Methods for statistical detection of GRBs in the context of the LST-CTAO

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ABSTRACT

Gamma Ray Bursts (GRBs) are rapidly decaying signals that pose significant detection challenges. In this study, we compare various alternative statistical methods for detecting GRB emission, with the one currently used, called Li&Ma. The performances of these methods for the LST-1 of CTAO are computed based on simulations. For some of the methods, when the GRB is rapidly observed (tens or hundreds of seconds of delay), an improvement of more than a factor two in the fraction of detected GRBs can be seen.

Supported by:

ACKNOWLEDGMENTS

This work has been done thanks to the facilities offered by the Univ. Savoie Mont Blanc - CNRS/IN2P3 MUST computing center.
We thank the LST-CTAO Collaboration for providing the Instrument Response Functions.

1. INTRODUCTION

Gamma Ray Bursts (GRBs) are transient events from extragalactic sources. Detecting GRBs is among the primary scientific objectives of the CTAO collaboration, with the first Large-Sized Telescope (LST-1). However, due to their rapidly varying flux and their distance, it proves to be challenging. A robust statistical test is needed to decide if a GRB signal has been recorded after observations.

2. METHODS

The method commonly used is Li&Ma [1]. This last is perfectly adapted to steady sources. However, in case of rapidly varying signal, it is not optimal because it only considers mean values of signal and background to perform a ratio likelihood test. Thus, the signal could be buried in the background. Tab. 1 presents the alternative methods that take advantages of the temporal behavior.

Methods	Working principle
Time-dependent Li&Ma	Same as Li&Ma but with signal time profile instead of mean signal value [2]
Temporal ON OFF	Same as Li&Ma but considering temporal regions [3]
ExpTest	Estimator to quantify the distribution deviation of time interval between events [4]
CuSum	Same as ExpTest, with cumulative sum variance as estimator [5]
LiFT	Ratio likelihood test based on IACT data fit results

Tab. 1: Working principles of all tested methods

3. SIMULATIONS

To test the methods, simulations have been performed, using Gammapy-1.3 [6]. All the bursts follow spectral and temporal power law models, based on observation references [7]. Two cases are studied: early and late observation (Fig. 1). Extragalactic background light effects are included [8].

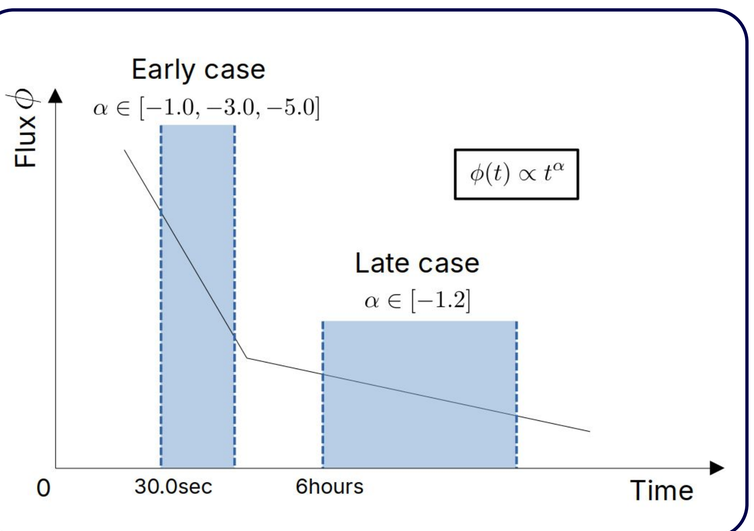

Fig. 1: GRB behavior, in the two studied cases, early and late observation

4. RESULTS

In the early case, all the alternatives methods offer better performances than Li&Ma. Time-dependent delivers more than **twice the detection fraction** (Fig. 2, left panel). In the late case, as the signal decay is slower [7], Li&Ma, its time-dependent variant and LiFT are the best (Fig. 2, right panel).

5. DISCUSSION

This study shows that introducing a temporal model significantly increases LST-1 GRB detection ability. As all the methods are fast computing, except LiFT, they could be implemented to the Real Time Analysis of LST-1, to provide first results during the observation night.

