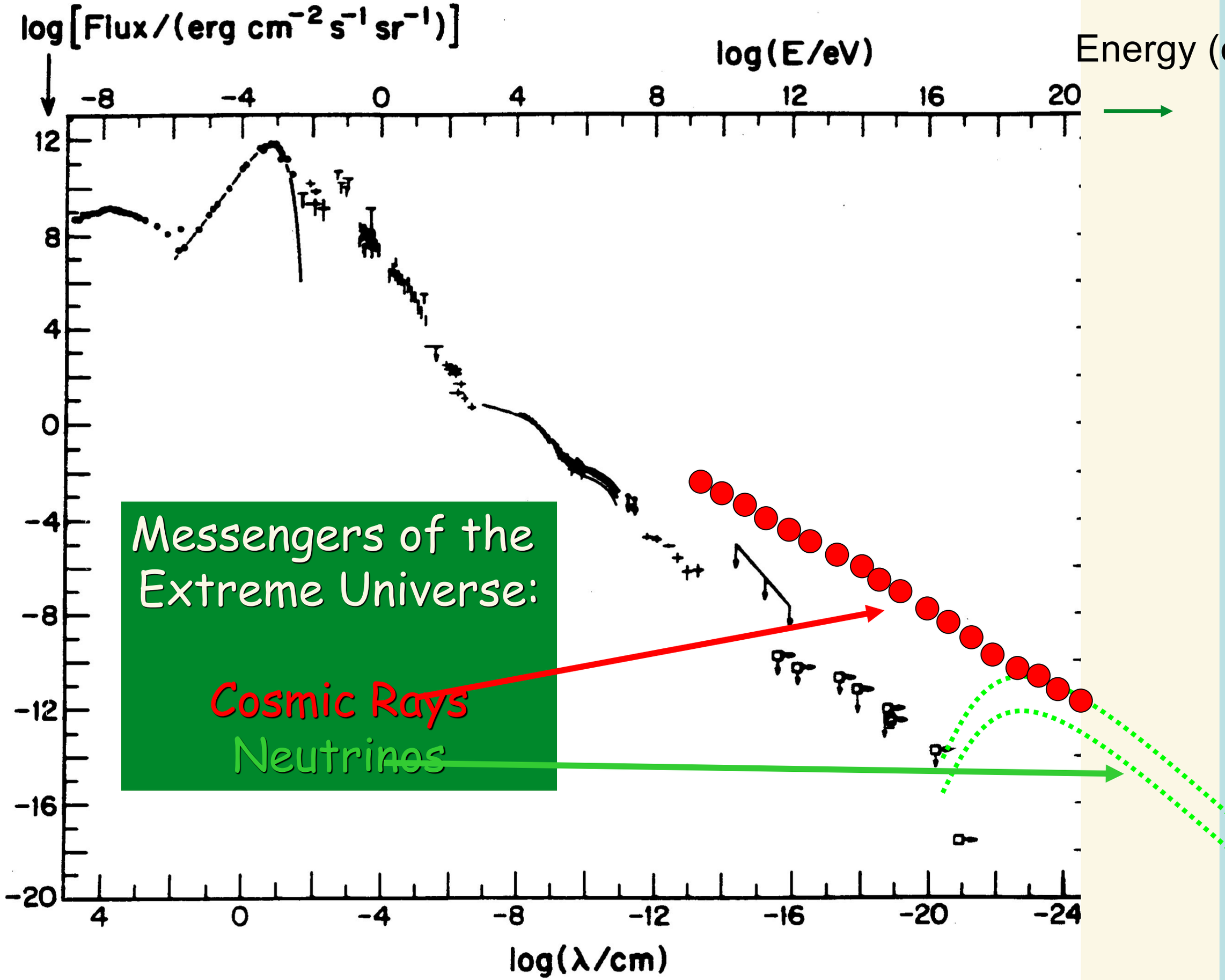
Come si puo’ fare astronomia con la radiazione cosmica?


log[Flux/(erg cm^{-2} s^{-1} sr^{-1})]
log(E/eV)
Energy (eV)
-8
-4
0
4
8
12
16
20
12
8
4
0
-4
-8
-12
-16
-20
Messengers of the Extreme Universe:
Cosmic Rays
Neutrinos
4
0
-4
-8
-12
-16
-20
-24
log(λ/cm)

The discovery of the Gamma-Ray Sky

IL NUOVO CIMENTO Vol. VII, N. 6 16 Marzo 1958

On Gamma-Ray Astronomy.

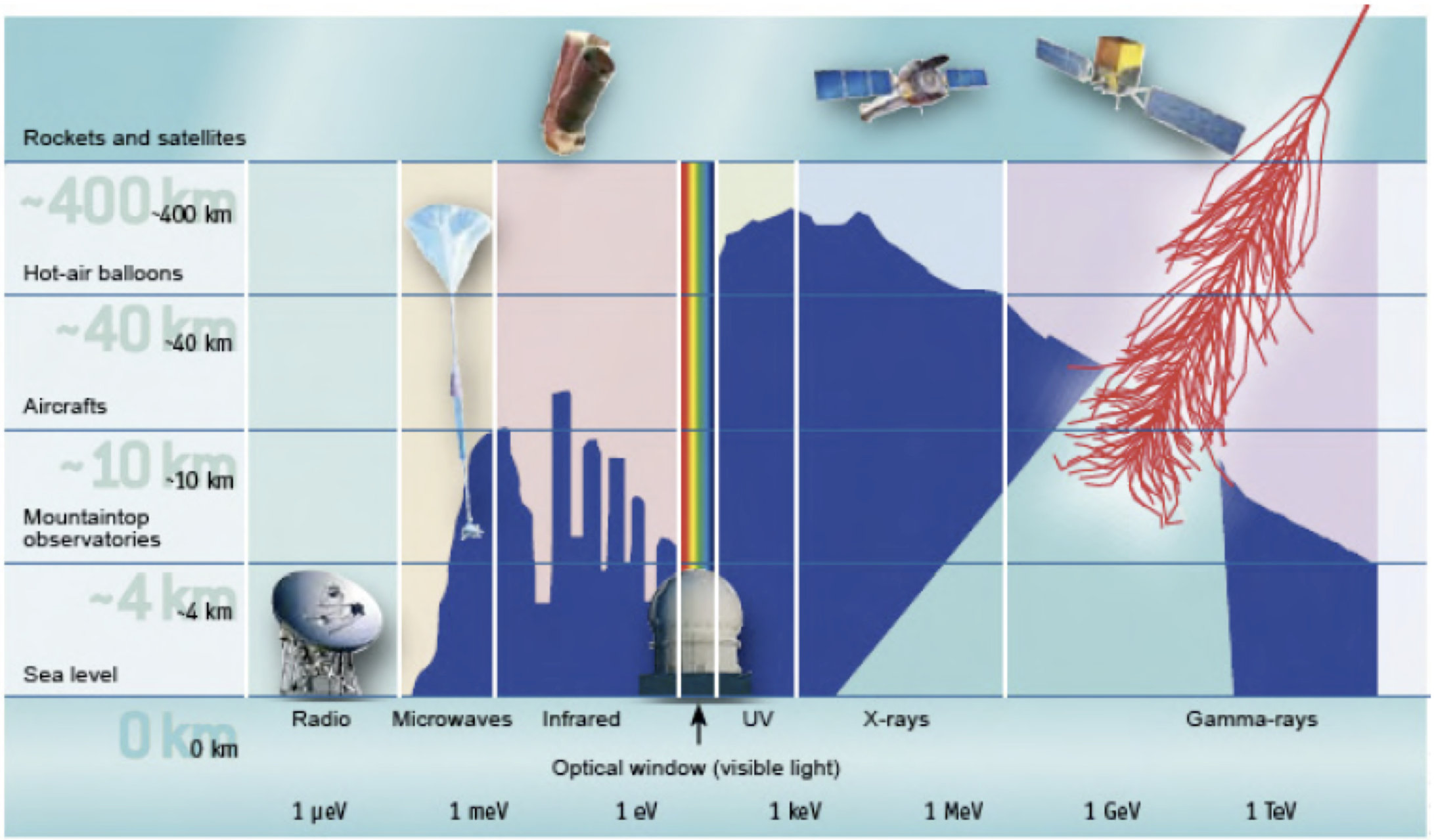
P. MORRISON
Department of Physics, Cornell University - Ithaca, N. Y.

