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Variation of Cosmic Ray Intensity during Different Types of Solar Eclipses from 1990 to 2017 (August)

Abdullah Al Zaman MD[1*] and Jahan Monira N[2]

[1,2]Department of Physics, University of Chittagong, Bangladesh

[*]**Corresponding author:** Abdullah Al Zaman MD, Department of Physics, University of Chittagong, Bangladesh, Tel: +880 1713-171330; E-mail: proyashzaman1@gmail.com

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Abstract

In this study, we have calculated the variations of cosmic ray intensity during the solar eclipses (including Annular, Total, Partial and Hybrid) from 1990 to 2017 (August) by using the online cosmic ray data from Mexico City Cosmic Ray Observatory. We haven't found significant changes in the cosmic ray intensity during the solar eclipses in most of the cases. The increment and decrement tendencies of intensity have been observed but in 95% occasions variation didn't go beyond 2% relative to the days close to the eclipse. The highest amount of variation found is 4.25% (decreased) during an annular eclipses in 2003. If we had analyzed the composition of the cosmic rays with their energies, we could have got a clearer picture.

Keywords: ***Cosmic rays; Universe; Atmosphere; Earth; Solar eclipses***

Introduction

Cosmic rays are particles that bombard our earth's atmosphere. We actually get the low energy secondary cosmic rays which are produced by the interactions between our earth's atmosphere and the highly energetic primary cosmic rays. Primary cosmic rays are extremely energetic that even our highly improved machinery cannot attain or generate such level of energies. These rays are the messengers of our universe giving us information about the fabric of our universe and much more. Through the cosmic rays, we have discovered Positrons (1932) and Muons (1937).

After the discovery of the cosmic rays back in 1912, scientists didn't have much idea about the sources of these cosmic rays. Yes, they were clear about the concept that most of these rays or particles were not from our sun, but they didn't have any clearer picture. Even today we cannot exactly locate the sources of the cosmic rays but today we do know that the supernova explosions of the dying stars are the most probable sources of the cosmic rays. But exactly which one we cannot detect that.

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Cosmic rays can be classified into two classes. First, Galactic cosmic rays, coming from different parts of our own galaxies and other galaxies and second Solar cosmic rays coming from our own star Sun. The intensity and flux of the Galactic cosmic rays are much higher than the solar cosmic rays. In fact, we get a few cosmic rays with relatively lower energies from our Sun.

A solar eclipse is a celestial event in which the Moon passes between the sun and Earth and blocks all or a part of the sun for up to about three hours, from beginning to end, as viewed from a given location. There are four types of solar eclipse namely, Total, Partial, Annular and Hybrid. In a total eclipse the Sun is totally covered by the Moon i.e. the Moon completely covers the photosphere. In a partial eclipse, only a part of the photosphere is covered wherein an Annular eclipse a thin ring of very bright sunlight remains around the black disk of the Moon as the apparent size of the Moon is not large enough to completely cover the Sun. A Hybrid eclipse appears annular and total along different sections of its path.

During the solar eclipse, the solar radiations are blocked by the Moon. And this depends on the type of the eclipse. There has been reporting of variations in the secondary cosmic ray flux [1-4] and geomagnetic or surface parameters [5,6]. But we have worked only with the secondary cosmic ray counts.

Methodology

Mexico City Cosmic Ray Observatory (FIG. 1) is a property of the National Autonomous University of Mexico UNAM (Universidad Nacional Autónoma de México, https://www.unam.mx). It detects high energy particles coming from outer space and continuously impinging on the earth´s atmosphere from all directions [7]. It is part of the World Network of Neutron Monitors. The Cosmic Ray Observatory is installed on the Campus of the UNAM (19°19'23.3"N 99°11'07.6"W). It consists of two types of detectors: a Neutron Supermonitor 6NM64 and a Muon Telescope, detecting the nucleonic and the hard components of secondary cosmic radiation, respectively. The detection range of these instruments ranges from 8.5 to 200 GeV of energy.

FIG. 1. **Mexico City Cosmic Ray Observatory.**

The Mexico City Neutron Monitor has a cutoff rigidity of 8.2 GV it is in continuous operation since 1990. The 6NM64 consists of six proportional counters of Boron Trifluoride (BF3). The intensity of cosmic radiation is affected by pressure changes, so it is necessary to make some corrections to the intensity detected by the instruments to eliminate the variations due to the atmosphere. To do that, the atmospheric pressure is registered concomitant to the cosmic ray intensity and a digital barometer Meteolabor-ag GB1 is used to obtain the five-minute readings of the height of the barometer.

