2° Forum della Ricerca Sperimentale e Tecnologica

GRB detection with Poisson-FOCuS, a novel optimal trigger algorithm

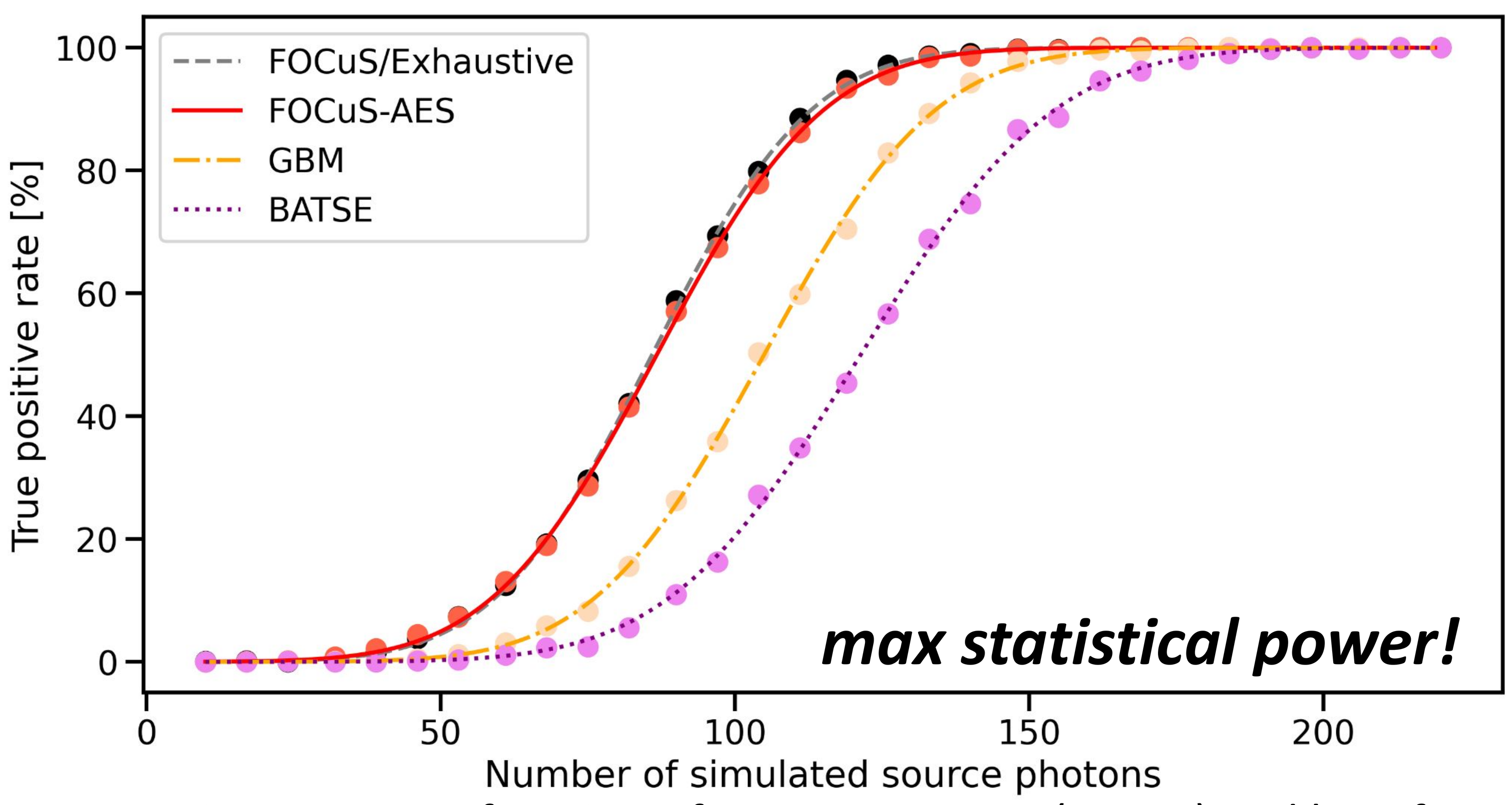
G. Dilillo (INAF-IAPS), K. Ward, P. Fearnhead, I. Eckley (University of Lancaster), Riccardo Crupi (University of Udine) and others.

