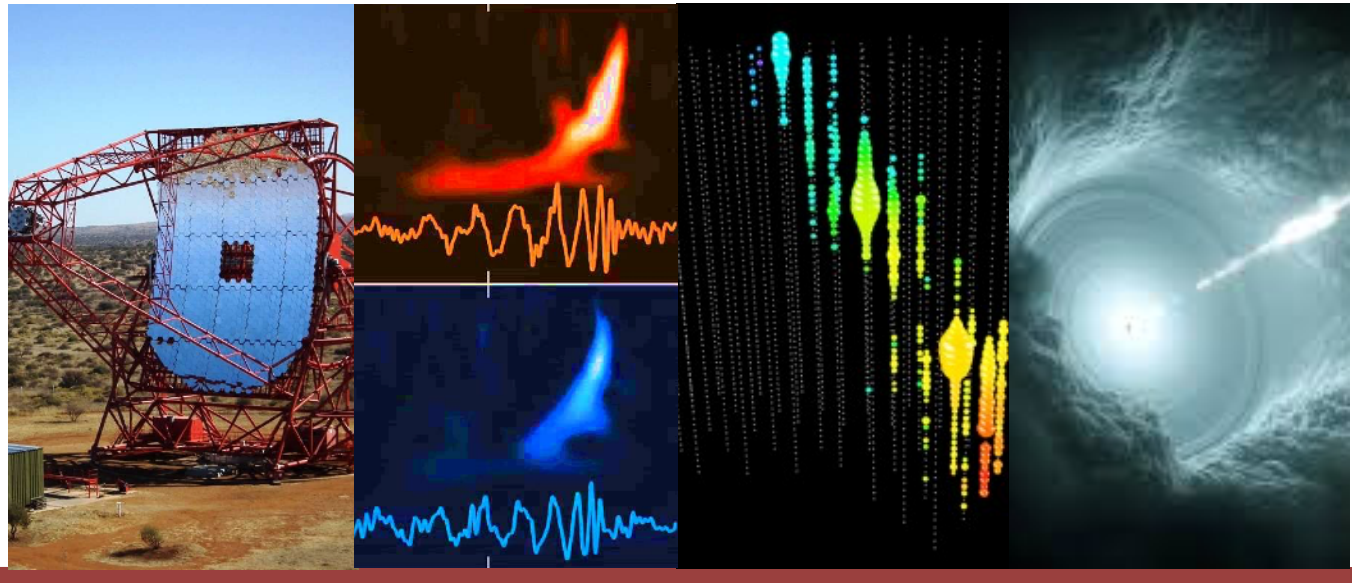


Running Cherenkov telescopes

Matteo Cerruti

Université de Paris

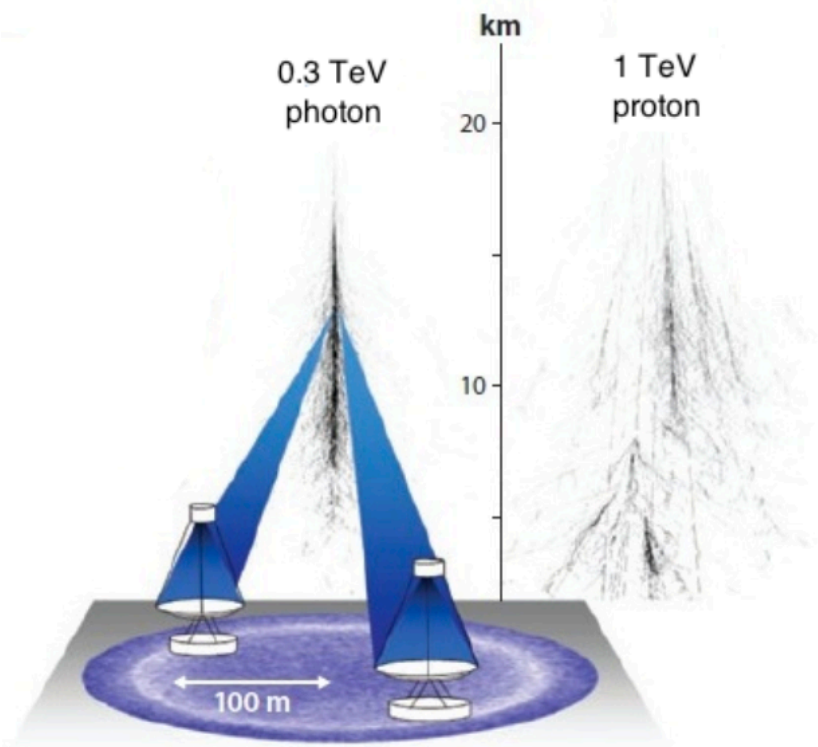
Astroparticules et Cosmologie (APC)

Low-latency alerts and data analysis
for multi-messenger astrophysics

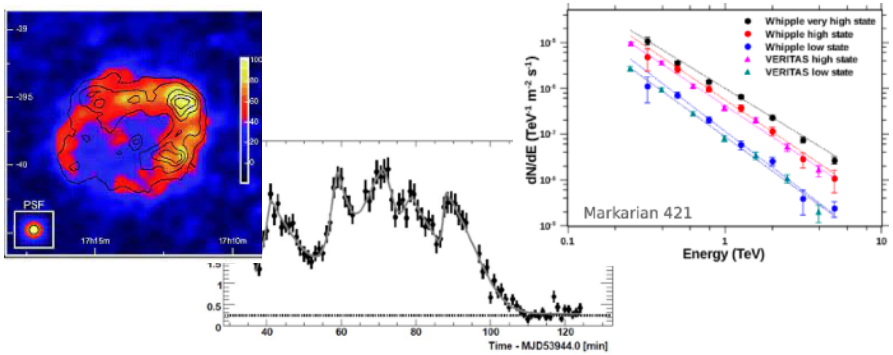
January 13, 2022

CHERENKOV TELESCOPES

Measurement of Cherenkov light produced by the interaction of TeV photons with the Earth's atmosphere



