Refinement of the Proposed Gamma-Ray Burst Time Delay Model

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Introduction

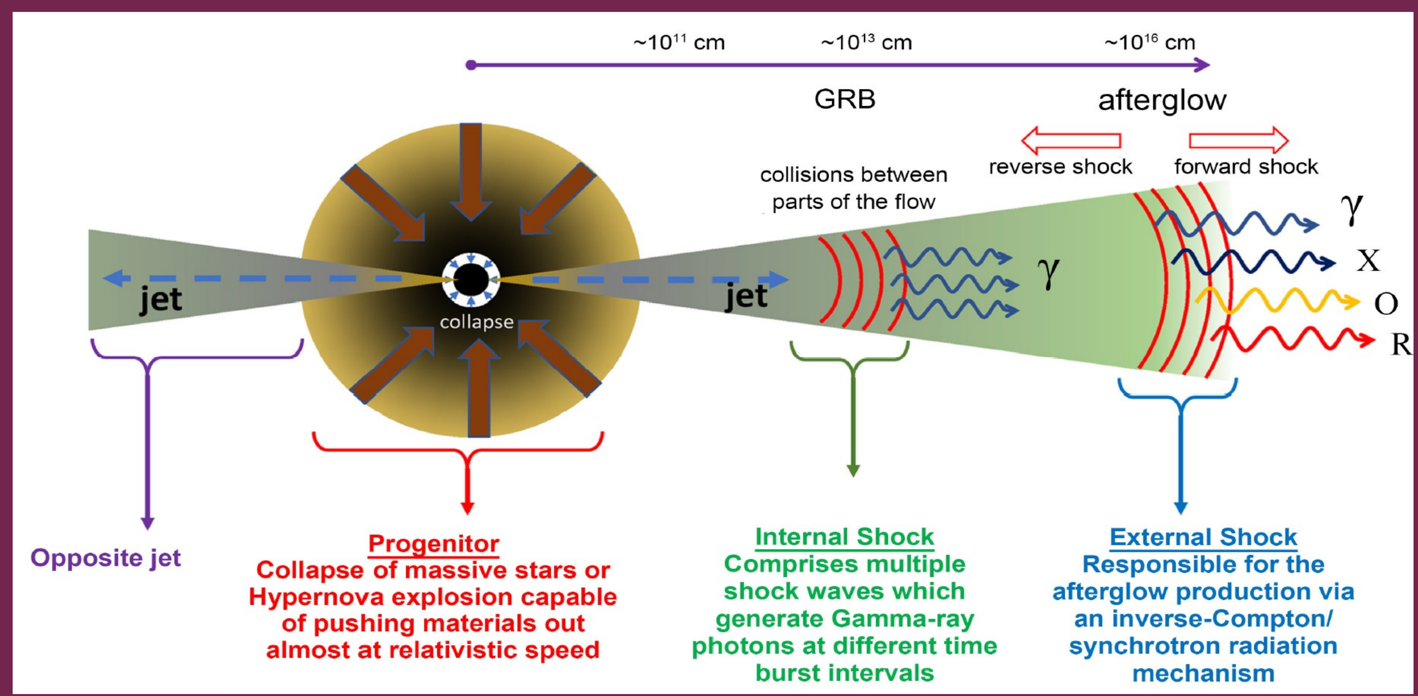

Figure 1: A modified cartoon depiction showing schematics of the fireball model and the basic components of the internal and externa Shocks of GRB Jets

Time Delay Phenomenon

- (Albert et al., 2008; de Farias et al., 2021; Martínez & Errando, 2009; Zhang, 2019)

Causes of Time delay

- Plasma Effect and Photon Mass Effect : $\Delta t = K\left(\nu_h^{-2} - \nu_l^{-2}\right)$
- FDSL Model: $\Delta t = K\left(\nu_h^{-1} - \nu_l^{-1}\right)$

Specific Objectives

- To propose an alternative model based on a frequency-dependent speed of light (FDSL) in cosmic plasma (Eq. 1)
- To refine the previous GRB time delay by accounting for the non-simultaneous, systematic photon emission from the shock front (Eq. 2)
- Obtain a unified model for time delays across four different GRBs using a relative distance mechanism (Eq. 3)
- Estimate the frequency equivalence of the interstellar medium (ISM)'s conductance (Eq. 5)
- Obtain the Average distances to the four GRB samples (Eq. 5)

Data Sample

- Zhang et al. (2016) used their GRB data to constraint the cosmological upper mass limit of the photon mass
- Chandra and Frail (2012) compiled 304 radio observations of GRB afterglows procured between January 1997 and January 2011.

