

Afstanden

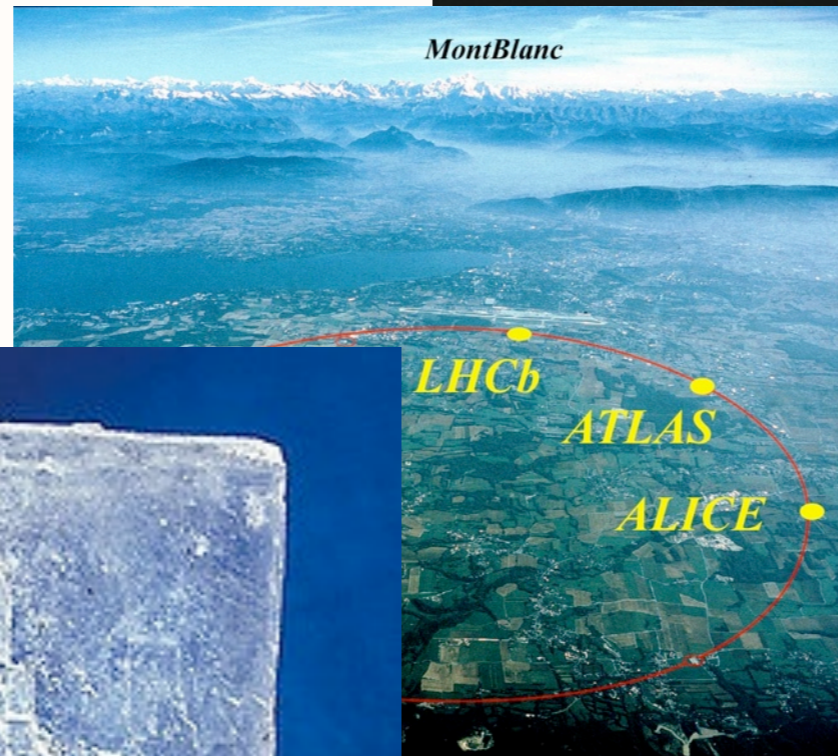
2.000.000 lichtjaar



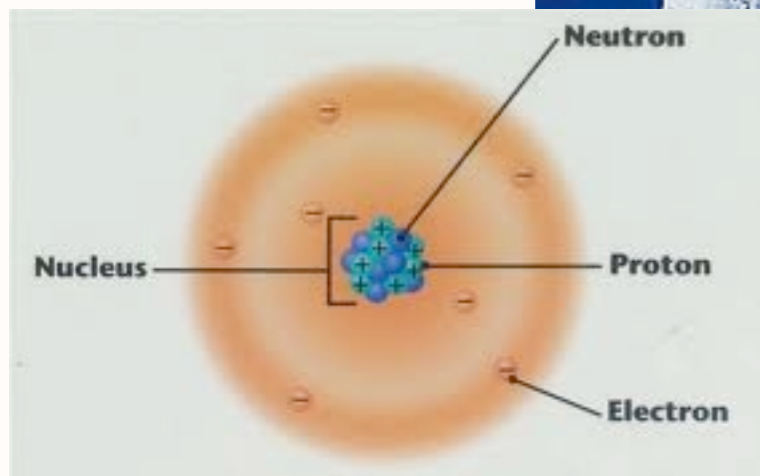
300.000 km



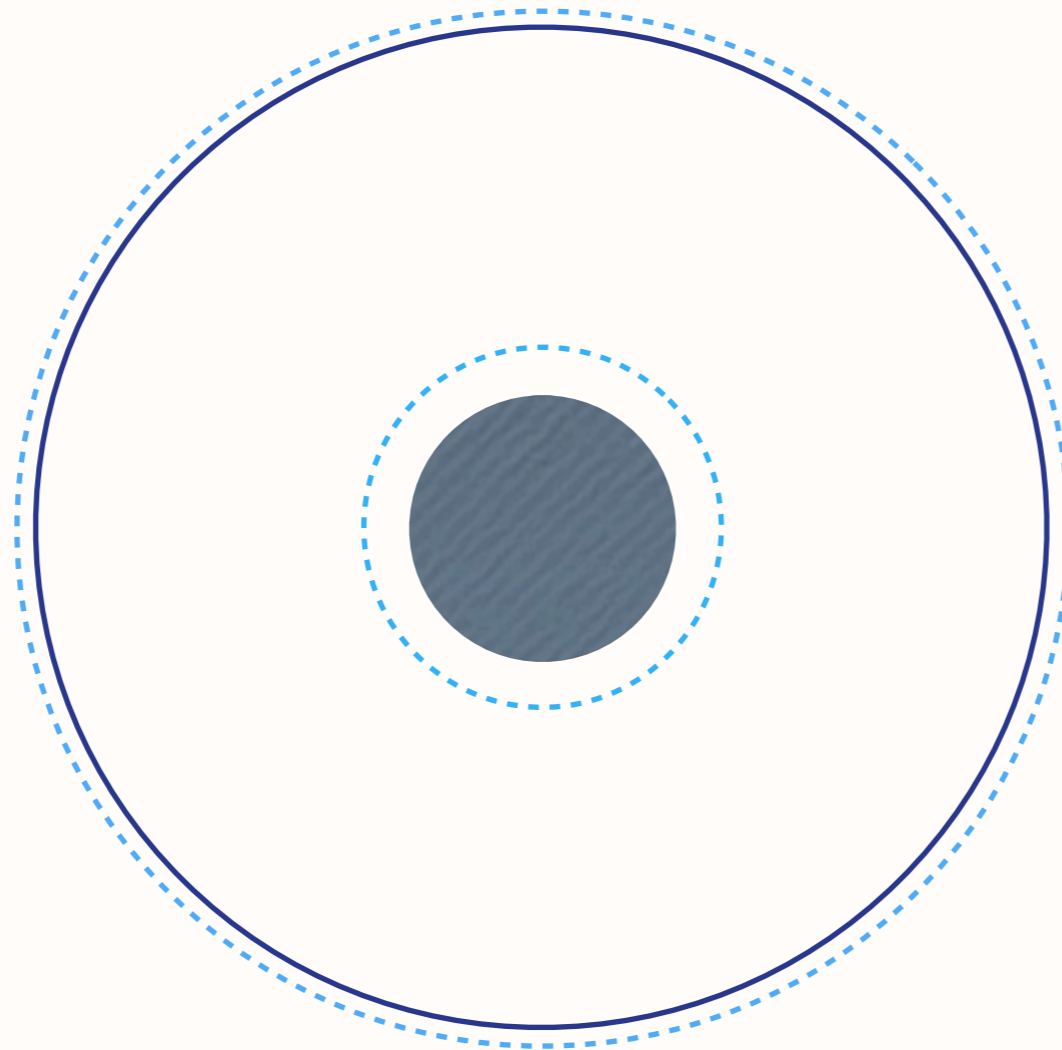
30 km



1 mm



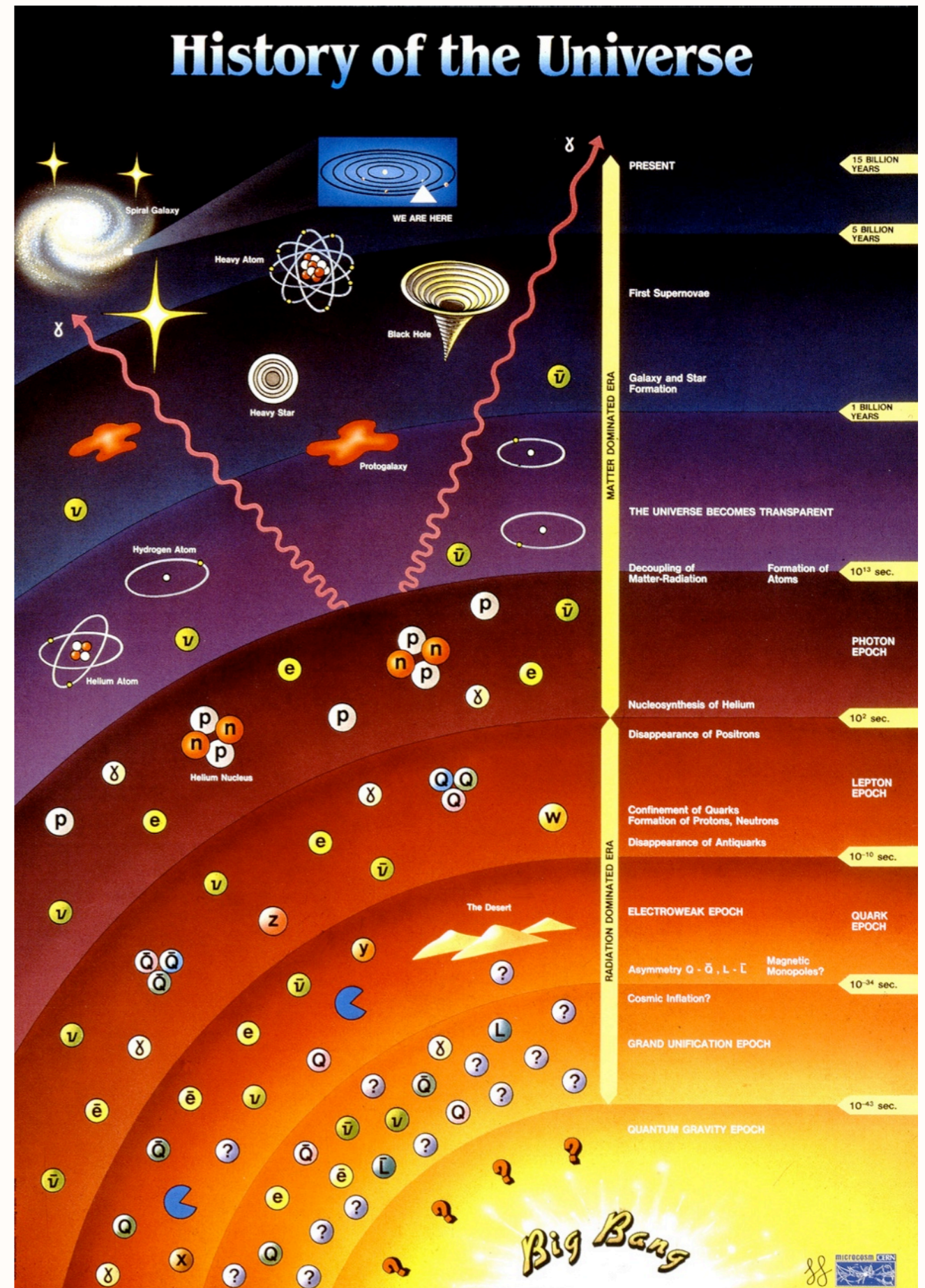
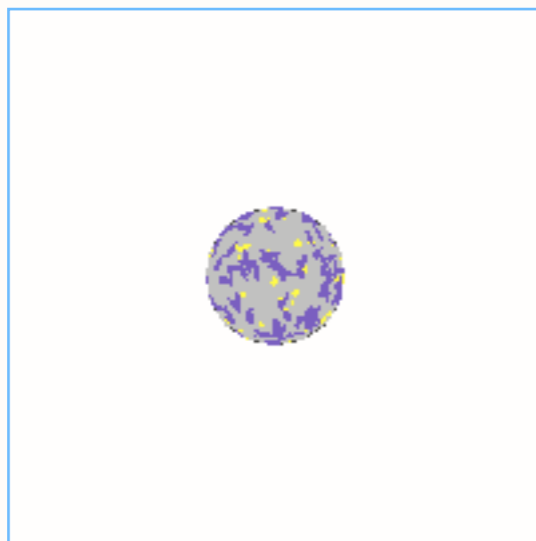
0,000.000.1 mm



$$M \sim R^3$$

$$g \sim \frac{M}{R^2} \sim R$$

Tijden



Vormen van materie beweging en transformatie in ruimte en tijd

- Behoudswetten:
 - behoud van energie, elektrische lading,
- Bewegingswetten:
 - krachtwetten (zwaartekracht, elektrische en magnetische krachten,)
- Statistische wetten:
 - gaswetten, hydrodynamica, thermodynamica,

Elementen



D. Mendeleev

PERIODIC TABLE
Atomic Properties of the Elements

Frequently used fundamental physical constants
For the most accurate values of these and other constants, visit physics.nist.gov/constants
1 second = 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of ^{133}Cs

speed of light in vacuum c 299 792 458 m s⁻¹ (exact)
Planck constant h 6.626 069 3 × 10⁻³⁴ J s ($h = h/2\pi$)
elementary charge e 1.602 176 634 × 10⁻¹⁹ C
electron mass m_e 9.109 383 56 × 10⁻³¹ kg
 $m_e c^2$ 0.5110 MeV
proton mass m_p 1.672 621 6 × 10⁻²⁷ kg
fine-structure constant α 1/137.036
Rydberg constant R_∞ 10 973 731.76 m⁻¹
 $R_\infty hc$ 3.289 842 × 10¹⁵ Hz
 $R_\infty hc$ 13.605 693 eV
Boltzmann constant k 1.380 658 × 10⁻²³ J K⁻¹

☐ Solids
☐ Liquids
☐ Gases
☐ Artificially Prepared

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Physics Laboratory
physics.nist.gov
 Standard Reference Data Group
www.nist.gov/srd

