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ENERGETIC ELECTRONS FROM THE ACTIVE REGION MacMATH NO. 8905 DURING 20 JULY AND 5 AUGUST, 1967

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ENERGETIC ELECTRONS FROM THE ACTIVE REGION MacMATH NO. 8905 DURING 20 JULY AND 5 AUGUST, 1967

by

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ABSTRACT

The active region MacMath No. 8905 produced 16 distinct electron events associated with solar flares during its passage across the solar disk from 21 July to 4 August, 1967. An increase of the background flux of energetic electrons was also observed in association with the passage of this active region during this period. Based on the analysis of the characteristics of this active region, it is shown that these electrons were continuously accelerated in and ejected from this active region. Distinct electron events seem to have been produced as a result of the sudden release of excess energetic electrons due to the variation of the state of the active region by solar flares.

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1. INTRODUCTION

Based on observations of many distinct electron events, Lin and Anderson (1967) described two types of events which were characterised by their association with type I noise sources and were classified as Simple or Complex events.

Rao and McCracken (1970) and Sakurai (1971a) have shown that their classification is only apparent since the two types are fully explained by taking into account the narrow directivity of metric type I radio noise storms.

As studied by Lin (1970), the active region MacMath No. 8905 was associated with 16 solar flares which produced distinct electron events. This region was active in the emission of type I noise storms for the whole period of its passage across the solar disk. This region might be associated with continuous emission of Kev electrons into interplanetary space.

This paper aims to study some characteristics of active regions which are the source of the emission of energetic electrons associated with solar flares.

2. ENERGETIC ELECTRONS ASSOCIATED WITH THE ACTIVE REGION MacMATH NO. 8905

The active region MacMath No. 8905 appeared at the east limb on 21 July, disappeared at the west limb on 4 August, and passed central meridian on 28 July. After this region appeared on the east limb, the electron flux (> 20 Kev) near the earth began to increase gradually. When this region passed central meridian, the rate of electron flux increase became sharper as shown in Fig. 1. Such increases were observed by two channels for electron measurement (> 20 Kev and > 45 Kev) (Lin, 1970).

Sixteen distinct electron events were produced from solar flares which occurred in this region. Most of them were observed after this region had reached the western hemisphere. This seems to be due mainly to the propagation condition of these electrons in interplanetary space. As is seen in Fig. 1, these electron events were superposed on the increase of electron background flux.

If we identify the chain lines in Fig. 1 with the trends of the background electron fluxes, it is certain that these fluxes reached maximum around 31 July to 2 August. During this time, the region MacMath No. 8905 was located between 30° and 60° west of central meridian. This fact is evident from Fig. 2, which shows the passage of this region on the solar disk. Black circles indicate the positions of solar flares, irrespective of importance, associated with this region. Open circles are the flare positions which were not associated with this region. We can see that one active region existed just east of the active region under consideration in this figure. This active region was identified as MacMath No. 8907. Both active regions were very close to each other in the northern hemisphere. In this figure, the black circles with plus sign indicate the position of solar flares which produced distinct electron events as shown in Fig. 1.

The transit time to the earth of electron streams associated with the 16 solar flares tends to be minimum when region MacMath No. 8905 is located about 50 degrees west of central meridian (Fig. 3). As discussed before, the background flux of solar electrons was almost maximum around this time while this region was 50^{o} west of central meridian. In Fig. 3, the open and solid circles indicate the positions of solar flares associated with Complex and Simple electron events, respectively. A similar tendency of transit time is seen statistically for the transit time of solar cosmic rays of Mev-energy (e.g., Obayashi, 1964).

3. CHARACTERISTICS OF RADIO AND OPTICAL ACTIVITY OF THE ACTIVE REGION MacMATH NO.8905

The active region MacMath No. 8907 was located just east of the region MacMath No. 8905. The flare activity for both regions was almost the same. In fact, the numbers of flares for these two active regions were 225 and 231, respectively, irrespective of their importance during their passage across the solar disk. These data were taken from Solar Geophysical Data.

The distribution of flare importances for the two active regions is shown in Fig. 4. It is clear that the distribution of flare importances is very similar, although the active region MacMath No. 8905 seemed to be slightly more active in producing solar flares of importance $\geq$ IN. The result shown in this figure means that the optical activity of flare occurrence was almost the same for both active regions.

Solar flares which occurred in the active region MacMath No. 8907, however, did not produce distinct electron events. This result may be related to the difference of physical condition between these two active regions on the generation of Kev electrons.

It is thought at present that Kev electrons trapped in the extended sunspot magnetic fields contribute the emission of type I noise storms at metric frequencies (e.g., Takakura, 1963, 1967; Fokker, 1965; Trakhtengerts, 1966). The data on type I noise activity during the period under consideration provides the path of the type I noise source on the solar disk as shown in Fig. 5. The time of central meridian passage of the active region MacMath No. 8905 is indicated by the solid circle with error bar in the figure and is clearly coincident with the CMP time of the type I noise source. Other type I sources were intermittently observed during this period as is seen in this figure, but were associated with the active regions MacMath Nos. 8909 and 8911. We can, therefore, conclude that no strong type I noise source was associated with the active region MacMath No. 8907.

