

La Cosmologia

La geometria e l'infinità dell'Universo
Un altro viaggio nell'Astrofisica contemporanea

Francesco Longo

Incontri Interdisciplinari

15 dicembre 2025

Sommario

- Il cielo stellato…
- La grandezza del cielo …
- Le dimensioni dell'Universo
- La matematica e l'Universo
- E ora?



IL CIELO STELLATO

Il Sole



Il Cielo stellato

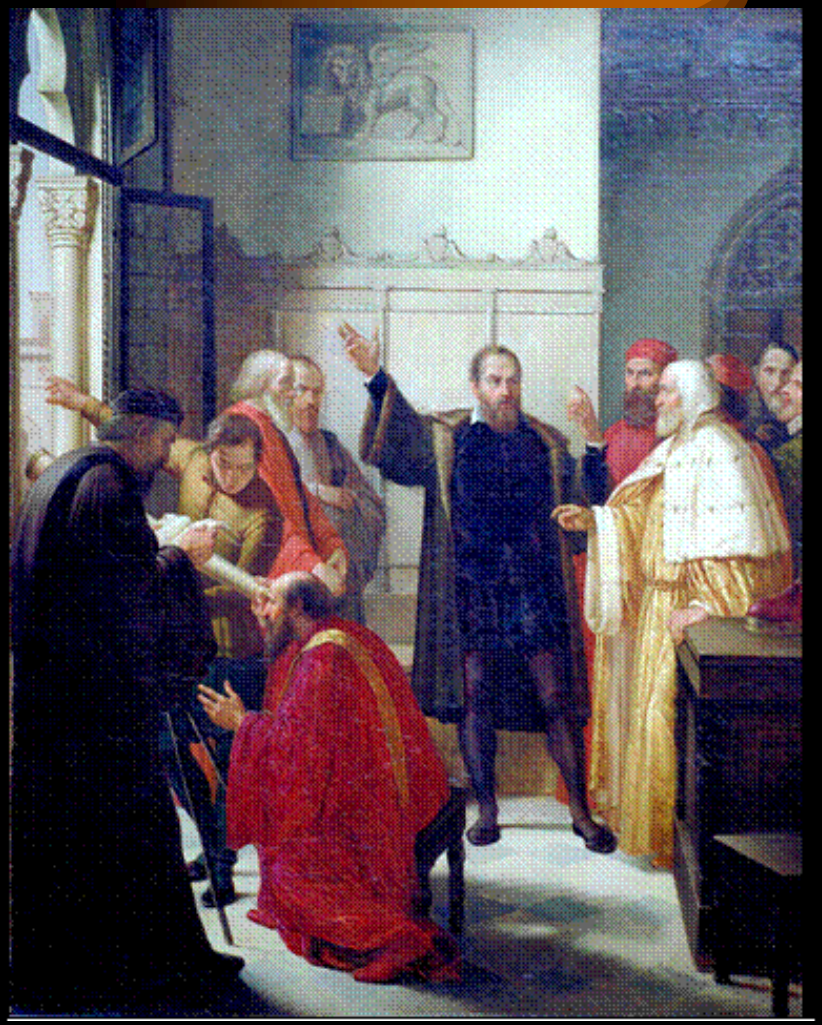


Il cielo stellato

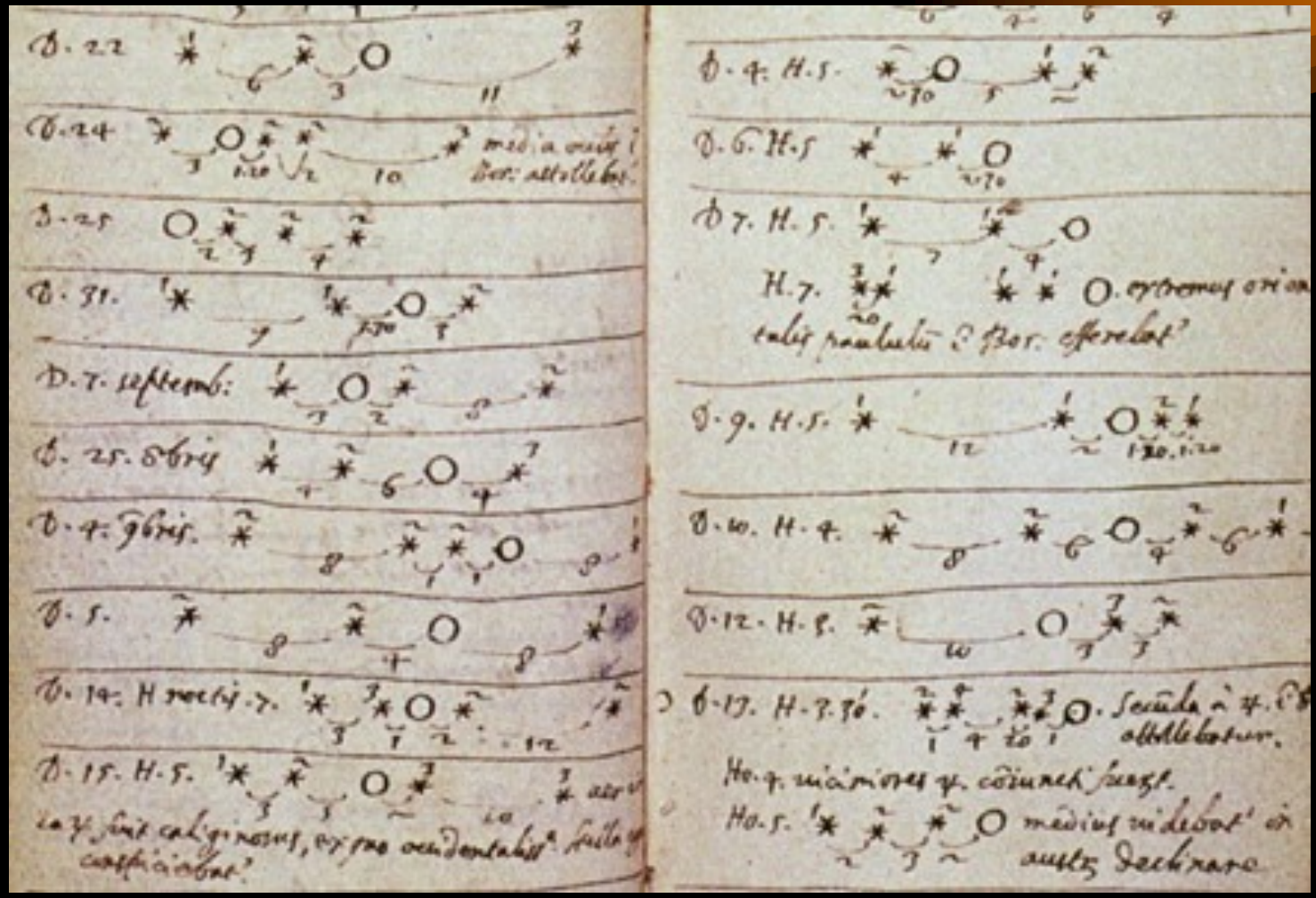


Il cannocchiale





I Satelliti di Giove

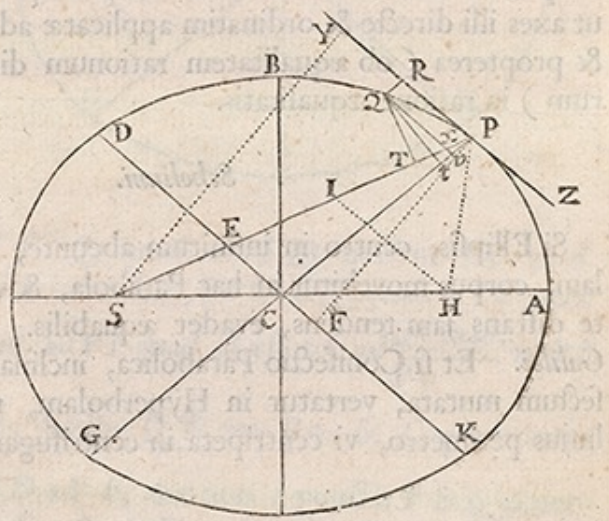


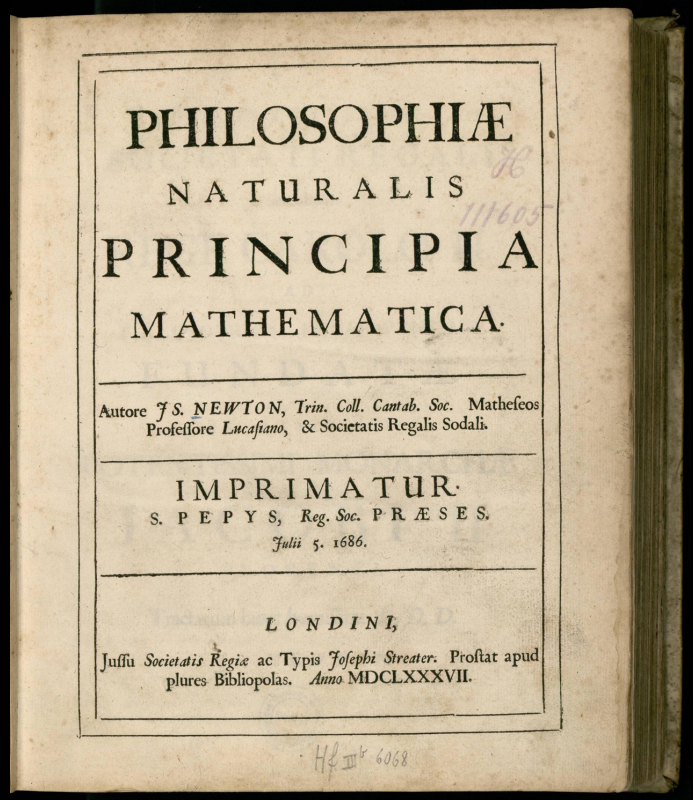
La legge di Gravitazione Universale

Prop. XI. Prob. VI.

Revolvatur corpus in Ellipſi: Requiritur lex vis centripetæ tendentis ad umbilicum Ellipſeos.

Eſto Ellipſeos ſuperioris umbilicus S. Agatur *SP* ſecans Ellipſeos tum diametrum *DK* in *E*, tum ordinatim applicatam *Qv* in *x*, & compleatur parallelogrammum *Qx*P*R*. Patet *EP* æqualem eſſe ſemiaxi majori *AC*, eo quod acta ab altero Ellipſeos umbilico H linea *HI* ipſi *EC* parallela, (ob æquales *CS*, *CH*) æquentur *ES*,*EI*,adeo ut *EP* ſemiſumma ſit ipſarum PS, P*I*, id eſt (ob parallelas *HI*, P*R* & angulos æquales *IP**R*, *HPZ*) ipſorum PS, P*H*, quæ conjunctim axem totum 2*AC* adæquant. Ad SP demittatur perpendicularis *QT*, & Ellipſeos latere recto principali (ſeu




PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore *J. S. NEWTON*, *Trin. Coll. Cantab. Soc.* Matheſeos Profeſſore *Lucaſiano*, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

LONDINI,
Juſſu *Societatis Regiæ* ac Typis *Joſephi Streater*. Proſtat apud plures Bibliopolas. *Anno* MDCLXXXVII.

Stelle e Galassie

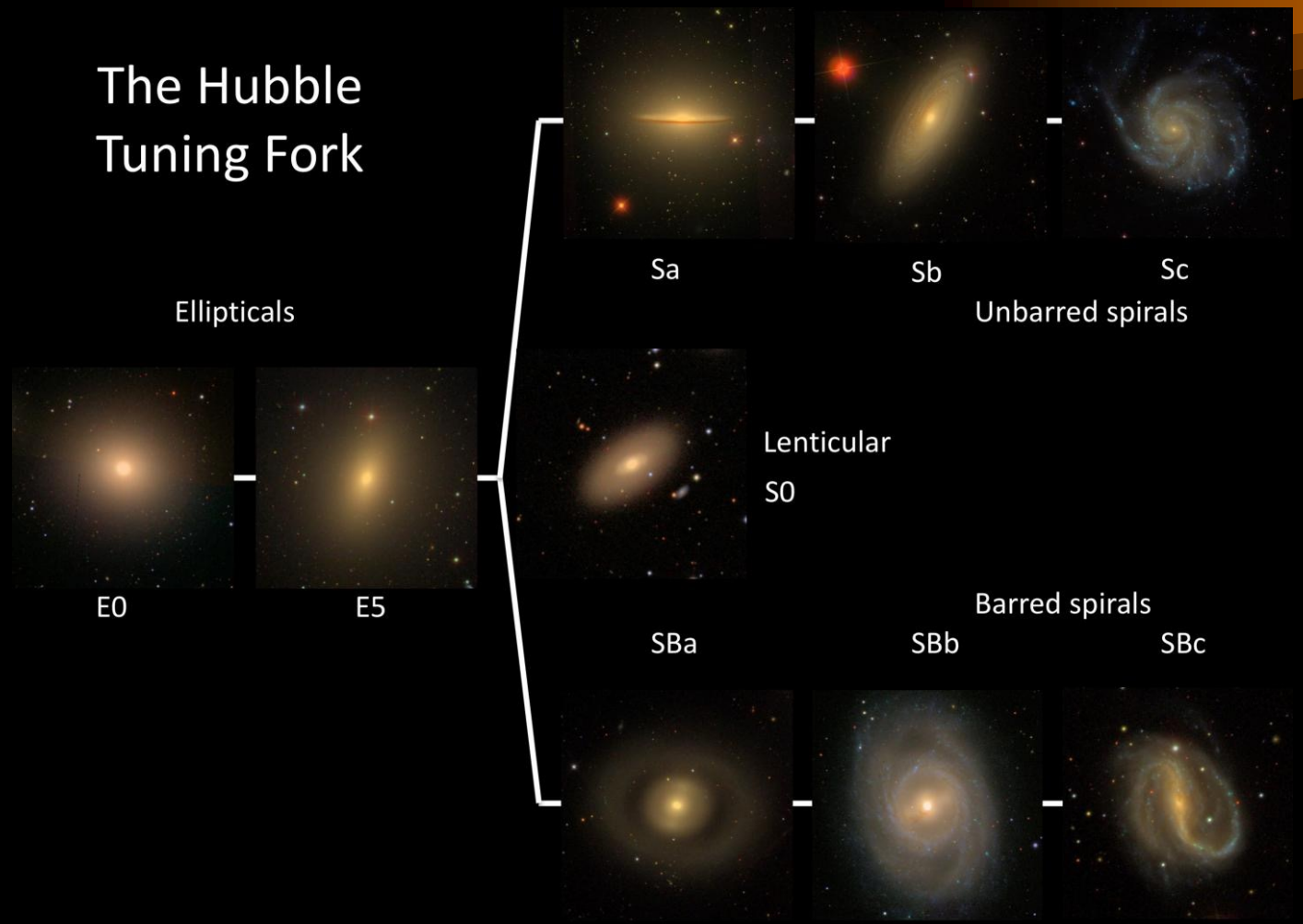


Galassia M106

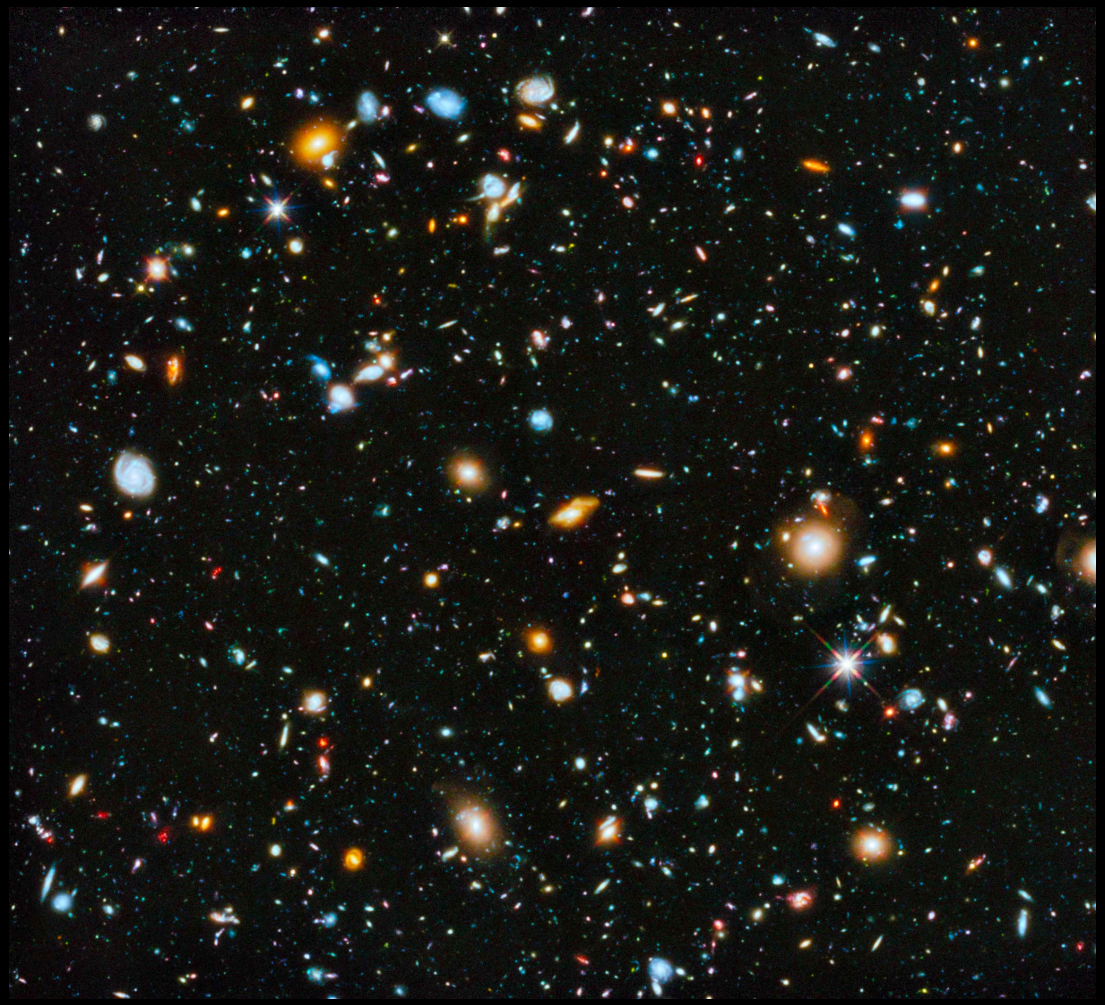
La via Lattea



Le Galassie

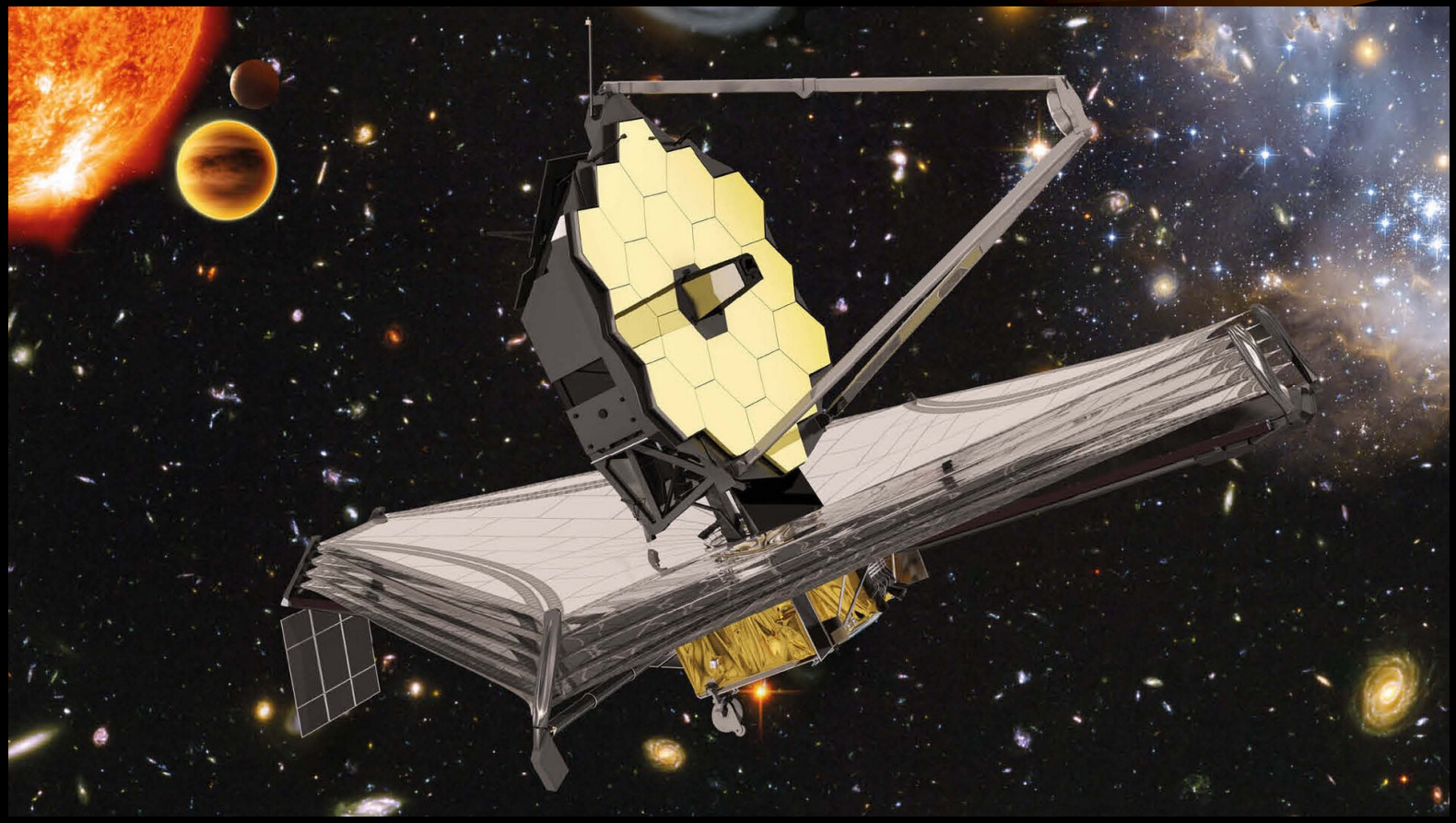

The Hubble
Tuning Fork
Ellipticals
E0
E5
Lenticular
S0
Sa
Sb
Sc
Unbarred spirals
Barred spirals
SBa
SBb
SBc

