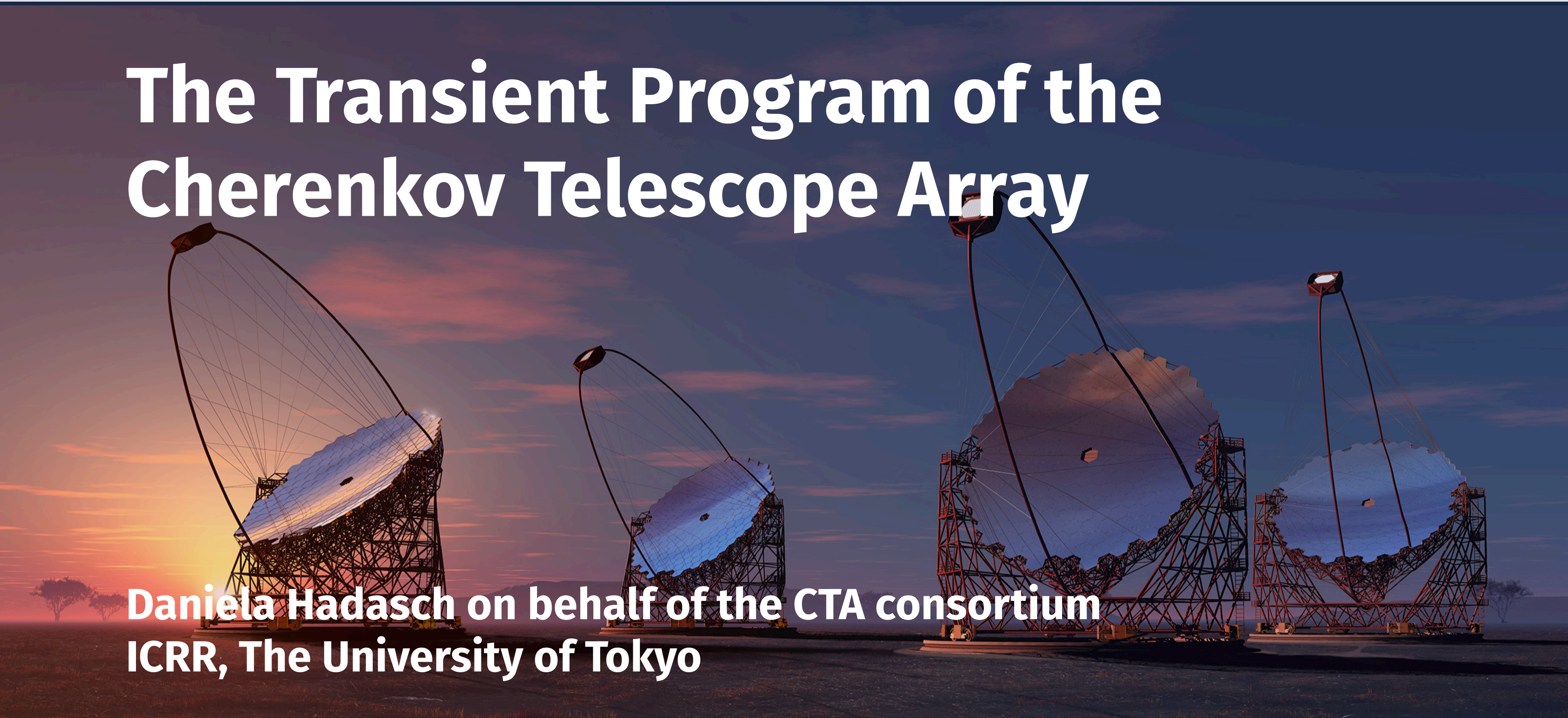


The Transient Program of the Cherenkov Telescope Array

Daniela Hadasch on behalf of the CTA consortium
ICRR, The University of Tokyo

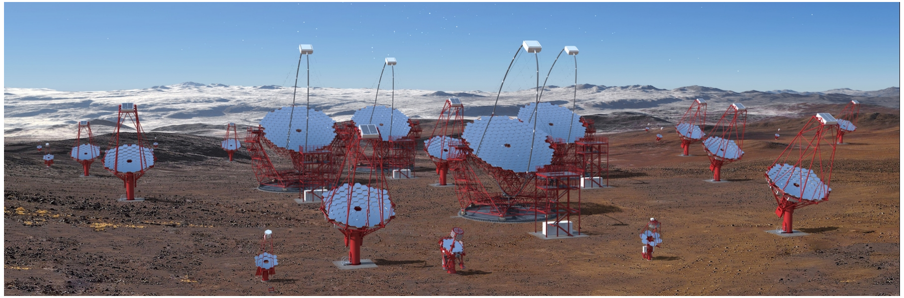
Overview

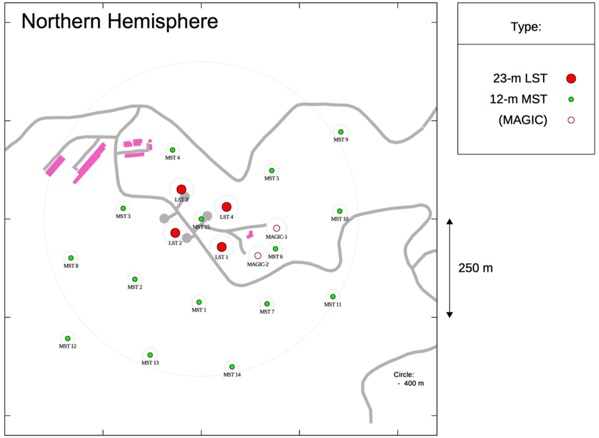
- Introduction of the Cherenkov Telescope Array (CTA)
- Focus on Gamma ray bursts (GRBs), Gravitational waves (GWs) and high-energy neutrino studies with CTA
- Conclusions & Outlook

Two sites for all sky observatory

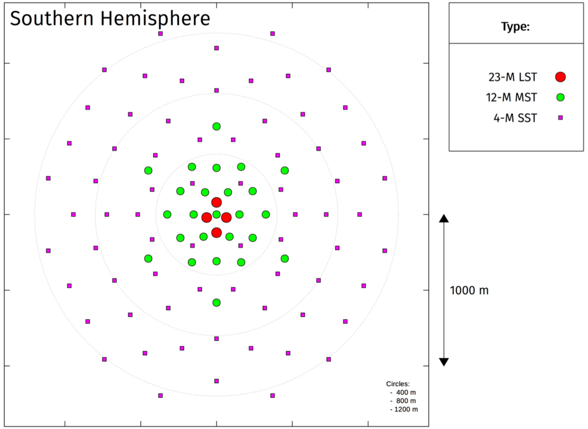
Roque de los Muchachos Observatory, La Palma, Spain

