X-615-70-33
PREPRINT

NASA TM X-63827

THE ROTATING MOTION AND PRE-FLARE ACTIVITY OF THE SUNSPOT GROUPS ASSOCIATED WITH THE SOLAR PROTON FLARE ON 7 JULY 1966

KUNITOMO SAKURAI

JANUARY 1970

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

THE ROTATING MOTION AND PRE-FLARE ACTIVITY OF THE SUNSPOT GROUPS ASSOCIATED WITH THE SOLAR PROTON FLARE ON 7 JULY 1966

by

Kunitomo Sakurai*
NASA, Goddard Space Flight Center
Greenbelt, Maryland

ABSTRACT

The rotating motion of the sunspot group McMath No. 8362 is examined by using the observational data. This motion is counterclockwise so that the preceeding and following parts of the sunspot group gradually move northward and southward, respectively, during the growth of the sunspot group. When the sunspot group developed into a δ -type, the proton flare of 7 July 1966 was produced within this sunspot group. The activity of sub-flares before this occurrence suggests that the energy release from the sunspot group is inhibited by some mechanism which allows the accumulation of flare energy.

*NAS-NRC Associate with NASA

Many theories have recently been proposed for the mechanism of solar flares and the generation of energetic particles such as solar cosmic rays (e.g., Smith and Smith, 1963; Hess, 1964; Sweet, 1969). At present, however, no theory or model can fully explain the development of solar flares and the associated phenomena.

In order to understand the mechanism of solar flares, we must examine first the observational data on the sunspot magnetic configuration and its proper motion associated with the occurrence of solar flares. As pointed out by Sakurai (1967, 1969), the sunspot groups which produce solar proton flares rotate counterclockwise (clockwise) in the northern (southern) hemisphere when viewed from the earth. This rotating motion is different than that associated with most sunspot groups as discussed by Kiepenheuer (1953) which, however, do not produce solar proton flares. It may well be that the rotation discussed above is related only to the production of solar proton flares and to the acceleration of energetic particles.

In this paper, in order to investigate this rotating motion in detail, we will examine the growth and motion of the sunspot group (McMath No. 8362) which produced the solar proton flare on 7 July 1966. At first, as shown in Figure 1, the group obeyed the usual polarity distribution (Kiepenheuer, 1953), i.e. the preceeding part of the group was located more southward compared to the following part at the early stage of development. The polarities of the preceeding and following parts were south and north respectively.

With increasing time, the boundary line separating north and south polarity in the sunspot group, as shown by the black line in the figure, rotated counterclockwise with the growth of the sunspot umbra, penumbra, magnetic field intensity and area. On 6 July, the two polarity regions coalesced within the same sunspot umbra as is seen in Figure 1. This situation can be identified with the δ-type of sunspot groups recently proposed by Künzel (1960). As is evident from this figure, the umbral region, containing both polarities, is surrounded by a large penumbra from 5 July through 8 July. These situations are favorable for the occurrence of solar proton flares according to the statistical results obtained by Anderson (1961) and Warwick (1966).

The solar proton flare of importance 2B was, in reality, produced at 0023 UT on 7 July when the sunspot group was well developed. As is inferred from Figure 1 this sunspot group, since its formation, continued to gradually rotate counterclockwise. This rotating motion seems to be important for the formation of sunspot groups of the δ-type which are causally related to the occurrence of solar proton flares. Furthermore, this rotating motion may be related to some instability of the sunspot magnetic configuration which triggeres solar proton flares.

We may conclude that sunspot groups producing proton flares are initiated through this rotational motion and the coalecence of the two polarity regions. This seems to be a necessary condition for the occurrence of solar proton flares. This pattern of rotation is not consistent with the model which has been discussed by Sturrock (1967). The cases considered by him seem to correspond to sunspot groups which have not been associated with the production of solar proton flares. As suggested by Sakurai (1967), the rotating motion as described in this paper seems to be connected with the convective flows within and near the sunspot groups. But as yet there is no information on the relation between this rotating motion and such convective flows.

