Recent highlights from H.E.S.S.

Irfu - CEA Saclay
Institut de recherche sur les lois fondamentales de l'Univers

Fabian Schüssler

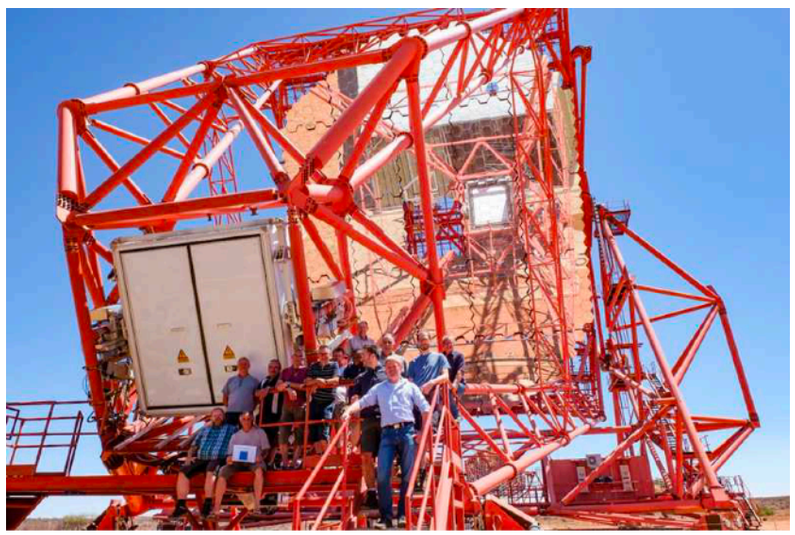
September, 2022

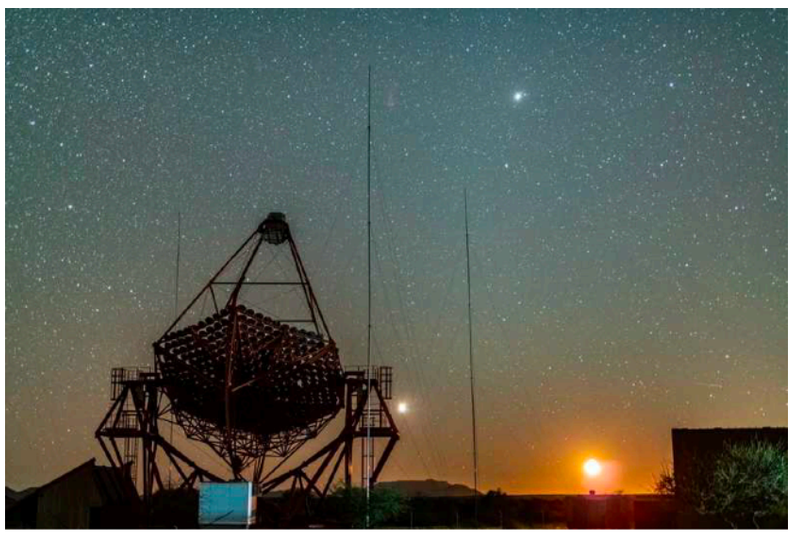
université PARIS-SACLAY

H.E.S.S.-XX

- **20 years of VHE observations in Namibia**
  - Start of stereoscopic observations in 2002 (+ official inauguration)
  - Start of H.E.S.S.-II including the 28m telescope in 2012

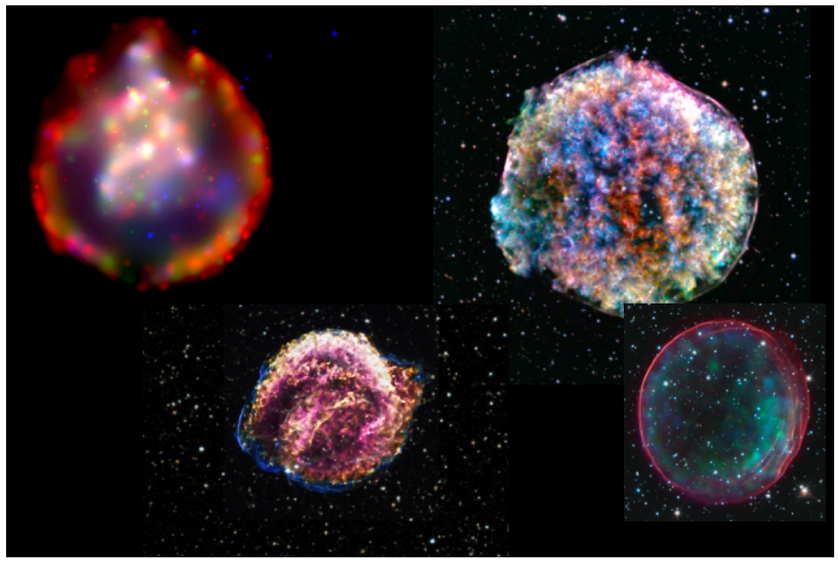
- Still going strong
  - New camera on 600 m^2-CT5 starting in 2019 (FlashCam-prototype and Nectar-chip based HESS1U cameras)
  - Changes to operational procedures and monitoring (e.g. moonlight/twilight observations)
  - All telescopes, cameras, subsystems show high operational efficiency
  - Average losses due to technical failures <2%/telescope and <5% full array
  - Low weather losses → >1200h darktime data, ~1500h incl. conservative moonlight/twilight

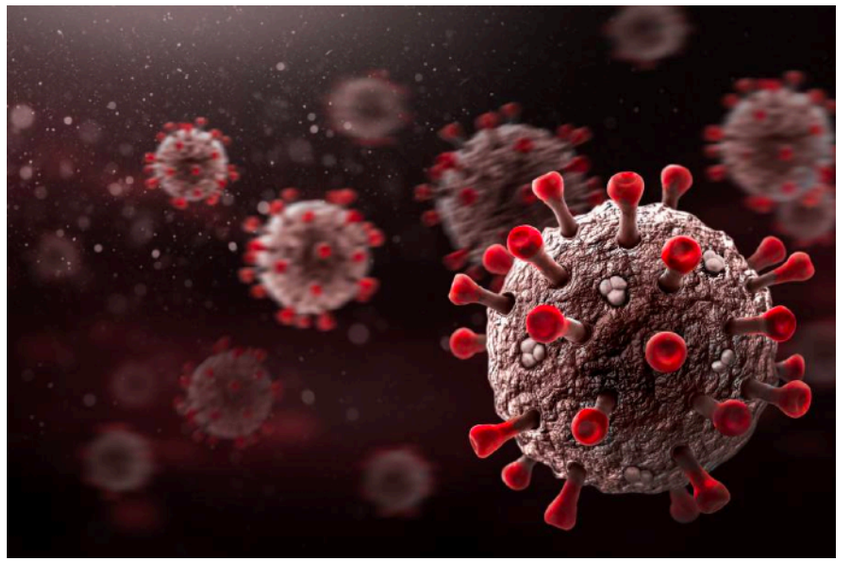




H.E.S.S. during the Covid-19 pandemic

- 1st extension phase started October 1, 2019 (for 3 years)
- Covid restrictions starting Feb. 2020
- Observers not allowed to leave to Namibia in March 2020 => “The long shift” (cf. YouTube)





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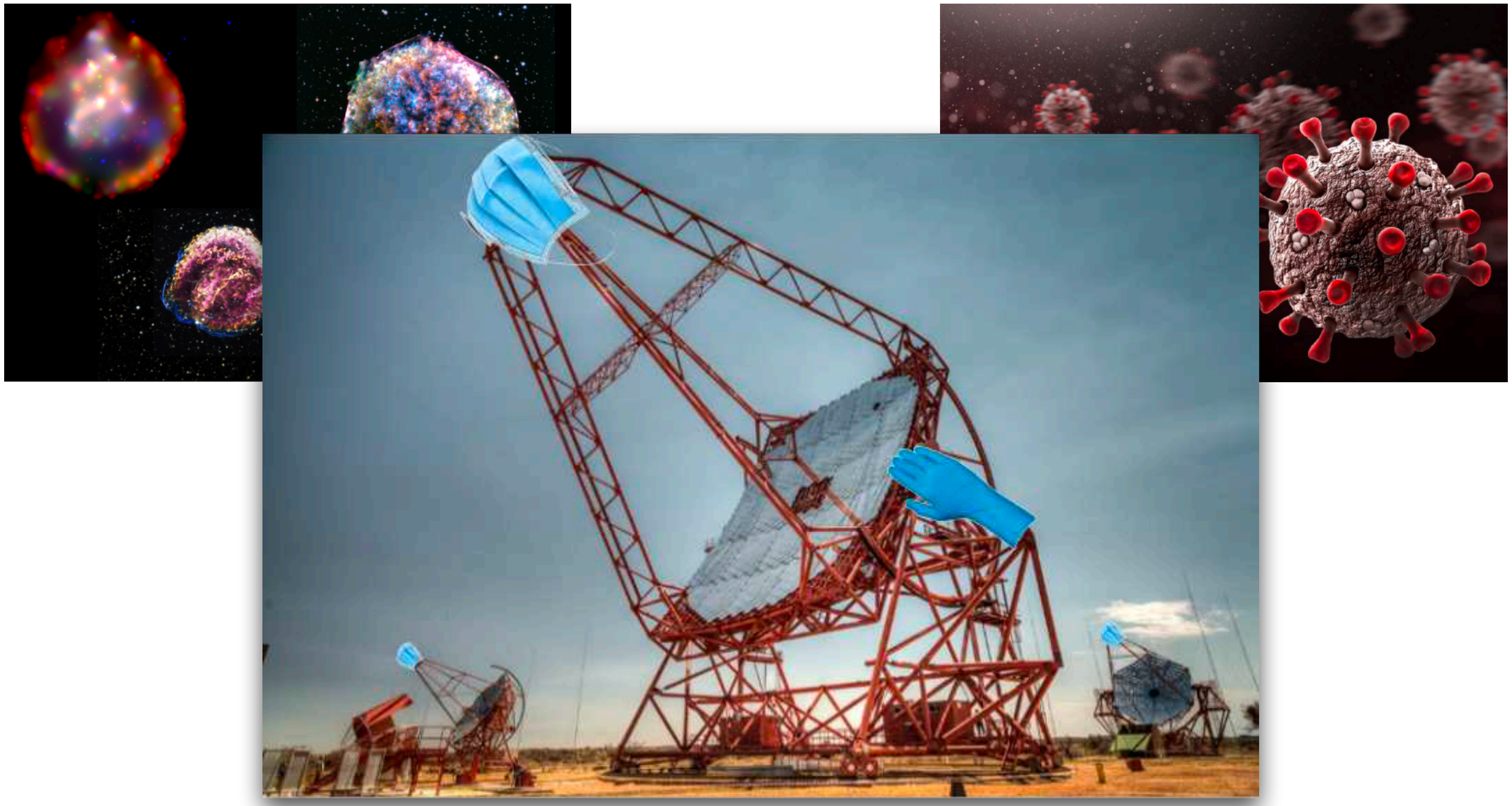

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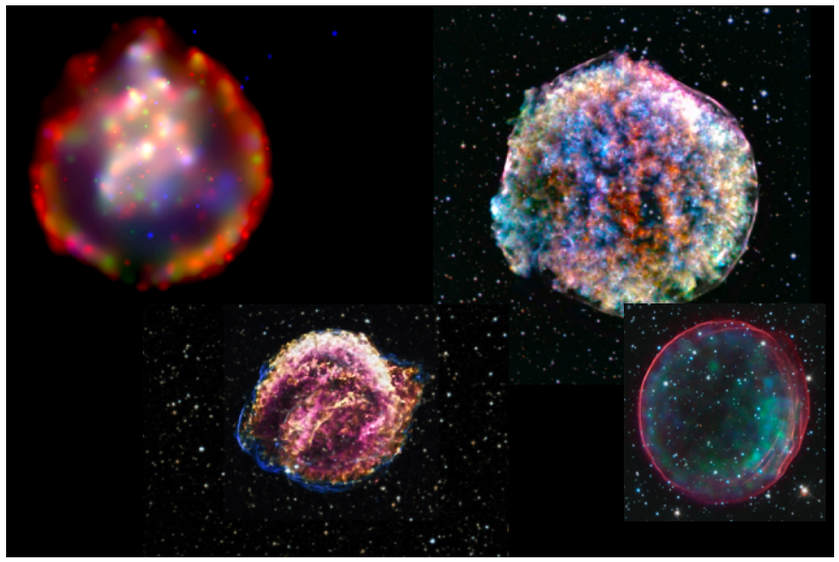
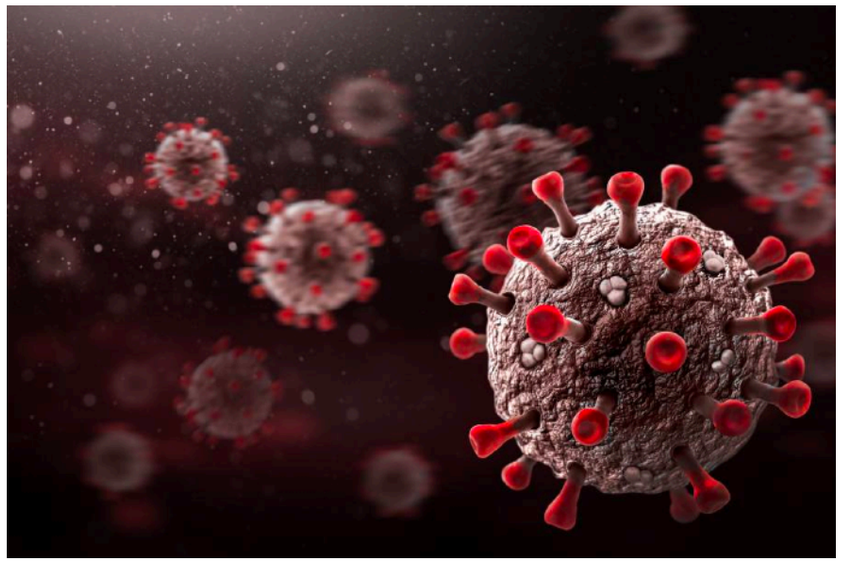
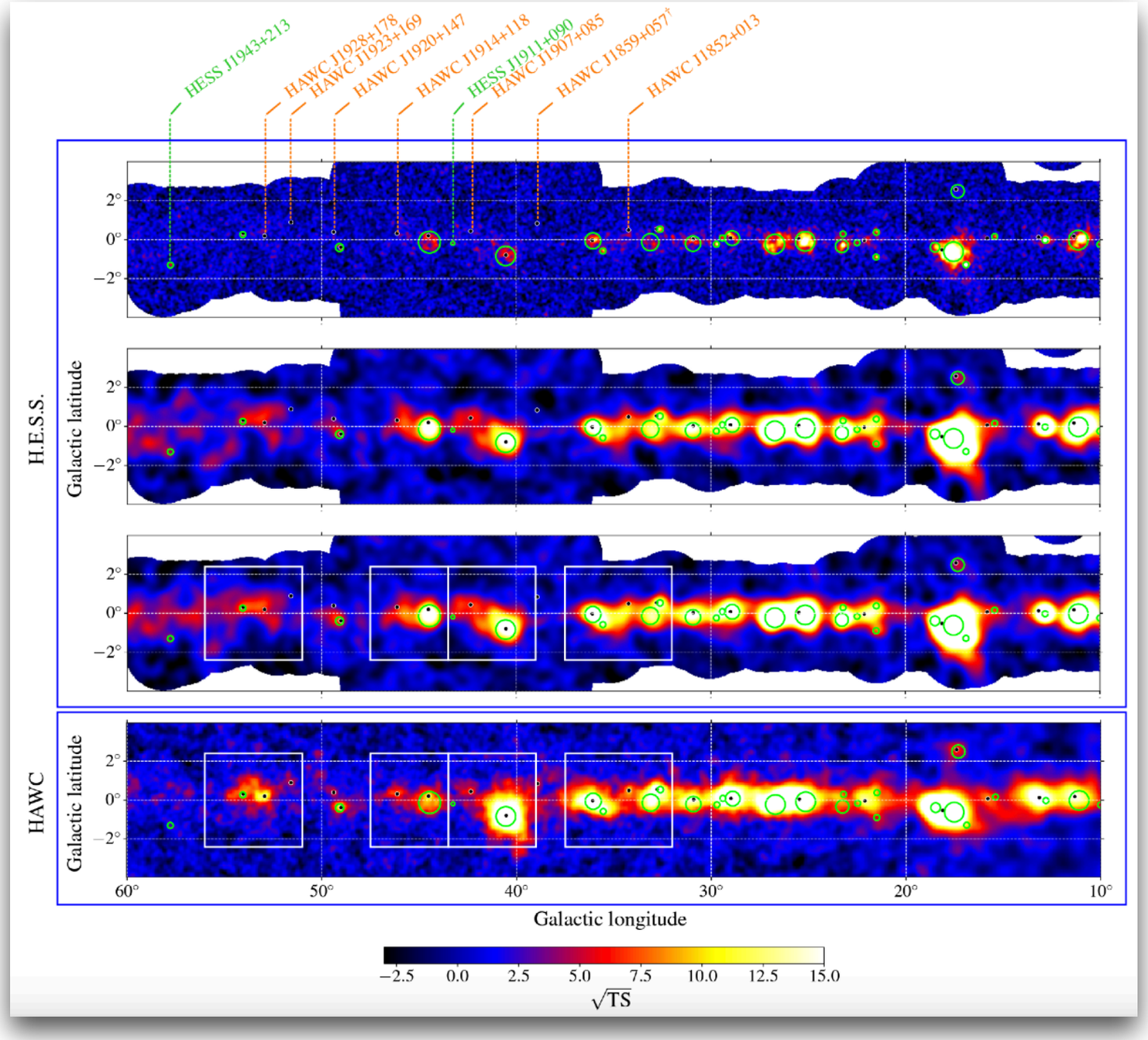




