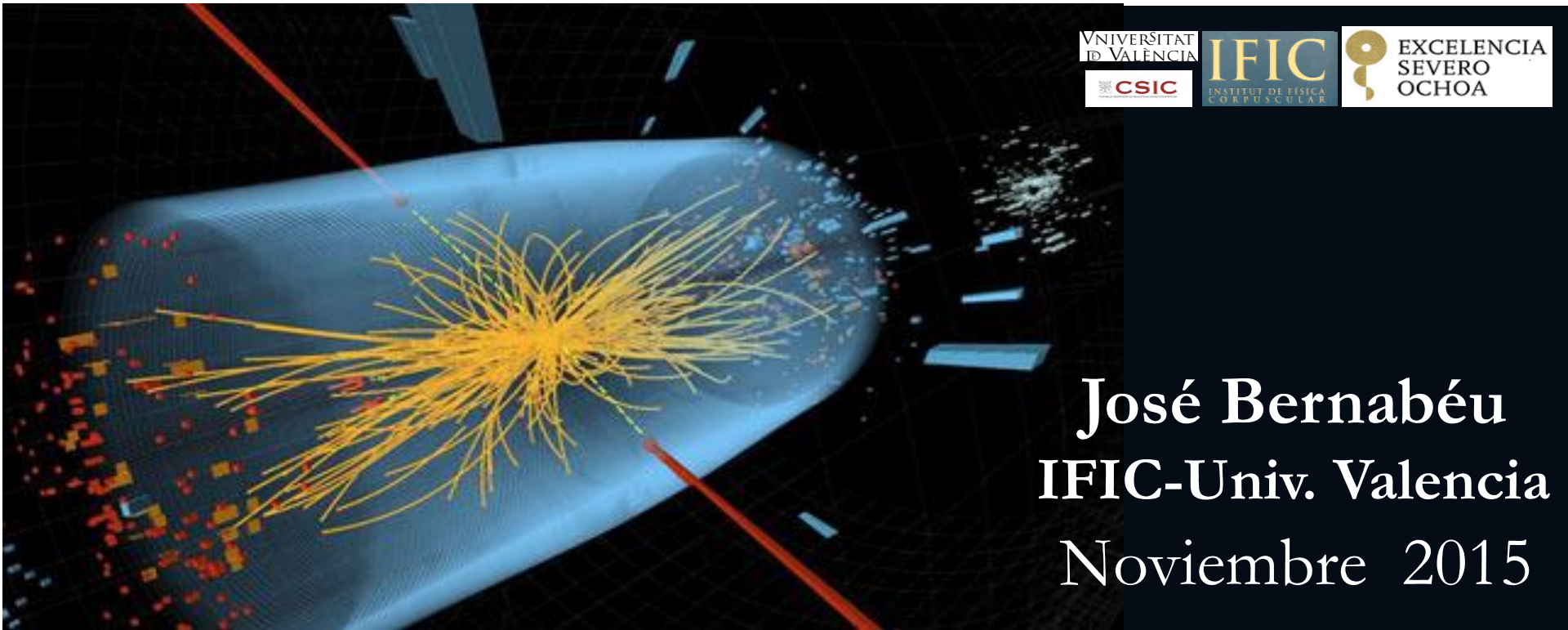
FRONTERAS DEL CONOCIMIENTO: PARTICULAS, FISICA MEDICA, COSMOLOGIA



José Bernabéu
IFIC-Univ. Valencia

Noviembre 2015

THE FRONTIERS

➢ The advance of knowledge in Science is measured by

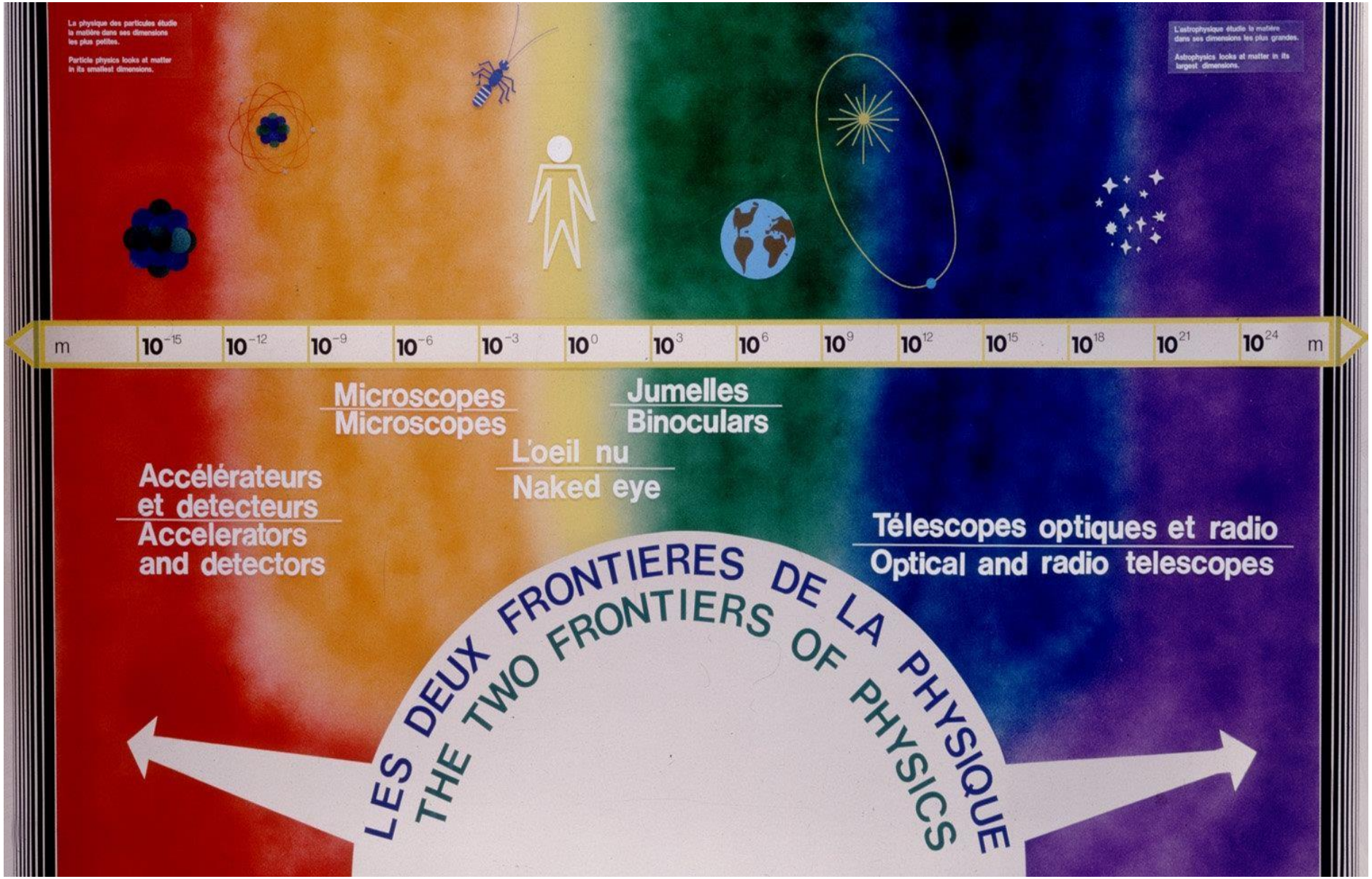
the degree of synthesis,
the explanation of novel observed phenomena,
the unification which allows the increase of the validity domain, ...

➢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.

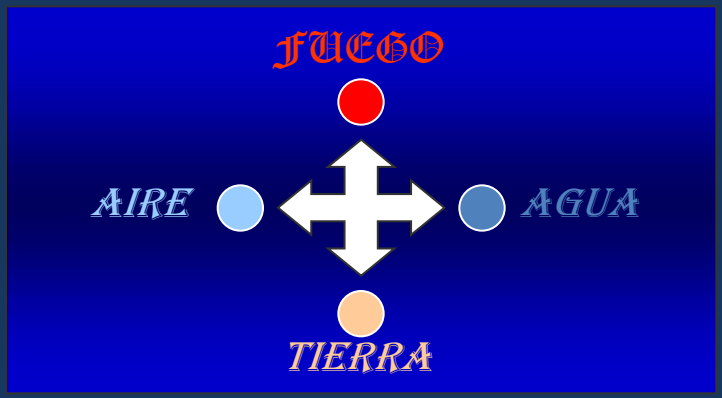
"The advance of knowledge generates and increases the number of questions in the frontiers"

LAS DOS FRONTERAS DE LA FÍSICA

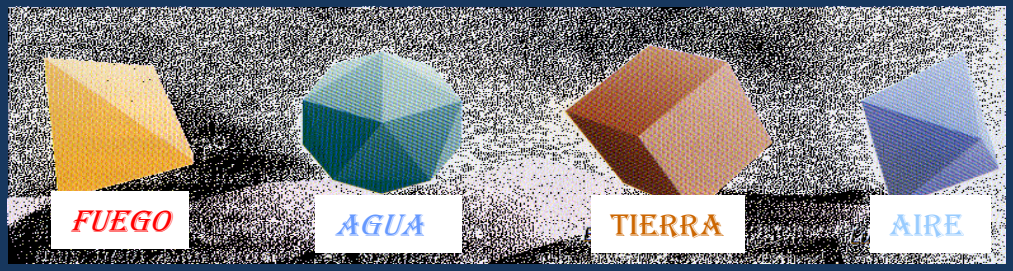


Filosofía natural de los Griegos

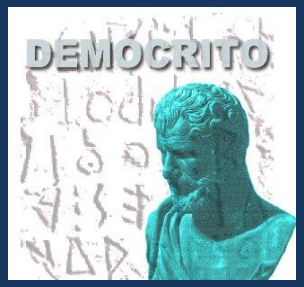
- Empédocles (500-430 B. C.)



- Platón (427-347 B.C.)



- Demócrito (460-371 B. C.)