- Background subtraction & identification of gamma-like showers
- Estimation of incoming direction and energy
- Reconstruction of spectra, sky maps, light-curves

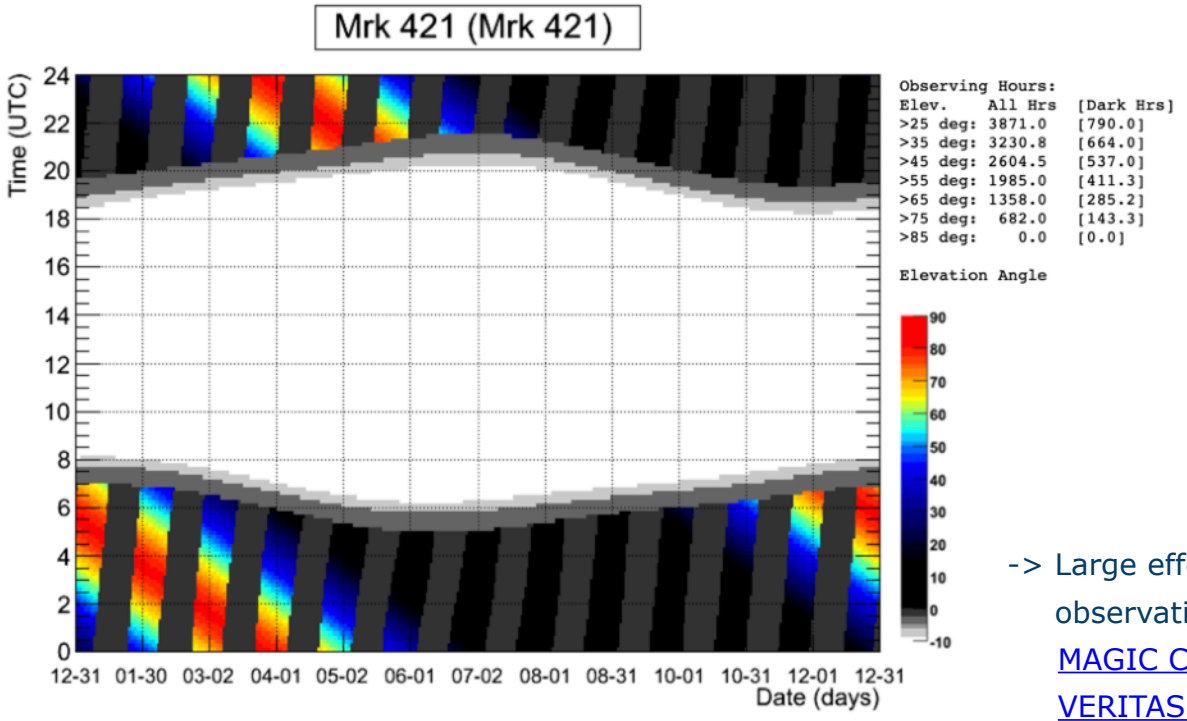


- Energy band: ~100 GeV - 100 TeV
- Energy resolution: ~10% at 1 TeV
- Angular resolution: <0.1º at 1 TeV
- Field of View: 3º - 5º

CHERENKOV TELESCOPES

CHERENKOV TELESCOPES

Observational constraints:
1) we observe with DARK sky only



Visibility plot of Mrk 421 from MAGIC site (tevcat.uchicago.edu)

-> Large efforts by all collaborations to extend observations into moonlight.

MAGIC Collaboration 2017

VERITAS Collaboration 2017 & 2015

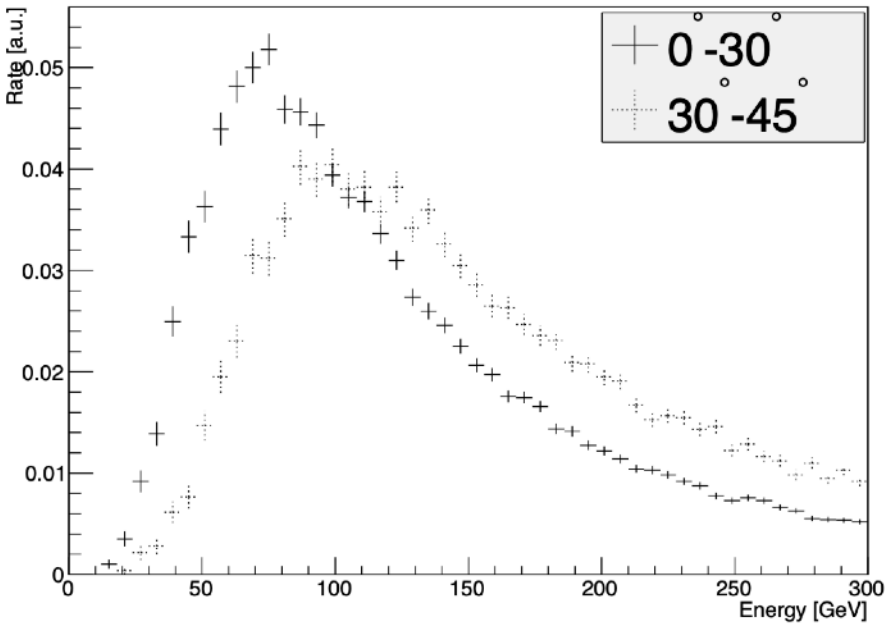
HESS too (no publication yet)

