Recent results from H.E.S.S.

and some personal considerations for a next generation large FoV instrument

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cea

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Puebla, November 2016

H.E.S.S.

Overview

- The H.E.S.S. instrument
  - H.E.S.S.-II
- Recent highlights
  - HGPS
  - Galactic Center
  - RXJ1713
- Multi-Messenger program
  - Neutrinos + Gravitational Waves
  - ToO/alert follow-up
    - ToO follow-up performance
    - GRBs / FRBs

The H.E.S.S. experiment

H.E.S.S. phase I

- four 12m telescopes
- FoV 5deg
- energy threshold ~100GeV
- angular resolution <0.1deg

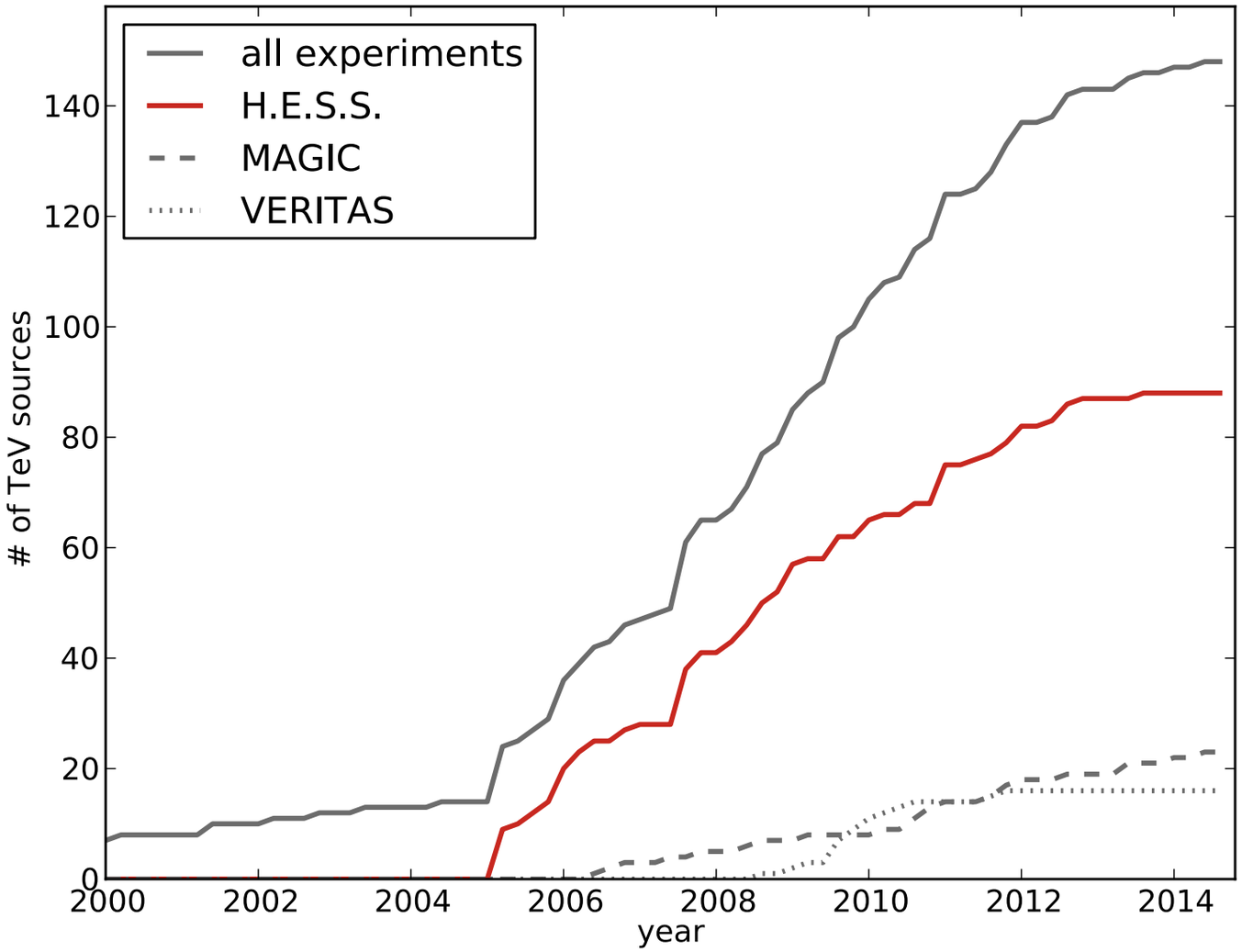
H.E.S.S. phase II

- four 12m telescopes
- one 28m telescope (FoV 3.5deg)
- energy threshold ~30GeV
- angular resolution from 0.4 to less than 0.1deg

2012

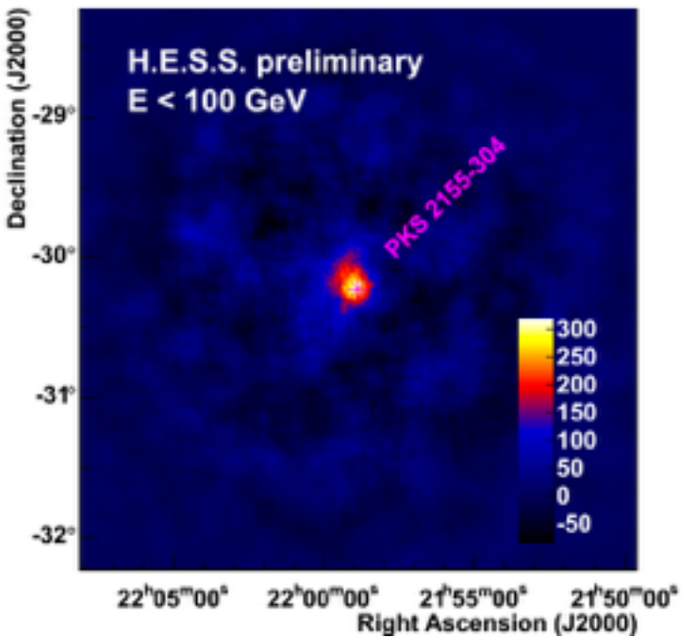
H.E.S.S. phase I → H.E.S.S. phase II

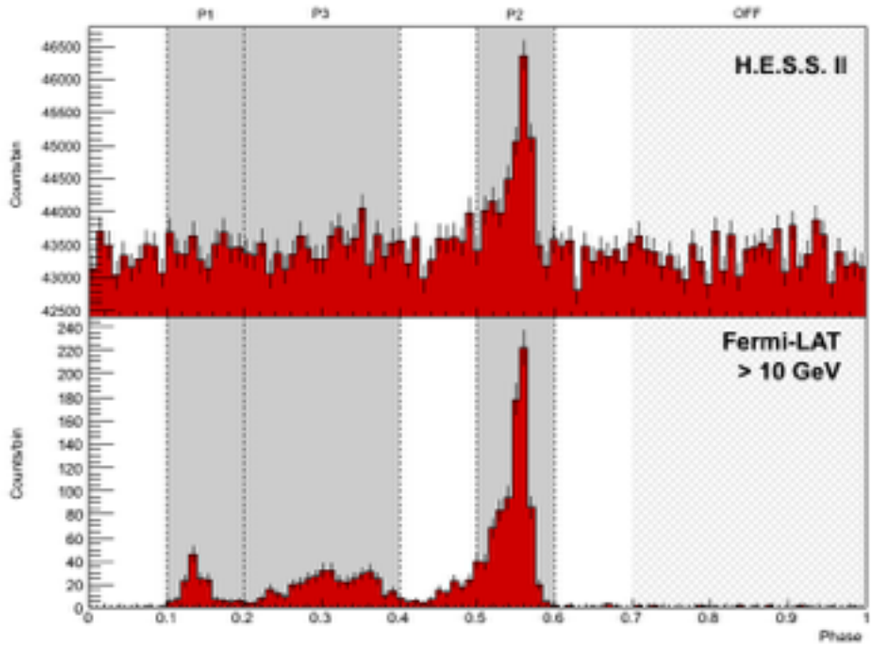
Status of TeV gamma-ray astronomy

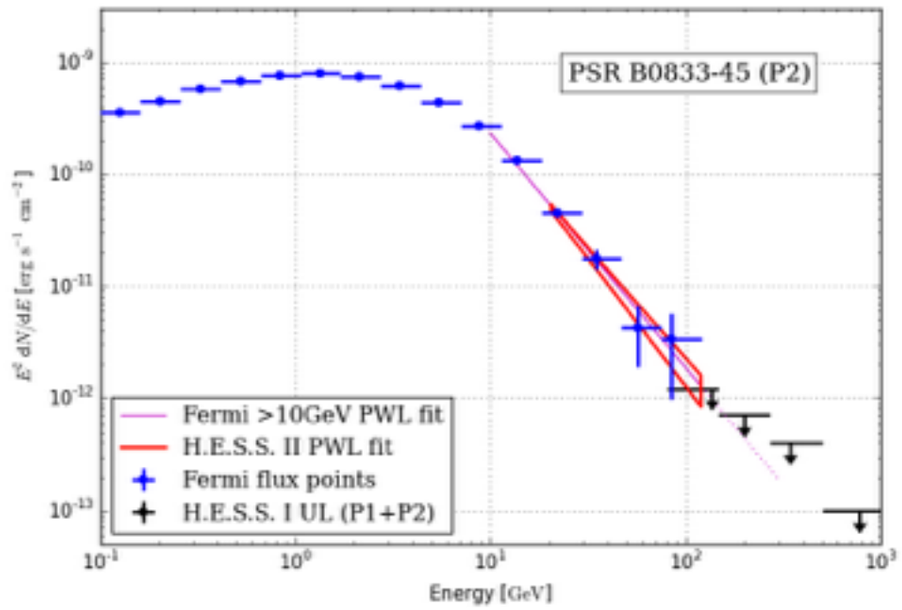


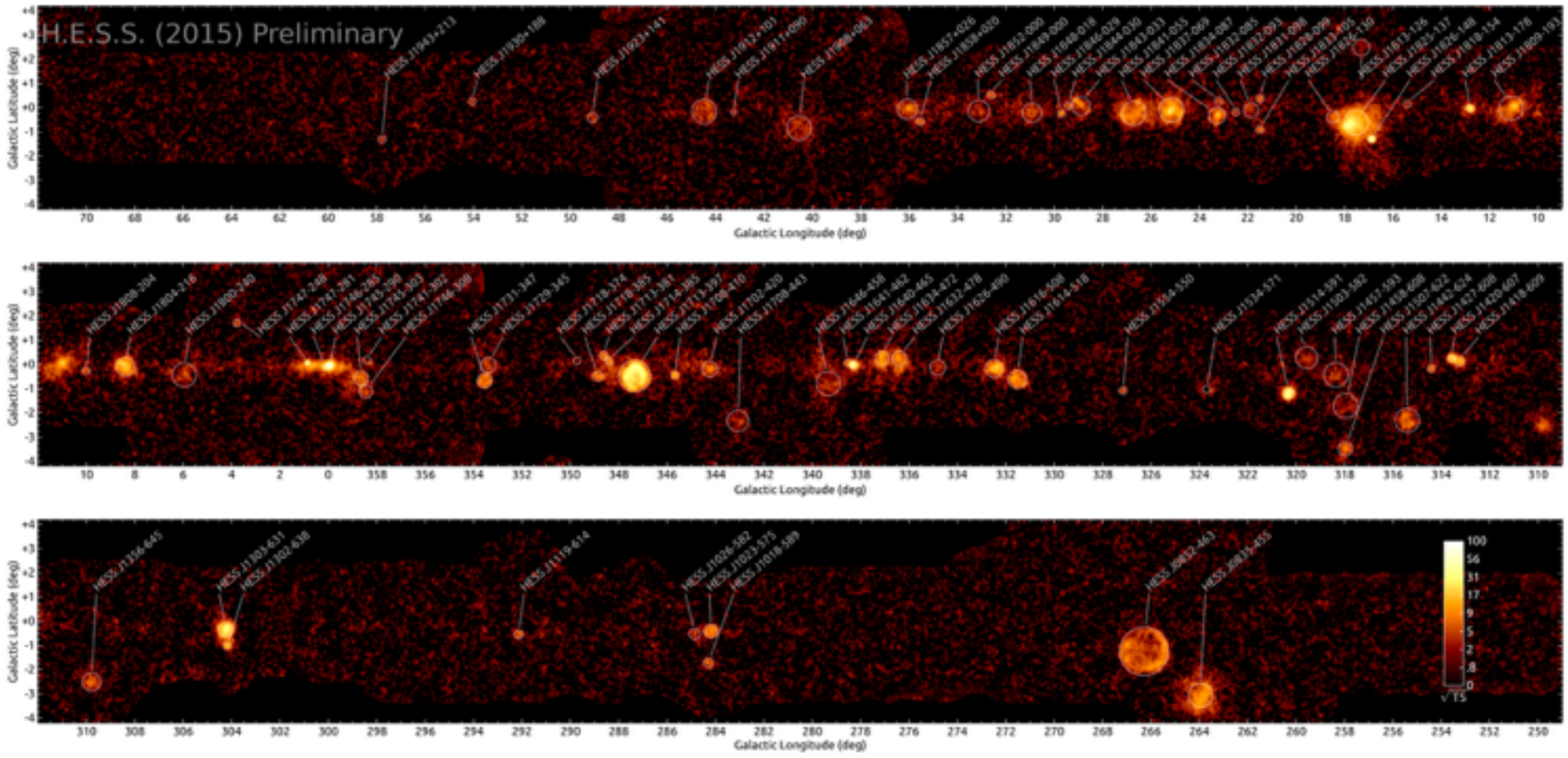
- H.E.S.S. phase I
  - more than 10.000 hours of data
  - discovered over 80 new VHE gamma ray sources
- H.E.S.S. phase II
  - lower energy threshold (e.g. overlap with Fermi-LAT)
  - rapid response to transients

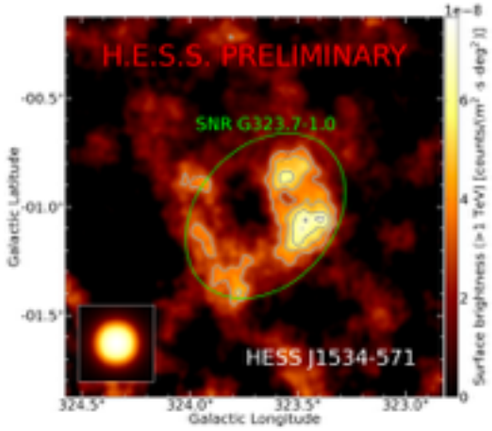
Recent results

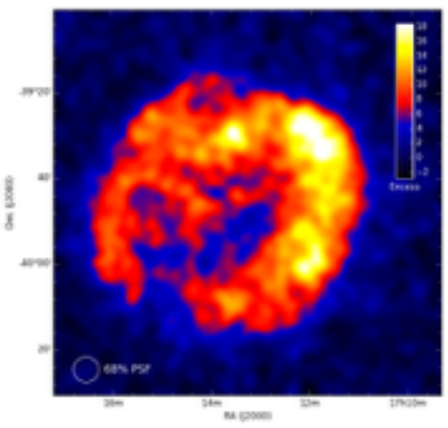




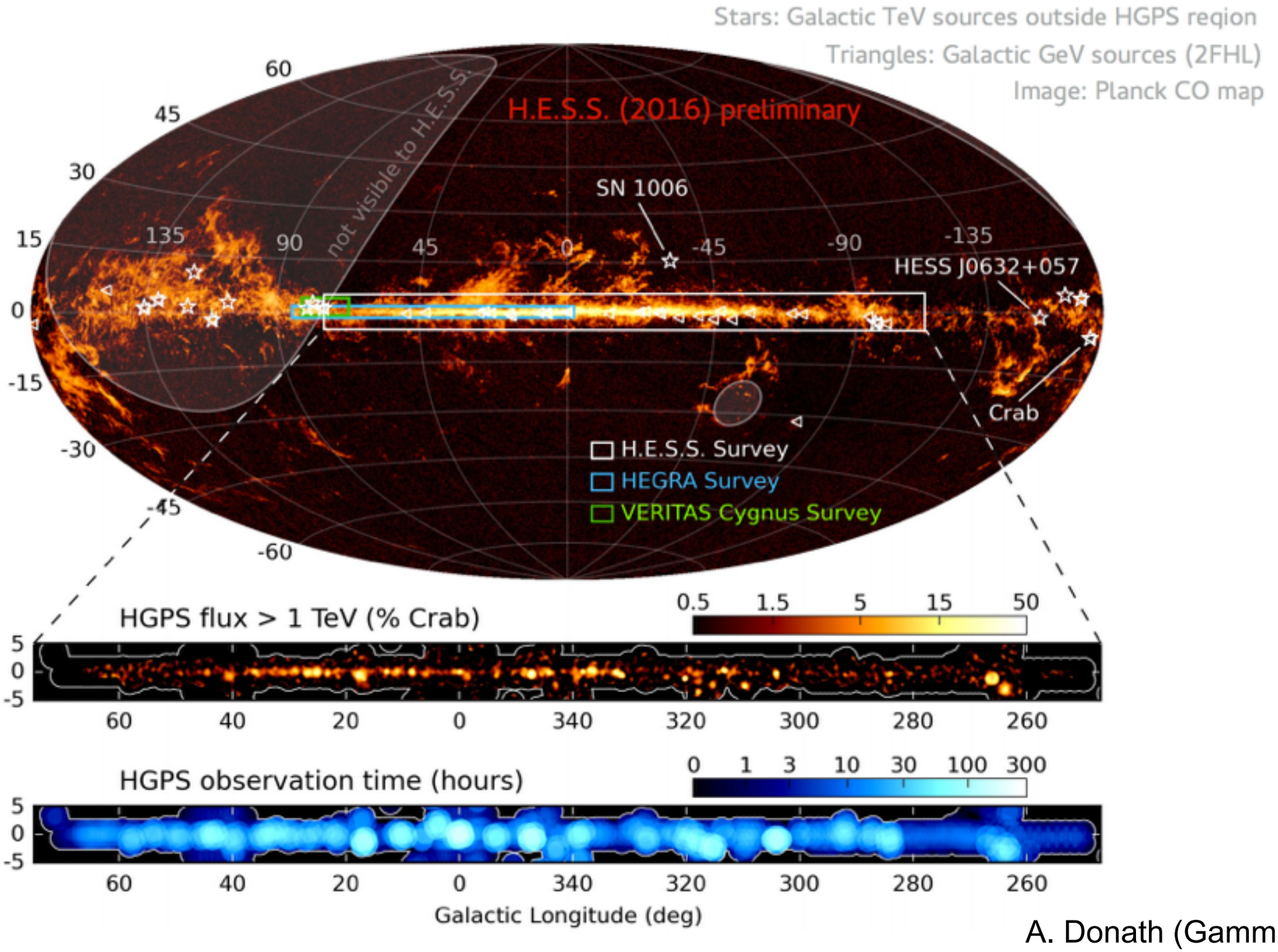








The H.E.S.S. Galactic Plane Survey



A. Donath (Gamma16)

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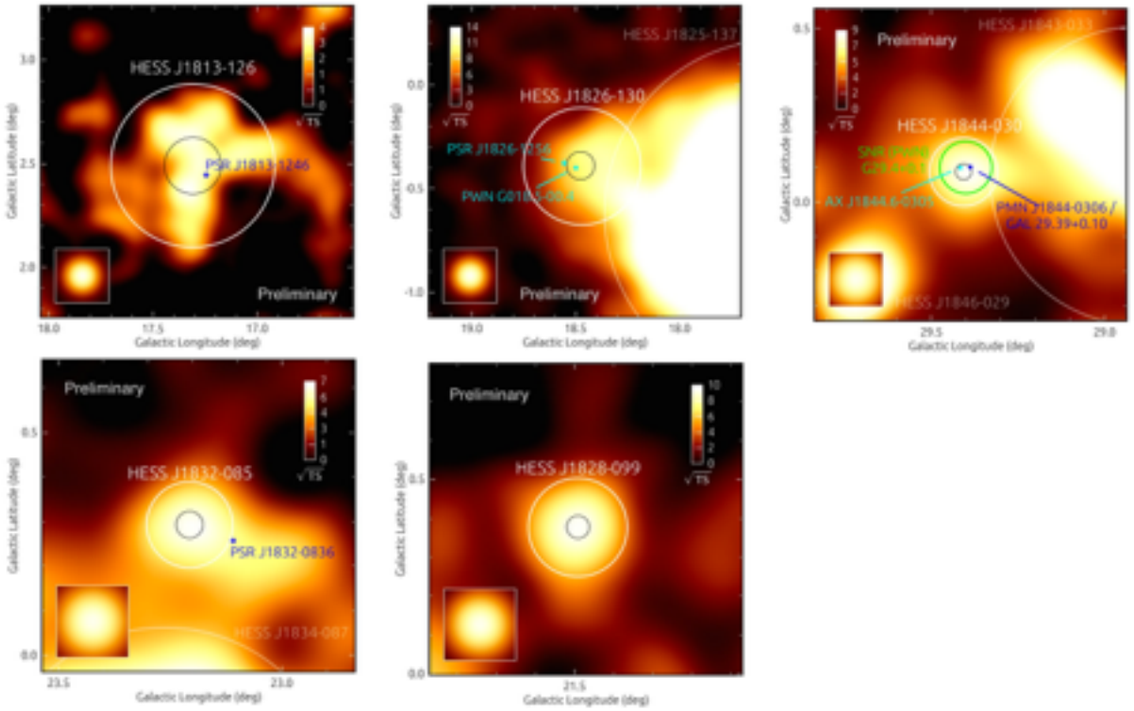