Hence we may summarize the result obtained above as follows: Even if some sunspot groups are very active in the occurrence of solar flares, those which are not active in the emission of metric type I noise storms do not produce both an increase of solar electron background fluxes and distinct electron events.

Type I noise activity at 100 and 200 MHz has been examined during the period from 20 July to 5 August. The result is shown in Fig. 6 and indicates that such type I activity is highly dependent on the position of the radio source of the solar disk. The peak fluxes for these two frequencies were attained around the days while the radio source was passing through the central meridian. This fact is explained by considering the narrow directivity of type I noise storms (e.g., Fokker, 1965).

As shown in the same figure, the occurrence frequency of solar flares began to gradually decrease after 25 July in a monotonous way. This tendency indicates that the increase of electron background flux after 28 July (Fig. 1) was independent of the activity of solar flares optically observed. In other words, the increase of electron background flux was dependent on the position of type I noise active region on the solar disk. It seems that this increase reached a peak when the type I active region was situated such that the electrons could be well channeled to the earth or its neighborhood by the interplanetary magnetic field lines.

The generation of distinct electron events is connected with solar flares which occur in sunspot groups which are active in the emission of type I noise storms. Therefore, the existence of type I activity seems to be important in producing such electron events. The relationship between type I noise sources and the emission of continuous electron streams seems to be very important on the understanding of the acceleration and emission mechanism of Kev electrons.

4. CONTINUOUS ACCELERATION OF KEV ELECTRONS AND THE EMISSION ASSOCIATED WITH SOLAR FLARES

The continuous emission of Kev electrons and the distinct emission of Kev electrons from solar flares were associated with the active region MacMath No. 8905. As discussed in the last section, both emissions of electrons are related to the passage of the sunspot group which was active in the emission of type I noise storms. This sunspot group seemed to continuously accelerate Kev electrons, the main part of which were supplied to the type I noise source. Some of them were steadily emitted into interplanetary space as is shown in Fig. 1.

We do not know as yet what acceleration mechanism is working to produce these Kev electrons. But, it is certain, as suggested by Sakurai (1971a), that the enormous number of Kev electrons exists in the sunspot group which is active in type I noise emission. A part of these electrons is probably continuously emitted from such a sunspot group which is active in type I noise emission. They are observed as the background flux increase of Kev solar electrons (e.g., Sakurai, 1971b; Sakurai, Stone and Fainberg, 1971).

During the passage of the active region MacMath No. 8905 on the solar disk, sixteen distinct electron events were produced from solar flares in this region. Except for the event at 0900 UT on 3 August, which accompanied relativistic electrons, the energy range of these ejected electrons seems to have been almost the same as that for the background solar electrons. In other words, it seems that these electrons ejected from flares were not largely accelerated in association with flares. Thus we may say that the role of such flares mainly was to work as a triggering agent to eject those electrons into outer space from type I noise sources, although these flares may accelerate them instantaneously during the explosive phase.

When we assume the role of solar flares of small importance (Fig. 4(a))to be as considered above, we can reasonably interpret why no solar Kev electrons were emitted from the active region MacMath No. 8907 in association with solar flares. Namely, the emission of solar Kev electrons is necessarily associated with solar flares which occur in sunspot groups which are active in the emission of type I noise storms.

The peak flux of background solar electrons was attained several days after the central meridian passage of the active region MacMath No. 8905 (Fig. 1). This result is well explained by taking into account the curved path of the propagation of these electrons (e.g., McCracken, 1962; Fan et al., 1968).

As shown in Fig. 2, the sector boundary passed by the earth about 5.5 days after the central meridian passage of the above active region. The adjacent active regions MacMath Nos. 8907, 8909 and 8911 consecutively passed by the central meridian of the solar disk. When we refer to the median speed of the solar wind during this period (Hundhausen, et al., 1970), it follows that the root of this sector boundary is projected on to the region where four active regions conglomerate. This result suggests that the energetic electrons continuously emitted from the active region MacMath No. 8905 mainly propagated along the interplanetary magnetic field lines near or in this sector boundary.

5. CONCLUSION

We have studied the Kev electrons associated with solar flares with a point of view that these electrons are continuously gnerated in type I noise active regions. The role of these flares is to disturb the configuration of active regions and thus to release excess fluxes of such electrons into interplanetary space. These in turn are observed as distinct electron events at the earth.

It has been considered that Kev electrons are continuously emitted from type I noise source above the active region MacMath No. 8905 and are observed as the background flux increase of electrons at the earth during the passage of the active region on the solar disk. This increase and its day-to-day variation seem to be dependent on the circumstance of the channeling by the interplanetary magnetic field lines between the sun and the earth. This channeling is also applied to interpret the observed result on the transit time of the prompt onset component of distinct electron events associated with solar flares as shown in Fig. 3.

