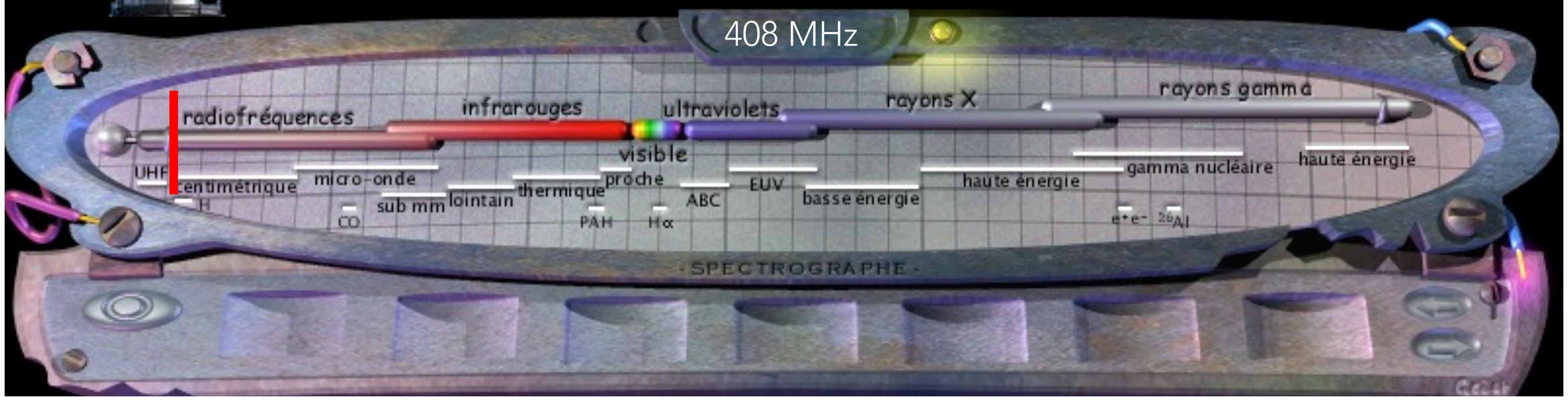
neutron matter

structure of the Galaxy

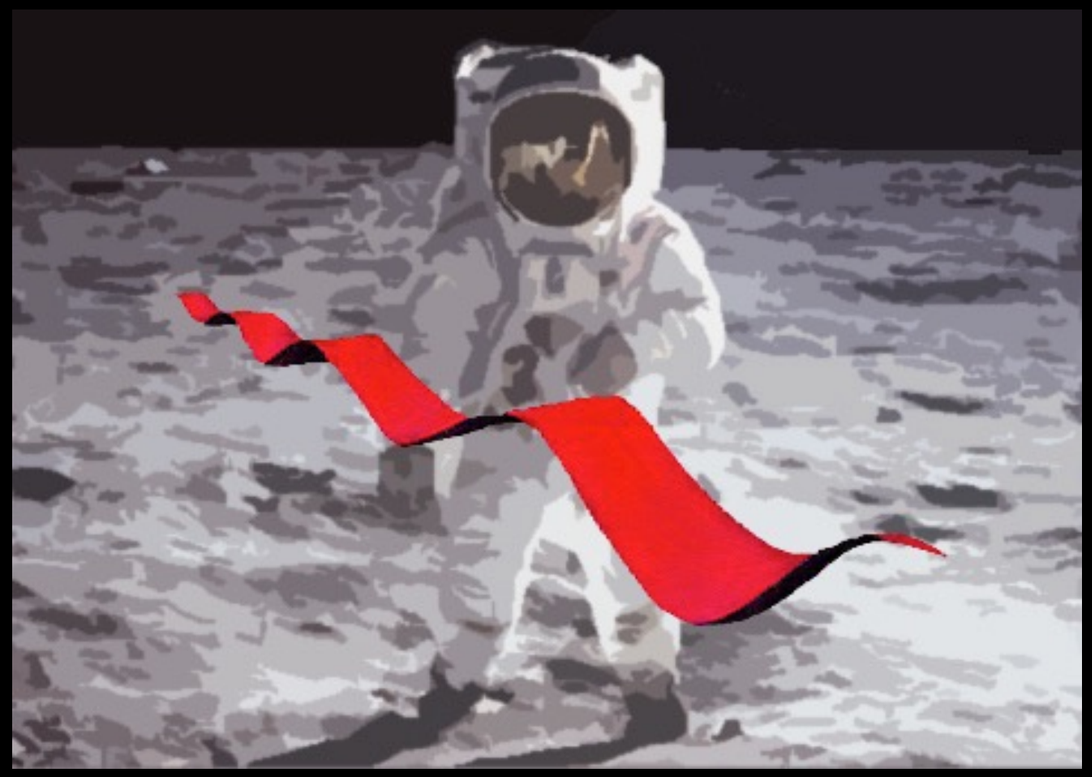
quasars

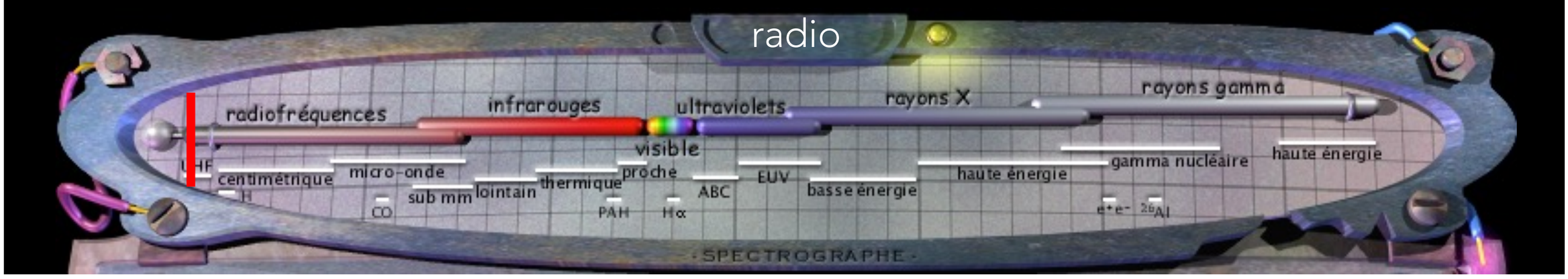
gravitationnale waves (indirectly)

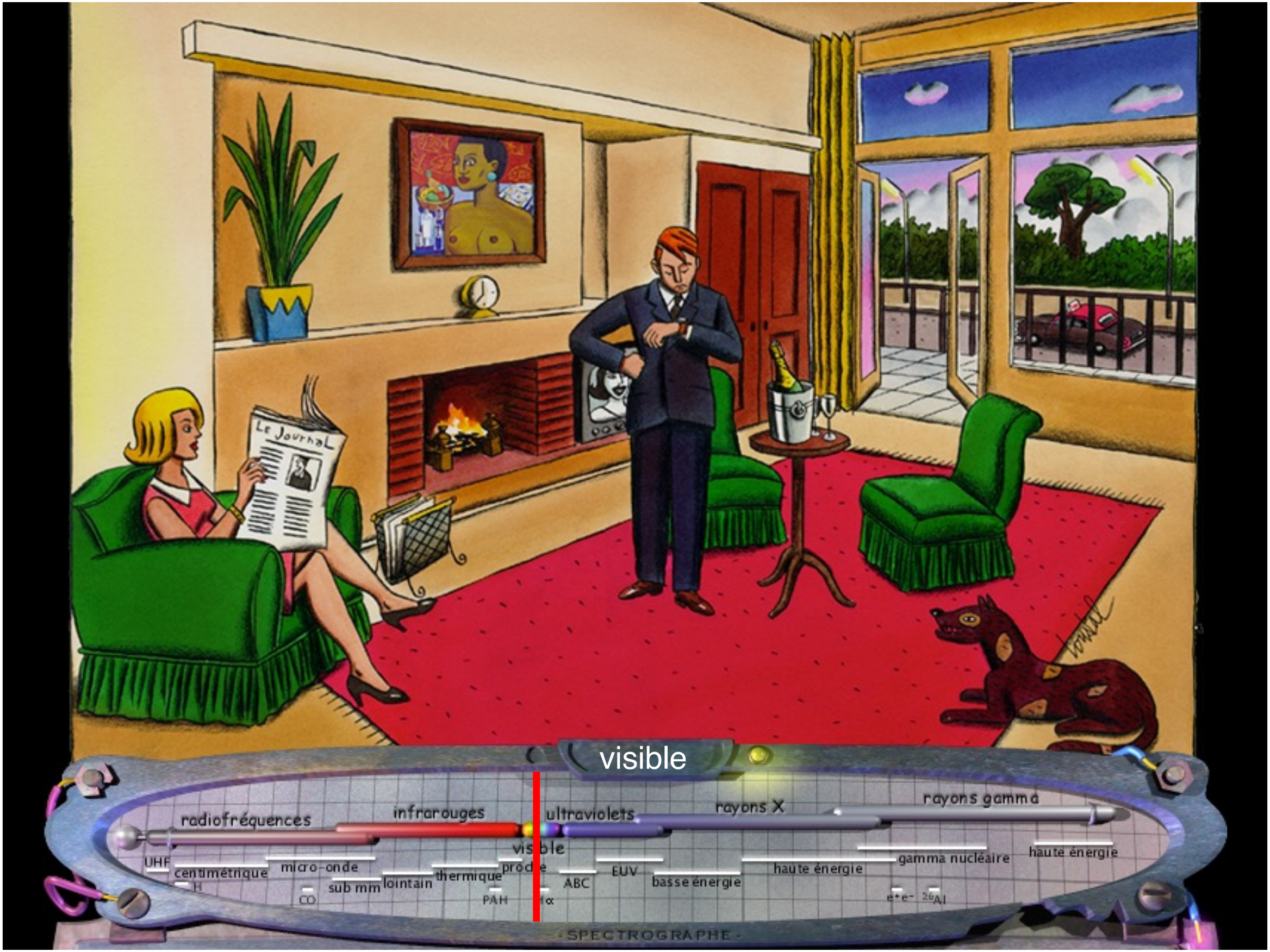
etc

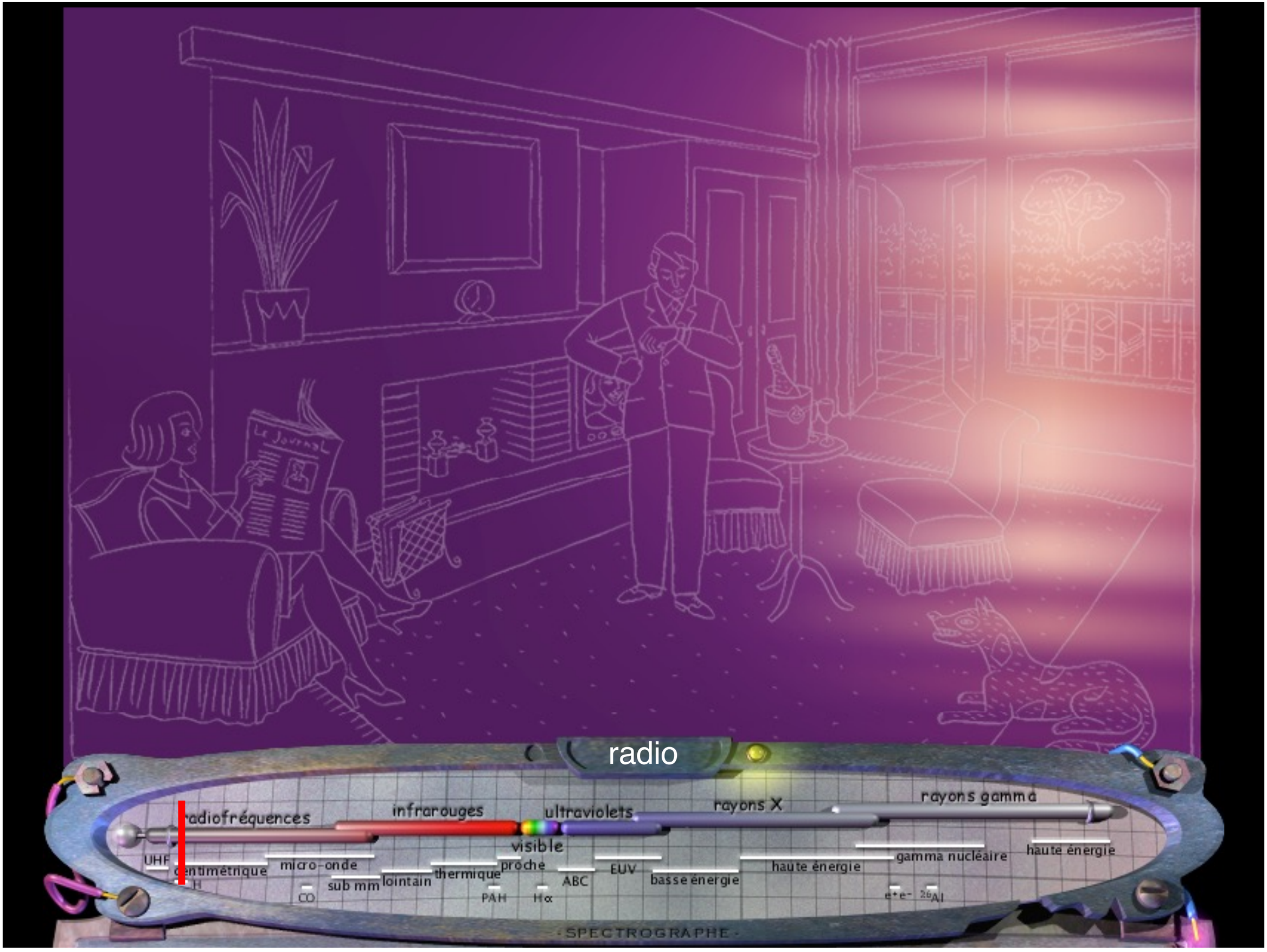


dashbord : radio-waves






Le Journal
visible
radiofréquences
infrarouges
ultraviolets
rayons X
rayons gamma
UHF
centimétrique
micro-onde
sub mm
lointain
thermique
proche
ABC
EUV
basse énergie
haute énergie
gamma nucléaire
haute énergie
H
CO
PAH
Hα
e+e-
26Al
SPECTROGRAPHE


