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ARTICLE

Variation of Secondary Gamma Radiation Flux during Closest Approach of Mars towards Earth, Mars at Opposition and Transit of Moon across Different Constellations and Planets in the Month of October, 2020 at Udaipur, India

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Abstract: The experimental studies of closest approach of Mars towards Earth on October 6 & 7, 2020, Mars at opposition on October 13, 2020 and transit of Moon across different constellations and planets at Udaipur (27^0 43' 12.00" N, 75^0 28' 48.01" E), Rajasthan, India were conducted in the month of October, 2020 using a ground-based NaI (Tl) scintillation detector. For the closest approach of Mars, the data files were stored in computer for a half-hour duration from 20.30 IST to 1.00 IST on the dates of October 6 & 7, 2020, for Mars at opposition data files stored in computer for a half-hour duration from 18.00 IST to 20.00 IST on the date of October 13, 2020 and for Moon in the constellation experimental study the data files were stored in computer for a half-hour duration for the time 18.30 IST – 19.00 IST in the month of October, 2020 dated 19, 21, 22, 23, 25, 27, 28 and 29 at Udaipur (27^0 43' 12.00" N, 75^0 28' 48.01" E), Rajasthan, India, using a ground-based NaI (Tl) scintillation detector. For these experimental studies, the calibration of the scintillation detector was 2 keV per channel using a standard Cs^{137} source. Therefore, we detected the secondary radiation flux in the energy range from 2 keV to 2 MeV.

Analyzed data of closest approach of Mars revealed a significant enhancement of secondary gamma-radiation flux (SGR) of about 4.5% on closest approach of Mars towards Earth at time 00.00 IST -00.30 IST (October 7) in comparison to the time 20.30 IST -21.00 IST (October 6). We interpret that such enhancement of SGR flux is on the basis of closest approach of Mars towards Earth, reflection of solar radiation from Mars towards Earth and gravitational lensing effect produced by Mars. For Mars at opposition, the analyzed data revealed a significant enhancement of secondary gamma-radiation flux (SGR) of about 1.7% in between times 19.00 IST – 19.30 IST. We interpret such enhancement of SGR flux on the basis of Mars at opposition, combined gravitational pull due to planet Mars, planet Earth and the Sun and gravitational lensing by Mars and for transit of Moon, the analyzed data revealed a significant variation of secondary gamma radiation flux (SGR) in the month of October. We interpret such variation of SGR flux on the basis of transit of Moon across different constellations and planets in the month of October.

Keywords: Cosmic radiation, Reflection of solar radiation, Secondary gamma radiation, Closest approach of Mars, Mars at opposition, Combined gravitational pull and gravitational lensing effect by Mars, Transit of Moon across different constellations and planets.

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Introduction

Radiation coming towards the Earth from all directions is called cosmic radiation (CR) and such radiation has charged particles that travel at nearly the speed of light. Composition of CR is about 89% nuclei of protons, 10% nuclei of helium and 1% nuclei of other heavier elements (Lithium, Beryllium and Boron) [1, 2, 3]. Energy range of primary cosmic radiation is from 10^9 eV - 10^{20} eV or more [4]. In comparison, through interstellar abundance of elements and solar system with help of cosmic radiation, we can understand their origin and propagation process through interplanetary space and arrival on Earth. Simpson (1983) [5] pointed out chemical abundance of cosmic radiation in different energy ranges. He made a comparison between solar system abundances and estimated abundances for the local interstellar medium and observed that carbon, nitrogen, oxygen and iron groups are present both in the cosmic radiation and solar system abundances. In the atmosphere above 50 km from the surface of the Earth, the intensity of primary cosmic radiation flux is almost the same as in the interstellar space, but at about 20 km, secondary cosmic radiation produces a denser ionization. The number of particles reaching the Earth's surface is related to the energy of the primary cosmic radiation that struck the upper atmosphere. When high-energy primary cosmic radiation undergoes collisions with atoms of the upper atmosphere, it produces a cascade of lighter particles known as "secondary" particles and called secondary cosmic radiation [6]. In the atmosphere, there is a production of showers of secondary cosmic particles. These particles have X- rays, protons, alpha particles, pions, muons, electrons, neutrinos and neutrons. These particles increase rapidly as they move downward in the atmosphere and in each interaction, the particles loose energy [7, 8]. A small fraction of these particles usually comes down to the ground. In this way, secondary cosmic particles shower down through the atmosphere to the Earth's surface [9]. Such radiation has three components; an electromagnetic component, a hadronic component and a masonic component [10, 11, 12]. In the electromagnetic component, there is a presence of electrons and gamma particles. The hadronic component has low-energy protons and neutrons, while the masonic component has pions, muons, neutrinos and kaons. Therefore, penetrating cosmic radiation produces secondary shower [13]. Produced secondary cosmic radiation flux can be detected using an appropriate detector on the ground [14, 15].

