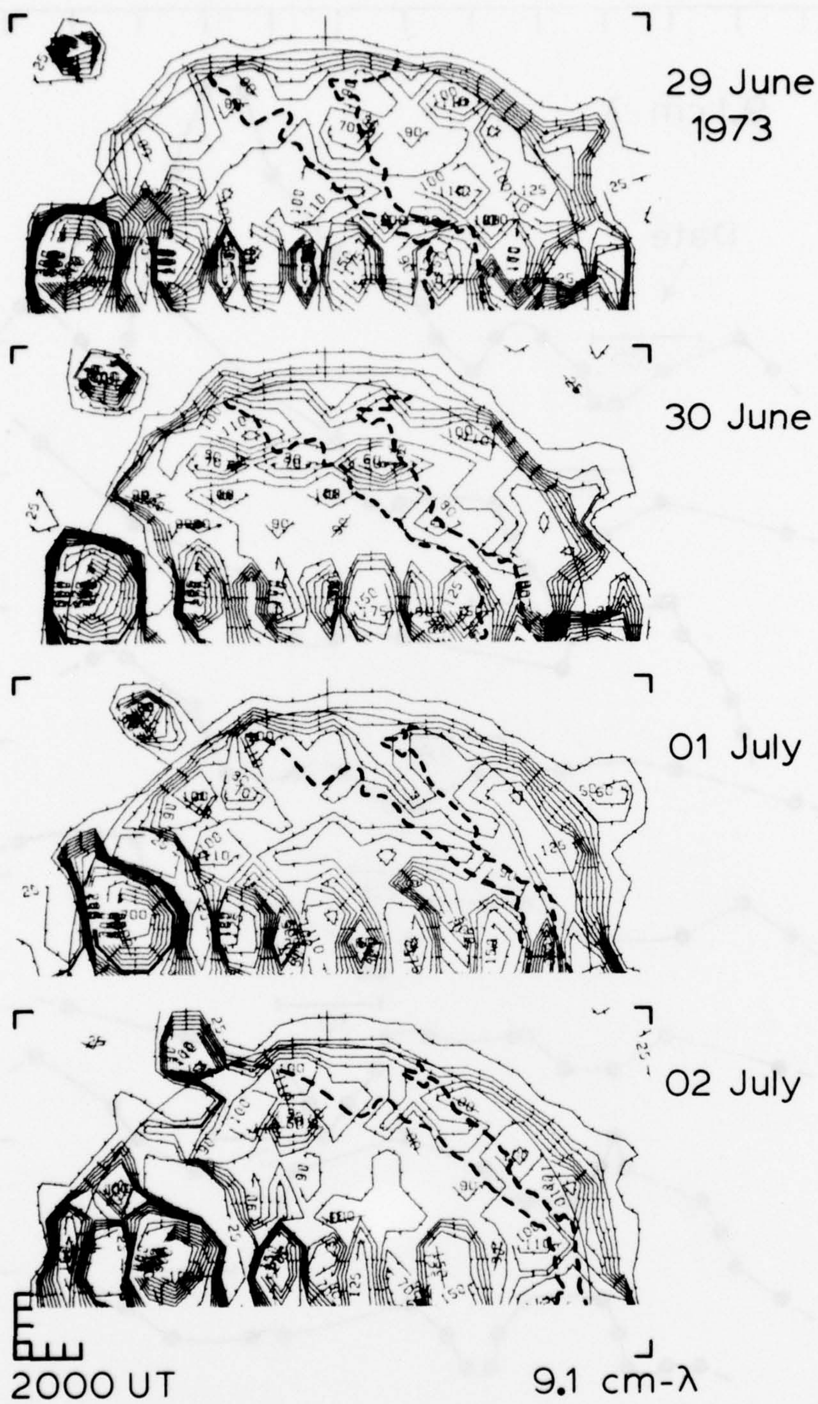


FIGURE 6 (continued)

