SOLAR NEUTRON OBSERVATIONS DURING THE COMING SOLAR MAXIMUM:

A Plan on the Japan-China Collaborative Project

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ABSTRACT

Neutrons are sometimes released from solar flares accompanied by generation of high energy protons and other nuclei and some of them occasionally reach the earth before they decay radioactively. Together with the satellite observations on gamma ray and neutron emissions associated with such flares, the ground-based observations of these neutrons give us a clue to understand the possible nuclear interactions of those protons and nuclei with gases ambient in the solar atmosphere. A review is given on the Japan-China collaborative program on the ground-based observations of these neutrons for the coming solar maximum, though there still remain obstacles to be resolved.

It is known that non-thermal neutrons are sometimes produced in association with solar proton flares and then partly released from the sun into outer space (e.g., Chupp, 1984). Before they decay radioactively, some of these neutrons occasionally reach the sunlit side of the earth and are recorded by neutron monitors appropriately located on the earth.

On June 3rd of 1982, some of these neutrons were detected with gamma-ray spectrometer on board the SMM satellite and also the rest of them were recorded partly by the neutron monitors located at Jungfraujoch (Debrunner et al., 1983). Scientists interested in the high energy phenomena on the sun were urged to investigate, both experimentally and theoretically, all possible nuclear processes associated with the development of solar flares by using the data obtained from the direct access of the neutrons released from the sun into the earth's environment, since the observed results on the intensity-time profiles on the neutron flux can give us some crucial information to these processes in the solar atmosphere.

It has been shown that these neutron events are almost always associated with solar flares accompanied by the acceleration of high energy particles, both nuclei and electrons (e.g., Chupp, 1984). Because the occurrence frequency of these flares becomes higher as the solar activity increases, the neutron events tend to occur more frequently during the maximum phase than during the other phases of the solar activity (e.g., Sakurai, 1974). To investigate the characteristics of the solar neutron events and the details of the nuclear processes related to the production of neutrons in solar flares, the maximum phase in the solar cycle just begun in 1987 would, therefore, be the best period because solar flares accompanied by high energy phenomena are expected to occur frequently during this phase. As is well known to scientists engaged in the research for these phenomena on the sun, the Japanese program called Solar-A mission is under way with the aim to

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observe high-energy photon emissions from solar flares (e.g., Ogawara, 1987). Together with the ground-based observations on the solar neutrons, the observed results on these emissions would give us some insight essential for our understanding to the acceleration mechanism of high energy particles in solar flares and the nuclear interactions of these particles with gases ambient in the solar atmosphere, some of which are responsible for the production of neutrons (Ramaty et al., 1979).

As has been theoretically estimated, most neutrons are produced from the disintegrations of various atoms and ions ambient in the solar atmosphere which occur as the results of their interactions with accelerated nuclei in solar flares. After thermalization due to slowing down in their passsge through the solar atmosphere, a part of these neutrons are captured by hydrogen atoms ambient there as producing deuterons. Gamma-ray line emissions of 2.223 MeV are emitted simultaneously in association with the production of these deuterons (e.g., Ramaty et al., 1979). These emissions were detected many times by two solar observing satellites, SMM and HINOTORI from 1980 through 1982 (Chupp. 1984). When we refer to the history for the research on the nuclear processes in solar flares, it should be noted that the production of neutrons associated with solar proton flares has been known since the first detection of 2.223 MeV gamma-ray photons accompanied by large solar flares in August 1972 (Chupp et al., 1973).

The first ground-based observations of the neutrons released from the sun was made by the neutron monitors located at Jungfraujoch in association with a solar proton flare on June 3, 1982 (Debrunner et al., 1983). As cited earlier, some of these neutrons were also recorded by the gamma-ray spectrometer on board satellite SMM as shown in Fig. 1 (Debrunner et al., 1983). It seems clear that most neutrons were produced during the initial stage of the solar flare, although the arrival times of these neutrons were scattered between 1142 and 1152 UT because of the delayed arrivals of neutrons due to the dispersin of their energies.