Results, Discussion and Conclusion

For all types of eclipses mentioned above we've got both the increment and decrement in cosmic ray counts relative to the average counts before and after 10 days of eclipse. We have used equation (1) for determining relative variations in intensity.

$$\text{Relative Variation} = \frac{Average\,counts\left(for\,20\,days\right) \sim Eclipse\,day\,counts}{Average\,counts} \times 100 \qquad (1)$$

TABLE 1. **Variation of cosmic ray counts during annular eclipses.**

No. of observations	Date	Eclipse day counts	Average counts for 20 days	Counts status	Relative variation (In %)
1	1/26/1990	1799461	1816446	Decreased	0.94
2	1/15/1991	1837356	1841592	Decreased	0.23
3	1/4/1992	1751490	1754563	Decreased	0.18
4	5/10/1994	1854282	1848521	Increased	0.31
5	4/29/1995	1873060	1882593	Decreased	0.51
6	8/22/1998	1866409	1856573	Increased	0.53
7	2/16/1999	1835541	1852602	Decreased	0.92
8	12/14/2001	1861947	1832290	Increased	1.62
9	6/10/2002	1828319	1827689	Increased	0.03
10	5/31/2003	1716736	1834763	Decreased	4.25
11	10/3/2005	1887000	1875672	Increased	0.60
12	9/22/2006	1923063	1914033	Increased	0.47
13	2/7/2008	1971616	1969753	Increased	0.09
14	1/26/2009	2004097	1999015	Increased	0.25
15	1/15/2010	2000215	2007975	Decreased	0.39
16	5/20/2012	1961979	1967412	Decreased	0.28
17	5/10/2013	1933108	1919994	Increased	0.68
18	4/29/2014	1945674	1939314	Increased	0.33
19	9/1/2016	1972346	1967234	Increased	0.26
20	2/26/2017	2002738	2003049	Decreased	0.02

After analyzing the intensity of the cosmic rays for 55 different types of solar eclipses in the earth surface, we have observed that there is very small amount of variation during the solar eclipses. The intensity of the cosmic rays increased and decreased in comparison with the average intensity for before and after 10 days of the solar eclipses. The deviations were not greater than 1% most of the cases. In the very small number of occasions, the variation has crossed the 2% mark (FIG. 2 to 5 and TABLE 1,4). The highest amount of variation was found on 31st May 2003 (TABLE 1). an annular eclipse that was visible across central partiality was visible throughout Europe, Asia and far northwestern Canada. In that day the intensity was decreased by 4.25% [10]. In TABLES 3 and 4 we have just shown the data and the variation of intensity in the cosmic rays during Hybrid eclipses. Indirectly this study also shows that the cosmic rays intensity didn't change much or almost unchanged over the period 1990-2017 [11,12].

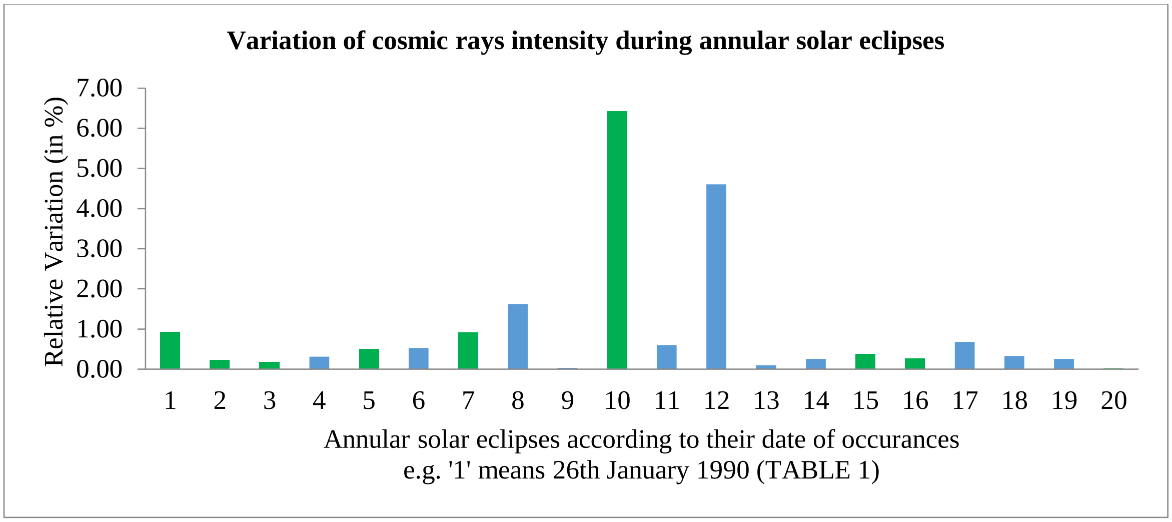

FIG. 2. **Variation of cosmic ray counts during annular eclipses (1990-2017). The green bars signify the decrement of cosmic ray intensity where the blue bars represent the increment in cosmic ray intensity.**

