cta
cherenkov telescope array

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On behalf of the CTA Collaboration

Texas Symposium
São Paulo, Brazil, 2012

(c) F. Acero & H. Gast

Thanks to W. Hoffmann, B. Rudak, E.Moulin

cta

cherenkov telescope array

- CTA concept
- CTA performance
- CTA science
- Who, where, when

(c) F. Acero & H. Gast

CTA project aims the construction of the next generation ground-based gamma-ray observatory

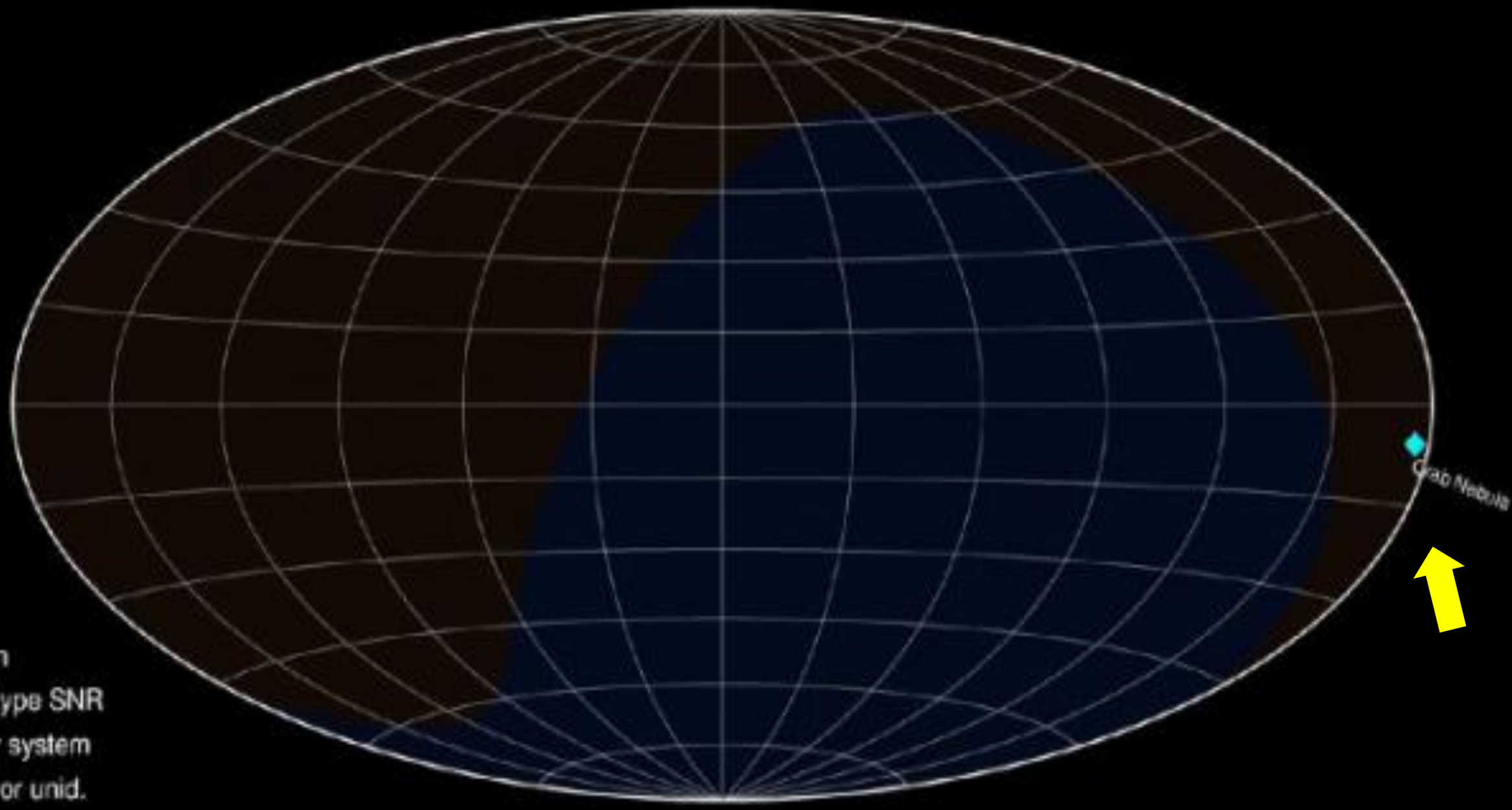
THE CTA CONCEPT

20 years ago

The High-Energy Gamma Ray Sky (1989)

E > 100 GeV

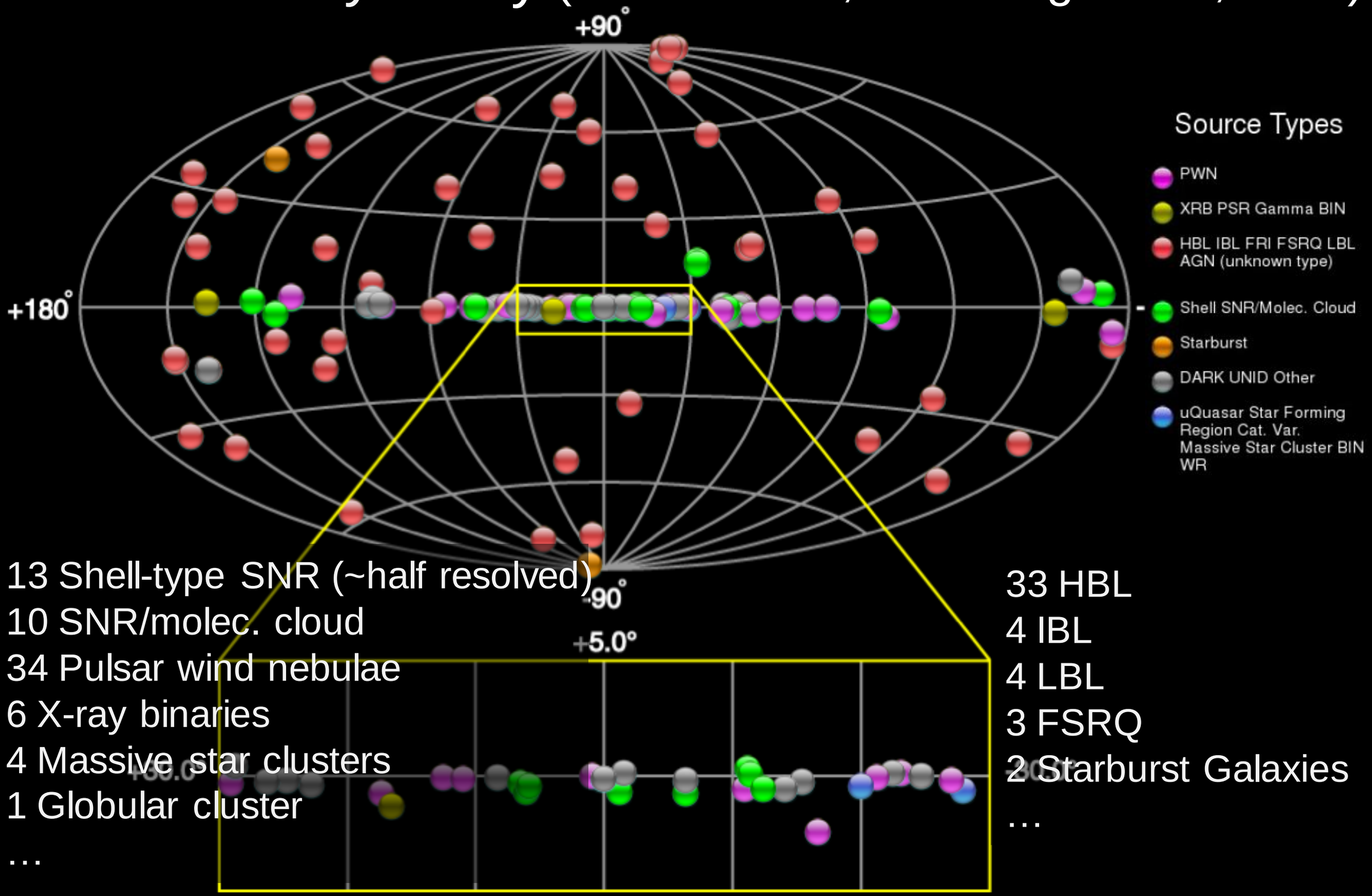
(Galactic coordinates)



Background colours indicating northern / southern sky

http://tevcat.uchicago.edu/

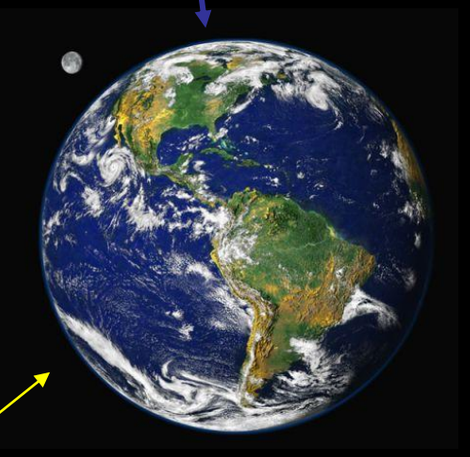
The TeV sky today (143 sources, 48 extragalactic, 2011)



13 Shell-type SNR (~half resolved)
10 SNR/molec. cloud
34 Pulsar wind nebulae
6 X-ray binaries
4 Massive star clusters
1 Globular cluster
…

33 HBL
4 IBL
4 LBL
3 FSRQ
2 Starburst Galaxies
…

Imaging Cosmic Particle Accelerators



Spectra
and flux reflect
those of acc. particles

p + nucleus → π +X

$\pi^{o} \rightarrow \gamma\gamma$

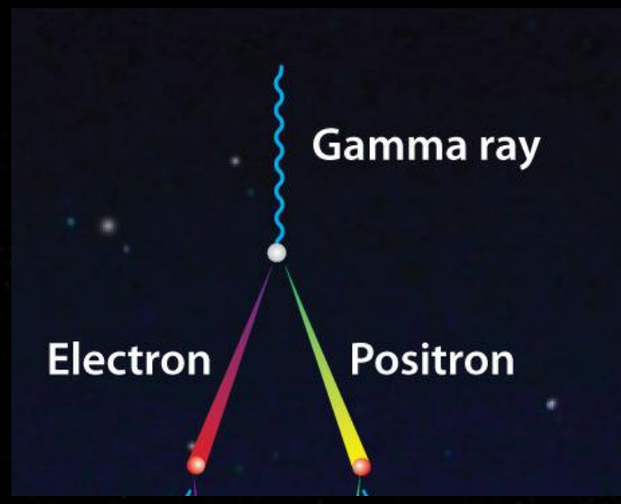
$\pi^{\pm} \rightarrow \mu^{\pm} \nu$

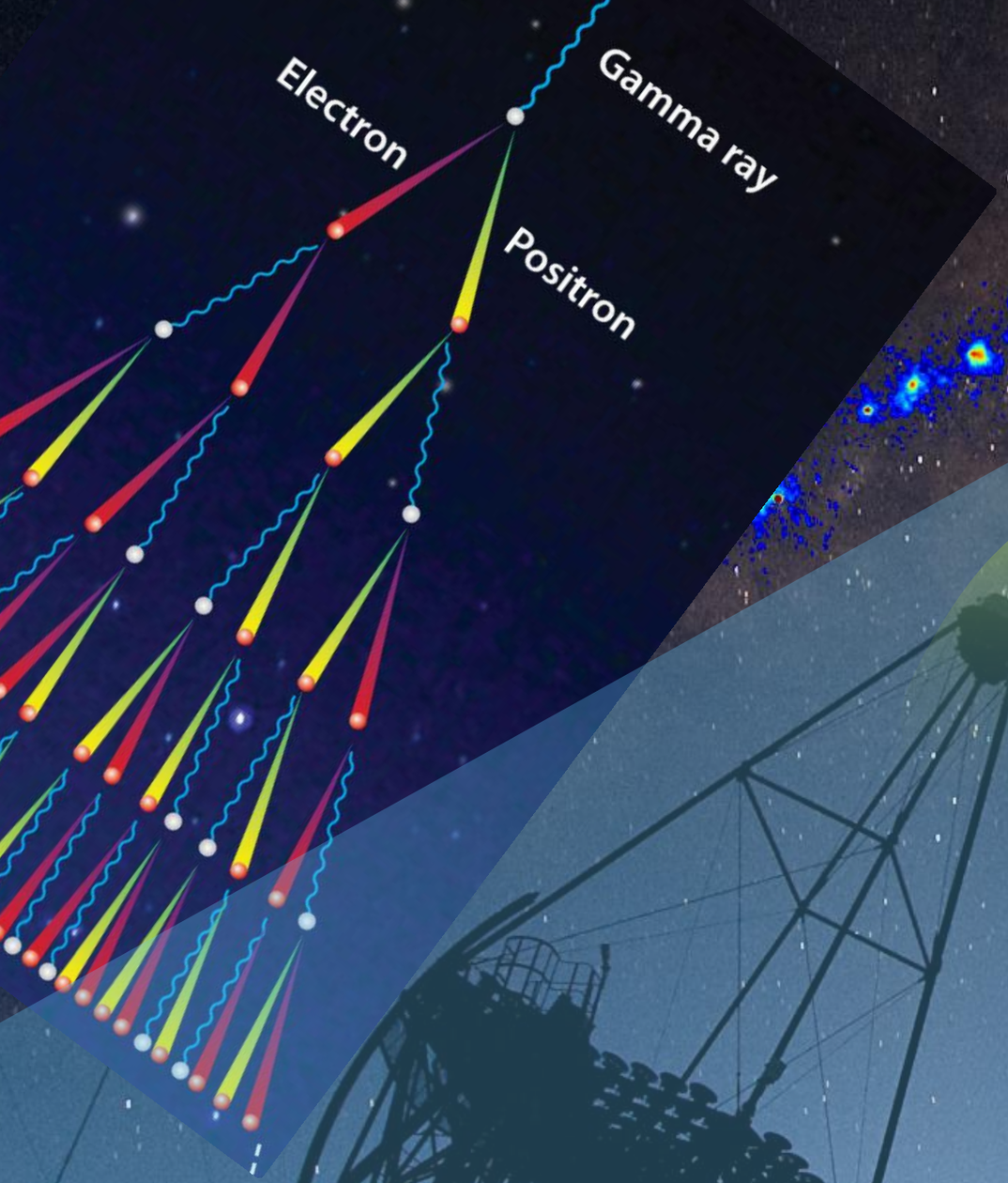
Fermi Large Area Telescope

Anticoincidence shield
to reject cosmic rays

Silicon strip detector tracker
➜ photon direction

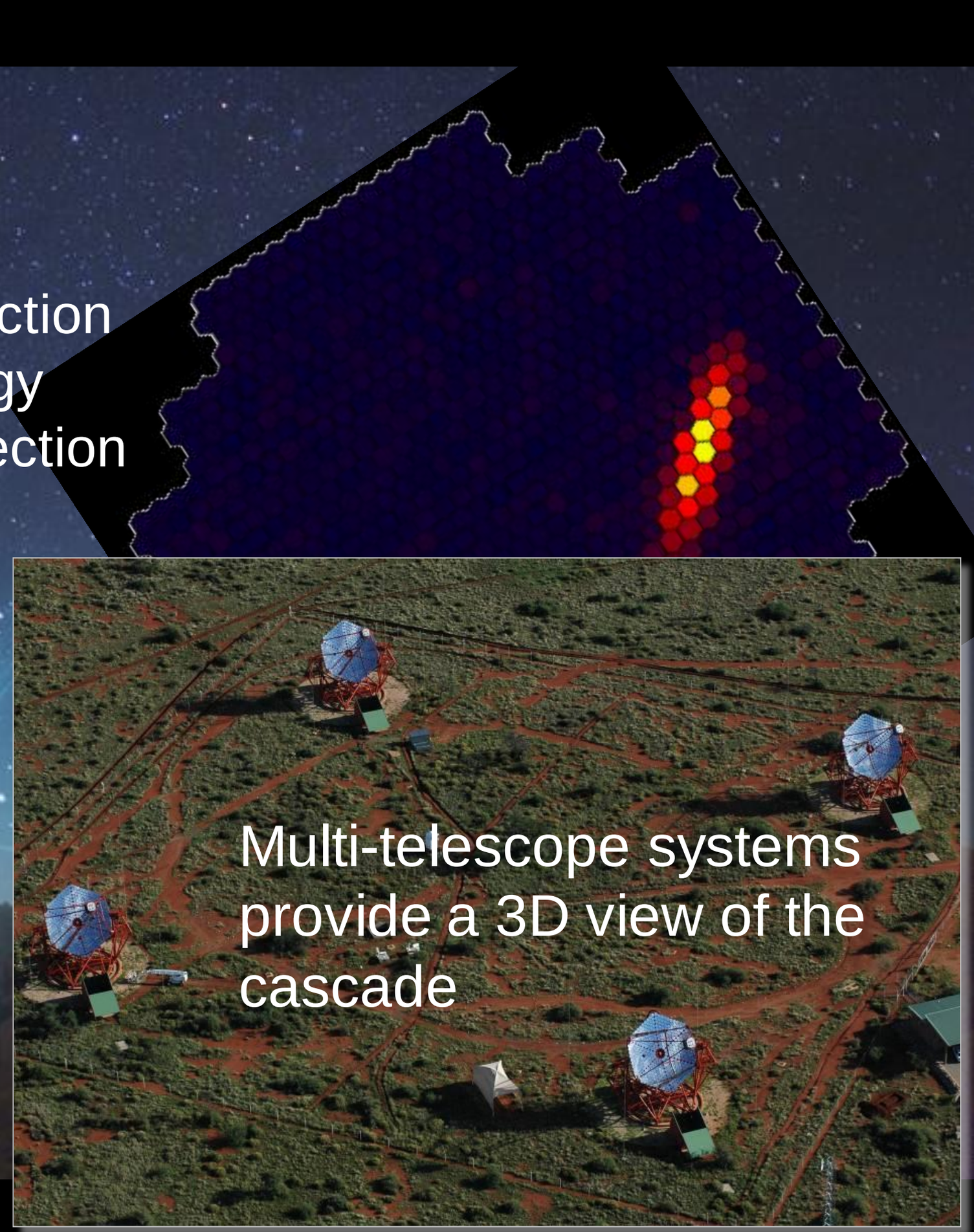
Calorimeter
➜ photon energy





Cherenkov Telescopes

Clue:
imaging the cascade
geometry ➜ photon direction
intensity ➜ photon energy
shape ➜ cosmic ray rejection