In order to directly catch those neutrons with neutron monitors on the ground,

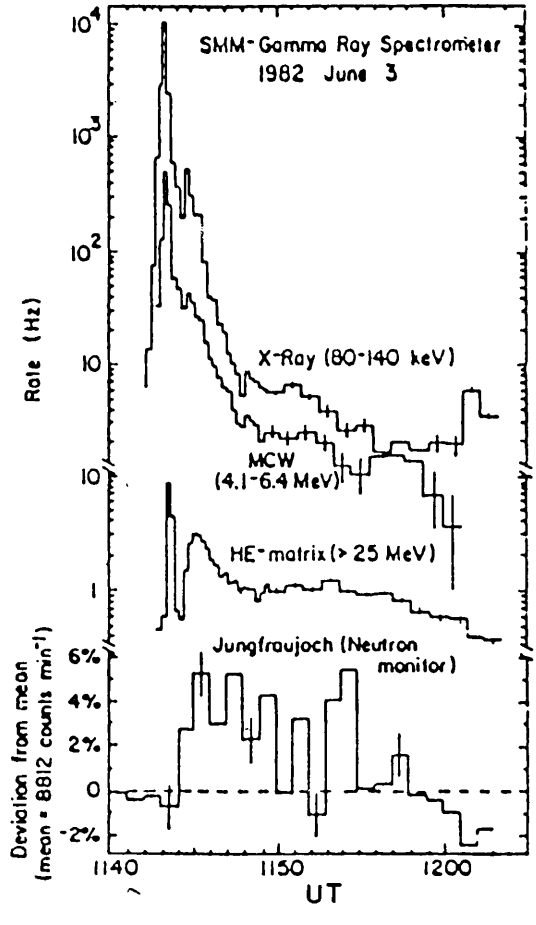

Fig. 1 High energy neutral emissions from a solar flare on June 3, 1982. The data on neutron flux were obtained at Jungfraujoch (Debrunner et al., 1983) (the lowest in the figure).

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these monitors should be located high up at the top of any high mountains or its neaby site near the equatorial region, because the earth's atmosphere is a burden as the absorber of these neutrons. Although it is, however, impossible to find such ideal observing stations in Japan, we have chosen the station near the top of Mt. Norikura (2770 m high, 36.1°N, 137.6°E) as an alternative. As one of the collaborative programs between us and Chinese scientists, Yangbajain has then been selected as an ideal site to this program. Its location is at 30.7°N, 90.3°E on the Tibetan plateau and 4300 m high above the sea level. Counting rates expected for incoming neutron flux and other parameters for these two stations are summarized in Table 1, in which the quality of neutron monitors and their characteristics are assumed as identical to both stations under the present plan (Takahashi, 1988).

Table 1

Station	Geographic Loc. Lat.°	Long.°	Altitude (m)	Cut-Off Rigidity(BV)	Counting Rate!	S/N (1 min)
Mt. Norikura	36.1N	137.6E	2770	11.4	16.8	4.0*
Yangbajain	30.7N	90.3E	4300	14.1	68.7	28.0**

!: E05/hr, *: The case for 10 monitors, **: The case for 18 monitors

It is clear that the detection efficiency for the solar neutrons can be improved much more for the observations at Yangbajain as compared to that for at Mt. Norikura. As indicated in Table 1, the signal to noise ratio for the counting rate of neutrons is also much improved at Yangbajain, too. Because of those merits, we have decided to establish the collaborative program as mentioned above between Chinese scientists and us for the observations of the solar neutrons during the coming solar activity maximum. According to our program for the years from 1989 to 1993, two observing stations at Mt. Norikura and Yangbajain are to take every opportunity to observe neutrons released from the sun in association with solar proton flares, since the success of this program would be considered as the one of the great contributions to the progress in the research for the high energy phenomena on the sun. At the present moment, however, we have been facing a problem related to the research fund, which seems inevitably attatched for some international cooperative programs. Even if so, we are ready to start our program at Mt. Norikura, since all of neutron monitors in use have been already up-dated and replaced by better ones in accordance with our plan.

According to the Japanese space program, at present, two Japanese satellites, Solar-A and Geotail, are to be launched under the international cooperation during the coming solar activity maximum. Together with the ground-based observations on the solar neutrons, the observed records from these two satellites on the high energy quanta and particle emissions from the sun would be a great contribution to the progress in the research on the high energy phenomena on the sun.

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Finally, it is noted that this is the program to be operated under the cooperation of scientists at the Research Institute for Physics and Chemistry, Rikkyo University, Kochi University and Kanagawa University. The Chinese program is to be operated at Institute of Space Physics, Beijing.

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