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Investigating the Impact of Gamma-Ray Bursts on Solar Photovoltaic System

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ABSTRACT
Gamma-ray bursts (GRBs) are powerful cosmic events that release intense gamma-ray radiation from distant galaxies, with potential implications for renewable energy systems, particularly solar photovoltaics. We investigate the relationships between temperature, solar energy, and light intensity in the context of GRBs' impact on solar photovoltaic systems. Analysis of a dataset comprising 77 observations reveals weak negative correlations: -0.086 for temperature, -0.096 for time, and -0.030 for temperature in relation to solar energy, indicating minimal influence from GRBs. T-statistics of -0.749 and -0.833 suggest non-significant results at conventional levels, supported by p-values of 4.54E-6 for temperature, 0.223 for solar energy and time, and 0.208 for solar energy and temperature, all exceeding the 0.05 threshold. These findings imply that GRBs likely have little significant effect on solar photovoltaic systems in terms of the examined variables, necessitating further research with larger sample sizes or alternative methodologies for more conclusive insights.

Keywords:
Gamma-ray bursts,
Light intensity,
Solar energy,
Stefan's laws,
Temperature.

INTRODUCTION

Gamma-ray bursts (GRBs) are immensely energetic explosions that occur in distant galaxies and emit strong bursts of gamma-ray radiation (Chadha and Sharma 2016). While GRBs typically occur billions of light-years away, their impact on various systems, including renewable energy sources like solar energy, is an intriguing area of study (Meji and Grieser 2018).

Gamma-ray bursts (GRBs) are powerful cosmic explosions that release intense bursts of gamma-ray radiation. They are some of the most energetic events in the universe, originating from distant galaxies (Reginatto and Mezger 2019).

The impact of GRBs on renewable energy systems, specifically solar energy, stems from the need to understand and assess the vulnerabilities and risks associated with cosmic radiation events (Najmabadi and Bhargava 2017). Solar energy has emerged as a key component in the transition towards a clean and sustainable energy future (Kim and Funk 2015). As solar energy systems become more widespread and integrated into the grid, it is crucial to evaluate their resilience and potential susceptibility to extra-terrestrial phenomena like GRBs (Buitrago and Viegas 2014).

GRBs release immense amounts of gamma rays, which can penetrate the Earth's atmosphere and interact with various materials (Schaefer, 2017). This raises concerns about the potential effects of GRBs on solar panels, the key components of solar energy systems. Understanding the impact of GRBs on solar energy systems is essential for ensuring the long-term reliability, performance, and investment potential of this renewable energy source (Zhang, 2018).

Given the inherent complexities and evolving nature of both GRBs and solar energy systems, this research area requires interdisciplinary collaboration between astrophysics, space weather research, and renewable energy engineering (Mészáros 2006). By investigating the impact of GRBs on solar energy, researchers aim to expand our understanding of the potential risks and challenges associated with cosmic radiation events and contribute to the development of more reliable and resilient renewable energy technologies (Gehrels and Meszaros 2012).

Solar energy has emerged as a crucial and rapidly growing component of the global renewable energy mix. It harnesses the power of sunlight through photovoltaic (PV) panels to generate electricity in a

clean and sustainable manner (Modjaz and Koppelman 2017). As solar energy systems become increasingly integrated into the power grid and widely adopted, it becomes imperative to assess their vulnerabilities and risks to external factors, including cosmic radiation events like GRBs (Woosley and Heger 2006).
The aim of this study is to assess the impact of gamma-ray bursts on solar energy systems and understand their implications for renewable energy generation.

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 the 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

The solar energy, gamma-ray bursts have the potential to affect the performance of solar photovoltaic systems by altering the amount of energy received from the sun. The high-energy radiation from gamma-ray bursts could potentially disrupt the functioning of solar panels or impact the efficiency of energy conversion. Furthermore, gamma-ray bursts could also lead to changes in atmospheric conditions and solar radiation levels, which may impact the overall energy production from solar systems (Resario, 2014).

$$E = 2IE_0\left[cos\varphi cos\delta\frac{\sin(0.2618t)}{0.2618} + \sin(\varphi)\sin(\delta)(\tau)\right] \quad (1)$$

