Volume 15, Number 2, 2022. pp. 201-206

Jordan Journal of Physics

ARTICLE

Decrement of Secondary Gamma Radiation Flux during Solar Eclipses on January 4, 2011 and December 26, 2019 at Udaipur, India

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Doi: **https://doi.org/10.47011/15.2.10**

Received on: 19/12/2020; Accepted on: 18/01/2021

The solar eclipses at Udaipur (27^0 43' 12.00"N, 75^0 28' 48.01"E), India were experimentally observed on January 4, 2011 and December 26, 2019 using a ground-based NaI (Tl) scintillation detector. For the solar eclipse on January 4, 2011, the data files were stored in a computer for a thirty-minute duration from 14.30 IST to 15.00 IST on pre-eclipse normal days as well as on post-eclipse normal days and also on partial eclipse day (January 4, 2011). For solar eclipse on December 26, 2019, cadences of data were collected for three hours from 8 AM to 11 AM on pre-eclipse normal days as well as on post-eclipse normal days and also on eclipse day (December 26, 2019). The analyzed data revealed significant decrement of secondary gamma radiation flux (SGR) on solar eclipse day (January 4, 2011) of about 10 % and on solar eclipse day (December 26, 2019) of about 17 % in the counts of SGR flux on comparison to average counts of normal days. We interpret such decrement of SGR flux on the basis of obstruction effect produced by the Moon during solar eclipses.

Keywords: Solar eclipse, Cosmic radiation, Solar radiation, Secondary gamma radiation, Obstruction effect by the Moon.

Introduction

High-energy charged particles represent about 89% of nuclei of protons, 10% of nuclei of helium and about 1% of nuclei of others heavier elements, such as carbon, oxygen, magnesium, silicon and iron, known as cosmic radiation [9]. The cosmic radiation (CR) is almost isotropically distributed and propagates through space while arriving on the Earth [6]. Radiation coming from the Sun is known as solar radiation (SR) and has energetic particles that are associated with energetic events on the Sun.

It was observed by many scientist groups that during different celestial events, cosmic radiation and solar radiation are modulated. Modulated radiation strikes the atmosphere of the Earth, causing the formation of secondary radiation flux. Such secondary radiation flux contains an electromagnetic component known as secondary gamma radiation and detected by appropriate detectors on ground [8, 4]. On January 4, 2011, a partial solar eclipse was witnessed over Europe, the Arabian Peninsula, North Africa, eastern, north-western and southern Asia including northern and western parts of India, as shown in Fig. 1.

On January 4, 2011 in India at Udaipur, Rajasthan, where the first contact P1 began at 11:40:11.3 IST, the fourth contact P4 ended at 16:00:53 IST and the maximum partial eclipse occurred at 14:20:00 IST. The eclipse magnitude recorded at above geometric coordinates was 0.8576 with gamma=1.0627, Saros series =151, member = 14 of 72. The geometric coordinates

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of the Sun and the Moon at maximum eclipse were R.A. = 18h59m14.9s, Dec. = - 220 44’21.1”, S.D. = 00016’15.9”, H.P. = 00000’8.9” and R.A. = 18h58m23.85 Dec. = -21046’01.2”, S.D = 00015’18.1”, H.P. = 00056’09.6” res.

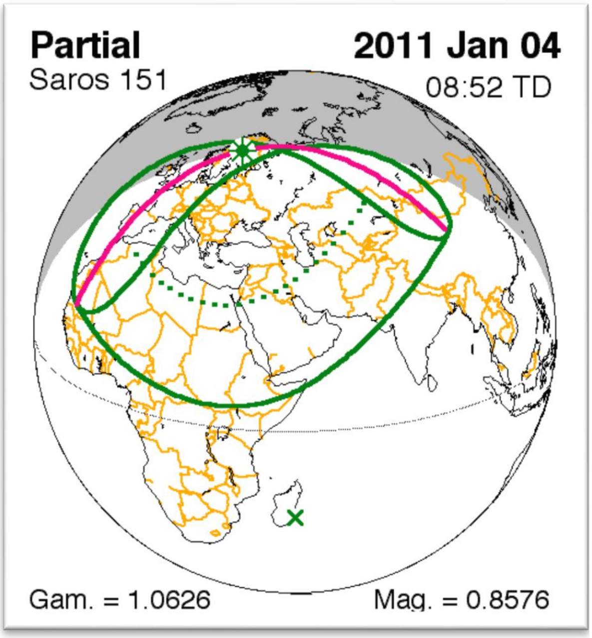

FIG. 1. Partial solar eclipse witnessed on Jan. 4, 2011.