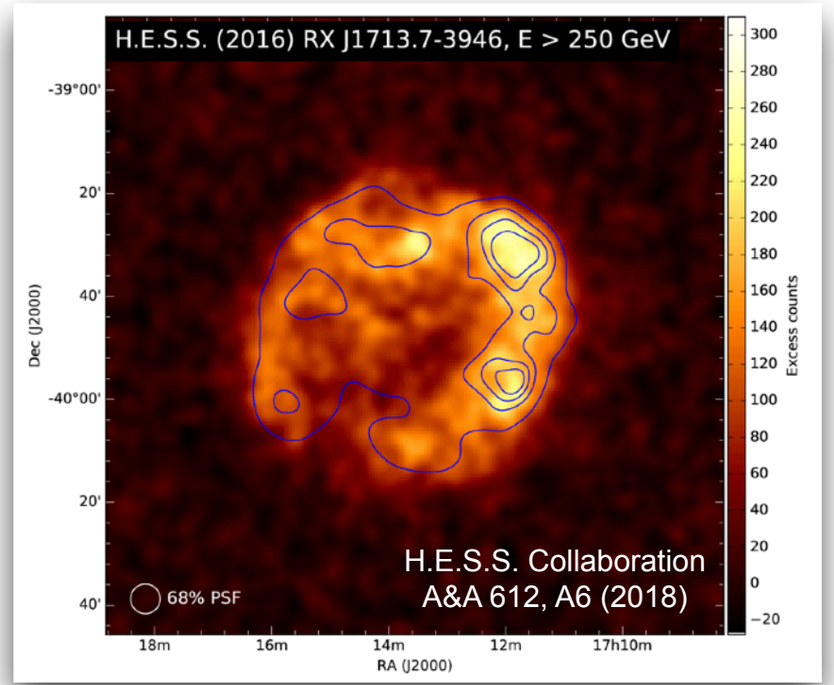
- Operations with local observers/telescope operators
  - H.E.S.S. continued to take data throughout the entire pandemic
- Improved operations
  - Observations during moderate moonlight: tests in 2020, fully integrated starting January 2021
  - Remote operations from Desy-Zeuthen

Galactic survey and deep studies of Galactic sources

- High resolution crucial for source identification + morphologies!



0.1deg



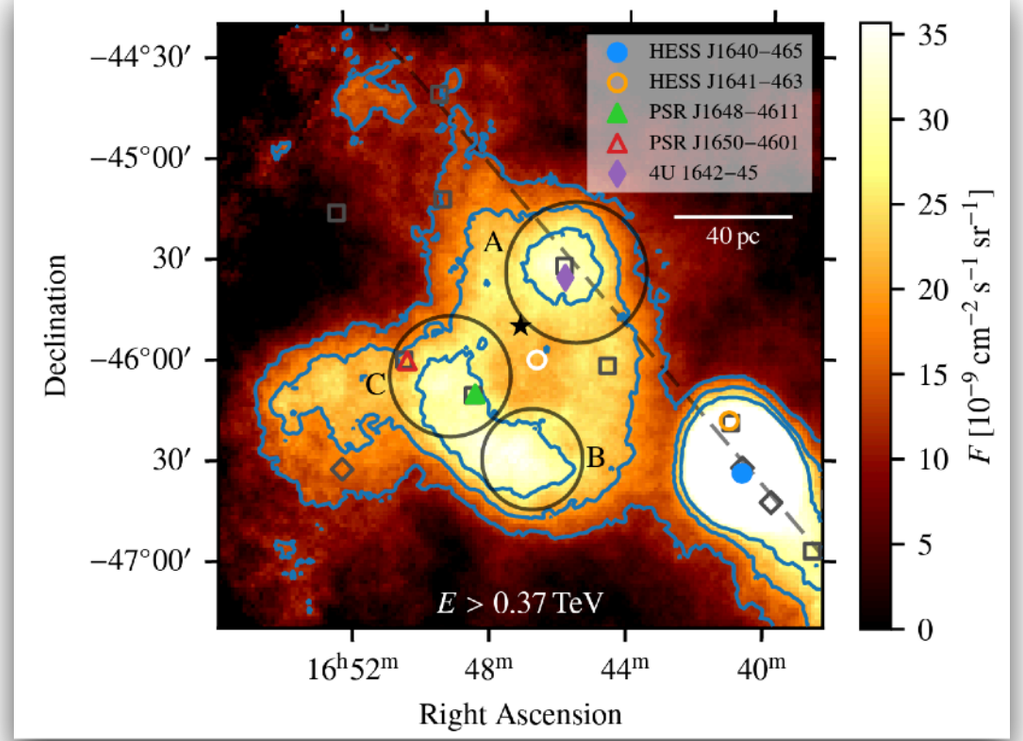
0.4deg

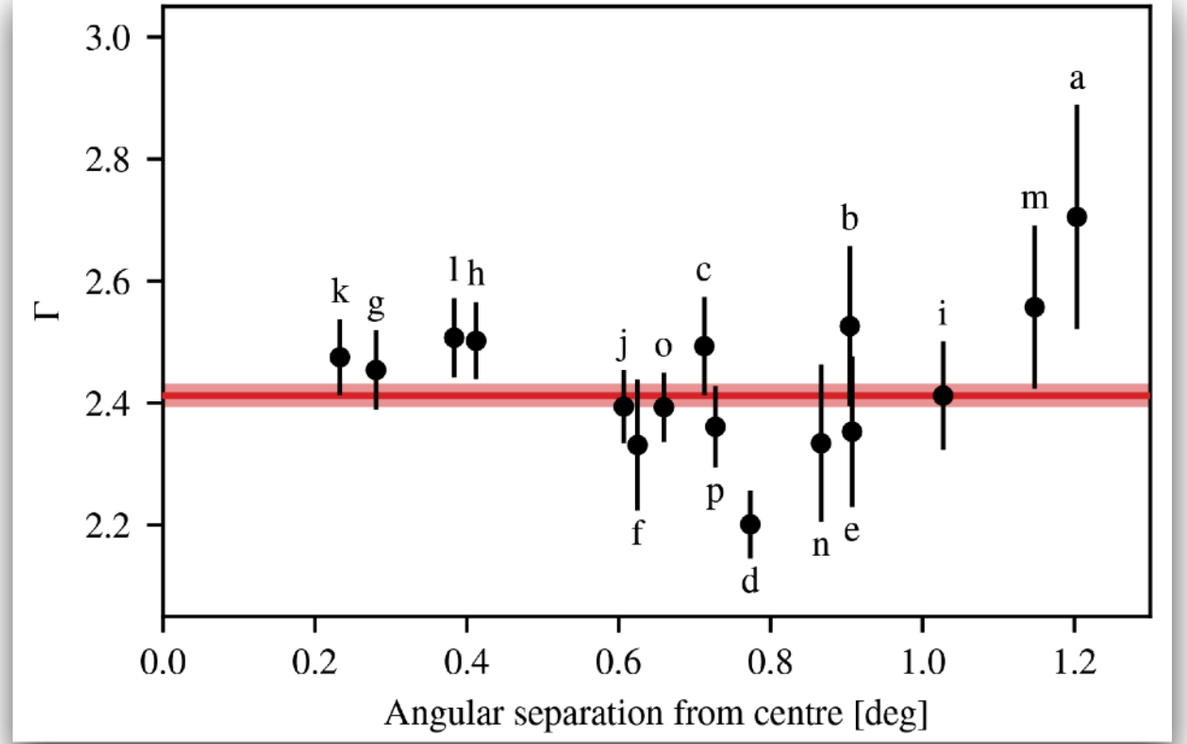
0.4deg

H.E.S.S. and HAWC collaborations
ApJ **917** 6 (2021)

Recent example: Westerlund 1

- Most massive open cluster in the local group
- VHE source HESS J1646-458 detected in 2012
- New deep (164h)
  - shell-like structure, centered on cluster extending beyond Wd1
  - 4 sources on top of/adjacent to the shell (HESS J1645−455, HESS J1647−465, HESS J1649−460, and HESS J1652−462)
  - Remarkably homogenous spectra throughout the complex region
  - Possibly CR acceleration at the cluster wind termination shock

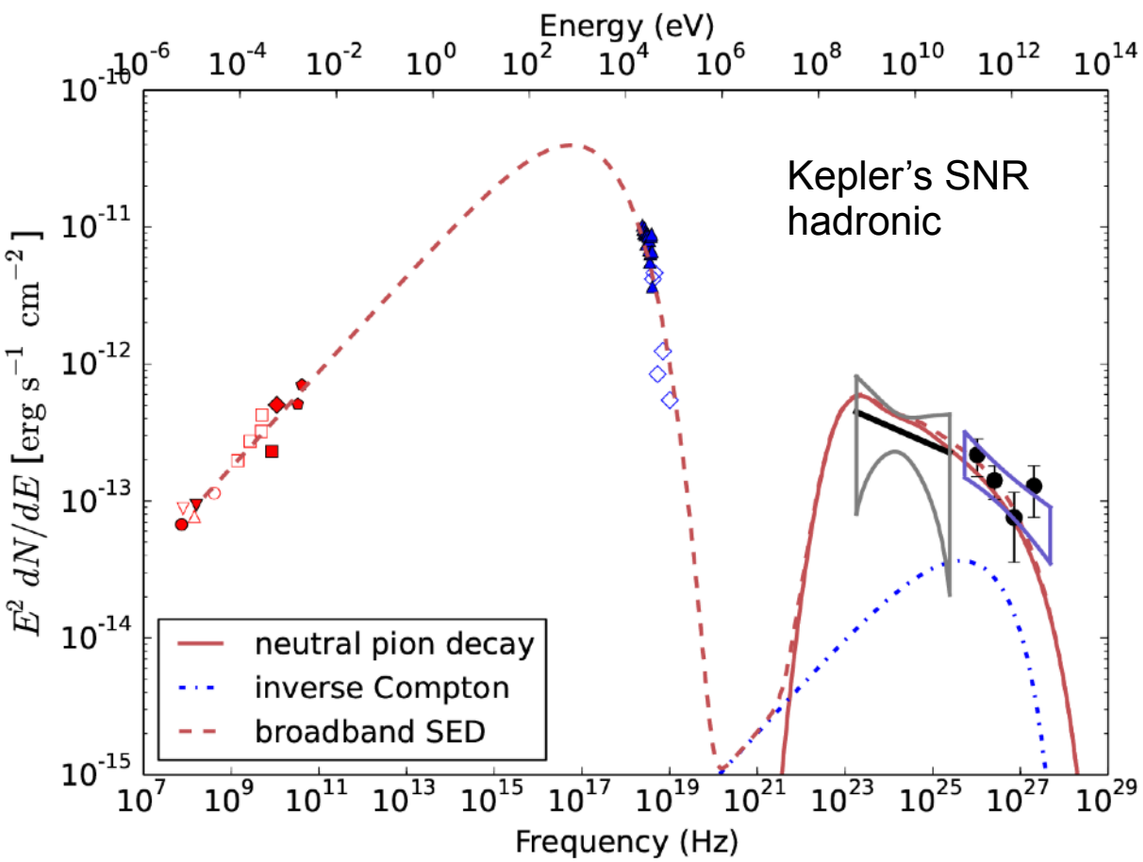


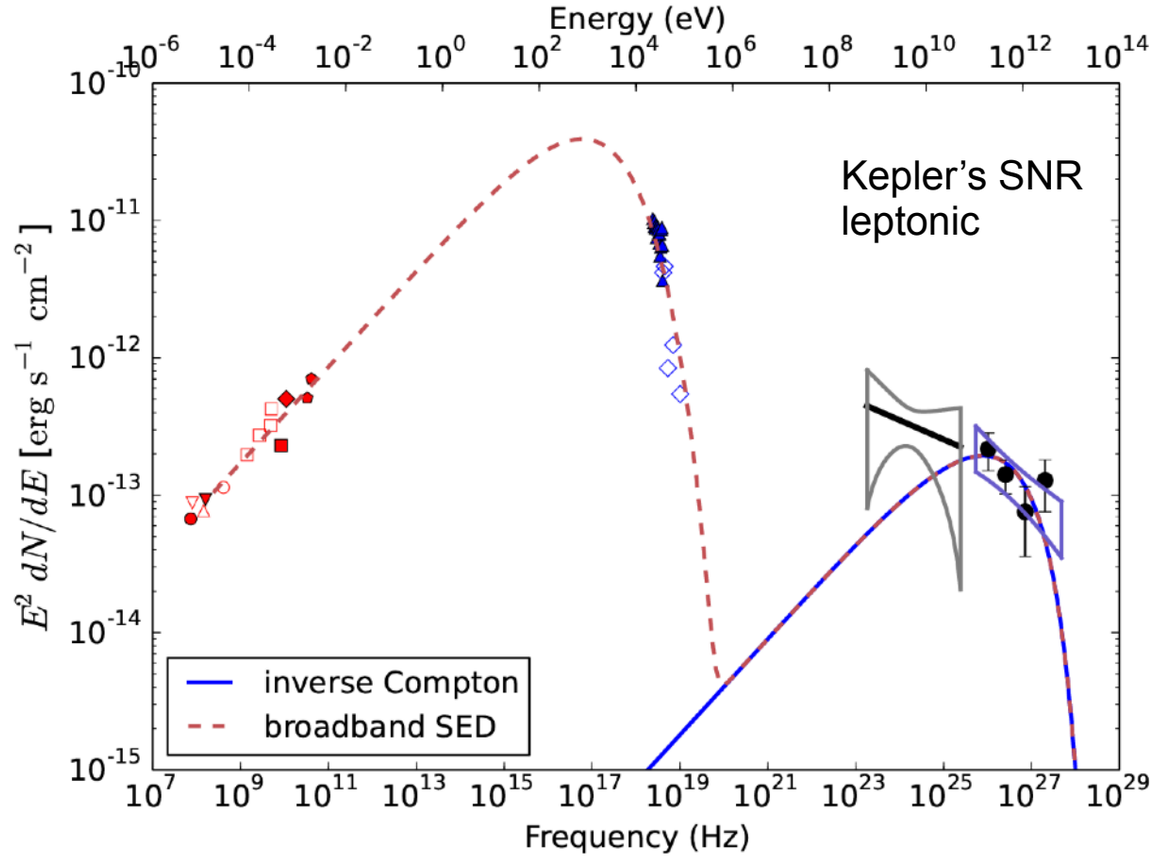


Accepted by A&A; arXiv:2207.10921

MWL and multi-messenger synergies

- Comparisons and joint analyses crucial for (all?) science results
- Source identification + morphologies
- Spectral energy densities + modeling