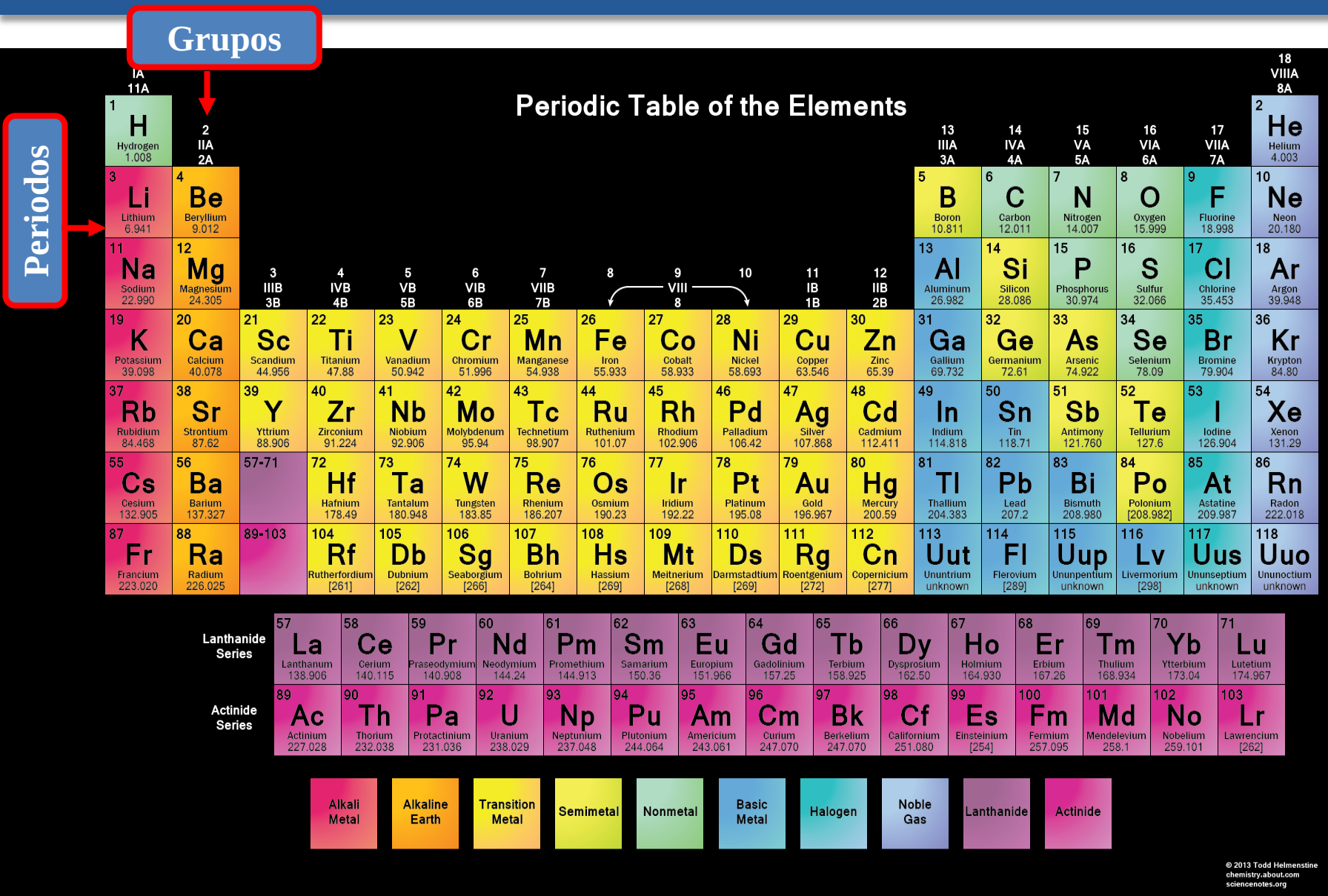


-Átomos: diferentes formas y pesos

- Aristóteles (385-347 B. C.)

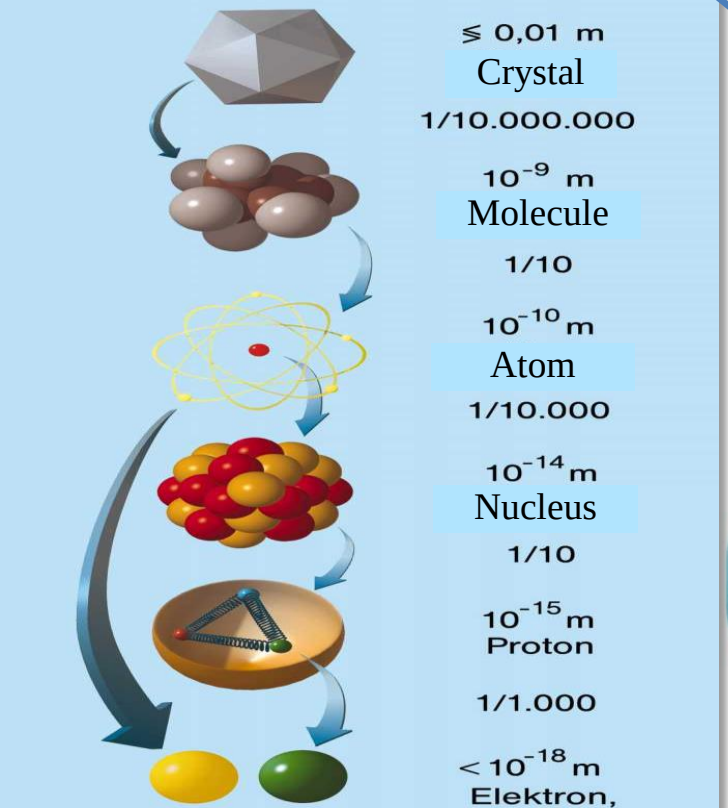
- Añadió a los cuatro elementos un quinto: el éter o quintaesencia, que formaba las estrellas, mientras que los otros cuatro formaban las sustancias terrestres.

