



H.E.S.S. multi-messenger and real-time follow-up observations



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H.E.S.S. multi-messenger contact



AMON workshop, Cochem, 2016





On behalf of the H.E.S.S. multi-messenger and GRB team

A. Balzer, M. Backes, E. Bissaldi, F. Brun, P. Brun, M. Füssling, C. Hoischen, T. Garrigoux, J.-P. Lenain, I. Lypova, A. Mitchell, P. O'Brien, S. Ohm, R.D. Parsons, G. Pühlhofer, A. Reimer, G. Rowell, F. Schüssler, M. Seglar-Arroyo, P.H.T. Tam, S. Wagner

+ partners from IceCube, ANTARES, Virgo/Ligo, Parkes, etc.



The H.E.S.S. experiment



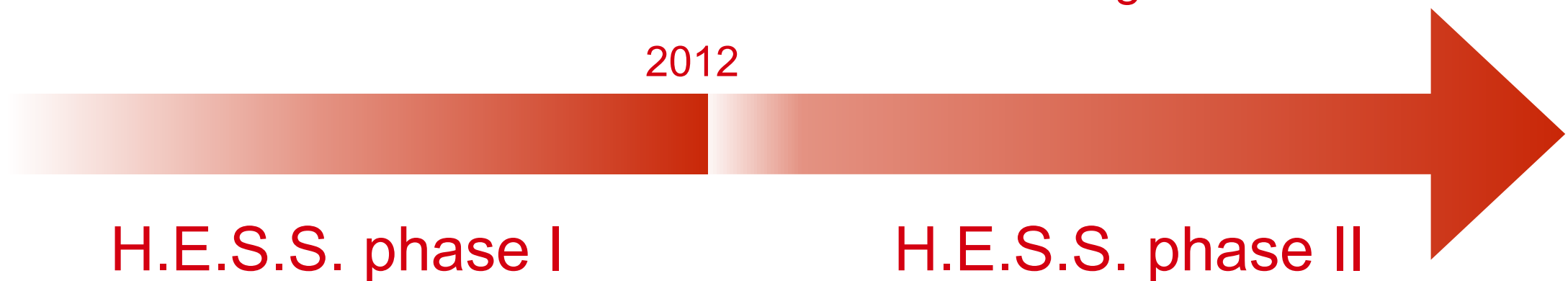
H.E.S.S. phase I

- four 12m telescopes
- FoV 5deg
- energy threshold $\sim 100\text{GeV}$
- angular resolution $< 0.1\text{deg}$



H.E.S.S. phase II

- four 12m telescopes
- one 28m telescope (FoV 3.5deg)
- energy threshold $\sim 30\text{GeV}$
- angular resolution from 0.4 to less than 0.1deg



The H.E.S.S. multi-messenger program

■ Gravitational waves

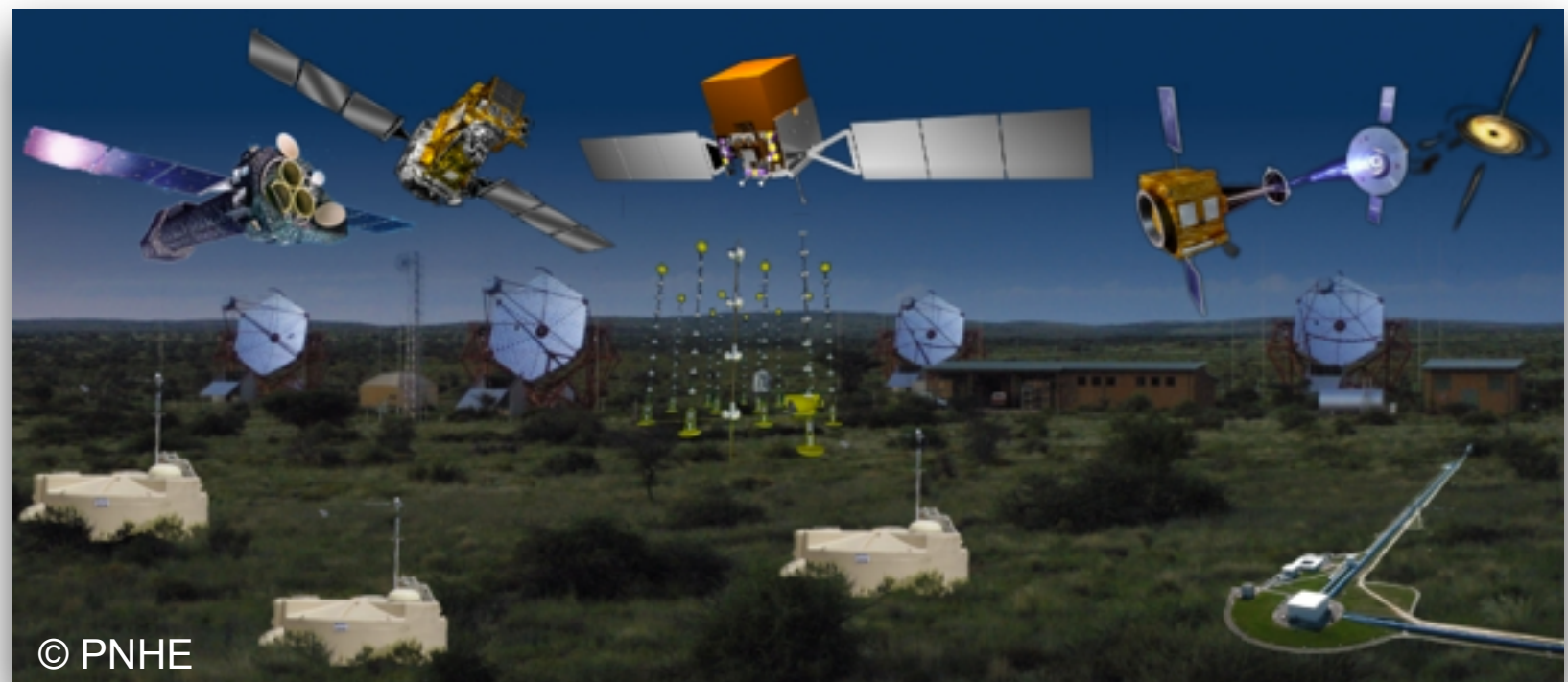
- major breakthrough in 2015 thanks to Advanced Virgo/Ligo
- H.E.S.S. member of the Virgo/Ligo EM follow-up effort since early 2014
- follow-up difficult due to large localization uncertainties
 - important input from additional EM detection, galaxy catalogs, etc.
 - benefit from large FoV

■ Neutrinos

- ROIs
 - neutrino hotspots
 - IceCube HESE events
- ToOs

Gamma-Ray Bursts

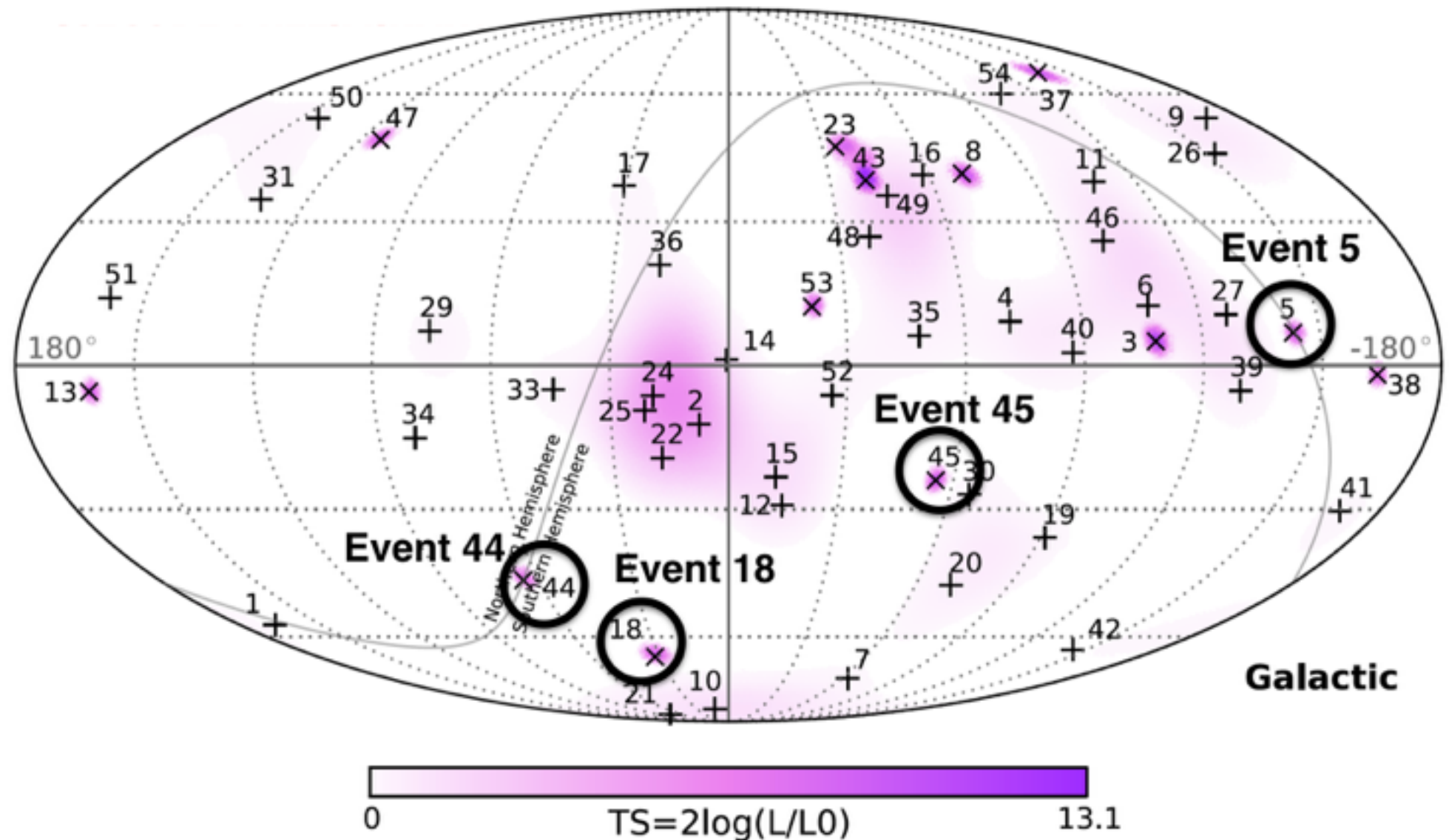
Fast Radio Bursts



Multi-messenger program: IceCube HESE tracks

- H.E.S.S. observations of IceCube High Energy Starting Events
 - track like events (angular uncertainty < FoV)
 - H.E.S.S. visibility + constrains by other observations
 - high energy, etc.