H.E.S.S. Collaboration, A&A 662, A65 (2022)

Transient astrophysical sources

Flaring stars

CVs / Novae

Supernovae

Gamma-ray Bursts

Gravitational Waves

Gamma-ray Binaries

Microquasars

Unknowns

Active Galactic nuclei

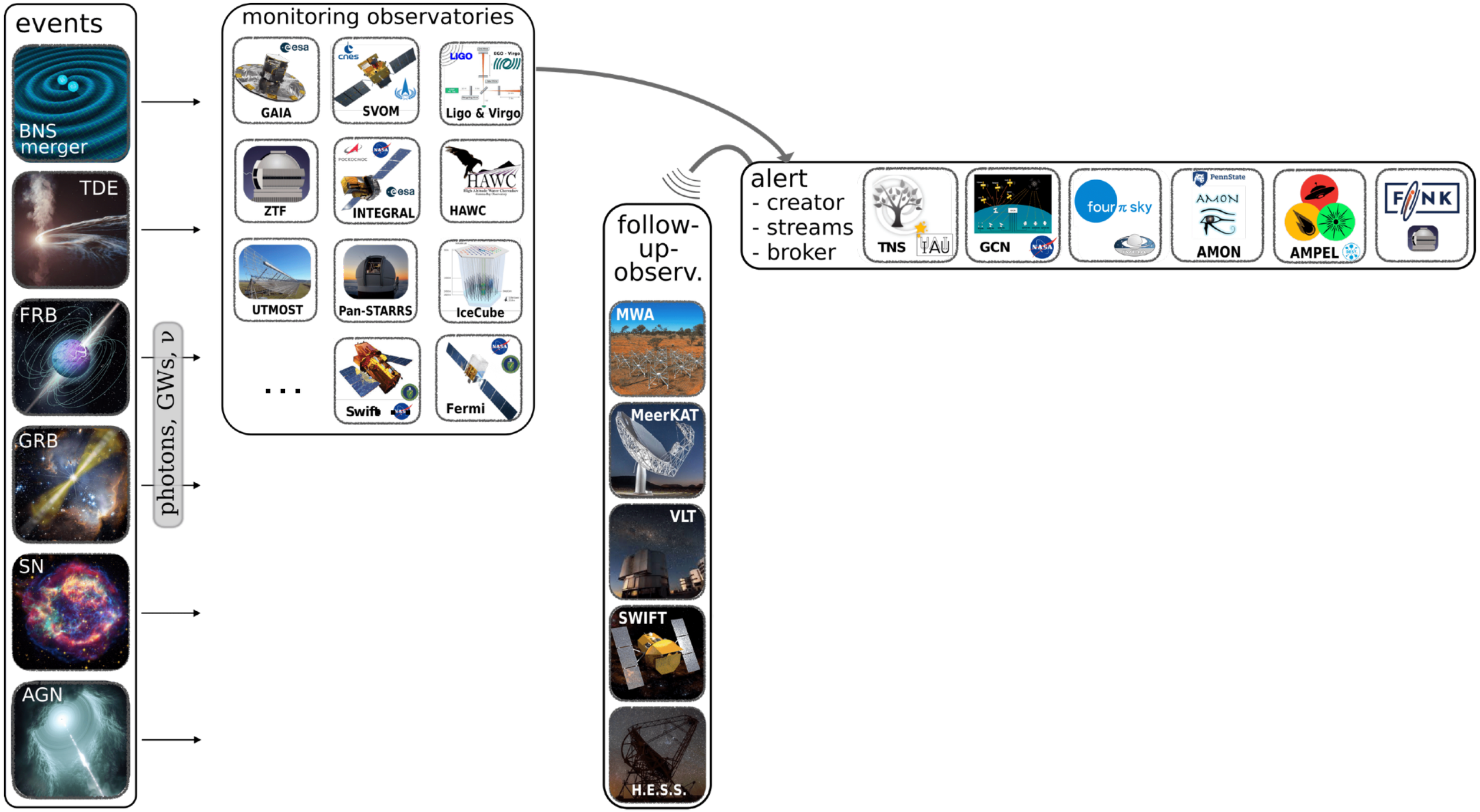
Tidal Disruption Events

Neutrinos

Fast Radio Bursts

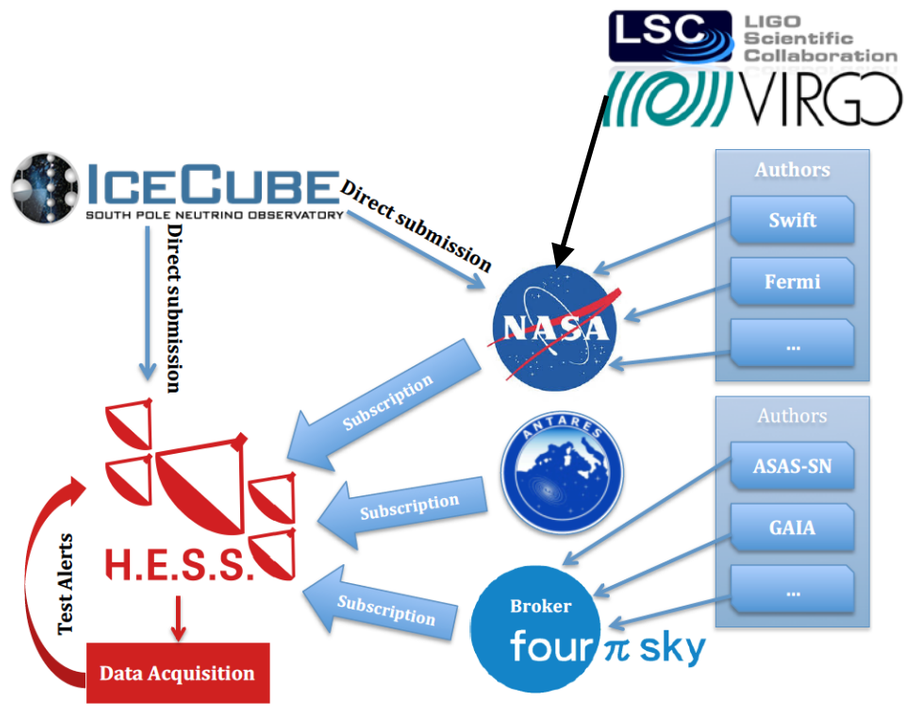
Soft Gamma-ray Repeaters

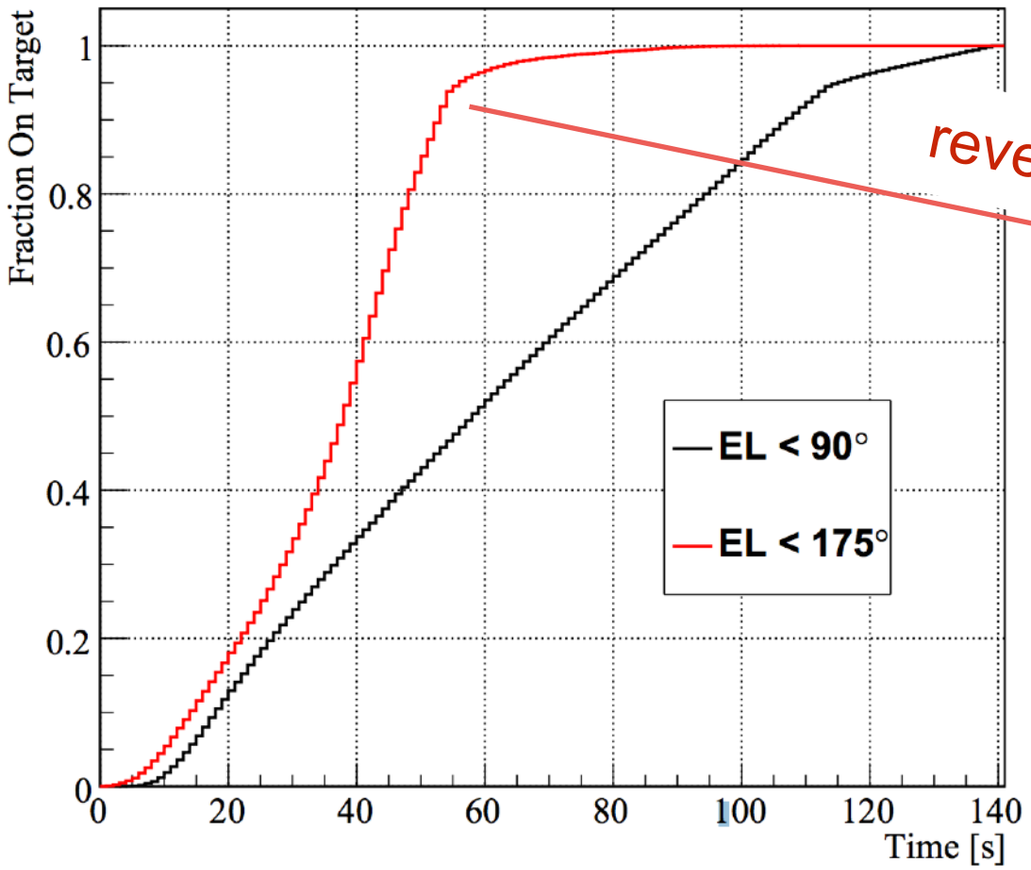
The MWL/MMA alert landscape



Time domain astronomy: ToOs

- Example: design principles of the H.E.S.S. 28m telescope
  - large photon collection area (614 m² mirror area; largest IACT worldwide)
  - **rapid response time**
  - **flexible + fully automatized alert system**

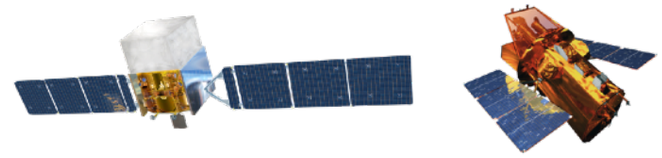




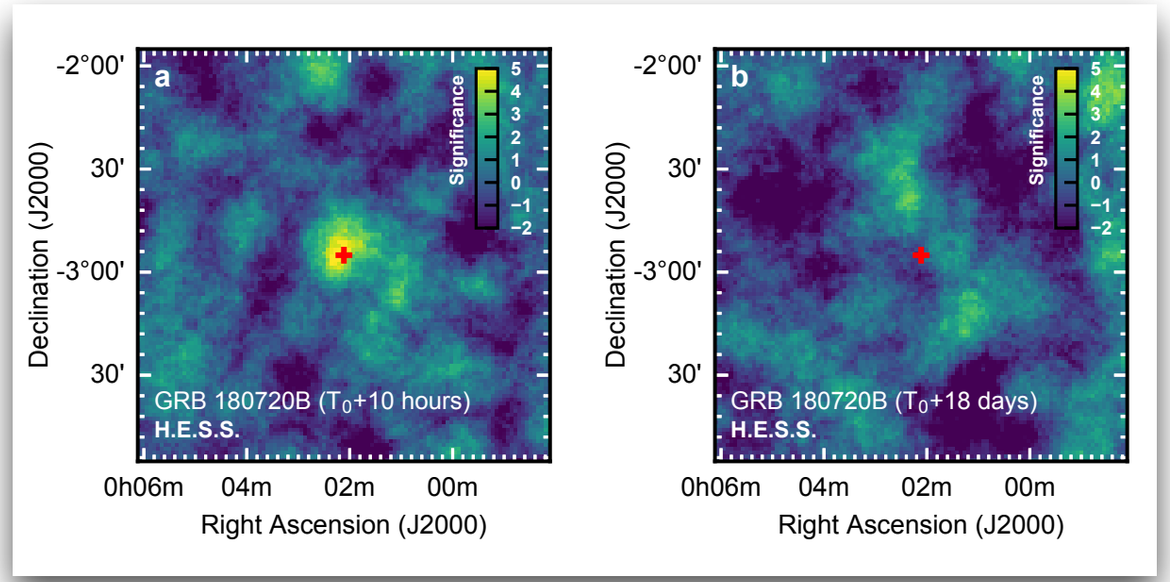
reverse tracking

Hofverberg et al., ICRC 2013

Gamma-ray bursts
time evolution of flux and spectra at very-high energies

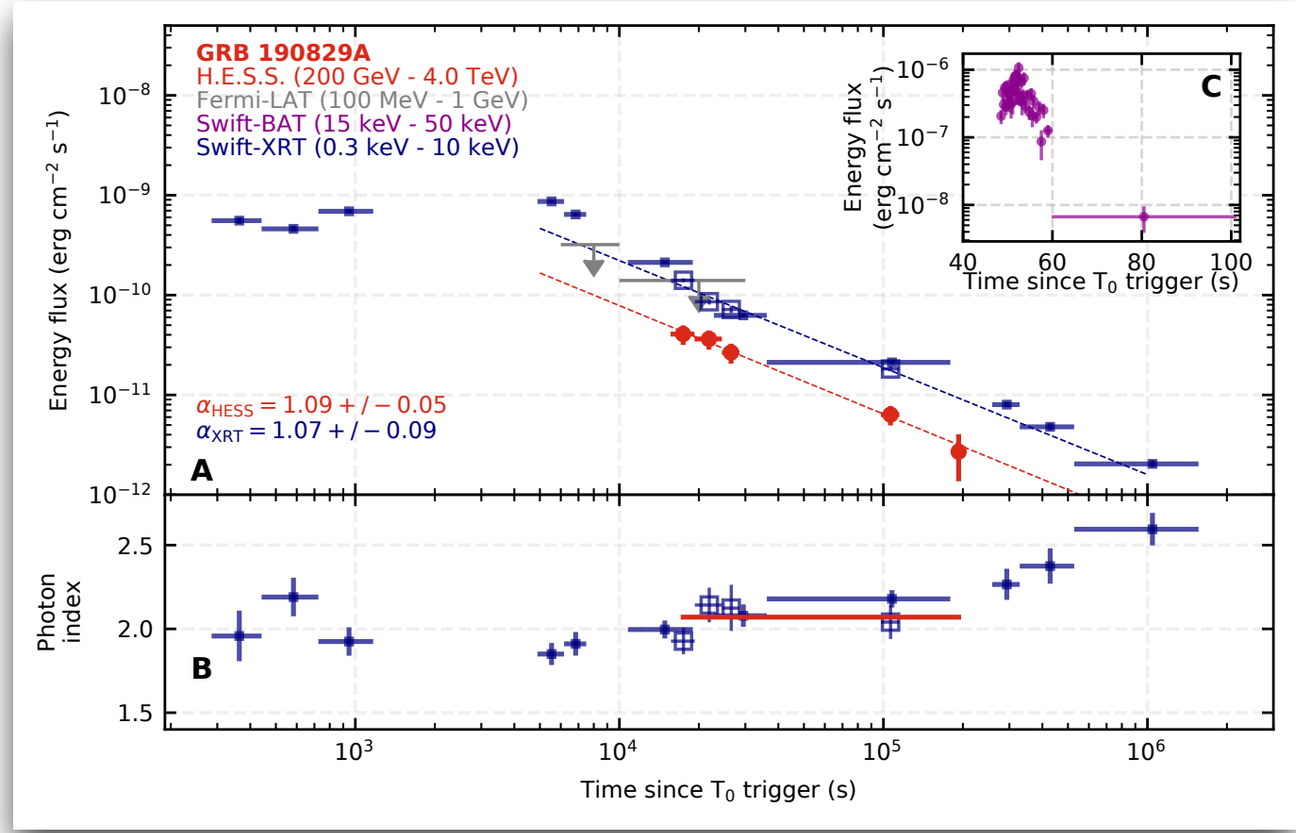


GRB 180720B



Nature 575, 464–467 (2019)