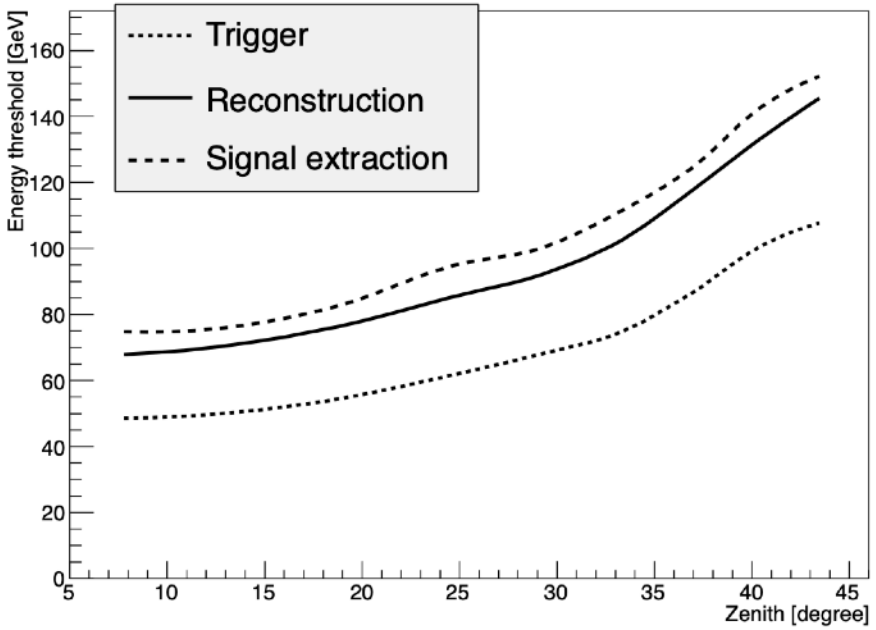
FACT camera can observe under moonlight

CHERENKOV TELESCOPES

Observational constraints:

2) the lower the zenith angle, the higher the energies



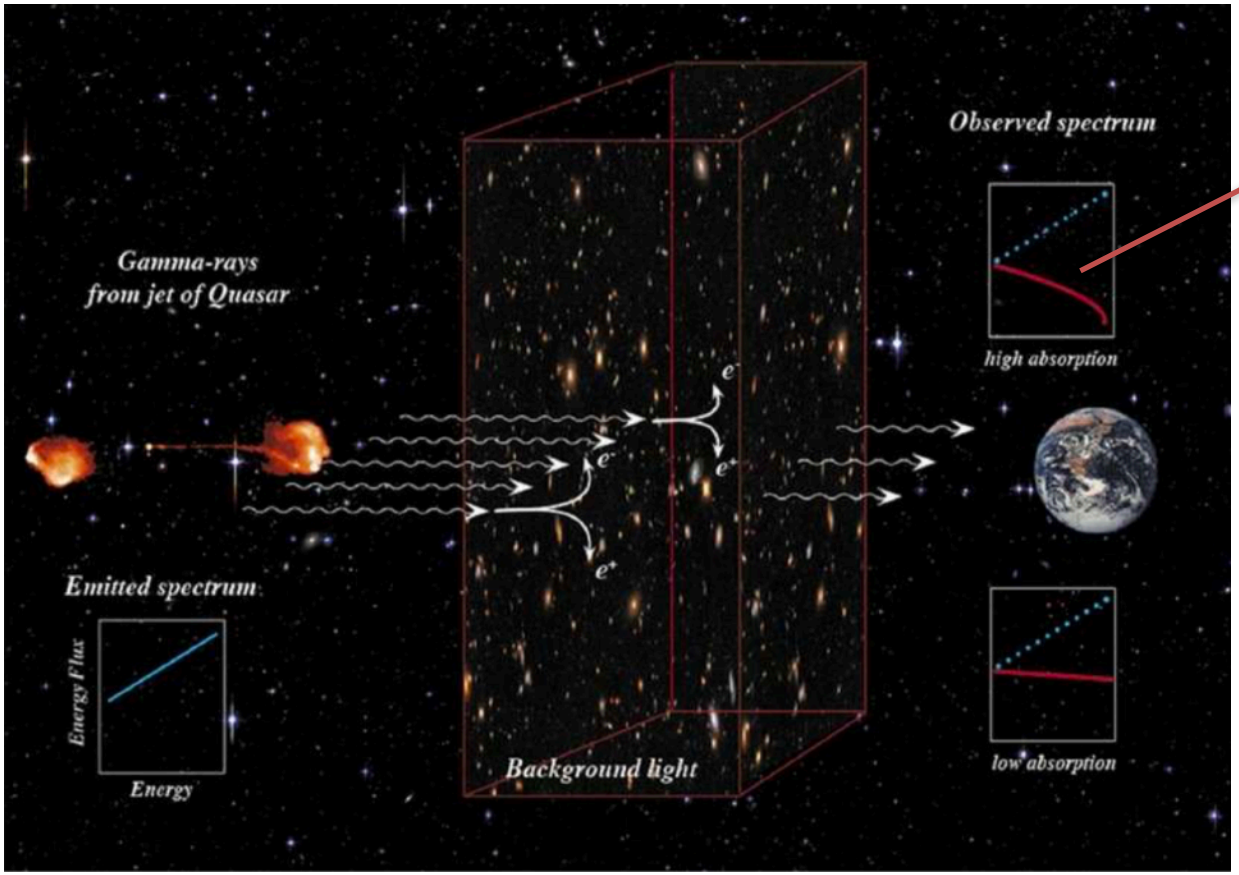


MAGIC Collaboration 2016

CHERENKOV TELESCOPES

Observational constraints:

3) the Universe is opaque to TeV photons



The more distant, the redder

Most distant published detection:

S3 0218+35 (z=0.95)

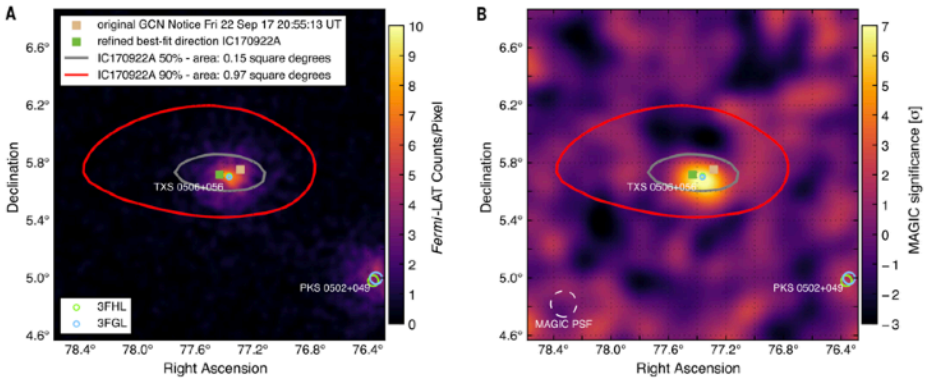
Most distant preliminary detection:

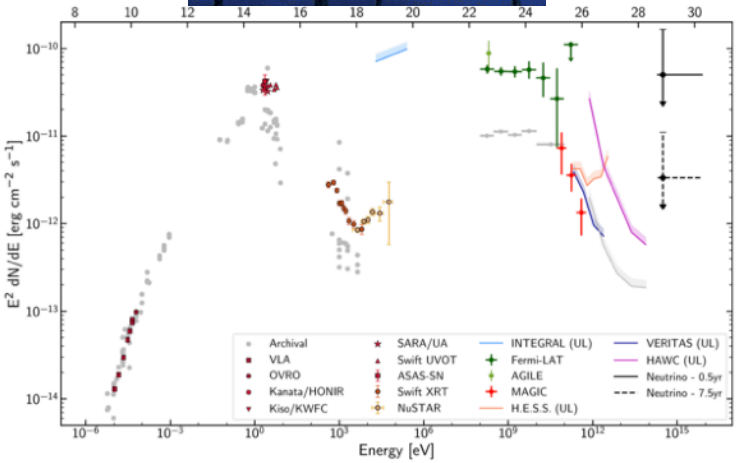
GRB 201216C (z=1.1)

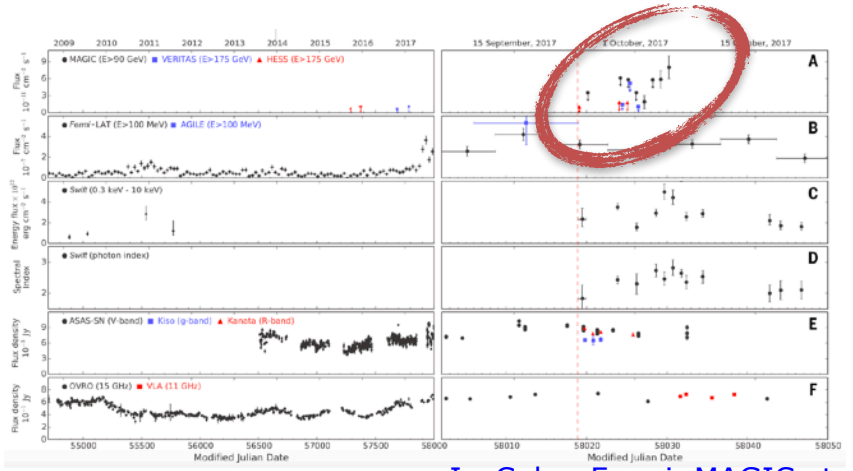
PKS 0346-27 (z=0.99)

IACTs IN THE MULTI-MESSENGER NEWS

Most significant association (3σ)
of a high-energy (290 TeV) neutrino with an astrophysical source







[IceCube, Fermi, MAGIC et al. 2018]

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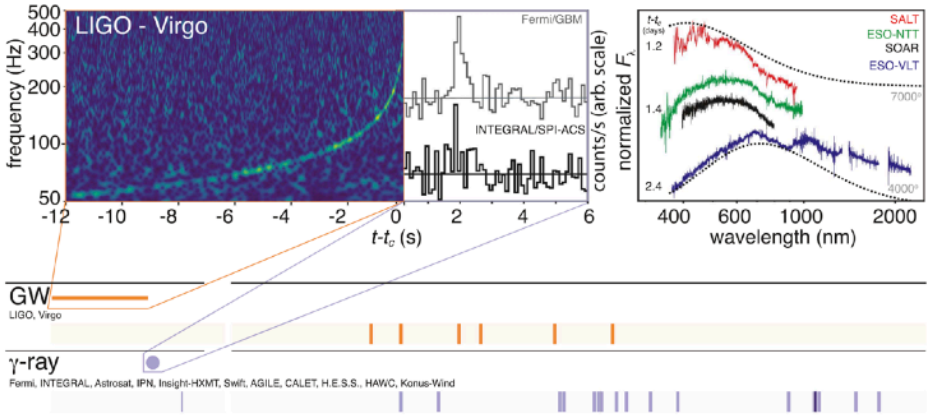
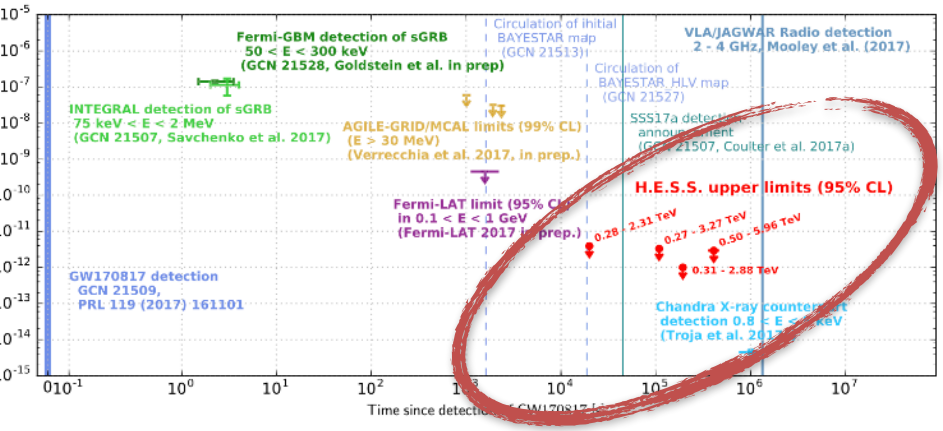
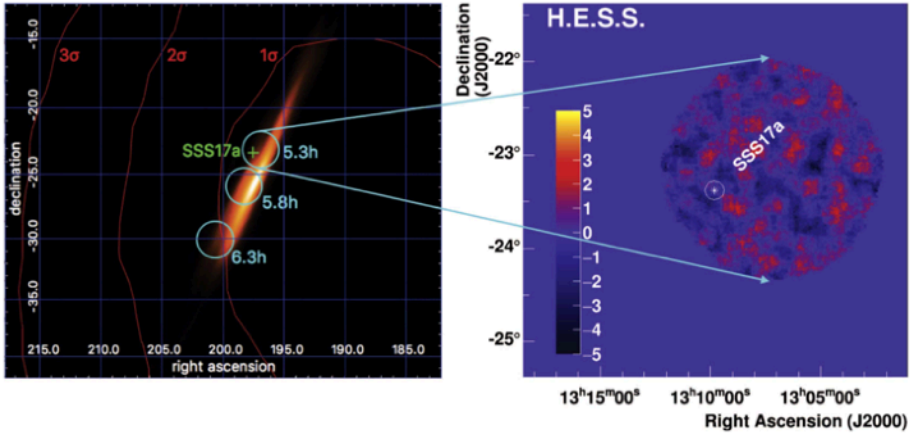
IACTs IN THE MULTI-MESSENGER NEWS