LOS ELEMENTOS EN EL SIGLO XIX: MENDELEEV

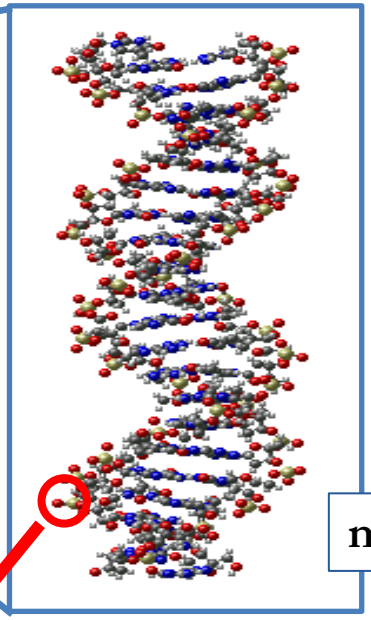


I.PARTICULAS

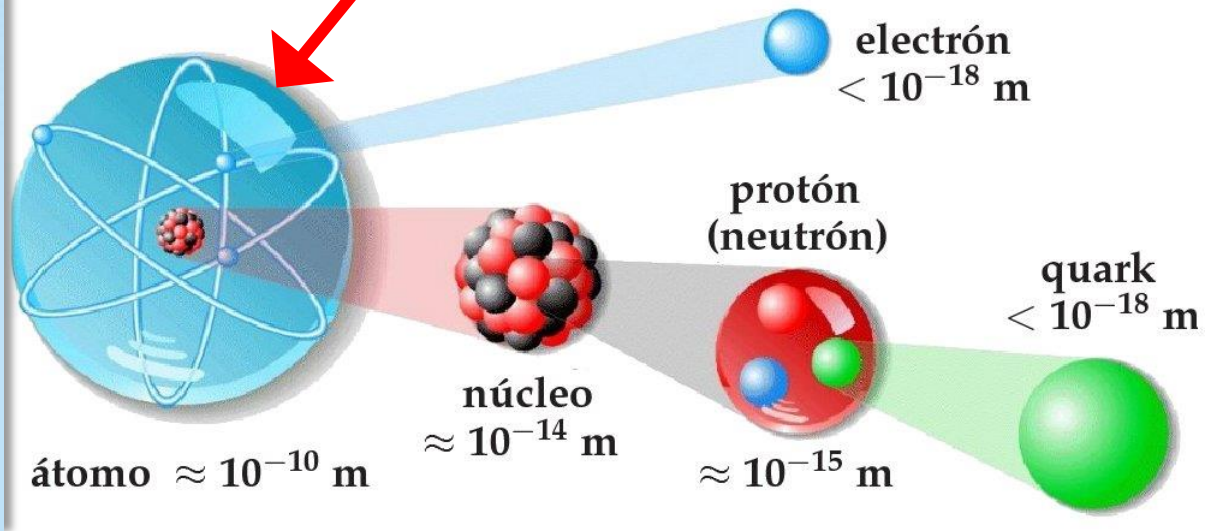
CONSTITUYENTES DE LA MATERIA



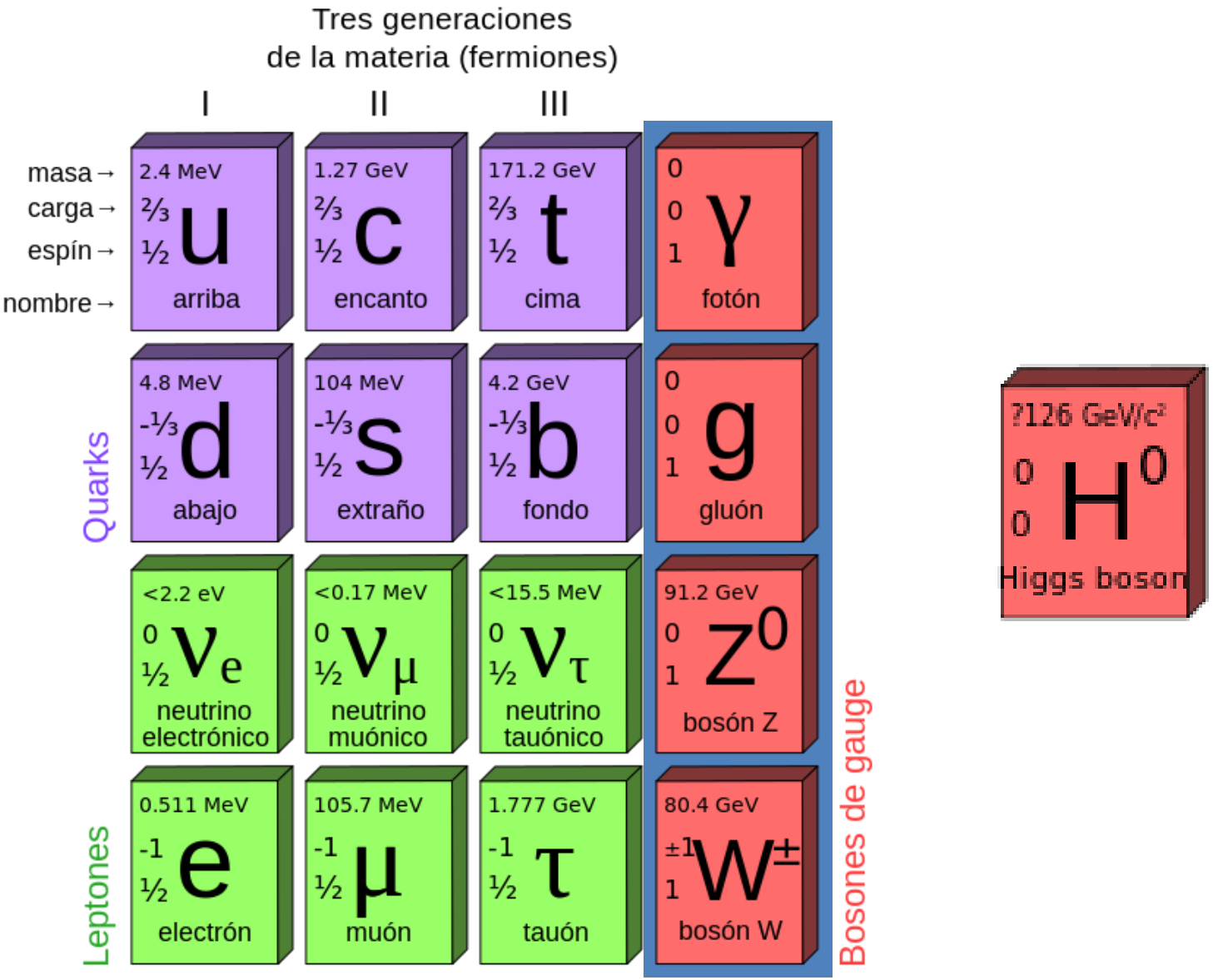
Estructura de la materia



molecula



PARTÍCULAS ELEMENTALES



LAS FUERZAS FUNDAMENTALES

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

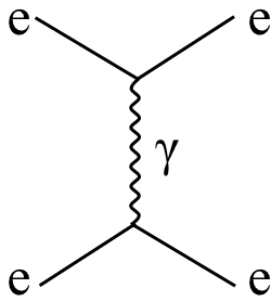
MODELO ESTANDAR – ORIGEN DE LAS CARGAS

- 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 ORICEN DE LA MASA?**

- Se necesita un RUPTURA DE LA SIMETRIA muy sutil →

"MECANISMO DE BROUT-ENGLERT-HIGGS“

EL LABORATORIO EUROPEO DE FISICA DE PARTICULAS: CERN

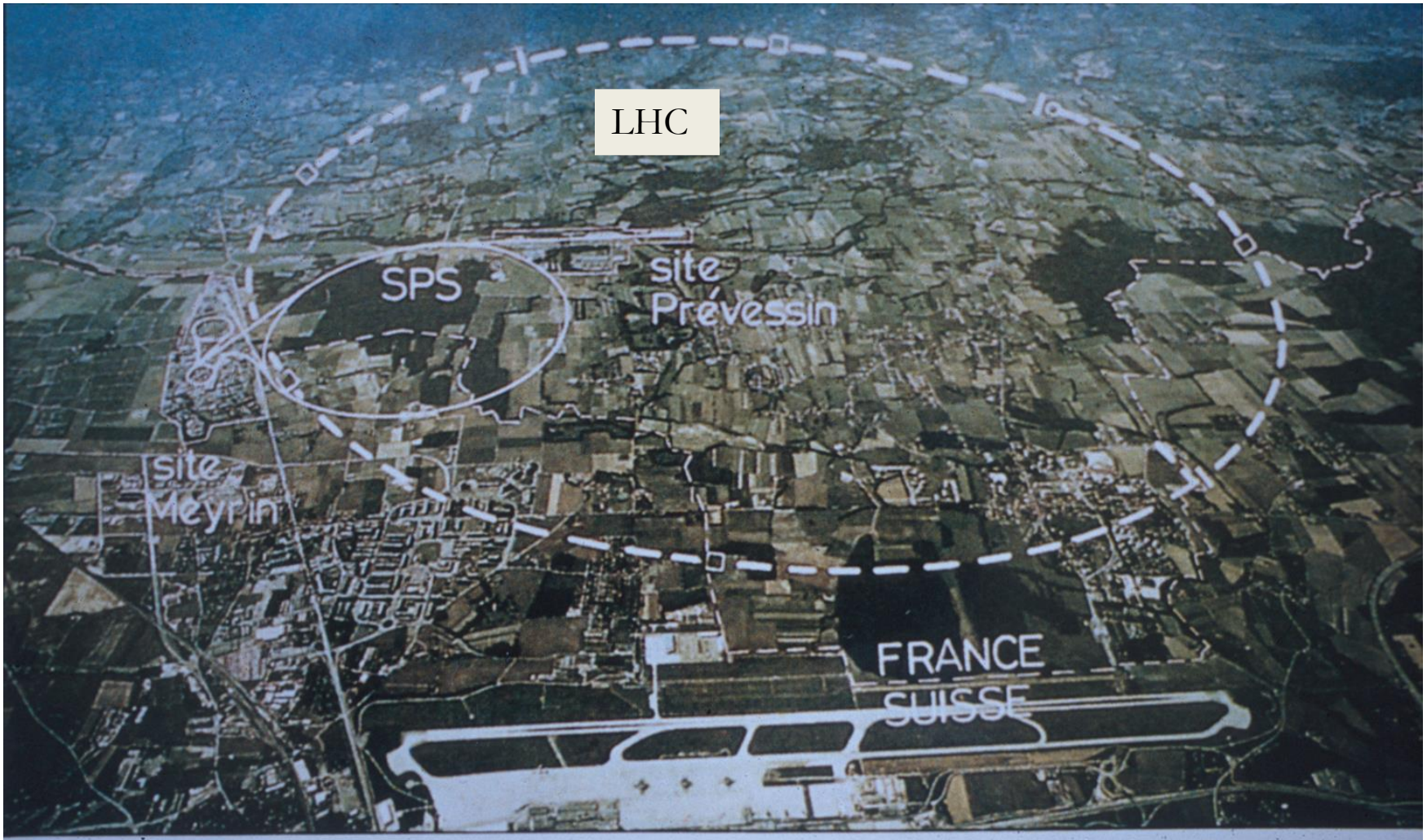
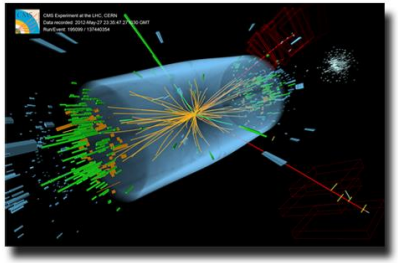
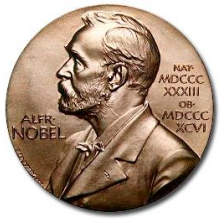


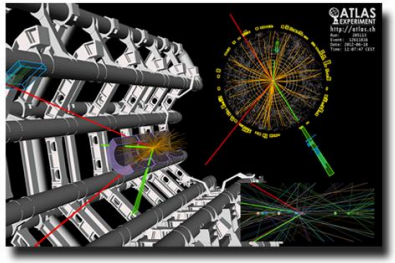
Figura 1.– Visita aérea del CERN con las montañas del Jura al fondo.

The Nobel Prize in Physics 2013

The origin of mass







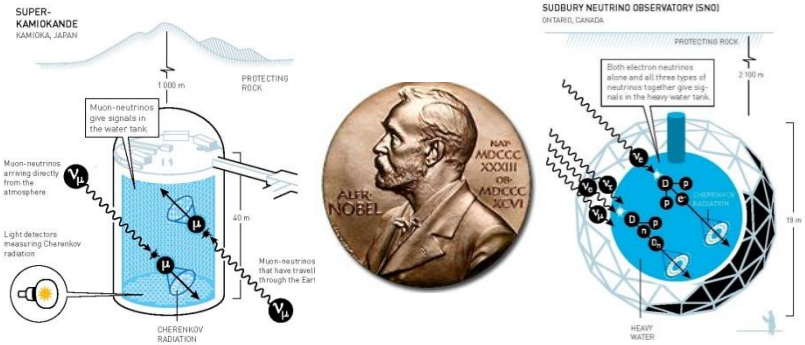
The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental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

