Statistical properties of Greiner's GRB table

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Abstract

The Jochen Greiner's GRB table represents one of the most comprehensive, although subjective, repository of Gamma-Ray Burst localizations, spanning several decades of observations from BeppoSAX to the latest missions like Swift, Fermi, and the Einstein Probe (EP). Due to the diverse nature of the instruments and localization procedures involved the statistical analysis of this dataset requires careful consideration of selection effects and instrumental biases. In this study, we perform a multi-dimensional statistical analysis of the Greiner table to uncover underlying patterns in the global properties of GRBs. By employing advanced statistical methods, we evaluate how the inclusion of various mission data affects the homogeneity of the catalog. Our results provide insights into the evolutionary effects of the GRB population and offer a critical assessment of the catalog's utility for cosmological studies. This work serves as a foundational statistical characterization of the dataset, supporting the synergy between legacy catalogs and future high-energy surveys.

Introduction

The Database: Greiner's GRB Compilation

Jochen Greiner's Gamma-Ray Burst (GRB) table represents a major, multi-decadal repository of localized GRBs. It integrates detections from a wide array of space missions and instruments spanning several generations of observational astronomy — ranging from pioneering observatories like *BATSE* and *BeppoSAX*, through the prolific eras of *Swift* and *Fermi*, up to current next-generation missions such as *SVOM* and the *Einstein Probe*.

The Challenge: Inherent Heterogeneity

Because it aggregates data from instruments with vastly different spectral sensitivities, varying angular resolutions, and shifting trigger criteria, the catalog is highly heterogeneous and inherently subjective. It is significantly impacted by complex instrumental biases, non-uniform sky exposure, and diverse observational selection effects.

The Core Question: Physical Reality vs. Artifacts

Can such a mixed, unstructured dataset be reliably utilized for high-precision cosmological large-scale structure studies? Specifically: **are the massive anisotropic patterns observed in the GRB distribution genuine cosmic superstructures, or are they mere geometric artifacts born from observational selection effects?**

Methodology

We filtered the Greiner dataset to include only Gamma-Ray Bursts (GRBs) with known redshifts (z), resulting in a final sample of 712 objects. To rigorously address the inherent selection effects and instrumental biases of this heterogeneous catalog, we categorized the sample based on the method of redshift determination into four distinct groups:

- Host galaxy identification (53 GRBs)
- Photometric measurements (43 GRBs, including 19 high-uncertainty cases)
- Spectroscopic measurements (588 GRBs — the most precise category)
- Upper limits (28 GRBs)

Furthermore, we cross-tabulated these redshift categories against the discovering space missions and localization instruments (such as *Swift*, *Fermi*, *BeppoSAX*, and recent missions like *SVOM* and the *Einstein Probe*). While the sample is heavily dominated by *Swift* (562 out of 712 objects, $\sim 79\%$), the vast majority of the overall dataset ($\sim 82.6\%$) relies on high-quality spectroscopic data, providing a solid statistical foundation.

Finally, we mapped the spatial distribution of these categorized groups in Galactic coordinates (l, b) to search for large-scale statistical homogeneities, anisotropic patterns, or cosmic structures.

