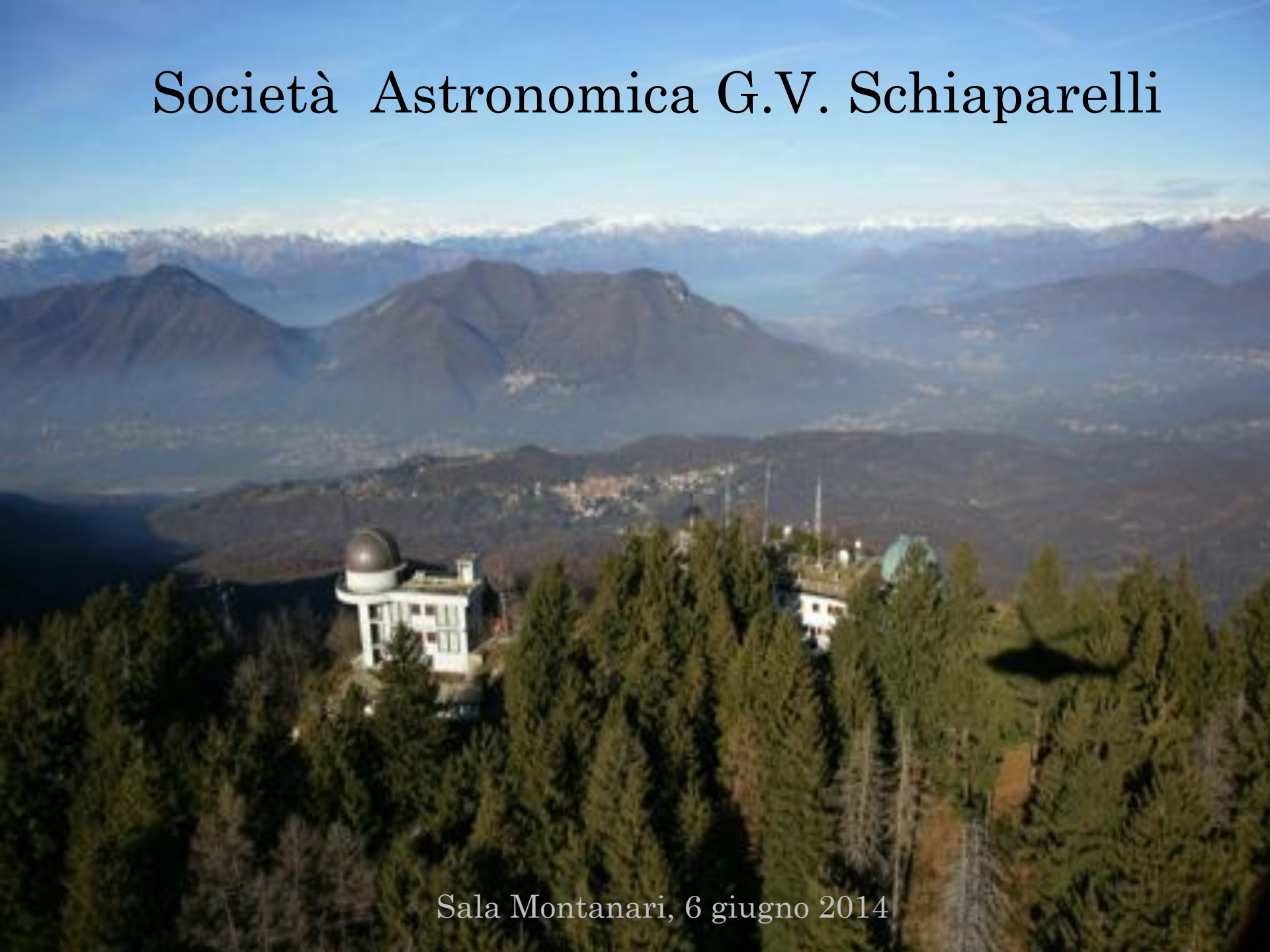
Società Astronomica G.V. Schiaparelli



Sala Montanari, 6 giugno 2014

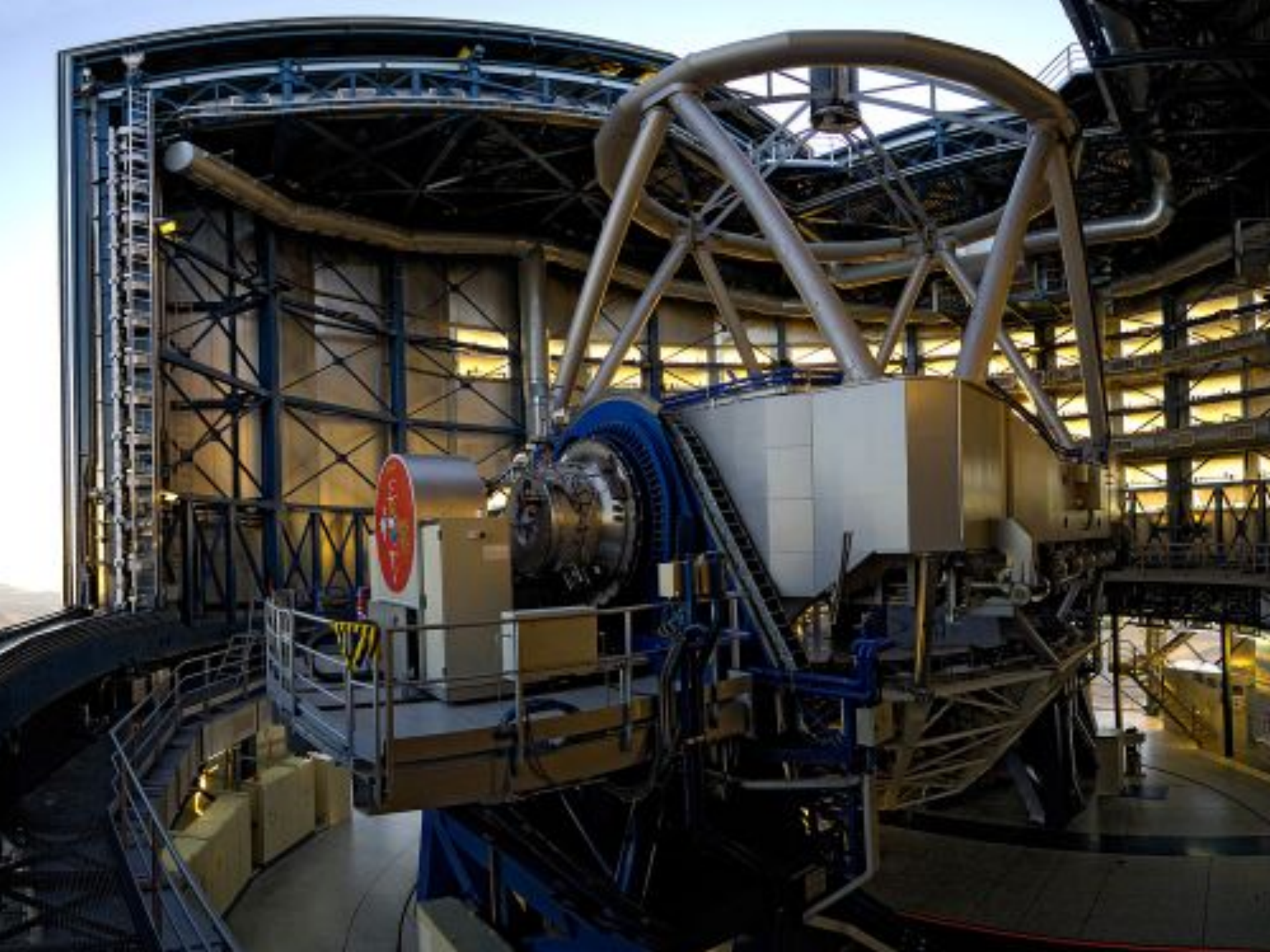
Con le tenebre si apre l'abisso,
e il cielo si popola di mondi e
luci lontane . . .

NPS photo

uno spettacolo immenso si
manifesta ai nostri occhi

ESO/H.H. Heyer

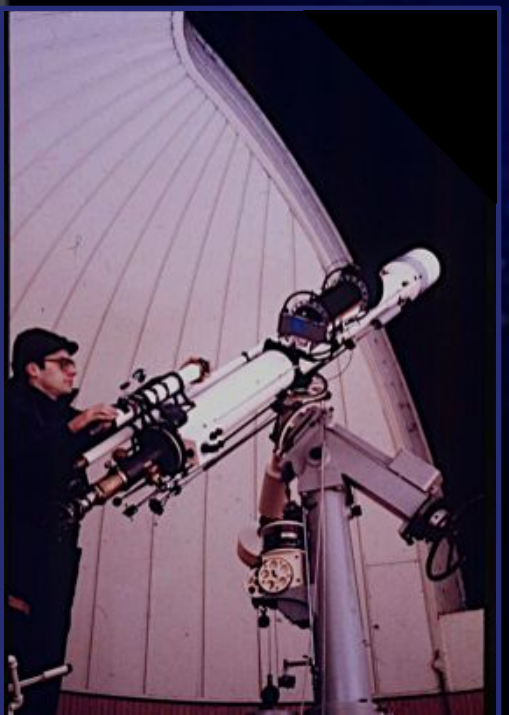
e per comprenderlo
dobbiamo misurarlo



E’ nella nostra natura inquieta
di provvisori abitanti esplorare
i confini e lo spazio

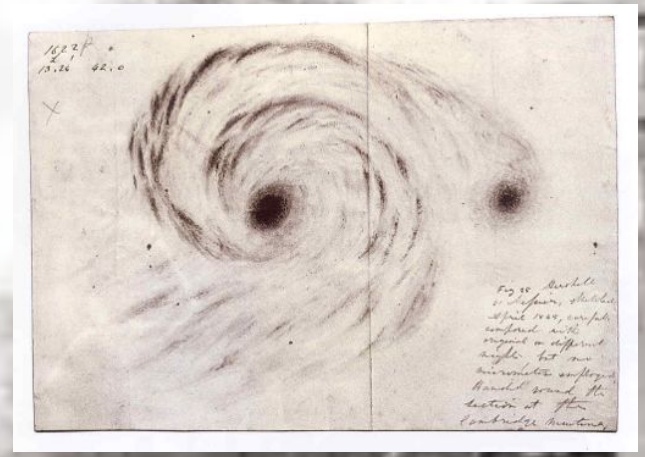
e ricercare un disegno

Dedico questo racconto
all'amico Paolo Battaini,
autentico cercatore d'oro

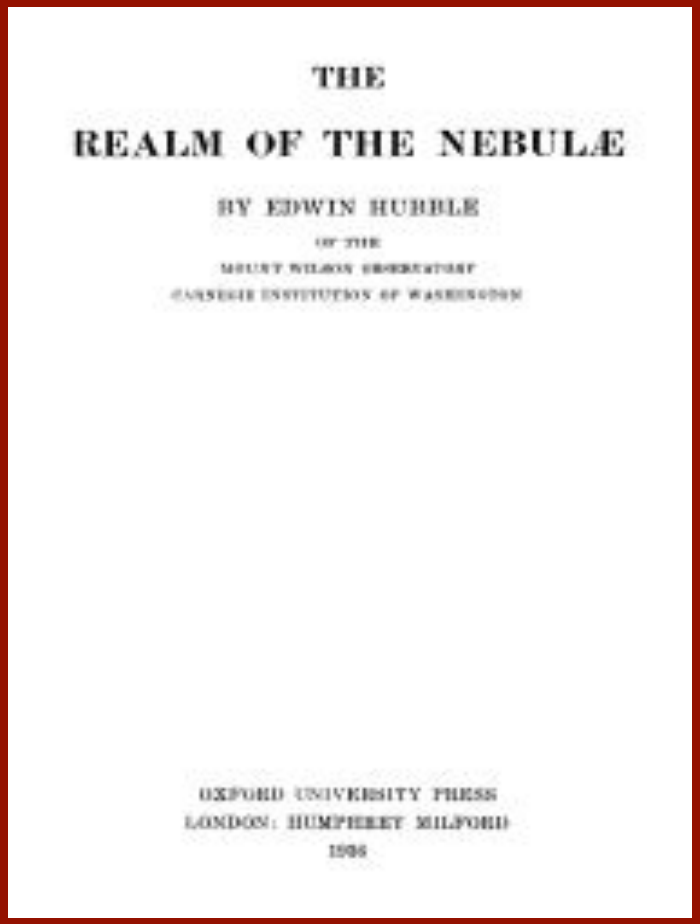


La cosmologia studia
le origini e l'evoluzione
dell'universo.

Cosa sono le galassie?
Sistemi planetari nascenti?
Universi isole?



Nessuno lo sapeva prima del 1900.
Pochissimi lo sapevano nel 1920.
Tutti gli astronomi lo seppero nel 1924.
(A. Sandage)


THE

REALM OF THE NEBULÆ

BY EDWIN HUBBLE

OF THE

MOUNT WILSON OBSERVATORY

CARNEGIE INSTITUTION OF WASHINGTON

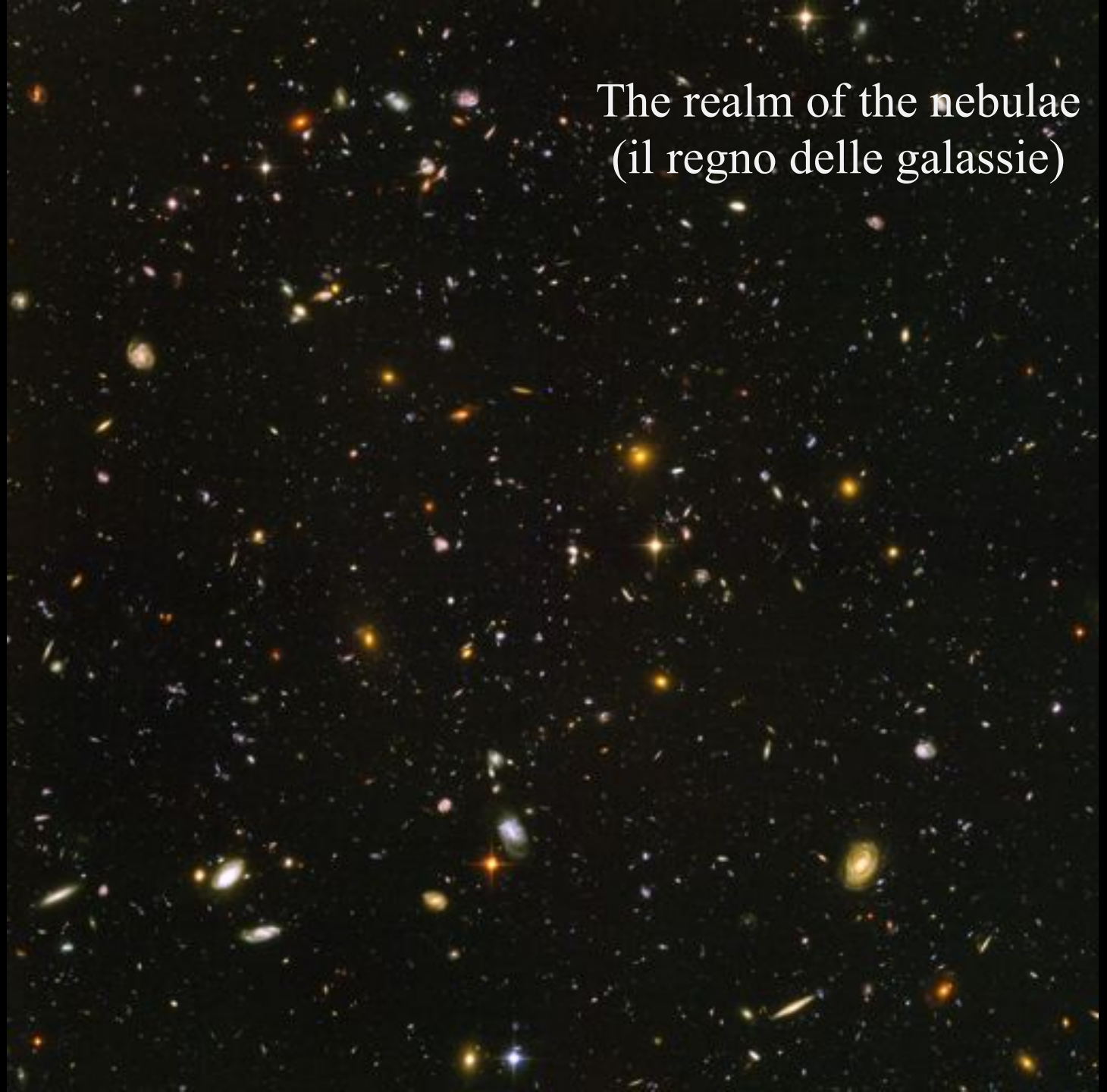
OXFORD UNIVERSITY PRESS

LONDON: HUMPHREY MILFORD

1936

Edwin Powell Hubble

1889 - 1950


The realm of the nebulae
(il regno delle galassie)

Tra i mondi ipotizzati dalle teorie, le osservazioni di Hubble col telescopio piu` potente del mondo hanno selezionato il **BIG-BANG**: l'universo si espande!

Dopo Hubble sono avvenute nuove scoperte.
Il nostro universo e` pieno di materia oscura
ed energia oscura: l'espansione accelera!