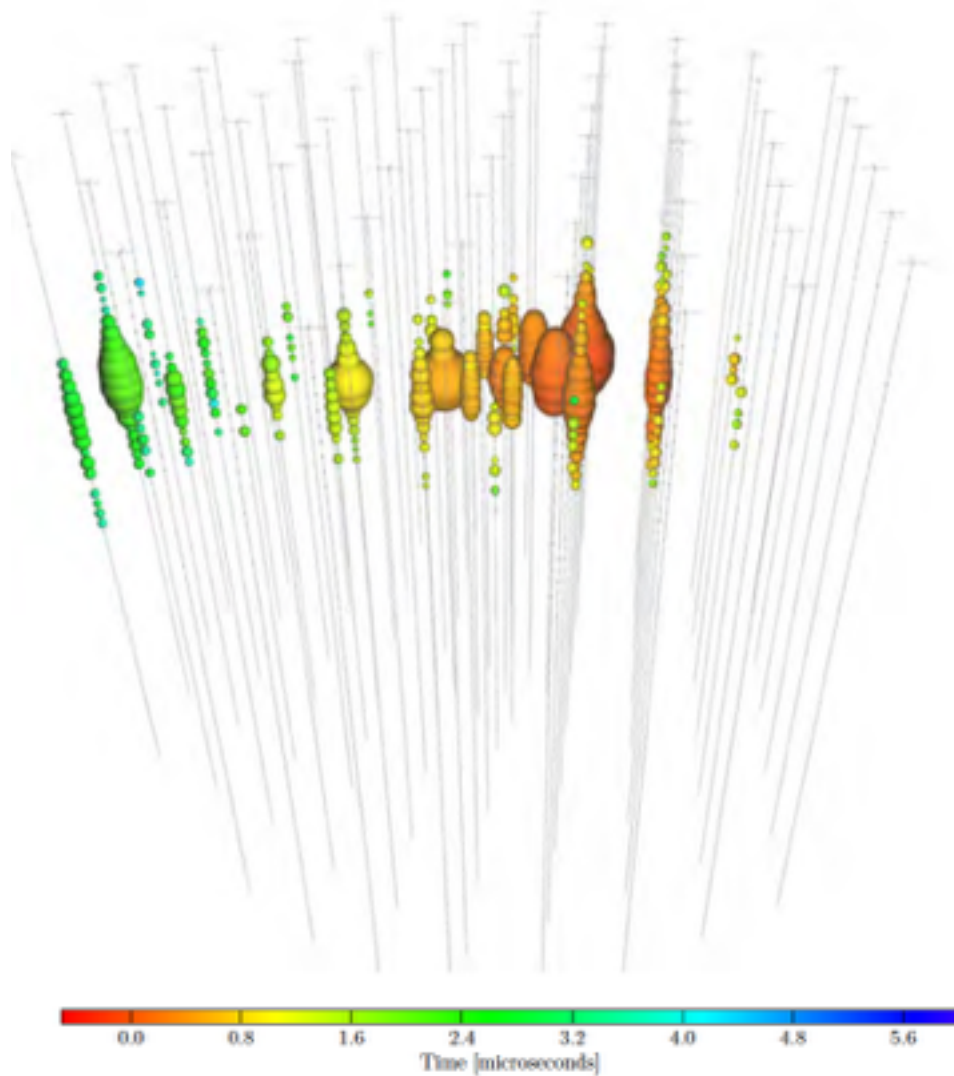
C. Kopper, ICRC 2013



IceCube events: examples

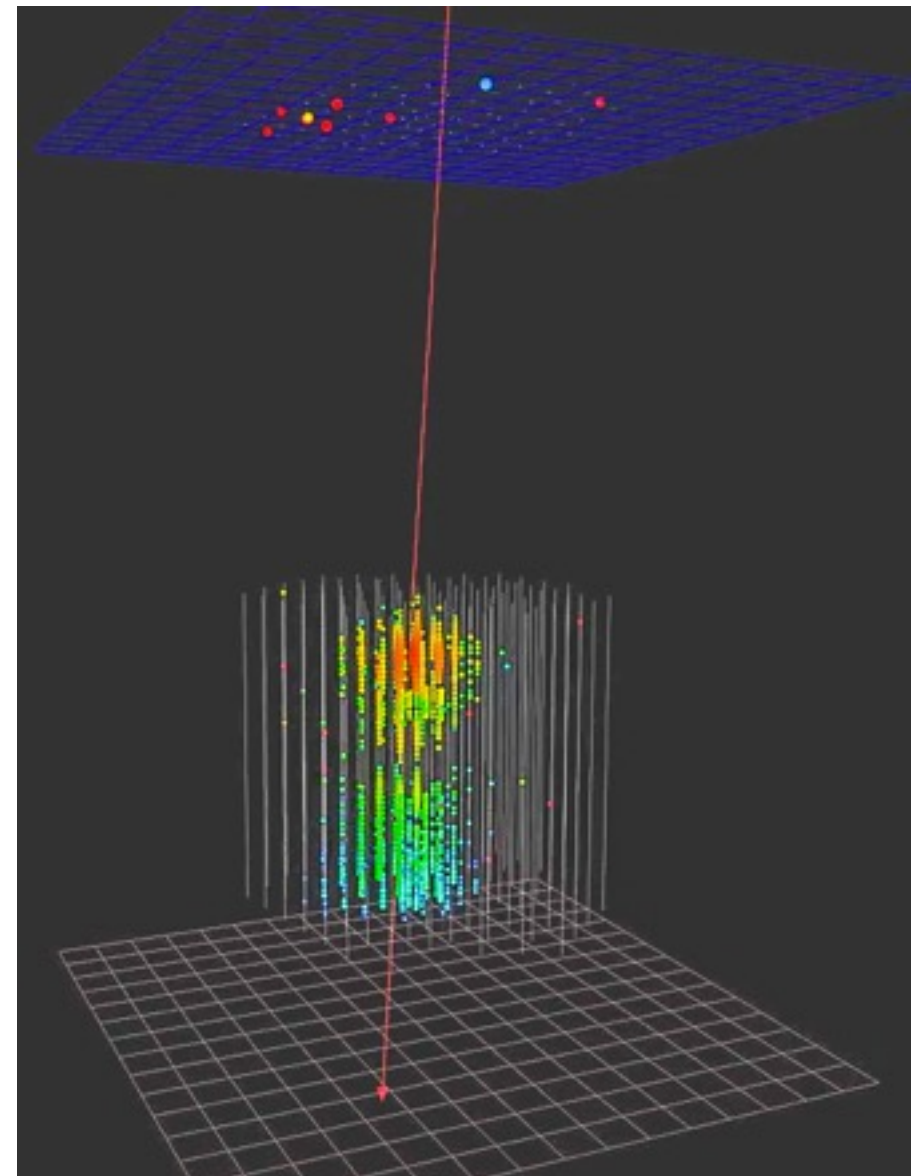
IceCube Event 5

- deposited energy: 71.4^{+9}_{-9} TeV
- Ra=110.6deg / Dec=-0.4deg



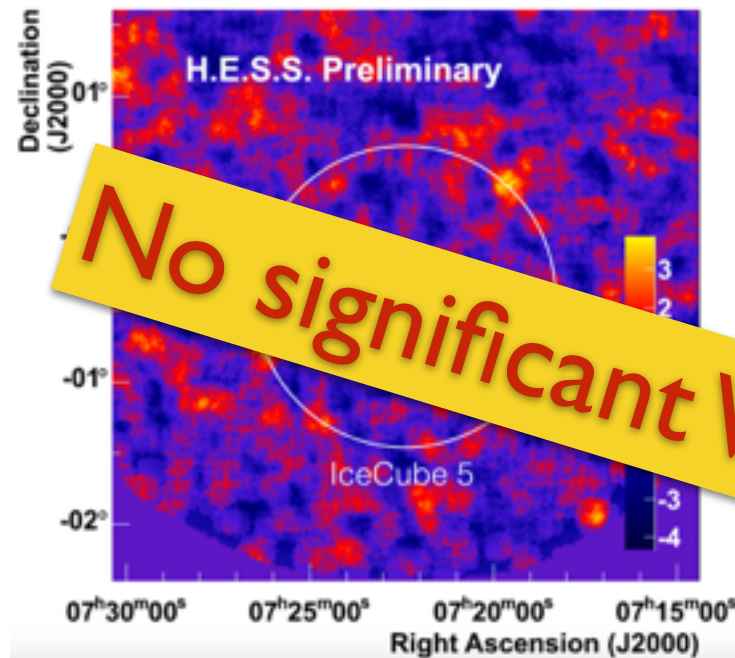
IceCube Event 45

- deposited energy: $429.9^{+57.4}_{-49.1}$ TeV
- Ra=219deg / Dec=-86.3deg

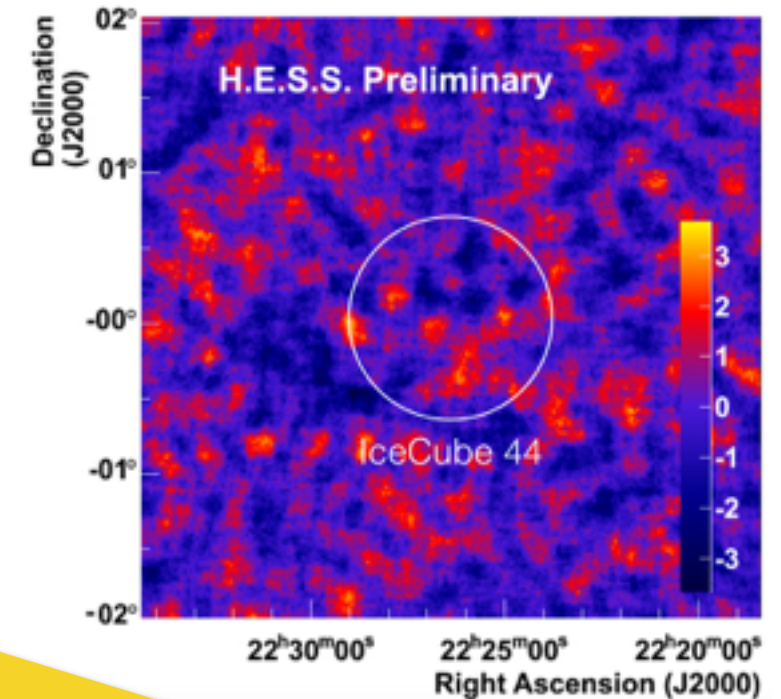


IceCube HESE tracks: H.E.S.S.

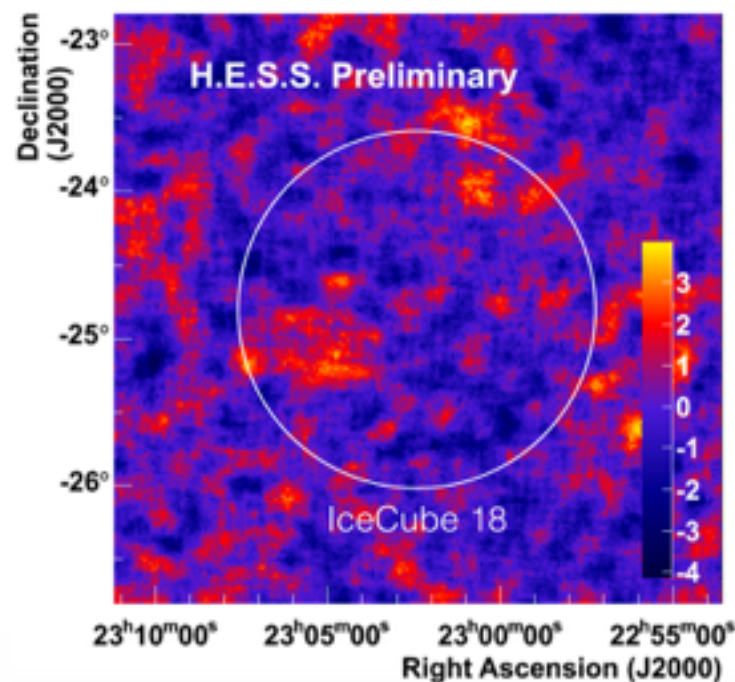
■ IceCube 5



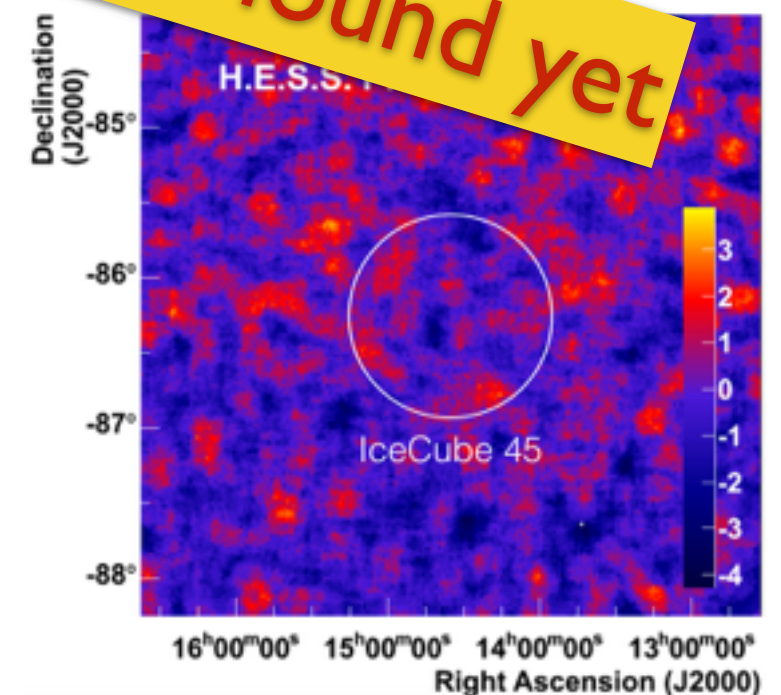
■ IceCube 44



■ IceCube 18



■ IceCube 45

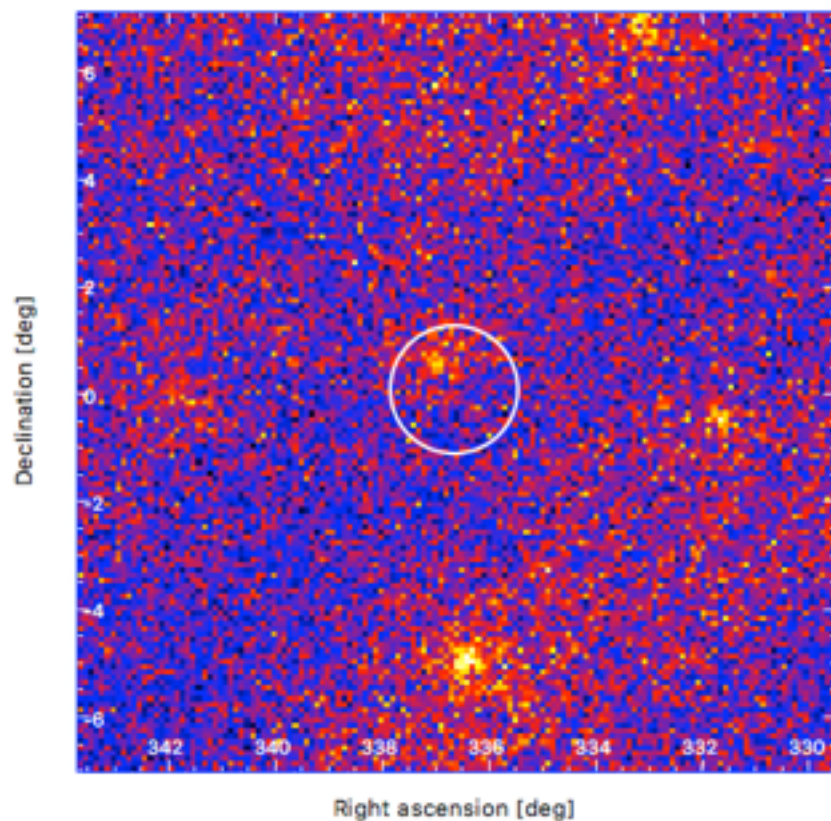


IceCube HESE tracks: Fermi-LAT

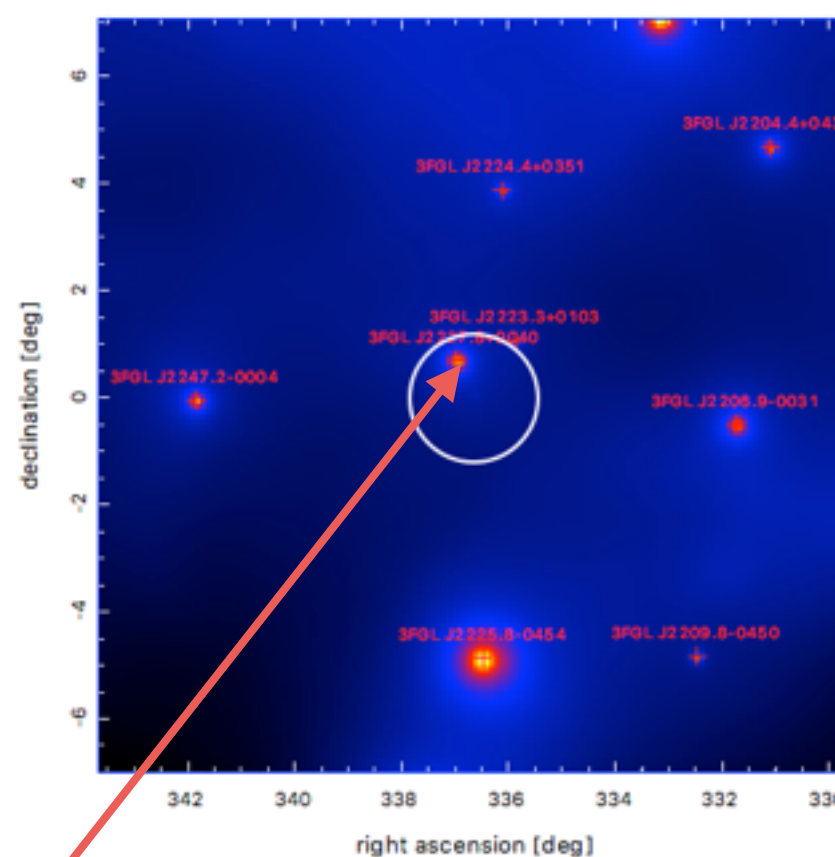
- Event 5 + 18: period 08/2008-05/2015; P7Rep, 100MeV-300GeV
- Event 44 + 45: period 08/2008-05/2016; Pass8, 100MeV-300GeV