Le Galassie



Hubble Deep Field

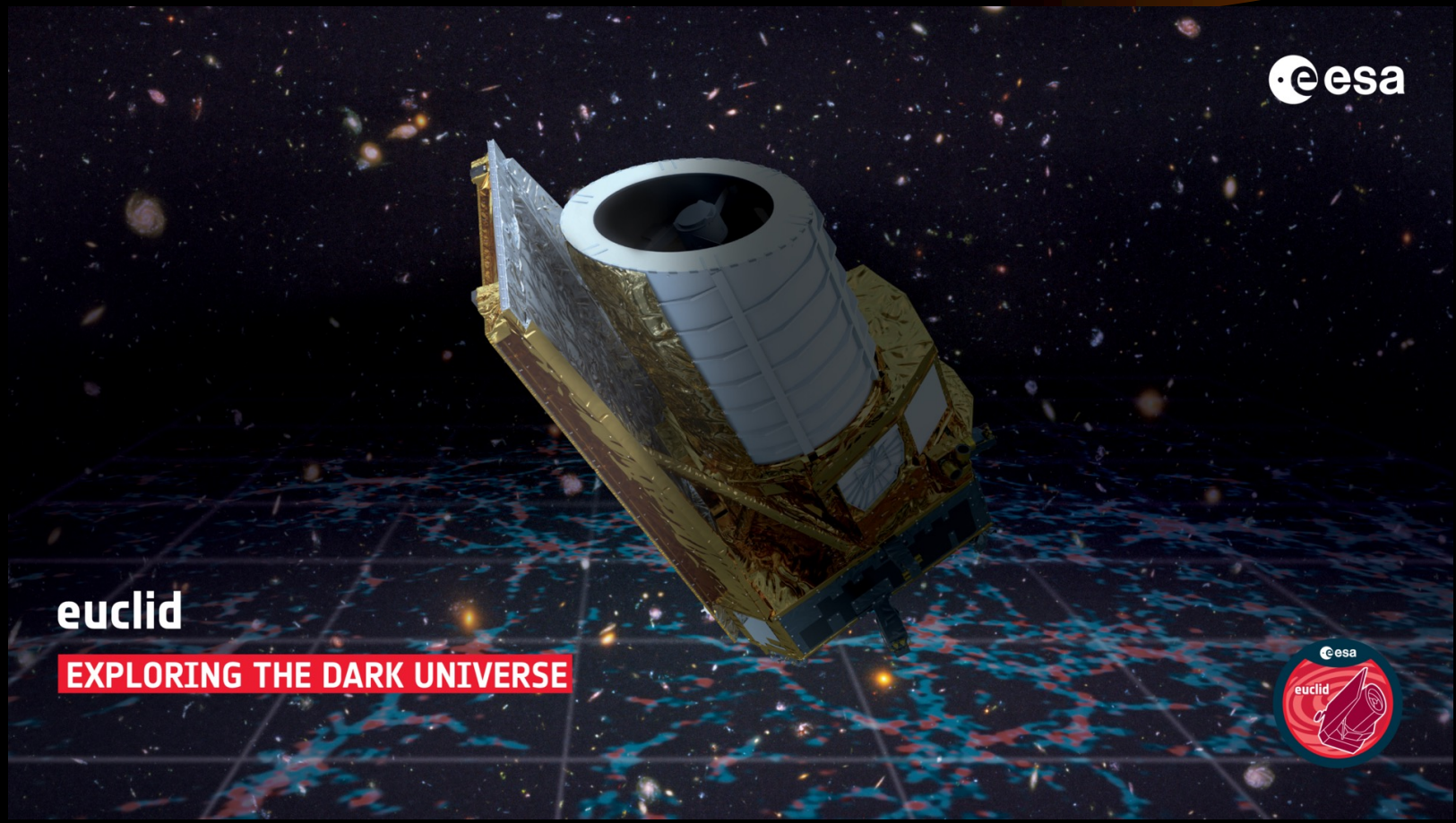
The James Webb Telescope



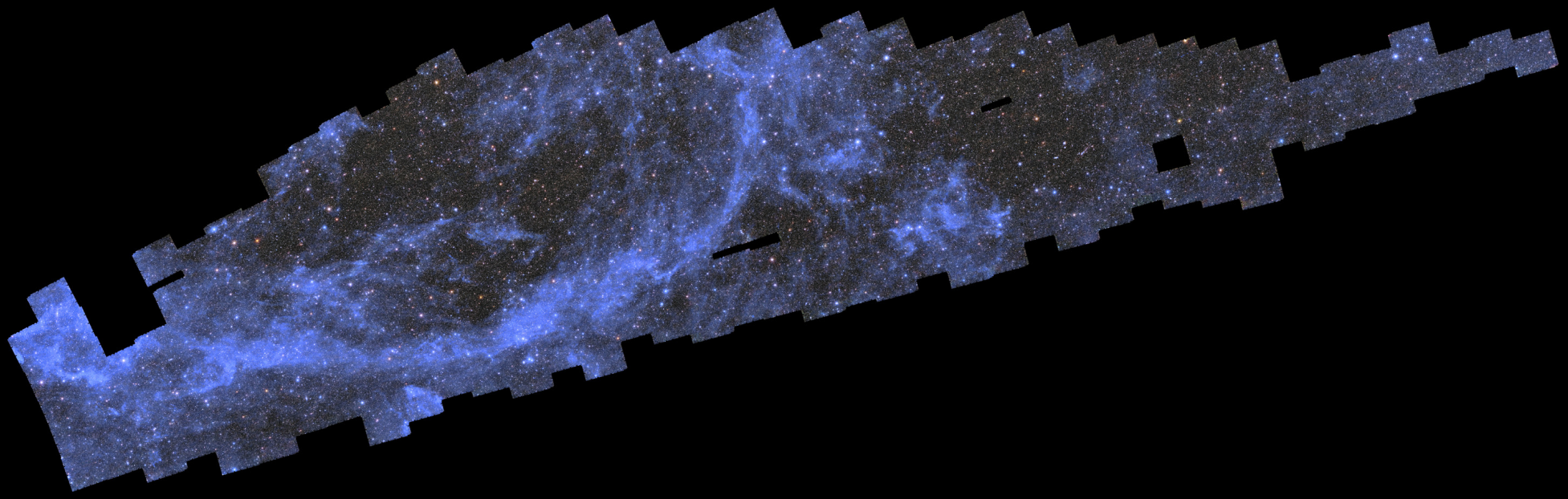
The James Webb Telescope



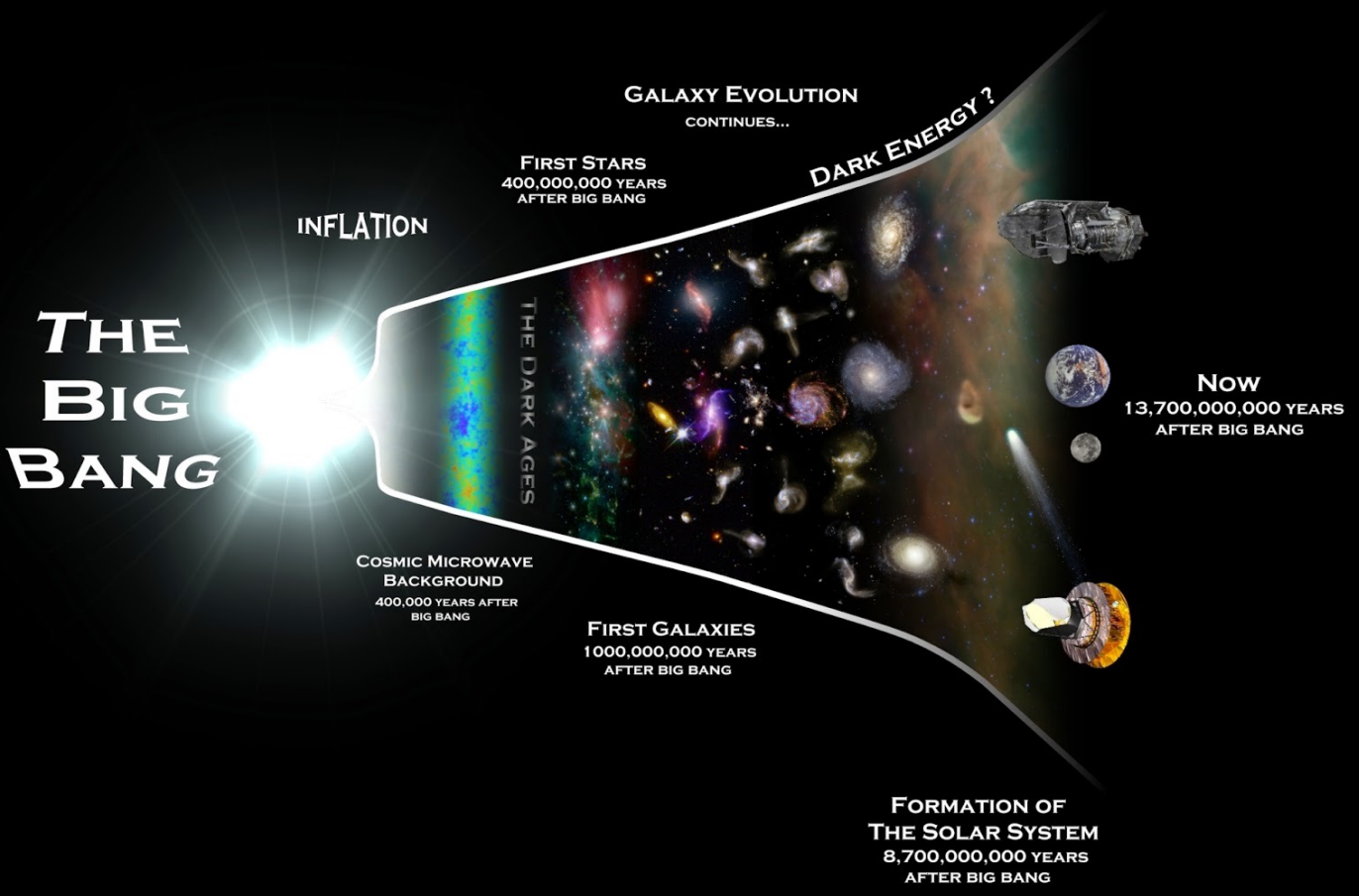
The Euclid Telescope



The Euclid Telescope



Da dove e verso dove?



Sommario

- Il cielo stellato…
- La grandezza del cielo …
- Le dimensioni dell'Universo
- La matematica e l'Universo
- E ora?

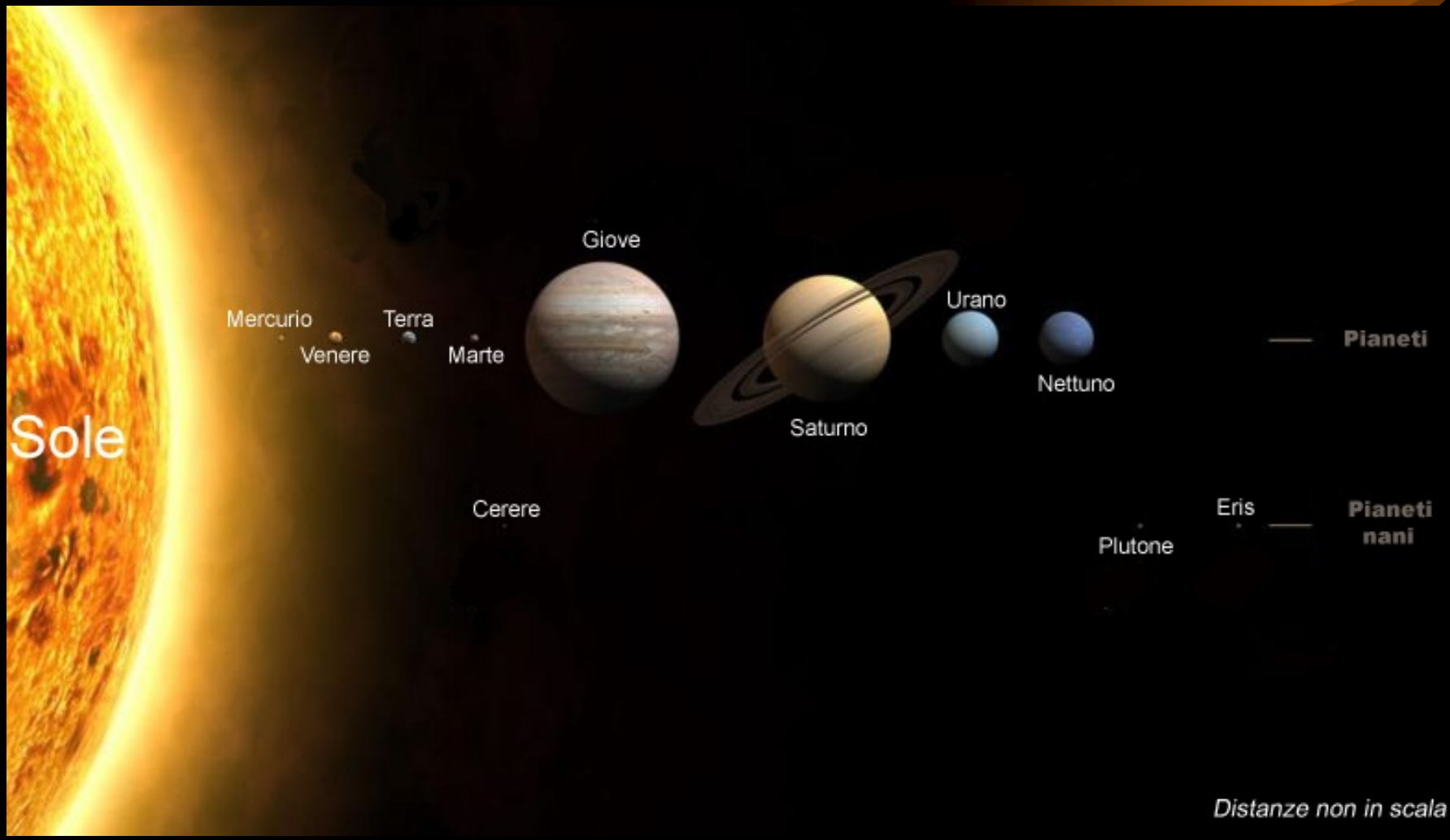


LA GRANDEZZA DEL CIELO

La sonda Voyager (1977)



Il Sistema Solare



Le distanze in Astrofisica

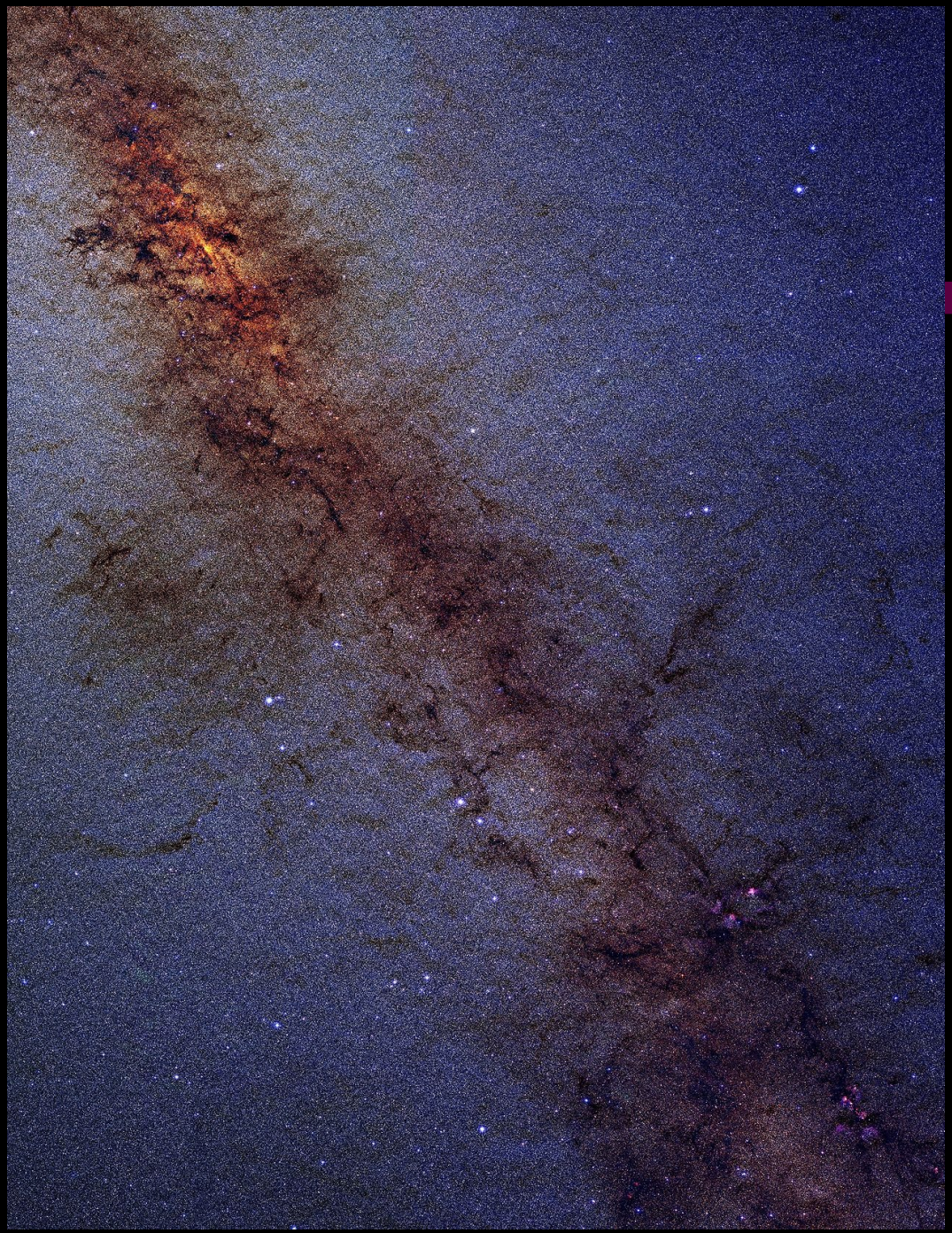
- La distanza dalla Terra alla Luna = 384.400 km
- Circa 1 secondoluce.
- La stazione spaziale orbita a circa 408 km dalla Terra ..

