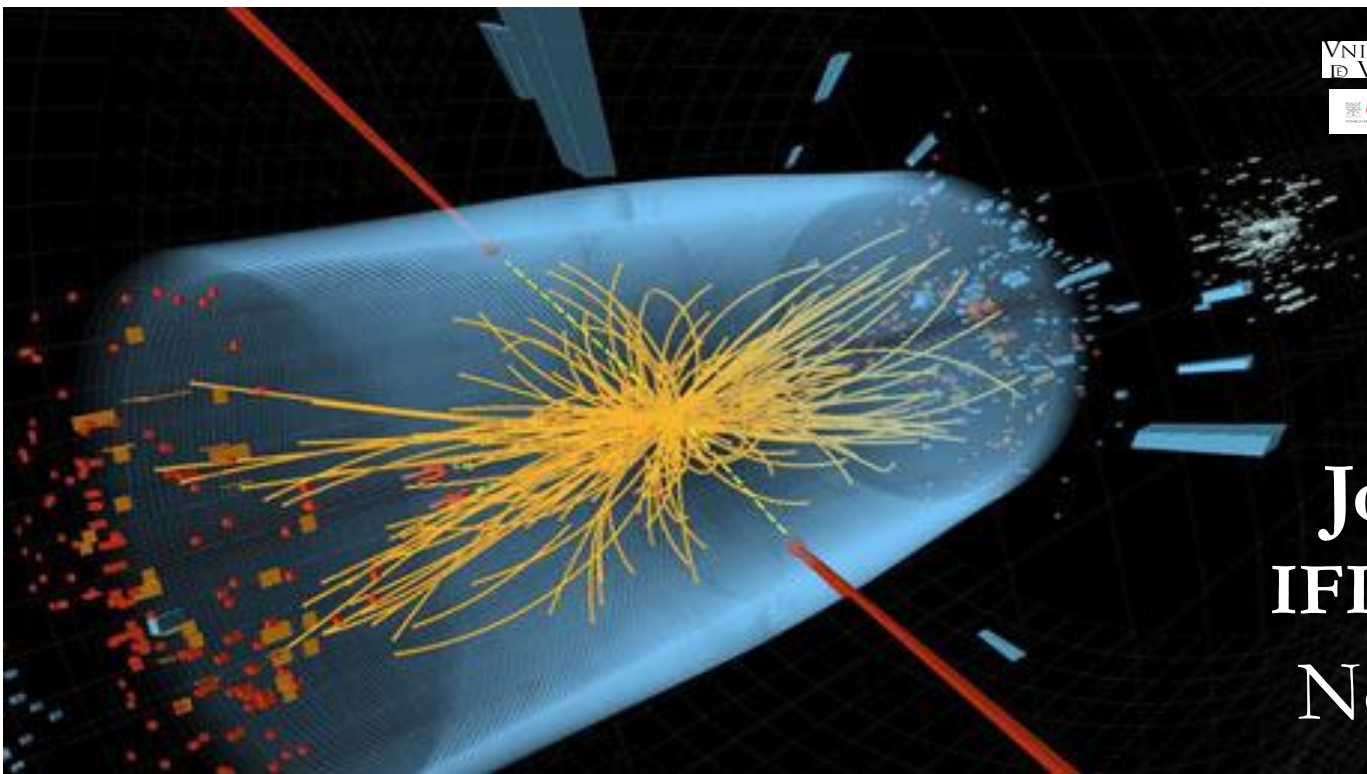




REIAL ACADÈMIA DE MEDICINA
I CIÈNCIES AFINS
DE LA COMUNITAT VALENCIANA



FRONTERAS DEL CONOCIMIENTO: PARTICULAS, FISICA MEDICA, COSMOLOGIA



José Bernabéu
IFIC-Univ. Valencia
Noviembre 2015

THE FRONTIERS

➤ The advance of knowledge in Science is measured by

the degree of synthesis,
the explanation of novel observed phenomena,
the unification which allows the increase of the validity domain, ...

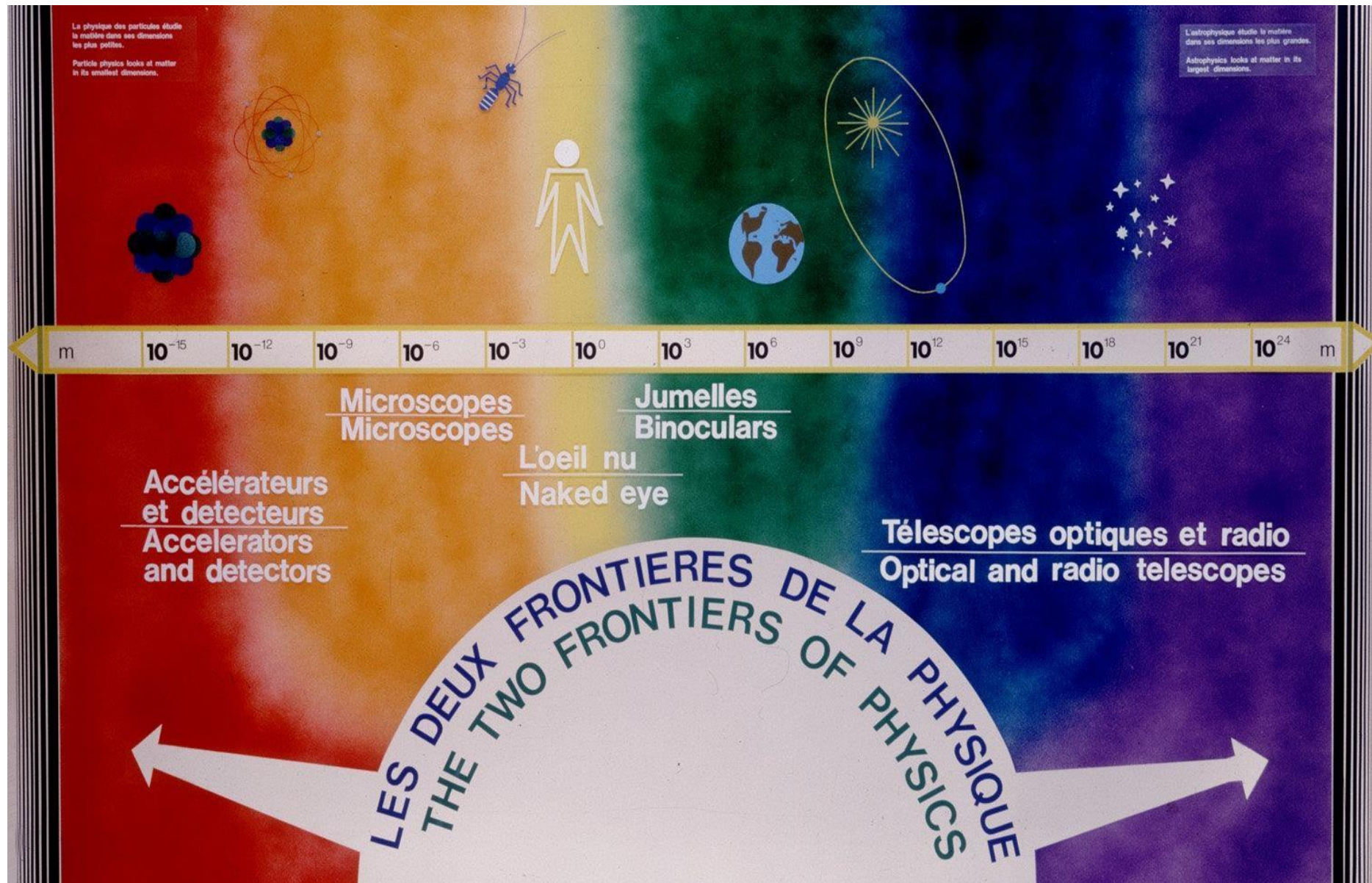
➤ Novel open problems not glimpsed before appear, and its resolution leads to a deeper understanding and the formulation of new questions.

➤ I do not have a linear vision of the advance of Science, on the contrary there are many frontiers.



"The advance of knowledge generates and increases the number of questions in the frontiers"

LAS DOS FRONTERAS DE LA FÍSICA

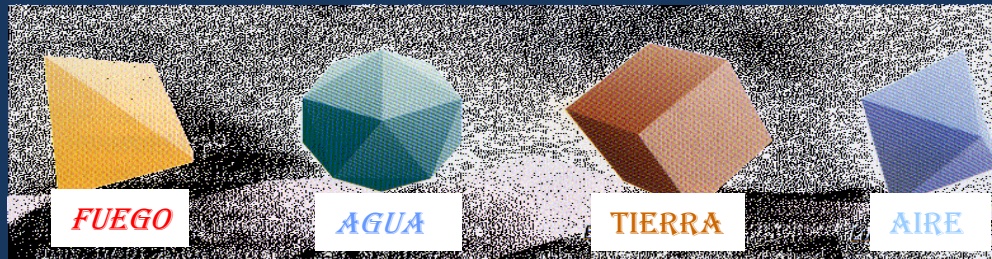


Filosofía natural de los Griegos

■ Empédocles (500-430 B. C.)

