Identification of Extended Emission Gamma-Ray Burst Candidates Using Machine Learning

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Garcia-Cifuentes, **Becerra**, De Colle et al.
ApJ, Volume 951, July 2023

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Motivation of the work

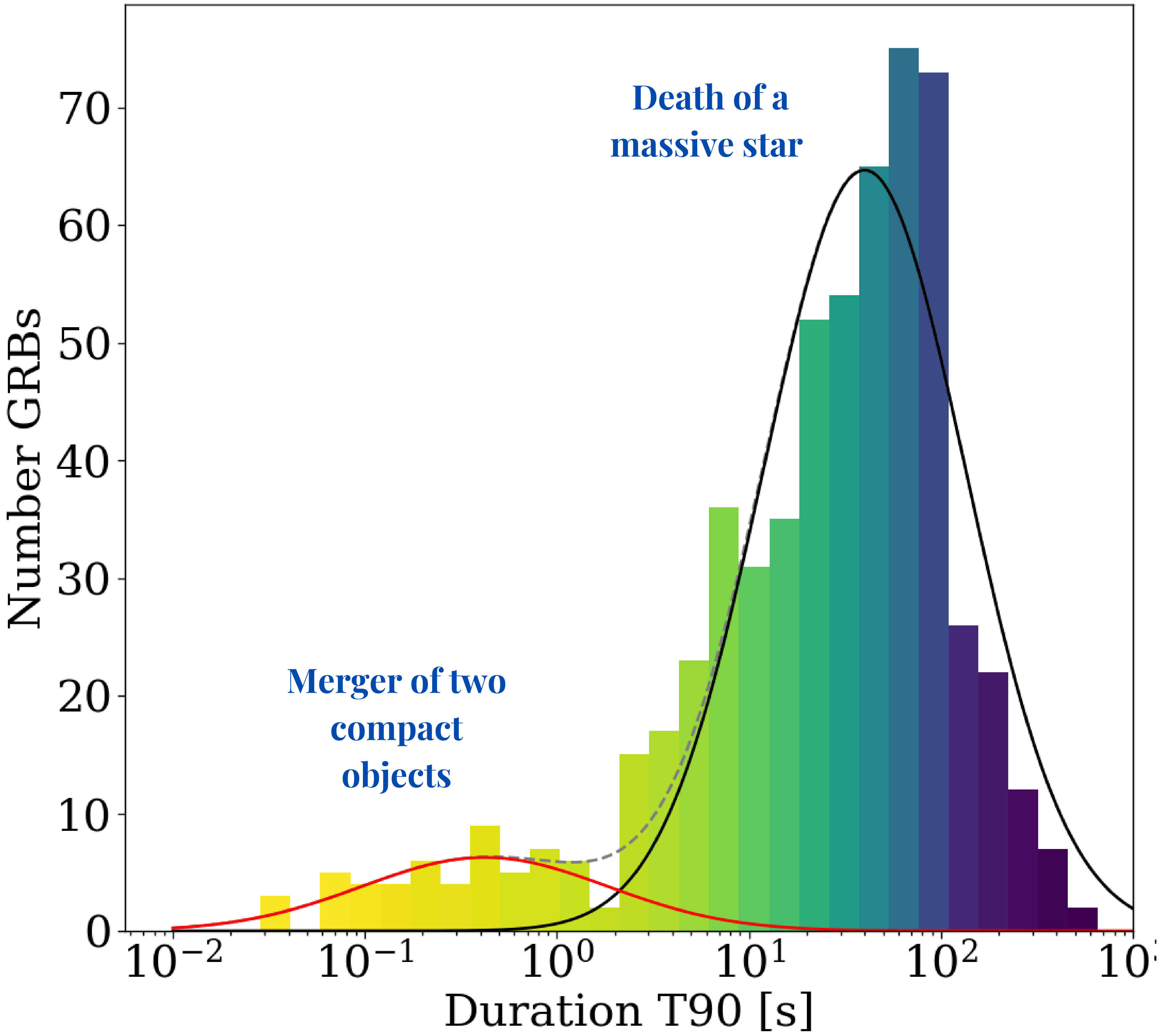
Classification of GRBs

CURRENT CLASSIFICATION

The identification of subclasses in the GRBs is evidenced by plotting the histogram of its duration T90 and its cut-off at 2 seconds

T90 interval is defined by the time at which 5% and 95% of the total counts have been detected.

There are events whose properties of populations are hybrid: Extended Emission GRBs (GRB 211211A)



Motivation

Classification of GRBs- Different progenitors

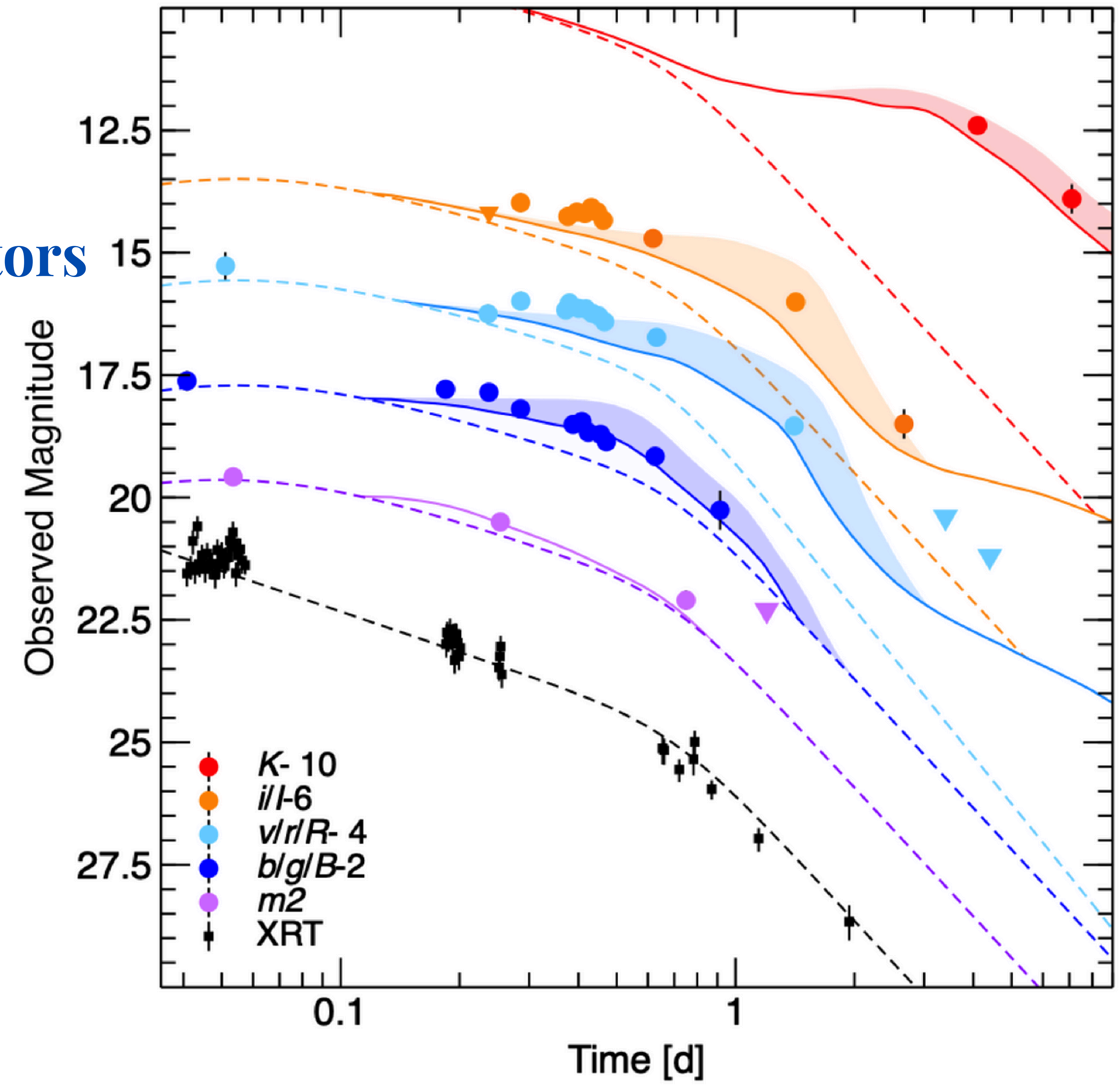
IS THIS A RIGHT CLASSIFICATION?