The active region MacMath No. 8907 was active in flare production as in the case of MacMath No. 8905, but the former did not produce any distinct electron event. This is deeply connected with the fact that the former was not associated with type I noise source. In reality, sunspot groups which produce solar flares associated with distinct electron events are active in the emission of metric type I noise storms, Kev electrons are continuously accelerated in such sunspot groups and thus become the source of type I noise storms. The acceleration mechanism may be related to the wave-particle interaction triggered by unstable modes associated with the sunspot magnetic configuration (Sakurai, 1971a).

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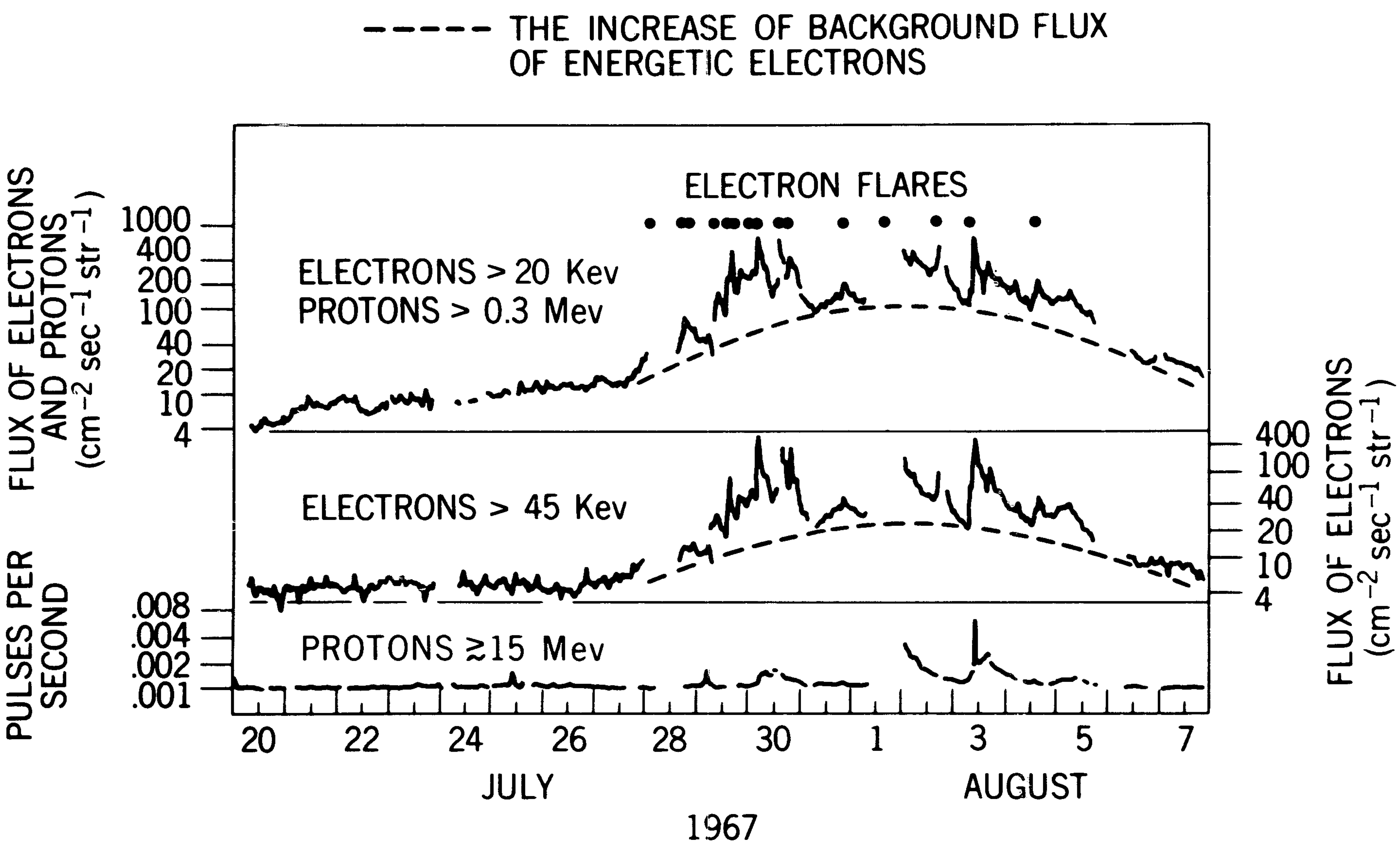


Figure 1. The electron fluxes from the sun during 20 July and 7 August, 1967 (after Lin, 1970). Solar flares associated with distinct electron events are indicated by the solid circles.