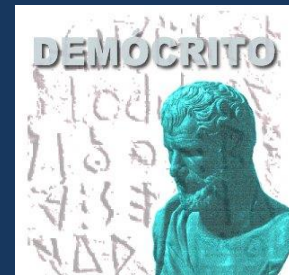


■ Platón (427-347 B.C.)



■ Demócrito (460-371 B. C.)

- Átomos: diferentes formas y pesos



■ Aristóteles (385-347 B. C.)

- Añadió a los cuatro elementos un quinto: el éter o quintaesencia, que formaba las estrellas, mientras que los otros cuatro formaban las sustancias terrestres.



LOS ELEMENTOS EN EL SIGLO XIX: MENDELEEV

		Periodic Table of the Elements																				
		Grupos																				
Periodos	1 IA 11A	2 IIA 2A															13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
	1 H Hydrogen 1.008	2 He Helium 4.003															5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
	3 Li Lithium 6.941	4 Be Beryllium 9.012															13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
	11 Na Sodium 22.990	12 Mg Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80				
	19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29				
	37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018				
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown					
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]											
		Lanthanide Series																				
		Actinide Series																				
		Alkali Metal																				
		Alkaline Earth																				
		Transition Metal																				
		Semimetal																				
		Nonmetal																				
		Basic Metal																				
		Halogen																				
		Noble Gas																				
		Lanthanide																				
		Actinide																				

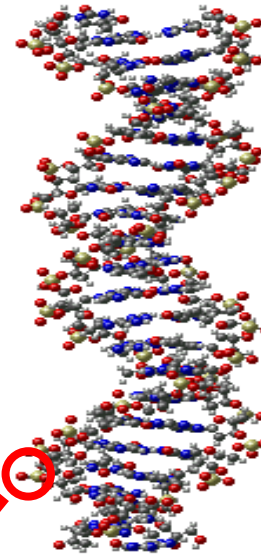
I. PARTICULAS

A dark blue L-shaped graphic element is positioned on the right side of the slide. It consists of a vertical bar on the right and a horizontal bar at the bottom, meeting at a right angle. The horizontal bar has a diagonal cut on its left end, and the vertical bar has a diagonal cut on its top end.

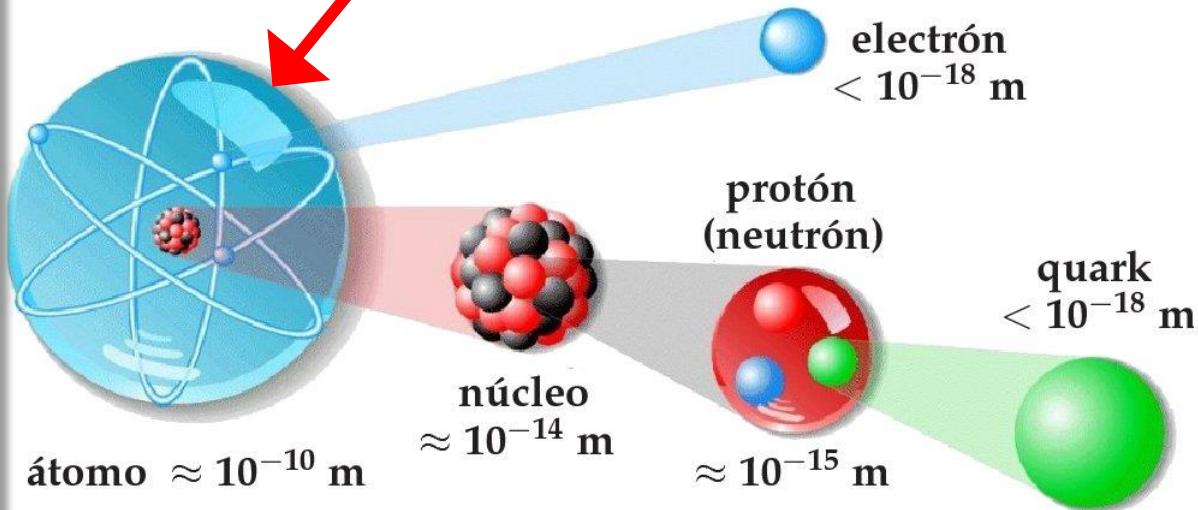
CONSTITUYENTES DE LA MATERIA



Estructura de la materia



molecula



$\leq 0,01 \text{ m}$
Crystal
 $1/10.000.000$

10^{-9} m
Molecule
 $1/10$

10^{-10} m
Atom
 $1/10.000$

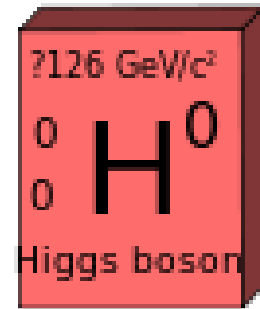
10^{-14} m
Nucleus
 $1/10$

10^{-15} m
Proton
 $1/1.000$

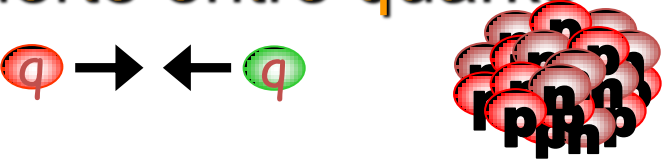
$< 10^{-18} \text{ m}$
Elektron,
Quark

PARTÍCULAS ELEMENTALES

Tres generaciones de la materia (fermiones)				
	I	II	III	
masa →	2.4 MeV	1.27 GeV	171.2 GeV	0
carga →	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0
espín →	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
nombre →	u arriba	c encanto	t cima	γ fotón
Quarks	4.8 MeV $-\frac{1}{3}$ $\frac{1}{2}$ d abajo	104 MeV $-\frac{1}{3}$ $\frac{1}{2}$ s extraño	4.2 GeV $-\frac{1}{3}$ $\frac{1}{2}$ b fondo	0 0 1 g gluón
	<2.2 eV 0 $\frac{1}{2}$ ν_e neutrino electrónico	<0.17 MeV 0 $\frac{1}{2}$ ν_μ neutrino muónico	<15.5 MeV 0 $\frac{1}{2}$ ν_τ neutrino tauónico	91.2 GeV 0 1 Z^0 bosón Z
	0.511 MeV -1 $\frac{1}{2}$ e electrón	105.7 MeV -1 $\frac{1}{2}$ μ muón	1.777 GeV -1 $\frac{1}{2}$ τ tauón	80.4 GeV ± 1 1 $W^\pm$ bosón W
Leptones				
				Bosones de gauge



LAS FUERZAS FUNDAMENTALES

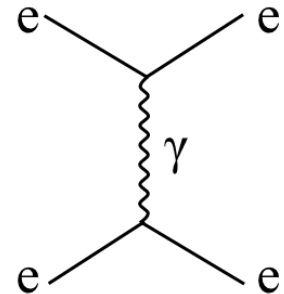
Fuerza	Cuanto	Masa	Alcance
Gravedad 	gravitón ?	0	∞
Electromagnética $+\rightarrow \leftarrow -$ 	fotón	0	∞
Débil $n \rightarrow p + e^- + \bar{\nu}_e$ $\nu + p \rightarrow \nu + X$	$W^\pm, Z$	80, 90 GeV	$\sim .001$ fm
Fuerte entre quarks 	gluones	0	$O(1)$ fm (confinamiento)

MODELO ESTANDAR – ORIGEN DE LAS CARGAS

- Los constituyentes elementales, quarks y leptones, organizados en tres familias replicando sus números cuánticos de cargas. Tienen valores crecientes de sus masas.
- **Todos, excepto quizá (?) neutrinos, tienen una o mas cargas no nulas y sus ANTIPARTICULAS.**

- Las Fuerzas entre ellos se inducen requiriendo **SIMETRIAS DE LAS LEYES FISICAS** bajo **TRANSFORMACIONES GENERADAS POR LAS CARGAS**:
"COLOR" FUERTE de quarks, DEBIL de todos, ELECTRICA excepto neutrinos.

- Las Fuerzas resultantes son "DE INTERCAMBIO DE MEDIADORES":
 - . GLUONES para la interacción de color de los quarks.
 - . W^+ y Z para la interacción débil.
 - . FOTON para la interacción electromagnética.



