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High Energy Photons detection using Scintillation Counter during Total Solar Eclipse of October 24, 1995

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Abstract

We report the first observations of absorption and enhancement in flux of high energy photons during the total solar eclipse of October 24, 1995. For the purpose of these observations, we employed a scintillation counter to detect high energy radiation in the energy range of 10 KeV to 5MeV. The scintillation detector was coupled with ADCAM 100 ORTEC computer for data acquisition and analysis. We interpret the absorption in the flux below 300 KeV due to the passage of the Moon between the Sun and the Earth, while enhancement above 300 KeV could have occurred due to the production of secondary radiations from high energy photons.

Key Words : Total solar eclipse, High energy photons, Secondary radiations

Introduction

While penetrating into the atmosphere the high energy radiations in the range of KeV to GeV produce secondary radiations which arrive all the way to the surface of the Earth. Thus, the characteristics of the primary cosmic rays can be determined with precision only before they start to interact with the atmosphere where they produce a shower of secondary particles (Culhane and Sanford, 1981). However, a coarse study of incident flux of secondary radiations, in the high energy band reaching to the surface of the Earth, can be made if a photon detector with facility of integrating the counts over time used. Further, this coarse study may lead to interesting results when a comparison of cosmic ray flux is carried out between a normal day and an abnormal day such as total solar eclipse day.

The cosmic rays originating in the galaxy are almost isotropically distributed in the vicinity of the Earth (Fulka. 1975), however, a small but discernible diurnal intensity variation has been observed using counters aboard balloon and satellite and also from ground observations (Herman and Goldberg 1978). The incident flux of solar and galactic cosmic rays is expected to be affected by the passage of the moon through the Sun–Earth line at the time of Total Solar Eclipse (TSE). Thus, our first goal was to observe a coarse variation in cosmic ray flux in KeV to MeV range during the TSE on 24 October 1995. However, the high energy solar and cosmic radiation would make strong impact on the surface of the Moon which does not have the cover of atmosphere. The strong impact may produce secondary radiations in the energy range of KeV to MeV through Inverse Compton effect and excitation and de-excitation of elements on the Moon, which may perhaps be detected on the surface of the Earth. This idea led us to attempt to observe any such variation in the high energy spectrum.

Experimental Set up and Observations

The scintillation detector was employed to detect the high energy solar and galactic radiations during solar eclipse in the energy range of 10 KeV to 5 MeV. The radiations were allowed to enter in the NaI (T1) crystal, 50mm thick and 44.5mm in diameter, optically coupled with photo multiplier tube (PMT) RCA 8575. This integral line was connected to a high tension voltage supply of 1100 volts DC. The negative signal of about 0.5 volts was amplified to 5 Volts positive pulse using negative polarity of spectroscopic amplifier ORTEC model 451. This signal was fed to analog to digital counter (ADC) model 917 to provide appropriate input to ADCAM 100 ORTEC for data acquisition and analysis. In ADCAM multichannel buffer all 1024 energy channels were kept open to collect the counts as a function of time so as to make our study more precise as compared to short duration collection of counts. The energy calibration was observed to be 4.54 KeV per channel using standard radioactive sources C_o^{60}, C_s^{134}, Ba^{133} and Hf^{181}. During collection of data, the integral line of scintillation counter was monitored with the Sun so as to receive maximum radiation flux.

The instruments for observations were mounted on the terrace of the Govt. Senior Secondary School, Paota on Jaipur - Delhi National Highway where 100% totality of Solar eclipse was observed. The uninterrupted and stabilized power supply was obtained from a generator coupled with high voltage stabilizer for everyday observations because the loss of data could have discontinued the sequential study of Total Solar Eclipse in comparison to ordinary days.

The data were collected from 22 to 26 October 1995 for the specified period between the first and last contact of the total solar eclipse on 24 October 1995. For background subtraction, the observations in the night periods were also taken. Further, the Earth's background was eliminated by shielding the detector with a 100mm thick lead from all sides except the window.

