



AstroVal – Quand l'invisible devient visible

Voir l'invisible: les rayons X et gamma comme scanner cosmique

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Astroval, Le Chenit, Suisse

2 Septembre 2025

- ① Lumière et ondes électromagnétiques
- ② Observer le ciel à hautes énergies depuis l'espace
- ③ Observations indirectes depuis le sol

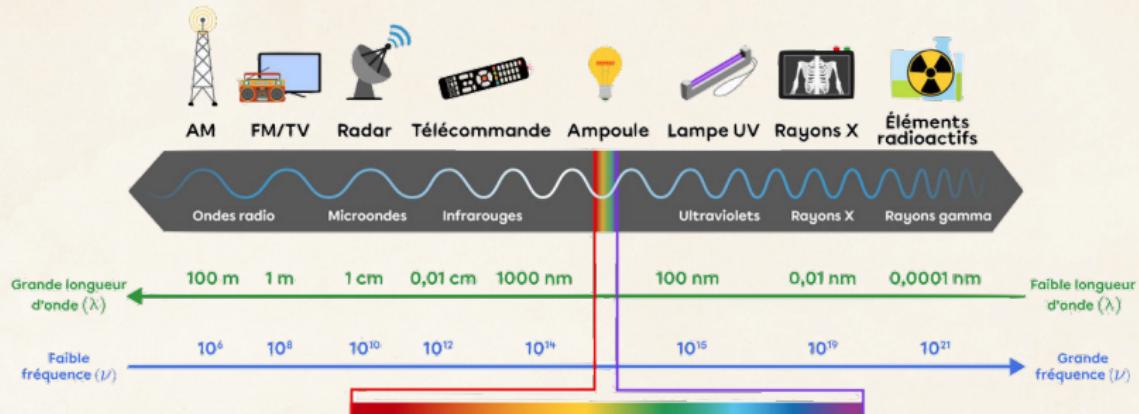


Section 1

Lumière et ondes électromagnétiques



Le spectre électromagnétique



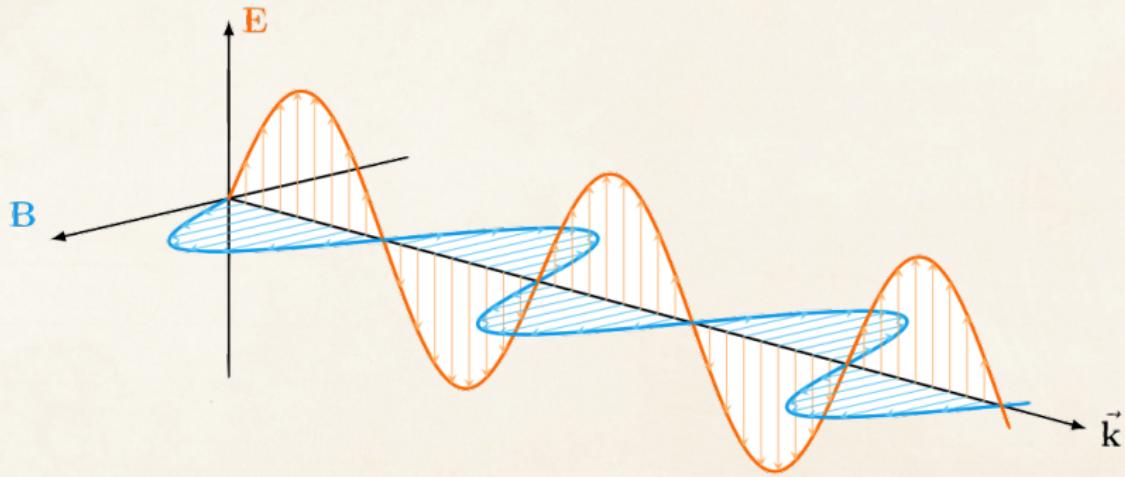
$$\text{Planck-Einstein: } E = h\nu = hc/\lambda$$

Qu'est-ce qu'une onde?



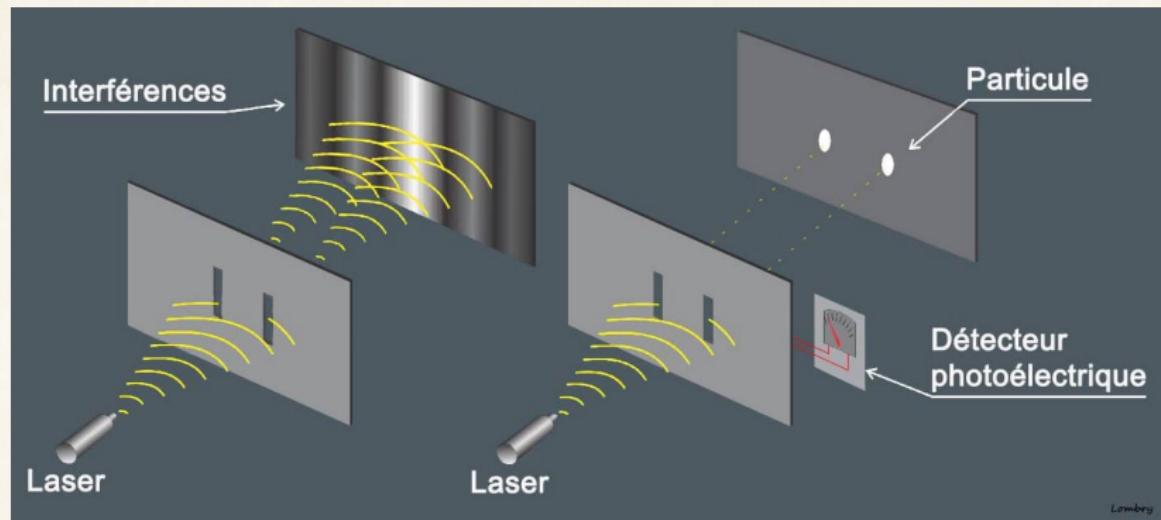
Ondes électromagnétiques

Ondes **Electro-Magnétique** : champs électrique et magnétique orthogonaux qui oscillent dans le temps et dans l'espace



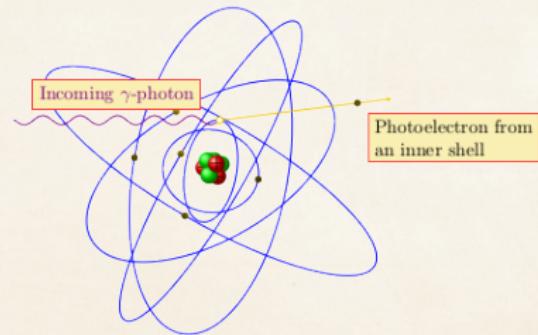
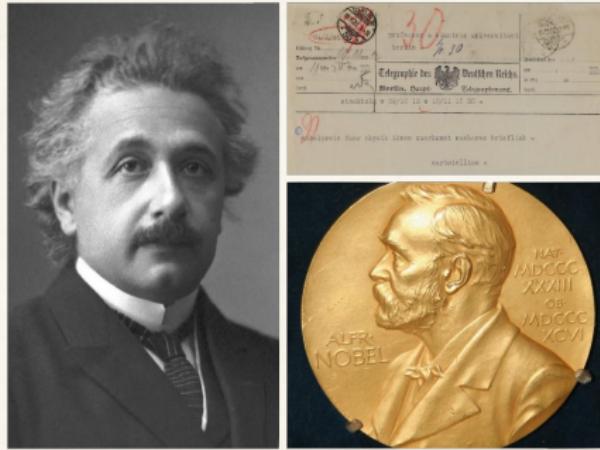
Dualité onde-particle

