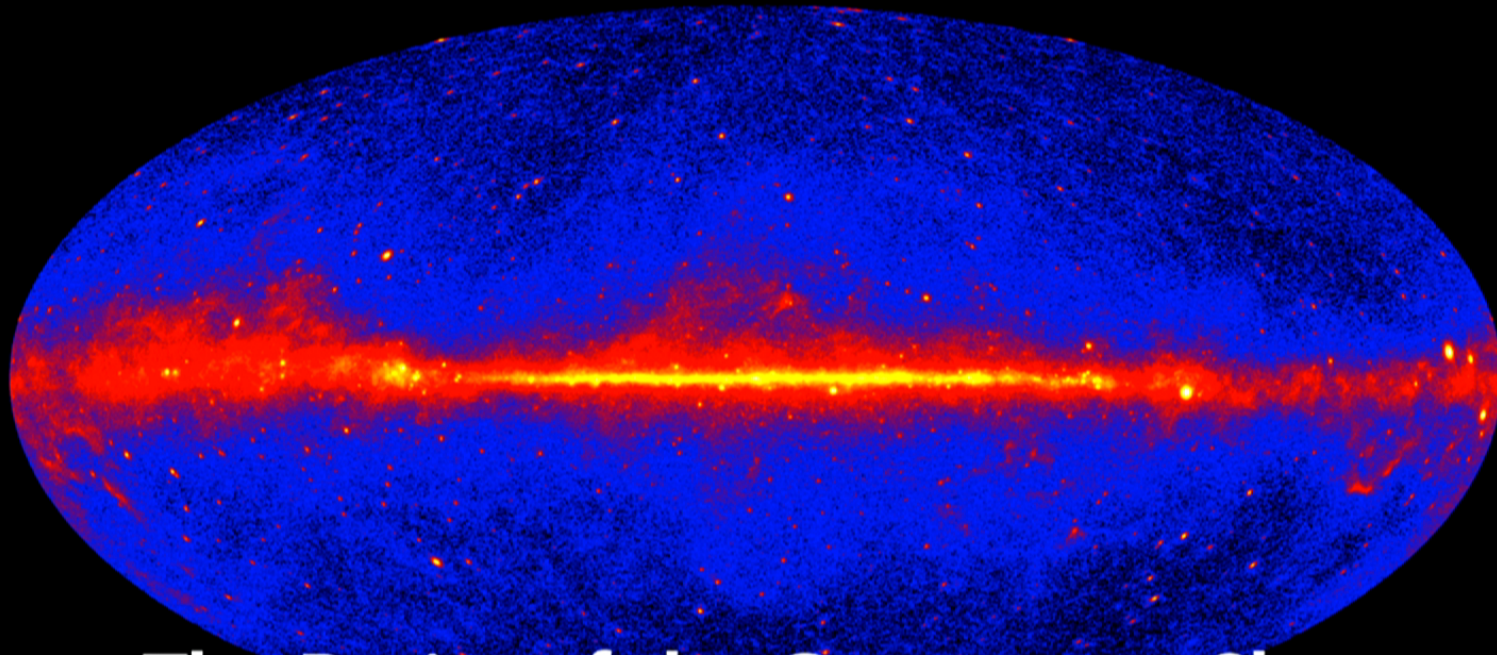


Title: The Basics of the Gamma-ray Sky: current observational status and future perspectives

Date: Mar 14, 2016 11:00 AM

URL: <http://pirsa.org/16030089>

Abstract:



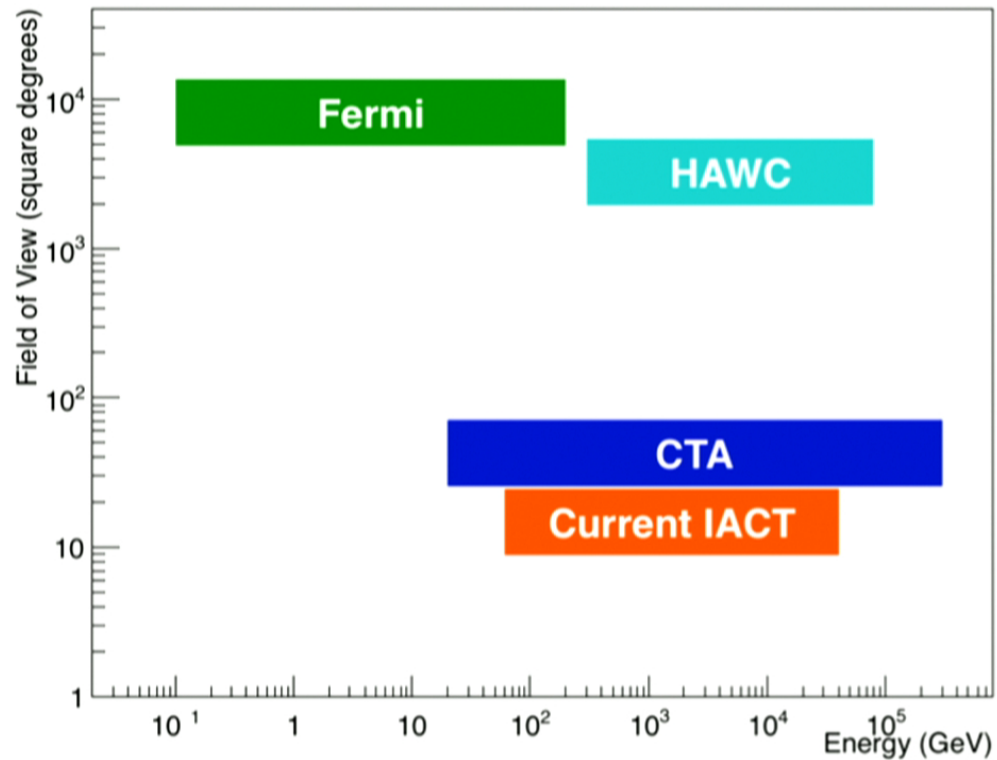
The Basics of the Gamma-ray Sky: Current Observational Status and Future Perspectives

Jim Hinton - MPIK Heidelberg

*Feedback over 44 orders of magnitude: from Gamma-rays to the Universe,
Perimeter Institute, 14th March 2016*



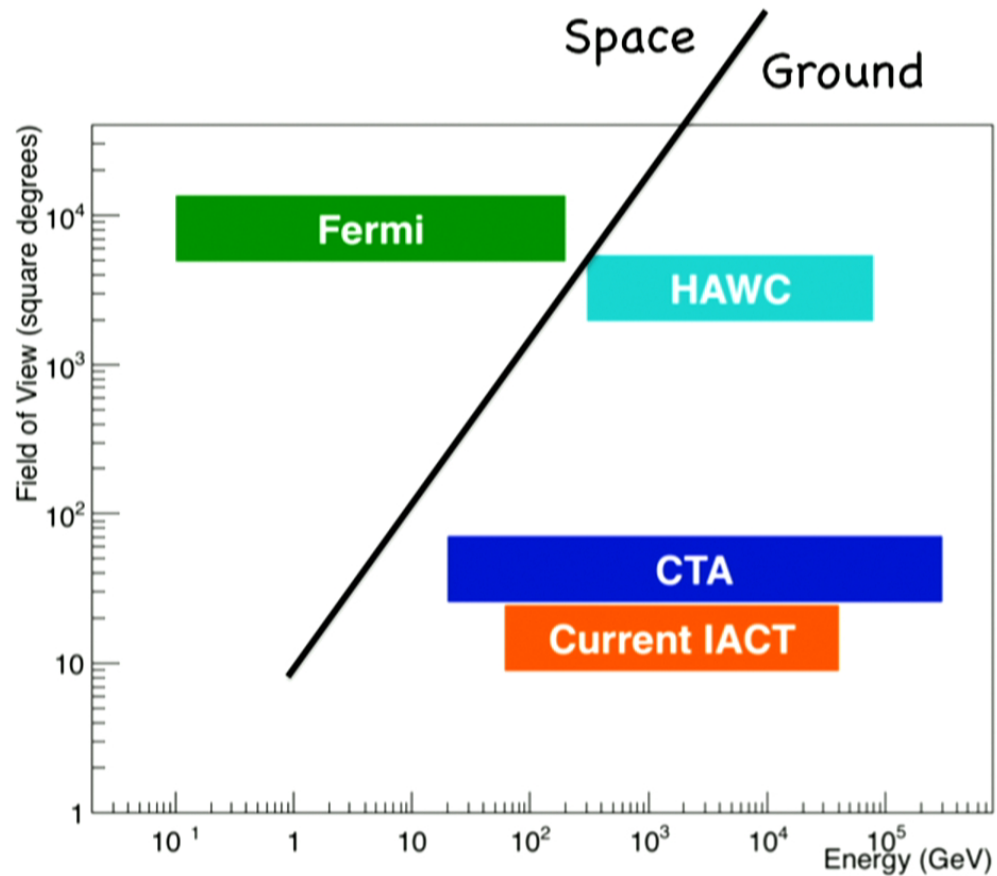
High Energy Gamma-ray Instruments



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

2

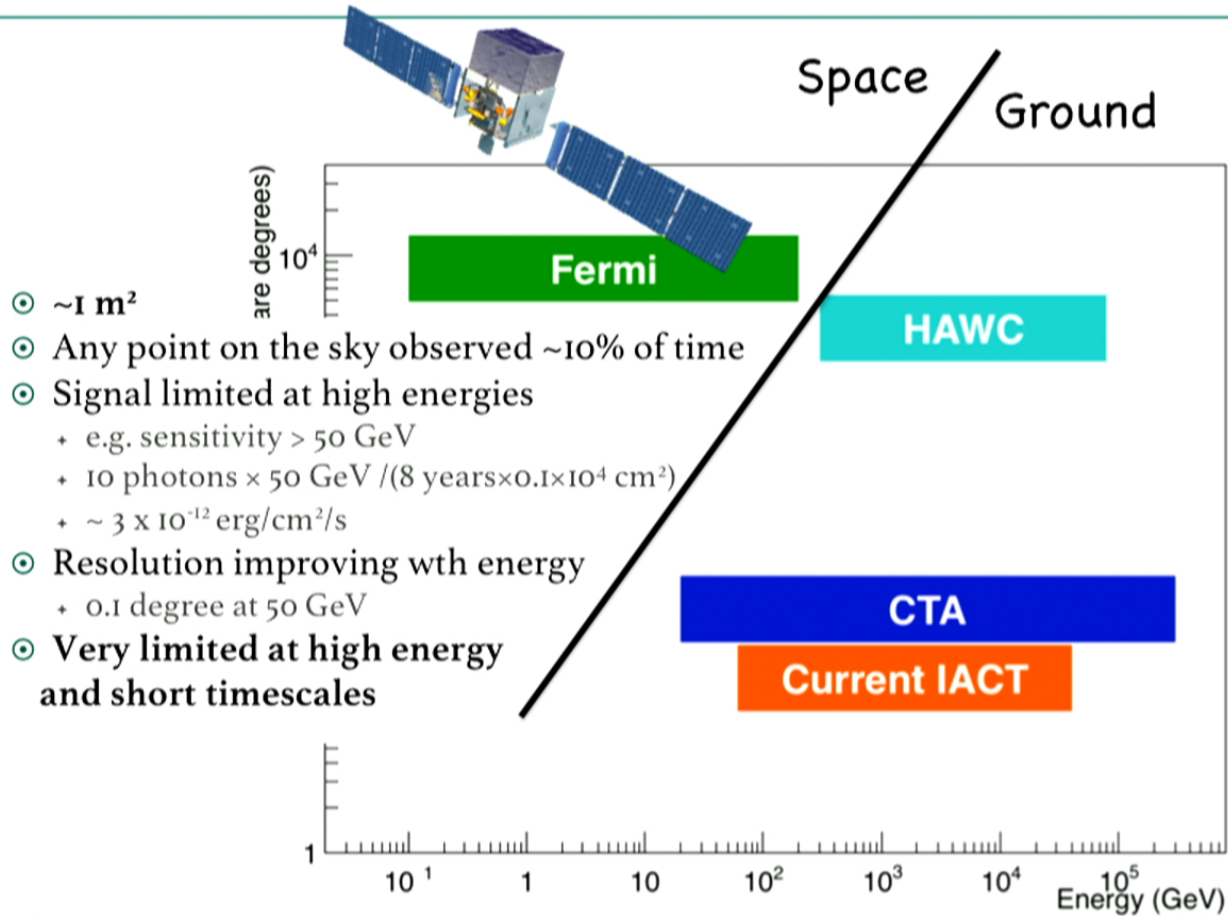
High Energy Gamma-ray Instruments



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

3

High Energy Gamma-ray Instruments

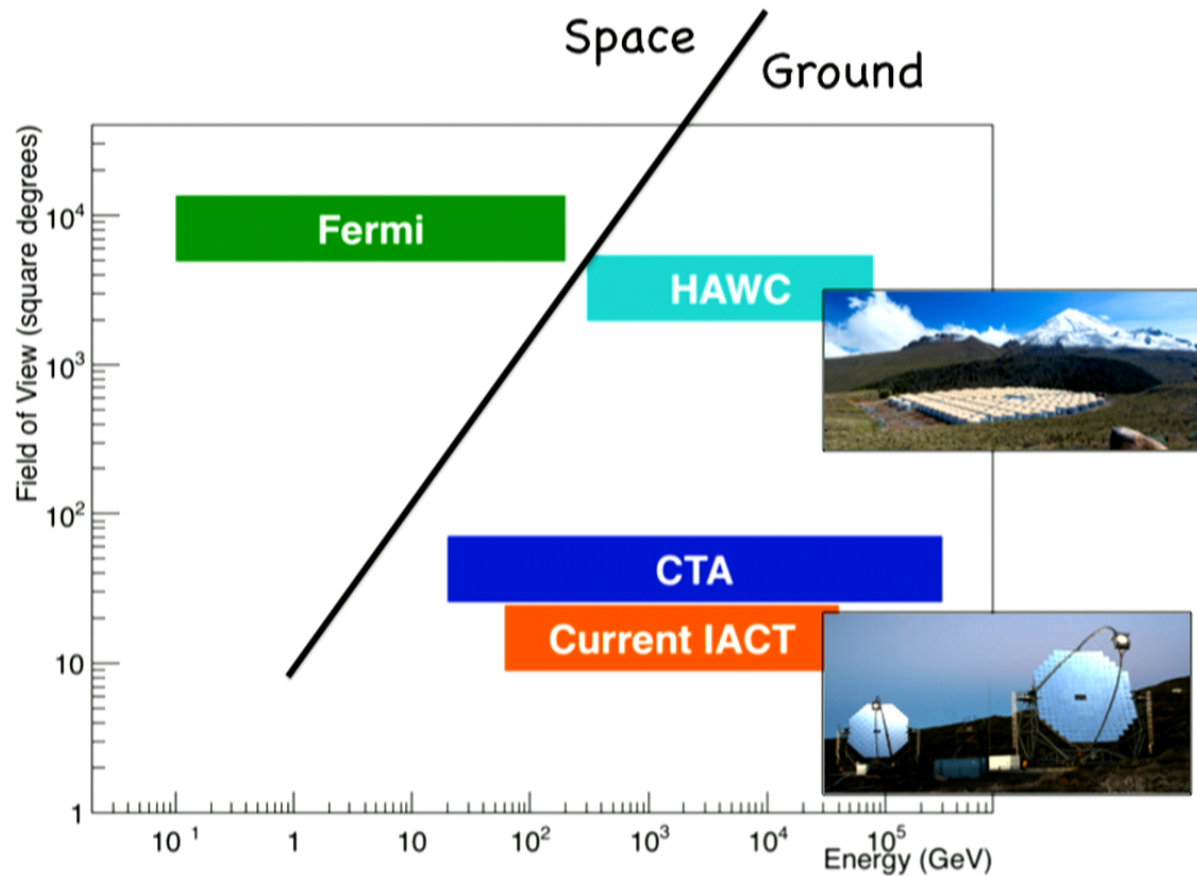


- ⊙ ~1 m²
- ⊙ Any point on the sky observed ~10% of time
- ⊙ Signal limited at high energies
 - + e.g. sensitivity > 50 GeV
 - + 10 photons × 50 GeV / (8 years × 0.1 × 10⁴ cm²)
 - + ~ 3 × 10⁻¹² erg/cm²/s
- ⊙ Resolution improving with energy
 - + 0.1 degree at 50 GeV
- ⊙ **Very limited at high energy and short timescales**