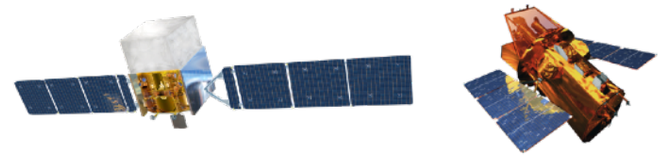
GRB 190829A

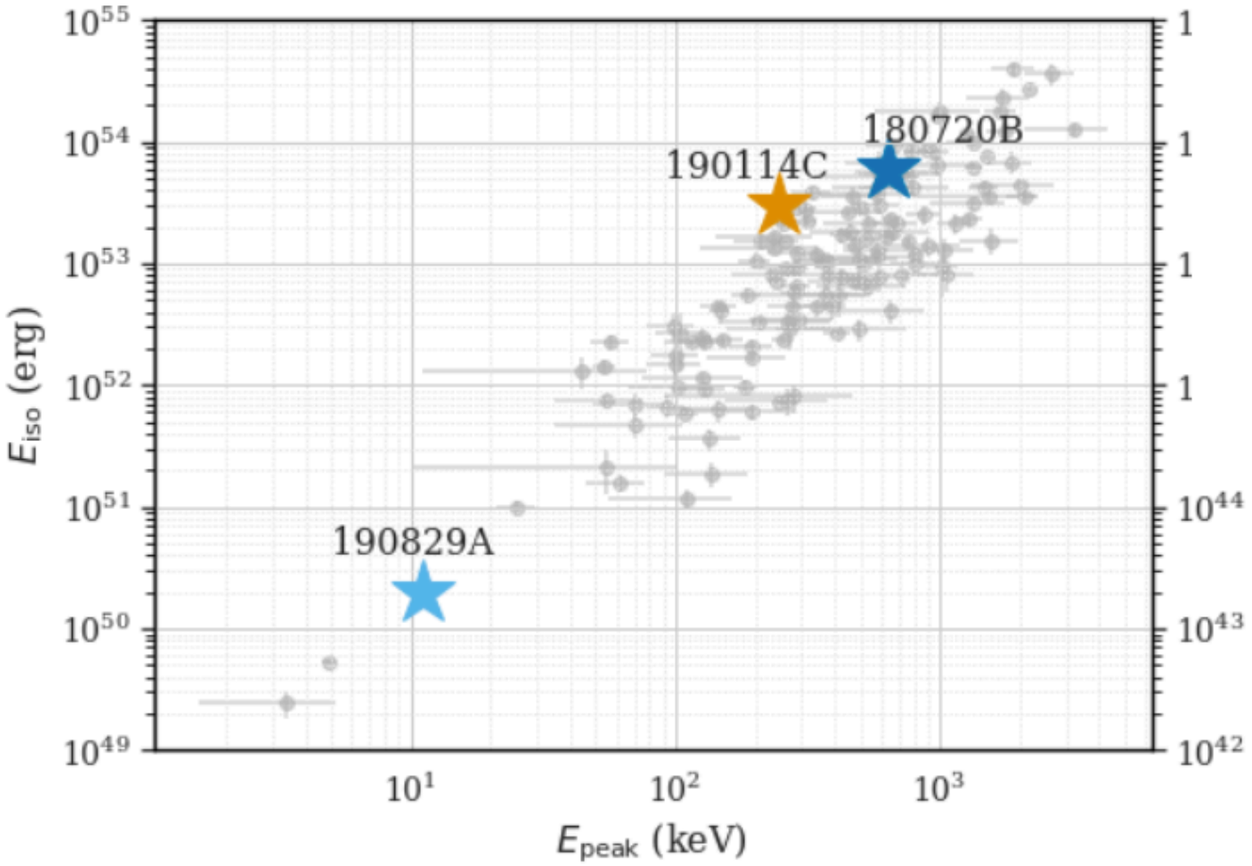


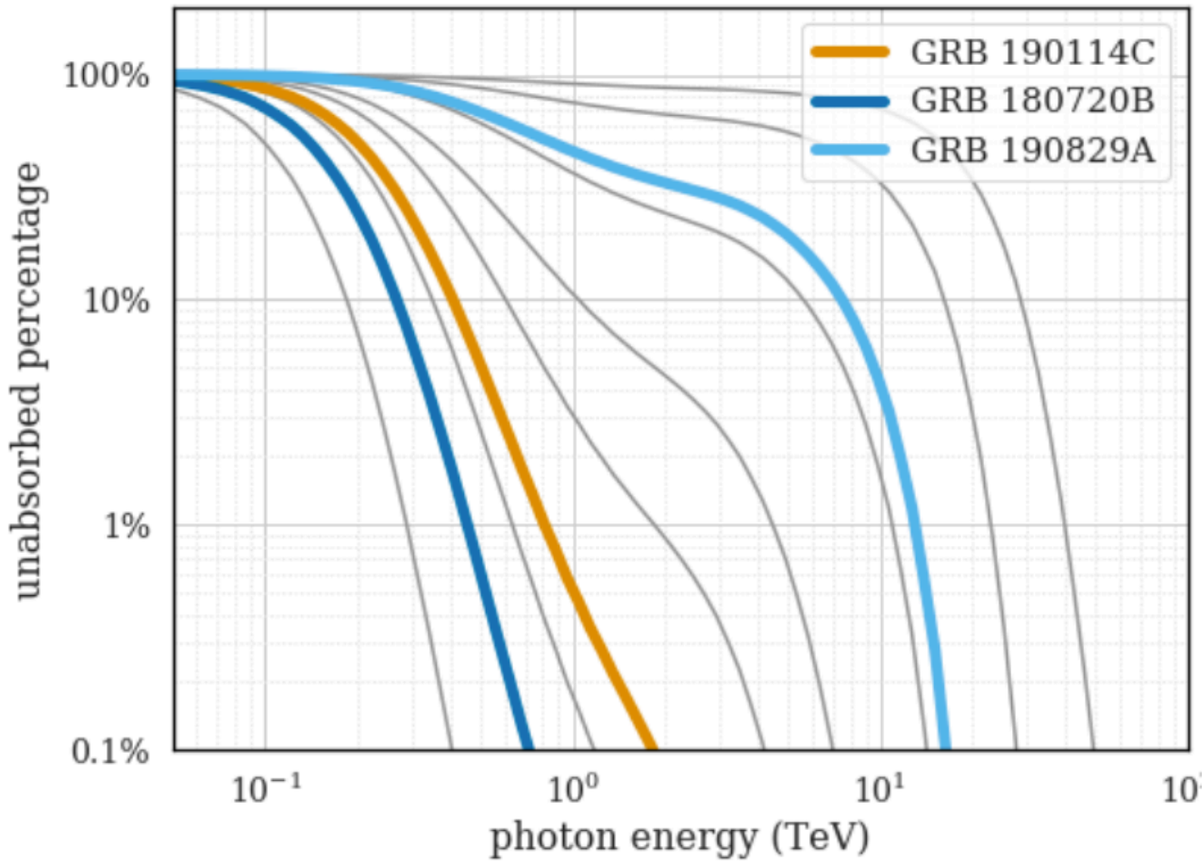
Science 372, 6546 (2021)

Gamma-ray bursts

Towards population studies at VHE energies

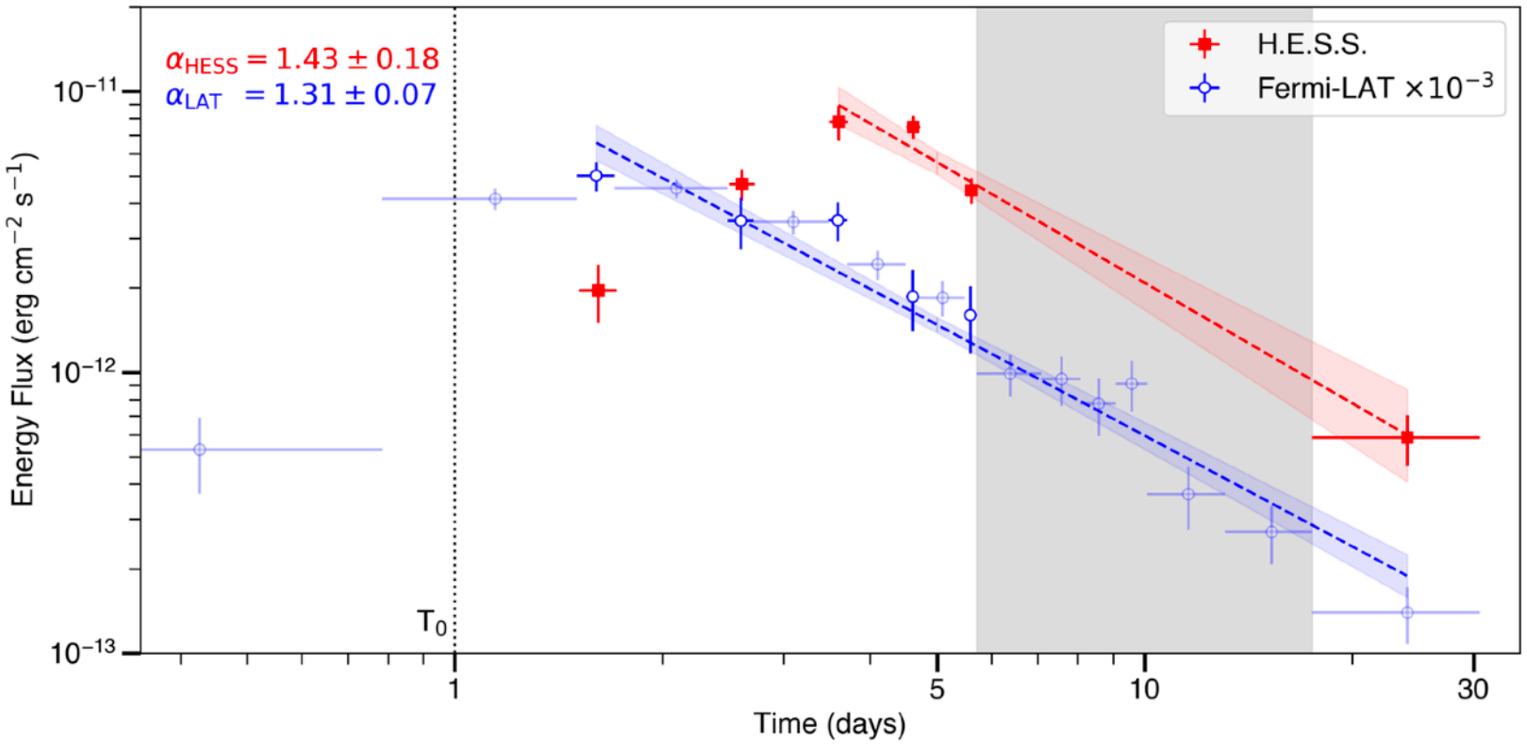


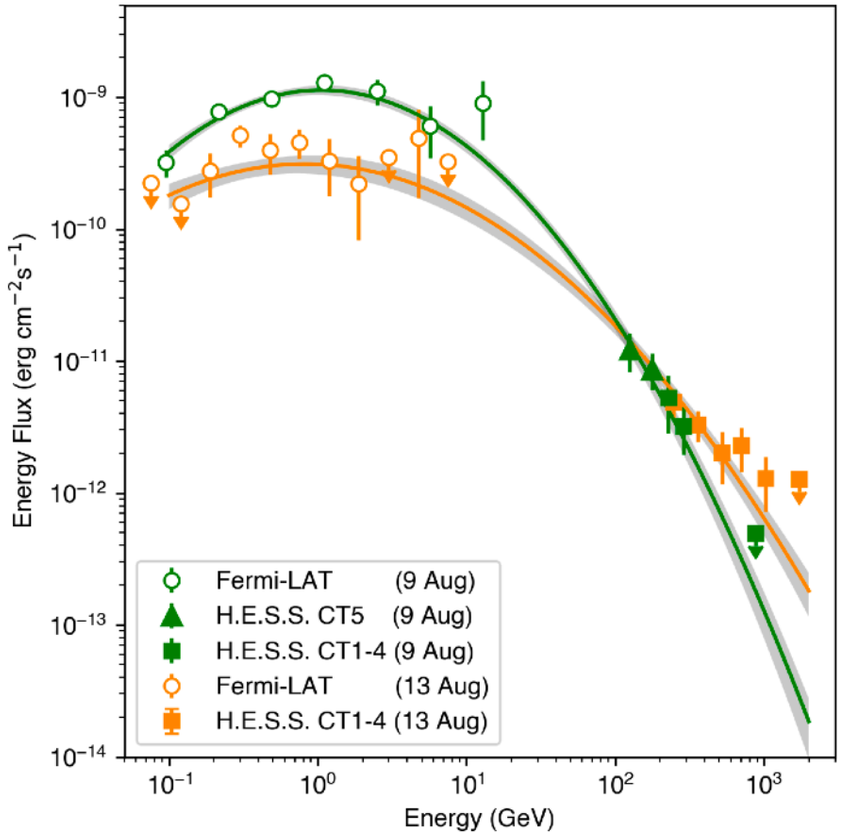




(Recurrent) novae
Efficient hadronic acceleration in RS Ophiuchi

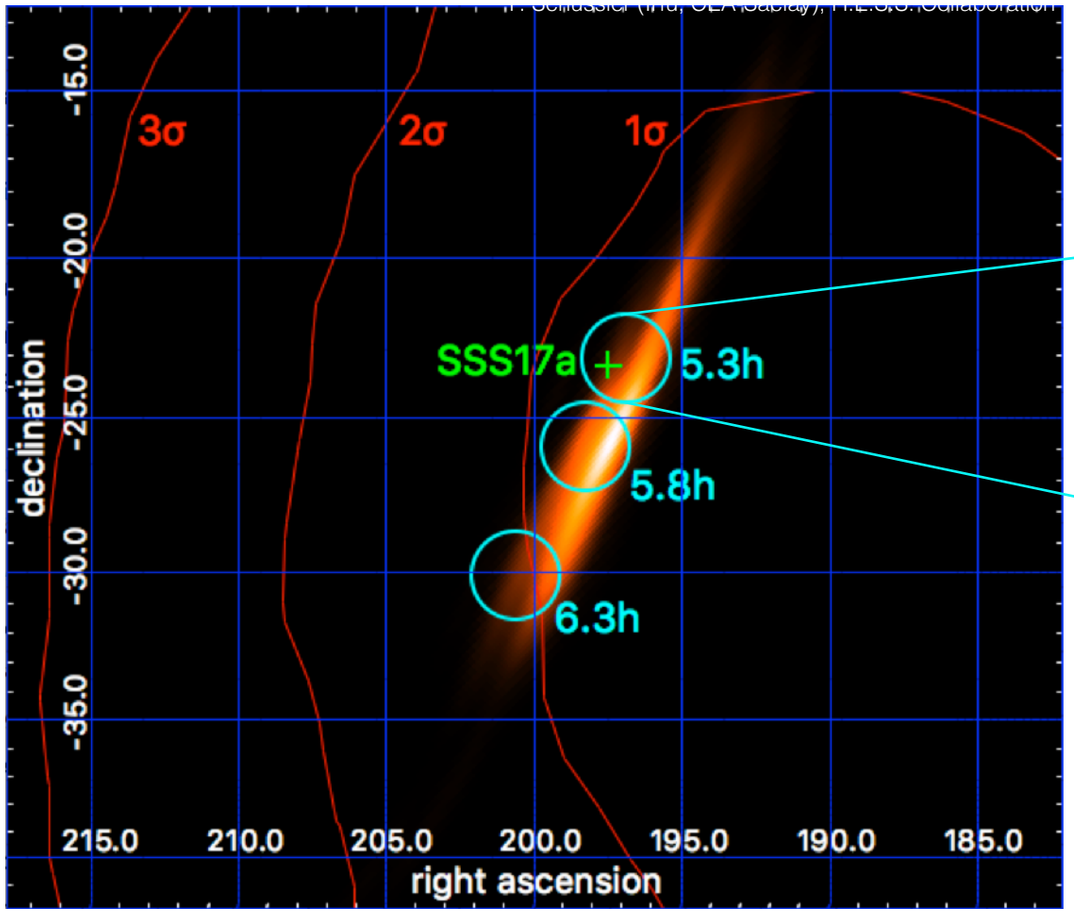
- 1st Galactic transient
- Well-known recurrent nova; 2021 outburst detected by amateur astronomers
  - 2006 outburst in February restricted observation time for VHE follow-up
- H.E.S.S. VHE detection over ~20 days!
- VHE peak flux 2 days after Fermi-LAT (3 days after optical); comparable decay slope
- Conclusion: hadronic scenario preferred; reaching theoretical limit for Emax via diffusive shock acceleration