(ricevuto il 22 Dicembre 1957)

Summary. — Photons in the visible range form the basis of astronomy. They move in straight lines, which preserves source information, but they arise only very indirectly from nuclear or high-energy processes. Cosmic-ray particles, on the other hand, arise directly from high-energy processes in astronomical objects of various classes, but carry no information about source direction. Radio emissions are still more complex in origin. But γ-rays arise rather directly in nuclear or high-energy processes, and yet travel in straight lines. Processes which might give rise to continuous and discrete γ-ray spectra in astronomical objects are described, and possible source directions and intensities are estimated. Present limits were set by observations with little energy or angular discrimination; γ-ray studies made at balloon altitudes, with feasible discrimination, promise valuable information not otherwise attainable.

Extreme High-Energy end of EM spectrum => extreme universe.

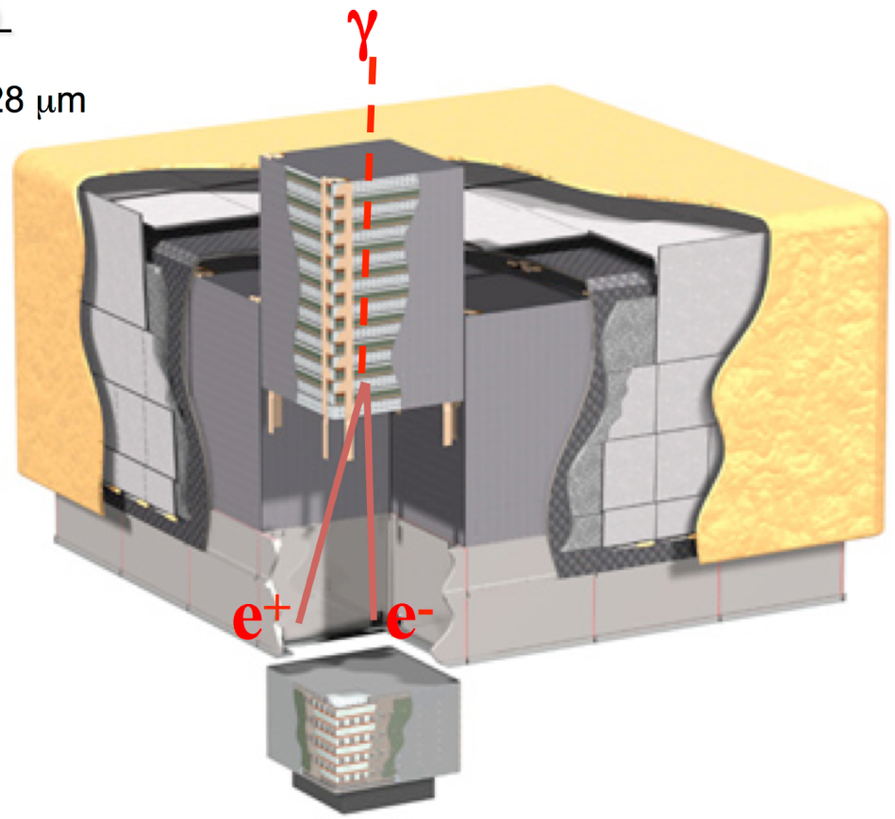
Gamma rays interact with the atmosphere



=> GeV (HE) detection requires satellites; TeV (VHE) can be done at ground

Detectors

Precision Si-strip Tracker (TKR)
18 XY tracking planes
Single-sided silicon strip detectors 228 μm pitch, 8.8 10^5 channels
Measure the photon direction

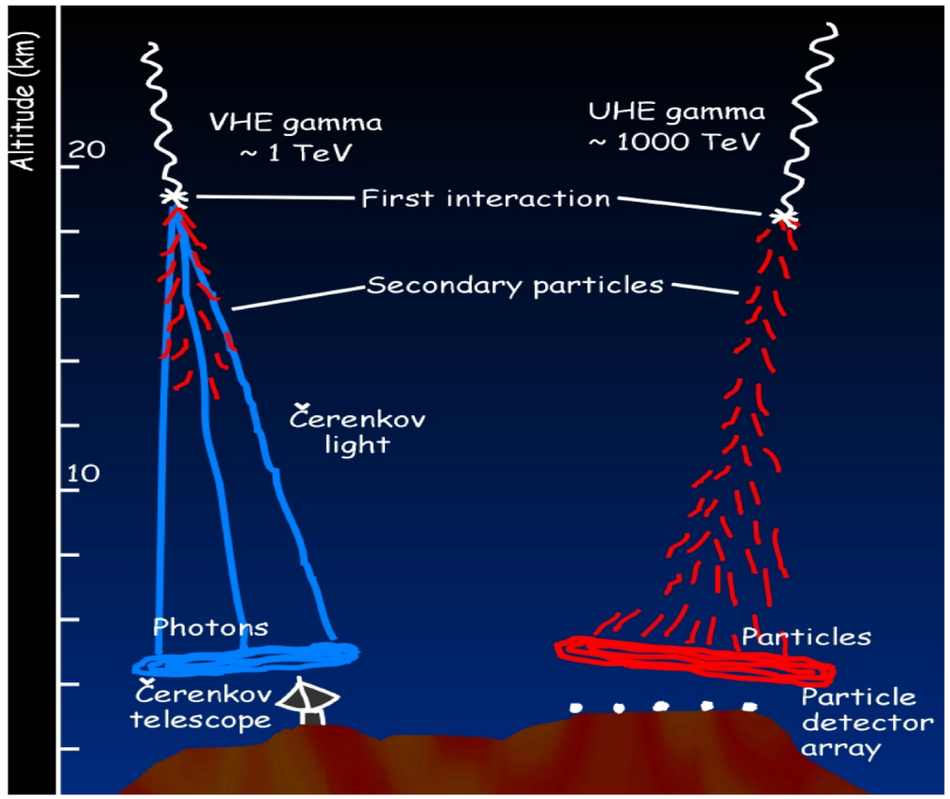


- Satellites (AGILE, Fermi)
  - Silicon tracker (+calorimeter)

- Cherenkov telescopes (HESS, MAGIC, VERITAS)