Le distanze in Astrofisica

- Distanza Terra - Sole = 149,6 milioni di km
- Distanza Terra – Marte = 225 milioni di km
- Distanza Terra – Giove = 588 milioni di km
- Distanza Terra – Nettuno = 4500 milioni di km
- Dimensioni del Sistema Solare = 18,7 miliardi di km

Le distanze in Astrofisica

- Distanza Terra - Sole = 8,3 minutiluce
- Distanza Terra – Marte = 12,5 minutiluce
- Distanza Terra – Giove = 32,7 minutiluce
- Distanza Terra – Nettuno = 250 minutiluce
- Dimensioni del Sistema Solare = 17,3 oreluce



La Via Lattea

La Grande Nube di Magellano



La Piccola Nube di Magellano

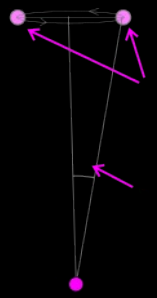


La Galassia di Andromeda



Le distanze in Astrofisica

- La stella più vicina – ProximaCentauri = 4,2 anniluce
- Il centro della Galassia = 8000 parsec
- 1 parsec = 3,26 anniluce
- Le Galassie vicine = 158.200 anni luce
- Le Galassie vicine = 48.500 pc
- La Galassia di Andromeda = 2,54 milioni di al
- La Galassia di Andromeda = 78 kpc



Gli ammassi di Galassie



Il gruppo locale



Il super ammasso della Vergine



Le distanze in Astrofisica

- La Galassia di Andromeda = 2,54 milioni di al
- La Galassia di Andromeda = 78 kpc
- Le dimensioni del gruppo locale = 5.1 Mpc
- Le dimensioni del super ammasso della Vergine = 16.3 Mpc

Sommario

- Il cielo stellato…
- La grandezza del cielo …
- Le dimensioni dell'Universo
- La matematica e l'Universo
- E ora?

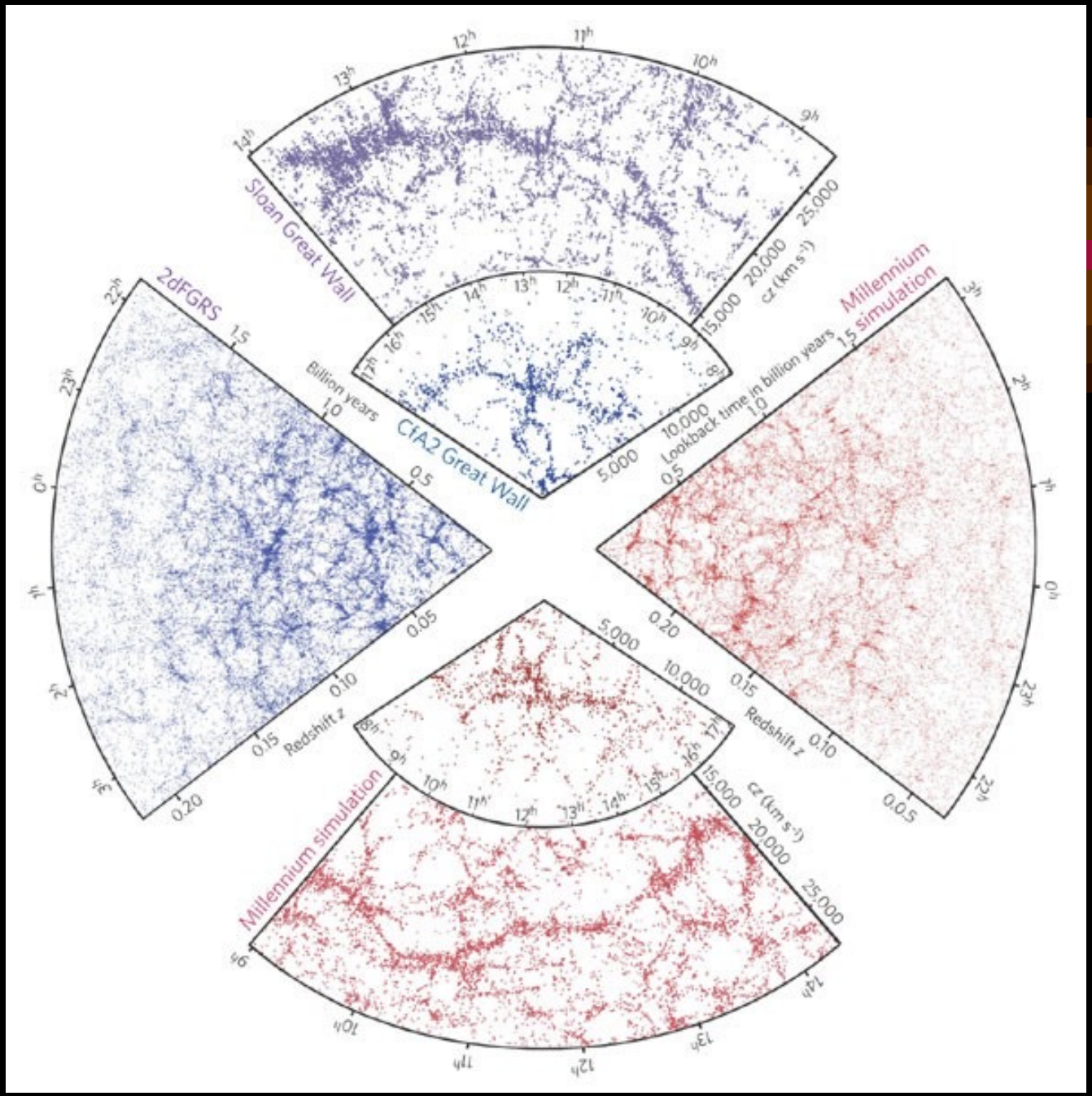


LE DIMENSIONI DELL'UNIVERSO

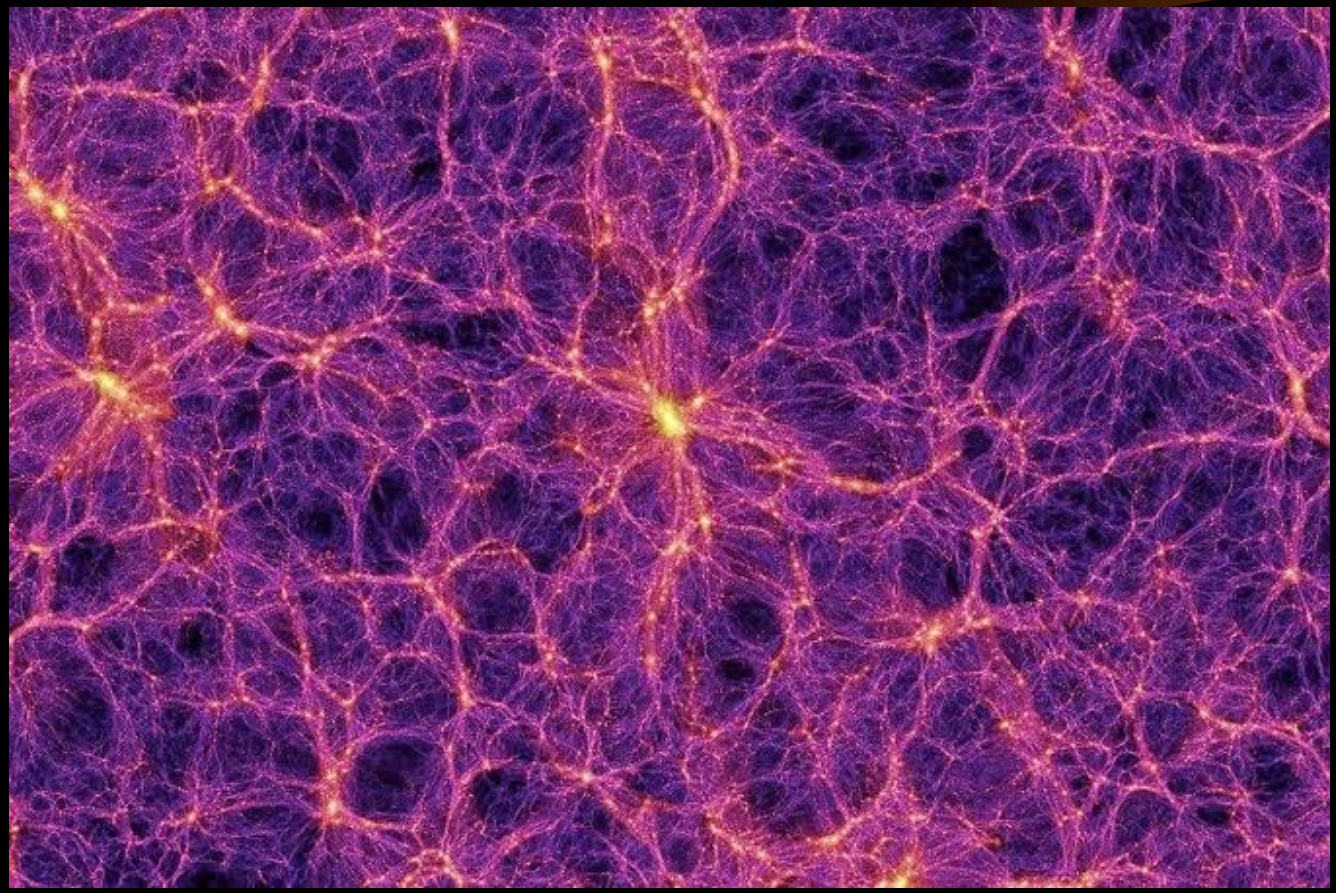
"mappare" l'Universo



E poi?


Sloan Great Wall
2dFGRS
CfA2 Great Wall
Millennium simulation
Millennium simulation
Billion years
Lookback time in billion years
Redshift z
cz (km s⁻¹)