"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

4

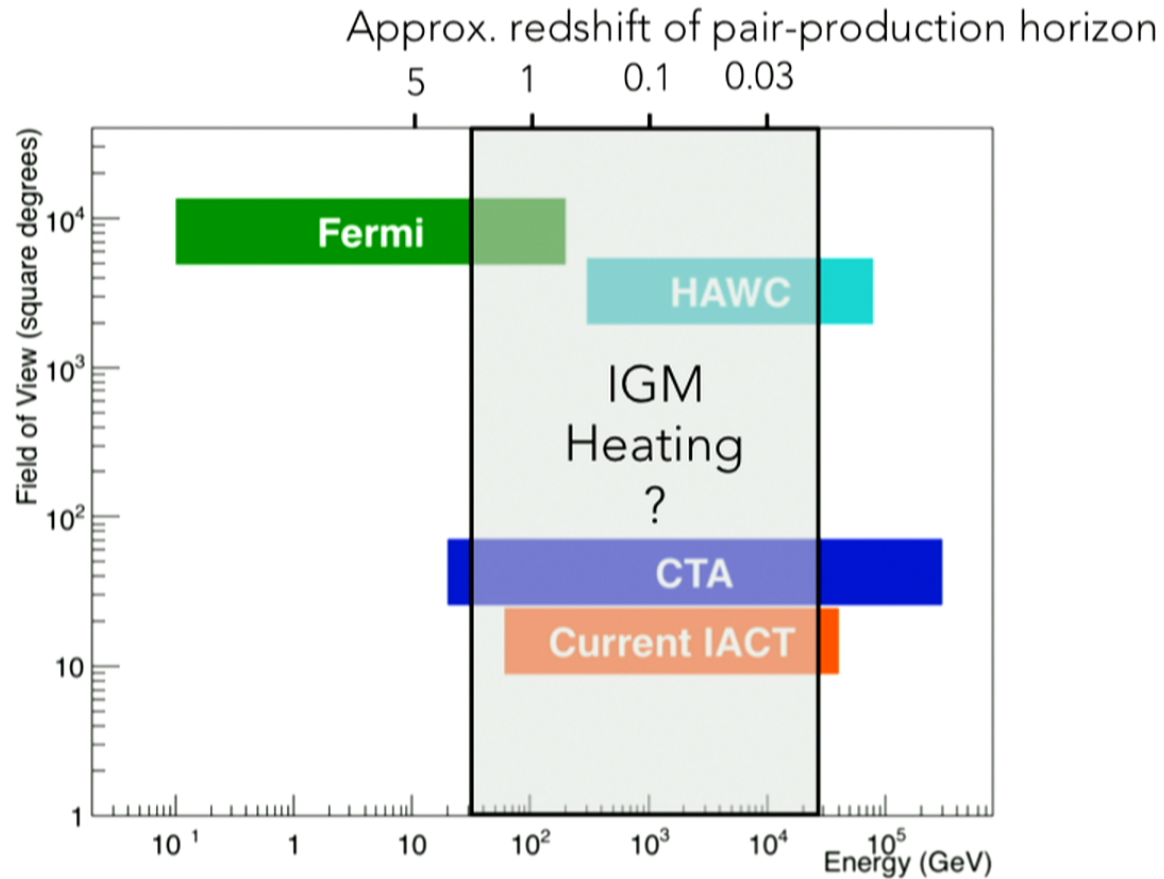
High Energy Gamma-ray Instruments



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

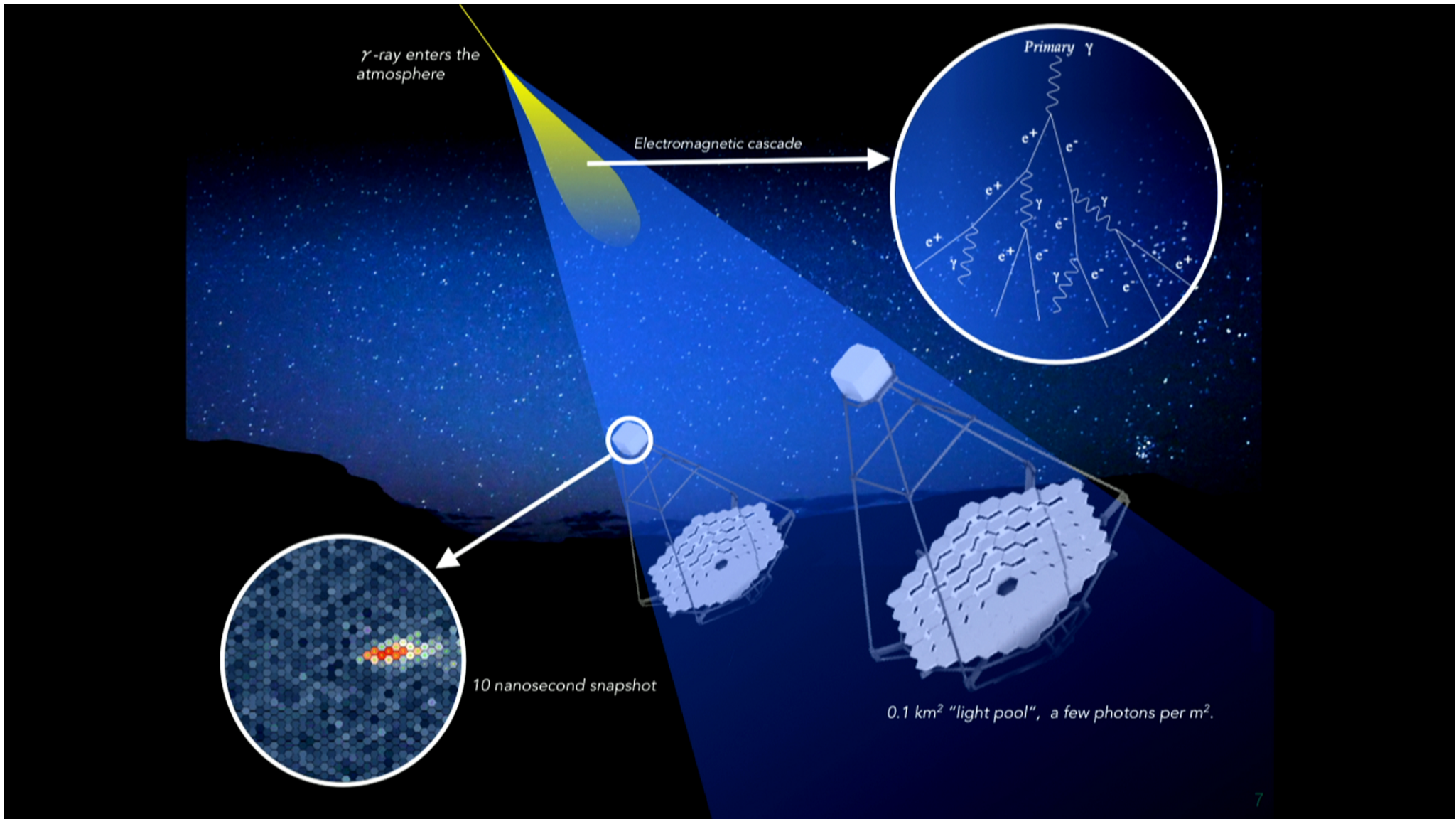
5

High Energy Gamma-ray Instruments



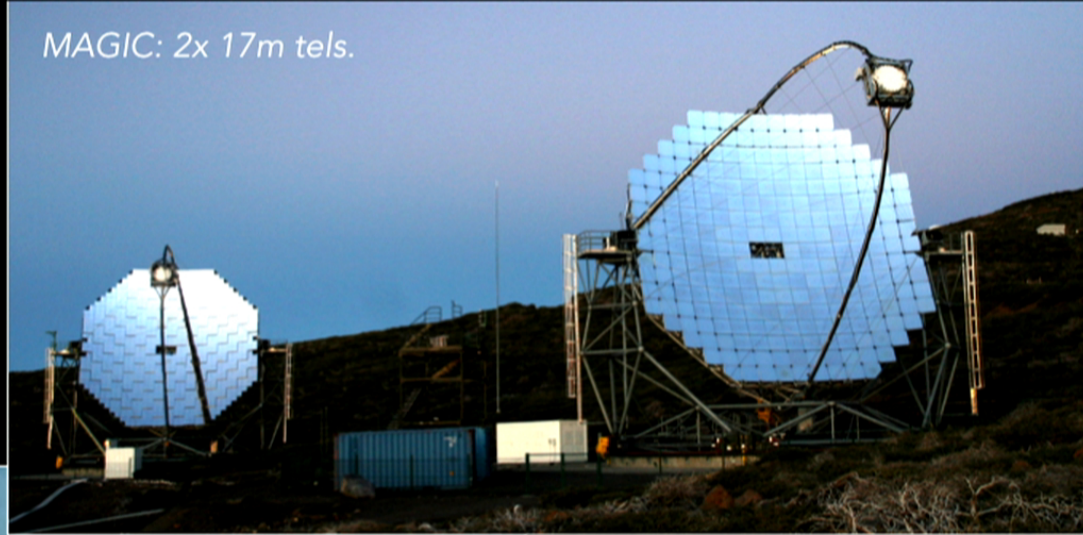
"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

6



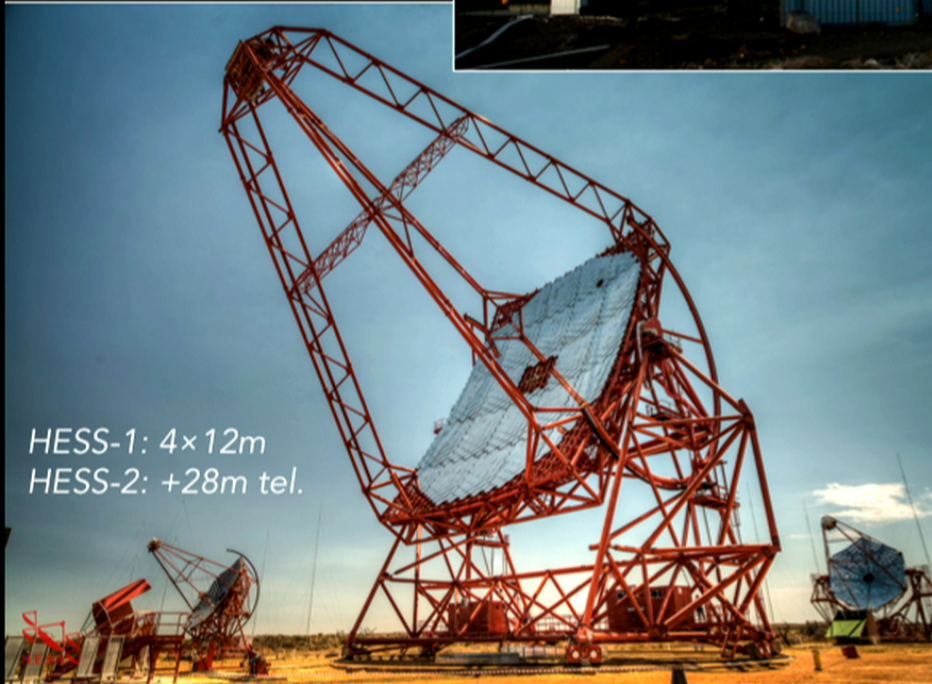
Namibia

MAGIC: 2x 17m tels.



Canary Islands

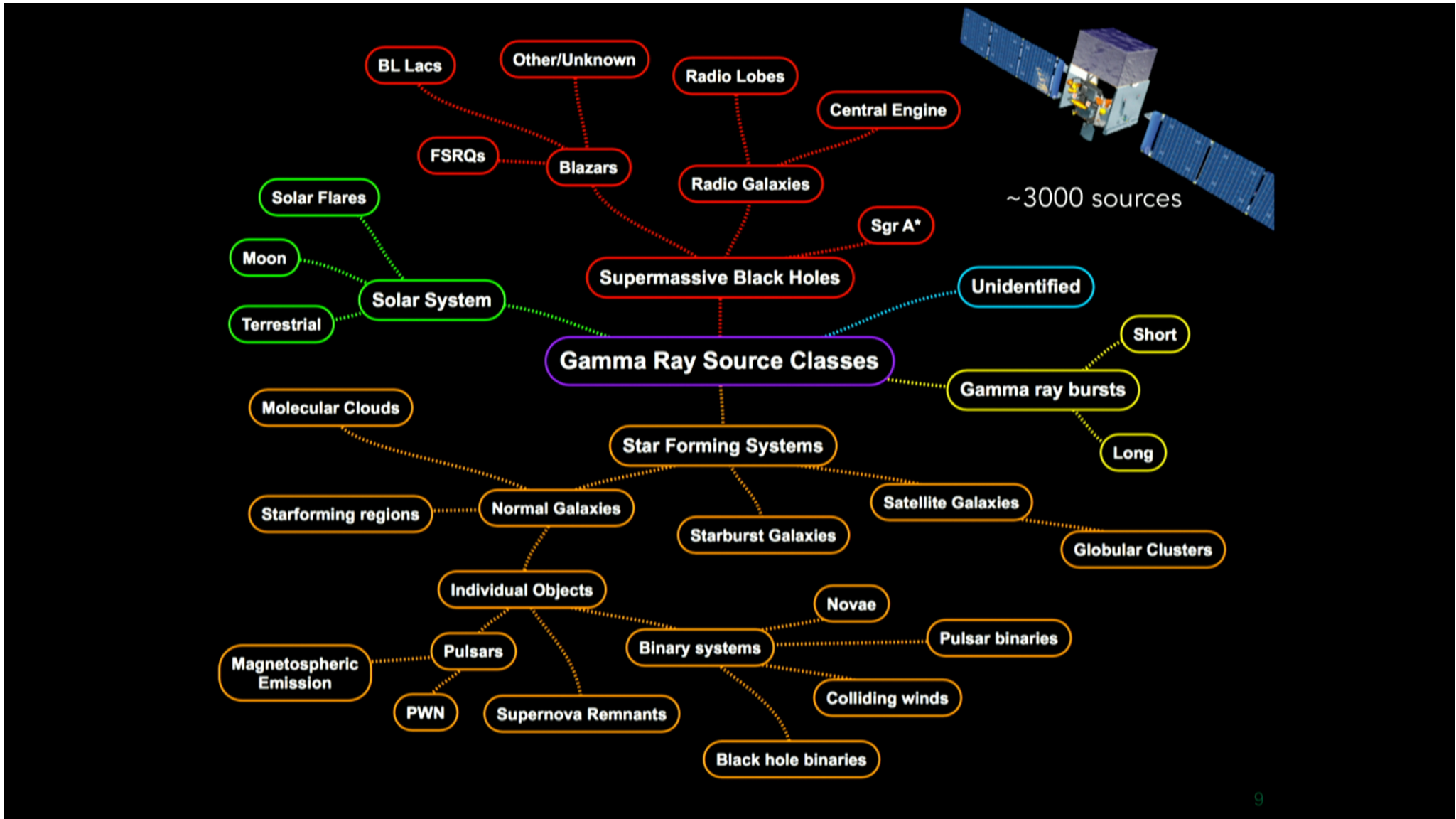
HESS-1: 4x 12m
HESS-2: +28m tel.