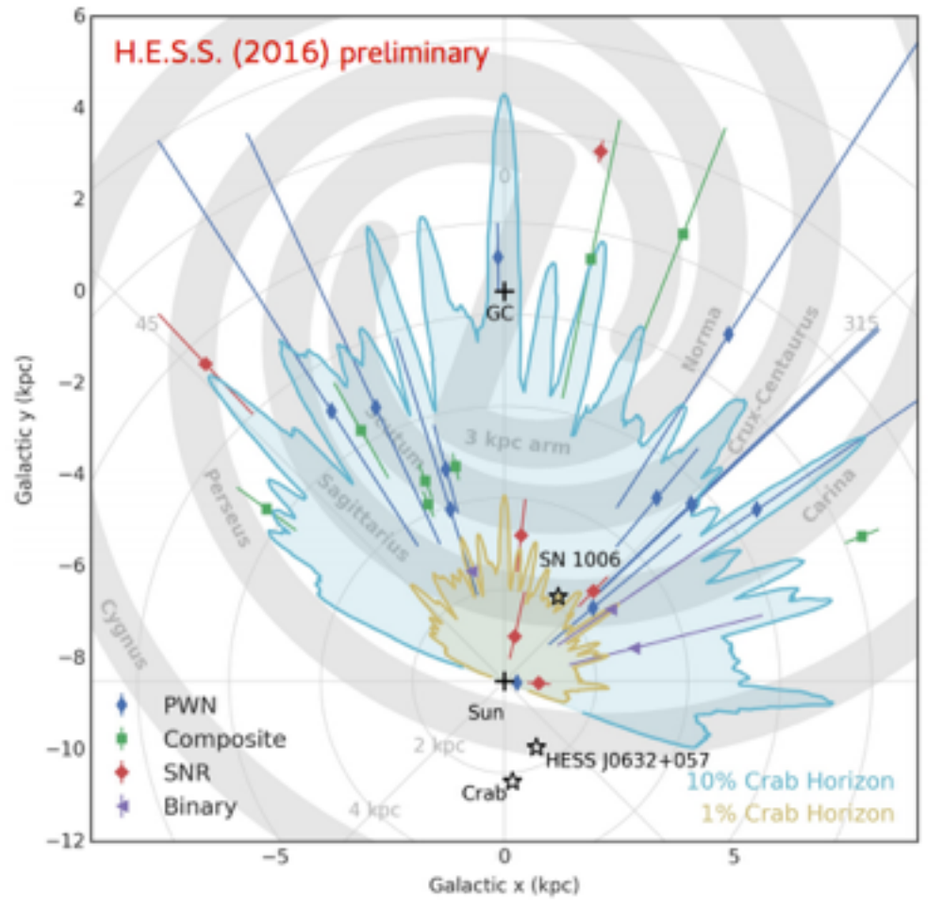

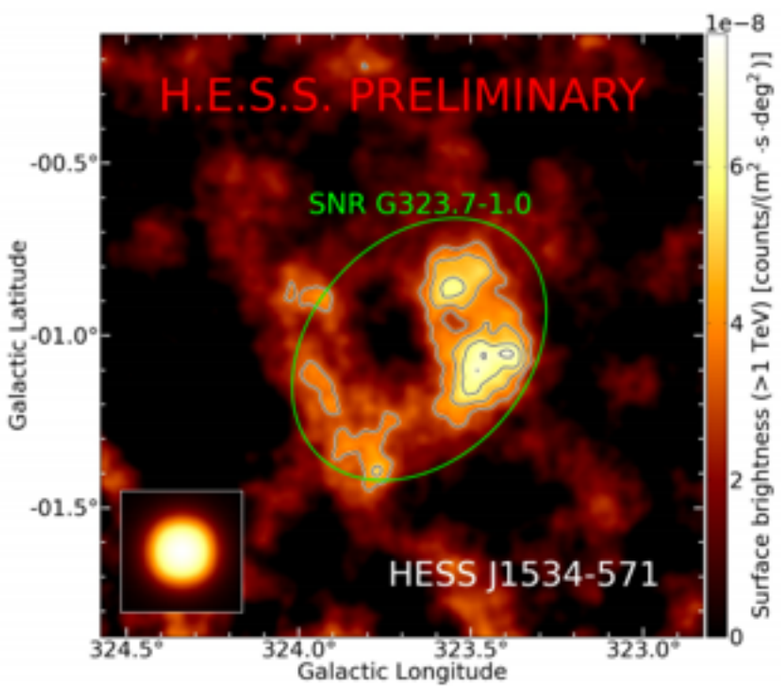

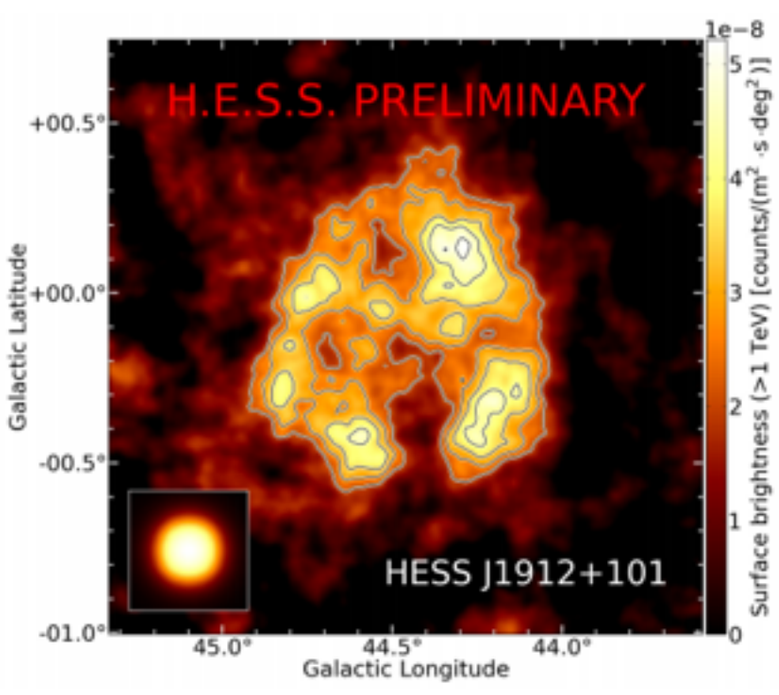

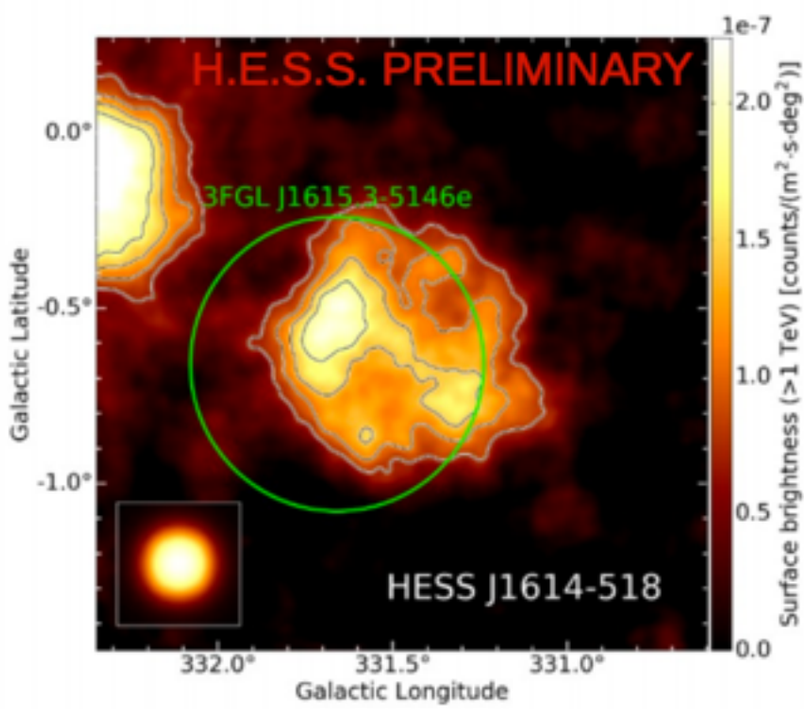

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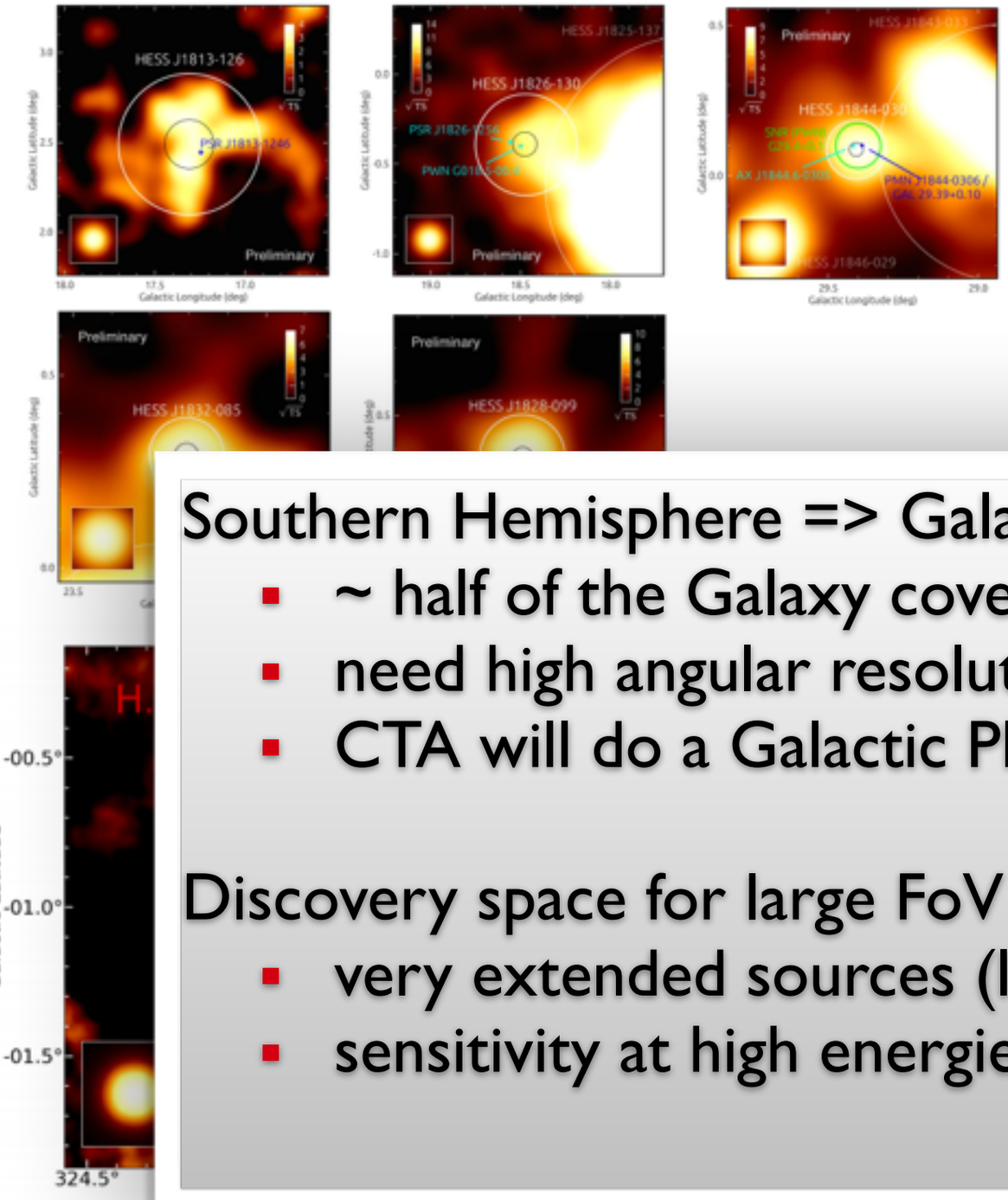
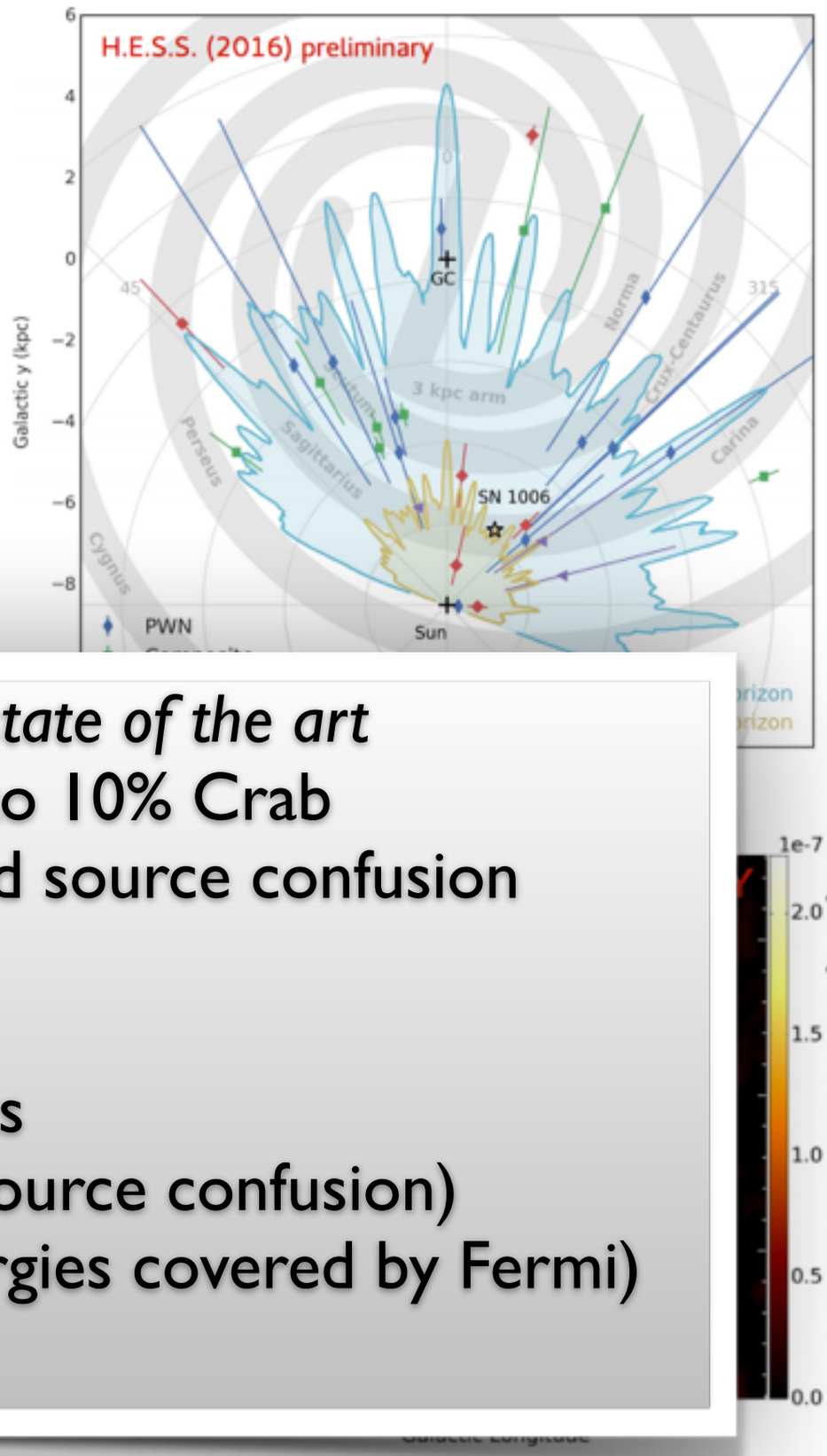




Southern Hemisphere => Galactic Plane *state of the art*

- ~ half of the Galaxy covered down to 10% Crab
- need high angular resolution to avoid source confusion
- CTA will do a Galactic Plane Scan

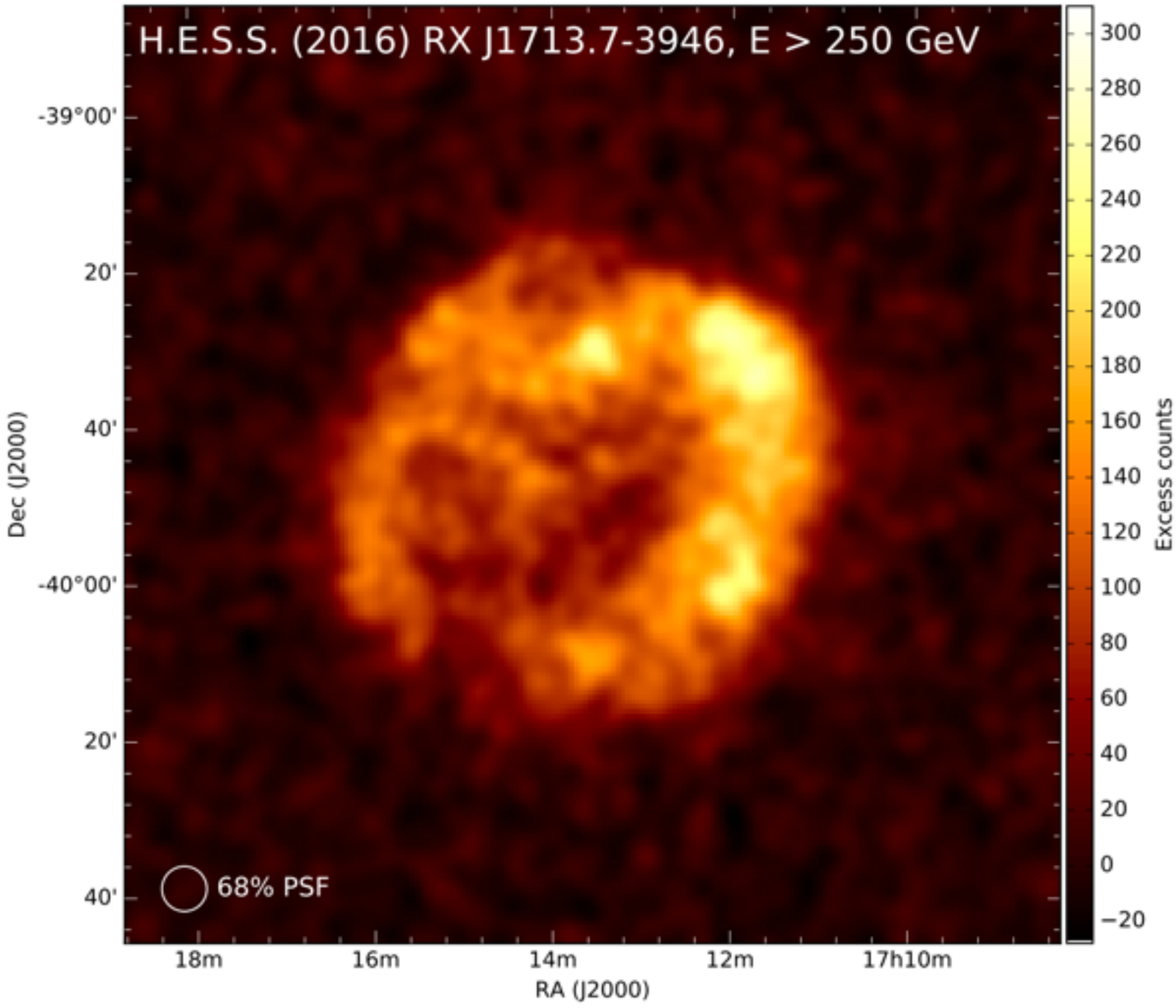
Discovery space for large FoV instruments

- very extended sources (limited by source confusion)
- sensitivity at high energies (low energies covered by Fermi)

A. Donath (Gamma16)

H.E.S.S.: RXJ1713.7

- 2004-2012
- livetime: 164h (spectrum:116h)



H. Abdalla et al. (H.E.S.S.), arXiv:1609.08671

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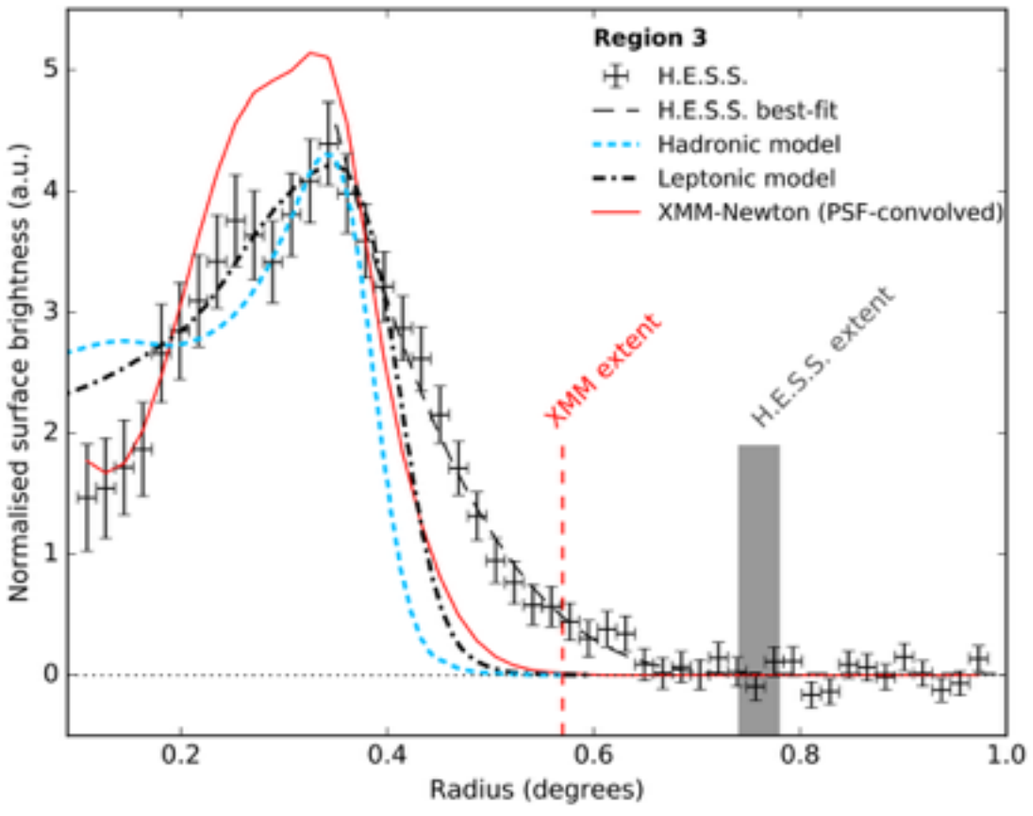

