

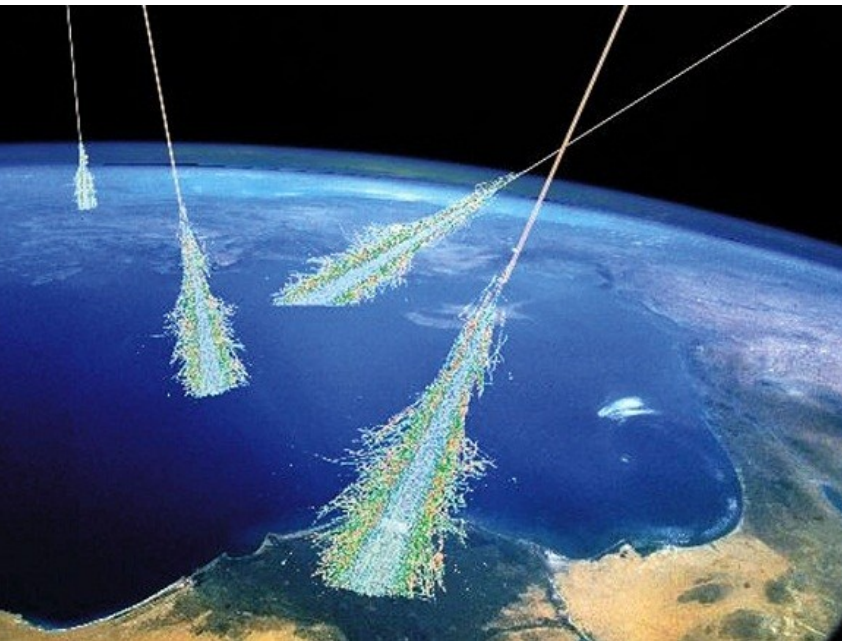
PIERRE
AUGER
OBSERVATORY



cherenkov
telescope
array

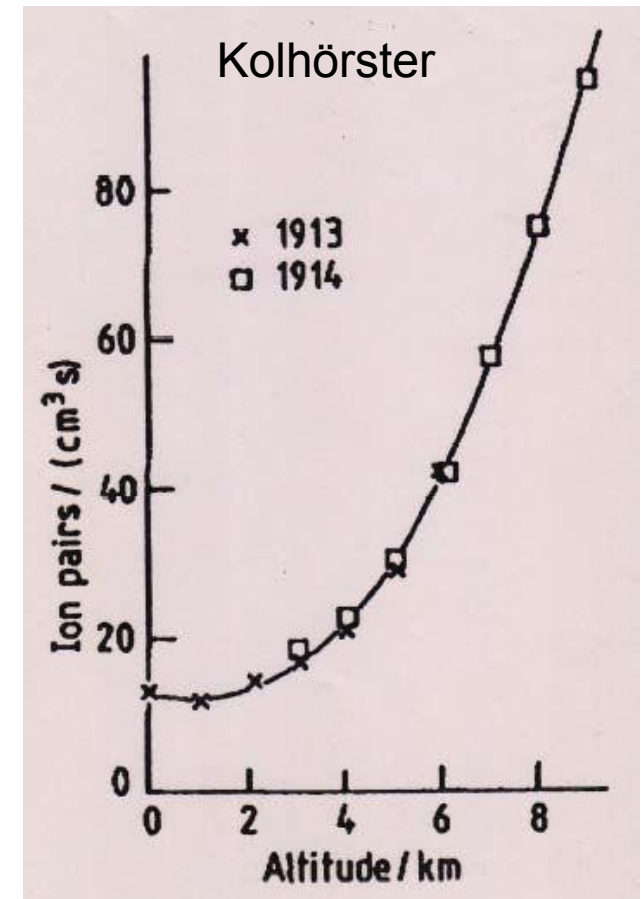


Astroparticules au LPNHE

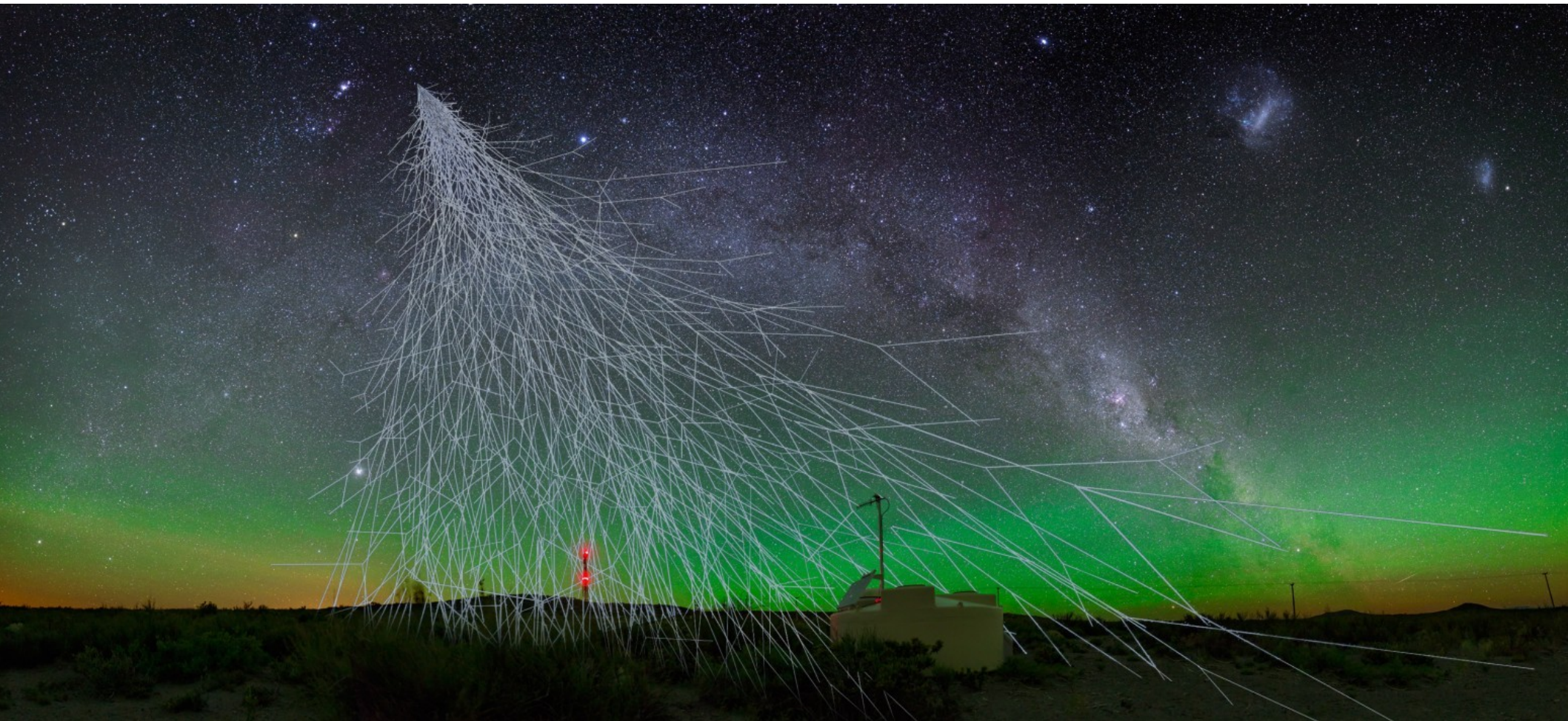


J.-P. Lenain (LPNHE, CNRS/IN2P3)

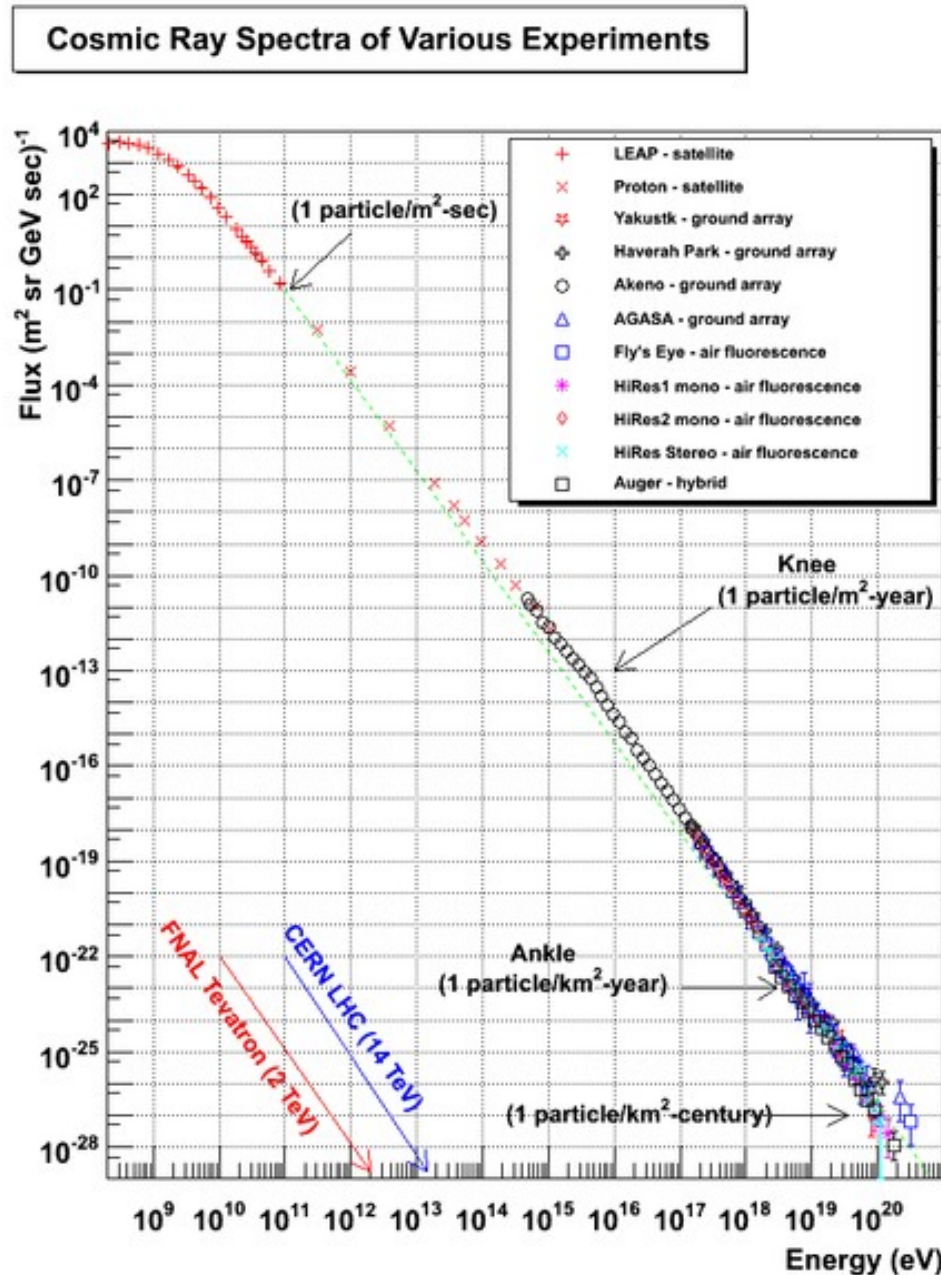
Rayons cosmiques



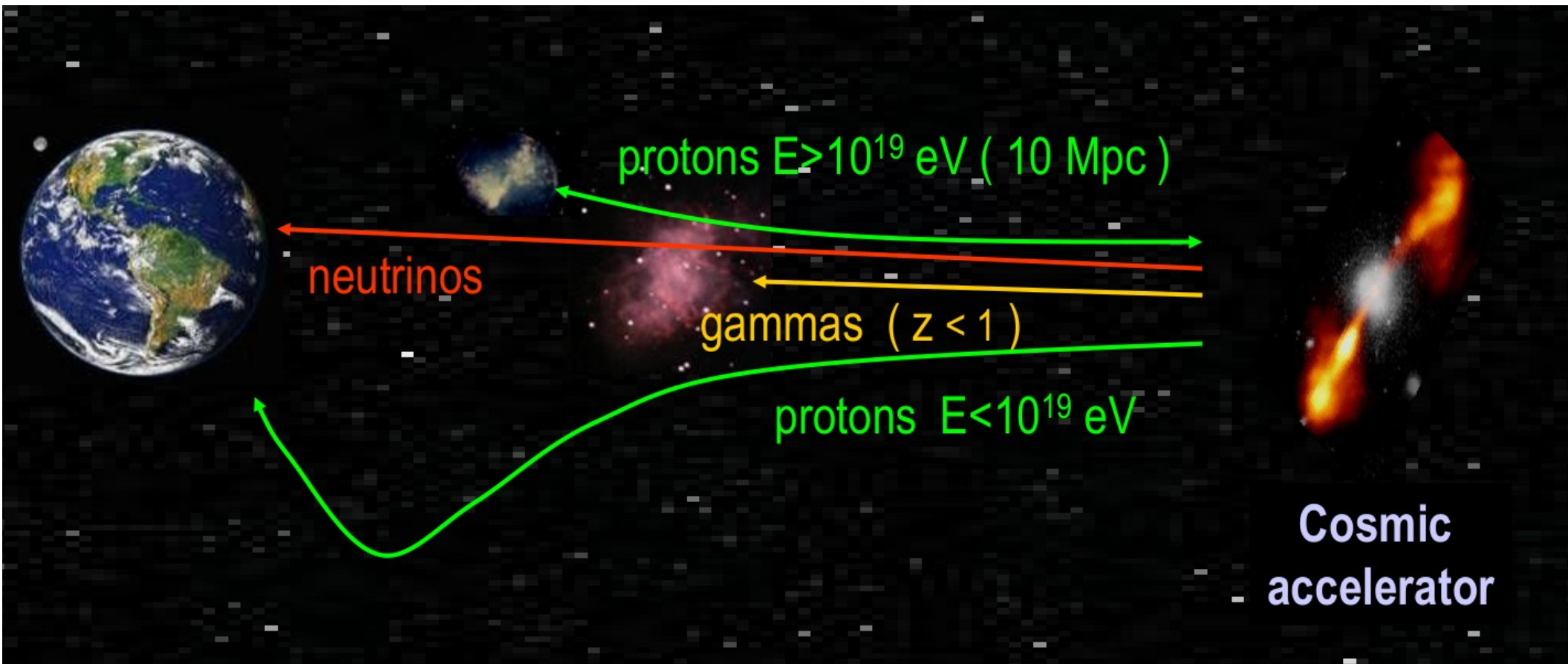
Rayons cosmiques et gerbes atmosphériques