Group 1 IA	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 ¹ H Hydrogen 1.007 94 13.596 4												5 ¹⁰ B Boron 10.811 14.323 8	6 ¹² C Carbon 12.010 7 14.534 1	7 ¹⁴ N Nitrogen 14.006 4 14.534 1	8 ¹⁶ O Oxygen 15.999 4 14.534 1	9 ¹⁹ F Fluorine 18.998 403 2 17.422 8	10 ²⁰ Ne Neon 20.179 7 21.564 5
2 ⁷ Li Lithium 6.941 14.323 8	3 ⁹ Be Beryllium 9.012 182 14.323 8											11 ²³ Na Sodium 22.989 769 3 14.323 8	12 ²⁴ Mg Magnesium 24.305 0 14.323 8				
3 ¹¹ Na Sodium 22.989 769 3 14.323 8	4 ¹² Mg Magnesium 24.305 0 14.323 8	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
4 ¹⁹ K Potassium 39.098 3 14.323 8	5 ²⁰ Ca Calcium 40.078 14.323 8	6 ²¹ Sc Scandium 44.955 910 14.323 8	7 ²² Ti Titanium 47.867 14.323 8	8 ²³ V Vanadium 50.941 5 14.323 8	9 ²⁴ Cr Chromium 51.996 1 14.323 8	10 ²⁵ Mn Manganese 54.938 045 14.323 8	11 ²⁶ Fe Iron 55.845 14.323 8	12 ²⁷ Co Cobalt 58.933 200 14.323 8	13 ²⁸ Ni Nickel 58.693 4 14.323 8	14 ²⁹ Cu Copper 63.546 14.323 8	15 ³⁰ Zn Zinc 65.38 14.323 8	16 ³¹ Ga Gallium 69.723 14.323 8	17 ³² Ge Germanium 72.64 14.323 8	18 ³³ As Arsenic 74.921 60 14.323 8	19 ³⁴ Se Selenium 78.96 14.323 8	20 ³⁵ Br Bromine 79.904 14.323 8	21 ³⁶ Kr Krypton 83.798 14.323 8
5 ³⁷ Rb Rubidium 85.4678 14.323 8	6 ³⁸ Sr Strontium 87.62 14.323 8	7 ³⁹ Y Yttrium 88.905 85 14.323 8	8 ⁴⁰ Zr Zirconium 91.224 14.323 8	9 ⁴¹ Nb Niobium 92.906 38 14.323 8	10 ⁴² Mo Molybdenum 95.94 14.323 8	11 ⁴³ Tc Technetium (98) 98.906 254 14.323 8	12 ⁴⁴ Ru Ruthenium 101.07 14.323 8	13 ⁴⁵ Rh Rhodium 102.905 50 14.323 8	14 ⁴⁶ Pd Palladium 106.42 14.323 8	15 ⁴⁷ Ag Silver 107.868 2 14.323 8	16 ⁴⁸ Cd Cadmium 112.411 14.323 8	17 ⁴⁹ In Indium 114.818 14.323 8	18 ⁵⁰ Sn Tin 118.710 14.323 8	19 ⁵¹ Sb Antimony 121.760 14.323 8	20 ⁵² Te Tellurium 127.60 14.323 8	21 ⁵³ I Iodine 126.904 47 14.323 8	22 ⁵⁴ Xe Xenon 131.293 14.323 8
6 ⁵⁵ Cs Cesium 132.905 45 14.323 8	7 ⁵⁶ Ba Barium 137.327 14.323 8		8 ⁷² Hf Hafnium 178.49 14.323 8	9 ⁷³ Ta Tantalum 180.947 9 14.323 8	10 ⁷⁴ W Tungsten 183.84 14.323 8	11 ⁷⁵ Re Rhenium 186.207 14.323 8	12 ⁷⁶ Os Osmium 190.23 14.323 8	13 ⁷⁷ Ir Iridium 192.222 14.323 8	14 ⁷⁸ Pt Platinum 195.078 14.323 8	15 ⁷⁹ Au Gold 196.966 55 14.323 8	16 ⁸⁰ Hg Mercury 200.59 14.323 8	17 ⁸¹ Tl Thallium 204.383 3 14.323 8	18 ⁸² Pb Lead 207.2 14.323 8	19 ⁸³ Bi Bismuth 208.980 38 14.323 8	20 ⁸⁴ Po Polonium (209) 209 14.323 8	21 ⁸⁵ At Astatine (210) 210 14.323 8	22 ⁸⁶ Rn Radon (222) 222 14.323 8
7 ⁸⁷ Fr Francium (223) 223 14.323 8	8 ⁸⁸ Ra Radium (226) 226 14.323 8		9 ¹⁰⁴ Rf Rutherfordium (261) 261 14.323 8	10 ¹⁰⁵ Db Dubnium (262) 262 14.323 8	11 ¹⁰⁶ Sg Seaborgium (266) 266 14.323 8	12 ¹⁰⁷ Bh Bohrium (264) 264 14.323 8	13 ¹⁰⁸ Hs Hassium (277) 277 14.323 8	14 ¹⁰⁹ Mt Meitnerium (268) 268 14.323 8	15 ¹¹⁰ Uun Ununium (281) 281 14.323 8	16 ¹¹¹ Uuu Ununium (272) 272 14.323 8	17 ¹¹² Uub Ununium (285) 285 14.323 8		18 ¹¹⁴ Uuq Ununquadium (289) 289 14.323 8		19 ¹¹⁶ Uuh Ununhexium (292) 292 14.323 8		
		Lanthanides: 57 ¹³⁹ La Lanthanum 138.905 5 58 ¹⁴⁰ Ce Cerium 140.907 65 59 ¹⁴¹ Pr Praseodymium 140.907 65 60 ¹⁴² Nd Neodymium 144.24 61 ¹⁴⁴ Pm Promethium (145) 62 ¹⁵⁰ Sm Samarium 150.36 63 ¹⁵² Eu Europium 151.964 64 ¹⁵⁷ Gd Gadolinium 157.25 65 ¹⁵⁸ Tb Terbium 158.925 34 66 ¹⁶² Dy Dysprosium 162.500 67 ¹⁶³ Ho Holmium 164.930 32 68 ¹⁶⁷ Er Erbium 167.259 69 ¹⁶⁹ Tm Thulium 168.934 21 70 ¹⁷³ Yb Ytterbium 173.04 71 ¹⁷⁵ Lu Lutetium 174.967															
		Actinides: 89 ²²⁷ Ac Actinium 227 90 ²³² Th Thorium 232.038 1 91 ²³¹ Pa Protactinium 231.036 8 92 ²³⁸ U Uranium 238.028 91 93 ²³⁷ Np Neptunium 237 94 ²⁴⁴ Pu Plutonium 244 95 ²⁴³ Am Americium 243 96 ²⁴⁷ Cm Curium 247 97 ²⁴⁷ Bk Berkelium 247 98 ²⁵¹ Cf Californium 251 99 ²⁵² Es Einsteinium 252 100 ²⁵⁷ Fm Fermium 257 101 ²⁵⁸ Md Mendelevium 258 102 ²⁵⁹ No Nobelium 259 103 ²⁶² Lr Lawrencium 262															

Atomic Number
 Symbol
 Name
 Atomic Weight
 Ground-state Configuration
 Ionization Energy (eV)

58 ¹⁴⁰Ce
 Cerium
 140.116
 [Xe]4f15d1s2
 5.538 7

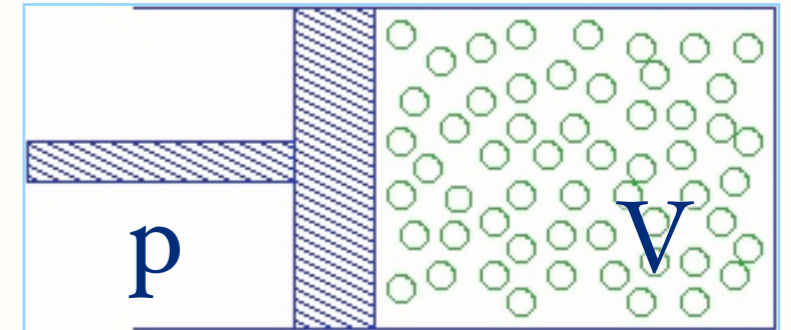
1Based upon ^{12}C . () indicates the mass number of the most stable isotope.
 For a description of the data, visit physics.nist.gov/data
 NIST SP 966 (September 2003)

atomaire bouwstenen van de chemie

Atomen en gassen

Gaswet:

$$pV = N k T$$



→ bij dezelfde (p, T) is het
aantal deeltjes per volume-eenheid
voor verschillende gassen gelijk

Loschmidt (1865):

$$N_0 = 2,687 \times 10^{22} \text{ deeltjes/liter}$$

bij 273 K en 1 atm

of $k = 1,381 \times 10^{-23} \text{ J/K}$
(constante van Boltzmann)

Atoommassa's

	relatief
H: 1,68	1
He: 6,65	4
N: 23,3	14
O: 26,6	16
Fe: 92,3	56
U: 399,7	238

$\times 10^{-24} \text{ g}$

Atomaire afmetingen

van der Waals:

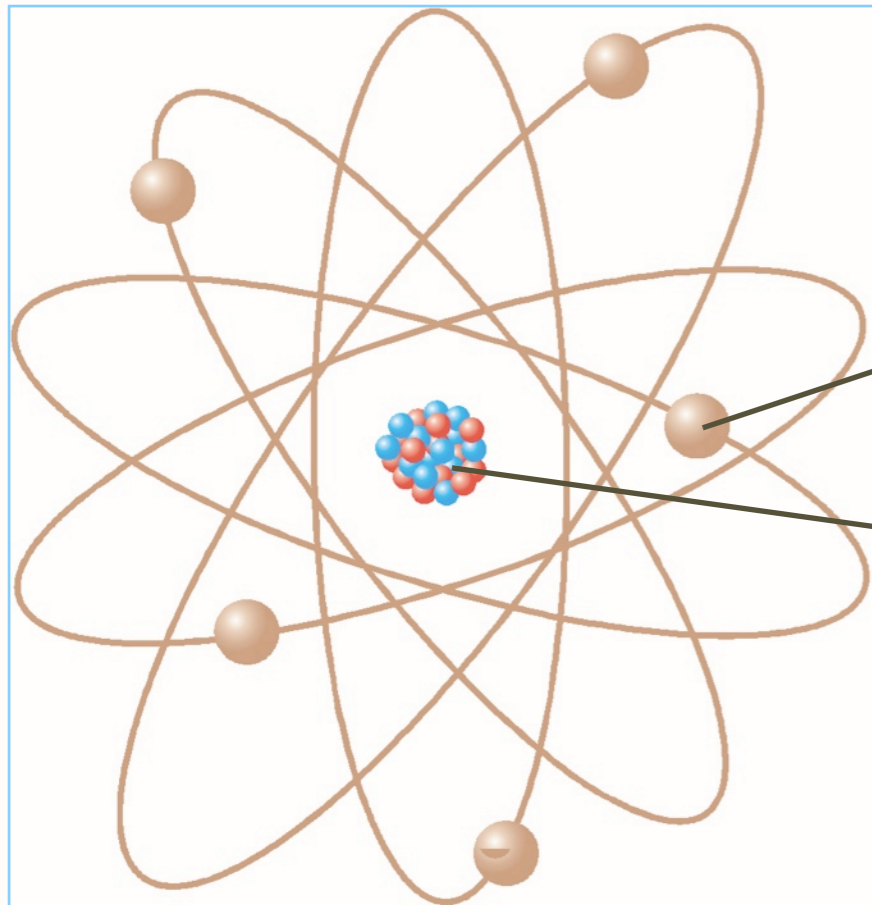
$$p (V - Nb) = N k T$$

$$d(\text{H}) = 0,11 \text{ nm}$$

$$d(\text{He}) = 0,06 \text{ nm}$$

$$d(\text{O}) = 0,15 \text{ nm}$$

$$d(\text{Fe}) = 0,25 \text{ nm}$$



elektron
lading $-e$

kern
lading Ze
 Z = aantal protonen
atoomgetal
 A = aantal kerndeeltjes



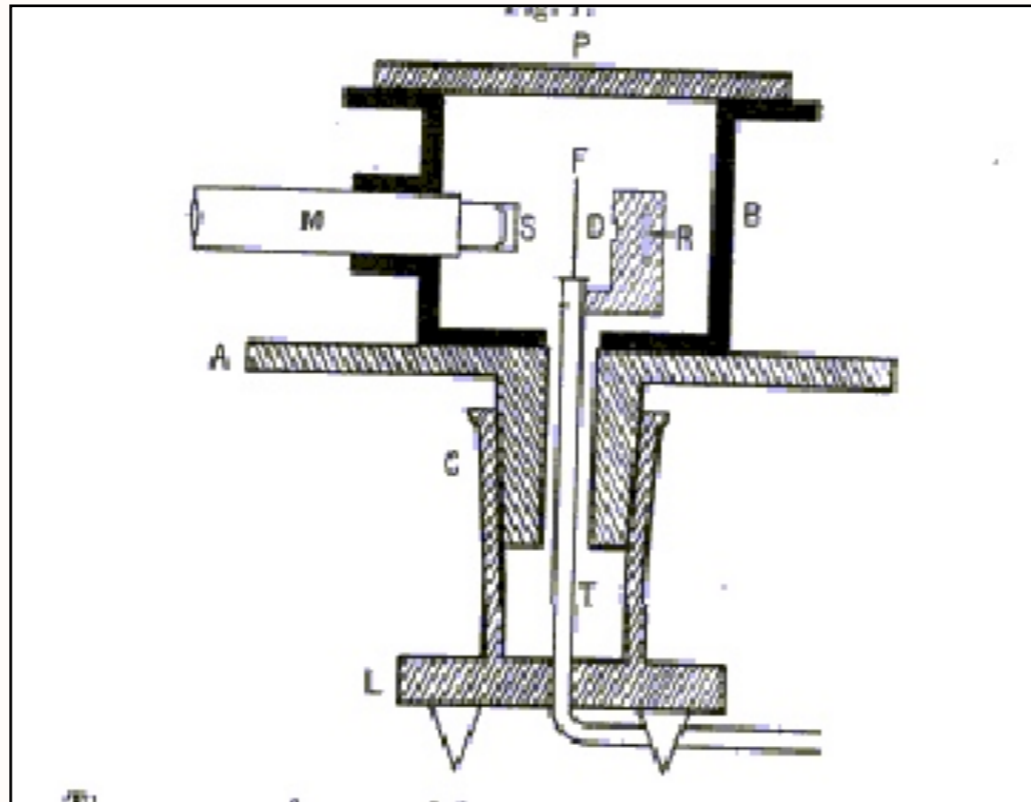
E. Rutherford



H. Geiger

$$e = 1,602 \times 10^{-19} \text{ C}$$

Het Geiger -Rutherford experiment



R - α -radioactieve bron

F - folie (goud)