Example: Event 44

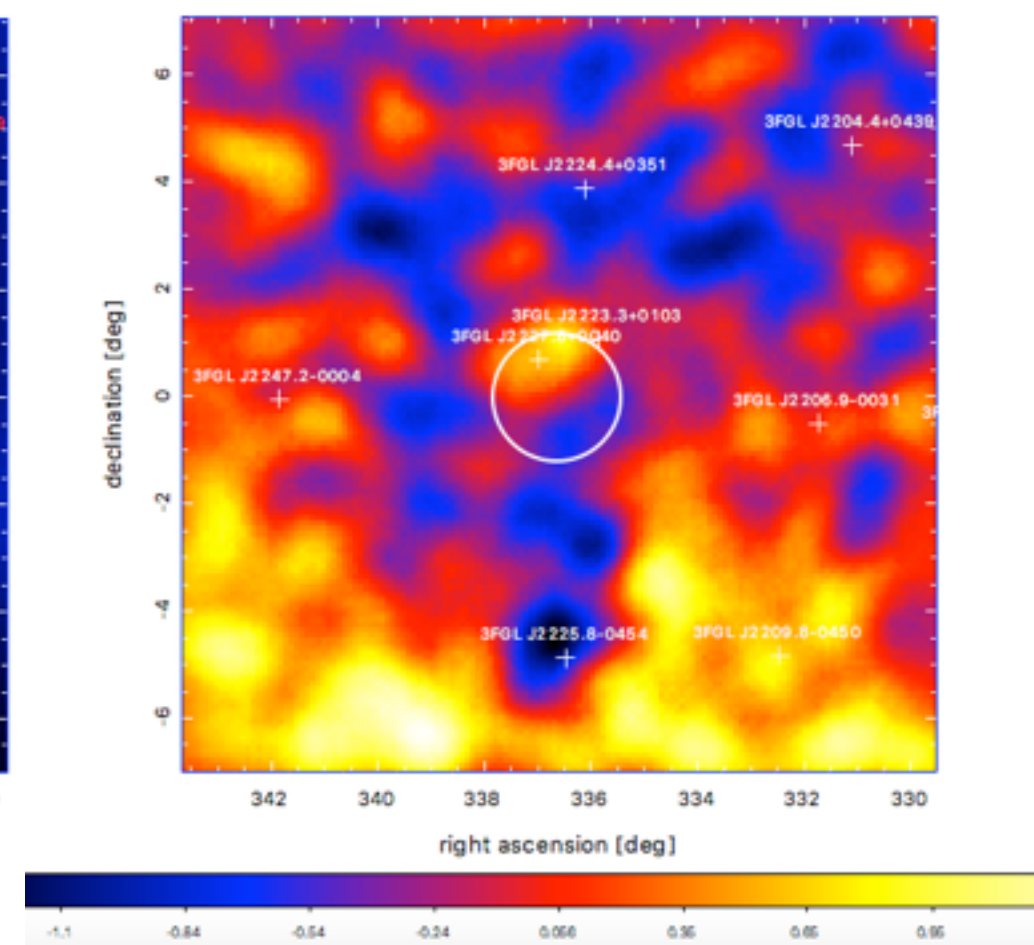
counts



model



residuals



3FGL J2227.8+0040
J222743.7+005729: Blazar at $z \sim 1.3$

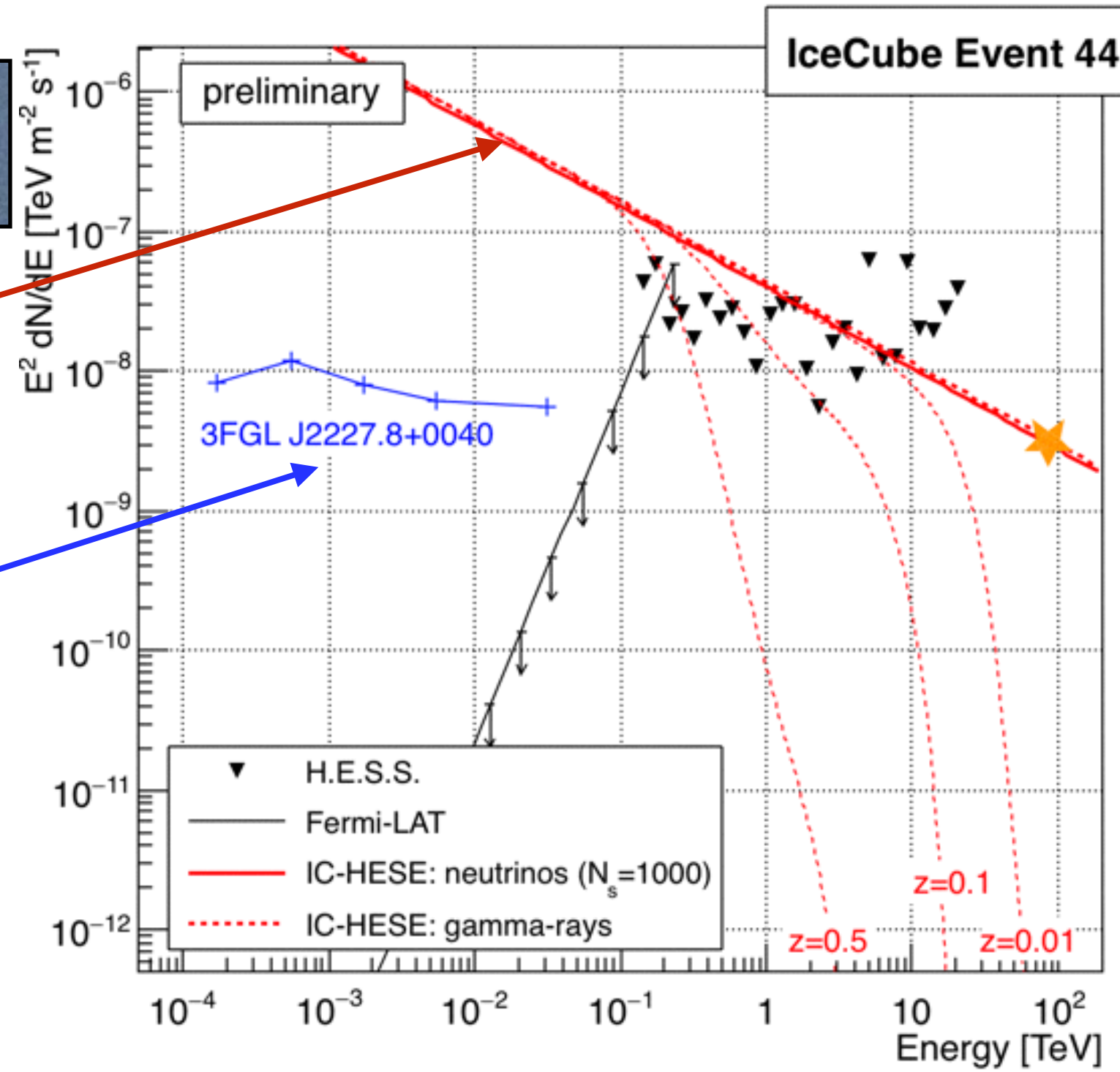
IceCube HESE tracks: Limits

■ Example: Event 44

H.E.S.S. + Fermi-LAT limits
for point-source in the ROI center
(acceptance smooth => representative for ROI)

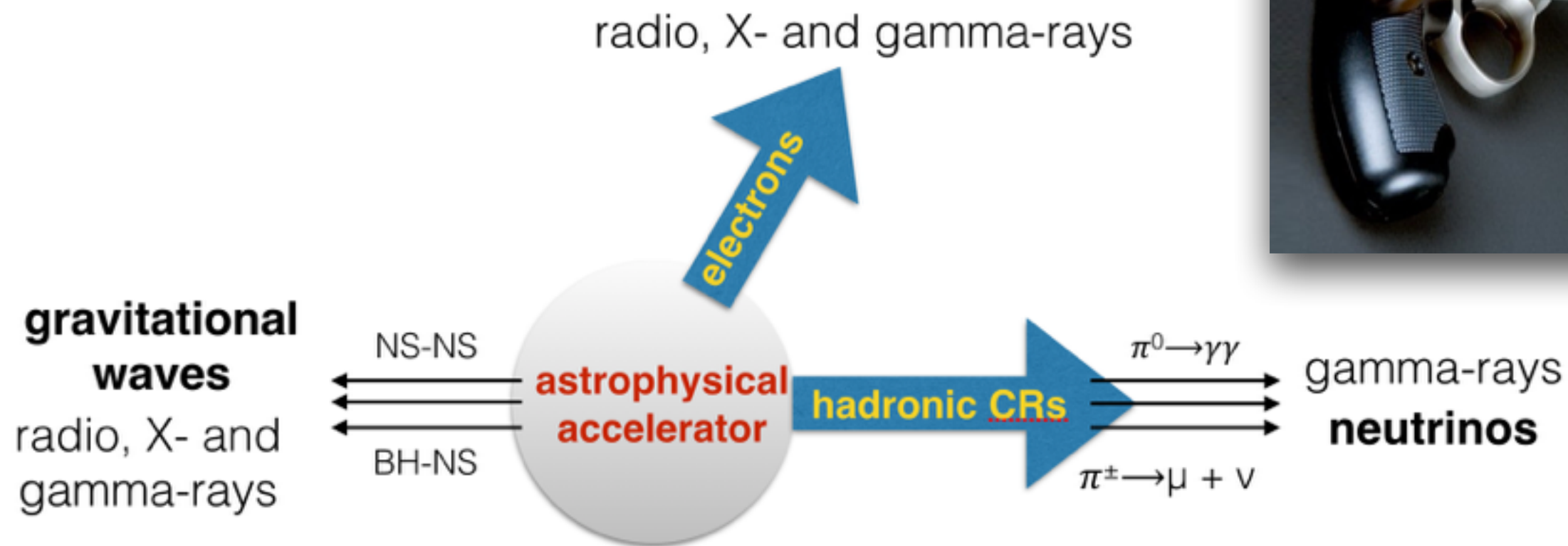
diffuse IceCube flux:
 $\phi(E) = 2.2 \times 10^{-8} E^{-2.58} \text{ GeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$
assuming 1000 sources

3FGL "candidate" source
within IceCube ROI



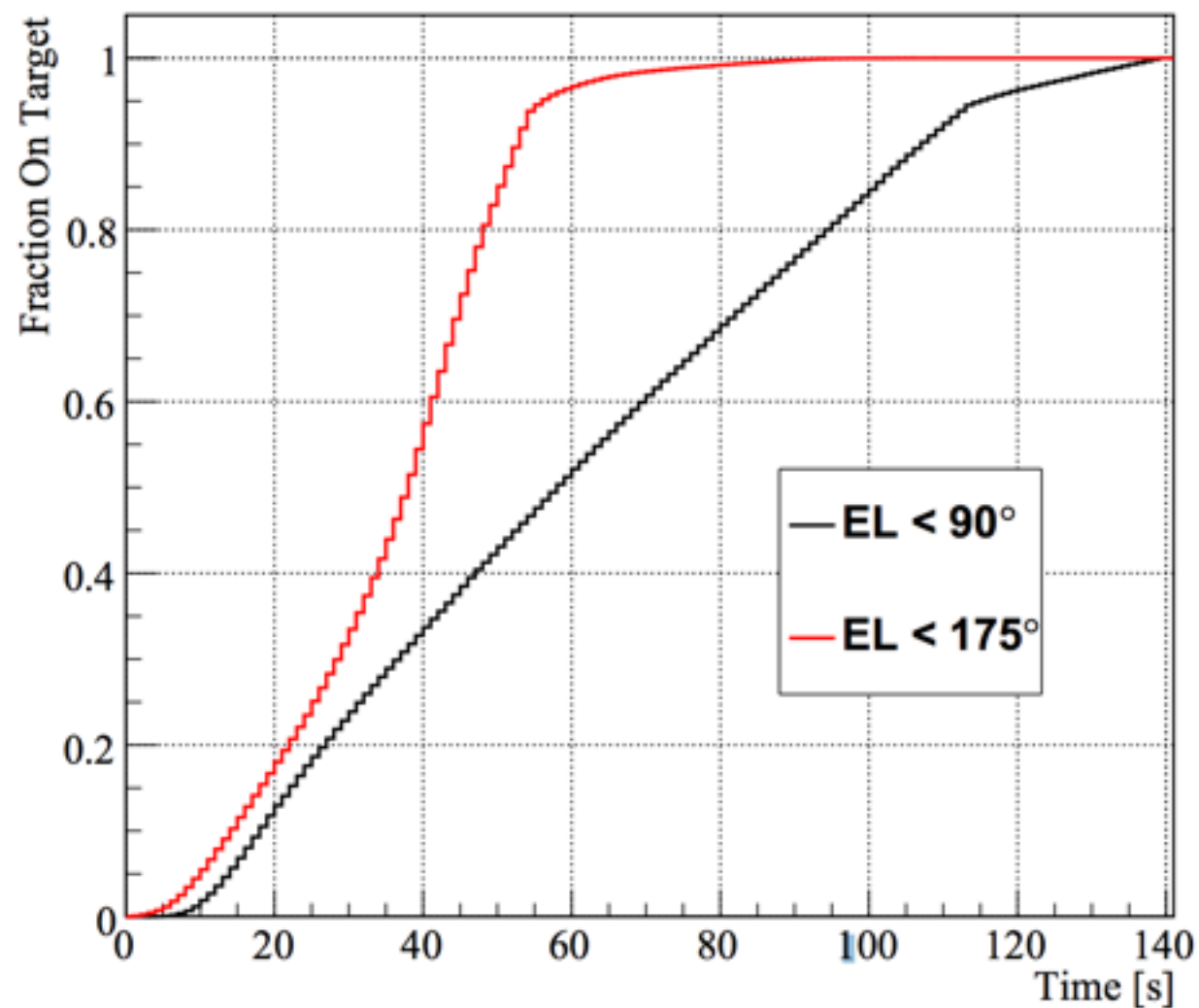
Future of the H.E.S.S. Multi-messenger program: alerts and ToOs

- Interpretation of potential gamma-ray source within the neutrino error box difficult (has to rely on basic energetics and follow-up observations)
- **Space and time correlations** would provide "smoking gun" signal for joint emission processes => CR interaction/acceleration



H.E.S.S. II: ToO follow-up performance

- main design principles of the H.E.S.S. 28m telescope
 - large photon collection area → 614 m² mirror area (largest IACT worldwide)
 - rapid response time

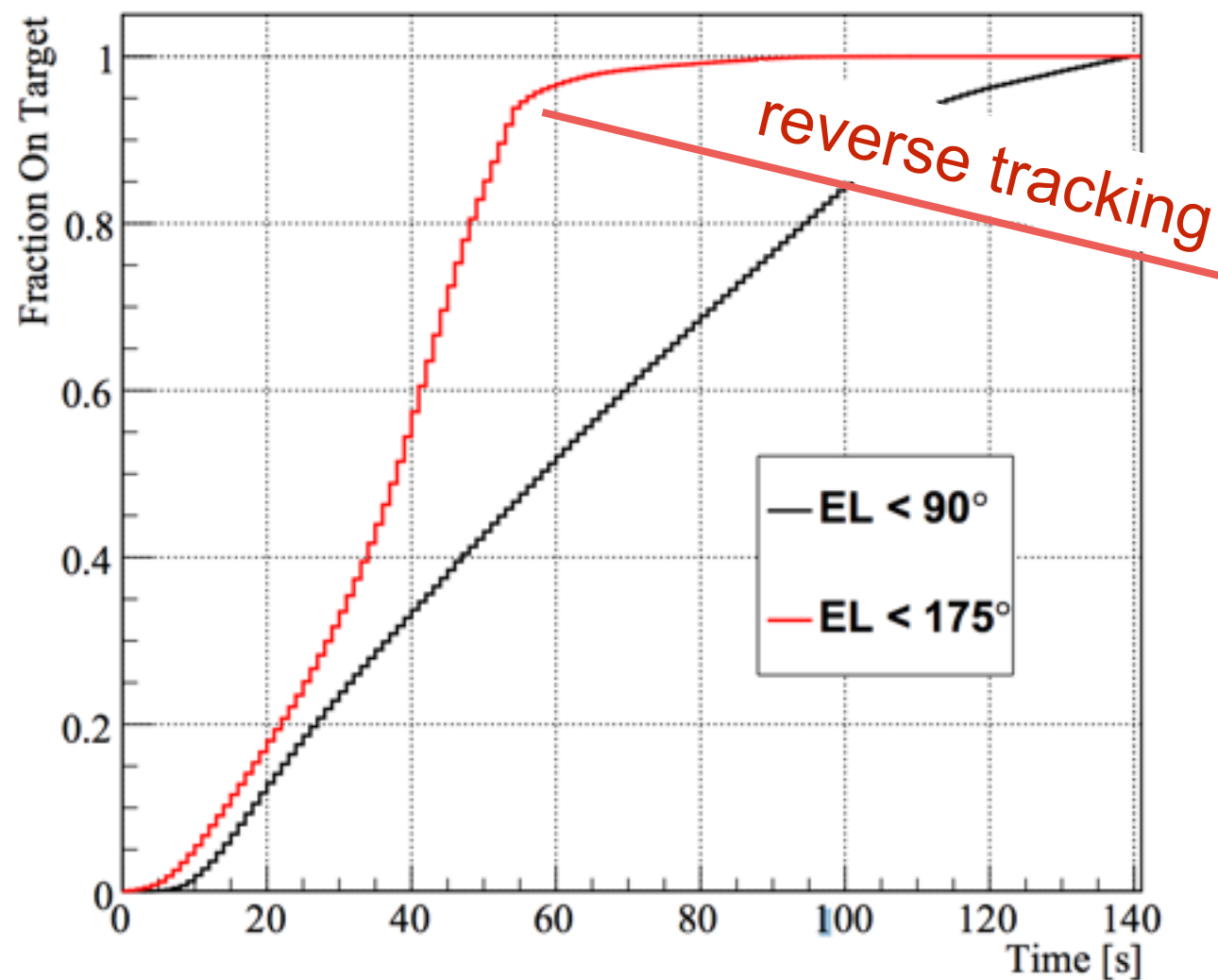


Hofverberg et al., ICRC 2013



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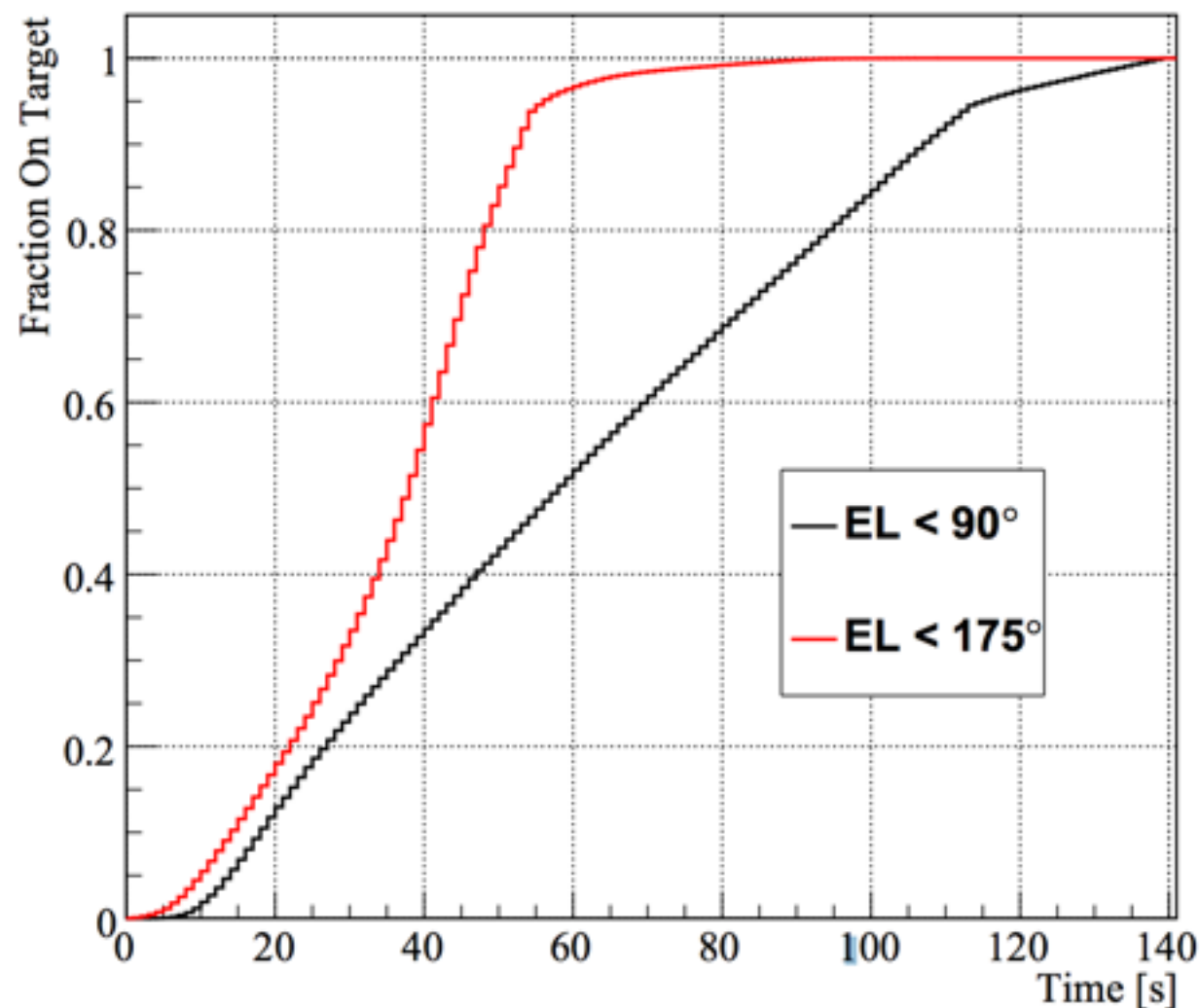