It was observed that when the electromagnetic radiation passes near a massive object, then due to the gravitational field of the object, it bends. This phenomenon is called gravitational lensing. The object could be a galaxy, a star or a cluster of galaxies [16, 17, 18]. Gravitational lensing effect was proved by A. S. Eddington and collaborators in a famous experiment during a total solar eclipse in 1919.

Celestial Events and Variation of Radiation Flux

Secondary cosmic and solar radiation flux was observed by many scientist groups during normal days and on days of special celestial events, such as solar eclipse, lunar eclipse, appearance of comets in the sky, phases of the moon, closest approach of celestial objects, transit of celestial objects, … etc. with the help of an efficient counter system.

During solar eclipse, to observe the variation in secondary radiation flux, many experimental studies were conducted by scientist groups, such as Bhattacharya et al. [19], Kandemir, G. et al. [20], Nayak et al. [21], Bhaskar et al. [22] and Pareek et al. [23].

We conducted a solar eclipse study to understand the interaction of GCR and SR flux with gravitational fields (gravitational lensing) of the sun and well-established shadowing effect of the moon [23].

During lunar eclipse, to observe the variation in secondary radiation flux, many experimental studies were conducted by scientist groups, such as Pareek et al. [24], Raghav et al. [25] and J.N. Ananda Rao et al. [26].

Pareek et al. [24] did an experimental study to observe the variation of secondary cosmic and solar gamma radiation flux at some energy ranges. Such interesting finding can be explained on the basis of bending of primary cosmic radiation and solar radiation by combined gravitational lensing effect of Sun and Earth, backscattered secondary flux form the Moon, combined magnetic field of the Sun and the interplanetary magnetic field.

An experimental study of comets was conducted by Pareek et al. [27] using a scintillation counter with lead shield in the energy range of 10 keV to 5 MeV. We observed an unusual variation of secondary cosmic radiation flux in the energy spectrum of specific energies of about1.127 MeV, 2.29 MeV and 3.66 MeV.

At the celestial event of transit of Venus on June 6, 2012 at Udaipur India, an experimental study was conducted by Pareek et al. [28]. After analyzing the collected data, it was observed that there was a 2 % decrement of secondary solar radiation gamma-ray flux.

A lunar phase ground-based experimental study was conducted by Pareek et al. using a scintillation counter in the month of September 2000 [29]. This experimental study provided information regarding the GCR, SR modulation at the time of new Moon, Full Moon and different phases of the Moon with different backgrounds of constellations in the sky. During the passes of Moon through the background of Capricornus constellation, an abrupt change in energy spectra was noticed on 9th and 10th September 2000 due to gravitational lensing effect.

With the fact that different celestial events happen in the sky, to study modulate terrestrial secondary flux of cosmic and solar radiation, we attempted to see the effect of closest approach of Mars, Mars at opposition and transit of Moon on secondary gamma-radiation flux on the surface of Earth.

The closest approach of Mars on October 7, 2020 was at the time 00.00 IST - 00.30 IST. The data was collected using a scintillation detector on the dates of 6 & 7 October from 20.30 IST to 1.00 IST.

The celestial event Mars at opposition occurred between times 19.00 IST-19.30 IST on October 13, 2020. During Mars at opposition, the planet Mars, Planet Earth and the Sun are in a straight line and the planet Mars was opposite to the Sun.

For transit of Moon study, the data files were stored in computer for a half-hour duration for the time 18.30 IST – 19.00 IST in the month of October, 2020 on dates 19, 21, 22, 23, 25, 27, 28 and 29.

