Rayons Cosmiques
Une autre image de l'Univers

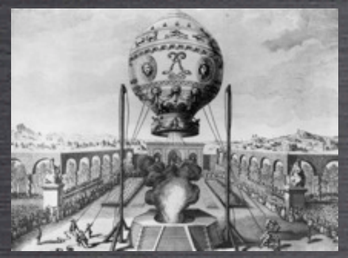


Cheminement



La découverte des radiations

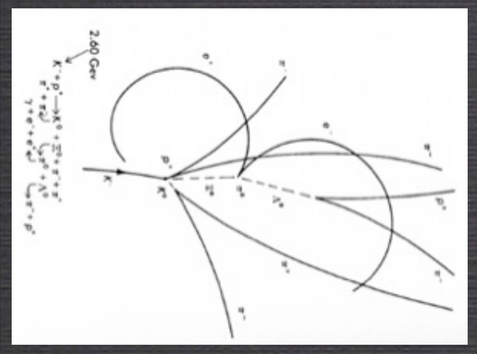
Les premiers Pas

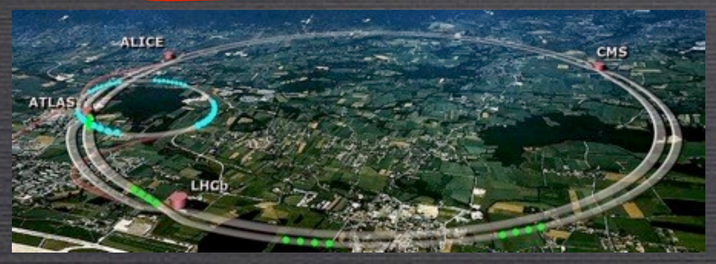


Le quête vers les énergies extrêmes

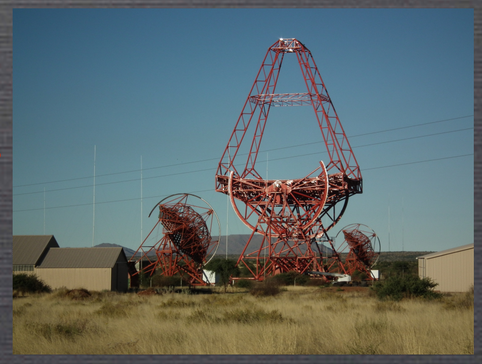


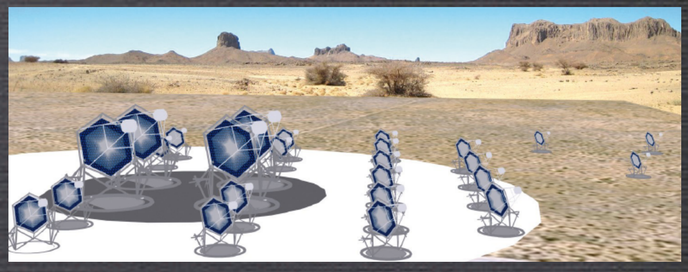






La physique des particules





L'astronomie Gamma 1980 - 2012...

Rayons Cathodiques (1870) & Électrons (1897)

Sir William Crookes

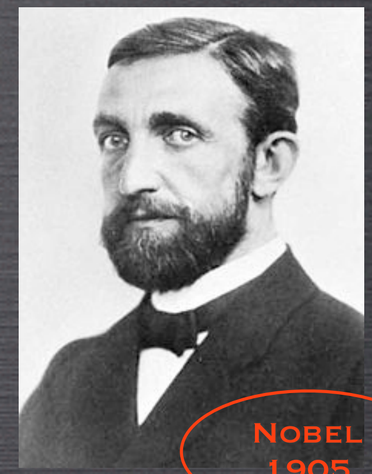






Johann Wilhelm Hittorf

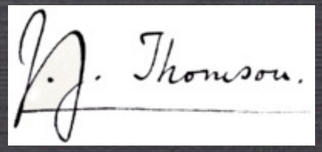
Philipp Lenard

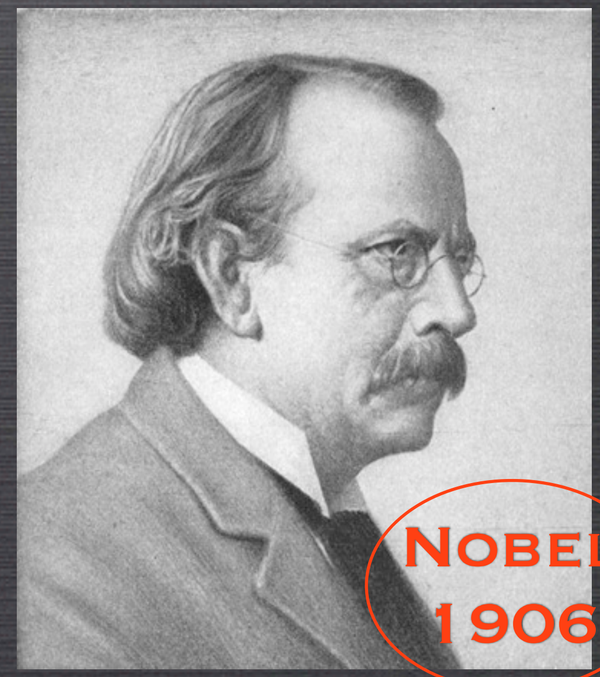


Nobel 1905



Eugen Goldstein





Nobel 1906

Rayons Cathodiques (1870) & Électrons (1897)

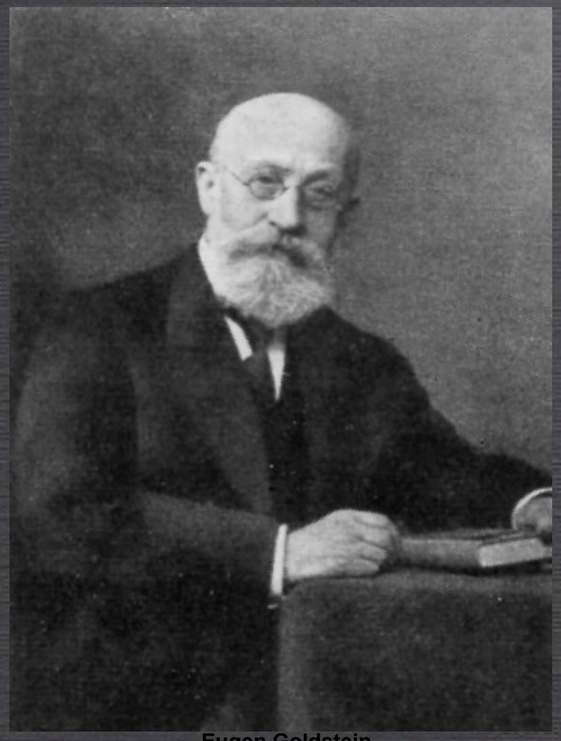
Sir William Crookes





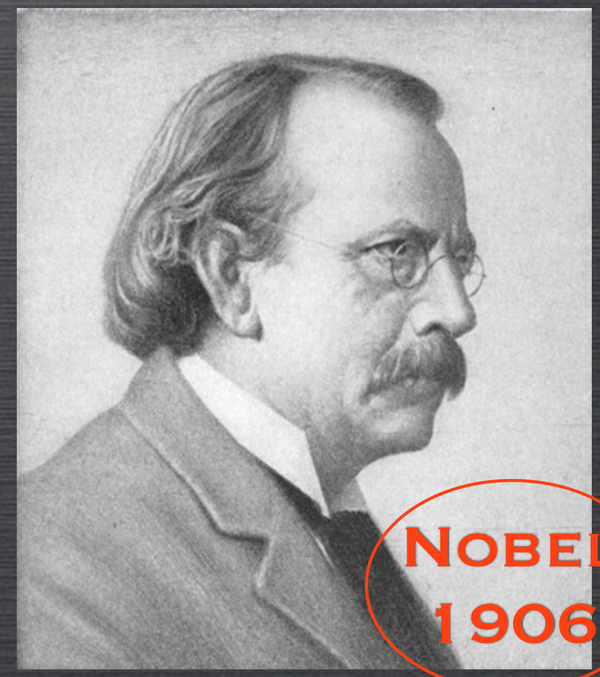


Johann Wilhelm Hittorf



Eugen Goldstein





Rayons X (1895)



Nobel 1901

W. Röntgen



1895



1896

Rayons X (1895)



Nobel
1901

W. Röntgen



1895

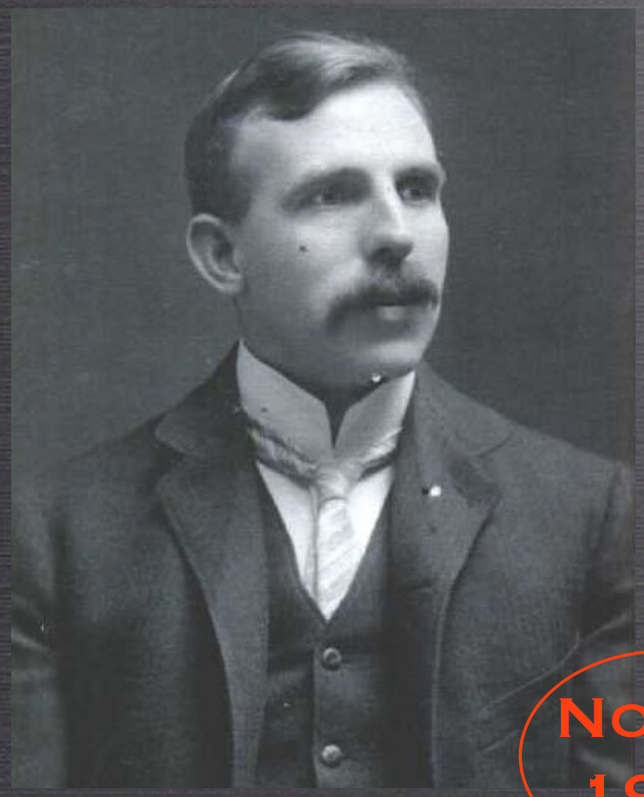


1896

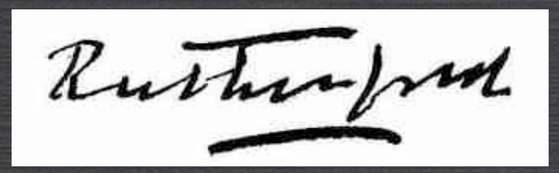


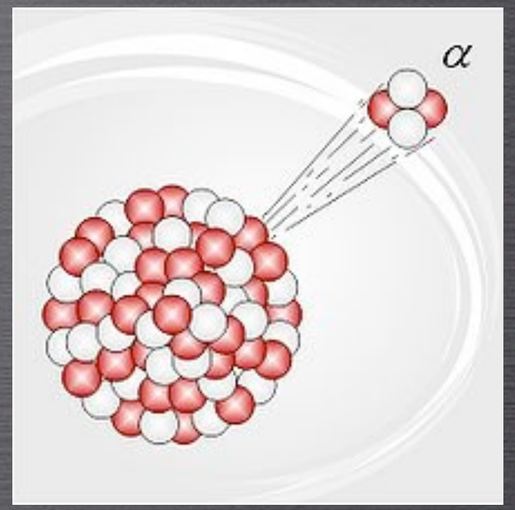
Rayons Alpha & Beta (1899)

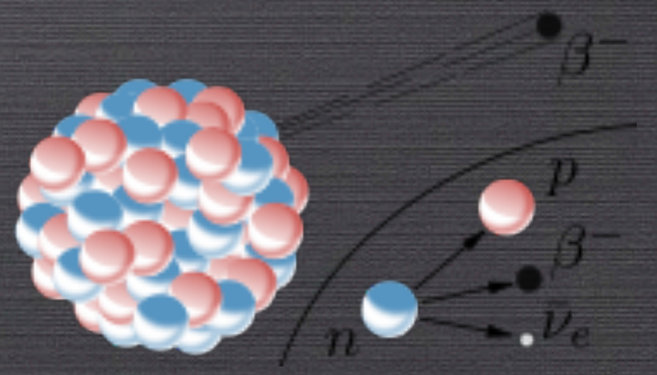




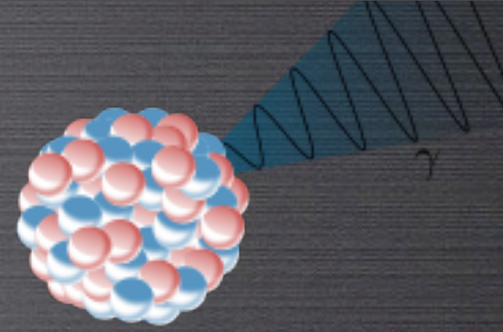
Nobel
1908



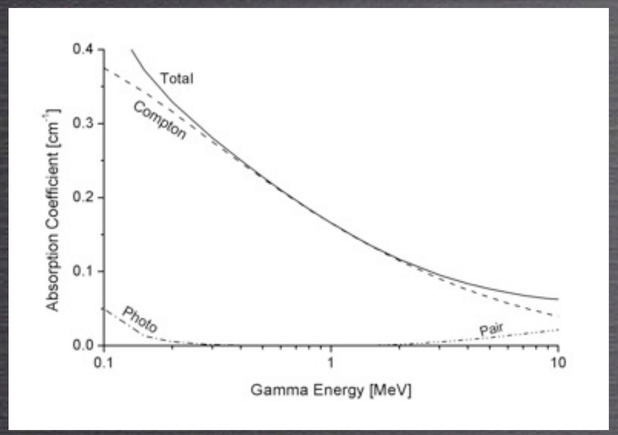




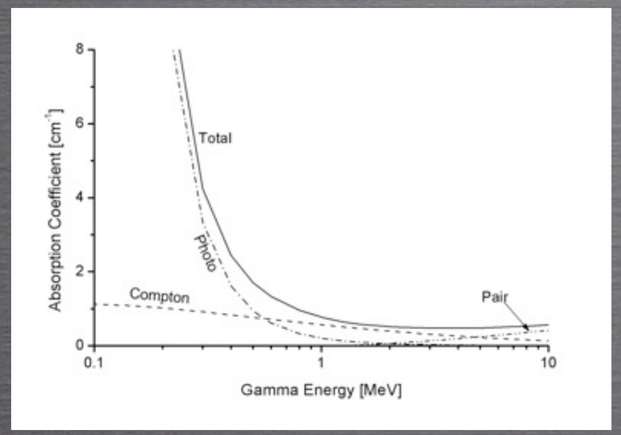
Rayons Gamma (1900)

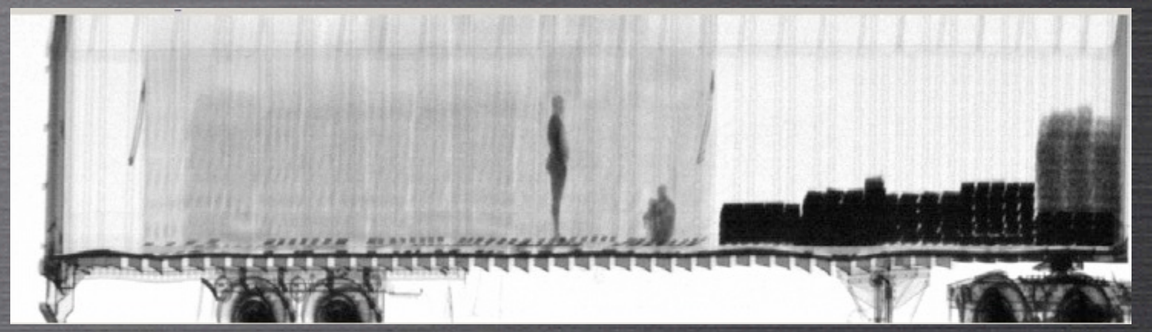


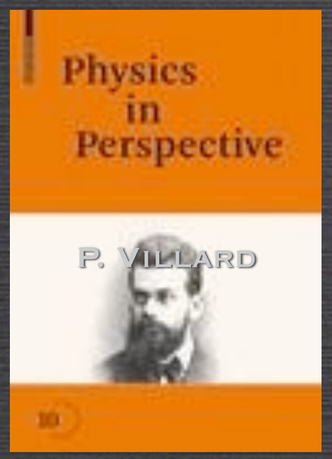
Al

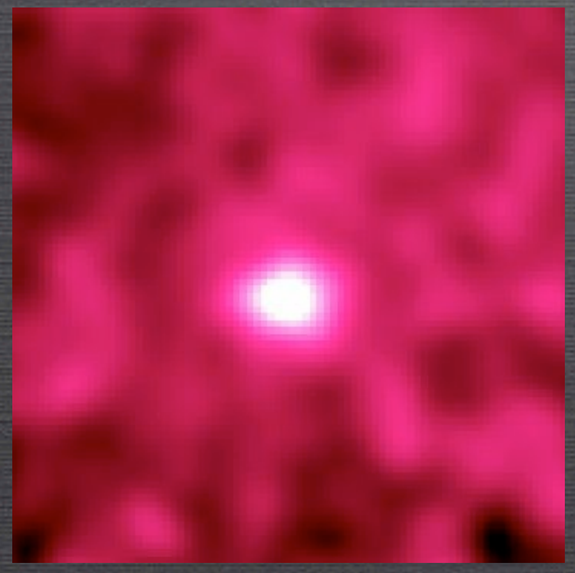


Pb

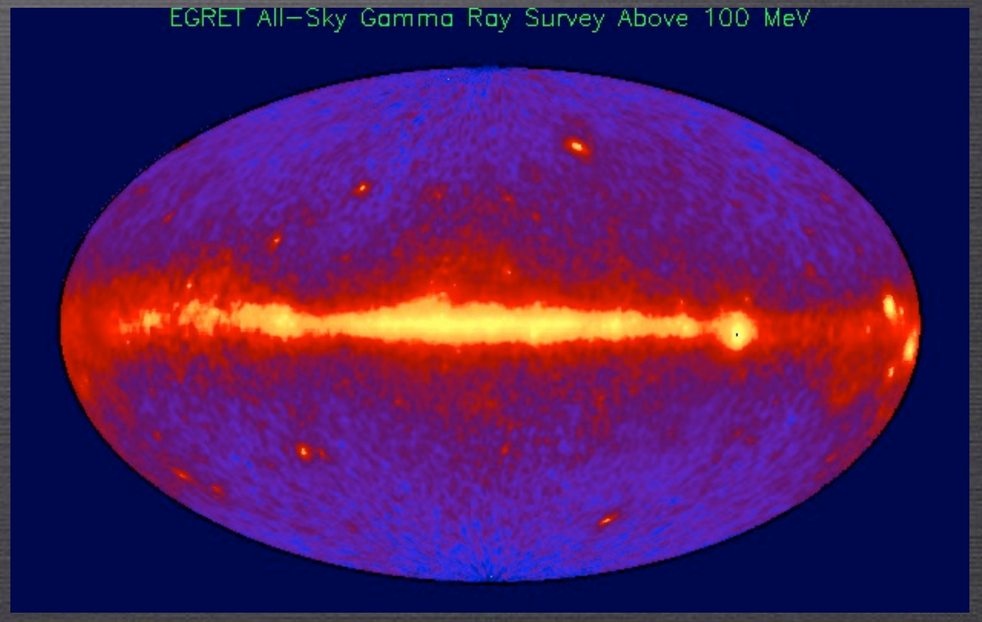






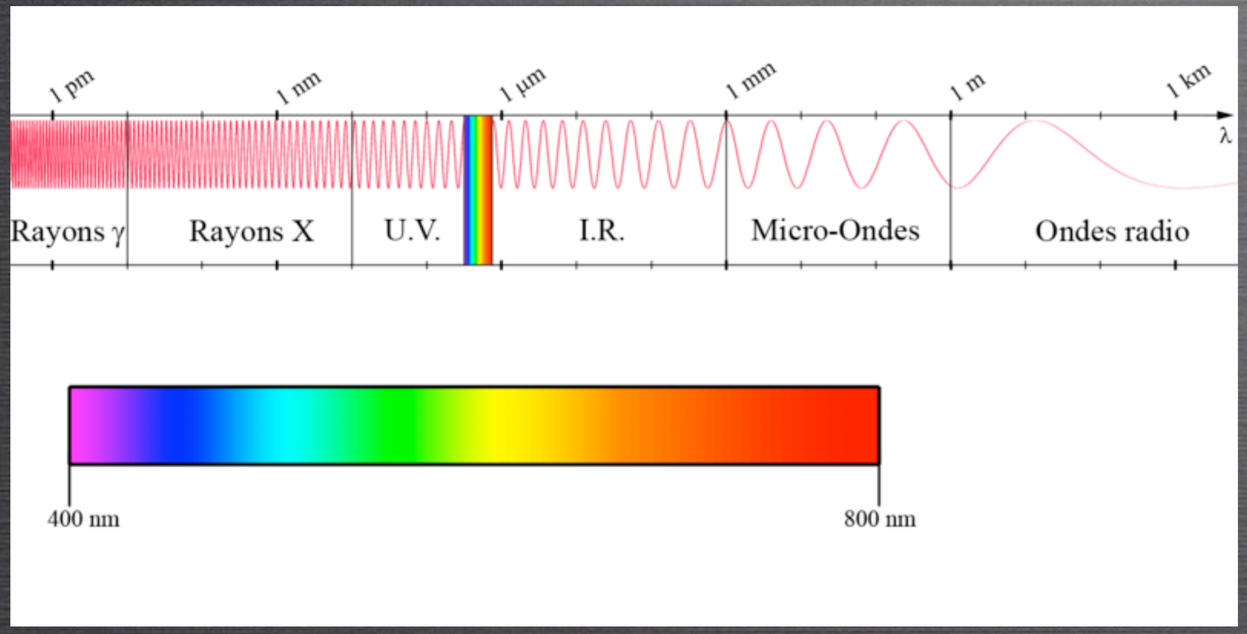


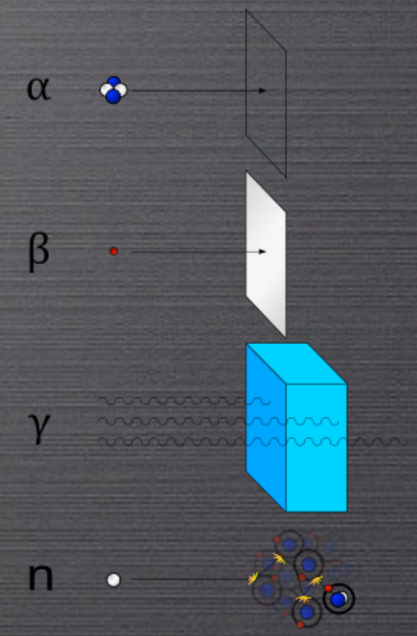
Moon



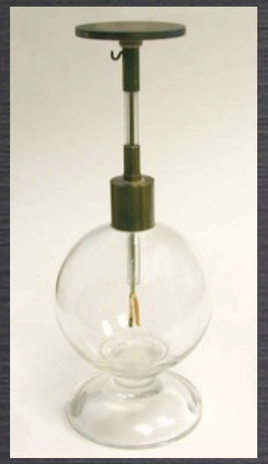
EGRET instrument aboard the Compton Gamma Ray Observatory

Les Rayonnements au début du XXième siècle





Différents types de radiations
Plus ou moins pénétrantes

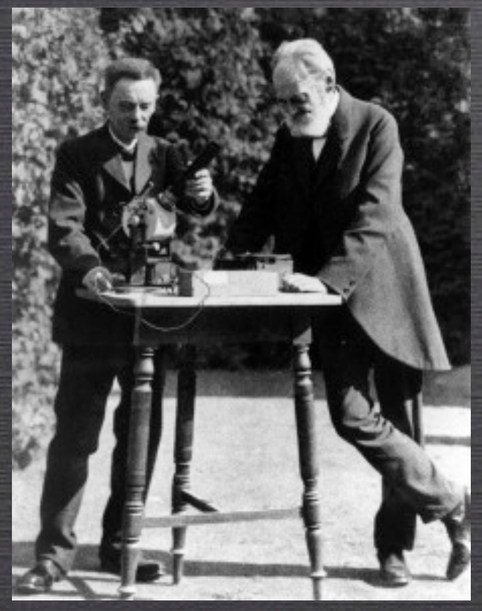


Premiers Pas

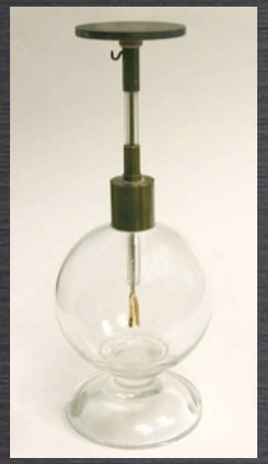
La Décharge Des électroscopes...







ELSTER & GEITEL

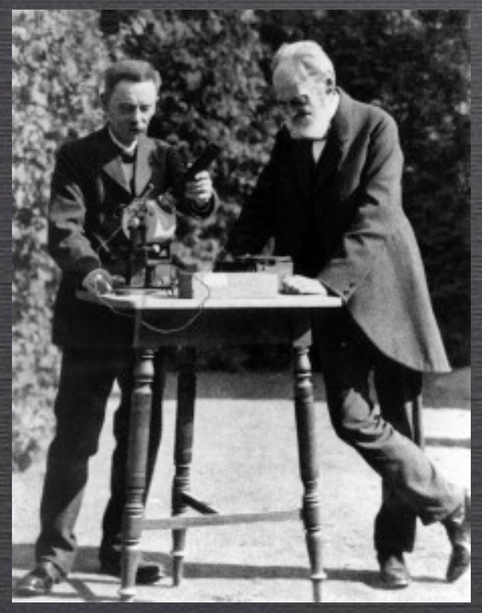


Premiers Pas

La Décharge Des électroscopes...





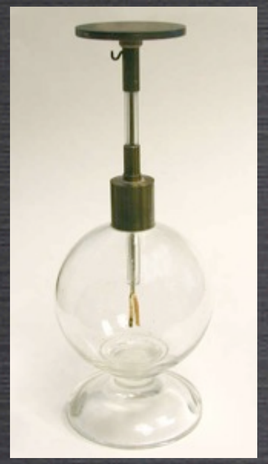


ELSTER & GEITEL



CHARLES_THOMSON_REES_WILSON

"...due to radiation from sources outside our atmosphere, possibly radiation like Röntgen rays or like cathode rays, but of enormously greater penetrating power."

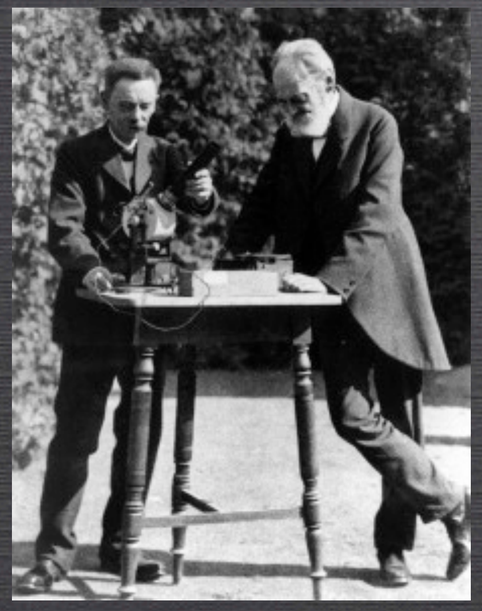


Premiers Pas

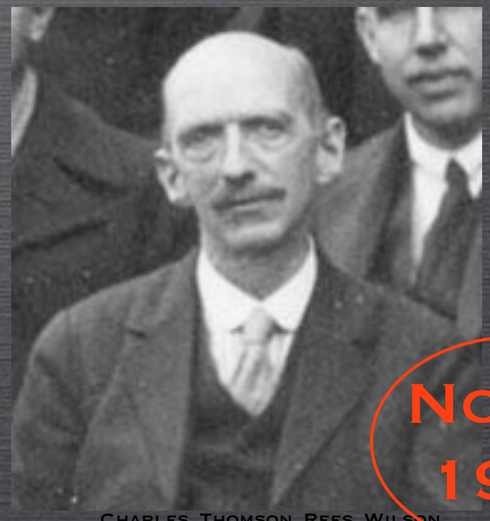
La Décharge Des électroscopes...







ELSTER & GEITEL



CHARLES_THOMSON_REES_WILSON

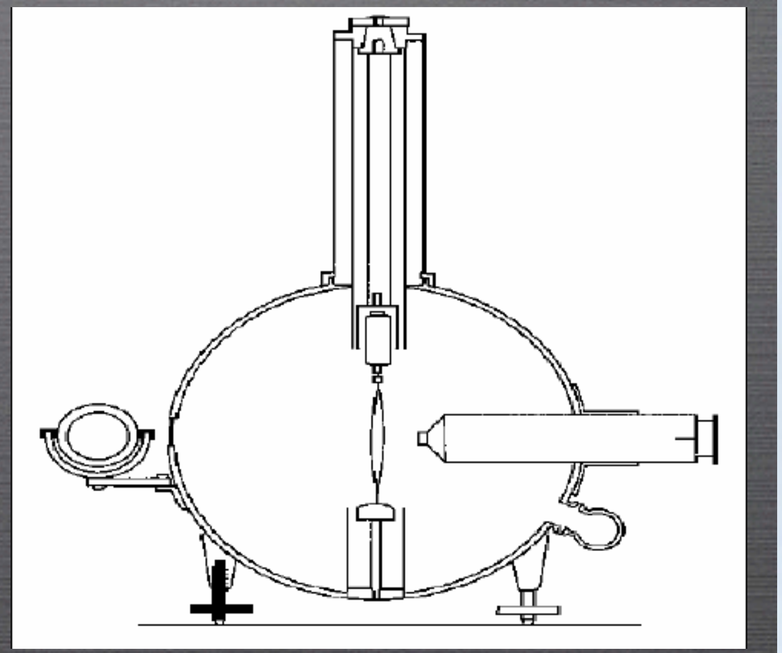
NOBEL
1927

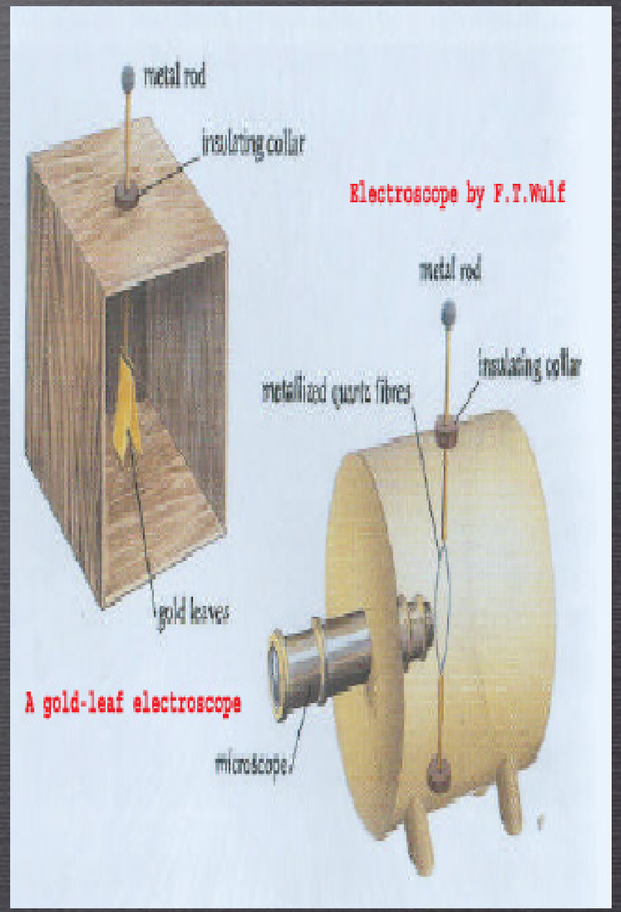
"...due to radiation from sources outside our atmosphere, possibly radiation like Röntgen rays or like cathode rays, but of enormously greater penetrating power."