Spectre des rayons cosmiques



Propagation

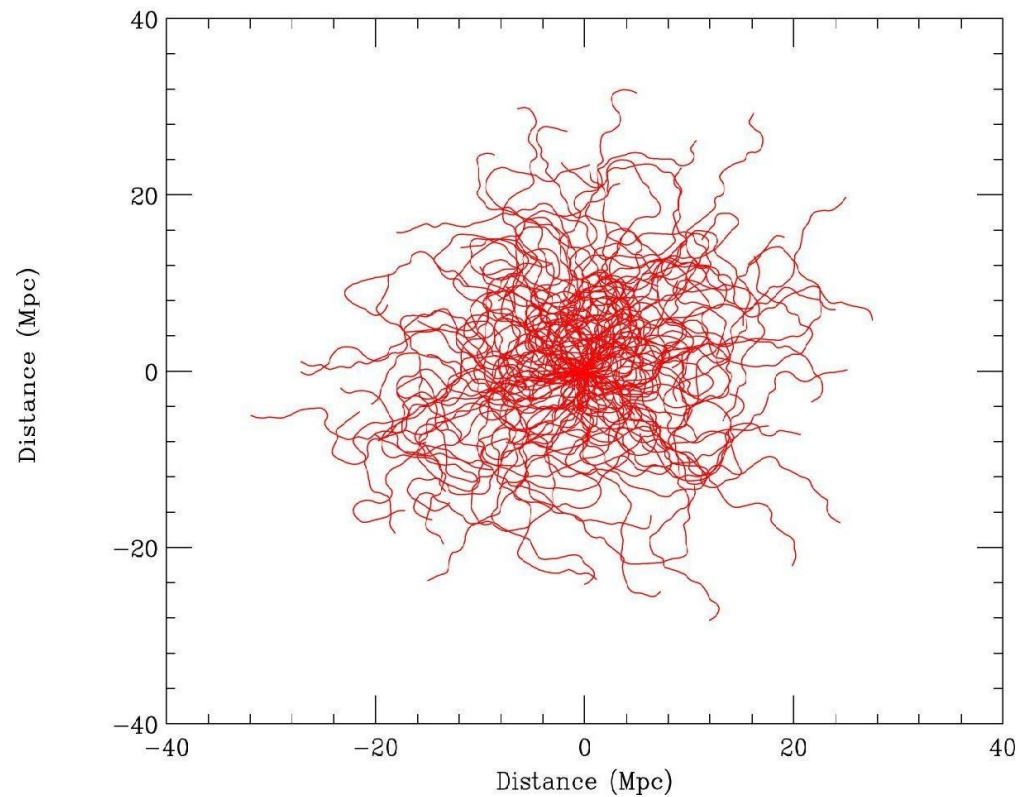


Photons: Absorbés par poussières et rayonnement (par ex. création de paires sur CMB)

Protons/noyaux: Déviation par champ magnétique, absorbés par CMB (effet GZK)

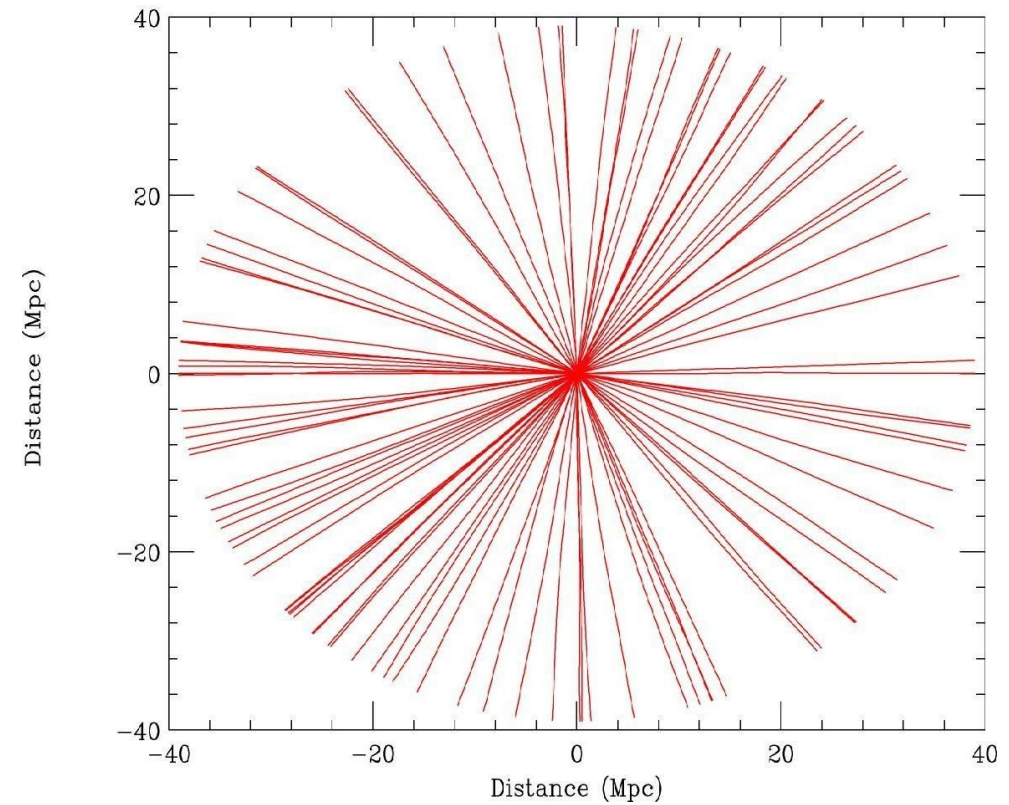
Propagation

Trajectories of 10^{18} eV protons in random nanogauss field with 1Mpc cell size



10^{18} eV

Trajectories of 10^{20} eV protons in random nanogauss field with 1Mpc cell size

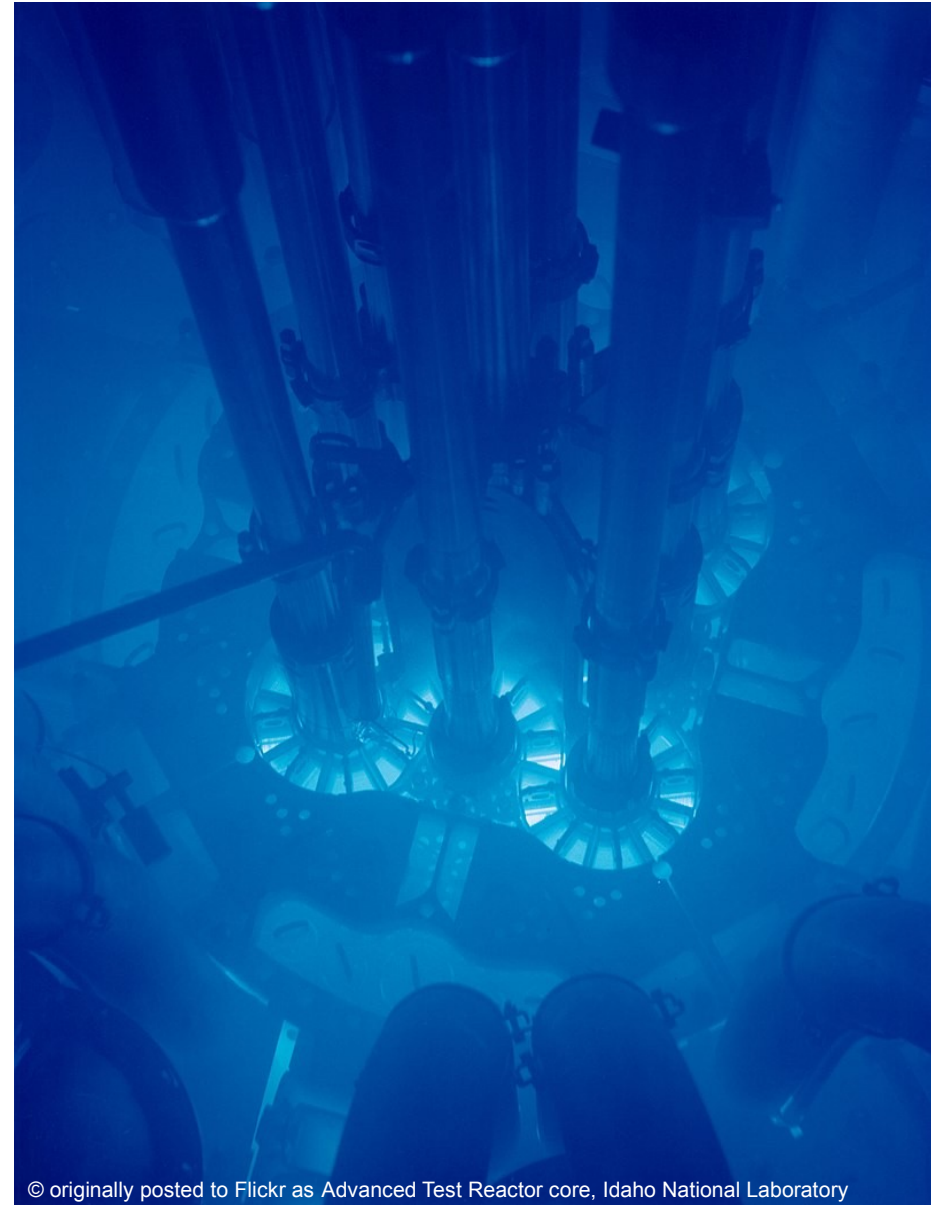
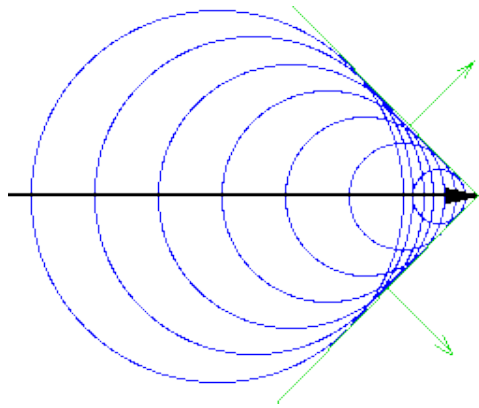