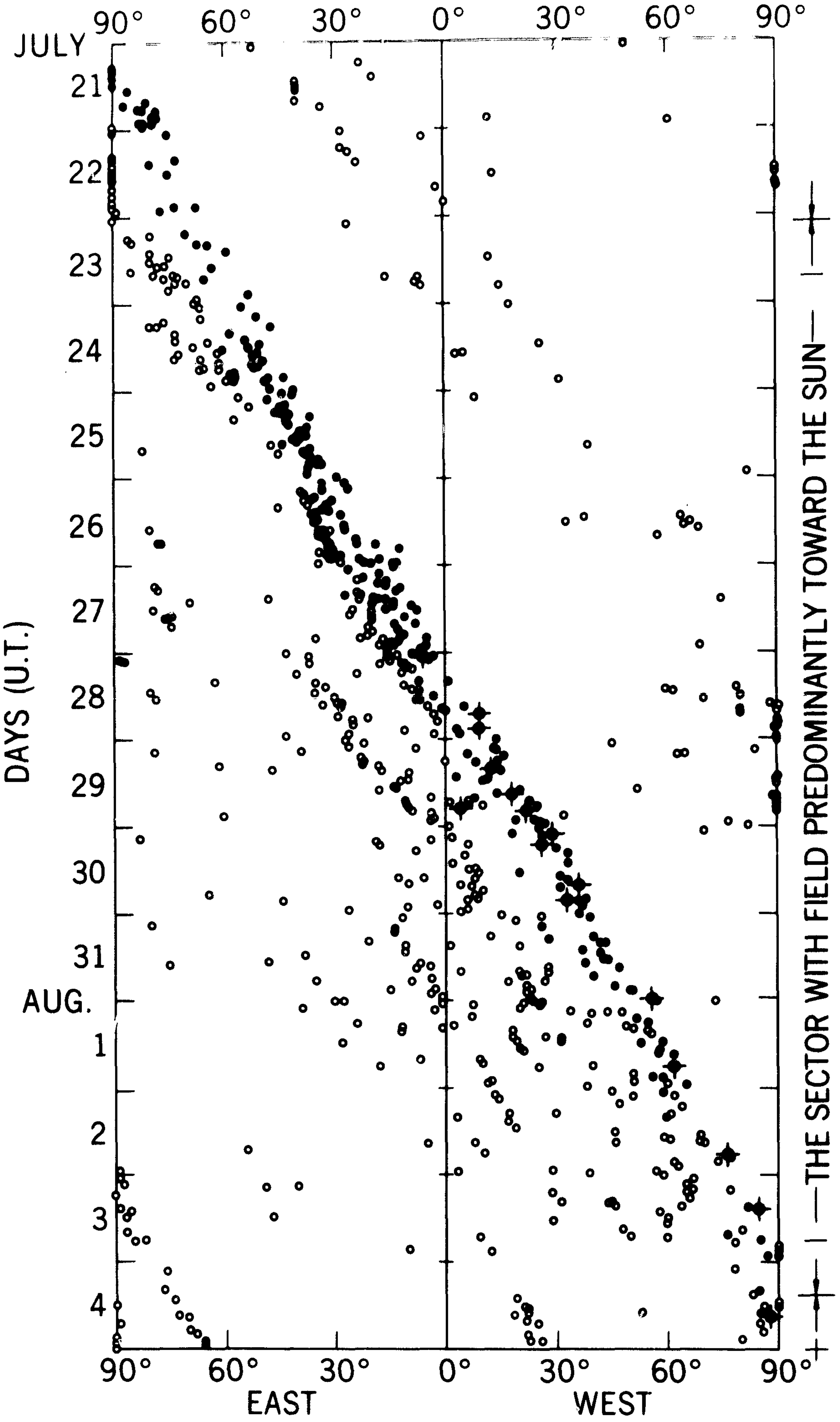


Figure 2. The passage of the active region MacMath No. 8905 of the solar disk. Solar flares associated with this active region are shown by solid circles. The solid circles with the plus sign are the positions of solar flares associated with distinct electron events.