The Nobel 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

FISICA MEDICA

The Physics OF Cancer — Structure, Dynamics — Complex Systems

The Physics IN Cancer — Imaging, Accelerators — Particle Physics

Spin-Off of Centres of Fundamental Physics

IFIMED < ---- > IFIC

At present, PARTICLE THERAPY and IMAGING

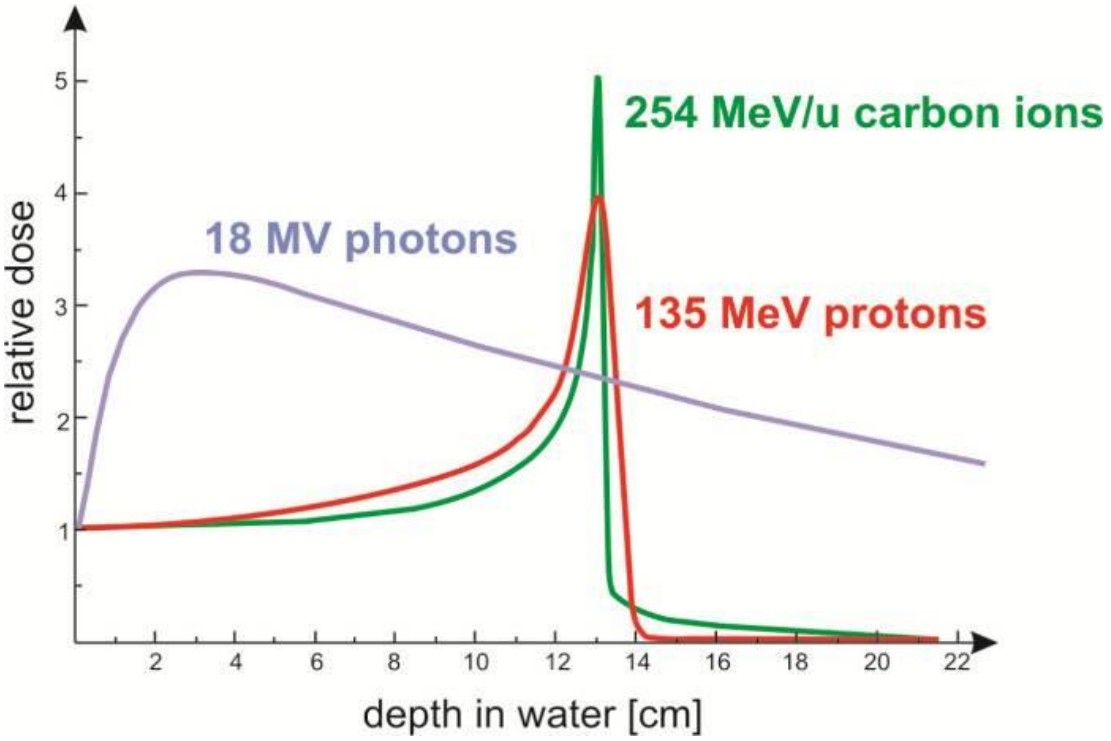
are no longer Disjoint Activities, they are Complementary.

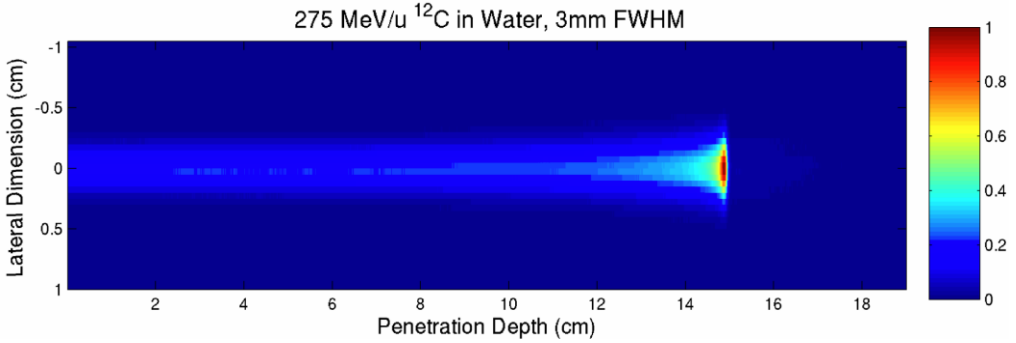
THE RATIONALE OF HADRON THERAPY

Conformal dose distribution results in saving healthy tissue

- **Dose distribution**

- Verification



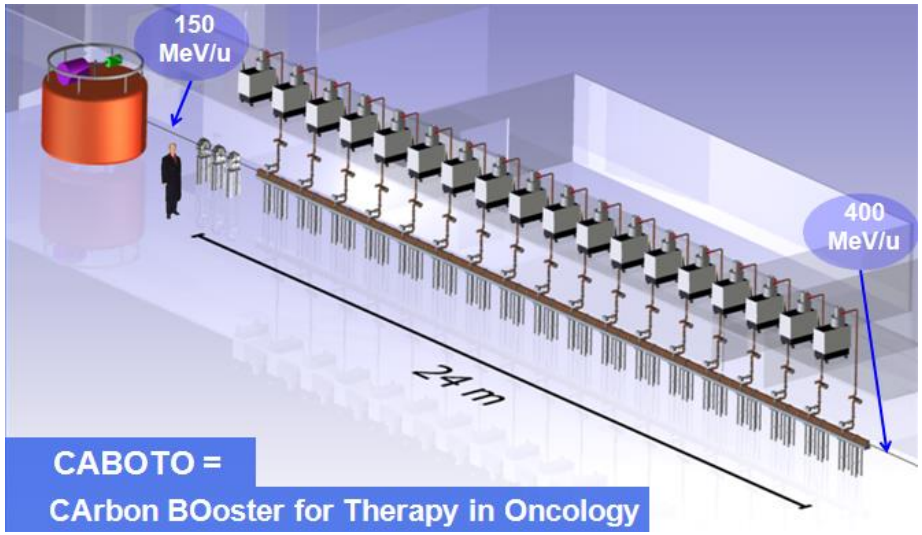


IFIMED

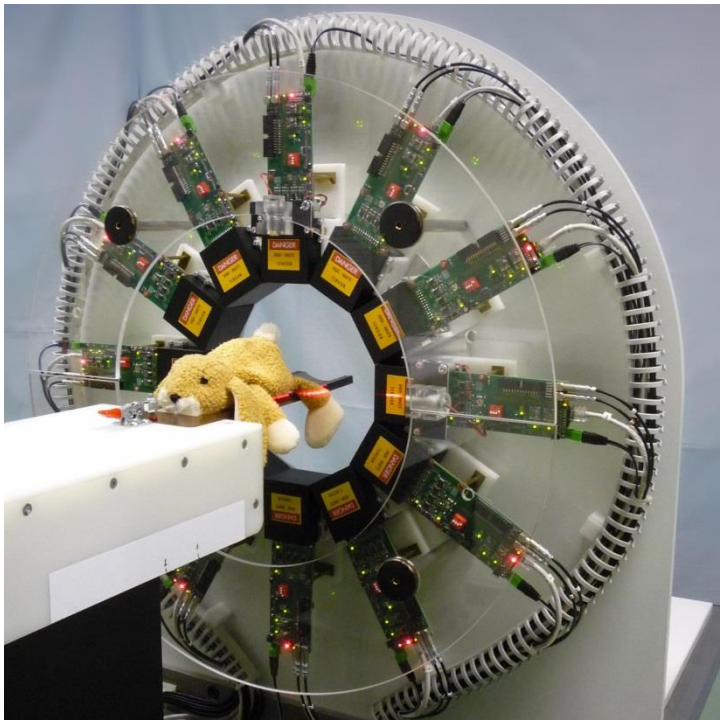
IFIMED is a Facility for Research and Development of applications of the techniques of Particle and Nuclear Physics to the therapy and diagnostics of oncological and neuro-degenerative diseases. Such a facility has in phase I scientific equipment for RESEARCH in components of particle accelerators, particle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

GAP

Cyclinac = cyclinac
+ fast-cycling high-frequency RF linac



Variable Beam Energy
+ High Gradient



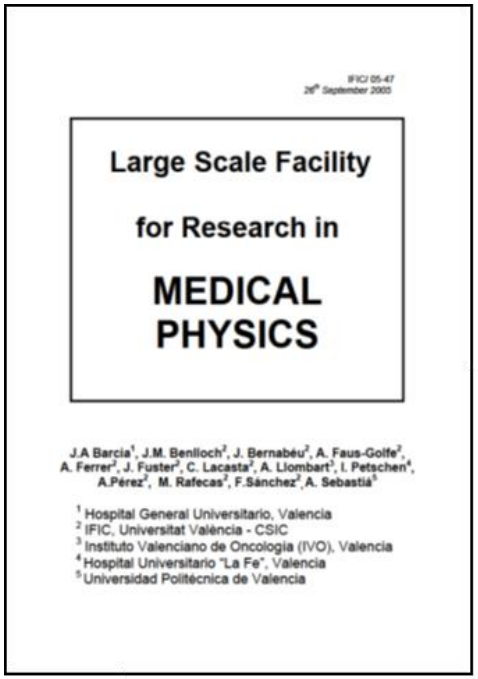
SMALL PET SCANNER
BASED O MRI-COMPATIBLE LIGHT SENSOR

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.