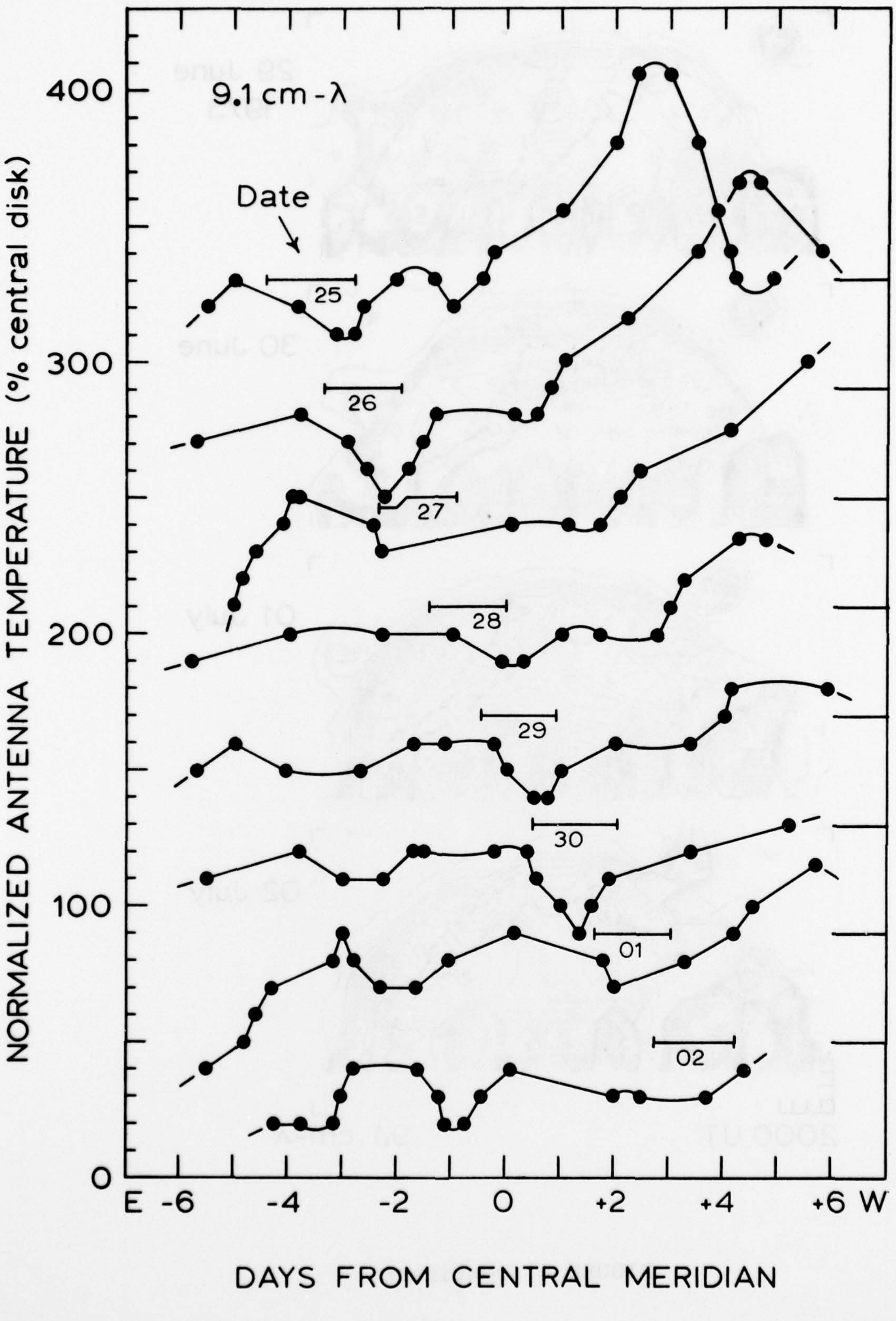

9.1 cm - λ
Date
25
26
27
28
29
30
01
02
400
300
200
100
0
NORMALIZED ANTENNA TEMPERATURE (% central disk)
E -6
-4
-2
0
+2
+4
+6 W
DAYS FROM CENTRAL MERIDIAN

FIGURE 7

3.8 cm, and 9.1 cm are nearly the same. A similar displacement appears to be present in the 2.8 cm observations by Fürst and Hirth (1975). Dulk et al. (1977) mention several instances of westward displacements as well as enhanced emission at 3.75 m.

Acknowledgements

We want to thank the staff of the Haystack Observatory for their valuable assistance during the 3.8 cm observations. Research with the Haystack antenna is supported by the NSF under Grant MPS71-02109A07. We wish also to thank Max P. Bleiweiss of the Naval Electronics Laboratory Center for providing the 8.6 mm and 2.0 cm data. This work was supported by Air Force Contract No. F 19628-77-C-0189 with the AFGL.

References

Chiuderi-Drago, F: 1974, paper presented at the Skylab Conference, Florence, March 21 - 22, 1974.

Covington, A.E.: 1976, AAS Bulletin 8, 339

Dulk, G.A. and Sheridan, K.V.: 1974, Solar Phys. 36, 191.

Dulk, G.A., Sheridan, K.V., Smerd, S.F. and Withbroe, G.L.: 1977, Solar Phys. 52, 349.

Fürst, E. and Hirth, W.: 1975, Solar Phys. 42, 157.

Graf, W.: 1976, private communication.

Krieger, A.S., Timothy, A.F. and Roelof, E.C.: 1973, Solar Phys. 29, 505.

Kundu, M.R. and Liu, Sou-Yang: 1976, Solar Phys. 49, 267.

Kundu, M.R.: 1977, private communication.

Lantos, P. and Avingnon, Y.: 1975, Astron. & Astrophys. 41, 137.

Nolte, J.T. Krieger, A.S., Timothy, A.F., Vaiana, G.S. and Zombeck, M.V.: 1976, Solar Phys. 46, 291.

Solar Geophysical Data: 1971, Number 317 - Part I (prompt reports), 65.

Wefer, F.L., Bleiweiss, M.P. and Hurst, M.D.: 1976, Megatek Corporation report R2005-031-F01, 1 July.

Wefer, F.L. and Bleiweiss, M.P.: 1976, AAS Bulletin 8, 338.