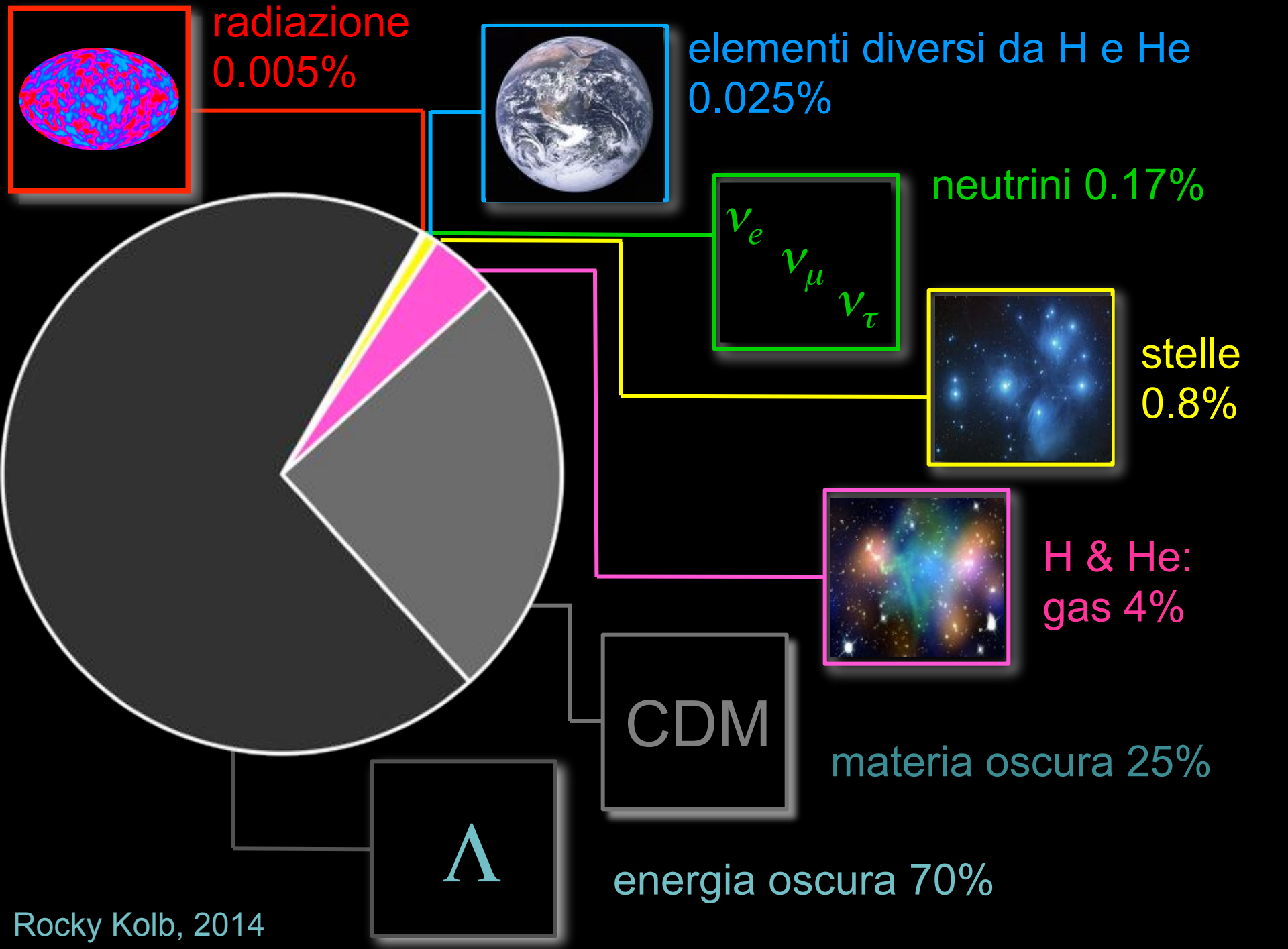
Ogni mese arXiv.org sforna migliaia di articoli di ricerca di fisica di libero accesso. La nuova teoria dell'universo si chiama **ΛCDM**

ΛCDM

L'UNIVERSO OSCURO

Luca G Molinari

Varese, 6 giugno 2014


radiazione
0.005%
elementi diversi da H e He
0.025%
neutrini 0.17%
ν_e ν_μ ν_τ
stelle
0.8%
H & He:
gas 4%
CDM
materia oscura 25%
Λ
energia oscura 70%
Rocky Kolb, 2014

Cornell University Library

Cornell University Library
We gratefully acknowledge support from
the Simons Foundation
and member institutions

arXiv.org

Login
Search or Article-id
(Help | Advanced search)
All papers Go!

Open access to 936,742 e-prints in Physics, Mathematics, Computer Science, Quantitative Biology, Quantitative Finance and Statistics

Subject search and browse: Physics Search Form Interface Catchup

10 Apr 2014: Introducing q-fin.EC and q-fin.MF
See cumulative "What's New" pages. Read robots beware before attempting any automated download

Physics

- Astrophysics (**astro-ph** new, recent, find)
  includes: Astrophysics of Galaxies; Cosmology and Nongalactic Astrophysics; Earth and Planetary Astrophysics; High Energy Astrophysical Phenomena; Instrumentation and Methods for Astrophysics; Solar and Stellar Astrophysics
- Condensed Matter (**cond-mat** new, recent, find)
  includes: Disordered Systems and Neural Networks; Materials Science; Mesoscale and Nanoscale Physics; Other Condensed Matter; Quantum Gases; Soft Condensed Matter; Statistical Mechanics; Strongly Correlated Electrons; Superconductivity
- General Relativity and Quantum Cosmology (**gr-qc** new, recent, find)
- High Energy Physics - Experiment (**hep-ex** new, recent, find)
- High Energy Physics - Lattice (**hep-lat** new, recent, find)
- High Energy Physics - Phenomenology (**hep-ph** new, recent, find)
- High Energy Physics - Theory (**hep-th** new, recent, find)
- Mathematical Physics (**math-ph** new, recent, find)
- Nonlinear Sciences (**nlin** new, recent, find)
  includes: Adaptation and Self-Organizing Systems; Cellular Automata and Lattice Gases; Chaotic Dynamics; Exactly Solvable and Integrable Systems; Pattern Formation and Solitons
- Nuclear Experiment (**nucl-ex** new, recent, find)
- Nuclear Theory (**nucl-th** new, recent, find)
- Physics (**physics** new, recent, find)
  includes: Accelerator Physics; Atmospheric and Oceanic Physics; Atomic Physics; Atomic and Molecular Clusters; Biological Physics; Chemical Physics; Classical Physics; Computational Physics; Data Analysis, Statistics and Probability; Fluid Dynamics; General Physics; Geophysics; History and Philosophy of Physics; Instrumentation and Detectors; Medical Physics; Optics; Physics Education; Physics and Society; Plasma Physics; Popular Physics; Space Physics

arXiv – 2013

PHYSICS

astro-ph	12475
cond-mat	12746
hep-xxx	11672
math-ph	1170
nlin	890
nucl-xxx	1826
phys-xxx	7506
quant-ph	4049

MATH 26785

Open access to 944,498 e-prints in Physics, Mathematics, Computer Science, Quantitative Biology, Quantitative Finance and Statistics

La distanza delle galassie

La relazione periodo-luminosita`
delle stelle variabili Cefeidi
(una scoperta fondamentale)

.

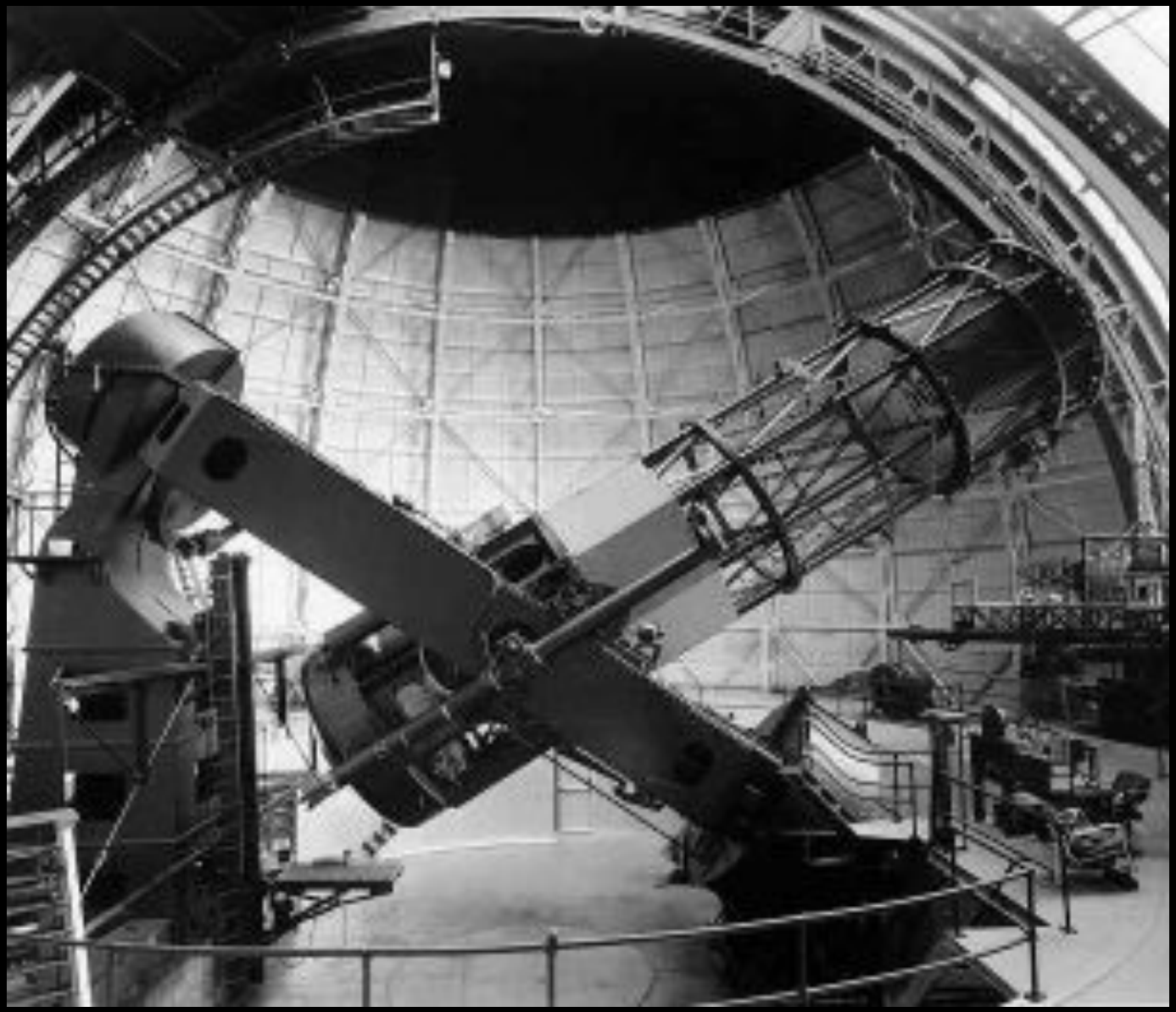
Seleziona 16 stelle variabili nella nube di Magellano e osserva:

The brighter ones have longer periods.

“1777 variables in the Magellanic Clouds” Ann. Astr. Obs. Harv. (1908)

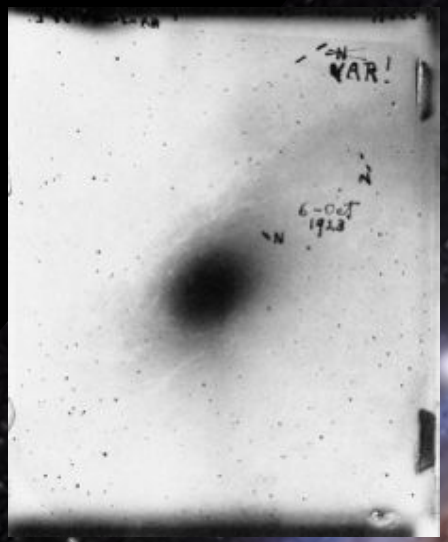
Le stelle cefeidi sono pietre miliari nel cielo (candele standard)

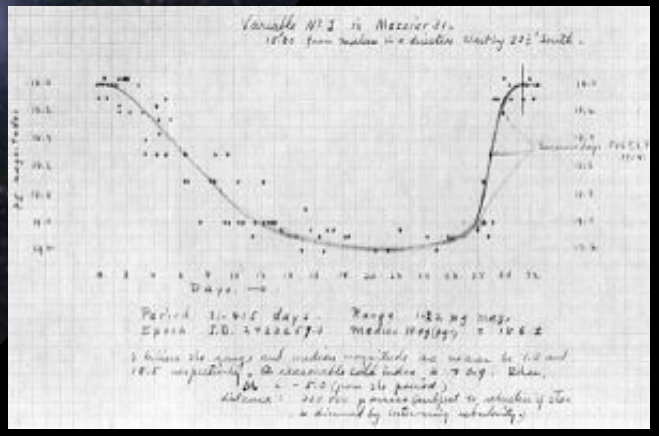
Shapley misurò la Via Lattea con le Cefeidi e gli ammassi globulari



Mount Wilson, 100’’ Hooker telescope

VAR!



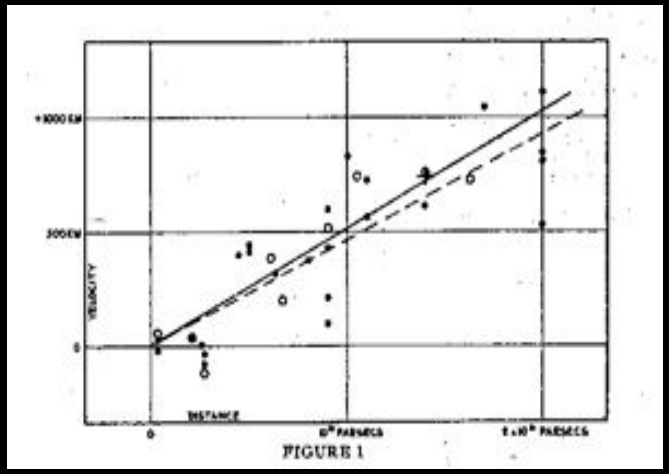


2,3 milioni di anni luce

La legge di Hubble e l'espansione dell'universo (il BIG BANG)

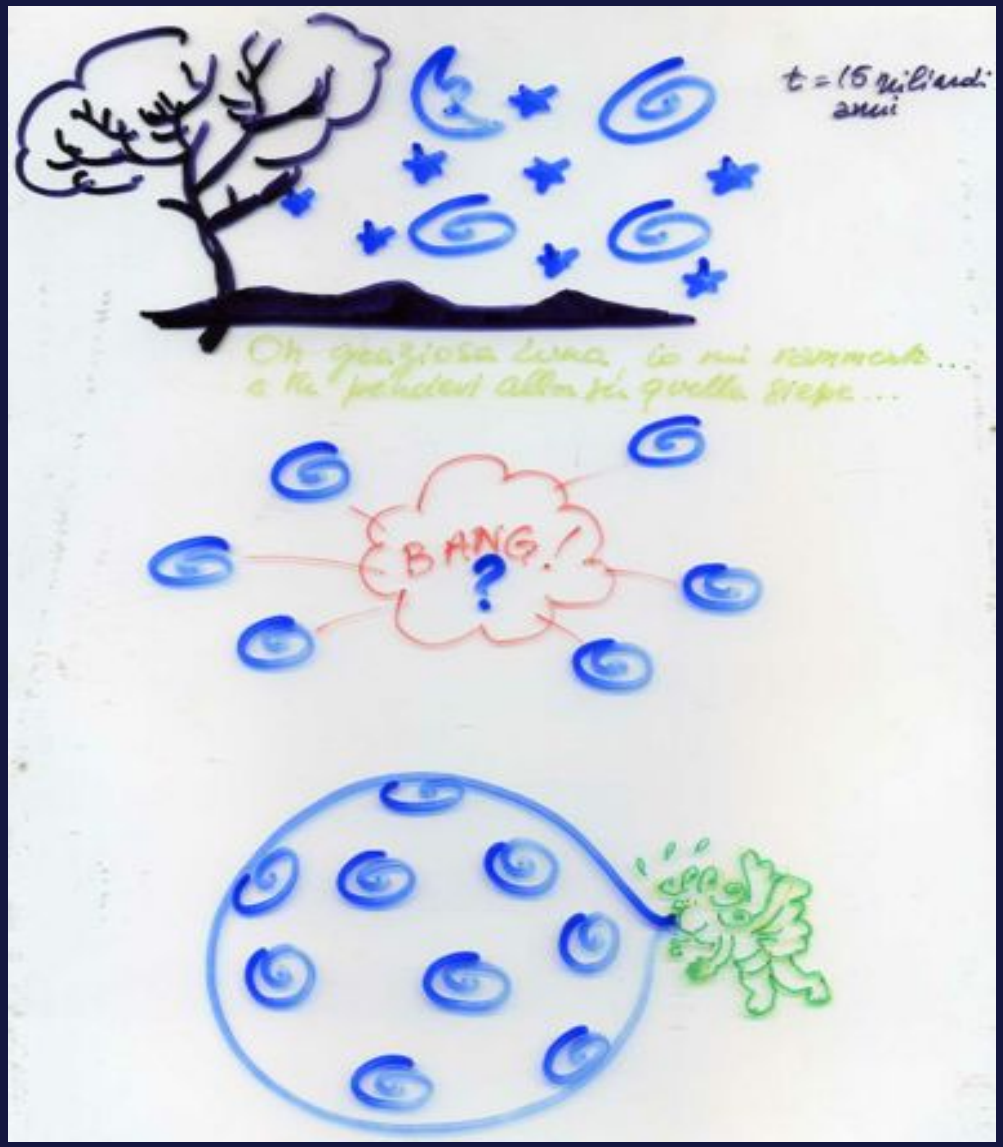
LA LEGGE DI HUBBLE

Le nebulae si allontanano da noi
con velocità fino a 2000 km/s
(redshift delle nebulae, Vesto Slipher 1914)



v = H d

(1929)


t = 15 miliardi di anni
Oh graziosa Luna, io mi rammento...
e ho perduti alcuni di quelle stelle...
BANG!
?

