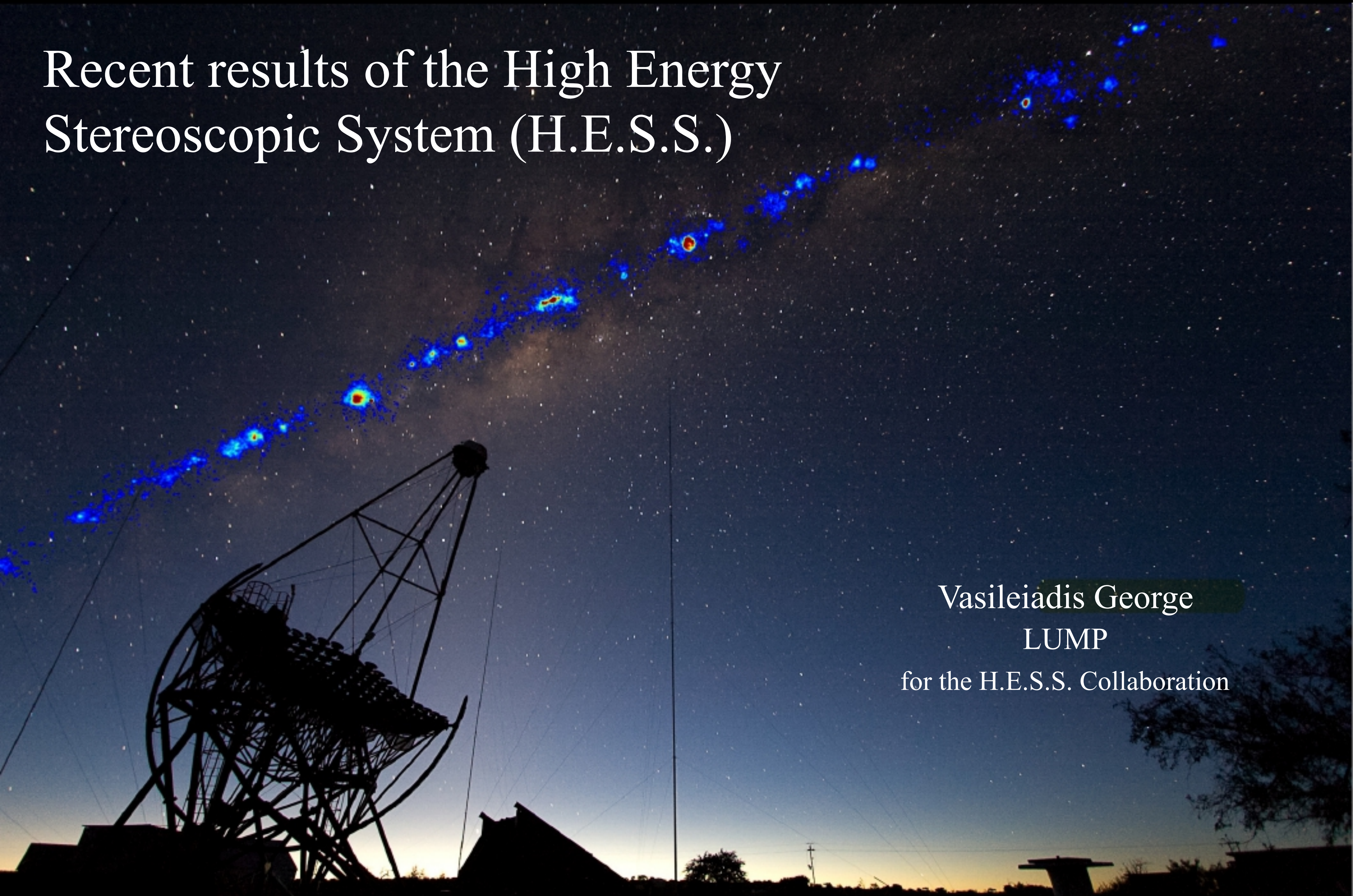
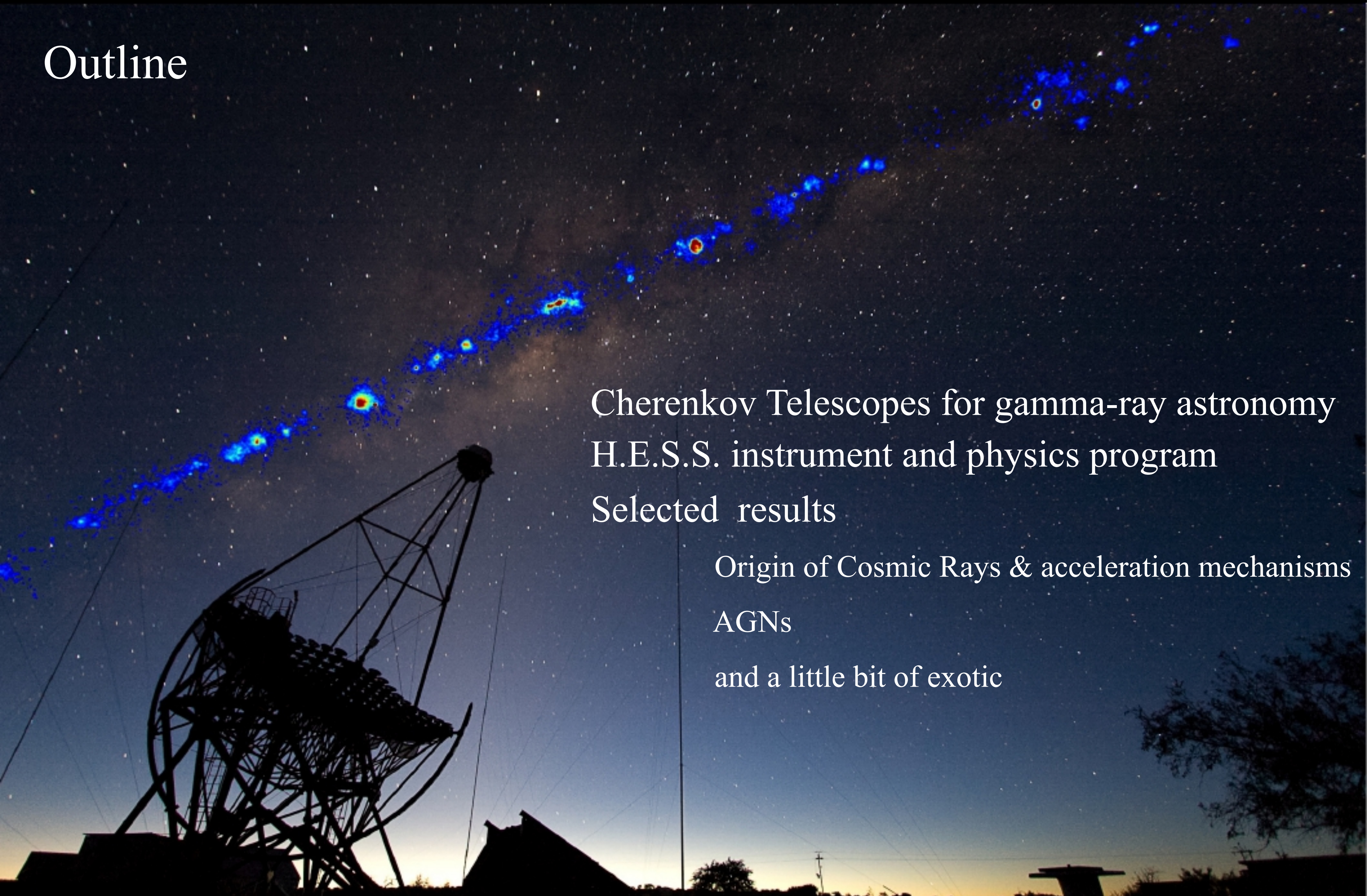
Recent results of the High Energy Stereoscopic System (H.E.S.S.)



Vasileiadis George
LUMP
for the H.E.S.S. Collaboration



Outline

Cherenkov Telescopes for gamma-ray astronomy

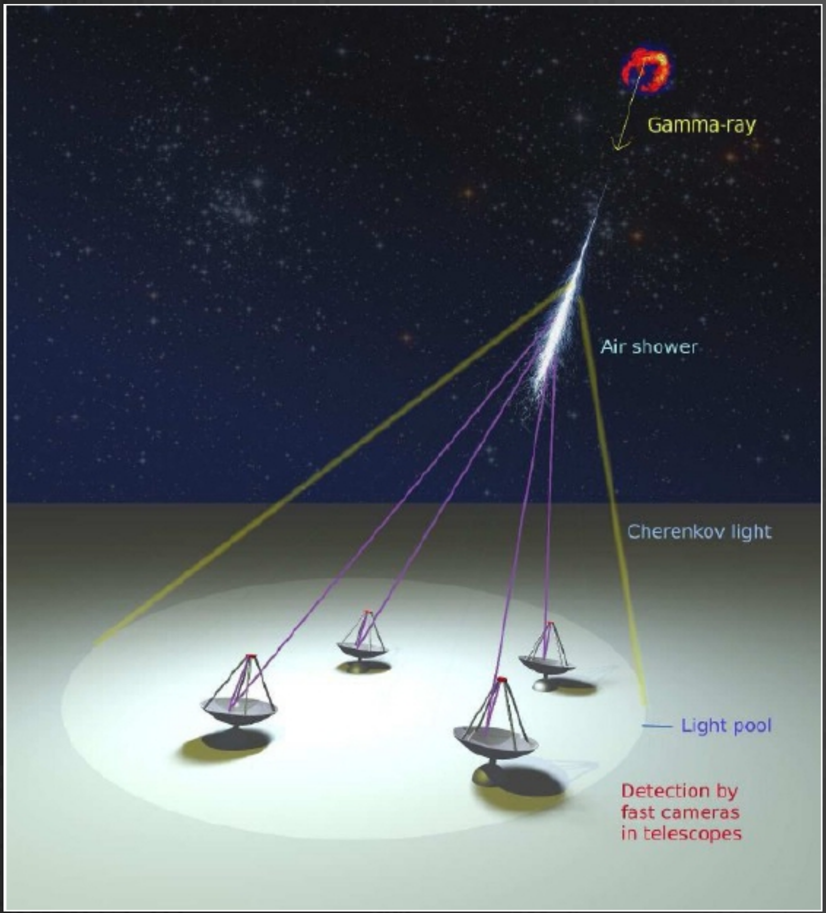
H.E.S.S. instrument and physics program

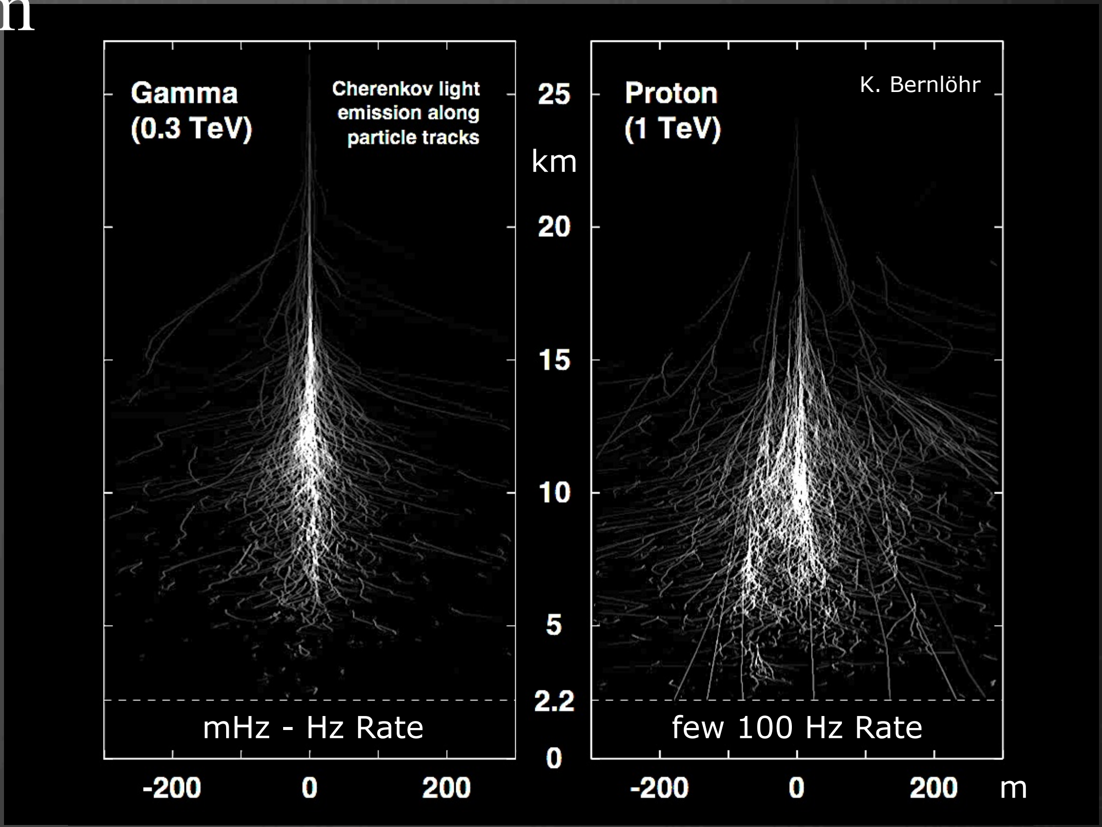
Selected results

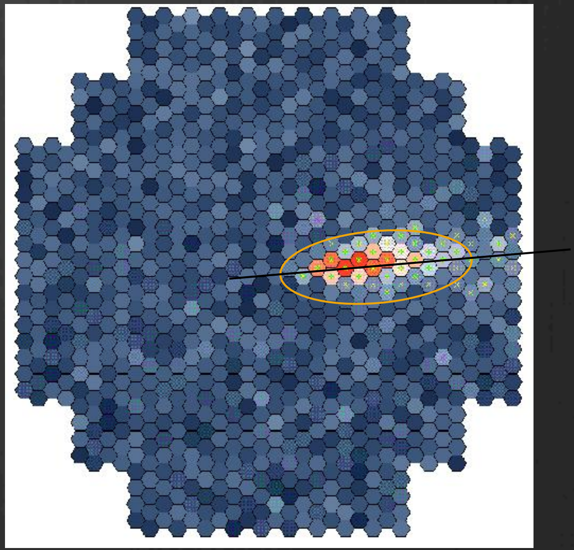
- Origin of Cosmic Rays & acceleration mechanisms
- AGNs
- and a little bit of exotic

Cascades and how to use them

mHz-Hz rate few 100 Hz rate







Geometry = Photon direction
Intensity = Photon energy
Shape = Cosmic ray direction
Faint blue flash (nsec, few 10ph/m^2)


Namibia, Khomas District, 1800m Altitude, Latitude 23° south
H.E.S.S

Key design of H.E.S.S.

