Follow-up observations of multi-messenger alerts with H.E.S.S.

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for the H.E.S.S. Collaboration

H.E.S.S.

The High Energy Stereocopic System (H.E.S.S.)

Imaging Atmospheric Cherenkov Telescopes Array in Namibia

- Sensitive to gamma-ray energies from ~30 GeV to 100 TeV
- Operational since 2002 with major upgrade in 2012

Phase I

- 4x 12m telescopes
- 5 degree field of view
- Energy threshold ~100 GeV
- Angular resolution ~0.1deg

Phase II

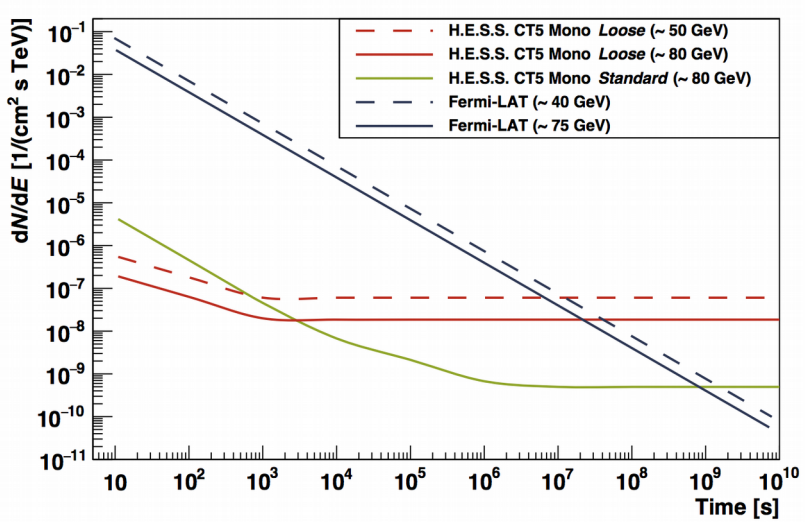
- Additional 28m telescope
- 3.2 degree FoV
- Energy threshold ~30 GeV
- Angular resolution 0.1-0.4 deg

H.E.S.S. activities in the multi-messenger context

H.E.S.S. is very well suited to follow-up transient alerts

- Excellent gamma-ray sensitivity paired with a large FoV
- Rapid follow-up response time (~30 seconds) thanks to fully automatic online transient alert system

→ see technical details in C. Hoischen's talk



M. Holler et al., ICRC 2015

Search for electromagnetic counterparts of transients in the very-high-energy regime

- Prompt follow-up of multi-messengers alerts
  - Gamma-ray bursts & Fast Radio Bursts
  - Neutrino events
  - Gravitational wave events
  - AGN flares
- Long-term follow-up of electromagnetic counterparts
  - GW counterparts
  - Monitoring of AGN

Gravitational Wave Alerts – Prompt follow-up

GW signals are the „new“ messenger of the Universe

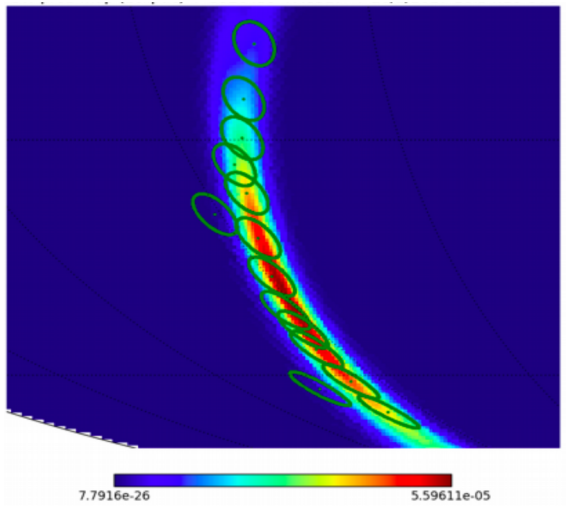
- All Cherenkov telescopes have dedicated follow-up programs → see talk by M. Seglar-Arroyo
- Main drawback for pointed observations: relatively large uncertainties on localization

H.E.S.S. strategy on prompt follow-up of GW alerts

- Dedicated algorithms to determine optimized schedule
  - 3D-correlation with galaxy catalog (GLADE)
  - Implementation of observational constraints
- Runs fully automatic within the transient alert system onsite (~1 minute from alert to start of observation)

GW alerts in O2 followed up by H.E.S.S.

