Lecture 2:
Gamma-ray Astrophysics

Ultra High Energy \\ Cosmic Rays

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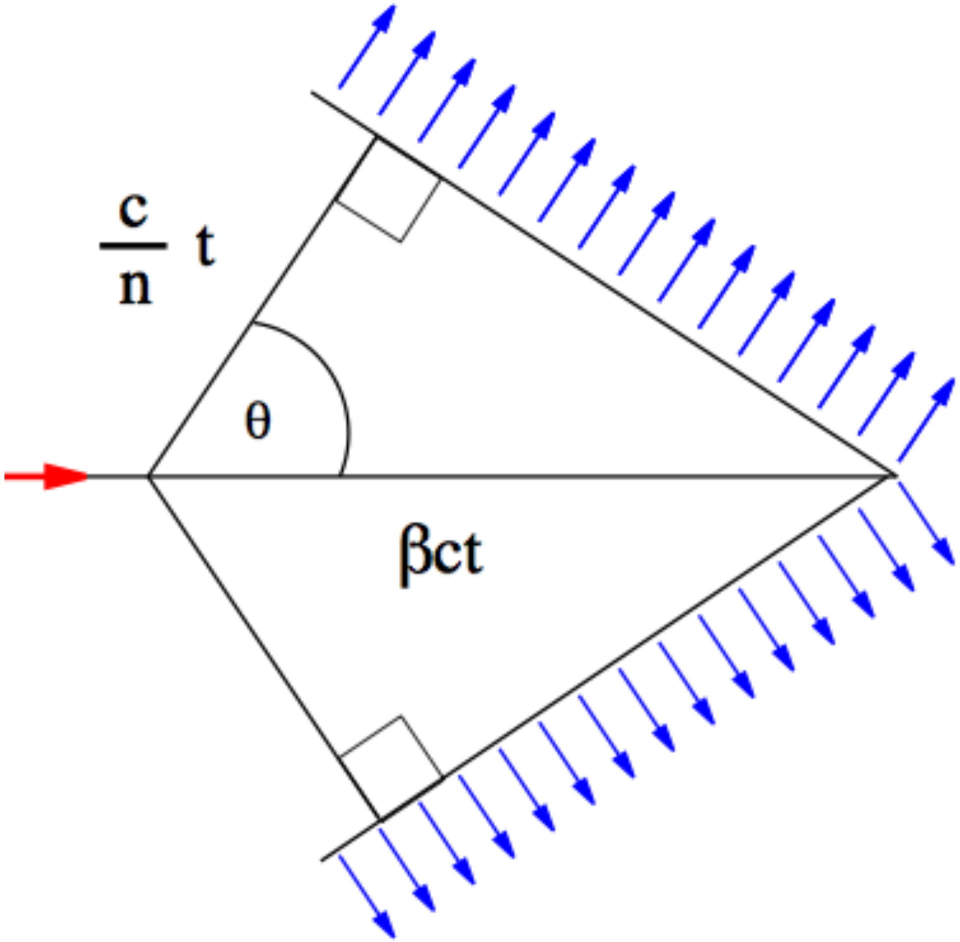
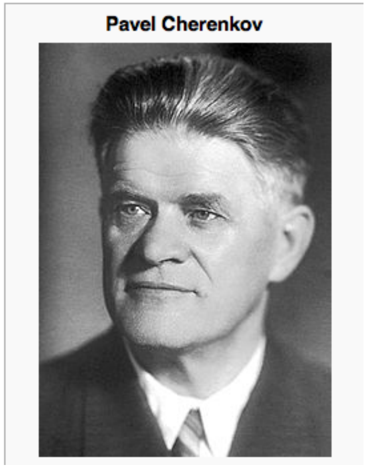
Overview:

- Cherenkov radiation
- Detection technics
- Present and future experiments
- Galactic gamma-ray sources and diffused background
- Extragalactic sources and backgrounds
- Study of intergalactic magnetic fields
- Indirect detection of Dark Matter
- Conclusions

Cherenkov radiation

Cherenkov radiation





Discovery 1934

Nobel prize 1958

Cherenkov radiation

$$V > V_m = c/n$$

n is refractive index of medium

$n = 1.008$ air

$n = 1.33$ water

The charged particles polarize the molecules, which then turn back rapidly to their ground state, emitting prompt radiation

Cherenkov light is emitted under a constant Cherenkov angle with the particle trajectory, given by

$$\cos\delta = \frac{V_m}{V} = \frac{c}{nV} = \frac{1}{\beta n}$$

- Minimal energy of charge particle

$$\gamma_{\min} = \frac{n}{\sqrt{n^2 - 1}}$$

Main processes used in gamma-ray astrophysics

$$\gamma + \gamma_B \Rightarrow e^- + e^+$$

$$e^{\pm} + \gamma_B \Rightarrow e^{\pm} + \gamma$$

$$e^{\pm} + B \Rightarrow e^{\pm} + \gamma_{synch}$$

$$e^{\pm} + A_B \Rightarrow e^{\pm} + A_B + \gamma_{brems}$$

$$P + \gamma_B \Rightarrow N + \pi$$

$$P + P_B \Rightarrow N + N + \sum \pi$$

$$\pi^0 \Rightarrow 2\gamma$$

Detection technics

Fermi Large Area Telescope (LAT)

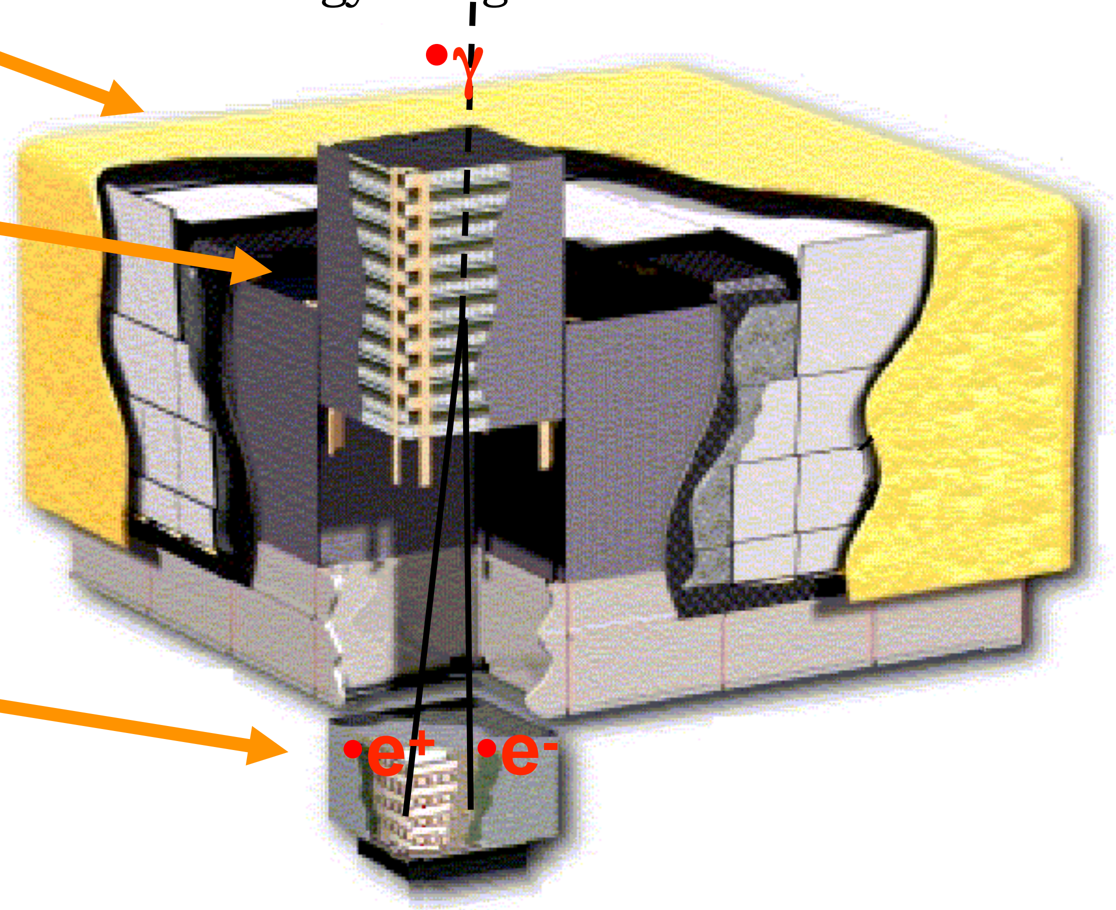
Large Field of View >2.4 sr

Broad Energy Range 20 MeV - >300 GeV

- **ACD**
- scintillator
- 89 tiles

- **Tracker**
- Si strip detectors
- Tungsten foil converters
- pitch = 228 um
- 8.8×10^5 channels
- 18 planes

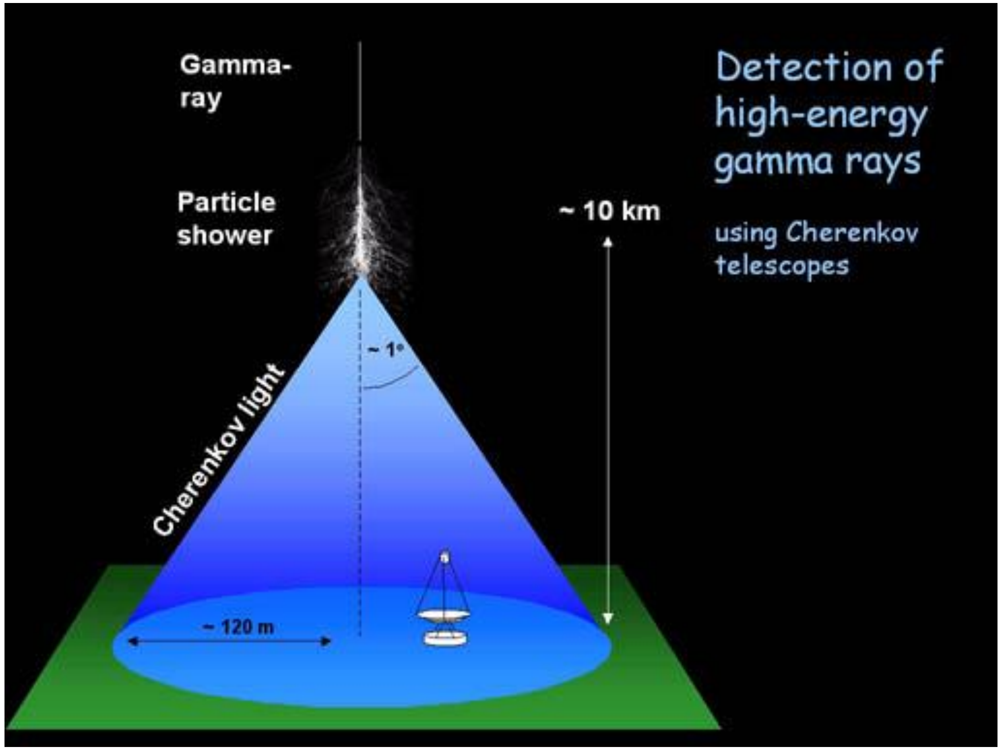
- **Calorimeter**
- CsI crystals
- hodoscopic array
- 6.1×10^3 channels
- 8 layers



Cherenkov telescopes

Very high energies, above 50 GeV

- Crab nebula: flux(E > 1 TeV) = 2×10^{-11} cm^{-2} s^{-1}
- Large effective detection areas (>30 000 m^2) needed
- -> Back to the ground
- Use the atmosphere as a
- huge calorimeter and
- detect γ-ray-induced
- atmospheric showers
- through Cherenkov light
-



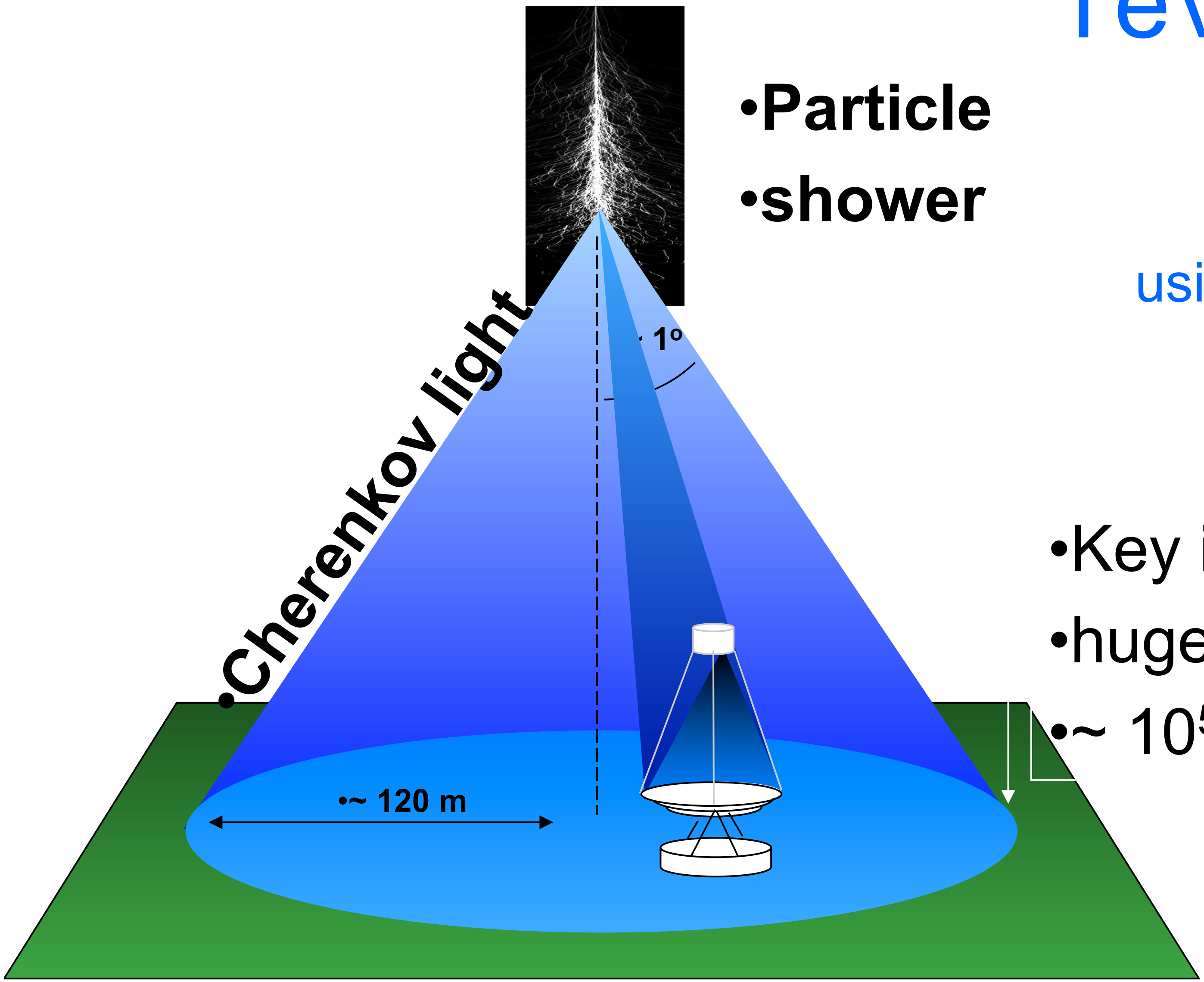
Experimental challenges

- Reduce the energy threshold as much as possible

  Try to get some overlap region with space observations
- Increase flux sensitivity
- **Remove the huge background** of showers induced by charged particles **(cosmic ray protons, ions and electrons)**

Detection of TeV gamma rays

using Cherenkov telescopes



•Key issue:

•huge detection area

•~ 10^5 m^2

From W.Hofman

Hardonic rejection

- Image shape:

  Electromagnetic showers:

  elongated, quasi-elliptic shape

  Hadronic showers:

  more irregular shape

- Image direction:

  Electromagnetic showers:

  point to the source (the center of the field of view)

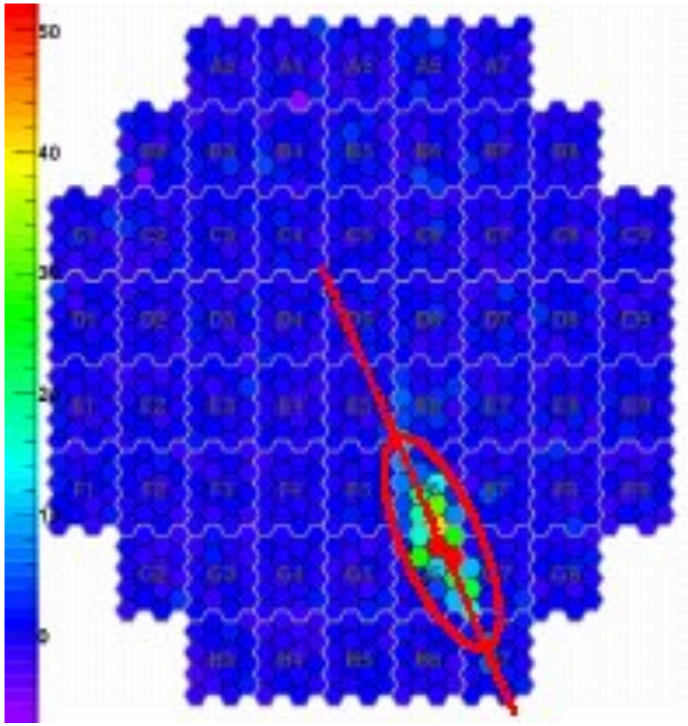
  Hadronic showers:

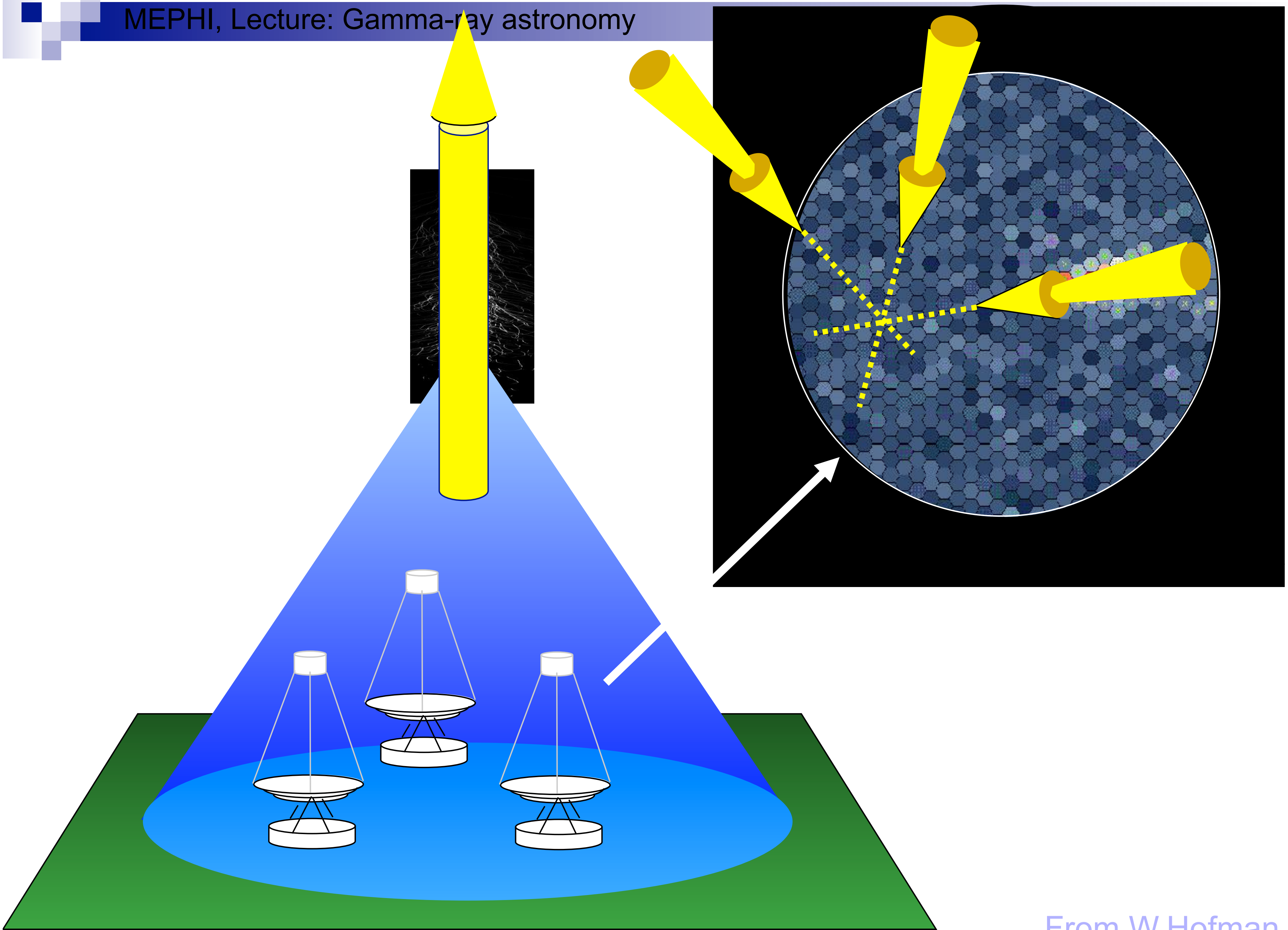
  randomly oriented in the focal plane

- Image light profiles

  (longitudinal and transverse)

  help finding the source position

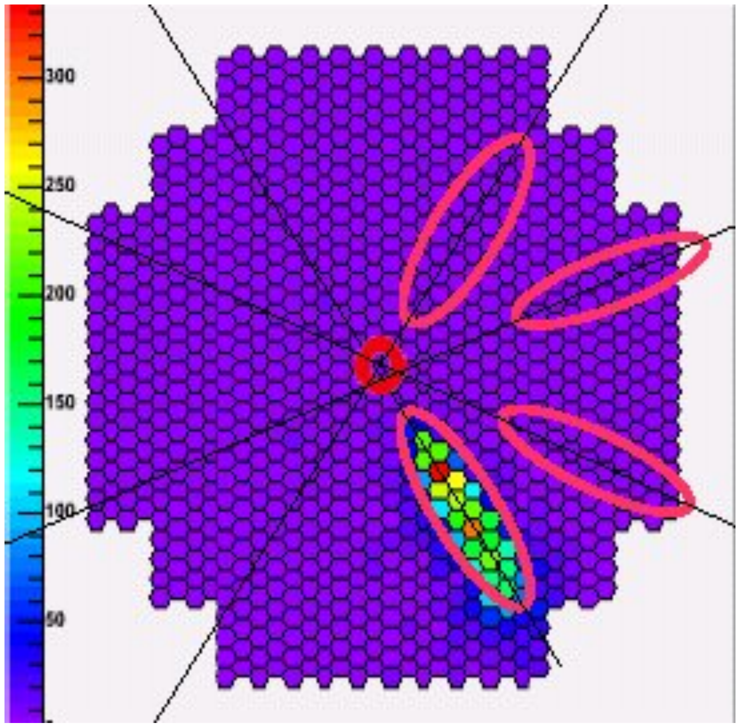


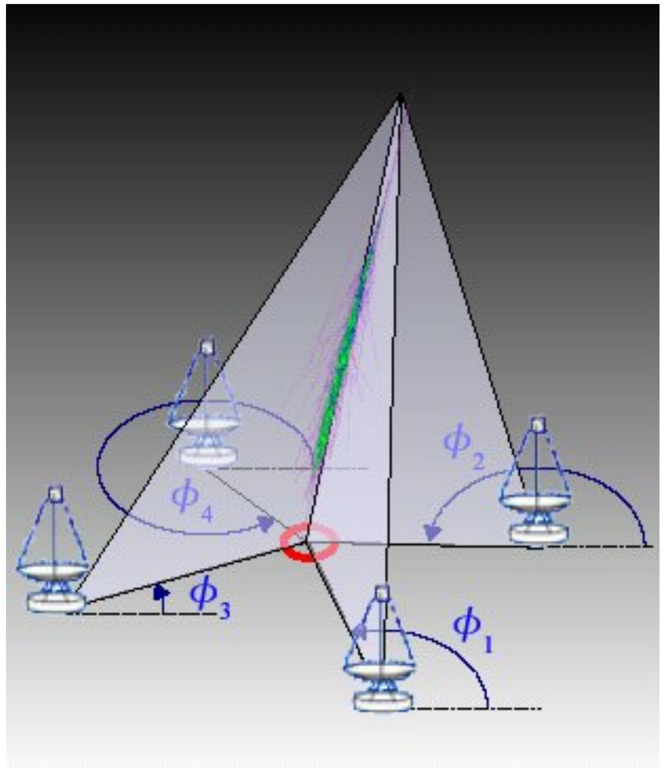


From W.Hofman

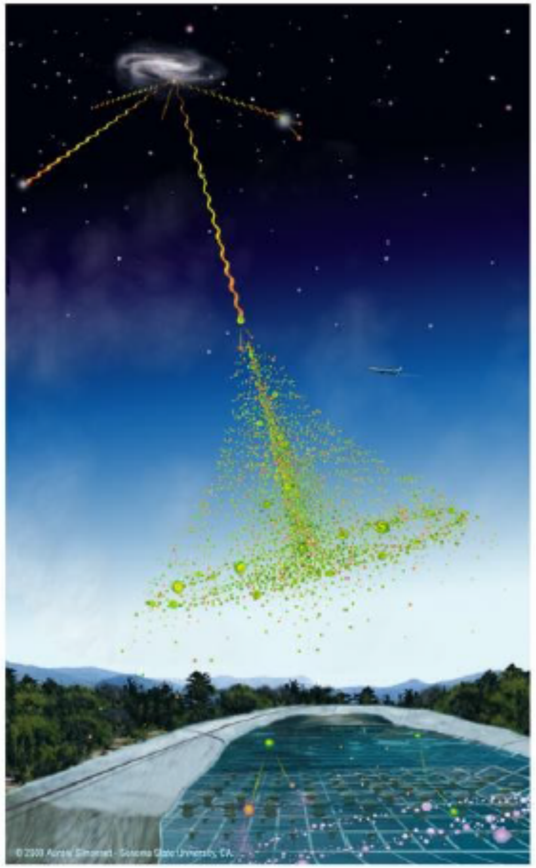
Stereoscopic measurement (e.g. HEGRA, H.E.S.S. VERITAS, MAGIC)

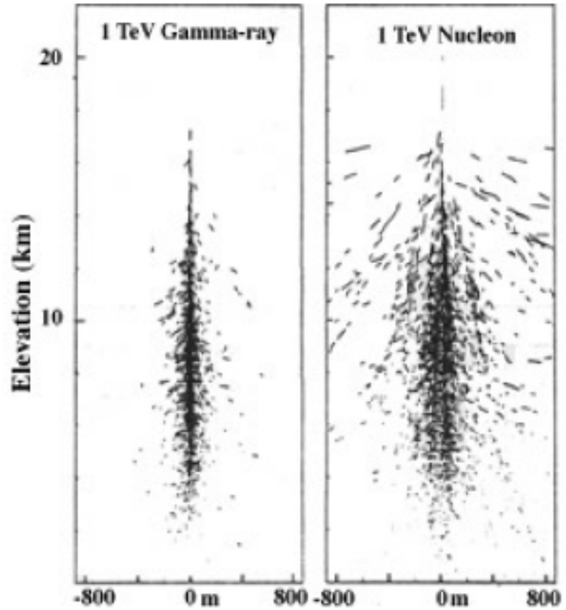
- Direct measurement of the **γ-ray origin** in the field of view (important for extended sources)
- Direct measurement of the **impact on the ground** (important for energy measurement)
- Better hadronic rejection
- Much better angular resolution

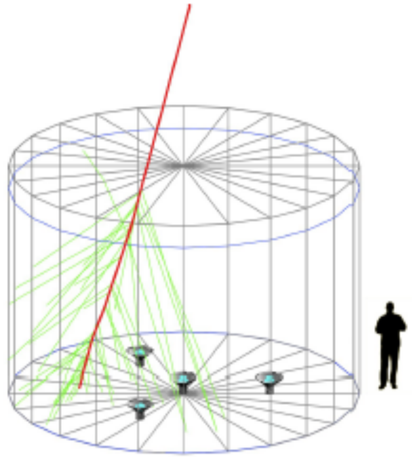




Detection Technique of the EAS Arrays





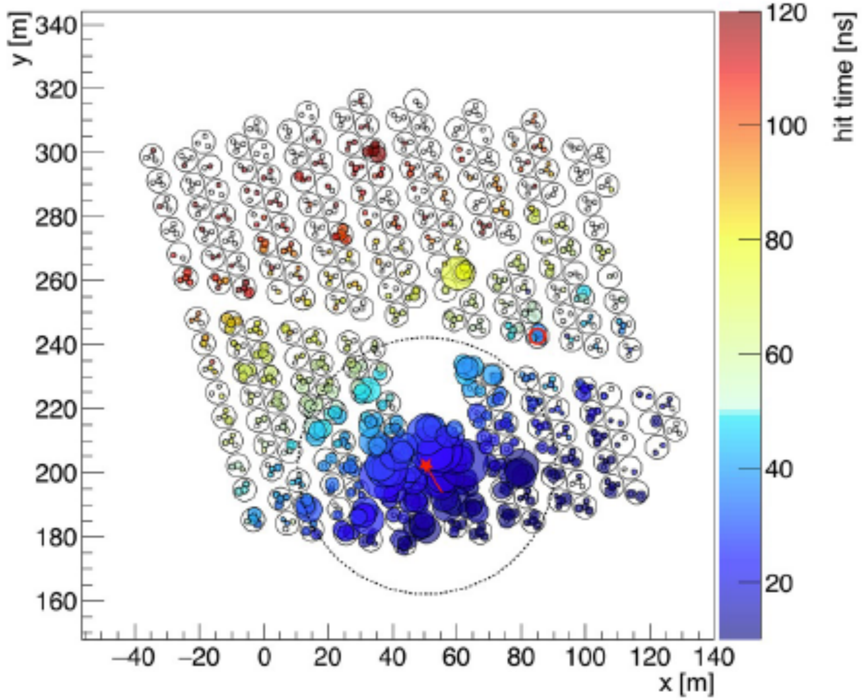


- The particle detectors can be tanks full of water. Particles from the shower pass through the water and induce Cherenkov light detected by PMTs.
- Gamma/hadron can be discriminated based on the event footprint on the detector. Although is one of the challenges of this kind of detectors.

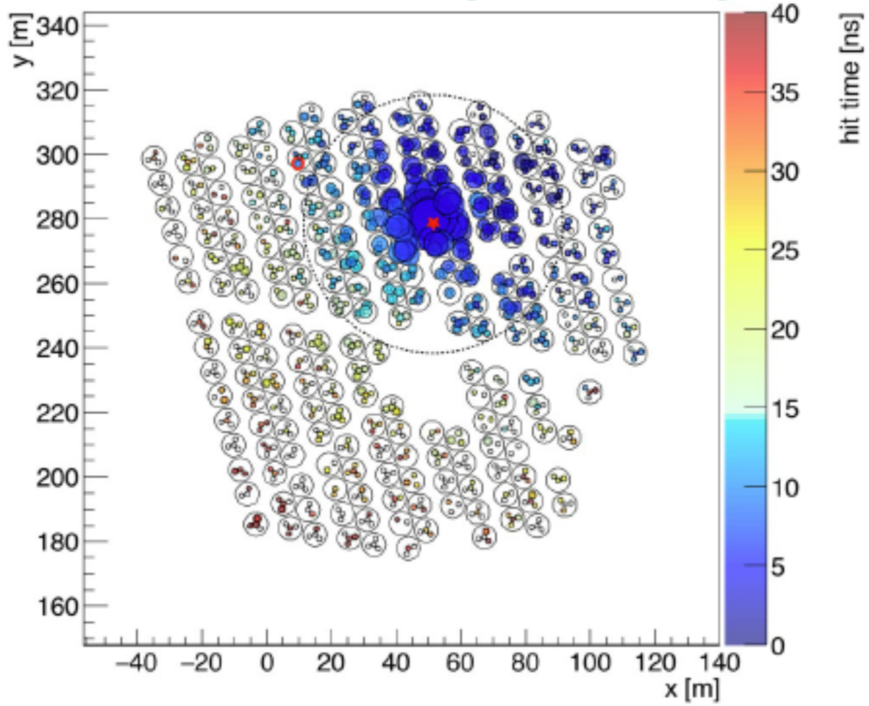
Gamma/Hadron Separation

- Main background is hadronic CR, e.g. 400 γ/day from the Crab vs 15k CR/s.
- In gamma-ray showers, most of the signal at ground level is located near the shower axis.
- In charged cosmic rays tend to "break apart", much messier signals at ground level.

HAWC Data – Hadron Shower



HAWC Data – Likely Gamma Ray

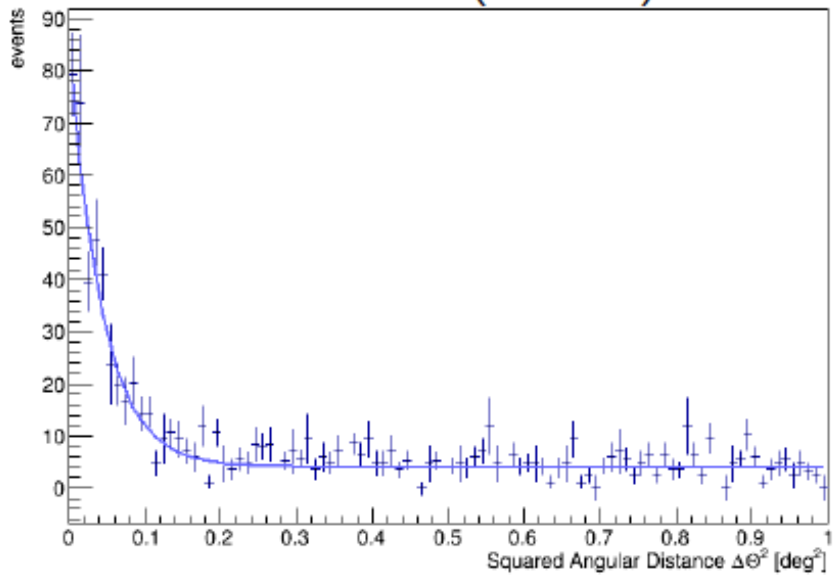


Pass 4 Preview: Crab Data

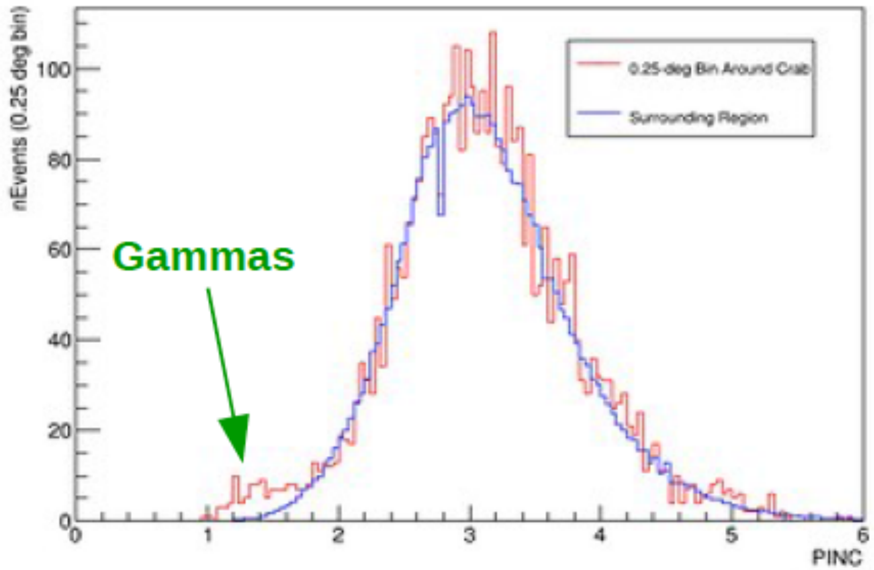
- Reconstruction and calibration improvements.

PRELIMINARY

> 62% PMTs hit (bins 7-9)



>85% PMTs Hit (bin 9)

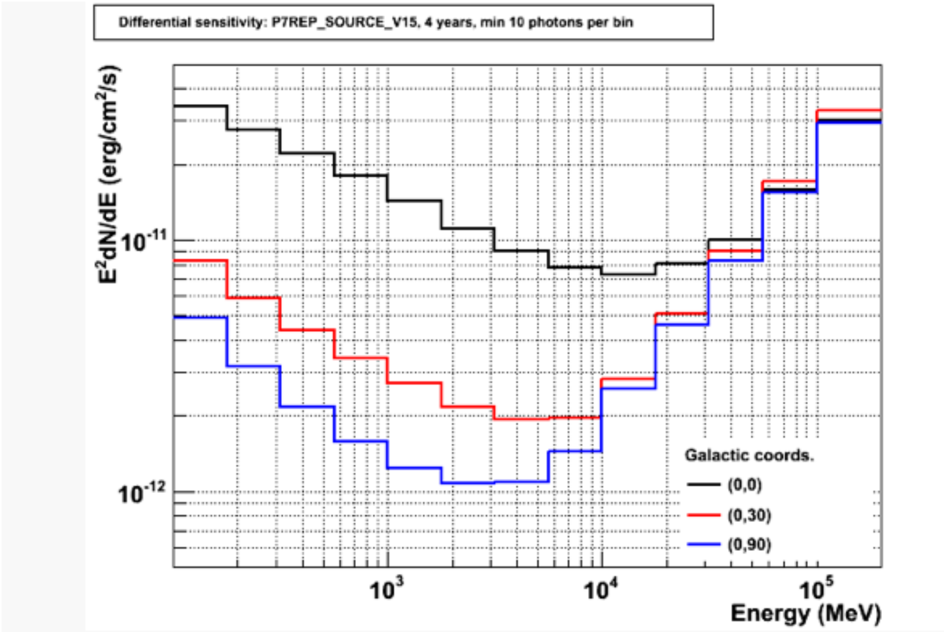


Angular resolution (68% containment): 0.24º for large event, achieving proposed resolution.

Gamma/Hadron separation:
Reject >99.9% of hadronic background for large events while retaining >50% of gamma rays.