Théodore Wulf (1907)



330 M

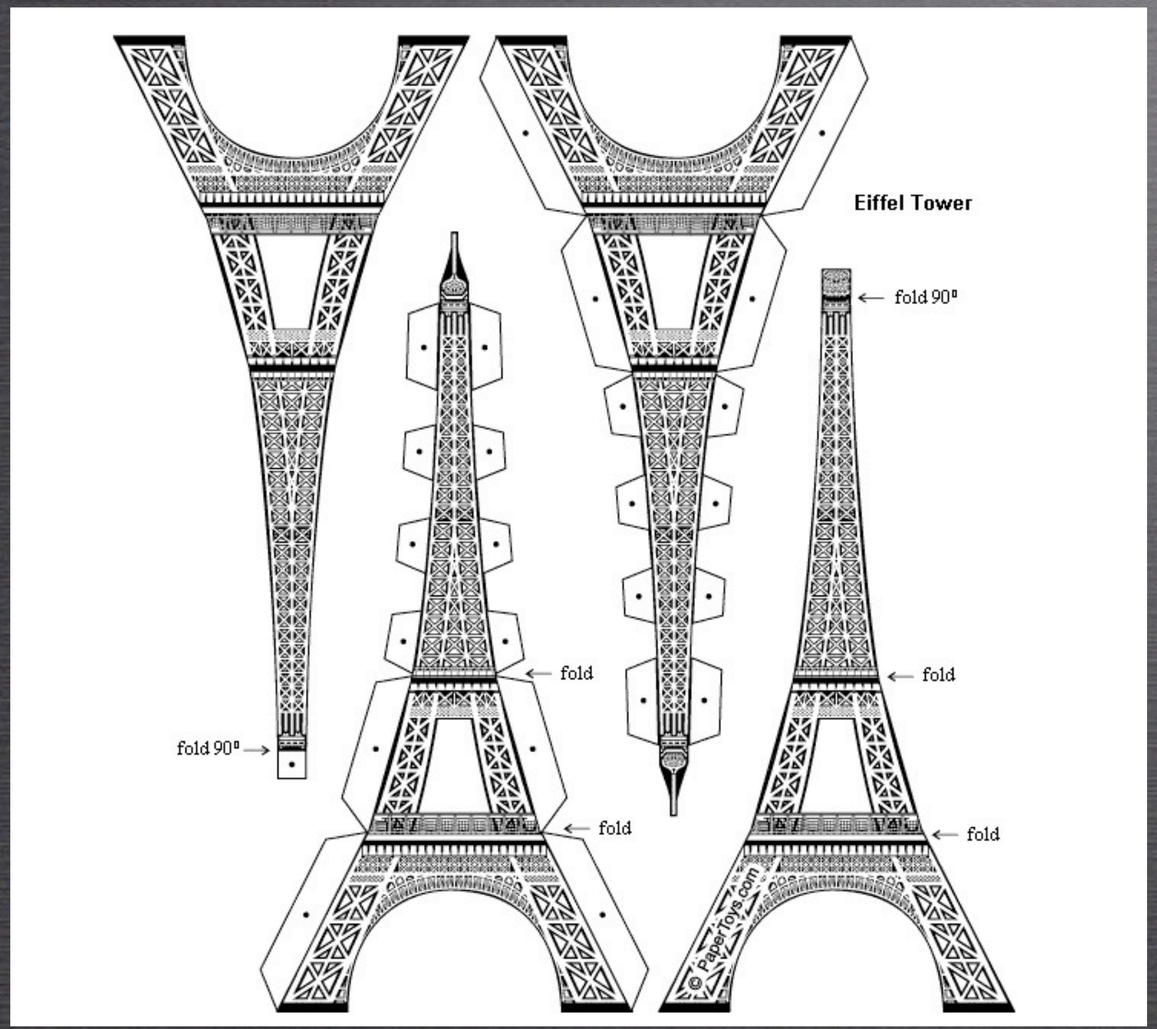




Réduction Attendue:

50% tous les 80m soit plus de 90% au sommet

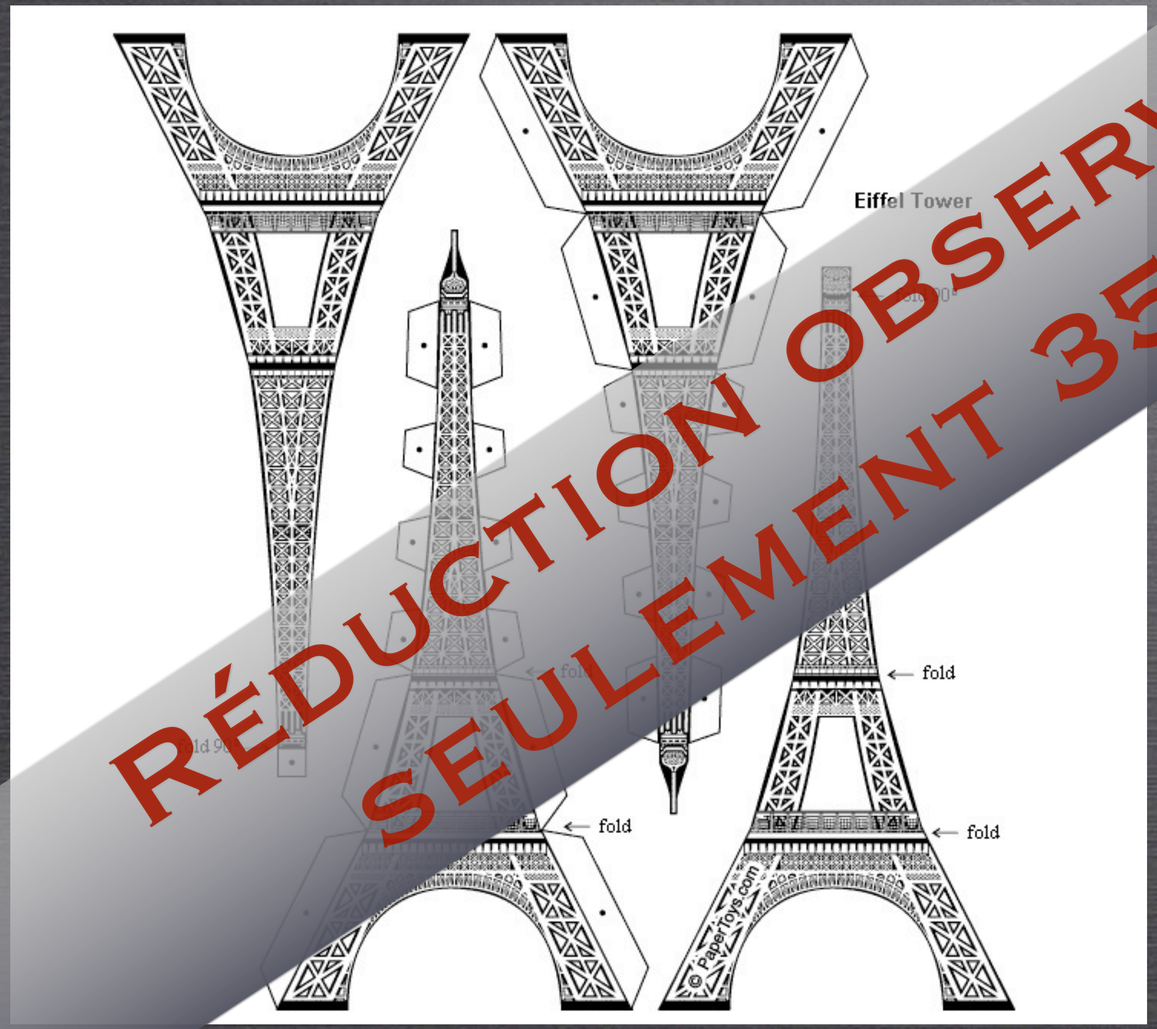
Théodore Wulf (1907)



330 M



Théodore Wulf (1907)



RÉDUCTION OBSERVÉE :
SEULEMENT 35% !

330 m

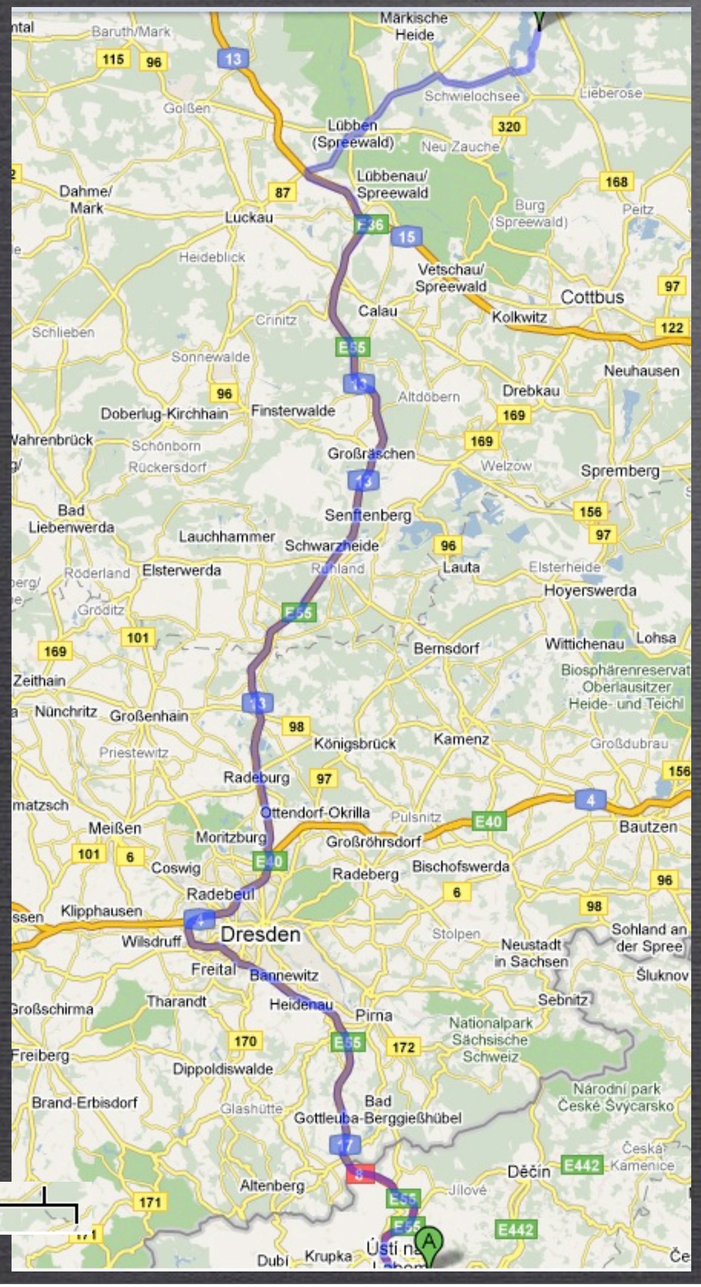


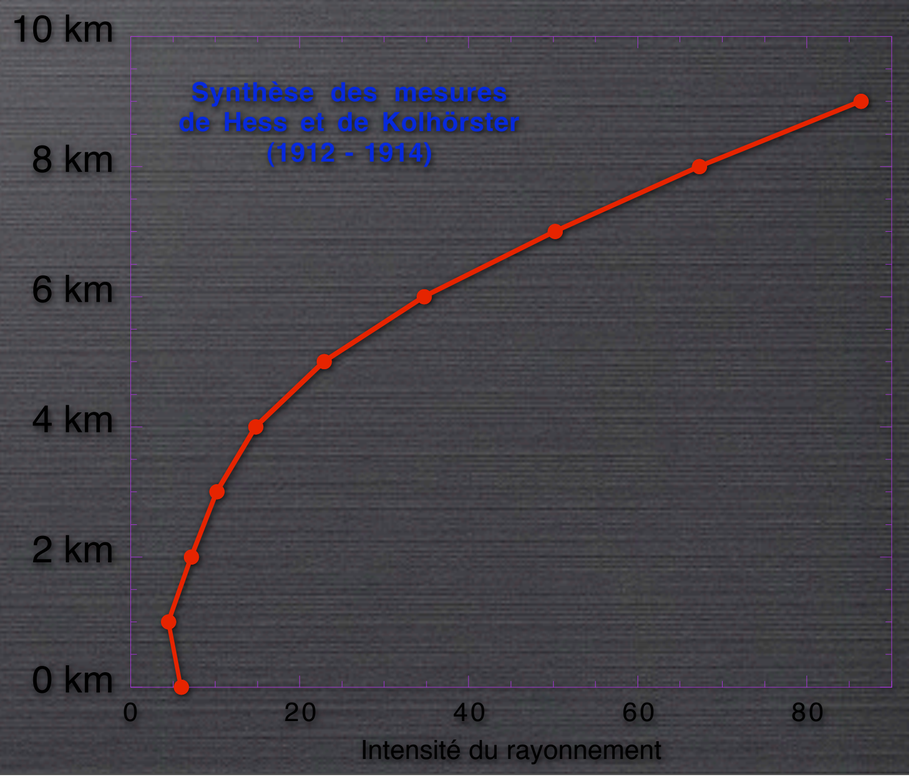
Victor Hess (1912)



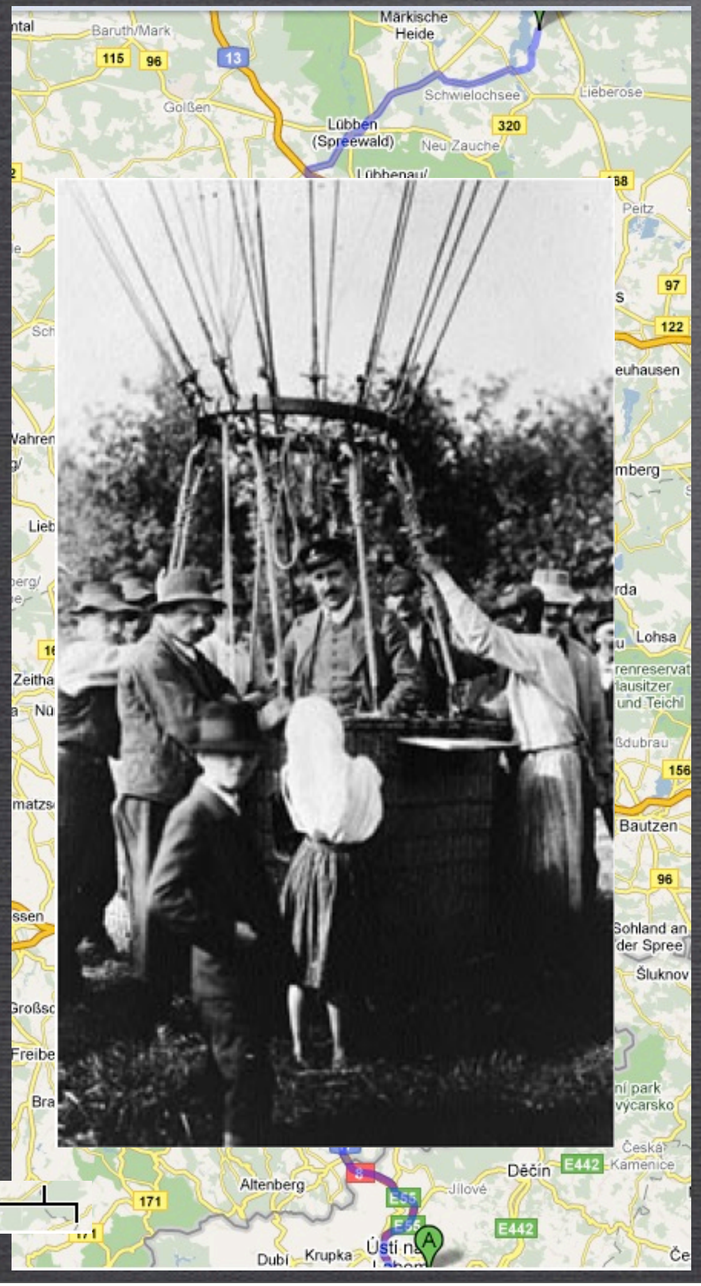








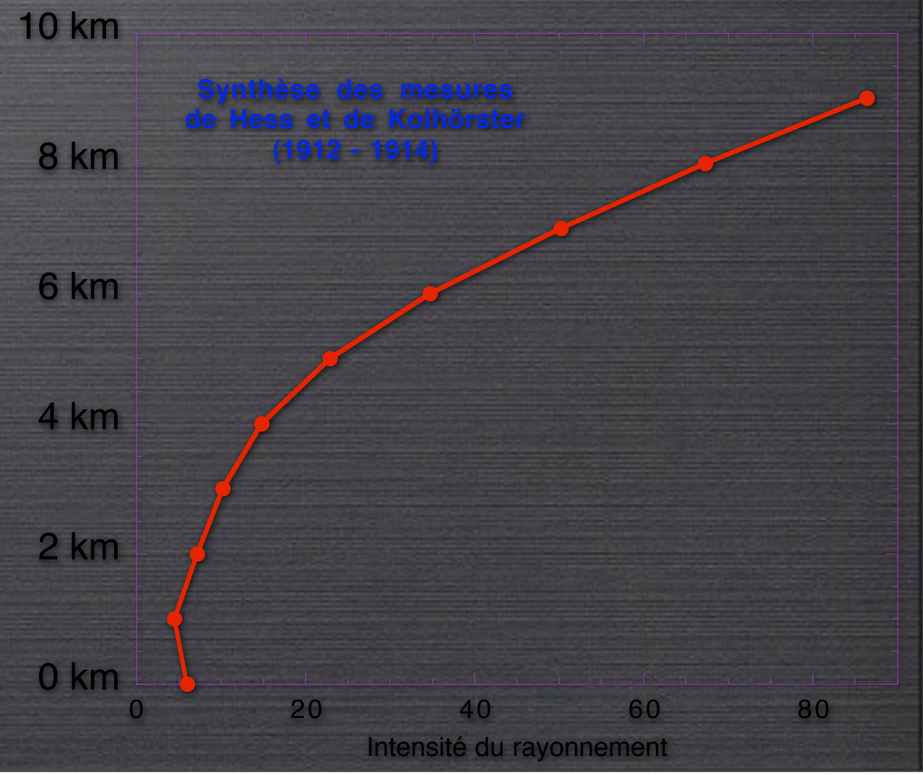
Victor Hess (1912)



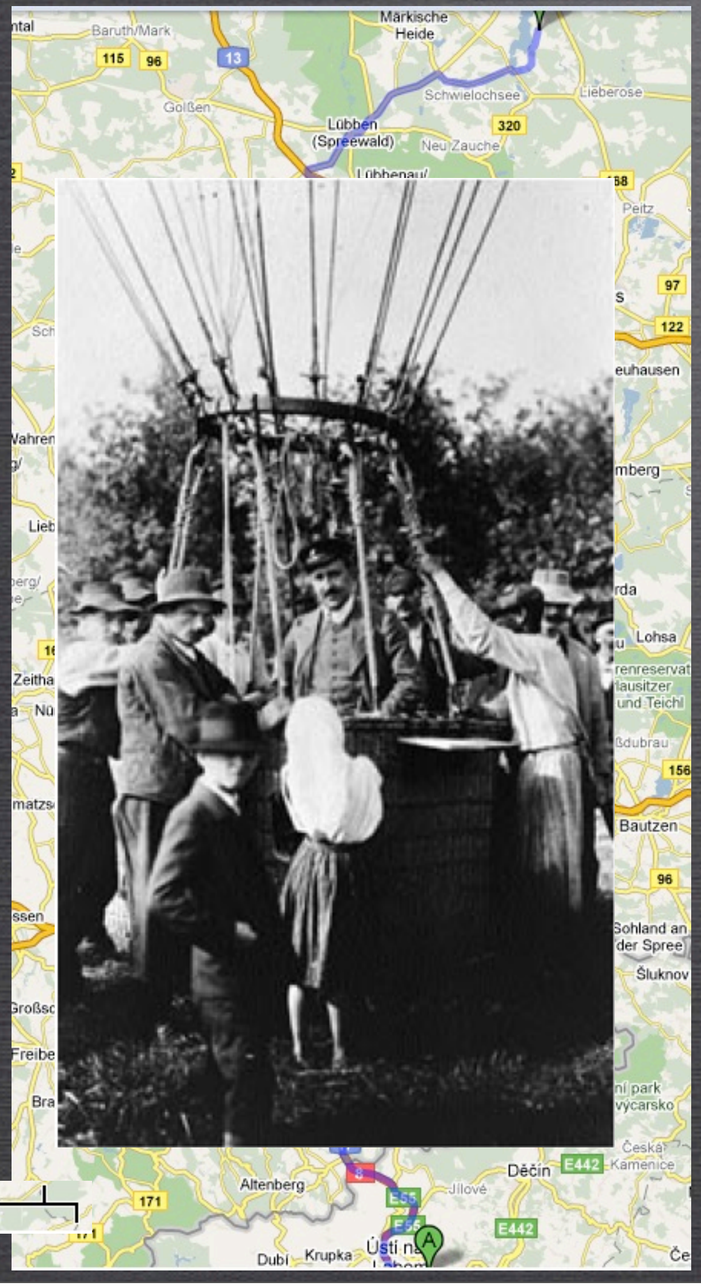






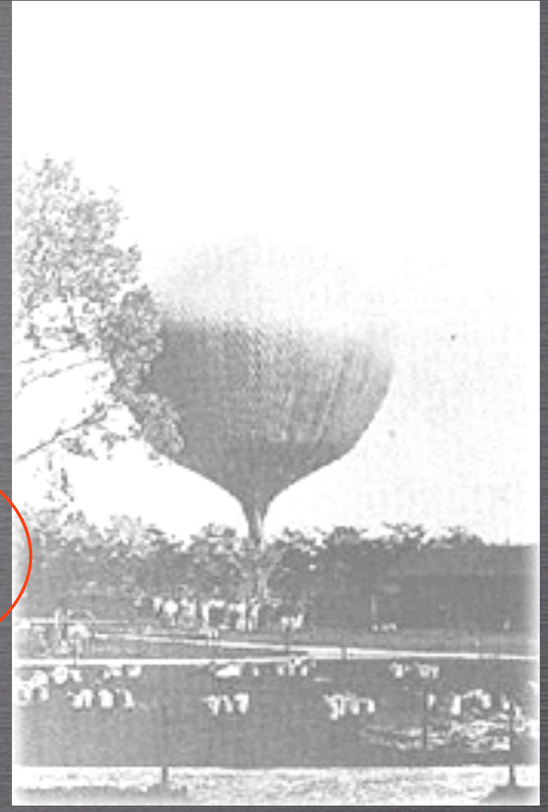


Victor Hess (1912)

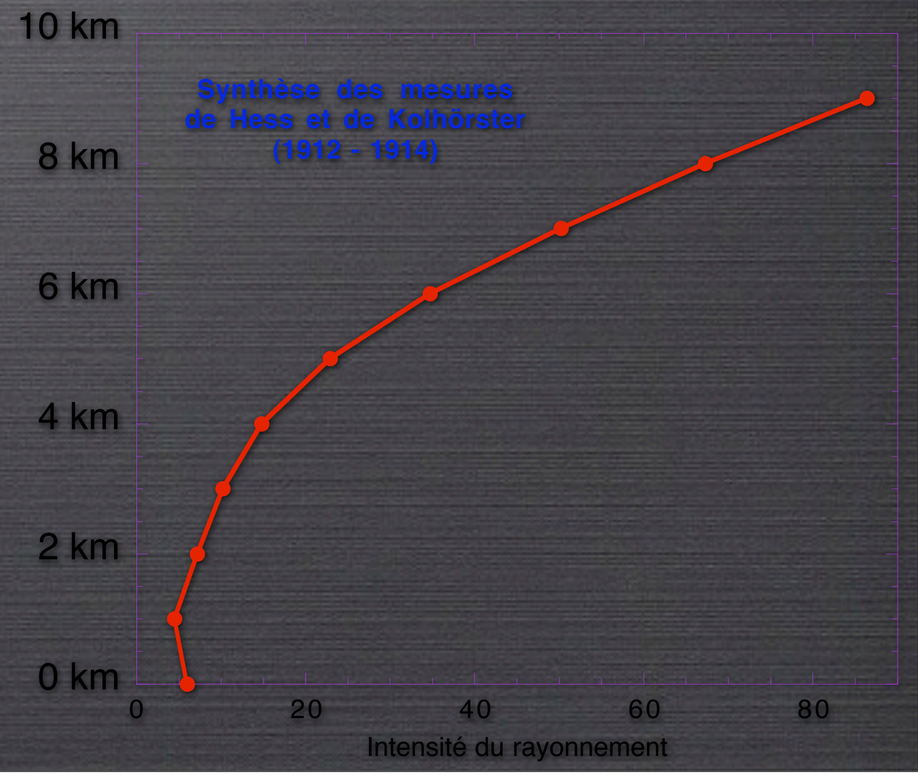




Nobel 1936

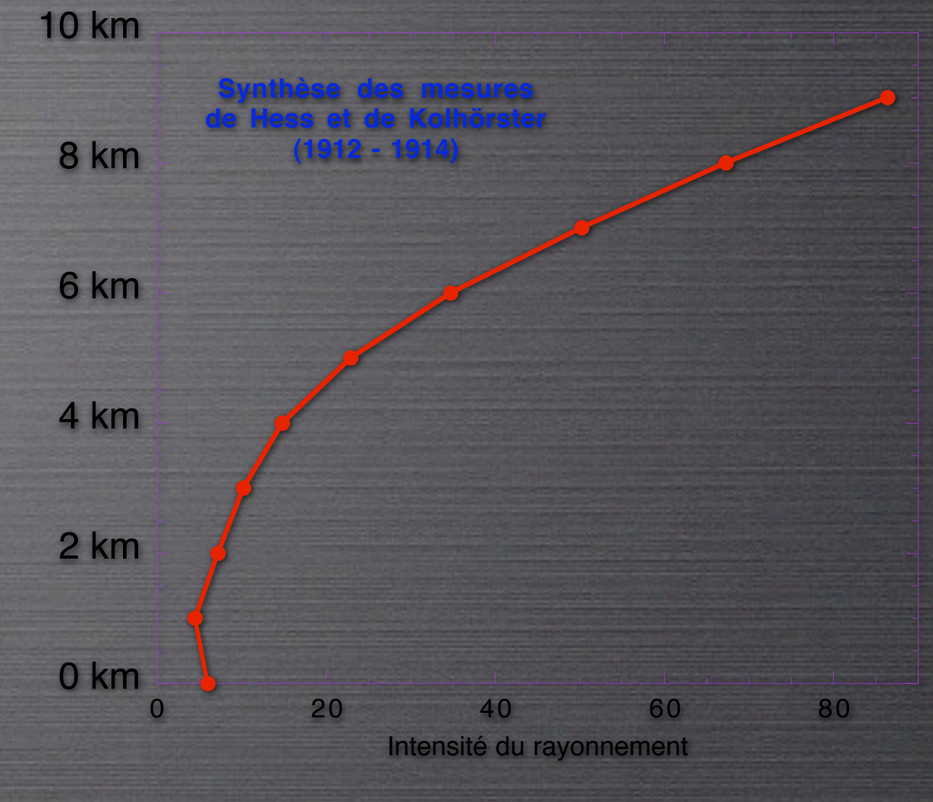






Victor Hess (1912)

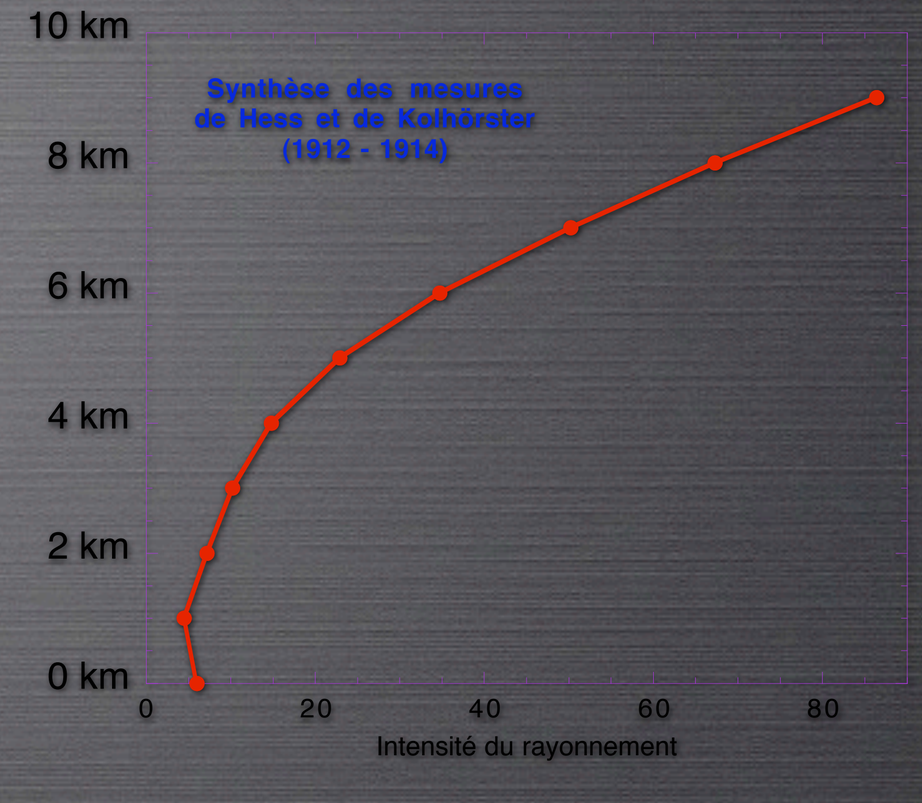




<< Theses observations can be most simply explained assuming that an extreemly penetrating radiation is coming from above >> (V. Hess)

Victor Hess (1912)





« Theses observations can be most simply explained assuming that an extreemly penetrating radiation is coming from above » (V. Hess)

Ces observations s'explique le plus simplement si on admet qu'une radiation extrêmement pénétrante arrive par le haut

Naissance de la physique des particules
30 ans de découvertes majeures

1913-1914 Kolhörster Confirme l'augmentation de l'ionisation (x7à 9km)

1923-1926 Millikan, Bowen, Cameron Observent à 15km (coupure géomagnétique)

Nobel 1923

Rayon gamma très pénétrants de hautes énergies

Les Rayons Cosmiques

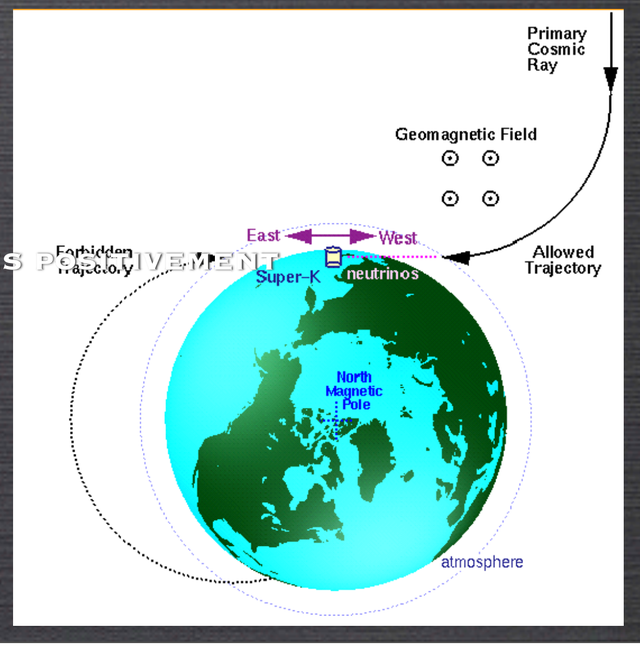
1927: During his trip from Amsterdam to Java, J. Clay – by carrying ionization detectors aboard ships – discovered that the ionization rate increased with latitude. It was the first observation of a *geomagnetic latitude effect* and very important evidence that the sources of ionization were, at least in part, *charged particles* deflected by an external field. In the period from 1928 to 1932 Clay investigated the latitude effect further by taking the ionization camber on 3 sea voyages between Europe and Java via the Suez Canal. He again found a consistently lower intensity near the equator.
1930: Bruno Rossi, using Störmer's theory, showed that if the cosmic rays were predominantly of one charge or the other there should be an *east–west effect*.
1933: Two American groups, Thomas H. Johnson of the Bartol Research Foundation and Luis Alvarez and Arthur H. Compton of the University of Chicago, simultaneously and independently measured the east–west effect predicted by Rossi. It showed the cosmic radiation to be predominantly *positively charged*.

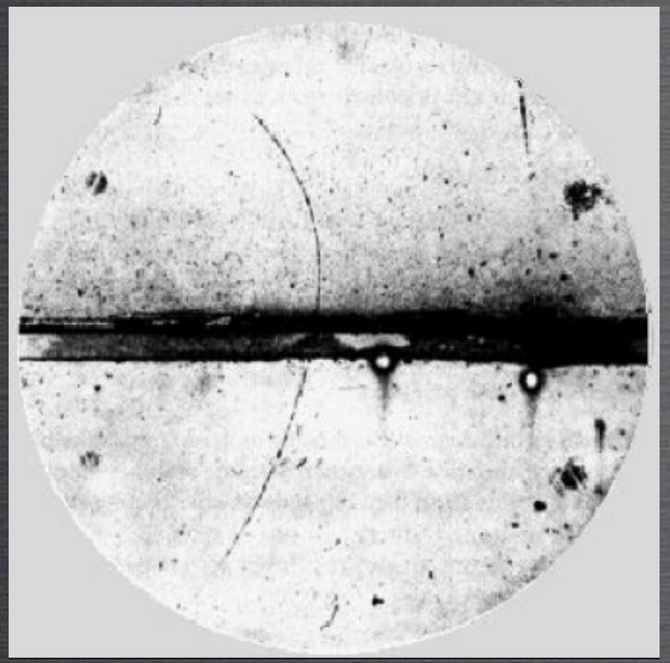
Cri de naissance des atomes

1927 Clay Effet géomagnétique

1930-1933 Rossi, Johnson, Alvarez, Compton Les R.c. sont préférentiellement chargés positivement

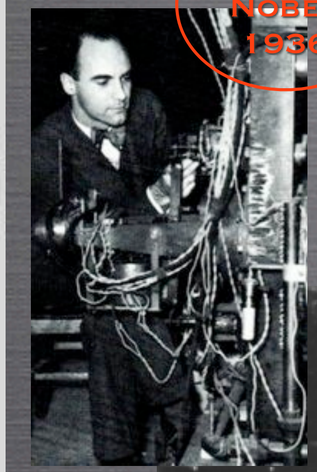
Nobel 1927





1932 Anderson Découvre l'antimatière (le positron) prédite par Dirac en 1928

Nobel 1936

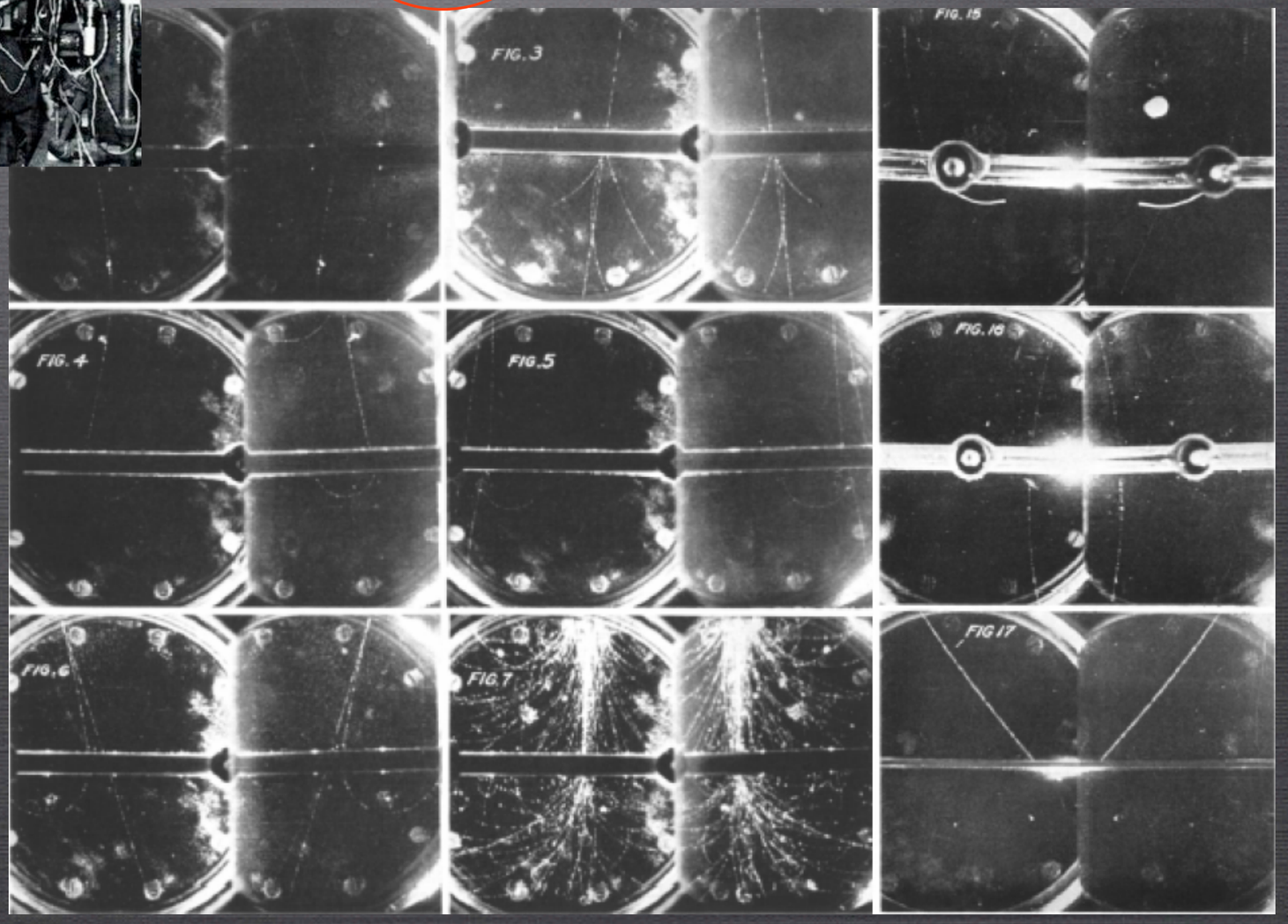


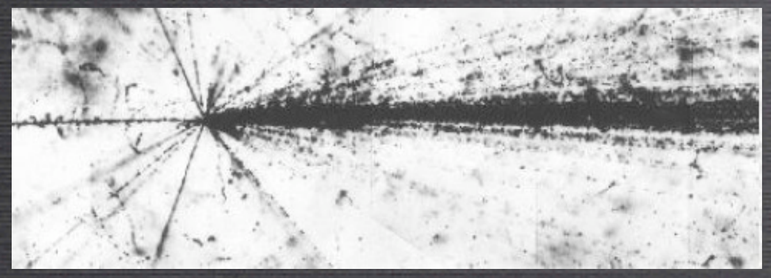
1932 Anderson & Neddermeyer Découvre le Muon

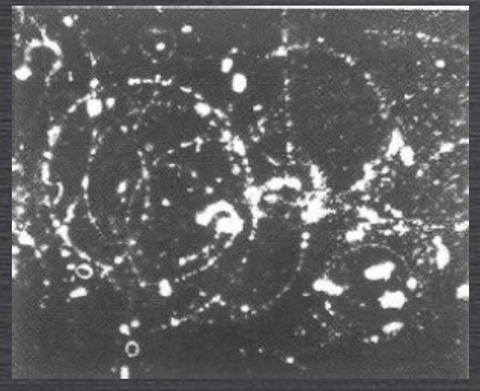
1947 Powell, Lattes & Occhialini Découvre le Pion

Nobel 1950

\+ ...