On December 26, 2019, a solar eclipse was witnessed over Eastern Europe, much of Asia, north and west Australia, east Africa and the Pacific and Indian Oceans as shown in Fig. 2.

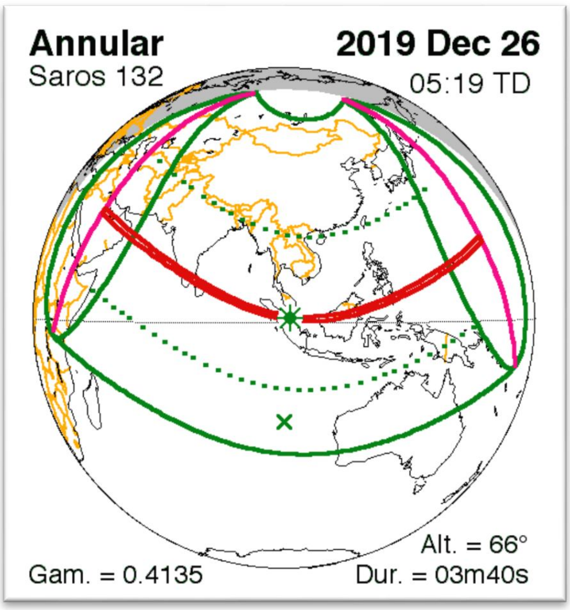

FIG. 2. Solar eclipse witnessed on Dec. 26, 2019.

On December 26, 2019, there was an annular solar eclipse at Udaipur, India from 8.00 AM to 11.00 AM with gamma = 0.4135, magnitude = 0.9701, Saros series =132 and member = 46 of 71.

Solar Eclipse and Variation of Radiation Flux

Many scientist groups, such as Ananda Rao, J.N. [1], Bhaskar et al. [2], Bhattcharya et al. [3], Chintalapudi, S.N. et al. [5], Kandemir, G. et al. [7] and Nayak et al. [10], observed the variation of secondary radiation flux during solar eclipse.

To observe the decrement in secondary gamma radiation flux caused by ground-based solar eclipses: (January 4, 2011), (26 December 2019), studies at Udaipur, India were conducted using a scintillation counter system.

Local Temperature and Whether at Udaipur

TABLE 1. The conditions of temperature and whether on pre-, post- and eclipse days for solar eclipse on January 4, 2011.

Date	Whether	Temperature (o_c)	
		Max.	Min.
2.1.2011	Sunny	18	7
3.1.2011	Sunny	17	6
4.1.2011	Sunny	17	6
5.1.2011	Sunny	18	5
6.1.2011	Sunny	19	6

TABLE 2. The conditions of temperature for solar eclipse on December 26, 2019.

Date	Temperature (o_c)	
	Max.	Min.
23.12.2019	25	19
25.12.2019	24	18
26.12.2019	21	15
27.12.2019	23	14
28.12.2019	22	13

Experimental Set-up and Observations

For the experimental study of solar eclipse on January 4, 2011, the scintillation detector used was of Model 802 (make: Canberra Genie 2000) to detect SGR flux produced during partial solar eclipse [Fig. 3]. Secondary radiation flux was incident on an NaI (Tl) crystal, 50 mm in thickness and 44.5 mm in diameter. This detector was coupled with a photo multiplier tube (PMT) of Model 2007P. This counter system has a high-tension voltage supply of Model 3102D with 1100 Volts DC. Using negative polarity of a spectroscopic amplifier of Model 2022, a negative signal of about 0.5 Volt was amplified to a 5-Volt positive pulse. The signal was fed to a multi-channel analyzer with a multi-channel buffer of 1024 energy channels. The detector was put into a lead shield. The data files were stored in a computer for half an hour duration from 14.30 IST to 15.00 IST on pre-eclipse normal days 2,3 January as well as on post-eclipse days 5, 6 January 2011 and also on partial-eclipse day January 4, 2011.

