ORIGIN OF CORONAL AND INTERPLANETARY SHOCK AND PARTICLE ACCELERATION OF A FLARE/CME EVENT

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ABSTRACT

By using radio data from ground-based telescopes (from 270 MHz to 25 MHz), and from the Radio and Plasma Wave experiment (WAVES) on board the WIND spacecraft (1-14 MHz and several kHz-11 MHz), as well as FY-2 satellite data, the origin of coronal and interplanetary shock and particle acceleration of the 14 July 2000 flare/CME event (the Bastille day event) have been studied. Main conclusions are as follows: (1) We investigate the causal relationship between metric type II bursts observed by the digital IZMIRAN radio spectrograph and type II radio emissions in the frequency range from 1-14 MHz and several kHz-11 MHz observed by the WAVES/WIND. The analysis indicate that the fast CME is the origin of both coronal and interplanetary shocks. (2)According to the time profiles of Hard X-ray, and energetic particles (include proton, ^{3}He, and ^{4}He) from FY-2 satellite, it is obvious that the Bastille day event is the event, in which both impulsive and gradual phenomena occur. The energetic particles accelerated not only in flare but also in CME.

INTRODUCTION

It is widely accepted that type II radio bursts are generated by shocks propagating through the solar corona or interplanetary medium, and metric type II and interplanetary type II radio emissions are of different origin. Metric type II bursts are believed to be generated by coronal shocks driven by flare, whereas interplanetary type II radio bursts are generated by interplanetary shocks driven by coronal mass ejections (CMEs). With the launch of the Wind spacecraft, it offers a good chance to study the relationship between metric and interplanetary type II bursts. More recently, Cliver (1999) has suggested the view that both metric and interplanetary type II radio bursts are generated by fast CME-driven shocks.

For nearly more than 30 years it was thought that all solar energetic particles (SEPs) were accelerated in solar flare. During recent years, observations have revealed two distinct populations of SEPs-gradual and impulsive event. The former is associated with CME, and another one is associated with impulsive flare. The properties of gradual and impulsive events are summarized by Reames (1996). Cliver (1996) has suggested that this simple two-class division requires the addition of a new class of hybrid-events with a mixed composition of flare and shock-accelerated particles.

A large number of papers have already been published on Bastille day event (Reames et al 2001, Tylka et al 2001, Lepping et al 2001). In this paper, by using both data from ground-based telescope and spacecraft, we present that fast CME is the origin of both metric and interplanetary shock. Second, from FY-2 data, it is obvious that the Bastille day event is a mixed event, in which both impulsive and gradual phenomena occur.

DATA

A solar flare, X5.7/3B, occurred on 2000 July 14 in the NOAA active region No. 9077, located close to the disk center at N22 and W7. The GOES soft X-ray flux started to increase at 10:03 UT and peaked at about 10:24 UT. In association with this flare a bright, fast, halo coronal mass ejection (CME) was observed. A large fast ”halo” CME, first visible in the west side of the LASCO/SOHO instrument at 10:42UT, was observed by C2 and C3 coronagraphs

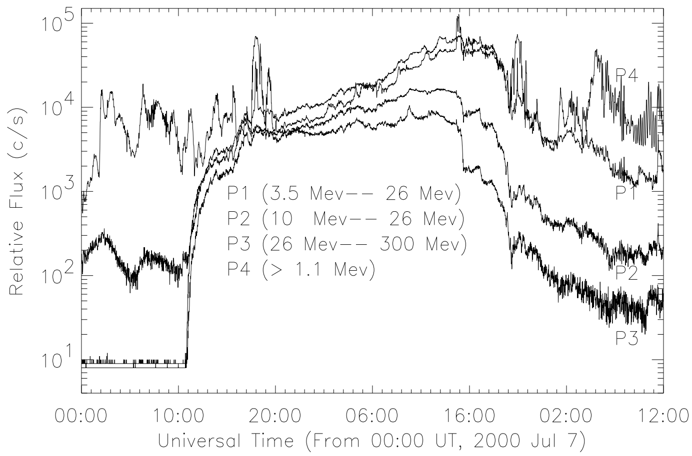

Fig. 1. Time history of solar proton flux from FY-2 satellite

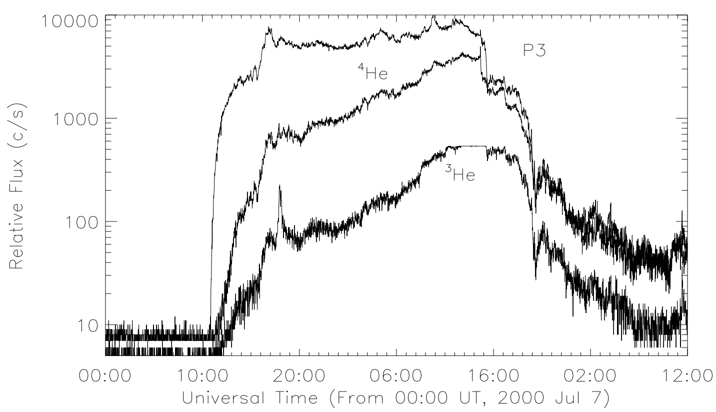

Fig. 2. Time history of solar particle flux from FY-2 satellite

(Andrews 2001).

The dynamic spectra observed by the digital IZMIRAN radio spectrograph (http://helios.izmiran.rssi.ru/) and the lower frequency WAVES spectrum (http://lep694.gsfc.nasa.gov/waves.html) during the 14 July 2000 event have been obtained. Particle data from FY-2 satellite in the ranges 3.5-300 Mev, 3.5-26 Mev for proton, ^{3}He and ^{4}He respectively, in the ranges 20.0- 38.1 kev for hard X-ray, by the Space Particle Monitor(SPM) (Lin Hua- An et al, 2000)were obtained(Figure 1, Figure 2 and Figure 3).

