Prima del novecento

Si deve ai popoli dell'antichita` (babilonesi, caldei, egizi, sumeri, fenici, ecc..) la nascita della nostra civilta`.
Il mondo ellenistico fece una sintesi delle loro conoscenze e diede origine alla scienza classica.

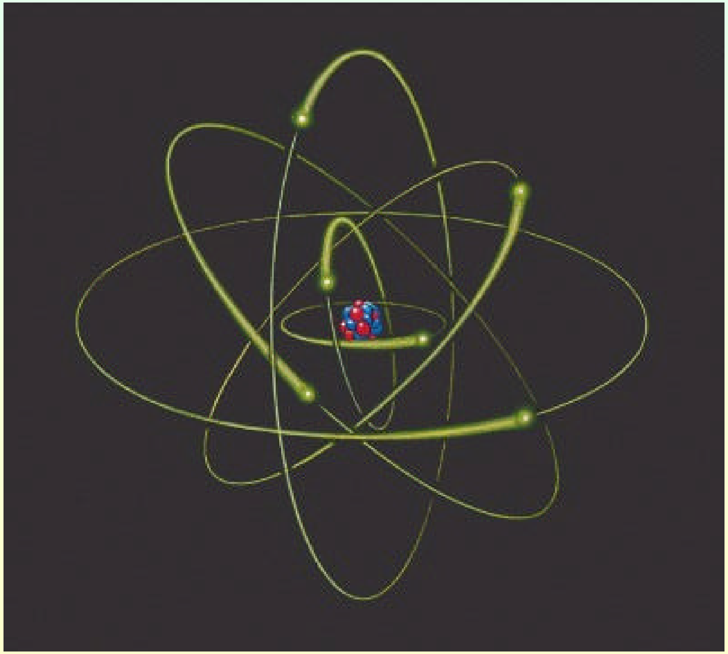
La **Fisica di Aristotele**: gli elementi fondamentali della natura (terra, acqua, aria, fuoco) e le forze che agiscono tra loro.
La **teoria atomistica**: Democrito, Pitagora, Lucrezio.
Astronomia e cosmologia degli antichi greci: Tolomeo e Ipparco.
Le nuove idee: Bruno e Campanella.

La **prima rivoluzione scientifica**: **Copernico, Galileo, Keplero, Cartesio, Newton, Boyle, Laplace**.

La **seconda rivoluzione scientifica** e la nascita della scienz moderna. Teorie, esperimenti e osservazioni.

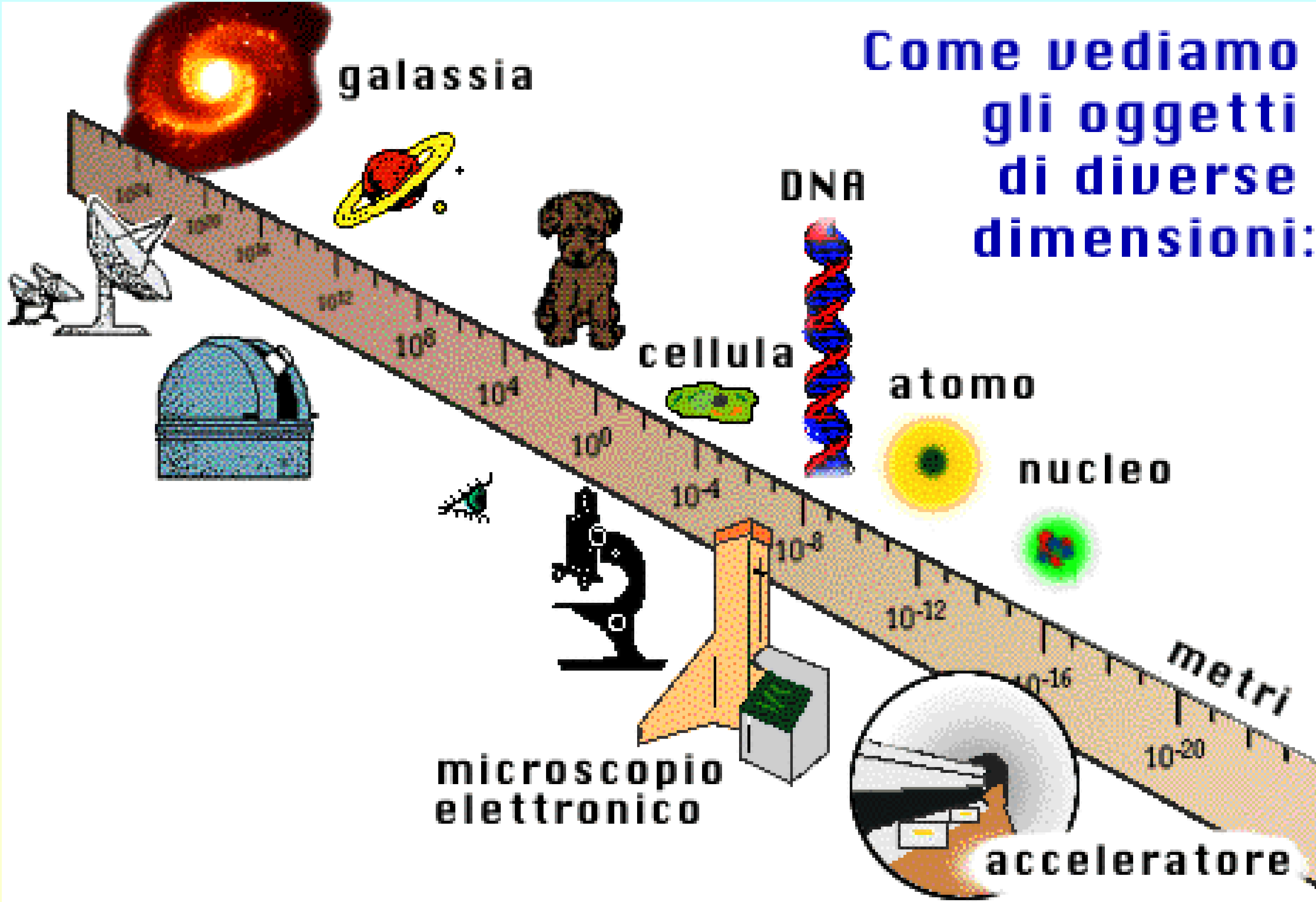
Einstein e la relativita`. **Planck** e la meccanica quantistica.

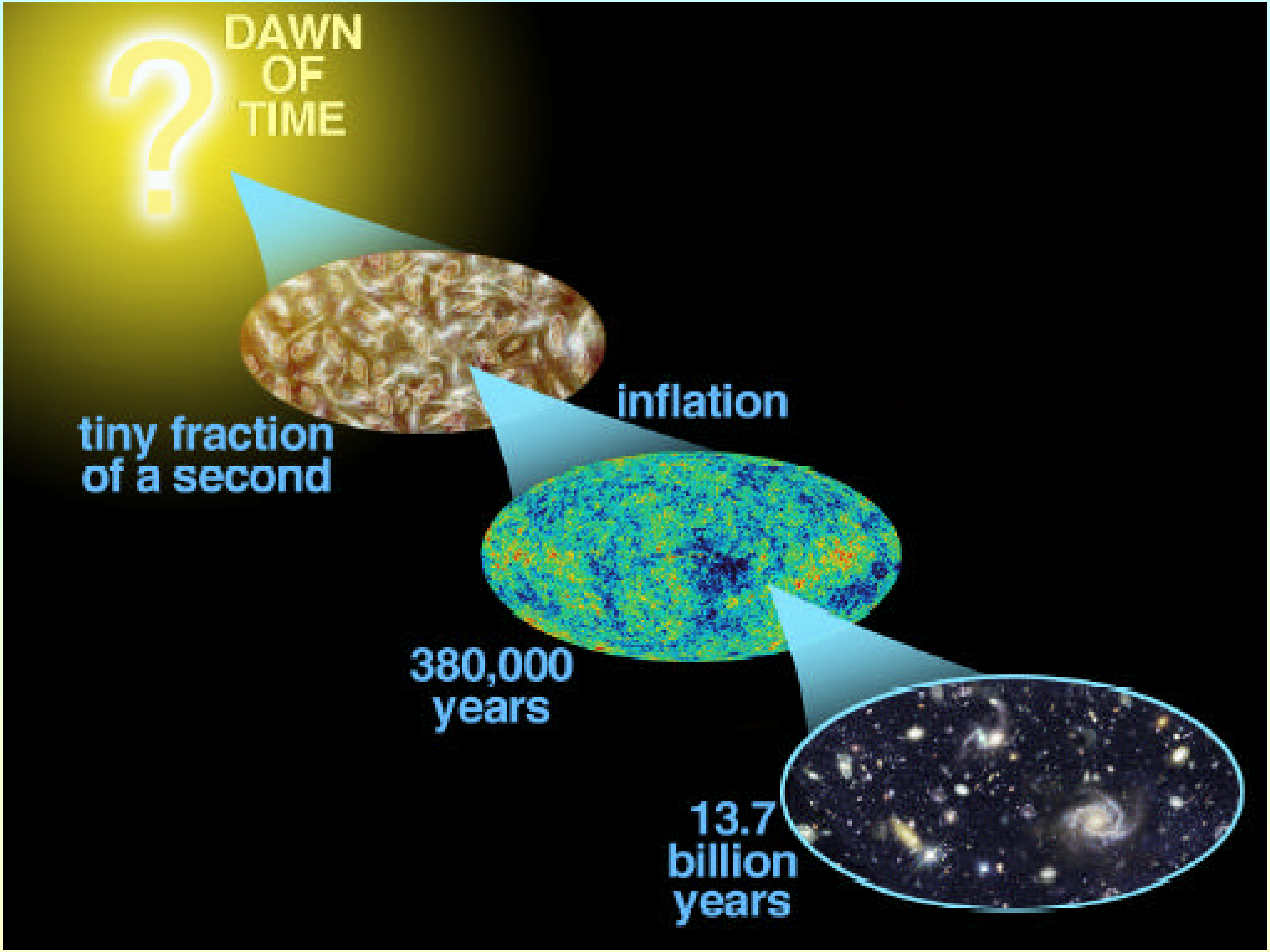
L'atomo di **Bohr** e la nascita della **fisica atomica**. La **fisica nucleare**, la radioattivita`, fissione e fusione nucleare.



- Particelle elementari: **quark** e **leptoni.**
- Astrofisica e cosmologia moderne: il **Big Bang**.
- Radiazione cosmica e **Fisica astroparticellare**.


human curiosity

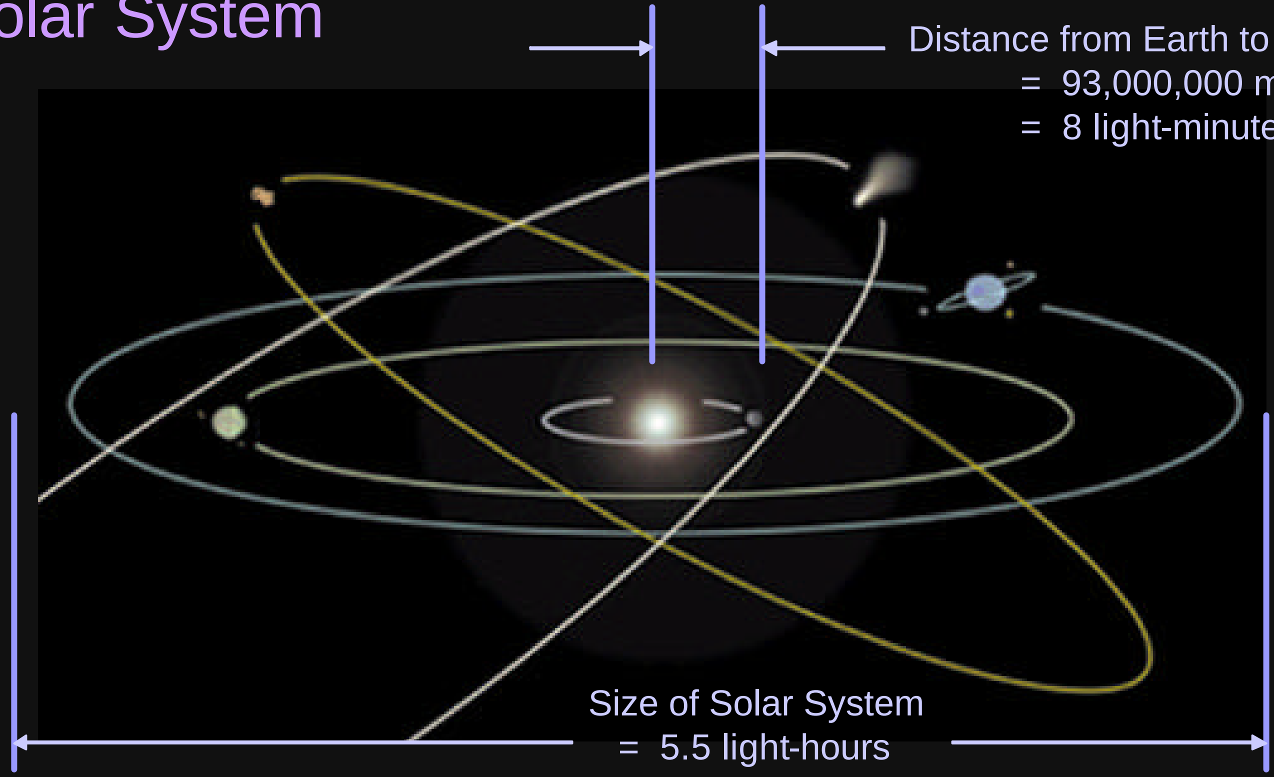

Come vediamo gli oggetti di diverse dimensioni:
galassia
DNA
cellula
atomo
nucleo
microscopio elettronico
acceleratore
metri
10^{8}
10^{4}
10^{0}
10^{-4}
10^{-8}
10^{-12}
10^{-16}
10^{-20}


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

Il Very Large Array (VLA) nel New Mexico

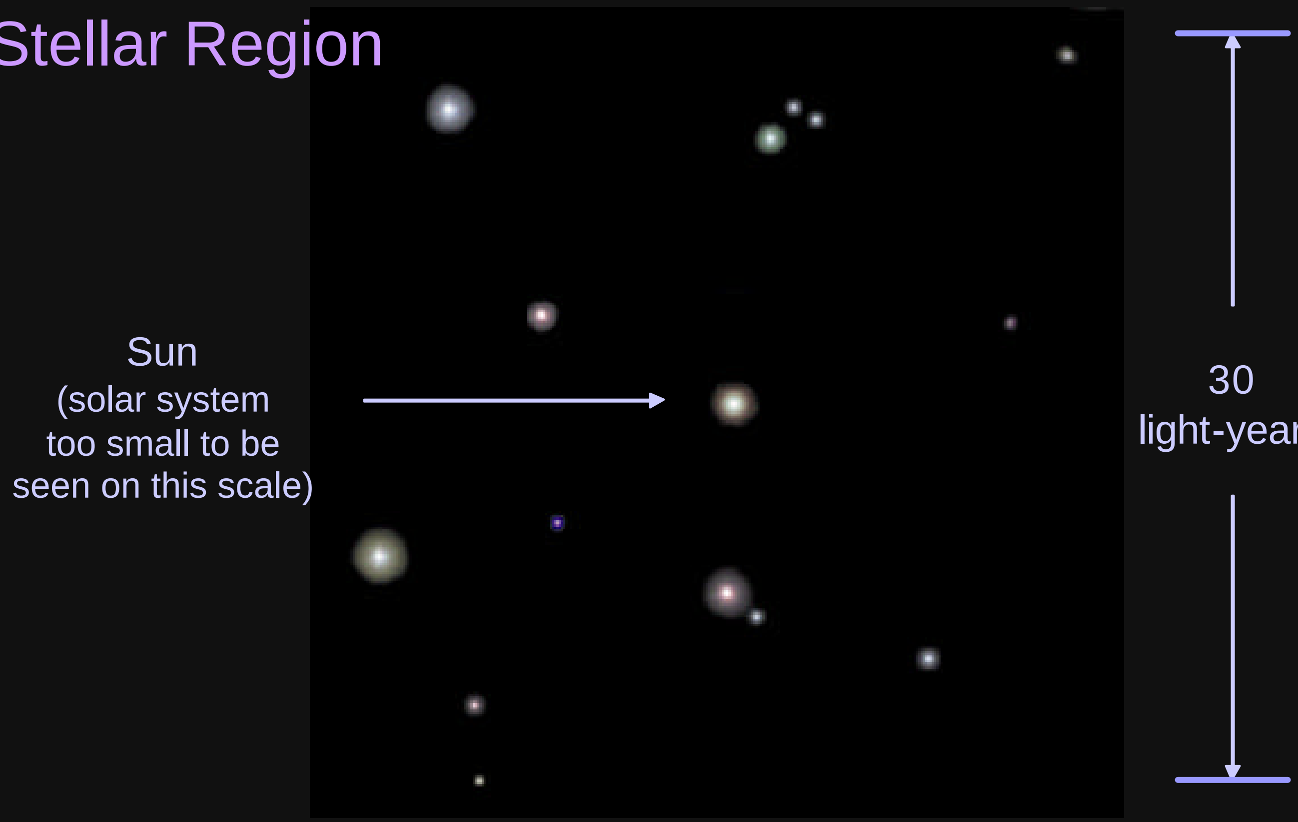
What is a Galaxy ?

