Sixteenth Marcel Grossmann Meeting - MG16

Virtual Meeting - July 5-10, 2021

cta cherenkov telescope array

UNIVERSITÉ DE GENÈVE

The Cherenkov Telescope Array capabilities for GRB follow-up

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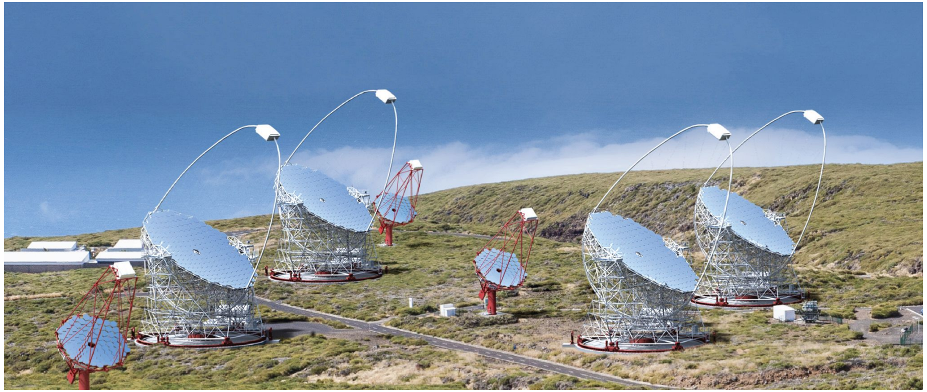
(*) Speaker - Université de Genève - DPNC

for the **CTA Consortium**

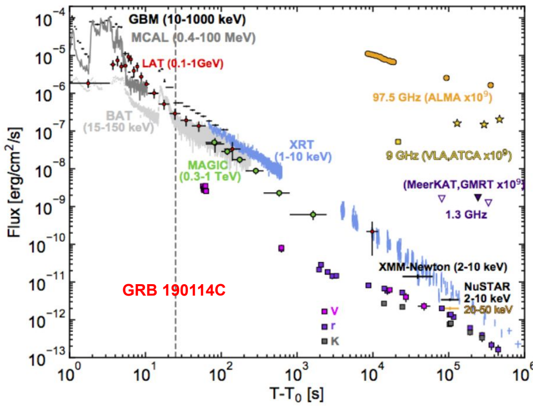


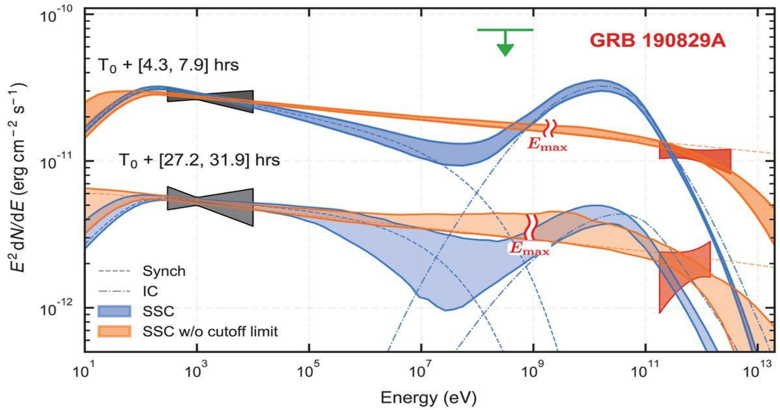
GRB at VHE: a long-awaited result

VHE Transient Astrophysics is "warming up" in the last years:

- **GRB detection at VHE: a long-awaited result after a 20-years quest !**
  (<u>see presentation on Monday session</u>)