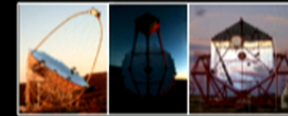
Arizona

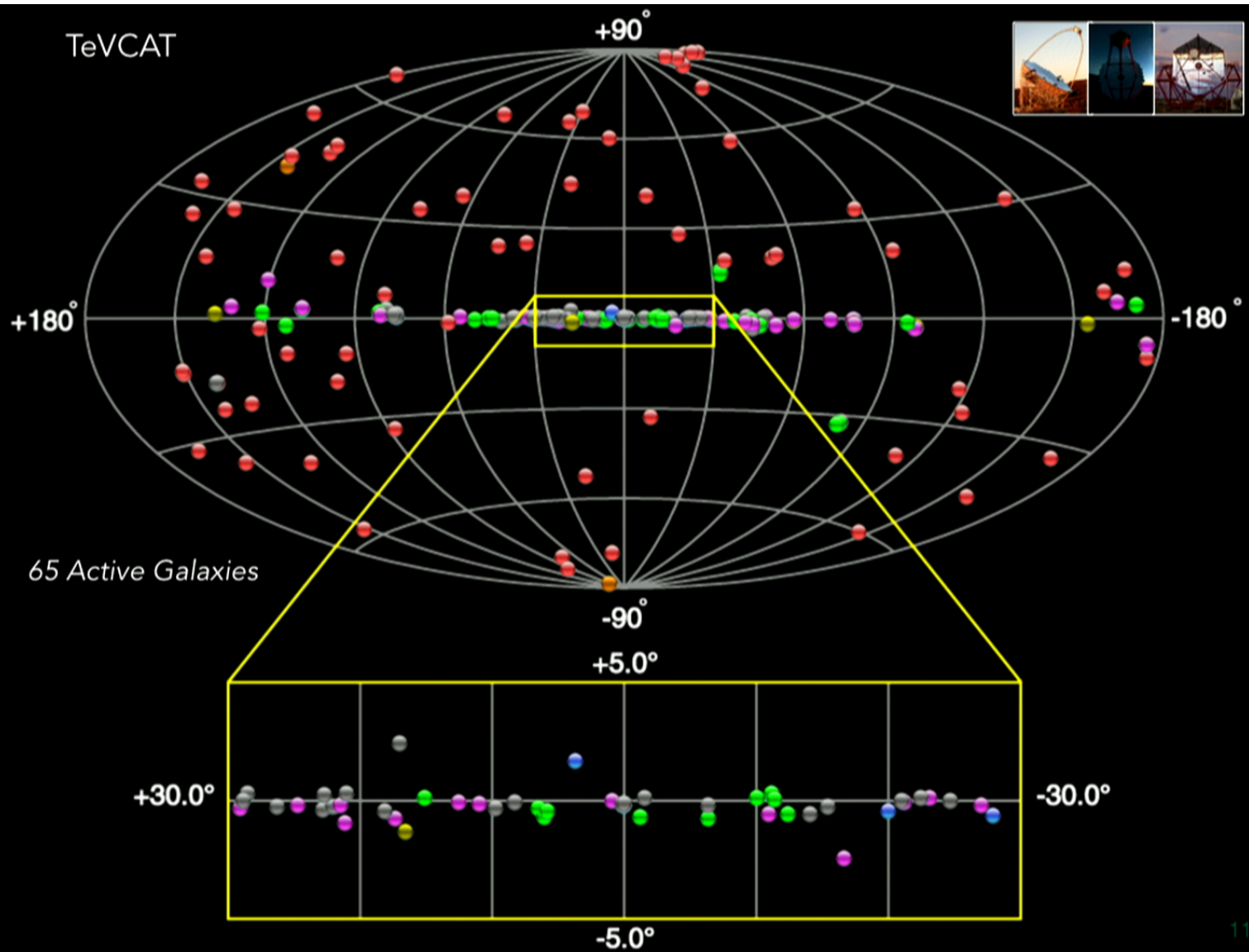
VERITAS: 4x 12m tels.





175 Sources
Ground-based
'TeV' instruments

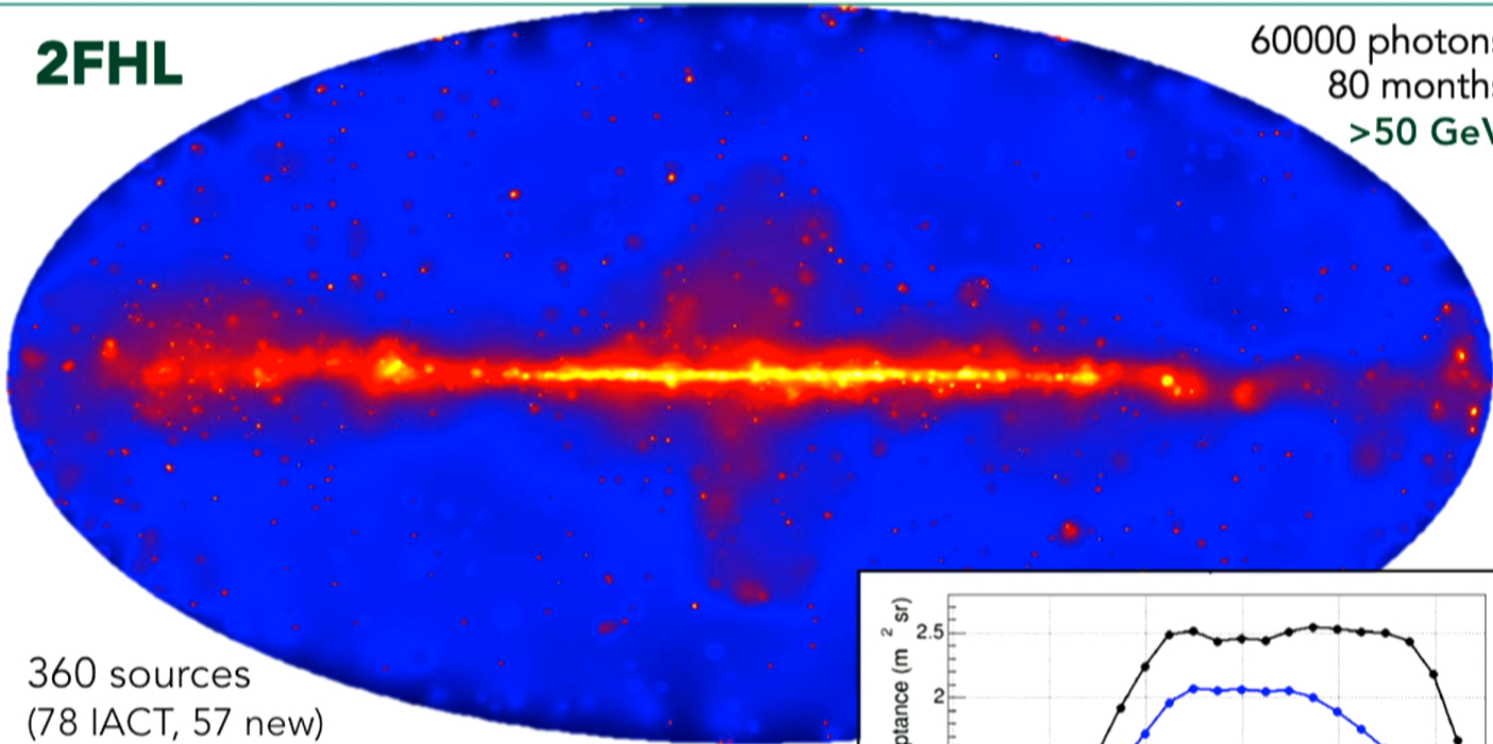




Second Fermi Hard Source Catalogue

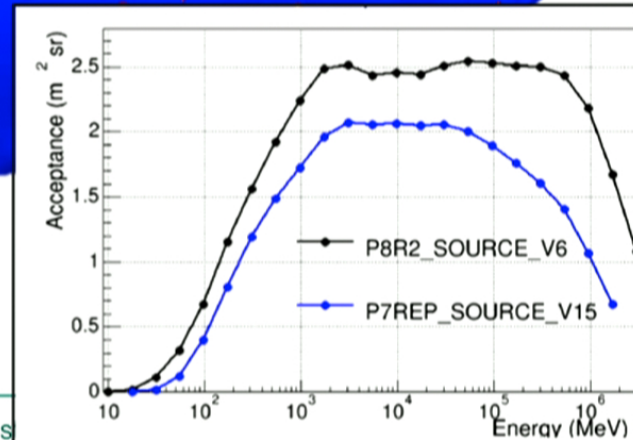
2FHL

60000 photons
80 months
>50 GeV



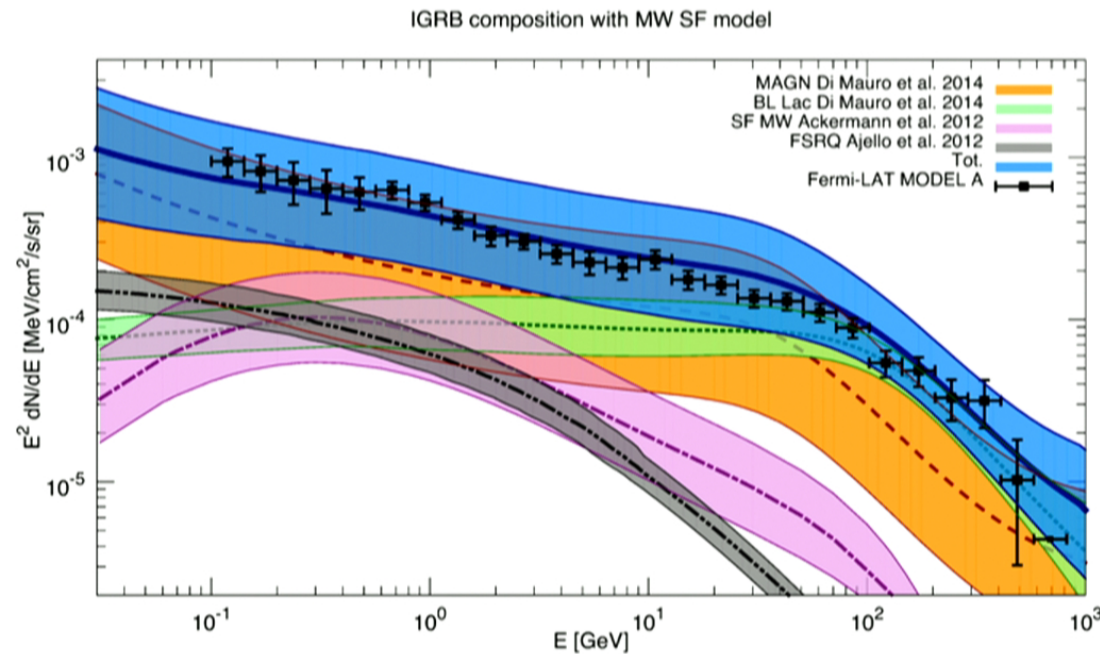
360 sources
(78 IACT, 57 new)
75% AGN
11% Galactic Association
14% Unidentified

Fermi LAT Coll. 2015



"Feedback over 44 orders of magnitude", Perimeter Ins

Extragalactic Background



arXiv1601.04323

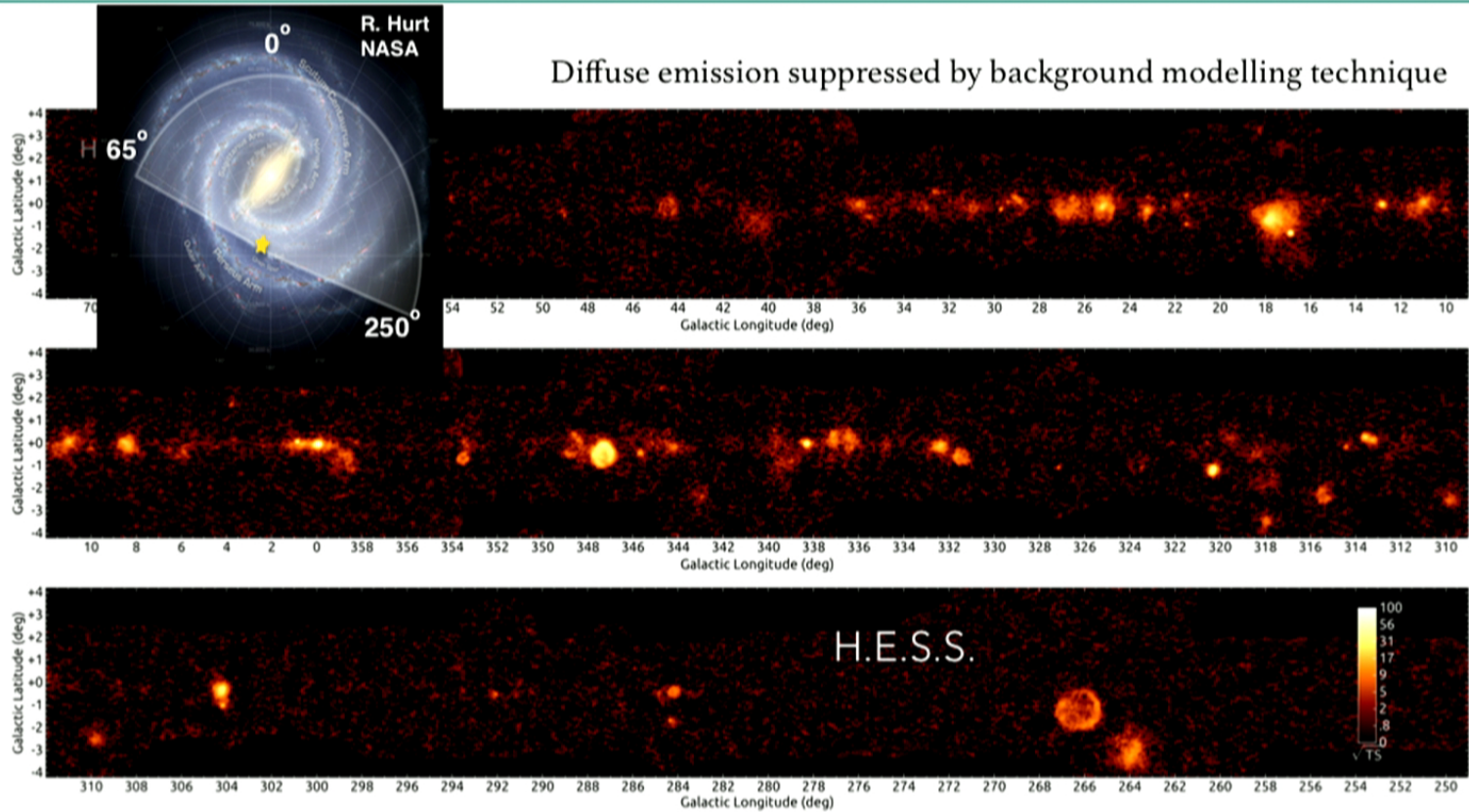
- ⊙ ~90% of EGRB from blazars! , BL Lacs dominate above 100 GeV
- ⊙ Many puzzles here (will come back to that if time)



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

13

The TeV Galactic Plane



Sensitivity 0.5-2% of Crab Nebula Flux



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

14

HAWC



Last Tank Constructed Dec. 2014

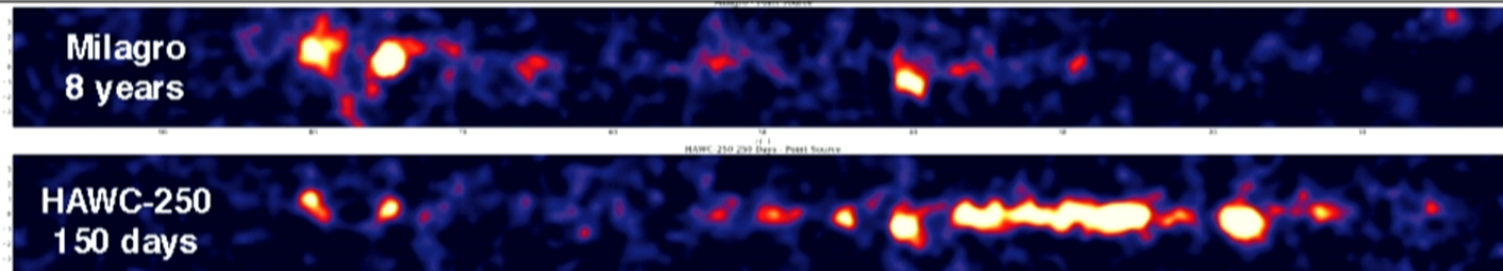
- ⊙ Very wide field of view, very high duty cycle