- The populations are not separated
- Isolated progenitors?
- Hybrid events, as short GRBs with EE.
- Instrumental selection effects

So...

...the classification is not perfect!

Troja et al. 2022, Nature



Kilonova component in GRB 211211A (T90=50 seconds)

Objectives

Classification of GRBs

USING A MACHINE LEARNING APPROACH WE COULD:

- Find correlations based on GRBs' light curves or their features.
- Associate them with their progenitors and subjacent physical processes.
- Provide a simple way to characterize any event concerning the total sample rapidly.

Research Timeline

ApJ

Jespersen et al. (2020)

- Present the ML classification framework
- Uses a dataset of 1254 GRBs from Swift/BAT

MDPI

Salmon et al. (2022)

- Changes data pre-processing by using Wavelets
- Uses datasets from Swift/BAT, BATSE, and Fermi GBM
- Discern two groups of GRBs within the first burst second

ApJ

Steinhardt et al. (2023)

- Added UMAP as a clustering alternative
- Confidence analysis, EE GRBs cannot be robustly classified

ApJL

Dimple et al. (2023)

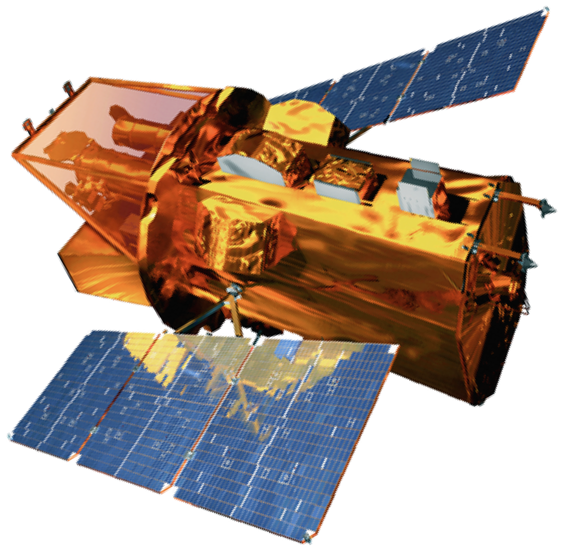
- Found KN-associated GRBs are located in separate clusters

ApJ

Garcia-Cifuentes et al. (2023)

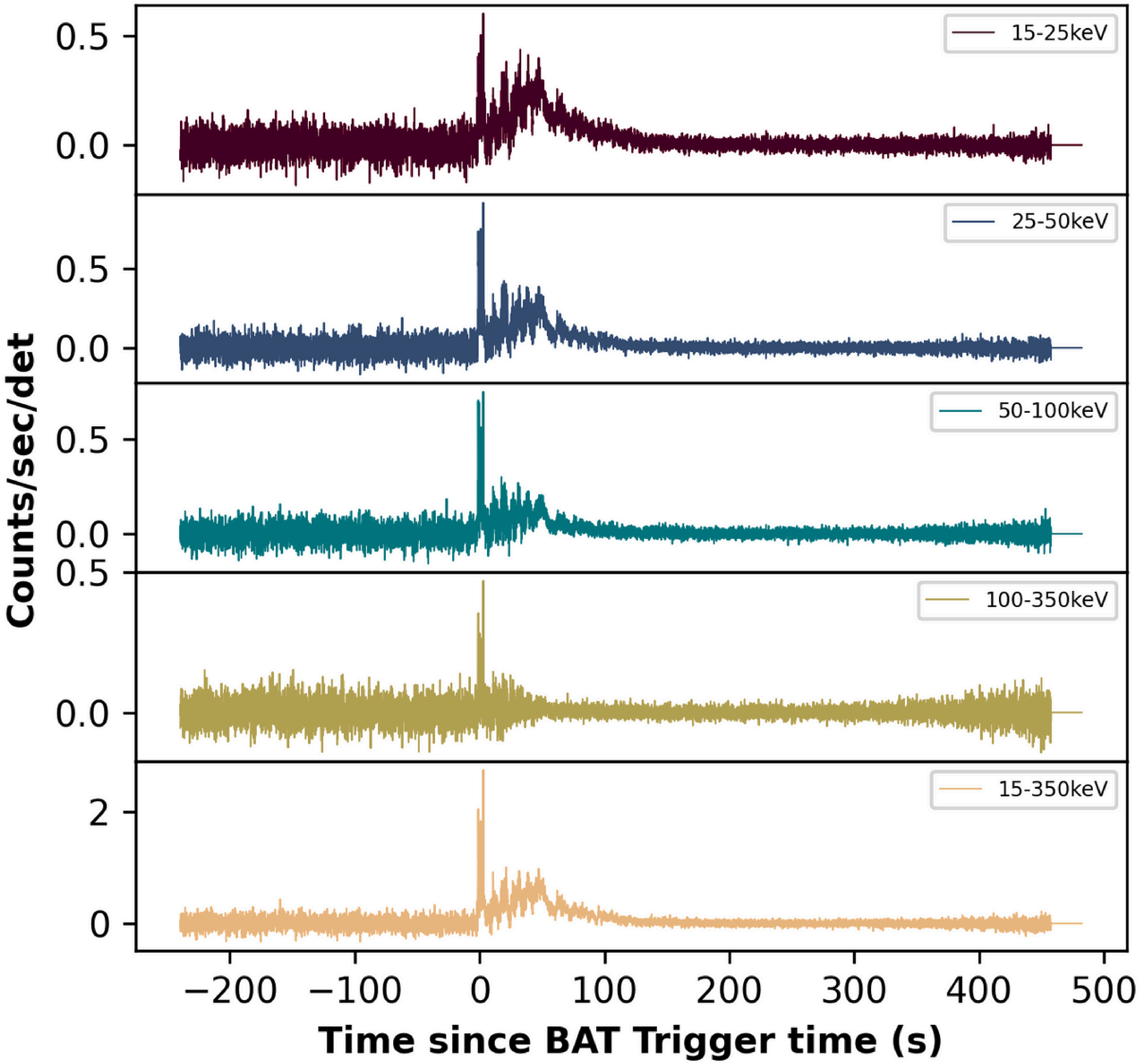
- **Extend analysis from Swift/BAT data to 1527 GRBs**
- **Improve classification by reducing noise on data**
- **EEGRBs are clustered on the edges of the clusters**

Data



The Neil Gehrels Swift Observatory Data set

1527 light curves of GRBs from Swift/BAT
Available in: swift.gsfc.nasa.gov/results/batgrbcat/



Example: GRB 060614 light curve in 64ms

Data Pre-processing

GRBs vary significantly in duration, it is essential to standardize the data set of each event in such a way that preserves intrinsic properties but removing differences without a physical origin.

Jespersen et al. (2020) ApJL, 896, L20.