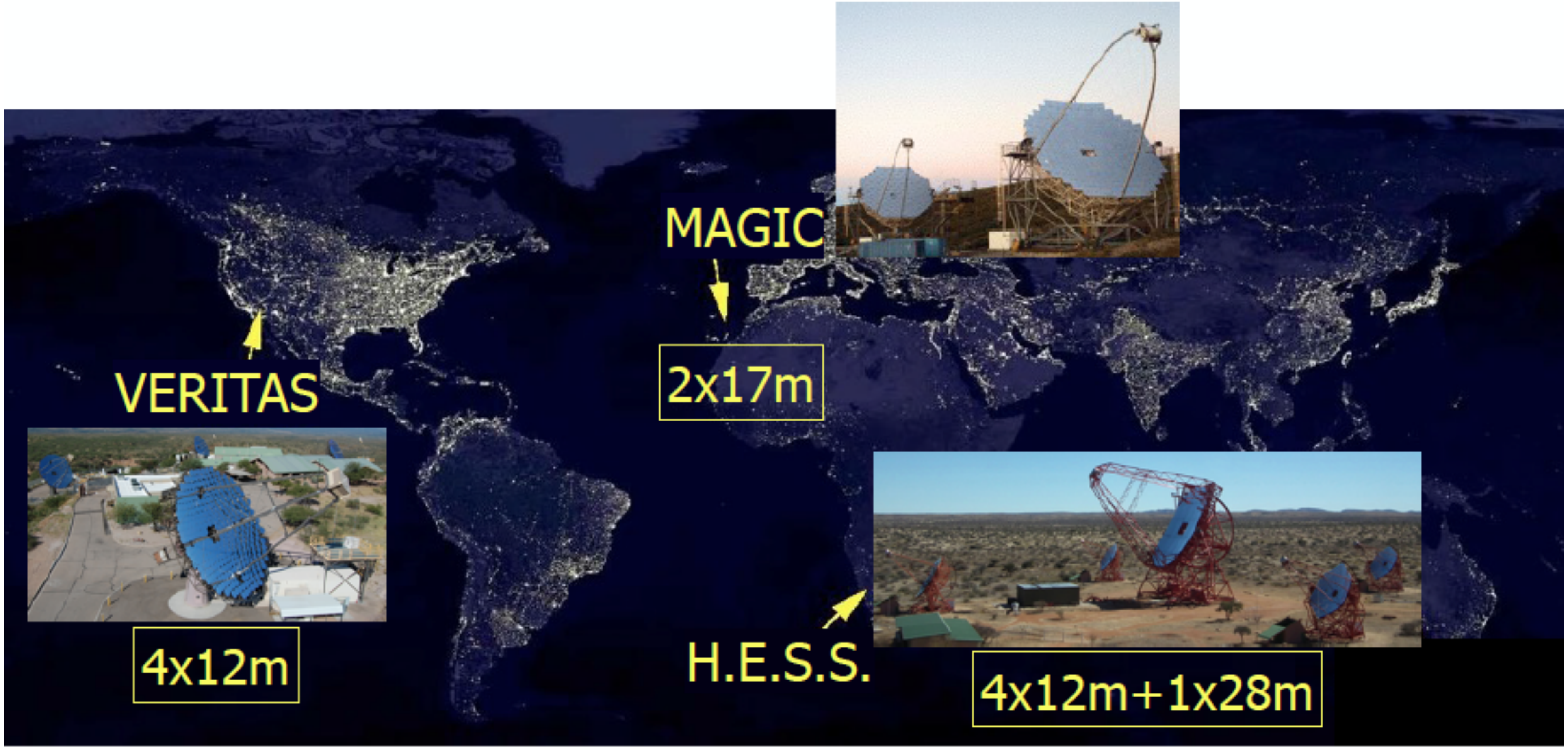
Fermi LAT gamma-rays 20 MeV-300 GeV

Fermi LAT


Differential sensitivity: P7REP_SOURCE_V15, 4 years, min 10 photons per bin
E²dN/dE (erg/cm²/s)
10⁻¹¹
10⁻¹²
10³
10⁴
10⁵
Energy (MeV)
Galactic coords.
(0,0)
(0,30)
(0,90)

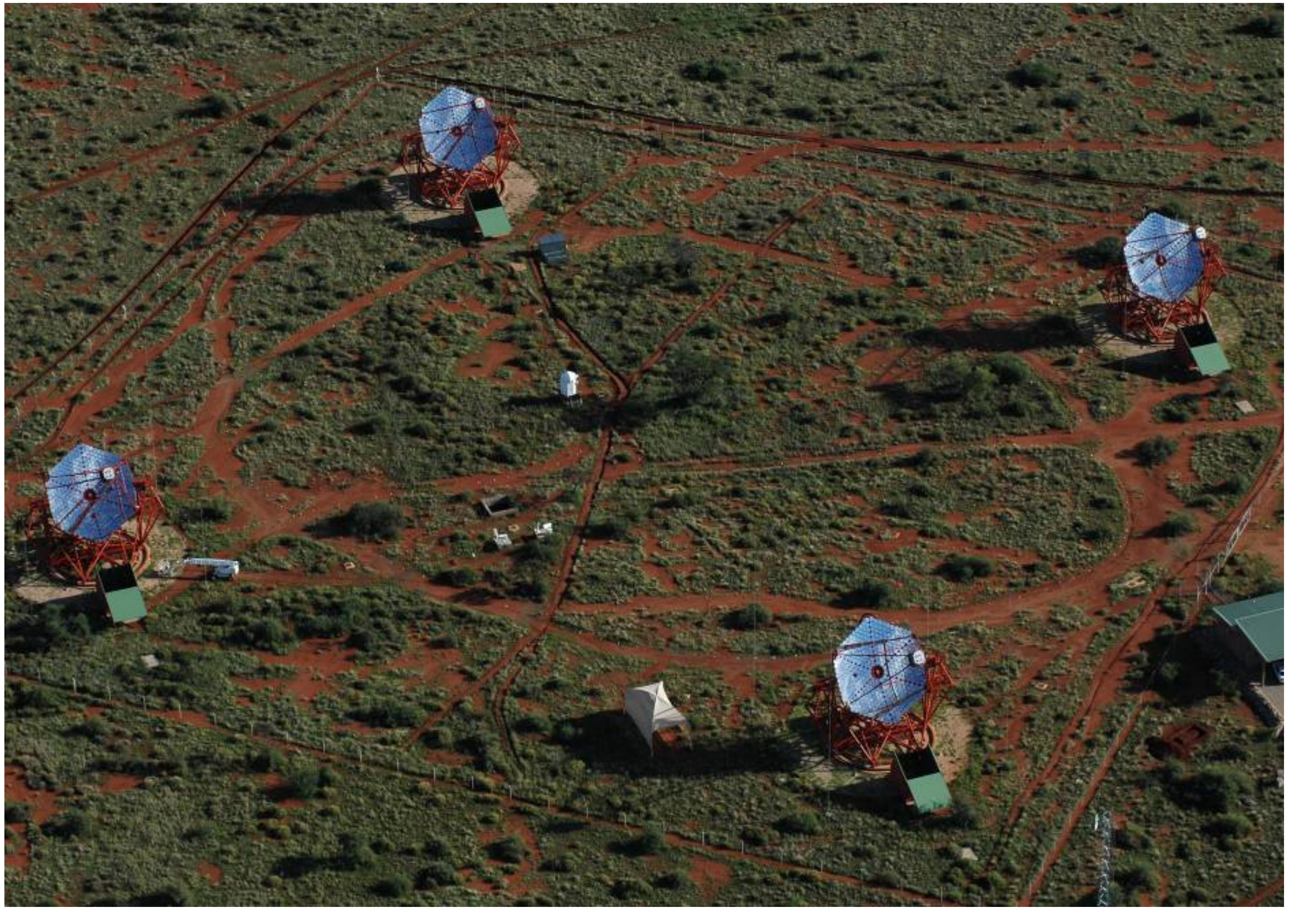
TeV telescopes 50 GeV-20 TeV

Cherenkov telescopes today



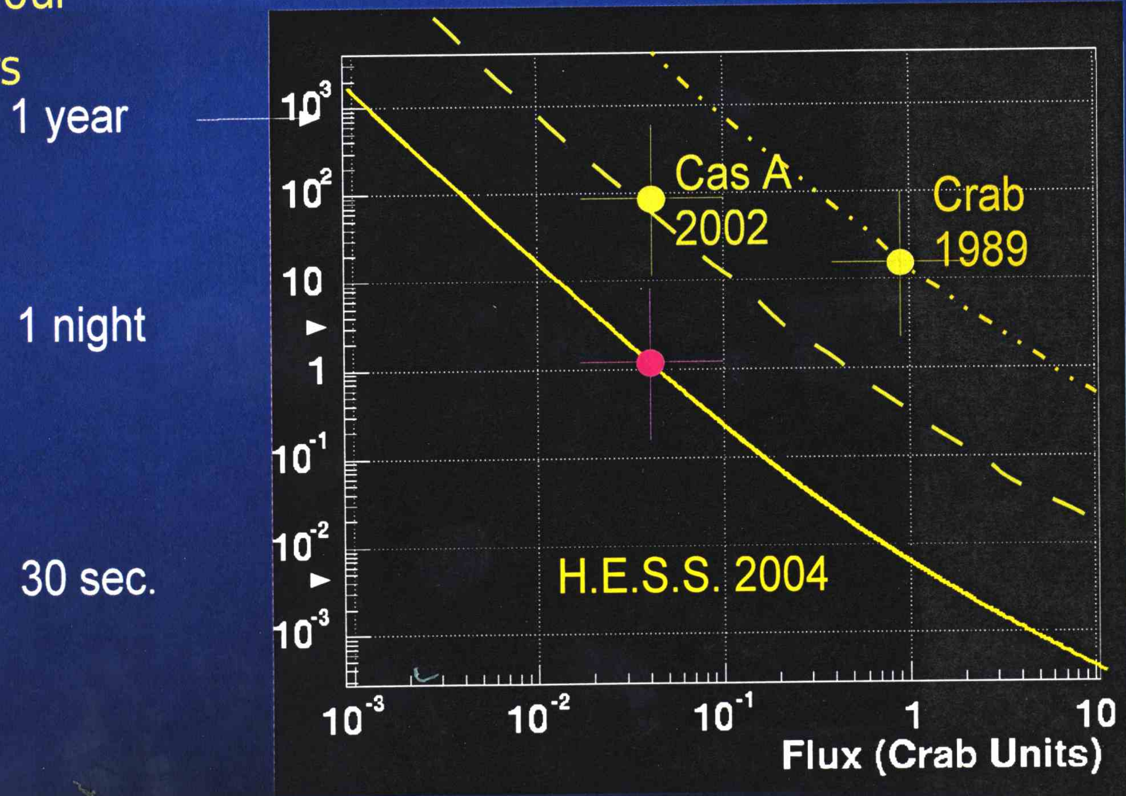
•HESS

- European Collaboration; M.P.I (Heidelberg)
- 4 x 12 m Telescopes
- Completed in Dec. 2003; located in NAMIBIA



H.E.S.S. Sensitivity

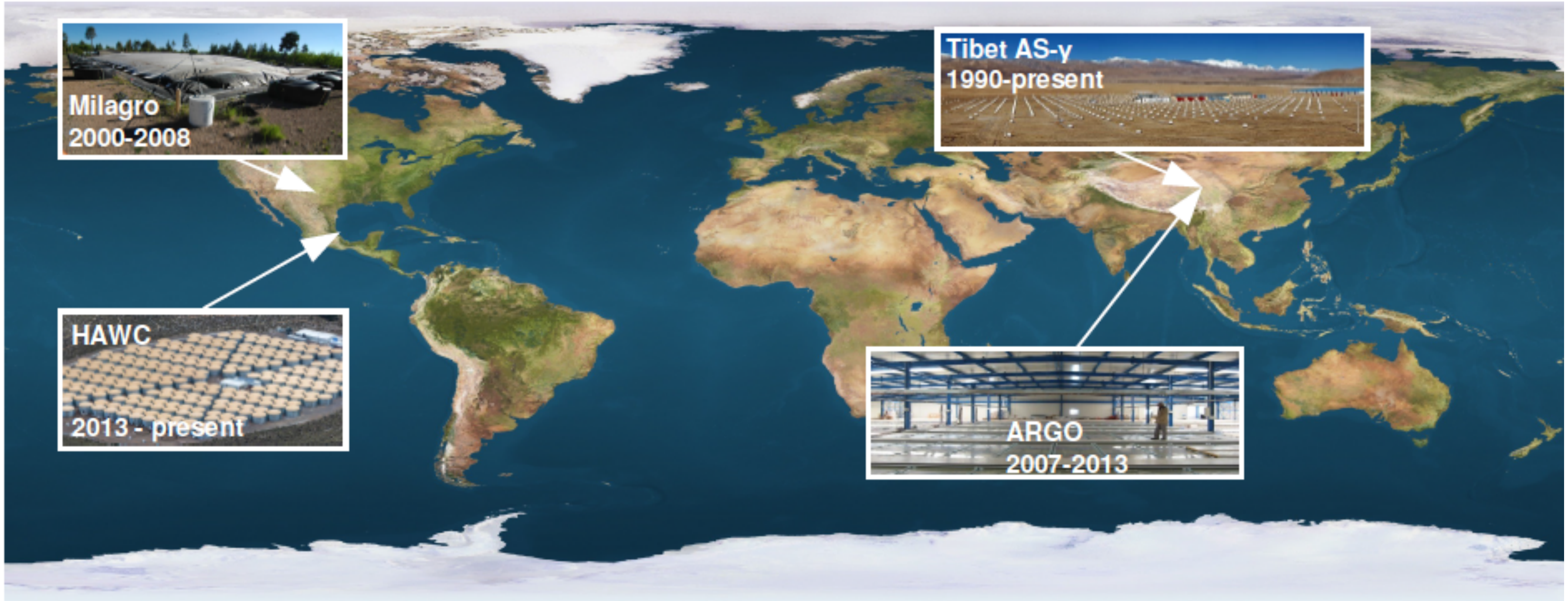
- HEGRA
  - 5% of Crab flux in 100 hours
- H.E.S.S.
  - 5% of Crab in 1 hour
  - 0.5% in 100 hours



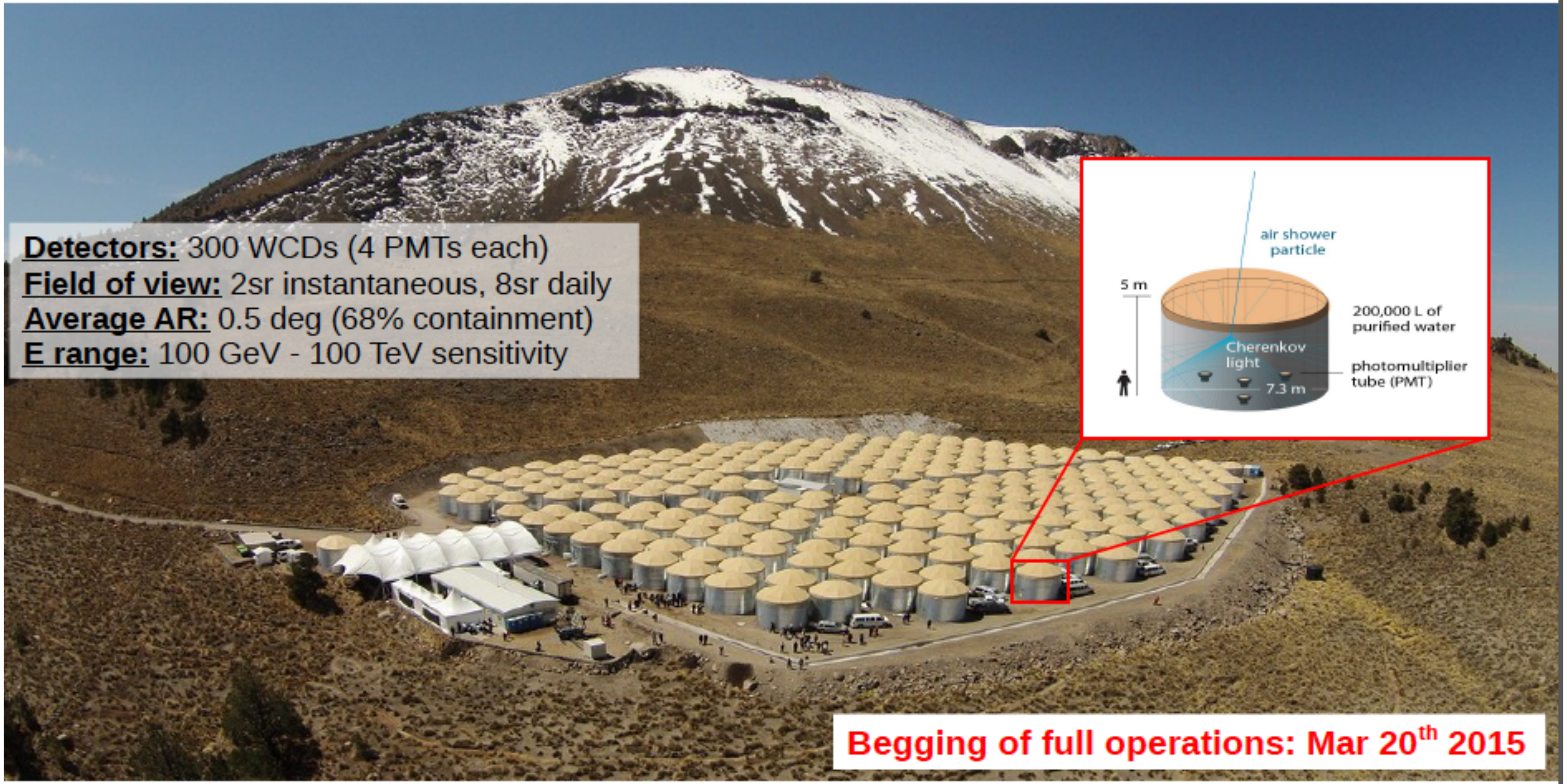
LAST
UCLA

EAS Detectors

- Several EAS arrays have been operational using different detection techniques.
- It is time for second generation experiments like HAWC.



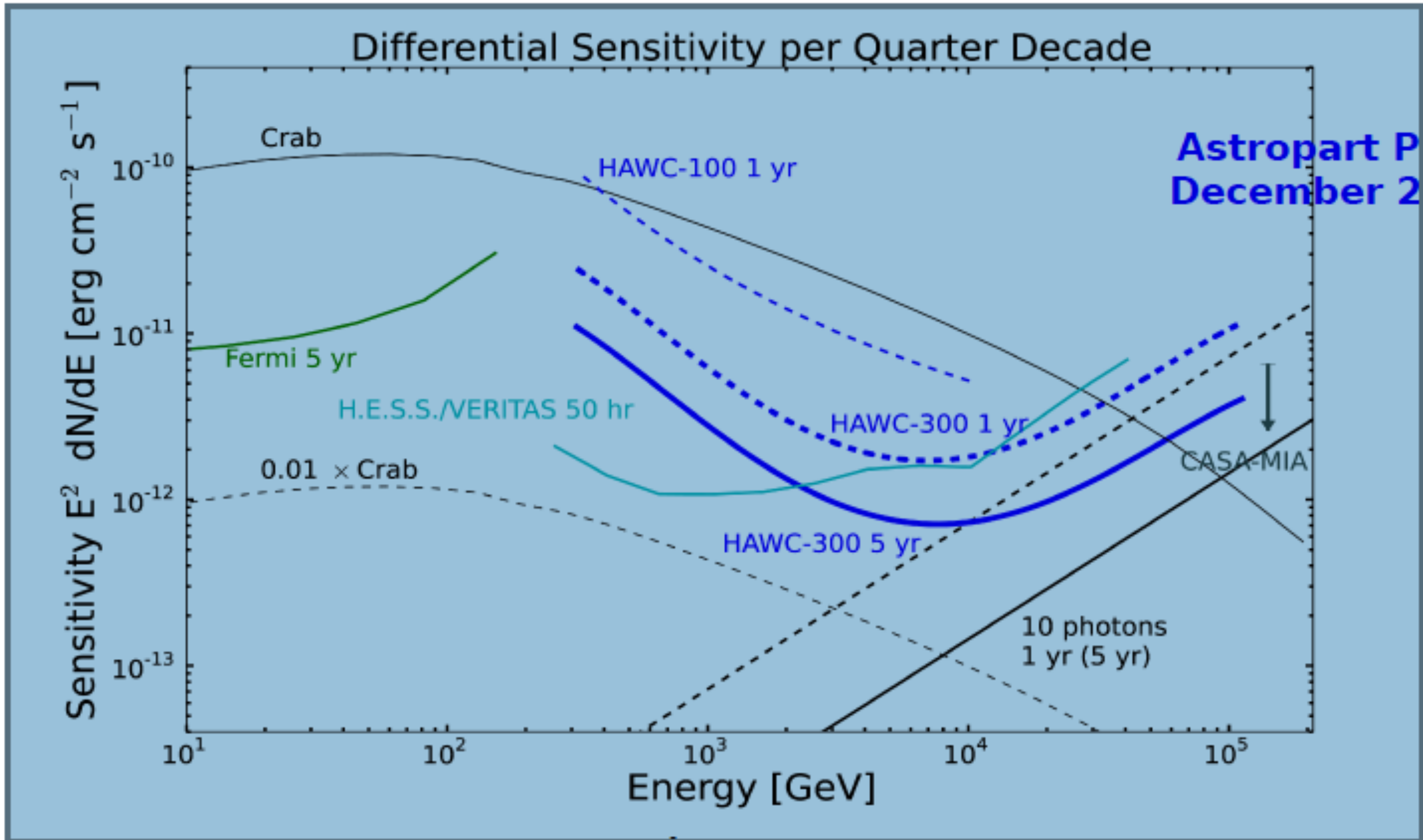
HAWC Inauguration



HAWC Designed Sensitivity

- Instantaneous sensitivity 15-20x less than IACTs.
- Exposure (sr/yr) is 2000-4000x higher than IACTs.

Survey > half the sky to:
40 mCrab [5σ] (1yr)
<20 mCrab [5σ] (5yr)

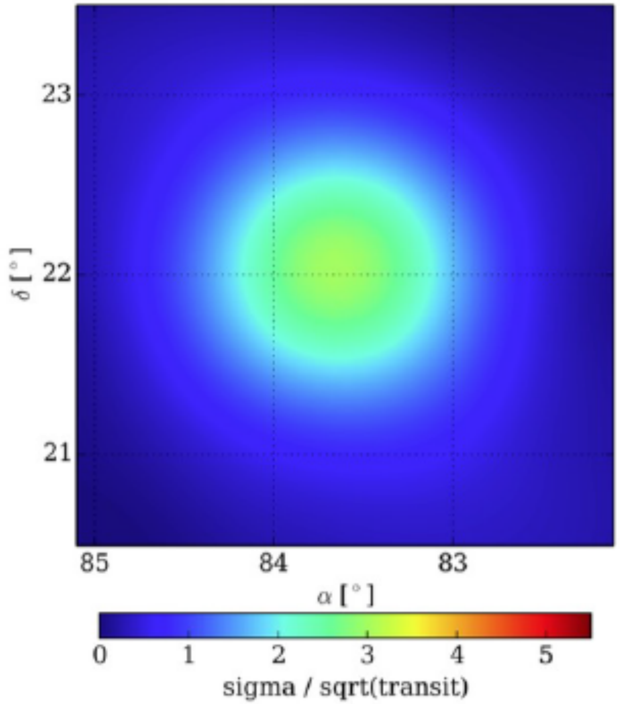


Astropart Phys 50-52, December 2013, 26-32

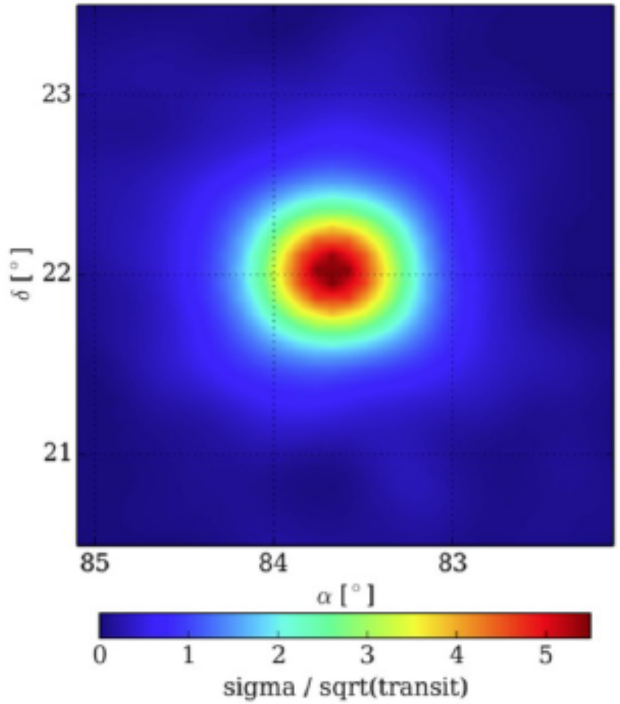
Pass 4 Preview: Crab Data

- Recovers the designed sensitivity.
- Already running online: presently getting >5σ per day on the Crab.

PRELIMINARY



Pass 3
3.1σ/sqrt(day)

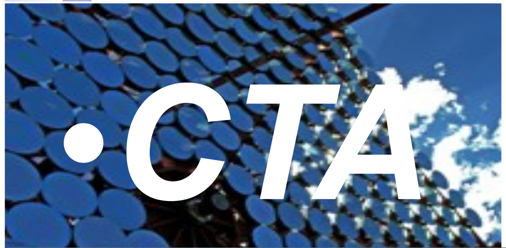


Pass 4
5.5σ/sqrt(day)

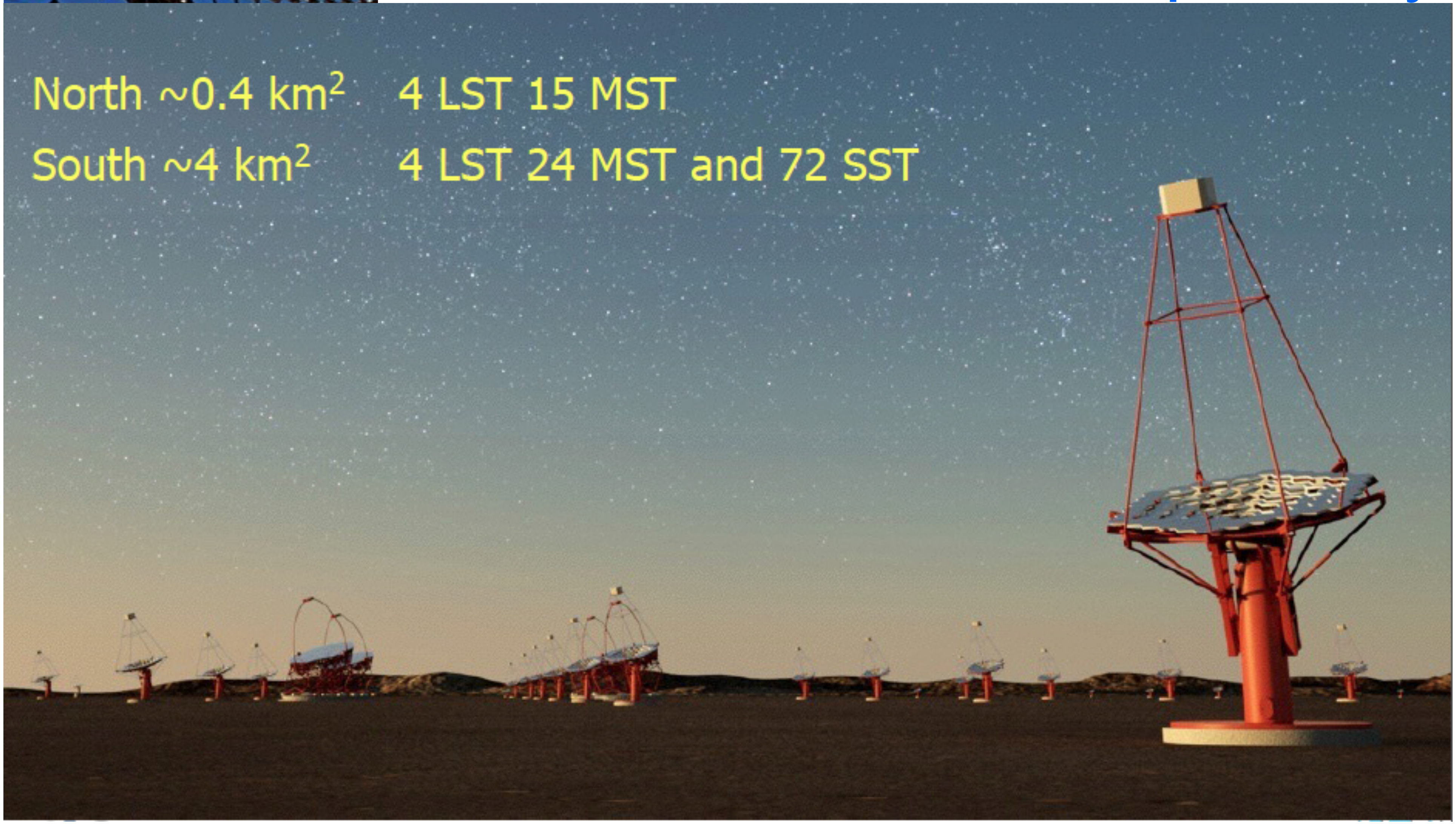
Future TeV telescopes

Wish list

- Higher sensitivity at TeV energies (x 10)
  - more sources
- Lower threshold (some 10 GeV)
  - pulsars, distant AGN, source mechanisms
- Higher energy reach (PeV and beyond)
  - cutoff region of Galactic accelerators
- Wide field of view
  - extended sources, surveys
- Improved angular resolution
  - structure of extended sources
- Higher detection rates
  - transient phenomena

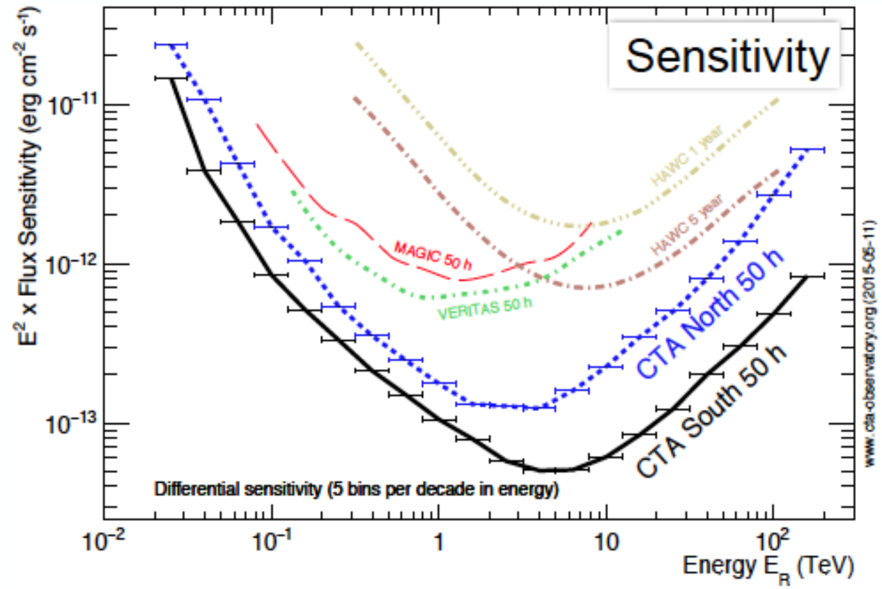


The Next Generation:
The Cherenkov Telescope Array

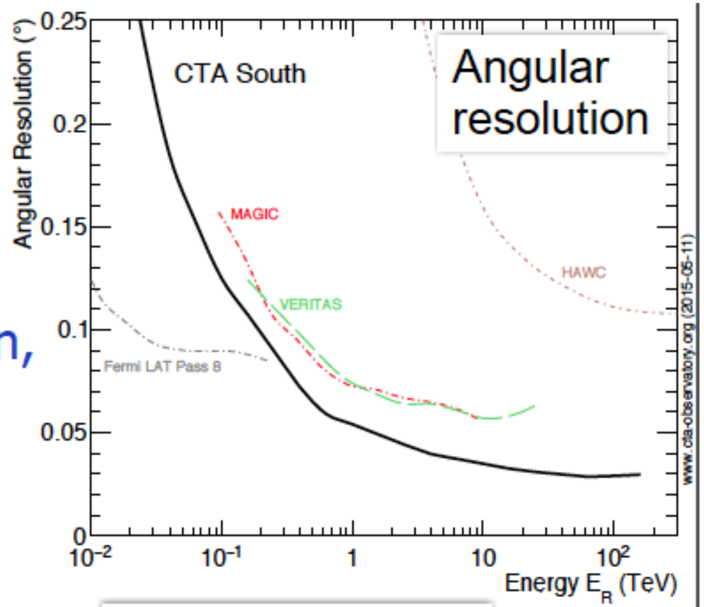


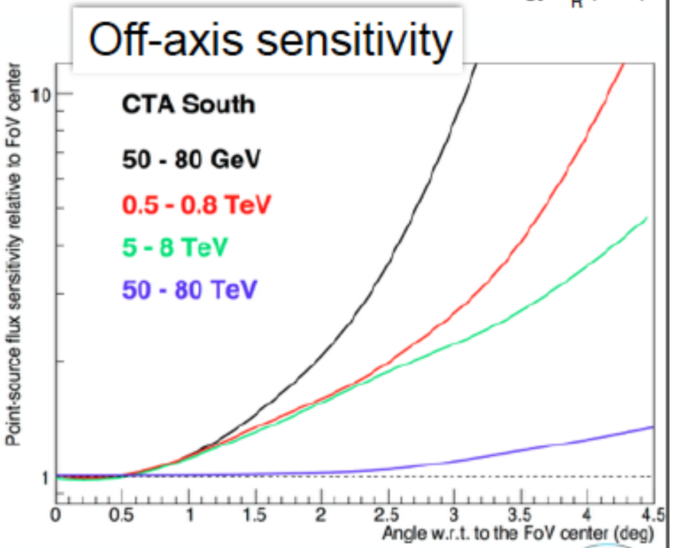
CTA Performance

> Result of large-scale simulations (900 telescopes for layout optimisation, CTA-GRID) and analysis



https://portal.cta-observatory.org/CTA_Observatory/performance/SitePages/Home.aspx

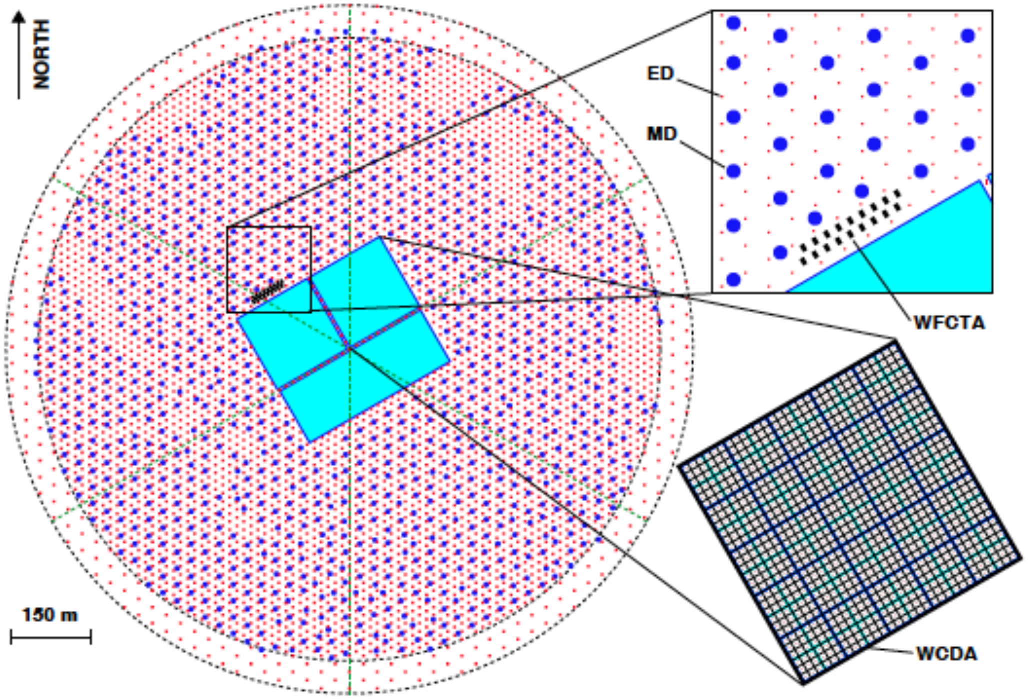




> MC Prod3 started recently – more realistic estimation of CTA performance

The LHAASO experiment

- 1 km^2 array, including 4941 scintillator detectors 1 m^2 each, with 15 m spacing.
- An overlapping 1 km^2 array of 1146, underground water Cherenkov tanks 36 m^2 each, with 30 m spacing, for muon detection (total sensitive area ≈ 42,000 m^2).



- A close-packed, surface water Cherenkov detector facility with a total area of 80,000 m^2.
- 18 wide field-of-view air Cherenkov (and fluorescence) telescopes.

Status of LHAASO

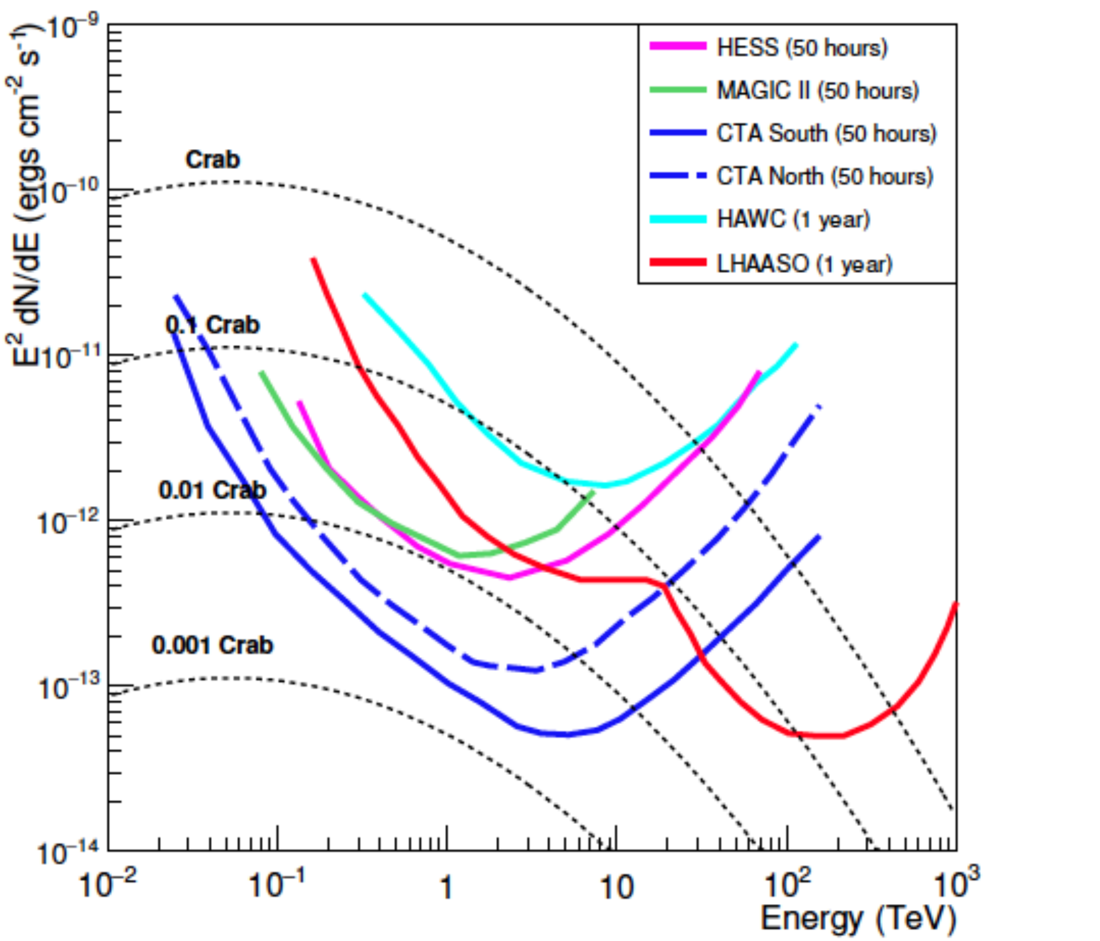
- LHAASO is finally approved and funded for detectors and infrastructures
- Construction of infrastructures started in July 2015.
- Installation of detectors started in September 2015 for tests.
- Spring 2016: Start of construction of the first water pond.

★ 2018: commissioning first pond and the first 25% of KM2A.

★ 2021: conclusion of installation of main components.

