Possible Relation Between Fast Radio Bursts and Gamma Ray Bursts

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Abstract. Fast Radio Bursts (FRBs) have remained an enigmatic cosmic radiation phenomenon with an elusive origin and the question of their potential association with Gamma-Ray Bursts (GRBs) requires further examination. Some of recent studies have indicated a lack of observable data correlation between GRBs and FRBs. This may be attributed to the inadequacy of the currently available datasets, underscoring the necessity for comprehensive data integration from multiple projects. This paper undertakes an analysis of recent hypotheses positing a correlation between FRBs and GRBs. To substantiate these hypotheses, the study compares 680 FRB signal datasets provided by CHIME and FRBCAT with a total of 2975 GRB datasets from Fermi, Swift, and HESS. The objective is to identify correlated FRB-GRB signal pairs. However, it is essential to note that many of the newly collected GRB signals lack crucial measurements, such as afterglow data and redshift values. Consequently, to establish a more robust correlation between specific FRBs and GRBs, additional data collection and subsequent analysis are imperative. In conclusion, this paper summarizes and discusses methods for observing the redshift of subsequent GRBs and presents models for inferring redshift through FRB dispersion. Additionally, it analyzes the temporal distribution of the approximately 109 correlated data points, providing insights into the timing of these cosmic events.

Keywords: Cosmic ray; gamma ray burst; fast radio burst; magnetar.

1. Introduction

Fast Radio Bursts (FRBs) have remained an enigmatic cosmic radiation phenomenon with an elusive origin. There is a diverse array of proposed origin models, and despite a substantial body of theoretical work aimed at explaining their source, none have yet received definitive empirical confirmation [1]. Currently, the source of FRBs remains undetermined, and the question of their potential association with Gamma-Ray Bursts (GRBs) requires further examination. Some theoretical frameworks have suggested that young magnetars, known for producing GRBs, might serve as plausible central engines for FRBs [2, 3]. FRBs represent a novel class of transient high-energy cosmic radio signals, and many research questions surrounding FRBs persist. Foremost among these is the determination of their origin. Currently, a prevalent hypothesis posits that repeating FRB signals originate from magnetars [4]. Magnetars are neutron stars with exceptionally strong surface magnetic fields, typically on the order of 1015 G. Their interiors comprise neutron matter, quarks, and exotic states like Bose-Einstein condensates, with the magnetic field possibly arising from the transition of these internal materials into superconducting fluids [5]. However, there is still a lack of sufficiently detailed observational evidence supporting this hypothesis. Moreover, it remains crucial to refine models for the propagation of FRBs, including their susceptibility to magnetic fields, intervening media, as well as the computation of dispersion and distance.

The identification of FRBs related to GRBs could provide insights into at least a subset of FRB origins, thus constraining current hypotheses. One prominent hypothesis regarding the correlation between FRBs and GRBs suggests that after the birth of a magnetar, which generates a GRB signal, interactions may occur between the magnetar and its surrounding supernova remnant (SNR), potentially leading to subsequent repeated FRBs [6]. The discovery of such signal pairs could contribute significantly to the study of these high-energy celestial bodies. To validate the magnetar model, further analysis of the afterglow luminosity of GRBs is necessary after identifying signal pairs with matching positions. This analysis can help determine whether the GRB afterglow aligns with the current magnetar model. Additionally, in the ideal scenario, FRB signals should appear later than GRB signals and exhibit repeatability. Furthermore, the combination of GRB redshift measurements and FRB dispersion measurements (DM) holds the potential to advance new cosmological research. Zang et al. proposed that high-redshift FRB/GRB composite samples can aid in calculating the baryon mass fraction of the intergalactic medium, specifically by measuring redshift from GRB and DM from FRB in signal pairs. This approach can yield the baryon mass fraction at low redshift, aiding in the study of the reionization history of hydrogen and helium in the cosmos [7].

Numerous studies presently analyze the correlation between FRBs and GRBs using data collected from various instruments. However, the datasets employed, as well as the criteria for signal selection in terms of time constraints and error ranges, exhibit notable variations. Many of these recent studies have yielded preliminary results that do not indicate strong correlations within smaller datasets.