Einstein incontra Hubble (e Adams)
La teoria incontra l'osservazione

L'universo in espansione era gia` previsto dalla teoria di Einstein!
L'osservazione seleziona un possibile mondo della teoria

Le geometrie non-Euclidee

Per un punto passa una e una sola retta parallela a una retta data

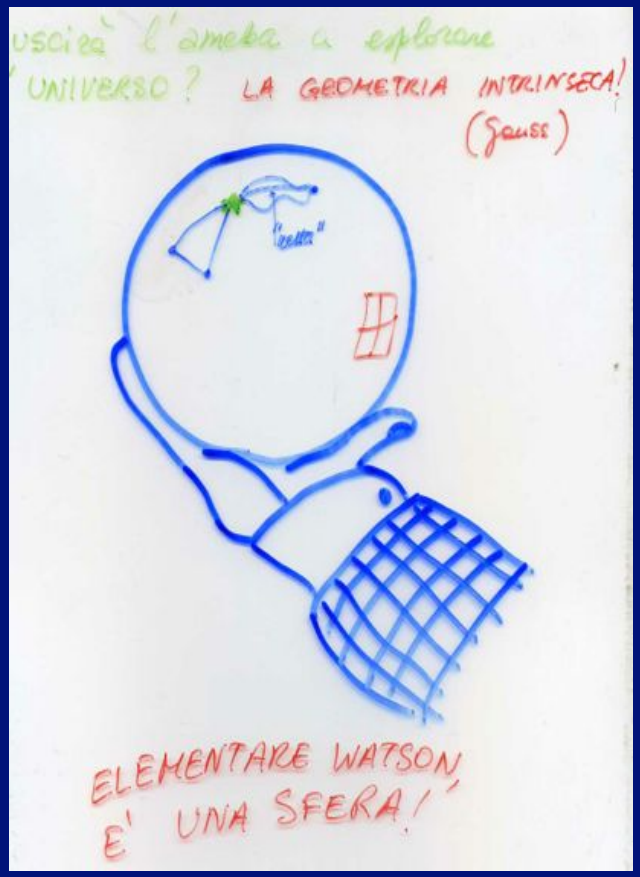
Karl F. Gauss

Janos Bolyai

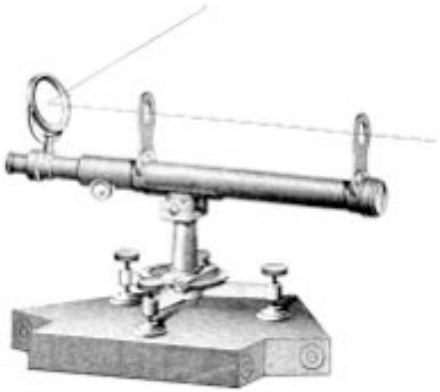
Nikolaj Lobacevskij

... Lodarlo sarebbe infatti lodare me stesso; tutto il contenuto dell'opera spianata da tuo figlio coincide quasi interamente con quanto occupa le mie meditazioni da trentacinque anni a questa parte ...

L’universo dell’ameba non e` euclideo. Perche’ mai dovrebbe esserlo il nostro?

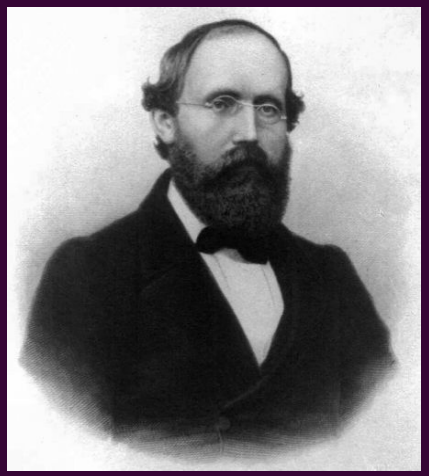


Karl F Gauss



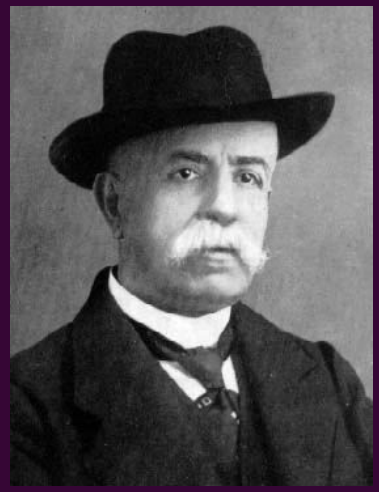
Eliotropo

La geometria moderna



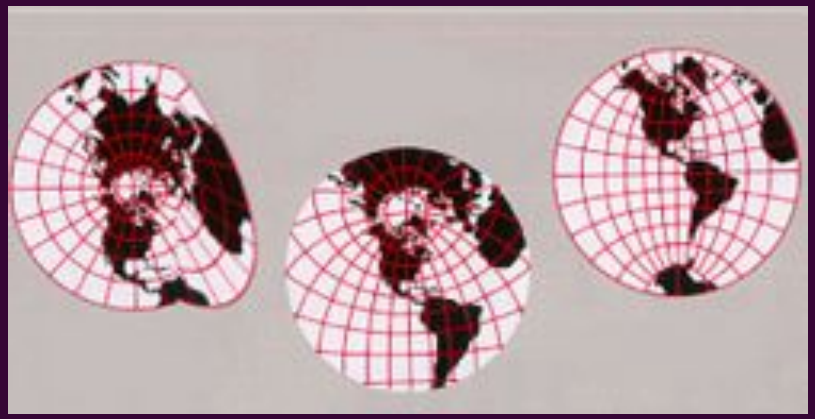
Bernhard Riemann

Elwin B.Christoffel



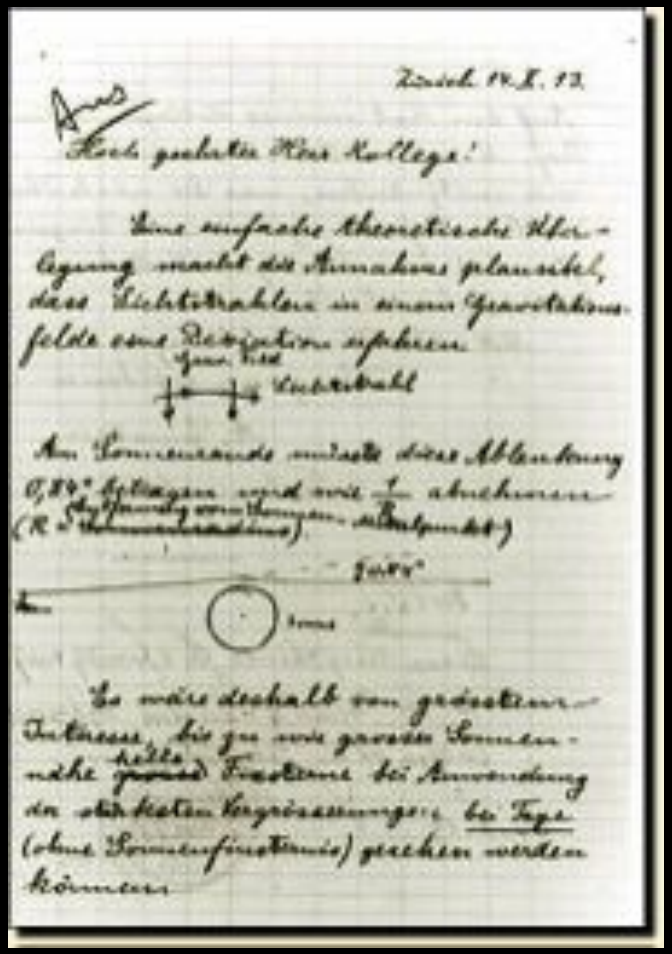
Gregorio
Ricci-Curbastro

Tullio Levi Civita



Il calcolo differenziale assoluto

La Relativita` Generale (1916)



Zürich 14. XI. 15.

Hochgeehrter Herr Kollege!

Eine einfache theoretische Überlegung macht die Annahme plausibel, dass Lichtstrahlen in einem Gravitationsfelde eine Deviation erfahren.

Ganz nah — Lichtstrahl

Am Sonnenrande müsste diese Ablenkung 0,84" betragen und wird — abnehmen — (R = Sonnenradius).

0,84"

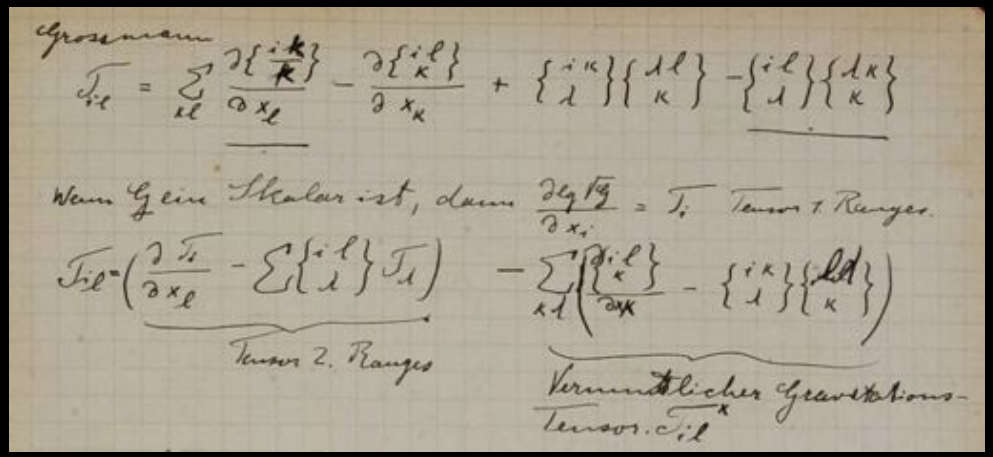
Sonne

Es wäre deshalb von grösstem Interesse, bis zu wie grossen Sonnendistanzen hellen Fixsterne bei Anwendung der stärksten Vergrösserungen bei Tage (ohne Sonnenfinsternis) gesehen werden können.

Descrizione geometrica della gravita`:

LA GEOMETRIA DIRIGE
LA MATERIA
E
LA MATERIA DETTA LA
GEOMETRIA DELLO SPAZIO

Le equazioni di Einstein

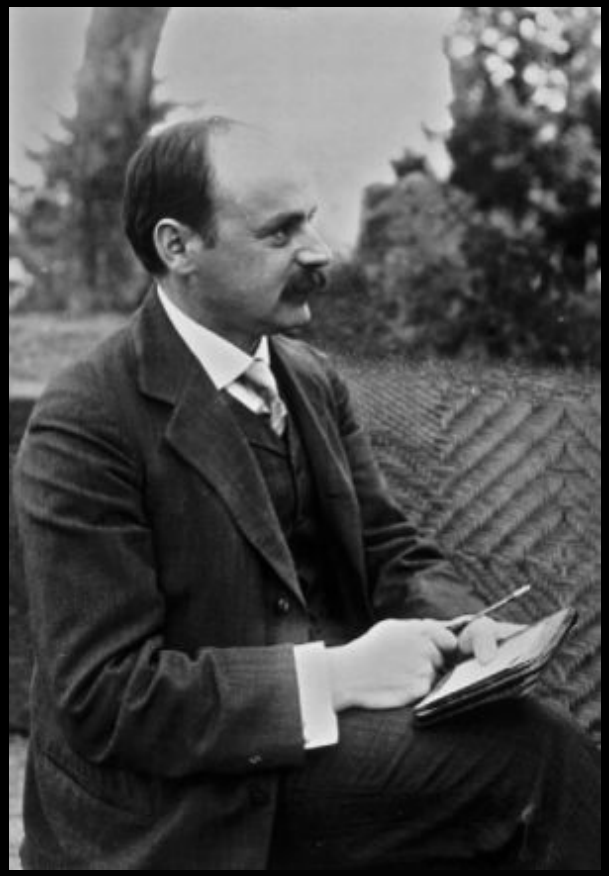


da sin: M. Grossmann, A. Einstein

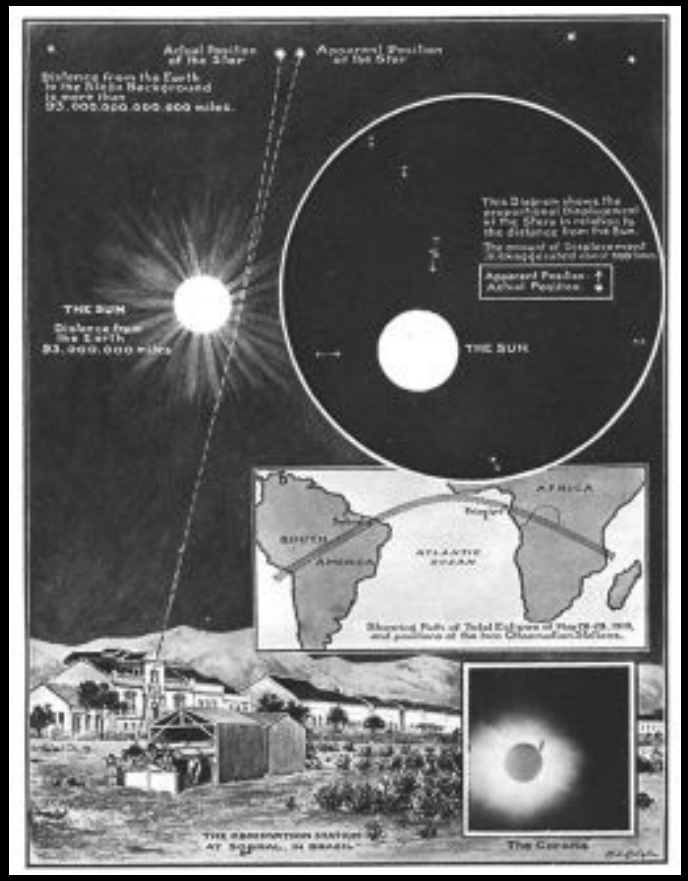
$$R_{\mu\nu} - \tfrac{1}{2} g_{\mu\nu} R - \Lambda g_{\mu\nu} = 8 \pi G T_{\mu\nu}$$

La soluzione di Schwarzschild (1916)

(spazio vuoto attorno a una massa sferica - possibilita' dei buchi neri)



Karl Schwarzschild



Eclisse di Sole 1919, Sir A. Eddington

La soluzione di Friedmann (1922)

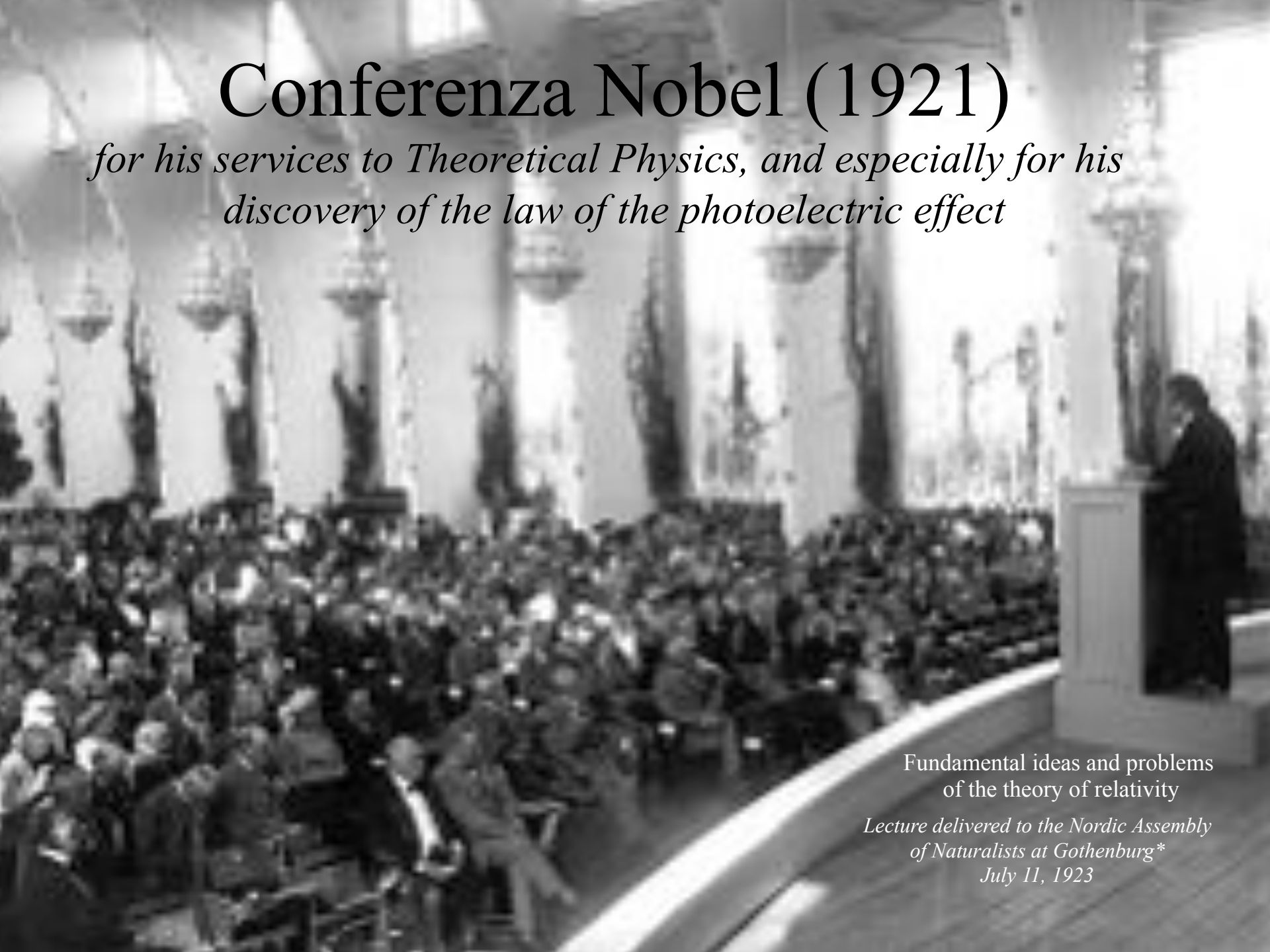
Nel 1922 Friedmann invio` il lavoro "Sulla curvatura dello spazio" alla rivista Zeitschrift für Physik.
In una breve nota il grande Einstein senza mezzi termini giudico` il lavoro "matematicamente sbagliato" (Einstein pensava che l'universo dovesse essere stazionario ed eterno).