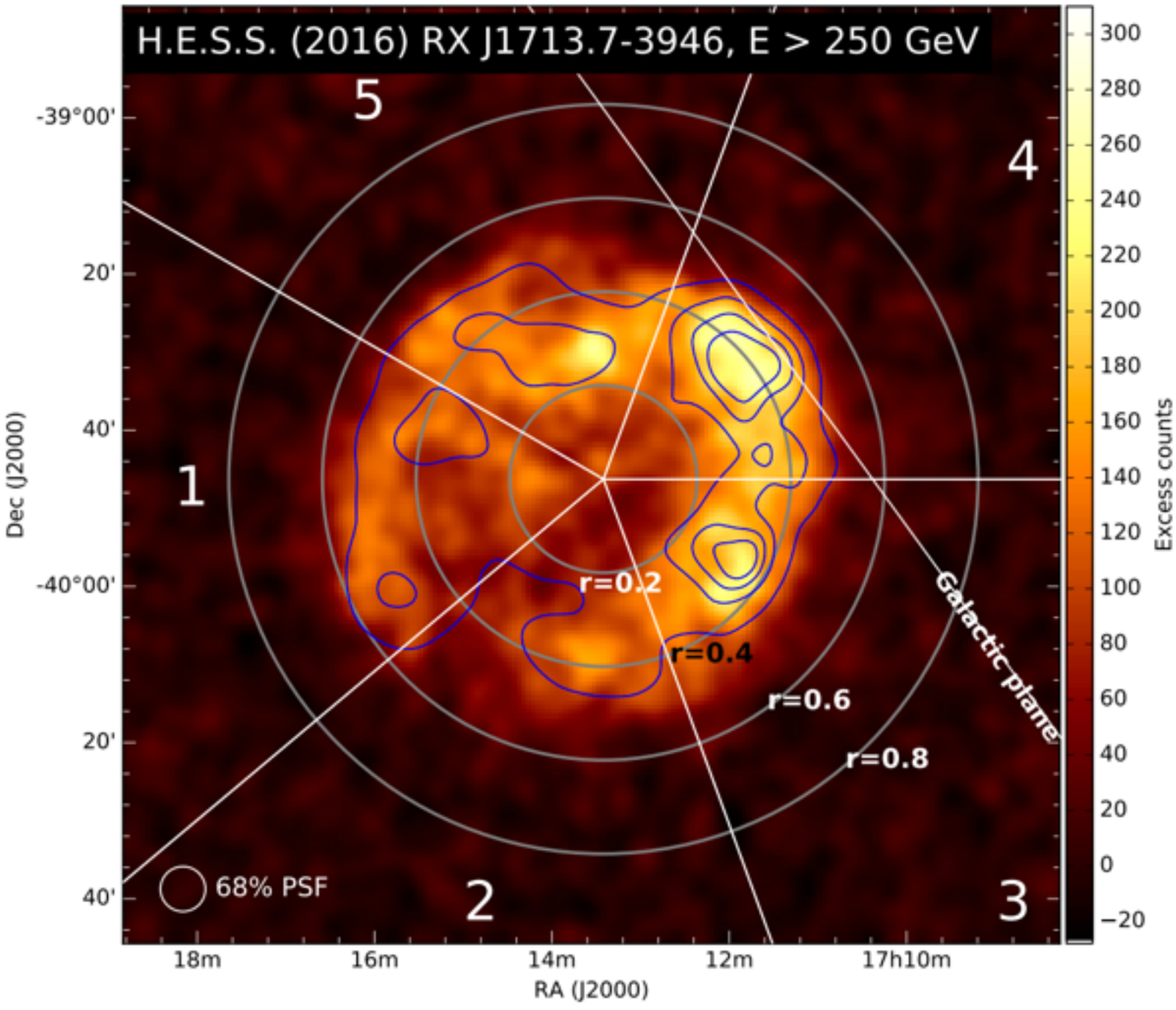

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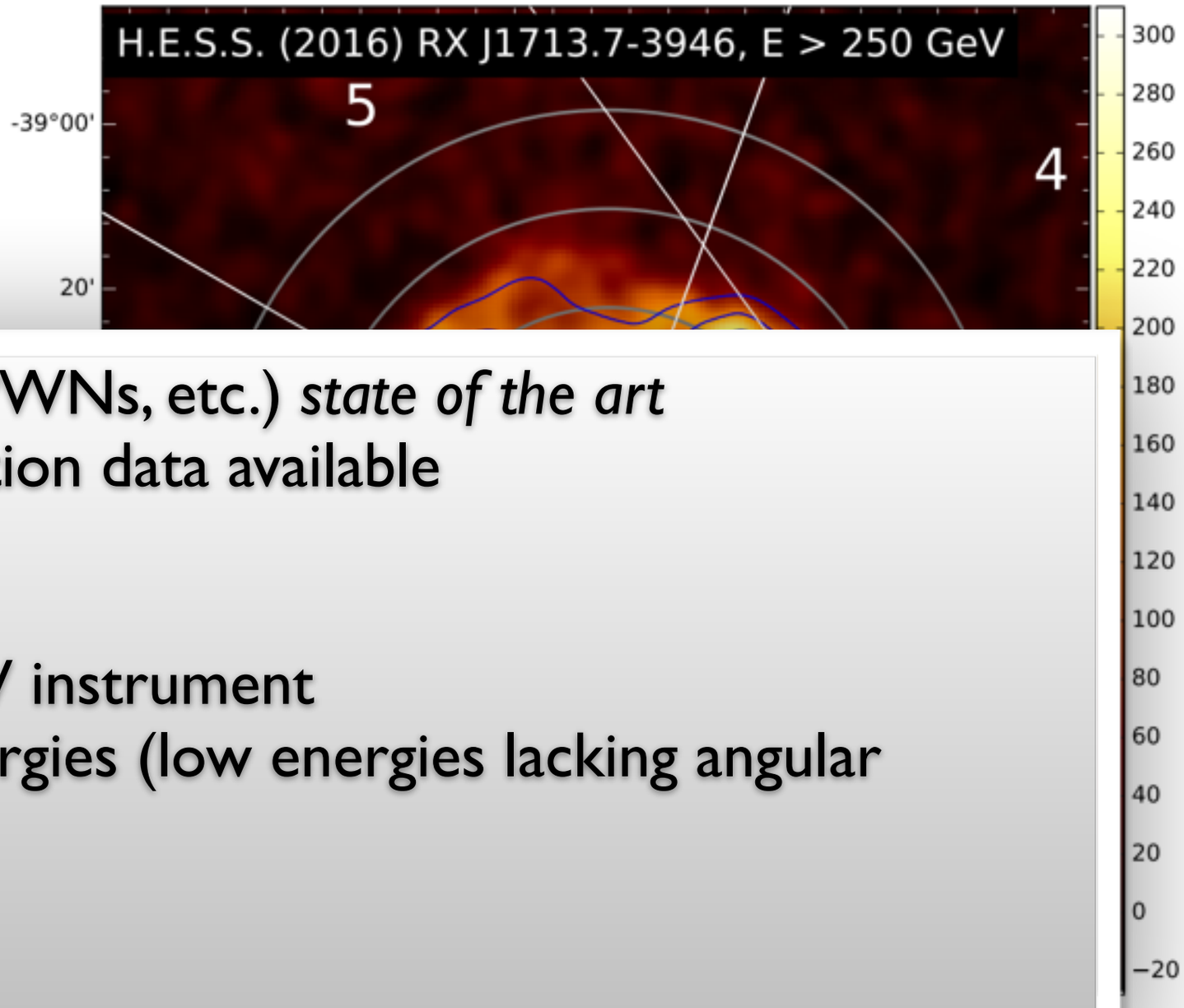
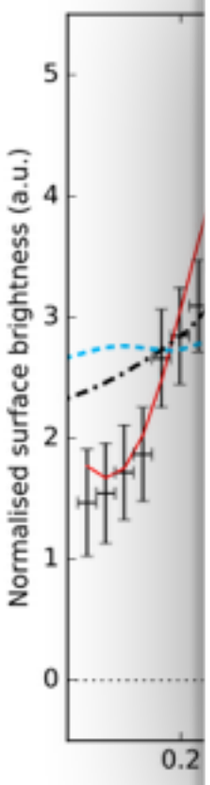




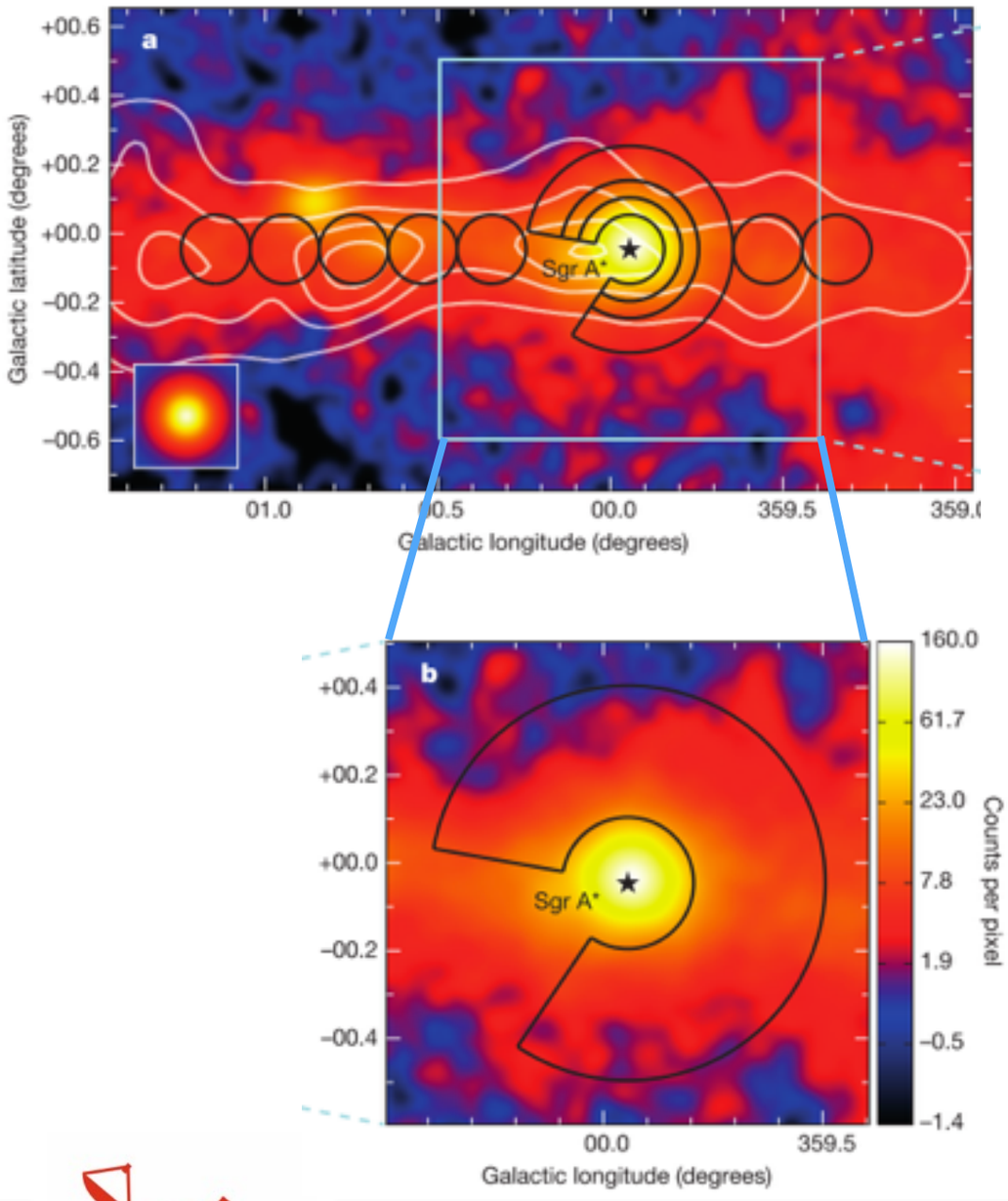
Individual sources (SNRs, PWNs, etc.) *state of the art*
- deep and high resolution data available
- CTA

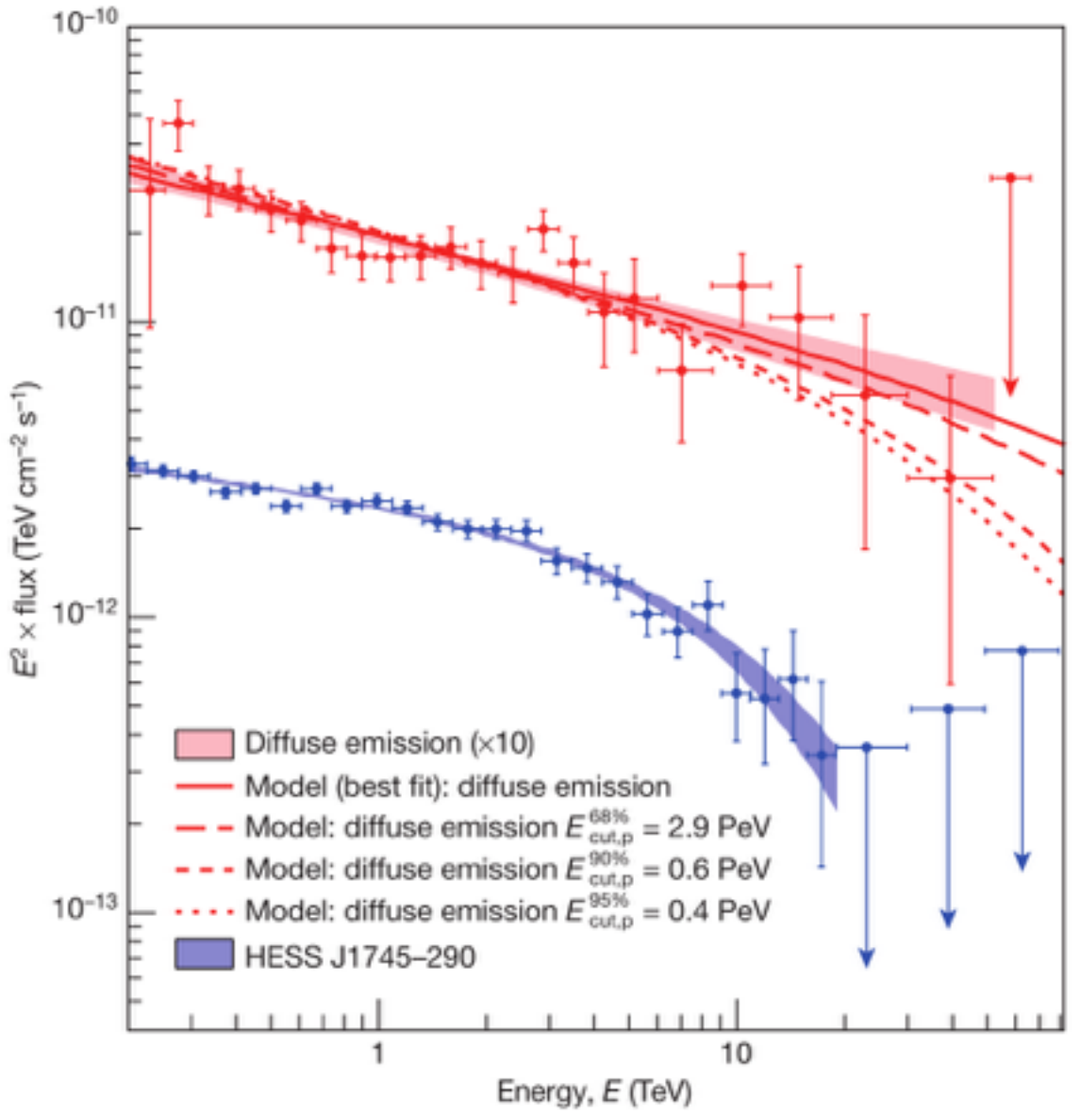
Physics case for a large FoV instrument
- sensitivity at high energies (low energies lacking angular resolution)

H. Abdalla et al. (H.E.S.S.), arXiv:1609.08671

The Pevatron at the Galactic Center

- 10 years of H.E.S.S. observations
- central source + extended diffuse emission without energy cutoff





H.E.S.S., Nature (2016)

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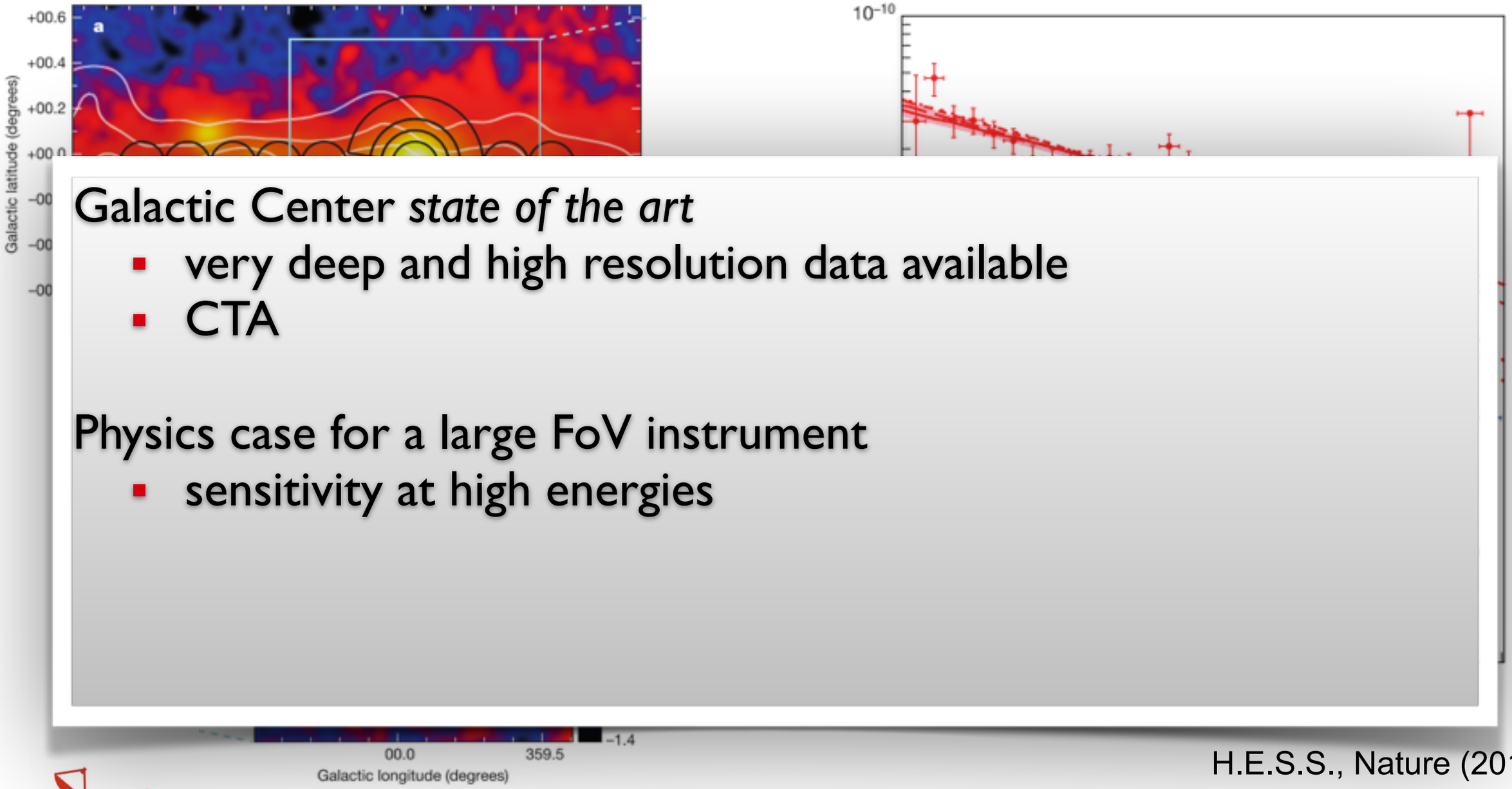


Galactic Center *state of the art*

- very deep and high resolution data available
- CTA

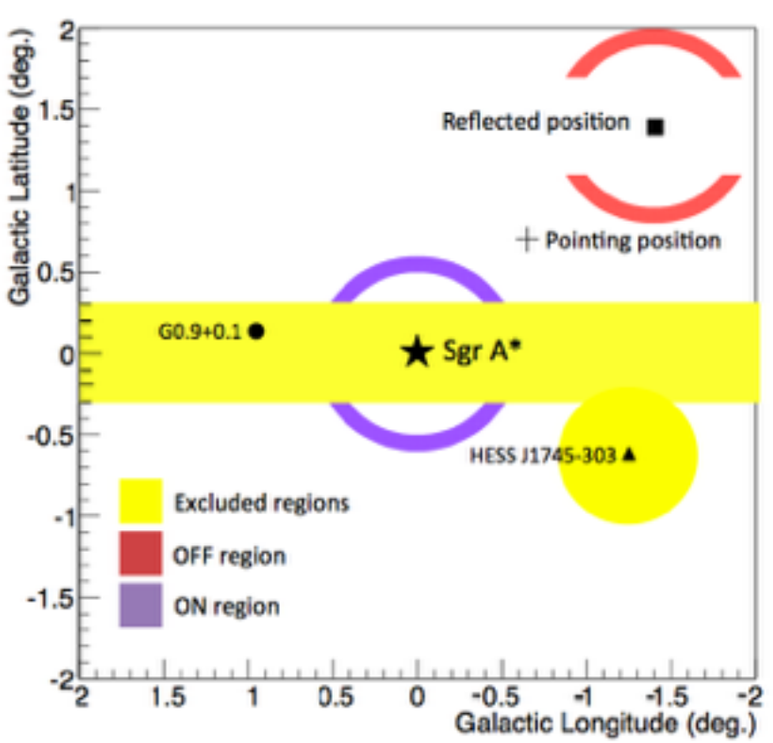
Physics case for a large FoV instrument

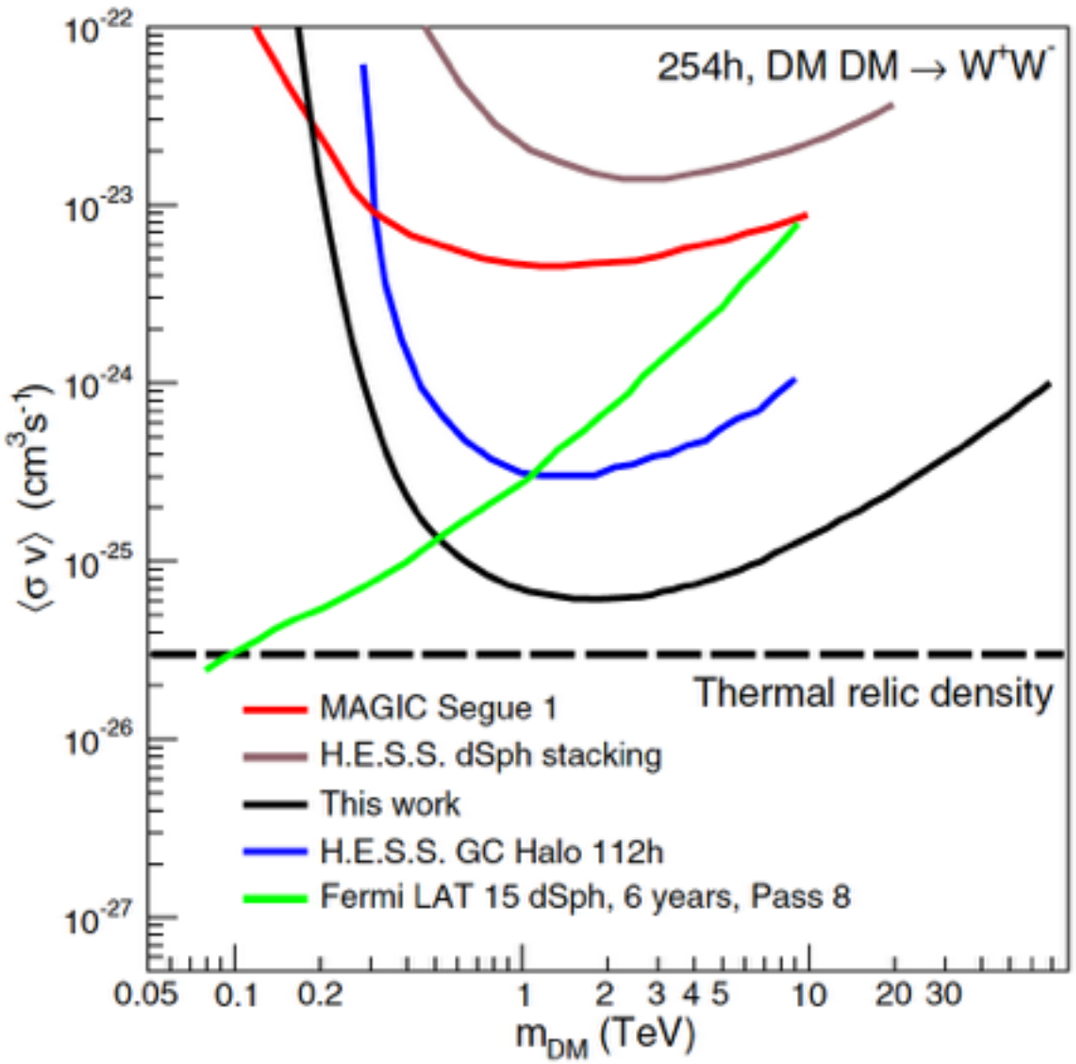
- sensitivity at high energies

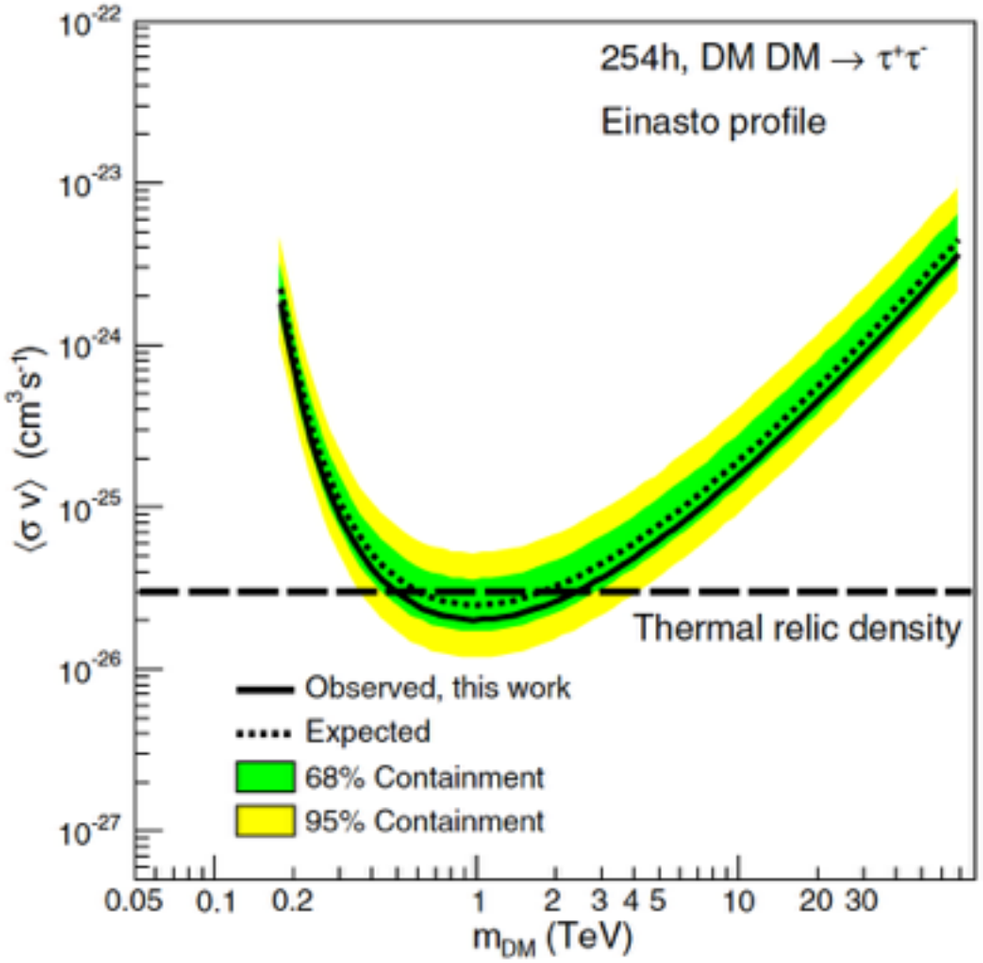
H.E.S.S., Nature (2016)