“mappare” l’Universo



Il Telescopio Spaziale Hubble

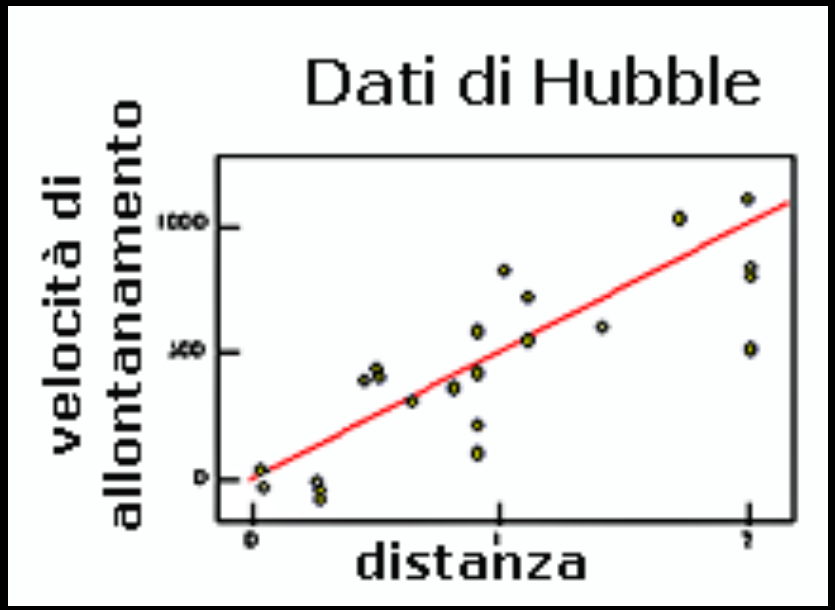


hubblesite.org/

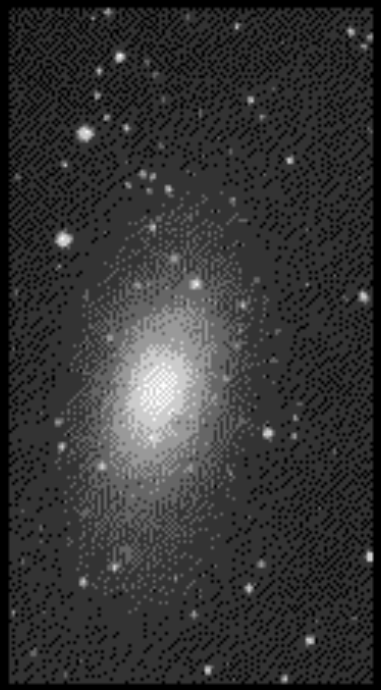
Edwin Hubble

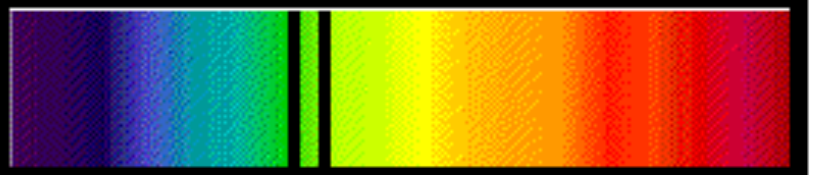


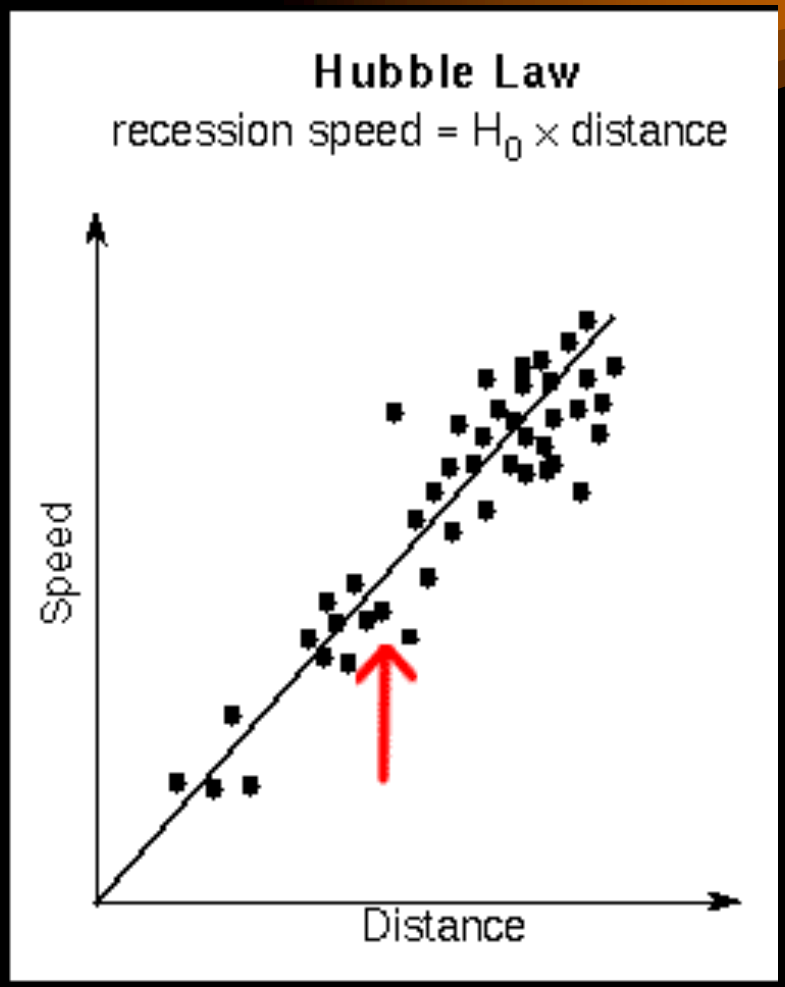




L'allontanamento delle Galassie

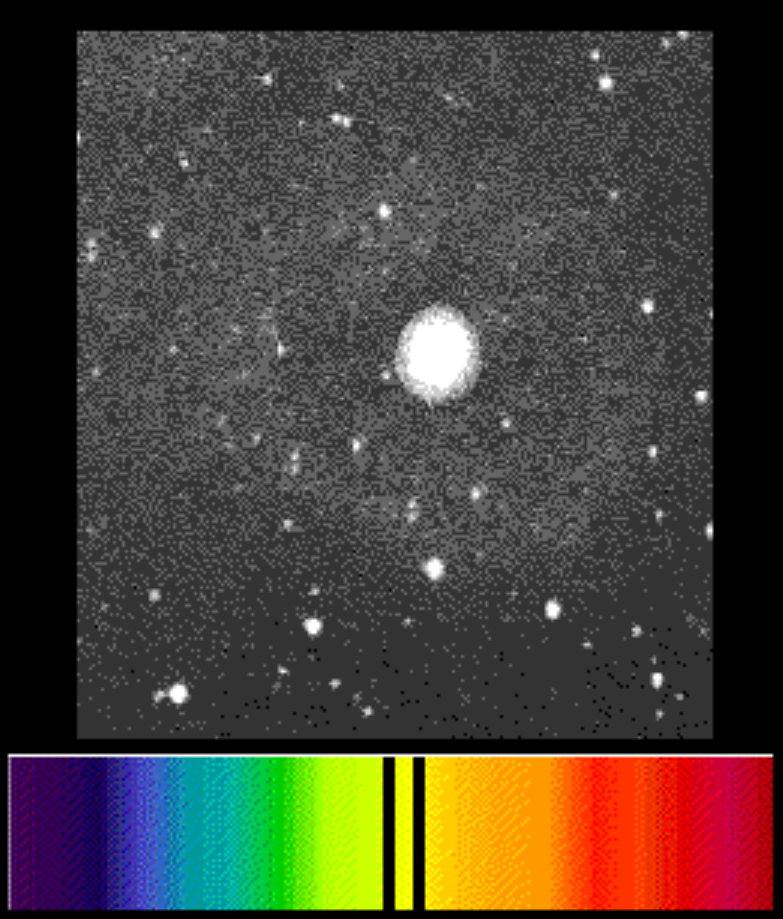


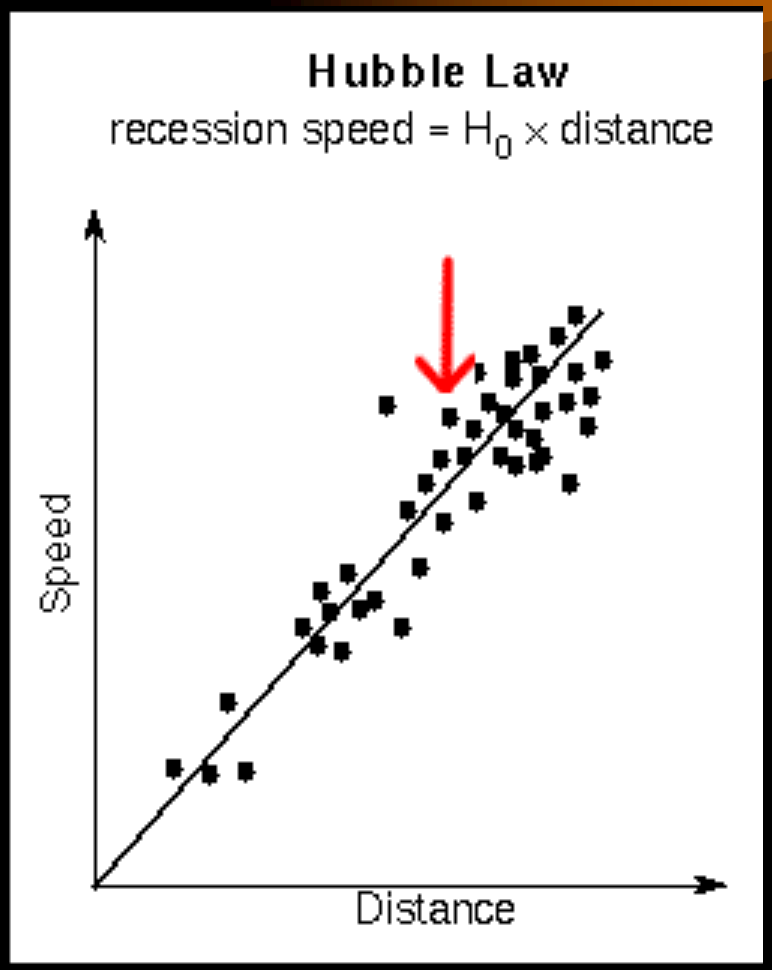




Hubble – Lemaitre law

L'allontanamento delle Galassie

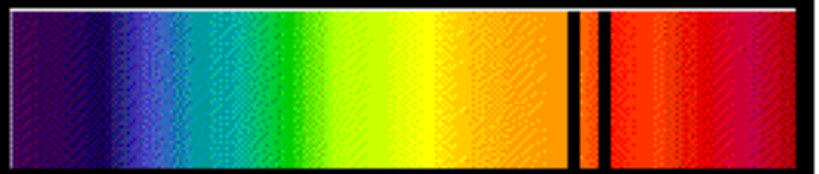


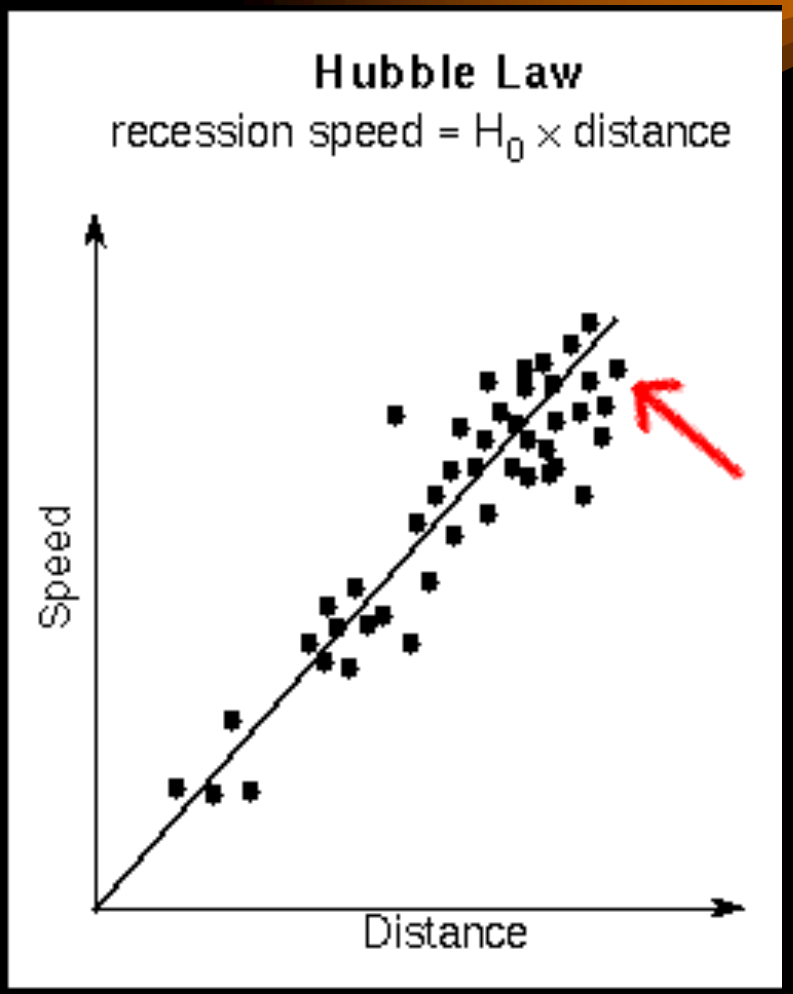


Hubble – Lemaitre law

L'allontanamento delle Galassie

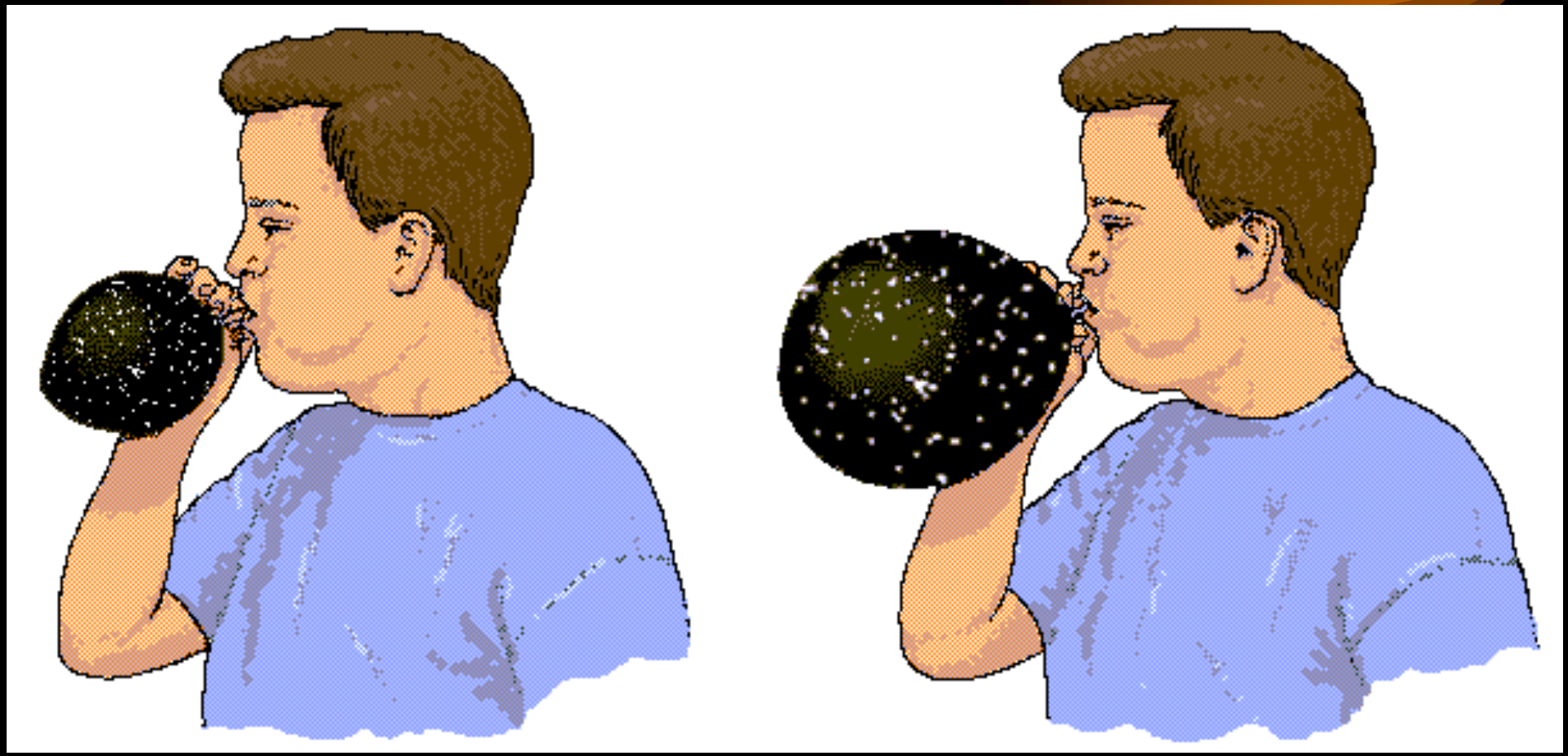




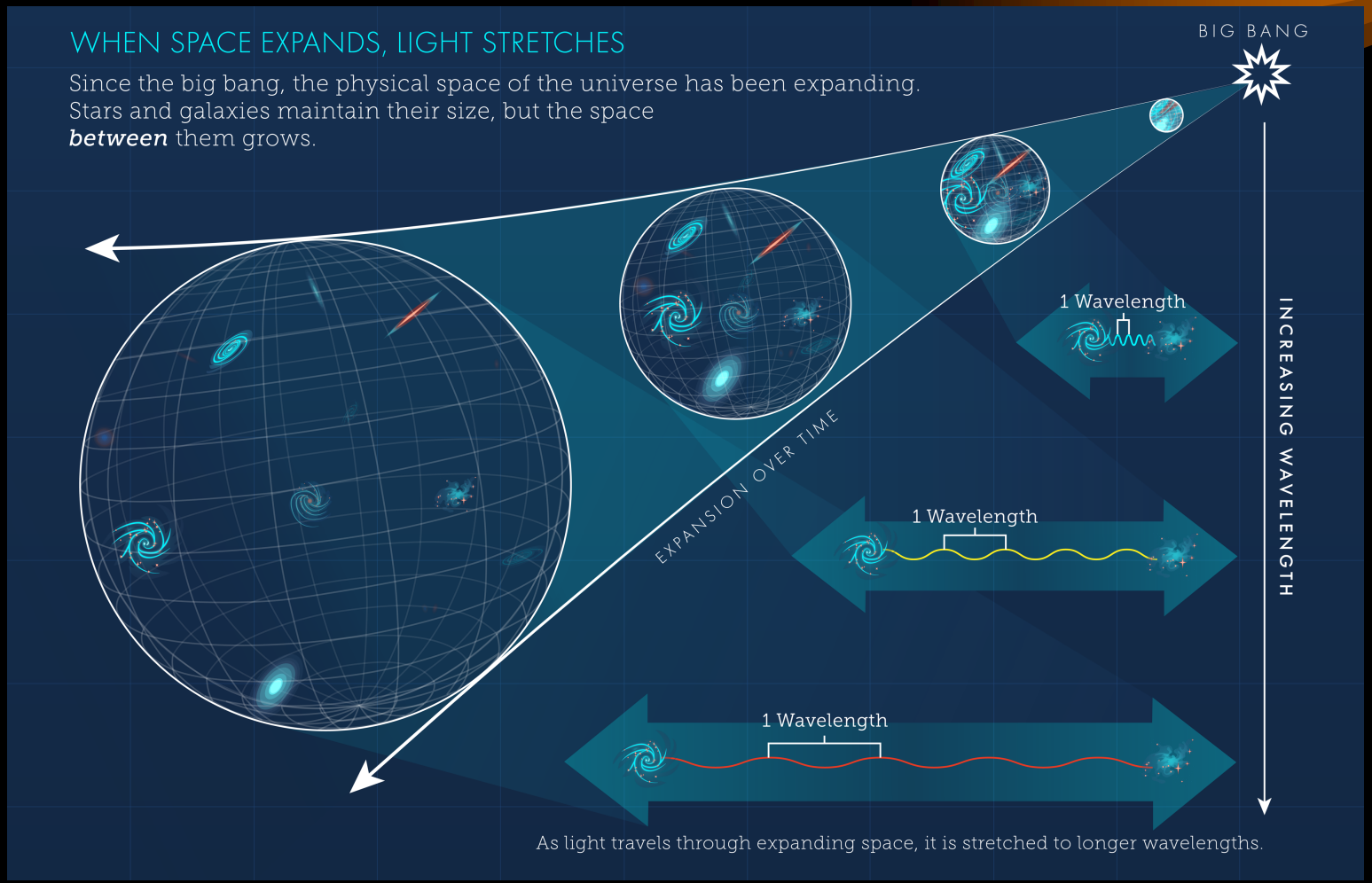


Hubble – Lemaitre law

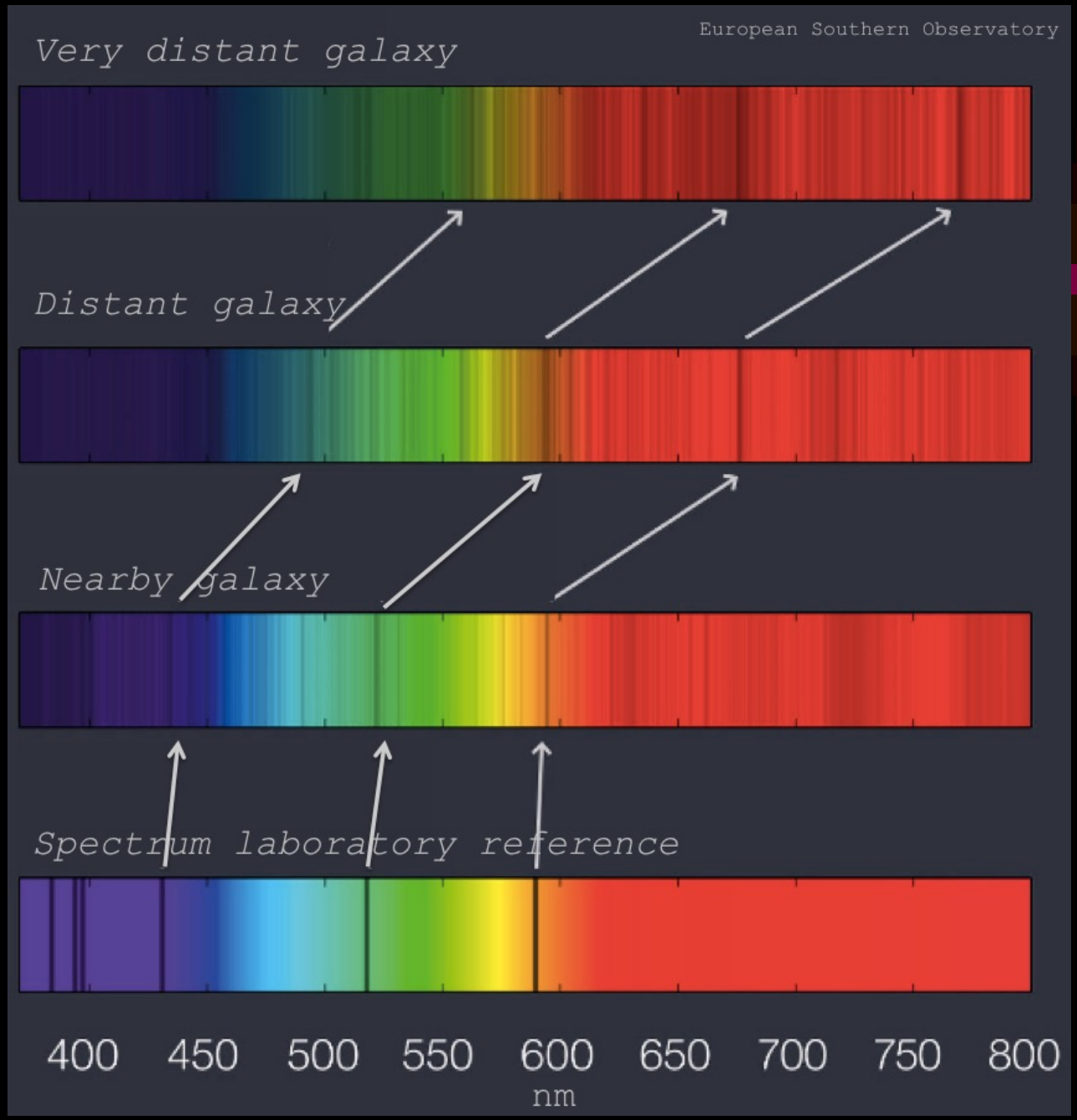
L'allontanamento delle Galassie



Il redshift


WHEN SPACE EXPANDS, LIGHT STRETCHES
Since the big bang, the physical space of the universe has been expanding. Stars and galaxies maintain their size, but the space ***between*** them grows.
BIG BANG
EXPANSION OVER TIME
1 Wavelength
1 Wavelength
1 Wavelength
INCREASING WAVELENGTH
As light travels through expanding space, it is stretched to longer wavelengths.

Il redshift


European Southern Observatory
Very distant galaxy
Distant galaxy
Nearby galaxy
Spectrum laboratory reference
400
450
500
550
600
650
700
750
800
nm

Il redshift

Calculation of redshift, z

Based on wavelength	Based on frequency
$z = \frac{\lambda_{\text{obsv}} - \lambda_{\text{emit}}}{\lambda_{\text{emit}}}$	$z = \frac{f_{\text{emit}} - f_{\text{obsv}}}{f_{\text{obsv}}}$
$1 + z = \frac{\lambda_{\text{obsv}}}{\lambda_{\text{emit}}}$	$1 + z = \frac{f_{\text{emit}}}{f_{\text{obsv}}}$

Le distanze in Astrofisica

- z = 0.1 – 463.4 Mpc or 1.512 Gly
- z = 0.5 – 2863.1 Mpc or 9.338 Gly
- z = 1.0 – 6701.2 Mpc or 21.857 Gly
- z = 5.2 – 49894.0 Mpc or 162.734 Gly
- z = 12 – 130540.7 Mpc or 425.770 Gly
- z = 1000 – 13946225.5 Mpc or 45486.866 Gly

I tempi in Astrofisica

- z = 0.1 – 12.411 Gyr
- z = 0.5 – 8.628 Gyr
- z = 1.0 – 5.903 Gyr
- z = 5.2 – 1.129 Gyr
- z = 12 – 0.372 Gyr
- z = 1000 – 0.434 Myr

Le distanze in Astrofisica

Enter values, hit a button

69.6 H_o
0.286 $Omega_M$
3 z
Open Flat
0.714 $Omega_{vac}$
General

Open sets $Omega_{vac}$ = 0 giving an open Universe [if you entered $Omega_M$ < 1]
Flat sets $Omega_{vac}$ = 1-$Omega_M$ giving a flat Universe.
General uses the $Omega_{vac}$ that you entered.
Source for the default parameters.

For H_o = 69.6, $Omega_M$ = 0.286, $Omega_{vac}$ = 0.714, z = 3.000

- It is now 13.721 Gyr since the Big Bang.
- The age at redshift z was 2.171 Gyr.
- The light travel time was 11.549 Gyr.
- The comoving radial distance, which goes into Hubble's law, is 6481.3 Mpc or 21.139 Gly.
- The comoving volume within redshift z is 1140.389 Gpc^3.
- The angular size distance D_A is 1620.3 Mpc or 5.2846 Gly.
- This gives a scale of 7.855 kpc/".
- The luminosity distance D_L is 25924.3 Mpc or 84.554 Gly.

1 Gly = 1,000,000,000 light years or $9.461*10^{26}$ cm.
1 Gyr = 1,000,000,000 years.
1 Mpc = 1,000,000 parsecs = $3.08568*10^{24}$ cm, or 3,261,566 light years.