radio
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ultraviolets
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rayons gamma
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gamma nucléaire
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PAH
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e+e-
26Al
SPECTROGRAPHE

electromagnetic wave

$$\nabla \cdot \mathbf{E} = 0$$

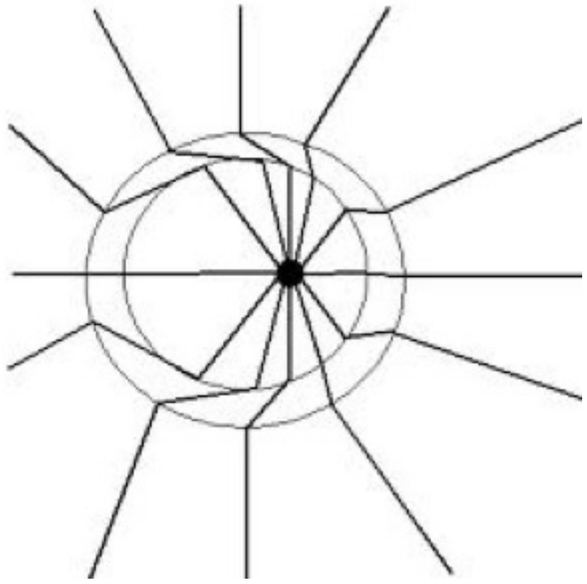
$$\nabla \times \mathbf{E} = -\mu_o \frac{\partial \mathbf{H}}{\partial t}$$

$$\nabla \cdot \mathbf{H} = 0$$

$$\nabla \times \mathbf{H} = \varepsilon_o \frac{\partial \mathbf{E}}{\partial t}$$

$$\frac{\partial^2 \mathbf{E}}{\partial t^2} - c_0^2 \cdot \nabla^2 \mathbf{E} = 0$$

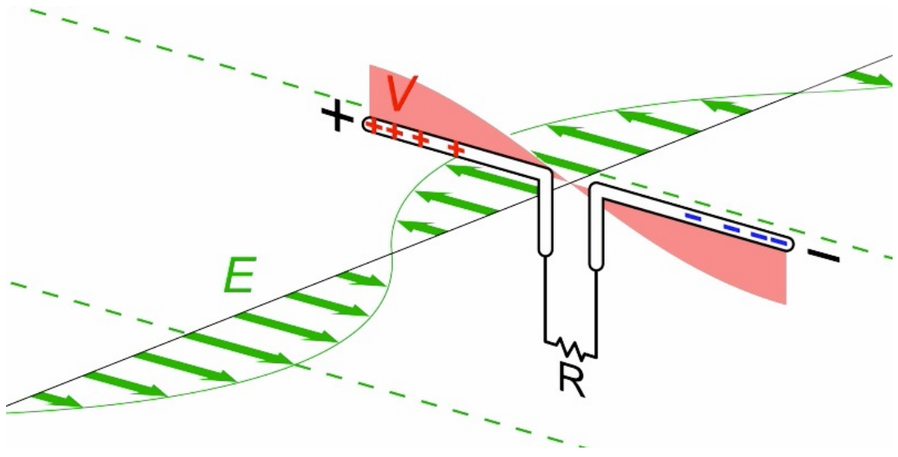
$$\frac{\partial^2 \mathbf{B}}{\partial t^2} - c_0^2 \cdot \nabla^2 \mathbf{B} = 0$$



$$c_0 = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 2.99792458 \times 10^8 \ \mathrm{m/s}$$

emission

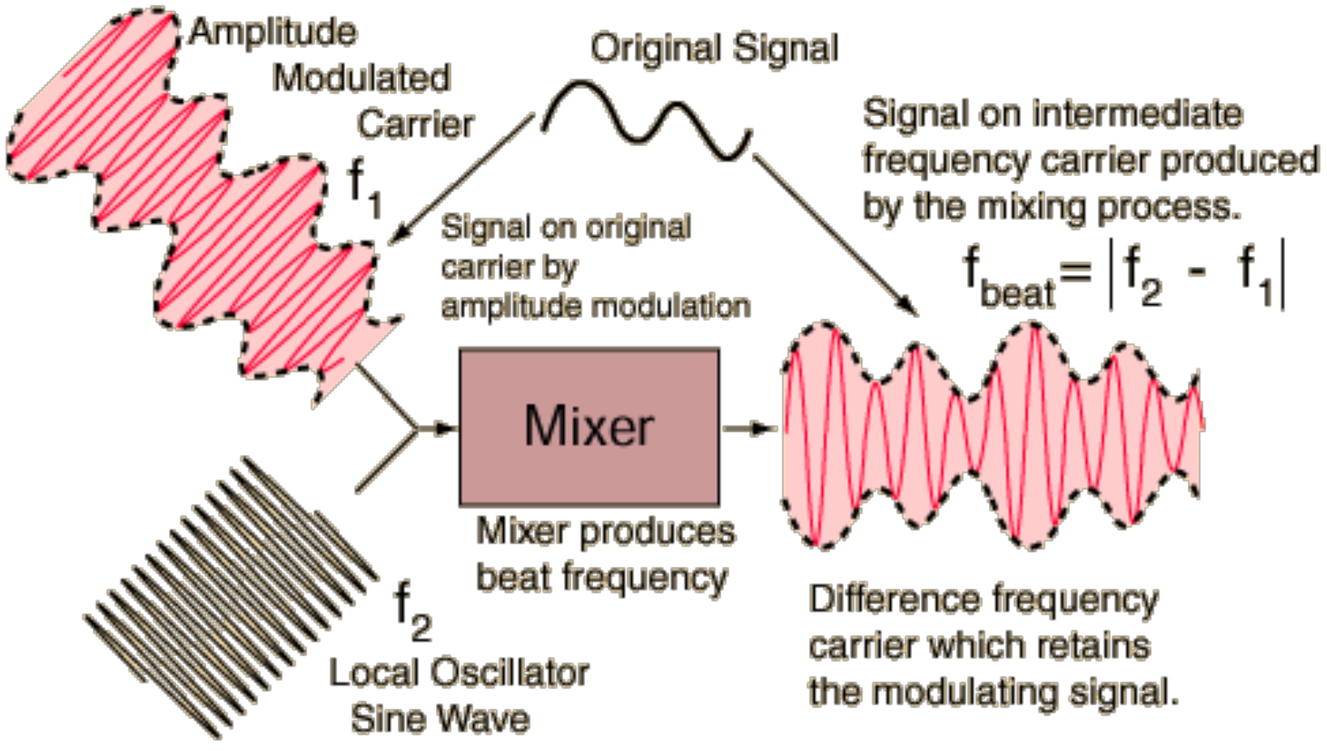
reception



La détection hétérodyne

Heterodyne detection relies on the use of a non-linear element - the mixer - which converts the signal to the observed radio frequency ν_s into an intermediate frequency (beating frequency) ν_i by having it interfere with the of fixed frequency ν_0 produced by a local oscillator.

This system, used in most telecommunications devices, has several advantages over solutions without a mixer : eg by changing the frequency ν_0 (local oscillator), a range of signal frequency ν_s can be observed withour changing the rest of the detecting chain – ie the intermediate frequency wich stays fixed ("aligned").