Solar System



What is a Galaxy?

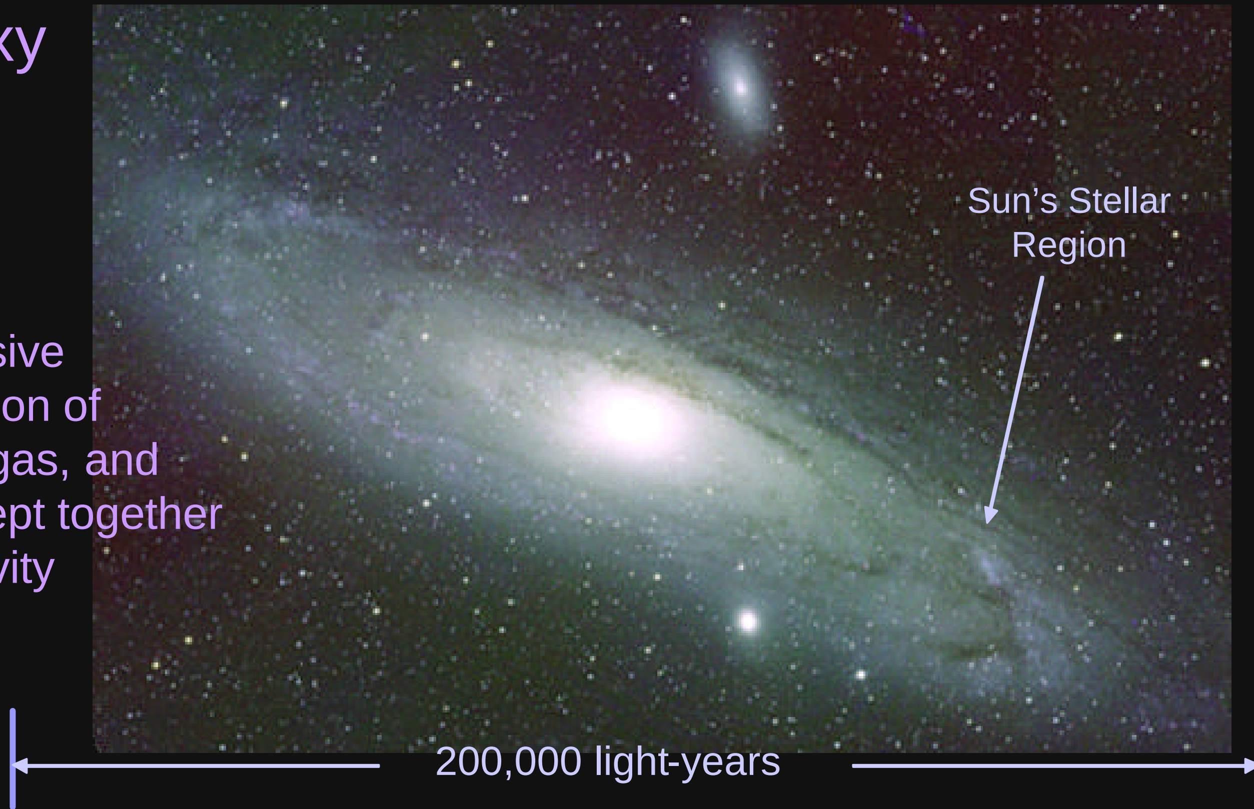
Stellar Region



What is a Galaxy?

Galaxy

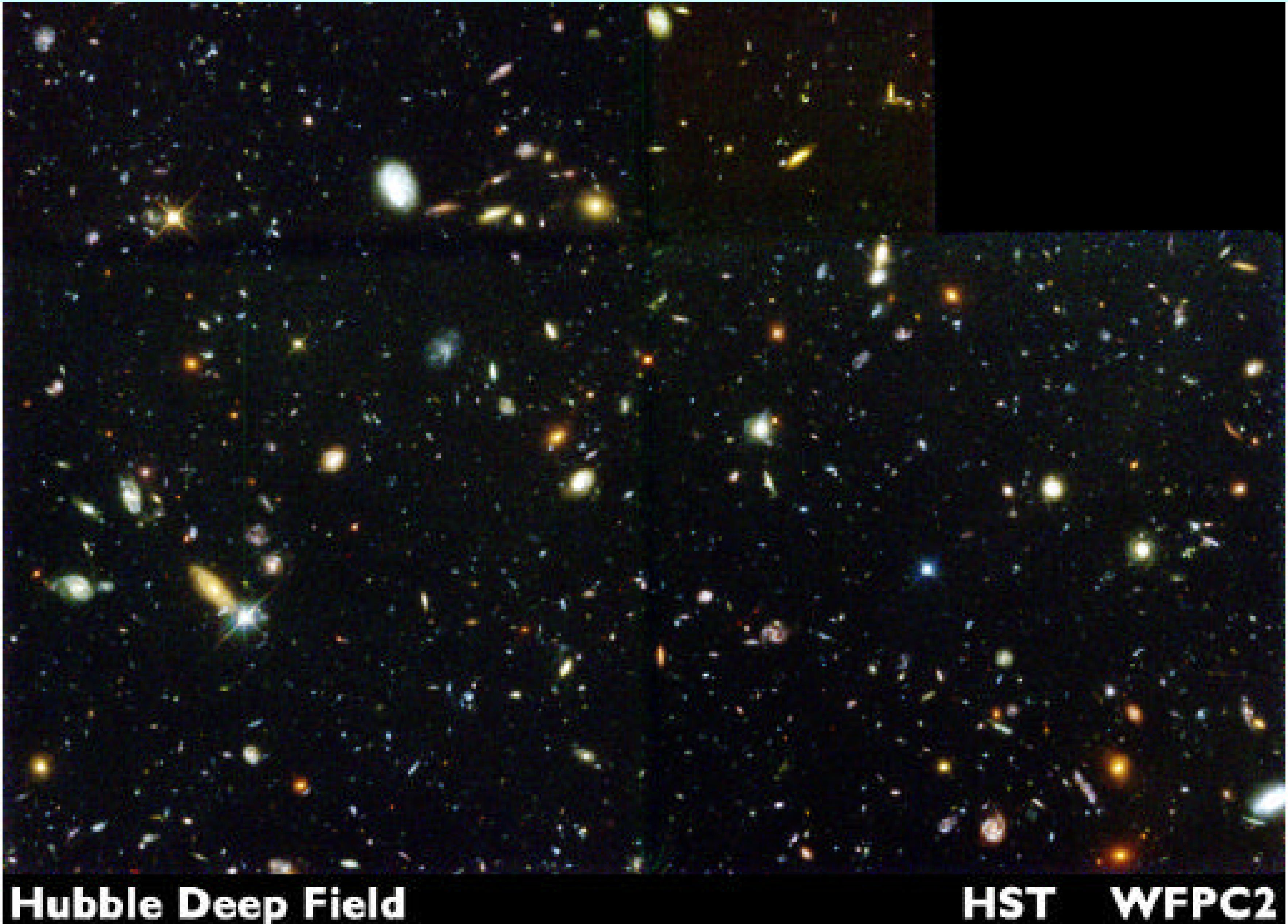
a massive collection of stars, gas, and dust kept together by gravity




Galaxies NGC 2207 and IC 2163
Hubble
Heritage

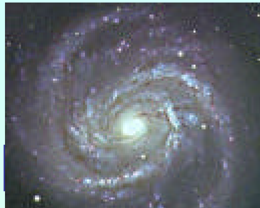

ANDROMEDA
GALAXY


Radio galassia Centauro A


Hubble Deep Field
HST WFPC2

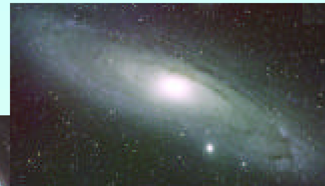
Types of Galaxies

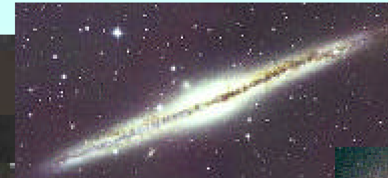
Spiral

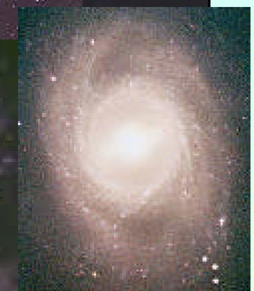


disk-li[…] with arms of star[…] dust forming a s[…] pattern

Barred Spiral

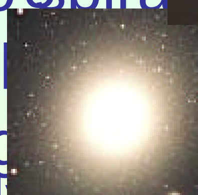






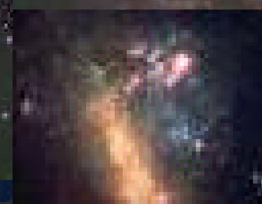
similar to spira[…] with a brig[…] of stars and g[…]ough the center

Elliptical



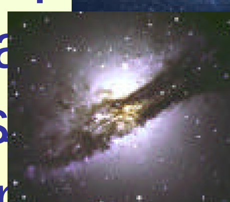
elliptically-shaped, with less gas […]st than spirals, n[…] “arms”

Irregular

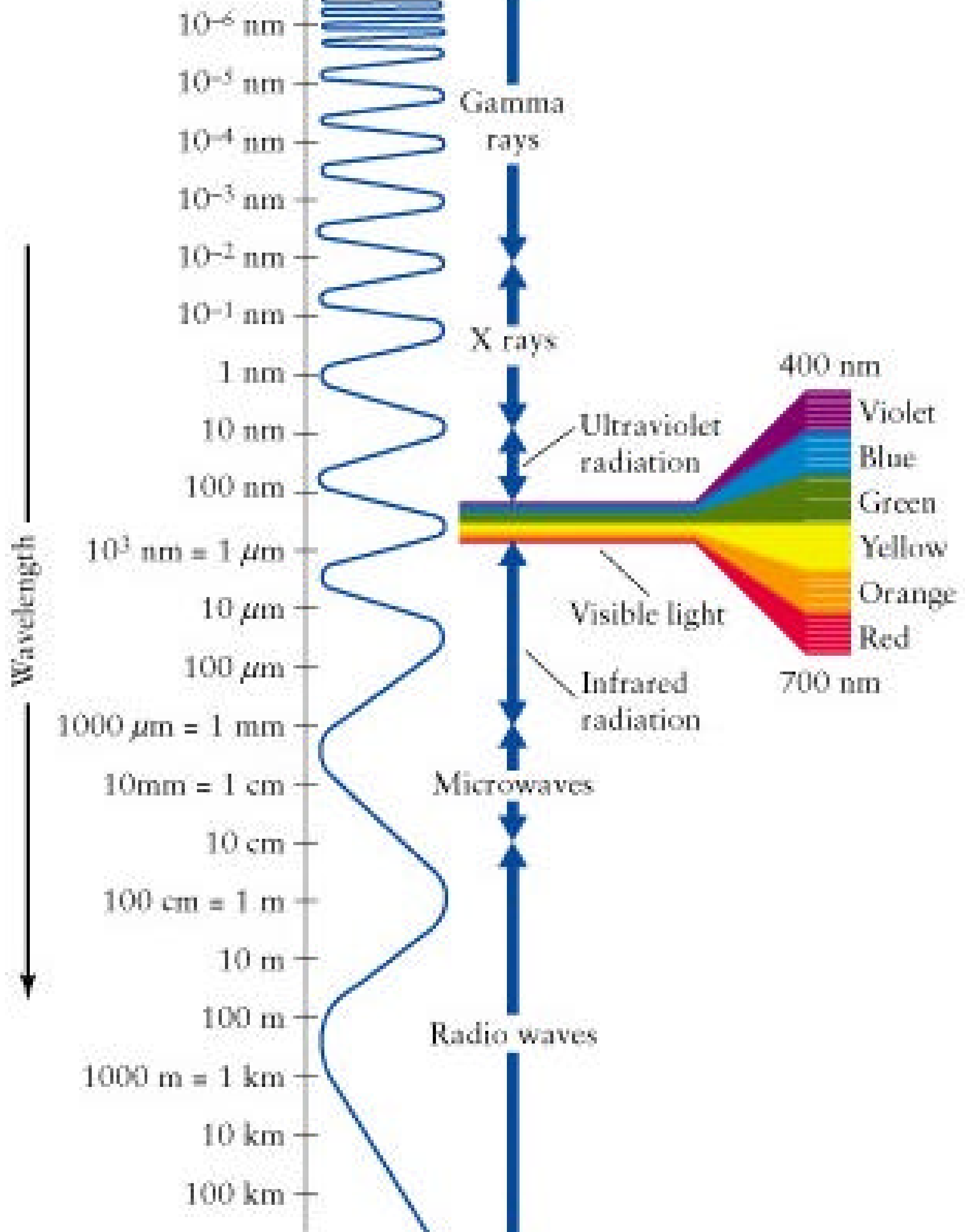


neither ellip[…] or spiral in sha[…] and dust as in s[…]ut n[…] defined “arm[…]

