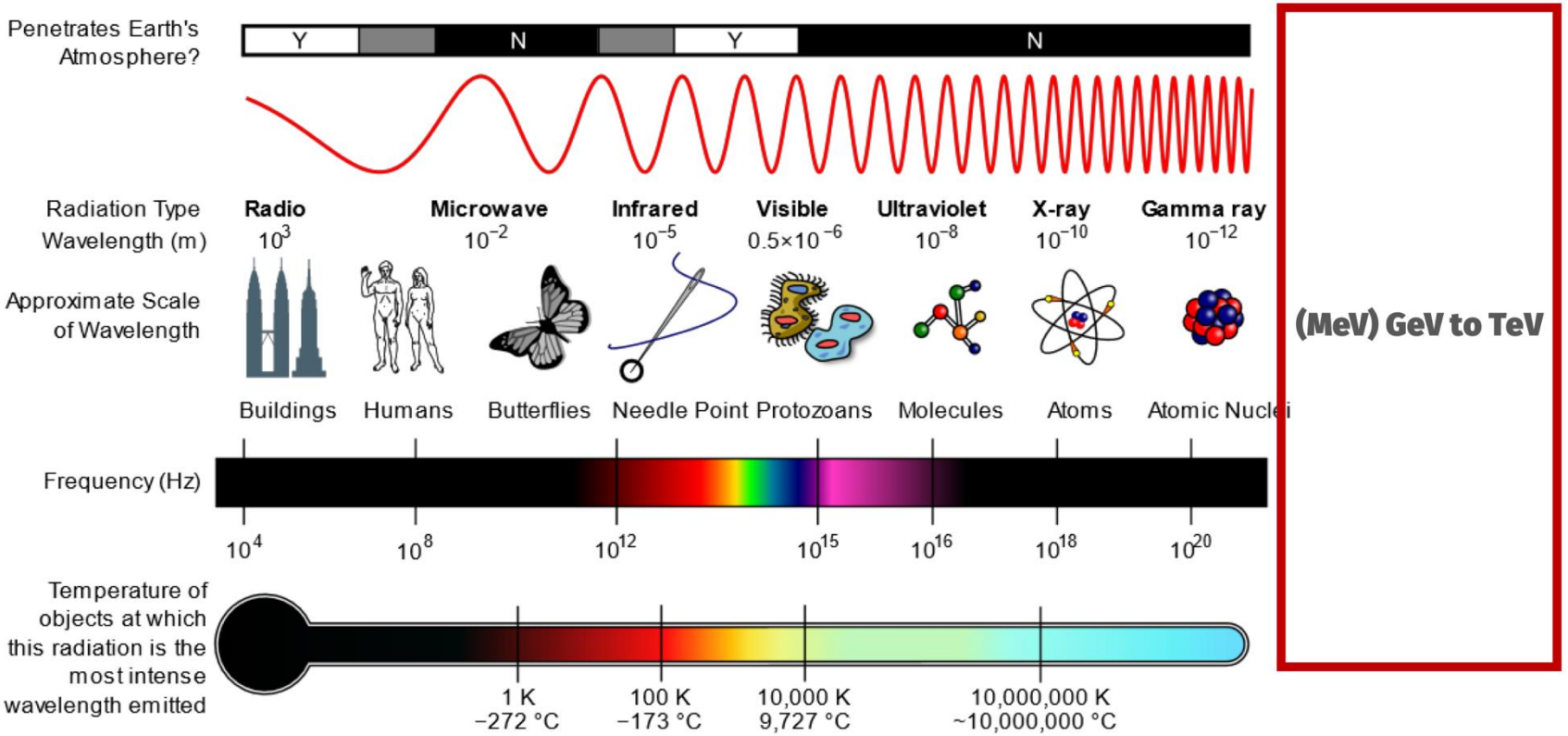
TeV transient sources with H.E.S.S.

