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SEARCH FOR SOLAR NEUTRONS USING NM-64 EQUIPMENT

N.J. Martinic, A. Reguerín, E. Palenque, M.A. Taquichiri
Chacaltaya Cosmic Ray Laboratory, University of La Paz
M. Wada, A. Inoue, K. Takahashi
Institute of Physical and Chemical Research, Tokyo

ABSTRACT
Two years (1980-1982) neutron monitor data from the Chacaltaya (geographic coordinates: N16.32°, W68.15°; cutoff rigidity: 13.1 GV; altitude: 5,300 m a.s.l.) station has been scanned; the sampling time of the 12NM-64 neutron monitor is 5 min. The nucleonic component increases have been correlated with 66 hard X-, gamma-rays satellite data from solar origin, as reported by several groups. We present typical neutron monitor time profiles of the events. Chree-analysis was performed discriminating the events according its solar coordinates. Ground data from solar limb locii are more enhanced at the time of the onset than other geometrically visible flares. We present also Chree histograms of neutron monitor out-put profiles from geometrically invisible events from the Chacaltaya station.

1. Introduction

The search for solar neutrons using evaporation neutrons of the nucleonic components of the cosmic rays detected by ground based instruments has led to scan out-puts of high altitude, high cutoff rigidity stations. The low attenuation length of such stations makes it possible to recognize additional, from solar origin, neutron enhancements one is expected to identify. On the solar surface neutrons are available as secondary particles of the interactions of energetic nuclei in the base of the corona; also, ^{1}H capture of neutrons radiate gamma lines of 2.22 MeV (Prince et. al., 1983). Other photons: the 0.5 MeV positron annihilation and the Π^0 decay furnishes the other gammas; the hard X-rays are produced via bremmsstrahlung from the enrgetic electrons.

We assume that a solar flare is related with some kind of acceleration mechanisms for electrons or/and protons and other species; and that neutrons (or the energetic photons) shall, in general, follow the trajectories of the accelerated parents. The latter has, in general, preferred directions, say, parallel to the solar surface. Less energetic neutrons and X-rays may be produced isotropically.

In this phenomenological analysis we assume that the neutron generationis impulsive (typical life-time: ≃ 100 s) and that at least 0.5 of the neutrons can escape the solar atmosphere. We present below statistical analyses of 66 solar events correlated to the ground based 12 NM-64 of the Chacaltaya station.

2. Data treatment

From the 66 solar events we investigate, we show in Fig. 1 a typical time profile as seen by the 5-min Chacaltaya monitor. The short sample of 3 hours exhibit an increase synchronic with the onset time of the reported satellite data; however, notice other increases more important than the former one. The sigma, σ, of this short sample is 0.3 % taken during 6 hours data. As can be checked on Table III, the parent flare was a limb one and the onset was on 21:15 of Dec. 23th 1980. It was a short lived

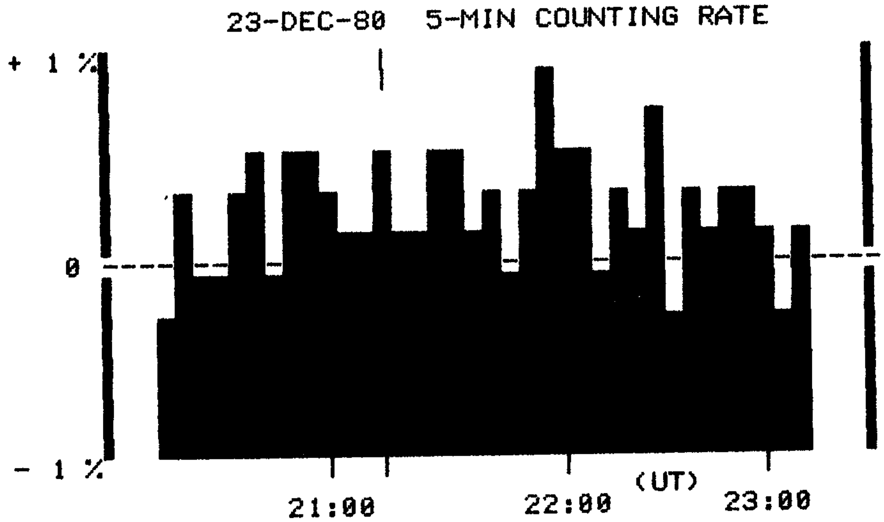

Fig.1: Nucleonic component NM-64 time profile.
The solar gamma ray event is shown with a dash.