1. **Limit out of duration intervals**
2. **Reduce Noise**
3. **Normalize by total fluence of each event**
4. **Standardize the size of events: Zero-pad**
5. **Perform Discrete Fourier Transform**

t-distributed stochastic neighbor embedding (t-SNE)

...in a nutshell

ABOUT

t-SNE is a popular non-linear dimensionality reduction technique used for visualizing high dimensional data sets.

ADVANTAGES

t-SNE has an impressive ability to create compelling two-dimensional maps from data with hundreds or even thousands of dimensions.

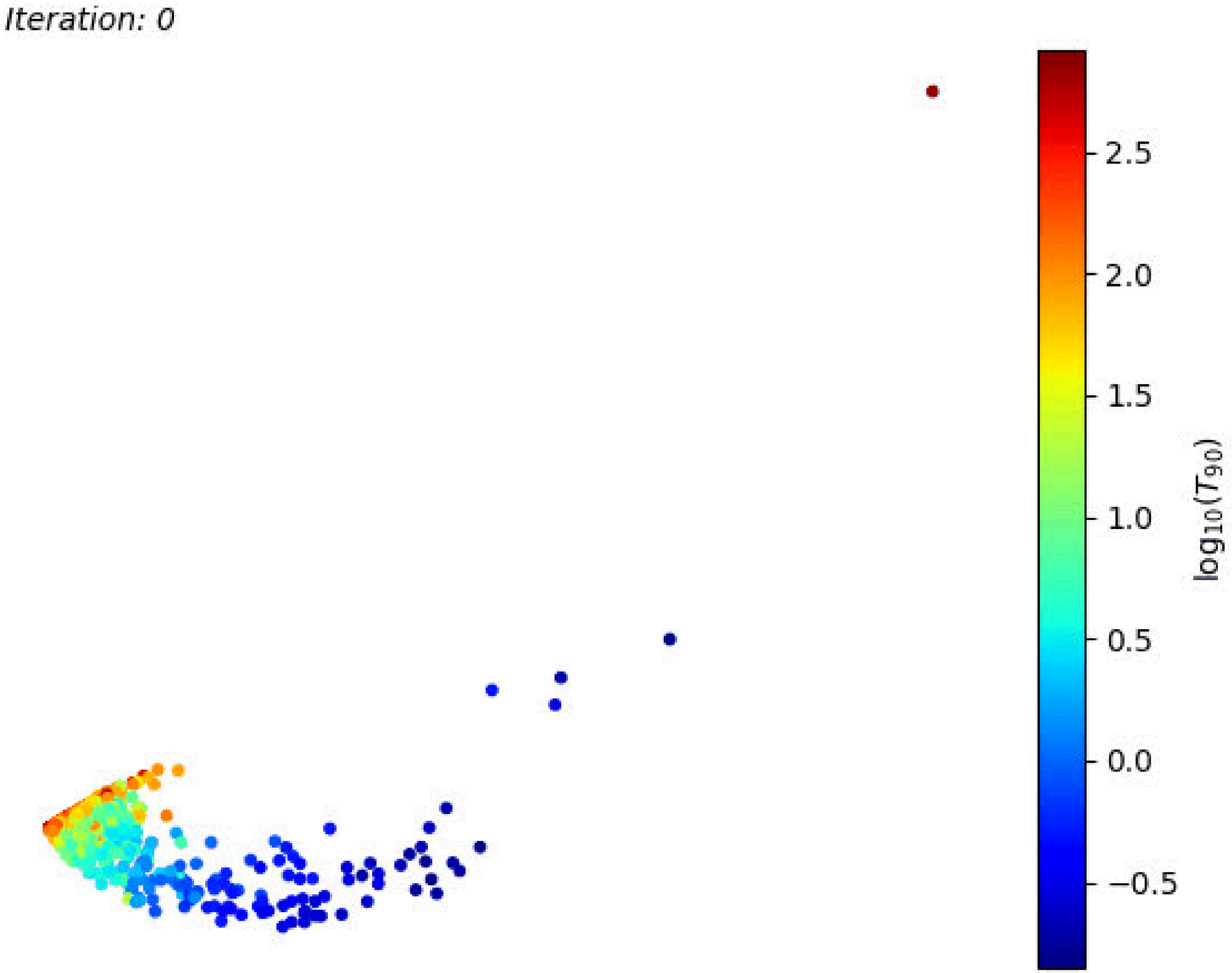
DISADVANTAGES

t-SNE doesn't always produce similar output on successive runs, and there are additional hyperparameters related to the optimization process.

To probe that our method is valid

Convergence

There is a clear correlation between each GRB duration and its position on the map