For instance, Palaniswamy et al. conducted observations of five 2.3 GHz gamma-ray bursts using a 26-meter radio telescope and performed dispersion measurements searching for pulse data up to 5000 pc cm-3. Nonetheless, they did not detect any GRB-FRB related events within a range smaller than 6σ [8]. Abdalla et al. pursued subsequent observations of extremely high-energy gamma-ray domains using HESS. They attempted to locate FRBs with consistent dispersion characteristics by imaging the atmospheric Cherenkov telescope system within 14.5 hours following gamma-ray bursts. However, no indications of high-energy FRB afterglow emissions were found [9]. Curtin et al. employed CHIME to investigate whether any class of FRB radio emissions coincided spatially and temporally with 81 GRBs detected by Swift/BAT and Fermi/GBM between July 17, 2018, and July 8, 2019. However, no statistically significant overlapping pairs meeting the criteria of being within 3σ of each other spatially and having a time difference of up to one week were discovered [10]. Bouwhuis et al. utilized data from 20 GRBs collected by the Australian Square Kilometre Array Pathfinder at frequencies ranging from 1.2 to 1.4 GHz. They did not observe any correlated pulse radio emissions exceeding 6 Jyms (w/1ms)-1/2 within 11 hours of GRB [11]. In contrast, Wang et al. identified a potential correlation between FRB 171209 and LGRB: GRB 110715A within a dataset consisting of 110 FRBs and 1440 GRBs. The confidence level for this correlation ranged from 2.28σ to 2.55σ. Although this singular detection cannot definitively rule out the possibility of coincidence, modeling of the LGRB afterglow suggests that both signals likely originate from a magnetar. Subsequent observations of FRB 171209 to confirm its repeatability will serve as a crucial means of validating this hypothesis [12].

This paper begins by presenting the current state of research on FRBs and GRBs separately in the second section. The third section summarizes and synthesizes the hypotheses proposed regarding the correlation between FRBs and GRBs. The study utilizes data selected from two primary sources: the CHIME website's open-source database containing repetitive and non-repetitive FRBs from 2018 to 2021 [13, 14], and data compiled from various telescopes spanning from 2010 to 2020, accessible through the FRBCAT catalog [15]. This dataset comprises a total of 680 FRB records. To establish correlations, this dataset is compared with integrated data from three distinct sources: Swift/BAT's third GRB measurement catalog [16], Fermi's fourth decade of GRB measurement catalog [17], and a collection of 74 GRB datasets gathered by H.E.S.S. during the period 2019-2023 [18]. An incremental filtering approach is employed to identify relevant signal pairs. Initially, the entire dataset undergoes spatial filtering, evaluating whether differences in Right Ascension (RA) and Declination (Dec) in the J2000 standard fall within the provided uncertainty ranges. Subsequently, an analysis of the time difference distribution for signal pairs meeting the criteria is conducted, followed by further refinement based on established models of correlation. In the fourth section, the paper outlines the specific methods for data selection and integration, along with the results obtained after processing the positional information [19]. The fifth section discusses subsequent approaches for comparing redshift data, analyzing the existing models for converting FRB Dispersion Measure (DM) values into redshift values, and presenting the measurement methods for determining GRB redshift values based on observations of GRB afterglows. Building upon these models and methods, the study conducts an analysis of the potential origins of the filtered correlated signals. The paper concludes by summarizing and discussing the feasibility of using this methodology to identify correlated signal pairs between GRBs and FRBs. It also highlights the need for further refinement and expansion of this approach in future research.

2. Model Description of GRB and FRB

2.1. Gamma-Ray Bursts

GRBs are one of the most powerful cosmic radiation events in the universe . These transient, high-luminosity gamma-ray emissions are naturally generated by relativistic jets or shockwaves, with a requirement of high angular momentum and strong magnetic fields for the GRB emission jets. Some detected features of GRB signals indirectly reflect the presence of a central engine, possibly a magnetar [20]. T90, which is the time duration during which 5% to 95% of the total photon fluence is accumulated, serves as a critical criterion for the traditional classification of GRBs, categorizing them into short and long bursts [21]. Apart from their duration, Short Gamma-Ray Bursts (SGRBs) typically exhibit harder spectra compared to Long Gamma-Ray Bursts (LGRBs) [22]. Most SGRBs are often about ten times fainter in gamma-ray emissions than LGRBs, and as the burst progresses in time, the energy conversion to SGRBs gradually decreases, while the energy of most LGRBs remains constant throughout the burst [23]. They are generally believed to have different origins. Several possible central engine models have been proposed for different types of GRBs: LGRBs are typically associated with relativistic supernovae and the core collapse of massive stars, while SGRBs are likely produced by the mergers of compact objects such as binary neutron stars or black hole-neutron star pairs [24]. Other possible origins include highly magnetized neutron stars (magnetars) that rotate rapidly, approaching their breakup limit with millisecond rotation periods; and rapidly forming stellar-mass black holes that accrete matter at very high rates (≤(0.1-1) Ms-1) from remnants [25]. Massive magnetars could potentially form from the remnants of binary neutron star mergers and, in principle, could persist for a long time, emitting magnetar flares, explaining the observed extended emissions of SGRBs. When a magnetar loses angular momentum and collapses into a black hole, the extraction of energy through accretion from the rotating black hole can also lead to the extended signals of SGRBs. If SGRBs originate from the merger of compact objects mentioned in the second scenario, it is possible that events similar to FRBs may occur before the formation of SGRBs [10].

