Systèmes d'observation pour le domaine visible

- le rôle de l'observation en astrophysique

- telescopes
  - systèmes optiques (réfracteurs, réflecteurs)
  - montures
  - optique active
  - optique adaptative

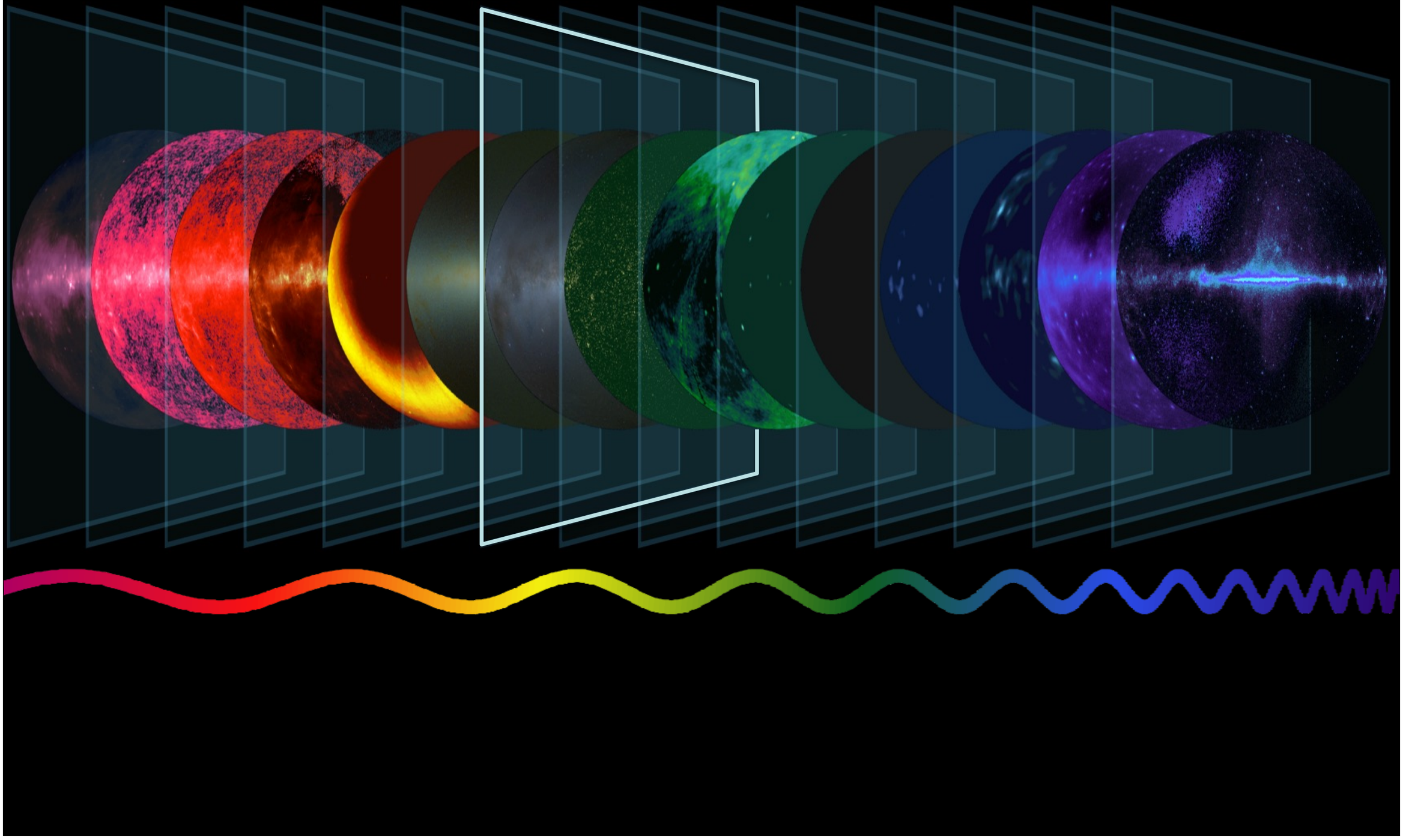
- instrumentation focale
  - les détecteurs pour le domaine visible
    - photométrie
    - imagerie
    - spectroscopie

- caractéristiques du système d'observation

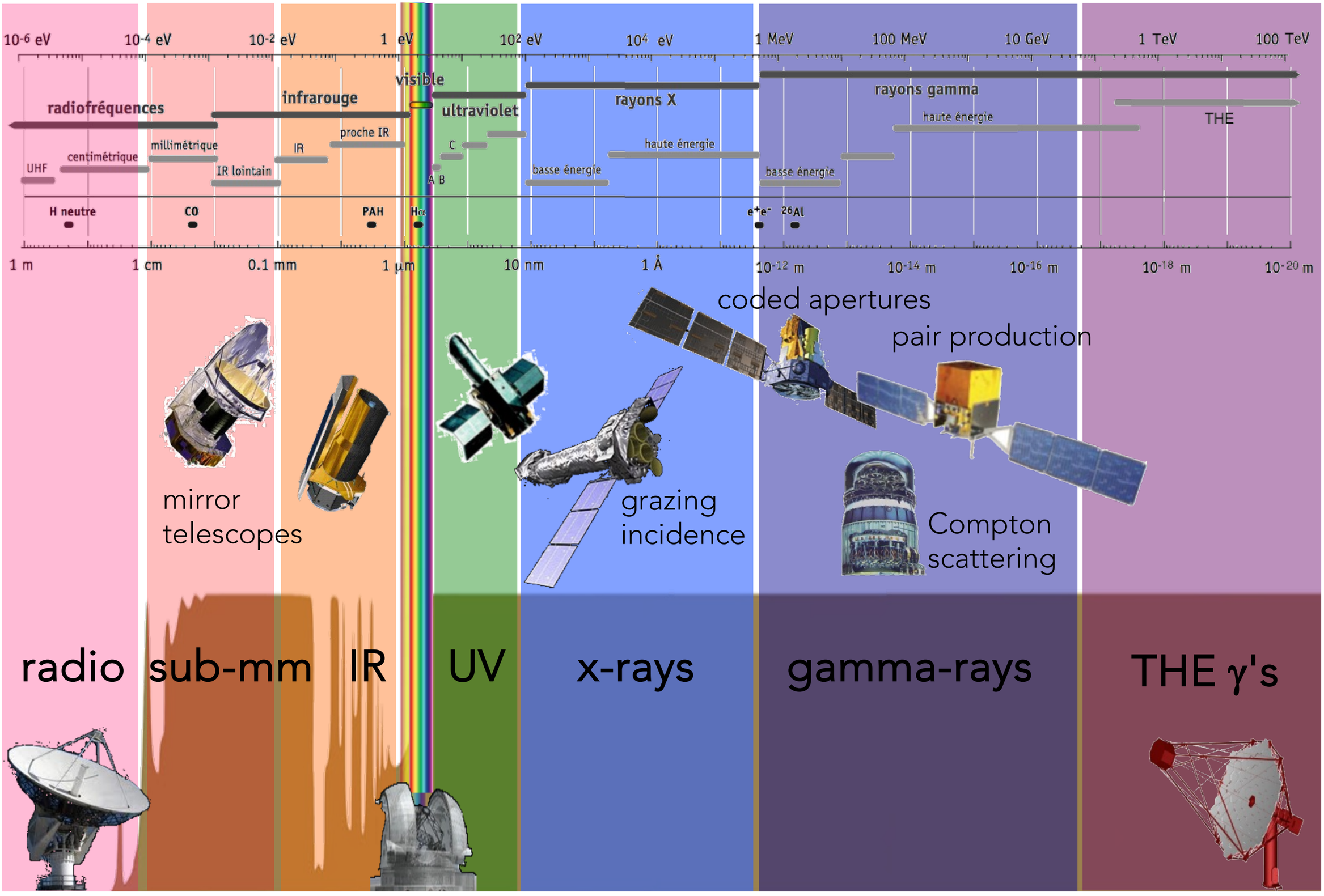
➡ l'astronomie multi-longueur d'onde (bonus slides 2024)

bonus slides 4/2024 : multi-wavelenght astronomy

radio sub-mm IR visible X gamma



instruments for multi-wavelength astronomy



Telescope / Detector systems

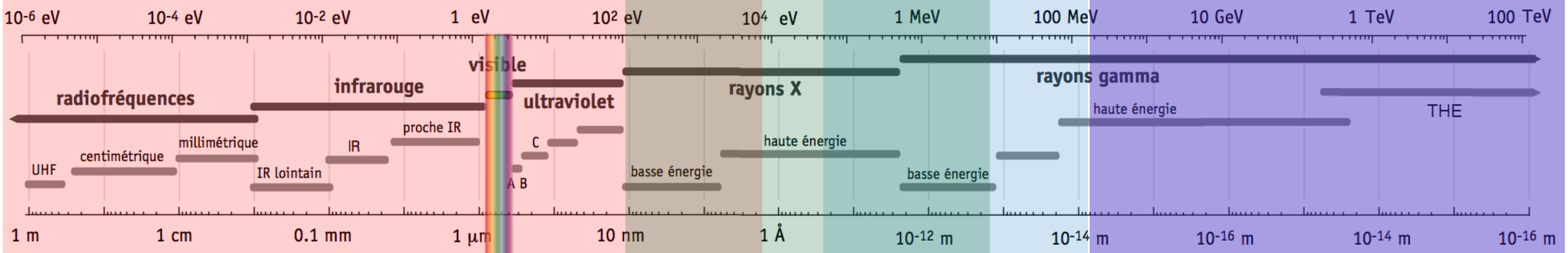
optics / telescope

antenna
mirror
lens
Compton D1 detector
hodoscope
pinhole
coded mask
no selection / 4π

detector / instrument

retina
coherent / heterodyne detector
bolometer
photovoltaic detector
film
photon counter
gaz-detectors (Geiger, proportional counters)
HP semiconductor detectors (x/gamma-ray domain)
Transition edge sensors

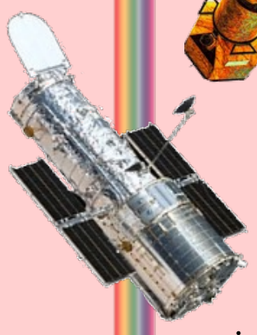
telescopes / optics - overview



geometric optics

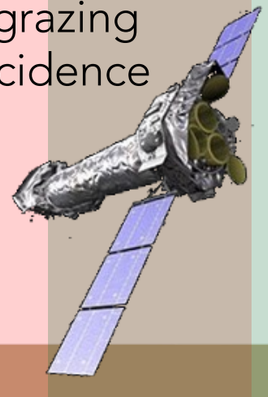
wave optics - total external reflection

quantum optics

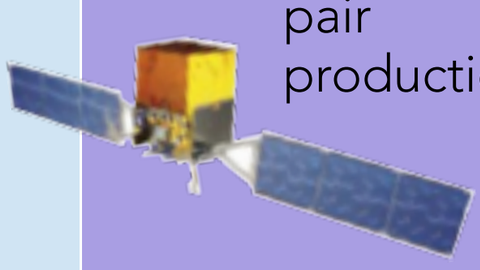


mirror optics

grazing incidence



coded masks

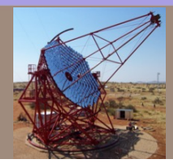


pair production

Compton. scattering

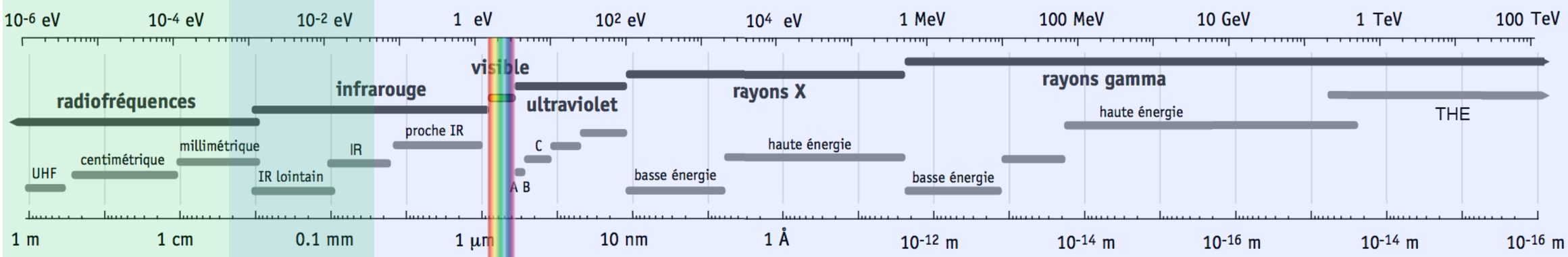
air Cherenkov

water Cherenkov



radio sub-mm IR V UV x-rays gamma-rays

physical effects and detectors for photon detection



COHERENT DETECTION

INCOHERENT DETECTION

physics

induced current

photovoltaic - photoelectric effect

Compton

Pair production

Cerenkov

detectors

bolomètres

retina

bolomètres/calorimètres

gaz detectors

antennas
heterodyne detectors

emulsions

scintillators & PMTs

PMTS

HE solid state detectors

pair trackers

CCD / CMOS

air Cerenkov tel.