- **Resultados Experimentales <-> Acuerdo con MODELO ESTANDAR.**

- Sin embargo, las SIMETRIAS son EXACTAS solo si las partículas son de MASA NULA (como el fotón). **¿CUAL ES EL ORIGEN DE LA MASA?**

- Se necesita una RUPTURA DE LA SIMETRIA muy sutil →
"MECANISMO DE BROUT-ENGLERT-HIGGS"

EL LABORATORIO EUROPEO DE FISICA DE PARTICULAS: CERN

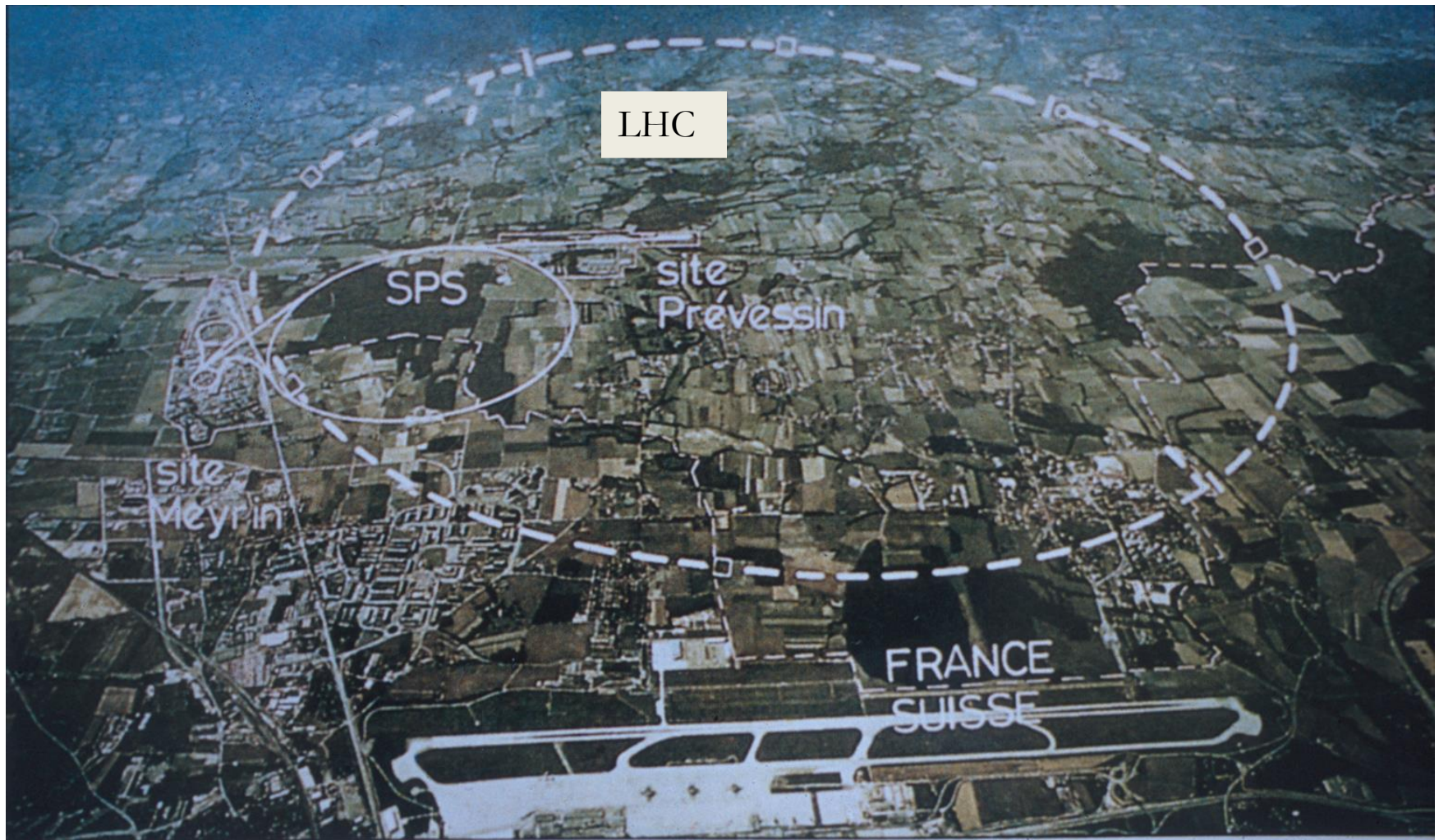


Figura 1.- Visita aérea del CERN con las montañas del Jura al fondo.

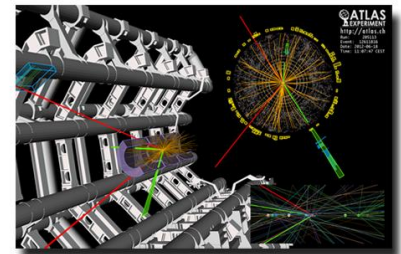
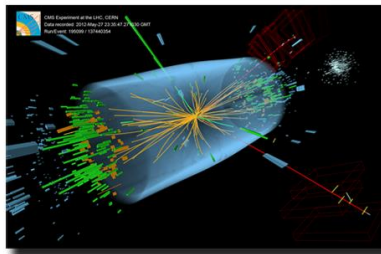


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Photo: Lovisa Engblom.

The Nobel Prize in Physics 2013



The origin of mass



The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"*



© The Nobel Foundation.
Photo: Lovisa Engblom.

The Nobel Prize in Physics 2015

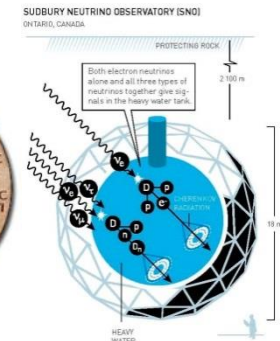
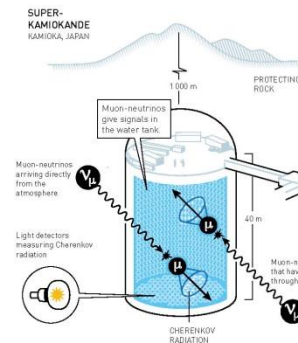


Takaaki Kajita



Arthur B. McDonald

NEUTRINO OSCILLATIONS

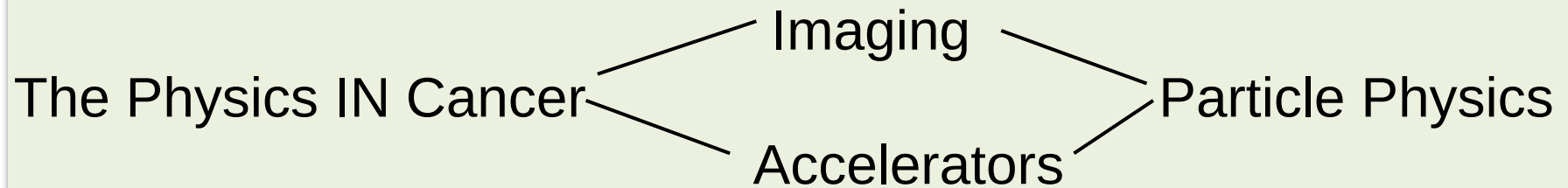
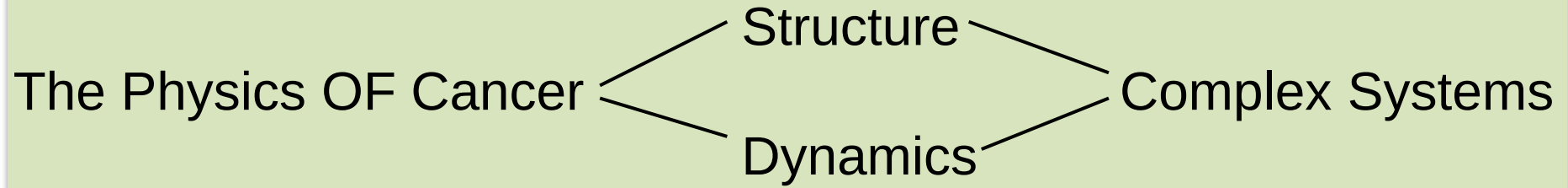


The Nobel Prize in Physics 2015 was awarded jointly to Takaaki Kajita and Arthur B. McDonald *"for the discovery of neutrino oscillations, which shows that neutrinos have mass"*

II.FISICA MEDICA

A dark blue L-shaped graphic element is positioned on the right side of the slide. It consists of a vertical bar on the right and a horizontal bar extending to the left from its base. The horizontal bar has a pointed left end, while the vertical bar has a slightly angled top edge.