ANALYSIS AND RESULTS

It often happens that a flare and the lift-off of a CME occur almost simultaneously during the flare/CME event. This makes it difficult to distinguish which of these coronal disturbances is responsible for the observed type II radio emission and particle fluxes enhancement.

When trying to study the causal relationship between a metric type II burst and a kilometric type II burst, it is necessary to consider the physics of the shock dynamics through the solar corona (Reiner et al., 1999). The shock propagation through a given corona model which determines the observed frequency drift rate for a type II radio burst, this frequency drift rate determine the shock dynamics.

The digital IZMIRAN radio spectrograph reveals narrow-band type II bursts at 10:18.9 UT-10:26.3UT and 10:24

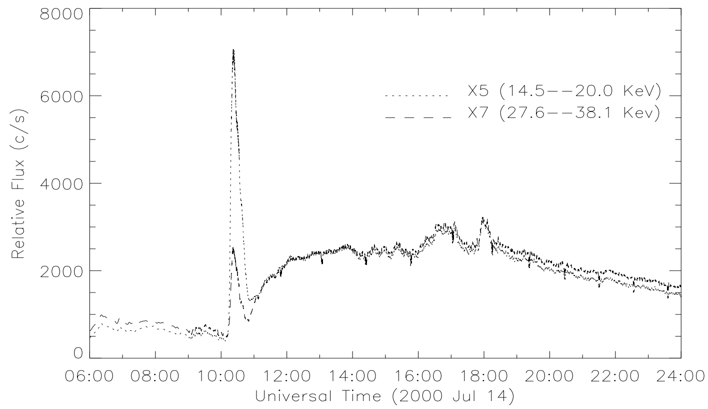

Fig. 3. Time history of hard X-ray from FY-2 satellite

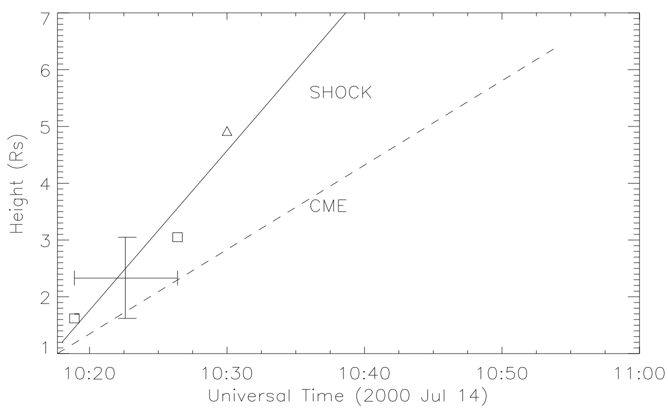

Fig. 4. Linear fit shows a single CME-driven shock (solid line) connects the coronal type II and the interplanetary type II bursts. The horizonal and vertical bar denote the temporal and spatial duration of the coronal type II burst respectively (also showed by the little squares). The little triangle denotes the start of interplanetary type II bursts. The CME's propagation is illustrated by the dash line.

UT- 10:34 UT, covering the frequency range of 175 MHz-35 MHz and 150 MHz-45 MHz respectively. By importing the empirical atmosphere model developed by Sittler & Guhathakurta (1999), and assuming that type II bursts are generated in upstream region of shock where the density may increase by 3 times (Reiner et al., 2001), we obtain the two shocks' speed, 2255km/s and 1867 km/s, respectively. The LASCO's observations show that the CME also has a high speed of 1674 km/s and its lift-off time is about 10:17:40 UT. The good relationship between the former shock and the CME in timing and speed makes us believe this shock is presumably driven by the CME. In the lower frequency WAVES spectrum, extremely broadband type II bursts started at about 10:30 UT with the frequency 14 MHz, the upper limit of the instrument, and lasted for more than one day. It is in general believed that interplanetary type II bursts are produced by electrons accelerated by at discrete locations along the shock, driven by relatively fast CMEs. Linear fit is incorporated to establish whether the type II bursts observed by WAVES/Wind instrument are generated by the same shock in low corona. Although this fit is not precisely, but it is reasonable (Reiner et al., 2001). Figures 4 shows our fit connects the IZMIRAN and WAVES type II bursts. It can be concluded that the coronal (evidenced by IZMIRAN type II emissions) and interplanetary (evidenced by WAVES type II emissions) shocks have the same driver agency, that is, the fast CME.

From Figure 3 we can see that it shows both impulsive and gradual enhancement in hard X-ray emission. From

Figure 2, the ratio of ^{3}He/ ^{4}He is about 0.1 in the energy range of 3.5-26 Mev/ nucl and much larger than the coronal value (about 0.0005). Usually ^{3}He enhancement is a valuable diagnostic of the impulsive flare acceleration. But recently Mason et al (1999) suggested that suprathermal ions may be a source population that is available for further acceleration by interplanetary shocks that accompany large SEP events, thereby leading to the 3He enhancement in a significant fraction of large SEP events. From figures 1 and 2, we can also see that the proton, ^{3}He,and ^{4}He are accelerated not only in flare but also in the shock driven by the CME. Since late in the event the reconnection may stop, but the shock acceleration continues far out in the heliosphere, lasting for the time scale of days. About ^{3}He acceleration in this event, we study it in another paper.

CONCLUSIONS

The conclusions of this paper can be briefly summarized as follows:

(1)The analysis indicate that the coronal (evidenced by IZMIRAN type II emissions) and interplanetary (evidenced by WAVES type II emissions) shocks have the same driver agency, that is, the fast CME.

(2) The Bastille day event may be a ^{3}He-rich event, and mixed event, in which both impulsive and gradual phenomena simultaneously occur.

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