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ARTICLE

Enhancement of Secondary Gamma Radiation Flux Energies in the Energy Region from 1400 Kev to 1500 Kev during Lunar Eclipse on June 16, 2011 at Udaipur, India

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Abstract: The lunar eclipse at Udaipur (27^0 43' 12.00" N, 75^0 28' 48.01" E), India was experimentally observed on June 16, 2011 using ground-based NaI (Tl) scintillation detector. Cadences of data were collected at intervals of half an hour. The analyzed data revealed a significant enhancement in the energy region from 1400 keV to 1500 keV of secondary gamma radiation flux (SGRF) on comparison to pre- and after lunar eclipse days**.** On June 16, we observed additional peaks in the energy spectrum of SGR flux in the energy region extending from 1461.010 keV to 1472.536 keV during the progress of lunar eclipse. We interpret such enhancement of SGR flux energies on the basis of combined phenomenon of gravitational lensing effect of Sun and Earth as well as the Sun's magnetic field and the interplanetary magnetic field. Due to such combined effect, primary cosmic and solar radiations bend and may cause strong hitting on the less air surface of the Moon, resulting into emission of secondary particle flux mostly gamma radiation, high energy photo electrons, hard X -radiation, muons, protons and neutrons which may be regarded as back scattering from the Moon surface. Energy of backscattered secondary flux is large enough that it gives such enhancement in the energy region from 1400 keV to 1500 keV during lunar eclipse observation. Also, due to combined gravitational effect, cosmic radiation bent and impinged deep inside the atmosphere of Earth, producing a large shower of secondary radiation particles. These collective effects may give such enhancement of secondary gamma radiation flux energies.

Keywords: Lunar eclipse, Solar magnetic field, Interplanetary magnetic field, Gravitational lensing, Bending of primary cosmic and solar radiations.

1. Introduction

Cosmic radiation - known as galactic cosmic radiation (GCR) - is high-energy charged particles and a composition of cosmic radiation form about 89% of protons, 10% of helium, and about 1% of other heavier elements, such as carbon, oxygen, magnesium, silicon and iron [12]. Charged cosmic particles radiation is almost isotropically distributed and propagates through interplanetary space while arriving on Earth [9]. If these particles have energies of the order of 10 TeV or lower, then they will bend under the influence of solar and interplanetary magnetic fields [8]. Energetic particles that are associated with energetic events on the Sun, known as solar radiation (SR), are accelerated in interplanetary space. It is believed that the bending of cosmic flux becomes significant when the Moon is in the line joining the centers of the Sun and the Earth during the eclipse [1], [6], [20], [2], [3]

It was observed that when the electromagnetic radiation passes near a massive object, then due to gravitational field of the object, it bends. Such phenomenon is called gravitational lensing. The object could be a

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galaxy, a star or a cluster of galaxies. This was proved by A. S. Eddington and collaborators in a famous experiment during a total solar eclipse in 1919.

Due to the combined effect of gravitational lensing, strong solar and interplanetary magnetic fields, the primary high-energy cosmic radiation and solar radiation bend. These bent radiations strike on the airless surface of the Moon. Therefore, from surface of the moon; mostly gamma radiation, high-energy photo electrons, hard x-rays, muons, protons and neutrons are emitted as secondary emission in the range of several hundred keV to MeV [13], [21], [22].

It is very interesting to collect data of radiation during different celestial events occurring at various times, because it is observed that during such events, GCR and SR are modulated. When high-energy GCR and SR undergo collisions with atoms of the upper atmosphere, they produce a cascade of "secondary" particles known as secondary radiation (SR) and produce a shower of secondary particles. These particles increase rapidly as these move downward in the atmosphere and in each interaction, the particles lose energy. Small fraction of these particles usually comes down to the ground because of the large width of secondary cosmic shower. These particles are detected by appropriate detectors on ground [11], [7].

The secondary radiation can be divided into three components as electromagnetic component, hadronic component and mesonic component. In the electromagnetic component, there is a presence of electrons and gamma radiation. Hadronic component has low-energy protons and neutrons, while mesonic component has pions, muons, neutrinos and kaons. The secondary flux has one component of secondary gamma radiation which is measured by efficient scintillation detectors.

On 15th and 16th June 2011, a Lunar eclipse was witnessed over much of Europe, much of Asia, Australia, Africa, South America, the Pacific, Atlantic, the Indian Ocean and Antarctica [Fig. 1].

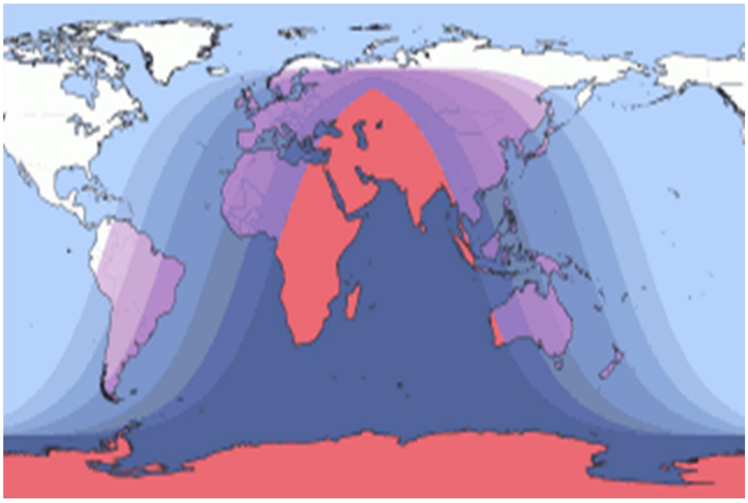

FIG. 1. Lunar eclipse.

