29th International Cosmic Ray Conference Pune (2005) **00**, 101-104

The Solar Event on 20 January 2005 observed with the Tibet YBJ Neutron monitor observatory.

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The X7.1 class flare of 20 January 2005 has produced a ground level enhancement (GLE) event which was observed with several neutron monitor observatories. The Tibet Yangbajing Neutron monitor (here after YBJ NM) located at the existing highest cutoff observatory has also observed this event as 6:49 UT onset time of GLE and 2% of peak excess from background. This indicates an extremity hard spectrum of solar nucleons accelerated near the Sun associated with this solar flare. According to the RHESSI measurement, nuclear de-excitation line flux has increased between 06:44 UT and 07:00 UT. We calculated YBJ NM response function and also survey the relativistic solar neutrons for this event.

1. Introduction

Series of solar flare has been produced at active region 710 start from January 16 2005 till active region moved around the back side at January 22. While this flares, many observatories observed this phenomenon. Solar flare on January 20 produced the hardest and most energetic proton event of Cycle 23. GOES observed X7.1 flare onset 06:35 UT January 20, 2005. The >100 MeV protons peaked at 07:10 UT was the highest >100 MeV proton flux level observed since 1989 October. LASCO onboard SOHO observed CME launch around 6:40 UT. Radio type II and III has measure onset 6:44 UT. RHESSI has measure nuclear de-excitation line flux onset at 6:44 UT (private communication G.H. Share, 2005).

While these flare, many neutron monitors observed relativistic solar nucleon event, GLE. Figure 1 show 13 neutron monitors count rate increases (in percent) between 06:00 UT and 10:00 UT on January 20, 2005. Intensity time profiles have been ordered by low to high cutoff rigidity station in this figure. GLE onsets were around 06:48 UT and high latitude observatory measured up to 400 % of increase. As figure 1b show, some of the mid-low latitude observatory which has high rigidity cutoff also observed small increases.

In this paper, we report January 20, 2005 event observed with YBJ NM including with other neutron monitor observations.

2. Observation

The Tibet YBJ neutron monitor observatory station is located at 30.11N 90.53E, 4300m above sea level [6]. YBJ NM consists with 28 counters of NM-64 and counting rates is 10^7 counts/hour which is highest count rates of reliable neutron monitors even with high cutoff rigidity as 14.1GV.

Due to this high cutoff rigidity, YBJ NM have not observe GLE from the previous observation. However, while these flare YBJ NM also observed GLE. Figure 2 shows YBJ NM count rate increases (in percent) between 0600UT and 1000UT on 20 January 2005. Top and bottom panel are count rate increase (in percent) of neutron monitor single counts rate and multiplicity 1. Onset of GLE was 0648UT and peak intensity was ~ 2% at 0705UT.

3. Modeling of GLE

Instead of using whole neutron monitors including high cutoff station which has wide opening viewing direction, we restrict to use only low cutoff station to study anisotropy of this GLE. (cf. [2], [5])

8 neutron monitors shown in figure 1a were fitted to the simple first-order function

$$f(\theta,\phi) = n(1+\xi_x \sin\theta \cos\phi + \xi_y \sin\theta \sin\phi + \xi_z \cos\theta) \quad ...(1)$$

where $f(\theta,\phi)$ is the intensity measured by a station with an asymptotic viewing direction defined by θ (colatitude) and φ (longitude), n is the particle density, and (ξ_x, ξ_y, ξ_z) are the three components of the anisotropy vector.

Results of the first-order fit are shown in figure 3. Top panel shows cosmic ray density expressed as in percentage from Galactic cosmic rays background. Bottom panel shows anisotropy defined as $\xi = \left(\xi_x^2 + \xi_y^2 + \xi_z^2\right)^{1/2}$.

a)

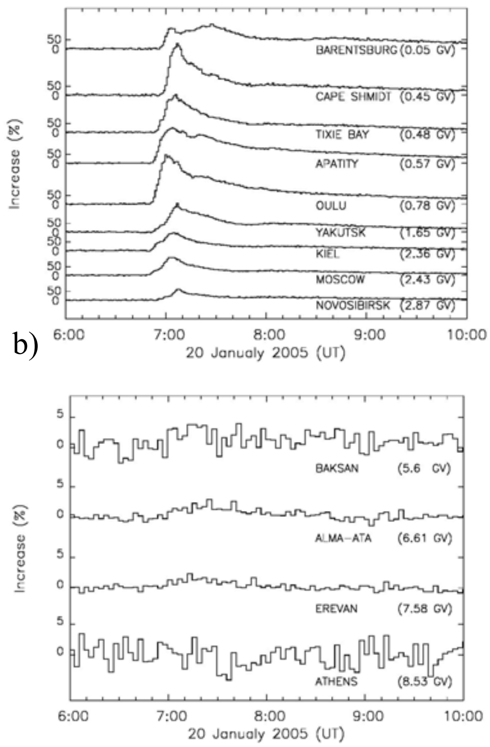


Figure 1. Neutron monitor count rate increases (in percent) between 0600UT and 1000UT on 20 January 2005. From top to bottom, each station has been order by low to high cut off rigidity. Each station name and cutoff rigidity is shown as well.