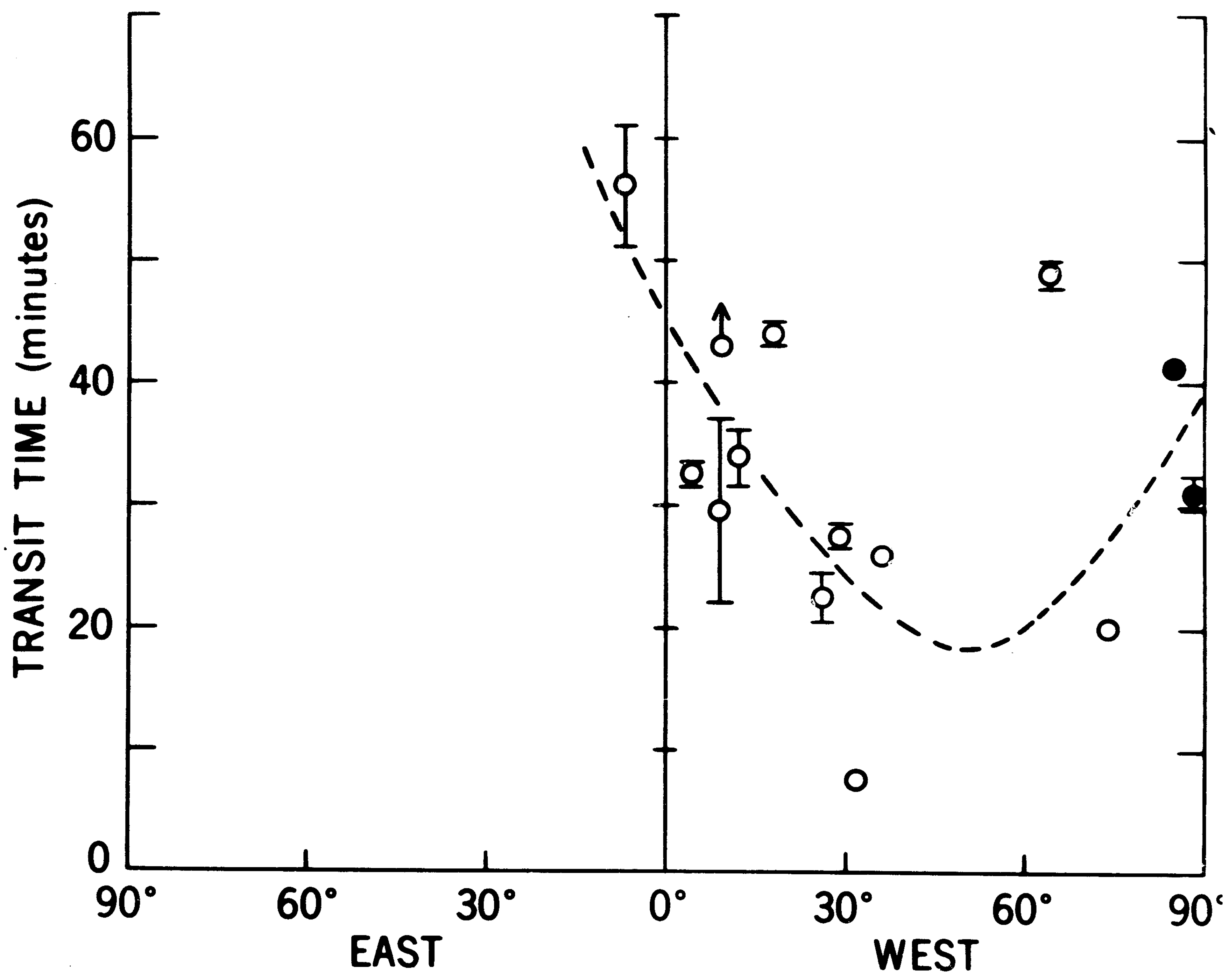


Figure 3. The transit times of Kev electrons associated with solar flares with respect to the heliographic longitude.