10^{20} eV

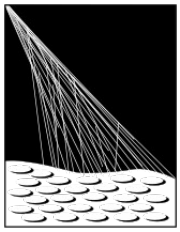
Le rayonnement Cherenkov

- Particules avec $\frac{c}{n} < v < c$

~ onde de choc photonique

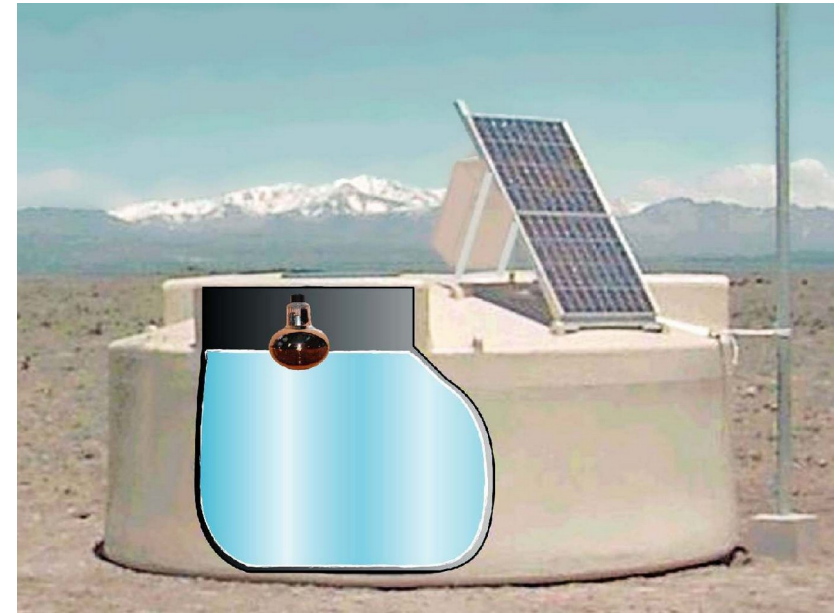
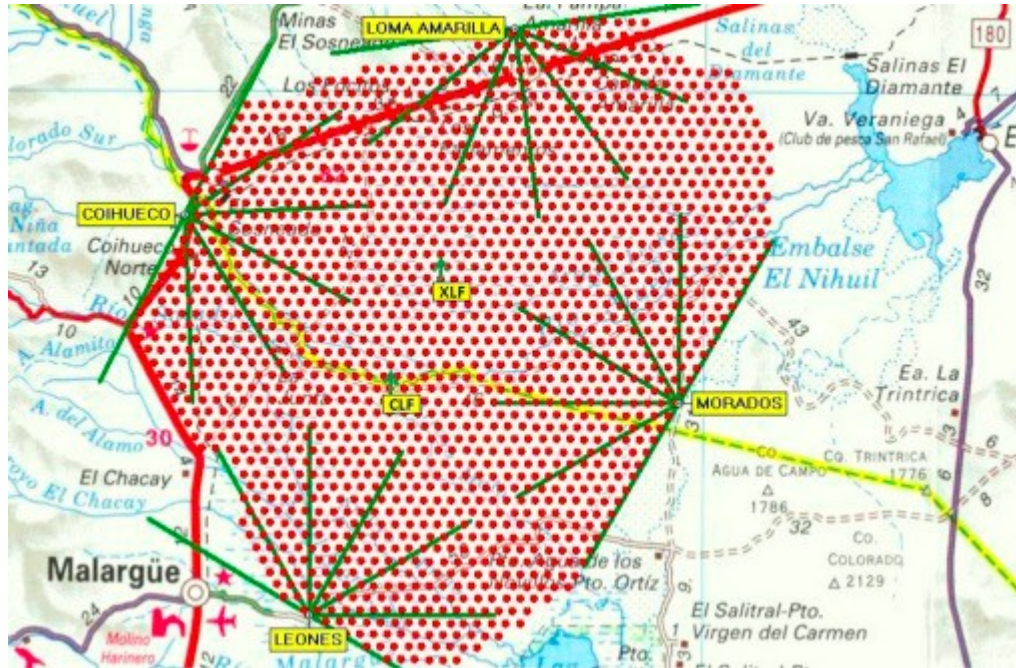


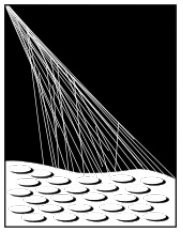
© originally posted to Flickr as Advanced Test Reactor core, Idaho National Laboratory



PIERRE
AUGER
OBSERVATORY

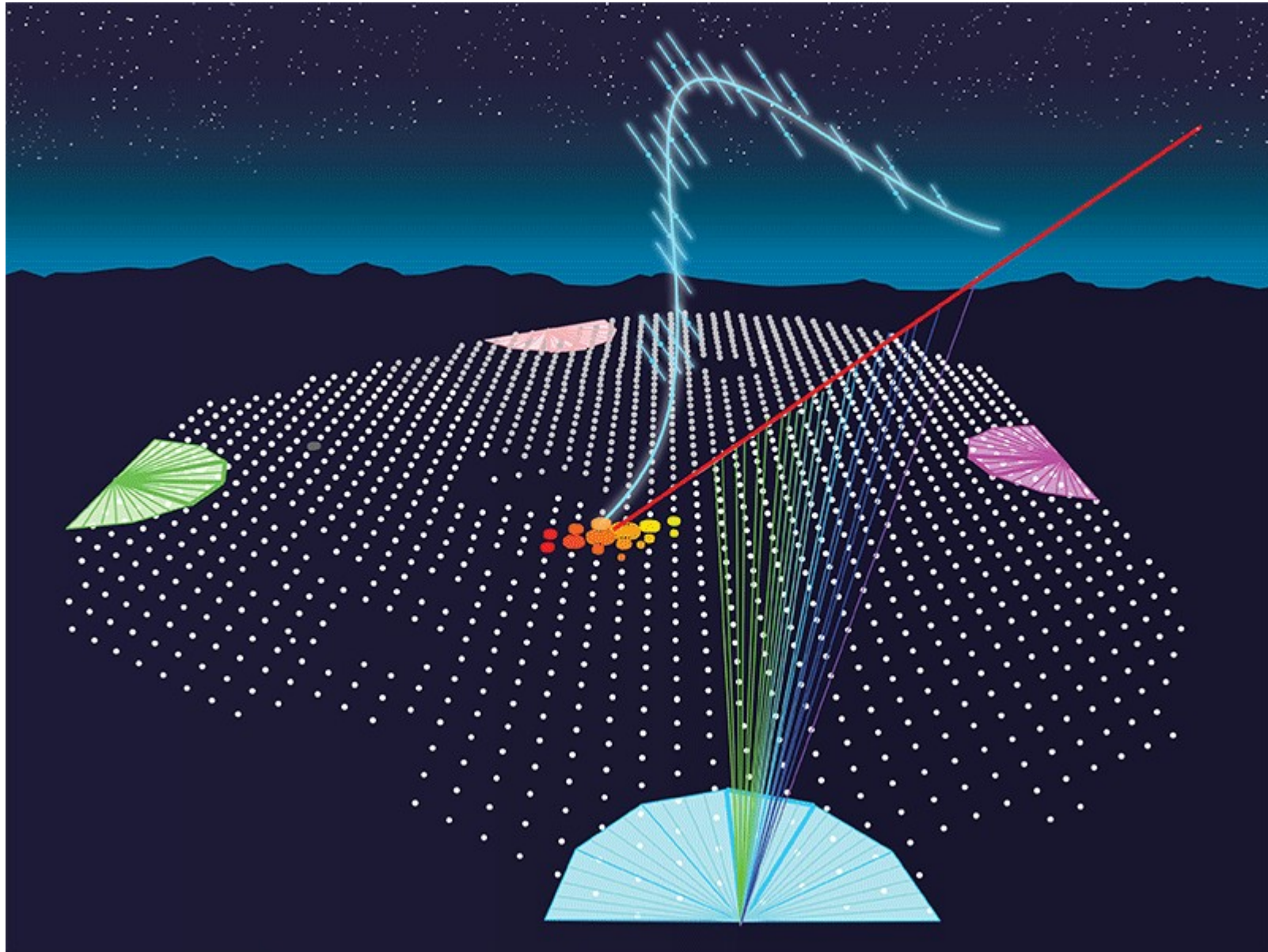
L'observatoire Pierre Auger

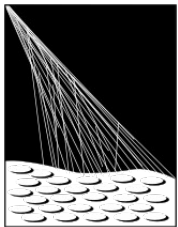




PIERRE
AUGER
OBSERVATORY

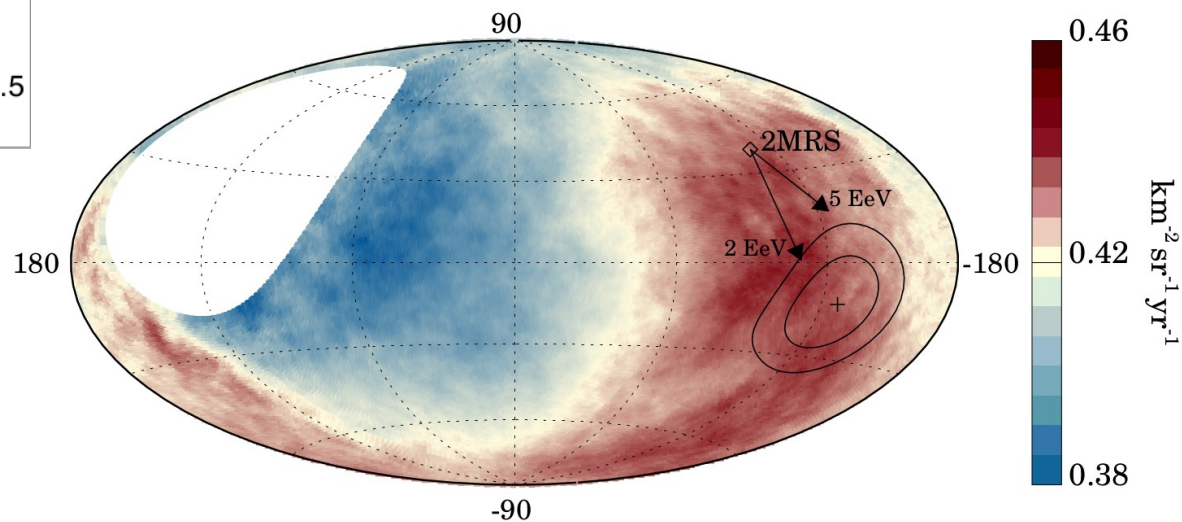
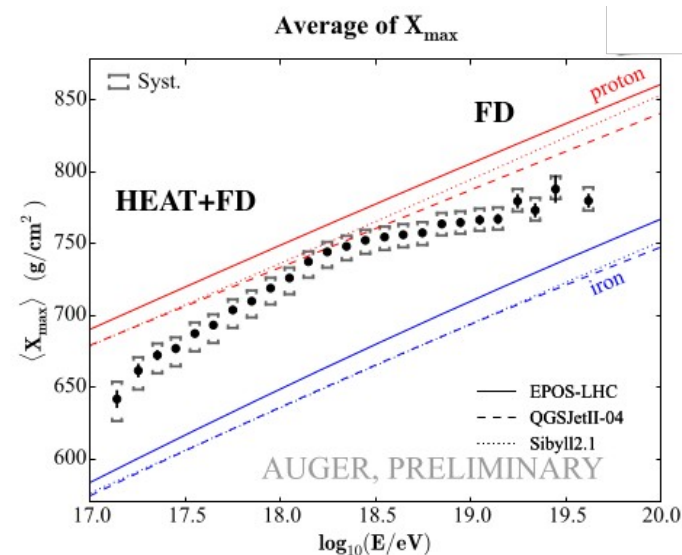
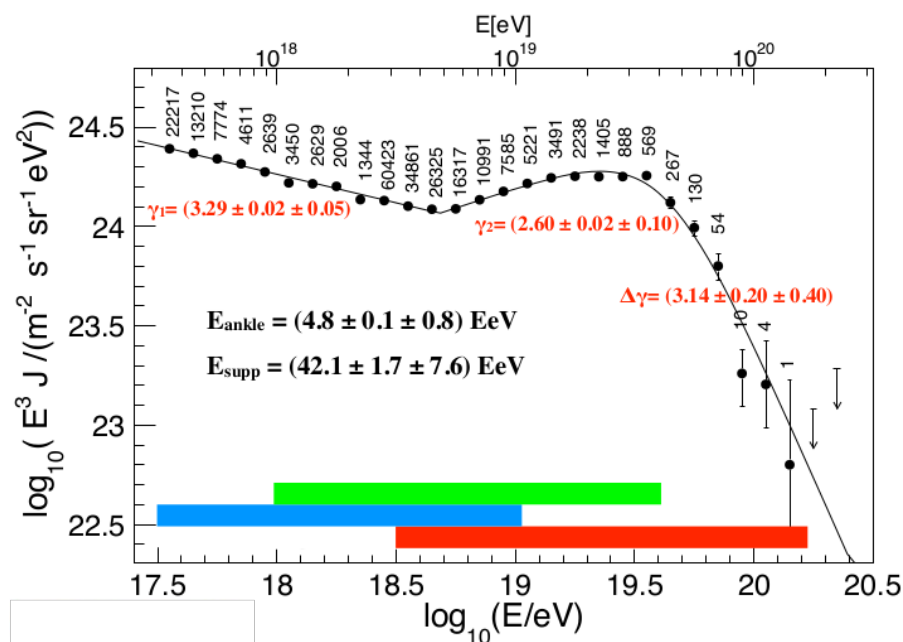
L'observatoire Pierre Auger