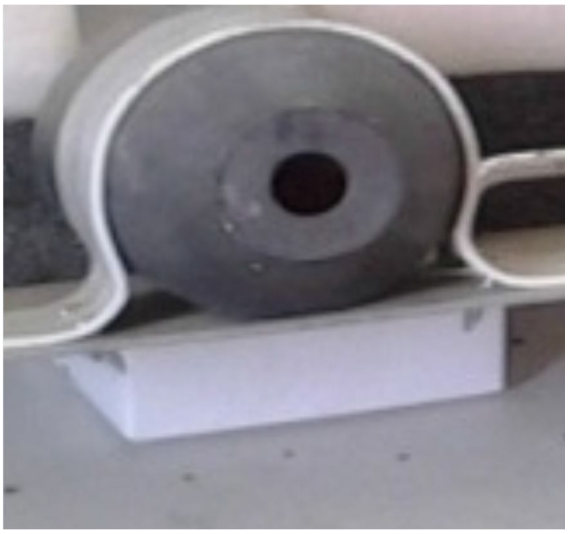

FIG. 3. Scintillation detector.

For the experimental study of solar eclipse on December 26, 2019, a scintillation detector [Fig. 4] of Model (GR611M) was used to detect the secondary gamma radiation flux. The radiations were allowed to enter the NaI (Tl) crystal of 14” width x 10” height x 11.5” depth optically coupled with a photo multiplier tube. This integral line was connected to a high-tension voltage supply of 2000 Volts DC (HV 502). A negative signal of about 0.5 Volt was amplified to a 5-Volt positive pulse using the negative polarity of the linear amplifier (LA 520). This signal was fed to an analog - to - digital counter circuit (SC 530). This digital circuit has a counter circuit (CT 541A) to count the secondary gamma radiation particles.

Scintillation counter was kept open to collect the counts as a function of time. This scintillation counter was shielded with lead. Data was collected from 8:00 AM to 11:00 AM on 23, 25, 26, 27 and 28 December 2019. The pre-eclipse days were 23, 25 and the post-eclipse days were 27, 28. On 26 December 2019, there was an annular solar eclipse at Udaipur, India from 8.00 AM to 11.00 AM.

