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γ and X ray measurements during Total Solar Eclipse on October 24, 1995 at Diamond Harbour

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Abstract

The γ-ray and X-ray background was measured at Diamond Harbour located on the total eclipse phase path, during the total solar eclipse (TSE) which occurred on October 24, 1995. The data taken by two high resolution γ ray detectors, a γ discriminator system comprising a liquid scintillator system and a high resolution Si(Li) x-ray detector when analysed show a sharp dip in both γ-ray and X-ray integral counts over the energy range 150 KeV to 1300 KeV and 1-80 KeV respectively coinciding with the TSE time. Also the Integral background spectrum vs eclipse time indicates from the sharp peaking in the background reduction coinciding with exact total eclipse time, that most of this 9% to 10% reduction in both γ and X rays is from the central portion of the Sun. This also agrees with the optical phases of the Sun. The preliminary analysis and inferences of the data are presented in this paper. Further analysis of the data is in progress.

Key Words : Total solar eclipse, γ-ray, X-ray measurements

Introduction

The surface of the earth has a continuous low energy γ-ray and X-ray background which has been measured extensively and is known to be constant except for a small variation of 0.6 to 0.8%, diurnally and even over long periods of measurements. All the γ-ray measurements carried out in laboratories contain this background which is invariably subtracted for the γ spectroscopy analysis. It has been well understood that this background which includes our Sun, the nearest major star to earth, and partially from the radioactivity of earth's own mineral sources like, Radon, Thorium, Potassium, etc. From among the contributors of the background from the cosmic rays, our Sun is not known to be a particularly strong γ-ray emitter. The contributions of the earth's minerals to the background radiations on earth have been well known. However, since Sun is one of the largest stars, it will have, besides hydrogen burning, nucleo-synthesis continuously taking place in it. One can expect, reasonably, that the different processes of nucleo-synthesis will generate considerable γ-ray and X-ray intensities. The γ and X ray intensities generated in the Sun should therefore have some contribution to the background of the respective radiations on the earth's surface. Under normal conditions a direct measurement of Sun's contribution to this background on earth is not possible as the earth is more or less a point object to the sun due to the very large distance between them. The total solar eclipse phase path gives an excellent opportunity to measure this contribution as the entire mass of the moon shields the earth from the sun and therefore may cause a large absorption of these radiations. Keeping the above in view, γ and x ray measurements were carried out, using high resolution HP Ge γ detectors, a BC 501 Liquid scintillator system and a Si (Li) X-ray detector. The results of the measurements show sharp and interesting dips of both the γ and X-ray background in terms of integral y counts for the energy regions 150-KeV to 1350 KeV and 1000 KeV to about 8000 KeV and hard X-rays from 1-8- KeV respectively. The results are consistent in all the detectors and compare well with other gross measurements. In this paper we describe the objective of measuremens, method of data collection, analysis of data and preliminary results.

Aims and objectives of the measurements

The measurements were planned with the following aims which were two fold. The objectives of the planned analysis are multifold.

The aims of the planned measurements constitute

a) Recording the γ-ray and X-ray background spectra with high resolution detectors before, during and after the Total Solar Eclipse (TSE).

b) Look for any neutron bursts and record the same with a suitable detector.

Objectives of analysis

1. Analyze the recorded spectra both during the TSE and the non-TSE periods and obtain any variation during eclipse time in terms of integral count as a first step.

2. Look for any structure in the integral count plots.

3. Plot also the non-TSE background integral count data and compare the same with the TSE background integral count plot.

4. Compare the data thus analysed with any other integral data, either in literature or other measurements during the TSE, if any, from other groups in the respective areas as also the other measurements like radio wave intensities or optical phases.

5. As a second step analyze the integral count plots energy byte wise to see which range of the γ ray integral energy count is effected during the TSE.

6. As a third step analyze the intensities of each of the photo peaks of different γ-rays of each of the spectra recorded during, before and after the solar eclipse and specially those in the energy bytes identified as affected during the TSE.

7. Identify the nuclear species responsible for each of the above photo peaks from the known γ-decay characteristics. From the intensity variations estimate the relative densities of these nuclei in the solar matter of the respective regions of the Sun during TSE and compare them with the normal density distribution.

8. Find the possible links of this analysis to the nuclear astrophysical phenomena of nucleo-synthesis in the solar matter.

Experimental systems and method

Several detector systems and associated data acquisitions systems have been used for the measurements and are detailed below.

