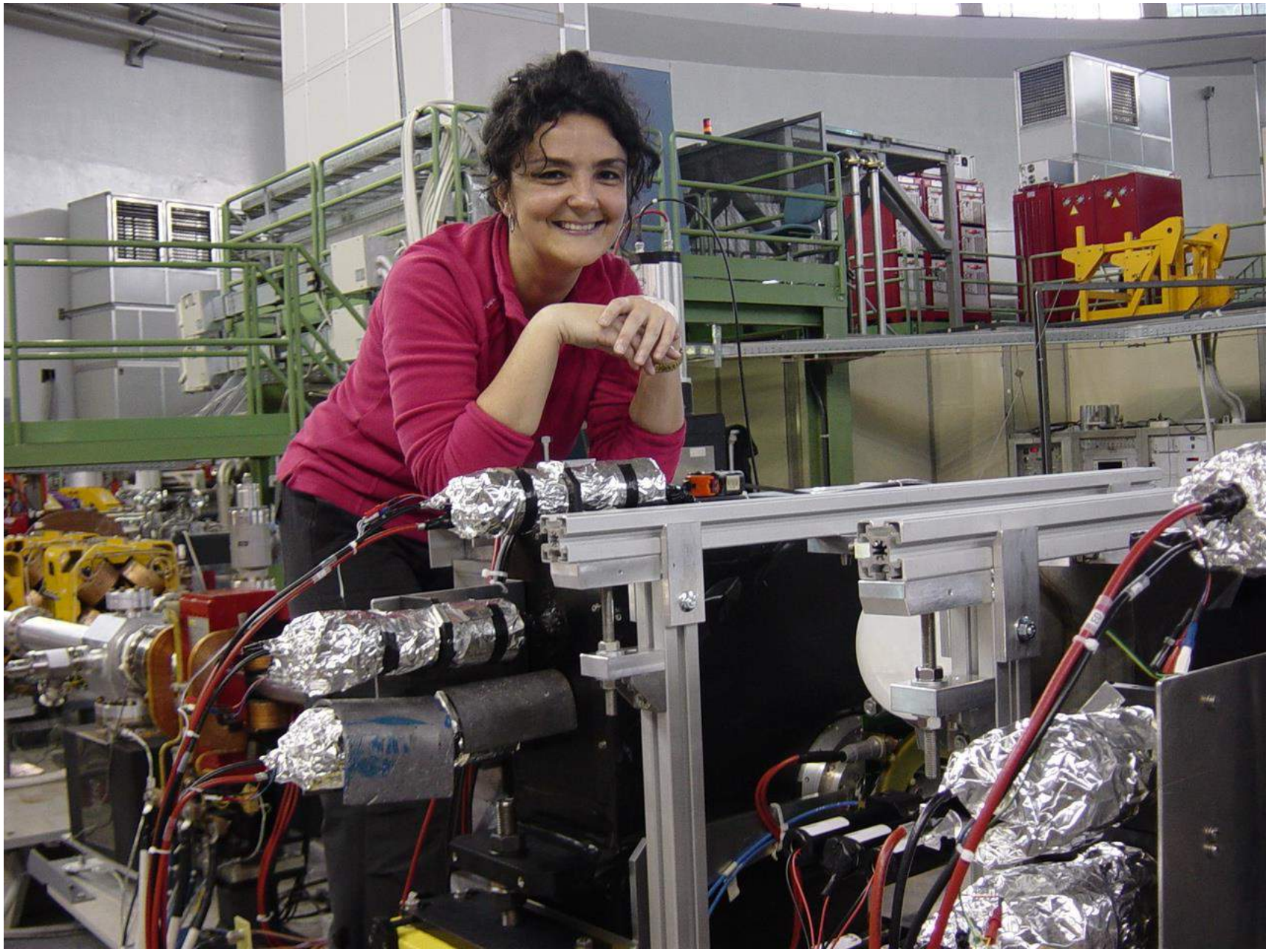
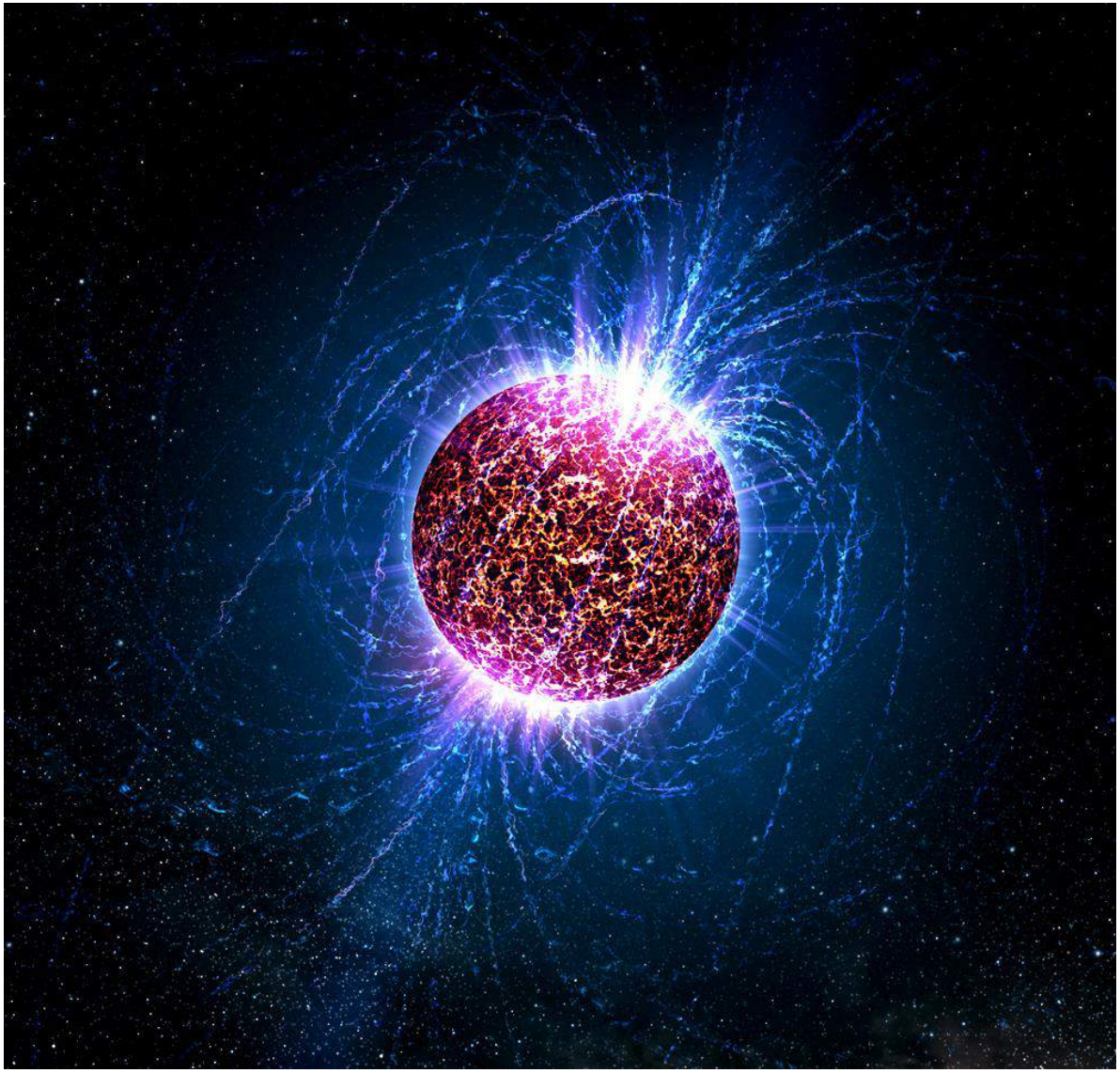
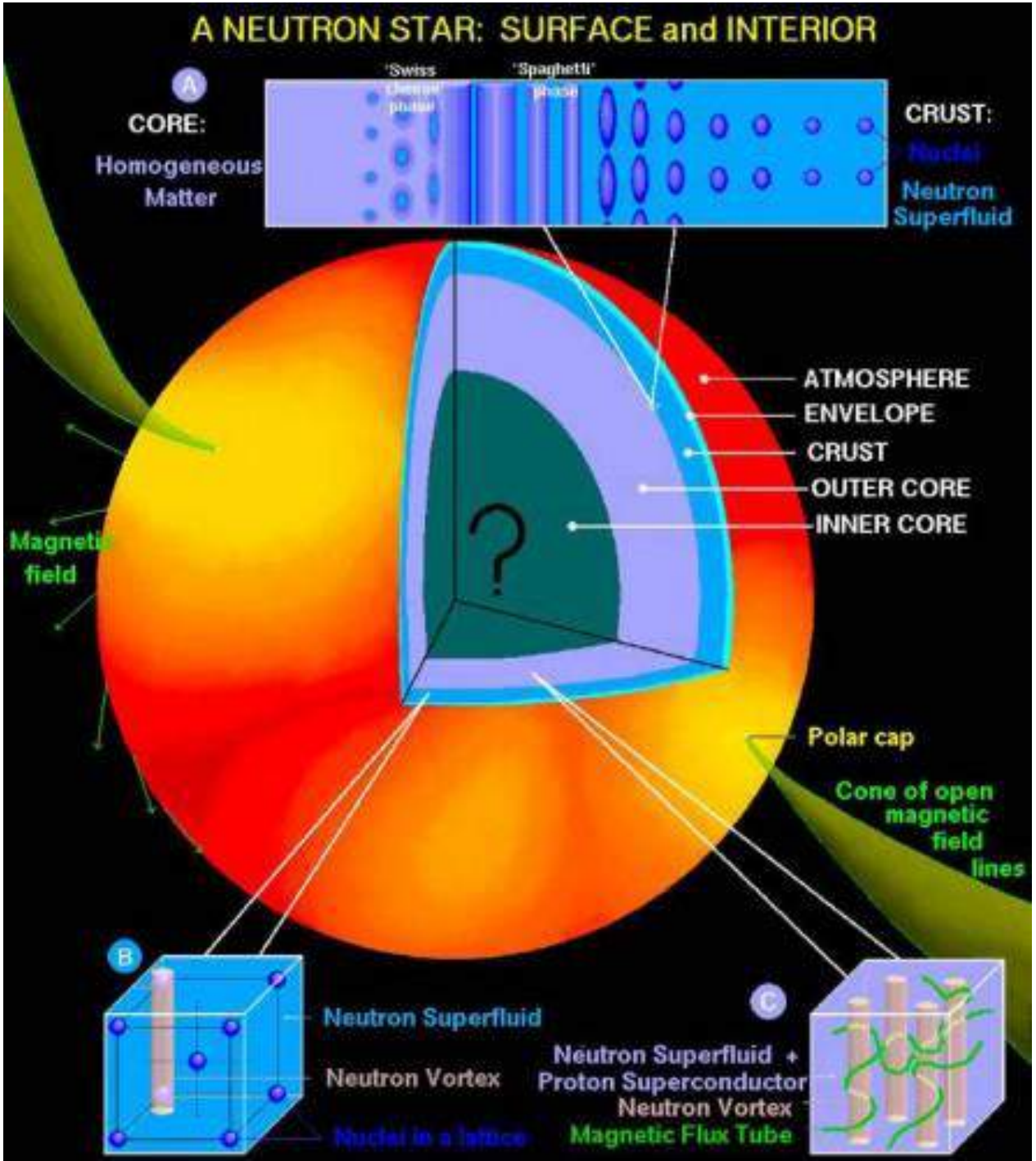
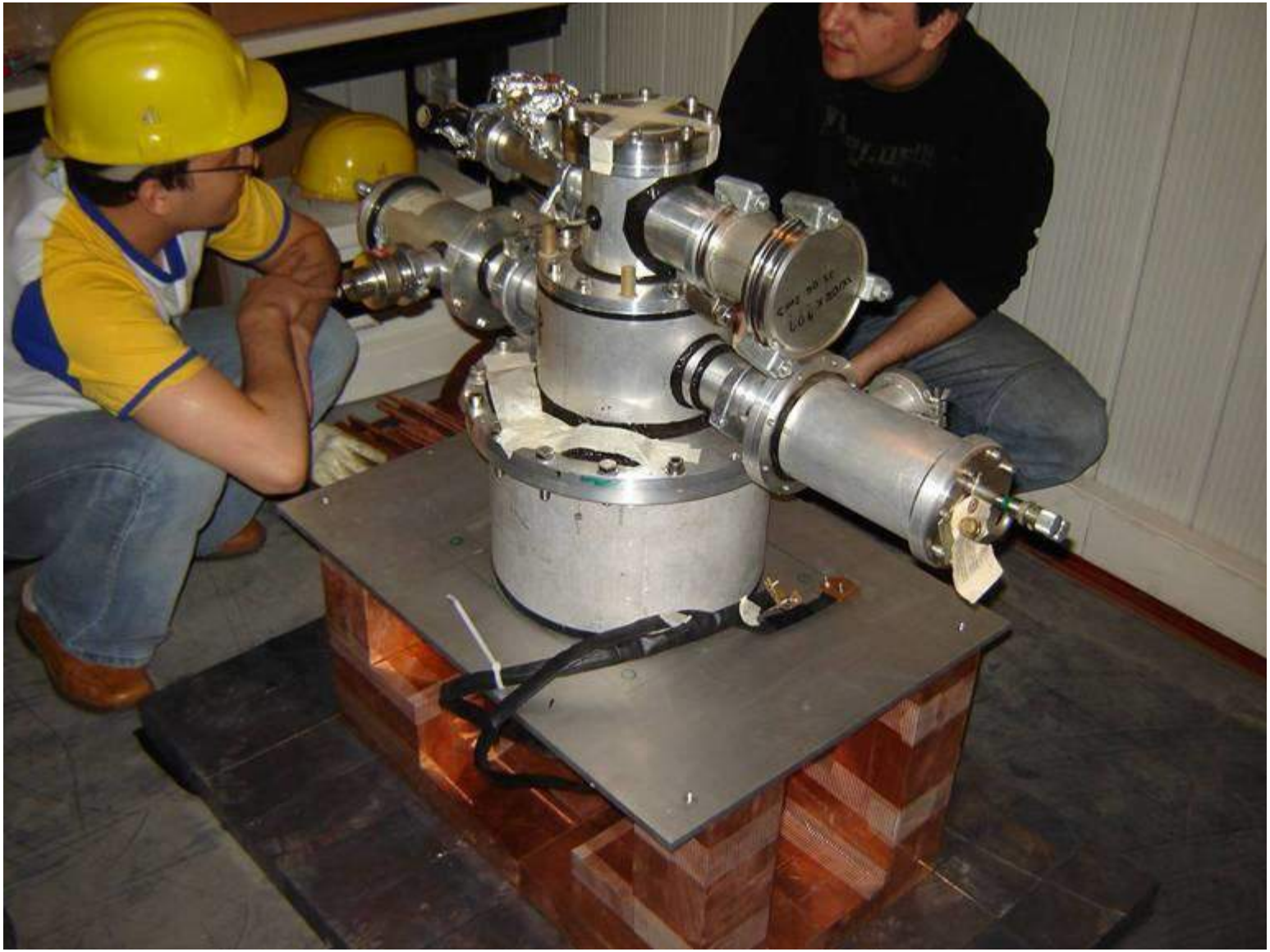

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati
John Templeton Foundation
FQXi
Foundational Questions Institute
Centro Fermi
Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi
Dal Big Bag ai buchi neri
Le meraviglie dell'Universo!
Catalina Curceanu, LNF-NFN
Liceo Marconi, Pesaro, 3 maggio 2016



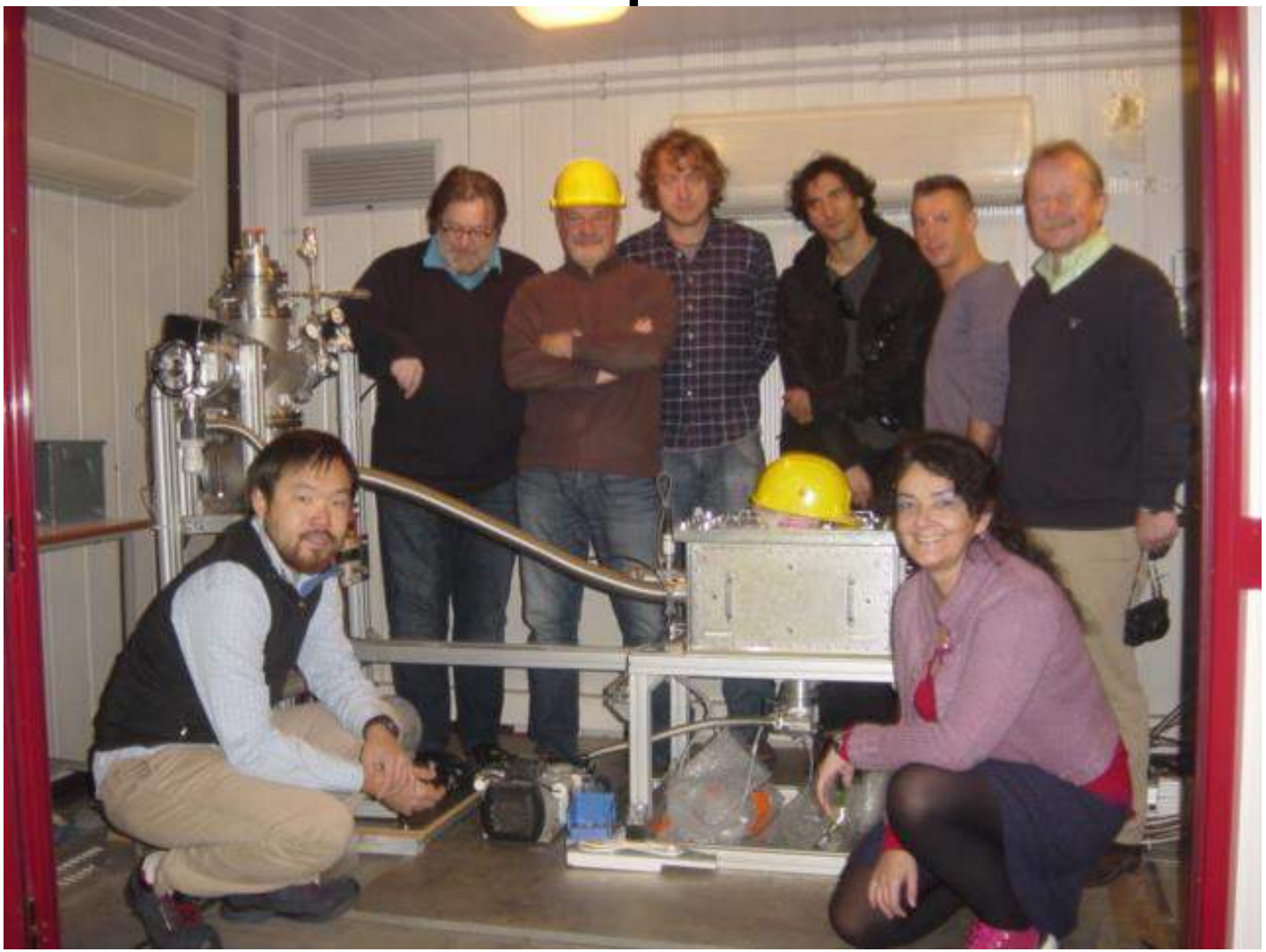



A NEUTRON STAR: SURFACE and INTERIOR
A
CORE:
Homogeneous Matter
'Swiss cheese' phase
'Spaghetti' phase
CRUST:
Nuclei
Neutron Superfluid
ATMOSPHERE
ENVELOPE
CRUST
OUTER CORE
INNER CORE
?
Magnetic field
Polar cap
Cone of open magnetic field lines
B
Neutron Superfluid
Neutron Vortex
Nuclei in a lattice
C
Neutron Superfluid +
Proton Superconductor
Neutron Vortex
Magnetic Flux Tube