Experimental Set-up and Observations

In these experimental studies, we used a scintillation detector (SD 152 F) of flat type (Fig. 1), Nucleonix made, to detect the secondary gamma-radiation flux. The radiation was allowed to enter in the NaI (Tl) crystal of size 2” x 2”, optically coupled with a photo-multiplier tube. This integral line was connected to 1k multi-channel analyzer (MC 1000), Nucleonix made, with a USB interface built-in in a high-voltage shaping amplifier.

This scintillation counter system was kept open to collect the counts as a function of time on the roof of the Astronomy Laboratory of the Department of Physics, Bhupal Nobles University, Udaipur (Rajasthan), India. For closest approach of Mars, data was collected from 20.30 IST to 1.00 IST on the dates of 6 & 7 October 2020 and for Mars at opposition, the data files were stored in computer for a half-hour duration from 18.00 IST to 20.00 IST on the date of October 13, 2020. For transit of Moon study, the data files were stored in computer for a half-hour duration for the time 18.30 IST – 19.00 IST in the month of October, 2020 on dates of 19, 21, 22, 23, 25, 27, 28 and 29. For this experimental study, the detector is kept towards the Moon.

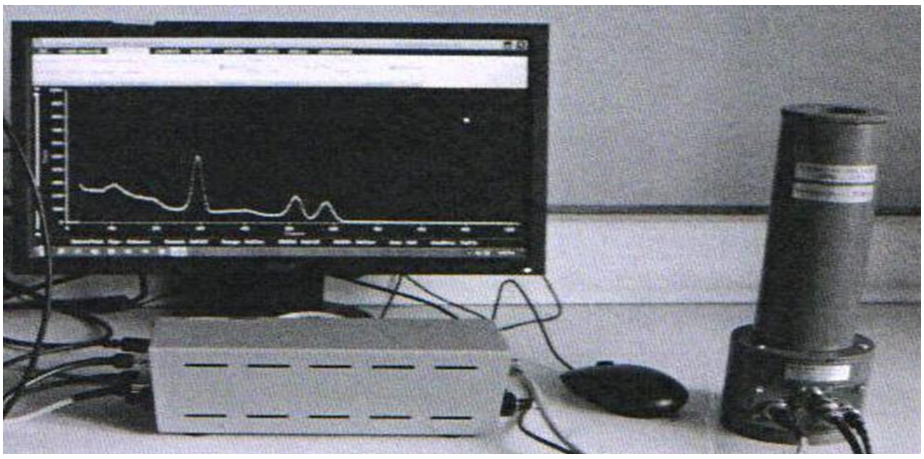

FIG. 1. Scintillation counter system.

Analysis and Results

As depicted in Table 1, the integrated counts of secondary gamma-radiation flux on the dates of 6 & 7 October 2020 from 20.30 IST to 1.00 IST for the experimental study closest approach of Mars towards Earth and using this Table 1, we plotted Fig. 2 between integrated counts and time of secondary gamma-radiation flux. For Mars at opposition, as given in Table 2, the integrated counts of secondary gamma-radiation flux on the date of 13th October 2020 from 18.00 IST to 20.00 IST are shown. Using this Table 2, we plotted Fig. 3 between integrated counts of secondary gamma-radiation flux and time.

TABLE 1. Closest approach of Mars.

Sr. No.	Time (IST)	Integrated Counts
1	20.30 – 21.00	317618
2	21.00 -21.30	320670
3	21.30 – 22.00	322044
4	22.00 – 22.30	327856
5	22.30 – 23.00	329391
6	23.00 – 23.30	329276
7	23.30 – 00.00	330220
8	00.00 -00.30	332178
9	00.30 – 1.00	329331