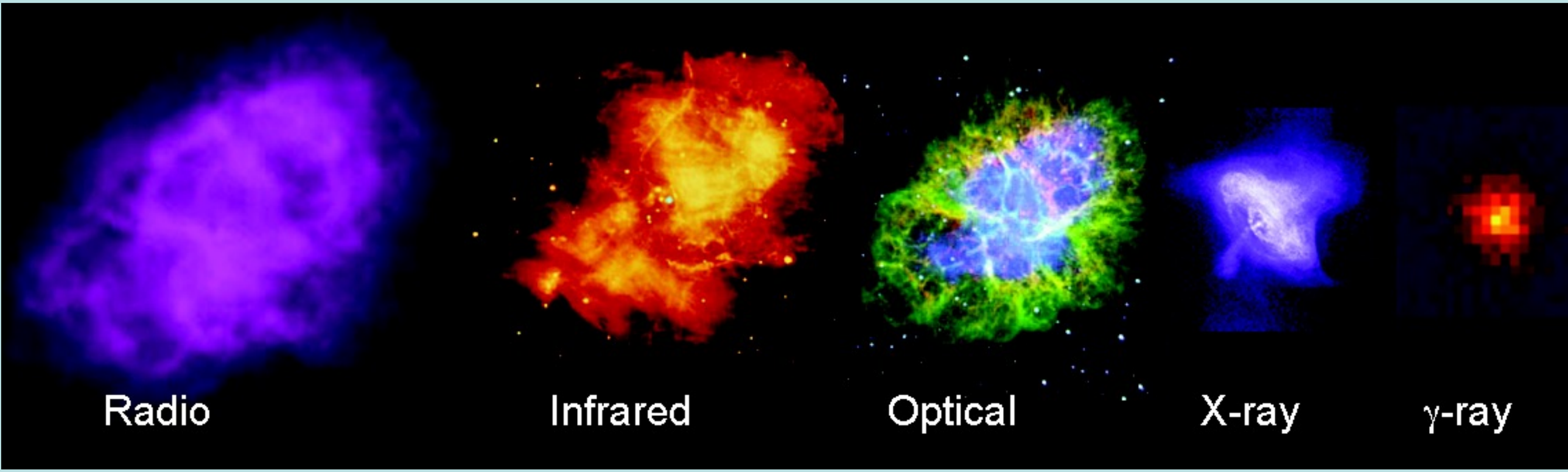
- Extensive Air Shower det. (ARGO): RPC, scintillators

HEP detectors!



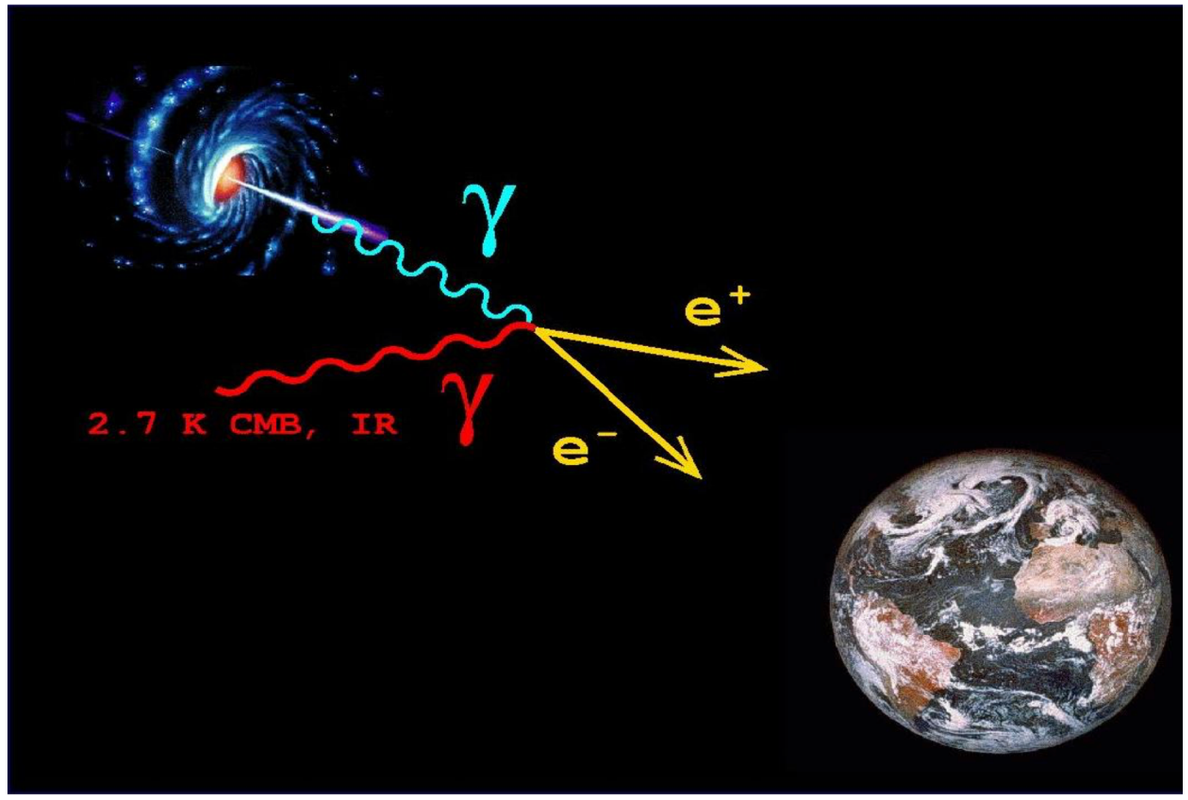
COS' È L'ASTRONOMIA GAMMA?

Ciascuna regione dello spettro elettromagnetico fornisce informazioni su particolari fenomeni dell'Universo e ci mostra diversi aspetti di uno stesso oggetto...



Nebulosa del Granchio a diverse lunghezze d'onda.

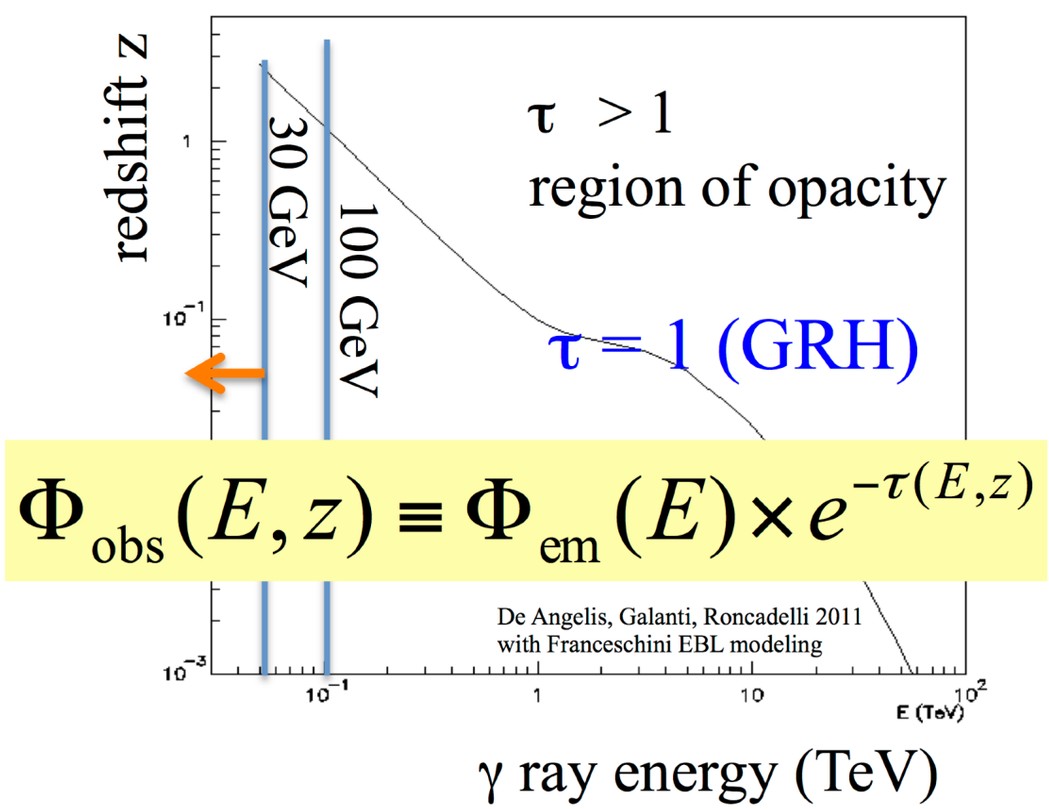
How do gamma rays reach us?