INAF RSN-5 mini-grant 1.05.12.04.05, "Development of novel algorithms for detecting high-energy transient events in astronomical time series";

Project outline

The conventional approach to real-time gamma-ray burst detection is a brute force one.
The computational cost of a conventional algorithm with no loss of statistical power grows as the square of the number of data points (O(n^2)), making the strategy unfeasible for streams of data.
To circumvent this problem, detection power is traded for smaller computational costs, limiting the search to a pre-defined grid of timescales. This approach introduces biases and reduce statistical power.

We developed an anomaly detection algorithm with both optimal detection power and optimal computational costs**,** called Poisson-FOCuS. The algorithm was applied to search GRBs and characterized against a large dataset of real and synthetic GRB lightcurves. Moreover, Poisson-FOCuS was applied in combination with a neural network for estimating background count intensity, searching the Fermi-GBM dataset for long, faint GRBs, finding many candidate events.



True positive rates as a function of source intensity (points) and best fit to error function (lines) over the short GRB dataset.

	Poisson-FOCuS [ms]			Benchmark [ms]		
N	4.0	16.0	64.0	4.0	16.0	64.0
2048	0.04	0.04	0.04	0.08	0.08	0.08
4096	0.09	0.08	0.08	0.16	0.16	0.17
8192	0.17	0.16	0.15	0.32	0.33	0.34
16384	0.33	0.32	0.30	0.63	0.63	0.66
32768	0.67	0.63	0.59	1.24	1.25	1.31
65536	1.33	1.28	1.19	2.45	2.50	2.57
131072	2.65	2.51	2.36	4.86	4.92	5.09
262144	5.29	5.06	4.69	9.66	9.84	10.12
524288	10.59	10.16	9.45	19.31	19.71	20.33
1048576	21.21	20.24	18.84	38.65	39.19	40.48

Time, in milliseconds, required by Poisson-FOCuS and a benchmark emulator for the Fermi-GBM algorithm to run over Poisson-distributed count time series with four different means (4.0, 16.0, 64.0) and geometrically increasing lengths (N), using a retail 3.2 GHz ARM processor.

half the computational cost!

State of the project

Project status

The project is complete.

Strengths and criticalities

An interdisciplinary collaboration between physicist and mathematicians from Italy and UK stemmed from this project.
Cool math, cool code, cool papers but still little adoption.

Cost

The project cost around 10keur (out of a total of 15keur minigrant fundings), which were spent for covering costs for publishing, travelling and conference partecipation.

Scientific output

Three papers on top ranking journals on astrophysics and statistics.

Dilillo, G., Ward, K., Eckley, I. A., Fearnhead, P., Crupi, R., Evangelista, Y., ... & Fiore, F. (2024). Gamma-ray burst detection with Poisson-FOCuS and other trigger algorithms. *The Astrophysical Journal, 962(2), 137.*
Ward, K., Dilillo, G., Eckley, I., & Fearnhead, P. (2023). Poisson-FOCuS: An efficient online method for detecting count bursts with application to gamma ray burst detection. *Journal of the American Statistical Association, 1-13.*
Crupi, R., Dilillo, G., Bissaldi, E., Ward, K., Fiore, F., & Vacchi, A. (2023). Searching for long faint astronomical high energy transients: a data driven approach. *Experimental Astronomy, 56(2), 421-476.*

Free **code and datasets**:

https://github.com/peppedilillo/grb-trigger-algorithms
https://github.com/rcrupi/DeepGRB
https://zenodo.org/records/10034655

Poisson-FOCuS is being used as the basis for hbstools, the HERMES-Pathfinder ground pipeline for searching GRBs.

email: ***giuseppe.dilillo@inaf.it***
personal website: ***www.gdilillo.com***