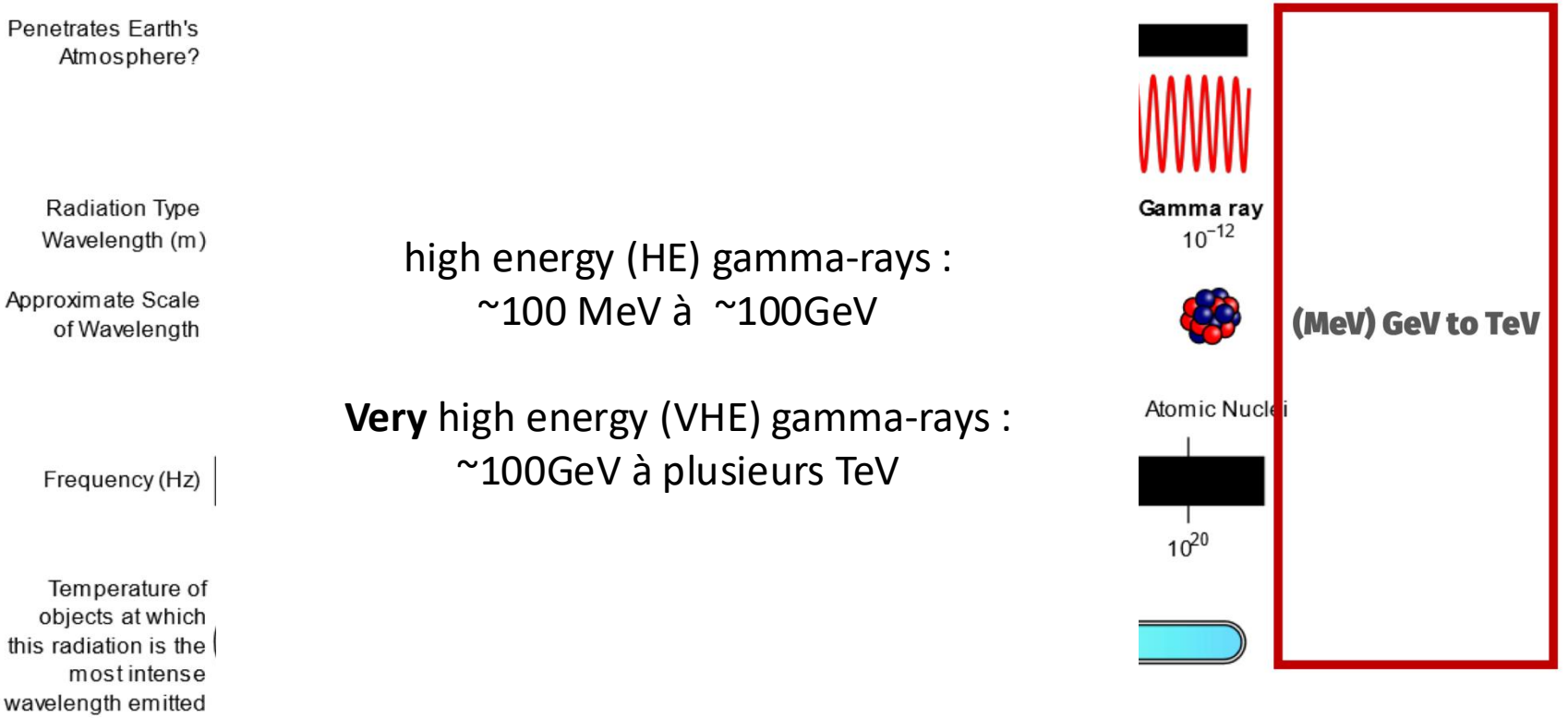
Congrès des doctorants 2026

Pierre Pichard – 2nd year PhD student @ APC

Electromagnetic spectrum



Electromagnetic spectrum



high energy (HE) gamma-rays :
~100 MeV à ~100GeV

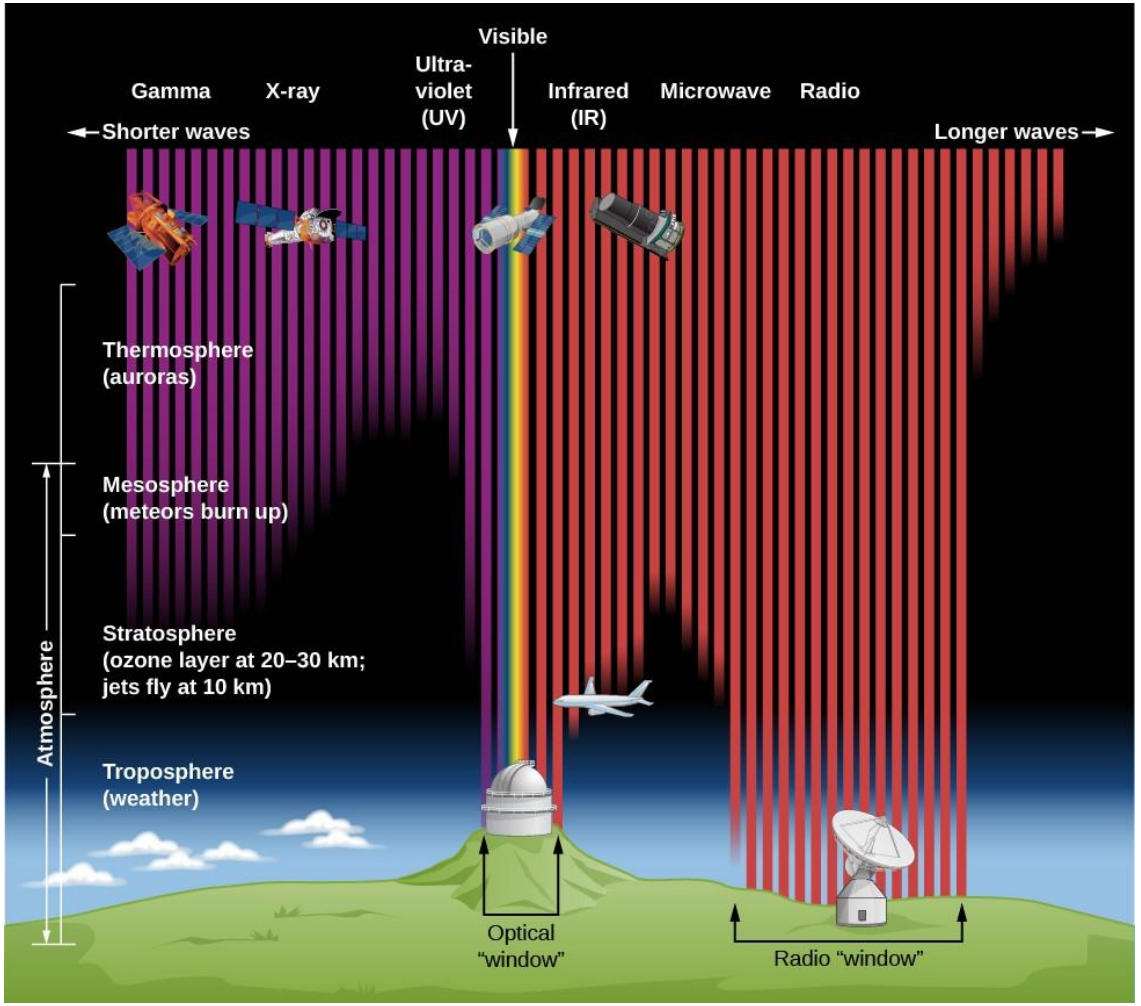
Very high energy (VHE) gamma-rays :
~100GeV à plusieurs TeV