Louis De Broglie, Prix Nobel de Physique 1929 "for his discovery of the wave nature of electrons"



L'effet photo-électrique

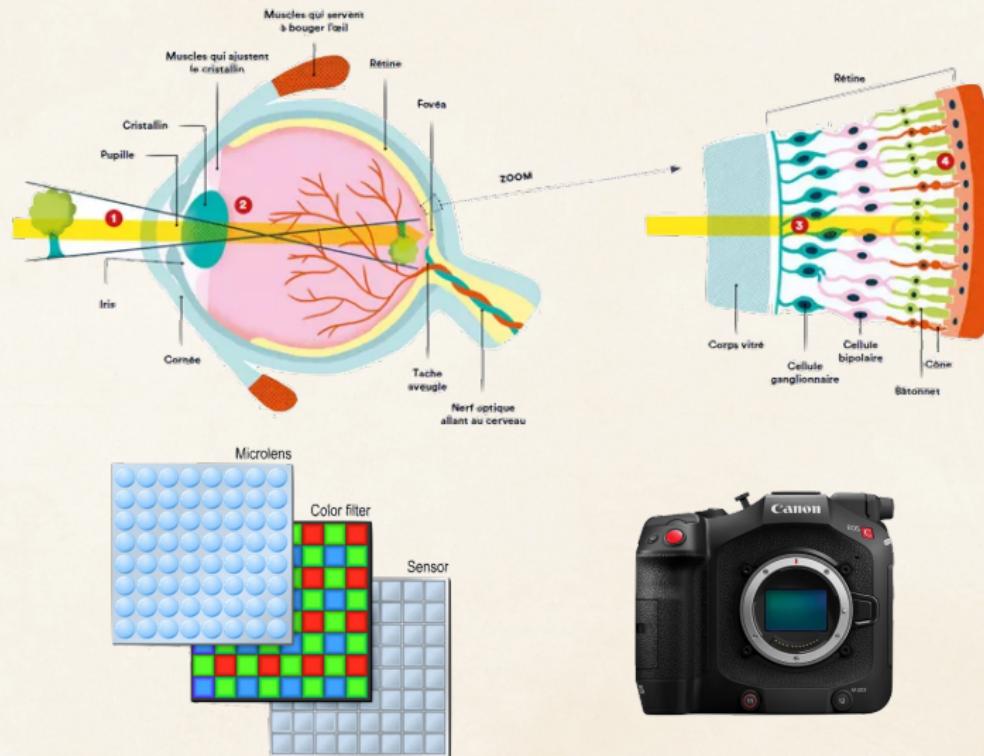
Albert Einstein, Prix Nobel de Physique 1921 "for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect"



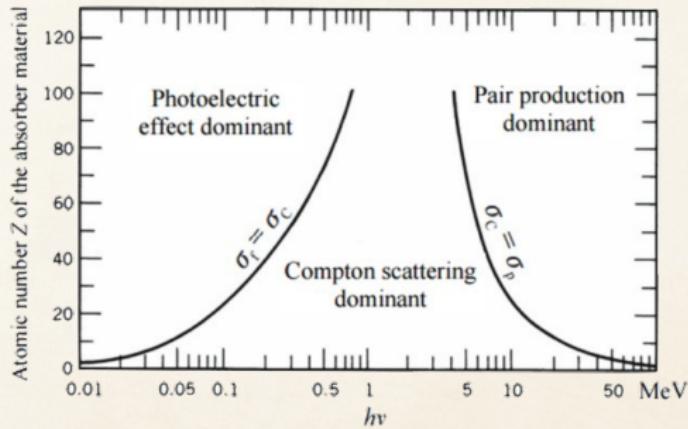
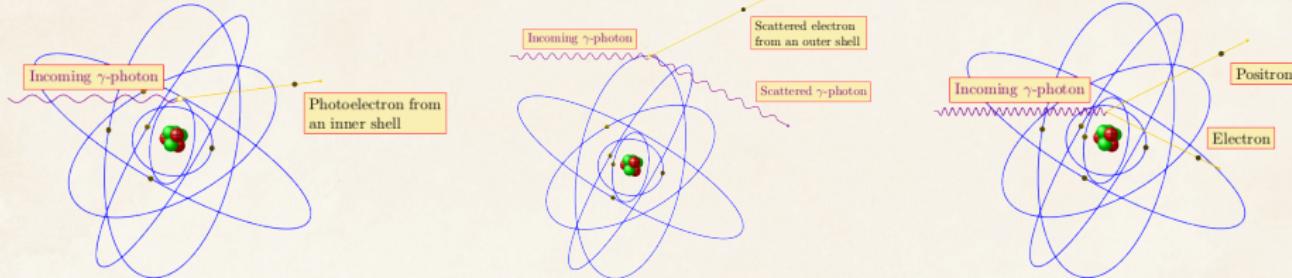
L'effet photo-électrique

Détection de lumière

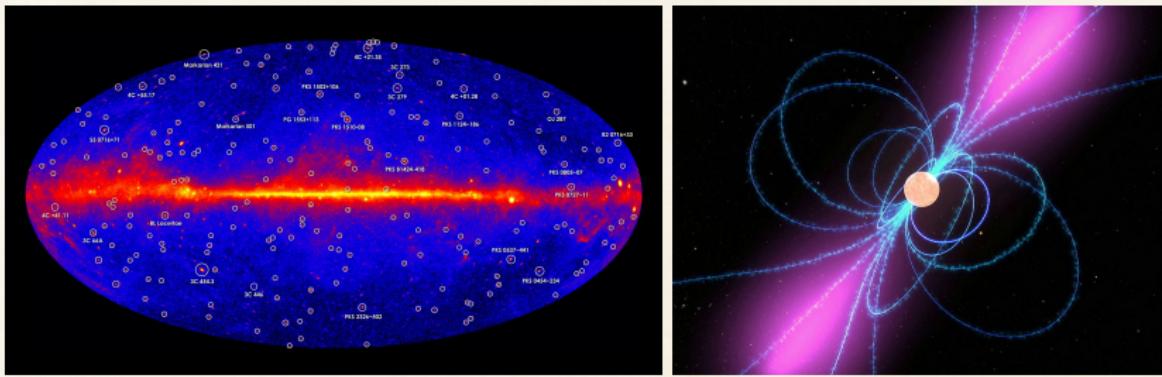
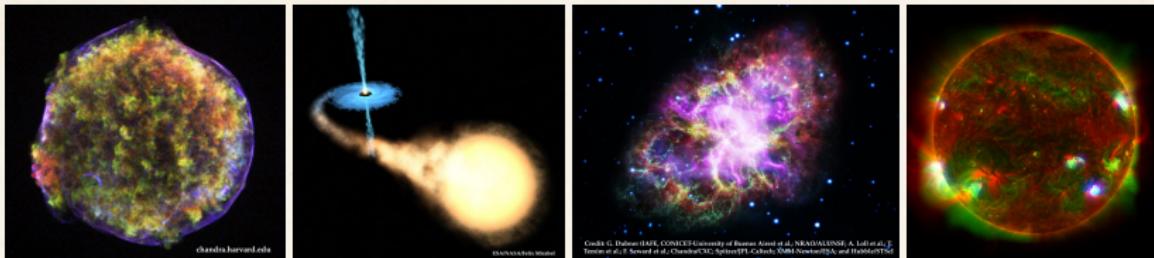
L'effet photo-électrique à la base de la détection de lumière.