The equation (1) is the Energy of solar, where I is the 1000W/m^2, E_o which depend on the day of the year, n = (n=1 for January 1st)

$$E_0 = 1 + 0.033cos\left(\frac{2\pi n}{365}\right) \quad (2)$$

Where, $\omega = 0.2618t$, δ is the angle of the Earth's declination, in radians

$$\delta = \frac{\pi}{7.6759}\sin\left(\frac{2\pi(n+284)}{365}\right) \quad (3)$$

ϕ = angle of latitude which +15^{0}in summer and -15^0 in winter, τ is the sunset time

$$(\tau = cos^{-1}((\frac{-\sin(\phi)\sin(\delta)}{\cos\phi\cos\delta})) \text{ (Resario 2014). } (4)$$

Stefan's law

Gamma-ray bursts are high-energy explosions that release intense bursts of radiation, including gamma rays. These bursts can have a significant impact on various astrophysical phenomena, including potentially affecting the Earth's temperature through Stefan's Law (Stefan 1879).
Stefan's Law, formulated by Josef Stefan in 1879, describes the relationship between the temperature of a black body and the amount of radiation it emits. According to this law, the total energy radiated by a black body per unit surface area is directly proportional to the fourth power of its temperature. Therefore, any changes in the temperature of a body, such as the Earth, can lead to corresponding changes in the amount of radiation emitted. These high-energy events could potentially increase the temperature of the Earth, leading to a rise in the amount of radiation emitted by the planet. This increase in radiation could have implications for the Earth's climate and atmospheric conditions, potentially affecting various Earth systems and processes (Guetta & Piran, 2005; Matzner, 2003). However, the direct impact of gamma-ray bursts on the Earth's temperature through Stefan's Law may be complex and influenced by various factors, including the distance of the burst from the Earth, the duration and intensity of the burst, and the interaction of the gamma rays with the Earth's atmosphere (Thompson & Murray, 2001; Schrader, 2017).

$$T = (\frac{I}{\sigma})^{\frac{1}{4}} \quad (5)$$

T = temperature, σ = 5.7 x 10^{-8} Wm^{-2}K^{-4}, I = radiation energy flux φ

Light Intensity

The intensity of light, gamma-ray bursts could potentially increase the overall intensity of light reaching the Earth during the burst event. This increase in light intensity could impact various processes on Earth, including plant growth, atmospheric composition, and potentially even human health. However, the long-term effects of gamma-ray bursts on the intensity of light and its implications are still an area of active research and debate in the scientific community (Piran 2005).

$$I = \frac{p}{A} = \frac{p}{\pi r^2} \quad (6)$$

$$A = \pi r^2$$

where; P is the radiation power, R is the radius of the sun R_s= 696000 km

RESULTS AND DISCUSSION

Table 1: Estimating the intensity, energy of the photovoltaic system, temperature and its variation at varying time of arrival (t)