S - scintillatorplaatje

M - microscoop

Straling

Zwart lichaam: perfecte absorptie en emissie



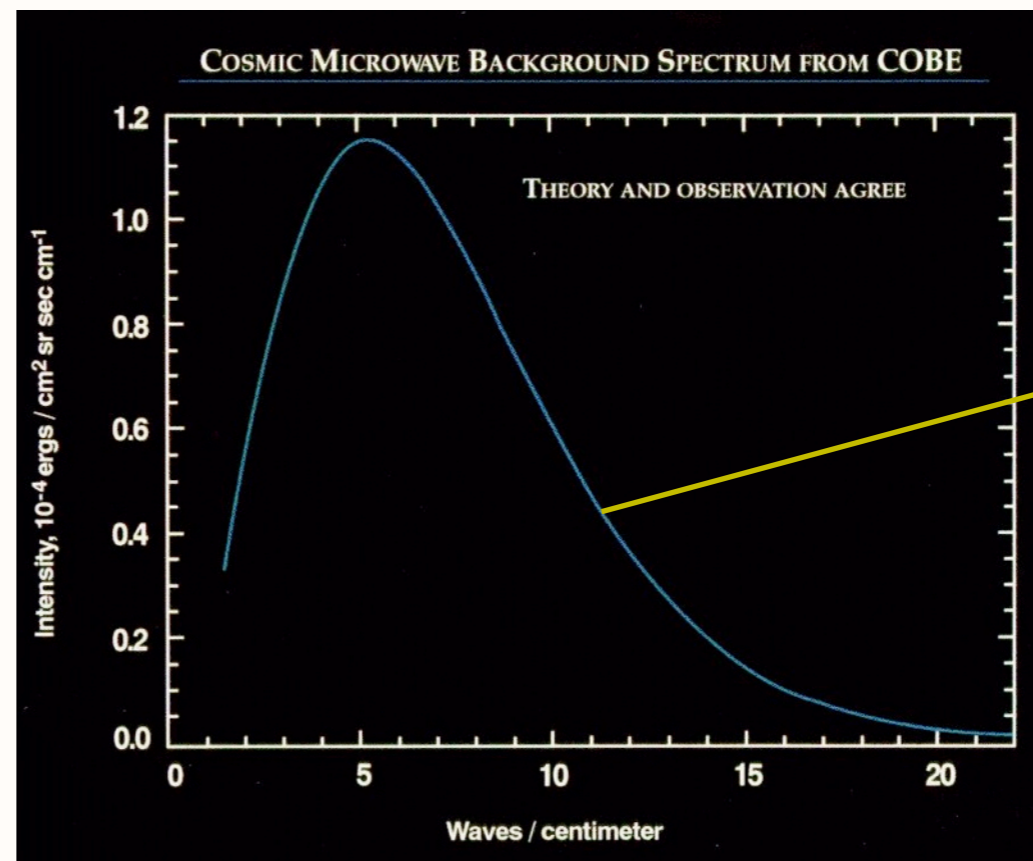
M. Planck

Planck/Einstein:
fotonen

$$E = h f = h c q$$

$$h = 6,63 \times 10^{-34} \text{ Js}$$

Intensiteit



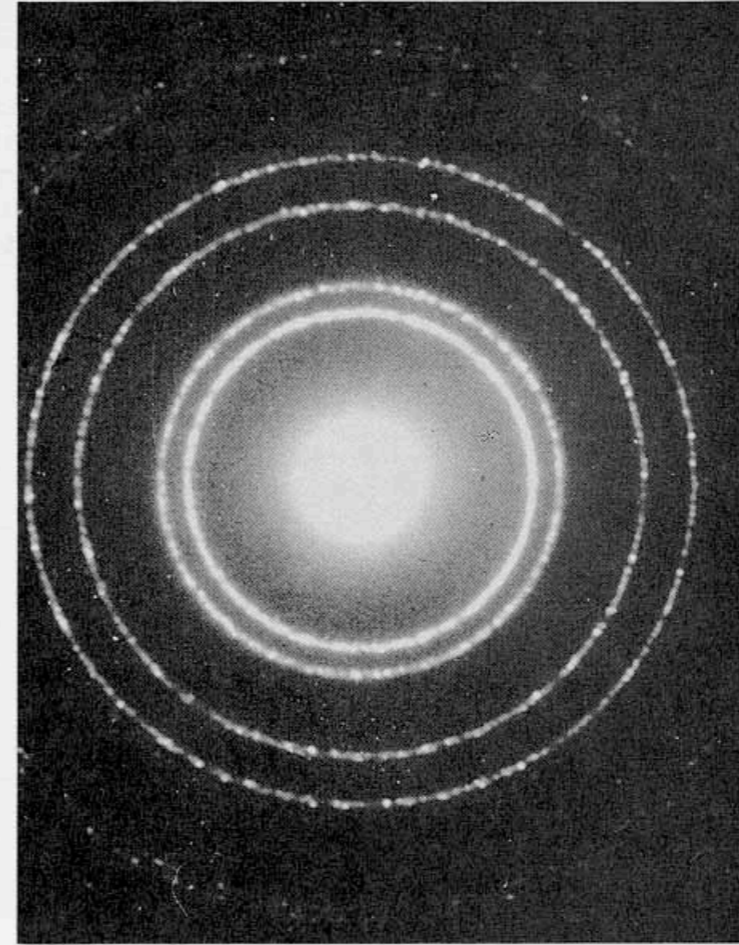
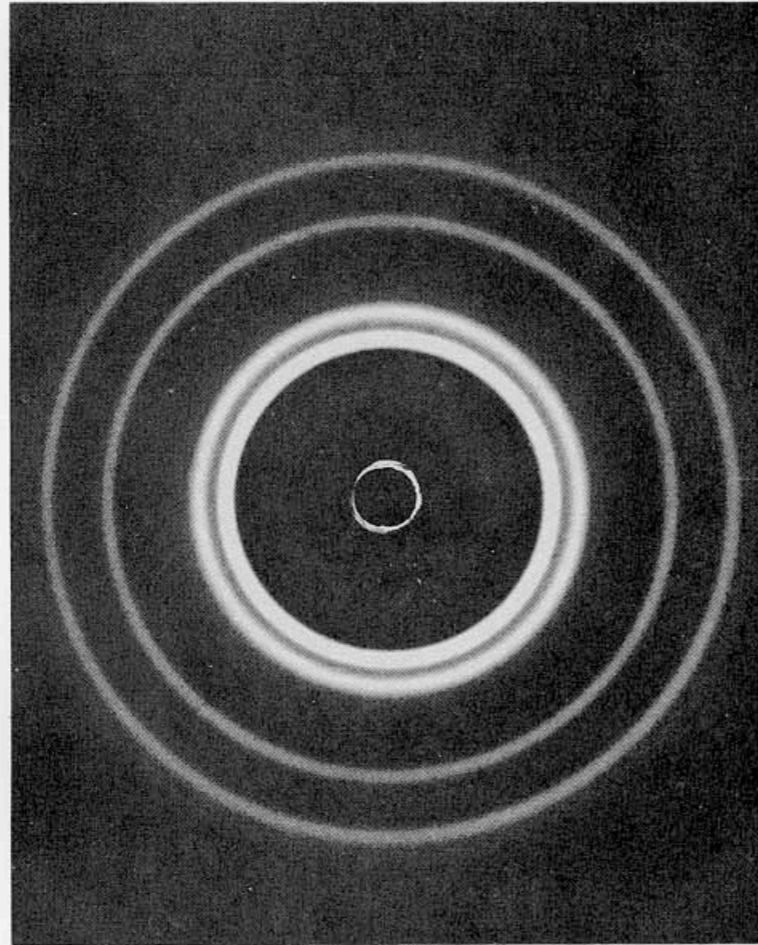
$$T = 2,73 \text{ K}$$

Golfgetal

$$q = \text{aantal golven/cm} \\ = 1 / \lambda$$

Materiegolven

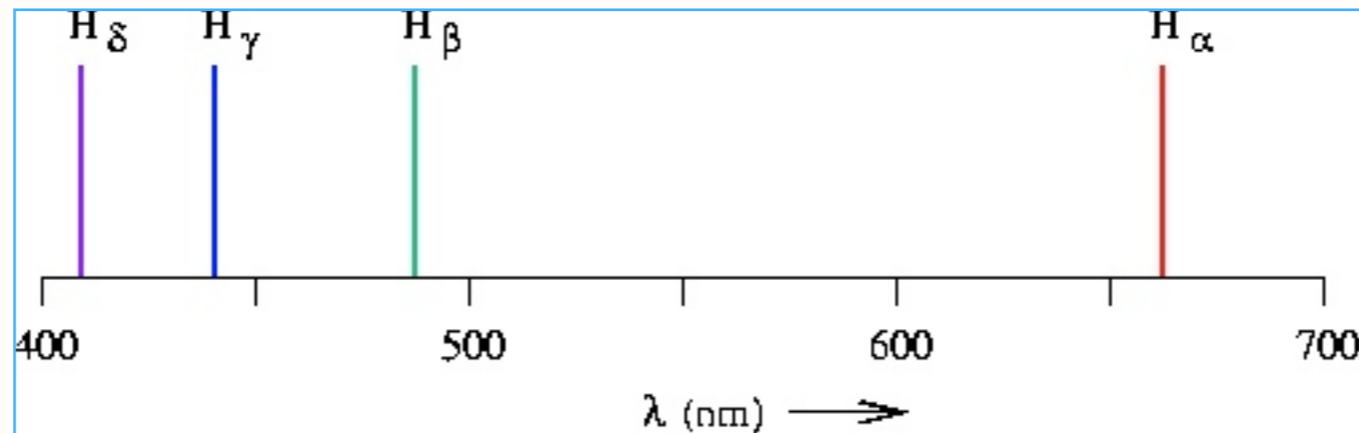
The diffraction pattern on the left was made by a beam of x rays passing through thin aluminum foil. The diffraction pattern on the right was made by a beam of electrons passing through the same foil.