2. Celestial Events and Variation of Radiation Flux

Many ground-based experimental studies for observing secondary cosmic and solar radiation flux were conducted during normal days and on days of special celestial events, such as solar eclipse, lunar eclipse, appearance of a comet in the sky, phases of the Moon and closest approach of Venus, with help of scintillation counter.

In lunar-eclipse studies, variation of secondary cosmic and solar gamma radiation flux at some energy had been observed. Such interesting finding can be explained on the basis of bending of primary cosmic radiation and solar radiation by the combined effect of the magnetic field of the Sun and the interplanetary magnetic field, the combined gravitational lensing effect of Sun and Earth and the backscattered secondary flux form the Moon [16]

To observe the variation of secondary radiation, we conducted an experimental study during lunar eclipse on June 16, 2011 at Udaipur, India.

3. Experimental Set-up and Observations

In this experimental study, an efficient scintillation detector of Model 802 was used, made by: Canberra Genie 2000, to detect SCGR (secondary cosmic gamma radiation) produced by the GCR and SR during partial lunar eclipse in the energy range from 2 keV to 2048 keV [Fig. 2]. Diameter of the detector crystal is 50 mm with a thickness of 44.5 mm. NaI (Tl) crystal is optically coupled with photo multiplier tube (PMT) of Model 2007P. To provide high-tension voltage, high-tension voltage supply Model 3102D of 1100 Volts DC was connected with integral line. Using negative polarity of spectroscopic amplifier Model 2022, the negative signal of about 0.5 Volt was amplified to a 5-Volt positive pulse, then the signal was fed to a multi-channel analyzer with 1024 energy channels for acquisition and analysis. The detector system was put into a 2.5-inch lead shield with a small opening pointed towards the partial lunar eclipse. We collected data as a function of time after intervals of half an hour and the data files were stored in computer from 12.00 AM to 3.30 AM on June 15, 16 and 17, 2011. June 15 was a pre-eclipse normal day and June 17 was a post-eclipse day. In India, lunar eclipse began from June 15 at 11.53 PM and ended on June 16 at 3.32 AM. Maximum eclipse was at 1.43 AM. The energy calibration was observed to be 2.0 keV per channel using the standard radioactive source Cs^{137}.

FIG. 2. Scintillation detector.

4. Analysis and Results

As depicted in the panels of Figs. 3, 4 and 5, the energy spectra of SGR flux on pre-eclipse day (15th June), partial eclipse day (16th June) and post-eclipse day (17th June) in the energy range between 800 keV and 2000 keV were taken from 12.00 AM to 3.30 AM with a duration of half an hour integrated data files.

Panels of Figs. 6, 7 and 8 show the existence of specific peaks with the progress of time from 12.00 AM to 3.30 AM. We used Lorentz peak fit concept in order to understand the characteristics and energy variation of SGR flux peaks in the energy range from 1300 keV to 1600 keV.