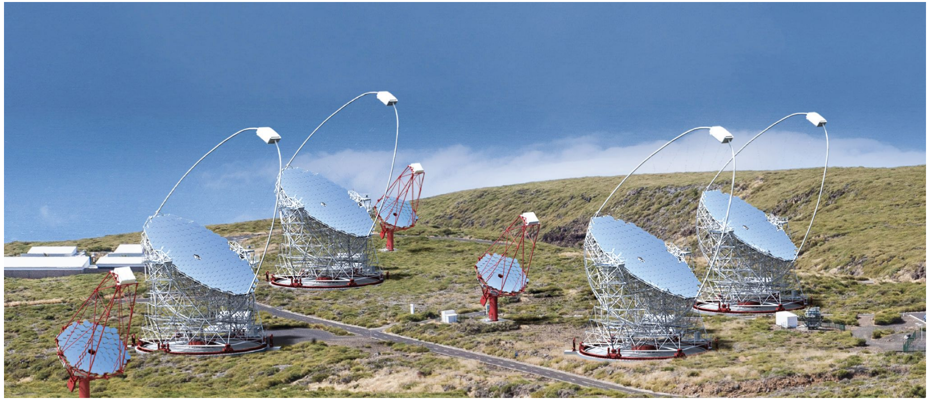
MAGIC GRB 190114C… (2019, Nature, 575, 455/459)
H.E.S.S. GRB 190829A… (2021, Science , 372, 6546)





and more events announced after these (GRB 160821B, GRB 180720B, GRB 201015A, GRB 201216C….)

The Cherenkov Telescope Array



A facility for Very High Energy gamma-ray astrophysics in the next decades

<u>alpha configuration:</u>

North: 4 LST + 9 MST
South: 14 MST + 37 SST

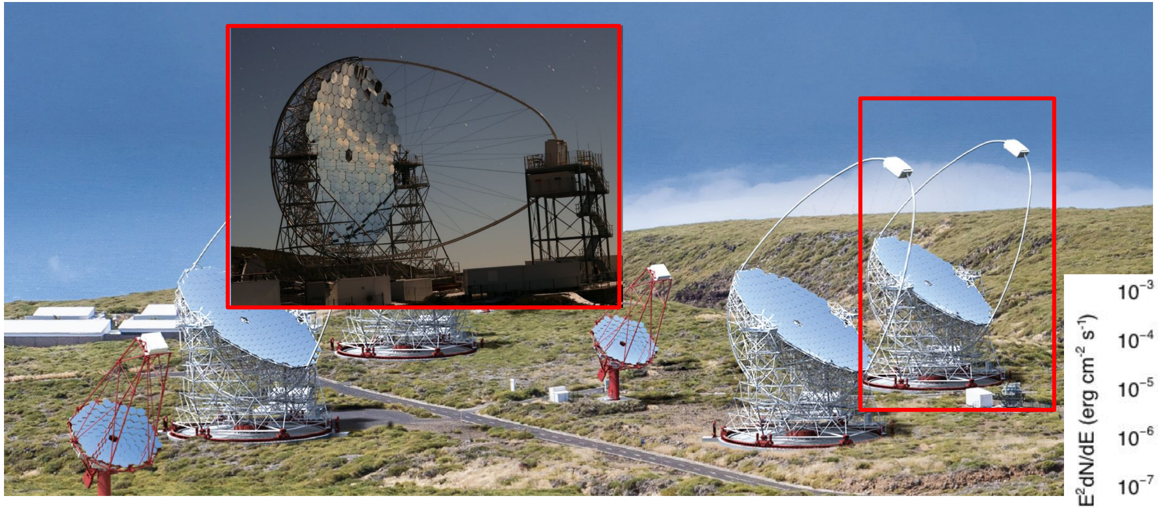
extragalactic science, transients...