- + More modest resolution and background rejection power

- ⊙ Very early days but

- + Will reach comparable sensitivity to HESS survey (at \sim TeV energies) for extended objects (\sim 0.3 degrees) very quickly \rightarrow huge improvement for very extended emission
- + Planned outrigger extension (2016) - improved high energy performance

\rightarrow Lots of potential, exciting times



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

HAWC



Last Tank Constructed Dec. 2014

⊙ Very wide field of view, very high duty cycle

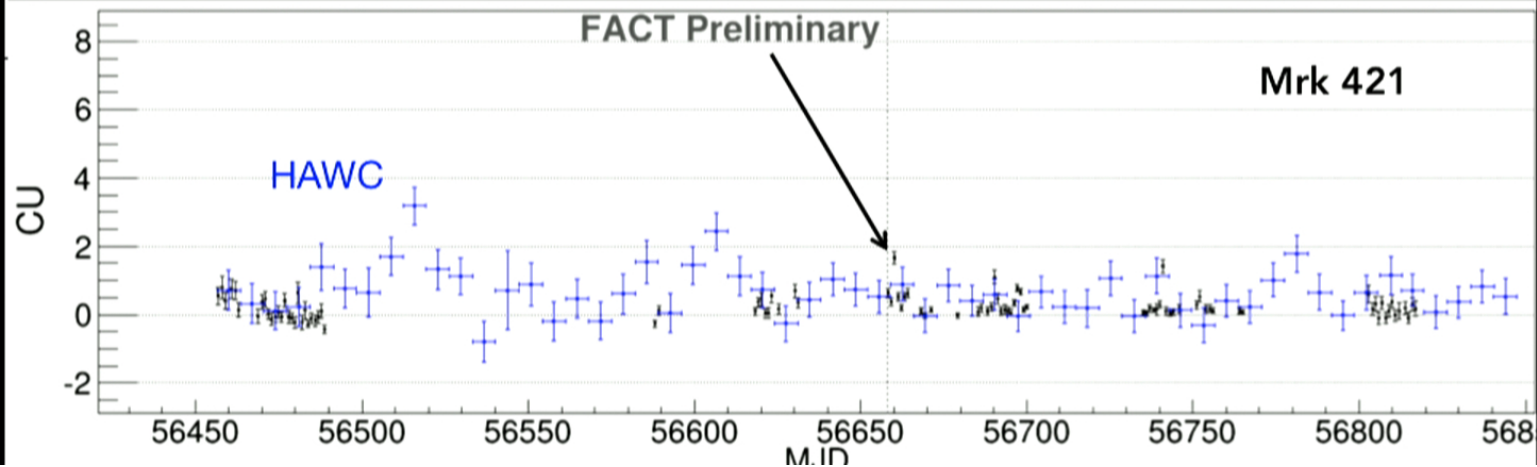
+ More modest resolution and background rejection power

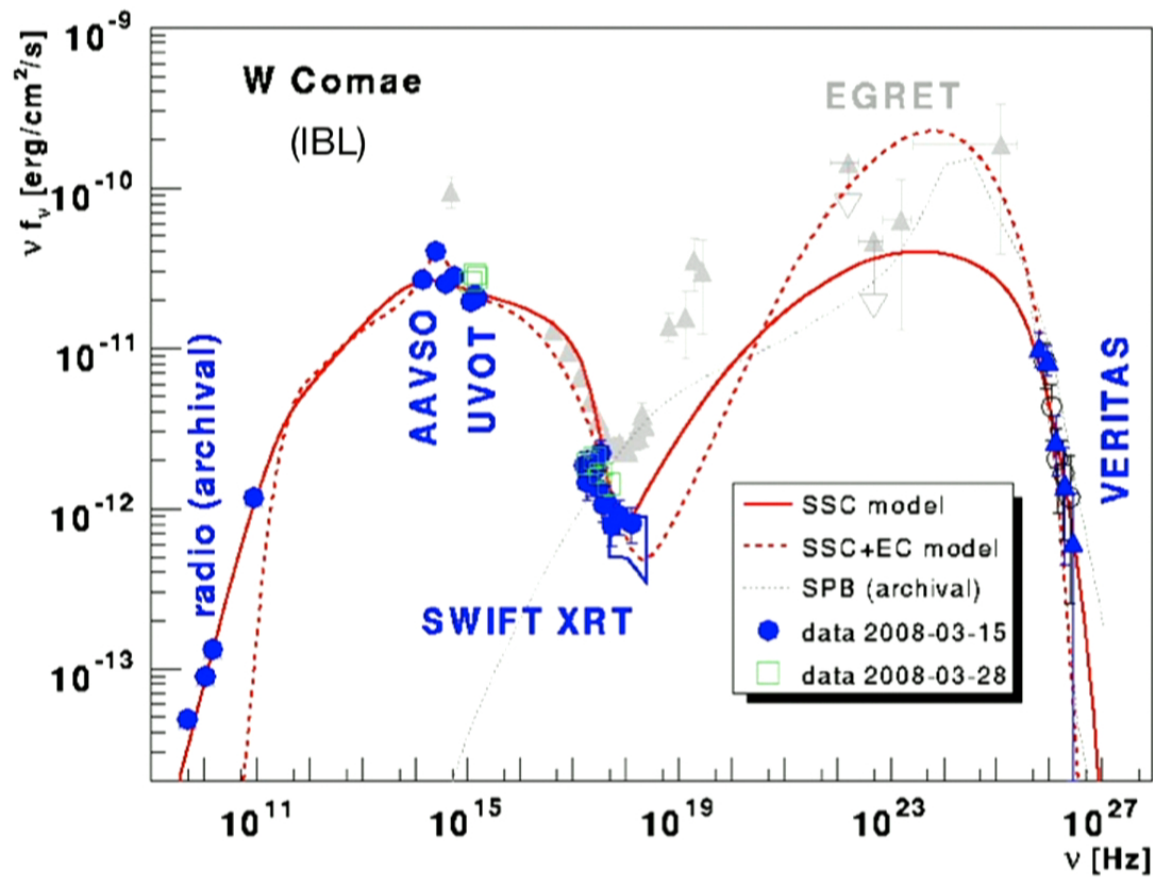
⊙ Very early days but

+ Will reach comparable sensitivity to HESS survey (at \sim TeV energies) for extended objects (\sim 0.3 degrees) very quickly \rightarrow huge improvement for very extended emission

+ Planned outrigger extension (2016) - improved high energy performance

\rightarrow Lots of potential, exciting times

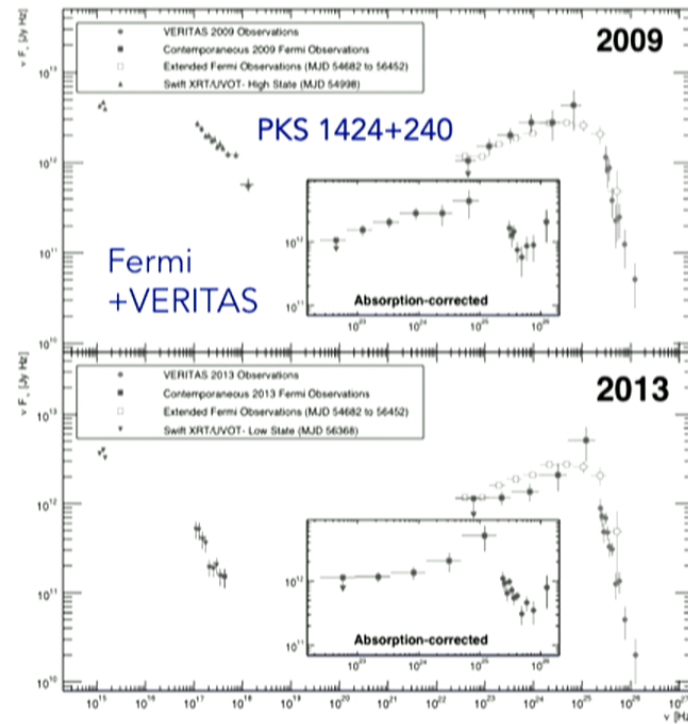
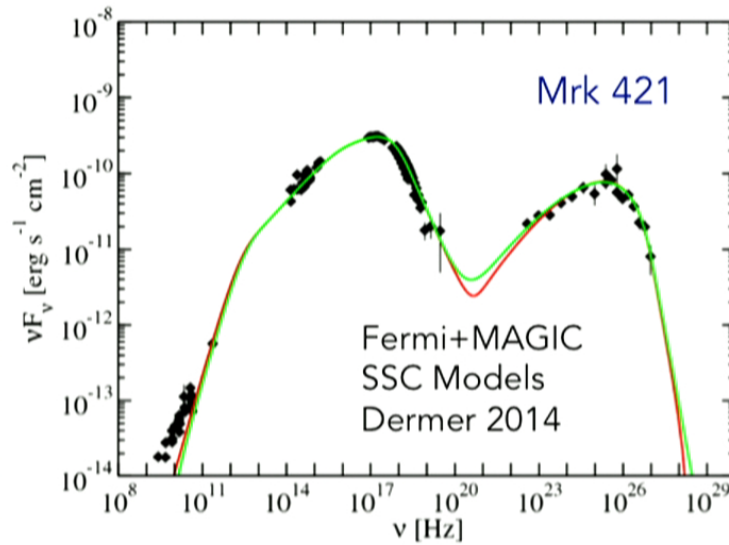




⊙ Very poor experimental situation 1-100 GeV pre-Fermi

TeV Blazars

⊙ High energy peaked BL Lac objects – the typical TeV-emitting AGN



“Feedback over 44 orders of magnitude”, Perimeter Institute, March 14th 2016

18

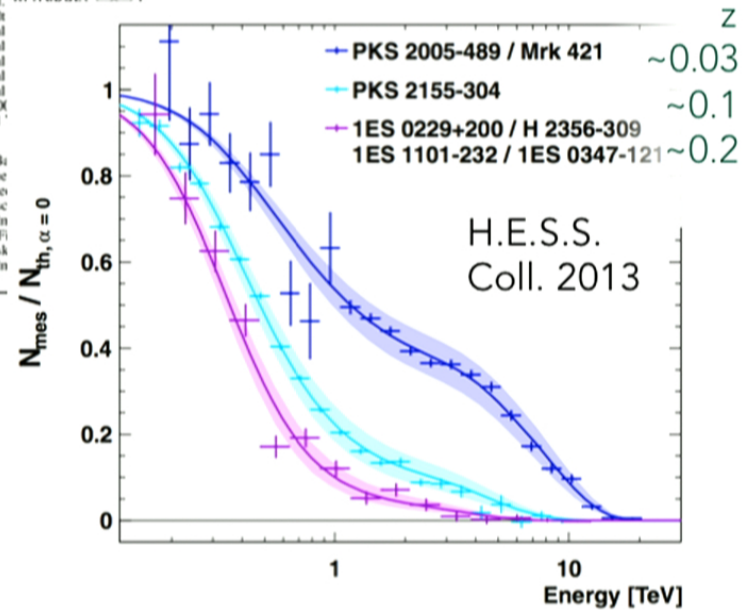
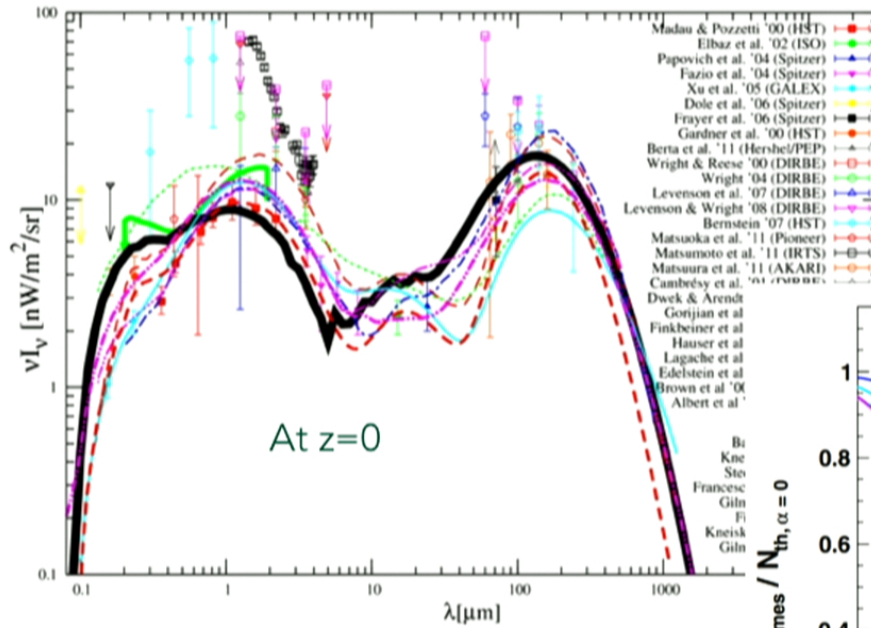
EBL Absorption



Threshold:

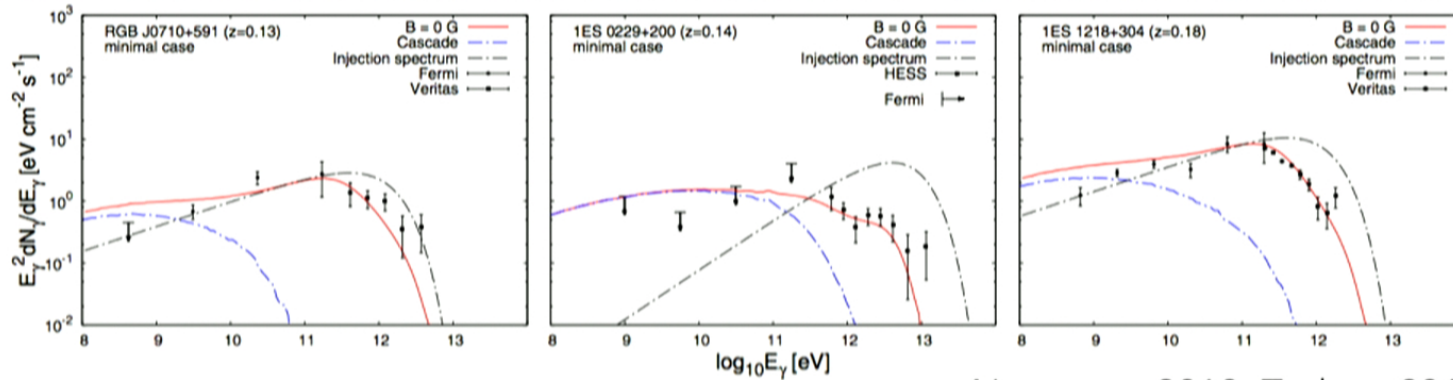
$$E_\gamma E_T > m_e^2 c^4$$

$$\text{or } E_{\text{TeV}} > 0.26/E_{\text{eV}}$$

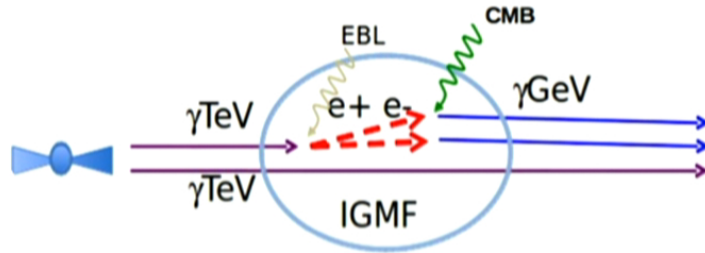


- ⊙ 1 μm background → 200 GeV γs
- ⊙ 100 μm background → 20 TeV γs
- ⊙ Pairs can IC scatter → cascades