FISICA MEDICA



Spin-Off of Centres of Fundamental Physics

IFIMED < ---- > IFIC

At present, PARTICLE THERAPY and IMAGING

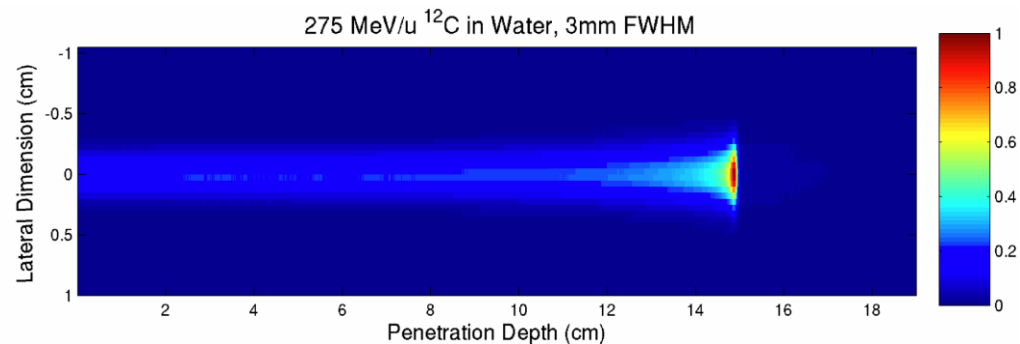
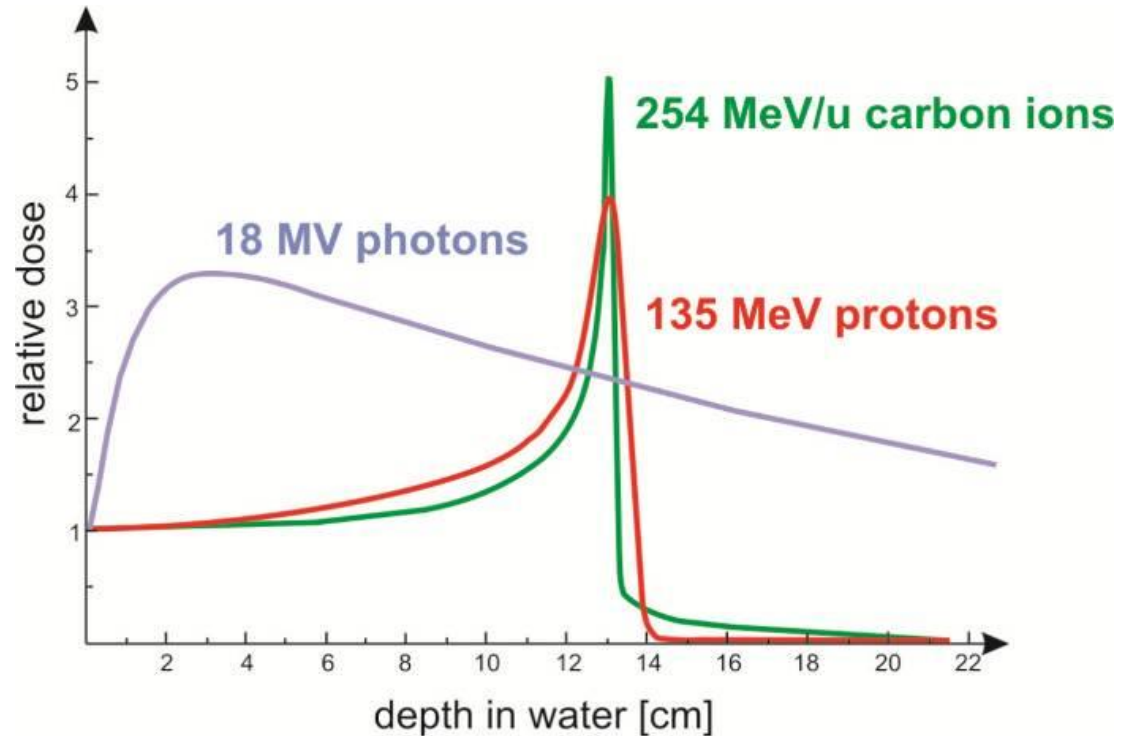
are no longer Disjoint Activities, they are Complementary.

THE RATIONALE OF HADRONS THERAPY

Conformal dose distribution results in saving healthy tissue

- Dose distribution

- Verification



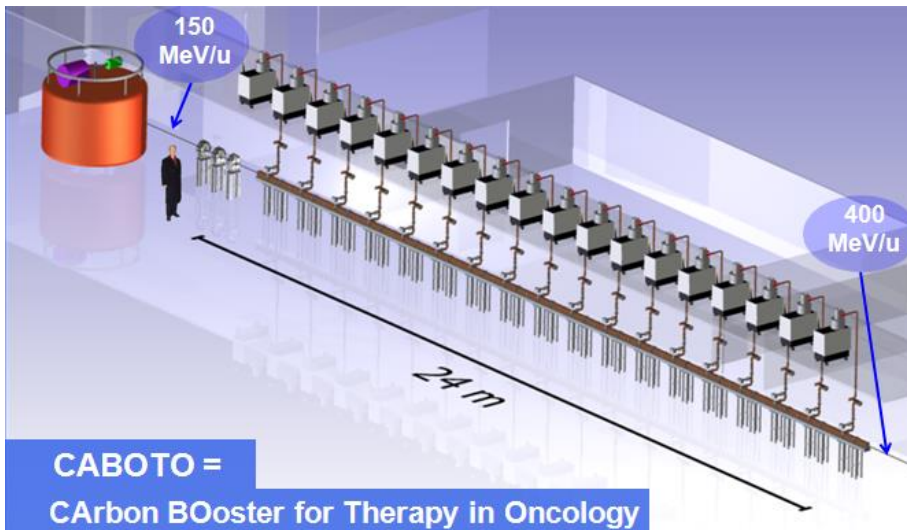
IFIMED

IFIMED is a Facility for Research and Development of applications of the techniques of Particle and Nuclear Physics to the therapy and diagnostics of oncological and neuro-degenerative diseases. Such a facility has in phase I scientific equipment for RESEARCH in components of particle accelerators, particle detectors and image science, as well as a research PET scanner for, among other topics, radiobiological studies.