Interaction de la lumière avec la matière

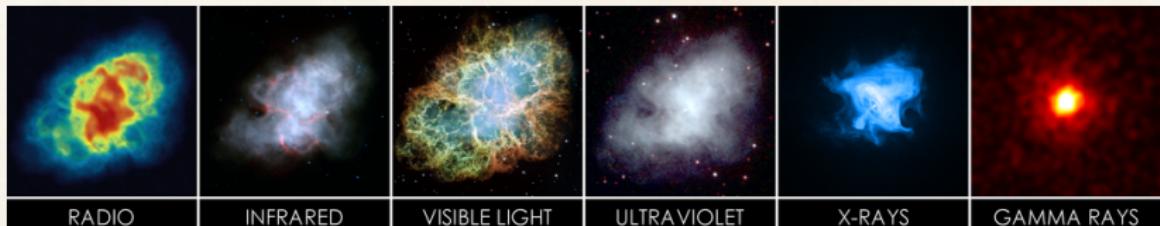
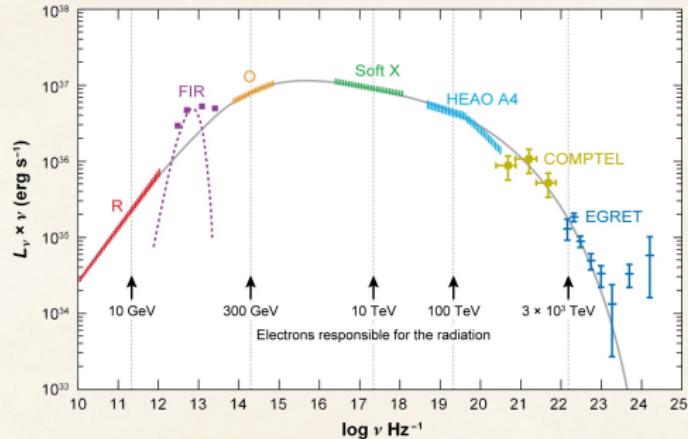


L'univers à hautes énergies



Astronomie multi longueurs d'ondes

Observer dans différentes bandes d'énergie permet d'acquérir des informations complémentaires sur les sources cosmiques



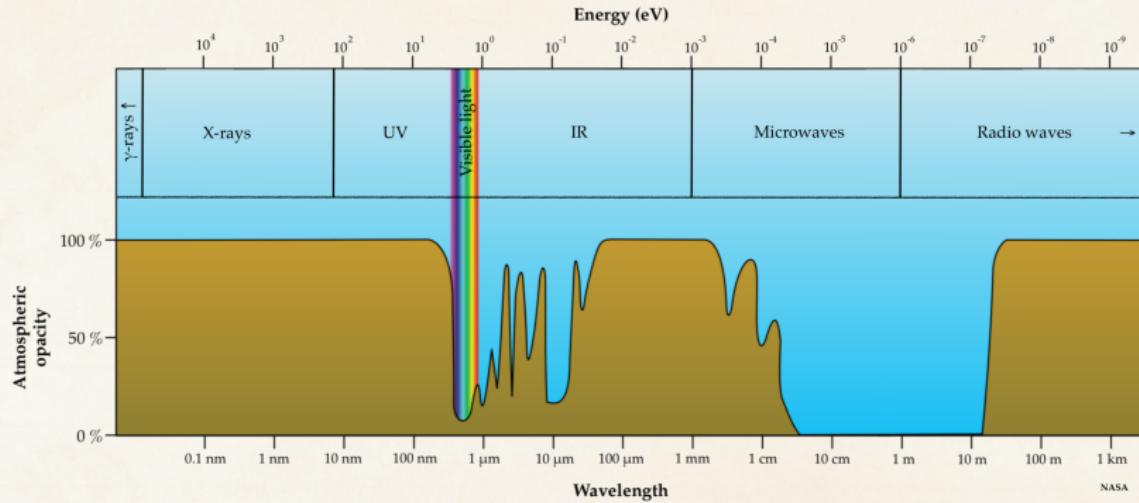
Sources: Radio: NRAO/AUI and M. Bietenholz, J.M. Uson, T.J. Cornwell; Infrared: NASA/JPL-Caltech/R. Gehrz (University of Minnesota); Visible: NASA, ESA, J. Hester and A. Loll (Arizona State University); Ultraviolet: NASA/Swift/E. Hoversten, PSU; X-ray: NASA/CXC/SAO/F. Seward et al.; Gamma: NASA/DOE/Fermi LAT/R. Buehler



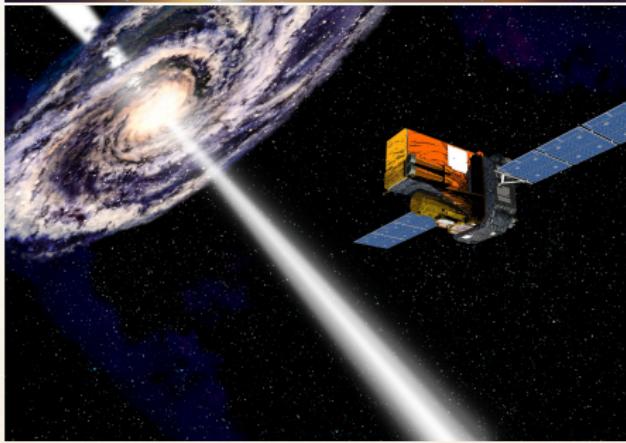
Section 2

Observer le ciel à hautes énergies depuis
l'espace

Absorption atmosphérique



Satellites et station spatiales



Chandra (NASA), Integral (ESA),
Fermi (NASA)