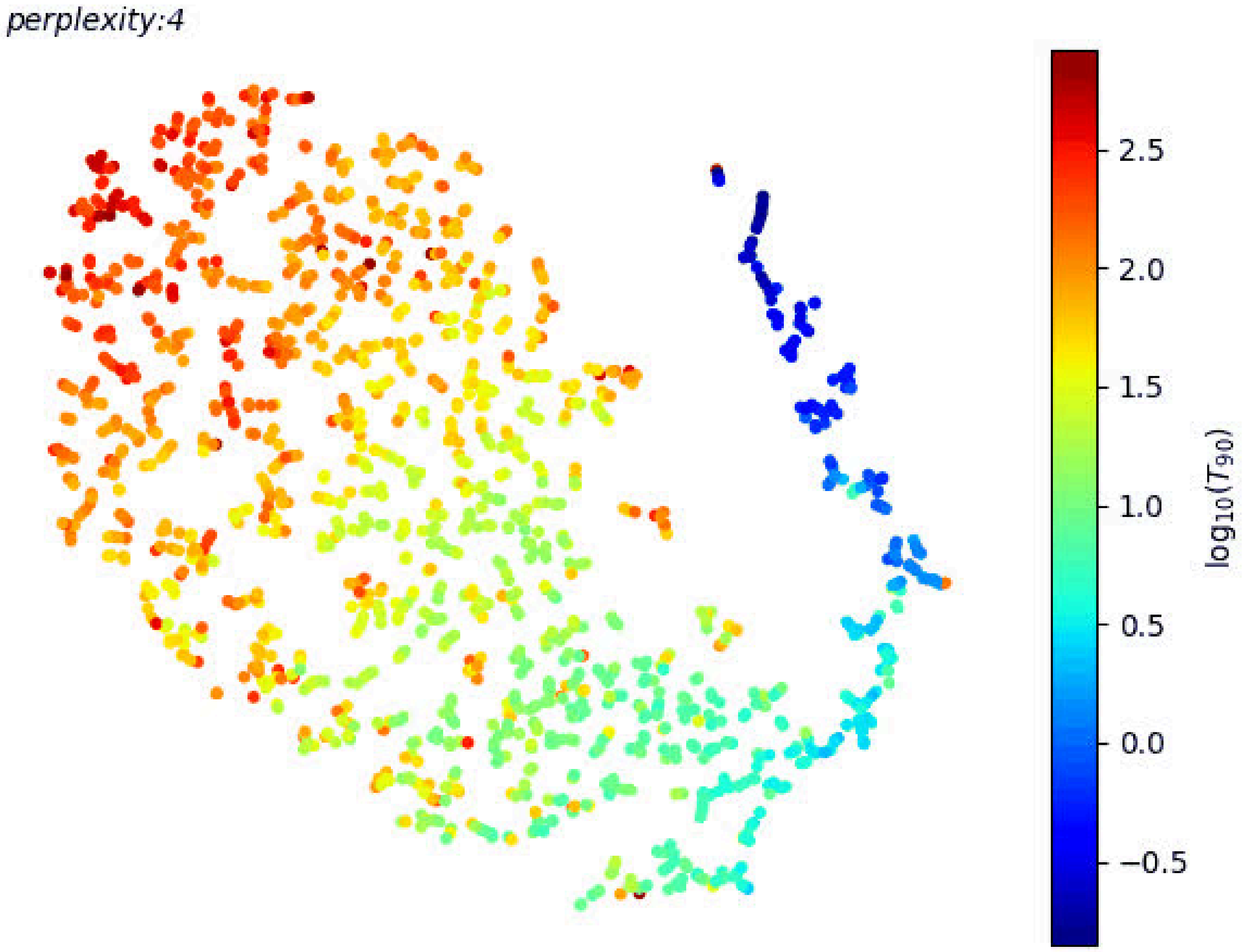


Credits: ClassiPyGRB

Hyperparameter Optimization

Perplexity

Credits: ClassiPyGRB



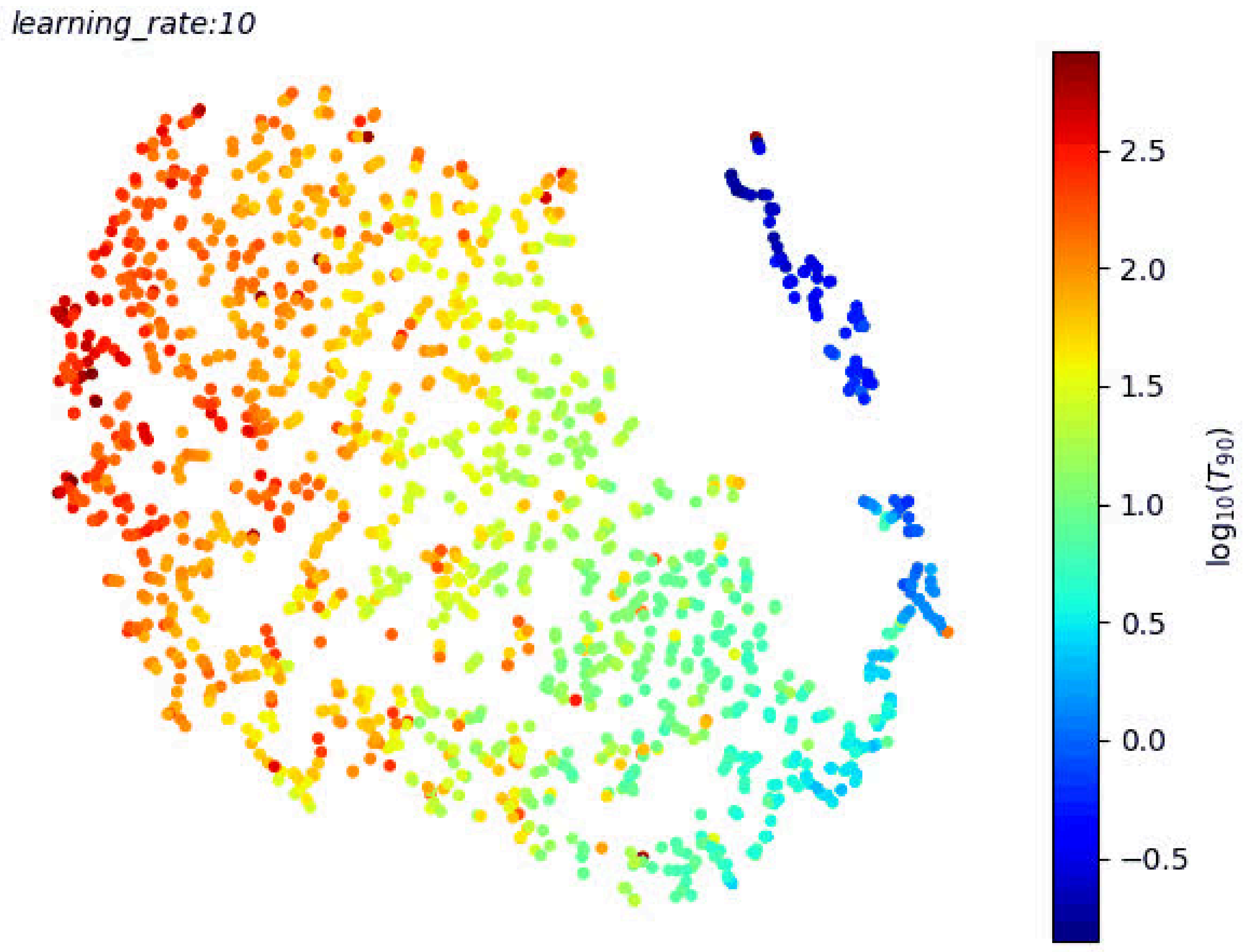
“It is related to the number of nearest neighbors that is used in other manifold learning algorithms”

Key Points

- Duration structure remains independent
- At low perplexities, the cluster separation increases.
- Equilibrium between physics and plot.

Hyperparameter Optimization
Learning Rate

Credits: ClassiPyGRB

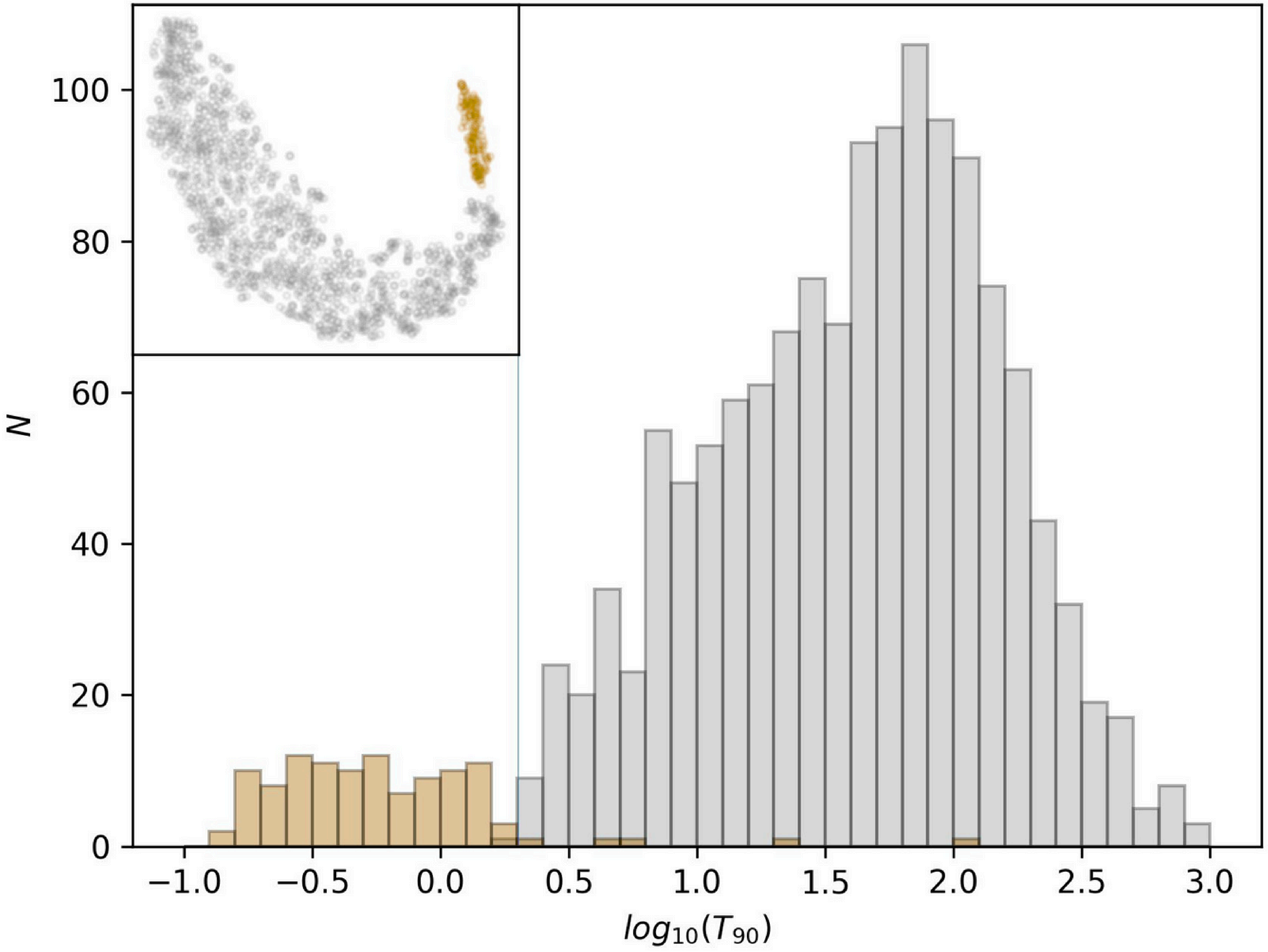


Key Points

- General structure remains independent.
- At low perplexities, adjusting learning rate plays a significant role in separating clusters. We have to be careful.