VIP setup at LNGS



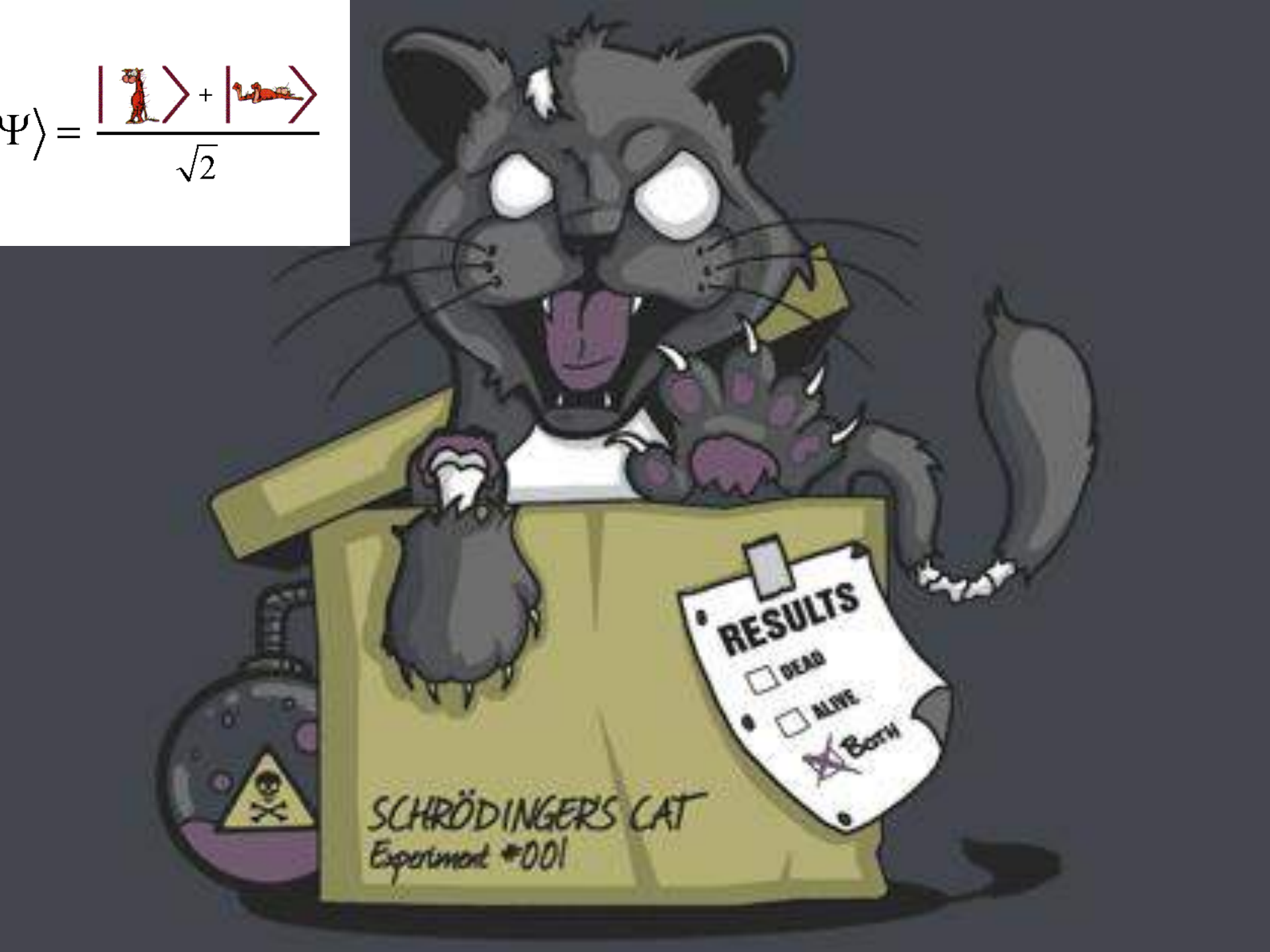
Final setup at LNGS



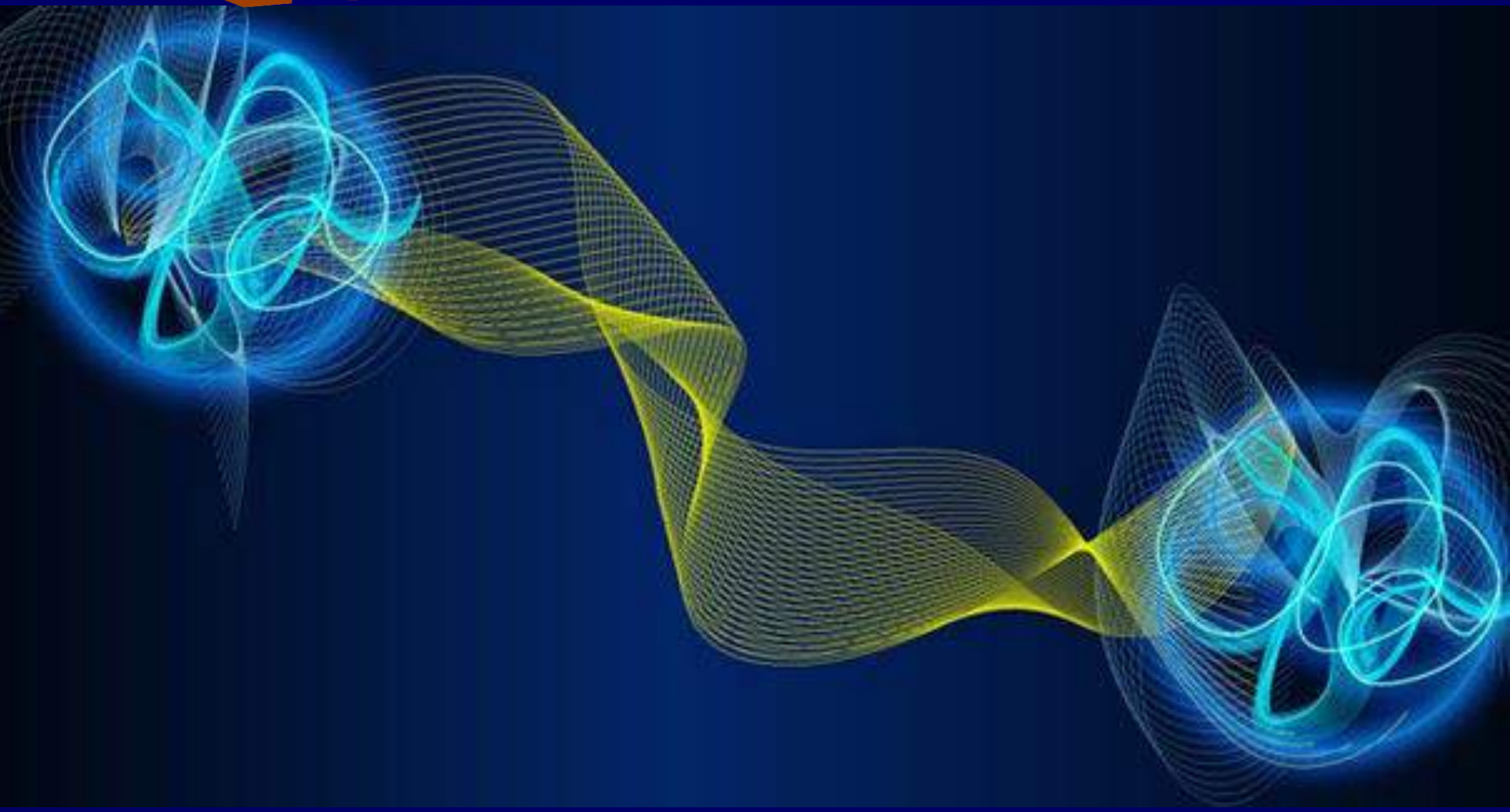
Principio di sovrapposizione quantistica

$$\Psi = c_1 \psi_1 + c_2 \psi_2$$

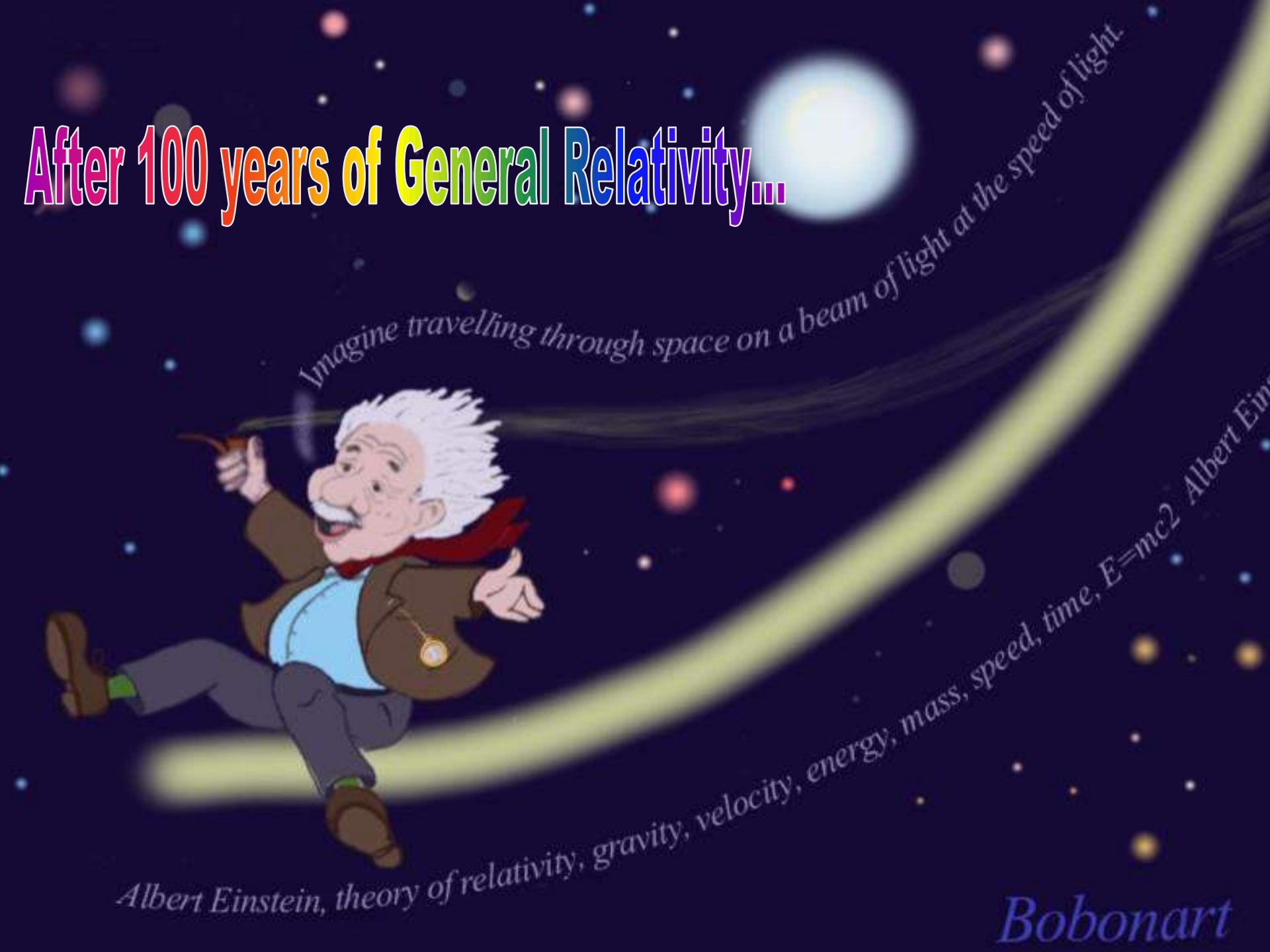
$$|\Psi\rangle = \frac{|\text{alive}\rangle + |\text{dead}\rangle}{\sqrt{2}}$$



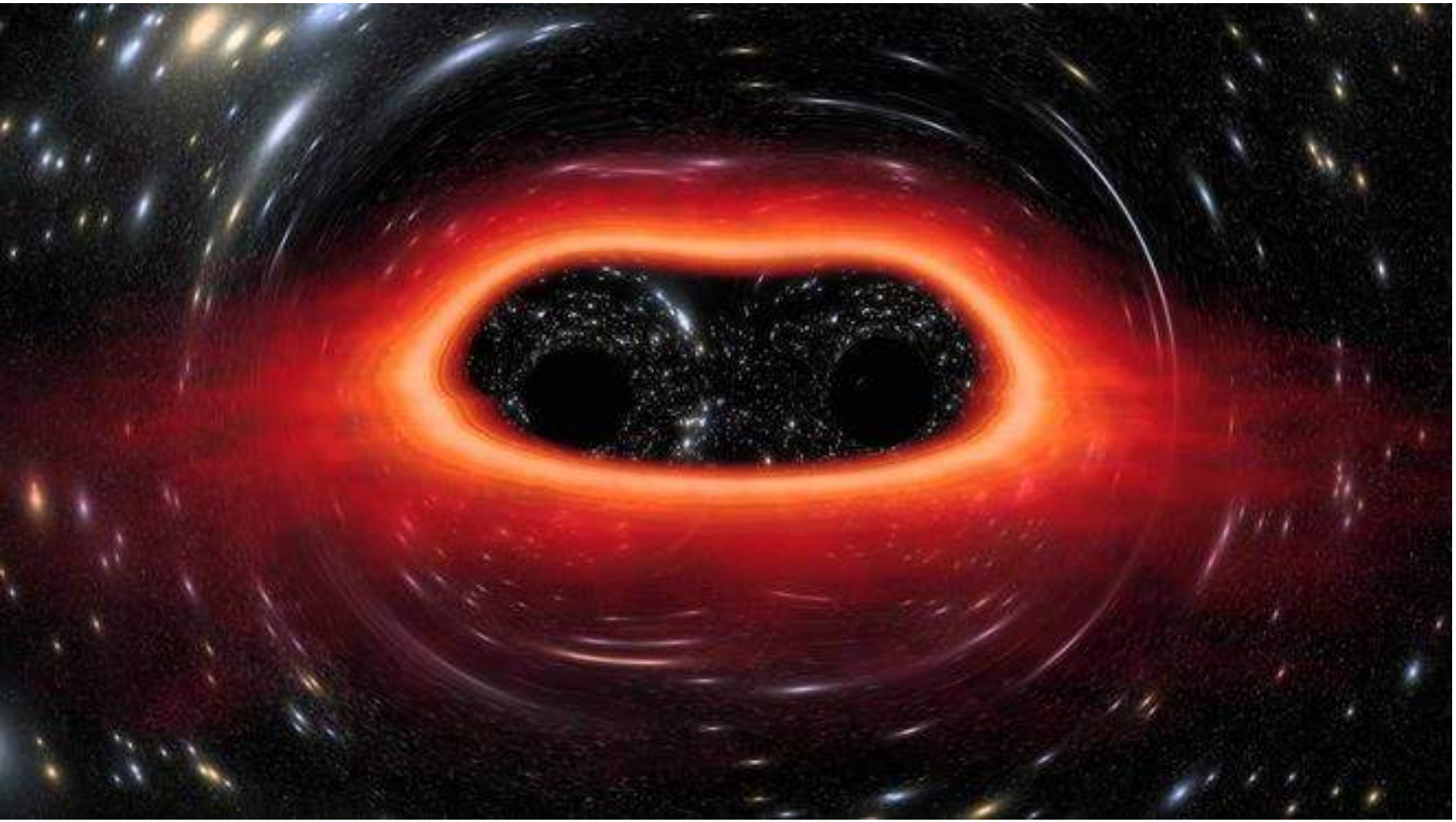
L'entanglement



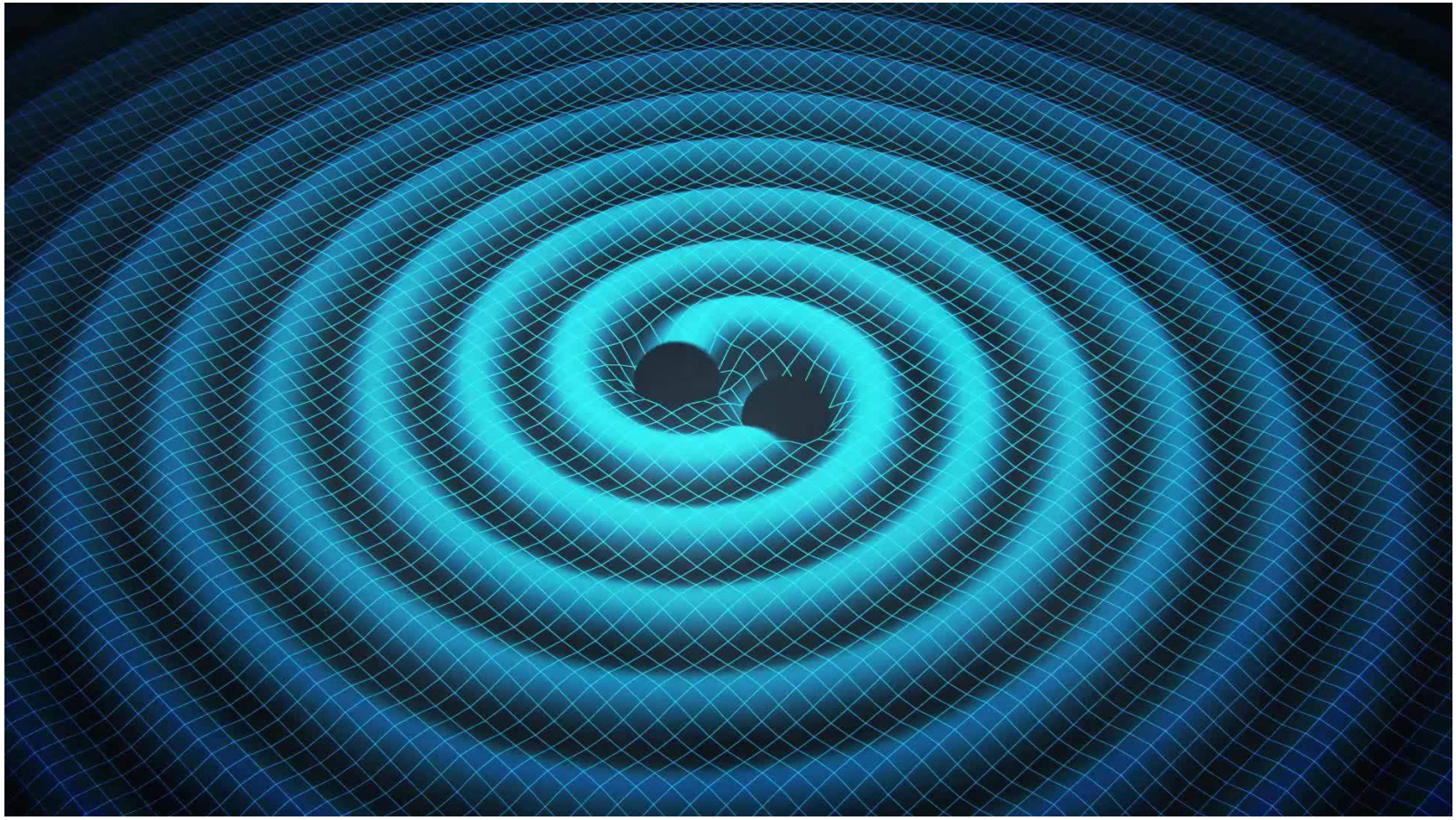
After 100 years of General Relativity...

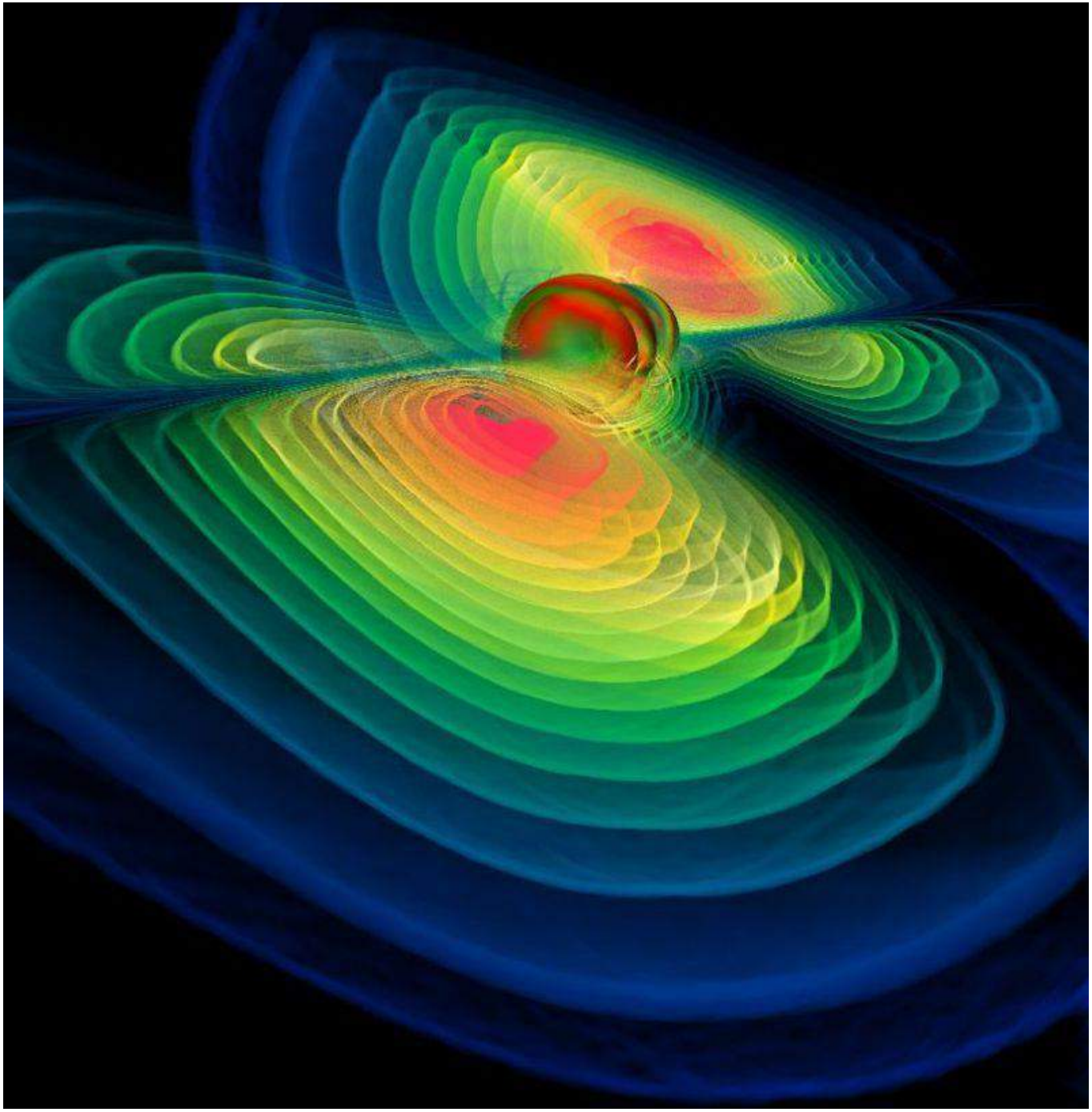


Scoperta delle onde gravitazionali (14 Sept. 2015 -> 11 Feb 2016)



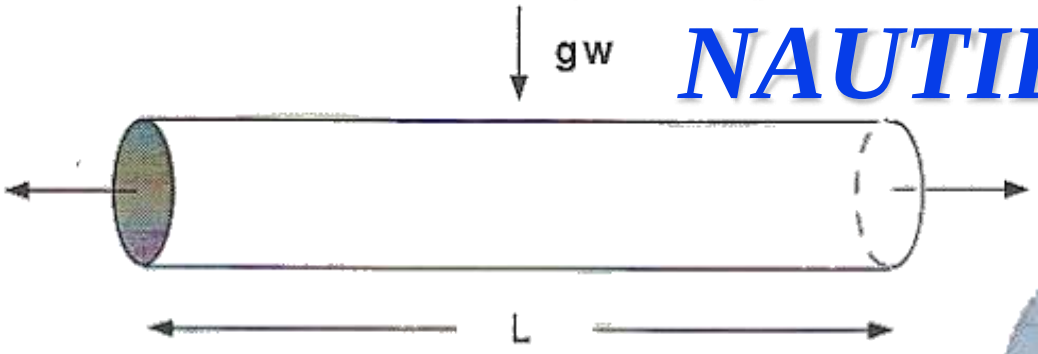
Onde gravitazionali (14 Sept. 2015 -> 11 Feb 2016)





