Comprehension of jet physics from the analysis of Swift Gamma-Ray Bursts

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Abstract

The first observation of a short Gamma-Ray Burst in association with a Gravitational Wave opened a new era in the high energy astrophysics. The measured T90 of GRB170817A, of about 2 s, reinforces the necessity of a new way of classification. For this reason, we analyse at the Swift-BAT prompt emission data by applying a classification procedure that uses a machine learning technique that searches for similarities in the light curves. Two distinct groups could be identified, although still correlated with standard T90 duration. Since a jet viewed off-axis could explain the emission from GRB170817A, the modelling of this kind of sources is of great importance. A public code called JetFit, based on the "boosted fireball" model, is applied to fit Swift-XRT afterglow light curves of short and long Gamma-Ray Bursts, with known redshift, from 2005 to 2021. JetFit does not model the flaring activity. For this reason, a new procedure to remove the flaring phases has been developed. The distributions of the best-fit parameters, grouped according to the classification given by the machine learning algorithm, describe the physics of our sample. The mean values of the JetFit parameters can be used to compute the Synchrotron part of a typical Gamma-Ray Bursts afterglow emission model. Given the Synchrotron mechanism, it is possible to obtain a prediction on the Synchrotron Self-Compton high-energy component by building a general model based on physical parameters of the afterglow.