Paranal, Chile





4 LS4 LSTs, 15 MSTs



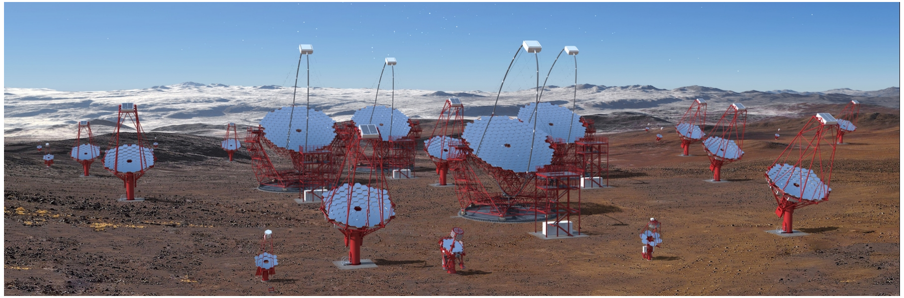
4 LSTs, 25 MSTs, 70 SSTs

Status of all sky observatory

Roque de los Muchachos Observatory, La Palma, Spain

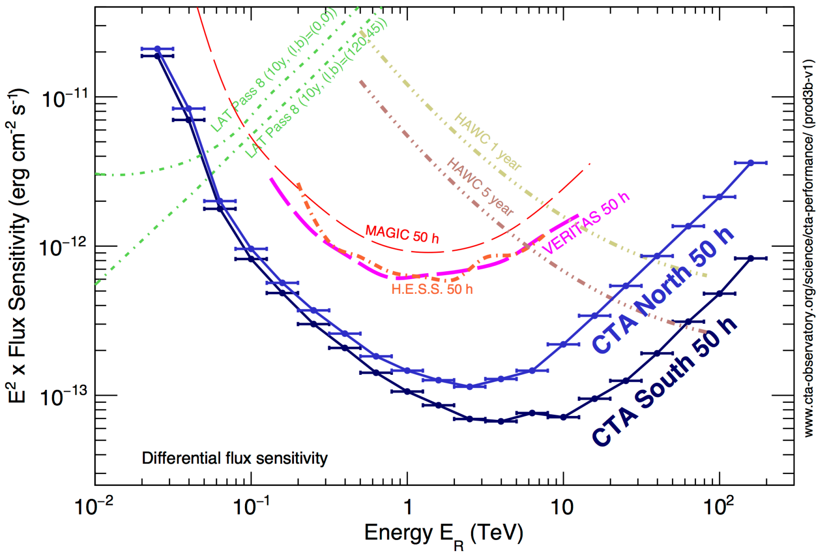
Oct 2018: Inauguration of LST1

Paranal, Chile



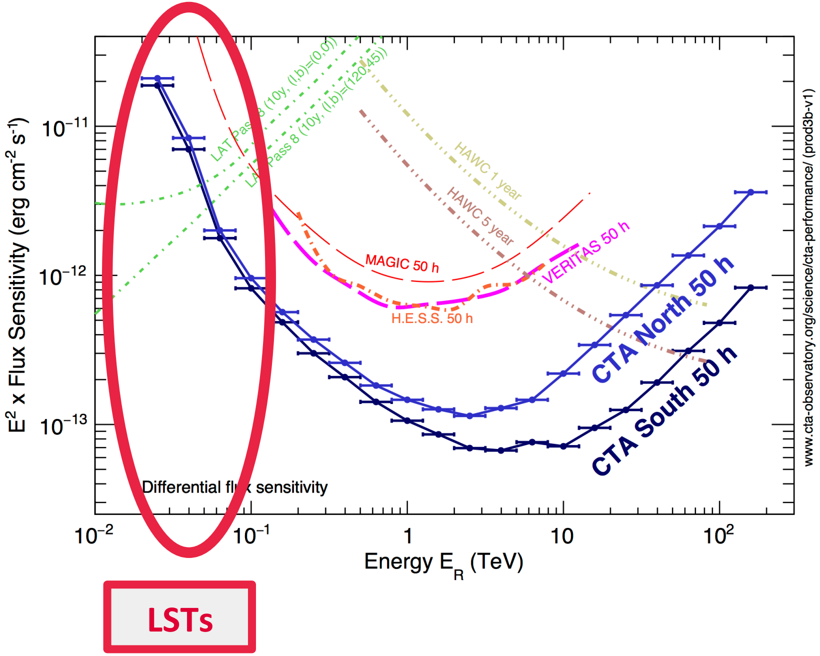
December 2018: MoUs were signed

Improvement over existing experiments



- Energy range 20 GeV – 300 TeV
- CTA-LST array crucial for improved sensitivity at low energies >20GeV
- ~10x more sensitive than current IACT
- Angular resolution improved by factor 2