NAUTILUS ai LNF-INFN

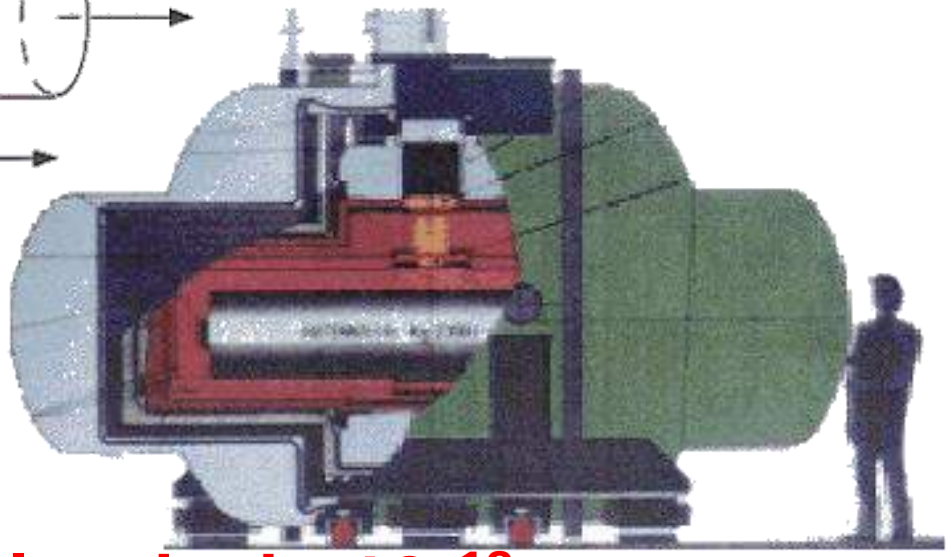
Search for gravitational waves: NAUTILUS



vibrations in the bar

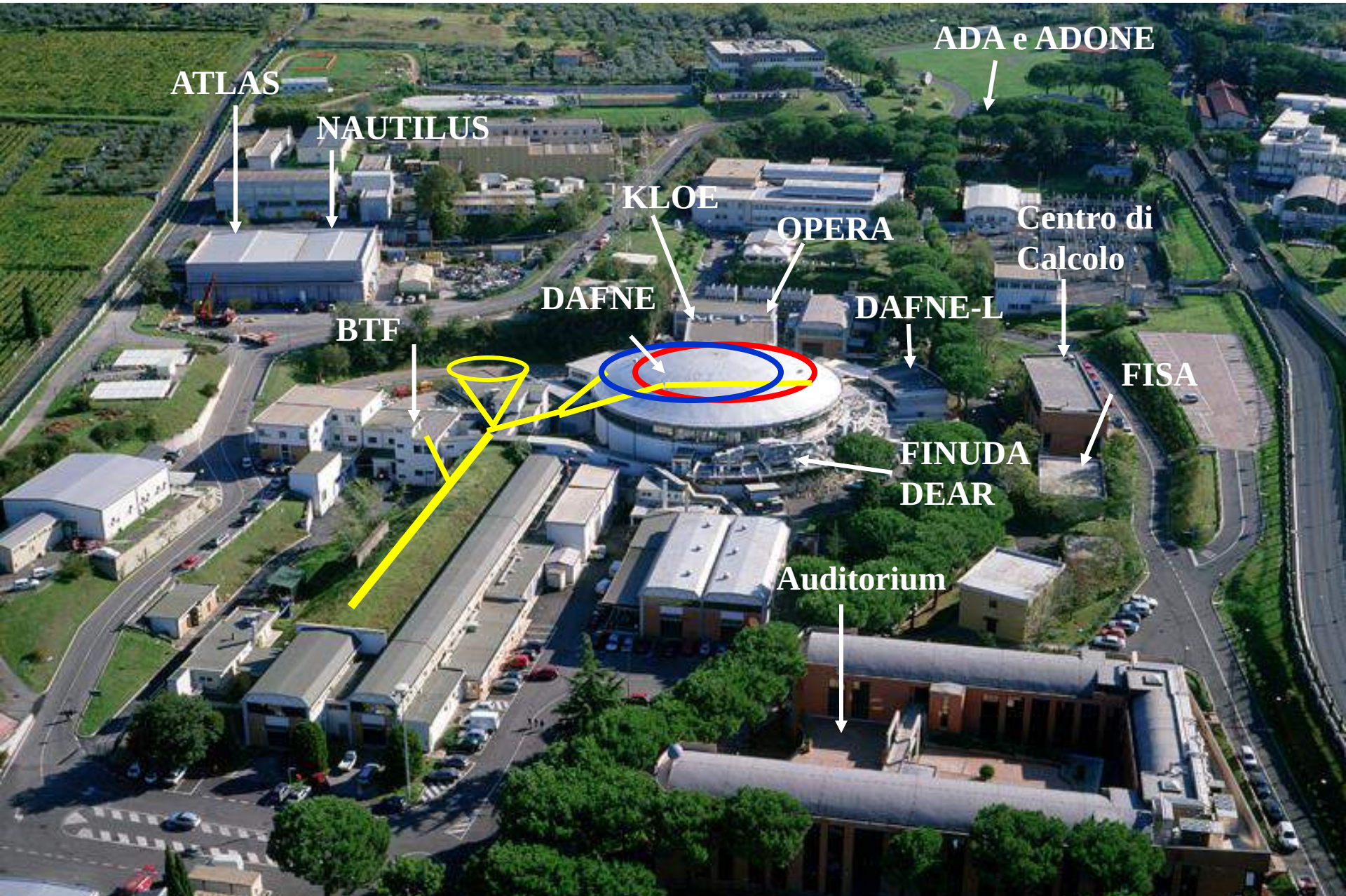
(for Al, L=3 m, f=915 Hz)

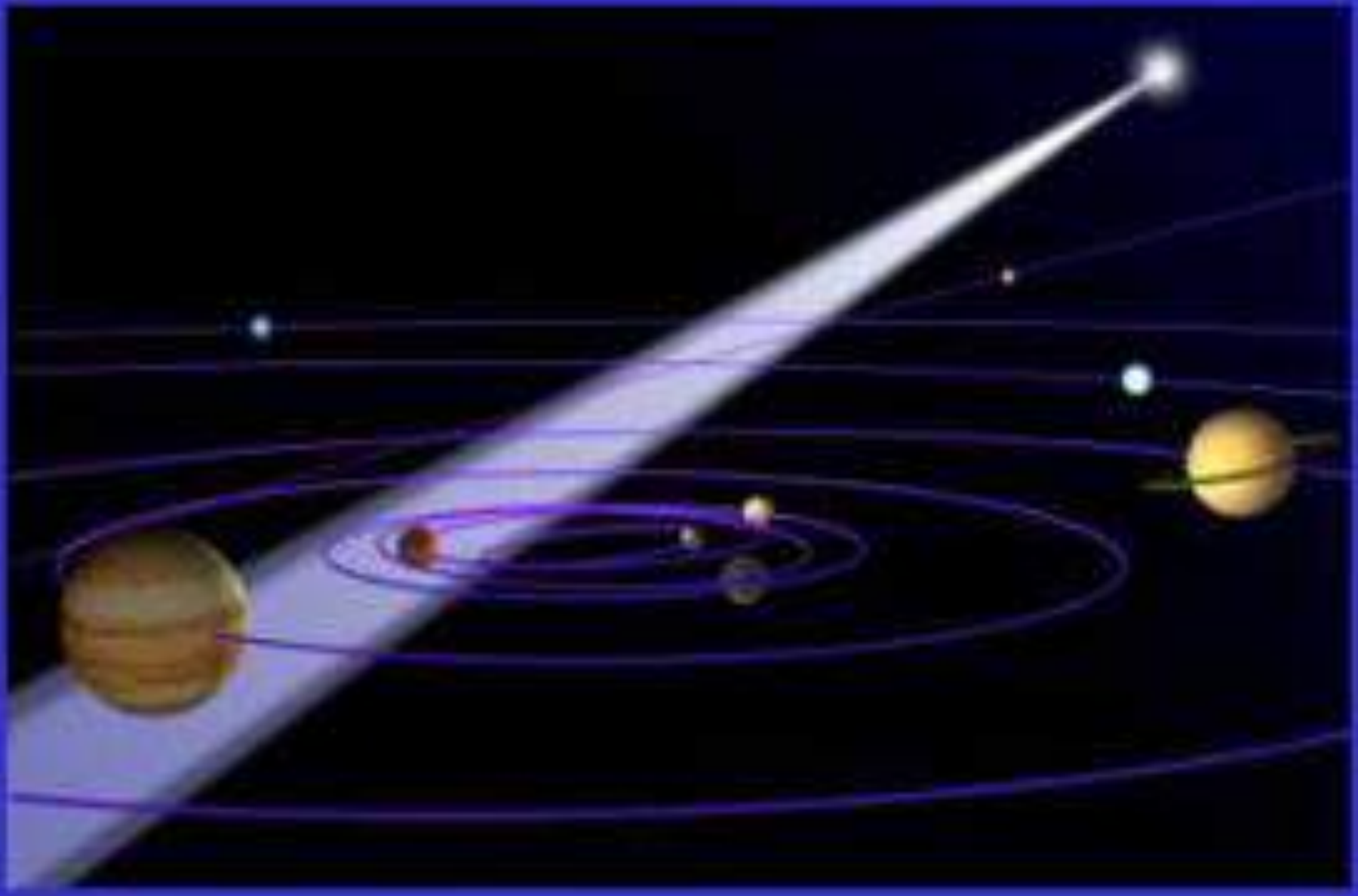
$$\frac{\Delta L}{L} \approx h$$

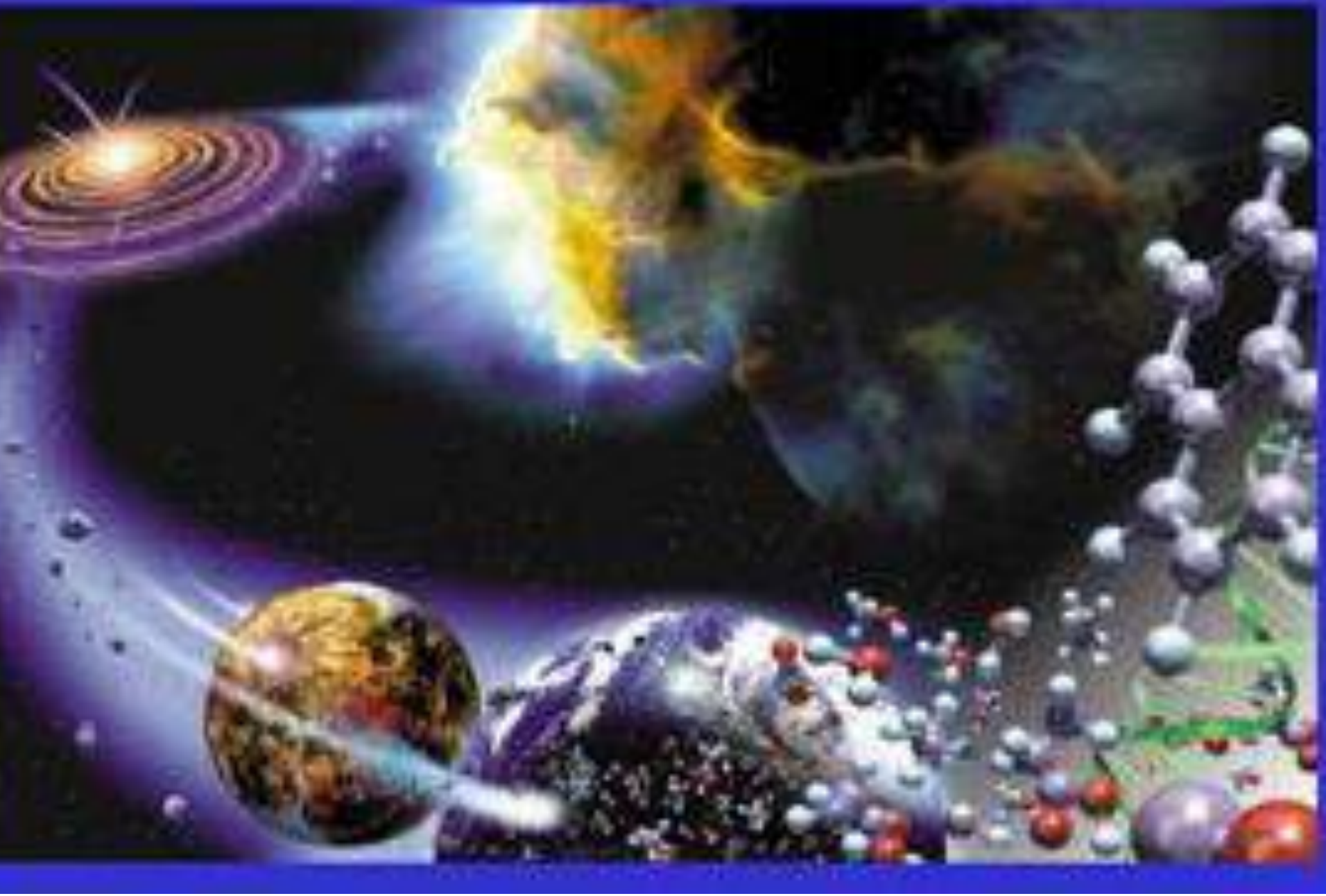


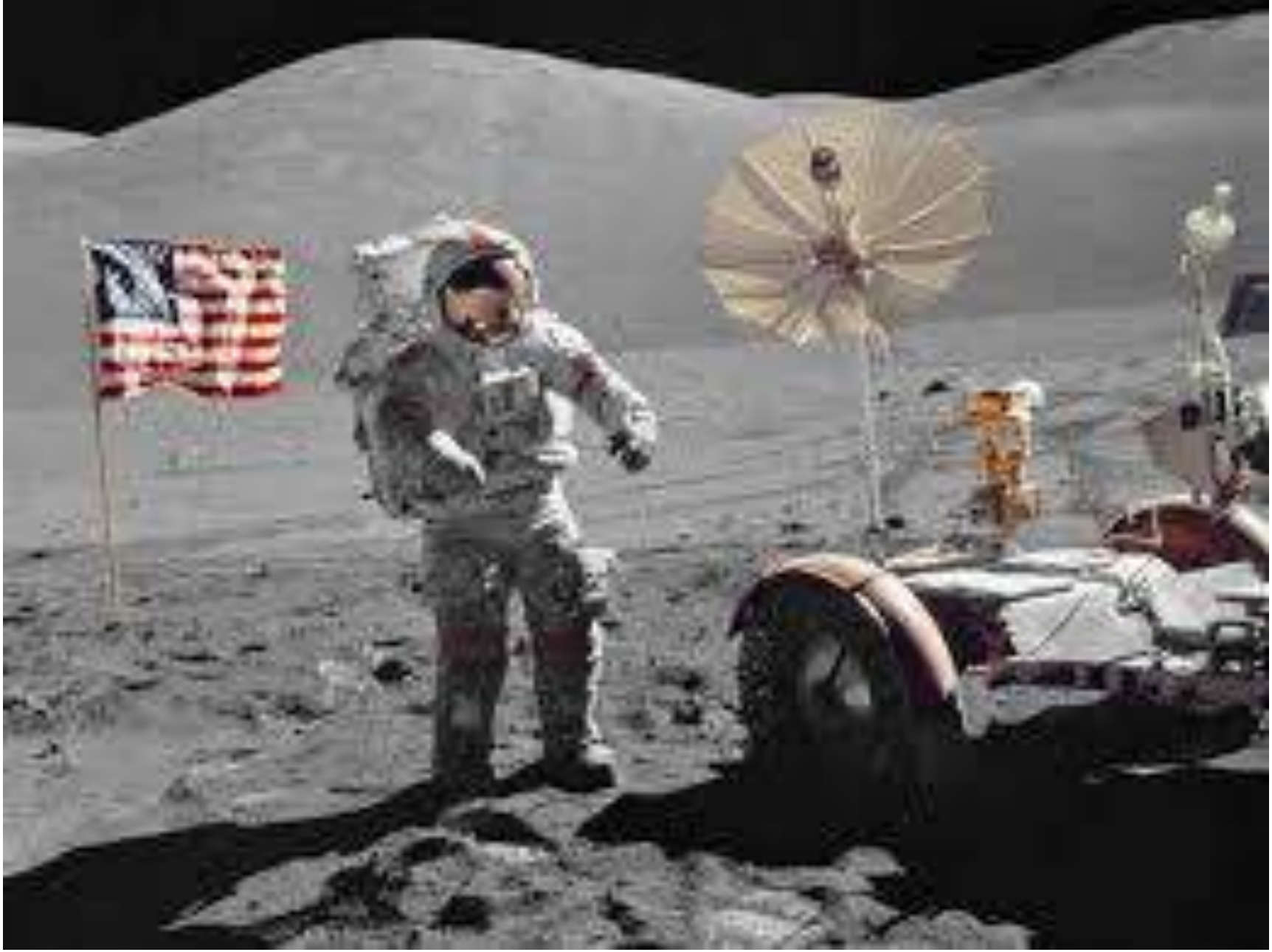
- **Supernova in our Galassia $h=10^{-18}$**
- **Supernova in Virgo $h=10^{-21}$**
- **Thermal noise @ T=300 K, $\Delta L=10^{-16}$ m**
- **Thermal noise @ T=3 K, $\Delta L=10^{-17}$ m**
- **Thermal noise @ T=300 mK → $\Delta L=10^{-18}$ m**

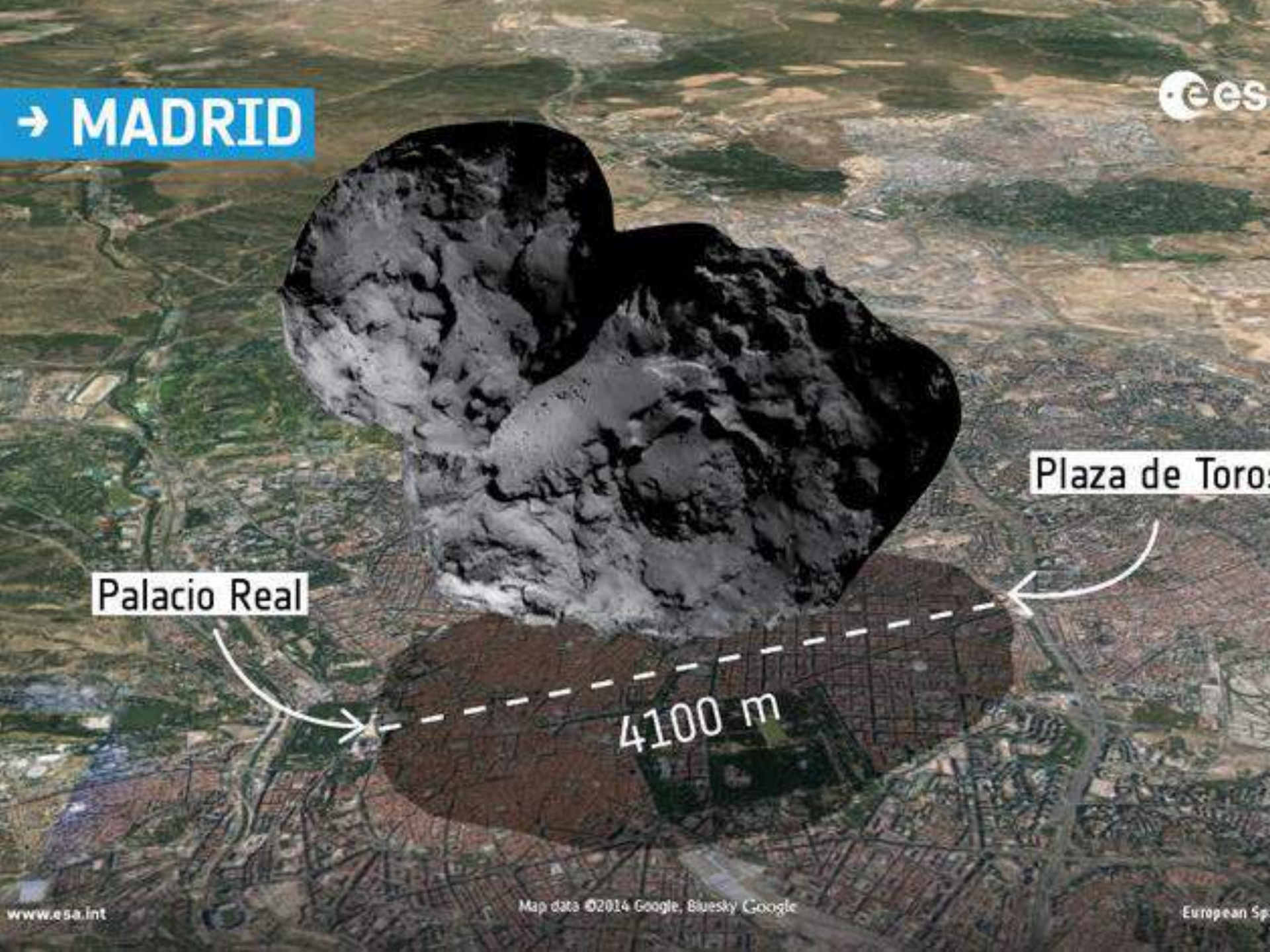
Laboratori Nazionali di Frascati, info: http://www.lnf.infn.it/sis/