First multi-messenger campaign on neutron star mergers





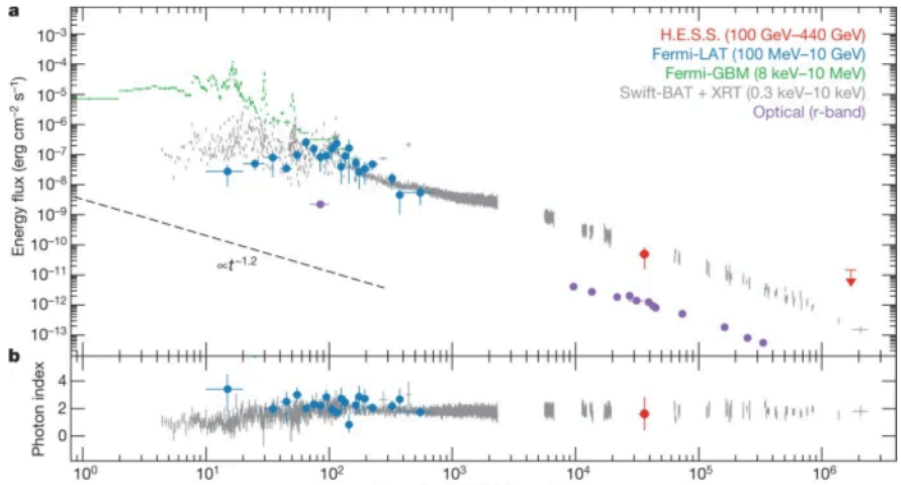


[LIGO-VIRGO+++ 2017]
[HESS Collaboration 2017]

IACTs IN THE (MULTI-MESSENGER) NEWS

GRBs in the TeV band (not multi-messenger yet)

Fig. 1: Multi-wavelength light curve of GRB 180720B.



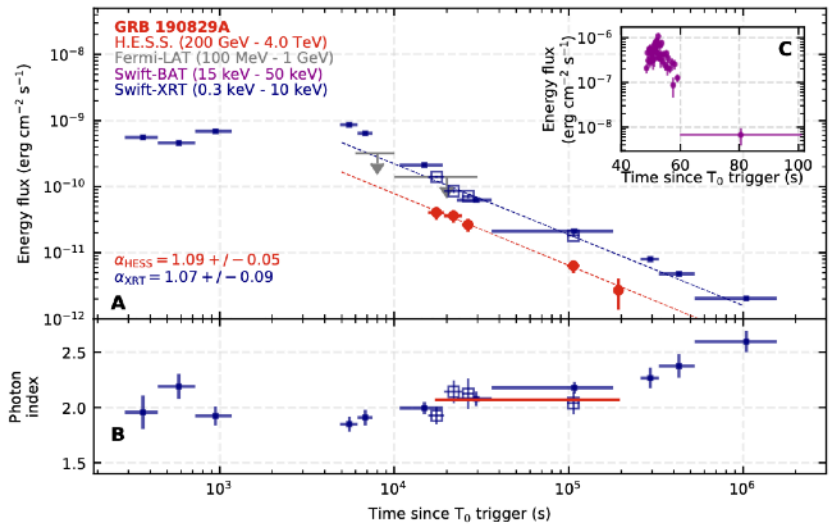
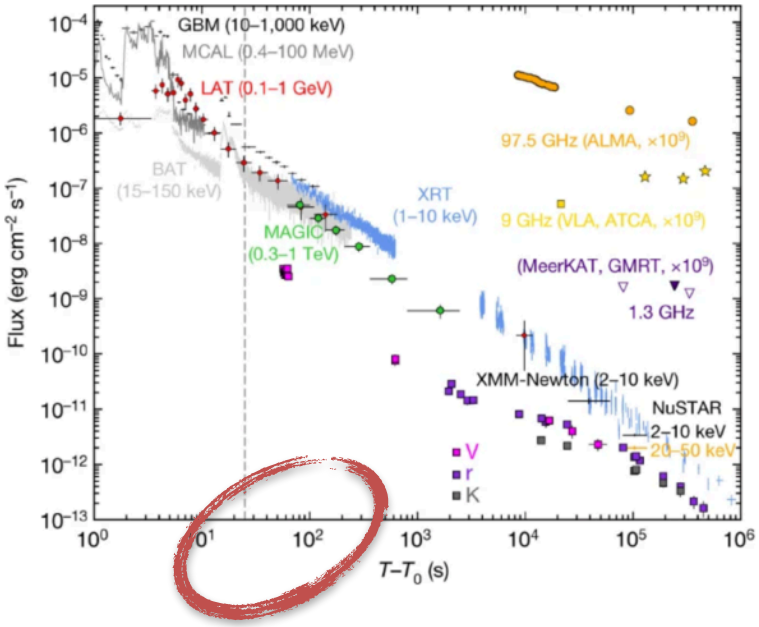


Fig. 1: Multi-wavelength light curves of GRB 190114C.