Improvement over existing experiments



- Energy range 20 GeV – 300 TeV
- CTA-LST array crucial for improved sensitivity at low energies >20GeV
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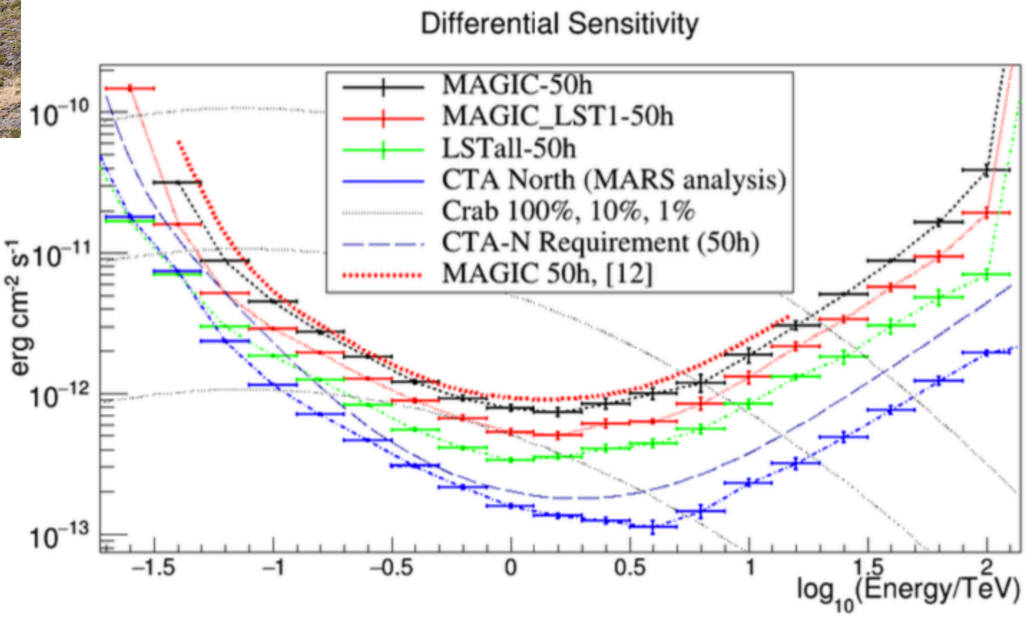
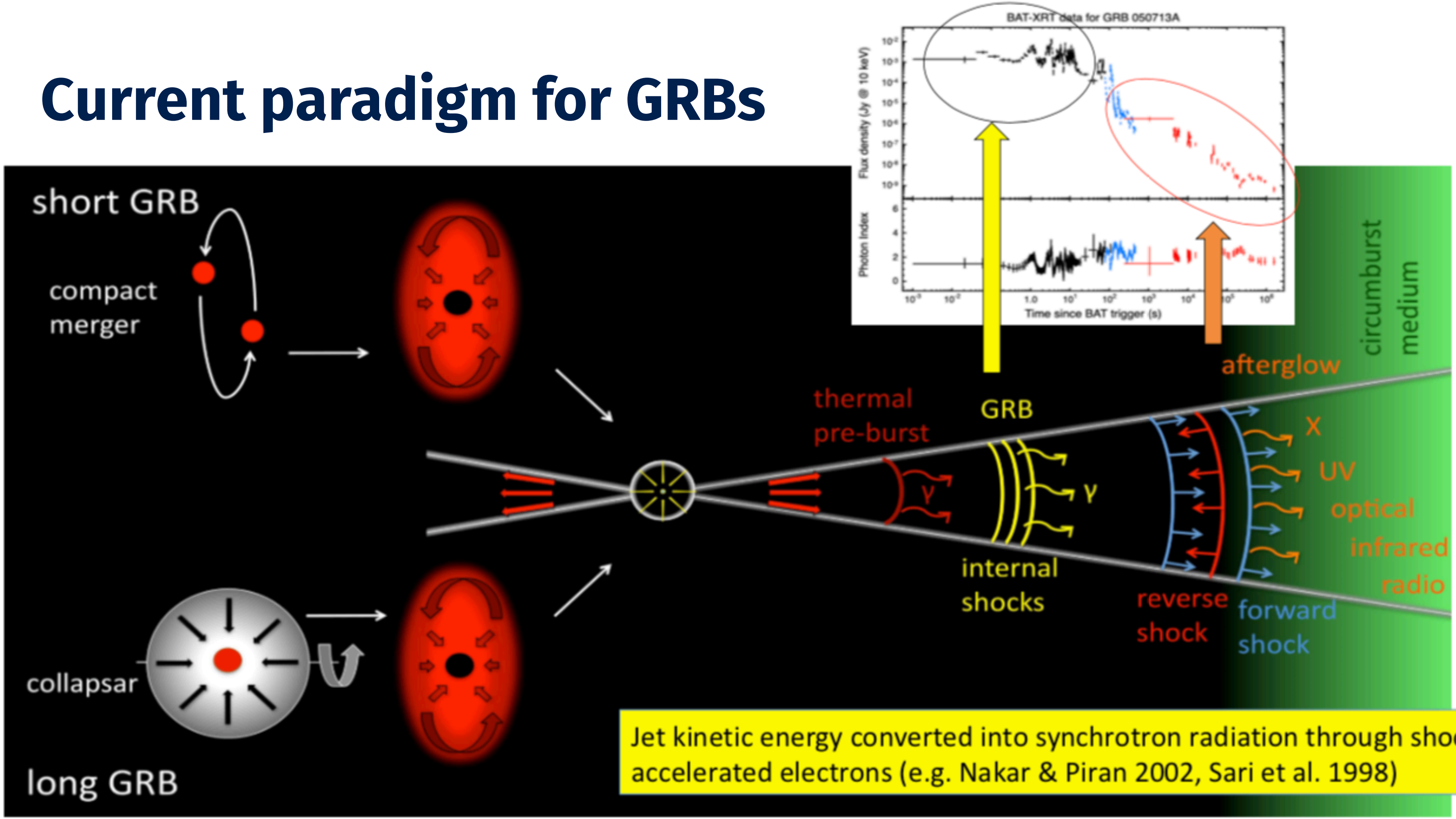
- Angular resolution improved by factor 2

Combined MAGIC and LST1 Observations



F. Di Pierro 2019, ICRC proc.

Current paradigm for GRBs

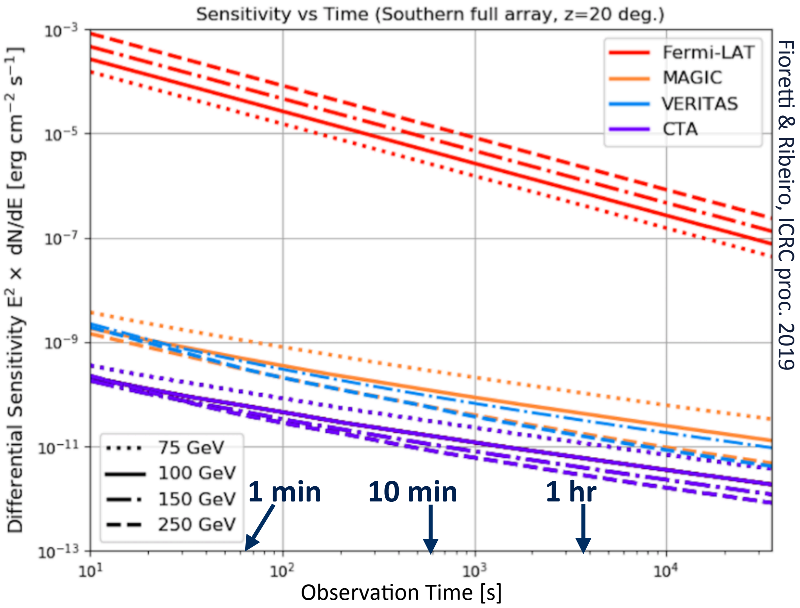


Jet kinetic energy converted into synchrotron radiation through shock-accelerated electrons (e.g. Nakar & Piran 2002, Sari et al. 1998)

