The CTA Multi-messenger and multi-wavelength program

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cherenkov telescope array

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Abstract

The Cherenkov Telescope Array (CTA) will allow observations in the >10 GeV range with unprecedented photon statistics and sensitivity to investigate the yet-unexplored physics of short-time-scale transient events. The CTA Transient program includes follow-up observations of a wide range of multi-wavelength and multi-messenger alerts, ranging from Galactic binary systems to extragalactic events such as Gamma-ray Bursts (GRBs). In recent years, the proven connection between gravitational waves and short GRBs as well as the detection of VHE signal associated to GRBs and the possible neutrino-blazar association on TXS 0506+056 has shown the importance of coordinated follow-up observations triggered by these different cosmic signals. In the next years, CTA will play a major role in this type of observations by taking advantage of its fast slewing (for LST), large effective area and good sensitivity, opening new opportunities for time-domain astrophysics in an energy range not affected by selective absorption processes typical of other wavelengths.

The CTA Transient working group

Transients are integral part of the CTA “Key Science Projects”. A dedicated Science Working Group (Transient and MWL SWG) is in place to prepare first observations (react to fast ToO, definition of observation program, preparation of science analysis, etc..) and setup the needed multi wavelength/multimessenger connections and synergies with external facilities. The main scientific outcome of the group, involves the release from 2021 of consortium publications focused on key topics such as GRB, gravitational wave, neutrino ToO and galactic transients. A further new consortium publication has been recently accepted on Core Collapse Supernovae (not presented on this poster). The group is also involved in other activities such as the detection prospects of serendipitous VHE transients identified via the CTA real-time analysis and the VHE transient survey, by exploring the divergent pointing capability and in association with the CTA extragalactic survey.

Gamma-ray Burst

From “empirical” to “theoretical” approach:

- Simulation of a GRB population by assuming a few intrinsic properties (E_{peak} & z distribution + E_{peak}-E_{iso} correlation)
- Bulk Lorentz factor distribution obtained by measured time of afterglow onset → Bulk Lorentz factor of the coasting phase
- Assumed spectrum allow to compute the flux and fluence in the energy bands corresponding to the instruments used to calibrate the sample
- Calibrated over BAT6 + SBAT4 catalogues

outcome
- GRB detection rate and parameter space study
- Spectra & Light curves
- Assess the effect on different array conf.

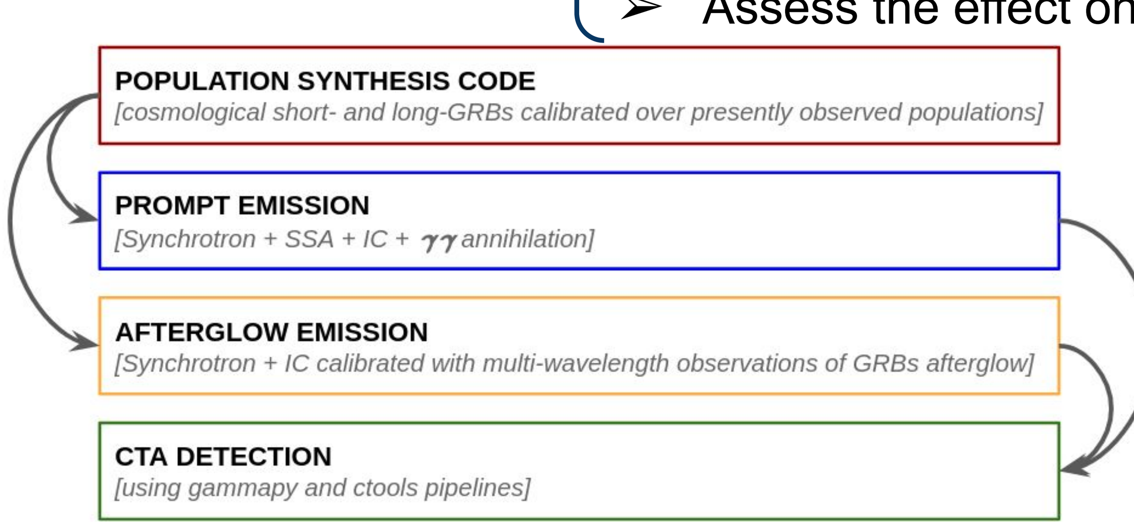


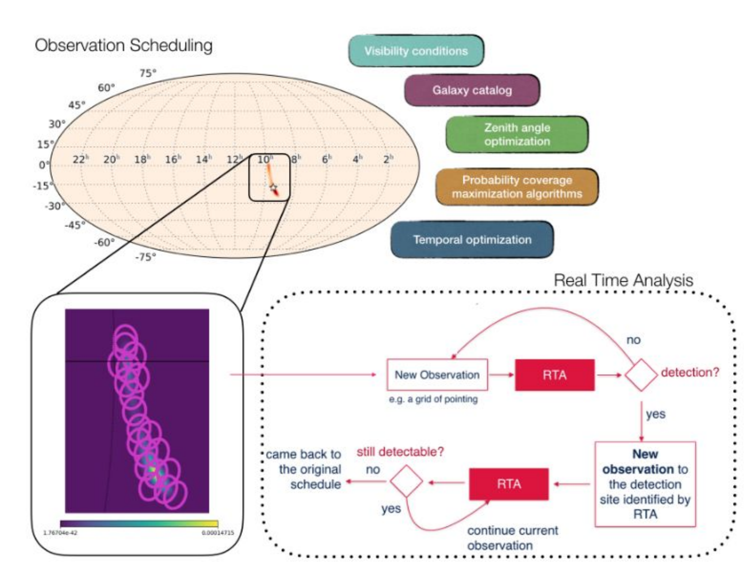
Fig 1: *Scheme of the GRB consortium publication work. Synthetic spectra and light curves are obtained by a population synthesis code and used to feed CTA analysis pipeline*