- GW170814 (BBH), GW170817 (BNS)



M. Seglar-Arroyo et al
ICRC 2015

GW170817 – Prompt observations

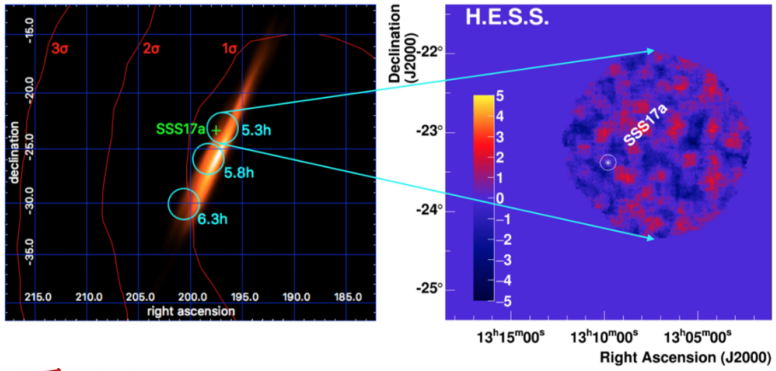
H.E.S.S. Collaboration,
ApJL 855 (2017)

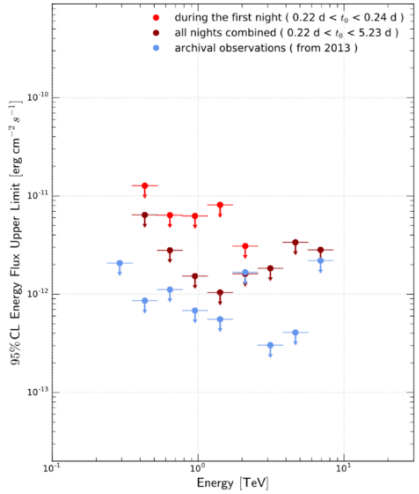
GW170817/GRB170817a trigger

- First detection of gravitational waves coming from a Neutron Star Merger
- First coincidence detection of the GW and EM signatures

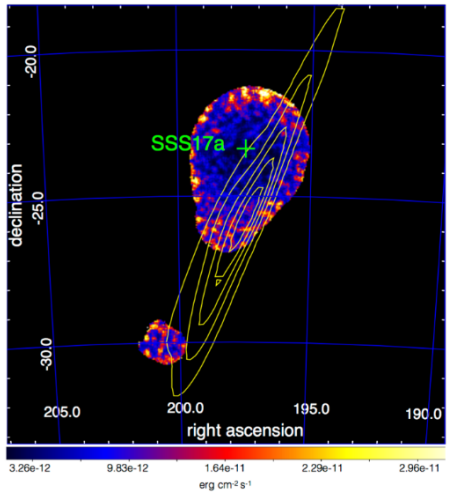
H.E.S.S. observations were first pointed observations

- Scan of error region during the first night (3 pointings)
- Follow-up campaign during the next nights on target (~8h)
- No signal: Φ (0.27<E[TeV]<8.55) < 1.5 x 10^{-12} erg cm^{-2} s^{-1}