Multi-telescope systems provide a 3D view of the cascade

Current IACTs

Adapted from J. Hinton

What one would love to have:

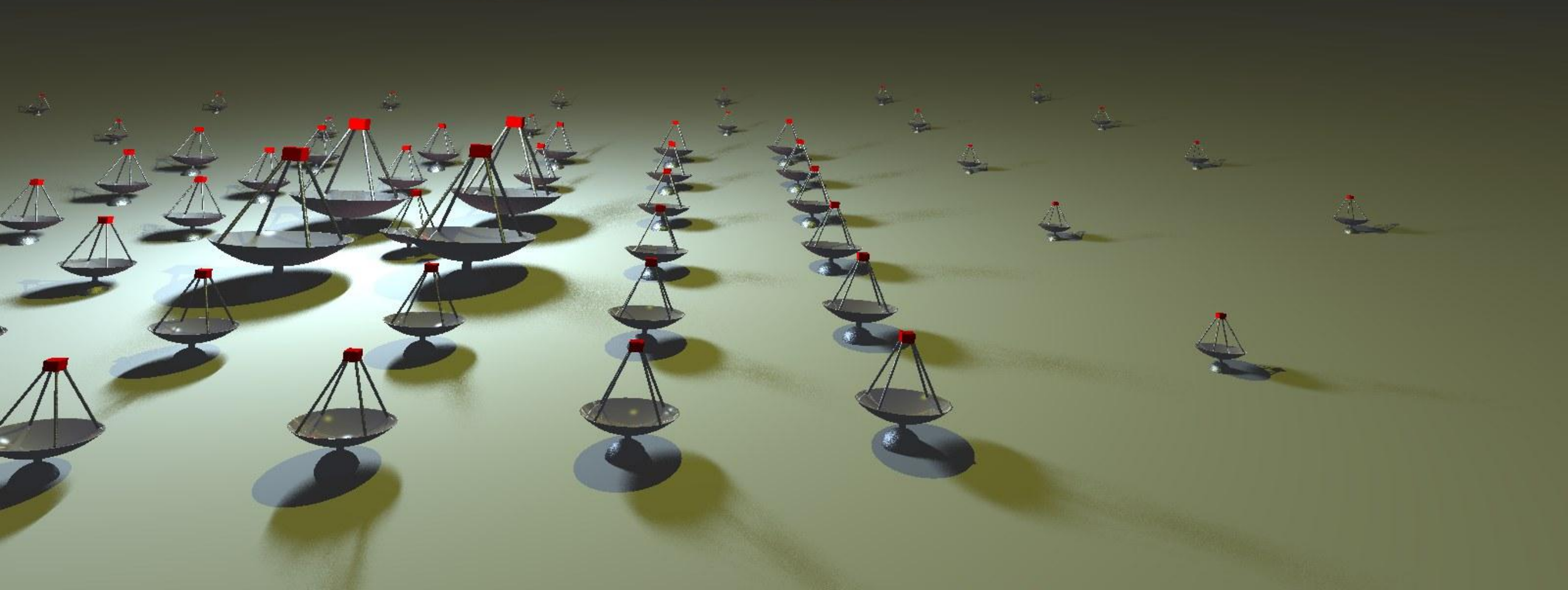
Performance only limited by fluctuations in shower development

➜ *0.005° angular resolution @ 1TeV*

What one can (hopefully) afford:

Key design goals:

- 10-fold increased sensitivity at TeV energies
- 10-fold increased effective energy coverage
- Larger field of view for surveys
- Improved angular resolution
- Full sky coverage: and array in each hemisphere



(one) possible configuration

Southern 100 M€ Array (2006 costs)

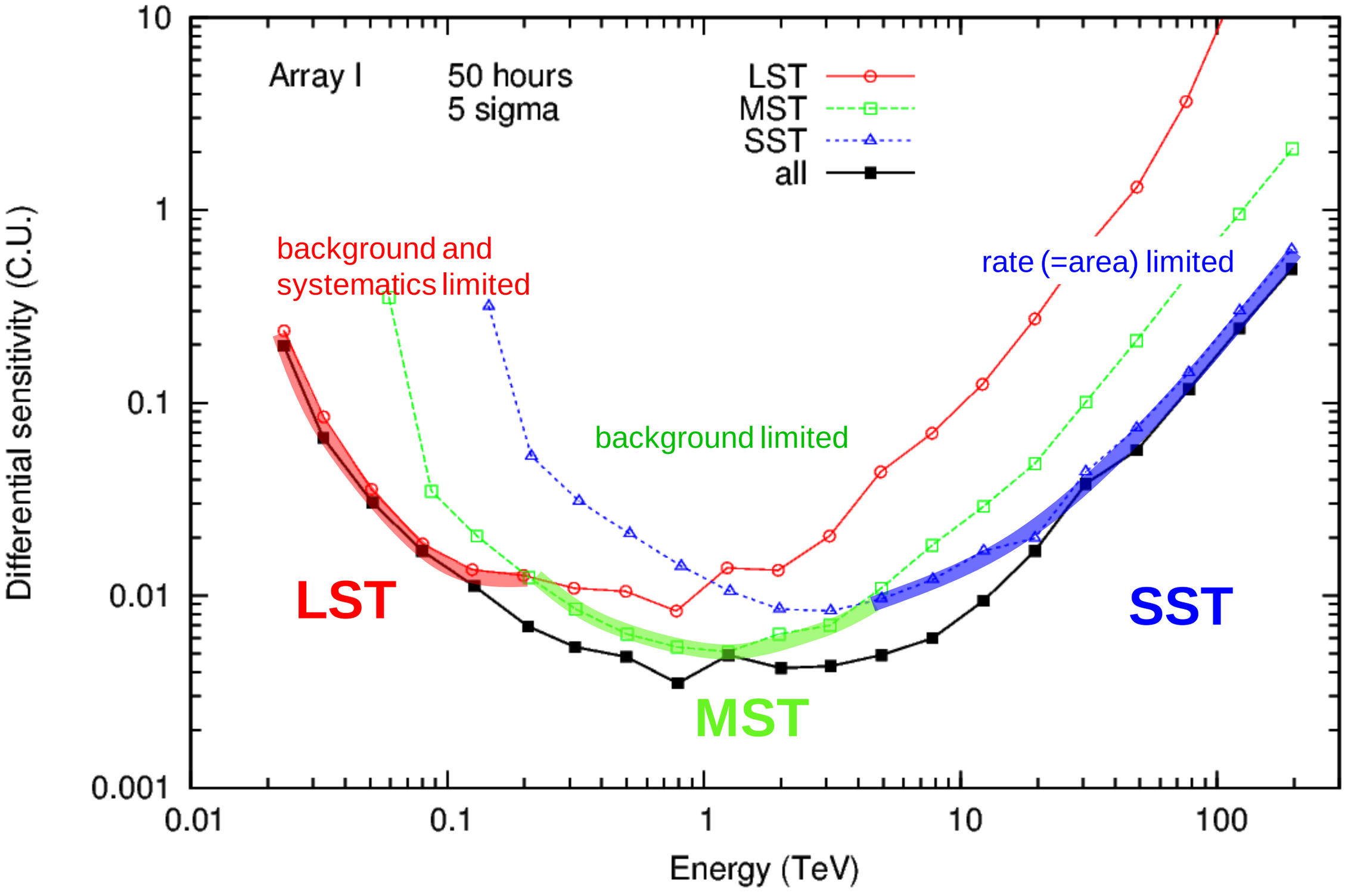
Low-energy section:
4 x 23 m tel. (LST)
- Parabolic reflector
- FOV: 4-5 degrees
energy threshold
of some 10 GeV

Core-energy array:
23 x 12 m tel. (MST)
Davies-Cotton reflector
- FOV: 7-8 degrees
mCrab sensitivity
in the 100 GeV–10 TeV
domain

High-energy section:
32 x 5-6 m tel. (SST)
Davies-Cotton reflector
(or Schwarzschild-Couder)
- FOV: ~10 degrees
10 km^2 area at
multi-TeV energies

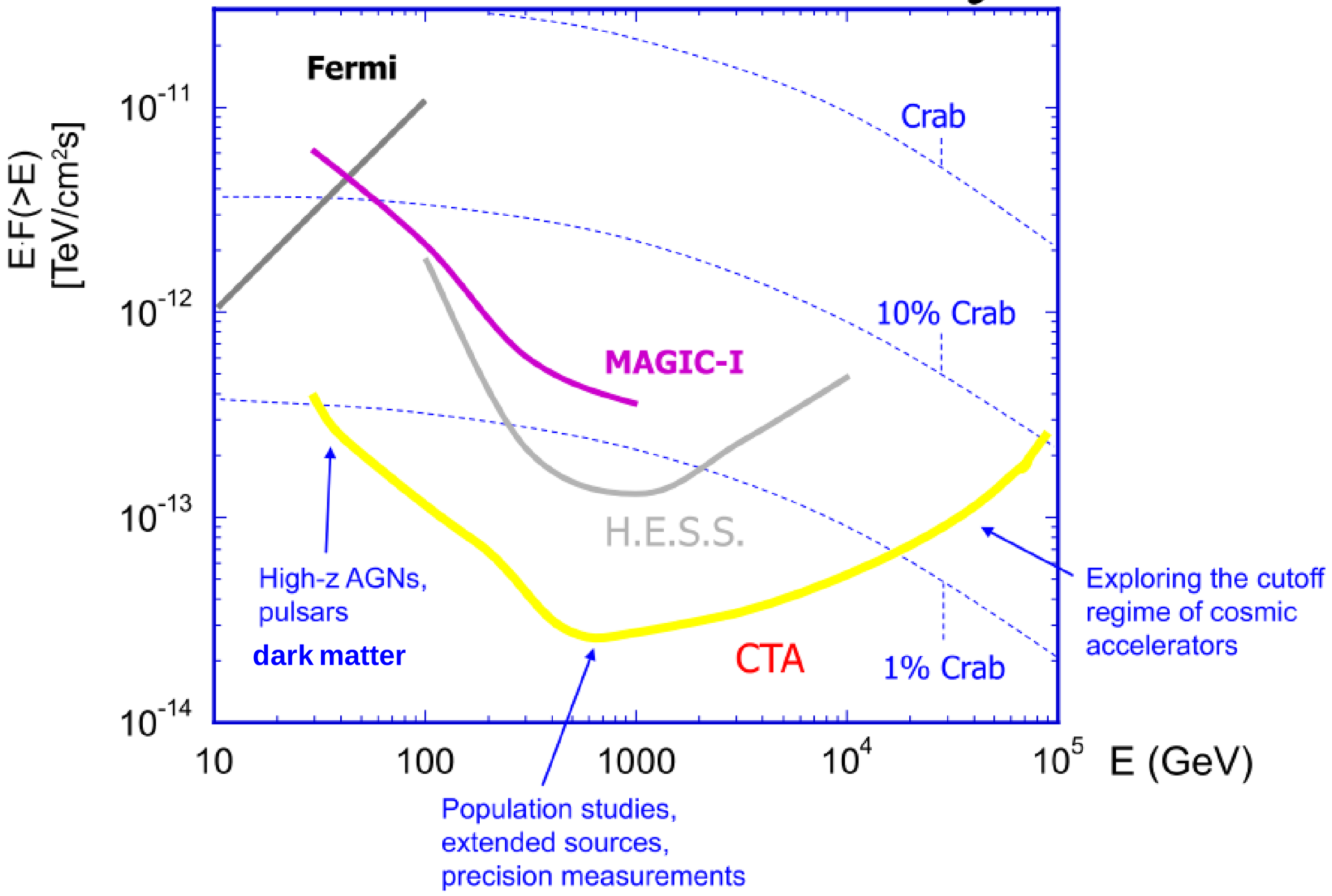
Sensitivity (in units of Crab flux)

for detection in each 0.2-decade energy band



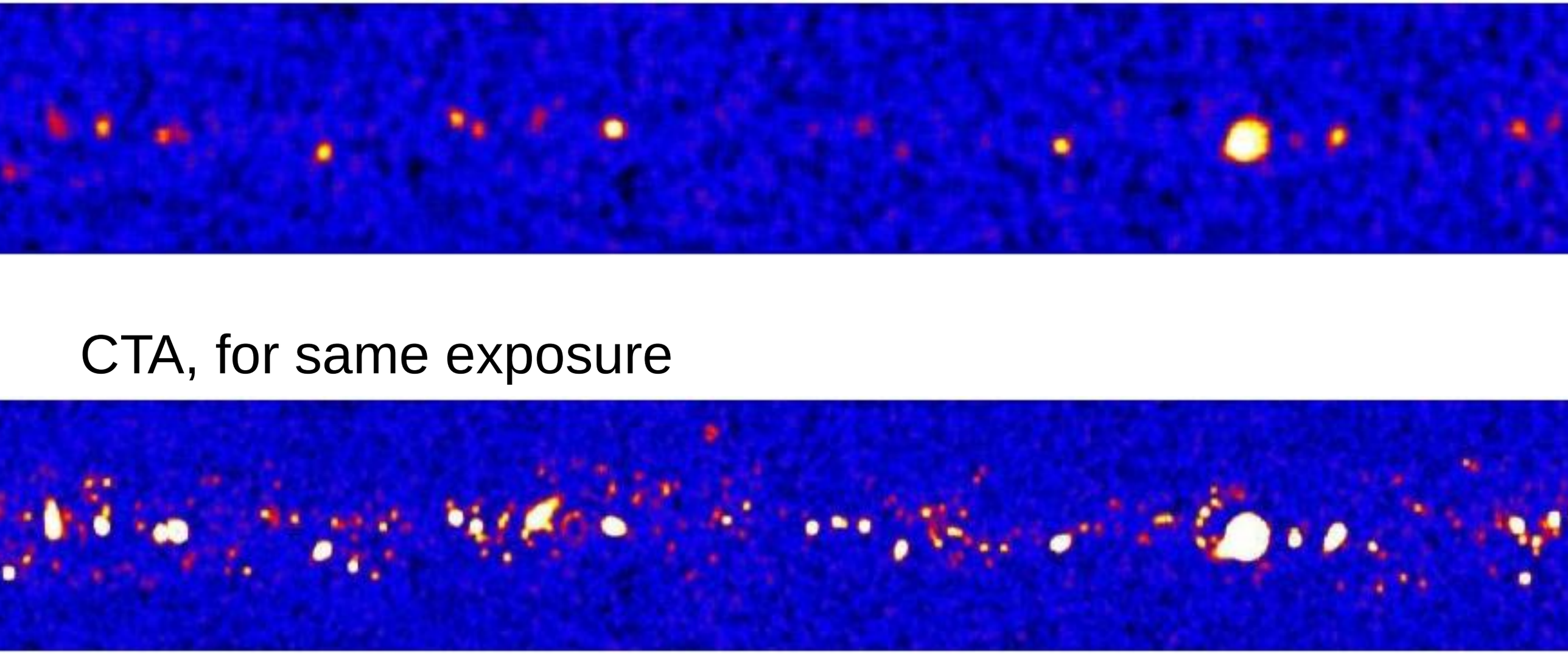
CTA PERFORMANCE

Goal CTA sensitivity



Example: Galactic Plane Survey

H.E.S.S.

