Laboratoire d'Annecy de Physique des Particules

Observations at the tera-electronvolt of the extragalactic sky: a selection of important results

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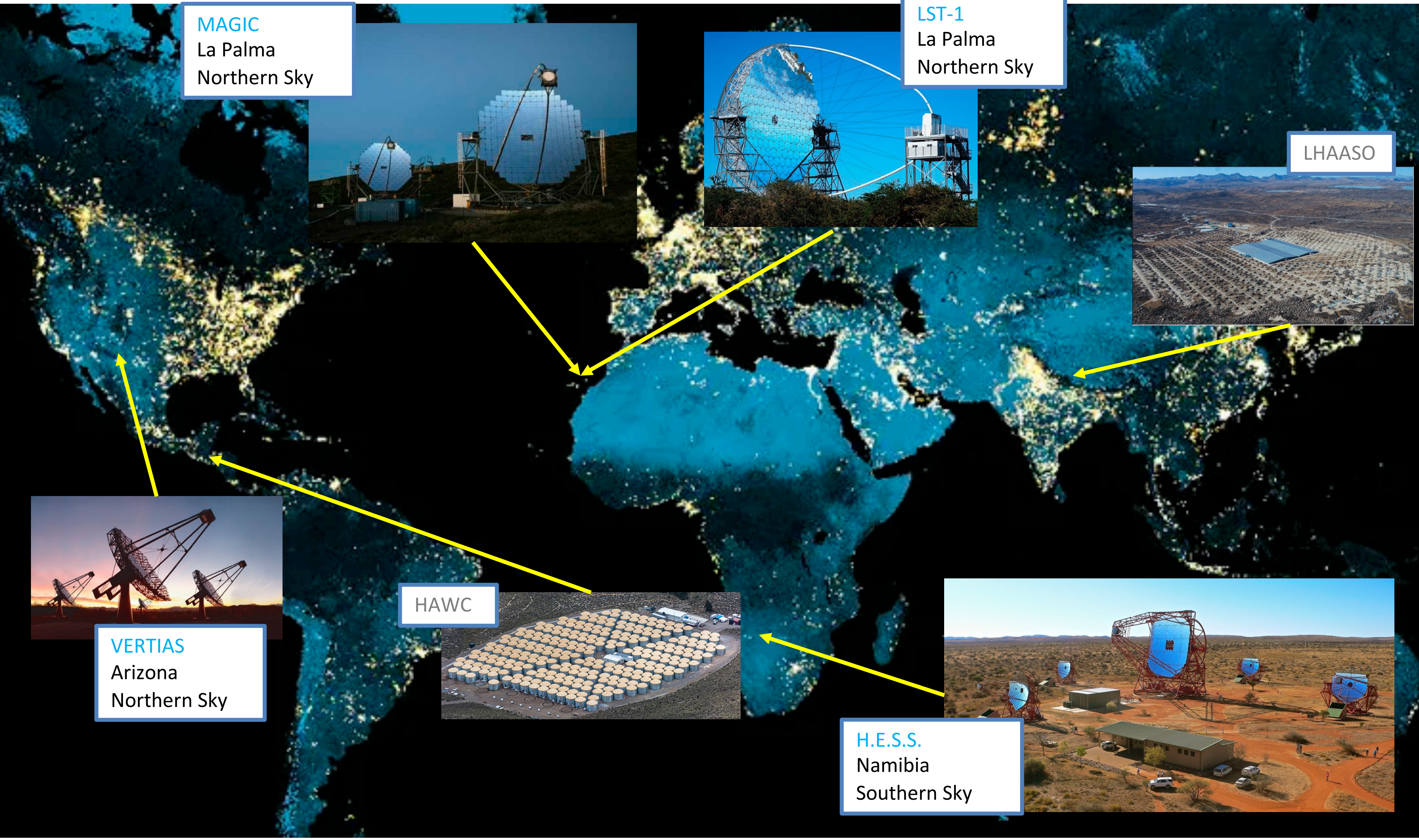
UNIVERSITÉ SAVOIE MONT BLANC

Astrophysics at the Tera-electronvolt

The major VHE experiments



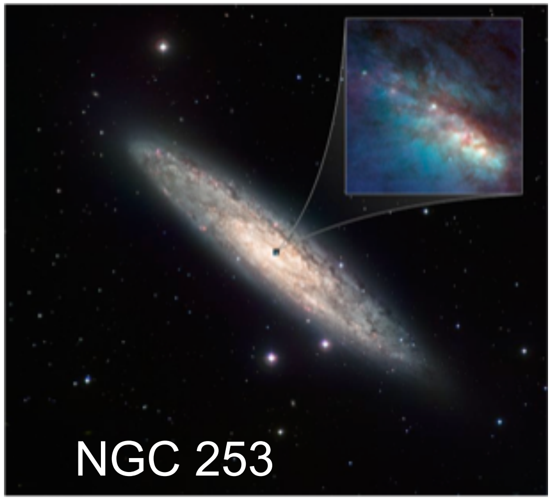
Imaging Atmospheric Cherenkov Telescope

Different types of sources

- Actives Galactic Nuclei
- GRBs
- Starburst

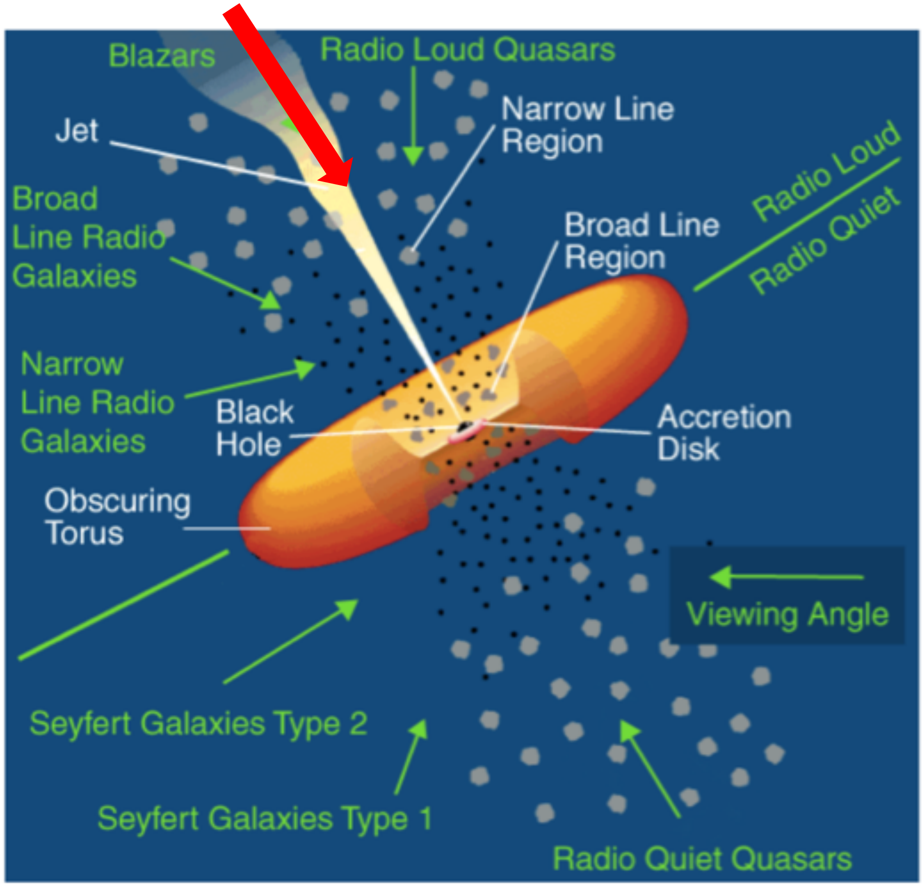
More fundamental physique

- Extragalactic background light
- Lorentz invariance violation
- Axion-like particles, DM



Centaurus A: our close neighbour

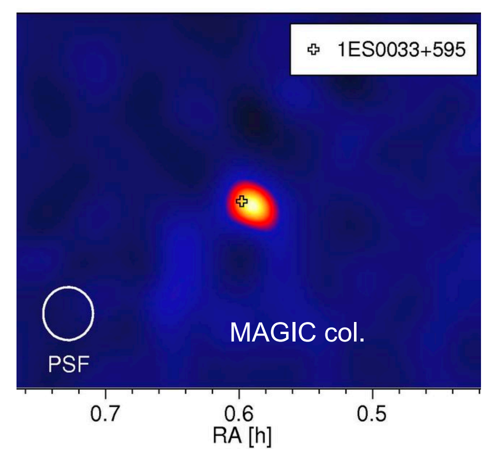
Blazars



- 10% of galaxies are Active
- 10% of AGN have a jet

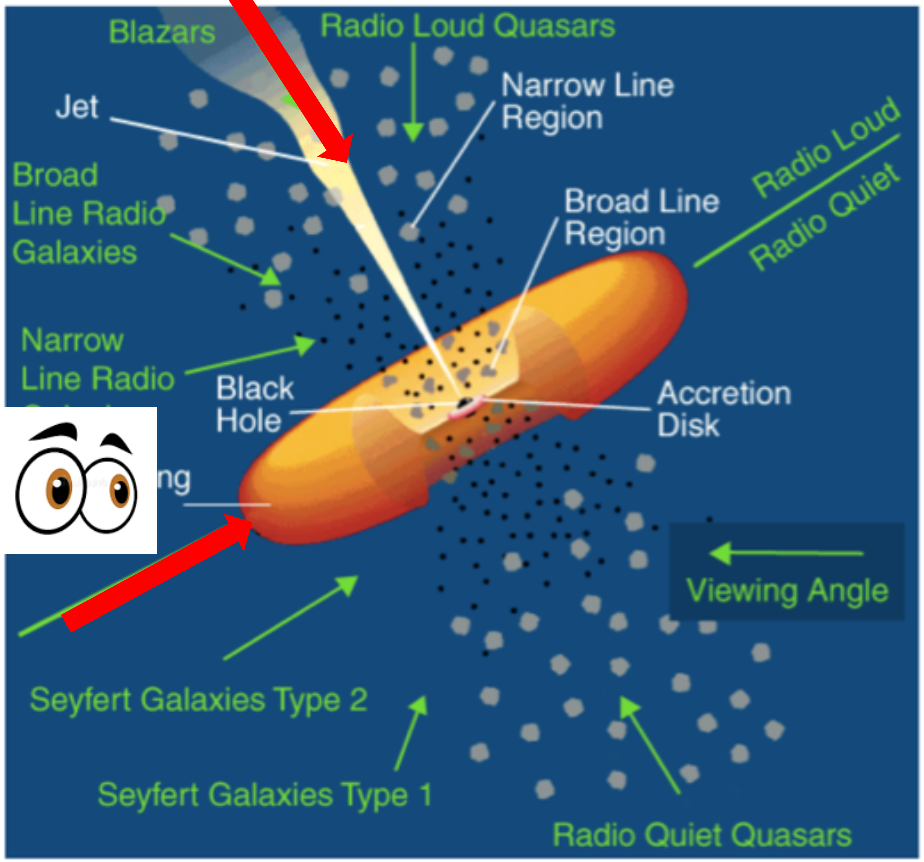
In TeV energies

- 80 Blazars
- 4 Radio-Galaxies
- 2 Unknow types



Blazars can not be resolve by IACTs.
How to locate the emission zone?

Blazars



Radio-Galaxies

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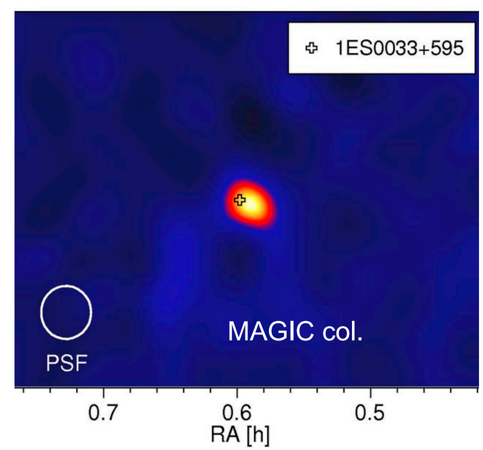


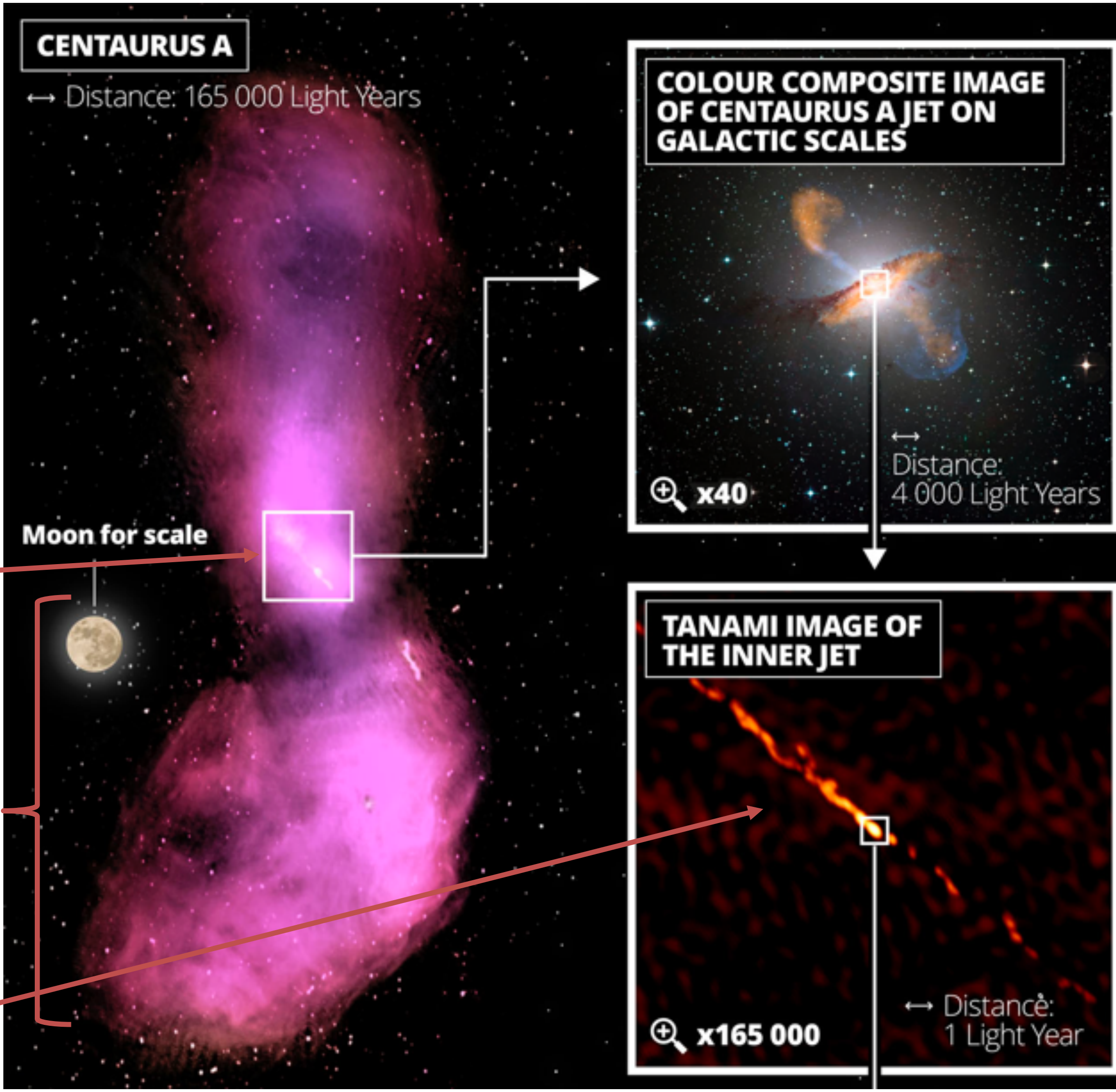
Centaurus A
Radio galaxy (NGC 5128)

-> Nearest active galaxy at a distance of 3.7 Mpc
-> Detailed morphological analysis (1◦ ≃ 65 kpc).

