Detection methods for the Cherenkov Telescope Array at very-short exposure times

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cherenkov telescope array

ABSTRACT

The Cherenkov Telescope Array (CTA) will be the next generation ground-based observatory for very-high-energy gamma-ray astronomy, with the deployment of tens of highly sensitive and fast-reacting Cherenkov telescopes. It will cover a wide energy range (20 GeV - 300 TeV) with unprecedented sensitivity. Our study is focused on real-time detection at very-short timescales(from 1 to 100 seconds). We built and characterized an analysis and detection pipeline, and tested it via the verification of the Wilks' theorem for false-positives. The performance was evaluated in terms of sky localization accuracy, detection significance and detection efficiency for different observing and analysis configurations. Our goal is to determine the feasibility of the analysis methods at very-short exposure times. We also investigated the sensitivity degradation which is expected in a real-time analysis context and compared it to the requirement of being better than half of the CTA sensitivity. In this work, we present a general overview of the pipeline and the performance obtained for the use-case of a blind-search and detection following an external alert,such as from a gamma-ray burst or a gravitational wave event.

1 - Introduction

The Cherenkov Telescope Array (CTA) will be the next generation ground-based observatory for very-high-energy (VHE) gamma-ray astronomy, with the deployment of tens of highly sensitive and fast-reacting Cherenkov telescopes. It will cover a wide energy range (20 GeV - 300 TeV) with unprecedented sensitivity. The observatory will be provided with a Sciance Alert Generation (SAG) system that will search for transient and variable phenomena in the field-of-view on timescales from 10 seconds to 30 minutes.

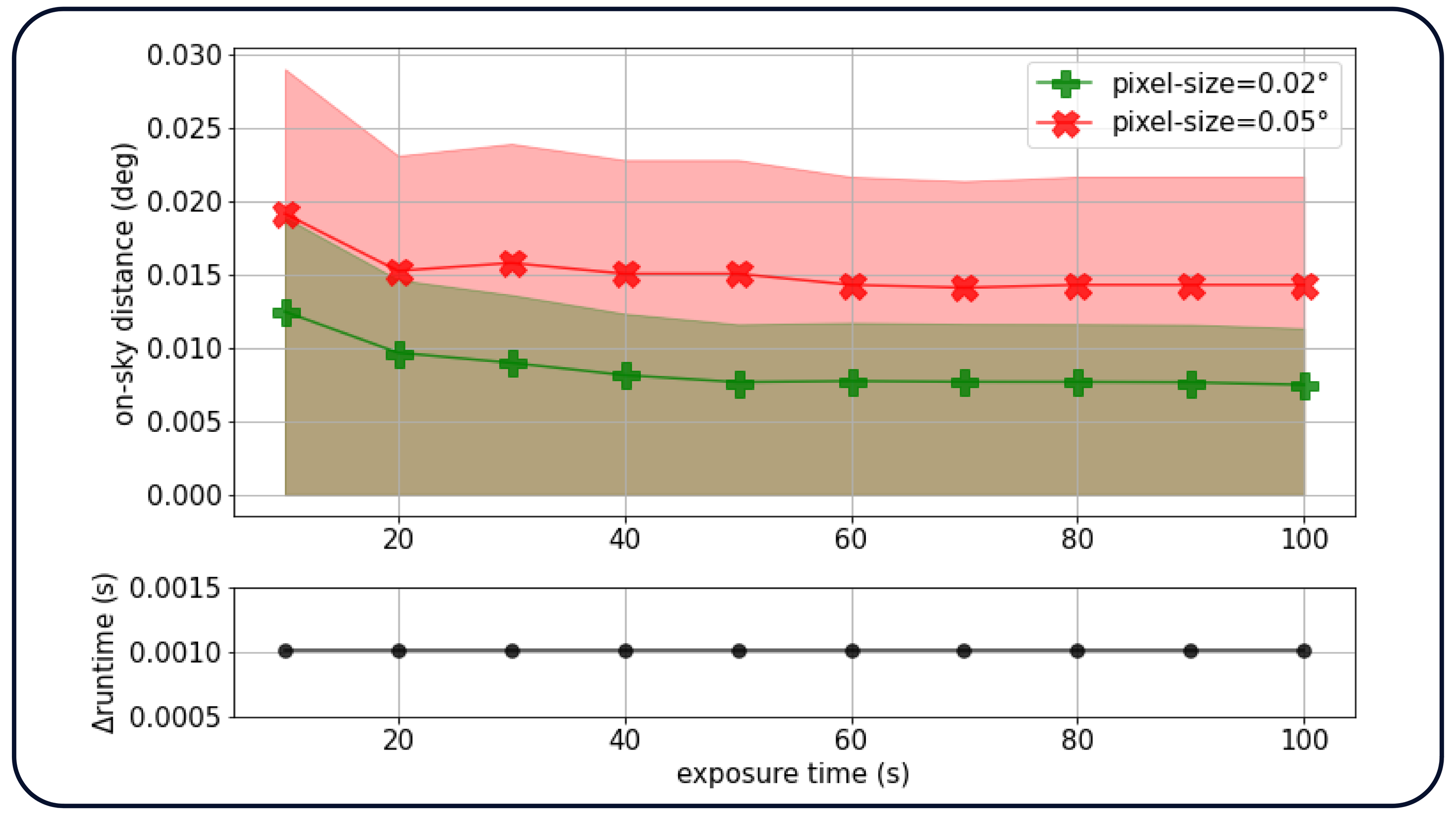

Fig. 1: peak accuracy of the sky localization at given exposure time, shaded areas provide the R68 containment. The energy range is 40 GeV – 150 TeV.

