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Gamma-Ray Burst Propagating Strong Photon Intensity Interaction

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ABSTRACT

Gamma-ray bursts (GRBs) are the most energetic explosions that occurs in the universe, we explored the interactions between high-energy photons and their surroundings during the propagation of the GRBs. The Gamma-ray burst data were obtained from the sample of GRBS, whose jet break times were measured in the radio, optical and x-ray afterglow light curves. We invoke Light intensity by measuring the amount of power either emitted or reflected by a source, and was calculated using the luminosity or brightness. With some plausible assumption; the observable data yield I=-2317t+45409 where 'I' light intensity,'t' is time. The observation of a negative slope in the regression plot suggests a decrease in intensity over time for GRBs shown in the table 1, 2 and 3. This observation implies that the energy emitted during the burst diminishes as the event progresses. The negative slope attributed to various factors including the propagation effects of gamma-ray photons, absorption by intervening matter, or energy dissipation mechanisms within the source of the burst. It helps in elucidating the mechanisms behind the energy release and the behaviour of gamma-ray radiation during these intense cosmic events. To validate the obtained equation and strengthen the understanding of the intensity-time relationship of GRBs and strong photon interactions, it is recommended to conduct further research using a larger dataset. This will increase the reliability and generalizability of the equation.

Keywords:
Gamma-Ray Bursts,
Intensity,
Photon.

INTRODUCTION

Gamma-ray bursts (GRBs) are the most energetic explosions known to occur in the universe. They are extremely intense bursts of gamma-ray radiation that last for only a few milliseconds to a few minutes. GRBs were first detected in the 1960s by the Vela satellites, which were designed to monitor for nuclear explosions on Earth (Anup, 1998). The intensity of a GRB refers to the amount of energy emitted per unit time, and it is typically measured in units of energy per square centimeter per second. GRBs can emit as much energy in a few seconds as the Sun will emit during its entire 10-billion-year lifetime (Rosalba, 2003).Gamma-ray bursts(GRBs) are expected to be emitters of high-energy gamma rays, possibly up to tera electron volt (TeV) energies and above. Such TeV photons can interact with photons of the cosmic infrared background (CIB) to produce electron-positron pairs, which in turn generate secondary inverse Compton (IC) gamma rays in the 1-100GeVrange that arrive with a characteristic time delay (Takahashi, 2008). Gamma-ray bursts (GRBs) are short and intense bursts of γ- rays from distant galaxies that are detected by space satellites at a rate of $R_{GRB} \sim 10^3$per year (Arnon and Rainer,1999).

The propagation of GRB intensity refers to the way in which the intensity of the gamma-ray radiation decreases as it travels through space. As gamma-rays are extremely energetic, they can travel vast distances through the universe without being significantly absorbed or scattered by matter. However, as they travel, the intensity of the gamma-ray's decreases due to a process called cosmological redshift (Wen, 2015).

Cosmological redshift occurs because the universe is expanding (Alan, 2004). As the gamma-ray photons travel through space, the expansion of the universe causes the wavelength of light to stretch, making it appear redder (Balbi, 2007). This stretching of the wavelength is similar to the Doppler effect observed with sound waves. The expansion of the universe stretches the wavelengths of the photons, reducing their energy and intensity as they reach us (Bertone et al., 2006).

More realistically, the fireball is contaminated by baryonic matter, whether released during the explosion or surrounding the explosive object beforehand (Anotz, 1994). GRBs are the most luminous cosmic explosions and therefore serve as beacons at the edge of the visible universe that can be used as cosmic probes (Edo et al., 2003). GRBs provide short-timescale insight into end-stage stellar evolution, and serve as probes of extremely energetic particles and relativistic bulk motions. They are also promising sources of high-energy neutrinos and gravitational waves (Jonathan et al., 2015).

As gamma-ray photons travel through space, various factors can influence their intensity. One of the factors is absorption. Photons can be absorbed by intervening matter, such as interstellar gas or dust, which can decrease the overall intensity of the burst. This absorption can also cause the observed gamma-ray spectrum to change, as some photons are selectively absorbed based on their energy (Ridgers et al., 2013).

The distance at which a GRB is detected can also affect its observed intensity. The farther away a GRB is, the longer the time it takes for the gamma-rays to reach us. This time delay can cause a decrease in the observed intensity of the GRB (Fishman and Meegan, 1995).

In this study we investigate the physical processes and understand the dynamics of these cosmic events. The research focuses on exploring the interactions between high-energy photons and their surroundings during the propagation of GRBs.