IFIC/ 05-47
26th September 2005

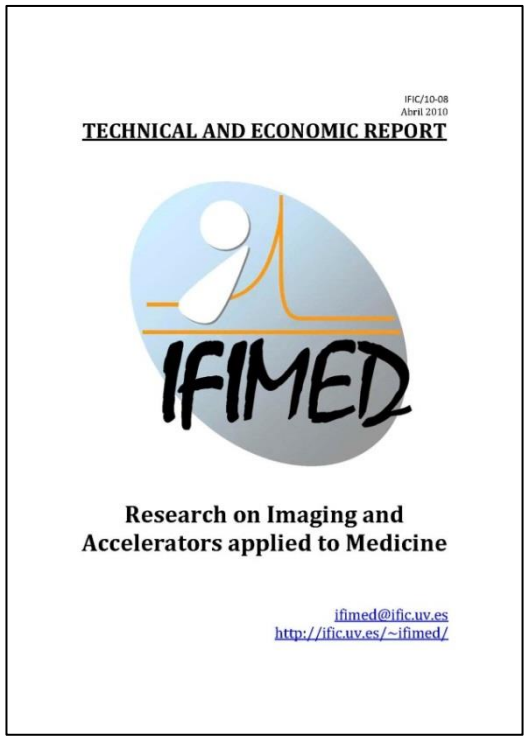
Large Scale Facility

for Research in

MEDICAL PHYSICS

J.A Barcia[1], J.M. Benlloch[2], J. Bernabéu[2], A. Faus-Golfe[2], A. Ferrer[2], J. Fuster[2], C. Lacasta[2], A. Llombart[3], I. Petschen[4], A.Pérez[2], M. Rafecas[2], F.Sánchez[2], A. Sebastiá[5]

[1] Hospital General Universitario, Valencia
[2] IFIC, Universitat València - CSIC
[3] Instituto Valenciano de Oncología (IVO), Valencia
[4] Hospital Universitario "La Fe", Valencia
[5] Universidad Politécnica de Valencia



IFIC/10-08
Abril 2010

TECHNICAL AND ECONOMIC REPORT

IFIMED

Research on Imaging and Accelerators applied to Medicine

ifimed@ific.uv.es
http://ific.uv.es/~ifimed/

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/

ENLIGHT

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

ENVISION

COOPERATION

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:

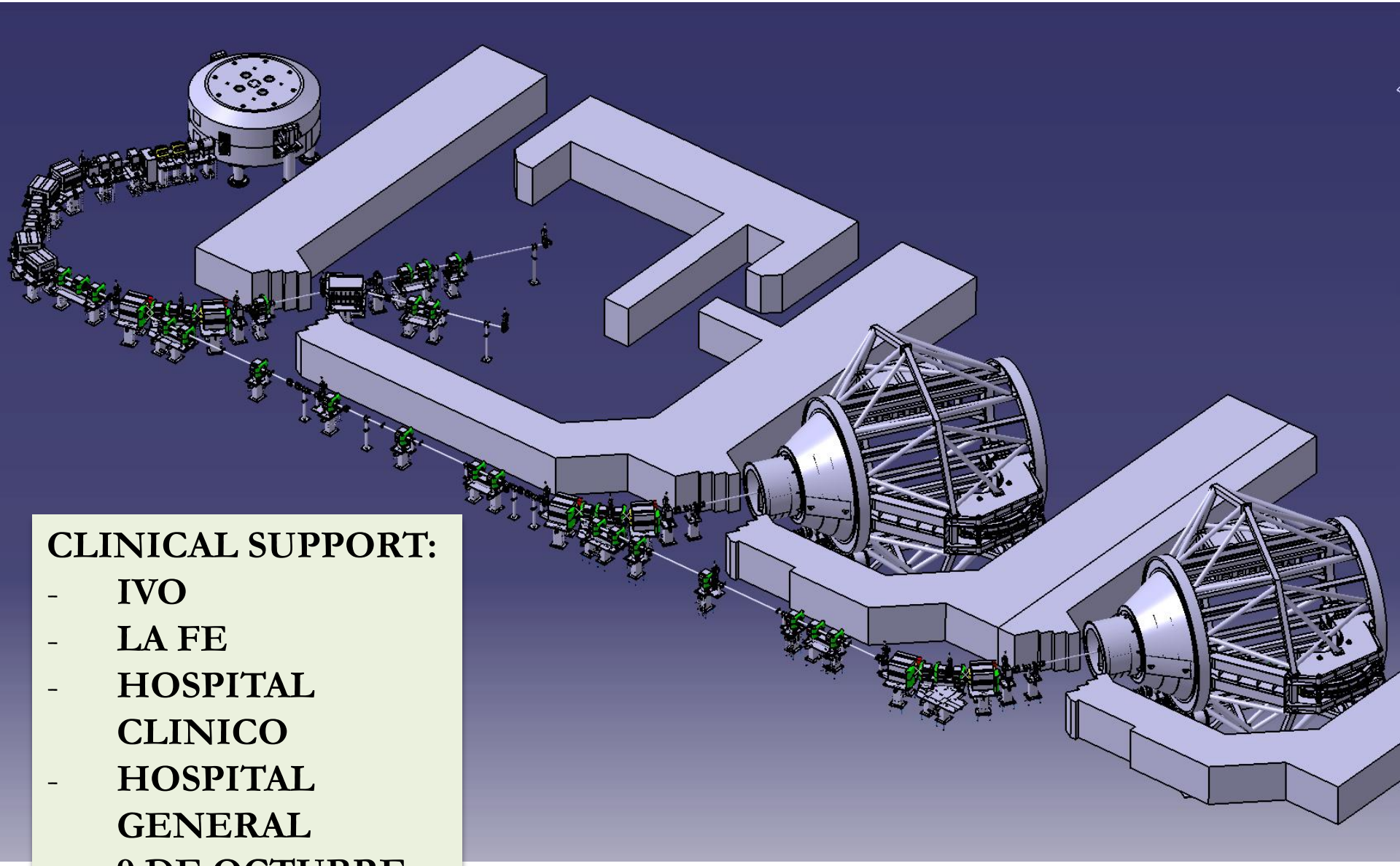
- Aarhus (DK), 2018
- Archade, Caen (F), 2018
- Delft (2017)
- Groningen (NL)

In operation In construction

Tenders & Planned:

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

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.

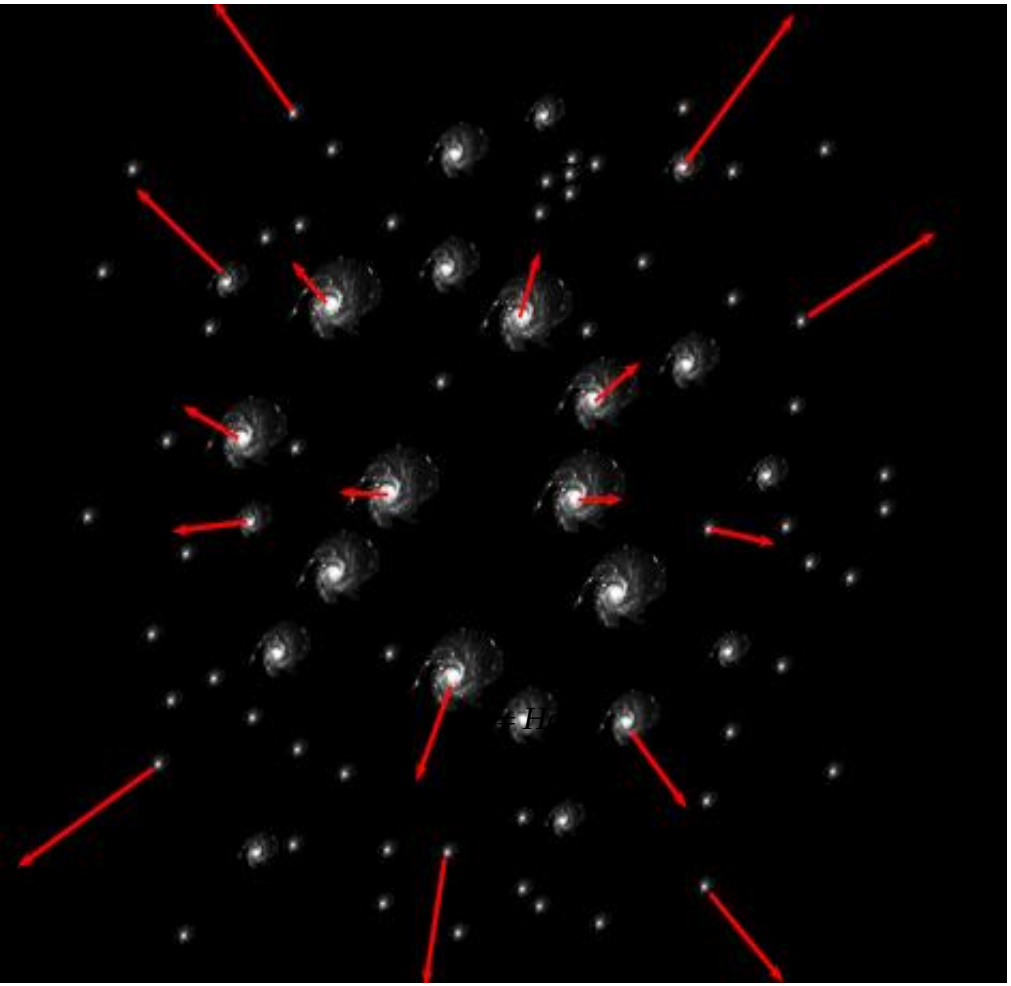
FINAL OBJECTIVE → Ideal Design and Construction of an Accelerator Prototype for PARTICLE THERAPY

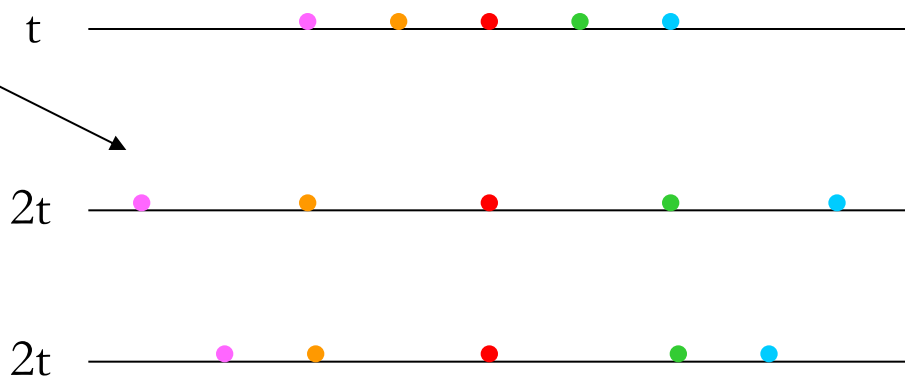
Bi-Annual Meetings for the Follow-Up of the Project: Divonne, France, 2014, 2016, ...

