CORONAL PROPAGATION OF SOLAR FLARE PARTICLES OBSERVED BY SATELLITE

Tsuyoshi KOHNO, Nariaki NITTA, Masami WADA and Tomoshige SUDA*

Institute of Physical and Chemical Research
7-13, Kaga-1, Itabashi, Tokyo 173, Japan

Meteorological Research Institute*
1, Nagamine-1, Yatabe, Tsukuba, Ibaraki 305, Japan

Abstract

Propagation of solar flare particles in corona was studied using the satellite data at the geostatrionary orbit. By selecting very fast rise time events only, the interplanetary propagation were assumed to be scatter free arrival The results show that the propagation in corona does not depend on particle energy in 4 - 500 MeV protons, and the time delays from optical flare do not depend on the distance between the flare site and the base of the interplanetary magnetic field which connects to the earth

1. Introduction

Energetic particles accelerated in a solar flare play an important role in the flare energetics. Because of the propagation effects, however, it is very difficult to know the total energy of all particles in a flare using particle data observed at interplanetary space. There are two propagation effects ; one is coronal propagation from the flare site to the point where they are released from the sun to the interplanetary space , and the other is interplanetary propagation from that point to the earth. Many studies have been done for both propagation processes (Ma Sung et. al. 1975, Schatten and Mullan 1977, Mullan 1983 for coronal propagation and Jokippi 1971, Earl 1976, Ma Sung and Earl 1978, Owens 1983 for interplanetary propagation). Using 80 solar flare data, Ma Sung et. al. showed that particle propagation is independent of both rigidity and energy This is very hard to understand with normal diffusion processes such as proposed earlier by Reid 1964. Schatten and Mullan proposed a magnetic bottle model to interpret the fast non diffusive propagation in the corona

2. Observation and data presentation

The solar proton data were obtained from Japanese Geostationary Meteorological Satellite (GMS-1,GMS-2). The continuous data are available from February 1978 GMS-1 was switched to GMS-2 on December 21, 1981. The energy range of data used here is 4 - 500 MeV and 4 - 100 MeV for GMS-1 and -2, respectively. The differentially divided energy channels are seven and five for each.

We assumed that the coronal propagation effect can be separated from interplanetary one by selecting very fast rise time event only, which can be considered as scatter free propagation in the interplanetary space. We have chosen 18 events in the period from September 1977 to December 1982. The criterion of "fast rise" is not so severe but we selected having a rise time (from start of increase to the maximum) of less than a few hours We assume the time profiles at the base of the garden hose lines of interplanetary magnetic field which connect to the earth can be seen from these so-called scatter free events which means the modulation during the propagation in space can be neglected

Table 1 Scatter free arrival events observed by GMS-1, -2.

Date	G	Hα flare onset	location	imp	SID onset	imp	SWV km/sec	IMF deg	ρ deg
Sep 19 77	G	0955	N08 W57	3B	1028	3	330	W69	12
Sep 24 77	G	0539?							
Apr 11 78		1334+8	N22 W56	3	1401	3	505	45	30
Sep.23 78	G	1944+3	N35 W50	3B	0945	2+	340	66	32
Feb 17 79		1905	N16 W28	SB	1905	1-	310	73	50
Aug 21 79	G	0550	N17 W40	2B	0607	1-	600	38	10
Apr 10 81	G	1632	N08 W36	2B	1642	3	380	59	27
Apr 24 81		1346	N20 W50	2B	1348	2+	780	29	32
May 10 81		0715	N06 W73	1B	0717	1	340	66	11
Jul 20 81		1310	S26 W75	1B	1310	1	410	55	37
Jan.31 82		0020E	S13 E08	2N	2329)	3	(380)	59	66
Mar. 7 82		0308E	N17 W53	2B	0303	2	370	61	25
Jul.22 82		1648	N16 W89	1F	1645	2+		55	35
Nov.22 82		1741	S11 W36	1N	1742	2		55	23
Nov 26 82		0230	S11 W86	2B	0235	2		55	33
Dec.17 82		1820	S07 W20	3B	1820	3		55	35

G: Ground level enhancement, SWV. Solar Wind Velocity
ρ: angular distance between flare site and the base of IMF

Fig 1 gives intensity time profiles of typical example of a flare of August 21, 1979 Time A means the Hα flare start. The two lines in the each energy channel indicate the time delay band from optical flare observation assuming the travelling distance of 1 2 AU with the particle speed corresponding to each energy band In the bottom of Fig.1, we can see that the intensity time profiles and the onset times of increase of all channels nearly coincide after correction of the propagation time For the other events, nearly the same tendency can be seen with two exceptions (May 7, 1978 and Dec 7, 1981), although the average shape of time profiles and the onset time delays from the optical flare are different from flare to flar- These 16 flare characteristics are summarized in Table 1. We understand the two exceptions are special cases which can be interpreted by some interplanetary modulation as already reported by Kohno and Wada 1979.