Friedmann scrisse ad Einstein una lettera coi calcoli dettagliati, invitandolo, qualora si convincesse dell'esattezza dei suoi calcoli, a informare il direttore della rivista.Dopo mesi senza risposta affido` la lettera all'amico Krutkov, che doveva incontrare Einstein.
Il padre della relatività mando` una nota alla rivista, in cui ammise il proprio errore e la correttezza dei risultati di Friedmann.

Alexander Friedmann
1888 - 1925

Conferenza Nobel (1921)

for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect



Fundamental ideas and problems of the theory of relativity

Lecture delivered to the Nordic Assembly of Naturalists at Gothenburg July 11, 1923*

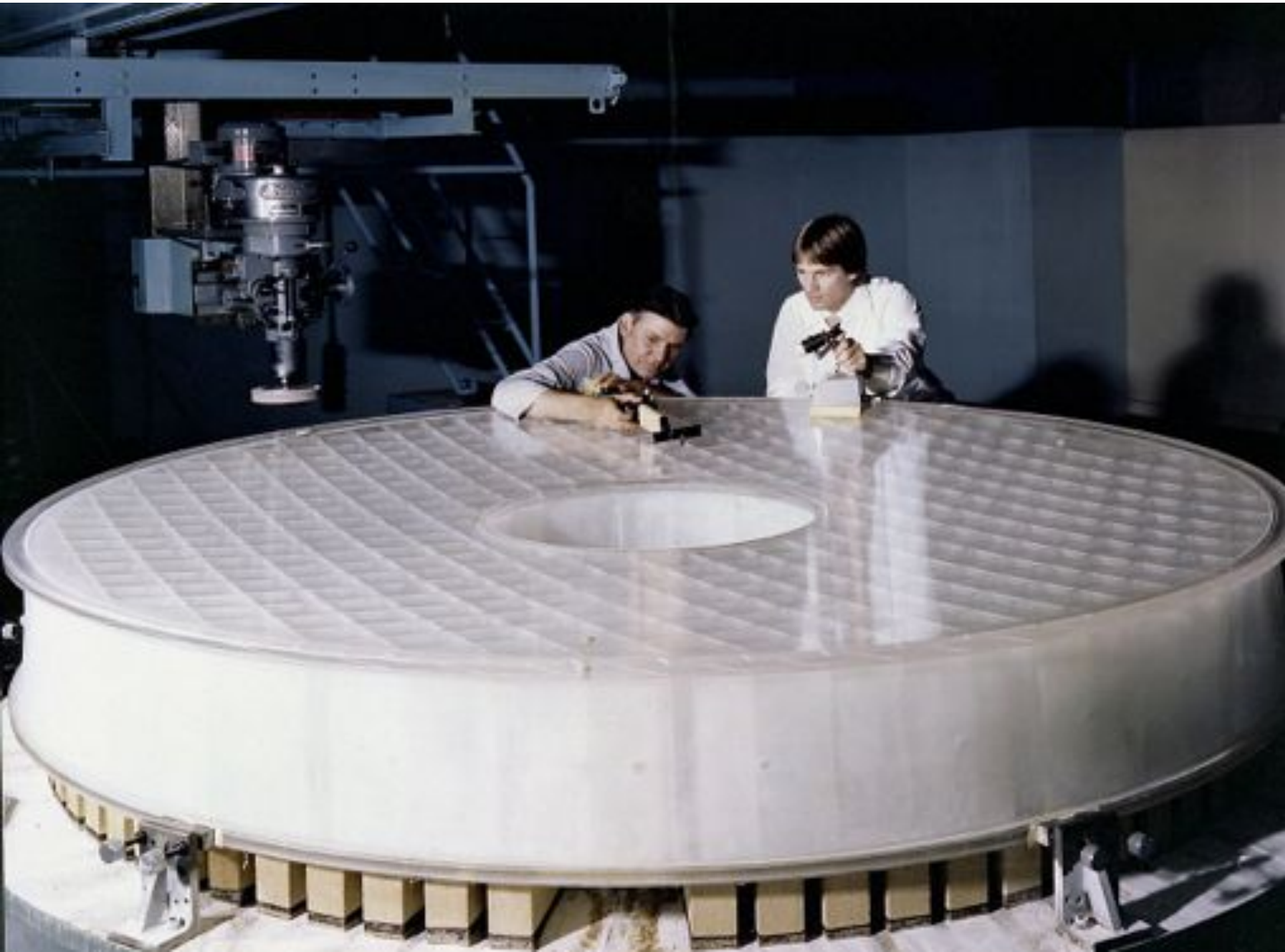
La materia agisce come lente gravitazionale
sulla luce di sorgenti retrostanti

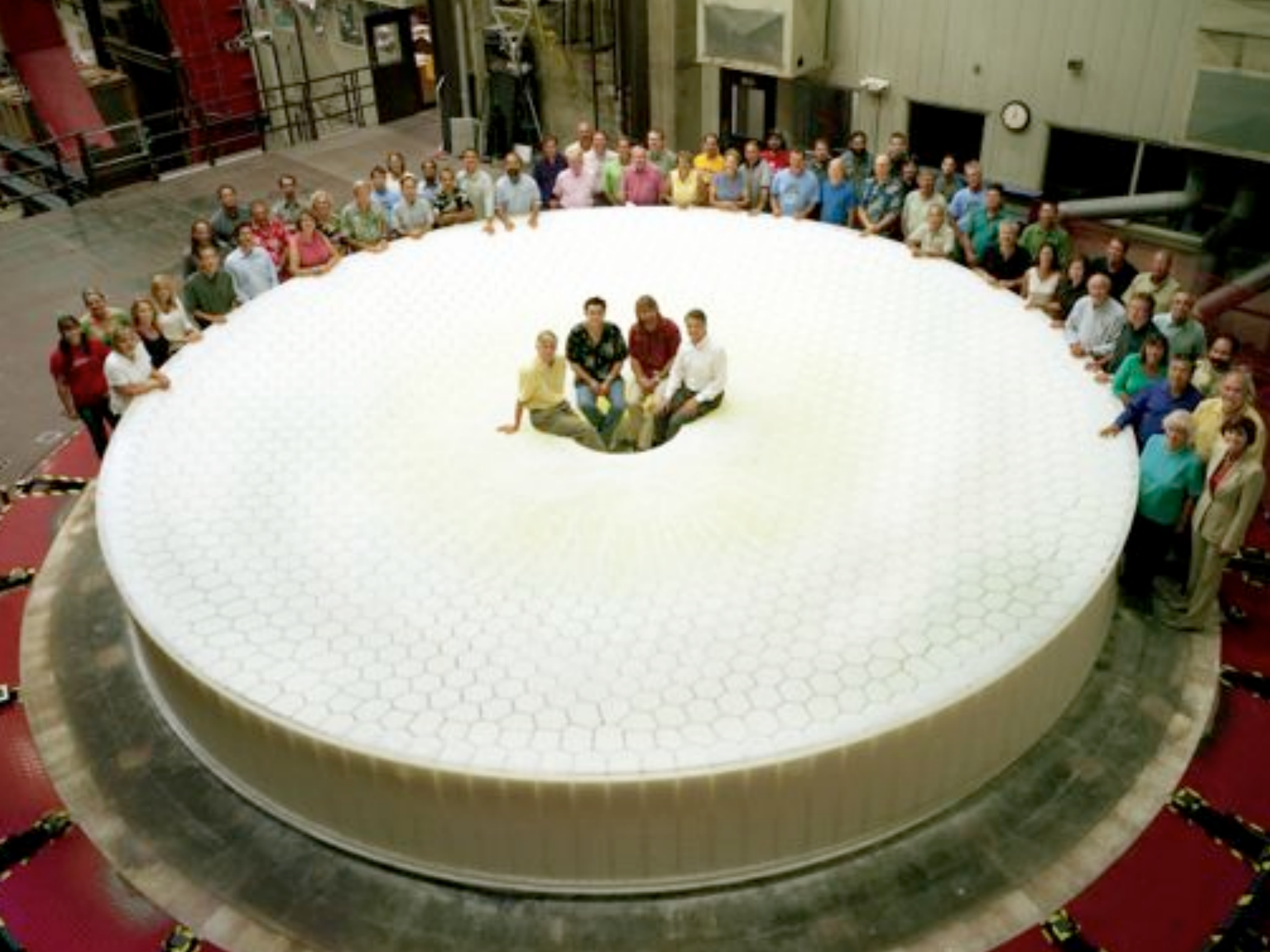
The observable region is our sample of the universe.
If the sample is fair, its observed characteristics will determine the physical nature of the universe as a whole.
(E. Hubble, 1936)

Principio cosmologico:
L'universo appare,
nello stesso tempo e su grande scala, uguale in tutte le direzioni e per qualunque osservatore

Inaugurazione di Palomar 1948

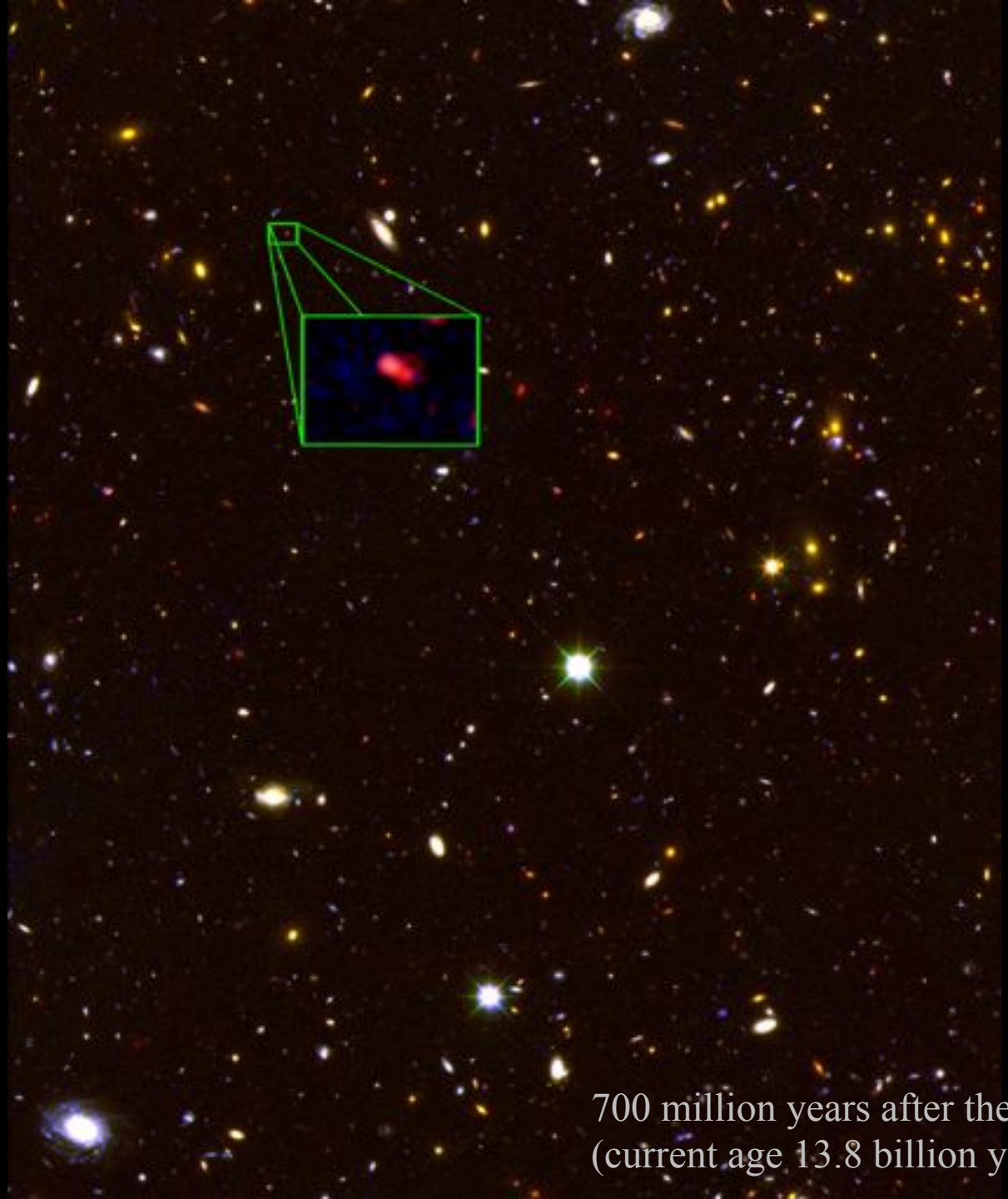
Hubble Space Telescope





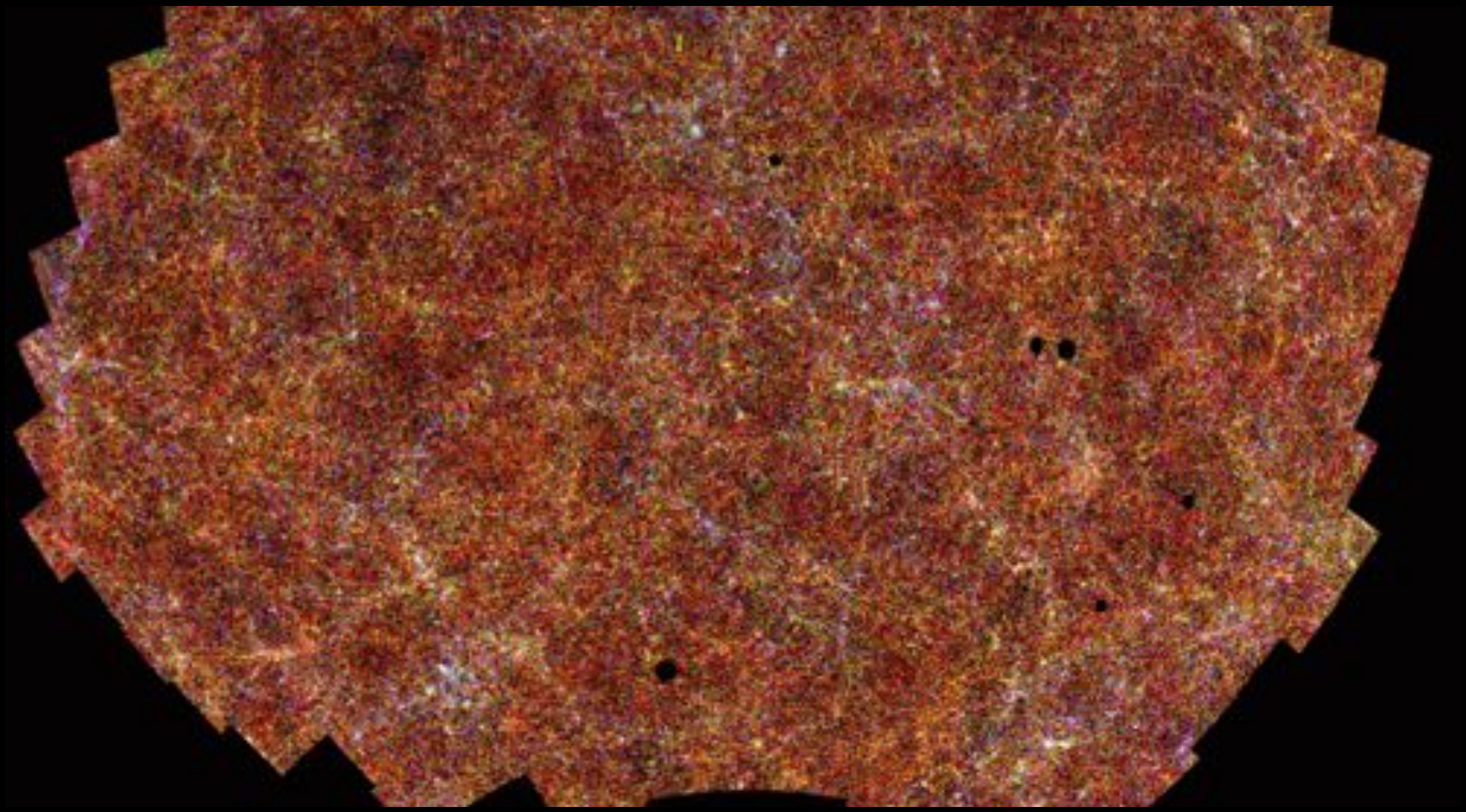
NGC 1132

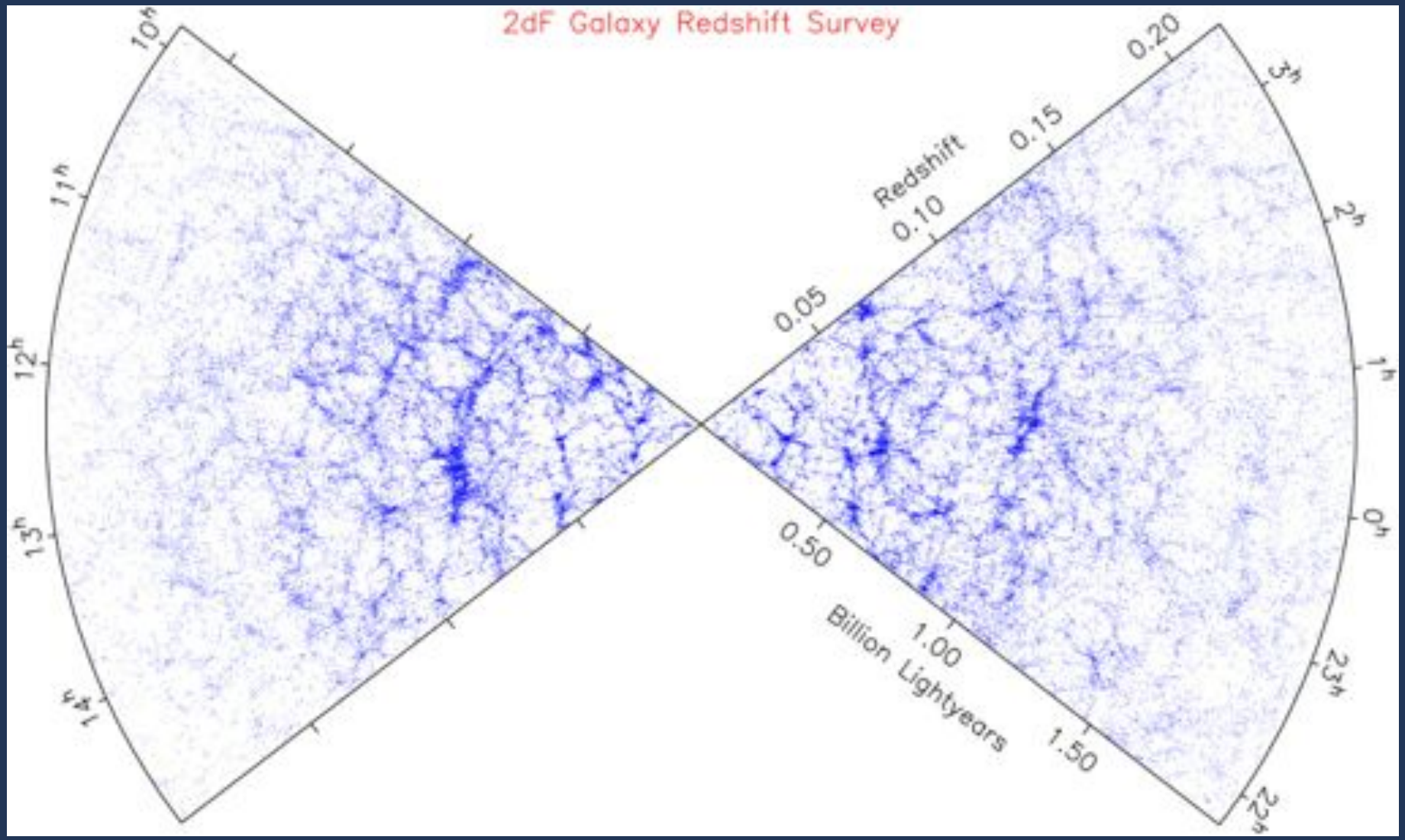
Ammasso Abell2218, dist: 2,1 Miliardi a.l.