Hofverberg et al., ICRC 2013



H.E.S.S. II: ToO follow-up performance

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 - rapid response time



Hofverberg et al., ICRC 2013

- ToO+DAQ re-organization in 2014/2015
 - reaction time dominated by slewing: O(60s)

VoEvent alert system

First H.E.S.S. reaction to Multi-messenger alerts and ToOs

■ IceCube

- real-time alerts on HESE + EHE events
- expected delays $O(10\text{min})$

Example: HESE-20160731

■ ANTARES

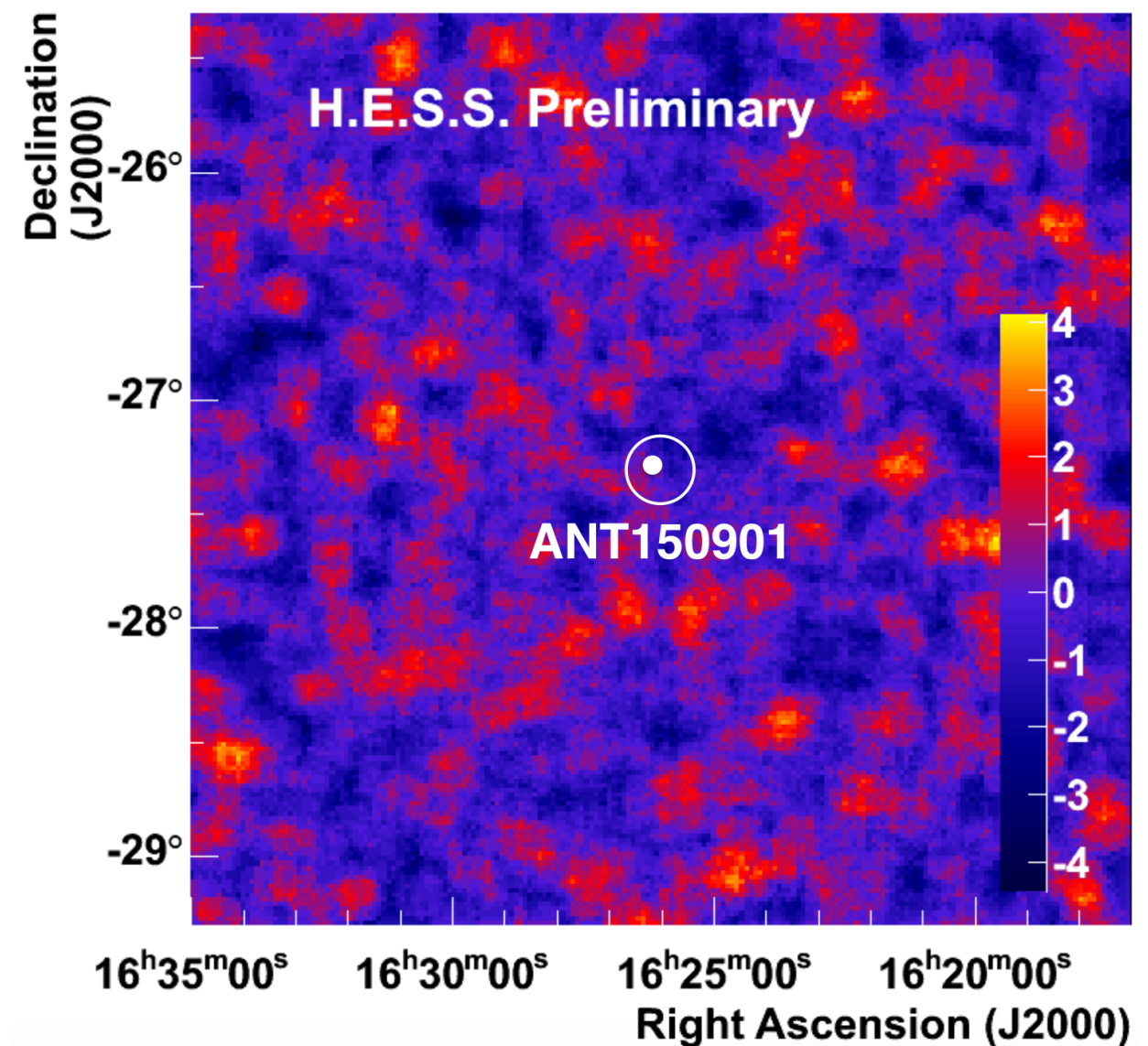
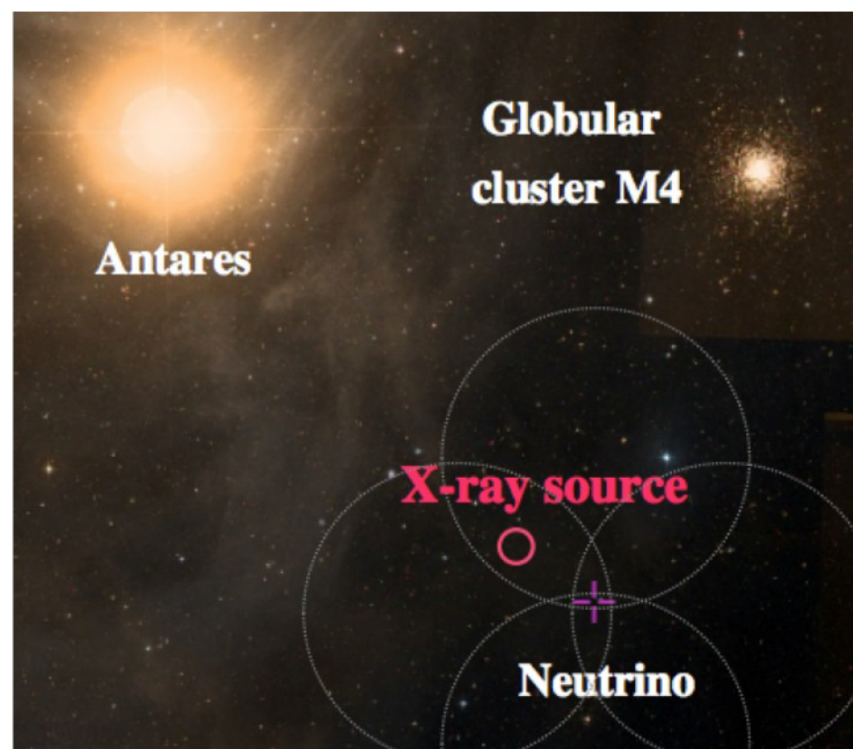
- online reconstruction and rapid alert emission: TAToO (Ageron et al., APP 35 (2012) 530)
- delays $O(10\text{s})$

Example: ANT150901



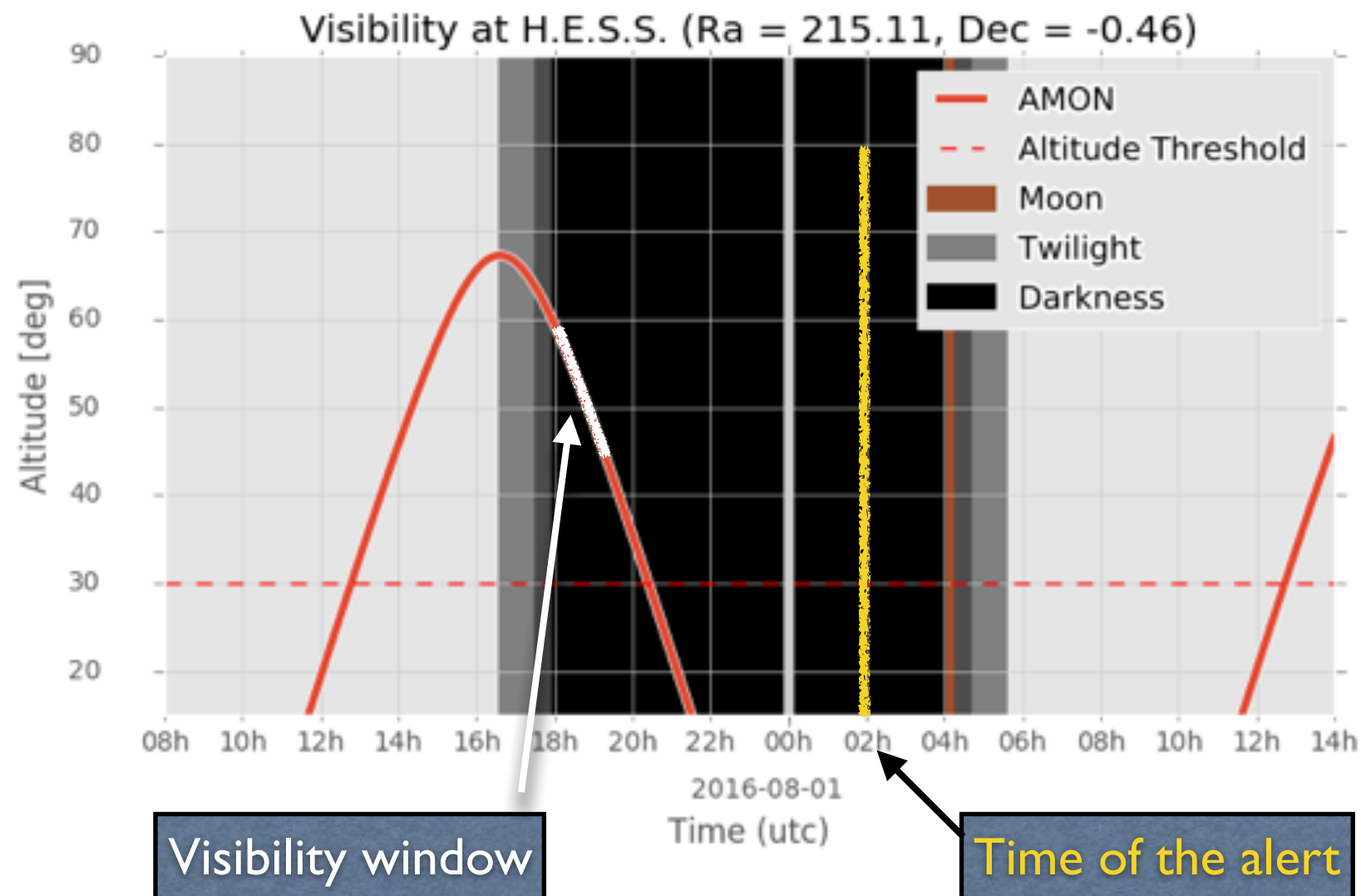
Antares/Swift ATEL: ANT150901

- 2015-09-01: Antares/TAToO alert to optical telescopes and Swift
- 2015-09-03: Swift detection of unknown, bright, variable X-ray source (ATEL 7987)
- 2015-09-03: H.E.S.S. follow-up
 - 1.5h of observations
 - $\Phi(E > 320 \text{ GeV}, 99\% \text{CL}) < 2.4 \times 10^{-7} \text{ m}^{-2} \text{ s}^{-1}$



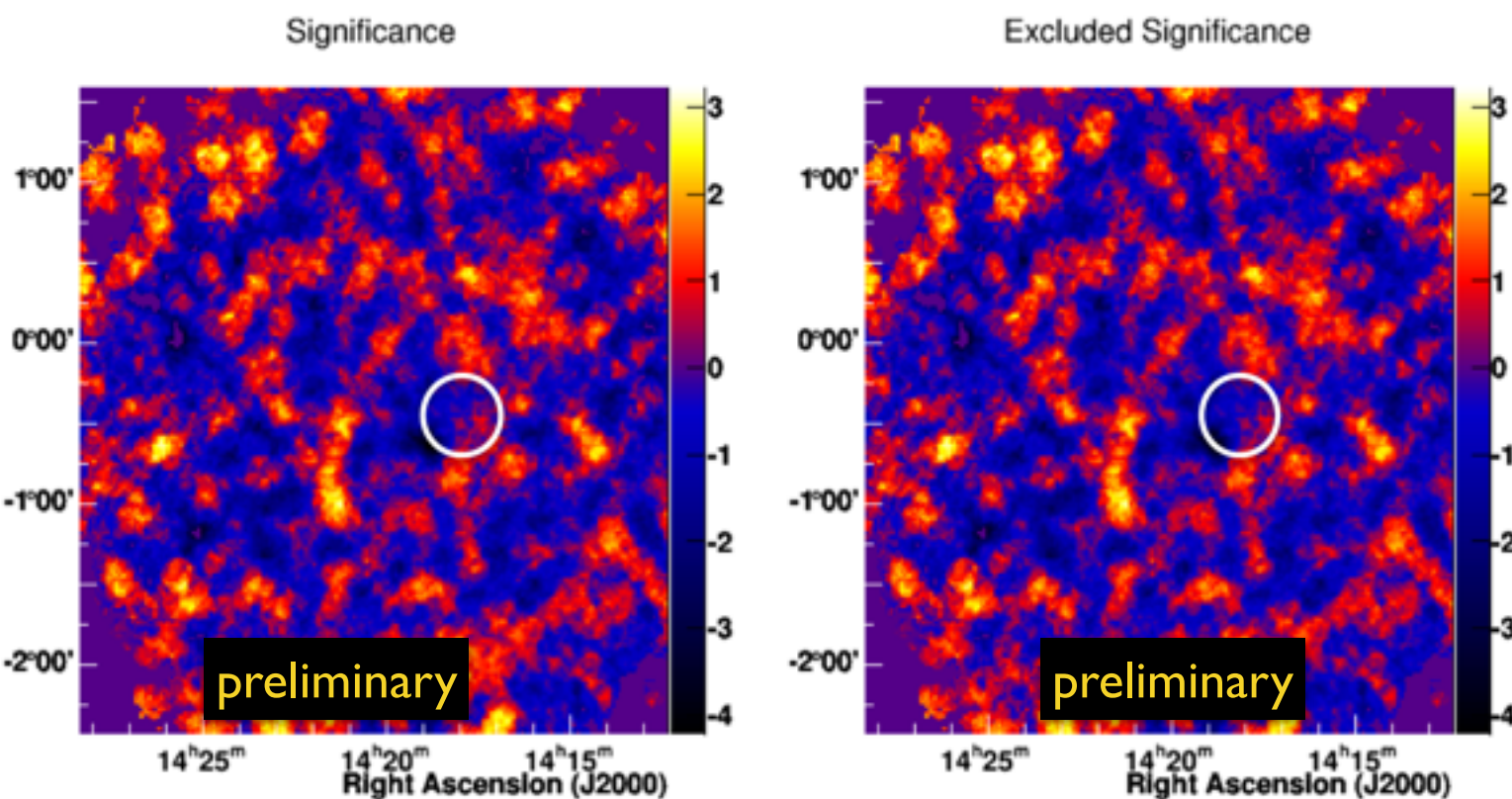
IC-EHE/HESE-21060731

- 2016-07-31 (1:55 UT): IceCube/AMON alert on a EHE/HESE event
 - not visible at the time of the alert
- 2016-08-01 + 2016-08-02: visible for ~1h above 45deg elevation