Dark matter at the Galactic Center

- 10 years of H.E.S.S. observations
- exclude central source(s)
- 2D-likelihood (spatial + energy)



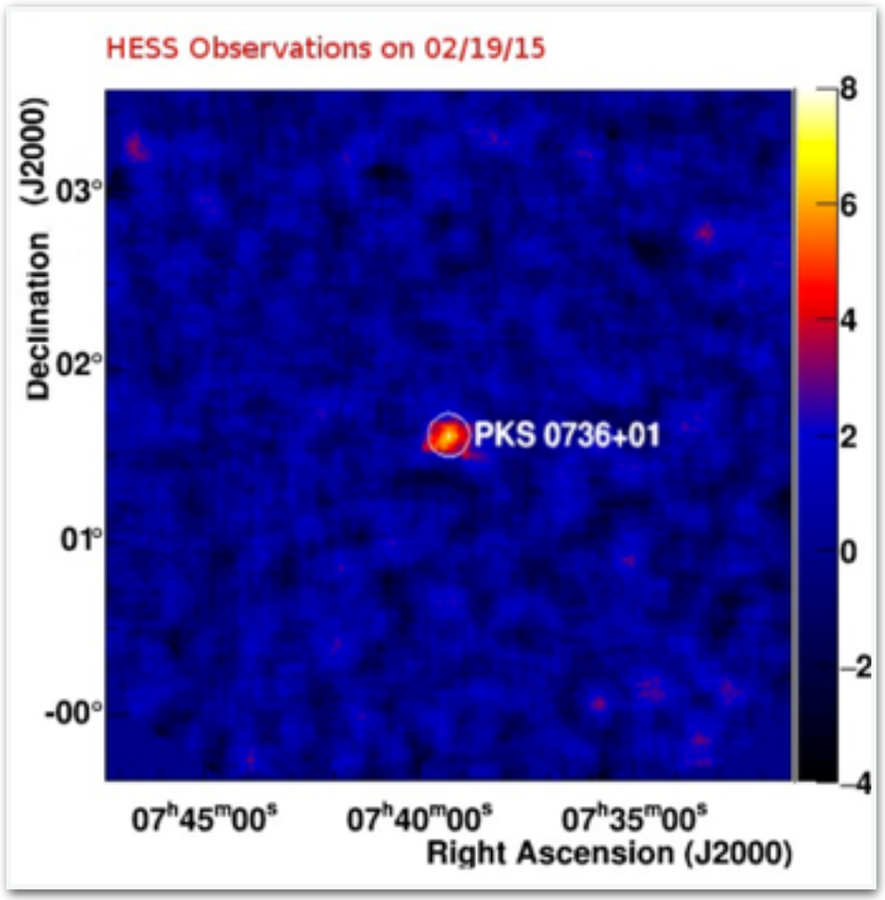


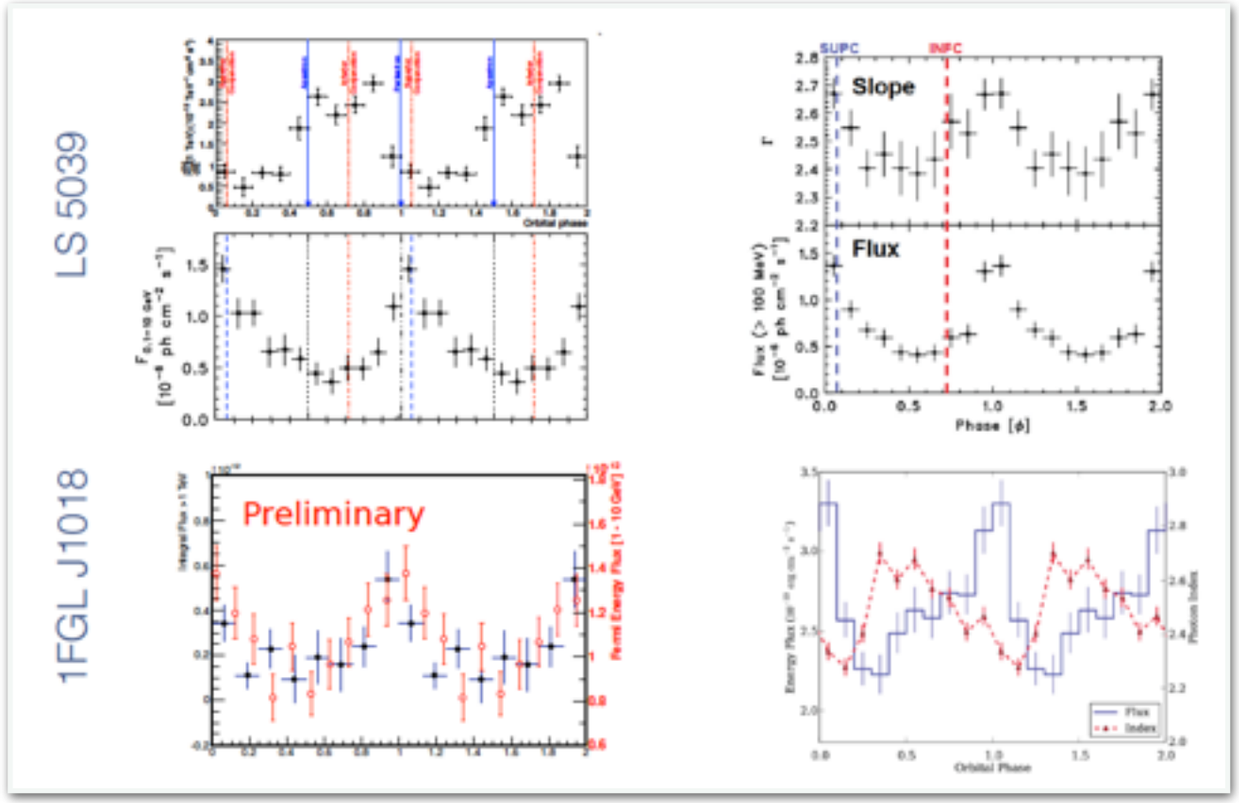


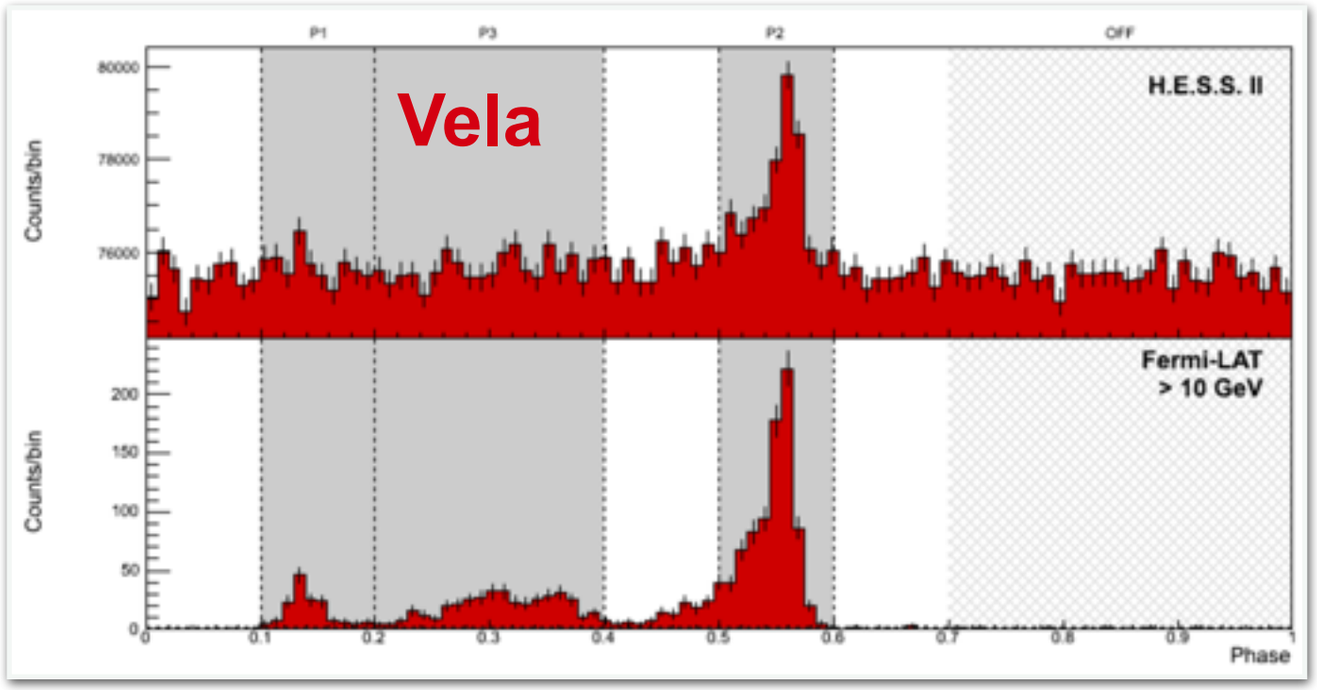
H.E.S.S., PRL (2016)

Multi-wavelength connections, only a few examples

- GeV-TeV connection very important
  - e.g. variable systems like binaries
  - (anti)- correlations between GeV-TeV domains
  - AGN flares



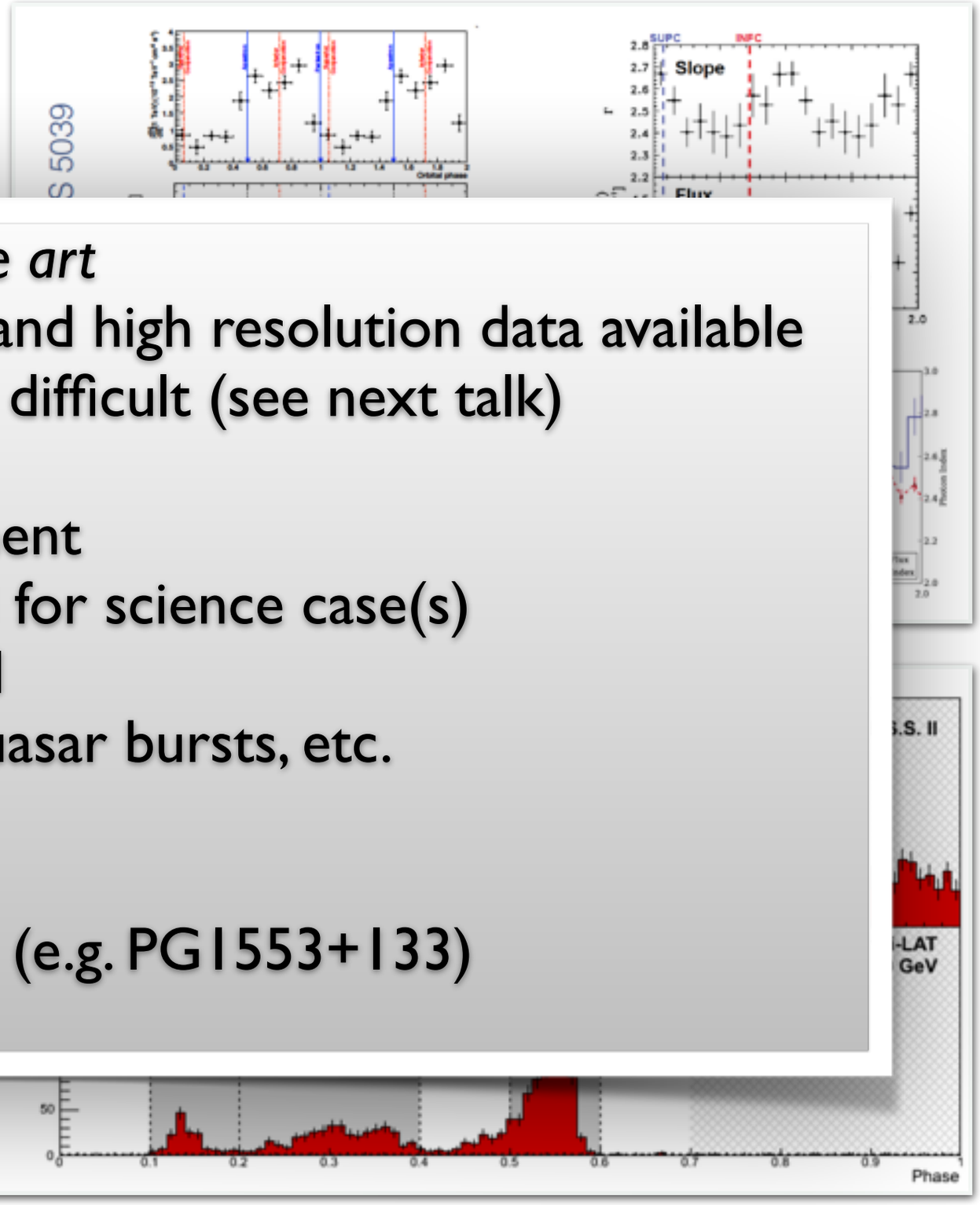




Multi-wavelength connections, only a few examples

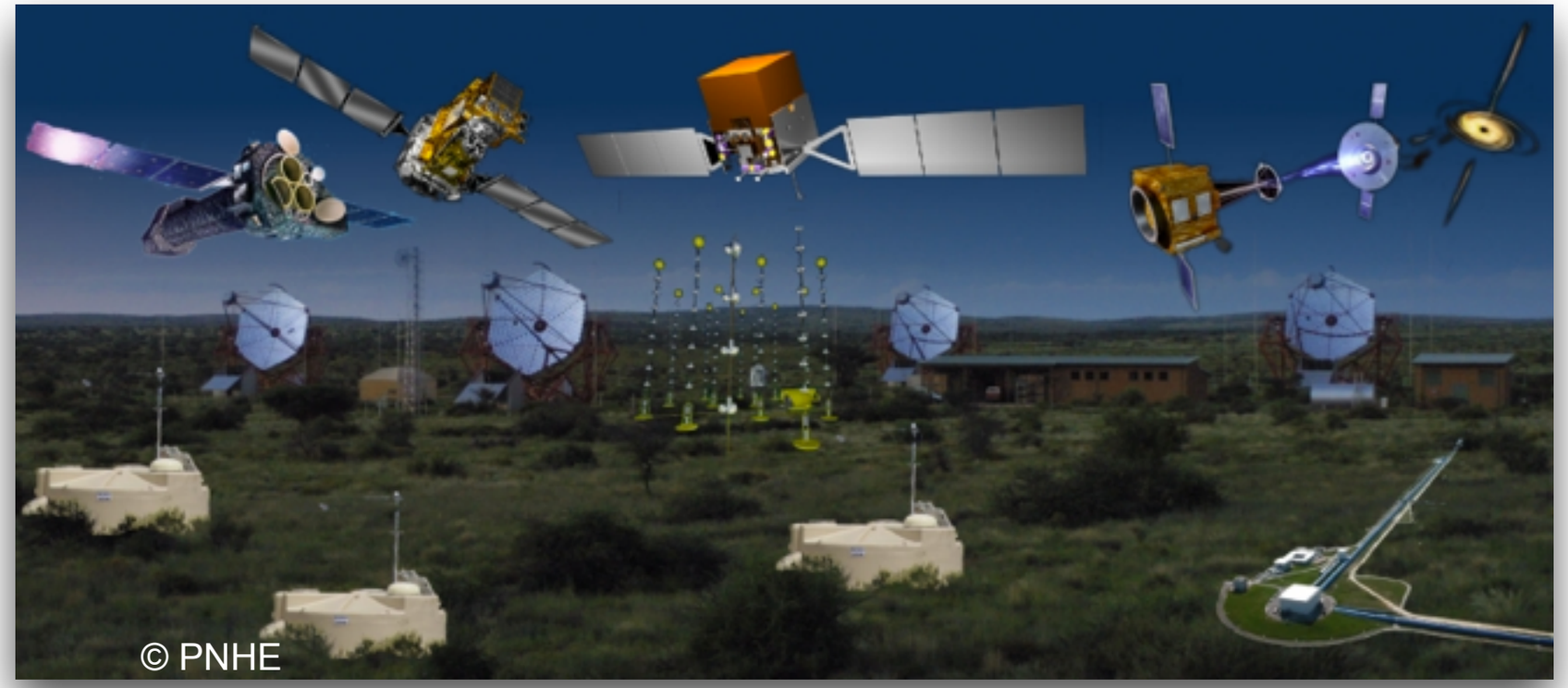
- GeV-TeV connection very important
  - e.g. variable systems like binaries
  - GeV + variable sources *state of the art*
    - periodic sources: very deep and high resolution data available
    - flaring sources: observations difficult (see next talk)

  - Main impact for large FoV instrument
    - low energy threshold crucial for science case(s)
    - long-term monitoring crucial
      - Galactic: Binaries, microquasar bursts, etc.
      - Extragalactic:
        - AGN flares
        - long-term modulations (e.g. PG1553+133)



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

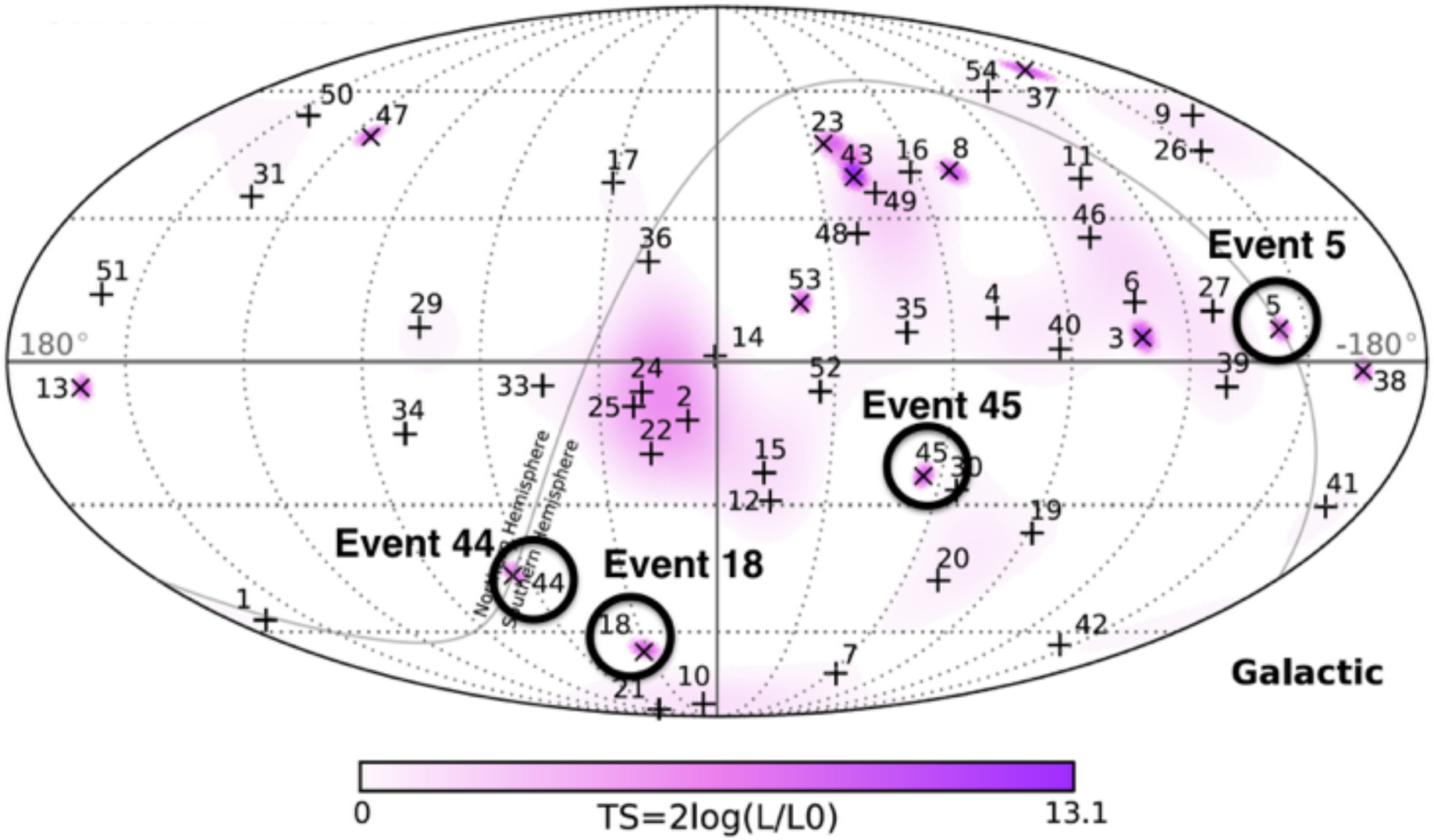
- Gravitational waves
  - major breakthrough in 2015 thanks to Advanced Virgo/Ligo
  - H.E.S.S. member of the Virgo/Ligo EM follow-up effort since early 2014
  - follow-up challenging due to large localization uncertainties
    - important input from additional EM detection, galaxy catalogs, etc.
    - benefit from large FoV
- **Neutrinos**
  - ROIs
    - neutrino hotspots
    - IceCube HESE events
  - ToOs



Multi-messenger program: 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.