Classification Properties

Garcia-Cifuentes, K. et al. (2023)



Key Points

- Similar to duration-based classification
- It is based on light curve properties, instead of one single parameter

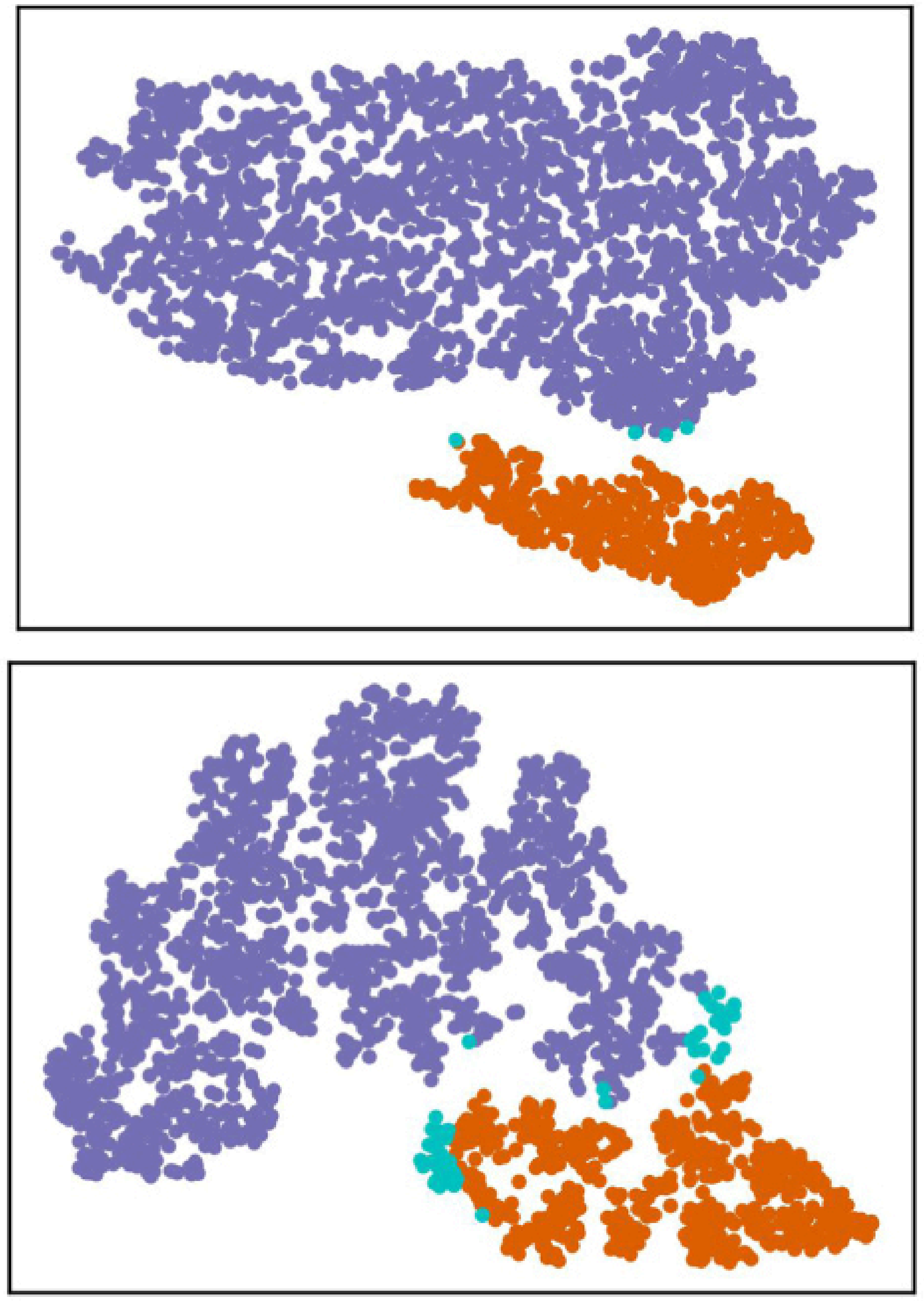
Classification Properties

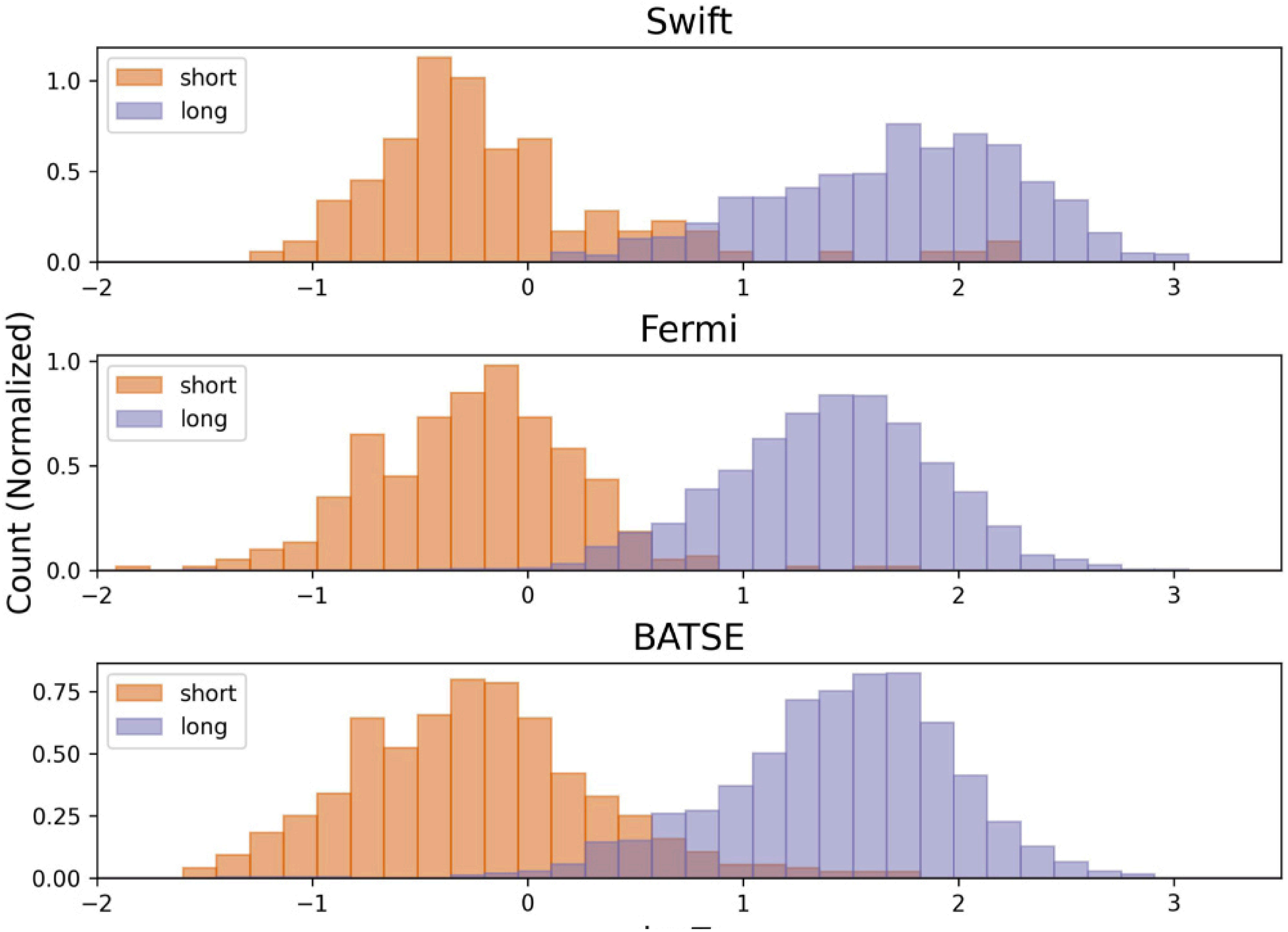
Credits: Steinhardt et al. (2023), ApJ, 965