water tanks

origin of the elements

expansion of the Universe

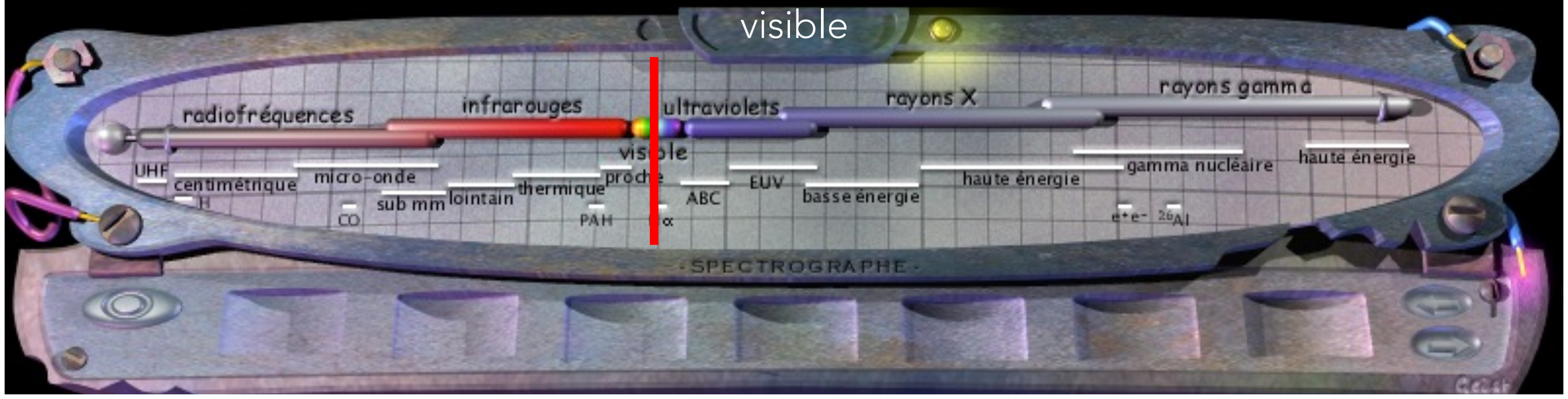
architecture of the Universe

dark matter

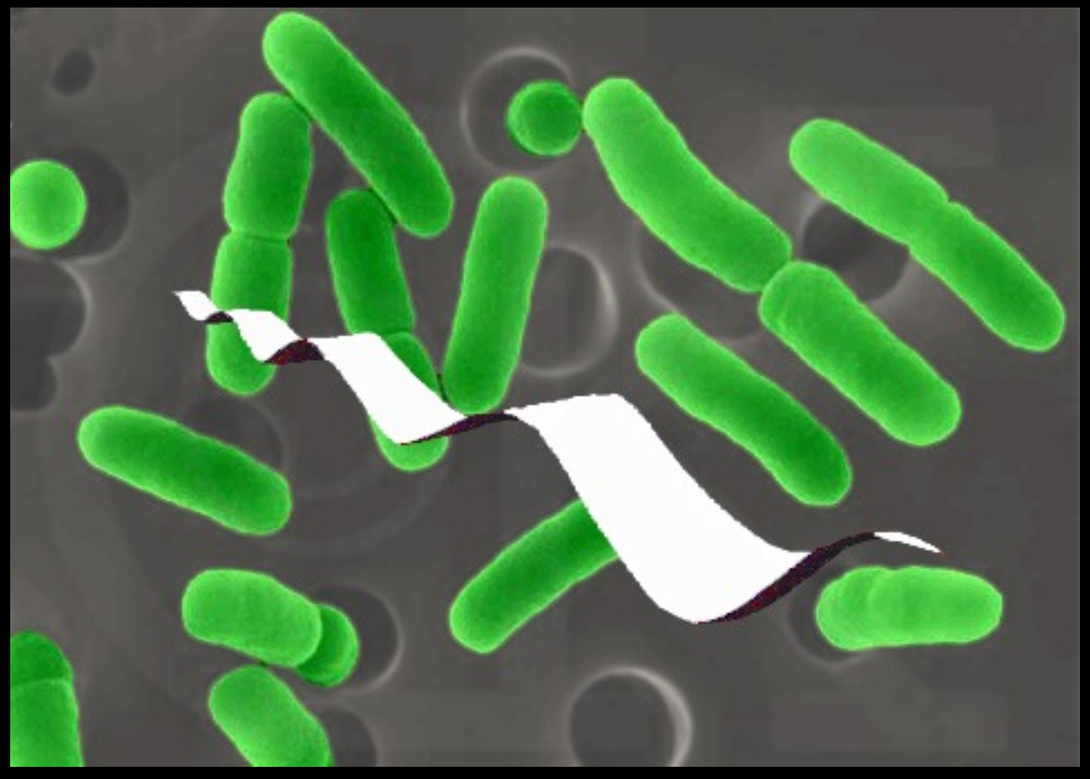
exoplanets

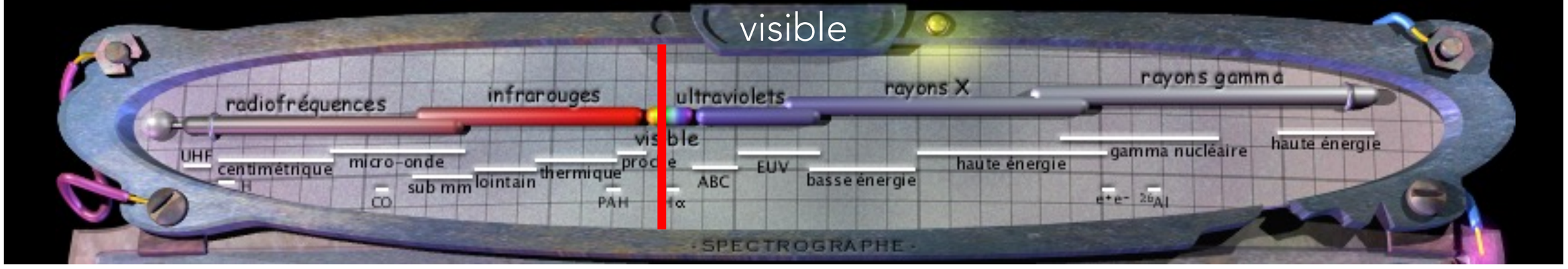
dark energy

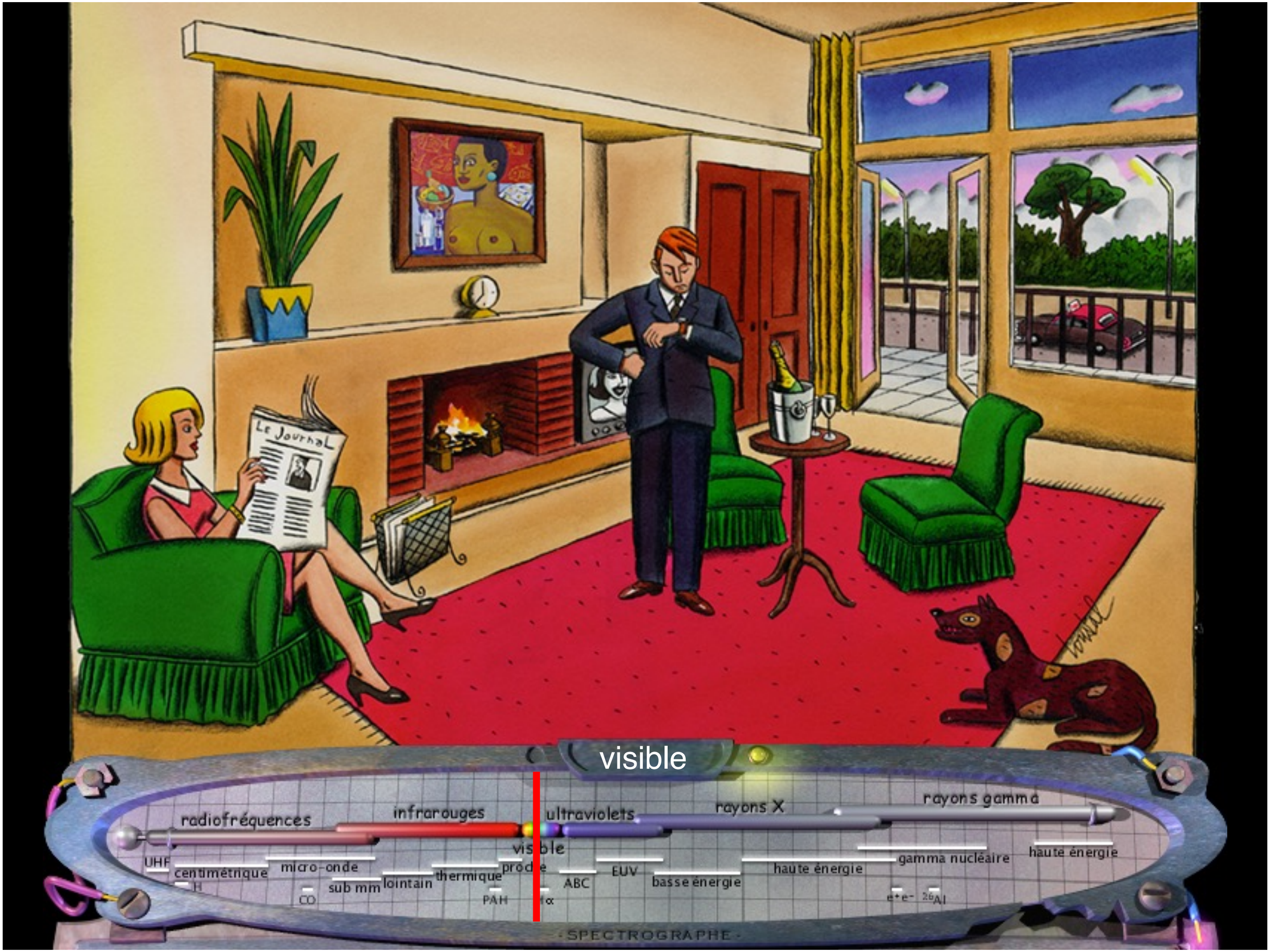
etc :...

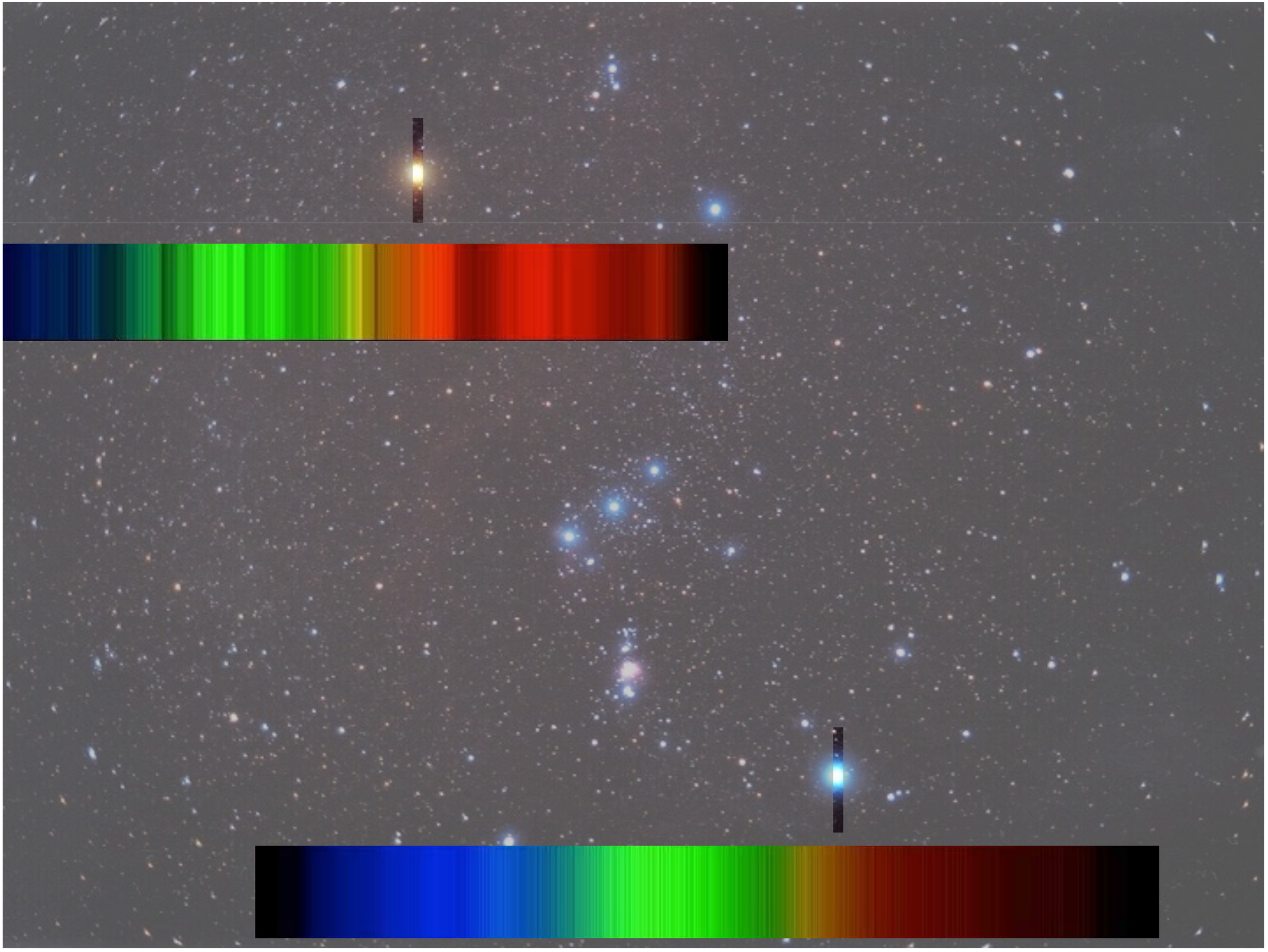


dashbord : visible light

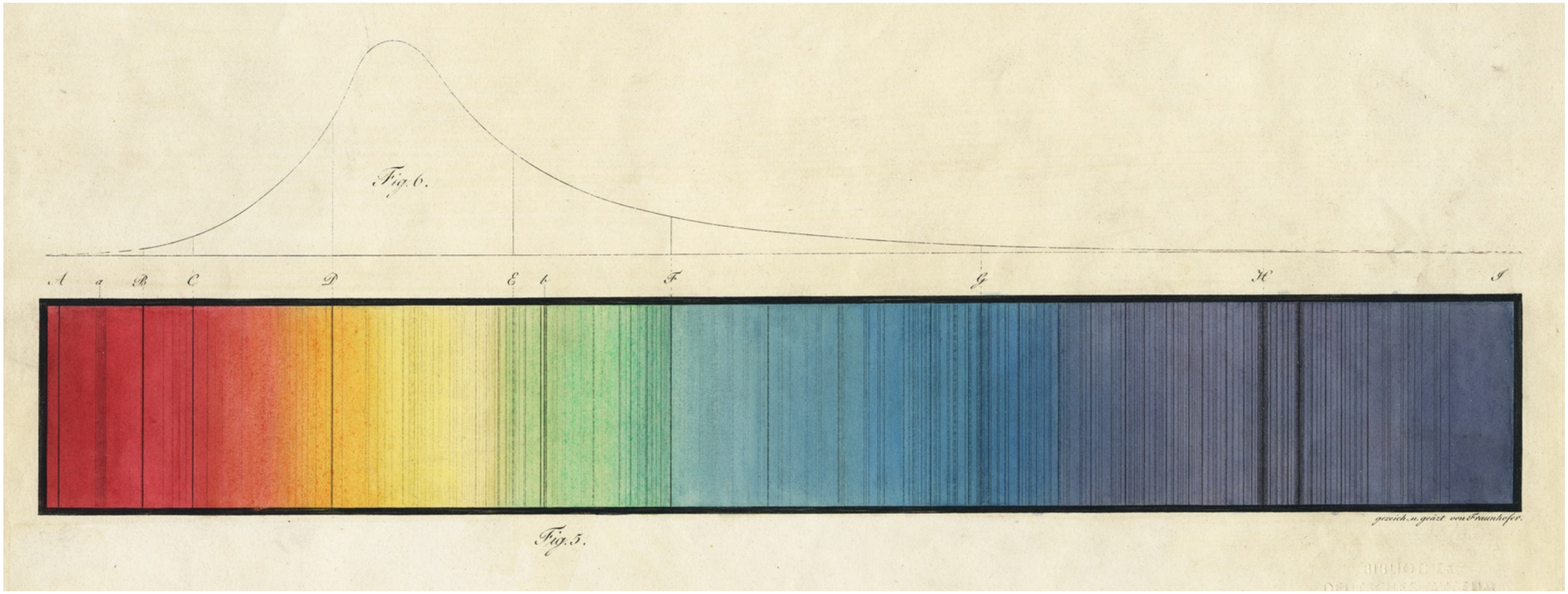




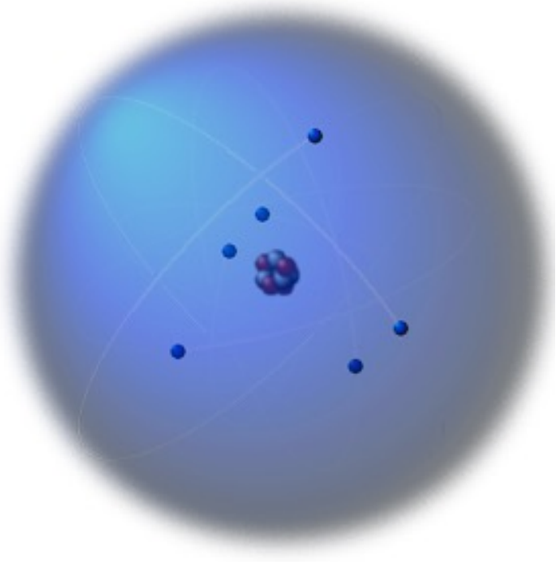

Le Journal
visible
radiofréquences
infrarouges
ultraviolets
rayons X
rayons gamma
UHF
centimétrique
micro-onde
sub mm
lointain
thermique
proche
ABC
EUV
basse énergie
haute énergie
gamma nucléaire
haute énergie
H
CO
PAH
Hα
e+e-
26Al
SPECTROGRAPHE