Diagram: Gomboc et al. 2012

Slide from G. Stratta 2019

Improvement on short time scales



- ~10000 better sensitivity for GRBs than Fermi-LAT (but 10% efficiency against ~90%)
- GRB Prompt emission and evolution of afterglow detectable with the fast rotation of the LSTs (20 sec)

GRBs with CTA: EBL studies

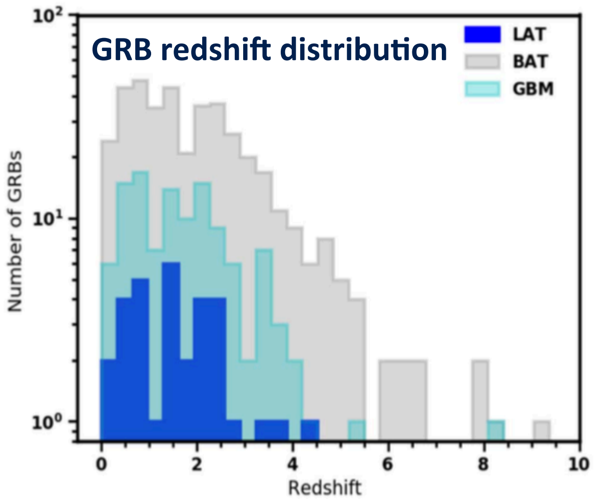
- **Extragalactic Background Light:** diffuse, nearly isotropic background of IR/opt/UV radiation
- Fundamental information on global evolution of stars & supermassive BH in the Universe
- **GRBs observed with CTA are excellent EBL probes**:

  High-quality HE spectra

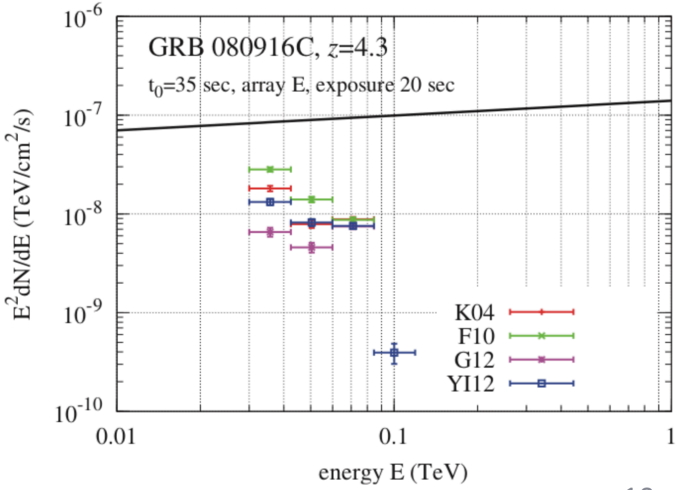
  → can trace photon-photon interaction attenuation feature that is an indirect EBL probe

  High-redshift GRBs can be detected

  → can probe early Universe complementary to past studies (e.g. blazar at ~TeV up to z<0.9)



Ajello+ 2019

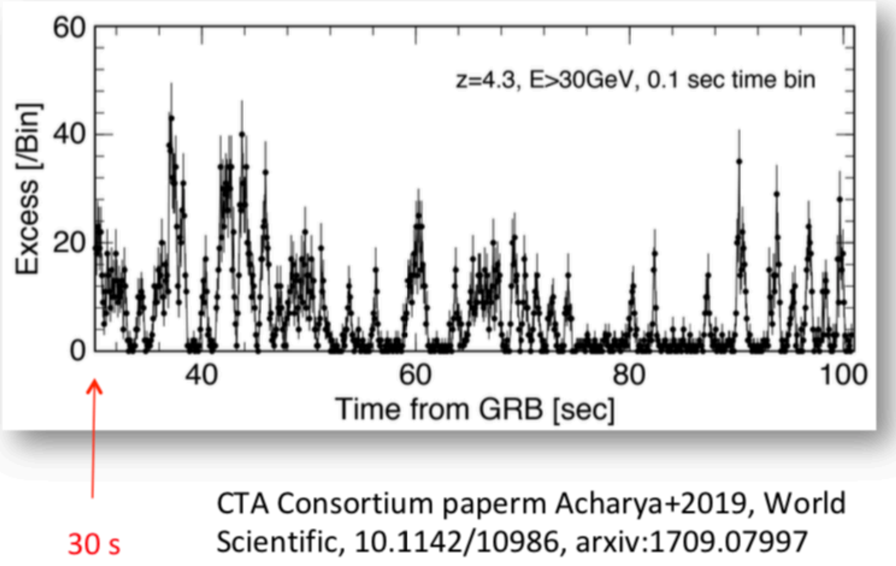


"Science with CTA" Consortium paper, World Scientific, 10.1142/10986

GRBs with CTA: LIV studies

- Some model of quantum gravity allow violation of Lorentz invariance
  → the photon propagation speed can depend on energy
- All methods of constraint LIV require sources with:
  - Short time-scale variability
  - Bright VHE emission
- **GRB observed with CTA can test LIV through high-resolution VHE light curves**
  - **Prompt phase**
  - **Afterglow (flares)**

Simulated GRB 080916C based on Fermi/LAT spectra+EBL



CTA Consortium paperm Acharya+2019, World Scientific, 10.1142/10986, arxiv:1709.07997

GRB with CTA: Expected rates and strategy

- **CTA will respond to external GRB alerts** from satellites (currently Fermi/GBM, Swift, SVOM, etc.) (12/yr/site follow-up expected during dark moon & z<70°)
- Real Time Analysis will check for GRB detection ~T_{slew}+30s
- Detection rate: **~ 1 GRB/yr/site**; based on
  1. GRB population model tuned to match Swift observations
  2. Assumptions on VHE based on Fermi/LAT observations

Strategy	Expected event rate (yr^{-1})	Exposure per follow-up (h)	Exposure per year (h yr^{-1})
Prompt follow-up of accessible alerts	$\sim$12	2	25
Extended follow-up for detections	0.5–1.5	10–15	10–15
Late-time follow-up of HE GRBs not accessible promptly	$\sim$1	10	10