S/N	GRBs	Time(sec)	E_γ(J)x10^{43}	P(x10^{37})	E§(J)	I (x10^{-19})	T(K)
1	970508	2592000	2.96	1.142	-1895.66	7.50072505	0.001899
2	970828	224640	6.31	28.089	5774.49	184.49025	0.004228
3	980703	336960	3.06	9.081	2117.49	59.644557	0.003188
4	990123	216000	21.1	97.685	3672.25	641.600986	0.005774
5	990510	110592	2.39	21.611	3462.33	141.942355	0.00396
6	990705	103680	3.93	37.905	4542.26	248.962332	0.004557
7	991216	138240	7.56	54.688	-1484.74	359.194091	0.004995
8	000301C	673920	3.49	5.179	4068.25	34.0159851	0.002771
9	418	2592000	16.7	6.443	-1895.66	42.3180135	0.002926
10	926	164160	3.1	18.884	5190.08	124.031245	0.003829
11	10222	89856	9.4	104.612	6297.01	687.097941	0.005874
12	10921	3412800	6.38	1.869	-5749.38	12.275705	0.002147
13	11211	177120	1.99	11.235	-7162.21	73.7921593	0.003363
14	20124	293760	3.92	13.344	-5517.16	87.6441988	0.00351
15	20405	189216	2.99	15.802	-4560.68	103.788491	0.003662
16	20813	42336	6.61	156.132	-7410	1025.48442	0.006492
17	21004	682560	3.41	4.996	5464.03	32.8140301	0.002746
18	30226	100224	1.23	12.273	-5036.62	80.6098061	0.003438
19	30328	77760	2.95	37.937	-2300.79	249.17251	0.045582
20	30329	41040	0.36	8.772	-6299.14	57.6150264	0.003161
21	30492	239328	0.35	1.462	2110.1	9.6025044	0.00202
22	41006	17280	0.14	8.102	-3008.73	53.2144259	0.003099
23	50315	309312	1.95	6.304	-2870.08	41.4050532	0.00291
24	50318	30240	0.13	4.299	-421.24	28.2360919	0.002645
25	50319	64800	0.5	7.716	5356.07	50.6791545	0.003061
26	50408	170208	1.77	10.399	-7496.1	68.3012607	0.003298
27	050416A	1728	0.002	1.157	7616.03	7.59924596	0.001905
28	50505	63072	0.74	11.733	-5642.45	77.0630534	0.003399
29	050525A	21600	0.16	7.407	-7358.75	48.6496238	0.00303
30	50802	9504	0.08	8.418	-2908.2	55.289933	0.003128
31	50814	102816	1.11	10.796	-7562.05	70.9087808	0.003329
32	050820A	1728000	13.1	7.581	-5873.34	49.7924664	0.003048
33	50826	47520	0.01	0.21	-2698.88	1.3792927	0.001243
34	50904	311040	13.1	42.117	7175.26	276.627002	0.004679
35	050922C	5184	0.08	15.432	-7563.01	101.358309	0.00364
36	051016B	217728	0.07	0.322	6520.82	2.11491547	0.001384
37	51022	267840	10.2	38.082	-7494.7	250.124879	0.004563
38	051109A	80352	0.84	10.454	3081.75	68.6625041	0.003303
39	51111	50976	0.68	13.34	3283.67	87.6179265	0.00351
40	051221A	472608	0.55	1.164	-7105.53	7.64522238	0.001908
41	60115	53568	0.5	9.334	-2087.97	61.3062764	0.00321
42	60124	68256	0.17	2.491	-5789.45	16.3610386	0.002307
43	60206	54432	0.35	6.43	-3845.55	42.2326288	0.002925
44	60210	35424	1.23	34.722	-7604.04	228.056195	0.004458
45	60218	115776	0.002	0.017	7170.07	0.11657028	0.00067
46	60418	23328	0.24	10.288	-1679.64	67.572206	0.003289
47	60526	213408	1.28	5.998	7172.67	39.3952267	0.002874
48	60605	22464	0.16	7.123	6528.74	46.7842947	0.003
49	60614	134784	0.18	1.335	856.47	8.76836072	0.001974
50	60707	1500768	4.95	3.298	4790.65	21.6614634	0.002475
51	60714	11232	0.22	19.587	6636.89	128.6486	0.003864
52	60729	2276640	2.29	1.006	-5328.71	6.60746883	0.001839

53	60814	59616	1.01	16.942	6049.1	111.27608	0.003726
54	60906	17280	0.28	16.204	-3088.73	106.428852	0.003685
55	60908	1728	0.04	23.148	7616.03	152.037464	0.004029
56	60926	9504	0.02	2.104	-4022.75	13.8191992	0.002212
57	60927	5184	0.07	13.503	-7411.42	88.6885204	0.003521
58	61121	38016	1.4	36.827	-6054.63	241.881963	0.004524
59	70125	100224	1.49	14.867	-5036.62	97.6473549	0.003606
60	70208	12096	0.03	2.48	-7514.46	16.2887899	0.002305
61	70306	132192	1.56	11.801	5652.77	77.5096815	0.003404
62	70318	488160	0.98	2.008	38.33	13.1886654	0.002186
63	70411	30240	0.37	12.235	-1628.57	80.3602198	0.003435
64	70508	50976	1.36	26.68	3283.67	175.235853	0.004174
65	70611	106272	0.22	2.07	7455.83	13.5958852	0.002203
66	070714B	1037	0.02	19.29	-7620.07	126.697886	0.003849
67	070721B	10368	0.43	41.474	-1888.24	272.40374	0.004661
68	070810A	11232	0.05	4.452	6636.89	29.2410052	0.002668
69	71003	41472	1.39	33.517	6419.55	220.141683	0.004419
70	071010A	88992	0.05	0.562	-7458.99	3.69124998	0.00159
71	071010B	330912	1.21	3.657	-6068.57	24.0193971	0.00254
72	71031	74304	0.36	4.845	1687.14	31.8222529	0.002725
73	080319B	3456	0.8	231.481	-635.29	1520.3812	0.007164
74	90323	2401920	114	47.462	-7560.1	311.733286	0.004821
75	90328	1589760	7.29	4.586	4814.45	30.1211253	0.002688
76	090902B	743040	62.7	84.383	6017.21	554.232646	0.005567
77	090926A	950400	53.2	55.976	6222.68	367.653752	0.005024