(a) SSS17a: H.E.S.S. limits



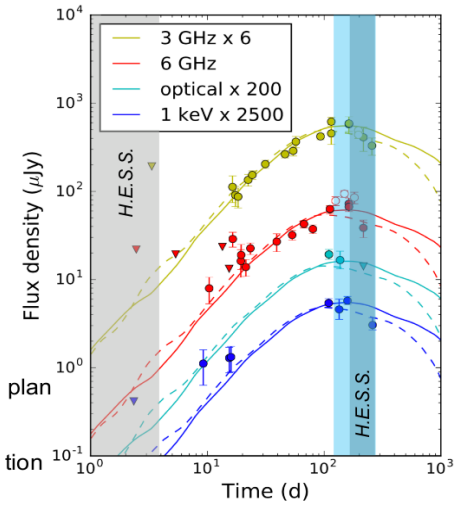
(b) GW170817: H.E.S.S. flux limit map

GW170817 – Long-term follow-up

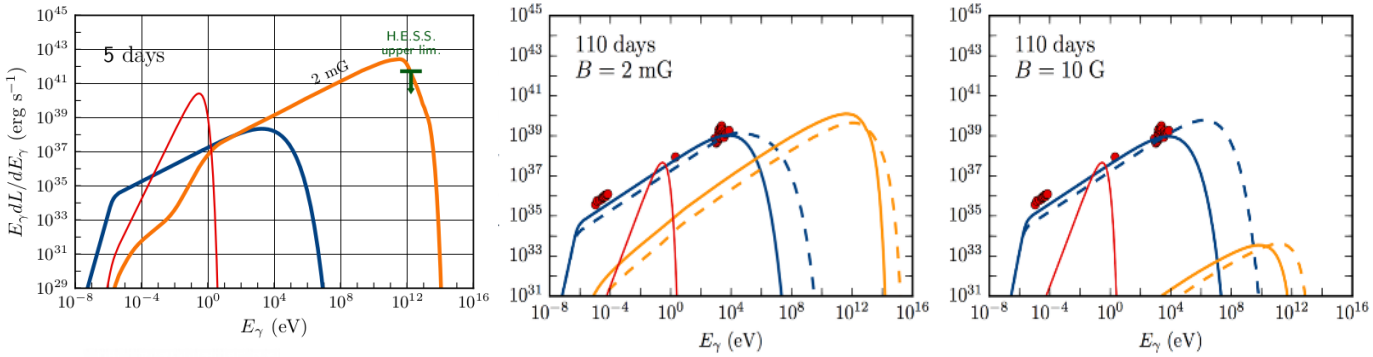
Late-time emission seen in X-rays and radio

- 10x flux increase in 150d with turnover ~220-260d
- Electrons are accelerated efficiently → good condition for gamma-ray production using synchrotron self-Compton
- VHE observations can be used (together with radio & X-ray) to break the ambiguity and constrain magnetic field

Alexander et al., 2018



Rodrigues et al., 2018



H.E.S.S. long-term observations

- About 50 hours around the high flux state in X-rays with all 5 telescopes
- Analysis nearly finished and interpretation ongoing

Follow-up of high-energy neutrinos

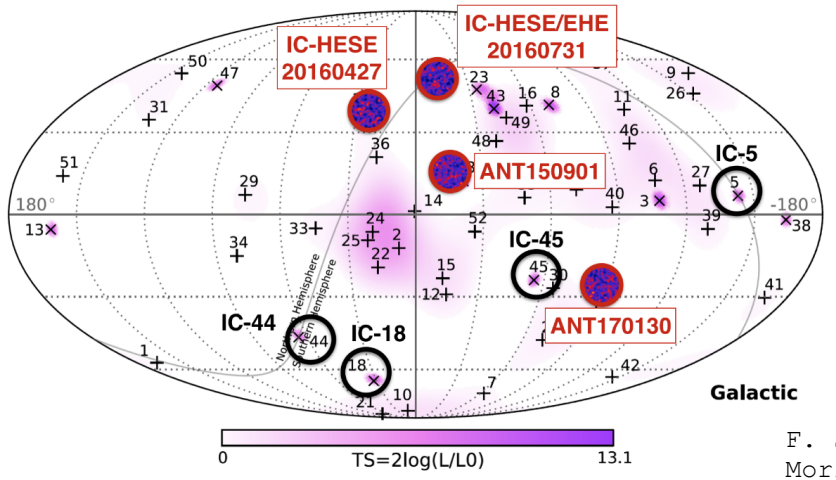
Smoking gun for hadronic particle acceleration in gamma-ray sources

Steady „sources“

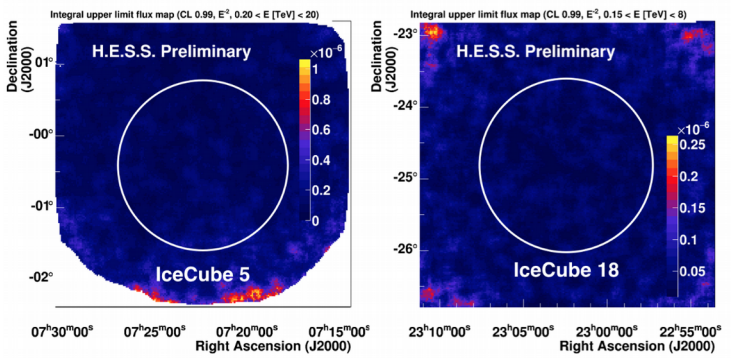
- Search for VHE gamma-ray sources at location of highest energy neutrino events
- No significant VHE emission found with H.E.S.S.