Fin du 1er Acte

- Les radiations ont ouvert un monde nouveau

- La terre est constamment bombardée de particules dont certaines N'avait jamais été vues auparavant

JWC - 9h00

De nombreuses techniques de production, et de détection de ces radiations et de ces particules sont mises au point.

ST - 9h45

Elles révolutionneront d'autres domaines que celui de la physique

UA - 15h45

La IIème guerre mondiale met provisoirement ces recherches entre parenthèse en europe

1945-1950 La guerre a ravagé l'europe. Le nucléaire a montré sa puissance

La physique nucléaire devient un enjeux stratégique majeur elle donnera naissance à la physique des hautes énergies auprès des accélérateurs.

Reconstruction de la physique en europe, naissance du CERN (1950) :

Pierre Auger, Lew Kowarski et Francis Perrin en France, Edoardo Amaldi en Italie et Niels Bohr au Danemark
L'age d'or de la physique des particules commence (et dure encore aujourd'hui)

Les physiciens des rayons cosmiques deviennent (un temps) les parents pauvres de la physique des particules ...

EK - 10h30

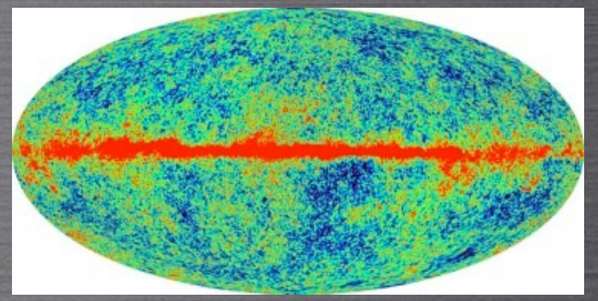
1965 - 1975
2 OBSERVATIONS MAJEURES

En 1966 Découverte du fond cosmologique de radiation



Penzias & Wilson

Nobel 1978



Les tenants de la théorie du “BIG-BANG” prennent clairement le pas sur ceux d’un Univers statique (en équilibre dynamique)

Au “commencement” était une soupe de particule chaude, très chaude ...

Cosmologie et Physique des hautes énergies sont intimement liées

Développement des QFT,
le modèle Standard des interactions électro-faibles,
l'unification des forces, l'origine des masses (Higgs)
Question sur l' "origine" de l'Univers
La barrière de Planck
quantification et unification de la gravitation

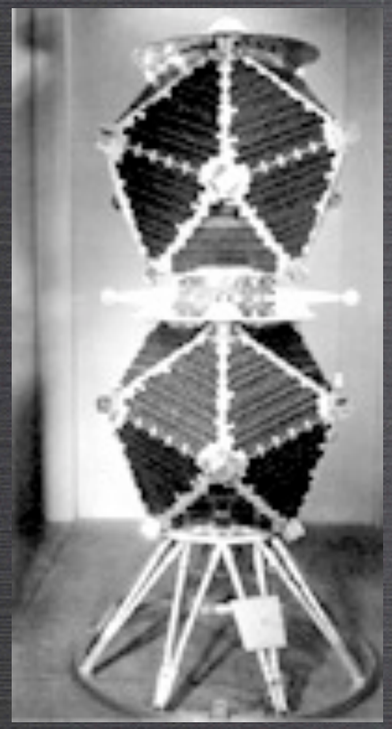
LA structure intime de la matière et L'Univers GV - 14h15

La nature du vide et de l'espace temps AdR - 11h15

Naissance d'une nouvelle branche de la physique :
l'Astroparticule

En 1967 (1973) découverte des sursauts gamma

Satellites espions



Vela



Cosmos

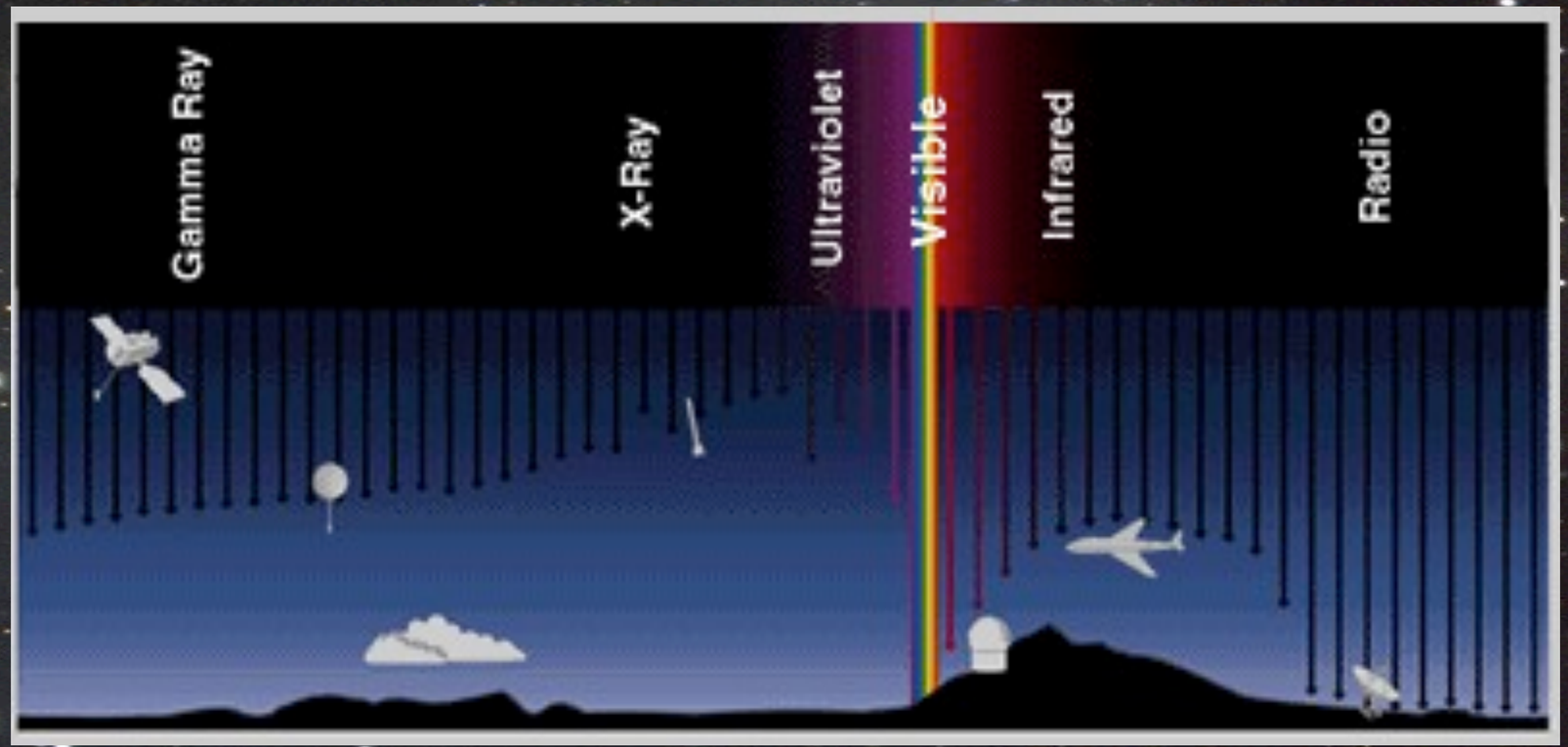


Les militaires américains et russes surveillent les essais nucléaires et découvrent des bouffées de rayons gamma provenant de l'espace

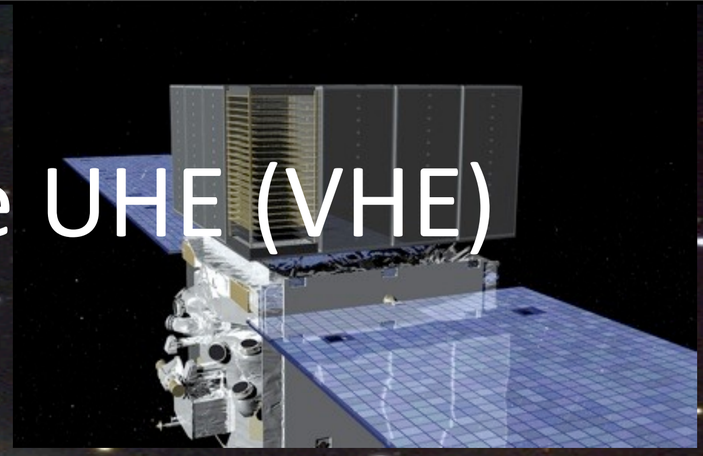
L'astronomie gamma est lancée (on avait déjà le crabe mais maintenant on a les sursauts, bien plus anciens et bien plus phénoménaux)

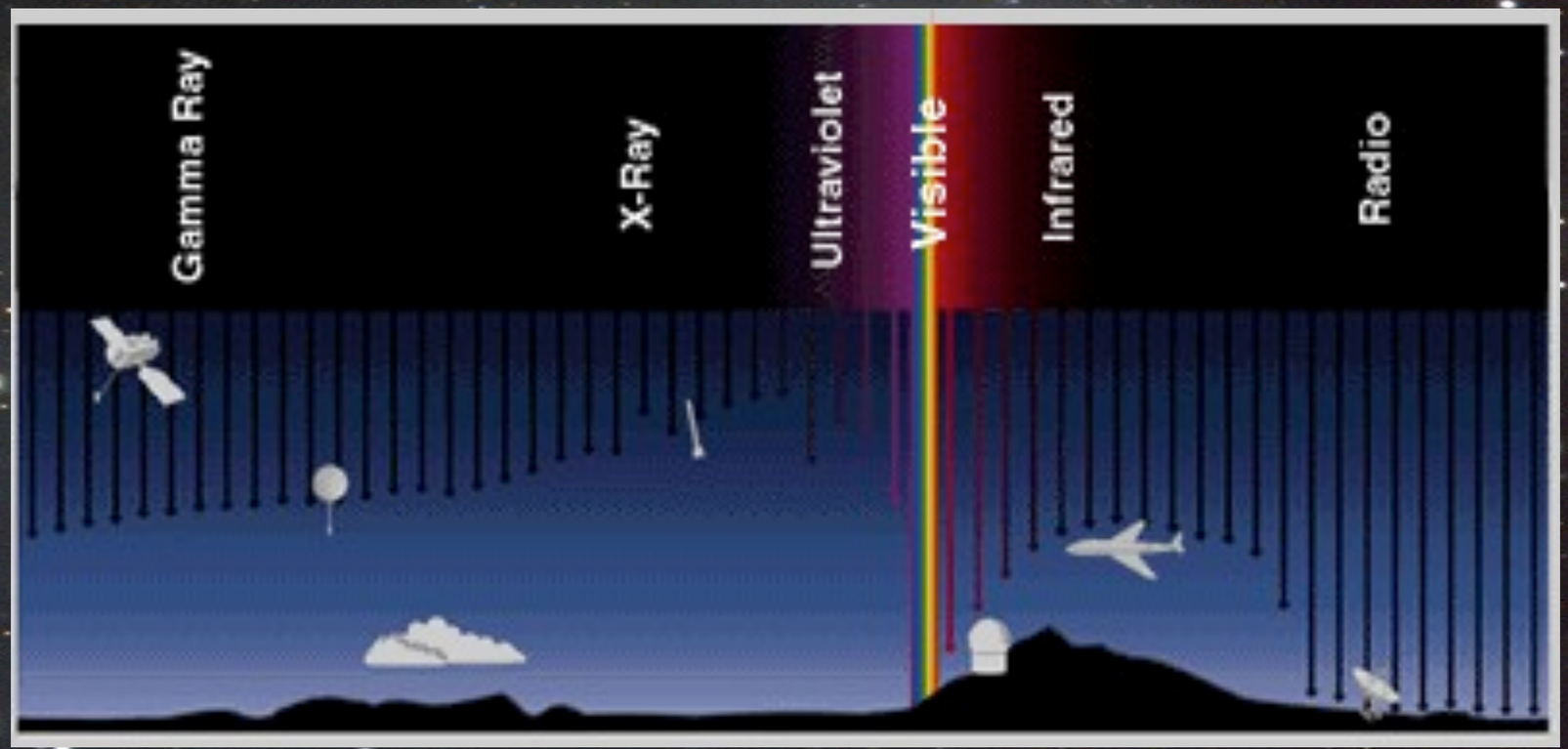
L'Astronomie Gamma
&
L'Observatoire HESS

Les rayonnements gamma de UHE (VHE)



Les rayonnements gamma de UHE (VHE)

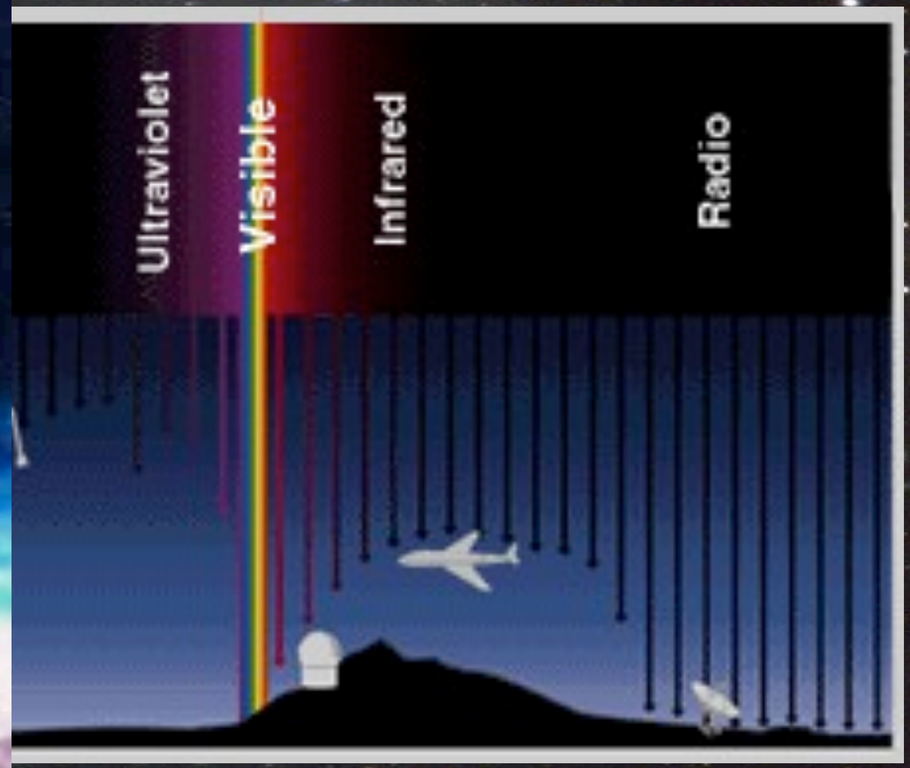




Les rayonnements gamma de UHE (VHE)