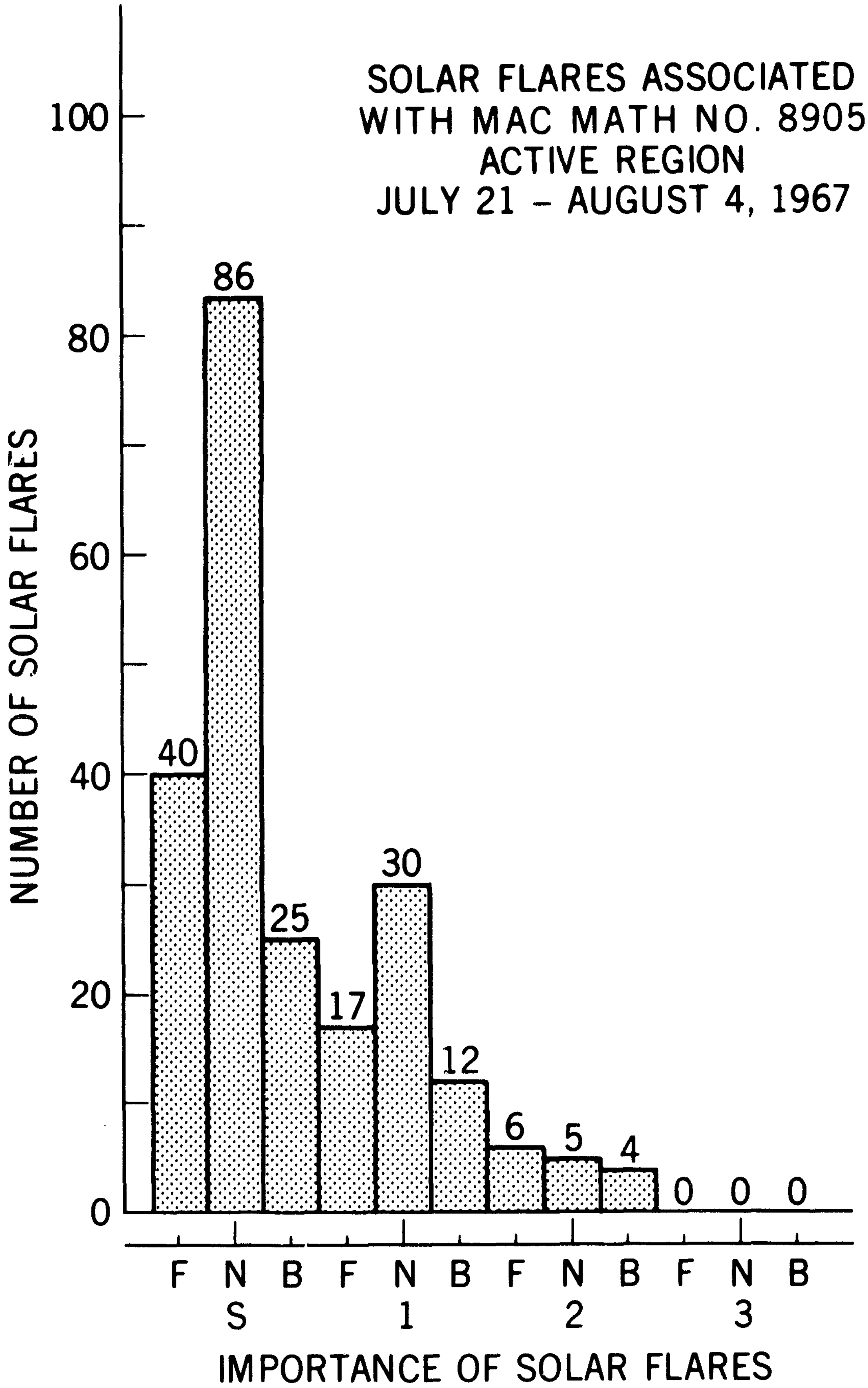
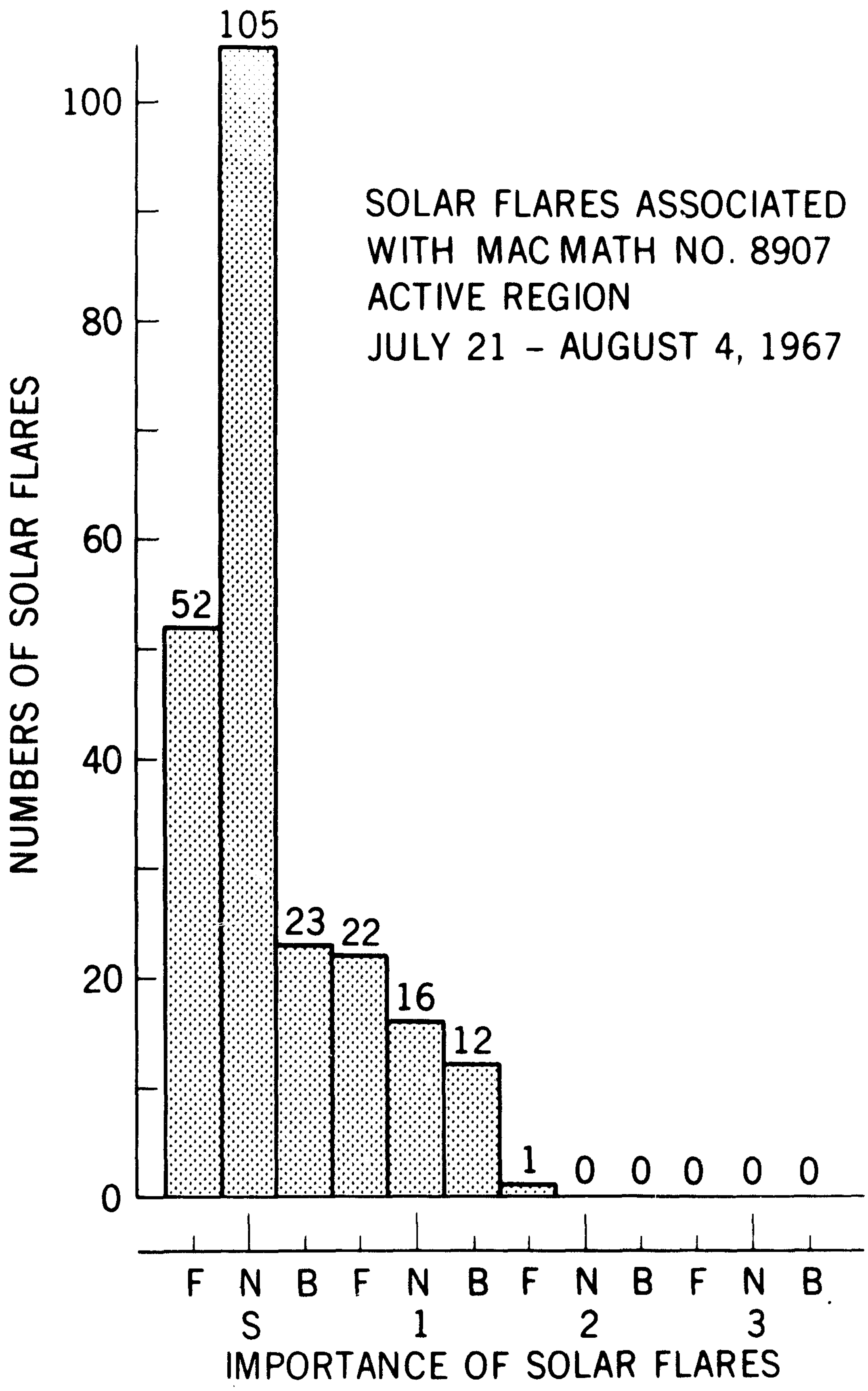