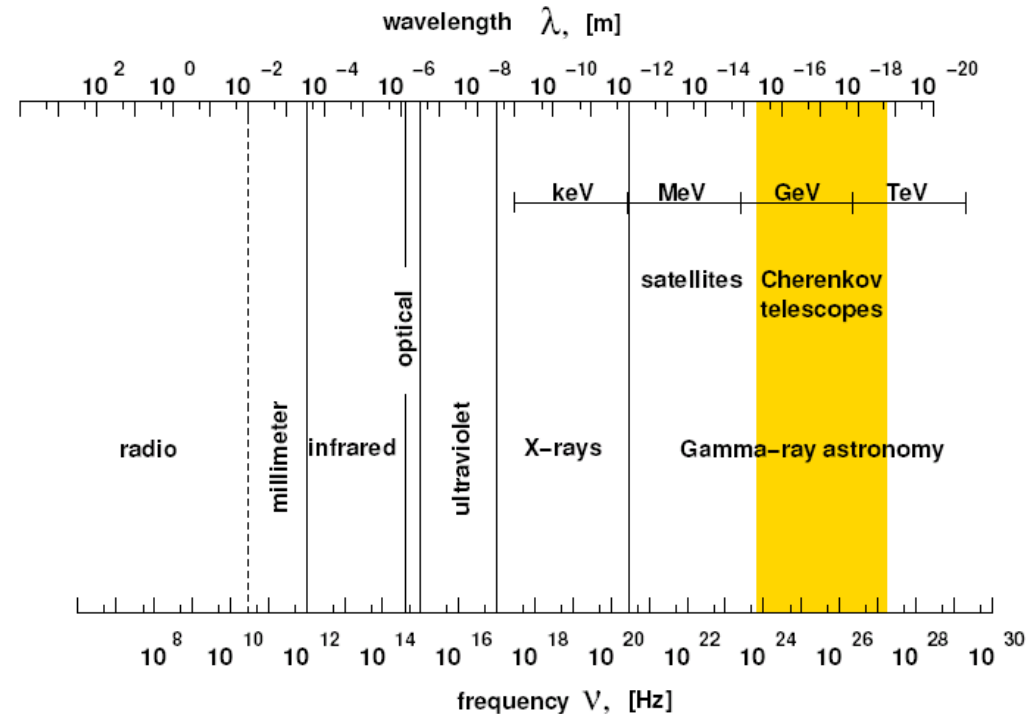
PIERRE
AUGER
OBSERVATORY

Auger: résultats



Auger collaboration (*Science*, 2017)
 $E > 8 \times 10^{18} \text{ eV}$

Le domaine des très hautes énergies



- VHE: $E > 100$ GeV.
- Satellites ($E < 100$ GeV):
“Basses” et hautes énergies
(faible surface de collection)
- Instruments au sol
(grande surface de collection)
Technique Cherenkov atmosphérique.



UHE ($E \sim 10^{19}$ eV)



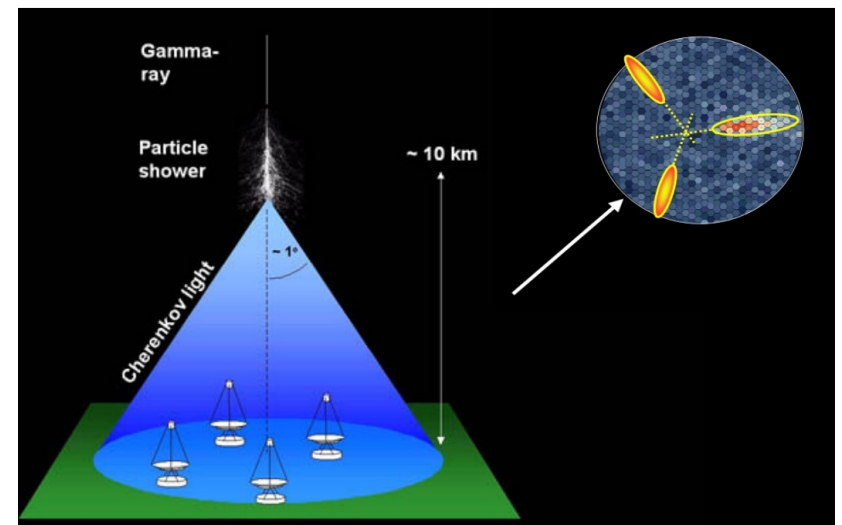
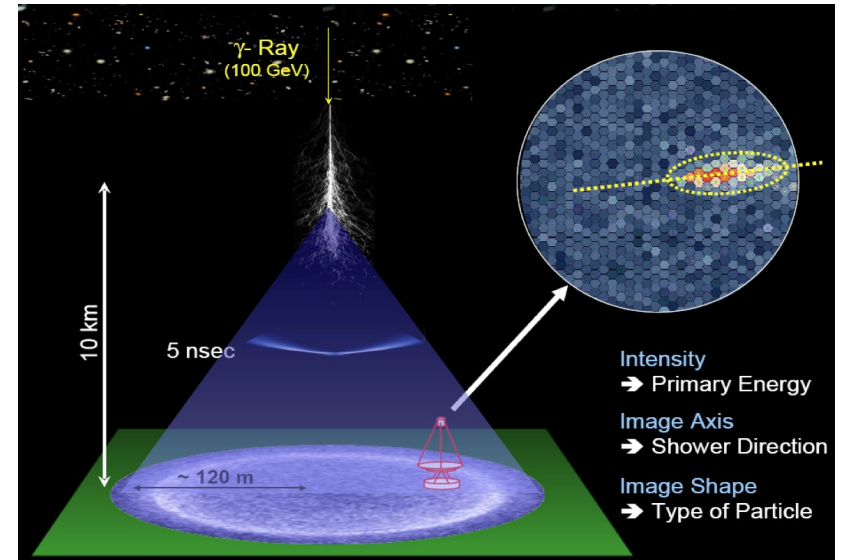
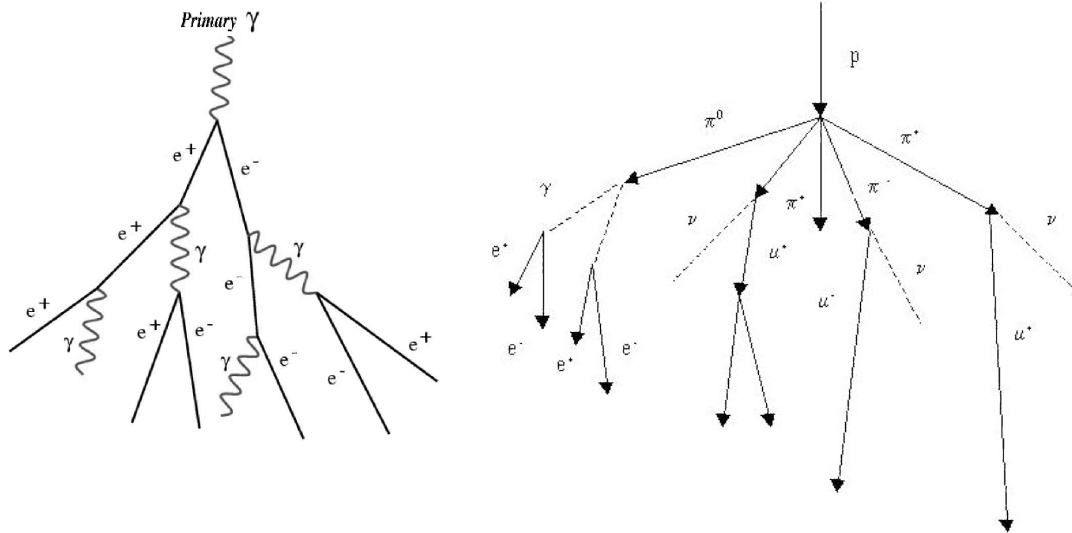
VHE ($E \sim 10^{12}$ eV)

High Energy Stereoscopic System (H.E.S.S.)



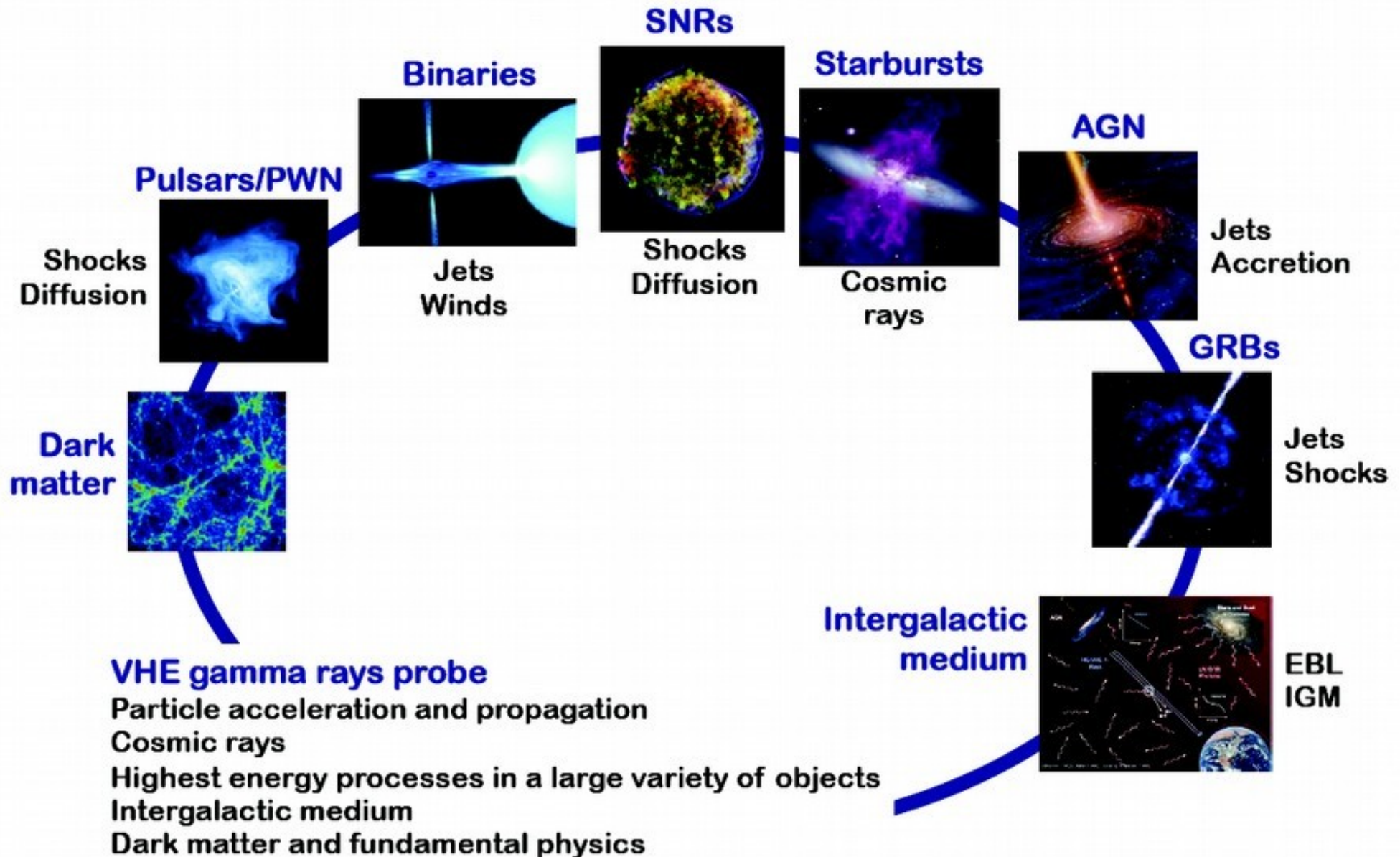
Principe de détection de rayons γ au sol

