The GRB quick analysis pipeline of SVOM ECLAIRs and GRM

T. Maiolino[1], T. Barlyaeva[1], M.G. Bernardini[1,2], F. Daigne[3], U. Jacob[1], F. Lacreu[3], P. Maeght[1], F. Piron[1], J. Wang[3], J.L. Atteia[4], L. Bouchet[4], J.P. Dezalay[4], O. Godet[4], S. Zheng[5], H. Shi[5], Y. Huang[5]

[1]Laboratoire Univers et Particules de Montpellier (Université de Montpellier, CNRS/IN2P3), [1,2]INAF-Osservatorio Astronomico di Brera, [3]Institut d'Astrophysique de Paris (IAP), [4]Institut de Recherche en Astrophysique et Planétologie (IRAP), [5]Institute of High Energy Physics (IHEP)

Introduction

The SVOM (Space-based multi-band astronomical Variable Objects Monitor) observatory is dedicated to the exploration and progress of Gamma-Ray Burst (GRB) science. The two wide field of view instruments on board the satellite – ECLAIRs (ECL) and the Gamma-Ray Monitor (GRM) – are currently monitoring the transient sky and detecting GRBs in both X- and gamma-ray energy bands (from 4 keV to 5 MeV, jointly). In this work, we present the ECLGRM-VHF pipeline running at SVOM French Science Center (FSC) which computes all the scientific products (SPs) (durations, peak fluxes, ground significance, hardness ratios, and event classification) that are used to promptly characterise a GRB candidate following a GRB trigger alert.

Input products and ECLGRM-VHF pipeline activation

The input products of the ECLGRM-VHF pipeline are created in a preprocessing phase by other two pipelines, the VHF Pre-processing and VHF Attitude pipelines, respectively. The former computes the Onboard Trigger and Localisation (OBALERT) and the Onboard Light Curves (OBLCs; in different energy bands), while the later creates the satellite attitude and position products. All these ECLGRM-VHF input files are stored in the SVOM Data Base (SDB), at the French Science Center (FSC).