- Telescope stereoscopy
- Telescope sizes 15m-28m "sweet spot" in energy
- Large 5^{o} field of view, uniform pixel size
- Small 0.17^{o} pixels ≙ 30 m @ 10 km
- Southern location (galactic plane)
- "simple" telescopes

More than 9415 h of data taken and 6361 million events

“Real astronomy” in a new energy band

High sensitivity

- 3 orders of magnitude dynamic range in flux

Wide spectral range

- >2 orders of magnitude coverage in energy, up to 10s of TeV
- 10-15% energy resolution

Resolved source morphology

- ~5’ angular resolution
- 10-20” source localization

Survey capability

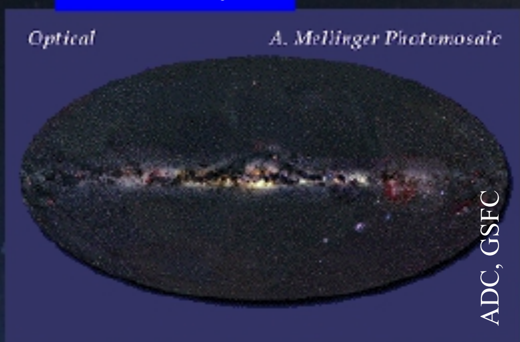
- H.E.S.S. Galactic Plane Survey:
- 2% Crab sensitivity

Well-resolved light curves

- Minute-scale variability of AGN

H.E.S.S. physics program

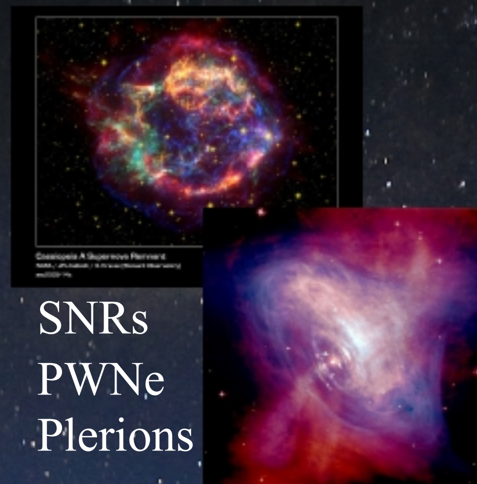
Survey



Galactic Plane Survey and follow-up observations

Galactic Center

SNRPP



SNRs
PWNe
Plerions

Extended extragalactic objects

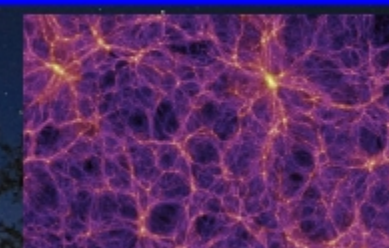
starburst galaxies
galaxy clusters
pair halos

AGN

radio galaxies
GRBs

Binaries

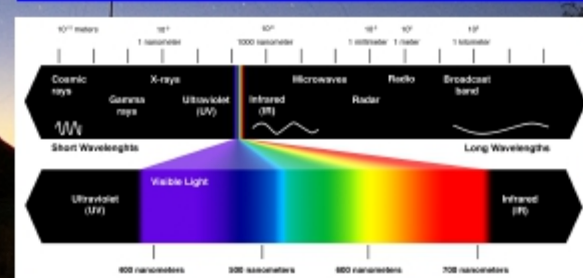
Astroparticle / Exotic



millenium simulation

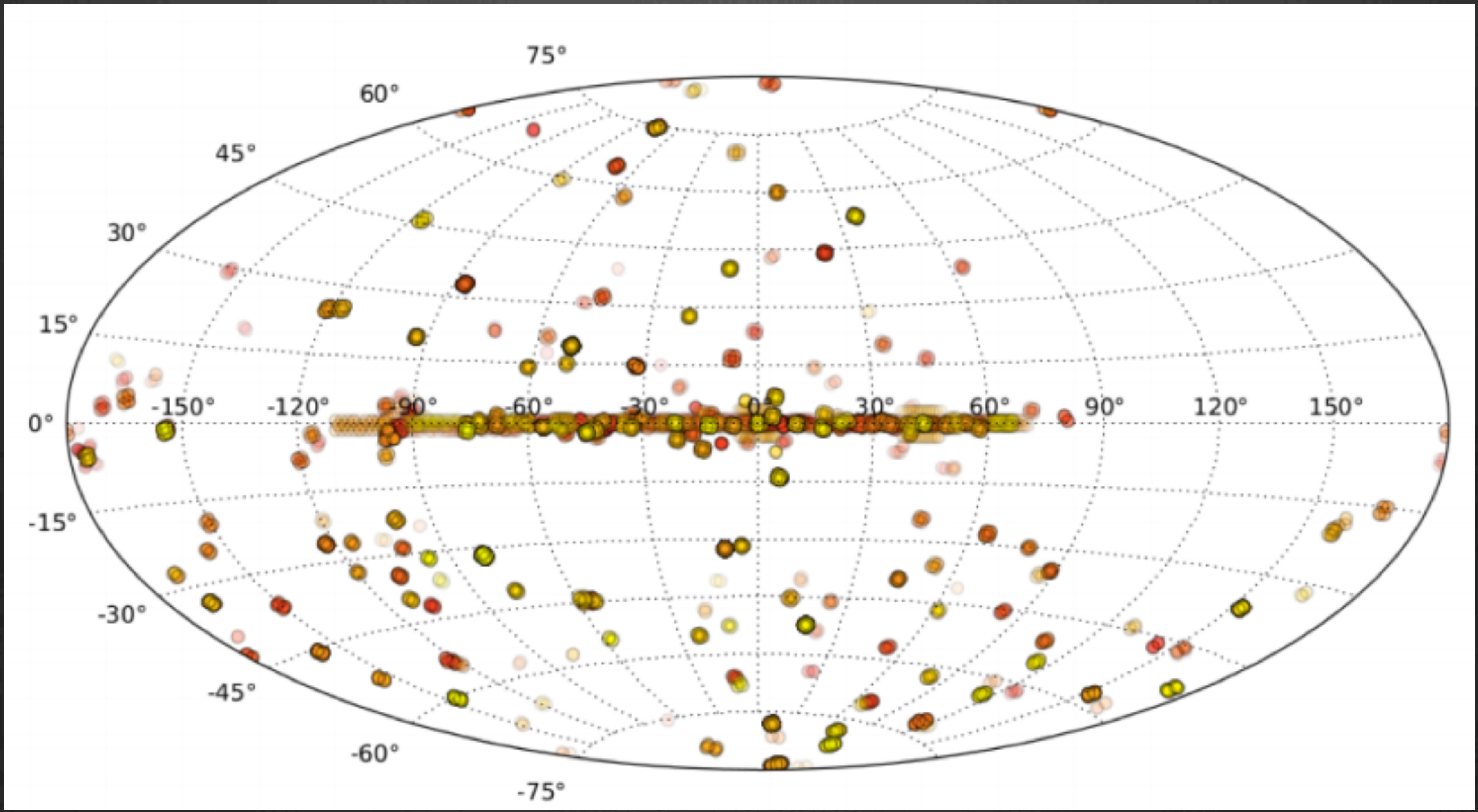
Cosmic rays
Dark matter
Lorentz invariance tests

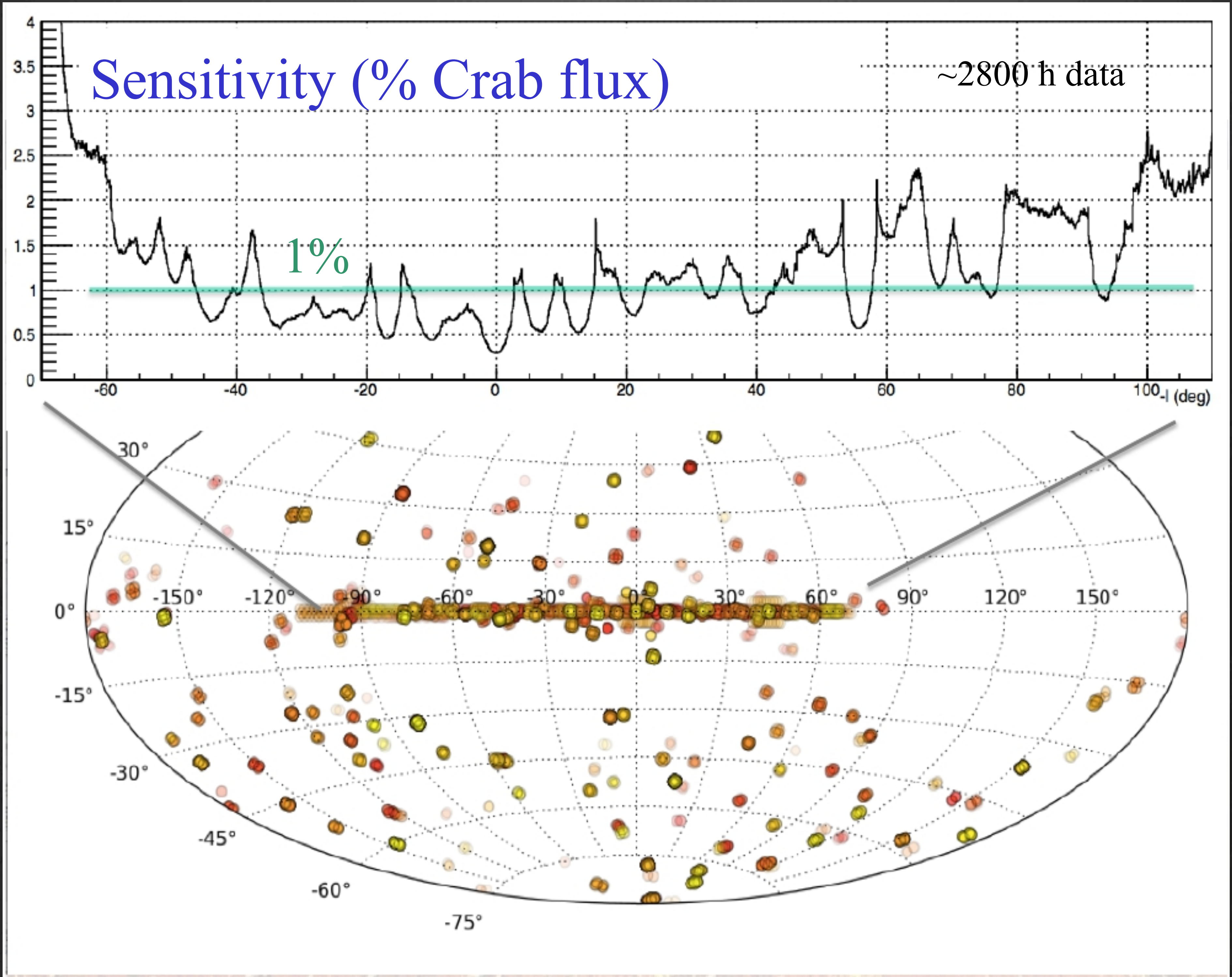
Multiwavelength



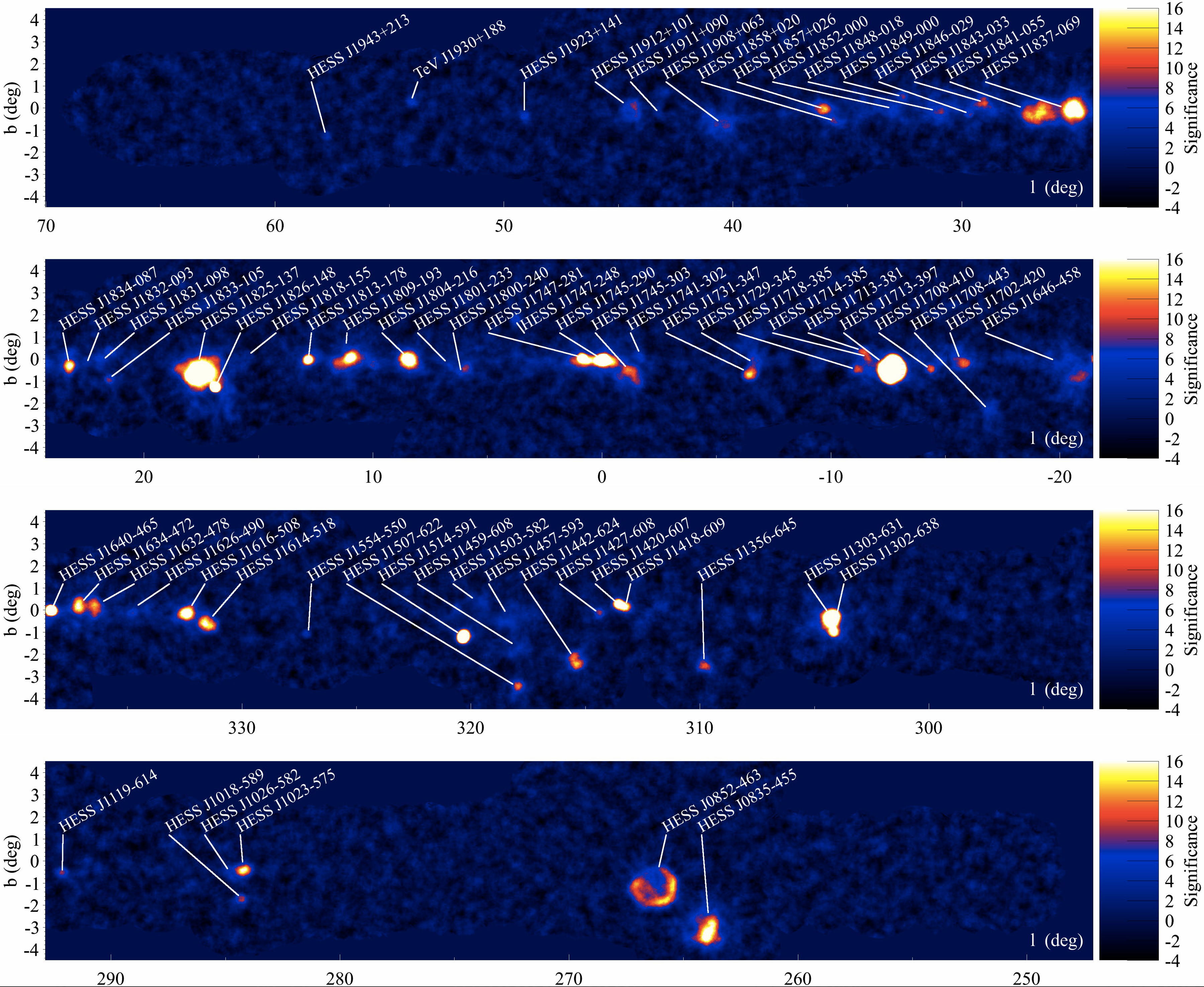
Slide following M. Daniel, with material from NASA/ESA