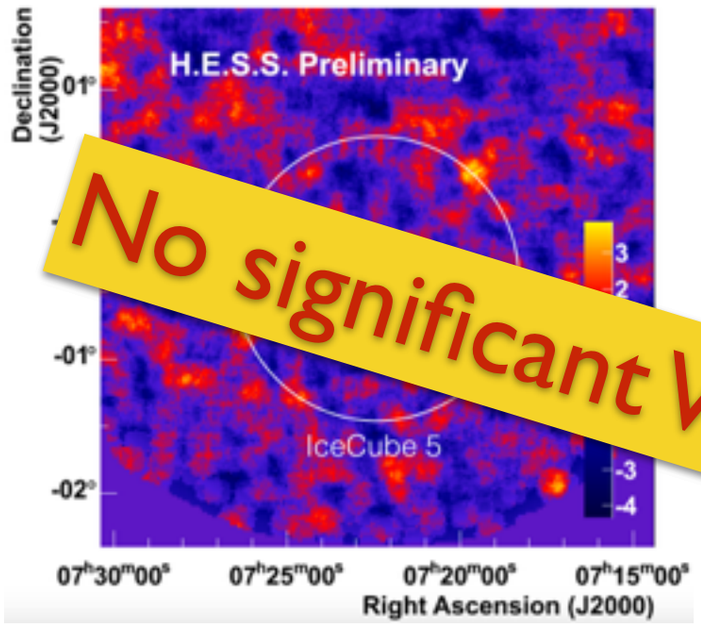
C. Kopper, ICRC 2013



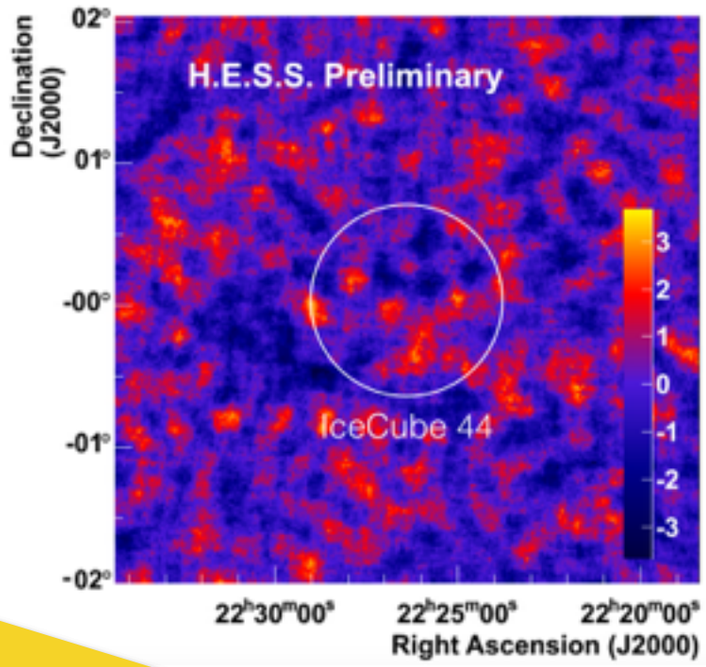
IceCube HESE tracks: H.E.S.S.

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

- IceCube 5

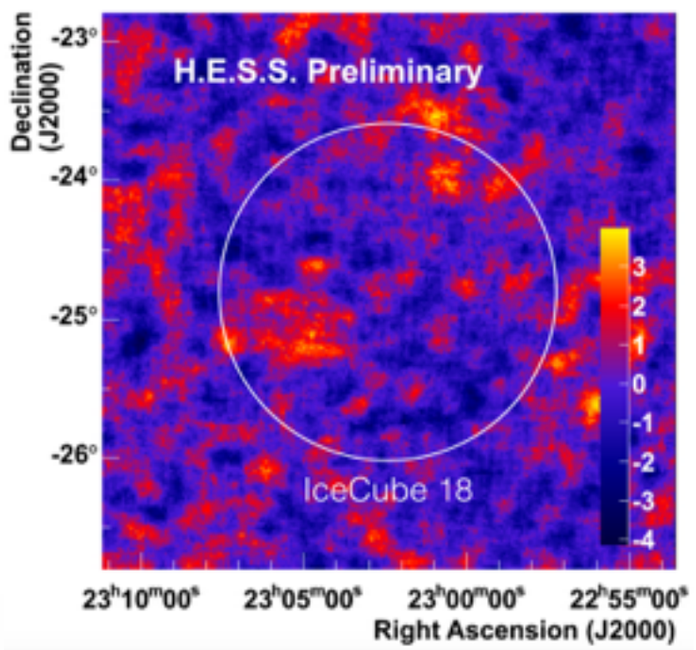


- IceCube 44

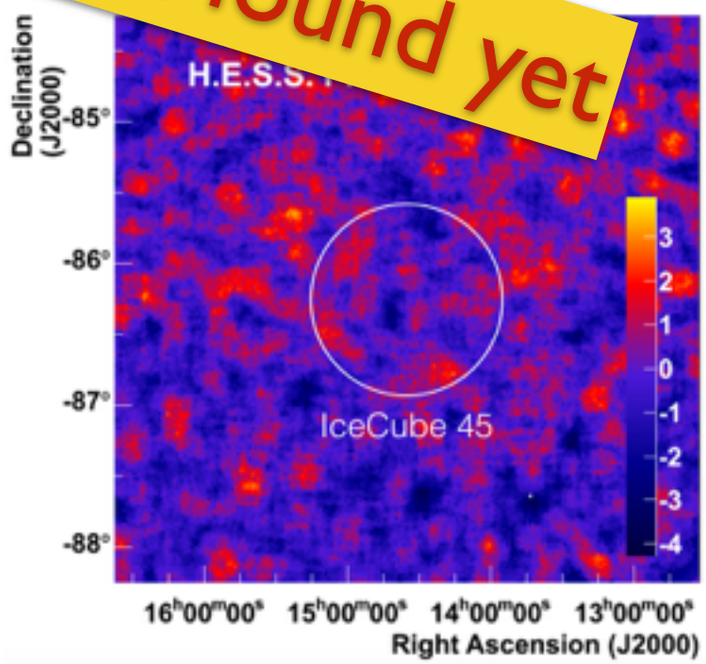


No significant VHE gamma-ray emission found yet

- IceCube 18

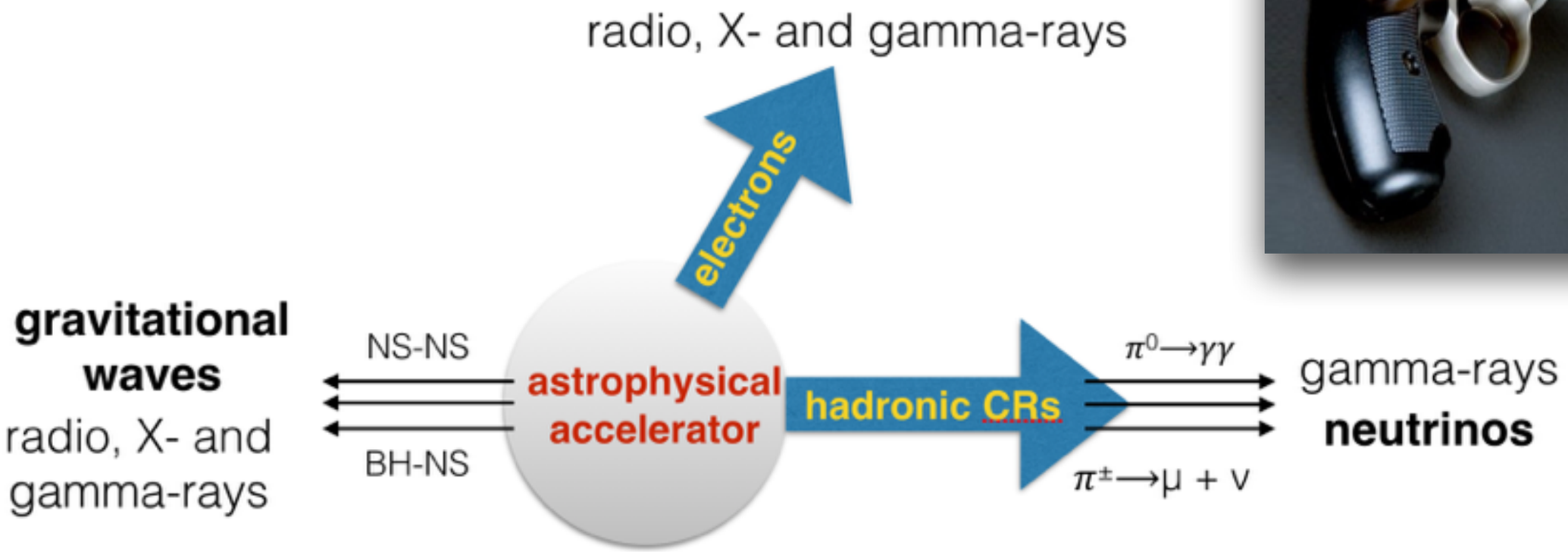


- IceCube 45



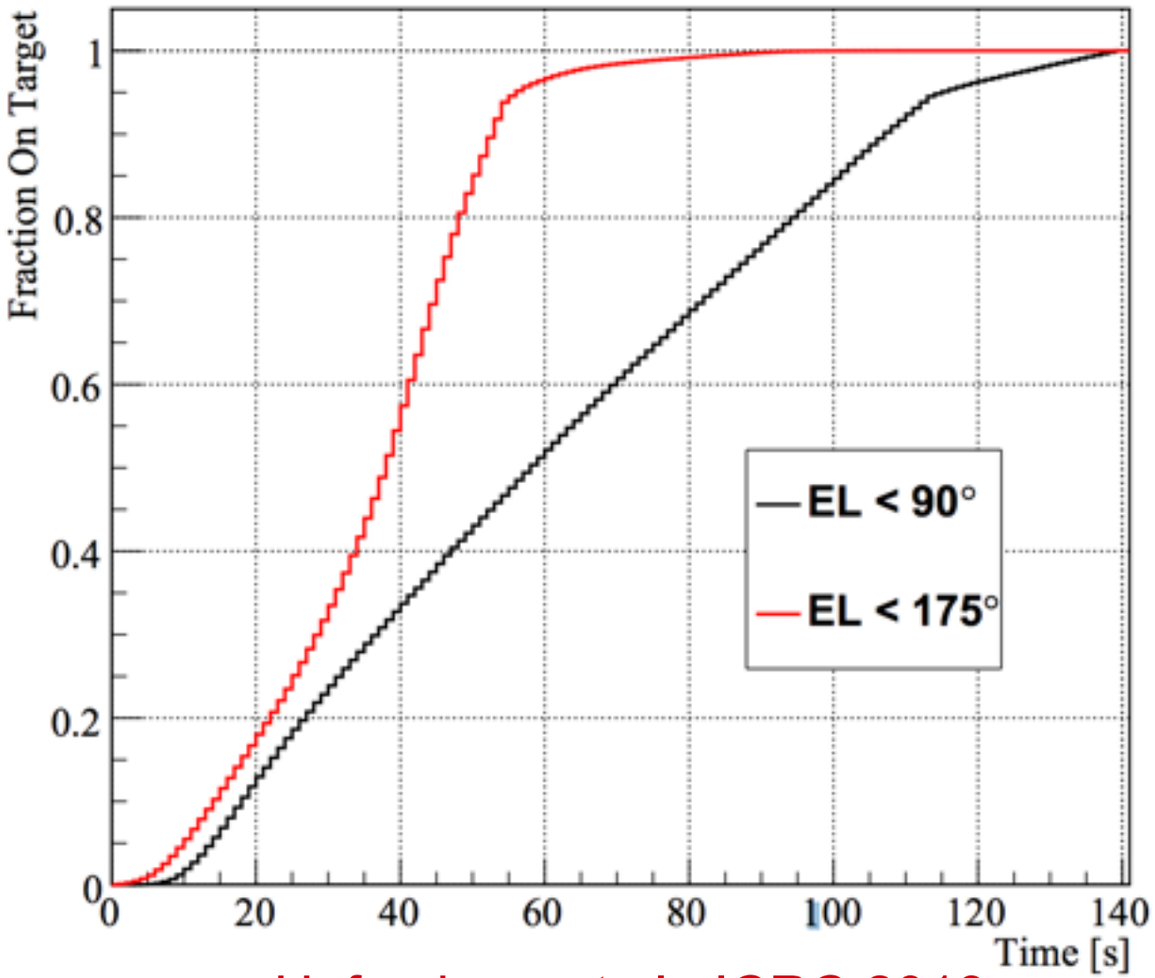
Future of the H.E.S.S. Multi-messenger program: alerts and ToOs

- 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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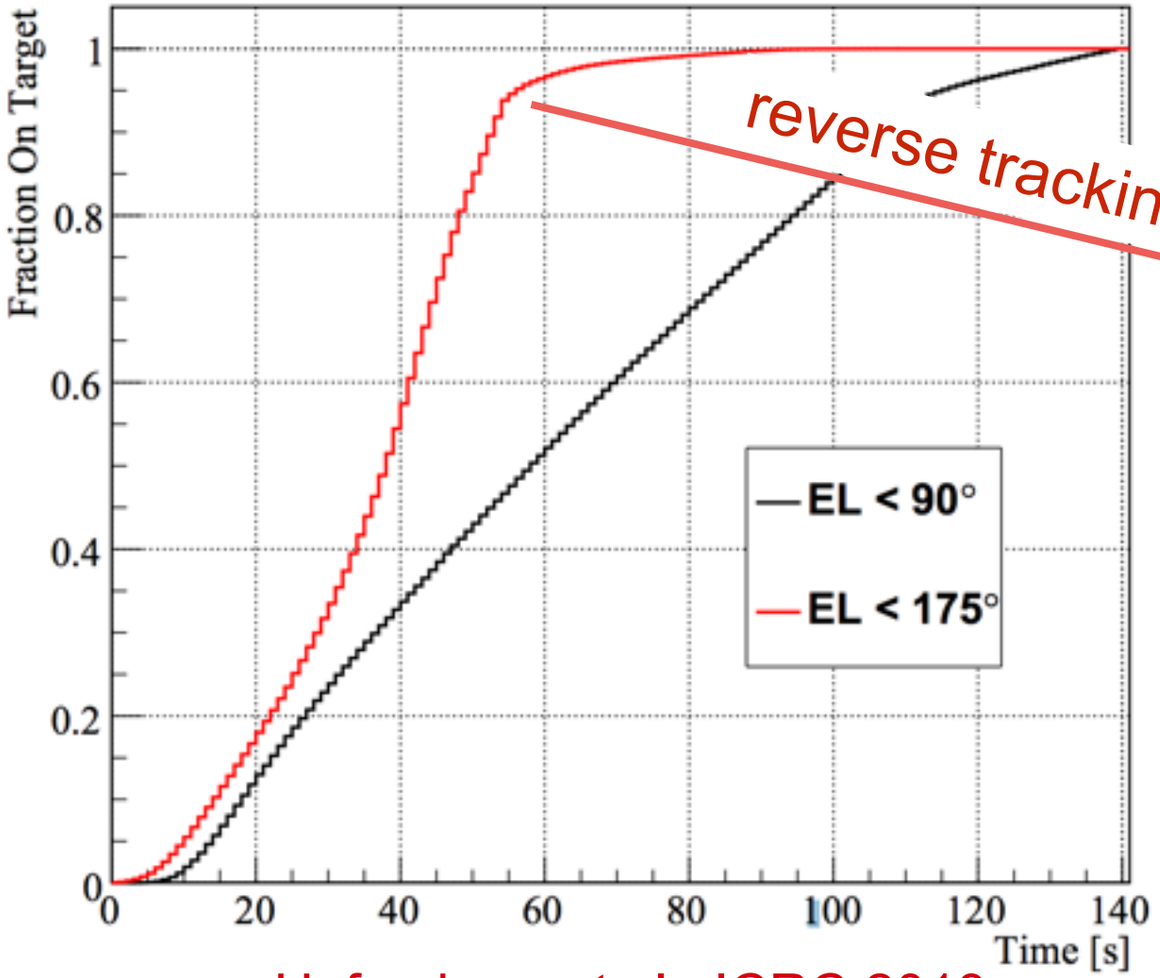

Hofverberg et al., ICRC 2013

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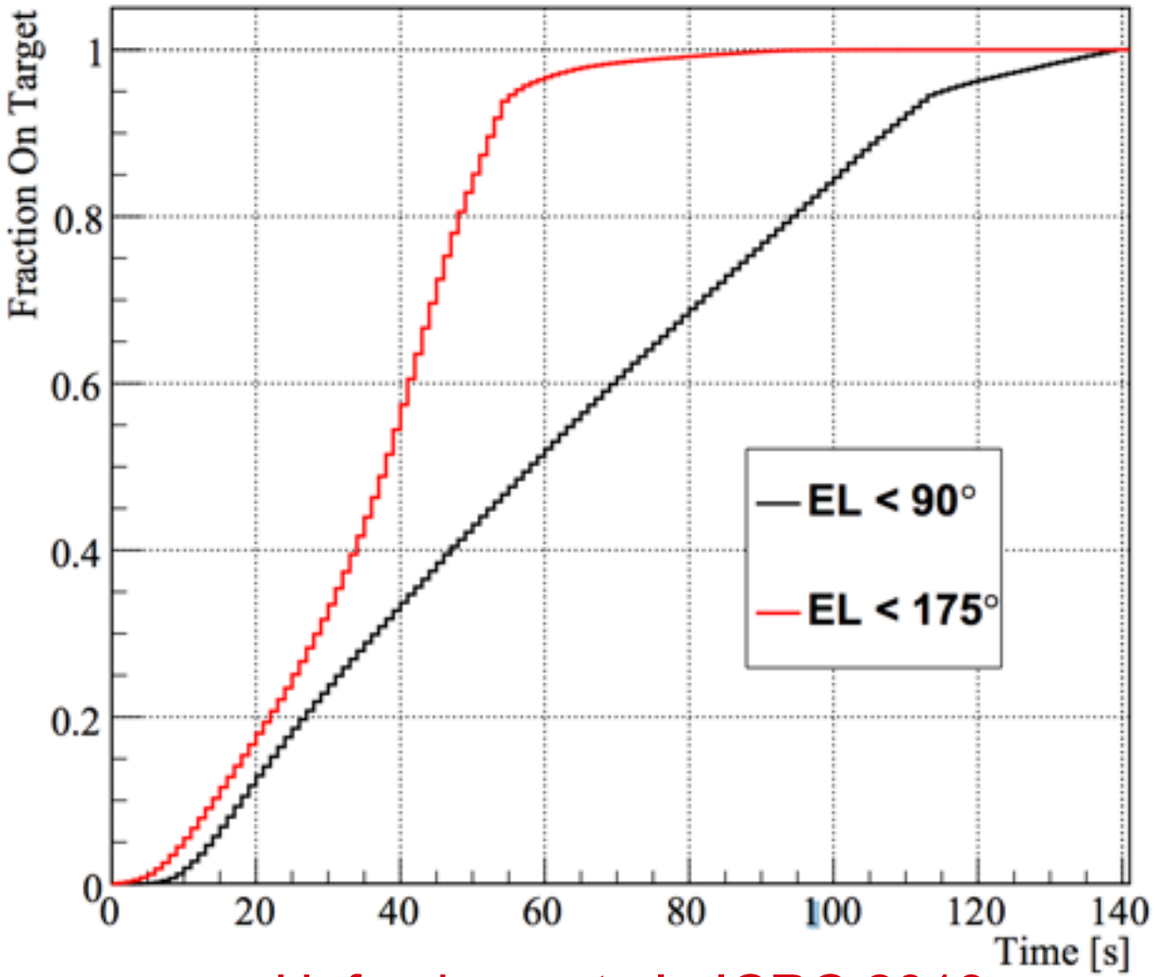