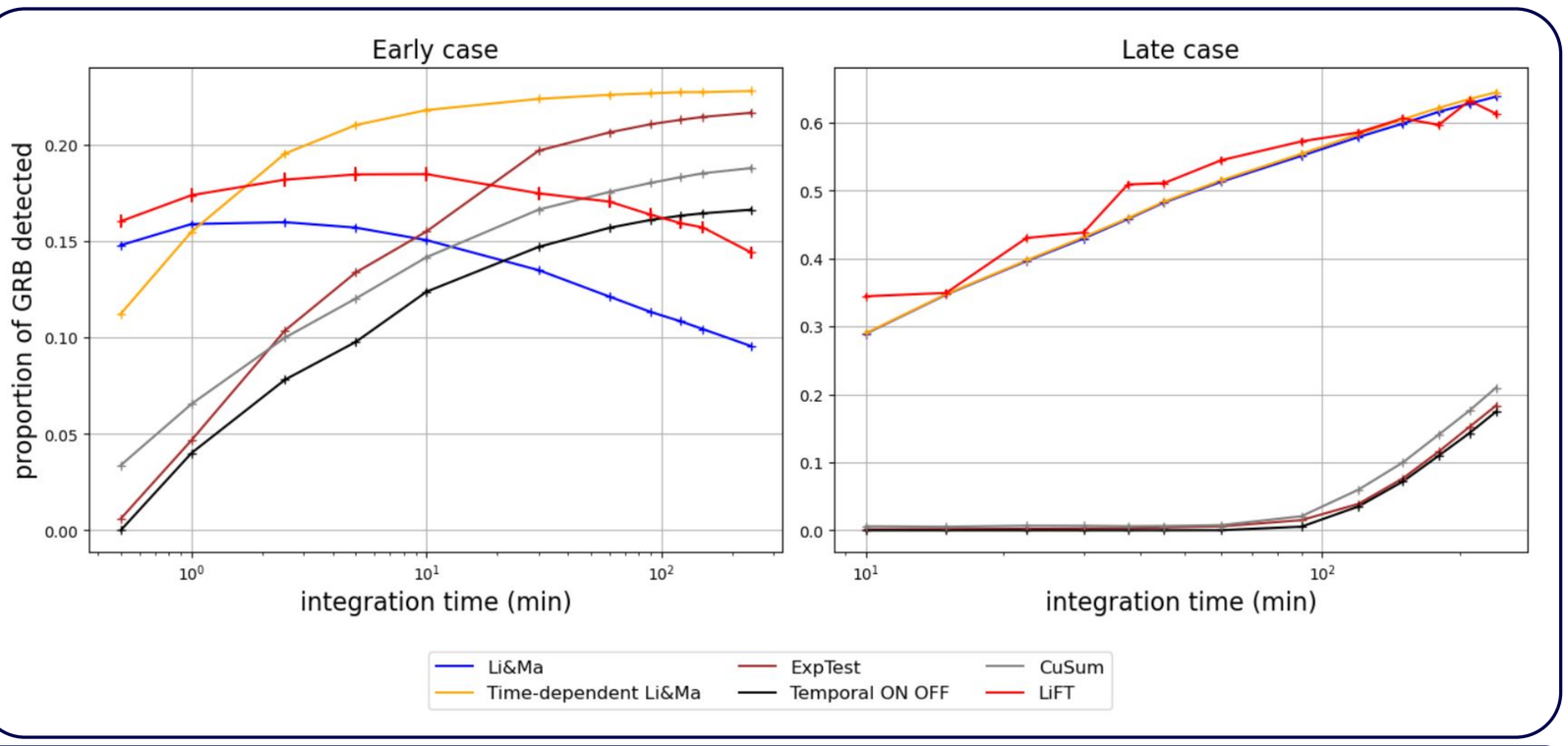

Fig. 2: Proportion of GRBs detected with the different methods depending on the integration time, with error-bars, in early and late cases

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