galactic, > 100 TeV

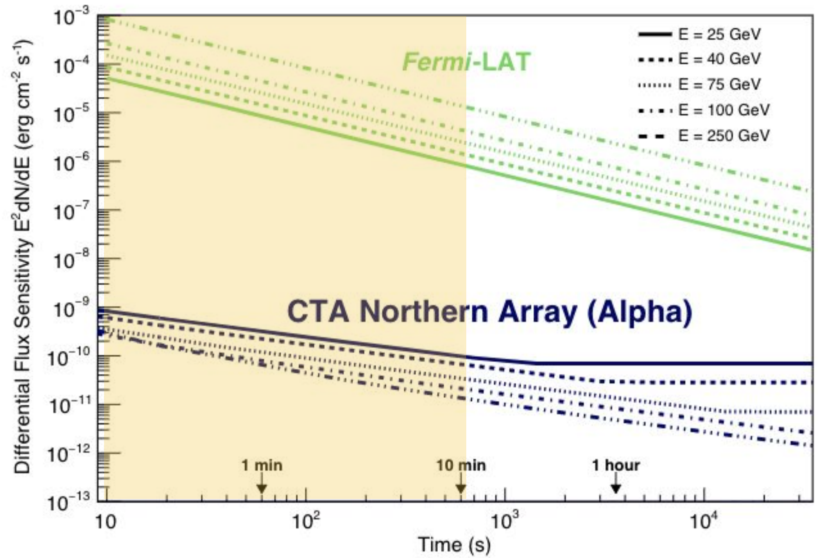
- ❑ 2 sites (north & south)
- ❑ 3 telescope size classes
- ❑ tens of telescopes

- near full sky coverage
- wider energy range (~20 GeV - 300 TeV)
- higher sensitivity: ~5-10x current IACT
- better angular resolution: ~5x current IACT
- larger FoV: 2.5x current IACT

The LST-1 prototype

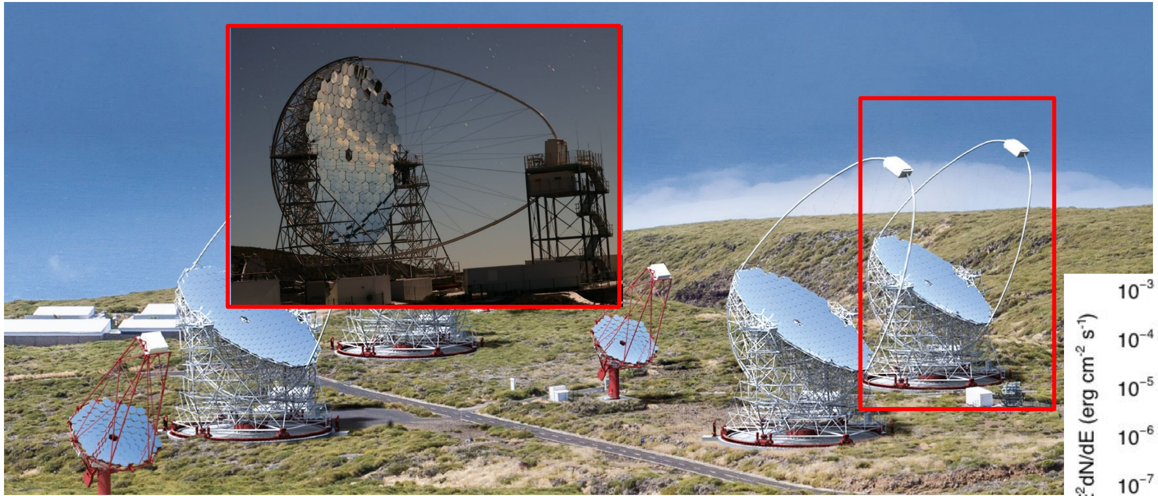


The LST-1 prototype, the first 23-m class telescope for the CTA, is finalizing its commissioning phase and entering regular scientific operations



- ❑ Low energy threshold (down to ~20 GeV)
- ❑ Larger effective area at multi-GeV range and better sensitivity compared to space-based instruments for short-time scale signal (~ 10^4 x *Fermi*-LAT @ ~ some mins. timescale)
- ❑ Fast slewing capabilities (~180^0/20s)