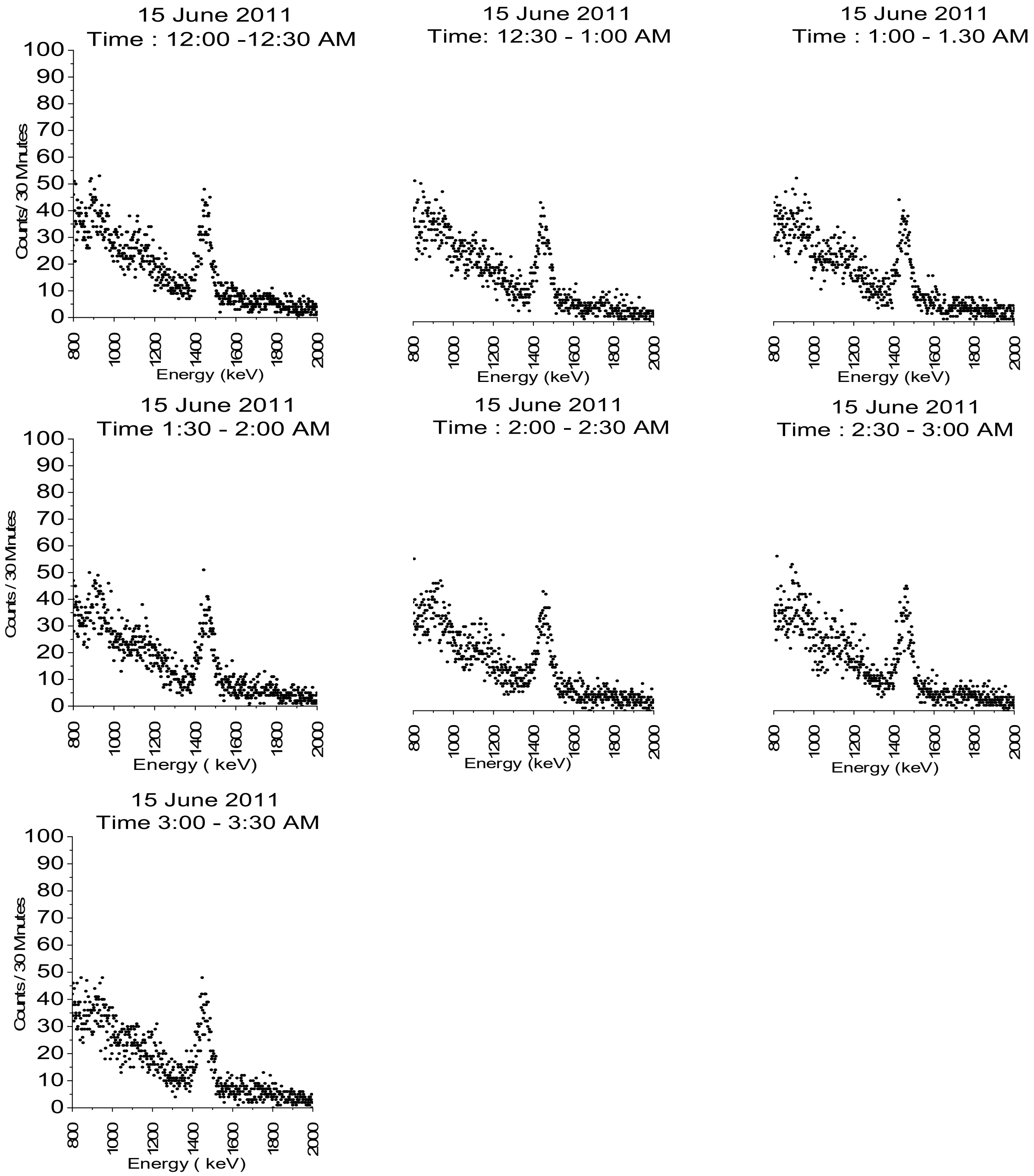

FIG. 3. Panel of energy spectrum of pre-partial lunar-eclipse day.