IC-EHE/HESE-20160731

- 2016-07-31 (1:55 UT): IceCube/AMON alert on a EHE/HESE event
 - not visible at the time of the alert
- 2016-08-01 + 2016-08-02: visible for ~1h above 45deg elevation
- OnSite analysis
 - no significant emission detected
 - 2016-08-02: ATEL #9301



[Previous | Next | ADS]

H.E.S.S. follow-up of IceCube-160731A

ATel #9301; *Mathieu de Naurois for the H. E. S. S. collaboration*
on 2 Aug 2016; 15:57 UT
Credential Certification: Fabian Schüssler (fabian.schussler@cea.fr)

Subjects: Gamma Ray, TeV, Neutrinos, Transient

Referred to by ATel #: 9303, 9313, 9315

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The H.E.S.S. instrument was used to carry out follow-up observations of a high energy neutrino detected by IceCube on the 31st July 2016 at 01:55:04 UTC. The IceCube best fit position is $R_{\alpha} = 214.54$, $Dec = -0.33$ with a radius of 0.75 deg at 90% confidence. The event was classified as Extremely-High-Energy (EHE) event suggesting a neutrino energy of more than 1 PeV. H.E.S.S. observed the region in two consecutive nights (2016-07-31/08-01 and 2016-08-01/02) for roughly 1 hour each. The observations were taken with the full array consisting of one 28m diameter telescope and four 12m diameter telescopes. A preliminary on-site calibration and analysis searching for a point-like gamma-ray source from within the 90% uncertainty region of IceCube160731 revealed no significant emission. H.E.S.S. is an array of five imaging atmospheric Cherenkov telescopes for the detection of very-high-energy gamma-ray sources and is located in the Khomas Highlands in Namibia. It was constructed and is operated by researchers from Armenia, Australia, Austria, the Czech Republic, France, Germany, Ireland, Netherlands, Japan, Poland, South Africa, Sweden, UK, and the host country, Namibia.

Related

- 9315 MAGIC follow-up observations of IceCube neutrino event 160731A
- 9313 MAXIGOSC observations of IceCube-160731A
- 9303 Fermi LAT Gamma-ray Observations of IceCube-160731
- 9301 H.E.S.S. follow-up of IceCube-160731A**
- 9298 MASTER follow up observation of IceCube 160731A event
- 9295 AGILE follow-up of the neutrino ICECUBE-160731 event
- 9294 Swift follow up of IceCube-160731A

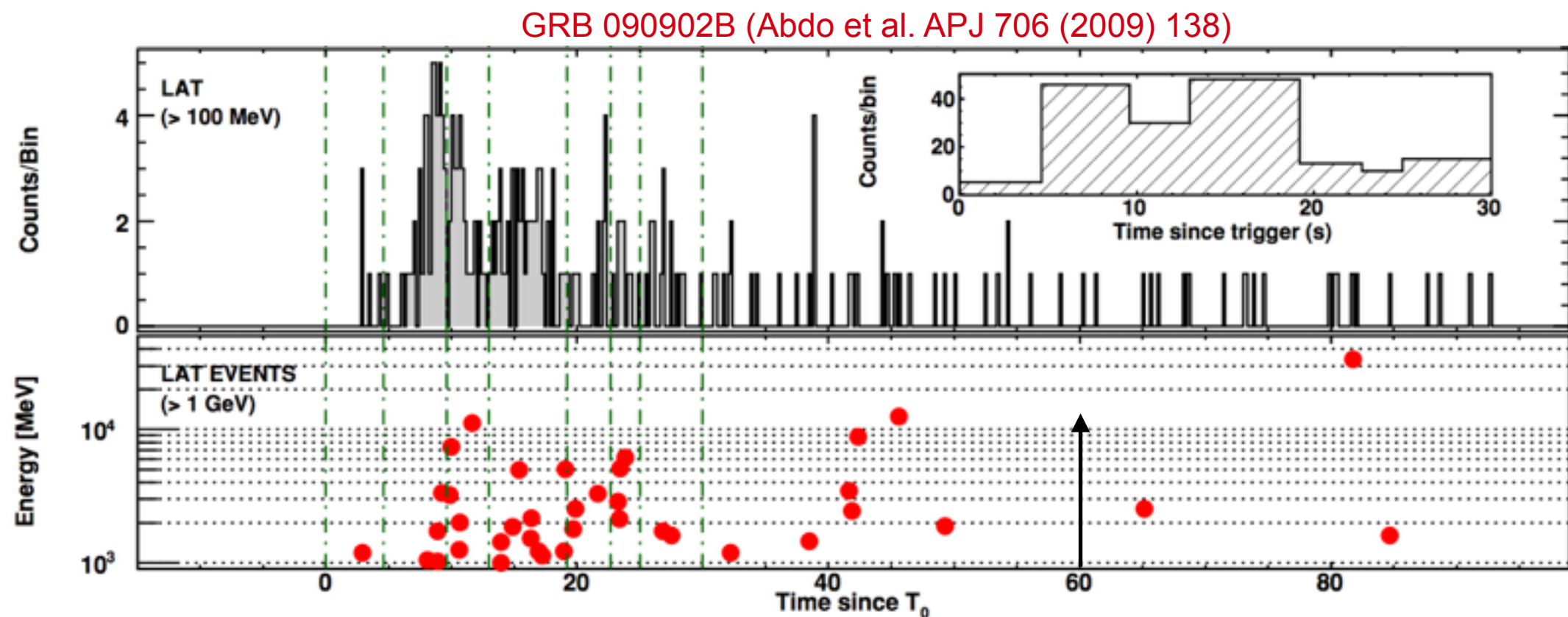


Other AMON/IceCube alerts with H.E.S.S. follow-up

- IC-HESE-20160427A
 - visible only after two days
 - 2h of observations available
 - analysis in progress
- IC-HESE-20161103A
 - observations started the same evening
 - cloudy night, observations stopped

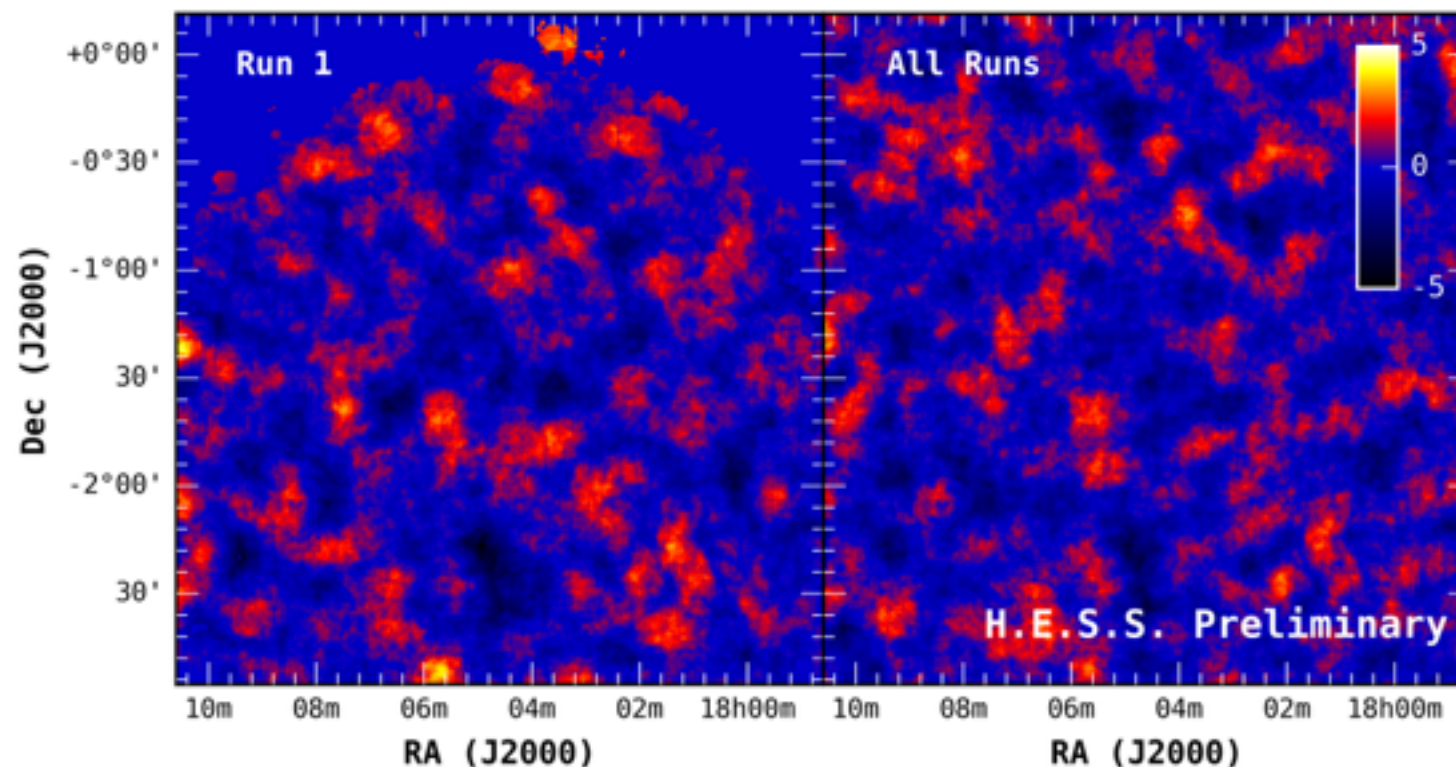
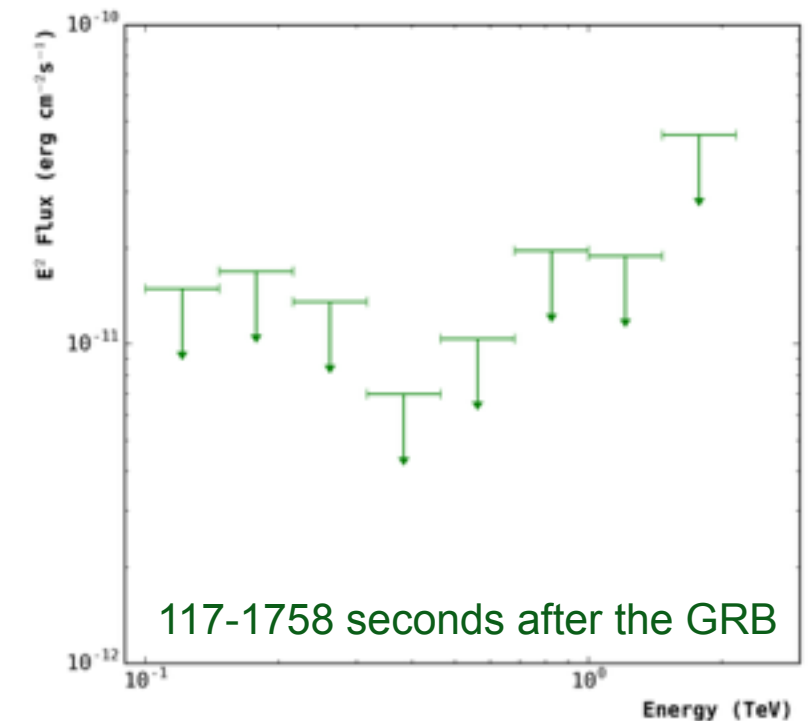
GRB follow-up with H.E.S.S.

- extensive follow-up program during H.E.S.S. phase I (e.g. A&A 495, 505-512 (2009))
- follow-up speed significantly increased with H.E.S.S. II
 - rapid slewing speed
 - fully automatic repositioning after the reception of a GCN alert
 - dedicated operation mode (e.g. data taking starts as soon as *source* enters the FoV)
 - GRBs have highest ToO priority (following all accessible alerts)



GRB follow-up: first results

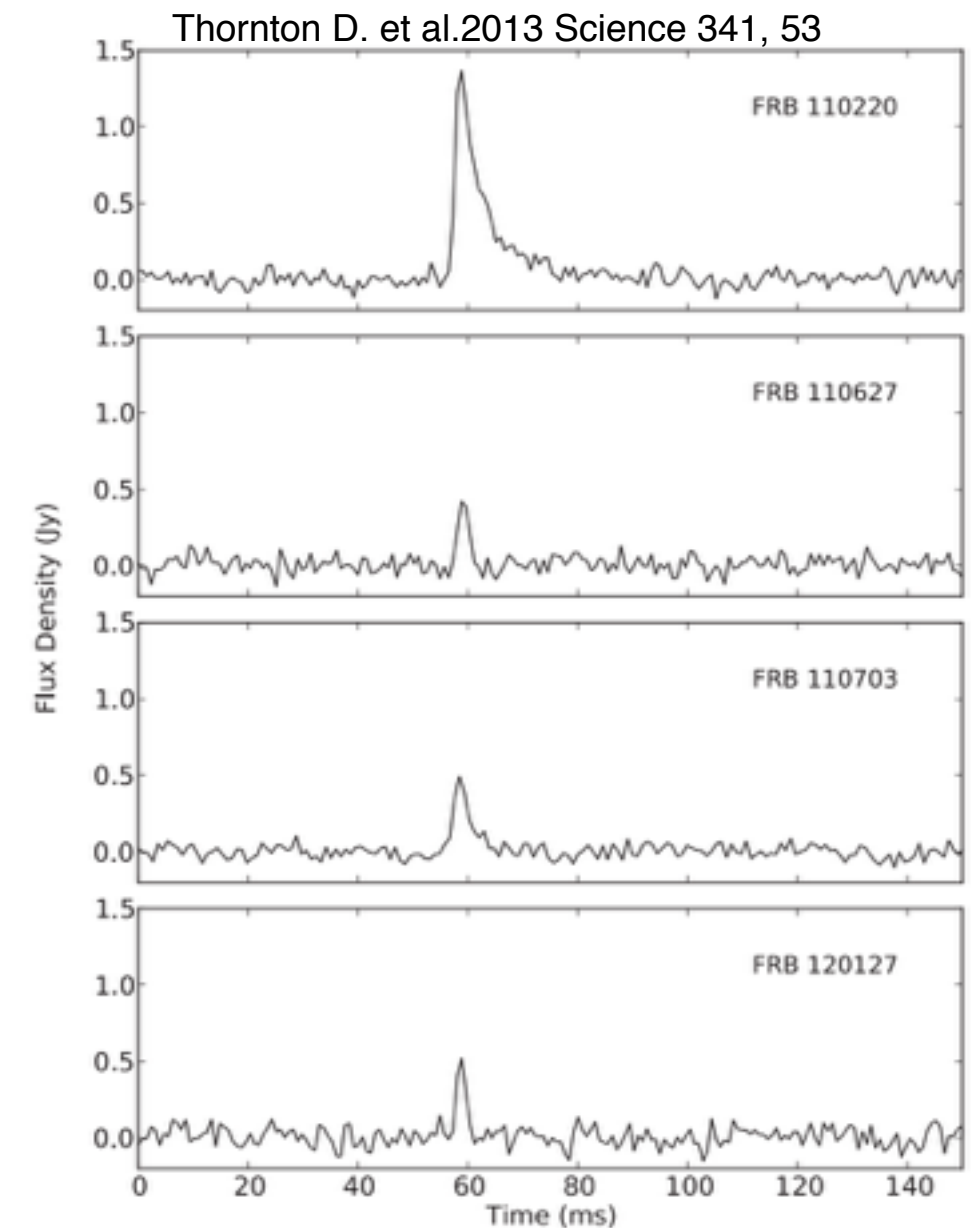
- strict data blinding procedure fixing reconstruction, cuts, analysis strategy, etc.
- GRB140818B
 - RA= +18h 04m 35s ; Dec=-01d 21' 40" (J2000)
 - T0: 18:44:16 UTC
- H.E.S.S. observations
 - starting 18:45:42 UT (<2min after the GRB)
 - *mono* analysis optimized for low energies