Key Points

The classification is almost independent of selection effects:

- ~97% of the GRBs between telescopes have the same classification.





Extended Emission GRBs

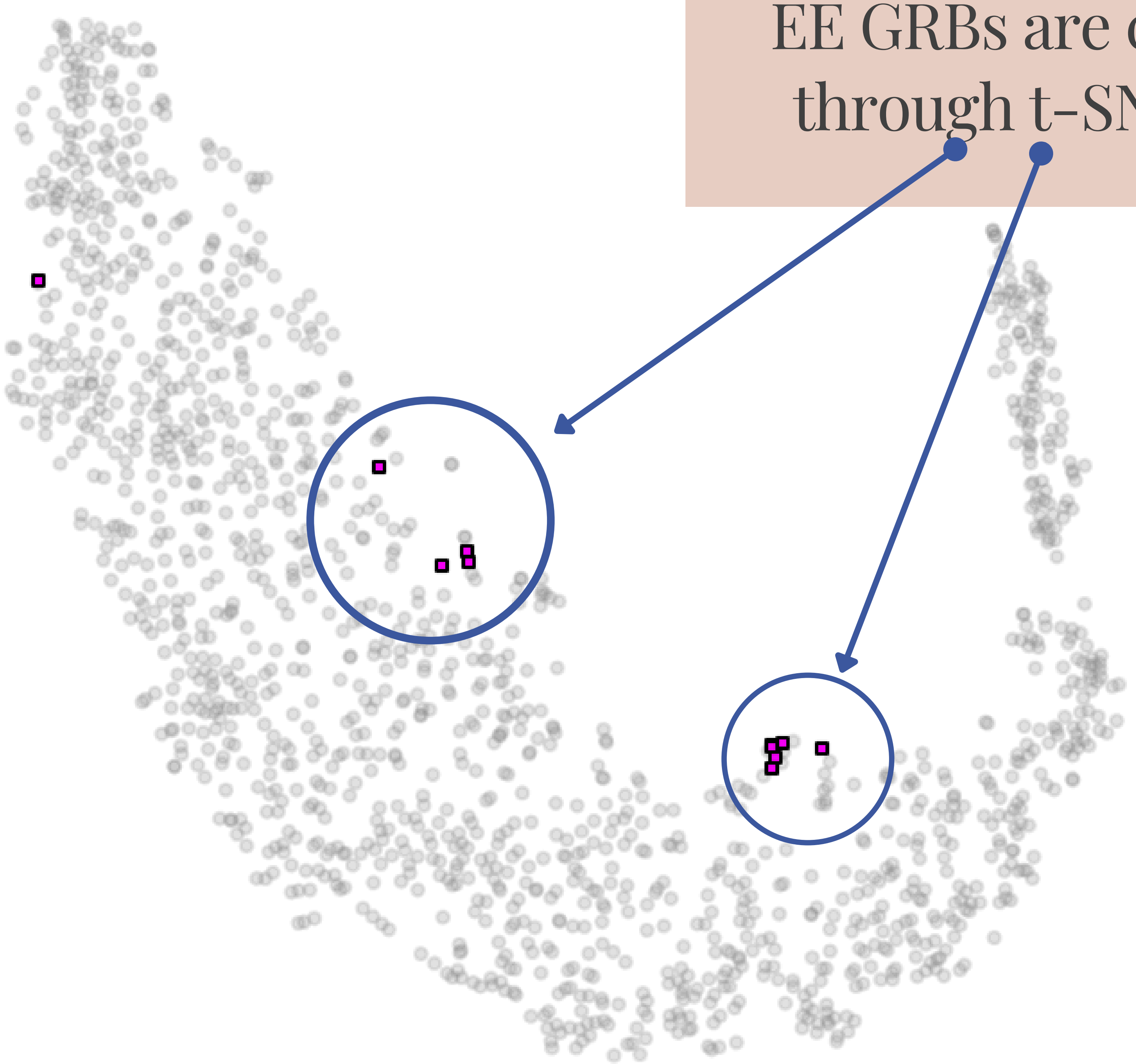
Key Points

Extended Emission GRBs, appear to be located on the edge of the diagrams.

Steinhardt et al.(2023) ApJ state:

"Tiny groups or individual objects with unique properties can be attached to the most similar group"