III. EL COSMOS

CORRIMIENTO HACIA EL ROJO : LEY DE HUBBLE

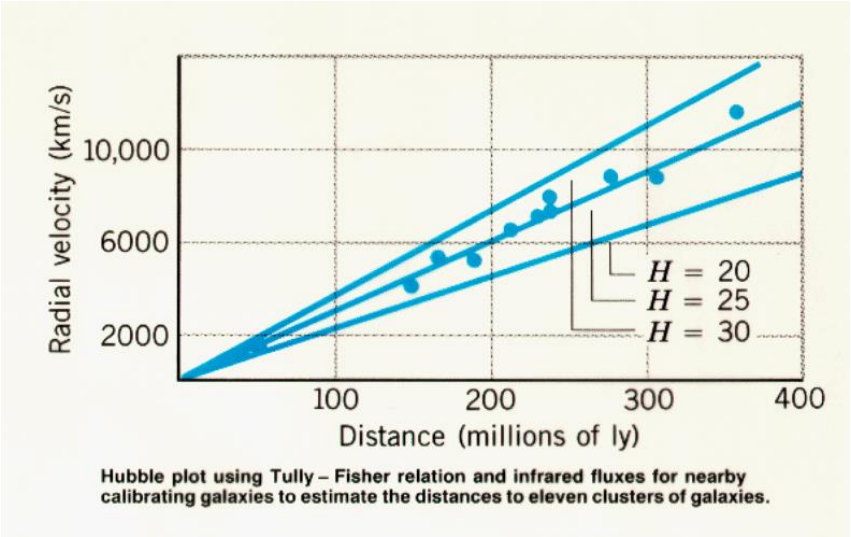
$$v = Hd$$





Edad del Universo:

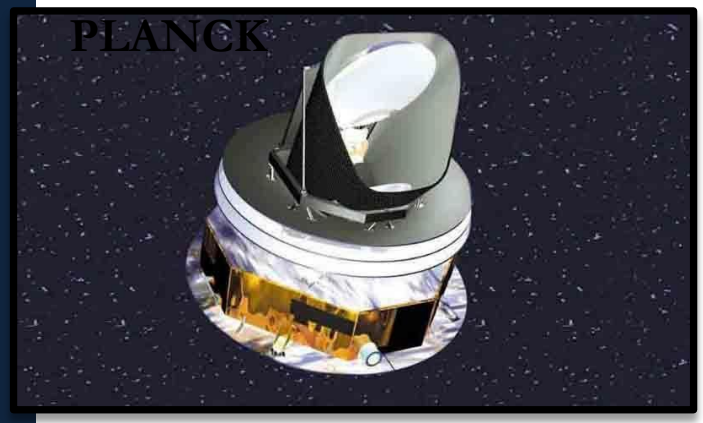
$H^{-1} \approx 1.4 \times 10^{10}$ **años**

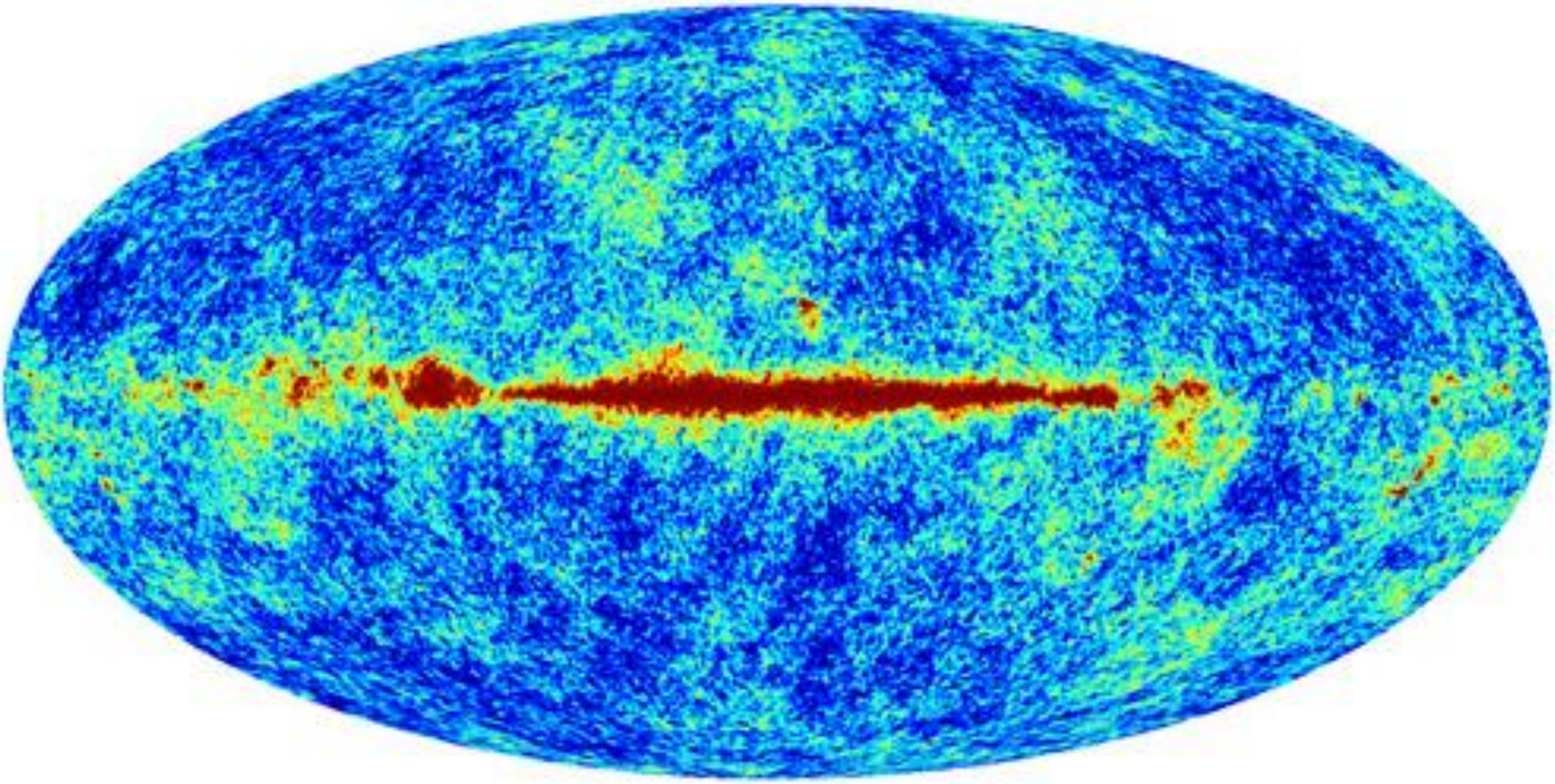


Hubble plot using Tully – Fisher relation and infrared fluxes for nearby calibrating galaxies to estimate the distances to eleven clusters of galaxies.

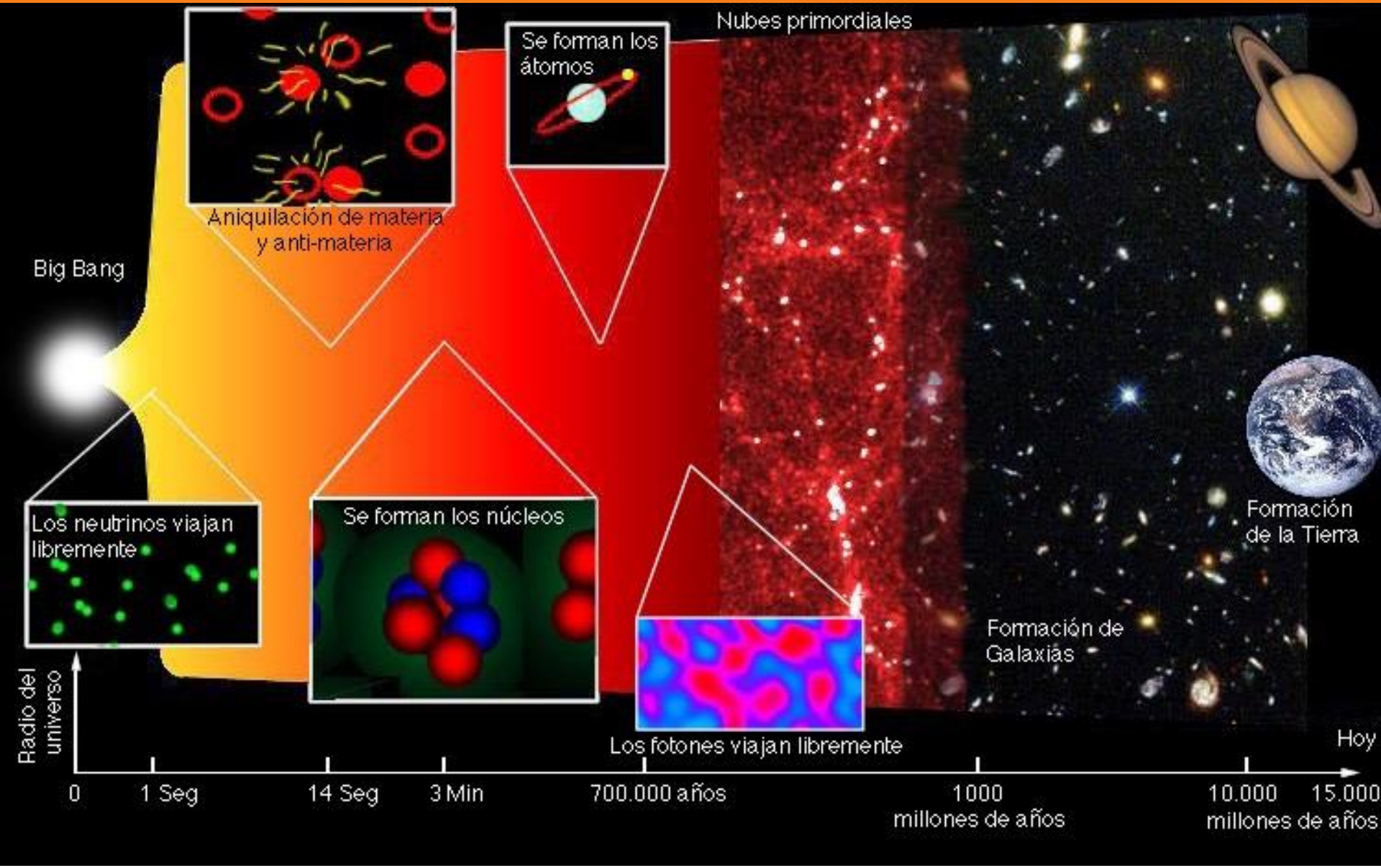
No hay centro del Universo ↔ Espacio expande en tiempo