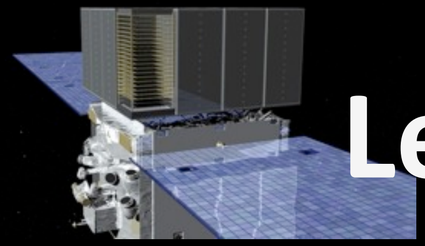






Les expériences en gamma

FermiLAT



AGILE



STACEE



MAGIC



MILAGRO



TIBET & ARGO-YBJ



TACTIC



VERITAS



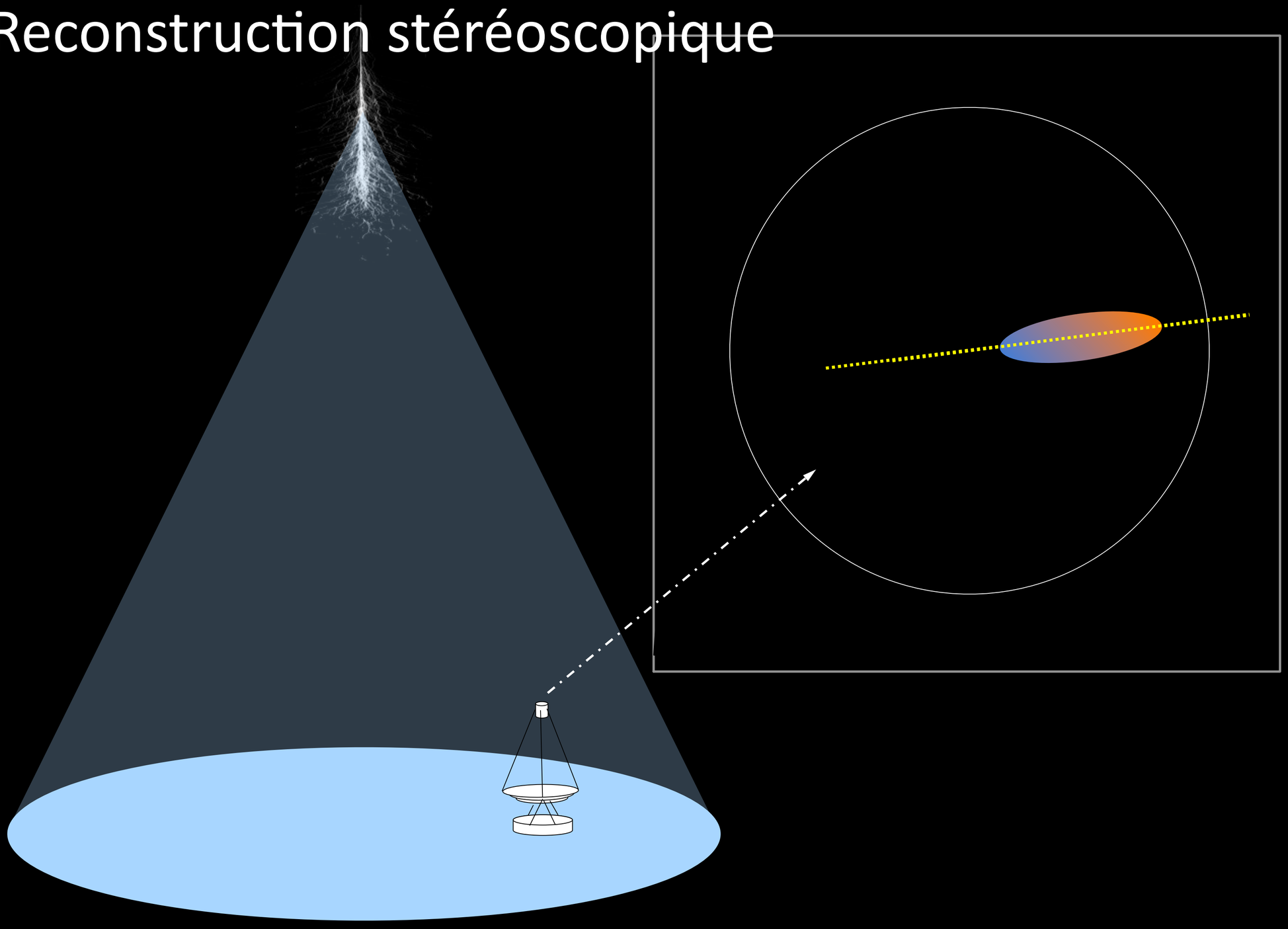
HESS



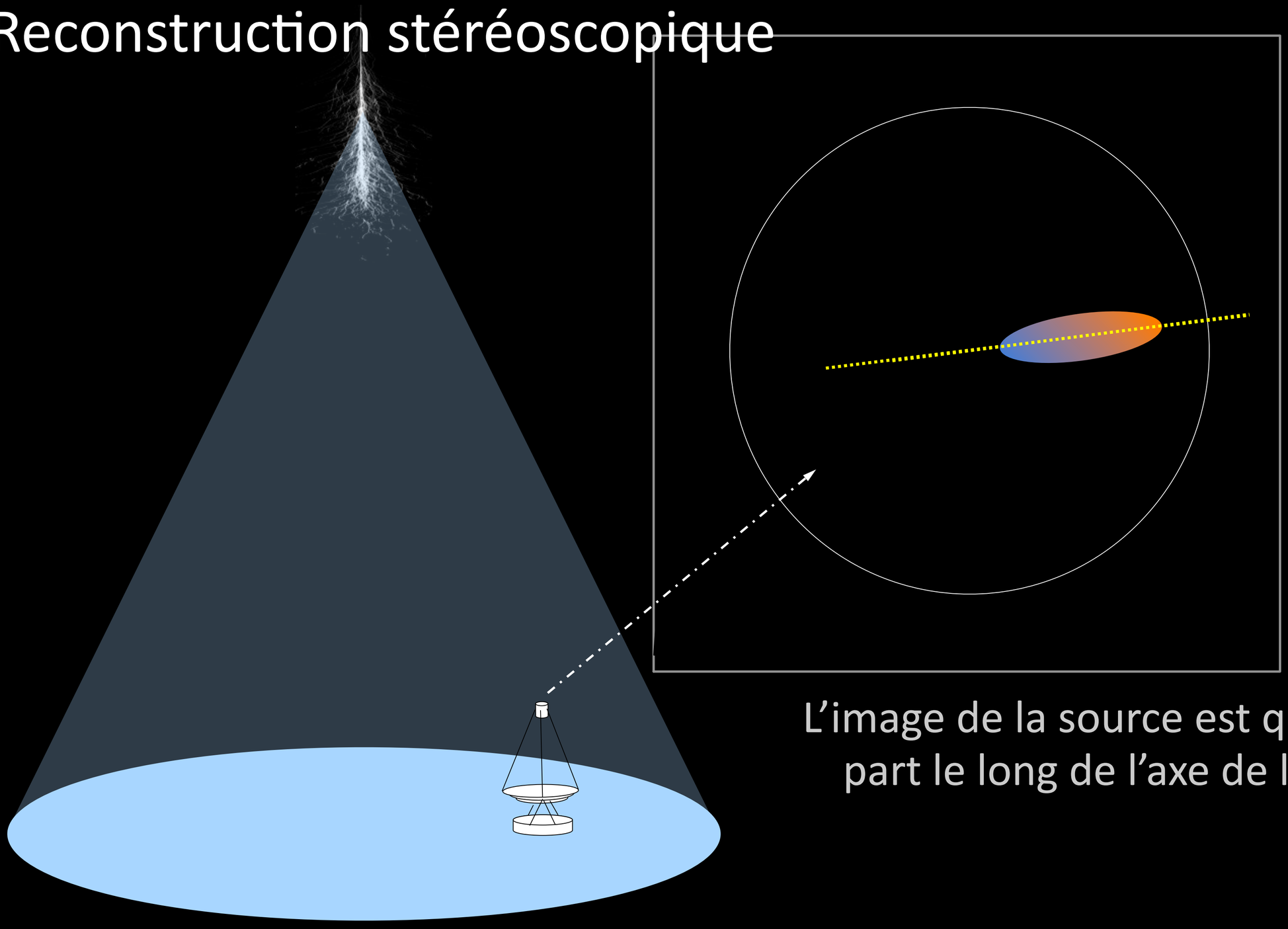
CANGAROO



Reconstruction stéréoscopique

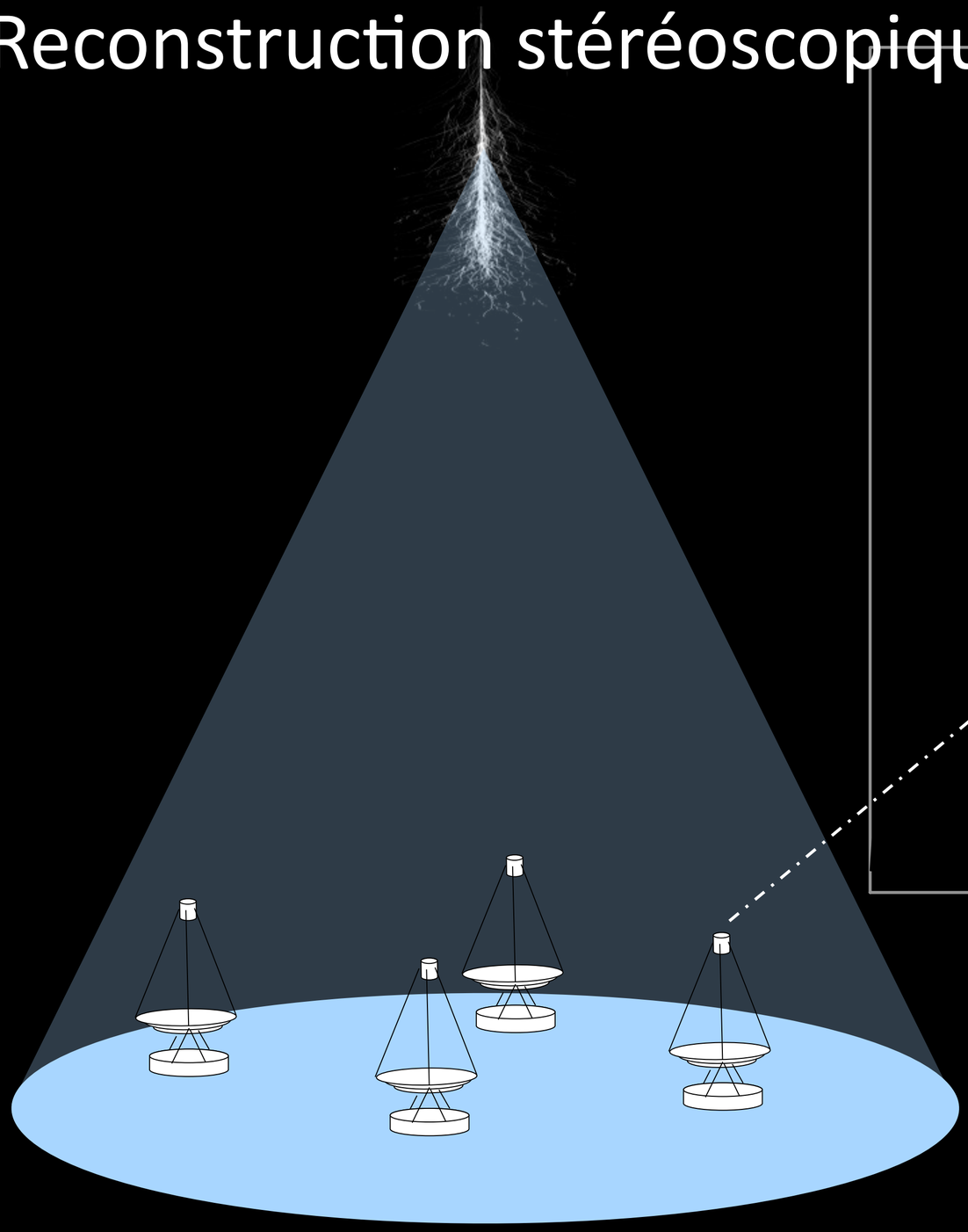


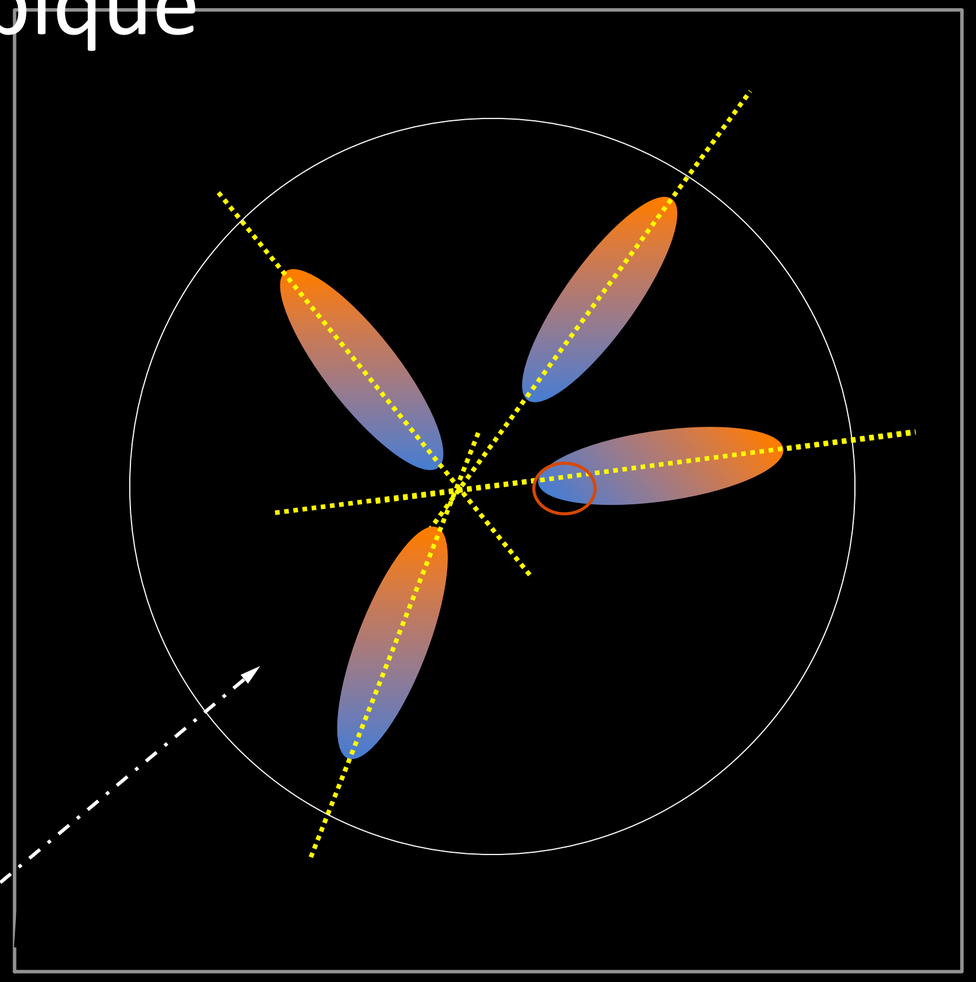
Reconstruction stéréoscopique



L’image de la source est quelque part le long de l’axe de l’image

Reconstruction stéréoscopique

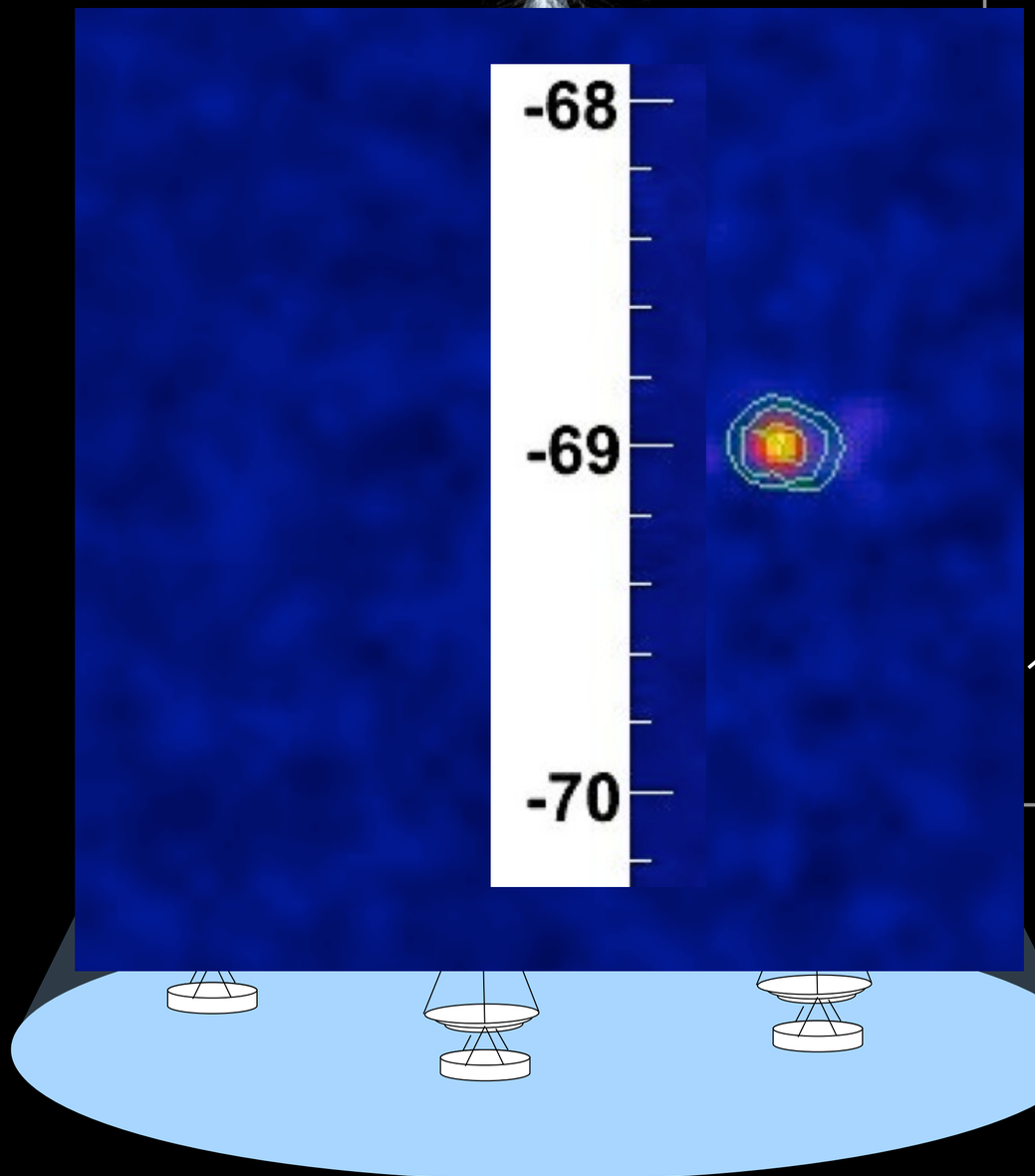


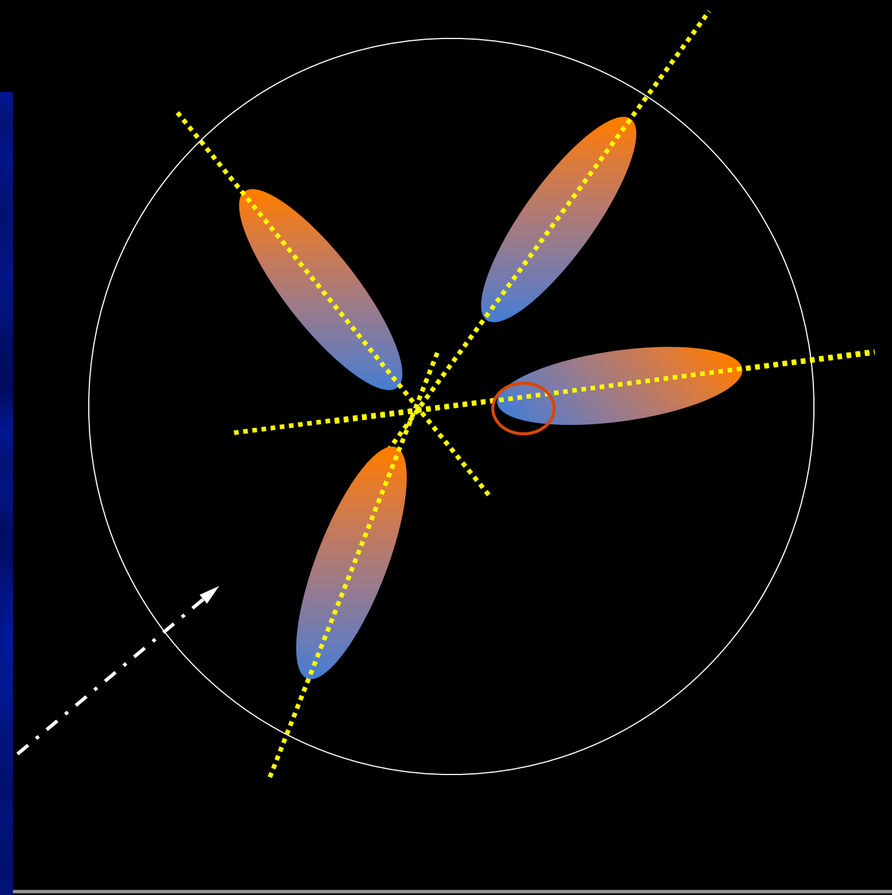


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Utilisation de plusieurs images

Reconstruction stéréoscopique



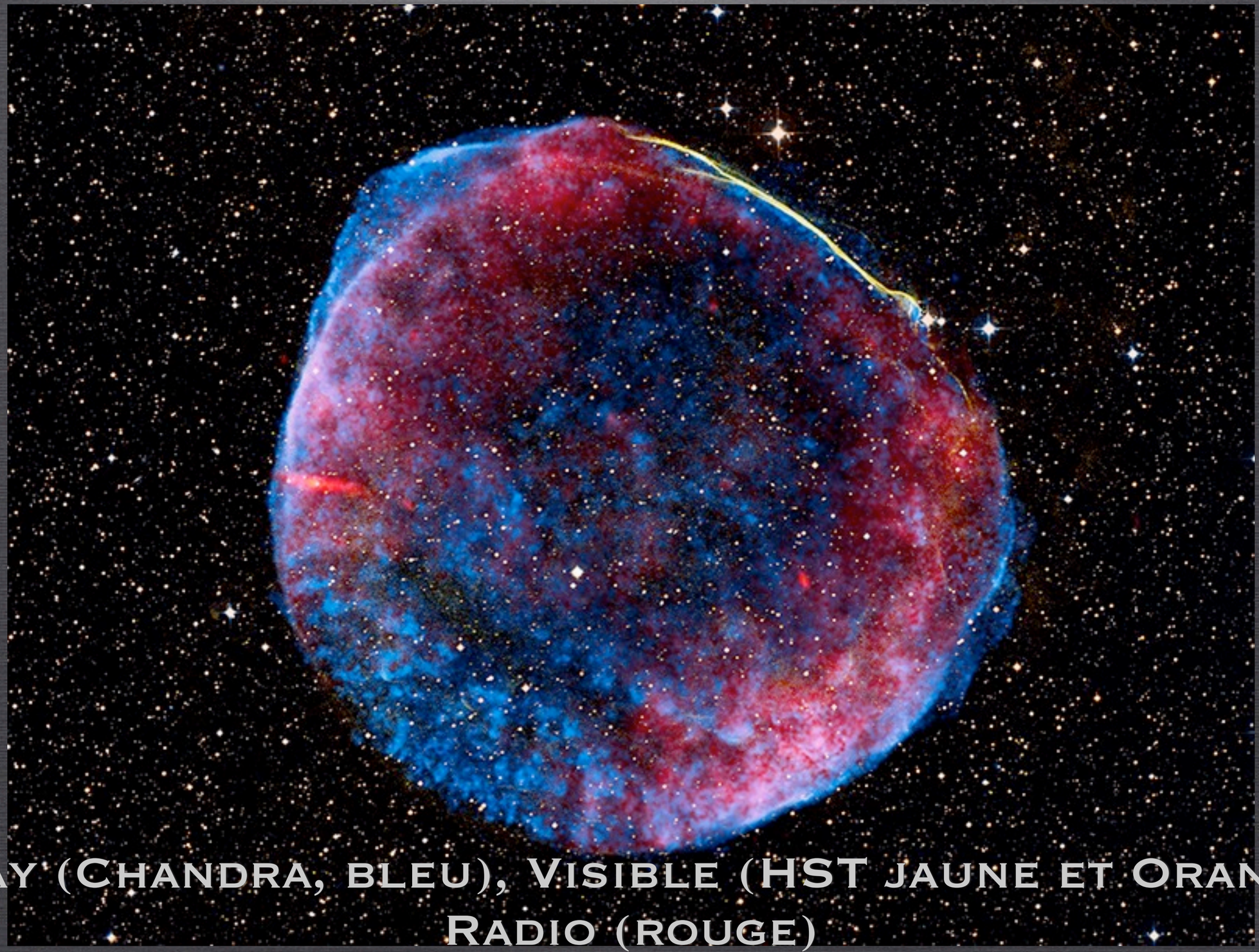


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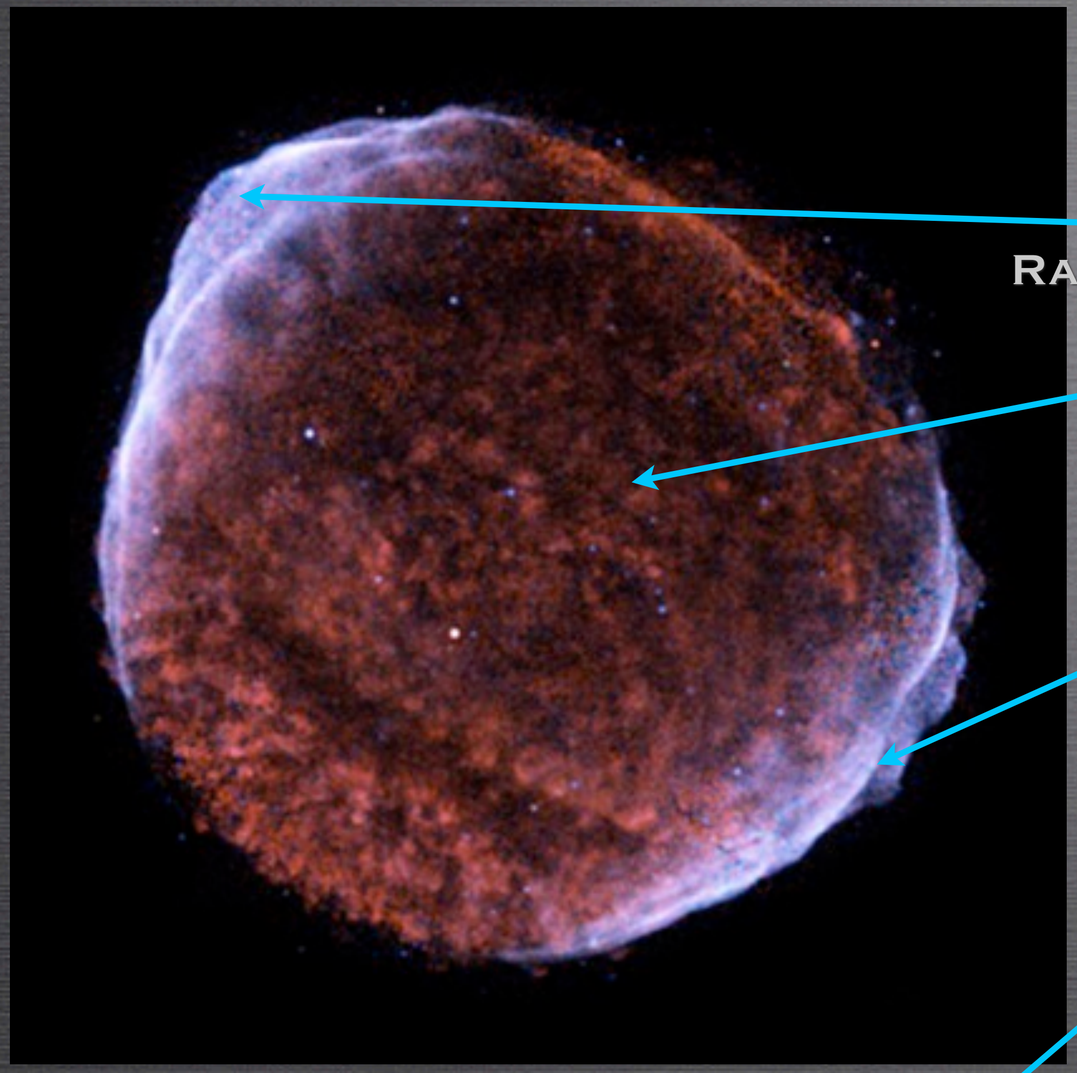
Utilisation de plusieurs images

A la recherche des sources

SN 1006 D = 7 500 A.L.

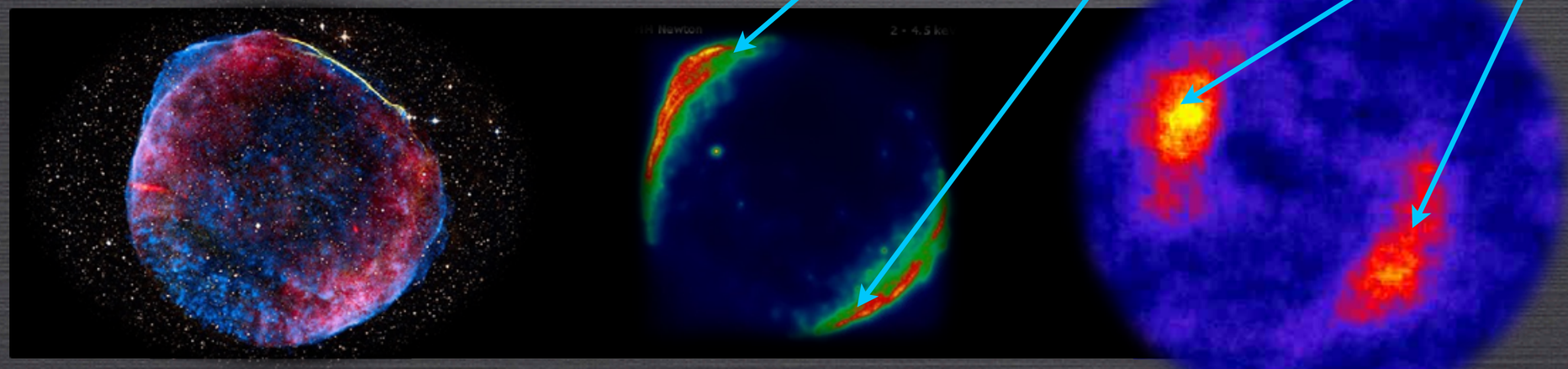


X-ray (Chandra, bleu), Visible (HST jaune et Orange),
Radio (rouge)

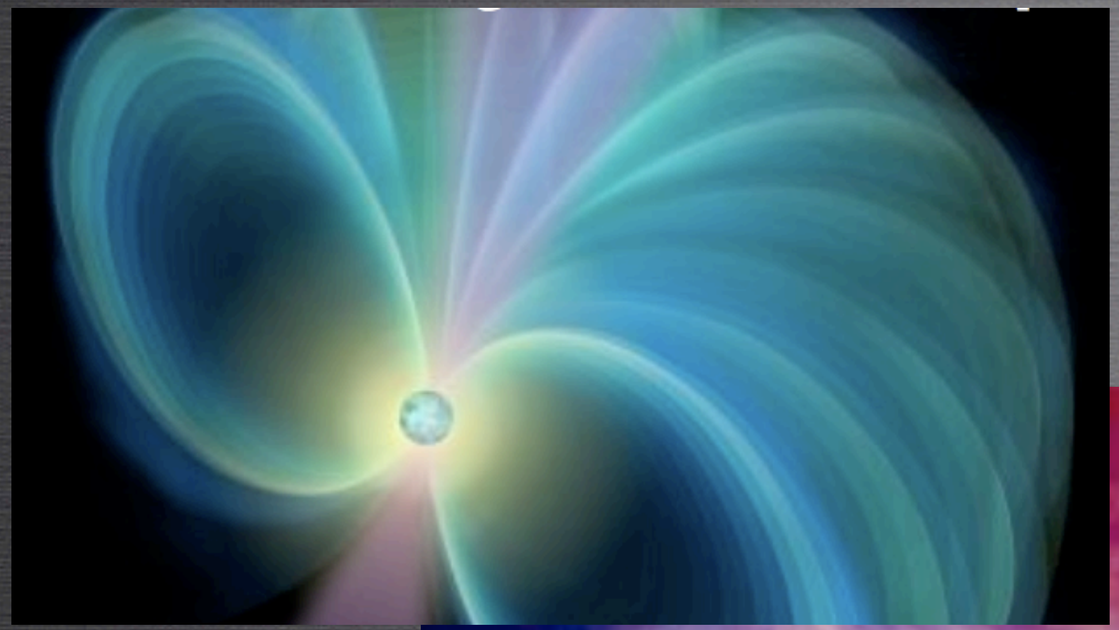


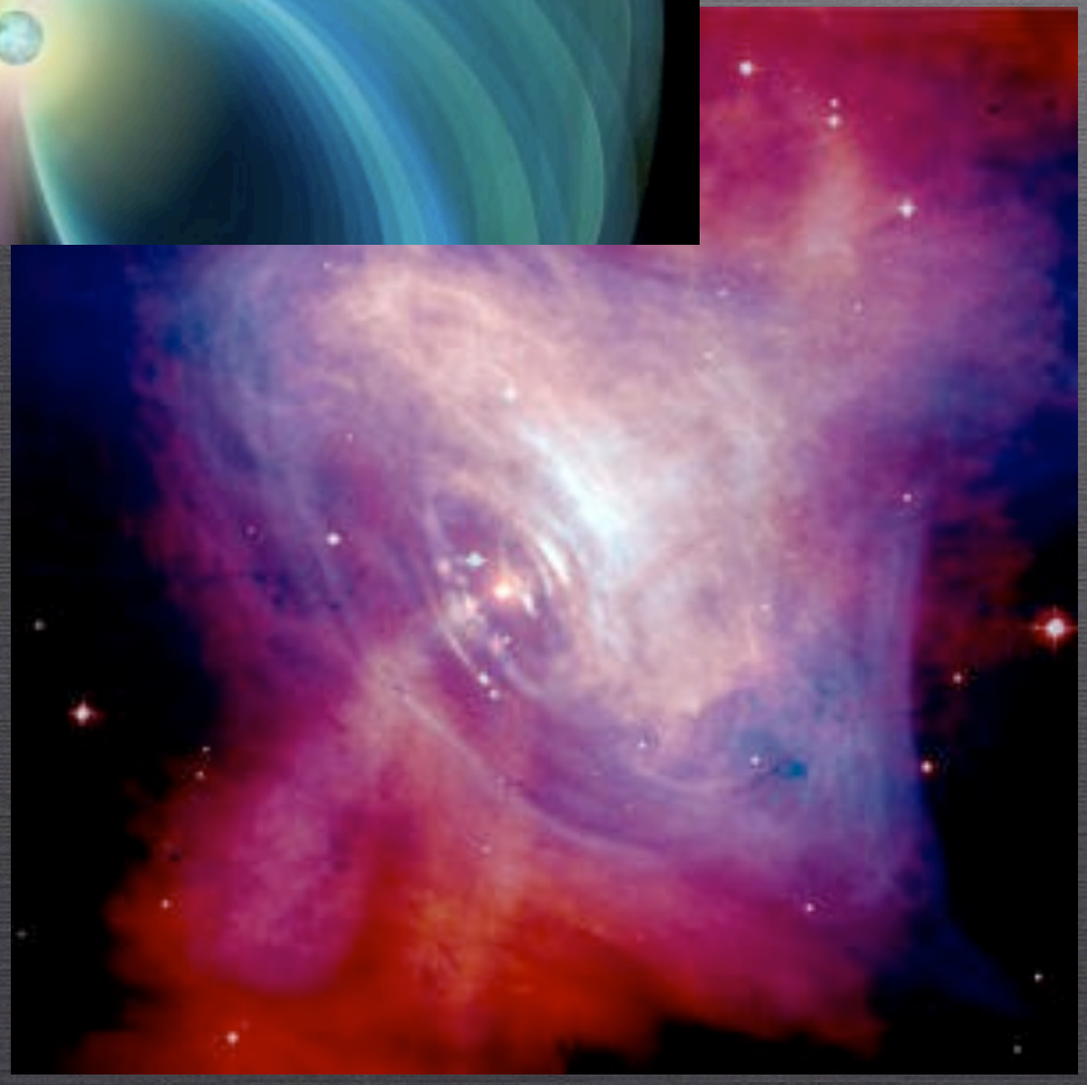
Rayons X, gas (rouge), particules (X-durs, bleu)

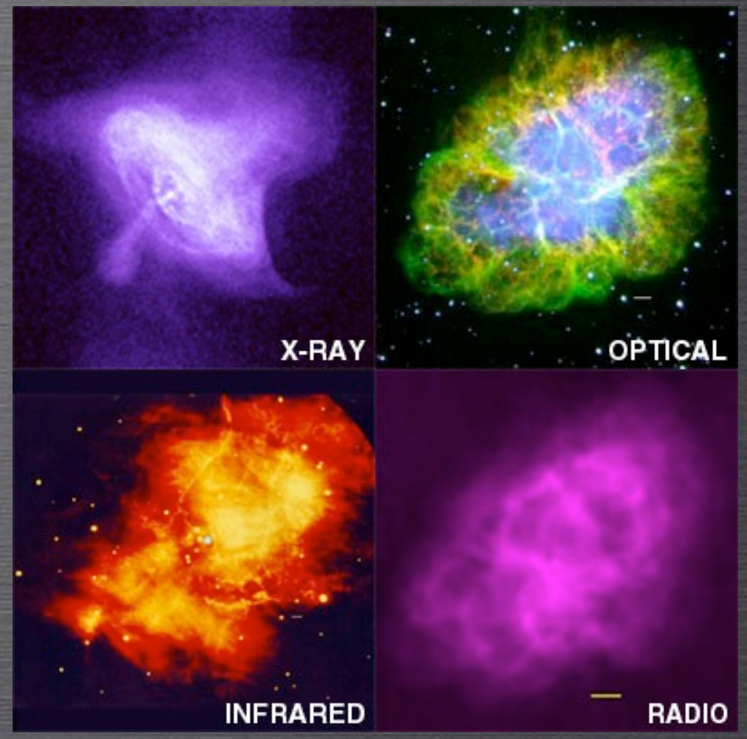
Rayons Gamma, HESS

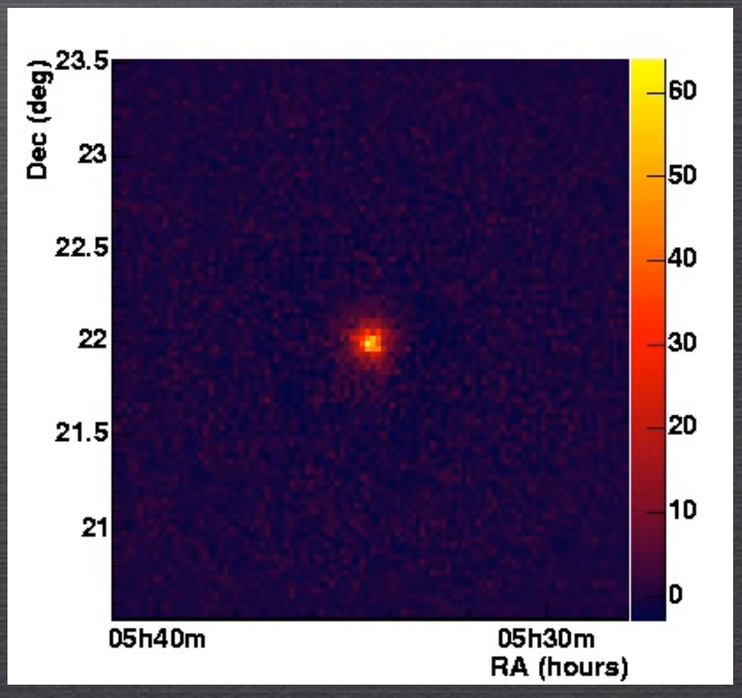


Nébuleuse du Crabe (Vent de pulsar et SNR)