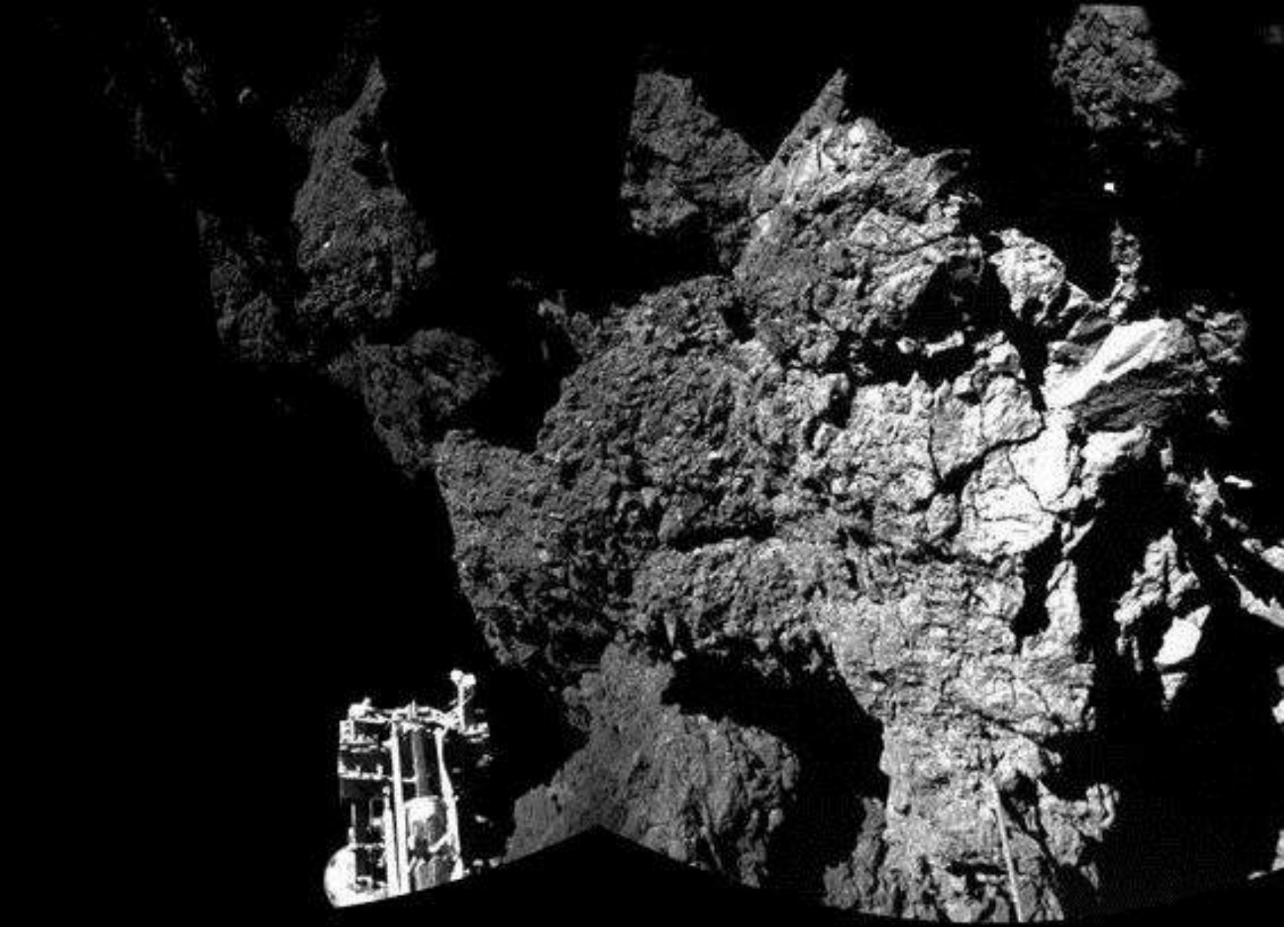




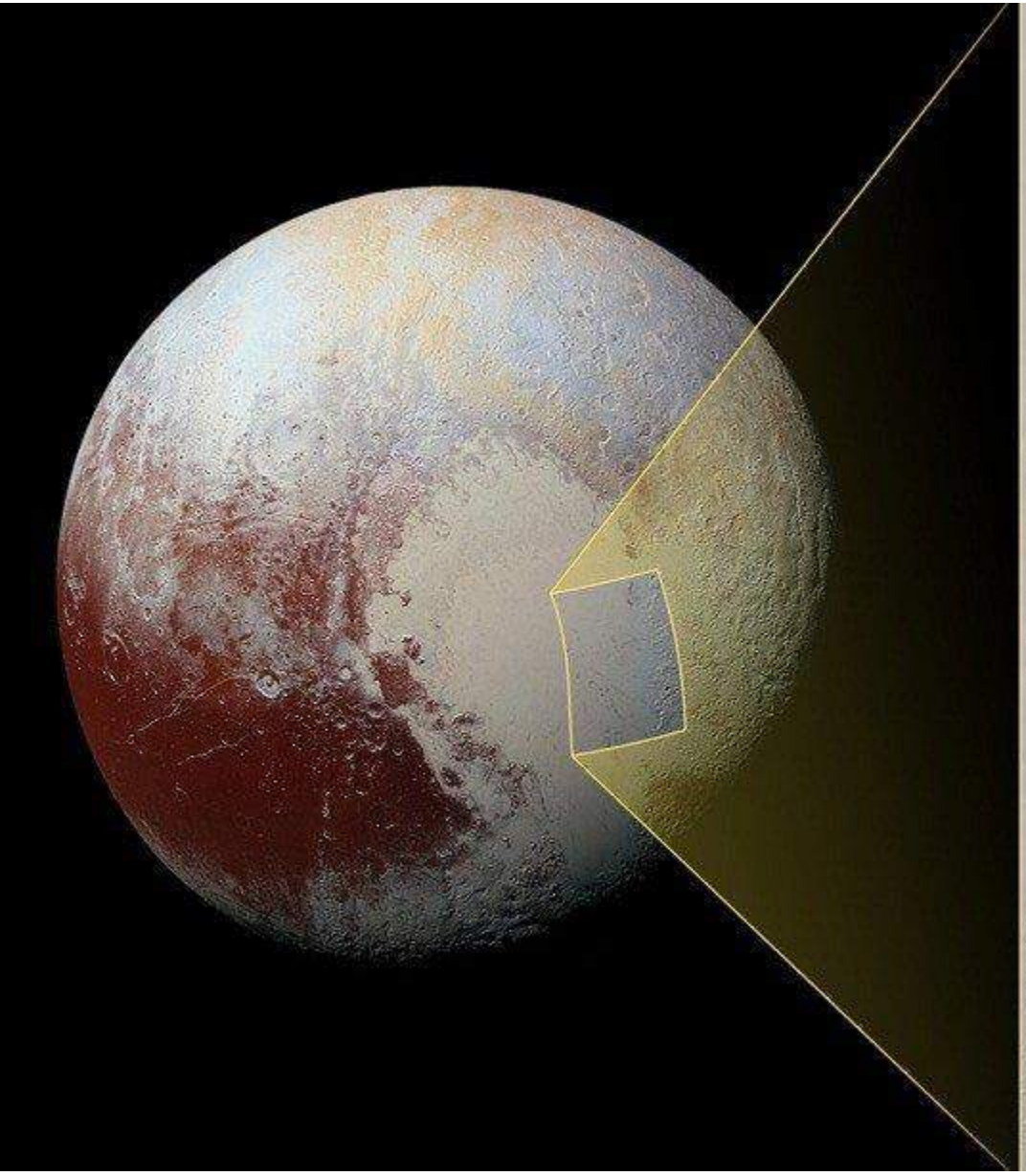


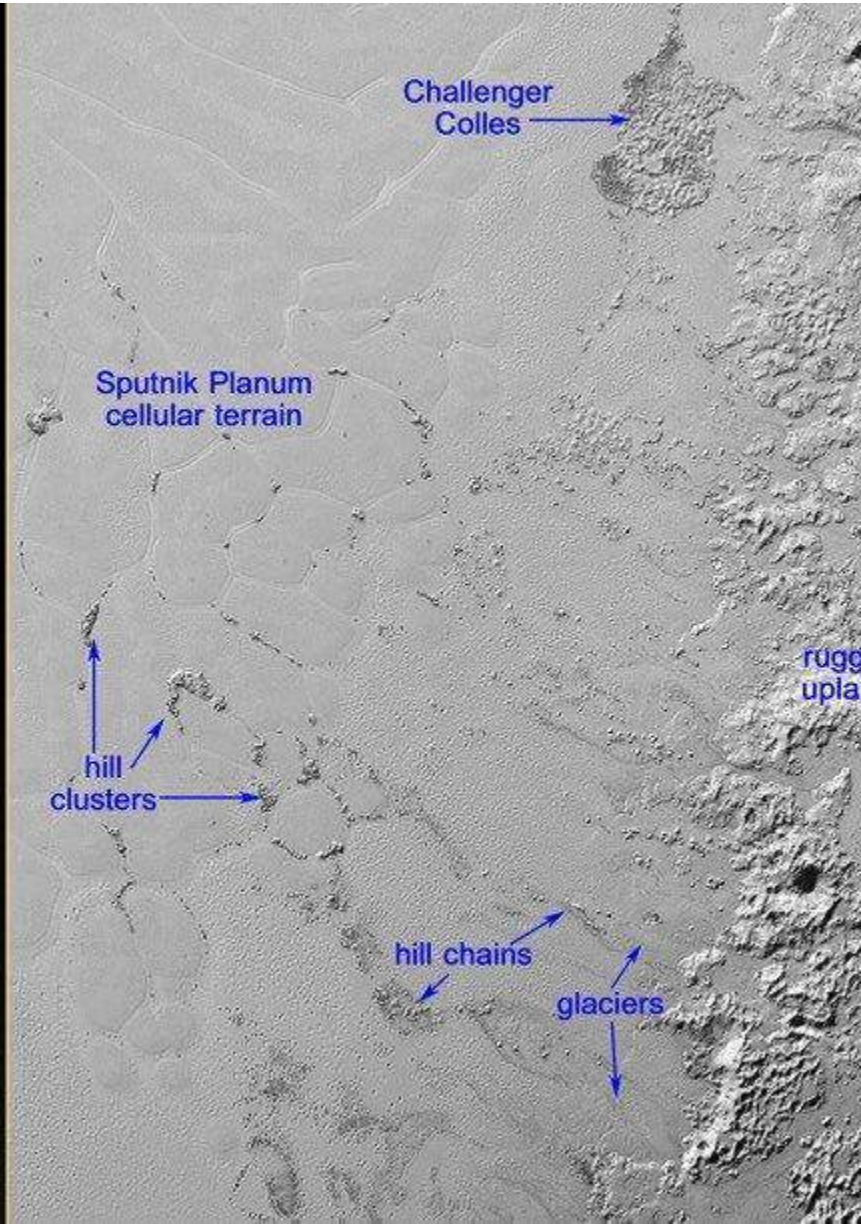


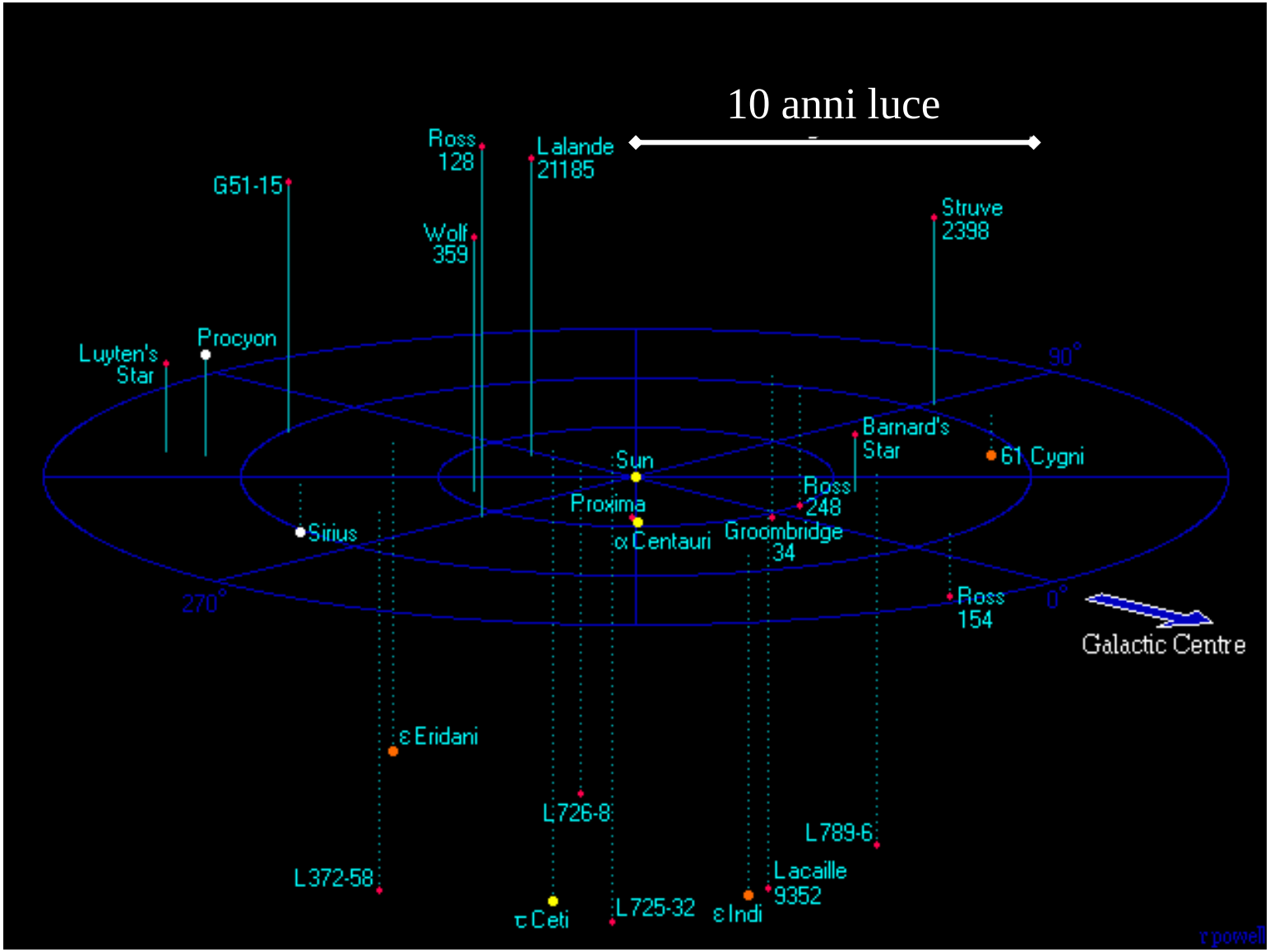

→ MADRID
Plaza de Toros
Palacio Real
4100 m
www.esa.int
Map data ©2014 Google, Bluesky Google



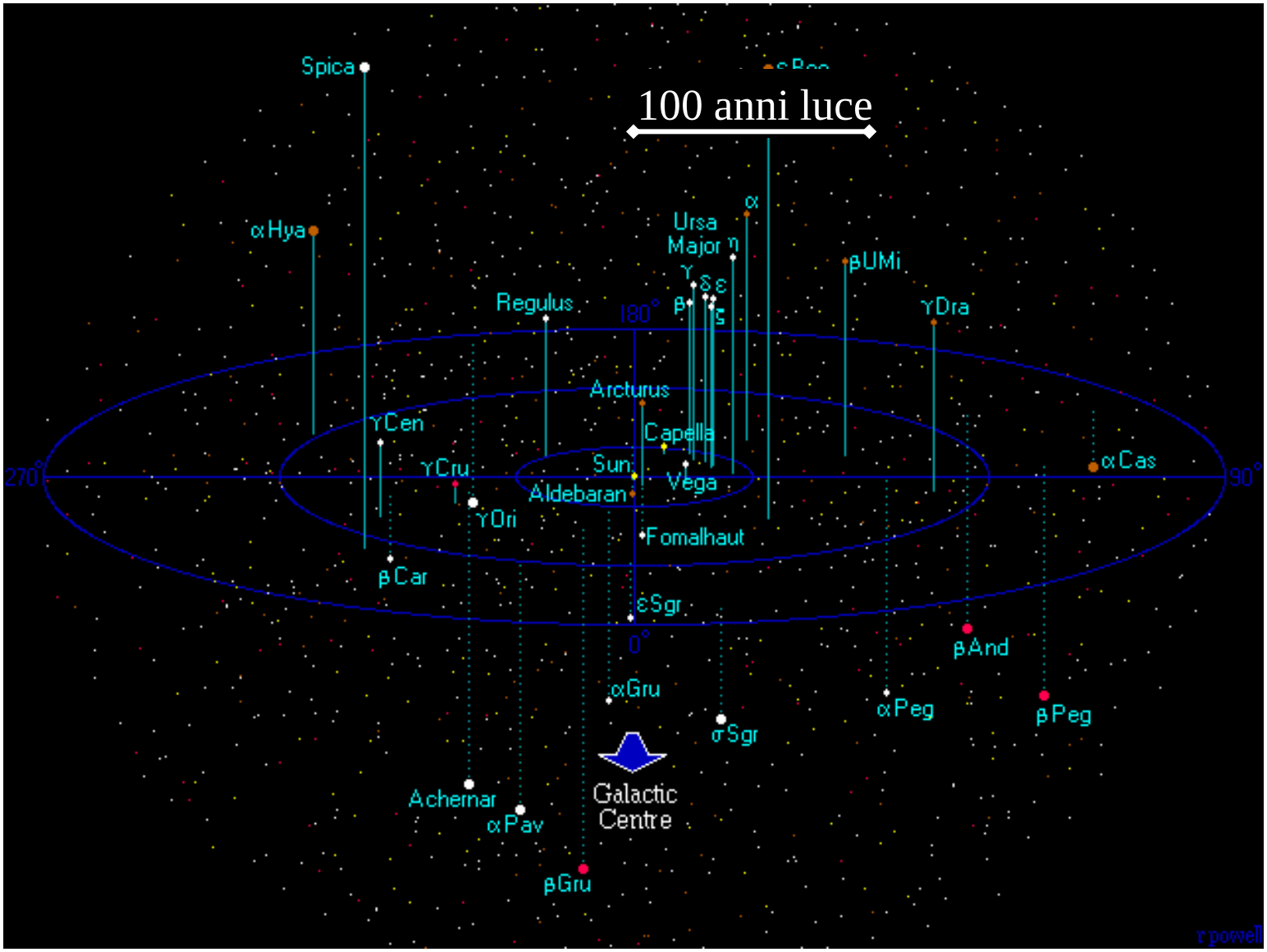

Philae carries 10 research tools and a transmitter that can communicate data to Rosetta to be relayed home. Philae can swivel on its base to sample different areas.
Lander
A monitor studies the magnetic field and solar wind
Ovens analyze comet material
When they're on opposite sides of the comet, Rosetta and Philae send each other radio signals to map 67P's internal structure
Solar cells gather weak sunlight to power the craft after the main battery dies
Seismographs in Philae's feet detect activity in 67P's core as
INSIDE THE COMET
A probe will penetrate the comet if the surface layers are porous
11 in. deep
Measurement will include th temperature and density o the comet's interior
10
YEARS
TO REACH




Challenger
Colles
Sputnik Planum
cellular terrain
hill
clusters
hill chains
glaciers

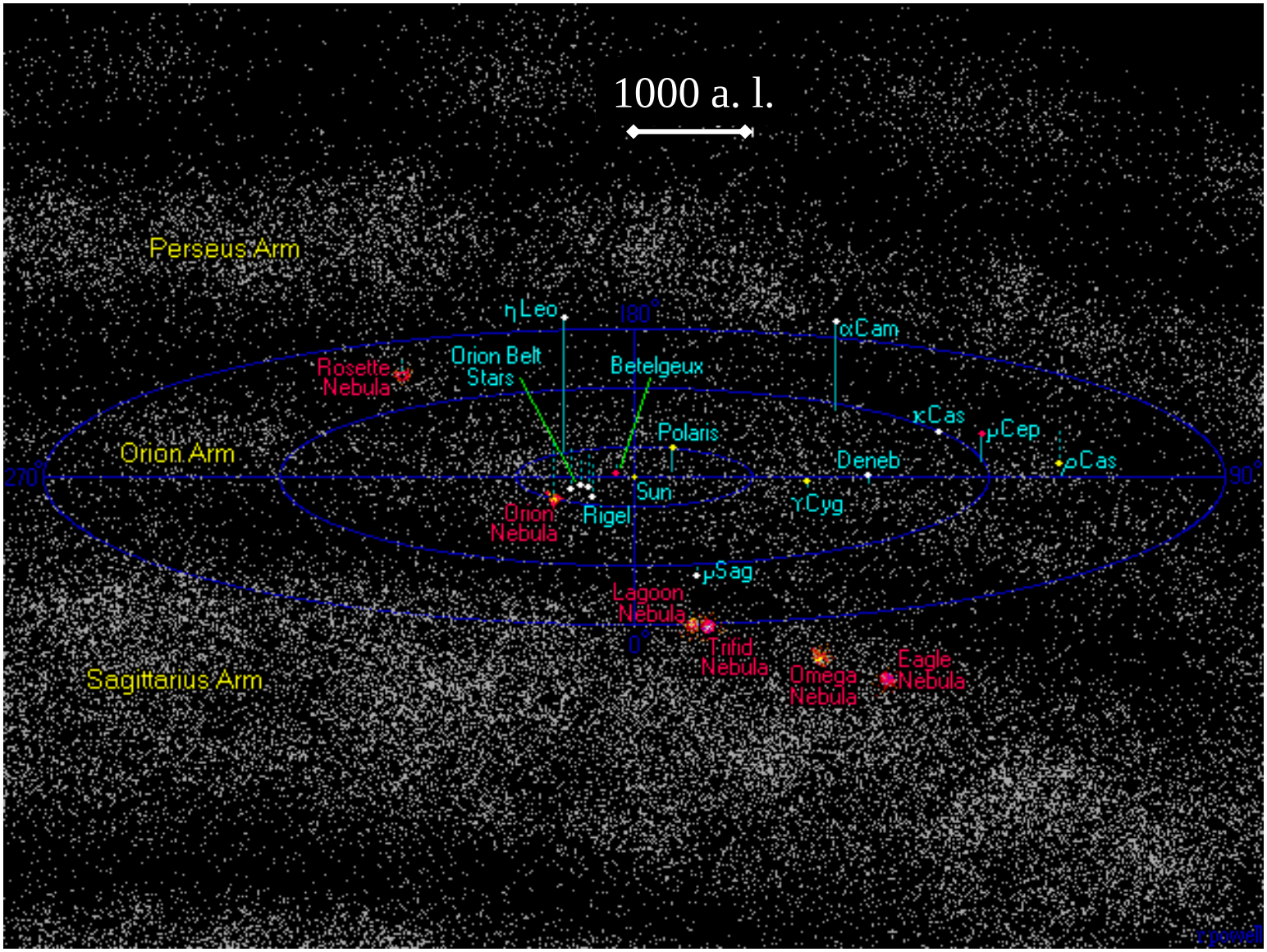

10 anni luce
Ross 128
Lalande 21185
G51-15
Wolf 359
Struve 2398
Luyten's Star
Procyon
90°
Barnard's Star
61 Cygni
Sun
Ross 248
Proxima
Sirius
α Centauri
Groombridge 34
270°
0°
Ross 154
Galactic Centre
ε Eridani
L726-8
L789-6
L372-58
Lacaille 9352
τ Ceti
L725-32
ε Indi
r powell