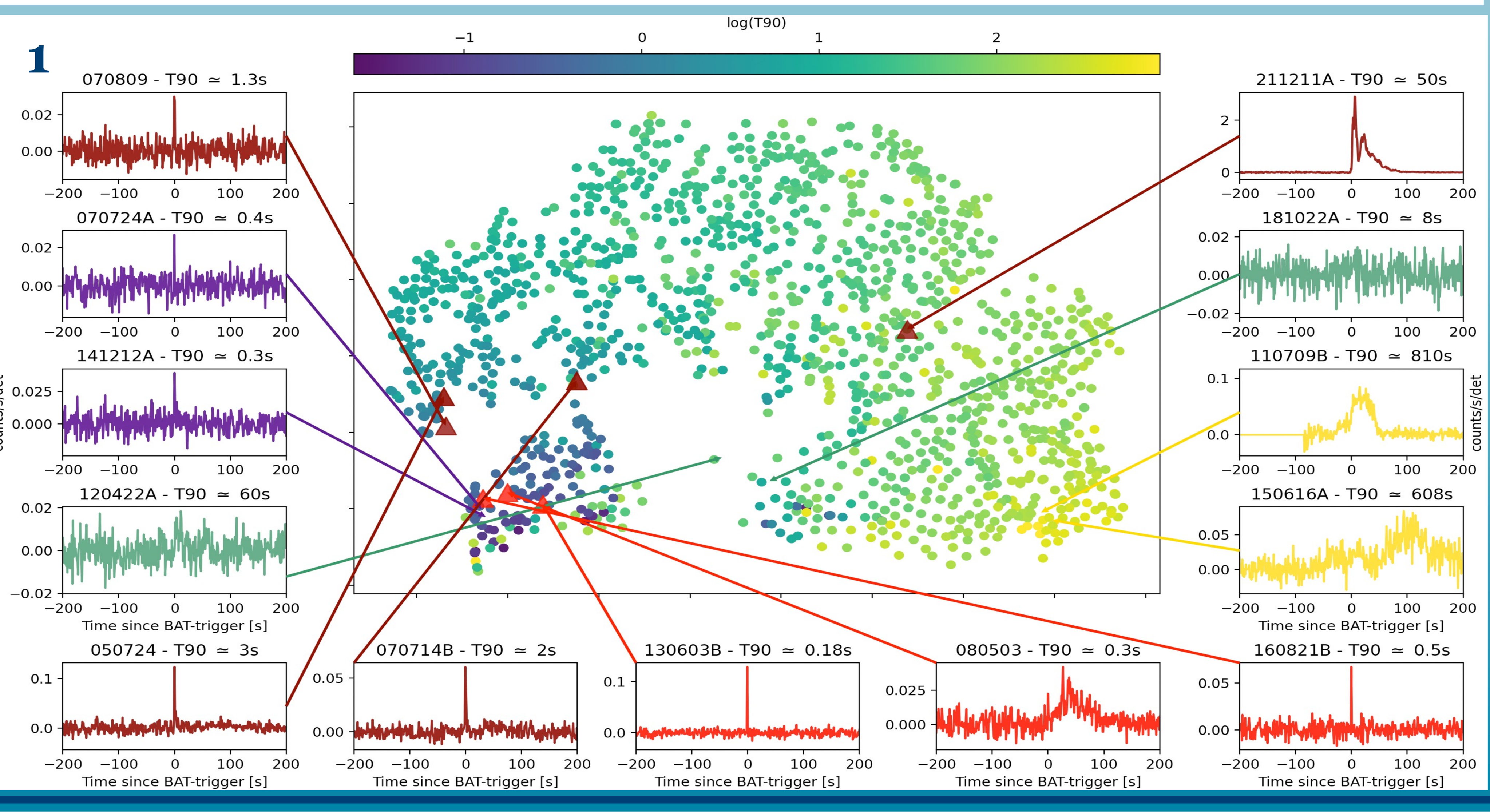
Introduction

A new era in the high energy astrophysics begun with the discovery of a short Gamma-Ray Burst (GRB170817A) in association with a Gravitational Wave and a bright kilonova[1]. The observation of another short GRB, GRB200826A[2], and a long one, GRB211211A[3], with possible associated kilonovas, strongly motivates the need of a new typology of classification, not only based on T90. Short GRBs are believed to be associated with the merger of compact objects and long GRBs with a collapsar system. A new kind of classification could in principle attribute different progenitors to different groups of bursts, based on physical parameters. We then apply the same method described in [4] on *Swift*-BAT[5] data, extending the original GRB sample till August 2020. Moreover we fit the afterglow light curves (LCs) using the "boosted fireball" model[6] and a Synchrotron emission mechanism. The "boosted fireball" model is characterised by two Lorentz factors (η_0 and γ_B) describing the geometry of the outflow, from the mildly-relativistic fireball to a highly collimated structured jet. The analysis presented in this poster can be divided in two parts.

t-SNE classification

t-SNE[7] application on the Fourier transform obtained from the Swift-BAT LCs (from 2005 to August 2020) -> the main result is the classification map in fig. 1. t-SNE classifies the bursts in two groups, being the classification still correlated with T90.

1



Fit with JetFit

Fit with JetFit[9] code of the Swift-XRT[10] LCs with known redshift from 2005 to 2021 -> the main result is a set of best-fit parameter distributions giving a general description of the sample. Some LCs present flares in their early afterglow phases (fig. 3). Since the model does not describe these particular behaviours, we developed a new technique to get rid of those points and improve the fit (fig. 4). As can be seen from the distributions of the Bulk Lorentz factor (fig. 5), the two groups present similar shapes.