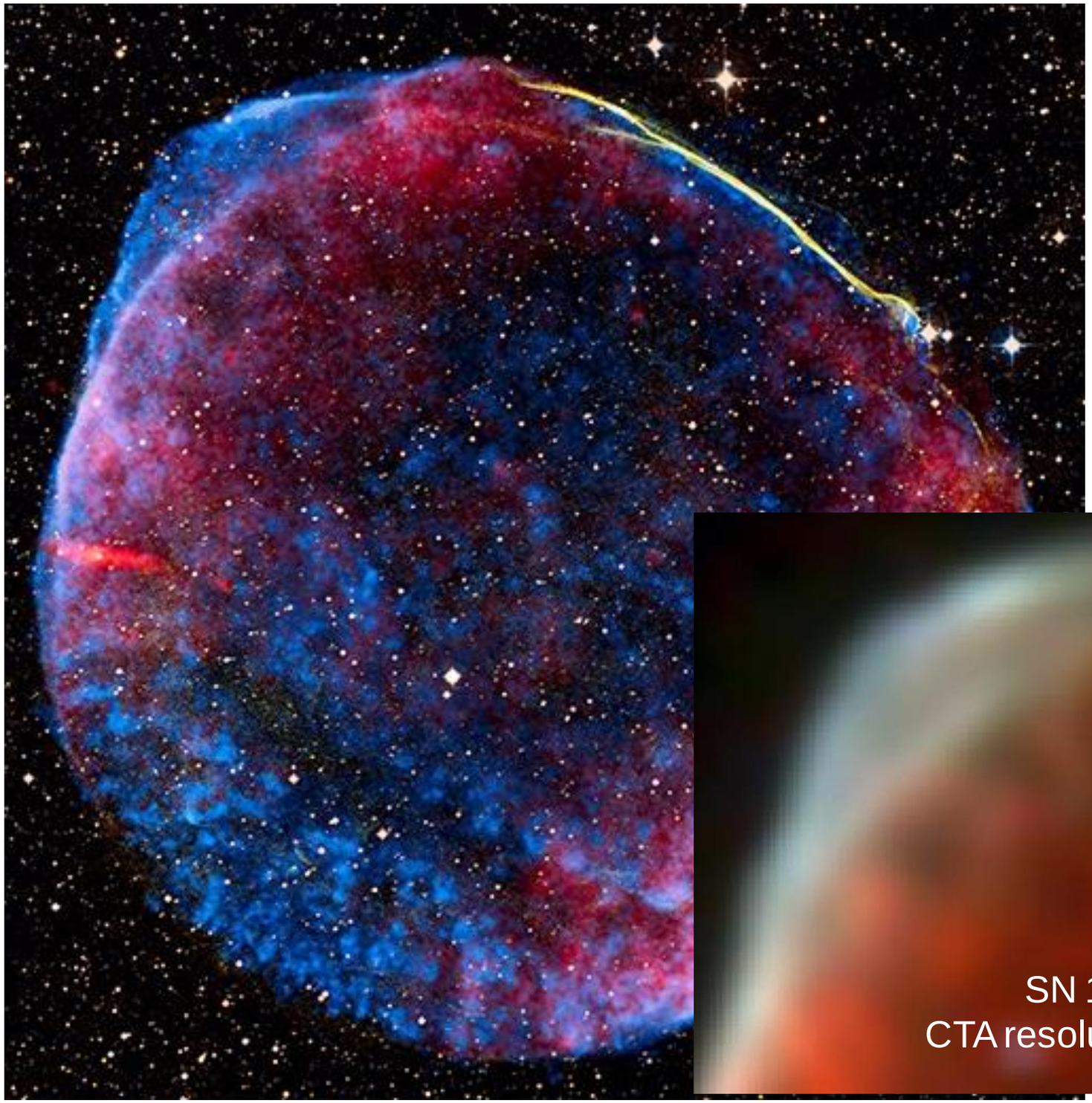


CTA, for same exposure

expect ~1000 detected sources

Resolving complex sources

SN 1006



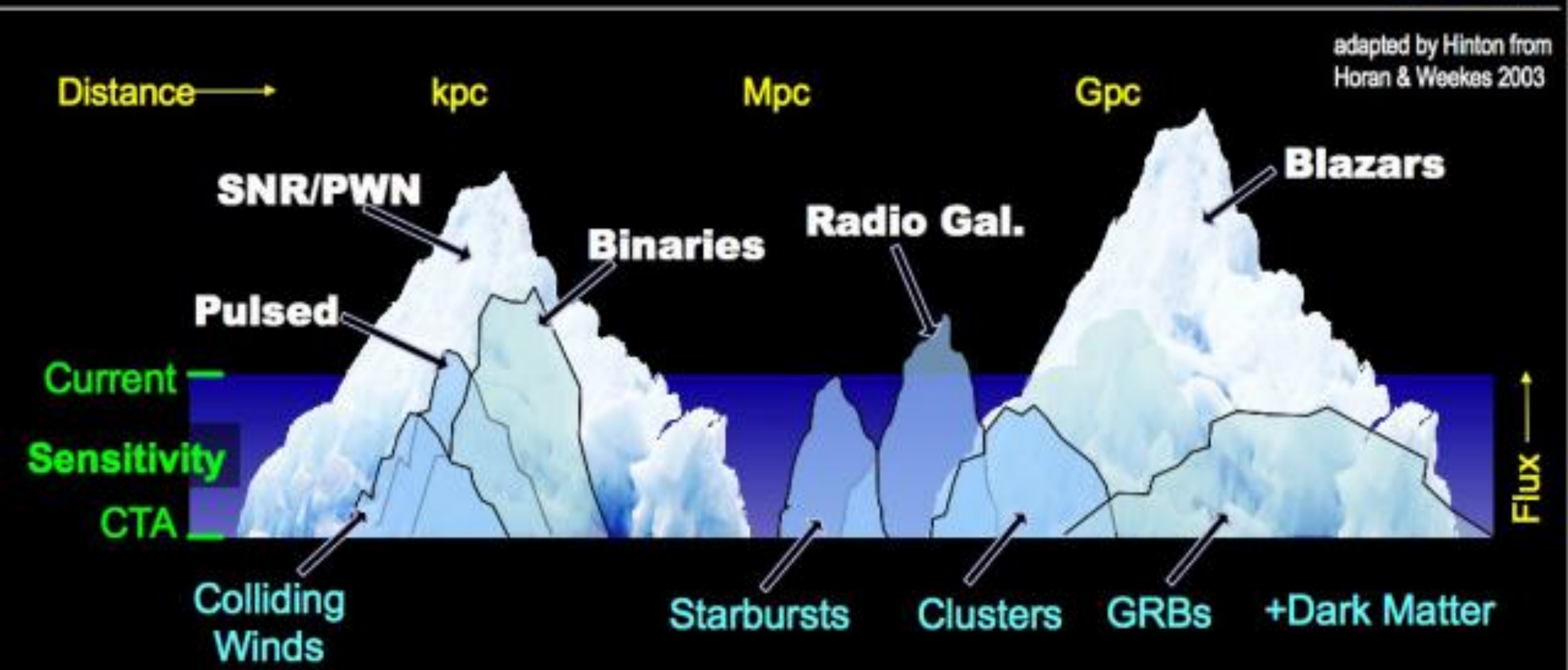
Maybe 1-2 dozen “young” SN in our Galaxy

ϕ_{snr} ~ 0.5 CU/d^2, d in kpc
with mCrab sensitivity,
visible to ~20 kpc
(all across the Galaxy)

CTA science impact

- **Cosmic rays: origin and they impact in the Universe**:
  - Particle accelerators: PSRs, PWN, SNRs and γ-ray binaries.
  - Effects on the environment: from massive SFR to starburst galaxies.
- **Nature of black hole particle accelerators**:
  - AGN, blazars and radio galaxies.
  - EBL, galaxy clusters, GRBs.
- **Dark matter search and physics beyond the standard model**:
  - Dark matter and their annihilation signatures
  - Lorentz invariance tests
  - New observational signatures that might change our understanding of the Universe.

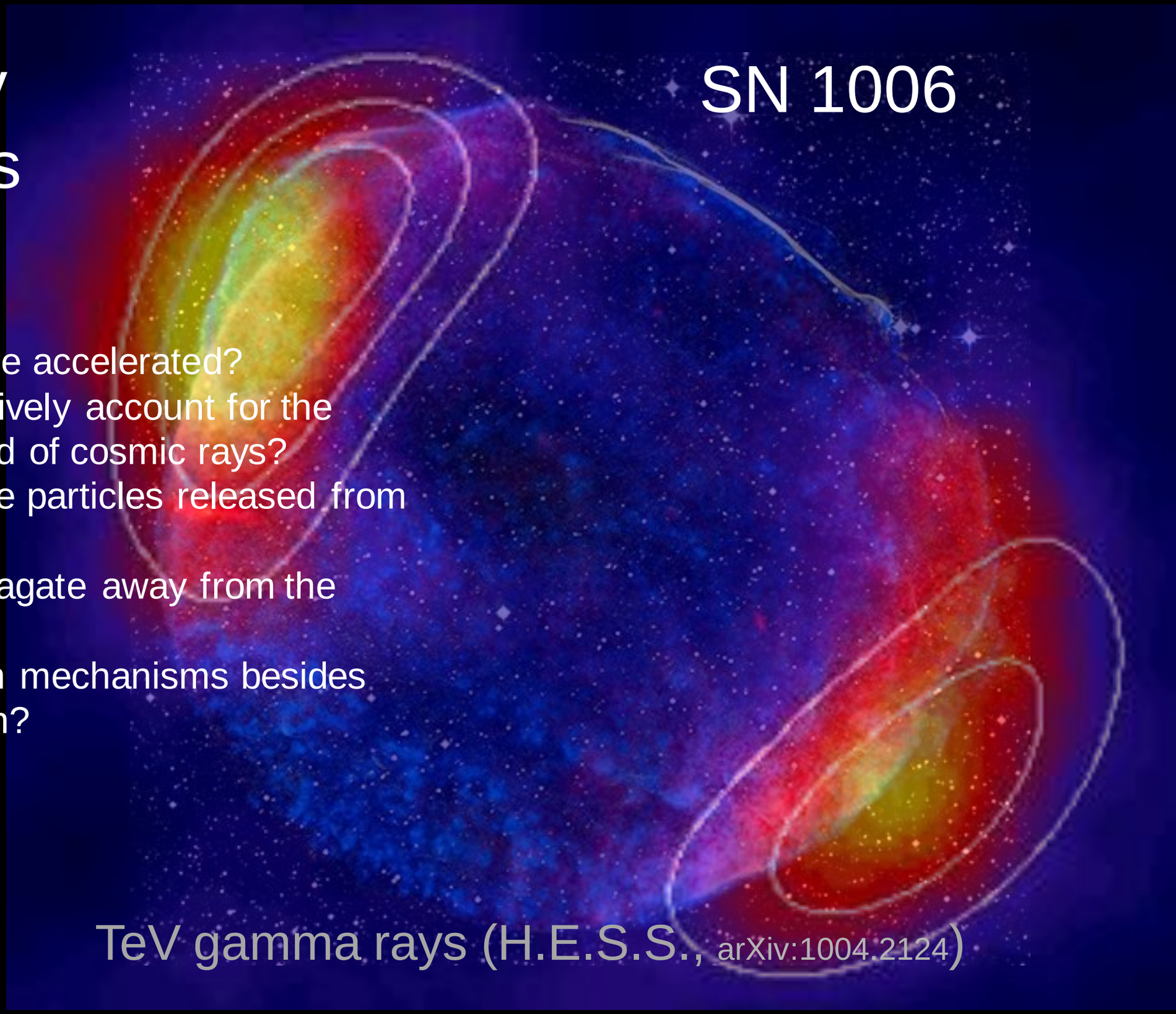
Science Potential



- **Current instruments have passed the critical sensitivity threshold and reveal a rich panorama, but this is clearly only the tip of the iceberg**
- **What big science questions remain ?**

Cosmic Ray Accelerators

- Which particles are accelerated?
- Can one quantitatively account for the spectrum and yield of cosmic rays?
- How and when are particles released from the accelerator?
- How do they propagate away from the accelerator?
- Other acceleration mechanisms besides shock acceleration?

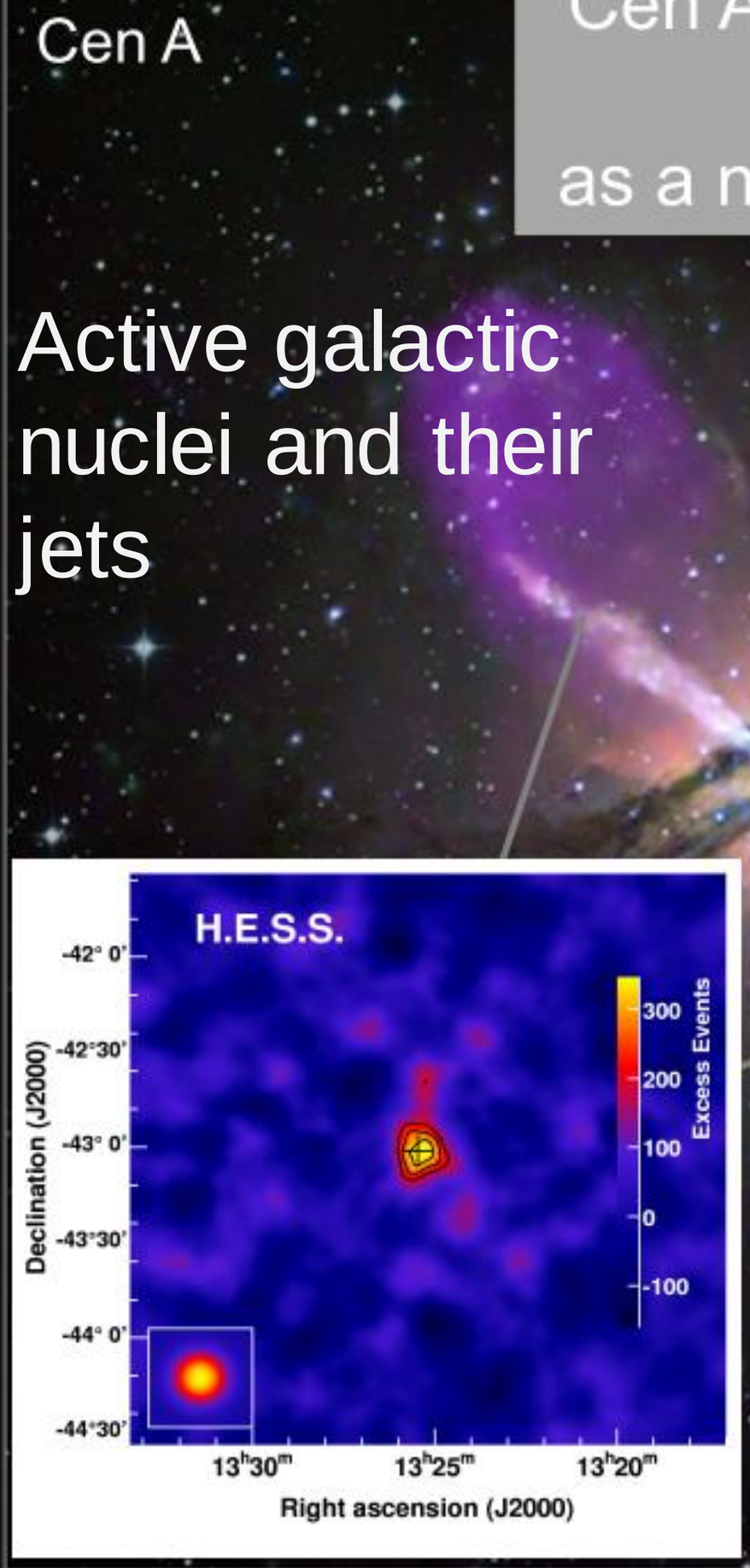


(Credit:X-ray: NASA/CXC/Rutgers/G.Cassam-Chenai, J.Hughes et al.; Radio: NRAO/AUI/NSF/GBT/VLA/Dyer, Maddalena & Cornwell; Optical: Middlebury College/F.Winkler, NOAO/AURA/NSF/CTIO Schmidt & DSS))