Figure 4. The distribution of solar flares with respect to the importance for (a) the active region MacMath No. 8905 and (b) the active region MacMath No. 8907.



105
52
23
22
16
12
1
0 0 0 0 0
100
80
60
40
20
0
NUMBERS OF SOLAR FLARES
SOLAR FLARES ASSOCIATED
WITH MAC MATH NO. 8907
ACTIVE REGION
JULY 21 - AUGUST 4, 1967
F N B F N B F N B F N B
S 1 2 3
IMPORTANCE OF SOLAR FLARES

Figure 4b.

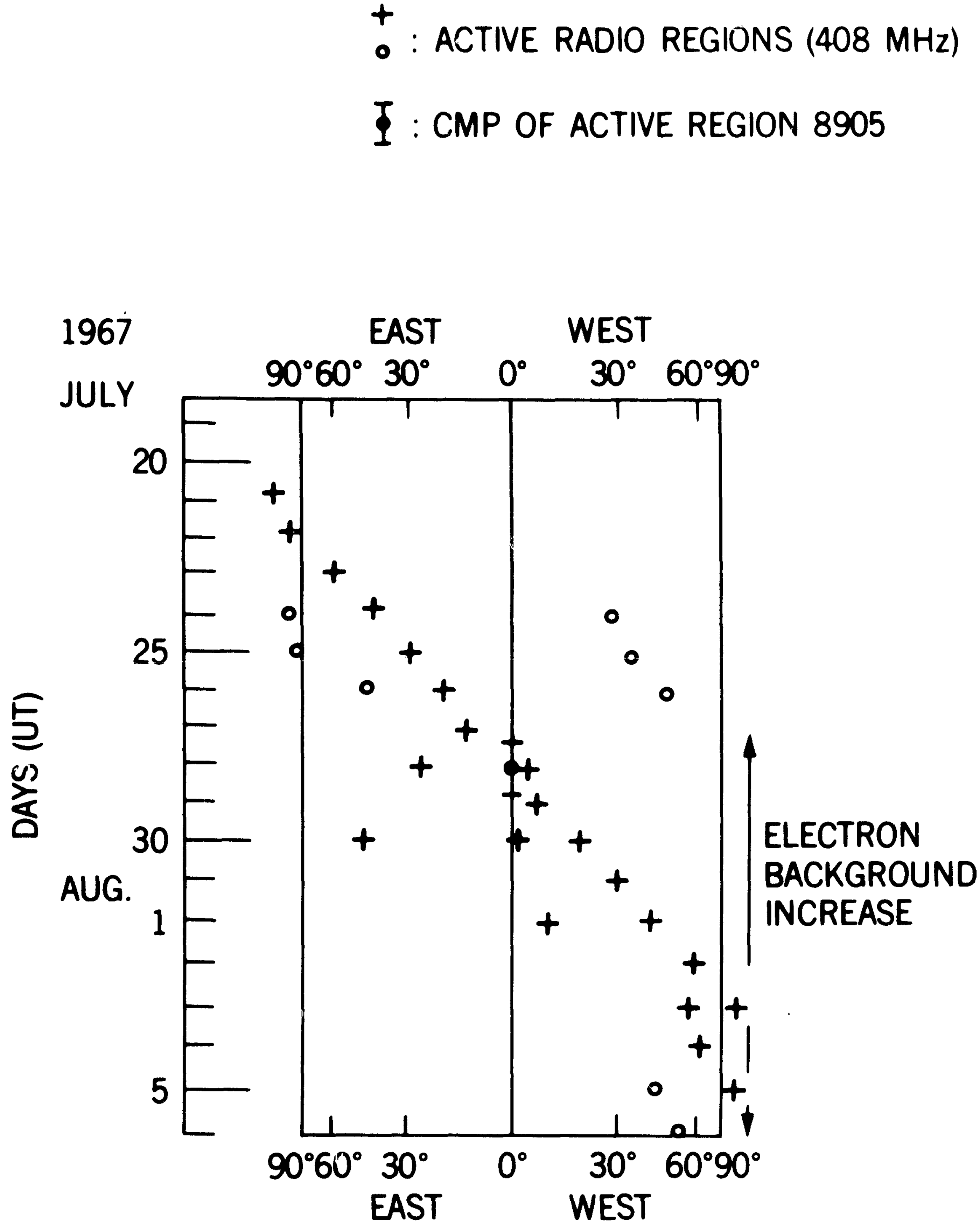