Detector Systems

Four different detectors were employed for the measurement of different ranges of γ-ray energies, a combination of total neutron and γ, and for X-rays, respectively. The detectors used their efficiencies purpose and range of energies for which they were employed are given in Table 1.

Table 1.

1.	HP Ge ORTEC	30%	γ	150 KeV - 1350 KeV
2.	HP Ge ORTEC	10%	γ	100 KeV - 8000 KeV
3.	Si (Li) ORTEC	10%	X	1 KeV - 80 KeV
4.	BC 501 A (Liquid Scint.) Bicron		γ	100 KeV - 8000 KeV all possible energies that can be recorded (both for integral counting only)

Detector Calibration

All the detectors were calibrated for their respective energy ranges using the γ-ray and X-ray standards, procured from M/s ECIL. The neutron - γ detector system was calibrated with the Am-Be source borrowed from the Variable Energy Cyclotron Centre, DAE, Calcutta. All the detectors were first calibrated at the centre in Calcutta and were thoroughly tested for their performance before despatching to Diamond Harbour four days prior to TSE. All these detectors were again re-calibrated on site located on the terrace of the sub divisional office of the south 24 Parganas district of West Bengal state. To avoid power failures the Government of West Bengal's sub divisional office ran diesel generator continuously from the evening of October 23, 1995 to evening of October 24, 1995. This power was fed through voltage stabilisers to the detectors, associated electronics, data acquisition and data analysing systems.

The four detectors used comprised two hyper pure germanium (HPGe), high resolution, γ-ray detectors of 30% and 10% efficiencies, of ORTEC, USA make, respectively for the low and high energy ranges as shown in Table 1. The n-γ detector comprised a Liquid Scintillator integral assembly of 2.5" x 2.5" BC 501 A supplied by M/S Bicron Corporation U.S.A. whose energy response function is same as that of the well known NE 213 liquid scitillator of M/S Nuclear Enterprises, U.K. The Si(Li) detector was a 19 mm^2 aperture and Si(Li). 3mm thick with 3 mil berelium window procured from M/S ORTEC, USA.

The measured energy resolutions for the detectors were 2.1 KeV and 3.1 KeV for the detector-1 and detector-2 respectively at 1330 KeV. The detector-3 namely the X-ray detector had an energy resolution of 200 eV at 5.9 KeV.

Data Aquisition system and procedure:

Each of the detectors with their preamplifiers were coupled to Ortec 674 spectroscopic amplifiers. The output signals from the amplifiers of the γ-detectors were coupled to a 386 computer based multi-parameter multichannel pulse height analyser system. The X-ray detector was coupled to an independent computer based multichannel pulse height analyser system. Similarly the n-γ descriminator system output was coupled to another independent computer based multichannel pulse height analyser system. The auto dump provisions of the software were utilised for auto dumping, auto reset and auto start mode of the system for the dumping of the data at the end of every run on the cassette recorders and floppies in the respective computers. The turn around times between the dumps, resets and starts were only a few microseconds and thus the loss of time between these operations at any stage was minimised to a negligible level.

Data Collection

The data collection was planned for four days starting from the night of 20th October till morning of 25th October. The systems were set up and calibrated accordingly on the 4th floor terrace of the SDO office of the 24 Parganas, south district office of West Bengal Government, at Diamond Harbour. "The data collection was started in the owl shift of 20th October, 1995. This data collection had to be stopped abruptly due to a sudden and very heavy down pour. Although the detectors and the data acquisition systems were covered by Tarpaulins, risk could not be taken. Subsequently the data aquisition electronics and the computers were shifted to the landing on the 4th floor with detectors left on the terrace. All the detectors were placed facing the direction of the Sun although not specifically oriented to any particular angle.

The data collection started round the clock in shifts from the morning of 22nd October and was planned to be carried out till the evening of 25th October. Erratic electrical power situation forced abandonment of data collection on the 22nd and 25th. Thus the actual data collection was carried out only on 23rd and till evening of 24th October except for some small spells on the night of 22nd. Identical schedules were adapted for recording and dumping data on storage devices on both 23rd and solar eclipse day.