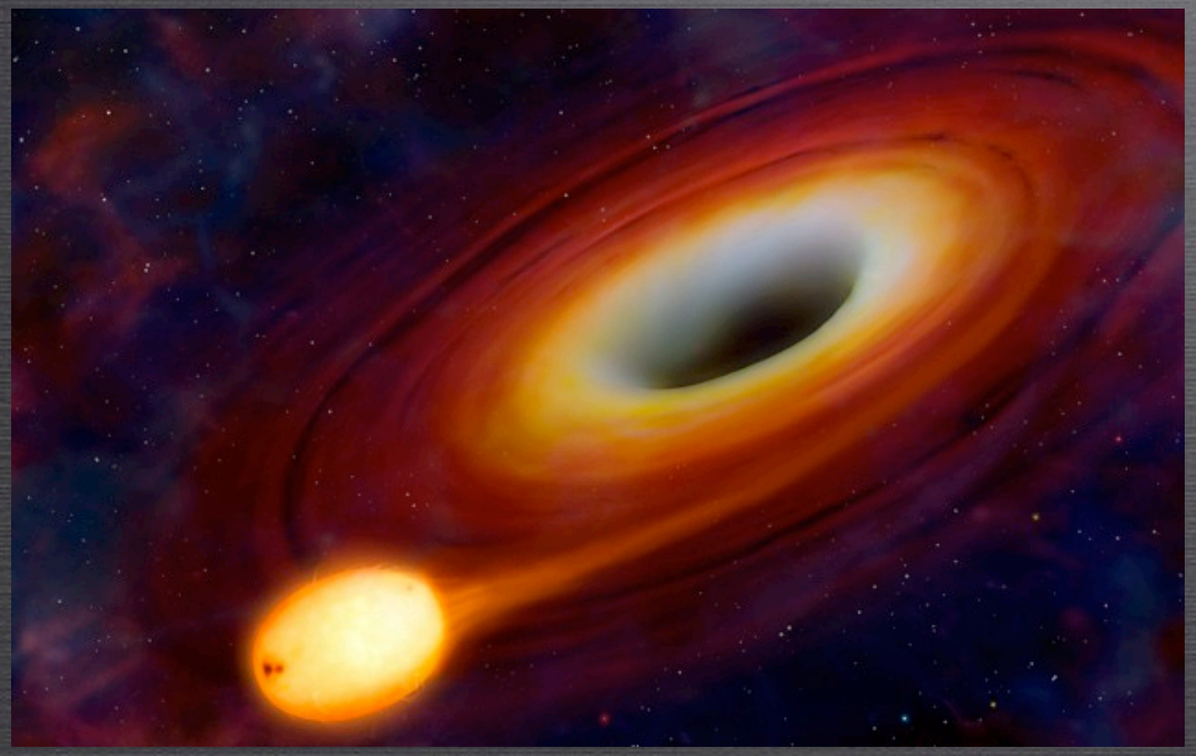






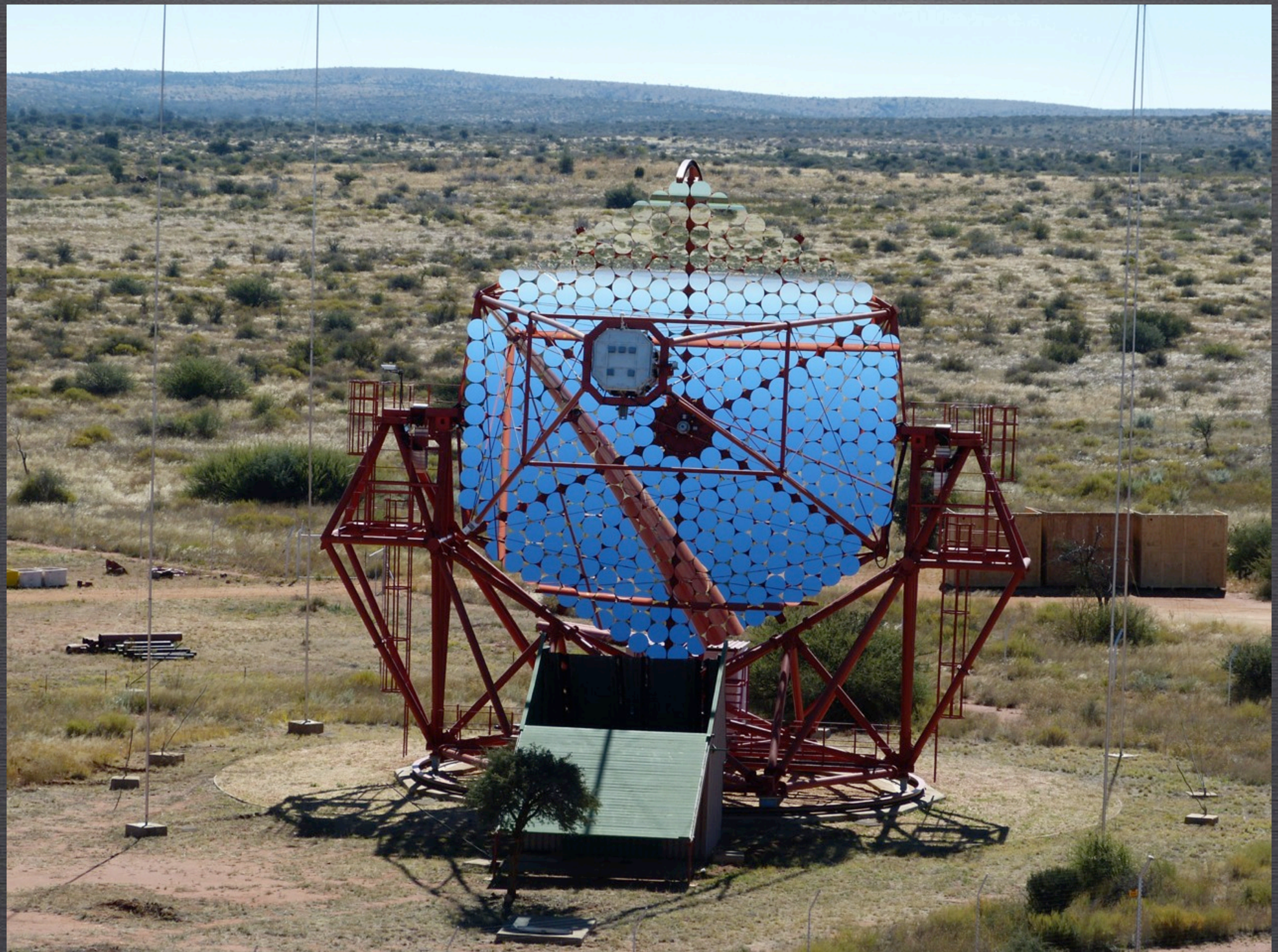


Trous noirs et Noyaux Actif de Galaxies

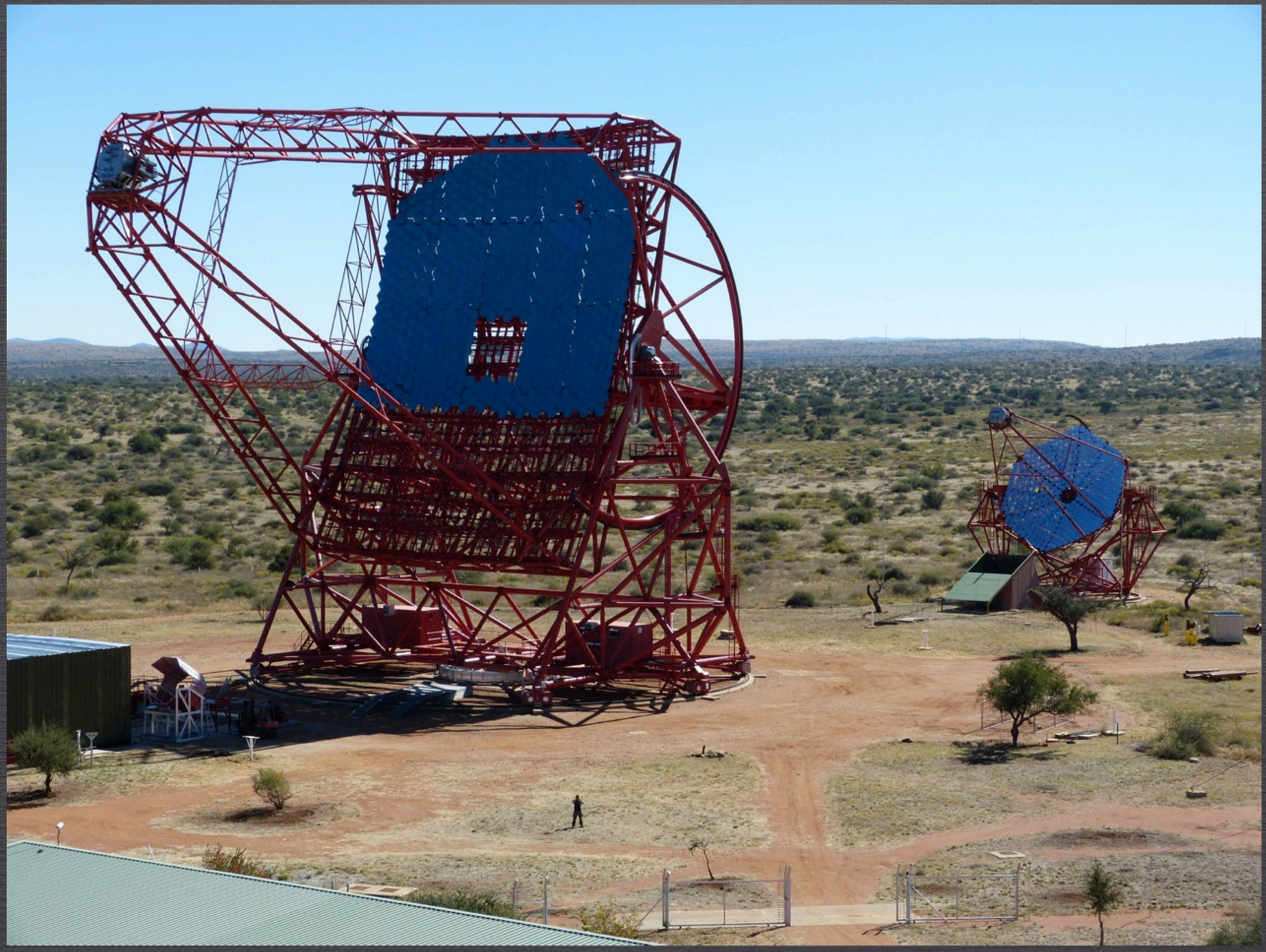




H.E.S.S ET H.E.S.S-II

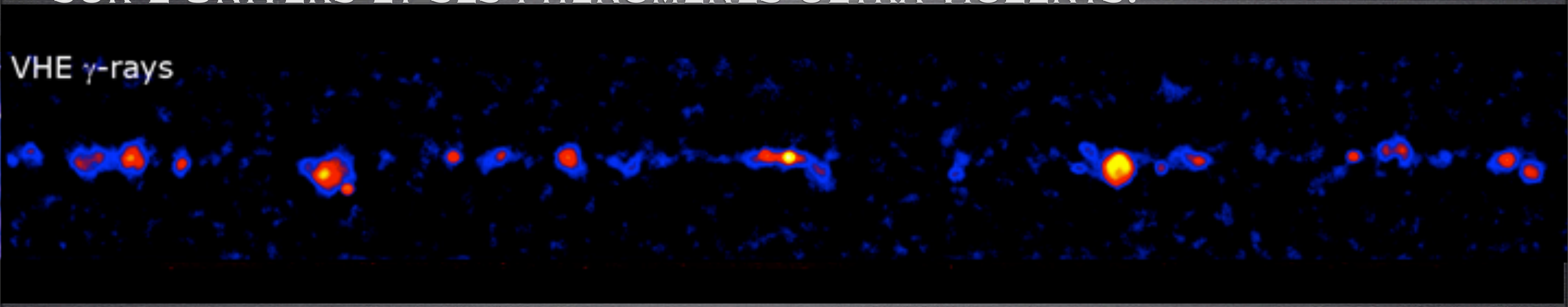


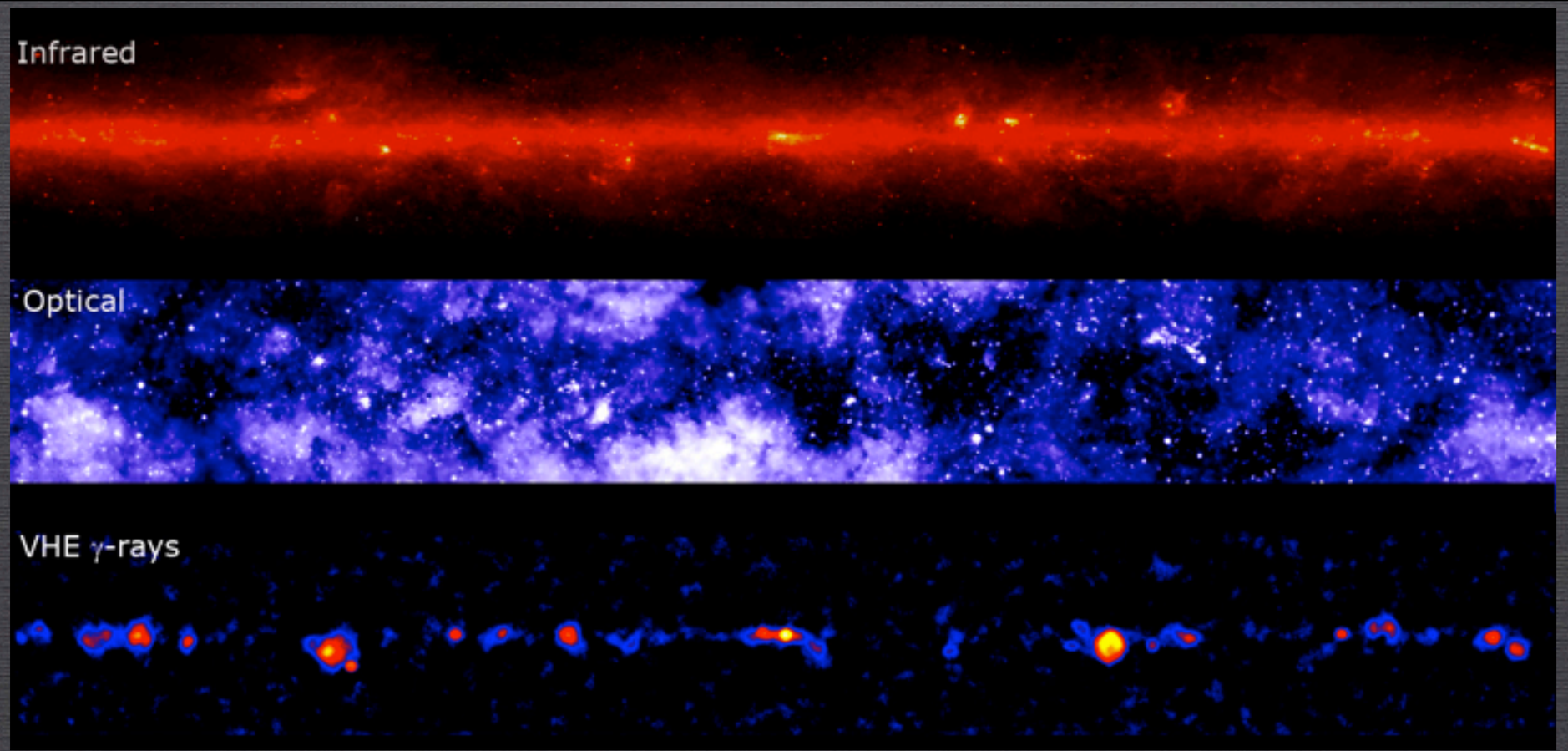
H.E.S.S et H.E.S.S-II



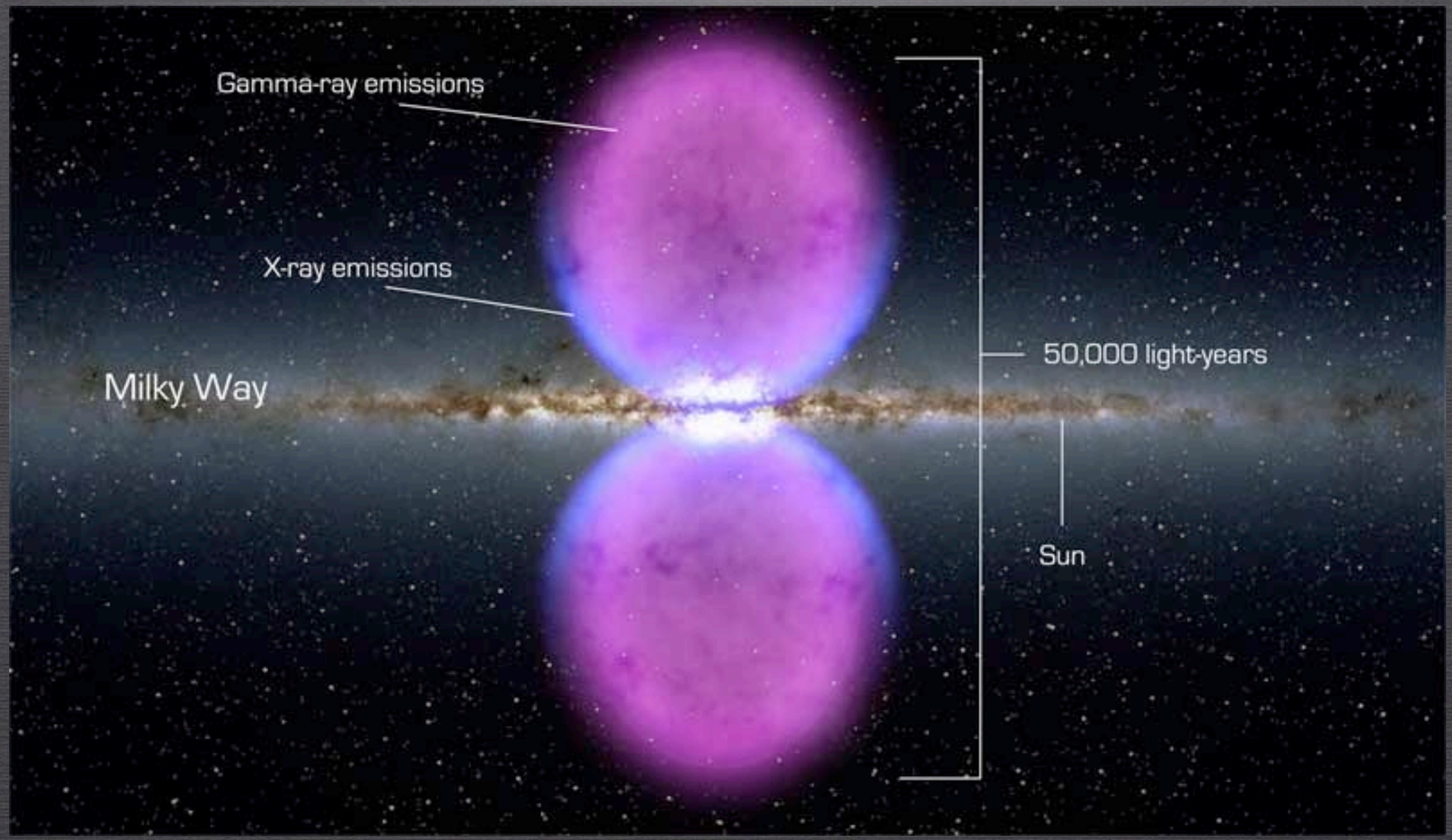
... L'Astronomie Gamma est née et c'est un nouveau point de vue sur l'Univers et ses phénomènes ultra violents.

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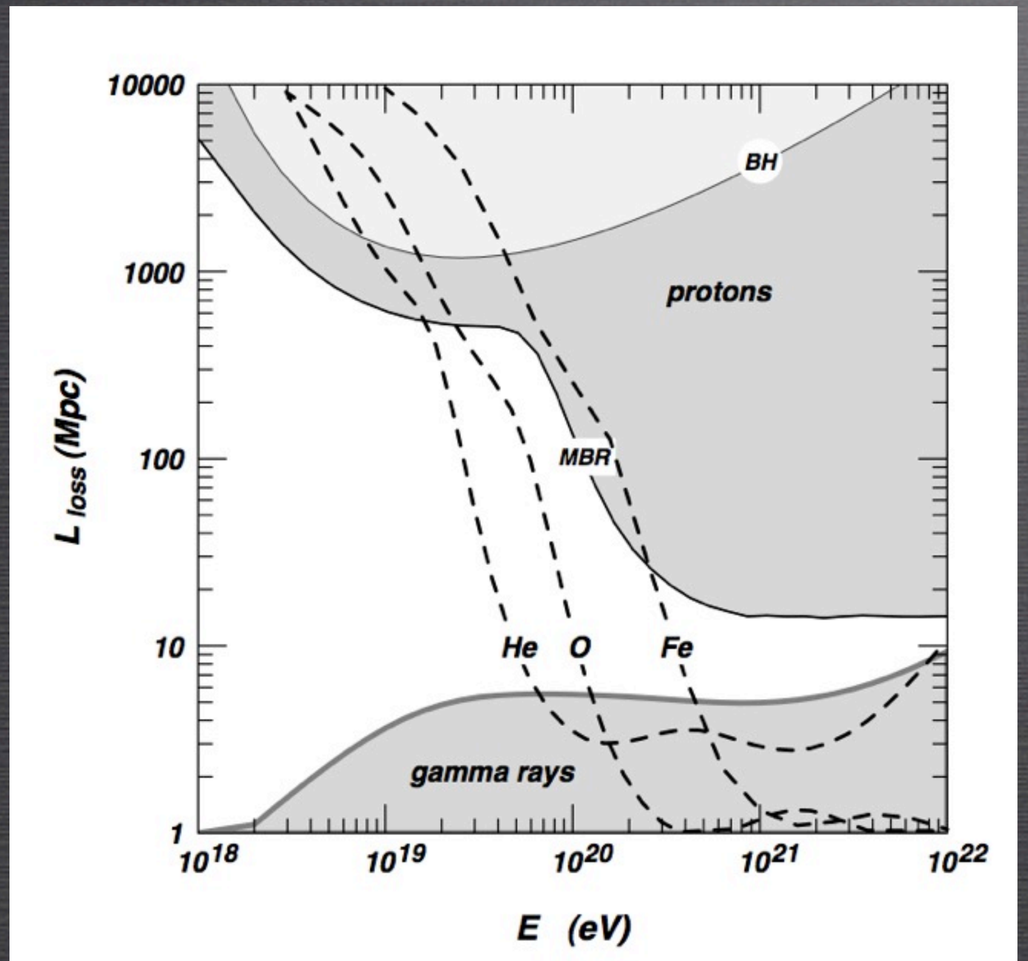
Et aussi les bulles de Fermi ....

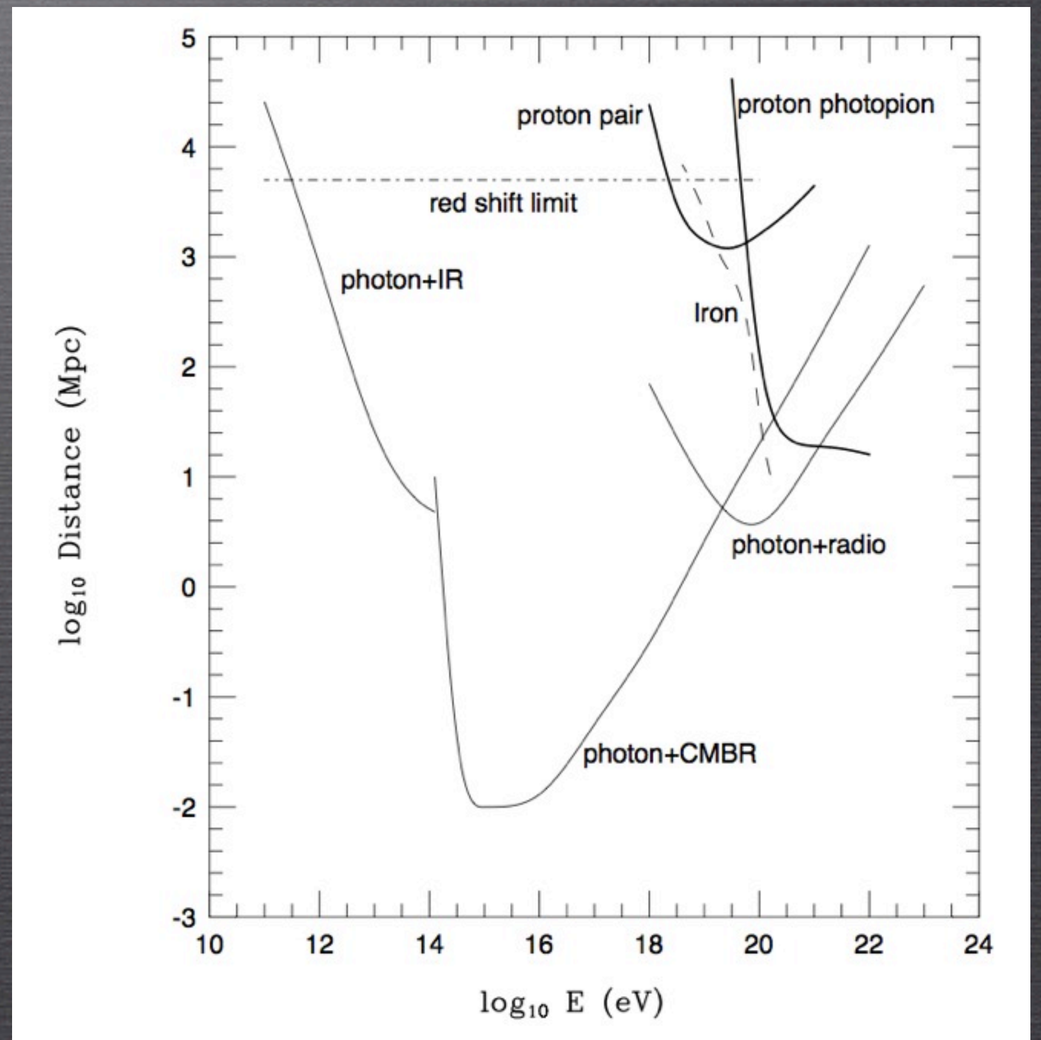


On a trouvé des sources
mais pour des énergies inférieures à 10^{15} eV

plusieurs mécanismes d'accélération
electroniques & Hadroniques

Les sources des RCUHE sont encore introuvables.... Mais ...





Retour aux années 40 et aux rayons cosmiques

Pierre Auger (1938)



Découverte des grandes gerbes atmosphériques



Pierre Auger (1938)

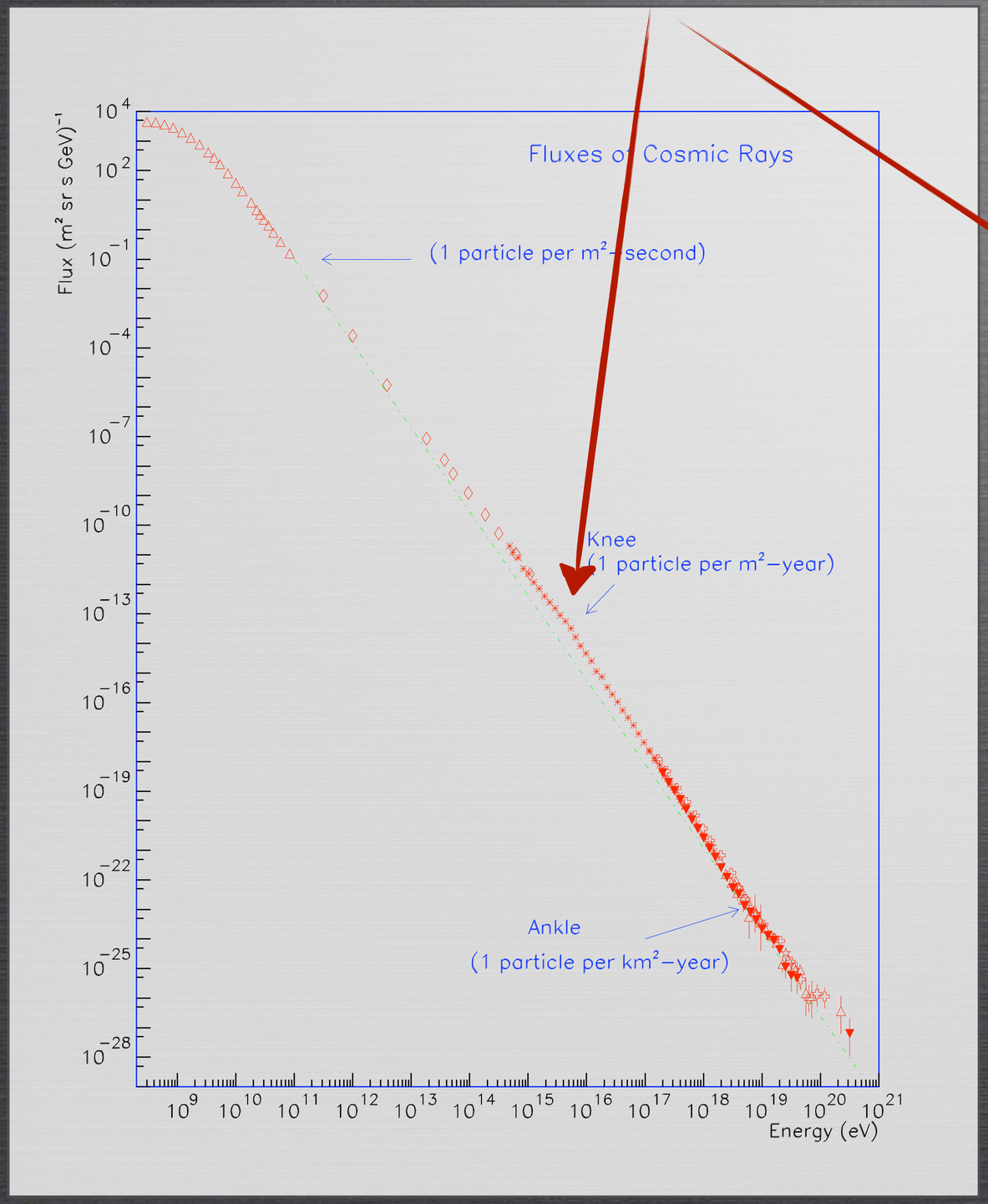


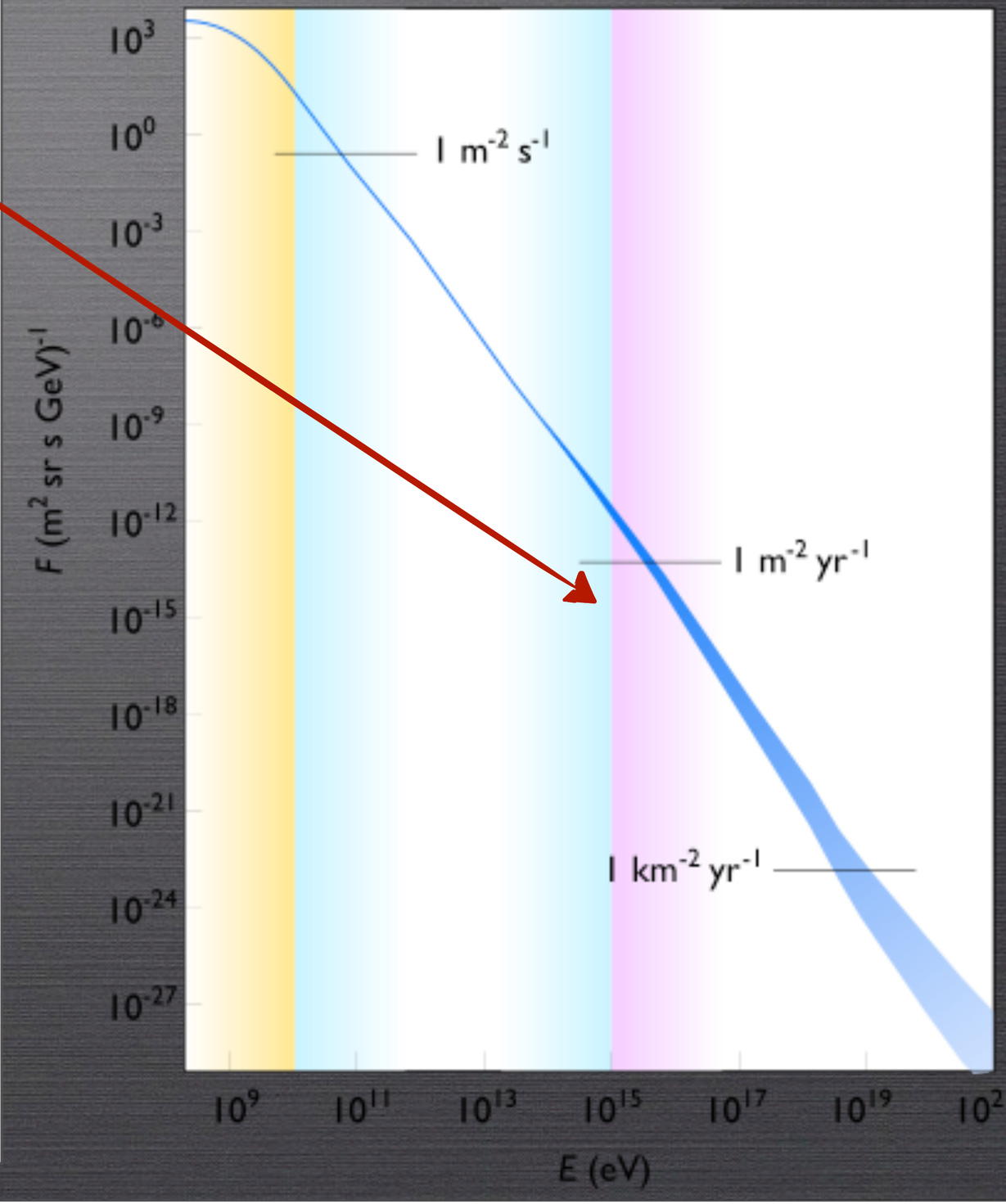
Découverte des grandes gerbes atmosphériques

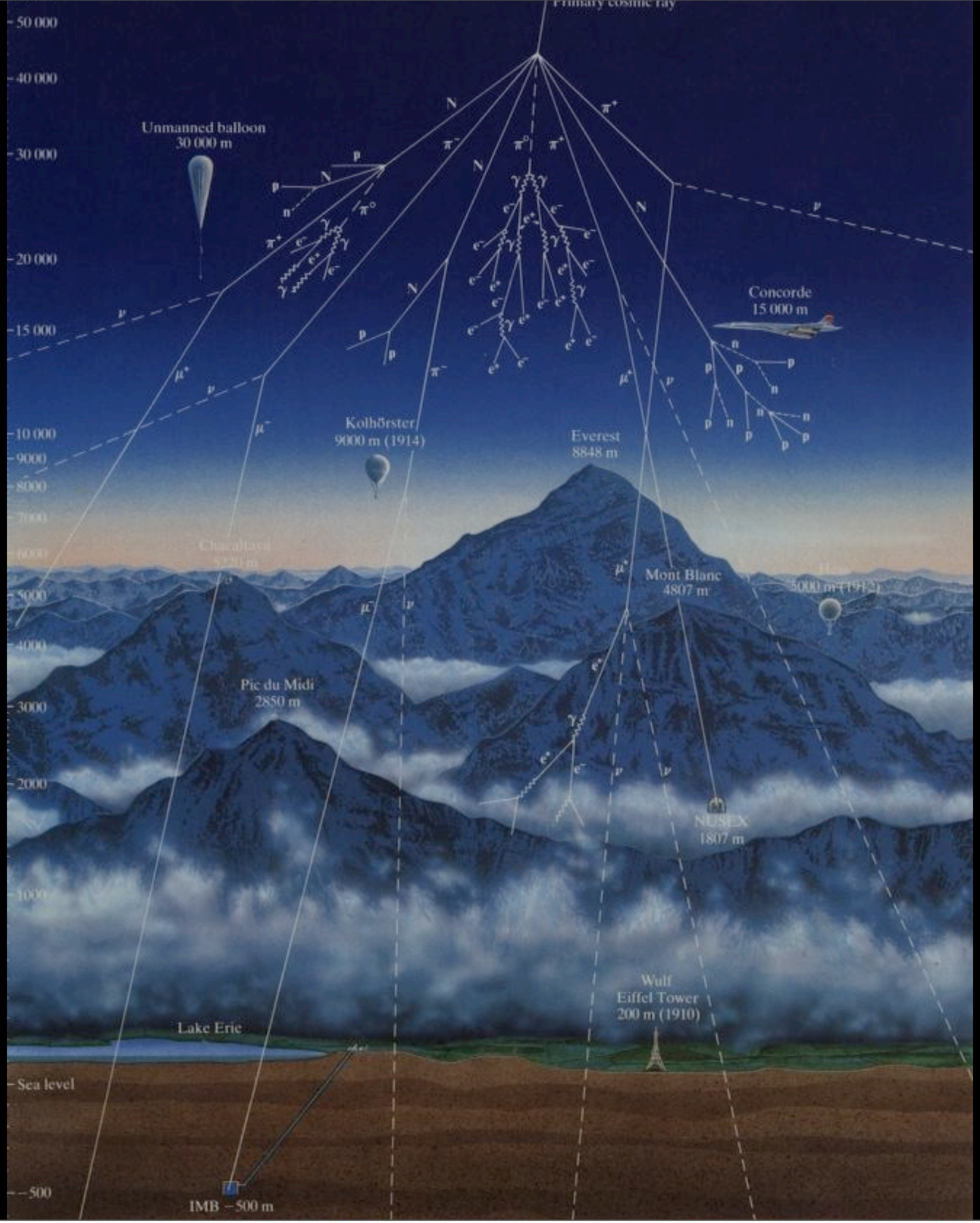


Auger 1938

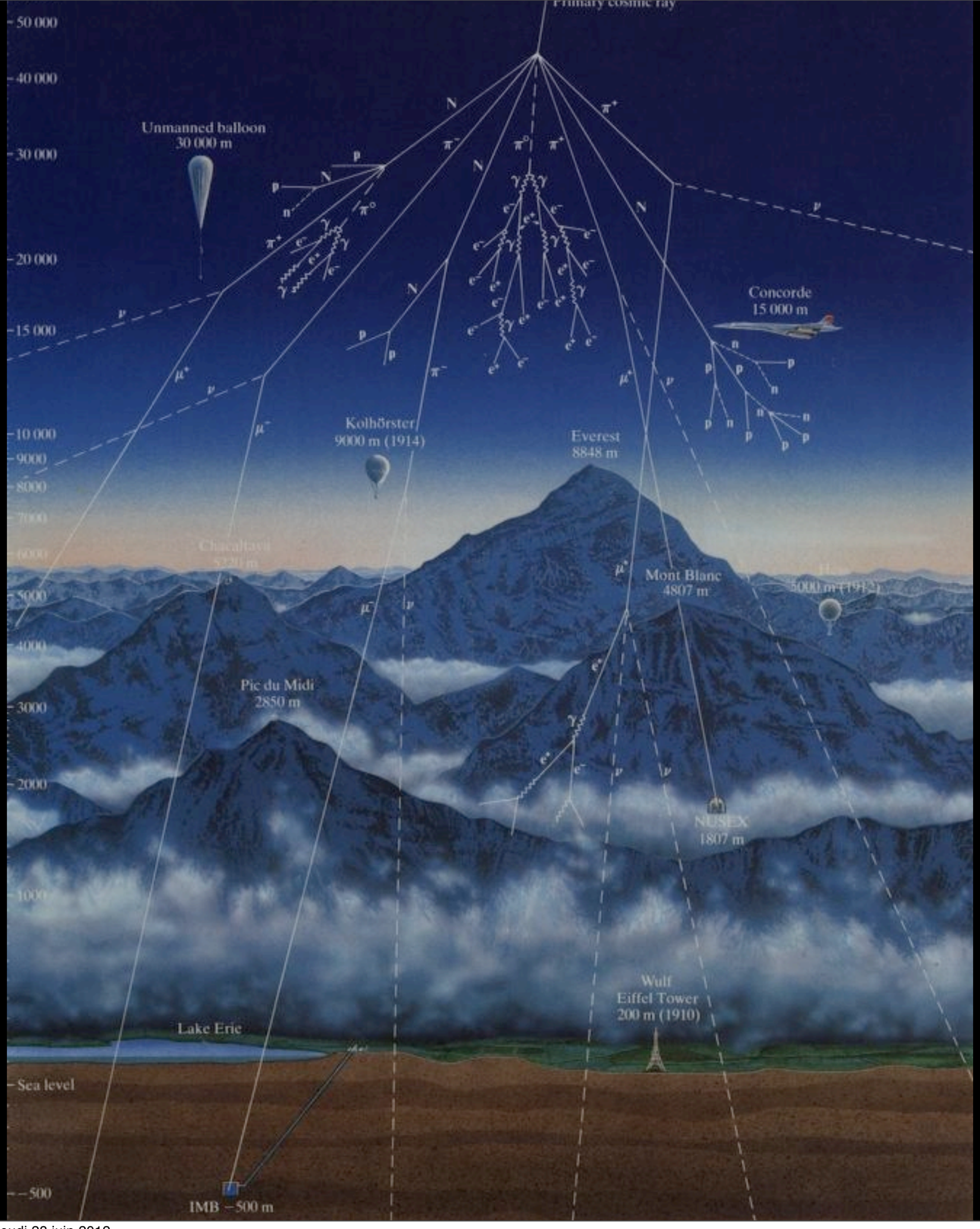
Le flux des rayons cosmiques






Primary cosmic ray
50 000
40 000
30 000
20 000
15 000
10 000
9000
8000
7000
6000
5000
4000
3000
2000
1000
Sea level
500
Unmanned balloon
30 000 m
Concorde
15 000 m
Kolhörster
9000 m (1914)
Everest
8848 m
Chacaltaya
5270 m
Mont Blanc
4807 m
Pic du Midi
2850 m
NUSEX
1807 m
Wulf
Eiffel Tower
200 m (1910)
Lake Erie
IMB −500 m

1960

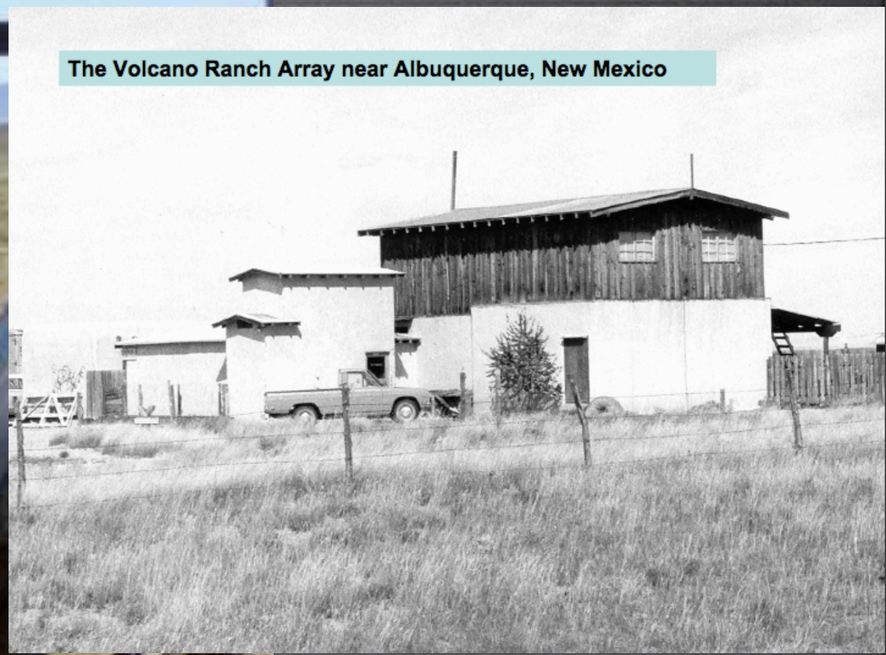

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Eiffel Tower
200 m (1910)
Lake Erie
IMB −500 m

1960

GRAND

John Linsley (1962) - Volcano Ranch - Nouveau Mexique

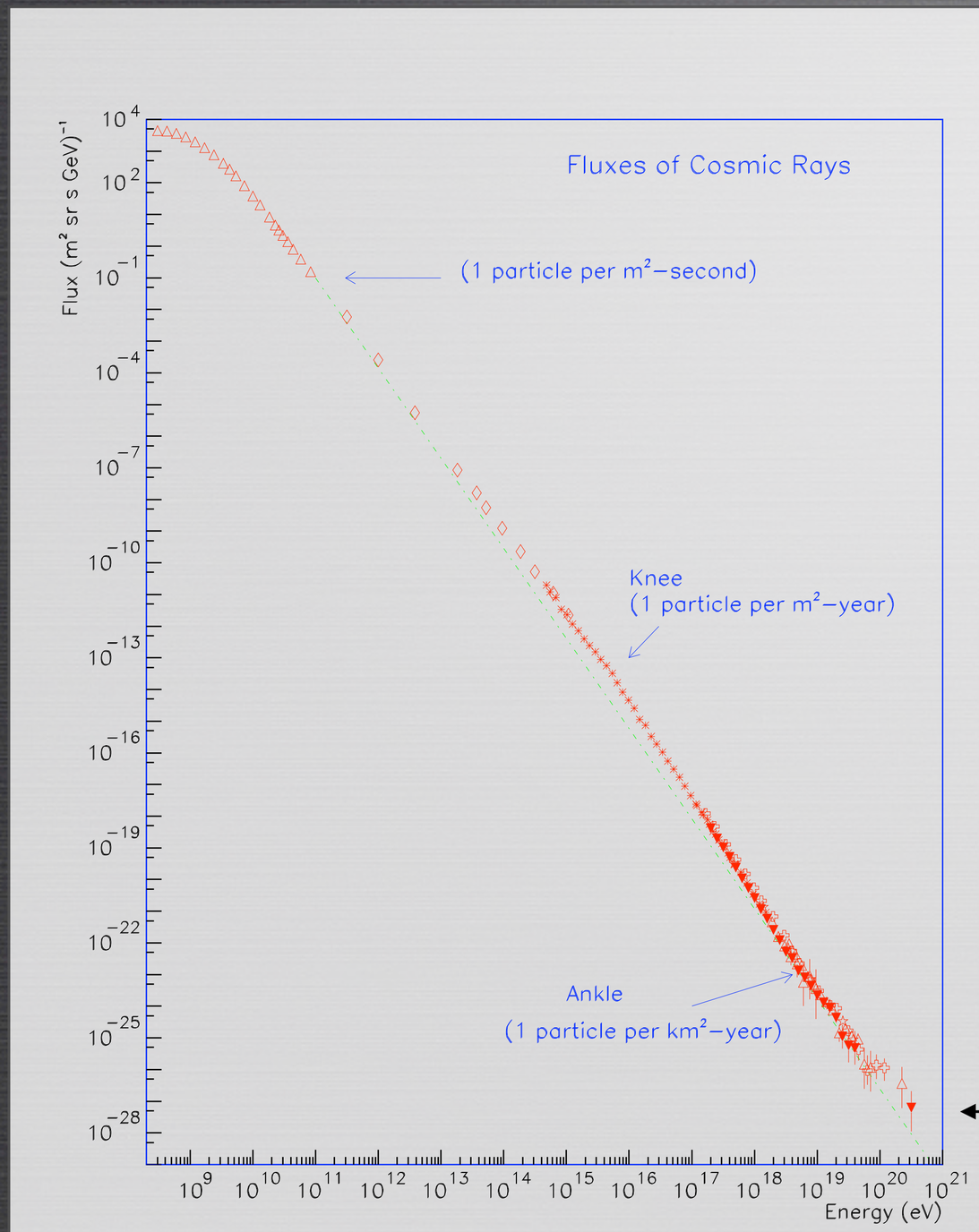






John Linsley was an epic character, he essentially ran the Volcano Ranch array of scintillators by himself for many years (59-63), in 1962 he recorded the first event with a claimed energy above 10^{20} eV.