2.2. Fast Radio Bursts

FRBs are bright, highly dispersed, and have millisecond-level durations, with an unknown origin. A distinctive feature of FRBs is their Dispersion Measure (DM), significantly exceeding the corresponding Galactic DM value [26, 27]. Due to the high electron column density integrated along the line of sight, larger DM values strongly suggest extragalactic origins, and precise host galaxy identifications for a few FRBs confirm their extragalactic nature [28]. FRBs exhibit a relatively high all-sky event rate, typically reaching 1100-7000 FRBs per day per sky [1]. While most FRBs detected to date have been isolated events, FRB 121102 was the first one found to repeat [29], and CHIME has since detected more repeating FRBs, indicating the existence of two populations: repeating and non-repeating FRBs.

The generation of FRBs requires intense radio emission, and current FRB origin models can be divided into catastrophic and steady-state categories. Catastrophic origin models suggest a direct connection between non-repeating FRBs and catastrophic events. Catastrophic models include the merger or collapse of compact objects. Similar to the neutron star origin model for Gamma-Ray Bursts (GRBs), the collapse of supermassive neutron stars into black holes could also be a source of FRBs [30]. When the event horizon engulfs the neutron star, the NS's magnetic field does not disappear; instead, the entire magnetic field can theoretically separate and reconnect outside the event horizon, releasing strong electromagnetic signals in the radio frequency range, forming an FRB. Furthermore, delayed collapses can occur within thousands to millions of years after the birth of a supermassive neutron star. Some of these internal bursts may also occur a few hundred to a few thousand seconds after the birth of the neutron star and can be observed in the early X-ray afterglow curves of some GRBs [3]. In addition, the merger of binary neutron stars is also a possible source of FRBs [31], and FRBs can also result from the merger of white dwarfs, where coherent emission originates from the polar regions of rapidly rotating and magnetized white dwarfs [3]. Similarly, catastrophic events that can produce SGRBs can also explain the origins of FRB subclasses, including various combinations of binary mergers involving white dwarfs, neutron stars, or black holes [10], in which case the time delay between non-repeating FRBs and catastrophic events may be relatively short. Massive magnetars could potentially form from the remnants of binary neutron star mergers and could exist for a longer time, allowing for longer time delays between non-repeating FRBs and catastrophic events [32]. So far, there is no sufficient observational data to prove that these individual bursts are part of repeating bursts, so the catastrophic natural model may still be correct.

On the other hand, steady-state origins are often used to explain repeating FRB signals, suggesting that repeating FRBs originate from a relatively stable celestial body, with most models involving pulsars and magnetar emissions. Some FRBs are associated with bright pulses from extragalactic pulsars [33]. Some known pulsars emit giant pulses, and the rate of formation of neutron stars in the Hubble volume is comparable to the rate of FRBs, and these extragalactic pulsars' giant pulses may be amplified through gravitational lensing by individual stars and observed, classifying this hypothesis as a pulsar-like origin model. FRBs may also be generated by eruptions from extragalactic young pulsars and magnetars [34]. Young neutron stars embedded in SNRs and interacting with them might produce FRBs, possibly driven by the magnetic field of the galactic center magnetar within hundreds of megaparsecs. Galactic FRBs and detections related to soft gamma-ray repeaters suggest that if all FRBs are indeed repeating sources but go undetected due to low sensitivity, then young magnetars can explain the origins of repeating bursts, namely the magnetar origin model for FRBs. Both of these origin models can be summarized as FRBs generated by magnetar wind nebulae of young magnetars embedded in supernova remnants (SNRs) or by giant pulses from rapidly rotating neutron stars. Such systems may leave observable afterglows. Furthermore, low-luminosity Active Galactic Nuclei (AGN) as continuous radio sources, either burst activities from AGNs themselves or interactions with nearby neutron stars, could also produce FRBs [7].