Missing cascade gammas



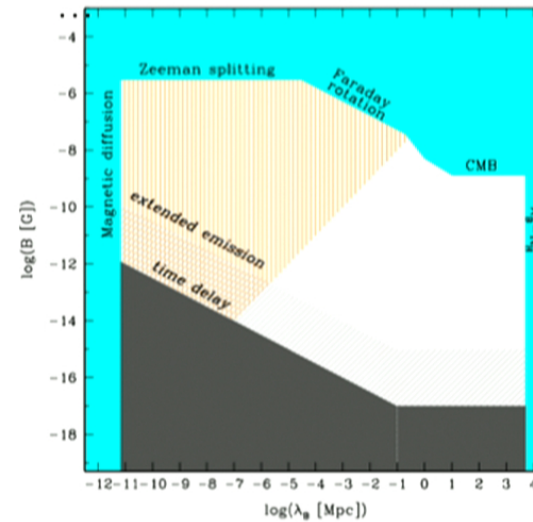
Neronov+ 2010, Taylor+ 2011



E. Prandini

⊙ Implies:

- + Pairs lose energy (by synch. ? ✗ need v. high B)
- + or deflections are big enough to make a halo which is hard to see



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

20

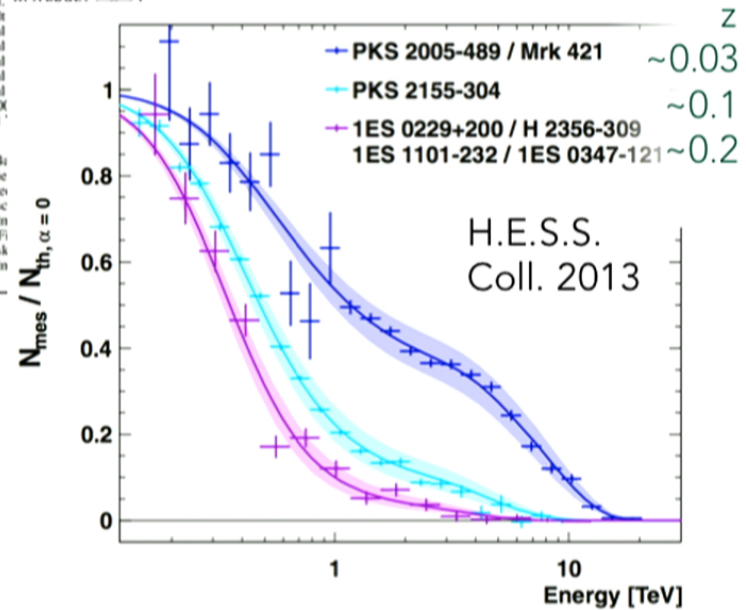
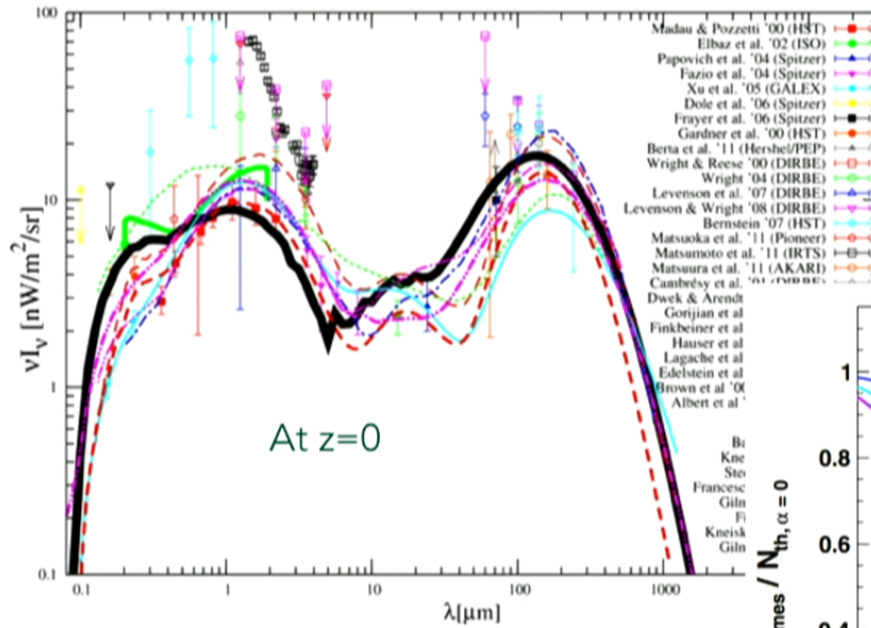
EBL Absorption



Threshold:

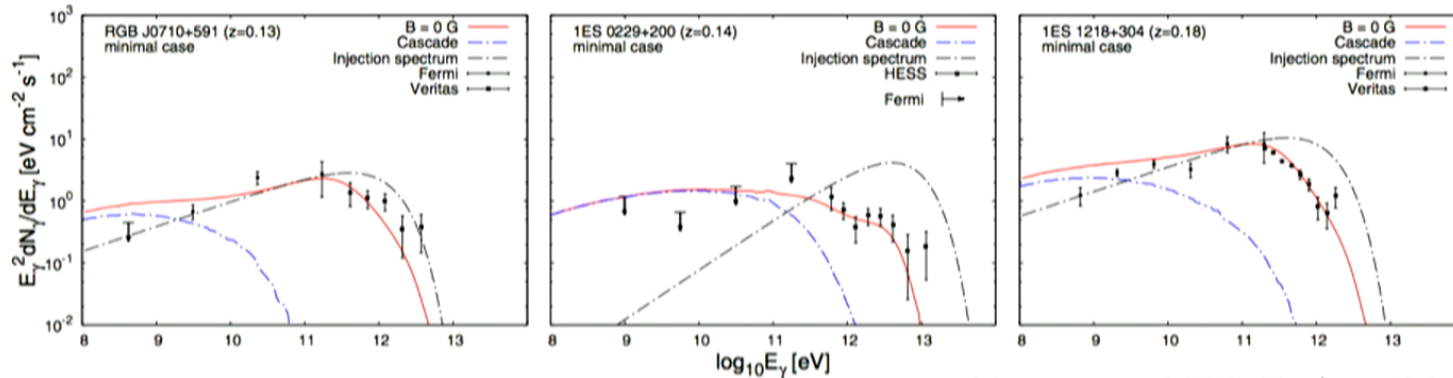
$$E_\gamma E_T > m_e^2 c^4$$

$$\text{or } E_{\text{TeV}} > 0.26/E_{\text{eV}}$$

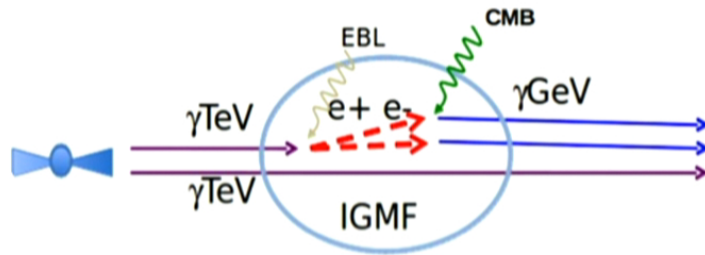


- ⊙ 1 μm background \rightarrow 200 GeV γ s
- ⊙ 100 μm background \rightarrow 20 TeV γ s
- ⊙ Pairs can IC scatter \rightarrow cascades

Missing cascade gammas



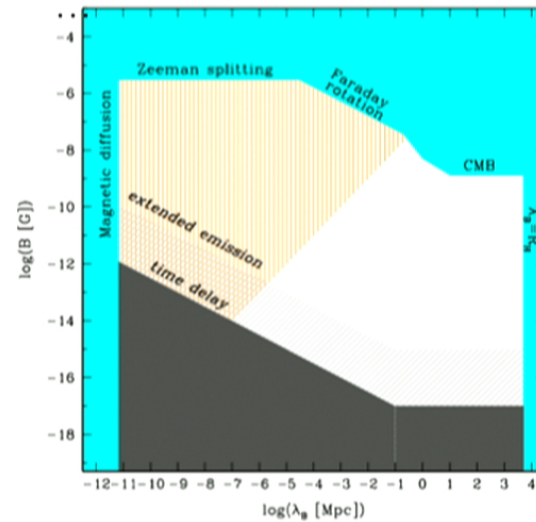
Neronov+ 2010, Taylor+ 2011



E. Prandini

Implies:

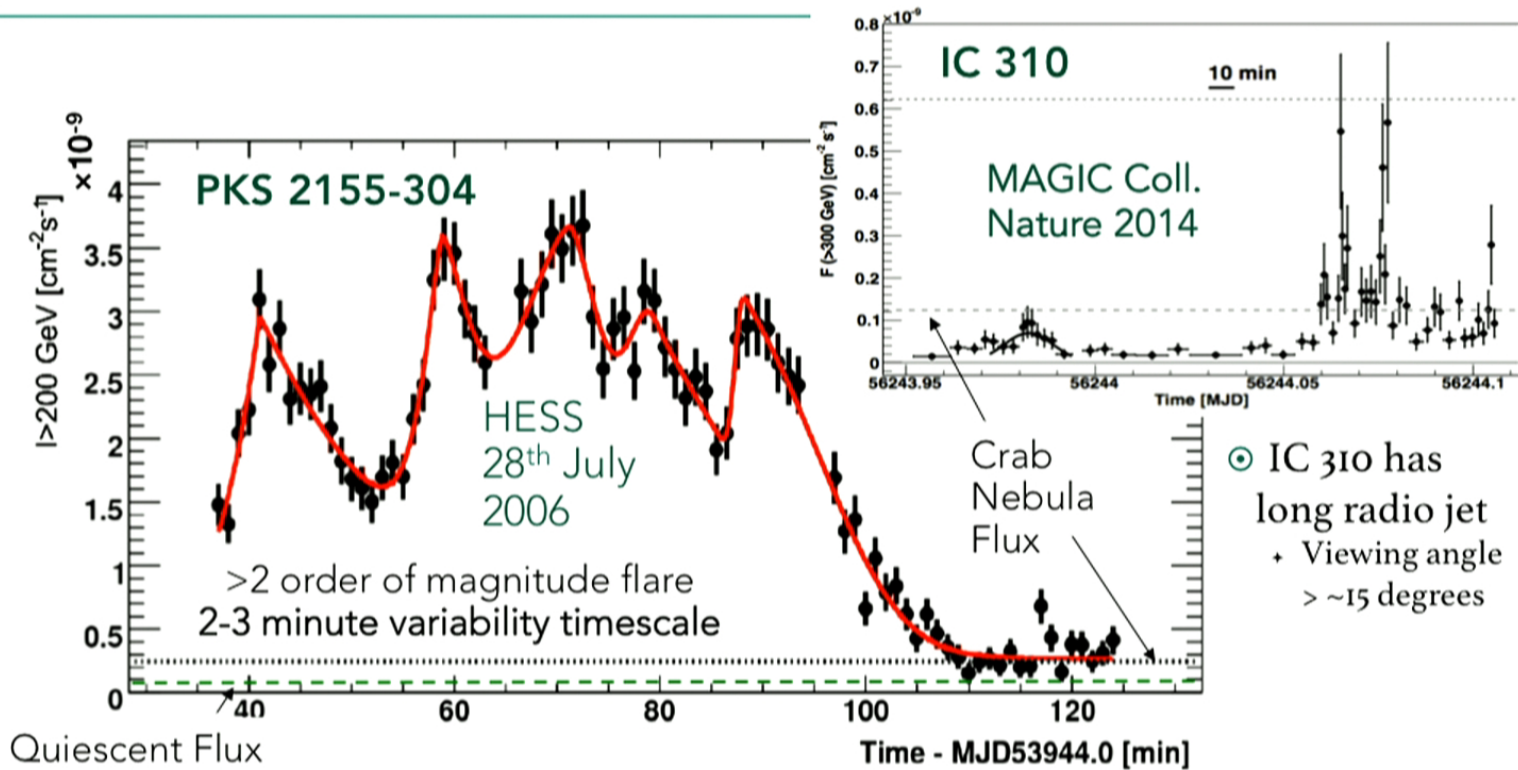
- + Pairs lose energy (by synch. ? ✗ need v. high B)
- + or deflections are big enough to make a halo which is hard to see



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

20

TeV Blazar Variability



- ⊙ Variability timescales down to $\sim 1\% R_S c$
 - + Causality requires $R < ct_{\text{var}} \delta$, emission region is very small, and
 - + Implies bulk motion with $\Gamma > 50$ (e.g. Begelman, Fabian, Rees 2008)

"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

21

The Future?

⊙ Continuations

- + HESS/MAGIC/VERITAS until ~2019
- + HAWC hopefully a bit longer (with outriggers)
- + Fermi until at least 2018

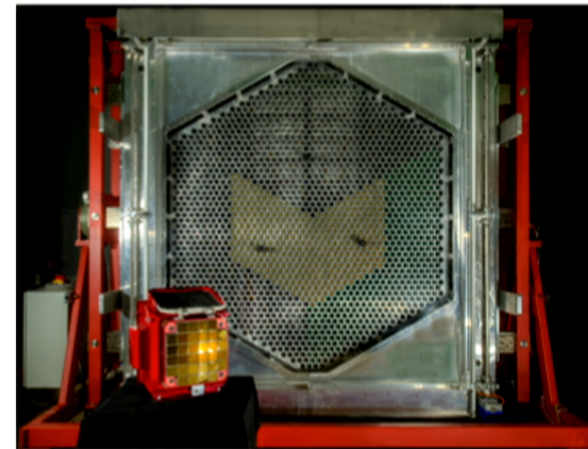
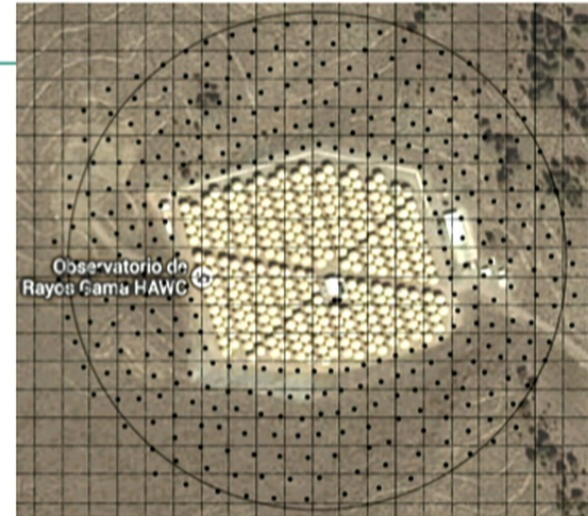
⊙ No instrument significantly better than Fermi >1 GeV is on the horizon

⊙ Ground based future much more positive

- + current instruments have relatively modest cost and technology/techniques are advancing