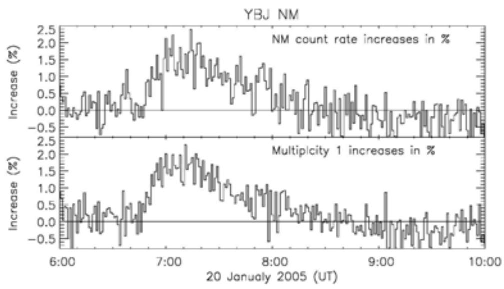
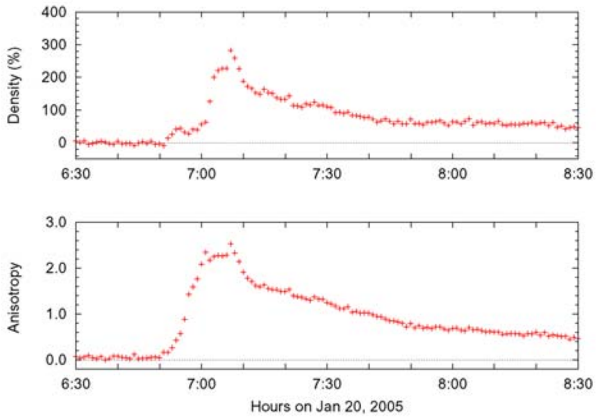


Figure 2. GLE observed by YBJ NM. Top and bottom panel shows, count rate increase (in percent) of neutron monitor single counts rate and multiplicity 1.



This high latitude neutron monitor's spatial anisotropy represents a relativistic solar nucleons event spatial distribution. Assuming this spatial distribution dose not change with energy, this spatial anisotropy can able to adapt to YBJ NM observations. Using YBJ NM's wide asymptotic cone will enables to determine the high-energy solar proton spectrum.

4. Search for the solar neutron event

Before few minutes while GLE occurred, YBJ NM observed pre-increase. This pre increase has seen between 0634 UT and 0643 UT and peak intensity was 1.2 % at 0637 UT. This time profile have very likely of relativistic solar neutrons events. However RHESSI observation did not observe any event while this period and rather this time period, RHESSI has measure nuclear de-excitation line fluxes between 06:44 UT and 07:00 UT (private communication G.H. Share, 2005). Note we refer to nuclear de-excitation lines rather than the 2.2 neutron capture line. The capture line has a ~100 sec delay because of the time it takes for the neutrons to slow down. According to this RHESSI observation, even if relativistic solar neutrons exist while this event, arriving time partially overlaps with GLE. Note, high cutoff station such as YBJ NM usually does not response to GLE and able to detect the only the solar neutron.

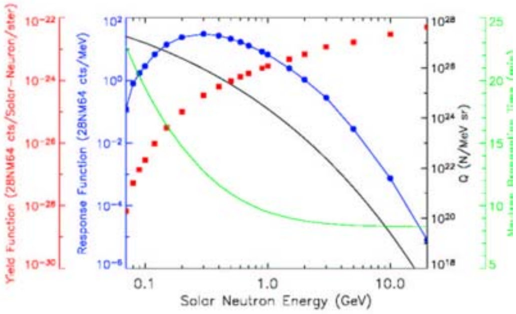


Figure 4. Yangbajing 28-NM-64 yield function versus energy for neutrons arriving 51degree from zenith (red squares), Chupp's [3] exponential spectrum (black curve), Yangbajing response function (blue), and propagation time of a neutron from the Sun to 1 AU (green).

Using a Monte Carlo code [4] to simulate high energy and nuclear transport through the atmosphere and through a 28-NM-64 neutron monitor, YBJ NM yield function for solar neutrons was calculated. (see also [1]). Figure 4 shows the yield function along with related quantities.
We assumed the relativistic solar neutron spectrum as,

$$Q = A \times 10^{B} E_n^{3/8} \exp\left[-(E_n / 0.016)^{1/4}\right], \quad \ldots(2)$$

where Q is the spectrum in units of (sr MeV)$^{-1}$, and E_n is neutron energy in MeV. Upper limit of relativistic solar neutrons are estimated from YBJ NM observation.

5. Acknowledgements

Apatity neutron monitor data were kindly provided by the Polar Geophysical Institute of the Russian Academy of Sciences (PGI, Apatity); we also thank the Oulu Neutron Monitor for the use of their data. Neutron monitors of the Bartol Research Institute and this work was partially supported by the U.S. National Science Foundation under grant ATM-0000315.

References

[1] J. W. Bieber et al., GRL, 32, L03S02 (2005).
[2] J. W. Bieber et al., ApJ, 601, L103-L106 (2004).
[3] E. L. Chupp, ApJ Suppl., 73, 213 (1990).
[4] J. Clem and L. Dorman, Space Sci. Rev., 93,335 (2000).
[5] J. L. Cramp et al., JGR, 102, 11, 24,237 – 24,248 (1997)
[6] T. Kohno et al., 26th ICRC. Salt Lake, (1999) 6, 62.