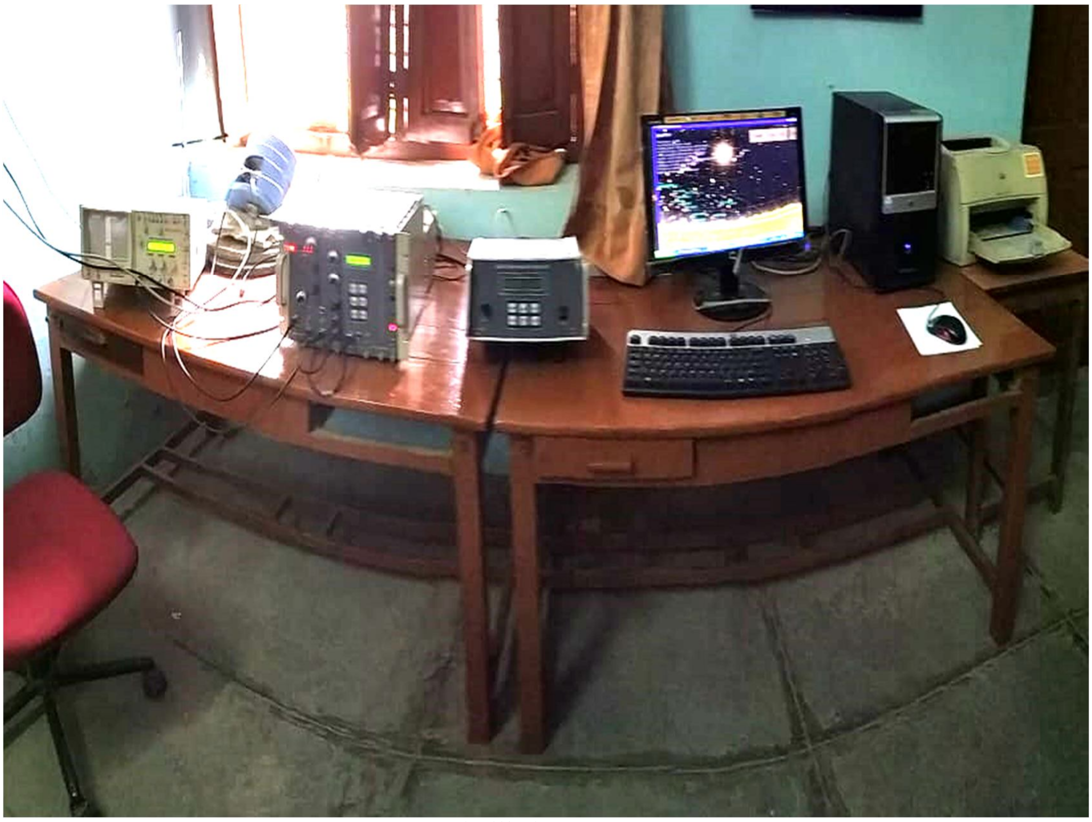

FIG. 4. Scintillation counter system.

Analysis and Results

TABLE 3. Integrated counts on the pre-, post- and solar eclipse days of secondary gamma radiation for solar eclipse on January 4, 2011.

Sr. No.	Date	Integrated Counts
1	2 (Pre-eclipse Day)	56553
2	3 (Pre-eclipse Day)	56672
3	4 (Solar Eclipse Day)	52524
4	5 (Post-eclipse Day)	60343
5	6 (Post-eclipse Day)	60990

By using Table 3, we made Fig. 5 to show the integrated counts *versus* date on pre-eclipse days 2, 3, post-eclipse days 5, 6 and solar eclipse day January 4, 2011.

Table 3 and Fig. 5 clearly show that on the pre-eclipse days 2 and 3, the integrated counts were 56553 and 56672, respectively. On the solar eclipse date of January 4, the counts were 52524. On the post-eclipse dates 5 and 6, the integrated counts were 60343 and 60990, respectively. When the average of integrated counts of all normal days 2, 3, 5 and 6 was taken, then the integrated counts were 58639. Therefore, in comparison, the average counts on solar eclipse day were decreased by 6115. To see the variation in secondary gamma radiation on the eclipse day, we used the following formula:

$$\%\text{ of variation} = \frac{\text{Average counts of normal days} - \text{counts on eclipse day}}{\text{Average counts of normal days}} \times 100.$$

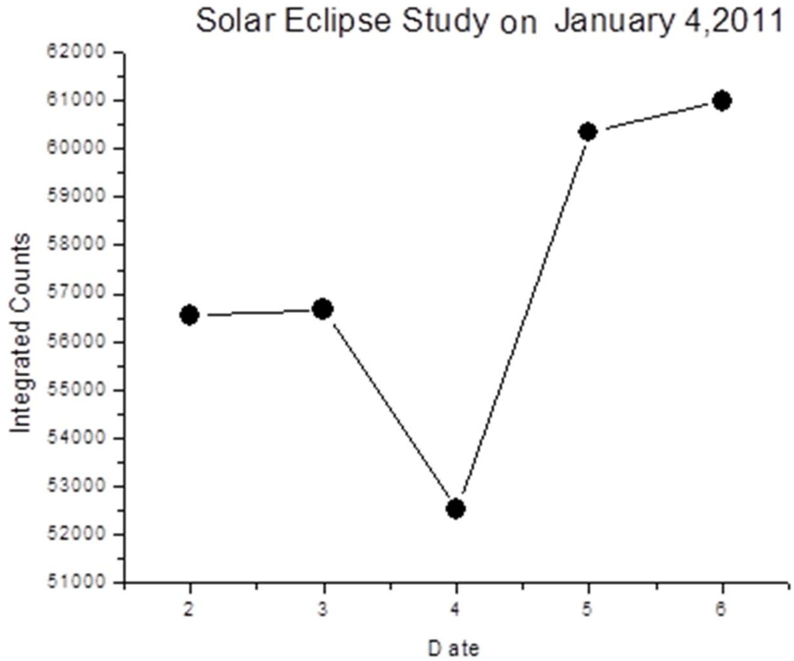

FIG. 5. Integrated counts of secondary gamma radiation *versus* date for solar eclipse on 4 Jan. 2011.

Using this formula, on the eclipse day, there is about 10 % decrement in the counts of SGR flux in comparison to the average counts on normal days.

TABLE 4. Integrated counts of secondary gamma radiation flux on the pre-, post- and solar eclipse days for solar eclipse on December 26, 2019.