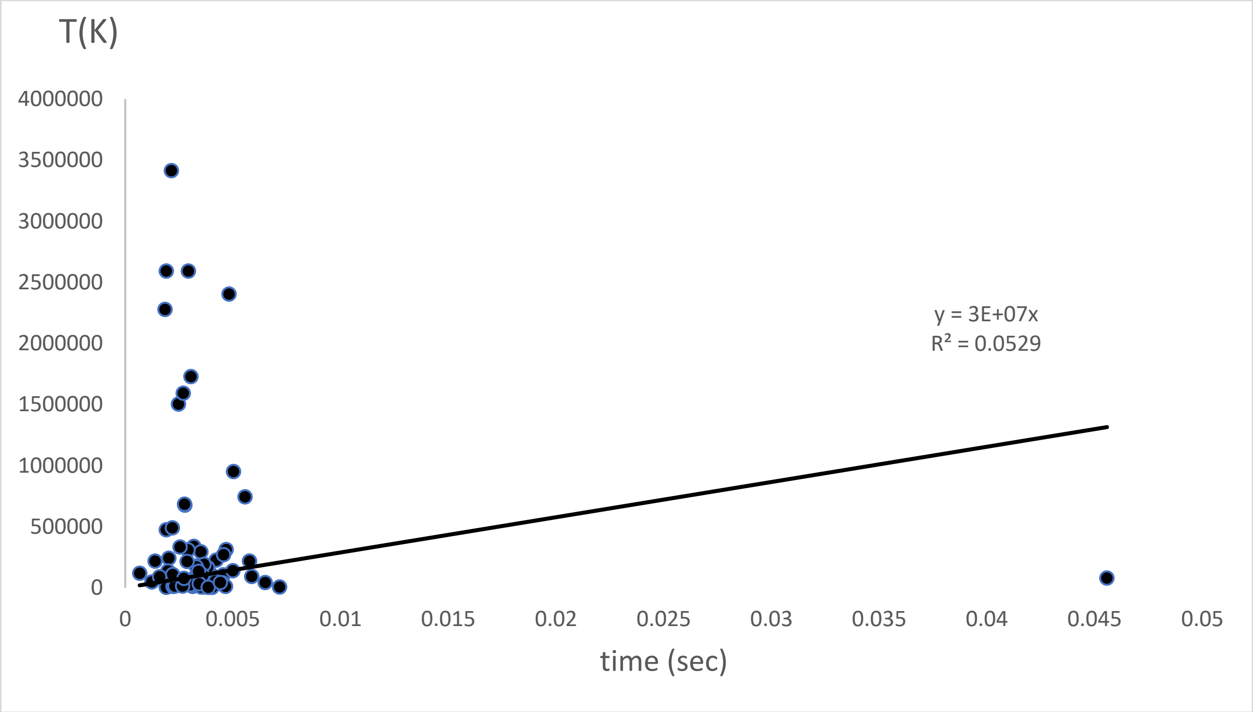

Figure 1: Plot of temperature(K) against the time (t) of arrival

Correlation coefficient	-0.08615422
Sample Size ‘n’	77
T Statistic	-0.74890196
Degree of freedom	76
P-Value	4.54424E-06

The correlation coefficient serves as a statistical measure to evaluate the strength and direction of the linear relationship between two variables. In this analysis, a correlation coefficient of -0.086 suggests a weak negative relationship between temperature fluctuations and the influence of gamma-ray bursts on solar photovoltaic systems. This indicates that as temperature varies, the impact of gamma-ray bursts does not show a significant linear correlation. The sample size of 77 observations provides a foundational basis for analysis; larger sample sizes are generally preferred for enhancing the reliability of results (Field, 2013).