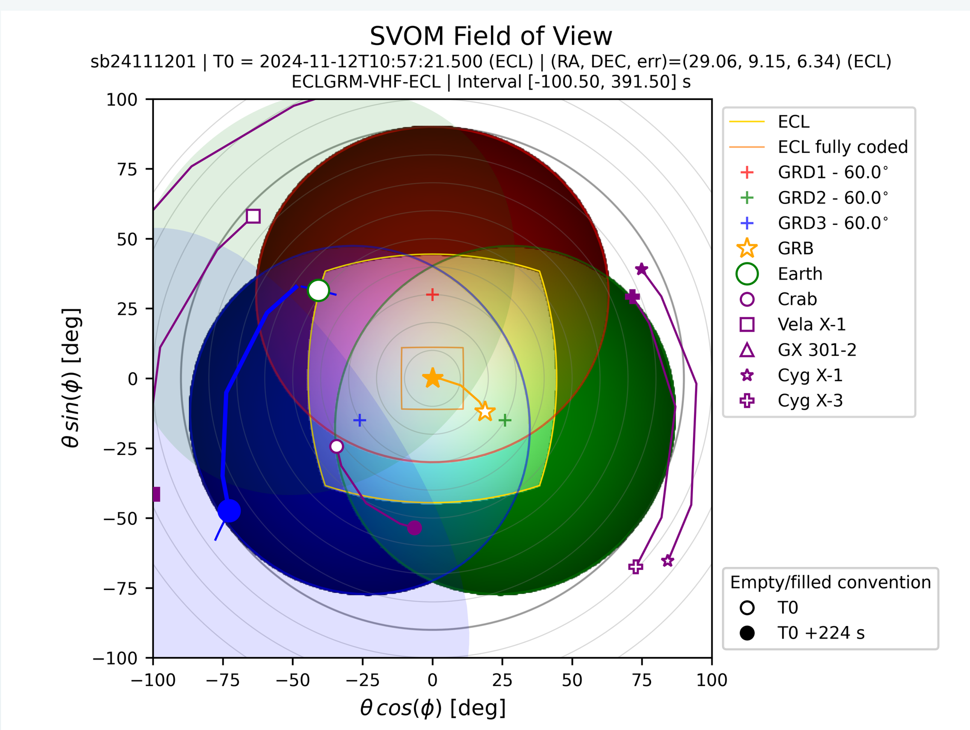

Fig 1. Localisation of the **GRB 241112B** in in the FoV of ECLAIRs and each of the 3 Gamma-Ray Detectors (GRDs) of the GRM.

The set of input products necessary to activate the ECLGRM-VHF pipeline depends on the SVOM trigger scenario — that is, if ECL triggers first or not, or if only the GRM instrument triggers. The pipeline is then activated accordingly by the so-called FSC Orchestrator, that is informed of the availability of the input products in the SDB and notifies the ECLGRM-VHF pipeline the so-called target to be activated. The SPs will be produced accordingly with the activated target.

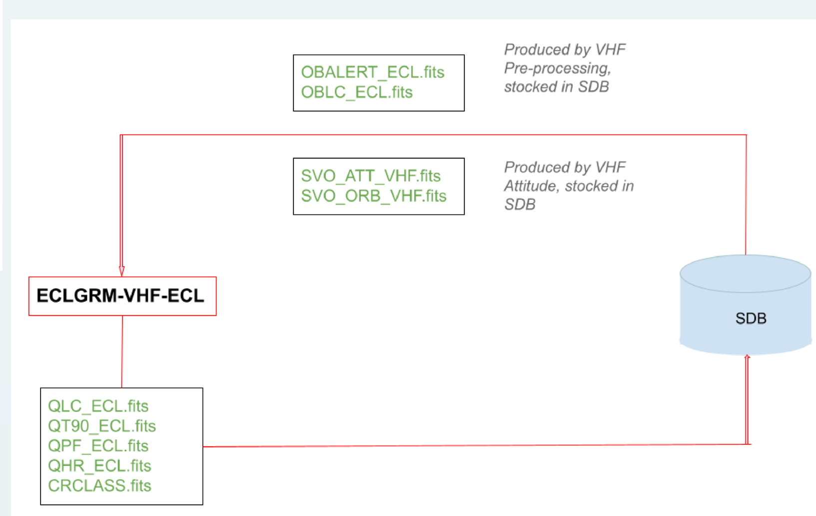

Fig 2. Sketch of the data flow for the target ECLGRM-VHF-ECL

There are three possible targets:

- ECLGRM-VHF-ECL (VHF-ECL)
- ECLGRM-VHF-GRM (VHF-GRM)
- ECLGRM-VHF-ECLGRM (VHF-ECLGRM)

The prompt computation of GRB scientific products

Following a TARGET activation, the ECLGRM-VHF pipeline computes the SPs through a set of structured steps so-called tasks, each task generates a specific type of SP. The tasks are ordered as follows:

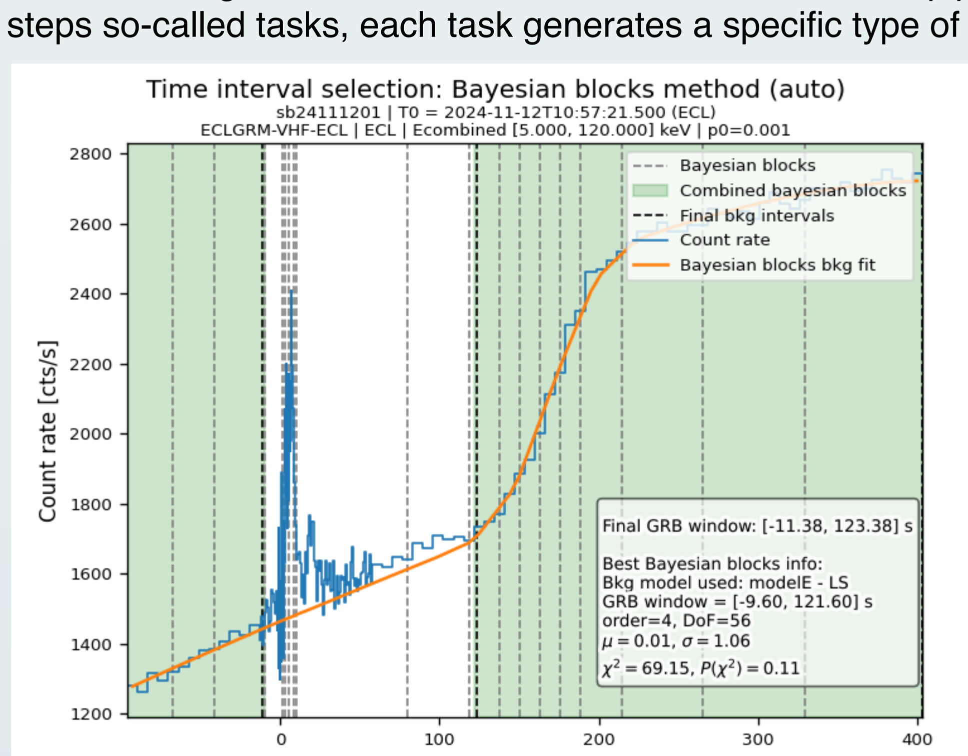

Fig 3. GRB and background windows of **GRB 241112B**, determined by the Bayesian Blocks method (ECL QLC with slew, in the 5-120 keV energy band).

1. Task Quick Light Curve (QLC):

- Computes the QLC in different energy bands
- Determines the GRB and background windows
- Fits the background (BKG) model
- Computes the Background Subtracted Count Light Curve (BSCLC)

TWO BACKGROUND MODELS ARE USED BY THE PIPELINE [1]:

- *model T*: simple polynomial function of time given by $r(I,t) = \sum_{m=0}^{n} p_m(I)\,.\,(t-t_0)^m$, where I is the energy band, n the polynomial degree, t_0 the reference time, and p_m the parameter to adjust.
- *model E:* polynomial function given by $r(I,t) = \sum_{m=0}^{n} p_m(I)\,.\,(cos\theta_E(t))^m$, where I is the energy band, n the polynomial degree, p_m the parameter to adjust, and θ_E the angle between the detector's main axis and Satellite-Earth direction

2. Task Quick T90 (QT90):

- Generates the *Background Subtracted Cumulative Count Light Curve* (BSCCLC), see Fig. 5
- Searches the final plateau on the BSCCLC and estimates the QT90, QT80 and QT50 durations

