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

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

Three Messenger Conference, Lake Baikal, 2016

Irfu
Institut de recherche sur les lois fondamentales de l'Univers

cea

The Lake Baikal Three Messenger Conference
29/08-03/09/2016

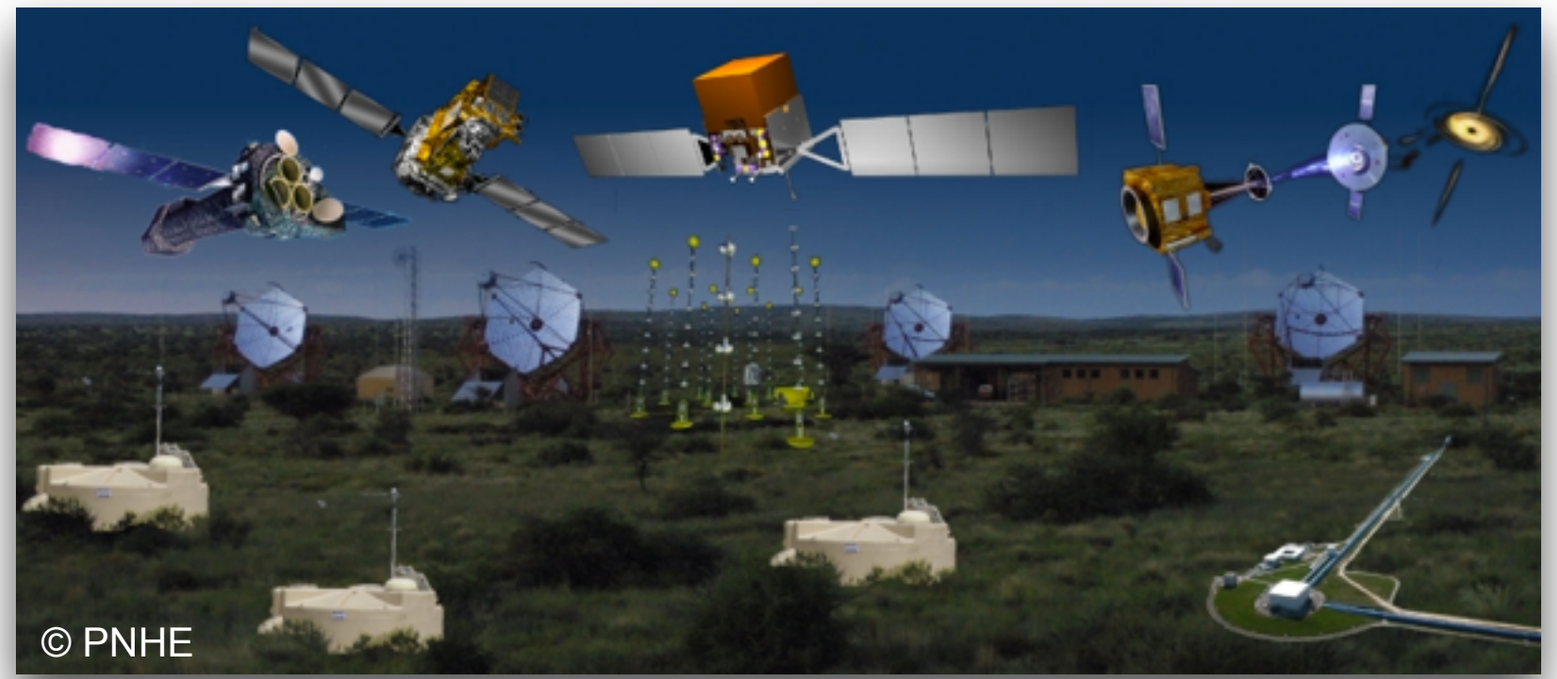
The H.E.S.S. multi-messenger and GRB team

A. Balzer, M. Backes, E. Bissaldi, F. Brun, P. Brun, W. Domainko, 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, P.H.T. Tam, S. Wagner

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

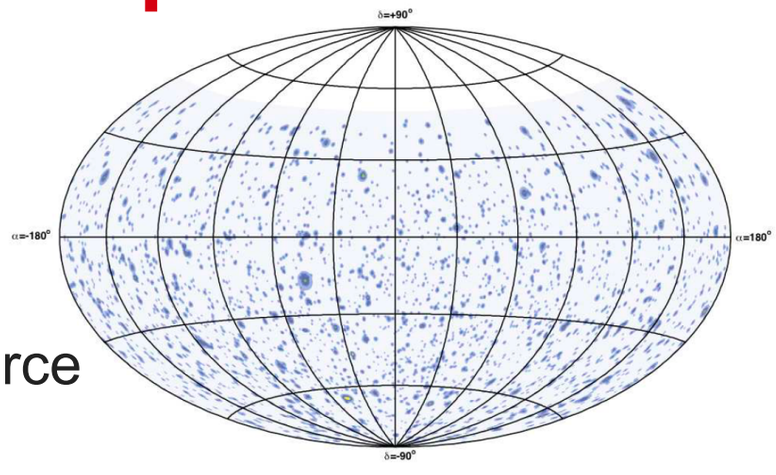
The H.E.S.S. multi-messenger program

- Cosmic rays
  - no time correlation (except neutrons): waiting for a small-scale excess ;-)
- 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

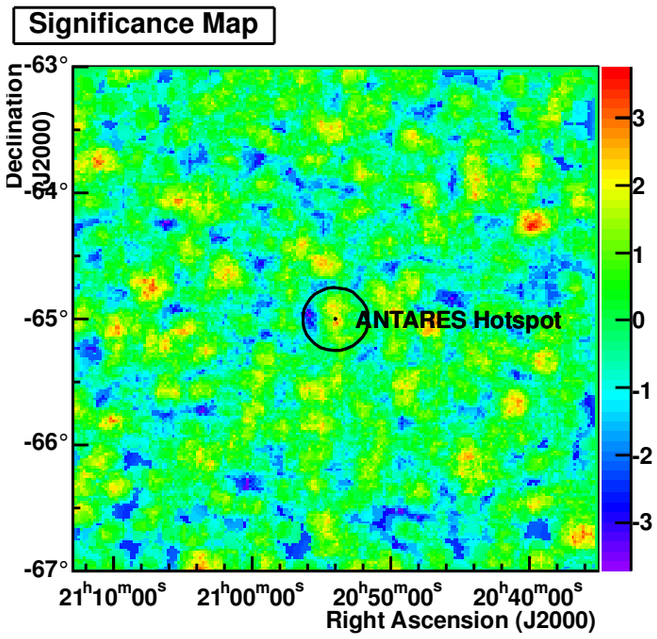


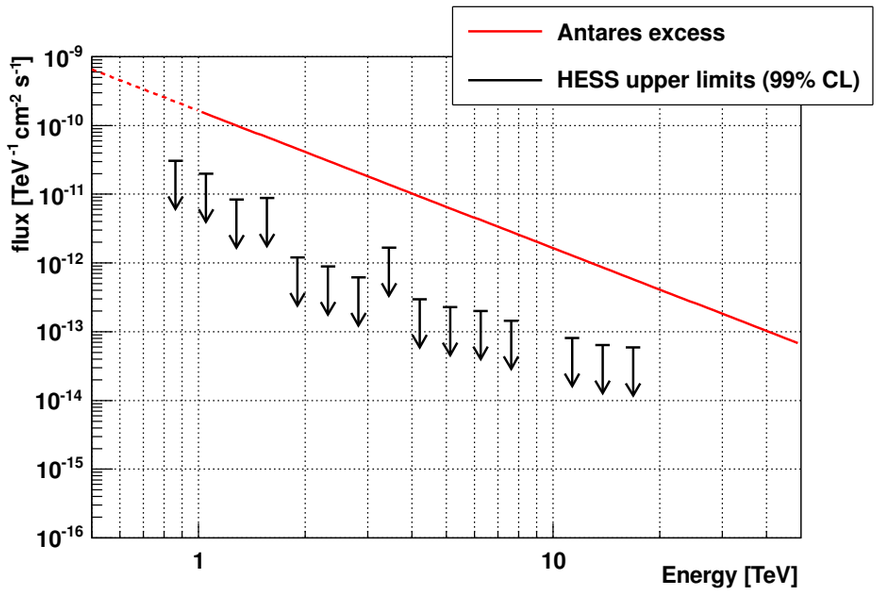
Multi-messenger program: Neutrino hotspots

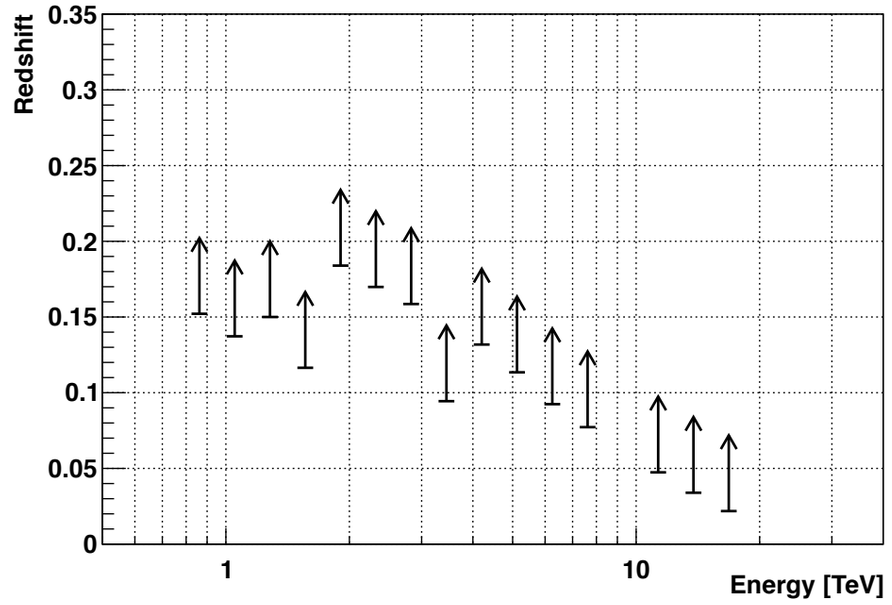
- Antares hotspot
  - 2.2σ excess (Adrian-Martinez et al., APJ 760 (2012) 53)
  - 2h of H.E.S.S. observations in 2013 ruling out close-by source



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





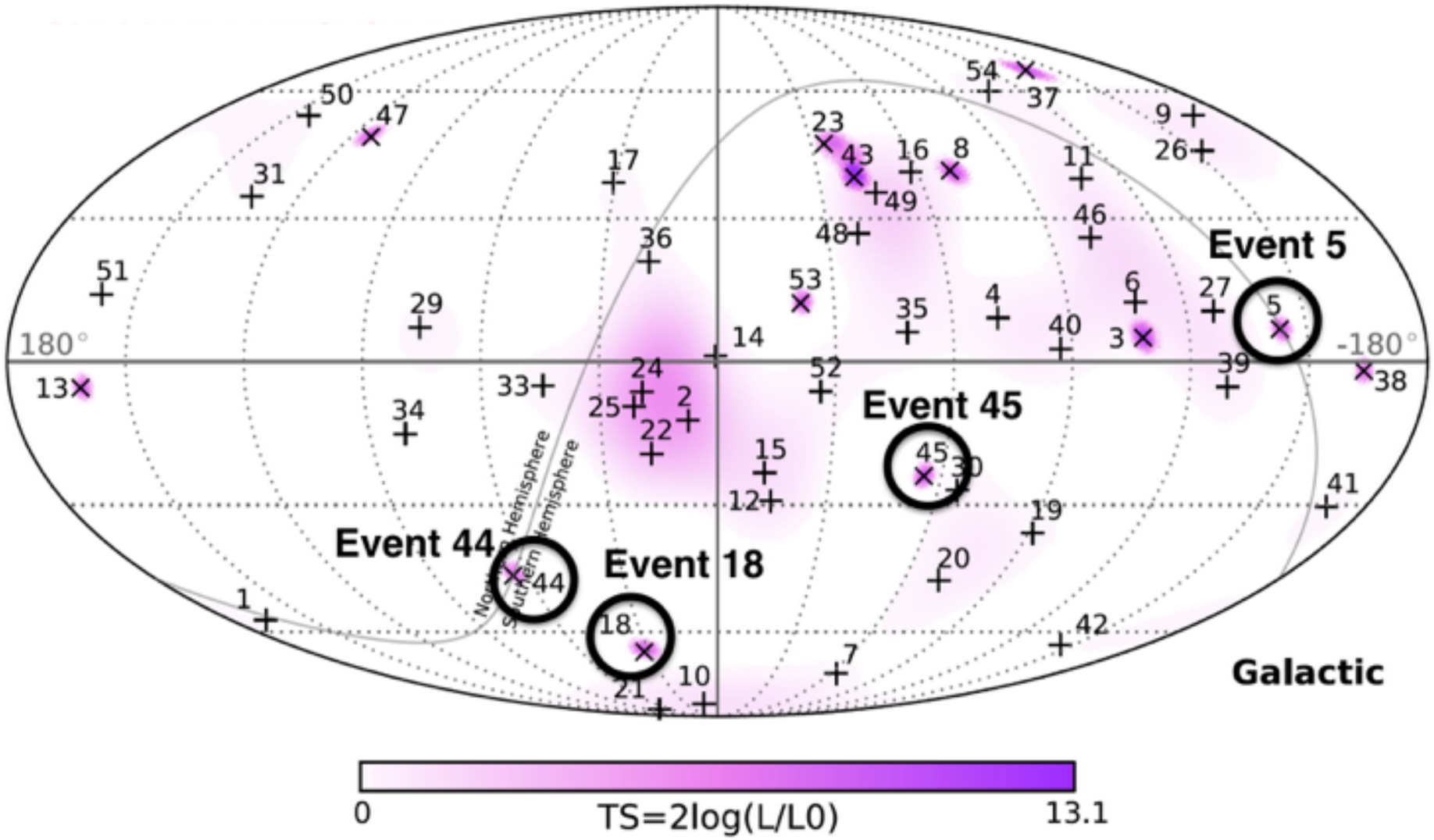


FS et al., ICRC 2013, arXiv:1307.6074

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.

