Bridging Gravitational Waves and High-Energy Gamma Rays: Searching for sGRB Afterglows from Compact Binary Coalescences with CTAO

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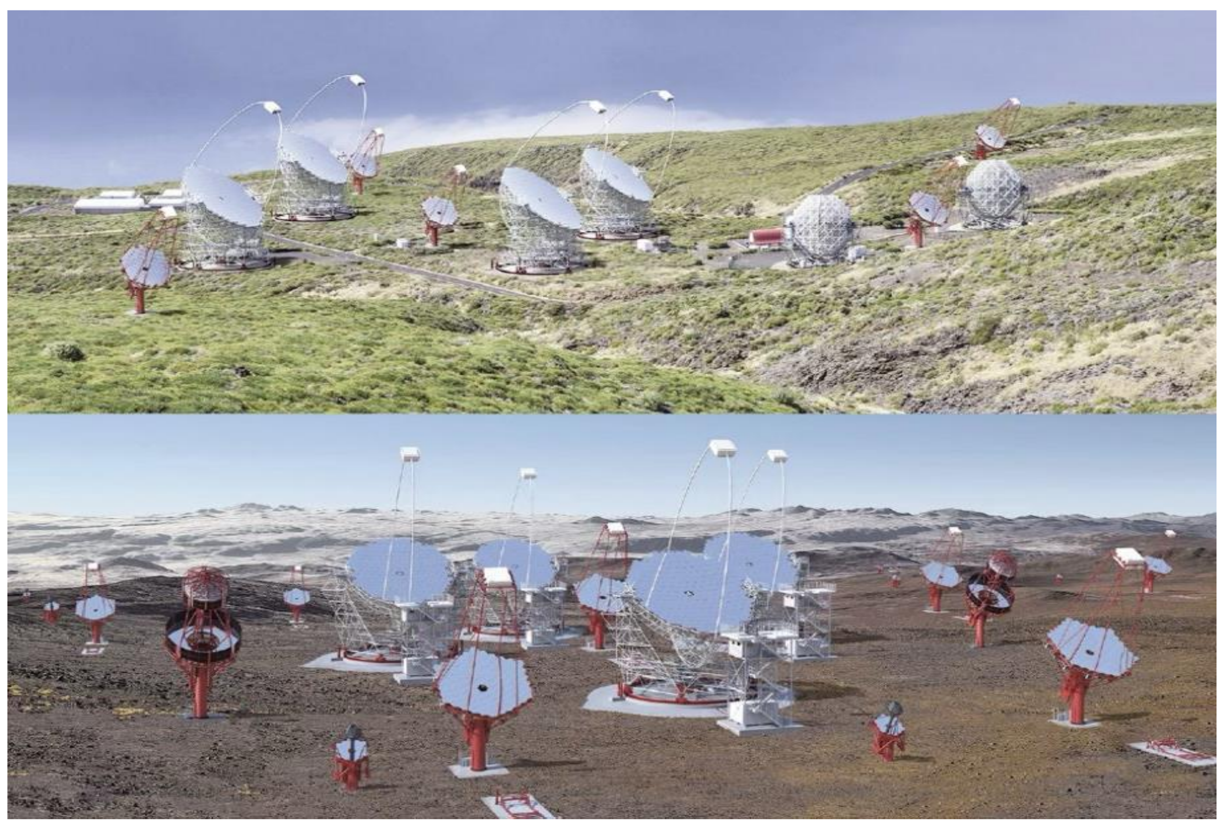
A complete understanding of compact binary coalescences requires combining gravitational wave (GW) observations with broadband electromagnetic data. The detection of GeV-TeV gamma rays will be crucial for probing the acceleration processes and environments near compact object mergers. The binary neutron star (BNS) merger GW170817 provided the first direct evidence that BNS mergers are progenitors of short gamma-ray bursts (sGRBs) with the detection of its electromagnetic counterpart. We present our approach to establish the prospects on binary neutron star (BNS) mergers that emit GeV-TeV gamma rays and are detectable by the Cherenkov Telescope Array Observatory (CTAO). With its unparalleled sensitivity, broad energy coverage (20 GeV - 300 TeV), and rapid sky-slewing capabilities, CTAO is uniquely positioned to play a key role in these searches. Using simulations of CTAO's response to phenomenological models describing sGRB afterglows associated with GW events, we address the challenge of large source localization uncertainties through a real-time strategy designed to coordinate searches over vast sky regions. We optimize potential multi-site follow-up strategies and provide an estimate of the number of joint sGRB-GW events from BNS mergers that CTAO could detect during future LIGO-Virgo-KAGRA (LVK) observing run O5. Our study aims to maximize the scientific return of CTAO observations by examining how key physical parameters—such as jet opening angle, luminosity, distance, and off-axis viewing angle—shape the expected gamma-ray emission.