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

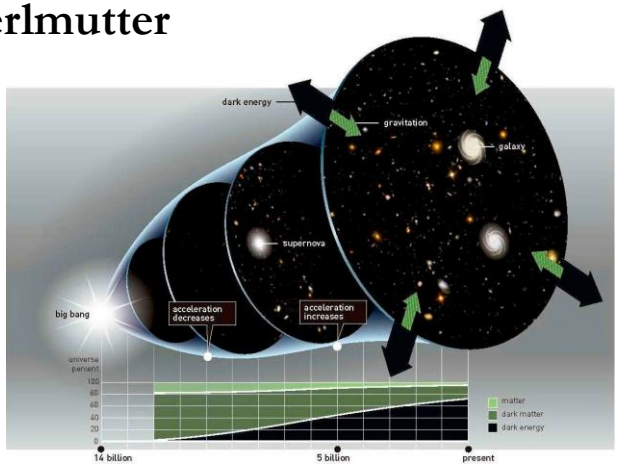
The Nobel Prize in Physics 2011

Saul Perlmutter

Brian P. Schmidt

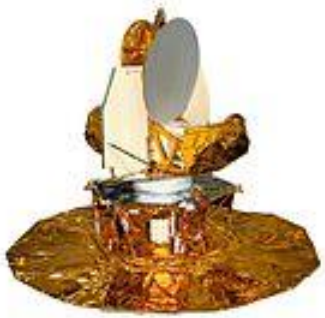
Adam G. Riess

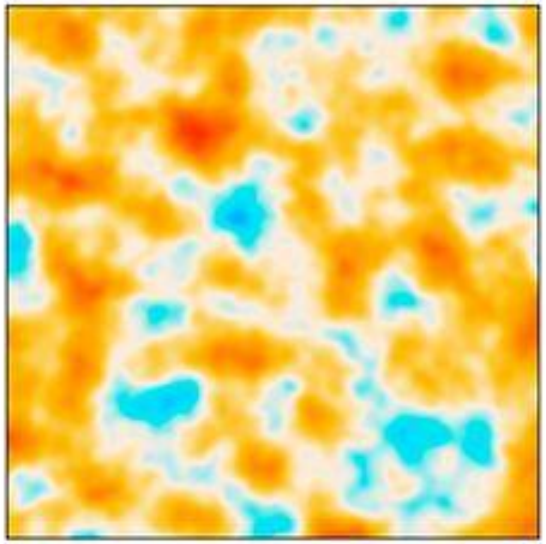
DARK ENERGY

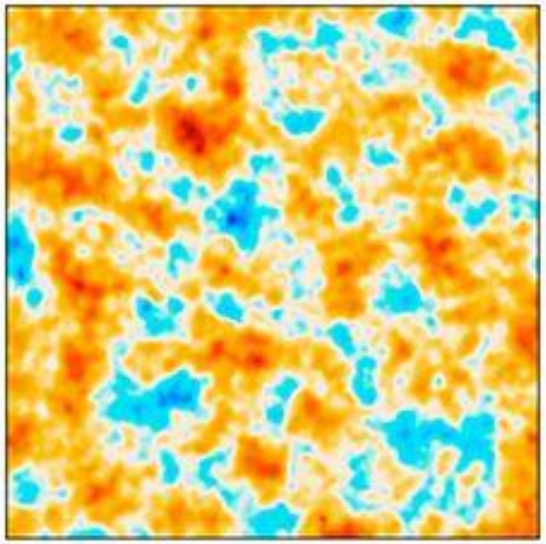


The Nobel Prize in Physics 2011 was divided, one half awarded to Saul Perlmutter, the other half jointly to Brian P. Schmidt and Adam G. Riess *"for the discovery of the accelerating expansion of the Universe through observations of distant supernovae".*