Construction of muon detectors

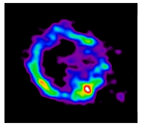
Sensitivity future detectors



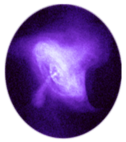
Overview of TeV gamma-ray Science

I. Astronomy and Astrophysics

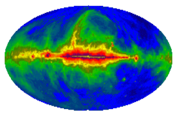
A. Galactic sources



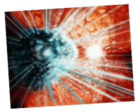
- **Shell-type Supernova Remnants**



- **Pulsar wind nebula**
- **Binary systems**
- **Microquasars**
- **Central black hole**



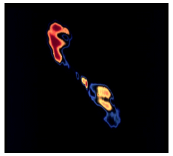
- **Galactic Diffuse Emission**



- **Galactic Cosmic Ray Origin**
- **Dark sources**

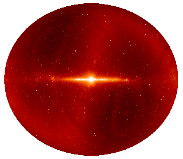
Overview of gamma-ray Science

B. Extra Galactic sources

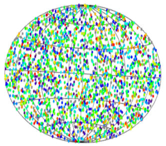


Radio galaxies

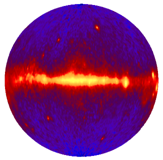
- **Blazars**



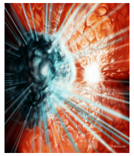
- **Extragalactic Background Light**



- **Gamma Ray Bursts**



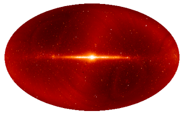
- **Unidentified Sources**



- **Ultra-High Energy Cosmic Ray Origin**

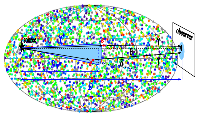
Overview of gamma-ray Science

Cosmology



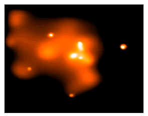
•**Extragalactic Background Light**

• **Primordial magnetic field**

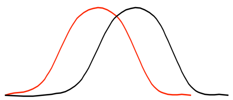


• **Distant Gamma Ray Bursts (GeV)**

Particle physics



•**Dark Matter**

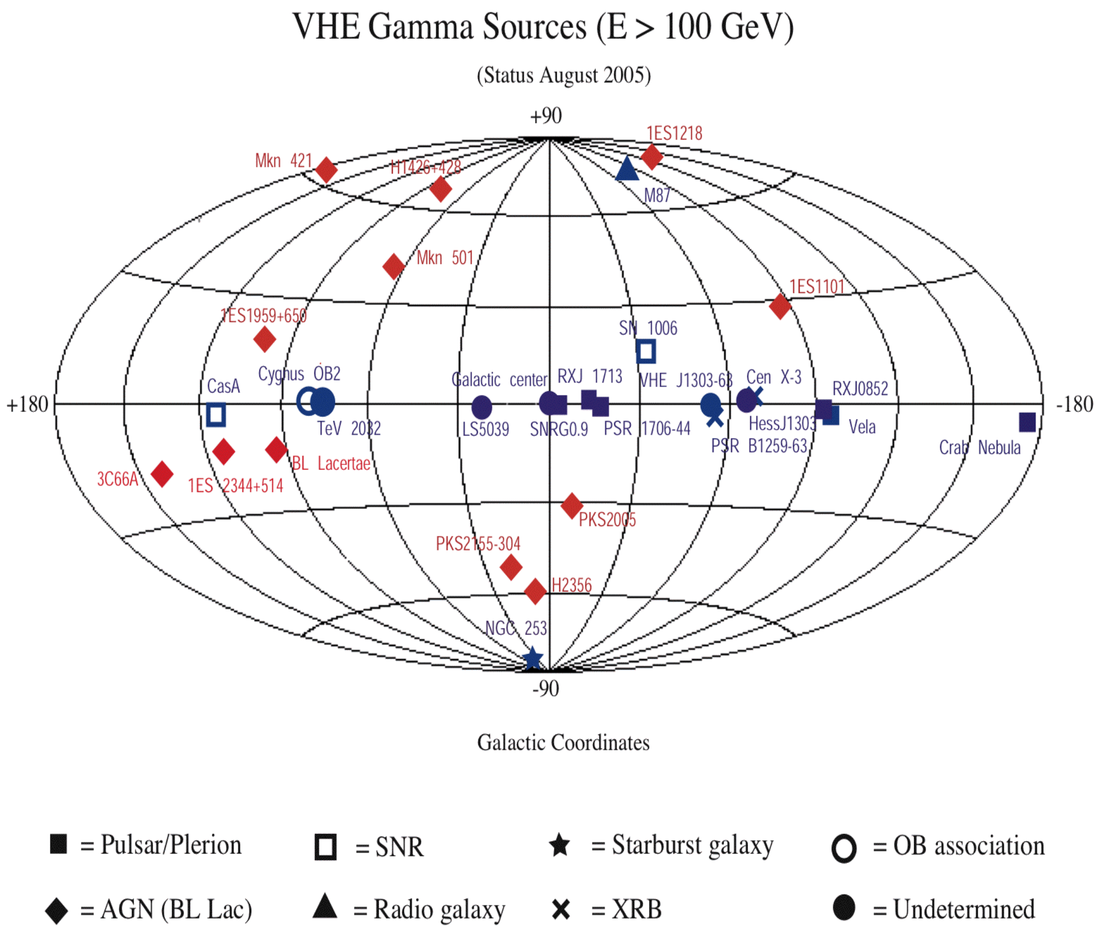


•**Lorentz symmetry violation**

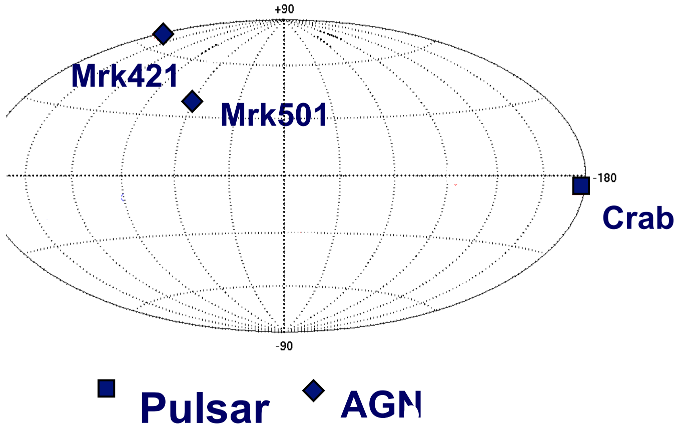
Gamma-ray sky

The VHE γ ray sky

2005

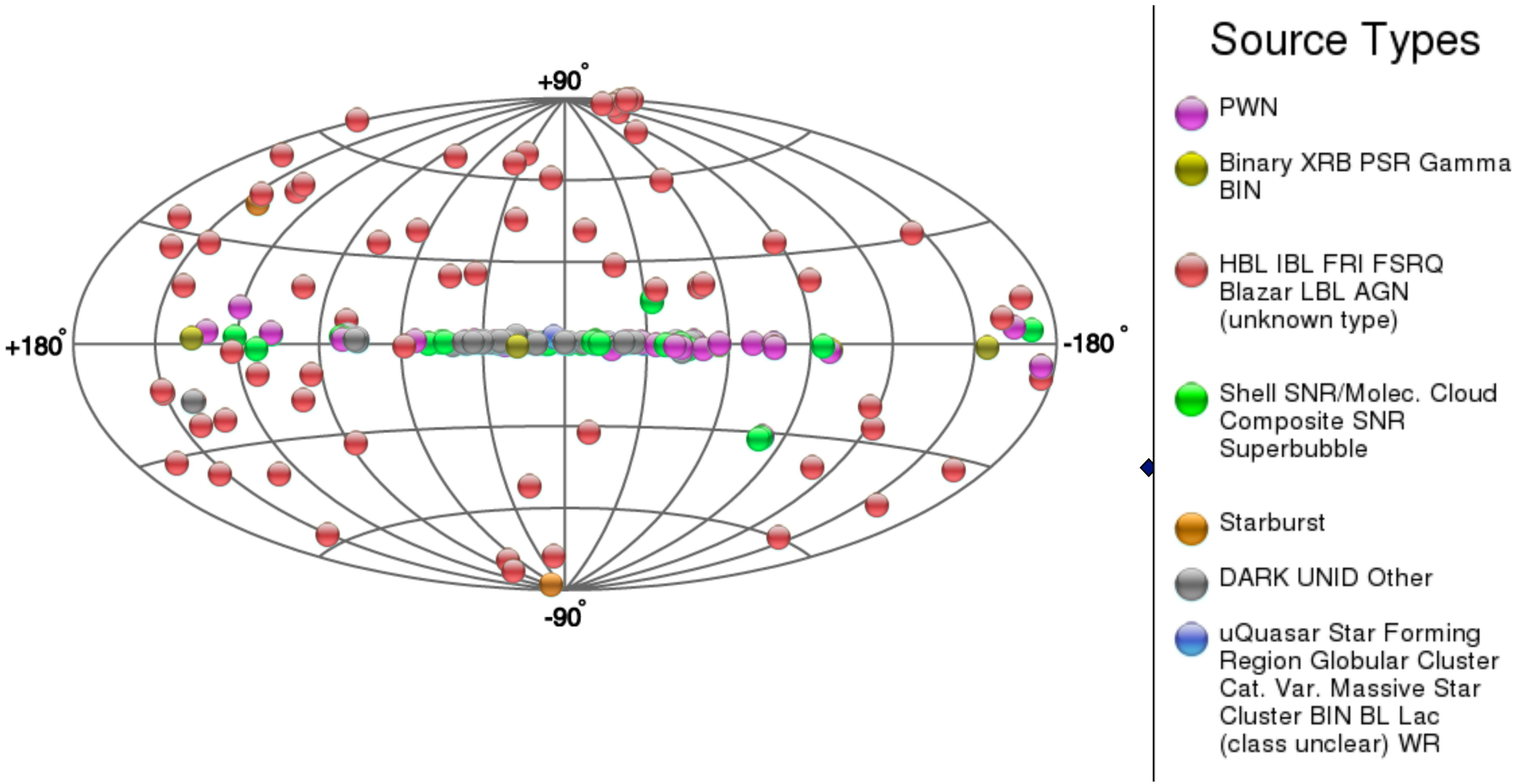


1995



The VHE γ ray sky Dec 2015

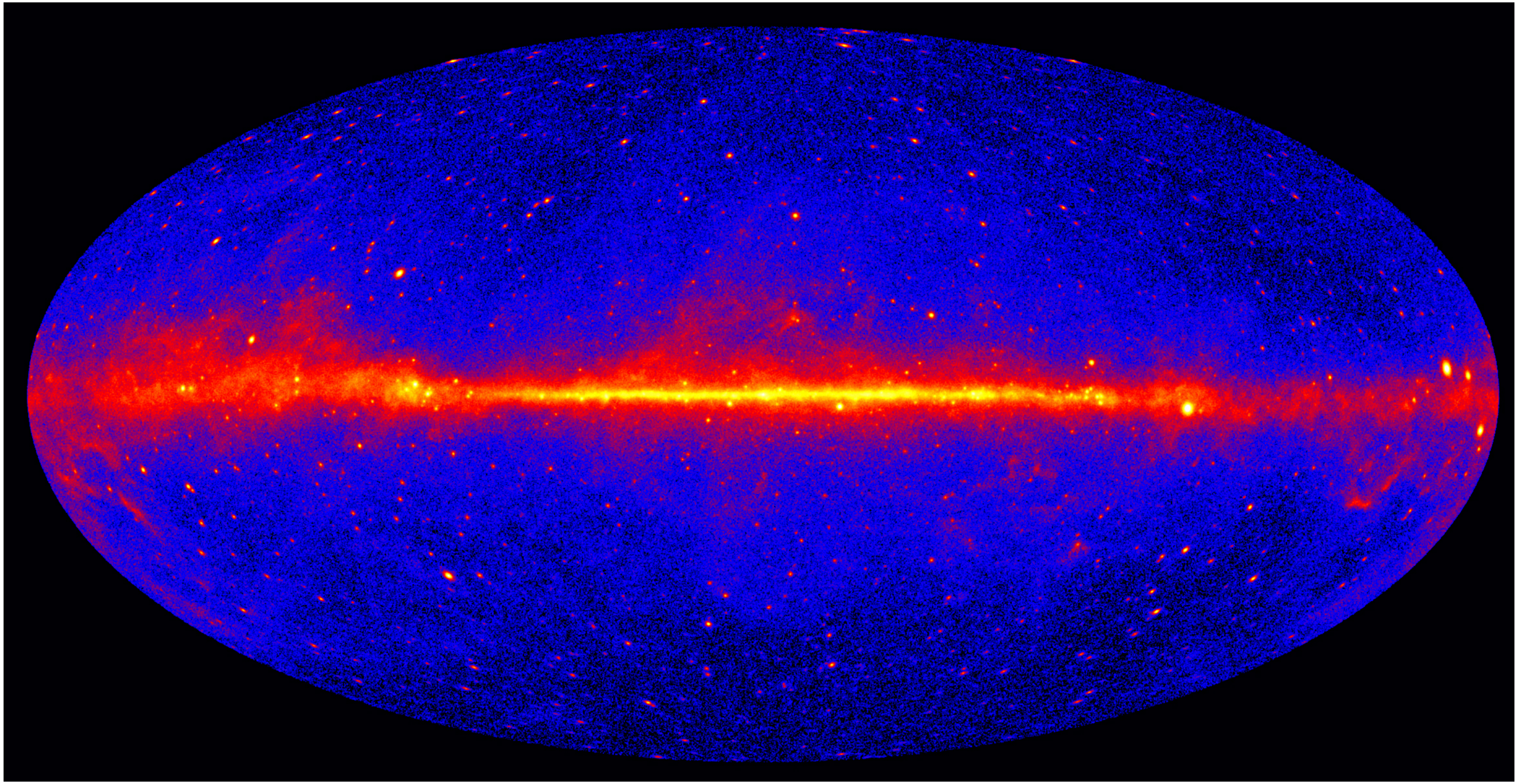
176 sources



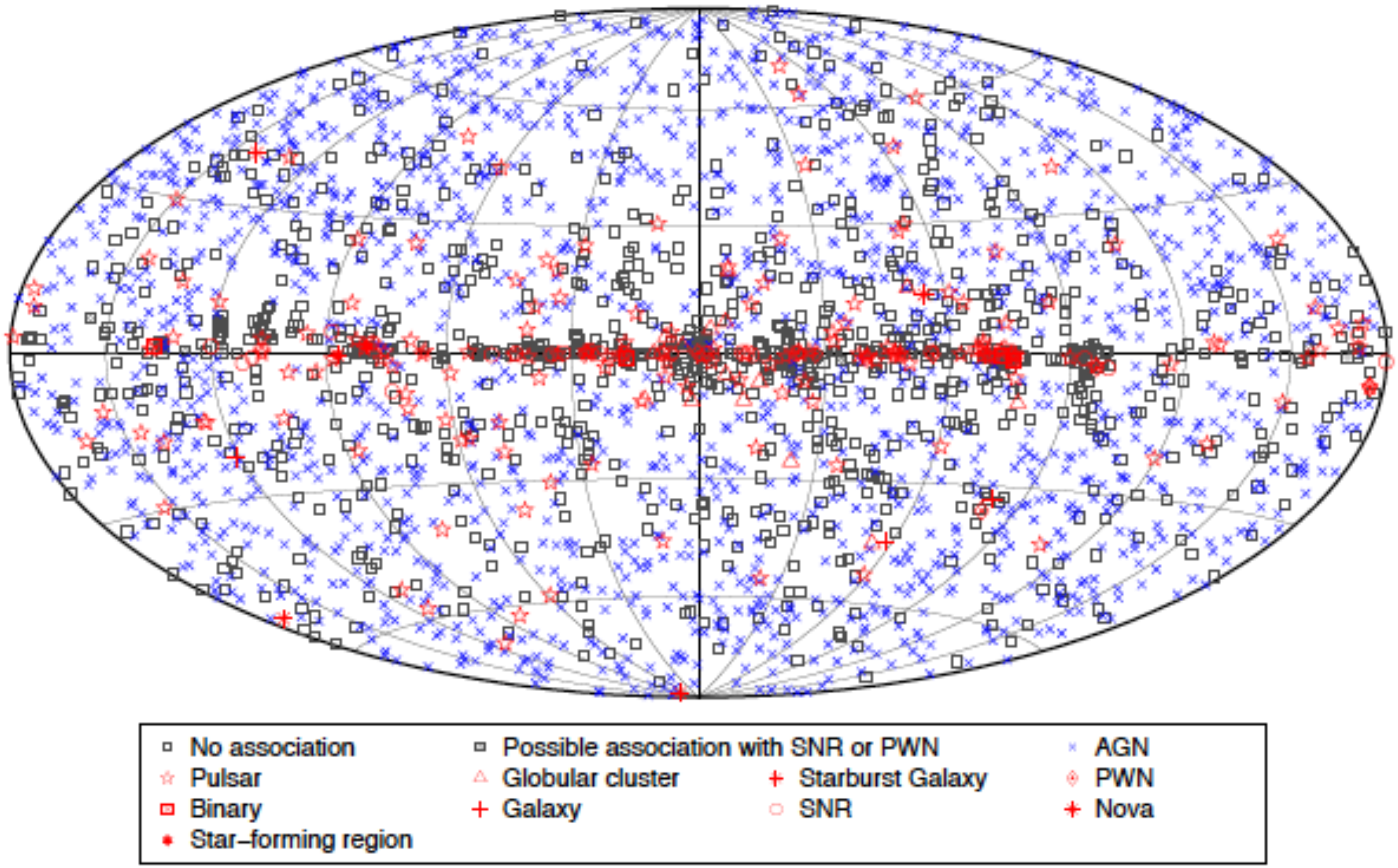
Source Counts

Source Type*	1995	2005	2015
Pulsar Wind Nebula (e.g. Crab, MSH 15-52 …)	1	5	37
Supernova Remnants (e.g. Cas-A, RXJ 1713 …)	0	4	15
Binary systems (B1259-63 etc)	0	1	6
X-ray binary	0	0	4
Galactic Center	0	1	1
Superbubble	0	1	2
Star clusters	0	0	4
Molecular clouds	0	0	2
BL LACs (e.g. Mkn 421, PKS 2155 …)	2	9	55
FSRQ	0	0	5
AGNs (M87, Cen A	0	1	4
Unidentified	0	6	42
TOTAL	[illegible]	[illegible]	[illegible]

Fermi LAT 5 years all sky 1GeV

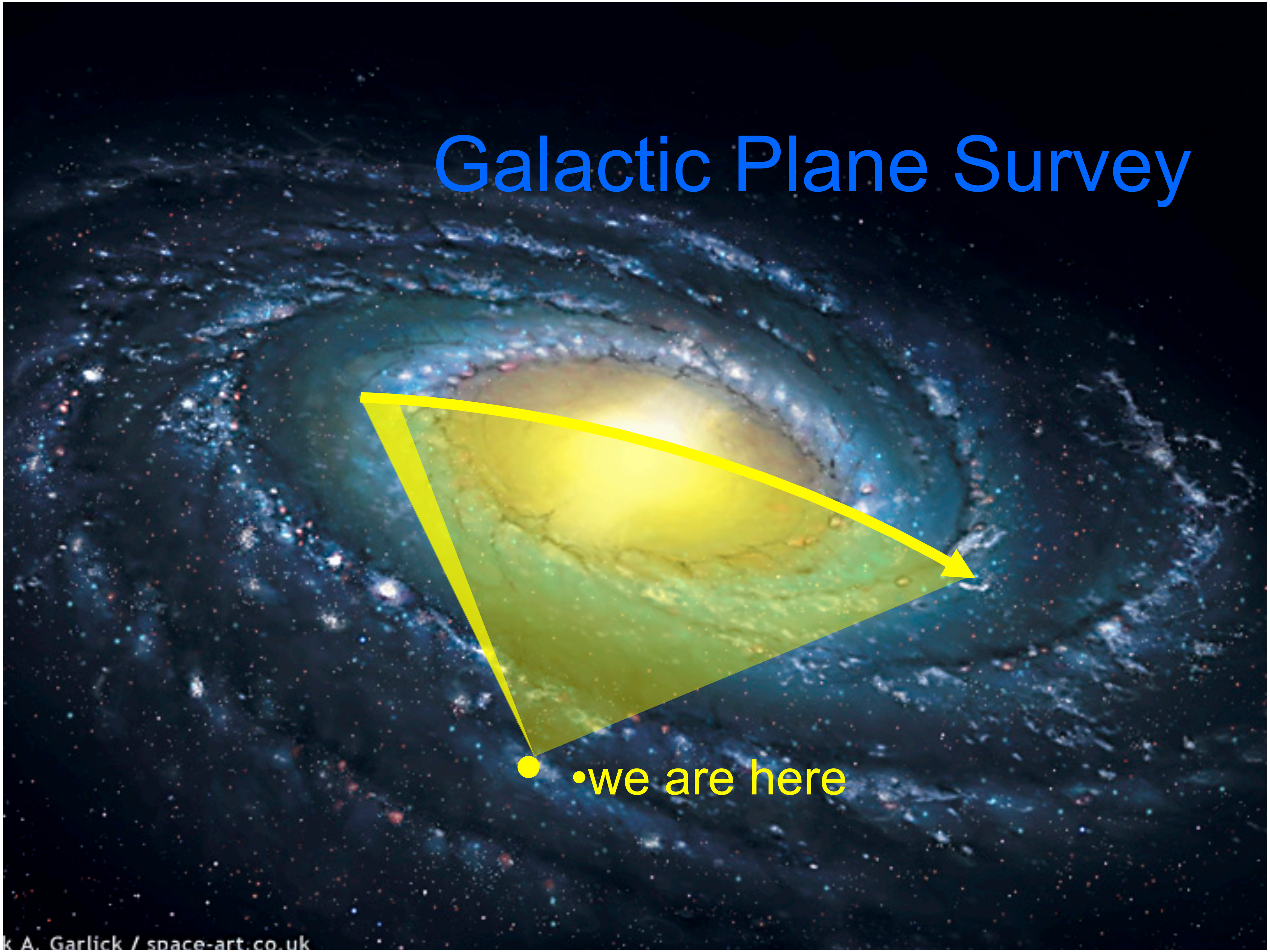


Fermi LAT source catalog: 3000 sources

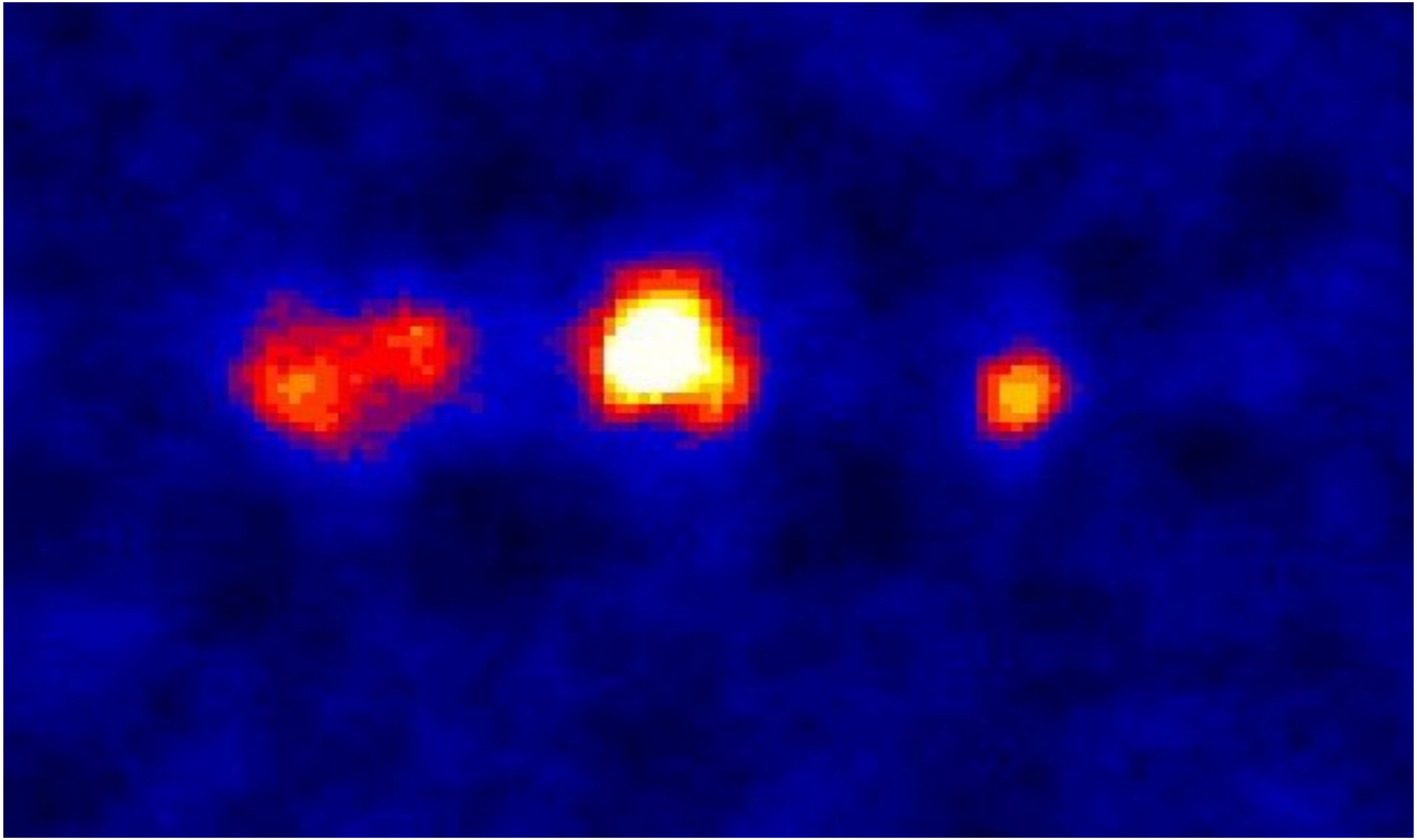


Galactic sources

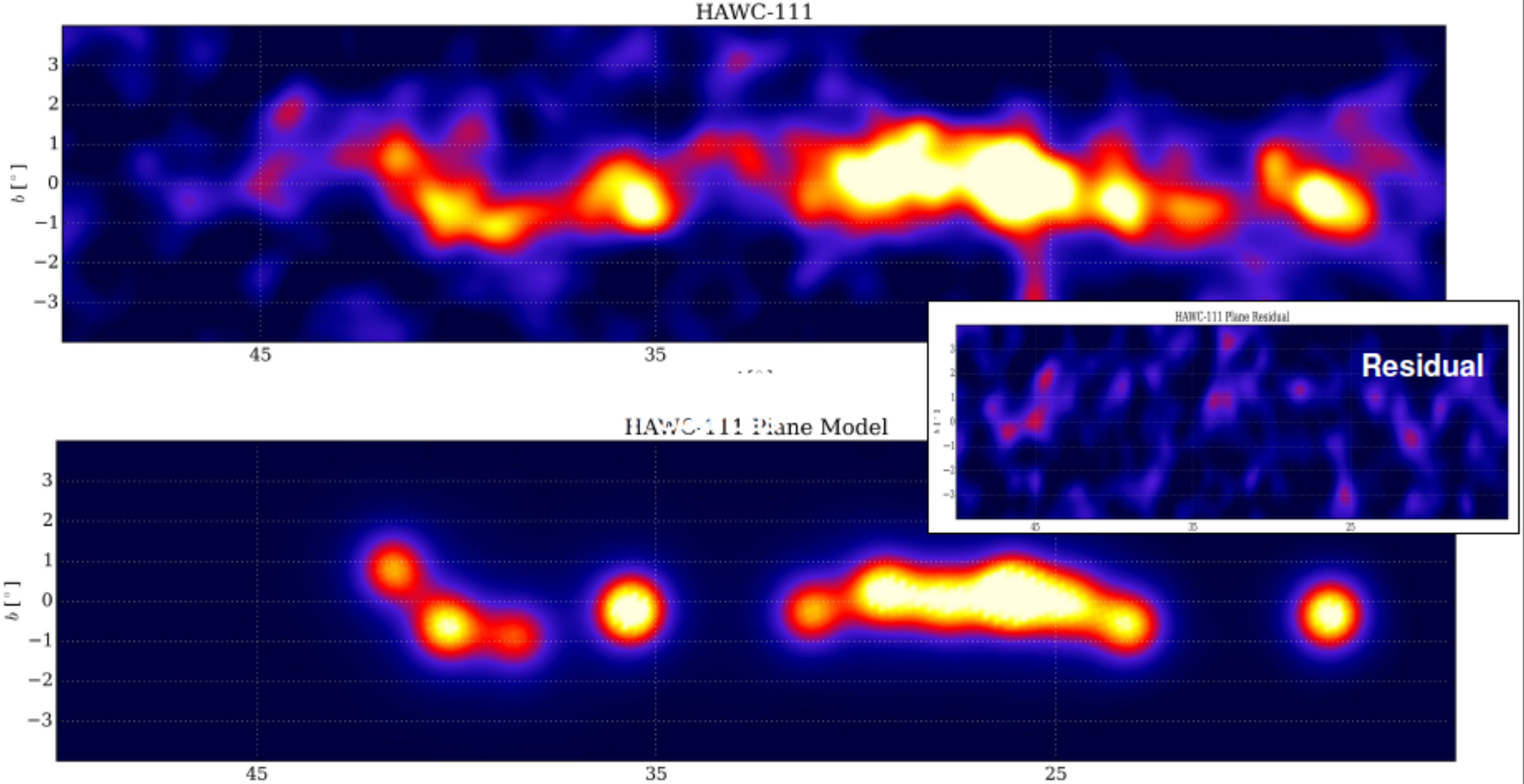
Galactic Plane Survey



H.E.S.S Galactic Plane Survey

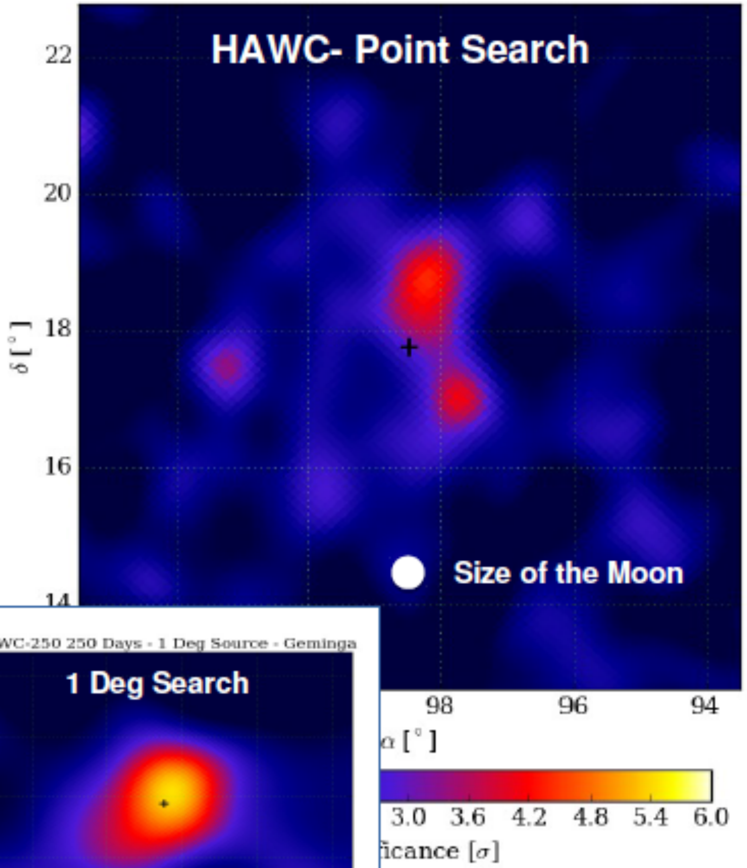


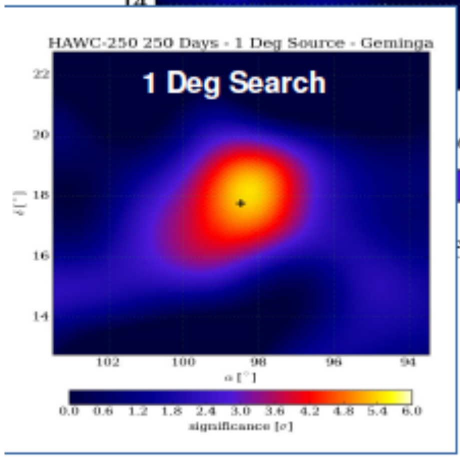
HAWC GP Survey

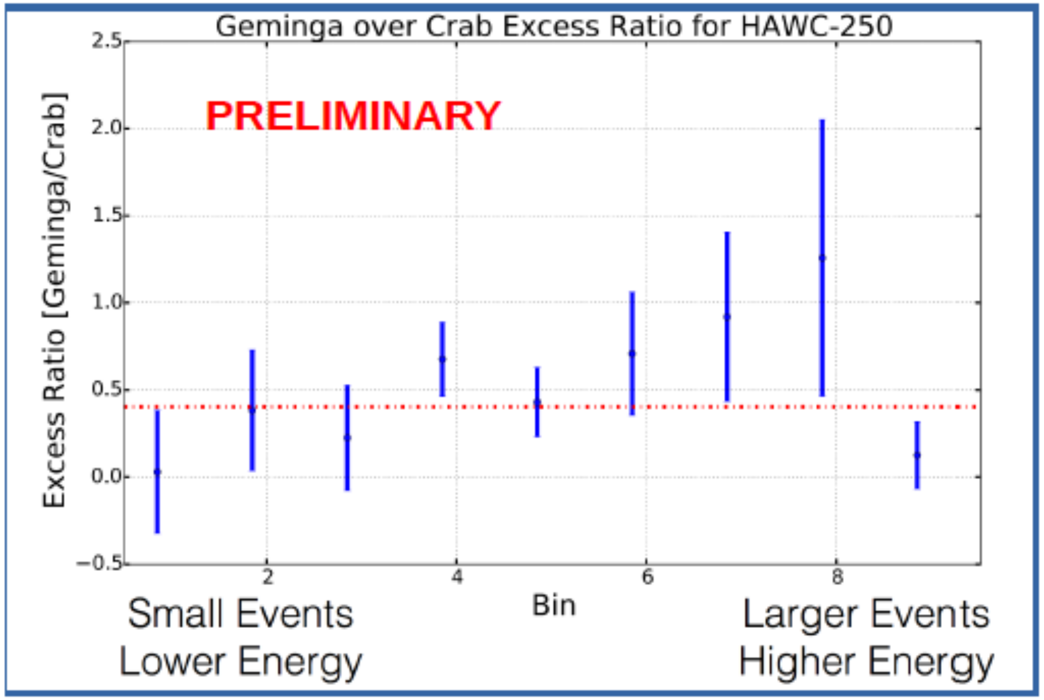


- 10 sources/candidates are >3σ post-trial: 3 firm detections (>5σ) and 7 candidates (<5σ).

Geminga



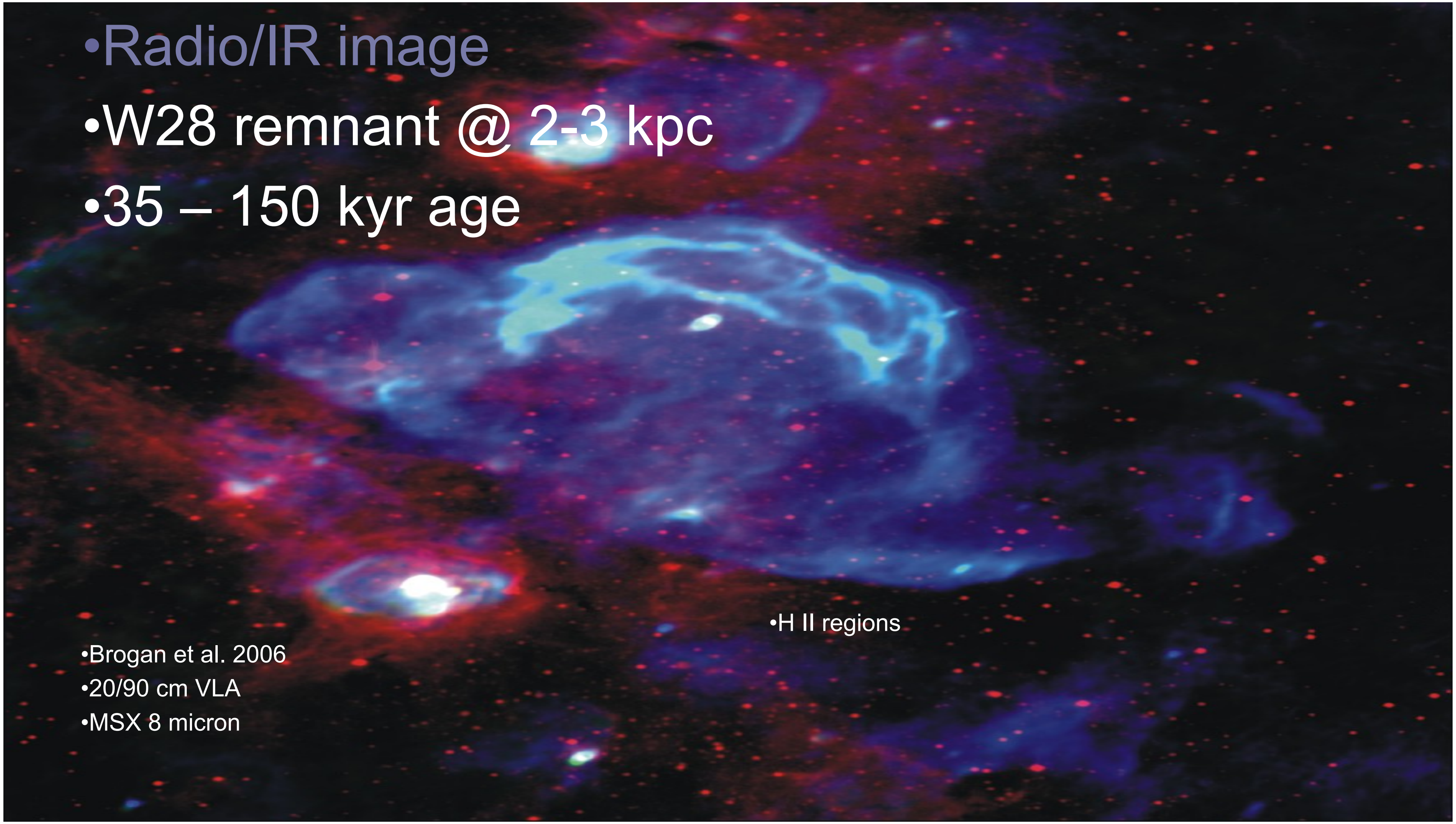




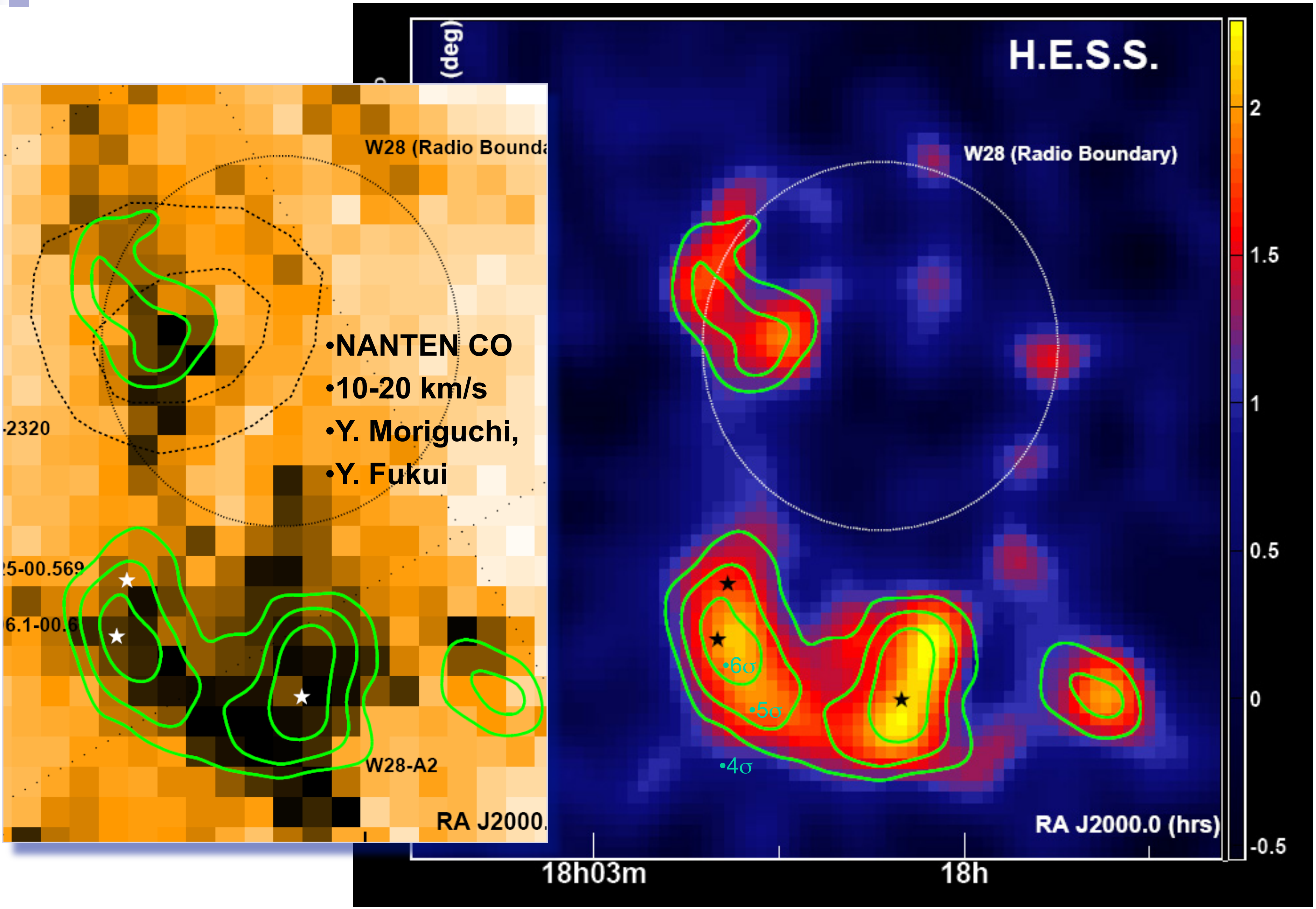
- Detected in HAWC (Pass 3) at ~6σ using a 3 deg search.
- Looks harder than the Crab.
- Analysis in progress.