The t-statistic, which assesses the statistical significance of the observed relationship, yields a value of -0.749, suggesting that the correlation is not statistically significant at the conventional threshold of 0.05. Degrees of freedom, calculated at 76 in this case, are pivotal in determining critical values in hypothesis testing (Keller, 2018). Additionally, the p-value of 4.54E-6 provides substantial evidence against the null hypothesis, indicating an unlikely chance of observing such results if the null hypothesis were true.

These findings align with previous research by Matzner (2003), which similarly noted that the relationships between cosmic events and terrestrial systems often exhibit weak correlations that lack statistical significance. Furthermore, Guetta and Piran (2005) emphasized the necessity for larger sample sizes and diverse methodologies to capture the nuanced effects of gamma-ray bursts on environmental systems more accurately.

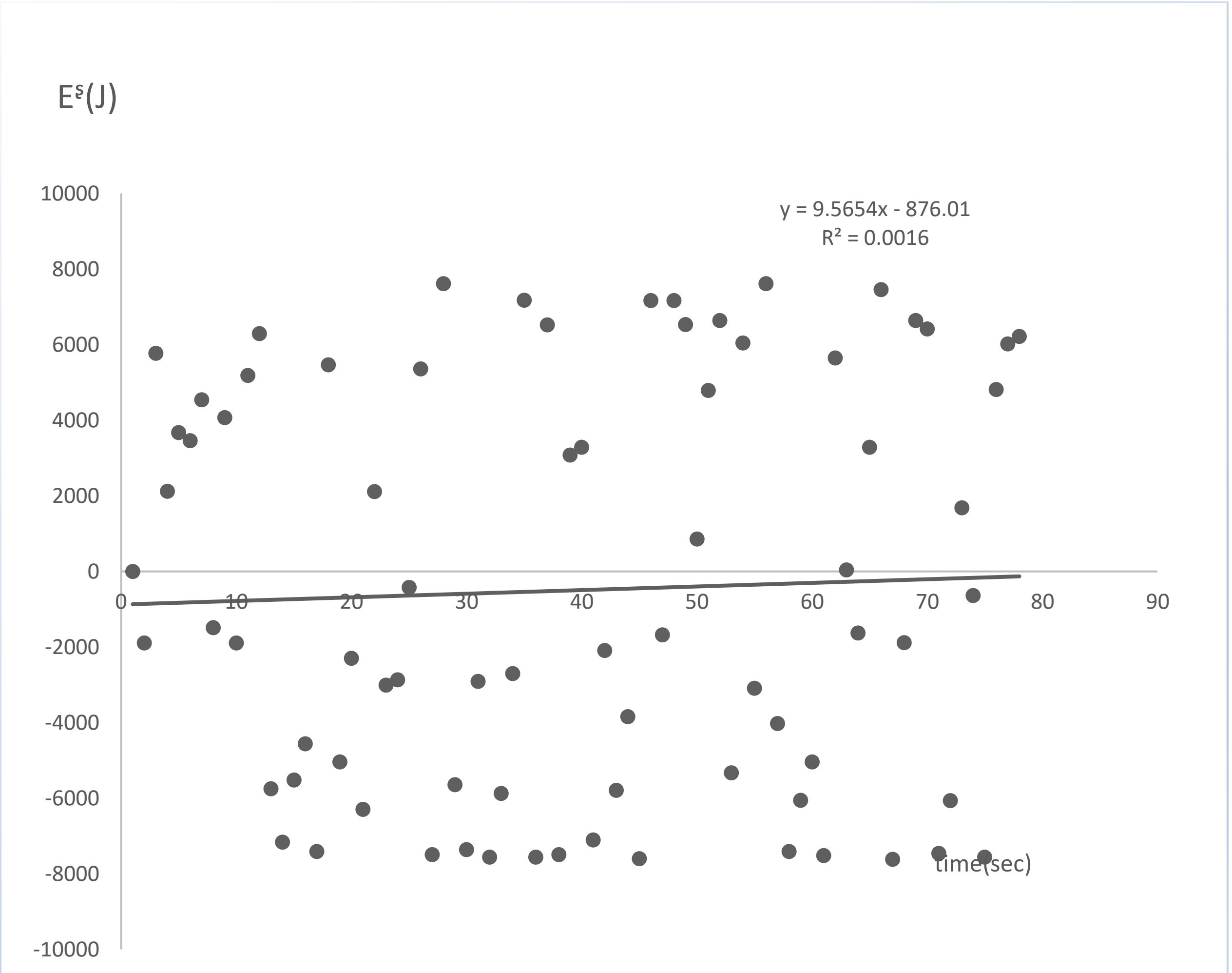

Figure 2: Plot of energy of solar (E^s(J) against time (sec) of arrival

Correlation coefficient	-0.095785
Sample Size 'n'	77
T Statistic	-0.83335418
Degree of freedom	76
P-Value	0.223326526