Core

Giant radio lobes

TANAMI Radio data
Müller *et al.*

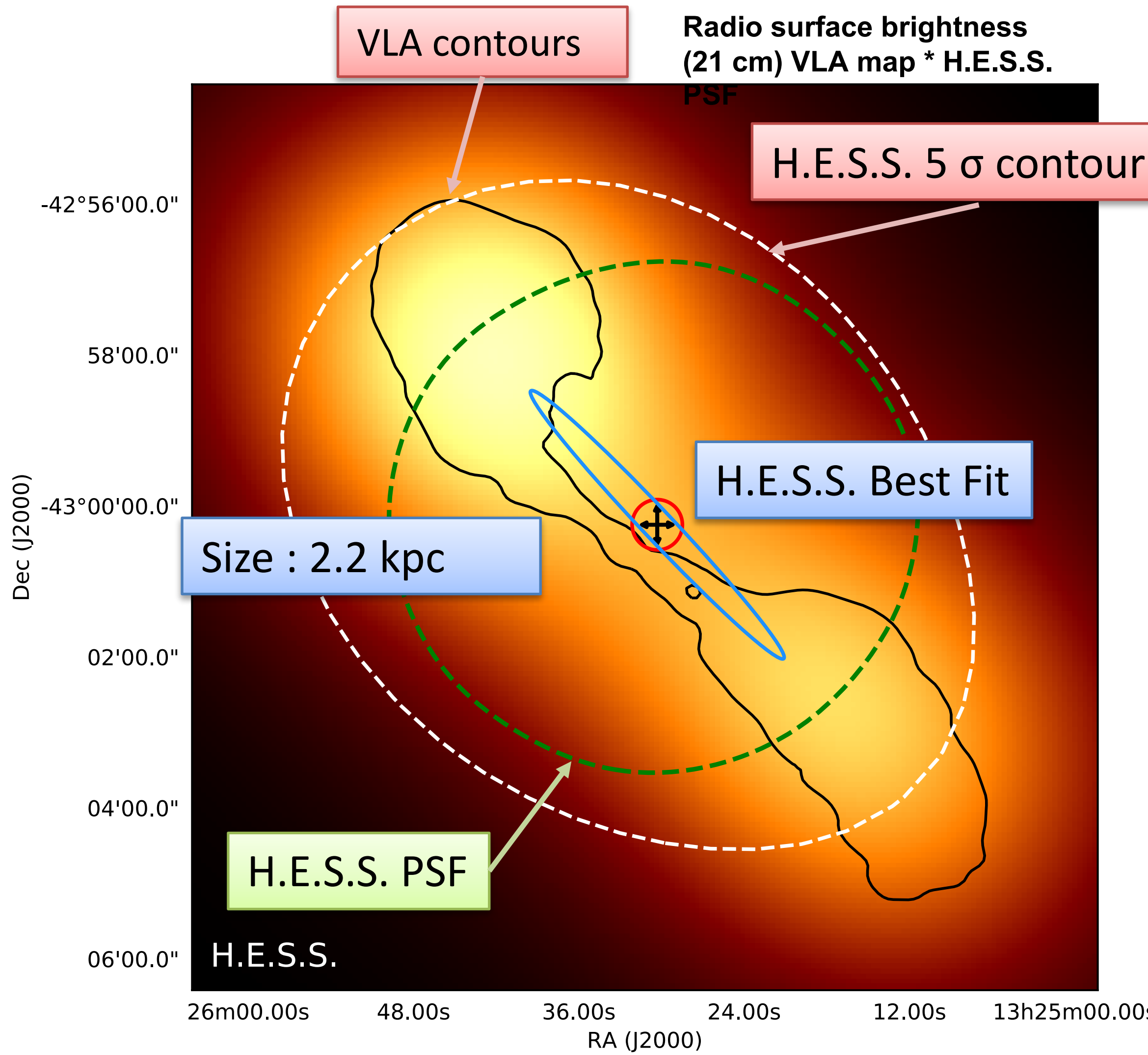


First Extended extragalactic source

- Large data set
- New analysis methods
- Close to the instrument limit

Electron lost energy on scale < 100 pc

The acceleration mechanism has to be distributed along the kpc x-ray jet

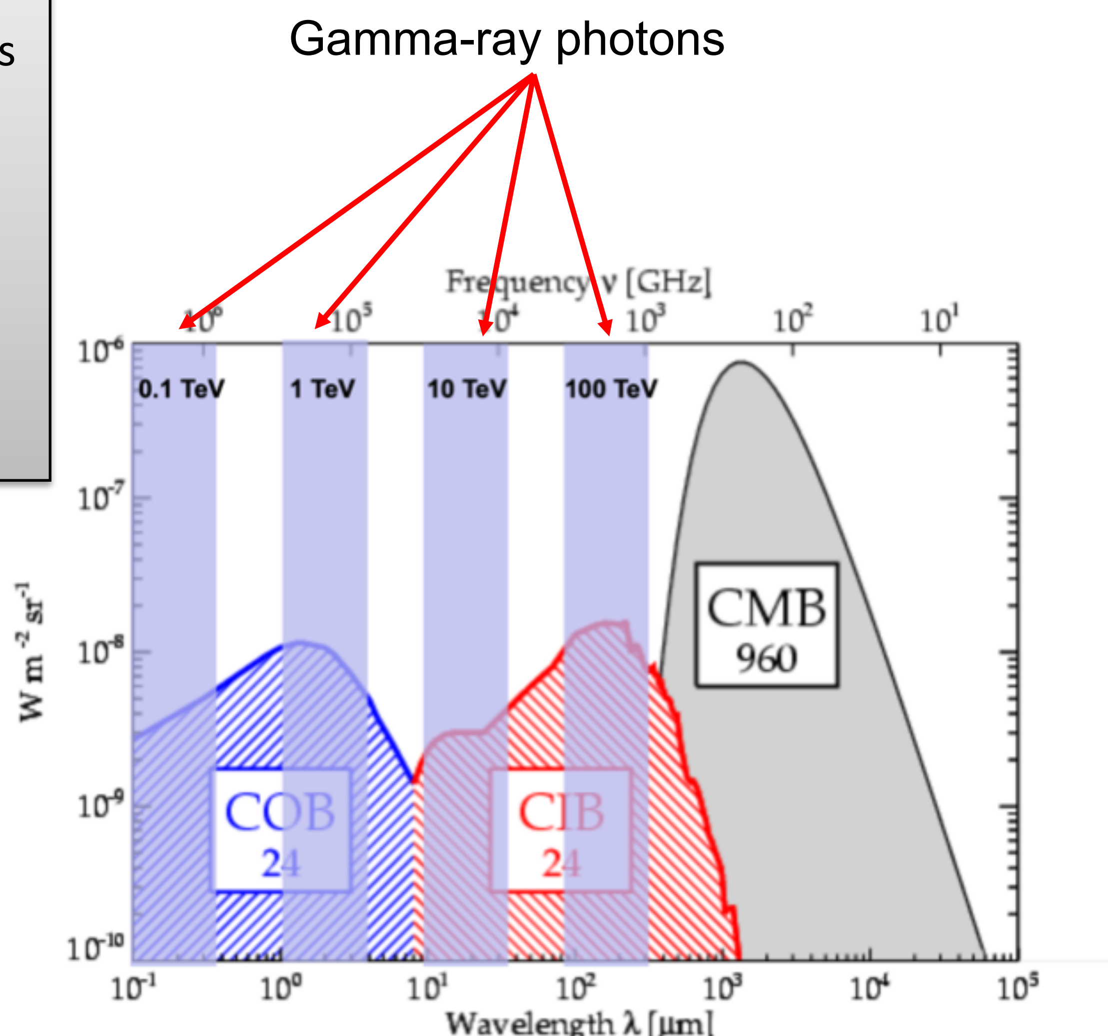


Extragalactic Background light

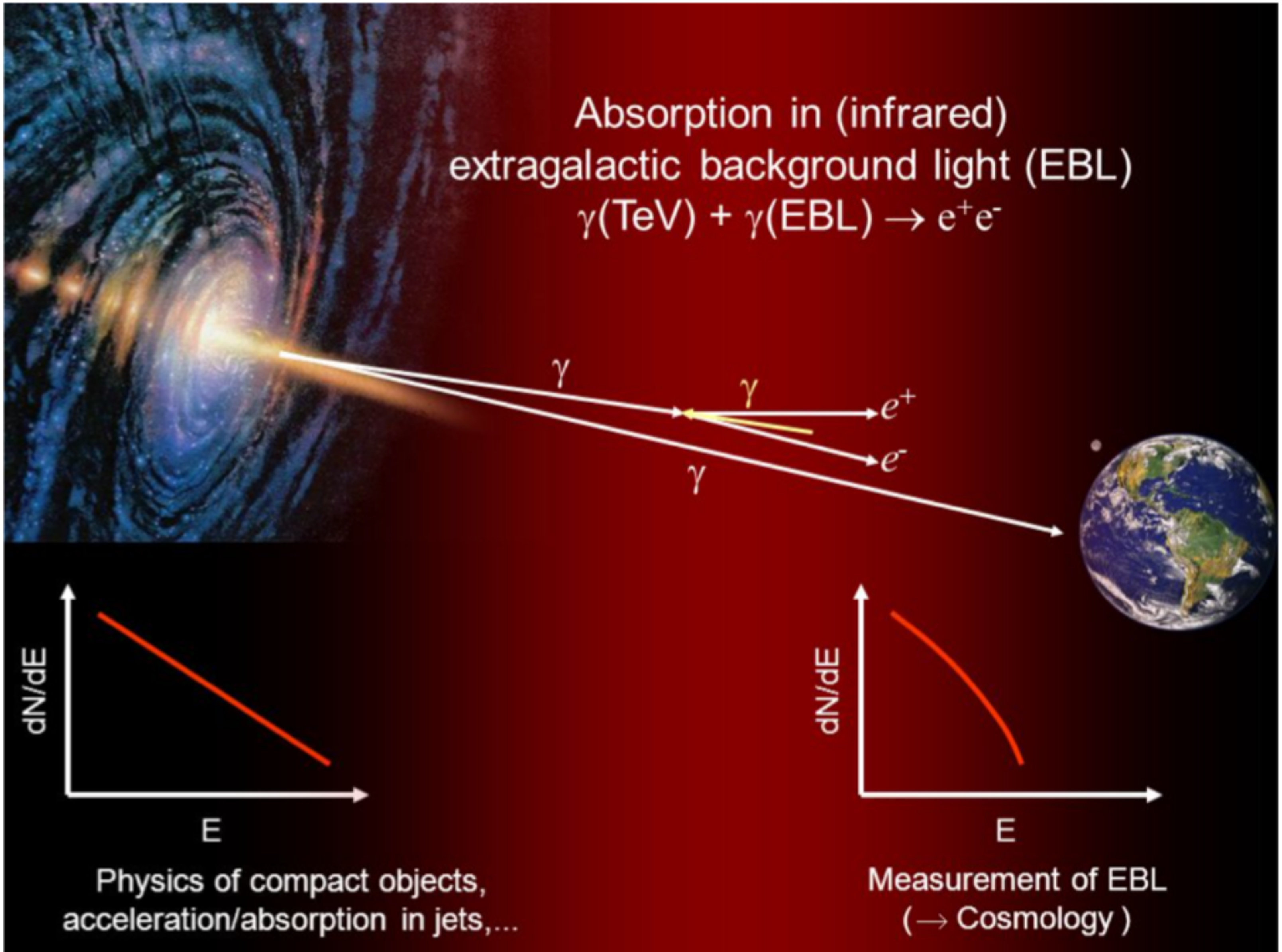
Extragalactic background light

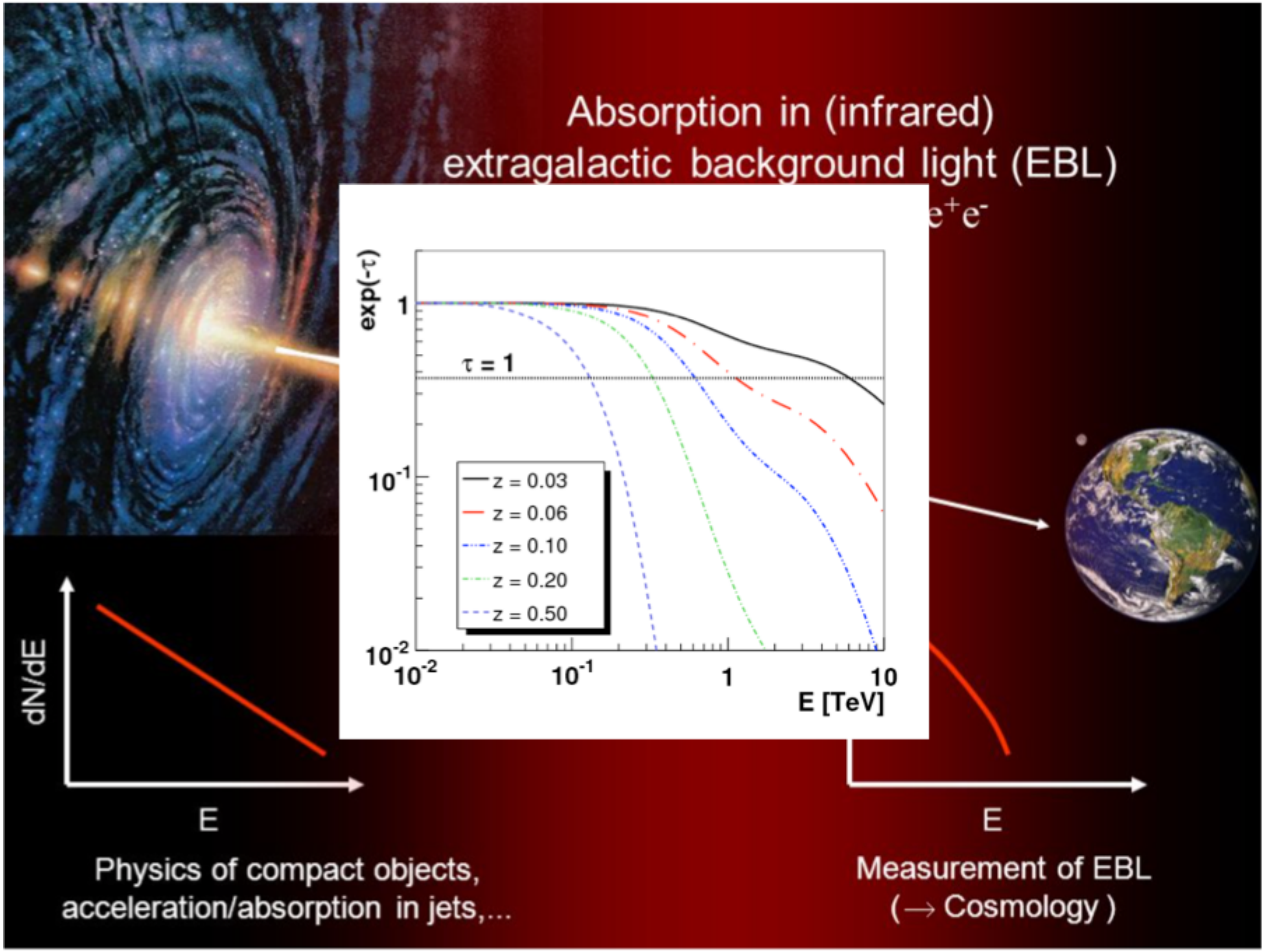
- Infrared light from dust and galaxies
- Difficult to measure it from Earth

- Energy budget of the Universe
- Cosmology
- Galaxies formation and population



Dole et al., 2006

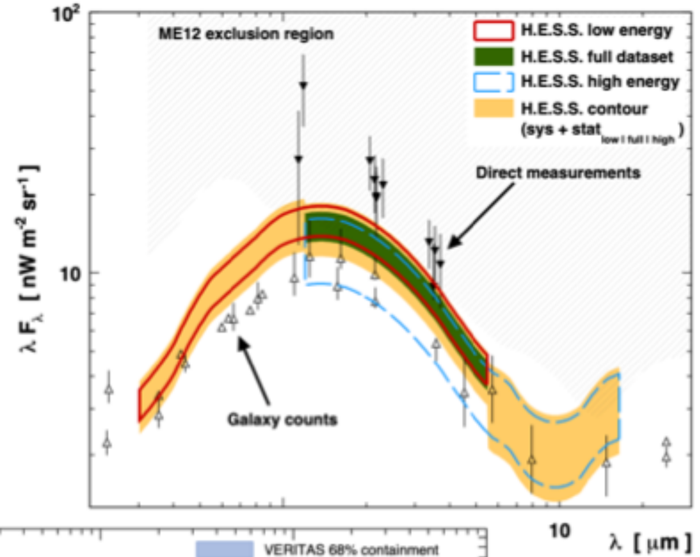

Absorption in (infrared)
extragalactic background light (EBL)
γ(TeV) + γ(EBL) → e⁺e⁻
γ
γ
e+
e-
γ
dN/dE
E
Physics of compact objects,
acceleration/absorption in jets,...
dN/dE
E
Measurement of EBL
(→ Cosmology)


Absorption in (infrared)
extragalactic background light (EBL)
e+e-
exp(-τ)
τ = 1
z = 0.03
z = 0.06
z = 0.10
z = 0.20
z = 0.50
E [TeV]
dN/dE
E
Physics of compact objects,
acceleration/absorption in jets,...
E
Measurement of EBL
(→ Cosmology)

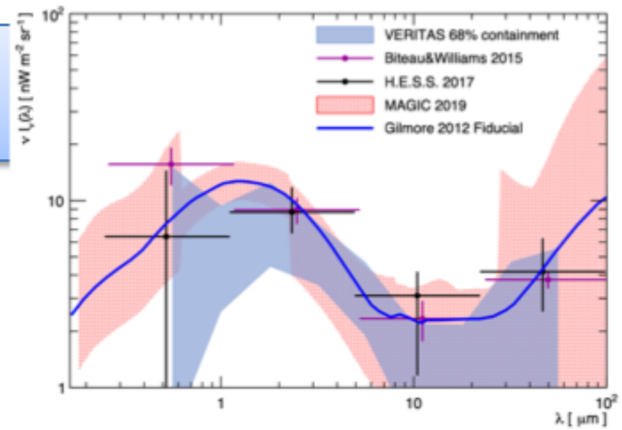
First measurement of EBL at TeV by H.E.S.S.

- Assume EBL model
- measure scale of this EBL model

H.E.S.S. ArXiv 1212.3409