sky coverage & sensitivity



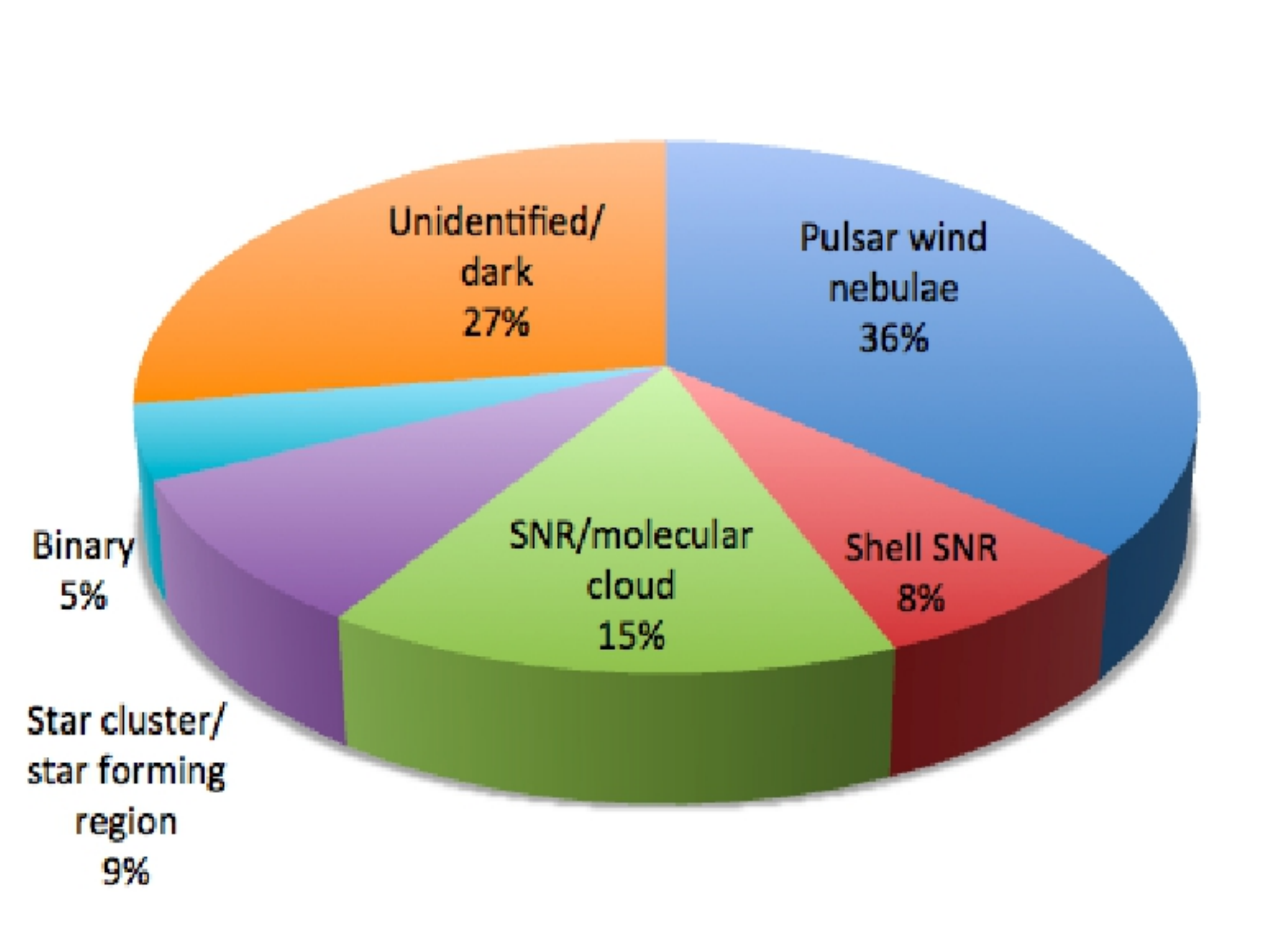


Sensitivity (% Crab flux)
~2800 h data
1%
l (deg)



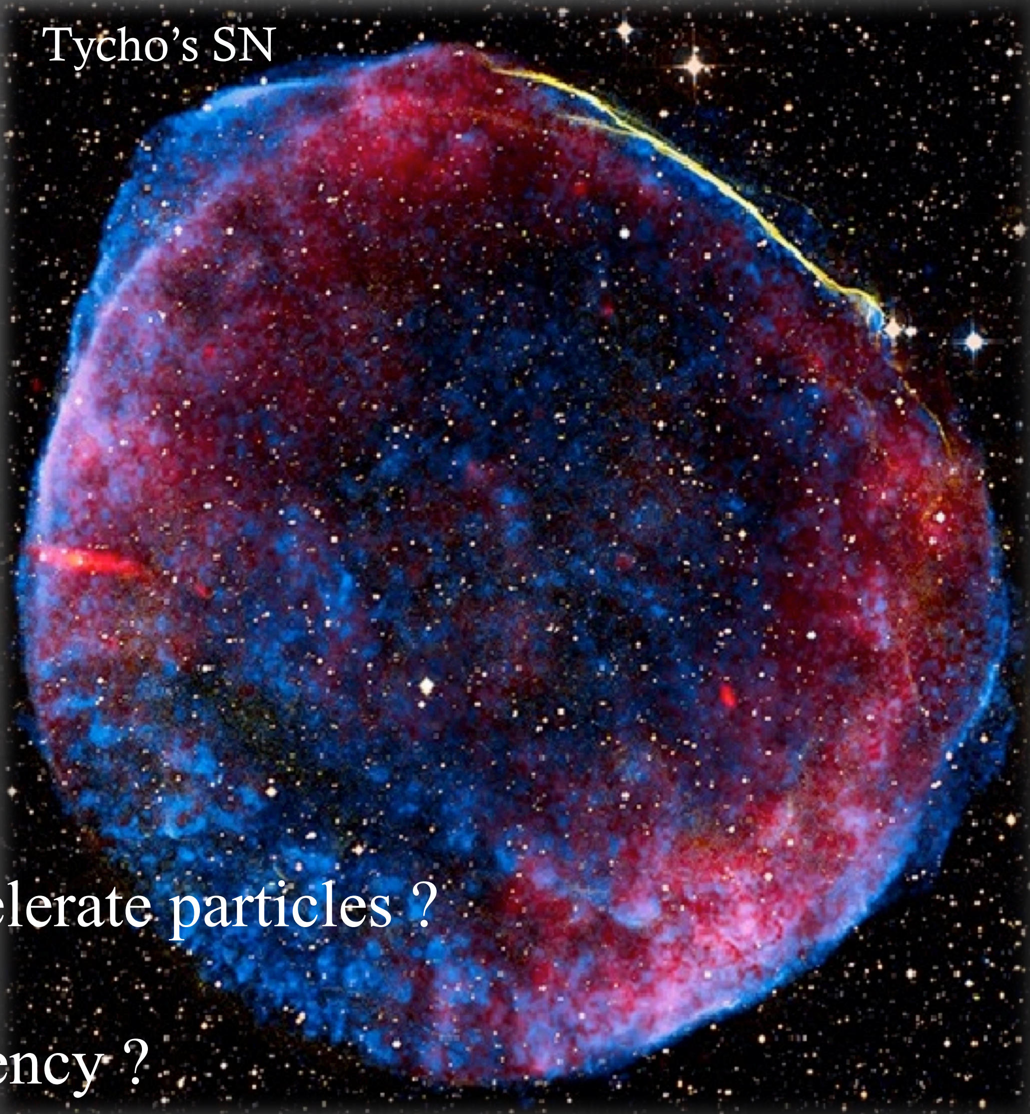
HESS J1943+213
TeV J1930+188
HESS J1923+141
HESS J1912+101
HESS J1911+090
HESS J1908+063
HESS J1858+020
HESS J1857+026
HESS J1852-000
HESS J1848-018
HESS J1849-000
HESS J1846-029
HESS J1843-033
HESS J1841-055
HESS J1837-069
HESS J1834-087
HESS J1832-093
HESS J1831-098
HESS J1833-105
HESS J1825-137
HESS J1826-148
HESS J1818-155
HESS J1813-178
HESS J1809-193
HESS J1804-216
HESS J1801-233
HESS J1800-240
HESS J1747-281
HESS J1747-248
HESS J1745-290
HESS J1745-303
HESS J1741-302
HESS J1731-347
HESS J1729-345
HESS J1718-385
HESS J1714-385
HESS J1713-381
HESS J1713-397
HESS J1708-410
HESS J1708-443
HESS J1702-420
HESS J1646-458
HESS J1640-465
HESS J1634-472
HESS J1632-478
HESS J1626-490
HESS J1616-508
HESS J1614-518
HESS J1554-550
HESS J1507-622
HESS J1514-591
HESS J1459-608
HESS J1503-582
HESS J1457-593
HESS J1442-624
HESS J1427-608
HESS J1420-607
HESS J1418-609
HESS J1356-645
HESS J1303-631
HESS J1302-638
HESS J1119-614
HESS J1018-589
HESS J1026-582
HESS J1023-575
HESS J0852-463
HESS J0835-455
b (deg)
l (deg)
Significance

Source classes



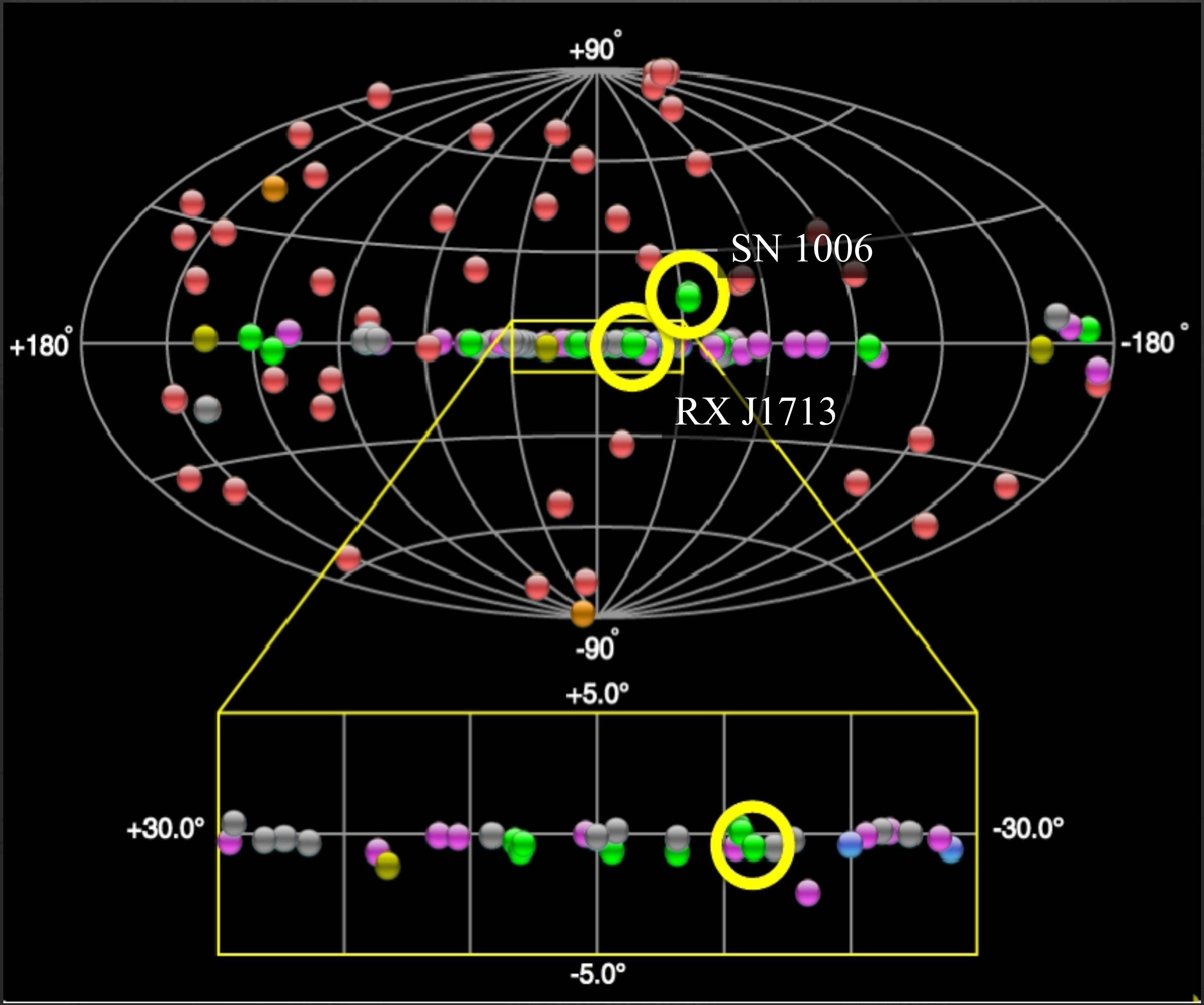
Why so many pulsars :

- The rotational energy of pulsars is an order of magnitude below the kinetic energy released in a SNR
- But much of the energy goes into electrons and positrons which are much more efficient in producing gamma rays compared to protons
- Also pulsars accelerate particles over a much longer time scale than SNR



Do supernova remnants accelerate particles ?
To PeV energies ?
With what conversion efficiency ?
How in detail are CR accelerated ?
What is the composition of accelerated particles?
How are they released from the remnant?
Can SNR account for flux and spectrum of galactic CR?