Cen A and M87 establish radio galaxies as a new class of VHE emitters

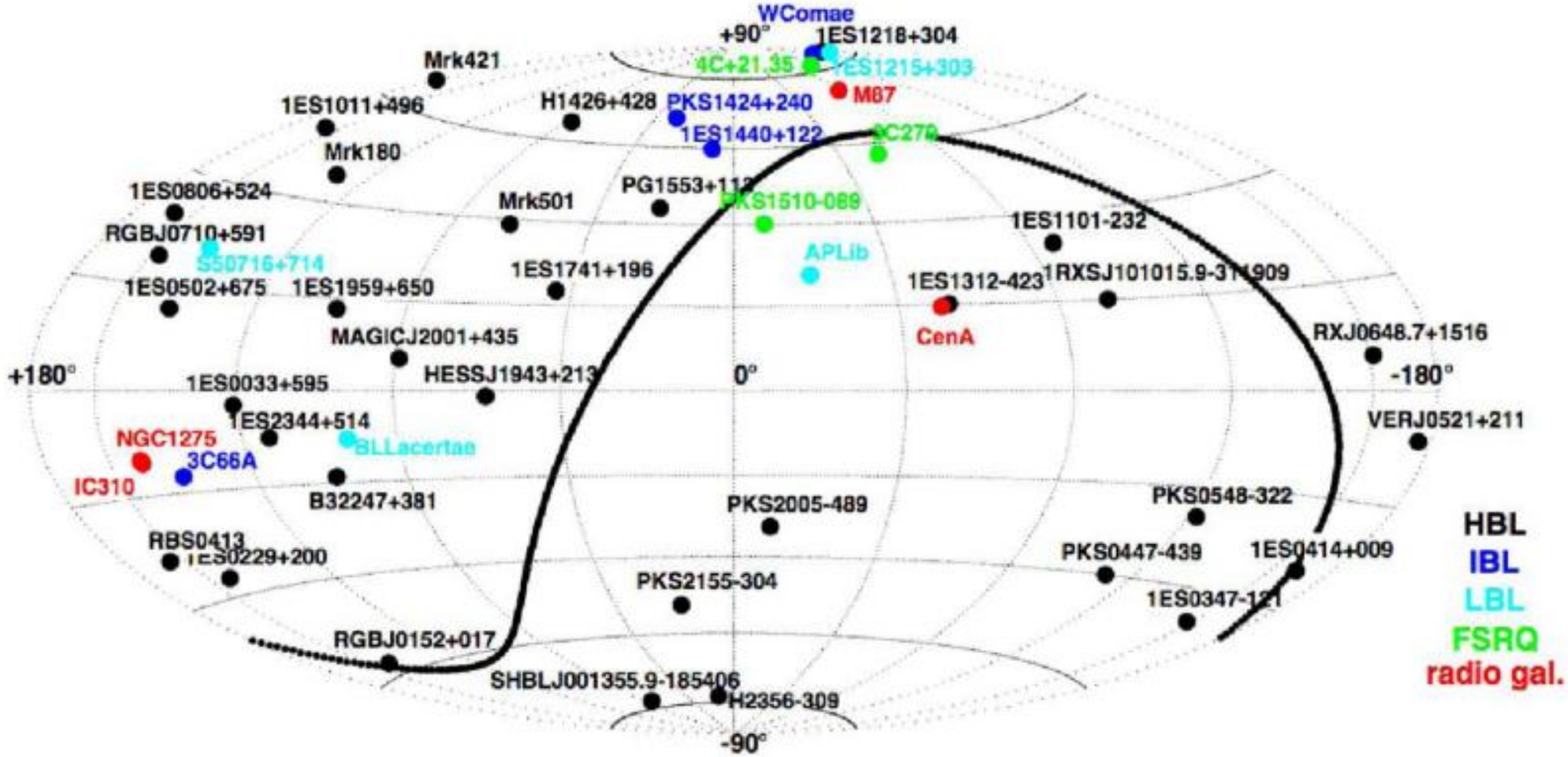
Cen A

Active galactic nuclei and their jets



AGN detected at VHE (status of November 2011) according to the TeVCAT catalog

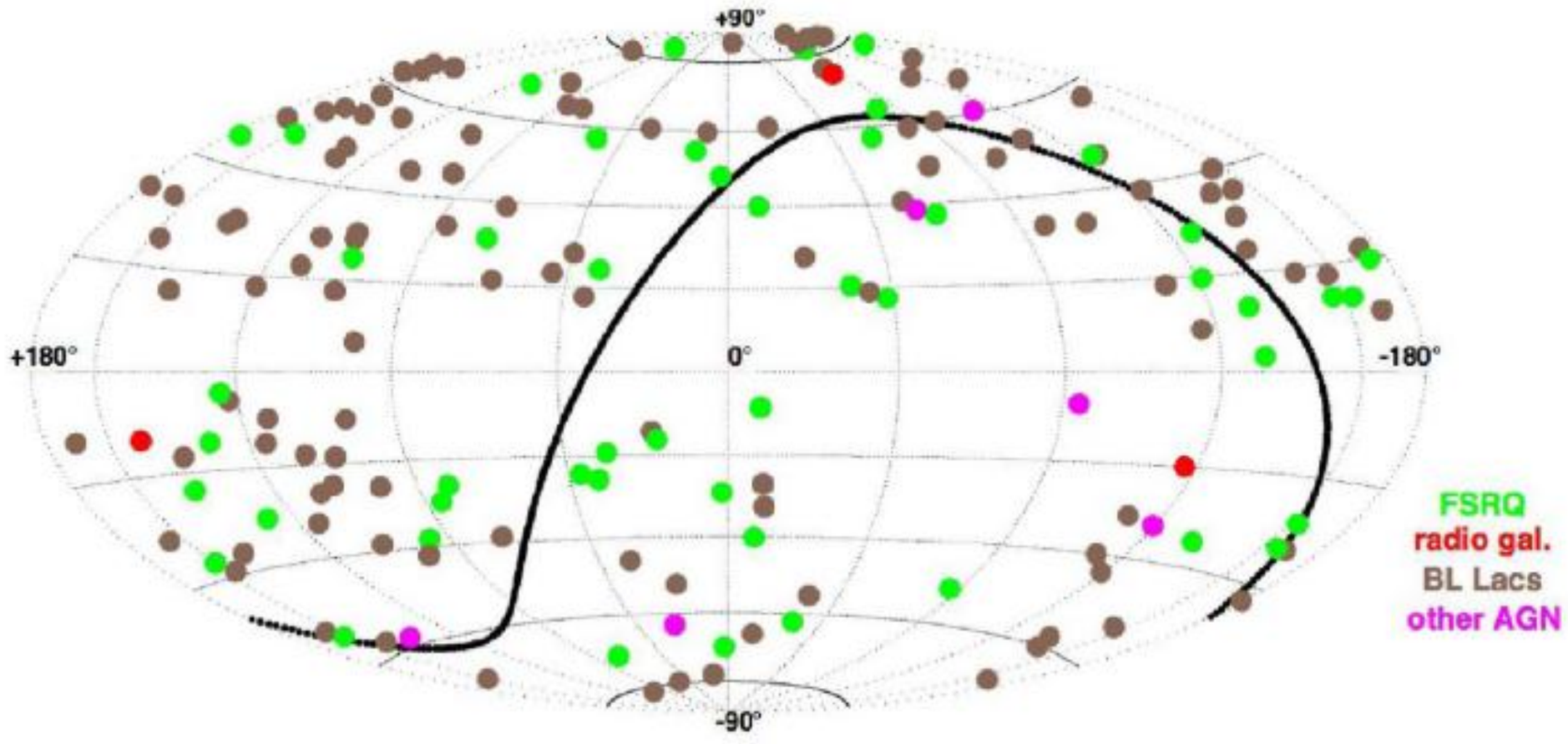
Zech et al. 2012

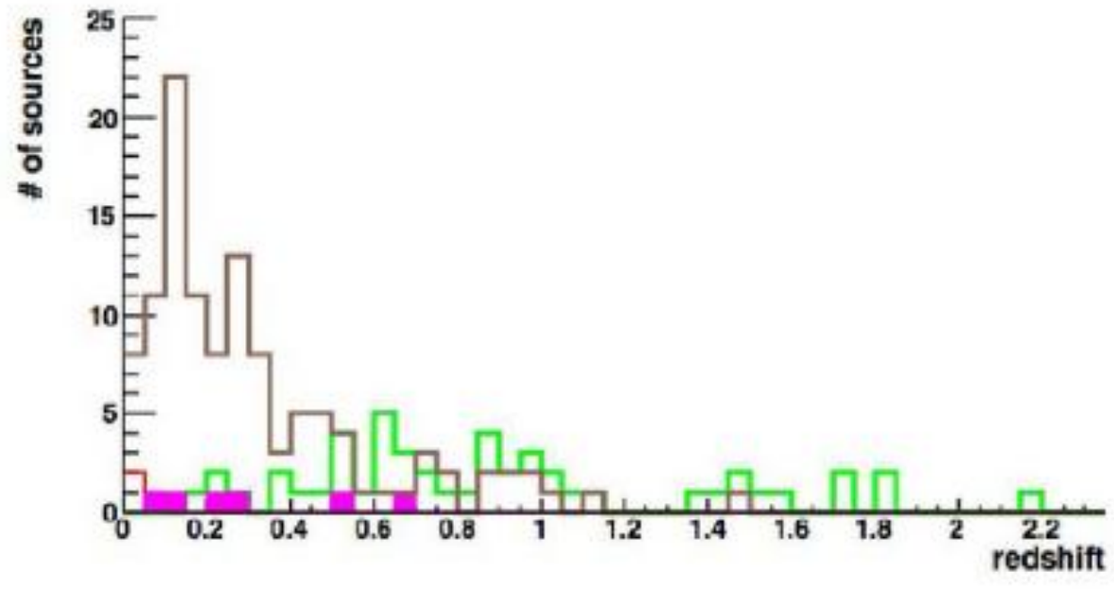


48 objects
(40% of currently detected VHE sources)

Predicted AGN detections with CTA based on extrapolations of Fermi-LAT spectra for a maximum observation time of 50 hr per source