Zoom Out x20



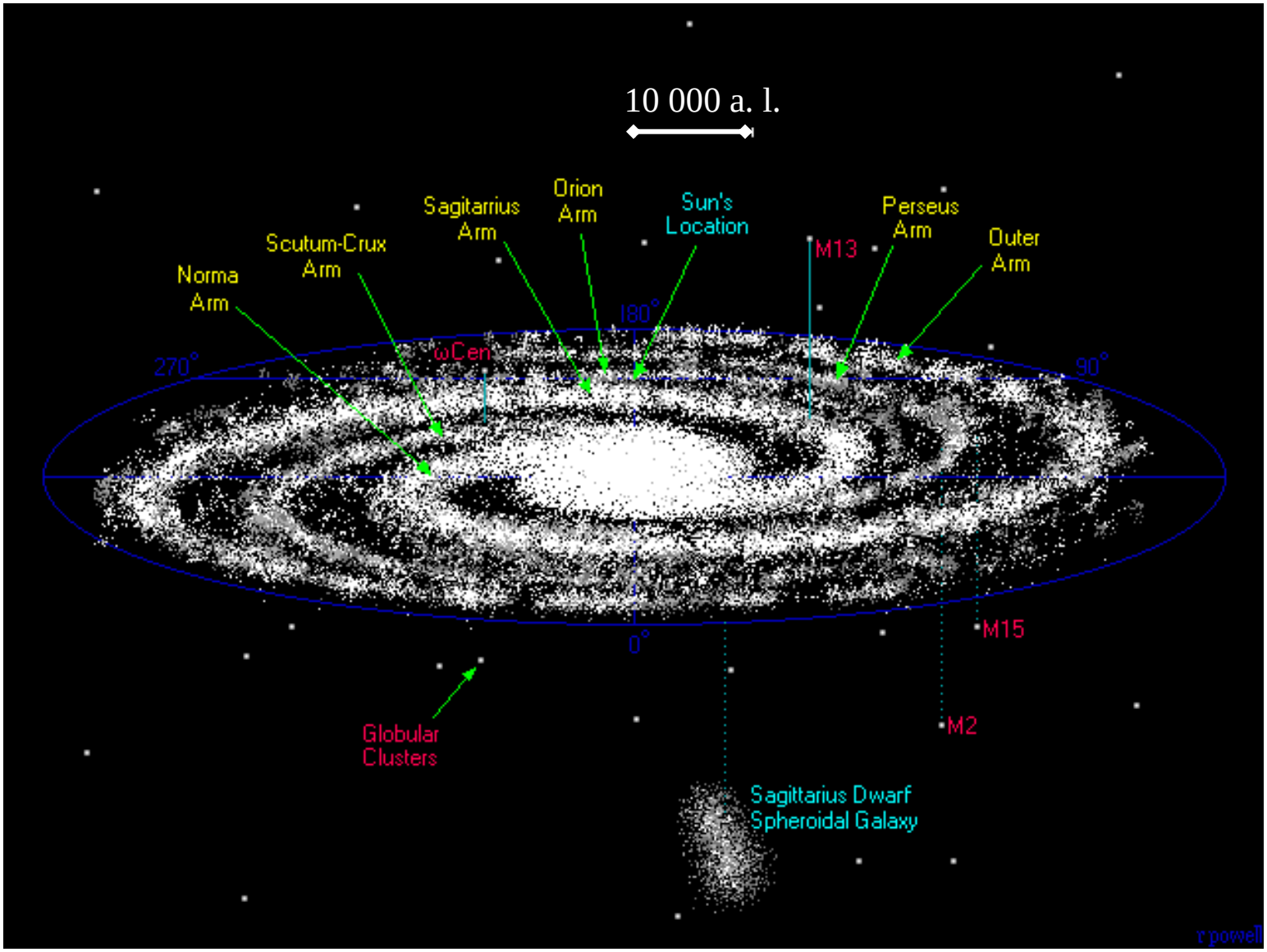
Zoom In x20

Zoom In x20



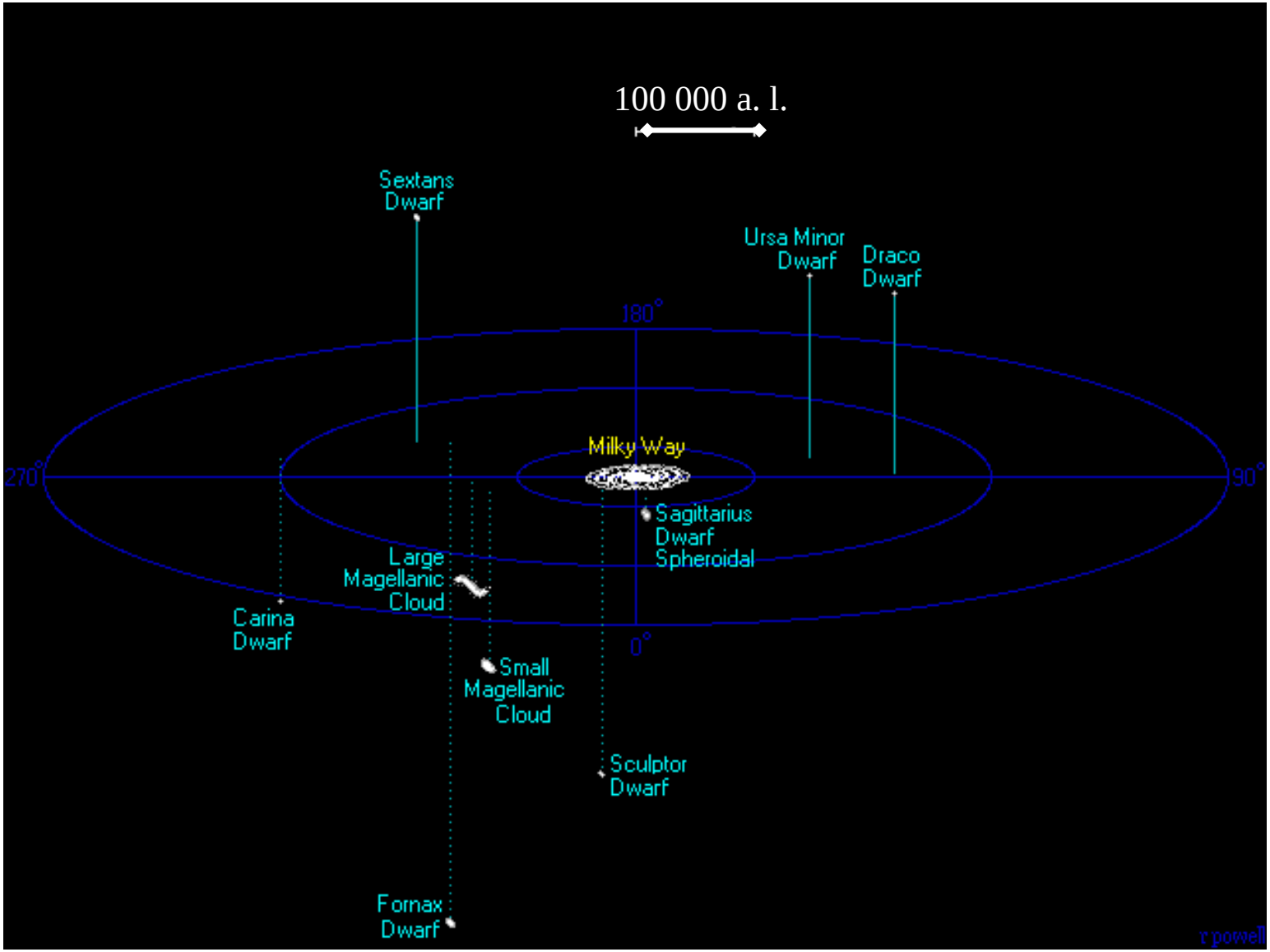
Zoom In x20

Zoom Out x10



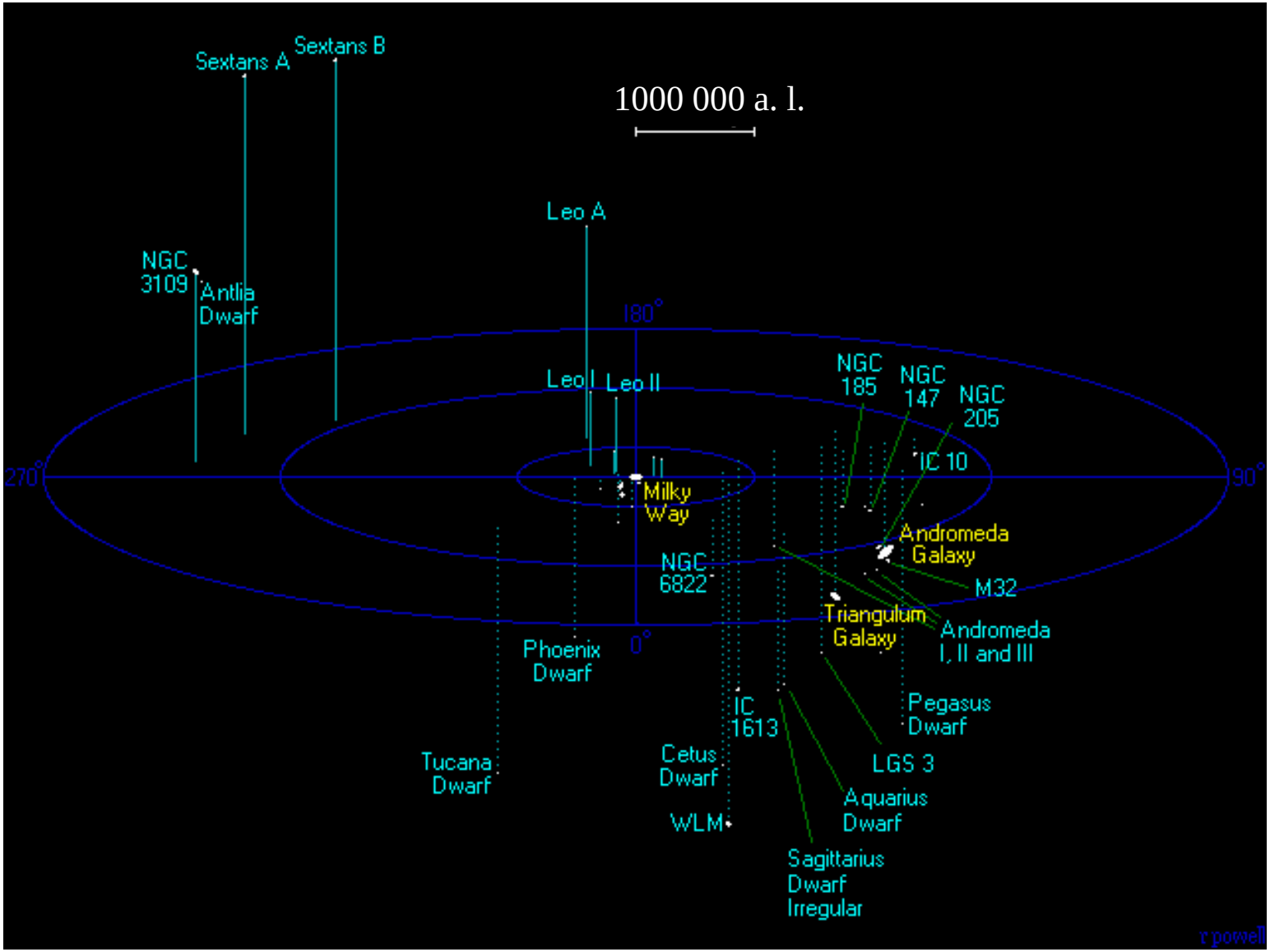
Zoom In x10

Zoom Out x10



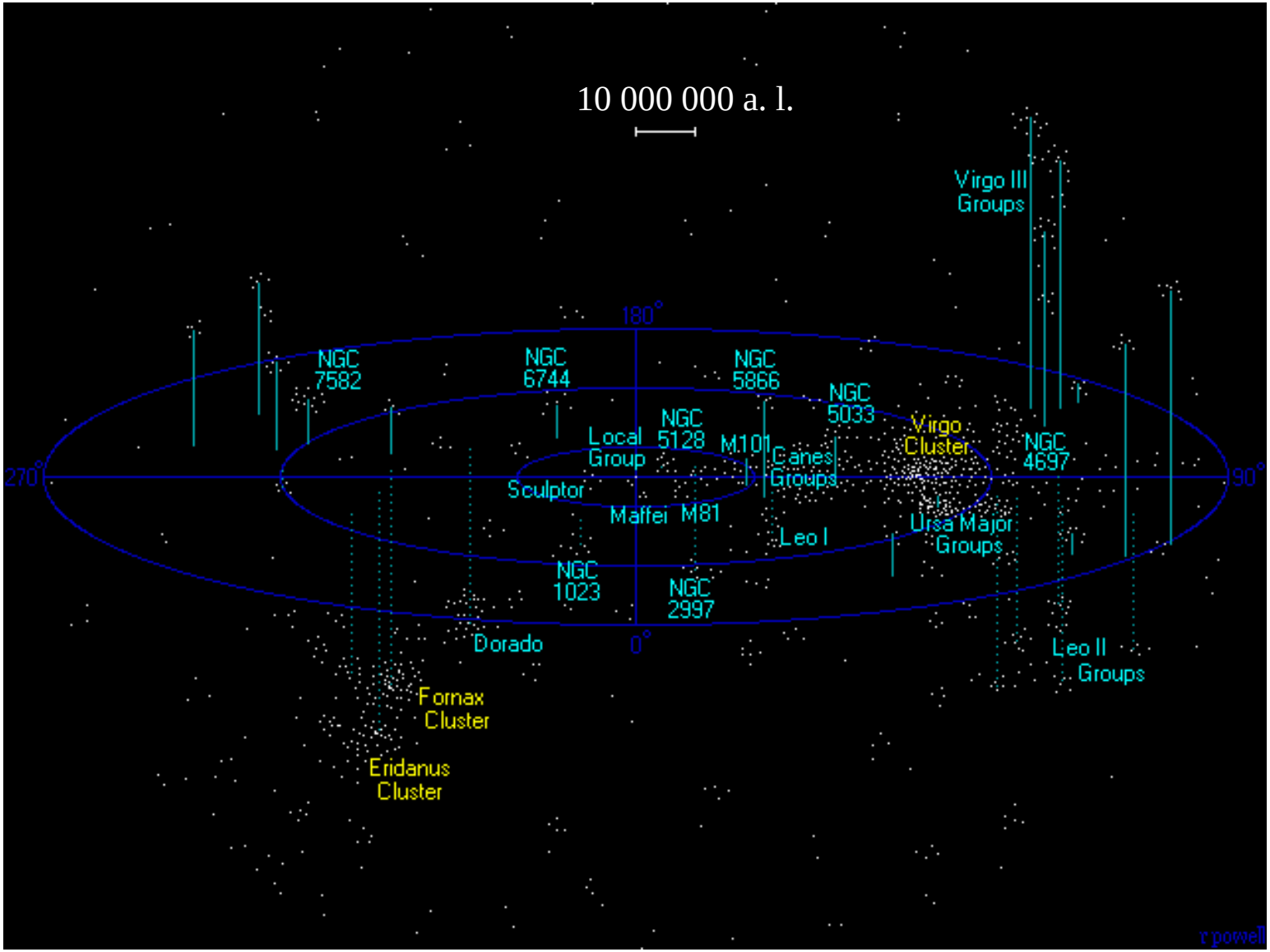
Zoom In x10

Zoom Out x10



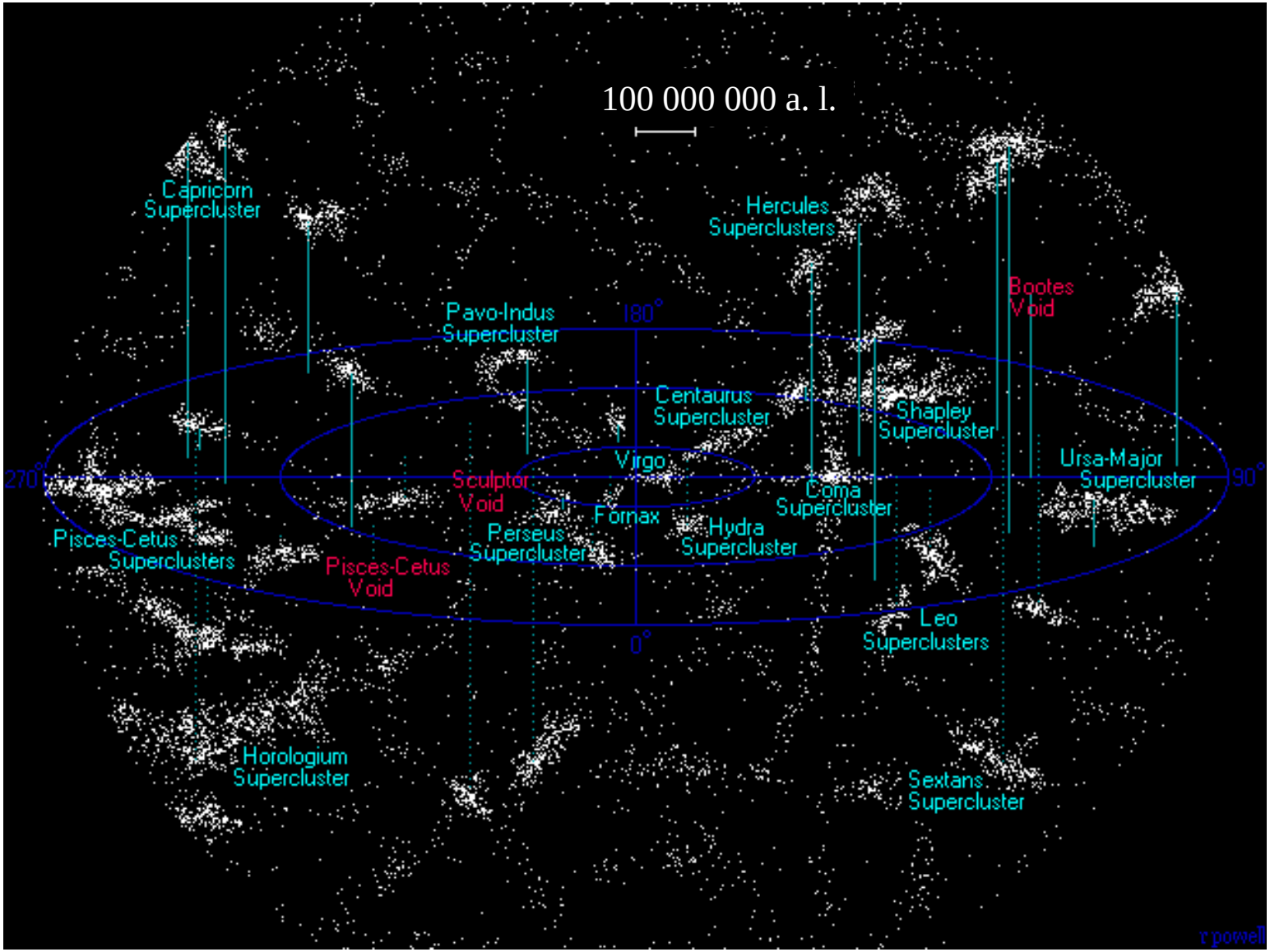
Zoom In x10

Zoom Out x20



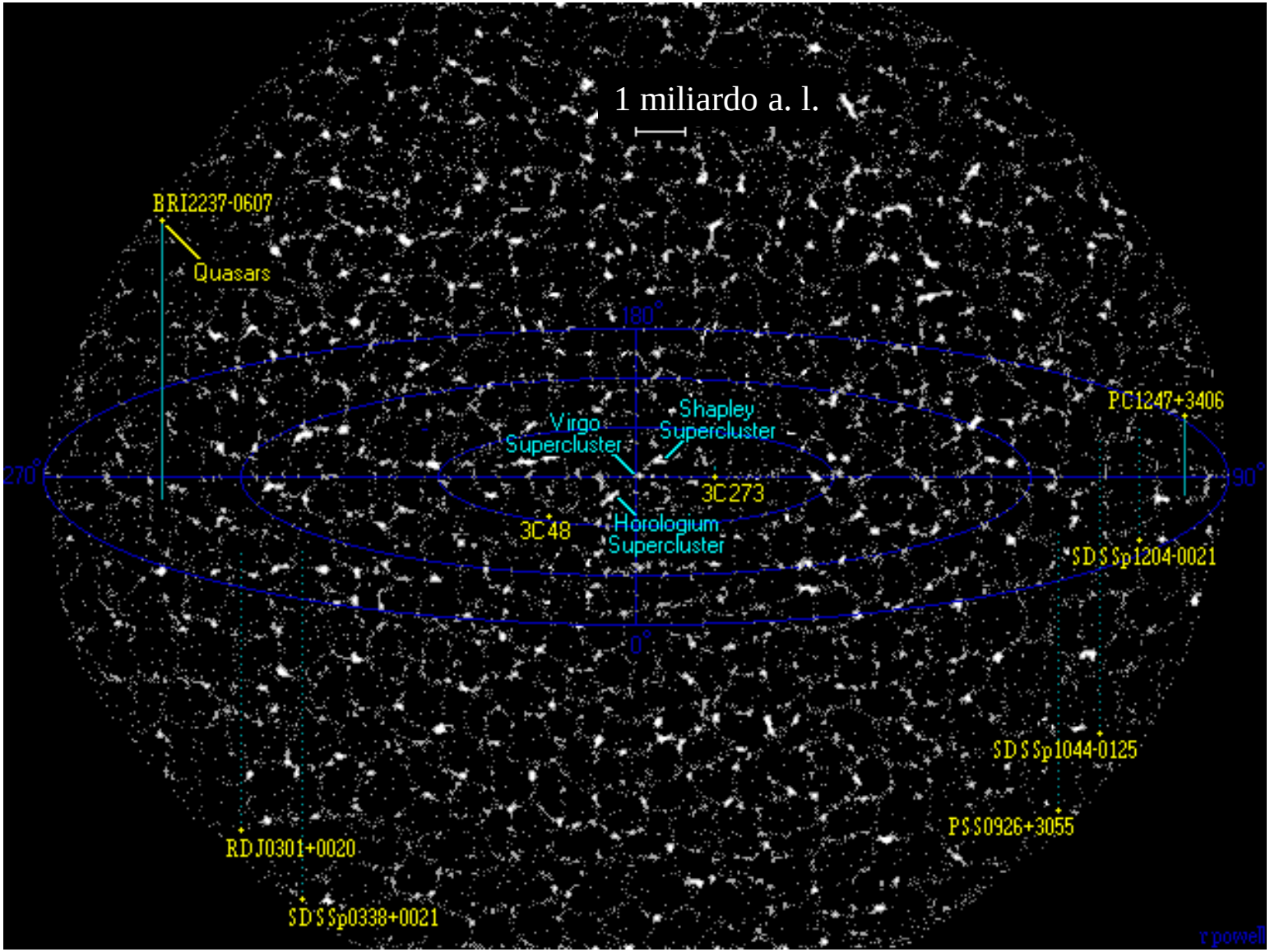
Zoom In x20

Zoom Out x10



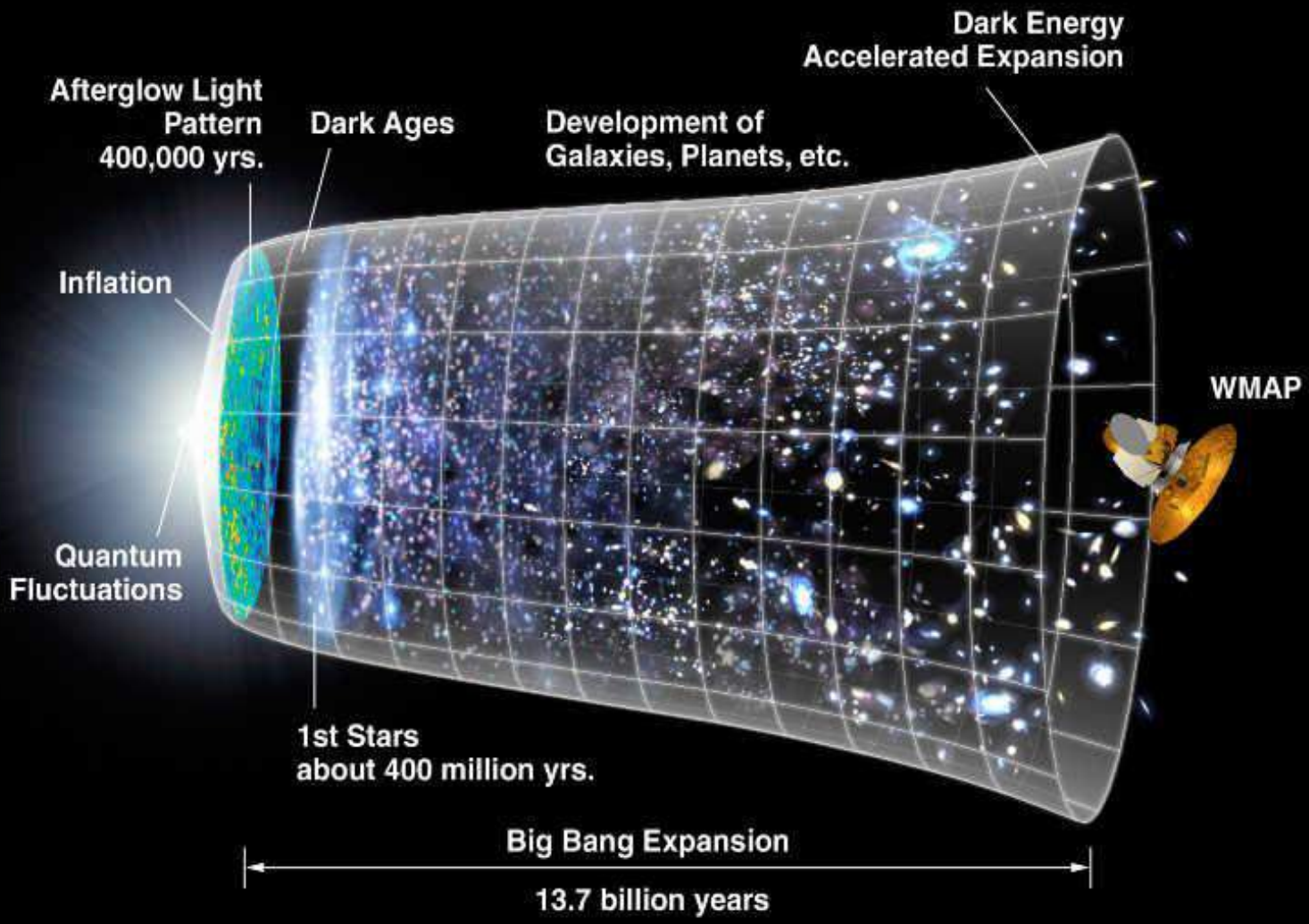
Zoom In x10

Zoom Out x15

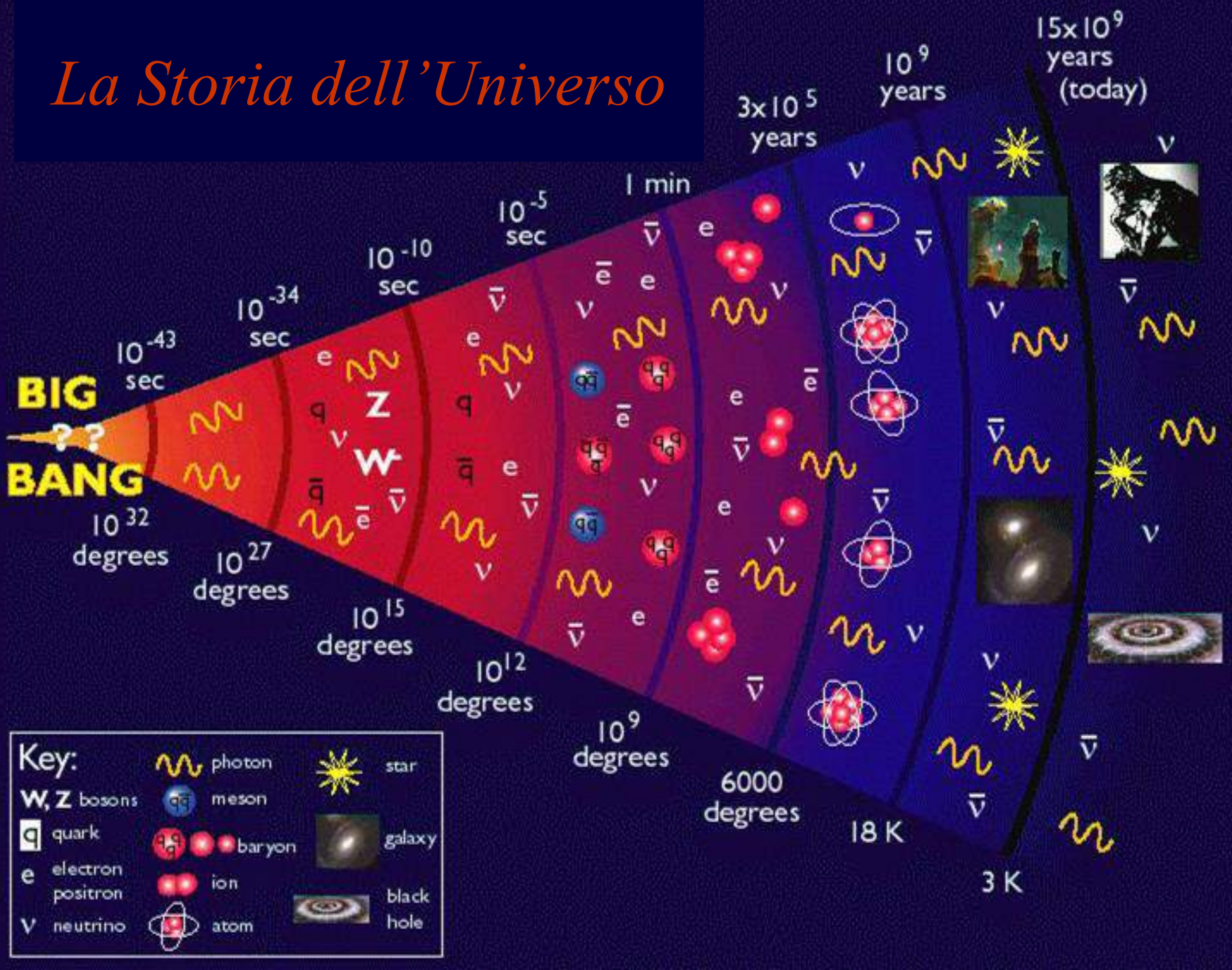

1 miliardo a. l.
BRI2237-0607
Quasars
180°
270°
90°
0°
Virgo
Supercluster
Shapley
Supercluster
3C273
3C48
Horologium
Supercluster
PC1247+3406
SDSSp1204-0021
SDSSp1044-0125
PSS0926+3055
RDJ0301+0020
SDSSp0338+0021
r powell

Zoom In x15

The Big Bang Model



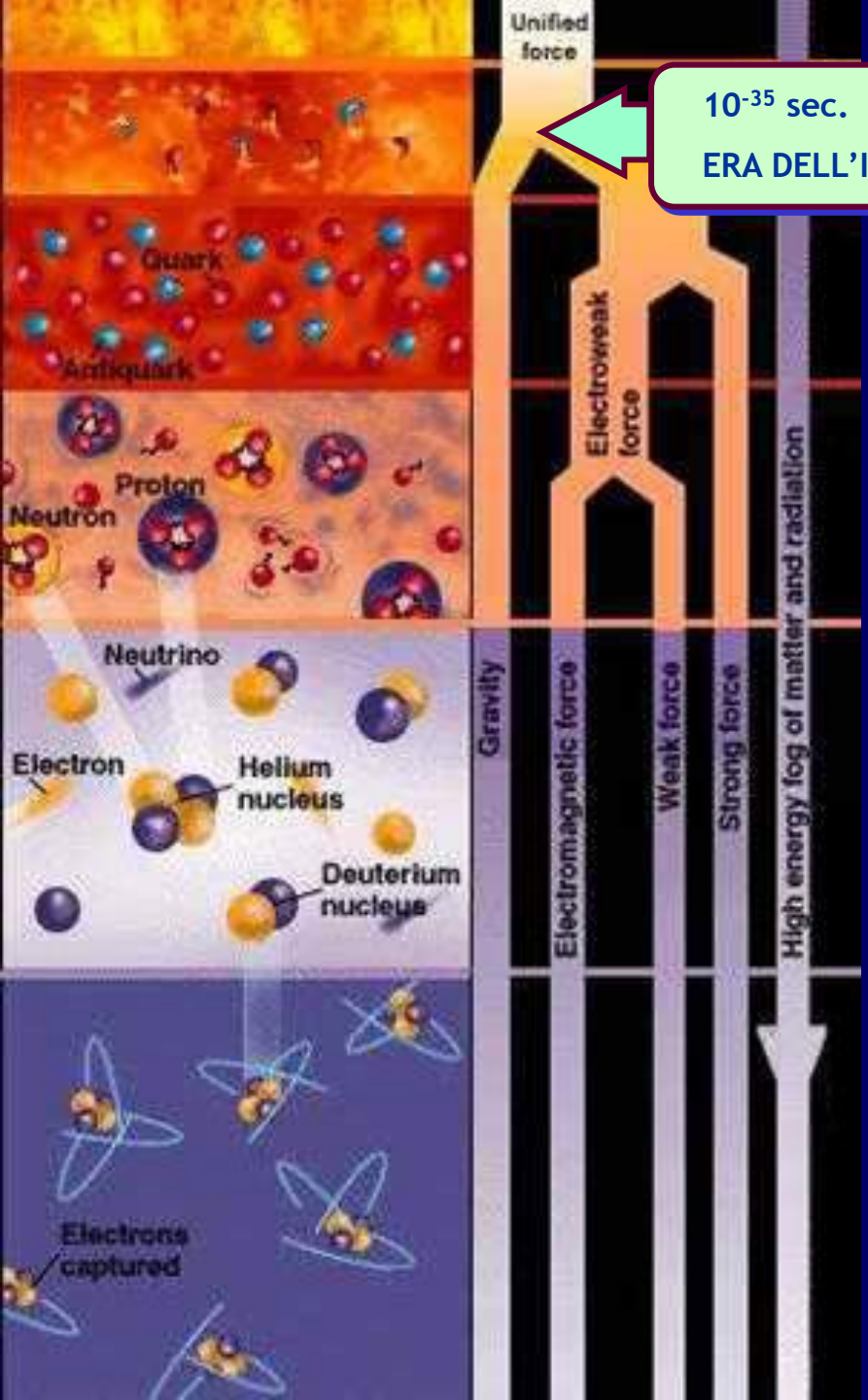
La Storia dell'Universo



Nascita del tempo e dello spazio