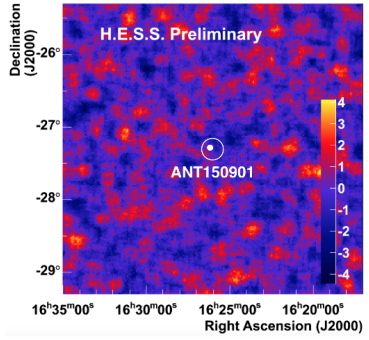
Transient sources

- Neutrino source identification through correlation in time and space (6 alerts by now)



F. Schuessler et al.
Moriond & ICRC 2017





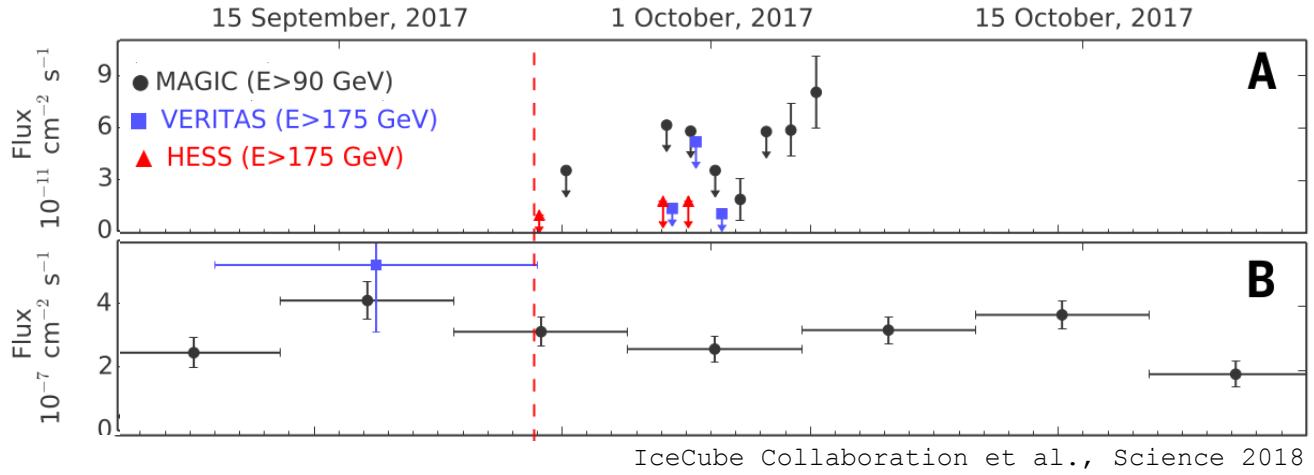
Follow-up of high-energy neutrinos

IceCube-170922 / TXS 0506+056

- Longest follow-up observation of a neutrino candidate (EHE 170922 with E ~ 290 TeV) so far at VHE
- Prompt search for VHE gamma-ray emission with H.E.S.S. (4h delay, no signal – ATel #10787)
- Long-term follow-up after announcement of increased gamma-ray activity seen by Fermi-LAT & the announcement of the detection at VHE by MAGIC

Physics interpretation challenged by chance coincidence consideration

- Are the AGN gamma-ray flares hadronic dominated?
- Need more of these high-energy ν-γ coincidences to make firm statements



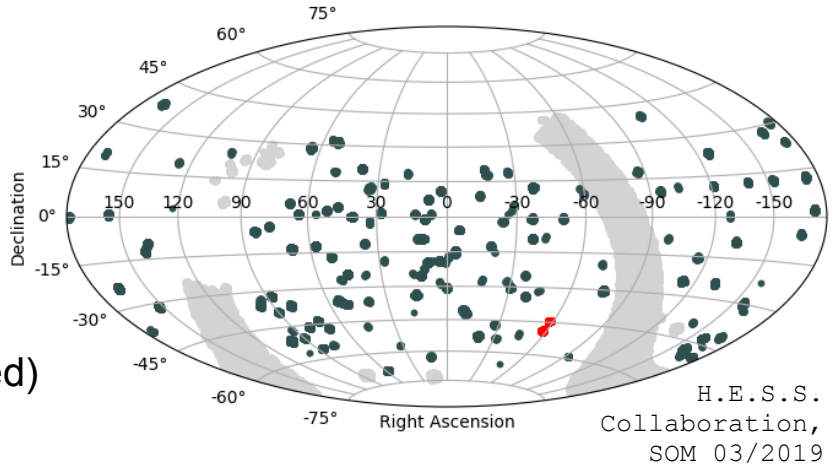
Observations of AGN with H.E.S.S.

AGN are strongly variable at all wavelengths

- Leptonic & hadronic emission models exist
- AGN as sources of ultra-high-energy cosmic rays?