Peculiar

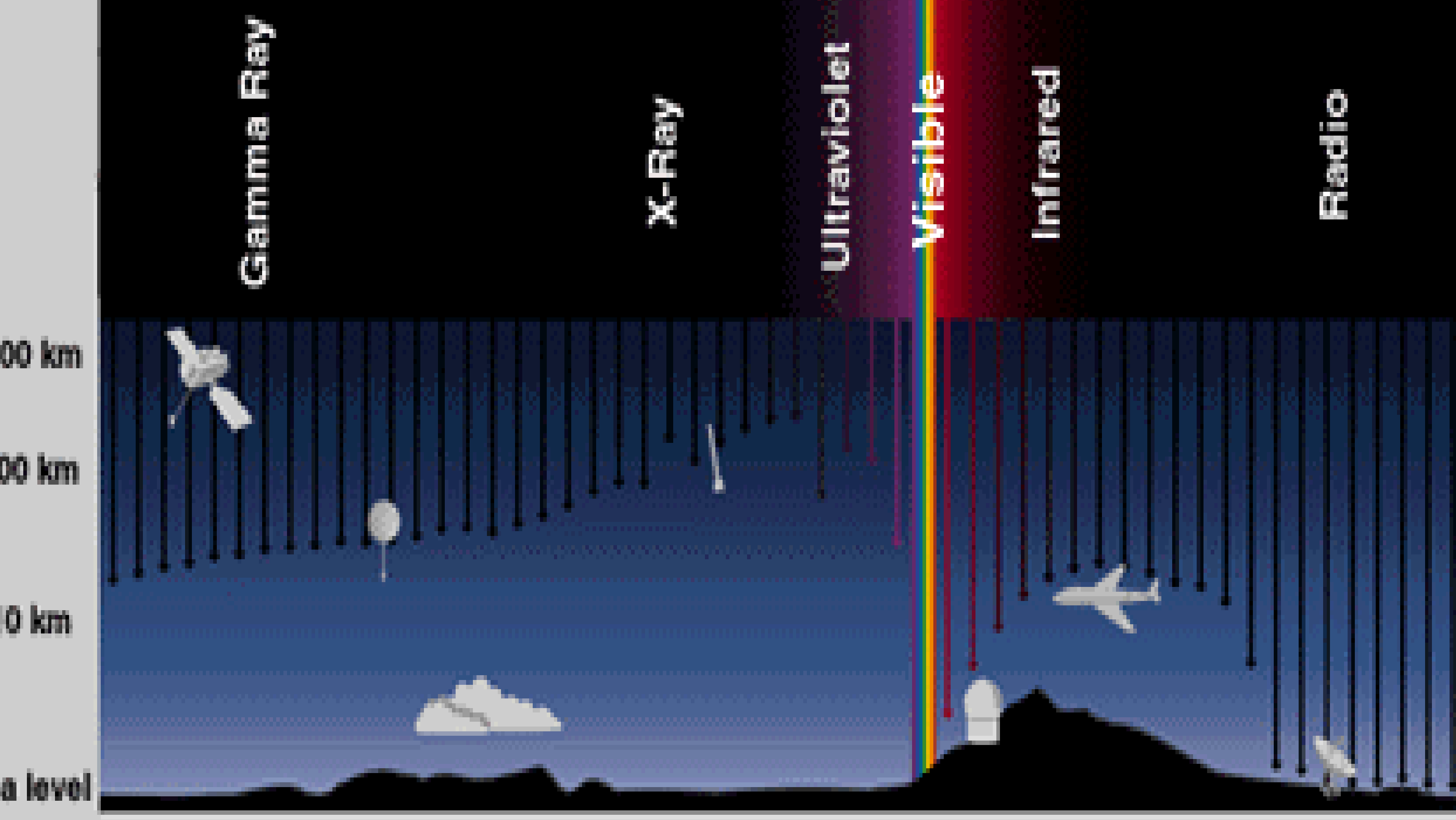


distorted […]one […]es, c[…] collision with another galaxy or similar catas[…]nt



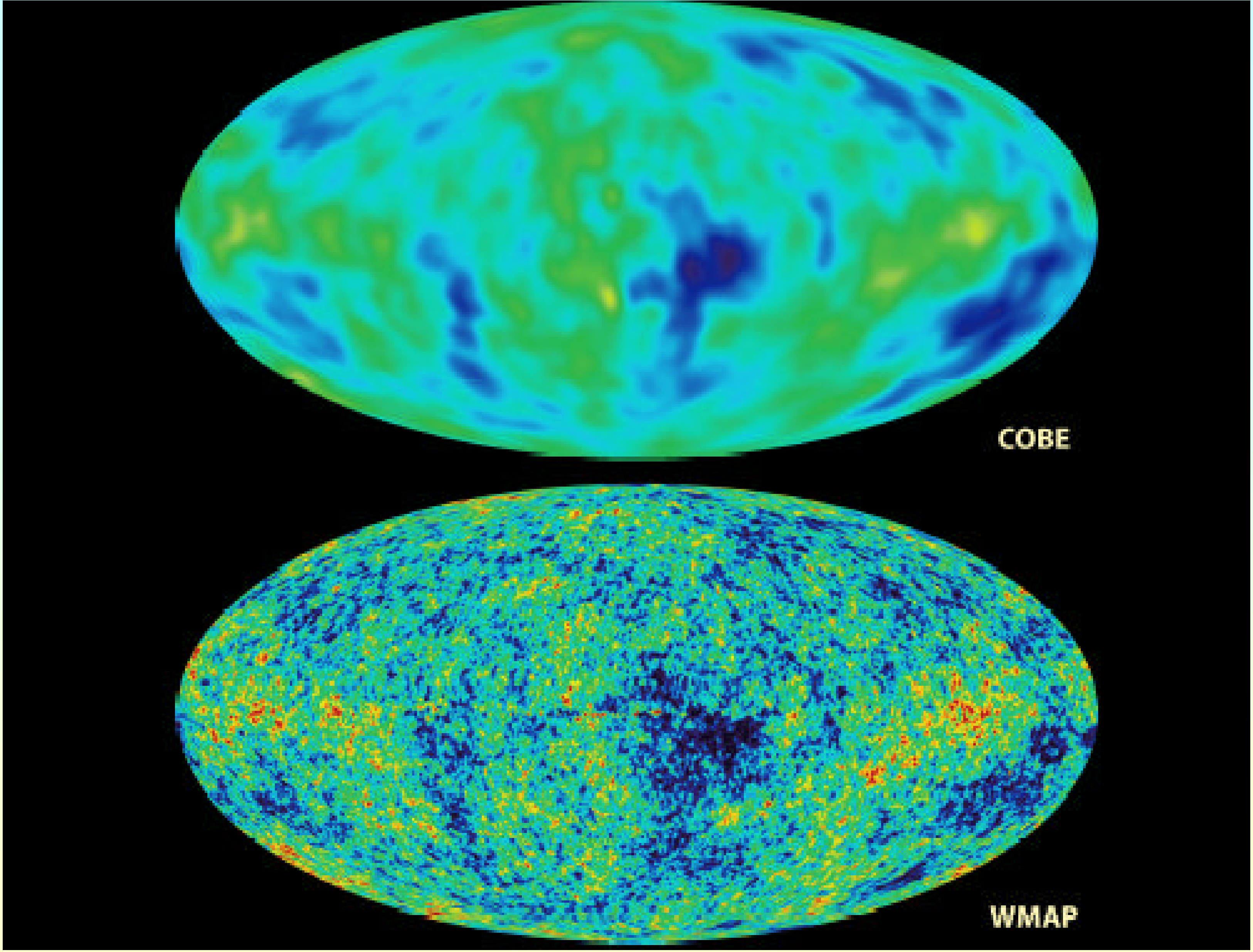
La luce visibile è solo un tipo di radiazione elettromagnetica emessa dai corpi

Ogni tipo di radiazione EM viaggia alla velocità della **luce: 300.000 km/s**



Si usano tecniche differenti per rilevare la luce a differenti lunghezze d’onda

Boomerang

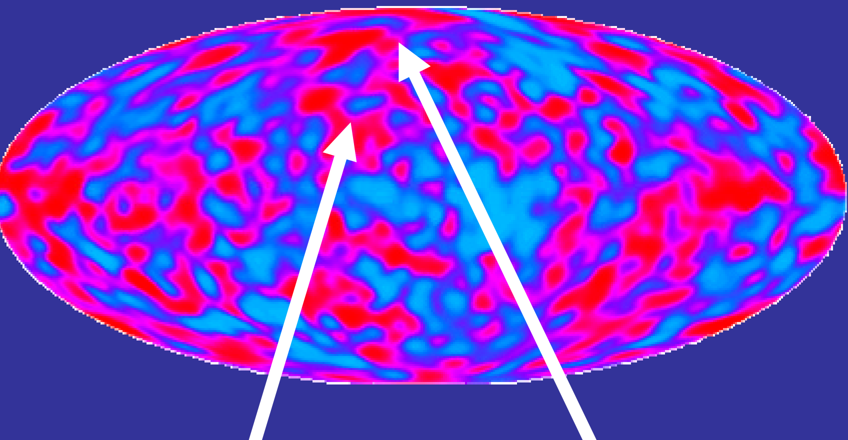

COBE
WMAP

CMB Anisotropies

$T_0 = 2.725 \pm 0.001K$

W_0 = 1.03 § 0.03

⇒ flat geometry



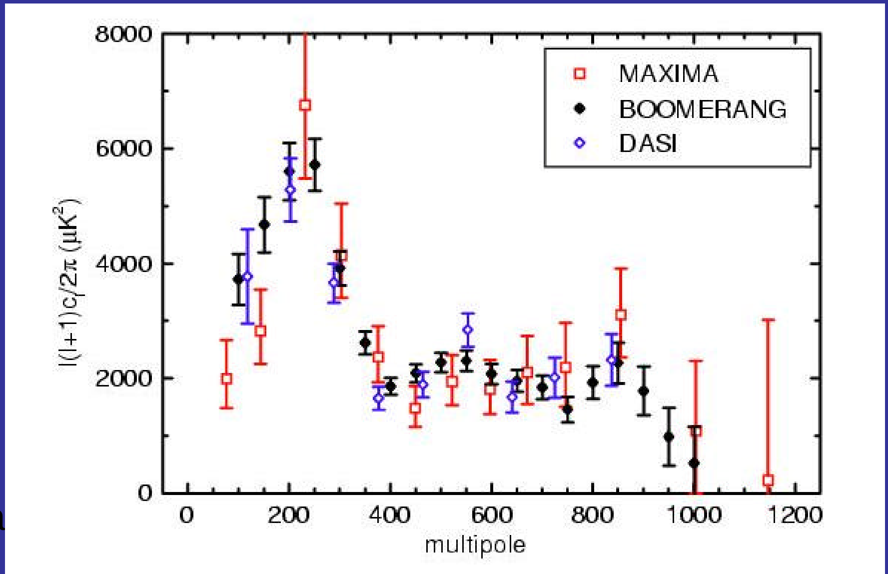
Dasi, Boomerang, MAXIMA, CBI

n = 1.05 § 0.06

$$T_1(q_1, f_1) \quad T_2(q_2, f_2)$$

$$\langle T_1 T_2 \rangle = \sum a_{lm} Y_{lm}(q, f)$$

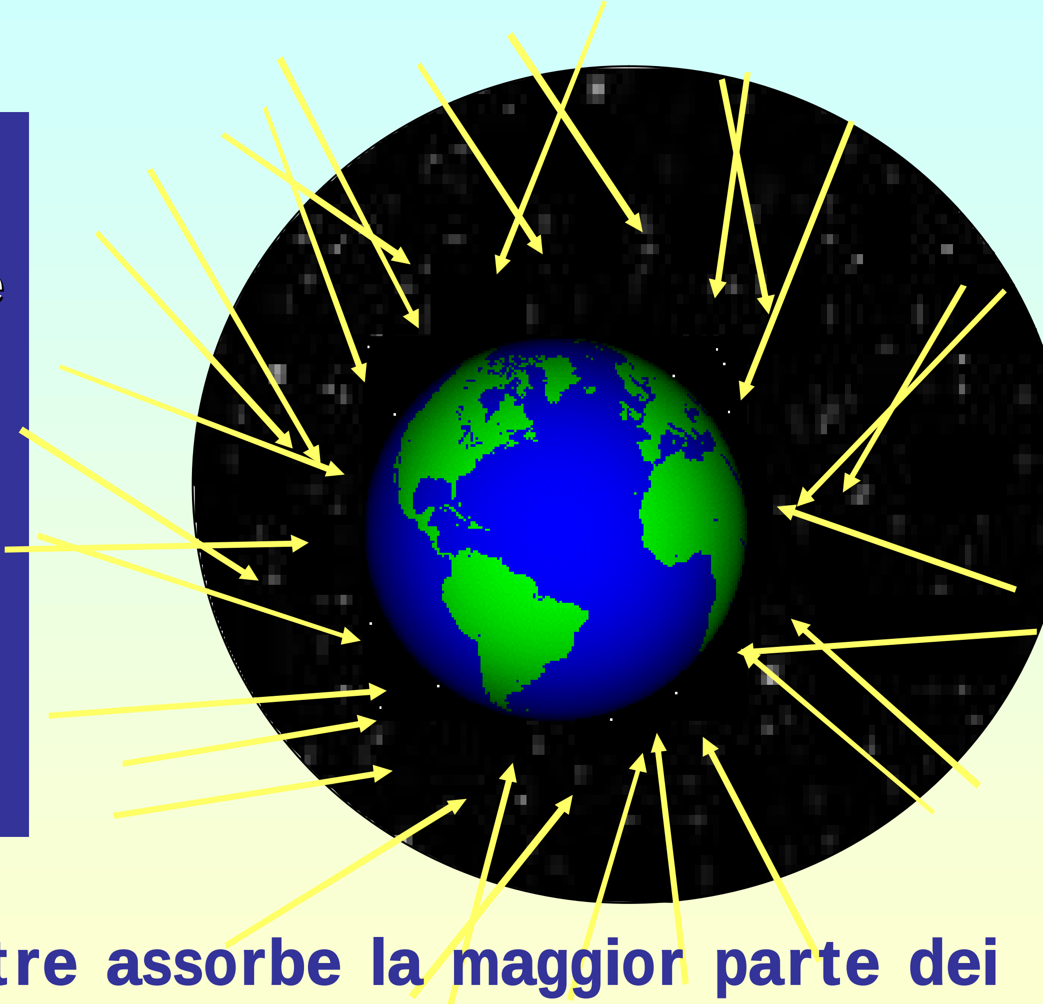
$$\left\langle \left| a_{lm} \right|^2 \right\rangle^{1/2} \equiv C_l$$



Cosa sono i raggi cosmici (CR) ?

I raggi cosmici sono particelle subatomiche cariche molto energetiche che bombardano continuamente la Terra.

Lo spettro energetico inizia da circa 10^9 eV e sembra non avere un limite superiore.

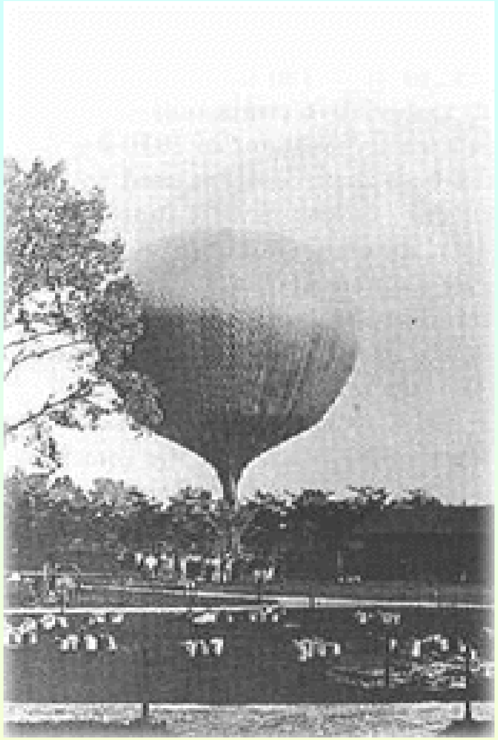


L'atmosfera terrestre assorbe la maggior parte dei raggi cosmici.