We will now consider a feature of the activity of sub-flares before the occurrence of the solar proton flare at 0023 UT on 7 July. The observational data on sub-flares are summarized in Table 1 (Fisher and Mann, 1969). As shown in Fig. 2 the rise time and duration of sub-flares, which are shown by the white and black circles respectively, tend to become shorter as the time for the occurrence of the proton flare approaches. This fact suggests that the magnitude of solar sub-flares became smaller with increasing time. Therefore, the rate of the energy release from the sunspot group seems to have slowed down gradually with increasing time before the onset of the proton flare. This suggests that the flare energy was continuously accumulated without being released to any great extent from the sunspot group. The intervals of two subsequent sub-flares as shown in Figure 3 do not show any systematic behavior as in the case of the rise time and duration of sub-flares shown in Figure 2.

The activity of sub-flares before the occurrence of proton flares may be useful for the prediction or warning of the occurrence of proton flares by compiling all of the sub-flares rise times and durations which are estimated from

H-alpha emission flux. If we consider the rotating motion of sunspot groups and the formation of δ-type sunspot groups in relation to the pre-proton flare sub-flare activity, we may be able to predict the occurrence of solar proton flares.

The rotating motion of sunspot groups, as considered in this paper, seems to provide the necessary energy to produce solar proton flares. This rotating motion, furthermore, seems to make sunspot magnetic lines of force in the chromosphere and the corona twisted in association with the growth of the sunspot group. This twisting and its instability would be important for the production of solar proton flares.

TABLE 1

TIMES AND POSITIONS OF SUB FLARES BEFORE THE OCCURRENCE OF PROTON FLARE

	TIME (UT)			POSITION	
	Begin	Max.	End	Lat.	Long
6 July					
1.	1640	1643	1700	$36^{o}N$	$47^{o}W$
2.	1730	"	1800	$36^{o}N$	$45^{o}W$
3.	1827	1834	1852	$35^{o}N$	$45^{o}W$
4.	1940	1944	1958	$36^{o}N$	$45^{o}W$
5.	2033	2034	2053	$36^{o}N$	$47^{o}W$
6.	2117	2120	2141	$36^{o}N$	$47^{o}W$
7.	2152	2154	2206	$36^{o}N$	$47^{o}W$
8.	2225	2227	2246	$36^{o}N$	$47^{o}W$
9.	2318	2320	2326	$35^{o}N$	$45^{o}W$
7 July					
10	0023	(0032)		$35^{o}N$	$47^{o}W$
(10)	(0032)	0042		$35^{o}N$	$47^{o}W$

REFERENCES

Anderson, K.A., NASA Rep. TN D-700 (1961).

Fisher, R.R. and Mann, G.R., in the Proton Flare Project (Annals of the IQSY), pp. 163-168, ed. by Stickland, A C., MIT Press, Cambridge (1969).

Hess, W.N. AAS-NASA Symp. on Physics of Solar Flares, NASA SP-50 (1964).

Kiepenheuer, K.O., in The Sun, pp. 322-465, ed. by Kuiper, G.P., Univ. of Chicago, Chicago (1953).

Künzel, H., Astron. Nach., 258, 271-273 (1960)

Sakurai, K., Rep. Ionos. Space Res. Japan, 21, 113-124 (1967).

Sakurai, K., J. Geomag. Geoel, 21, 463-470 (1969).

Smith, H.J. and Smith, E.vP., Solar Flares, MacMillan, New York (1963)

Sturrock, P.A., in Plasma Astrophysics, pp. 155-167, ed. by Sturrock, P.A., Academic Press, New York (1967).

Sweet, P.A., Ann. Rev. Astron. Astrophys. 7, 149-176 (1969).

Warwick, C S., Ap. J., 145, 215-223 (1966)

FIGURE CAPTIONS

Fig. 1 - The rotating motion of the sunspot group McMath No. 8362 associated with the growth.

Fig. 2 - The rise time and duration of sub-solar flares before the occurrence of the solar proton falre on 7 July, 1966.

Fig. 3 - The time interval of two subsequently occurring sub-flares.