Tutorial: Part 1 | Part 2 | Part 3 | Part 4
FAQ | Age | Distances | Bibliography | Relativity

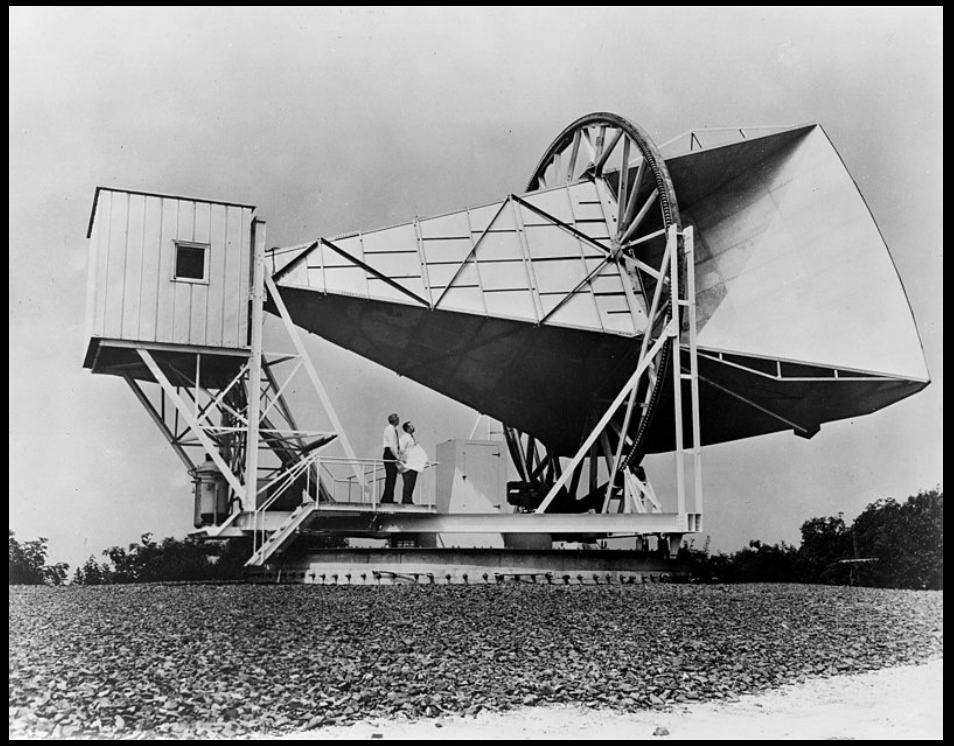
See the advanced and light travel time versions of the calculator.

James Schombert has written a Python version of this calculator.

Ned Wright's home page

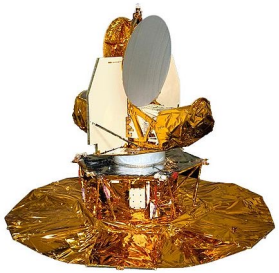
Misure della radiazione cosmica

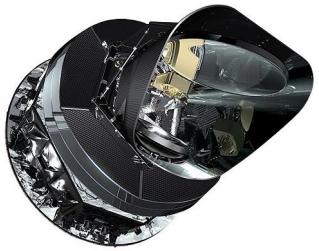


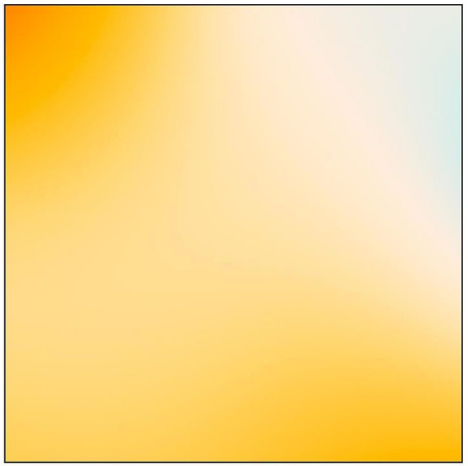


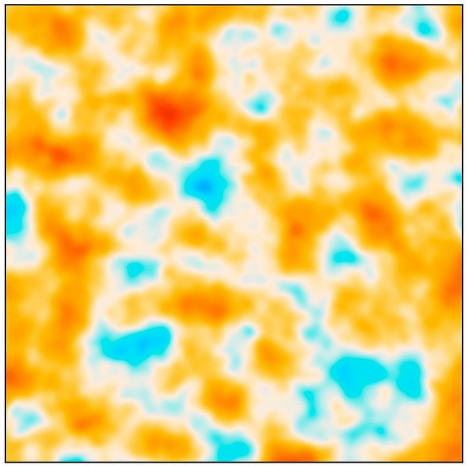
Misure della radiazione cosmica

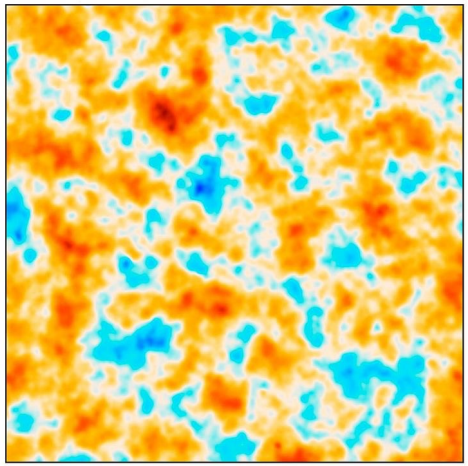










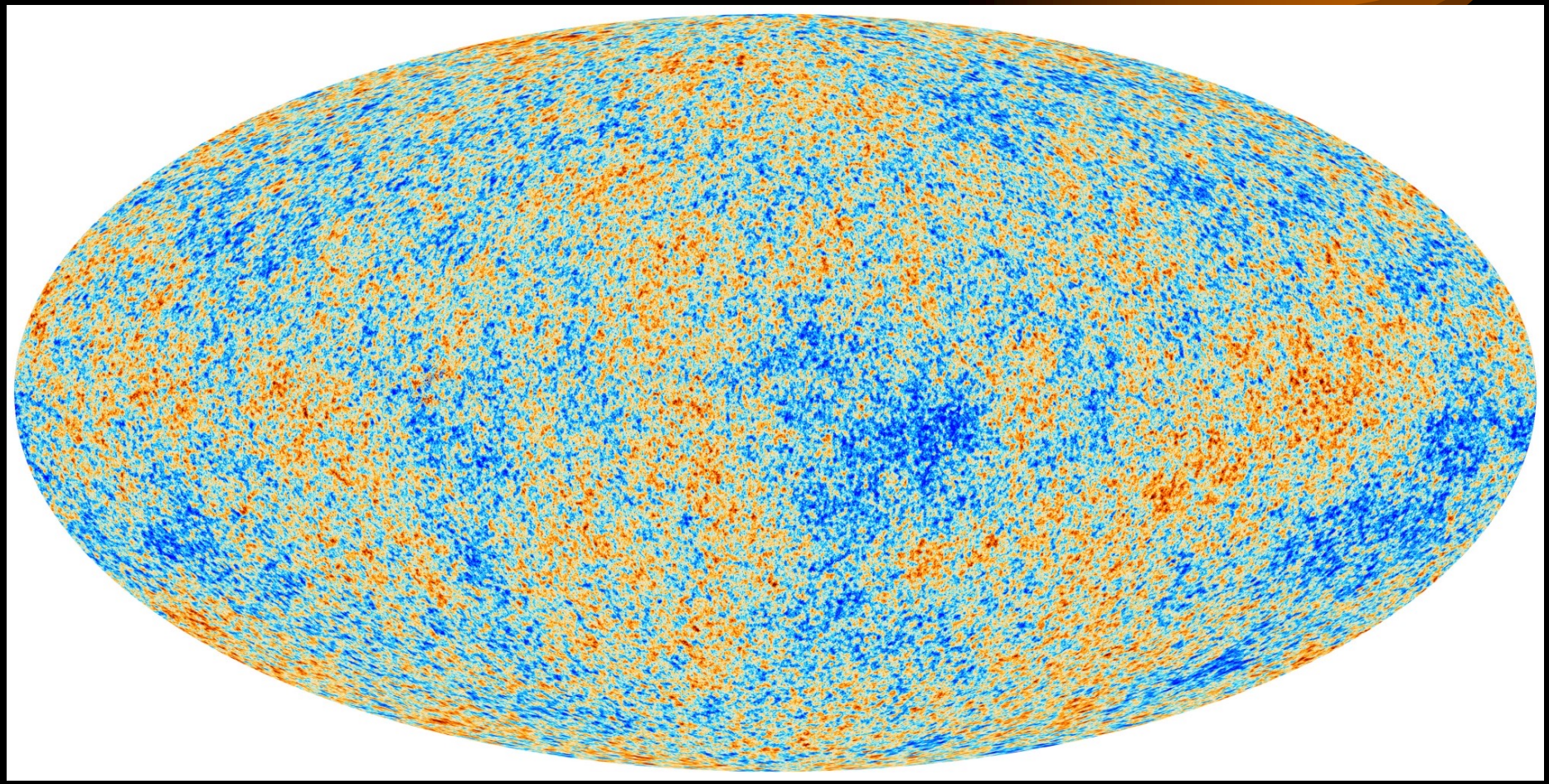


COBE

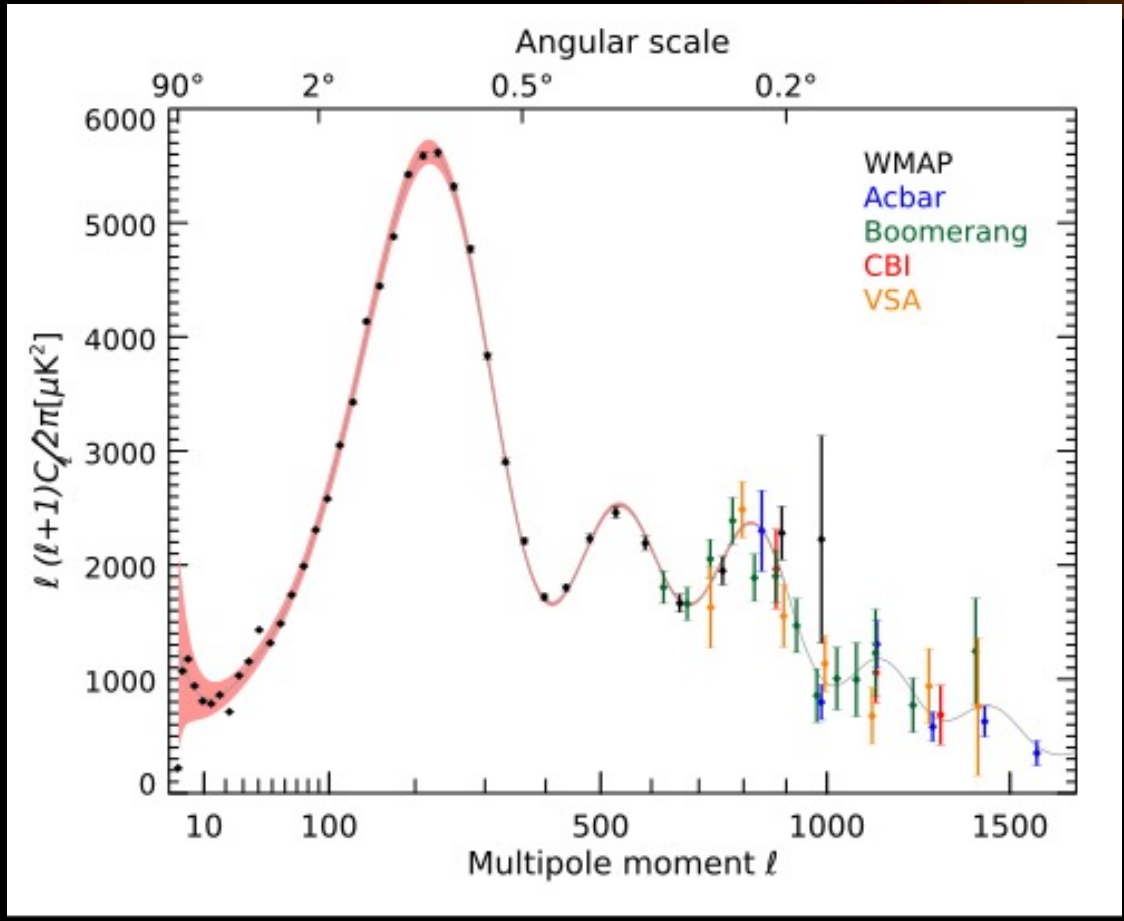
WMAP

Planck

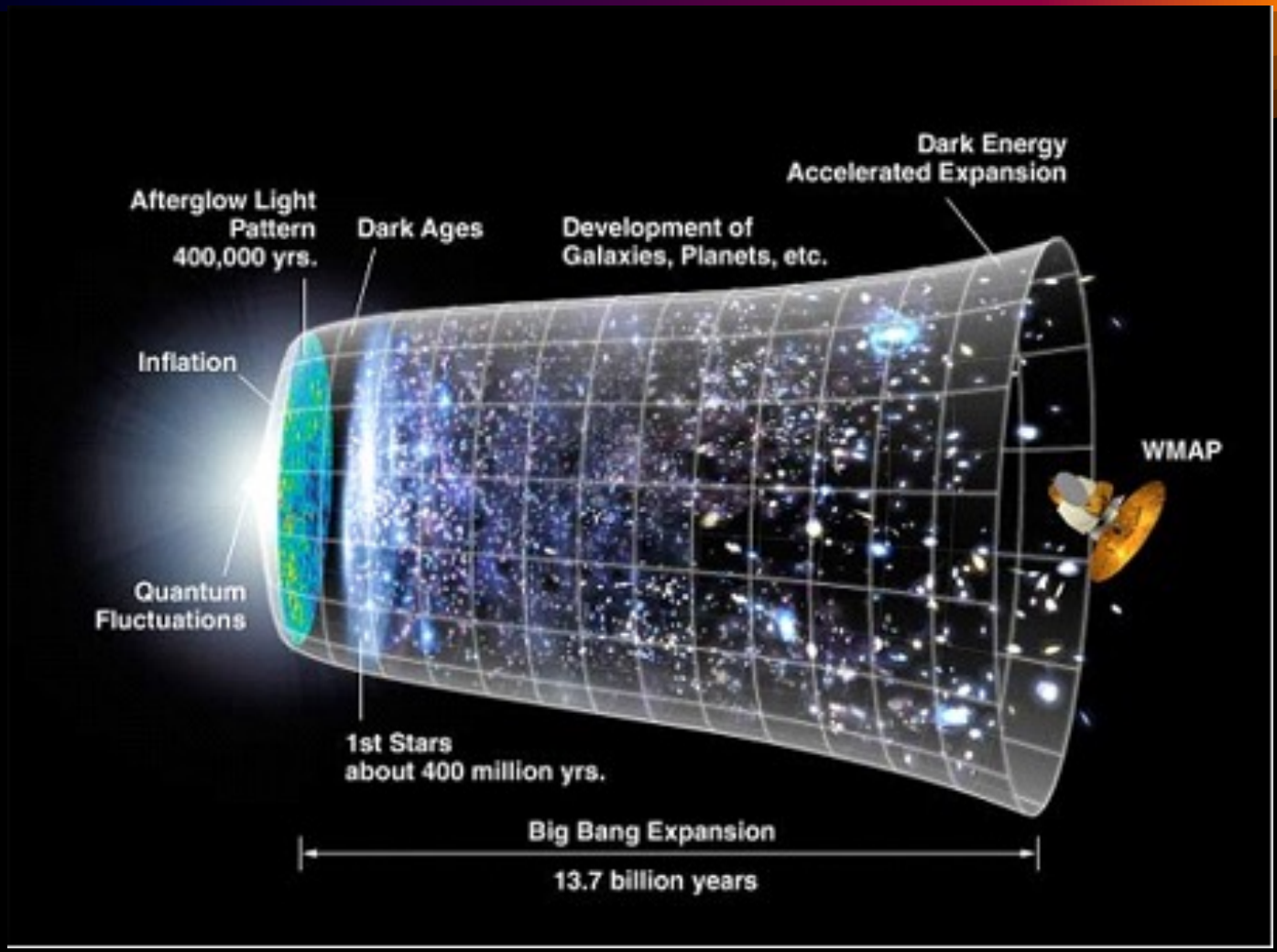
Osservare l'Universo



Misure della radiazione cosmica



Il Big Bang


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
WMAP
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

Sommario

- Il cielo stellato…
- La grandezza del cielo …
- Le dimensioni dell'Universo
- La matematica e l'Universo
- E ora?