Problem :

The atmosphere is:

Transparent in optical
(phew, we can see the sun)

Opaque to gamma-rays
(phew, we're not getting irradiated)
(damn, they're hard to observe)

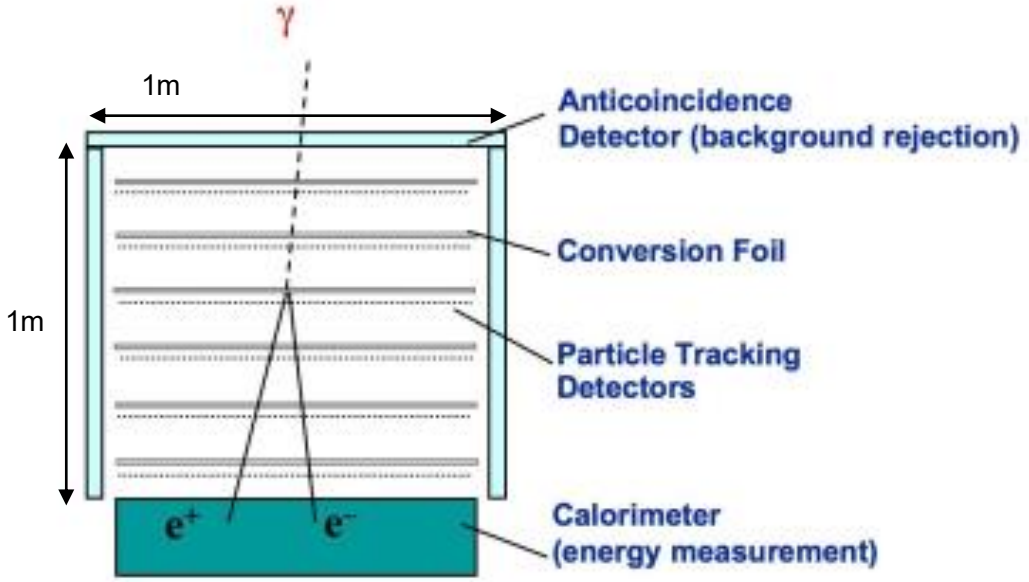


What can we do?

Solution(s) :

Obvious : go to space like NASA's Fermi satelite

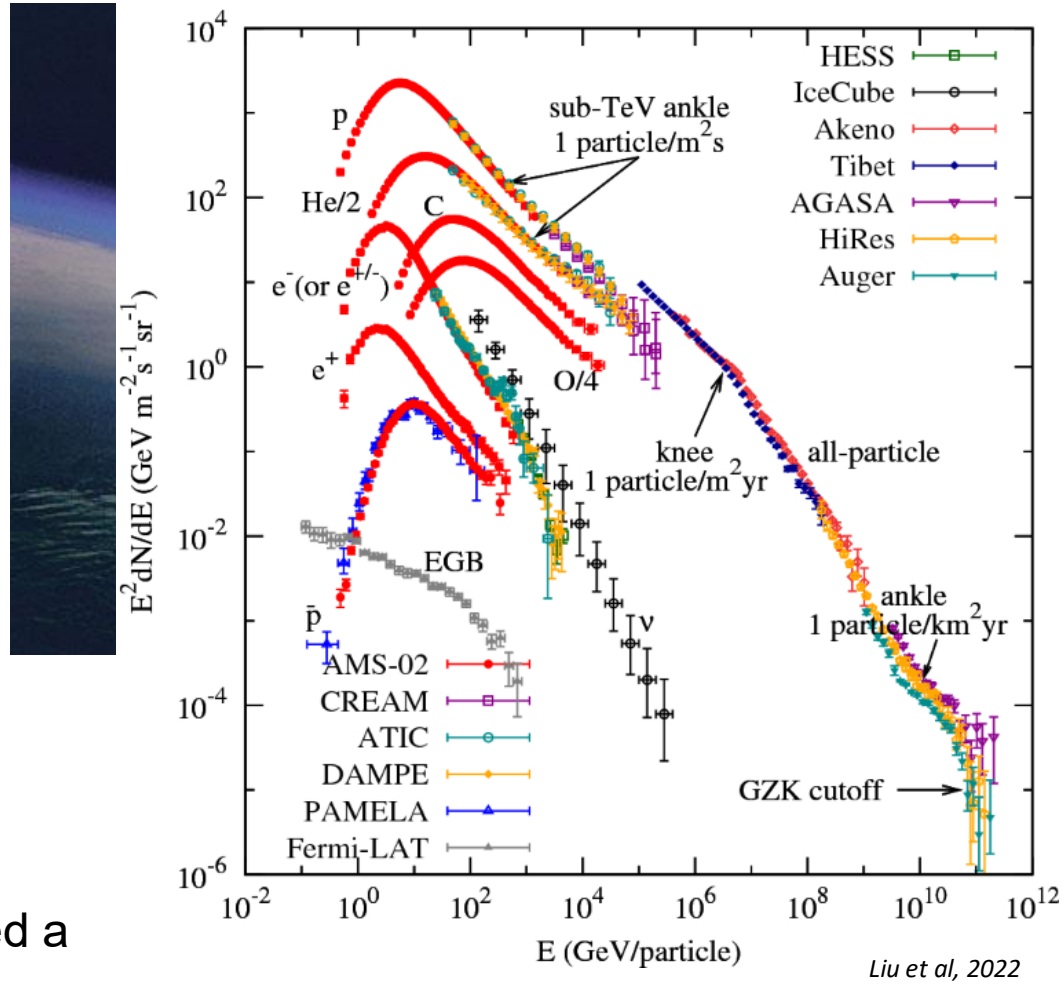
Mechanism: Pair production



Ok for gamma-rays until a few tens of GeV …

Problem:

As for cosmic-rays, the flux of ɣ-rays is decreasing when energy is increasing



Liu et al, 2022

For VHE ɣ-rays, flux too small : need a satellite of ~km^2!

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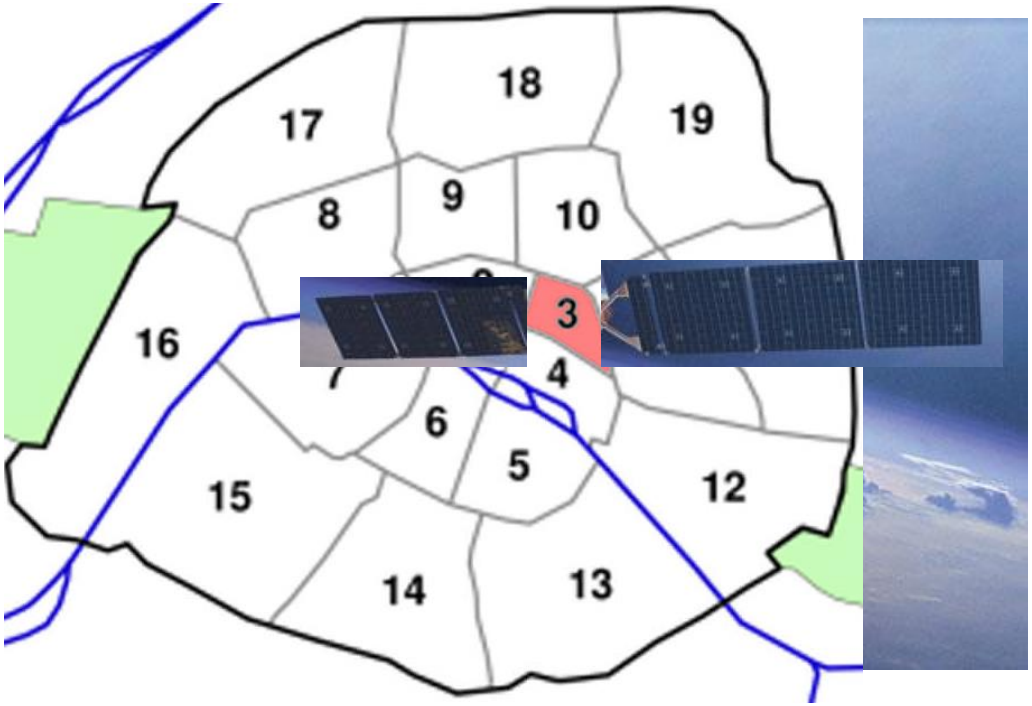


For VHE γ-rays, flux too small : need a satellite of ~km^2!

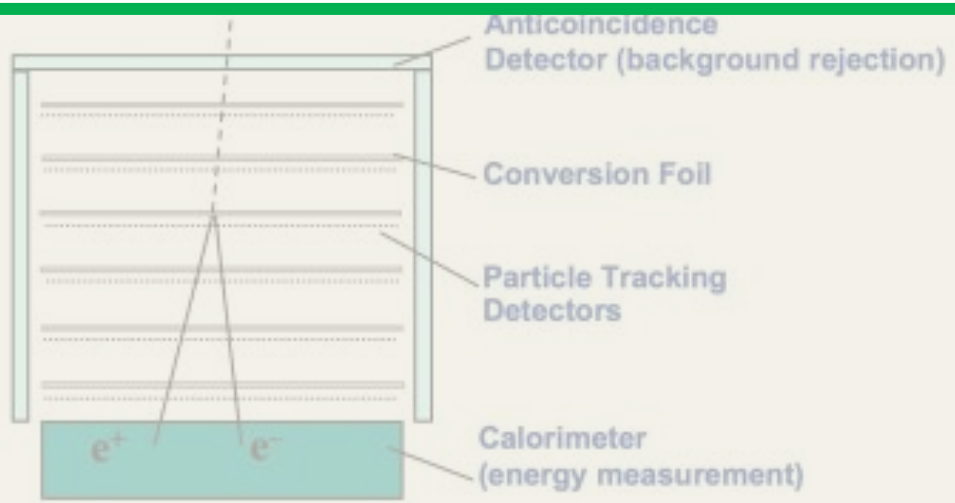
→ The area of Paris' 3rd arrondissement !