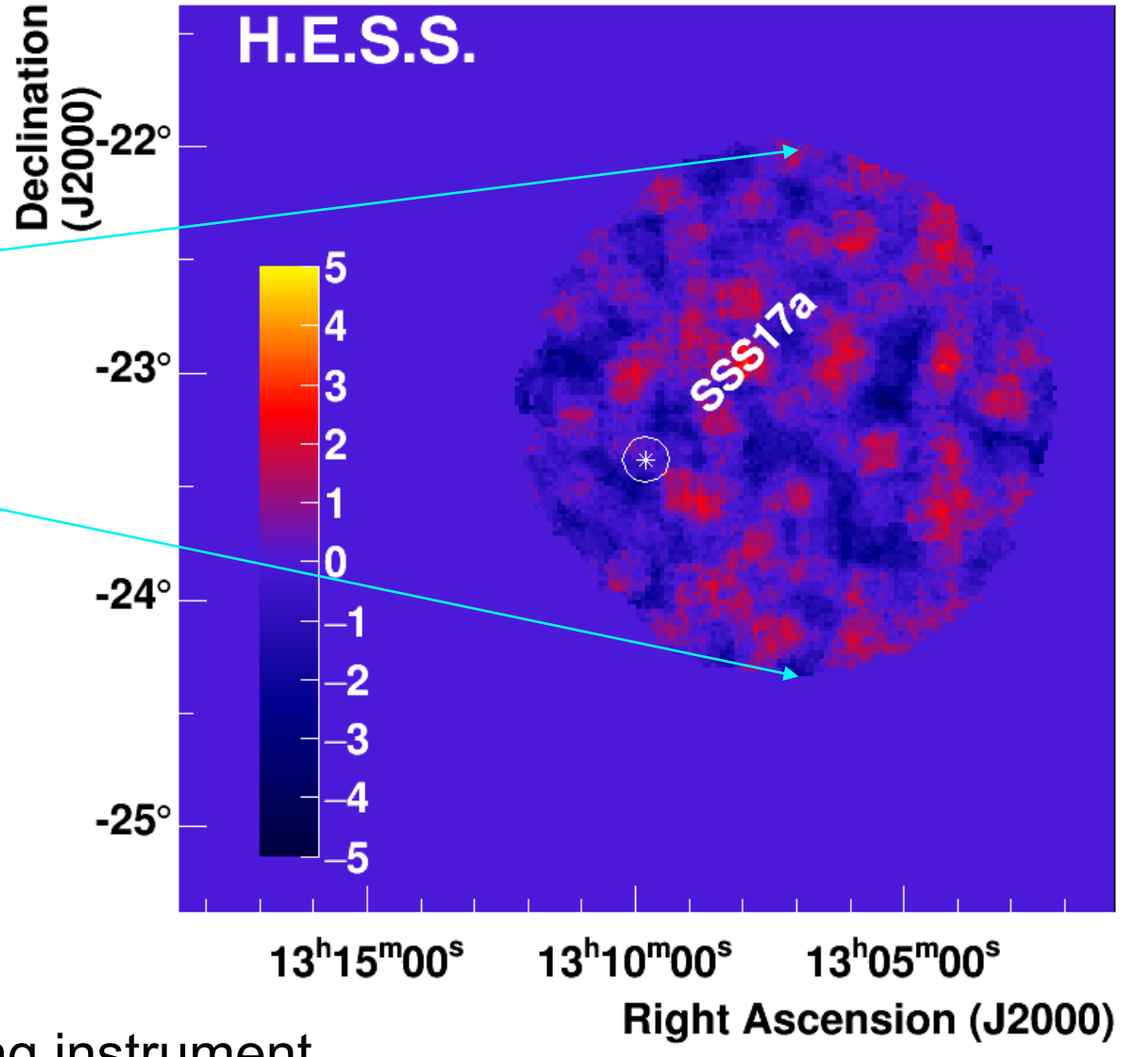




Science Vol 376, Issue 6588 (2022)


Gravitational waves
H.E.S.S. rapid follow-up of GW170817



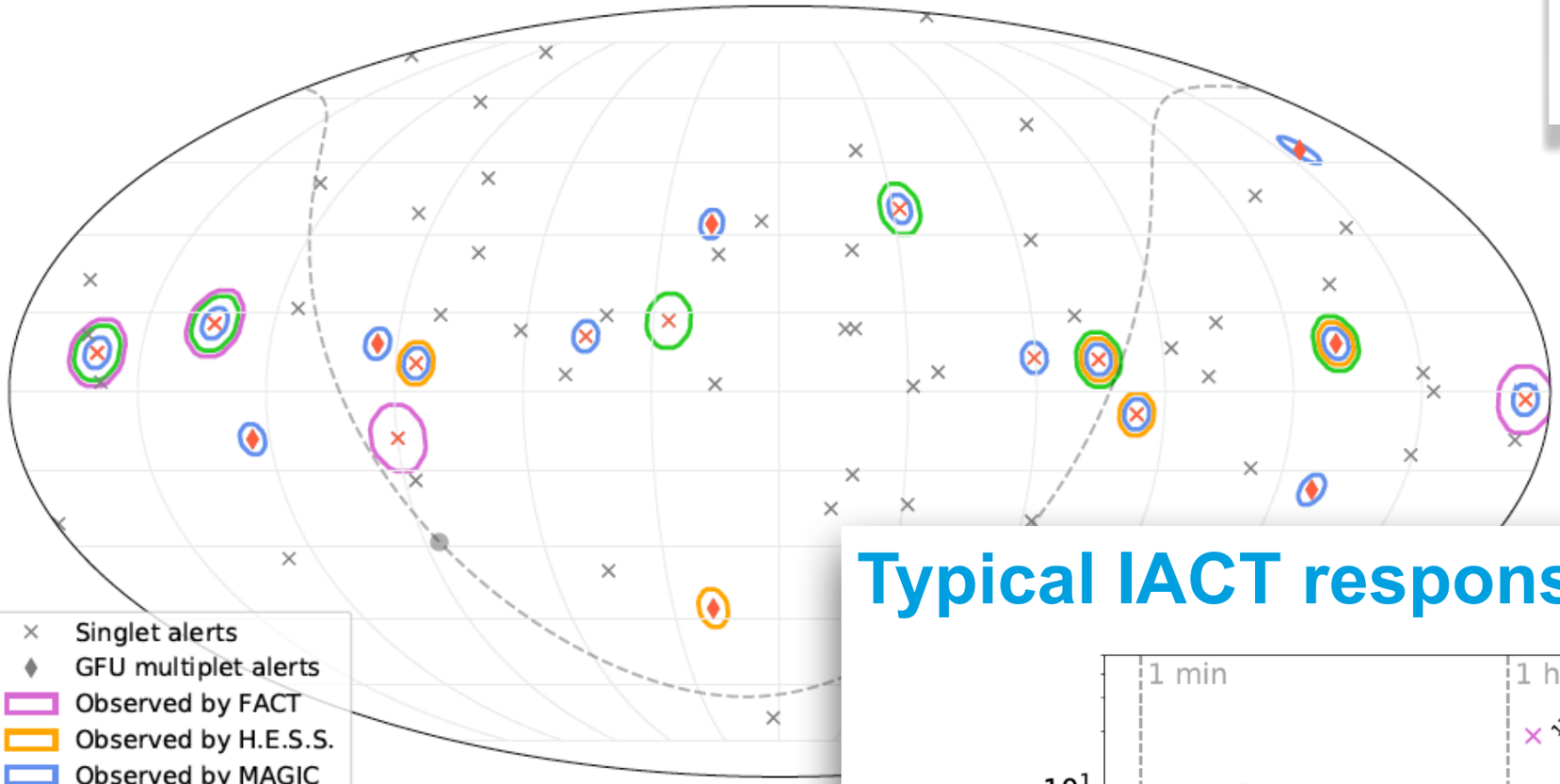


- First observations of a ground-based pointing instrument
  - 5.3 hours after GW170817 (5 minutes after the joint Ligo+Virgo analysis)
- Extensive monitoring of the remnant => limits on the magnetic field
- Complex scheme to optimize the tiling => ready for O4

ApJL 855:L22 (2017) + ApJL 894:L16 (2020) + H. Ashkar et al., JCAP03 45 (2021)

VHE emission associated to high-energy neutrinos

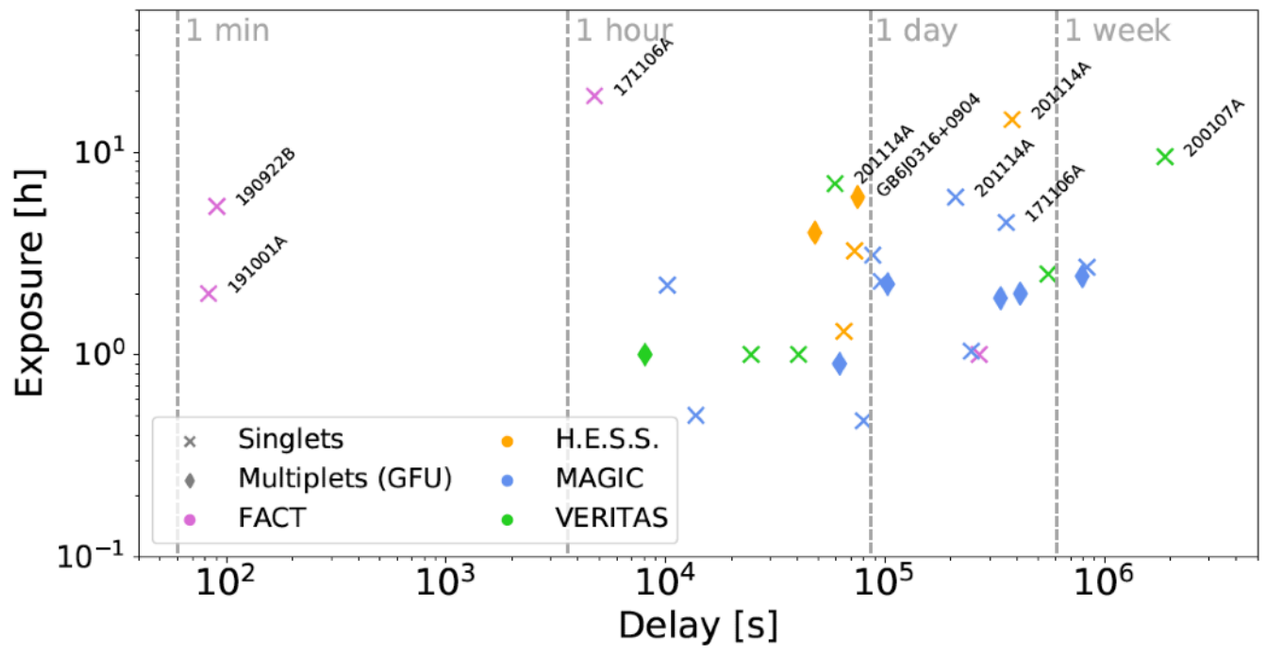
Alerts observed since October 2017



Alerts (Oct 2017 - Dec 2020):
62 singlets,
27 GFUs from 17 sources

Observed:
11 singlets,
GFUs from 7 sources

Typical IACT response



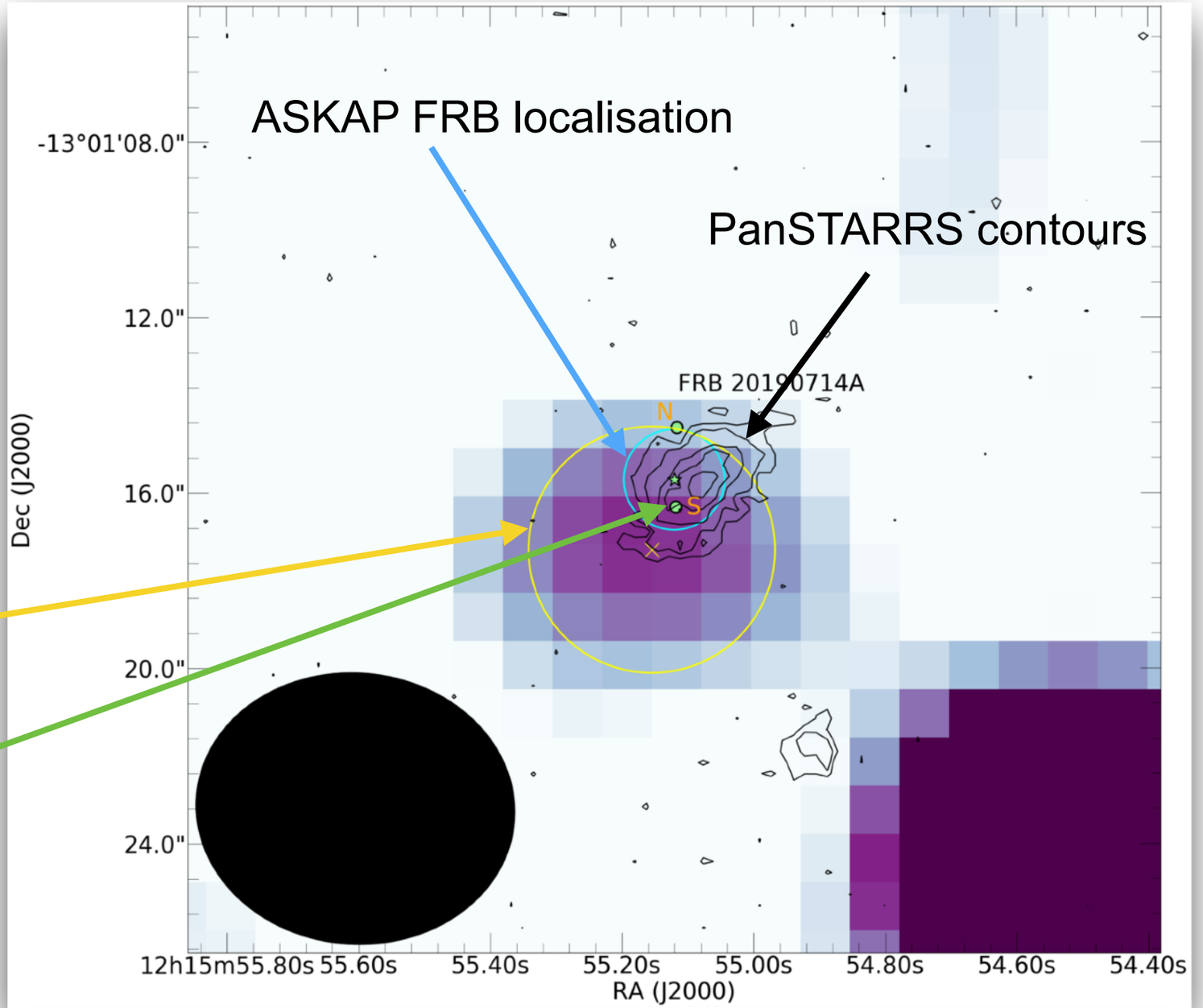
Joint effort by all IACTs

Santander et al. ICRC 2017
Satalecka et al., ICRC 2021

Fast Radio Bursts

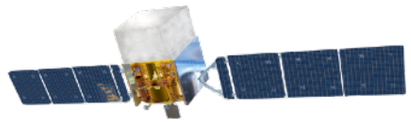
VHE afterglows, persistent emission, … => MWL campaigns