⊙ Major projects

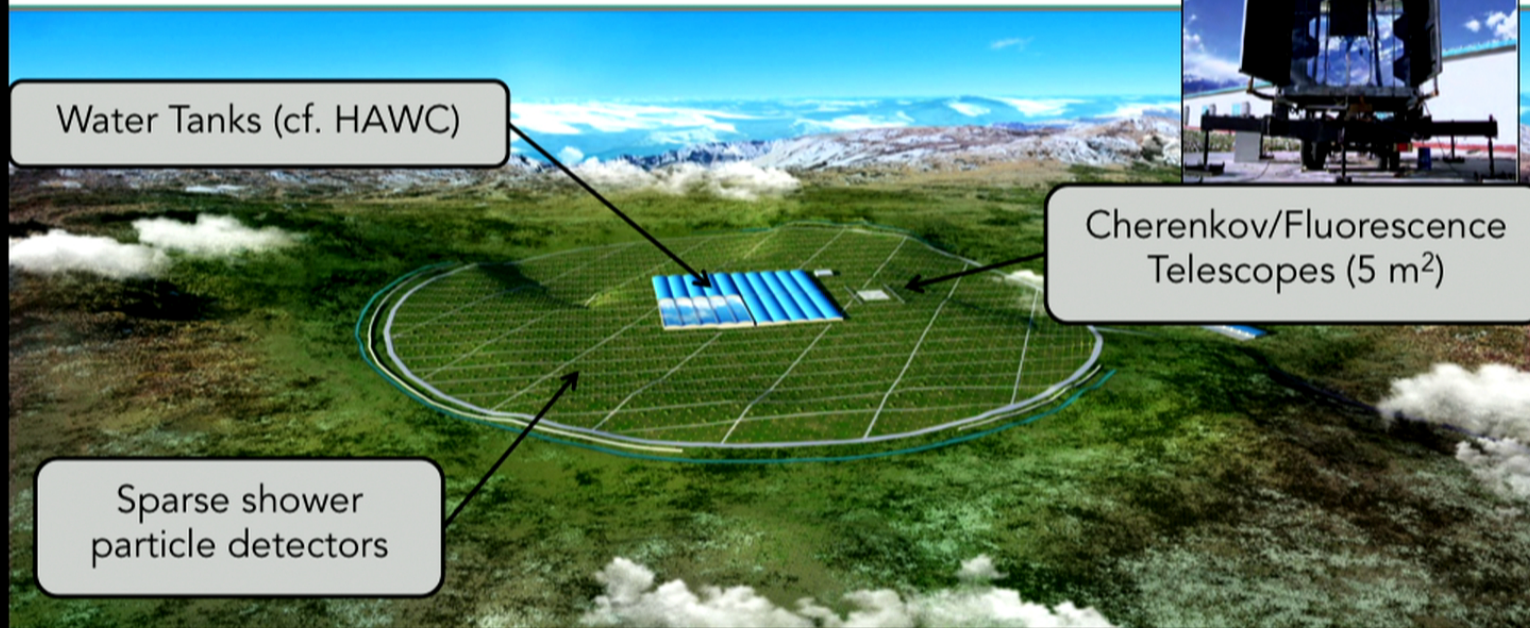
- + CTA
- + HAWC-like detector in southern hemisphere (under discussion)
- + LHAASO



“Feedback over 44 orders of magnitude”, Perimeter Institute, March 14th 2016

22

LHAASO



- ⊙ Multi-component detector for gamma-ray astronomy and cosmic ray studies to be constructed in Sichuan province of China (4.3km asl)
- ⊙ 1% prototype at ARGO site in Tibet is running
- ⊙ Deployment starting in 2016, completion ~2021



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

23

The Cherenkov Telescope Array

- ⊙ A huge improvement in all aspects of performance
 - + A factor ~ 10 in sensitivity, much wider energy coverage, much better resolution, field-of-view, full sky, ...
- ⊙ A user facility / proposal-driven observatory
 - + With two sites and a total of >100 telescopes
 - + User support, open archive, FITS data products
- ⊙ A major international project
 - + 31 nations, >1200 scientists
 - + Including the teams from HESS, MAGIC and VERITAS

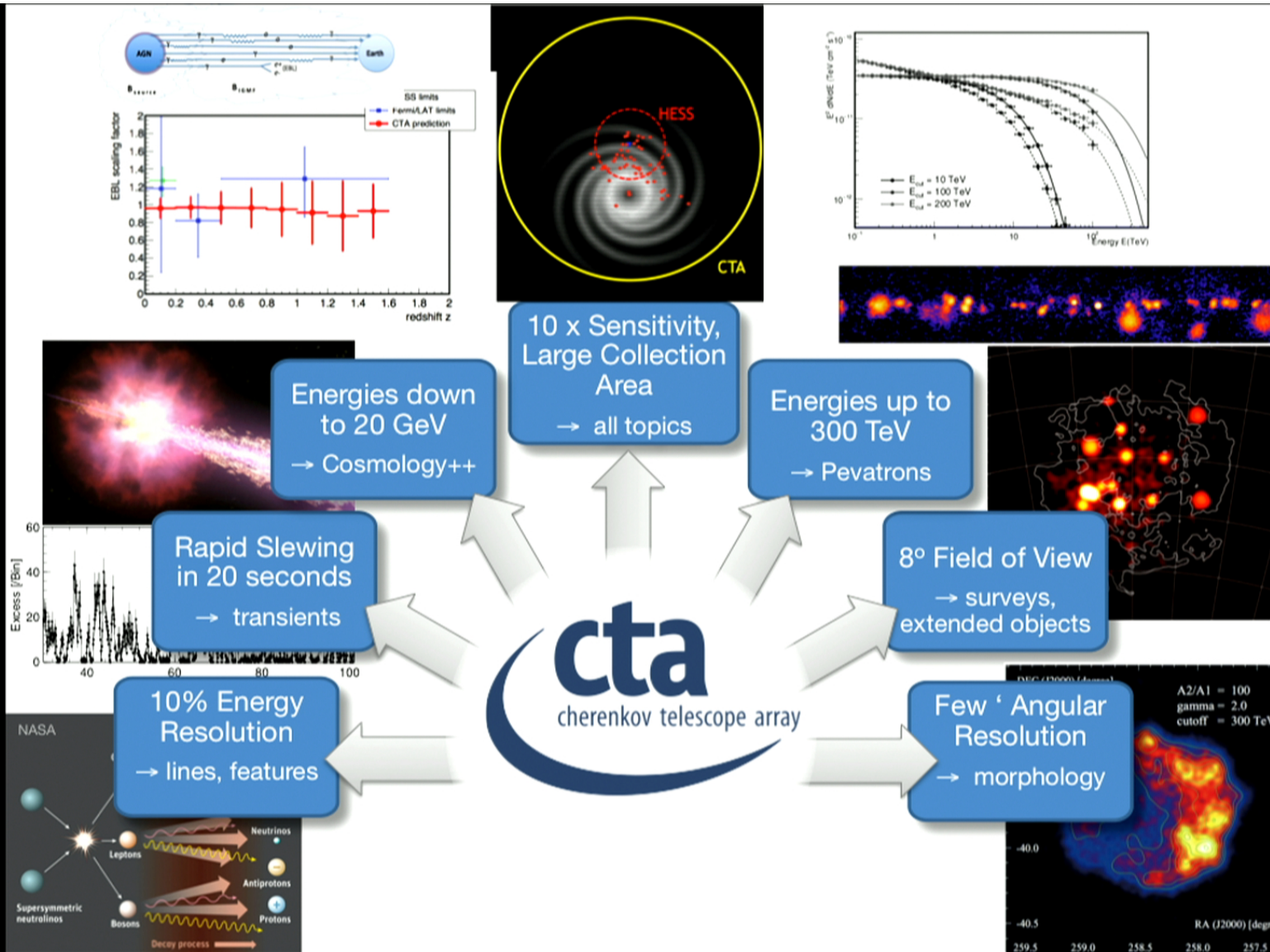
Prototyping -2016, Construction 2017-2020+, Science from ~2018



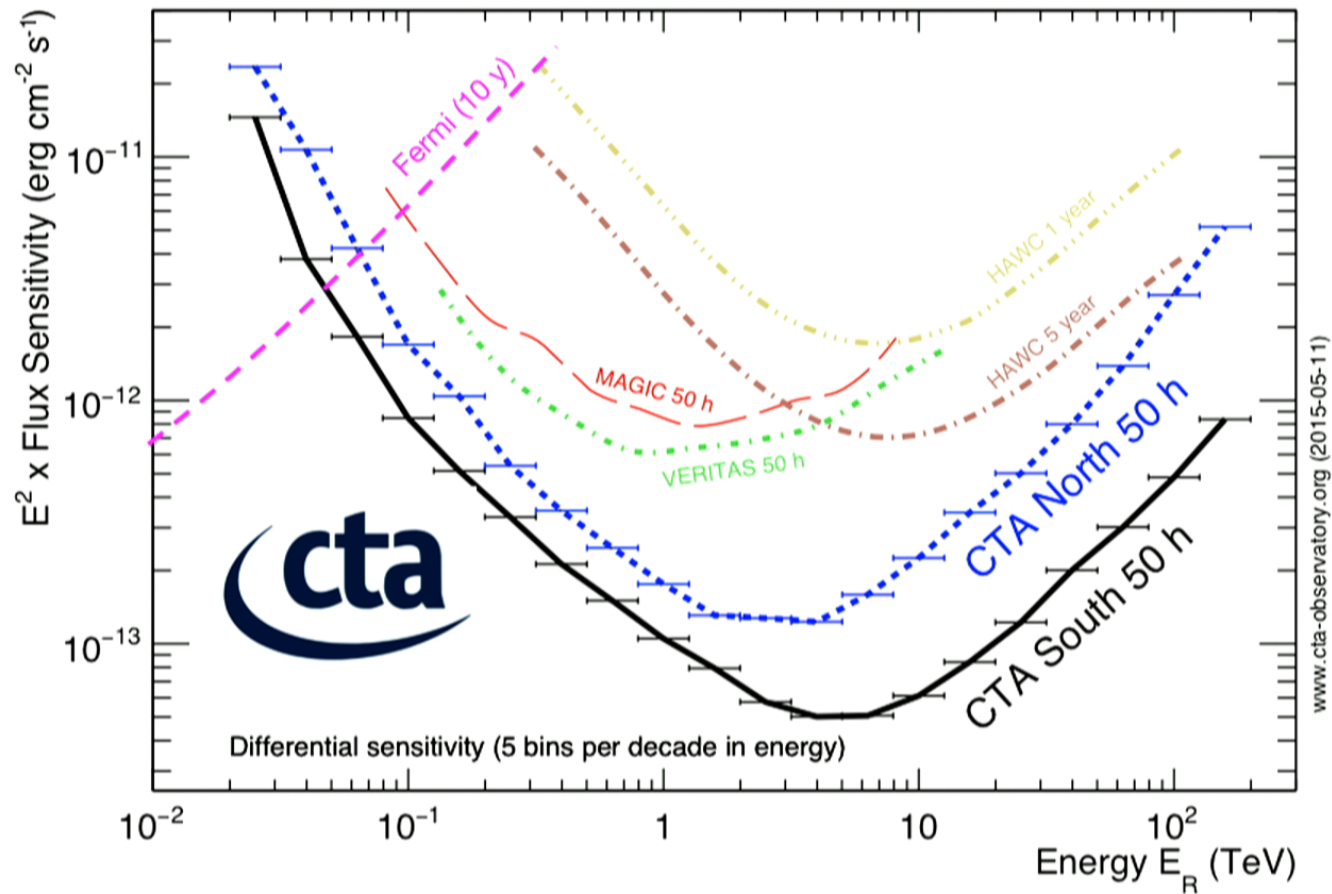
24

CTA Sites

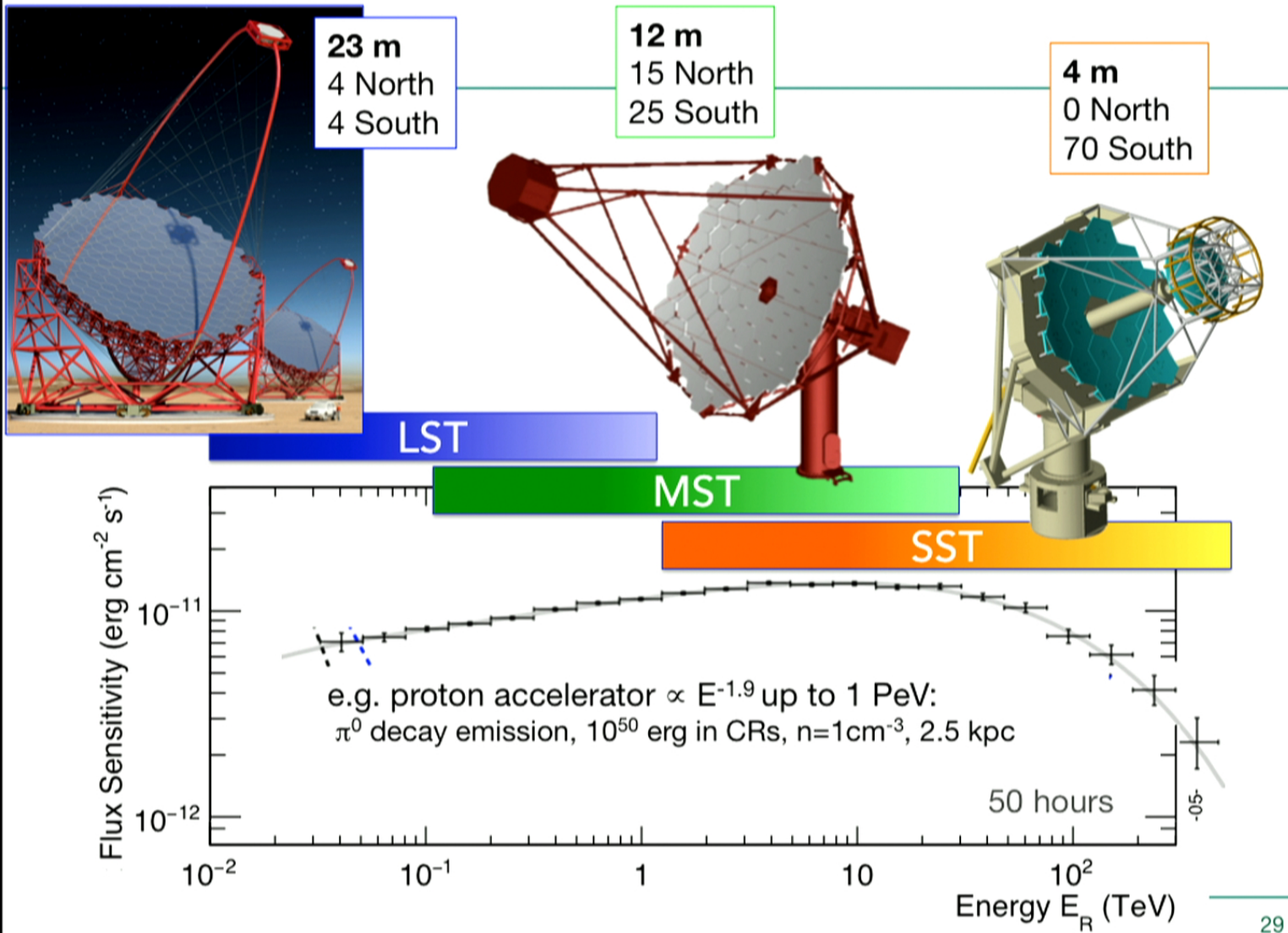




Sensitivity



See: <https://portal.cta-observatory.org/Pages/CTA-Performance.aspx>



SST-1M Prototype
Krakow



SST-2M Prototype
Paris



SST-2M
Prototype
Sicily



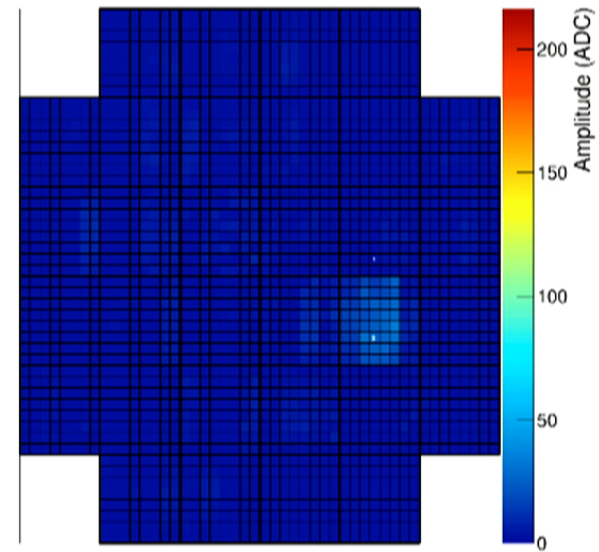
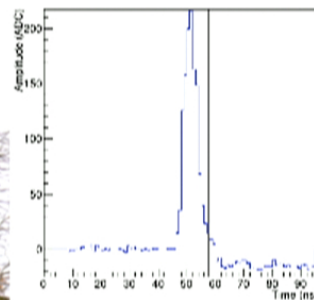
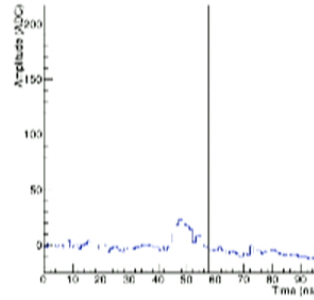
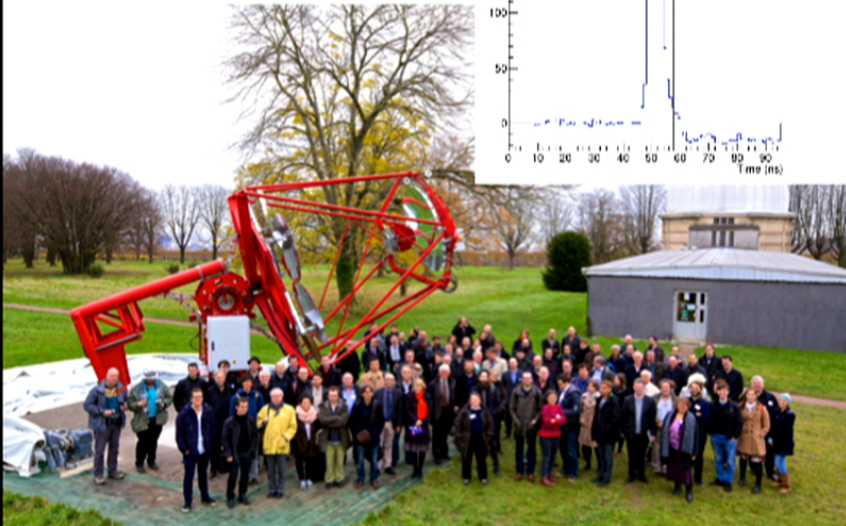
MST
Prototype
Berlin