Preliminary Analysis and Results

Shown in Figure 1 is the computer processed spectral evolution of high energy photons collected by scintillation counter during the total phase on 24 October and a reference day on 26 October 1995 at 0834 IST at same place and keeping all conditions almost same. The Figure 2 represents difference in counts i.e. number of counts subtracted from 24 Oct. to 26 Oct. 95 taking K^{40} peak from the Earth background as a reference point. The Figure 2 clearly

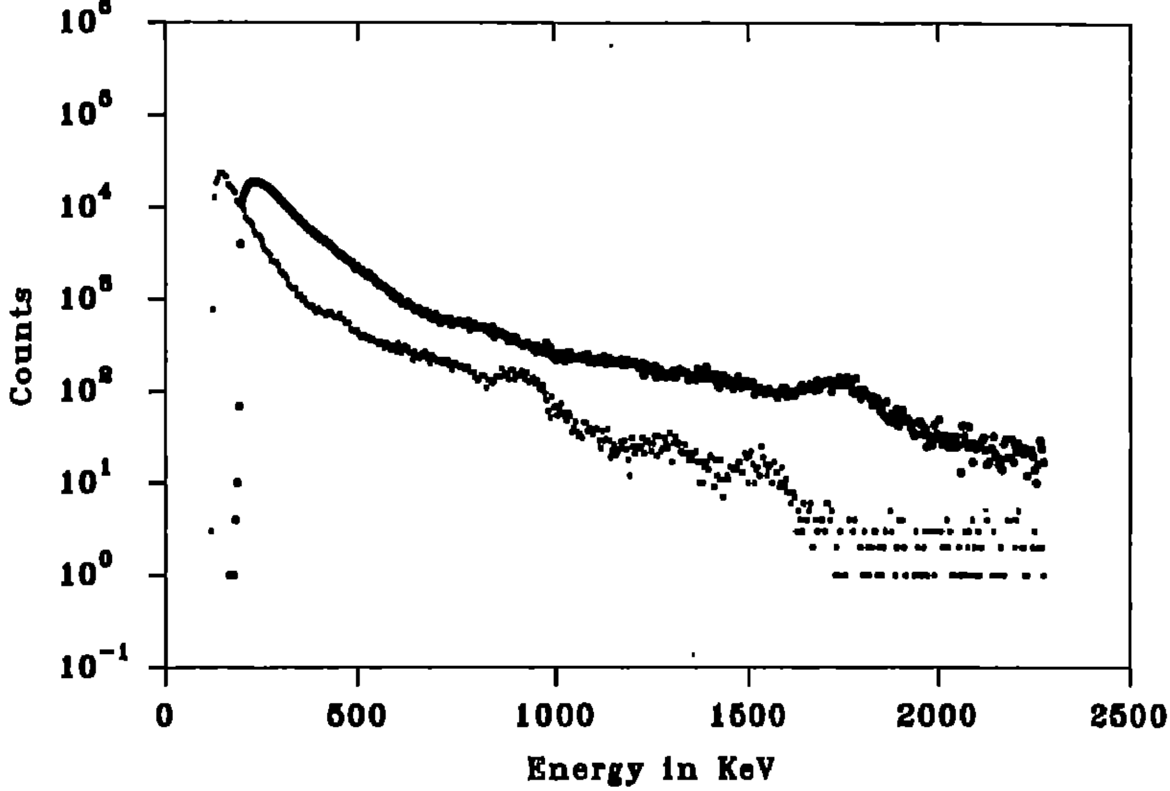

Figure 1 : Energy spectrum of solar and galactic photons during Total Solar Eclipse on 24 October, 1995 (0) and ordinary day on 26 October, 1995 (.) at 0834 IST. Each channel of the Multichannel buffer coupled with the scintillation detector corresponds to 4.54KeV. Add 180 KeV, corresponding to shifting of K^{40} to the reference point, to obtain the correct energy at every point.