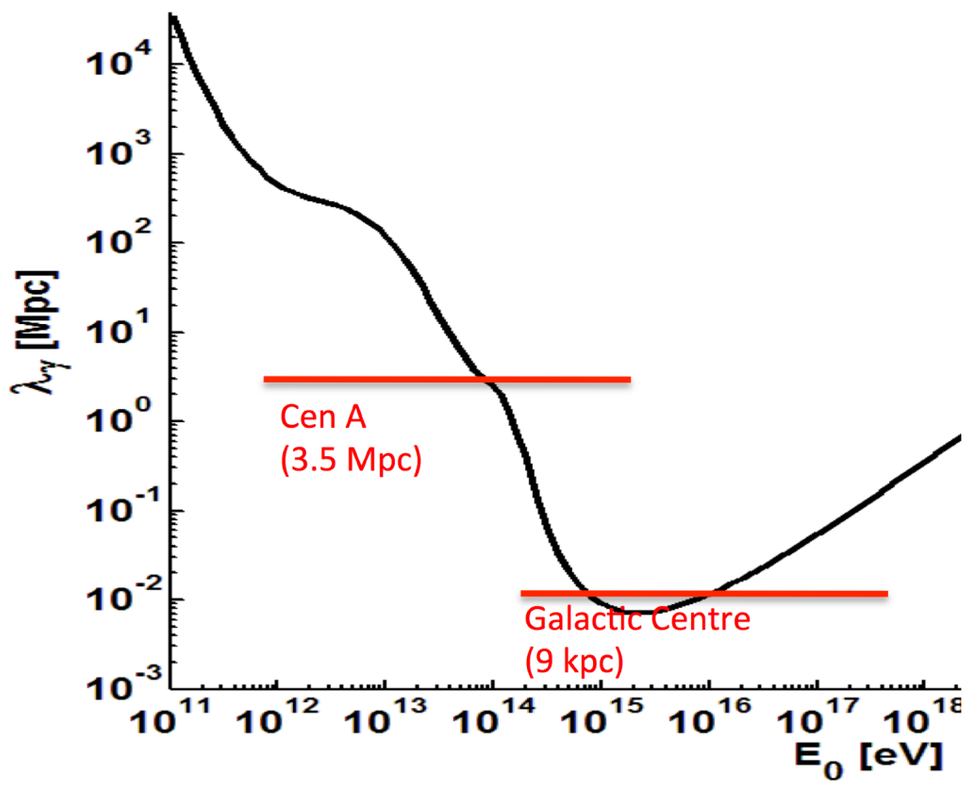
$\gamma_{VHE}\gamma_{bck} \rightarrow e^+e^-$

$$\sigma(\beta) \sim 1.25 \cdot 10^{-25}(1-\beta^2) \cdot \left[2\beta(\beta^2-2) + (3-\beta^4)\ln\left(\frac{1+\beta}{1-\beta}\right)\right] \mathrm{cm}^2$$

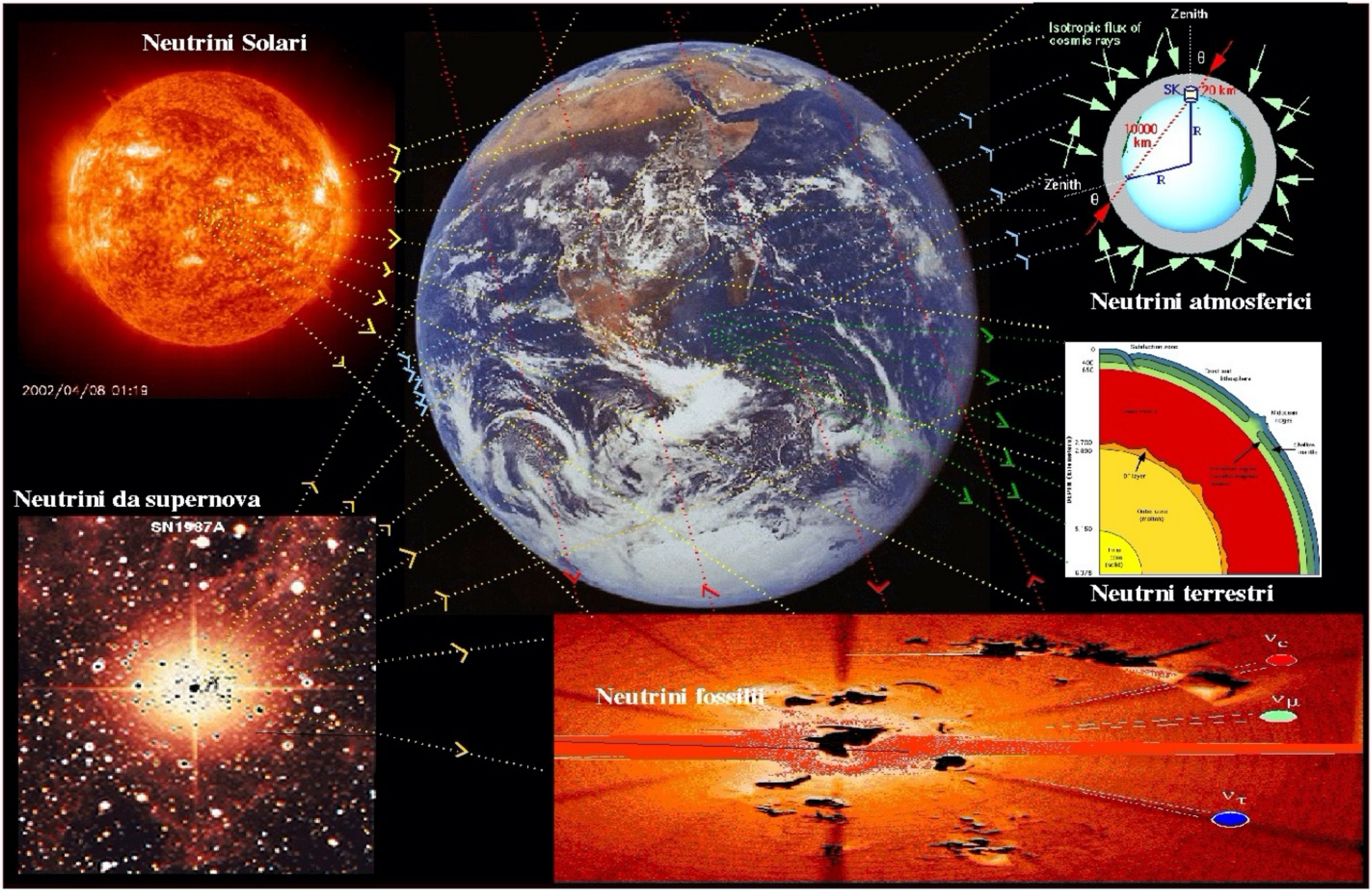
Max for: $\epsilon \simeq \frac{2m_e^2c^4}{E} \simeq \left(\frac{500\,\mathrm{GeV}}{E}\right)\mathrm{eV}$