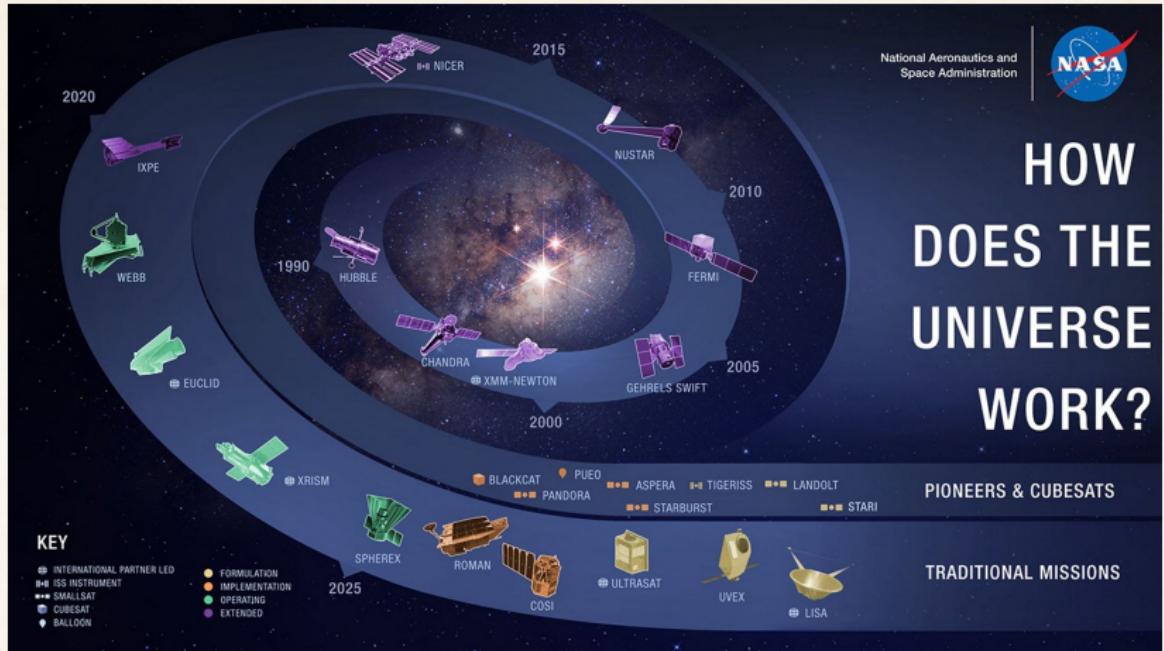




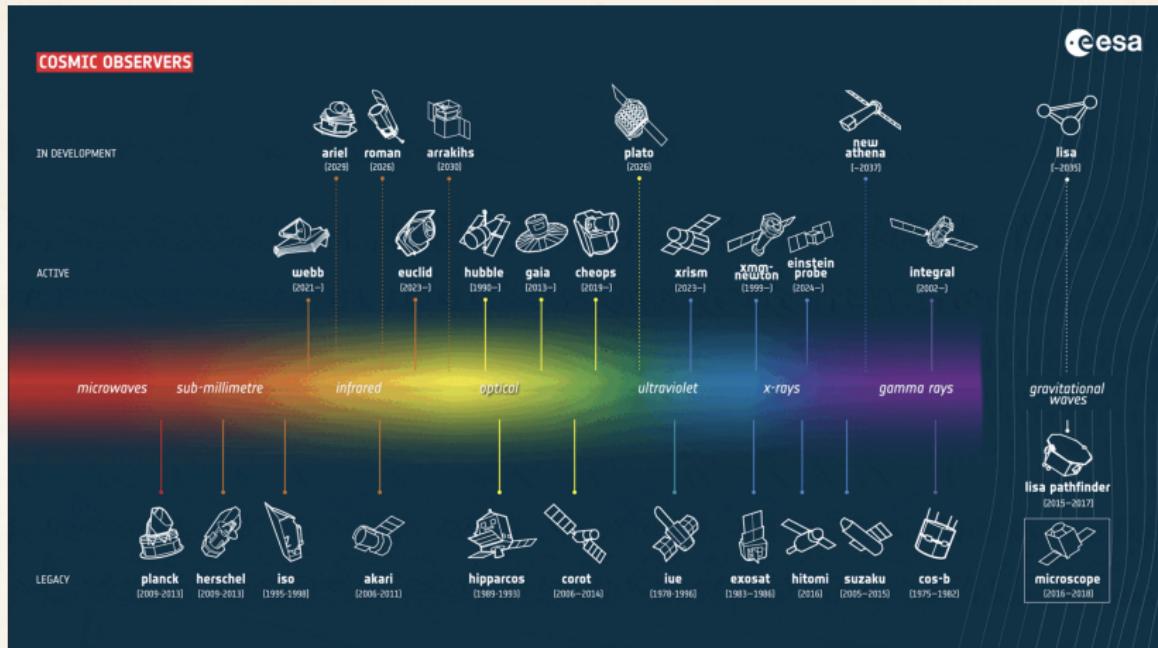
HOW DOES THE UNIVERSE WORK?