- 9 years of VERITAS observations
- Use a EBL grid models



EBL at z=0
Evolution with z ?

Veritas ArXiv : 1910.00451

First measurement of EBL at TeV by H.E.S.S.

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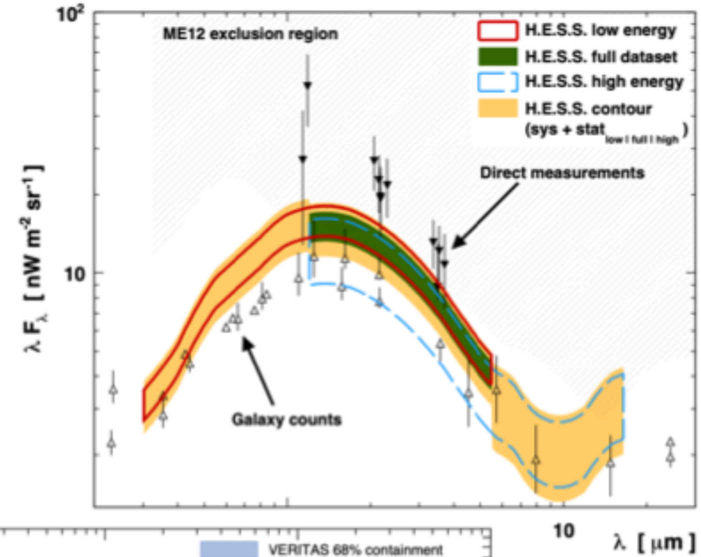
H.E.S.S. ArXiv 1212.3409



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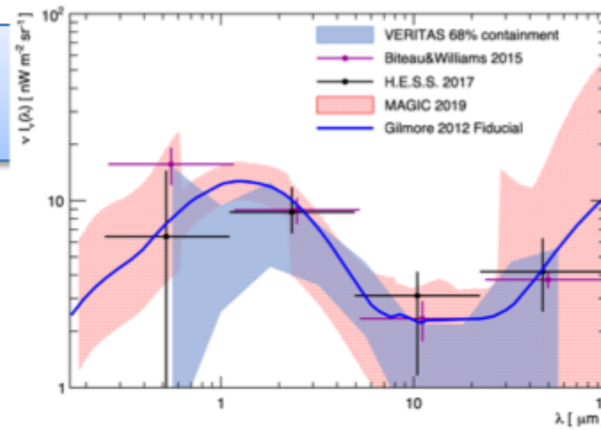

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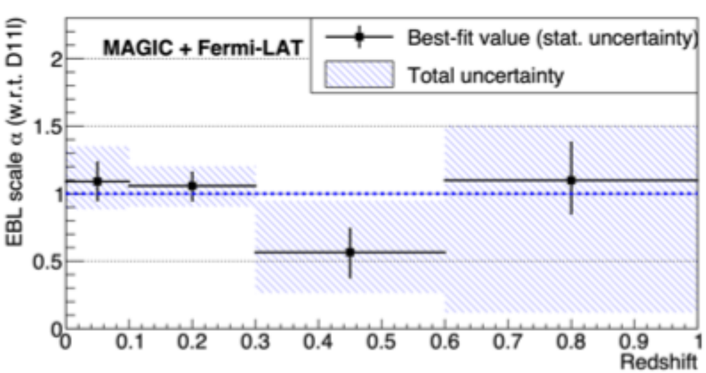
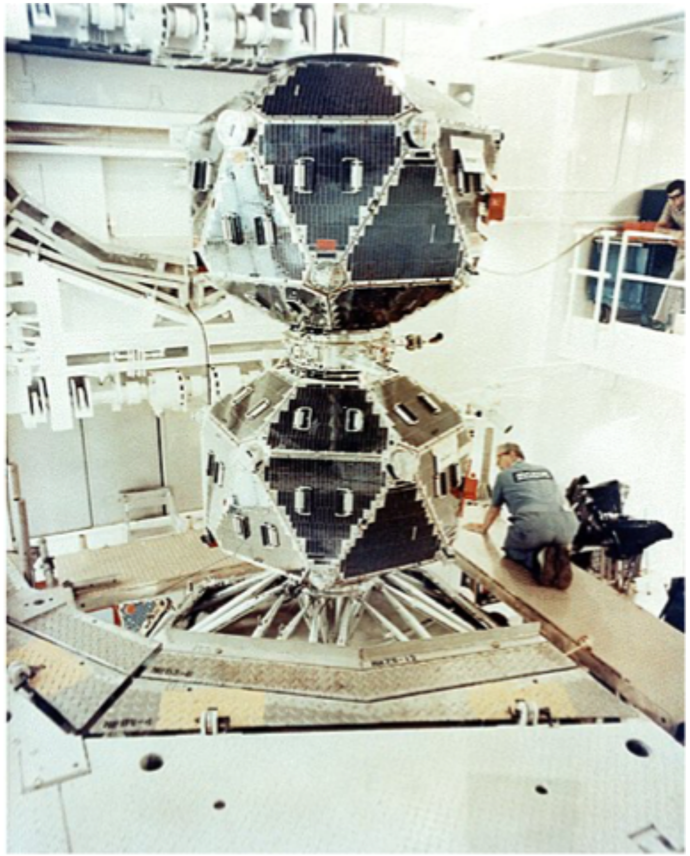
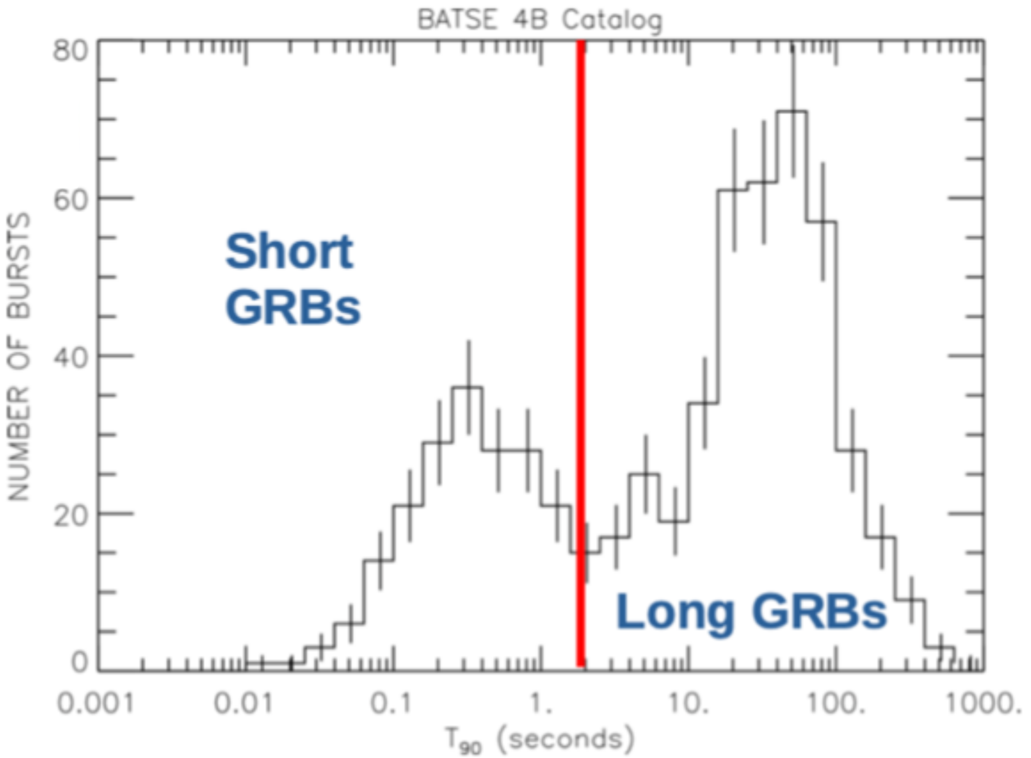


MAGIC measured the EBL up to a redshift of z=1

The Transient sky @ TeV energies



US military VELA program
7 pairs of satellites: 1963-70 → 1984



- MWL observation
  - From Radio to GeV energies
  - “canonical” light-curves in X-ray
    - Prompt and afterglow phases
  - More than 169 GRBs seen by LAT (>100MeV)

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- No TeV detection …
  - Difficult detections by IACTs
  - Fast even, could be at very high z

- **GRB 190114C** (MAGIC Coll., Nature, 2020)
  - 50 sigma detection
- **GRB 180720B** (H.E.S.S. Coll., Nature, 2020)
- **GRB 190829A** (H.E.S.S. Coll., Science, 2021)
  - For **3 nights**, low lum GRB?
- **GRB 201216C** (MAGIC Coll. ICRC021, S.Fukami)
  - Large value of **z=1.1**
- **GRB 221009A** (LHAASO, GCN 32677)
  - 18 TeV photons ?