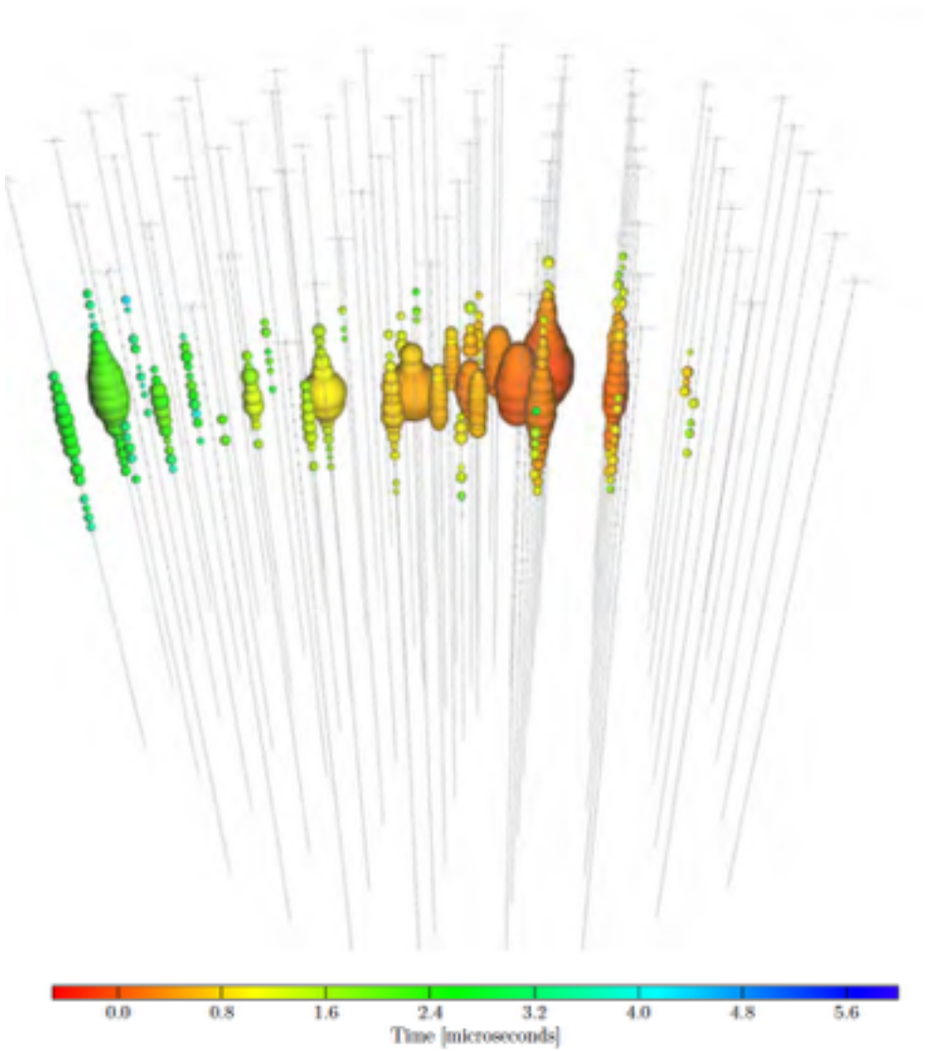
C. Kopper, ICRC 2013



IceCube events: examples

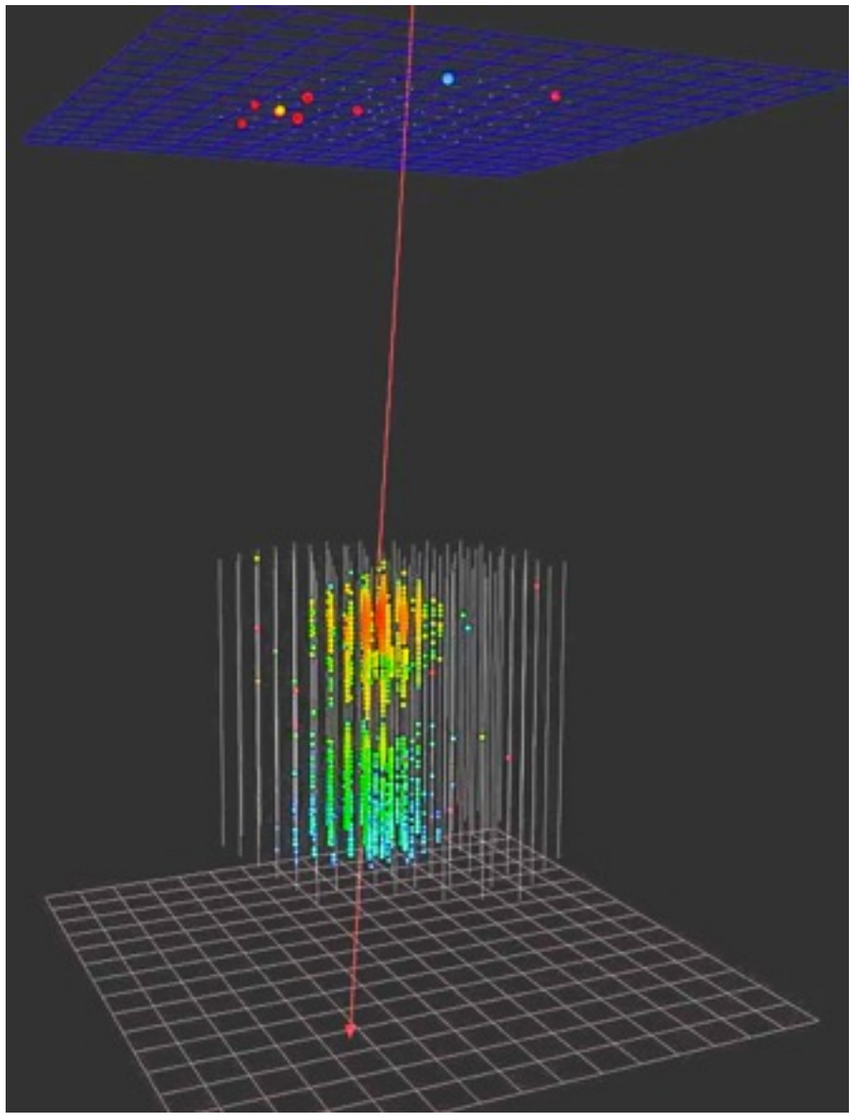
IceCube Event 5

- 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

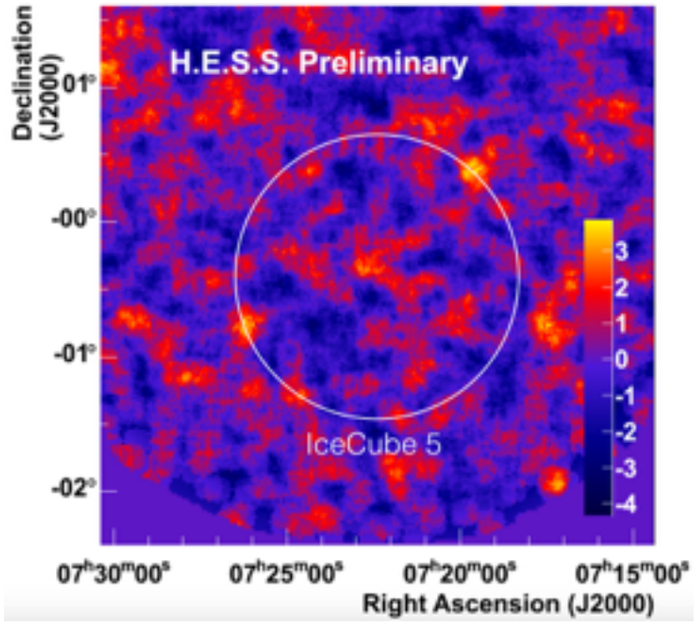


IceCube HESE tracks: H.E.S.S.

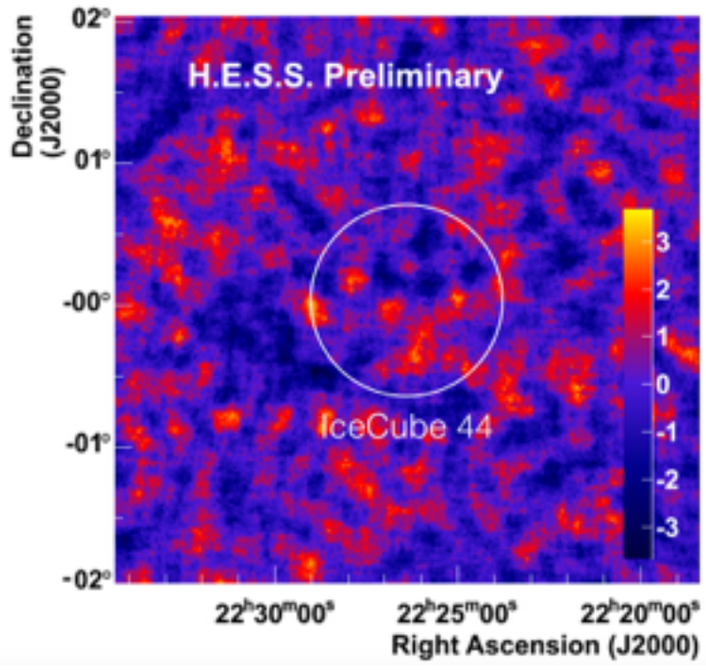
FS et al., ICRC 2015, arXiv:1509.03035

FS et al., Gamma 2016

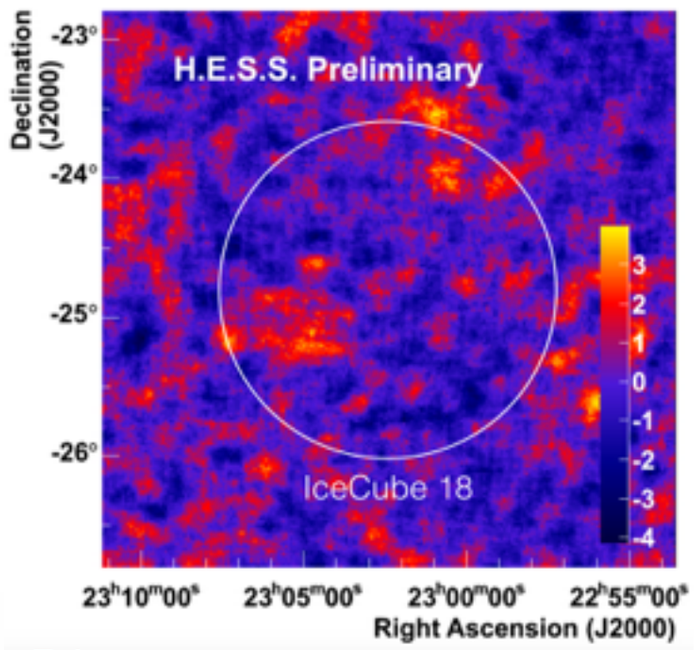
- IceCube 5



- IceCube 44



- IceCube 18



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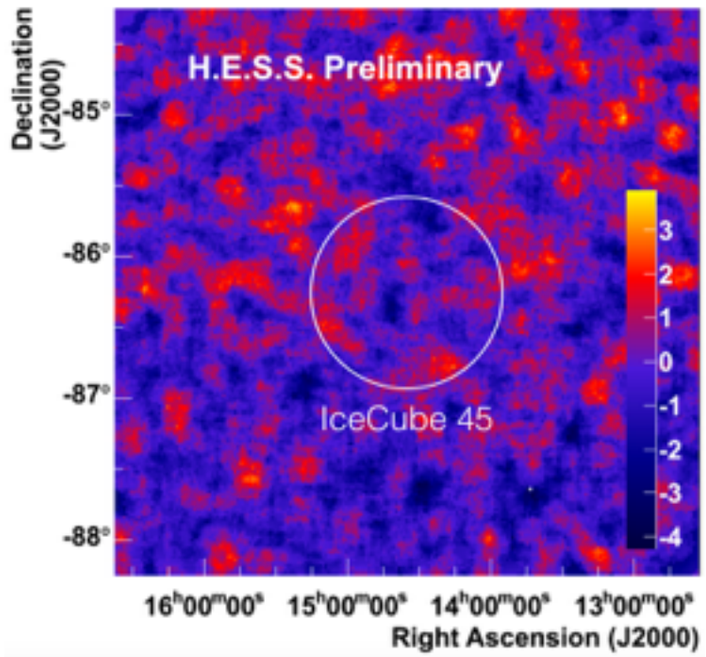