Solution(s) :

Obvious : be in space like

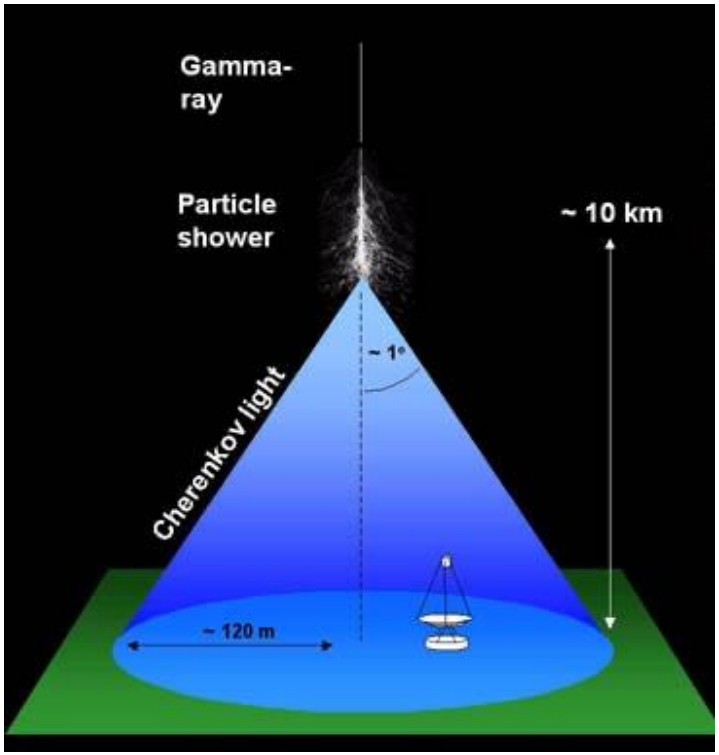
New solution : place ourselves on Earth and use the atmosphere!

Pair production



Ok for gamma-rays until a few tens of GeV …

Imaging Atmospheric Cherenkov Telescopes (IACTs)



H.E.S.S. website

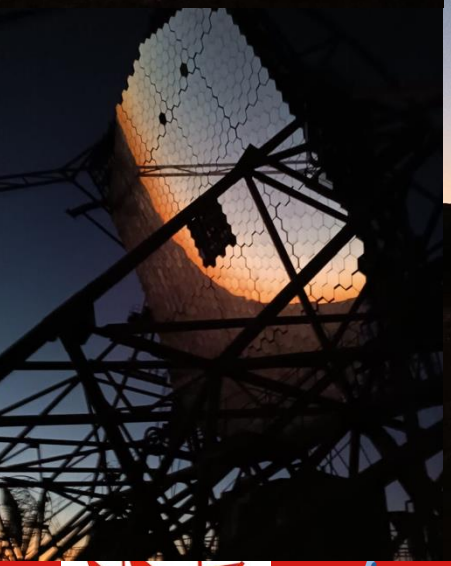
- γ-rays enter the high atmosphere and interact with an atom -> create chain of interactions : electromagnetic shower
- Particules of the shower are faster than c/n -> Cherenkov effect
- Cherenkov light is detected by ground telescopes

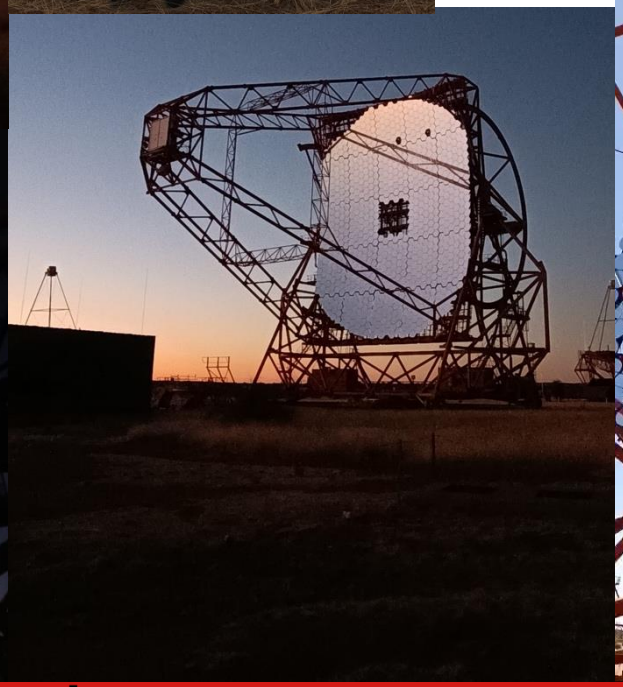
Easy ?

Not so much

- For every TeV γ-ray -> ~10k cosmic rays
- Need complex analyses to discriminate the type of particule (and get to the energy + arrival direction)

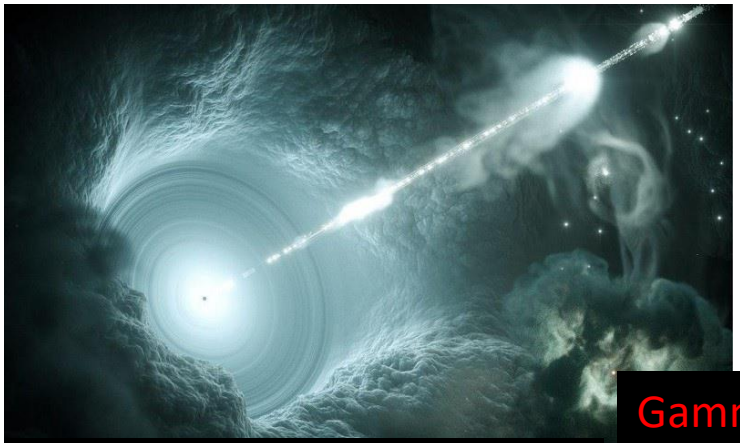
H.E.S.S. collaboration





- High Energy Stereoscopic System
- 5 Cherenkov telescopes (1x28m, 4x12m) in the Khomas Highlands in Namibia
- ~200 membres, including 13 at APC