EE GRBs are clustered through t-SNE maps

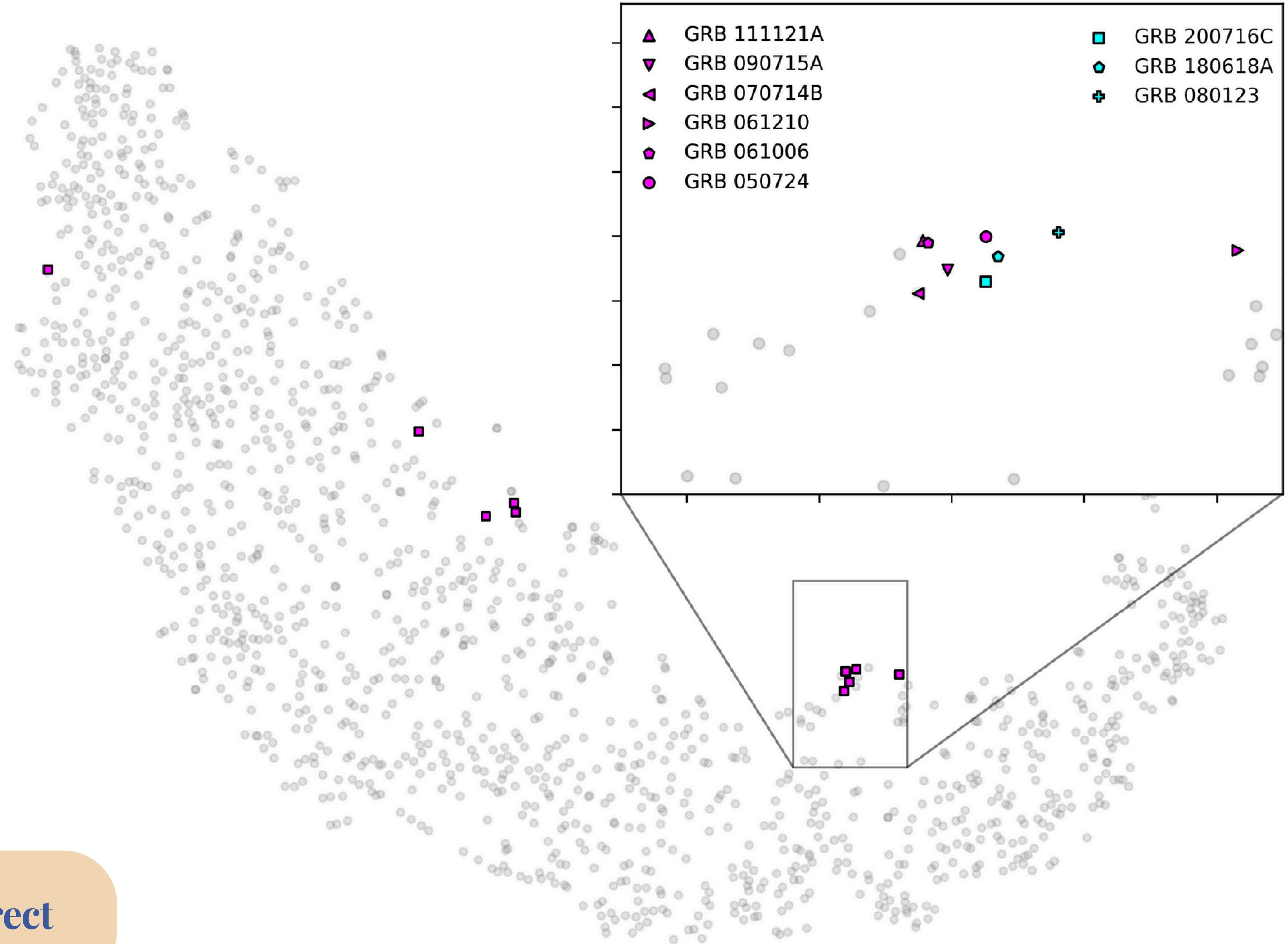


Garcia-Cifuentes, K. et al. (2023)

EEGRBs Candidates

Nearest neighbors to previous EE:

- GRB 200716C
- GRB 180618A
- GRB 080123

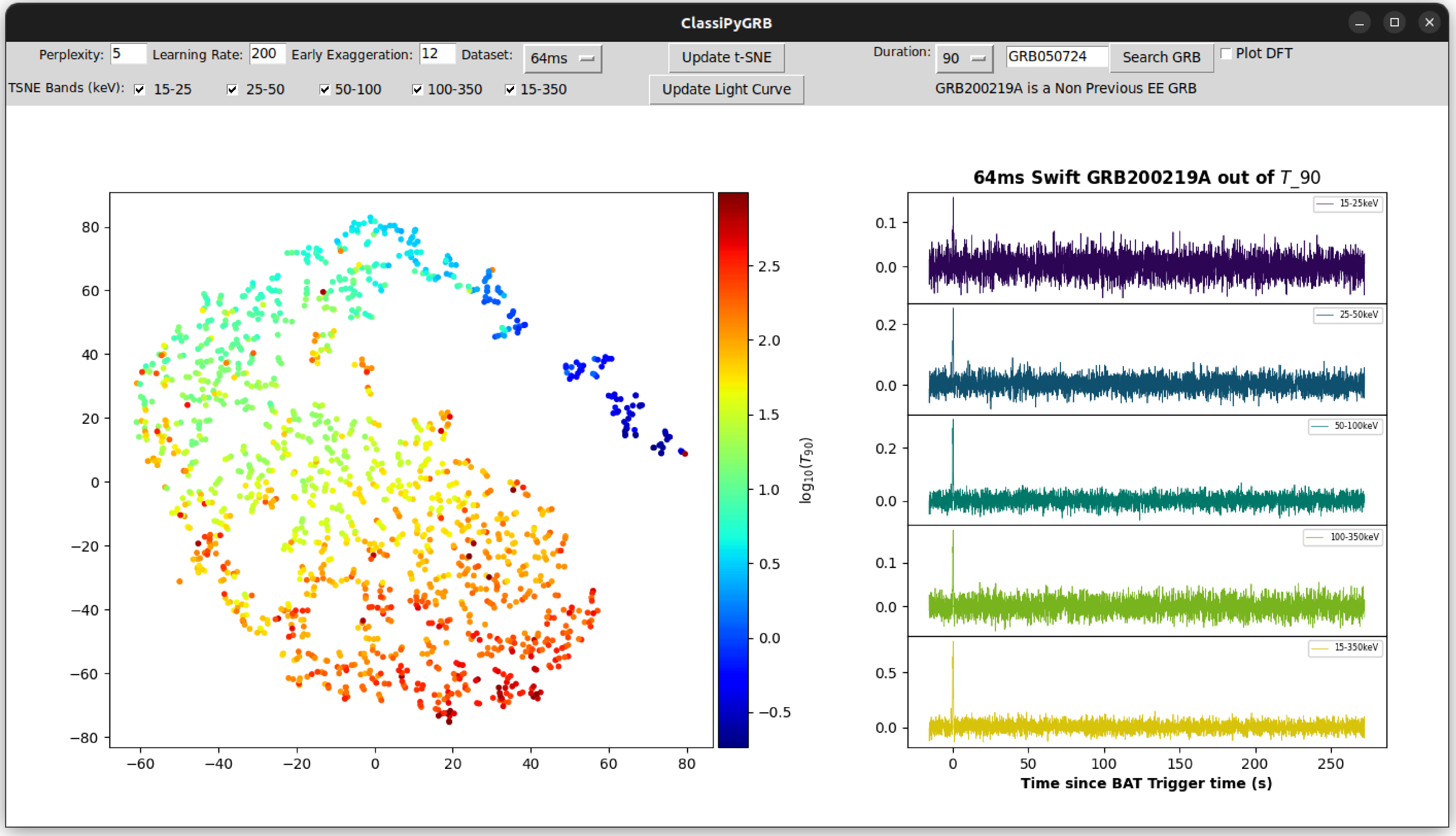


Our method was correct

Garcia-Cifuentes, K. et al. (2023)