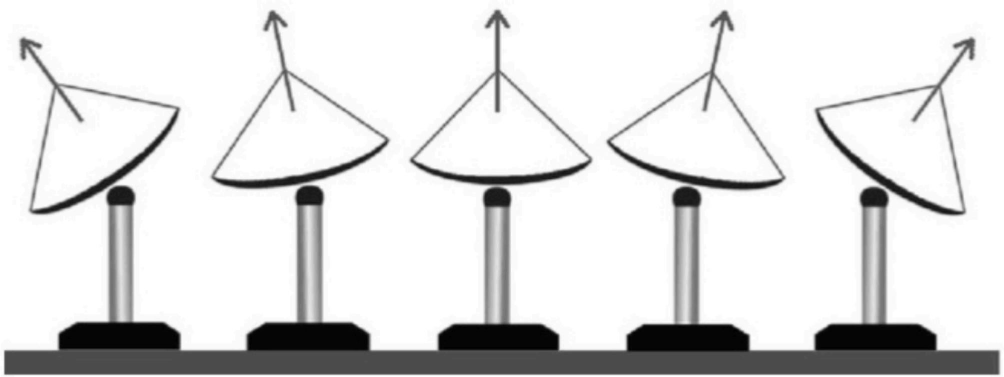
→ Real Time Analysis <30s

Summary of GRB follow-up strategy per one site
(see Table 9.2 from "Science with CTA" Consortium paper, World Scientific, 10.1142/10986, arxiv:1709.07997)

Slide from G. Stratta 2019

Divergent pointing

- Telescopes are inclined into the outward direction by an angle increasing with the telescope distance from the array center
  → Wider field of view
  → Possibility to detect GRB in the field of view → **observation from t_0**
  → **Boost rate of GRBs observable by CTA in prompt phase to ~2 per year.**



Szanecki et al. 2015

GRB population study: POSyTIVE project

POpulation Synthesis Theory Integrated code for Very high energy Emission

Consortium paper in preparation

POpulation Synthesis
Long
[Ghirlanda+2012;2015]
Short
[Ghirlanda+2016]

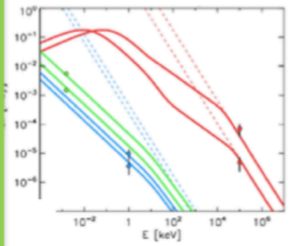
PROMPT EMISSION
Z. Bosnjak
Bosnjak et al. 2009, 2014

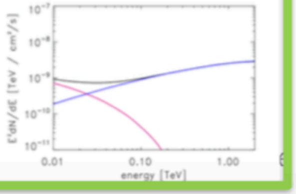
Prompt calibration

AFTERGLOW EMISSION
L. Nava
Nava et al. 2014
Beniamini, Nava et al. 2015

Afterglow calibration

Simulation
(ctools/gammapy)





Schüssler 2019, ICRC proc.

GRB population study: POSyTIVE project

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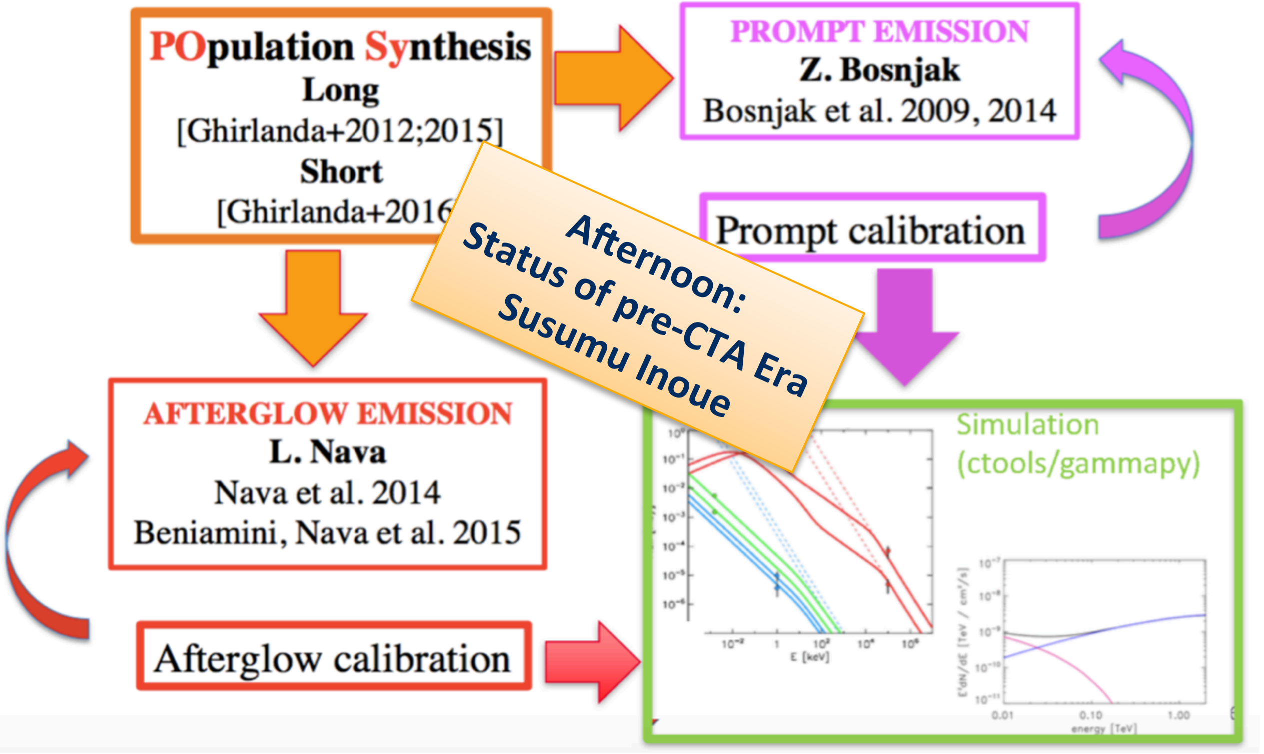
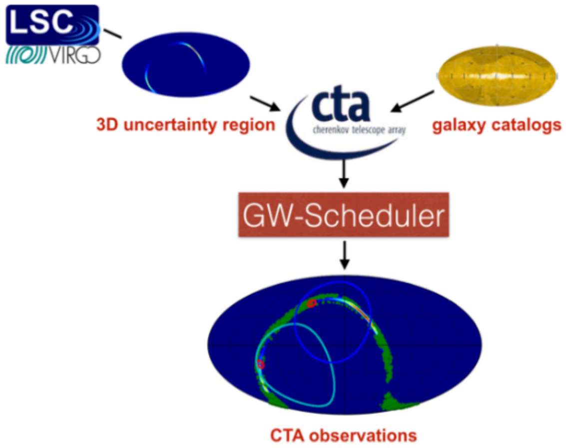


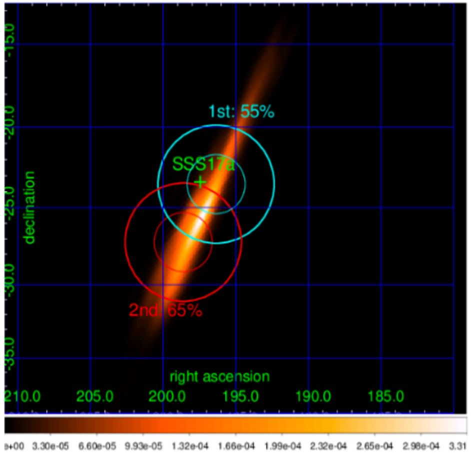
Schüssler 2019, ICRC proc.