… i raggi cosmici …

1912

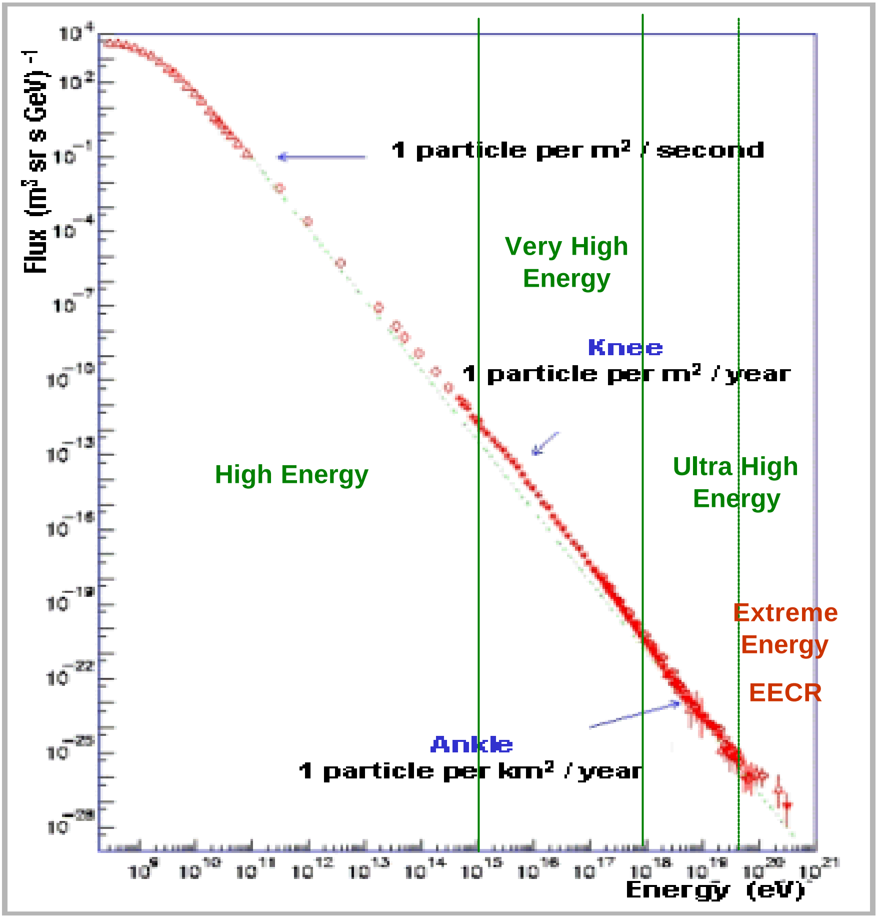
Il fisico austriaco Victor Hess compie dei voli in pallone a quota 5000 metri con degli elettroscopi per scoprire l'origine delle misteriose particelle che sembravano pervadere l'atmosfera e che si ipotizzava provenissero dalla Terra.



Scopre invece che più si sale di quota e più queste particelle aumentan e ne deduce che le particelle devono arrivare dallo Spazio, oltre il Sole.

… prende vita la scienza della fisica delle particelle elementari …

… il flusso dei raggi cosmici …



Il **numero di raggi cosmici** che colpiscono la Terra **diminuisce al crescere dell'energia**

E_0 » 10^8 eV → 100 eventi / m^2 / secondo

E_0 » 10^{15} eV → 1 evento / m^2 / anno

E_0 » 10^{19} eV → 1 evento / km^2 / anno

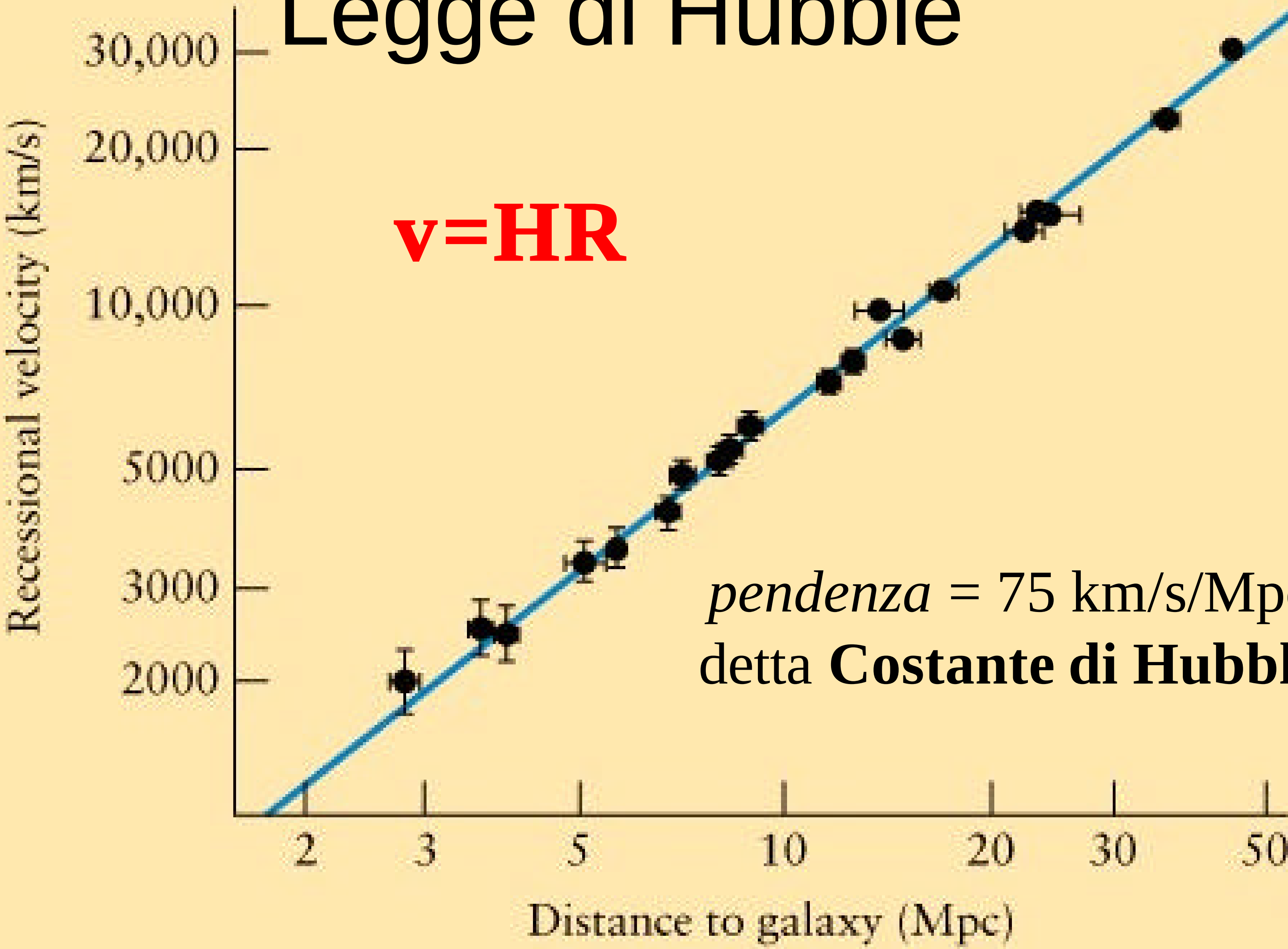
$E_0 > 10^{20}$ eV → 1 evento / km^2 / secolo

Per osservare raggi cosmici di energia estrema (**EECR, $E_0 > 5 \times 10^{19}$ eV**) ed ottenere una buona statistica osservativa in un tempo *"ragionevole"* servono **rivelatori di particelle** disposti su una **superficie enorme !**

EUSO a bordo della ISS

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
EUSO	A	B		C/D							

Legge di Hubble



v=HR

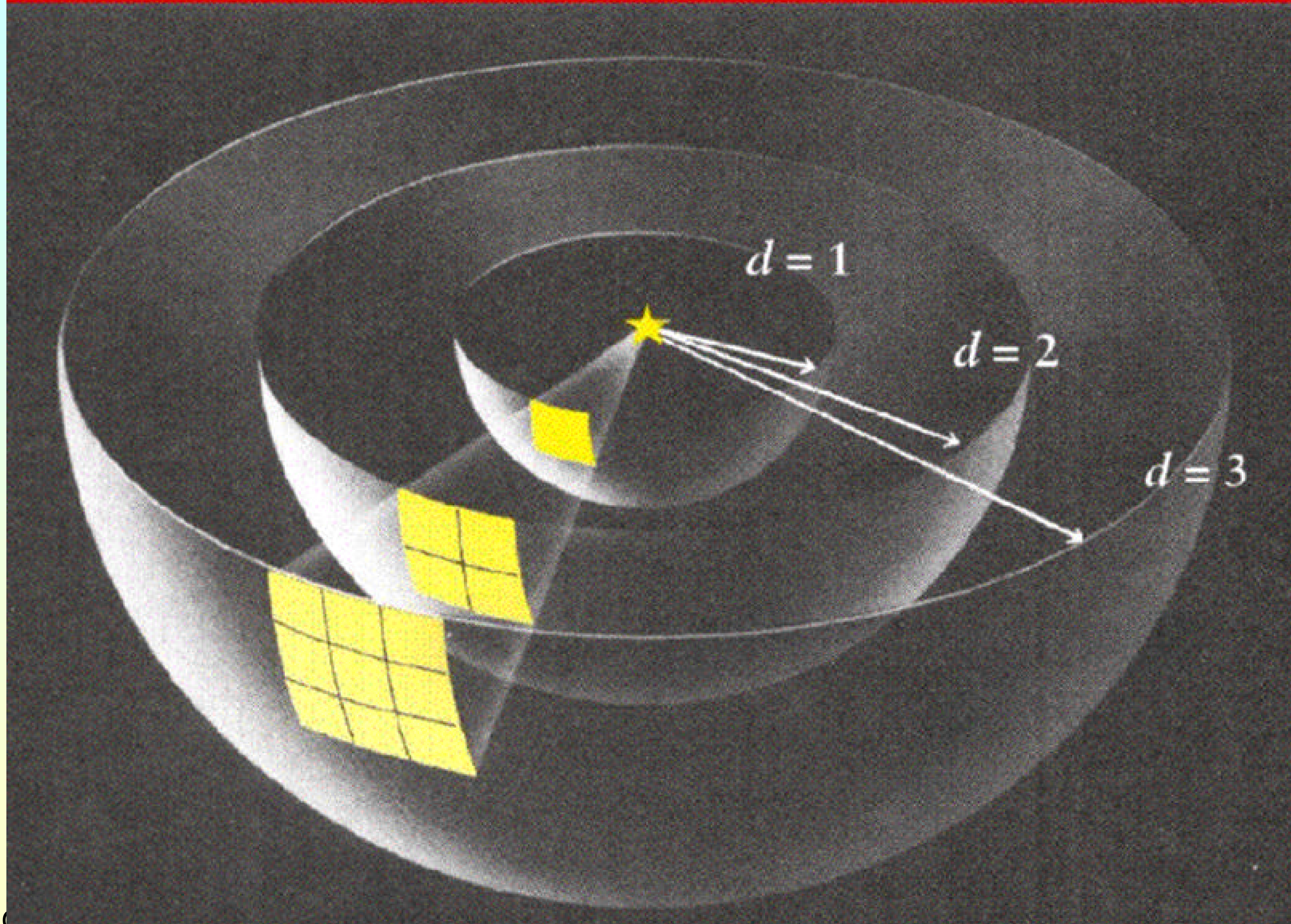
pendenza = 75 km/s/Mpc
detta **Costante di Hubble**

"Standard Candles"

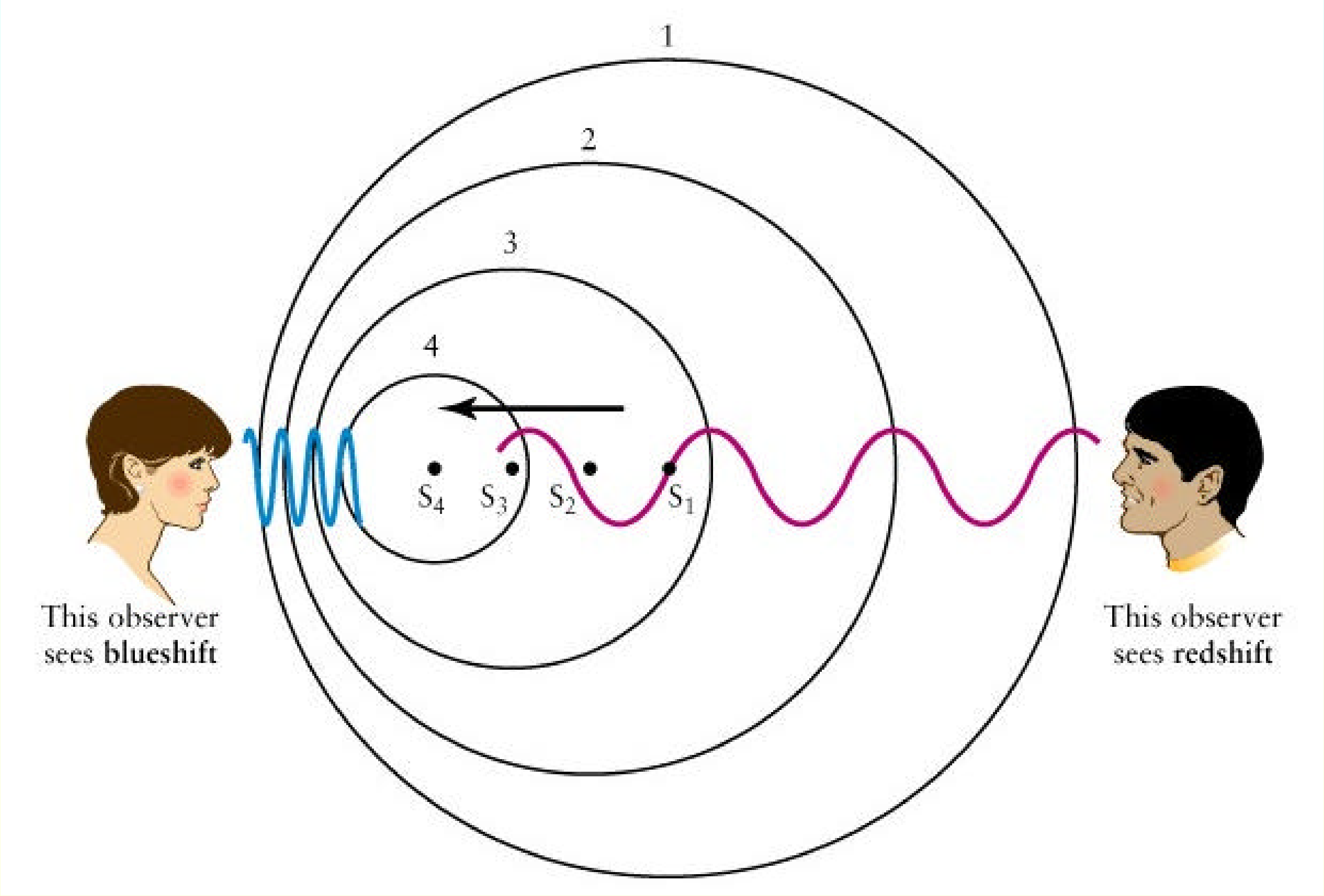
If we know how luminous an object is then we can translate it's apparent brightness into it's distance.