Old SNRs & interacting SNRs

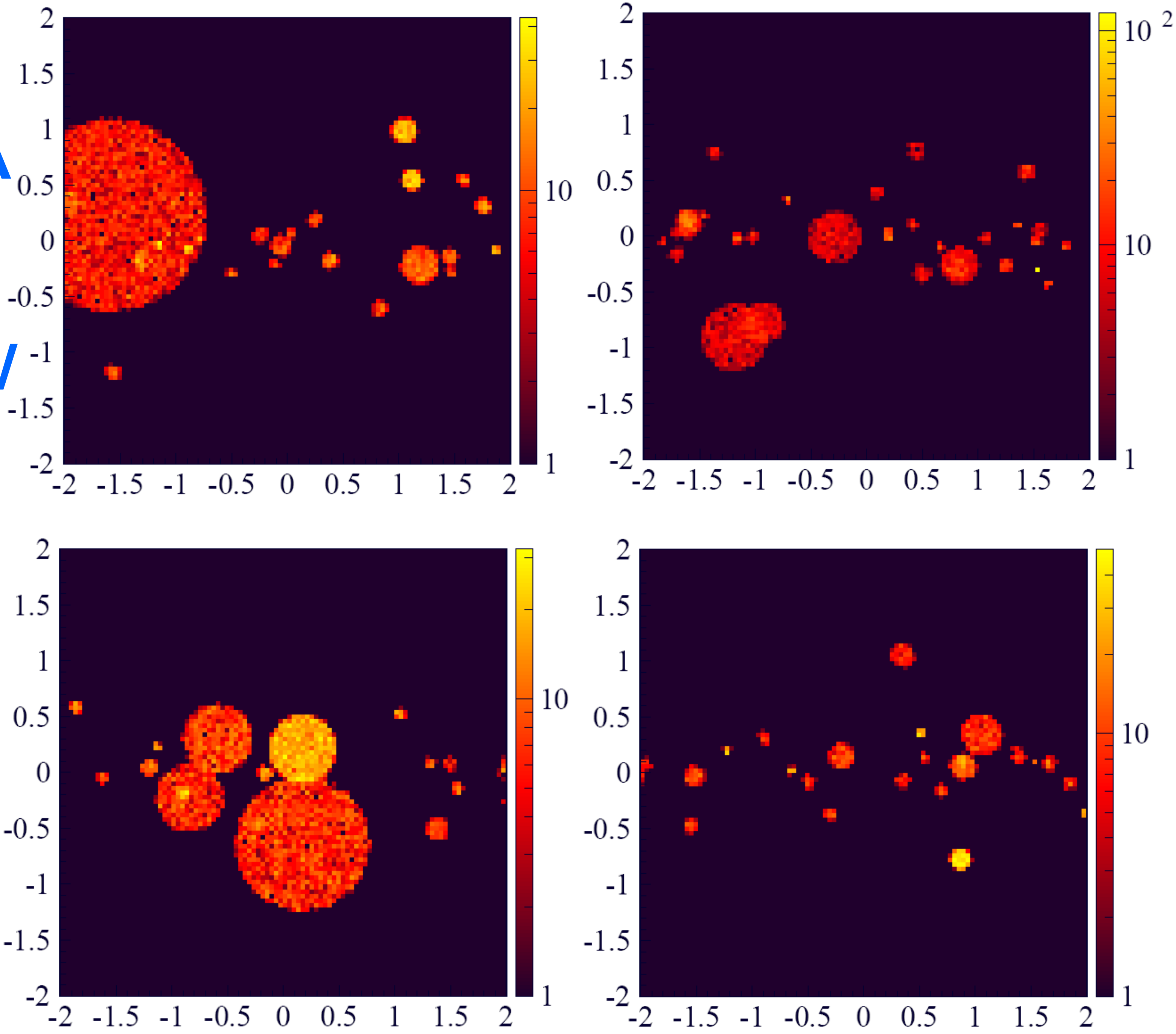
- Radio/IR image
- W28 remnant @ 2-3 kpc
- 35 – 150 kyr age



•Brogan et al. 2006
•20/90 cm VLA
•MSX 8 micron


W28 (Radio Bounda
•NANTEN CO
•10-20 km/s
•Y. Moriguchi,
•Y. Fukui
-2320
5-00.569
6.1-00.6
W28-A2
RA J2000.
H.E.S.S.
W28 (Radio Boundary)
(deg)
•6σ
•5σ
•4σ
RA J2000.0 (hrs)
18h03m
18h
2
1.5
1
0.5
0
-0.5

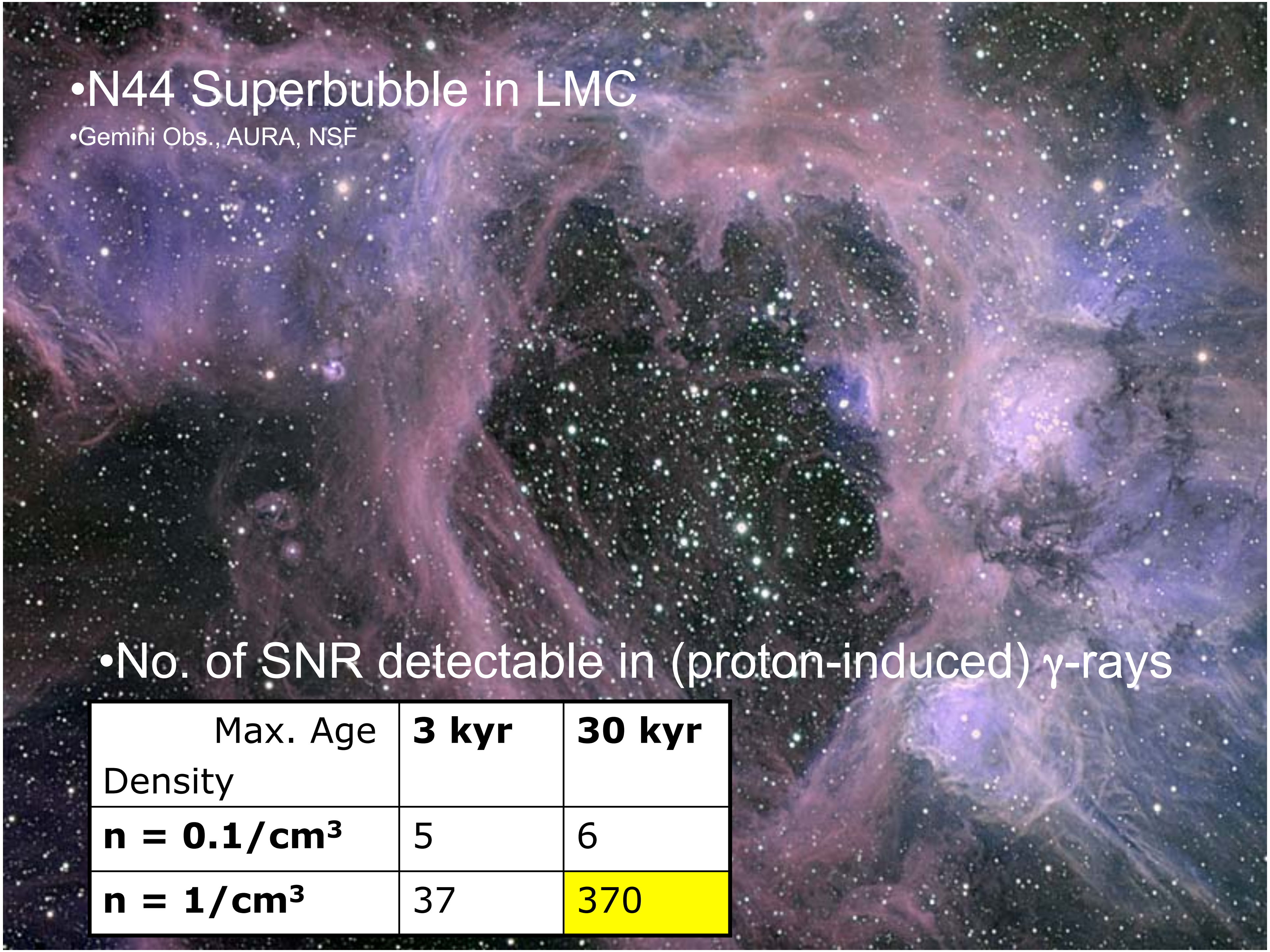
A CTA field of view



- SNR models
- using DAV 9
- n = 1
- ε = 0.1

- (consistent
- with HESS
- plane scan)

- assuming
- 1 mCrab

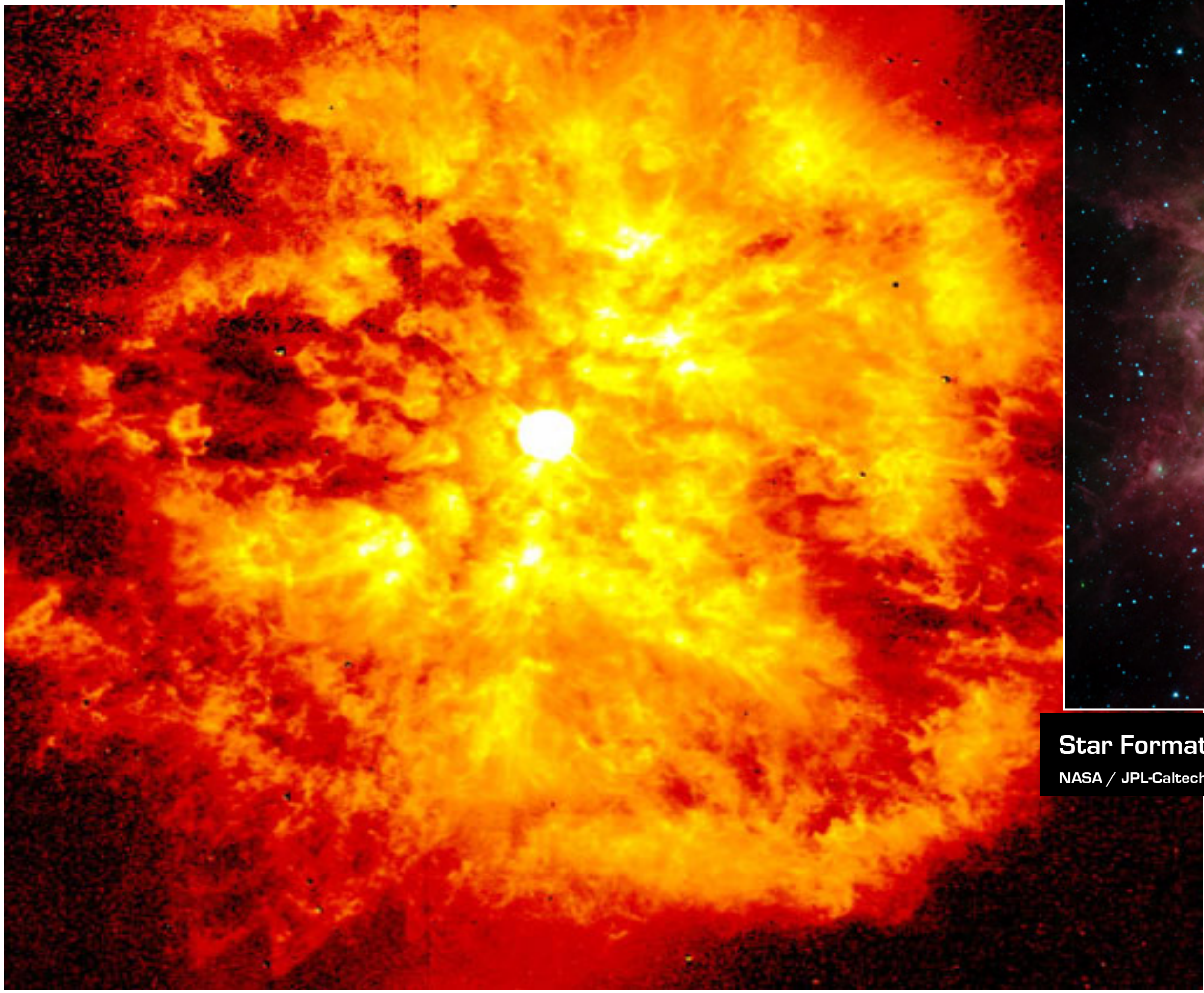


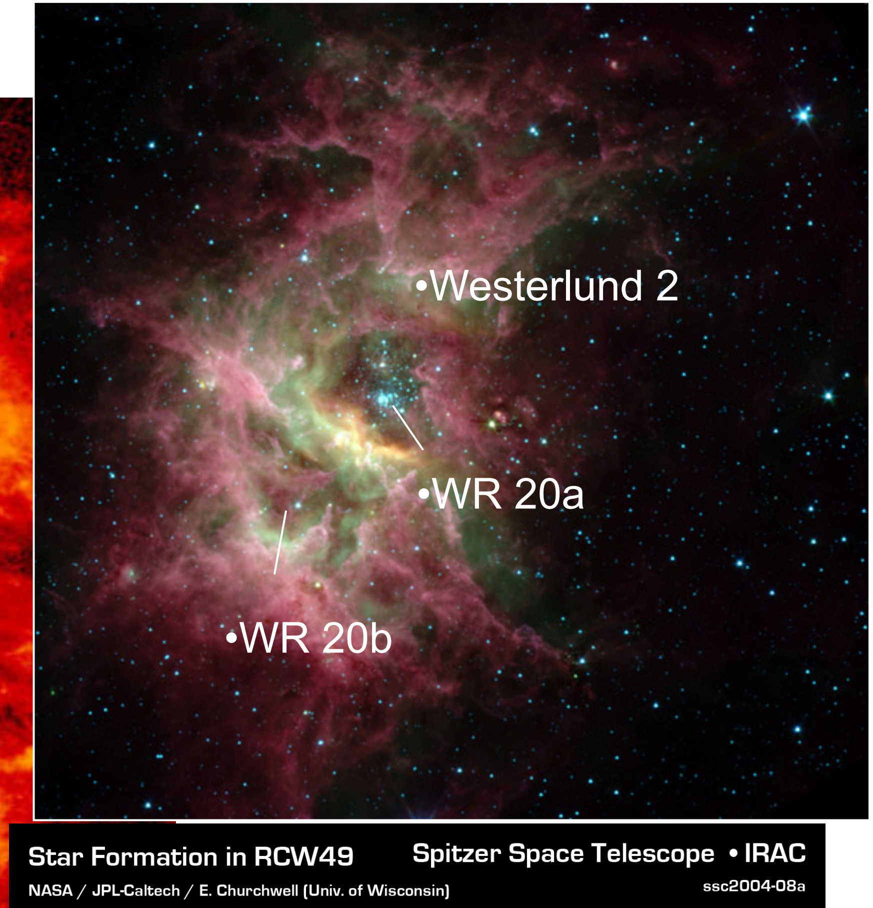
- N44 Superbubble in LMC
- Gemini Obs., AURA, NSF

- No. of SNR detectable in (proton-induced) γ-rays

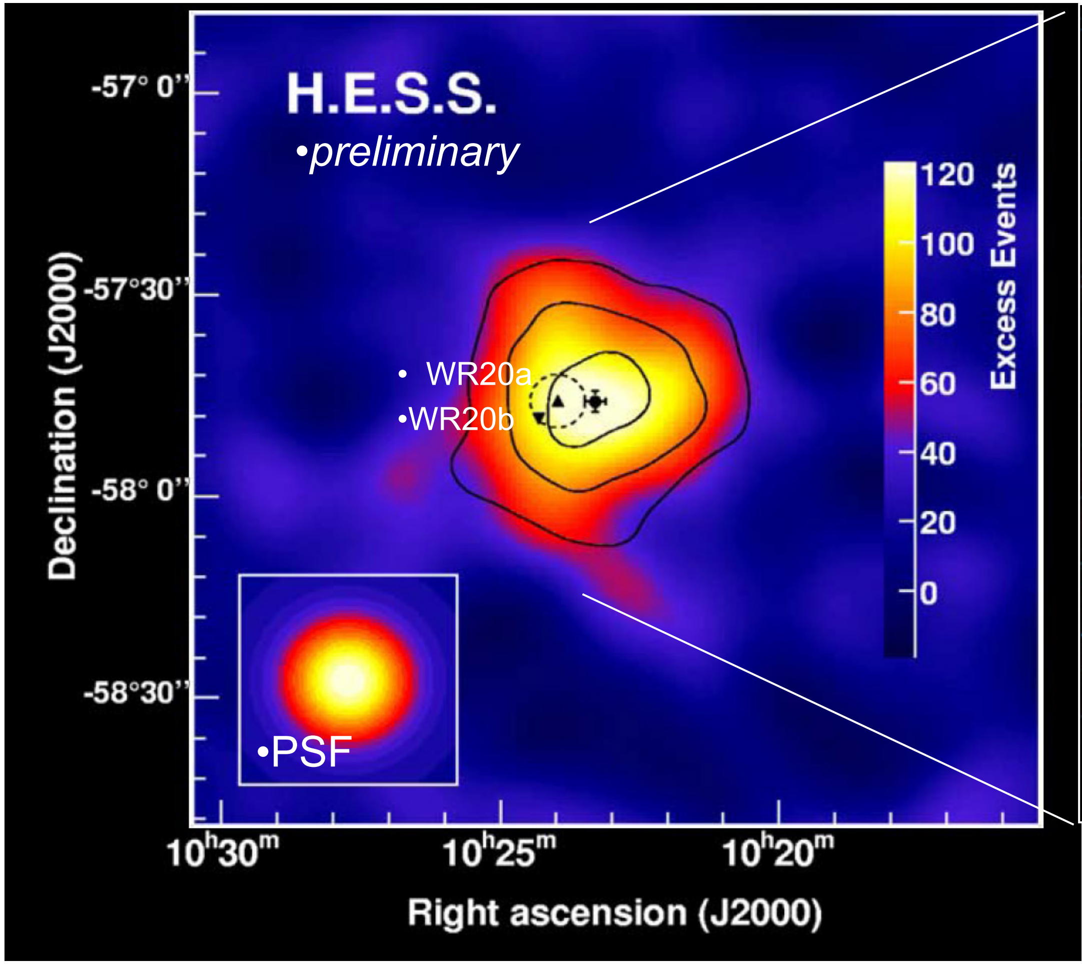
Max. Age / Density	**3 kyr**	**30 kyr**
n = 0.1/cm^3	5	6
n = 1/cm^3	37	370

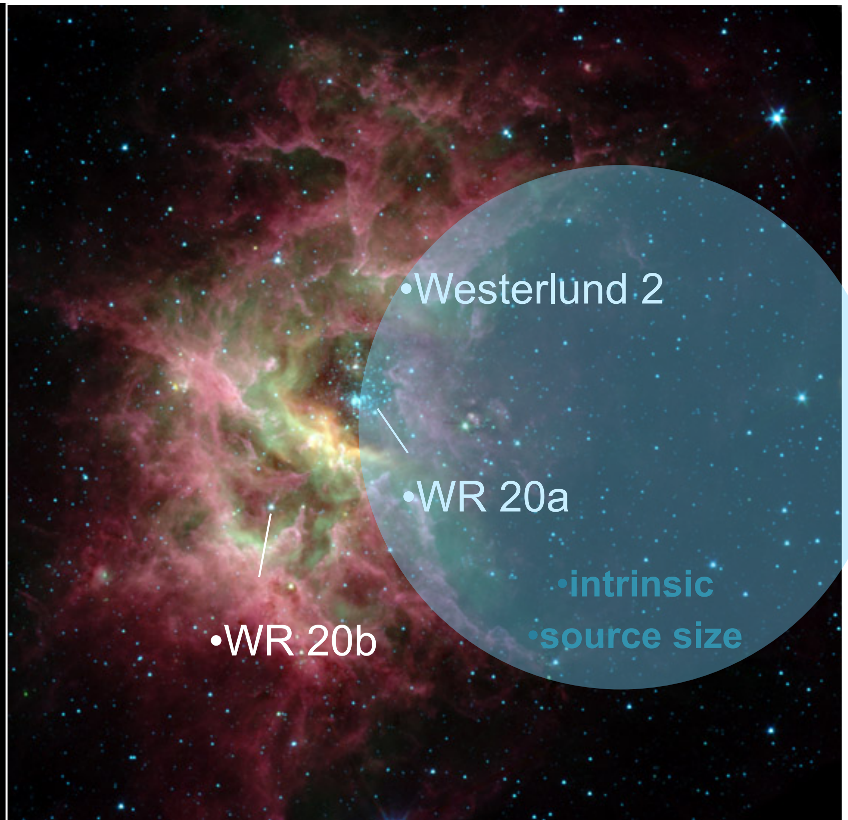
RCW 49:
Stellar Winds as Cosmic Accelerators





HESS J1023-575

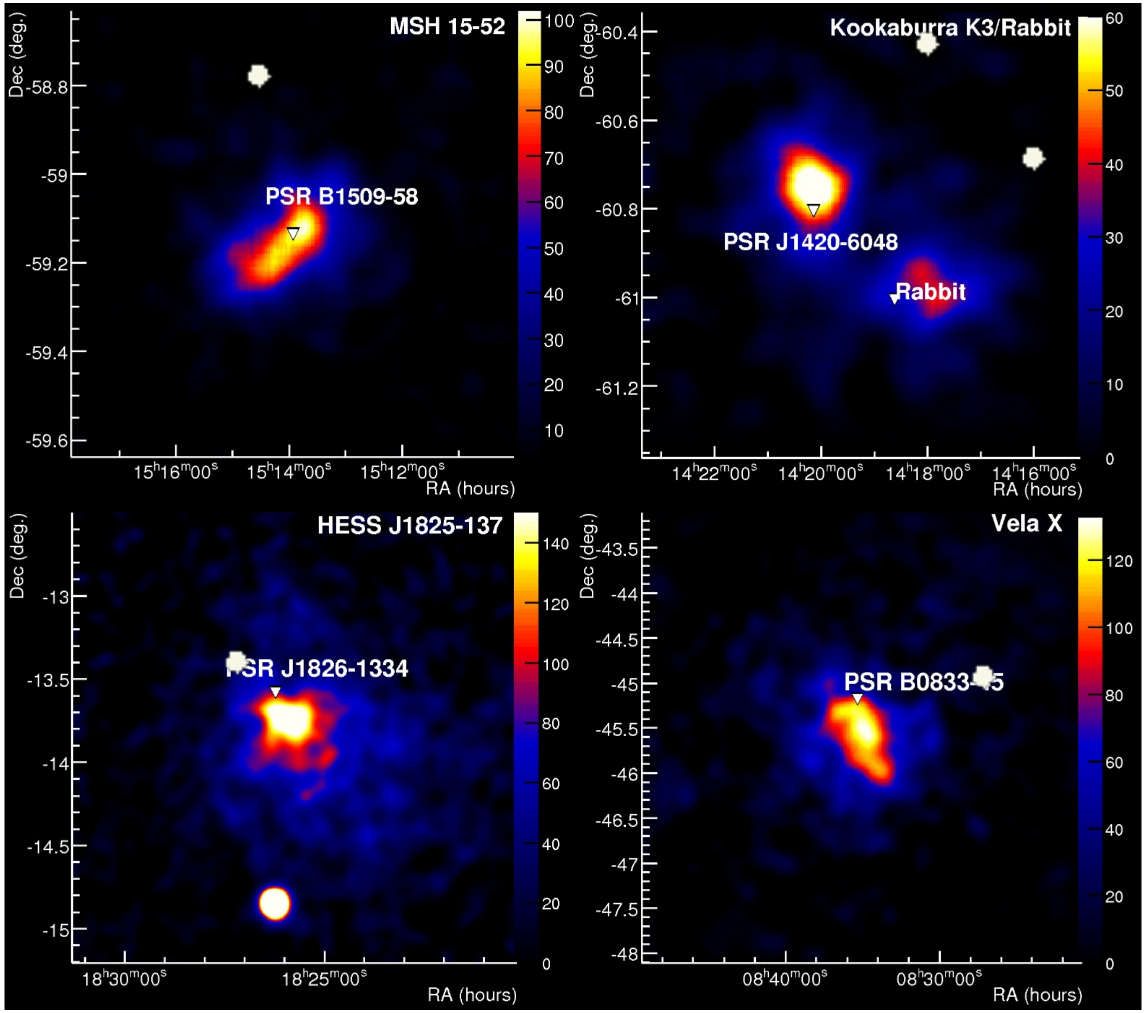




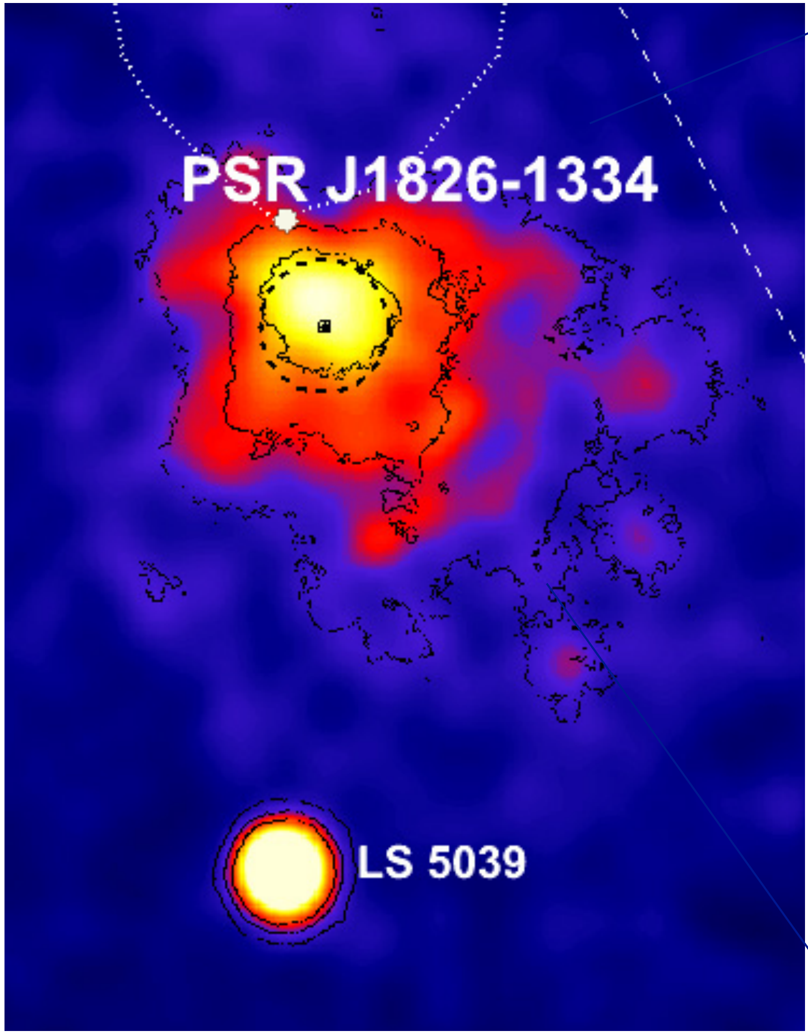
Pulsar Wind Nebulae

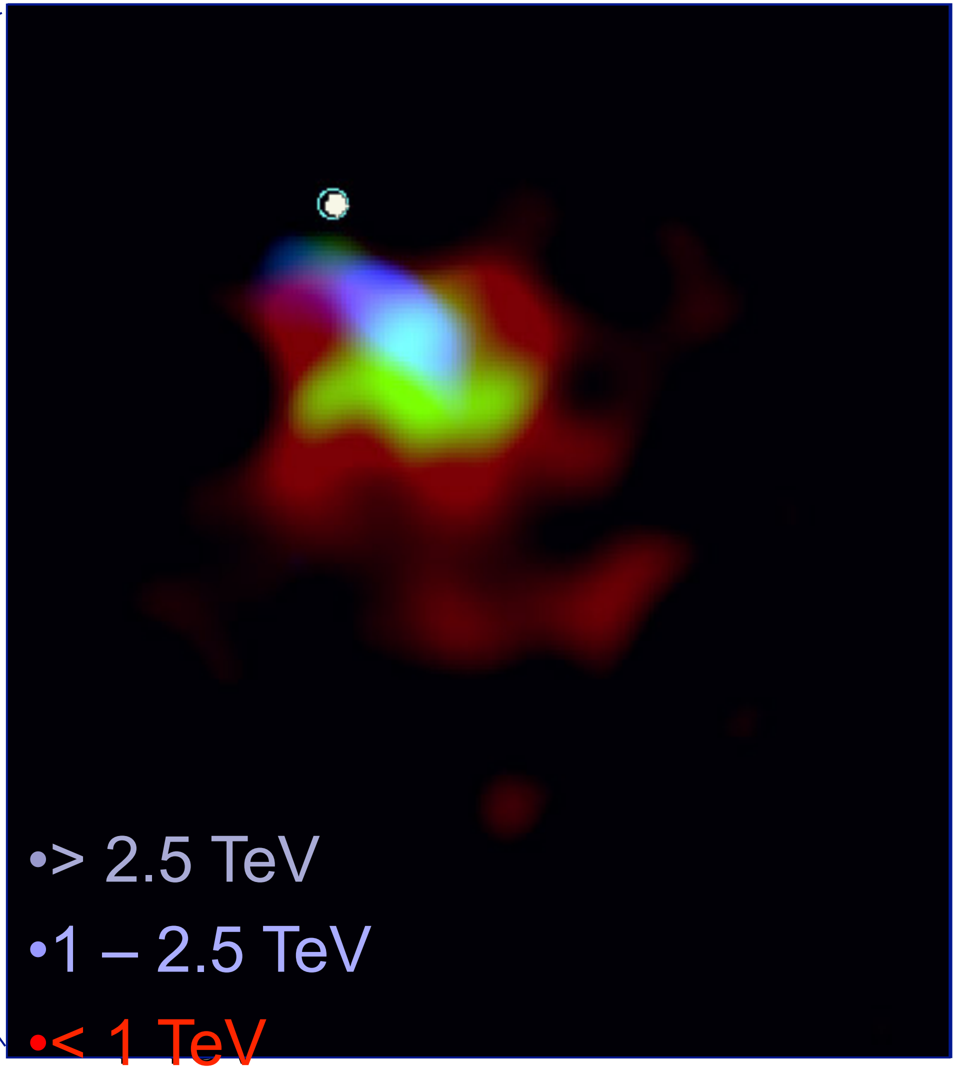
Extended

γ-ray sources

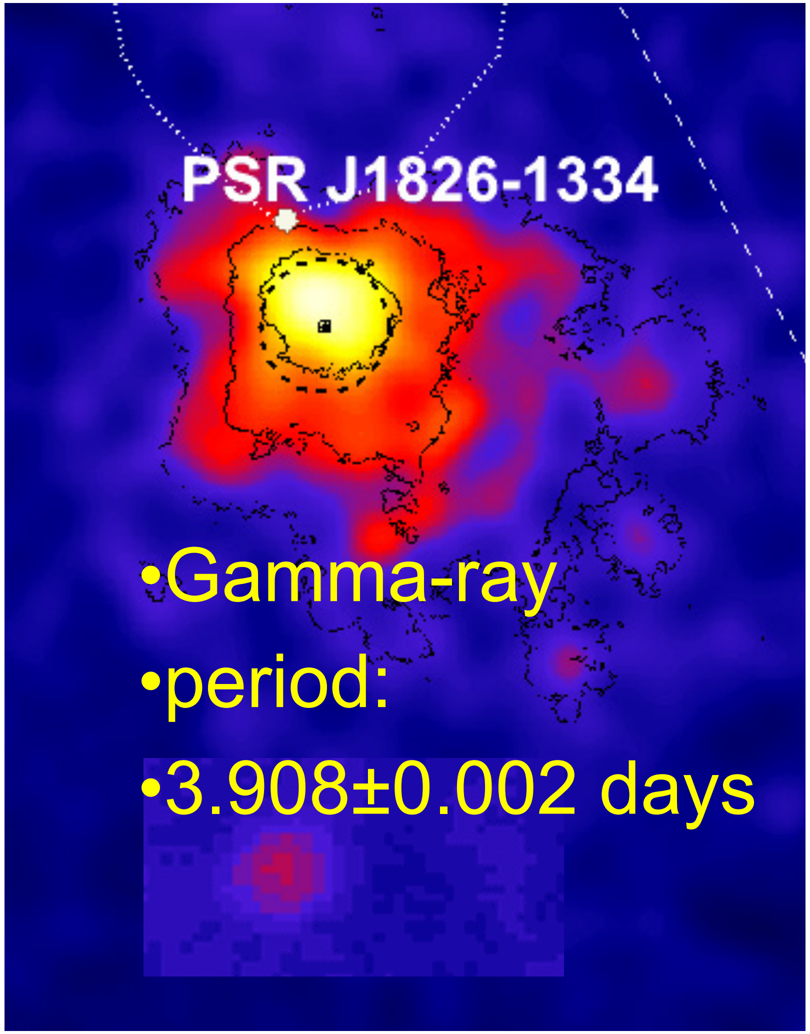


Morphology of PWN: HESS J1825-137

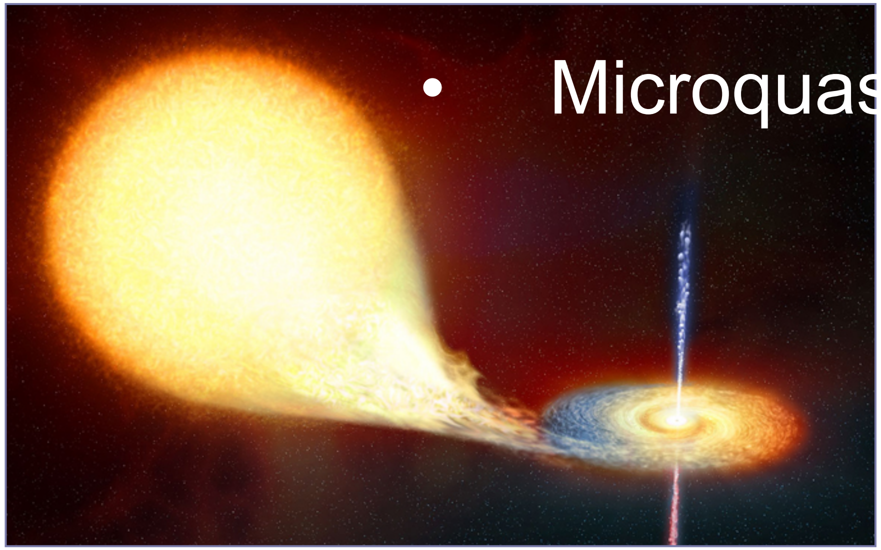




Binaries

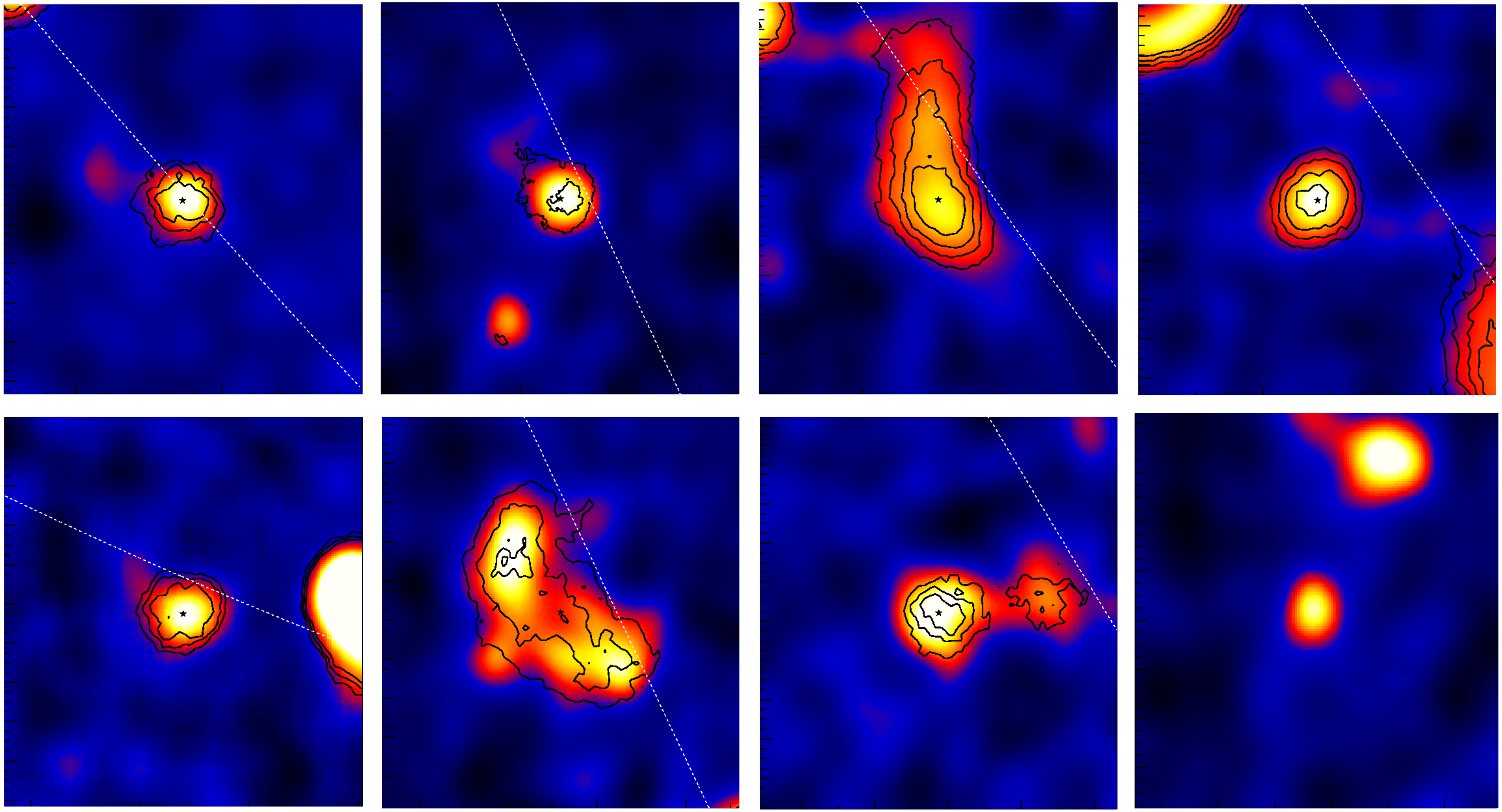


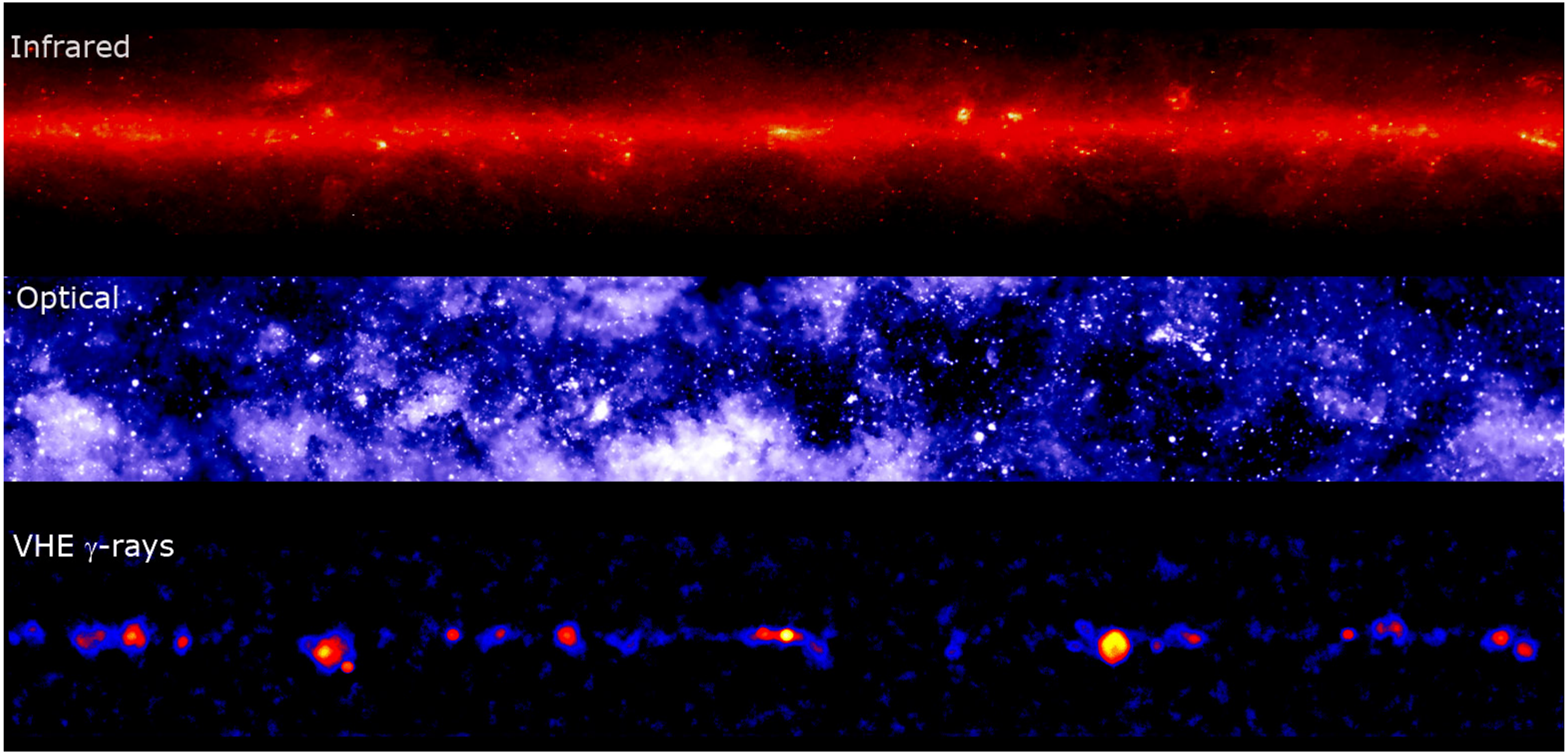
•Gamma-ray
•period:
•3.908±0.002 days



• Microquas

“Dark” sources: Objects which only shine in gamma rays !