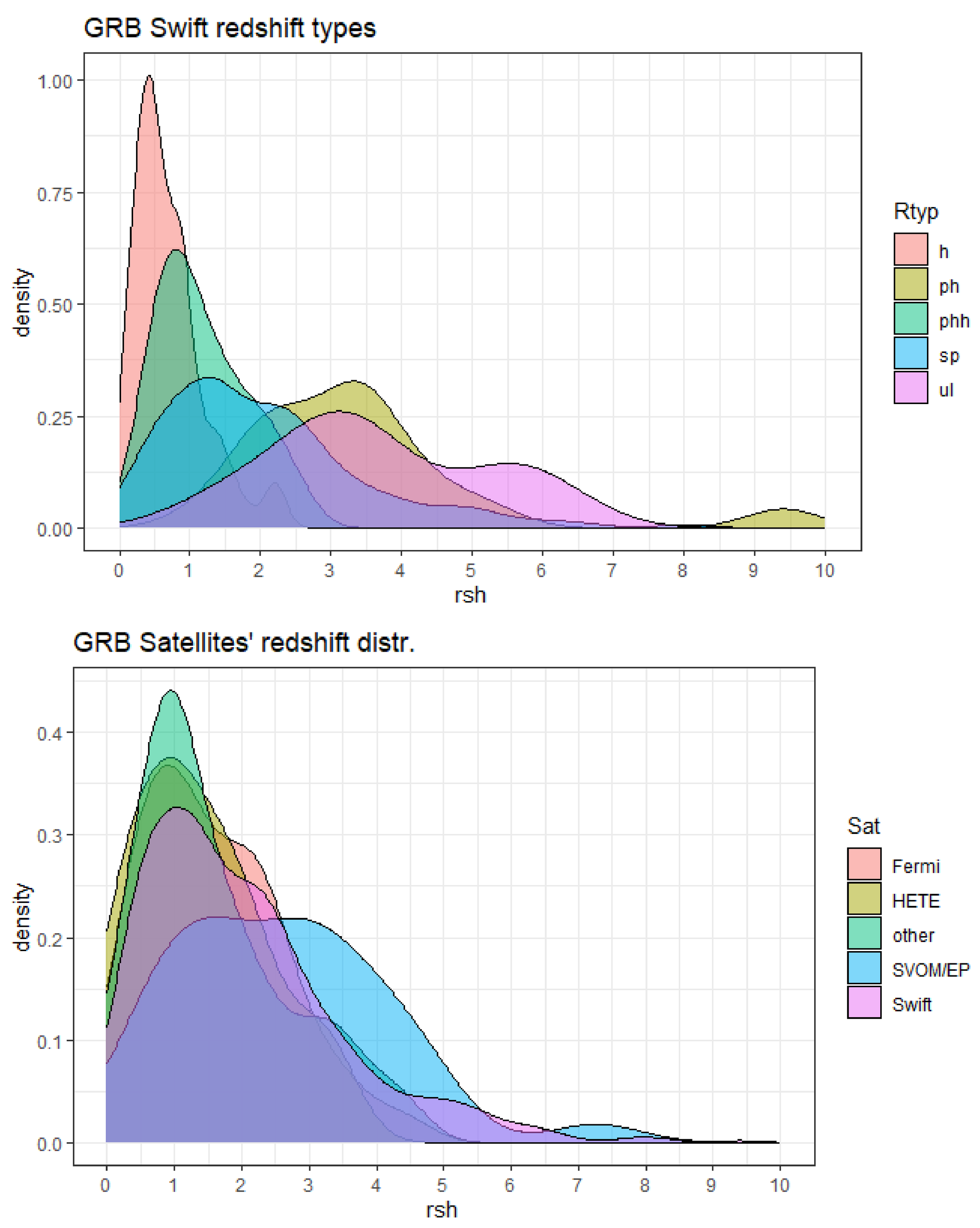

Figure 1: Distribution of redshift determination types and discovering instruments within the filtered sample.

Results

Our statistical analysis yields two major cosmological findings regarding the spatial distribution and data composition of the filtered Greiner catalog:

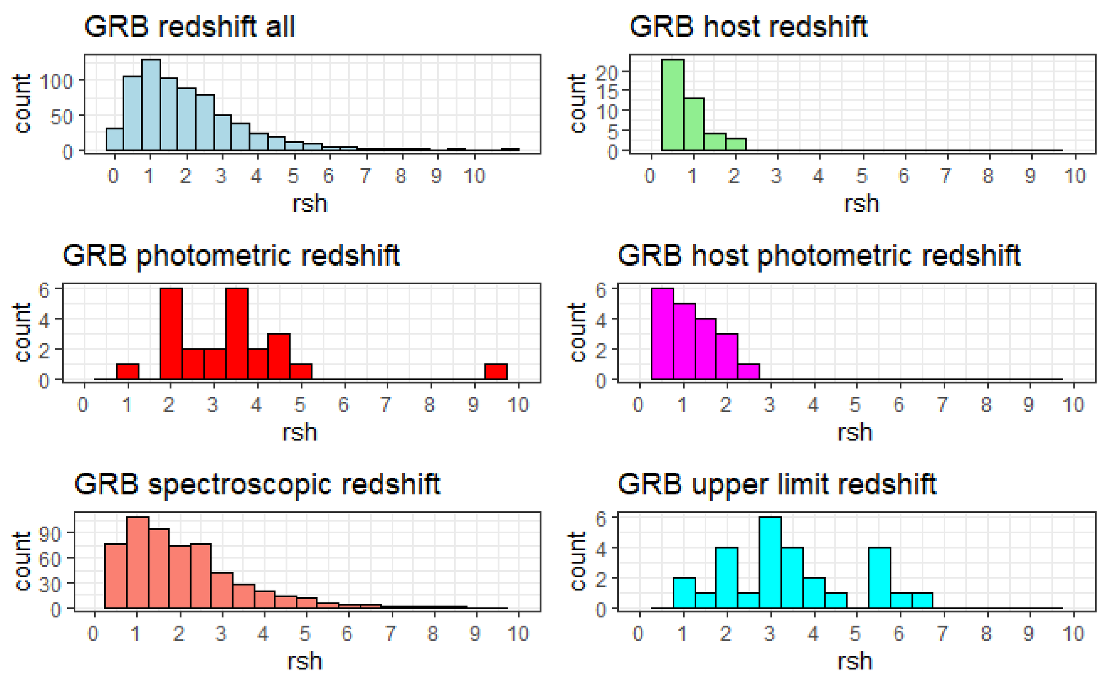

Figure 2: Redshift distribution histogram of the 712 analyzed GRBs from Greiner's table, color-coded by the method of redshift determination. The plot highlights the clear dominance of high-precision spectroscopic measurements (sp), which provide the robust statistical backbone for detecting large-scale anisotropic features like the GGR and HCBW.