Type Ia
supernova

Dilution of Brightness by Distance

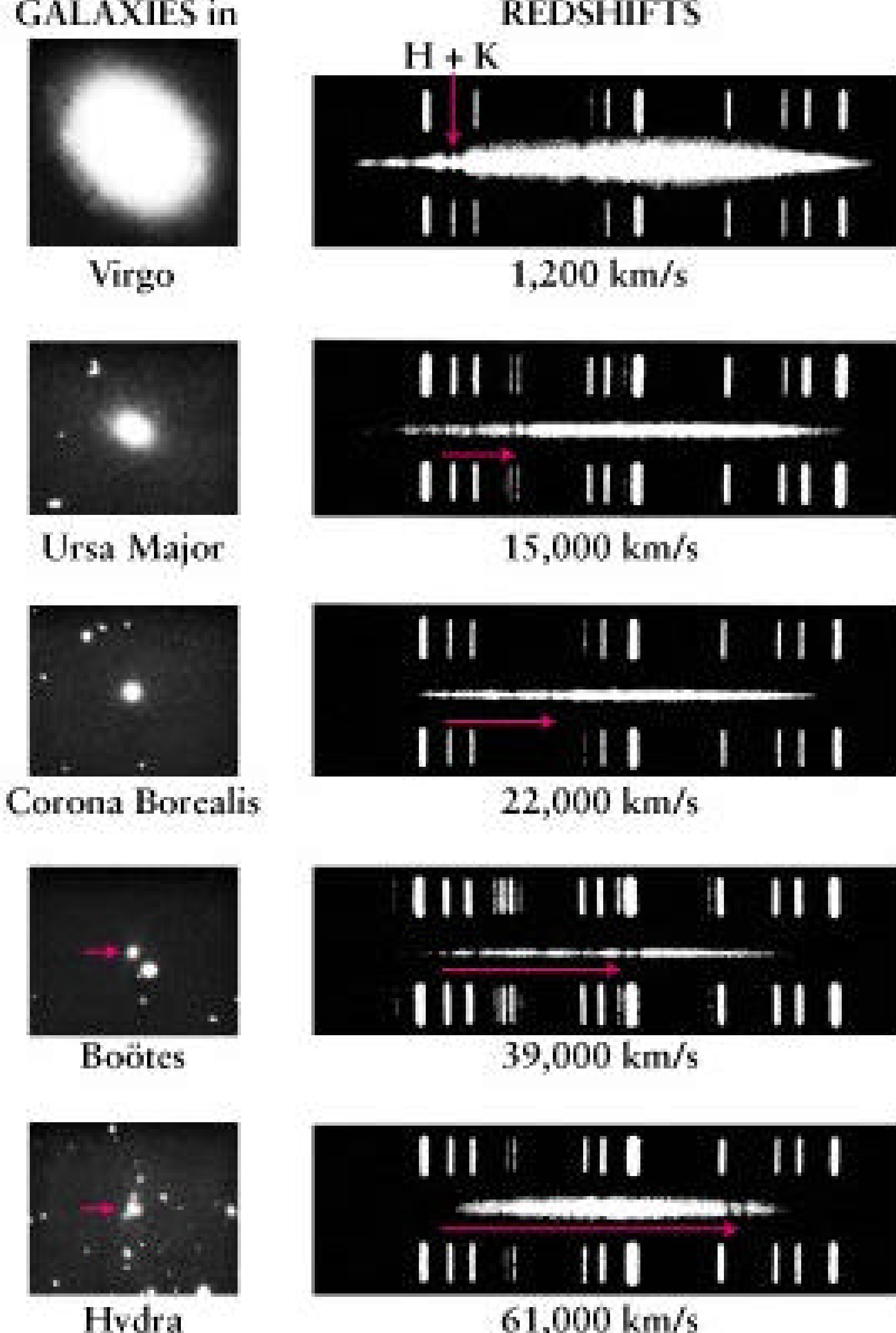


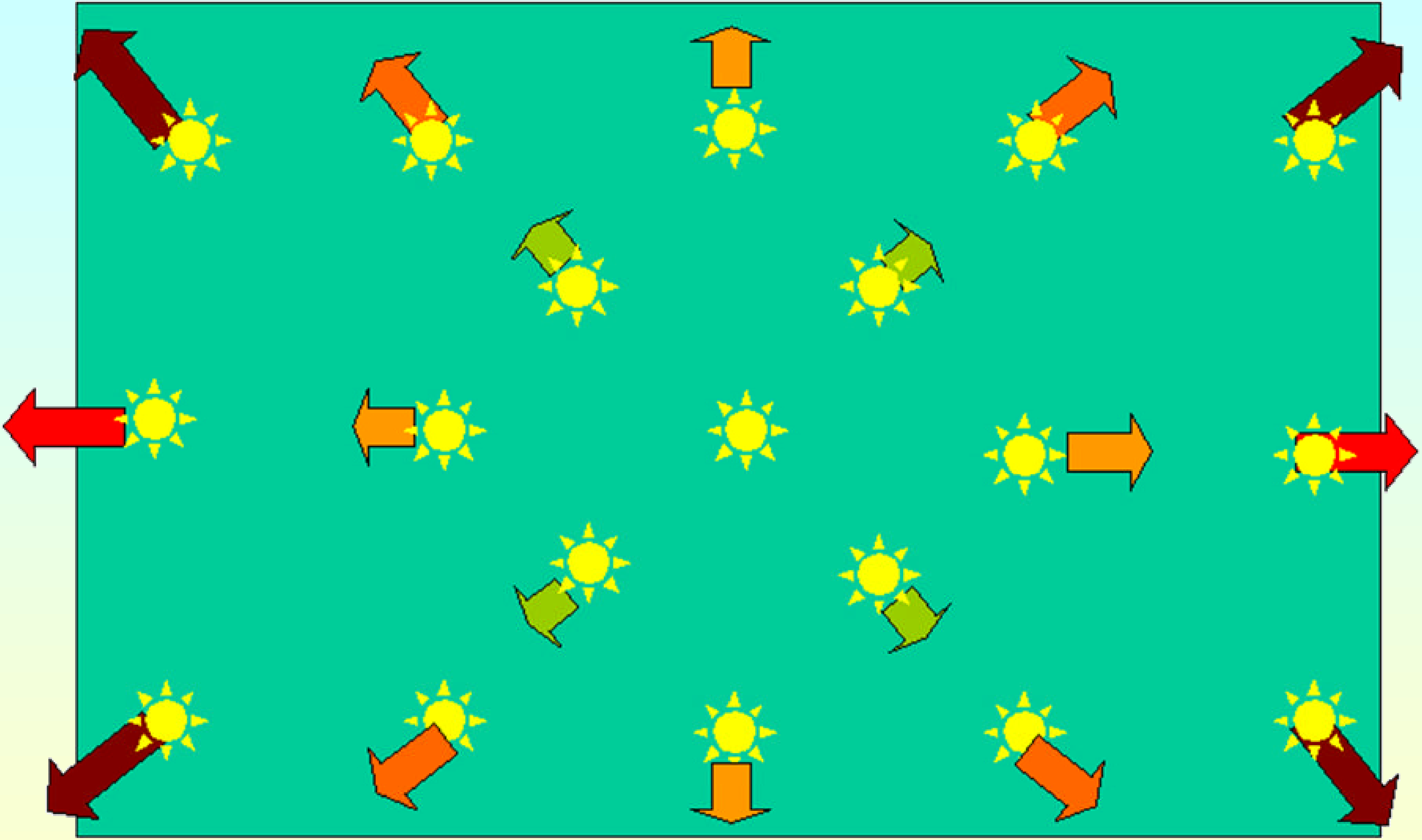
La frequenza della luce cambia per il moto relativo tra sorgente e osservatore



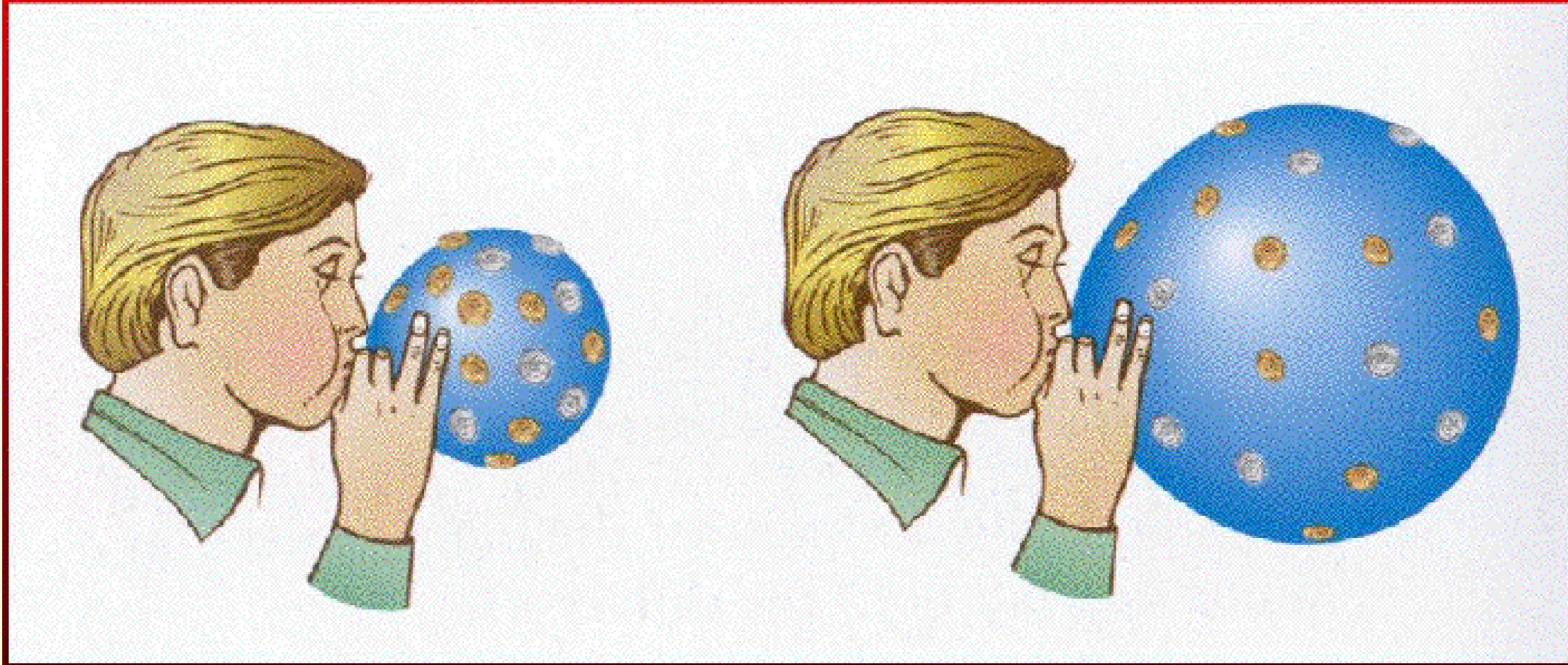
Lo spostamento Doppler permette di misurare velocità radiali

Ma anche quello delle galassie dallo spostamento verso il rosso (red-shift) delle righe spettrali.