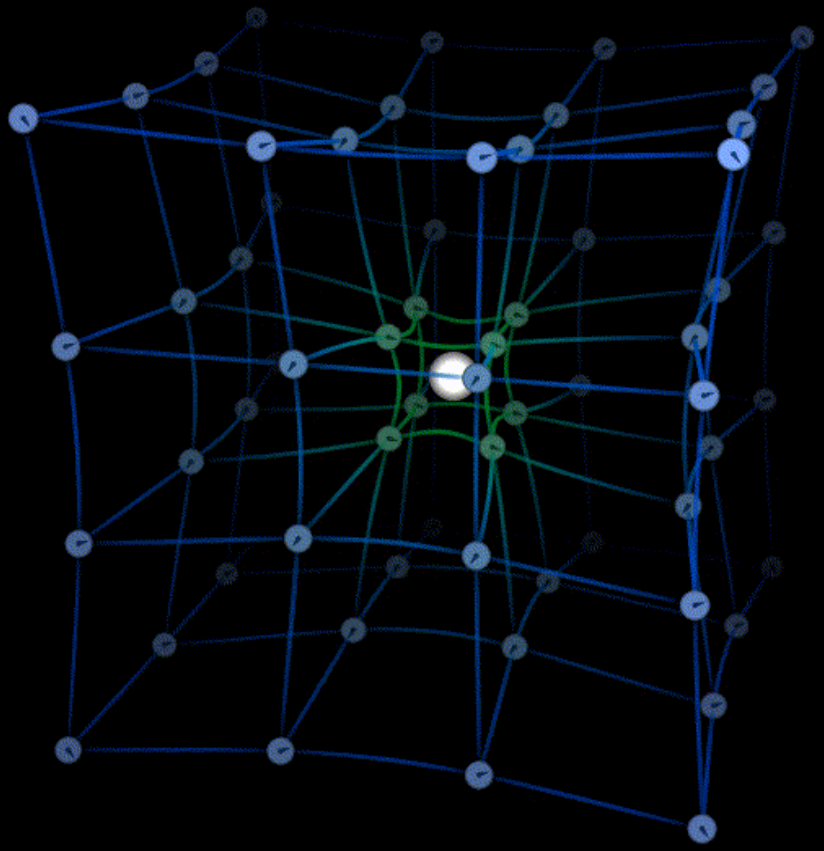


LA MATEMATICA E L'UNIVERSO

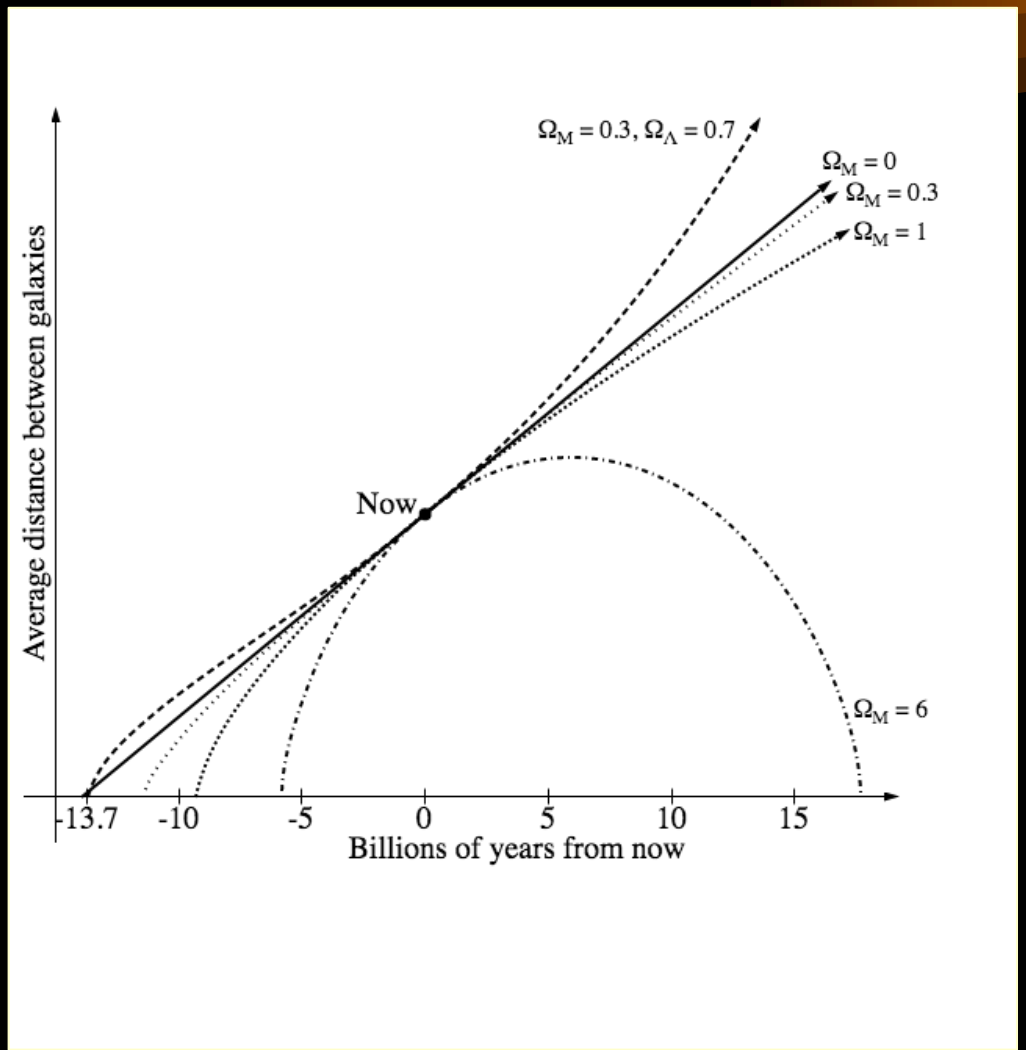
L;universo di Einstein

$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

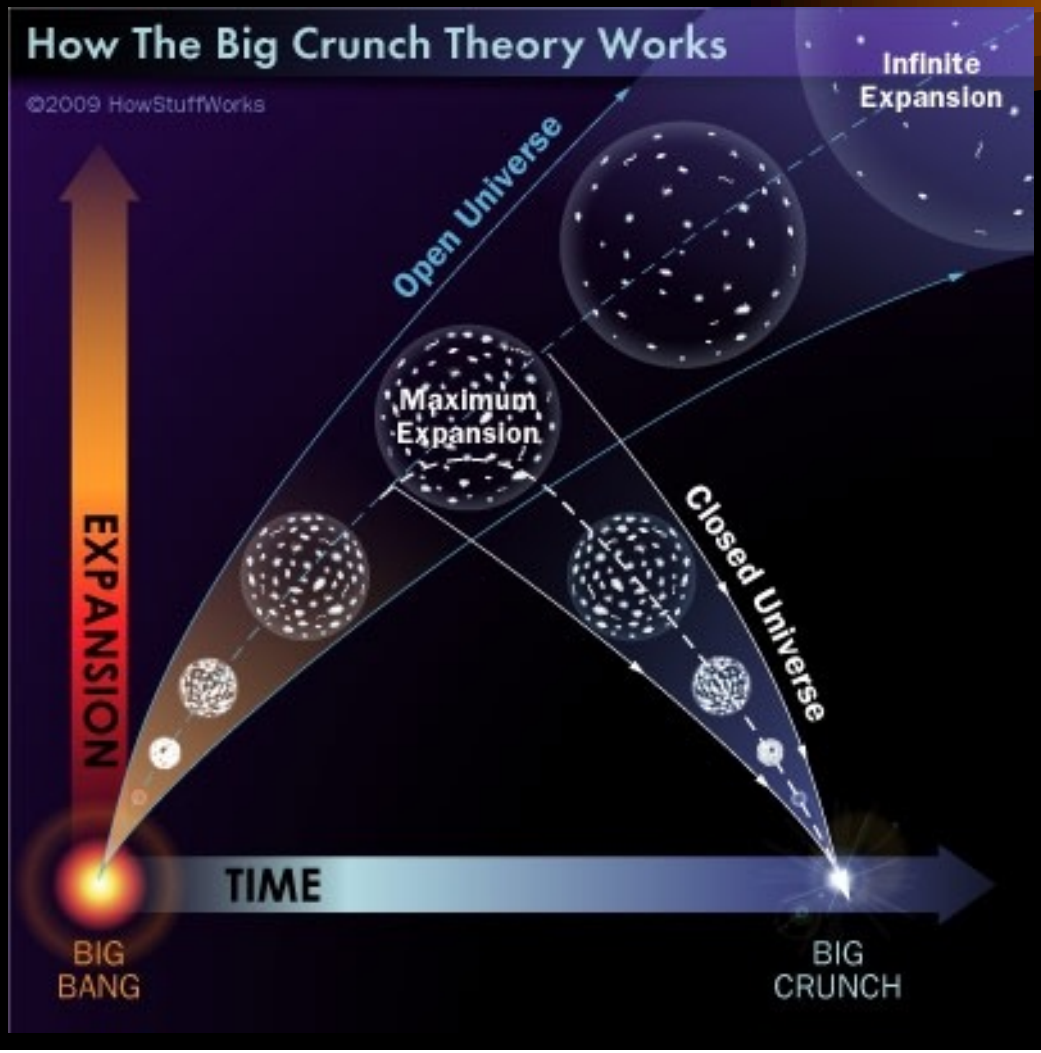
La geometria dello Spazio Tempo



L'Universo di Einstein



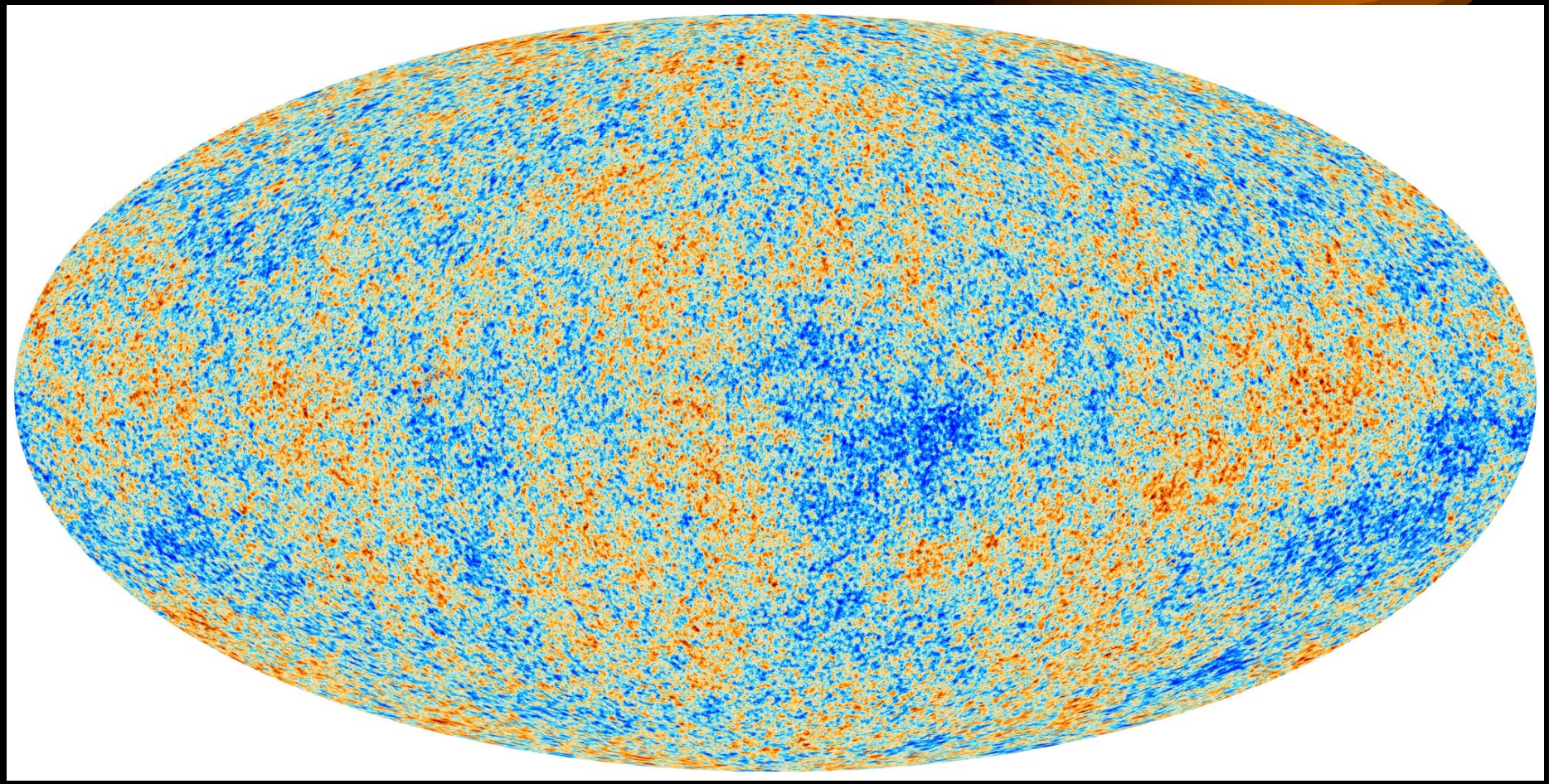
Verso dove?

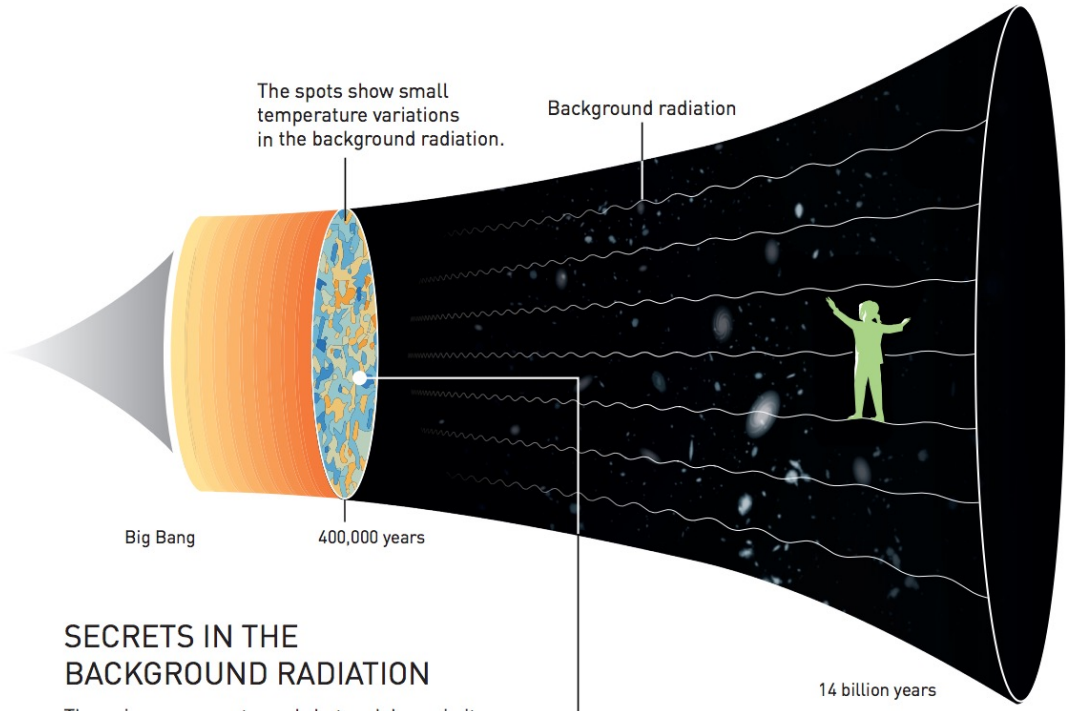

How The Big Crunch Theory Works
©2009 HowStuffWorks
Infinite Expansion
Open Universe
Maximum Expansion
Closed Universe
EXPANSION
TIME
BIG BANG
BIG CRUNCH

La teoria del Big Bang

- Stelle e Galassie
- L'allontanamento delle Galassie
- Spazio e Tempo → La teoria della relativita' di Einstein
- Osservare il Big Bang … ?
- Come e' fatto l'Universo? Come evolve?
- Cosa c'e' prima?

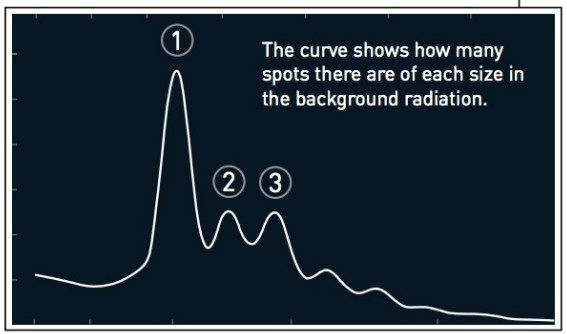
Osservare l'Universo

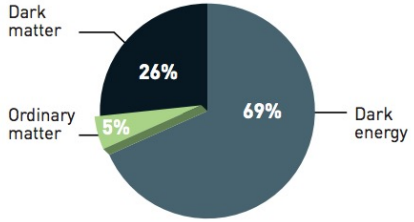




SECRETS IN THE BACKGROUND RADIATION

The universe was extremely hot and dense in its earliest moments, the Big Bang. Since then, the universe has been expanding, getting larger and colder. Almost 400,000 years after the Big Bang, the initial radiation began to travel through space. This radiation still fills the cosmos and, coded into it, many of the universe's secrets are hiding. Using his theoretical models, James Peebles was able to predict the shape of the universe and the matter and energy it contains (the below curve). His calculations were a good match with later measurements of background radiation.

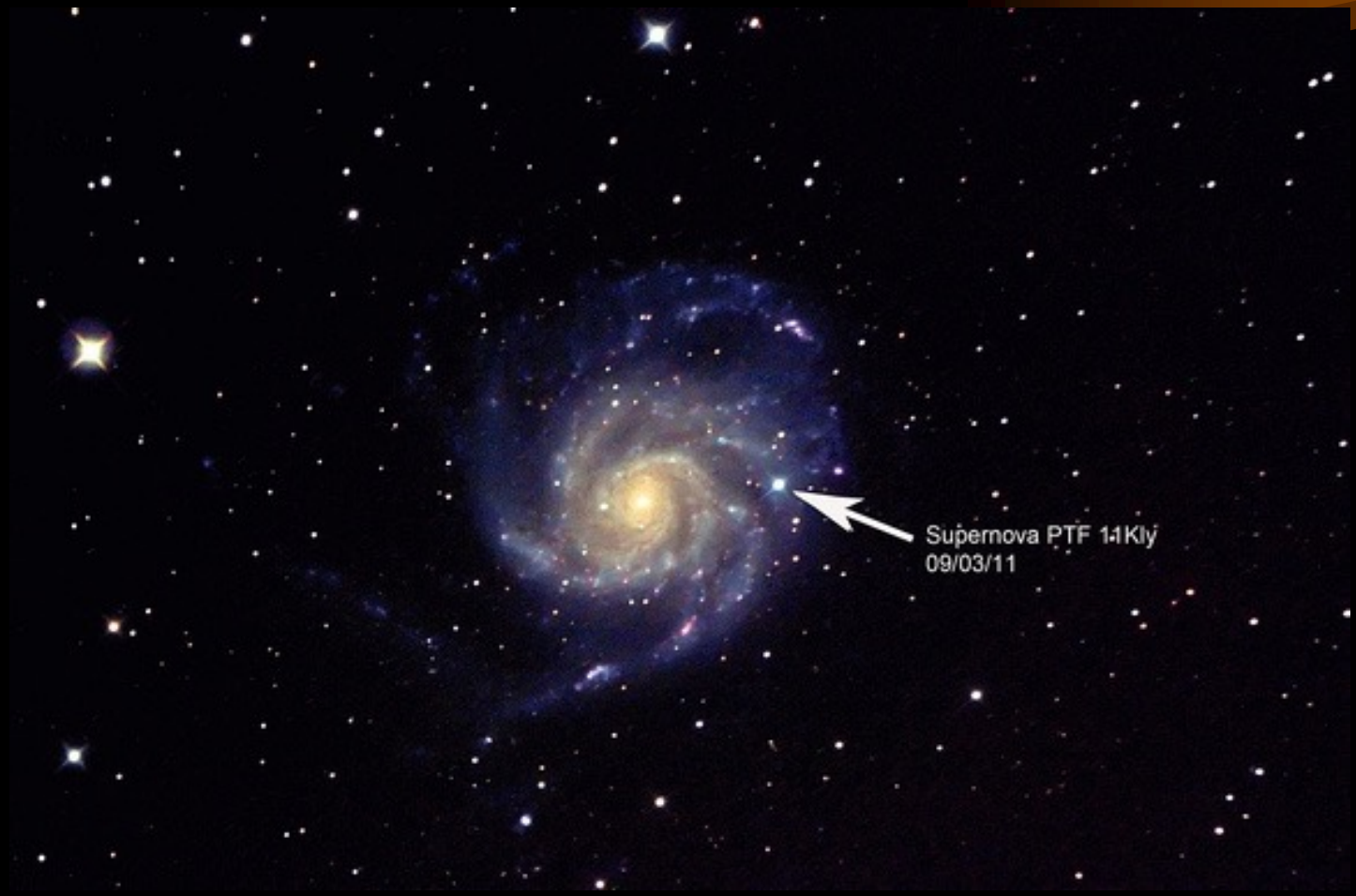




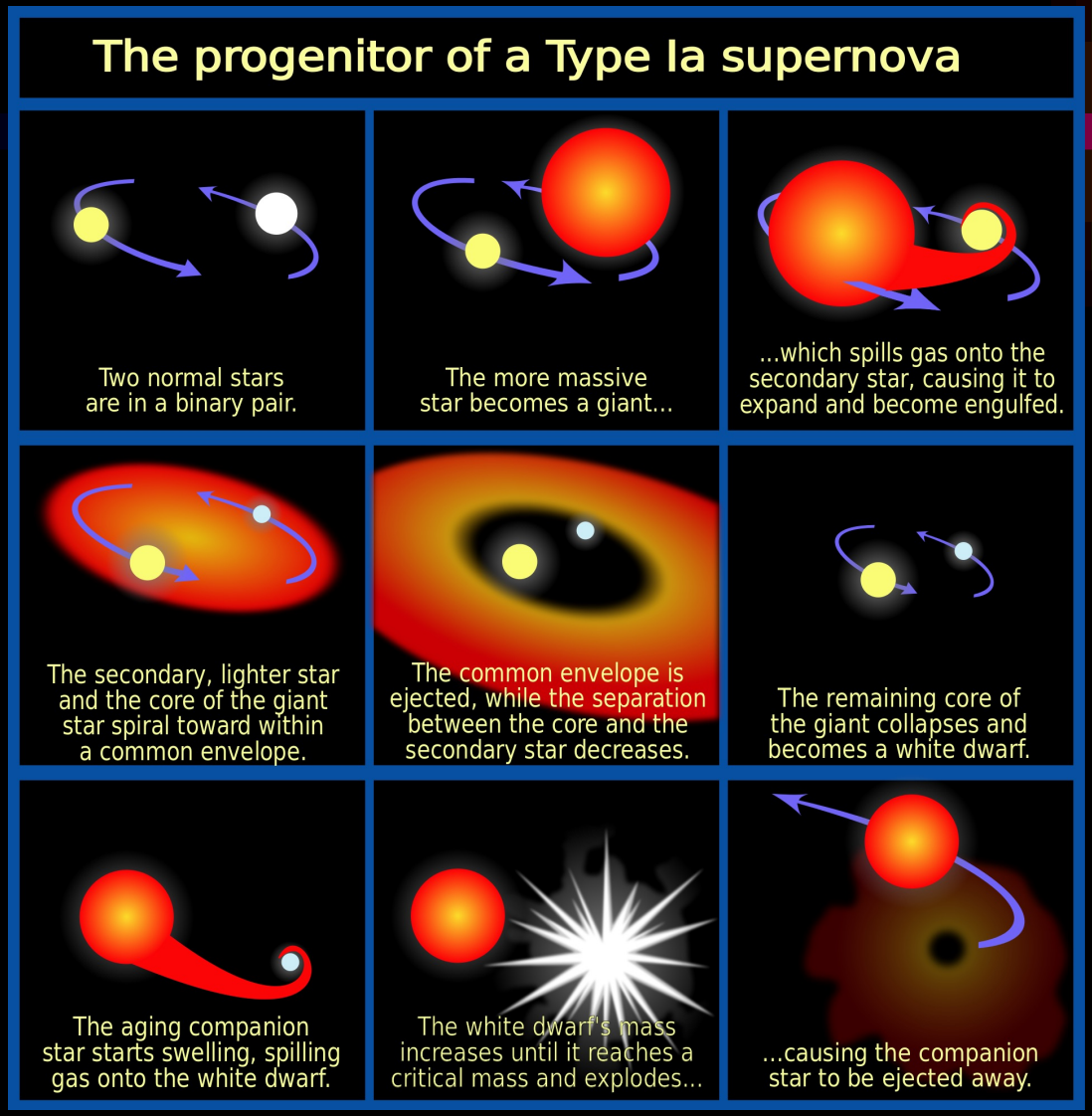
1. The first peak shows that the universe is geometrically flat, i.e. two parallel lines will never meet.
2. The second peak shows that ordinary matter is just 5% of the matter and energy in the universe.
3. The third peak shows that 26% of the universe consists of dark matter.