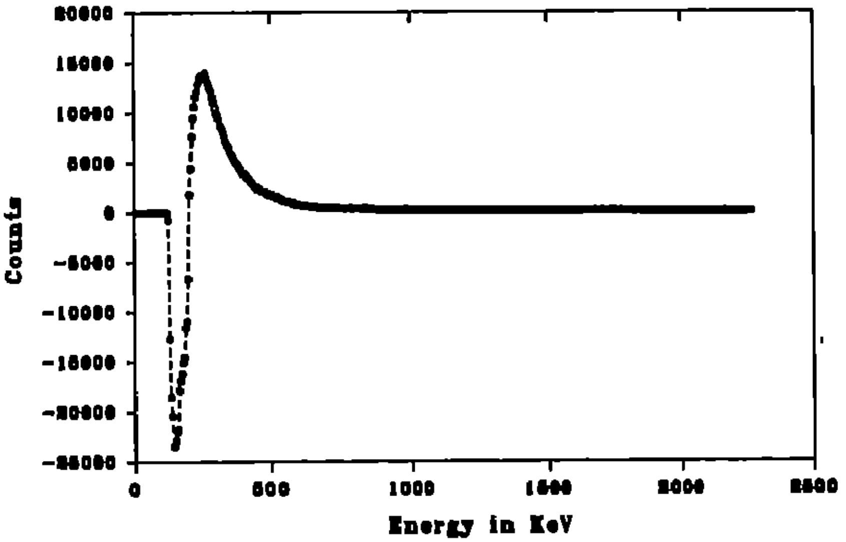

Figure 2 : Subtracted energy spectrum showing variation in flux during TSE on 24 October 95 as compared to the normal day, 26 October 95 at 0834 IST. The absorption and enhancement below and above 300 KeV are evident. Add 180 KeV, corresponding to shifting of K^{40} at the reference point, to obtain correct energy at every point.

exhibits the negative flux which corresponds to absorption in the energy range 200KeV to 300KeV at 0834 IST, near totality phase. However, a reversal in the spectrum has been observed showing prominent positive flux enhancement from 300 KeV to 2.27 MeV, peaking at 430 KeV with a FWHM of 140 KeV. Furthermore, beyond 600 KeV, enhancement of lower magnitude has been observed at discrete energy levels, as seen in Figure 3. However, we suspect that the variation in flux at higher energies could be more evident if a balloon - borne experiment might have been conducted. Shown in Figure 3 are time evolution plots of high energy photon flux during 0700 - 1020 IST on 24 and 26 October 95 which unambiguously show variation in the flux at 218, 523, 722 and 964 KeV during TSE on the eclipse day as compared to the reference day.