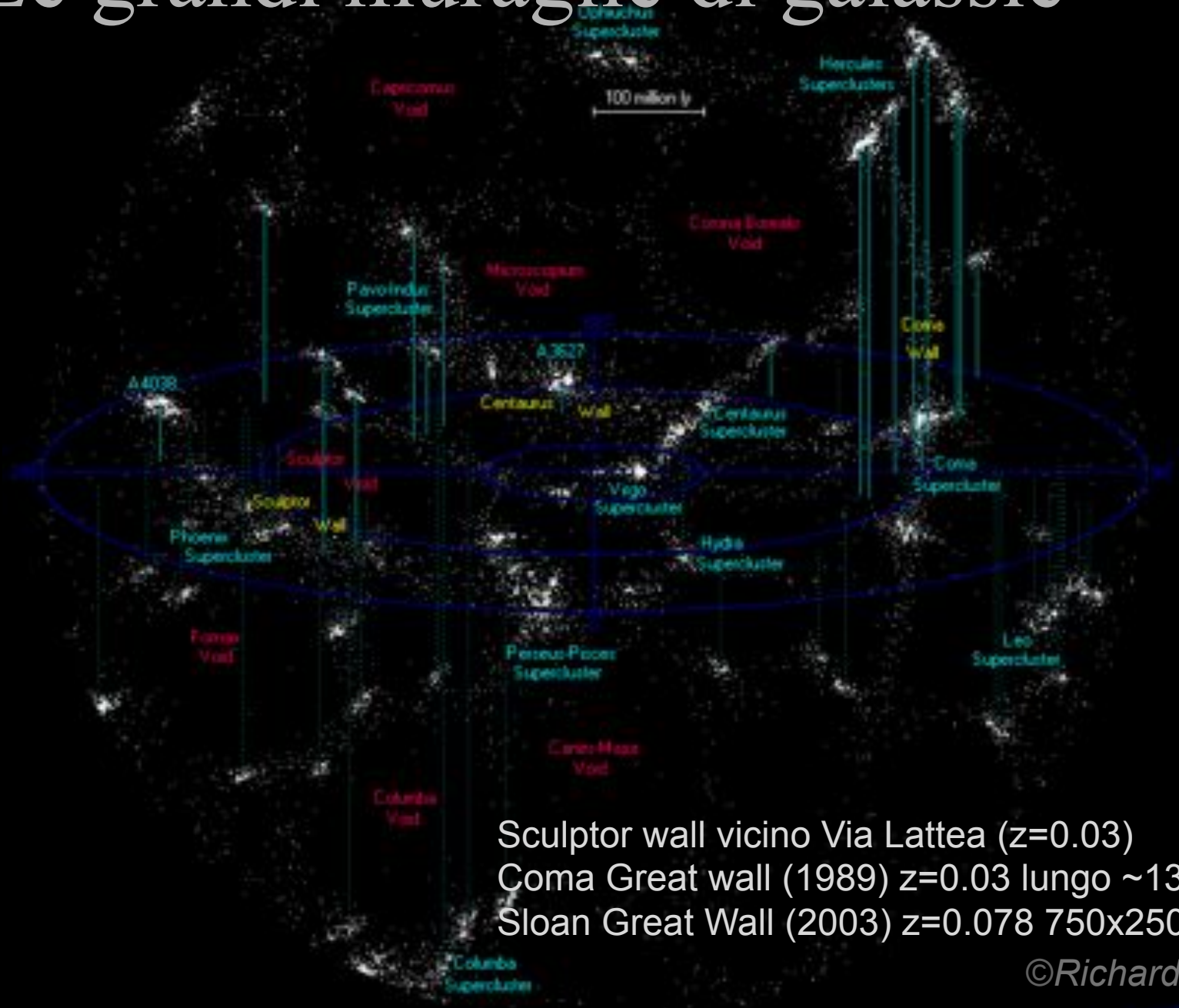
700 million years after the Big Bang
(current age 13.8 billion years) z=7.51

APM galaxy survey
(3 MILIONI DI GALASSIE)



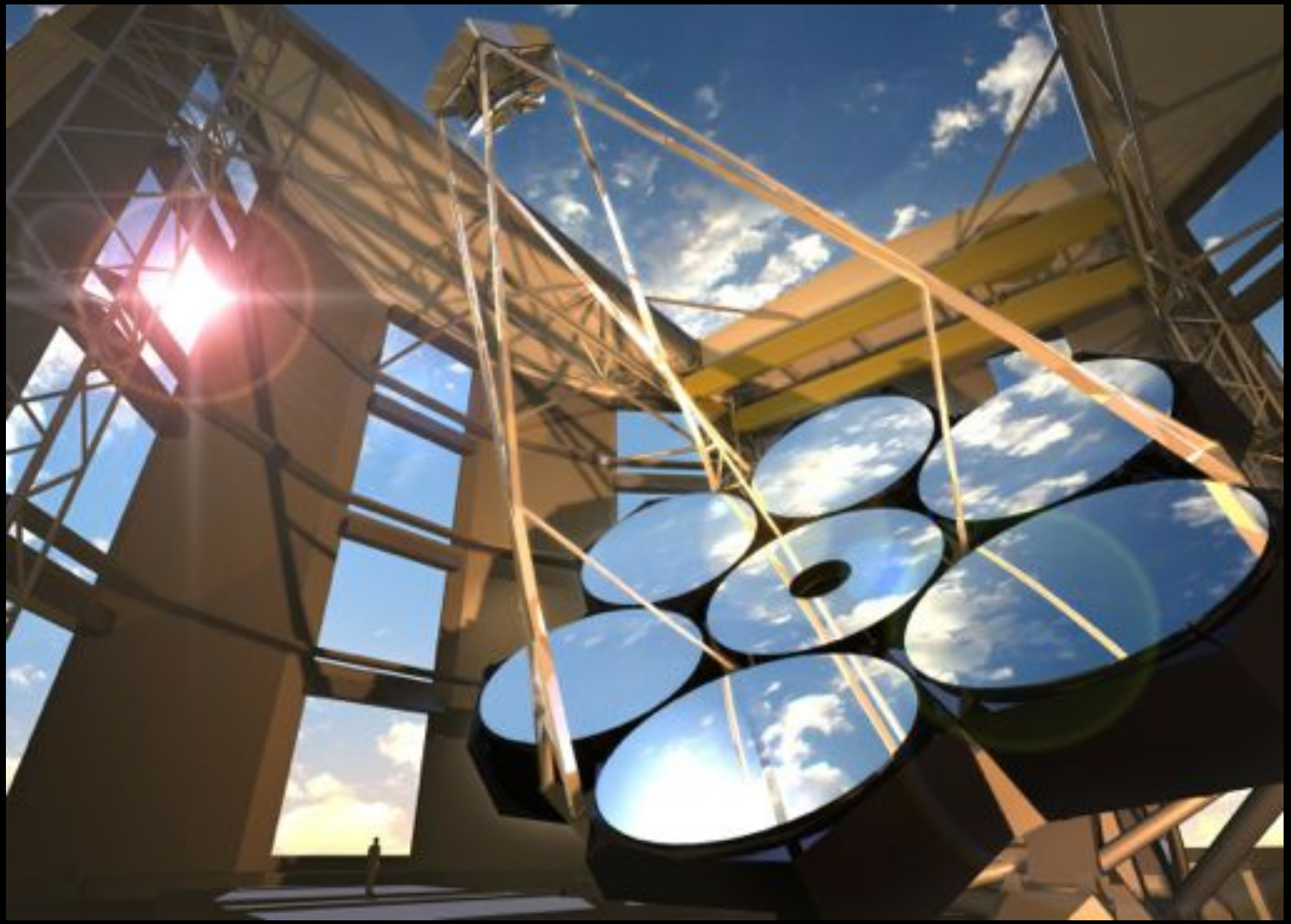

2dF Galaxy Redshift Survey
10h
11h
12h
13h
14h
Redshift
0.05
0.10
0.15
0.20
0.50
1.00
1.50
Billion Lightyears
3h
2h
1h
0h
23h
22h

Le grandi muraglie di galassie



Sculptor wall vicino Via Lattea (z=0.03)
Coma Great wall (1989) z=0.03 lungo ~1300 M a.l.
Sloan Great Wall (2003) z=0.078 750x250x20 M a.l.

©Richard Powell



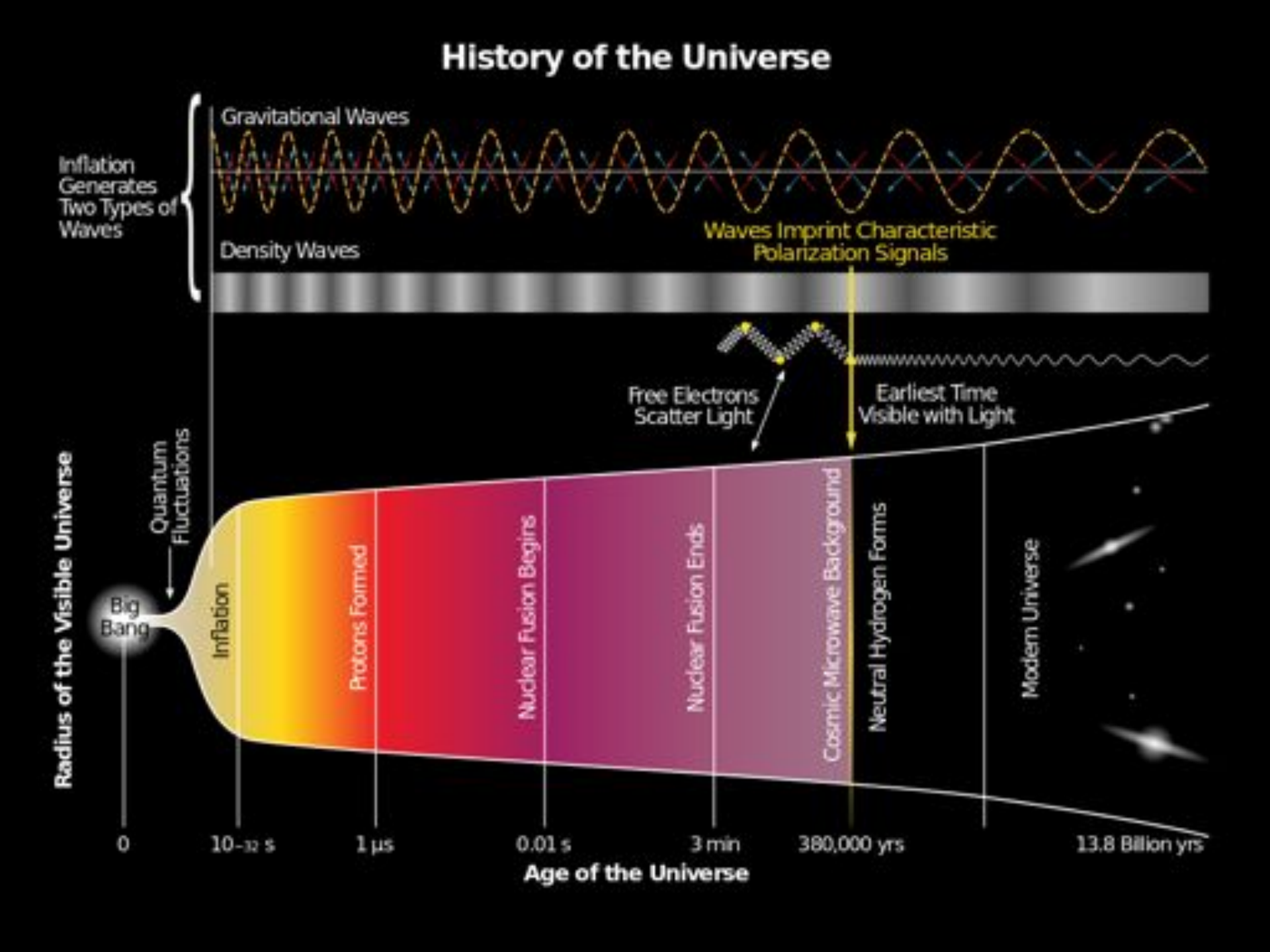
TELESCOPIO MAGELLANO (Acatama)

Big-Bang caldo:

Rapporto H / He nelle stelle antiche

Radiazione cosmica di microonde

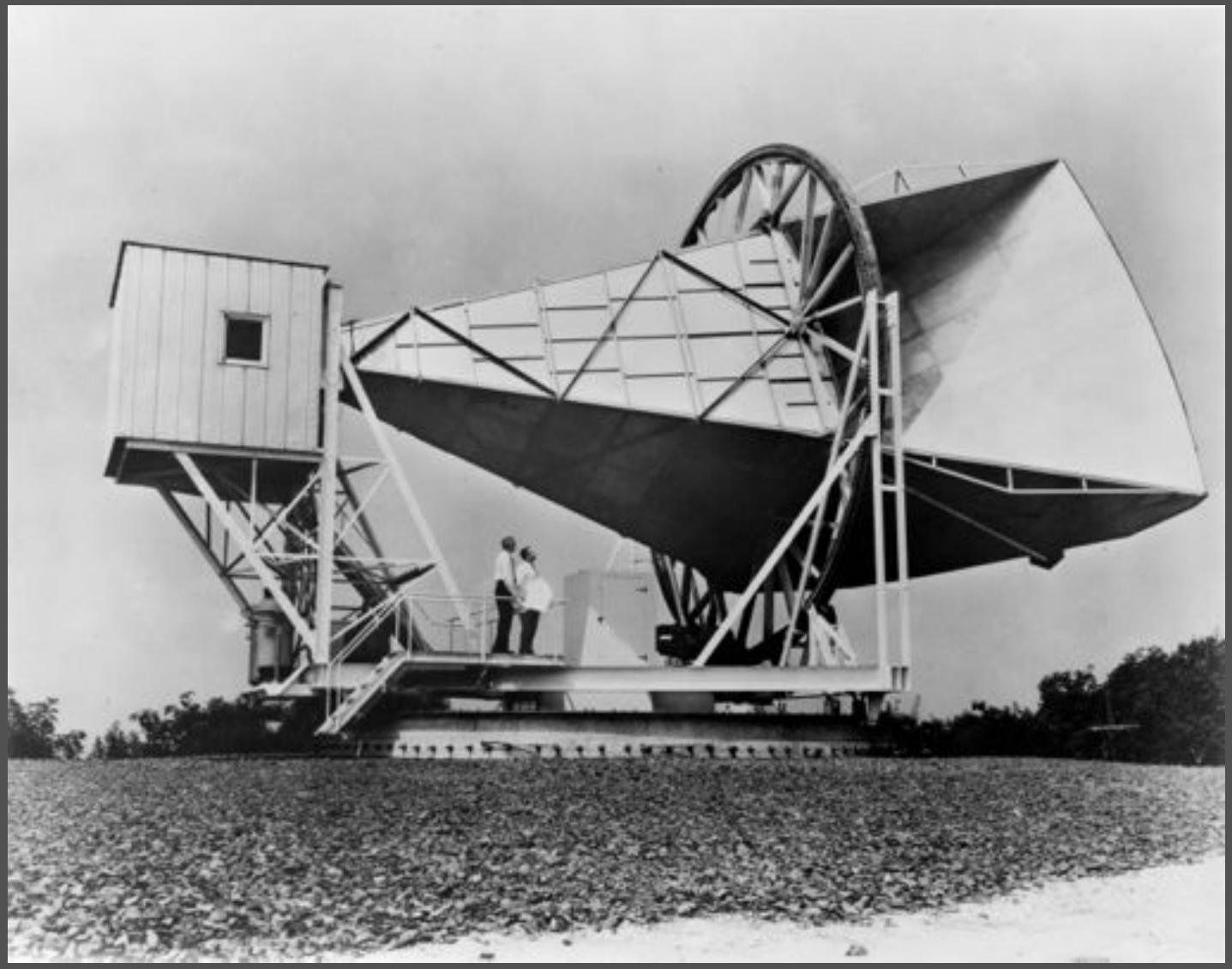
Gamow


History of the Universe
Gravitational Waves
Inflation Generates Two Types of Waves
Density Waves
Waves Imprint Characteristic Polarization Signals
Free Electrons Scatter Light
Earliest Time Visible with Light
Quantum Fluctuations
Big Bang
Inflation
Protons Formed
Nuclear Fusion Begins
Nuclear Fusion Ends
Cosmic Microwave Background
Neutral Hydrogen Forms
Modern Universe
Radius of the Visible Universe
0
10−32 s
1 μs
0.01 s
3 min
380,000 yrs
13.8 Billion yrs
Age of the Universe