[HESS Collaboration 2019](#) & [2021](#)

[MAGIC Collaboration 2019](#)

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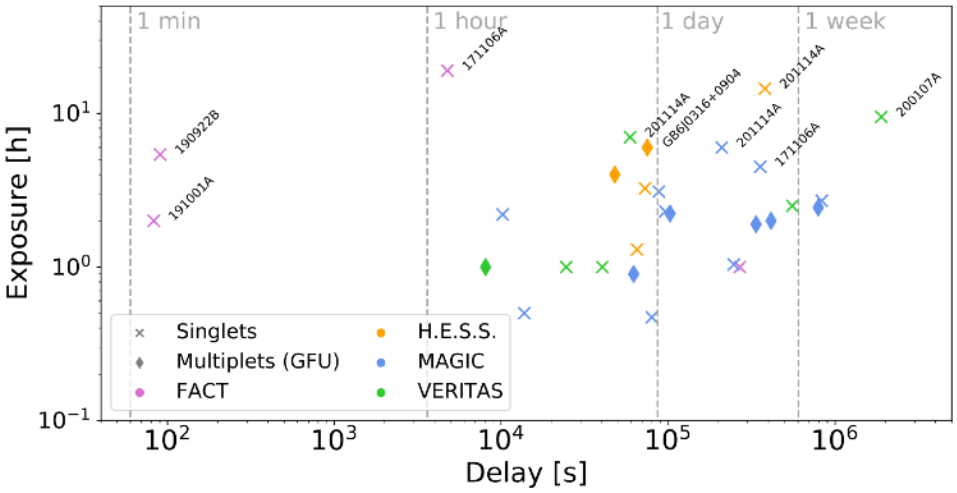
RECEIVING ALERTS: NEUTRINOS

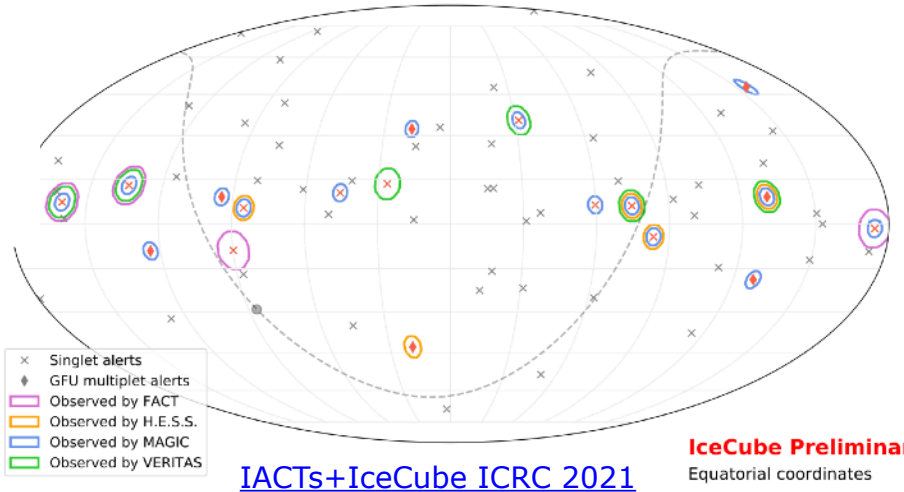
Follow-up of IceCube alerts:

- public alerts on high-energy single events
- Gamma-ray Follow Up (GFU) program



Automatic repointing if the location is visible during data taking

Otherwise rescheduled on best-effort



IACTs+IceCube ICRC 2021

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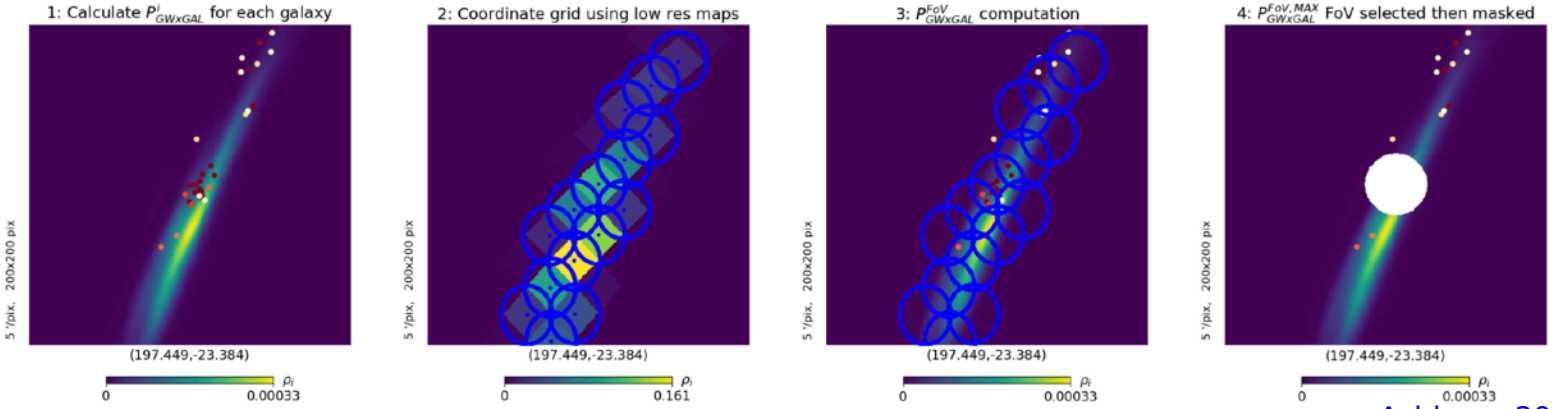
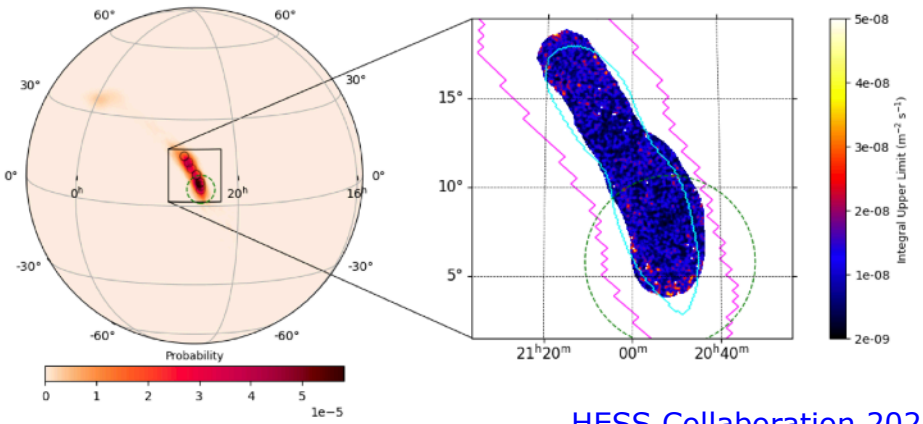
RECEIVING ALERTS: GW