There are numerous hypotheses regarding the origin of FRBs, but no definitive conclusions have been reached. Expanding and improving observational constraints are a crucial part of solving this problem. In addition to expanding the wavelength coverage, timely and wide-ranging observations are essential to cover as many potentials, very rapid emission signals as possible.

3. Relation between GRBs and FRBs

The analysis of the origin models for FRBs and GRBs mentioned in above sections have indicated that certain FRBs may be physically related to GRBs. In general, the search for a GRB-FRB correlation has so far lacked data that can confirm this viewpoint. Currently, GRBs are known energy transients, and although the frequency of observing GRBs is much lower than that of FRBs, there is evidence that a small subset of FRBs may be related to GRBs. From the origin models mentioned in the second section, supermassive neutron star/magnetar collapses into black holes as sources for both GRBs and FRBs, and FRBs may be related to the binary merger of objects that produce SGRBs. GRBs can interact with neutron star magnetospheres to produce FRBs. In these scenarios, FRBs can be observed a few milliseconds before or a few thousand seconds after the onset of GRBs. Furthermore, GRBs may originate from the birth of young magnetars, which could subsequently emit repeating FRBs, such as magnetars interacting with surrounding supernova remnants and generating FRBs through magnetic layer eruptions or through crustal cracking or magnetic reconnection to produce repeating FRB signals. Additionally, this magnetar model allows for longer time separations between FRBs and GRB signals, and theoretically, FRBs are likely to be repeating signals [3].

Cui et al. evaluated and constrained their origin models for different types of FRBs through statistical analysis, suggesting a tendency that repeating FRBs and LGRBs are more likely to be correlated, while the correlation between SGRBs and FRBs may be small, about 10% [35]. However, the accuracy of their analysis results awaits further validation as this statistical analysis only considered 18 repeating and 12 non-repeating fast radio bursts observed by the CHIME experiment in the 400-800 MHz frequency range. In the case of FRB-LGRB correlation, it's challenging to explain how the radio emission propagates through an extended stellar envelope. Currently, many researchers globally have used data collected from different instruments to analyze the correlation between FRBs and GRBs. However, the data sets used and the time constraints between the two signals are not very consistent. Most analyses of smaller data sets have shown that no strongly correlated signals have been found. Wang et al. searched for an FRB 171209 event possibly associated with LGRB: GRB 110715A in a dataset of 110 FRBs and 1440 GRBs. Although this single detection cannot rule out the possibility of chance, modeling of the afterglow of this LGRB suggests that both signals likely originated from a magnetar. Subsequent observations of whether FRB 171209 is a repeating signal will be an important means to verify this hypothesis [3]. This paper argues that there is a need to expand the dataset for analysis and to keep up with subsequent observations. Numerous projects are currently searching for GRB signals, including satellite space telescopes and ground-based Cherenkov telescope arrays. The latest CHIME project, focused on FRB detection, has already identified many repeating and non-repeating signals [36].

4. Data Souce

4.1. FRBs

Although the sample size of FRBs is smaller than that of GRBs, the FRBs in the CHIME sample also exhibit an isotropic distribution, consistent with their cosmic origin. This study selected 650 repeated and non-repeated FRB data from the open-source database provided by CHIME for the years 2018-2021 [13, 14]. In addition, it included 118 data points from various telescopes recorded in the FRBCAT catalog from 2010 to 2020 [15]. The selected data contained various pieces of information for comparison, such as identification numbers, detection times, right ascension and declination, dispersion measures, and their corresponding error values. Some data with excessively large error values were excluded, as well as identical data values for repeated FRB signals.