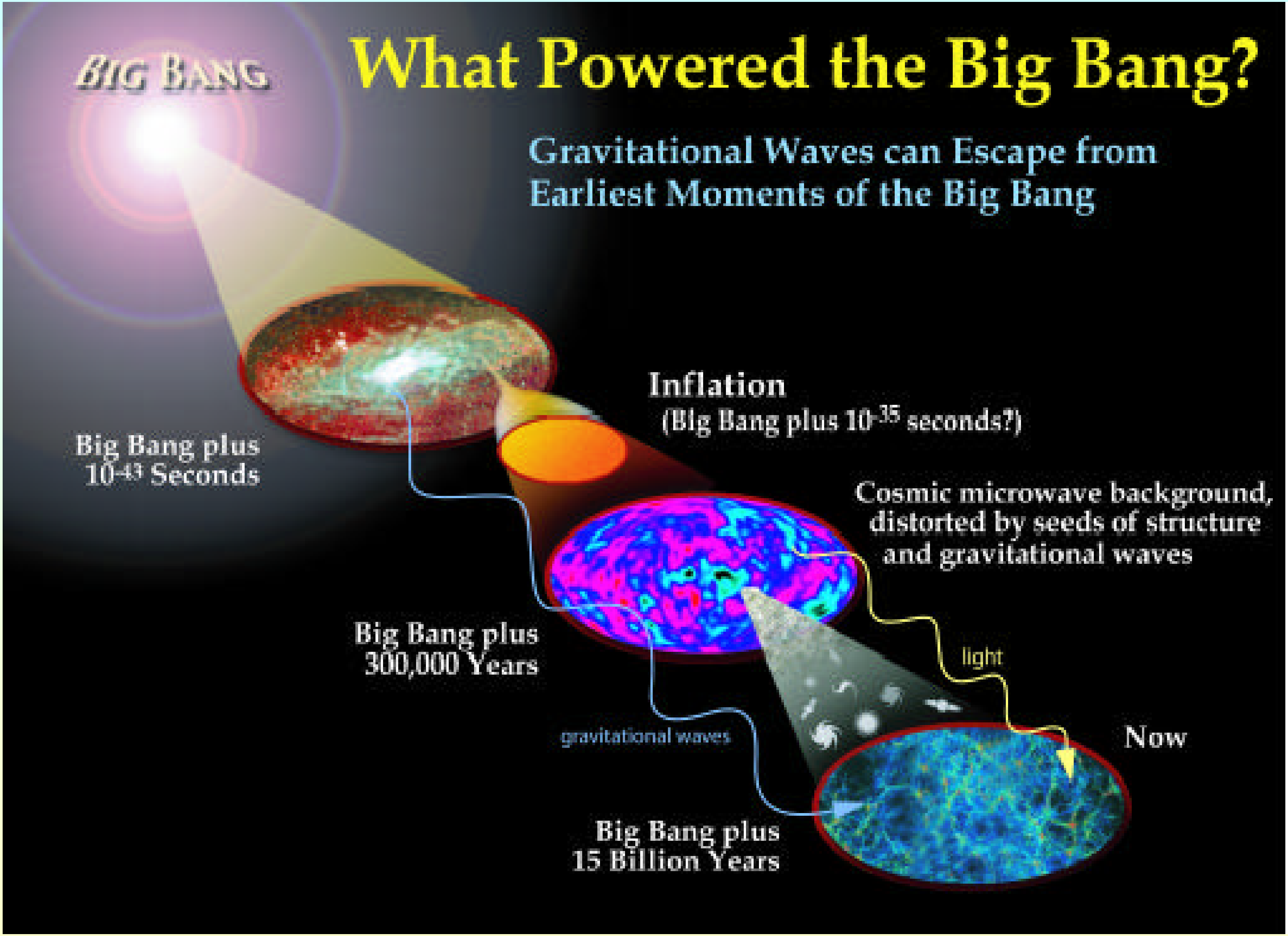


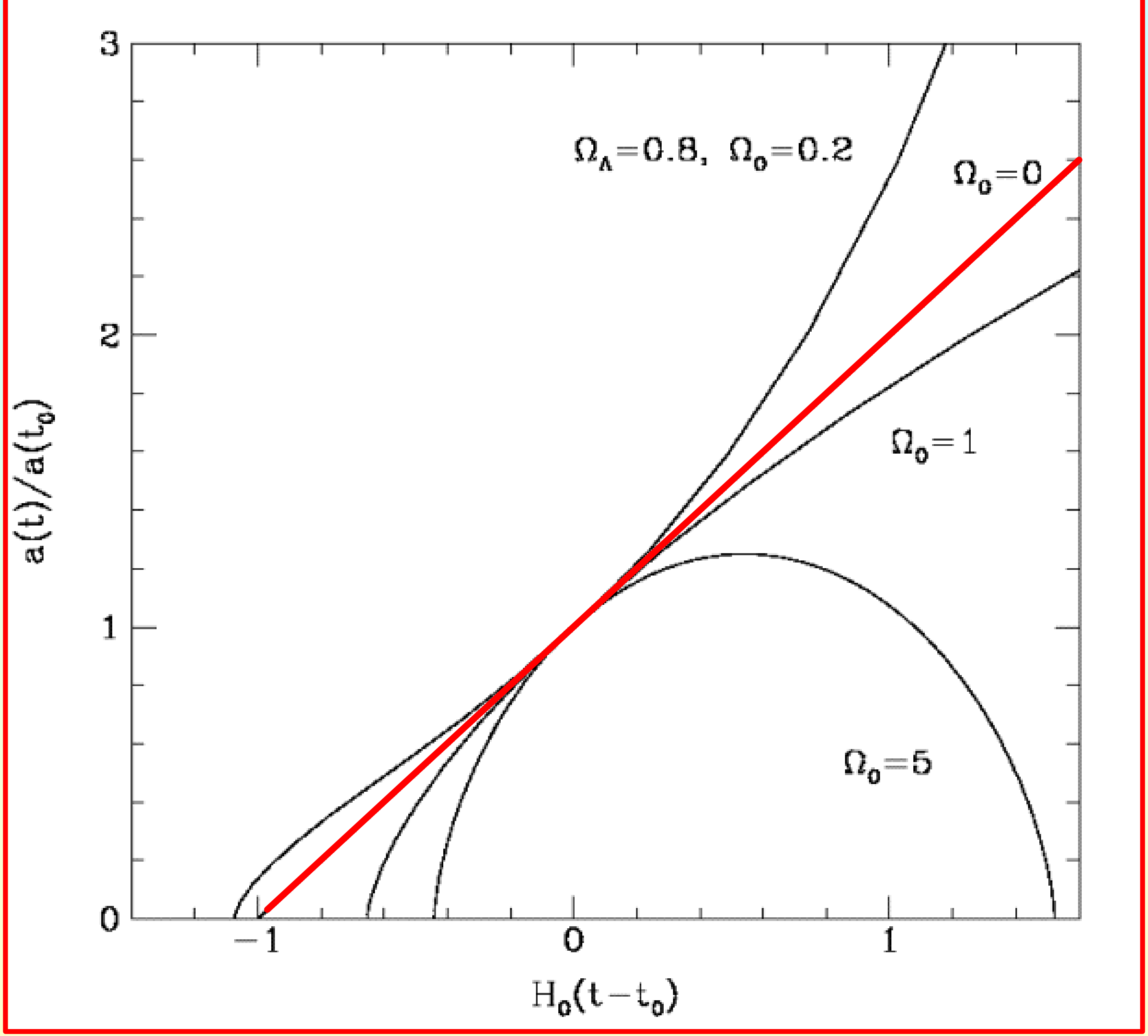


Expanding Universe?

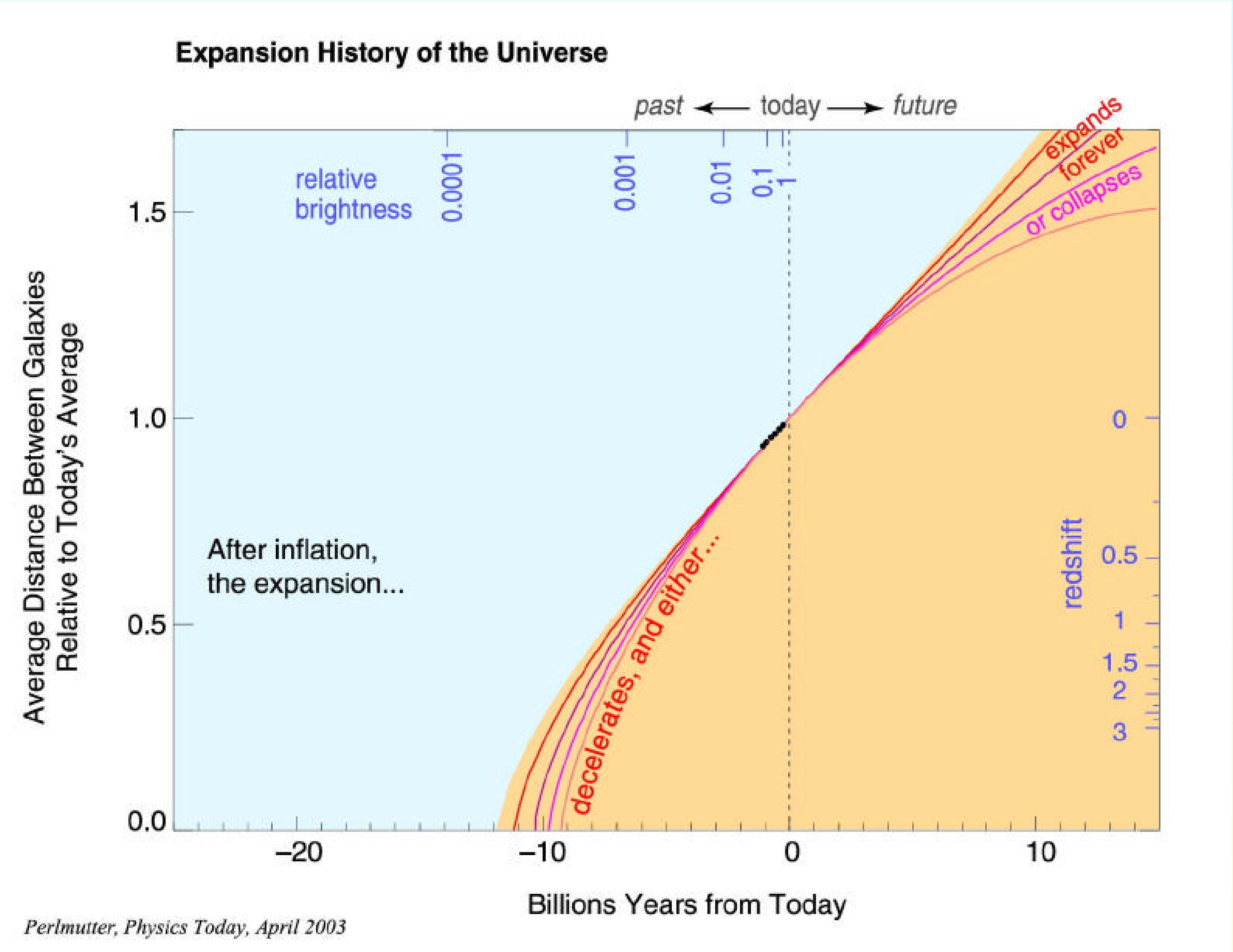


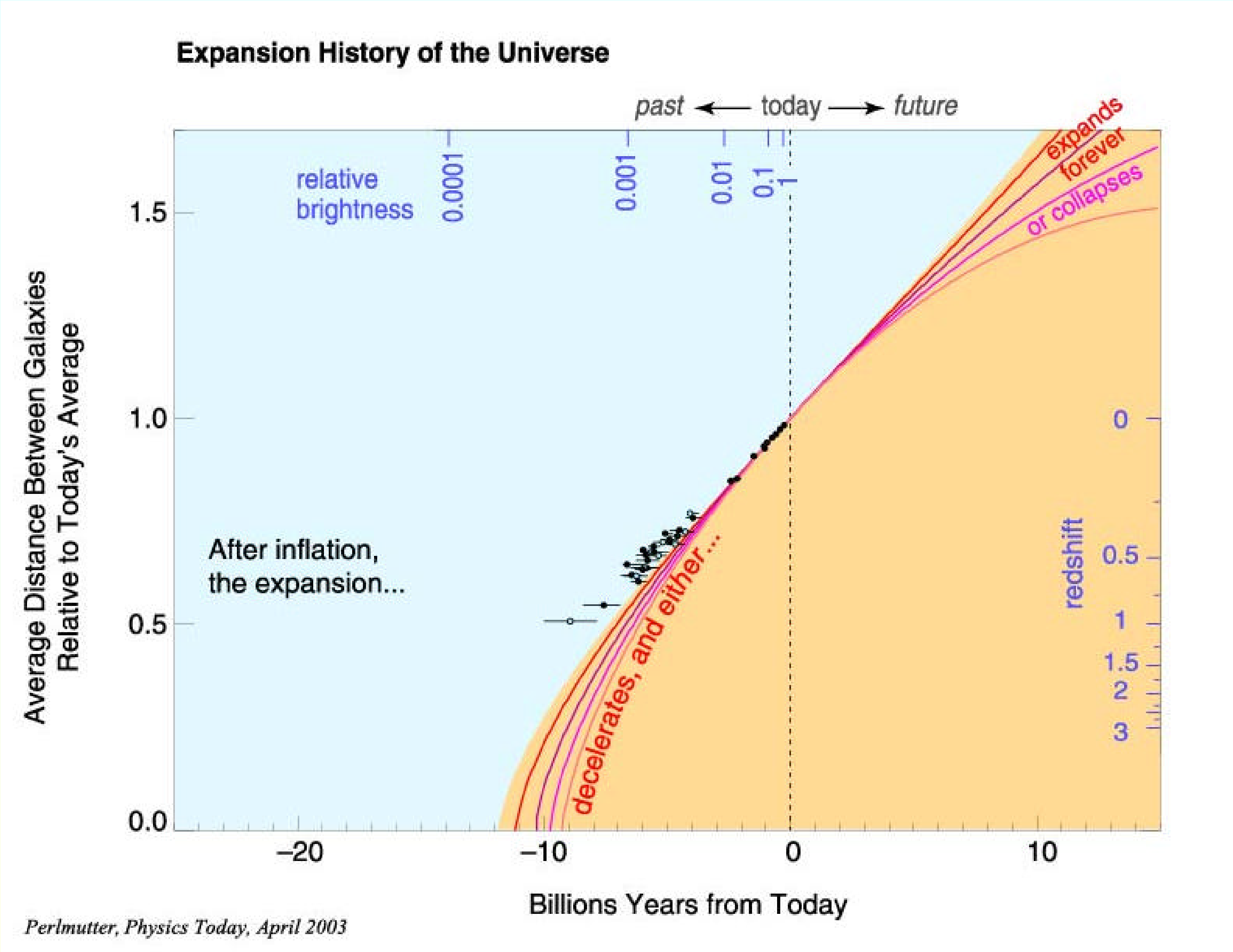
- Simplest explanation - the Universe itself is expanding!
- This will make more distant objects appear to recede faster.


What Powered the Big Bang?
BIG BANG
Gravitational Waves can Escape from
Earliest Moments of the Big Bang
Inflation
(Big Bang plus 10^{-35} seconds?)
Big Bang plus
10^{-43} Seconds
Cosmic microwave background,
distorted by seeds of structure
and gravitational waves
Big Bang plus
300,000 Years
light
gravitational waves
Now
Big Bang plus
15 Billion Years

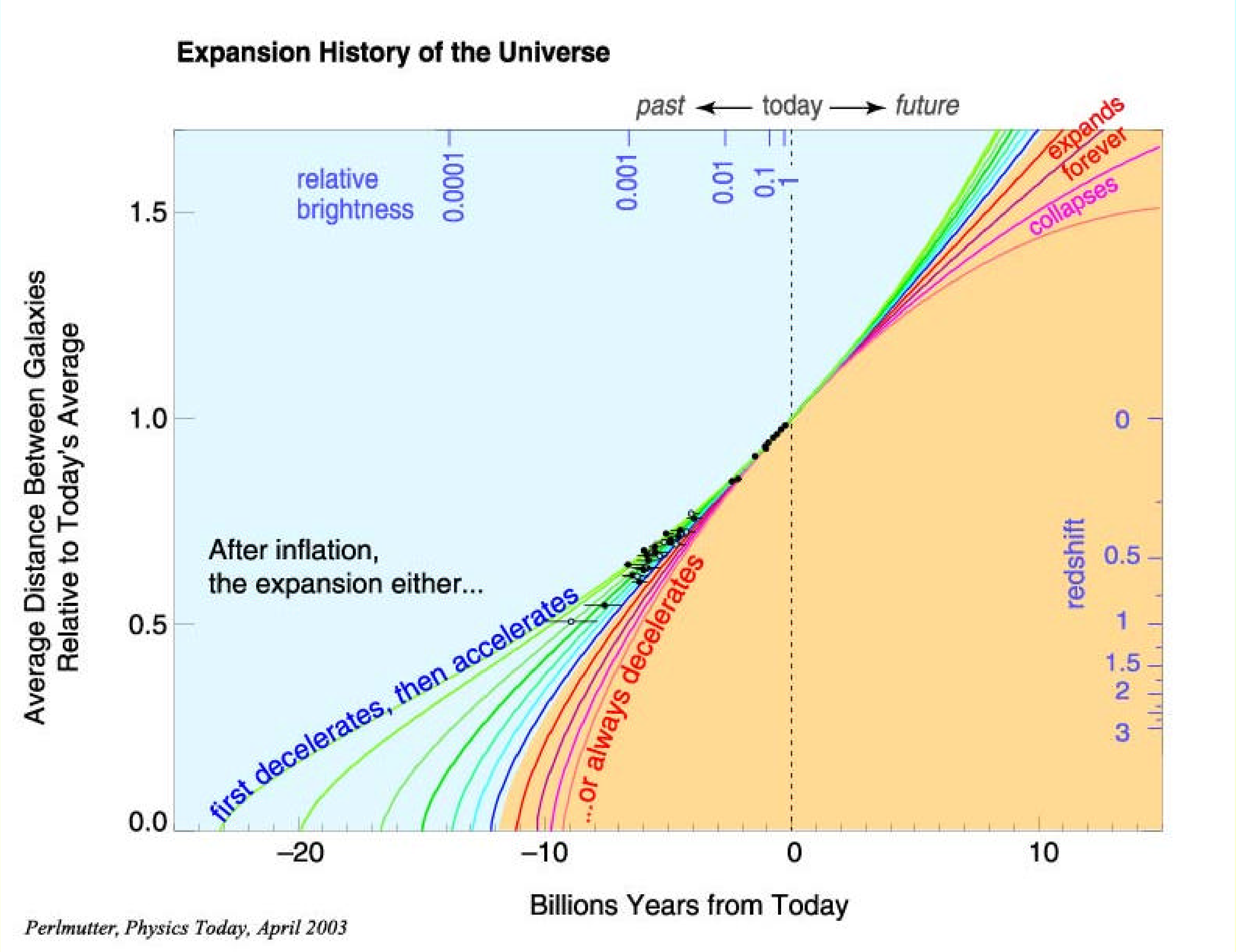


$\Omega_\Lambda=0.8,\ \Omega_0=0.2$
$\Omega_0=0$
$\Omega_0=1$
$\Omega_0=5$
$a(t)/a(t_0)$
$H_0(t-t_0)$
3
2
1
0
−1
0
1


Expansion History of the Universe
past ← today → future
relative brightness
0.0001
0.001
0.01
0.1
1
expands forever
or collapses
After inflation, the expansion...
decelerates, and either...
redshift
0
0.5
1
1.5
2
3
Average Distance Between Galaxies Relative to Today's Average
1.5
1.0
0.5
0.0
−20
−10
0
10
Billions Years from Today
Perlmutter, Physics Today, April 2003



Expansion History of the Universe
past ← today → future
relative brightness
0.0001
0.001
0.01
0.1
1
1.5
1.0
0.5
0.0
Average Distance Between Galaxies Relative to Today's Average
After inflation, the expansion...
decelerates, and either...
expands forever
or collapses
redshift
0
0.5
1
1.5
2
3
−20
−10
0
10
Billions Years from Today
Perlmutter, Physics Today, April 2003


Expansion History of the Universe
past ← today → future
relative brightness
0.0001
0.001
0.01
0.1
1
expands forever
collapses
1.5
1.0
0.5
0.0
Average Distance Between Galaxies Relative to Today's Average
After inflation, the expansion either...
first decelerates, then accelerates
...or always decelerates
redshift
0
0.5
1
1.5
2
3
−20
−10
0
10
Billions Years from Today
Perlmutter, Physics Today, April 2003