Hofverberg et al., ICRC 2013

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

VoEvent alert system

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

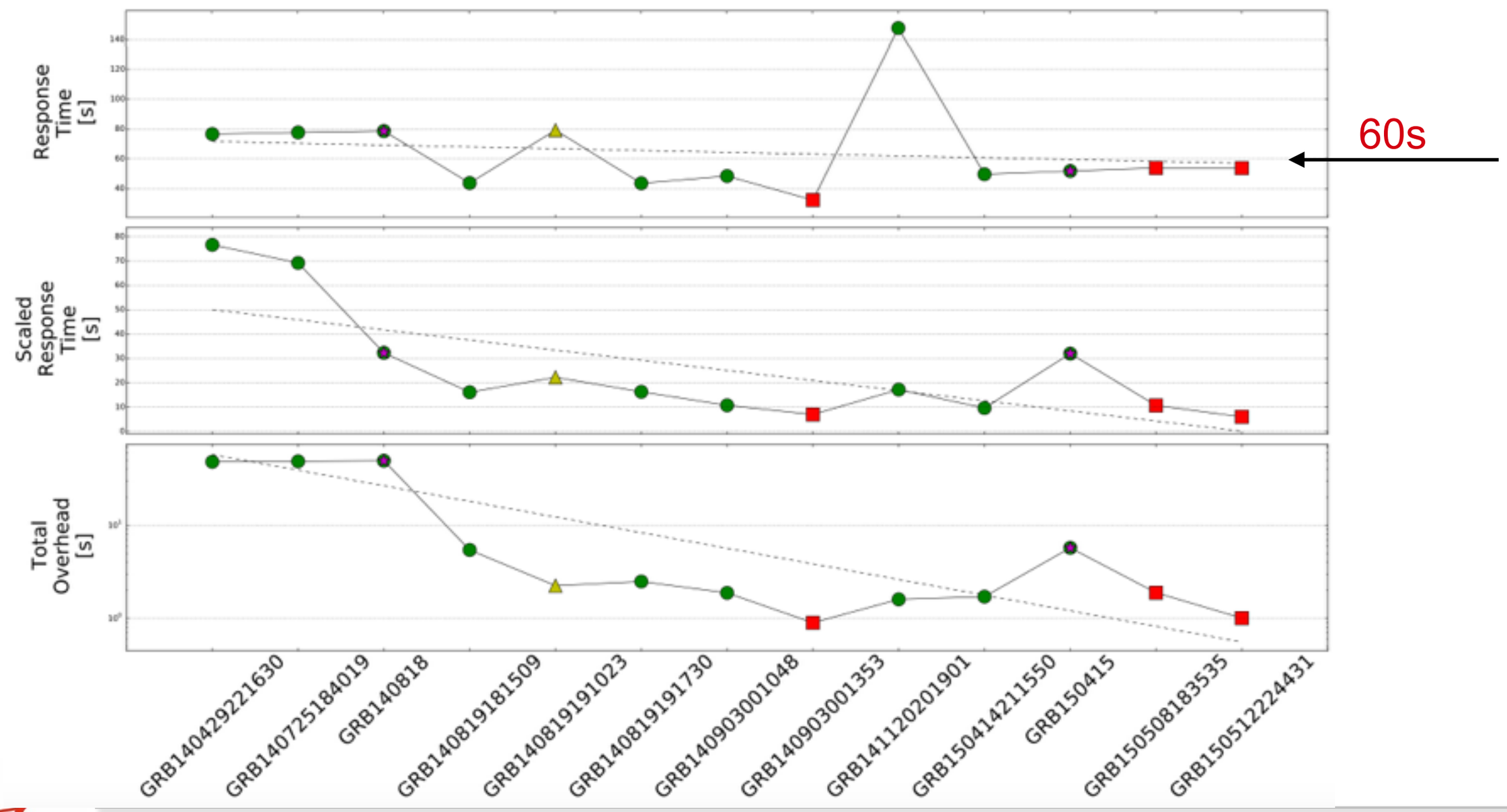
- Neutrino telescopes (IceCube + ANTARES)
  - real-time alerts on HESE + EHE events: e.g. ATEL #9301
  - delays before alert emission: O(sec - min)
- Gamma-ray Bursts
  - extensive follow-up program during H.E.S.S. phase I (e.g. A&A 495, 505-512 (2009))
  - follow-up speed significantly increased with 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)
- many other ToOs
  - Fast Radio Bursts (e.g. SUPERB@Parkes)
  - SGR/AXPs
  - …

A. Balzer et al., CHEP2015

D. Parsons et al., ICRC 2015, arXiv: 1509.05191

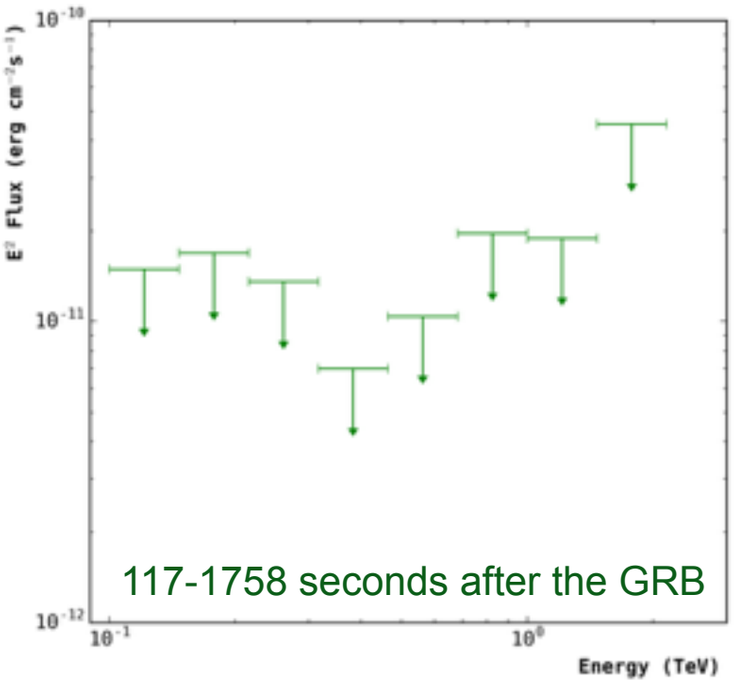
GRB follow-up: performance

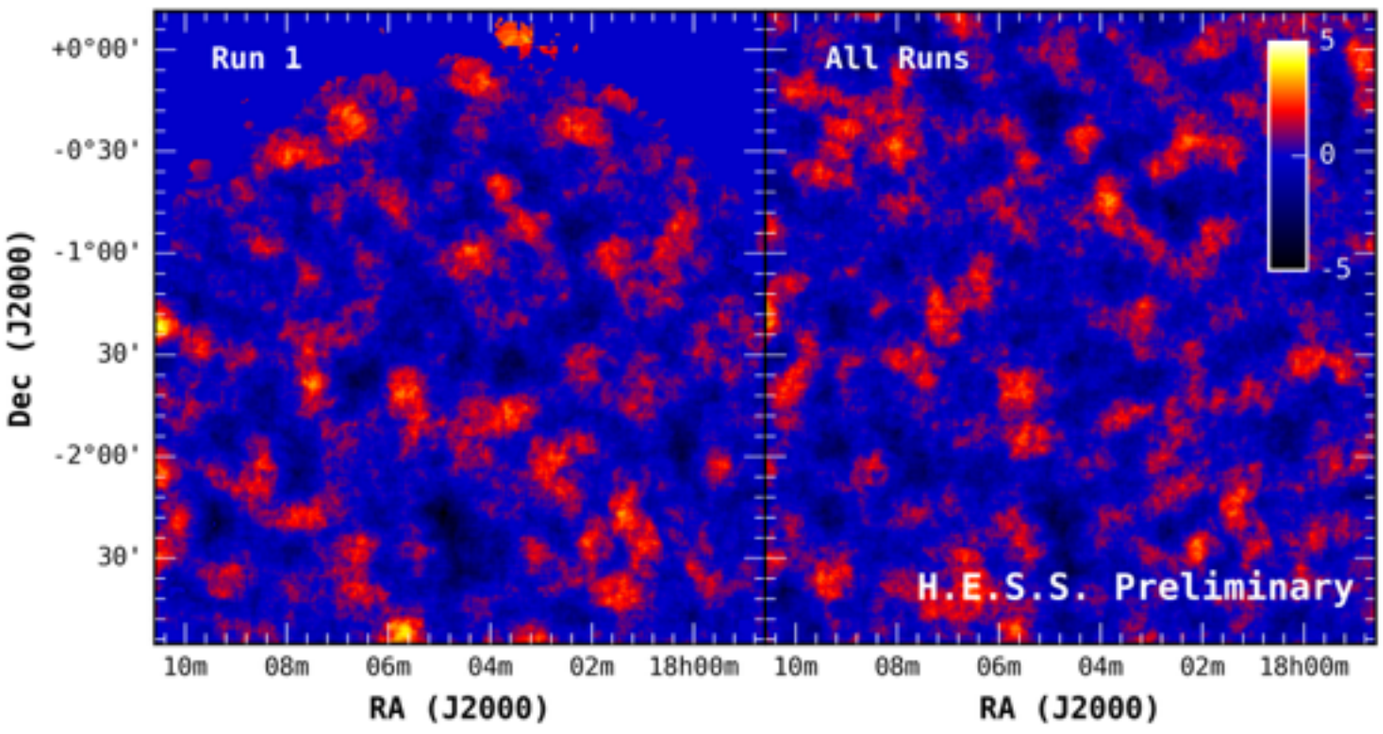
- DAQ re-organisation led to significant improvement of the response time
- continuous monitoring via ”fake GRBs”: end-to-end tests of the full chain



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

GRB follow-up: first results

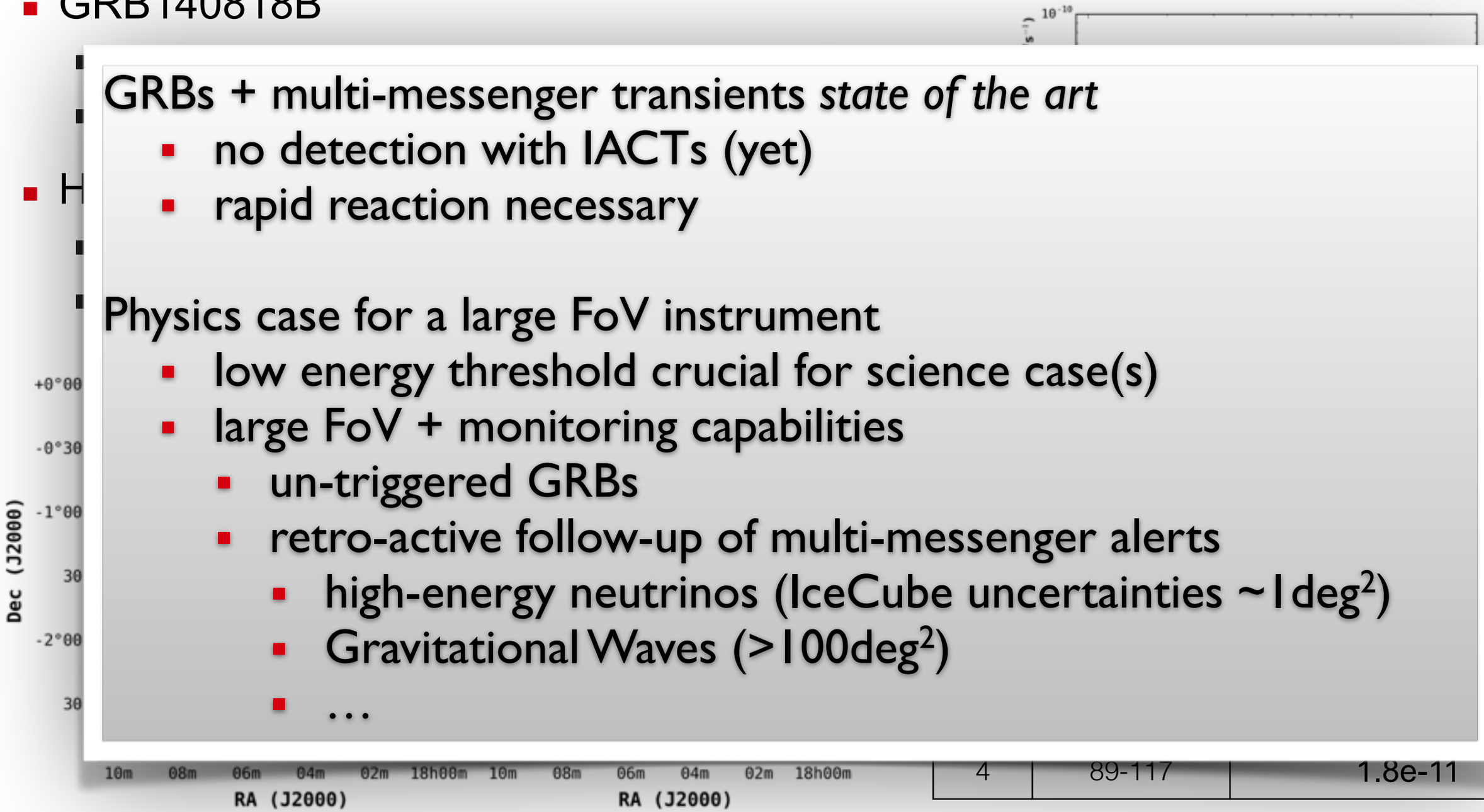
- strict data blinding procedure fixing reconstruction, cuts, analysis strategy, etc.
- GRB140818B
- H

GRBs + multi-messenger transients *state of the art*

- no detection with IACTs (yet)
- rapid reaction necessary

Physics case for a large FoV instrument

- low energy threshold crucial for science case(s)
- large FoV + monitoring capabilities
  - un-triggered GRBs
  - retro-active follow-up of multi-messenger alerts
    - high-energy neutrinos (IceCube uncertainties ~1deg^2)
    - Gravitational Waves (>100deg^2)
    - …



		GeV)
4	89-117	1.8e-11

Summary and outlook

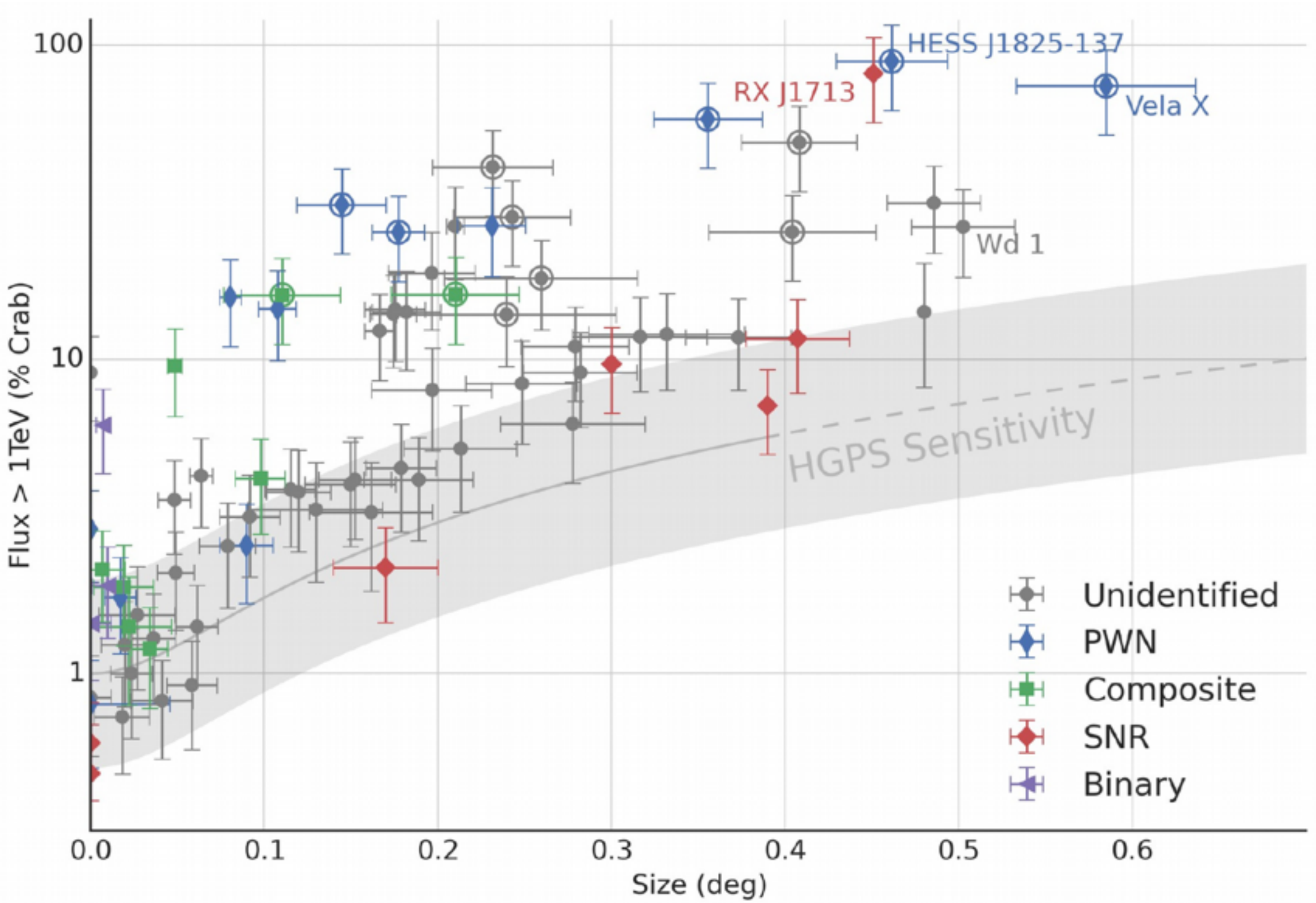
- H.E.S.S. phase I: extensive legacy dataset (e.g. HGPS, SNRs, etc.)
- H.E.S.S. phase II: lower energy threshold and rapid response
  - First physics results (e.g. AGNS, DM lines, etc.)
  - Multi-messenger program (neutrinos, GWs, Fast Radio Burts, etc.)
  - Follow-up of alerts and ToOs
    - GRBs
    - improved performance: response time < 1min
    - highest priority observations
- Upgrade of H.E.S.S. phase I camera electronics
  - improved reliability
  - lower dead time matching H.E.S.S. 28m

Some thoughts on a next generation large FoV instrument in the Southern hemisphere

- monitoring of transient phenomena
  - Galactic: microquasars, binaries, etc.
  - Extragalactic: AGNS, GRBs, multi-messengers, etc.
  - requires high sensitivity and low energy threshold
- low energy threshold: opens extragalactic sky (EBL absorption) => transients!!
  - large discovery space (no extensive surveys yet, CTA: 1/4 of the sky)
  - deep follow-up of new sources with CTA if necessary
- sensitivity at high energies: largely uncharted territory, Galactic Pevatron(s)
  - challenging due to limited angular resolution compared to IACTS

Backup

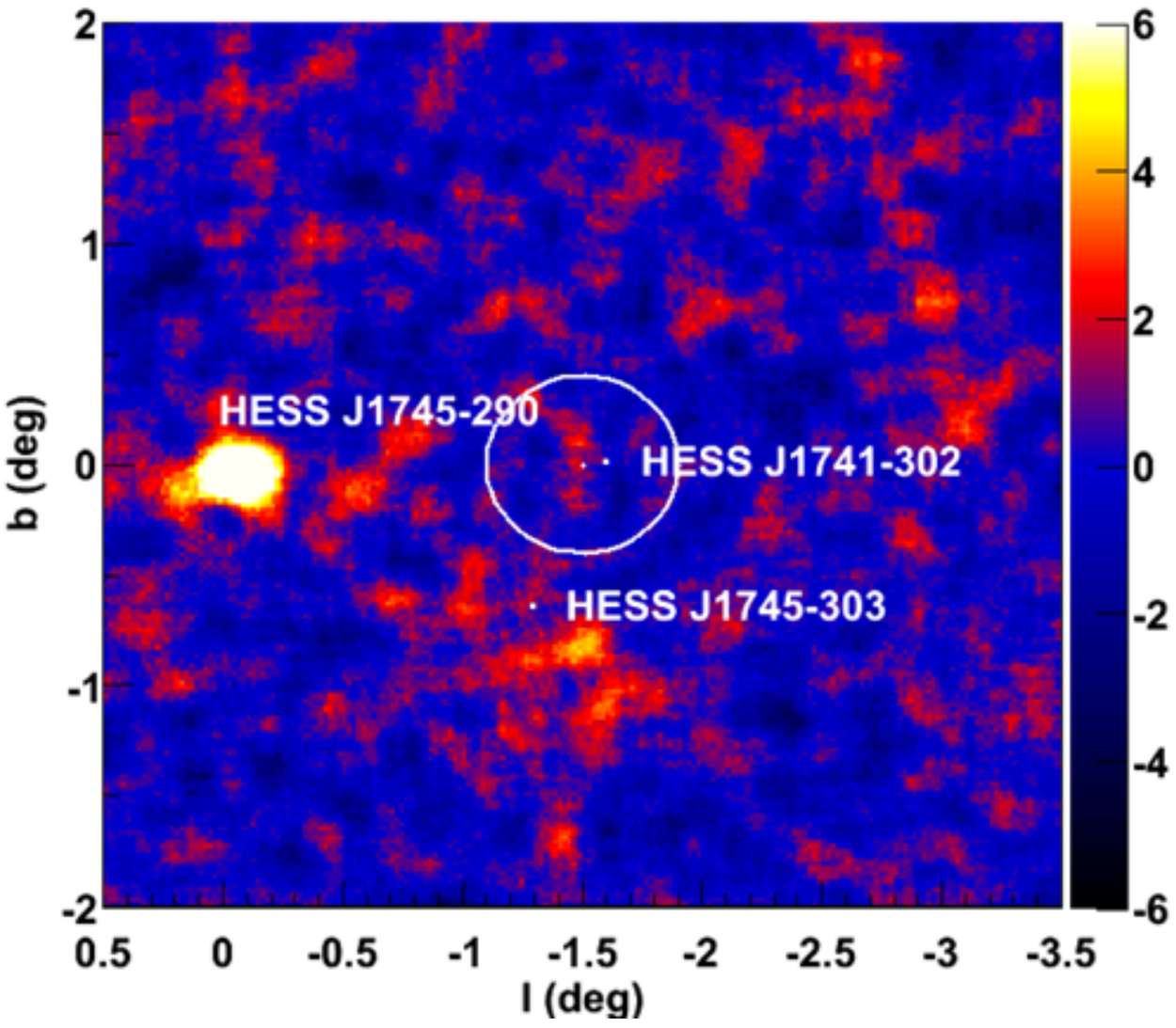
The H.E.S.S. Galactic Plane Survey

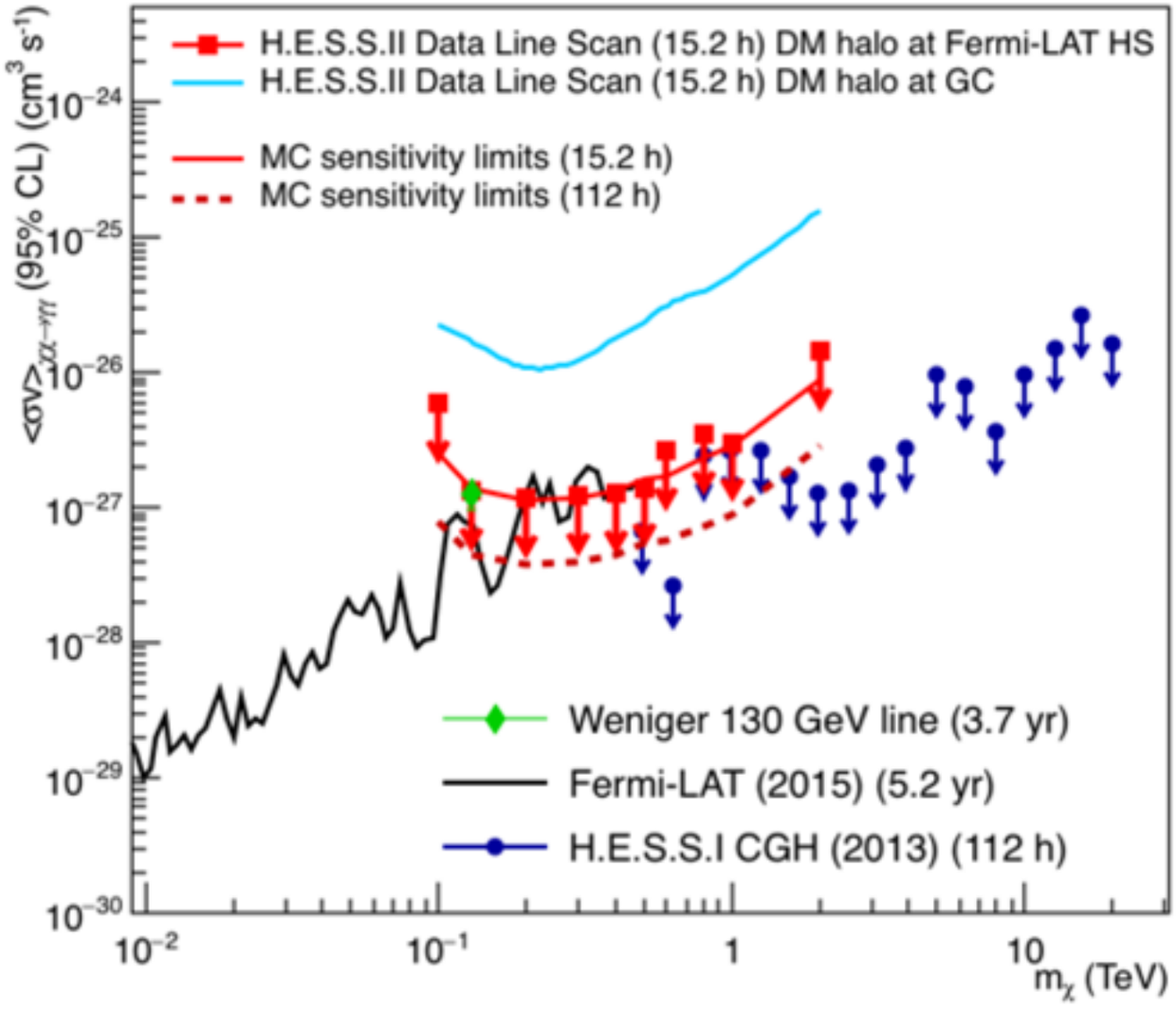


Upper Limits on the 130 GeV Fermi Line

Phys. Rev. Lett. 117, 151302

- HESS II stereo analysis shows no evidence of 130 GeV excess at the Fermi hotspot position
- Upper limits derived from H.E.S.S. II stereo analysis
- Exclude the 130 GeV line at 95% C.L.