Run	Time since T0 [min]	Integral Flux (E>100GeV) [m ⁻² s ⁻¹]
1	2-30	3.9e-11
2	31-59	2.6e-11
3	60-88	5.1e-11
4	89-117	1.8e-11

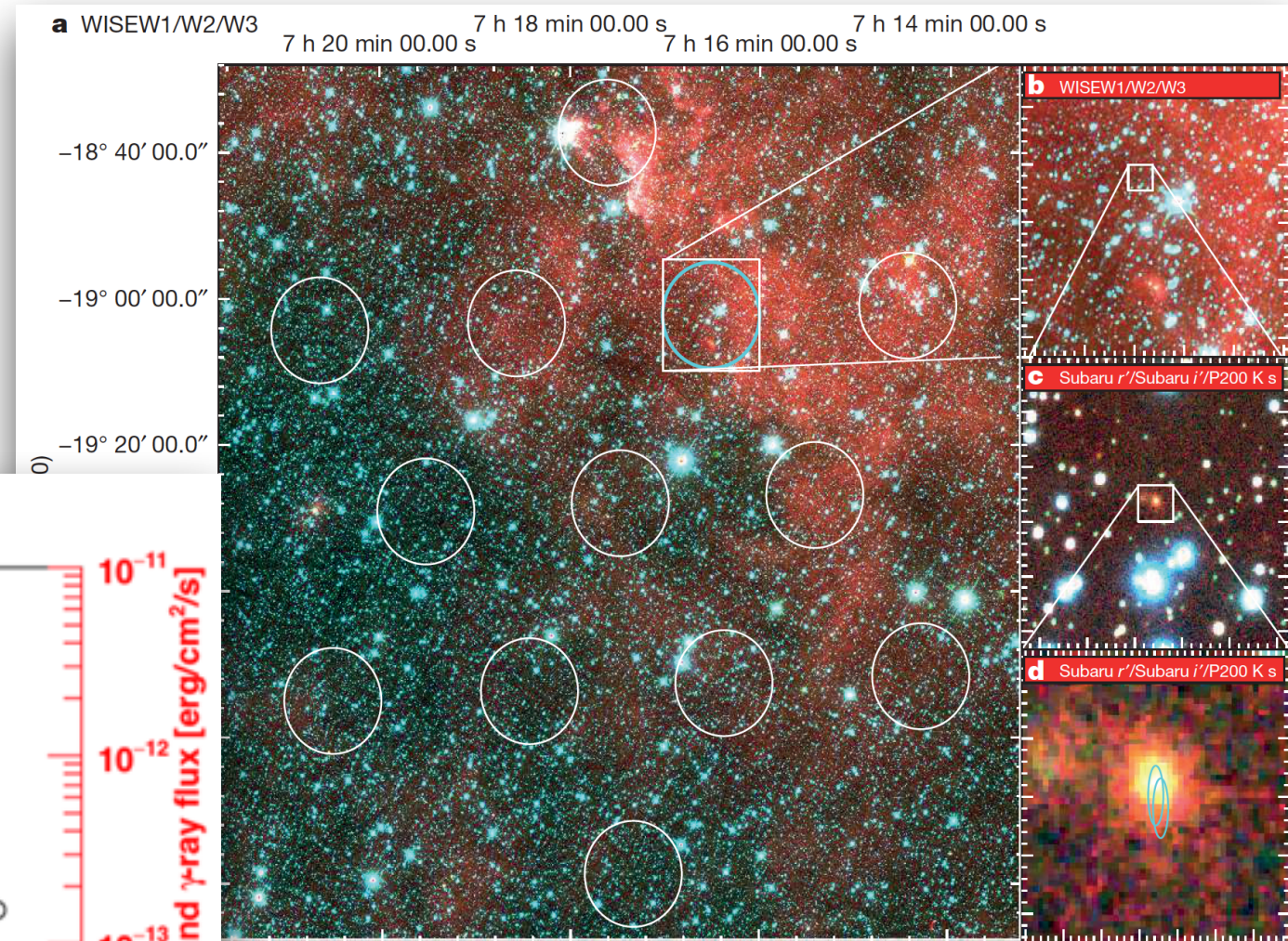
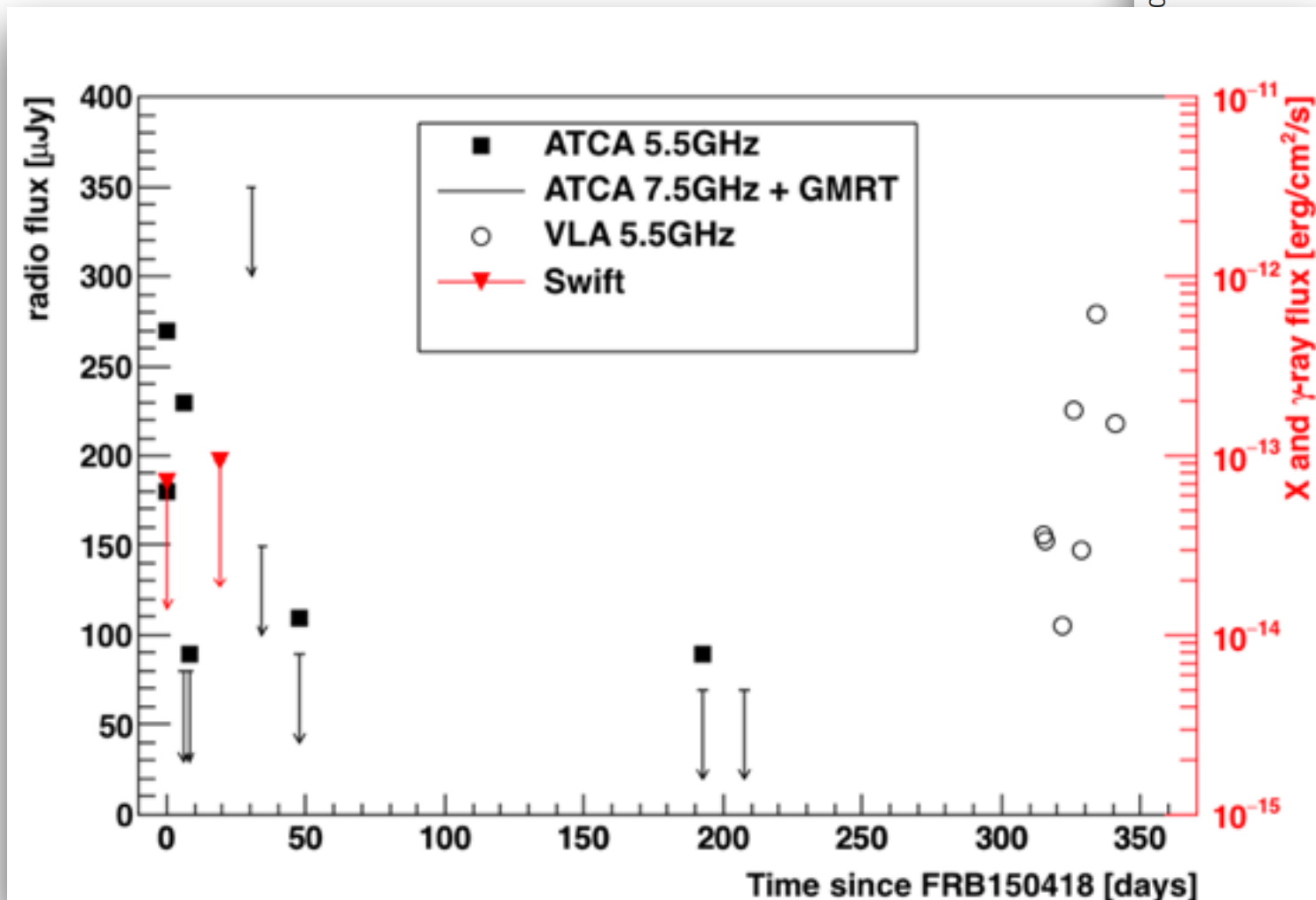
Fast Radio Bursts

- strong, millisecond radio burst of possibly extragalactic origin
- H.E.S.S. takes part in the SUPERB project @ Parkes
 - online searches for FRBs and other radio transients



FRB150418

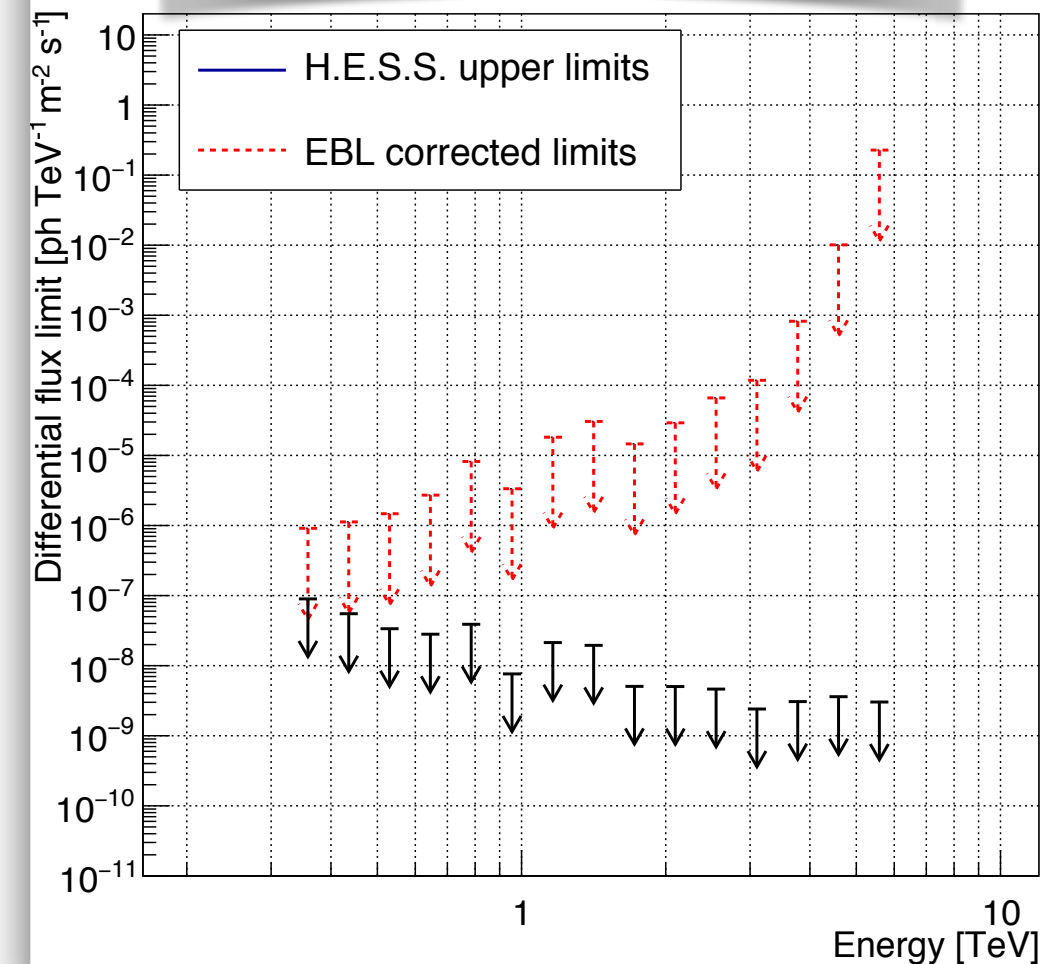
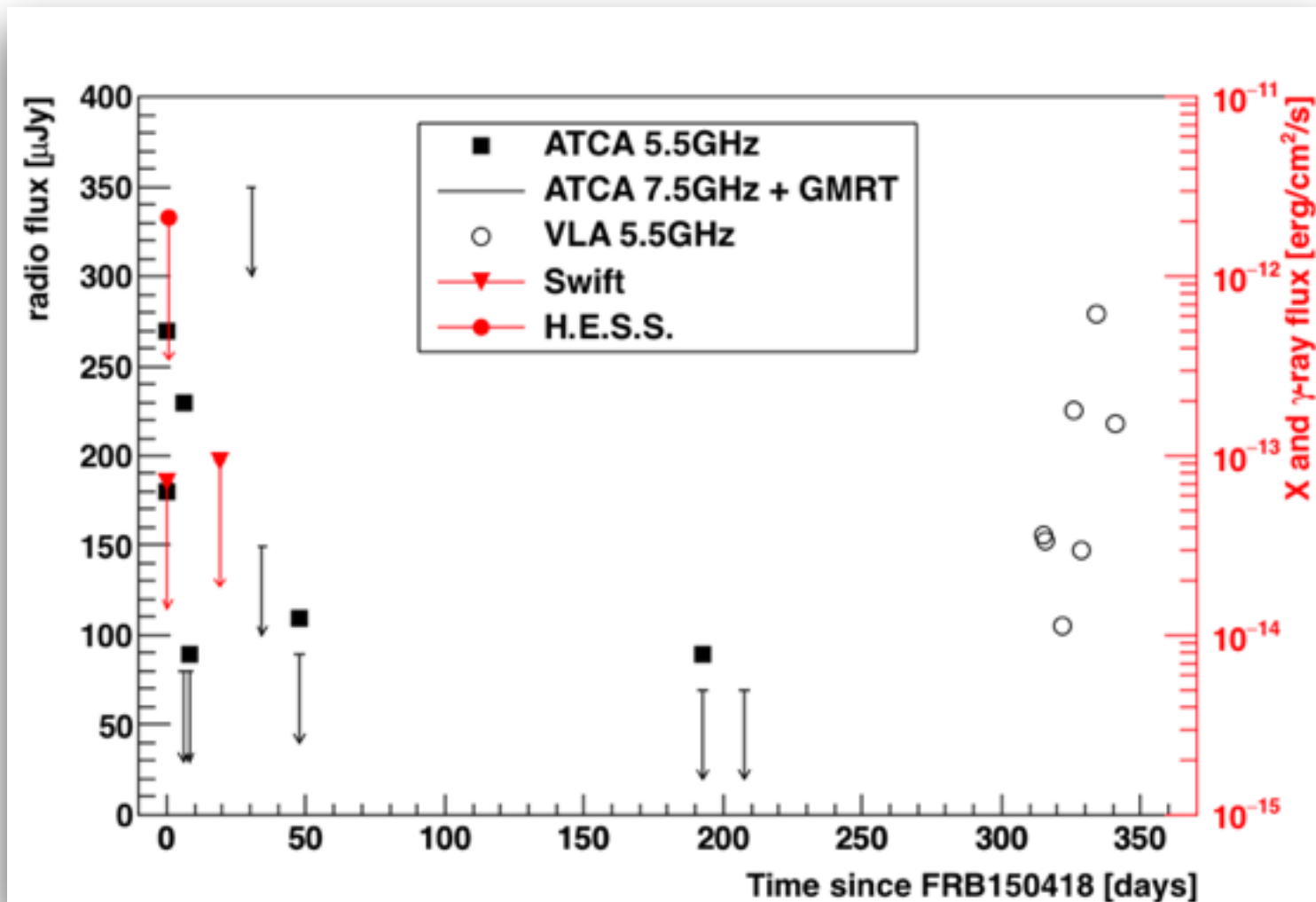
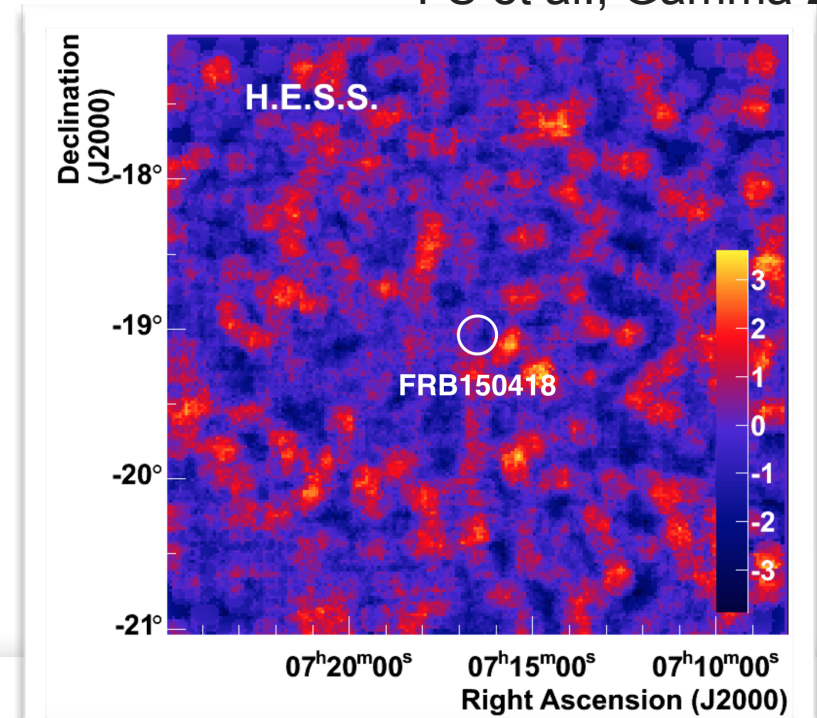
- detected 2015 April 18 04:29:07.056 UTC at SUPERB@Parkes
- ATCA: fading radio afterglow during ~6days
 - optical identification of galaxy at $z=0.492$