MATERIALS AND METHODS

Sources of Data

Gamma-ray burst data were obtained from sample includes all GRBs whose jet break times (t_j) were measured in the radio, optical, and x-ray afterglow light curves, regardless of whether the (t_j) are achromatic, or detected only in one band. The multi-wavelength emissions from these afterglows understand the environment surrounding the burst and the physical processes playing the role of light intensity (Rui-Jing et al., 2012).

Methods of Data Analysis

Gamma-ray bursts are highly energetic cosmic events that release an enormous amount of photons carry an extremely high intensity of light due to the strong processes involved in their generation and propagation.

Light intensity is a measurement of the amount of power either emitted or reflected by a source, and it can be calculated using the total wave output, luminosity, or brightness. Brightness is a function of luminosity and intensity.

$$I = \frac{p}{A} = \frac{p}{\pi r^2} \quad (1)$$

$$A = \pi r^2 \quad (2)$$

Where 'A' is the area of the sun, 'P' is the radiation power, 'r' is the radius of the sun 'r_s'= 696000km, 'I' is the light intensity and 'E' is the energy of the Gamma-ray Bursts (GRBs).

RESULTS AND DISCUSSION

Table 1: Estimating the intensity and its variation at varying time of arrival (t) using GRBs sample indicating one burst recorded on that specific day, by Rui-Jing et al. (2012)

S/N	GRBs	Time(sec)	E_γ(J)x10^{43}	P (x10^{37})	I (x10^{-19})
1	970508	2592000	2.96	1.142	7.500725
2	970828	224640	6.31	28.089	184.4903
3	980703	336960	3.06	9.081	59.64456
4	990123	216000	21.1	97.685	641.601
5	990510	110592	2.39	21.611	141.9424
6	990705	103680	3.93	37.905	248.9623
7	991216	138240	7.56	54.688	359.1941
	Means	531730.3	6.758571	35.743	234.7622

The results in Table 1 show the intensity (I), the radiation power (P) and the time of arrival of the gamma ray. average time was 188352 seconds with standard deviation of 89322.73 while its Energy(J) was 7.391667 and standard deviation of 6.998284. The power of the GRBs on the other hand was 41.50983 Watts with standard deviation of 31.52783 while the intensity (W/m2) was 272.6391 with standard deviation of 207.0767.

We see in Table 2 that the GRBs have a mean time of 333784.8 seconds with standard deviation of 483619, Energy(J) was 8.547 with standard deviation of 19.62964. The Power (watt) was 30.62319 with standard deviation of 58.56499 while the Intensity (W/m2) of the Gamma ray burst was 201.1349 with a standard deviation of 384.6584.

Table 2: Estimating the intensity and its variation at varying time of arrival (t) using GRBs sample indicating more than one burst recorded on that specific day, by Rui-Jing et al. (2012)

S/N	GRBs	Time(sec)	Eγ(J)x1043	Eγ(J)x1043	I (x10-19)
1	000301C	673920	3.49	5.179	34.01599
2	050416A	1728	0.002	1.157	7.599246
3	050525A	21600	0.16	7.407	48.64962
4	050820A	1728000	13.1	7.581	49.79247
5	050922C	5184	0.08	15.432	101.3583
6	051016B	217728	0.07	0.322	2.114915
7	051109A	80352	0.84	10.454	68.6625
8	051221A	472608	0.55	1.164	7.645222
9	070714B	1037	0.02	19.29	126.6979
10	070721B	10368	0.43	41.474	272.4037
11	070810A	11232	0.05	4.452	29.24101
12	071010A	88992	0.05	0.562	3.69125
13	071010B	330912	1.21	3.657	24.0194
14	080319B	3456	0.8	231.481	1520.381
15	090902B	743040	62.7	84.383	554.2326
16	090926A	950400	53.2	55.976	367.6538
Means		333784.8	8.547	30.62319	201.1349

Table 3: Estimating the intensity and its variation at varying time of arrival (t) using GRBs sample indicating one and more burst recorded on that specific day, by Rui-Jing et al. (2012)

S/N	GRBs	Time(sec)	Eγ(J)x10^{43}	P (x10^{37})	I (x10^{-19})
1	970508	2592000	2.96	1.142	7.50073
2	970828	224640	6.31	28.089	184.49
3	980703	336960	3.06	9.081	59.6446
4	990123	216000	21.1	97.685	641.601
5	990510	110592	2.39	21.611	141.942
6	990705	103680	3.93	37.905	248.962
7	991216	138240	7.56	54.688	359.194
8	000301C	673920	3.49	5.179	34.016
9	050416A	1728	0.002	1.157	7.599246
10	050525A	21600	0.16	7.407	48.64962
11	050820A	1728000	13.1	7.581	49.79247
12	050922C	5184	0.08	15.432	101.3583
13	051016B	217728	0.07	0.322	2.114915
14	051109A	80352	0.84	10.454	68.6625
15	051221A	472608	0.55	1.164	7.645222
16	070714B	1037	0.02	19.29	126.6979
17	070721B	10368	0.43	41.474	272.4037
18	070810A	11232	0.05	4.452	29.24101
19	071010A	88992	0.05	0.562	3.69125
20	071010B	330912	1.21	3.657	24.0194
21	080319B	3456	0.8	231.481	1520.381
22	090902B	743040	62.7	84.383	554.2326
23	090926A	950400	53.2	55.976	367.6538
Means		394029.1	8.002696	32.18139	211.3693