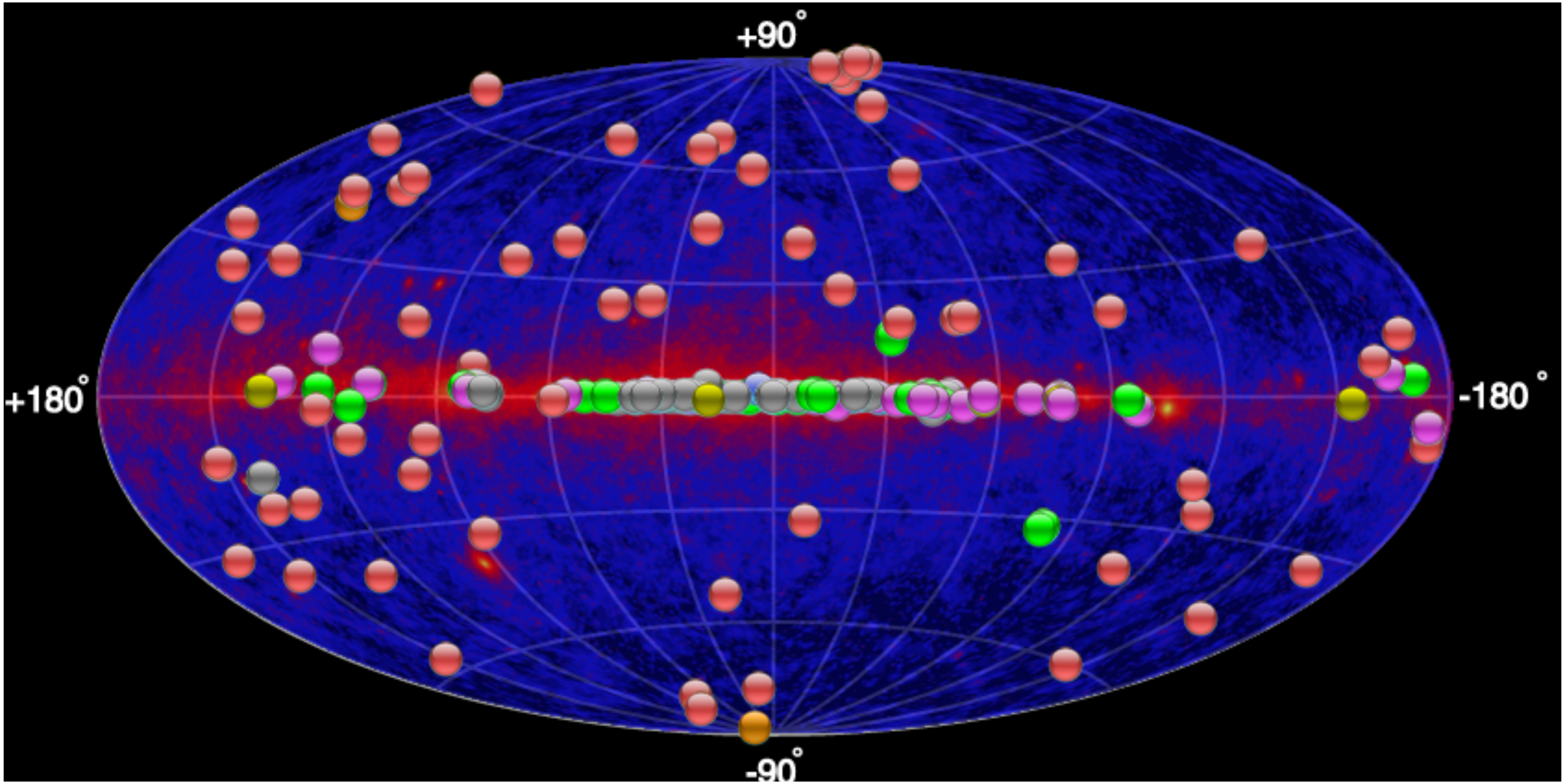




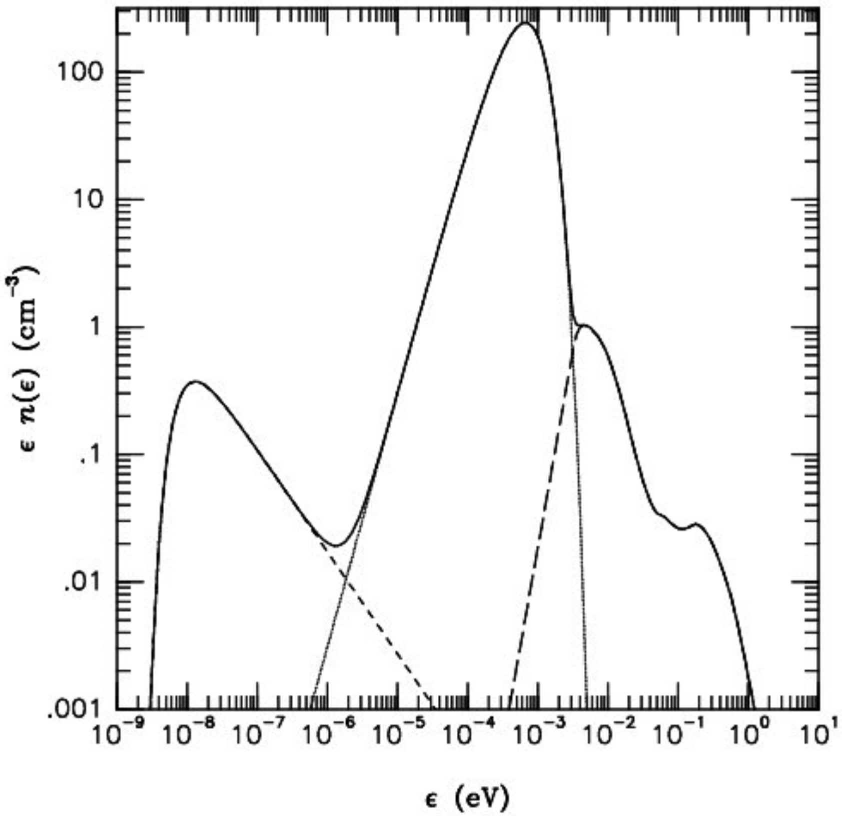
•The age of real VHE gamma ray astronomy has started

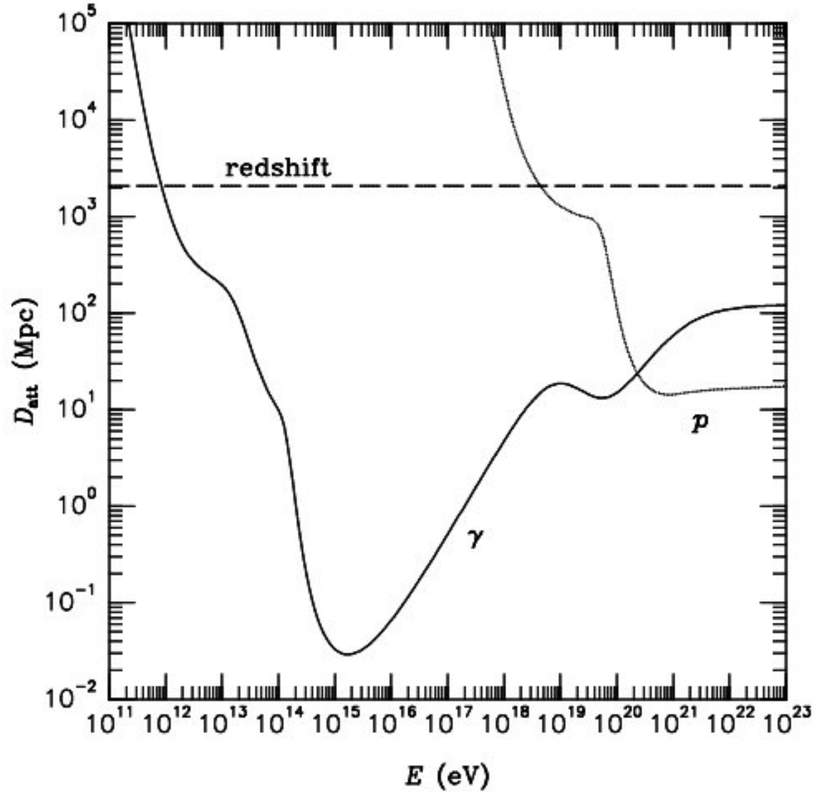
Extra-galactic gamma-ray sources and extragalactic background light

1000 sources in GeV and 60 in TeV



Diffuse backgrounds



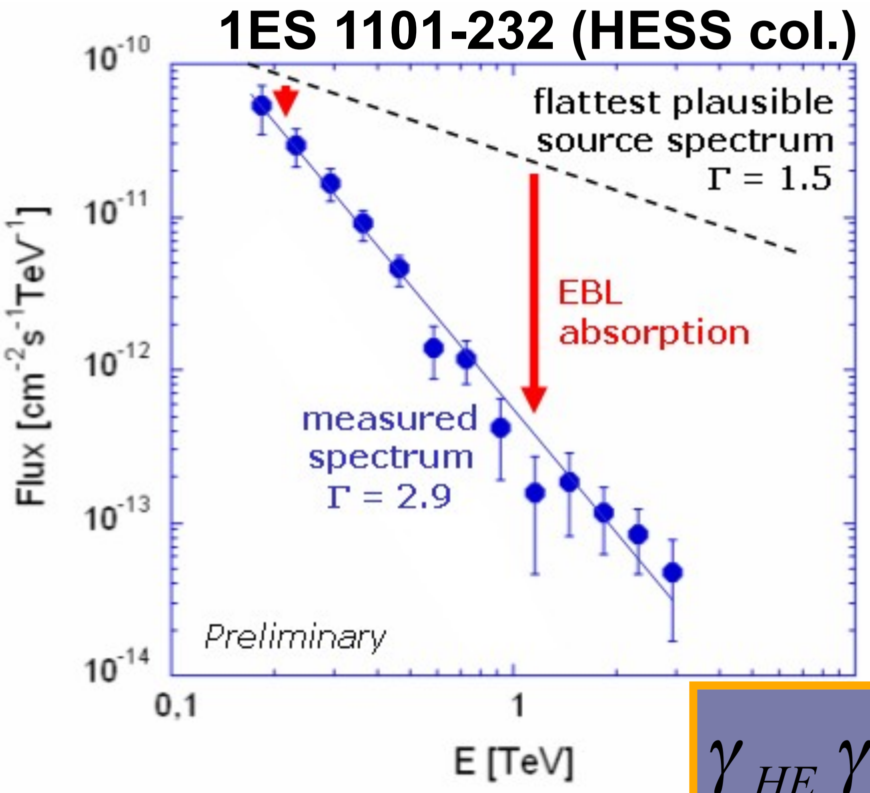


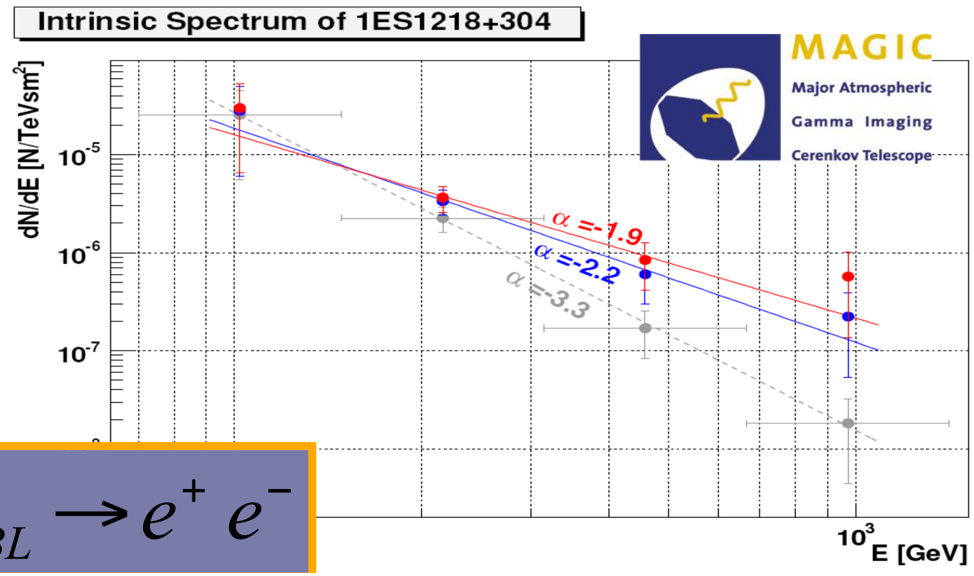
Extrag. Background Light

Cosmological radiation from star formation and evolution.

Spectral signature from gg absorption for Eg ~ 50-2000 GeV.

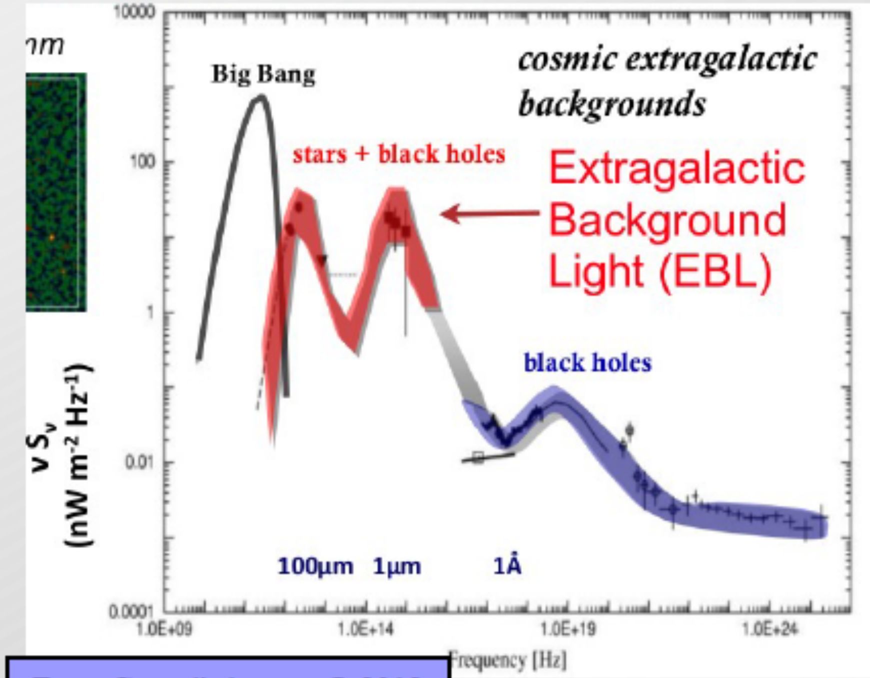
Use measured AGN spectra to constrain EBL.





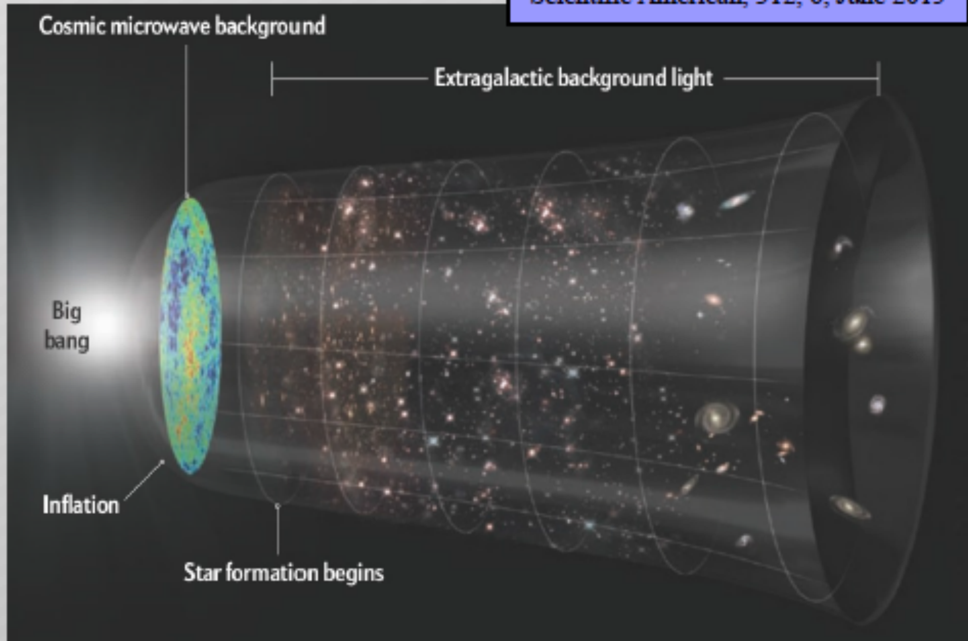
$$\gamma_{HE}\,\gamma_{EBL} \longrightarrow e^{+}\,e^{-}$$

Diffuse extragalactic backgrounds



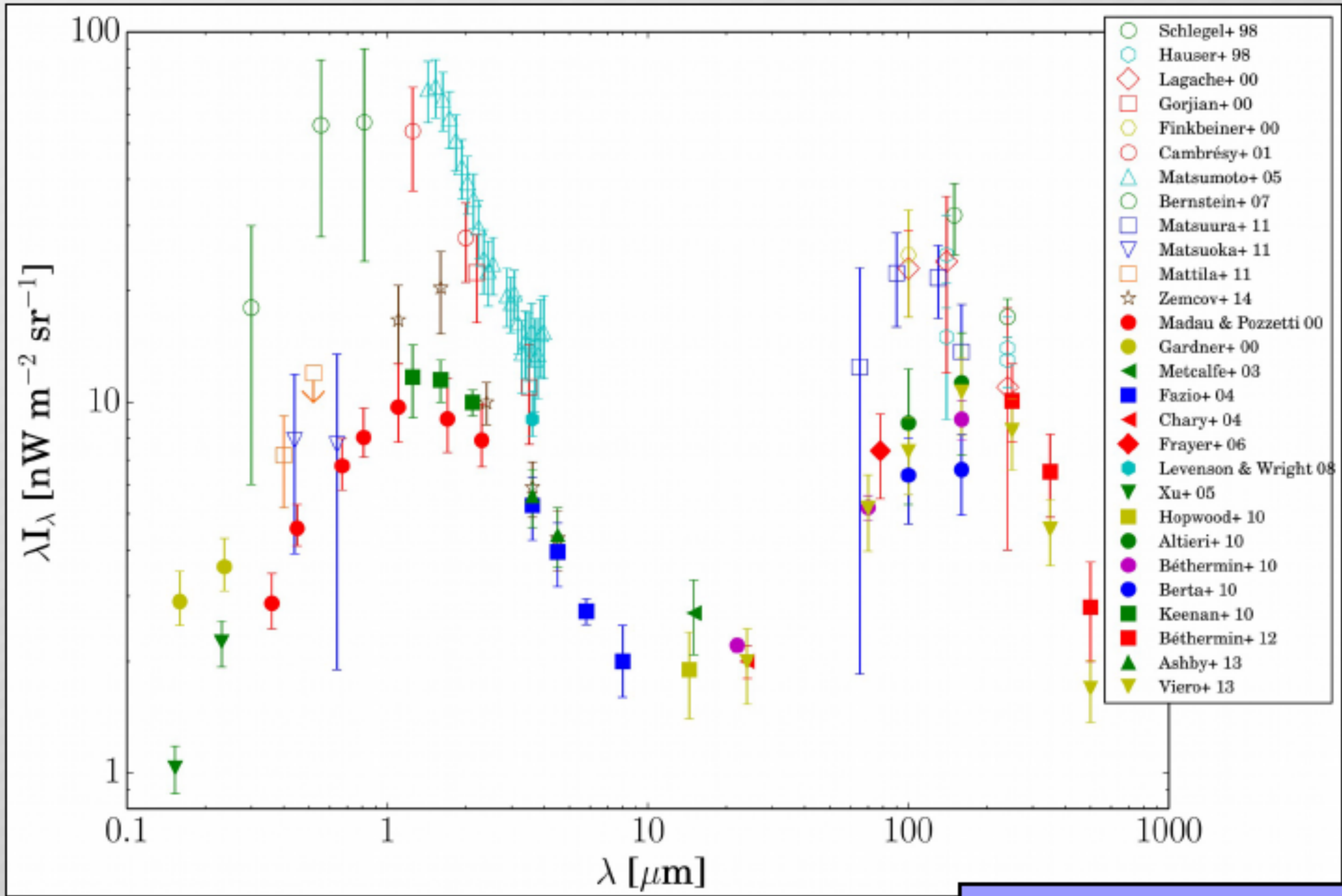
From Genzel's lecture @ 2013 Jerusalem Winter School

Scientific American, 312, 6, June 2015



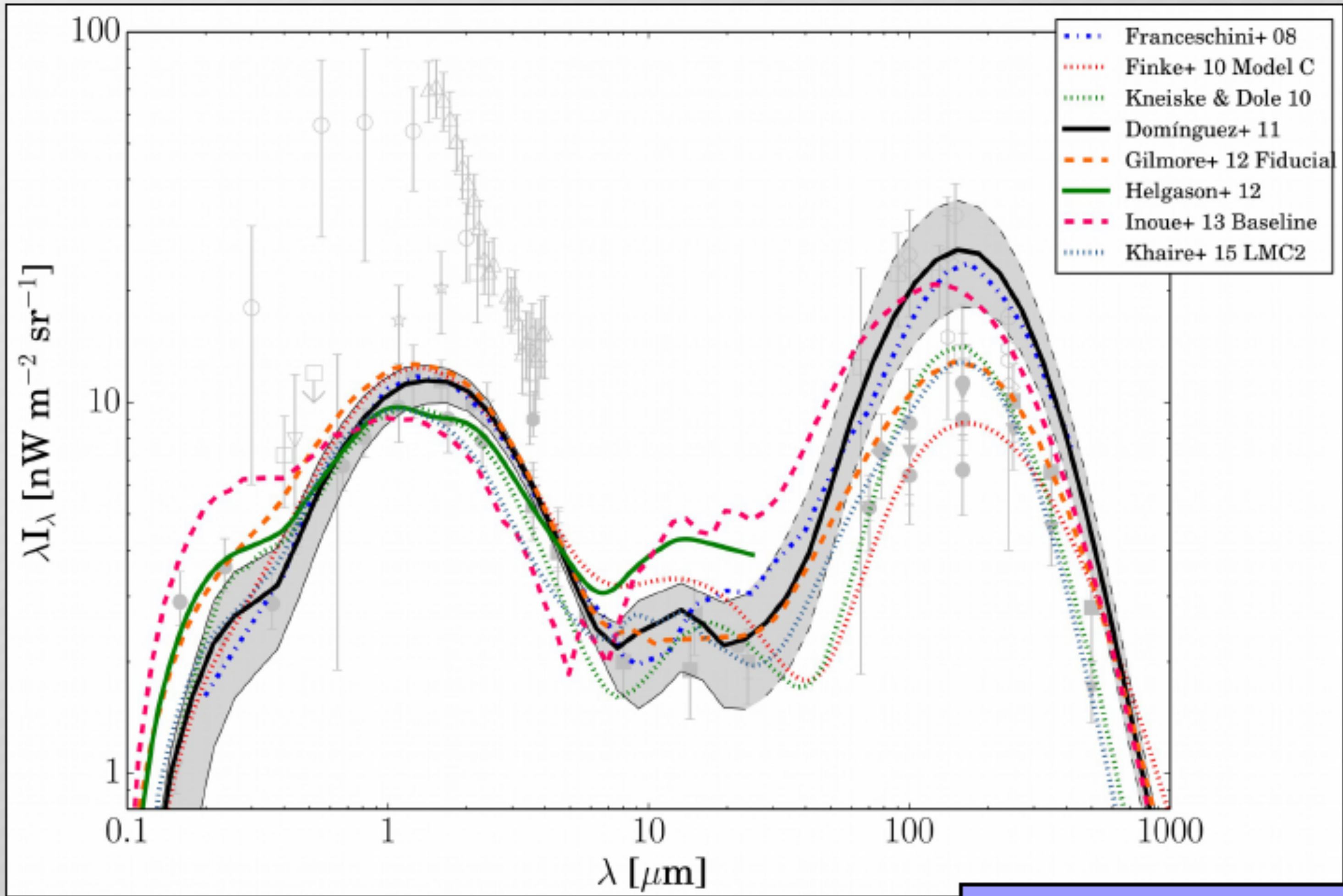
- The EBL is the accumulated diffuse light produced by star formation processes and accreting black holes over the history of the Univere from the UV to the far-IR.
- It contains fundamental information about galaxy evolution, cosmology, and it is essential for the full energy balance of the Universe.

Local EBL: Data and Models



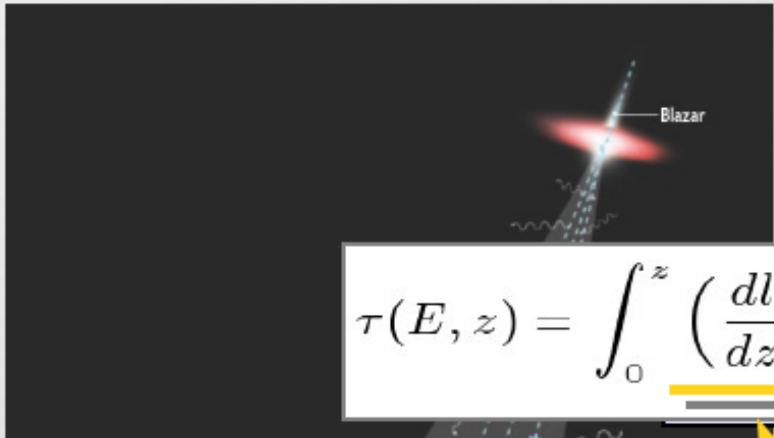
Domínguez & Primack, 15 in prep.

Local EBL: Data and Models



Domínguez & Primack, 15 in prep.

Gamma-Ray Attenuation



$$\left.\frac{dN}{dE}\right|_{obs} = \left.\frac{dN}{dE}\right|_{int} \exp\left[-\tau(E,z)\right]$$

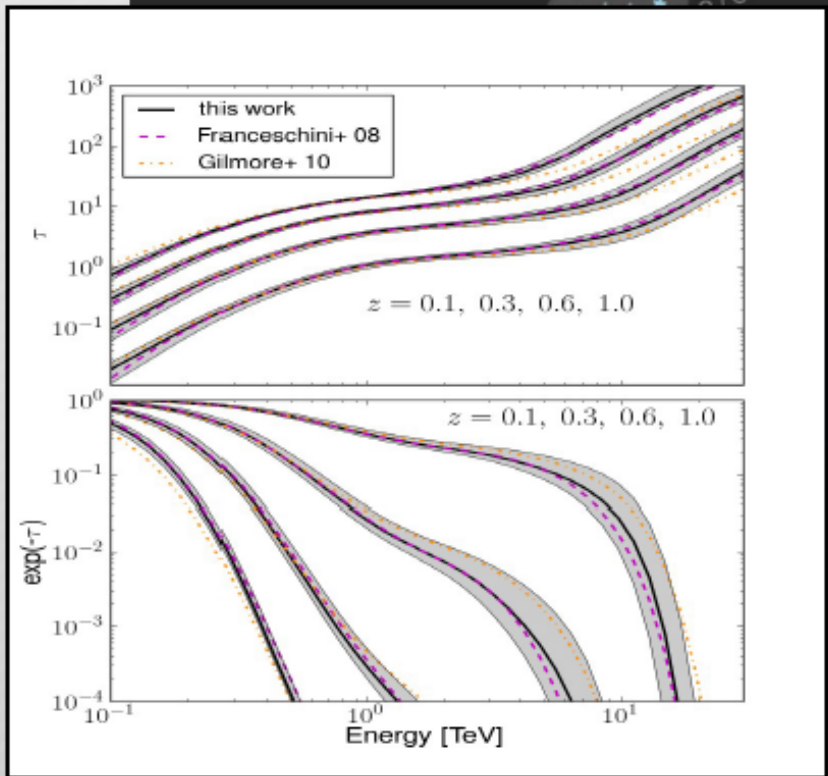
$$\tau(E,z) = \int_0^z \left(\frac{dl'}{dz'}\right) dz' \int_0^2 d\mu \frac{\mu}{2} \int_{\varepsilon_{min}}^{\infty} d\varepsilon' \; \sigma_{\gamma\gamma}(\beta') n(\varepsilon', z')$$

Distance (cosmology)

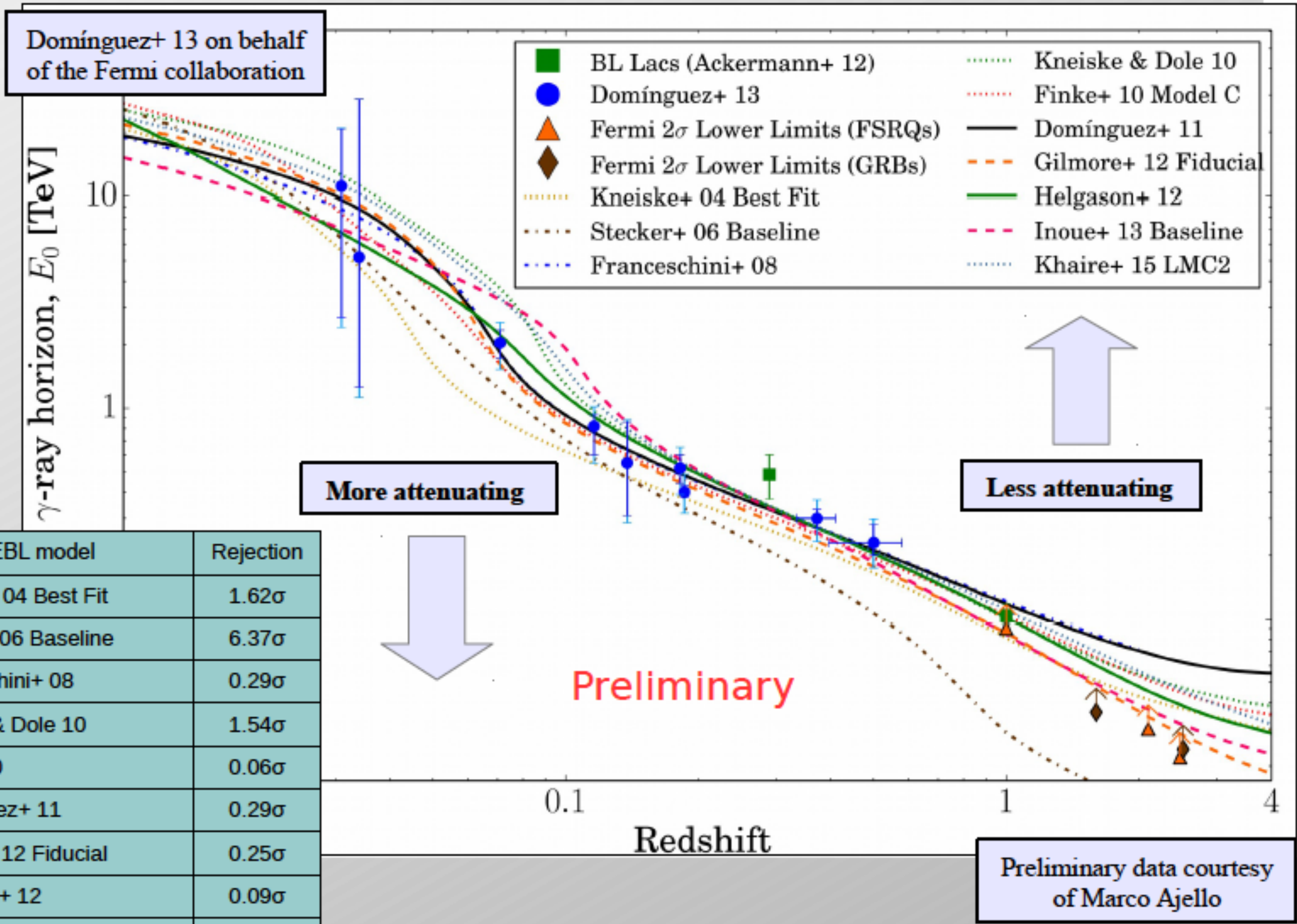
Interaction angle

Cross section

EBL photon density evolution (cosmology)

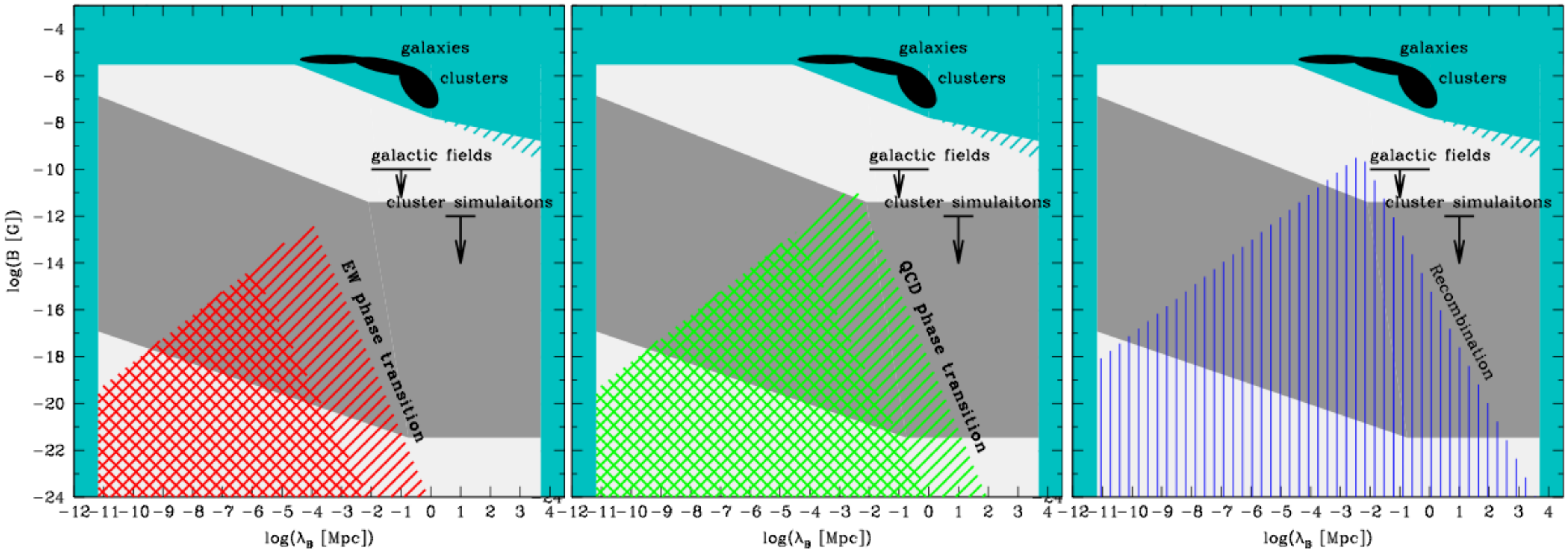


Cosmic γ-ray Horizon: Results



EBL model	Rejection
Kneiske+ 04 Best Fit	1.62σ
Stecker+ 06 Baseline	6.37σ
Franceschini+ 08	0.29σ
Kneiske & Dole 10	1.54σ
Finke+ 10	0.06σ
Domínguez+ 11	0.29σ
Gilmore+ 12 Fiducial	0.25σ
Helgason+ 12	0.09σ
Inoue+ 13 Baseline	2.12σ
Khaire+ 15 LMC2	1.27σ

Extra-galactic sources and determination of magnetic field



A.Neronov, D.S., PRD 2009, arXiv:**0910.1920**

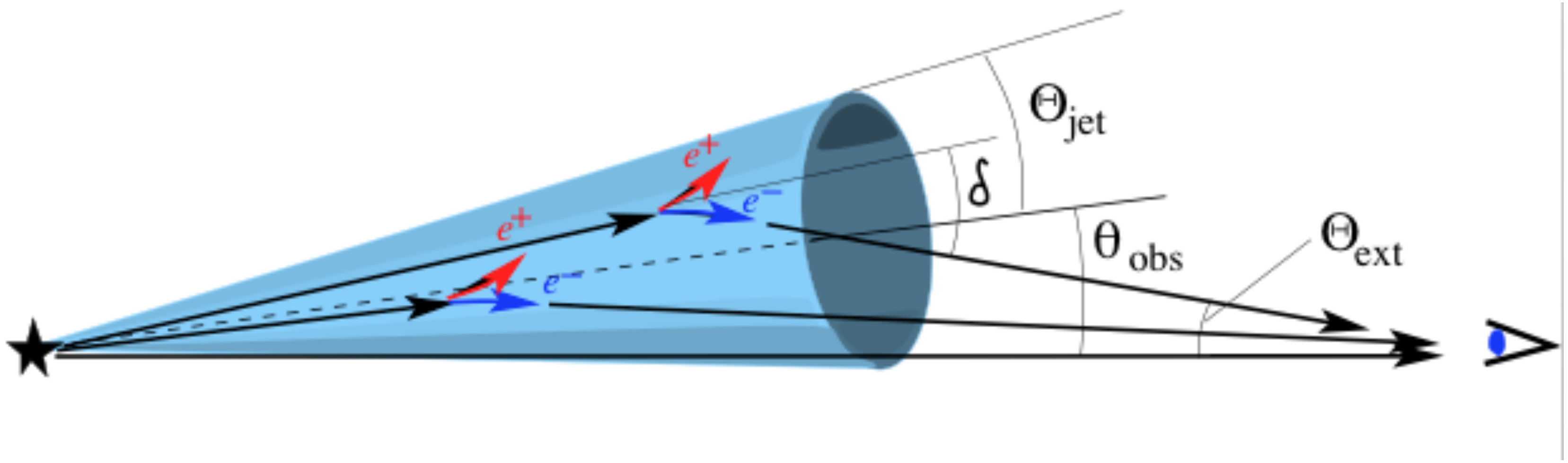
•Magnetic fields might be generated via "battery" effects during phase transitions in the Early Universe.