digitized sky survey

the Vela supernova remanent

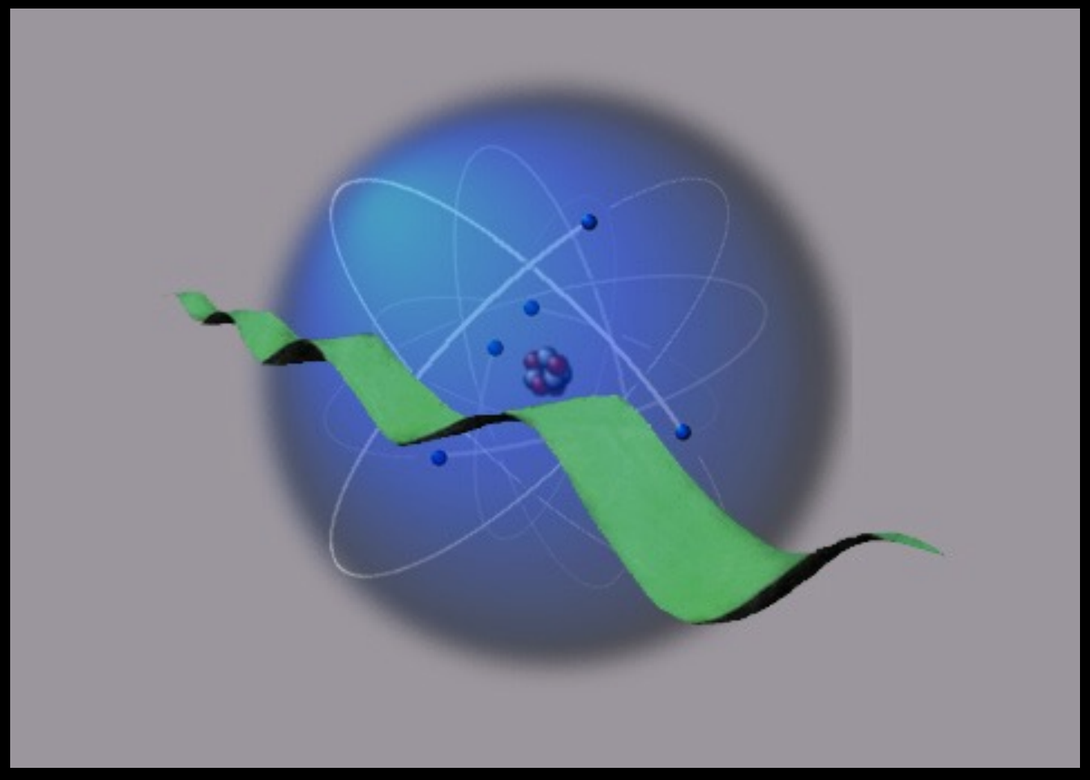
black holes

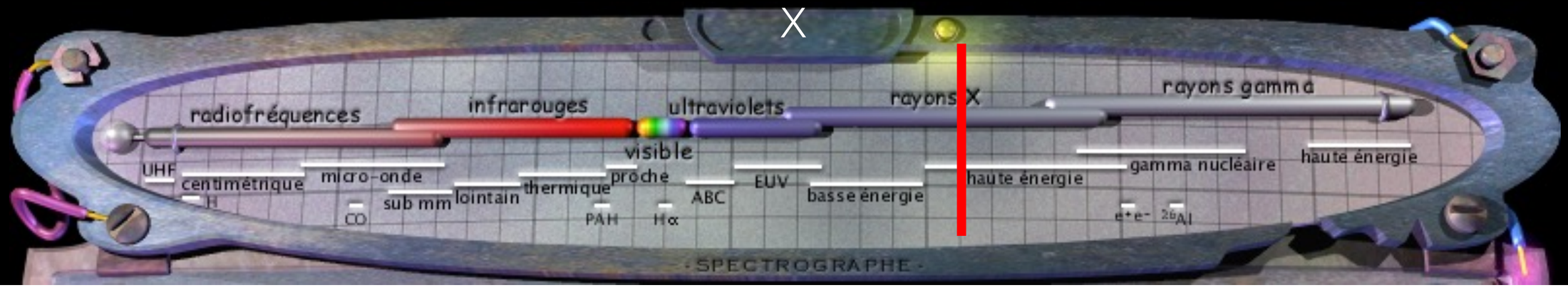
hot gas in galaxy clusters

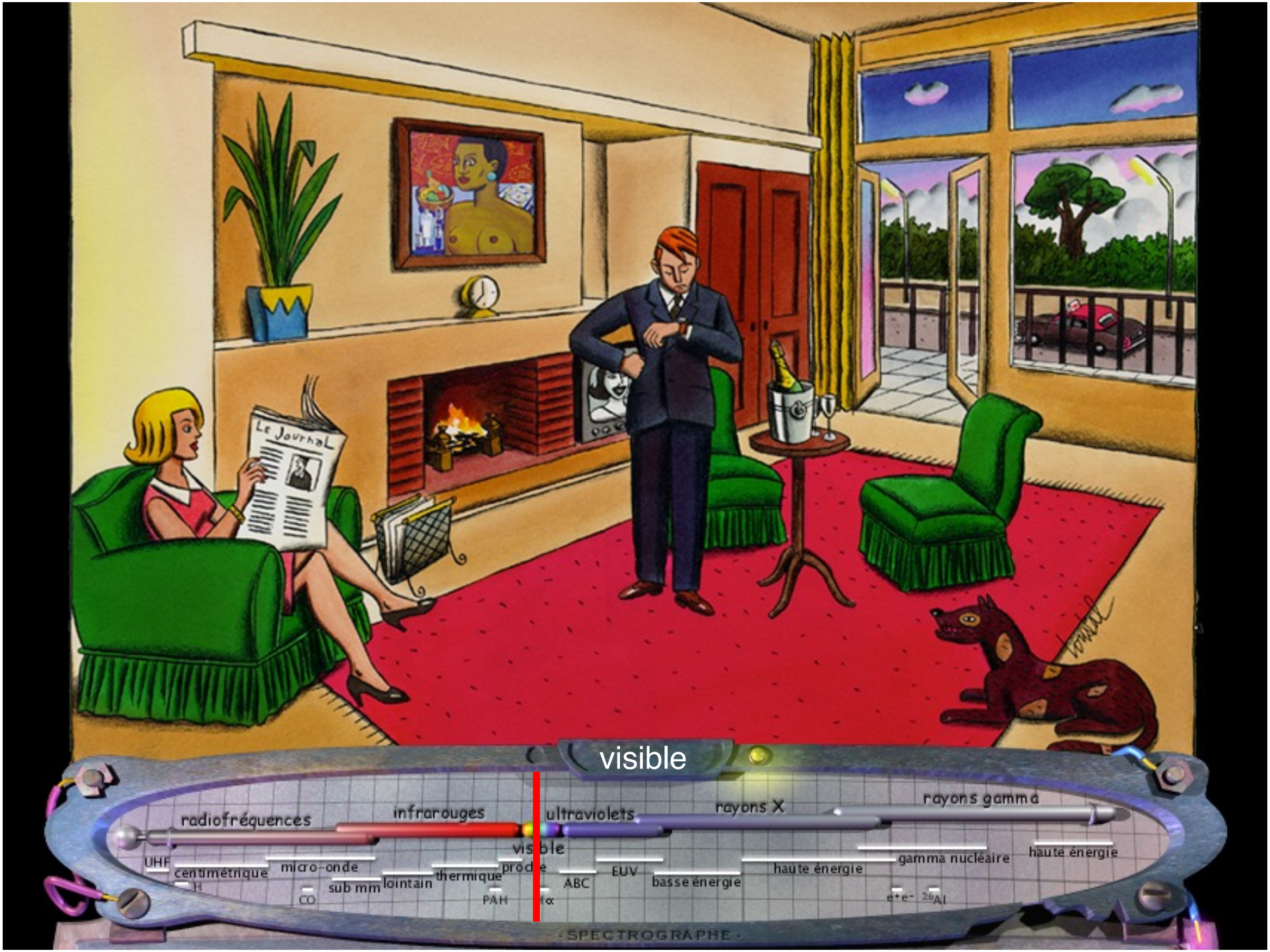
supernova remnants

disks and jets

dashbord : X-rays






Le Journal
visible
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rayons X
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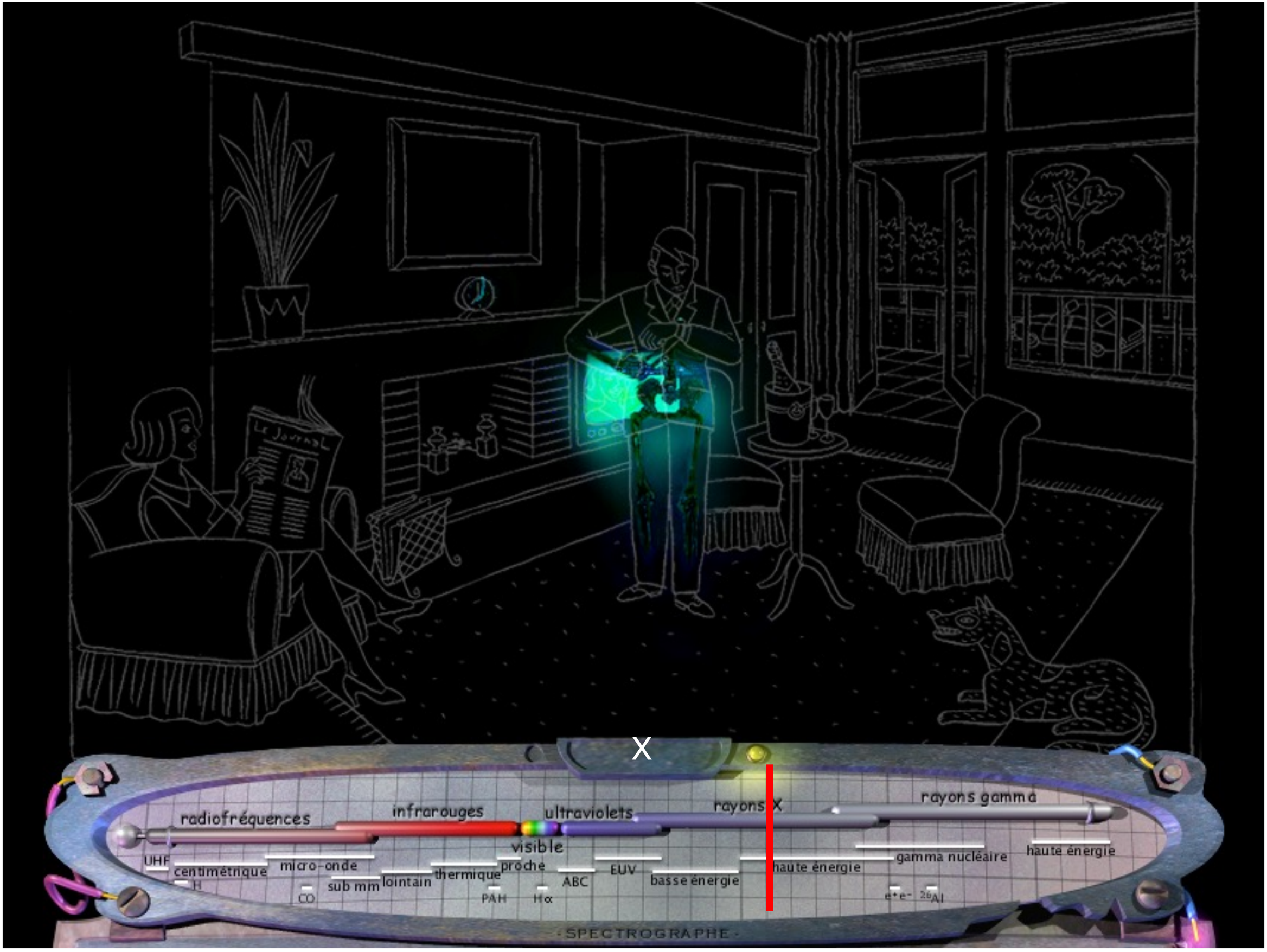
SPECTROGRAPHE


X
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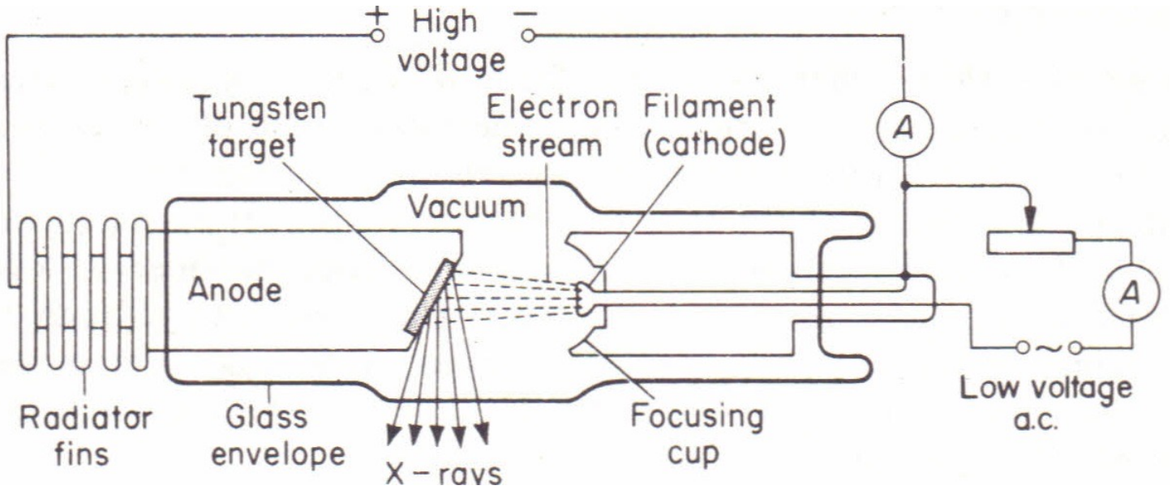
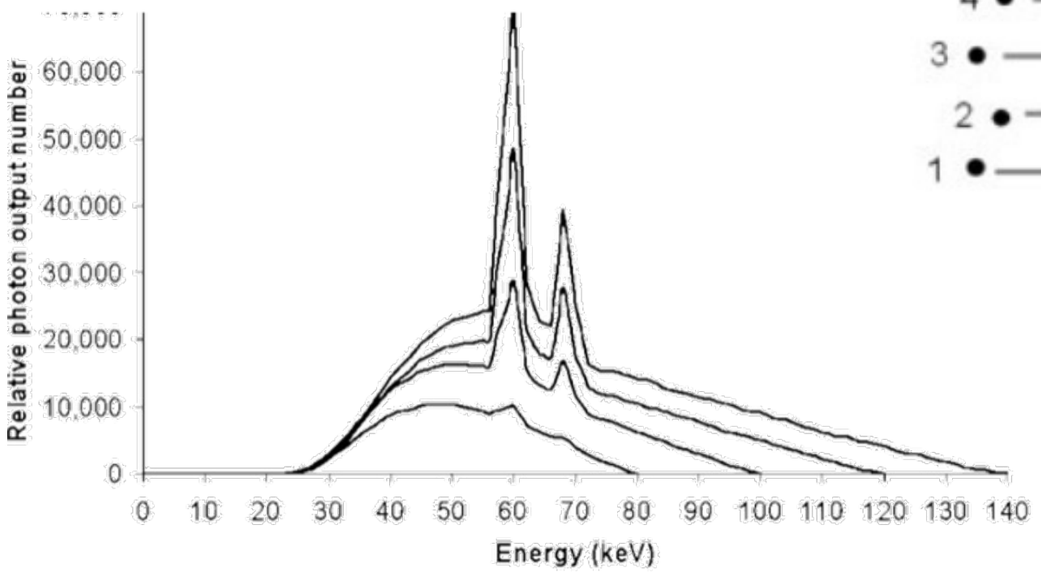
e+e-
26Al
SPECTROGRAPHE