The LST-1 prototype



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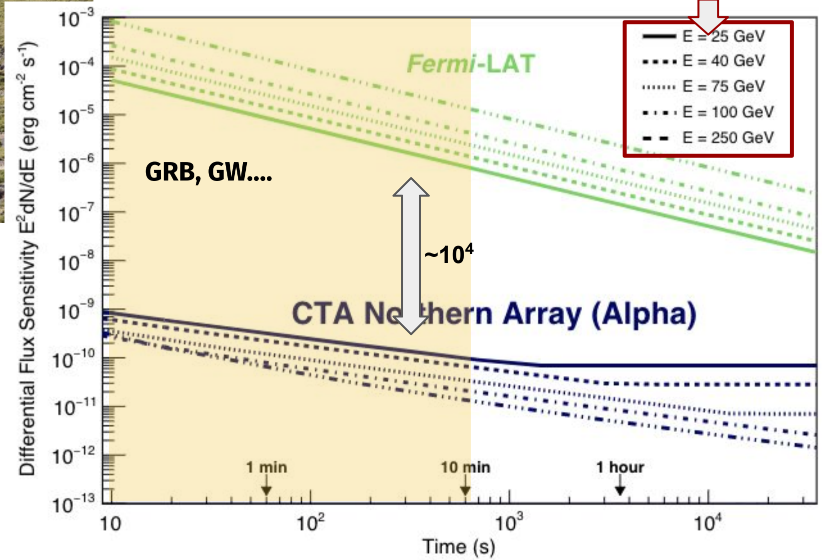
LST “sweet range”
(CTA sensitivity mainly dominated by LSTs)



The Transient Key Science Projects

Transient KSP

- Initially written in 2014
- several interactions since → discussion on modifications to proposed observation allocations (many news since 2014!)

arXiv:1709.07997

		Observation times (h yr^{-1} $site^{-1}$)			
Priority	Target class	Early phase	Years 1–2	Years 3–10	Years 1–10
1	GW transients	20	5	5	
2	HE neutrino transients	20	5	5	
3	Serendipitous VHE transients	100	25	25	
4	GRBs	50	50	50	
5	X-ray/optical/radio transients	50	10	10	
6	Galactic transients	150	30	0(?)	
	Total per site (h yr^{-1} $site^{-1}$)	390	125	95	
	Total both sites (h yr^{-1})	780	250	190	
	Total in different CTA phases (h)	1560	500	1520	2020

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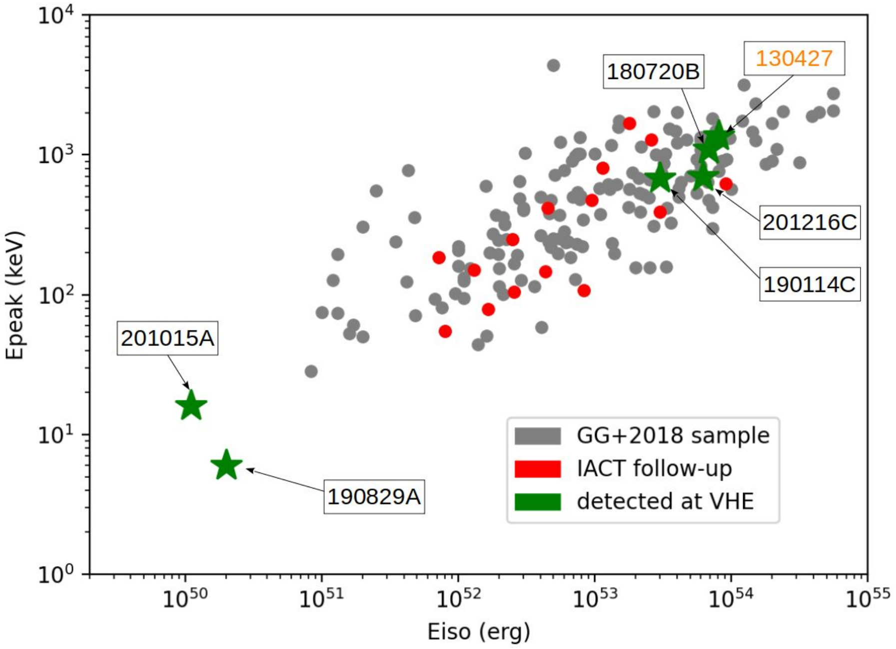
NEW DISCOVERIES → TO BE UPDATED!!