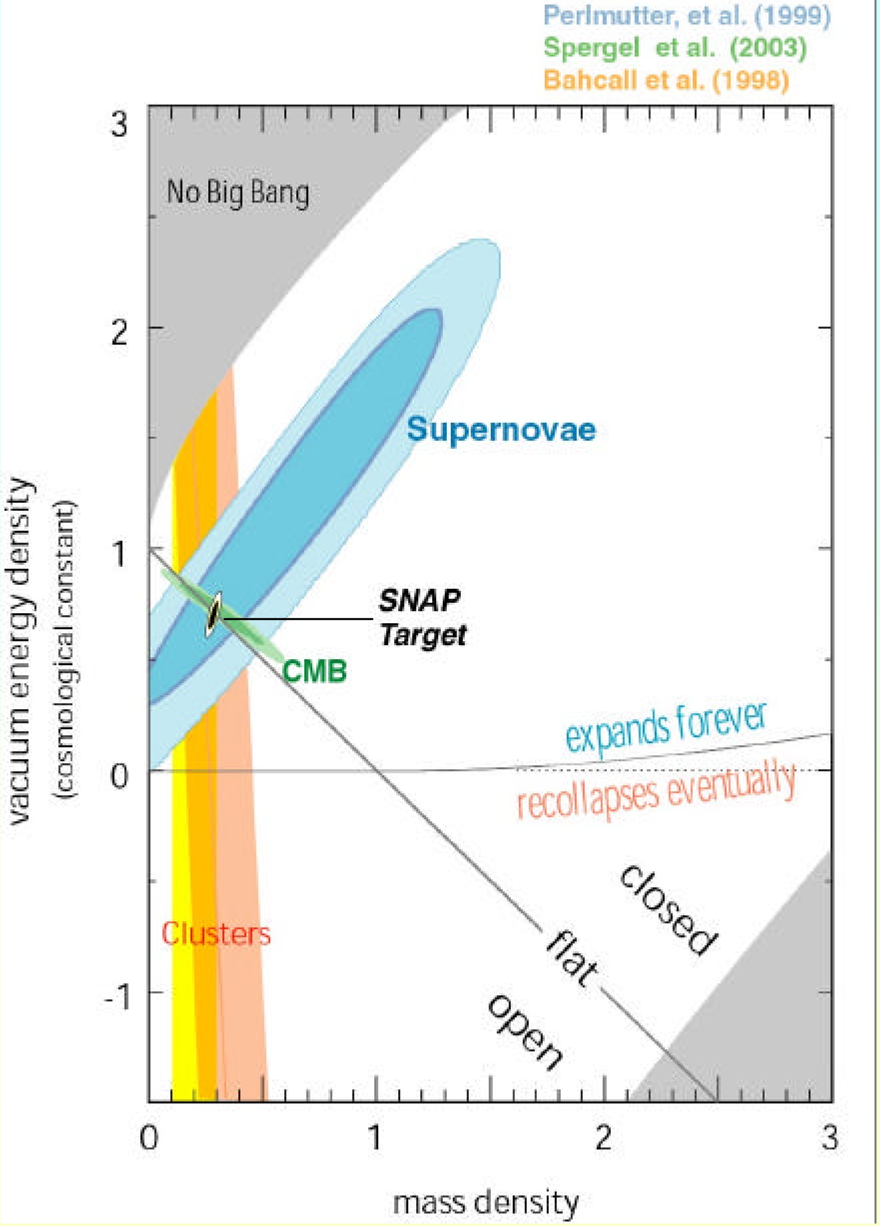
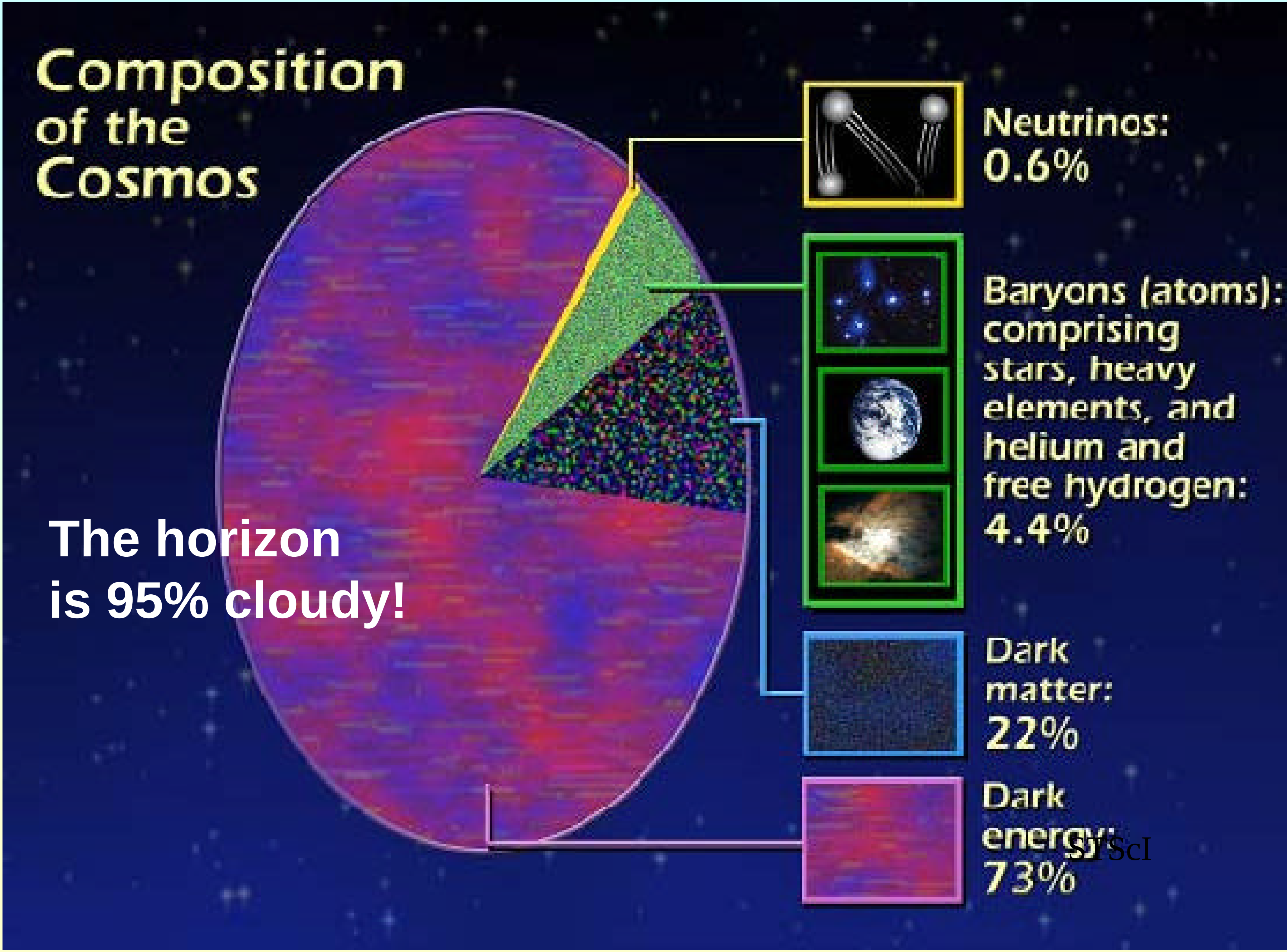

Perlmutter, et al. (1999)
Spergel et al. (2003)
Bahcall et al. (1998)
No Big Bang
Supernovae
SNAP
Target
CMB
expands forever
recollapses eventually
closed
flat
open
Clusters
vacuum energy density
(cosmological constant)
mass density
3
2
1
0
-1
0
1
2
3

Table of Cosmological Parameters

Part I: 9 global FLRW parameters:

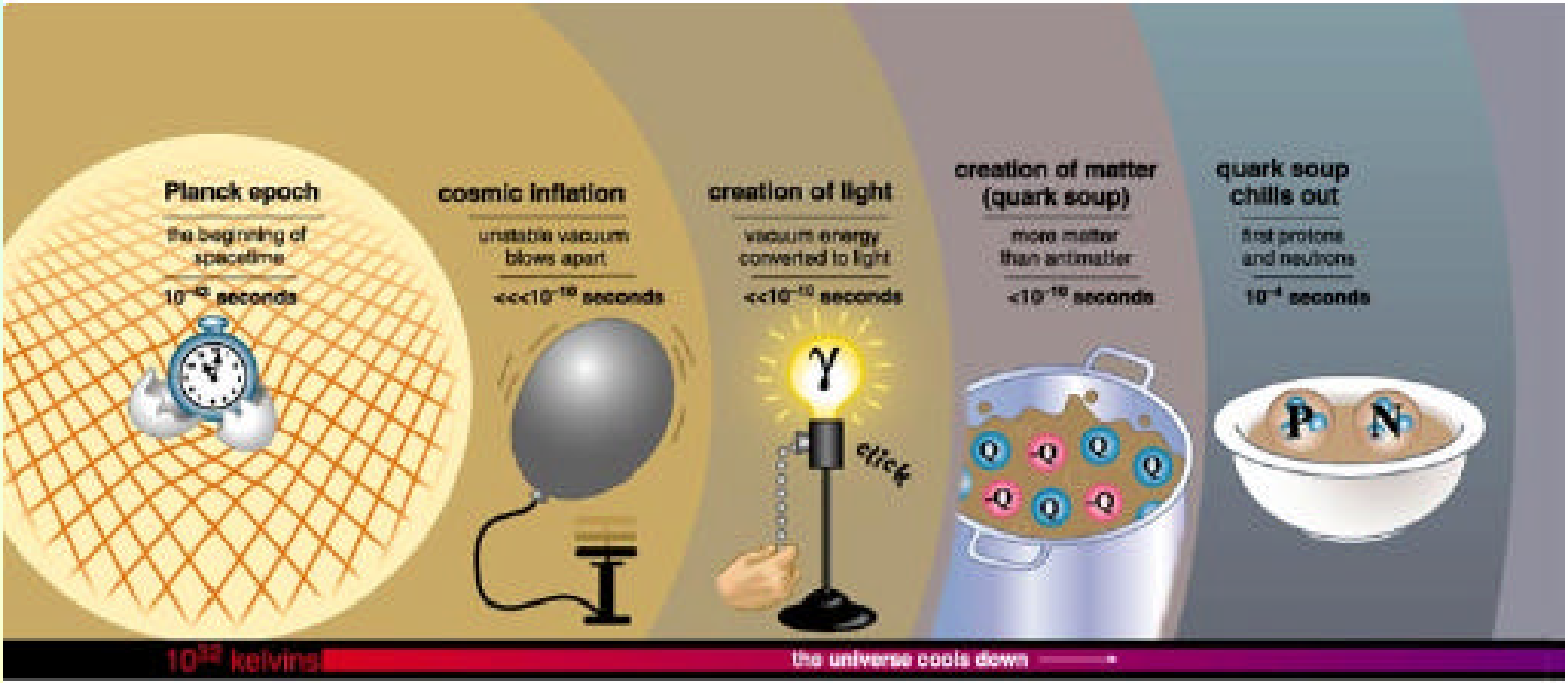
H_0	72§7km/sec/Mpc	Present expansion rate
q_0	-0.67 § 0.25	Deceleration parameter
t_0	13 § 1.5	Age of the Universe
T_0	2.725 § 0.001K	CMB temperature
W_0	1.03 § 0.03	Density parameter
W_b	0.039 § 0.008	Baryons
W_{CDM}	0.3 § 0.05	CDM
W_n	0.002 – 0.05	Massive neutrinos
W_X	0.7 § 0.1	Dark energy