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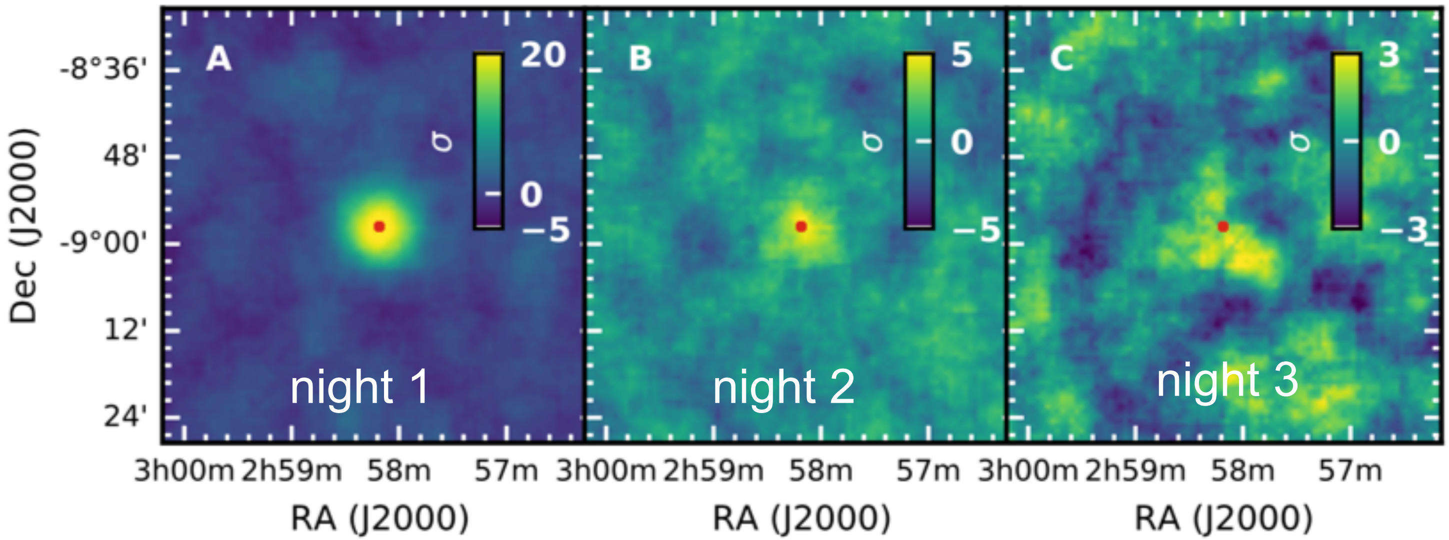

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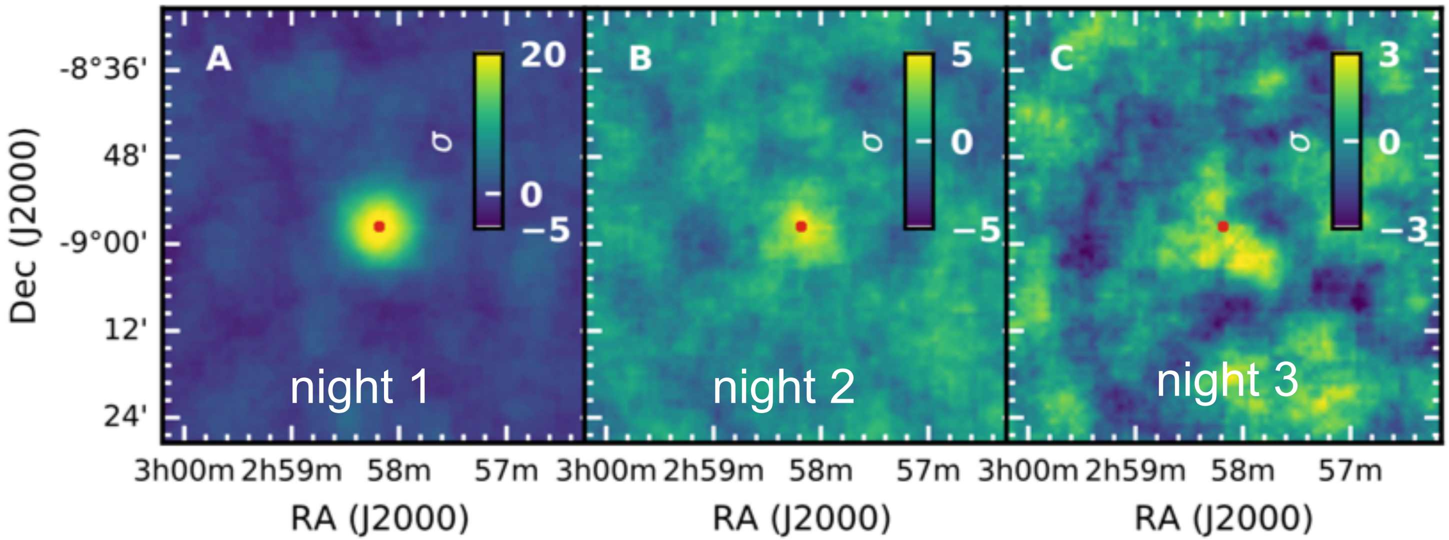
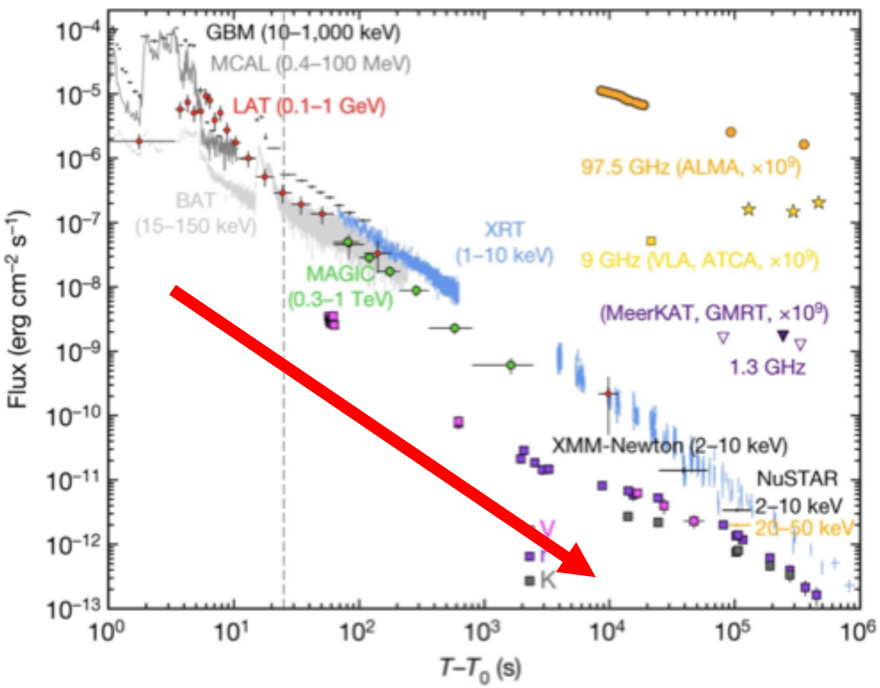
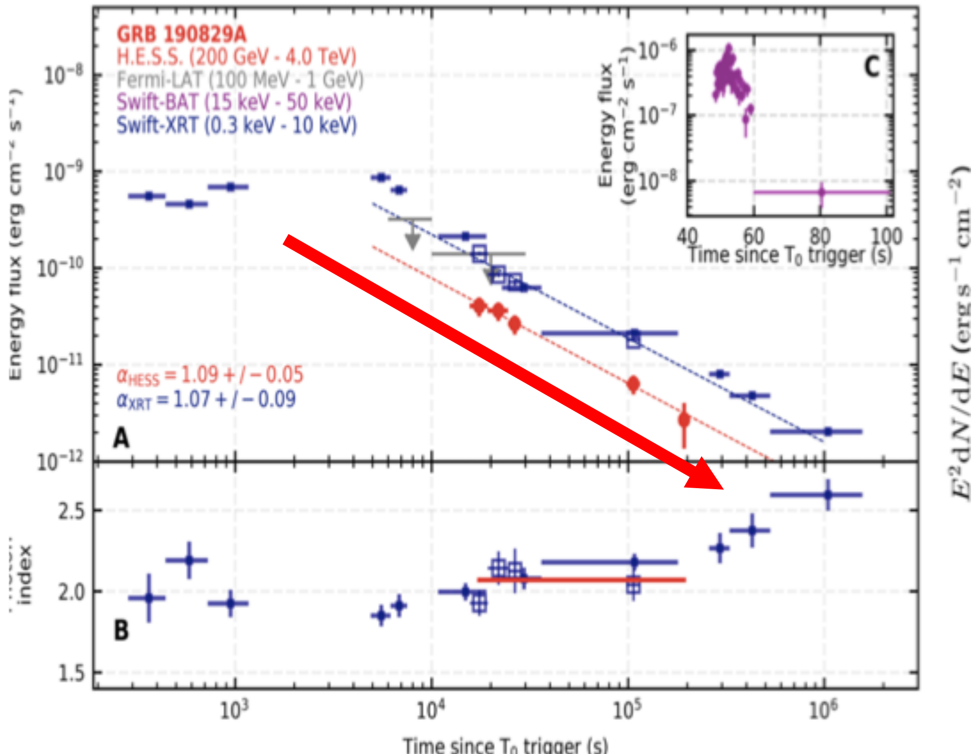
1) All detected GRB are long
2) Detection of afterglow days after T0
3) Extrem energies reached



GRB 190829A by H.E.S.S.

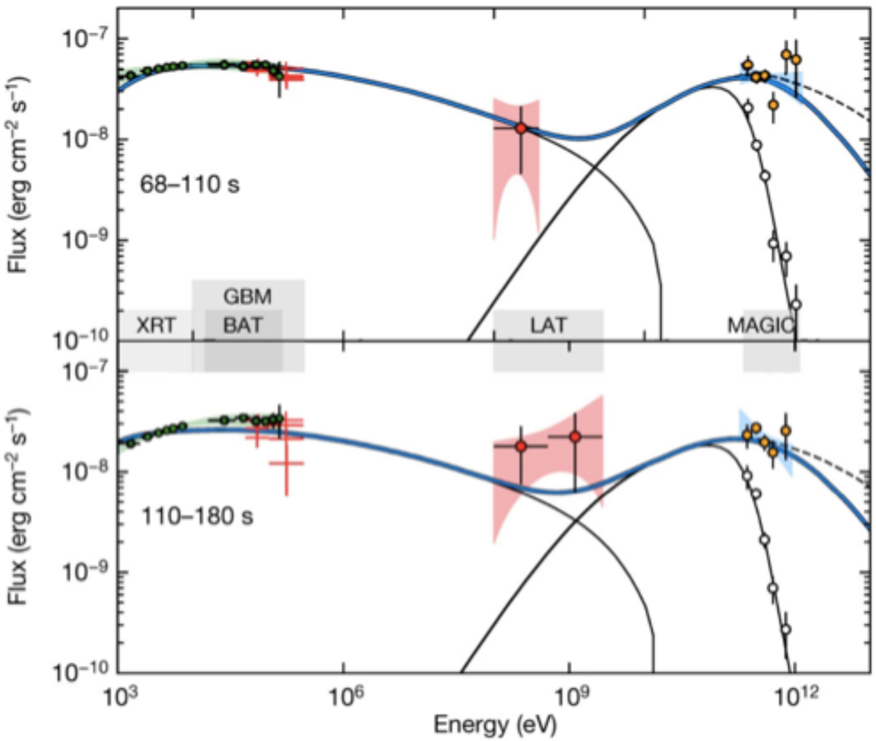


GRB 190114C

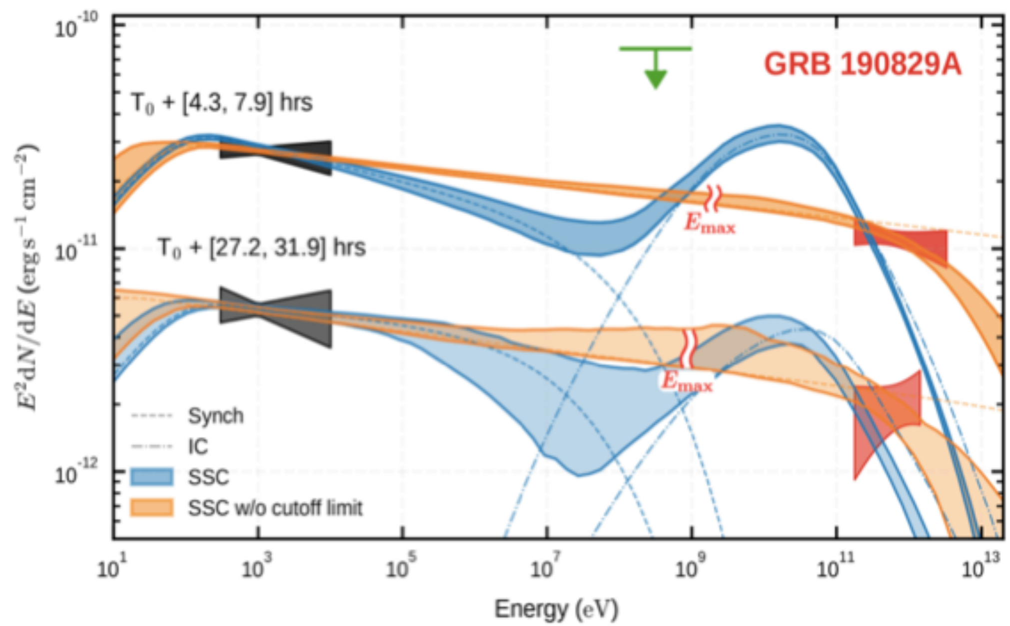


GRB 190829A

Similar trend in X-ray and TeV -> same population of particles ?