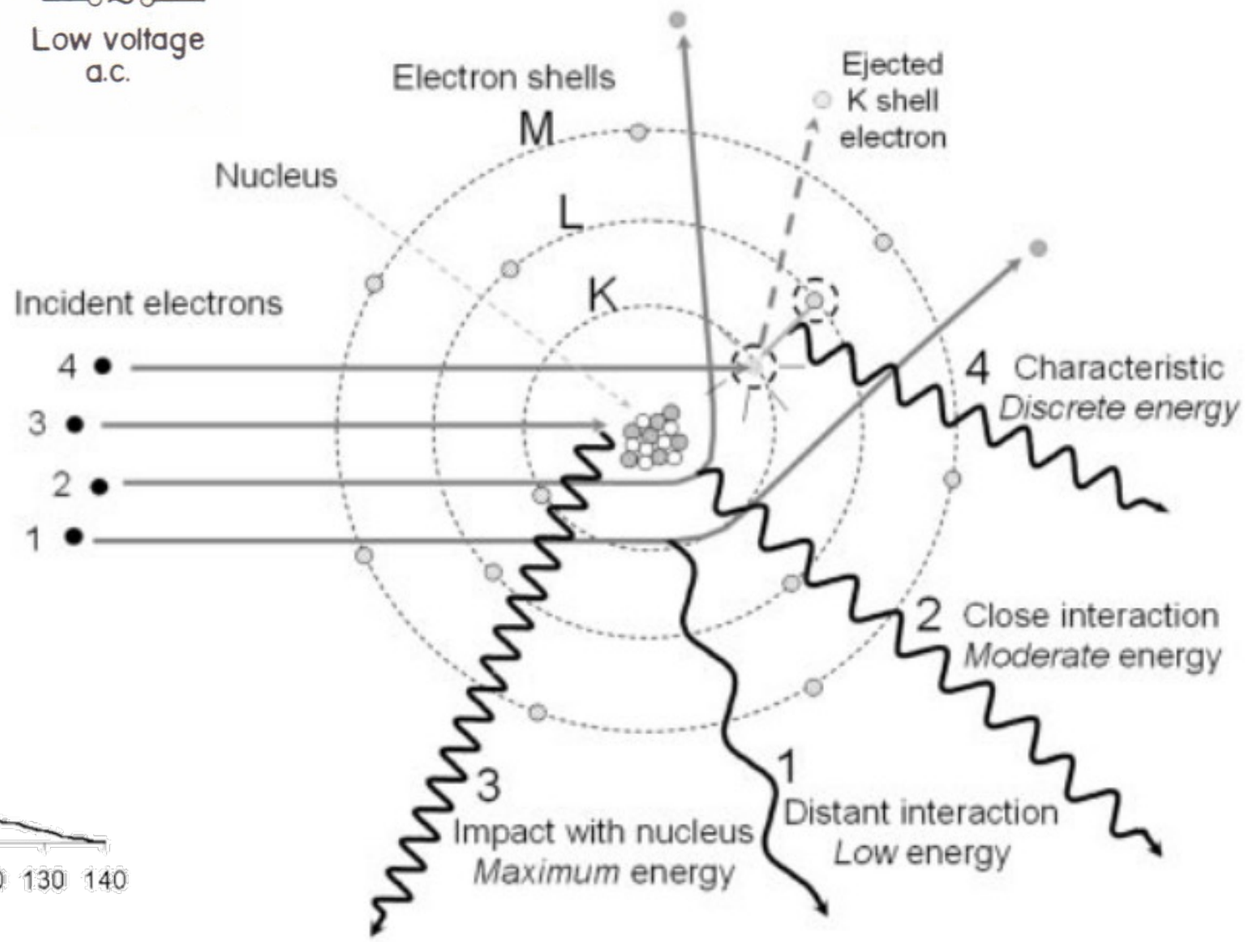
Bremsstrahlung



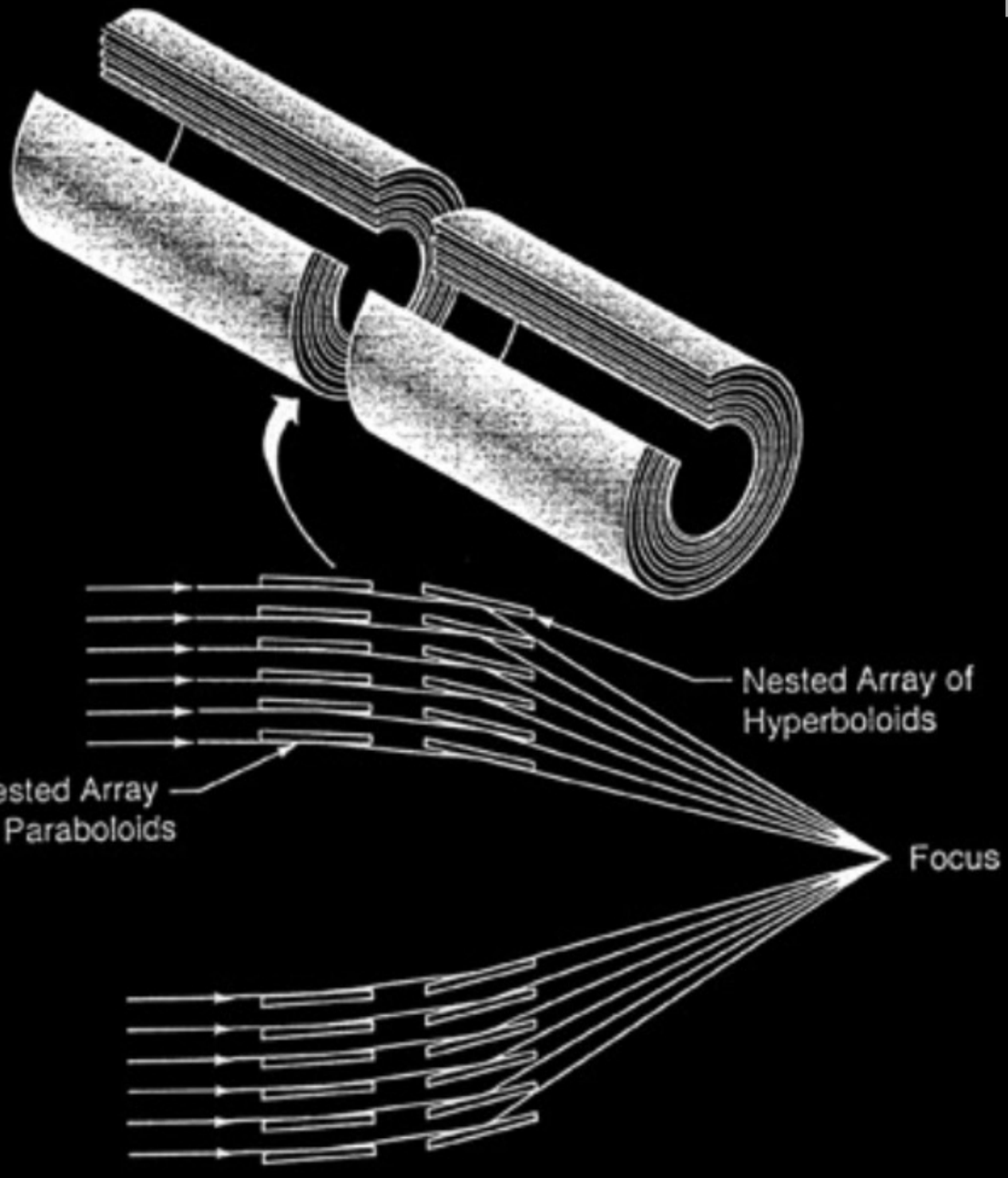
X-ray tube (Coolidge)

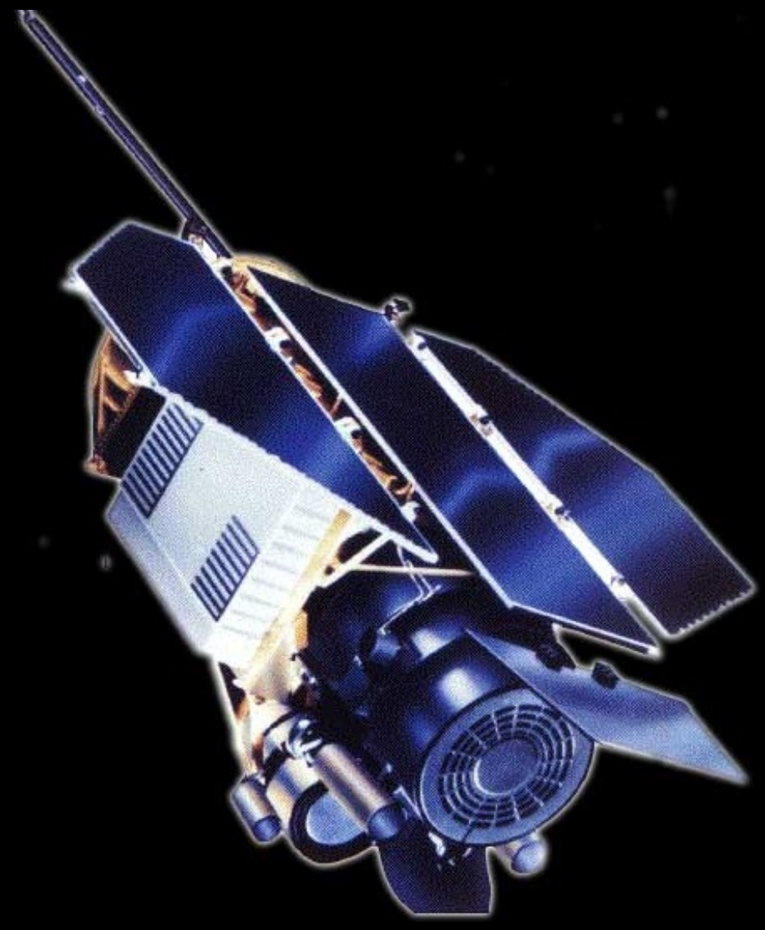


spectrum of an X-ray tube :
bremsstrahlung & characteristic X-rays



ROSAT

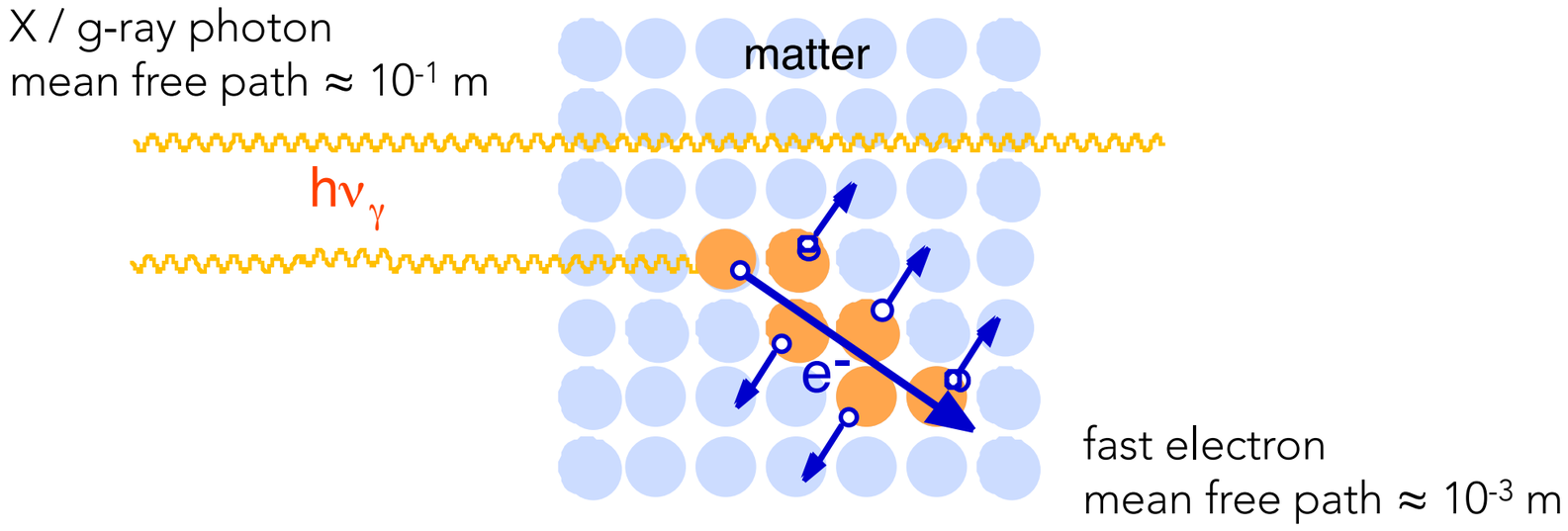




Wolter telescope (grazing incidence)

Detecting X- and gamma-rays

I conversion : In all cases of practical interest, Gamma-rays are detected by their production of secondary electrons. :



II ionization of detector medium by fast electrons -> creation of large number of charge carriers