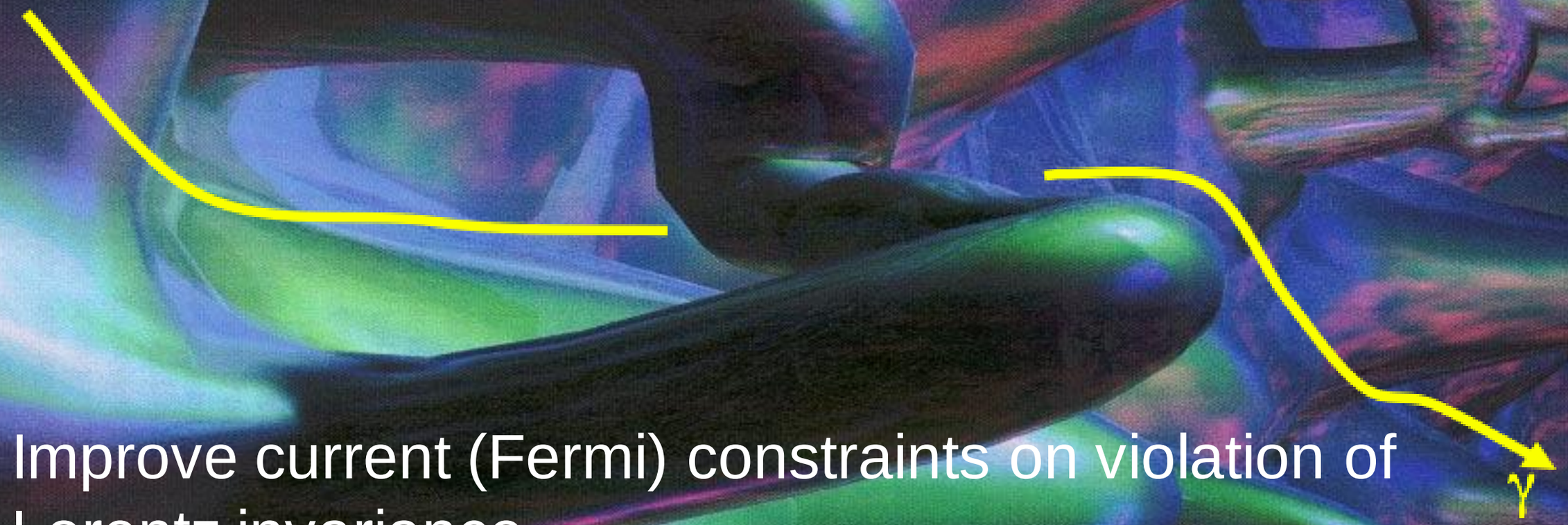
Zech et al. 2012





~170

Fundamental physics with gamma rays



Improve current (Fermi) constraints on violation of Lorentz invariance

Dark matter searches

Axion searches

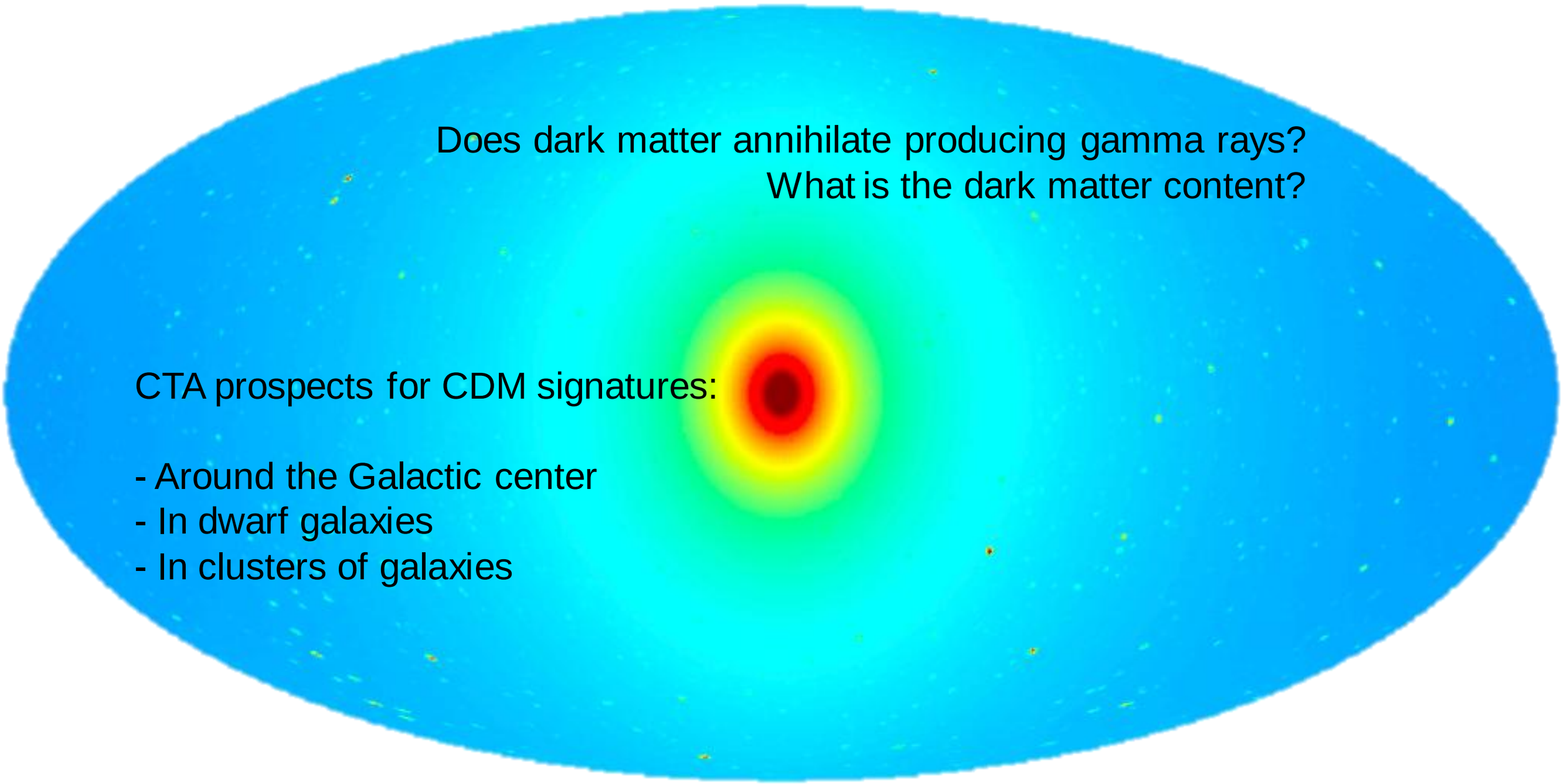
Cosmology

…

Searching for Dark Matter annihilation

Gamma-ray intensity

V. Springel et al.
arXiv:0809.0894

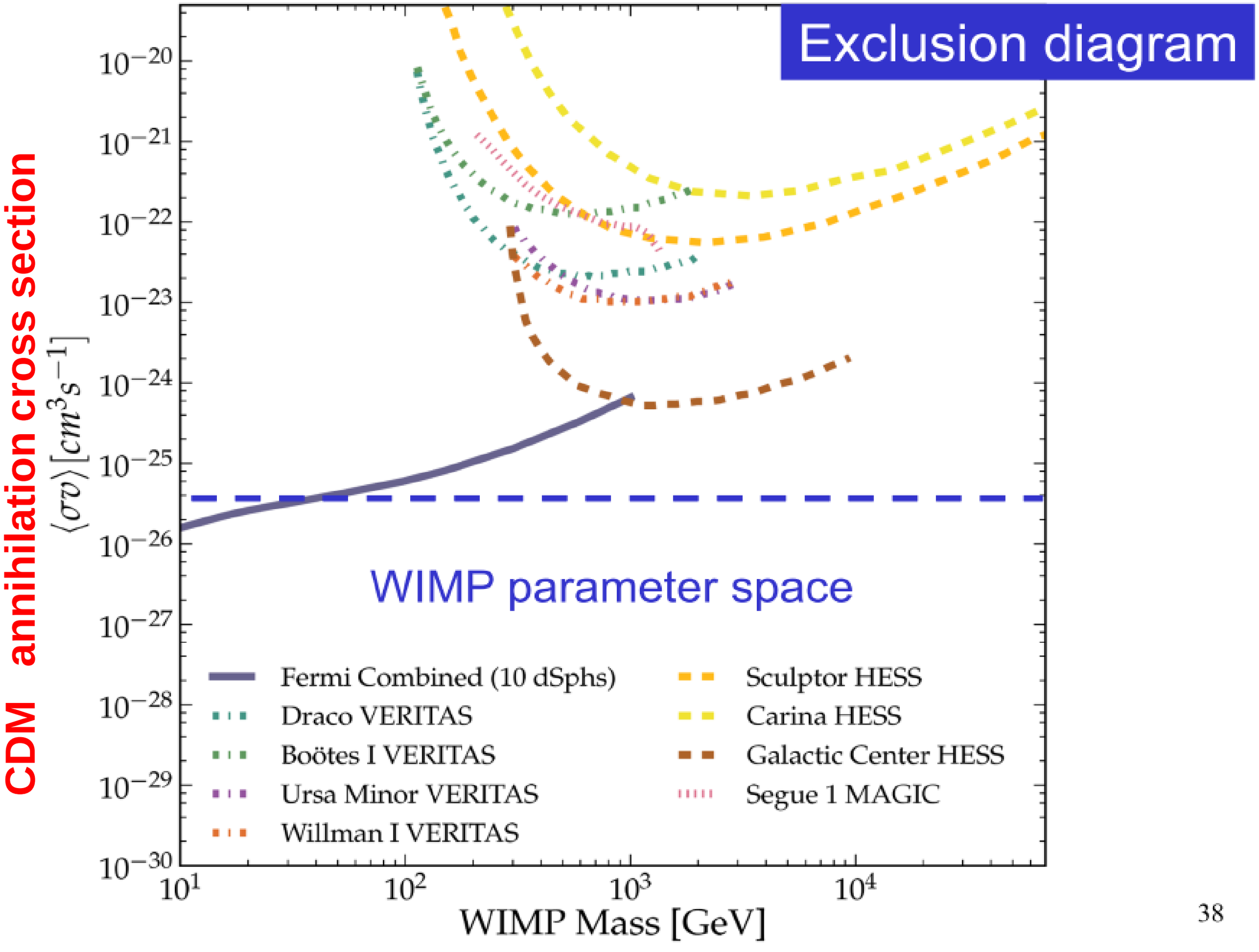


Does dark matter annihilate producing gamma rays?
What is the dark matter content?

CTA prospects for CDM signatures:

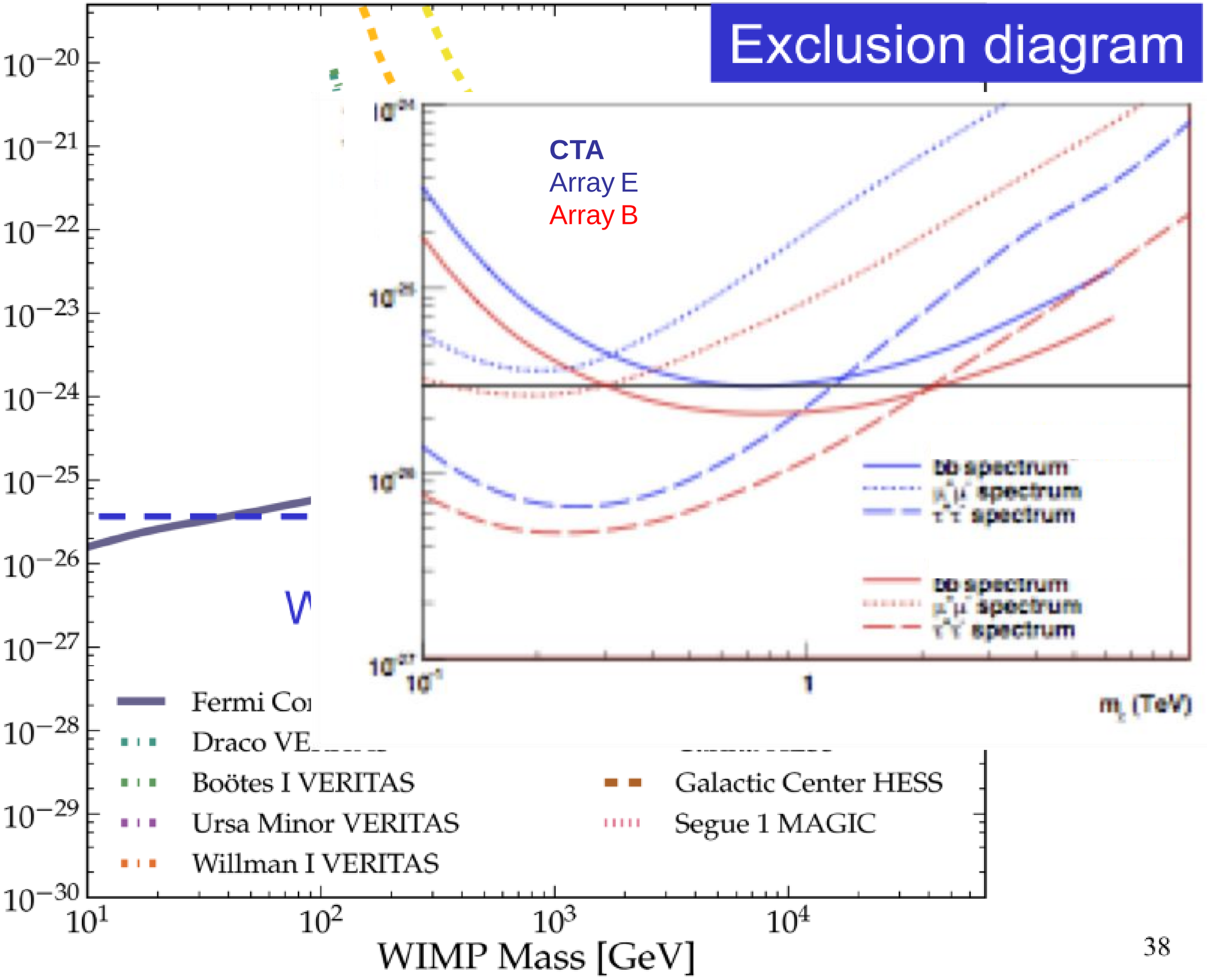
- Around the Galactic center
- In dwarf galaxies
- In clusters of galaxies

Exclusion diagram



Exclusion diagram

CDM annihilation cross section

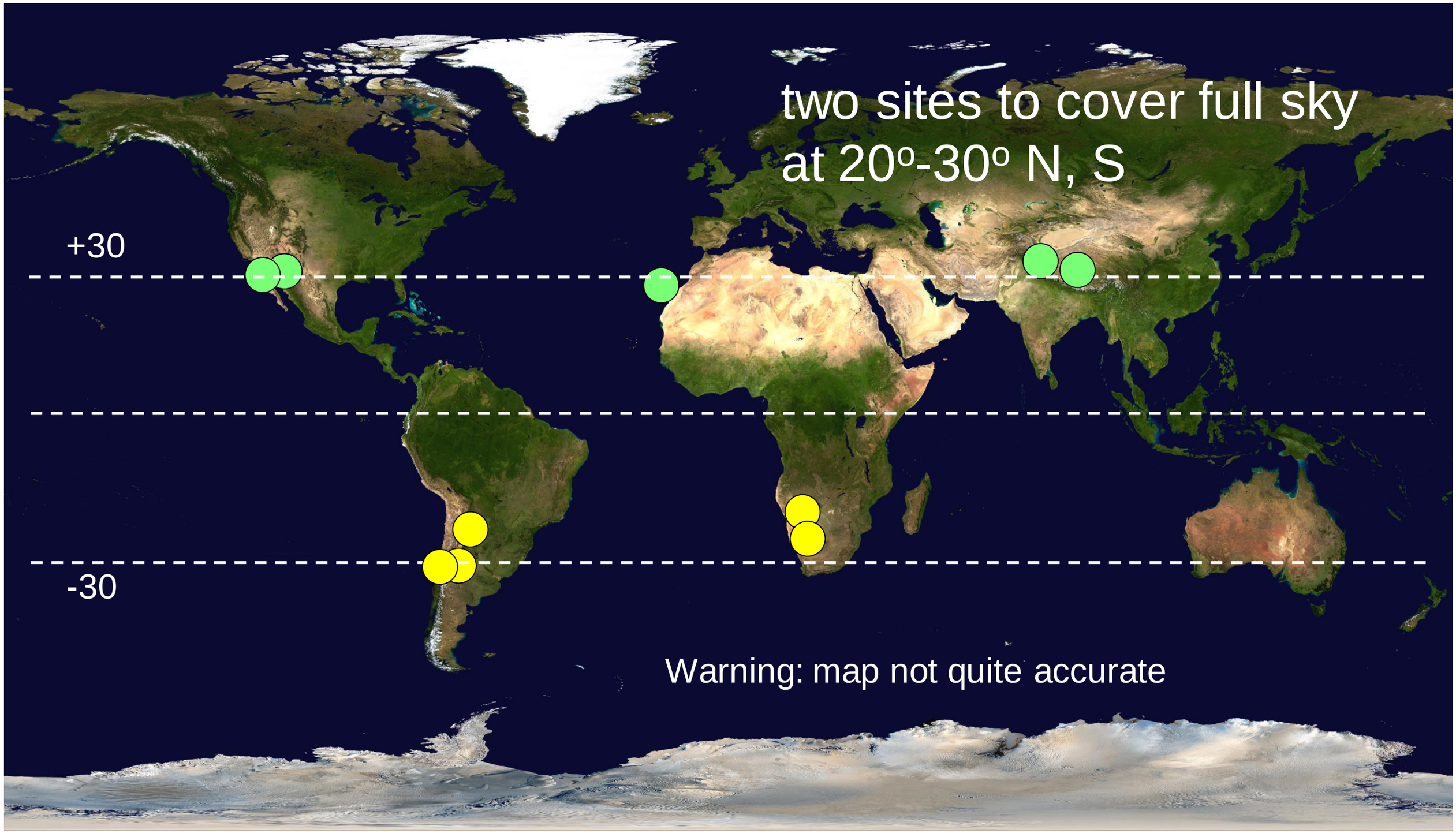


WHERE TO BUILD CTA

Basic requirements

- Reasonably flat area of 10 km^2 (South) and 1 km^2 (North)
- Altitude between ~1500 m and ~4000 m
- High fraction of cloudless nights
- Dark skies without light pollution
- Environmental condition allow operation of telescopes without protective enclosures

Site candidates



Namibia

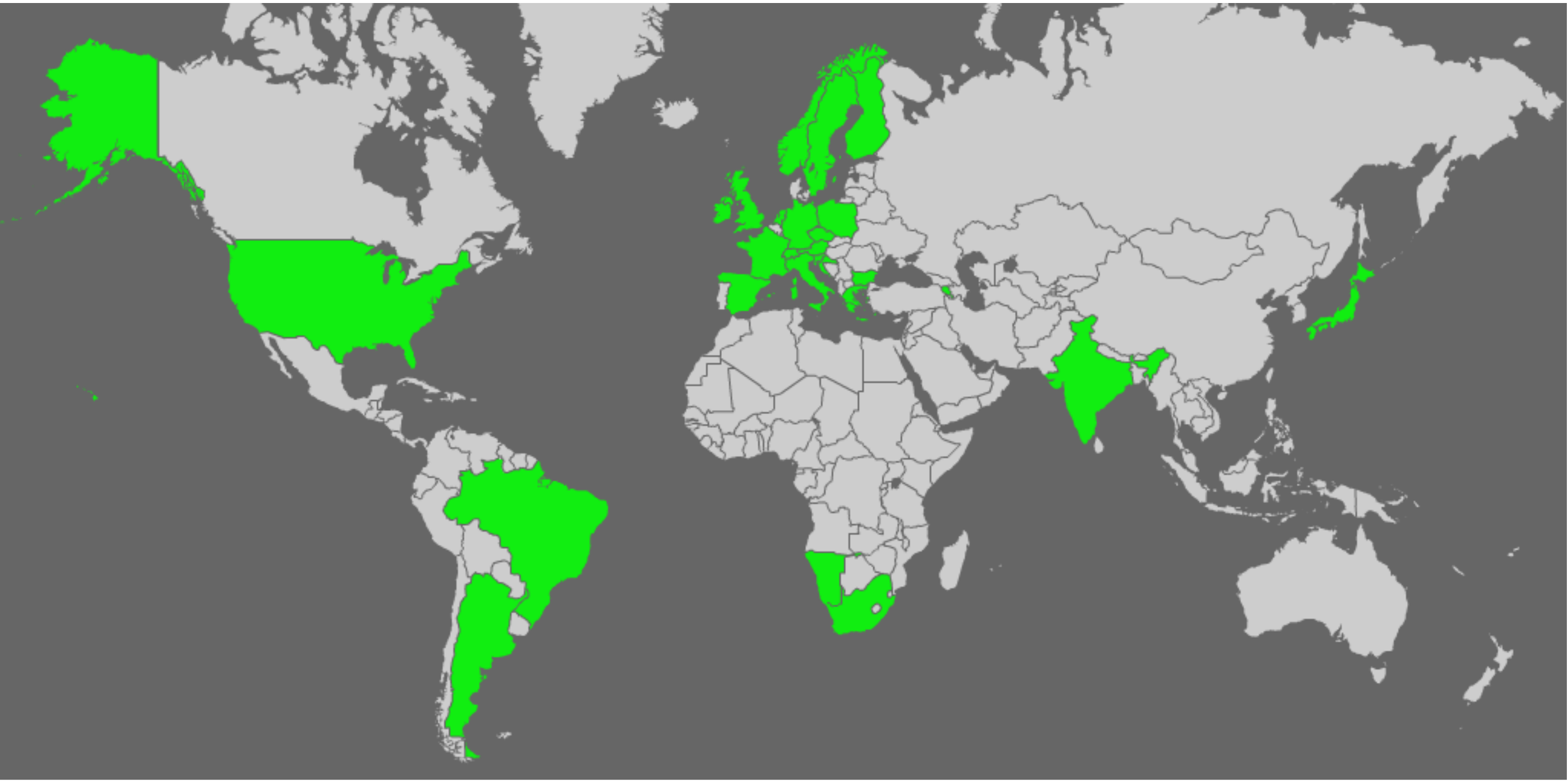
Chile
South
Candidates

Argentina

Argentina

CTA Members: 26 Countries

>800 scientists and engineers from >100 institutions



Argentina, Armenia, Austria, Brazil, Bulgaria, Czech Republic, Croatia, Finland, France, Germany, Greece, India, Italy, Ireland, Japan, Namibia, Netherlands, Norway, Poland, Slovenia, Spain, South Africa, Sweden, Switzerland, UK, USA

Made in Brazil

cta
cherenkov telescope array

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Instituto de Fisica de Sao Carlos

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Gustavo Rojas (UFSCar)