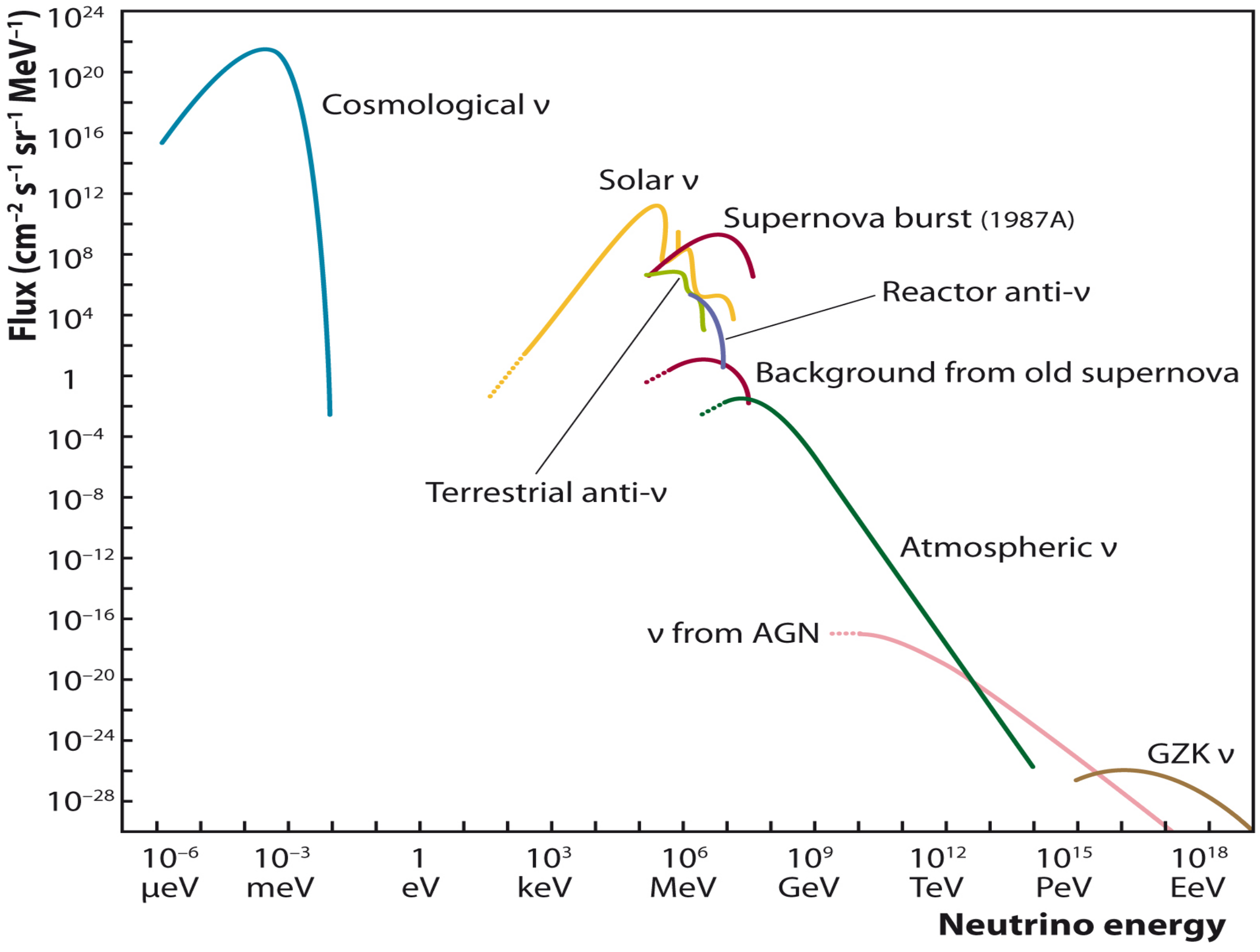


$$\Phi_{obs}(E,z) \equiv \Phi_{em}(E) \times e^{-\tau(E,z)}$$



NEUTRINI


Neutrini Solari
2002/04/08 01:19
Isotropic flux of cosmic rays
Zenith
θ
SK
20 km
10000 km
R
R
Zenith
θ
Neutrini atmosferici
Neutrini da supernova
SN1987A
Neutrni terrestri
Neutrini fossili
ν_e
ν_μ
ν_τ


Flux (cm⁻² s⁻¹ sr⁻¹ MeV⁻¹)
10²⁴
10²⁰
10¹⁶
10¹²
10⁸
10⁴
1
10⁻⁴
10⁻⁸
10⁻¹²
10⁻¹⁶
10⁻²⁰
10⁻²⁴
10⁻²⁸
Cosmological ν
Solar ν
Supernova burst (1987A)
Reactor anti-ν
Background from old supernova
Terrestrial anti-ν
Atmospheric ν
ν from AGN
GZK ν
10⁻⁶ μeV
10⁻³ meV
1 eV
10³ keV
10⁶ MeV
10⁹ GeV
10¹² TeV
10¹⁵ PeV
10¹⁸ EeV
Neutrino energy

X

What makes high-energy cosmic ν exciting?

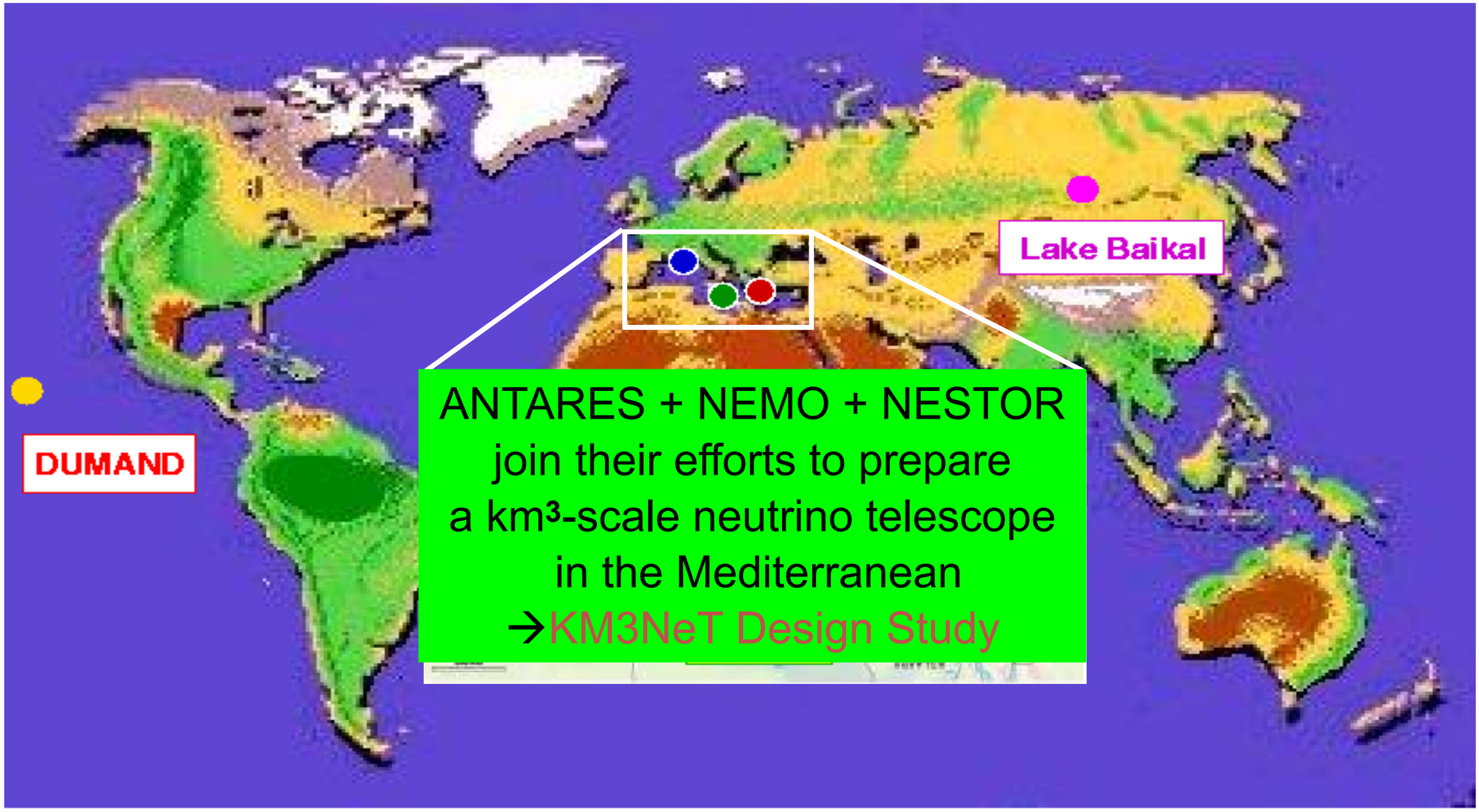
1. They have the highest energies (TeV–ZeV)
   Particle: Probe physics at new energy scales
   Astro: Probe the highest-energy non-thermal astrophysical sources