Röntgenstraling

elektronen

Atoomspectra

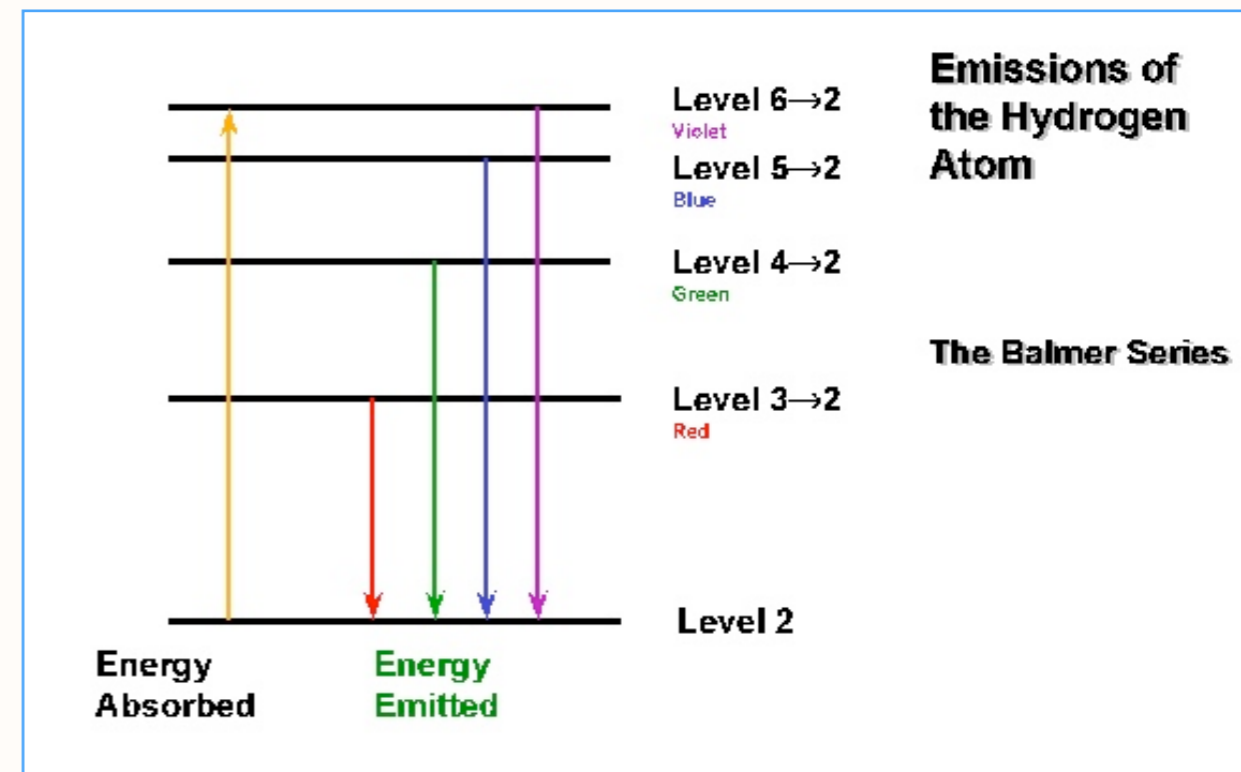


N. Bohr

Waterstofspectrum: Balmer lijnen

Energieniveaus van het elektron
in het waterstofatoom

$$2 \pi r = n \lambda$$





A. Einstein

De lichtsnelheid
 $c = 300\,000\text{ km/sec}$
is een universele
constante

Relativiteit

Equivalentie van massa en energie:

$$E = \gamma m c^2$$

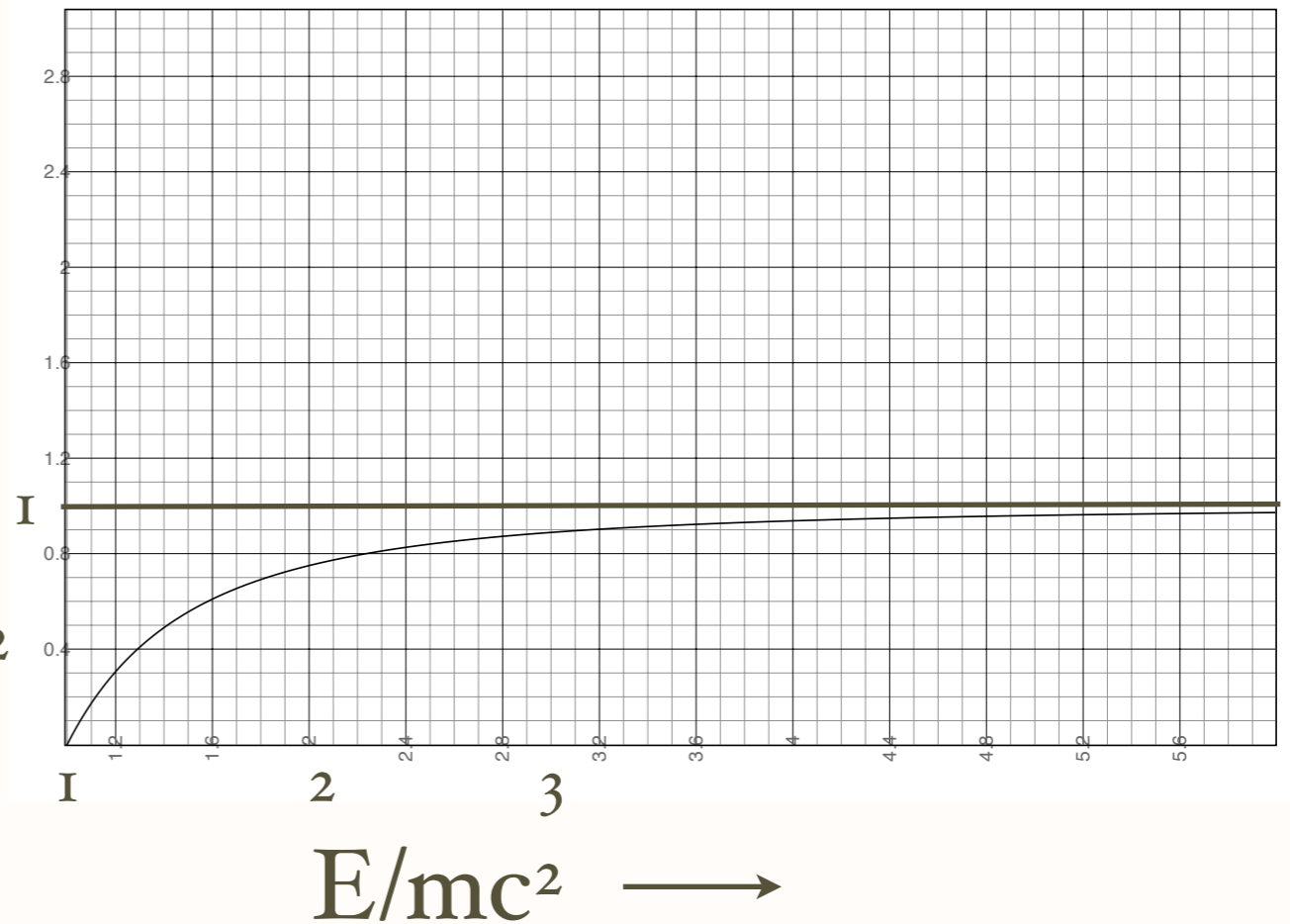
Tijddilatatie:
bewegende klokken lopen langzamer