Theoretical Framework

FDSL Model:
$$\Delta t = \frac{D\nu_*}{C}\left(\frac{1}{\nu_l} - \frac{1}{\nu_h}\right) \quad \text{.........(1)}$$

Non-Simultaneous Emission Model
$$\Delta t = \frac{\mathcal{D}\nu_*}{c_0}\left(\frac{1}{\nu_l} - \frac{1}{\nu_h}\right) + t_c \quad \text{.........(2)}$$

Refined FDSL Model:
$$\frac{\Delta t}{D_{\text{rel}}} = \frac{D_\dagger \nu_*}{c_0}\left(\frac{1}{\nu_l} - \frac{1}{\nu_h}\right) \quad \text{.........(3)}$$

Conductance of the ISM:
$$\sigma = \frac{8\pi\nu_*}{\mu_0 c_0^2} = 8\pi\varepsilon_0\nu_* \quad \text{.........(4)}$$

Distance Estimation:
$$S = \frac{D\nu_*}{c_0} \quad \text{.........(5)}$$

Results

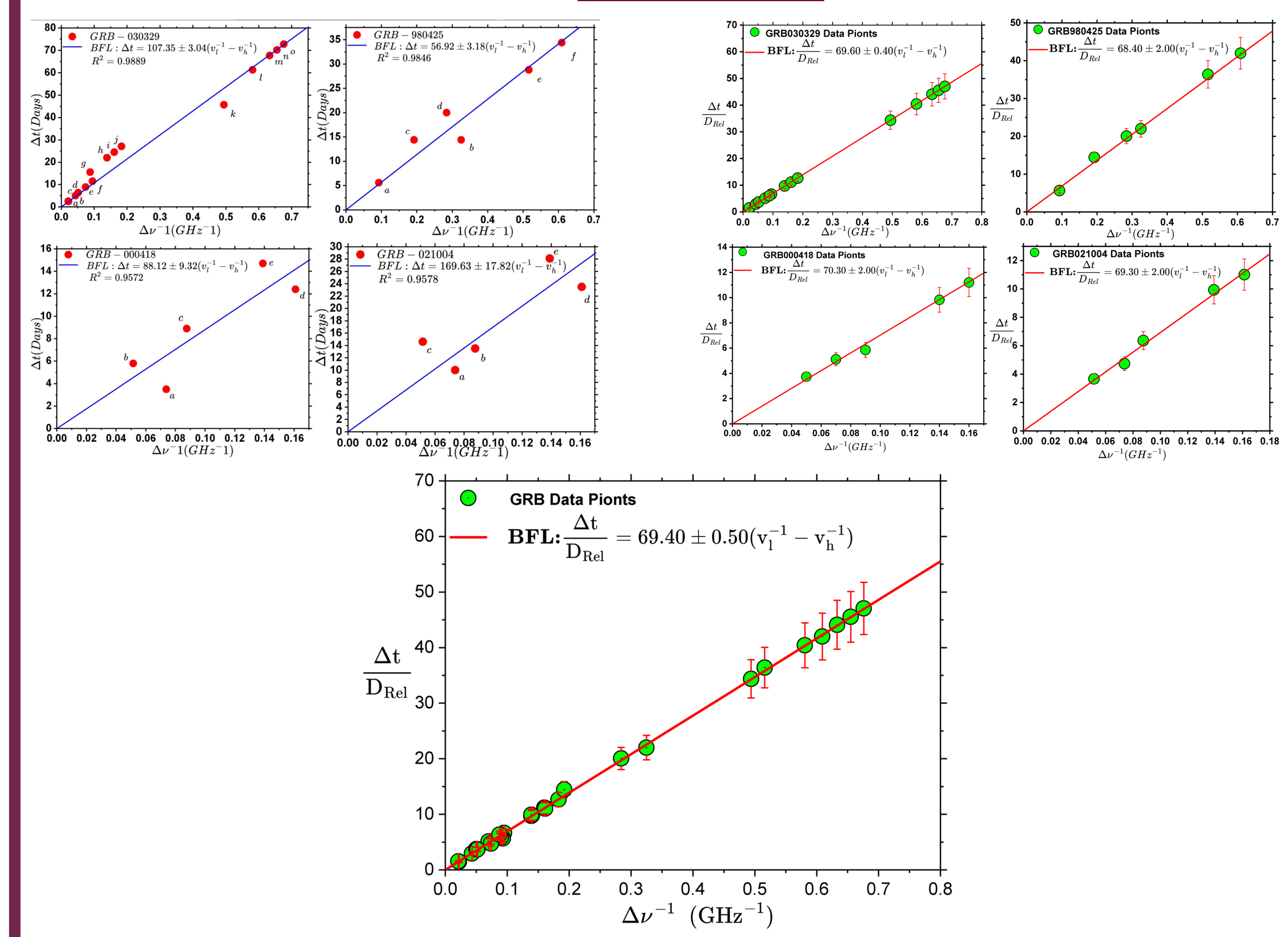

Figure 2:. Final plot for GRB 030329, 980425, 000418, 021004 before and after after time delay and the relative distance correctionused . Fitting passes through the origin (0, 0) naturally after the corrections were made indicating strong support for our model.

Source	Host Galaxy Redshift	Relative Distance	$\mathcal{D}_{\mathcal{L}}$ (Mpc)	D_{avg} (Mpc)	$D_\dagger \nu^* / c_0$ (10^{15})	R^2
GRB030329	0.1683 ± 0.0001	1.7360 ± 0.0030	838.9000	69.4000 ± 0.1000	10.0000 ± 0.1000	1.0000
GRB980425	0.0087 ± 0.0000	1.0000 ± 0.0000	40.0000	40.0000 ± 0.0000	6.0000 ± 2.0000	0.9985
GRB000418	1.1181 ± 0.0001	1.4600 ± 0.0100	7804.0000	58.4000 ± 0.4000	9.0000 ± 0.9000	0.9932
GRB021004	2.3304 ± 0.0005	2.1500 ± 0.0300	19188.0000	86.0000 ± 1.0000	13.0000 ± 3.0000	0.9916