Gravitational wave sources with CTA

Consortium paper in preparation



(a) Scheme of CTA reaction to GWs



(b) Simulated CTA follow-up of GW170817

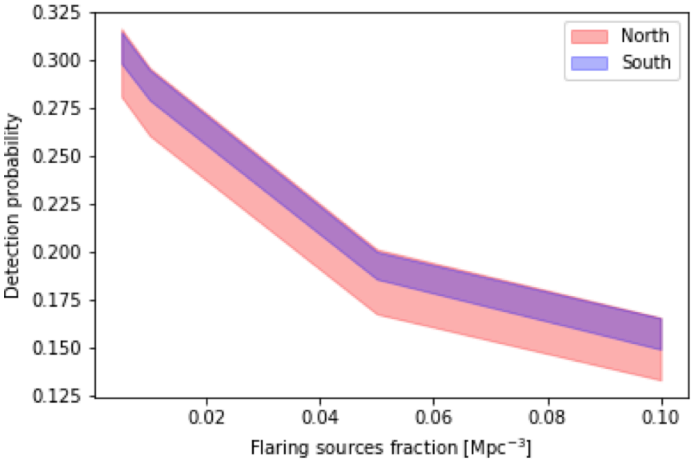
Schüssler 2019, ICRC proc.

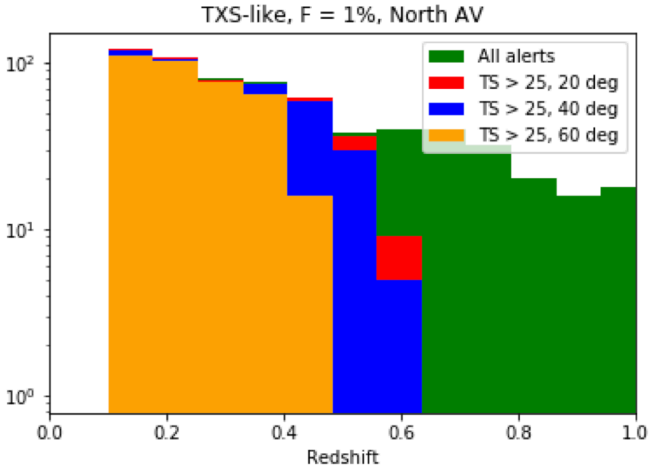
- Expected large uncertainties of the GW source localization need **dedicated follow-up strategies**
- **CTA can play a relevant role in case of coarse GRB localization from high-energy satellites (as for GRB170817):**
  - Fast reaction time (<20s)
  - Large field of view (4deg - 7deg)
- **Arcmin level localization** →follow-up with optical/radio facilities

High energy neutrinos with CTA

Consortium paper in preparation

- Correlation of IC170922A with the flaring blazar TXS0506+056
  → First hint for the success of VHE gamma-ray follow-up programs of high-energy neutrinos
- CTA NToO program defined by simulating source populations of joint neutrino and gamma-ray emitters and optimizing the simulated CTA follow-up.





Satalecka 2019, ICRC proc.

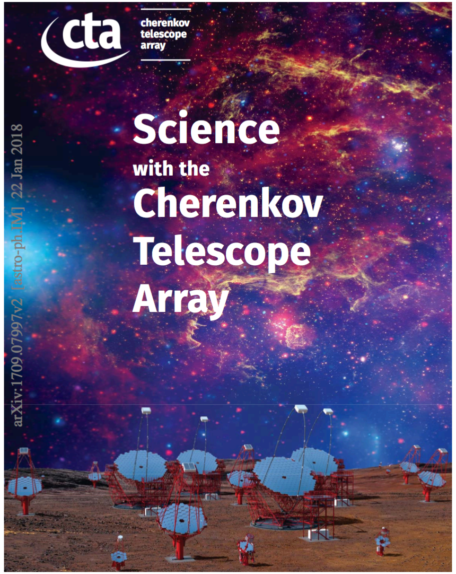
Observation times for follow-up targets

- Defined in the Transients Key Science Projects
  - First estimate for observation time allocated by the CTA observatory
  - Adjustments and updates are currently being discussed