From these three peaks, it is possible to conclude that if 31% (5%+26%) of the universe is composed of matter, then 69% must be dark energy in order to fulfil the requirement for a flat universe.

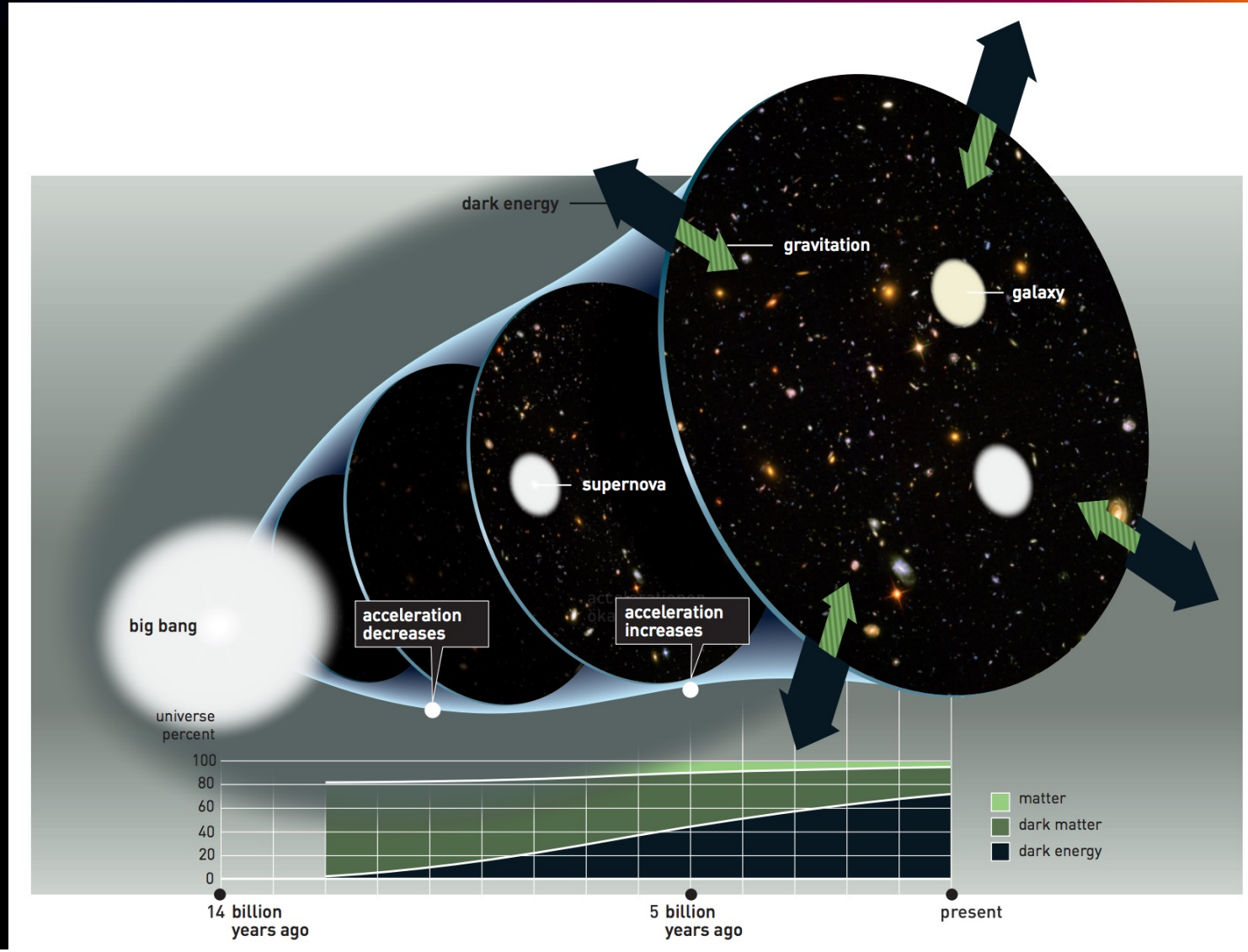
Le supernovae



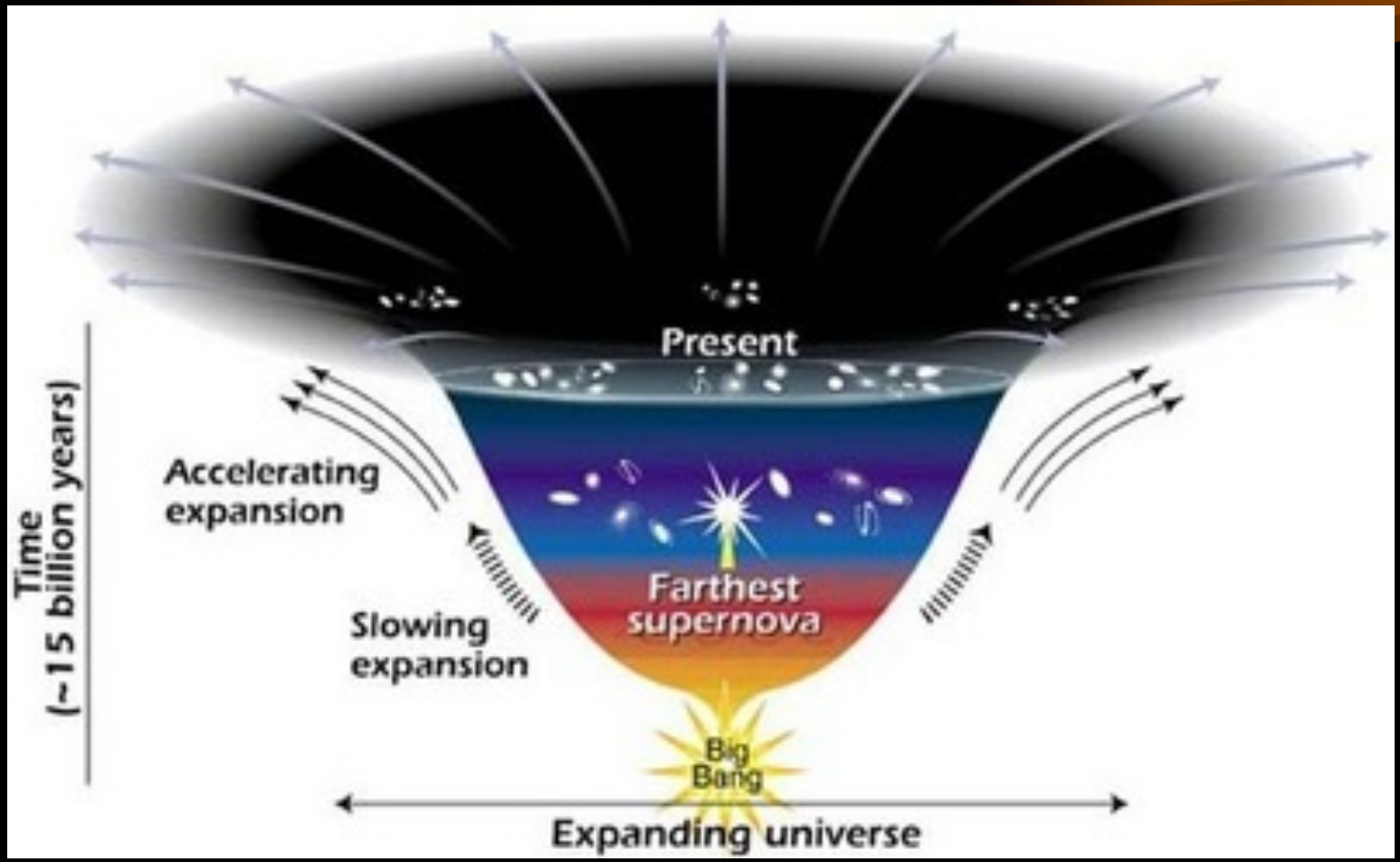
Le SN Ia


The progenitor of a Type Ia supernova
Two normal stars are in a binary pair.
The more massive star becomes a giant...
...which spills gas onto the secondary star, causing it to expand and become engulfed.
The secondary, lighter star and the core of the giant star spiral toward within a common envelope.
The common envelope is ejected, while the separation between the core and the secondary star decreases.
The remaining core of the giant collapses and becomes a white dwarf.
The aging companion star starts swelling, spilling gas onto the white dwarf.
The white dwarf's mass increases until it reaches a critical mass and explodes...
...causing the companion star to be ejected away.