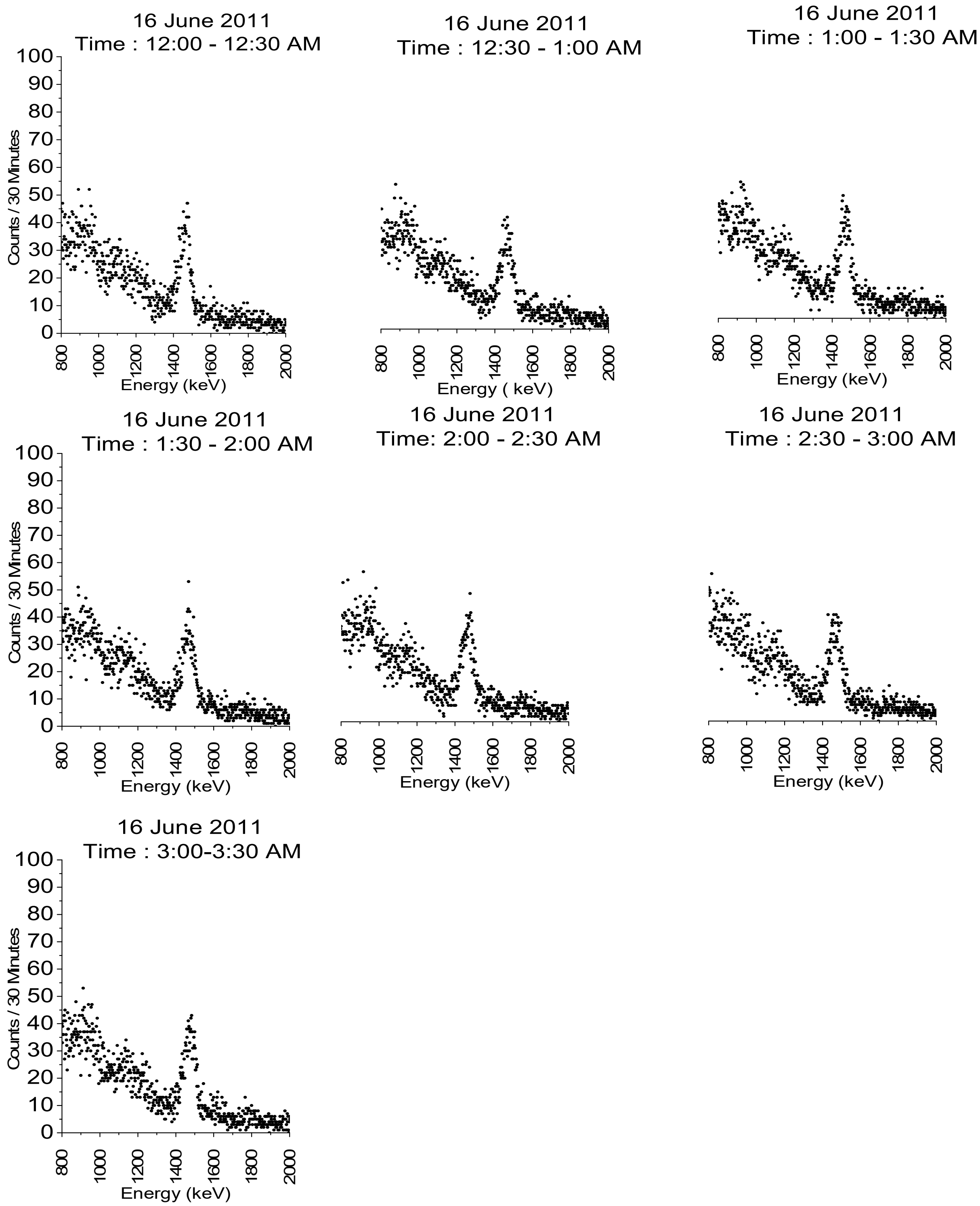

FIG. 4. Panel of energy spectrum of partial lunar-eclipse day.

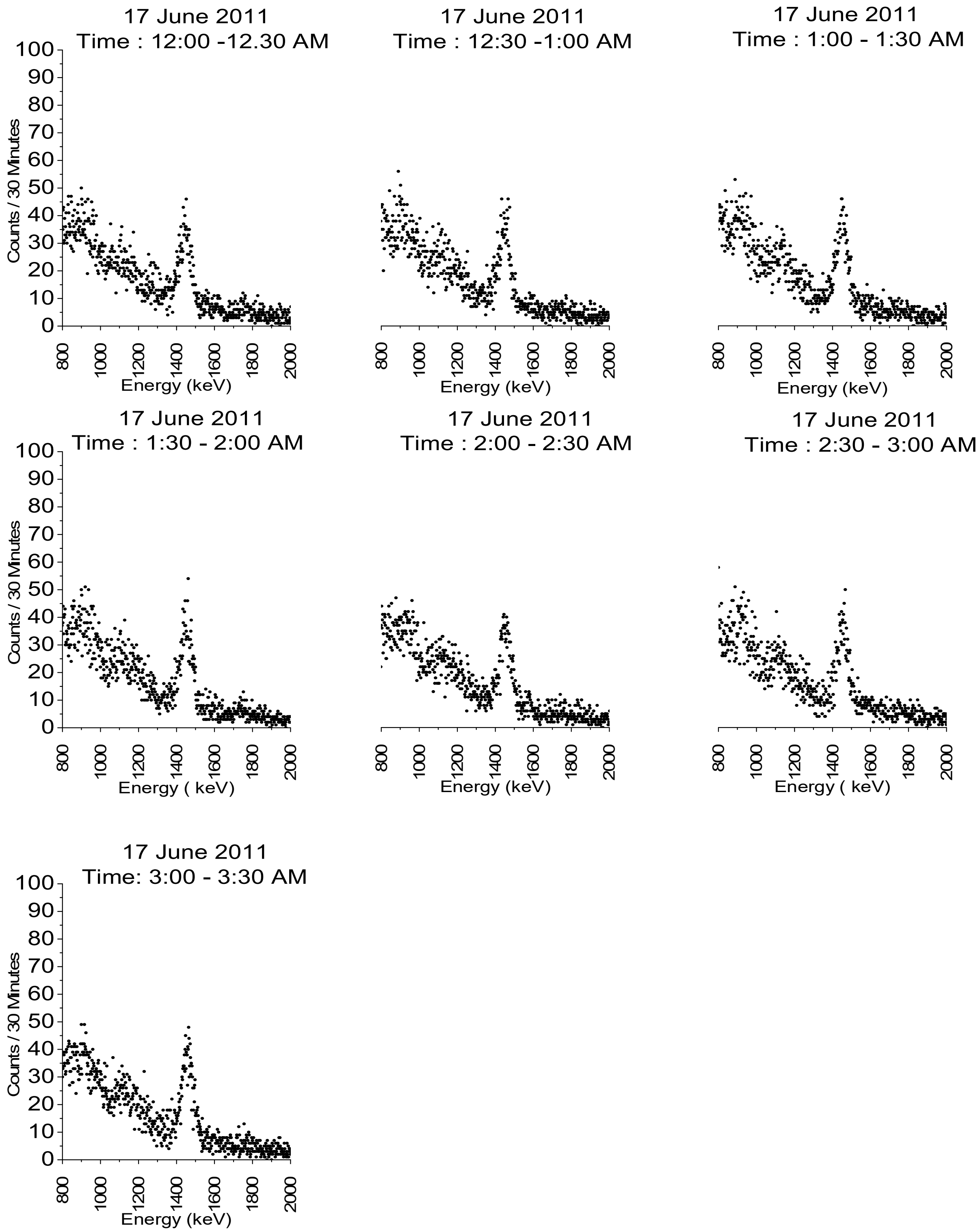

FIG. 5. Panel of energy spectrum of post-partial lunar-eclipse day.