		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	

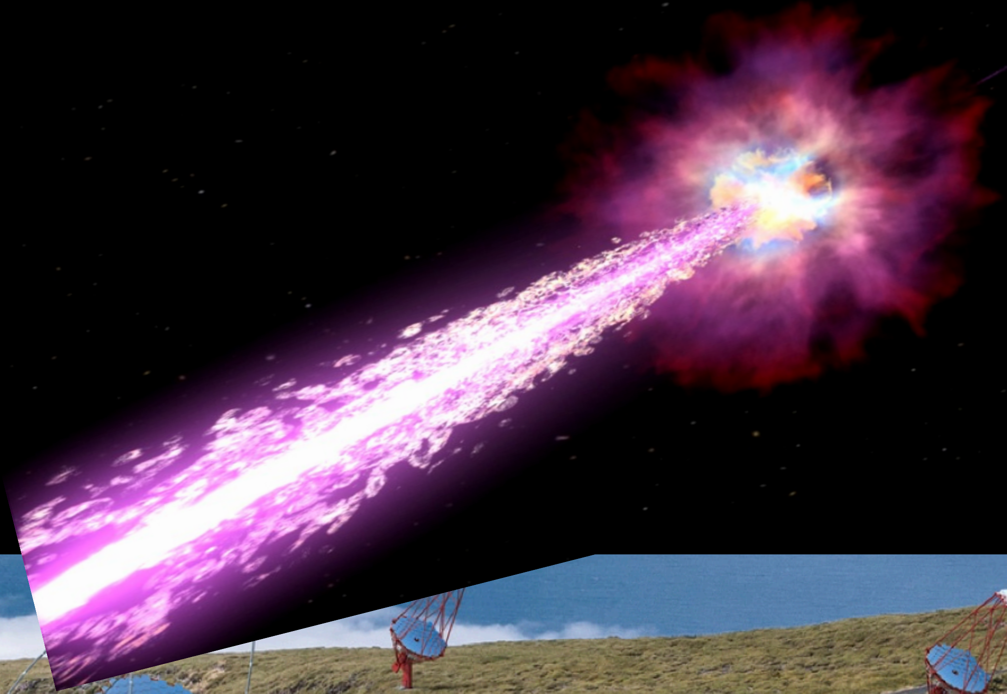
Conclusion & Outlook

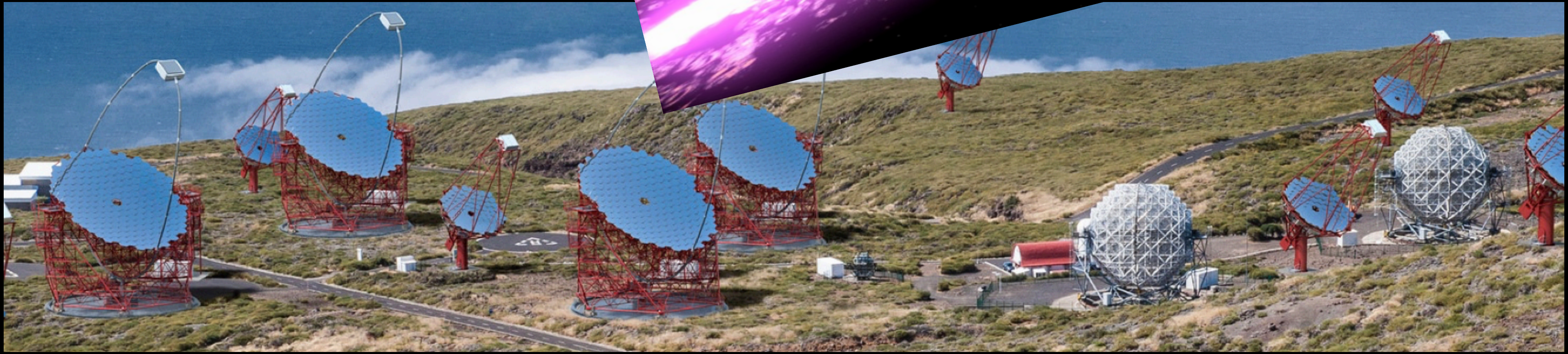
- CTA will provide: Low energy threshold, better sensitivity, all sky coverage
  - → Increased transient sources detection rate
  - → Broader & better energy spectra
- Real time analysis will be useful for scientific community
  - → Sending automatic alerts through GCNs, for example
- Divergent pointing possible → FoV increases from ~5 deg to ~20 deg
  - → Possibility for detection of GRBs from t_0



"Science with CTA" Consortium paper, World Scientific, 10.1142/10986 arxiv:1709.07997

Thank you!





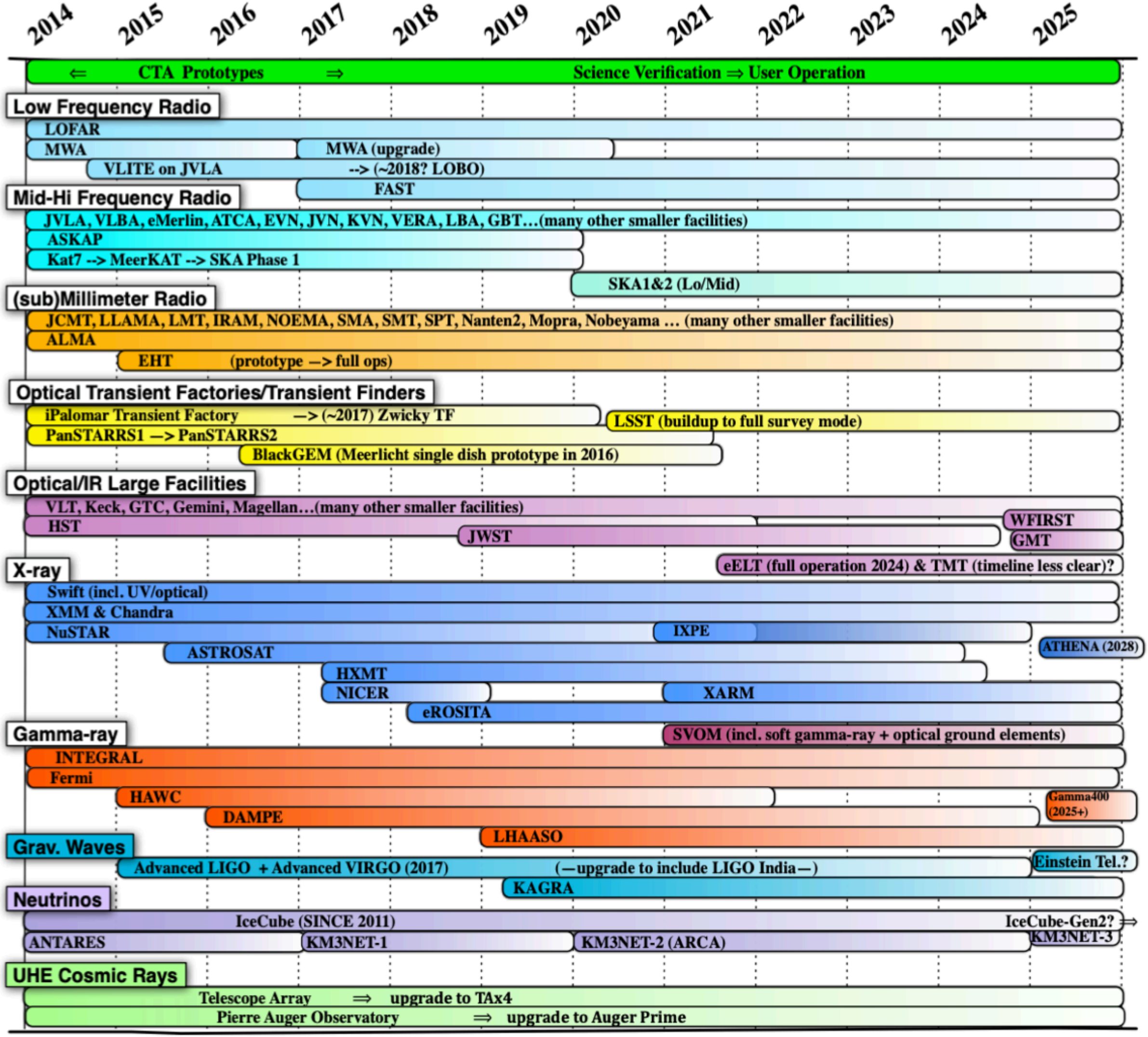
Back-up

CTA synergies

CTA will be fully operative in the golden era of **multi-messenger** astronomy and a fully mature era of **MW astronomy**

CTA Real-Time Analysis with **rapid communication** of some preliminary information is the key system

D. Hadasch



GRB detection with MAGIC and H.E.S.S.