Results and Discussion

The normalised integral counts from all the four detectors were plotted in real time as shown in Figures 1, 2 and 3. Following observations were made from the plot of this raw data:

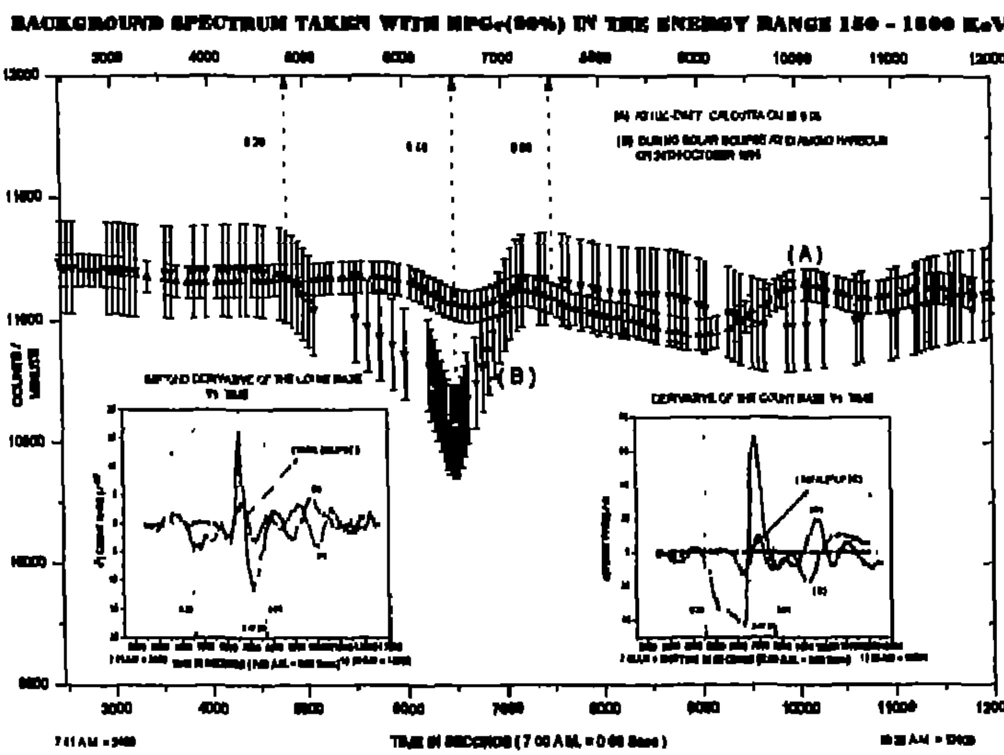

Figure 1 : Background spectrum taken with HPGe (30%) in the energy range 150-1300 KeV.

1. There is a prominent dip (~11%) in the intensity of γ rays exactly at the TSE time.

2. The spectrum shows a structure at the onset of the eclipse whereas after the TSE the intensity rise has a more or less smooth slope.

The raw data were then 3 point adjacent averaged, and compared with the background spectrum on different non-TSE days. Fig. 1 shows the TSE and non-TSE spectrum plotted on the same scale recorded by detector-1. It can be seen that the general background on a non-TSE day is constant within the standard deviation of the data, whereas, the TSE spectrum shows a prominent dip at the time of TSE indicating that the intensity of the γ rays was remarkably less during the period of TSE. The reduction in the intensity measured in the averaged spectrum was ~ 9% which remained constant even after doing further averaging. Further it can be seen that the TSE background merges with the general background in the non-TSE spectrum before and after the eclipse period.

To confirm the exact time at which the intensity of the γ rays was minimum and to assess and eliminate the non real events, if any in the data, the first derivative and the second derivative of the total, integral spectrum were plotted in real time (shown in the insets 1a and 1b of Fig. 1) It was observed that the time at which the first derivative became zero matched perfectly with the time at which the total integral counts was minimum. This was further confirmed by noting that the second derivative was positive at this time. It was also observed that at the time of the TSE the first derivative changes sharply from a large negative value to a large positive value. After comparison with the optical phases of the Sun during the eclipse it was found that this corresponds to the time at which the Sun was totally covered by the Moon.