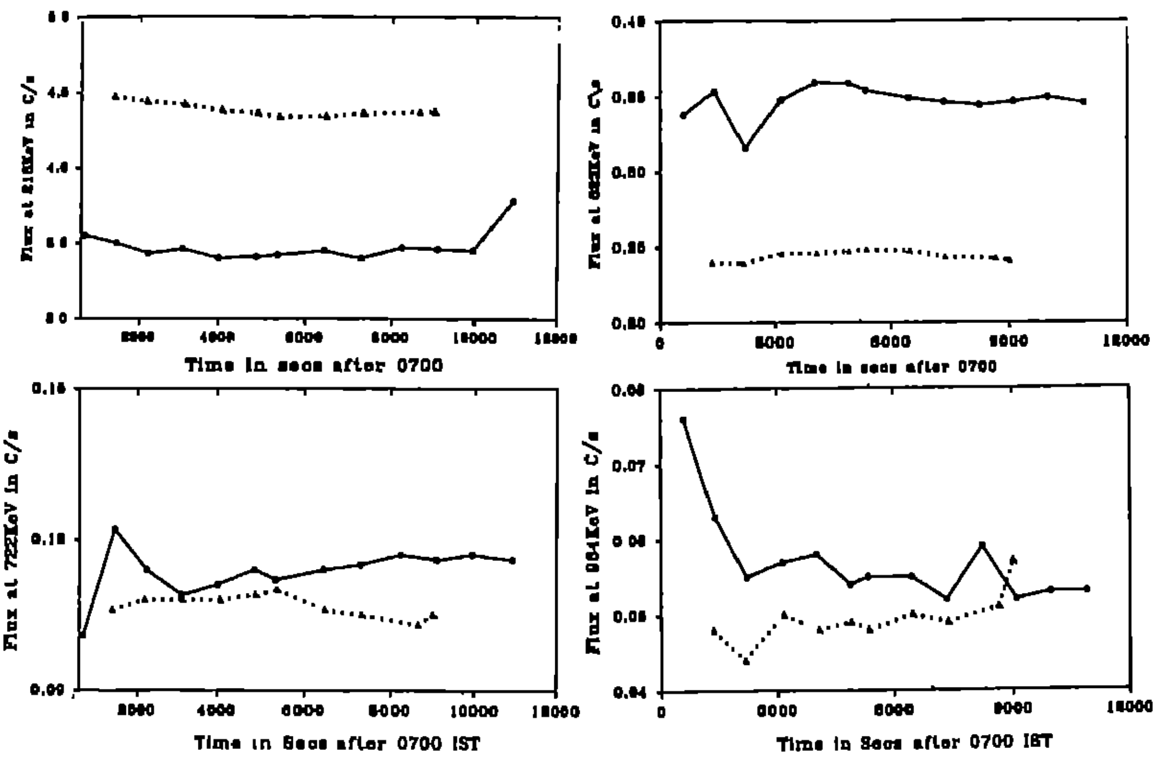

Figure 3 : Time evolution of photons at 218, 523, 722 and 964 KeV showing variation in flux on 24 October, 95 (0 - solid line) as compared to 26 October, 95 (dotted line) during 0700 - 1020 IST.

Discussion

The interpretation of the above results, reported for the first time, requires a detailed analysis. However, at present we suggest that the absorption of radiation below 300 KeV on the surface of the earth could be mainly due to block of radiations by the moon and partly due to more energy demand for the ionisation of earth's thicker column of atmosphere in the morning when the solar eclipse was in progress. On the other hand, the enhancement in the flux above 300KeV may be interpreted as following:

a) The high energy solar and cosmic radiation could make direct impact on the surface of the moon as it does not have any cover of atmosphere (Zeilik, 1978; Andouze and Israel, 1986). The strong impact of GeV primary radiations produce secondary radiations in the energy range of several hundred KeV to MeV. The high energy secondary radiations produced in this process near the limb of the moon could reach on the surface of the Earth and enhance the flux at the discrete energy levels as observed by the scintillation counter.

b) It is evident that injection of high energy solar protons produces ionisation above 20 km considerably in excess of the normal background from galactic cosmic rays in both sunspot minimum and maximum years (Webber, 1962 and Neher, 1971). The high energy solar protons modify the interplanetary magnetic field (IMF) which in turn modulates the galactic cosmic ray flux. This modulation may be manifested from the ground upto balloon altitudes (Webber and Lockwood, 1962) by observing the decrease in Bremsstrahlung ion production rates due to cosmic rays at altitudes below 20 km. During the eclipse the Moon blocked the solar input and in addition, no strong solar proton event was reported for that time. Thus IMF could not be modified significantly and in turn cosmic ray flux could not be modulated by IMF thereby showing the enhancement in high energy band.

c) Further, according to Inverse Compton Effect in high energy range, the electrons which are produced by impact of cosmic rays on the Moon's surface may enhance the energy of photons passing close to Moon's limb and reaching on the ground during eclipse.

In order to explain the above interesting results, which are in agreement with the results from a similar experiment conducted by Chintalapudi *et al.* (1996) in Calcutta during this total solar eclipse, more experiments over large energy range need to be conducted. Further, balloon-borne experiments with sophisticated detectors below and above 20 Km on the path of totality would be of specific importance to understand the basic mechanism and the physics involved in the observed phenomena.

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