GRB 190114C



GRB 190829A

Hints for a two-component SED
one zone SSC ?

X-ray spectrum extrapolation to the VHE domain
Synchrotron only ?

MAGIC Arxiv : 2006.07251

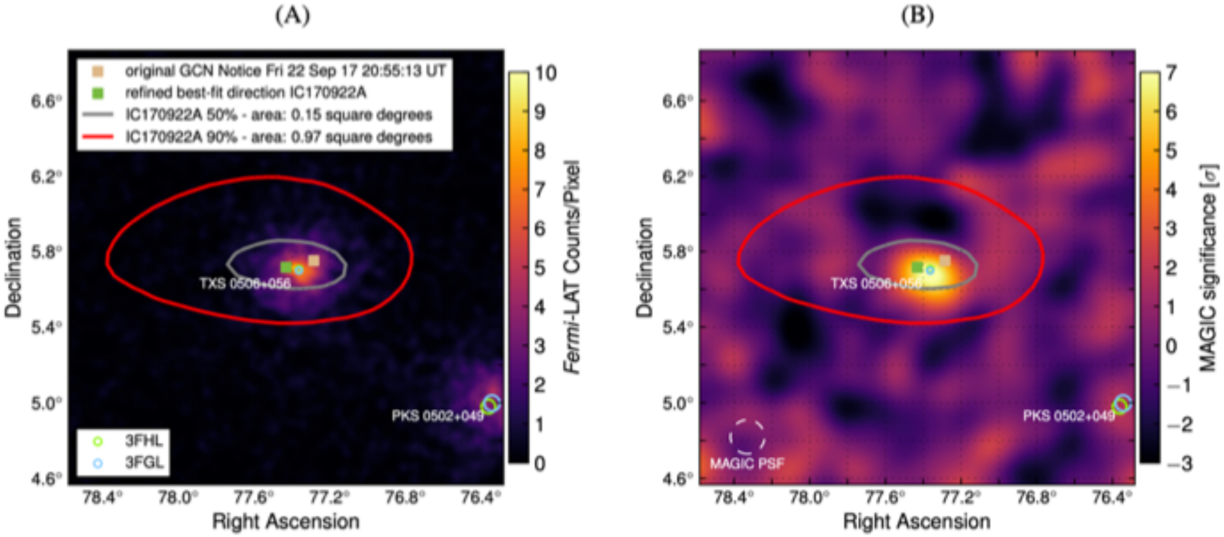
Multi-messenger astronomy

IC 170922A / TXS 0506+056

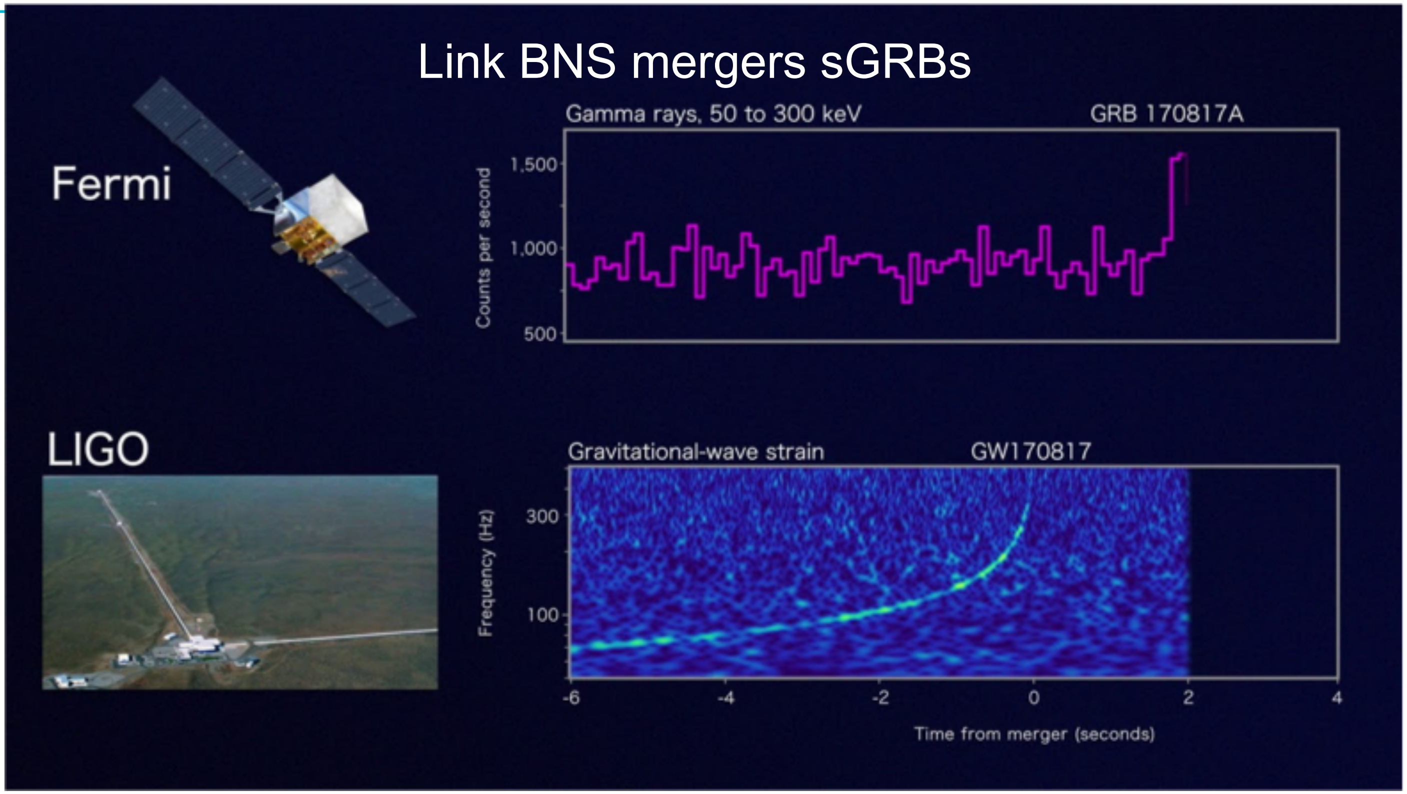
September 22 2017: IceCube alert
September 28 2017: Fermi-LAT detection of a gamma-ray flare from TXS 0506+056
consistent with the location of neutrino event IC 170922A **(Atel #10791)**
October 04 2017: MAGIC report detection at VHE (obs 28 Sept) **(Atel #10817)**

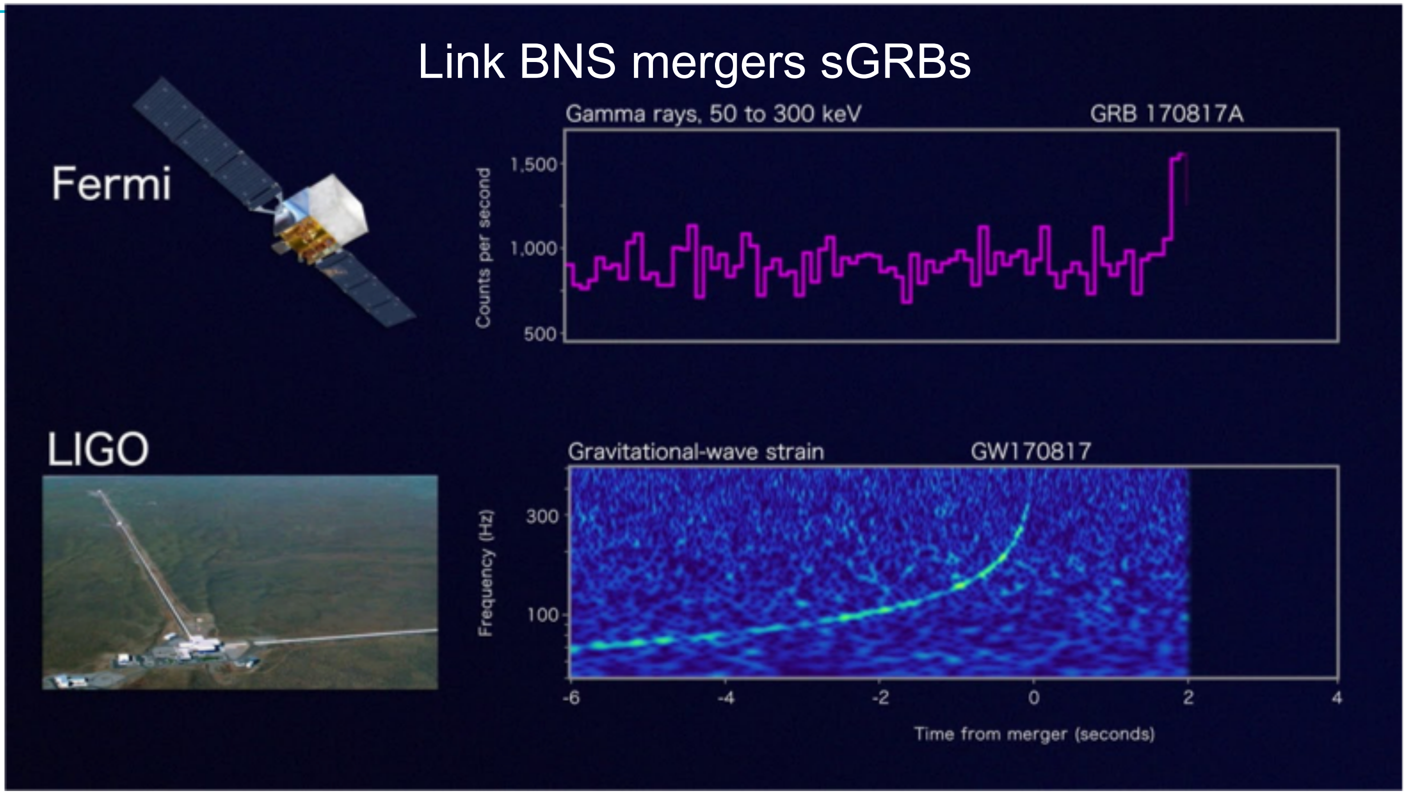
TXS 0506+056, first neutrino-blazar link

- Models has to include hadrons
- source of RC?
- Hint of hadronic component in blazars

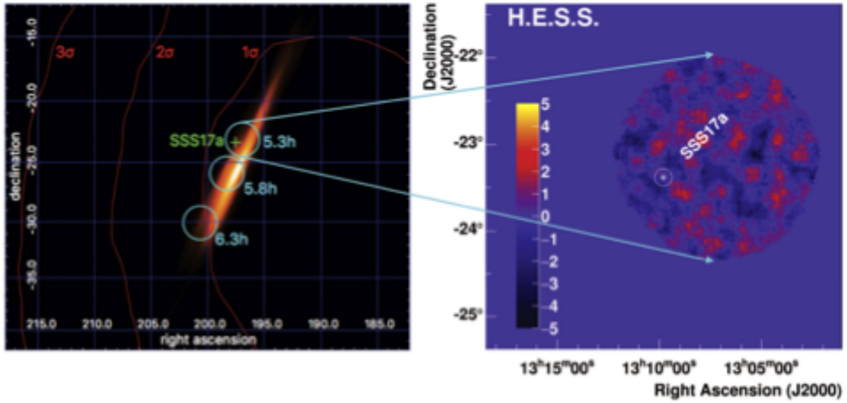


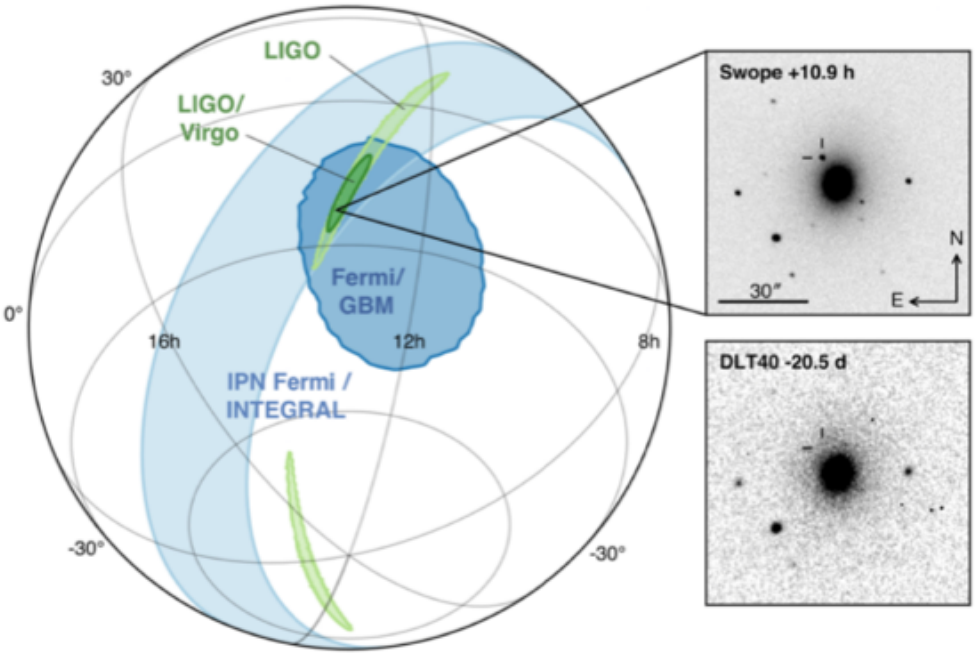
IceCube, Fermi, MAGIC et al. 2018


Link BNS mergers sGRBs
Fermi
LIGO
Gamma rays, 50 to 300 keV
GRB 170817A
Counts per second
1,500
1,000
500
Gravitational-wave strain
GW170817
Frequency (Hz)
300
100
-6
-4
-2
0
2
4
Time from merger (seconds)