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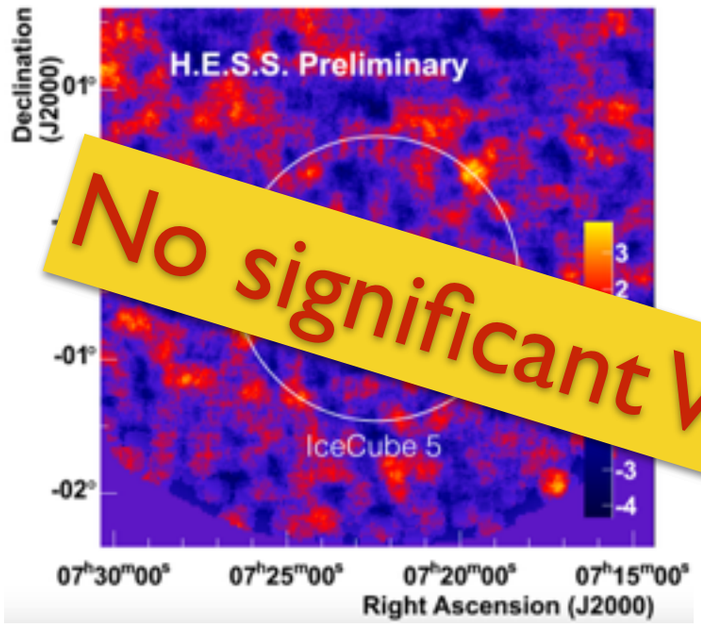

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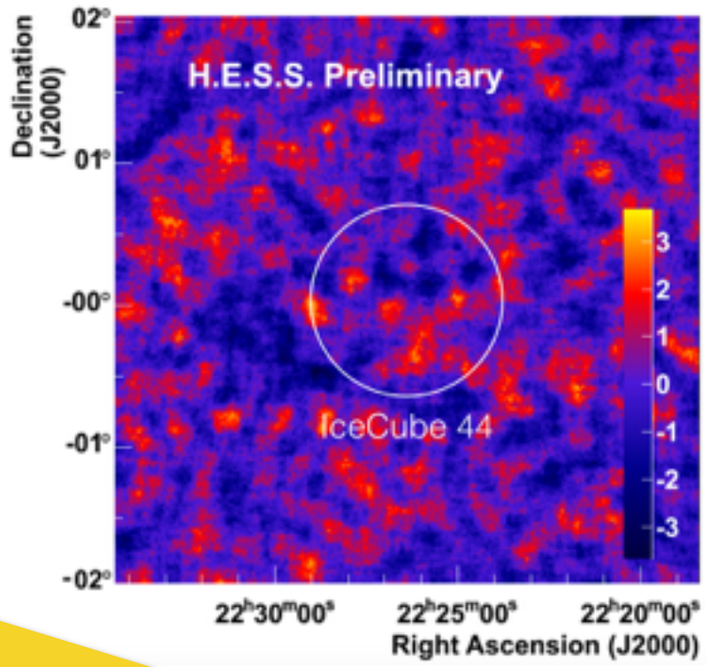
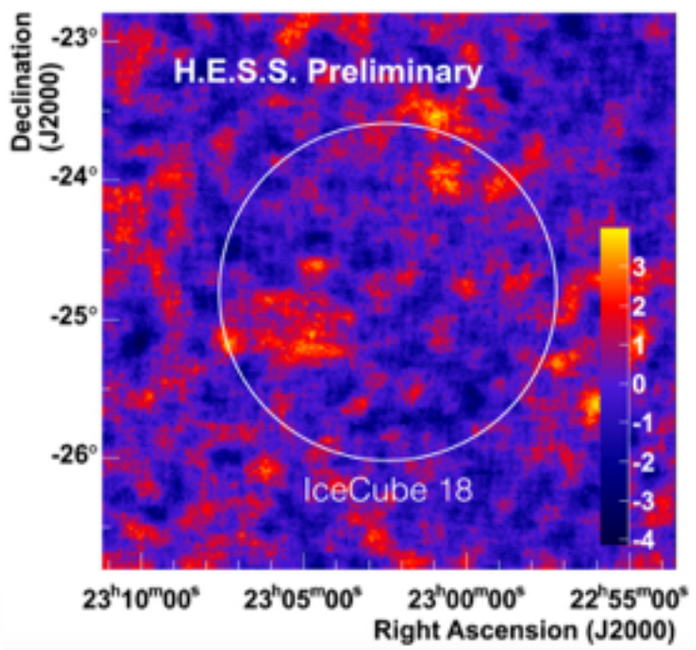


No significant VHE gamma-ray emission found yet

- IceCube 18



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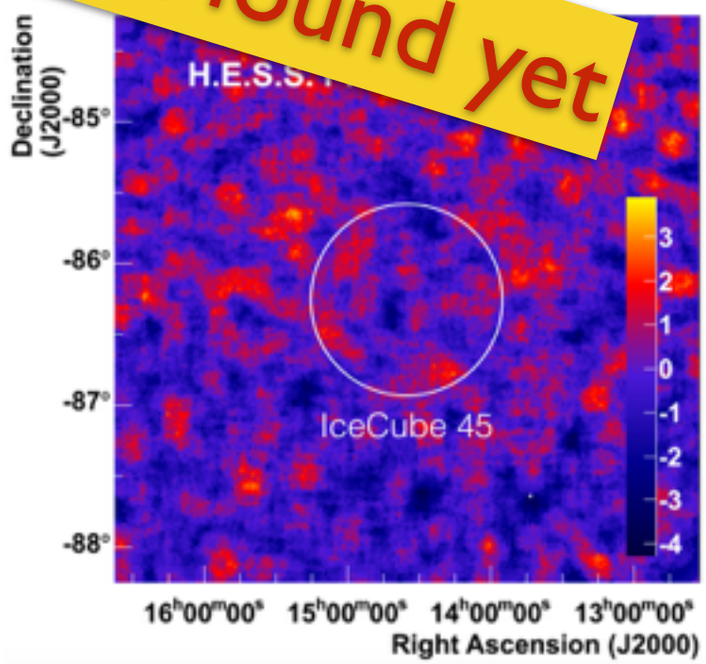


IceCube HESE tracks: Fermi-LAT

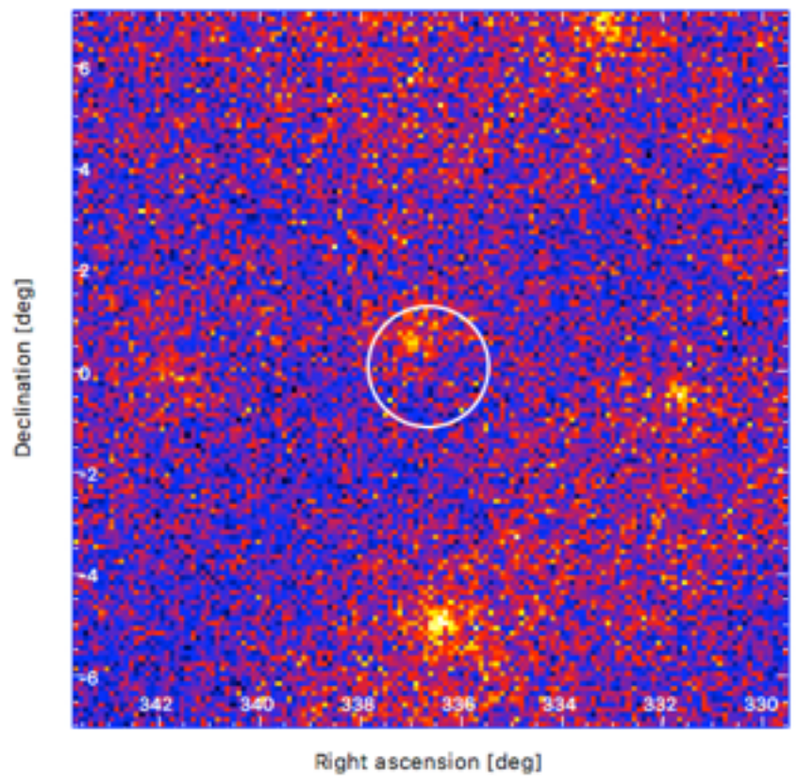
FS et al., ICRC 2015, arXiv:1509.03035

FS et al., Gamma 2016

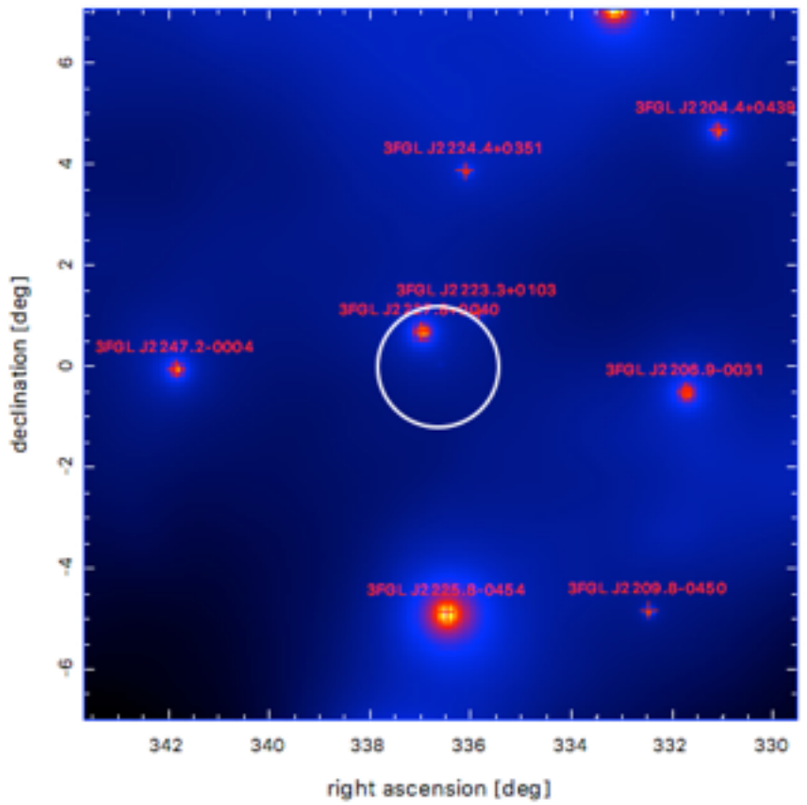
- Event 5 + 18: period 08/2008-05/2015; P7Rep, 100MeV-300GeV
- Event 44 + 45: period 08/2008-05/2016; Pass8, 100MeV-300GeV

Example: Event 44

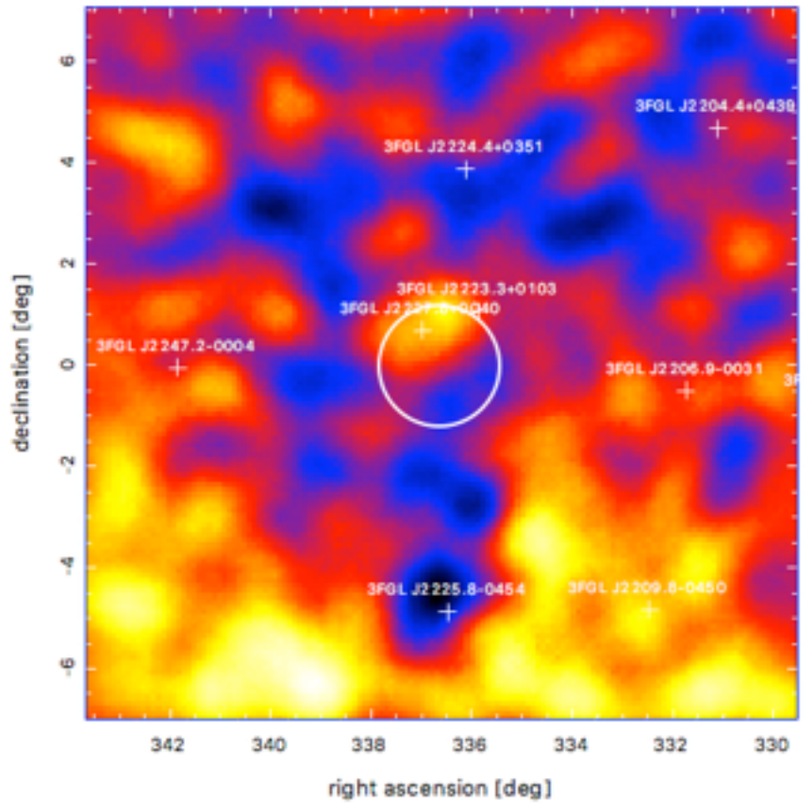
counts



model



residuals



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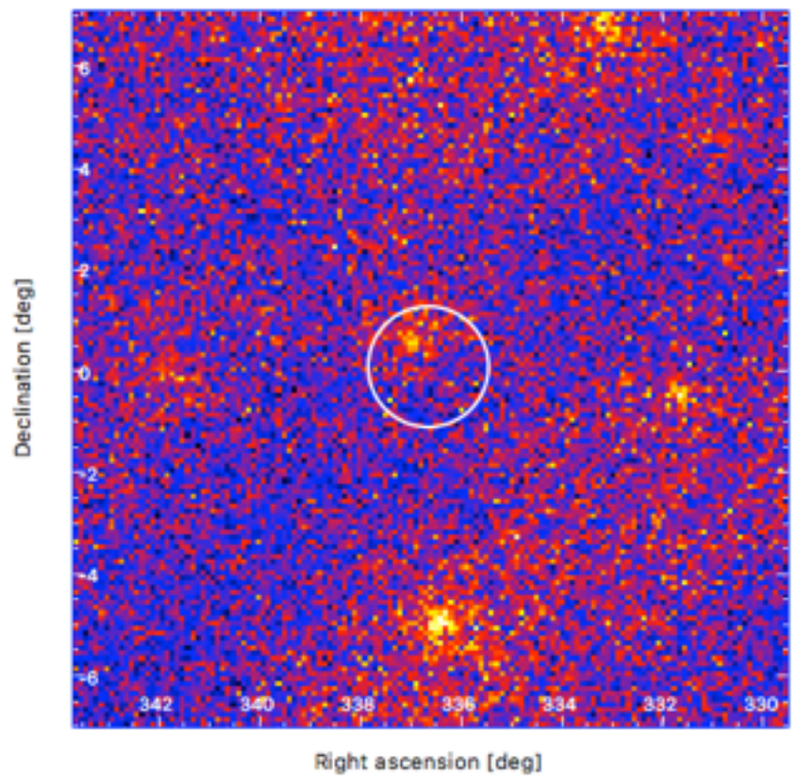