2 - Detection methods

Two detection methods were investigated for the short-term detection of sources: (a) the reflection method for a standard on/off analysis and (b) a full field-of-view maximum likelihood. At current times, two software packages are available for CTA data analysis: ctools and gammapy. For the SAG a third option comprises a dedicated aperture photometry tool. The main difference between the methods lies in the background estimation. Whilst the on/off reflection extracts the background within defined off regions that have the same characteristics of the aperture (on region) used to determine the source counts, the full field-of-view analysis performs a maximum likelihood fit assuming a priori knowledge of the background model over the entire field of view.

3 - Simulations

We simulate 10^2 realization of a gamma-ray burst afterglow, located at an offset from the center of the field of view. We focus on the scenario of an external alert follow-up and align the pointing to a peak sky localization probability.

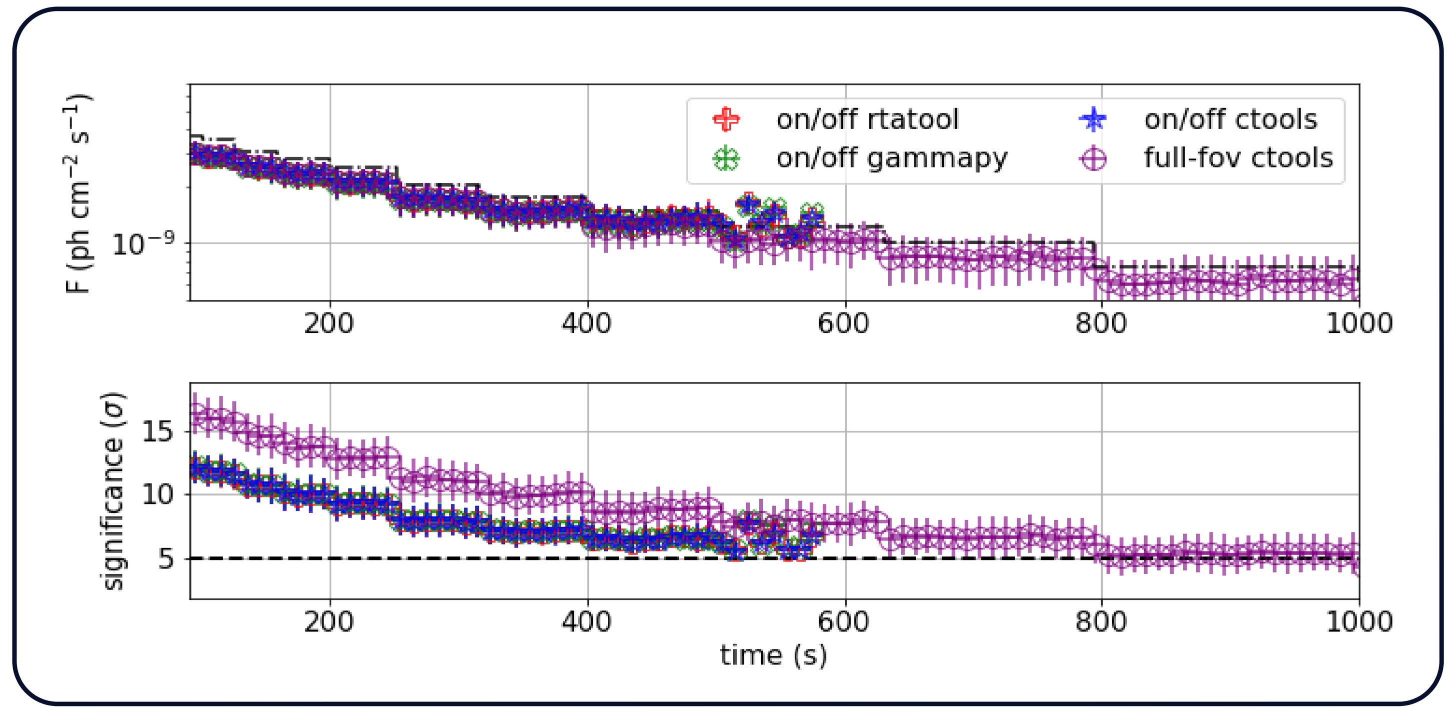

Fig. 3: 10 s time window lightcurve produced with on/off analysis and full field-of-view maximum likelihood, in the energy range 40 GeV – 150 TeV. In the top panel the flux, in the bottom panel the detection significance.

4 – Results

The presented results are for an integrated analysis between 40 GeV and 150 TeV, using CTA South instrument response functions for 40° of zenith angle and 30 minutes. We test the source localization in terms of the accuracy and precision at given configuration, i.e. comparing at increasing exposure time different binning of the sky map versus the computational time (Fig. 1) to determine the best trade-off between performance and quality of the analysis. We determine the significance and a first flux estimation using the different techniques, provided by one or more of the available science tools (Fig. 2) with the 1 standard deviation uncertainty of the measurements.

ACKNOWLEDGEMENTS

We gratefully acknowledge financial support from the agencies and organizations listed here: www.cta-observatory.org/consortium_acknowledgments

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