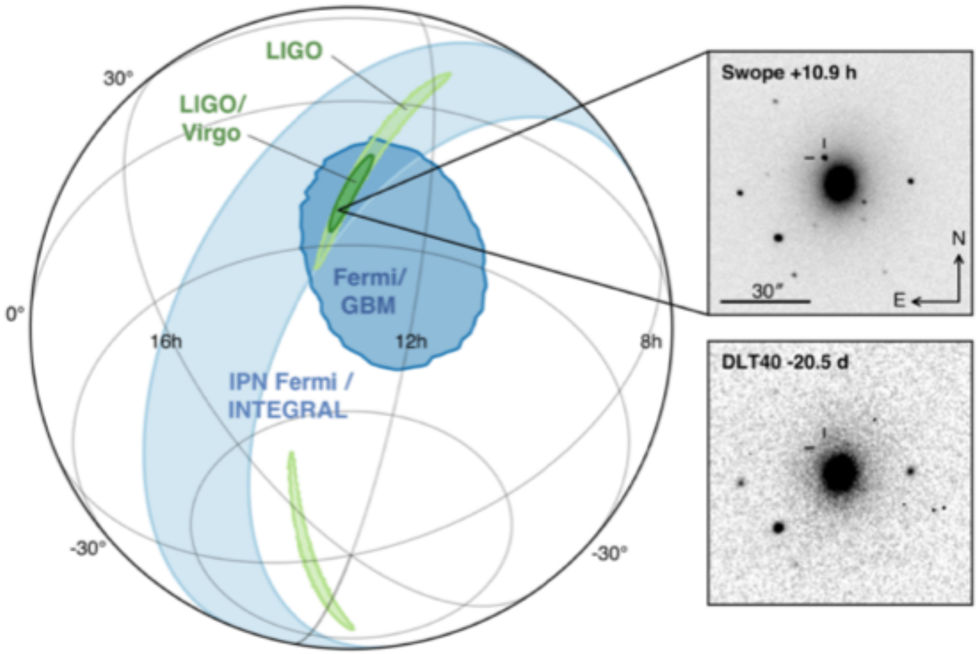
H.E.S.S. observations
Use of tilling methods
No TeV detection of this event





Large uncertainty region

Large than the IACT FoV (5 deg)



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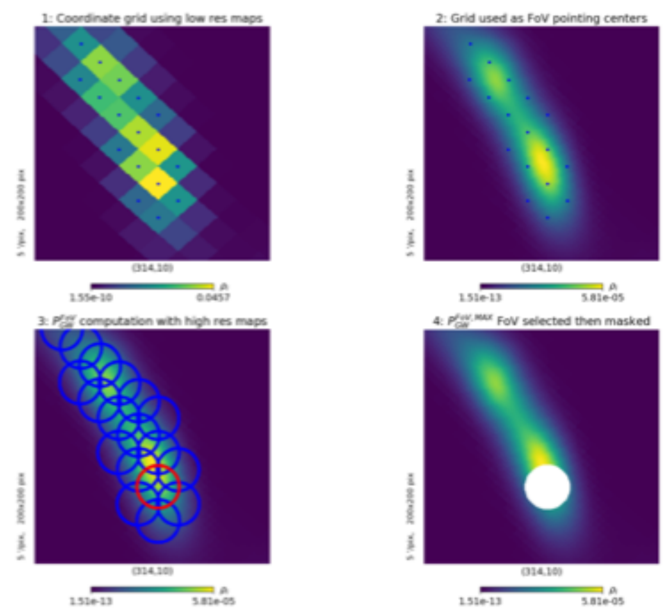


Need to use “clever” mapping methods to cover the large area

More events for O4

Aim : have a joint detection GW-TeV

Halim Ashkar phd

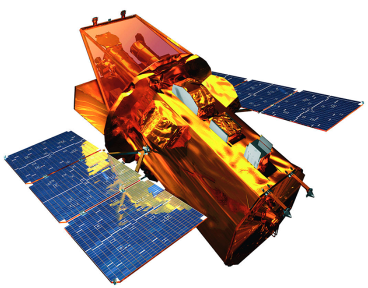
Current generation operates since early 2000

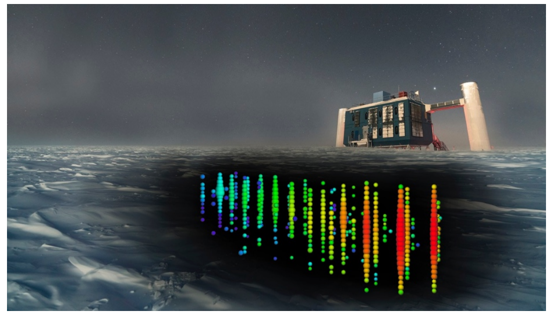
- 1 source per publication
- Few objects detected

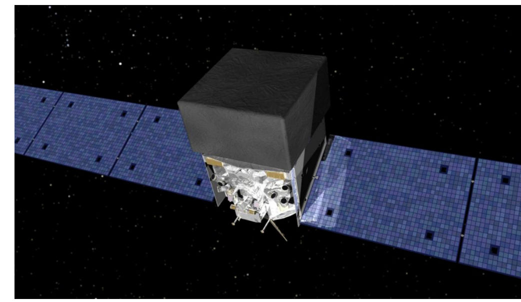
Last 15 years has seen a change in paradigm

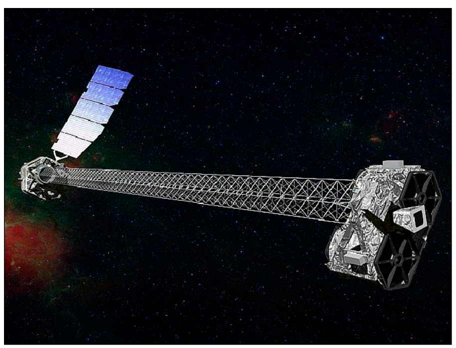
- Catalogs
- Transient sources
- Exploring other topics in physics

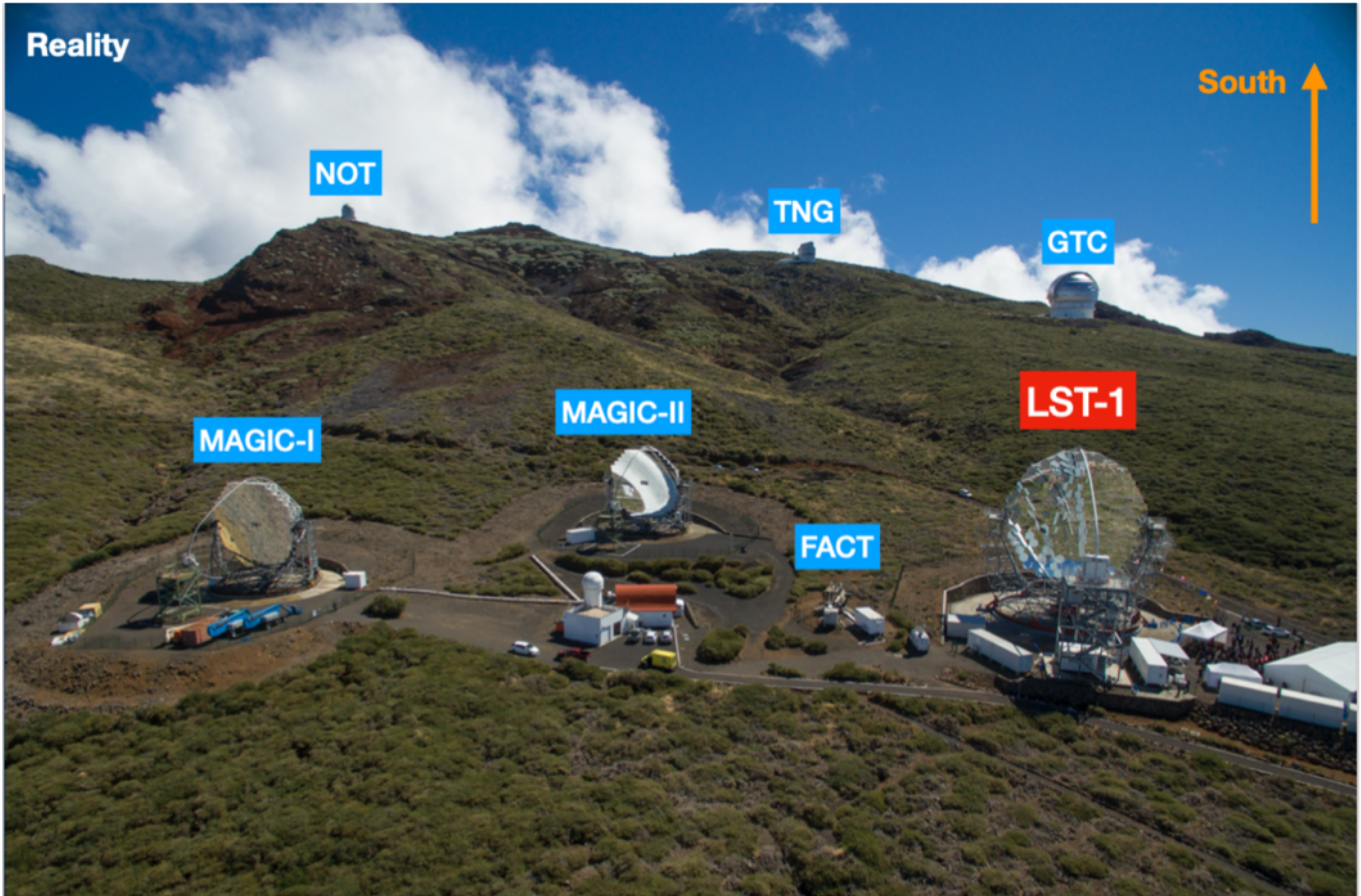
Multiwavelength, multi-messenger…



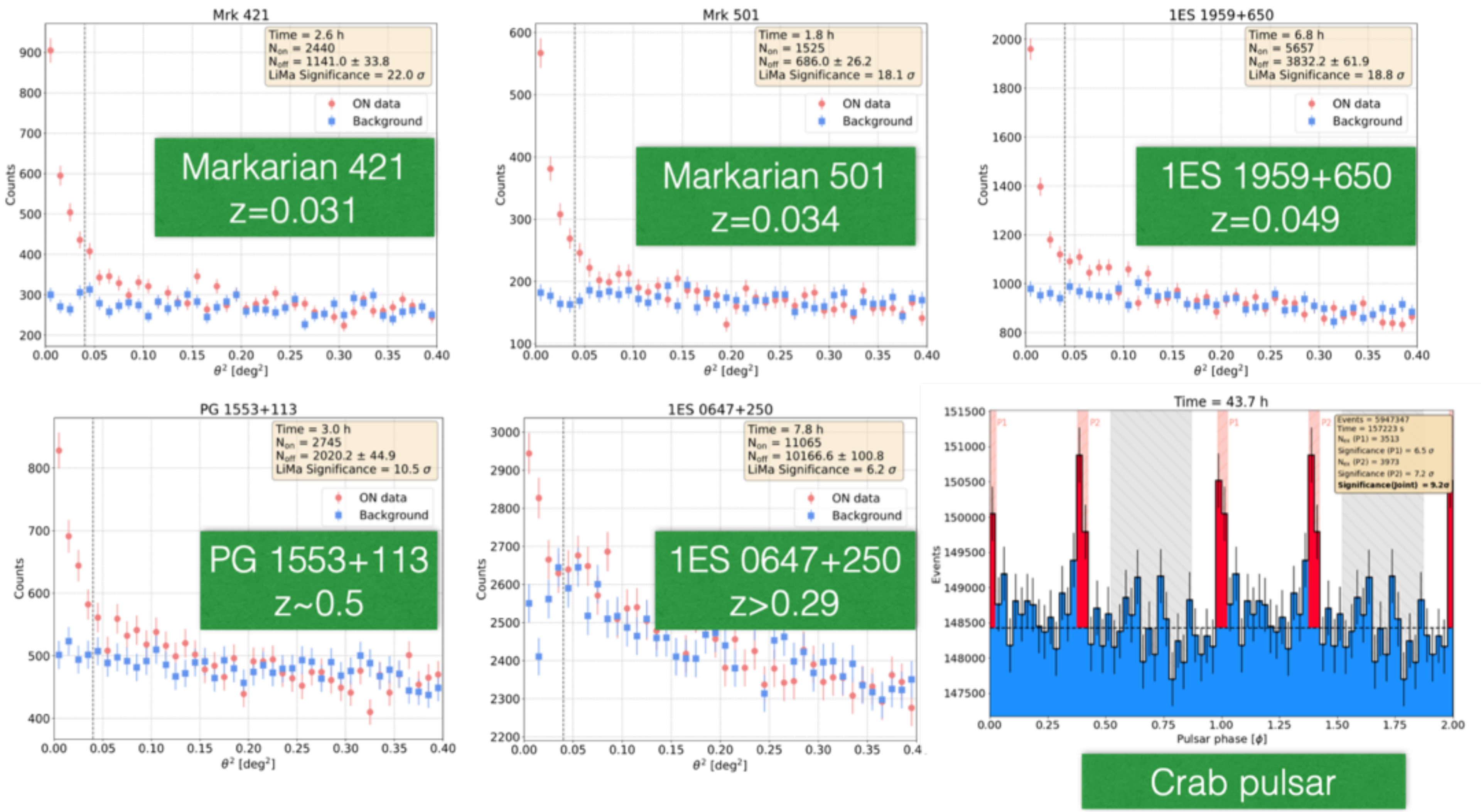







Reality
South
NOT
TNG
GTC
MAGIC-II
MAGIC-I
LST-1
FACT

Detection of several blazars and Crab pulsar



BL Lac (2021)
First detection of this flare by IACTs

[Previous | Next | ADS]

Detection of very-high-energy gamma-ray emission from BL Lac with the LST-1

ATel #14783; *Juan Cortina for the CTA LST collaboration*
on 13 Jul 2021; 21:03 UT
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