Spatial Non-Isotropy & Cosmic Superstructures

The spatial distribution of the investigated GRBs in Galactic coordinates is fundamentally non-isotropic. By mapping the sample, we successfully verify the existence of two cosmic superstructures that challenge the strict validity of the Cosmological Principle on these scales:

- **Giant GRB Ring (GGR):** A massive, ring-like configuration of bursts spanning billions of light-years.
- **Hercules–Corona Borealis Great Wall (HCBW):** The largest known superstructure in the observable Universe.

The Impact of Redshift Quality

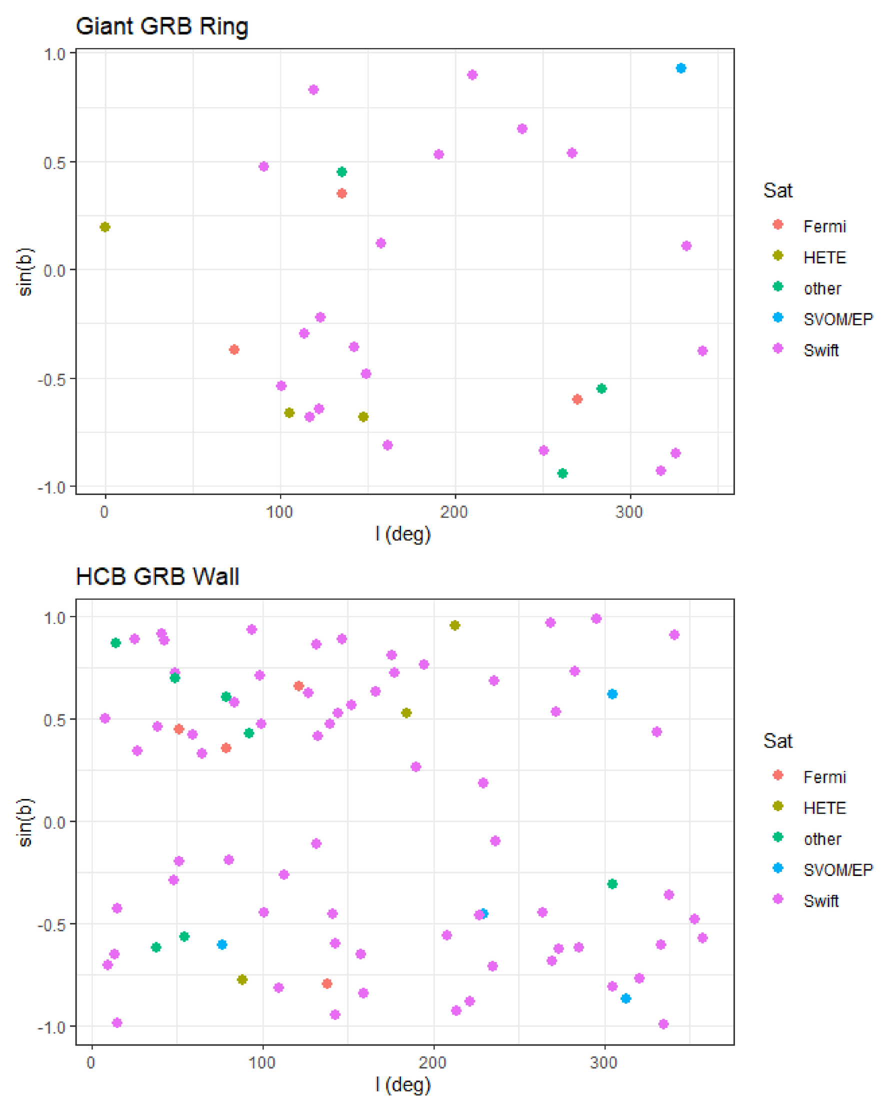

Figure 3: Sky distribution in Galactic coordinates of the GRBs associated with the two discovered superstructures, categorized by the locating space mission/instrument. **TOP:** The Giant GRB Ring (GGR) sample. **BOTTOM:** The Hercules-Corona Borealis Great Wall (HCBW) sample. The multi-instrument composition of both features provides strong evidence that these structures are real physical phenomena and do not originate from the selection effects or angular biases of a single satellite mission.

The most robust and critical result of our work is that **both the GGR and the HCBW are clearly and prominently displayed by the sub-sample of spectroscopic redshifts** (sp). Since spectroscopic measurements are the most reliable and precise, this statistical evidence strongly proves that these giant structures are **genuine physical phenomena** rather than artifacts caused by loose photometric redshift calculations or instrumental selection effects.

Conclusion

Crucial Finding: Both the Giant GRB Ring (GGR) and the Hercules-Corona Borealis Great Wall (HCBW) are clearly and robustly displayed by the sub-sample of GRBs with spectroscopically obtained redshifts.

Scientific Impact: Since spectroscopic redshifts are the most reliable and precise, this proves that these giant structures are real physical phenomena and not statistical artifacts caused by loose photometric errors or observational selection effects.

Takeaway: Despite its subjective nature, Greiner's table is a powerful tool for observational cosmology when properly filtered by redshift quality.

Contact Information

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Feel free to reach out for collaborations, data requests, or questions regarding the statistical methodology.