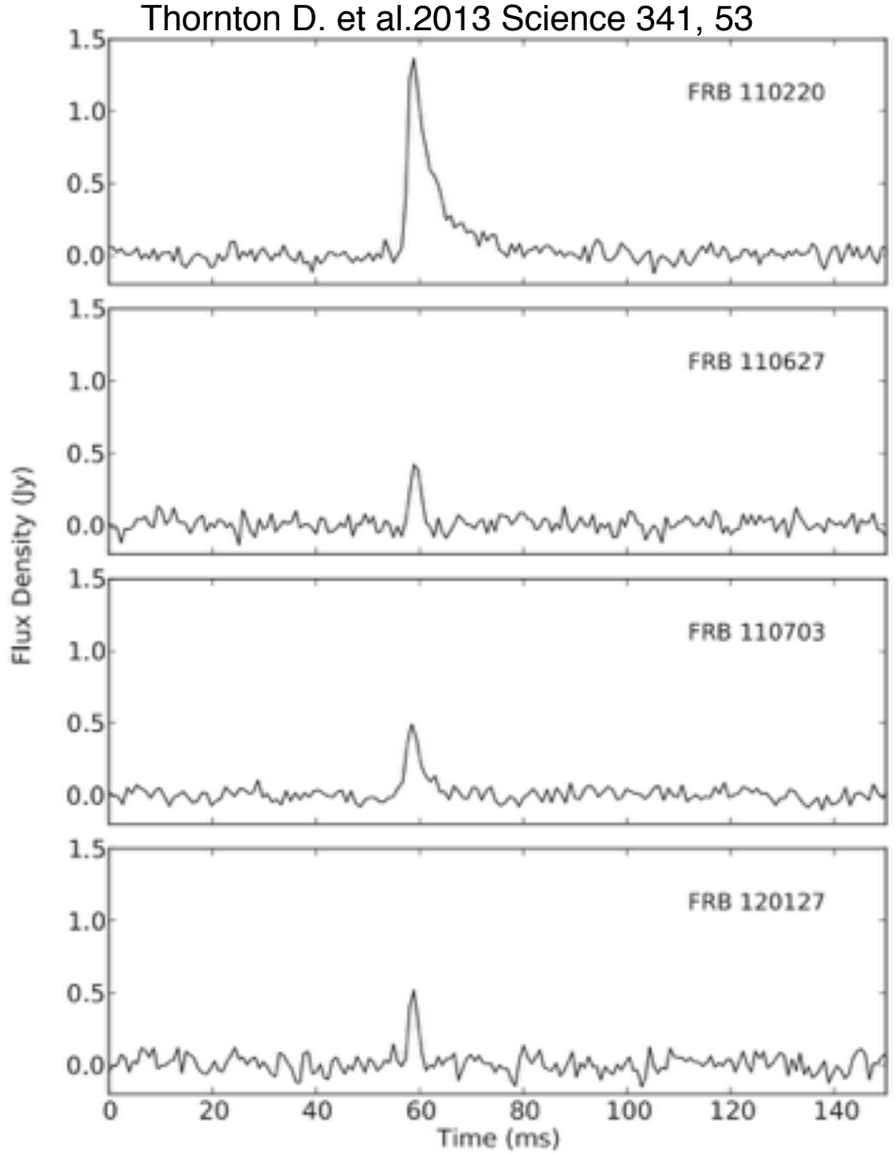




Fast Radio Bursts

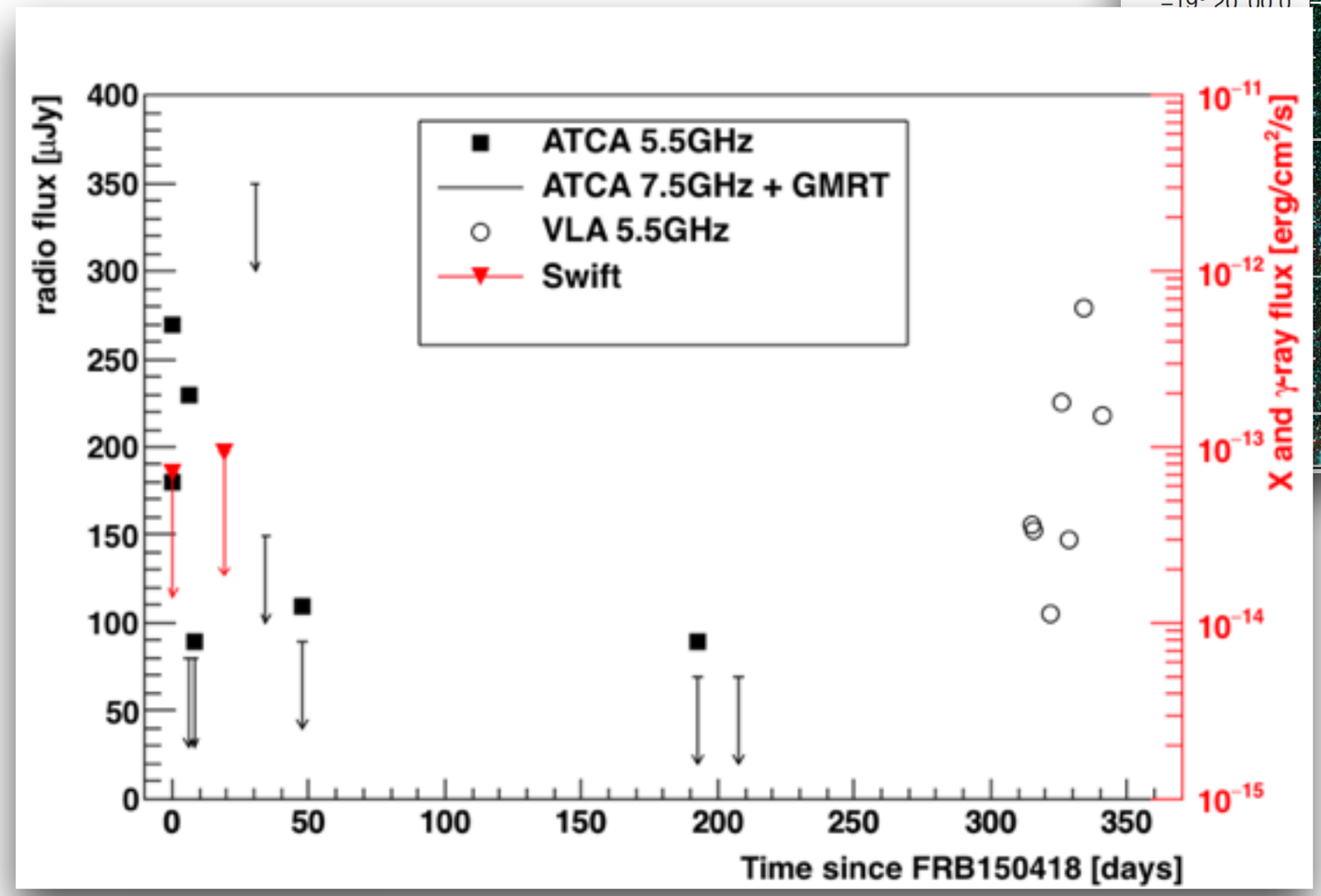
- strong, millisecond radio burst of possibly extragalactic origin
- H.E.S.S. takes part in the SUPERB project @ Parkes
  - online searches for FRBs and other radio transients

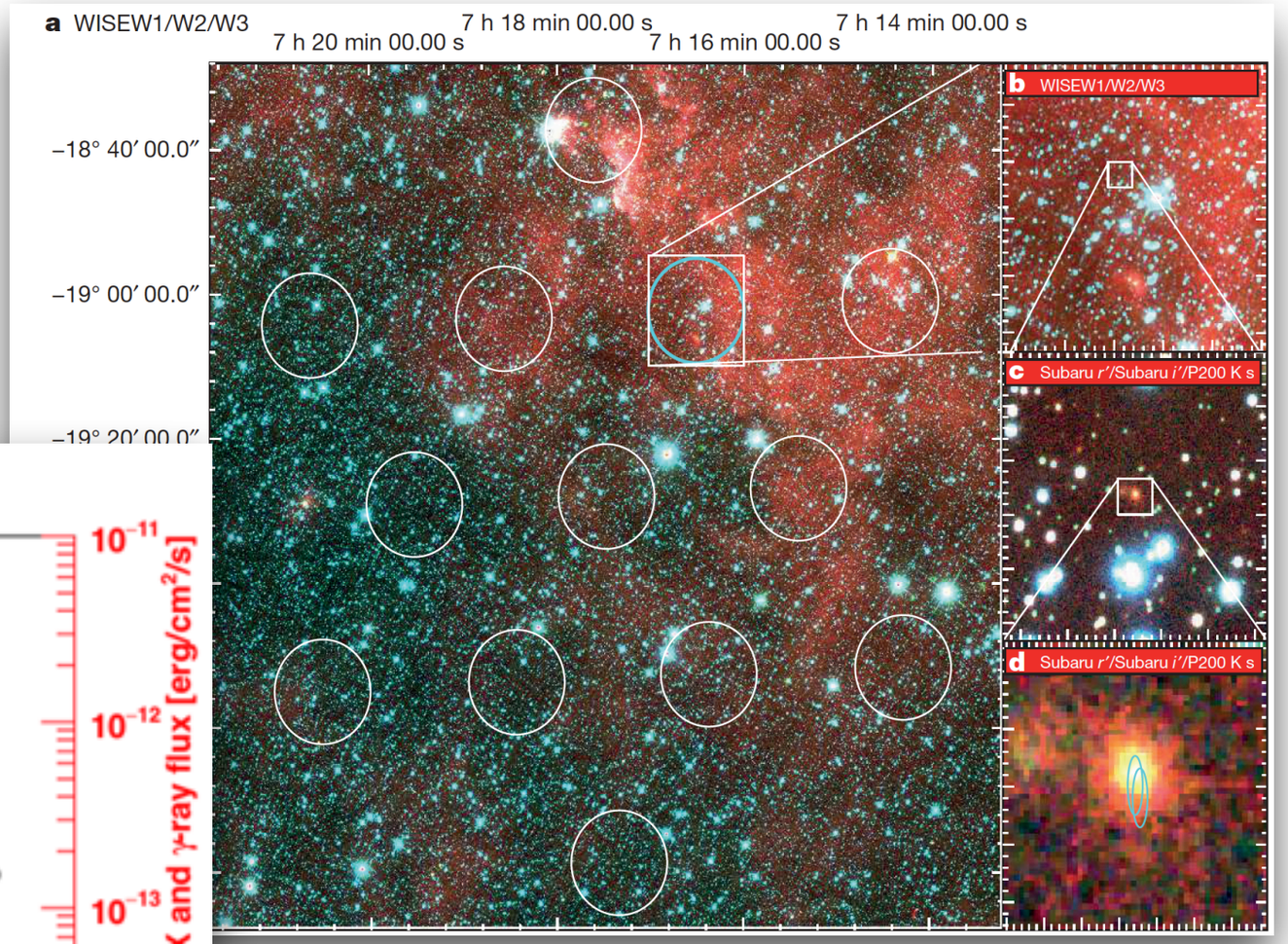
Thornton D. et al.2013 Science 341, 53



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

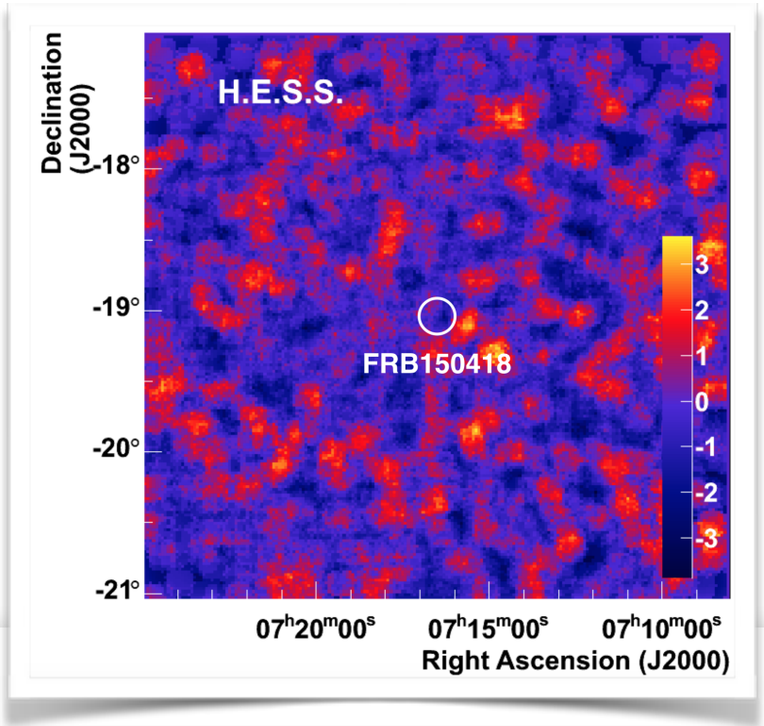


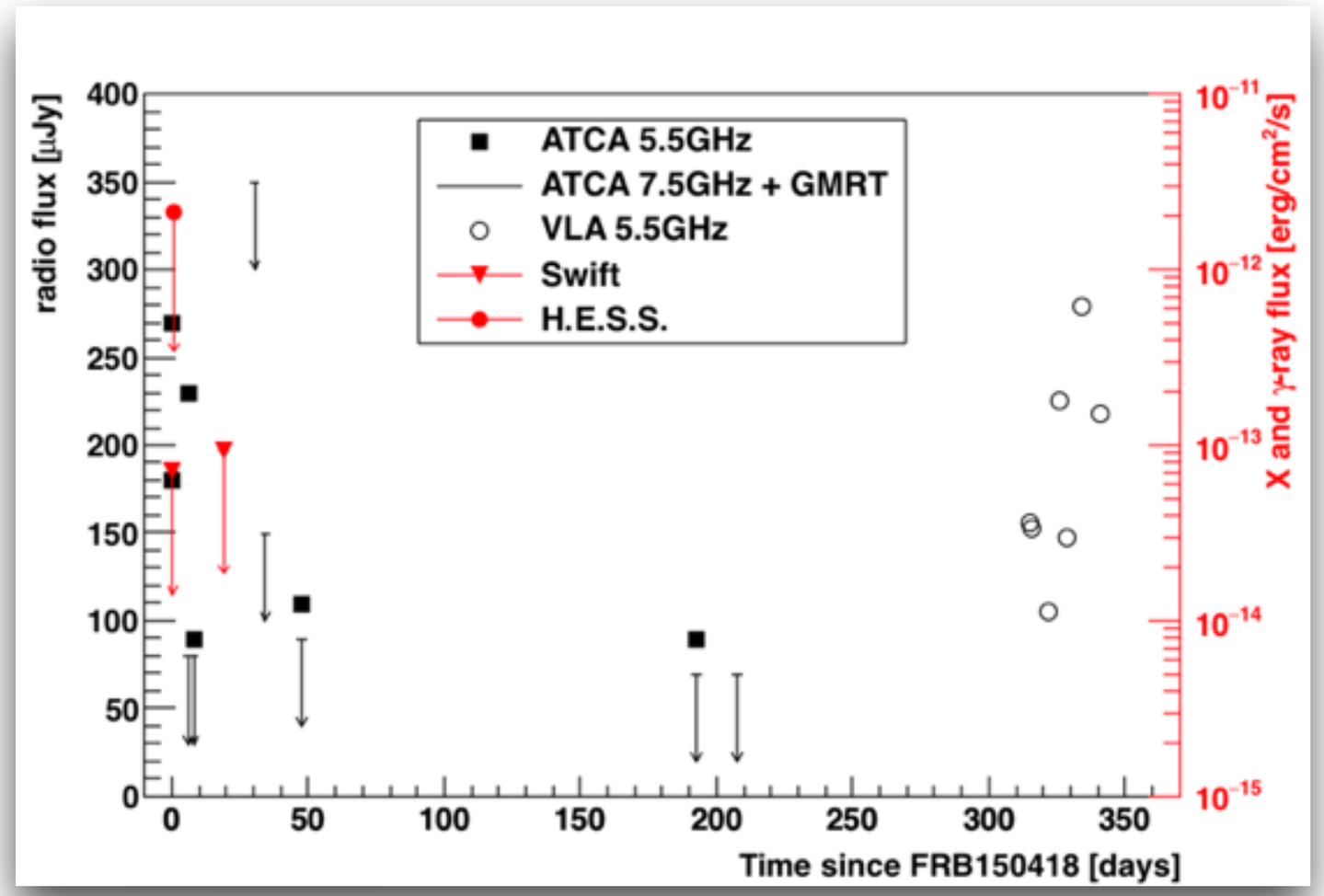


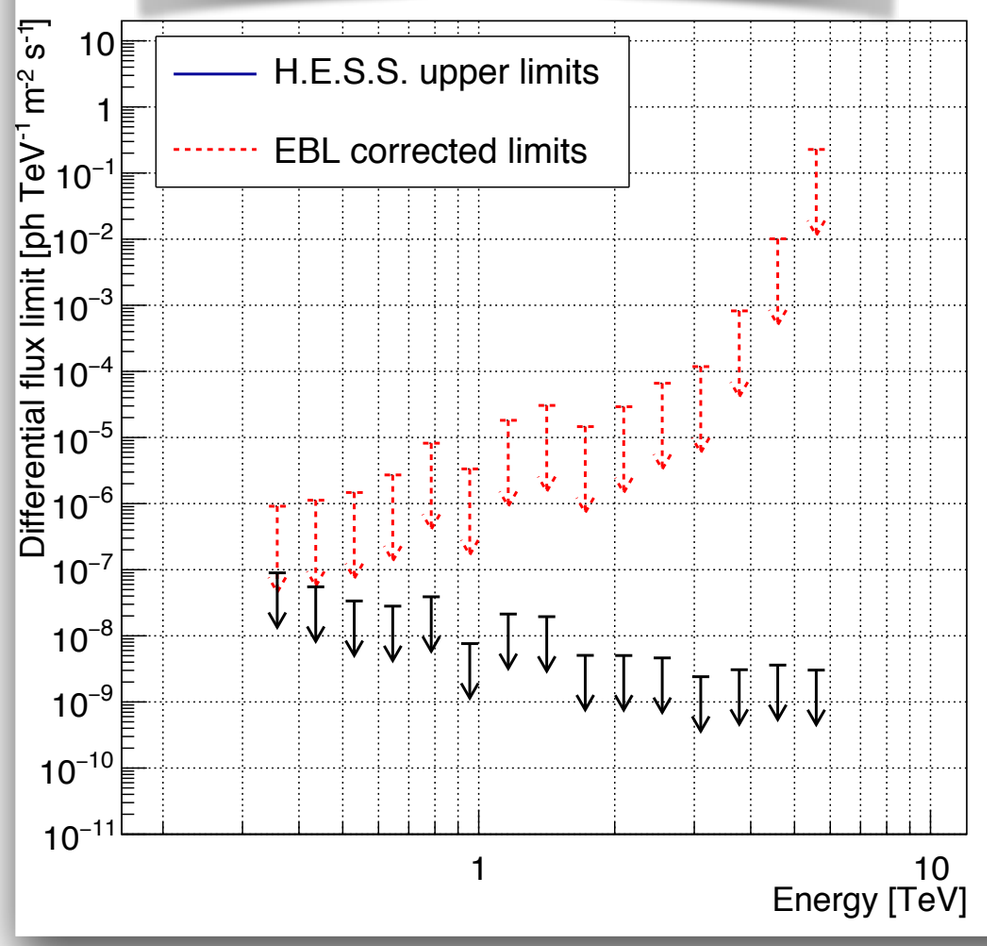
E. Keane et al., Nature 530 (2016)

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.)