Table 1. Integrates data from both repeated and non-repeated Fast Radio Bursts (FRBs) from CHIME and datasets from FRBCAT. (The full data table can be found in reference.)

tns_name	previous_name	repeater_name	ra	ra_err	dec	dec_err	m_fitb	dm_fitb_err
FRB20180725A	180725.J013+67	-9999	93.42	0.039	67.07	0.21	715.8093	0.0041
FRB20180814A	180814.J0422+73	FRB20180814A	65.54	0.19	73.63	0.27	189.286	0.076
FRB20180817A	180817.J1533+42	-9999	233.2	0.052	42.2	0.16	1006.771	0.0085 ......
frb_name	utc	telescope	rop_raj	rop_decj	rop_mw_dm_limit	rmp_dm	rmp_redshift_host	
FRB161202	0.017292	Pushchino	0.988889	+40:48:00	69.8	291+4	null	
FRB140514	0.009851	parkes	0.940347	-1:18:46	34.9	562.7+0.6	null	
FRB181016	0.011763	UTMOST	0.657186	-25:24:32.6	90	1982.8+2.8	null	

Table. 1 includes observations from various telescopes such as FAST, Parkes, ASKAP, and GBT. The data examples provided in the table encompass all the detector names. The table includes data related to the name and number of FRB signals, as well as their basic positional information — RA (Right Ascension) & Dec (Declination), along with their corresponding error values RA_diff & Dec_diff. For repeated signals, the table also indicates their original repeater source identifier (repeater_name). The data from CHIME additionally provides the dispersion measure fitting value (dm_fitb) for FRB signals, along with its fitting error (dm_fitb_err). Meanwhile, the data from FRBCAT, in addition to providing dispersion values (rmp_dm) and specific signal reception times (utc) for detectors, also offers some FRB signal-related values, including the Milky Way dispersion component (rop_mw_dm_limit) and redshift values for the host galaxies of a few signals (rmp_redshift_host).

4.2. GRBs

The Swift Gamma-Ray Burst Detector is a space observatory consisting of three telescopes used for studying Gamma-Ray Bursts (GRBs) and monitoring the X-ray and ultraviolet/visible light afterglows of burst locations. It has a burst detection rate of 100 per year. Swift is a multi-wavelength observatory with a measurable energy range of 10-300 keV. Its primary feature is its rapid response to newly detected GRBs and quick data dissemination. This paper selected 1525 GRB signals collected by Swift from 2004 to 2022. The Fermi Gamma-Ray Space Telescope (FGST) is dedicated to observing high-energy gamma rays. It provides sufficient sensitivity for gamma rays with an energy range of approximately 20 MeV to 300 GeV. The Gamma-Ray Burst Monitor (GBM) is sensitive to X-rays and gamma rays with energies between 8 keV and 40 MeV. This paper references data from the Fourth Fermi GRB Decade Catalog collected from 2008 to 2018.

HESS (High Energy Stereoscopic System) is a system of imaging atmospheric Cherenkov telescopes used to study cosmic gamma rays in the energy range from 10 GeV to 10 TeV. This paper utilizes publicly available data from H.E.S.S., comprising 95 GRBs collected during its operation from 2004 to 2020. Similar to processing FRB signal data, the aforementioned GRB signal data is integrated, selecting the right ascension and declination values along with their corresponding error values, GRB name numbers, and detection times for comparison. Unreasonable values are filtered out, and for signals with missing error values, estimated values are obtained based on the average error of the respective telescope and included in the data comparison.

Table 2. This table integrates GRB data from the Swift and Fermi space telescopes, as well as the HESS ground-based detection array telescopes. (The full data table can be found in reference.)

GRBname	Trig_ID	Trig_time_UTC	RA_ground	DEC_ground	Image_position_err
GRB 080714B	bn080714086	02 04 12.0534	41.9	8.5	7.5
GRB 080714C	bn080714425	10 12 01.8376	187.5	-74	8.7
GRB 080714A	bn080714745	17 52 54.0234	188.1	-60.2	0
......	......	......	......	......	......

The Table 2. includes the GRB signal's name identifier (GRBname) along with its right ascension and declination ground positions (RA_ground & Dec_ground) and their corresponding position error values (Image_position_err). Additionally, the Fermi and Swift telescopes provide signal trigger identifiers (Trig_ID) and the trigger times (Trig_time_UTC) when the GRBs were detected. In contrast, HESS provides the GRB signal name (GRB ID), trigger time (Alert time - T0), and basic position information (GRB RA (J2000) & GRB Dec (J2000)) in the data table.

