Time Determination of March 1991's CME Hitting Magnetosphere

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Abstract

The paper analyzes the sudden change in galactic cosmic ray (GCR) intensities caused by coronal mass ejection (CME) in March 1991 by using wavelet method to determine the moment of the CME hitting the magnetosphere. The results show that the moments of sudden change in GCR intensities observed at different stations are not the same meaning that the CME struck the magnetosphere on the skew. The sudden change in GCR intensities is caused by the CME and the moment of the CME reaching the magnetosphere was slightly earlier than 1021 UT, 24 March 1991.

1. Introduction

Solar active regions 6583,6545 and 6555 produced very intensive explosive activities causing a series of very intensive interplanetary, magnetosphere and other geophysical effects. A severe geomagnetic storm with sudden commencement was observed at 0342UT, March 24,1991. The Fig.1. shows the Dst index during the geomagnetic storm. The sudden commence of the geomagnetic storm was very strong. Many papers have been devoted to the event study. There was not a satellite in a suit position to observe the solar wind plasma so we can't know when the coronal mass ejection (CME) reached the earth. This paper tries to solve the problem.

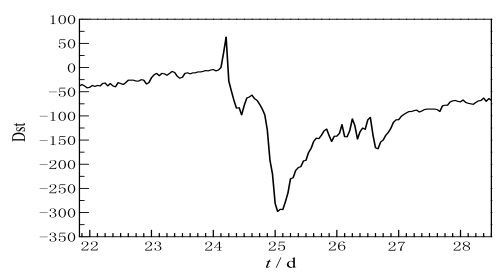

Fig. 1. Index of Dst (March 1991)

2. Data analysis

Decrease in the cosmic ray count rate caused by the CME recorded by McMurdo station and Beijing station shown in Fig.2. and Fig.3., respectively.

pp. 3601–3604

Also we present the CR intensities in vertical direction and south, north direction observed at Guangzhou station shown in Fig.4. and Fig.5., respectively. From the Fig.2. we can see that there were three times decrease in GCR intensities observed at MuMurdo station obviously. This properties were consistent with the conclusions got by Gao et al that there were three times disturbance in geomagnetic activity caused by the interplanetary disturbances. As if there were only two times decrease in GCR intensities observed at Beijing station shown in Fig.3. or the three times decrease were not obvious. There are always shock causing sudden commence of geomagnetic disturbance before CMEs. So we can know that the moment of CME reaching magnetosphere must be later than 0342UT, March 24,1991.

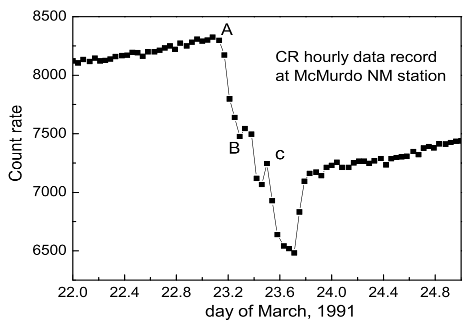

Fig. 2. The GCR intensities observed at Mumurdo NM station

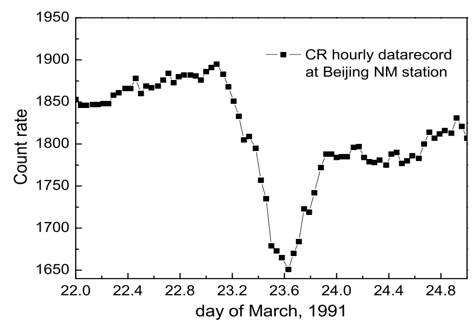

Fig. 3. The GCR intensities observed at Beijing NM station

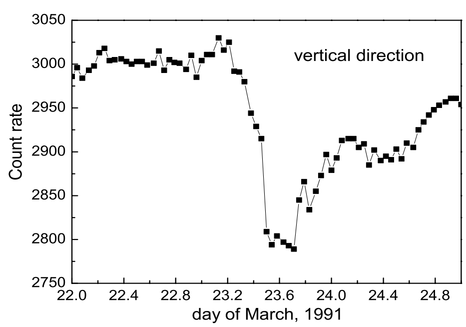

Fig. 4. GCR intensities in vertical direction

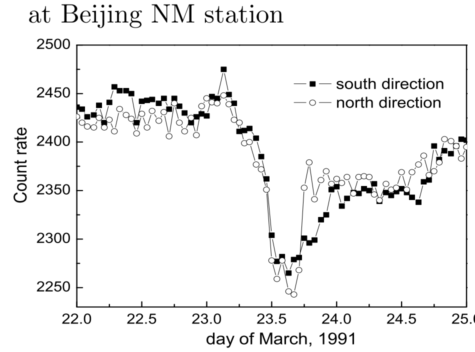

Fig. 5. GCR intensities in south and north direction

(data observed at Guangzhou station)

3. Wavelet analysis of the data

When a CME reaches the magnetosphere it often causes decrease in GCR intensities suddenly. One of the biggest advantages of Wavelet analysis is that it can find the sudden change point of a signal.