TABLE 2. **Variation of cosmic ray counts during total eclipses.**

No. of observations	Date	Eclipse day counts	Average counts (for 20 days)	Counts status	Relative variation (In %)
1	7/22/1990	1825171	1811952	Increased	0.73
2	6/30/1992	1838090	1840645	Decreased	0.14
3	11/3/1994	1860758	1868229	Decreased	0.40
4	10/24/1995	1877425	1872909	Increased	0.24
5	3/9/1997	1914701	1911811	Increased	0.15
6	2/26/1998	1897109	1911982	Decreased	0.78
7	8/11/1999	1871524	1825457	Increased	2.52
8	6/21/2001	1818389	1812684	Increased	0.31
9	12/4/2002	1833745	1807143	Increased	1.47
10	11/23/2003	1724551	1756730	Decreased	1.83
11	3/29/2006	1936182	1940835	Decreased	0.24
12	8/1/2006	1921352	1922704	Decreased	0.07
13	7/22/2009	2018138	2022315	Decreased	0.21
14	7/11/2010	1972843	1981505	Decreased	0.44
15	11/13/2012	1949809	1952704	Decreased	0.15
16	3/9/2016	1961515	1961190	Increased	0.02
17	8/21/2017	1961164	1976588	Decreased	0.78

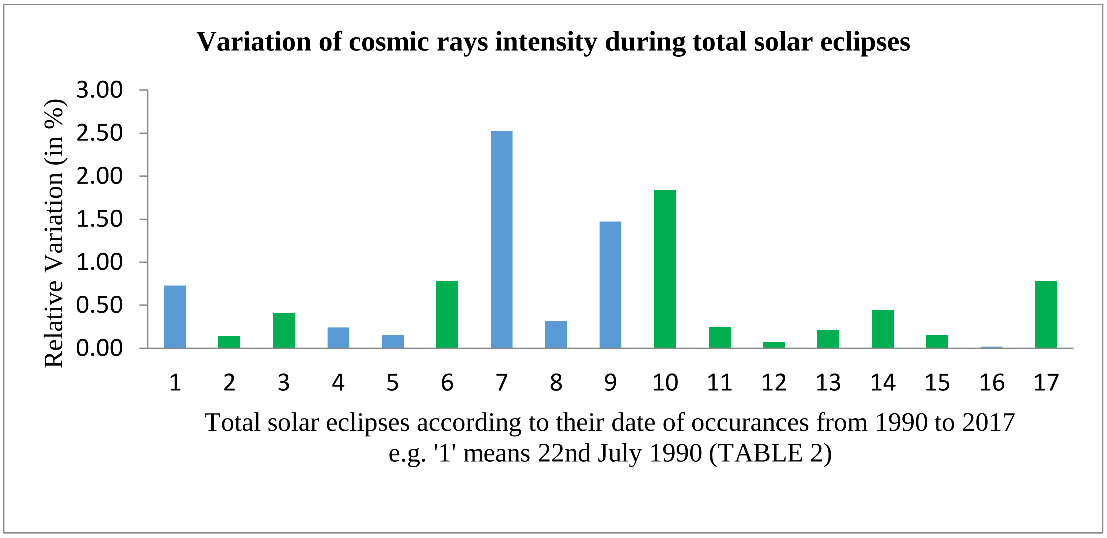

FIG. 3. **Variation of cosmic ray's intensity during total solar eclipses (1990-2017). The green bars signify the decrement of cosmic ray intensity where the blue bars represent the increment in cosmic ray intensity.**

TABLE 3. **Variation of cosmic ray's intensity during partial eclipses.**

No. of observations	Date	Eclipse day counts	Average counts (for 20 days)	Counts status	Relative variation (In %)
1	12/24/1992	1851797	1842174	Increased	0.52
2	11/13/1993	1865515	1853680	Increased	0.64
3	4/17/1996	1889430	1890545	Decreased	0.06
4	10/12/1996	1879806	1876139	Increased	0.20
5	7/31/2000	1779344	1753855	Increased	1.45
6	7/1/2000	1807427	1788201	Increased	1.08
7	2/5/2000	1848370	1847638	Increased	0.04
8	12/25/2000	1812893	1826601	Decreased	0.75
9	4/19/2004	1894309	1874673	Increased	1.05
10	10/14/2004	1897327	1899189	Decreased	0.10
11	3/19/2007	1952796	1945350	Increased	0.38
12	9/11/2007	1940286	1938670	Increased	0.08
13	1/4/2011	1986691	1986008	Increased	0.03
14	7/1/2011	1932927	1928455	Increased	0.23
15	11/25/2011	1967732	1962150	Increased	0.28
16	10/23/2014	1907724	1910445	Decreased	0.14