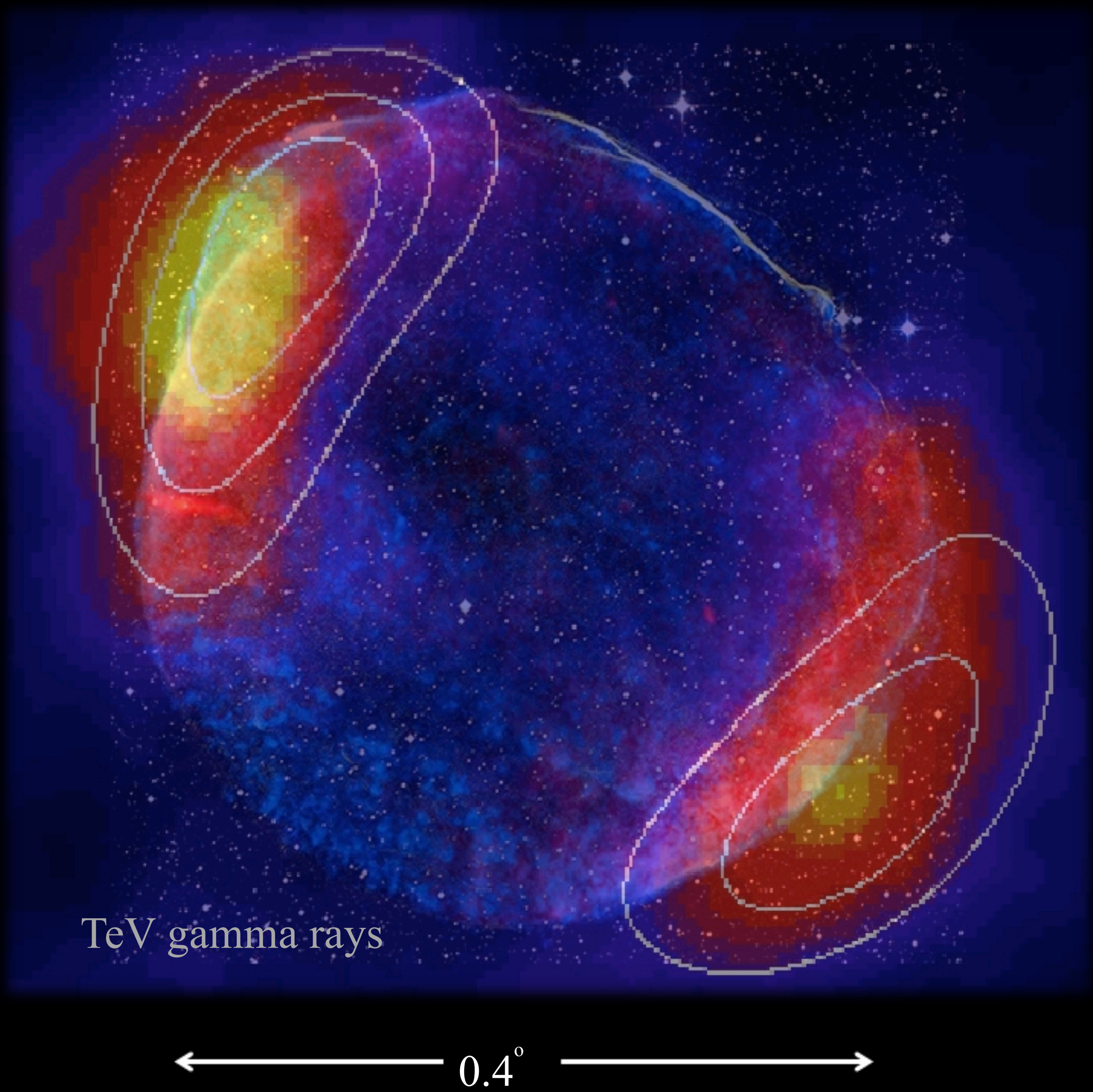
Supernova remnants



Do supernova remnants accelerate particles?

SN 1006

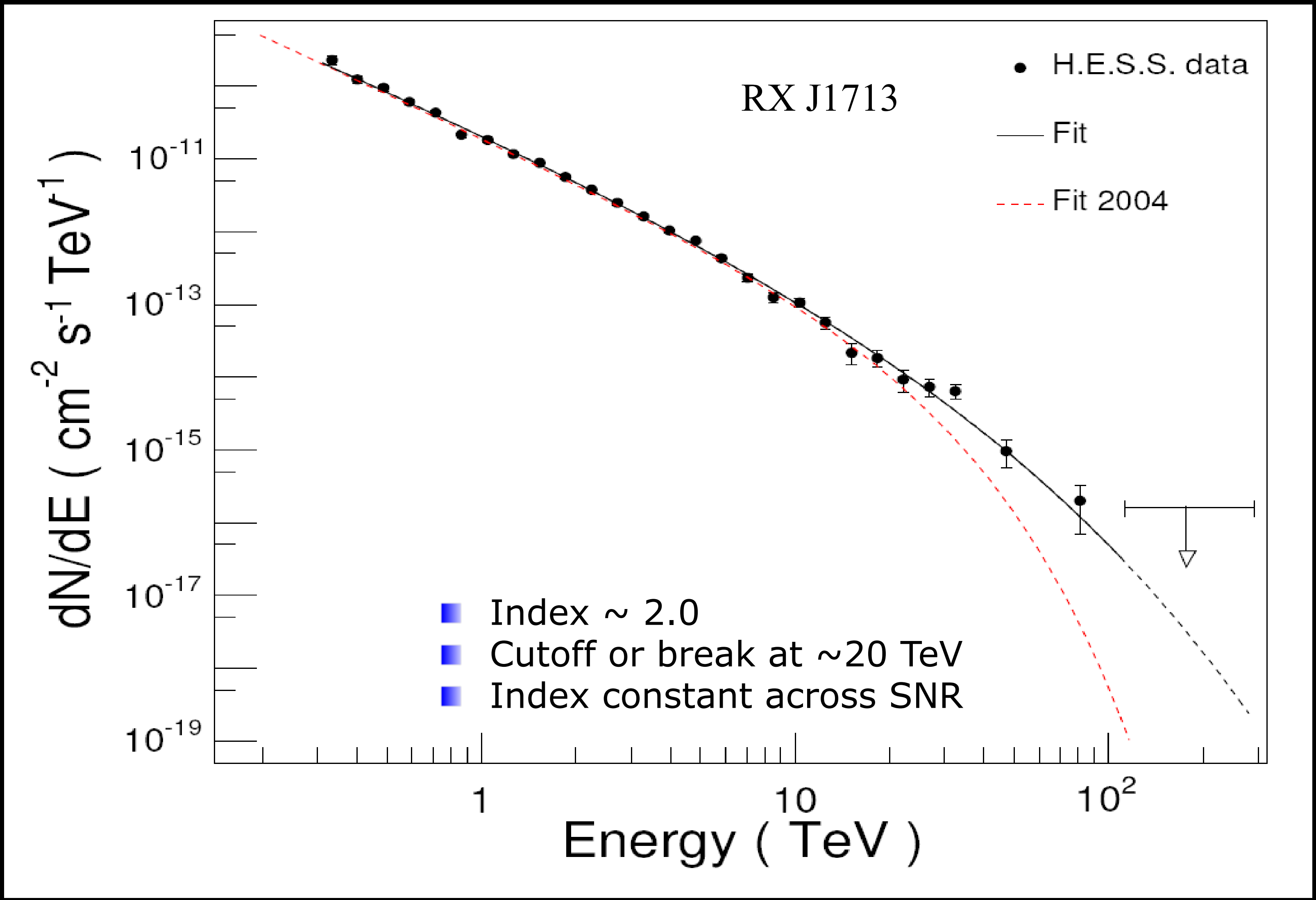
H.E.S.S.
arXiv:1004.2124

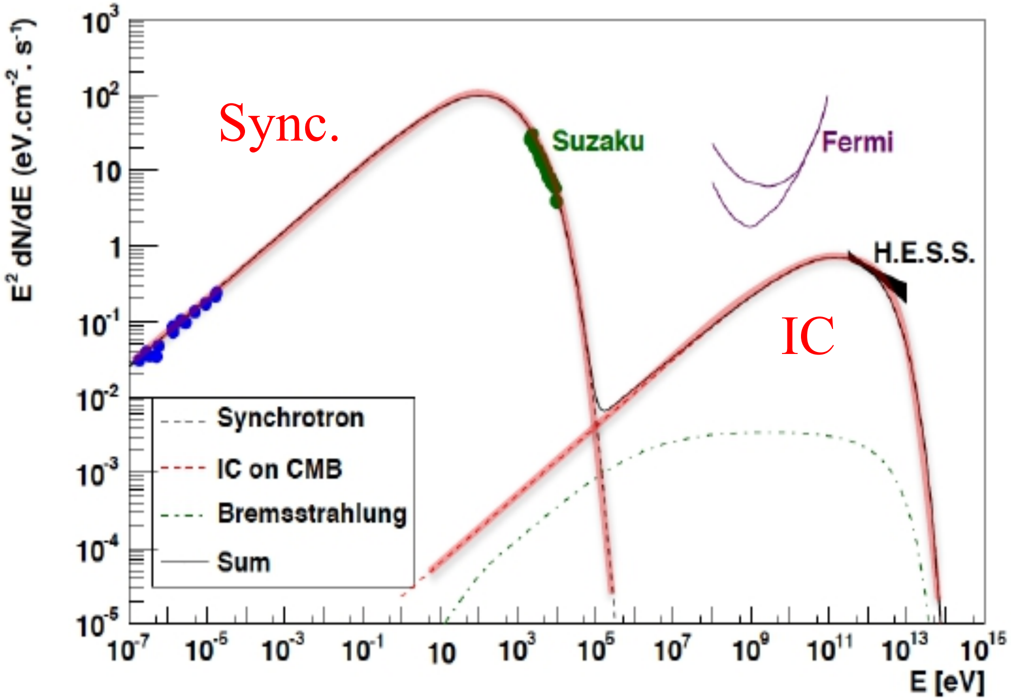


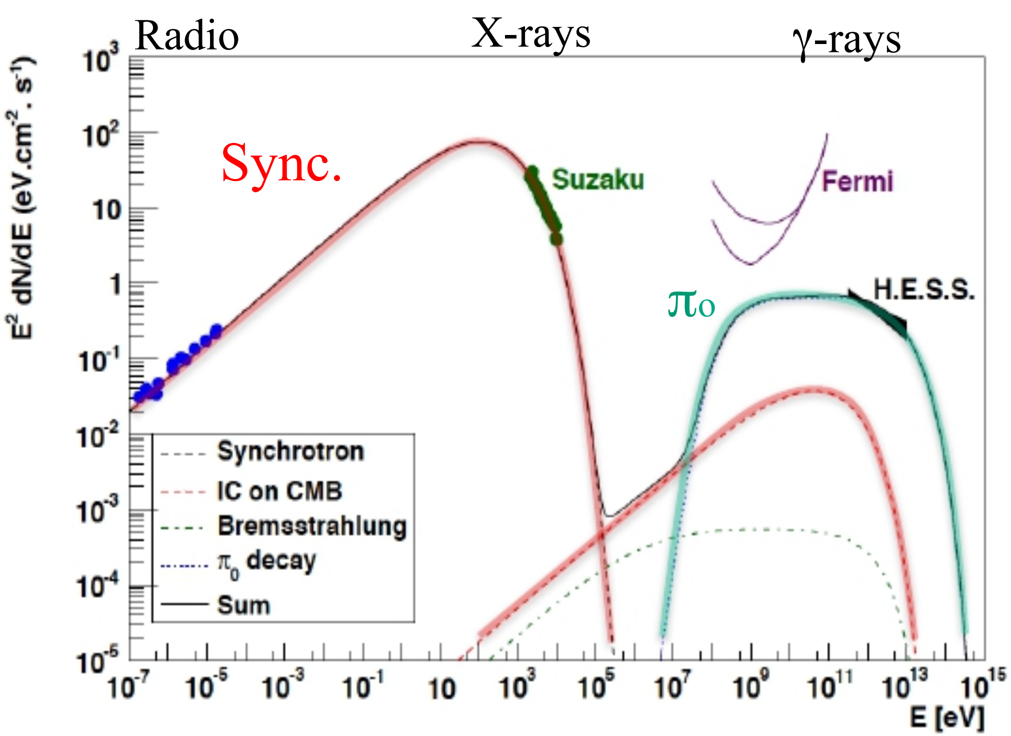
(Credit:X-ray: NASA/CXC/
Rutgers/G.Cassam-Chenai,
J.Hughes et al.; Radio: NRAO/
AUI/NSF/GBT/VLA/Dyer,
Maddalena & Cornwell;
Optical: Middlebury College/
F.Winkler, NOAO/AURA/NSF/
CTIO Schmidt & DSS)

To Pev energies ?

Particle acceleration to beyond 100 TeV







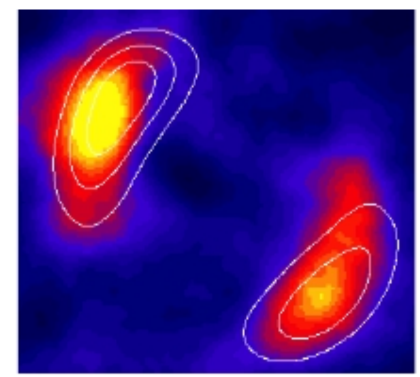
With what conversion efficiency ?

