Observation of the 2005 January 20 GLE Event Using Yangbajing Solar Neutron Telescope & Neutron Monitor*

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Abstract A solar cosmic rays Ground Level Enhancement(GLE) event associated with a X7.1/2b solar flare in 2005 January 20 was observed by the Yangbajing solar neutron telescope(SNT) and neutron monitor(NM), located at Yangbajing Tibet(90.53°E, 30.11°N, 4310m a.s.l) with the highest vertical geomagnetic cut-off rigidity of 14.1GV in NM network. The statistical significance of the counting rate enhancement recorded by solar neutron telescope in >40MeV channel was 3.7σ in the time window of 07:00—07:05UT and 6.0σ in the time window of 07:00—07:20UT, respectively. The onset time of 06:51—06:52UT for this GLE event was clearly observed by the Yangbajing NM. Our observation indicates that solar protons have been accelerated up to energies of >10GeV during this solar event.

Key words solar flare, Ground Level Enhancement(GLE) event, Forbush decrease, neutron monitor, solar neutron telescope

1 Introduction

It is well known that solar energetic particles (SEPs) accelerated in eruptive solar events may produce a solar cosmic ray flux enhancement near the earth and be registered by ground-based detectors, such as neutron monitors (NMs) and solar neutron telescopes(SNTs). Since the first GLE observation in 1942[1], 68 GLEs have been recorded and 14 of them occurred in current solar cycle[2, 3]. However, few events have been seen by the Yangbajing NM and SNT since their operation due to high geomagnetic cutoff rigidity. Therefore, the data about solar particles with energies above 10GeV[4] are rarely available at Yangbajing. In worldwide network of solar cosmic ray database, there are still limited observations to demonstrate acceleration of protons or ions beyond 10GeV[5—7]. The study of big GLE events allows us to obtain more information about solar flare process and acceleration mechanism of protons or ions.

On 20 January 2005, an intense solar flare (X7.1/2b) produced at solar active region 10720 was observed by GOES and other spacecraft-based detectors. Its optical heliographic coordinates was N12W58. The soft X-ray (SXR) began at 06:36 UT and ended at 07:26UT with a peak at 07:01UT. The solar fluxes measured by GOES11 for >100MeV protons reached a maximum amplitude of 652pfu at 07:10UT. Also the solar flare was accompanied by radio emissions and energetic CMEs. A large Type Ⅱ radio emission with 8,400sfu Tenflare occurred at 06:44UT and a Type Ⅳ radio swept at 06:43UT. At

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06:54UT CME first appeared in the LASCO[8] field of view and a strong interplanetary shock driven by CME was observed after about 23 hours. The total IMF field intensity rapidly increased to 38nT, the solar wind speed also rose quickly to a maximum of 987km/s at 19:26UT on January 21, 2005. During this flare SOHO also observed the rapidly increased fluxes of X-rays and low energy protons. As recorded by RHESSI, γ ray (25—100MeV) fluxes increased at 06:45:30UT indicating the production of protons with $E_{\rm P}>$200MeV[9].

On the ground, ∼30 NMs in the world observed this high energy event, including the Yangbajing NM and SNT which have so high geomagnetic cutoff rigidity. It is the most intense solar proton event measured by GOES satellites since 1976 and the largest GLE recorded by neutron monitors since 1956. In the next sections of this paper, we will present our observation and some discussions.

2 Experiment and observation

The Yangbajing NM consists of 28 NM-64 neutron counters to record counts of single channels and multiplicity channels from one to eight which respond to higher energy[10]. And the Yangbajing SNT consists of 9m^2 scintillation counters with the thickness of 40cm and four layers of proportional counters which can identify the arrival direction of the higher energy neutrons($E>$240MeV). The scintillation counters are surrounded by the anticoincidence proportional counters(PRCs) to veto cosmic ray charged particles. The pulses of recoil protons converted by lower energy incident neutrons in scintillator are discriminated with four levels which correspond to the energy of >40MeV, >80MeV, >120MeV, >160MeV (we designate ch1, ch2, ch3, ch4 correspondingly). Details of the detector can be found in other papers[11—13].