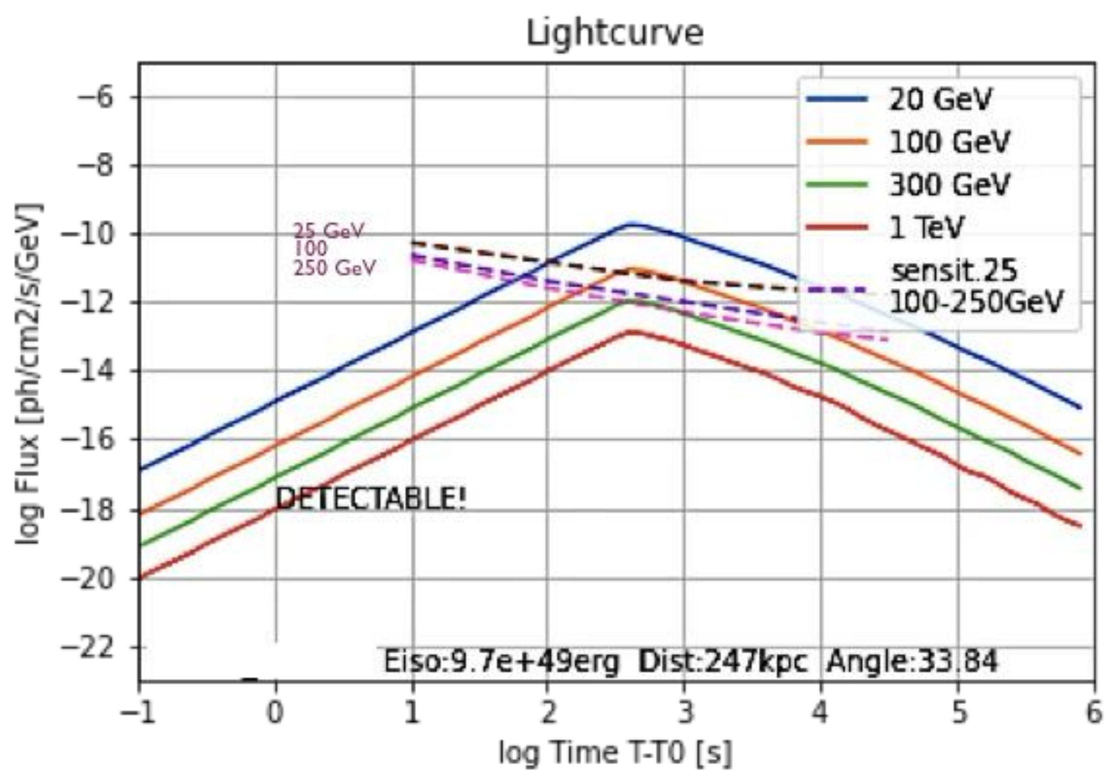
What is CTAO?

- The Cherenkov Telescope Array Observatory (CTAO) is a next-generation ground-based observatory for gamma-ray astronomy
- Two sites, one in the Northern Hemisphere and one in the South Hemisphere
- Three telescope design: Large, Medium, Small
- Large field of view, fast telescope slewing, broadband unparallel sensitivity in GeV-TeV range