2. They have the longest baselines (kpc–Gpc)
   Particle: Tiny new-physics effects can accumulate and become observable
   Astro: Bring information from high redshifts ($z > 1$)

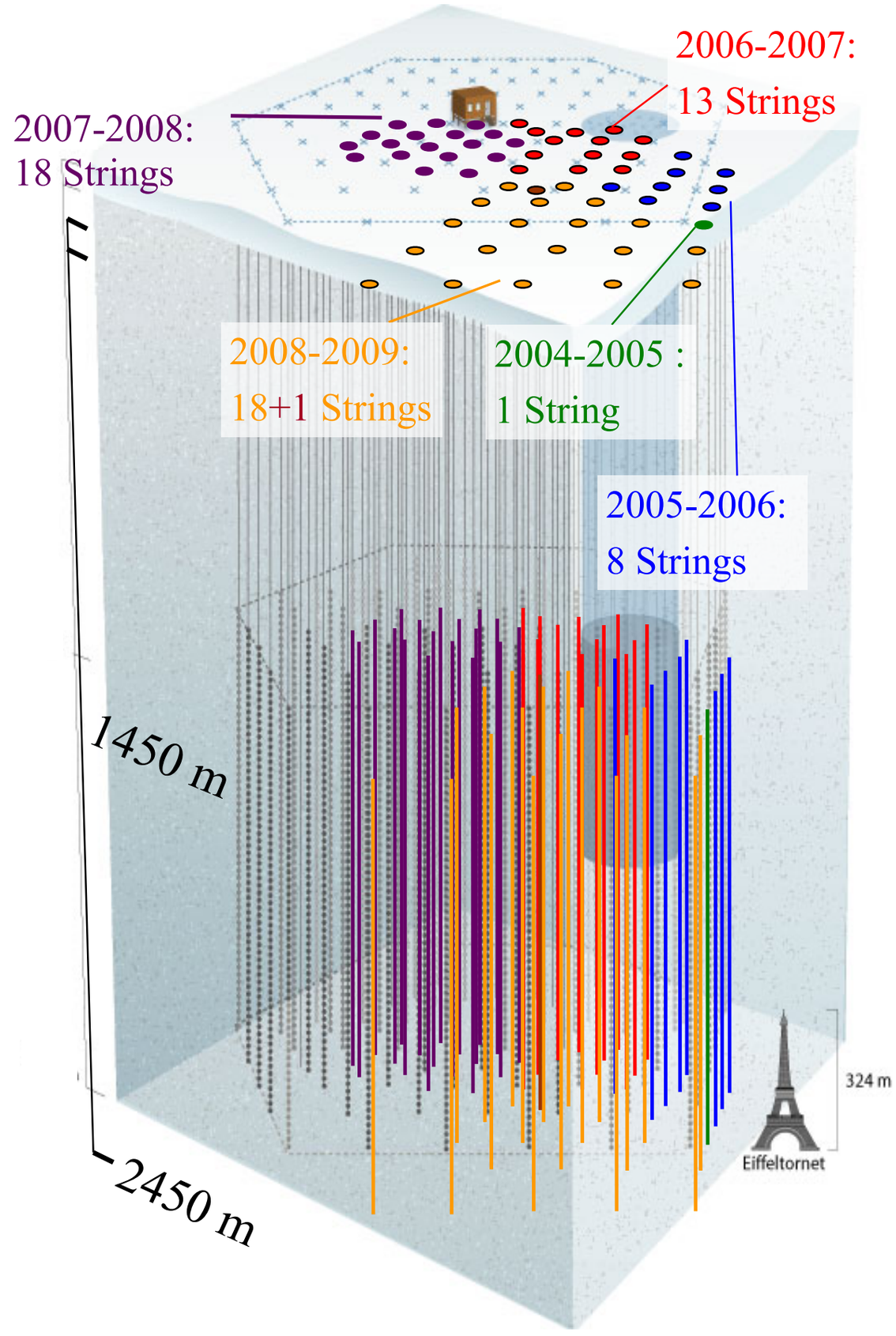
3. Neutrinos are weakly interacting
   Particle: New-physics effects may stand out more clearly
   Astro: Bring untainted information from distant sources

4. Neutrinos have a unique quantum number: flavor
   Particle: Versatile probe of flavor-sensitive new physics
   Astro: Can reveal the neutrino production mechanism