•In principle, the initial magnetic field energy density might provide non-negligible contribution to the overall energy density of the Universe.

•Magnetic field correlation length could not exceed the size of cosmological horizon; strength of magnetic field averaged over large distance scales could not exceed the "causality" limit

•Damping processes remove small-scale magnetic fields in the course of cosmological evolution.

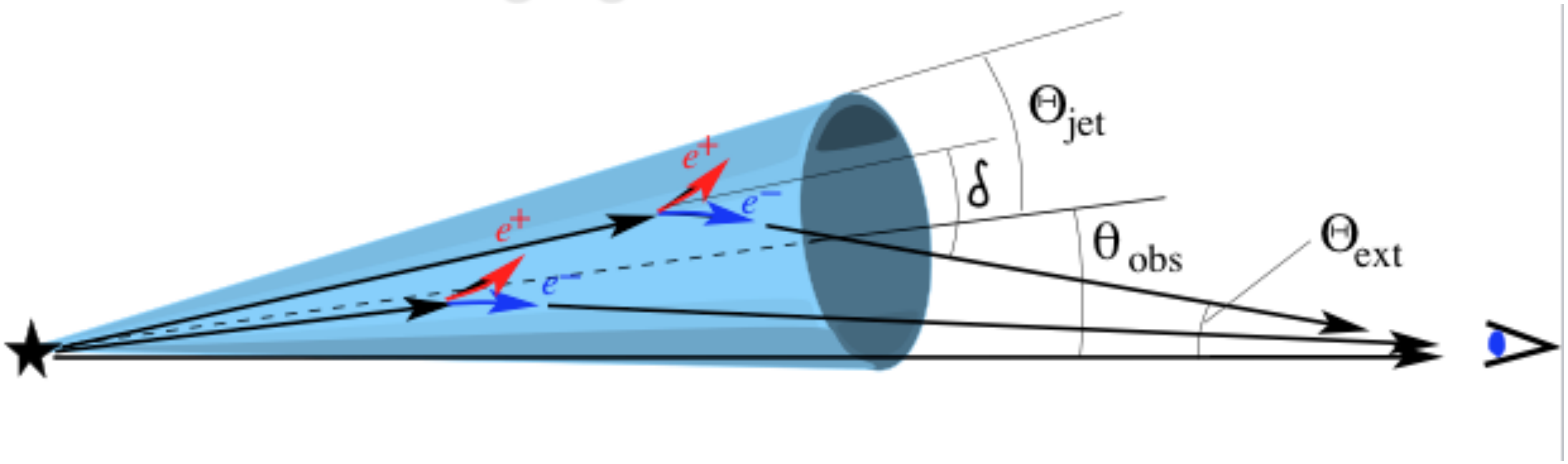
•Imaging of cascade: 3-d cascade needed



•3-d cascade in turbulent EGMF

•A.Neronov, D.S., M.Kachelriess, S.Ostapchenko and A.Elyev , 2009

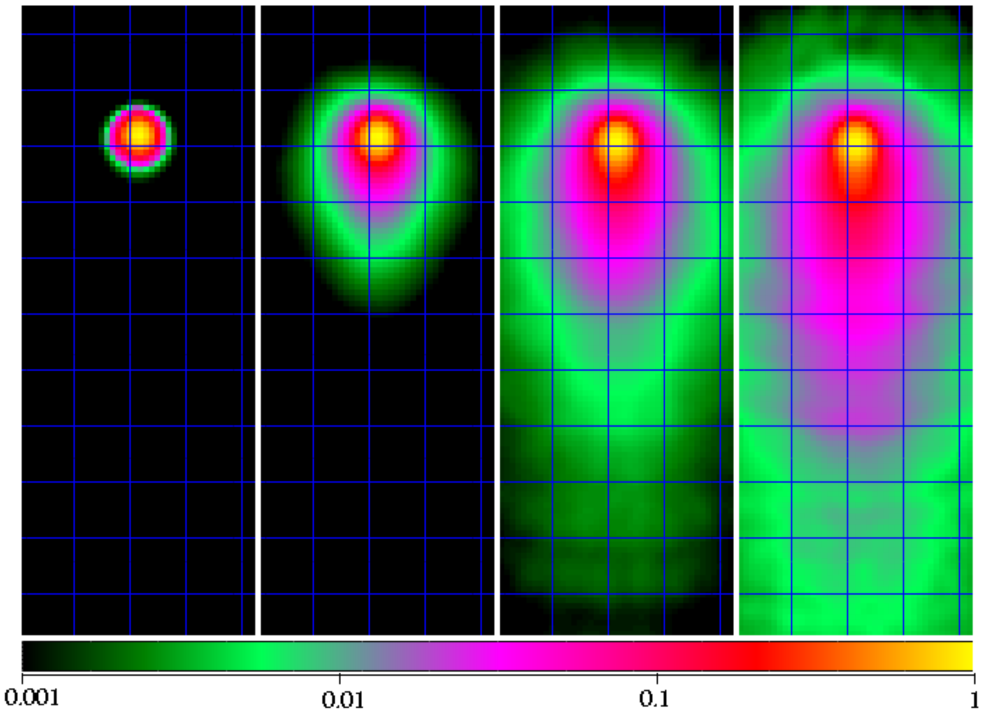
•Imaging of cascade: EGMF



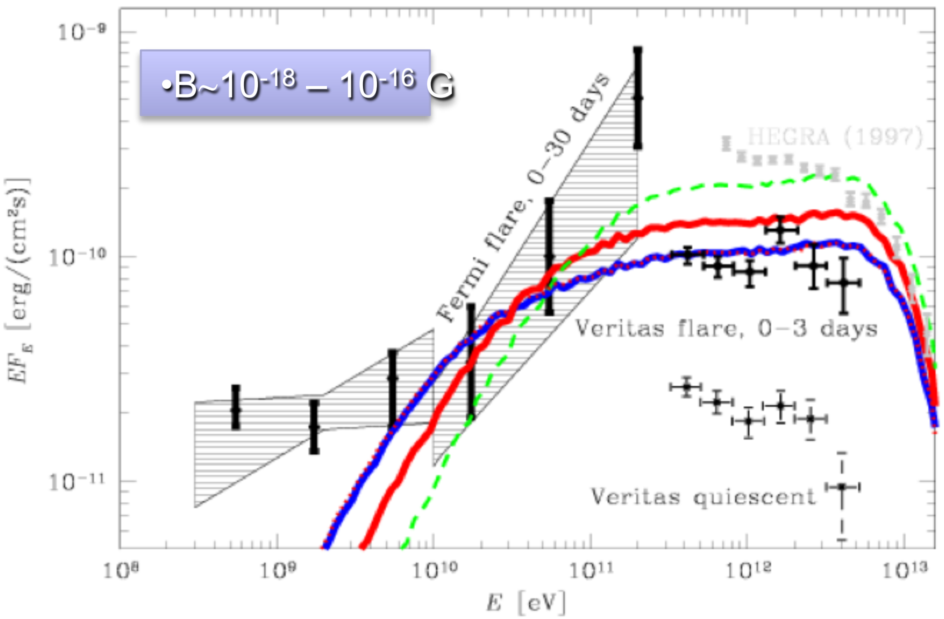
•**Imaging**: cascade component forms an extended emission around initially point source.

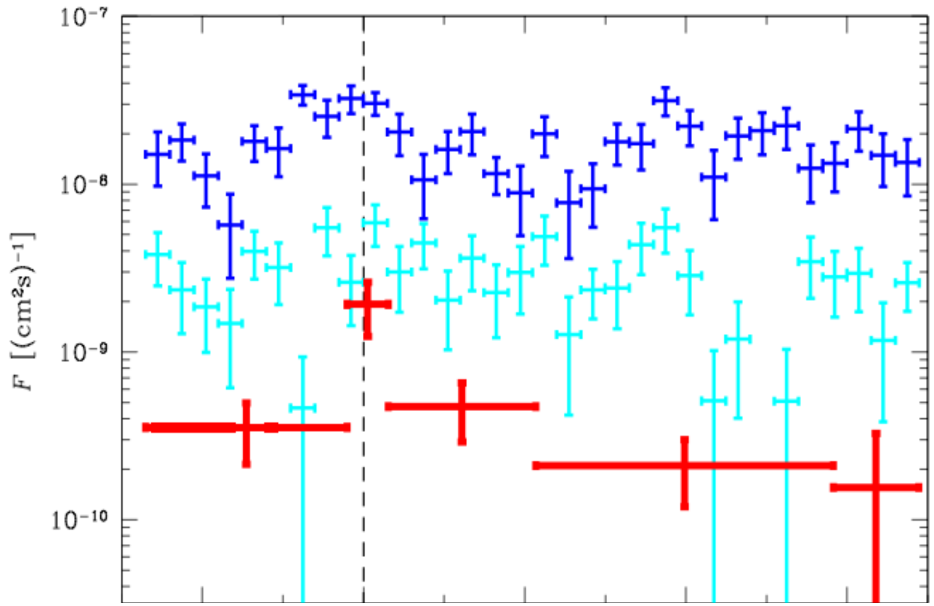
• – detectability depends on

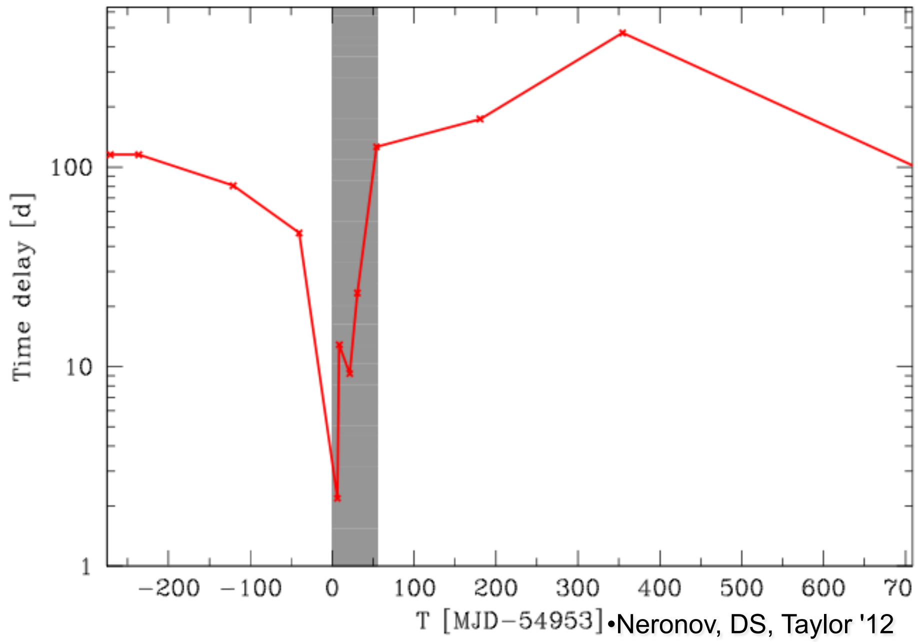
the telesope PSF and on the scale of angular deflections of e+e- pairs **(i.e. on the strength of EGMF)**



• Search for the time-delayed cascade emission







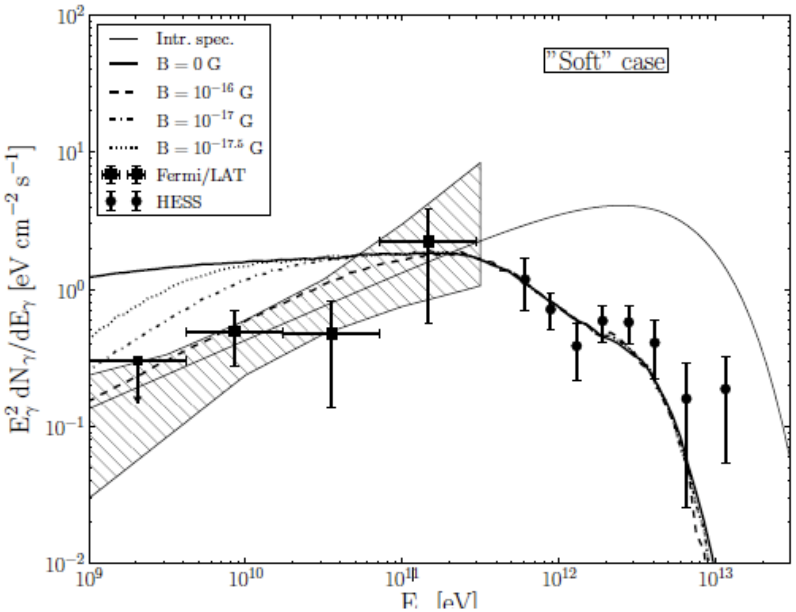
•Neronov, DS, Taylor '12

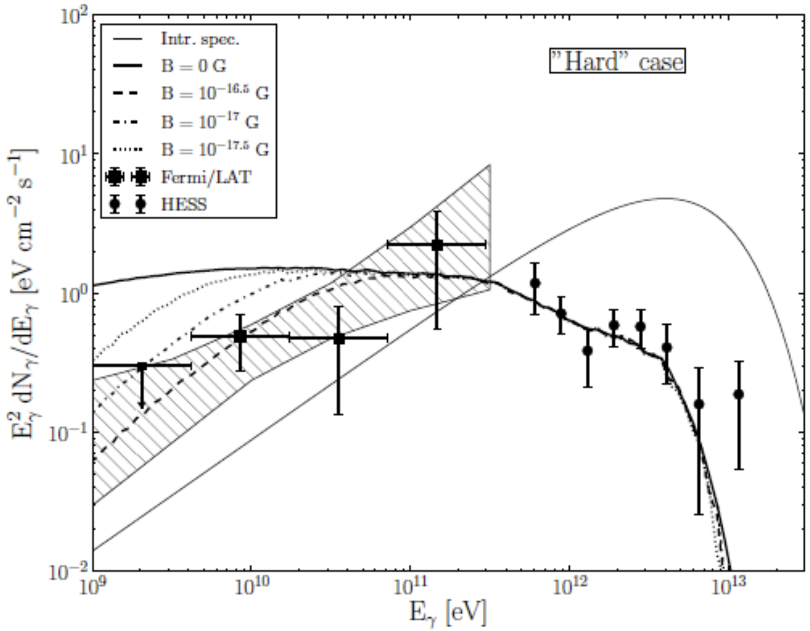
•The flare occurred during the multiwavelength campaing, including HE and VHE observations.

•Fermi data indicate that the flare lasted 30-50 days, but the VHE observations cover only the first three days of the flare.

•Fermi data indicate a peculiar hardening of the spectrum above ~10 GeV during the flare. One possibility for the explanation of the hard component is the cascade emission suppressed at low energies by too-large time delay.

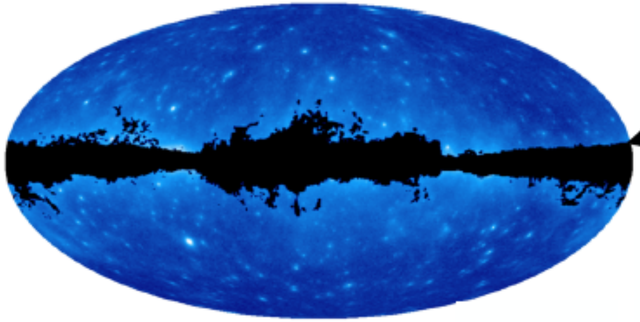
EGMF from 1ES 0229+200





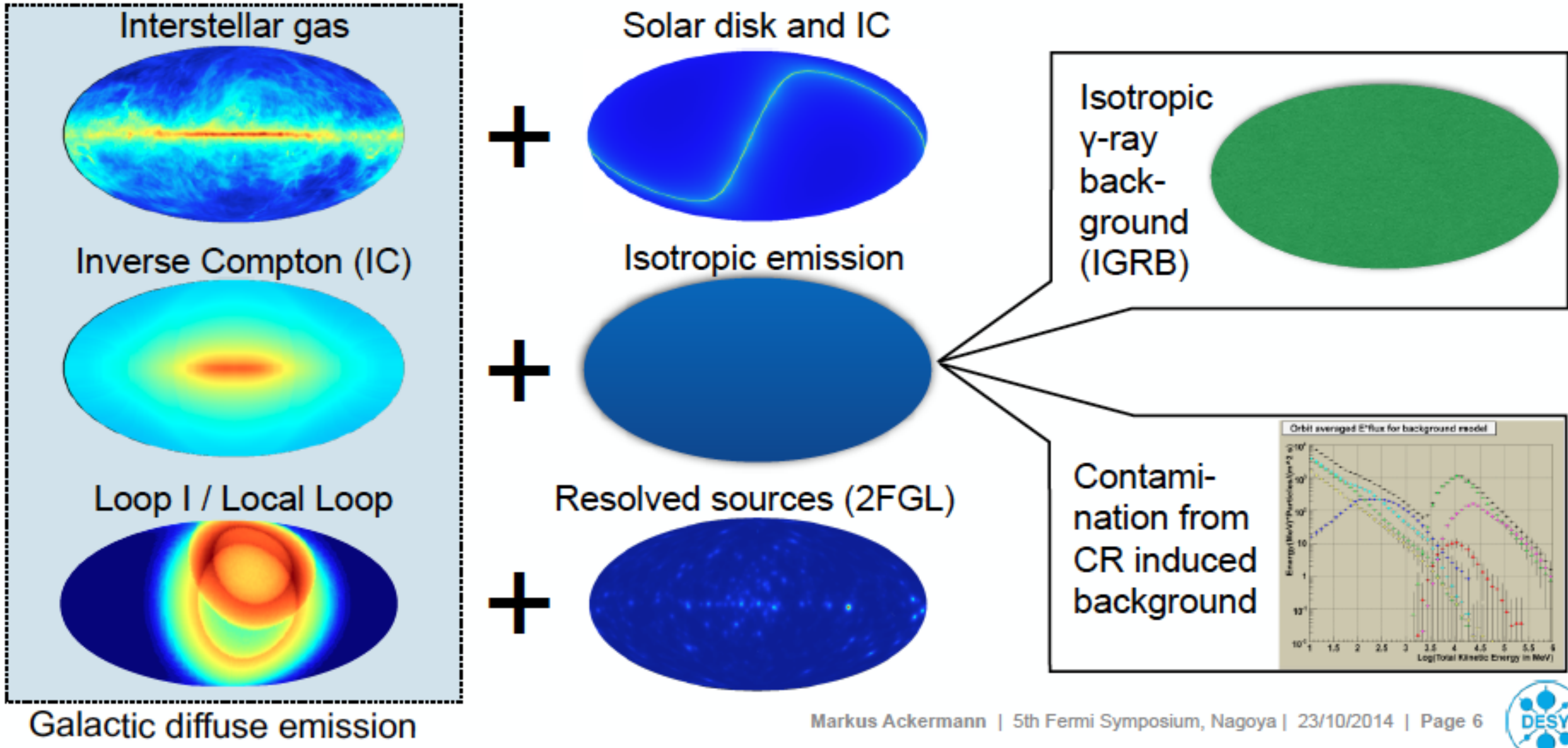
Diffuse gamma-ray background

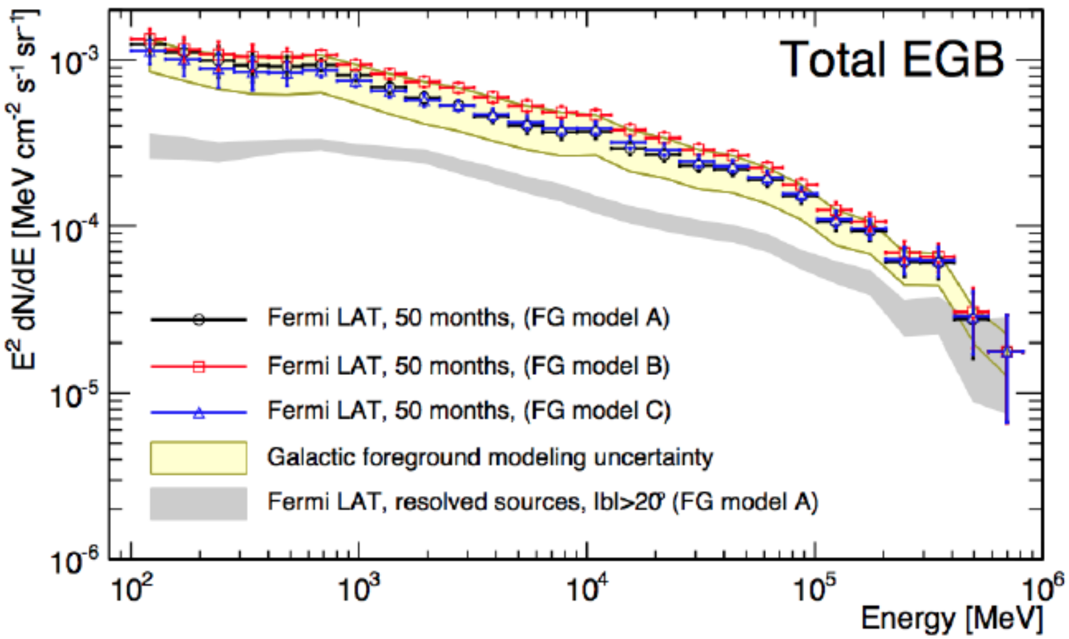
Derivation of the isotropic gamma-ray background



Not used in this analysis:
- Galactic plane
- Regions with dense molecular clouds
- Regions with non-local atomic hydrogen clouds

=





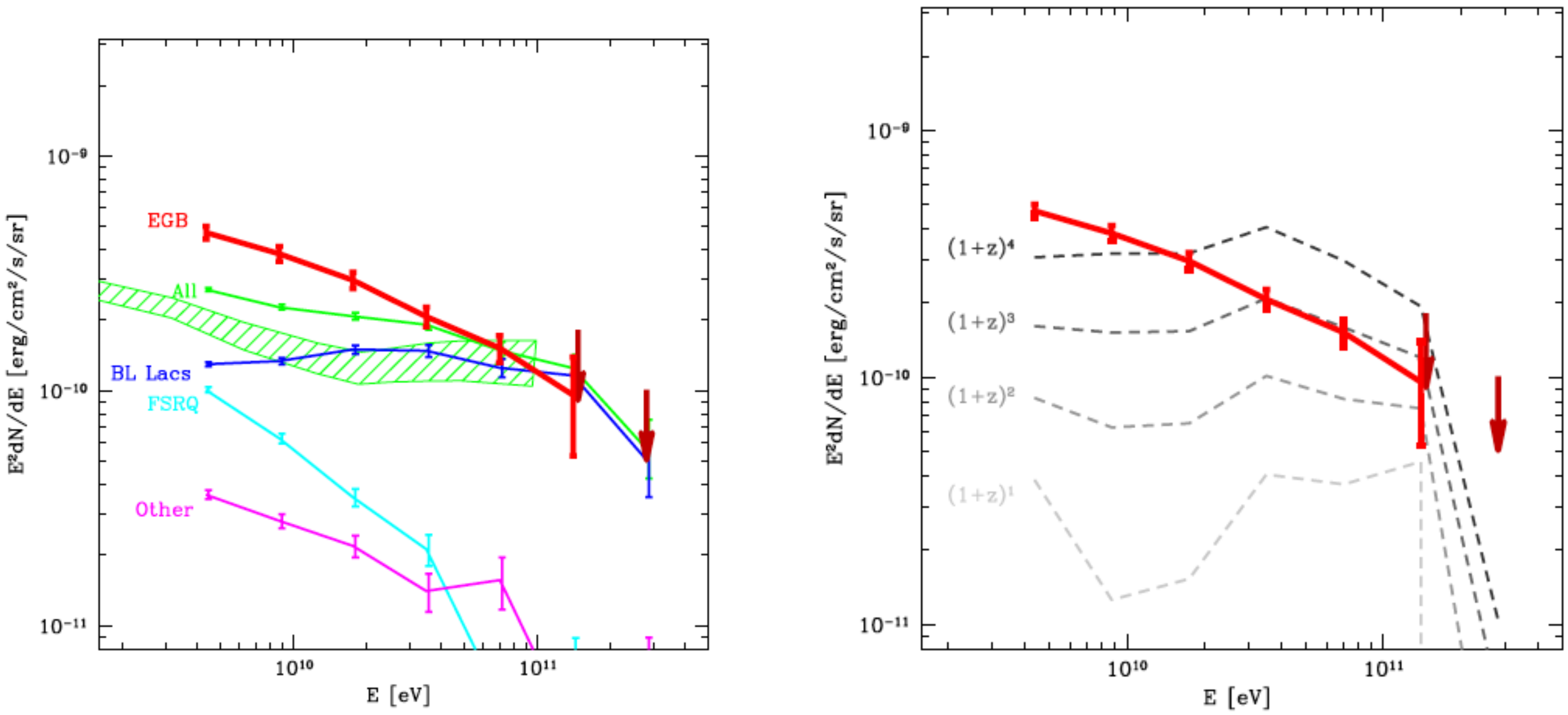
> **Sum of the intensities** of IGRB and the resolved high-latitude sources.

> Contribution of high-latitude Galactic sources **<< 5%.**

> Spectrum can be parametrized by **power-law with exponential cutoff**.

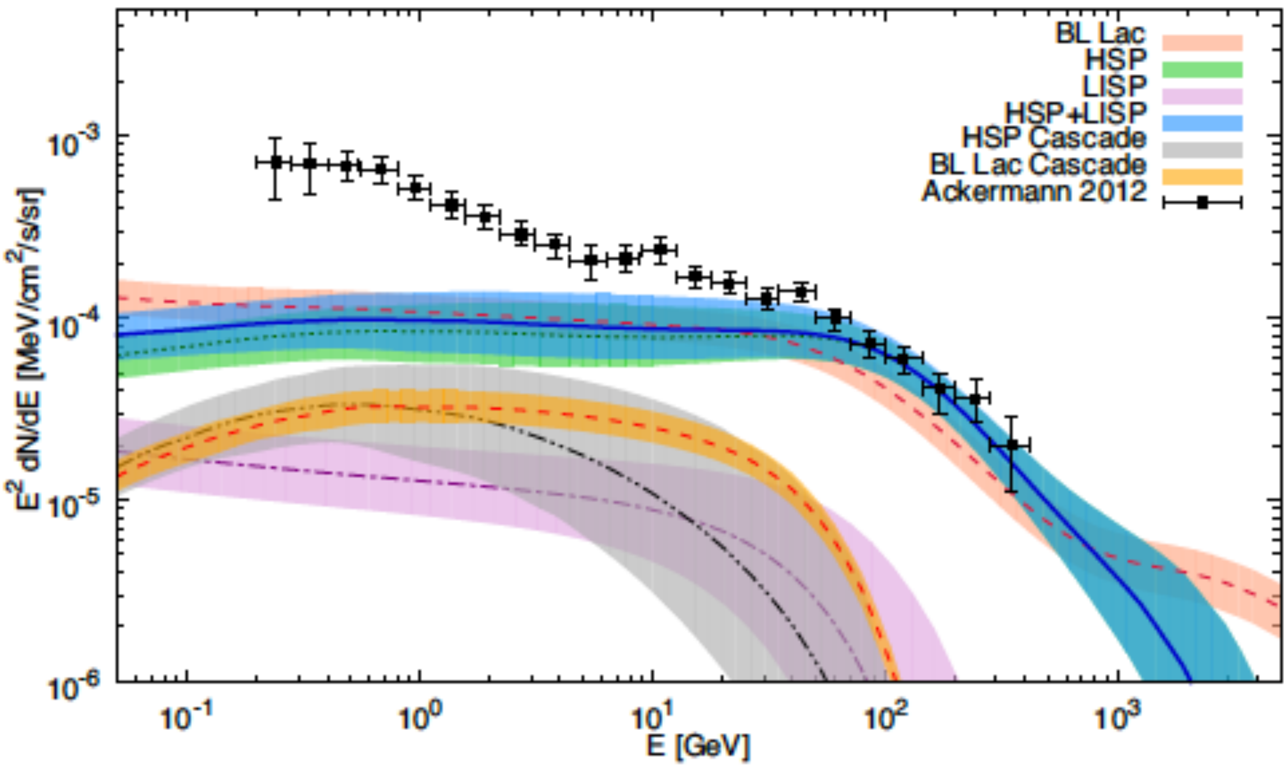
> Spectral index **~ 2.3**, cutoff energy **~ 350 GeV.**

BL Lacs give main contribution to diffuse gamma-ray flux



A.Neronov, D.S. Astrophys.J. 757 (2012) 61

BL Lacs give main contribution to high energy part of diffuse gamma-ray flux



•M. Di Mauro et al, arXiv:1311.5708

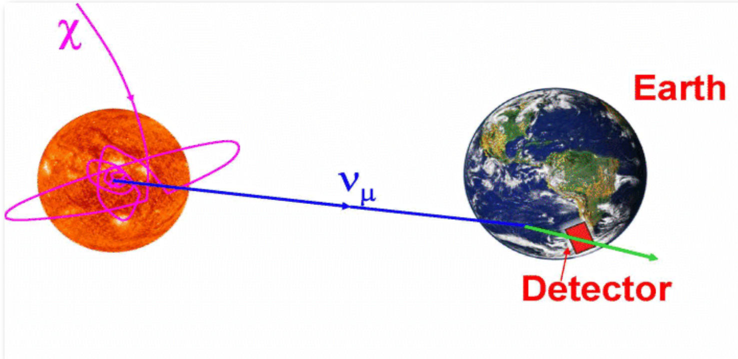
Fermi confirmed resolution of BL Lac sources above 50 GeV

cm^{-2} s^{-1}). We employ a one-point photon fluctuation analysis to constrain the behavior of dN/dS below the source detection threshold. Overall the source count distribution is constrained over three decades in flux and found compatible with a broken power law with a break flux, S_b, in the range $[8 \times 10^{-12}, 1.5 \times 10^{-11}]$ ph cm^{-2} s^{-1} and power-law indices below and above the break of $\alpha_2 \in [1.60, 1.75]$ and $\alpha_1 = 2.49 \pm 0.12$ respectively. Integration of dN/dS shows that point sources account for at least 86^{+16}_{-14}% of the total extragalactic γ-ray background. The simple form of the derived source count distribution is consistent with a single population (i.e. blazars) dominating the source counts to the minimum flux explored by this analysis. We estimate the density of sources

•**Fermi collaboration, arXiv:1511.00693**

Dark matter signatures

Indirect Detection of Dark Matter



Neutrinos

in the core of the Sun

Gamma Rays from annihilations

in the galactic halo, near the

galactic center, in dwarf galaxies, etc.

Positrons/Antiprotons from annihilations

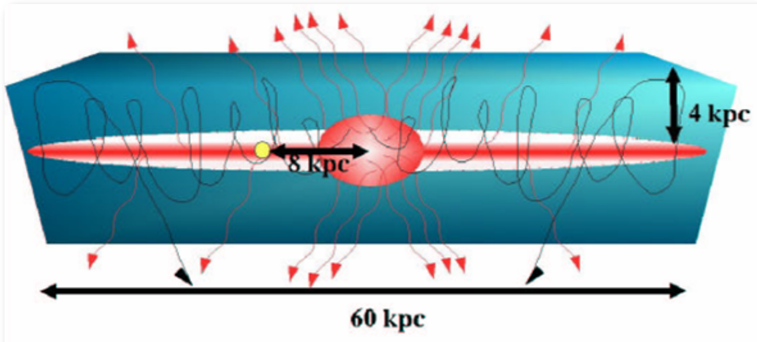
throughout the galactic halo

Synchrotron Radiation from electron/

positron interactions with the

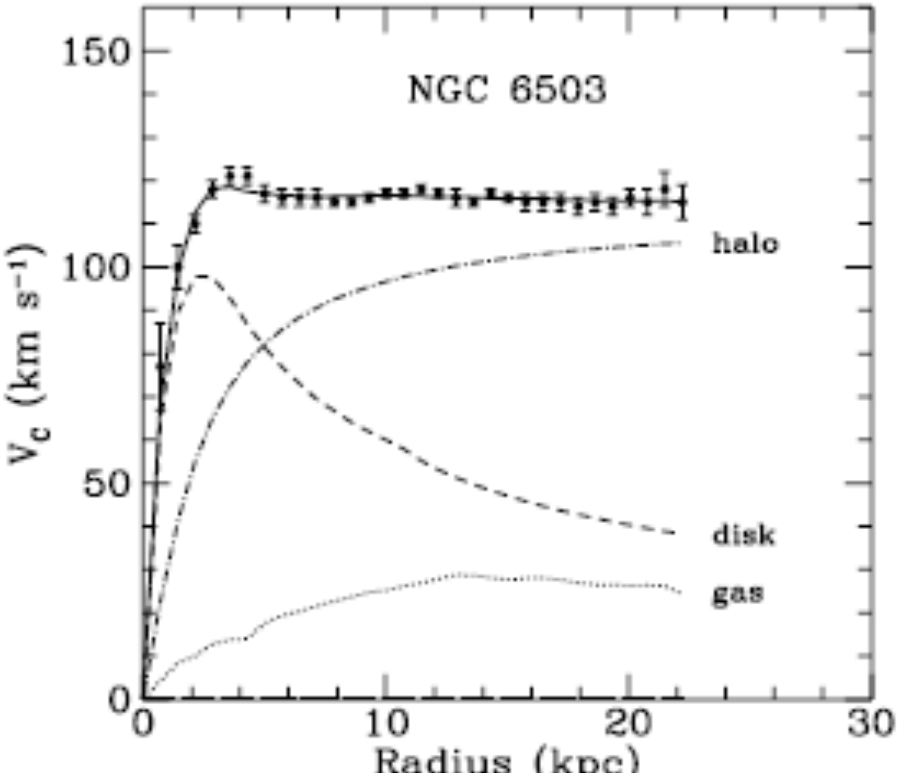
magnetic fields of the inner

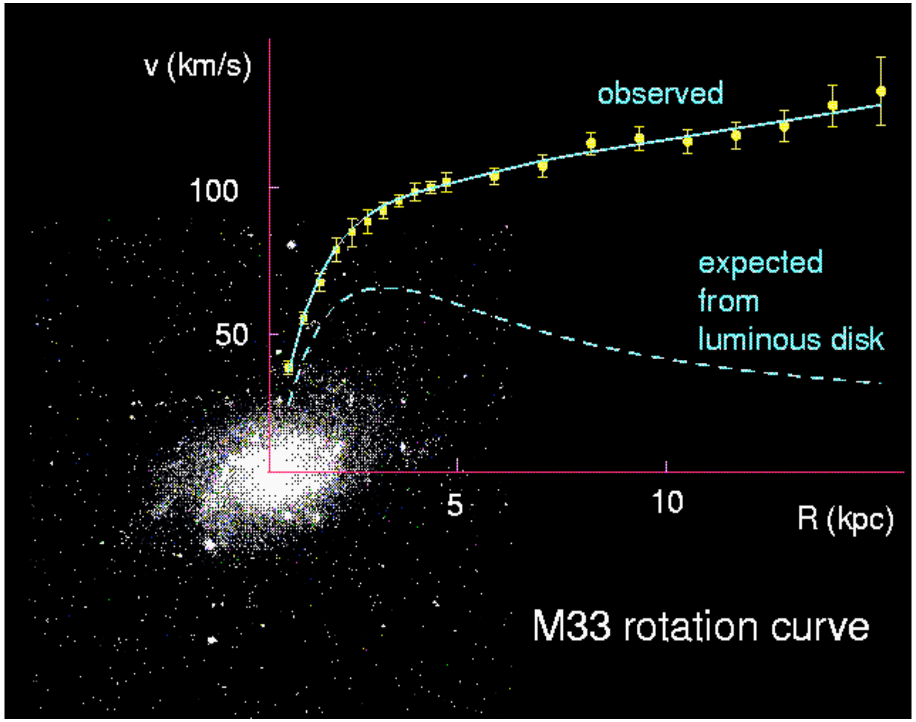
galaxy



•**From Dan Hooper**

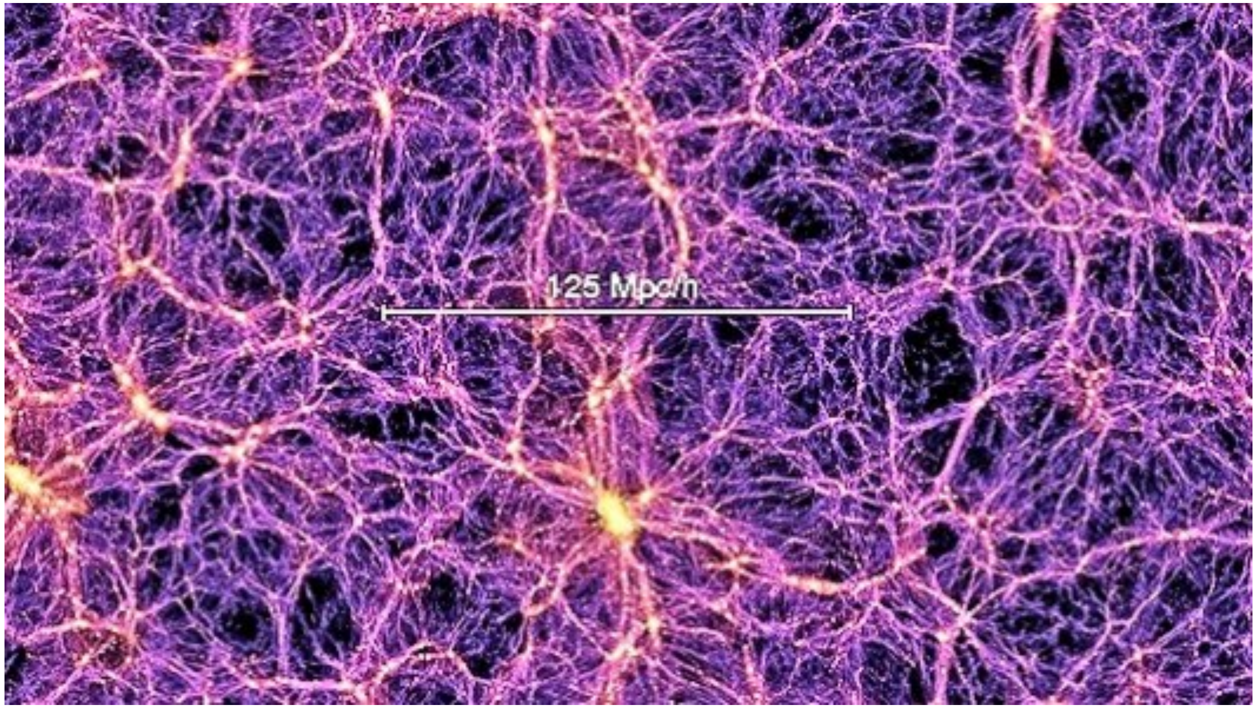
- Rotation Curves of galaxies





- Red Region: X Ray
- Blue Region: Gravitational lensing

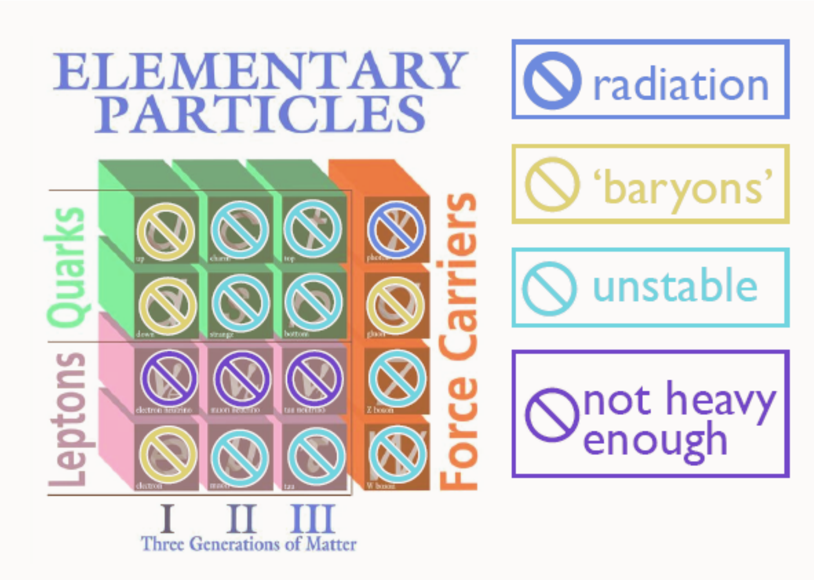
- Large Scale Structure



The N-body Simulation of Dark Matter Universe

Structure: Core, Filament and Cosmic Void.