Why we still need the CTA



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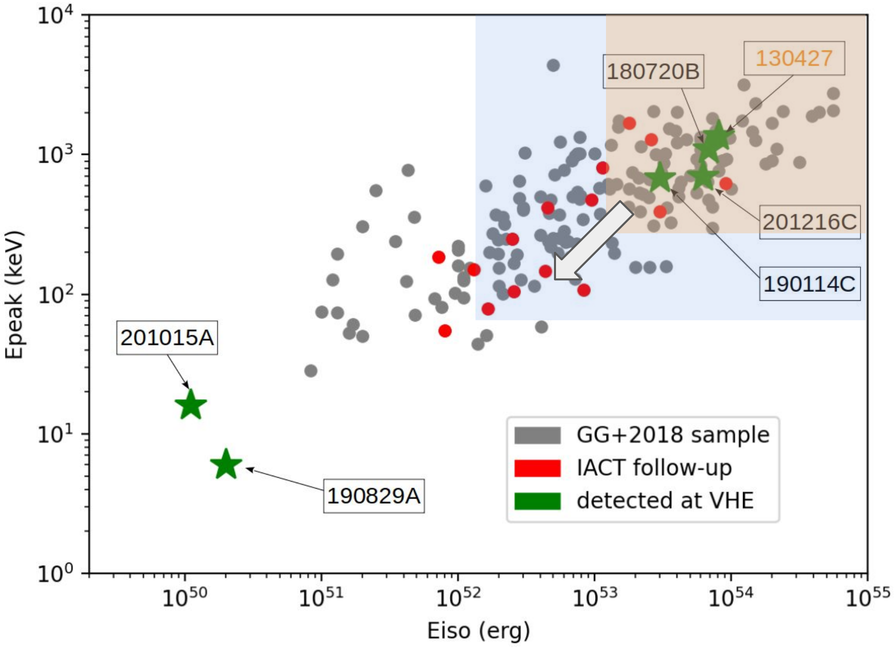
Why we still need the CTA



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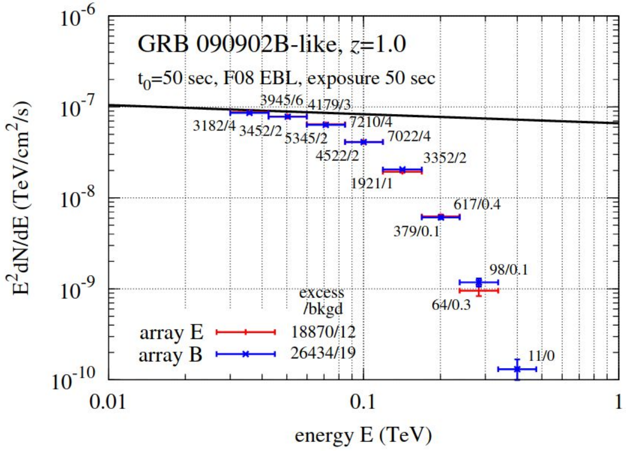
CTA will open the possibility to study a new parameter space region of GRB physics