5. Data Position Comparison

Based on the analysis of the correlation origin models between FRBs and GRBs in Sec. 3, this paper will use a step-by-step screening method to compare and screen out potential FRB and GRB signal pairs that may meet the corresponding conditions. First, a systematic search is conducted for data that meets the positional criteria, comparing the Ra & Dec data in both tables. If the positions coincide within the error range, then the redshift of the GRB is compared with the maximum FRB redshift derived from its DM, as well as the time difference between the detections of the two signals, in order to constrain and analyze the common origin models of the two signals that may be associated. By integrating all the aforementioned datasets and removing duplicate and excessively erroneous data, the scatter plot of the positions of FRBs and GRBs is obtained as follows. It can be observed that GRB data are widely and evenly distributed in terms of position, while due to the field of view limitations of the CHIME telescope, more FRBs are distributed in the sky area with Dec greater than 0, and the currently collected FRB dataset remains relatively limited (seen from Fig. 1).

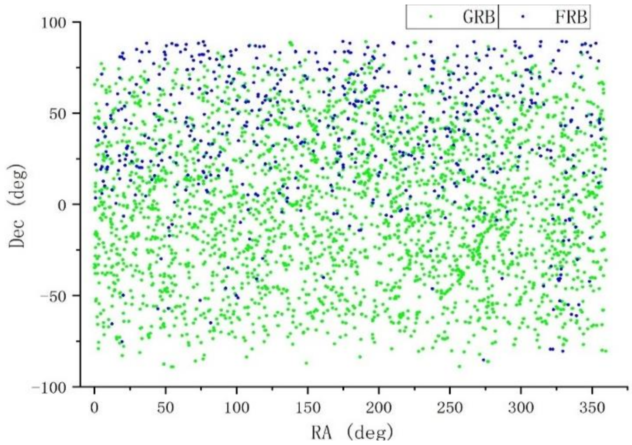

Fig. 1 The scatter plot designed to visually represent the distribution of GRB and FRB positions. The horizontal axis represents the Right Ascension (RA) in degrees, while the vertical axis represents the Declination (Dec) in degrees. The blue dots represent FRB signals from both the CHIME and FRBCAT data tables, while the green dots represent a compilation of GRB signal data collected from Fermi/Swift/H.E.S.S. telescopes.

5.1. RA and Dec

Basic analysis and comparison were conducted on the positional information of the integrated 680 FRBs and 2975 GRBs data mentioned above. It is shown that when adjusting the acceptable error range to 1 degree, 109 signal combinations met the condition of positional overlap. If one considers the measurement errors in the FRB data, with an RA error of 0.18 and a Dec error of 0.19, there are still 8 sets of data that meet the requirements for corresponding positions within the error range (as given in Fig. 2).

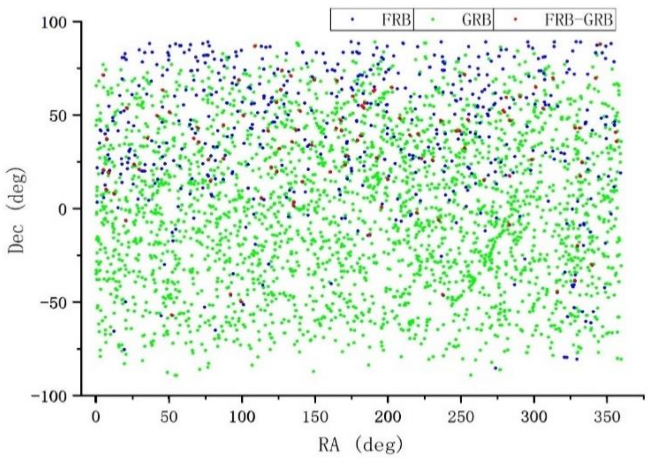

Fig. 2 A distribution map of FRB-GRB signal pairs with positional differences within a 1-degree range, along with a scatter plot comparing these signal pairs to the overall signal distribution. The horizontal axis represents Right Ascension (RA), the vertical axis represents Declination (Dec), and both are measured in degrees. Blue dots represent FRB signals from the CHIME and FRBCAT data tables, green dots represent GRB signal data collected from Fermi/Swift/H.E.S.S. telescopes, and red dots represent the 109 signal pairs that meet the condition of positional overlap.