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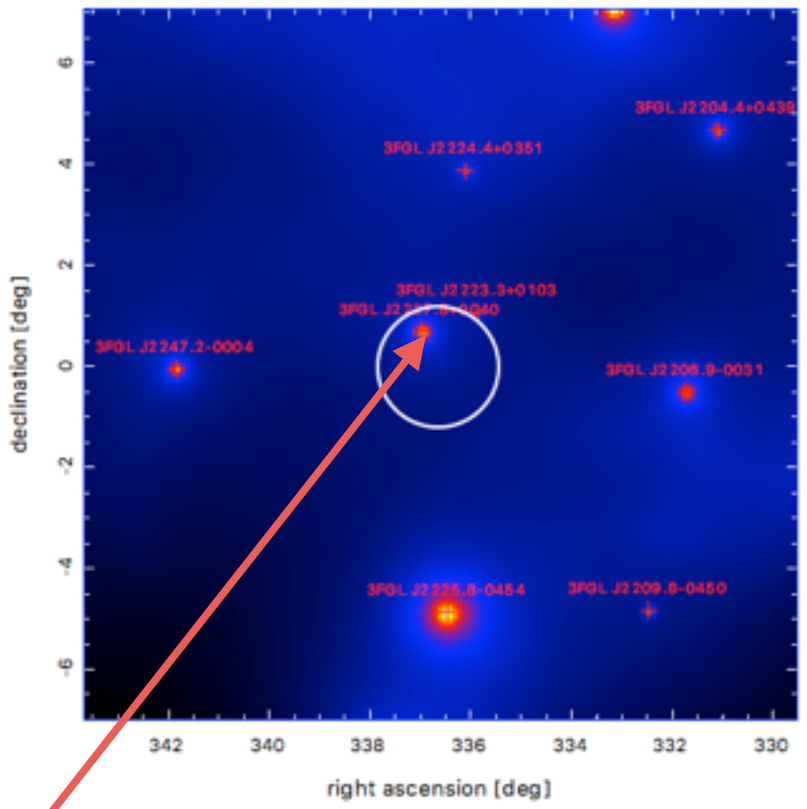

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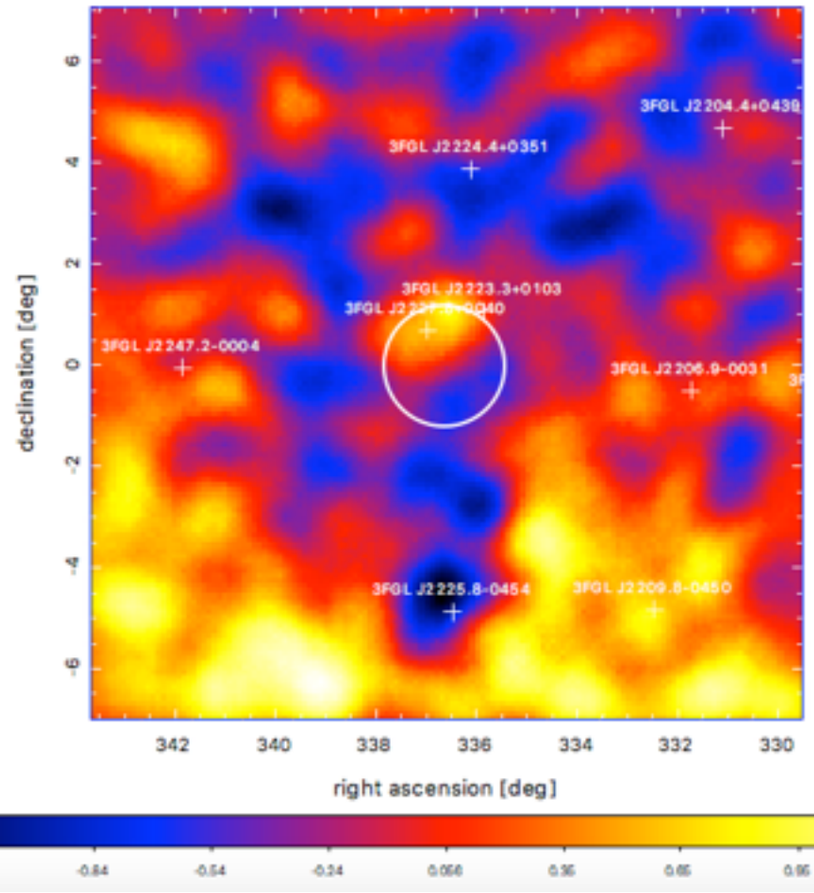


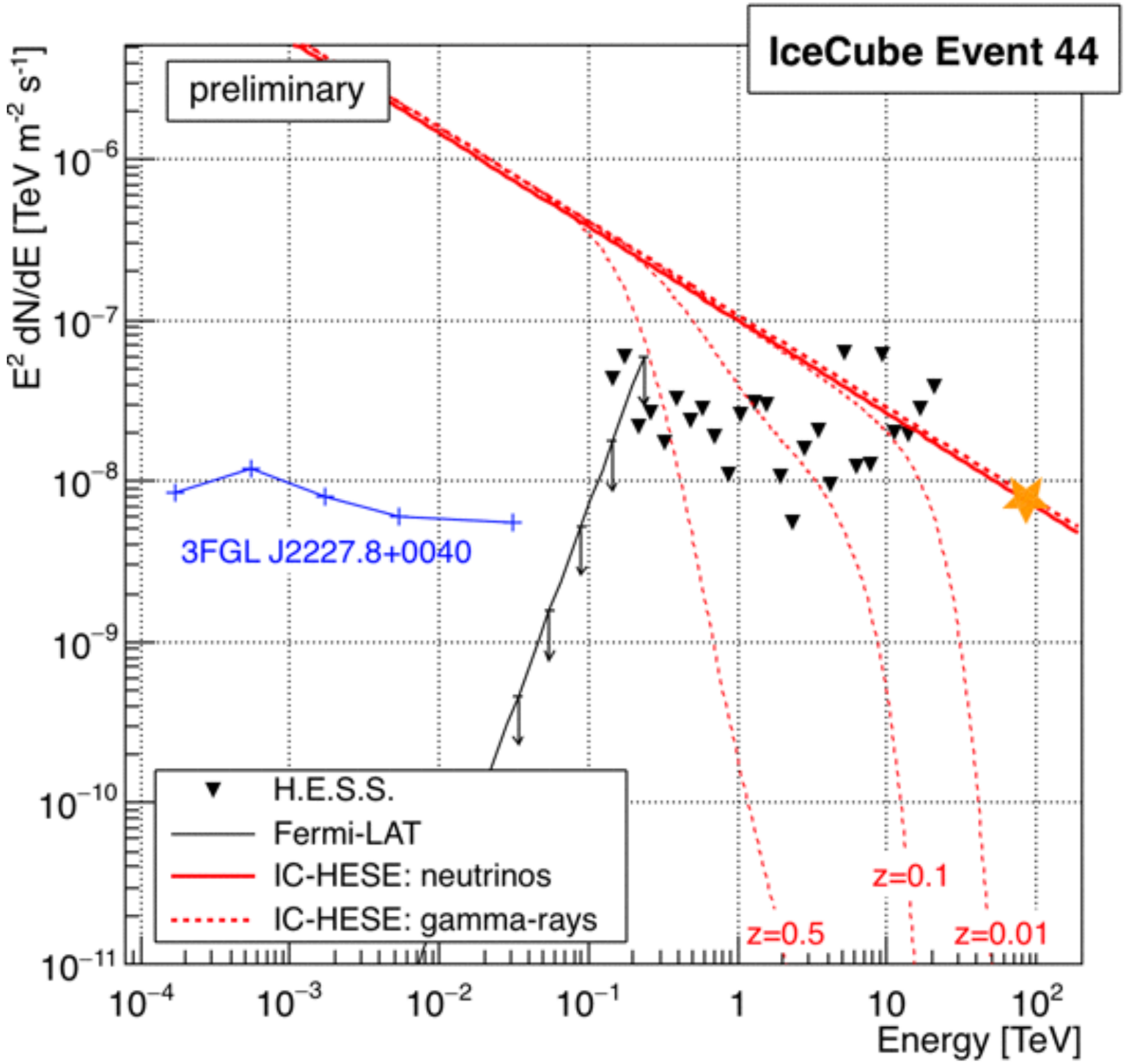
3FGL J2227.8+0040

J222743.7+005729: Blazar at z~1.3

IceCube HESE tracks: Limits

FS et al., ICRC 2015, arXiv:1509.03035
FS et al. Gamma 2016

- Example: Event 44



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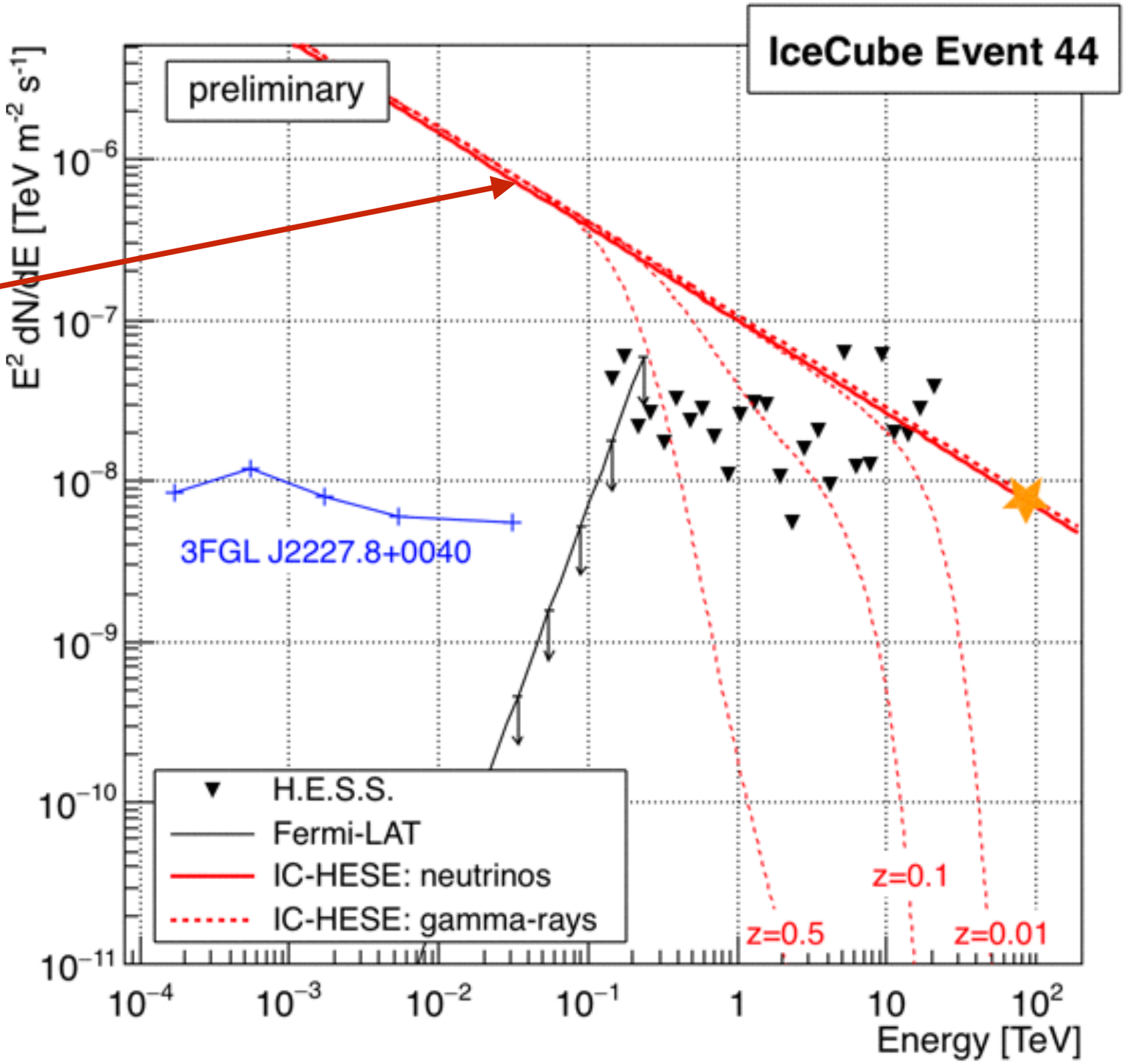
FS et al. Gamma 2016

- Example: Event 44

diffuse IceCube flux:
$\varphi(E) = 2.2 \times 10^{-8}\ E^{-2.58}$ GeV cm^{-2} s^{-1} sr^{-1}
within a point-like source (0.1deg)