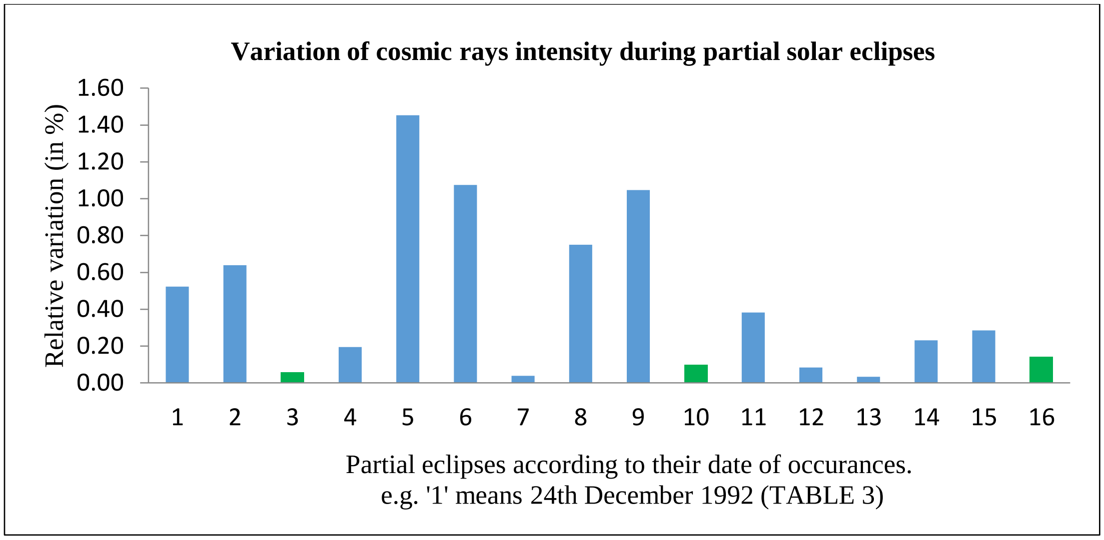

FIG. 4. **Variation of cosmic ray counts during partial eclipses (1990-2017). The green bars signify the decrement of cosmic ray intensity where the blue bars represent the increment in cosmic ray intensity.**

TABLE 4. **Variation of cosmic ray's intensity during hybrid eclipses.**

No. of observations	Date	Eclipse day counts	Average counts (for 20 days)	Counts status	Relative variation (In %)
1	4/8/2005	1893240	1887536	Increased	0.30
2	11/3/2013	1939314	1935290	Increased	0.21

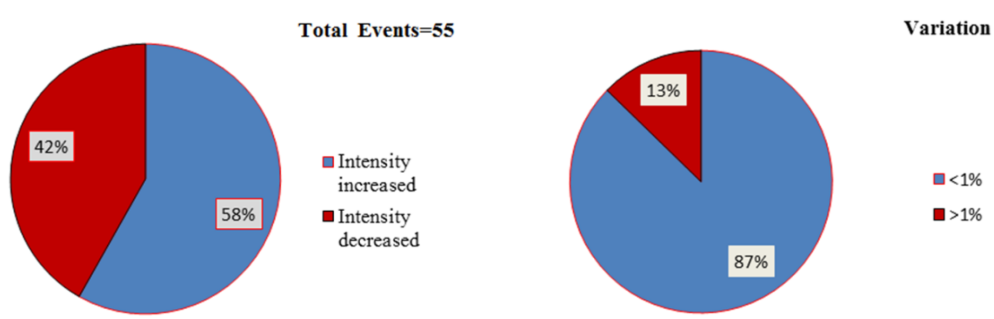

FIG. 5. **Variation overview.**

However, the data is so inadequate to visualize the exact situation. We know that the cosmic rays include many types of particles. There may have some variation in the composition of cosmic rays during the solar eclipses which cannot be determined by only analyzing the intensity or the daily counts [13]. We have applied simplest of the equation to study the variations which may not be sufficient enough here. It's only the average result while taking the data we have found some non-eclipse days where the intensity was below or average. This means that there are actually many other things that are responsible for the increase or decrease in the intensity of the cosmic rays in the earth surface which we haven't included in our study. We can also study the variation in the energies of the particles. The raw data can be accessed from data site [14].

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