- Un evento che diede inizio alla scala del tempo e dello spazio. Di conseguenza in origine tutto doveva essere concentrato in un minuscolo “punto”, dalla densità e gravità infinite, dove il tempo e lo spazio erano pari a zero e la temperatura dell'ordine di miliardi di miliardi di gradi.

- Cosa ci fosse prima rimane per ora un mistero



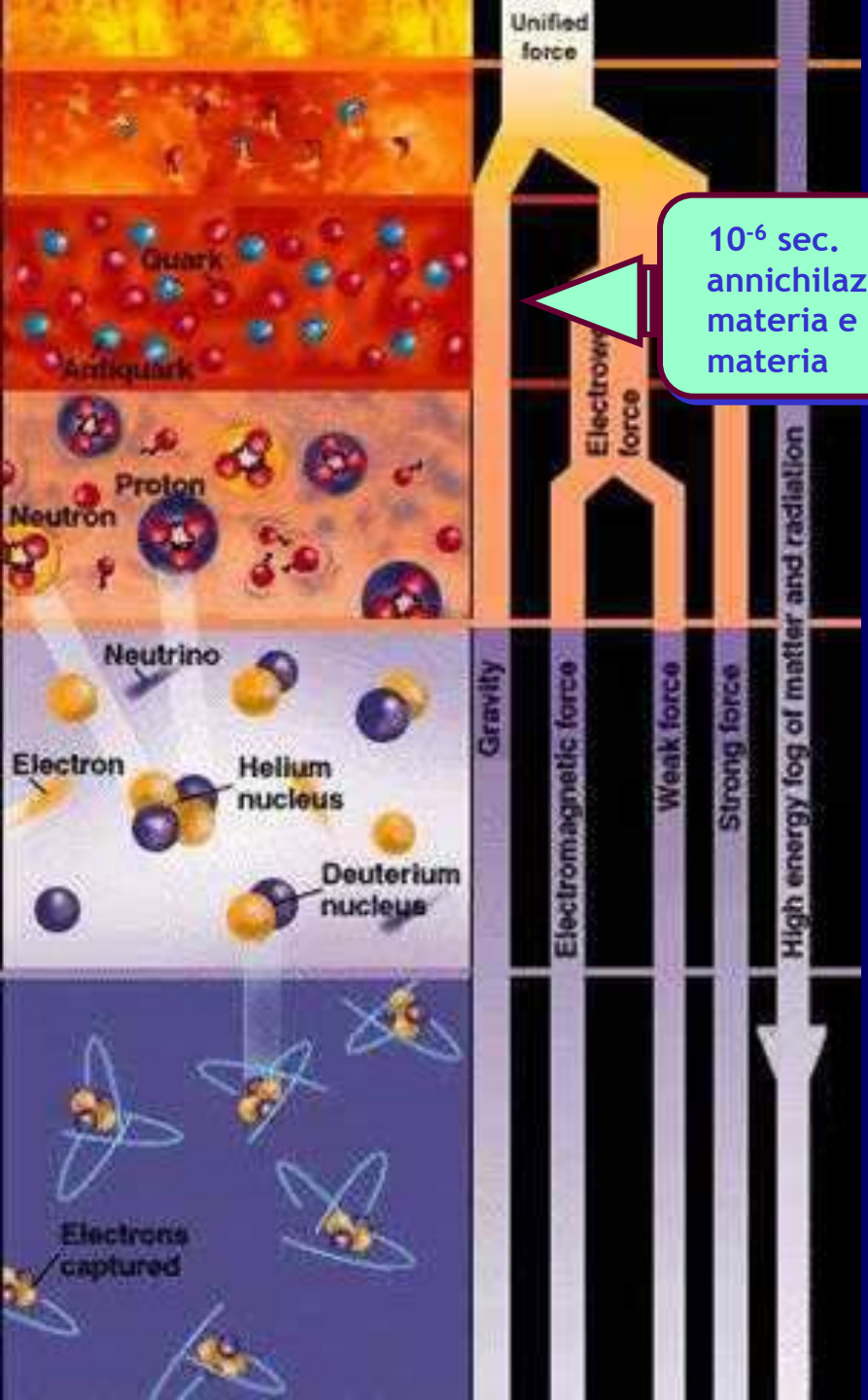
10^{-35} sec.

ERA DELL'INFLAZIONE

Il Big Bang

- Il Big Bang non è stato un esplosione nello spazio, ma l'espansione dello spazio.
- **Durante l'era dell'inflazione (10^{-35} sec.) l'universo si è espanso in modo esponenziale (con velocita' molto piu' grande di quella della luce....)**
- **? Commento: BICEP2.**

Il Big Bang

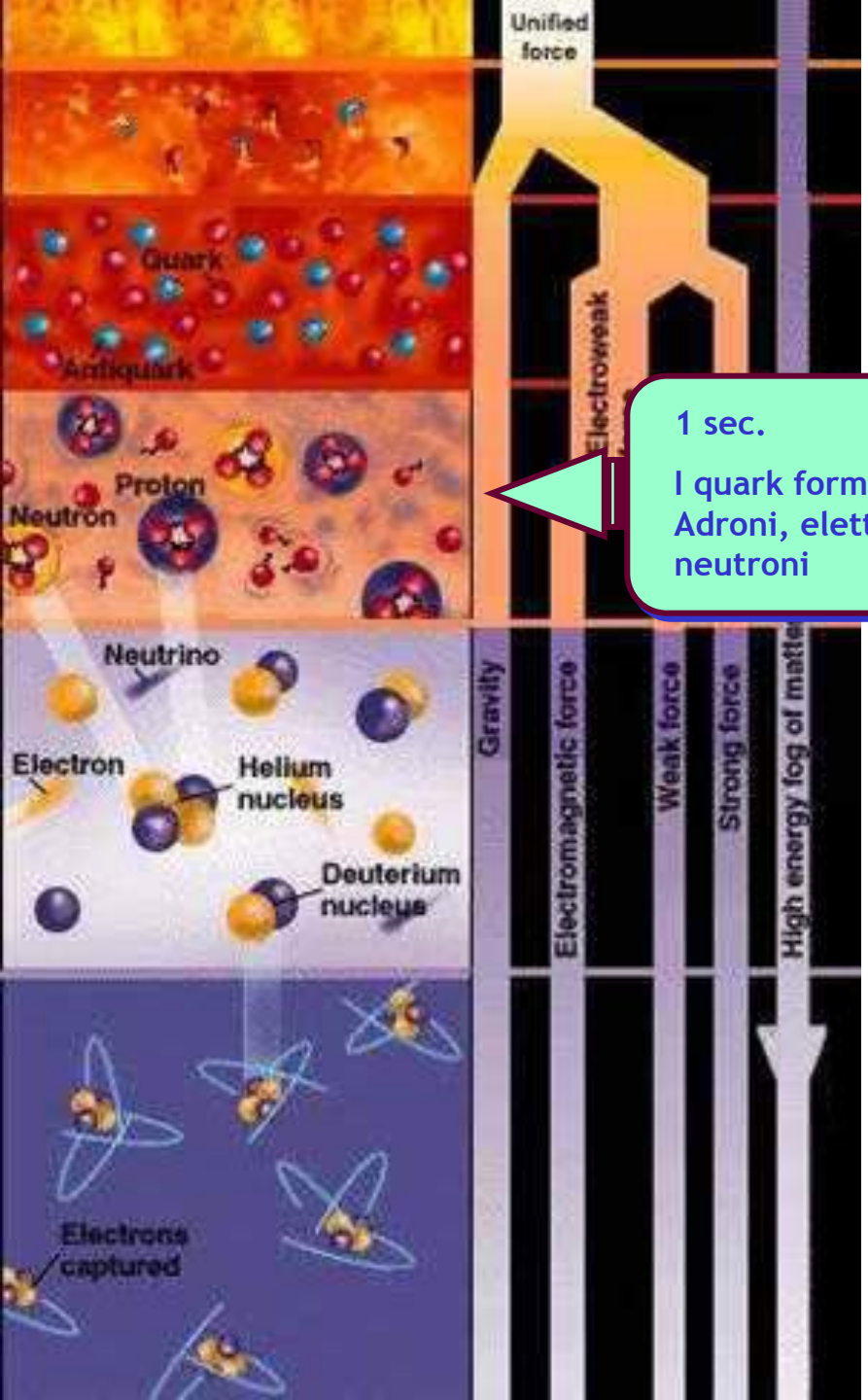


10^{-6} sec. annichilazione di materia e anti-materia

ERA DEI QUARK

- In questa fase si sono formate dall'energia moltissime copie di quark e antiquark, che si annichilivano ridiventando energia.
- Cosa succede all'antimateria?

Il Big Bang



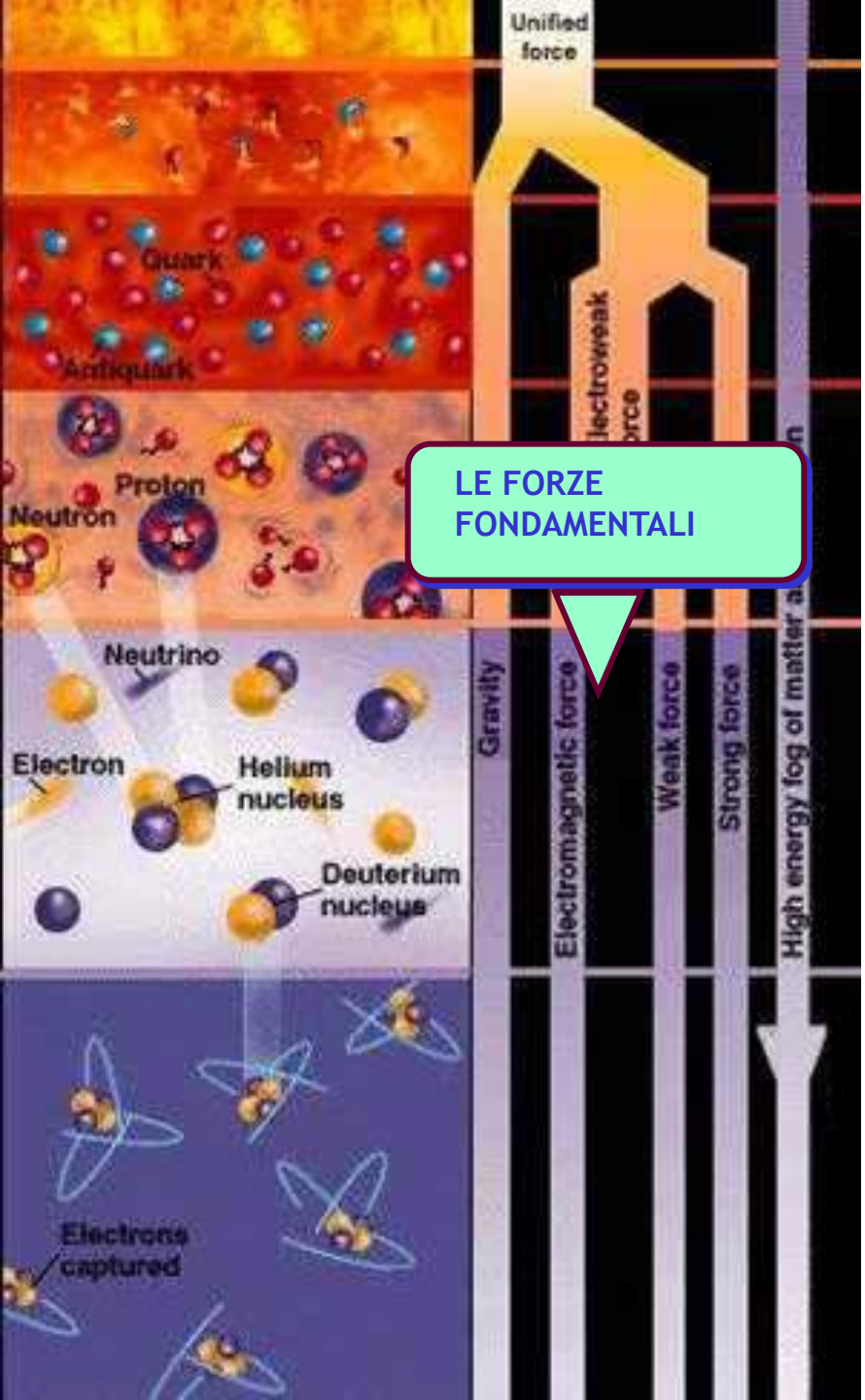
1 sec.