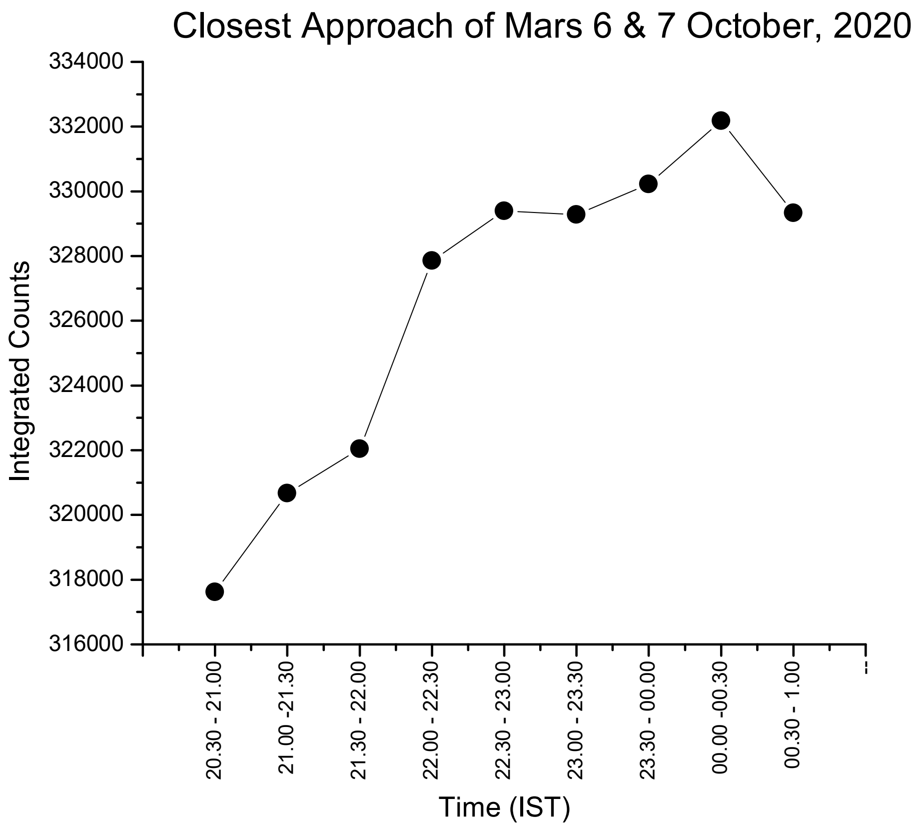

FIG. 2. Integrated counts of secondary gamma-radiation flux for closest approach of Mars on 6 & 7 October 2020.

Table 1 and Fig. 2 show that on the date of October 6, the integrated counts were 317618, 320670, 322044, 327856, 329391, 329276 and 330220 from time 20.30IST to 00.00 IST. On the date of October 7, the integrated counts were 332178 and 329331 from time 00.00 IST to 1.00 IST, respectively. On the date of October 6 at time 20.30 IST, the integrated counts were 317618, while at the closest approach of Mars towards Earth time (00.00 IST - 00.30 IST), the integrated counts were 332178. In comparison to closest approach of Mars towards Earth (00.00 IST -00.30 IST, on October 7) from the time 20.30 IST -21.00 IST (October 6) the increment in counts was 14500 i.e., 4.5 % enhancement of SGR flux counts. After closest approach of Mars time, the counts started to decrease from time 00.30 IST – 1.00 IST.

TABLE 2. Mars at opposition.

Sr. No.	Time (IST)	Integrated Counts
1	18.00 – 18.30	242481
2	18.30 – 19.00	242940
3	19.00 – 19.30	246732
4	19.30 – 20.00	246823

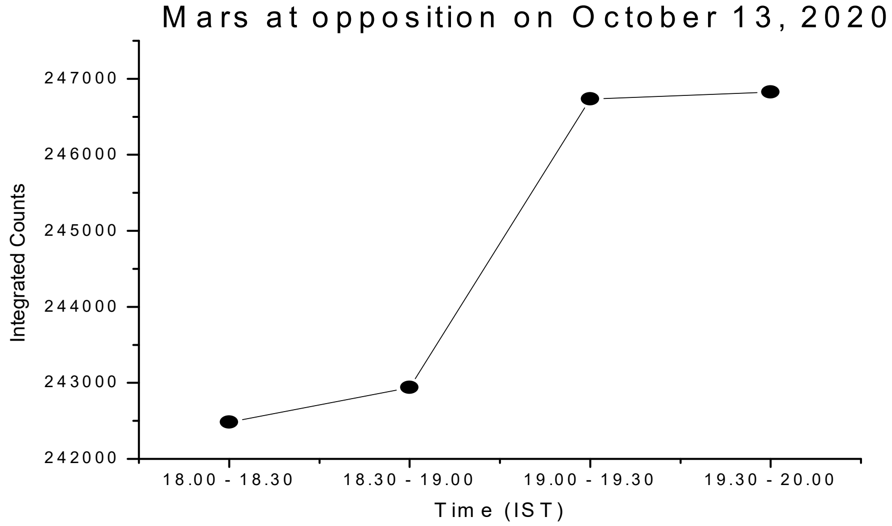

FIG. 3. Integrated counts of secondary gamma-radiation flux for Mars at opposition on 13 October 2020.