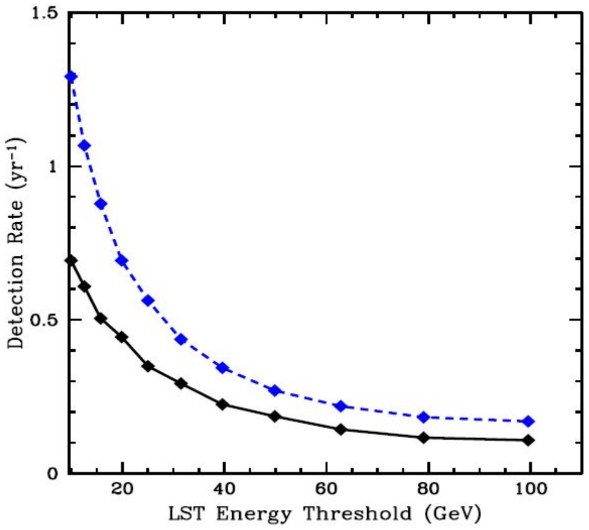
- Which are the emission mechanisms? VHE during afterglow and/or prompt? ***Do all GRB have a VHE component?*** Why haven't we detected GRB before ?!
- We have had some detections (such as GRB 180720B and GRB 190114C) that were somehow 'expected' (bright, powerful etc). However, we also have something that is (apparently) different (GRB 190829A). Are we observing the first (or one of the first) event of a new GRB population? Or do we just have to think that the parameters space of the possible VHE-emitter GRBs is much larger than we thought in the past?

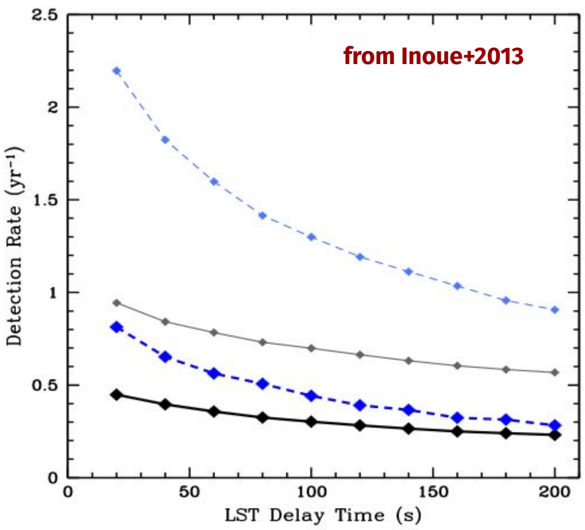
CTA capabilities for GRB follow up

Initial "empirical" approach:

- Some LAT-detected GRBs used as a template to extrapolate expected VHE spectrum & light curves
- Detection rates estimated by means of a simplified GRB population assuming 2 possible spectral model: *bandex* *(Band emission up to VHE range)* & *fixed* *(Band+power-law)*



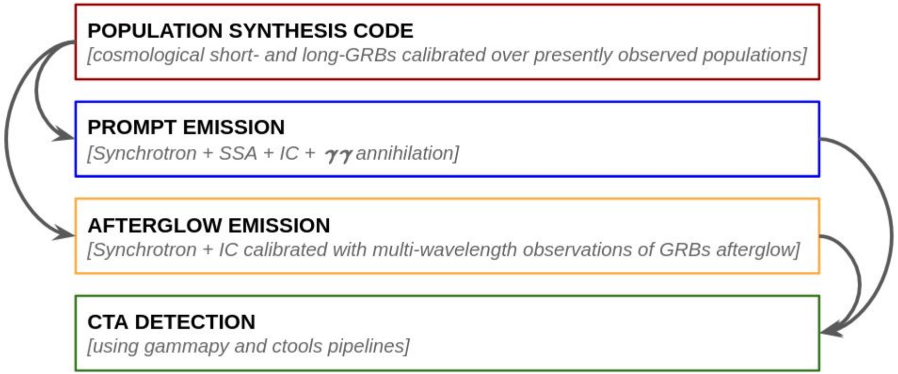




Expected detection rate ~ 0.5 GRB yr^{-1}
(depending on the assumed GRB model and array layout and performance)

CTA capabilities for GRB follow up

New “theoretical” approach:



POSyTIVE: *POpulation SYnthesis Theory Integrated model for Very high Emission.*

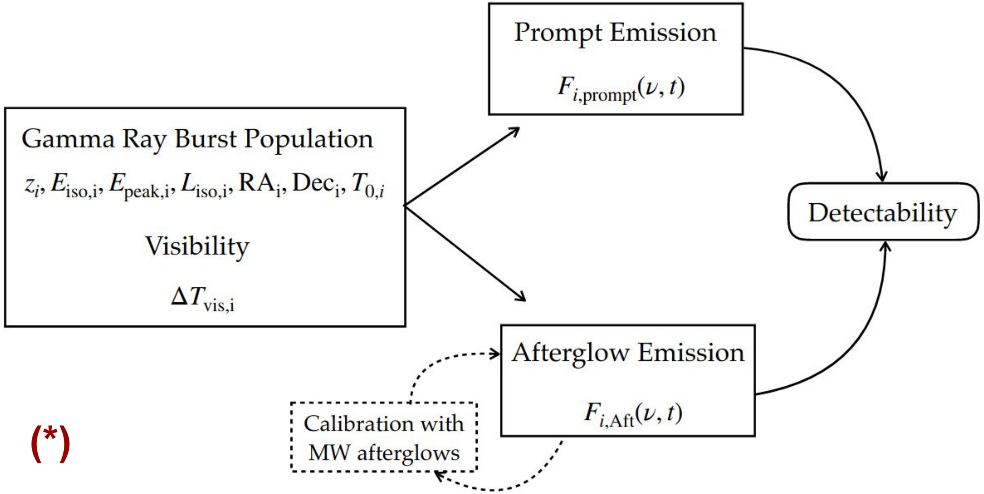
calibrated over:

- *The GRB population detected by Fermi-GBM*
- *The complete sample of Swift GRBs (BAT6 - SBAT4)*

Simulation of a GRB population by assuming a few properties:

- broken power law distribution of the rest frame peak energy E_{peak}
- z distribution (long GRB formation rate is assumed to be proportional to the cosmic star formation rate)
- E_{peak} - E_{iso} assumed (Amati relation)
- Bulk Lorentz factor distribution obtained from sample GRB for which onset time of the afterglow has been measured (Ghirlanda+2018)

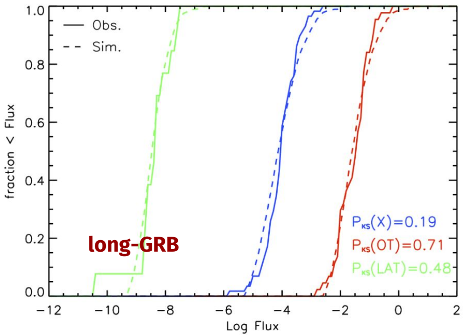
CTA capabilities for GRB follow up

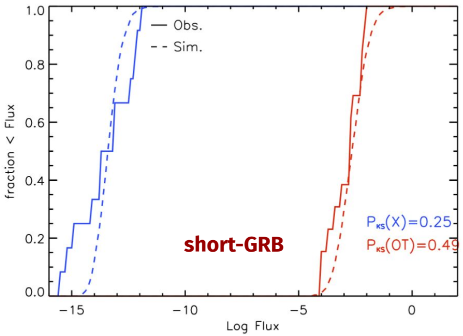


(*)

prompt & afterglow emission evaluated according to leptonic synchrotron + ssc model (Bošnjak+ 2014 & Sari+2001)

- synchrotron self-absorption & photon-photon annihilation taken into account (prompt)
- KN effect considered (afterglow)
- free parameters calibrated over real sample