I quark formano Adroni, elettroni e neutroni

I PRIMI PROTONI E NEUTRONI

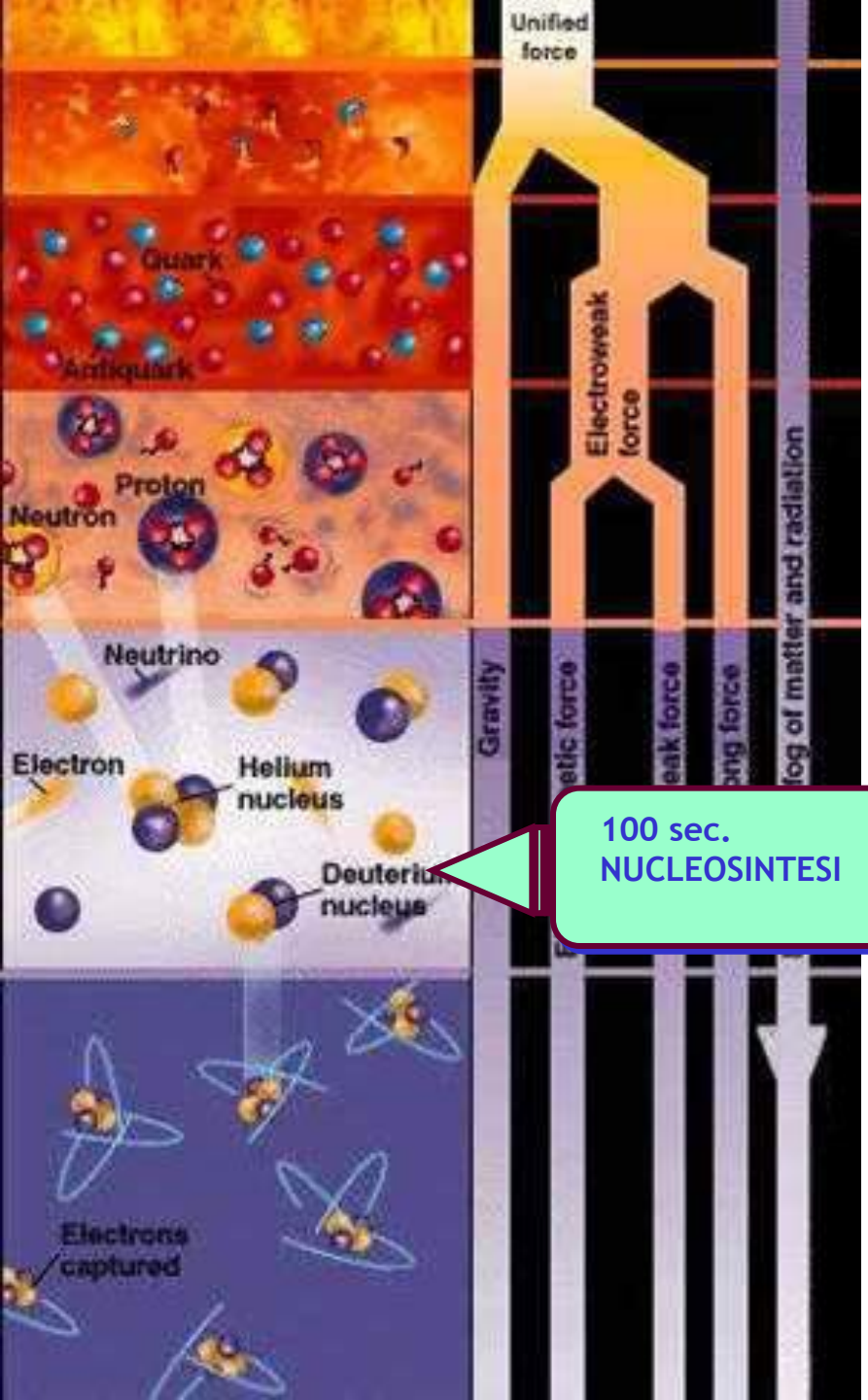
Dopo 1 μs l'universo era abbastanza freddo perché i quark potessero combinarsi e formare particelle più massicce: protoni e neutroni

Il Big Bang



- **Subito dopo entrarono in gioco le forze fondamentali dell'universo, ed alla già esistente forza gravitazionale, che regola l'attrazione fra le masse, si aggiunsero le altre tre che insieme a questa governano l'universo:**
  - **la forza debole, che agisce a livello atomico,**
  - **la forza forte che governa i nuclei atomici,**
  - **la forza elettromagnetica responsabile di tutti i fenomeni elettromagnetici quali la luce, le onde radio, ecc...**

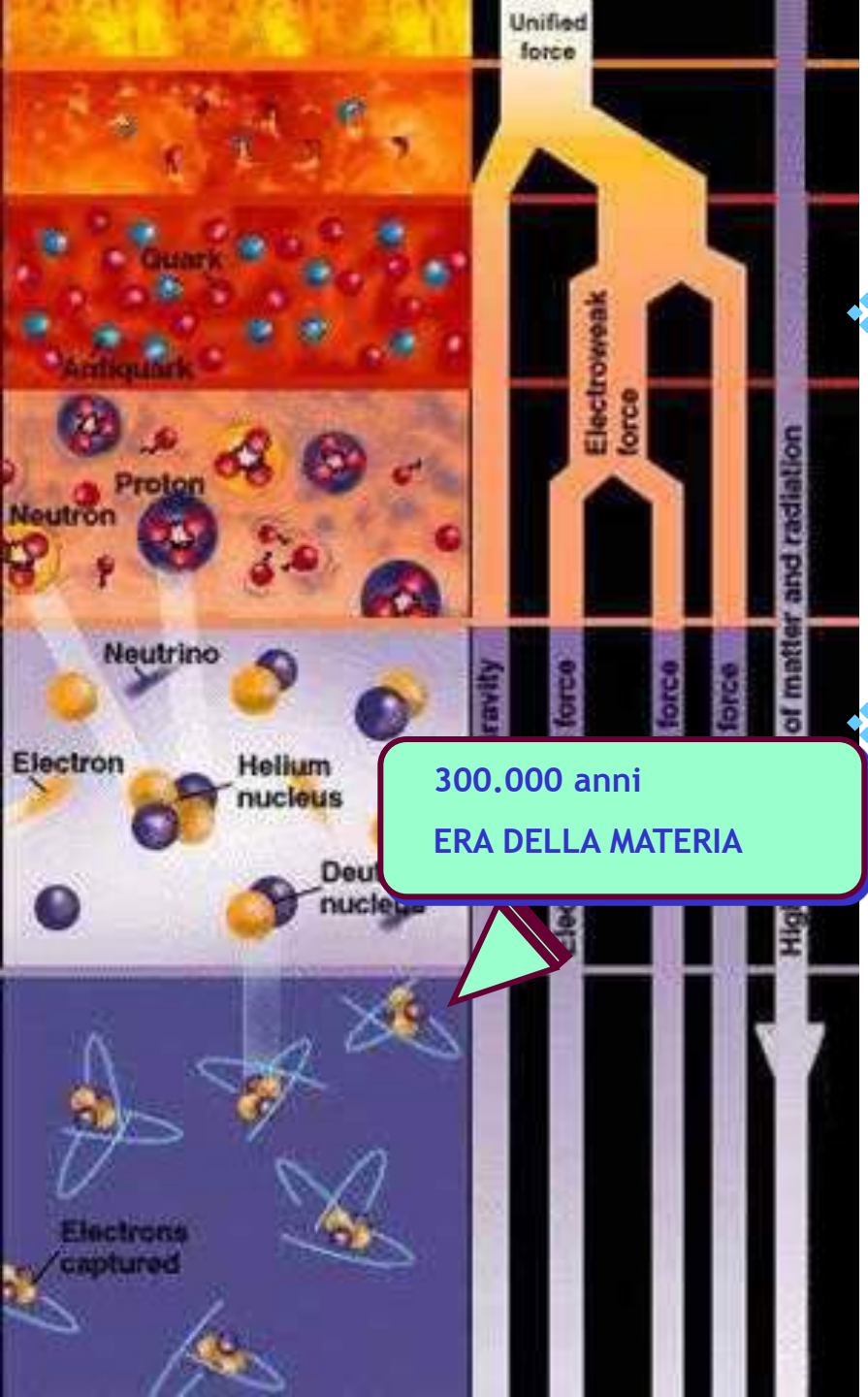
Il Big Bang



- ERA DELLA NUCLEOSINTESI

- **In questa fase i neutroni si sono gradualmente trasformati in protoni. Mentre la temperatura dell'universo si abbassava, gradualmente i neutroni si combinavano con i protoni per formare i primi nuclei di elio ognuno formato da 2 protoni e 2 neutroni**.

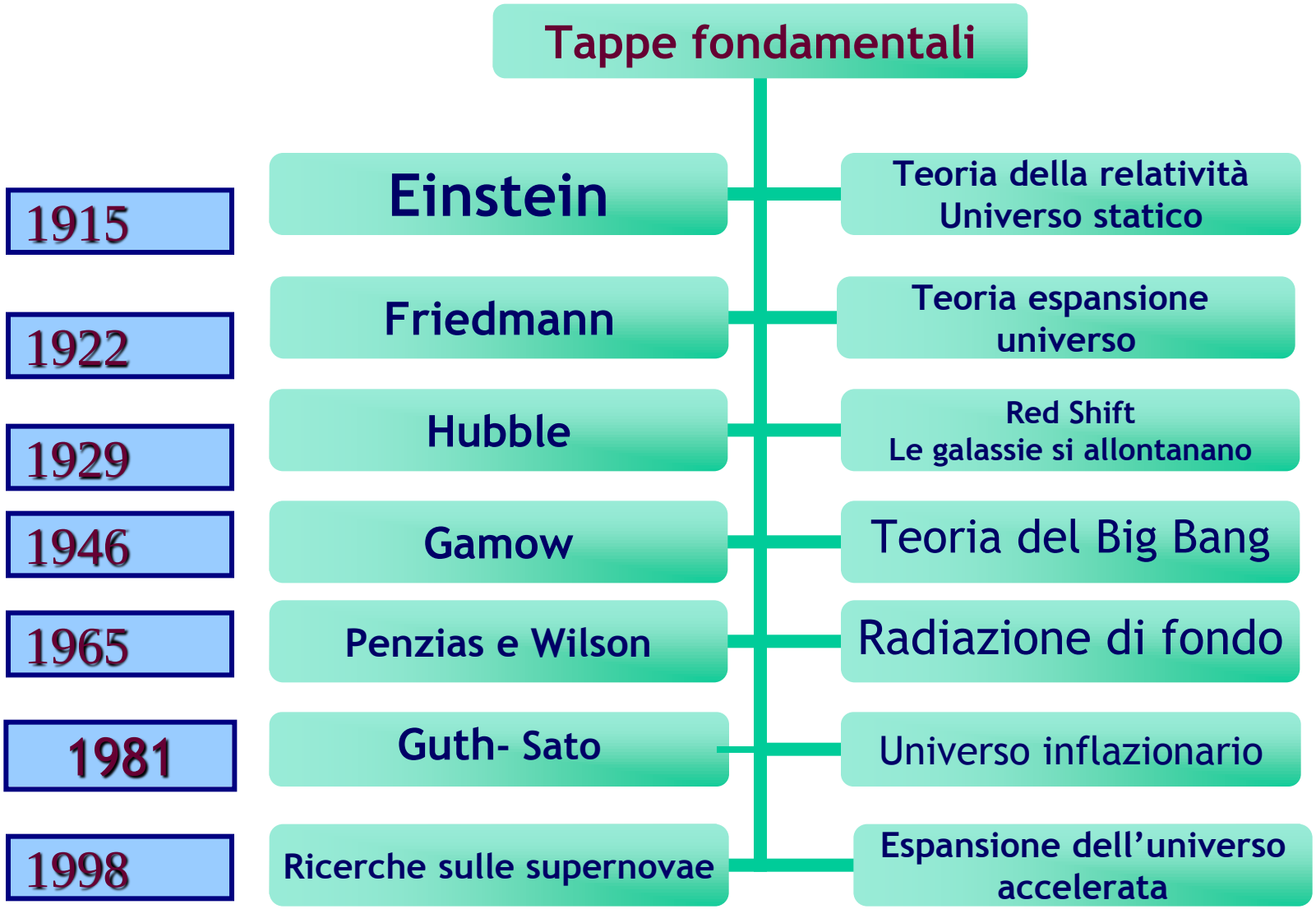
Il Big Bang



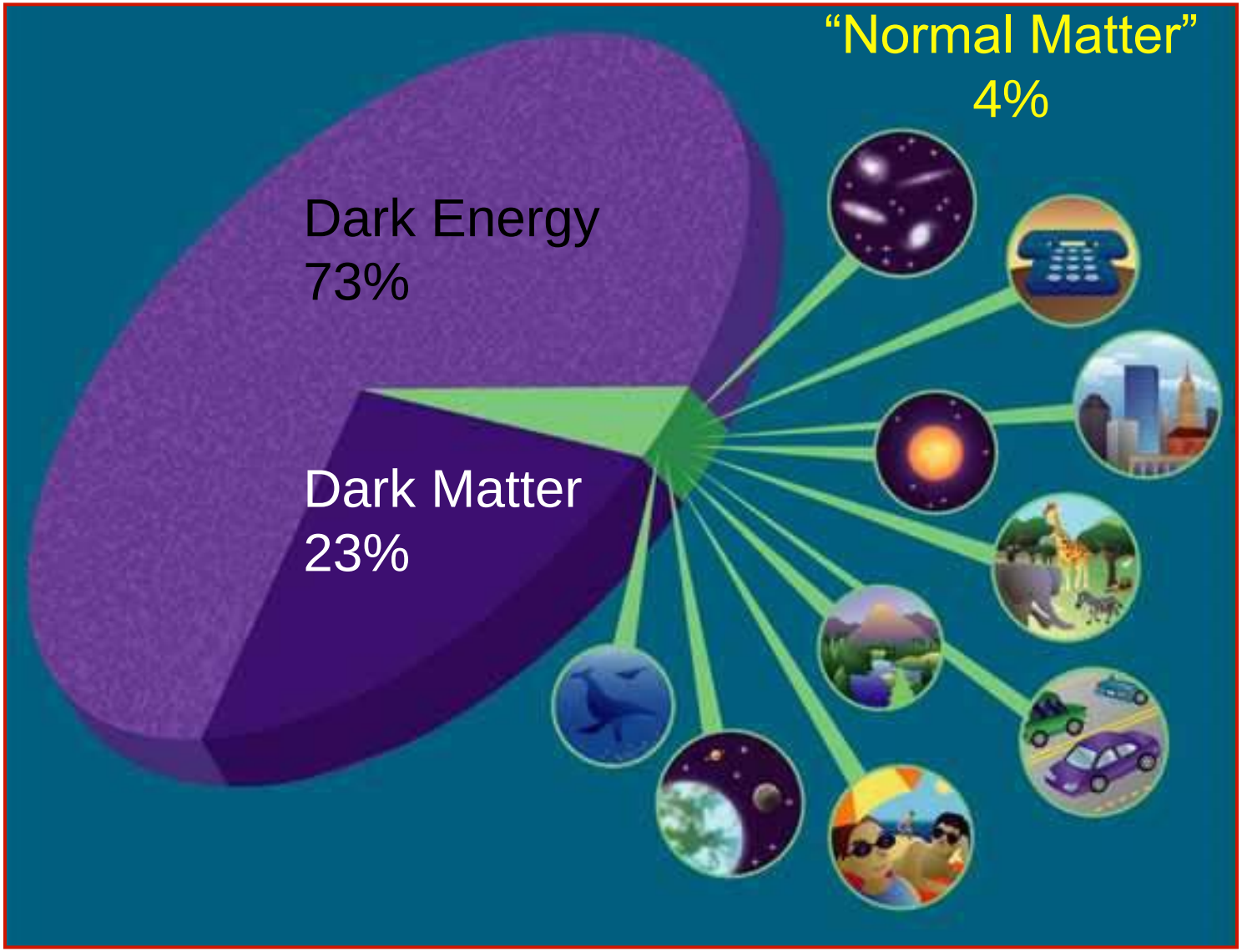
- **Dopo alcune centinaia di migliaia di anni, l'universo era divenuto ancora meno denso e più freddo, avveniva la "ricombinazione", i protoni e gli elettroni si combinavano per creare i primi atomi di idrogeno.**

- **Finiva a quel punto la prima parte della storia dell'universo, quella dominata dalla radiazione, ed iniziava "l'era della materia" che vedeva l'aggregazione delle particelle nelle prime forme atomiche, mentre i fotoni, liberi ormai da ogni vincolo, potevano così irradiarsi in tutte le direzioni sotto forma di radiazione cosmica di fondo.**

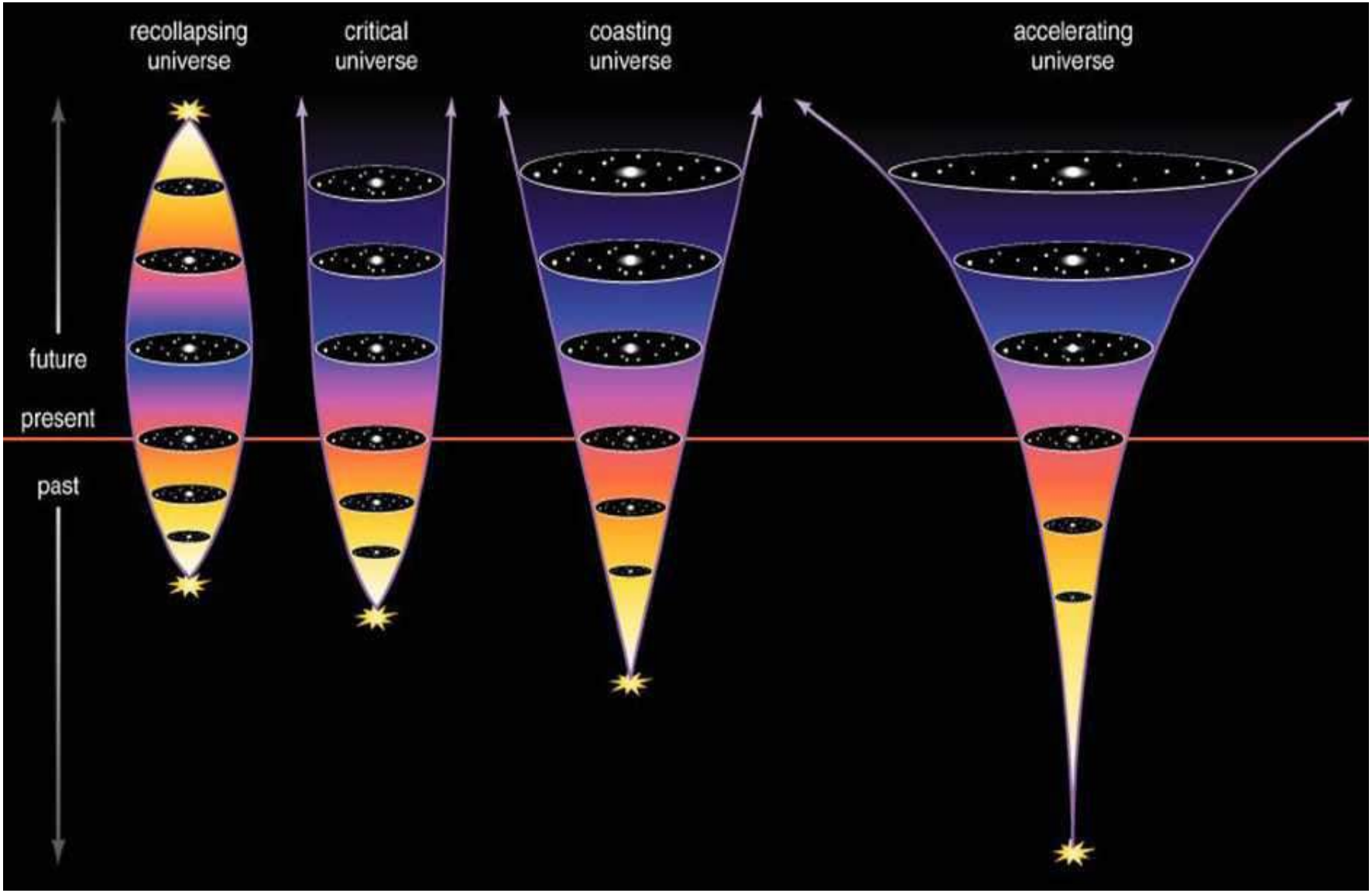
Cronologia delle scoperte



Materia ed energia



I modelli Cosmologici



Da cosa è costituita la materia oscura?

Non è fatta di materia barionica

ma di particelle sconosciute

(Forse LHC?)