For Gauss function $\theta(t) = \exp(-t^2/2)/\sqrt{2\pi}$,

$\psi^{(1)}(t) = \frac{d\theta}{dt} = -t\exp(-t^2/2)/\sqrt{2\pi}$, $\quad \psi^{(2)}(t) = -\frac{d^2\theta}{dt^2} = (1-t^2)\exp(-t^2/2)/\sqrt{2\pi}$,

then

$$W^{(1)}f(t) = f*\psi^{(1)}(t) = \int f(\tau)\frac{d}{dt}\theta(t-\tau)d\tau = \frac{d}{dt}\int f(\tau)\theta(t-\tau)d\tau = \frac{d}{dt}[f*\theta(t)] \quad (1)$$

$$W^{(2)}f(t) = f*\psi^{(2)}(t) = \int f(\tau)\frac{d^2}{dt^2}\theta(t-\tau)d\tau = \frac{d^2}{dt^2}\int f(\tau)\theta(t-\tau)d\tau = \frac{d^2}{dt^2}[f*\theta(t)] \quad (2)$$

The sudden change point of the signal $f(t)$ corresponds to the zero point of $W^{(2)}f(t)$. We can find the sudden change point of the signal by finding the zero point of $W^{(2)}f(t)$ using formula (2). The results of sudden changes in GCR intensities are shown in Fig.6. for Beijing station, Fig.7. for vertical direction of Guangzhou station data series and Fig.8. and Fig.9. for south and north direction of Guangzhou station, respectively.

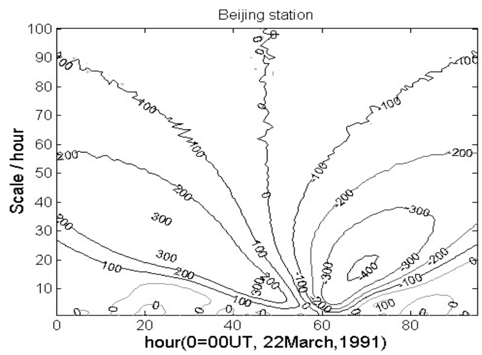

Fig. 6. Sudden change for Beijing station

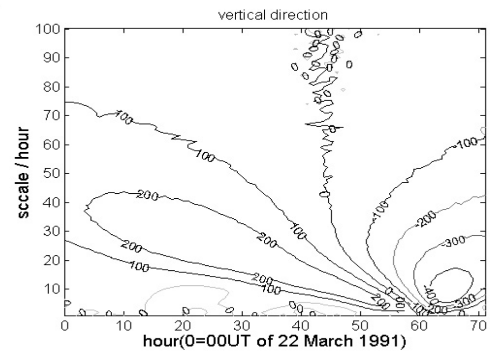

Fig. 7. Vertical direction sudden change for Guangzhou station

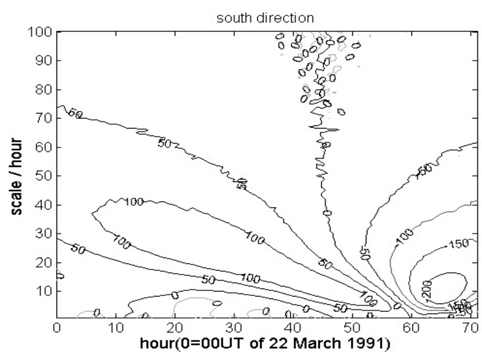

Fig. 8. South direction sudden change for Guangzhou station

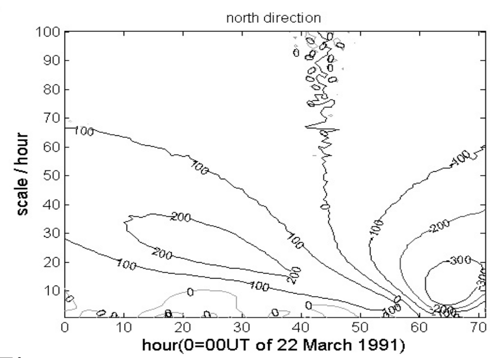

Fig. 9. North direction sudden change for Guangzhou station

The moment of sudden change for the Beijing station was 102053 (hhmmss) UT, 24 march 1991. The moment of sudden change for vertical direction of Guangzhou station was 103730 (hhmmss) UT, 24 march 1991. The moment of sudden change for south and north directions of Guangzhou station were 105212 (hhmmss) UT, 105320 (hhmmss) March 1991, respectively. Form these data we know that the moments of sudden change caused by the CME is not the same. This may reveal that the CME hit the magnetosphere on the skew. All the sudden change moment were later than SSC of the geomagnetic storm, so we can judge that the moments of sudden change in GCR intensities must be caused by the CME. Because the sudden changes in GCR intensities are caused by the CME, so we can judge that the CME hit the magnetosphere slightly earlier than 102053 (hhmmss), 24 March 1991. Because the SSC is 0342UT, March 24,1991 and the time of CME hitting the magnetosphere was slightly earlier than 102053 (hhmmss) UT, 24 March 1991, so the distance between the shock front and CME is about 0.22288AU (average speed of solar wind (about 1400km/s) times time), so the CME and the shock driven by the CME is very big.

4. Conclusions

The CME struck the earth on the skew. The time that the CME hit the magnetosphere was slightly earlier than 102053 (hhmmss) UT, 24 March 1991. The distance between shock front and CME is about 0.22288AU.

Acknowledge: The Dst index used in this paper is obtained from the website: http://swdcwww.kugi.kyoto-u.ac.jp/dstdir/dst1/final.html,while the data shown in Fig.2. is obtained from website:http://www.bartol.udel.edu/~pyle/bri_table.html.

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