More info: [1] [2]

Gravitational waves

In contrast to the GRB case, a purely phenomenological approach is used:

- A short GRB is associated to each simulated Binary Neutron Star (BNS) merger extracted from the public database GWCOSMos providing the GW skymap, distance and orientation
- VHE emission derived from the empirical correlations between X-ray and TeV luminosity (as in GRB 190114C)



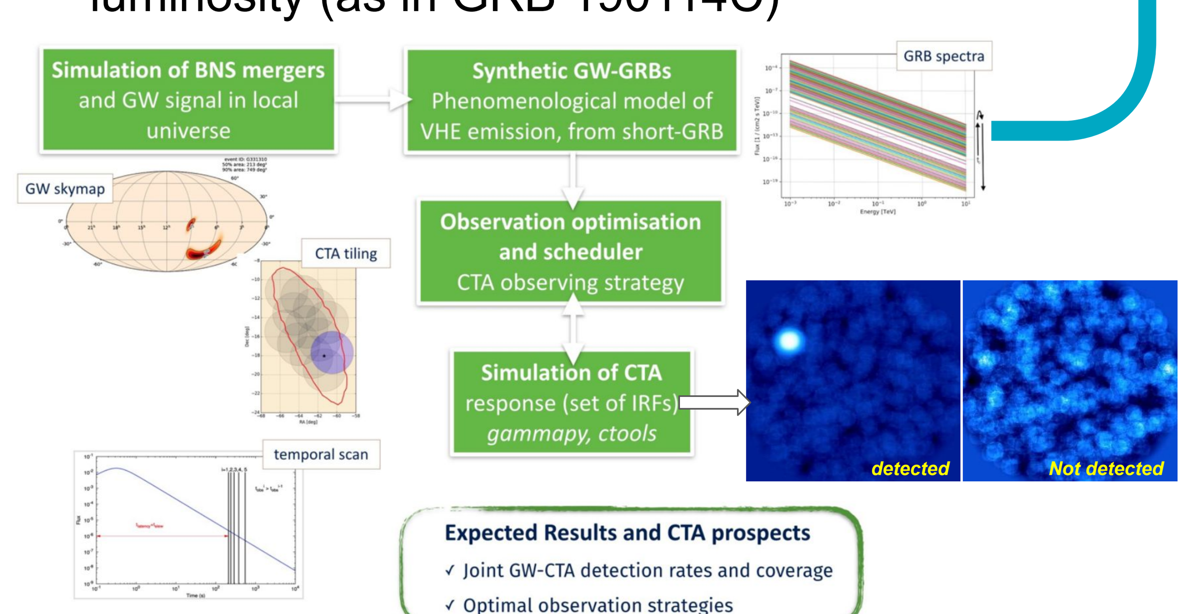


Fig 2: *Workflow of the GW consortium publication. After the simulation of BNS merger, a phenomenological (short) GRB is associated to it. The optimized pointing strategy is then obtained by dedicated algorithm in order to cover efficiently the sky area of the GW source. Each pointing is then analyzed by means of the CTA analysis pipeline.*

More info: [2] [3]

Galactic Transients

Work involving simulation and detection prospect for a wide range of galactic transients:

- Novae
- PWNe flares
- microquasars
- magnetars
- super giant fast X-ray transient (SFXTs)
- tMSPs

+

Detection prospect on possible flares or even steady emission from some specific sources: the microquasars Cygnus X-1 and Cygnus X-3 and the low-mass binary V404 Cygni; the microquasar SS433 (detected both by Fermi-LAT and at higher energies by HAWC); flares from the Crab Nebula PWN and emission from the tMSPs PSR J1023 and PSR J1227