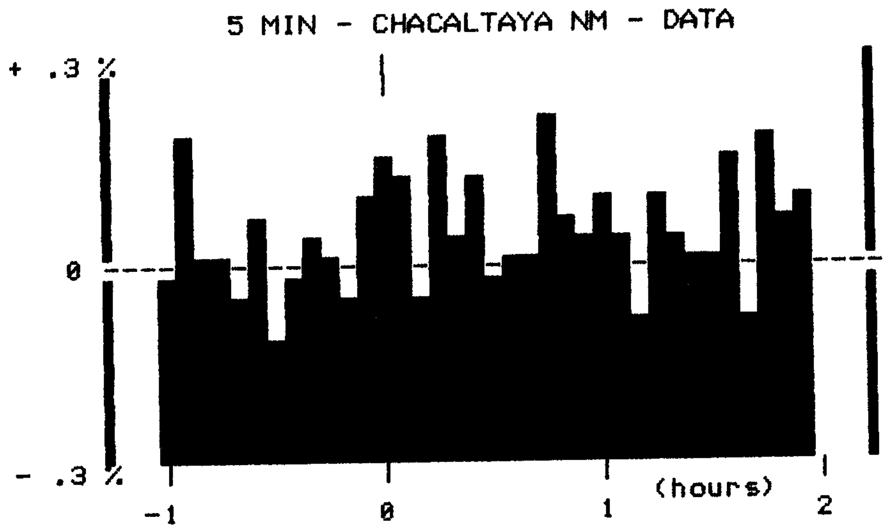

Fig.2: Chree Analysis of 11 visible gamma or X- flares (see Table III).
The ordinates are given in % of 6-hour mean value. The total length of the plotted data is three hours. The onset of the event is shown with a dash.

flare (15 s) with a peak emission above 0.3 MeV photons according to the SMM data; the GOES classification is M3. A special feature of this profile is that it appears en enhancement more or less continuous of the monitor data one hour before and one hour after the flare onset.

Fig. 2 illustrates a Chree analysis of 11 solar events when the sun is above the horizon (see Table III); the flare location is correlated with the limb of the sun. The criterion: If the solar longitudes are larger than 70°, then they belong to this group. The increases associated with these flares can be seen clearly on the onset of the event, above the statistical fluctuations. In Fig. 3 we present a superposed epoch analysis centered on the onset of the parent flares with coordinate positions on the disk

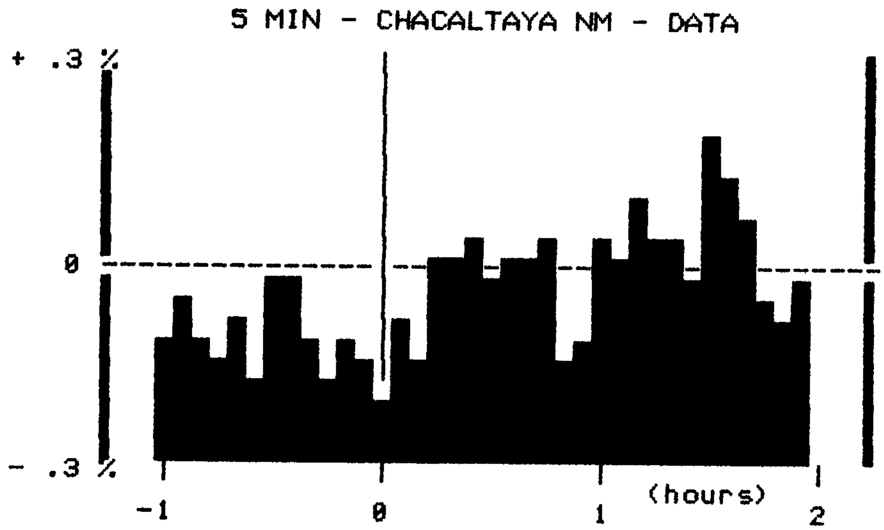

Fig.3: Chree Analysis of 21 visibles gamma or X- flares (see Table II). The ordinates are given in % of 6-hour mean value. The total length of the plotted data is three hours. The onset of the event is shown with a dash.

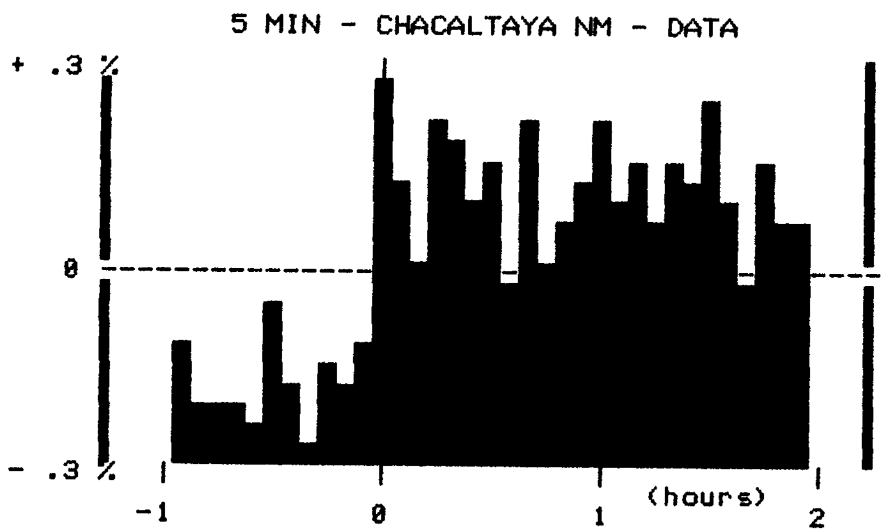

Fig.4: Chree Analysis of 16 invisible gamma or X- flares (see Table I). The ordinates are given in % of 6-hour mean value. The total length of the plotted data is three hours. The onset of the event is shown with a dash.