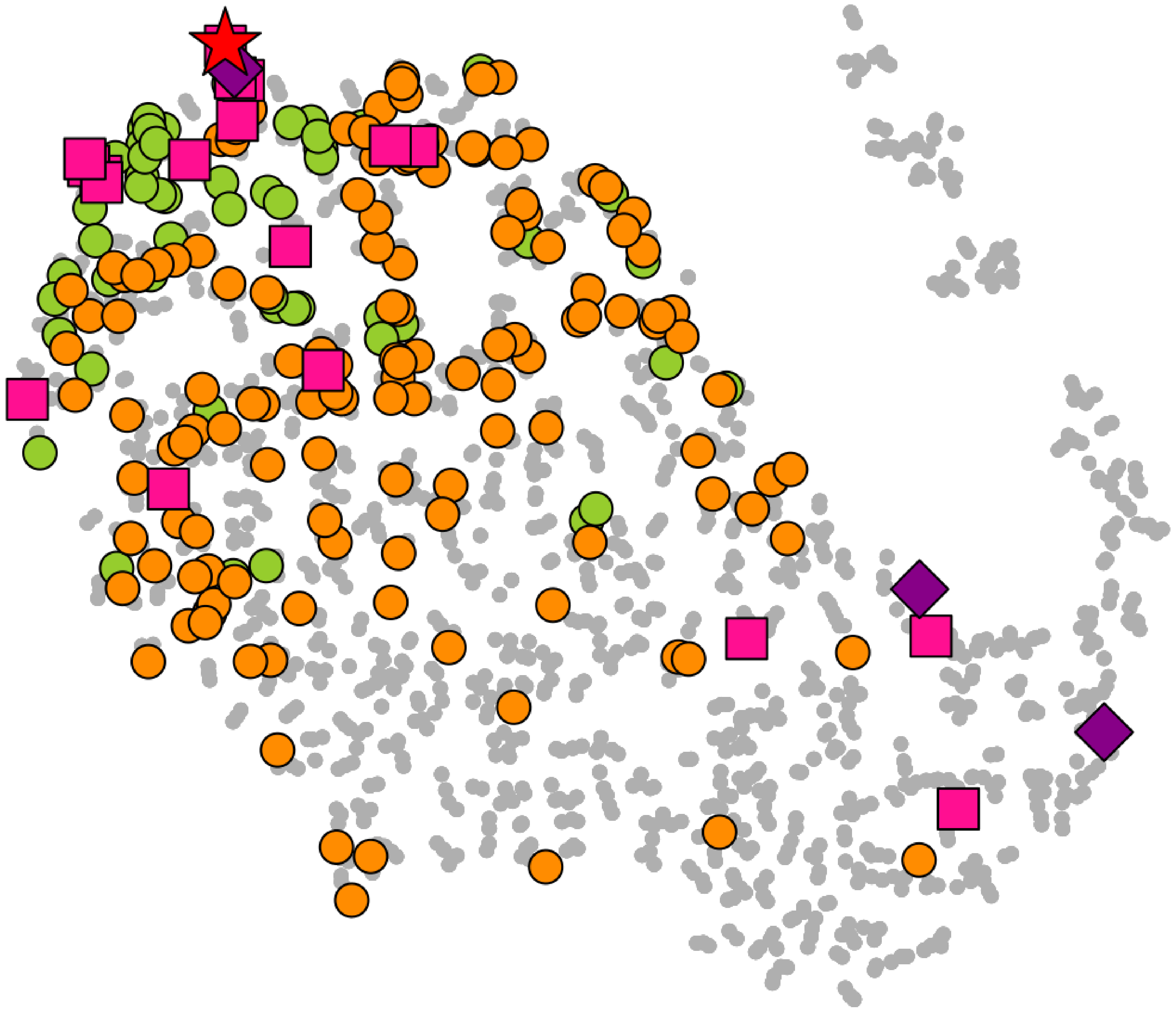
ClassiPyGRB

Open-source Python3 package to download, process, visualize and classify Gamma-Ray-Bursts (GRBs) from the Swift/BAT Telescope



ClassiPyGRB: Identification of subsamples of interest

1. Ultra-Long GRBs



Ror, A. K. et al 2024 (arXiv:2406.01220)

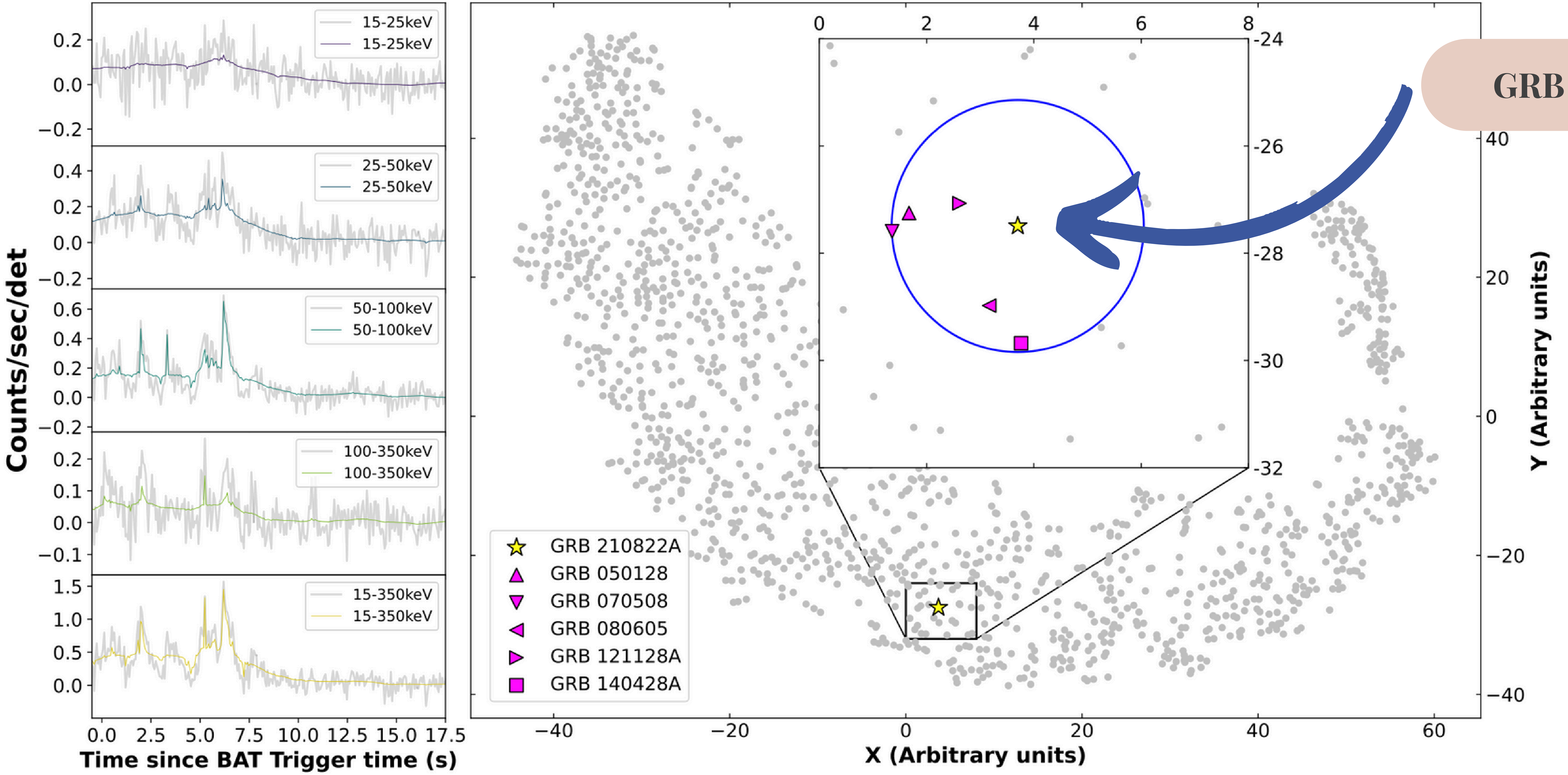
Ror, A. K. et al 2024 (arXiv:2406.01220)

"Exploring Origin of Ultra-Long Gamma-ray Bursts"

We have used a machine learning tool, t-Distributed Stochastic Neighbor Embedding (t-SNE), developed by Garcia-Cifuentes et al. (2023), to find differences between our selected sub-samples and other LGRBs and SGRBs detected by *Swift*-BAT till December 2023. t-SNE processes the high-energy light curve of GRBs and, based on similarities and dissimilarities between the light curves, places them in a two-dimensional map by forming a cluster of points where similar events lie close. The axes of this two-dimensional map do not

ClassiPyGRB: Identification of subsamples of interest

2. Bright GRBs



GRB 210822A

There are other similar GRBs in the gamm-rays component?

Angulo Valdez, C. et al 2024, ApJ 527

Thank You!

(Specially Maria & Gibrán)

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ClassiPyGRB Repository

https://github.com/KenethGarcia/ClassiPyGRB/

Identification of Extended Emission Gamma-Ray Burst Candidates Using Machine Learning, Garcia-Cifuentes, K et al. ApJ 591, 2023