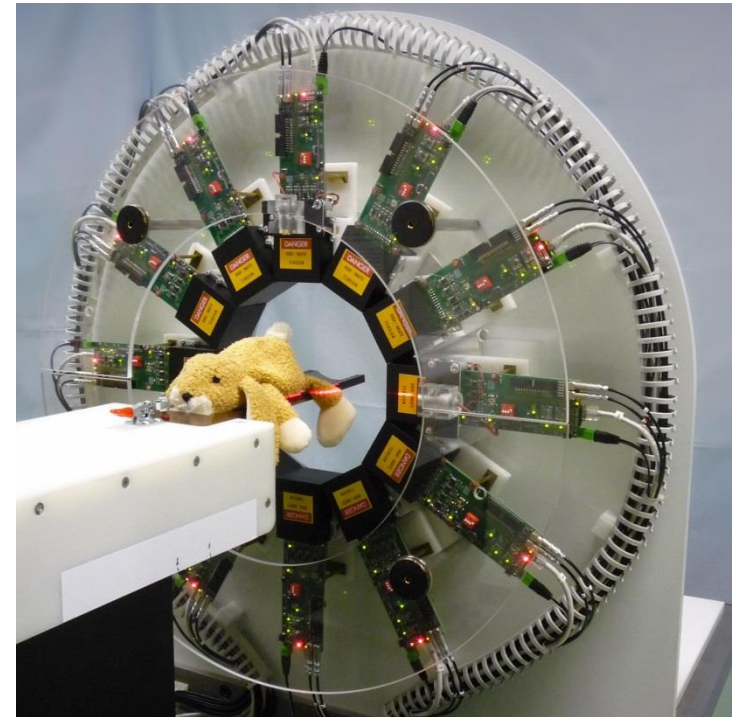
Cyclinac = cyclinac

+ fast-cycling high-frequency RF linac



Variable Beam Energy

+ High Gradient



SMALL PET SCANNER

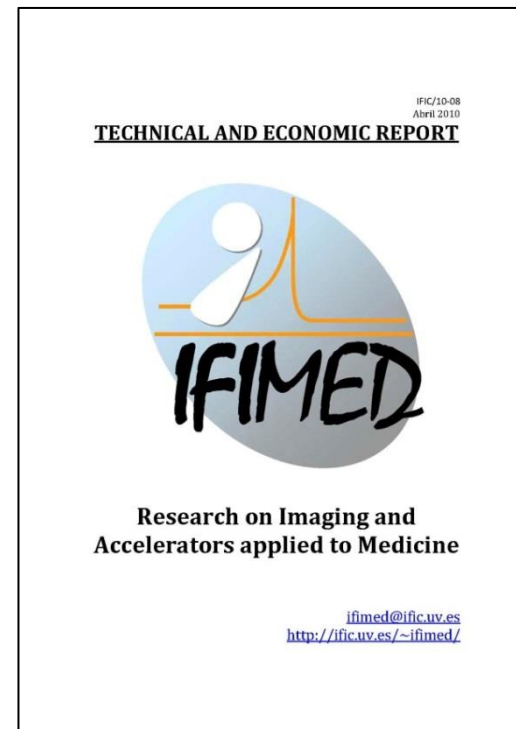
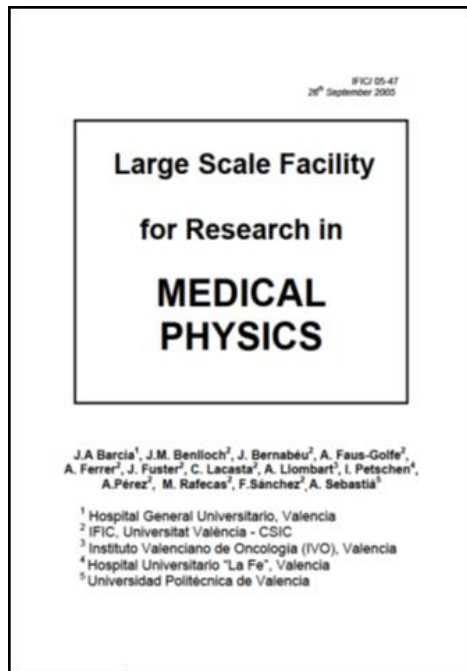
BASED O MRI-COMPATIBLE LIGHT SENSOR

IFIMED

The Conceptual Report on IFIMED was approved by the Spanish Ministry in 2006 to become a Singular Infrastructure as a Consortium between the Ministry and Generalitat Valenciana.

The Scientific-Technical and Economic Report was approved by CAIS, the Ministerial Committee for Singular Infrastructures, in 2010.

At present, Phase I for Scientific Equipment is completed supported by FEDER with Agreement between the State Secretary of Research and the University of Valencia.



INTERNATIONALIZATION

Since 2007, IFIMED is a member of ENLIGHT, the European Platform of Particle Therapy Centers for activity in Medical Physics, coordinated by CERN, the European Laboratory for Particle Physics. ENLIGHT has been essential in the promotion of European Collaborations and Projects funded by the EU.

These research projects include PARTNER, The Particle Training Network of European RadioTherapy, ENVISION, the on-line non-invasive monitoring of the application of hadrontherapy to patients -Imaging in Real Time-, ENTERVISION and OpenMED (Bio-LEIR), the design of a prototype of an ideal accelerator for Particle Therapy taking advantage of the Bragg Peak.

<http://partner.web.cern.ch/partner/>



<http://enlight.web.cern.ch/>



<http://envision.web.cern.ch/ENVISION/>



PROTON THERAPY IS BOOMING IN EUROPE

● Operational: 9 centres

1. DKFZ Heidelberg
2. Dresden (2014)
3. Essen (2014)
4. Munchen
5. Orsay
6. Pavia (2013)
7. PSI Villigen
8. PTC Prague (2013)
9. Trento (2014)

○ In tests: 4 centers

1. Krakow (2015)
2. Nice (2016)
3. Uppsala (2015)
4. Wiener Neustadt (2017)

Contracts signed:

- Aarhus (DK), 2018
- Archade, Caen (F), 2018
- Delft (2017)
- Groningen (NL)

Tenders & Planned:

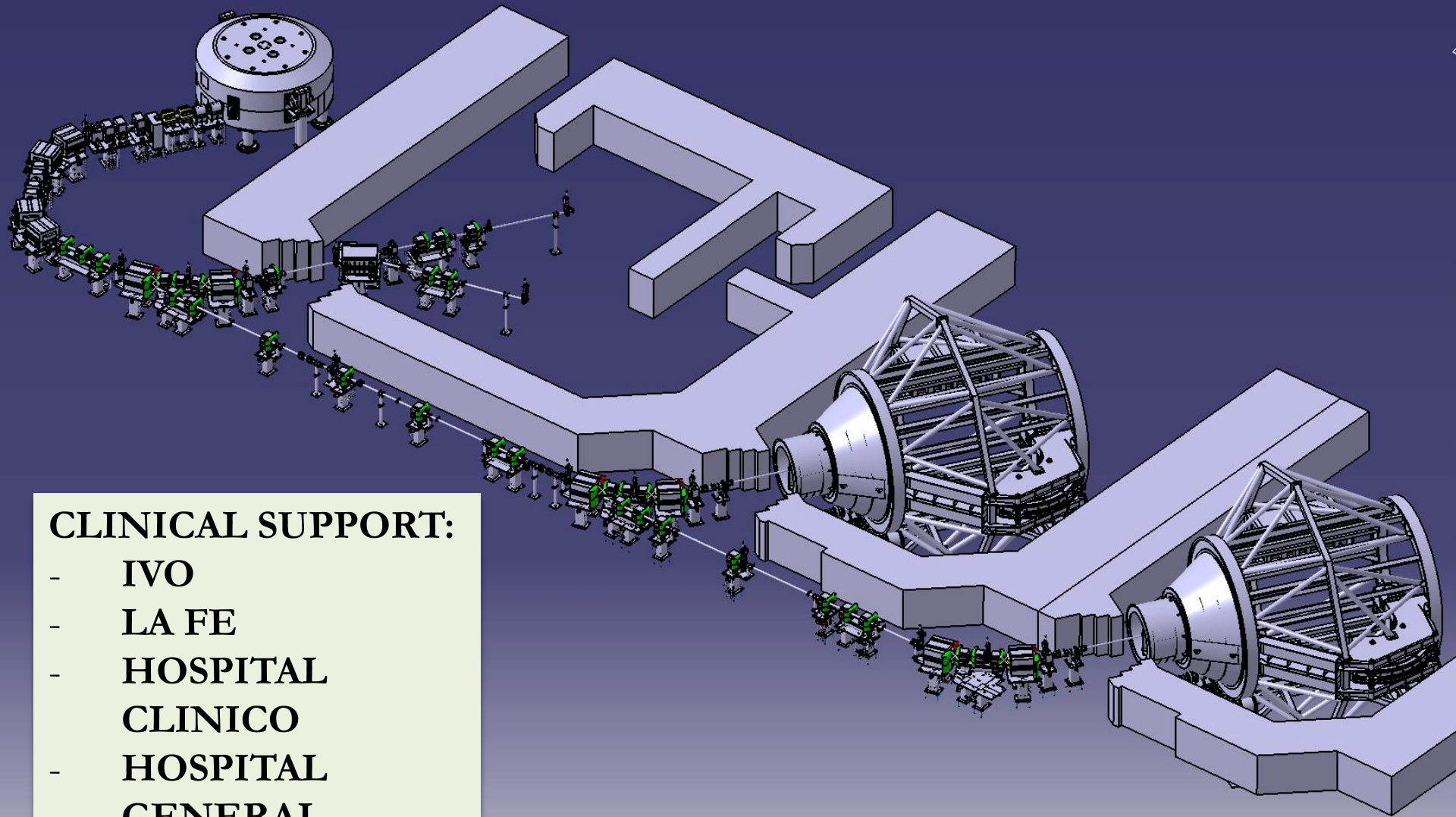
- UK (London, Manchester, Oxford)
- Maastricht (NL) – 2019
- Amsterdam (2019)
- Belgium – 2 centers
- Poznań, Warsaw



● In operation

○ In construction

MINIMAL FACILITY



CLINICAL SUPPORT:

- IVO
- LA FE
- HOSPITAL CLINICO
- HOSPITAL GENERAL
- 9 DE OCTUBRE
- ...

Proyecto Frontera: OPENMED at CERN

A Biomedical facility at CERN,

to provide particle beams of different types and energies to external users for radiobiology and detector development,

and to allow iterative experimental verification of simulation results.