Extreme transients



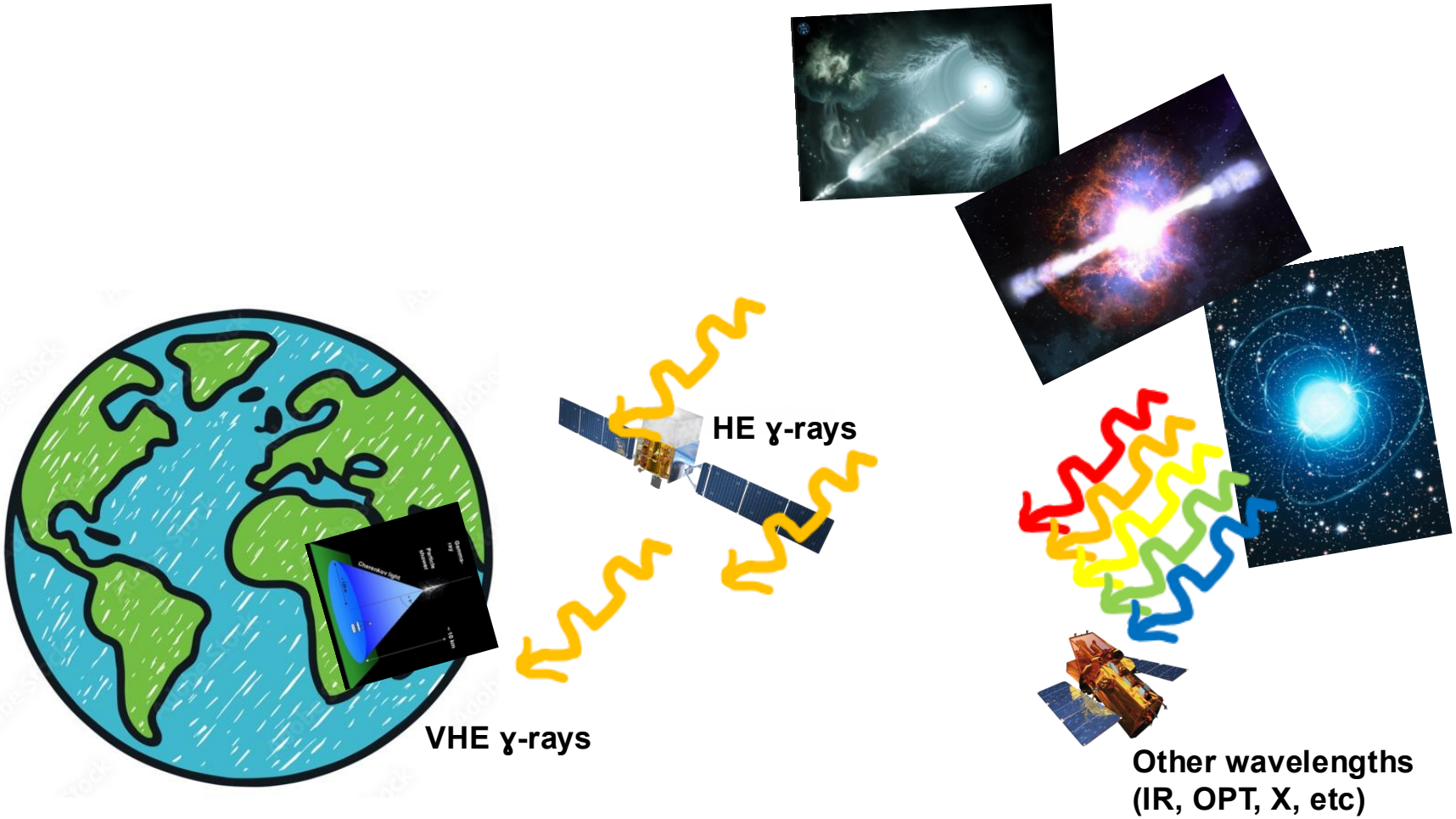
Active Galactic Nuclei (AGN)

Gamma Ray Burst (GRB)

Other (Nova, FRB, …?)

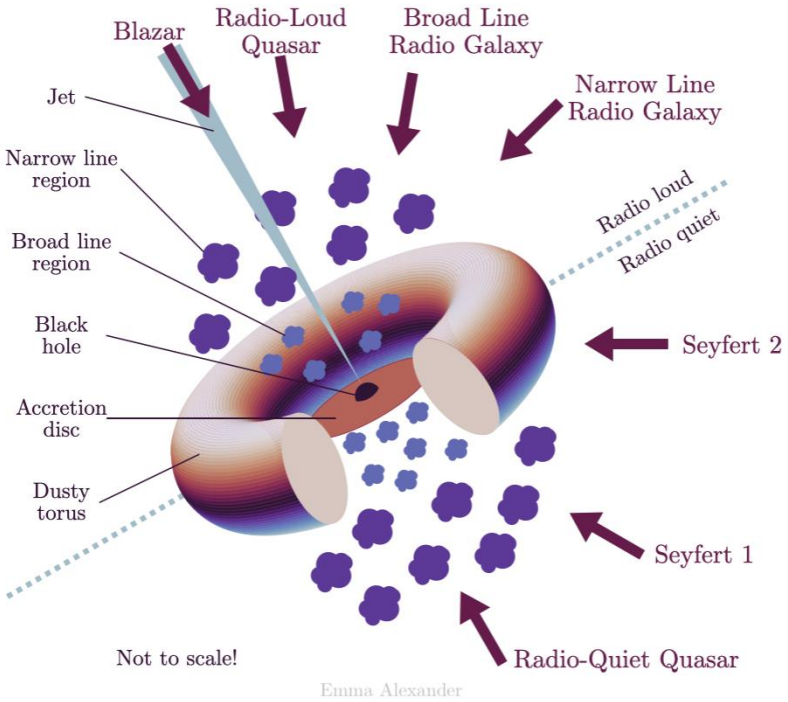
Very energetic phenomenon, very short (~days to ~seconds)