III collection (reconversion) of detector signal, amplify current and converted by an ADC

the Vela
supernova remanent

digitized sky survey

Abell 3528

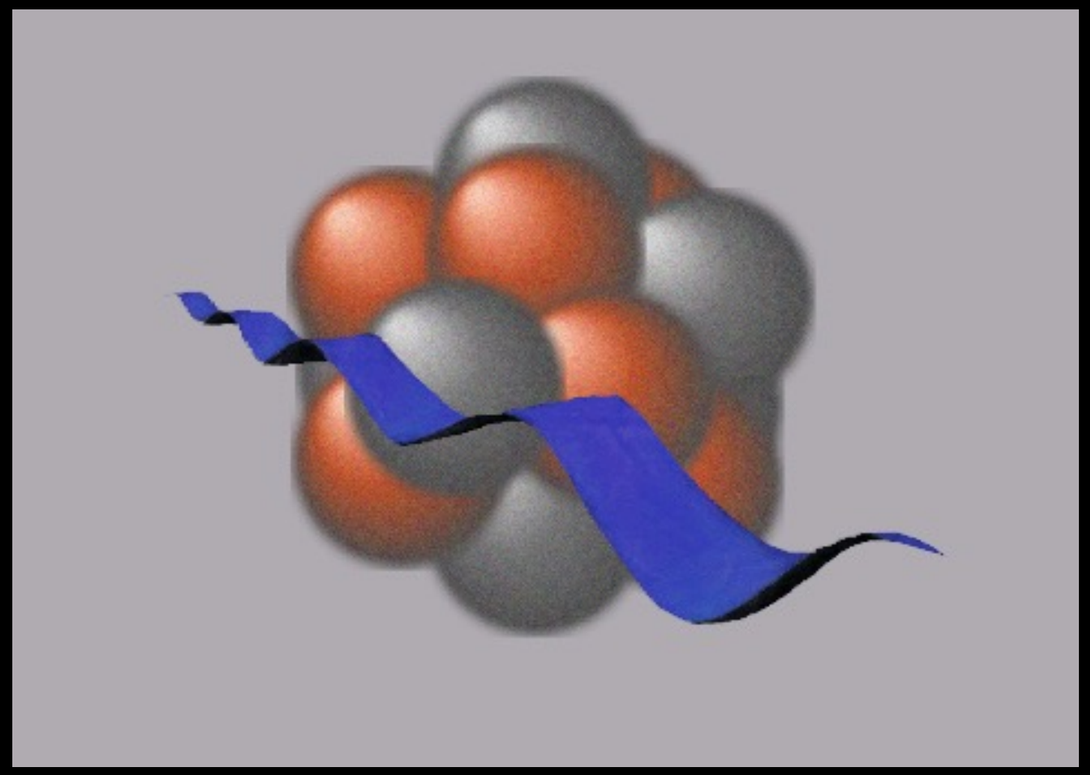
X rays : false colors

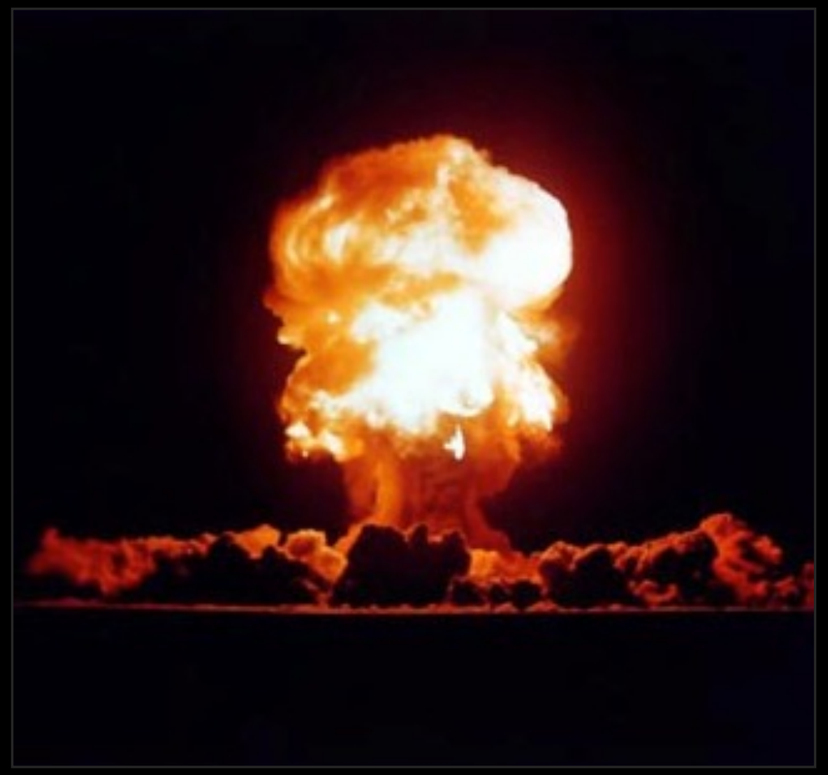
"visible" galaxies in black

(Schindler 2002)

the "potentisl wells"
of dark matter
are filled with thin hot gas

dashbord: gamma-rays





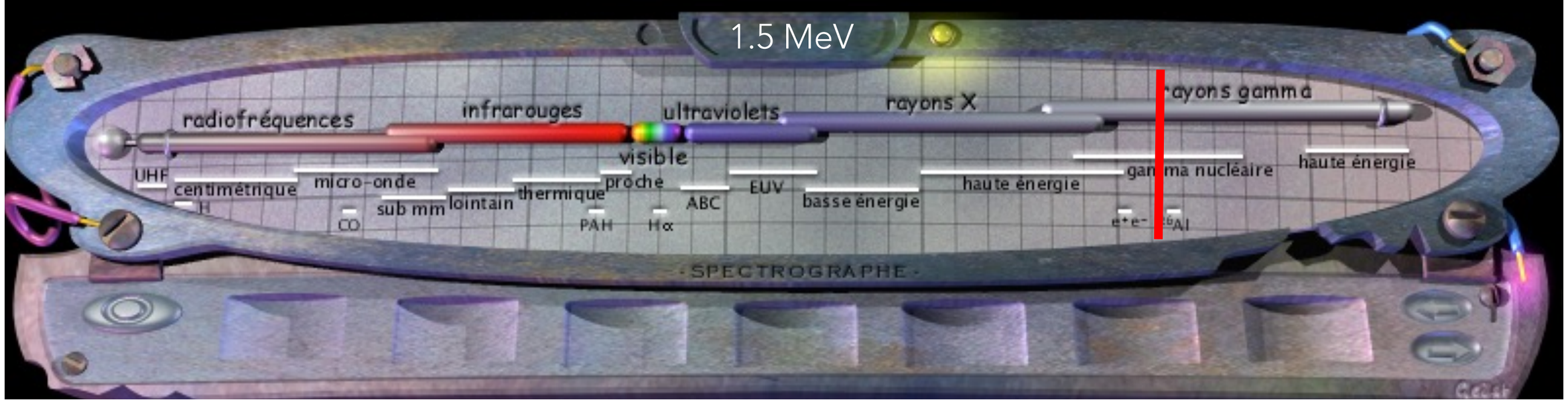
radioactivity

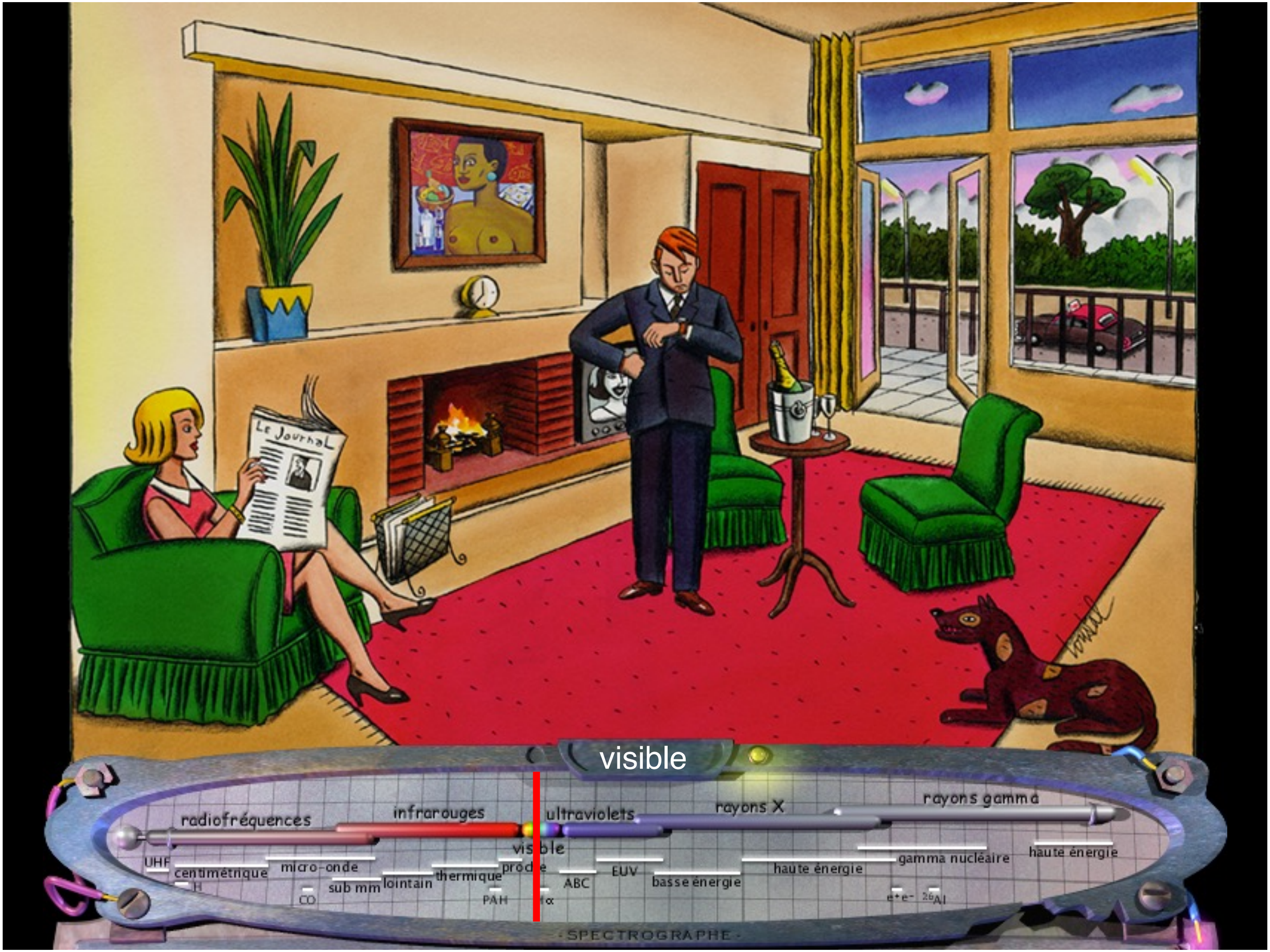
gamma-ray bursts

e^-e^+ annihilation

binaries, magnetars …

INTEGRAL




Le Journal
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SPECTROGRAPHE

gamma

radiofréquences
infrarouges
ultraviolets
rayons X
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gamma nucléaire
haute énergie
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Hα
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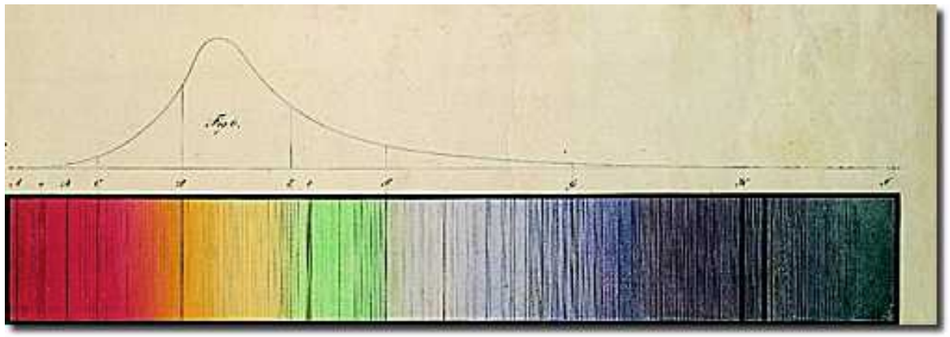
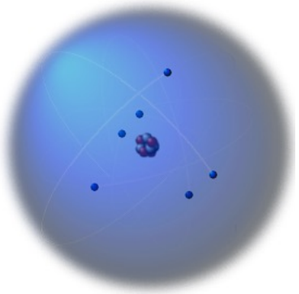
^{26}Al
SPECTROGRAPHE