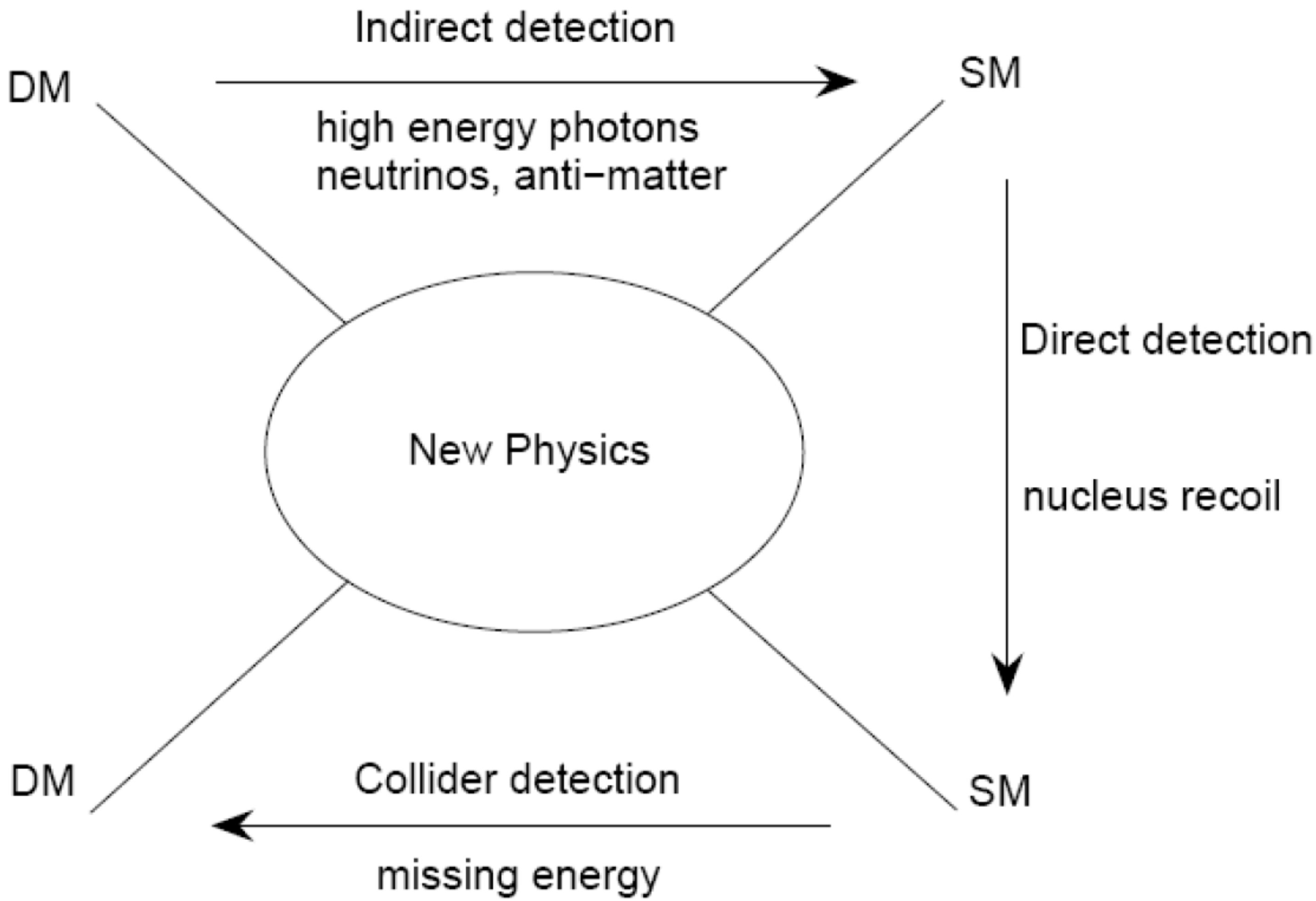
•What we know about DM particles so far ?



- **neutral**
- **cold** (part of it can be warm
- **weak interaction** (with itself and with ordinary matter) ? **Maybe!**
- **profile** (around us $\rho_\chi \approx 0.3 GeV/cm^3$ $V \approx 220$ km/s)

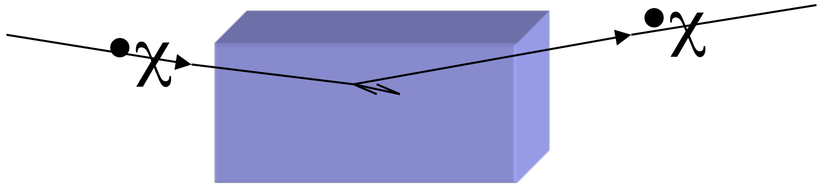
The methods of detecting Dark Matter

Detection of particle dark matter

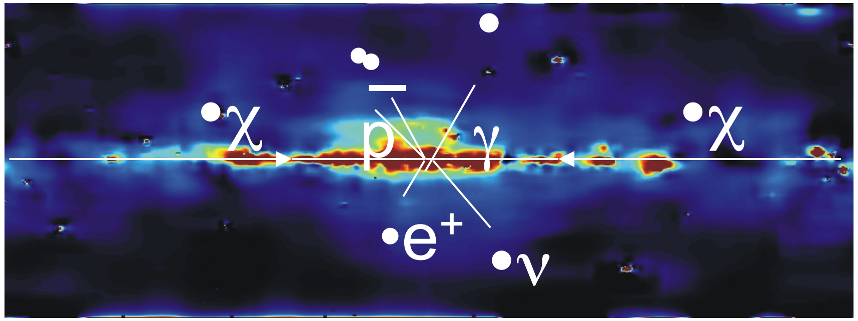


The detection of dark matter

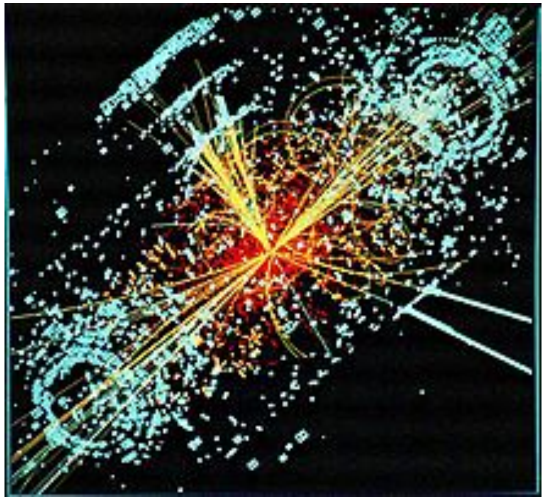
- Direct detection：PandaX, CDEX, Xenon, CDMS, DAMA, COGENT and so on



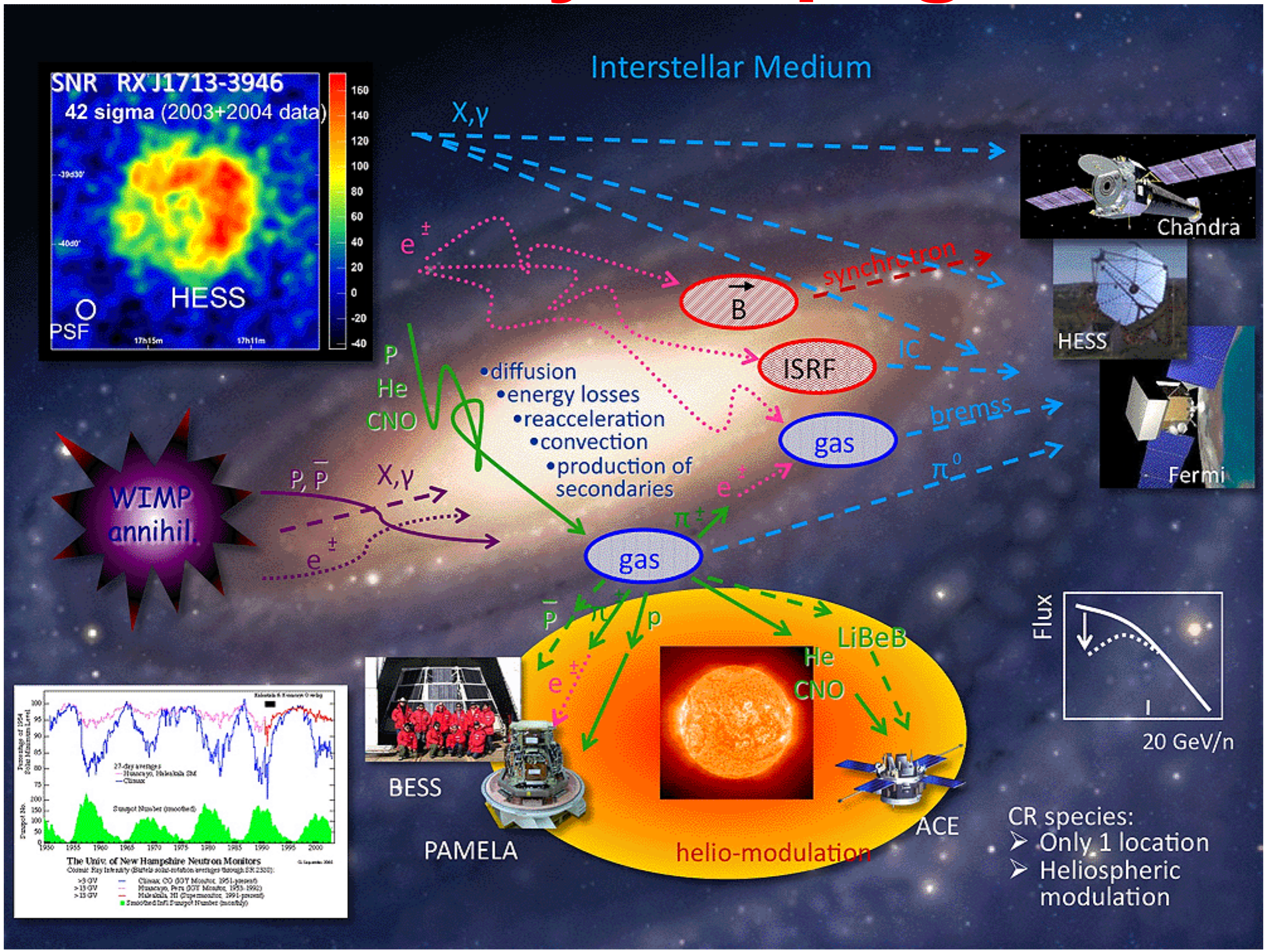
- Indirect detection ：Pamela ,ATIC, Fermi, HESS, AMS02, DAMPE and so on



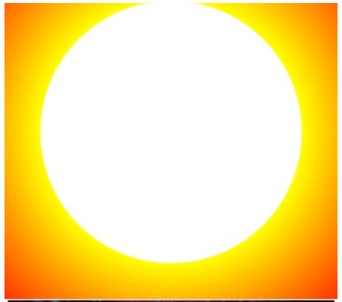
- Collider: LHC



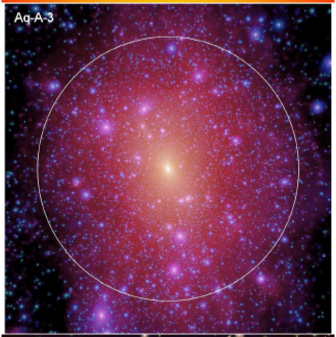
•Cosmic Ray Propagation



•Targets to detect dark matter particles

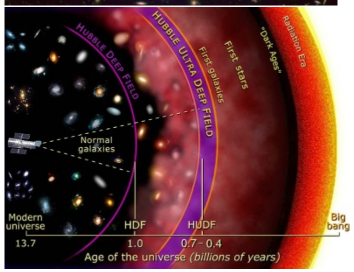


•Sun

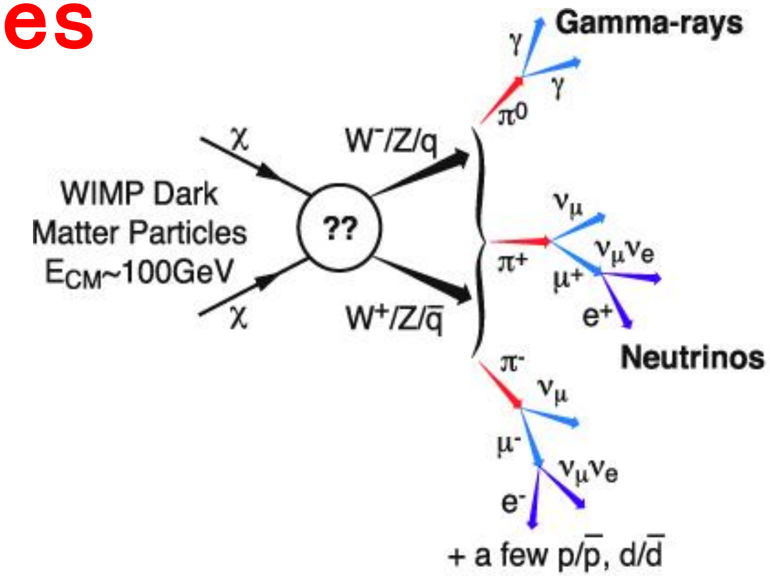


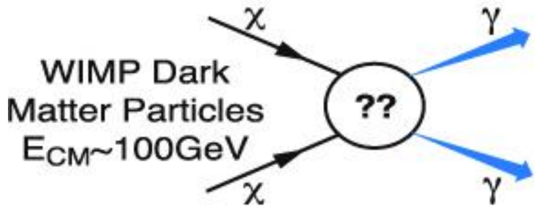
•Galaxy

•Galaxy Cluster



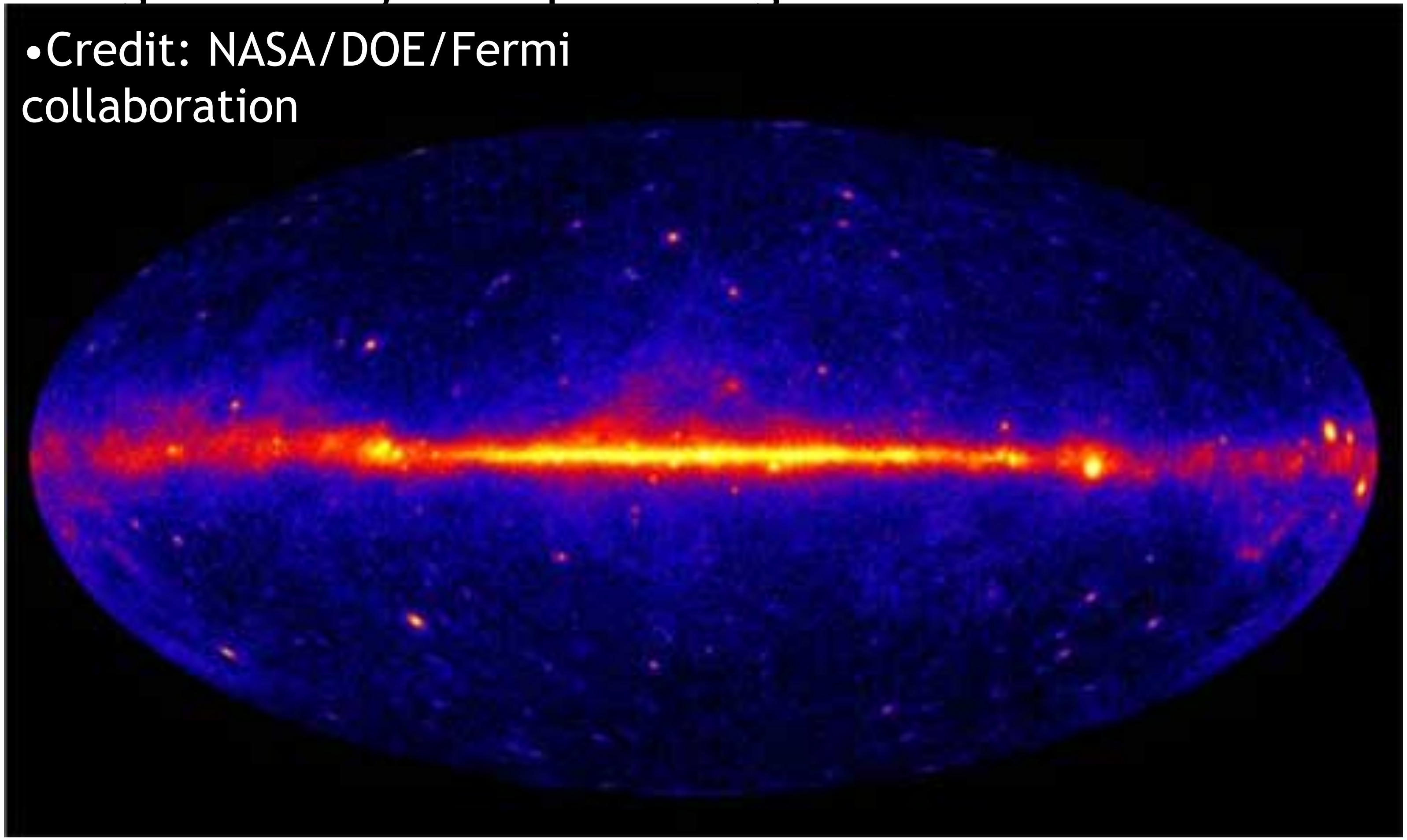
•Deep extragalactic space and early Universe





•Baltz et al. 2008

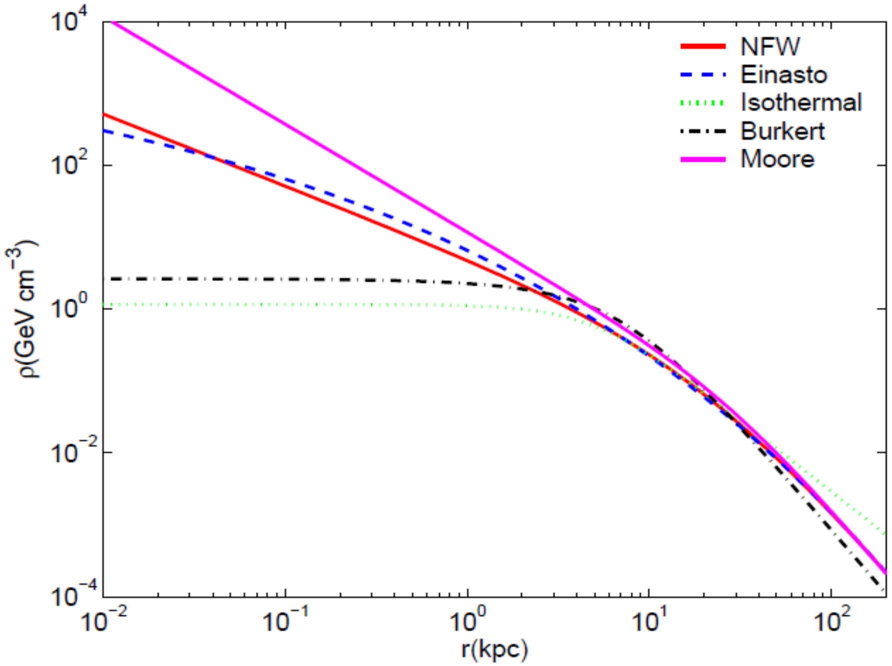
• Fermi gamma-rays can provide good test of the DM models



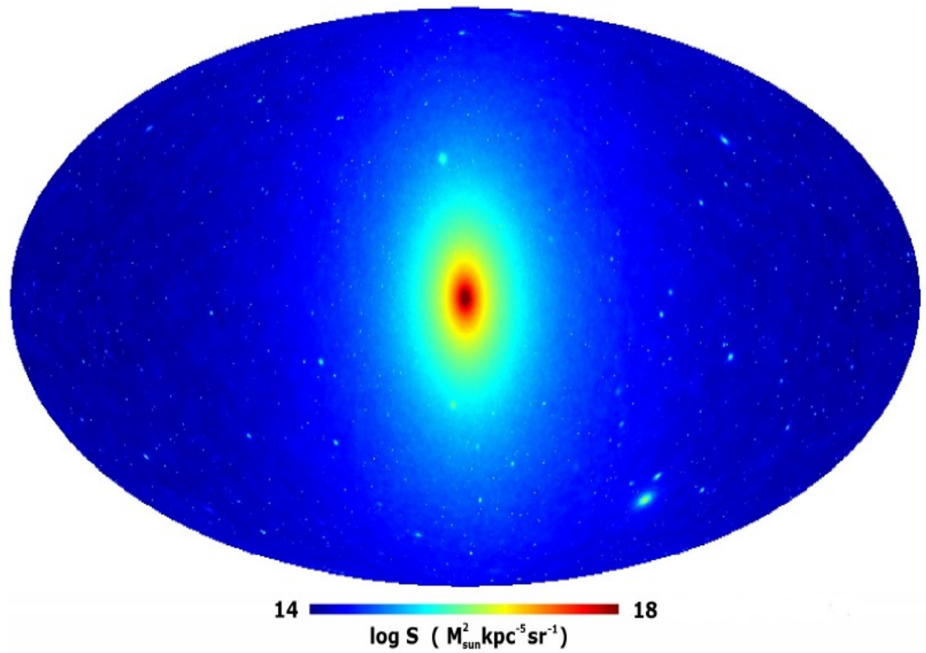
- Galactic center
- Galactic halo
- Dwarf galaxies

- Clusters
- Extra-galactic diffuse
- Line search

The gamma-ray sky map produced by dark matter annihilation in our Galaxy

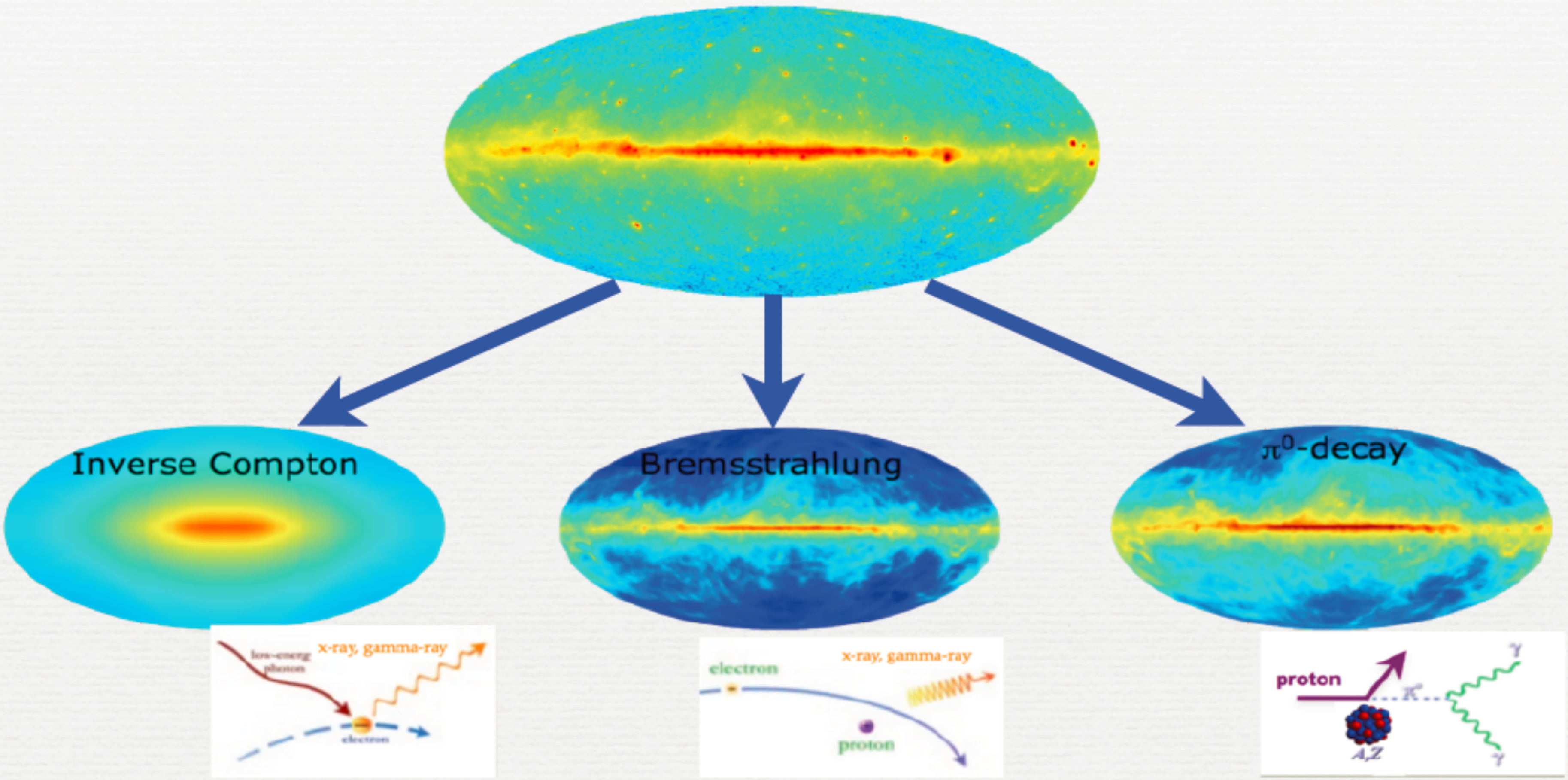


•The J-Factor of different dark matter profile models.

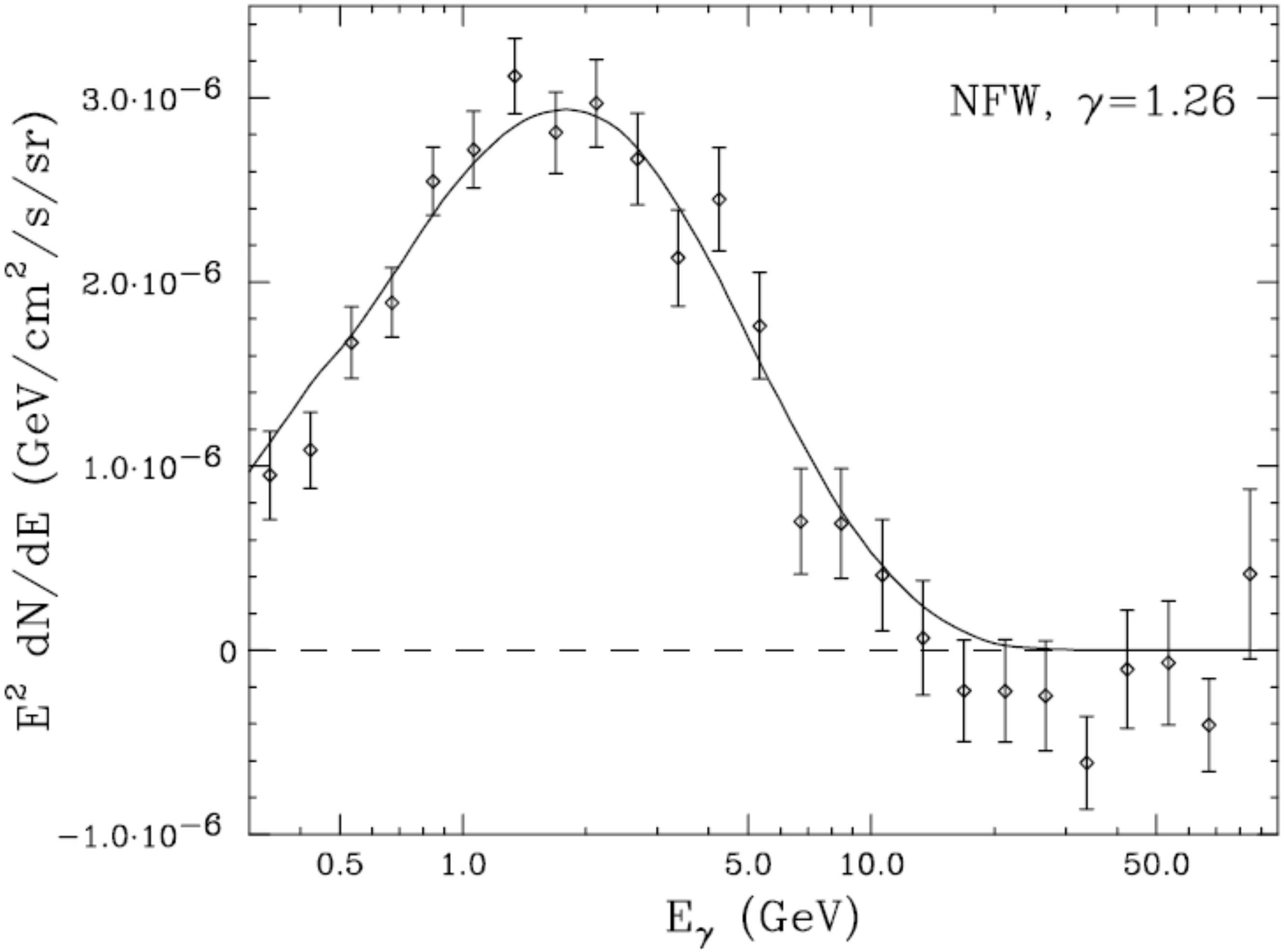


•The Galaxy center is the best region to detect dark matter.

Diffuse Galactic γ-ray Emission: Origin

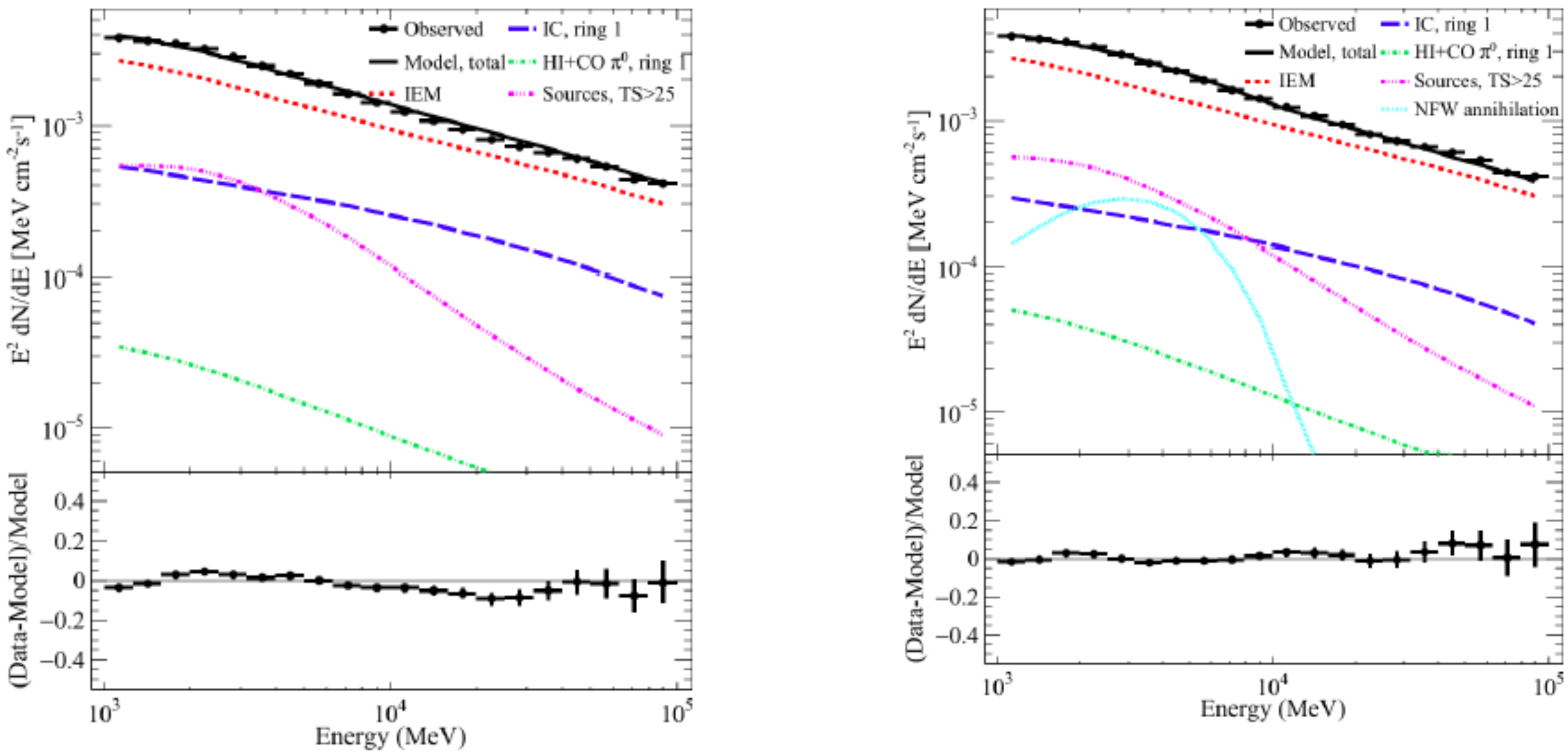


The GeV Excess



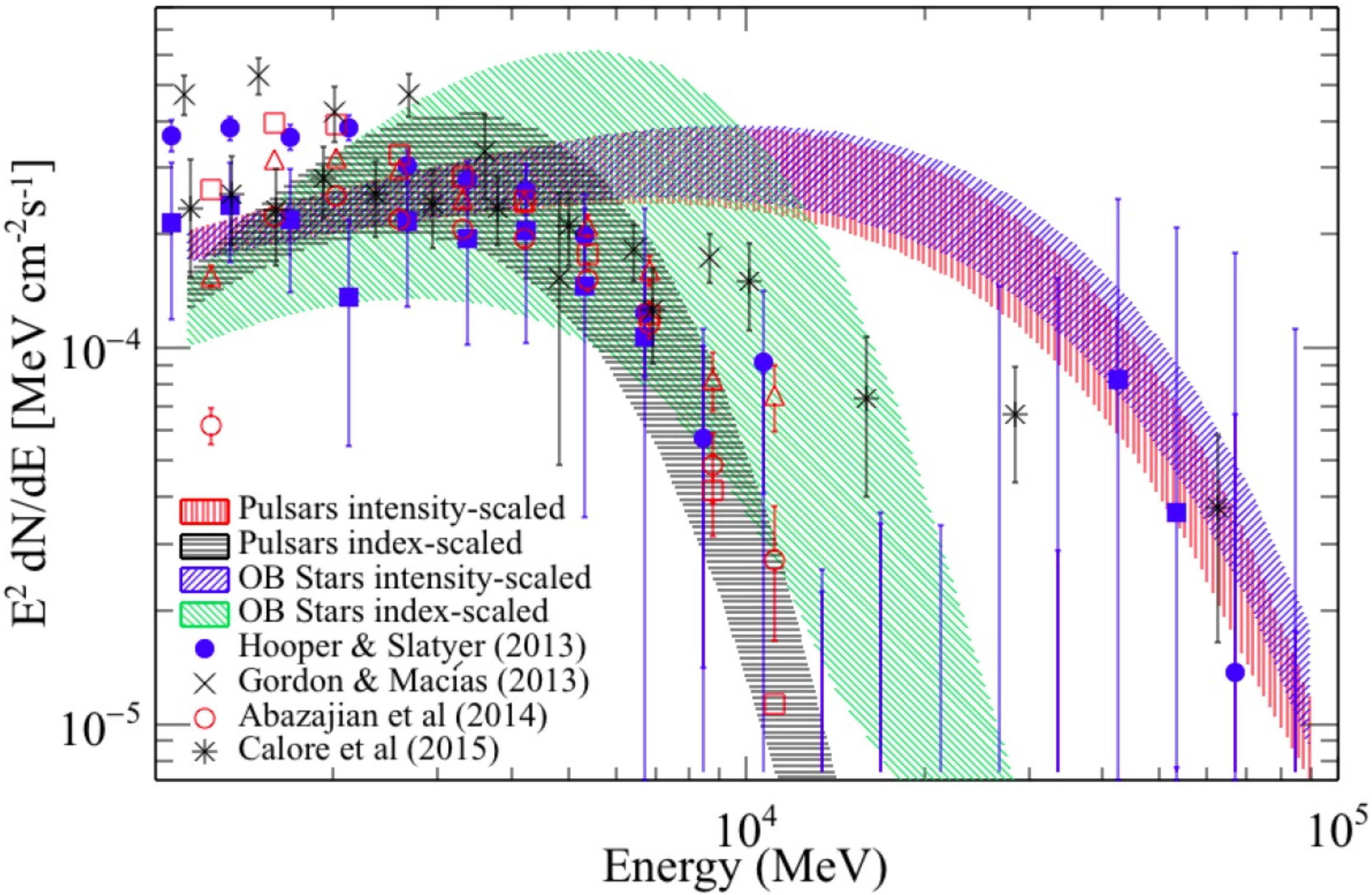
- Daylan et al. 2015

The GeV Excess



•Fermi collaboration 2015

GeV excess in Fermi Pass 8 data

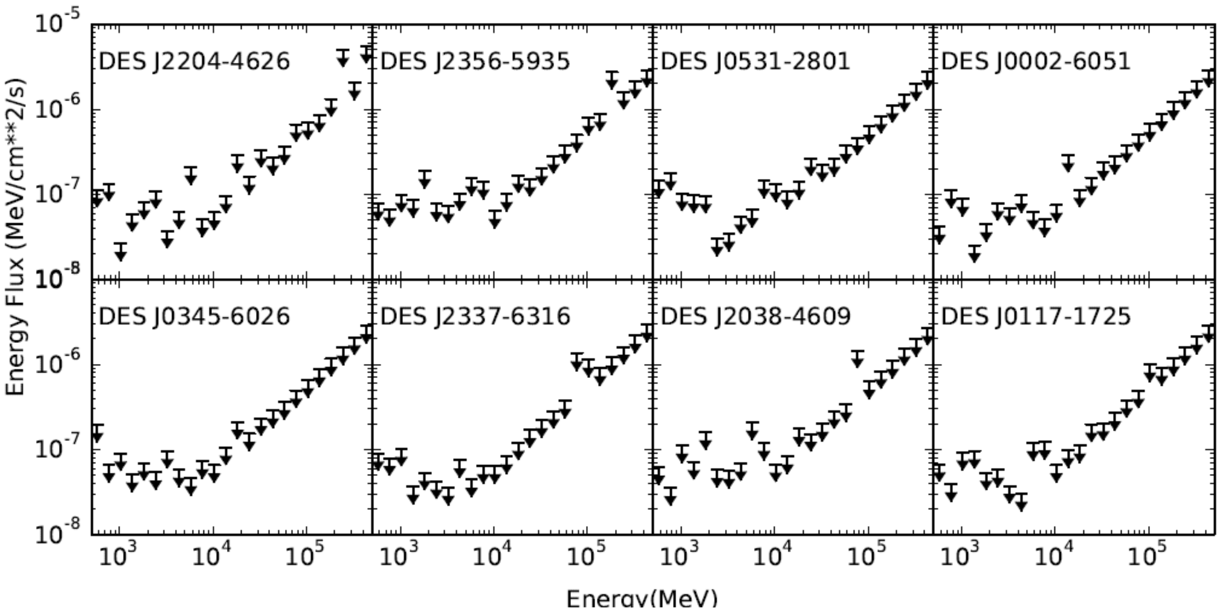


arXiv:1511.02938v1

GeV Excess in the dwarf galaxies?