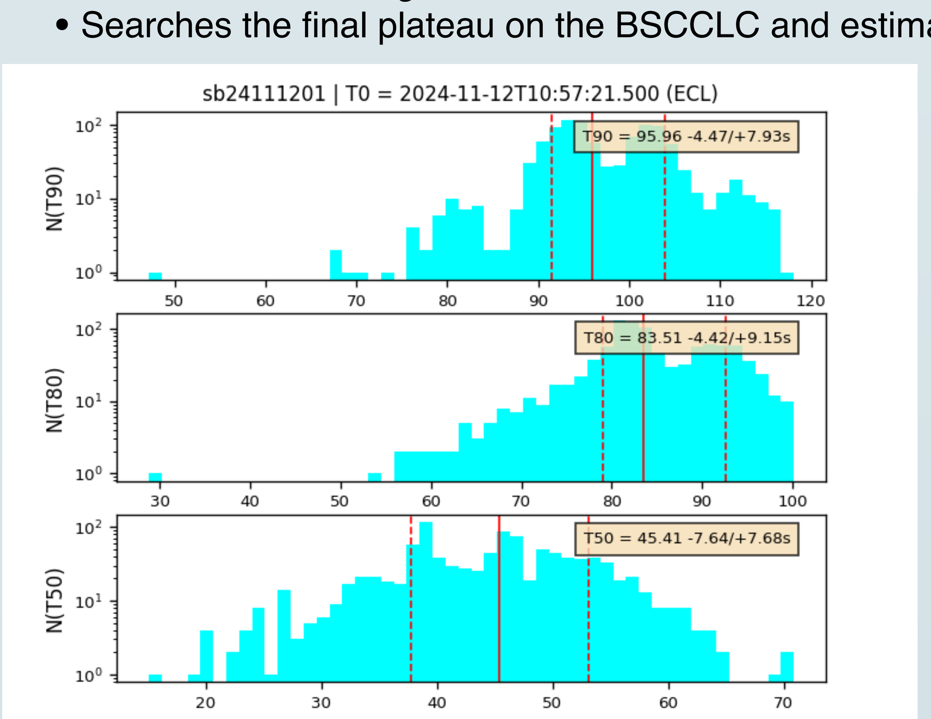

Fig 4. Duration distributions of **GRB 241112B** computed in the 5-120 keV energy band.

METHOD TO COMPUTE THE GRB DURATION

- Simulates 1000 QLCs and BSCCLCs (Poisson resampling)
- Finds a plateau for each BSCCLC, and computes the accumulation times t05, t95, t10, t90, t25 and t75
- Creates the duration distributions QT90, QT80 and QT50
- Computes the final duration QT90, as well as QT80 and QT50, as the median of its distribution, with 68% confidence interval.

- Calculation of the on-ground significance S [2] in the QT90 time interval, which is given by:

$$S = \sqrt{2(Clog(C/b_0^{mle})) + (B - b_0^{mle}/(2\sigma_B^2)) + b_0^{mle} - C}$$

$$b^{mle} = 1/2(B - \sigma_B^2 + \sqrt{B^2 - 2B\sigma_B + 4C\sigma_B^2 + \sigma_B^4}),$$

where C, B, and σ_B correspond, respectively, to the sum of photon counts, BKG counts and BKG error taken in the $t05 \leq t \leq t95$ time range.

3. Task Quick Peak Flux (QPF): The QPF task scans all the time bins of a QLC, and gets the maximum of count rates (cts/s), its respective error and peak time. This task is performed for all LCs in different energy bands.

4. Task Quick Hardness Ratio (QHR): The QHR task computes, for all targets, the ratio between the number of total counts (integrated in the QT90 time range) in two energy bands (high/low). For the VHF-ECLGRM target, high energy bands are taken from the QLC GRM, while low energy bands are taken from the QLC ECL.

5. Task Crude Classification (CRCLASS): The CRCLASS task aims to automatically classify ECL and GRM triggers as long GRBs (LGRBs), short GRBs (SGRBs), magnetars, solar flares, particle events, etc. The current algorithm, however, is simply on base of QT90, taking into account only the possibilities of LGRBs and SGRBs. A more sophisticated (Bayesian) classification scheme for different categories of trigger is under development.