Extreme transients



Extreme transients

Zoom on AGNs

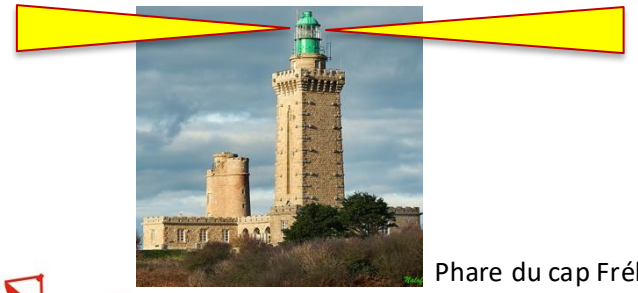


Supermassive BH in the center of galaxies (up to 10^{10} M_{sun})

10% of them : relativistic jets (visible in radio) = *radio loud*

Particles « boosted » depending on $\text{angle}_{\text{jet-observer}}$

$$\begin{aligned} \text{L'énergie E} &= \delta\ E' \\ \text{Le temps t} &= \delta^{-1}\ t' \\ \text{La fréquence } \nu &= \delta\ \nu' \\ \text{L'angle solide } \Omega &= \delta^{-2}\ \Omega' \\ \text{Le flux } F_\nu &= \delta^3\ F'_\nu \end{aligned}$$

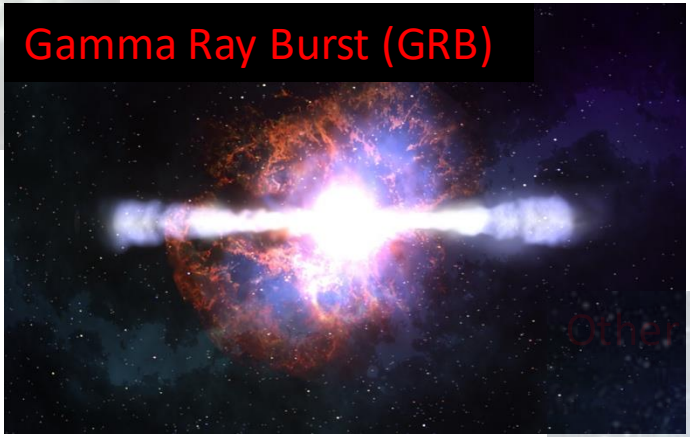


Phare du cap Fréhel

The **closer** the observer is **to the jet axis**, the **brighter** and **faster variable** the AGN will appear

AGNs for which those effects are the most visible are called **blazars**

Extreme transients



Gamma Ray Bursts

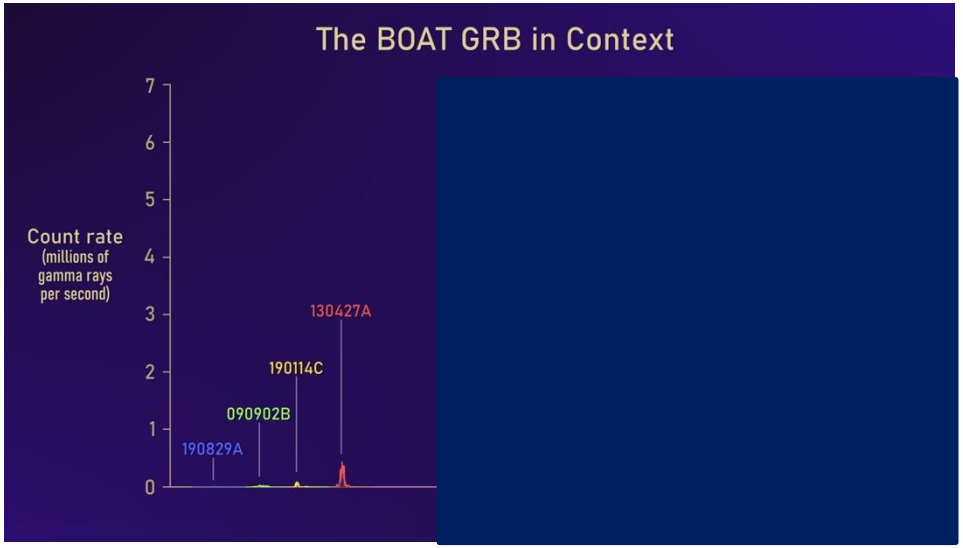
Short and intense emission of γ rays (**most luminous phenomenon other than the Big Bang !!!**)

- Short GRBs (< 2s) likely caused by neutron stars mergers
- Long GRBs (burst > 2s) caused by hypernovae (collapse of a **very** massive star)

Then afterglow lasting for hours/days in radio, optical, X-rays, VHE γ-rays, etc…