Gamma rays from electrons

$W_e = 3.3 \times 10^{47}$ ergs

$\varepsilon = 0.03\%$

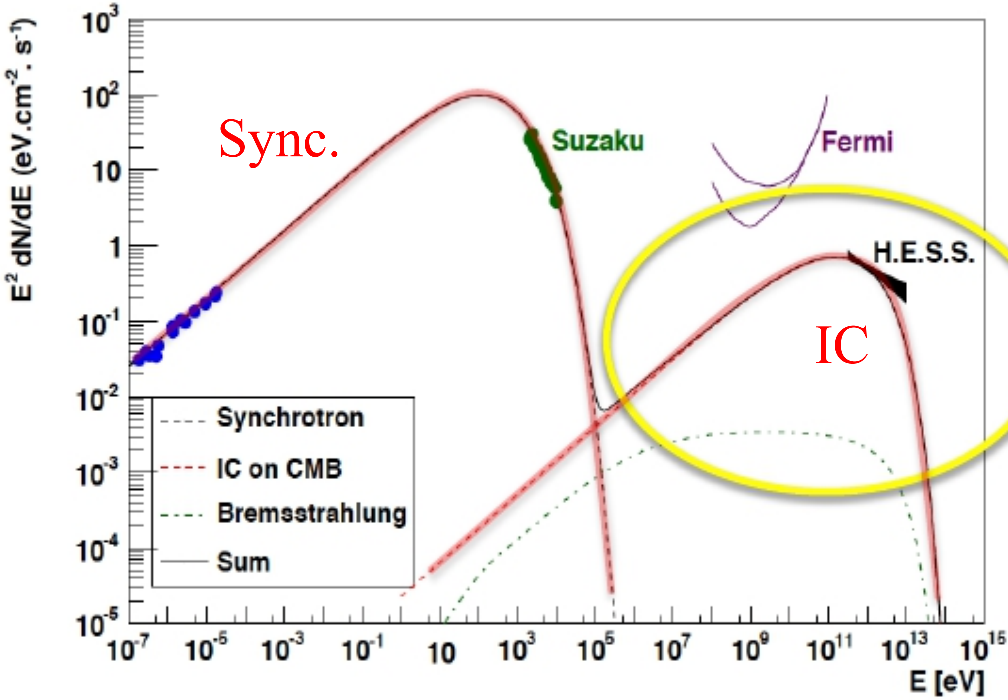
SN 1006



Gamma rays from protons

$W_P = 3 \times 10^{50}$ ergs

$\varepsilon = 30\%$

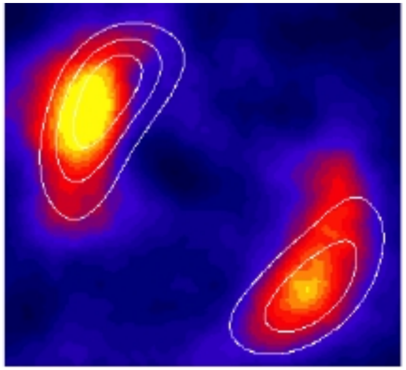


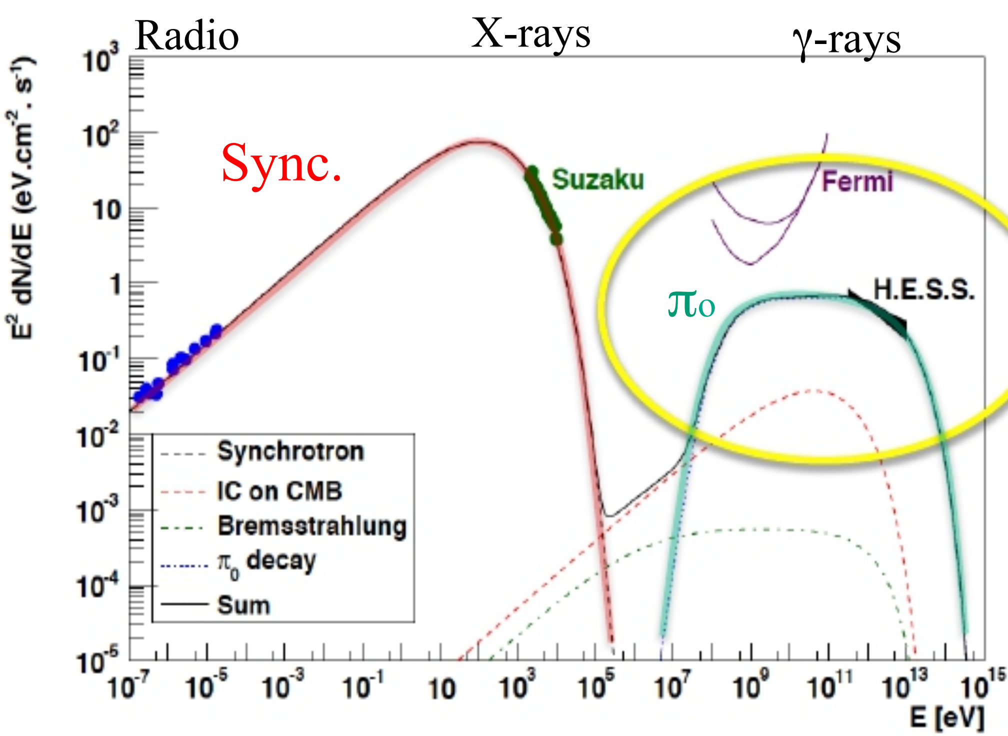
Gamma rays from electrons

Spectral index ~1.5

Rising SED

SN 1006





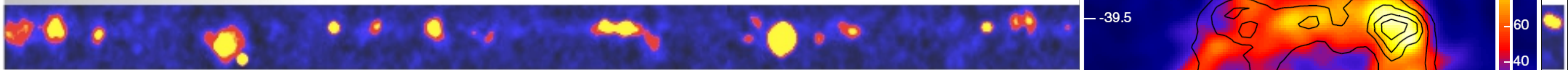
Gamma rays from protons

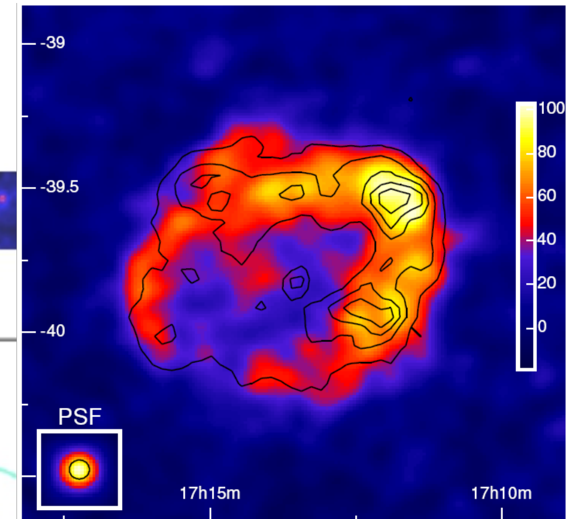
Spectral index ~2.0

Flat SED

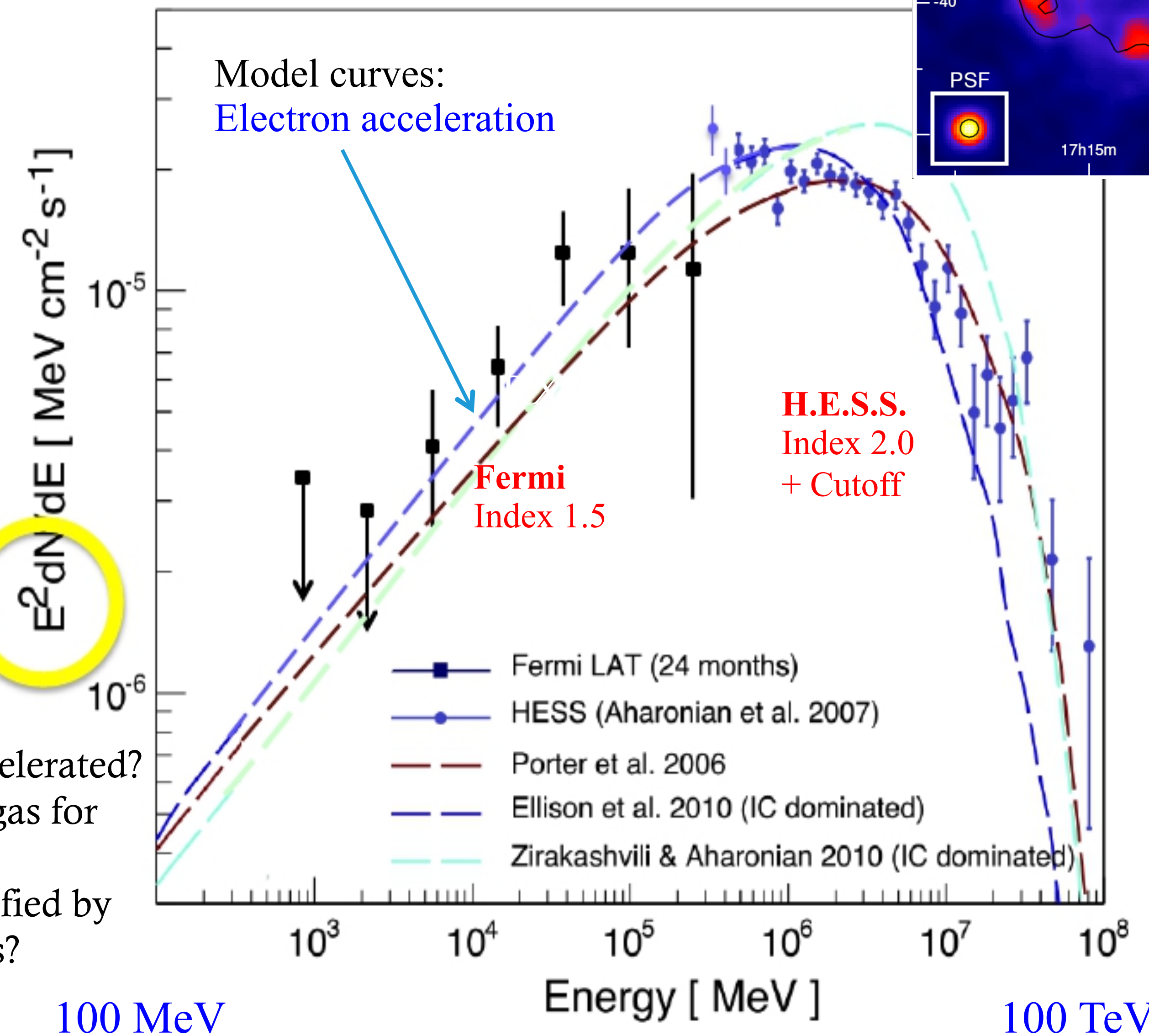
Lower cutoff at ~$m_\pi/2$

electrons or proton as origin of gamma rays?