E. Keane et al., Nature 530 (2016)

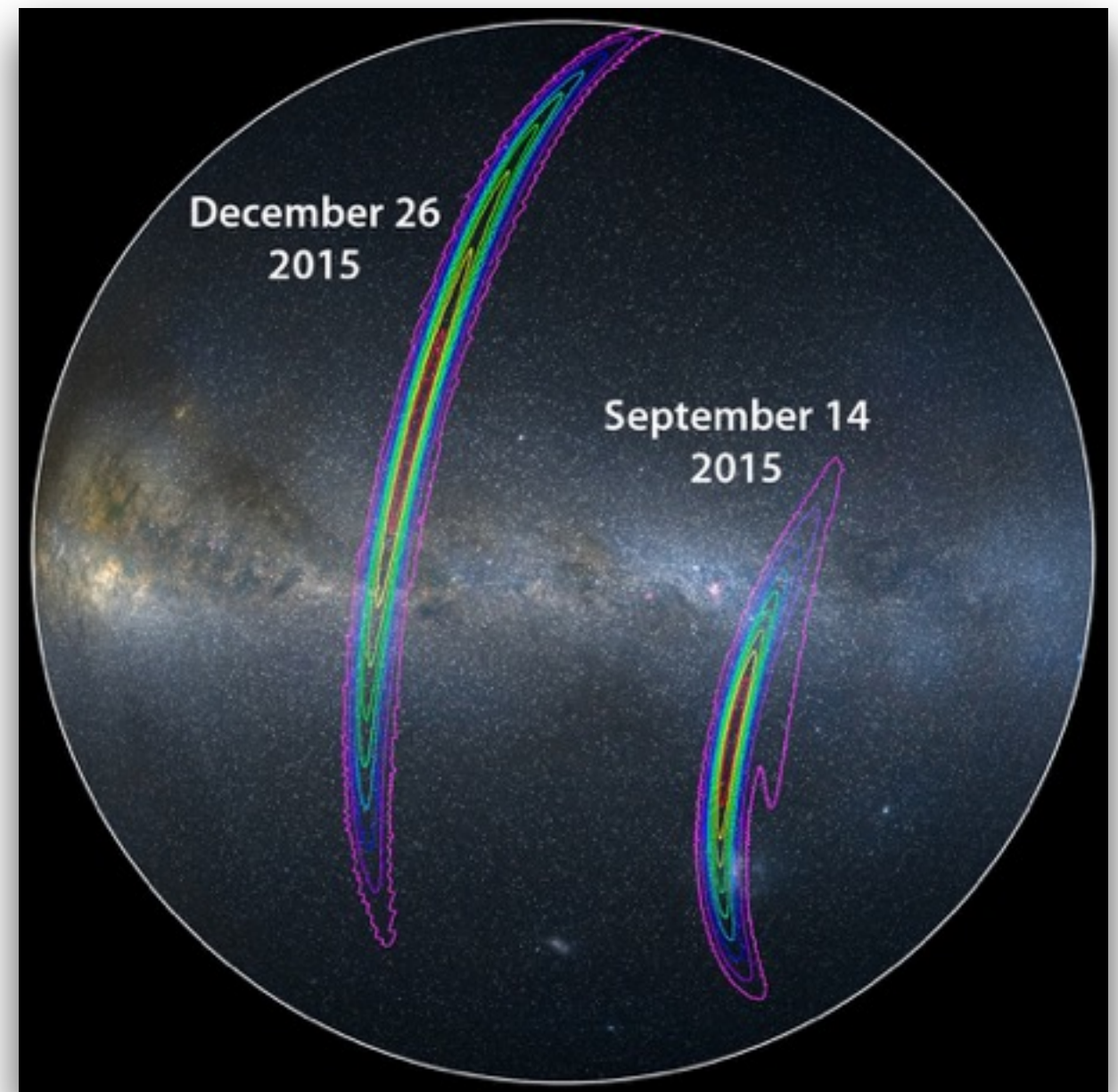
FRB150418

- detected 2015 April 18 04:29:07.056 UTC at SUPERB@Parkes
- ATCA: fading radio afterglow during ~6days
 - optical identification of galaxy at $z=0.492$
- H.E.S.S. observations the night after the burst
 - delay: ~14.5h
 - no VHE afterglow detected
 - $\Phi(E>350\text{GeV}) < 1.3 \times 10^{-8} \text{ m}^{-1} \text{ s}^{-1} (E^{-2}, 99\% \text{ C.L.})$



Gravitational Waves

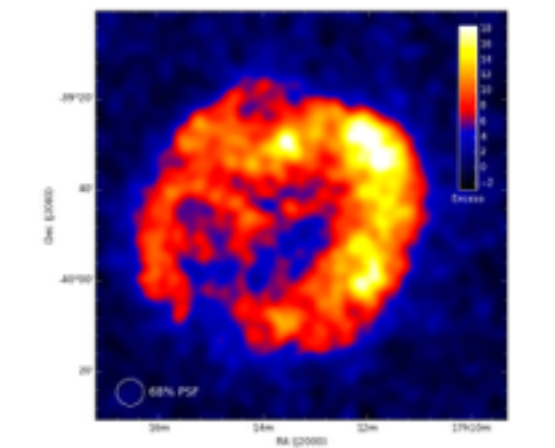
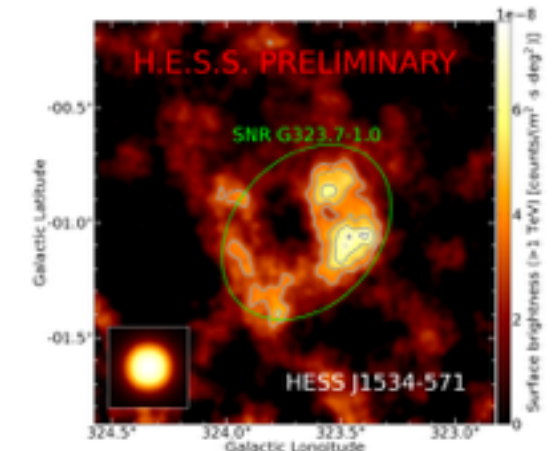
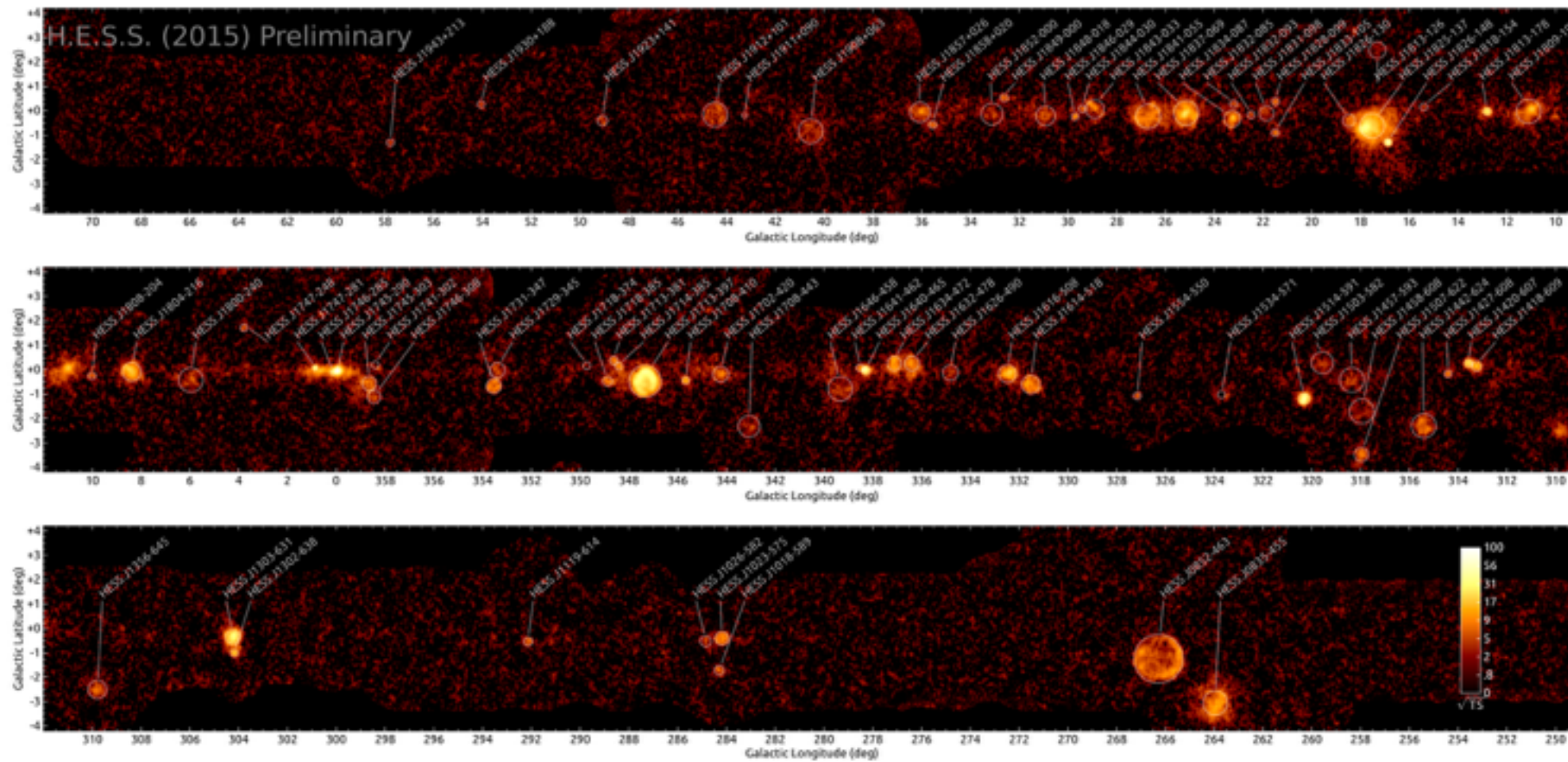
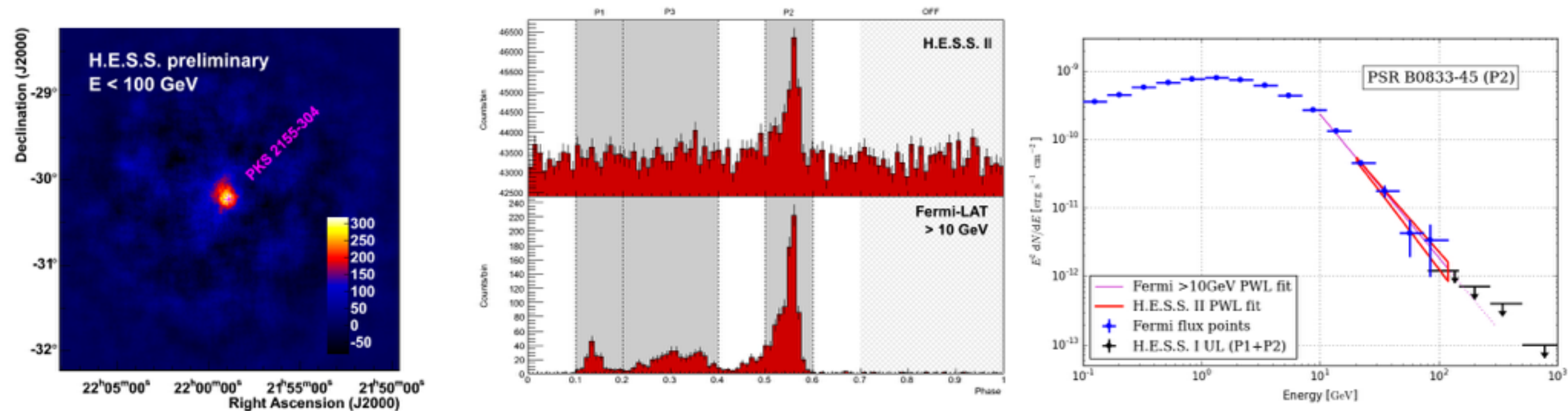
- Second physics run of Advanced LIGO/Virgo started recently
- Ligo only: localization typically poor $O(100 \text{ deg}^2)$
- H.E.S.S. part of the EM follow-up program since 2014
- rapid slewing, relatively large FoV
- follow-up decision on case-by-case basis