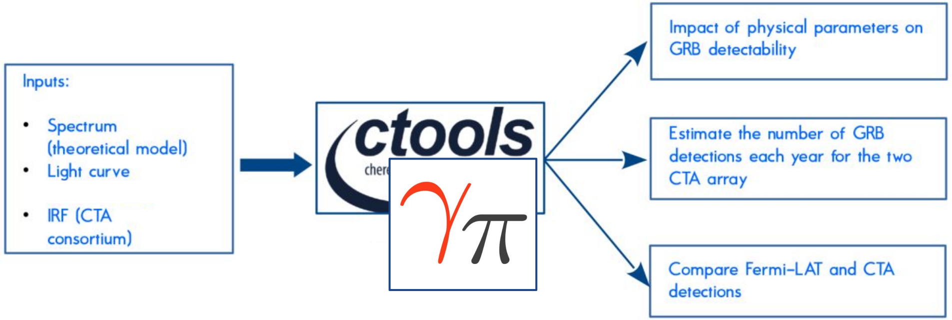




(*) From Bernardini+ 2019: *POSyTIVE - a GRB population study for theCherenkov Telescope Array*, PoS(ICRC2019)598

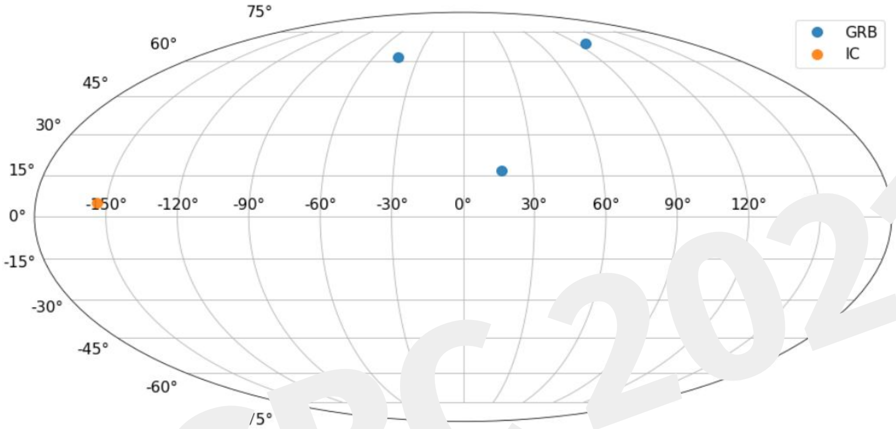
CTA capabilities for GRB follow up

Predicted VHE spectrum & light curves (including EBL attenuation) used to feed dedicated CTA analysis pipeline based on ctools and gammapy



Results to be published in a dedicated *consortium publication*….

Towards first observations



- **First regular follow-up with LST-1 started at the beginning of 2021 :**
  - a bunch of events observed so far (swift malfunctioning)
  - still human-in-the-loop follow-up but implementation of dedicated automatic procedure ongoing
  - initial science already possible

	T_0 [UTC]	T_{90} [s]	z	Start time [UTC]	Zenith [deg.]	Delay [s]	Trigger	VHE
GRB 201216C	23:07:31	48.0	1.1	20:57:03	40	79200	*Swift*	Y^{α}
GRB 210217A	23:25:42	4.2	-	23:40:22	44	880	*Swift*	N
GRB 210511B	11:26:39	6	-	03:37:54	45	58200	*Fermi*-GBM	N
IC 210210A	11:53:55	-	-	05:41:54	25	64134	IceCube	N

Conclusions

- GRBs are one of the main targets for the CTA transient key science program and they represent a frontier subject for VHE astrophysics.
- Within the CTA transient working group, dedicated activities have started to prepare such type of observations and to evaluate CTA capabilities in GRB follow up. Initial work based on empirical approach already provided estimated detection rate up to ~few GRB/year depending on the GRB spectral characteristic and array configuration
- A new theoretical approach is currently under development in order to simulate a realistic GRB population calibrated over a large sample of real data at different wavebands. The obtained extrapolation in the VHE band coupled with the use of dedicated analysis pipeline making use of the last available IRFs will allow a robust estimate of the expected detection rate and the determination of the GRB-physical parameters space accessible by CTA