PIONEERS & CUBESATS

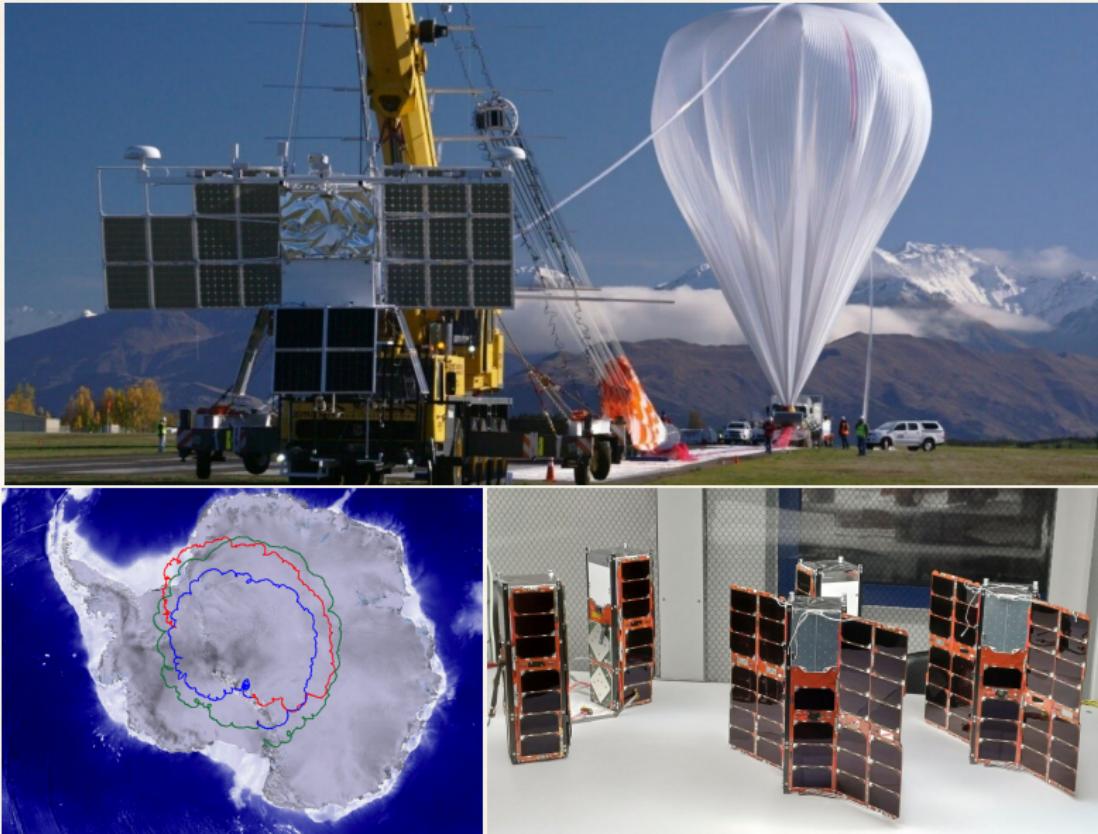
TRADITIONAL MISSIONS



Flotte européenne

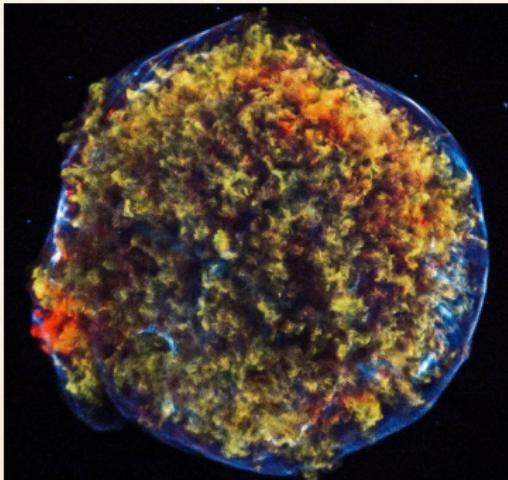
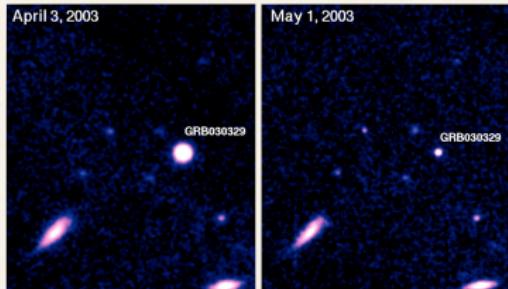
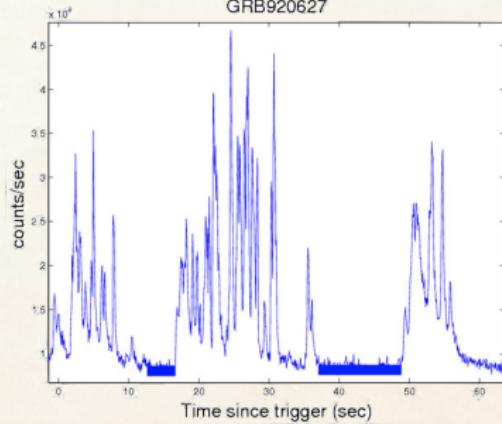
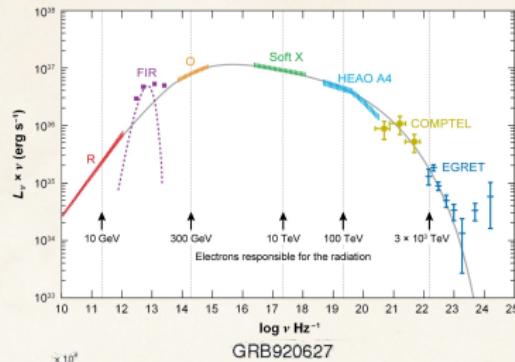


Ballons stratosphériques et cubesats

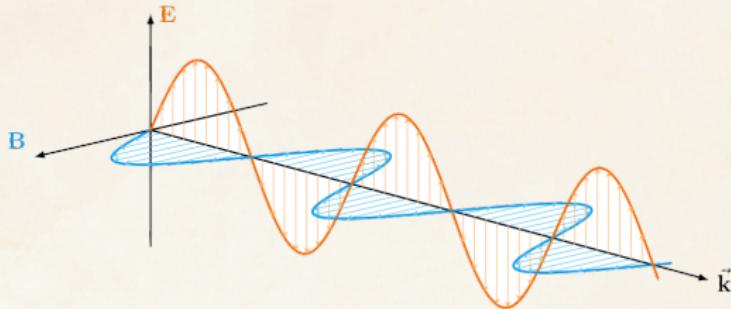


Mesures astrophysiques

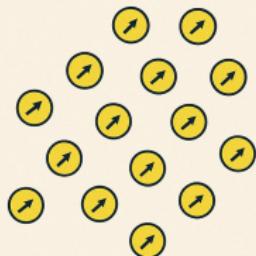
Spectres, Analyses temporelles, Localisation, Imagerie



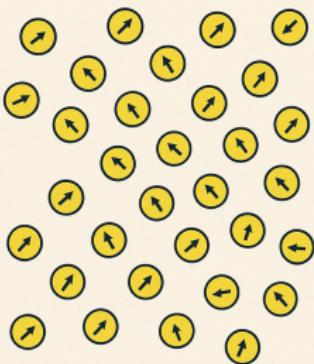
Polarisation



Polarized Light



Unpolarized Light

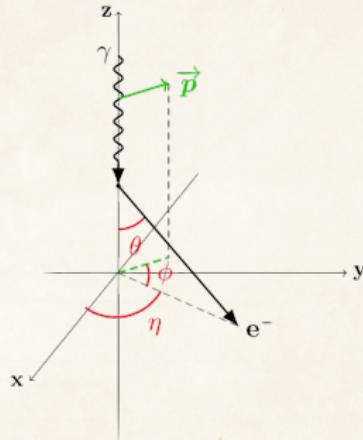


✓ Avec filtre polarisant



✗ Sans filtre polarisant

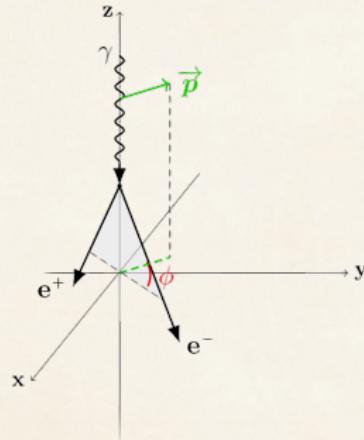
Effet Photo-électrique

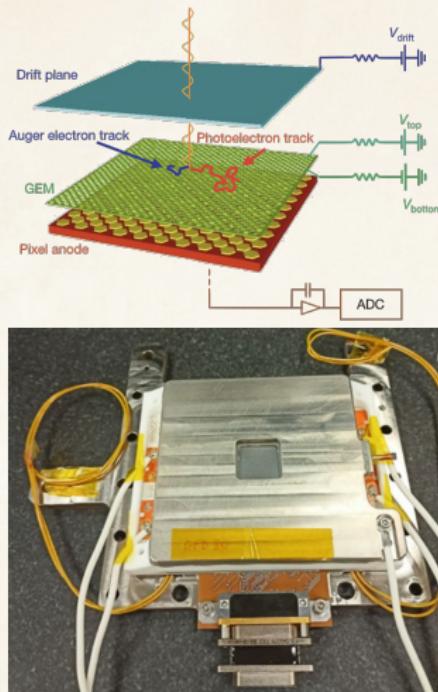


Diffusion Compton

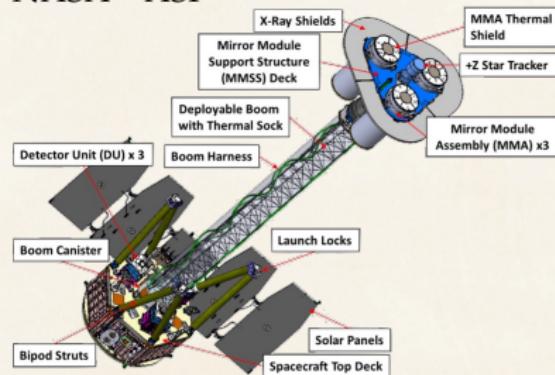


Production de paire





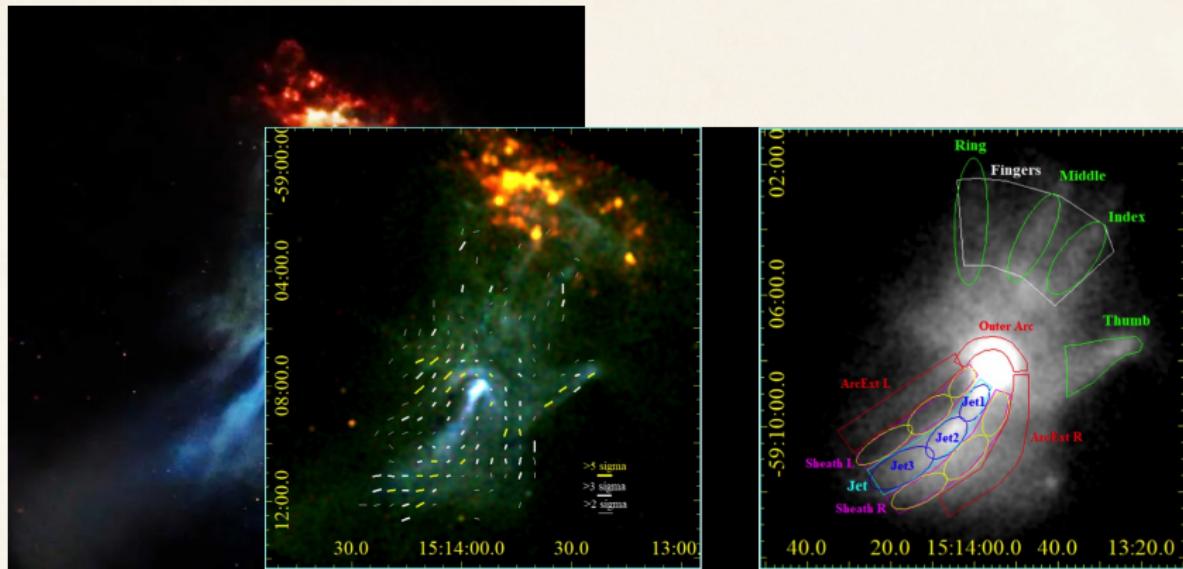
Imaging X-ray Polarimetry Explorer NASA – ASI