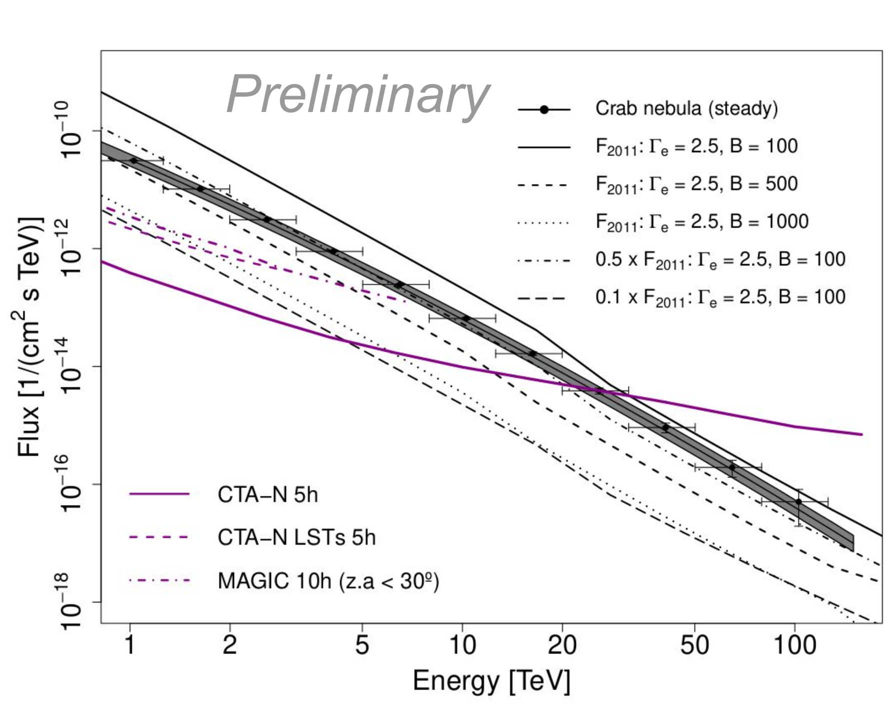


Fig 4: *The expected flux measured during a Crab flare in the TeV energy range, under different configurations of the CTA-North array (full array 5h, 4 LSTs 5 h and MAGIC sensitivity 10h, for comparison) for a variety of flares. From [7]*

More info: [8]

Neutrino

The aim of this study is to develop a strategy for CTA follow-up of neutrino alerts to maximizing chances of the VHE counterpart detection. Neutrino point sources simulations are based on FIRESONG [4], which take into account the cosmological evolution of different source classes and the recent results from IceCube (i.e., the measured diffuse flux of astrophysical neutrinos). These are then the input for simulating gamma-ray emission and CTA follow-up .

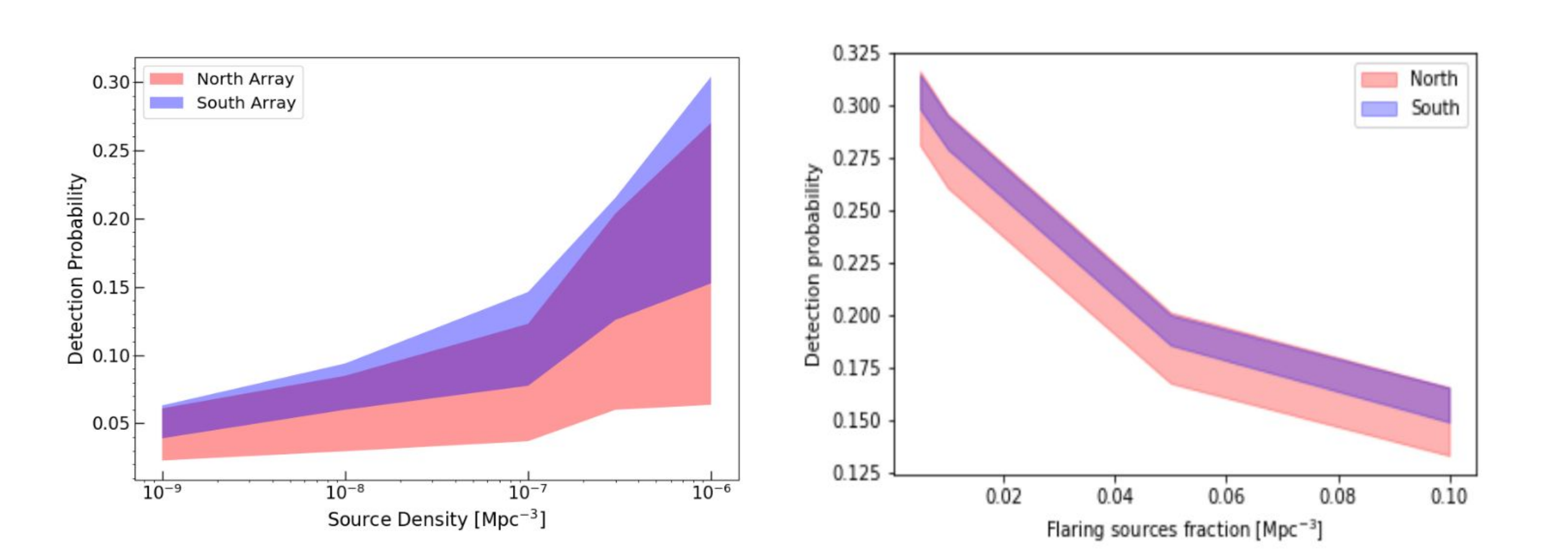


Fig 3: *Probability to detect a neutrino source with CTA in the case of a steady source as a function of the local source density (left panel) and in the case of a "TXS 0506+056 - like" blazars, based on the emission model proposed by [6] as a function of the flaring sources fraction (right panel). From [5].*

More info: [4] [5]

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