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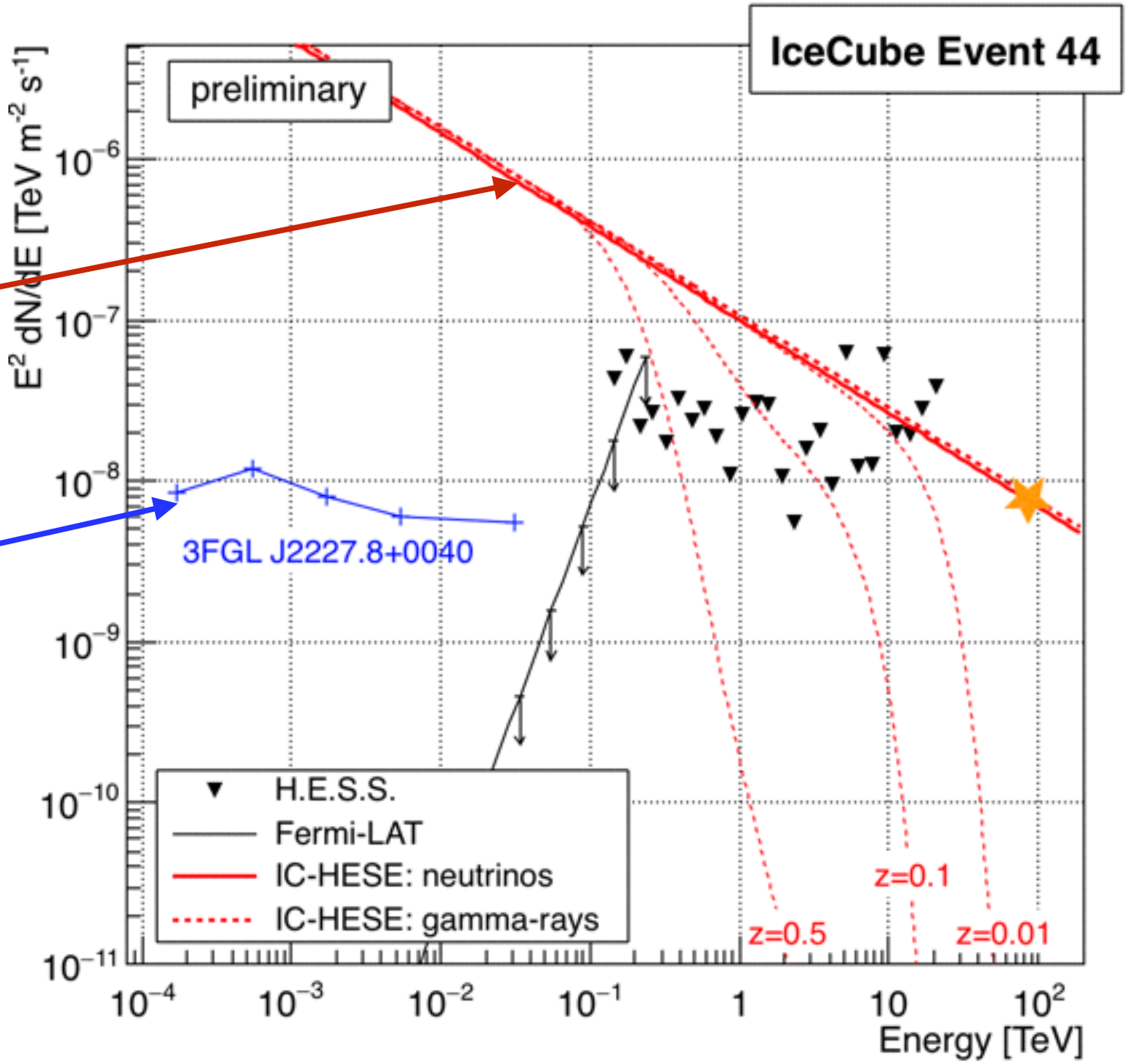
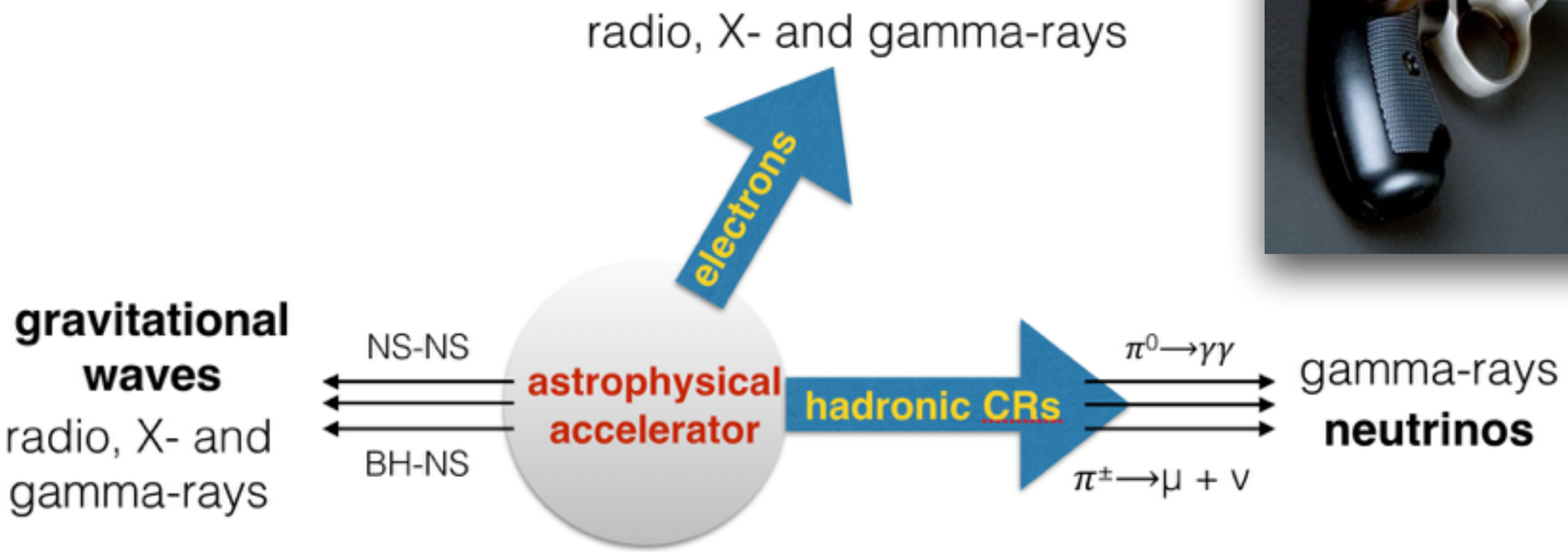
3FGL "candidate" source within IceCube ROI



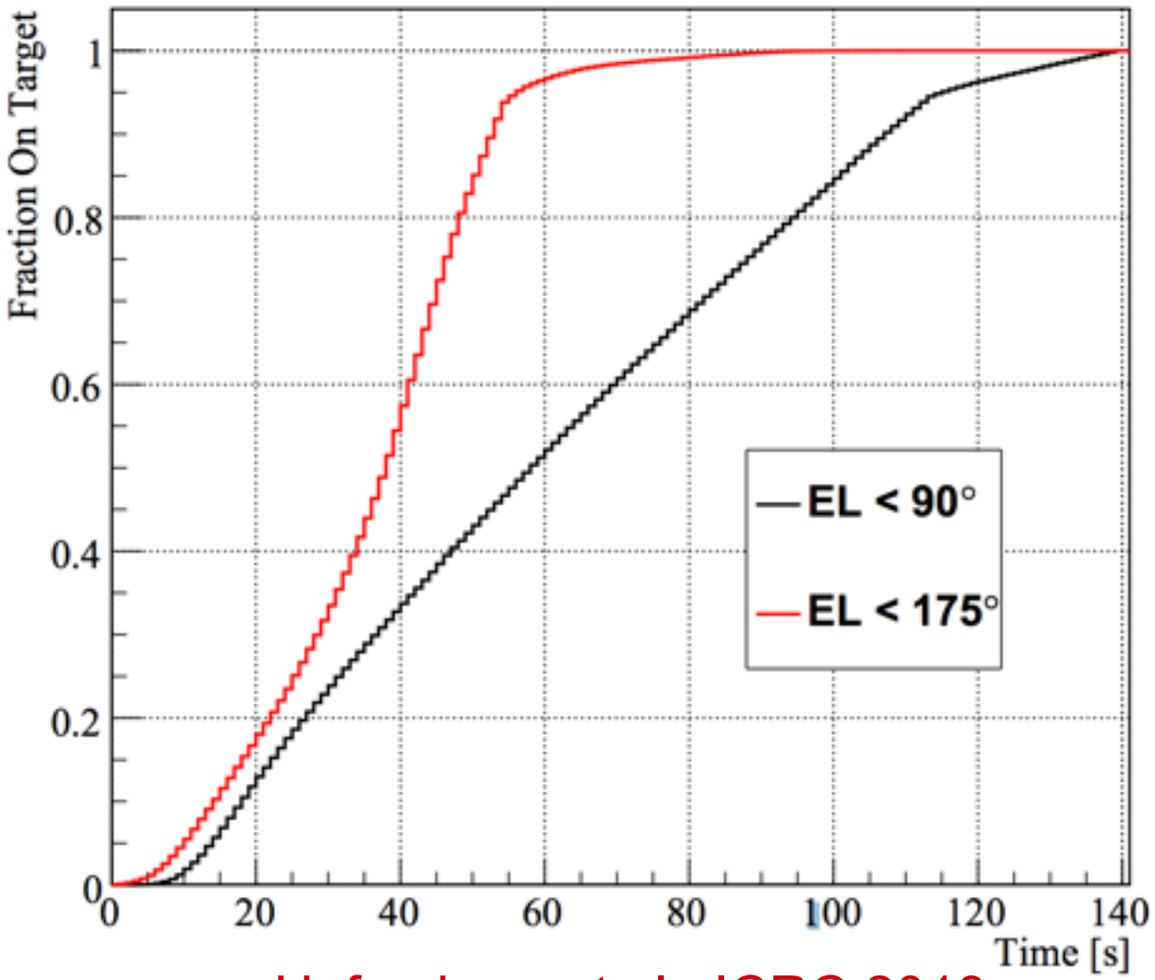
Future of the H.E.S.S. Multi-messenger program: alerts and ToOs

- 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 m^2 mirror area (largest IACT worldwide)
  - **rapid response time**



Hofverberg et al., ICRC 2013

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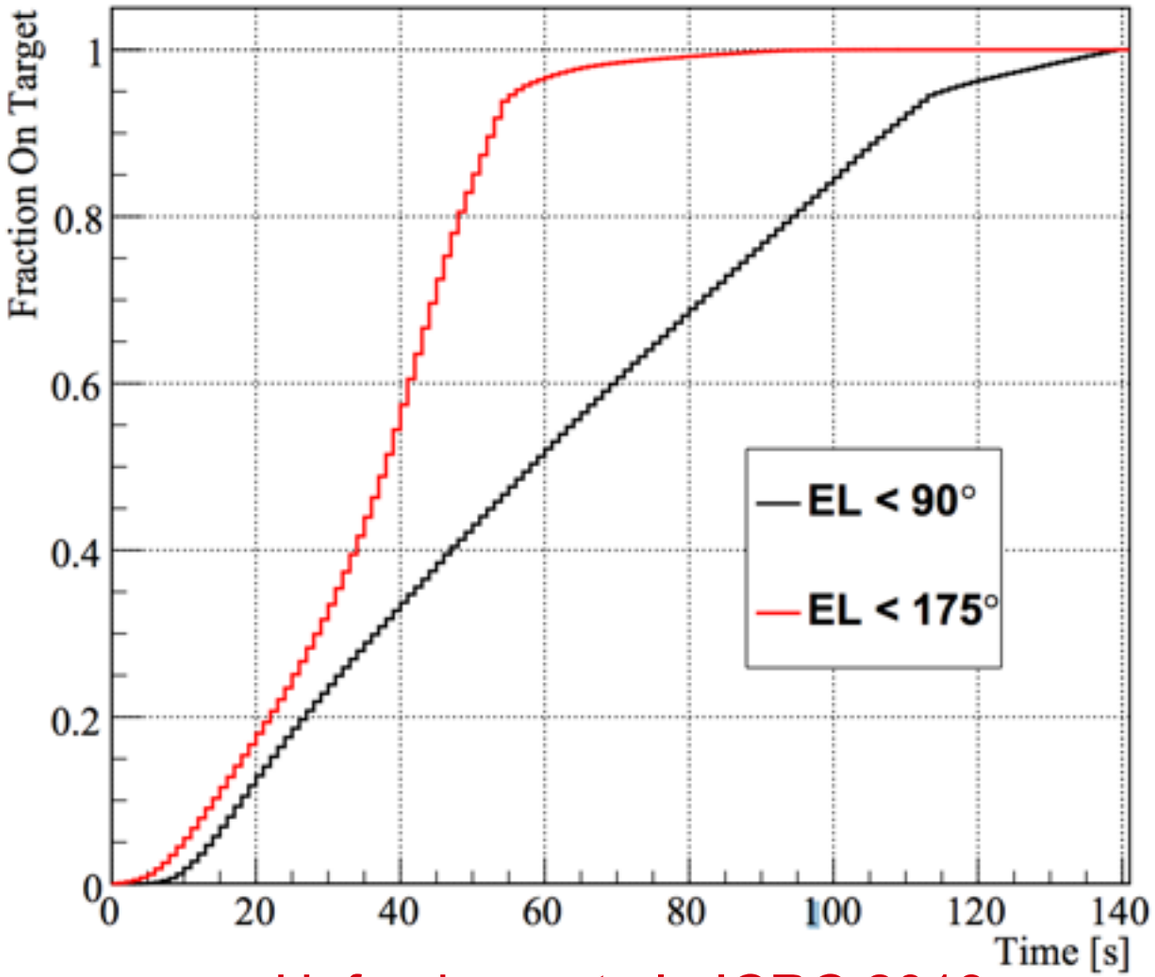