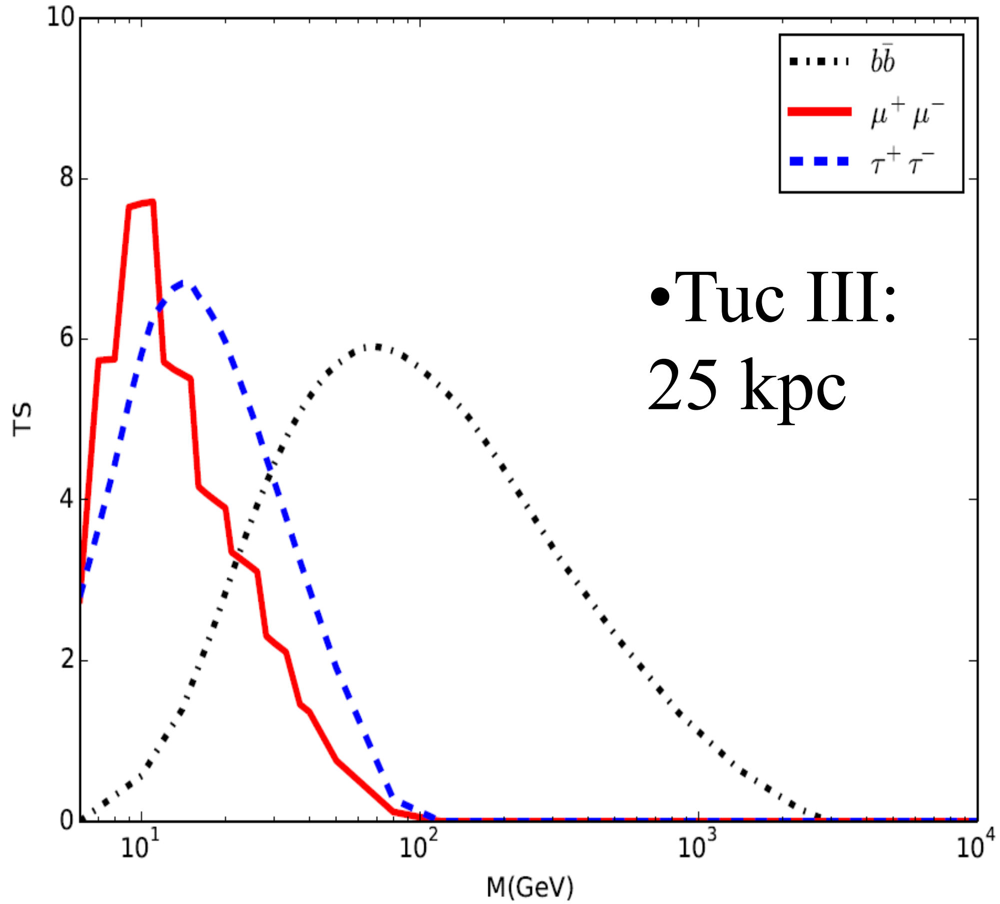
TABLE I: DES2 dSph Candidates and the Estimated J-factors

Name	$(l,b)^a$ (deg)	Distance[b] (kpc)	$\log_{10}$ (Est.J)[c] $\log 10(\mathrm{GeV}^2\mathrm{cm}^{-5})$
DES J2204-4626	(351.15,-51.94)	53 ± 5	18.8
DES J2356-5935	(315.38,-56.19)	25 ± 2	19.5
DES J0531-2801	(231.62,-28.88)	182 ± 18	17.8
DES J0002-6051	(313.29,-55.29)	48 ± 4	18.9
DES J0345-6026	(273.88,-45.65)	92 ± 13	18.3
DES J2337-6316	(316.31,-51.89)	55 ± 9	18.8
DES J2038-4609	(353.99,-37.40)	214 ± 16	17.6
DES J0117-1725	(156.48,-78.53)	30 ± 3	19.3



•**Shang Li 1511.09252**

•GeV Excess in the Dwarf Galaxies?



•(Li, S. et al. 2016)

Evidence for Gamma-ray Emission from the Newly Discovered Dwarf Galaxy Reticulum 2

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McWilliams Center for Cosmology, Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, USA

Savvas M. Koushiappas[‡]
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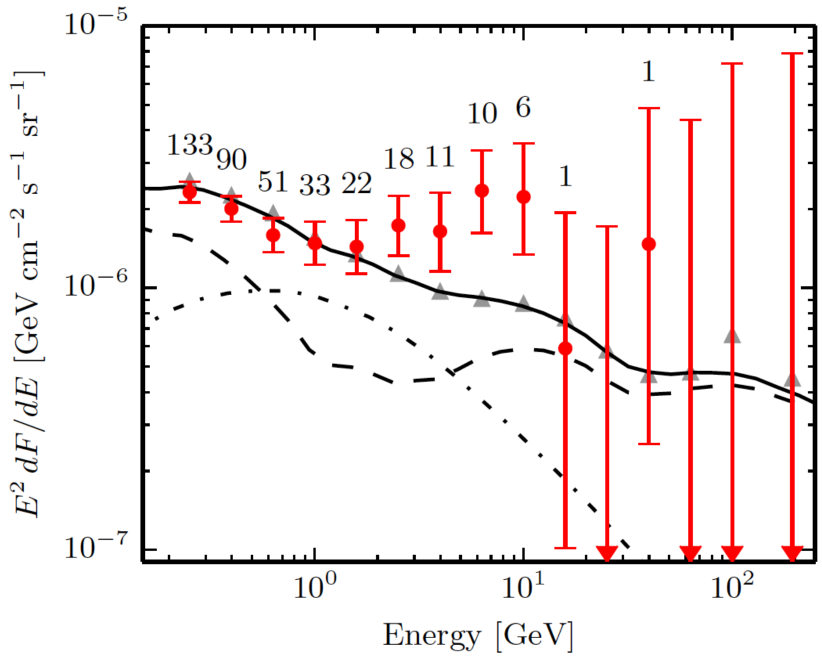
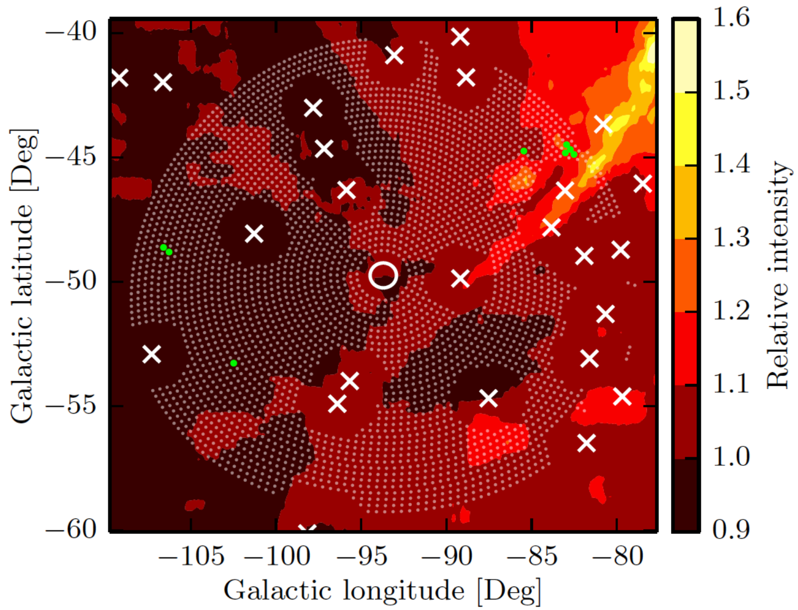
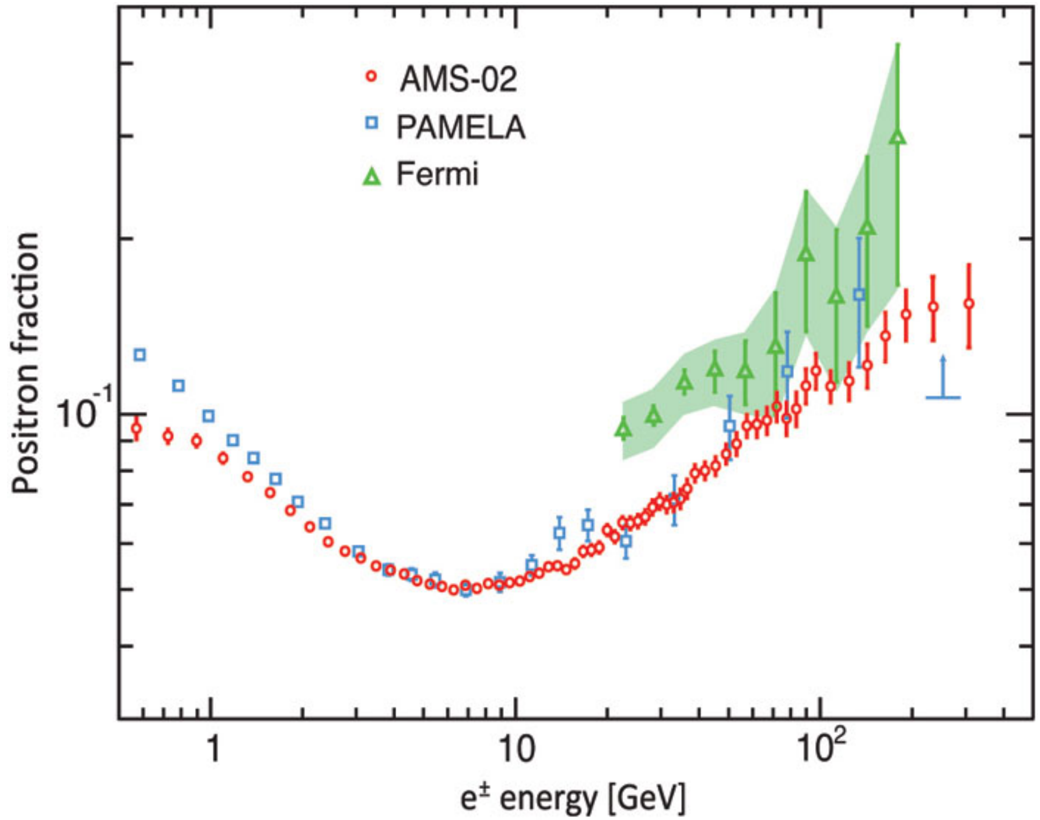
Sergey E. Koposov, Vasily Belokurov, Gabriel Torrealba, and N. Wyn Evans
Institute of Astronomy, University of Cambridge, Cambridge, CB3 0HA, UK
(Dated: March 10, 2015)



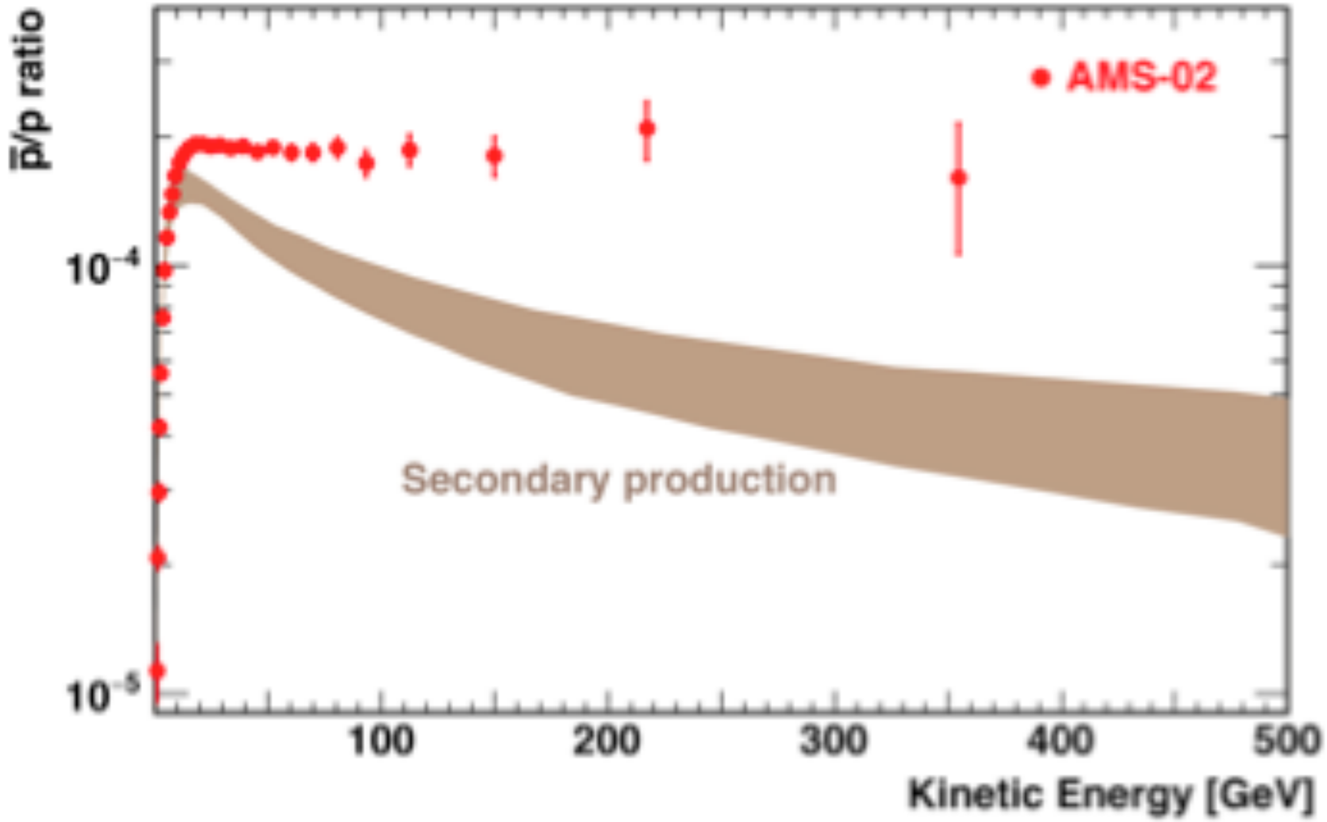


Comment on positron and anti-proton excess

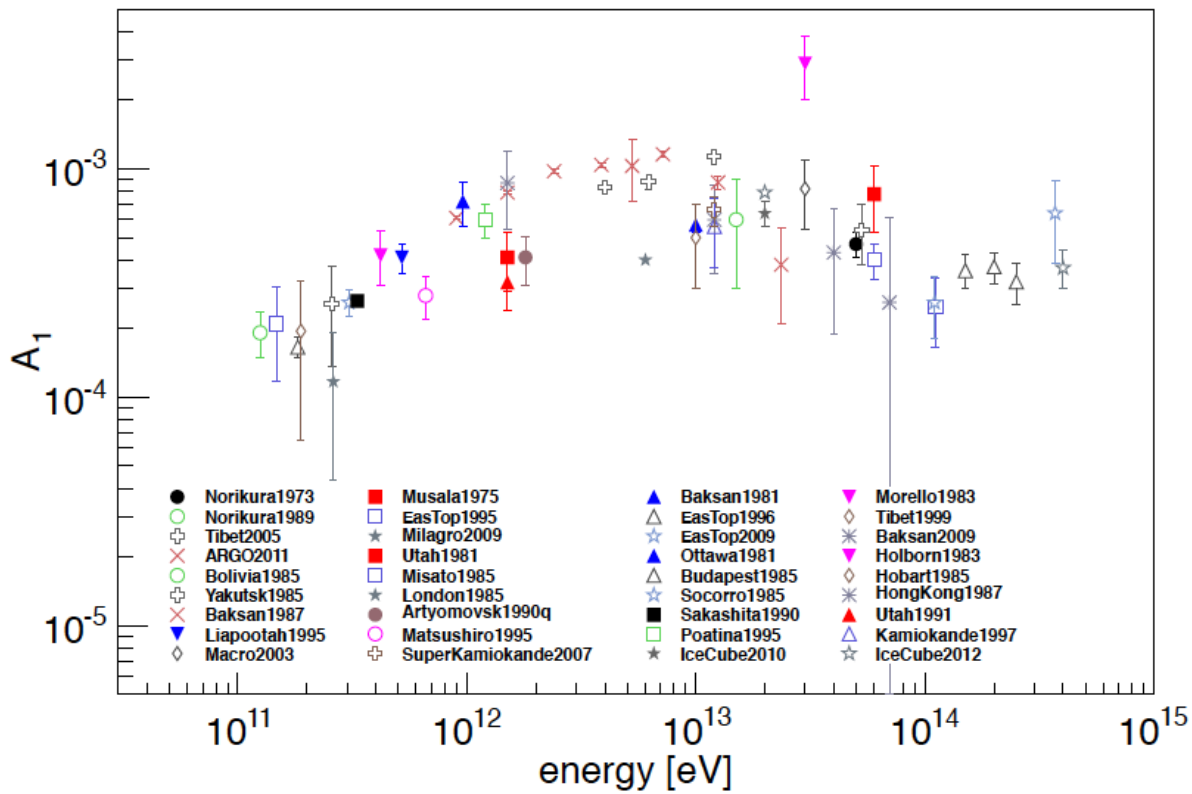
Positron to (electron + positron) ratio by PAMELA, Fermi, AMS-2



Anti-protons by AMS-2

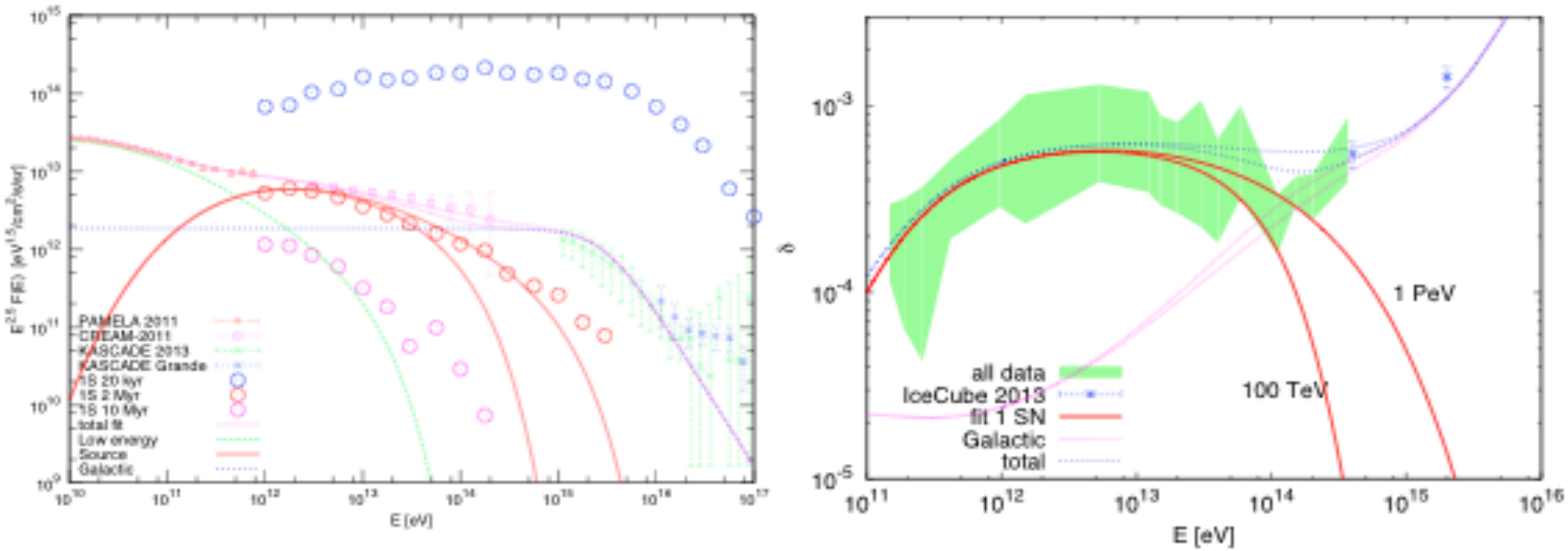


Dipole anisotropy of cosmic rays



- **G.Di Sciascio and R. Iuppa, arXiv: 1407.2144**

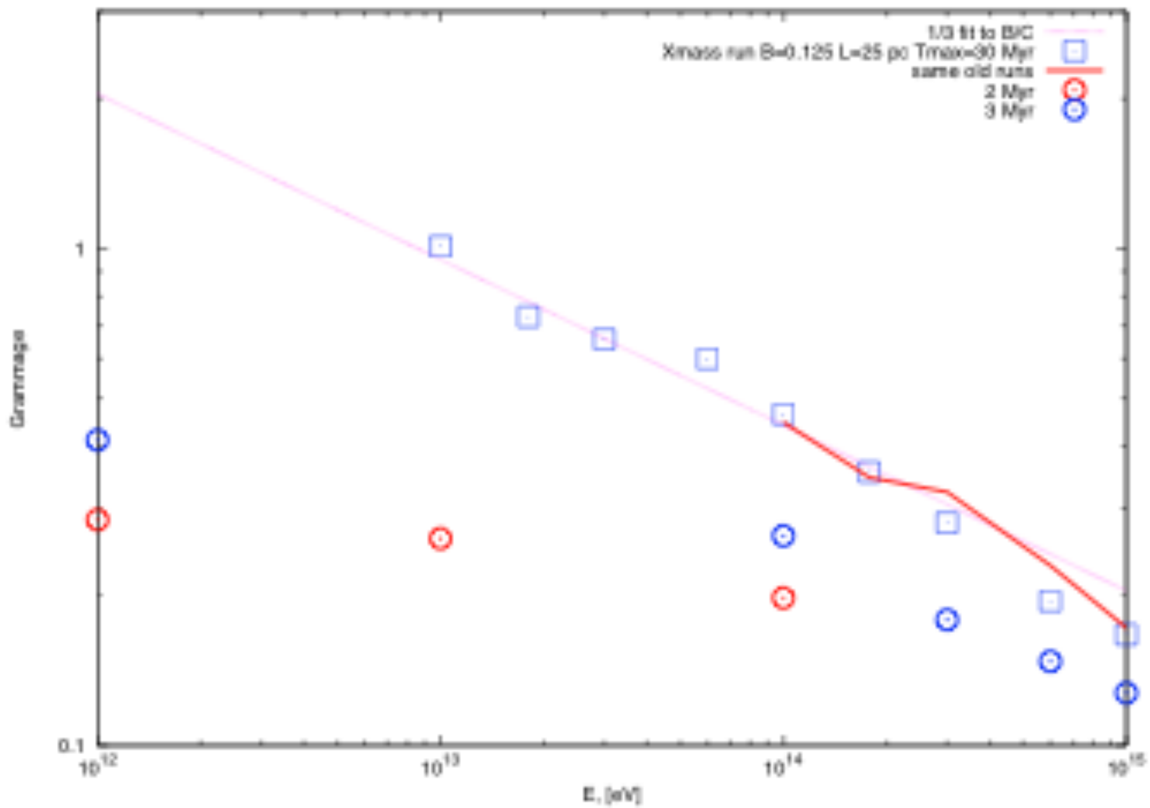
Anisotropy and flux from 2 Myr SN



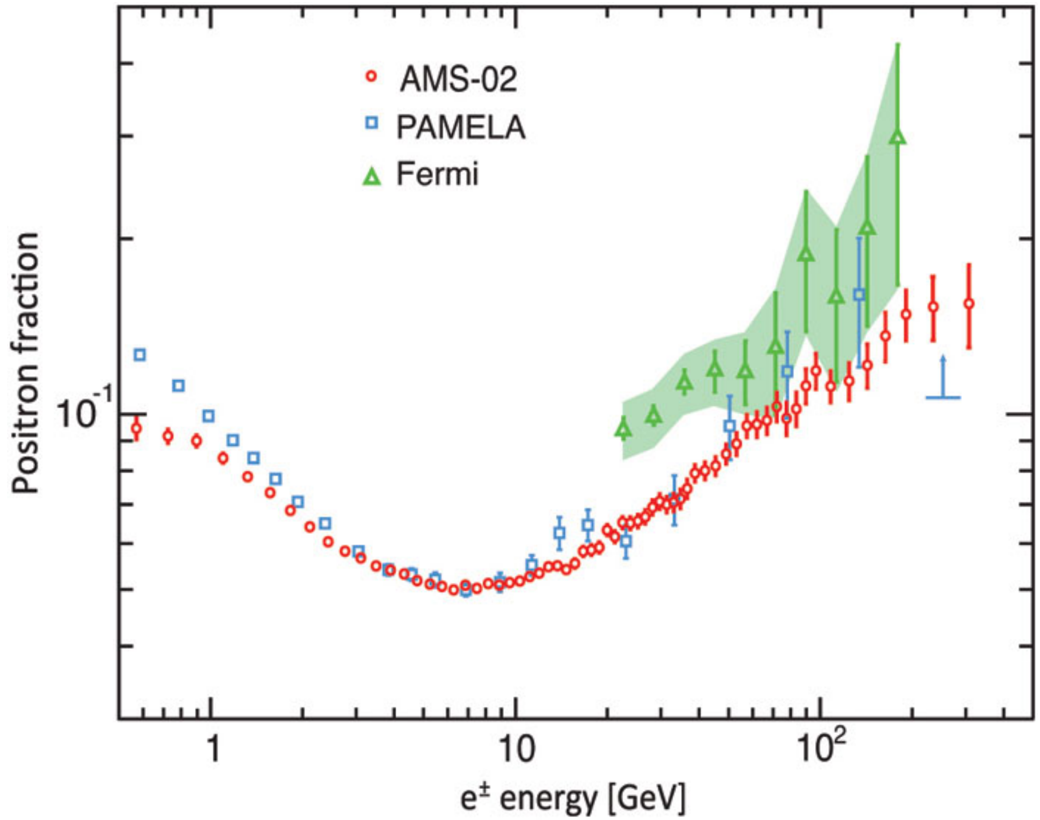
•A=3/2 R/T

- V.Savchenko, M.Kachelriess, and D.Semikoz, arXiv:1505.02720

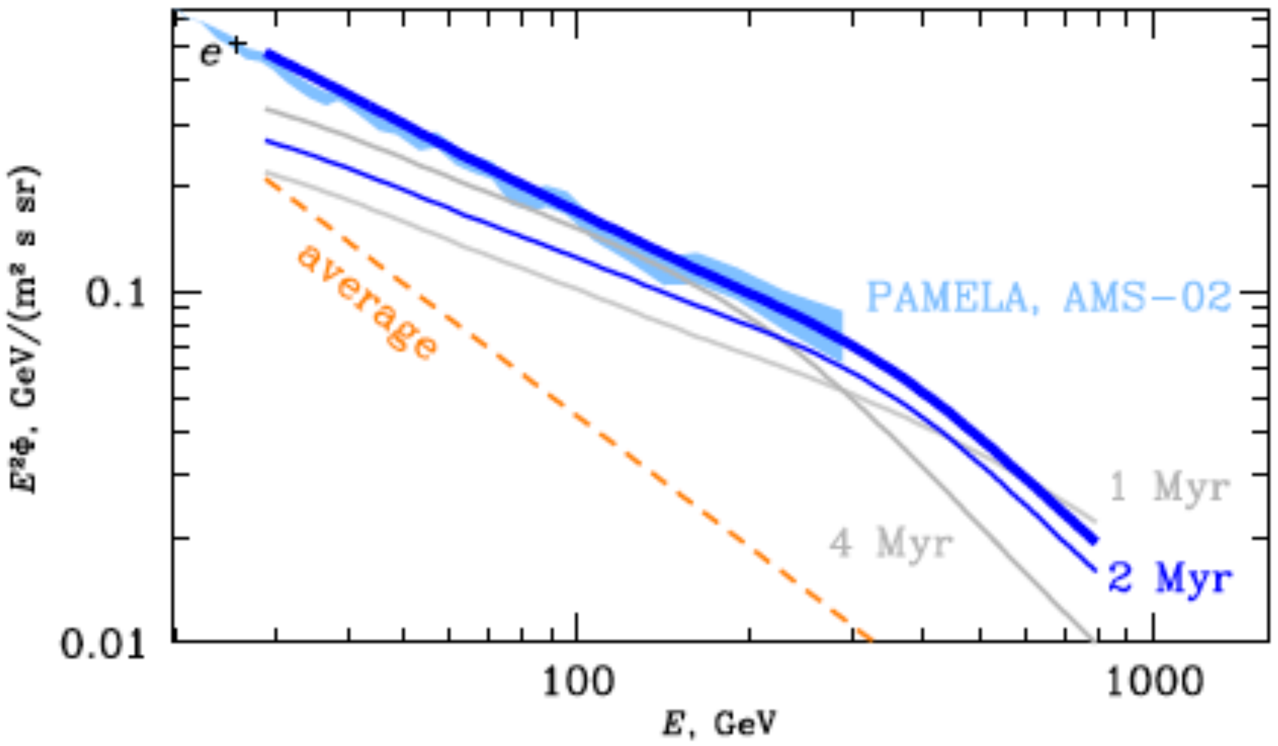
Grammage to create secondaries



Positron to (electron + positron) ratio

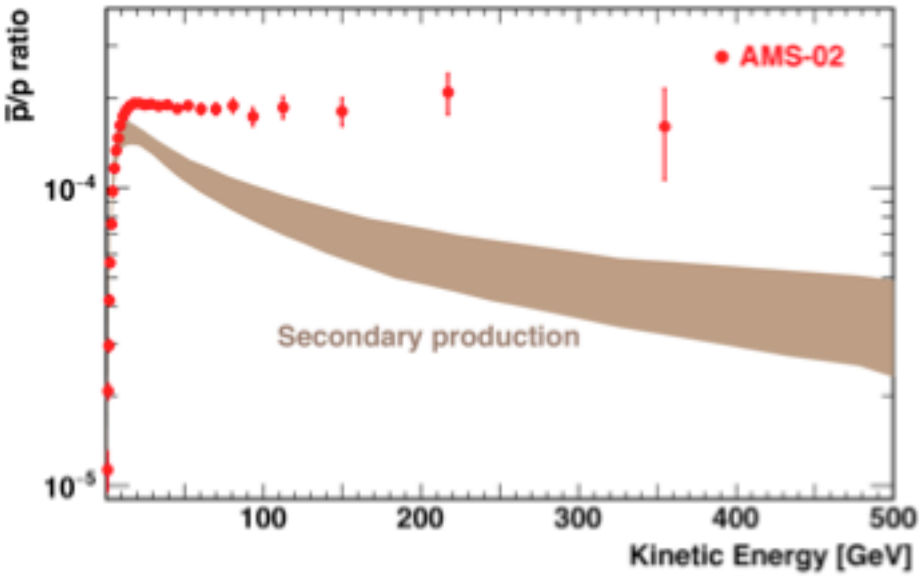


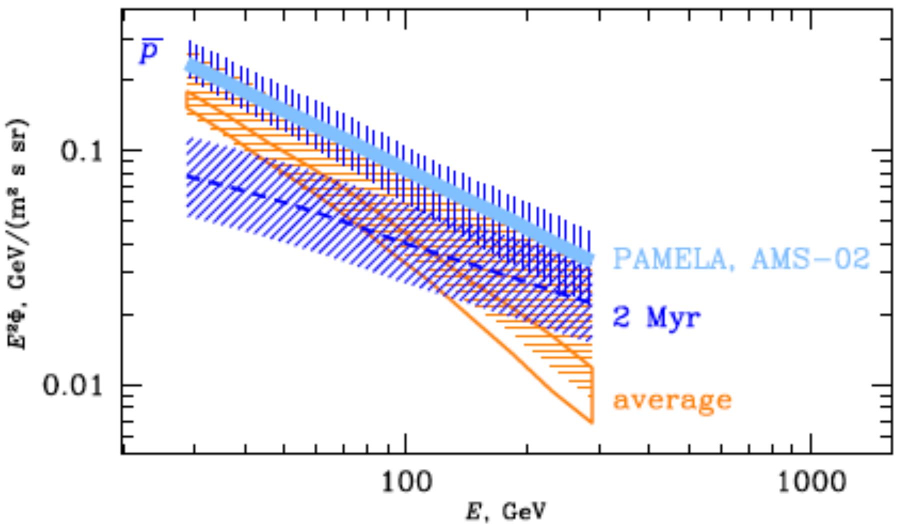
Positron flux PAMELA/AMS-II



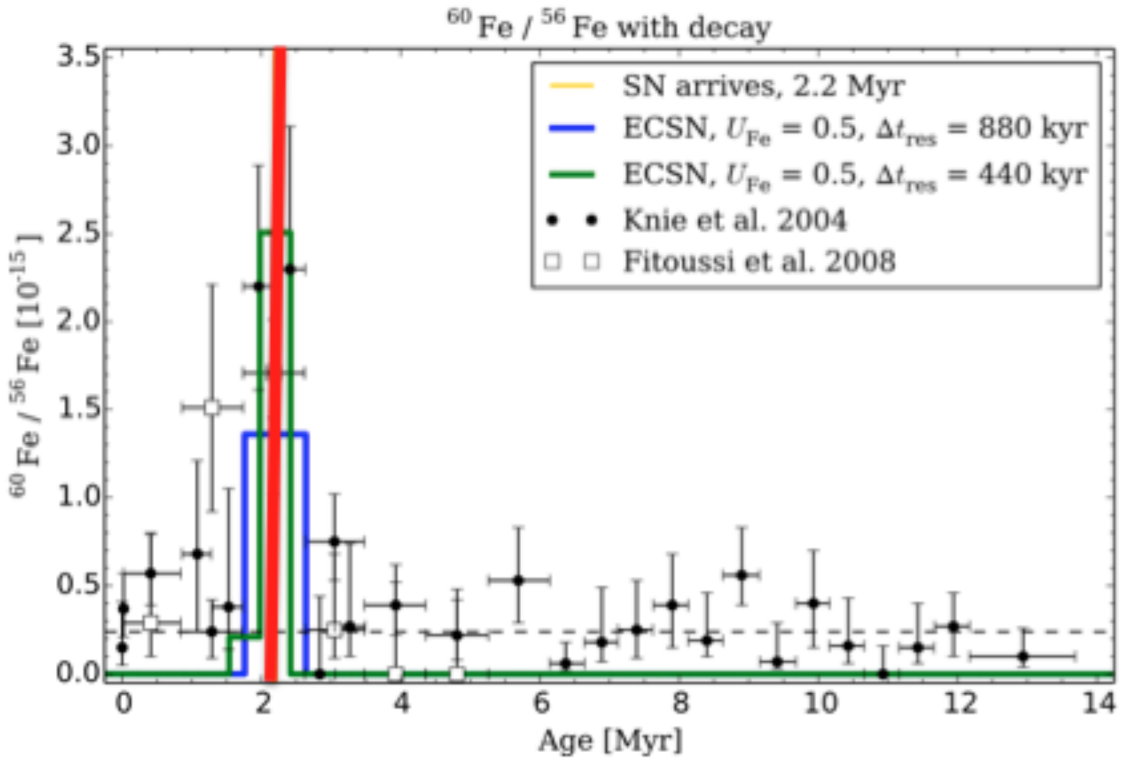
- M.Kachelriess, A. Neronov and D.Semikoz, arXiv:1504.06472

Antriprotons





Nearby SN from Fe60 in ocean crust



•Knie et al. '99, '04, Fry et al. '15

Conclusions:

- Gamma-ray astronomy works
- Will help to understand hadronic component in different kind of astrophysical sources
- helps to establish extragalactic IR/O backgrounds
- Diffuse gamma-ray background dominated by unresolved sources
- Will allow to study magnetic field in the voids of large scale structure: primordial magn. field!
- One more constraint/signature on Dark Matter