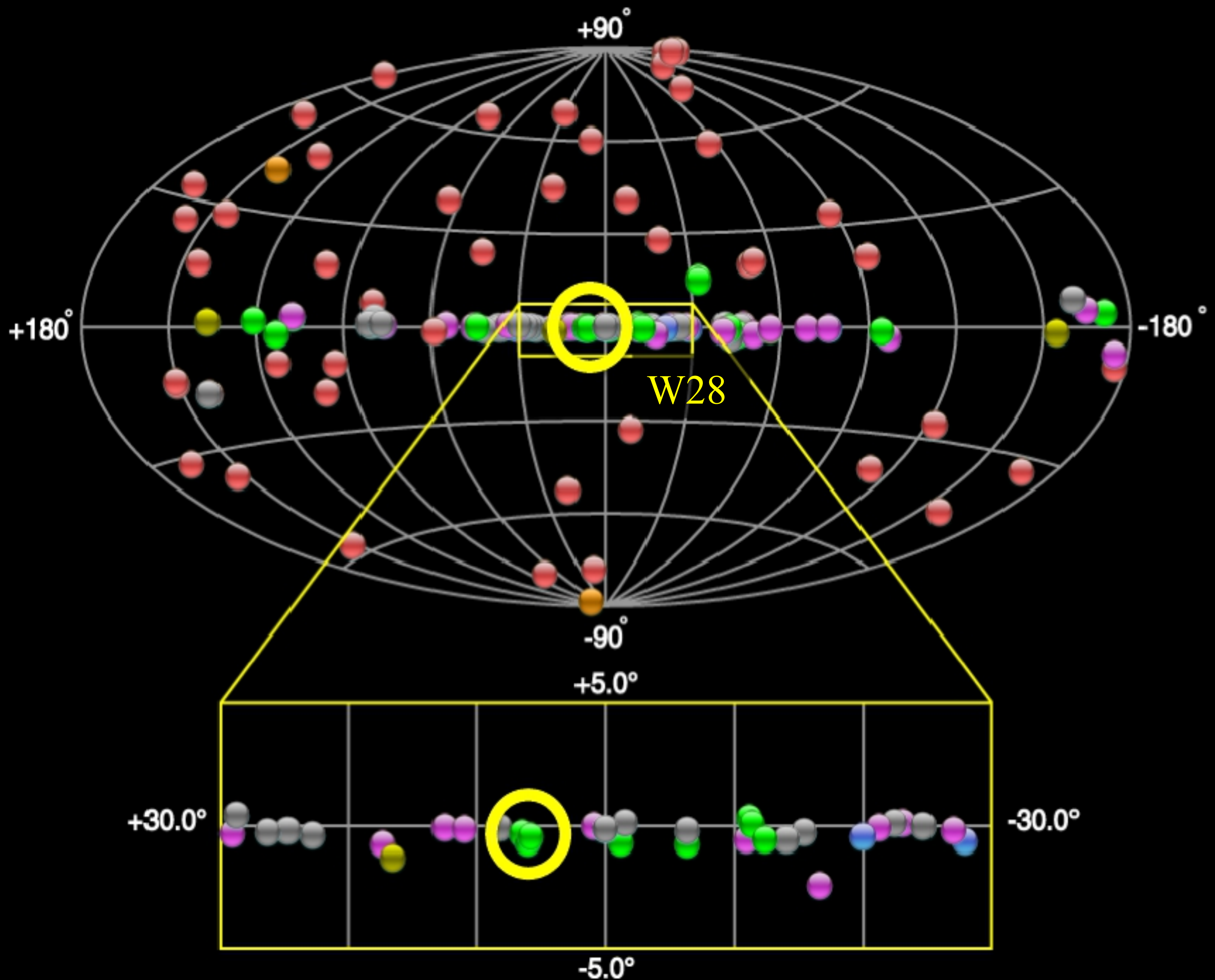


Fermi-LAT Collab.
arXiv:1103.5727



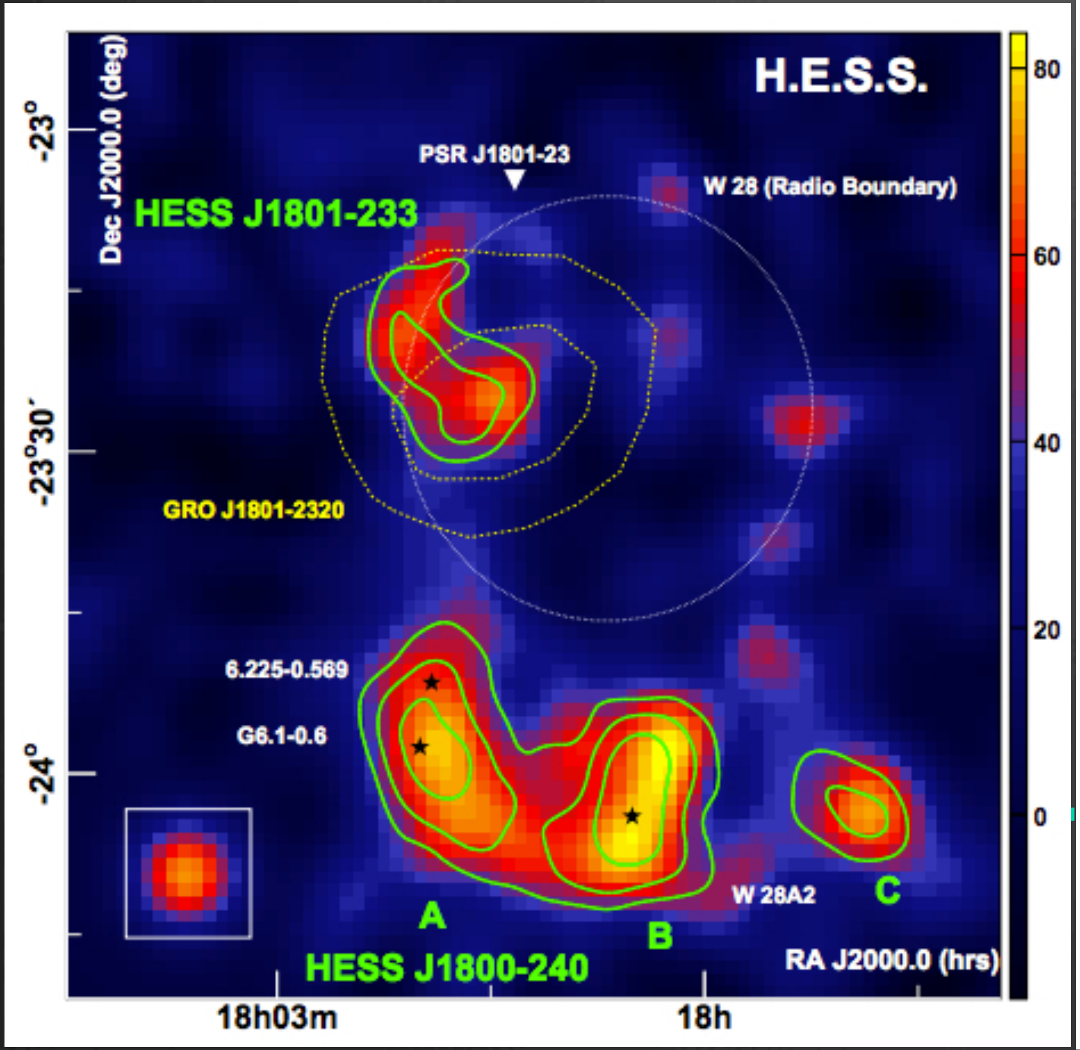
No protons accelerated?
Lack of target gas for protons?
Spectrum modified by diffusion effects?

Cosmic-ray release

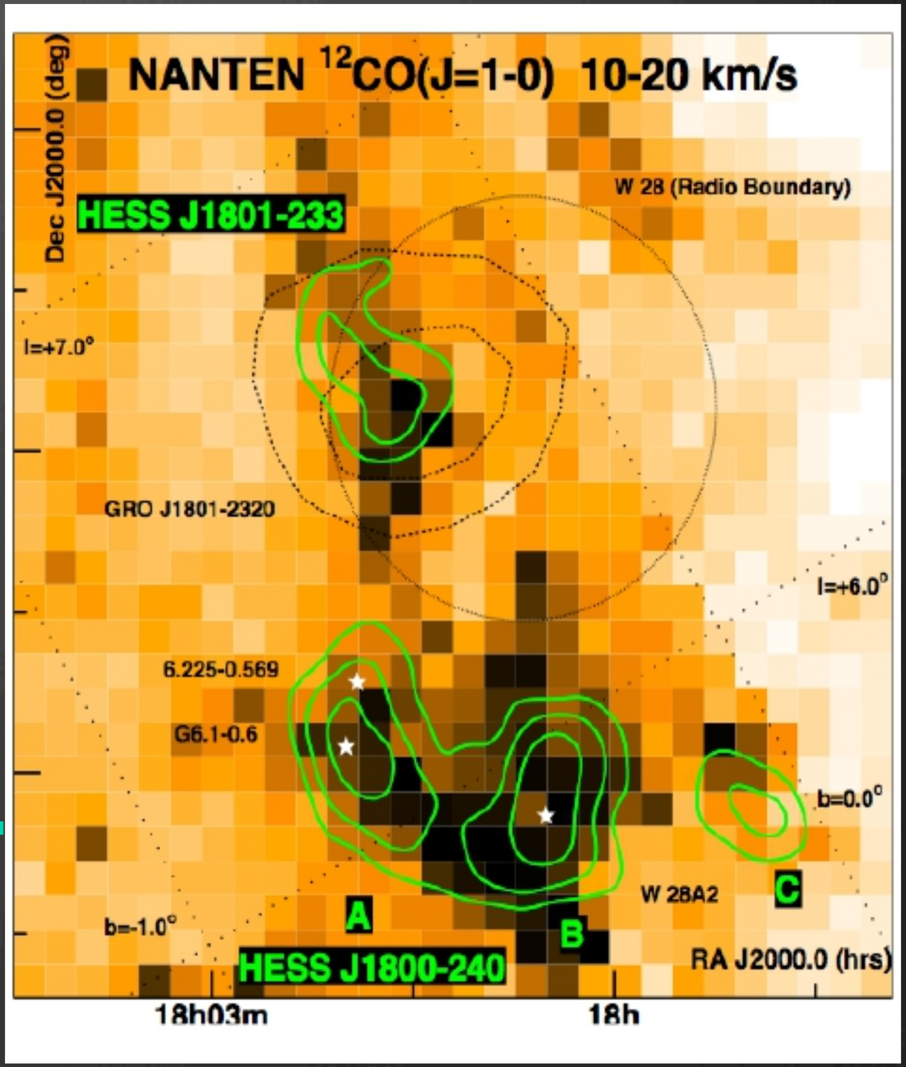


SNR W28

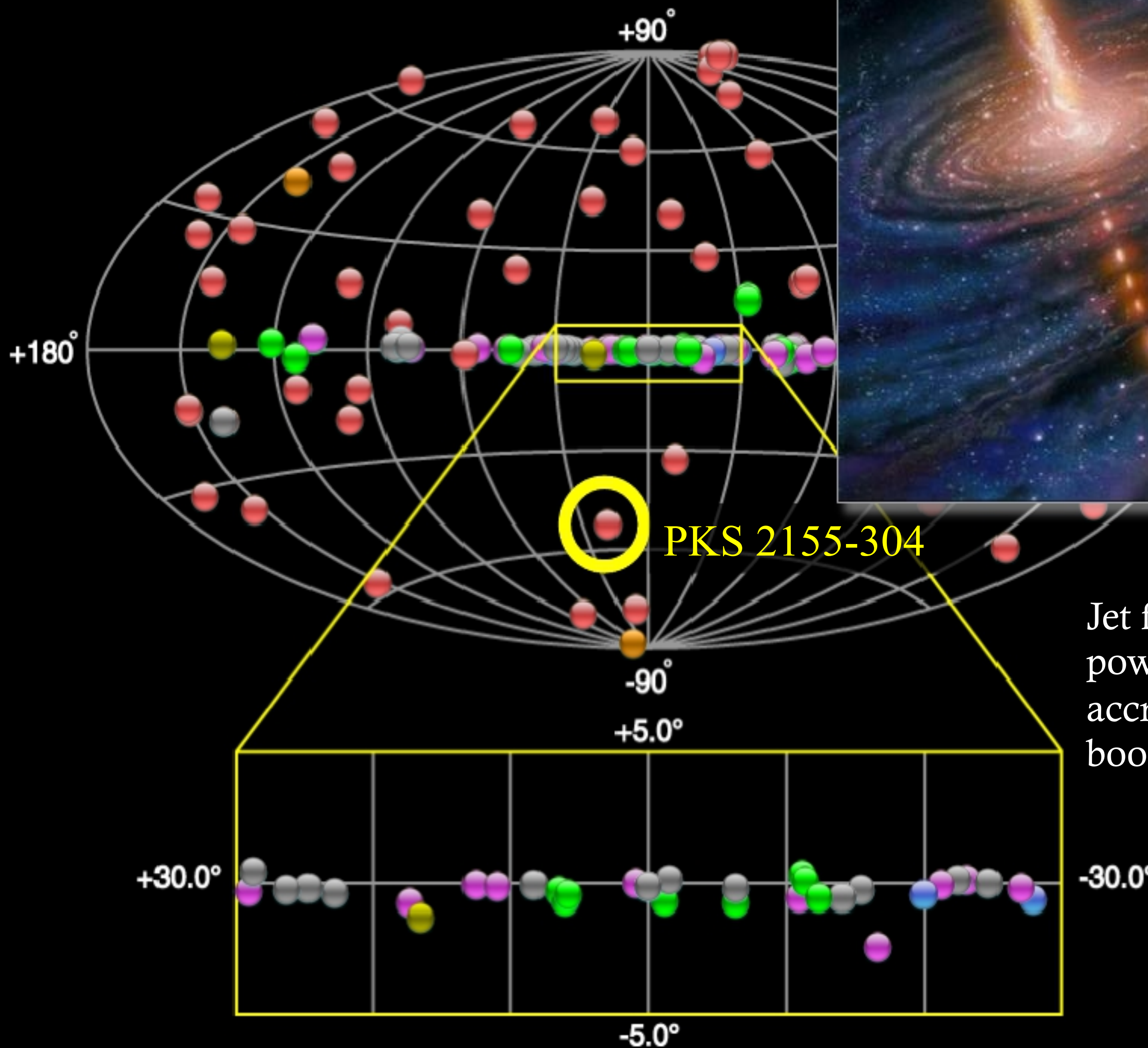
VHE gamma rays



Molecular clouds

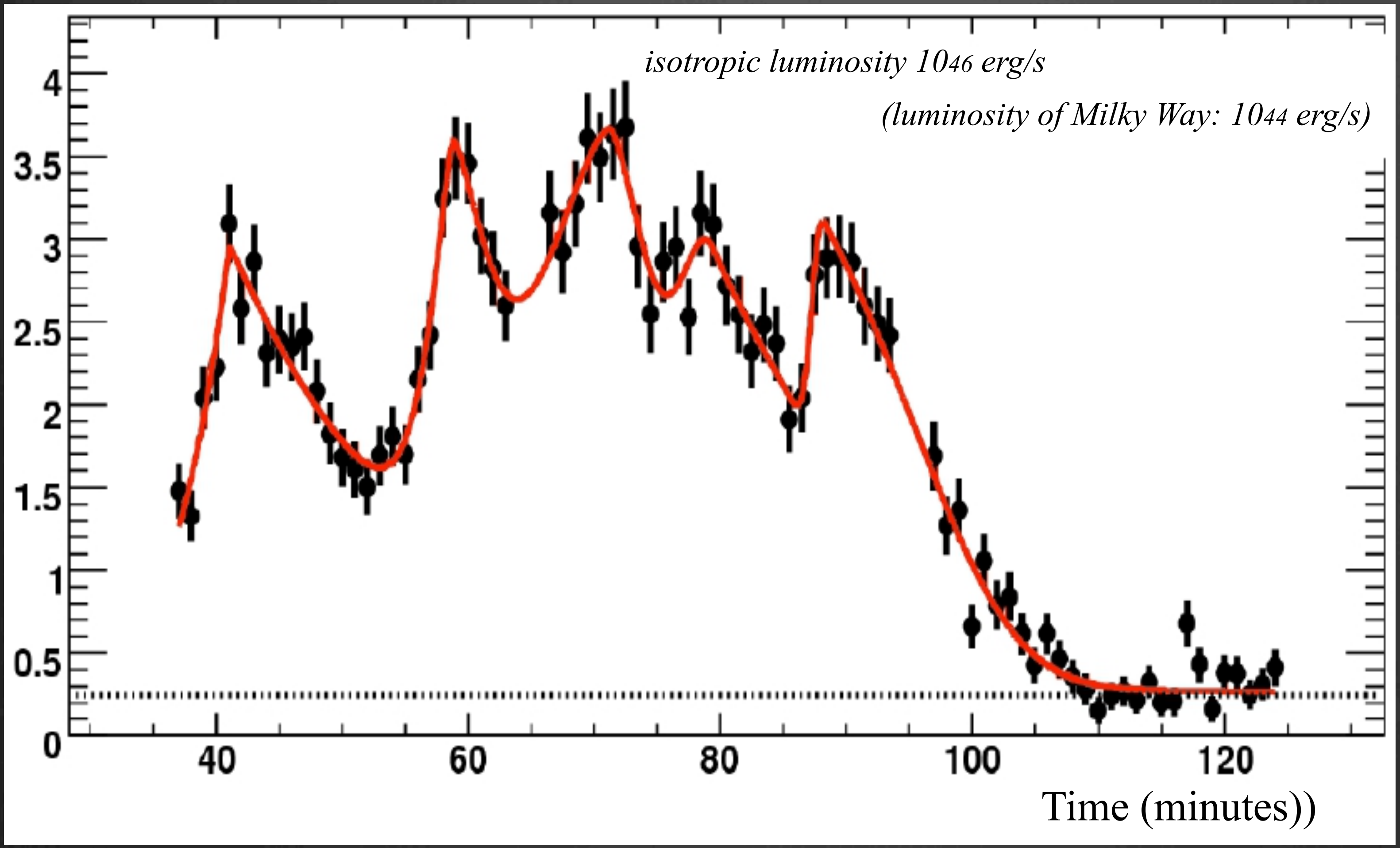


Active galactic nuclei



Jet formation powered by SMBH accretion, Doppler-boosted.