the discovery of the spectral lines -1814 Josef Fraunhofer

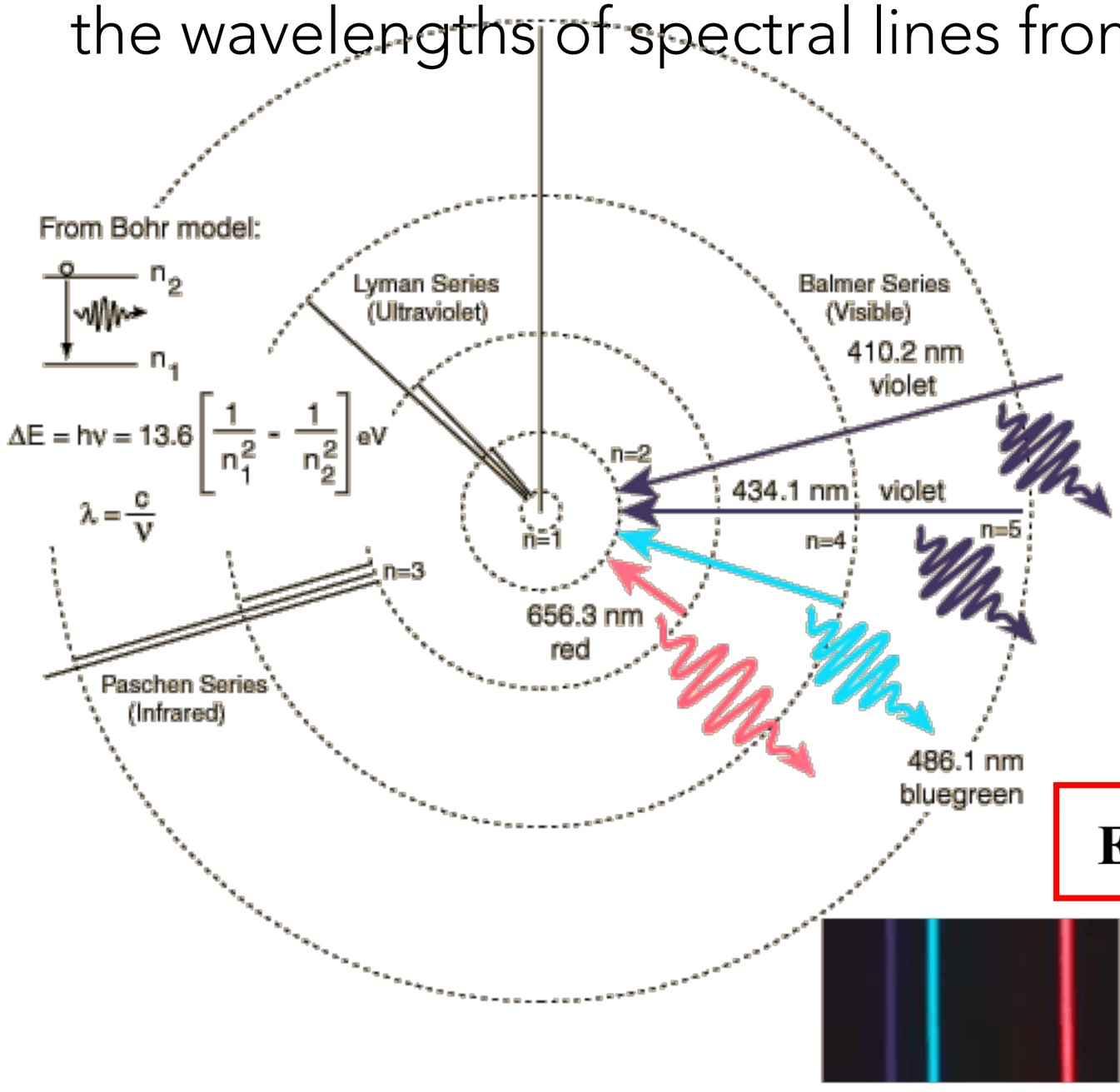


visible spectrum of the Sun



atomic (molecular …) spectroscopy
-> modern chemistry and physics !

the wavelengths of spectral lines from Bohr's atom

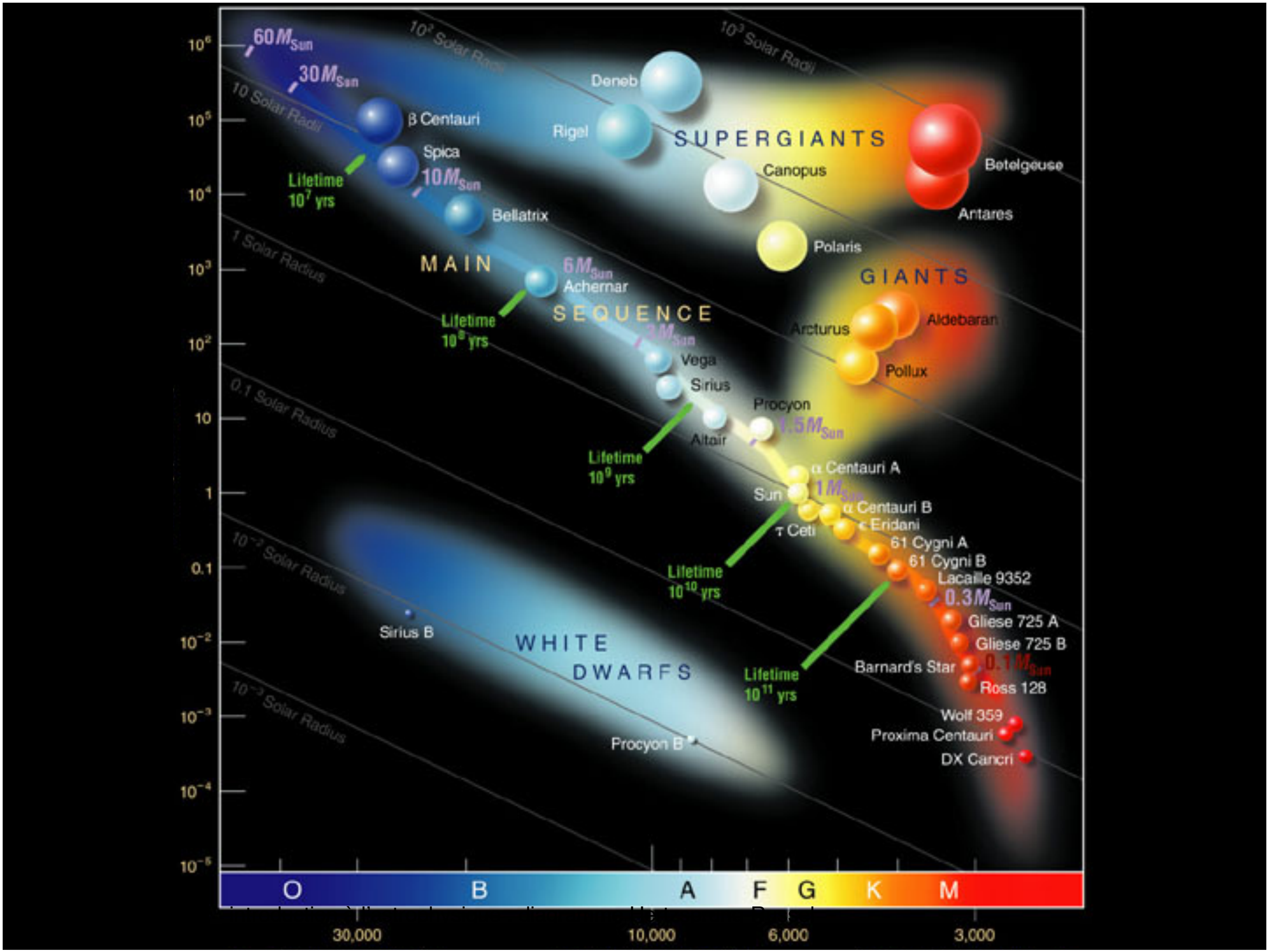


Here we describe the energy states of Hydrogen with a single integer variable, the principal quantum number n

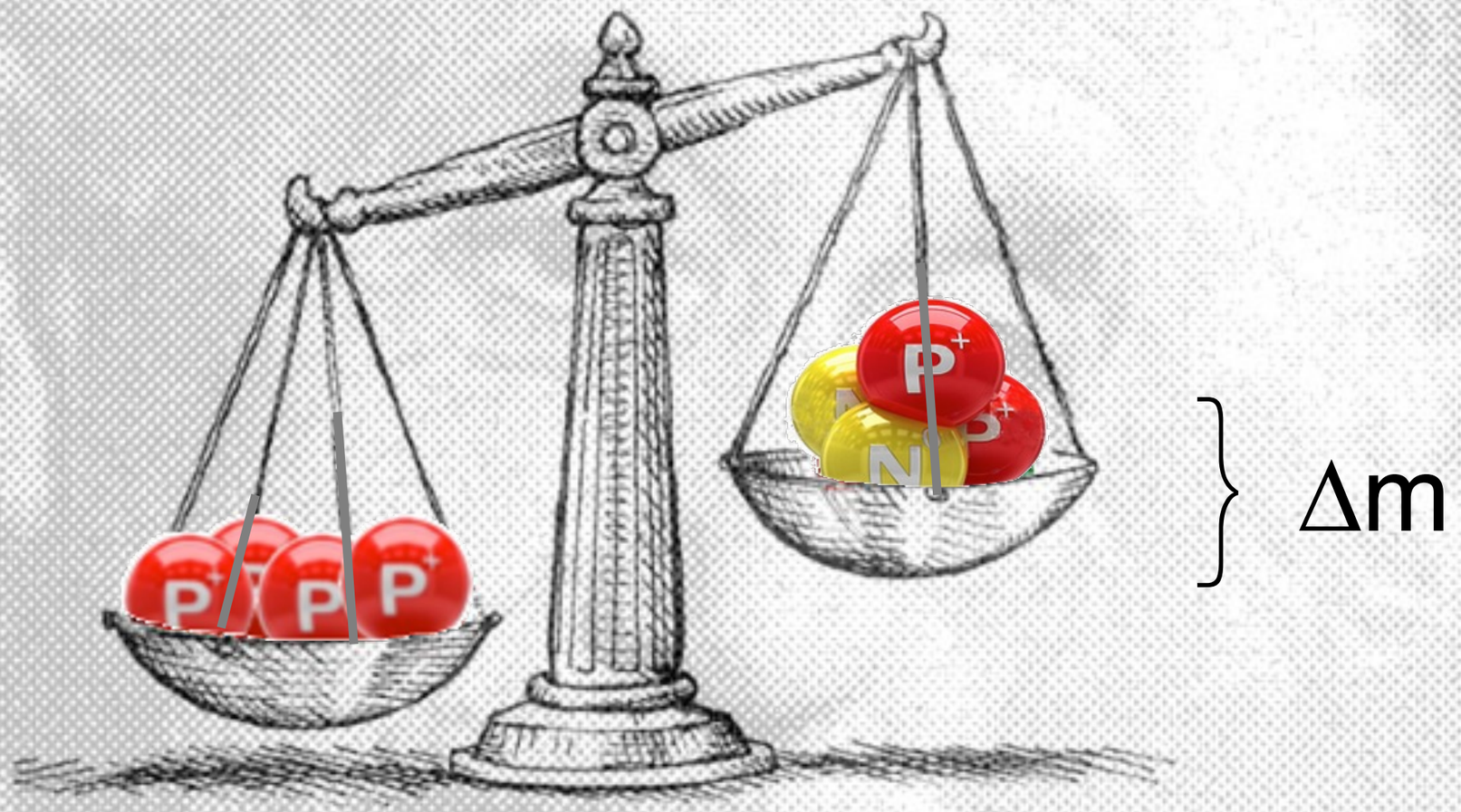
$$E = -E_0/n^2$$

In this simple form of Bohr's atom, the transition of n=3 to n=2 corresponds to a wavelenght of 6562.78 Å;
In the actual Hydrogen spectrum we measure a line at 6562.793 Å !