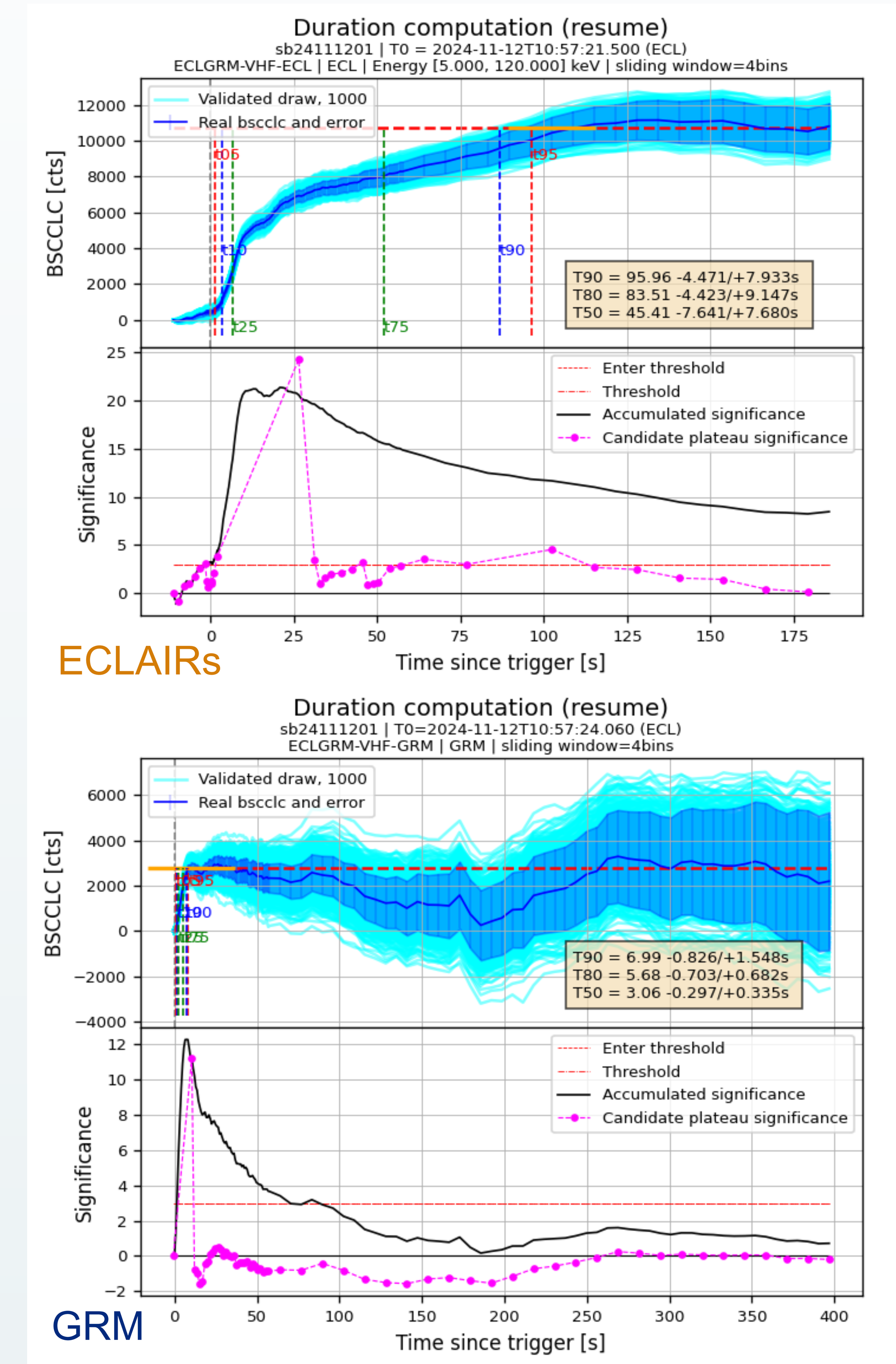

Fig 5. Final durations of **GRB 241112B** for ECL (5-120 keV; top panel) and GRM (4-550 keV; lower panel).

- For the VHF-ECLGRM target, only the QHR and CRCLASS tasks are activated

- **All Scientific Products are stored in the Science Data Base in FITS format**

Scientific Validation of QT90 and QHR

DURATION (QT90)

Before SVOM launch, several GRB catalogs were explored and a diversity of GRB prompt emission (with different shapes and durations) were simulated as SVOM ECLAIRs and GRM detections, and processed by the ECLGRM-VHF pipeline.

HARDNESS RATIO(S)

The QHR helps to classify the GRB (SGRB, LGRB, X-ray rich, X-ray flash).