Hofverberg et al., ICRC 2013

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

VoEvent alert system

- **Details in the next talk by Clemens Hoischen**

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

- IceCube
  - real-time alerts on HESE + EHE events
  - expected delays O(10min)

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

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

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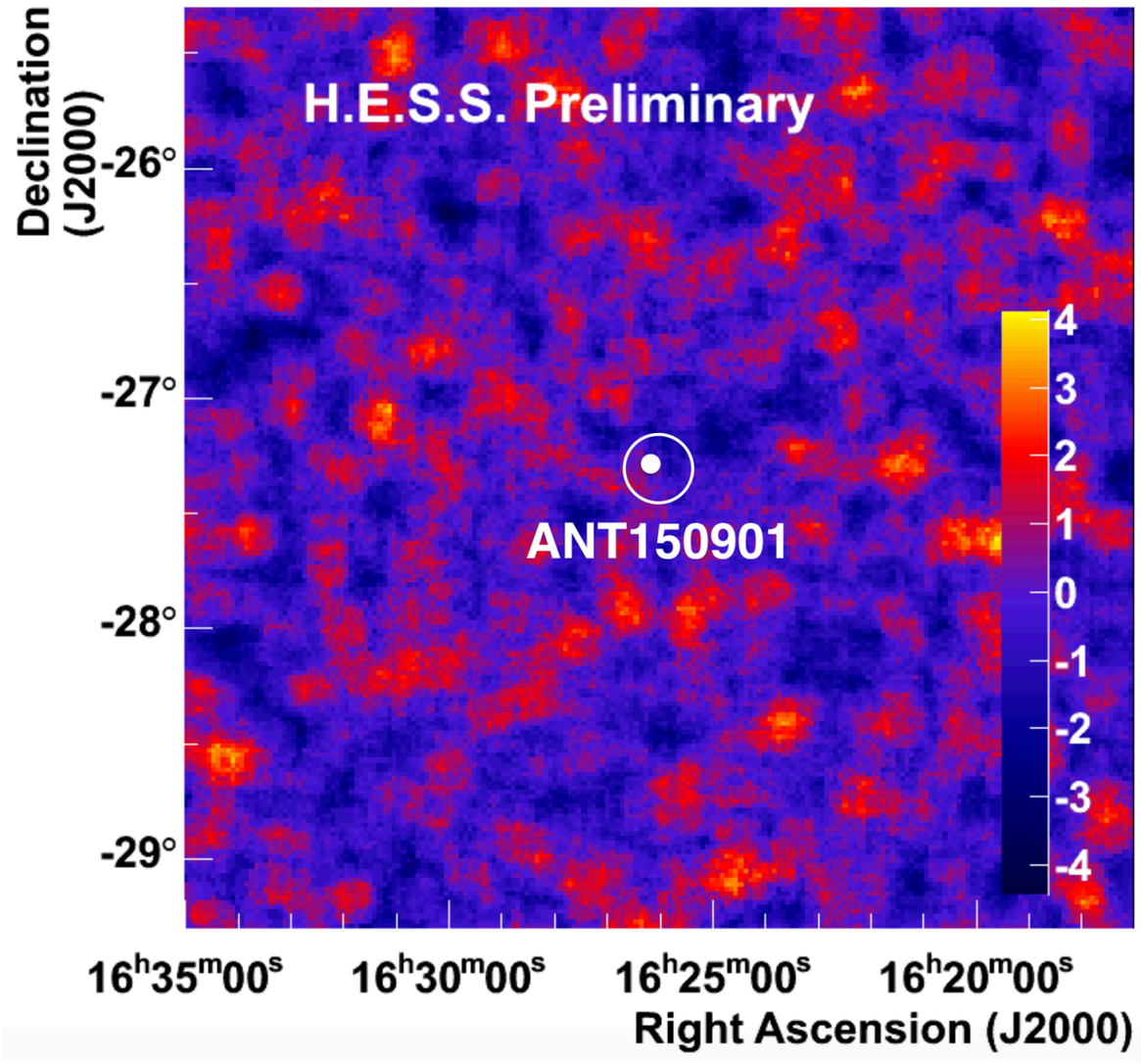
First follow-ups (see Clemens talk)

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

Example: ANT150901

Antares/Swift ATEL: ANT150901

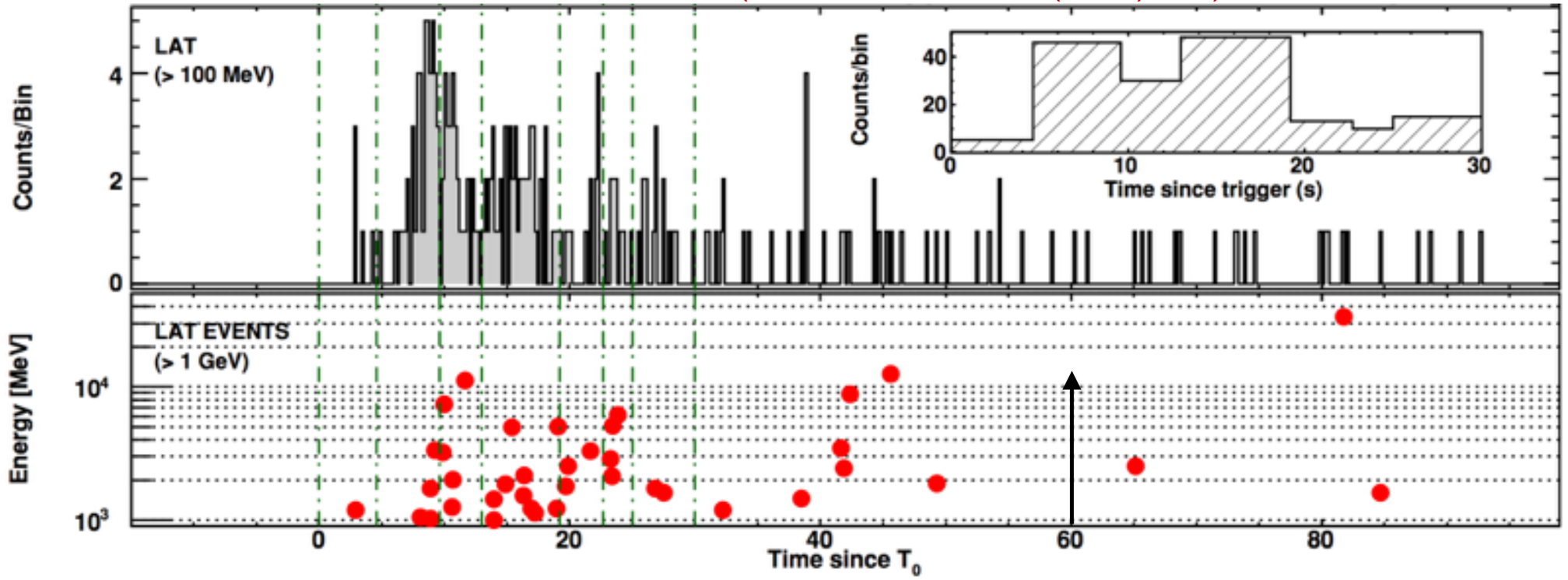
- 2015-09-01: Antares/TAToO alert to optical telescopes and Swift
- 2015-09-03: Swift detection of unknown, bright, variable X-ray source (ATEL 7987)
- 2015-09-03: H.E.S.S. follow-up
  - 1.5h of observations
  - $\Phi(E>320\text{GeV}, 99\%\text{CL}) < 2.4 \times 10^{-7}\ \text{m}^{-2}\ \text{s}^{-1}$



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 090902B (Abdo et al. APJ 706 (2009) 138)



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

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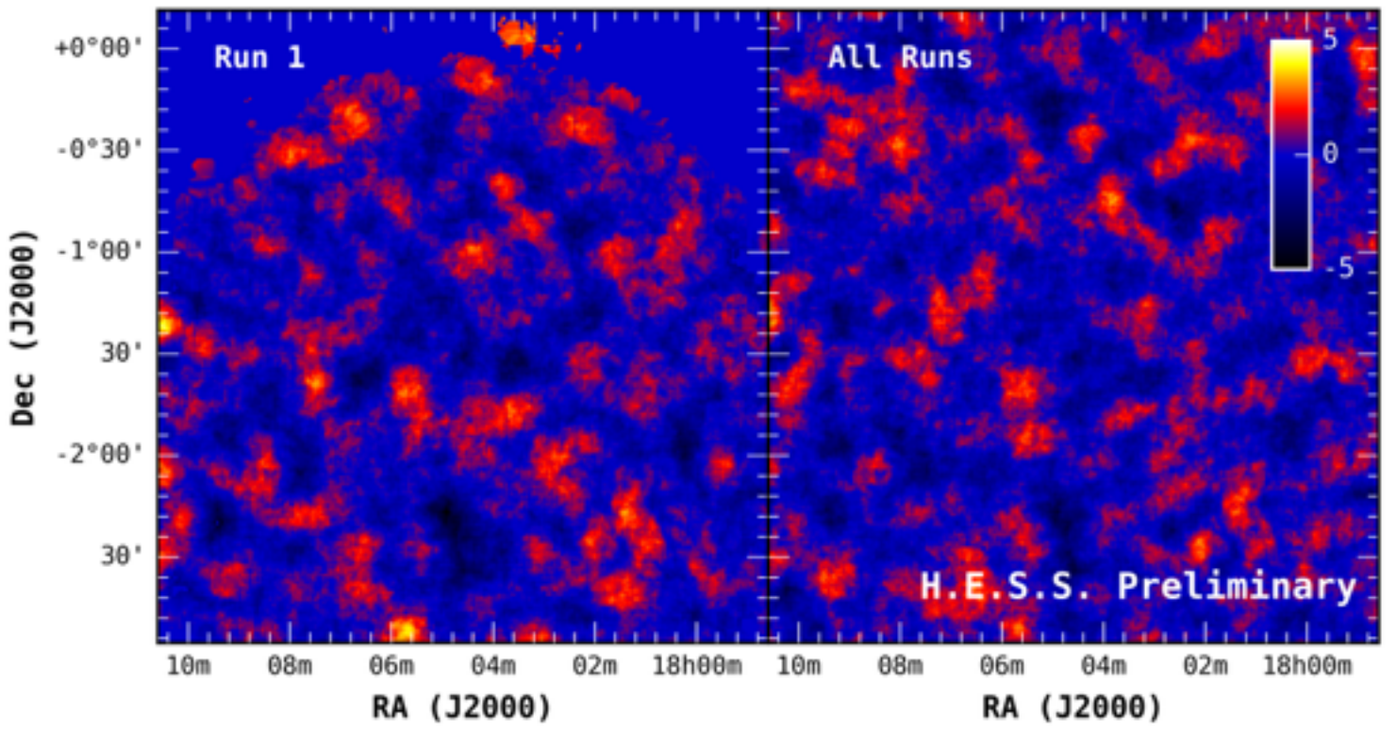