Sr. No.	Date	Integrated Counts
1	23 (Pre-eclipse Day)	4892
2	25 (Pre-eclipse Day)	5378
3	26 (Solar Eclipse Day)	4183
4	27 (Post-eclipse Day)	4895
5	28 (Post-eclipse Day)	5183

By using Table 4, we made Fig. 6 to show the integrated gamma radiation counts *versus* date on pre-eclipse days, post-eclipse days and solar eclipse day.

Table 4 and Fig. 6 clearly show that on the pre-eclipse days 23 and 25, the integrated counts were 4892 and 5378, respectively. On the solar eclipse day 26, the counts were 4183. On the post-eclipse days 27 and 28, the integrated counts were 4895 and 5183, respectively. The average of integrated counts of all normal days 23, 25, 27 and 28 was 5087. Therefore, in comparison, on the solar eclipse day, the integrated counts were decreased by 904.

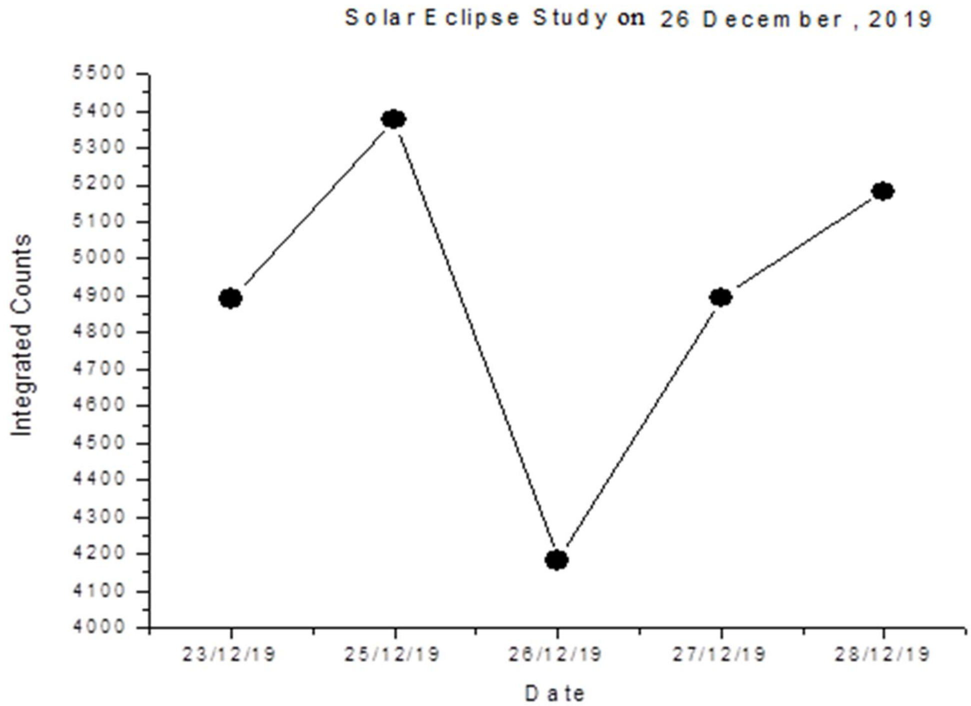

FIG. 6. Integrated counts of secondary gamma radiation *versus* date for solar eclipse on 26 Dec. 2019.

To see the variation in secondary gamma radiation on the eclipse day, we used the following formula:

$$\%\text{ of variation} = \frac{\text{Average counts of normal days} - \text{counts on eclipse day}}{\text{Average counts of normal days}} \times 100.$$

Using this formula, on the solar eclipse day, there is about 17 % reduction in the counts of SGR flux in comparison to the average counts on normal days.

Discussion

The probable reason in these present experimental studies for the decrement in SGR flux is as follows:

- During solar eclipse, the Moon comes between Sun and Earth. Therefore, the Moon acts as a big umbrella and cuts solar and cosmic radiations which are coming towards the atmosphere of the Earth. Hence, the production of secondary gamma radiation is less. Therefore, we observed a decrement of secondary gamma radiation by about 10 % on the solar eclipse day (January 4,2011) and 17 % on the solar eclipse day (December 26, 2019) in comparison to pre- and post-eclipse days.

Conclusion

From the results, we understand that the decrement of secondary gamma radiation flux was due to the obstruction effect produced by the Moon on radiations (CR and SR) during solar eclipse day.

Acknowledgments

The authors wish to thank the anonymous referees for their valuable comments.

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