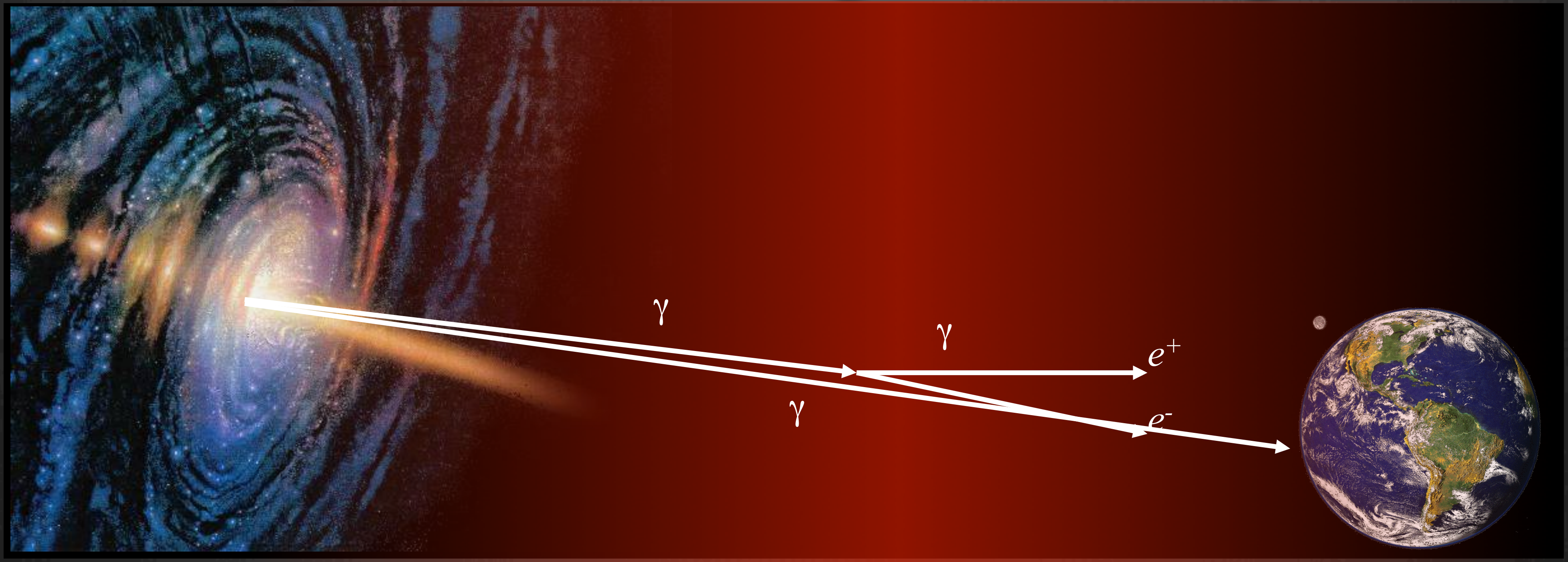
One of the most violent blazars: PKS 2155-304



TeV Flux

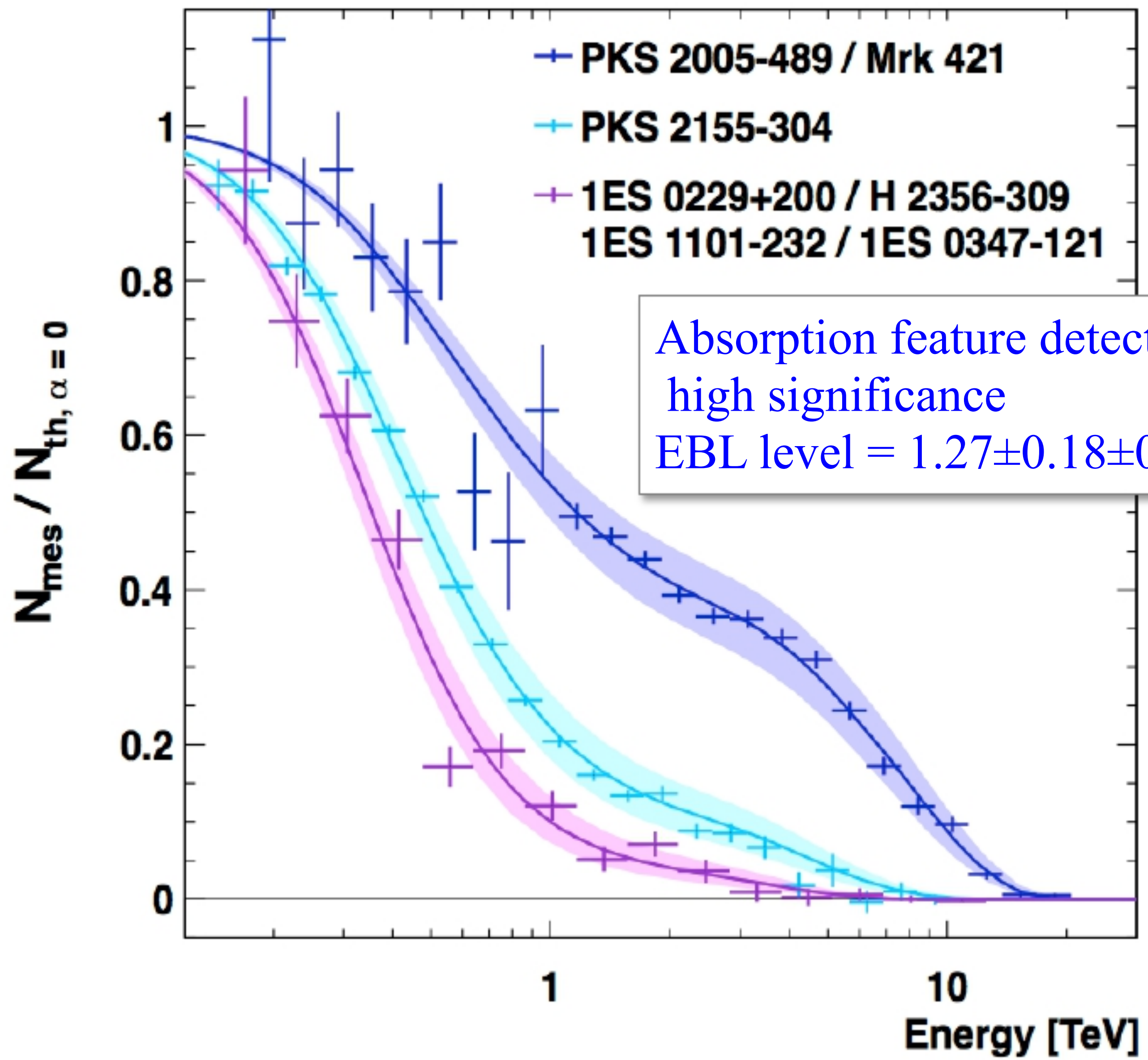
SMBH mass overestimated (to accommodate the high δ)
or variability not only related to BH.

Extra-galactic Background Light



EBL attenuation to leave unique redshift dependent and energy dependent imprint :
E>5-10 Tev sharp cut-off (CIB *UV re-emitted on the IR domain* related)
100 Gev < E < 5-10 Gev weaker modulation (COB *Optical emission due to nucleosynthesis*)

EBL absorption



Absorption feature detected at high significance
EBL level = 1.27±0.18±0.25 x model

H.E.S.S. arXiv:1212.3409

see also: Fermi Science (2012)

LIV searches

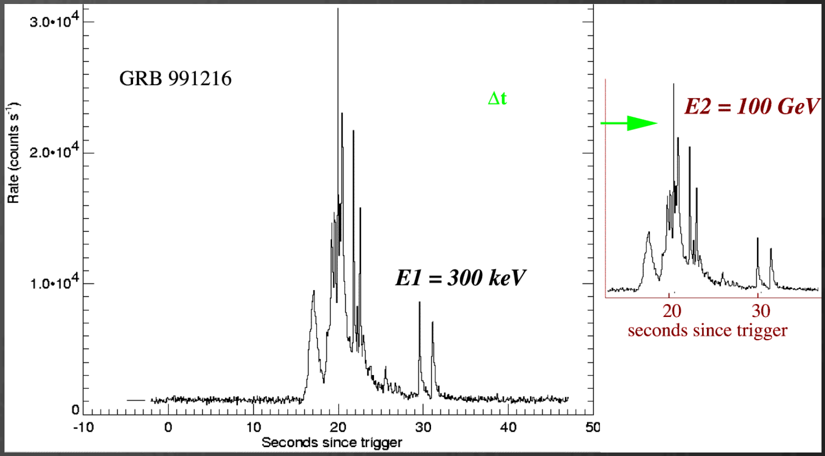
Fast transient phenomena providing a "time stamp" for the"simultaneous" emission of different energy γ –rays.

Good source candidates are:

- Very distant Blazars showing fast flares
- Gamma-Ray-Bursts (GBR)

Use pulse-shape of giant AGN flare, to search for energy-dependent velocity of gamma-ray photons.

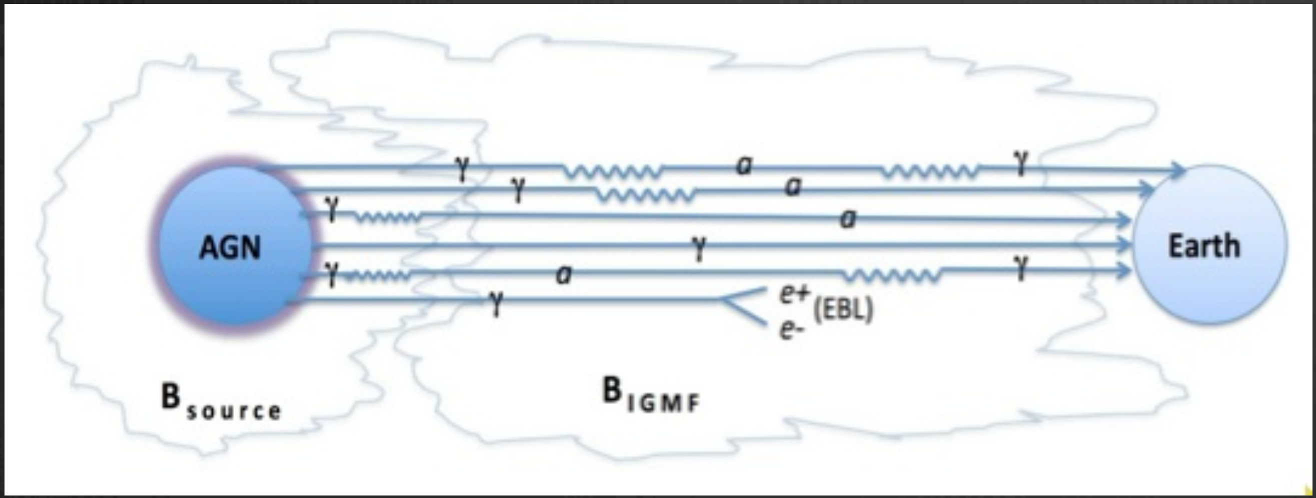
Ideal candidate: PKS 2155, 2006.

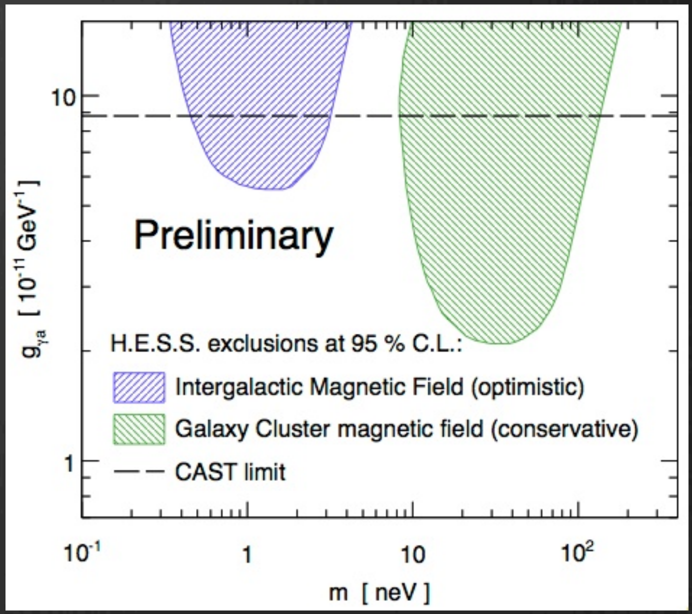


No hint for Lorentz invariance violation found. 95% CL upper limits (photon dispersion relatio):

$$M^{l}_{QG} > 2.1\ 10^{18}\ \mathrm{GeV} \quad M^{q}_{QG} > 0.5\ 10^{11}\ \mathrm{GeV}$$