$$\Delta t = \gamma \Delta \tau$$

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

$$\frac{v^2}{c^2} = 1 - \frac{m^2 c^4}{E^2}$$

↑
 v^2/c^2

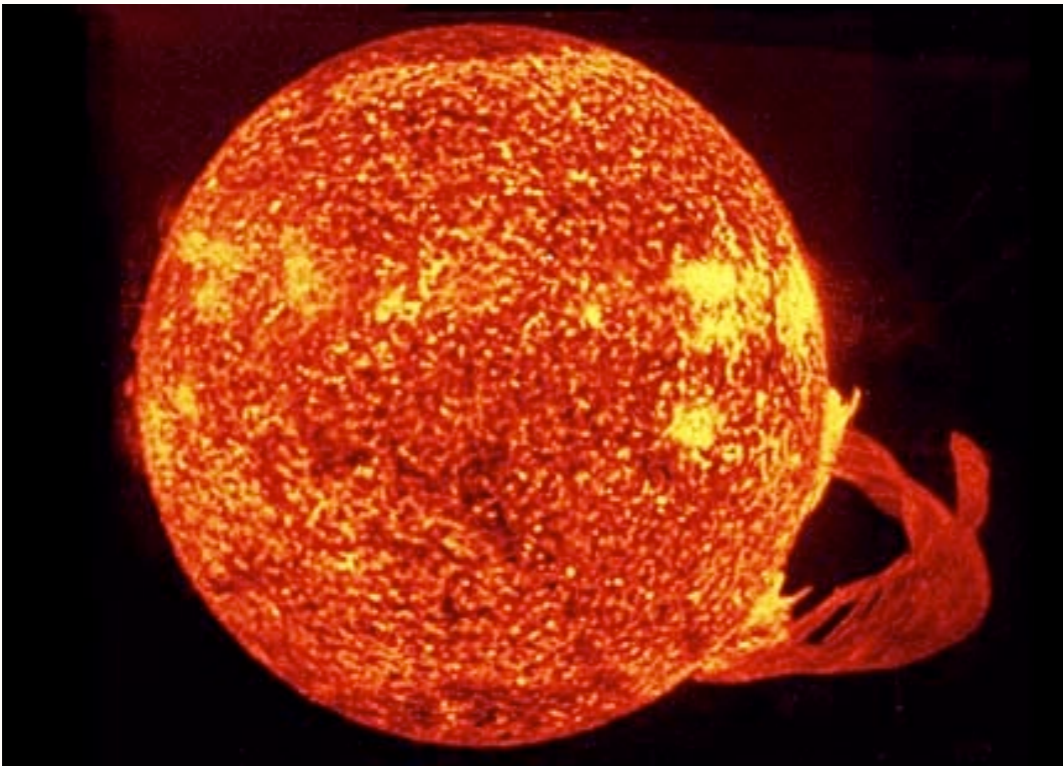


Lichtsnelheid = bovengrens

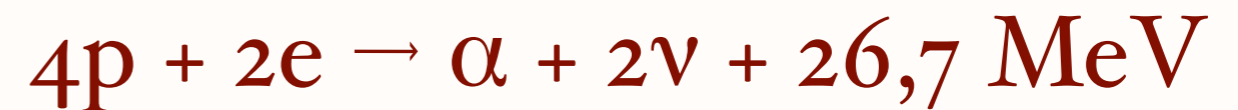
$v = 0$:

rustenergie $E_0 = m c^2$

Bij transformaties van de materie kan massa in energie worden omgezet, en omgekeerd.

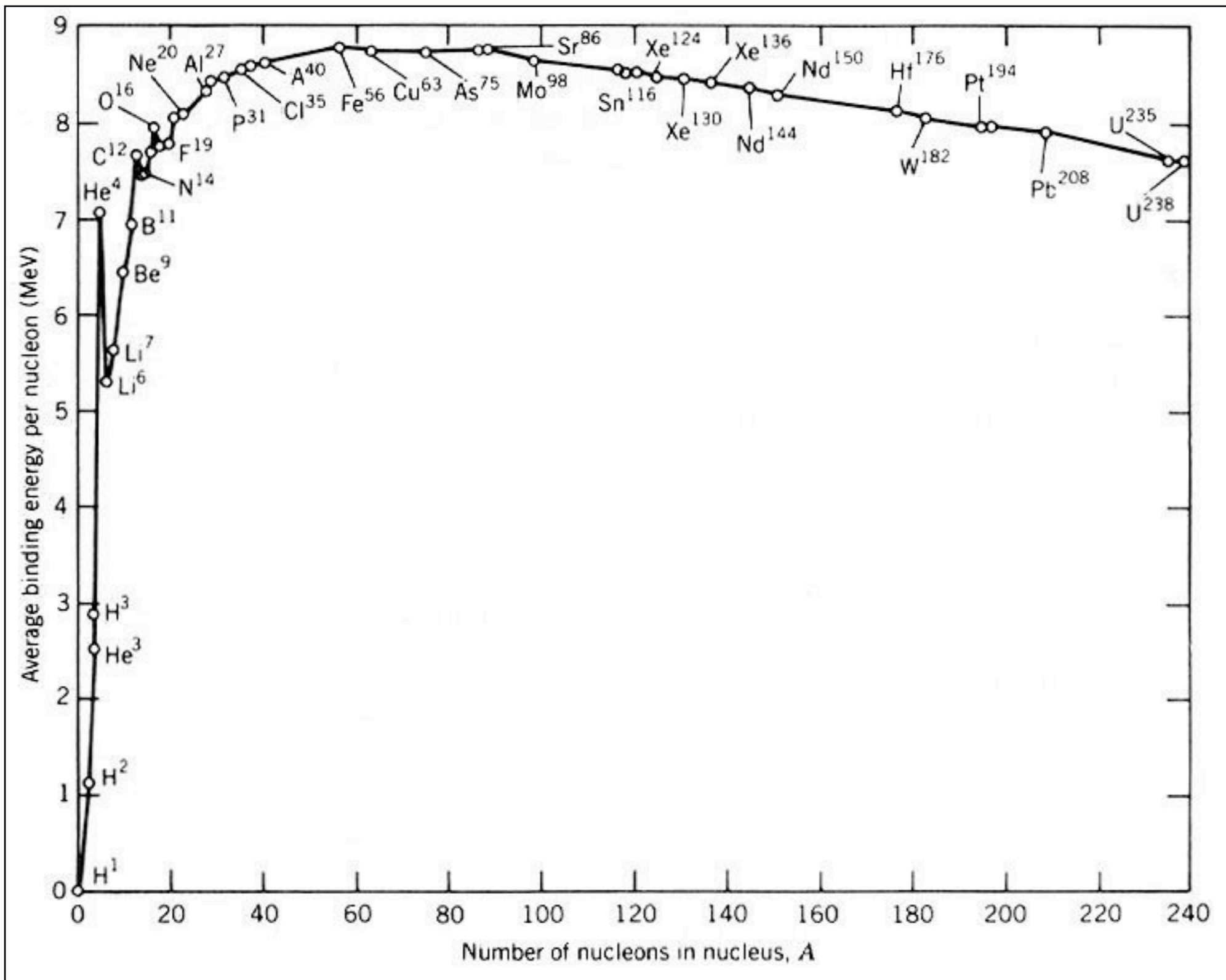


Kernfusie:



Onze zon zet iedere seconde 570 miljard kilogram waterstof om in helium en verliest alleen daardoor 4,5 miljard kilogram aan massa

(De totale massa van de zon is $1.988 \times 10^{30} \text{ kg}$)