Follow-up of gravitational alerts:

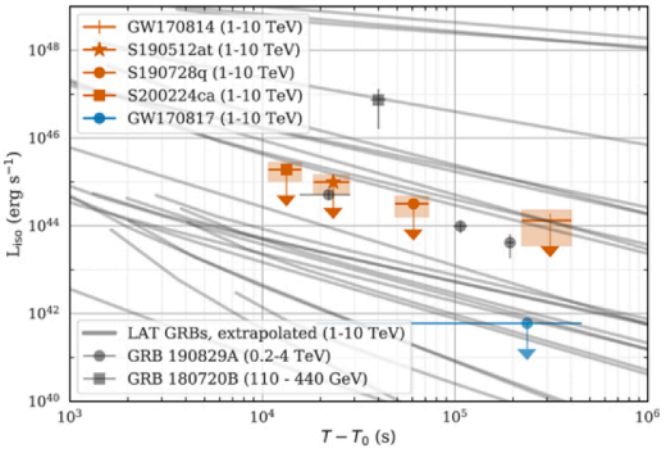
- large uncertainty region requires automatic tools to optimize the mapping



Ashkar+ 2021



HESS Collaboration 2021



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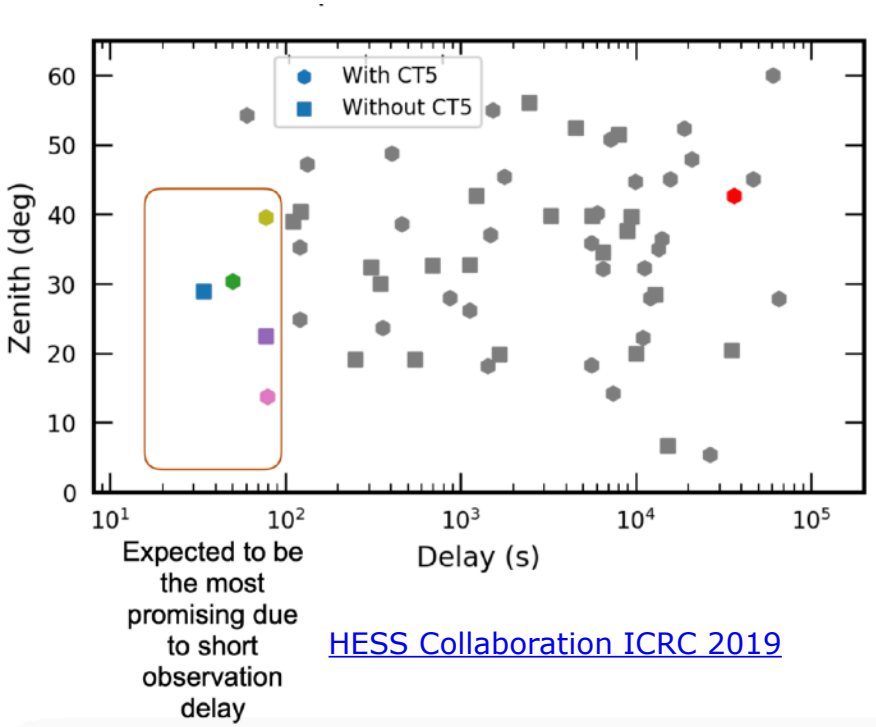
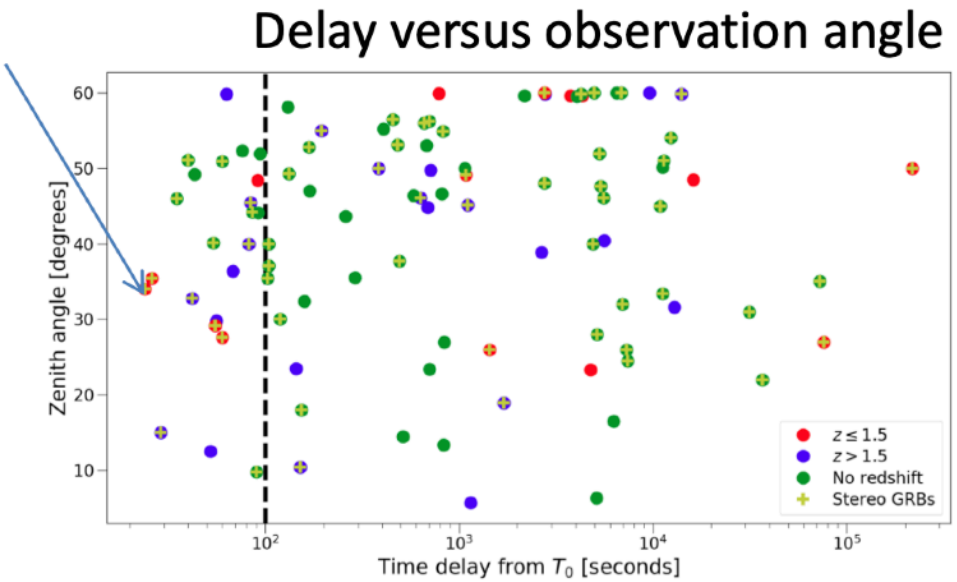
RECEIVING ALERTS: GRBs