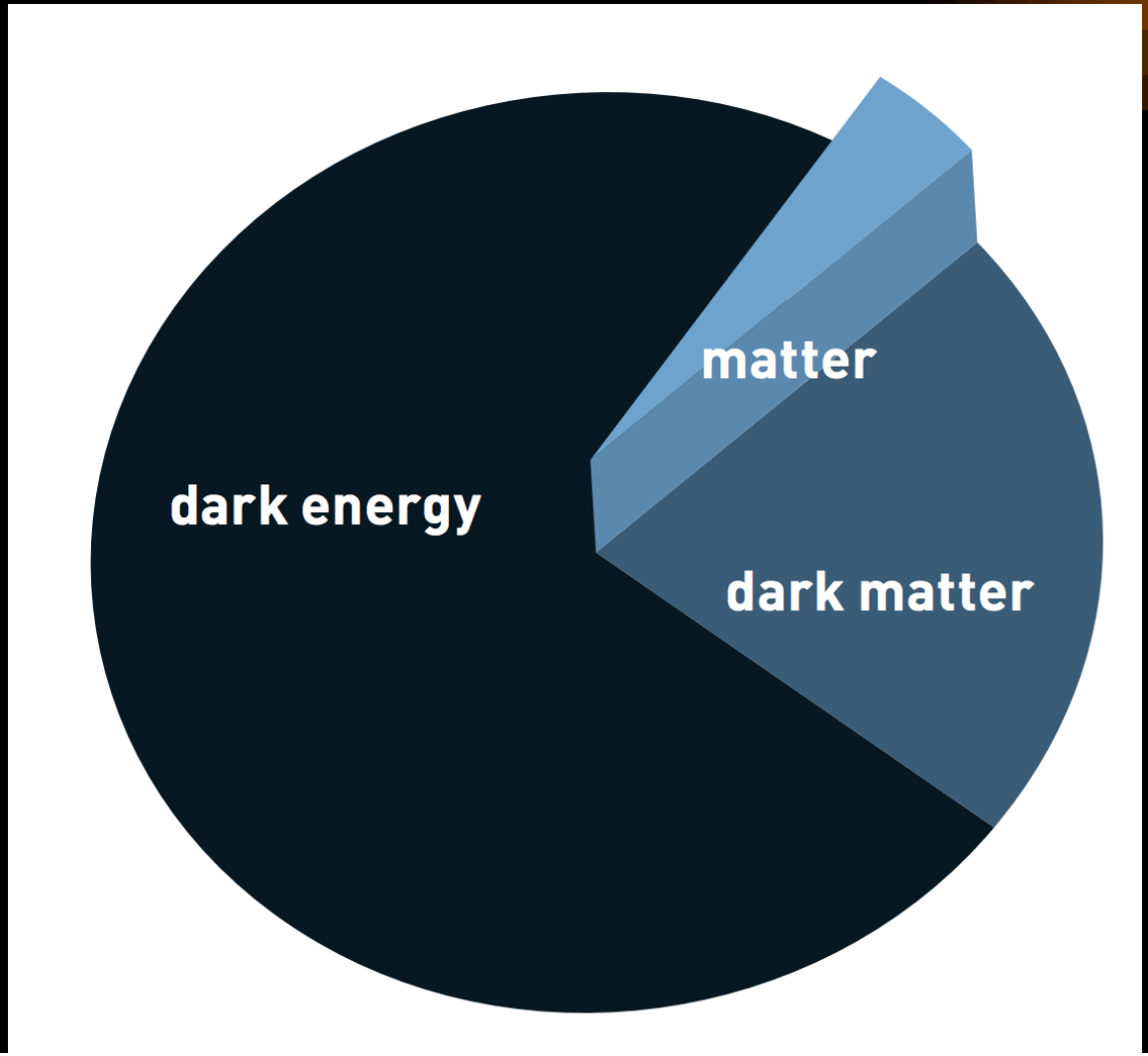
Osservare l'Universo



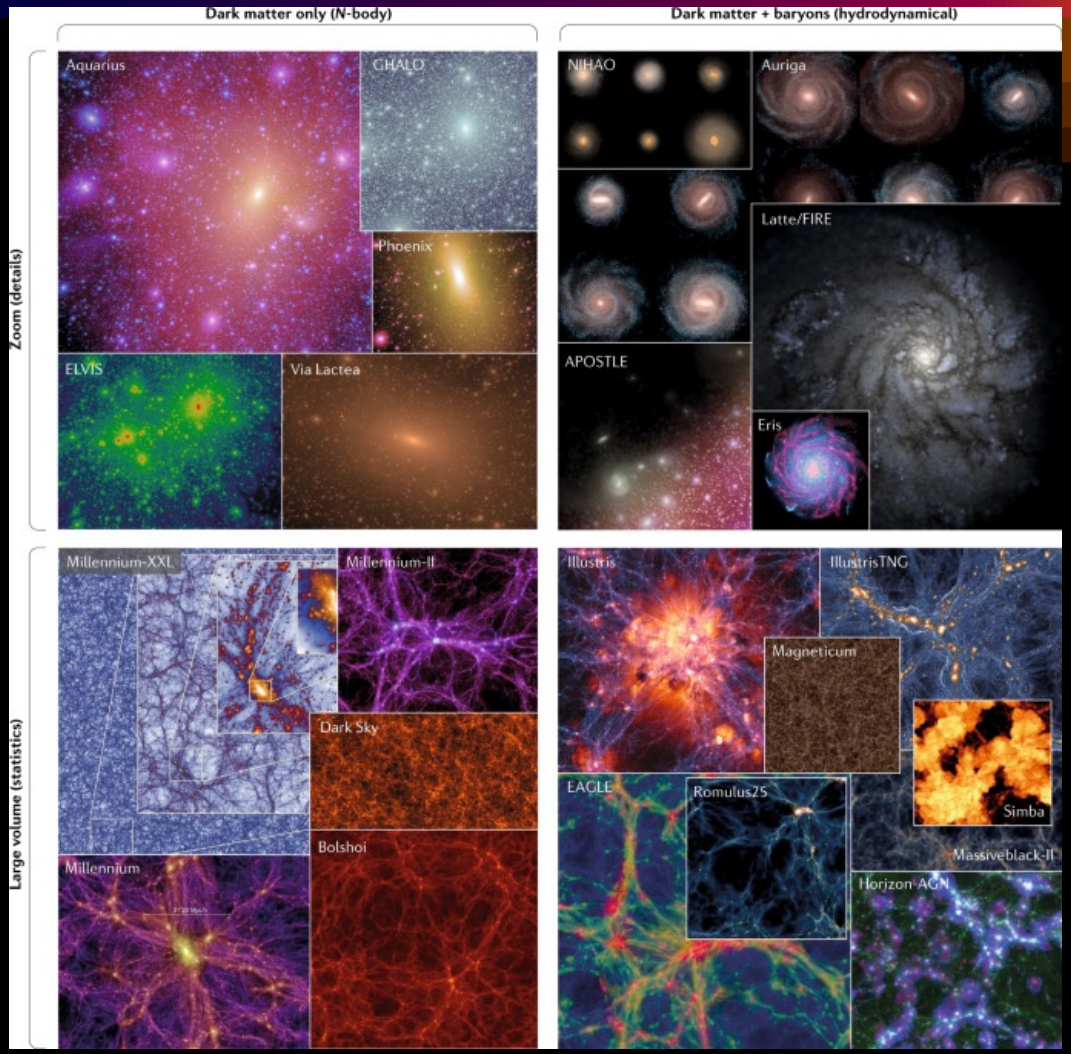
Osservare l'Universo



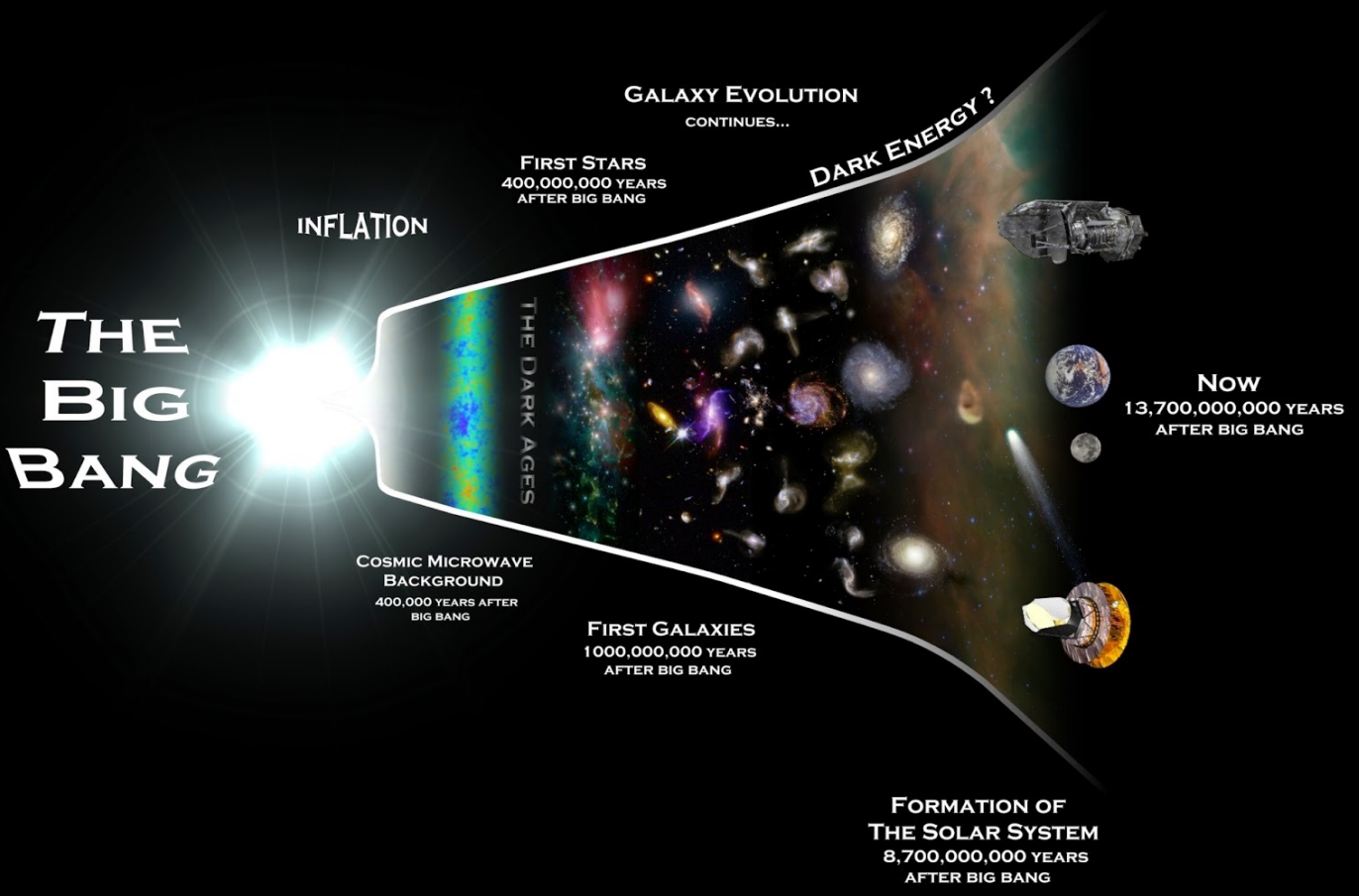
Osservare l'Universo



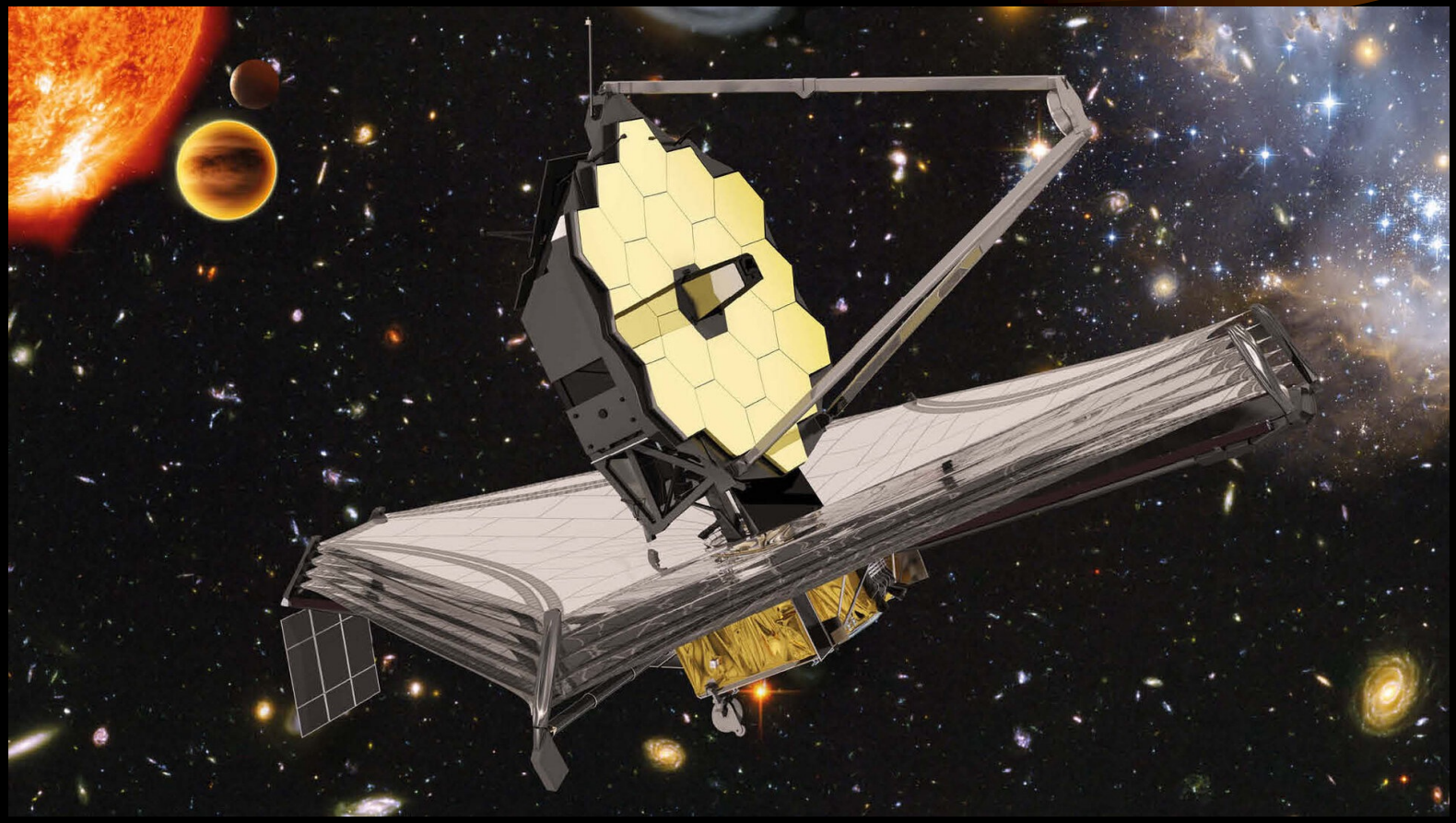
Osservare l'Universo



Verso dove?


THE BIG BANG
INFLATION
COSMIC MICROWAVE BACKGROUND
400,000 YEARS AFTER BIG BANG
THE DARK AGES
FIRST STARS
400,000,000 YEARS AFTER BIG BANG
GALAXY EVOLUTION
CONTINUES...
DARK ENERGY ?
FIRST GALAXIES
1000,000,000 YEARS AFTER BIG BANG
NOW
13,700,000,000 YEARS AFTER BIG BANG
FORMATION OF THE SOLAR SYSTEM
8,700,000,000 YEARS AFTER BIG BANG

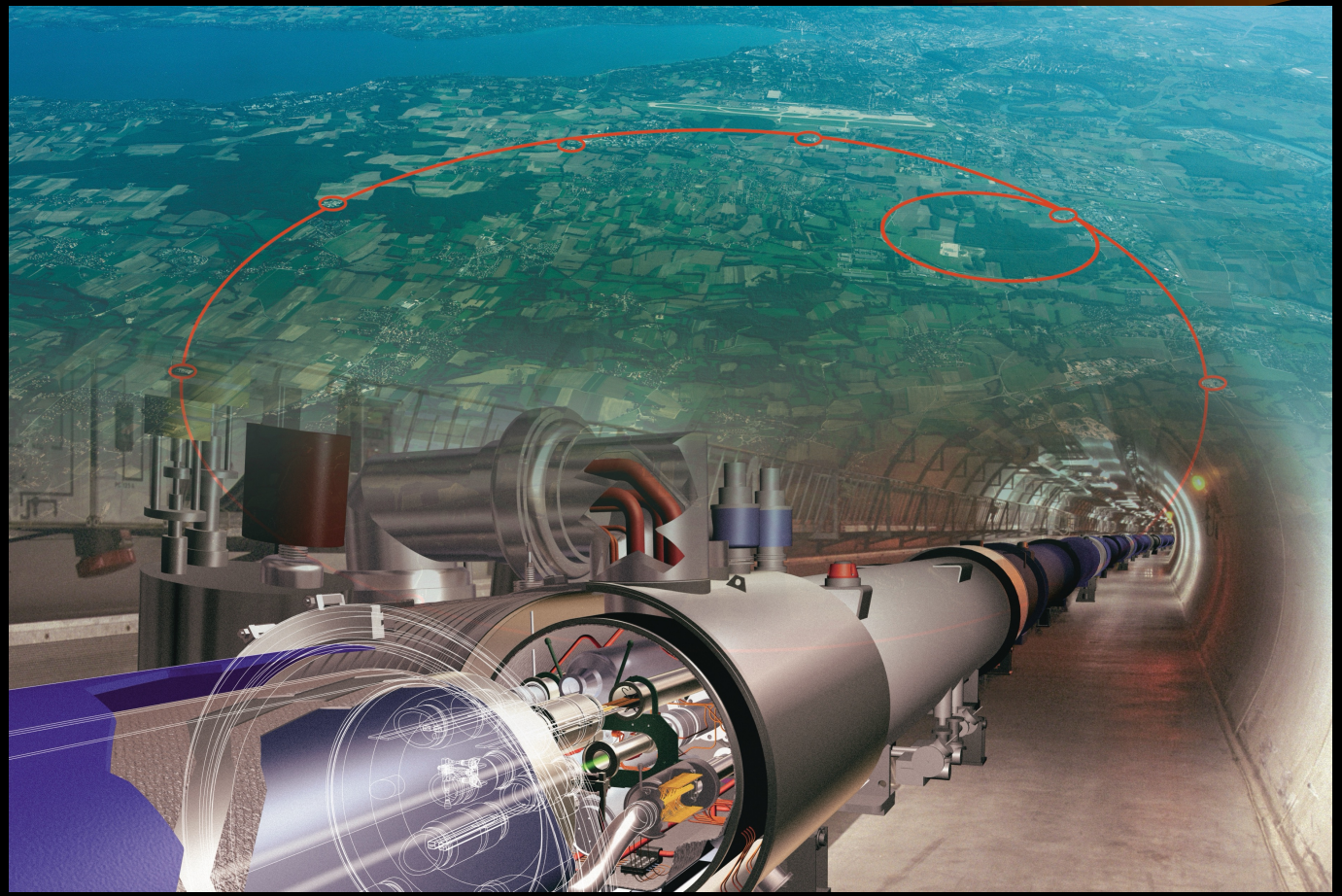
The James Webb Telescope



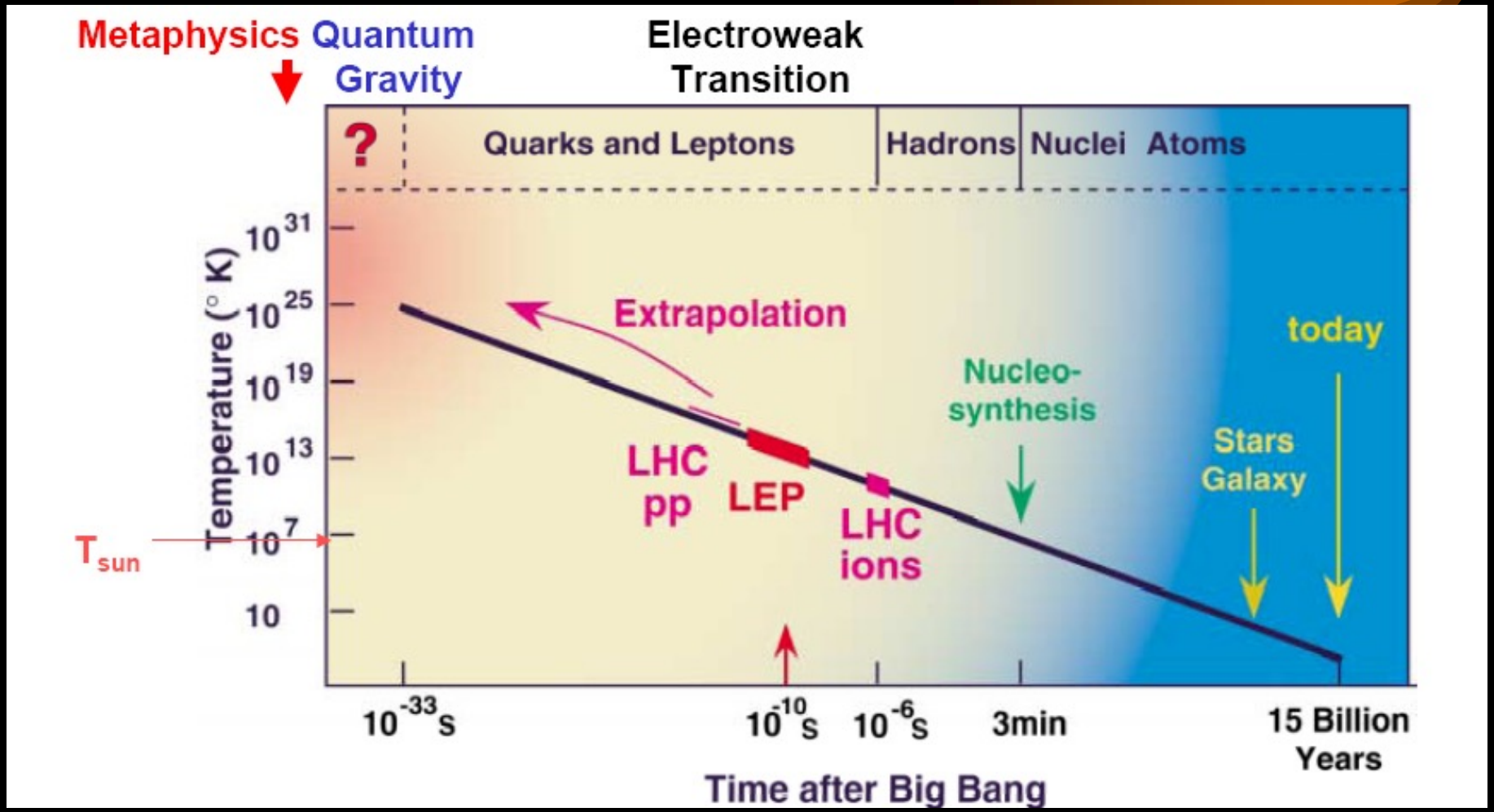
The James Webb Telescope



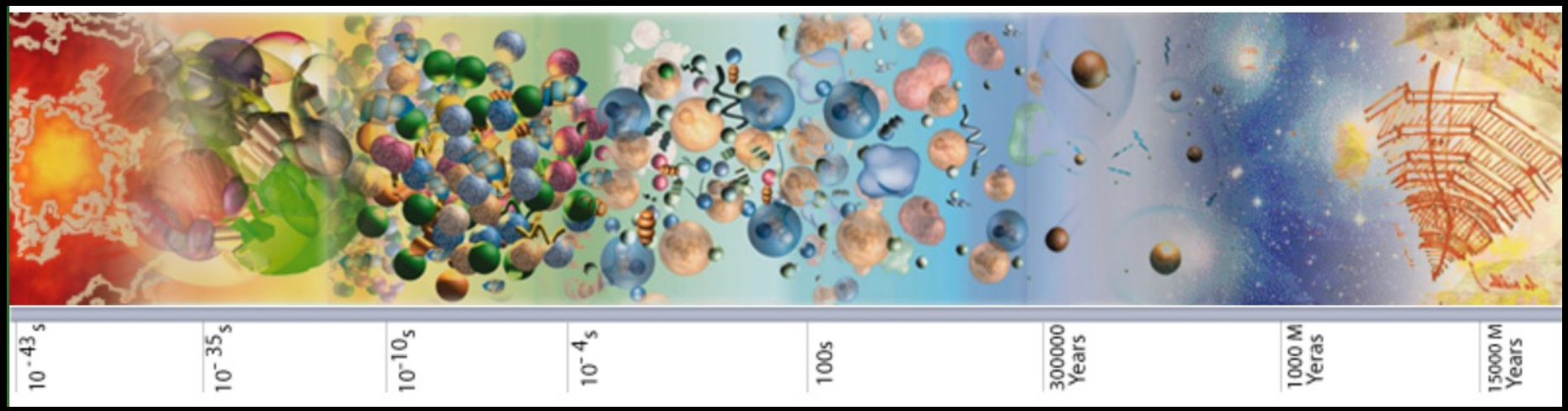
Osservare l'Universo



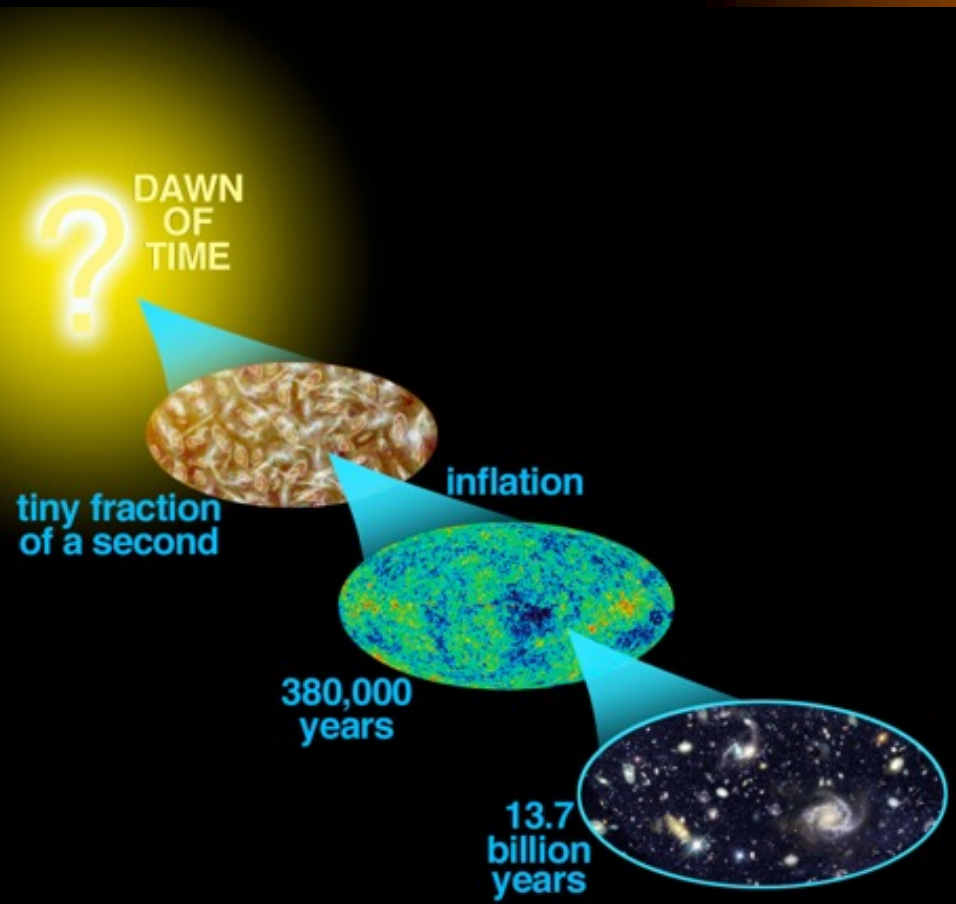
Alte Energie e Inizi dell'Universo



All'inizio dell'Universo



Come evolve l'Universo?



L'orizzonte cosmologico




francesco.longo@ts.infn.it