The Neutrino Telescope World Map

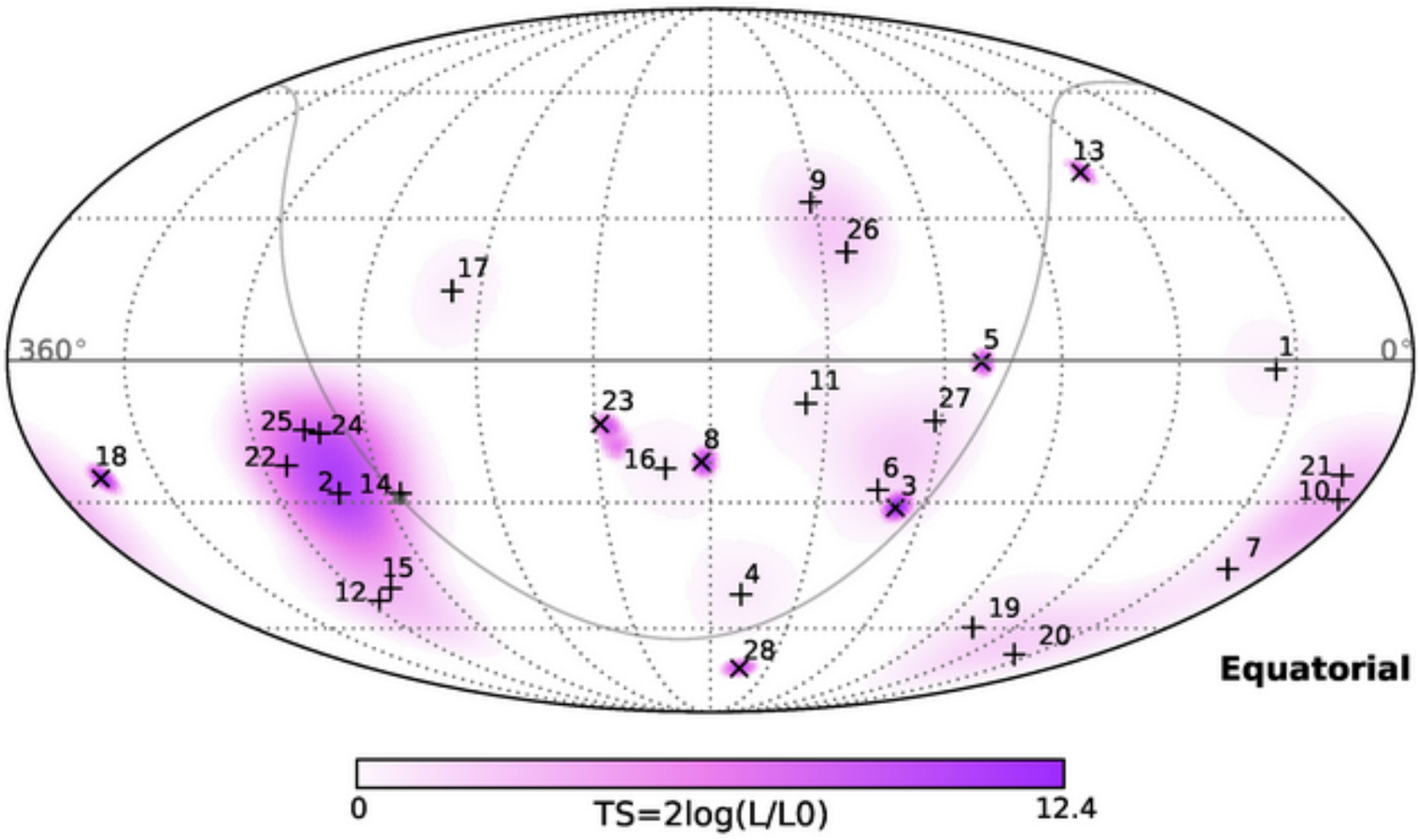


IceCube @ South Pole



X

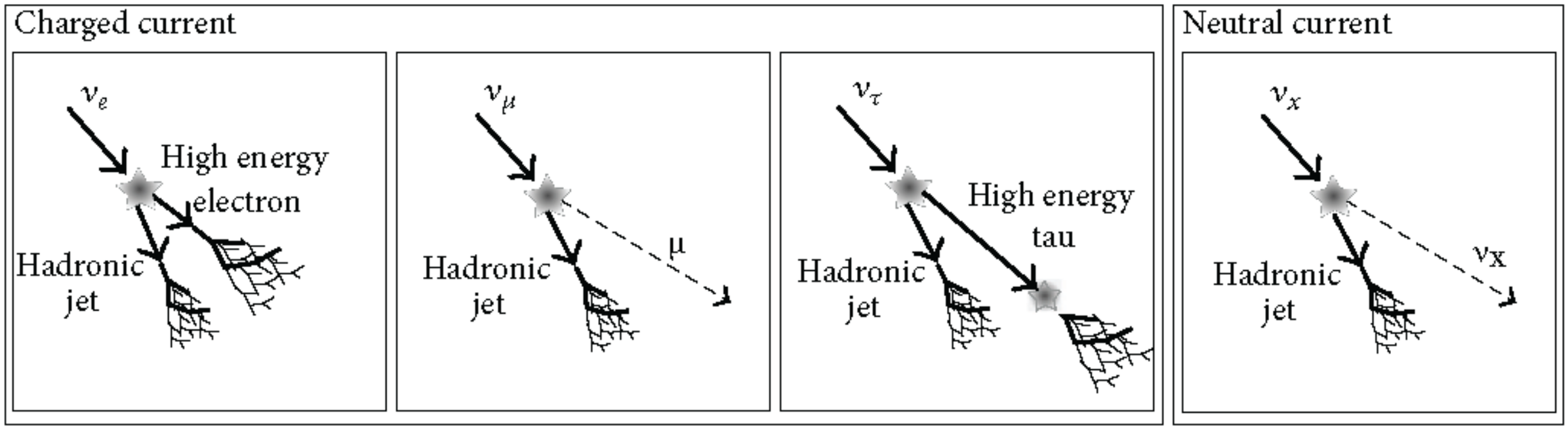
Neutrino sky-map

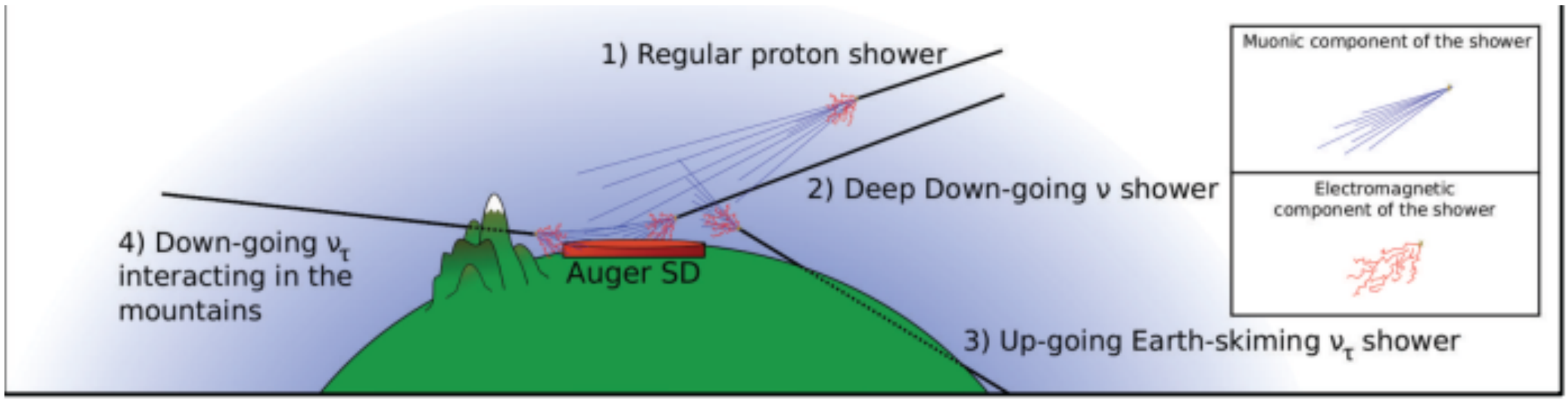


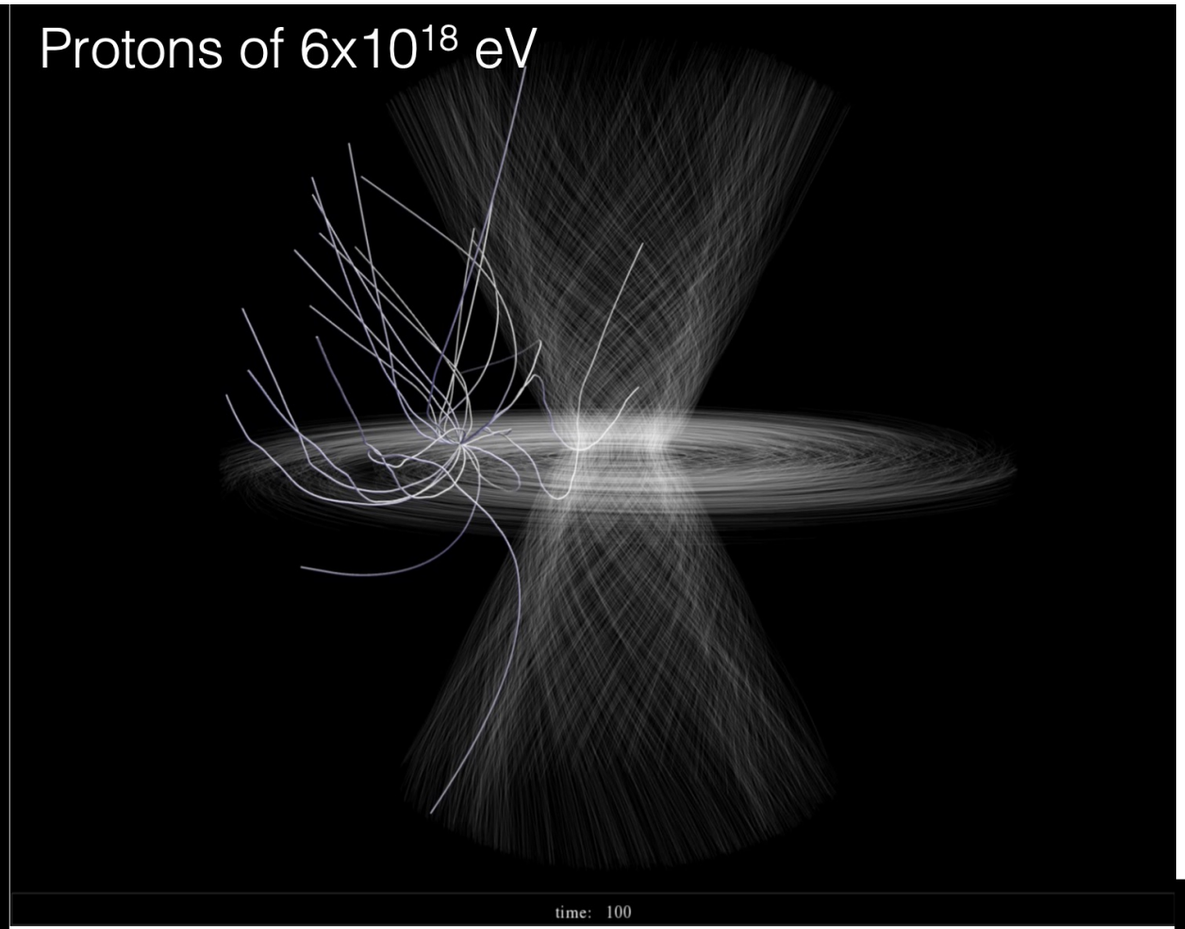
Skymap in equatorial coordinates of the point-source analysis. The most signicant cluster consists of five events—all showers and including the second-highest energy event in the sample—with a final significance of 8%. This is not sufficient to identify any neutrino sources from the clustering study. The galactic plane is shown as a gray line with the galactic center denoted as a filled gray square.