when the sun is above the Chacaltaya horizon. (Cf. Table II). The short plotted sample illustrates a smooth increase, starting at the onset time; no peaks can be observed. Among these events no discrimination was taken into account with the solar zenith angle as seen by Chacaltaya. Finally, Fig. 4 illustrates the histogram of a superposed epoch analysis of 16 solar events with coordinates on the solar disk (their solar longitudes are less than 70°) when the sun is below the Chacaltaya horizon and shows a step-like behaviour, well above the statistical fluctuations, of the mean value before and after the onset of the events. Other 'nocturnal' events, not shown here, do not present any special feature and its analysis shall be omited.

TABLE I

List of 16 Invisible Solar Flares with Solar Longitudes in the Disk

Date	Solar Coord.	Onset Time	Ref
06/04/80	S14E58	08:54	X
07/31/81	S12W35	05:55	X
08/10/81	S13W15	06:58	X
09/07/81	N08E67	00:00	X
11/05/81	S10W11	08:32	X
06/15/82	N13E52	00:30	X
06/15/82	N13E47	10:19	X
06/25/82	N17W61	21:33	X
07/09/82	N09E38	22:50	X
07/10/82	N16E69	03:16	X
07/10/82	N16E69	04:08	X
07/10/82	N16E69	08:30	X
07/11/82	- -	08:36	X
07/20/82	N11W69	04:17	X
08/08/82	S09W65	02:03	X
12/18/82	S10W20	08:21	X

TABLE II

List of 21 Visible Solar Flares with Solar Longitudes in the Disk

Date	Solar Coord.	Onset Time	Ref
04/26/80	S17E61	20:31	X
05/21/80	S14W15	20:54	X
07/01/80	S12W37	16:26	X
10/09/80	S17E50	11:23	X
11/02/80	S20W58	14:18	X
11/08/80	S08E57	14:52	X
11/11/80	S11W71	17:43	X
12/18/80	N07W11	19:21	X
17/02/81	N20W20	21:46	X
02/26/81	S12E53	14:24	X
03/23/81	- -	16:13	♦
04/10/81	N11E53	11:09	‡
04/24/81	N18W50	14:00	‡
05/05/81	N17W01	14:09	♦
07/26/81	S15E27	13:53	X
07/28/81	S10W18	20:05	X
10/16/81	S19W36	12:48	♦
02/15/82	N00E27	13:21	♦
06/15/82	S22E66	15:11	X
12/15/82	S10E15	16:30	X
12/17/82	S08W21	18:56	X

TABLE III

List of 11 Visible Solar Flares with Solar Longitudes in the Limb

Date	Solar Coord.	Onset Time	Ref
04/28/80	S14W89	20:30	X
12/23/80	S13E90	21:15	X
04/26/81	N12W74	11:44	X
04/26/81	N13W79	17:39	X
09/07/81	S13W83	20:05	♦
09/15/81	N10W78	21:13	X
10/14/81	S06E86	17:05	X
12/07/81	S06E90	14:50	X
02/08/82	S13W88	12:49	X
07/21/82	N23W88	18:22	X
12/08/82	N07E88	14:37	X

(X) SMM satellite
(♦) HINOTORI satellite
(‡) Other sources

3. Discussion

Althought satellite data is not available in order to discriminate solar sources of neutrons visible from the Chacaltaya neutron monitor, say according to its integral neutron intensity (which is model dependent), type of photon emission, and the like, we have presented a preliminary superposed epoch analysis of 66 events pint-pointed mainly via satellite flare survey. We concentrated on solar events of disk or limb parent flares location, and when the sun is above or below the Chacaltaya horizon. The search of solar neutrons via neutron monitor by other authors and known to us (Debruenner et al., 1983; Iucci et al., 1984) show positive identification of solar effects.

We summarize our work: The limb flares, when the sun is above or below the Chacaltaya horizon a) for local nocturnal flares no feature can be noticed and b) for diurnal ones the histogram may produce a peak. For parent flares located on the disk they produce an enhancement of the neutron monitor intensity before and after the onset times, when the sun is below the Chacaltaya horizon; otherwise no particular features can be seen.

References

Prince et al., 1983, 18th ICRC, Bangalore, 4, 79
Debruenner et al,, Chupp et al., 1983, 18th ICRC, Bangalore, 4, 75
Iucci et al., 1984, Rome, IFSI-report