GRB reaction time



HESS Collaboration ICRC 2019



MAGIC Collaboration ICRC 2019

RECEIVING ALERTS: LST

A new running IACT: CTA - LST1

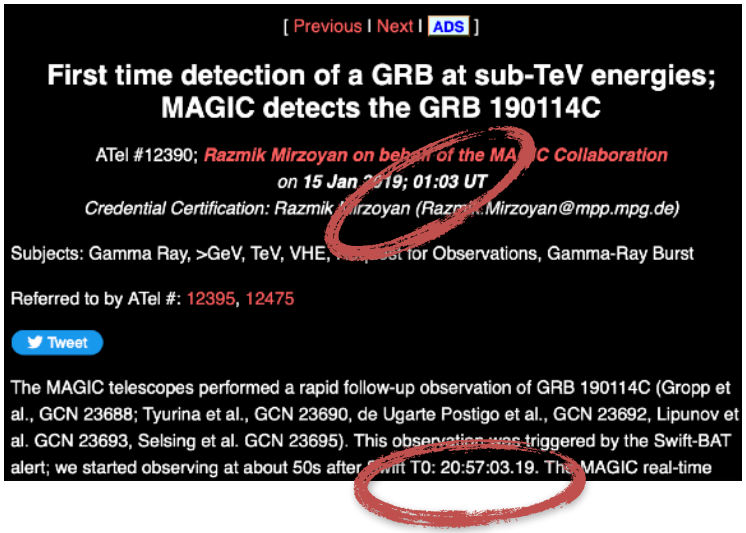
CTA-LST Collaboration ICRC 2021

	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

SENDING ALERTS

All IACTs have ***Real Time Analysis*** tools

Significance map in real time and capability to send alerts to the world
For bright and out-of-doubts signal reaction time can be fast


[Previous | Next | ADS]

First time detection of a GRB at sub-TeV energies; MAGIC detects the GRB 190114C

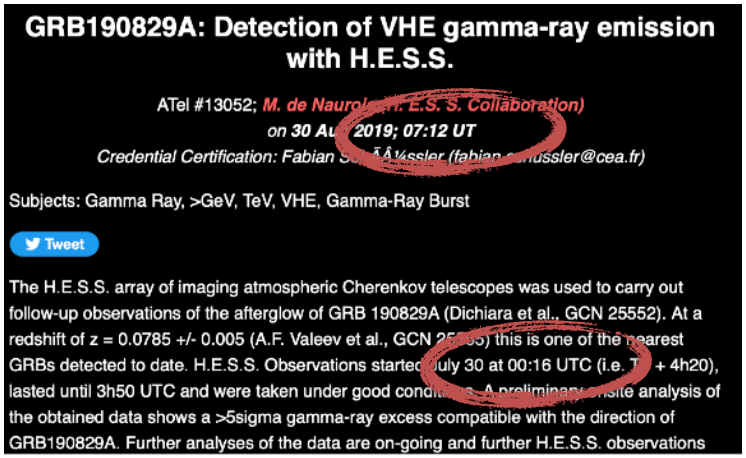
ATel #12390; *Razmik Mirzoyan on behalf of the MAGIC Collaboration*
on 15 Jan 2019; 01:03 UT
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Gamma Ray, >GeV, TeV, VHE, ToO, Request for Observations, Gamma-Ray Burst

Referred to by ATel #: 12395, 12475

Tweet

The MAGIC telescopes performed a rapid follow-up observation of GRB 190114C (Gropp et al., GCN 23688; Tyurina et al., GCN 23690, de Ugarte Postigo et al., GCN 23692, Lipunov et al. GCN 23693, Selsing et al. GCN 23695). This observation was triggered by the Swift-BAT alert; we started observing at about 50s after Swift T0: 20:57:03.19. The MAGIC real-time


GRB190829A: Detection of VHE gamma-ray emission with H.E.S.S.

ATel #13052; *M. de Naurois on behalf of the H.E.S.S. Collaboration)*
on 30 August 2019; 07:12 UT
Credential Certification: Fabian Schüssler (fabian.schussler@cea.fr)

Subjects: Gamma Ray, >GeV, TeV, VHE, Gamma-Ray Burst

Tweet

The H.E.S.S. array of imaging atmospheric Cherenkov telescopes was used to carry out follow-up observations of the afterglow of GRB 190829A (Dichiara et al., GCN 25552). At a redshift of z = 0.0785 +/- 0.005 (A.F. Valeev et al., GCN 25555) this is one of the nearest GRBs detected to date. H.E.S.S. Observations started July 30 at 00:16 UTC (i.e. T0 + 4h20), lasted until 3h50 UTC and were taken under good conditions. A preliminary on-site analysis of the obtained data shows a >5sigma gamma-ray excess compatible with the direction of GRB190829A. Further analyses of the data are on-going and further H.E.S.S. observations

MoU among IACTs on pre-defined list of *known* TeV blazars and pre-defined thresholds

Communication by email among shift crews

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CONCLUSIONS

All running IACTs have very active transients programs with specific focus on multi-messenger follow-ups

TeV data included in major multi-messenger campaigns in the last years

* On the receiving part, we can react down to sub-minute time-scales if the alert is received and visible during data taking

* On the sending part, we rely on real time analysis tools that need validation by humans. Fastest ATel ~4 hours after beginning of data taking