Le flux des rayons cosmiques





3×10^{20} eV = 50 joules = 1 Tyson ©

Un proton de 10^{20} eV
(100 000 000 000 000 000 000 eV)
c'est :

l'énergie de Myke Tyson dans une particule élémentaire

250 tonnes pour un simple moustique s'il voyageait à la même vitesse que ces protons cosmiques

1g d'entre eux permettrait d'alimenter la France en électricité pendant près de 6 millions d'années.

(Mais ils sont rare, il faudrait plus de dix millions de fois l'âge de l'Univers pour en recueillir autant)

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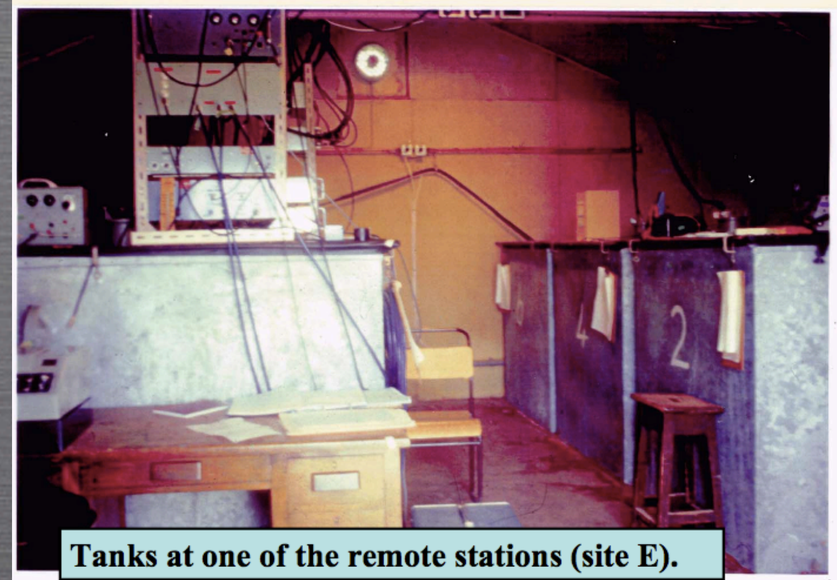
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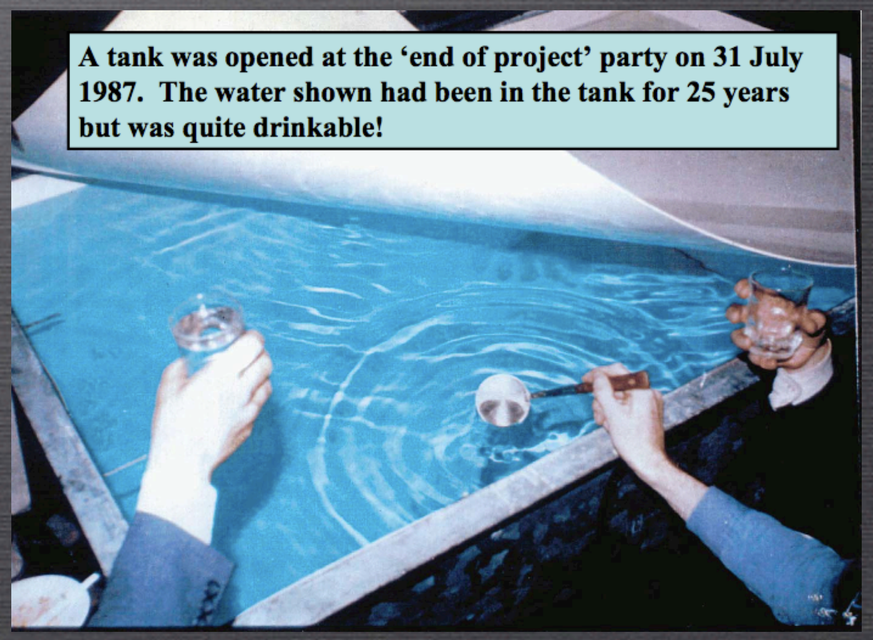
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Le réseau d'Haverah Park - Écosse - 1960-1987




Tanks at one of the remote stations (site E).


A tank was opened at the 'end of project' party on 31 July 1987. The water shown had been in the tank for 25 years but was quite drinkable!

Alan Watson started the Haverah Park water Cherenkov array in 1967 and ran it for 20 years in Scotland. As is customary in the highland you conserve water for many years in a can (although usually with some fermented malt) and then you happily drink it.

Yakutz



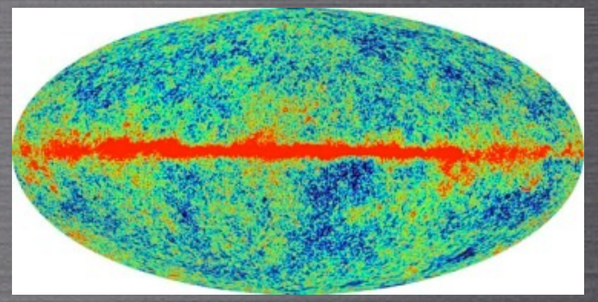
Zatsepin together with Kuzmin and independently of the work of Greizen predicted the now called GZK cutoff due to the interaction of hadrons with the photons of the CMB, either through

En 1966 Découverte du fond cosmologique de radiation



Penzias & Wilson

Nobel 1978



A très Hautes énergies L'univers devient opaque

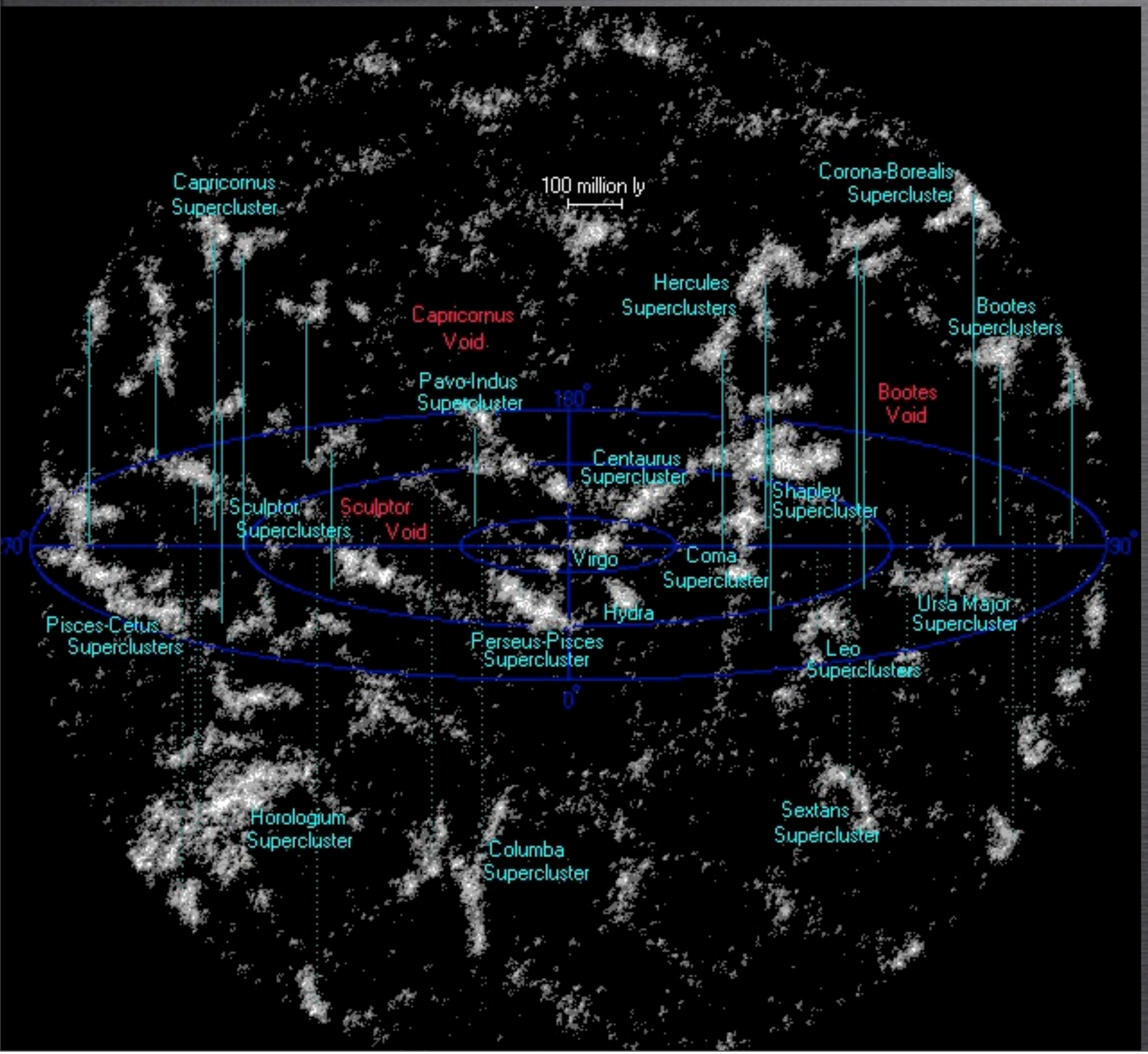
- Le flux de rayons cosmique devrait disparaître

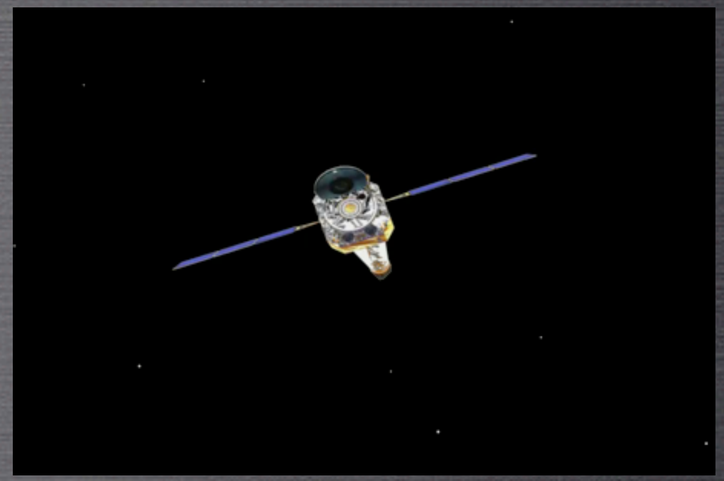
Prédiction de Greisen Zatsepin & Kuzmin [GZK]

- Si des particules de très hautes énergies subsistent les sources sont proches

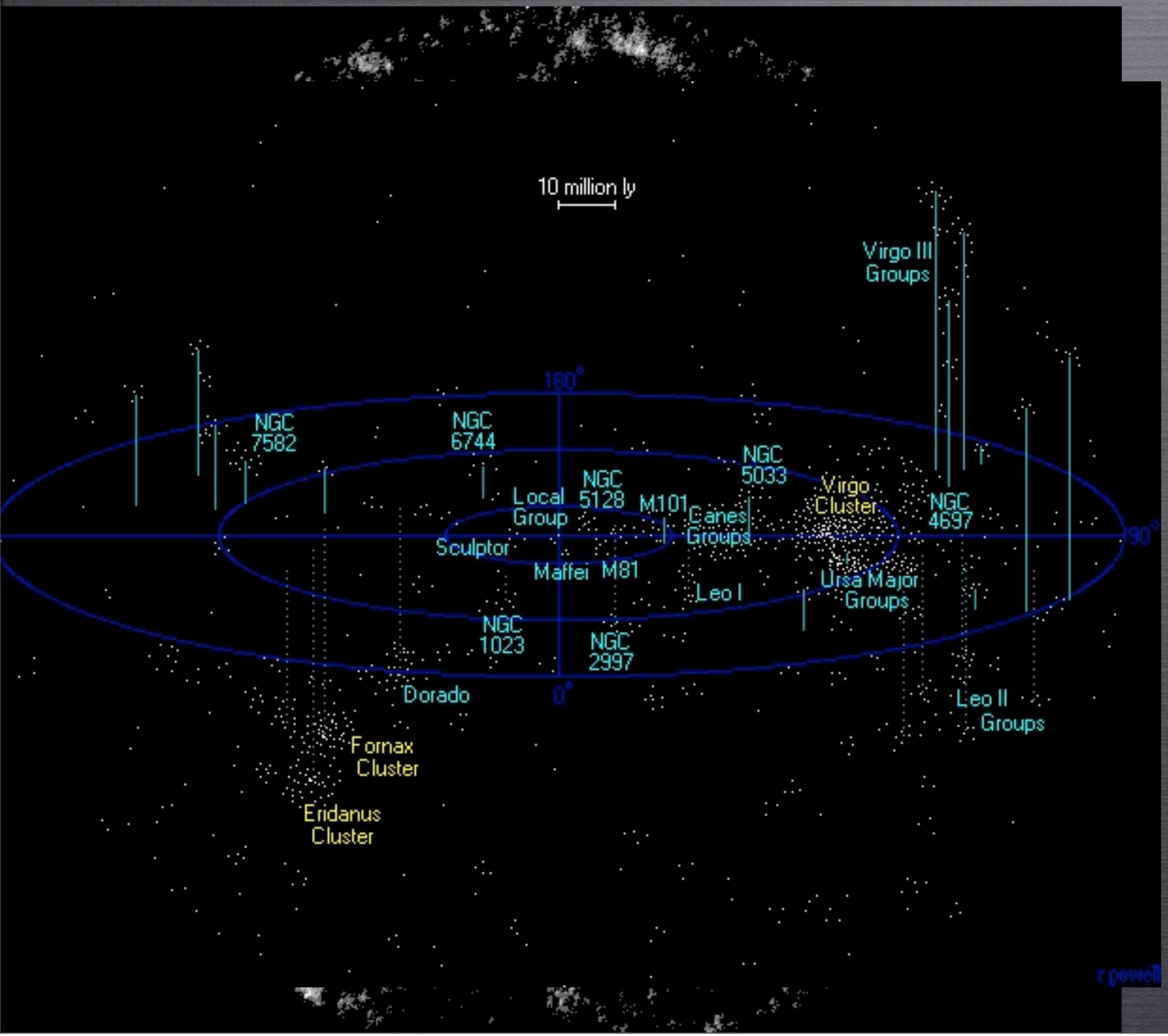
On peut les rechercher sur le ciel !

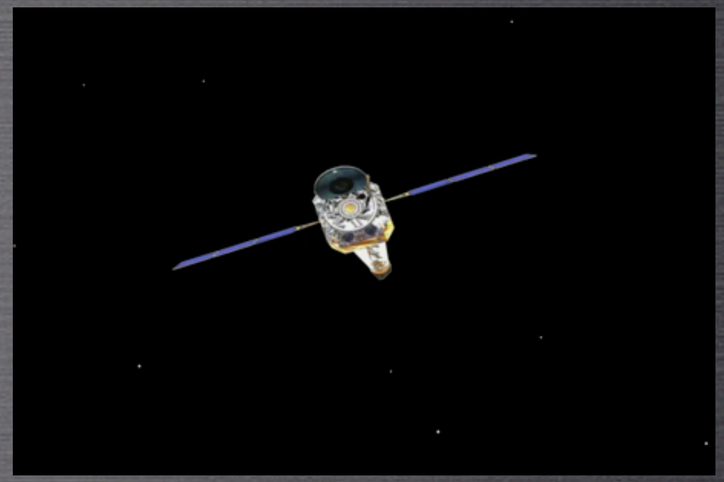
Des sources proches de la Terre ?



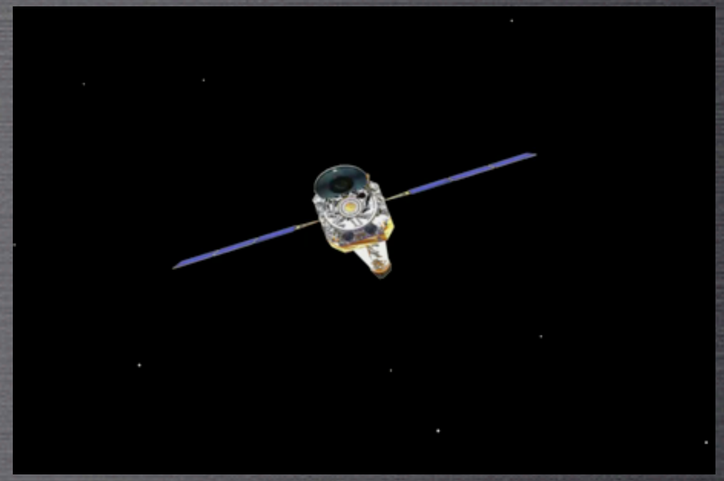


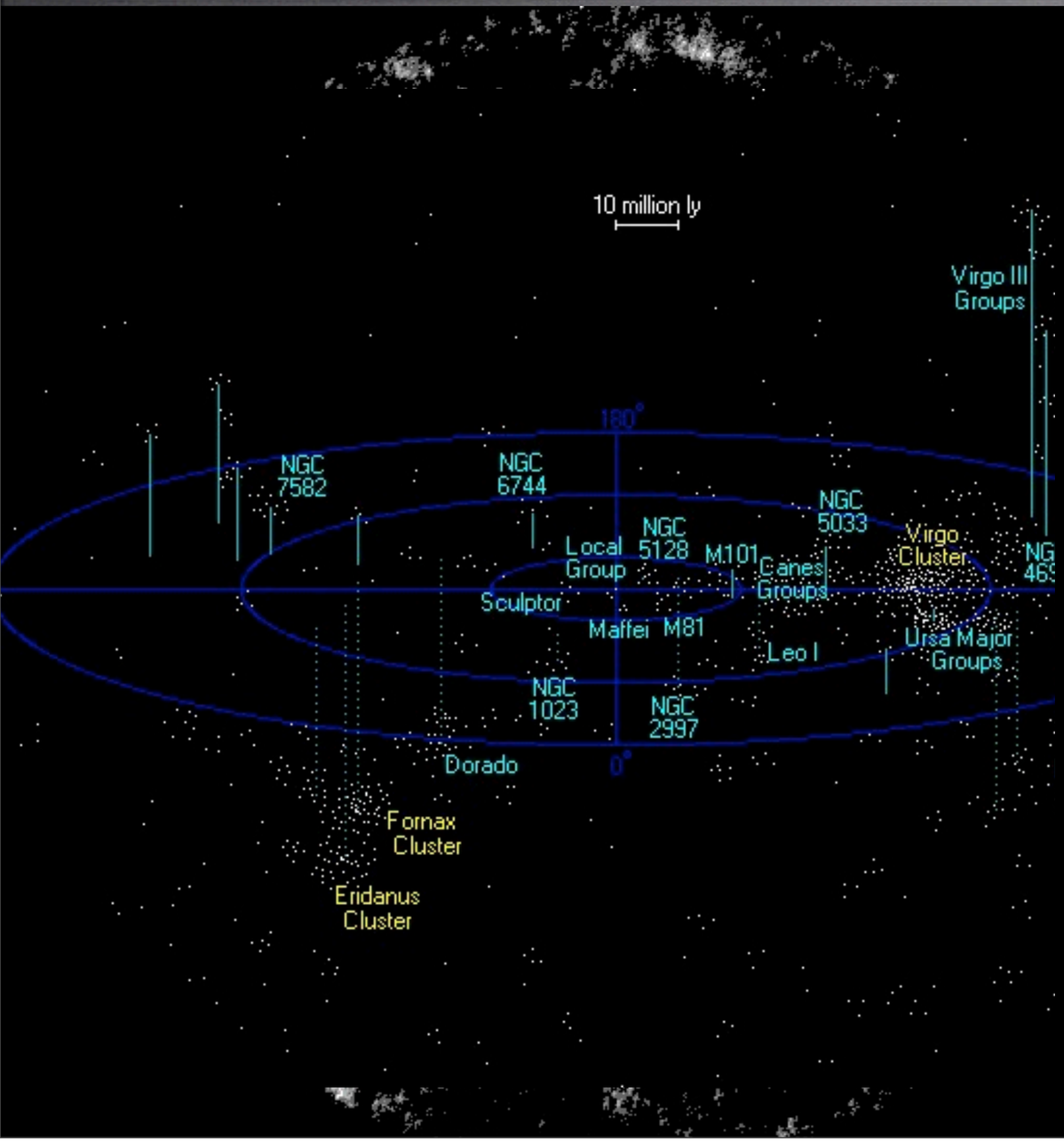
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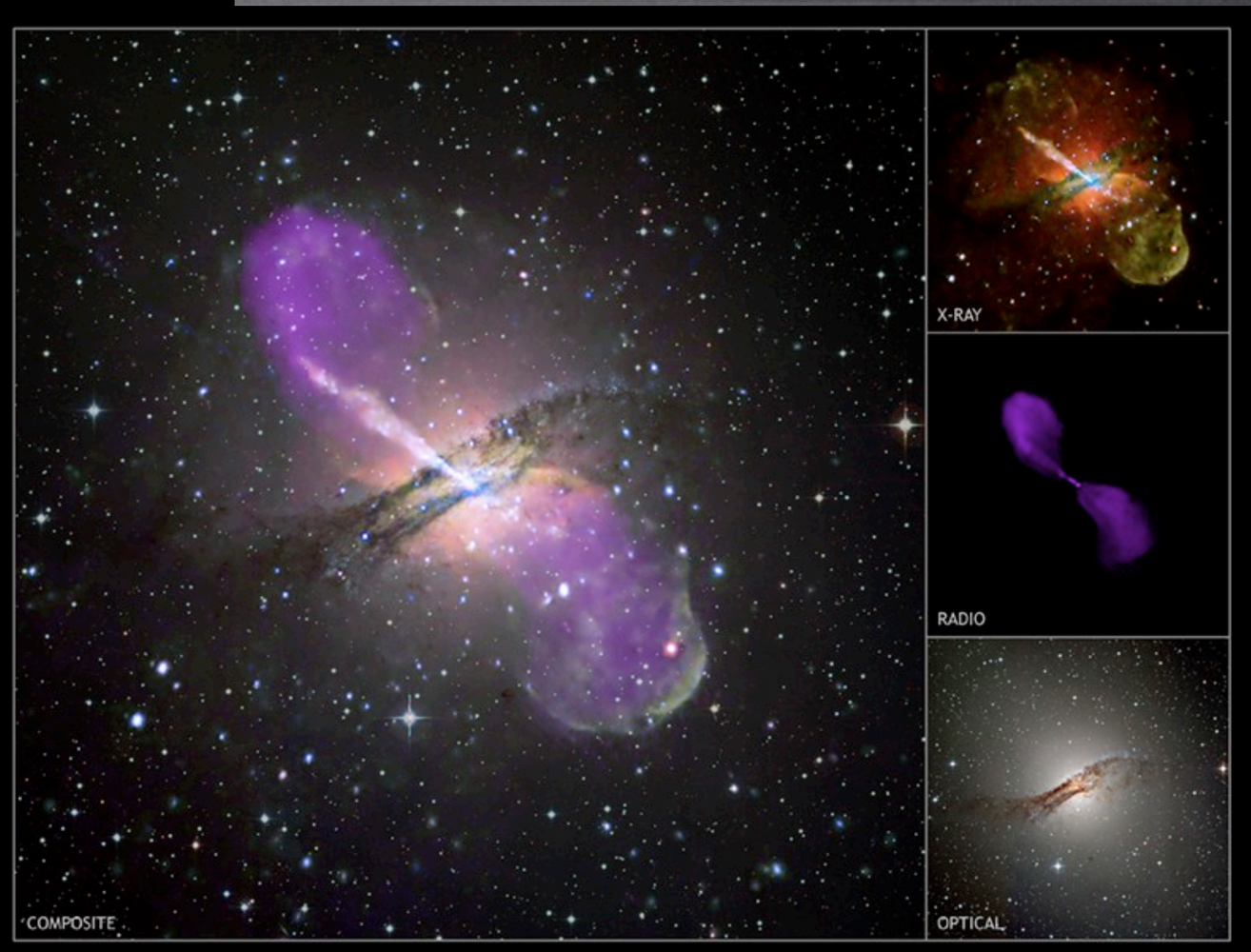




Des sources proches de la Terre ?



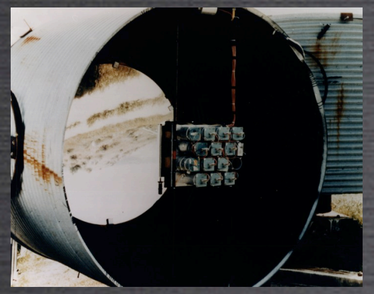




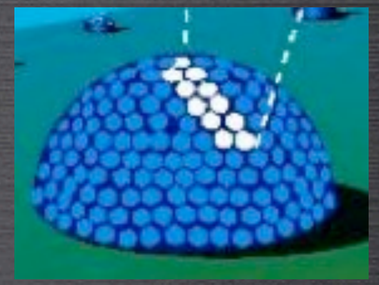
1980

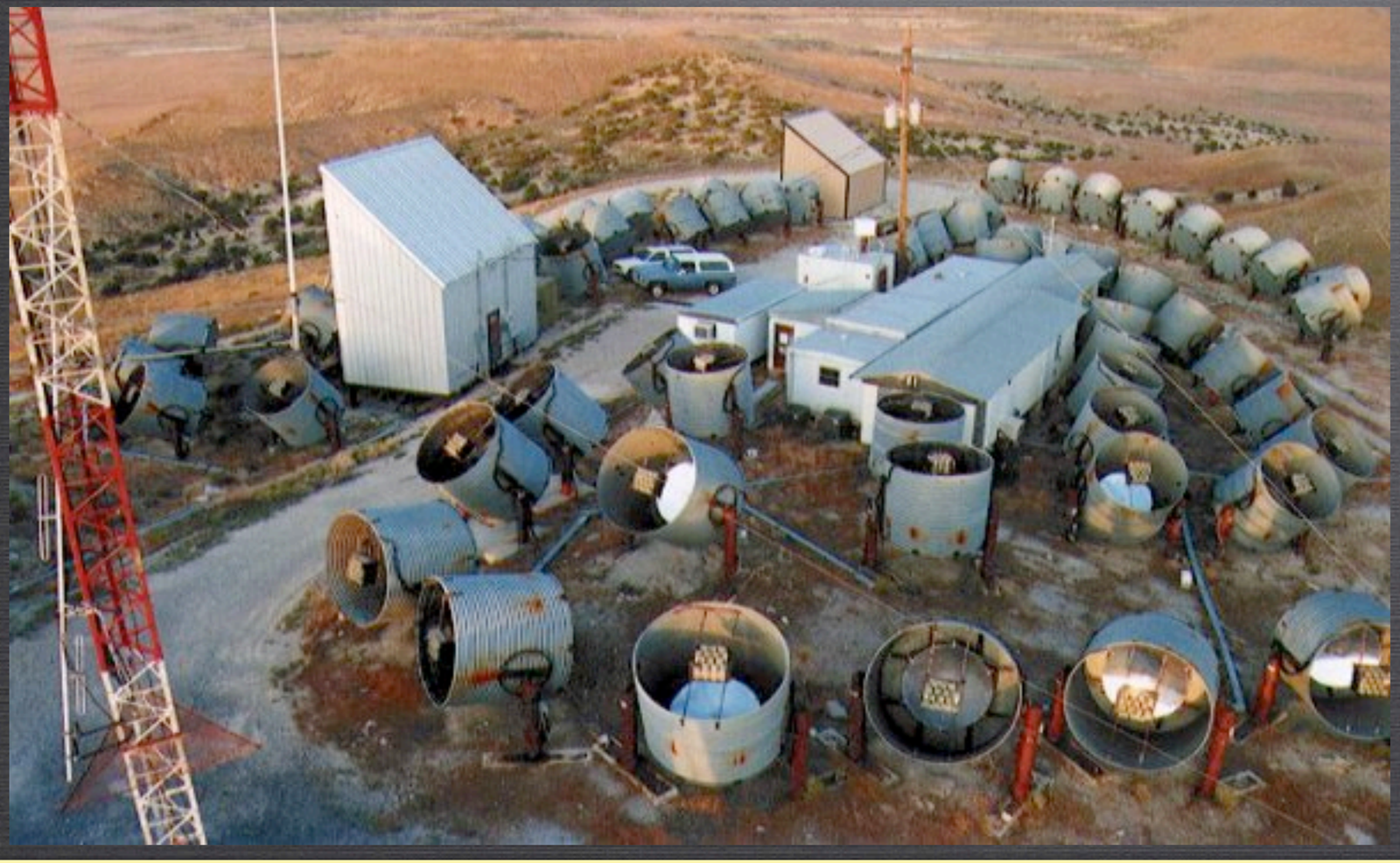
1980

PLUS GRAND



L'oeil de Mouche









A new technique is developed in the USA : the EAS evolution is measured during moonless clear nights tracking the fluorescence light they produce along their path in the atmosphere. Fly's Eye is the first instrument using this technique and measured the highest energy event ever recorded with 3×10^{20} eV . A n improved instrument, HiRes,

Le Réseau AGASA - Japon 1990-2001



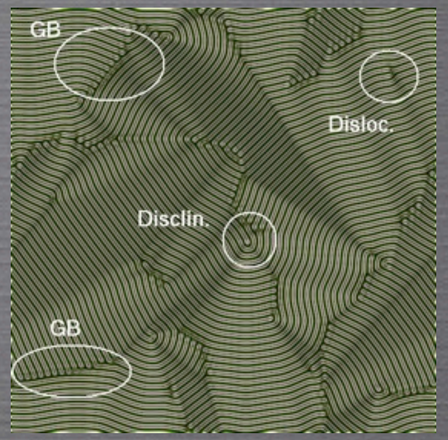


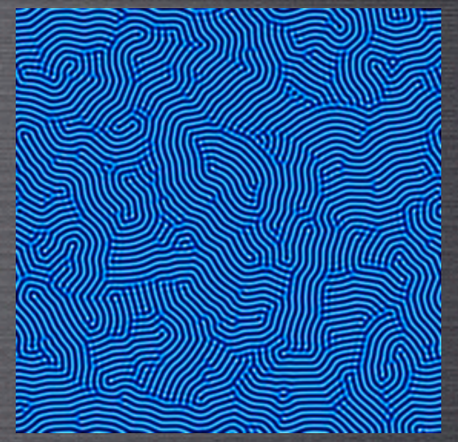
In Japan a 100 km^2 array operates for more than 10 years, its determination of the flux seems in contradiction with the results from Fly'sEye and Hires. Do we see the GZK cutoff or not?