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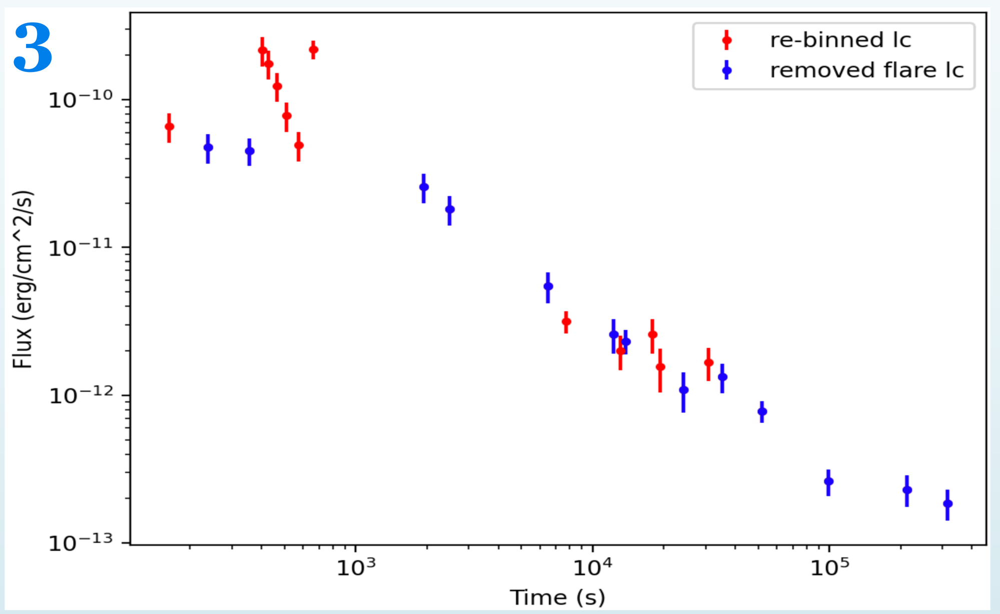

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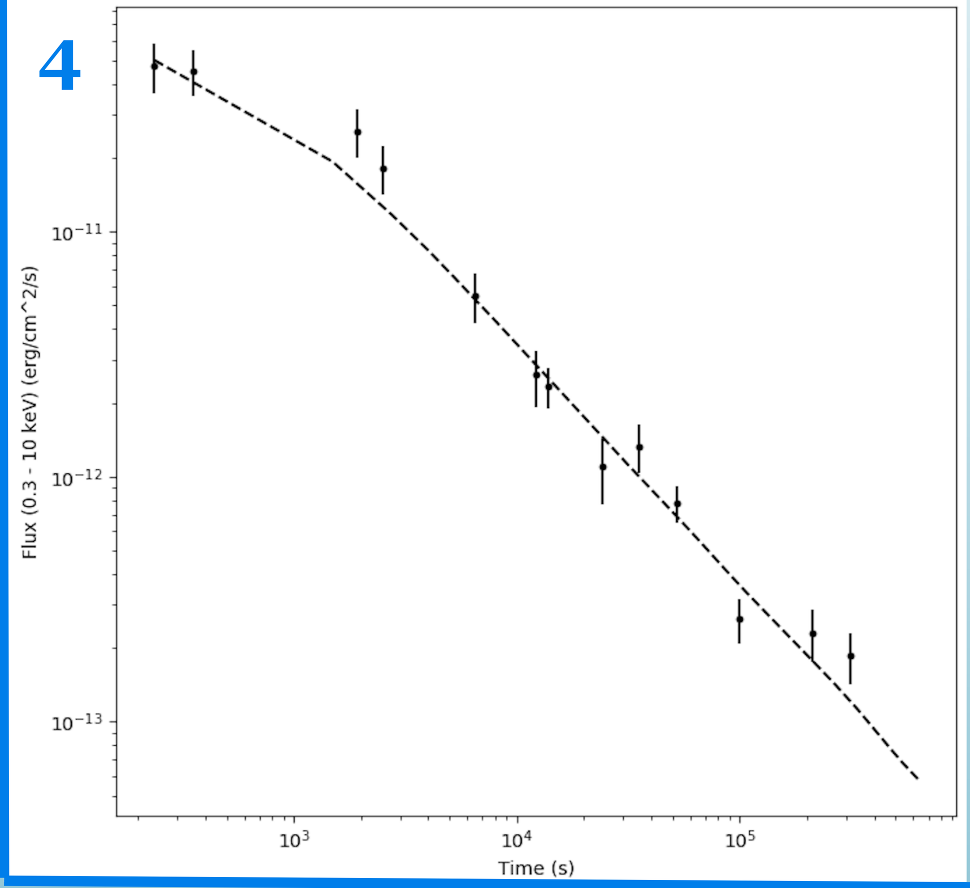