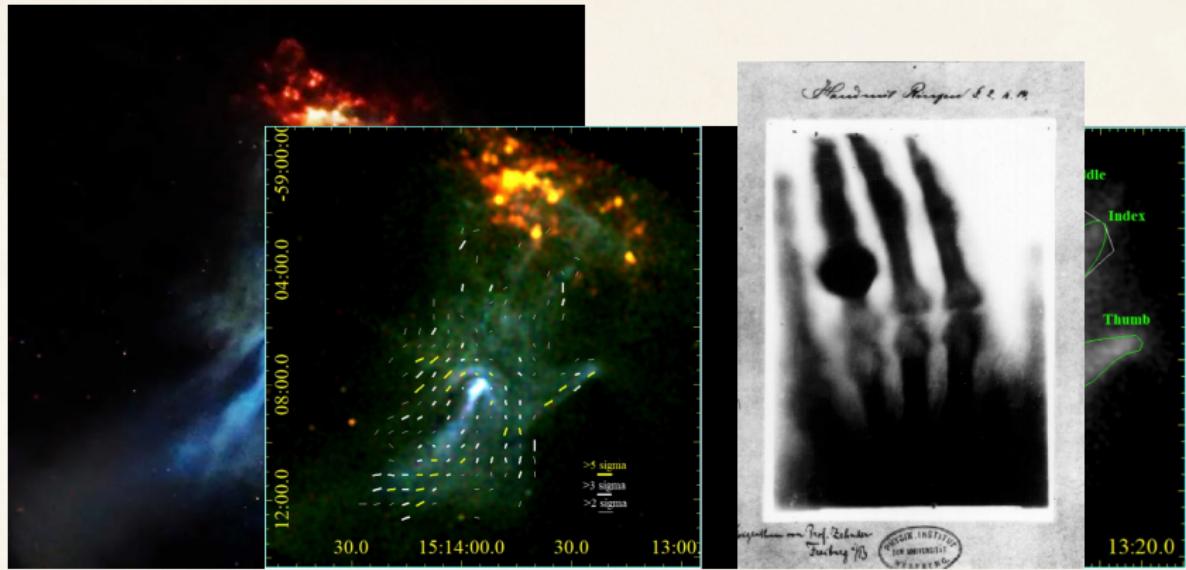
La main cosmique

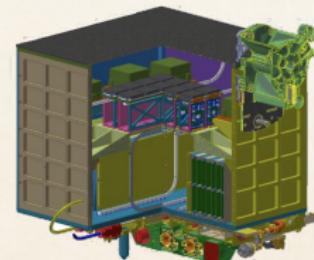
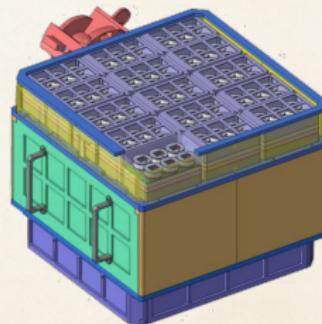
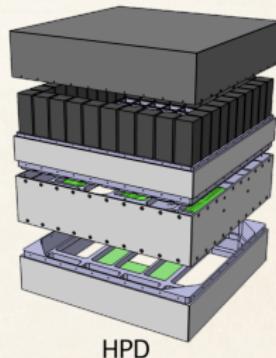
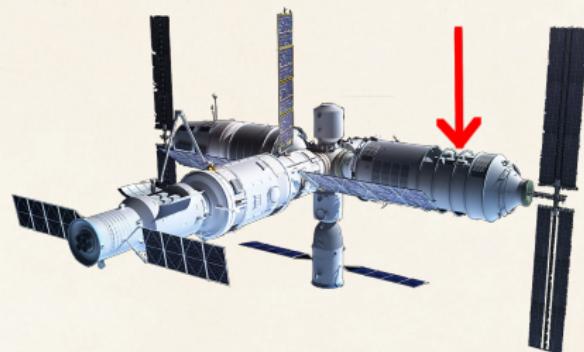
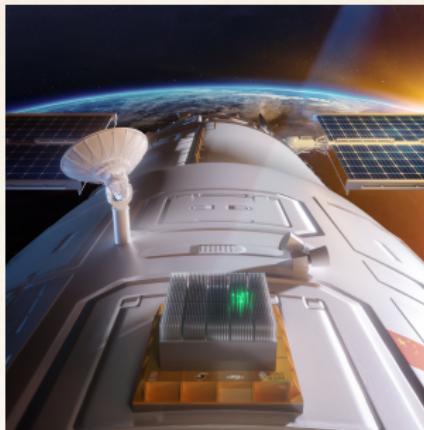


La main cosmique



La main cosmique





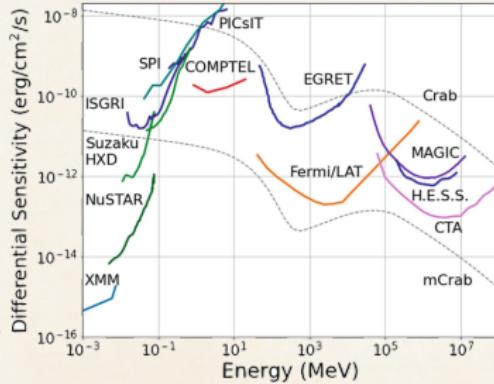
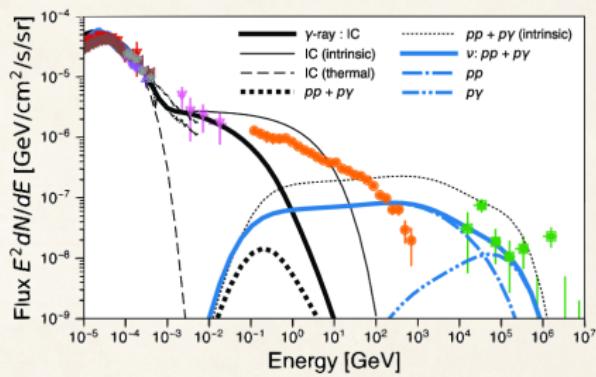
HPD

LPD

BSD

Limitations des missions spatiales

Les missions spatiales sont limitées par la taille et masse des instruments, limitant la sensibilité à très hautes énergies.