Universidade Federal do Rio

Edivaldo M. Santos
Joao Torres Mello

Centro Brasileiro Pesquisas Fisicas

Ulisses Barres de Almeida
Ronald Cintra Shellard

Recommended by relevant European roadmaps …

The future in very high energy gamma ray astronomy

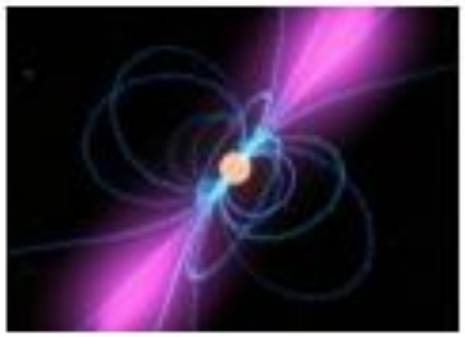
cta
cherenkov telescope array

- Perfect mix of guaranteed science and discovery potential
- Safe extrapolation of proven technologies, well-predictable performance
- Supported by a large and diverse community
- Highly ranked by major science roadmaps
- Currently in FP7-supported Preparatory Phase
- Aim for deployment over 5 years – 2014-2018

cta
cherenkov telescope array

EXTRA SLIDES

Pulsars physics goals with CTA



- Pulsed VHE emission from young pulsars

- Pulsed VHE emission from millisecond pulsars

- Unpulsed VHE emission from Globular Clusters

PWNe physics goals

- Maximum/minimum resolvable size

- Electron cooling effects

- Composite SNRs

- Population studies

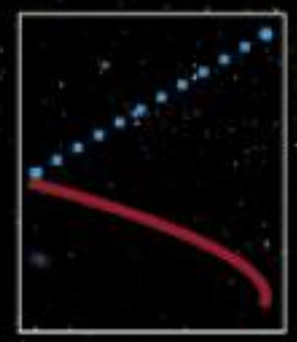
- Energy & morphology modelling

Studies of Extragalactic Background Light with CTA

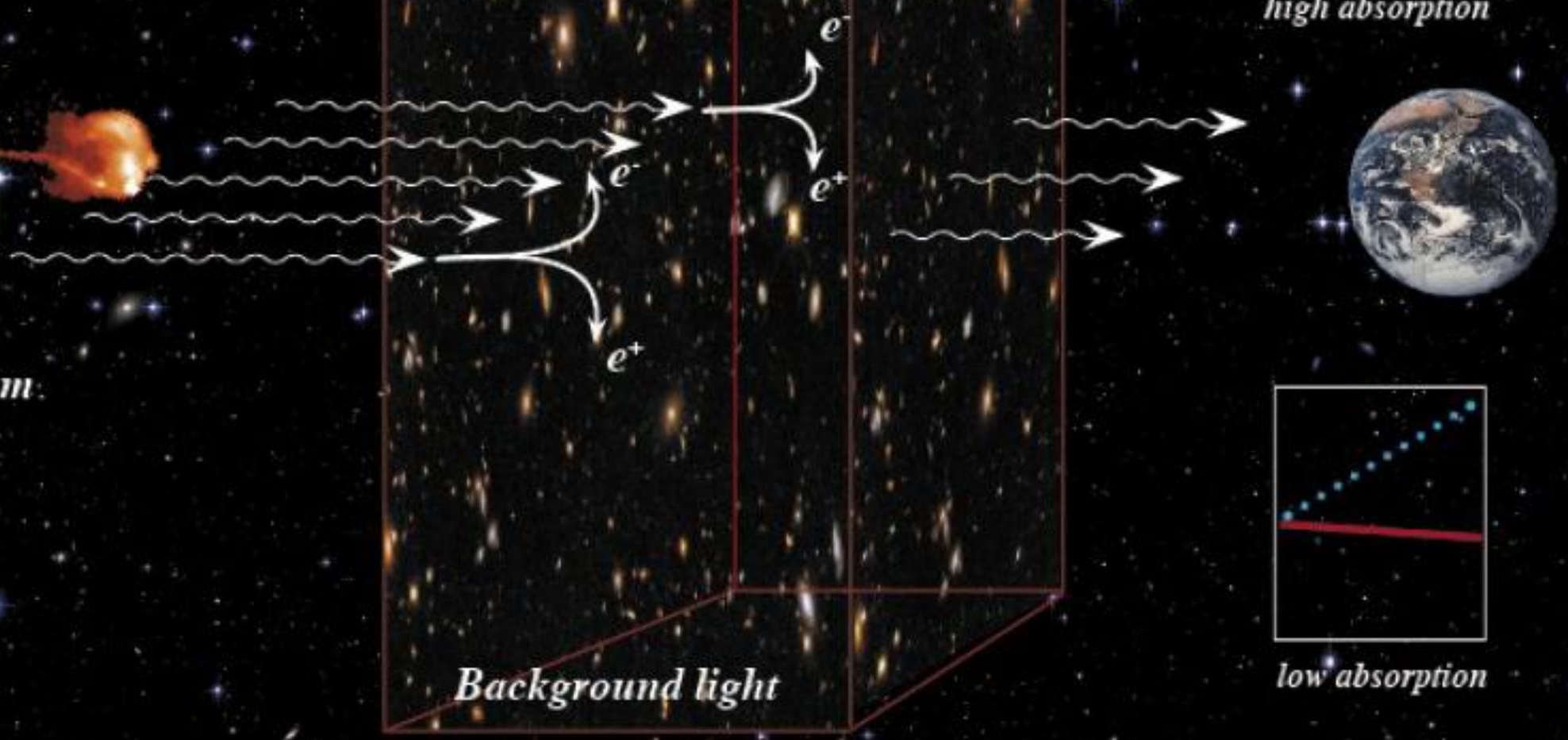
A.I. Nikishov, Sov. Phys. JETP 14 (1962)
Lebedev Physical Institue

Gamma-rays from jet of Quasar

Observed spectrum



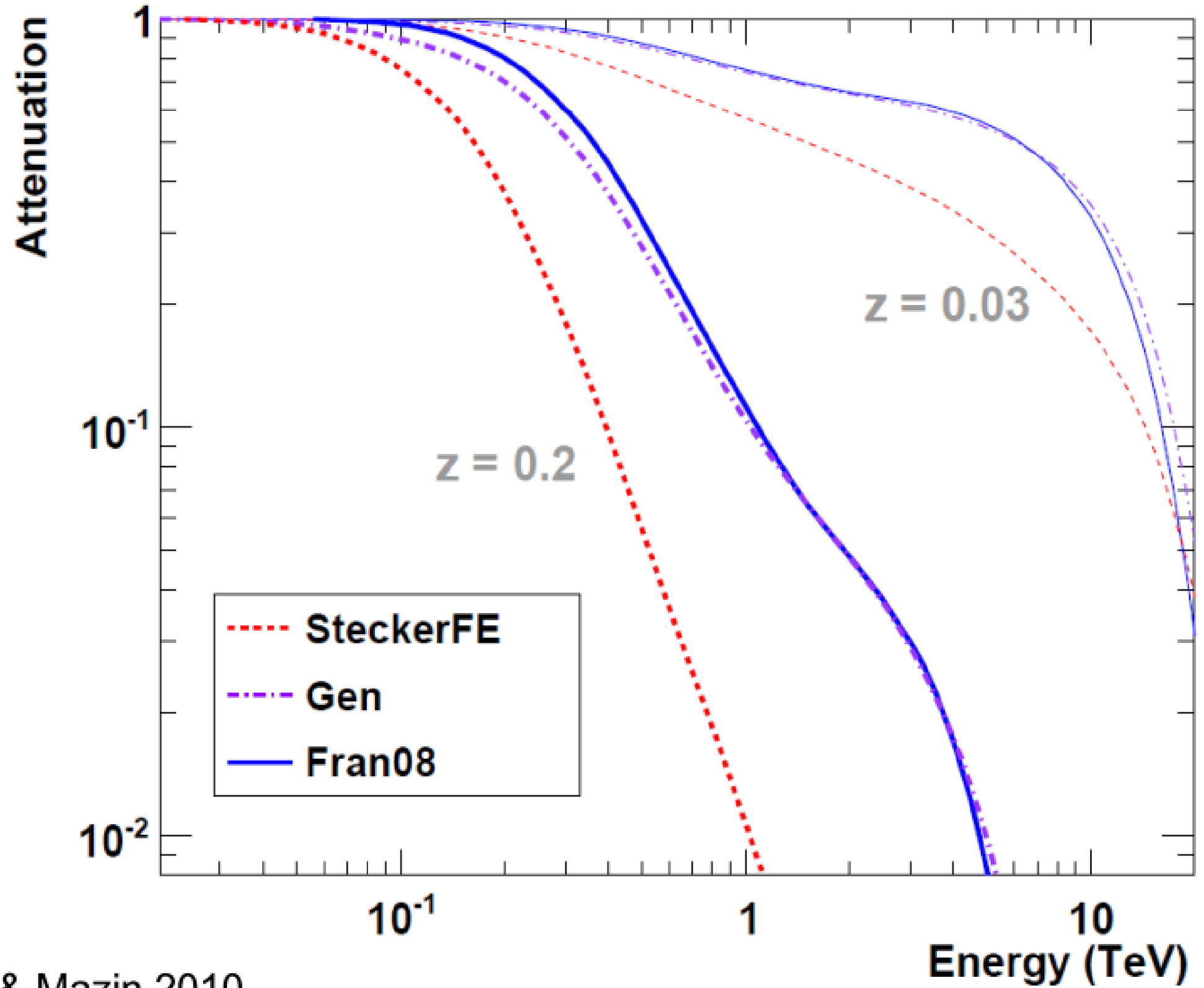
high absorption



Emitted spectrum

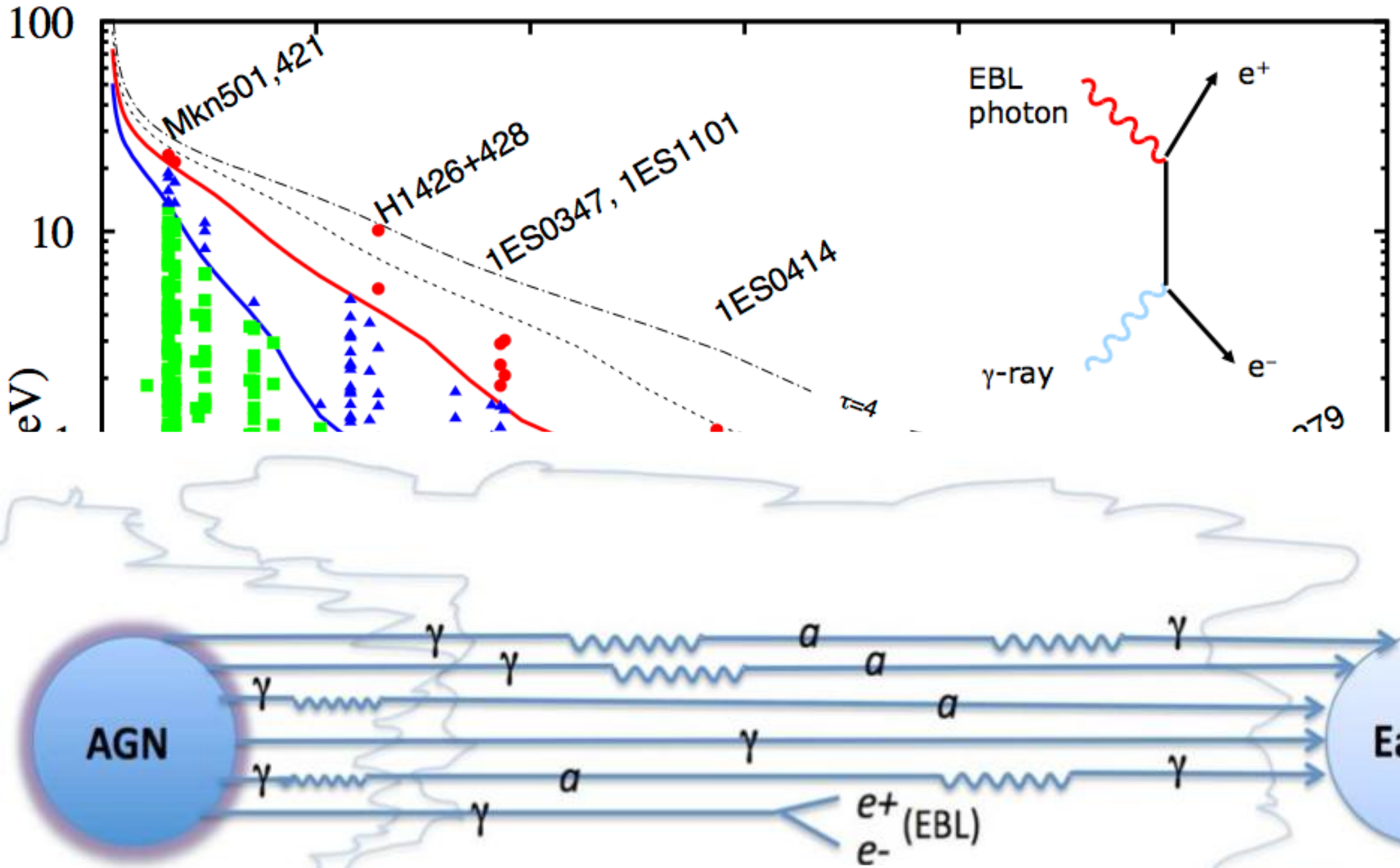
low absorption

CTA will allow for the observation of the unabsorbed part of the spectrum, together with the signature of attenuation at higher energies



Raue & Mazin 2010

AGNs: Is the Universe too transparent ?



Axion conversion ??

Sanchez-Conde et al.,
arXiv:0905.3270

Dark Matter and Fundamental Physics

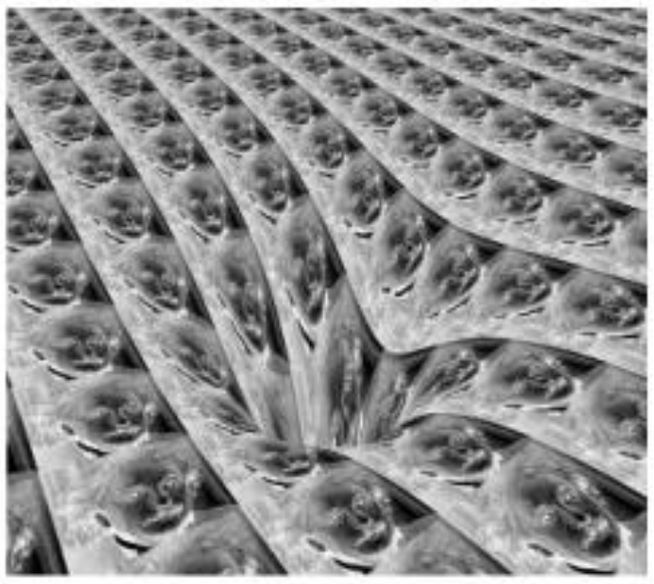
CTA prospects to search for CDM particles signatures:

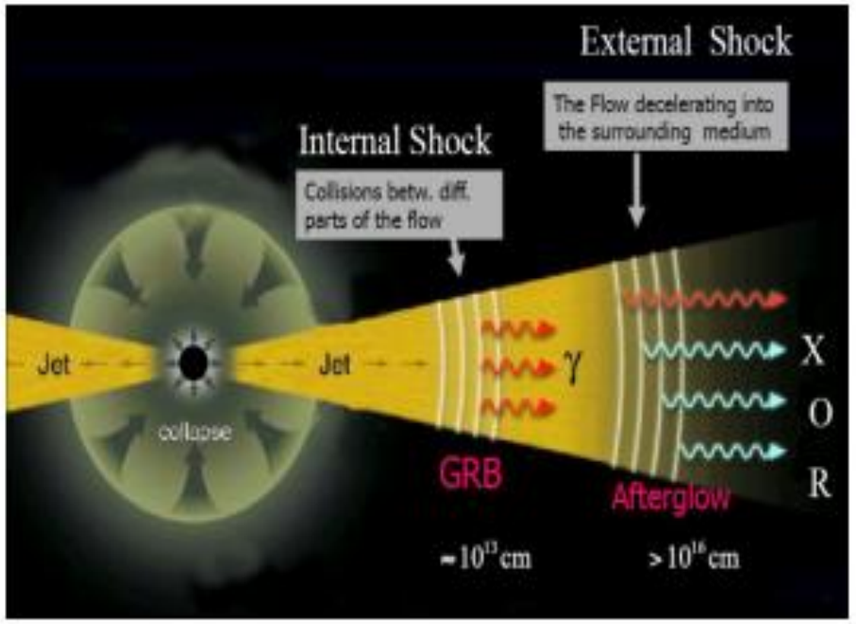
- in dwarf satellite galaxies of the Galaxy

- around the Galactic Center

- in clusters of galaxies

CTA prospects to constrain high energy violations of Lorentz Invariance relative to current limits (Fermi).