Axion searches





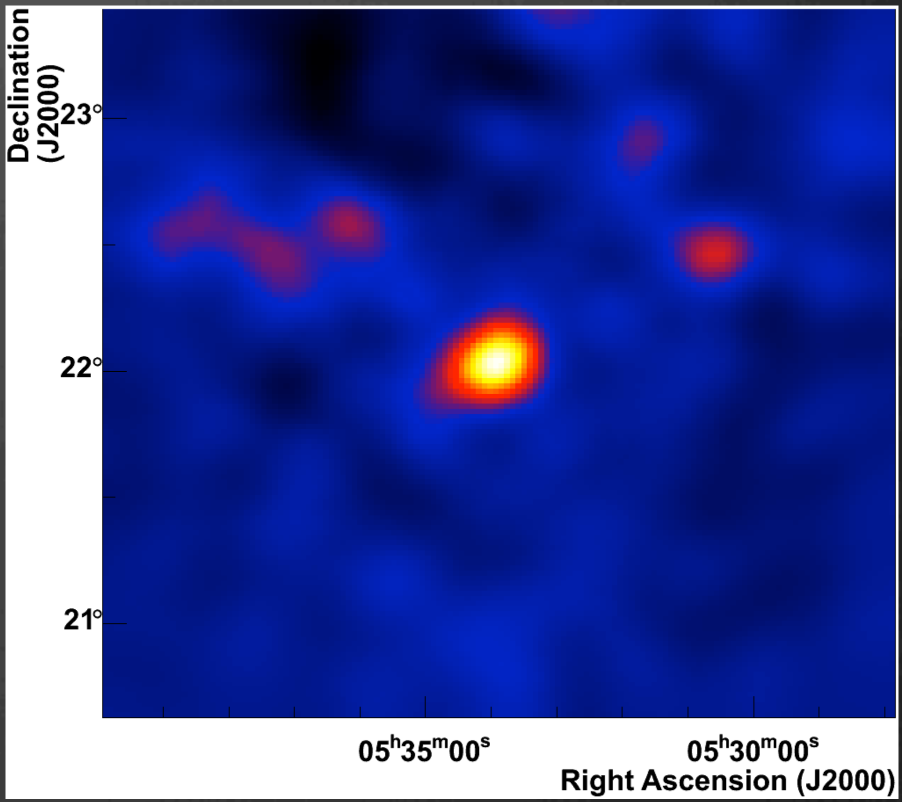
The future: H.E.S.S. II

- Dish
  - Total mirror area 614 m^2
  - Focal length 36 m
- Camera
  - 2048 PMTs
  - Field of 3.2°

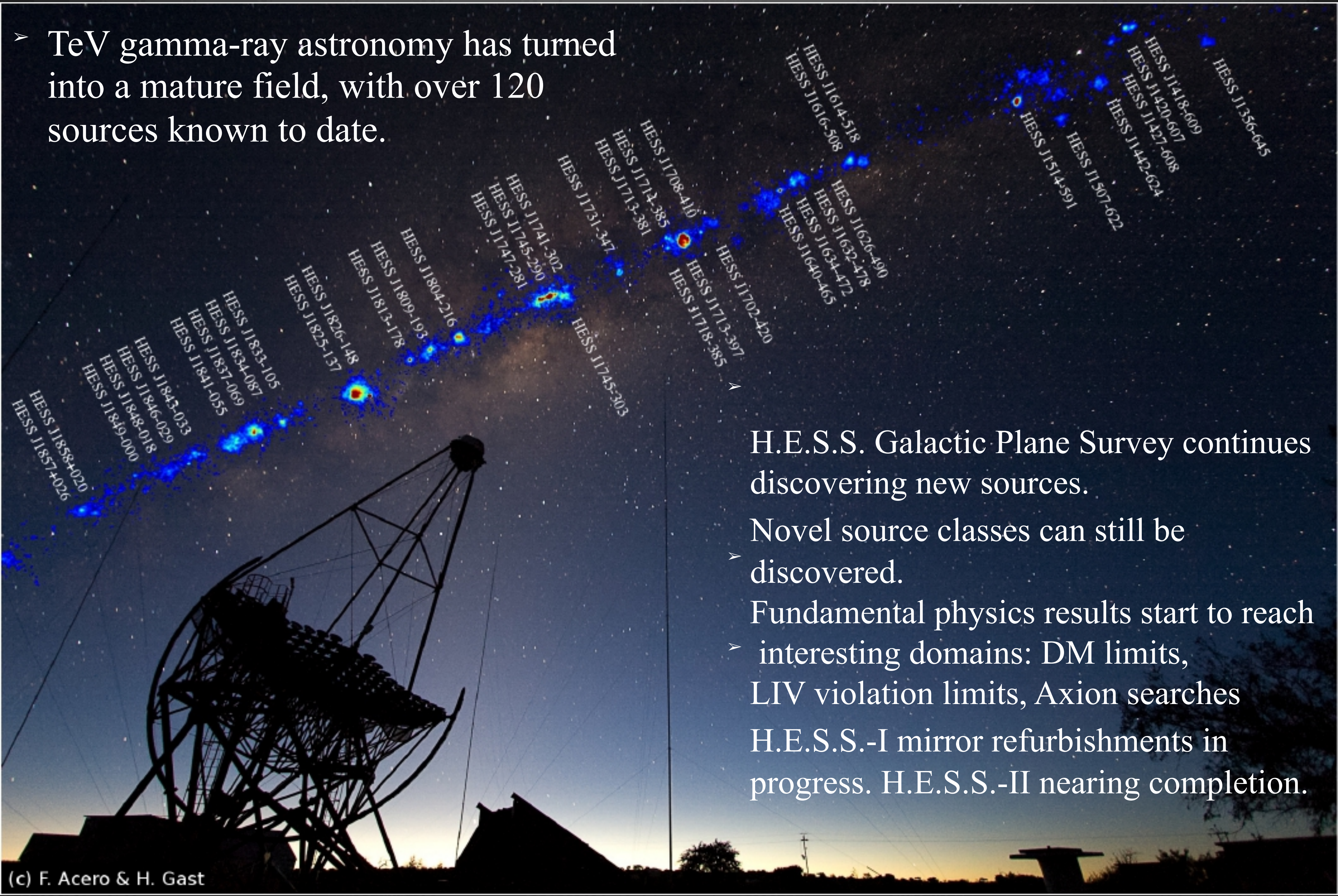
The Crab seen with H.E.S.S. II

- Analyzed first data from the Crab Nebula taken with the new H.E.S.S. telescope
  - Zenith angle: 46°
- Excess map with E > 50 GeV
- Previously: H.E.S.S. I measurements above 400 GeV (Aharonian et al. 2006)

preliminary



Summary



- TeV gamma-ray astronomy has turned into a mature field, with over 120 sources known to date.

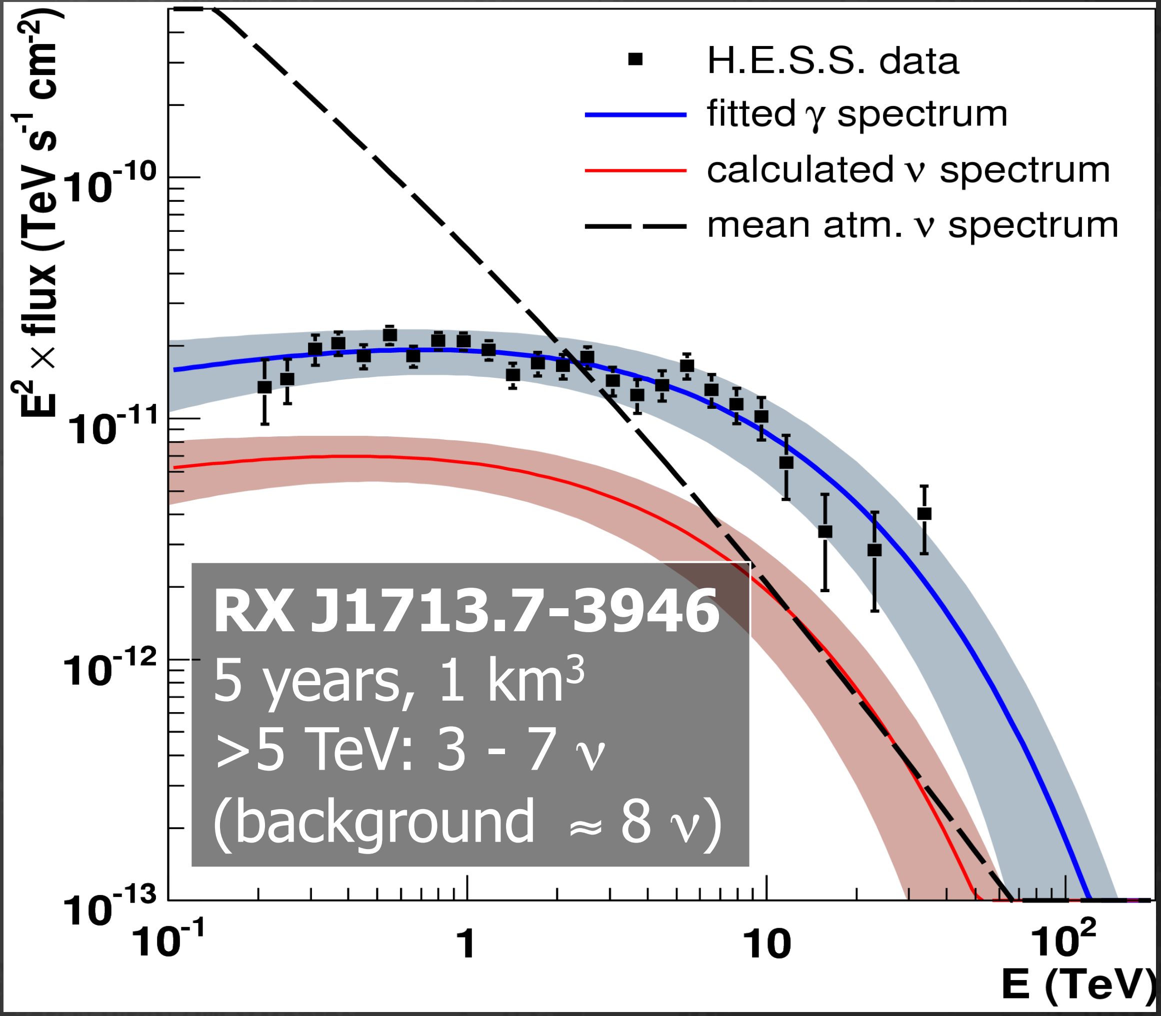
- H.E.S.S. Galactic Plane Survey continues discovering new sources.
- Novel source classes can still be discovered.
- Fundamental physics results start to reach interesting domains: DM limits, LIV violation limits, Axion searches
- H.E.S.S.-I mirror refurbishments in progress. H.E.S.S.-II nearing completion.

Implications for TeV neutrinos

- For systems with p - p γ-ray production (and no γ absorption) can predict neutrino fluxes:

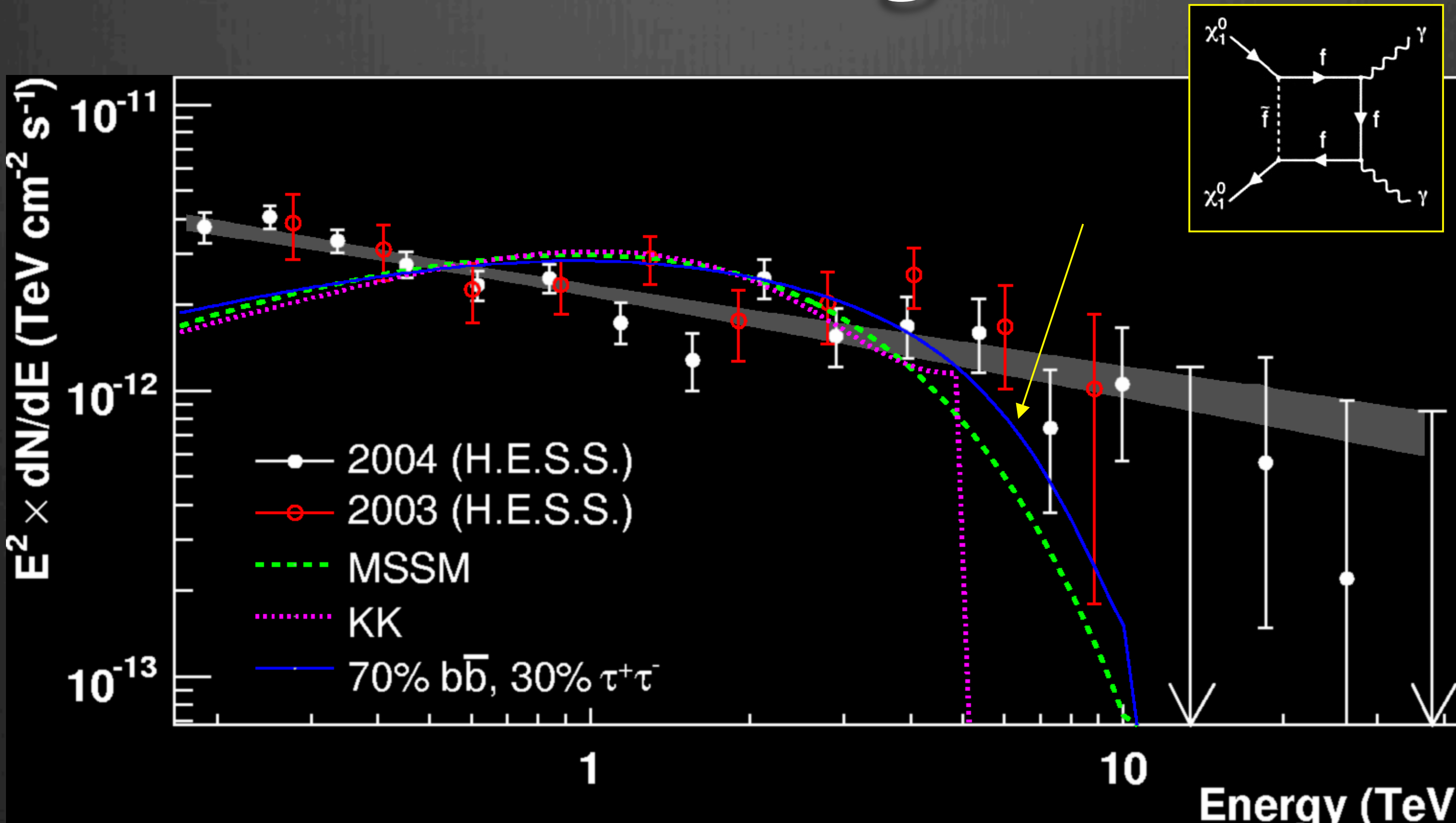
$$p + p \rightarrow \pi^0 + X$$
$$\hookrightarrow \gamma\ \gamma$$
$$\rightarrow \pi^{\S} + X$$
$$\hookrightarrow \mu + \nu_\mu$$
$$\hookrightarrow e + \nu_e + \nu_\mu$$

- Brightest γ-ray sources are very marginal for km³ scale neutrino detectors…



Kappes, Hinton, Stegmann, Aharonian 2007

Dark Matter : Sagittarius A



HESS
PRL
(2006)

- **Power-law spectrum – looks like accelerated particles not Dark Matter annihilation**
- **Astrophysical accelerator – but which one?**