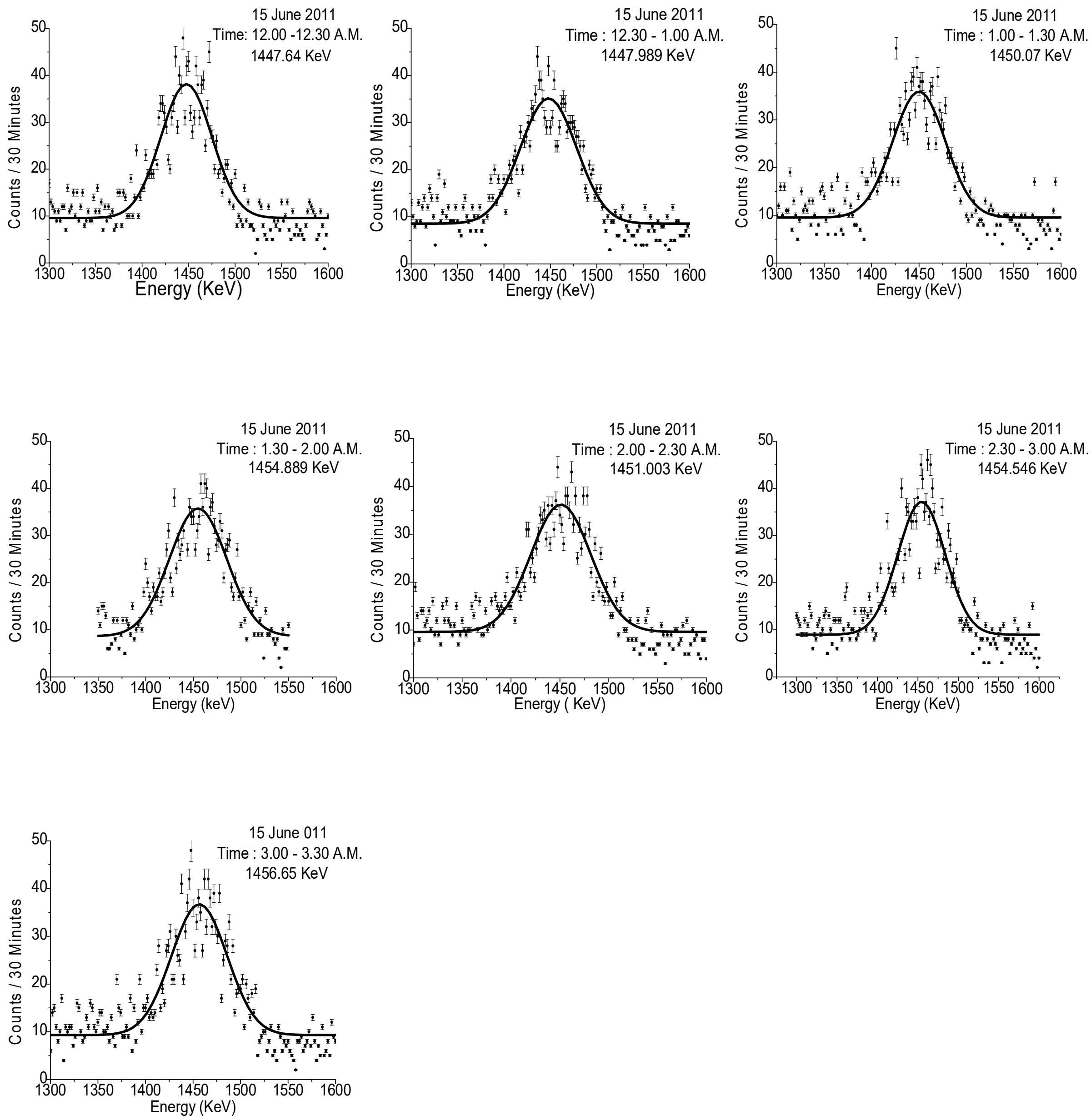

FIG. 6. Lorentz fit for specific peaks in data of SGRF on pre-partial lunar-eclipse day.