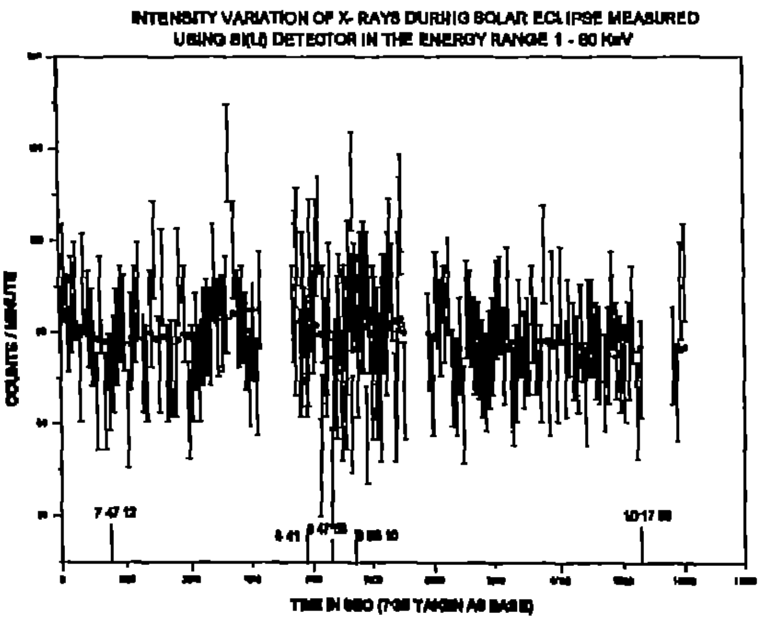

Figure 2 : Intensity variation of X-rays during solar eclipse measured using Si(Li) detector in the energy range 1-80 KeV.

Fig. 2 shows the normalised total integral counts for X-rays plotted in real time after 3 point adjacent averaging. The time at which the dip occurs in the intensity corresponds to the TSE time.

Fig. 3 shows the normalised total integral counts plotted for the γ ray intensity measured by BC501A assembly. The dip in this spectrum also corresponds to the TSE time consistent with the HPGe and the X-ray detector. No neutron peak was observed in the n, γ discriminator.

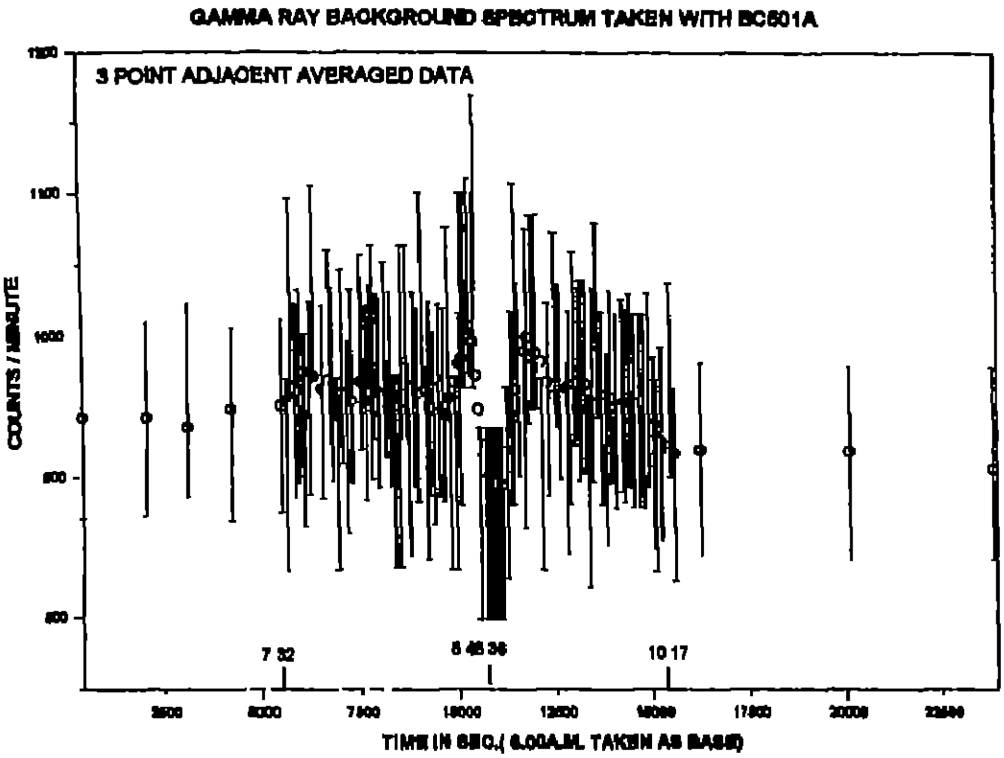

Figure 3 : Gamma ray background spectrum taken with BC 501A.

To understand the structure observed in the TSE spectrum at the onset of the eclipse the γ ray spectrum was divided into four energy bytes and the integral counts in these energy bytes were plotted in real time, as shown in Fig. 4. Preliminary analysis shows that the major contribution to the dip in the total integral counts came from the γ rays in the energy region 600-900 KeV and 900-1300 KeV. Detailed analysis of the energy bytes to account for the dip quantitatively and to explain the structure is currently in progress.