- Imagerie Cherenkov

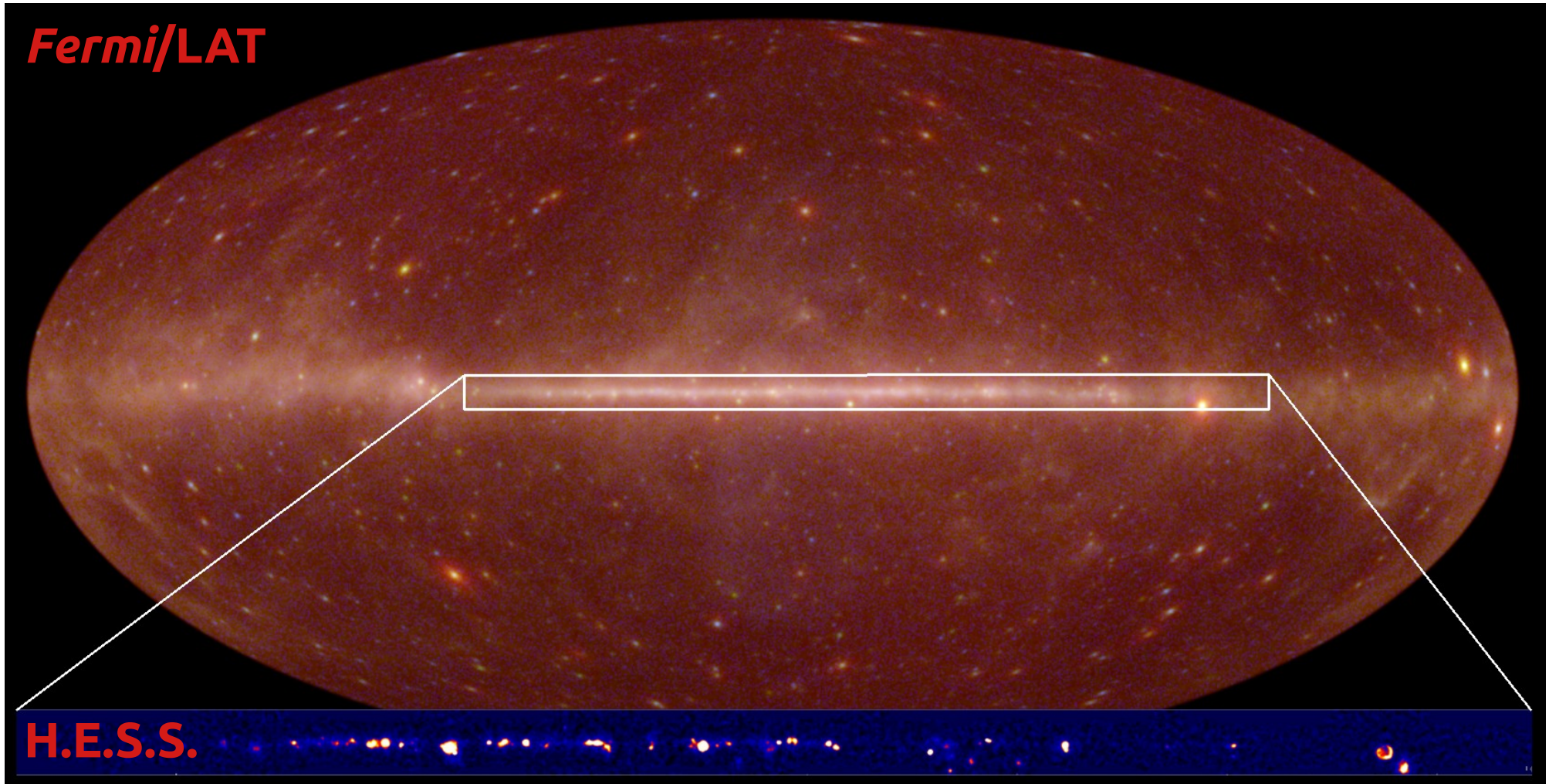


- Stéréoscopie

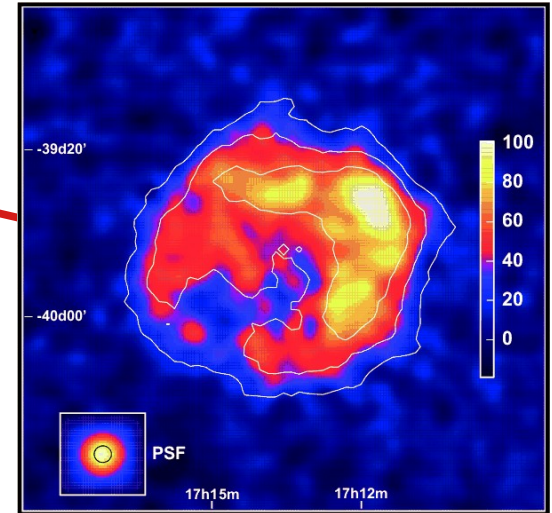
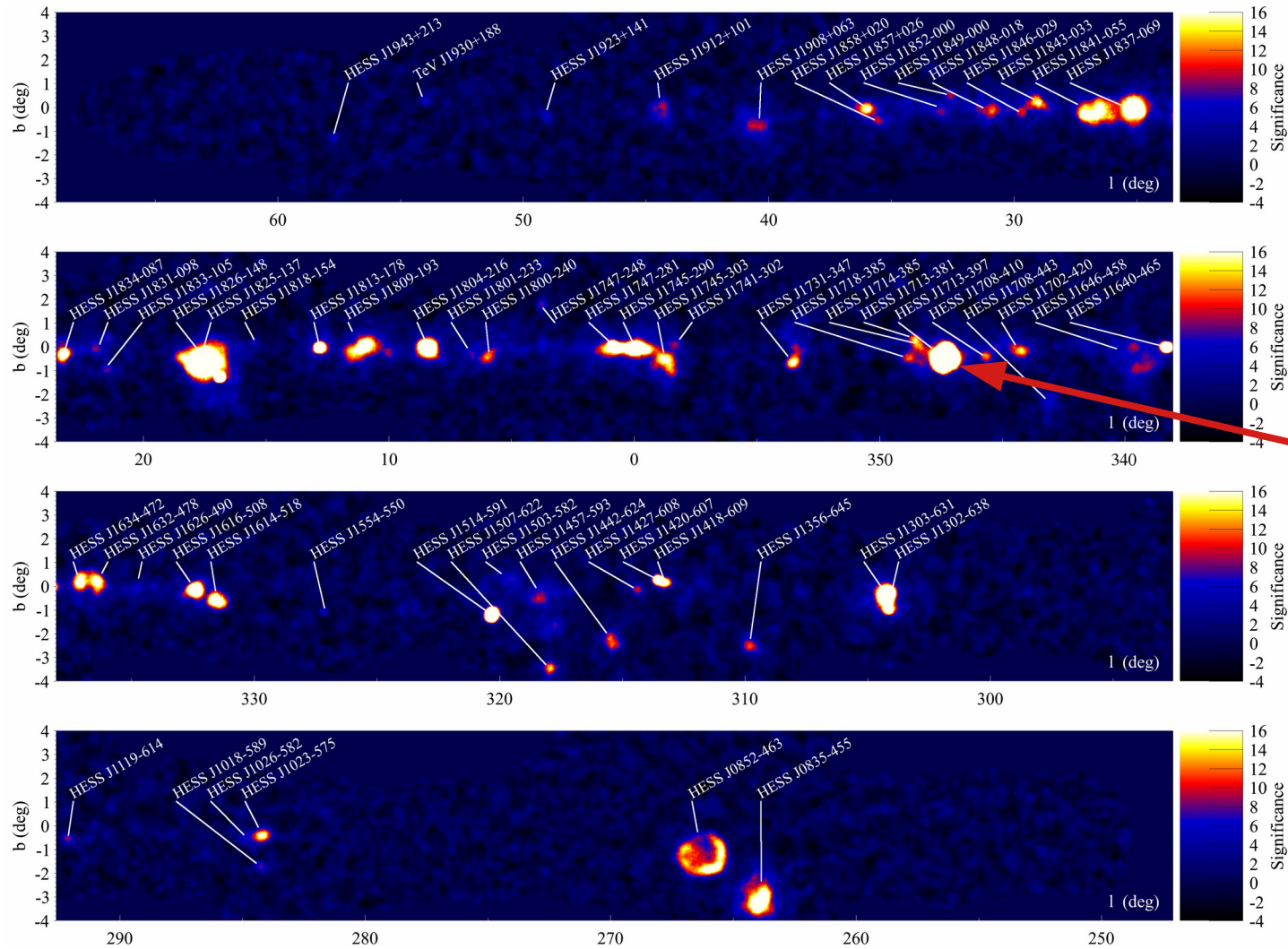
Astrophysique y de très hautes énergies



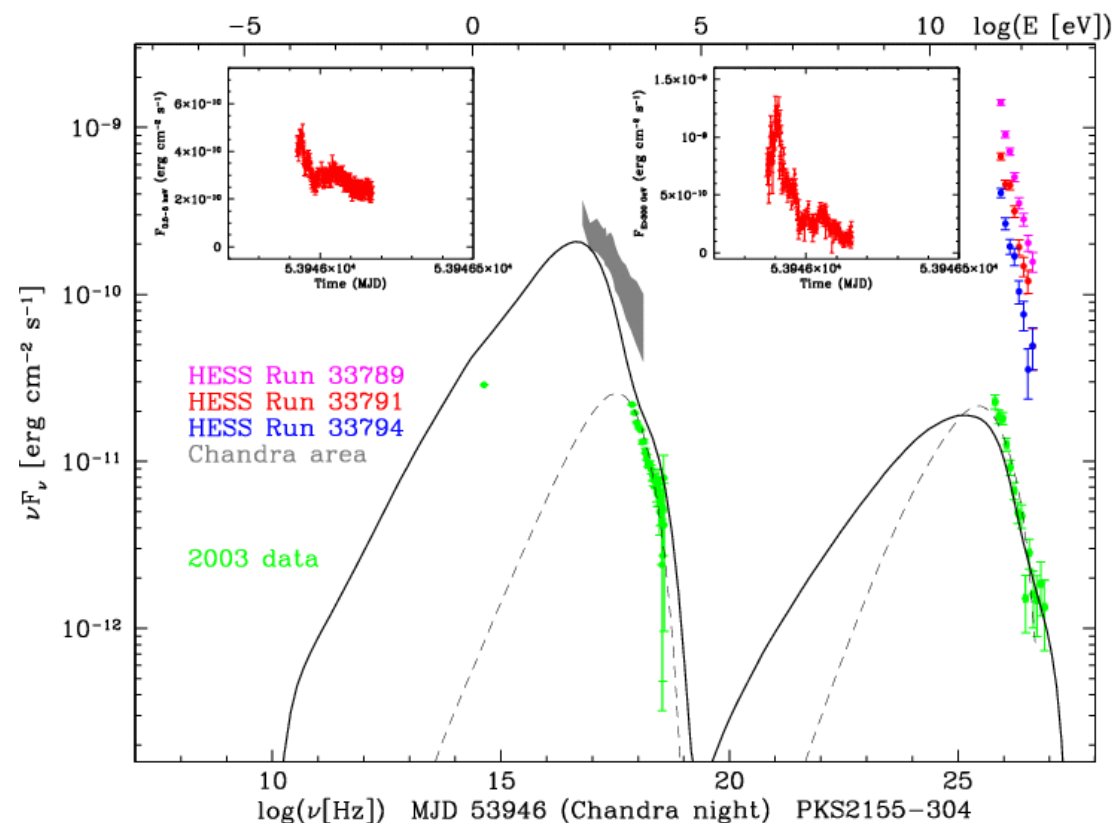
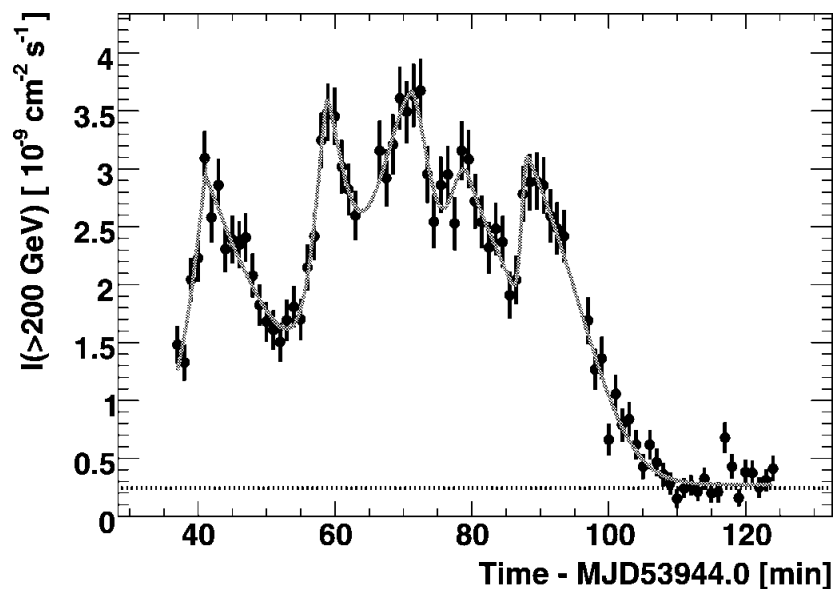
Quelques objets étudiés