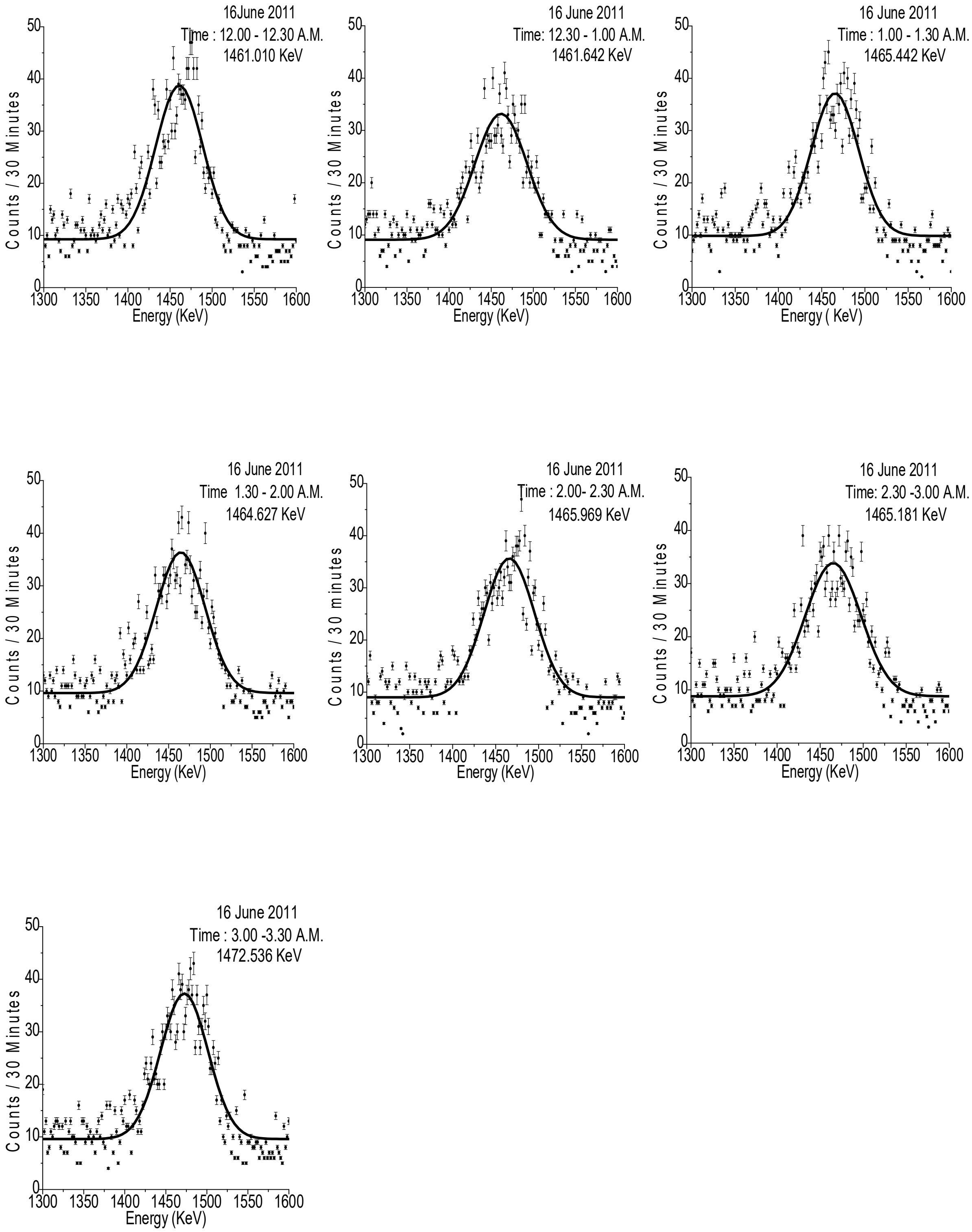

FIG. 7. Lorentz fit for specific peaks in data of SGRF on partial lunar-eclipse day.