MODERN COSMOLOGY







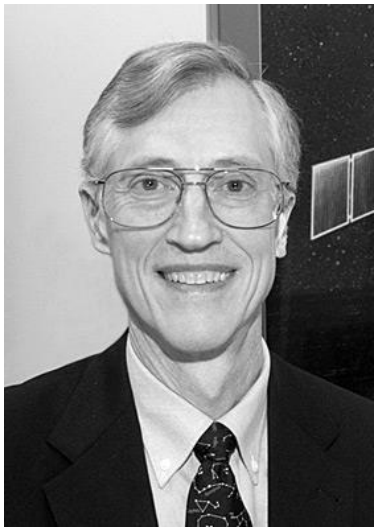
COBE

WMAP

Planck

Precision in temperature fluctuations of sky-map

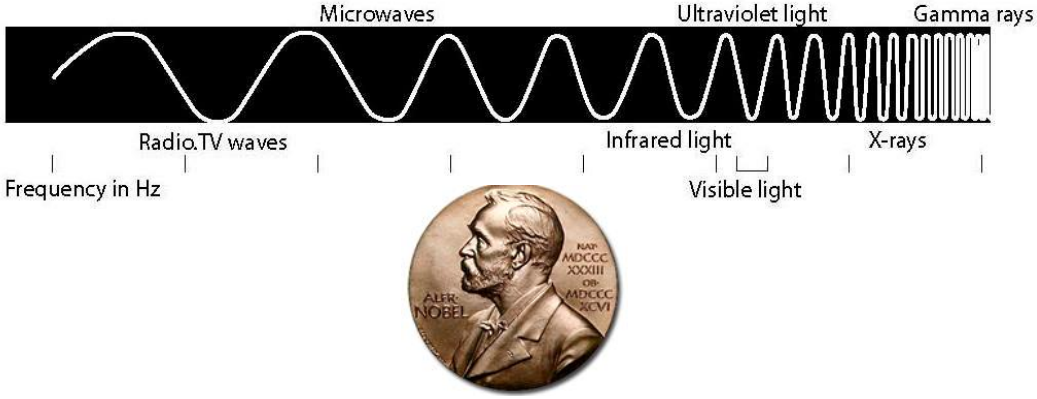
The Nobel Prize in Physics 2006



John C. Mather

George F. Smoot

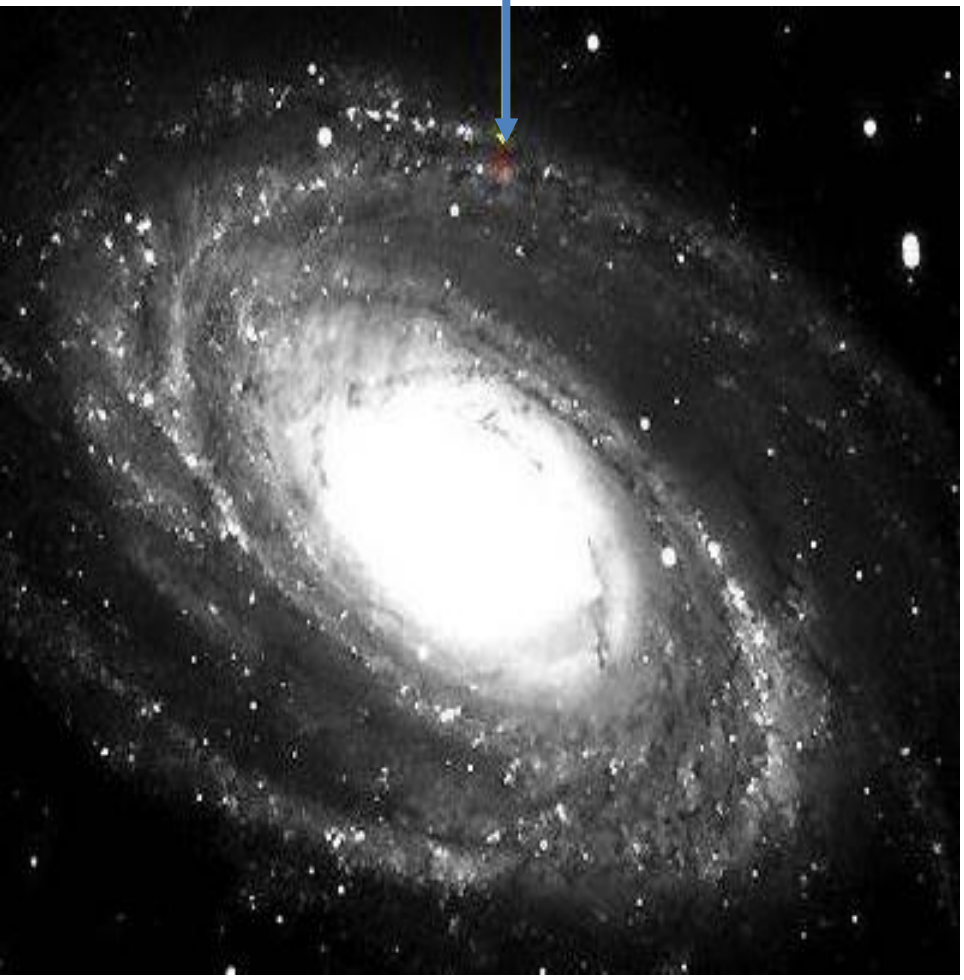
ANISOTROPY OF COSMIC MICROWAVE BACKGROUND RADIATION



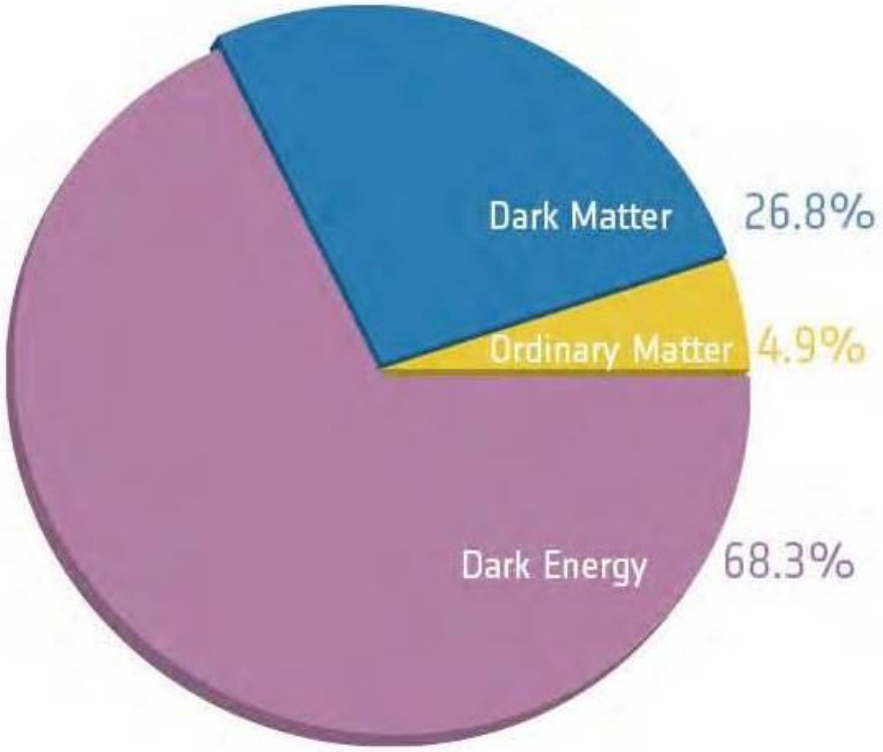
The Nobel Prize in Physics 2006 was awarded jointly to John C. Mather and George F. Smoot "for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation"

1RA REVOLUCIÓNCOPERNICANA

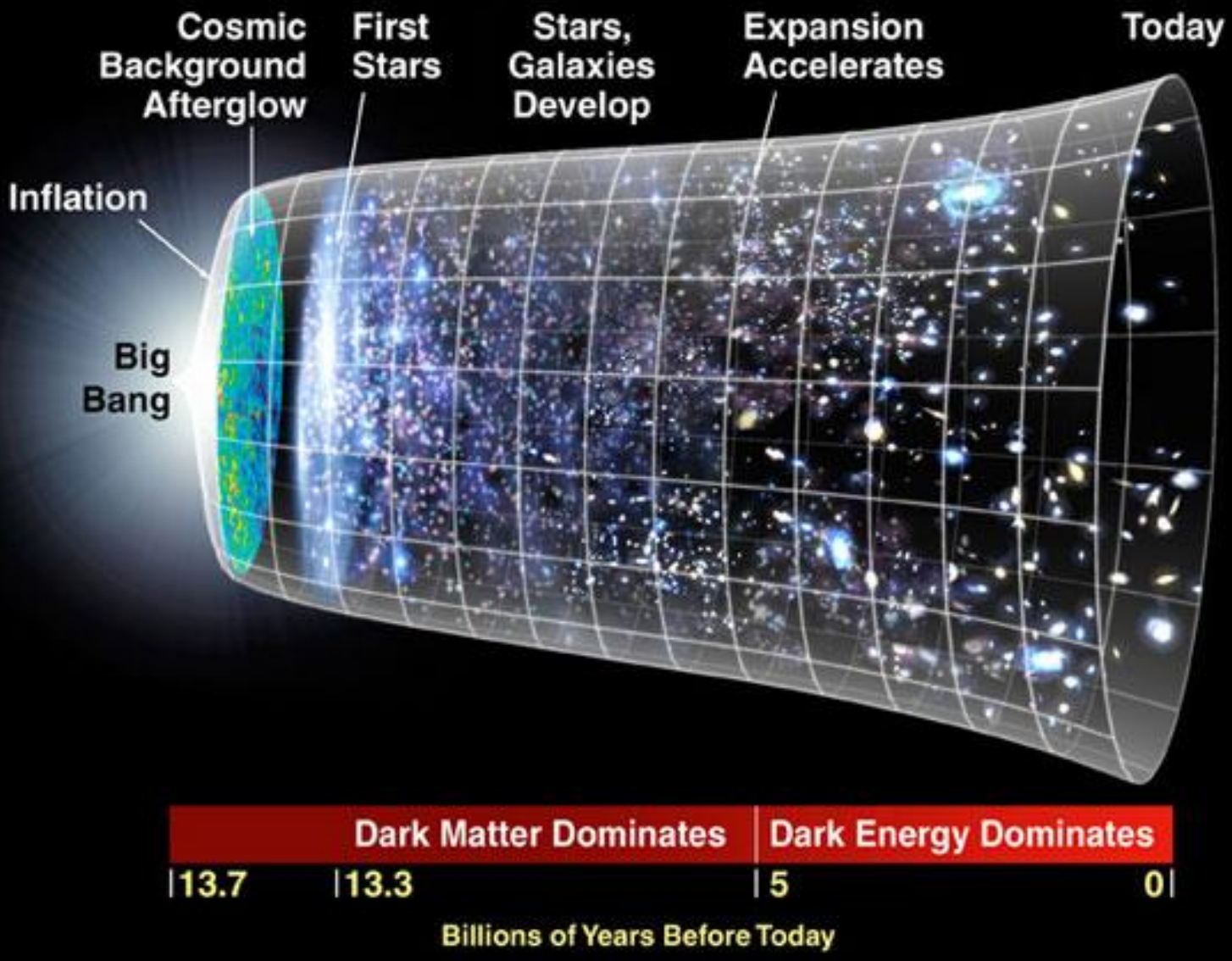
2a. revolución Copernicana

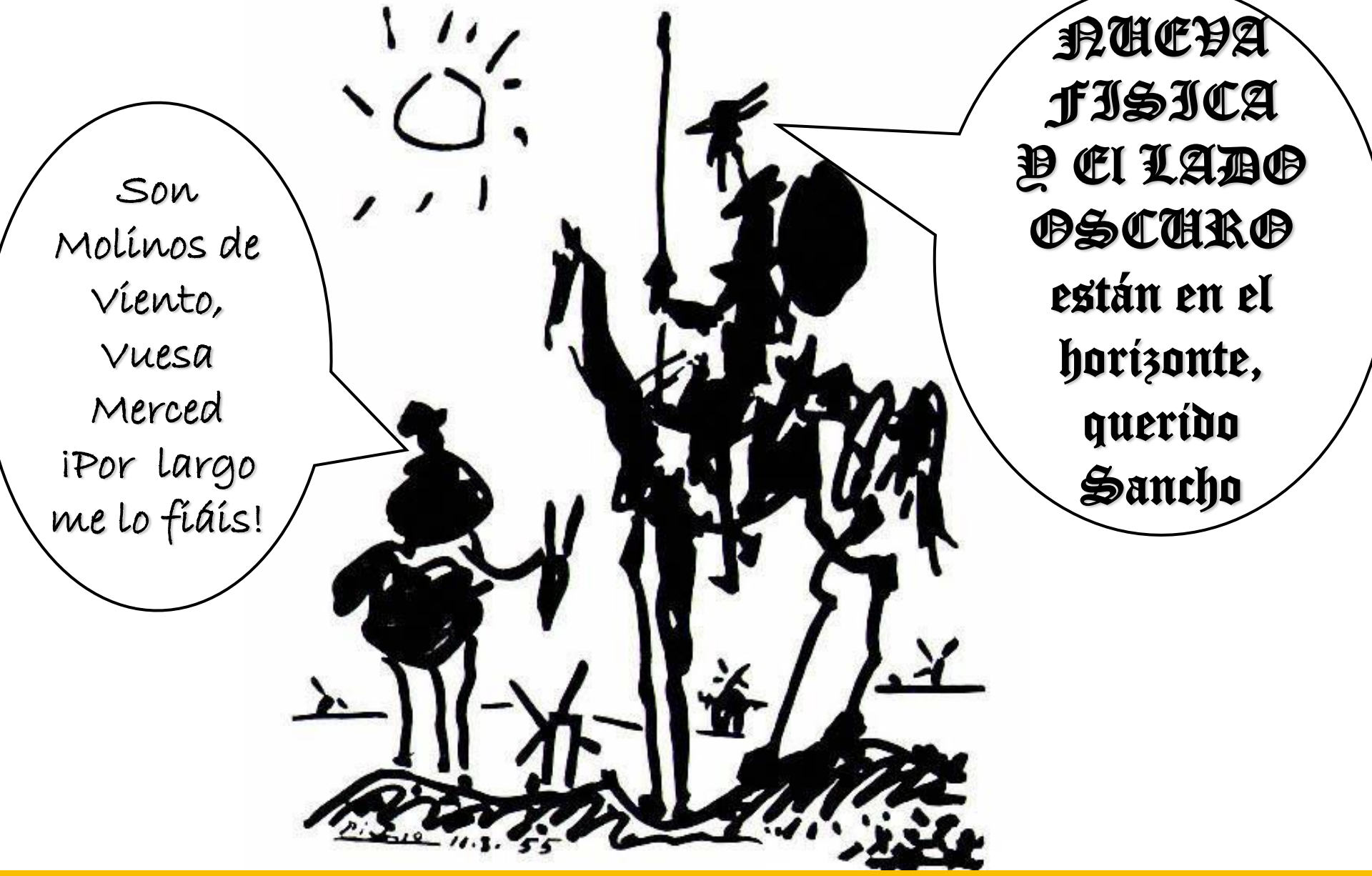


Contenido de materia-energía del Universo:



OPEN PROBLEMS: Radiation, Matter, Vacuum





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