Où sont les sources et que sont-elles ?



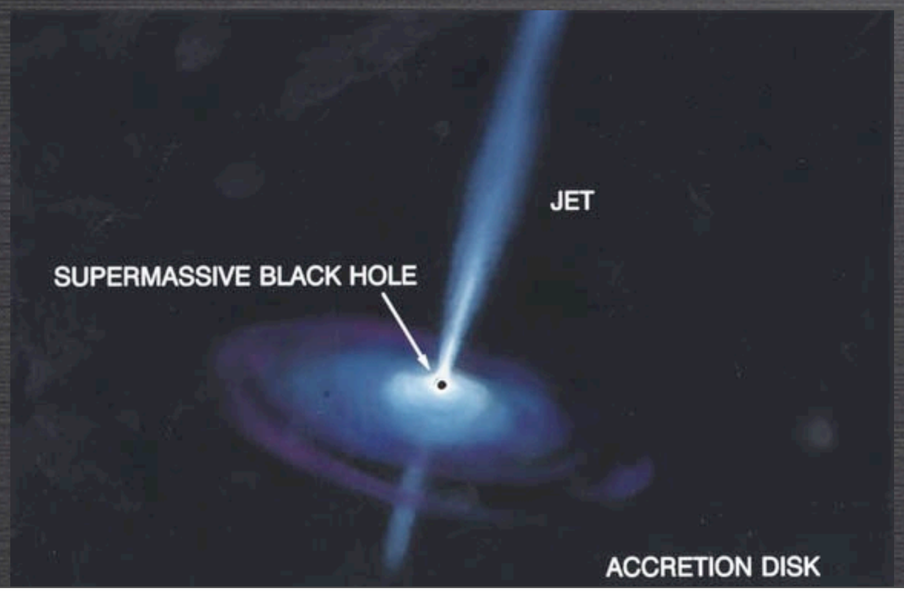
Accélérateurs cosmiques
AGN
Galaxies Radio
Jeunes étoiles à Neutrons
Sursauts Gamma



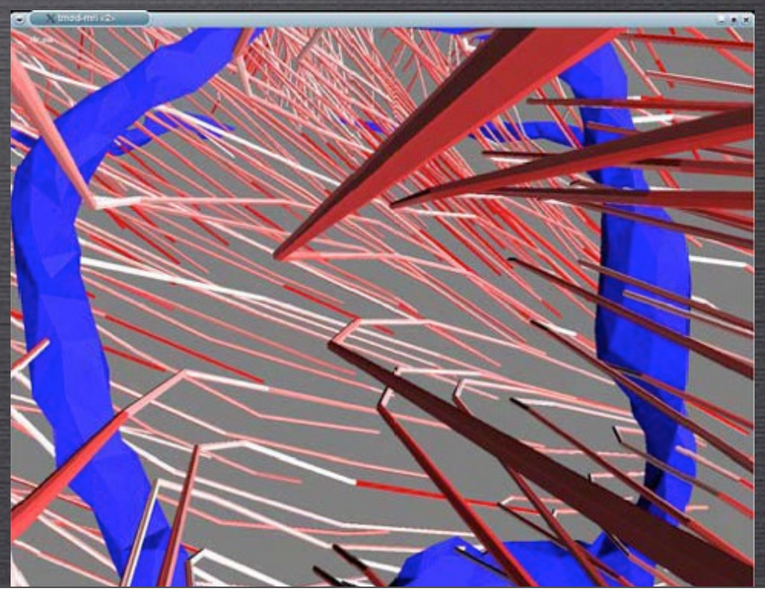


Production directe
Défauts Topologiques
Reliques (super) Massive du Big Bang

Les protons et les noyaux dominent



Les photons et les neutrinos dominent



1990

Nobel
1980

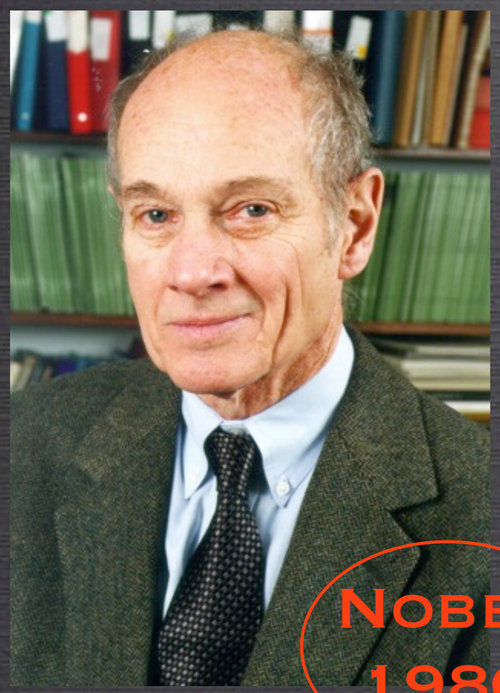
JWC - 9h00

1990

ENCORE

PLUS

GRAND

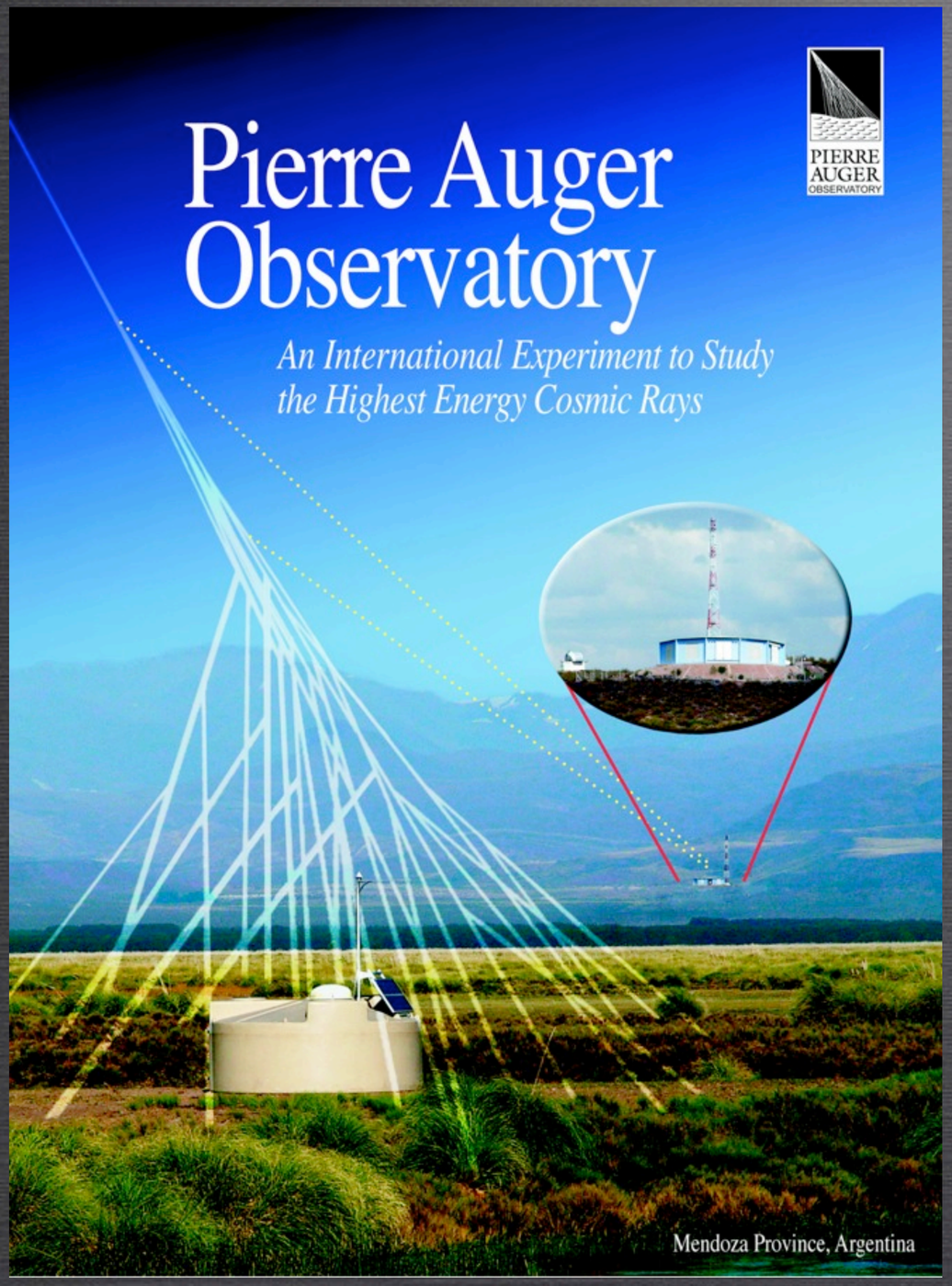


NOBEL
1980

JIM CRONIN PROPOSE UN DÉTECTEUR DE 5000 KM2 :
C'EST LA NAISSANCE DU PROJET AUGER

JWC - 9H00

L'OBSERVATOIRE PIERRE AUGER



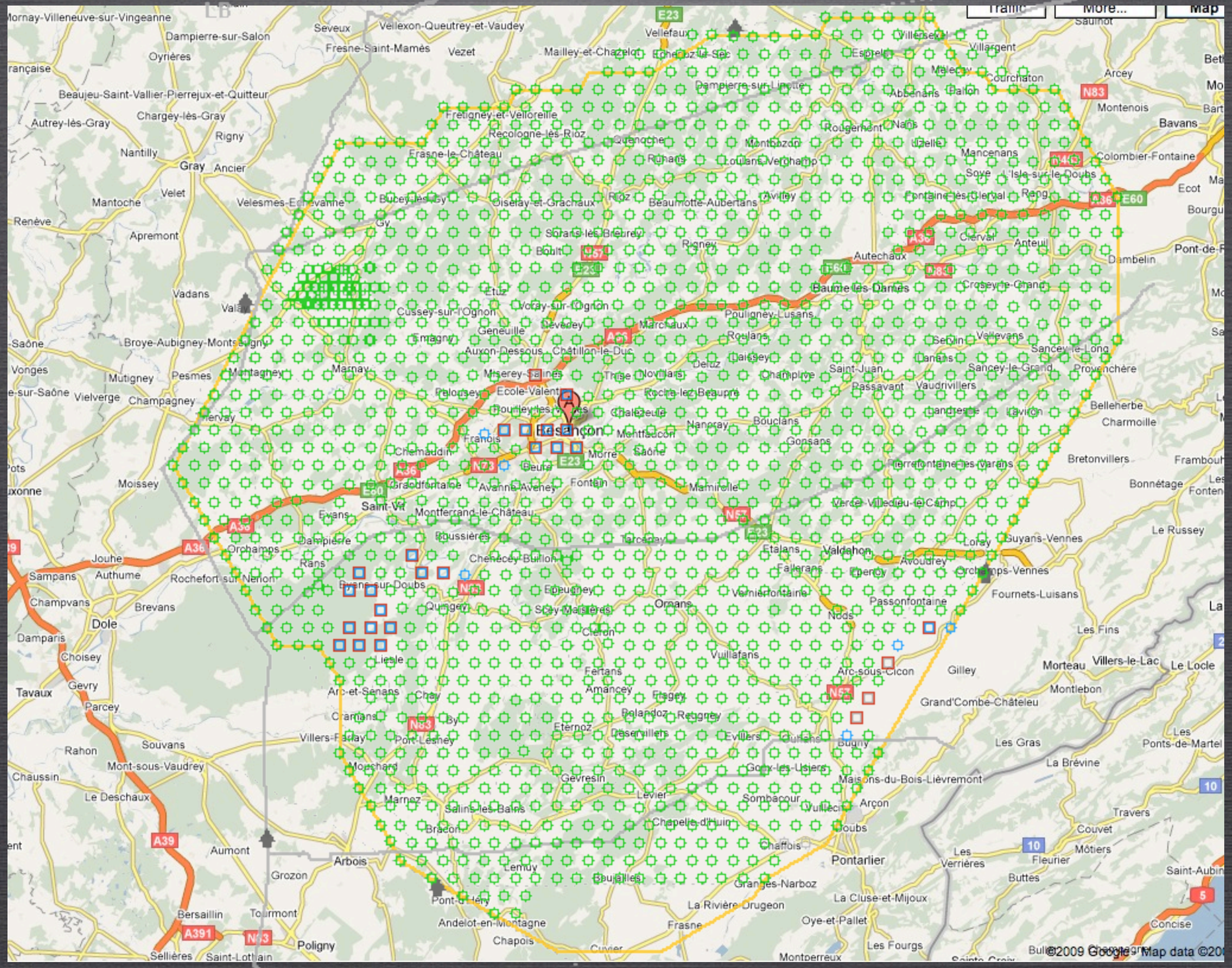
Un détecteur Hybride

Réseau de surface :
1600 cuves Chérenkov réparties tous
les 1,5 km sur une surface de 3 000 km2

Détecteur de Fluorescence :
4 site de 6 télescopes à fluorescence
pour regarder l'atmosphère au dessus
du réseau de surface

-

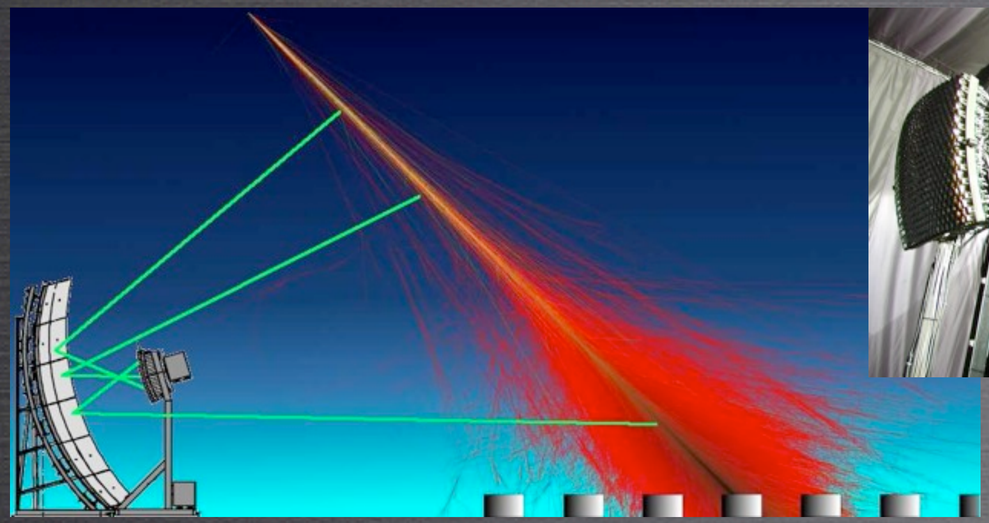
inter calibrage / précision /
stabilité & efficacité

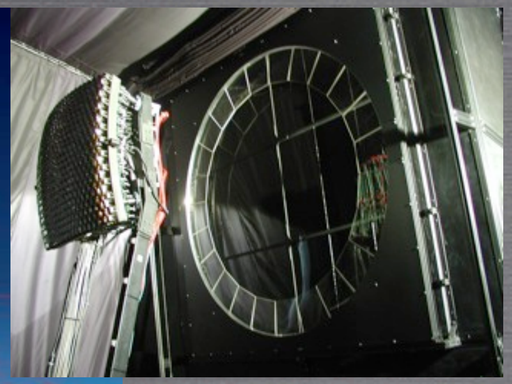

Traffic
More...
Map
Besançon
Pontarlier
Dole
Gray
Vesoul
Montbéliard
Baume-les-Dames
Arc-et-Senans
Saint-Vit
Arbois
Poligny
Salins-les-Bains
Quingey
Rioz
Marnay
Mamirolle
Avanne-Aveney
Chemaudin
Thise
Novillars
Roche-lez-Beaupré
Ecole-Valentin
Pelousey
Miserey-Salines
Auxon-Dessous
Châtillon-le-Duc
Cussey-sur-l'Ognon
Voray-sur-l'Ognon
Etuz
Boult
Scharrais-les-Bruyeres
Oiselay-et-Grachaux
Beaumotte-Aubertans
Fretigney-et-Velloreille
Recologne-lès-Rioz
Fraisne-le-Château
Ruhans
Quenoche
Montbozon
Loulans-Verchamp
Rougemont
Nans
Uzelle
Abbenans
Dampierre-sur-Linotte
Vellefaux
Mailley-et-Chazelot
Vellexon-Queutrey-et-Vaudey
Fresne-Saint-Mamès
Vezet
Seveux
Dampierre-sur-Salon
Oyrières
Beaujeu-Saint-Vallier-Pierrejux-et-Quitteur
Autrey-lès-Gray
Chargey-lès-Gray
Rigny
Nantilly
Ancier
Velet
Mantoche
Renève
Apremont
Velesmes-Echevanne
Bucey-lès-Gy
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Broye-Aubigney-Montseugny
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Mutigney
Pesmes
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Moissey
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Champvans
Brevans
Damparis
Choisey
Tavaux
Gevry
Parcey
Rahon
Souvans
Mont-sous-Vaudrey
Chaussin
Le Deschaux
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Gonsans
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Morre
Beure
Francis
Montfaucon
Chalezeule
Palente
Geneuille
Emagny
Devecey
Marchaux
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Poulingey-Lusans
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Mancenans
Colombier-Fontaine
Ecot
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Arcey
Bavans
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Malecey
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Esprels
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Saulnot
Bet
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Ba
Ma
Sa
Mc
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Provenchère
Vaudrivillers
Passavant
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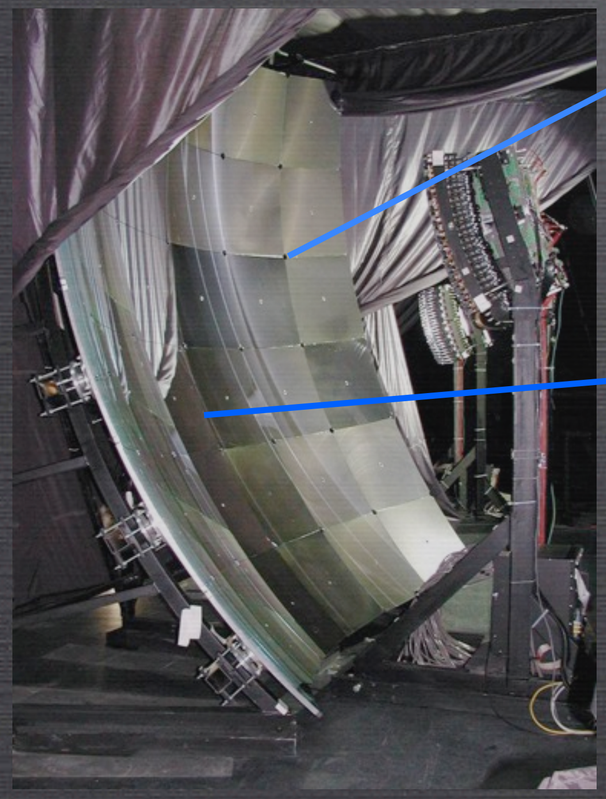