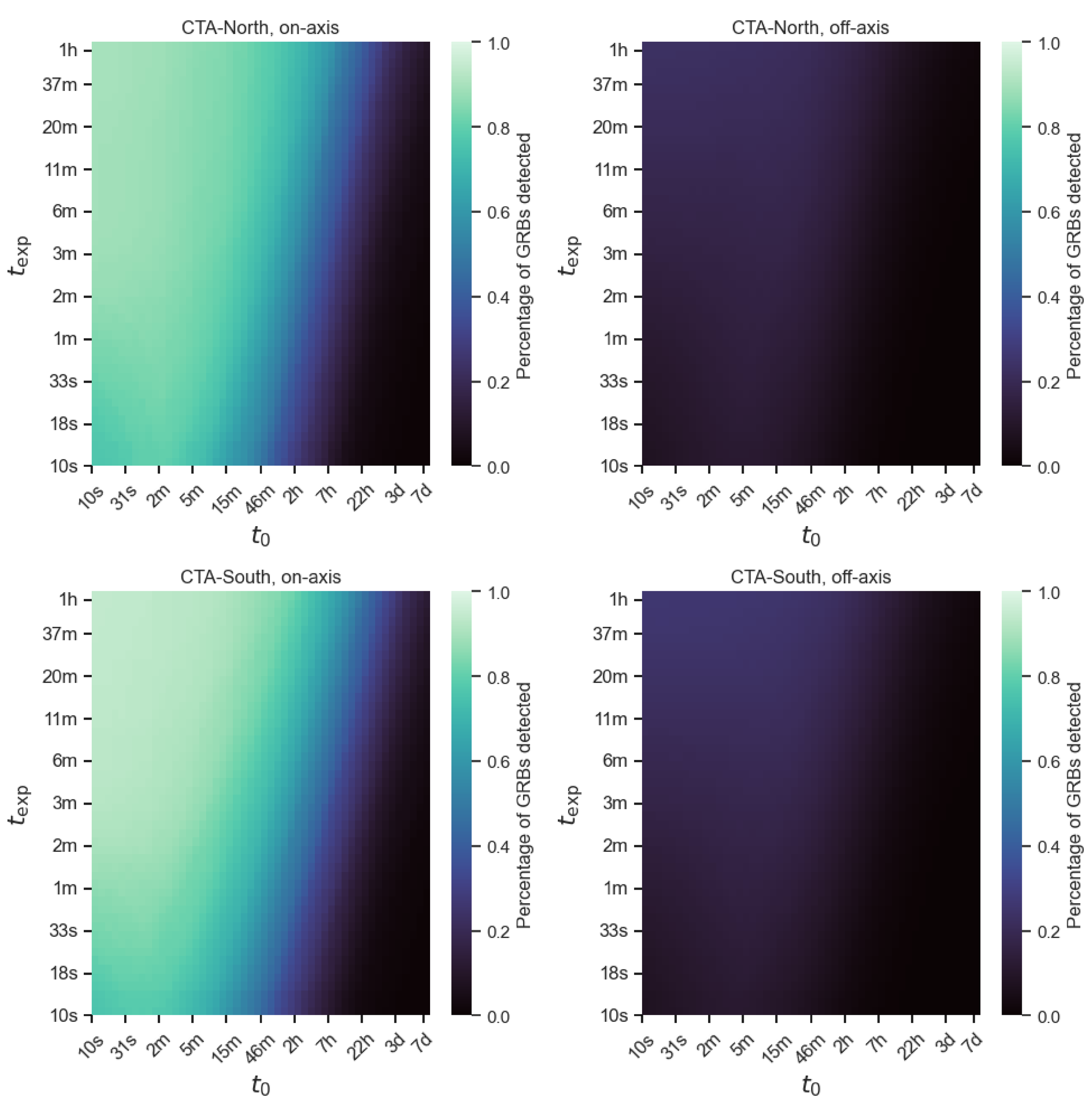
Simulated GW and short GRB emission

- GRB-GW170817 and the radio VLBI observations, showed that BNS mergers can produce short GRBs!
- From state of the art considerations of recent GRB detections and not detections at VHE, a phenomenological GRB catalog is obtained
  - **Jet opening angle** inferred from short-GRBs seen on-axis, average:~14deg
  - **Viewing angle** from the inclination of the BNS
  - **Lightcurve**: follows deceleration phase + similar temporal decay as in X-rays
  - **Spectrum**: Photon index ~-2; Density of the external medium ~0.1 cm-3
  - **Jet structure:** Gaussian distribution for both energy and Lorentz factor



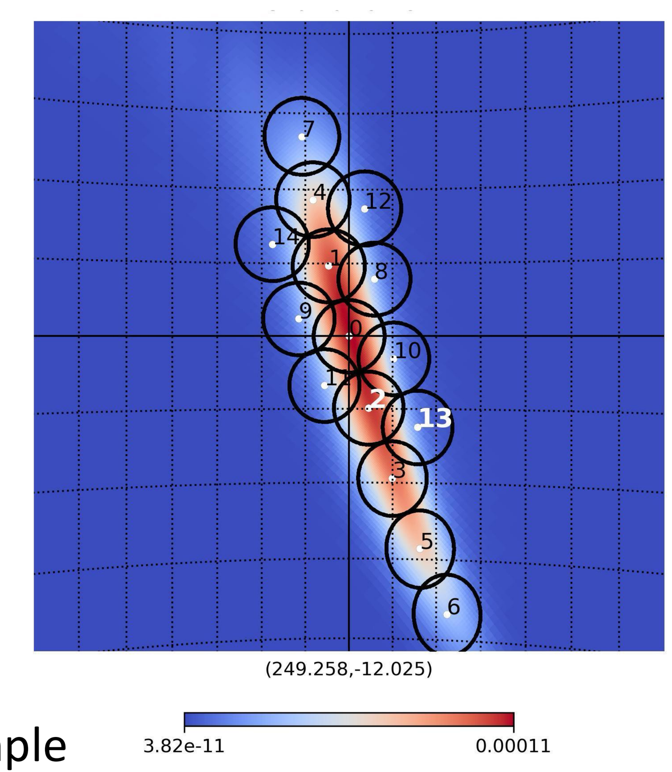
Studying the delay-exposure

- The detectability of the sGRB emission highly depends on the delay to observe the transient and the exposure to the source
- Poorly localized events add the complexity of the uncertainty on the localization



Observation

- Tilepy is used as observations scheduler to account for poorly localized events
- We have studied 5 different approach, for which the exposure is the main difference. These include 1-minute, 5- minute, 20-minute fixed windows, tailored approach per GRB (assuring that only observations for which detection is assured are scheduled) and a tailored approach to the average GRB
- The sGRB is covered in pointing 2 and 13 in the example



Conclusions

- We studied the detectability of sGRB emission and the impact of the observation scheduling
- The detailed prospects of joint detection rates of GW and sGRB for O5 by LVK and CTAO will be presented in an incoming publication