FINAL OBJECTIVE → Ideal Design and Construction of an Accelerator Prototype for PARTICLE THERAPY

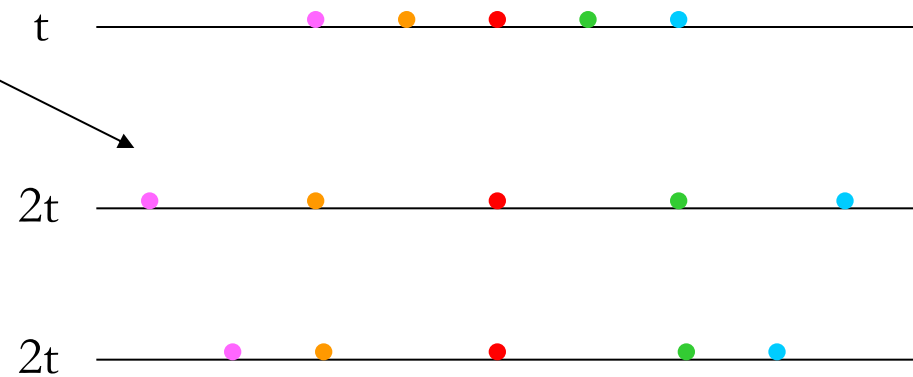
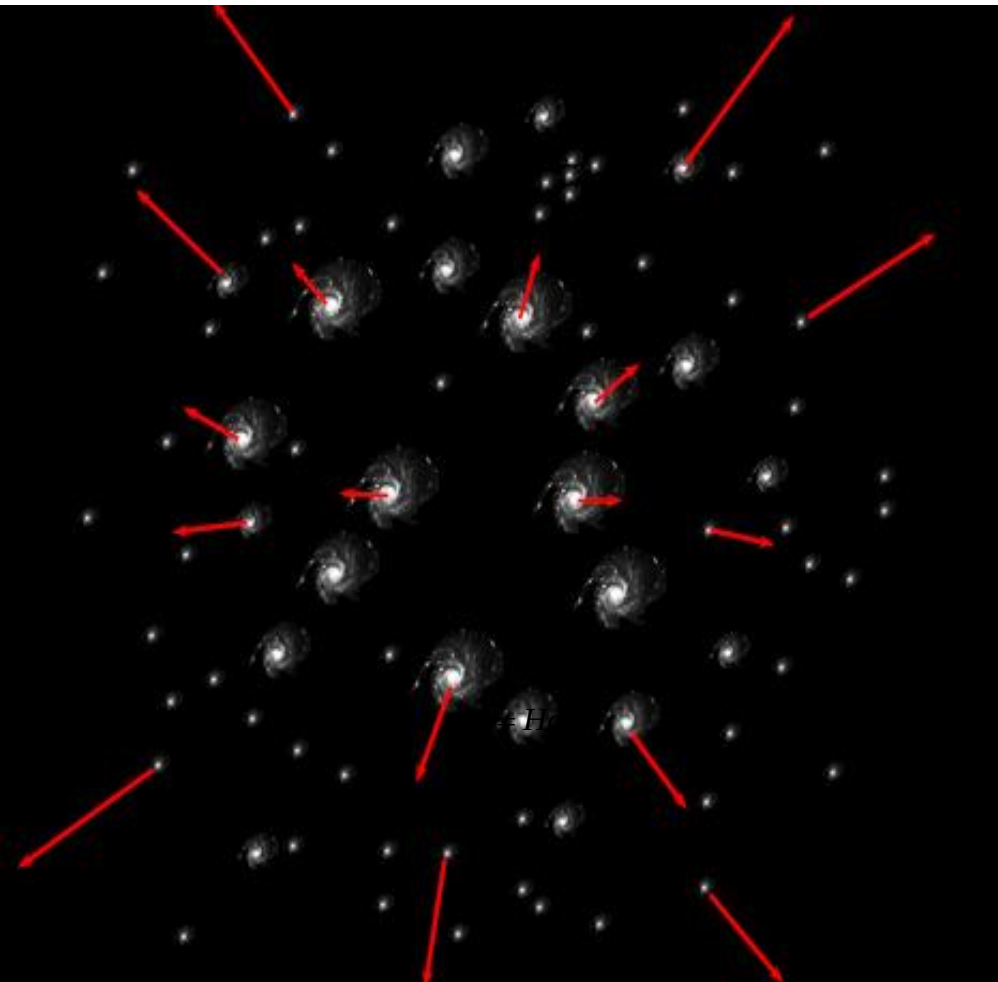
Bi-Annual Meetings for the Follow-Up of the Project:
Divonne, France, 2014, 2016, ...

III. EL COSMOS



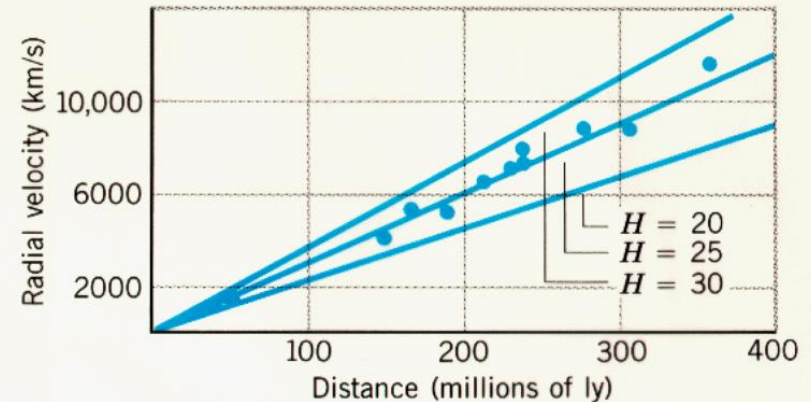
CORRIMIENTO HACIA EL ROJO : LEY DE HUBBLE

$$v = Hd$$



Edad del Universo:

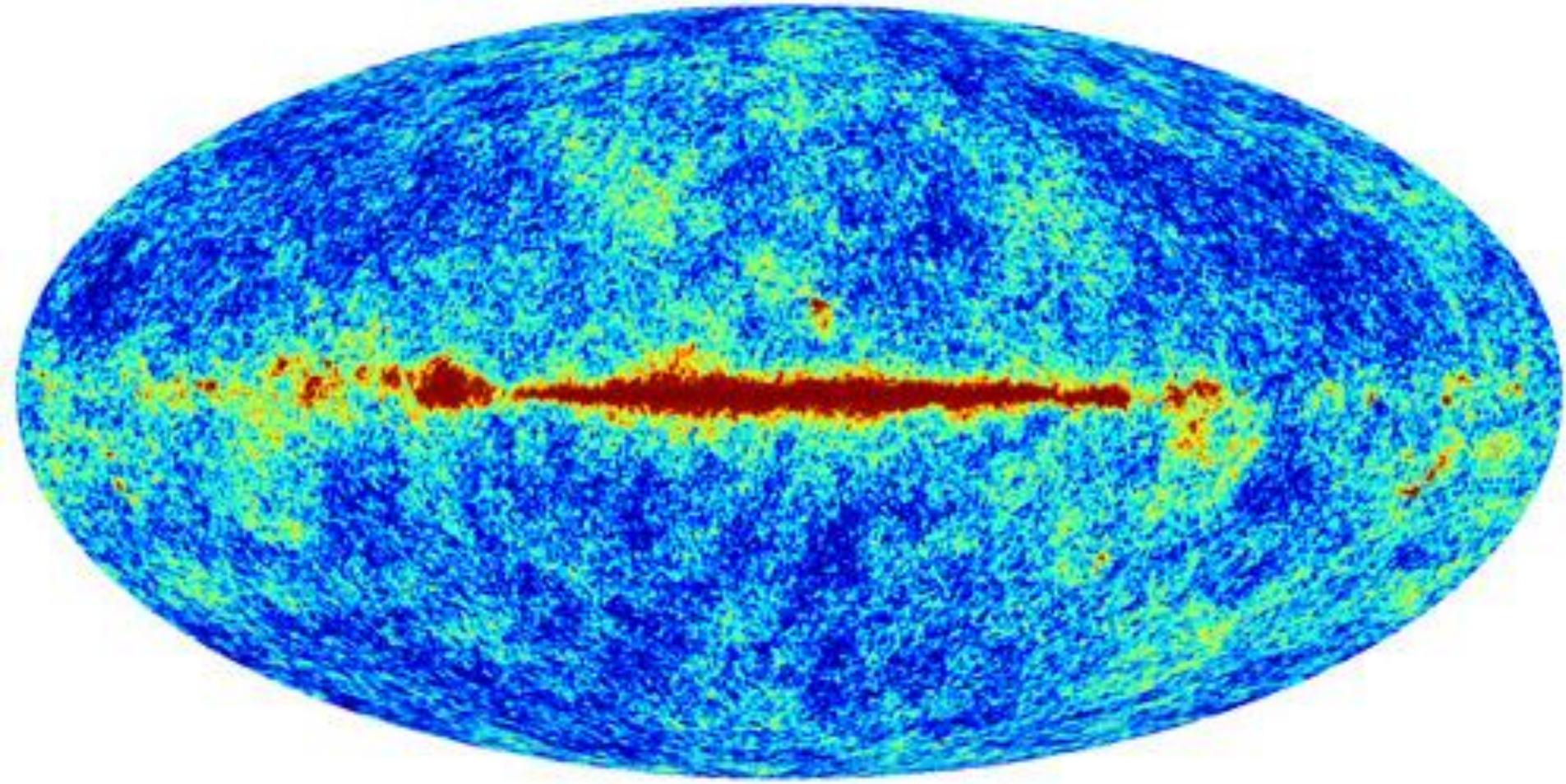
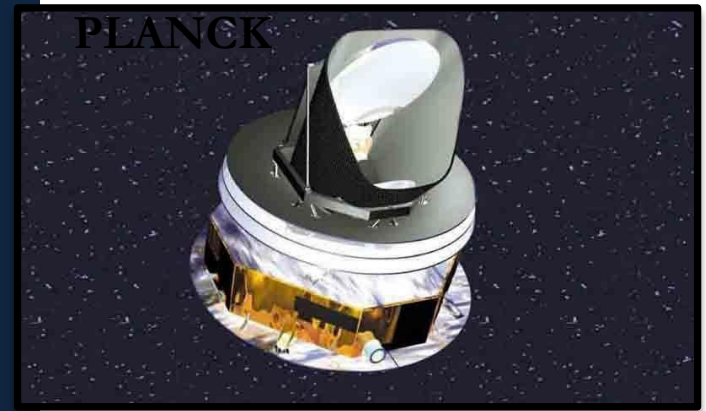
$$H^{-1} \approx 1.4 \times 10^{10} \text{ años}$$