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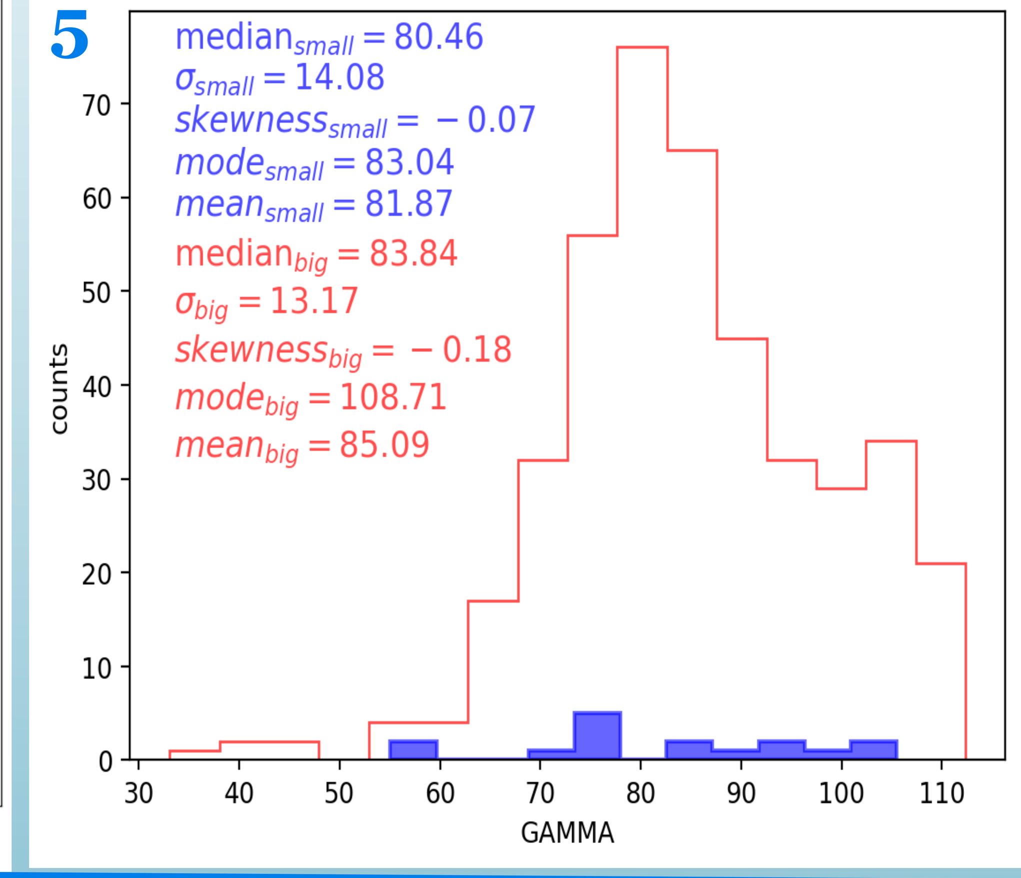
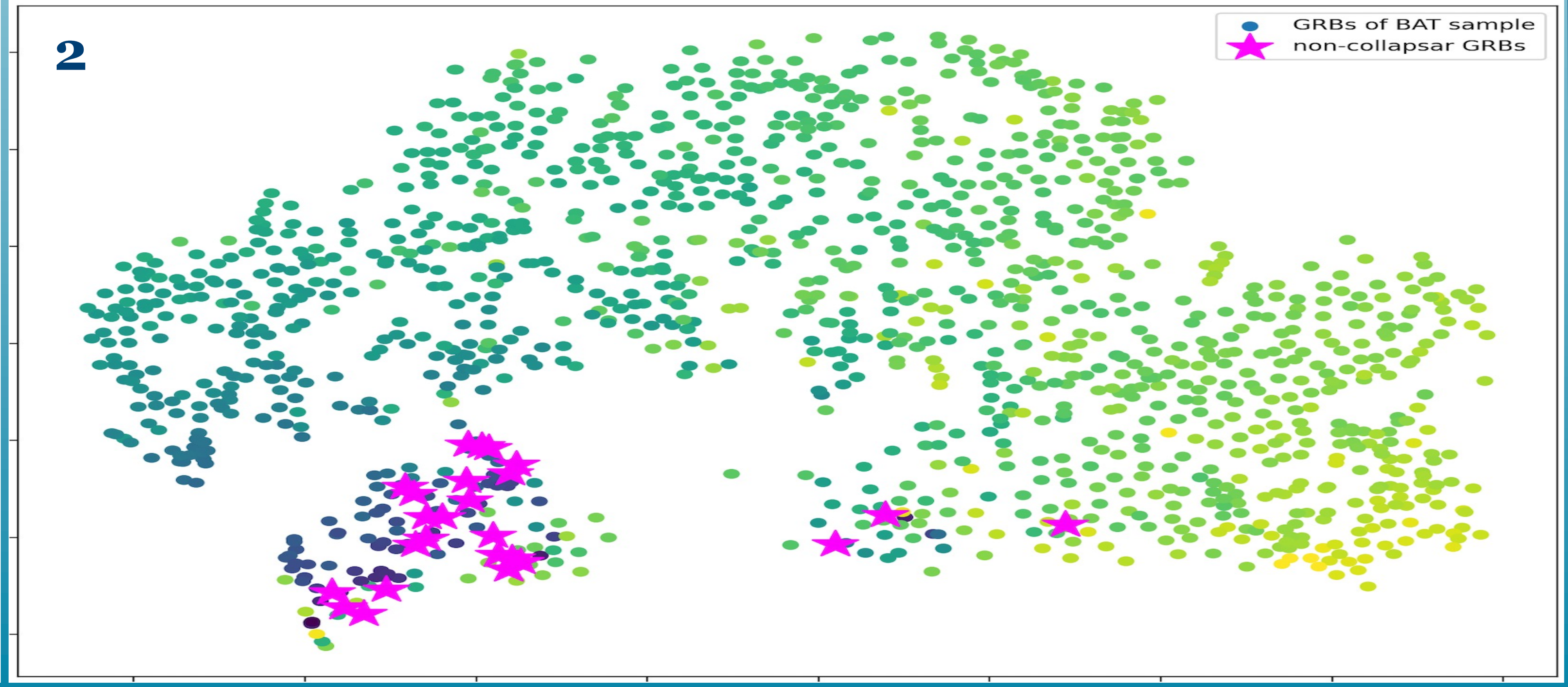