The coordinates shown in the map are the Test Statistic value from a maximized likelihood analysis. TS= 2 log(L=L0), where L is the maximized likelihood for a point source hypothesis at each point in the sky and L0 the one for the null hypothesis. The map reflects any excess concentration of events relative to a

Neutrinos


Charged current
ν_e
High energy electron
Hadronic jet
ν_μ
μ
Hadronic jet
ν_τ
High energy tau
Hadronic jet
Neutral current
ν_x
νx
Hadronic jet

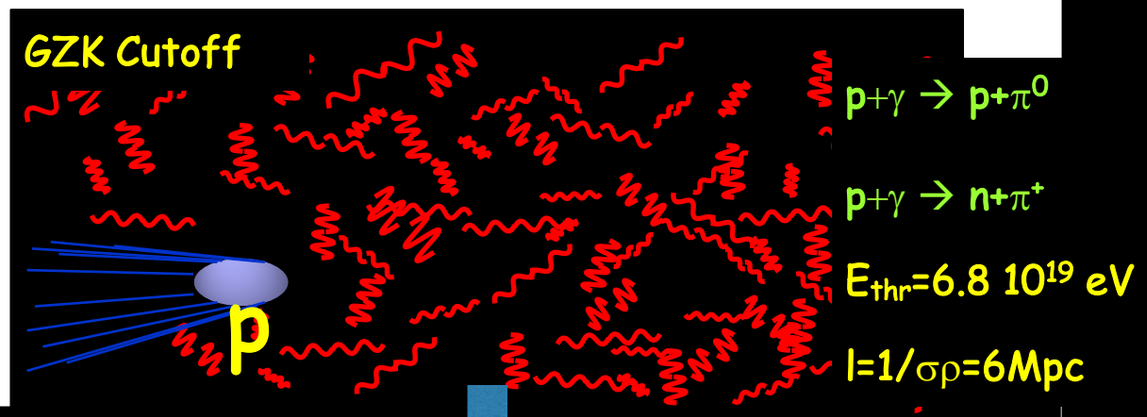

1) Regular proton shower
2) Deep Down-going ν shower
3) Up-going Earth-skiming ν_τ shower
4) Down-going ν_τ interacting in the mountains
Auger SD
Muonic component of the shower
Electromagnetic component of the shower

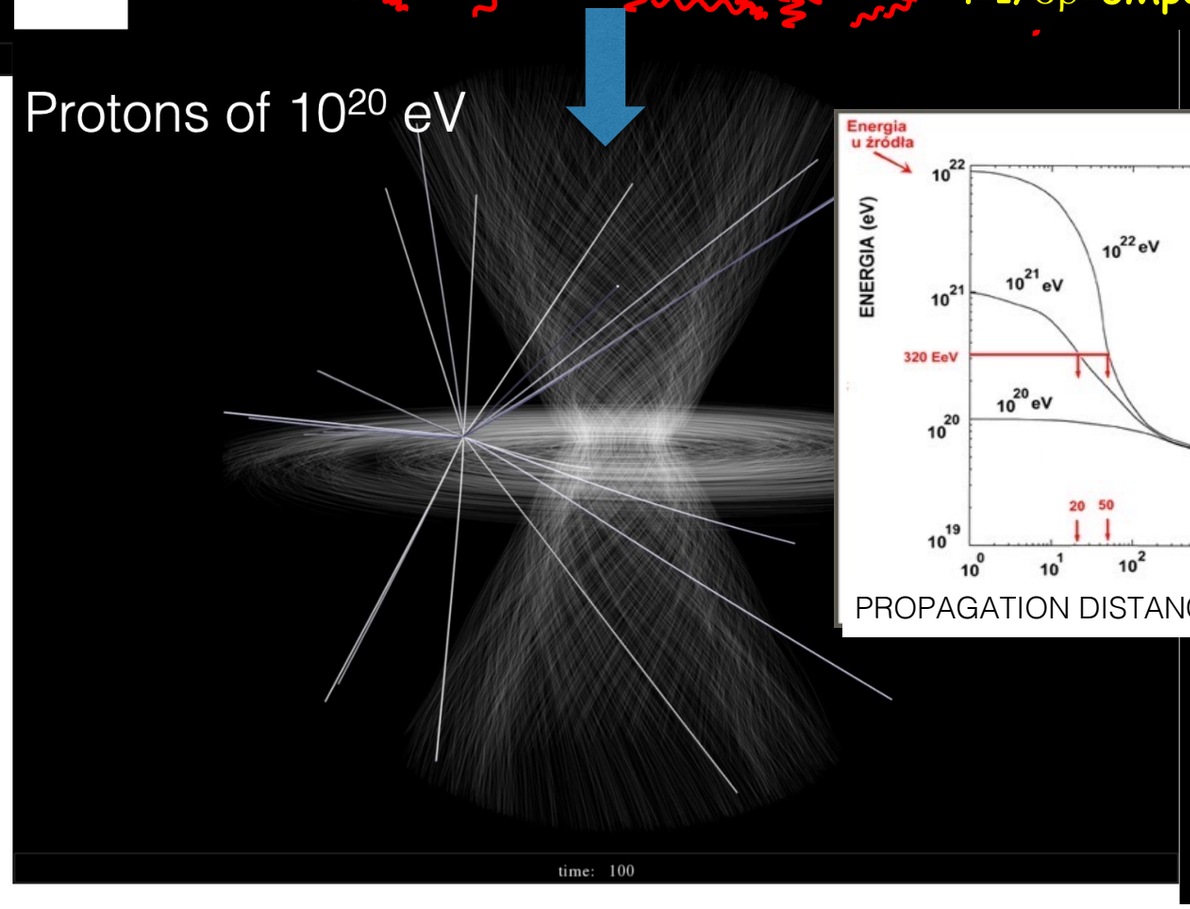


(G. Farrar & J. Sandstrom, NASA)

POSSIBLE TO TRACK BACK THE SOURCES →

NOT POSSIBLE TO TRACK BACK THE SOURCES ←





Cosmic rays with energy E> 7·10^19 eV must have their sources within 50Mpc