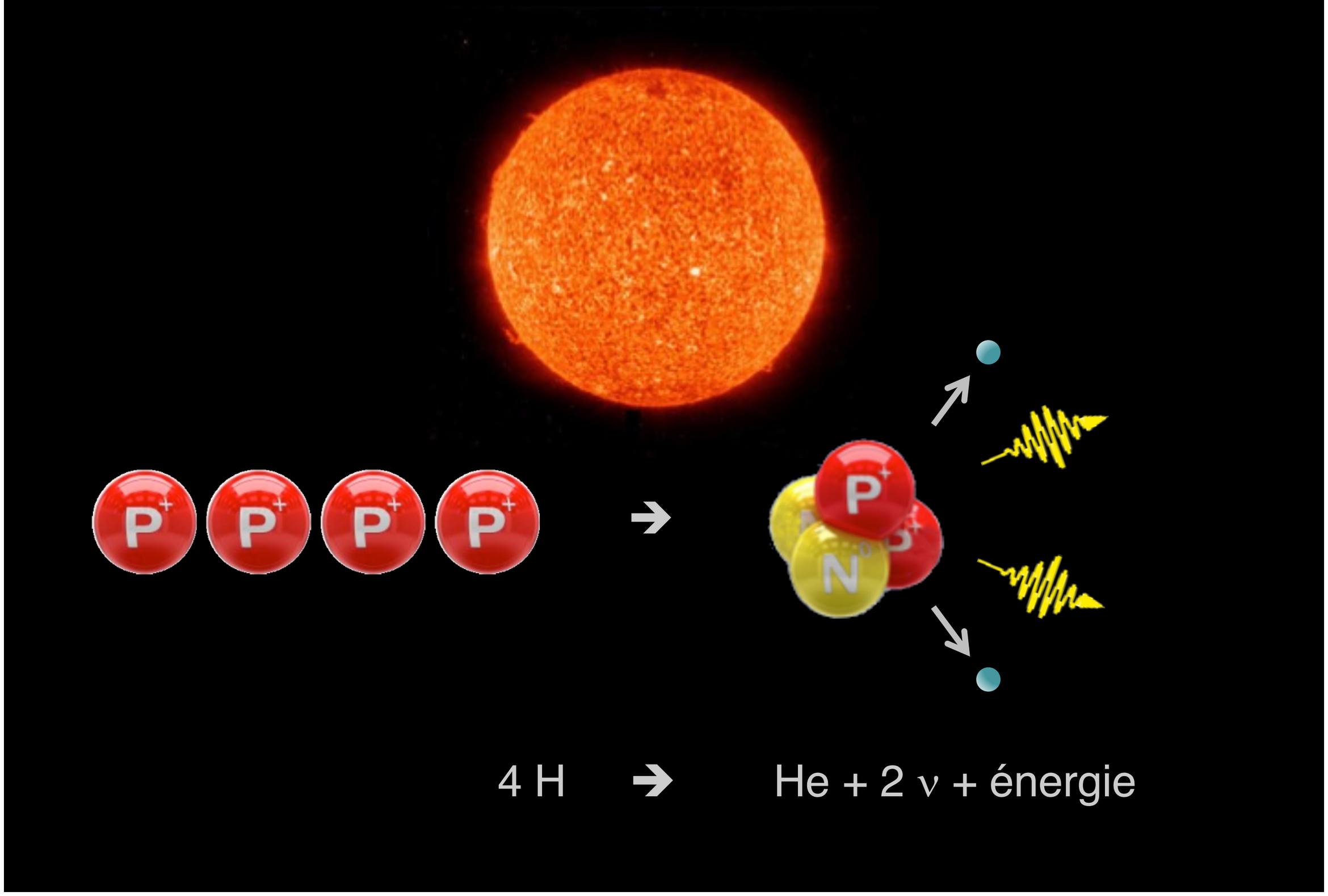

H_α


10^6
10^5
10^4
10^3
10^2
10
1
0.1
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^2 Solar Radii
10^3 Solar Radii
10 Solar Radii
1 Solar Radius
0.1 Solar Radius
10^{-2} Solar Radius
10^{-3} Solar Radius
$60M_{Sun}$
$30M_{Sun}$
$10M_{Sun}$
$6M_{Sun}$
$3M_{Sun}$
$1.5M_{Sun}$
$1M_{Sun}$
$0.3M_{Sun}$
$0.1M_{Sun}$
Lifetime 10^7 yrs
Lifetime 10^8 yrs
Lifetime 10^9 yrs
Lifetime 10^{10} yrs
Lifetime 10^{11} yrs
Deneb
Rigel
β Centauri
Spica
Bellatrix
Canopus
Betelgeuse
Antares
Polaris
SUPERGIANTS
GIANTS
MAIN SEQUENCE
Achernar
Arcturus
Aldebaran
Pollux
Vega
Sirius
Procyon
Altair
α Centauri A
Sun
α Centauri B
ε Eridani
τ Ceti
61 Cygni A
61 Cygni B
Lacaille 9352
Gliese 725 A
Gliese 725 B
Barnard's Star
Ross 128
Wolf 359
Proxima Centauri
DX Cancri
Sirius B
Procyon B
WHITE DWARFS
O
B
A
F
G
K
M
30,000
10,000
6,000
3,000

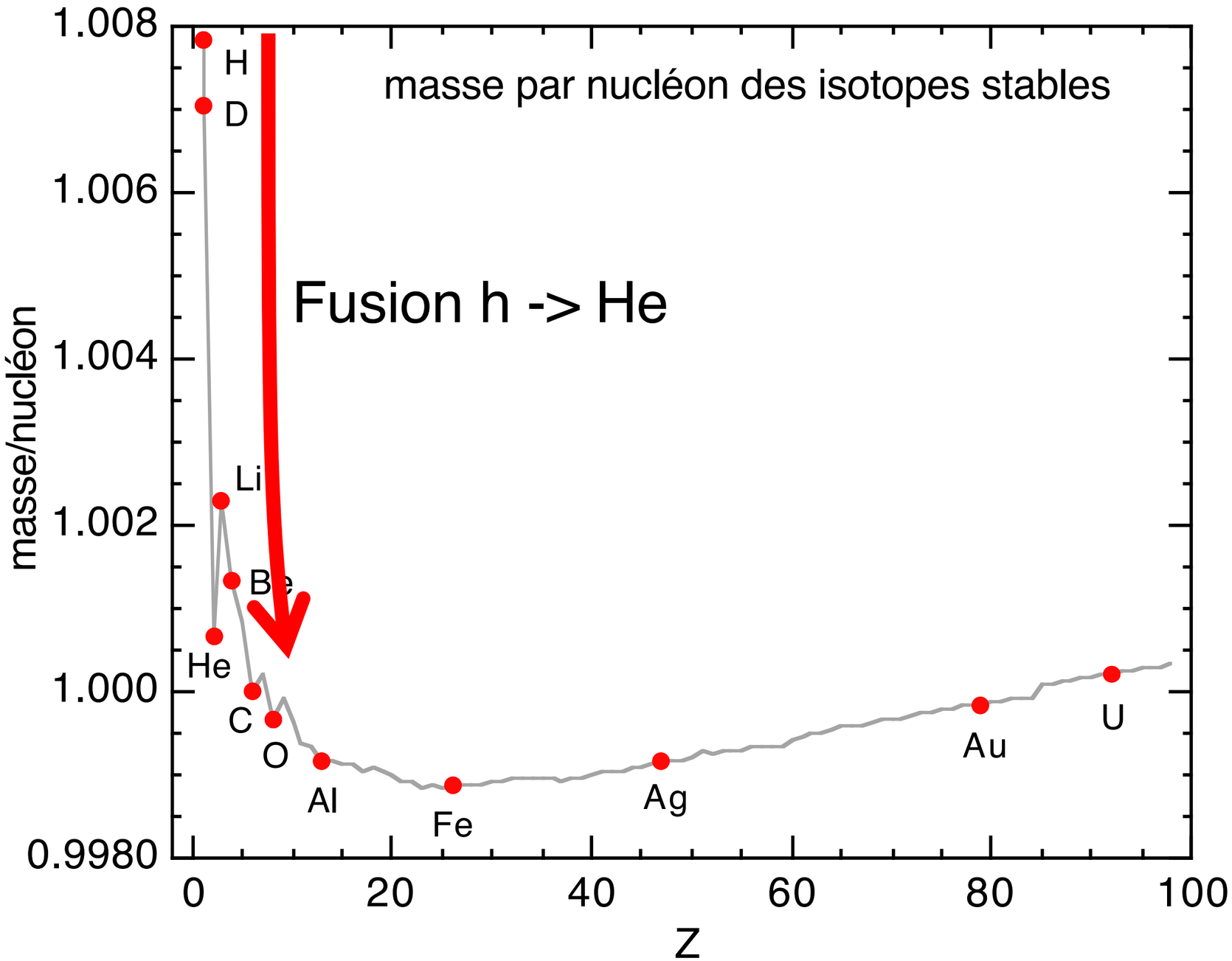
pp process
$E = mc^2$



The Sun and all main-sequence stars : fusion of H into He



la masse par nucléon en fonction du numéro atomique Z

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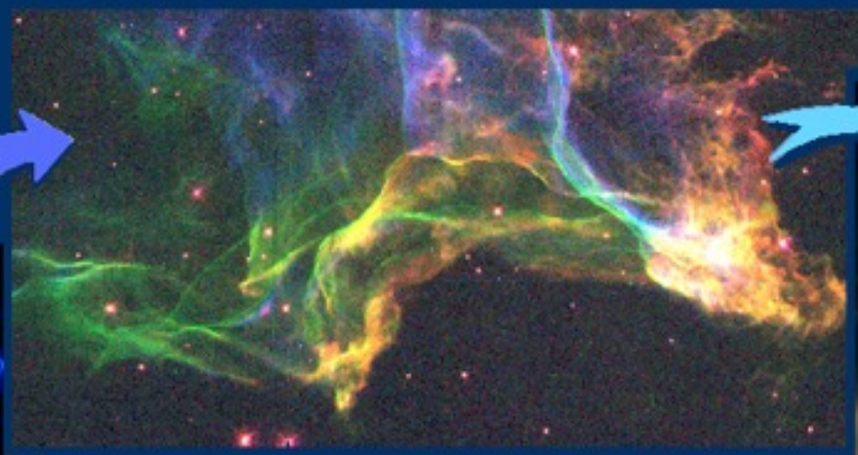
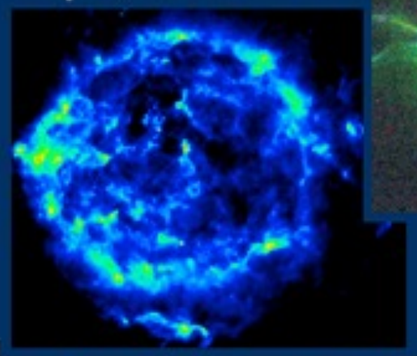
le cycle de la matière