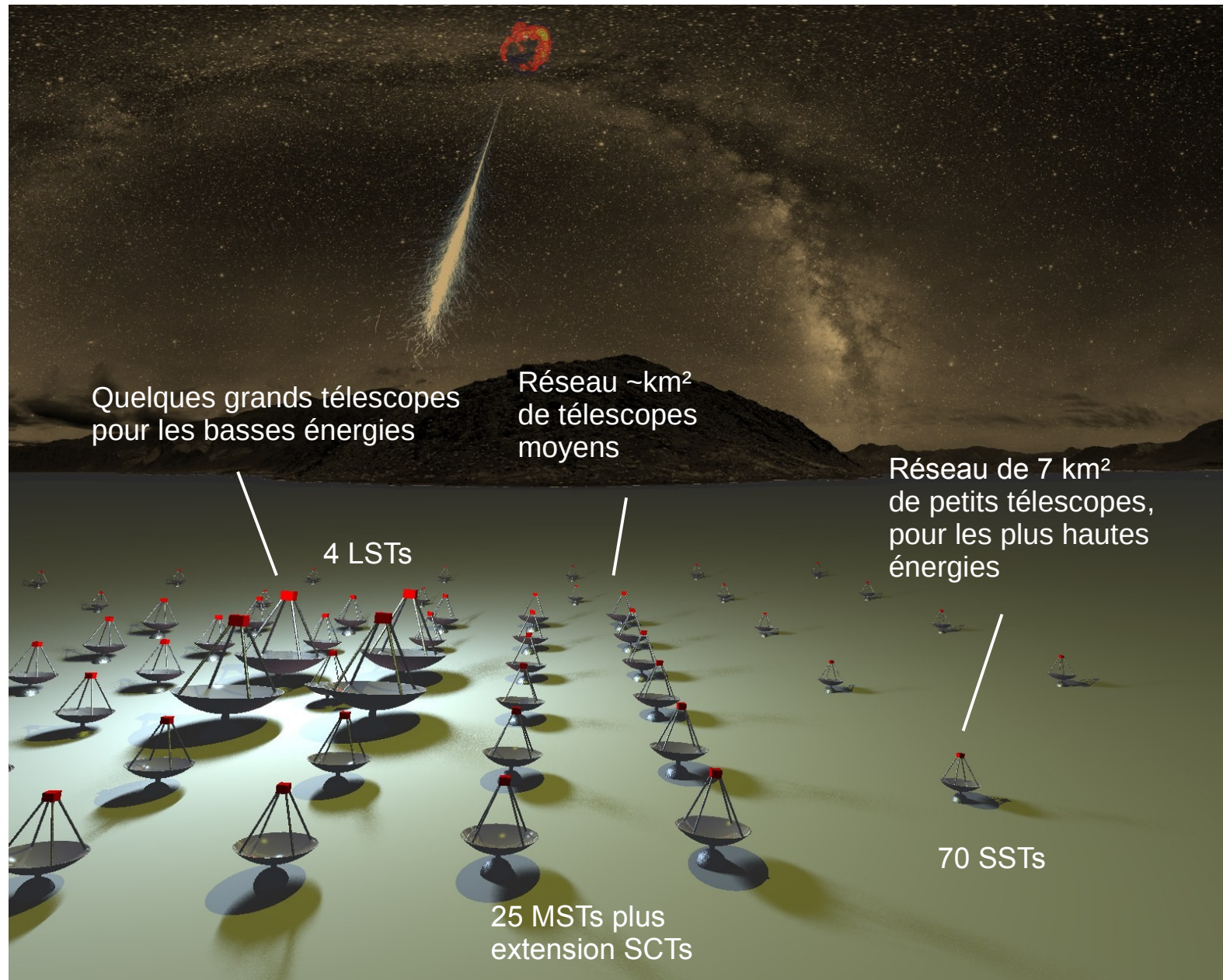
Quelques objets étudiés



Quelques objets étudiés

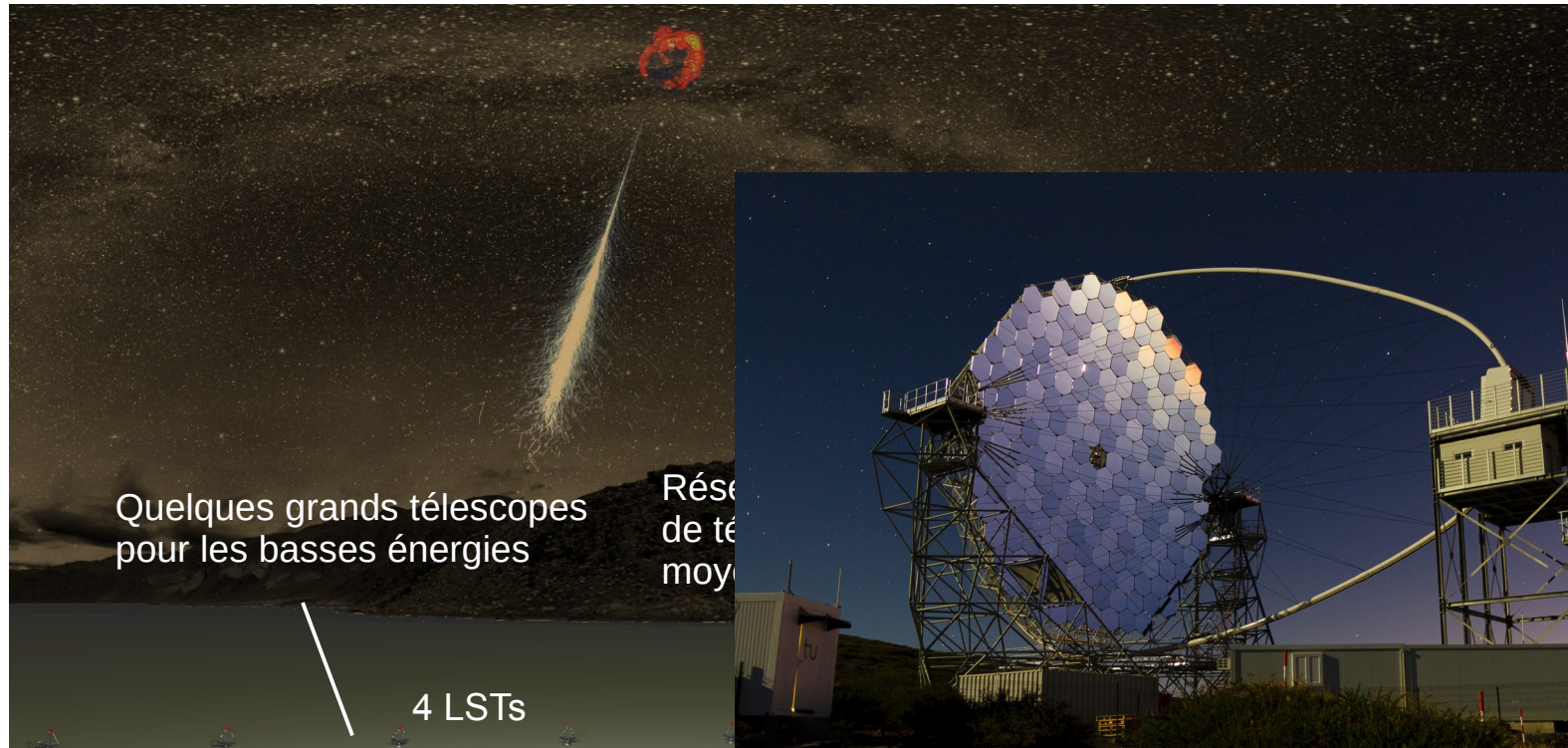


L'observatoire CTA

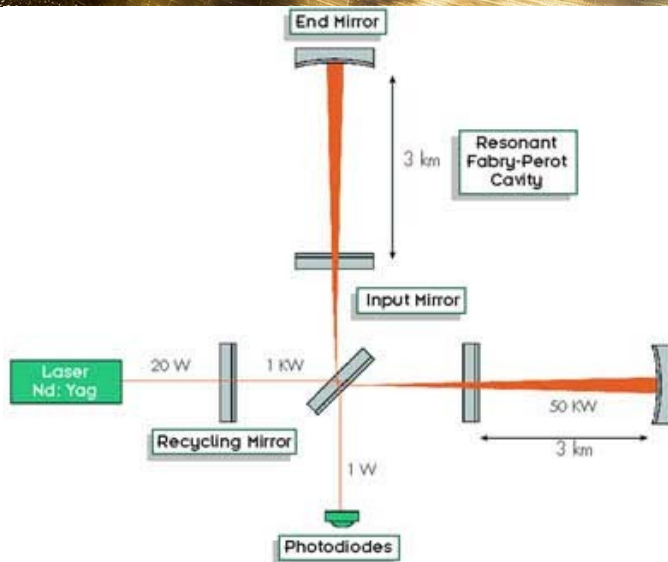
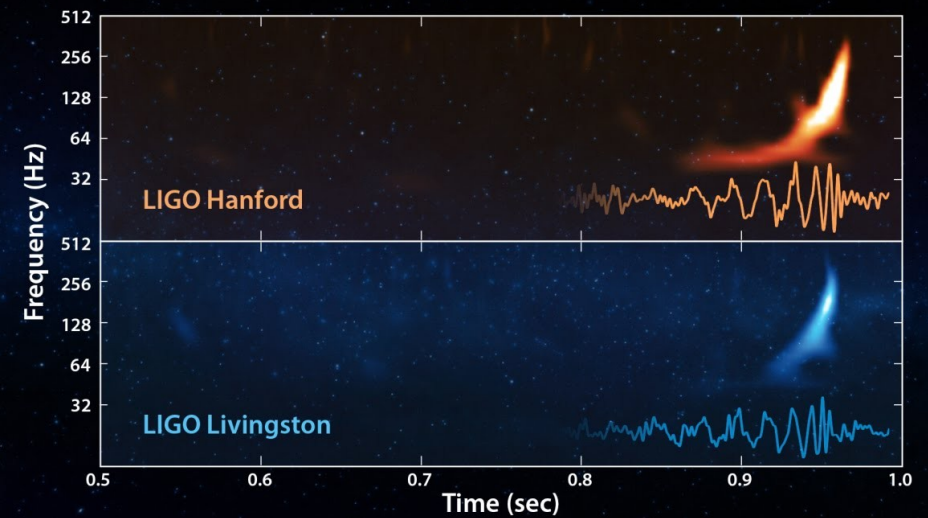
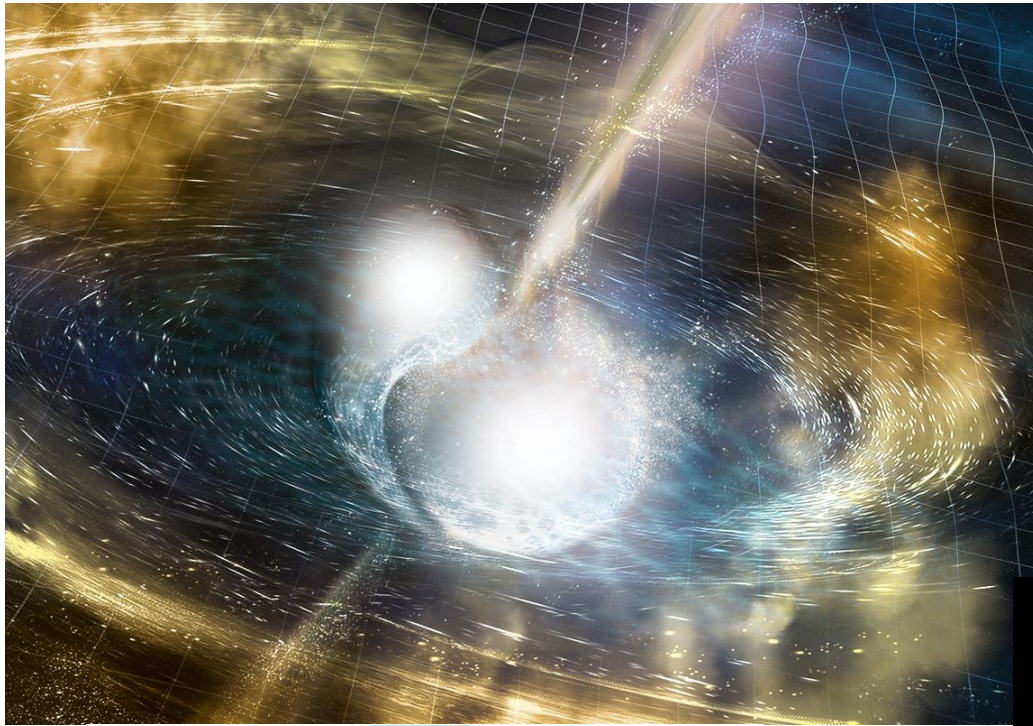