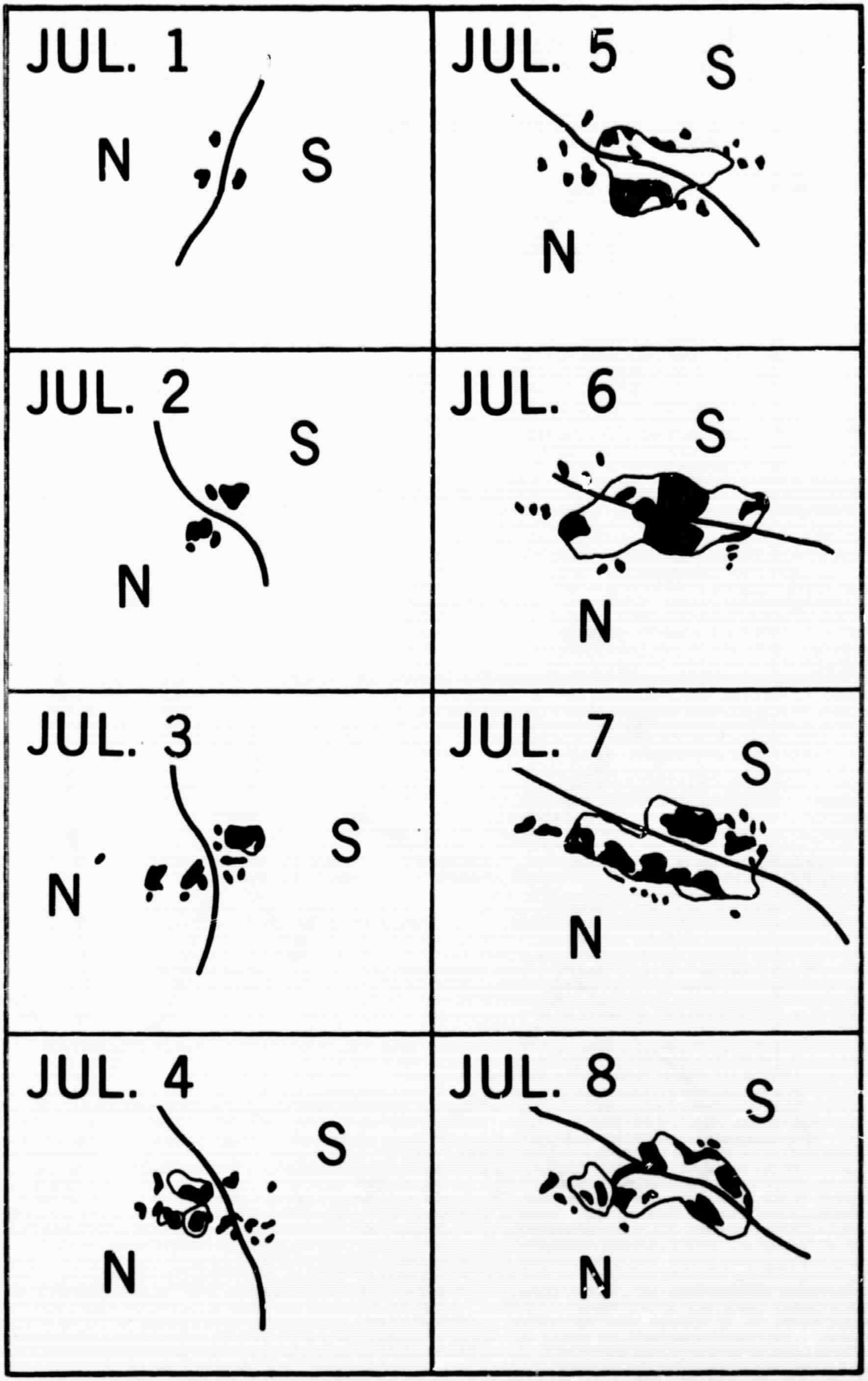