After the basic positional filtering, Table. 3 is obtained containing FRB and corresponding GRB data with positional differences falling within the range of measurement errors. This table includes FRB names (FRB_name) and their corresponding GRB names (GRB_name), CHIME-provided FRB dispersion measures (DM) and their errors (DM_err), as well as Right Ascension (RA) and Declination (Dec) errors (RA_err/Dec_err). Additionally, it provides the positional differences (diff_RA/diff_Dec) between FRB and GRB in terms of RA and Dec and the time difference between the two signals in days.

Table 3. The FRB-GRB signal pairs corresponding table with an error range based on FRB signal errors (RA error < 0.18; Dec error < 0.19).

FRB_name	RA	RA_err	Dec	Dec_err	DM	DM_err	GRB_name	RA	Dec	Image_err	diff_RA	diff_Dec	diff_time
FRB20190309A	278.96	0.23	52.41	0.24	356.9	0.026	GRB060502B	279	52.6	1.75	0.04	0.19	4694
FRB20190429A	281.09	0.24	59.42	0.24	470.884	0.011	GRB140713A	281	59.6	1.18	0.09	0.18	1751
FRB20181018C	67.15	0.17	37.57	0.17	411.1927	0.0023	GRB210308A	67.1	37.4	0.895	0.05	0.17	872
FRB20190604D	199.93	0.2	15.73	0.24	1021.169	0.01	GRB 100228A	199.8	15.6	9.3	0.13	0.13	3383
FRB20190304C	223.01	0.23	26.72	0.25	564.991	0.014	GRB201128A	223	26.7	2.4	0.01	0.02	635

Table 4. Table of FRB-GRB Repeater Signal Pairs within a 1-degree Error Range

FRB_name	RA	Dec	GRB_name	RA	Dec	RA_diff	Dec_diff
FRB171209	237.6042	-46.1722	GRB 090320A	238	-46.5	0.395833	0.327778
FRB171209	237.6042	-46.1722	GRB110715A	238	-46.2	0.395833	0.027778
FRB20181228A	7.26	10.22	GRB170607A	7.36	9.22	0.1	1
FRB20181228A	7.26	10.22	GRB100522A	6.99	9.4	0.27	0.82
FRB20190110C	246.98	41.42	GRB 091109C	247.7	42.3	0.72	0.88
FRB20190110C	249.325	41.445	GRB200224A	249	41.7	0.325	0.255
FRB20190317B	101.01	49.73	GRB080517	102	50.7	0.99	0.97
FRB20190317B	101.01	49.73	GRB090904A	101	50.2	0.01	0.47
FRB20190630B	328.21	43.01	GRB060501	328	44	0.21	0.99
FRB20190630B	328.21	43.01	GRB210209A	328	43.5	0.21	0.49
FRB20181213B	183.52	53.7	GRB130420B	183	54.4	0.52	0.7
FRB20181224D	182.45	54.85	GRB130420B	183	54.4	0.55	0.45
FRB20190601A	190.11	62.72	GRB 081115A	190.6	63.3	0.49	0.58
FRB20180920B	191.09	63.52	GRB 081115A	190.6	63.3	0.49	0.22

The integrated data table mentioned above contains a comparison of three key types of information. RA and Dec represent the basic position information of the signals, directly obtained from detector datasets, with varying error ranges from different detectors. DM and GRB redshift values provide spatial distance information, directly or indirectly measured by detectors. Some GRB redshift values can be determined by afterglows or host galaxies, while DM values of FRB need to be calculated into corresponding redshift values using conversion models. The common model formulas for calculating redshift values from dispersion are discussed in Section 5.2 of this paper. In the data processing, two crucial analyses are needed. To determine the correlation between FRBs and GRBs, it's crucial that their positional information falls within the error range. Since data from multiple instruments have been selected, comparisons need to be conducted separately for different error values. Secondly, if signal pairs with the same position are found, calculating their redshift values through FRB DM values will also influence the analysis of the signal pair's origin.

Table. 4 includes basic information for FRBs with multiple corresponding GRB signals and GRBs with multiple corresponding FRB signals. It consists of the right ascension (RA), declination (Dec), and signal names (FRB_name & GRB_name), along with the positional difference values (RA_diff & Dec_diff). The criterion for determining whether they meet the positional information standard is that the positional difference values fall within a 1-degree range. It's worth noting that among the 109 GRB-FRB signal pairs that meet the criterion of having position differences less than 1 degree, there are some one-to-many signal combinations. For instance, the positions of FRB20190630B, GRB060501, and GRB210209A all fall within the allowable error range. This may suggest that they originate from the same celestial body. In the time comparison, GRB210209A was detected after FRB20190630B, while GRB060501 was detected 13 years before the appearance of the FRB signal. If the redshift values of these four signals also align well with the same origin model, it would indicate that their origin is likely to be a stable celestial body, including the candidate source of a magnetar. For GRBs corresponding to multiple FRB signals, it is because of the repetitive bursts of FRBs themselves. Currently available data shows that in such cases, repetitive FRB signals appear after GRB signals, and the time intervals between repetitive FRBs are relatively short, generally not exceeding 1 year, which is consistent with the scenario described by the magnetar origin model.