gaz et poussières du milieu interstellaire



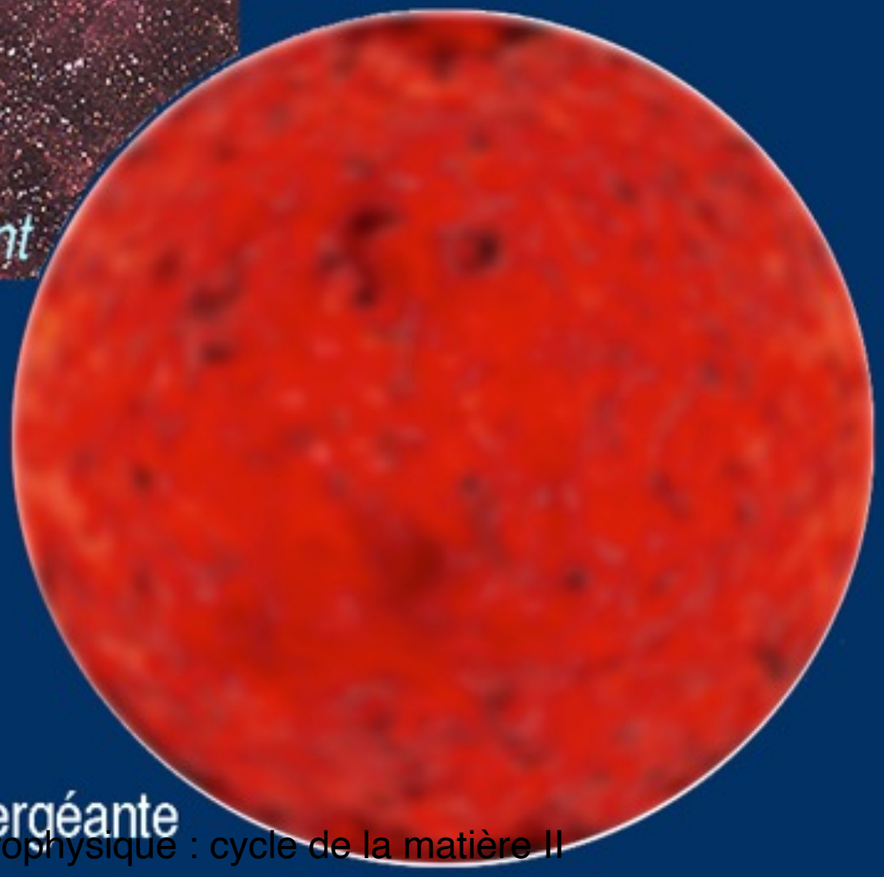
nuage moléculaire

reste de supernova

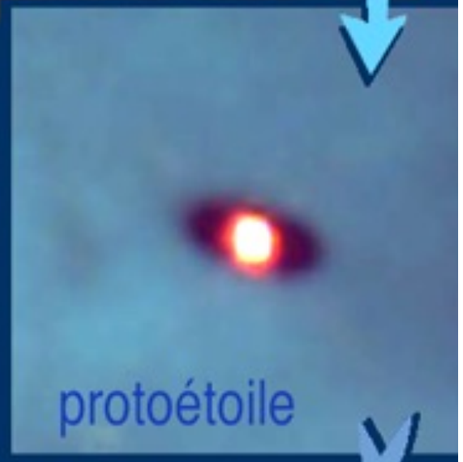


étoile à neutrons ou trou noir

supernova



supergéante



protoétoile

étoile massive

protostellar clouds

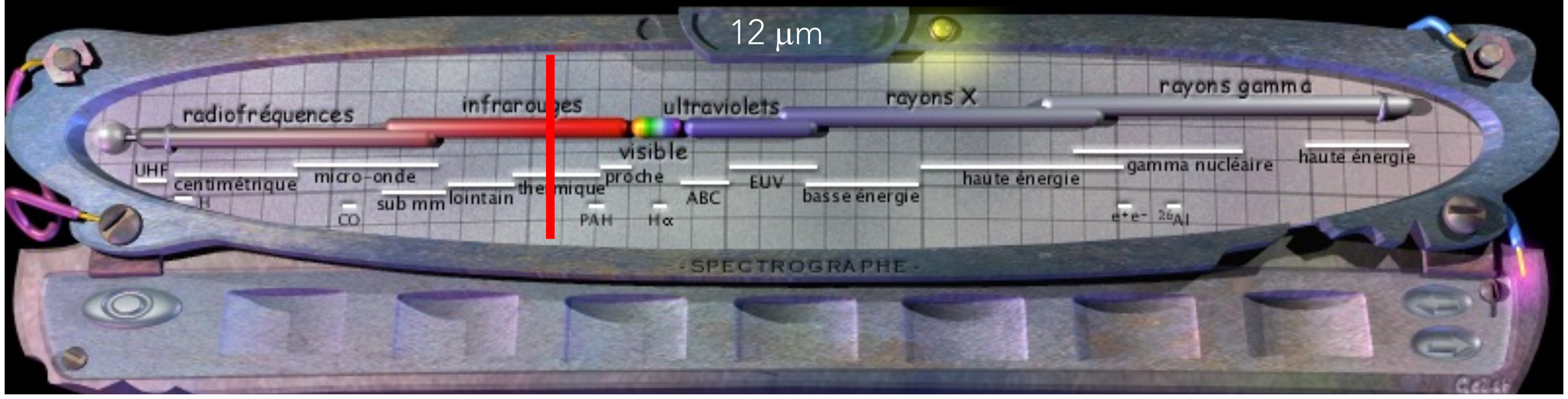
protoplanetary disks

water

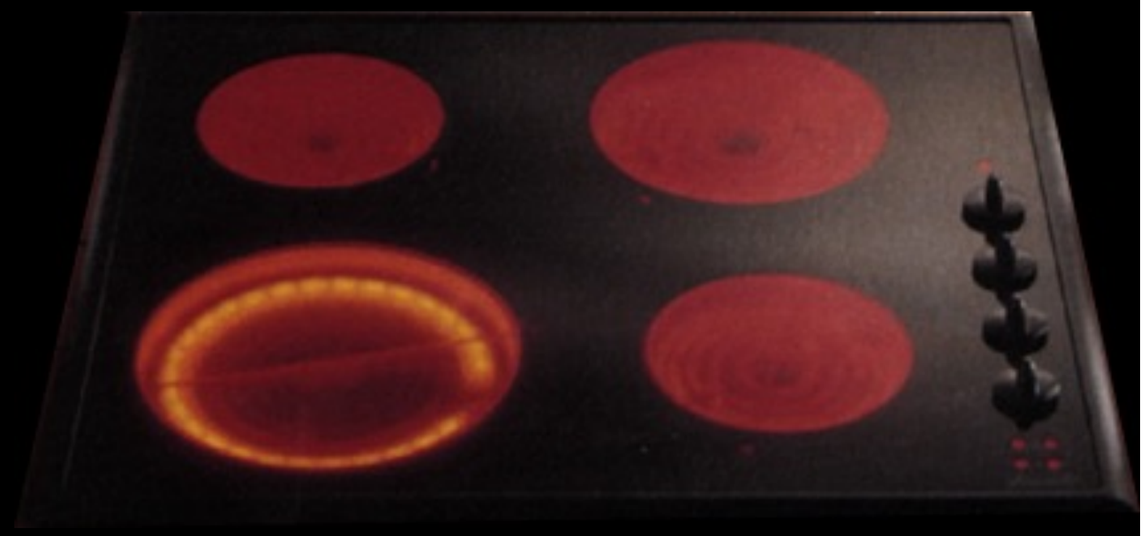
molecules … organic

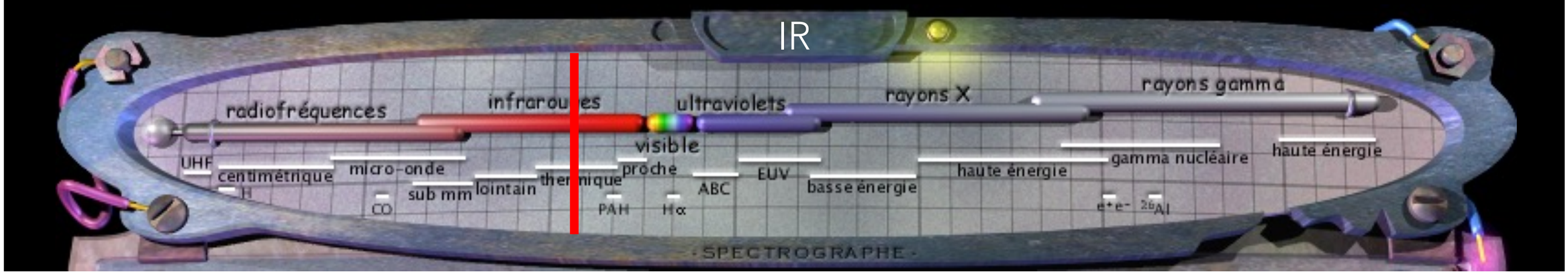
infrared galaxies

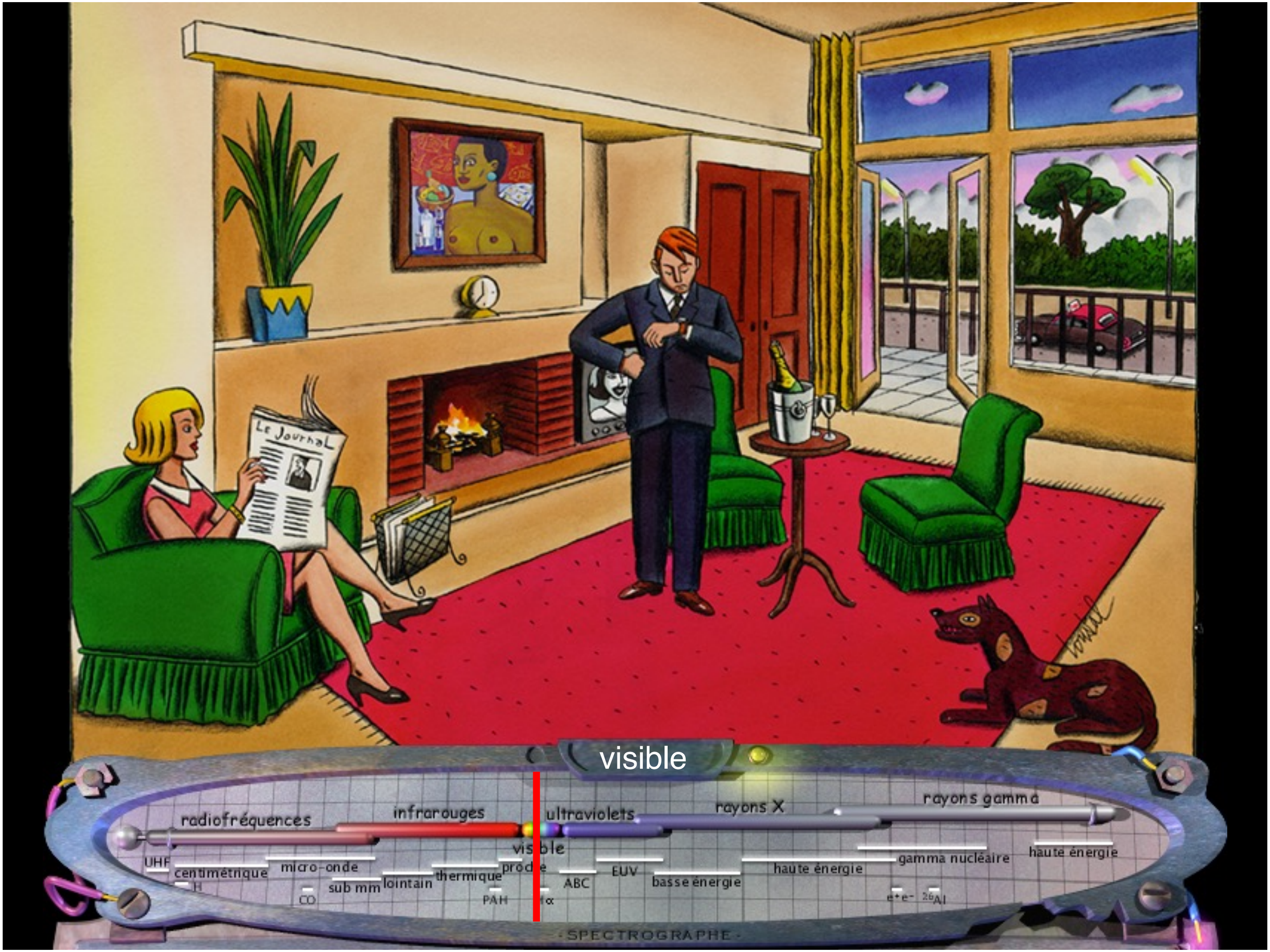
masers …



dashbord : infrared






Le Journal
visible
radiofréquences
infrarouges
ultraviolets
rayons X
rayons gamma
UHF
centimétrique
micro-onde
sub mm
lointain
thermique
proche
ABC
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gamma nucléaire
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H
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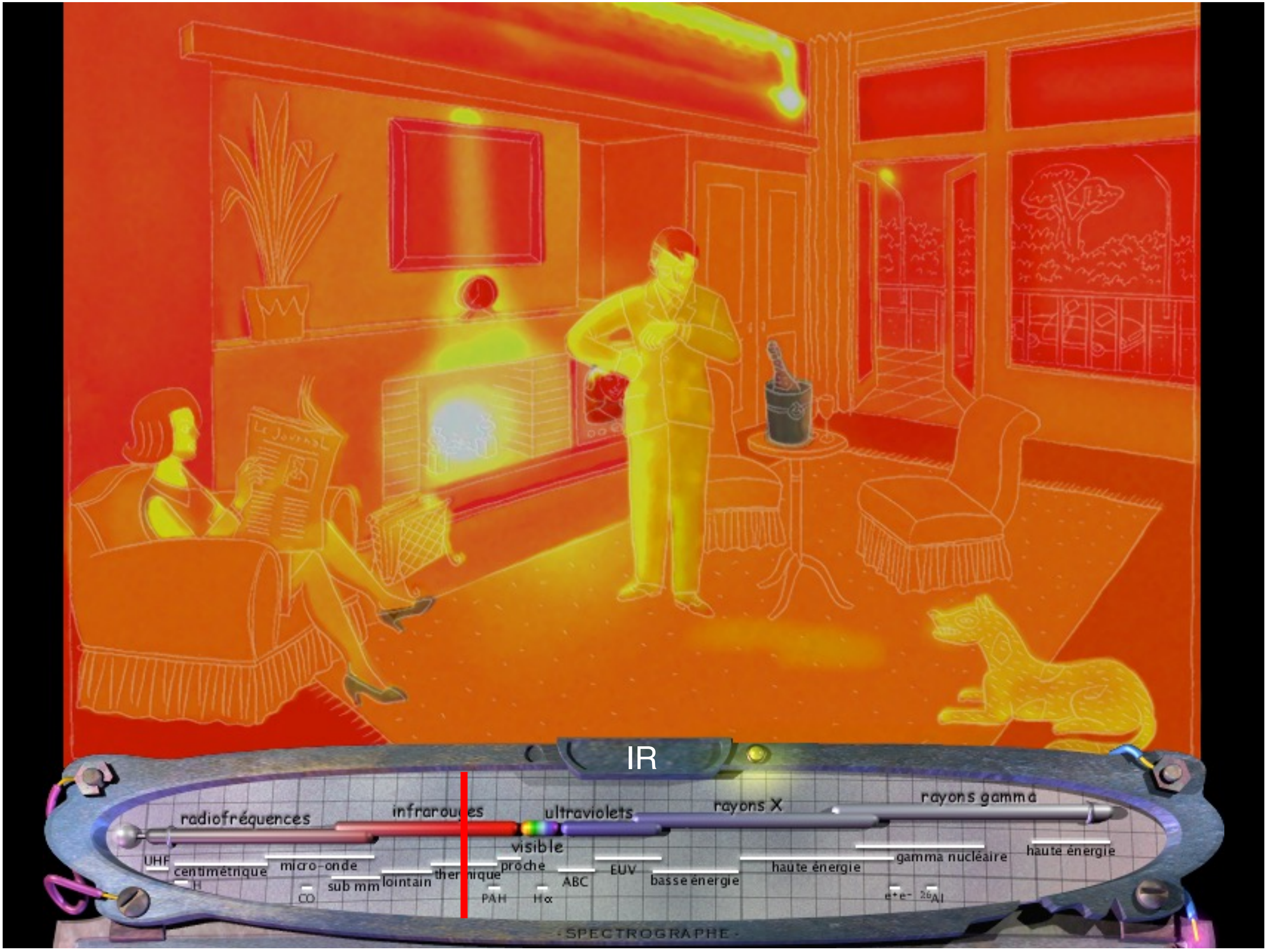
SPECTROGRAPHE


IR
radiofréquences
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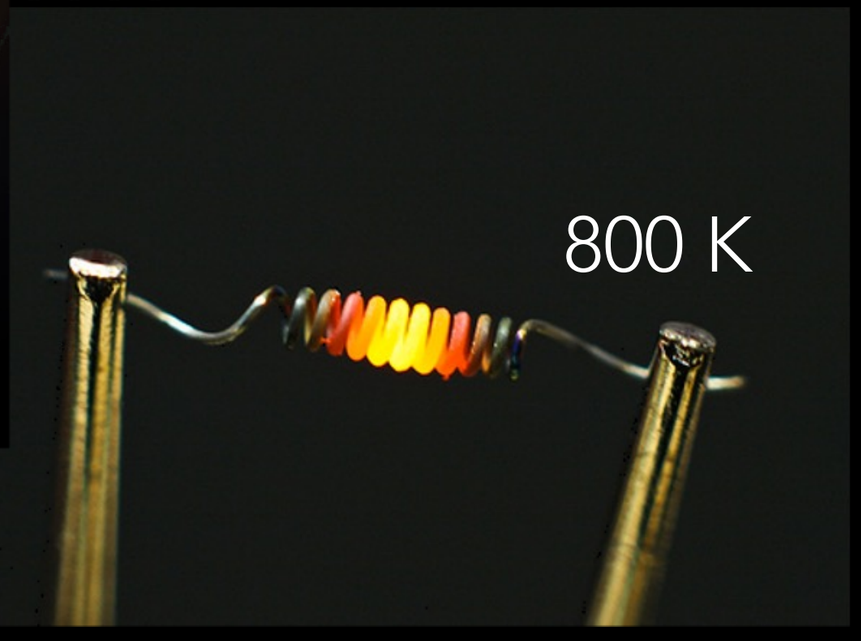
EUV
basse énergie
haute énergie
gamma nucléaire
haute énergie
H
CO
PAH
Hα
e+e-
26Al
SPECTROGRAPHE