			$\nu_* = 1.507 \pm 0.009$			

Key Findings

- **Frequency equivalent**: ν_* ~1.500± 0.009 Hz.
- **Distance Estimates:**
- GRB 030329 = 69.40 ± 0.10Mpc
- GRB 980425 = 40.00 ± 0.00Mpc
- GRB 000418 = 58.40 ± 0.40Mpc
- GRB 021004 = 86.00 ± 1.00Mpc

Discussions/Conclusion

- provide new insights into GRB jet dynamics and photon mass, reinforcing or challenging existing GRB models.
- The combined analysis of the four GRB sources strongly suggests that an independent distance measure to GRBs can be established because the graph of Δt Drel vs $\Delta\nu$ −1 supports this position since from this graph we obtain an impressively linear correlation
- The fact that the data points of the four GRBs can be grouped into two subgroups suggests that these subgroups may very well be independent shock systems. This needs further investigation and will be subject of our next instalment which have also been published.
- The FDSL model provides a stronger theoretical framework for understanding photon time delays in GRBs.
- The results support and refine key GRB models, advancing knowledge of relativistic outflows.
- Moreover, these results lend support to two existing GRB models: the fireball model and the multiple shock wave model.
- **Furture:** Explorae GRB archive involving large sample size of radio afterglow data.

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- National University of Science & Technology Zimbabwe

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