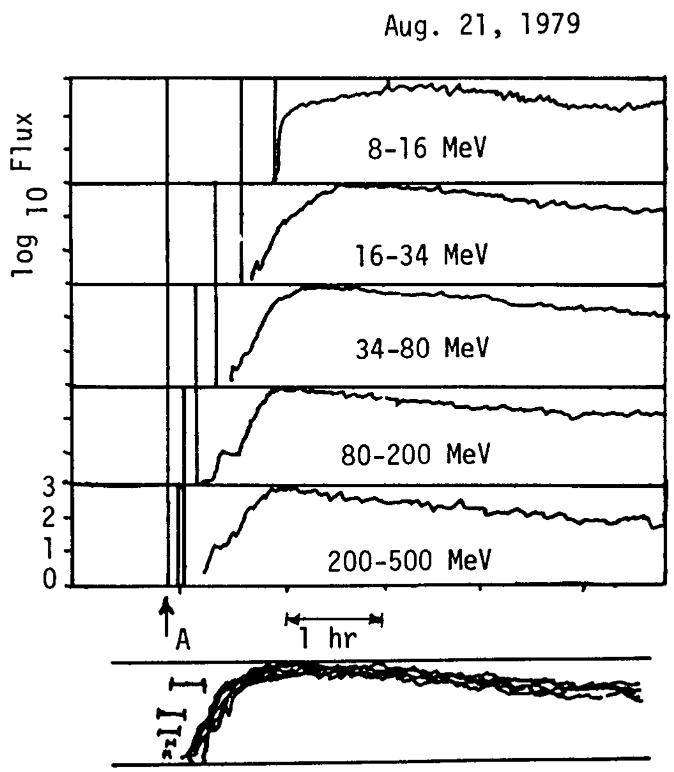


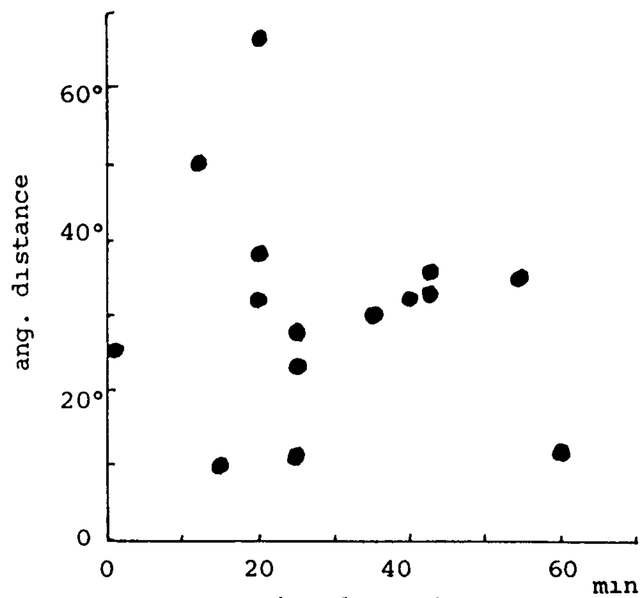
Fig 1 Examples of time profiles of two minutes averaged data normalized to the maximum flux. Time A shows the Hα start. two vertical lines in each channel indicate the time delay from optical observation depending on particles velocity of each channel

In order to see the dependence of the onset time delays from the optical flare on the distance between the flare site and the base of IMF which connects to the earth, we used the observed solar wind velocity data (King 1977, 1979) if available and mean value of 410 km/sec if not available These distances thus obtained are shown in the last column of Table 1. In Fig.2, the relation of this distance vs the onset time delay from optical flare is plotted. It is clear that there is completely no relation between the two parameters The mean value of the onset time delay from optical flare is about 30 minutes

3. Discussion and conclusion

What we have shown here can be summarized as ˙ i) When the travel times between the sun and the earth are adjusted, the intensity time profiles and the onset times of 4 - 500 MeV protons are almost same in a flare. ii) Distribution of onset time delays from optical flare has a mean value of 30 minutes and there is completely no relation with the distance between the flare site and the base of the IMF This is another proof of energy-rigidity independent propagation in corona in addition to the results of Ma Sung et. al. 1975. Schatten and Mullan have proposed the magnetic bottle model to interpret the rigidity-energy independent propagation in corona The bottles produced by flares serve as temporary traps of particles. They may have the dimension of half angle near 60° , which result in fast azimuthal propagation inside, and rather slow leakage from the bottle The present results of analysis may match to this model. Our mean time scale of particle release from that bottle is 30 minutes while their model suggests about 60 minutes

Fig 2
Relation of particle increase onset time delays from optical flare vs the distance between the flare site and the base of IMF As shown in Table 2, no appropriate flare was found for one sample out of 16.



Mason et al (1984) also showed that there is no correlation between the relative abundances and separation angle, nor is there a significant correlation between the sizes of the relative abundance fluctuations. They proposed from this results the possible large scale shock acceleration model. Our results also support their assumption

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