Freedman & Turner (Science, 200

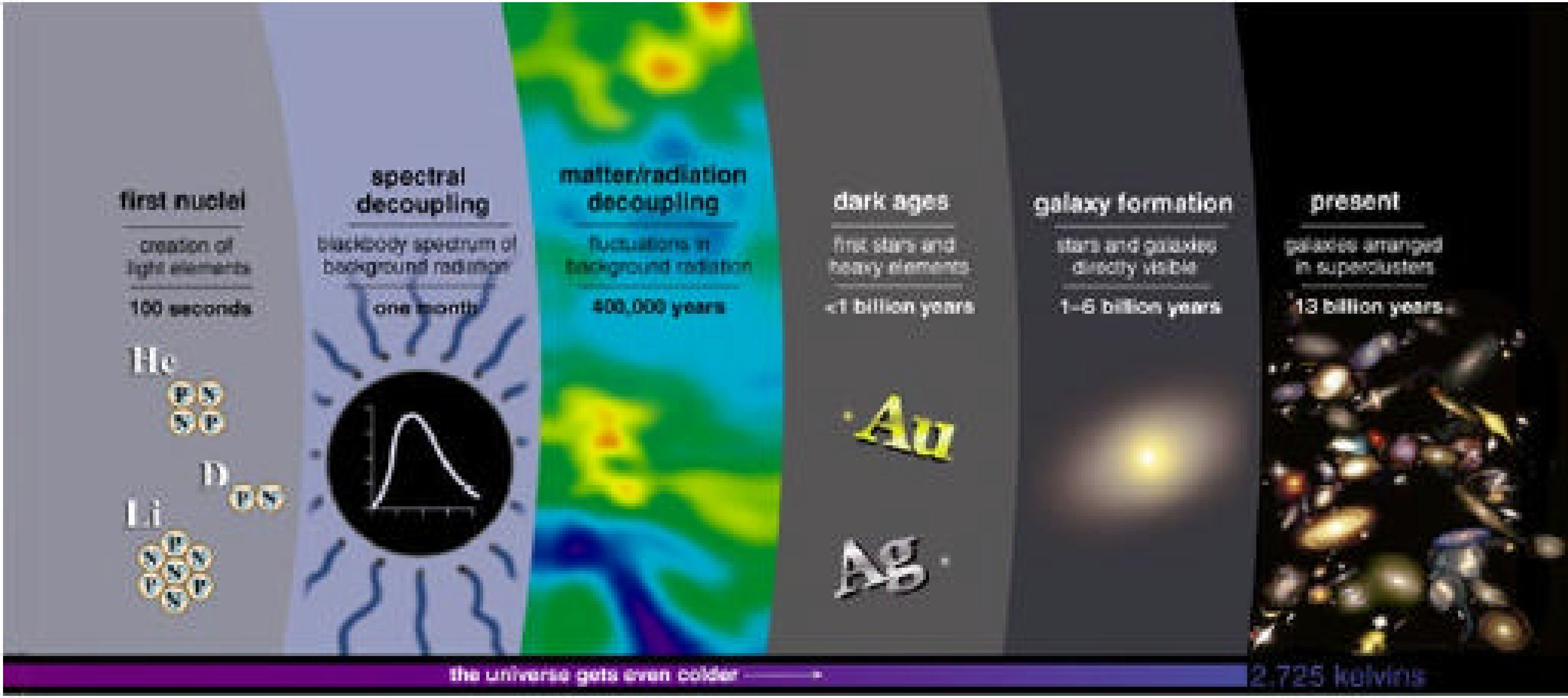


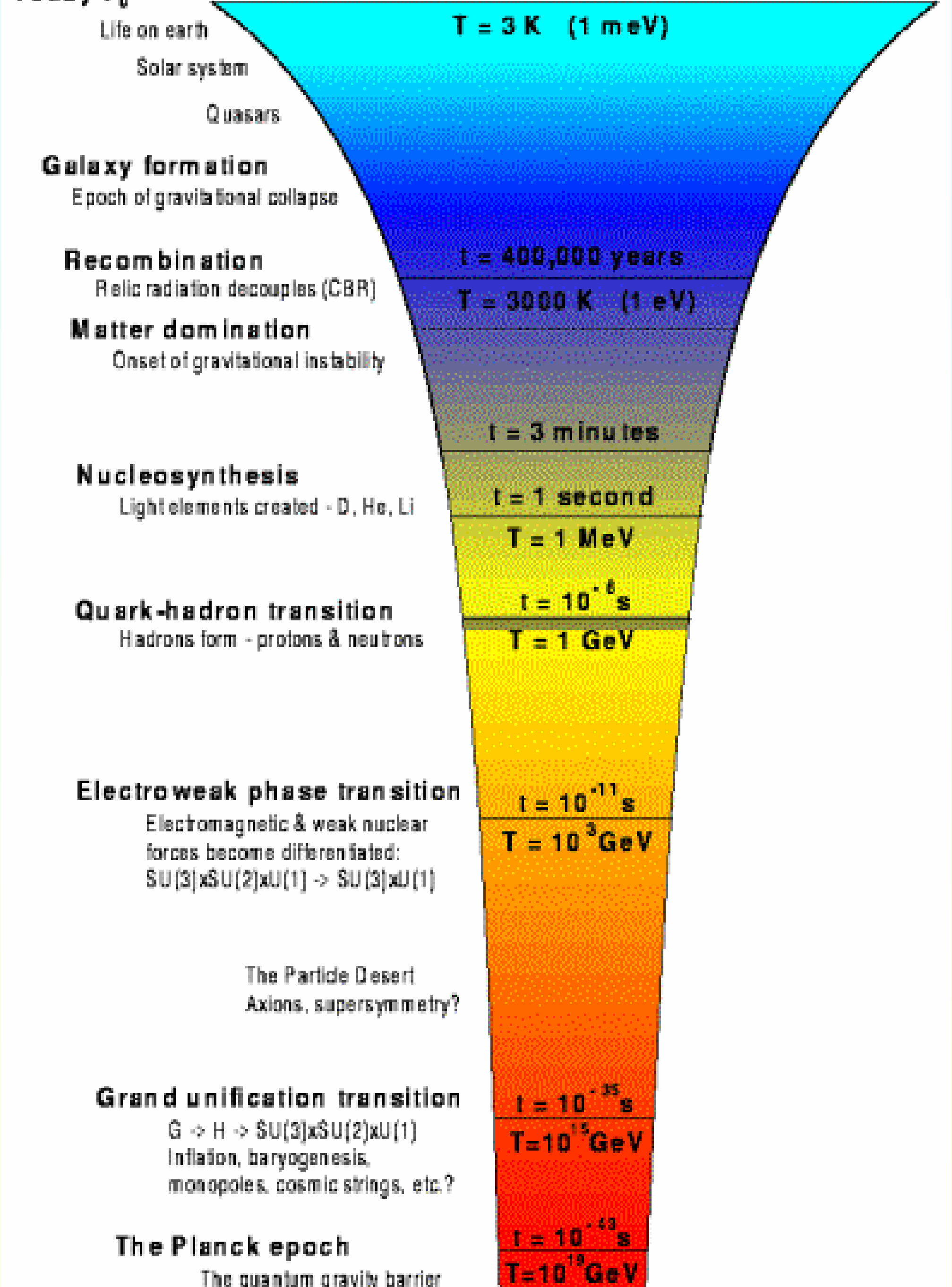
The horizon is 95% cloudy!

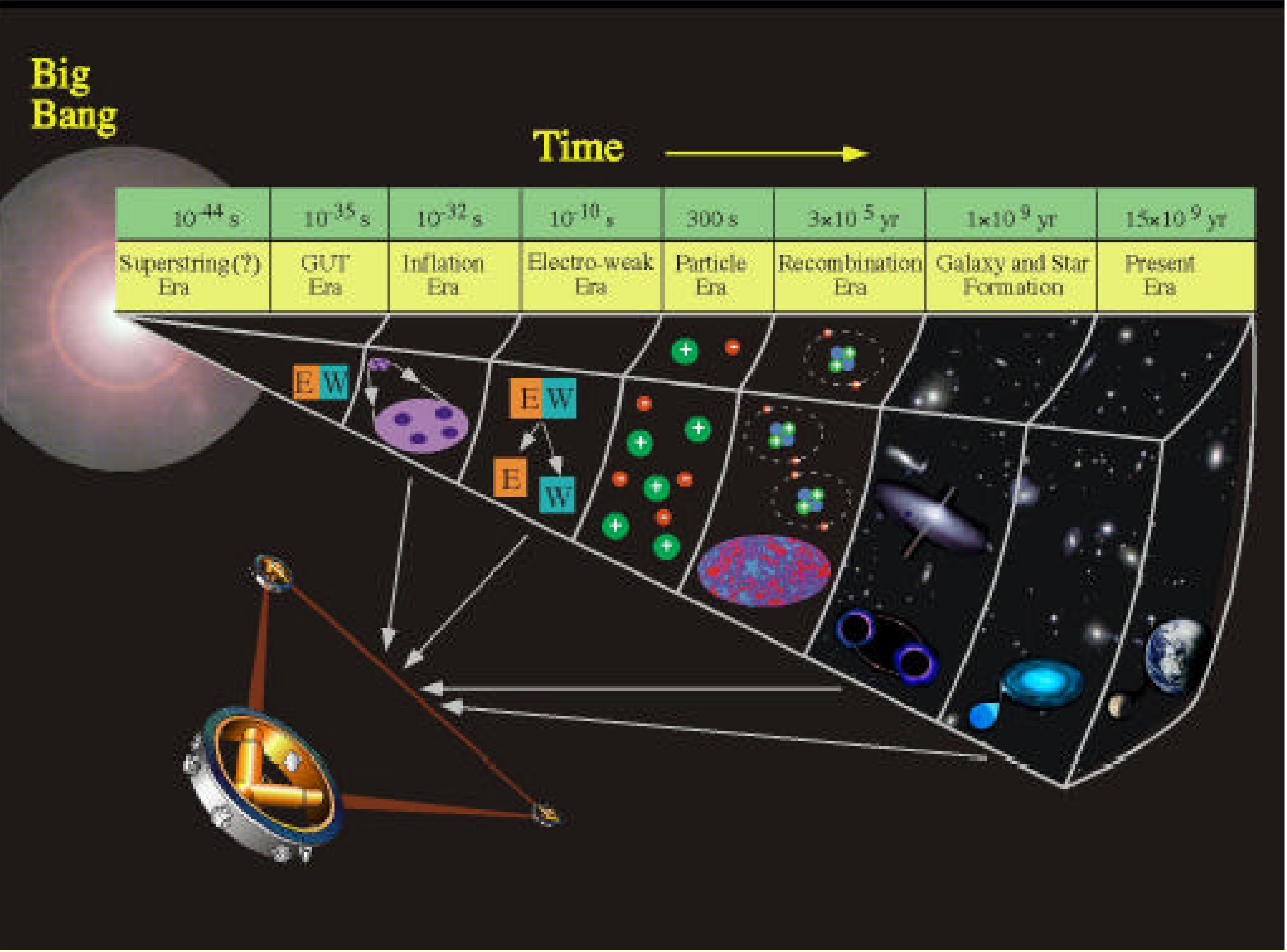
History of the universe I.



History of the Universe II.



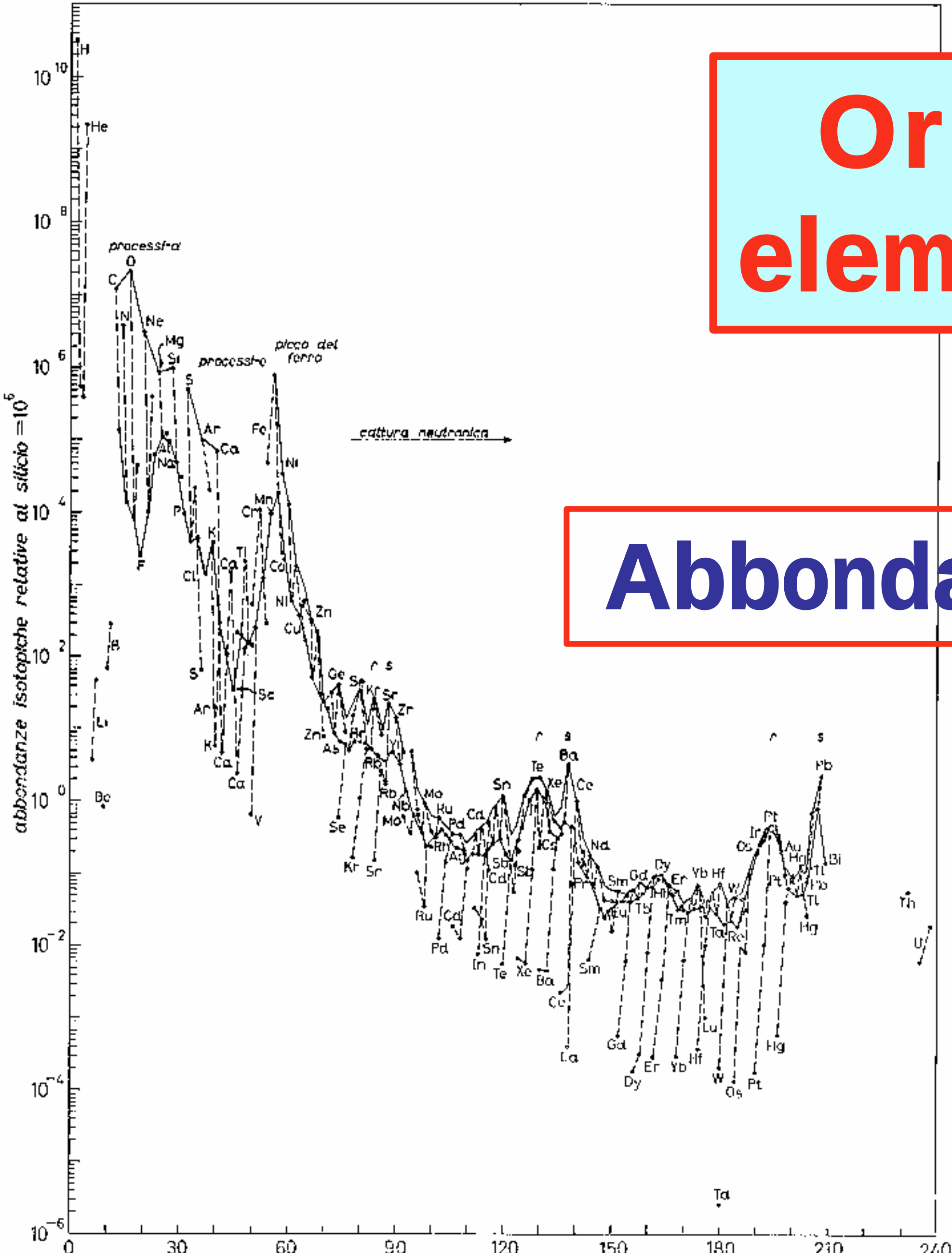

Life on earth
Solar system
Quasars
Galaxy formation
Epoch of gravitational collapse
Recombination
Relic radiation decouples (CBR)
Matter domination
Onset of gravitational instability
Nucleosynthesis
Light elements created - D, He, Li
Quark-hadron transition
Hadrons form - protons & neutrons
Electroweak phase transition
Electromagnetic & weak nuclear
forces become differentiated:
SU(3)xSU(2)xU(1) -> SU(3)xU(1)
The Particle Desert
Axions, supersymmetry?
Grand unification transition
G -> H -> SU(3)xSU(2)xU(1)
Inflation, baryogenesis,
monopoles, cosmic strings, etc.?
The Planck epoch
The quantum gravity barrier
T = 3 K (1 meV)
t = 400,000 years
T = 3000 K (1 eV)
t = 3 minutes
t = 1 second
T = 1 MeV
t = 10^{-6} s
T = 1 GeV
t = 10^{-11} s
T = 10^{3} GeV
t = 10^{-35} s
T=10^{15} GeV
t = 10^{-43} s
T=10^{19} GeV



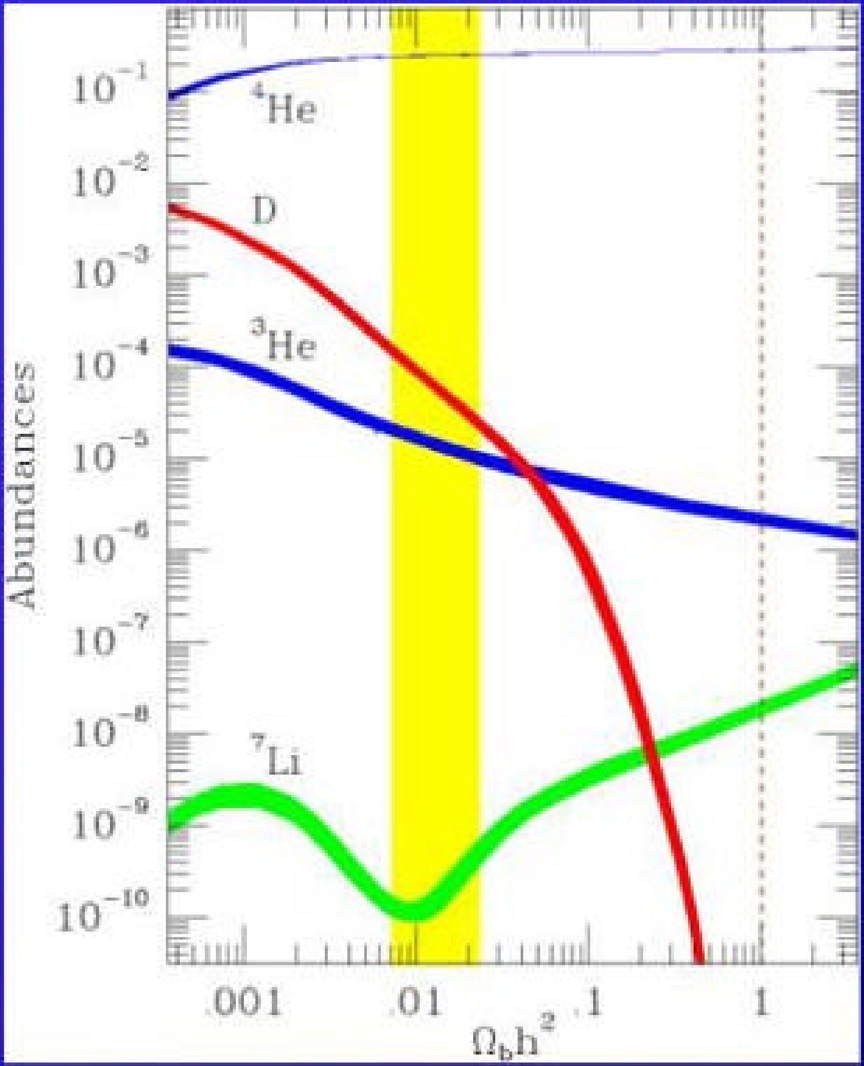
Big Bang
Time
10^{-44} s
10^{-35} s
10^{-32} s
10^{-10} s
300 s
3×10^{5} yr
1×10^{9} yr
15×10^{9} yr
Superstring(?) Era
GUT Era
Inflation Era
Electro-weak Era
Particle Era
Recombination Era
Galaxy and Star Formation
Present Era
E W
E W
E
W

Origine degli elementi chimici

Abbondanze universali



Quantifying the Asymmetry



- Remarkable region of concordance.
- Possible for a single value of $\eta \sim 10^{-10}$.
- A major test of the Big Bang theory …
- … and our earliest direct cosmological data.