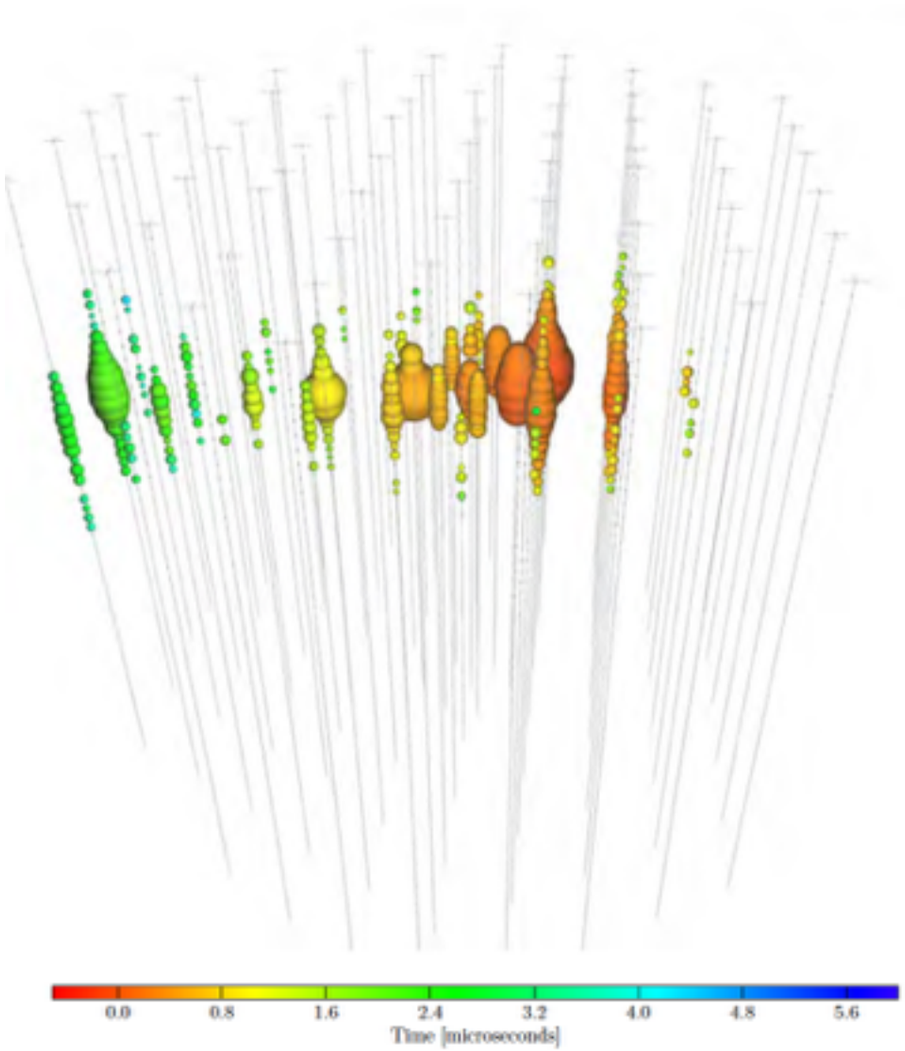




IceCube events: examples

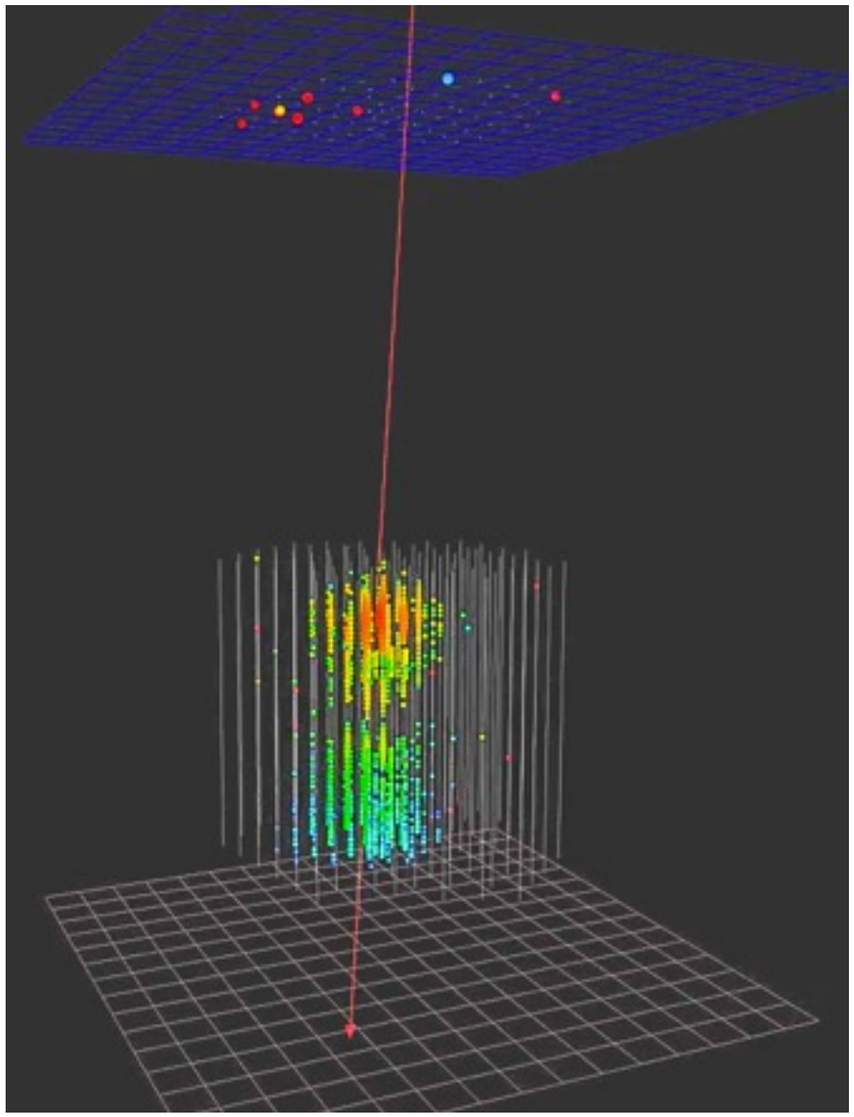
IceCube Event 5

- 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: Fermi-LAT

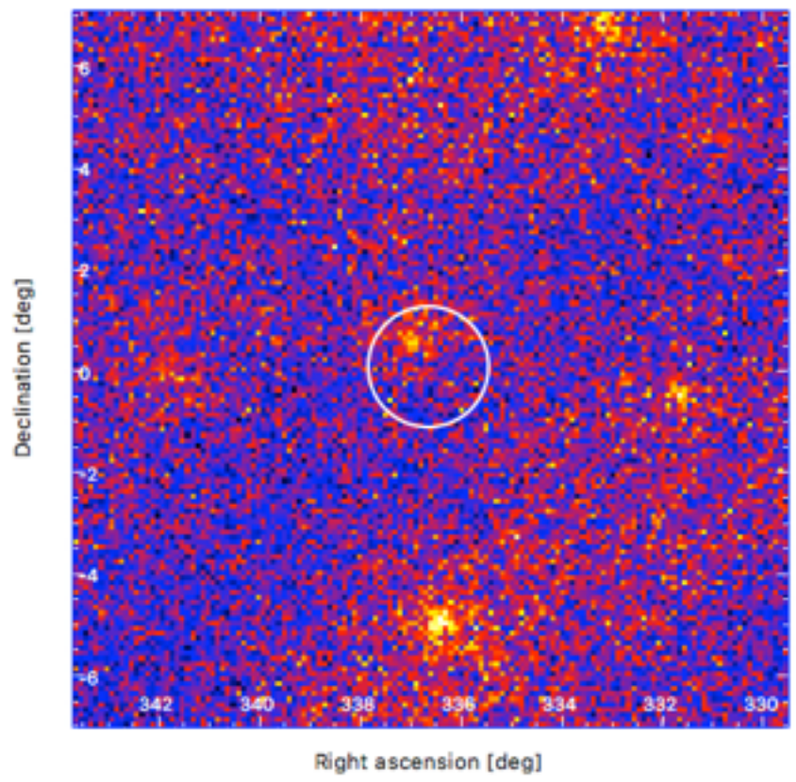
FS et al., ICRC 2015, arXiv:1509.03035

FS et al., Gamma 2016

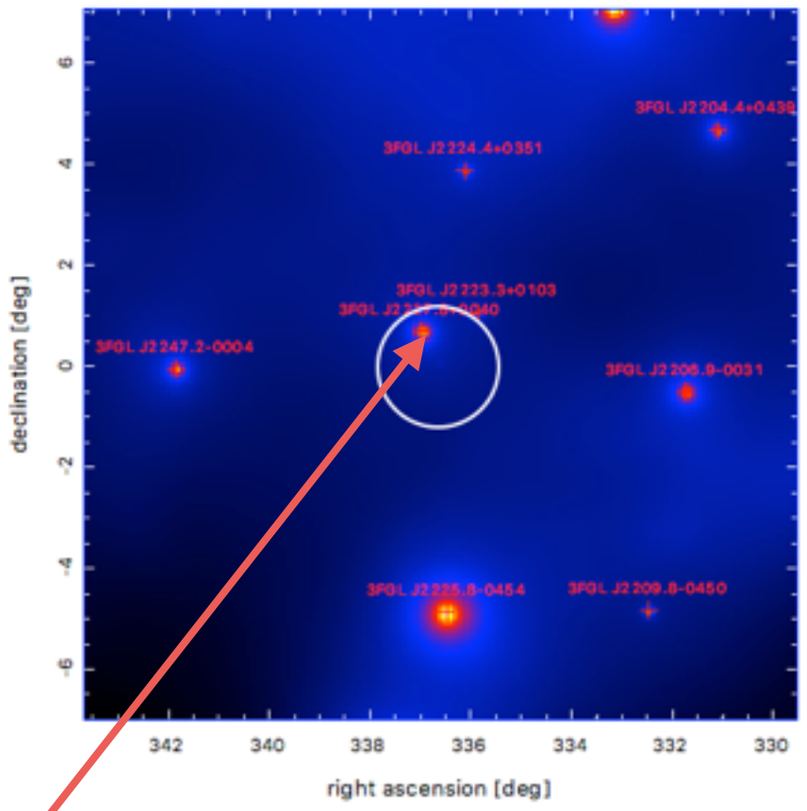
- Event 5 + 18: period 08/2008-05/2015; P7Rep, 100MeV-300GeV
- Event 44 + 45: period 08/2008-05/2016; Pass8, 100MeV-300GeV

Example: Event 44

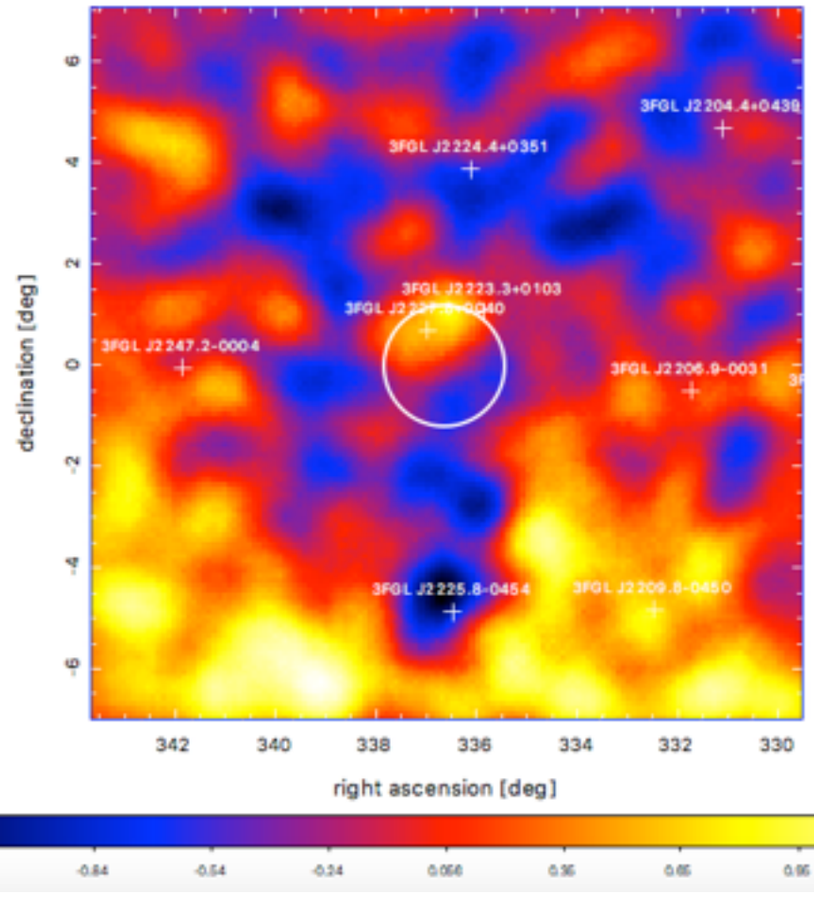
counts



model



residuals



3FGL J2227.8+0040

J222743.7+005729: Blazar at z~1.3

IceCube HESE tracks: Limits

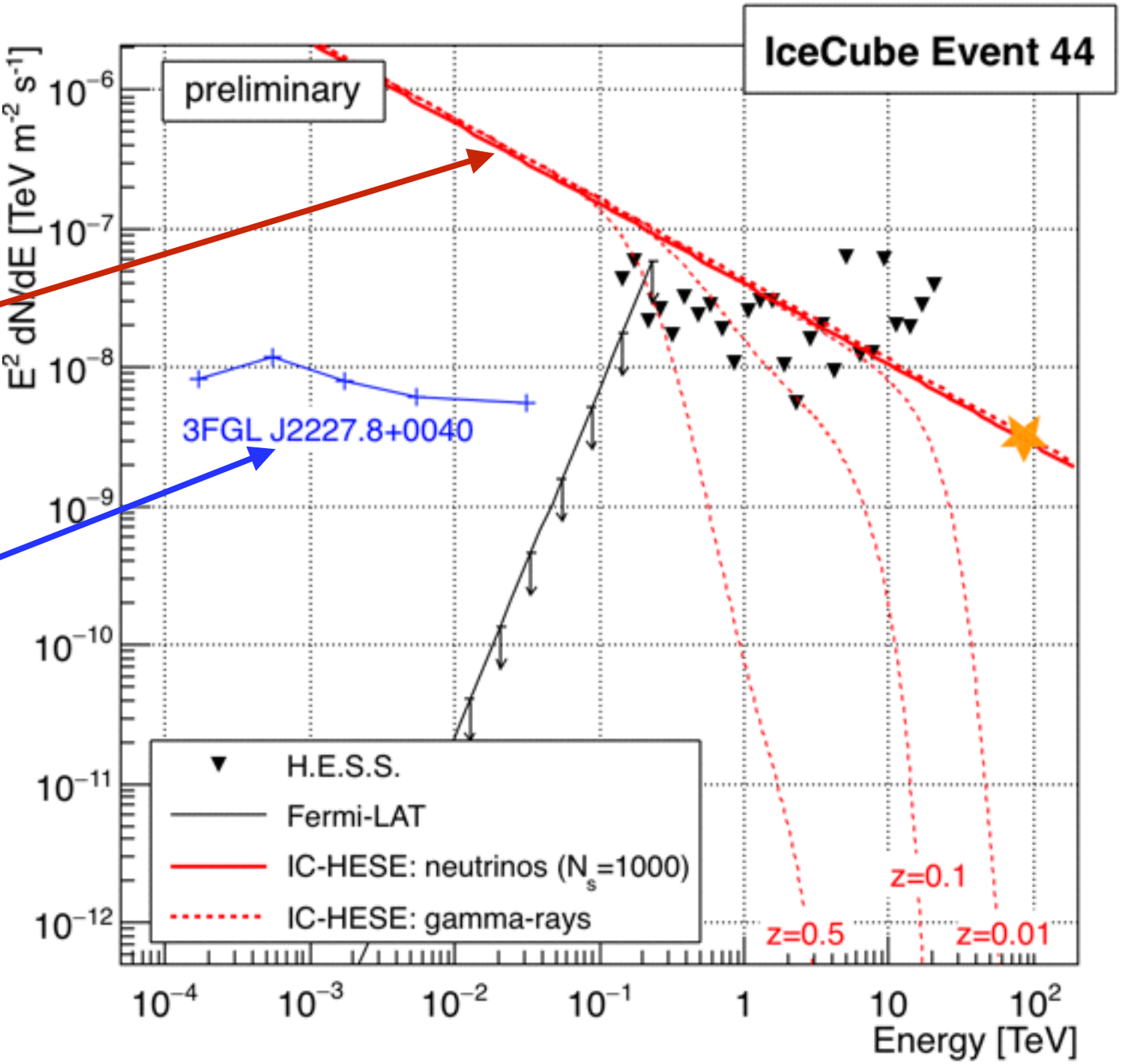
FS et al., ICRC 2015, arXiv:1509.03035
FS et al., Gamma 2016

- Example: Event 44

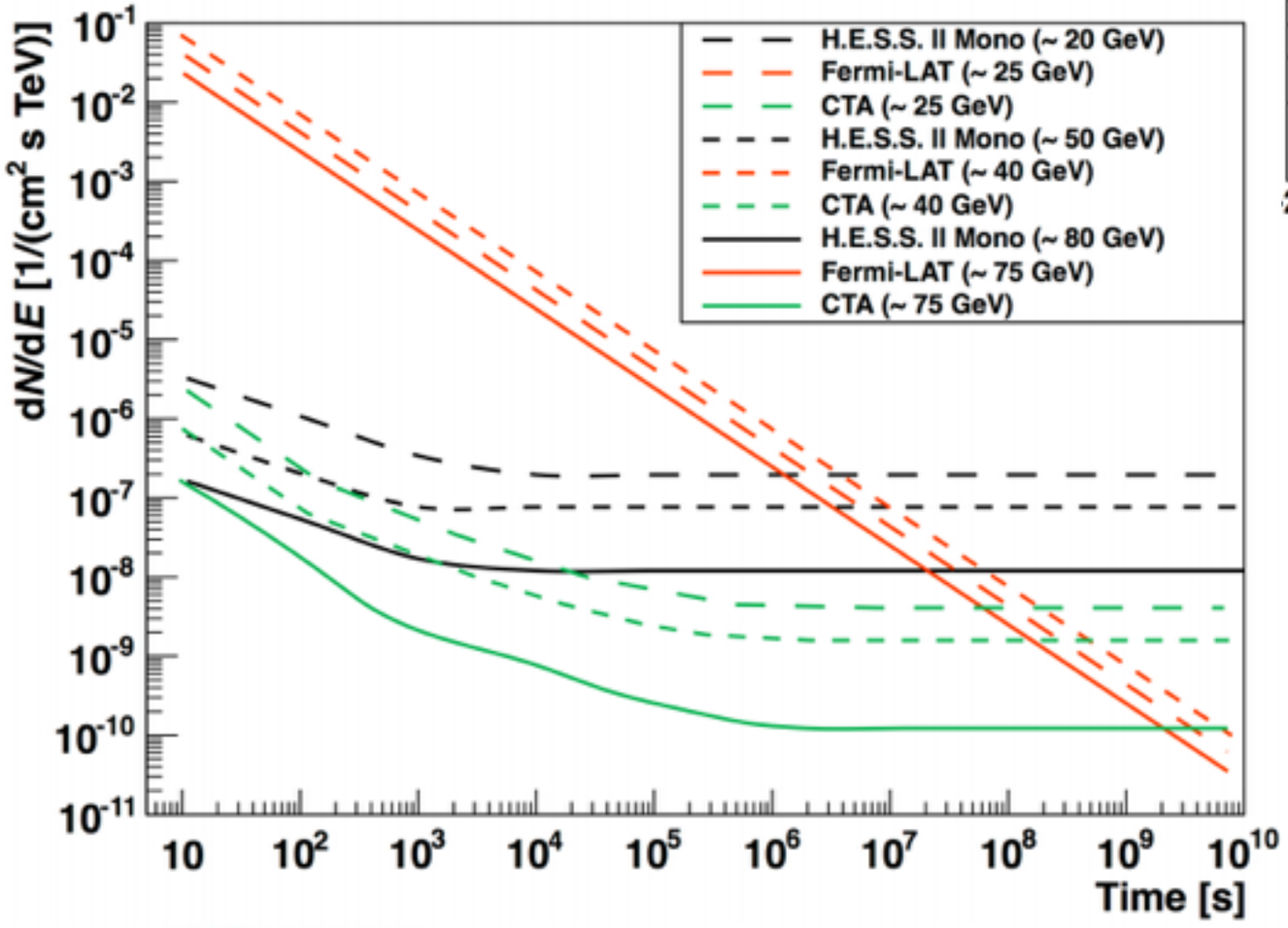
H.E.S.S. + Fermi-LAT limits
for point-source in the ROI center
(acceptance smooth => representative for ROI)

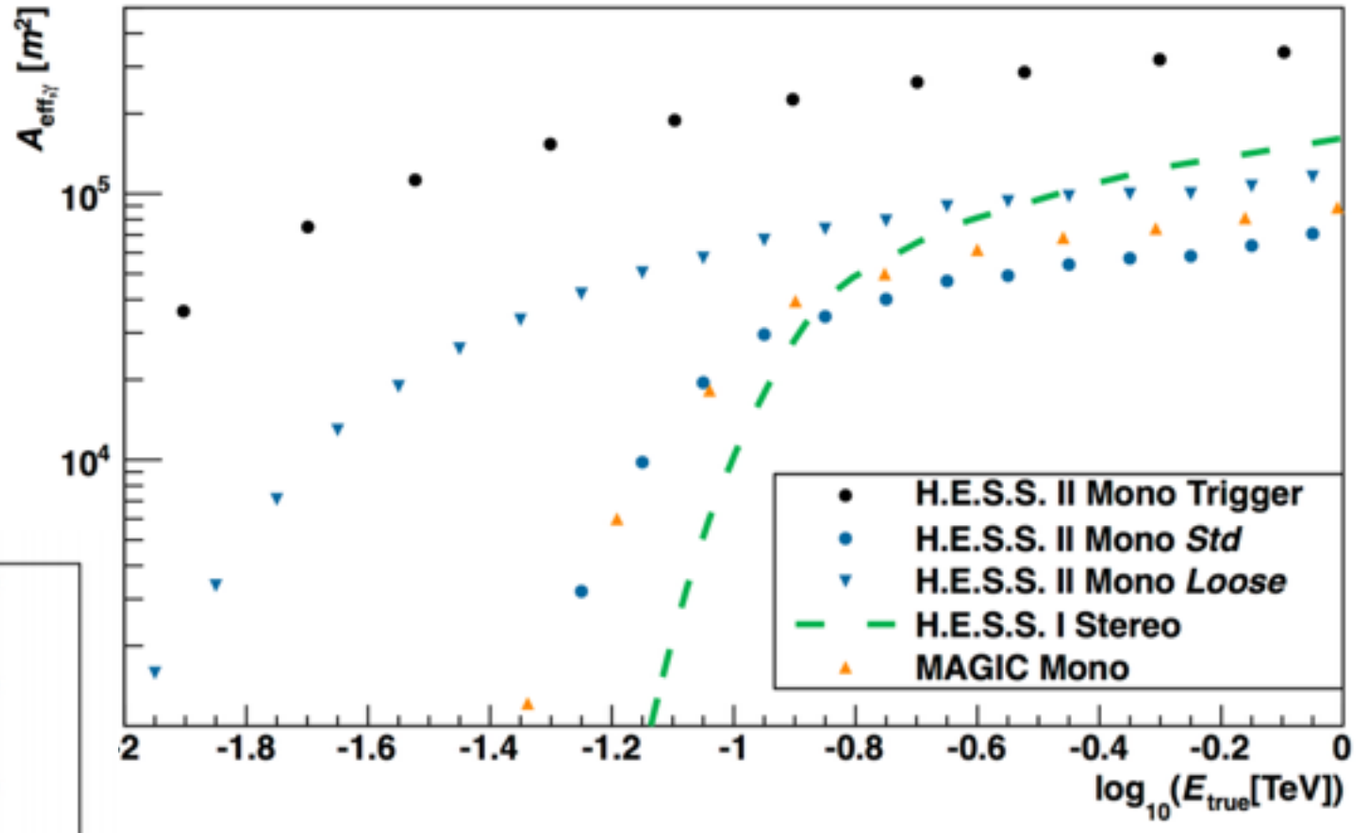
diffuse IceCube flux:
$\varphi(E) = 2.2 \times 10^{-8} E^{-2.58}$ GeV cm^{-2} s^{-1} sr^{-1}
assuming 1000 sources

3FGL "candidate" source
within IceCube ROI



GRB follow-up: sensitivity





- rapid response + best sensitivity
- waiting for the first detection ;-)