The altitude of the station is 4300m a.s.l. and the vertical air mass is ∼606g/cm^2. It is the midday of Tibet from 06:36UT to 07:26UT, at which the sun is in the direction of zenith between 52° to 53°. The air mass for the line of sight to the sun was ∼997g/cm^2, while the path length of the neutrons from the sun to the earth at Yangbajing turns about to be ∼747g/cm^2 if neutrons are scattered by 6° after each scattering with an attenuation length 100g/cm^2 according to Refs. [14,15].

The sun was very active between January 17 and January 23. A Forbush decrease with the onset time around noon GMT on January 17 and a maximum amplitude of about 7% and 5.0% at the end of January 18 recorded by the Yangbajing NM and SNT, respectively, was found in Fig. 1., which are consistent with what had observed by ARGO-YBJ spt[16] and Jungraujoch neutron monitor[17]. During its recovery phase a sharp increase associated with the 2005 January 20 solar flare also appeared as shown in Fig. 1.

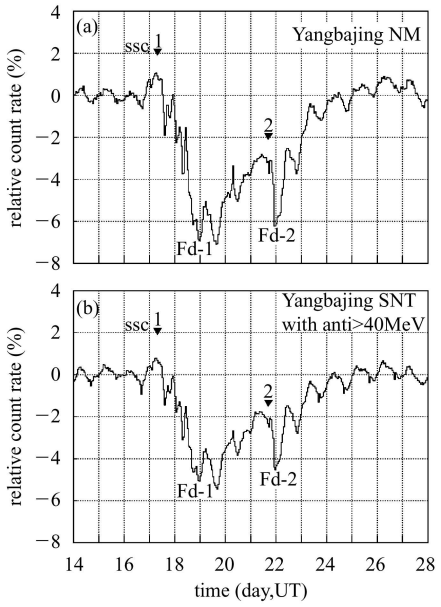

Fig. 1. The relative average hourly count rate of Yangbajing NM and SNT with >40MeV (exclude cosmic ray charged particles) for the time interval January 14—27, 2005.

The data recorded by the Yangbajing SNT during 04:00—10:00UT are shown in Fig. 2. A clear excess in ch1 was found in the time windows of 07:00—07:05UT and 07:00—7:20UT. The statistical significance of this excess is 3.7σ for the first time window and 6.0σ for the second time window, respectively. At the same time interval, however, no any excess was found in other channels (ch2,ch3 ,ch4).

The data of the solar neutron telescope are also analyzed according to the incidence direction of solar particles. In order to reduce the background of

galactic cosmic rays, for the sun's position and the refraction effect with neutron, 6 southernmost and northernmost directions from 81 directions are chosen to represent the solar direction and the anti-solar direction[18], respectively. The analysis is shown in the bottom panel of Fig. 2, and only 1.1σ excess was observed from the south(solar direction)during the interval of 07:00—07:20UT. There was also no clear statistical difference between the south and north direction during the time window of 07:00—07:20UT. The solar neutron telescope did not detect the higher energetic neutrons during this solar flare.

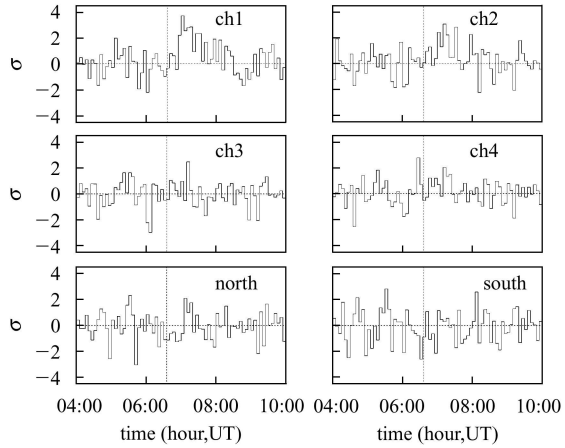

Fig. 2. Time profiles of counts (in sigma) in 4 low energy channels and 2 high energy direction channels of the Yangbajing SNT. Data are corrected with pressure and temperature. The background is fitted with data in 04:00UT—06:00UT and 08:30—10:00UT. The dashed line shows the onset time of this X-ray solar flare.