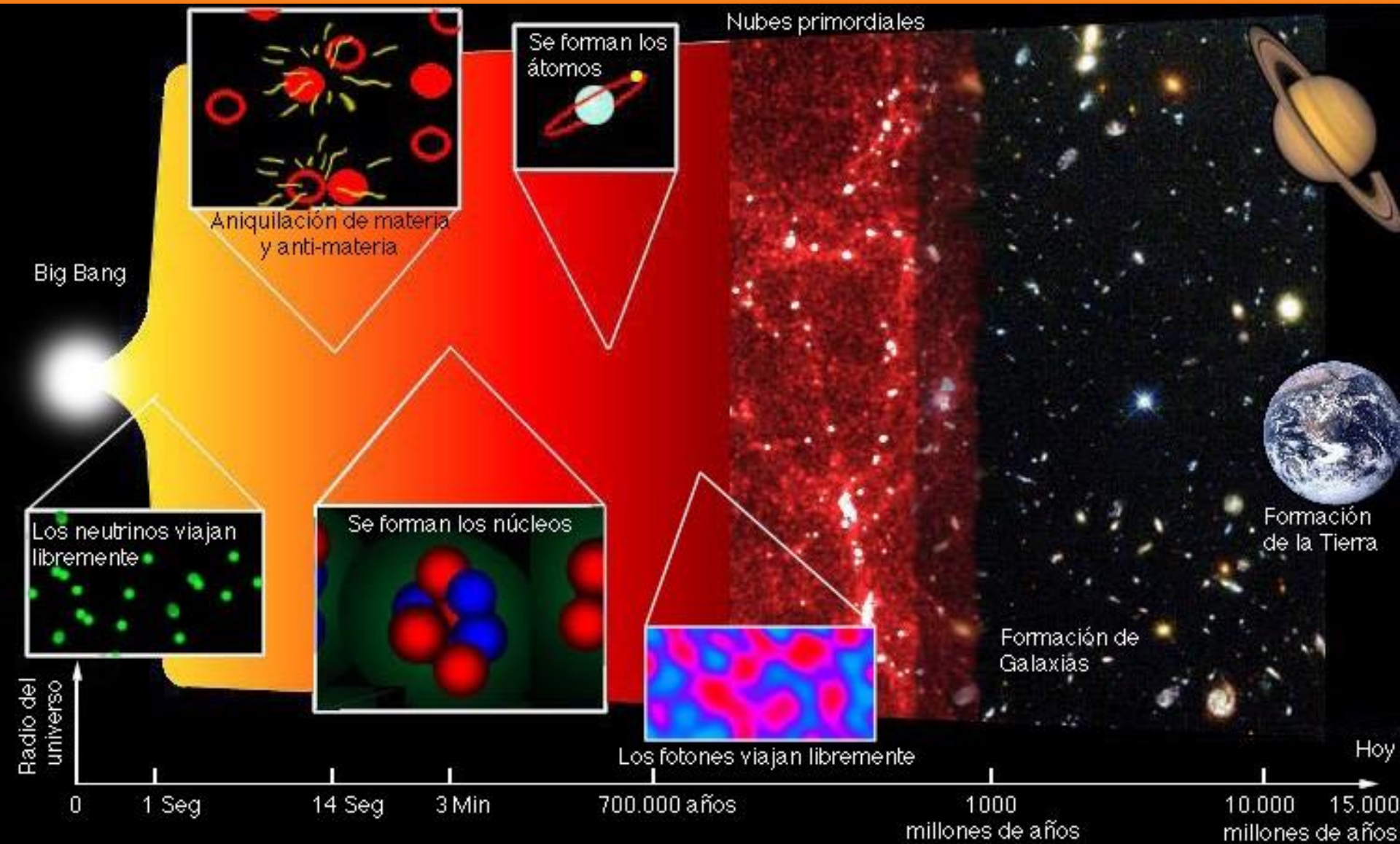
Hubble plot using Tully – Fisher relation and infrared fluxes for nearby calibrating galaxies to estimate the distances to eleven clusters of galaxies.

No hay centro del Universo ↔ Espacio expande en tiempo

EL PRINCIPIO COSMOLÓGICO



HISTORY OF THE UNIVERSE



Two Cosmological Methods:

- 1- Observing Far → Early Times → Supernova I Survey
- 2- RELICS → CMBR at time of (RE) COMBINATION



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Photo: Lovisa Engblom.

The Nobel Prize in Physics 2011

DARK ENERGY



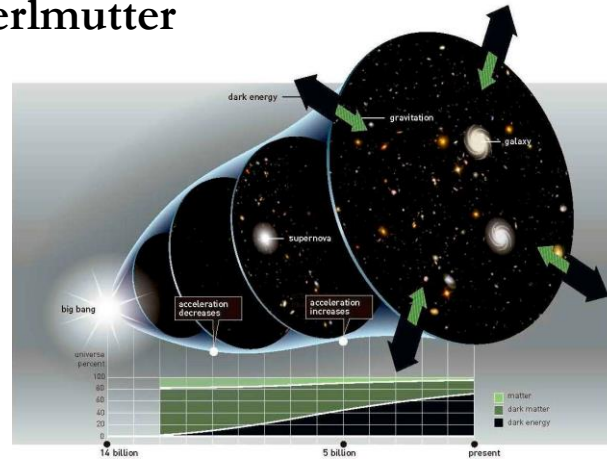
Saul
Perlmutter



Brian P. Schmidt



Adam G. Riess

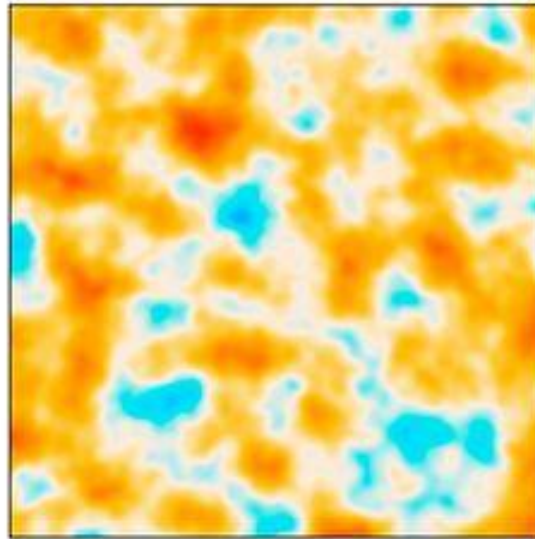
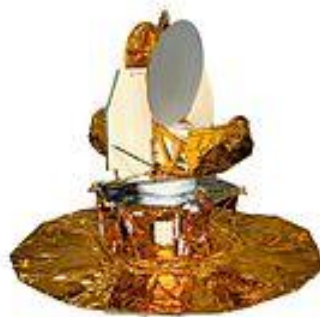


The Nobel Prize in Physics 2011 was divided, one half awarded to Saul Perlmutter, the other half jointly to Brian P. Schmidt and Adam G. Riess *"for the discovery of the accelerating expansion of the Universe through observations of distant supernovae"*.