In fig. 2, magenta stars mark GRBs with a probability>90% of having a merger origin from [8].This could indicate a possible attribution of a common merger origin for the small group.

2



SSC describing multiwavelength data of GRB 090510

Here we present a numerical implementation of a simple SSC model, assuming a spherical standard fireball. The Synchrotron part of the model is obtained form a Power Law distribution of electrons. The modeled Spectral Energy Distribution (SED) is obtained by fixing as a bulk Lorentz factor the median value obtained from the best-fit distribution of the GRBs classified by t-SNE in the small group. The model well describes the Swift-UVOT, Swift-XRT and Fermi-LAT multiwavelength SED of GRB090510[11]. The butterfly obtained with Fermi-LAT data has a photon spectral index of $\alpha = -2.05 \pm 0.06$[12].

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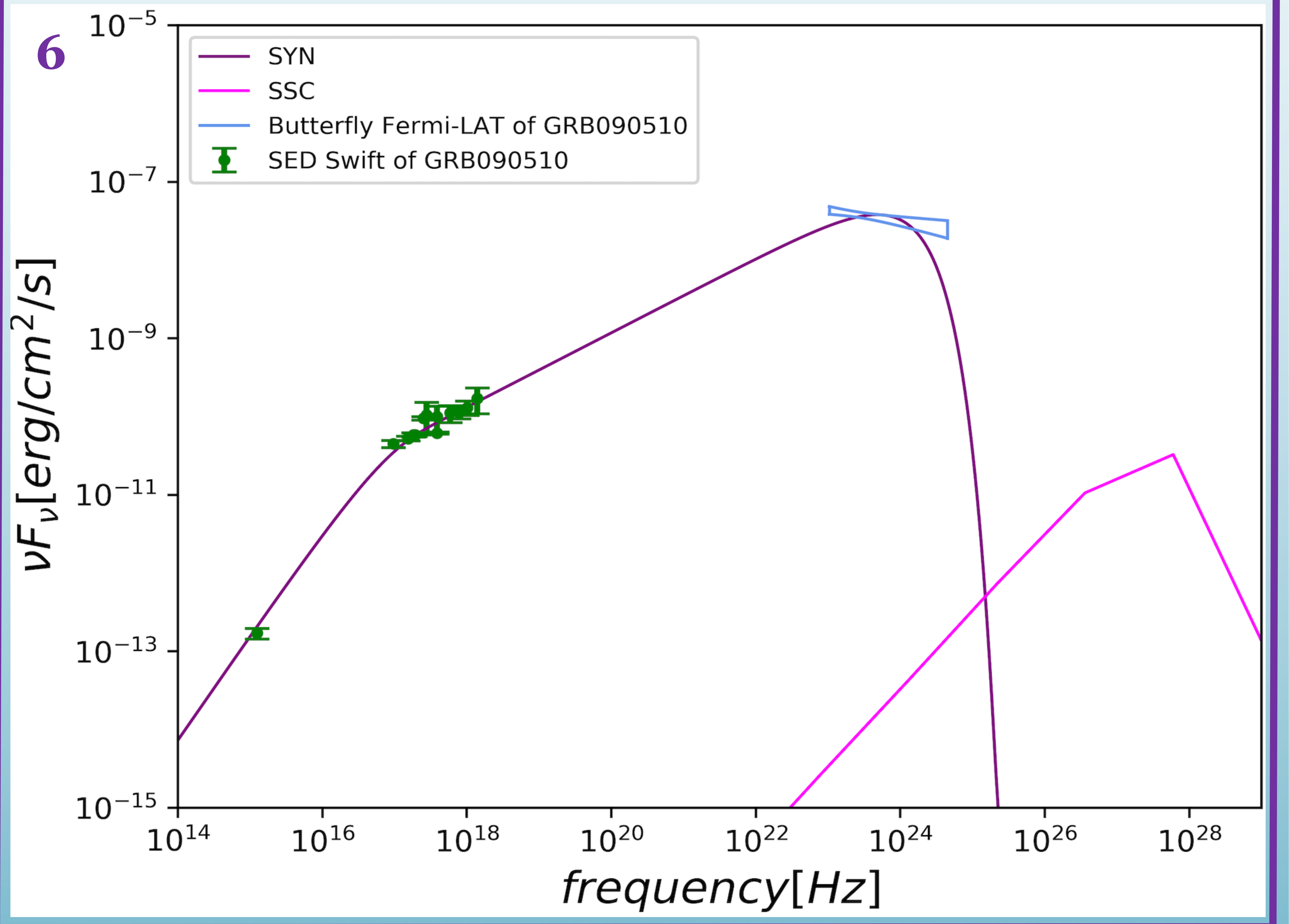

Results and conclusions

The median values extracted from the best-fit distributions obtained with JetFit could provide a realistic initial set of parameters for the construction of an SSC model. Here we apply our emission model to multiwavelength data of GRB 090510, demonstrating the reliability of our simple model. The next step of the analysis will be the implementation of a fit procedure, in order to provide robust constraints on model parameters and better understand the physics of the high-energy GRB emission.

Bibliography

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