Black body radiation

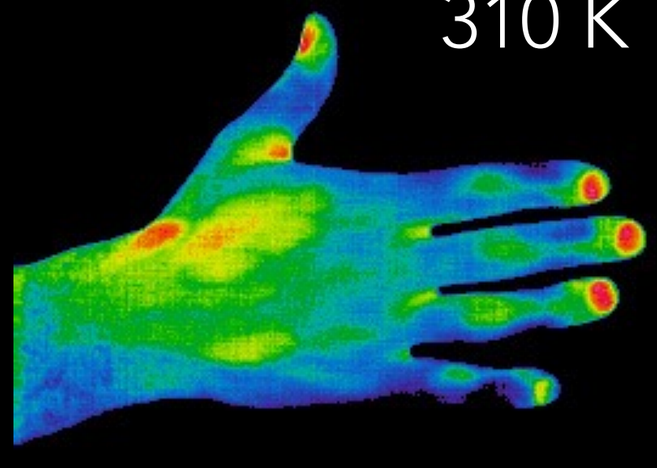
6000 K

3000 K

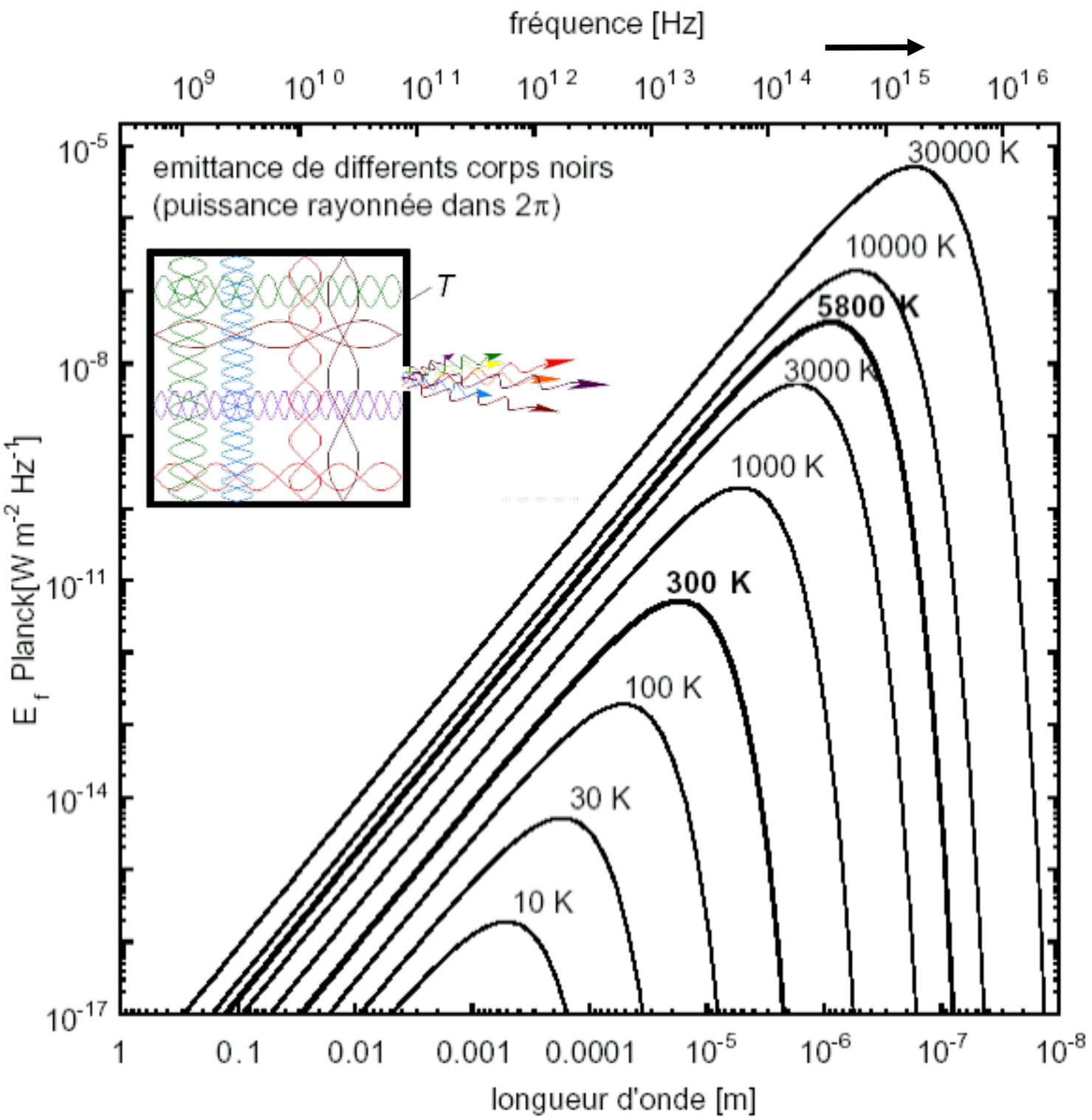


800 K

310 K

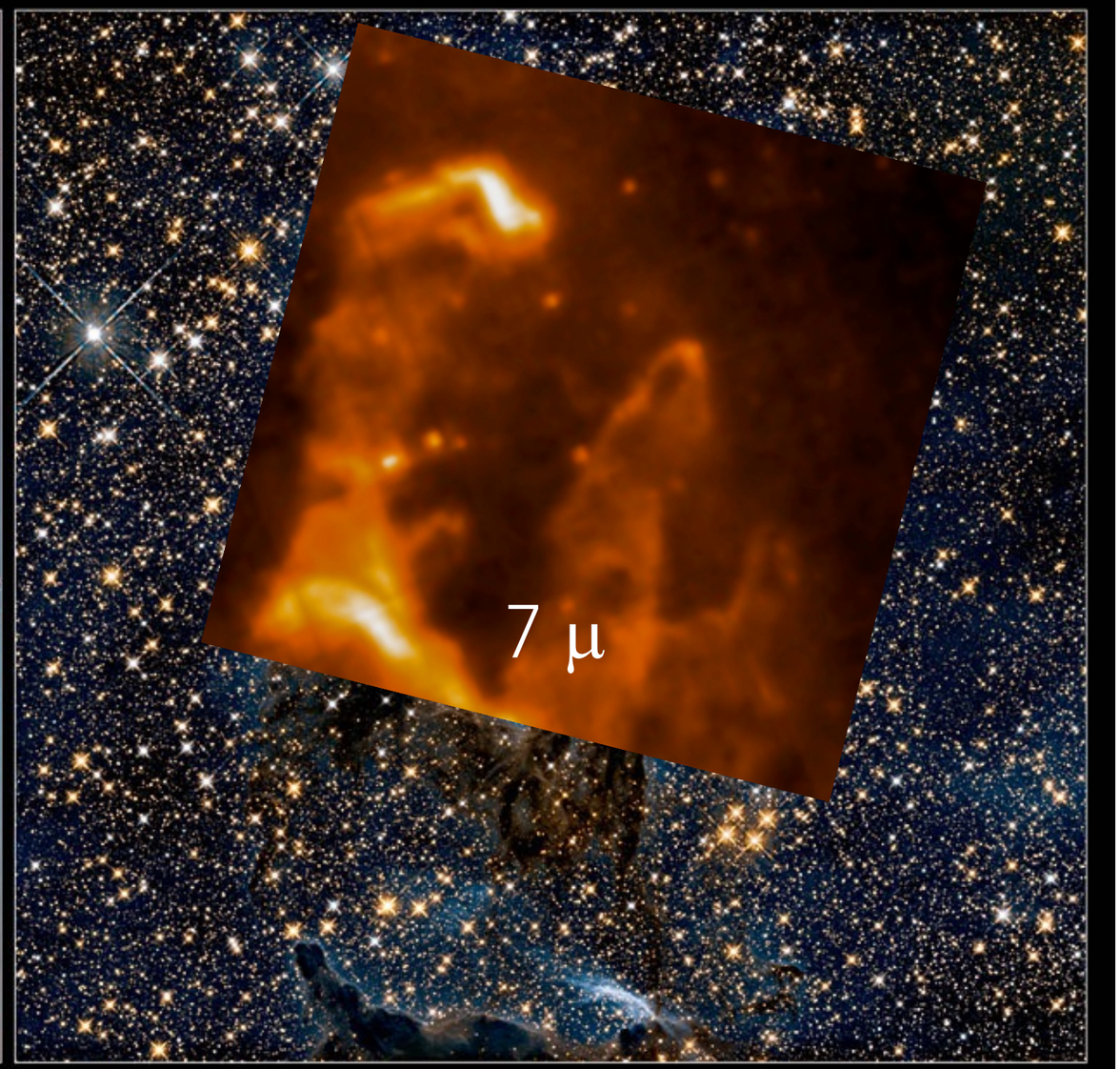


Black body radiation - emission of the sun, the earth...



M16 –"pillars of creation"