+LST Prototype / 1st LST
La Palma 2016

First Cherenkov Light

⊙ Inauguration 1st
December 2015



⊙ First Cherenkov
movies 26th
November 2015

stitute, March 14th 2016

31

First Cherenkov Light



stitute, March 14th 2016

32

CTA Science Themes

⊙ Cosmic Particle Acceleration, Propagation and Impact

- + Mechanisms for particle acceleration, galactic CR acceleration and Pevatrons, acceleration in jets and lobes of AGN, cosmic ray transport, ...
- + What role do accelerated particles play in feedback on star formation and galaxy evolution?

⊙ Probing Extreme Environments

- + Neutron stars and black holes, relativistic jets, winds and explosions, the contents of cosmic voids, ...

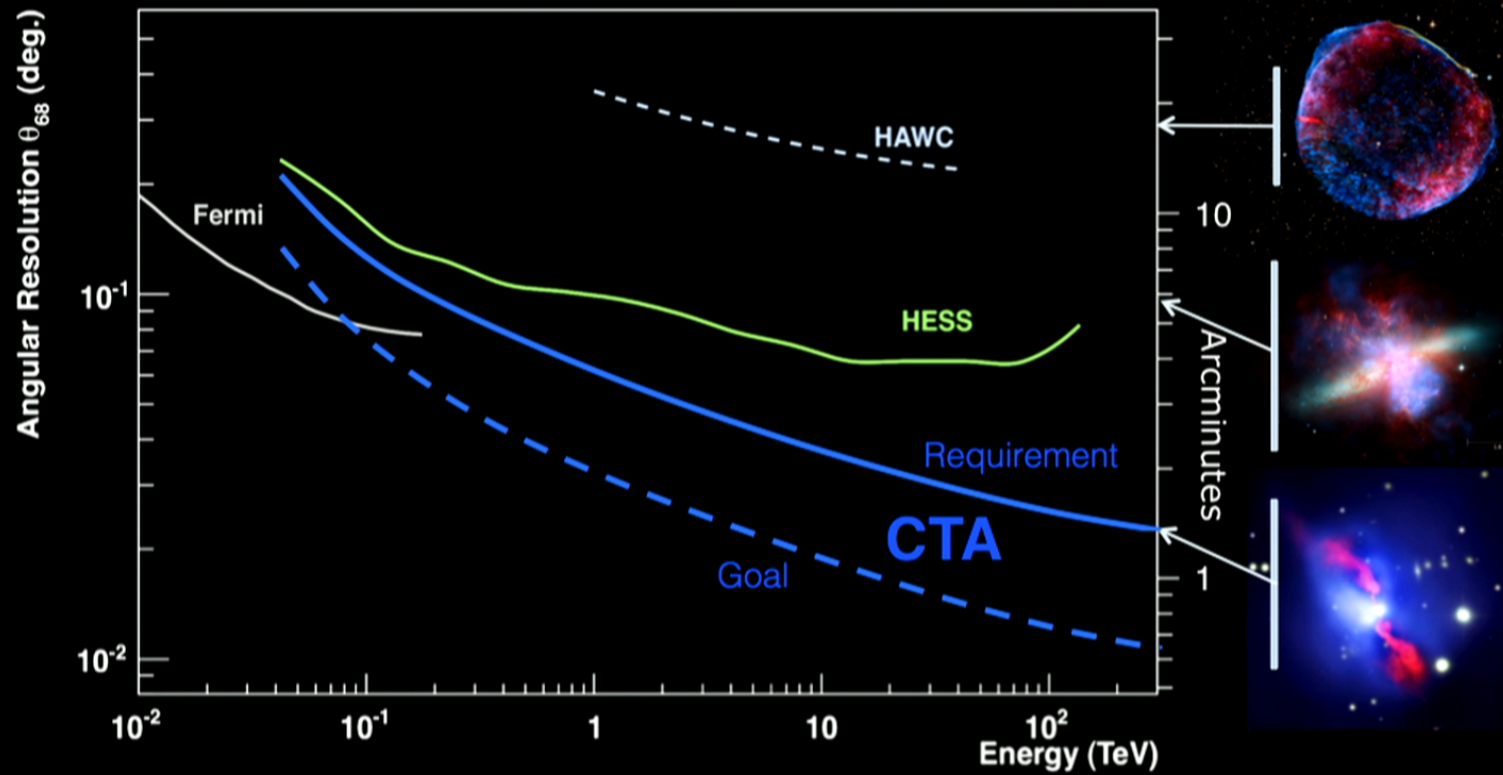
⊙ Physics Frontiers

- + What is the nature of Dark Matter? How is it distributed?
- + Is the speed of light a constant for high-energy photons?
- + Do axion-like particles exist?