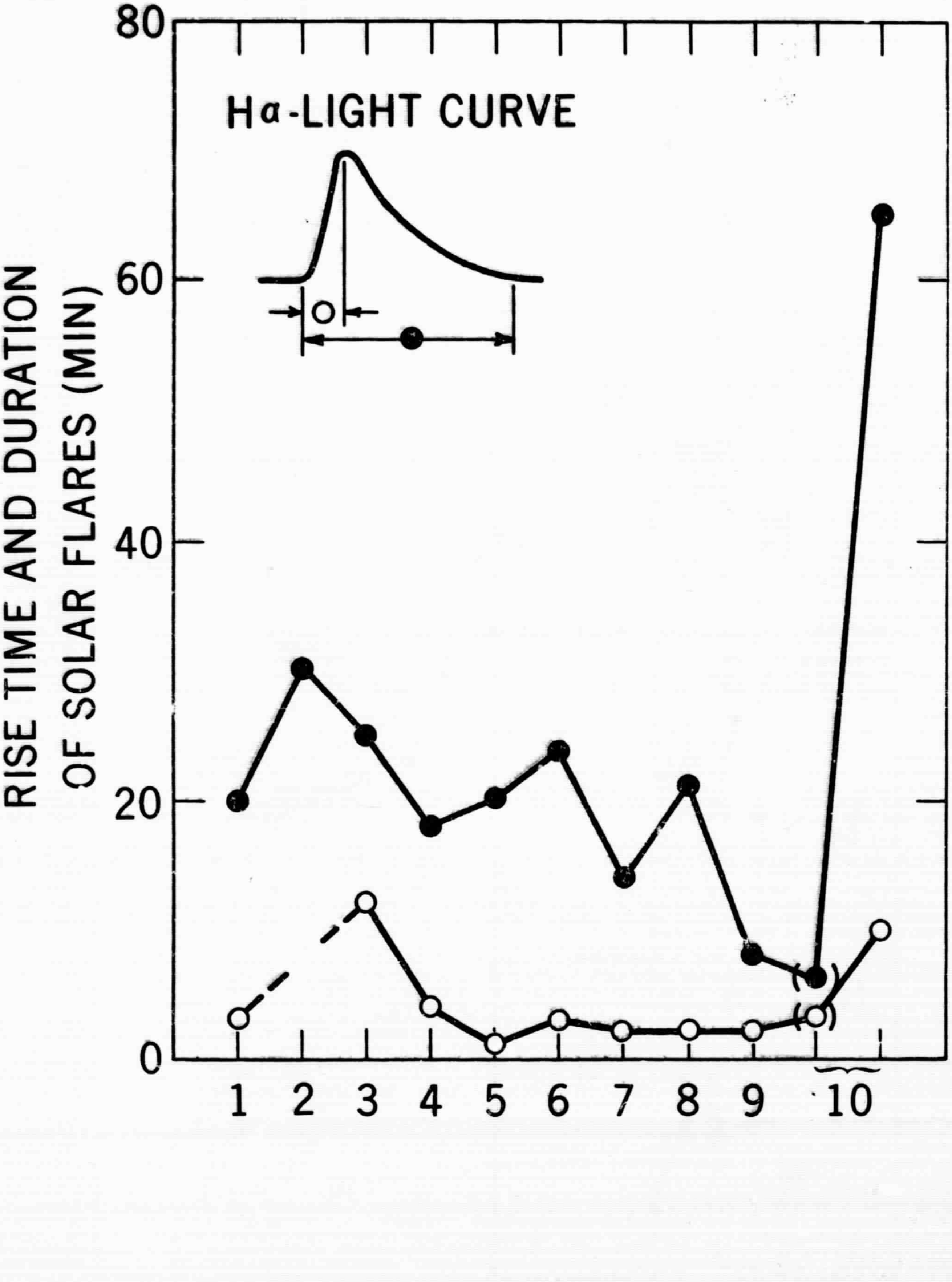