Visible · WFC3 · 2015

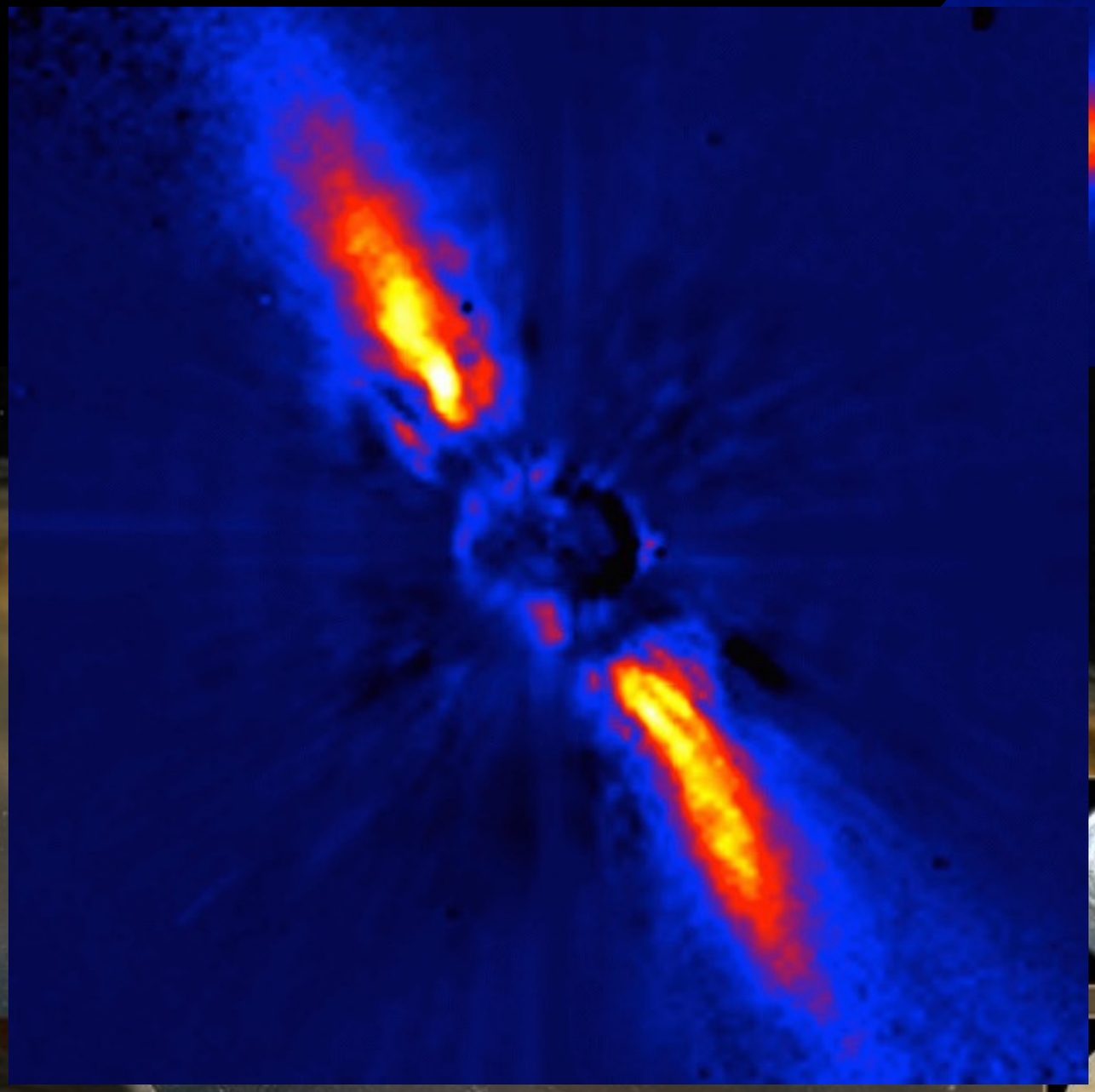


Infrared · WFC3 · 2015

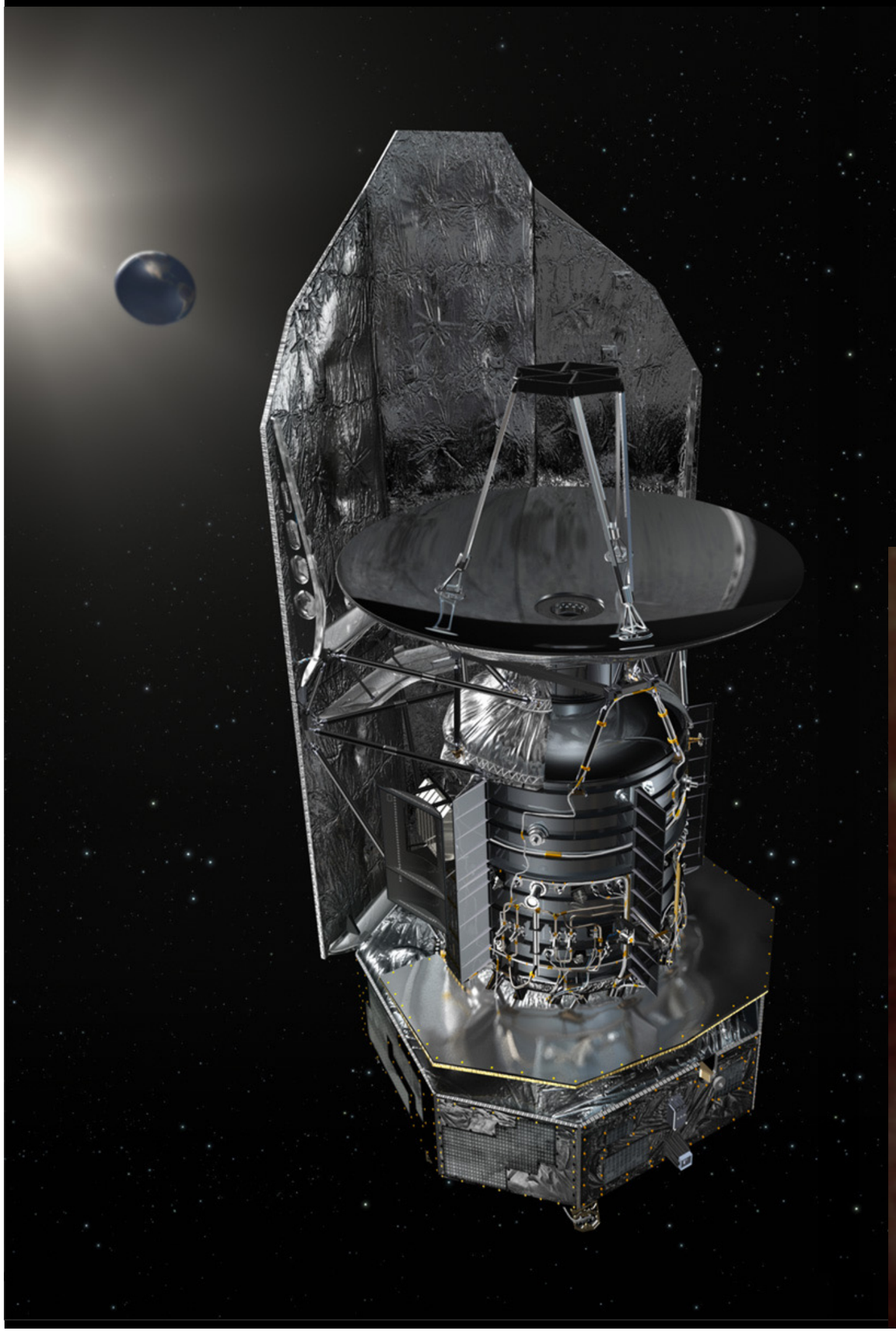
visible

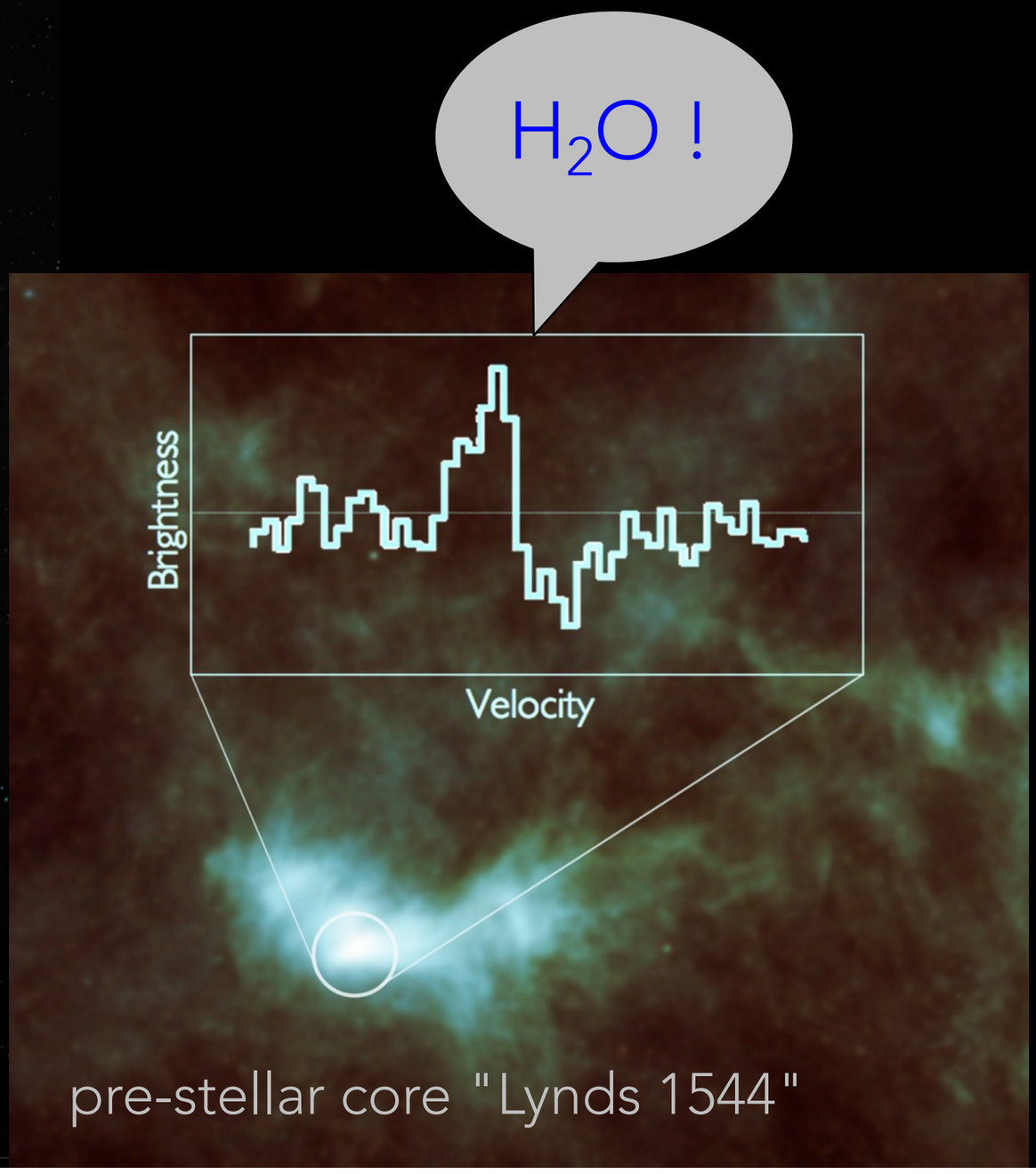
infrared 1.1 and 1.6 μ

IR excess of β Pictoris observed by IRAS in 1983
led to an optical follow-up => early evidence for extrasolar planet



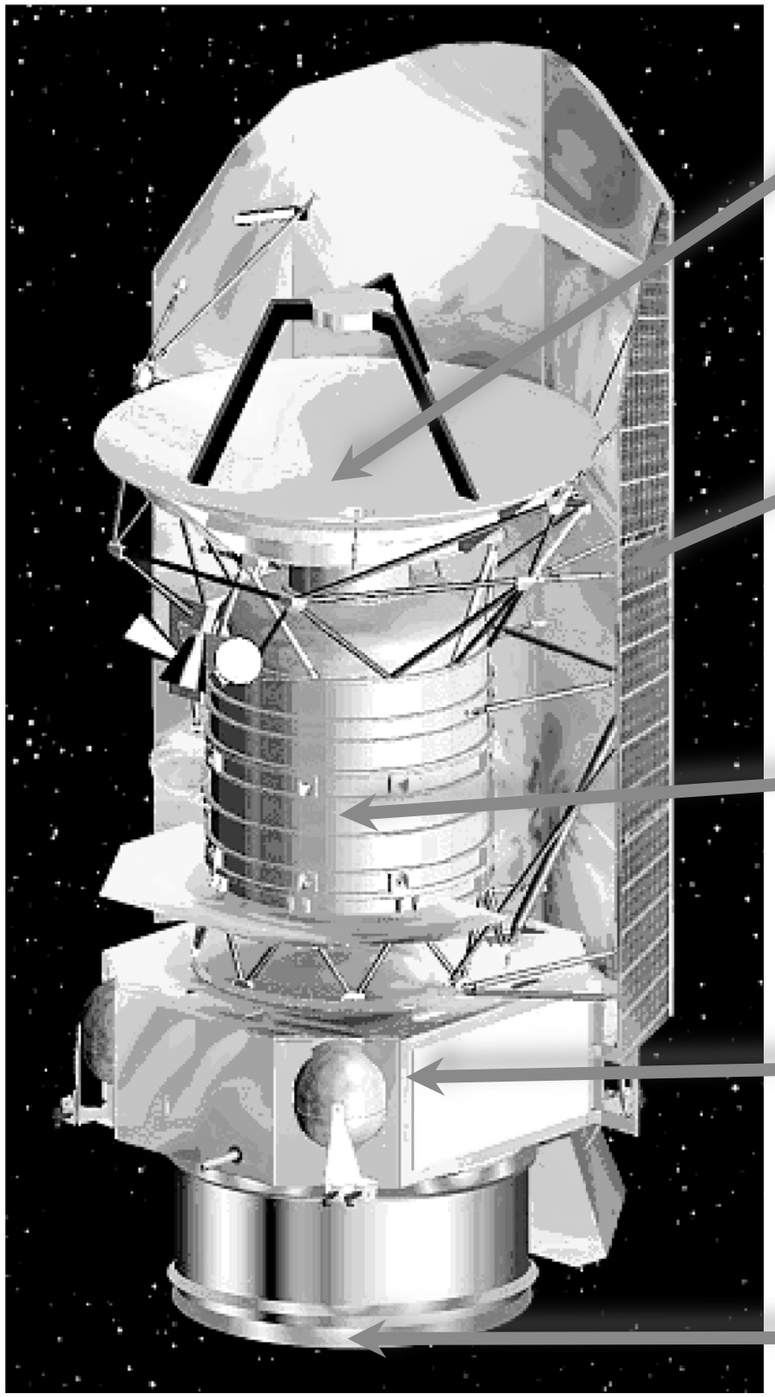
HERSCHEL (2009-2013)