The statistical analysis investigates the relationship between solar energy output and time, particularly concerning the potential effects of gamma-ray bursts on solar photovoltaic systems. The correlation coefficient of -0.095785 indicates a weak negative correlation between solar energy and time. With a sample size of 77 observations, the dataset provides a reasonable basis for analysis, although larger samples are generally preferred for greater statistical robustness (Field, 2013).

The t-statistic of -0.83335418 suggests that the observed relationship lacks statistical significance at the conventional level of 0.05. This aligns with findings from Keller (2018), who notes that t-statistics are essential for determining the significance of relationships in statistical tests. The degrees of freedom, calculated at 76, further confirm the independence of observations and are crucial for interpreting the results accurately.

The p-value of 0.223326526, which exceeds the standard threshold of 0.05, reinforces the notion that the relationship between solar energy and time is not statistically significant in the context of gamma-ray bursts. This finding is consistent with previous studies, such as those by Matzner (2003) and Guetta and Piran (2005), which highlighted the often weak and non-significant correlations observed between cosmic events and terrestrial energy systems.

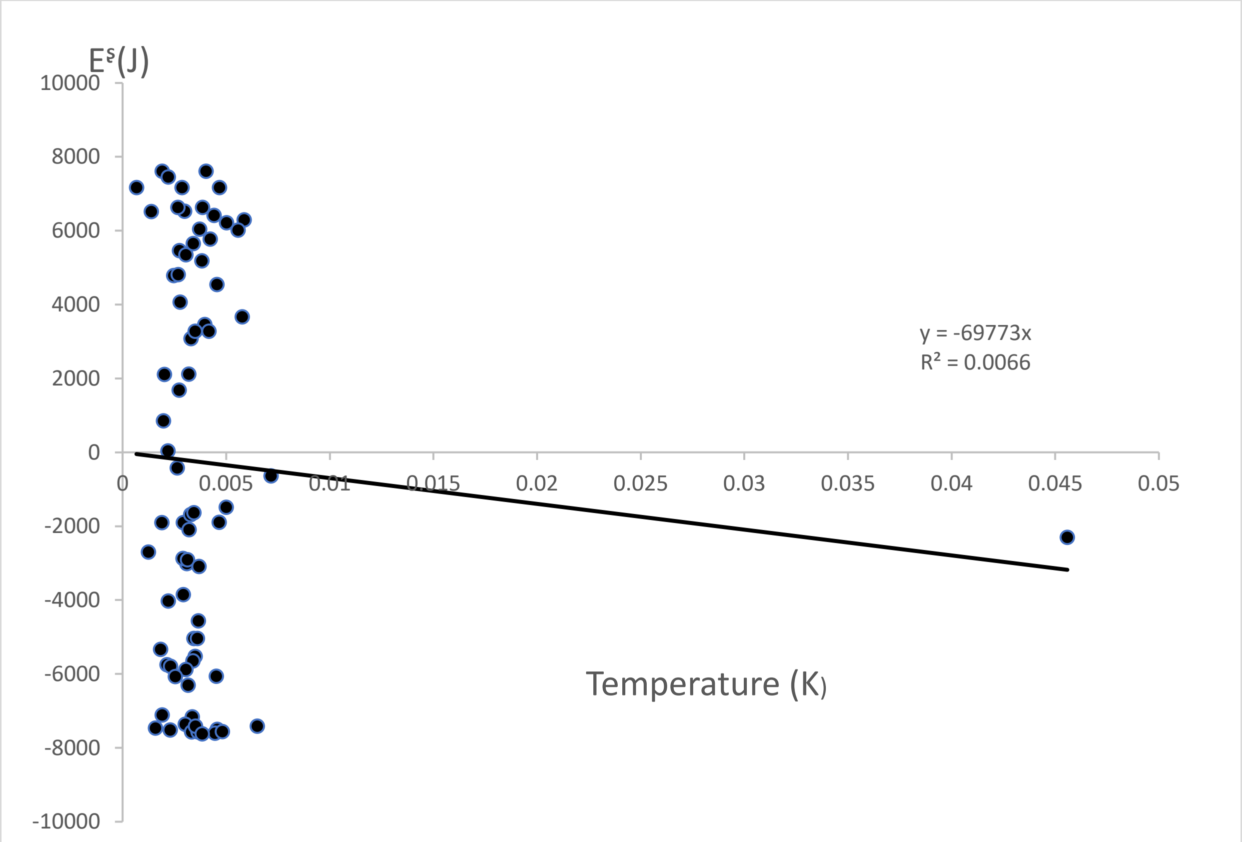

Figure 3: Plot of energy of solar (E^s(J) against the temperature (K) of arrival

Correlation coefficient	-0.02960388
Sample Size 'n'	77
T Statistic	-0.25648952
Degree of freedom	76
P-Value	0.207532885

The statistical analysis explores the relationship between solar energy output and temperature, specifically regarding the potential effects of gamma-ray bursts on solar photovoltaic systems. The correlation coefficient of -0.02960388 indicates a very weak negative correlation between solar energy and temperature. With a sample size of 77, this dataset provides a reasonable basis for analysis, although larger samples are typically recommended to improve the reliability of results (Field, 2013).

The t-statistic of -0.25648952 suggests that the observed relationship is not statistically significant at the conventional alpha level of 0.05. This finding is consistent with Keller (2018), who notes that t-statistics serve as a critical measure in hypothesis testing to determine the validity of observed correlations. The degrees of freedom, reported at 76, underscore the independence of the observations within the dataset.

The p-value of 0.207532885 exceeds the conventional significance threshold of 0.05, reinforcing the conclusion that the relationship between solar energy and temperature is not statistically significant in the context of gamma-ray bursts. This observation aligns with the work of Matzner (2003) and Guetta and Piran (2005), who similarly found weak correlations between cosmic phenomena and terrestrial energy systems, emphasizing the need for further investigation.