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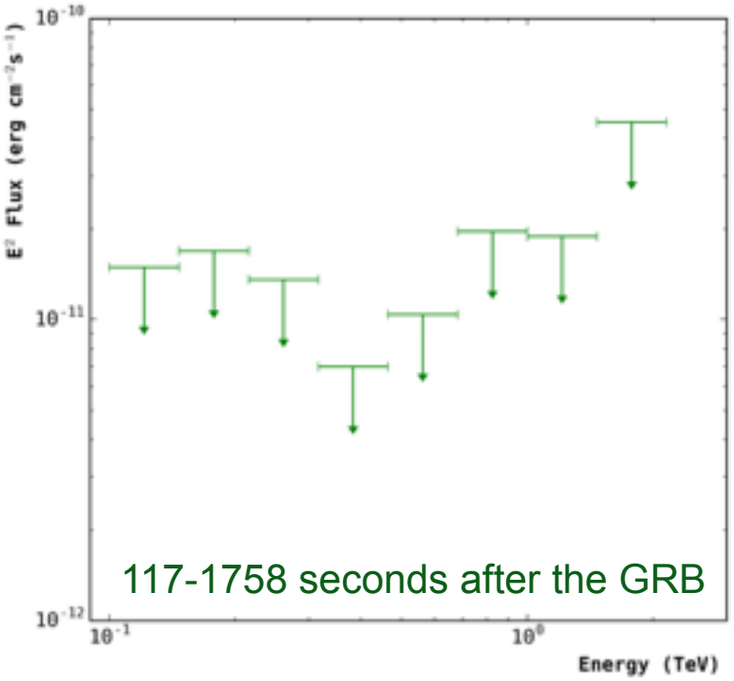
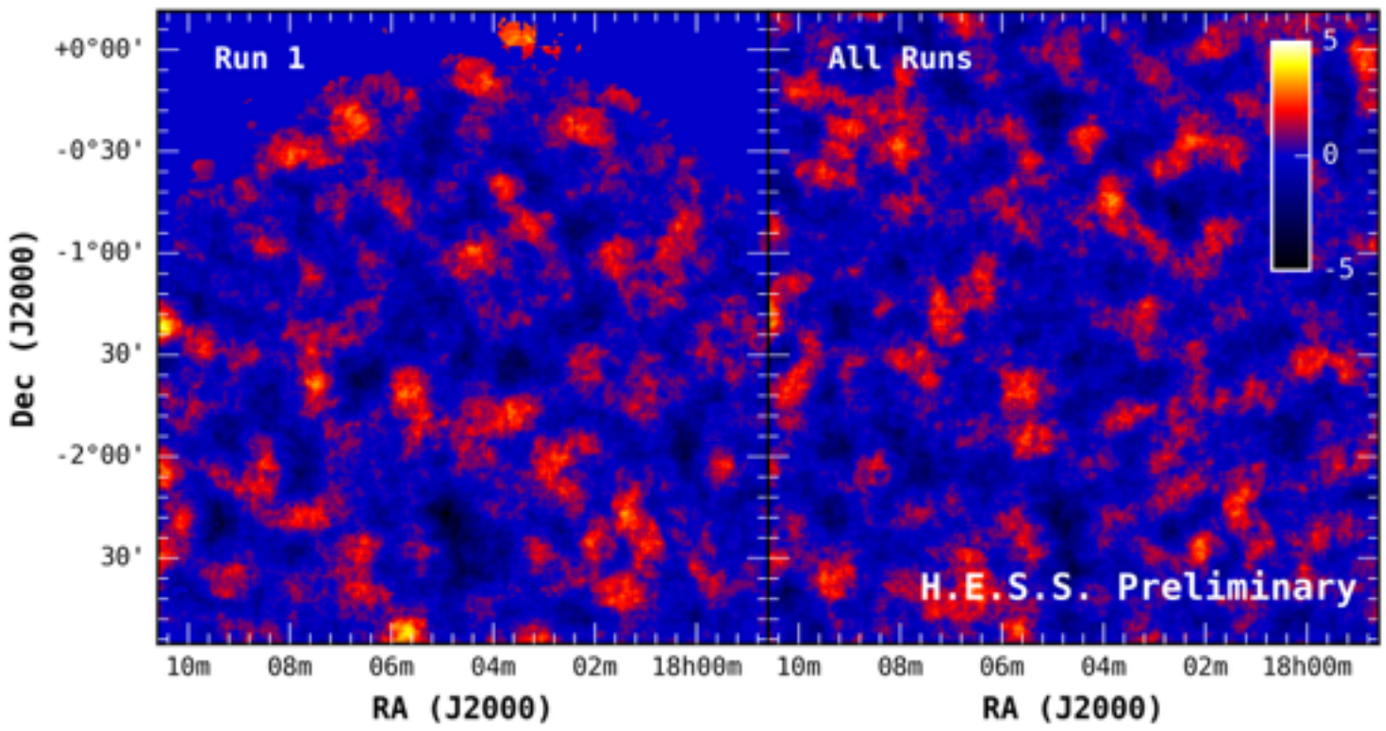


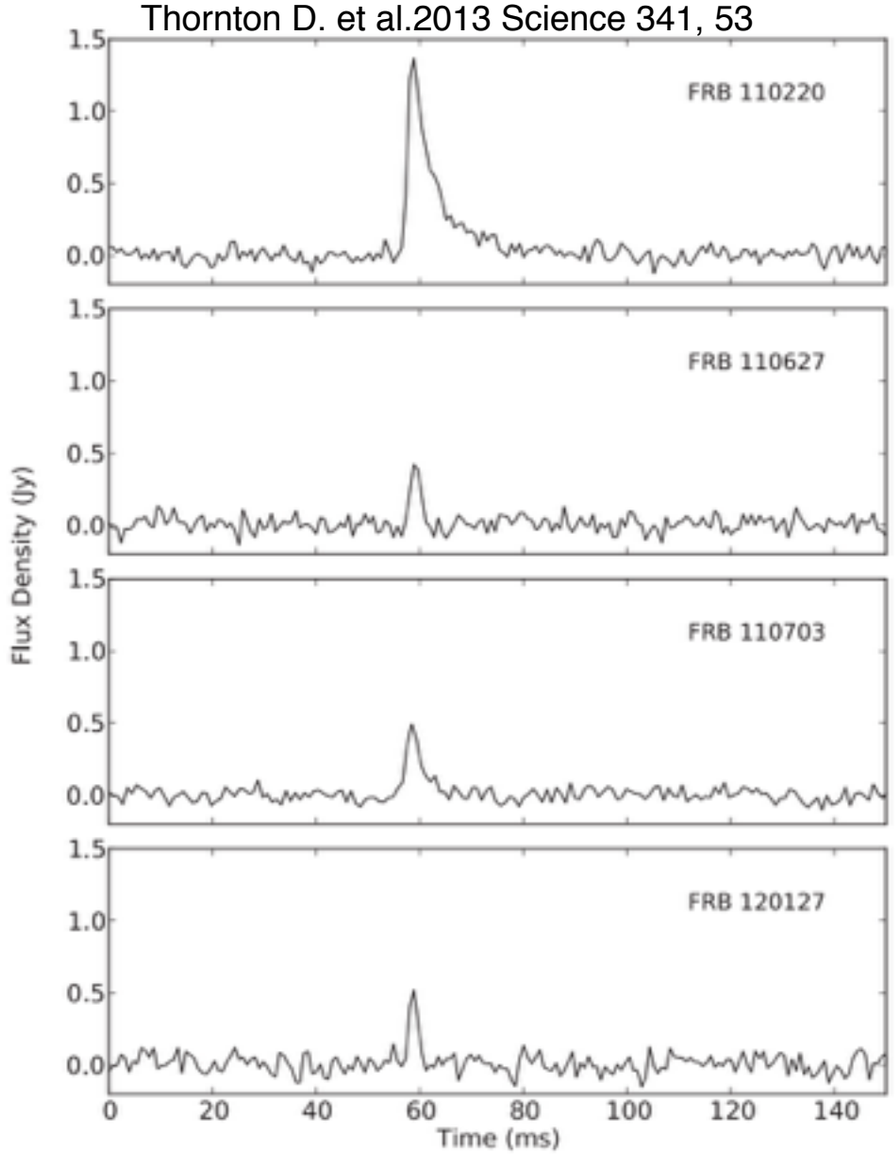


Run	Time since T0 [min]	Integral Flux (E>100GeV) [m^{-2} s^{-1}]
1	2-30	3.9e-11
2	31-59	2.6e-11
3	60-88	5.1e-11
4	89-117	1.8e-11

Fast Radio Bursts

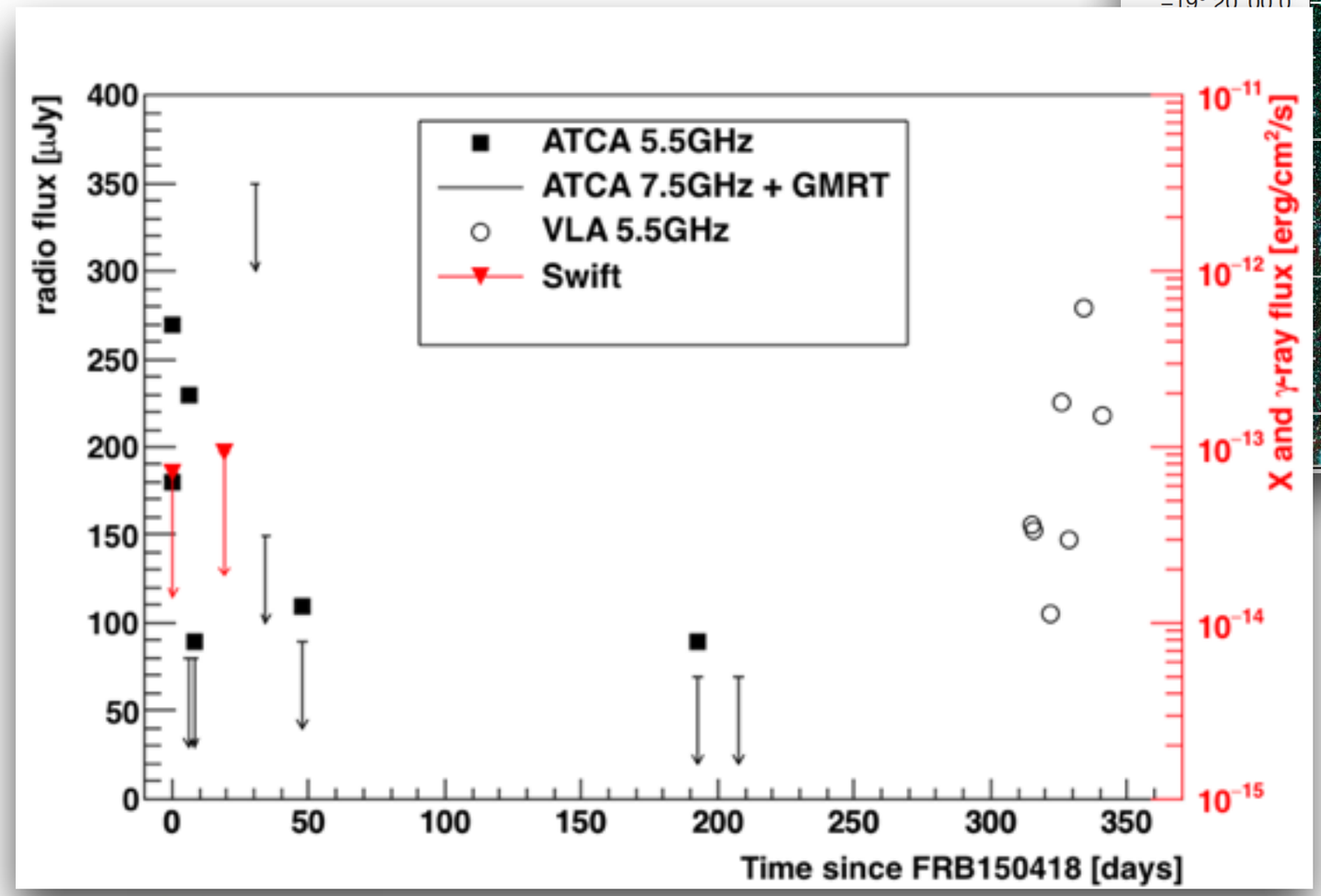
- strong, millisecond radio burst of possibly extragalactic origin
- H.E.S.S. takes part in the SUPERB project @ Parkes
  - online searches for FRBs and other radio transients