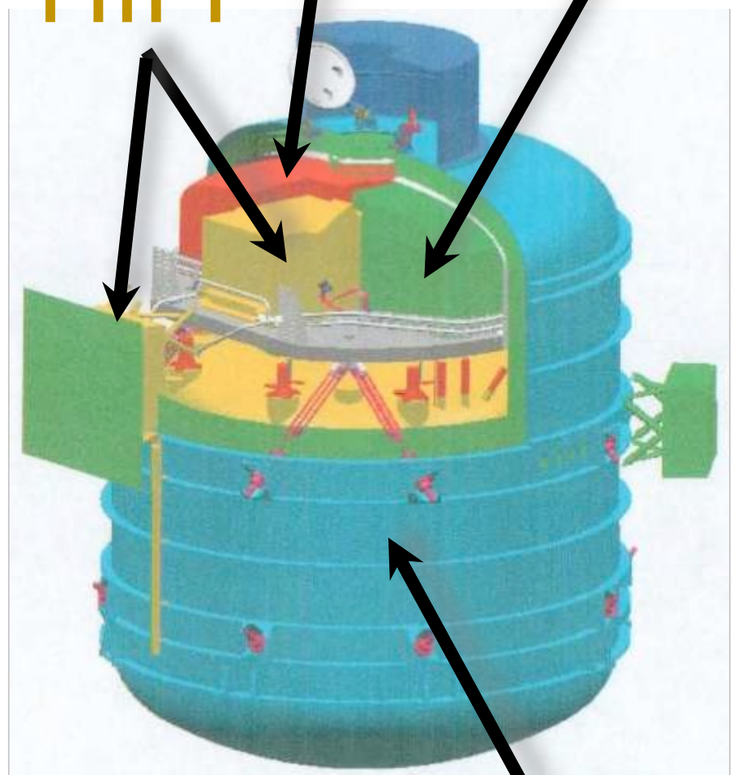




HSO the satellite

3.5 m Ritchey-Chrétien telescope made from SiC





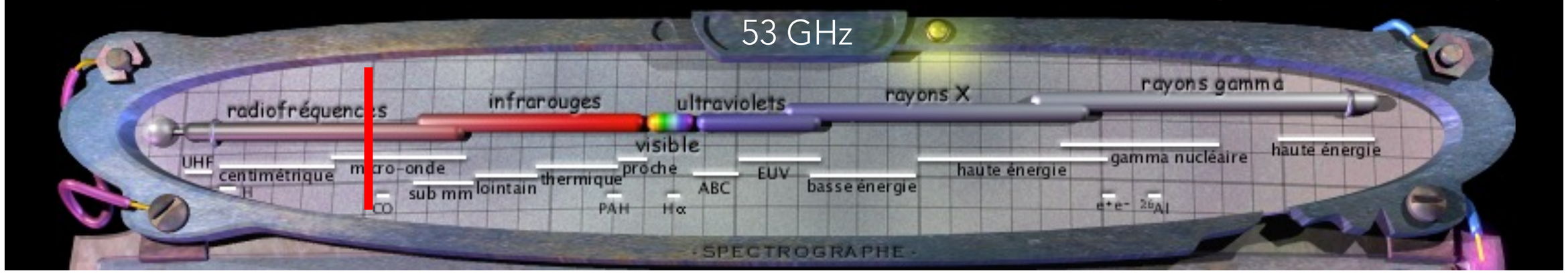
Cosmic Microwave Background

precise age of the Univers

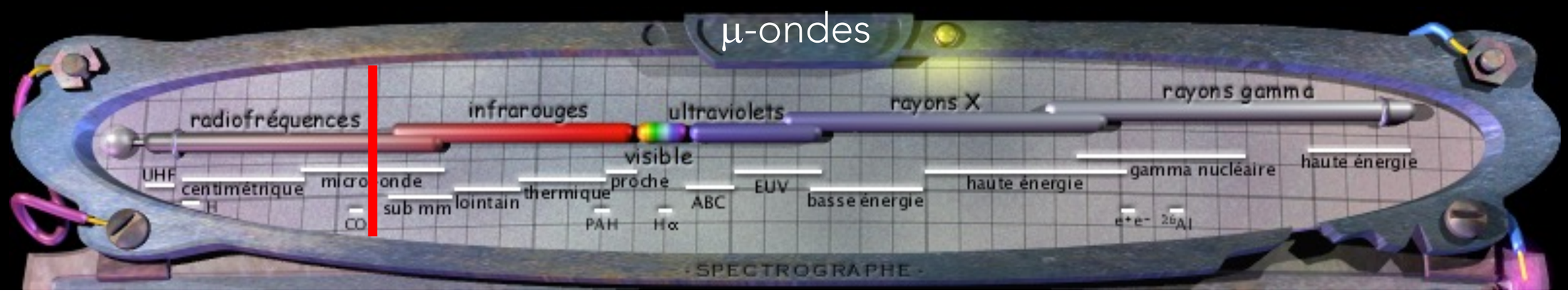
geometry of the Universe

PLANCK

=> the Universe has an age of 13.8 By

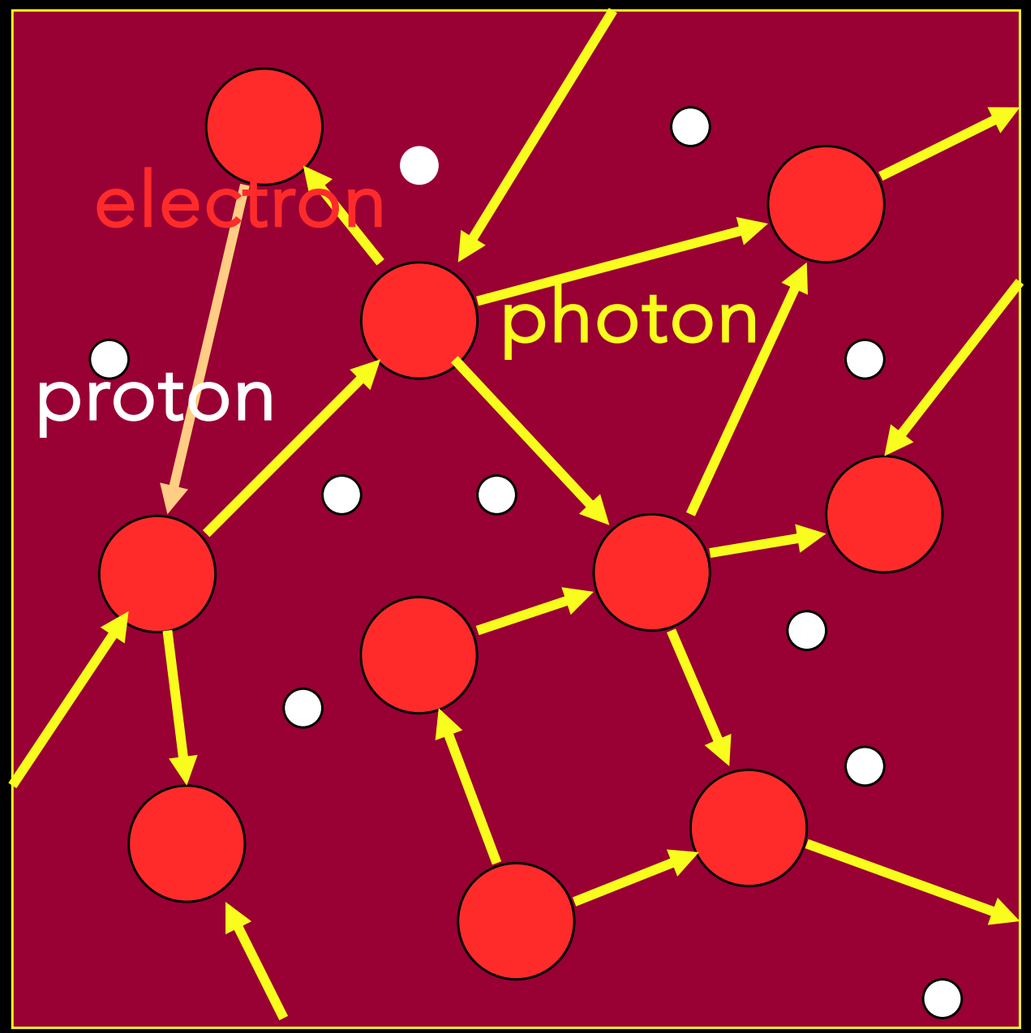


dashbord : micro-waves

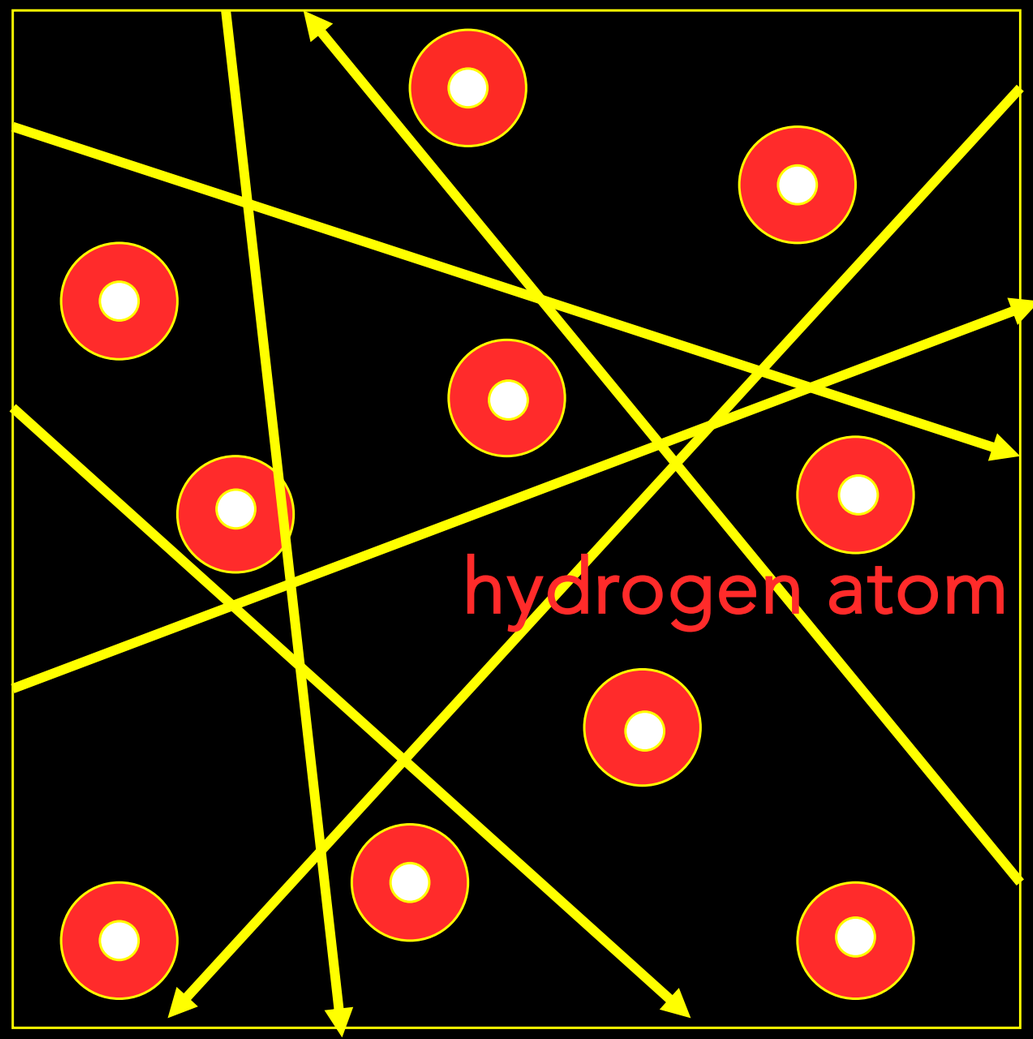


380'000 years after the Big Bang
light and matter "divorce"

before

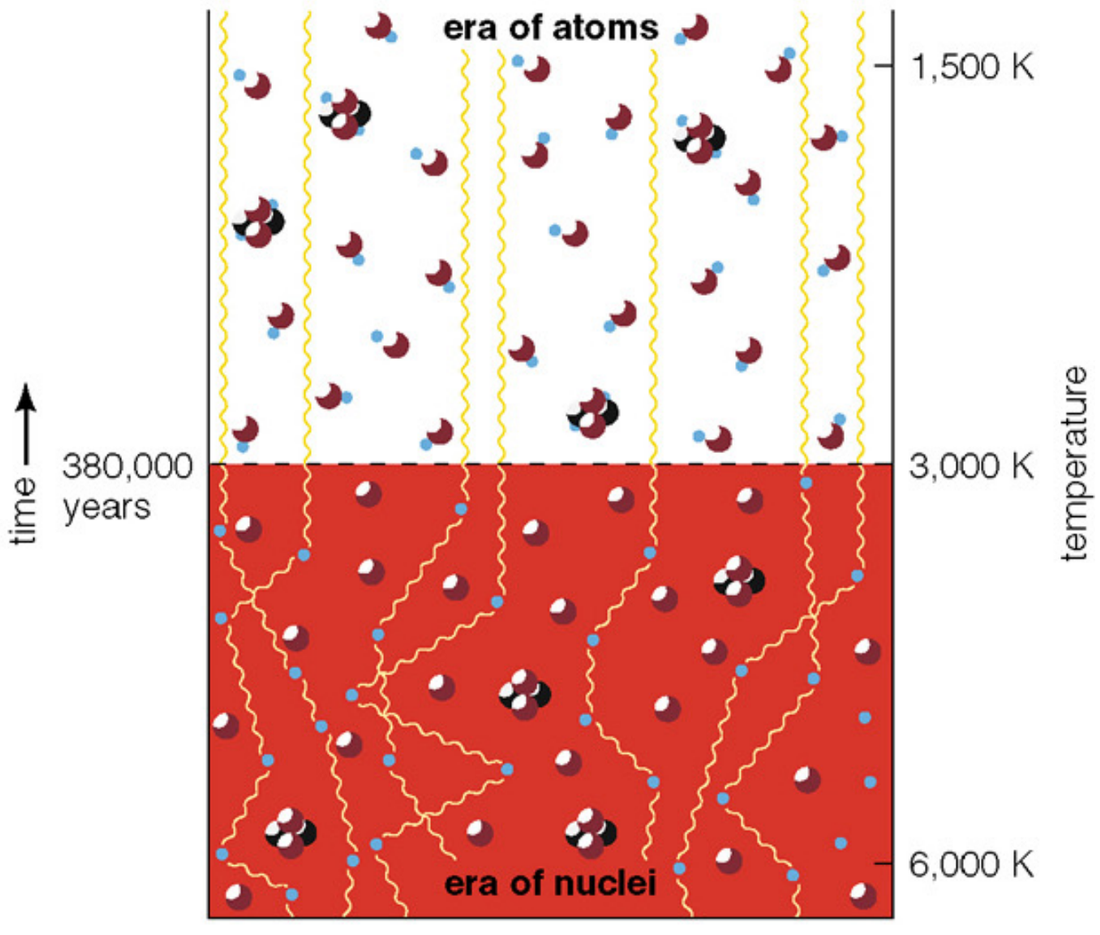


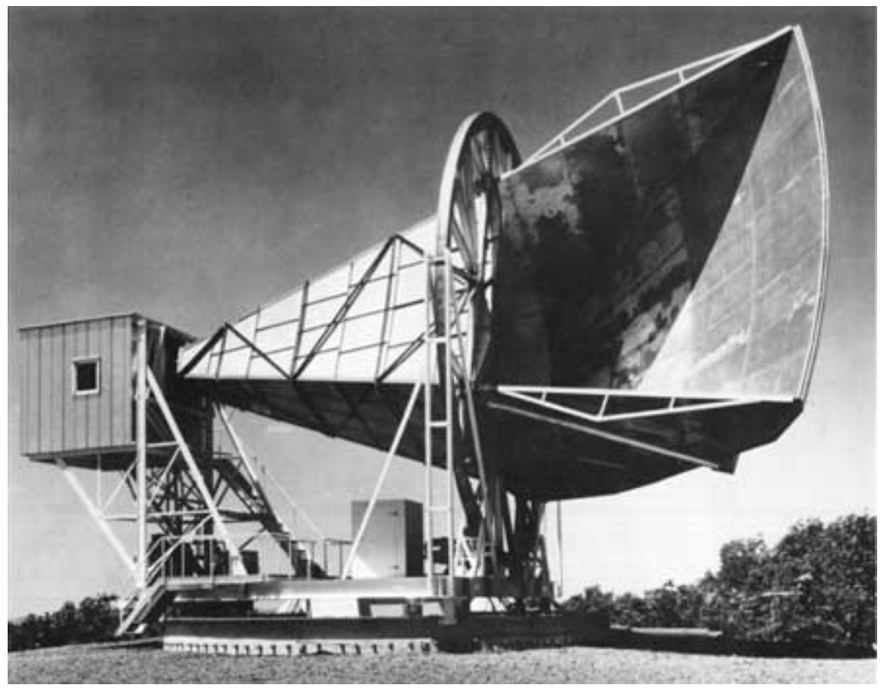
after



the Universe becomes transparent – atoms (H) are born

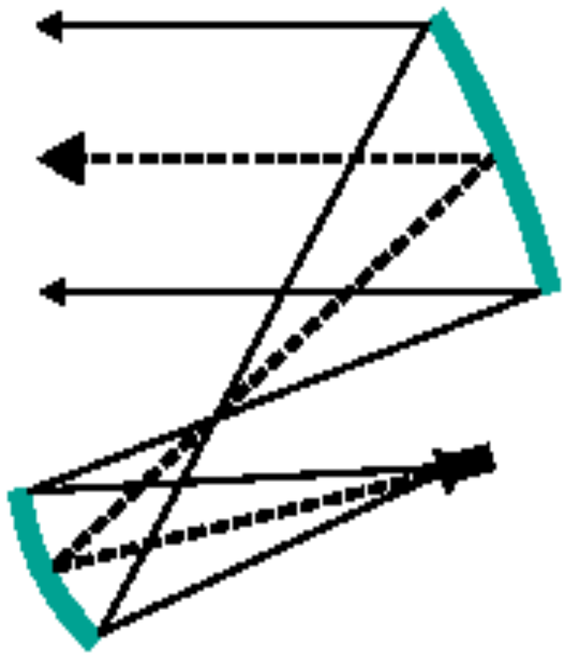
380'000 years after the Big Bang
light and matter "divorce"

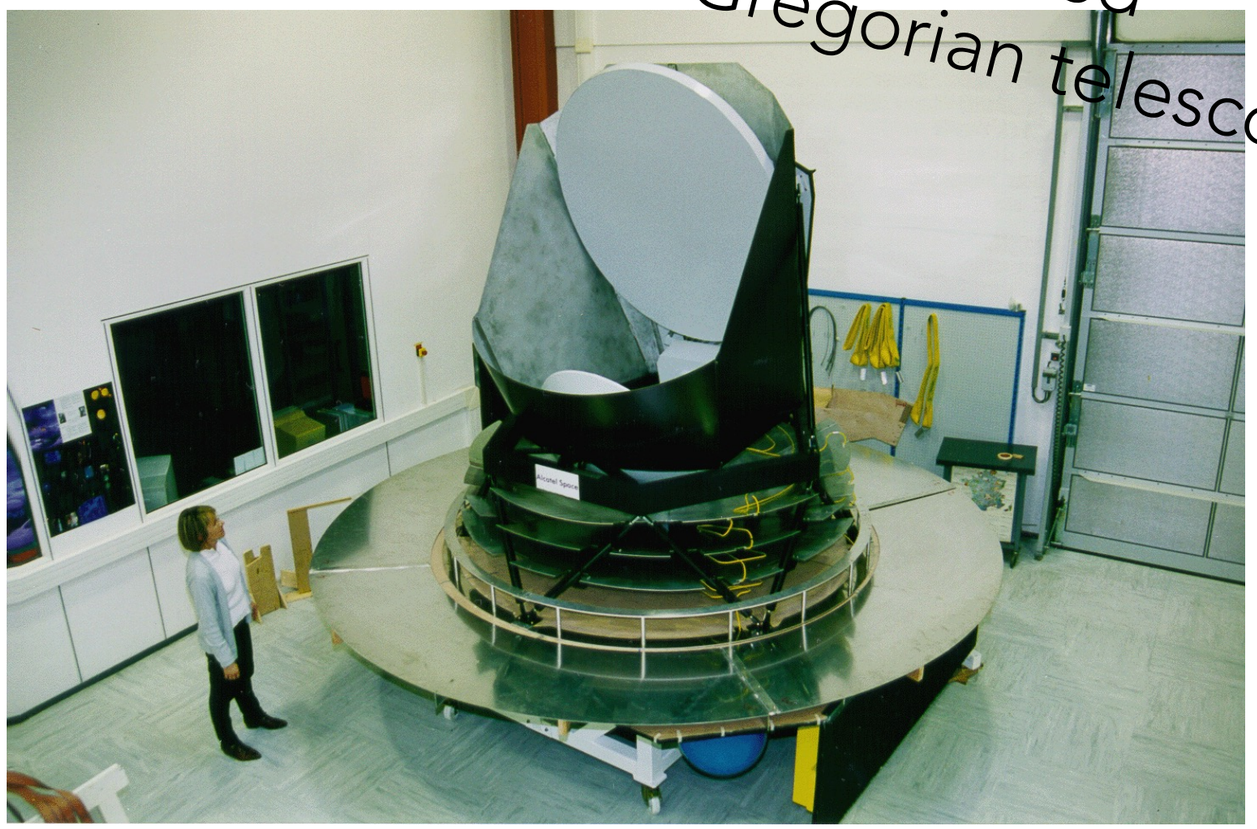




the Universe becomes transparent – atoms (H) are born

Planck : a question of temperatures !





off-axis tilted Gregorian telescope

advantage of an off-axis tilted Gregorian system
- not blocking the optical path
- compactness.

Primary mirror: 1.9 × 1.5 m, off-axis paraboloid,
Secondary mirror: 1.1 × 1.0 m, off-axis paraboloid