Gamma Ray Bursts @ VHE

- Quite unknown phenomena at VHE, 5 detections (including B.O.A.T.)
- 1 in 10.000 year GRB



BOAT's emission compared to previous top 4
credit : NASA's Goddard Space Flight Center and Adam Goldstein (USRA)

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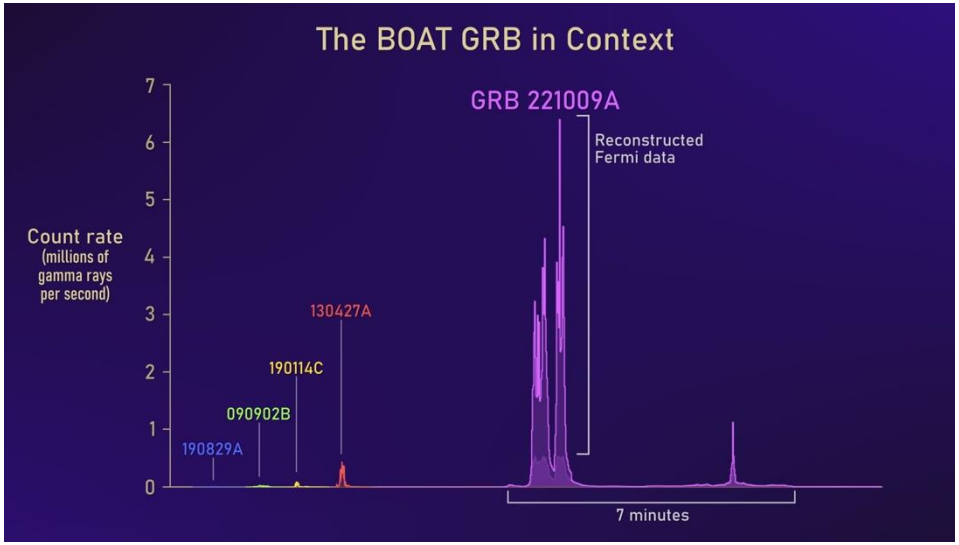

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Extreme transients

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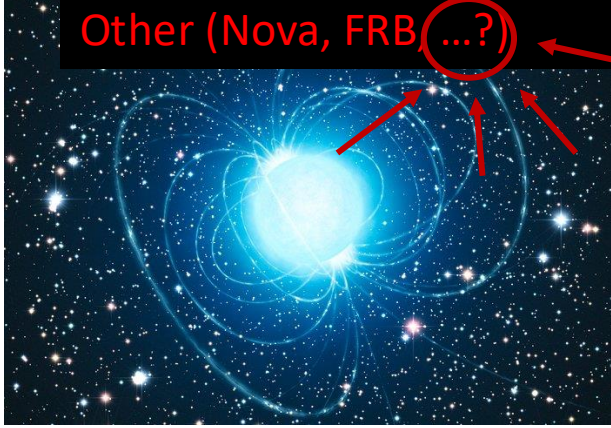
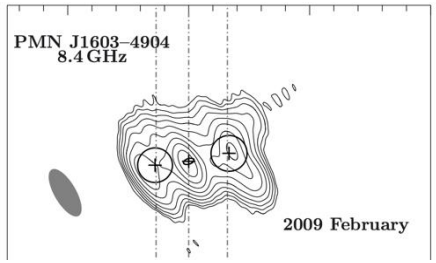
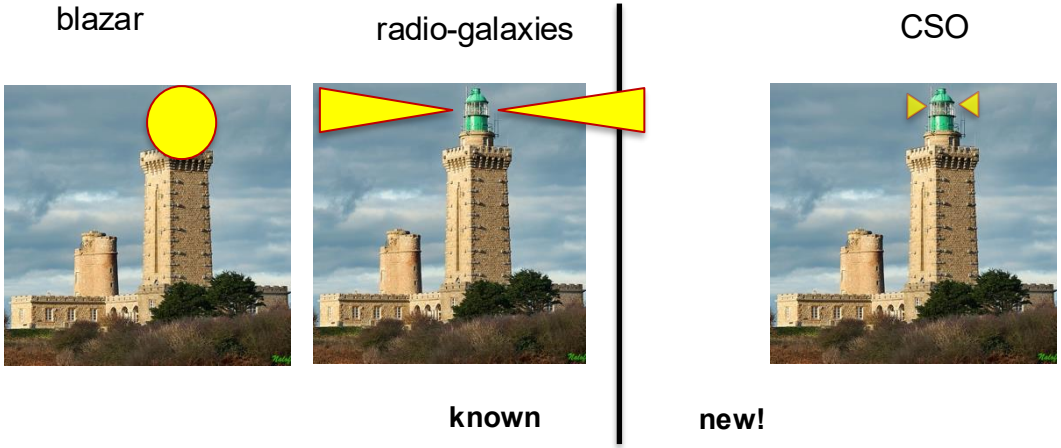
A new type of source?



- Compact symmetrical object (**CSO**), or young radio-galaxy : not a blazar, very small jets (<1kpc)
- **PMN J1603-4904**
- Detected by H.E.S.S. in May/June 2025 (ATel #17205)
- **First CSO seen by IACTs !**





Conclusion

The study of γ-rays needs to be done on Earth for the most energetic ones (VHE)

The technology to do so is Imaging Air Cherenkov Telescope (IACTs)

We can study the most energetic phenomenon with them (extreme transients)

It is a very new field: only ~100 AGNs; only 5 GRBs

We can discover new, unexpected, types of sources: exciting!

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Thank you ☺