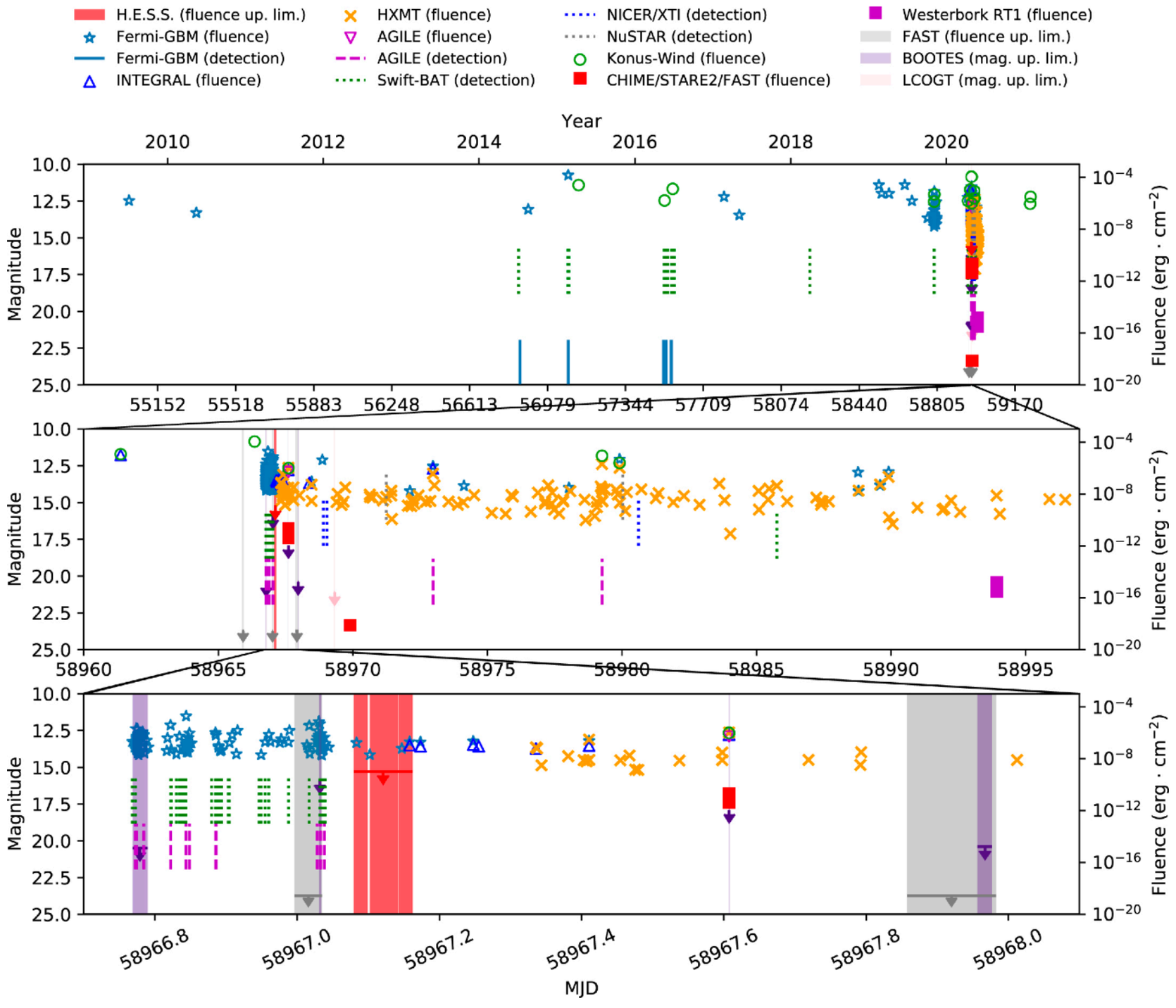
Dedicated campaigns with MeerKAT
Example: FRB 20190714A (non-repeating)



Chibueze et al. *MNRAS*, 515, 365–1379; arXiv:2201.00069

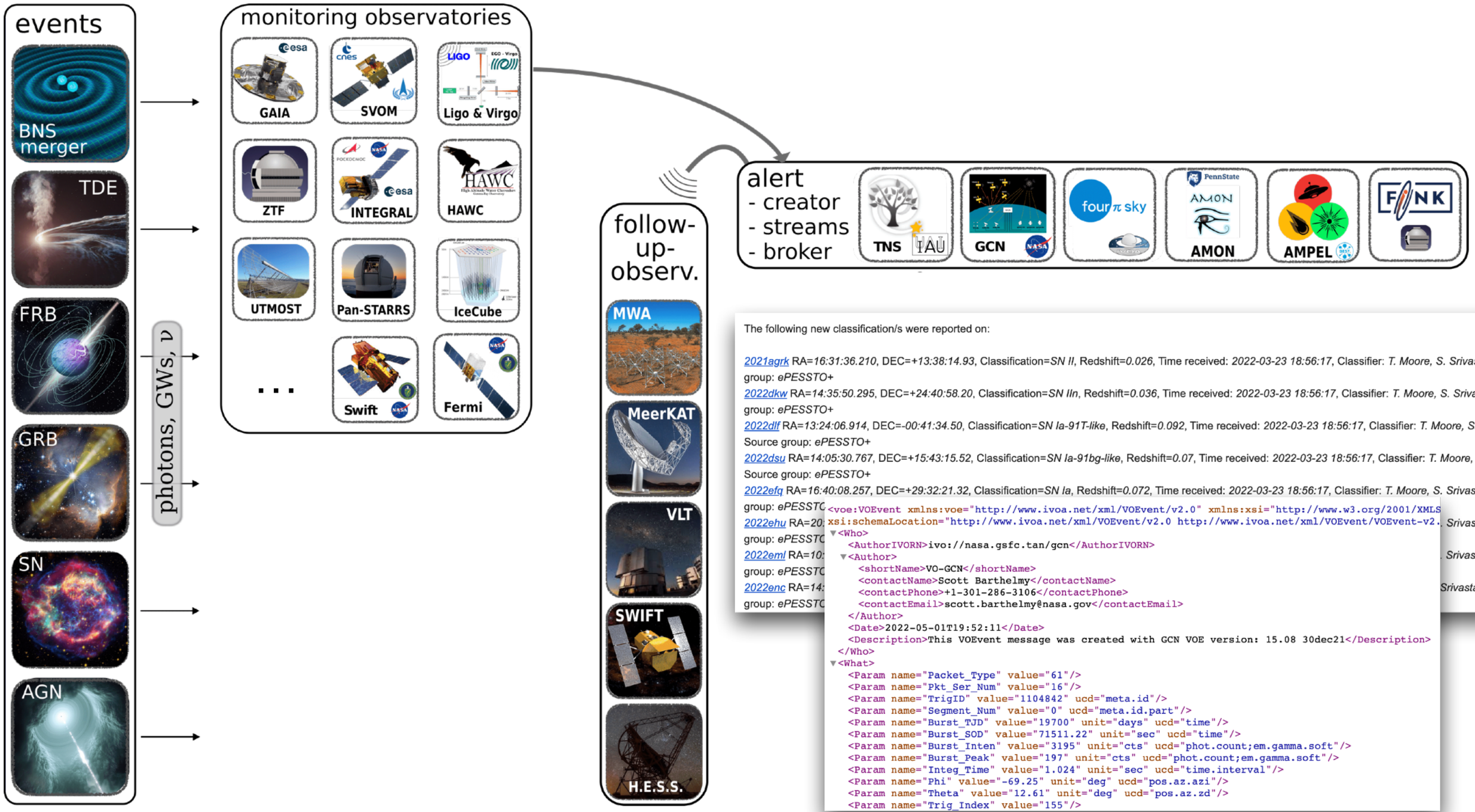
Fast Radio Bursts + SGRs
SGR 1935+2154 in May 2020





H. Abdalla *et al* 2021 *ApJ* **919** 106

The limits of the current MWL/MMA alert landscape



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group: ePESSTO+
2022dkw RA=14:35:50.295, DEC=+24:40:58.20, Classification=SN IIn, Redshift=0.036, Time received: 2022-03-23 18:56:17, Classifier: T. Moore, S. Srivastav, K
group: ePESSTO+
2022dlf RA=13:24:06.914, DEC=-00:41:34.50, Classification=SN Ia-91T-like, Redshift=0.092, Time received: 2022-03-23 18:56:17, Classifier: T. Moore, S. Srivastav, K.
Source group: ePESSTO+
2022dsu RA=14:05:30.767, DEC=+15:43:15.52, Classification=SN Ia-91bg-like, Redshift=0.07, Time received: 2022-03-23 18:56:17, Classifier: T. Moore, S. Srivastav, K.
Source group: ePESSTO+
2022efq RA=16:40:08.257, DEC=+29:32:21.32, Classification=SN Ia, Redshift=0.072, Time received: 2022-03-23 18:56:17, Classifier: T. Moore, S. Srivastav, K.
group: ePESSTO
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2022eml RA=10:
group: ePESSTO
2022enc RA=14:
group: ePESSTO

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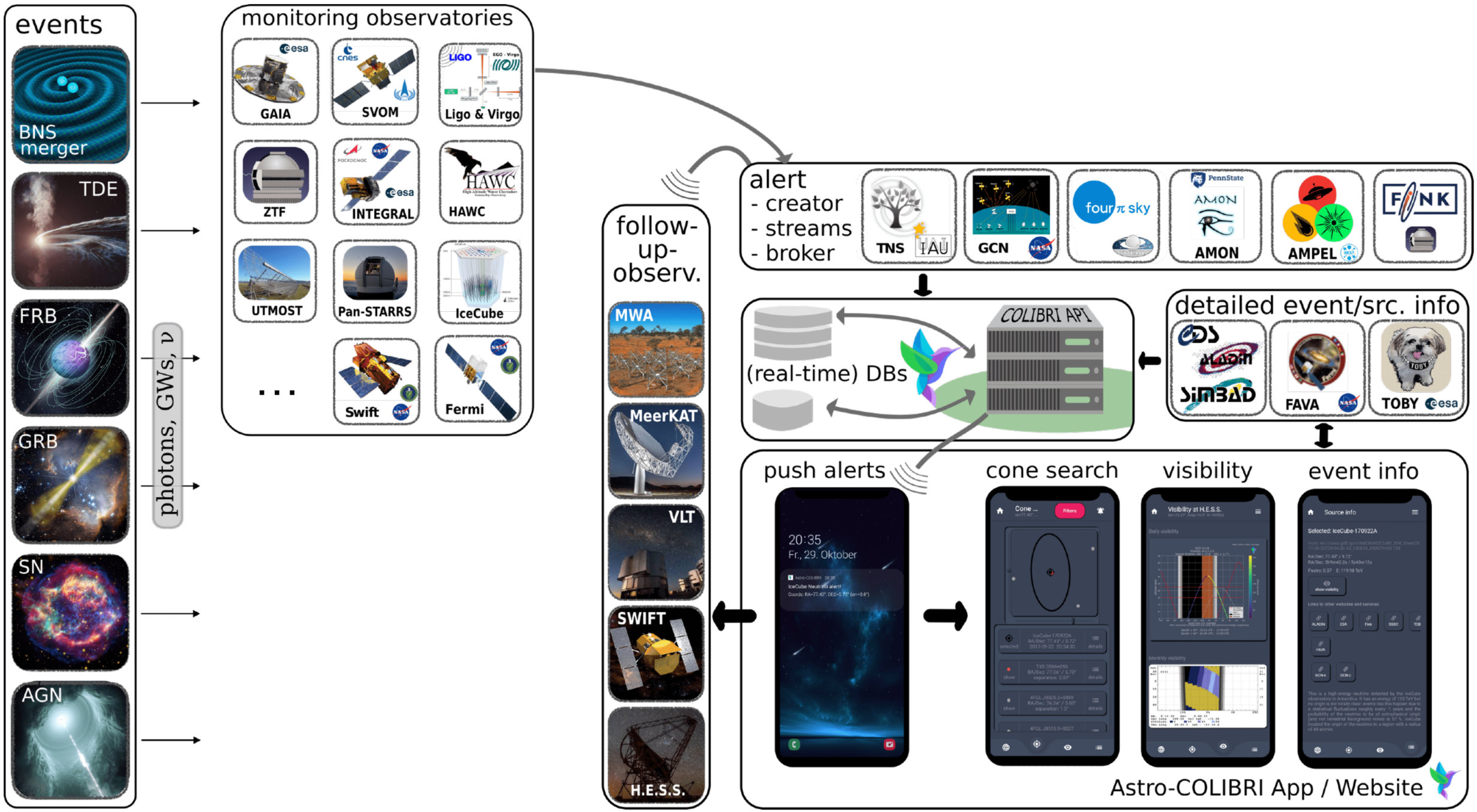
An *improved* MWL/MMA alert landscape



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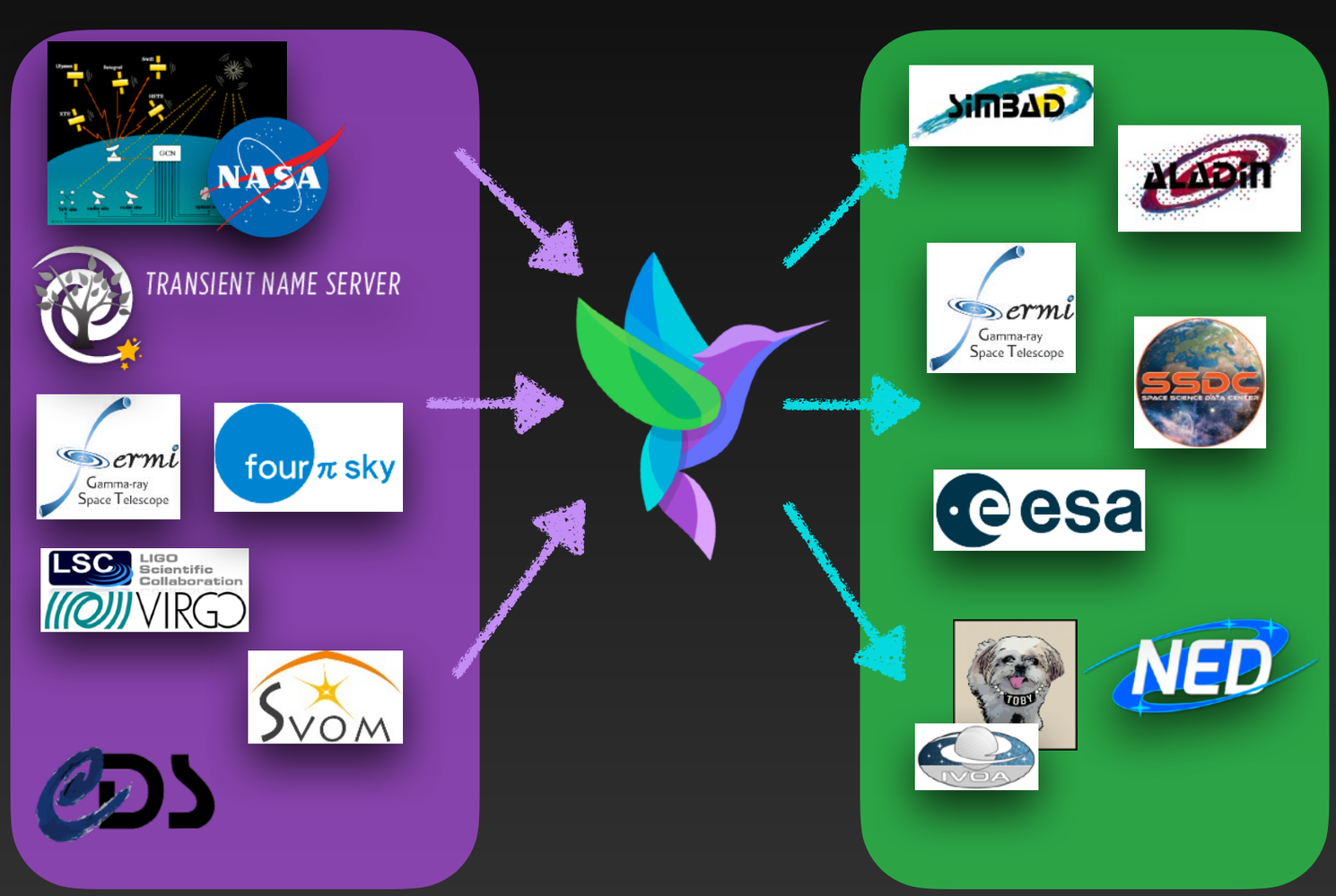
20 years of H.E.S.S. observations

- **Several years of preparation coming to fruition**
  - automatic alert systems + dedicated data analysis tools + MoUs + …
- **Gamma Ray Bursts**
  - major breakthroughs over the last years (GRB180720B, GRB190114C, GRB190829A, etc.)
  - many insights but also new questions
  - link to **gravitational waves** (e.g. rapid observations of GW170817)
- **High-energy neutrinos**
  - IceCube-170922A and TXS 0506+056: a first hint
- New VHE transients: **Galactic nova RS Ophiuchi**
  - Need for improved connections with the amateur astronomers community!
- Multi-wavelength and multi-messenger connections crucial for most science cases
- Huge data sets (600h+) covering many years with changing telescope/cameras configs
- Extensive work on systematics,MC, improved calibration and high-level analyses
  - choice of GammaPy as high-level tool (borne out of the 1HGPS)

Astro-COLIBRI

- Increasing number of multi-messenger transients + a large variety sources of information (alerts, catalogs, monitoring, etc.)