atoms and nuclei : energy levels and et resonances

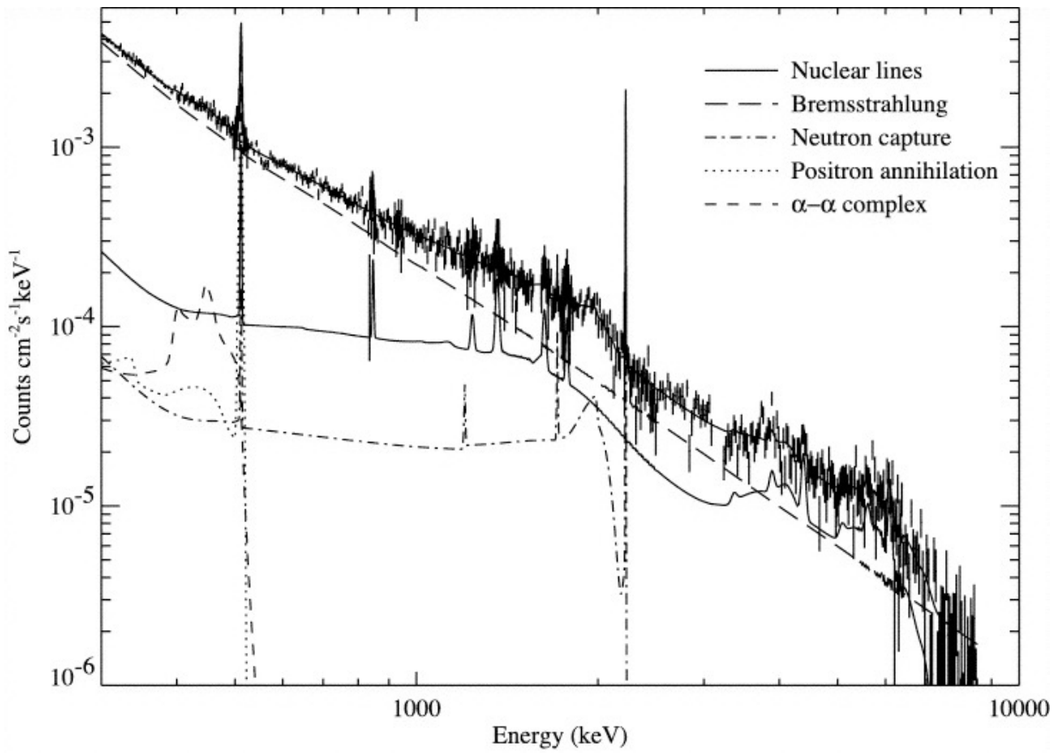


1814 Josef Fraunhofer

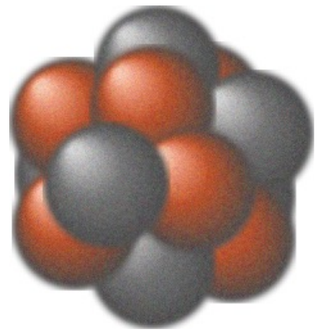


spectroscopy :
tool for the study of chemical elements
in stars

-> atomic physics



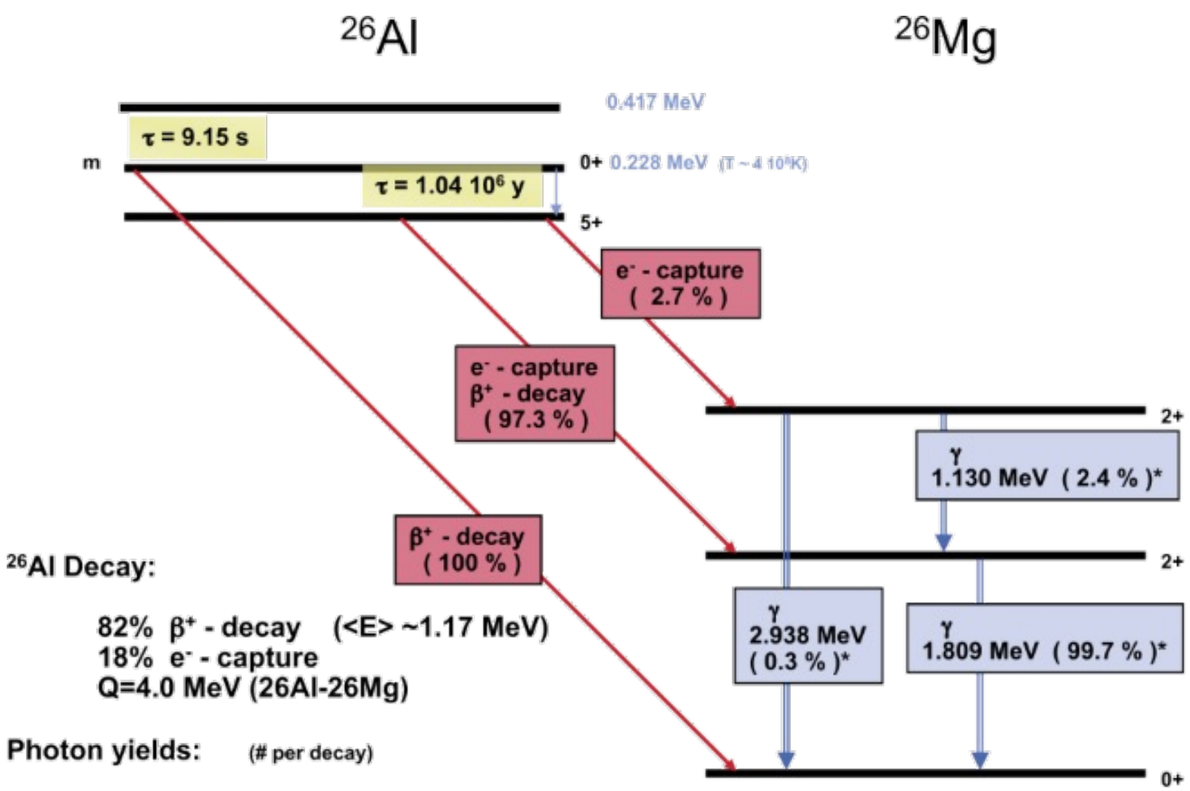
2003 RHESSI (R. Lin et al. 2003)

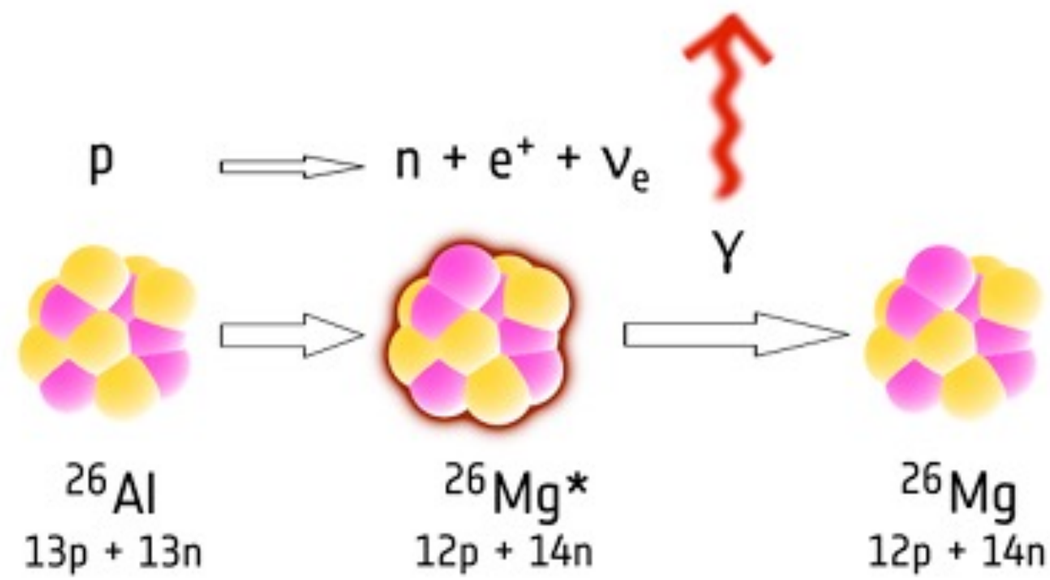


solar flare of 23.7 02
deexcitation lines
of Fe, Mg, Si, Ne, C, and O

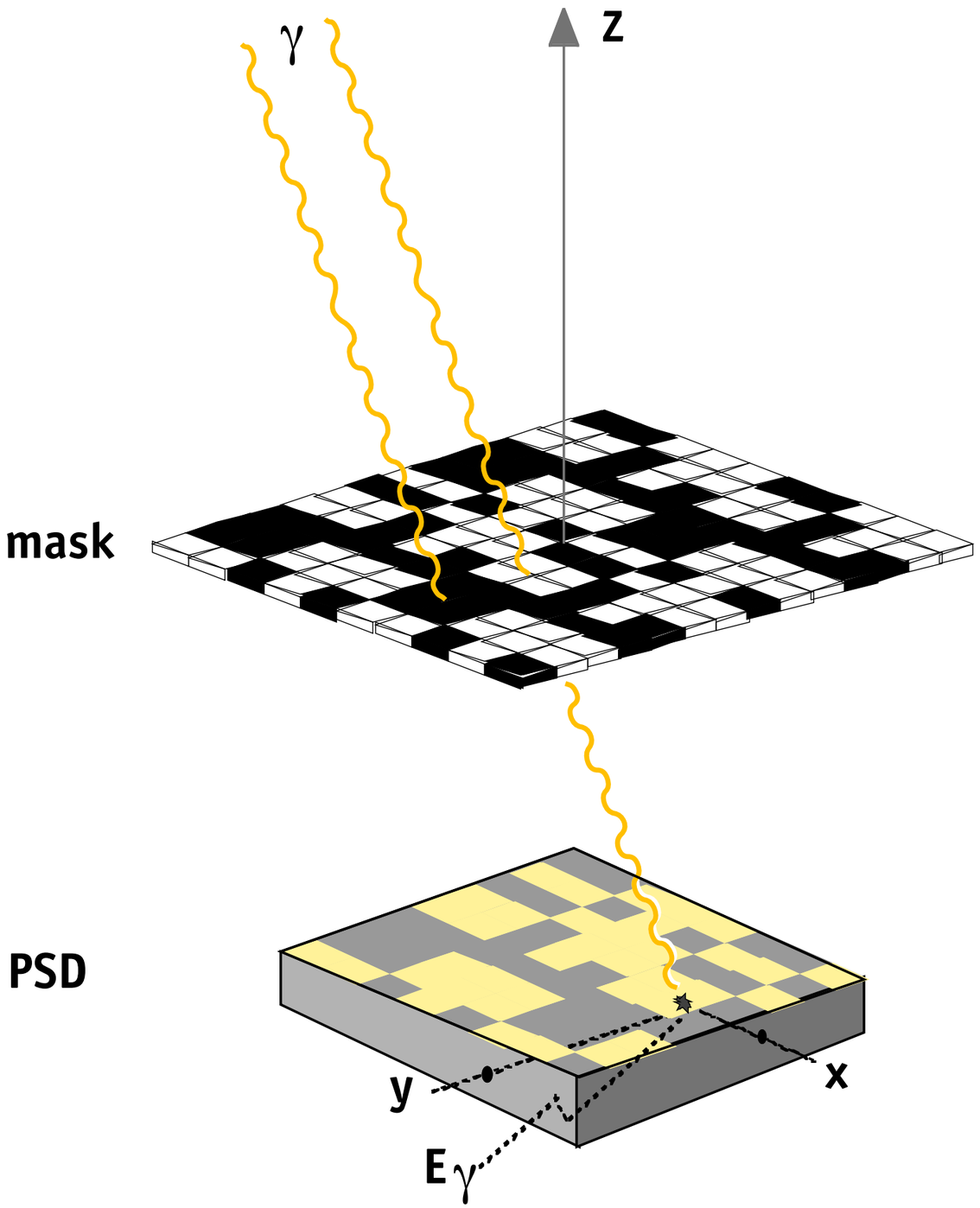
-> nuclear physics !