Table 2 and Fig. 3 show that on the date of October 13, the integrated counts were 242481, 242940, 246732 and 246823 from the time 18.00 IST to 20.00 IST. In comparison to time between 19.00 IST -19.30 IST, from the time 18.00 IST – 18.30 IST the increment in counts was 4251 i.e., 1.7 % enhancement of SGR flux and the SGR flux remains almost constant between the time 19.30 IST – 20.00 IST after Mars at opposition time.

For the experimental study transit of the Moon, as depicted in Table 3, the integrated counts of secondary gamma-radiation flux on the dates of 19, 21, 22, 23, 25, 27, 28 and 29 are shown. Using this Table 3, we plotted Fig. 4 between integrated counts of secondary gamma-radiation flux and dates.

TABLE 3. Transit of Moon.

Month of October, 2020 Time 18.30-19.00 (IST)		
Sr. No.	Date	Integrated Counts
1	19	255084
2	21	251022
3	22	259212
4	23	258957
5	25	240754
6	27	249136
7	28	248968
8	29	245372

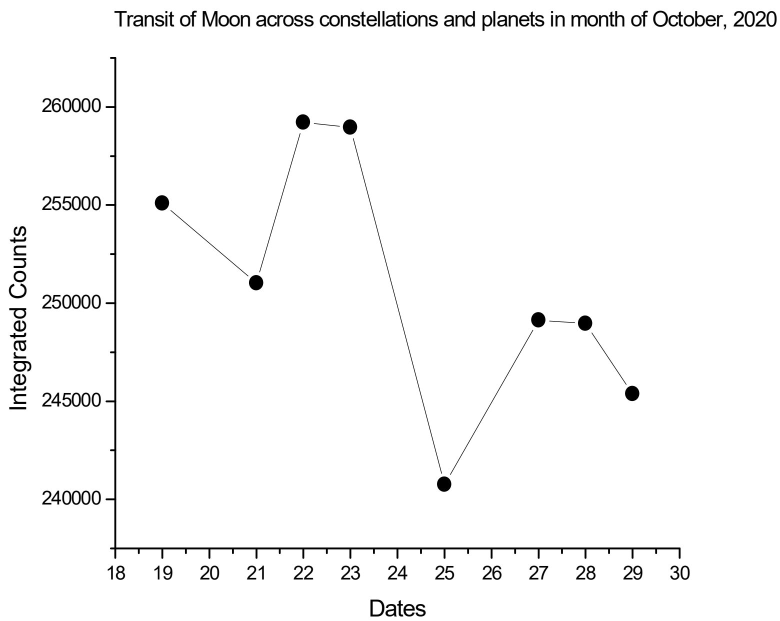

FIG. 4. Integrated counts of secondary gamma-radiation flux for transit of Moon across constellations and planets in October 2020.

Table 3 and Fig. 4 show that on the dates of 19, 21, 22, 23, 25, 27, 28 and 29 in the month October, the integrated counts were 255084, 251022, 259212, 258957, 240754, 249136, 248968 and 245372, respectively, in time 18.30 IST to 19.00 IST. On the date of 19 October, the Moon was close to the constellation Scorpius and then on the date of 21 October, it moved away from this constellation. On the date of 22, the Moon was in the constellation Sagittarius and close to planets Jupiter and Saturn. On the dates of 23 and 25, it moved away from the constellation and the planets. On the date of 27, the Moon was close to the constellation Aquarius and on onward dates 28 and 29, it moved away from this constellation.

Discussion

Closest Approach of Mars towards Earth

Table 1 and Fig. 2 clearly show that counts were increasing as the Mars approaches closer and closer towards the Earth. On the date of October 7, 2020 at time 00.00 IST – 00.30 IST, we observed the highest counts in comparison to other times of October 6 & 7, because at this time (00.00 IST – 00.30 IST), the planet Mars was closest to the Earth.