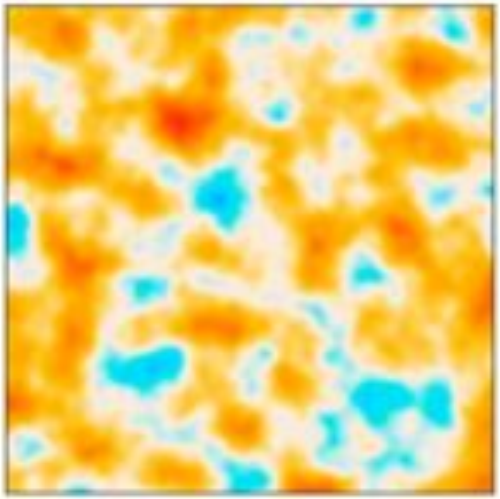
La radiazione cosmica a 2.7 K
(Cosmic Microwave Background)

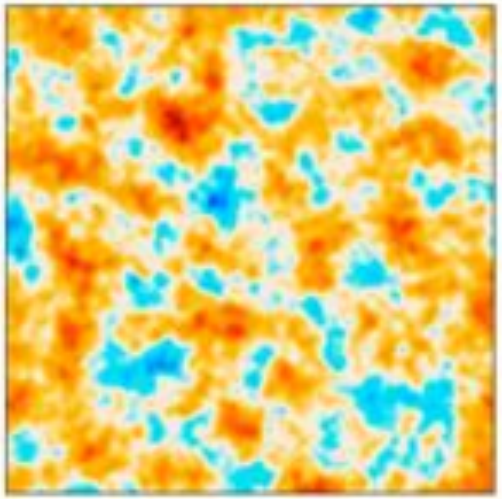
t = 380 mila anni

Il fondo cosmico di microonde a 2.7 K



The Nobel Prize in Physics 1978
Arno Allan Penzias and **Robert Woodrow Wilson**
“for their discovery of cosmic microwave background radiation”

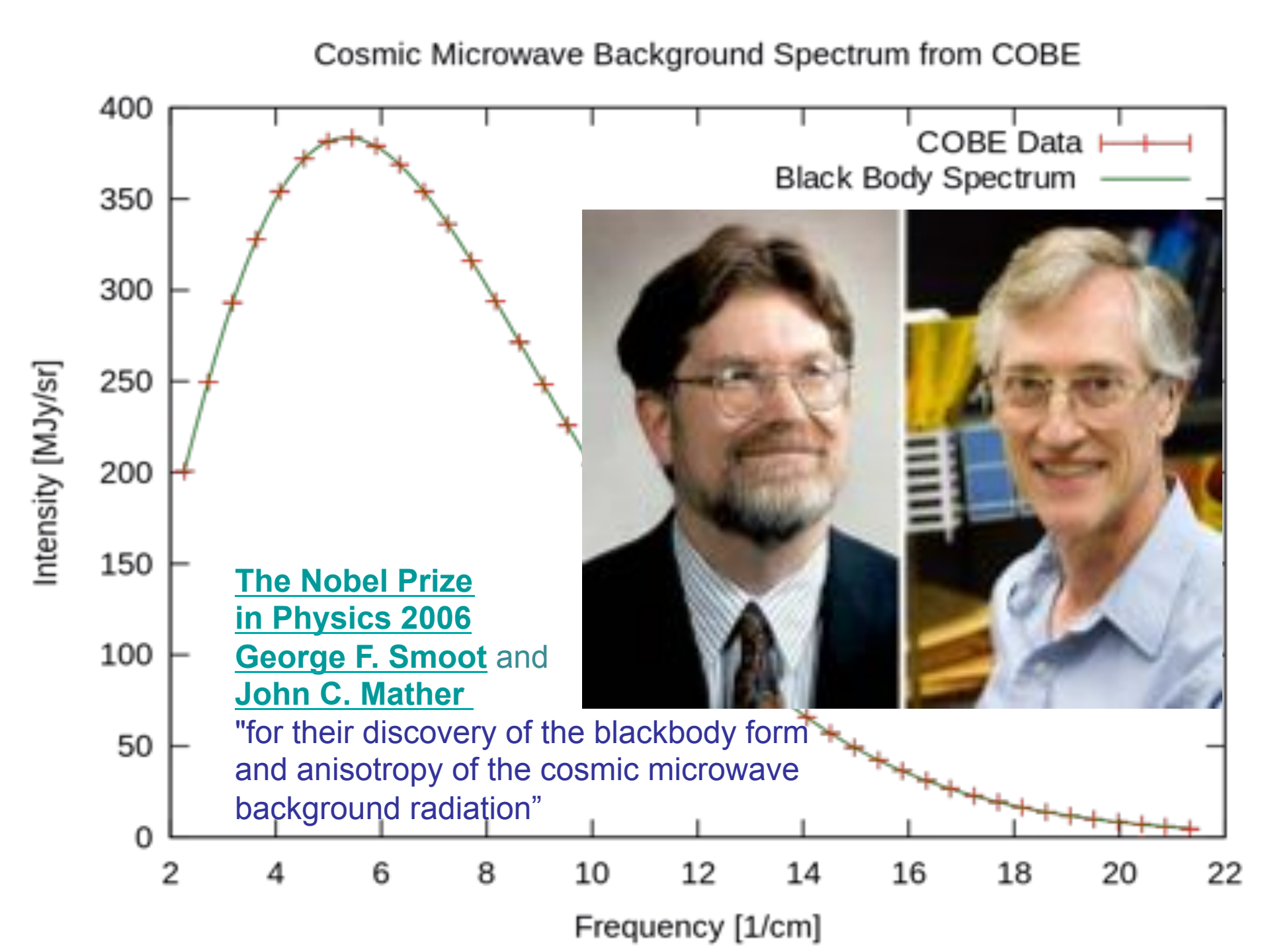




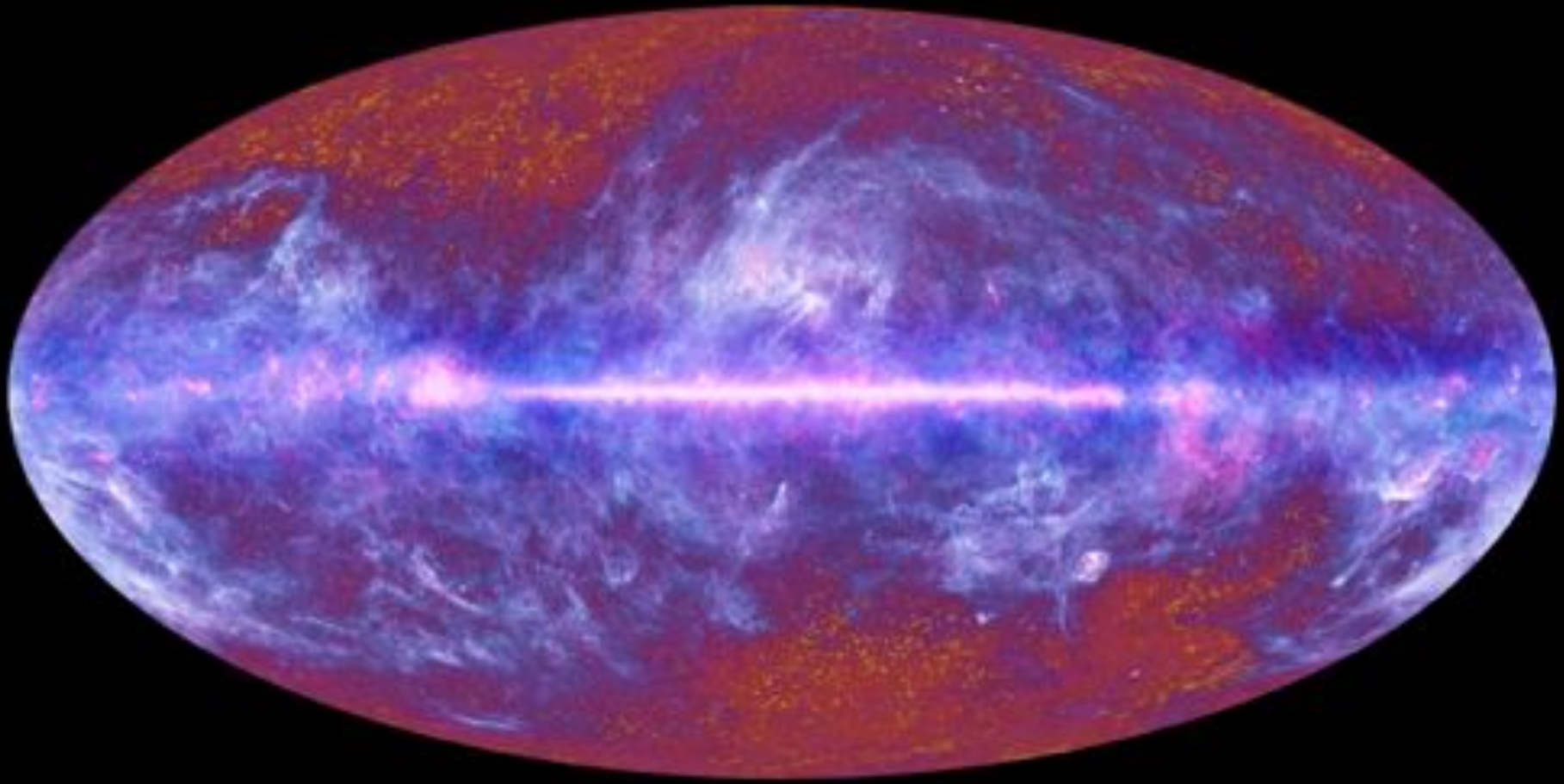
COBE

WMAP

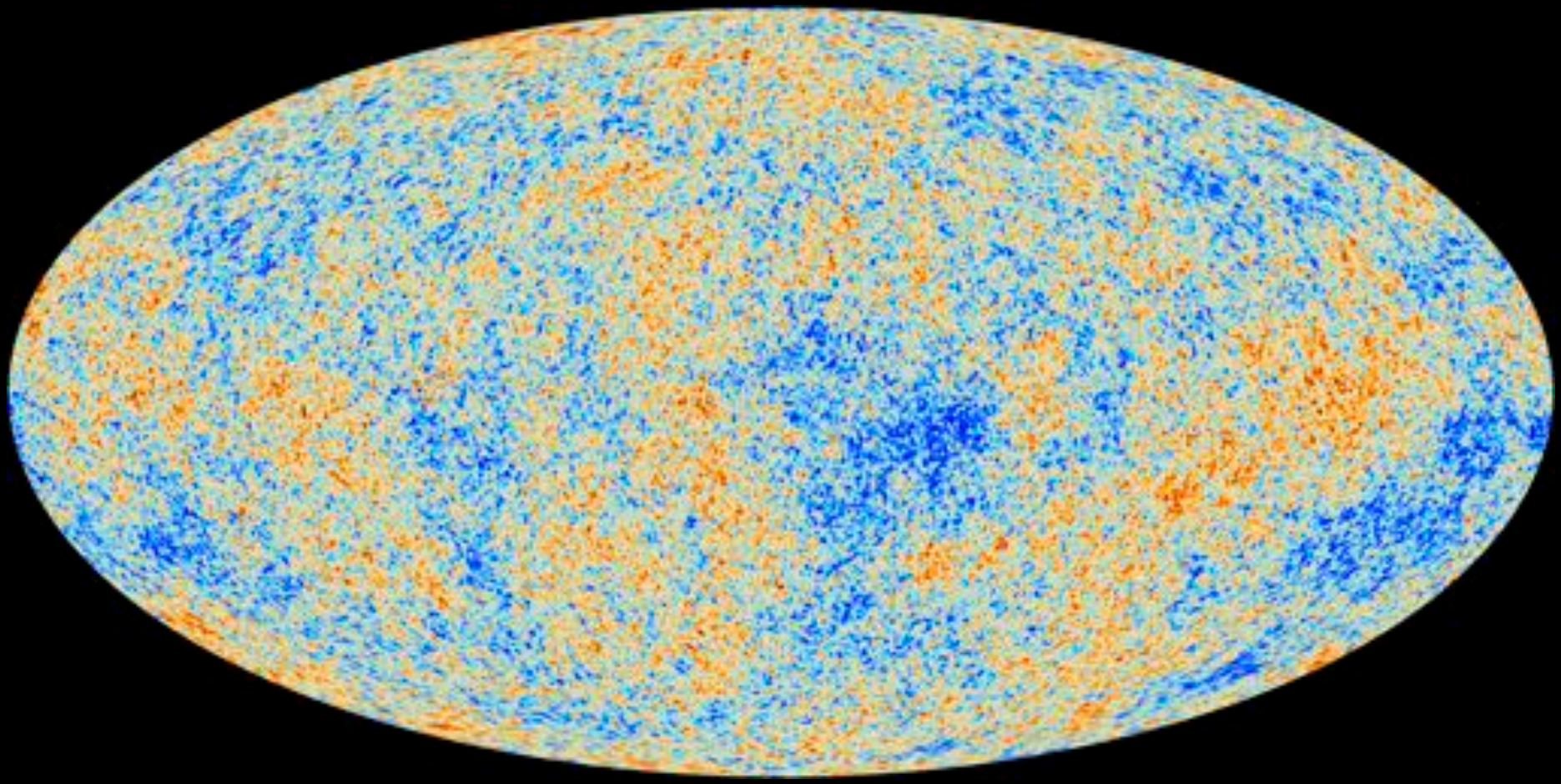
Planck


Cosmic Microwave Background Spectrum from COBE
COBE Data
Black Body Spectrum
Intensity [MJy/sr]
Frequency [1/cm]
0
50
100
150
200
250
300
350
400
2
4
6
8
10
12
14
16
18
20
22
The Nobel Prize in Physics 2006
George F. Smoot and John C. Mather
"for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation"

Il cielo visto dalla sonda Planck



La radiazione cosmica primordiale



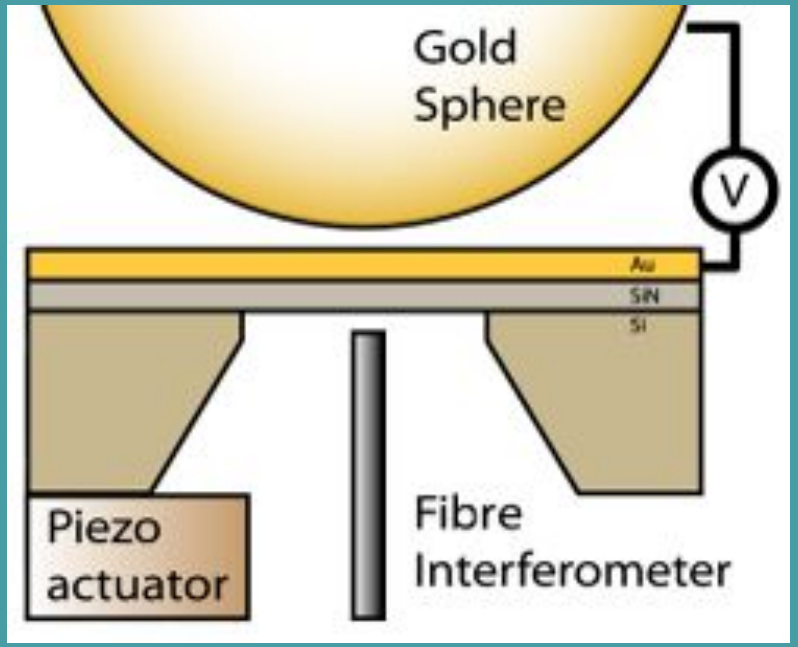
INFLAZIONE

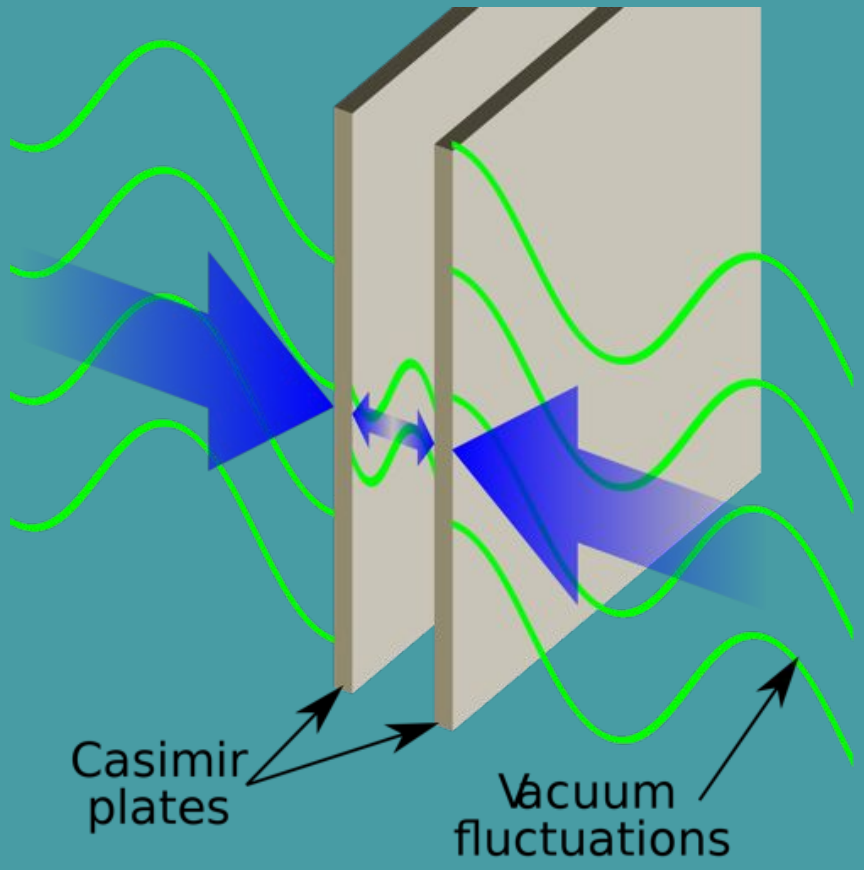
Spiega perche' l'universo e` uguale in tutte le direzioni
in regioni che non "si parlano"
e
come piccole fluttuazioni (quantistiche?) di densita` siano
cresciute a formare le grandi strutture nell'universo
(Guth, Linde)