5.2. DM and Redshift

For an FRB/GRB combination system, apart from the basic RA and DEC positional information, two precise measurements can be obtained. One is the system's redshift, which is typically derived from absorption lines or photometry in the optical afterglow spectrum of GRBs or from emission lines in the host galaxy's spectrum. The General Coordinates Network (GCN), a public collaboration platform provided by NASA, is an established platform for publishing discoveries and subsequent actions related to transient phenomena, including GRBs. Most GRB detection results and subsequent afterglow observation data are collected in Circulars forms [37]. Different detection instruments may lead to varying degrees of uncertainty, so the uncertainty of GRB position data requires more specific analysis. Additionally, it was found during the search for GRB signals that met the positional criteria mentioned above that most GRBs lacked definitive redshift analysis values. Further tracking observations of these GRB afterglows are necessary. The second measurement is the system's dispersion measure (DM) obtained from FRB. Generally, DM is defined as the delay of radio waves relative to the arrival time in vacuum. For FRB/GRB systems with known positional information, the measured total DM should include four components [7]:

$$DM_{tot} = DM_{MW} + DM_{IGM} + DM_{host} + DM_{GRB} \tag{1}$$

representing contributions from the Milky Way, intergalactic medium, host galaxy, and GRB explosion itself. Among these, DM_{MW} is determined by known Milky Way models, DM_{host} is determined based on the position in the galaxy, and the remaining DM overflow is attributed to DM_{GRB}. The subtracted DM_{IGM} will be used to calculate the redshift value. Currently, the widely accepted proportional relationship between DM_{IGM} and redshift z is approximately given as $\langle DM \rangle \approx z \times 10^3$ pc cm^{-3} [38]. Considering the dispersion enhancement during the propagation of FRBs, the redshift values theoretically derived from observed DM should be greater.

6. Discussion

It has explored and analyzed the potential association between two types of high-energy cosmic radiation signals, FRBs and GRBs, as well as the possibility of a common origin model for them. After analyzing the existing detection data, it was found that, despite the relatively low detection rate of GRBs and the current scarcity of the FRB dataset, there are still some signal pairs that meet the basic positional information criteria. This result indirectly suggests that some FRB signals are likely to have the same origin as previously detected GRB signals. However, in order to further analyze their specific origin models and constrain them, subsequent observations of these signals are essential. Due to the insufficient collection of redshift information for GRB afterglows at present, this result still has limitations, but the results of the selected signal pairs can provide a certain reference direction for follow-up observations. For FRBs, which are a newly discovered form of high-energy cosmic radiation, conducting comparative studies with the better-understood GRB signals contributes to our further exploration of the origin of them. Continued detection and data collection for these two types of high-energy cosmic radiation signals will expand the horizons of the research.

7. Conclusion

This paper explores and analyzes the potential correlation between two types of high-energy cosmic radiation signals, FRBs and GRBs, as well as the possibility of a common origin model for them. After analyzing the existing detection data, it was found that, despite the relatively low detection rate of GRBs and the current limited availability of the FRB dataset, there are still some signal pairs that meet the basic positional information criteria. This result indirectly suggests that some FRB signals are likely to share a common origin with previously detected GRB signals. However, in order to further analyze their specific origin models and impose constraints, subsequent observations of these signals are indispensable. Due to the insufficient collection of redshift information for GRB afterglows at present, this result still has limitations. Nevertheless, the results from the selected signal pairs can provide a certain reference direction for follow-up observations. Conducting comparative studies between FRBs, a newly emerging discovery in high-energy cosmic radiation, and the better-understood GRB signals, can assist us in delving deeper into the mystery of the origin of FRB signals. Continued detection and data collection for these two types of high-energy cosmic radiation signals will help pave the way for new avenues of research in the field of high-energy cosmic radiation.

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