In Table 3, the mean time (sec) was 394029.1with its standard deviation as 416361.6. The Energy was 8.002696 Joules with a standard deviation of 16.94606. The Gamma ray burst had power of Power 32.18139 Watts with standard deviation of 52.06913 while the Intensity in Watts/m2 was 211.3693 with a standard deviation of 341.9932. The results in Table 3 of the GRB sources, the standard deviation of time represents the variability in the duration of the bursts. Some GRBs last only a few milliseconds, while others can persist for several minutes or even longer. The standard deviation of time captures this range and provides insights into the diversity of burst durations.

On the other hand, the standard deviation of light intensity measures the variability in the brightness of GRBs. It reflects fluctuations in the energy release during the burst. GRBs can be extremely energetic, sometimes releasing more energy in a few seconds than the Sun will generate over its entire lifespan. So, the standard deviation of light intensity quantifies the extent to which the intensity of the gamma-ray emission varies during the burst.

The time duration of a GRB can vary significantly, the intensity of the gamma-ray emission may exhibit a smoother trend over time. The variations in light intensity within a GRB may be present but not as pronounced or rapidly changing as the burst duration.

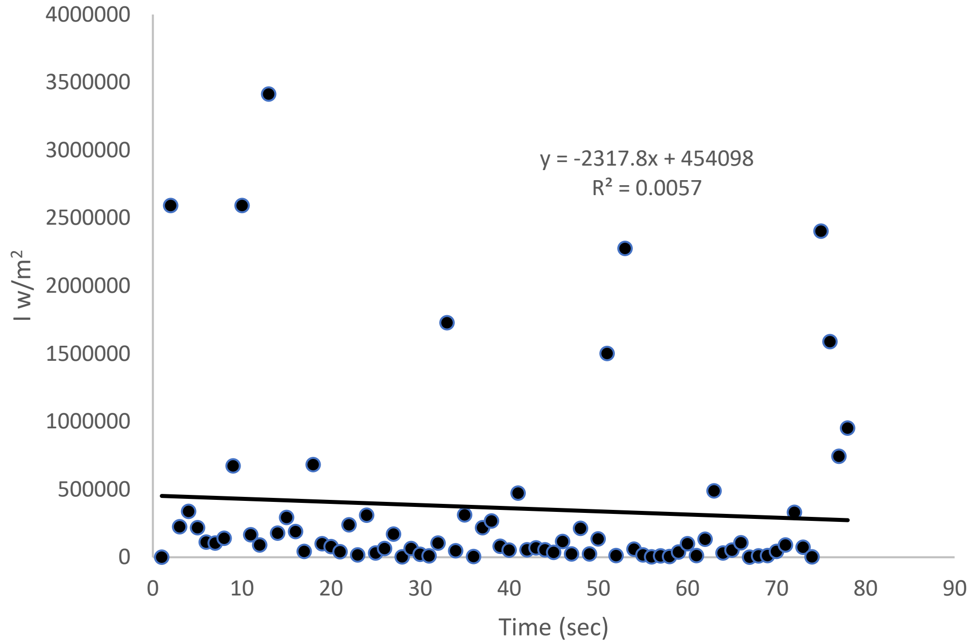

Figure 1.Plot of intensity (I) against the time (t) of arrival

Discussion

The observation of a negative slope in the regression plot of intensity against time for gamma-ray bursts (GRBs) in figure (1) is an intriguing result that offers important insights into the behaviour on the data from the X-ray and Gamma-ray monitor on-board the peppoSAX satellite to study the spectral properties of GRBs(Reichart et al.,2001). They found that a significant number of bursts exhibit a negative correlation between intensity and time, indicating a decreasing energy release over the duration of the bursts and evolution of these cosmic events shown in table 1, 2 and 3. One possible explanation for the negative slope is the concept of energy dissipation, the GRBs emission is the likely result of internal energy release in an ultra-relativistic flow. The dissipative and radiative mechanisms for the GRBs largely remain uncertain. A popular model for the energy dissipation invokes internal shocks in an unsteady flow (Giannios, 2008). GRBs are explosive events that release an enormous amount of energy (100 billion times that of the sun) within a short duration. As the burst progresses, this energy may be dissipated through various mechanisms, leading to a decrease(10^8- 10^4ergs.)in intensity over time shown in the table1, 2 and 3. These dissipation mechanisms could include internal shocks within the GRB source, interactions with the surrounding medium, or radiation losses as the burst expands and interacts with the interstellar medium (Felix and Vahe, 2002).