Subjects: TeV, VHE, Request for Observations, AGN, Blazar, Transient

Referred to by ATel #: 14820, 14826, 14839

Tweet

The LST-1 telescope has observed an increase in the very-high-energy (VHE; >100 GeV) gamma-ray flux from BL Lacertae (RA=22:02:43.3, DEC=+42:16:40, J2000.0). The preliminary offline analysis of the LST-1 data taken on 2021/07/11 (MJD 59406), triggered by an increase of the optical flux (see ATEL #14773 and references therein), has been detected with a significance of 8 sigma with a differential flux of 1.3 +/- 0.2 10^-9 cm-2 s-1 TeV-1 (25% of the Crab Nebula) at 100 GeV. Note though that this is the result of a quick-look analysis and the data were taken under non-optimal weather conditions (atmospheric transmission at 9km of ~50-60%), hence this flux measurement is a lower bound on the true flux. The LST-1 observations were performed during commissioning which began in 2018. LST-1 is a prototype of the Large-Sized Telescope for the Cherenkov Telescope Array, and is located on the Canary island of La Palma, Spain. The LST-1 is designed to perform gamma-ray astronomy in the energy range from 20 GeV to 3 TeV. LST-1 observations on BL Lacertae will continue during the next few nights, multi-wavelength observations are encouraged. The preliminary offline analysis has been performed by Daniel Morcuende (dmorcuen… and Rubén Lopez-Coto (ruben.lopezcoto@pd.infn.it). The LST-1 contact persons for these observations are

NGC 1275 (2022)

[Previous | Next | ADS]

Detection of enhanced very-high-energy gamma-ray emission from the radio-galaxy NGC1275 with the LST-1

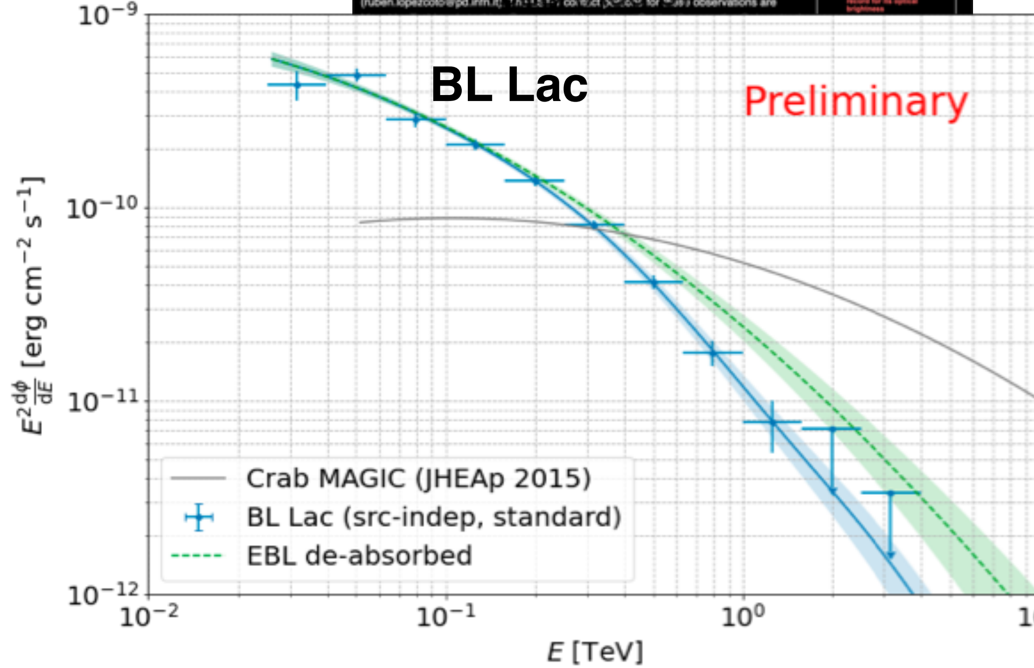
ATel #15819; *Juan Cortina (CIEMAT) for the CTA LST collaboration*
on 21 Dec 2022; 22:29 UT
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

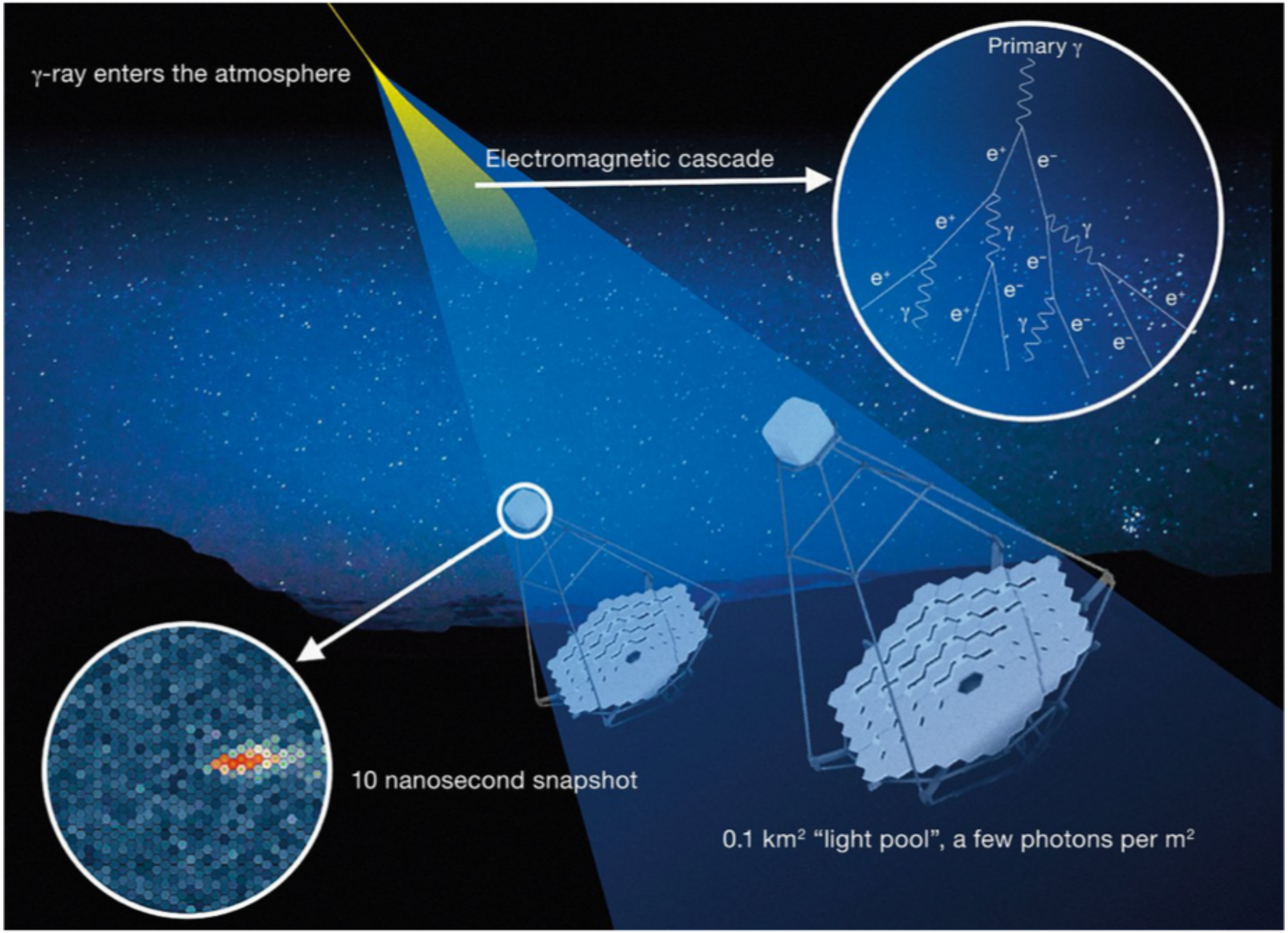
Subjects: Gamma Ray, TeV, VHE, AGN, Transient

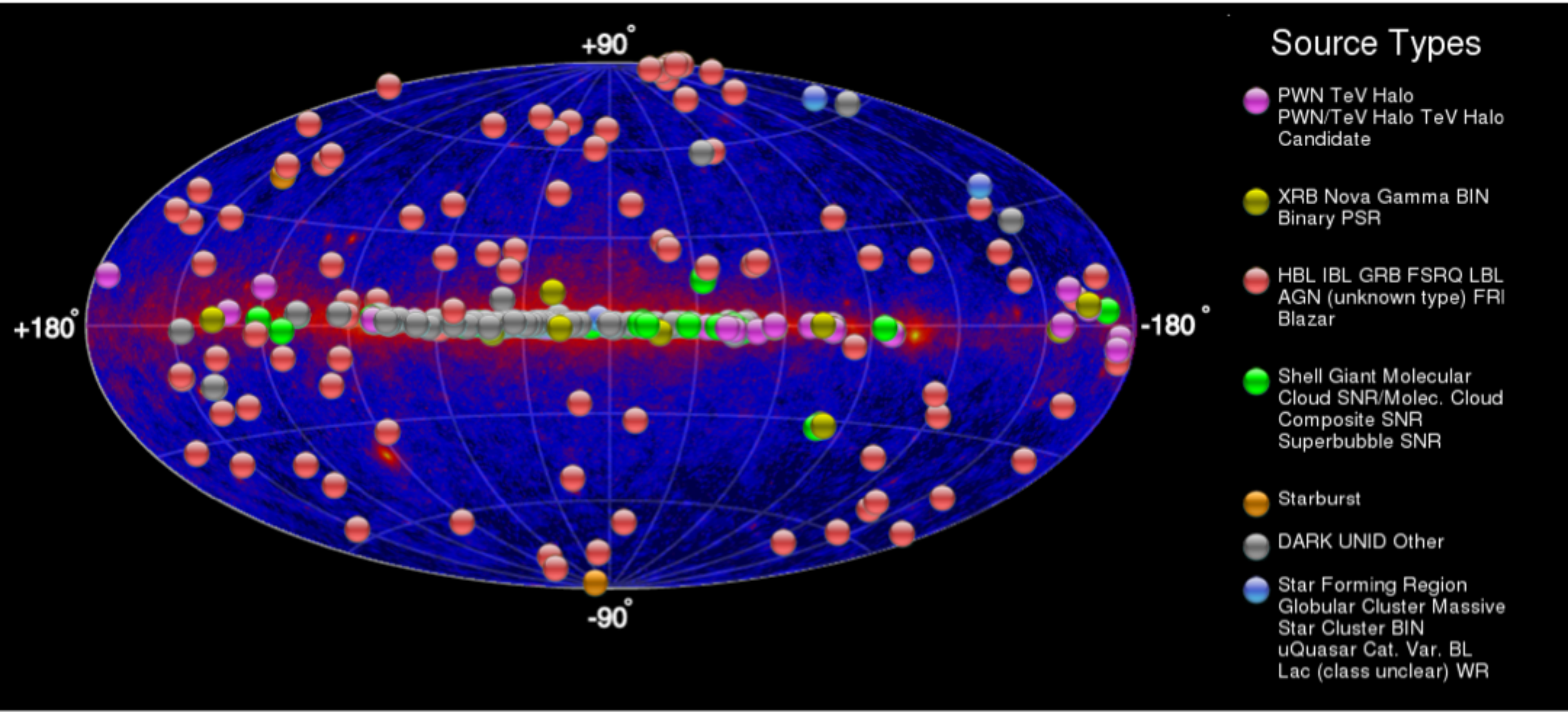
Referred to by ATel #: 15820, 15823, 15852, 15856, 15938

Tweet

The LST-1 telescope has observed an increase in the very-high-energy (VHE; >100 GeV) gamma-ray flux from the radio-galaxy NGC1275 (RA=03:19:48.1, DEC=+41:30:42, J2000.0). The LST-1 observed NGC1275 on the night of December 20 to December 21, 2022 (MJD 59934), triggered by an increase in gamma-ray flux detected by MAGIC and Fermi-LAT. In the preliminary offline analysis of the LST-1 data, NGC1275 has been detected with a significance of more than 10 sigma with an average flux of approximately 3.0 x 10^-10 cm^-2 s^-1 above 100 GeV, i.e. 70% that of the Crab Nebula, varying from 140% to below 30% at the beginning and at the end of the observation, respectively. Note though that this is the result of a quick-look analysis. The LST-1 observations were performed during commissioning which began in 2018. LST-1 is a prototype of the Large-Sized Telescope for the Cherenkov Telescope Array and is located on the Canary island of La Palma, Spain. The LST-1 is designed to perform gamma-ray astronomy in the energy range from 20 GeV to 3 TeV. LST-1 observations on NGC1275 will continue during the next few nights, multi-wavelength observations are encouraged. The preliminary offline analysis has been performed by Chaitanya Priyadarshi (cpriyadarshi@ifae.es) and Seiya Nozaki (nozaki@mpp.mpg.de). The LST-1 contact persons for these observations are Juan Cortina (juan.cortina@ciemat.es), Masahiro Teshima (mteshima@mppmu.mpg.de) and Mireia Nievas (mnievas@iac.es).