2018

First hint of VHE emission from the short GRB 160821B@z=0.16 (Berti+2018, 15° Marcel Grossman meeting 2018)

- MAGIC follow-up of started at T0+24 s
- **Hints of gamma-ray signal at >500 GeV found few hours after the burst**

Jan 2019

First strong detection from long GRB 190114C@z=0.42 (Mirzoyan et al. 2019, Atel#12390)

- MAGIC follow-up of started at T0+50 s
- **>20 sigma in the first 20 min for energies >300 GeV**

Afternoon:
Susumu Inoue

May 2019

Long GRB 180720B@z=0.654 (Ruiz-Velasco, CTA Symposium 2019)

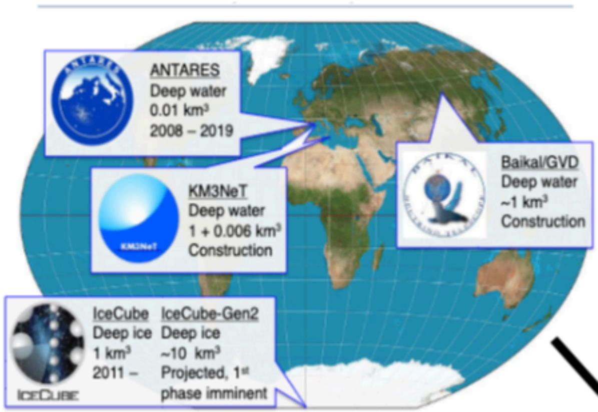
- H.E.S.S. follow-up started ~10hr after the burst trigger

Aug 2019

Long GRB 190829A@z=0.0785 (de Naurois et al. 2019, GCN 25566)

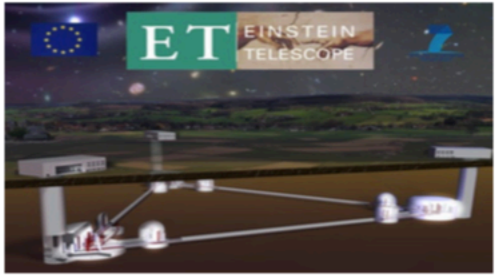
- H.E.S.S. follow-up started at T0+4h20 and lasted 3.5h
- **>5 sigma gamma-ray excess**

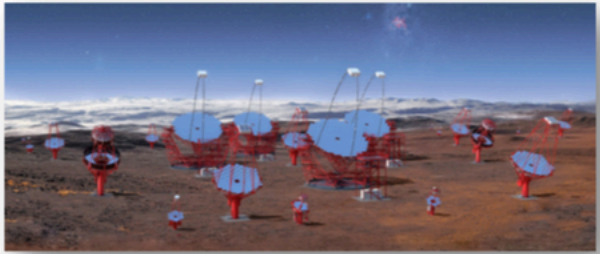
Transient sources and CTA: synergies ('30s)



Neutrino detectors major upgrades will be completed by that time

Will provide GRB alerts by '30s (still under evaluation at ESA, selection by 2021, launch by 2032)

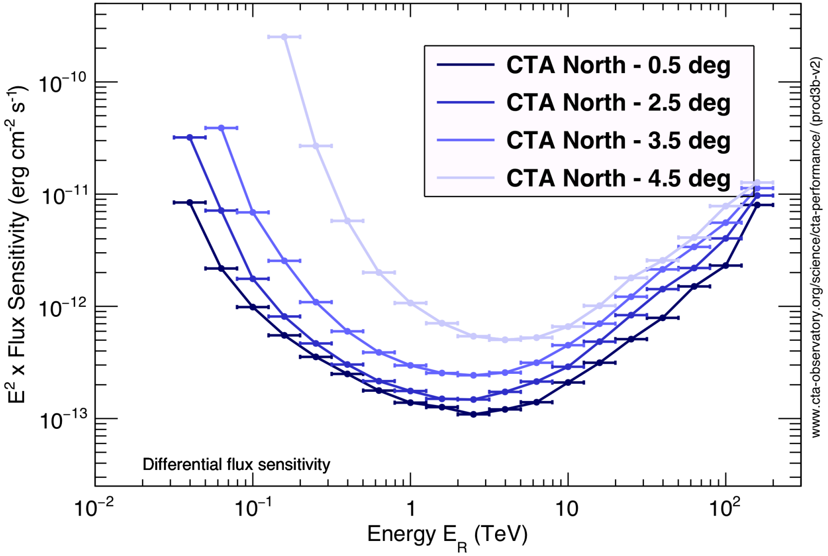


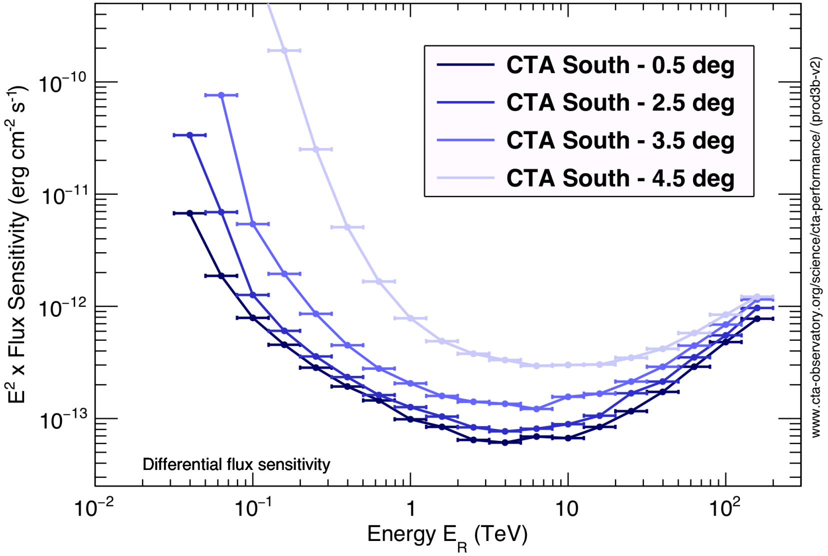


3rd generation GW interferometers (>2030) expected to detect GWs for all detectable short GRBs (and possibly for a fraction of long GRBs)

Slide from G. Stratta 2019

Off-Axis sensitivity





Angular resolution