atoms and nuclei : energy levels and et resonances

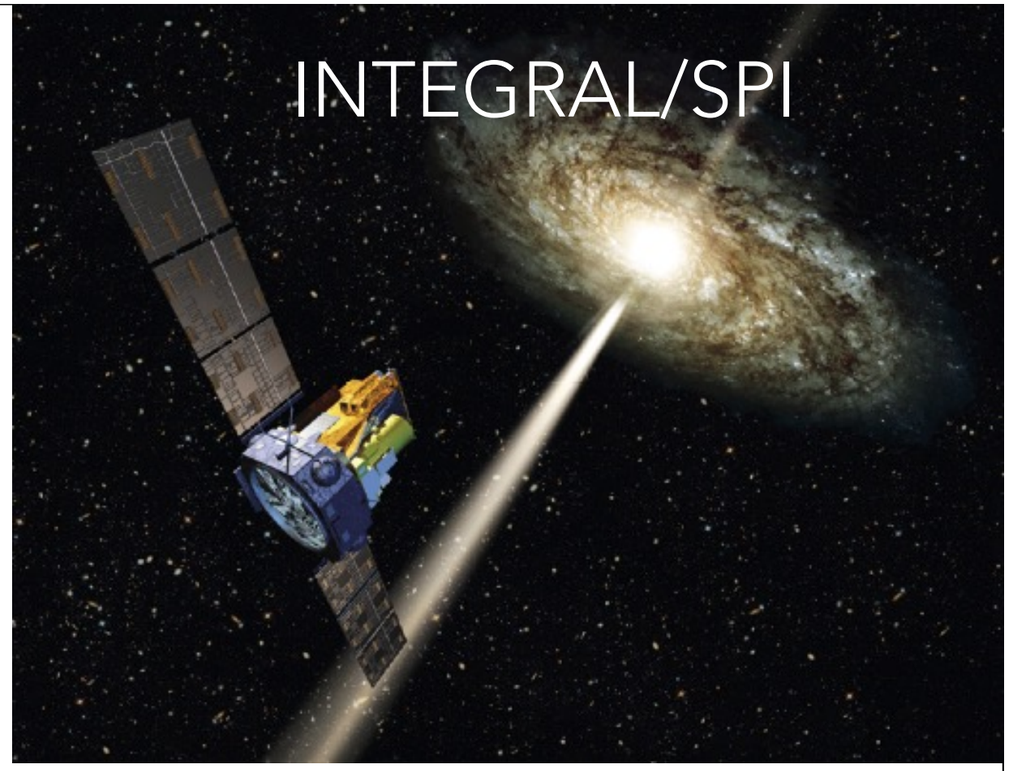




soft γ-rays : coded mask imaging

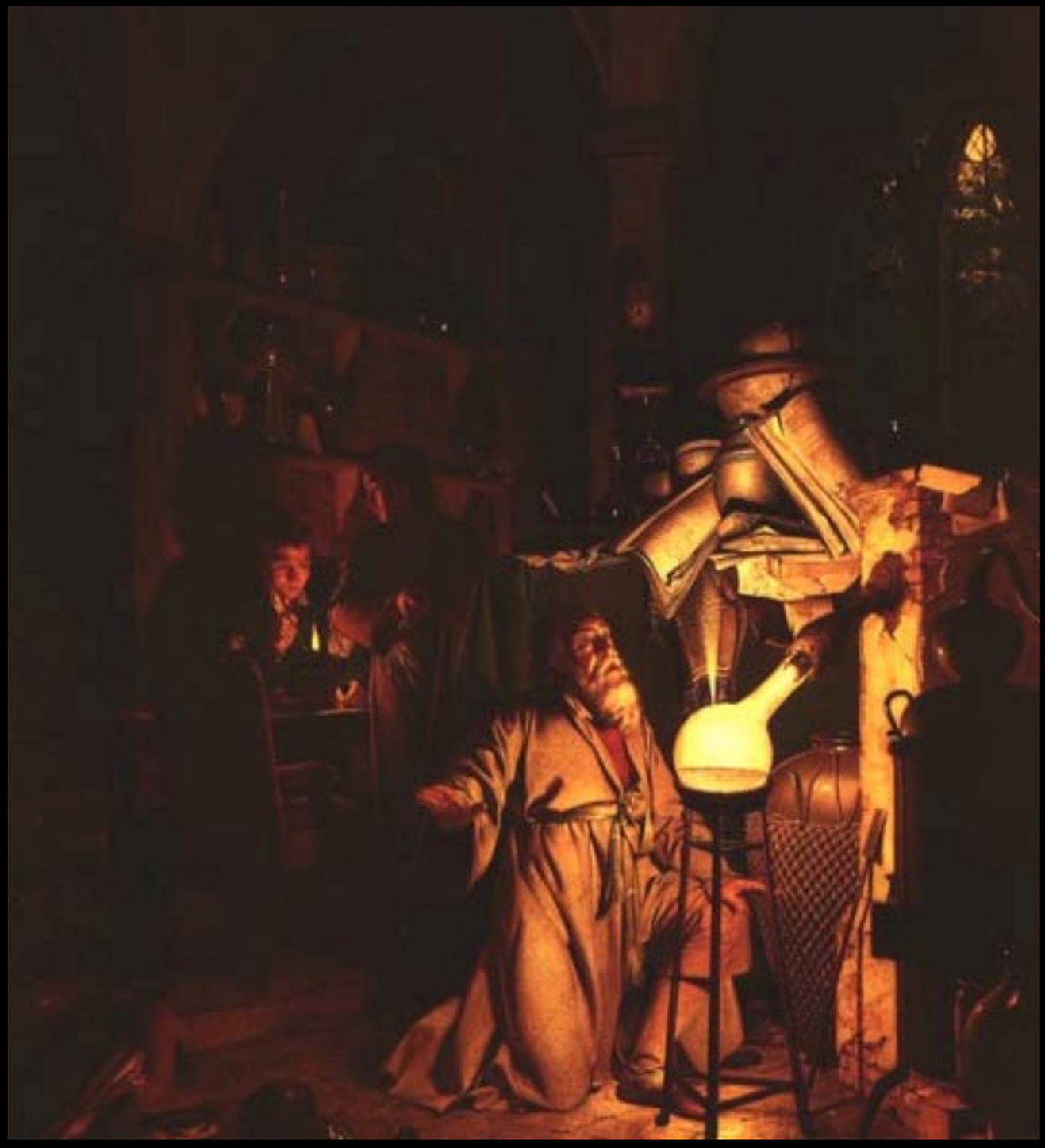


(PSD Position Sensitive Detector)



SPI mask : 3 cm thick tungsten

stellare evolution - the lifecycle of matter



the chemical elements

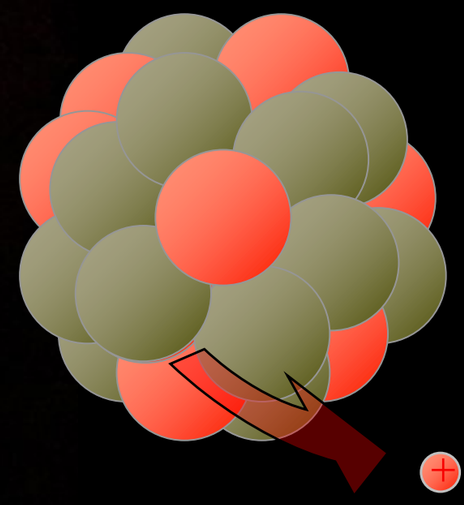
the Vela
supernova remanent

digitized sky survey

Cassiopeia A
Supernova remnant

Cosmic Explosions

origin of e^+
radioactive decays

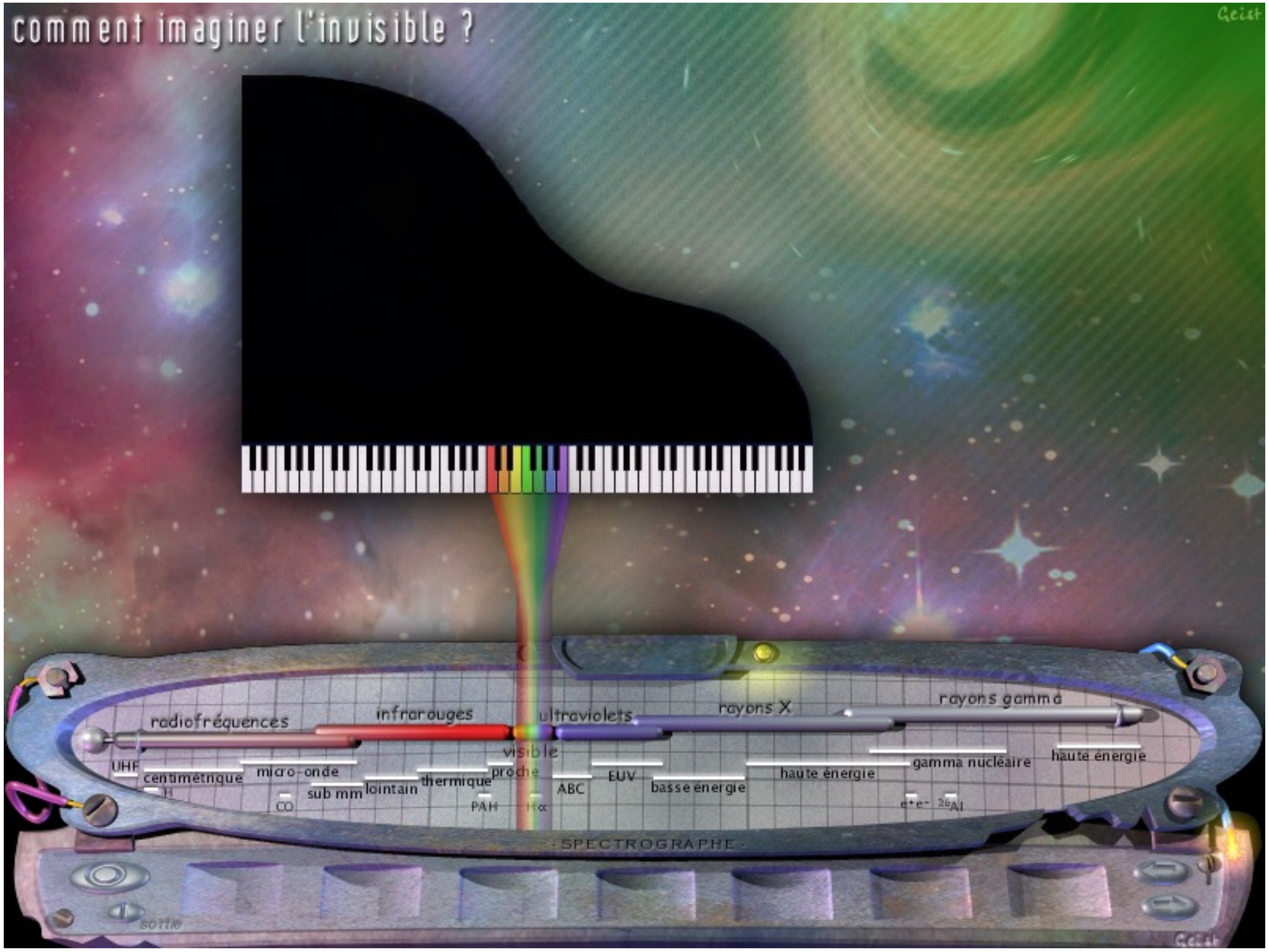


X-ray binary (artist's view)

Cosmic Accelerators

production of e^-e^+ pairs

comment imaginer l'invisible ?



5 % of what there is

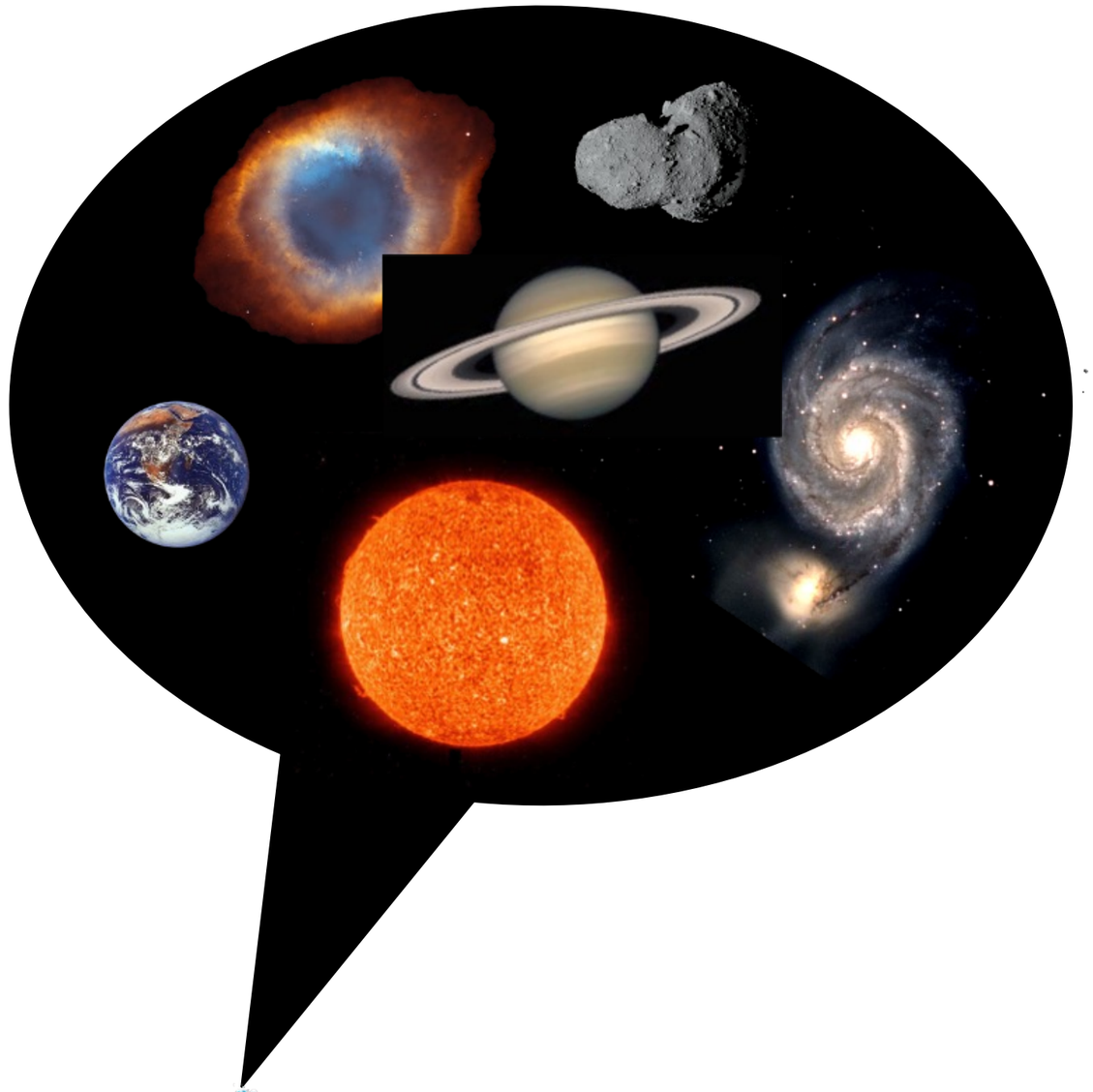
the tip of the iceberg :