We obtain an equation given by

$$I = -2317t + 45409 \qquad (3)$$

With a correlation coefficient (R ≅0.07)

Simplifying equation (3), we take anti-log on both side therefore, we obtain

$$I = 10^{(-2317t + 45409)} \qquad (4)$$

Opening the bracket of the expression, we obtain

$$I = 10^{(-2317t)} + 10^{45409} \qquad (5)$$

Hence equation (4.3) can become

$$I = (1x10^{45409})\, 10^{(-2317t)} \qquad (6)$$

Rearranging equation (6), we obtain

$$I = (1x10^{45409}) 10^{\log t\,(-2317)} \qquad (7)$$

Therefore, the relation becomes

$$I = (1x10^{45409}) t^{(-2317)} \qquad (8)$$

The last equation simply suggested that I varies with't' according to the relation:

$$I \sim t^{\psi} \qquad (9)$$

Where $\psi = -2317$ is the slope of the plot.

Correlation coefficient 'r'	-0.11456
Sample size 'n'	77
T –Statistic	-0.99873
p-value	1.731829

The correlation coefficient between the two variables is-0.11456. This is a negative correlation coefficient however,the test statistic is-0.99873 and the corresponding p-value is 1.731829. Since the p-value is greater than 0.05, the correlation between the two variables is statistically significant.

Another potential factor that can contribute to the negative slope is absorption (Piran, 2005). Photons emitted during a GRB may encounter intervening matter, such as interstellar gas or dust that can absorb or scatter these high-energy photons (Haowei and Bo-Qiang, 2018). This absorption of photons reduces the overall intensity of the burst as it propagates through space, resulting in a negative slope in the regression plot.

Additionally, the negative slope could be influenced by the phenomenon of redshift (Liu et al., 2006). As GRBs occur at cosmological distances, the expansion of the universe causes the wavelength of photons emitted during the burst to stretch, resulting in a decrease in their observed energy. This redshift effect can contribute to the observed negative slope in the regression plot as the burst evolves over time.

It is worth noting that the negative slope in the regression plot does not necessarily imply a linear decrease in intensity. The negative slope simply indicates that there is a decreasing trend in intensity over time, but the exact nature of this decrease can vary (Felix et al., 2019)

In reality, the intensity-time relationship for GRBs can be quite complex and can involve various behaviours. The intensity of a GRB may start high and then decrease rapidly, or it may exhibit multiple peaks and valleys before eventually decreasing. (Jay et al., 2005).Additionally, it is possible for the intensity to fluctuate or exhibit irregular patterns rather than follow a smooth decrease (Hakkila et al., 2008).Therefore, while a negative slope in the regression plot suggests a decreasing intensity over time; it does not provide precise information about the specific form or rate of the decrease. To fully understand the intensity-time relationship in GRBs, more detailed analyses are required, such as studying the light curves, spectral properties, and other factors that may contribute to the observed behaviour.

The actual shape of the intensity-time curve may exhibit variations, with fluctuations, plateaus, or other patterns, superimposed on the overall decreasing trend. While the negative slope in the regression plot provides important insights, it is also crucial to consider the limitations of the analysis. The data used for the regression may have uncertainties or biases, and the sample of GRBs analysed may not capture the full range of diversity within these events. Moreover, GRBs exhibit significant variations in their properties, including duration, energy release, and spectral characteristics, which can further complicate the interpretation of intensity-time trends (Kouveliotou et al., 1996).

Finally, the observation of a negative slope in the regression plot on intensity against time for GRBs suggests a decrease in intensity as the burst progresses. This could be driven by energy dissipation mechanisms, absorption of photons, or the redshift effect due to the expansion of the universe. (Gupta, 2018).Further research, including more extensive data analysis and theoretical modelling, is necessary to gain a deeper understanding of the underlying factors influencing the intensity-time relationship in GRBs.

CONCLUSION

The study suggests that the energy emitted during GRBs diminishes as the events progress. The negative slope in the regression plot can be attributed to various factors, including energy dissipation mechanisms, absorption of photons, and the redshift effect (Lui et al., 2006). These factors contribute to the overall decrease in intensity over time. One possible interpretation of the negative slope is that GRBs are gradually fading out or getting weaker over time. This could be due to various reasons such as the distance of the GRBs from Earth, the energy source of the GRB, or the dissipation of energy as the burst propagates through interstellar or intergalactic space.

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