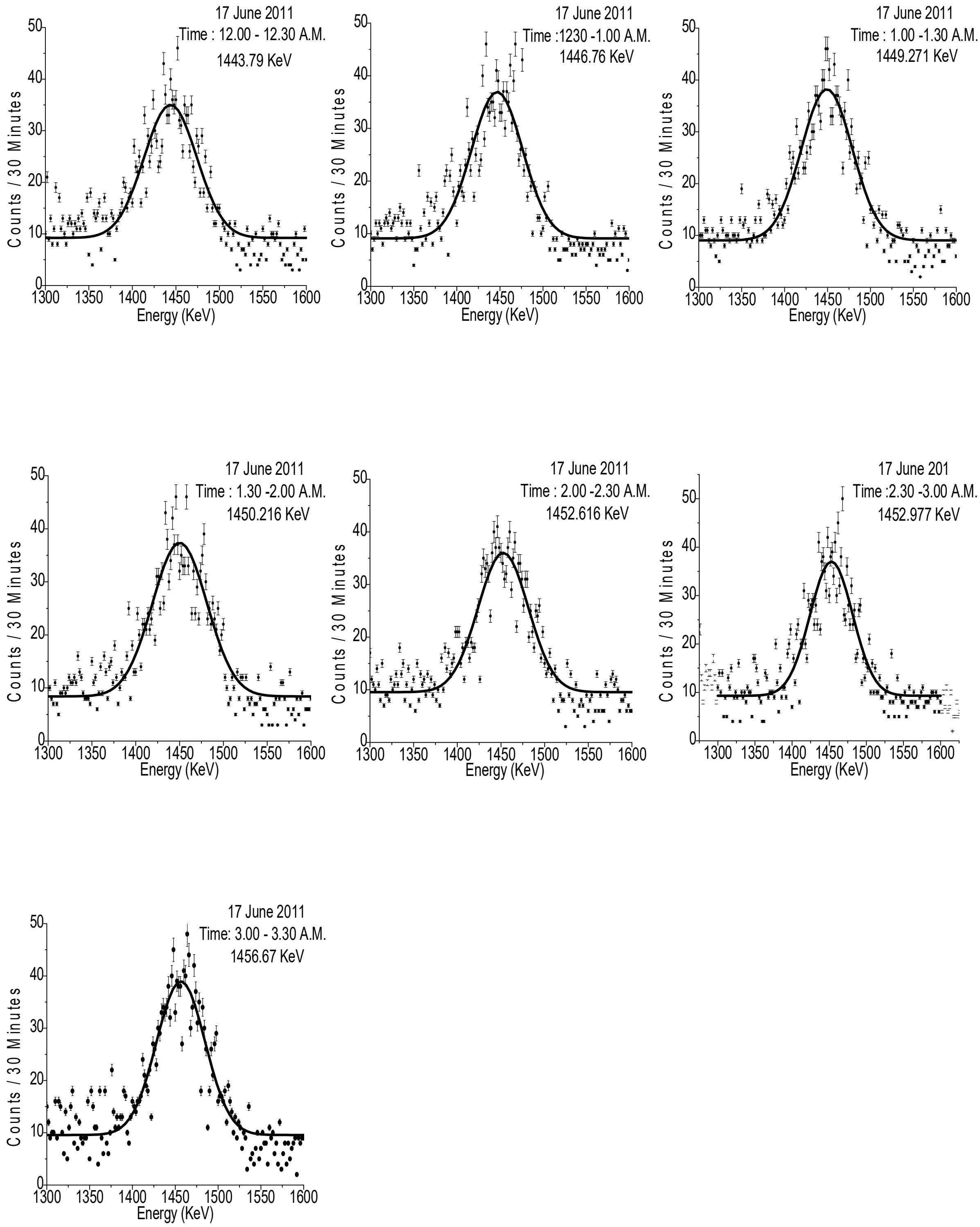

FIG. 8. Lorentz fit for specific peaks in data of SGRF on post-partial lunar-eclipse day.

The time-dependent energy spectrum analysis clearly showed that with the progress of the eclipse, the energy of the observed peak varied consistently from 1461.010 keV to 1472.536 keV on the eclipse day. The figures above show clearly that in comparison to normal days (15 and 17), on the eclipse day, there is an increase of energies of SGRF (secondary gamma radiation flux). The following tables represent the energies of SGRF on pre-lunar eclipse day, lunar eclipse day and post-lunar eclipse day using Figs. 6, 7 and 8, respectively.

SGRF energies			
on 15 June 2011(Energy Table)			
Sr. No.	Time	Energy (keV)	Mean
1	12.00 – 12.30 A.M.	1447.64	
2	12.30 – 1.00 A.M.	1447.989	
3	1.00 – 1.30 A.M.	1450.07	
4	1.30 – 2.00 A.M.	1454.889	1451.82671 keV
5	2.00 – 2.30 A.M.	1451.003	
6	2.30 – 3.00 A.M.	1454.546	
7	3.00 – 3.30 A.M.	1456.65	

on 16 June 2011 (Energy Table)			
Sr. No.	Time	Energy (keV)	Mean
1	12.00–12.30 A.M.	1461.010	
2	12.30 – 1.00 A.M.	1461.642	
3	1.00 – 1.30 A.M.	1465.442	
4	1.30 – 2.00 A.M.	1464.627	1465.201 keV
5	2.00 – 2.30 A.M.	1465.969	
6	2.30 – 3.00 A.M.	1465.181	
7	3.00 – 3.30 A.M.	1472.536	

on 17 June 2011 (Energy Table)			
Sr. No.	Time	Energy (keV)	Mean
1	12.00– 12.30 A.M.	1443.79	
2	12.30 – 1.00 A.M.	1446.76	
3	1.00 – 1.30 A.M.	1449.271	
4	1.30 – 2.00 A.M.	1450.216	1450.329 keV
5	2.00 – 2.30 A.M.	1452.616	
6	2.30 – 3.00 A.M.	1452.977	
7	3.00 – 3.30 A.M.	1456.67	

Using panels of Figs. 6, 7, 8 and the tables above, Figs. 9 and 10 clearly represent the energy variation of SGRF peaks in the energy range from 1400 keV to 1500 keV on the pre-, post- and lunar eclipse days, showing that there is an increase in energies of SGRF on lunar-eclipse day in comparison to other days, which is noticeable on the lunar-eclipse day.