"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

33

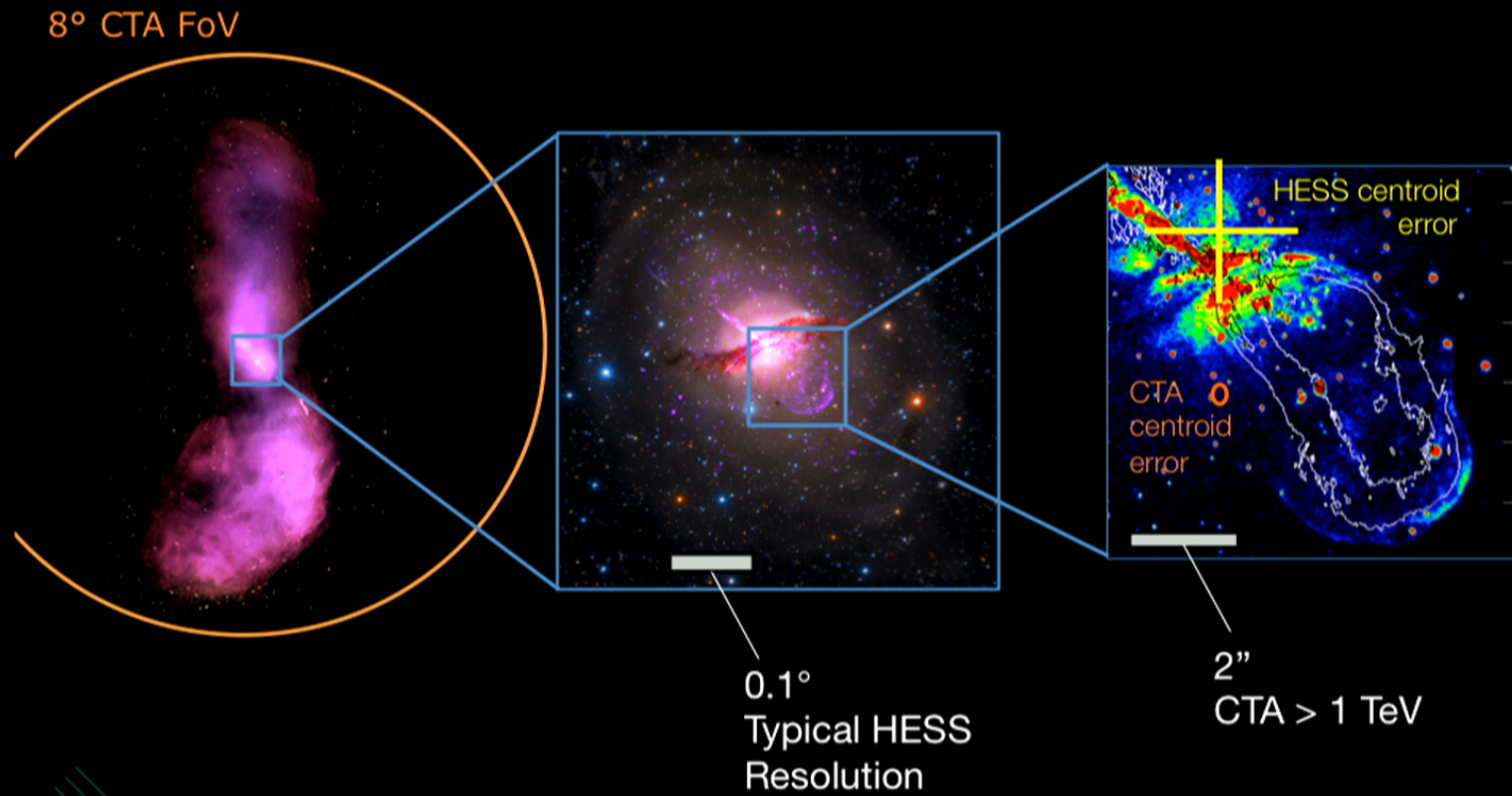
CTA Resolution



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

34

Example: Cen A

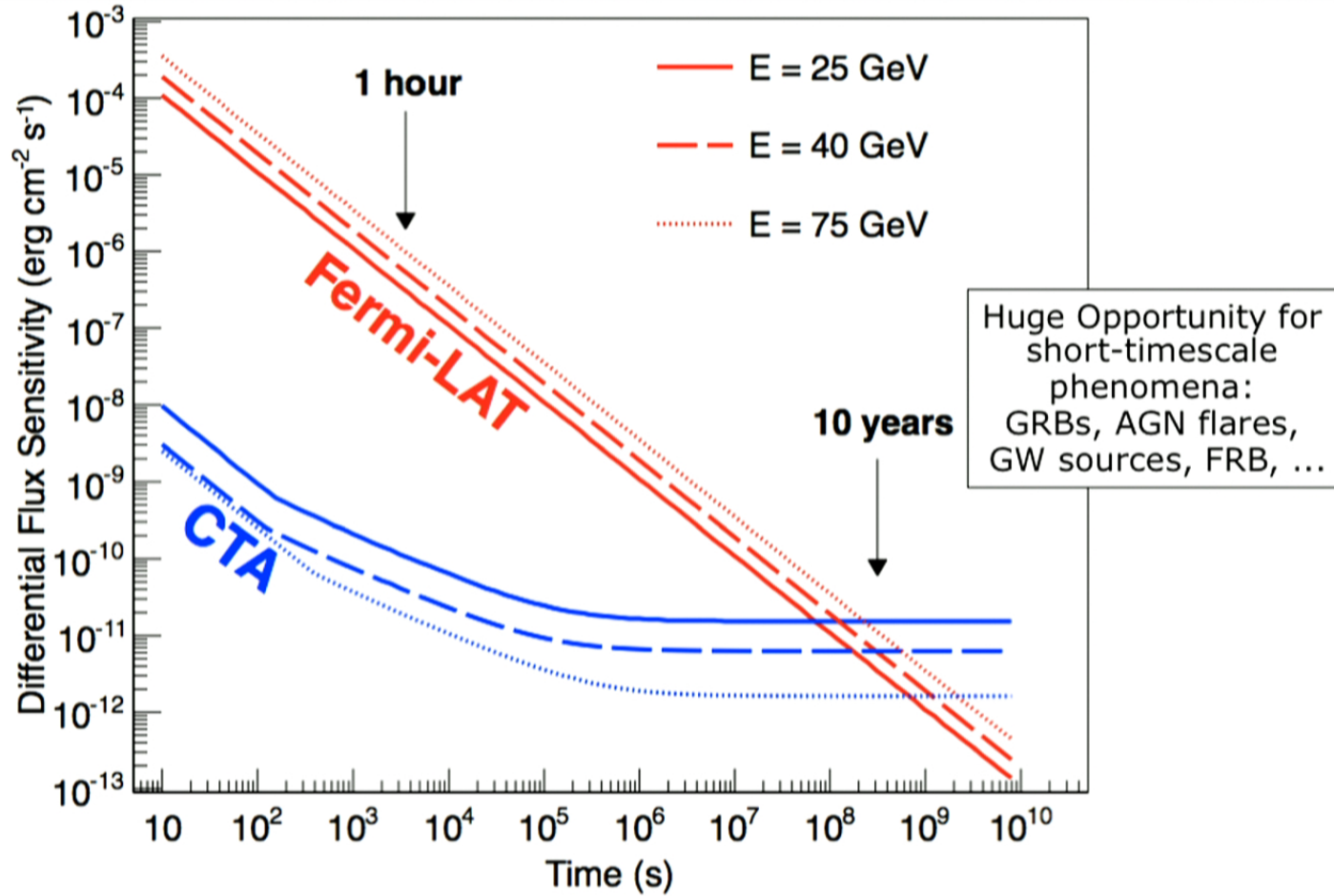


"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

35

Sensitivity versus Timescale

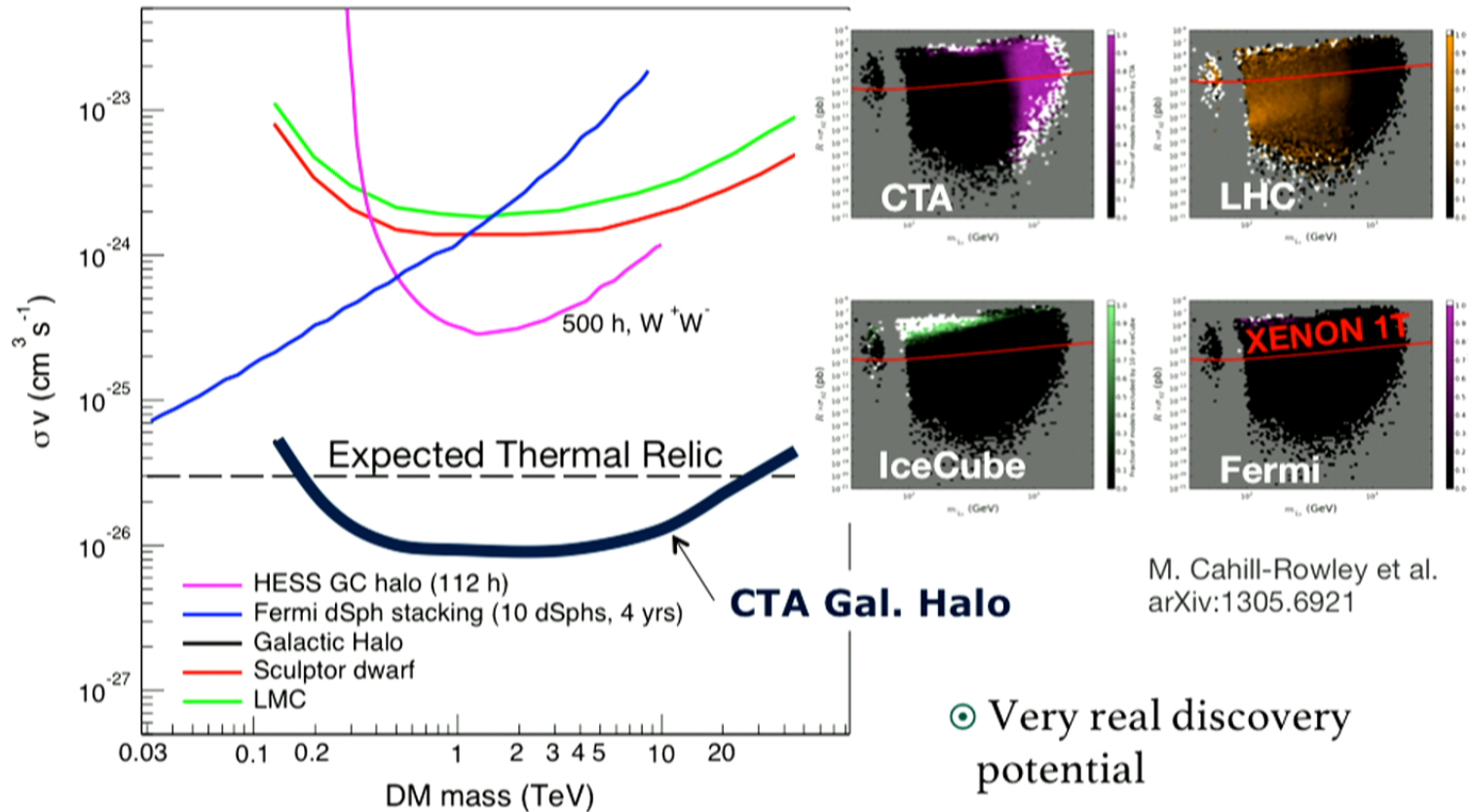
Adapted from Funk+Hinton 2012



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

36

Dark Matter Annihilation

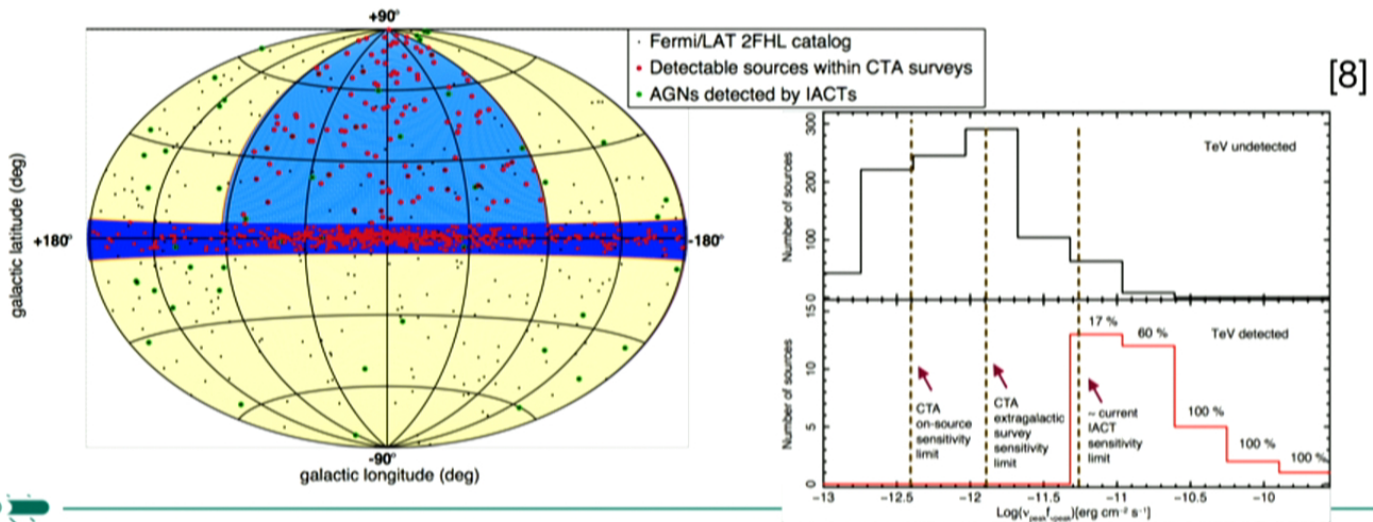


“Feedback over 44 orders of magnitude”, Perimeter Institute, March 14th 2016

37

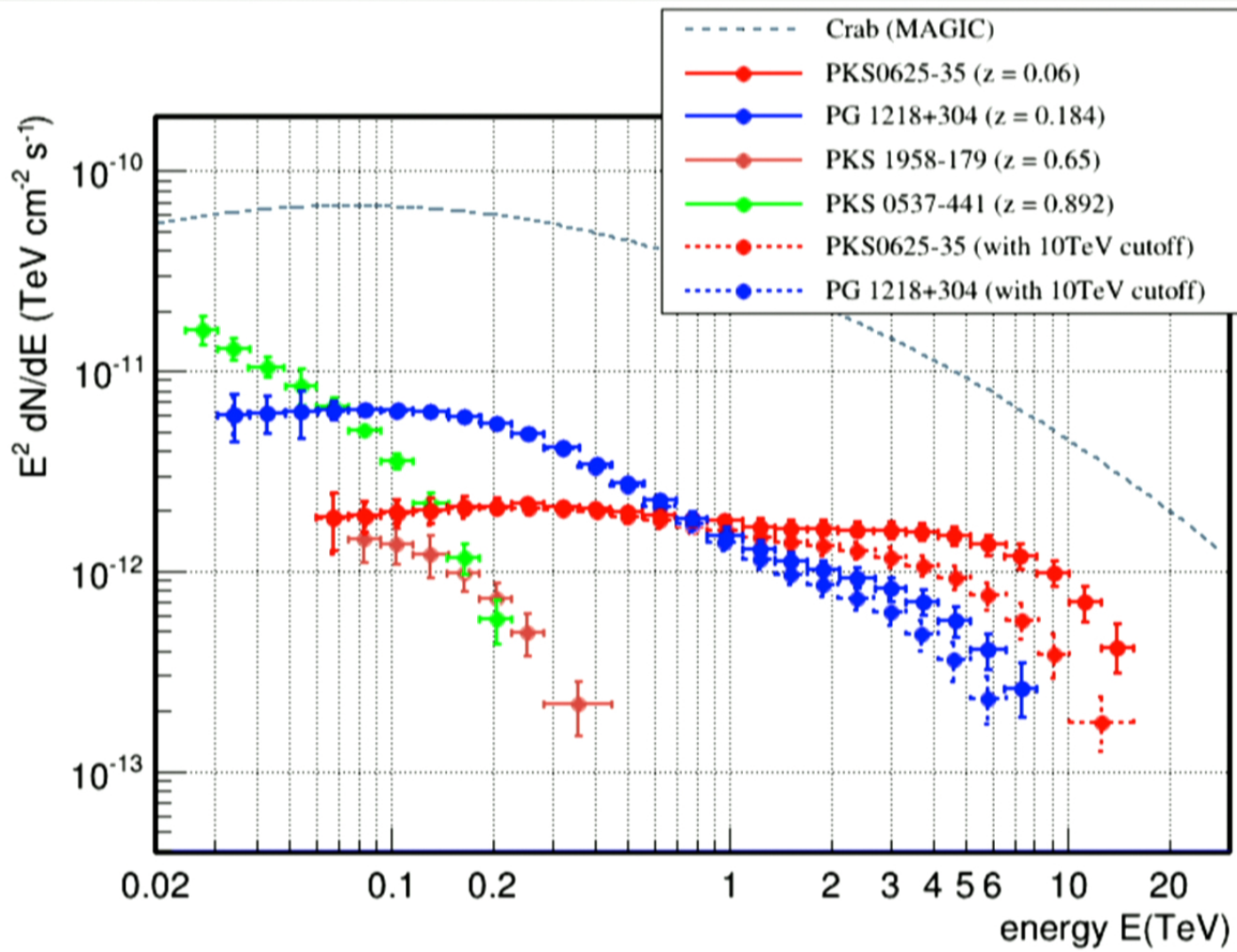
AGN population?

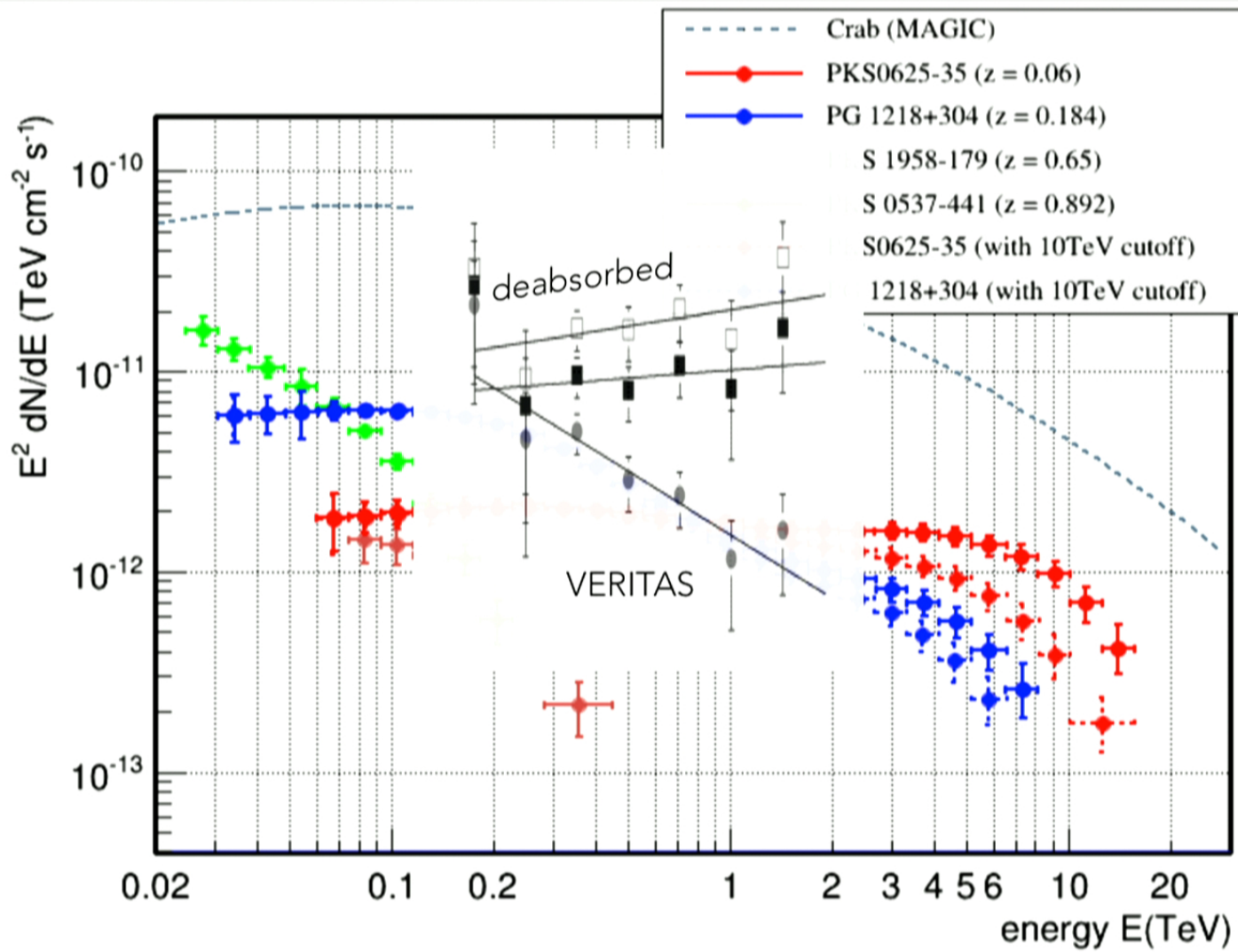
- ⊙ CTA will detect a sizeable population of TeV-emitting AGN through:
 - + Target observations / ToO from Fermi ++ - estimate ~200 objects
 - + Large field surveys – e.g. 25% EG sky survey for 240 hours
 - + 5 mCrab sens. → estimate 100-250 objects
 - + Serendipitous discoveries (8 degree FoV, 1300 hours per year , 2 sites...)
 - + No proper estimate made yet – but likely the dominate population in the end
- ⊙ Will be mostly HBLs
 - + CTA best sensitivity ~1 TeV, full field of view only > ~200 GeV



“Feedback over 44 orders of magnitude”, Perimeter Institute, March 14th 2016

38



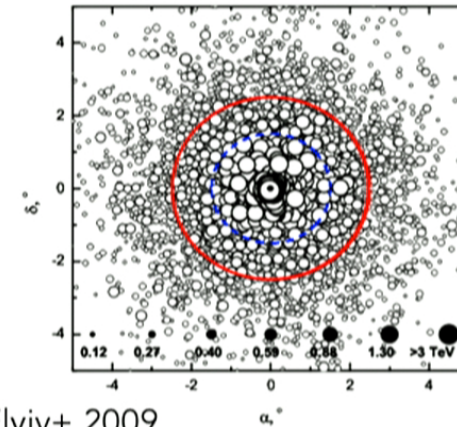


CTA Probes of IGM cascades

120 Mpc, 10^{-14} G

⊙ Pair Halos

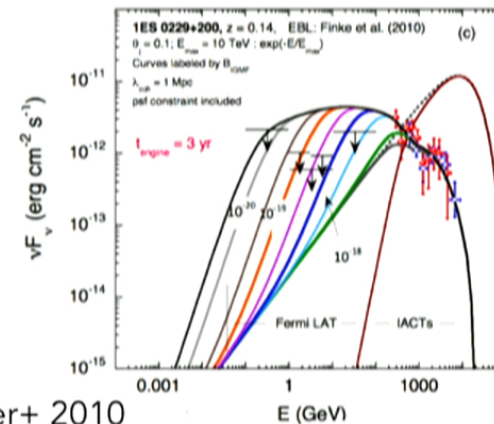
- + Electrons deflected more than \sim arcmin in IGM magnetic fields ($>10^{-16}$ G) – secondary gammas
- + Use angular resolution of to image halos /search for (energy-dependent) deviations from point-like behaviour – combination of improved angular resolution and better sensitive makes constraints much better than current IACT limits



Elyiv+ 2009

⊙ Pair Echoes (low IGMF strengths $\sim 10^{-16}$ G)

- + Very small deflections – travel time differences
 - + Flares delayed+washed out in cascade signal
- + Extractable from time-resolved spectral analysis



Dermer+ 2010

⊙ See upcoming public release of 'CTA Science' document



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

41

Conclusions

- ⊙ Improving view of the HE/VHE gamma-ray sky
 - + Fermi deeper exposures and Pass 8
 - + Gradually increasing catalogue of TeV detections / improved spectra from MAGIC, VERITAS, HESS-2
- ⊙ Major next step is CTA
 - + First science hopefully 2018, completion early 2020s
 - + Operating as an international user facility – access for all scientists of contributing countries
 - + See CTA web page for response info. + science doc. soon



"Feedback over 44 orders of magnitude", Perimeter Institute, March 14th 2016

42