W. Hofmann

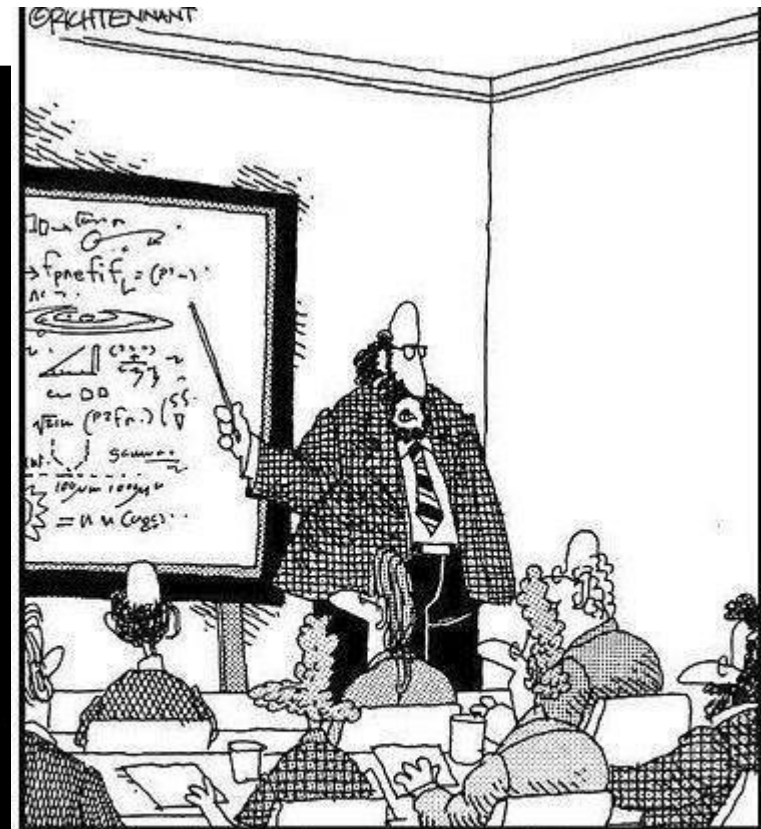
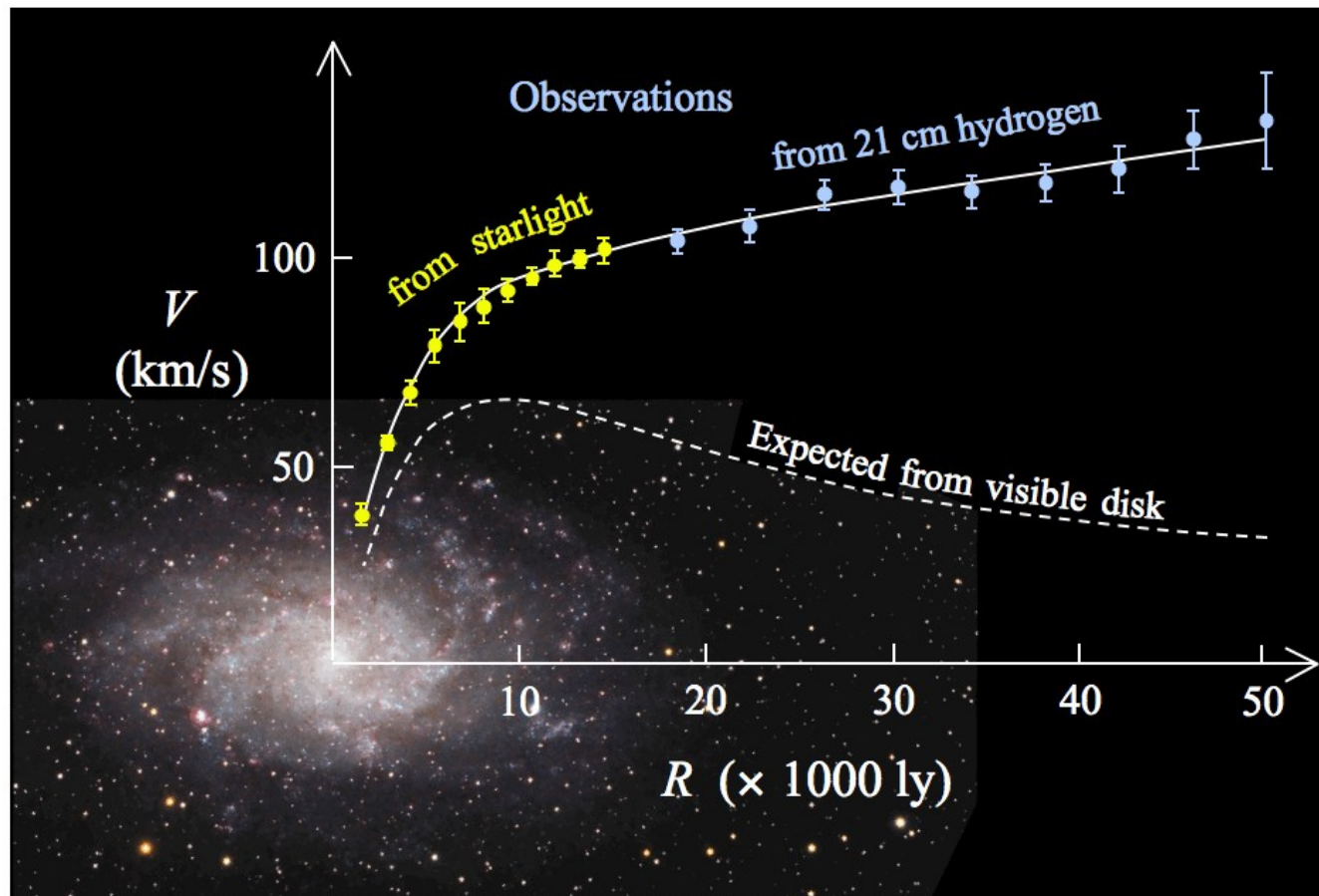
L'observatoire CTA



Astrophysique multi-messagers



Matière noire



"Along with 'Antimatter,' and 'Dark Matter,' we've recently discovered the existence of 'Doesn't Matter,' which appears to have no effect on the universe whatsoever."

Recherche de matière noire

Production

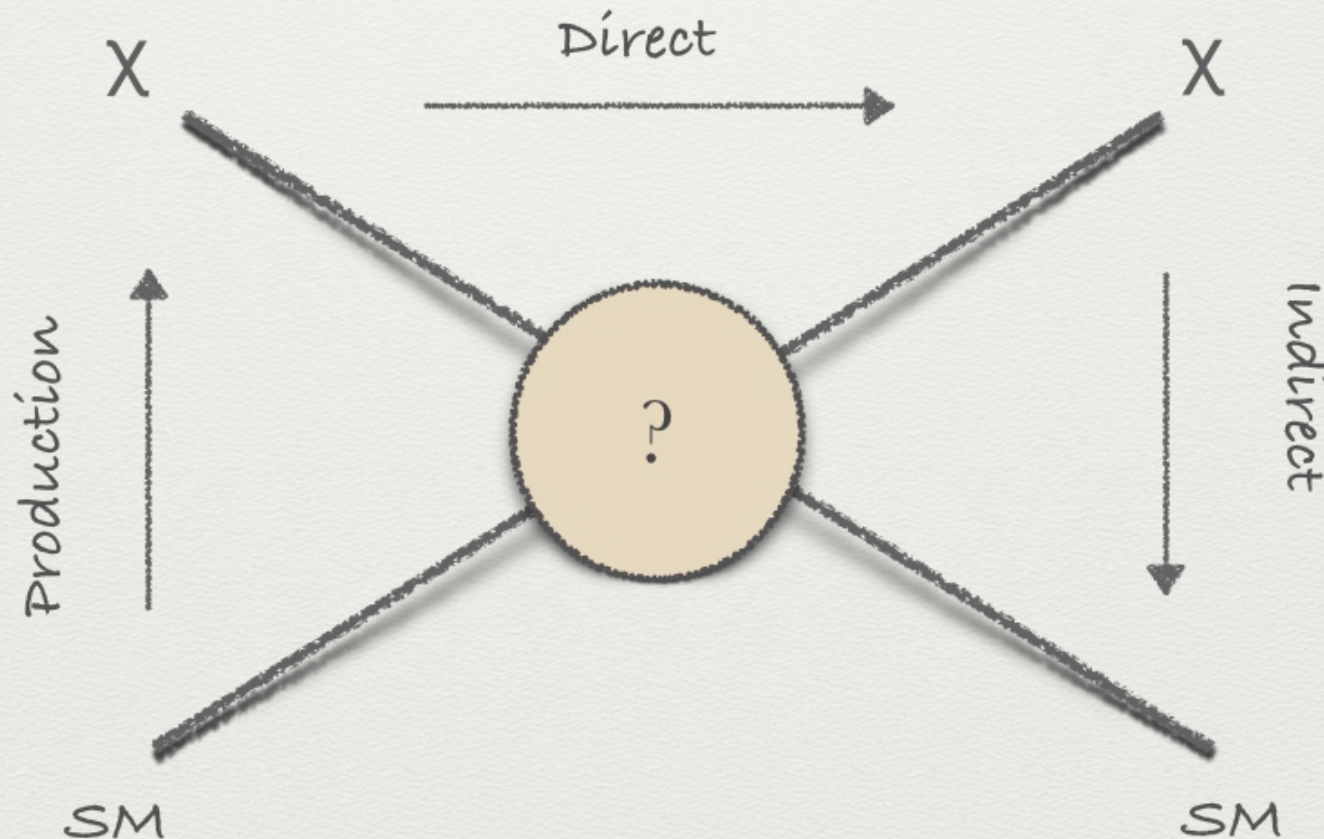
$$p + \bar{p} \rightarrow \chi + \chi$$

Indirect

$$\chi + \chi \rightarrow p + \bar{p}$$

Direct

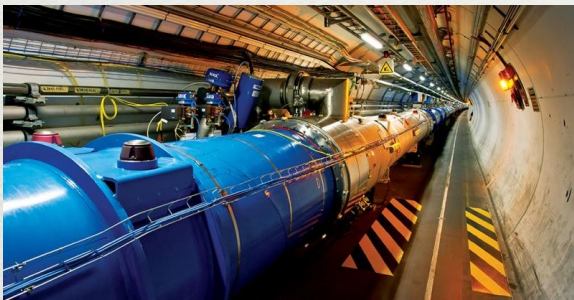
$$\chi + p \rightarrow \chi + p$$



Recherche de matière noire

Production

$$p + \bar{p} \rightarrow \chi + \chi$$



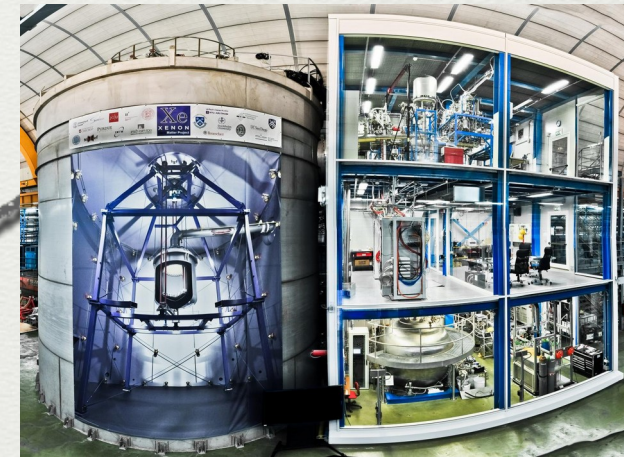
Indirect

$$\chi + \chi \rightarrow p + \bar{p}$$



Direct

$$\chi + p \rightarrow \chi + p$$



Production



Direct



?

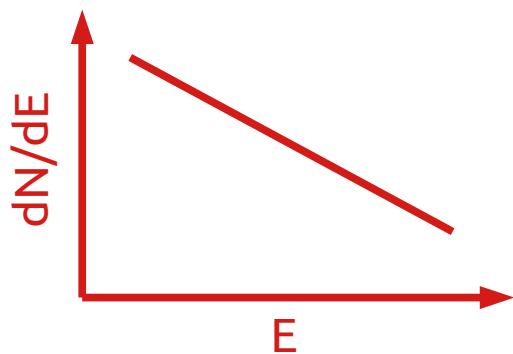
SM

SM

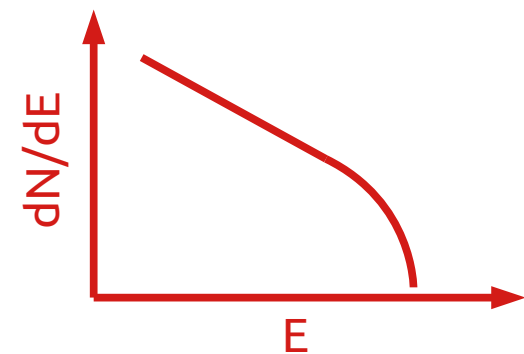
Merci !