The validation of the QHR energy bands was performed through XSPEC simulated spectra from spectral catalogs:

- Fermi/GBM catalog [3]: cutoff power-law model (50 SGRB, 396 LGRB) — ECL and GRM (GRD1) simulations
- HETE2 catalog [4]: cutoff power-law model (45 LGRB/soft) — ECL simulation

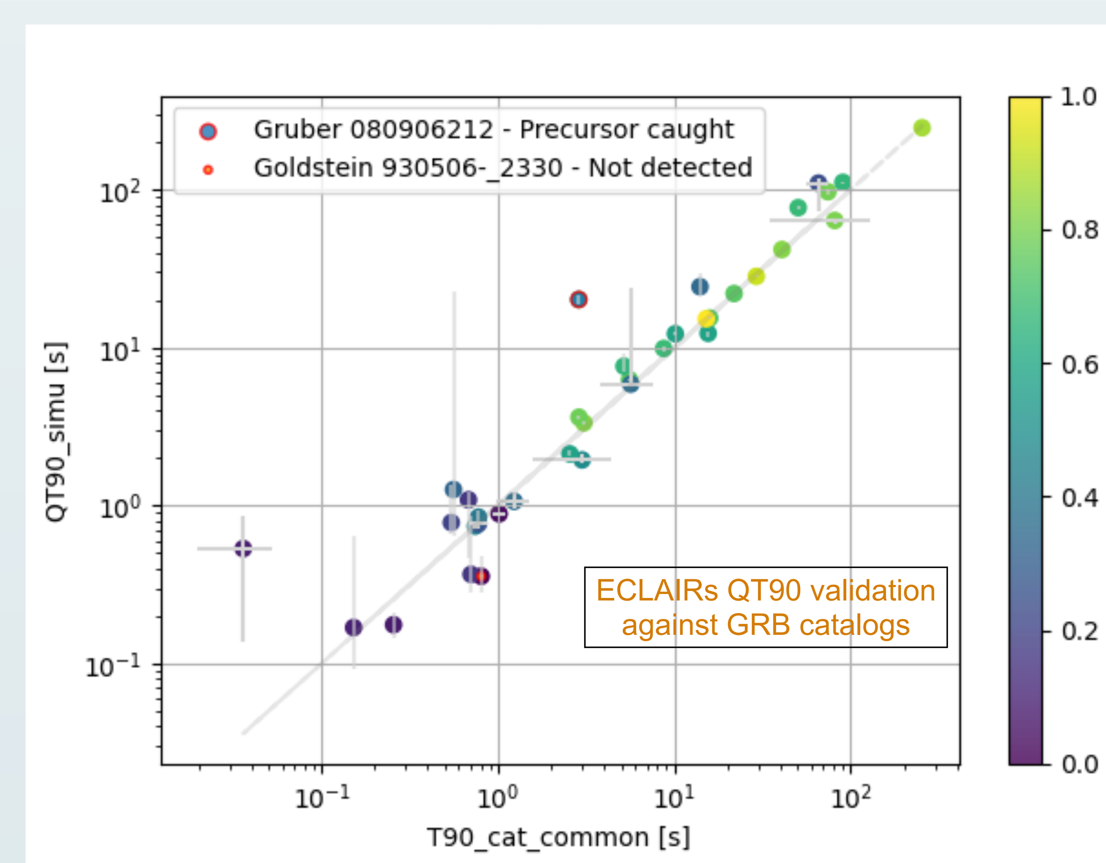

Fig 6. Scientific validation of QT90 for ECLAIRs computed in the 4-120 keV energy band.

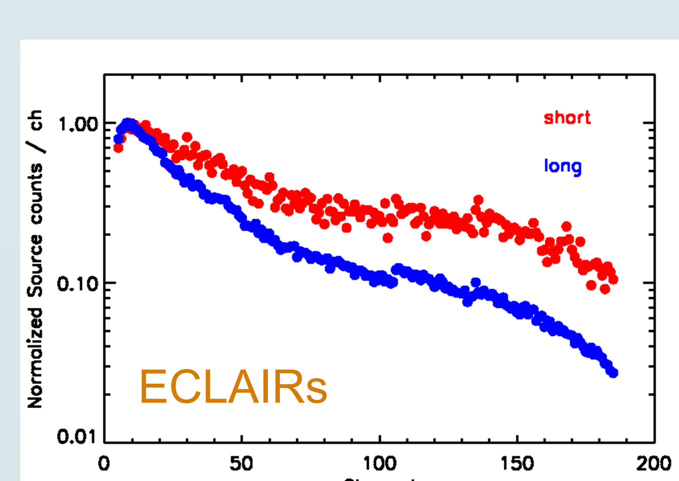

Fig 7. Normalized source counts/channel versus channel of average spectrum for Fermi/GBM GRBs.