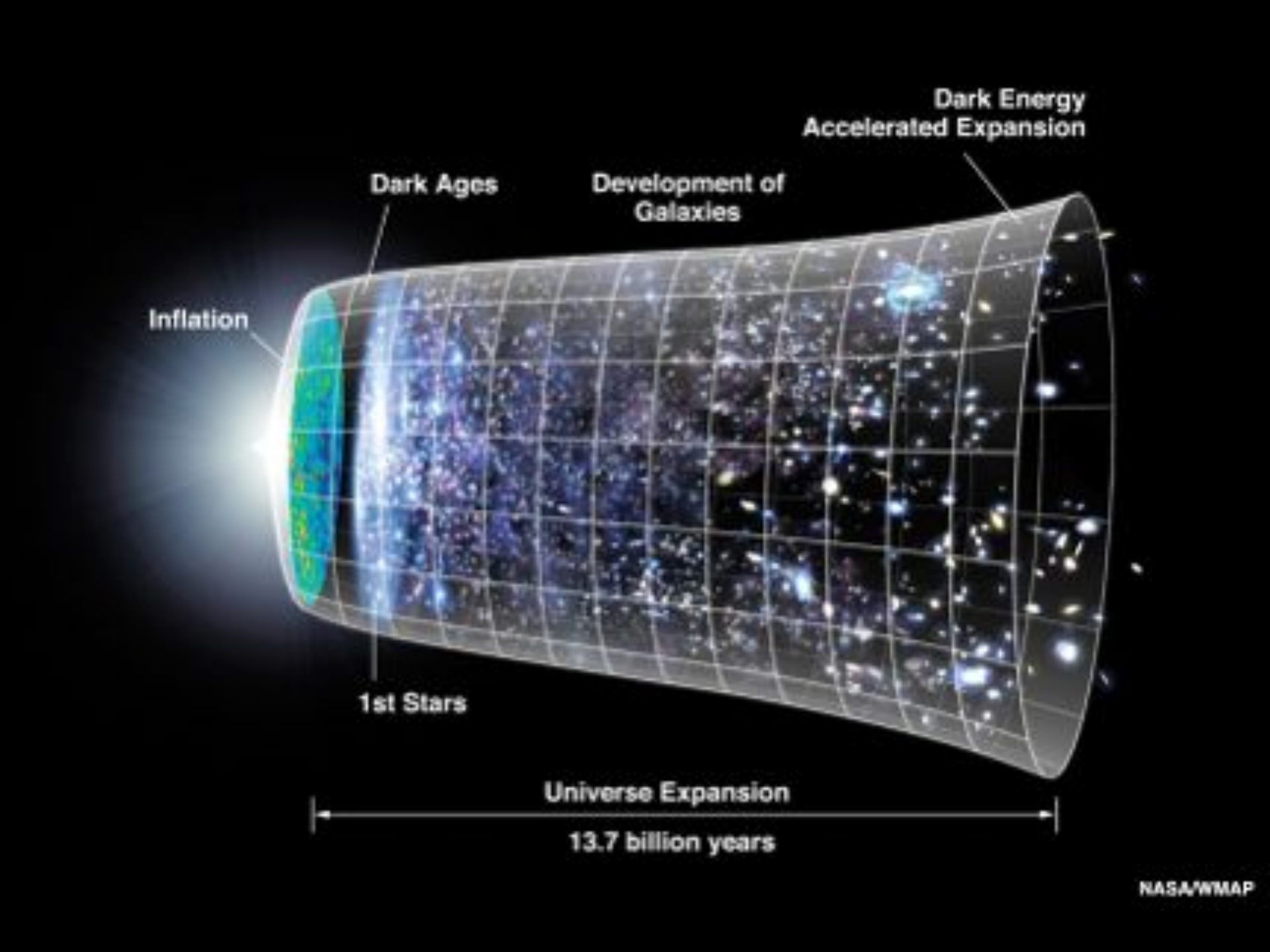
Il vuoto quantistico

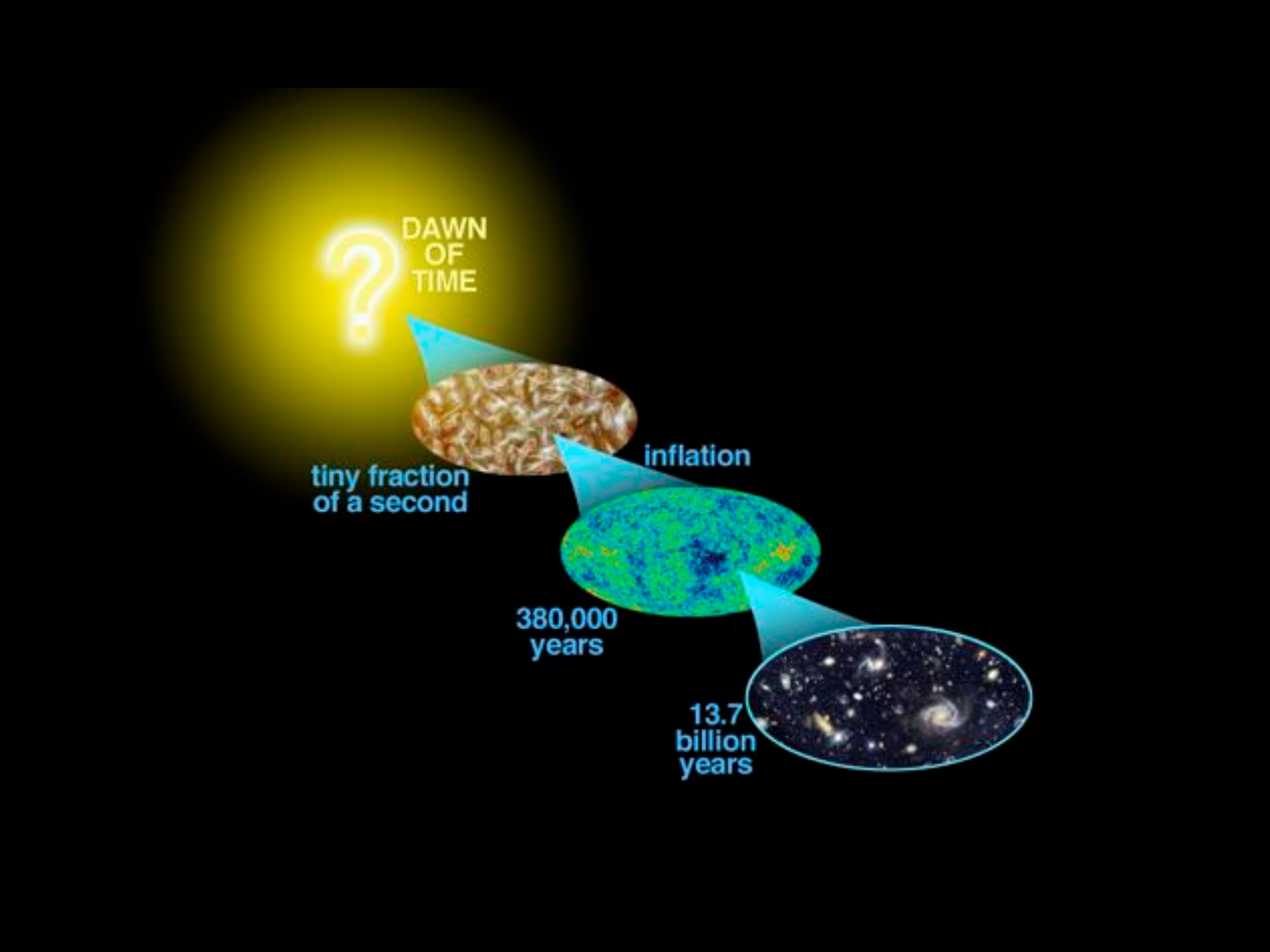
EFFETTO CASIMIR (1948)
Hendrick Casimir (Philips Lab.)

$$\mathcal{F} = -\frac{\hbar c \pi^2}{240 d^4}$$






Dark Energy
Accelerated Expansion
Dark Ages
Development of
Galaxies
Inflation
1st Stars
Universe Expansion
13.7 billion years
NASA/WMAP


DAWN
OF
TIME
tiny fraction
of a second
inflation
380,000
years
13.7
billion
years

Bicep 2

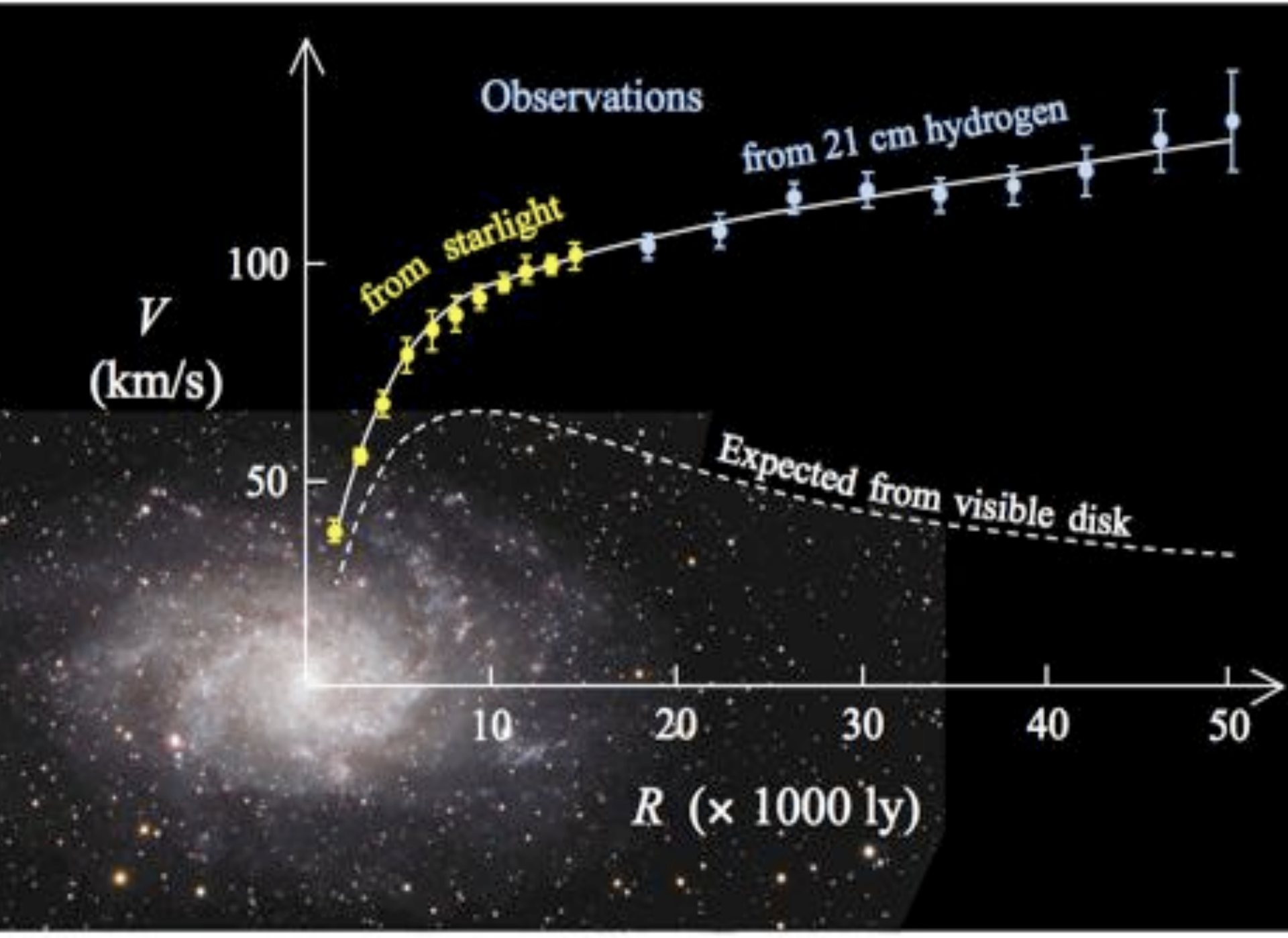
Background Imaging of Cosmic Extragalactic Polarization

Marzo 2014: Prova indiretta di onde gravitazionali emesse durante l'inflazione, impressa nella CMB

MATERIA OSCURA

ΛCDM

la materia visibile e` immersa in aloni giganteschi di materia invisibile e di natura sconosciuta, rilevabile come massa mancante


Observations
from 21 cm hydrogen
from starlight
100
V
(km/s)
50
Expected from visible disk
10
20
30
40
50
R (× 1000 ly)

Ammasso El Gordo dist=10 miliardi a.l.

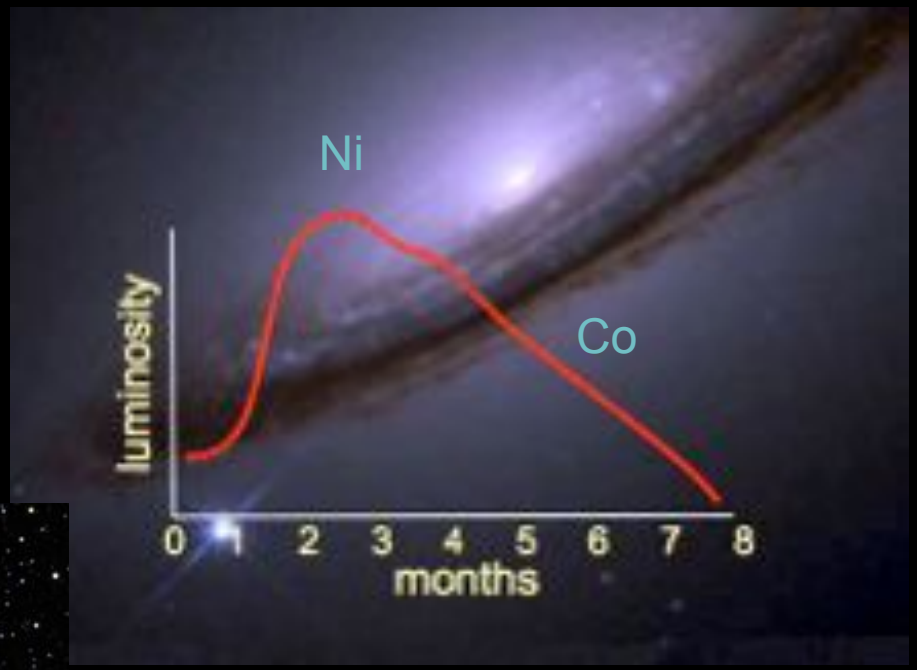
Ammasso di galassie
*Il weak lensing mostra presenza di DM di filamenti*u

ENERGIA OSCURA

(l'espansione dell'universo accelera)

ΛCDM

SUPERNOVA type Ia



Supernova Types

Type I

No H in spectra

Ia

Si Absorption line @ 615nm

Found everywhere in the universe

Always same luminosity?