Prompt GRB light curves and AGN light curves are used to determine the [lower limit of] Quantum Gravity scale by detection of the [lack of] delay between the arrival times of photons at different energies

The Lorentz invariance violating (LIV) part in the dependence of the photon momentum on its energy

$$c^2 p^2 = E^2 \left[1 \pm \xi_1 (E/E_{\mathrm{Pl}}) \pm \xi_2 (E/E_{\mathrm{Pl}})^2 \pm \ldots\right],$$

$$\Delta t \simeq \left(\frac{\Delta E}{\xi_\alpha E_{\mathrm{Pl}}}\right)^\alpha \frac{L}{c}$$

Current lower limit on the QG energy scale due to possible linear dependence of the speed of light on photon energy:

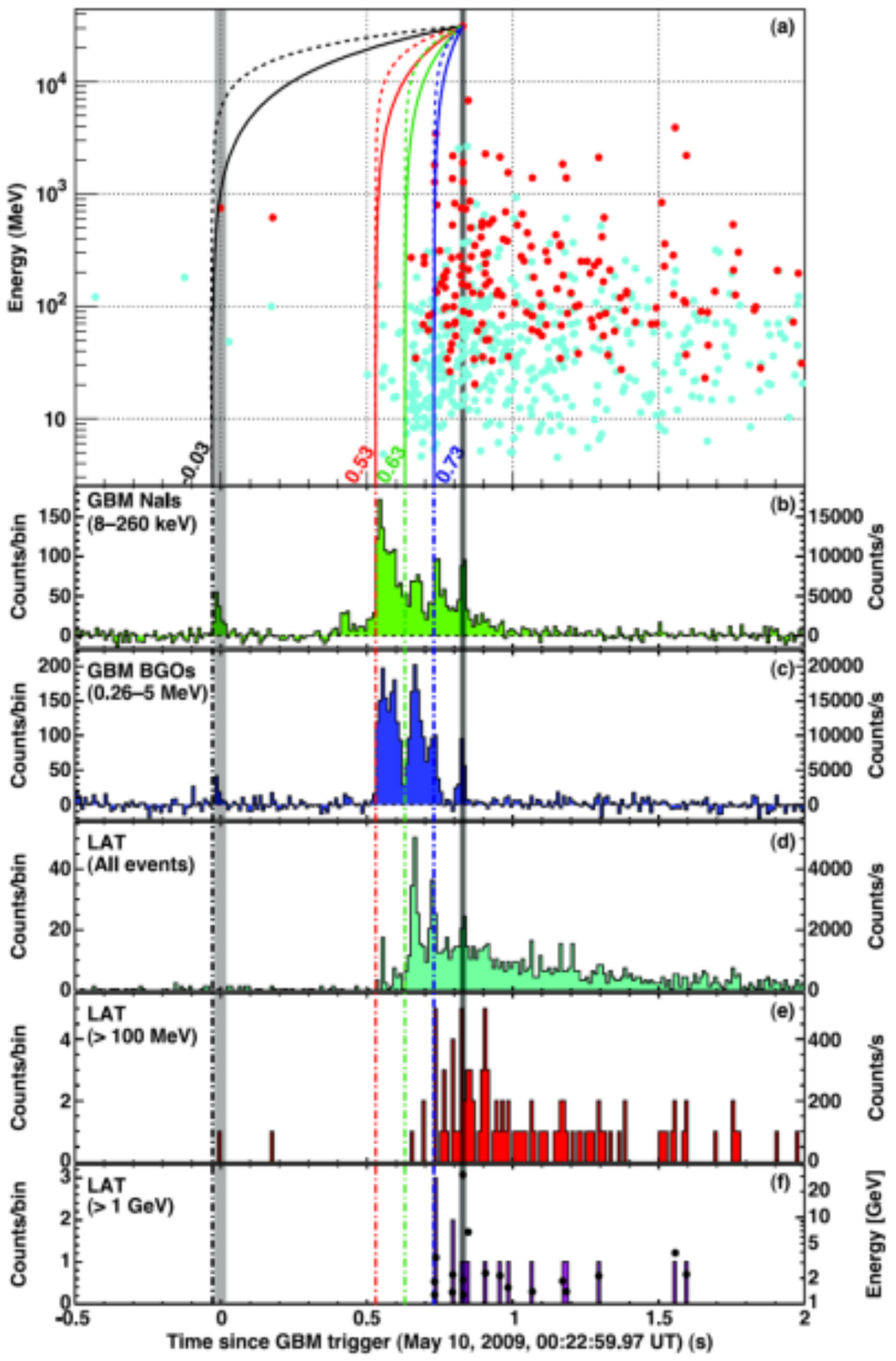
$$E_{QG,1} = \xi_1 E_{Planck}$$

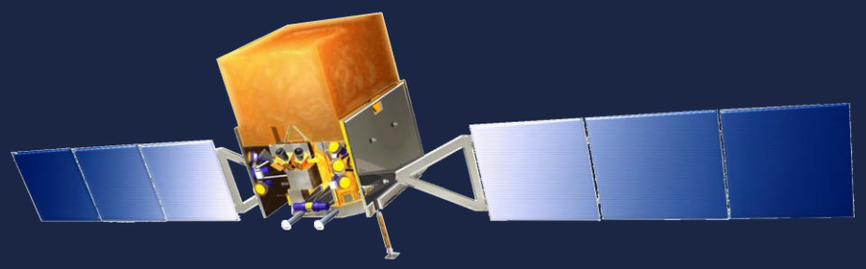
$$\xi_1 > 1.2$$

To test quadratic or higher order dependencies
the sensitivity of CTA will be needed

Fermi LAT and GBM light curves of GRB 090510

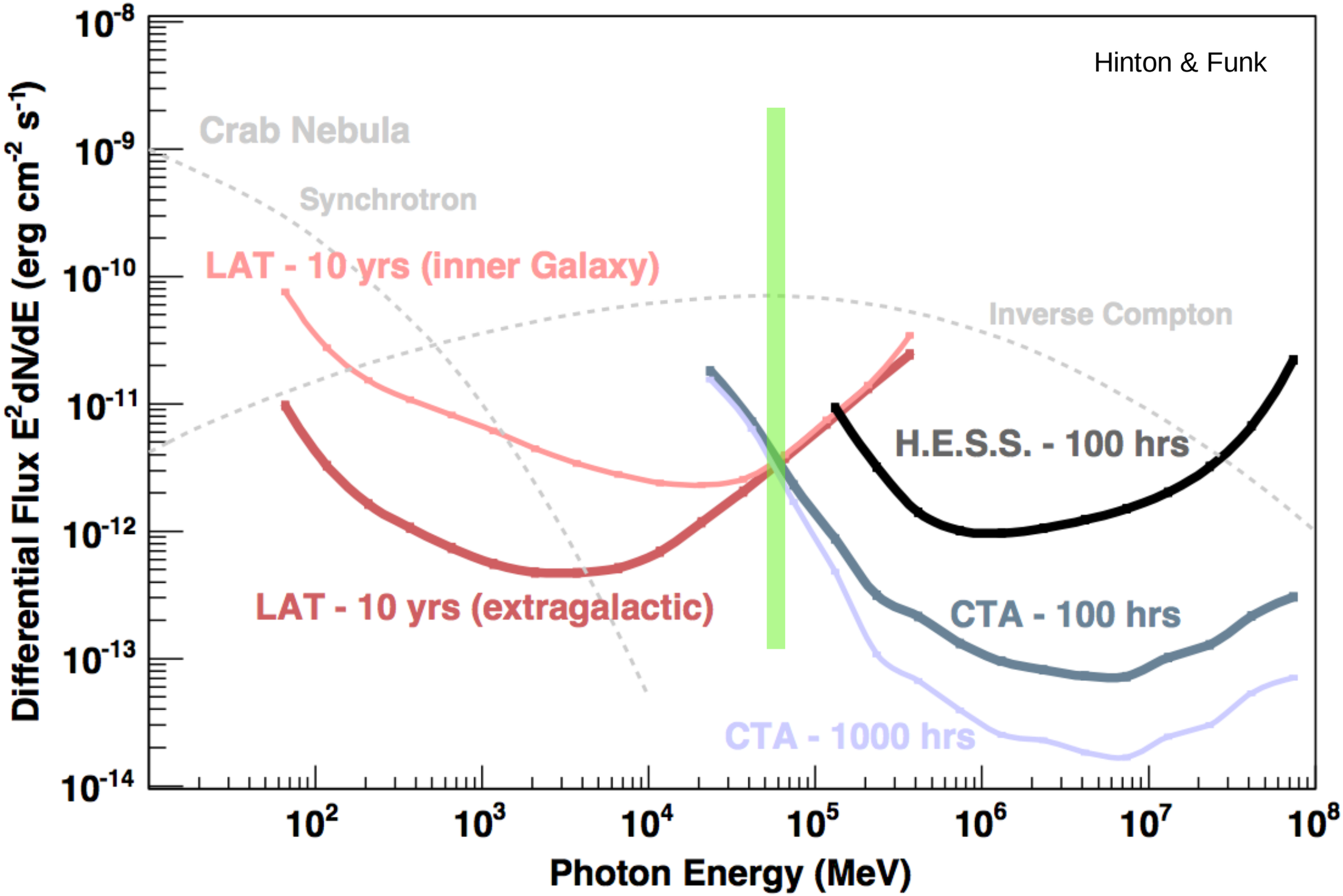
(Abdo et al. 2009)