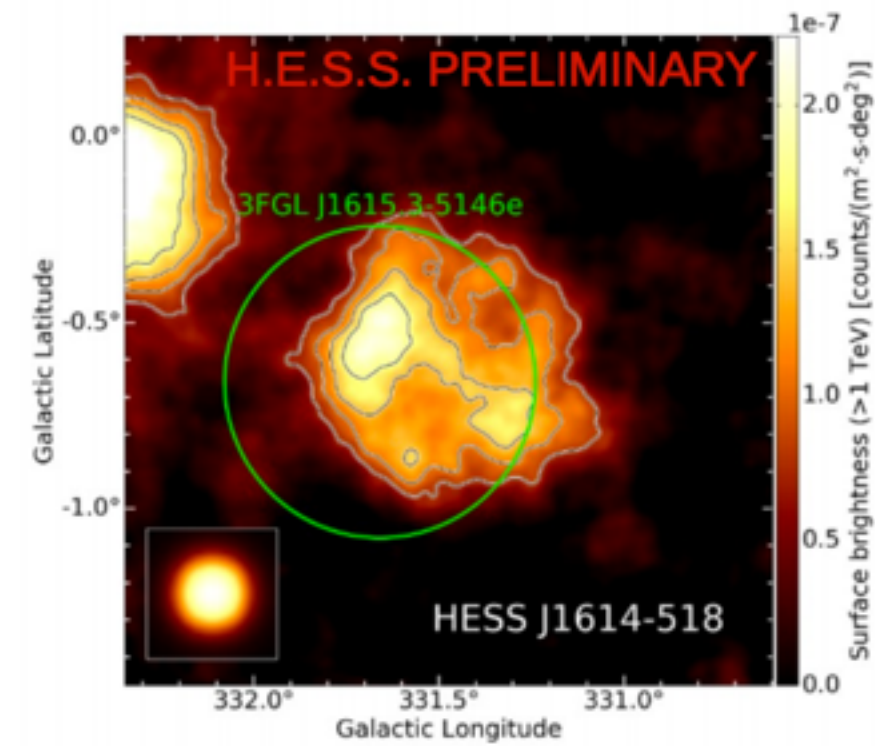
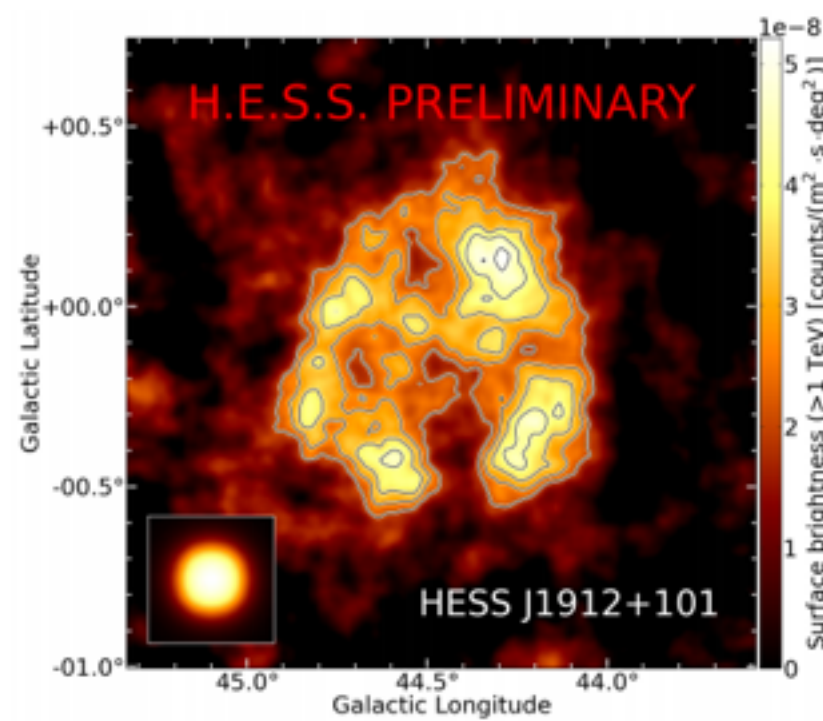
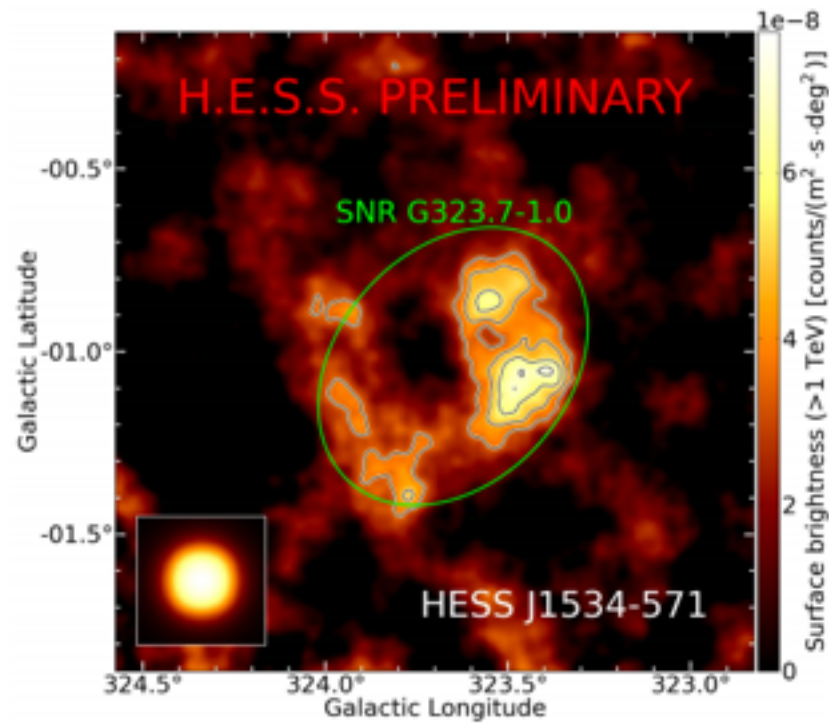
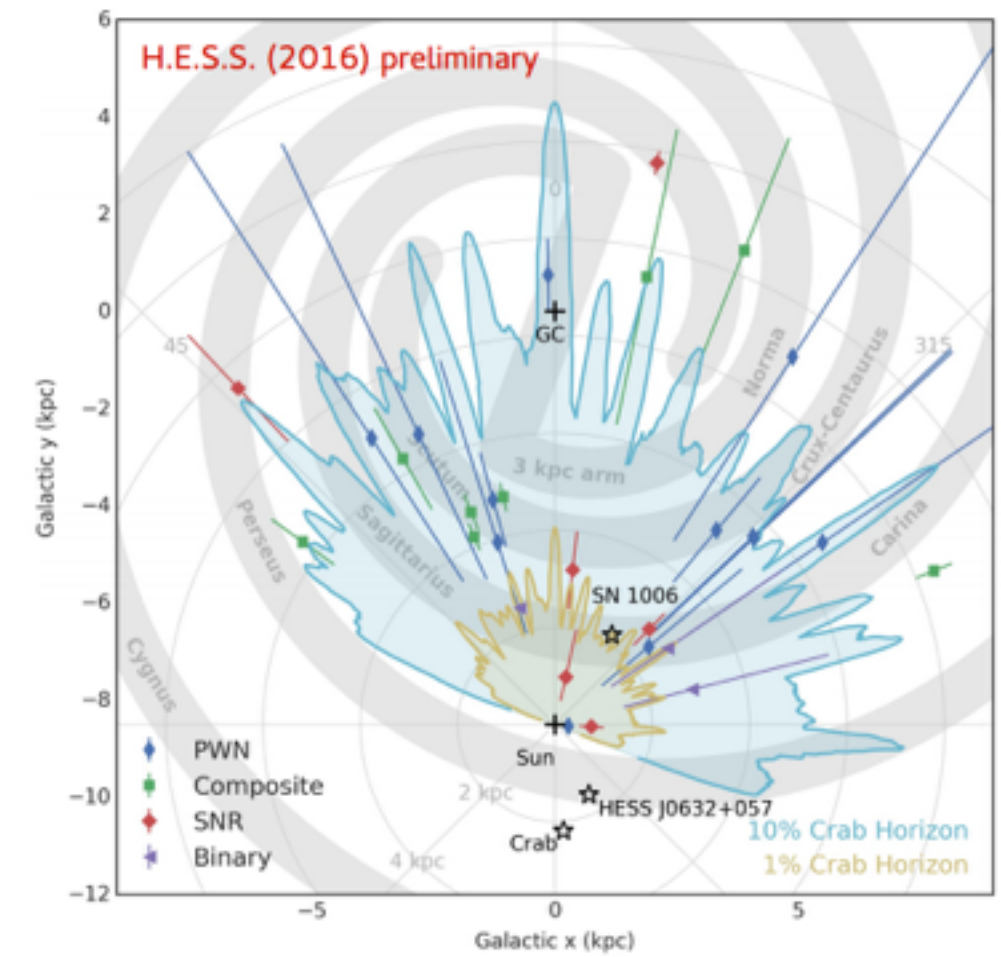
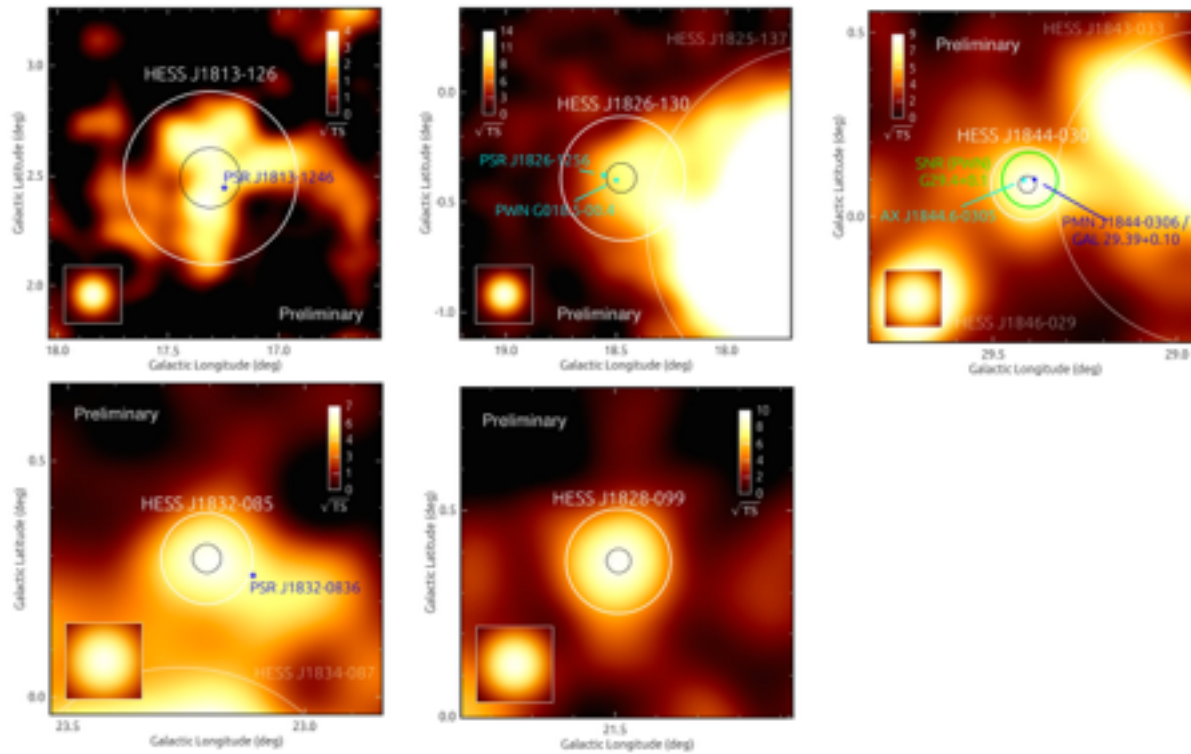
Summary

- H.E.S.S. phase II: lower energy threshold and rapid response
- Multi-messenger program
 - Neutrinos
 - hotspot + HESE source searches
 - focus on ToOs (e.g. IC-AMON alerts, ANTARES)
- Follow-up of alerts and ToOs
 - GRBs
 - improved performance: reduced response time
 - highest priority observations
 - Fast Radio Bursts
 - Gravitational Waves

Recent results



The H.E.S.S. Galactic Plane Survey

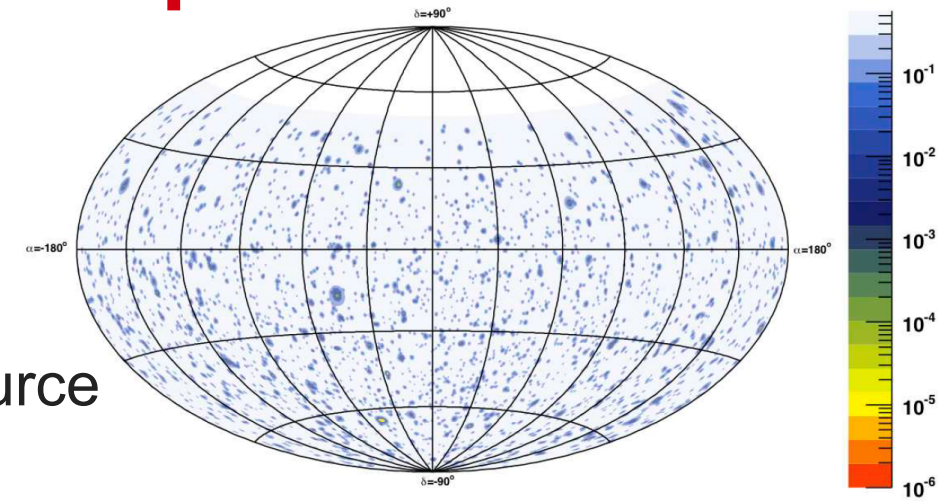


A. Donath (Gamma16)

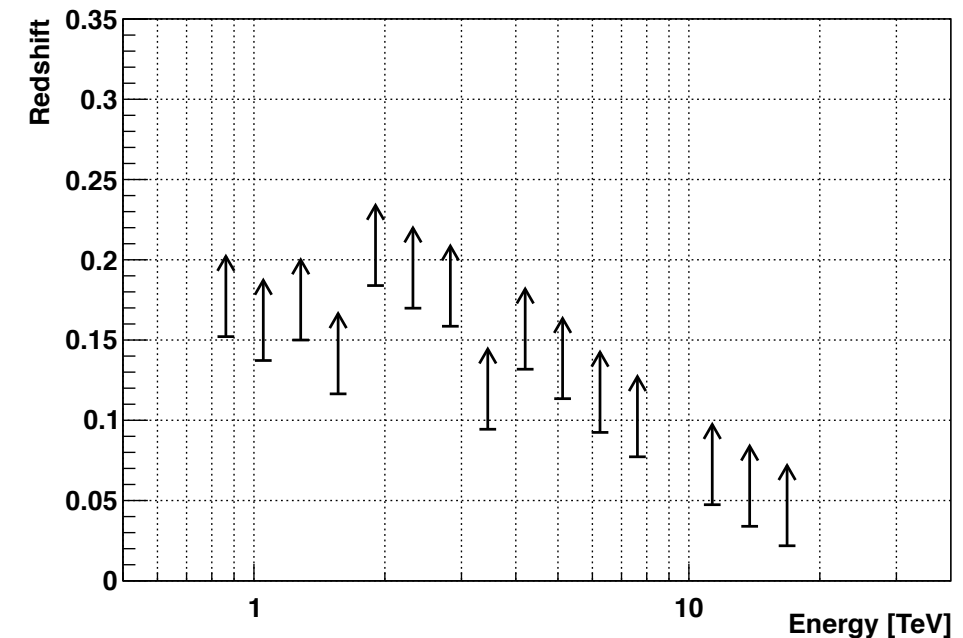
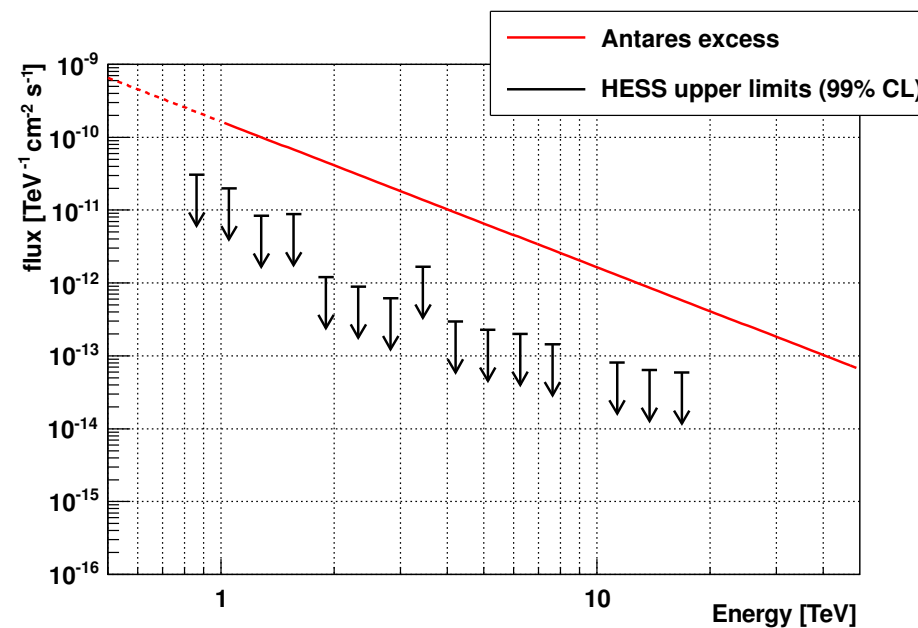
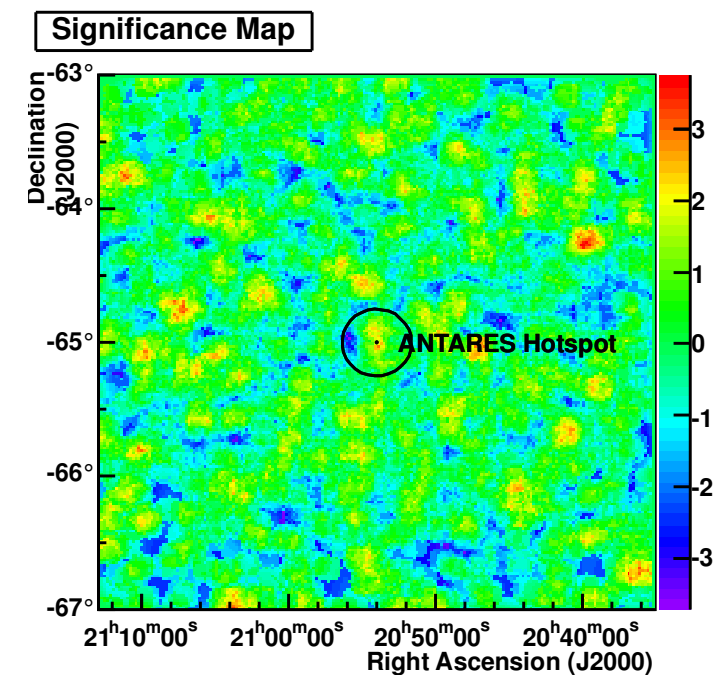
Multi-messenger program: Neutrino hotspots

■ Antares hotspot

- 2.2σ excess (Adrian-Martinez et al., APJ 760 (2012) 53)
- 2h of H.E.S.S. observations in 2013 ruling out close-by source



S. Adrian-Martinez (ANTARES Collaboration)
APJ 760 (2012) 53



FS et al., ICRC 2013, arXiv:1307.6074