Ib

No Si

Ic

No Si, No He

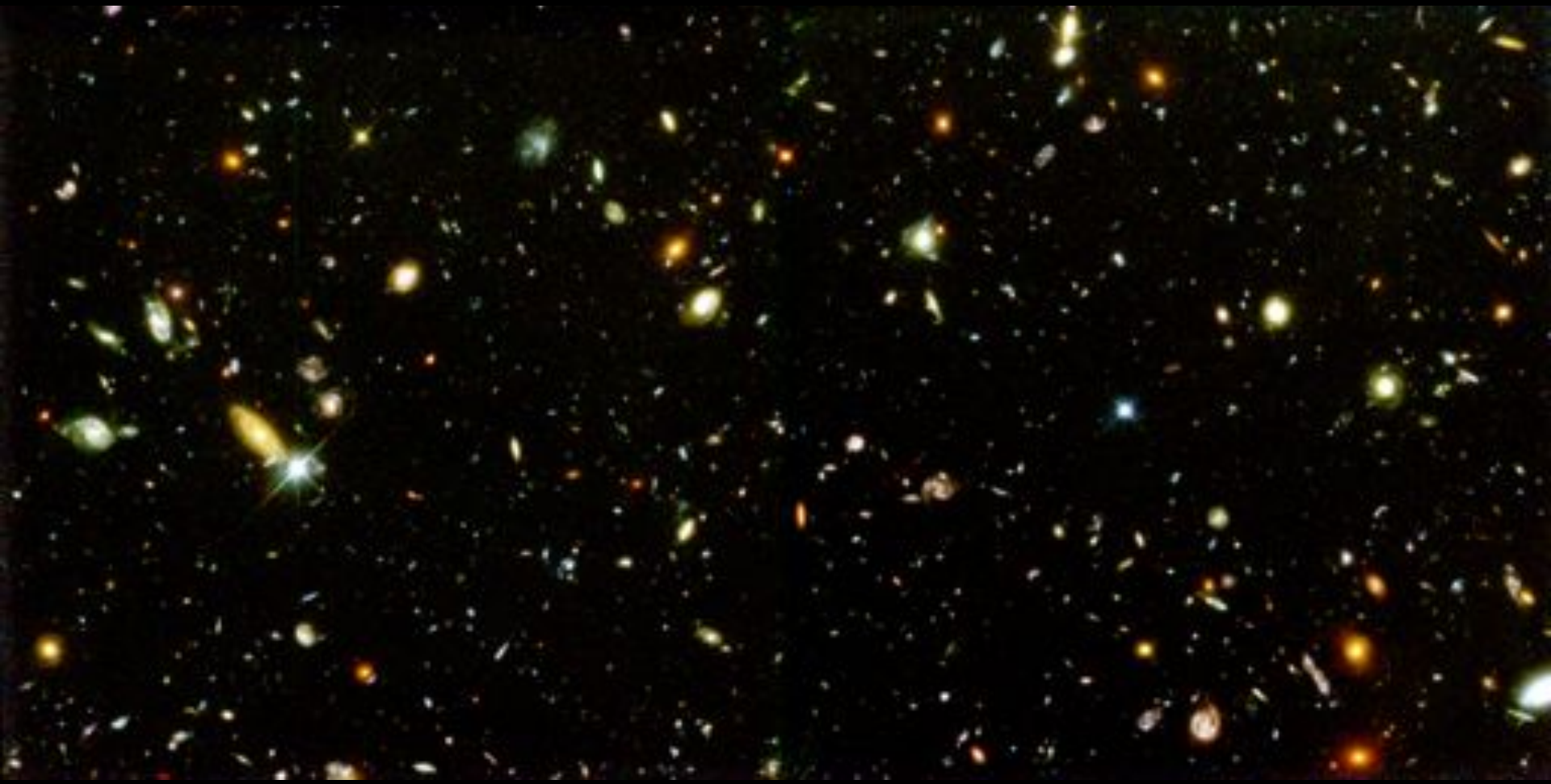
Found only in new star regions

Type II

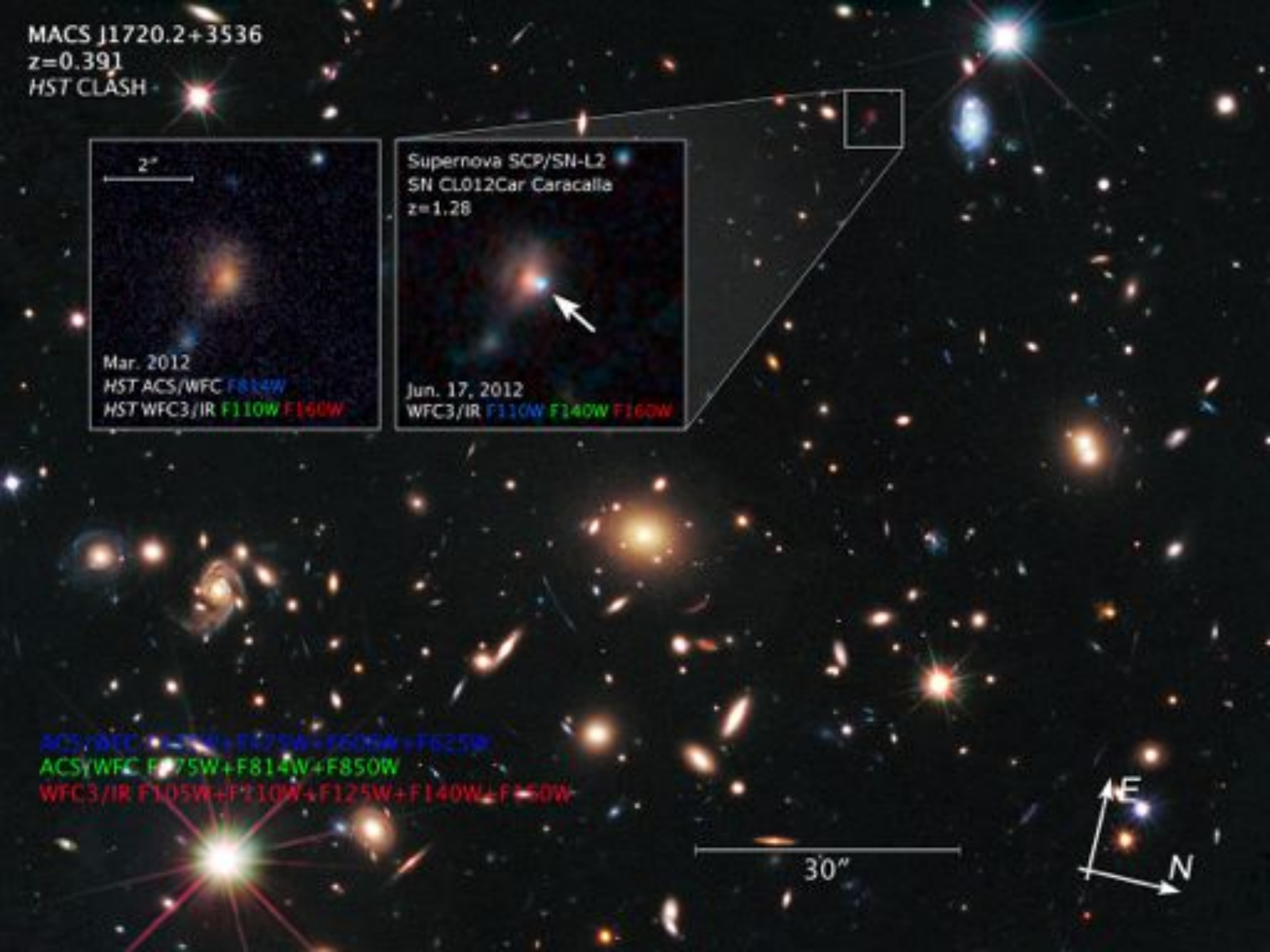
H in spectra

May be further subdivided based on light curves

SN2011fe in M101 (Kitt Peak, Mayall 4m)
d=20M a.l. (anno 2011, 2 settimane dopo il picco di luce)



SN1997ff (type 1a)
distanza ~10M a.l.


MACS J1720.2+3536
z=0.391
HST CLASH
2″
Mar. 2012
HST ACS/WFC F814W
HST WFC3/IR F110W F160W
Supernova SCP/SN-L2
SN CL012Car Caracalla
z=1.28
Jun. 17, 2012
WFC3/IR F110W F140W F160W
ACS/WFC F475W+F814W+F850W
30″
E
N

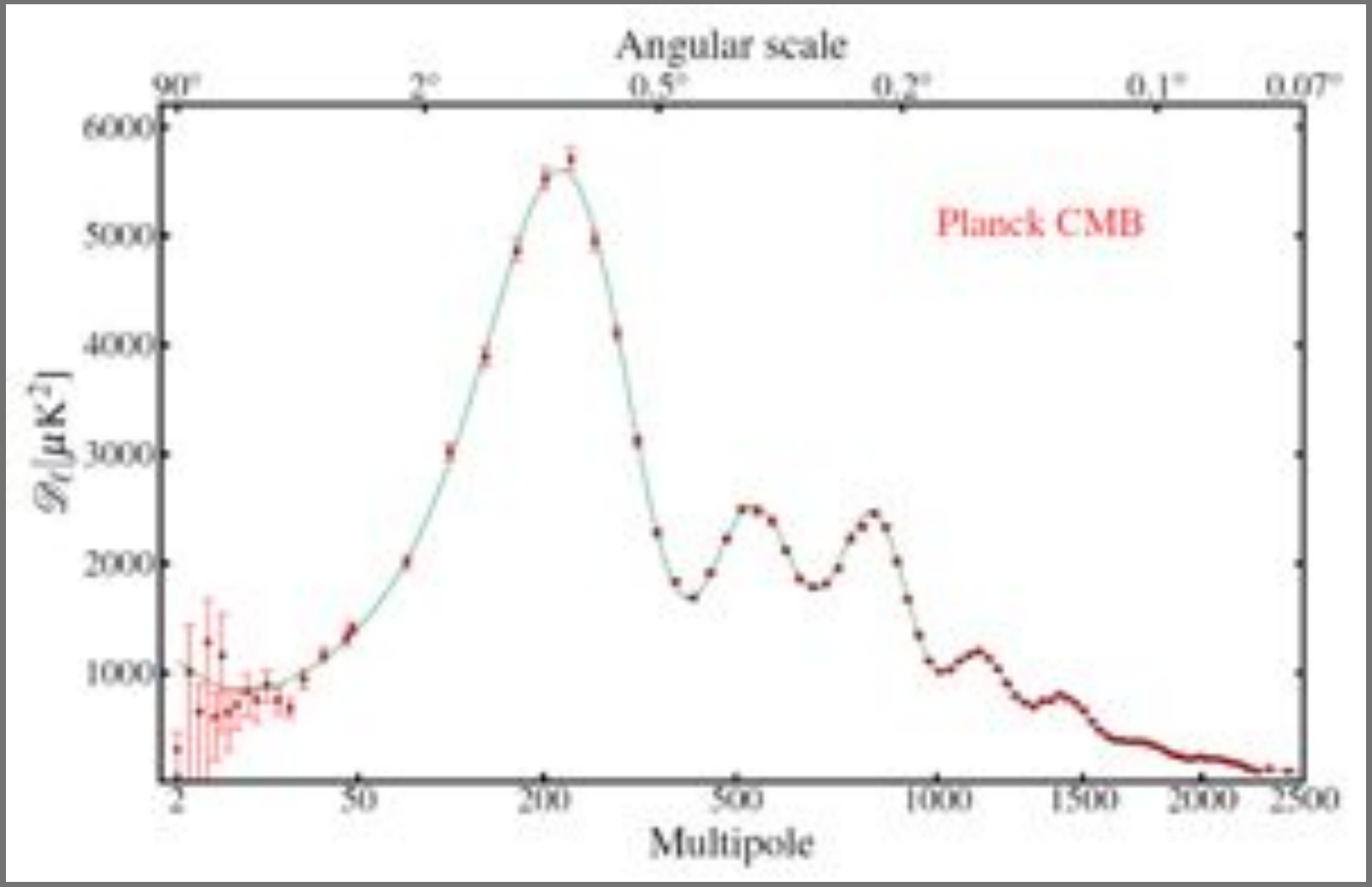
The Nobel Prize in Physics 2011
Saul Perlmutter, Brian P. Schmidt and **Adam G. Riess**
"for the discovery of the accelerating expansion of the Universe through observations of distant supernovae"

Dopo tanta
nebbia
a una
a una
si svelano
le stelle.

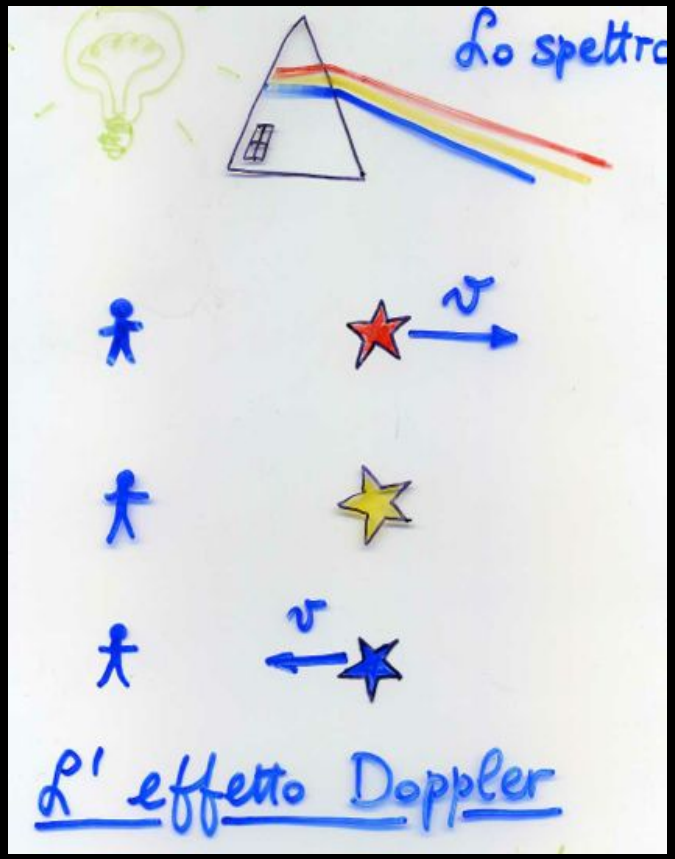
Respiro
il fresco
che mi lascia
il colore del cielo.

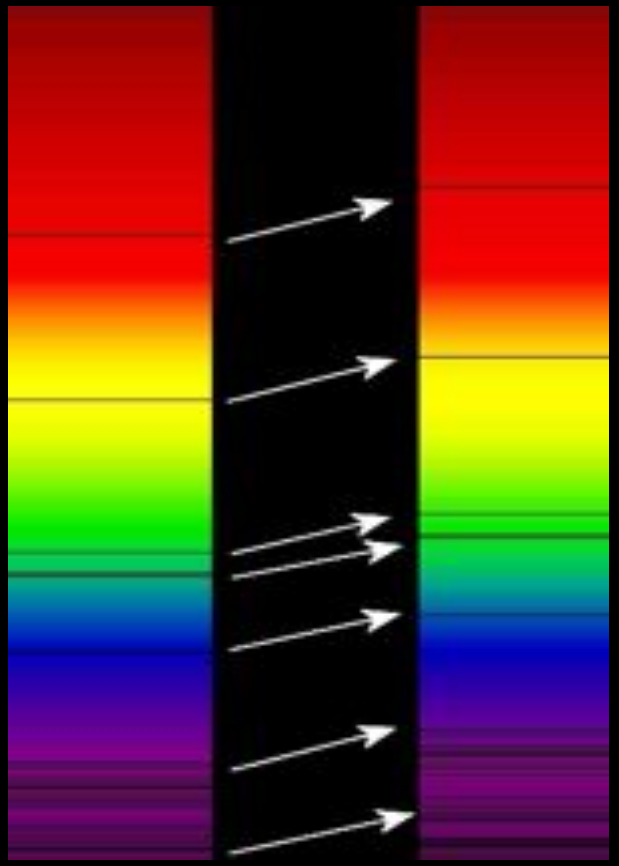
Mi riconosco immagine
passeggera
presa in un giro
immortale.

NPS photo

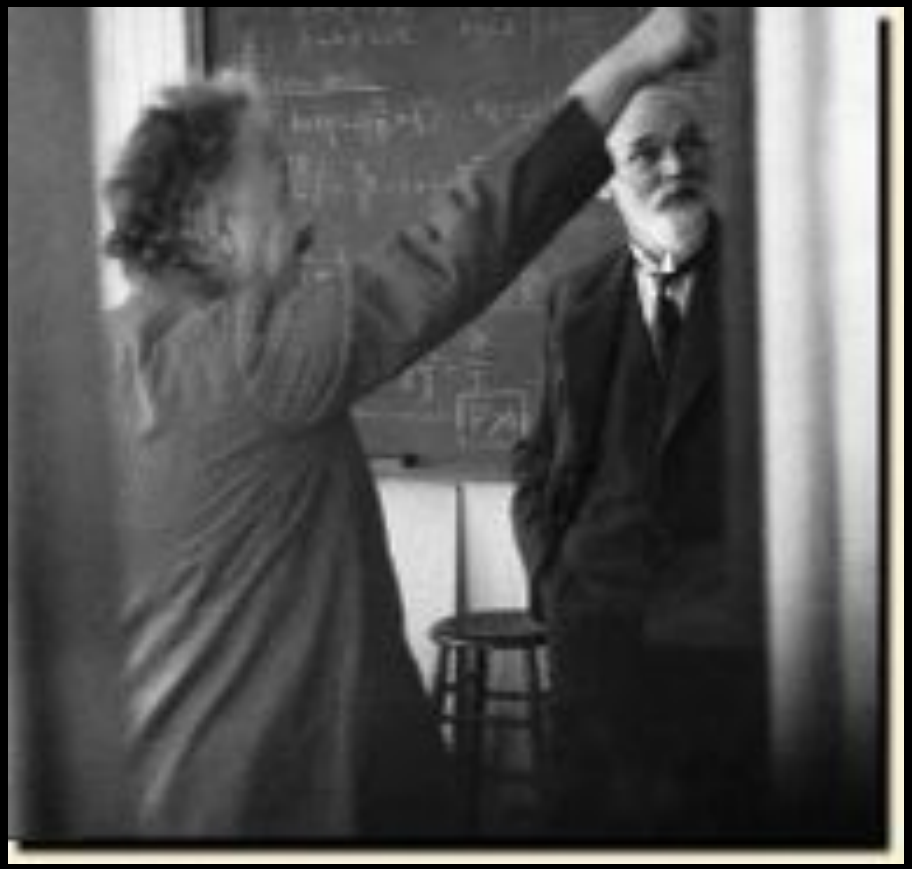

Angular scale
90°
2°
0.5°
0.2°
0.1°
0.07°
6000
5000
4000
3000
2000
1000
$\mathscr{D}_\ell [\mu K^2]$
Planck CMB
2
50
200
500
1000
1500
2000
2500
Multipole

L'effetto Doppler





La materia detta la geometria dello spazio, e la geometria dirige la materia.



Einstein e De Sitter

The Nobel Prize in Physics 2011

Saul Perlmutter, Brian P. Schmidt, Adam G. Riess

- **The Nobel Prize in Physics 2011**
- Saul Perlmutter
- Brian P. Schmidt
- Adam G. Riess

Photo: Roy Kaltschmidt, Courtesy Lawrence Berkeley National Laboratory

Saul Perlmutter

Photo: Belinda Pratten, Australian National University

Brian P. Schmidt

Photo: Homewood Photography

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"*.

SUPERNOVAE 1a