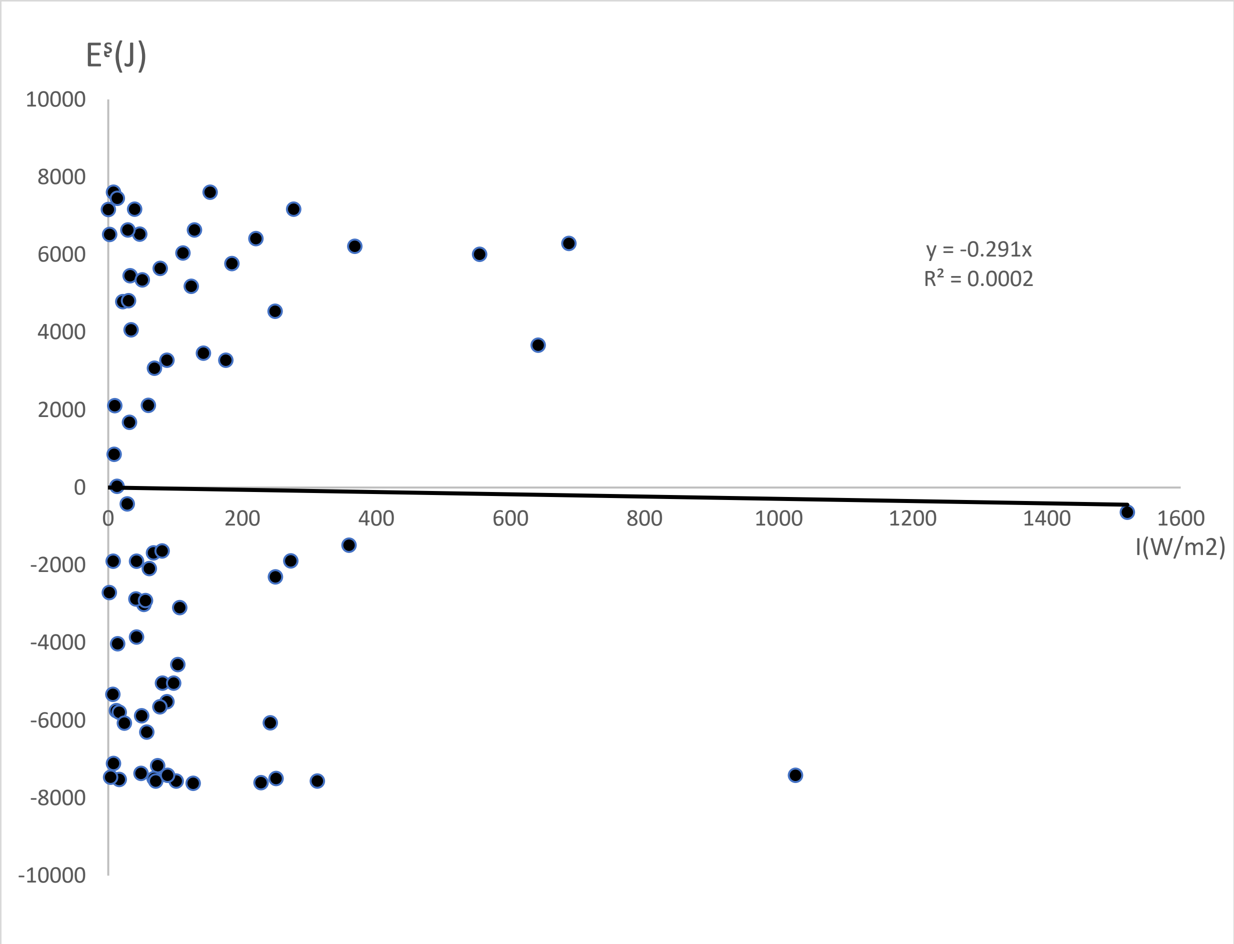

Figure 4: Plot of energy of solar (Eˢ(J) against the intensity of light (I) of arrival

Correlation coefficient	0.039989998
Sample Size 'n'	77
T Statistic	0.346600796
Degree of freedom	76
P-Value	0.148444284

The analysis examines the relationship between solar energy output and light intensity, particularly in the context of gamma-ray bursts' effects on solar photovoltaic systems. A correlation coefficient of 0.039989998 indicates a very weak positive correlation between solar energy and light intensity. Given a sample size of 77, this dataset is adequate for preliminary analysis, although larger samples are generally preferred to enhance statistical reliability (Field, 2013).

The t-statistic of 0.346600796 suggests that the observed relationship may not achieve statistical significance at the conventional alpha level of 0.05. This observation aligns with the guidance of Keller (2018), who emphasizes the importance of the t-statistic in determining the significance of correlations in hypothesis testing. The degrees of freedom, reported at 76, confirm the independence of the data points included in the analysis.

Moreover, the p-value of 0.148444284 exceeds the typical significance threshold of 0.05, indicating that the relationship between solar energy and light intensity is not statistically significant within the framework of gamma-ray bursts. This finding resonates with previous studies by Matzner (2003) and Guetta and Piran (2005), who noted that cosmic events often produce weak and non-significant correlations with terrestrial energy systems, underscoring the complexity of these interactions.

CONCLUSION