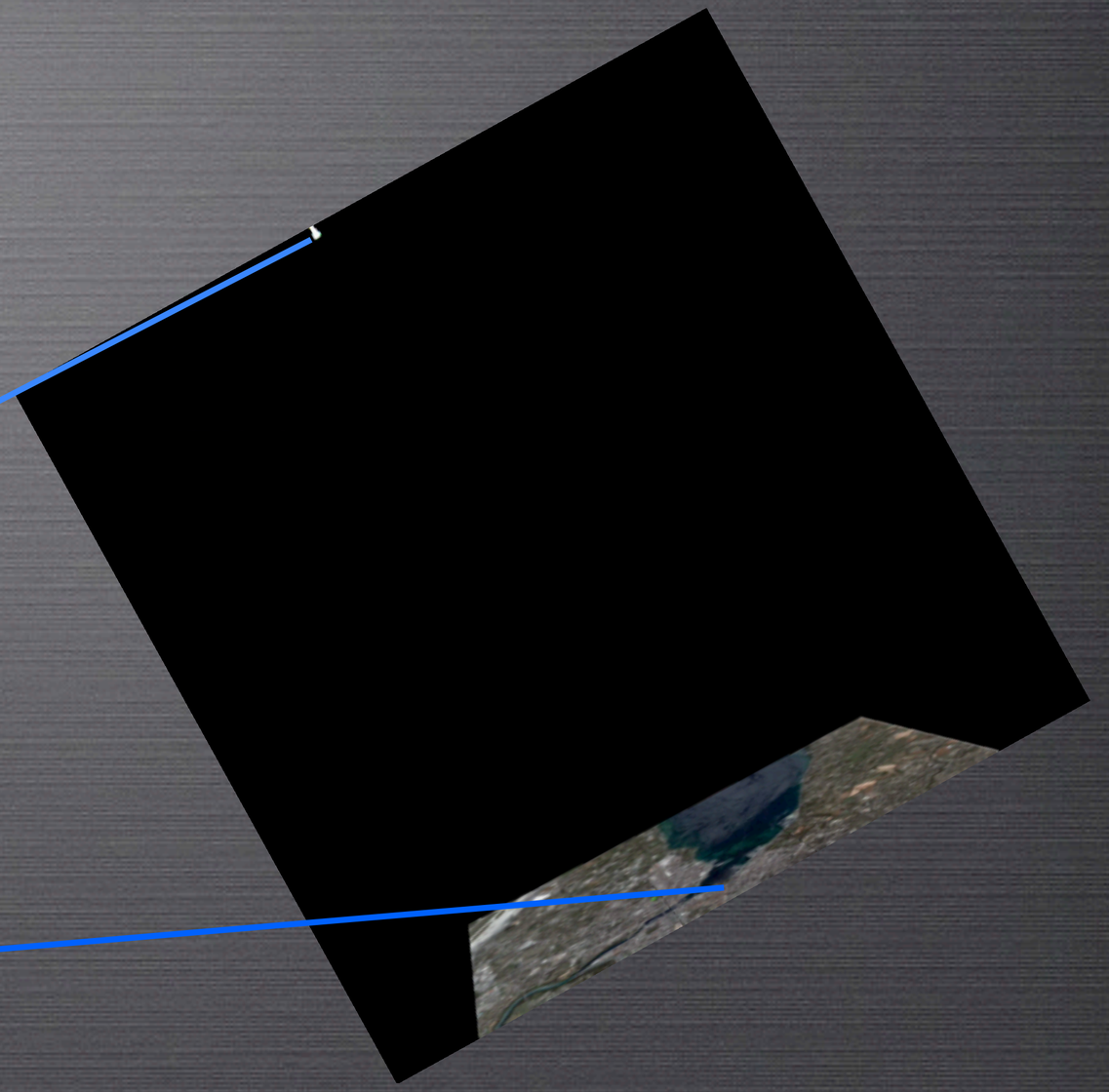

1,5 KM



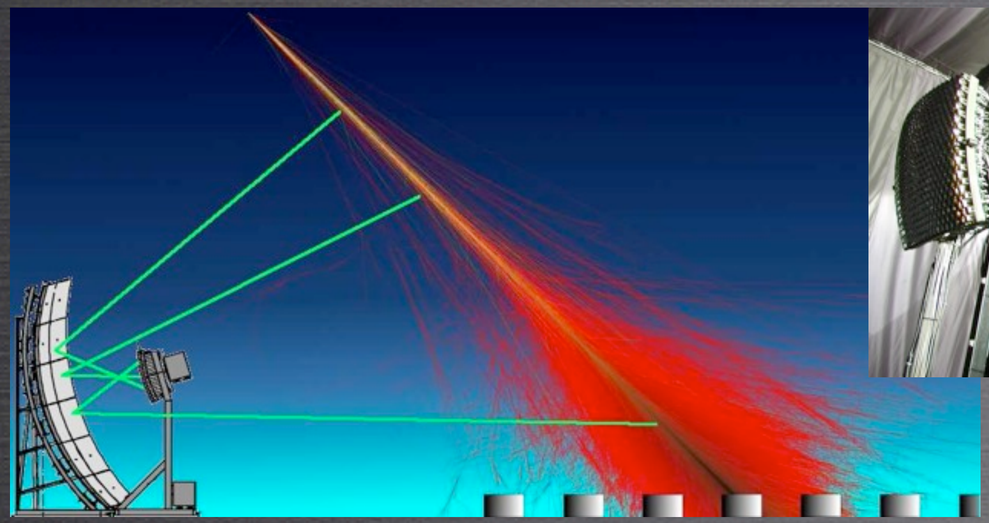


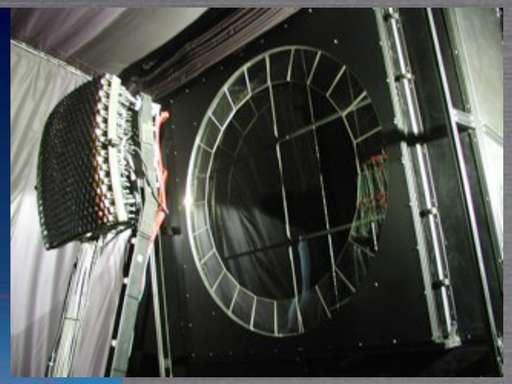


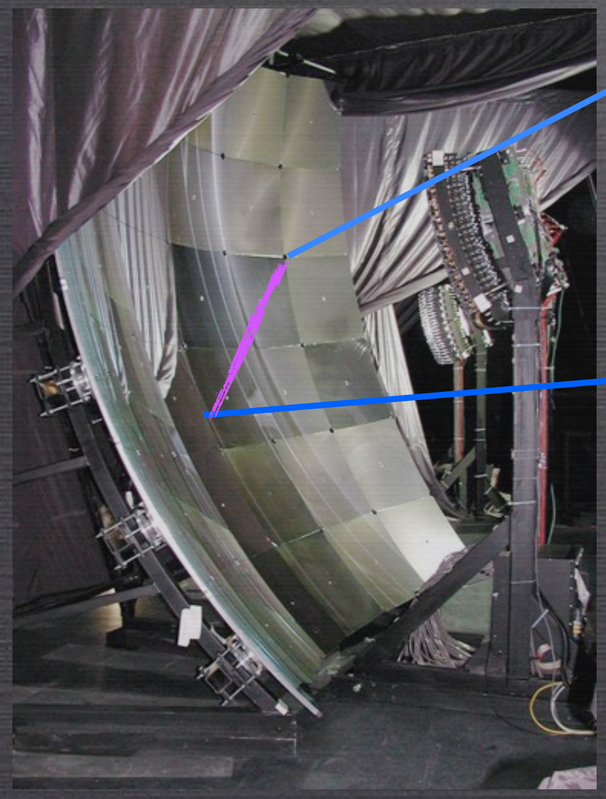


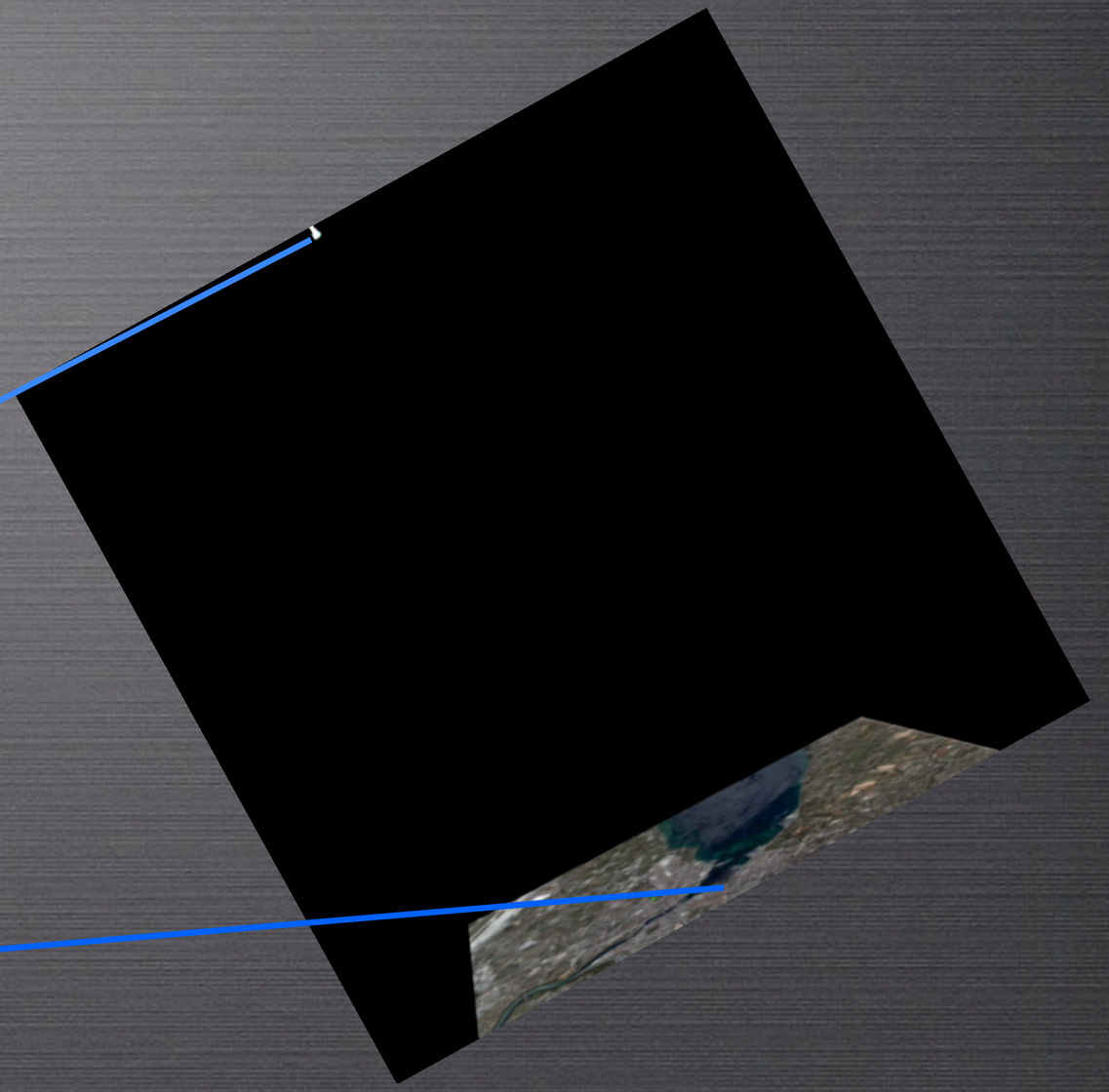


Un détecteur de fluorescence

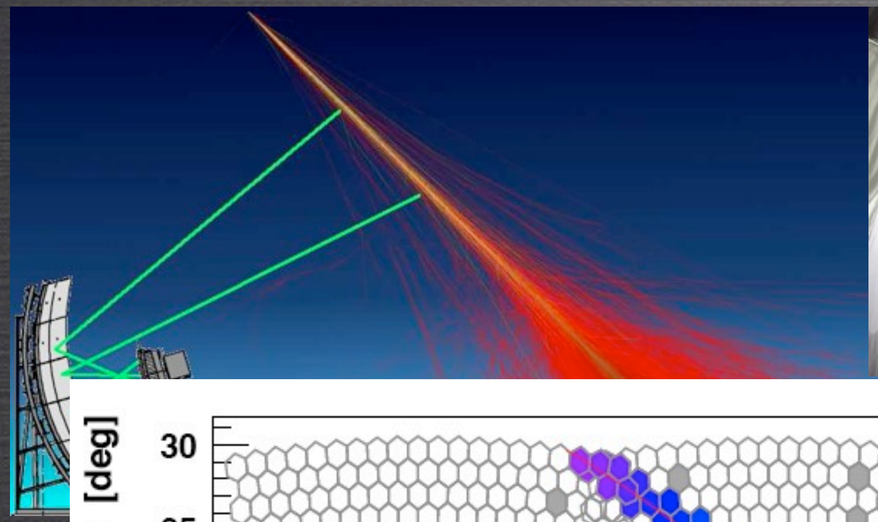


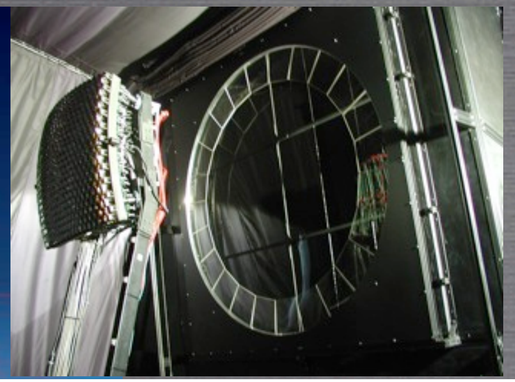


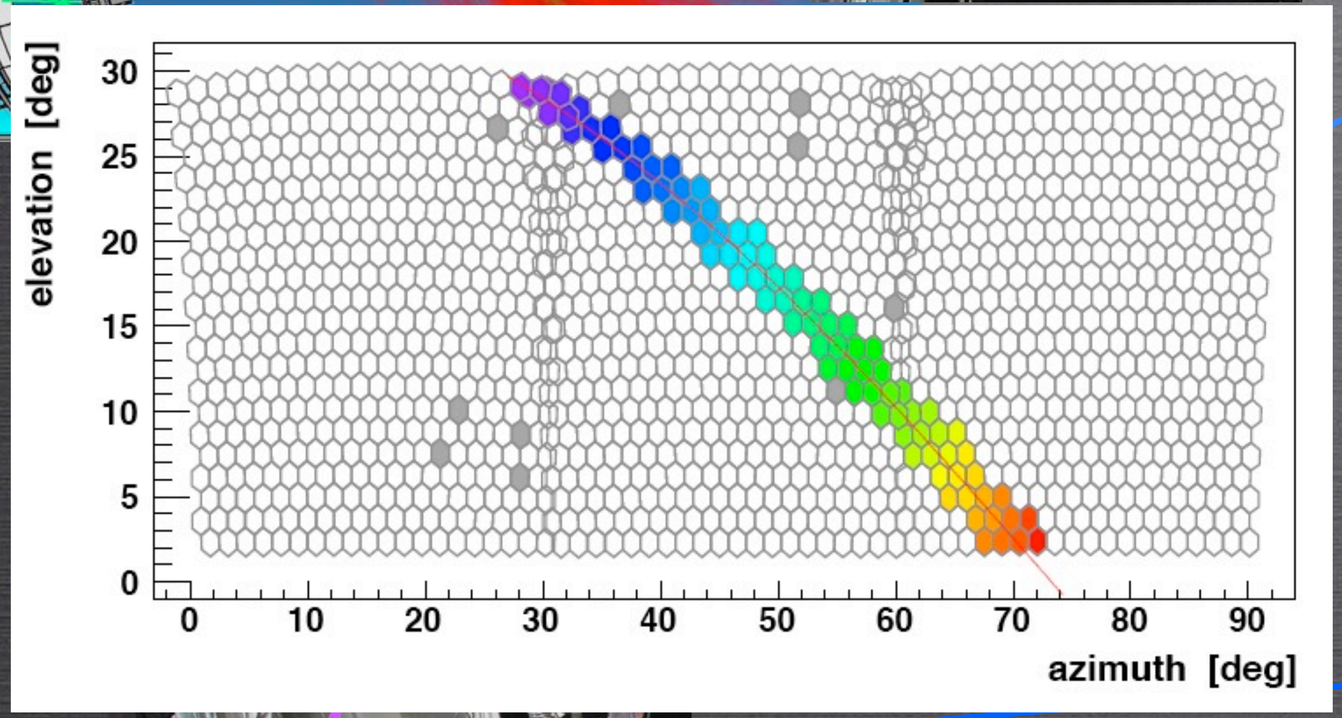


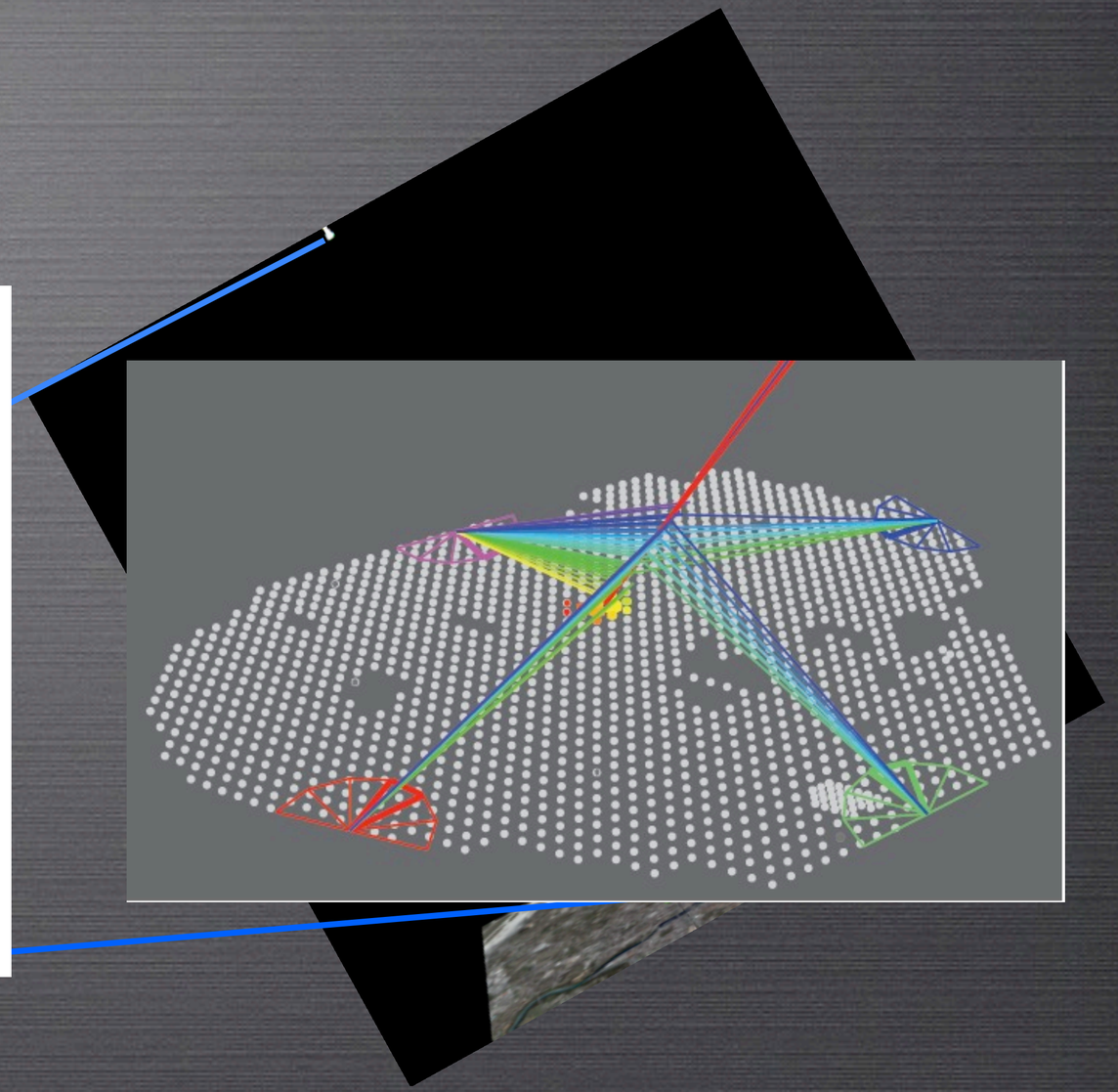


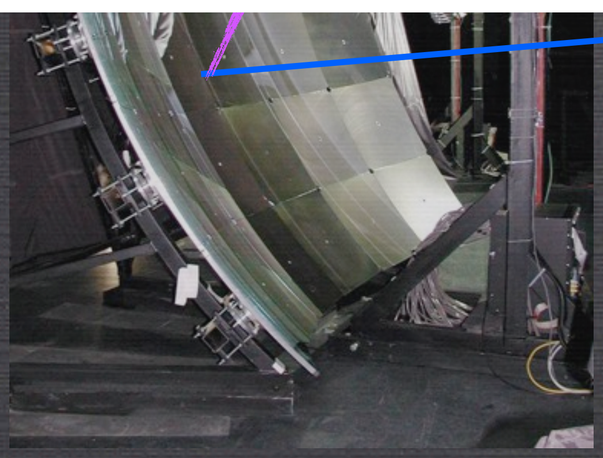
Un détecteur de fluorescence





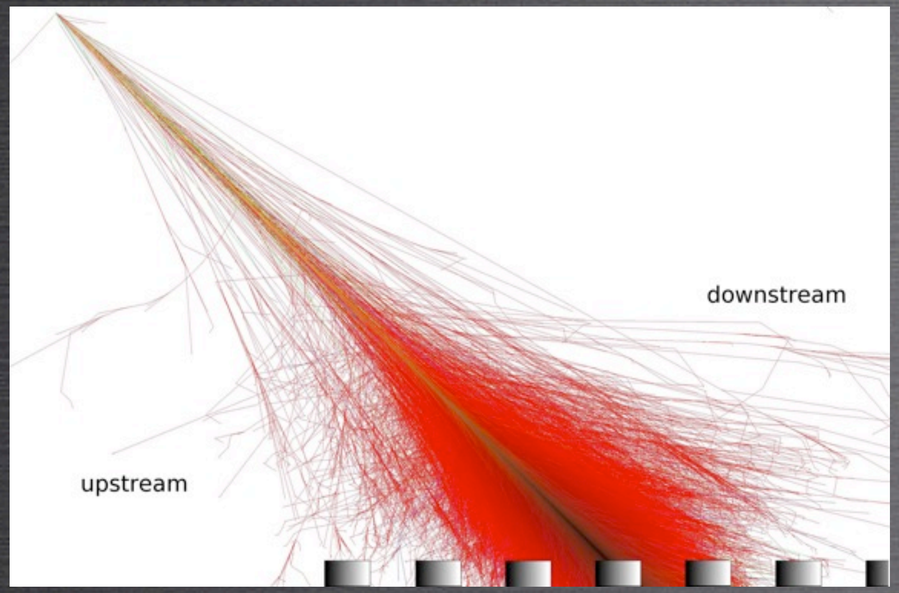


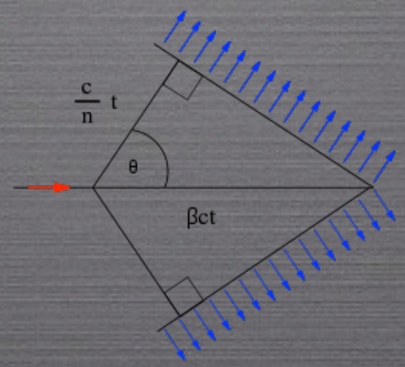


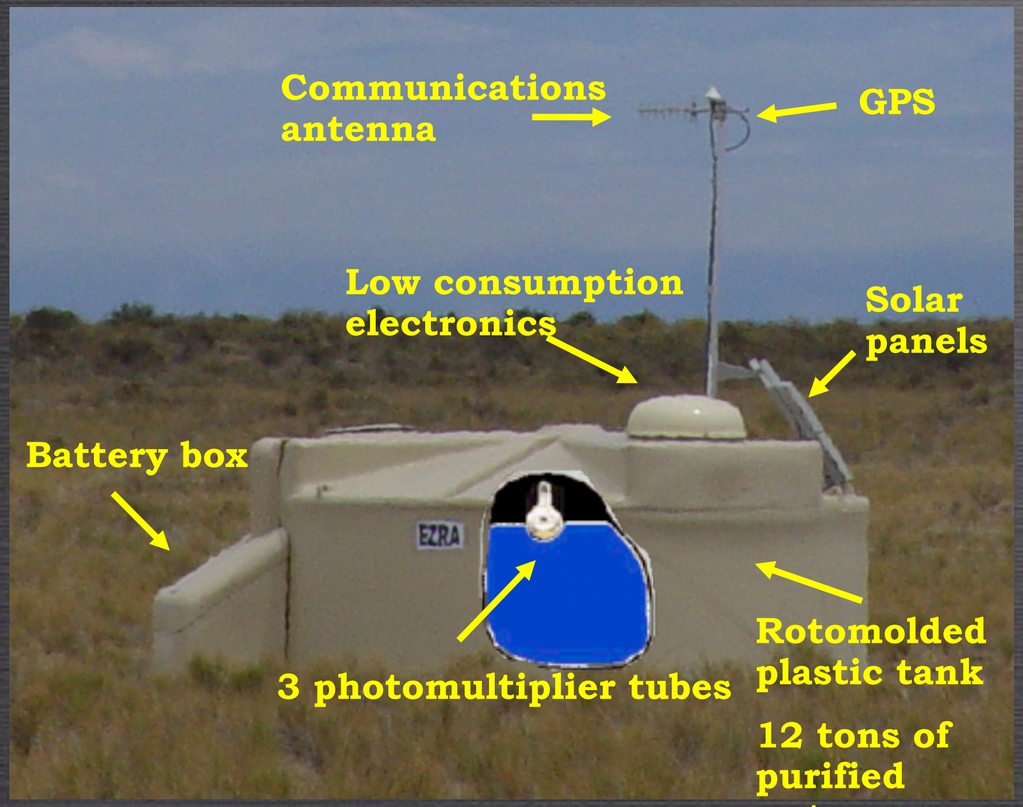


Un détecteur de fluorescence

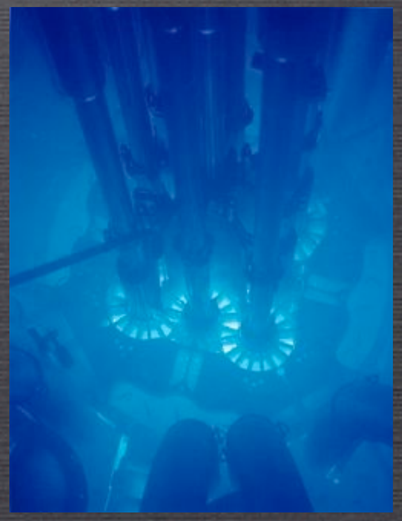
Un détecteur de surface & L'effet Cherenkov



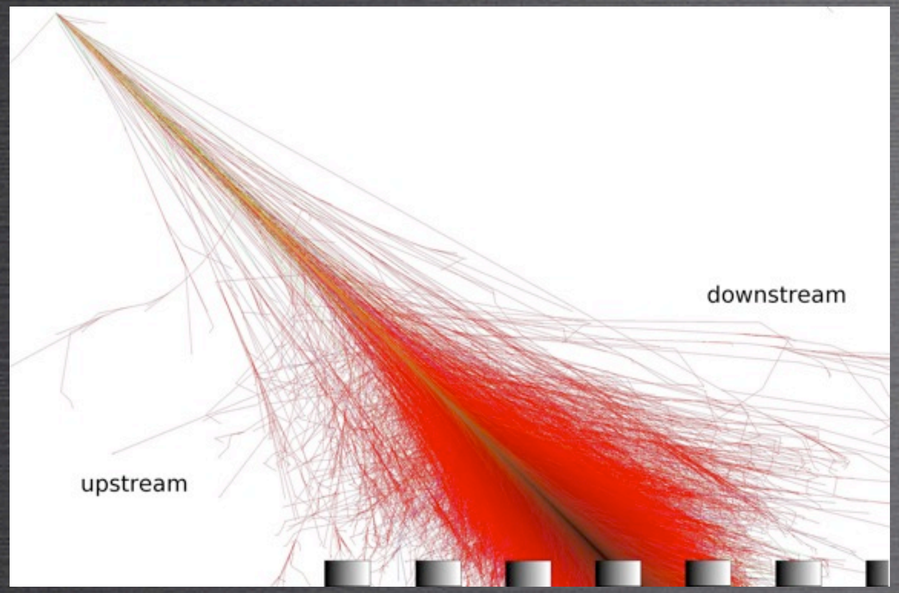


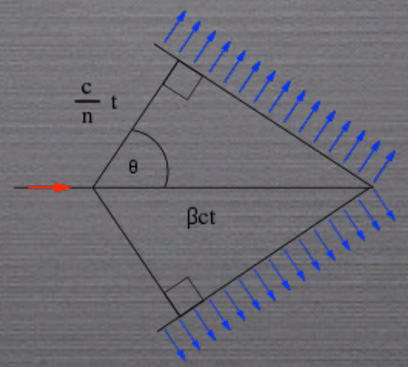


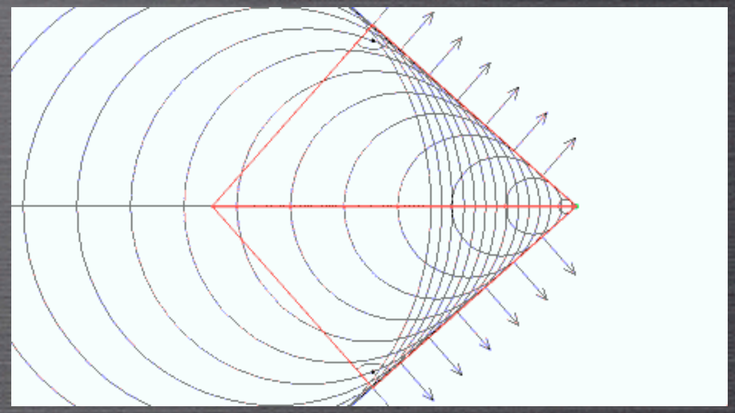


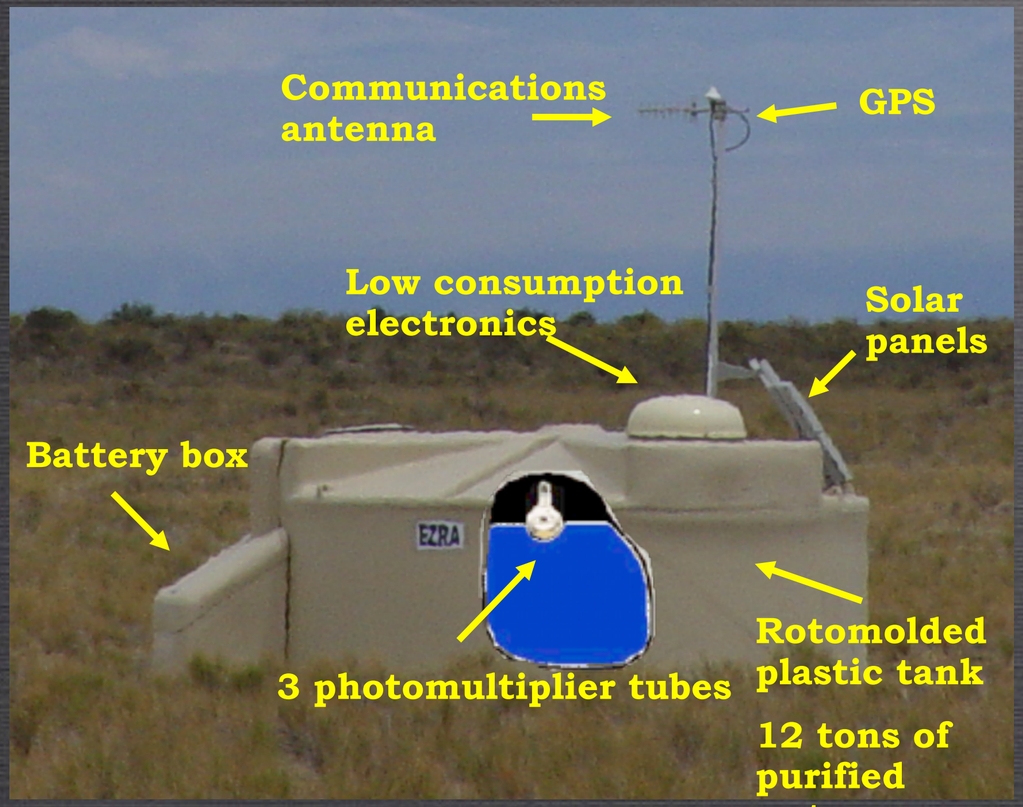


Un détecteur de surface & L'effet Cherenkov

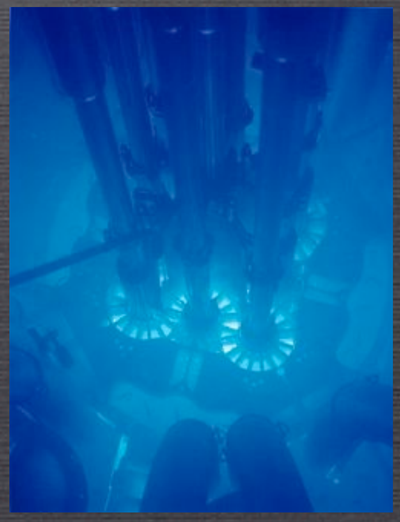












Novembre
2007

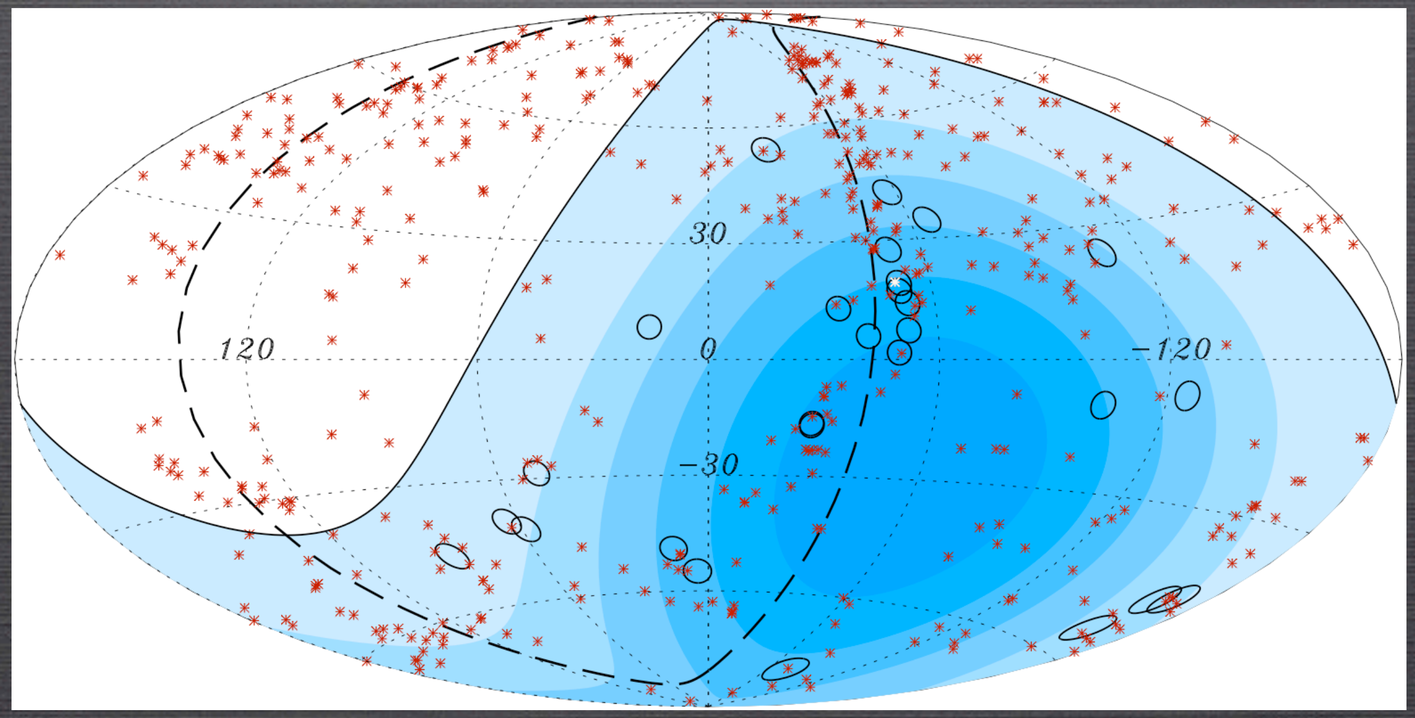
Les sources apparaissent-elles enfin ?



Novembre
2007

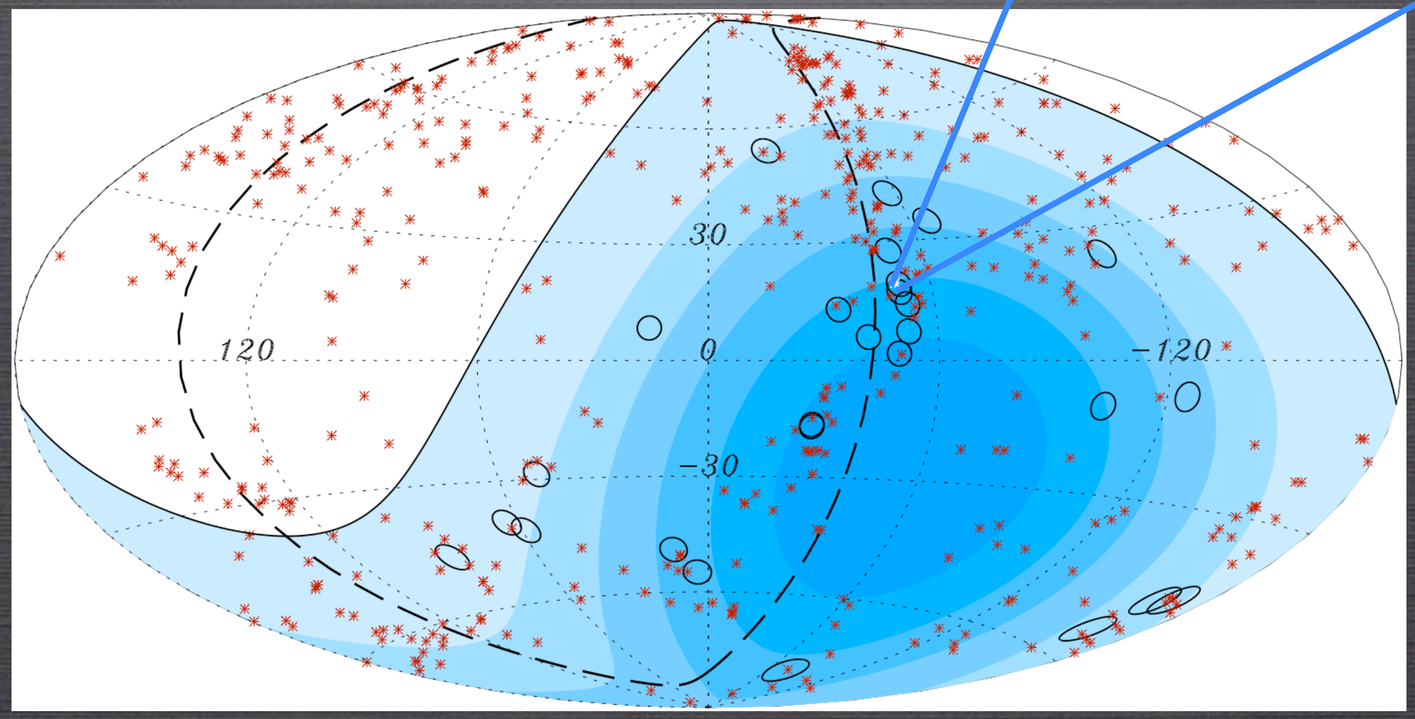
Les sources apparaissent-elles enfin ?

Noyaux Actifs de Galaxies - Centaurus A

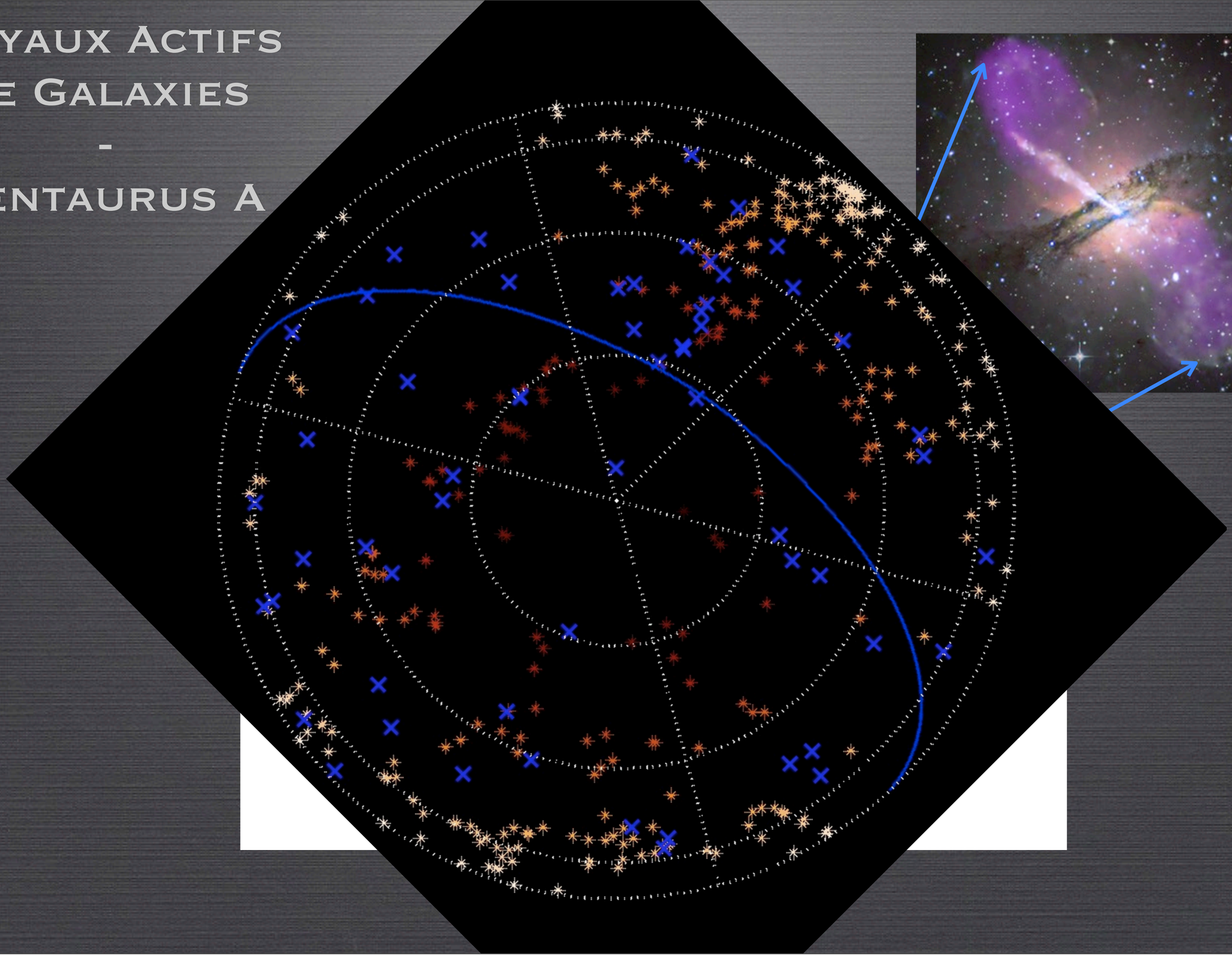


Noyaux Actifs de Galaxies - Centaurus A



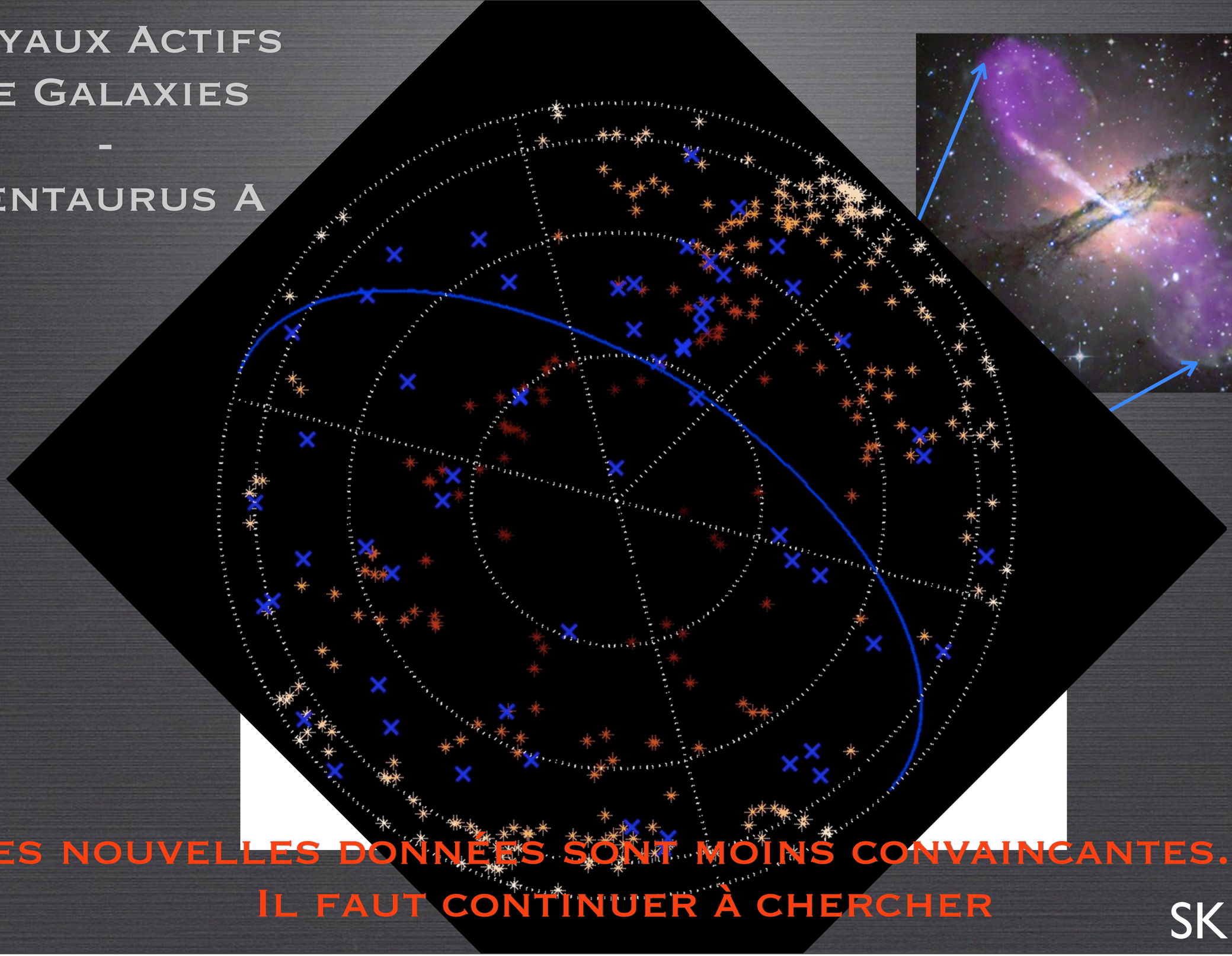


Noyaux Actifs de Galaxies - Centaurus A





Noyaux Actifs de Galaxies - Centaurus A





Les nouvelles données sont moins convaincantes....
Il faut continuer à chercher

SK - 15h00



Faut pas rêver - Arnaud Blin - FR3 automne 2008


OBSERVATORIO
PIERRE
AUGER