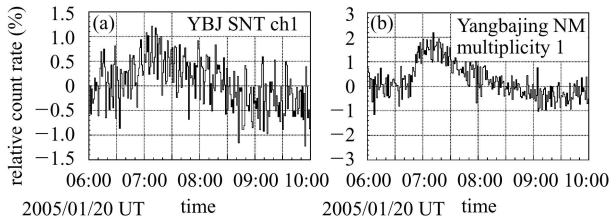

Fig. 3. Relative counting rates per 1 minute of the Yangbajing NM in multiplicity 1 and of the Yangbajing SNT in ch1.

Figure 3 shows the average counts per 1 minute of the Yangbajing SNT in ch1, and counting rates per 1 minute of multiplicity 1 of the Yangbajing NM during 04:00—10:00UT. A hump during 06:52—07:30UT was also seen in the left panel of Fig. 3. In the meanwhile the onset time of 06:51—06:52UT appeared clearly as shown in the right panel of Fig. 3.

3 Discussion and conclusion

Just as mentioned in the introduction, ∼30 NMs in the world observed this high energy event. The South Pole station had the highest amplitude of ∼5000% and showed an earliest sharp increase after 06:48 UT in the 1-minute data. The maximum counting rate was kept in the interval of 06:53—06:54UT[9]. The onset and peak time of some other NM stations were later, such as Inuvik NM with the onset time 06:55—06:57UT and the peak counts at 07:05—07:06UT on January 20 which are in coincidence with the observation at Yangbajing.

Apparently, the solar neutrons registered by the Yangbajing SNT were produced by the solar cosmic rays charged particles interaction with atmosphere nuclei when they entered the earth atmosphere, rather than directly from the sun. The solar protons and other ions could be accelerated to at least tens of GeV in big GLEs, solar protons in the famous 2000 Bastille Day event were accelerated up to 20GeV with the soft energy spectrum[19—21]. In this event the solar protons were accelerated up to higher energies due to its special associated performance, such as big x class flare, large Type Ⅱ radio emission, energetic and fast CME, as well as a good Sun-Earth connection[22].

It is a well acceptable fact that a small solar cosmic ray enhancement was recorded by both the Yangbajing SNT ch1 and the Yangbajing NM during 06:52—07:30UT on 20 January 2005 while other channels of the Yangbajing SNT did not record the signals for their higher threshold energy, and the solar protons were accelerated up to the energies above 10GeV in this event.

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羊八井太阳中子望远镜和中子监测器对2005年1月20日GLE事件的探测*

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摘要 西藏羊八井位于东经90.53°, 北纬30.11°, 海拔4310m, 垂直地磁截止刚度14.1GV. 2005年1月20日羊八井太阳中子望远镜和中子监测器探测到与X7.1/2b太阳耀斑相关的GLE事件, 其中太阳中子望远镜能量>40MeV的能道在5min (07:00—07:05UT) 和20min (07:00—07:20UT) 的时间间隔内计数率增长的统计显著性分别是3.7σ和6.0σ, 同时羊八井中子监测器也探测到计数率的增长, 初始时间为06:51—06:52UT. 观测表明在这次GLE事件中太阳质子可被加速到能量大于10GeV.

关键词 太阳耀斑 GLE事件 Forbush下降 中子监测器 太阳中子望远镜

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