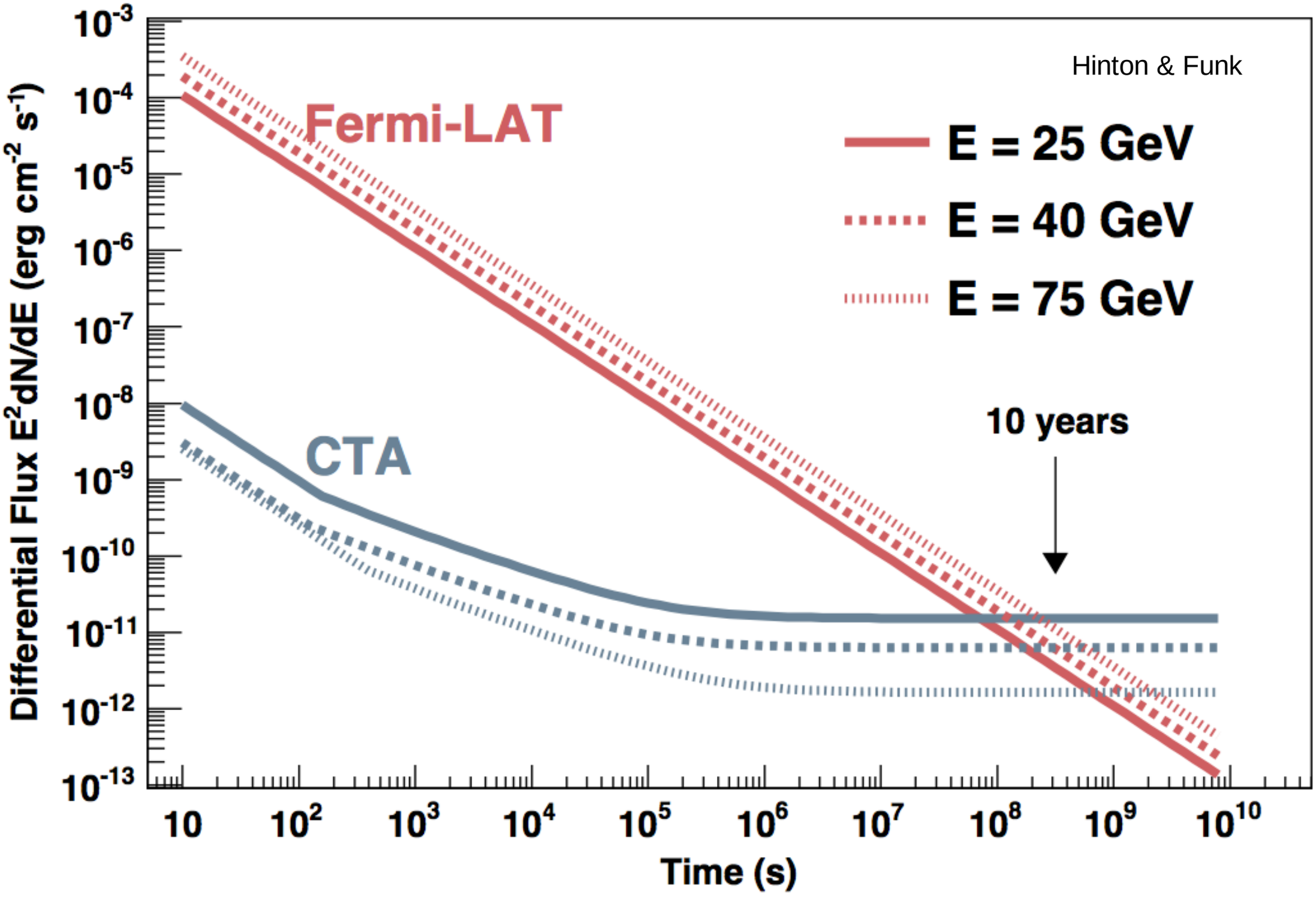


CTA AND FERMI

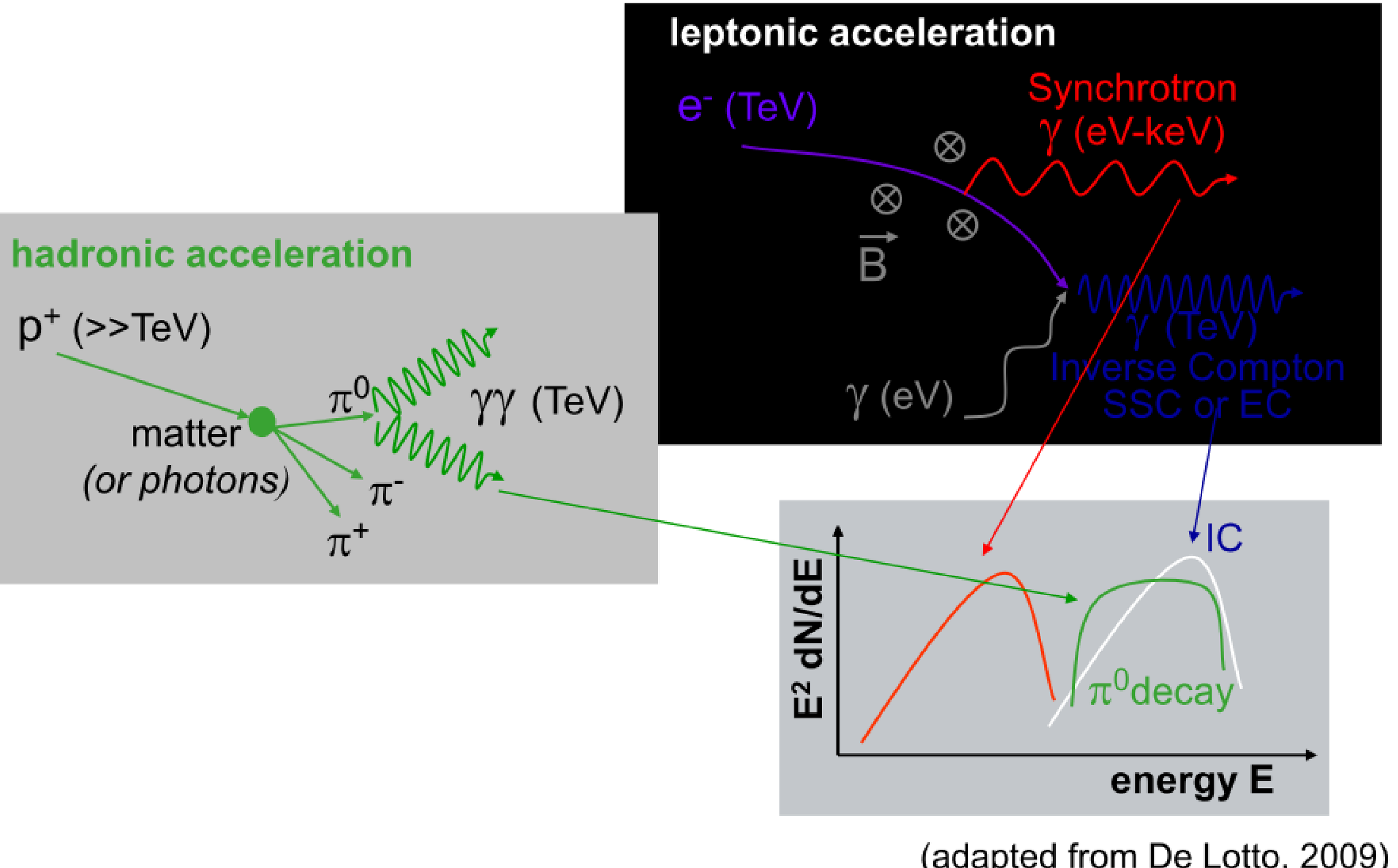
CTA versus Fermi – steady sources



CTA versus Fermi – transient sources

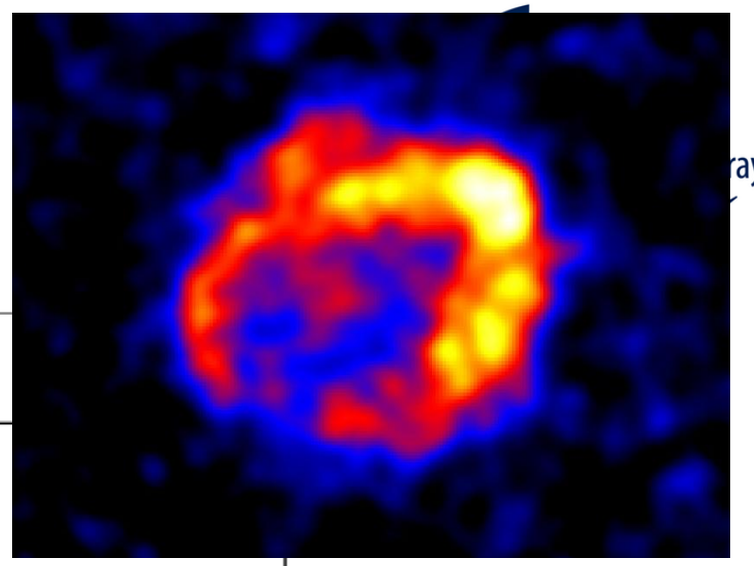


Basic scenarios for SED modeling

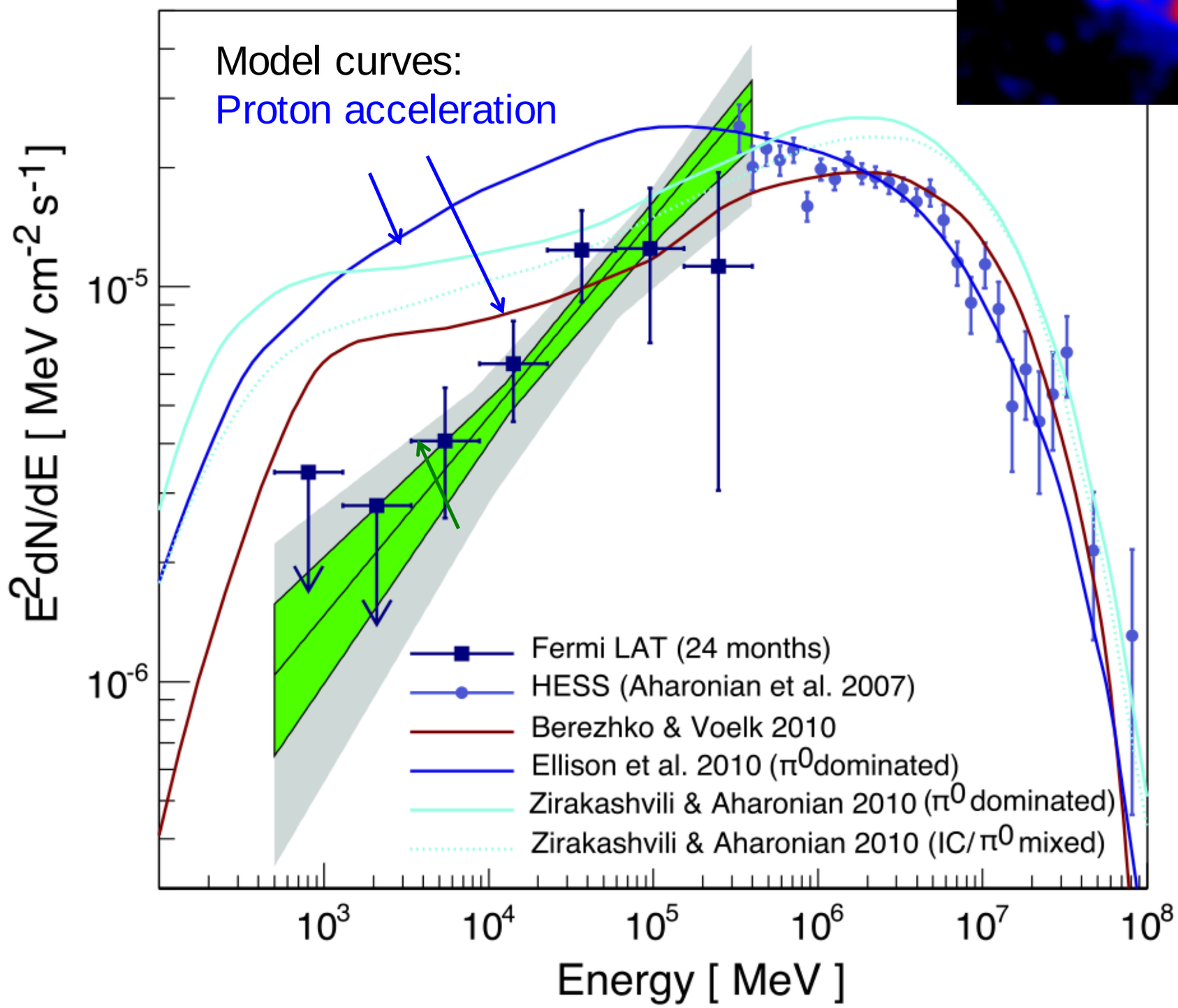


(adapted from De Lotto, 2009)

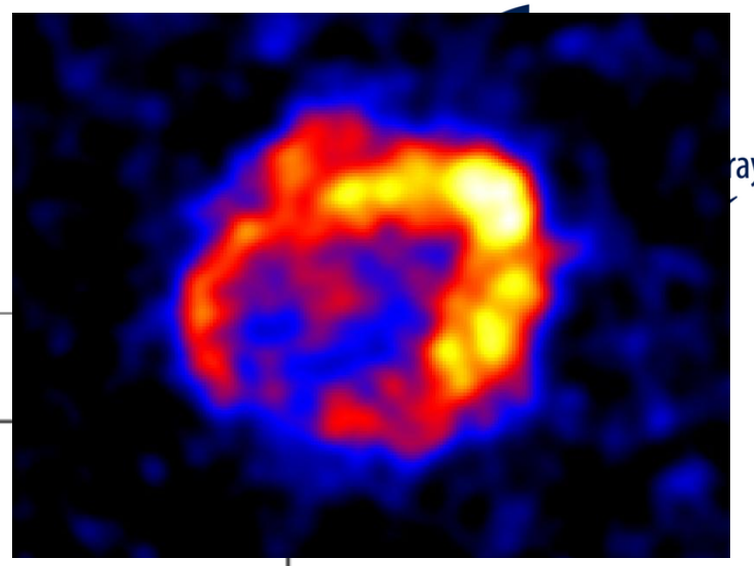
The remnant RX J1713.7-3946



Fermi-LAT Collab.
arXiv:1103.5727



The remnant RX J1713.7-3946



Fermi-LAT Collab.
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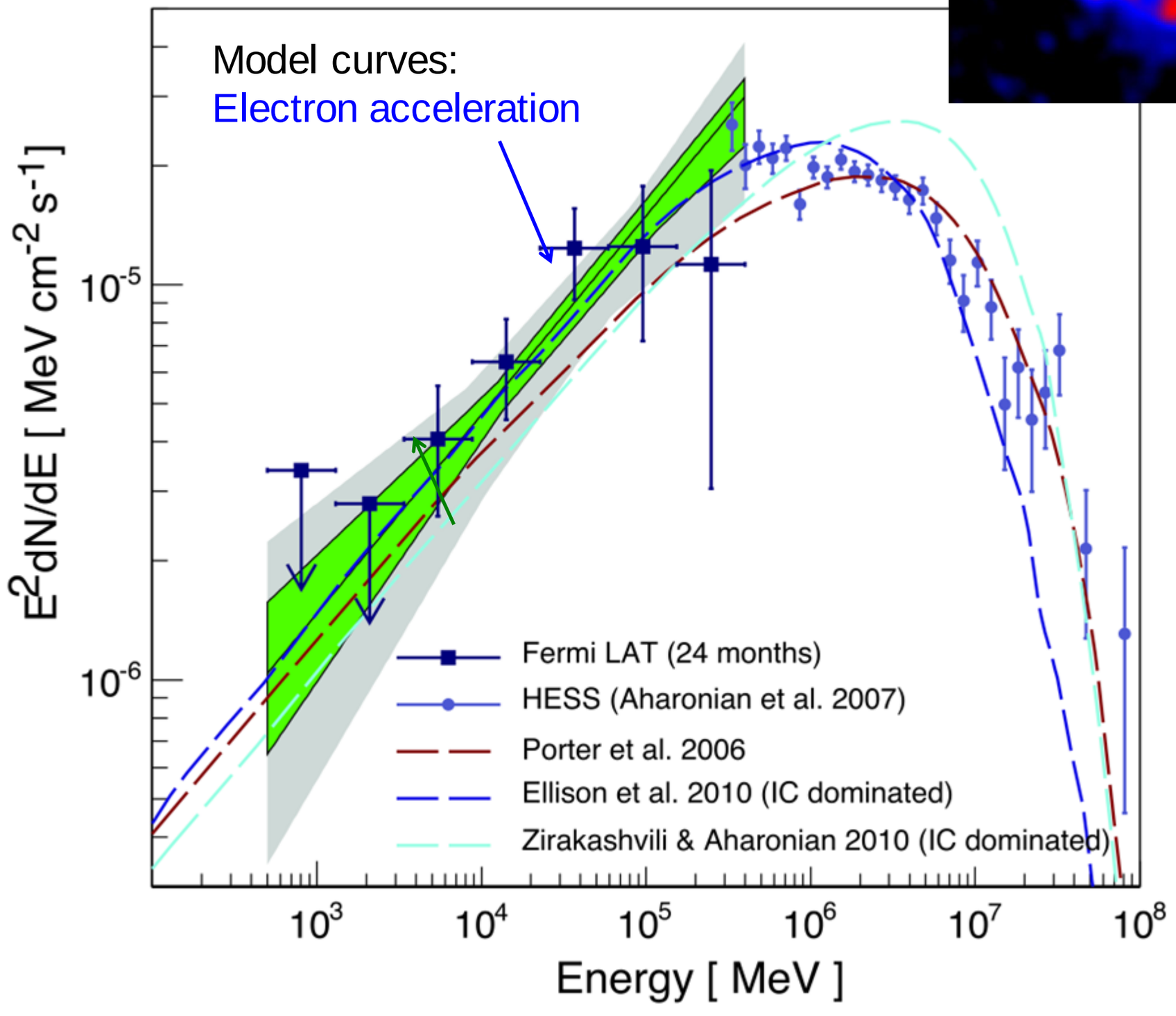
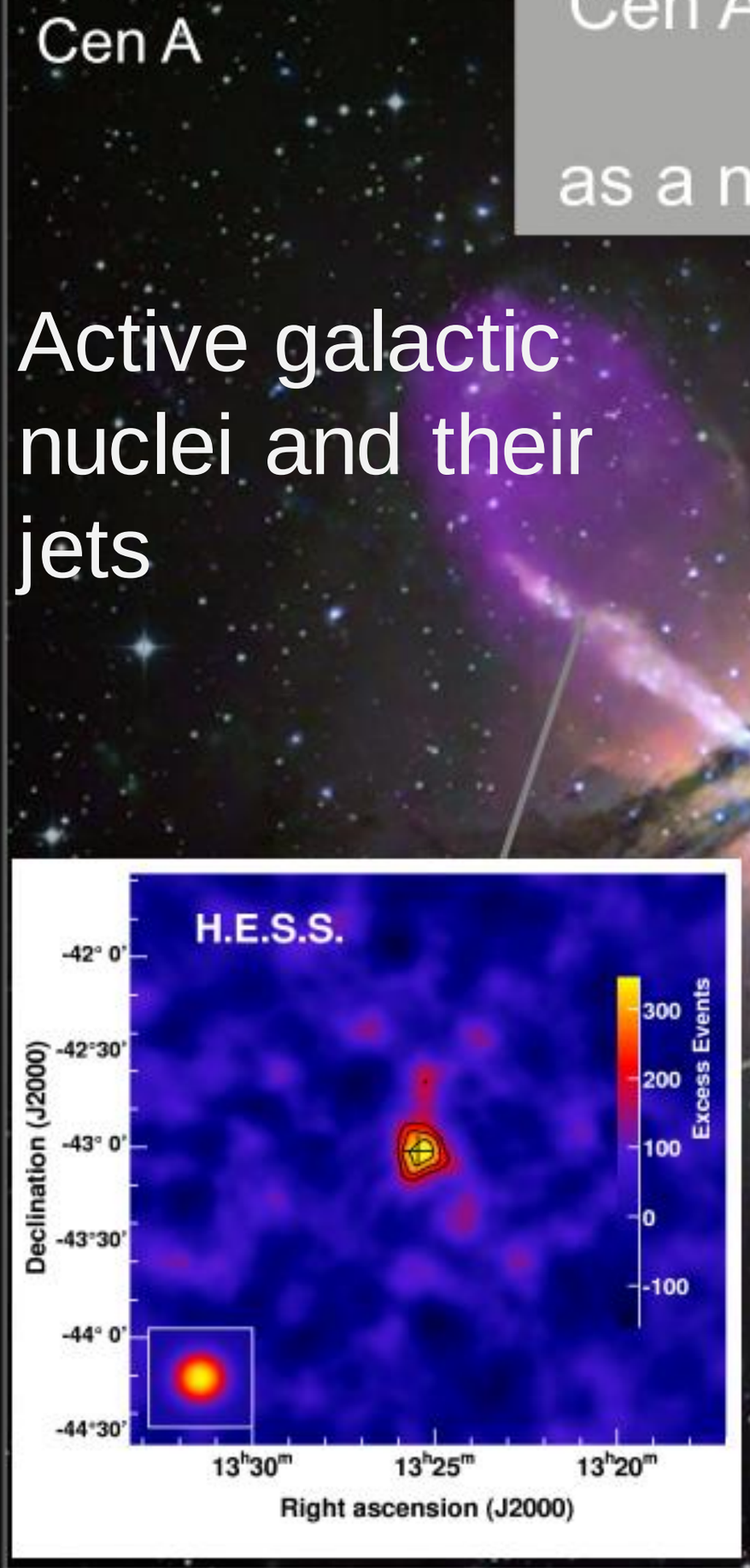


Cen A and M87 establish radio galaxies as a new class of VHE emitters

Cen A

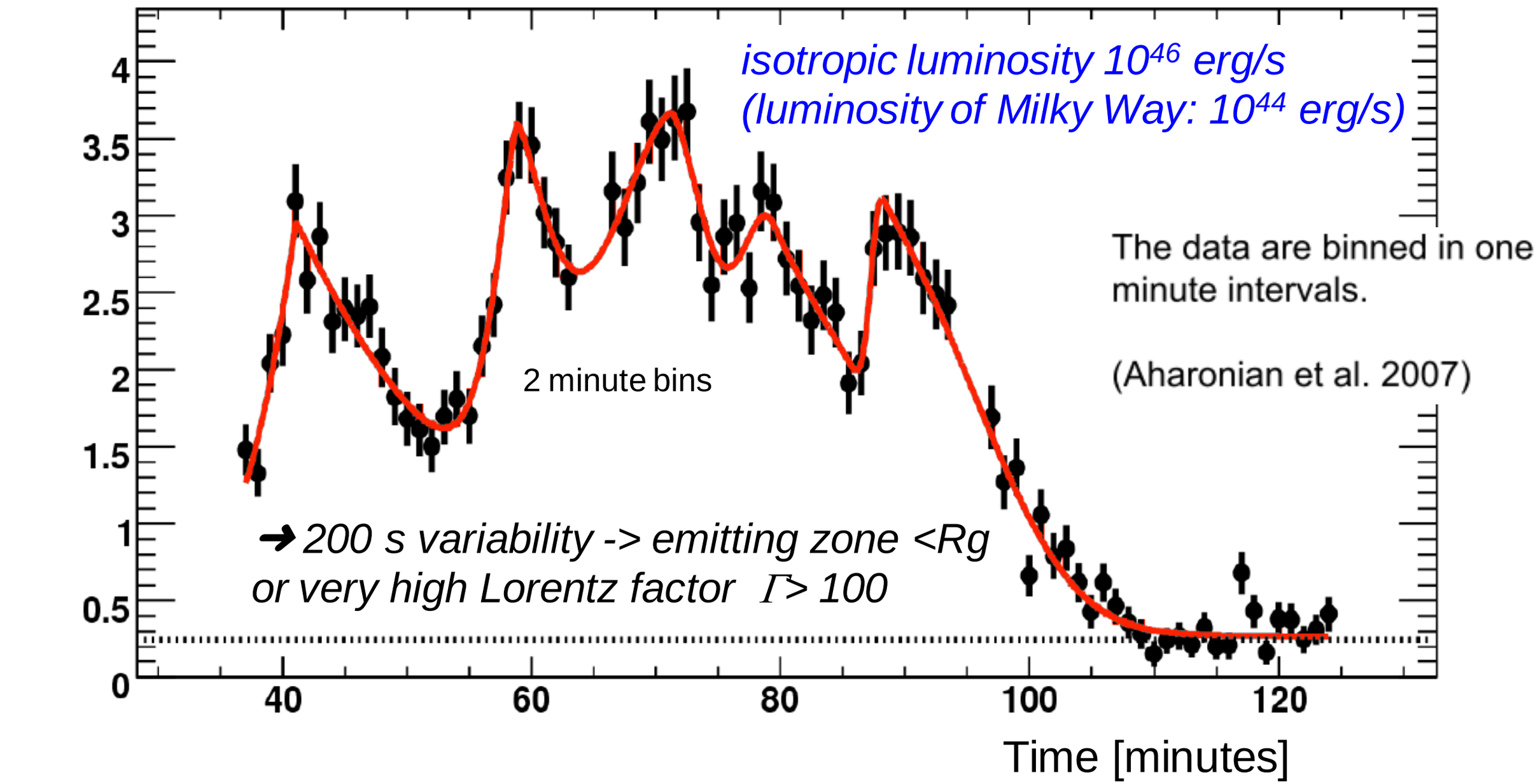
Active galactic nuclei and their jets



AGN: The most violent

PKS 2155-304 flare

arXiv:0706.0797
H.E.S.S.



THE CTA TELESCOPES

We know how to build such telescopes!

107 m^2 HESS ≃ MST

VERITAS ≃ MST

236 m^2 MAGIC ≃ 60% LST dish area

600 m^2 HESS II ≃
150% LST dish area