- Need for novel tools and platforms to keep track and make informed decisions



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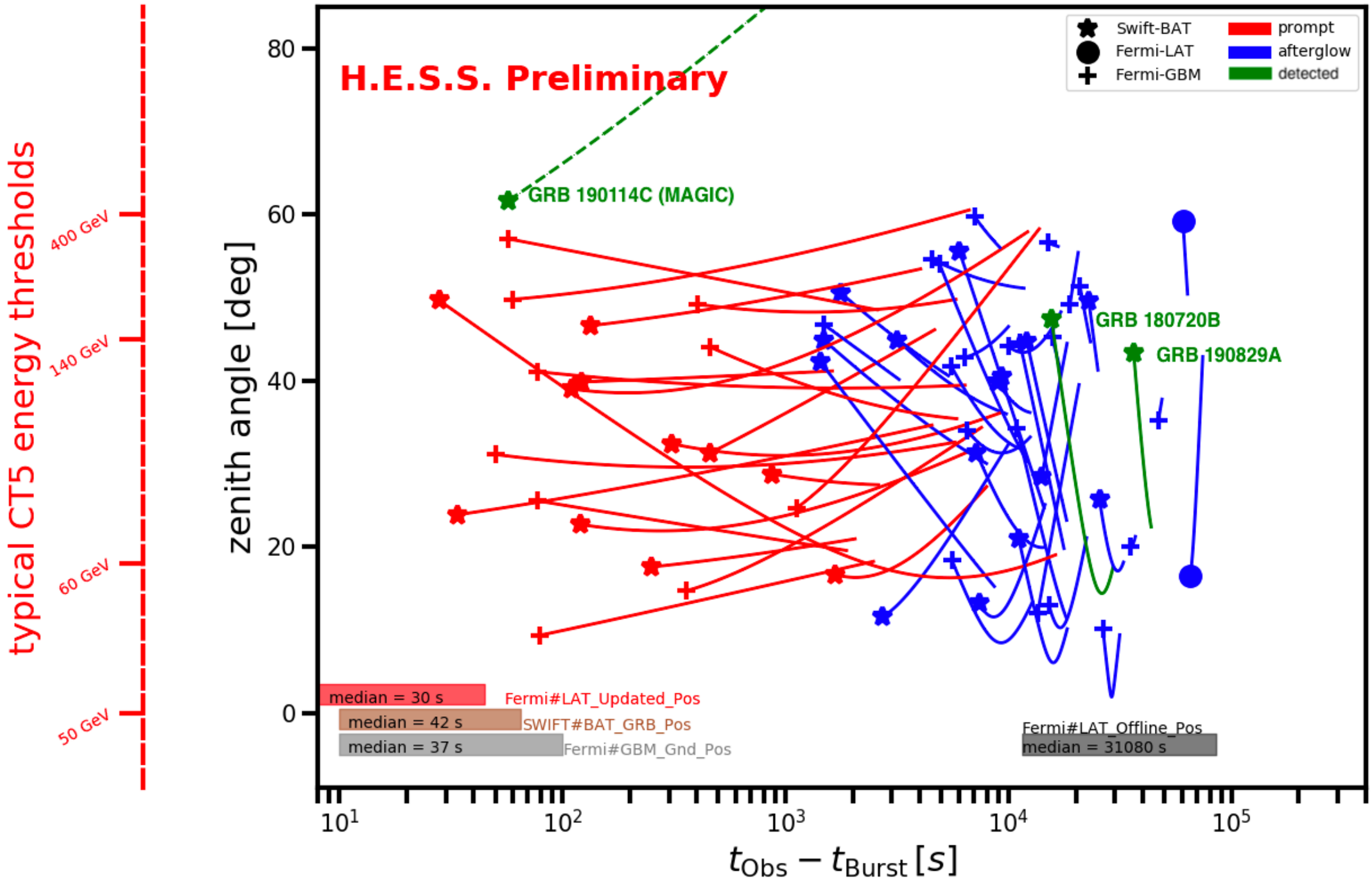
Finally: Gamma Ray Bursts @ IACTs

- short-GRB 160821B @ MAGIC: hint for detection (arXiv:2012.07193), later associated with a kilonova (Lamb et al. 2019 arXiV:1905.02159)
- GRB 180720B @ H.E.S.S.: >100GeV emission 10h after the burst (Nature 575, 464–467 (2019))
- GRB 190114C @ MAGIC: >300GeV emission 50s after the burst (Nature 575, 459 (2019))
- GRB 190829A @ H.E.S.S.: >180GeV during 56h; striking similarity between VHE and X-rays (Science 372, 6546 (2021))
- GRB 201216C @ MAGIC: >5sigma, observations >57s (ATEL #14275)

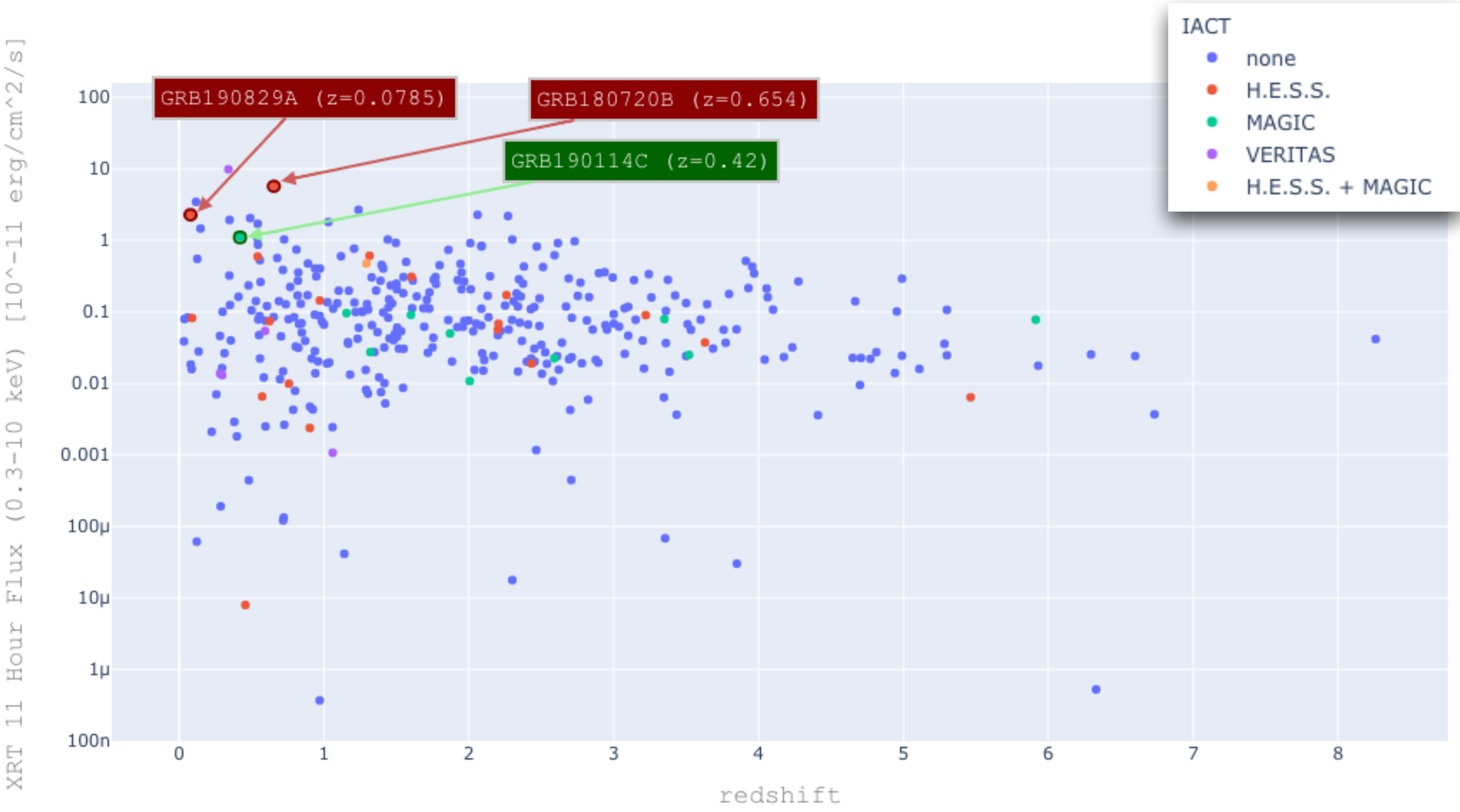
Hunting GRBs with IACTs

- The H.E.S.S. GRB program

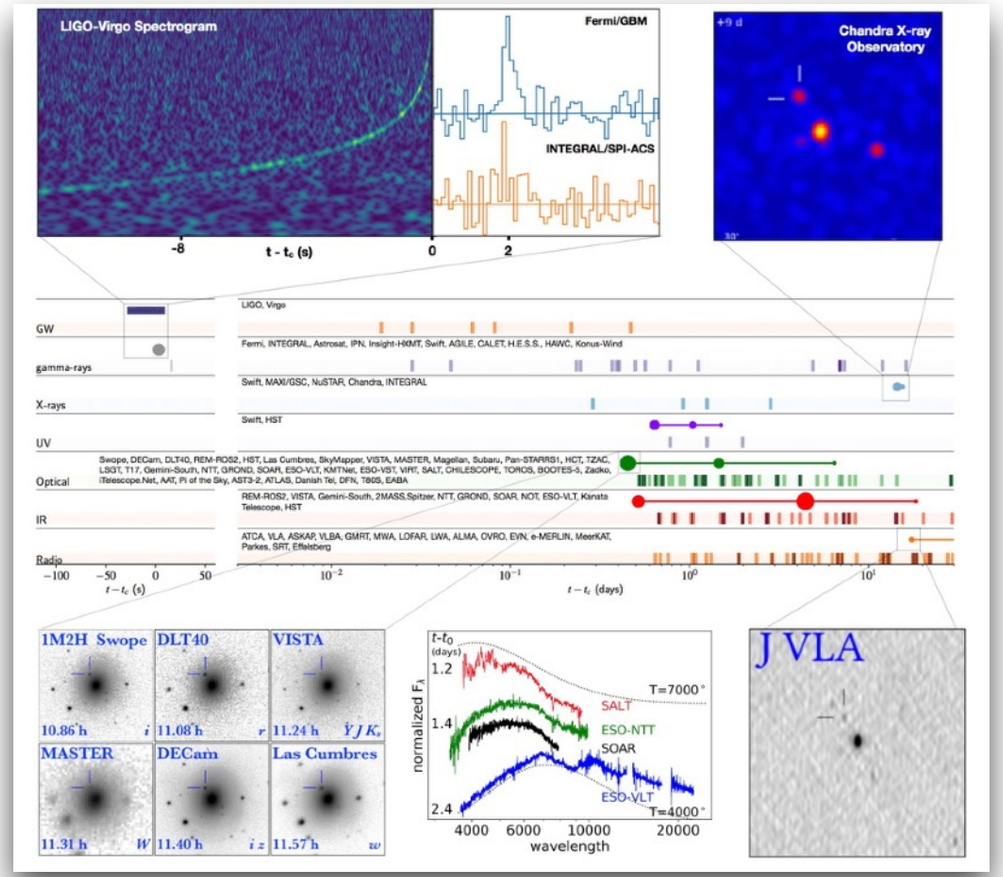


Updated from C. Hoischen et al., PoS(ICRC2017)636

Towards GRB population studies



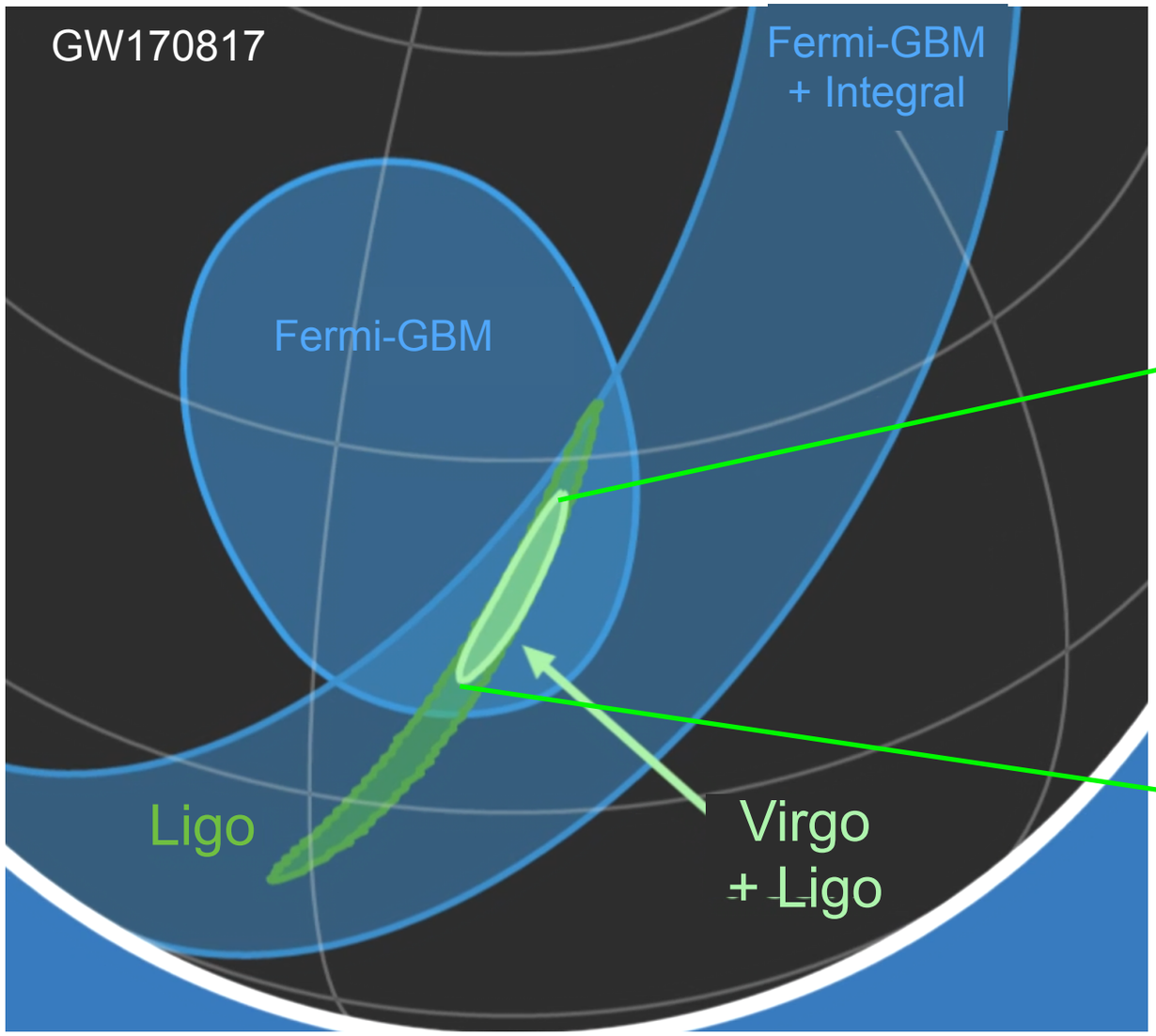
Gravitational waves and Gamma-Ray Bursts