γ-ray enters the atmosphere
Electromagnetic cascade
Primary γ
e+
e−
γ
10 nanosecond snapshot
0.1 km² "light pool", a few photons per m²



More than 250 sources both Galactic and Extragalactic

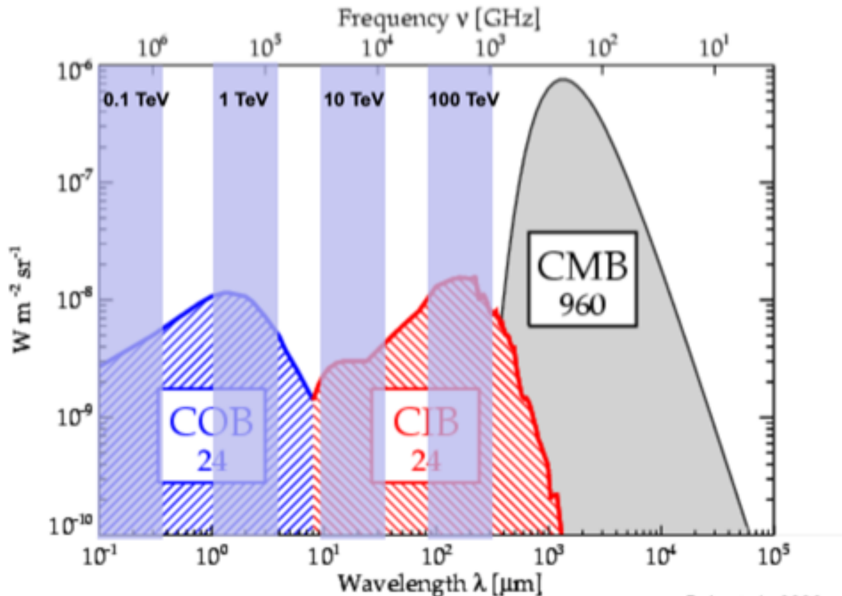
http://tevcat.uchicago.edu/

Absorption is used to Gamma-Gamma interaction

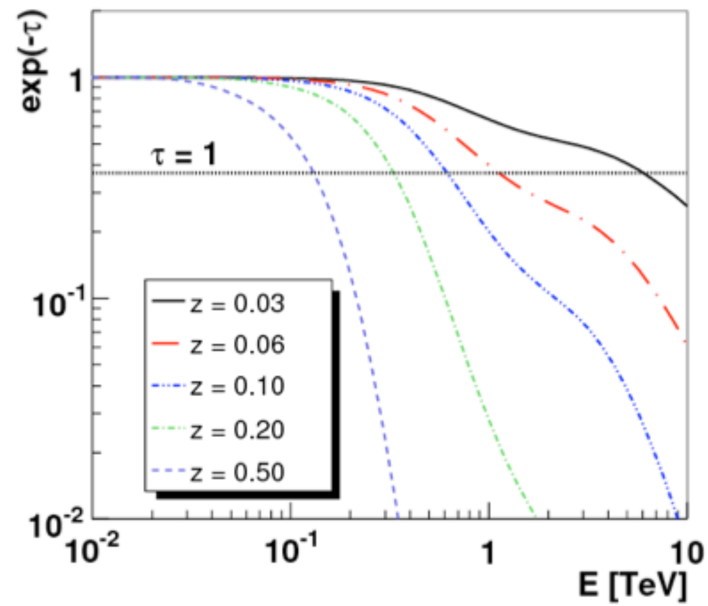
- Effect if z-dependent
- Non-linear effect -> footprint

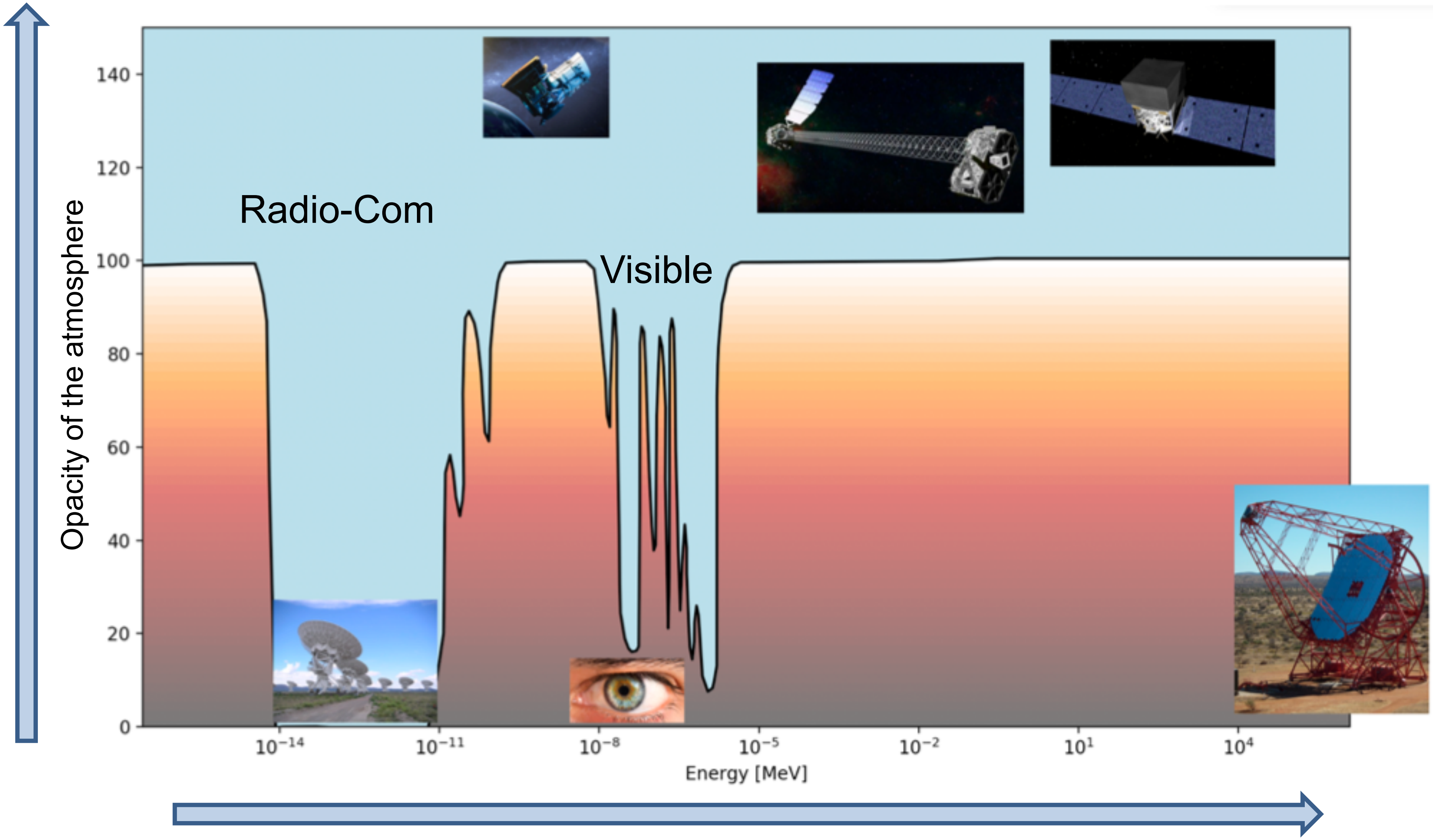
$$\phi(\theta) = \phi(N, \Gamma, z) = N \times (E/E_0)^{-\Gamma} \times e^{-\tau(z)}$$

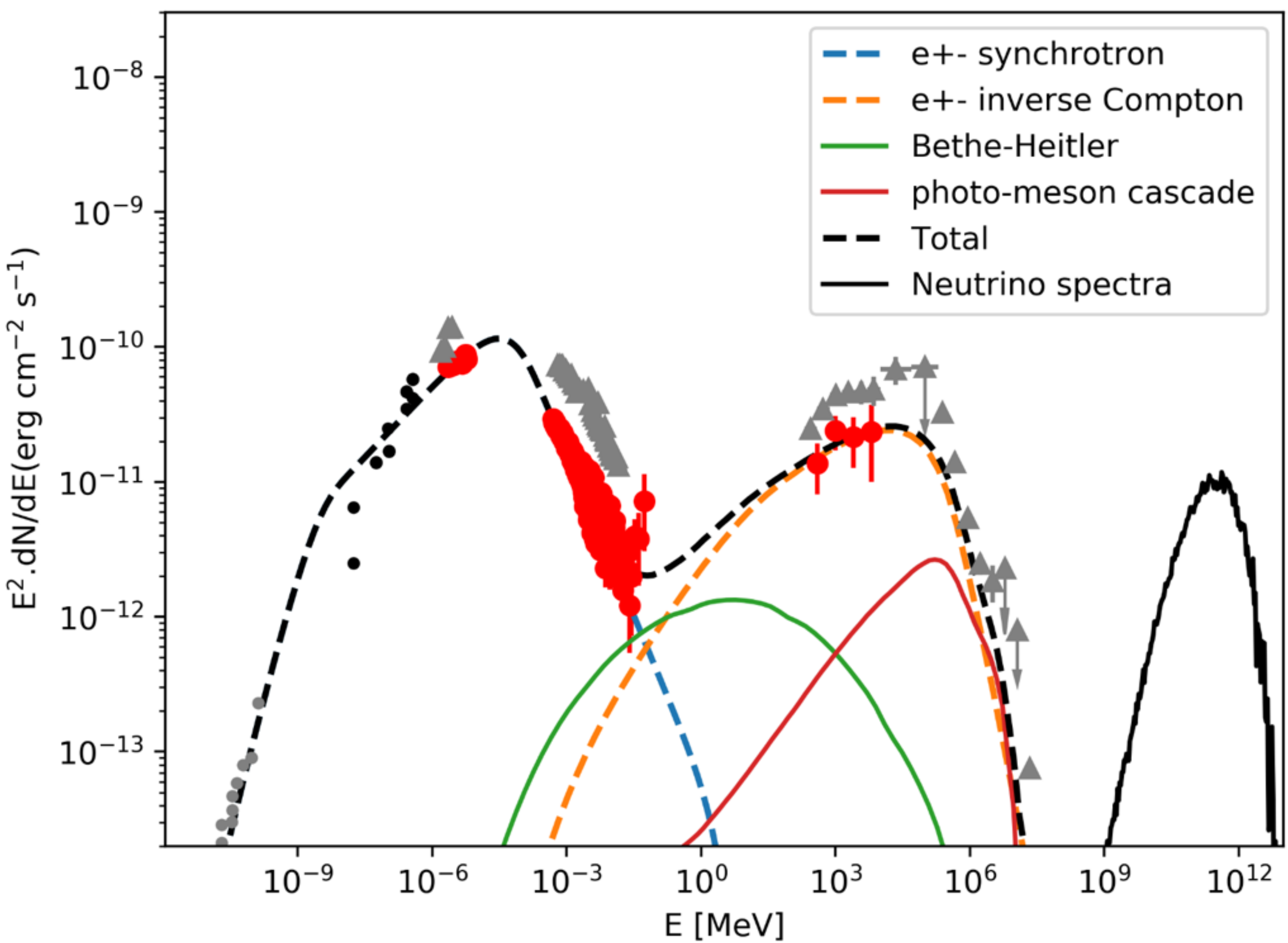
Effect can be seen in TeV with enough statistic



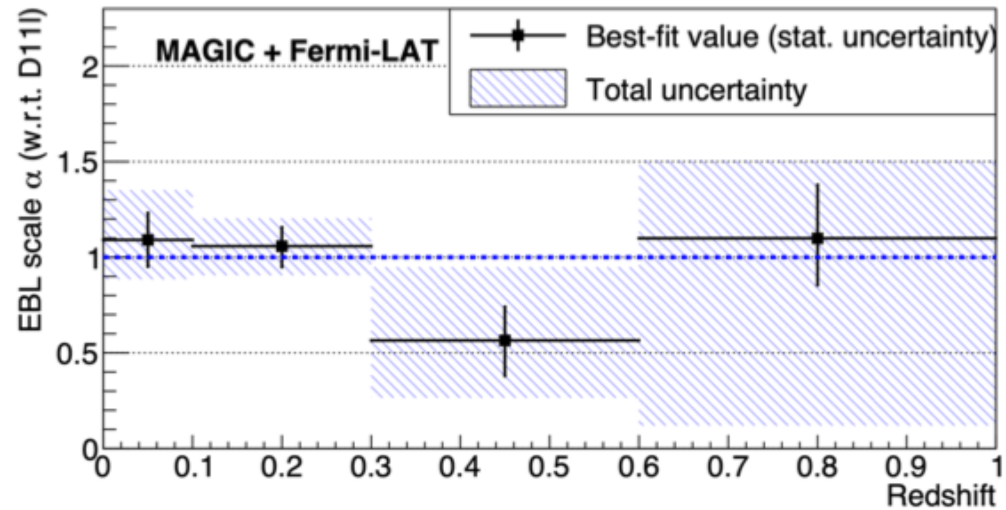
Dole et al., 2006



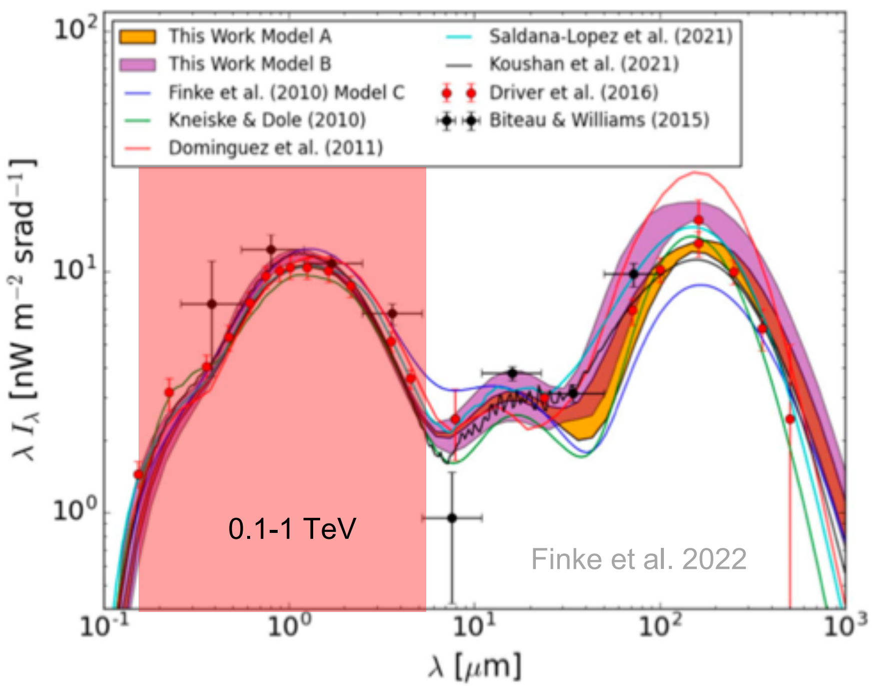

Radio-Com
Visible
Opacity of the atmosphere
140
120
100
80
60
40
20
0
10^{-14}
10^{-11}
10^{-8}
10^{-5}
10^{-2}
10^{1}
10^{4}
Energy [MeV]


e+- synchrotron
e+- inverse Compton
Bethe-Heitler
photo-meson cascade
Total
Neutrino spectra
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
$E^2.dN/dE(\mathrm{erg\ cm^{-2}\ s^{-1}})$
10^{-9}
10^{-6}
10^{-3}
10^{0}
10^{3}
10^{6}
10^{9}
10^{12}
E [MeV]

MAGIC measured the EBL up to a redshift of z=1



MAGIC ArXiv 1904.00134



Uncertainties on EBL are reduced now w.r.t. to the EBL 10-15 years ago