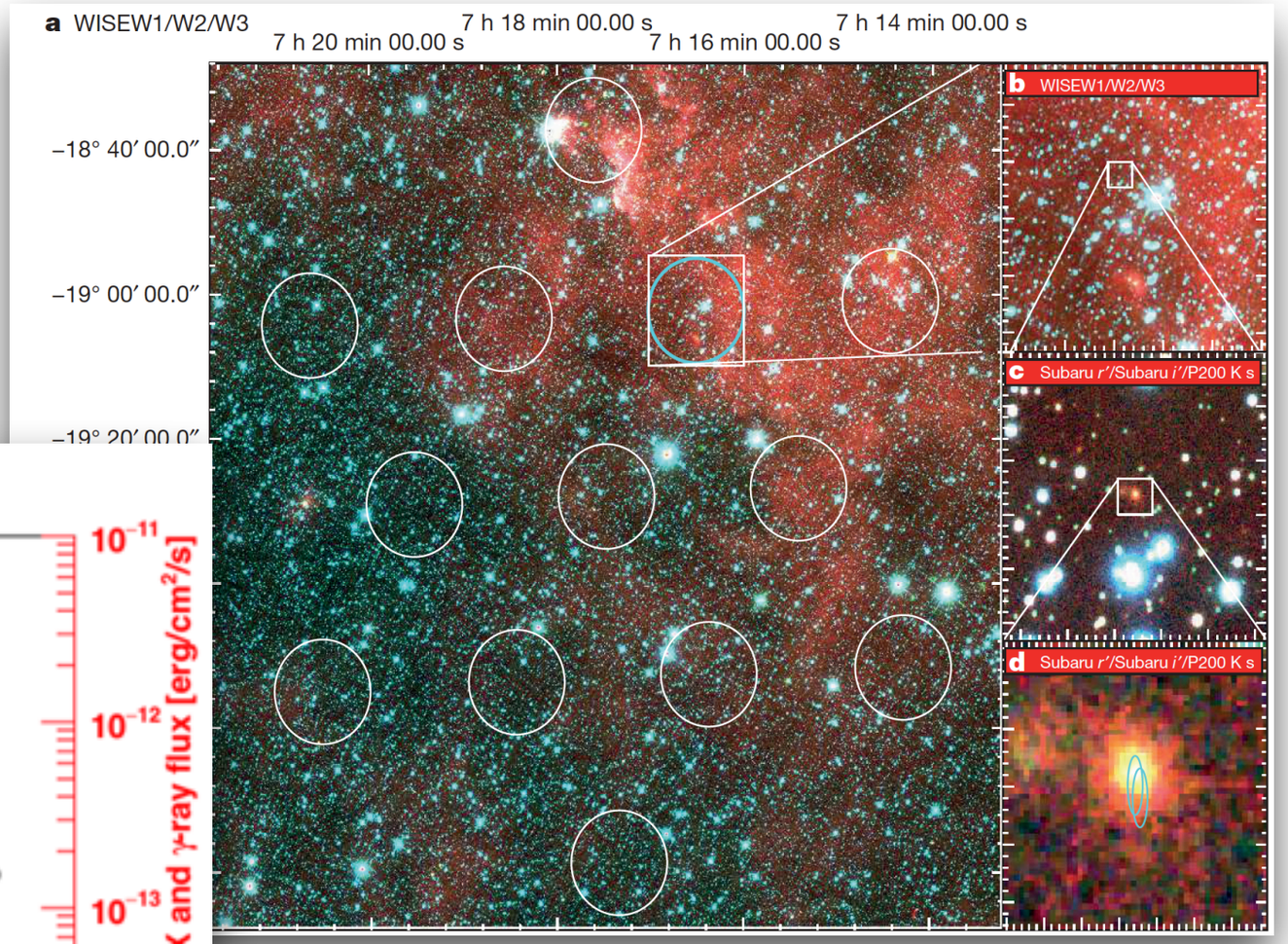
Thornton D. et al.2013 Science 341, 53



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

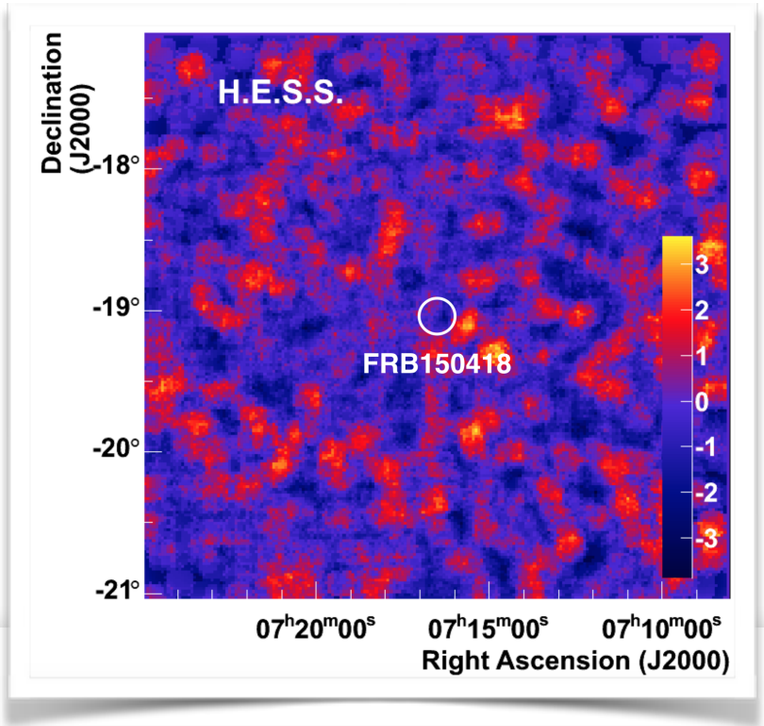


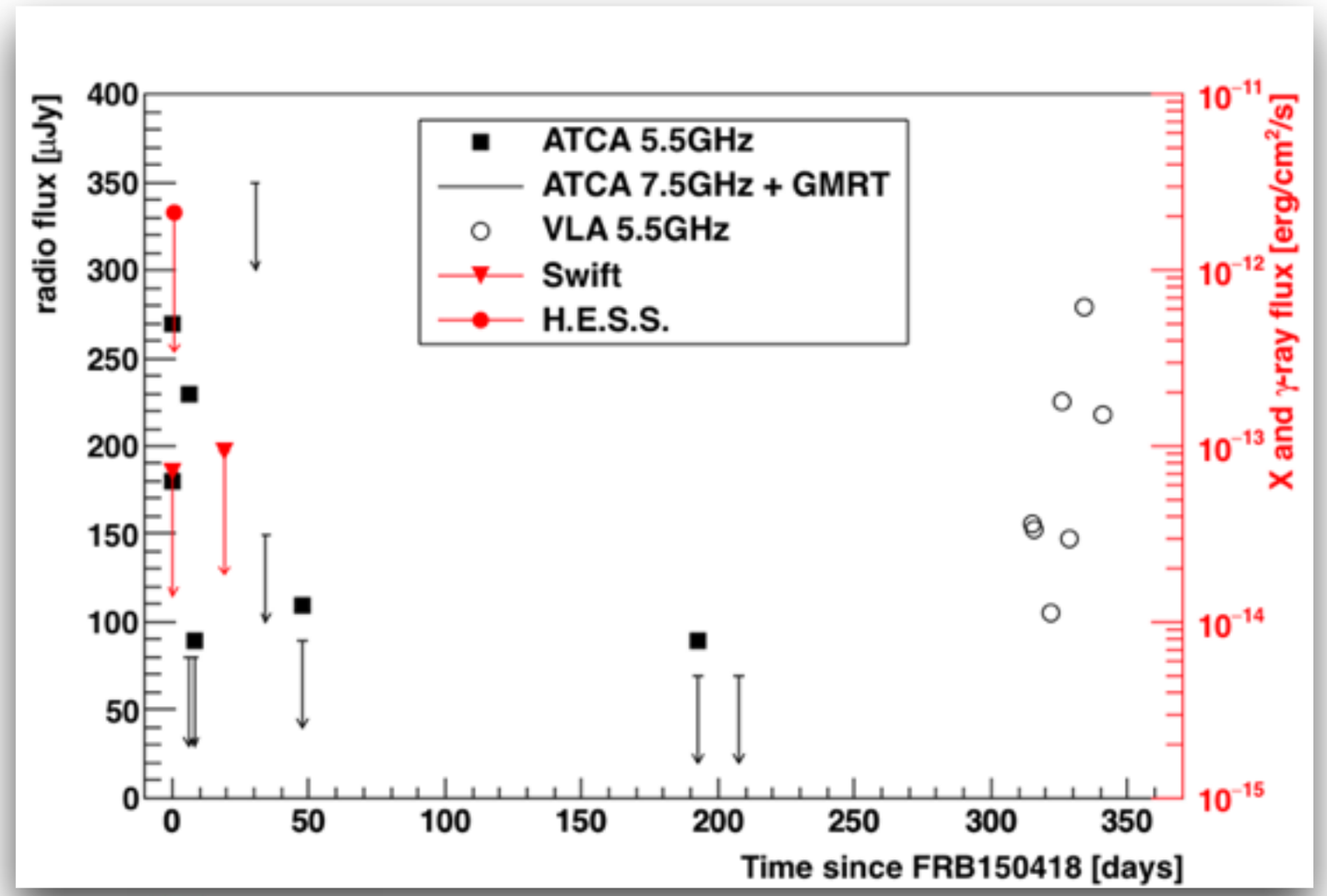


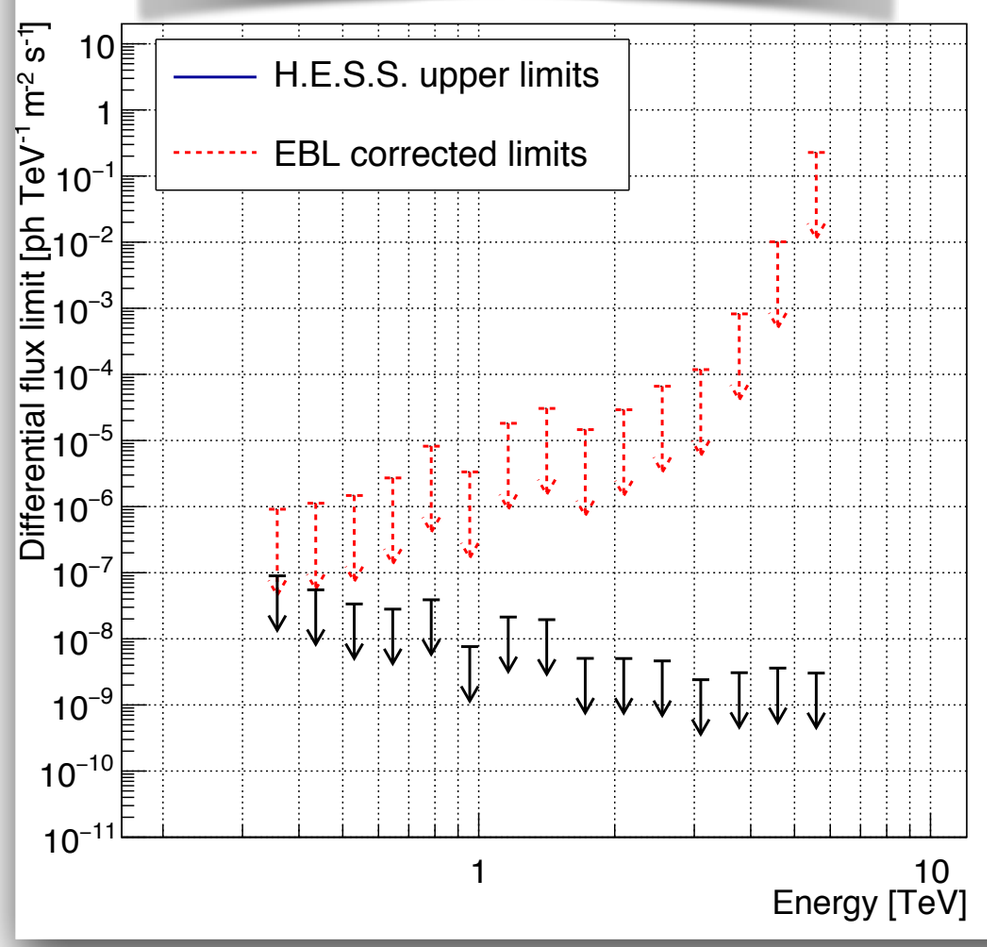
E. Keane et al., Nature 530 (2016)

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
  - $\Phi(E>350GeV) < 1.3 \times 10^{-8}$ m^{-1} s^{-1} (E^{-2}, 99% C.L.)

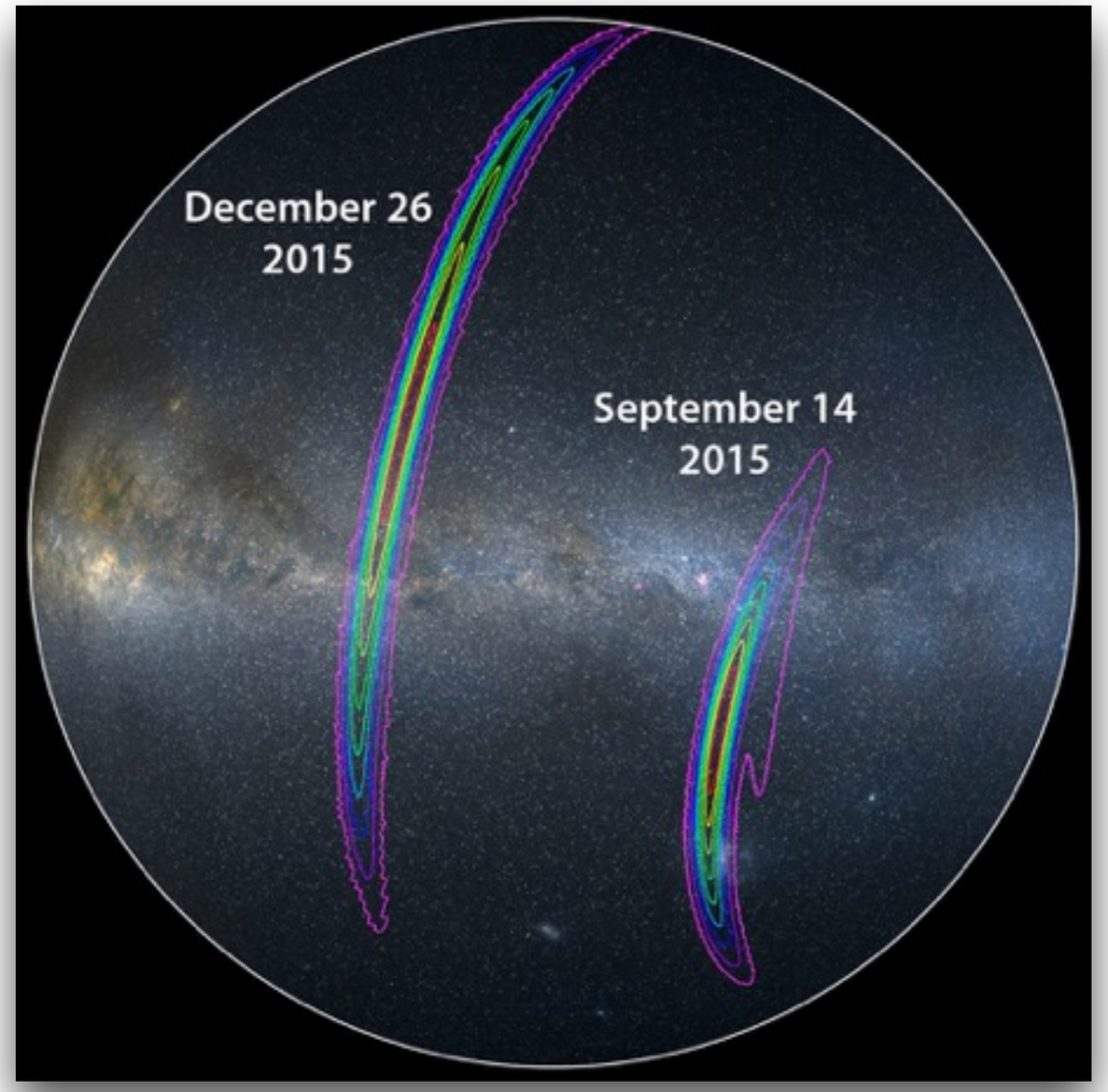






Gravitational Waves

- Second physics run of Advanced LIGO/Virgo starting soon
- Ligo only: localization typically poor O(100 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
    - ToO programs starting
- Follow-up of alerts and ToOs
  - GRBs
    - improved performance: reduced response time
    - highest priority observations
  - Fast Radio Bursts
  - Gravitational Waves