After identification of the energy bytes responsible for the observed dip in the γ ray intensity the intensities of each of the photopeaks of the different γ rays are being plotted in real time to identify the γ rays contributing to the dip. The analysis of the photopeak intensities is in progress.

The identification of the γ rays contributing to the dip will give an indication of the nuclear species responsible for each these γ rays from the known γ decay characteristics. From the intensity variations and with the knowledge of the motion of moon across the sun during the eclipse, the relative densities of these nuclei in the solar matter of the respective regions of the Sun will be estimated.

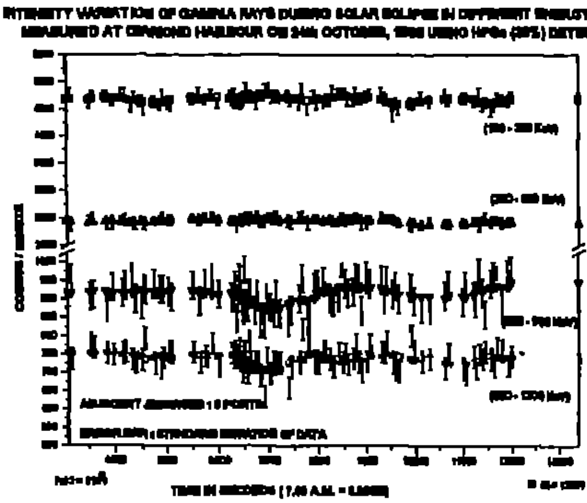

Figure 4 : Intensity variation of gamma rays during solar eclipse in different energy regions measured at Diamond Harbour on 24th October, 1995 using HPGe (30%) detector.

The data collected by the HPGe detector set for the energy range 1-8 MeV are yet to be analysed to get the complete understanding of the observations.

Our observations are also consistent with the radiowave measurements made by the ECRA. Chatterjee *et al.* (1996) have reported a similar dip in the intensity of the radiowaves as shown in Fig. 5. The asymmetry observed in the radiowave spectrum about the TSE time shows a sharp decrease in the intensity at the onset of the eclipse and slow rise to the normal background after the TSE time.

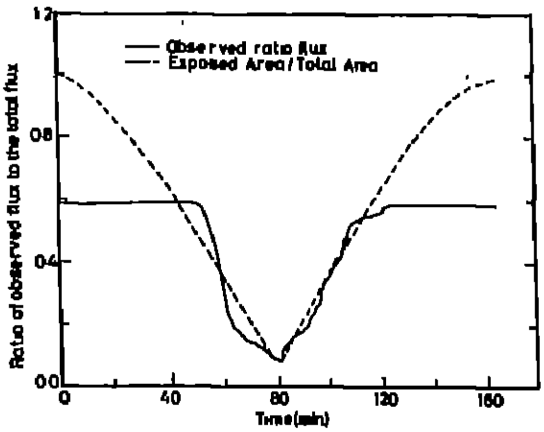

Figure 5 : Intensity of radio waves observed during the eclipse.

We did not come across any measurements of the kind we have carried out in literature survey. The results of some attempts made in India during the October 24th TSE are given in Table 2 and compared with Jaffery *et al.* (1996).

Table 2.

Institution	γ depression	X-ray depression	γ-ray Yield Photon/sec. / cm^2 / KeV	X-ray yield Photon/sec./ cm^2 / KeV	Remarks
IUC-DAEF CC, Diamond Harbour	−11%	−11%	1×10^{-4}	——	
VECC-DAE (Jayanagar) RKM "NIMPIT"	−12%	——	——	——	No detailed data recorded, Reported observations with NaI (Tl)
Sukhadia University "Paragpur"	——	——	1×10^{-5}	——	Data recorded in gross with NaI (Tl)

Conclusion

Our measurements yielded some interesting results.

The measurements and preliminary analysis indicate solar contribution of ~9% both in γ ray and X-ray background.

The gross features correlate with other reported measurements in India during the eclipse and also the phases of solar eclipse.

From the widths for low energy γ ray and X-ray data peaks it may be possible to estimate the surface area of Sun from which this γ ray and X-ray contribution emanates.

A preliminary analysis of widths of peaks indicates that the above emission is mostly from central portion of the Sun.

Further detailed analysis of over 600 spectra are being carried out to obtain the details of the structure and the nucleo-synthesis aspects for astro-physical interests. The results will be reported in due course.

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References

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