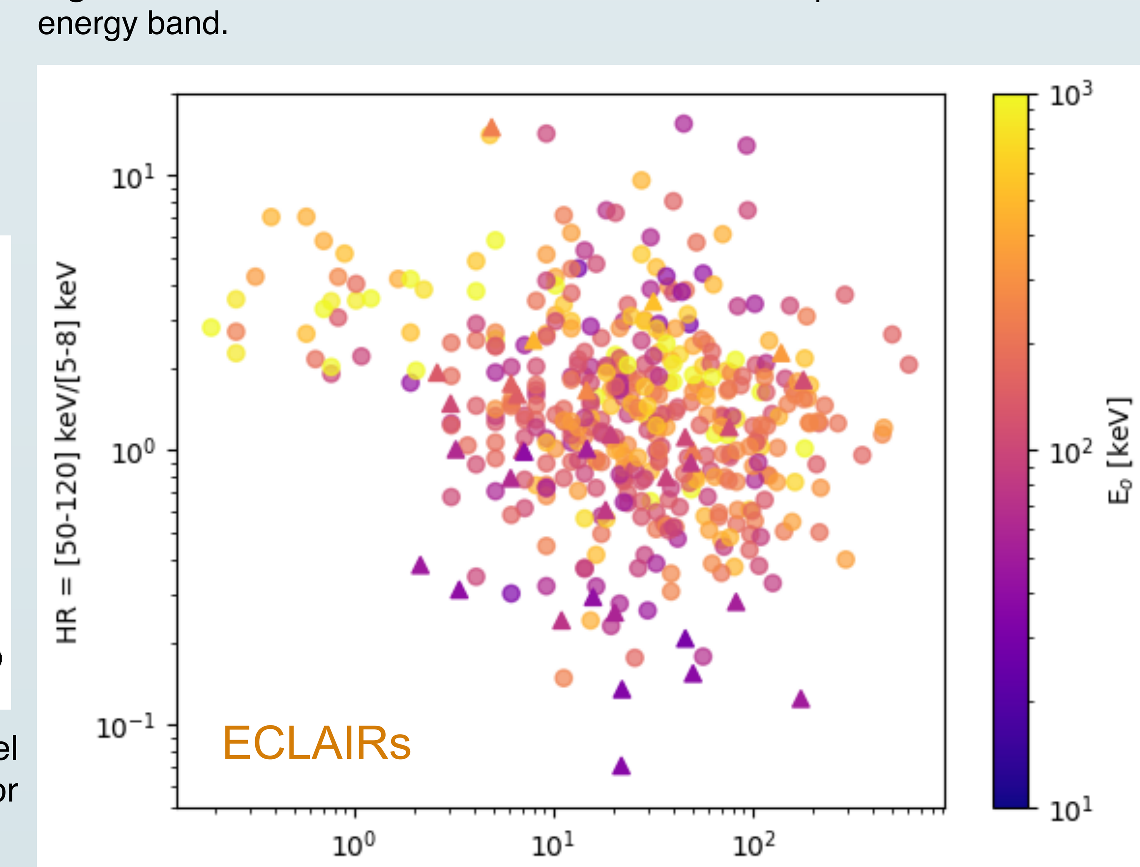

Fig 8. Hardness Ratio versus T90 for Fermi/GBM (circles) and HETE2 (triangles) catalogs simulated with ECLAIRs.

References

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