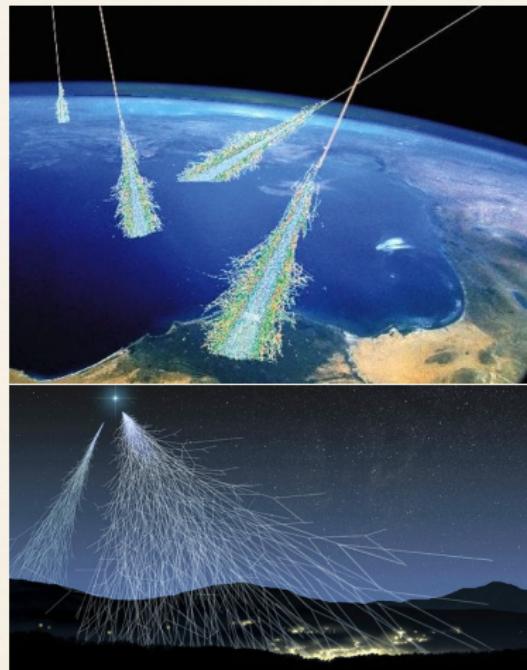
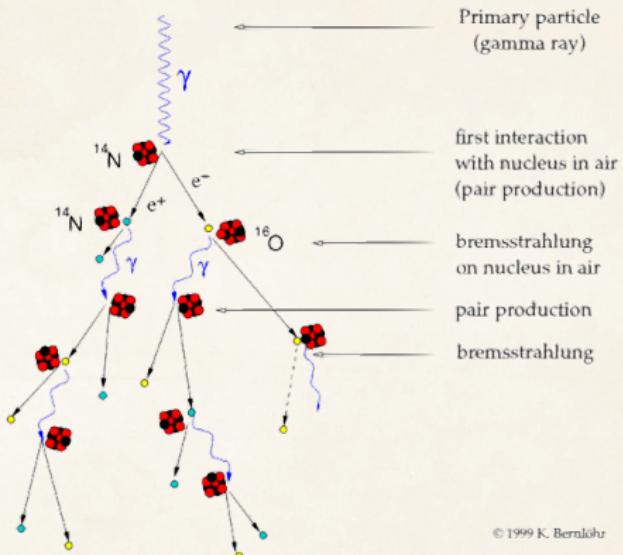


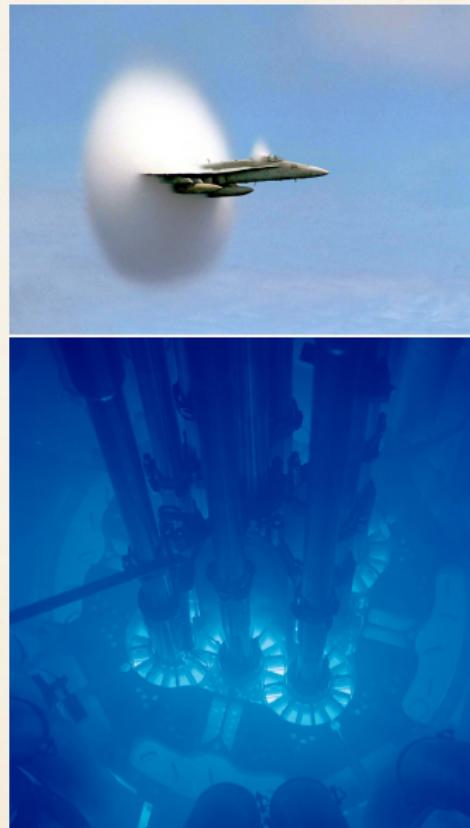
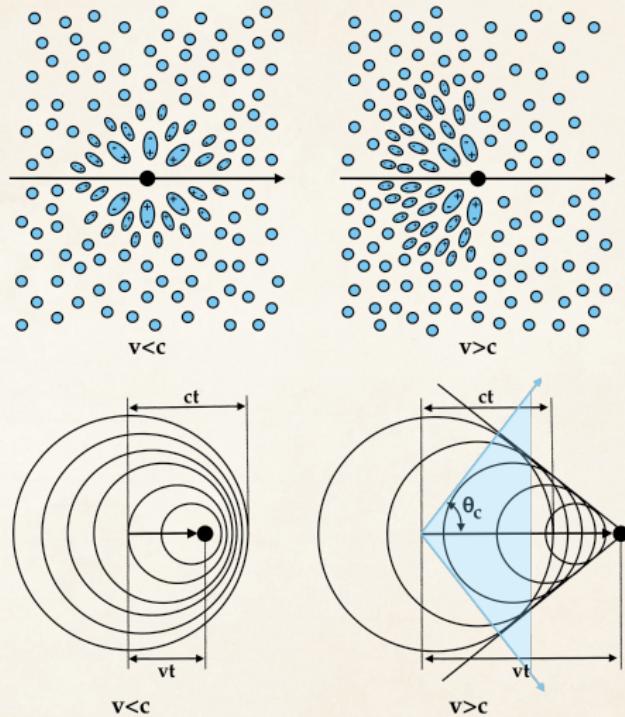
A detailed 3D rendering of a satellite in orbit around Earth. The satellite features a large white cylindrical body with various scientific instruments attached. A prominent feature is a white parabolic dish antenna mounted on a white cylindrical boom. To the right, there are two large rectangular solar panels with a grid of blue cells. The background shows the blue and white atmosphere of Earth's horizon against the black void of space.

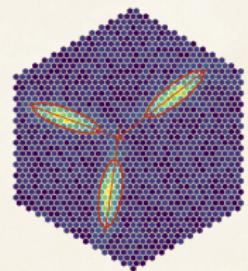
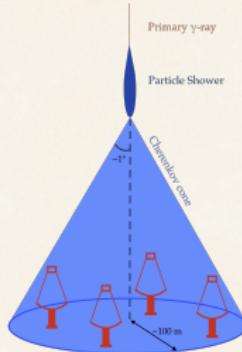
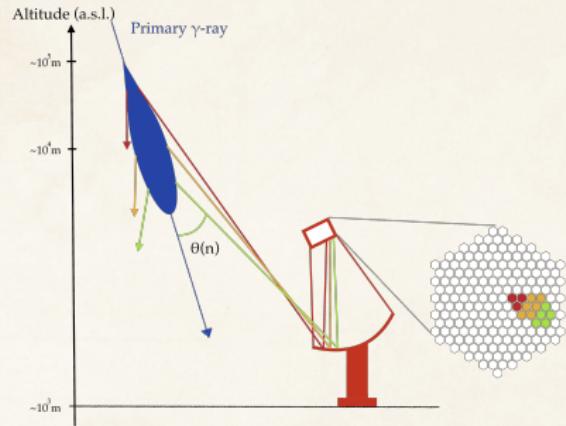
Section 3