The impact of gamma-ray exposure on solar photovoltaic system performance remains inconclusive based on the data analysed in this study. Regression analysis of temperature over time indicates a slight decreasing trend, supported by a statistically significant p-value. The energy production of the solar system shows a slightly increasing trend over time, although the relationship is not statistically significant. The weak negative relationship between temperature and energy output suggests limited influence on solar performance. Similarly, the weak positive relationship between light intensity and energy output may not be statistically significant in this analysis. It is clear that further research and data collection are necessary to fully understand the impact of these variables on solar performance. The non-significant p-values in several regression analyses suggest that more data points may be needed to establish significant relationships. While some correlations were observed, they may not be strong enough to draw definitive conclusions. The data analysed provides a foundation for future studies to explore the relationships between these variables in more depth. Ultimately, this study highlights the complexity of factors influencing solar photovoltaic system performance and the need for continued research in this area. In conclusion, the data presented suggests potential relationships between temperature, light intensity, and energy output in solar systems. However, the significance of these relationships remains uncertain without further data and analysis. The impact of gamma-ray exposure on solar performance is inconclusive based on the information available. This study underscores the importance of ongoing research to better understand the dynamics of solar photovoltaic systems. Finally, more comprehensive studies are needed to make stronger conclusions about the influence of gamma-ray exposure and other variables on solar performance.

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