Figure 5. The passage of type I noise active region at 408 MHz. on the solar disk. The time of the central meridian passage of the active region MacMath No. 8905 is indicated by the solid circle with error bar (after Solar Geophysical Data).

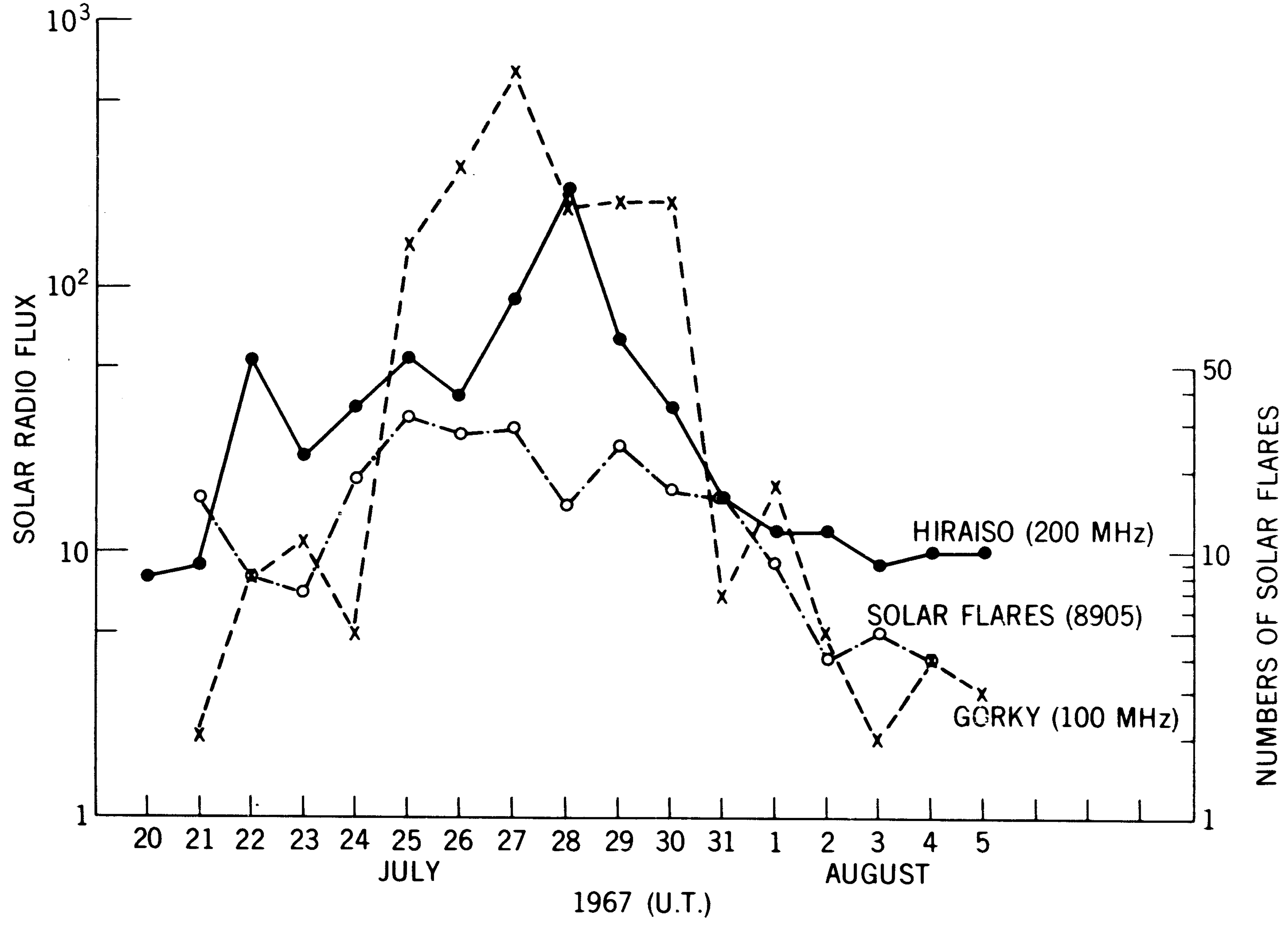


Figure 6. The daily variations of solar radio fluxes at 100 MHz (Gorky) and 200 MHz (Hiraise), and of solar flares associated with the active region MacMath No. 8905.