BACKUP

Horizon γ

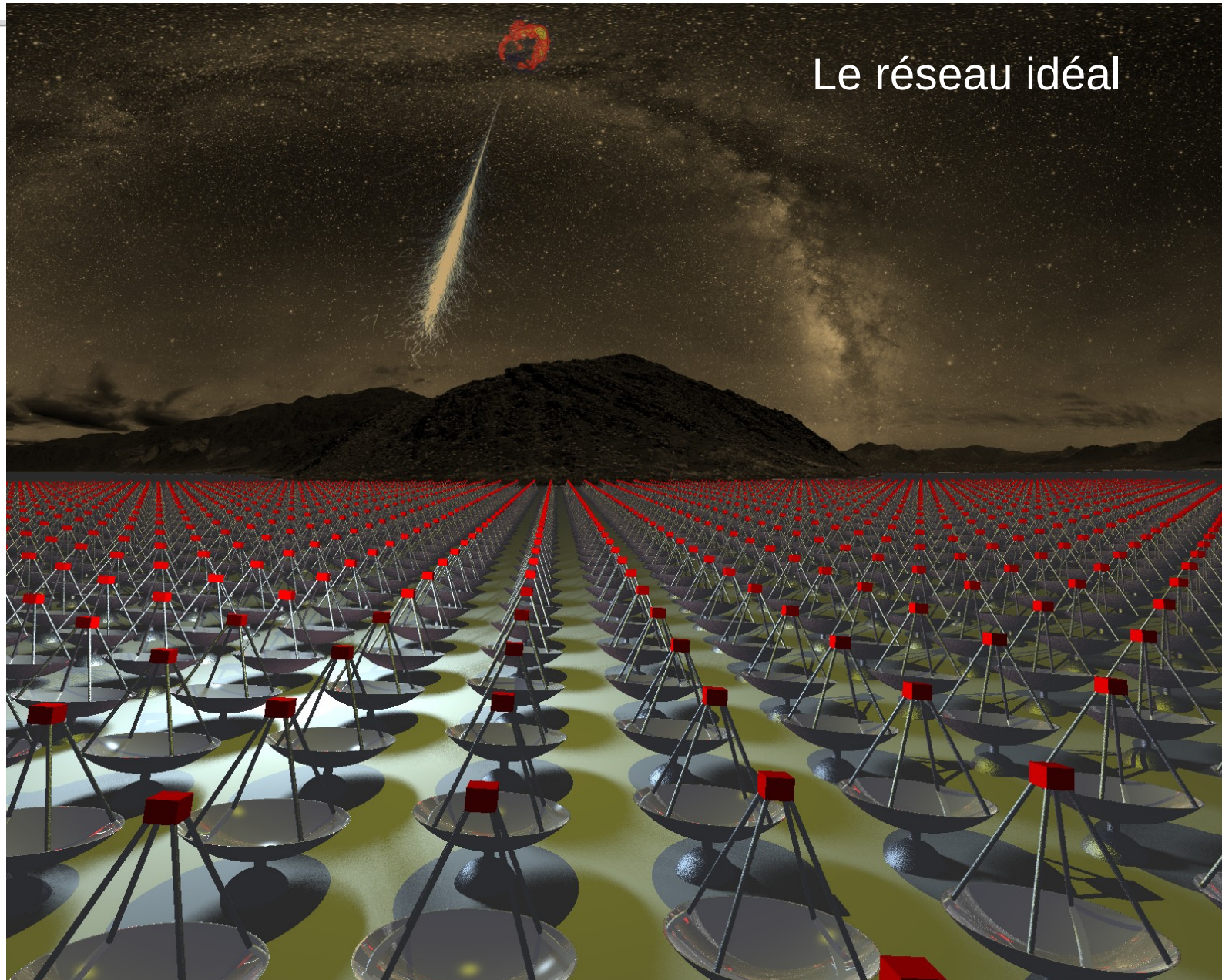


$$\gamma_{VHE} + \gamma_{O-IR} \rightarrow e^+ + e^-$$



Mesure indirecte du fond rayonnement stellaire+poussière
→ lien avec cosmologie

L'observatoire CTA



Les principaux télescopes à imagerie atmosphérique Cherenkov



VERITAS, 4 x 10m



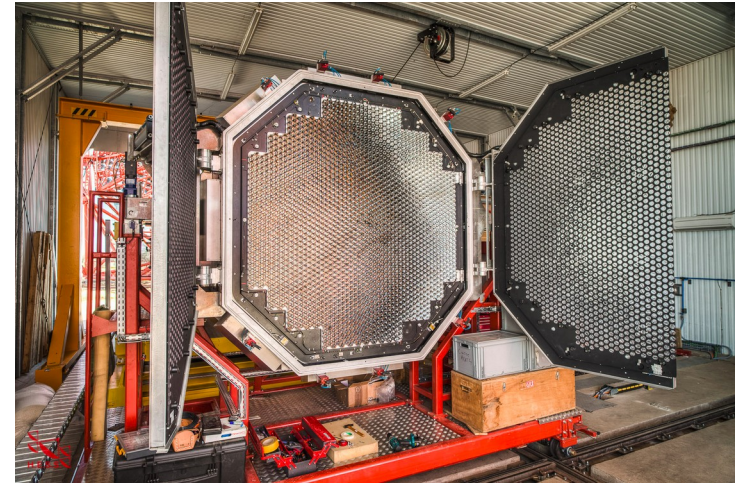
MAGIC, 2 x 17m



H.E.S.S., 4 x 13m + 28m

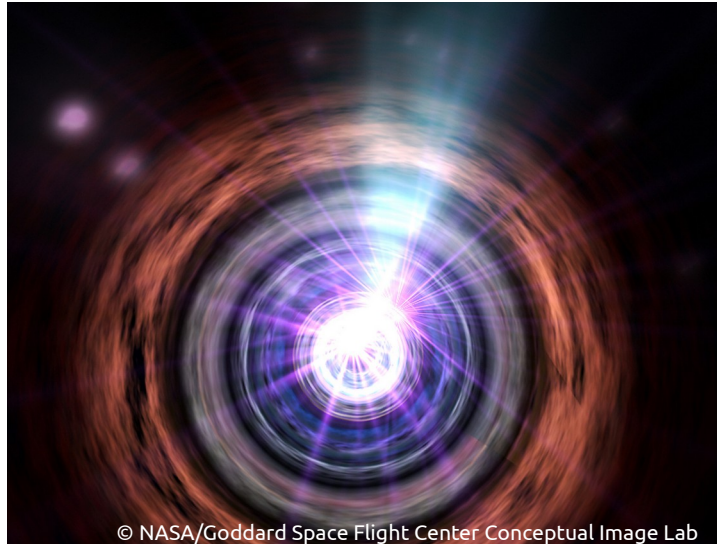
High Energy Stereoscopic System (H.E.S.S.)

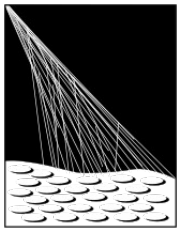
- H.E.S.S. I (2003–)
 - 4 tél. $\varnothing 13\text{m}$, surf. eff.=428 m²
 - Champ de vue=5°
 - Caméra: 960 PMT
 - $E_{\text{th}} \sim 200 \text{ GeV}$



- H.E.S.S. II (2012–)
 - 5e tél. $\varnothing 28\text{m}$, surf. eff.=600 m²
 - Champ de vue=3.2°
 - Caméra: 2048 PMT
 - $E_{\text{th}} \sim 30 \text{ GeV}$

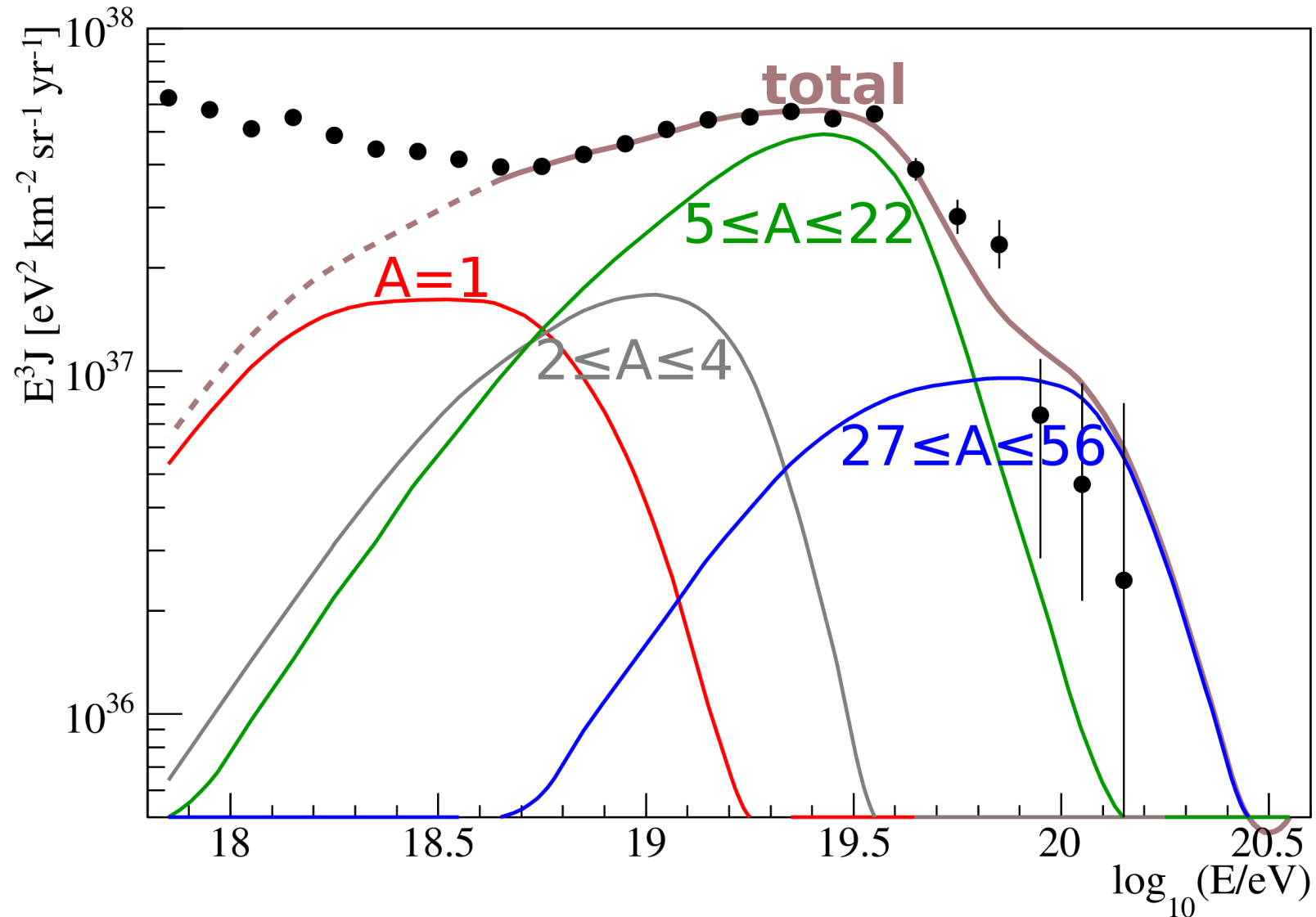
Quelques objets étudiés



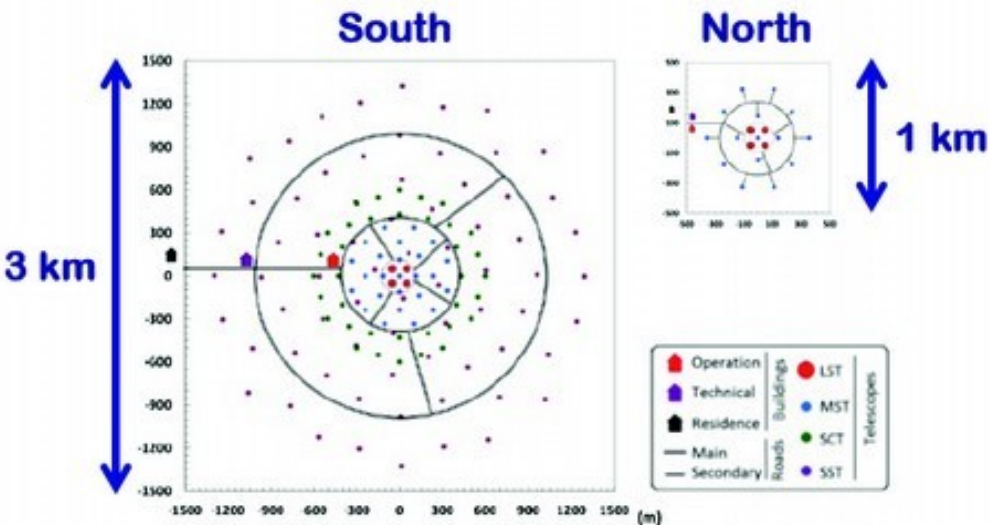


PIERRE
AUGER
OBSERVATORY

Auger: implications



L'observatoire CTA



Characteristics :

- 2 sites (Paranal, Chile and La Palma, Spain)
- 3 telescope size classes
- All-sky coverage
- An open observatory: guest observers via observing proposals (a part of the time)
- Worldwide consortium (~ 1500 members, 25 countries)