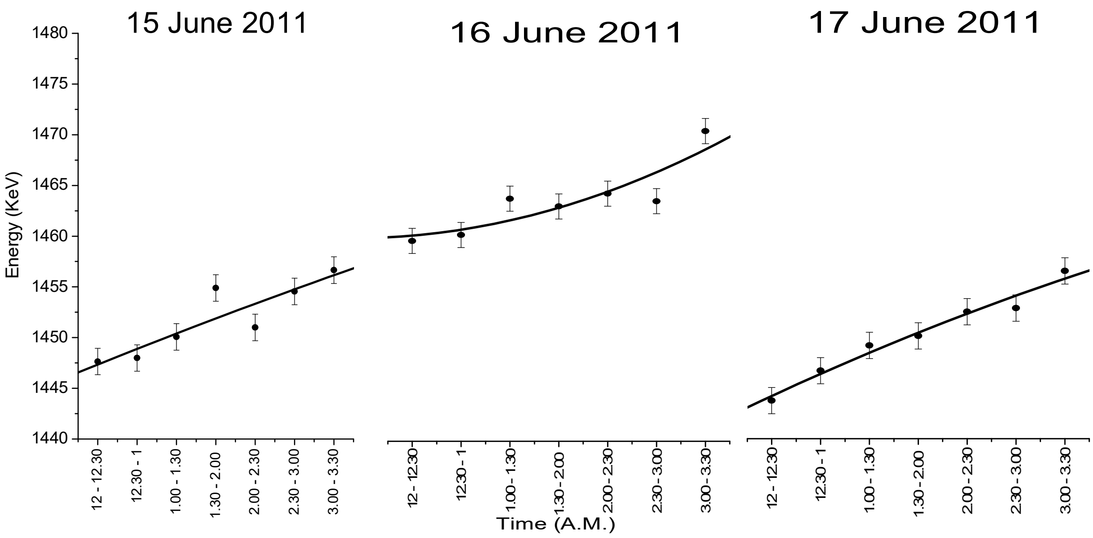

FIG. 9

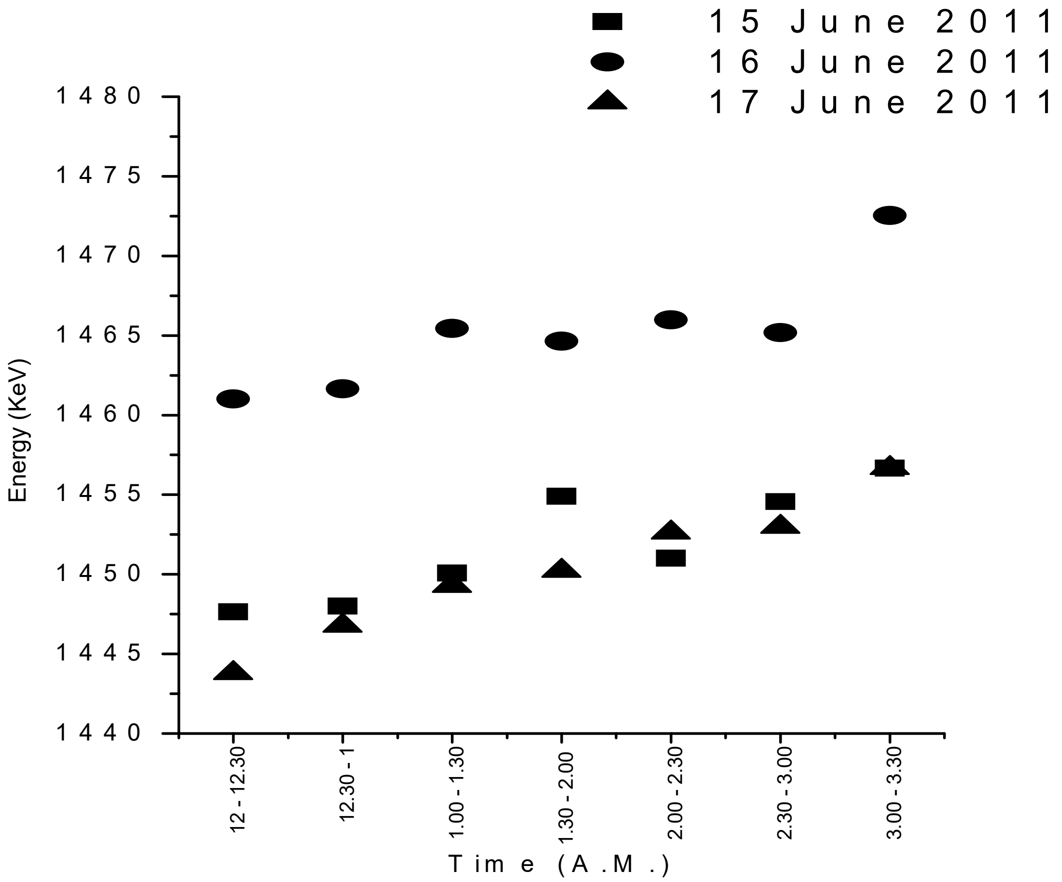

FIG. 10

5. Discussion

The probable reasons in this present study for the enhancement of SGR flux energies in the energy range from 1400 keV to 1500 keV are as follows:

1. Due to the combined effect of gravitational lensing, strong solar and interplanetary magnetic fields, the primary high-energy cosmic radiation and solar radiation bend. These bent radiations strike on the surface of the Moon. From the surface of the Moon, mostly gamma radiation, high-energy photo electrons, hard x-rays, muons, protons and neutrons are emitted as secondary emission in the range of several hundred keV to MeV. These secondary emissions may produce the enhancement of SGR flux energies in the energy range from 1400 keV to 1500 keV which is reported in this present study.
2. Bent primary cosmic radiation and solar radiation penetrate deep inside the atmosphere of the Earth, which produces more showers of secondary radiation particles. This secondary flux reaches the surface of Earth and may produce such enhancement of SGRF energies in the energy range from 1400 keV to 1500 keV

6. Conclusion

From points (1) and (2) above, we can understand that as the eclipse progresses, there is an unusual enhancement of SGRF energies in the energy range between 1400 keV and 1500 keV. This is a new observation reported in the present study for the first time during lunar eclipse and may be examined in detail with more statistics in the next experimental studies.

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