The probable reasons in this present study for the enhancement of SGR flux counts are as follows:

(1) On the dates of October 6 & 7, 2020 from time 20.30 IST to 00.00 IST -00.30 IST, Mars was regularly approaching closer and closer towards the Earth; therefore, the intensity of reflected solar radiation form the surface of Mars was increasing. Hence, the formation of secondary radiation flux became more and more in the atmosphere of the Earth.

(2) Due to closest approach of Mars, gravitational lensing effect becomes more significant. It was highest on the date (October 7, time 00.00IST to 00.30 IST) of closest approach of Mars towards the Earth. Therefore, more cosmic radiation came on the Earth atmosphere and the formation of secondary radiation became more.

Due to the above probable reasons given in points (1) and (2), we got 4.5% enhancement of secondary gamma-radiation flux counts on October 7, 2020.

This is a unique and new observation reported in the present study during the closest approach of Mars towards the Earth.

Mars at Opposition

Table 2 and Fig. 3 clearly show that counts during Mars at opposition time were 246732.

The probable reasons in this present study for the enhancement of SGR flux counts are as follows:

(1) On the date of October 13, 2020 between times 19.00 IST and 19.30 IST, the planet Mars, the planet Earth and the Sun are in a straight line and planet Mars is opposite to the Sun. Between these times, the combined gravitational pull due to all these celestial objects is significant and maximum. Therefore, more background radiation is pulled by this combined gravitational pull. Hence, the formation of secondary radiation flux became more in the atmosphere of the Earth.

(2) At time of Mars at opposition, the planet Mars produced a gravitational lensing effect. Therefore, more cosmic radiation was bent and came on the Earth atmosphere. So, the production of secondary radiation was more.

Due to the above probable reasons given in points (1) and (2), we got 1.7% enhancement of secondary gamma-radiation flux on October 13, 2020.

This is a unique and new observation reported in the present study during Mars at opposition.

Moon across Different Constellations and Planets

Table 3 and Fig. 4 clearly show the variation of counts during Moon across different constellations and planets.

The probable reasons in this present study are as follows:

1. On the date of 19 October, the Moon was close to the Scorpius constellation and on 21 October, the Moon was shifted away from this constellation and so, there was a decrease in counts from 255084 to 251022; i.e., the decrement in counts was 4062. This clearly represents the gravitational lensing effect on the background cosmic radiation due to constellation Scorpius and the radiation from this constellation.

2. On the date of 22 October, the Moon was in the constellation Sagittarius and close to the planets Jupiter and Saturn. Therefore, we observed the highest counts of 259212 in this observation. This is due to radiation coming from the constellation, gravitational lensing effect by the constellation on background radiation, combined gravitational lensing effect on background radiation due to planets and reflected solar radiation from planets. Therefore, more radiation was bent along with reflected solar radiation, which may produce more showers of secondary gamma-radiation particles in the atmosphere of the Earth.
3. On 27 October, again there was an increase in the integrated counts by 8382 in comparison to the date of 25. On this date, the Moon was close to constellation Aquarius. Therefore, due to gravitational lensing and radiation from the constellation, there was an increase in the counts of secondary gamma-radiation flux.

Therefore, whenever the Moon passes from a constellation, then due to gravitational lensing and radiation from the constellation, more cosmic radiation is bent. This bent radiation impinges deep inside the atmosphere of the Earth, which produces more secondary gamma-radiation particles that give such variation in the month October.

Also, when the Moon comes close towards planets, then there was an increment in the counts due to more formation of secondary radiation from reflected solar radiation and gravitational lensing effect due to planets on background radiation.

Due to the above probable reasons given in points (1), (2) and (3), we can understand the variation of secondary flux during transit of the Moon across different constellations and planets.

This is a unique and new observation reported during transit of the Moon across different constellations and planets.

Conclusions

(A) On October 7, 2020, the planet Mars was closest towards the Earth, so we observed an enhancement of secondary gamma-radiation flux of about 4.5 % on the surface of the Earth.

(B) On October 13, 2020 between times 19.00 IST – 19.30 IST during Mars at opposition, we observed an enhancement of secondary gamma-radiation flux of about 1.7% on the surface of the Earth.

(C) Experimental study transit of Moon gave information about variation of secondary gamma-radiation flux on the surface of the Earth due to transit of the Moon across different constellations and planets.

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