Figure 1



Hα-LIGHT CURVE
RISE TIME AND DURATION OF SOLAR FLARES (MIN)
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10

Figure 2

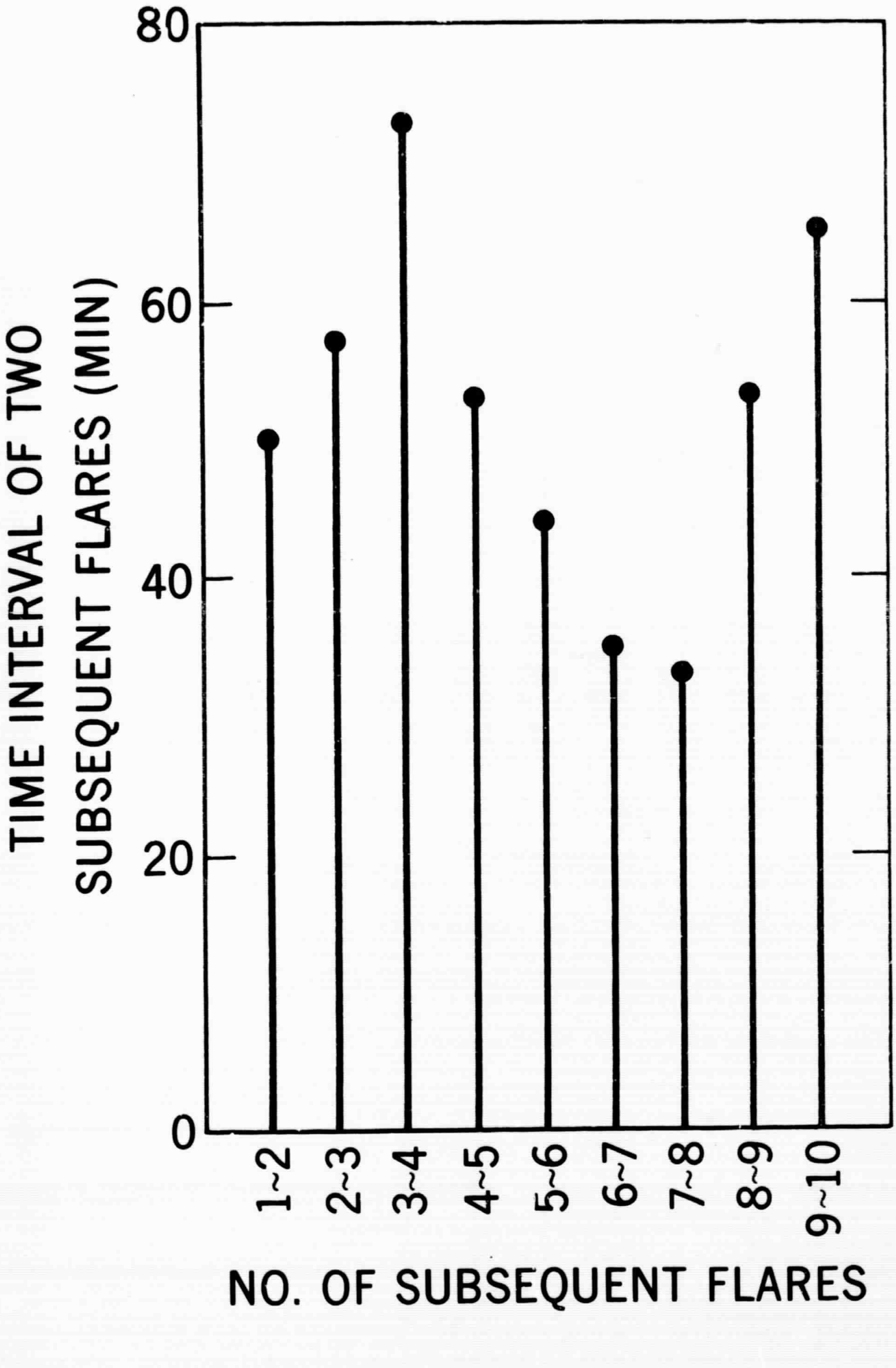

80
60
40
20
0
TIME INTERVAL OF TWO SUBSEQUENT FLARES (MIN)
1~2
2~3
3~4
4~5
5~6
6~7
7~8
8~9
9~10
NO. OF SUBSEQUENT FLARES

Figure 3