stars and planets

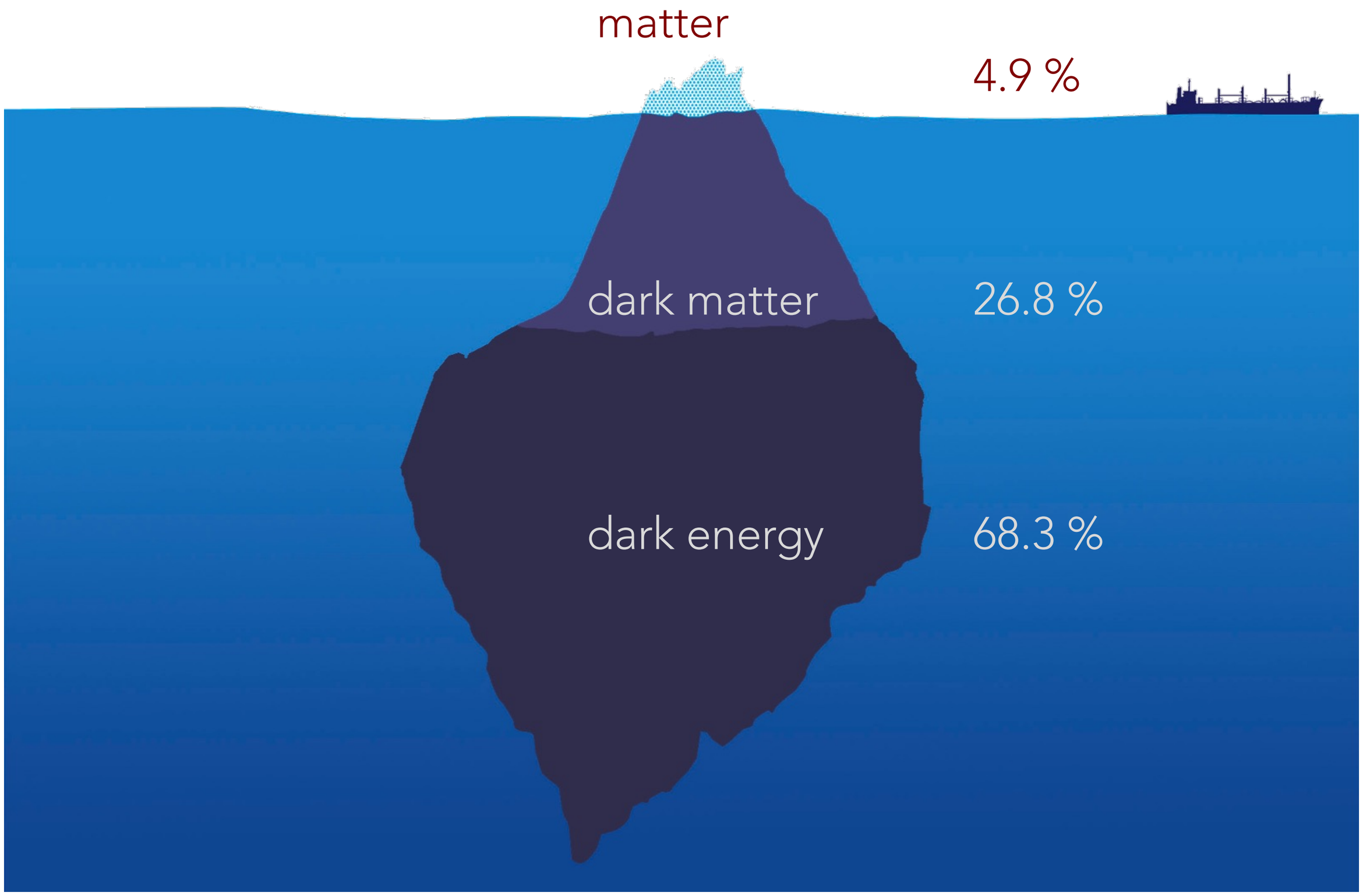
hot gas

light

neutrinos ....



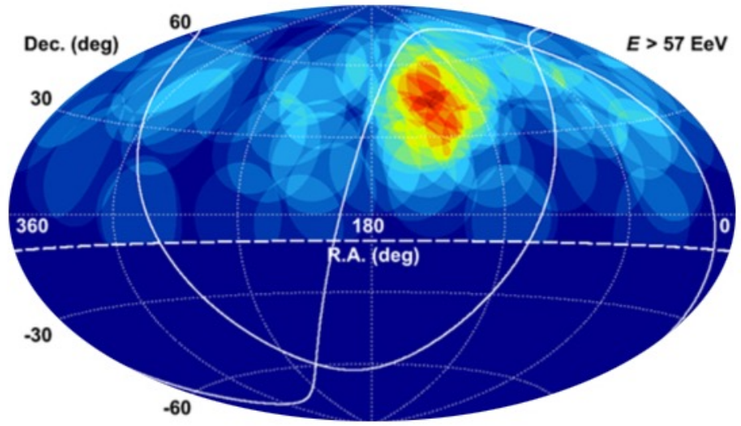
the tip of the iceberg :



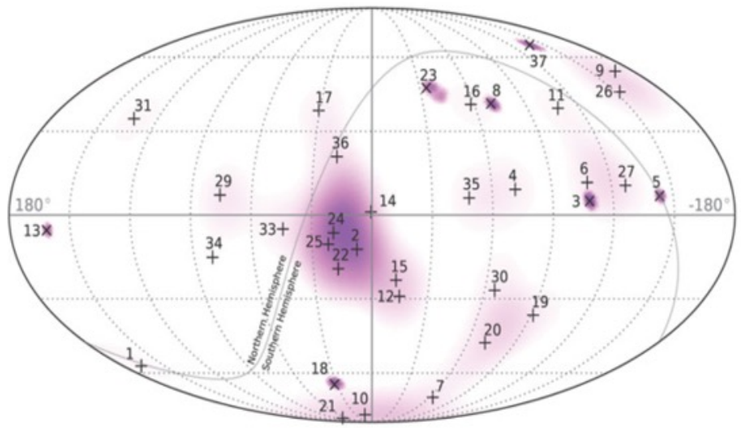
Multi-Messenger Astronomy

messengers	message, principal sources …
photons	quasi-everything we (think we) know
meteorites	history of the solar system
cosmic rays	their own origin, accelerators
neutrinos	very high energy processes
gravitational waves	"ballets" and "spirals" of death
?	dark matter
?	dark energy

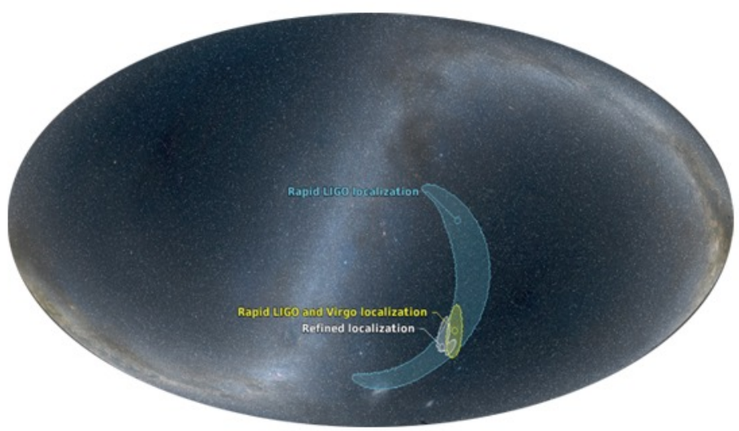
Three new Astronomies !



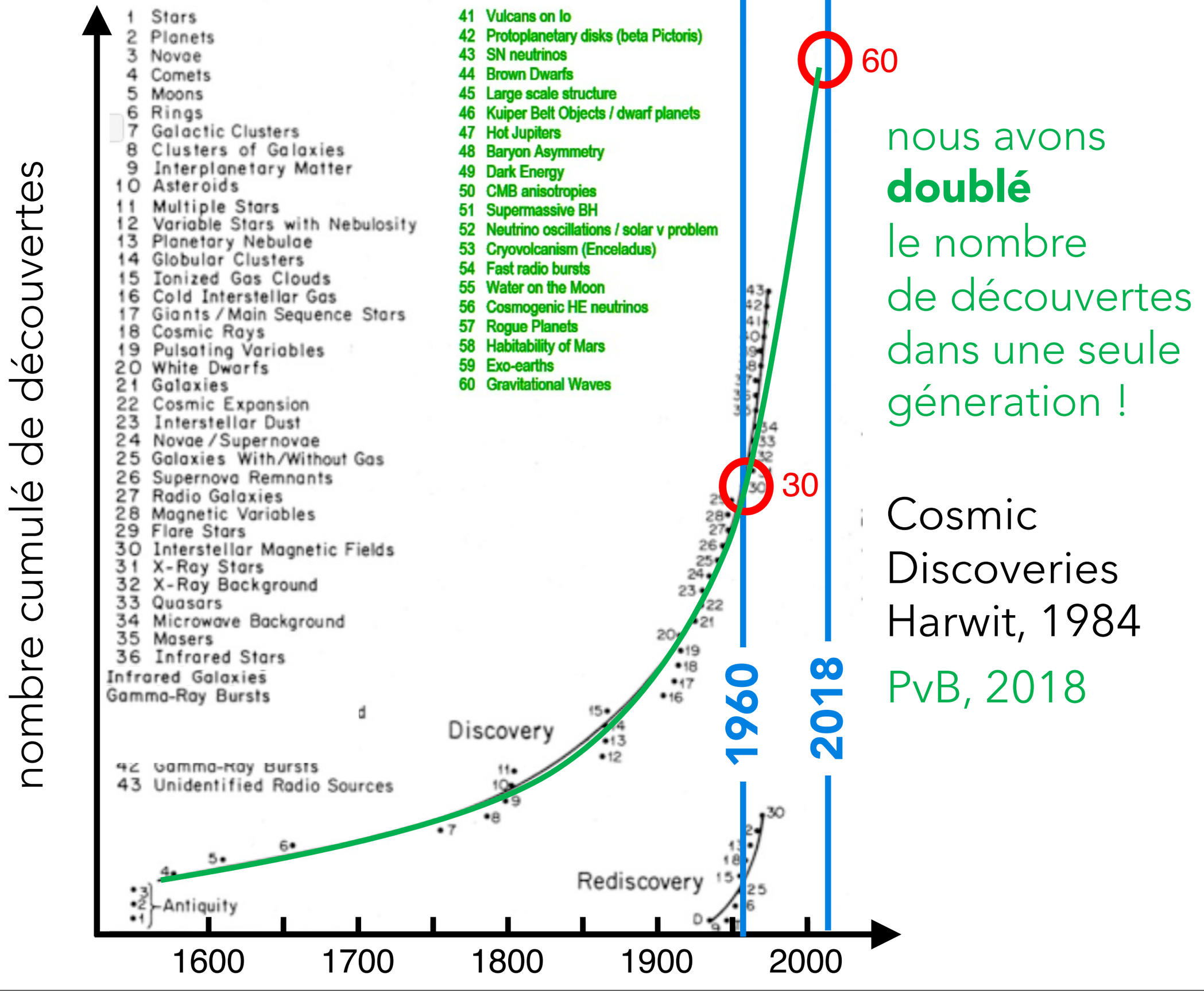
Rayons Cosmiques de Ultra-Haute Energie
Arrival directions of 72 cosmic-ray events with energy E > 57 EeV observed as measured by the Telescope Array Experiment (equatorial coordinates), Abbasi et al. 2014



Neutrinos
Arrival directions of 37 neutrinos observed in 3-years by the IceCube detector (galactic coordinates),
Aartsen et al. 2014



Ondes Gravitationnelles
Localization map for GW170818 detected by the *LIGO-Virgo collaboration*, (equatorial coordinates), Abbott et al. 2017


nombre cumulé de découvertes
1 Stars
2 Planets
3 Novae
4 Comets
5 Moons
6 Rings
7 Galactic Clusters
8 Clusters of Galaxies
9 Interplanetary Matter
10 Asteroids
11 Multiple Stars
12 Variable Stars with Nebulosity
13 Planetary Nebulae
14 Globular Clusters
15 Ionized Gas Clouds
16 Cold Interstellar Gas
17 Giants / Main Sequence Stars
18 Cosmic Rays
19 Pulsating Variables
20 White Dwarfs
21 Galaxies
22 Cosmic Expansion
23 Interstellar Dust
24 Novae / Supernovae
25 Galaxies With/Without Gas
26 Supernova Remnants
27 Radio Galaxies
28 Magnetic Variables
29 Flare Stars
30 Interstellar Magnetic Fields
31 X-Ray Stars
32 X-Ray Background
33 Quasars
34 Microwave Background
35 Masers
36 Infrared Stars
Infrared Galaxies
Gamma-Ray Bursts
42 Gamma-Ray Bursts
43 Unidentified Radio Sources
41 Vulcans on Io
42 Protoplanetary disks (beta Pictoris)
43 SN neutrinos
44 Brown Dwarfs
45 Large scale structure
46 Kuiper Belt Objects / dwarf planets
47 Hot Jupiters
48 Baryon Asymmetry
49 Dark Energy
50 CMB anisotropies
51 Supermassive BH
52 Neutrino oscillations / solar v problem
53 Cryovolcanism (Enceladus)
54 Fast radio bursts
55 Water on the Moon
56 Cosmogenic HE neutrinos
57 Rogue Planets
58 Habitability of Mars
59 Exo-earths
60 Gravitational Waves
Discovery
Rediscovery
Antiquity
1600
1700
1800
1900
2000
1960
2018
30
60
nous avons
doublé
le nombre
de découvertes
dans une seule
génération !
Cosmic
Discoveries
Harwit, 1984
PvB, 2018

the state of our knowledge