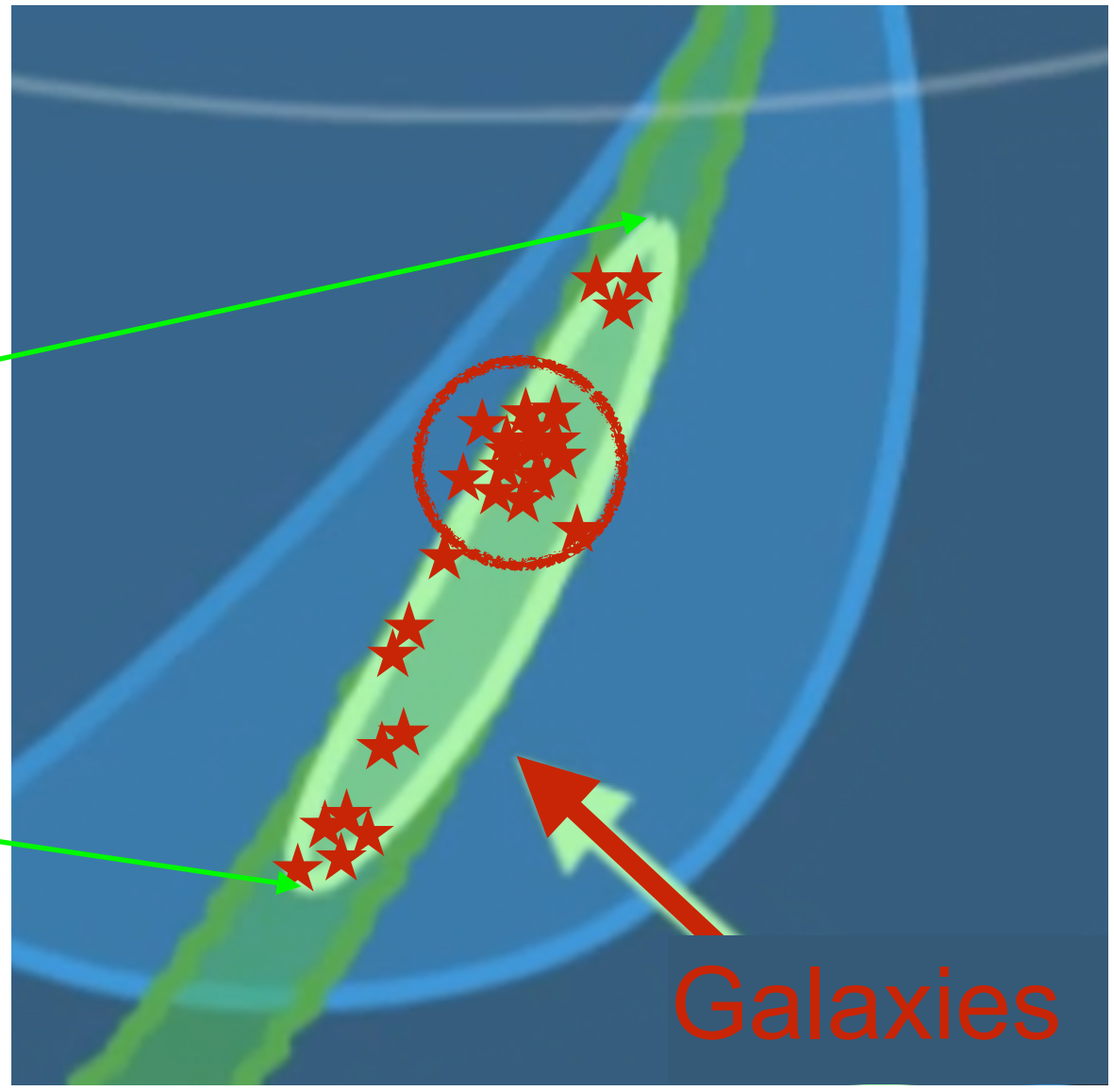


Abbott, B.P. et al 2017 ApJL 848 L12

- GW170817: NS-NS mergers are sources of (short) GRBs
- GRBs emit at VHE energies
- VHE emission is strong enough for current IACTs
- VHE emission is long-lasting (GRB190829A: >56h)
- Let's detect VHE emission from NS-NS (and NS-BH) mergers…

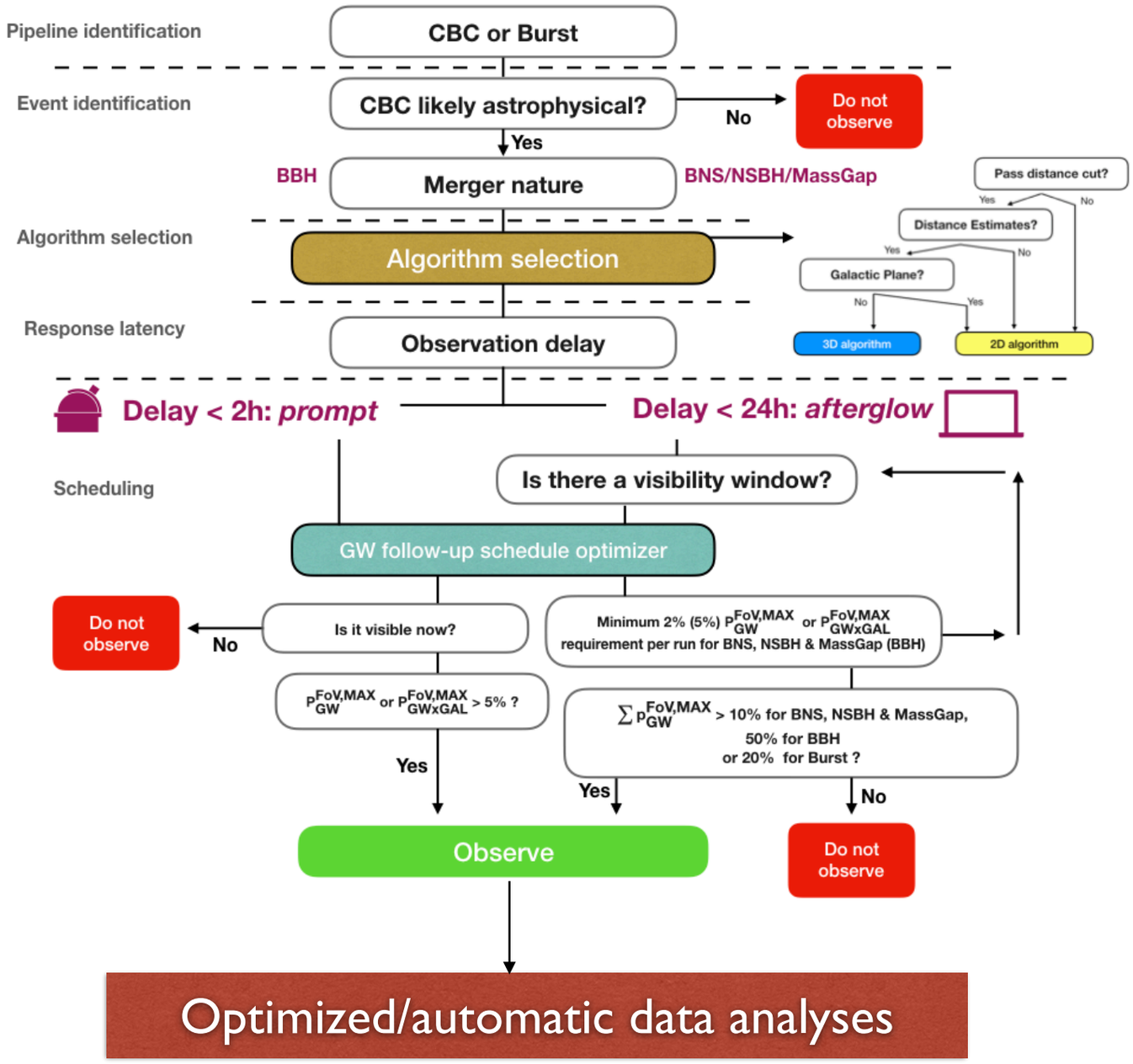
Scheduling and pointing strategy

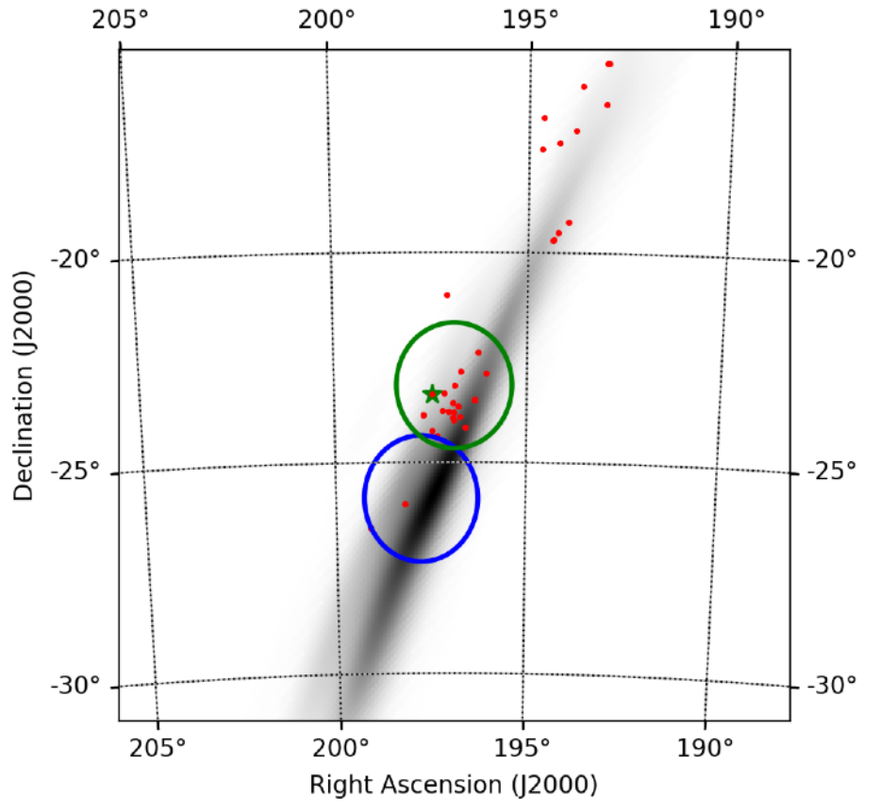


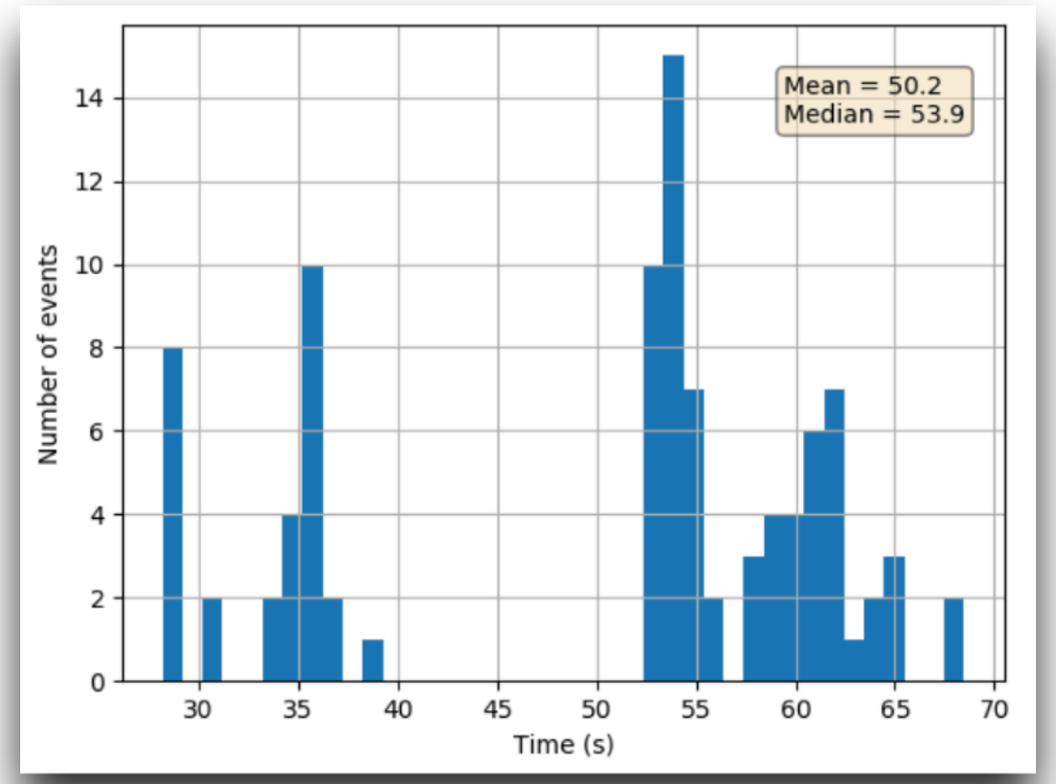


- automatic selection of regions of interest
  - correlation with galaxy catalog(s) in 3 dimensions
  - dedicated algorithms for the different possibilities (e.g. BNS, BBH, bursts, etc.)

Scheduling and pointing strategies



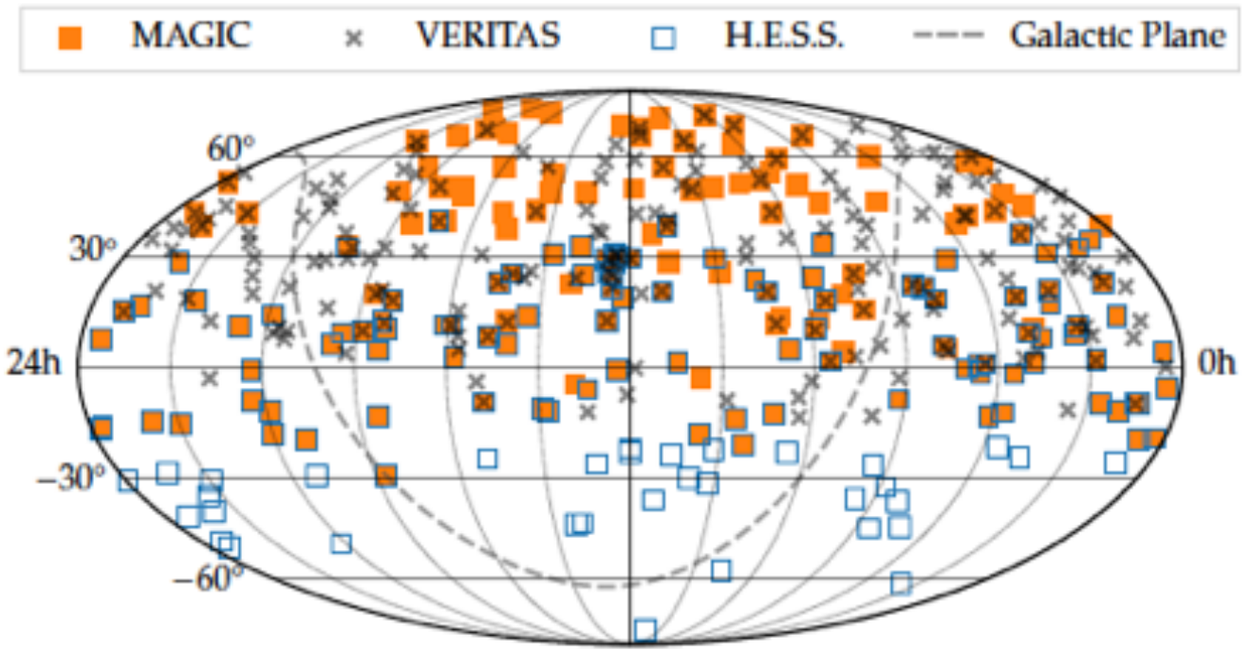




H. Ashkar et al., "The H.E.S.S. Gravitational Wave Rapid Follow-up Program", JCAP03(2021), 45

IceCube alert streams (I): Gamma-ray follow-up (“GFU”)

- Searches for neutrino multiplets (“flares”) in the IC online data stream
  - Time periods ranging from seconds to 180days
- Predefined targets + all-sky search (in preparation)
- Alerts distributed privately under MoU
  - Northern Sky: MAGIC & VERITAS since 2012
  - Southern Sky: H.E.S.S. since 2019
- Source selection based on 3LAC/3FHL/TeVCat; variability; distance; visibility
- Aim: determine the state of the source (quiescence vs flaring state; spectral changes)



Neutrino multiplet from 1ES 1312-423

- Neutrino ‘flare’ detected by IceCube (duration 6.5 hours)
- H.E.S.S. ToO observations => re-detection of the source (~4sigma)
- Contemporaneous MWL observations ATOM + Swift (UVOT + XRT)
- No significant change in the non-thermal emission during the ToO