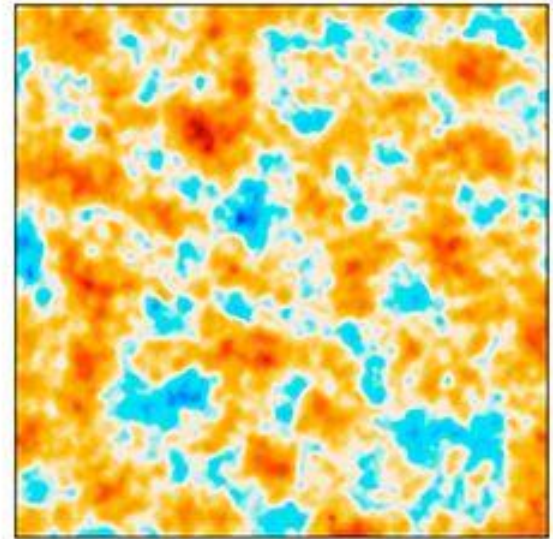
MODERN COSMOLOGY



COBE



WMAP



Planck

Precision in temperature fluctuations of sky-map



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Photo: Lovisa Engblom.

The Nobel Prize in Physics 2006

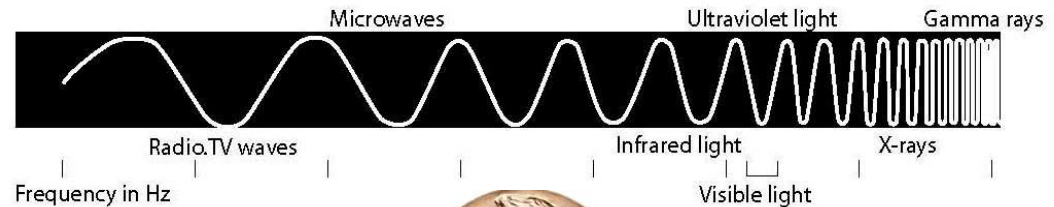
***ANISOTROPY OF
COSMIC MICROWAVE
BACKGROUND
RADIATION***



John C. Mather



George F. Smoot



The Nobel Prize in Physics 2006 was awarded jointly to John C. Mather and George F. Smoot "for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation"

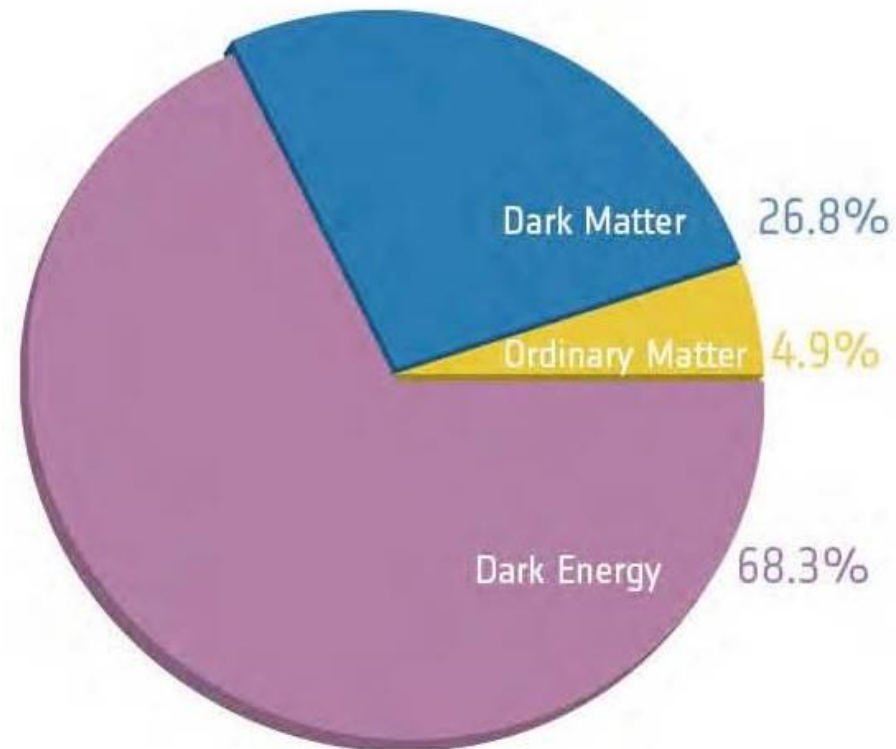
1^{RA} REVOLUCIÓN COPERNICANA

2a. revolución Copernicana

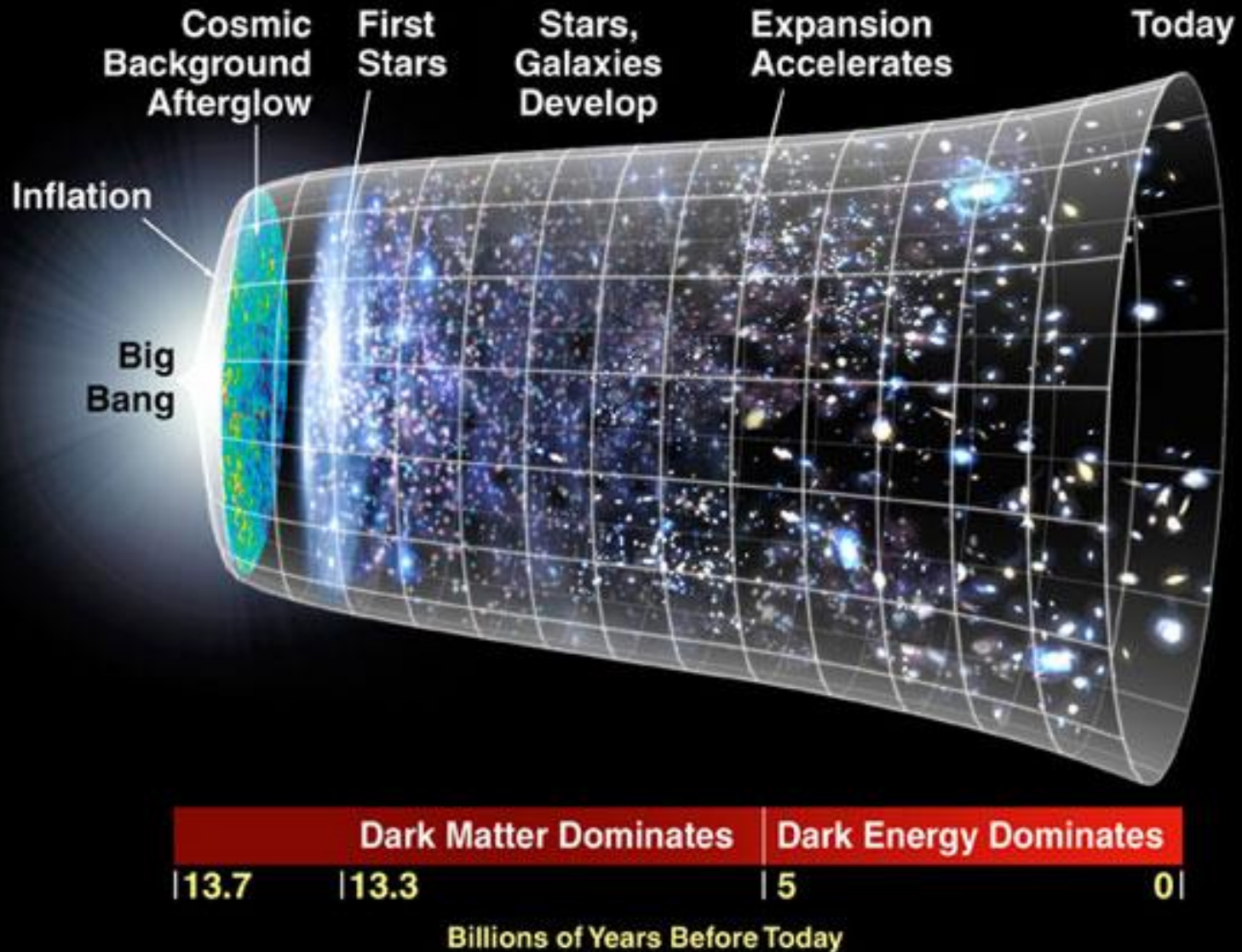
Estamos aquí



Contenido de materia-energía del Universo:



OPEN PROBLEMS: Radiation, Matter, Vacuum



Son
Molinos de
Viento,
Vuesa
Merced
¡Por largo
me lo fiáis!



NUEVA
FISICA
DE EL LADO
OSCURO
están en el
horizonte,
querido
Sancho

**Proyecto Frontera de Física Médica ->
OPENMED en CERN, participando IFIMED**