Long history of observations on AGN within H.E.S.S. I

- 2600h of extragalactic sky observations (~6% of it covered)
- 6 out of 24 (re-detected) sources exibit strong variability



H.E.S.S. II focus shifted towards deeper explorations the variable sky

- Long-term monitoring of bright, known VHE blazars
- Different running target of opportunity (ToO) programs
  - Follow-up of high-flux states seen at different wavelengths
  - Extension of H.E.S.S. observations if high VHE flux states identified

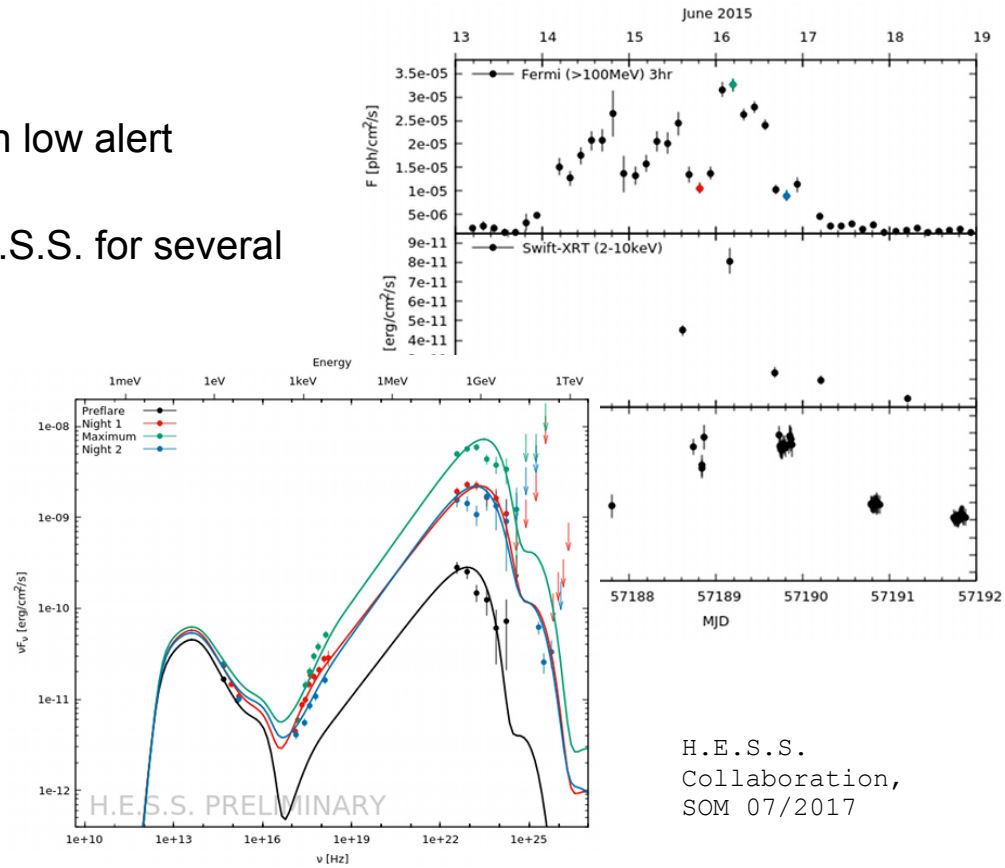
H.E.S.S. Target of Opportunity Program on AGN

Gamma-ray flaring AGN seen with *Fermi*-LAT

- Dedicated LAT data analysis chains in place with low alert thresholds + MoU based alerts
- About 5 alerts per year are followed-up with H.E.S.S. for several days to weeks (humans in the loop!)

Major successes of this program since 2012

- Detection of three FSRQs during gamma-ray flares (PKS 1510-089, 3C 279, PKS 0736+01)
  - High-statistics data sets allow detailed time-dependent modeling of VHE emission
  - One-zone leptonic models are challenged
  - External photon fields/hadronic components
- Included PKS 1510-089 for monitoring at VHE



H.E.S.S. Collaboration, SOM 07/2017

Summary & Outlook

H.E.S.S. covers a broad transient science program

- Observations will continue for the next 3 years with strong focus on variable sources

Prompt follow-up searches for high-energy gamma-ray counterparts of neutrino and GW alerts

- Close collaboration with IceCube and ANTARES on high-energy neutrino events
- Dedicated scan of the GW error region of prompt alerts
  (successfully applied to GW alerts in O2 – updated algorithms ready for O3)

Long-term follow-up of electromagnetic counterparts in the multi-messenger era

- Contraining the source physics of the remnants of GW mergers, e.g., the magnetic field strength
- Improving our understanding on the correlation of high-energy neutrino events and AGN flares
- Further monitoring of VHE-emitting AGN and follow-up of multi-wavelength alerts on flaring AGN

Thank you for your attention.

H.E.S.S.