Observations indirectes depuis le sol

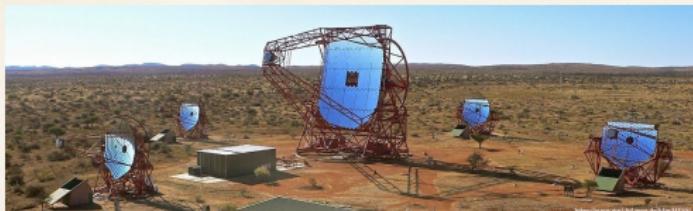
Gerbes atmosphériques







Observatoires actuels

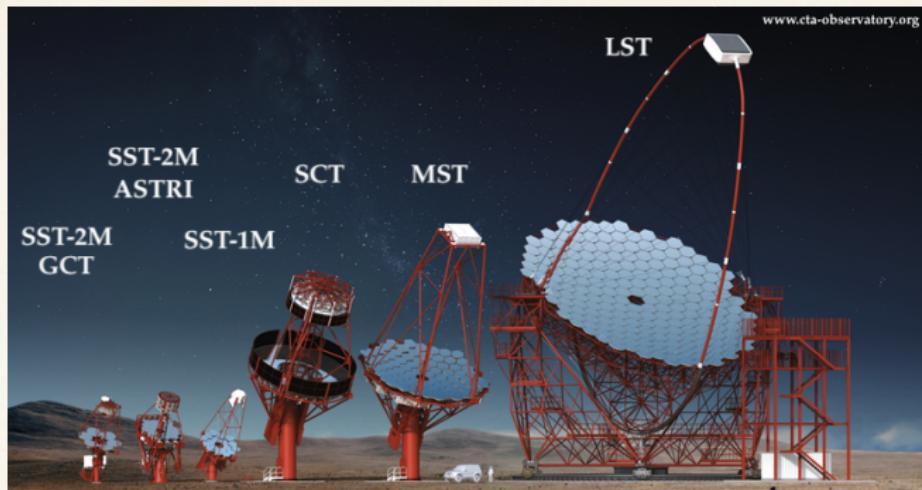


	HESS	VERITAS	MAGIC
Lieu	Namibie	Arizona, USA	La Palma, Espagne
Hemisphère	Sud	Nord	Nord
Nombre de télescopes	5	4	2
Champ de vue	5°	3.5°	3.5°
Interval d'énergie	30 GeV - 100 TeV	50 GeV - 50 TeV	30 GeV - 100 TeV
Diameter télescope	4 × 12 m + 1 × 18 m	4 × 12 m	2 × 17 m

Cherenkov Telescope Array (CTA)



Cherenkov Telescope Array (CTA)

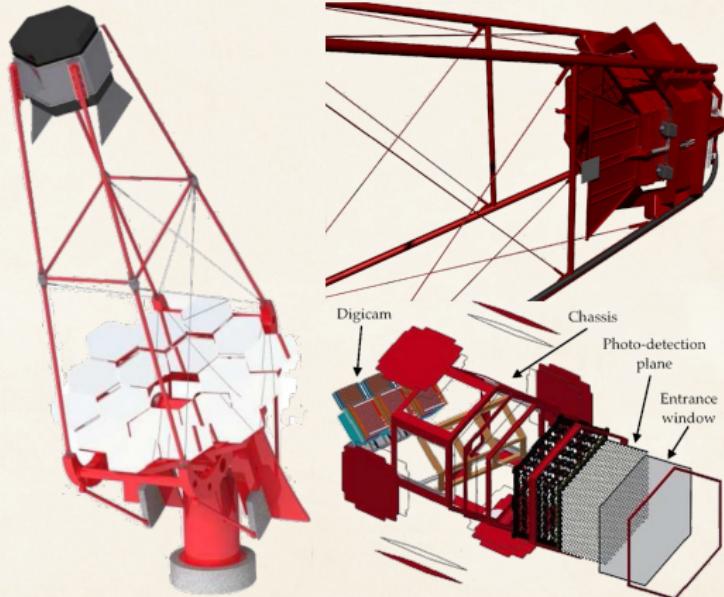


www.cta-observatory.org

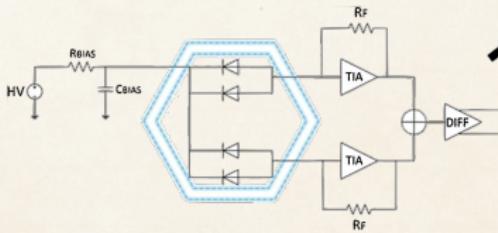
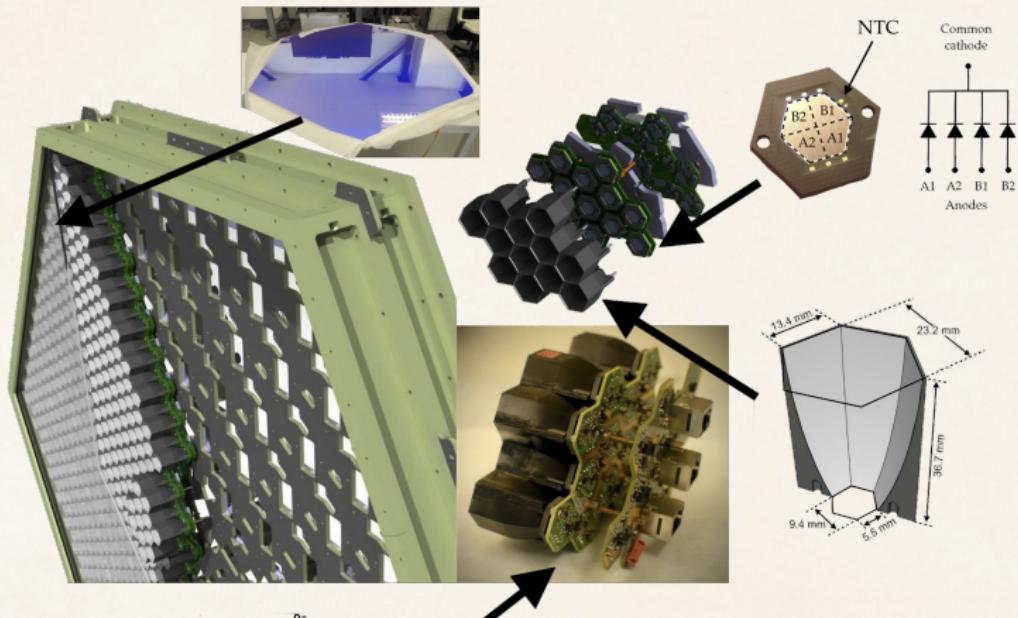
	LST	MST	SST
Interval d'énergie	20 GeV - 150 GeV	150 GeV - 5 TeV	5 TeV - 300 TeV
Nombre de télescopes	4 South + 4 North	25 South + 15 North	70 South
Diamètre miroir primaire	23.0 m	11.5 m	4.0-4.3 m
Champ de vue	4.3°	7.5°	8.3 – 10.5°
Détecteurs	PMT	PMT	SiPM

Télescope SST-1M

- Télescope 8.6 tonnes, caméra 200 kg
- 4 m diamètre, 5.6 m longueur focale
- Taille angulaire d'un pixel: 0.24°
- Design Davies-Cotton
- Miroirs: 18 facettes hexagonales



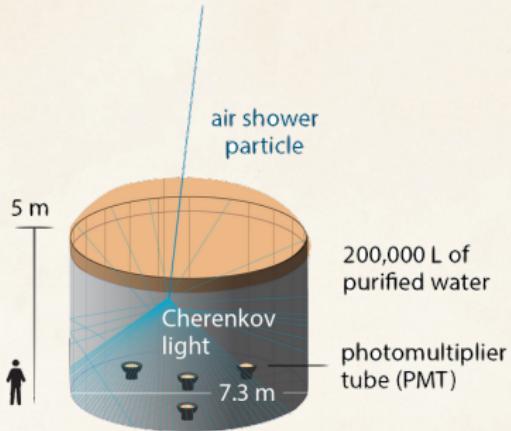
La caméra de SST-1M



Heller, Matthieu, et al. "An innovative silicon photomultiplier digitizing camera for gamma-ray astronomy." The European Physical Journal C 77.1 (2017): 47.

Réservoirs à eau Tcherenkov

HAWC, Mexique



Large High Altitude Air Shower Observatory





Questions ?