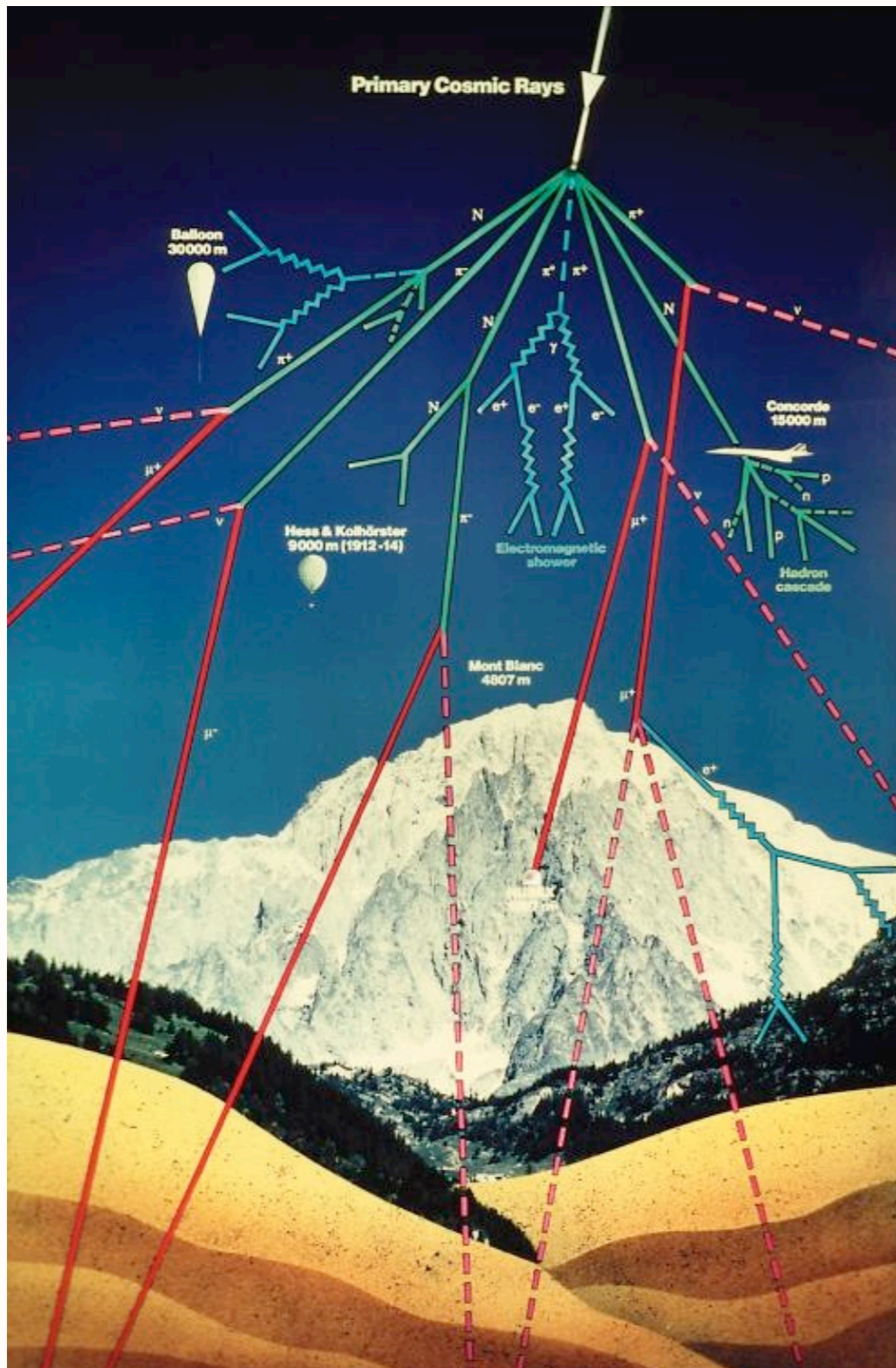
M. Goeppert -
Mayer

Bindingsenergie van kernen

Natuurlijke bronnen van hoog-energetische deeltjes

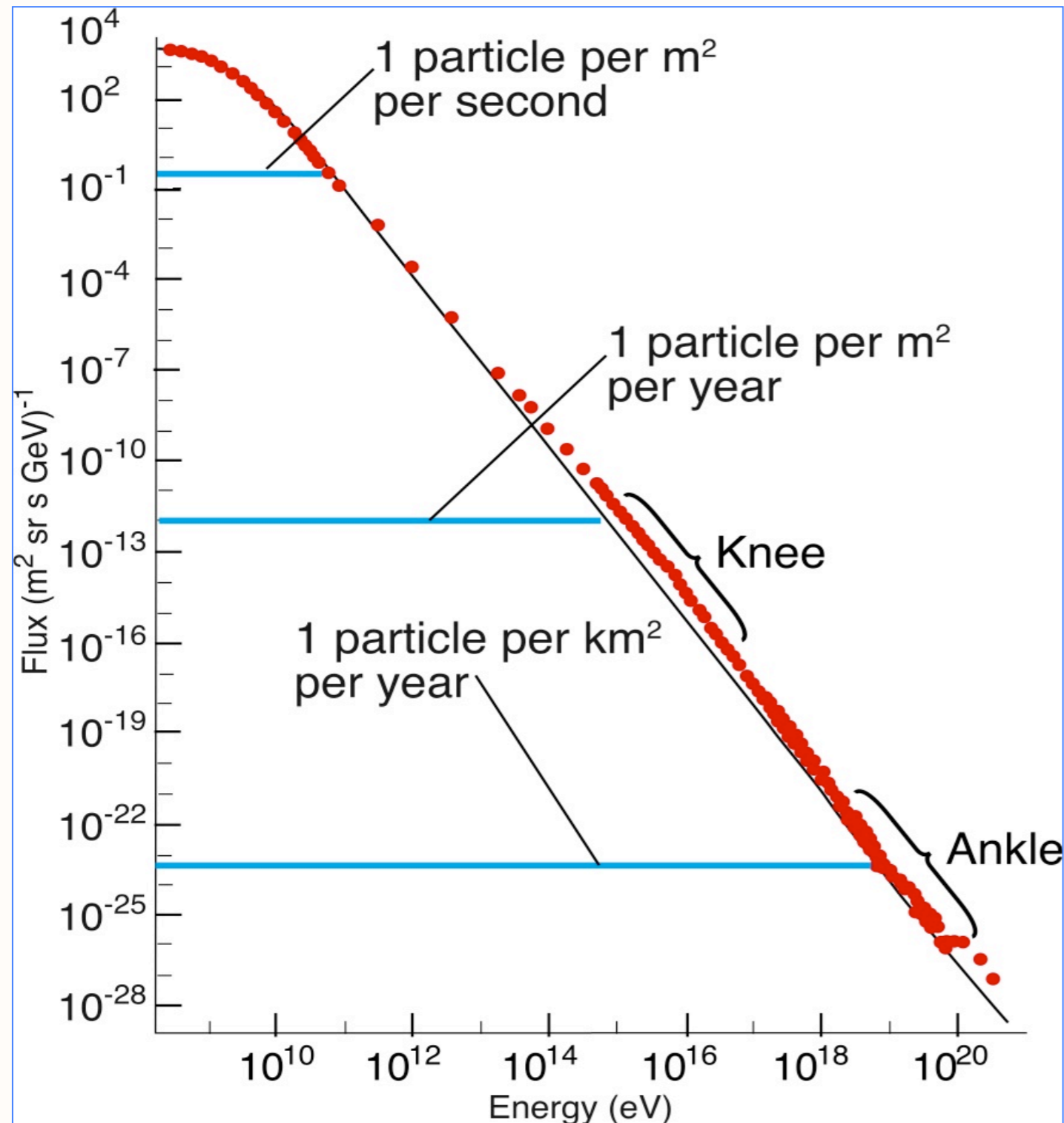
Kosmische straling:
ioniserende straling van
buiten de atmosfeer

- secondaire μ -deeltjes:
 $c \tau = 660 \text{ m}$
- produkt van botsingen
tussen kerndeeltjes



V. Hess





Energiespectrum
van de primaire
kosmische straling:

aantal deeltjes
per vierkante meter
per seconde
met energie tussen
 10^8 en 10^{20} eV
dat de atmosfeer
binnendringt