Una forza che

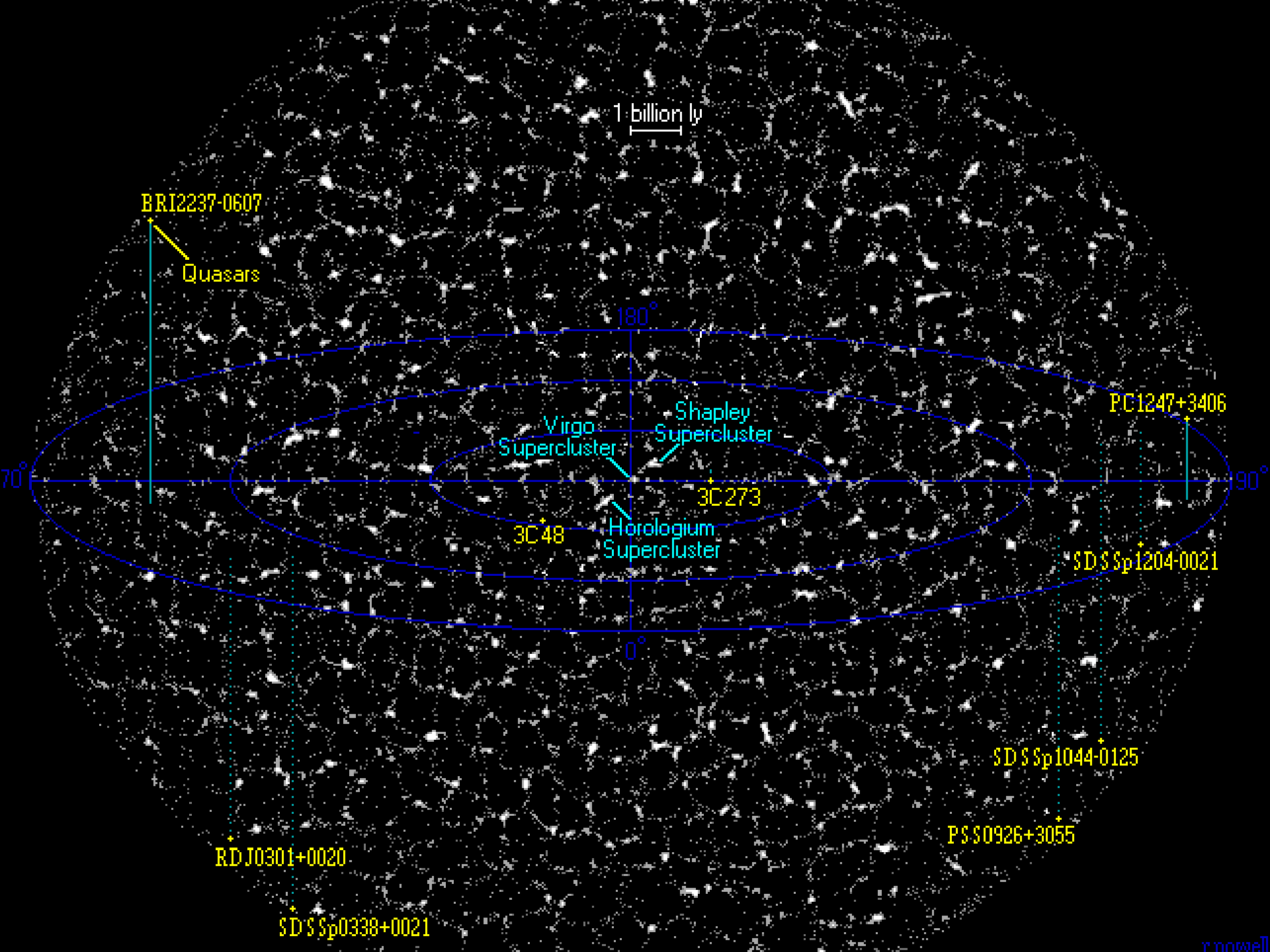
si oppone alla gravità

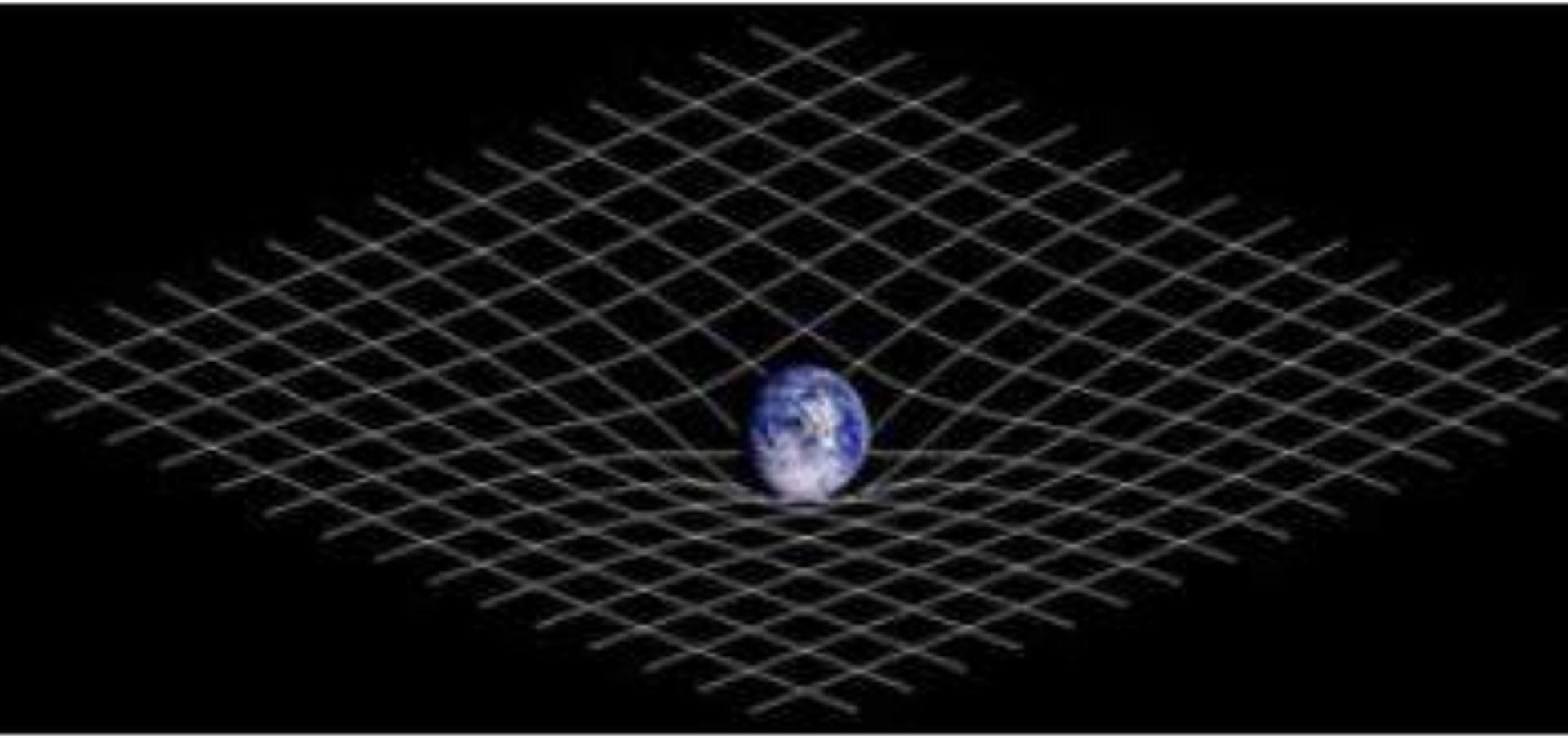
Antigravità

Quintessenza

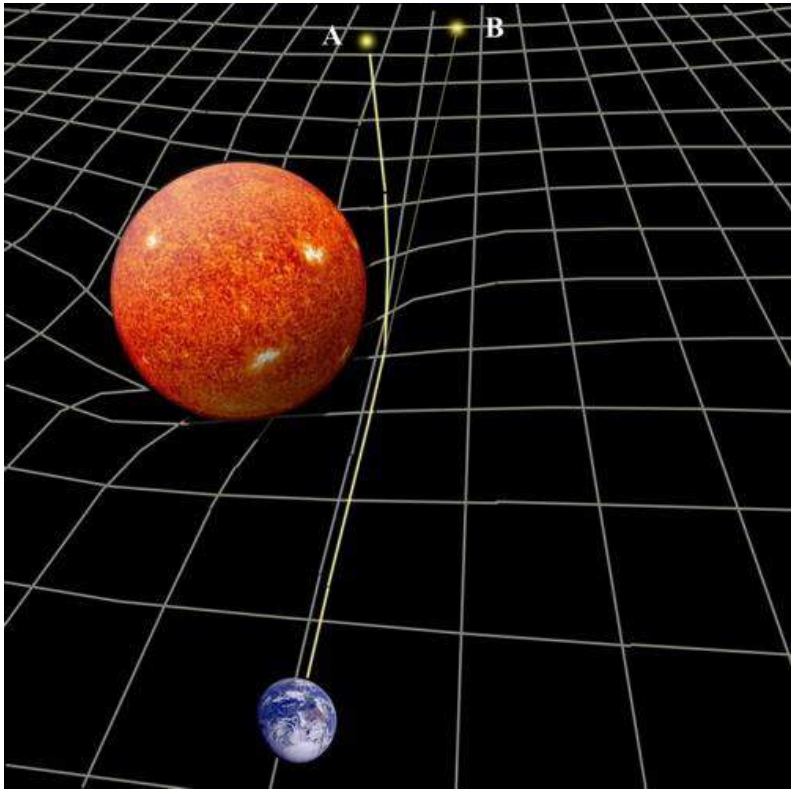
Costante cosmologica

Energia oscura


1 billion ly
BRI2237-0607
Quasars
180°
70°
90°
0°
Virgo
Supercluster
Shapley
Supercluster
3C273
3C48
Horologium
Supercluster
PC1247+3406
SDSSp1204-0021
SDSSp1044-0125
PSS0926+3055
RDJ0301+0020
SDSSp0338+0021



Relativita' generale

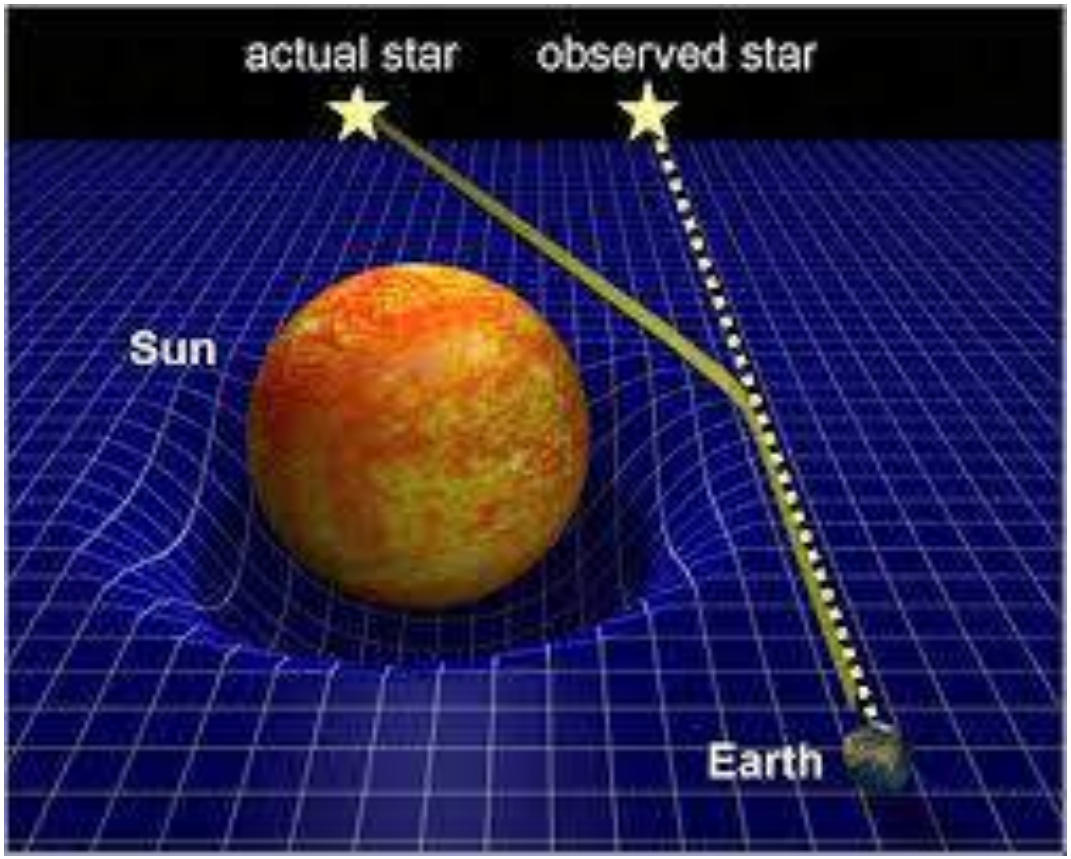


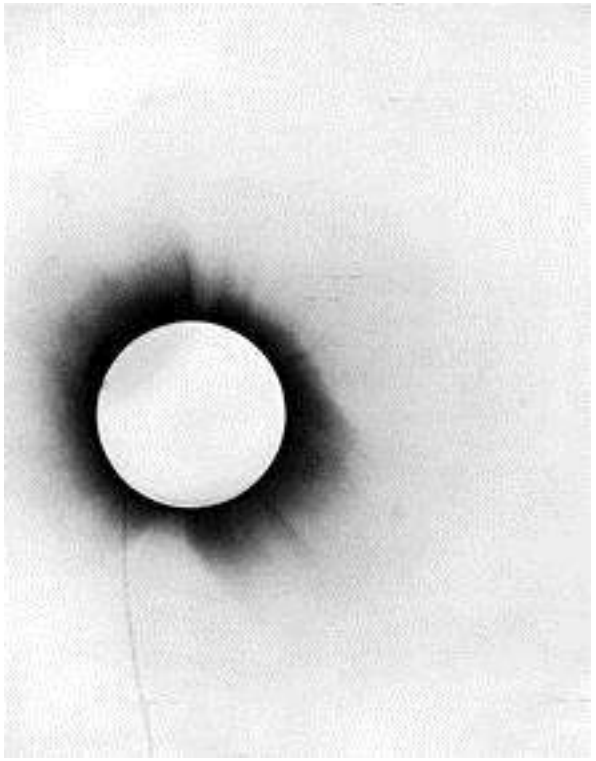
La materia dice allo spazio come curvarsi, *lo spazio dice alla materia* come muoversi.

Relativita' generale

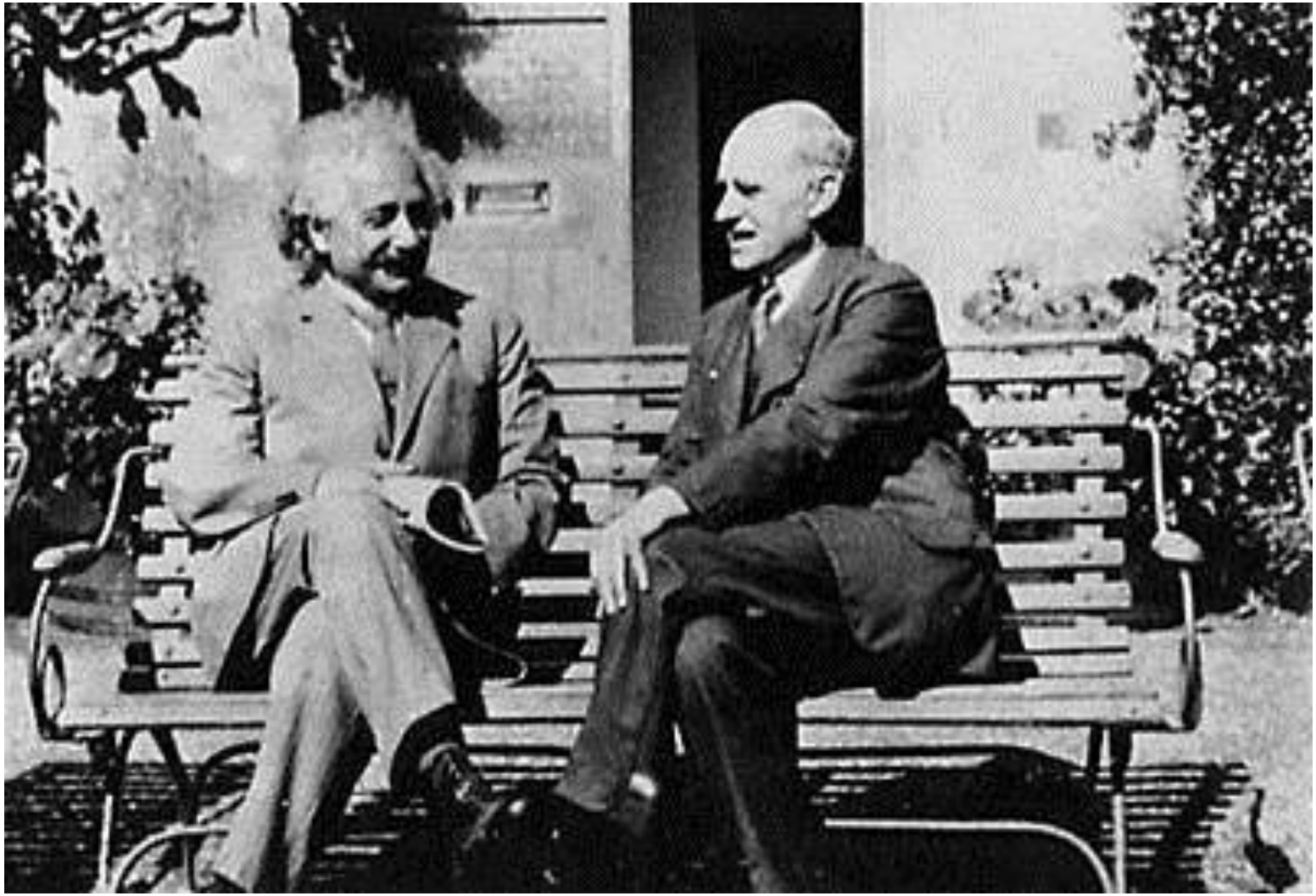
$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \overset{?}{\Lambda}\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Relativita' generale



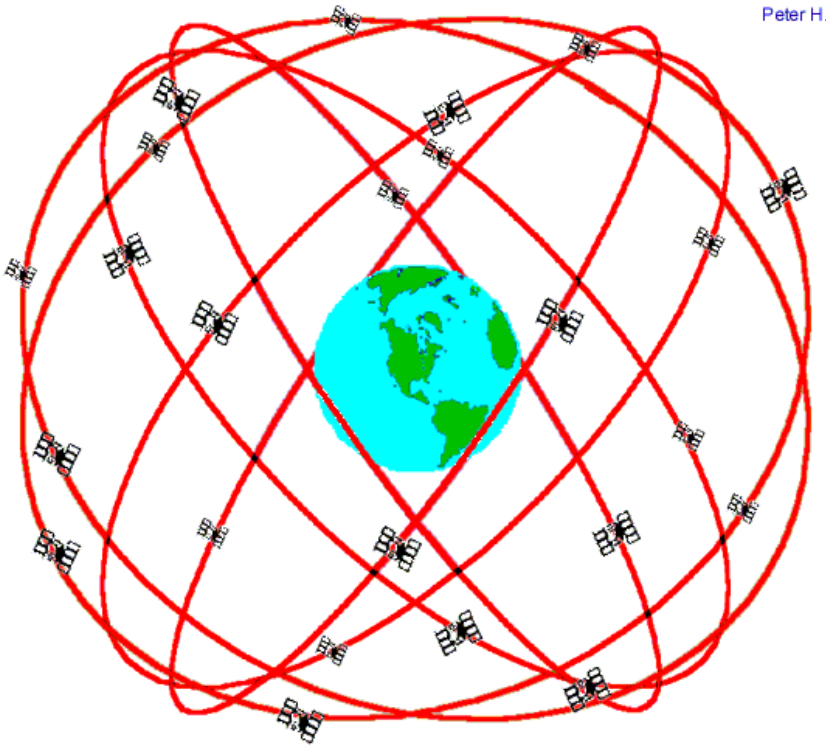


1919 – conferna relativita' generale: Sir Arthur Eddington (foto durante eclissi...)



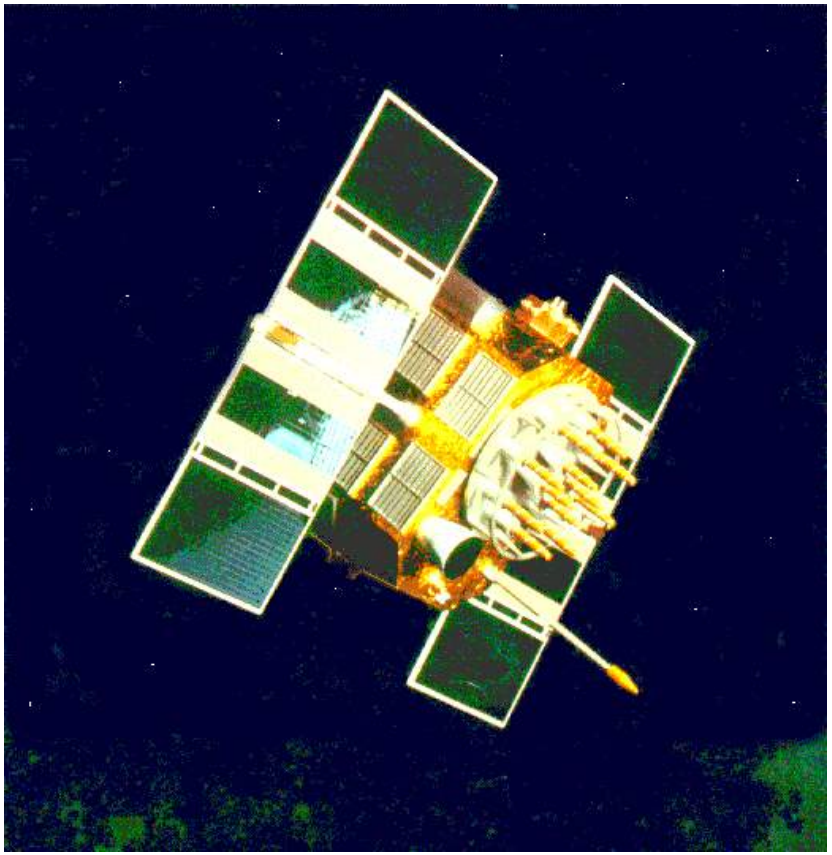
DAΦNE Collider at LNF-INFN

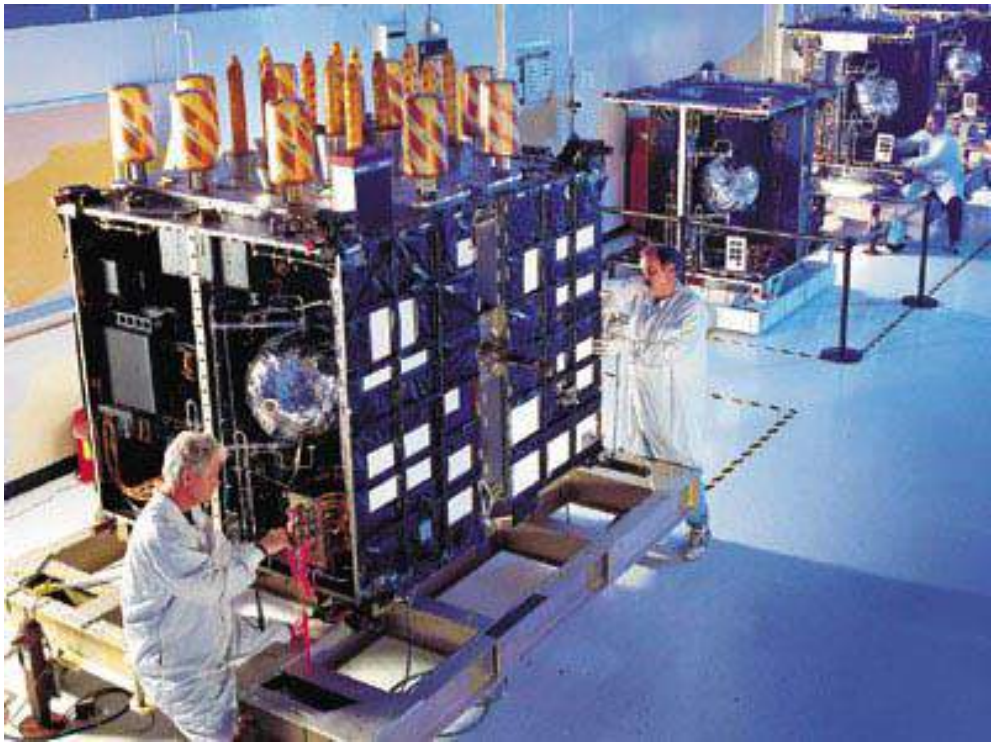
The Global Position System (GPS)



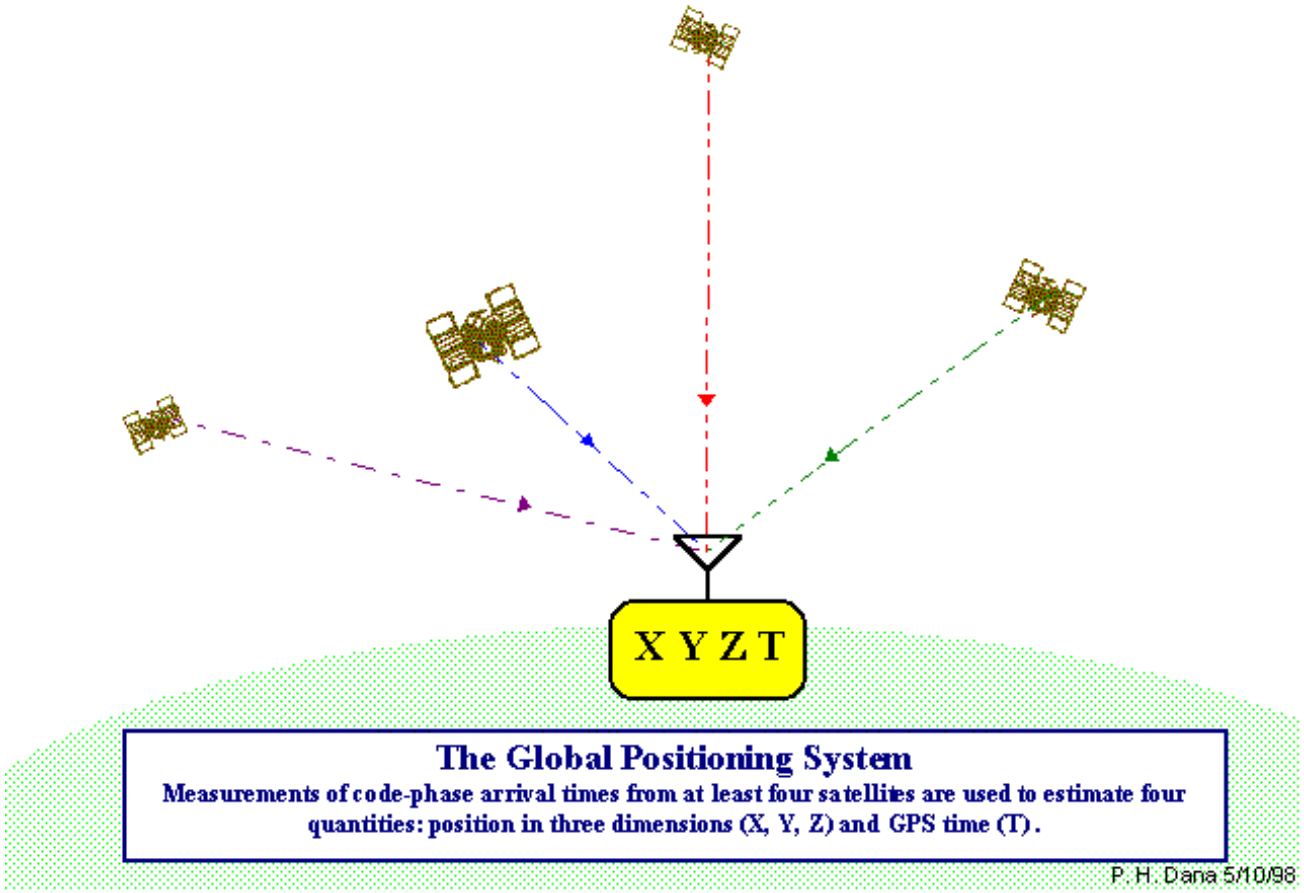
GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

The Global Position System (GPS)

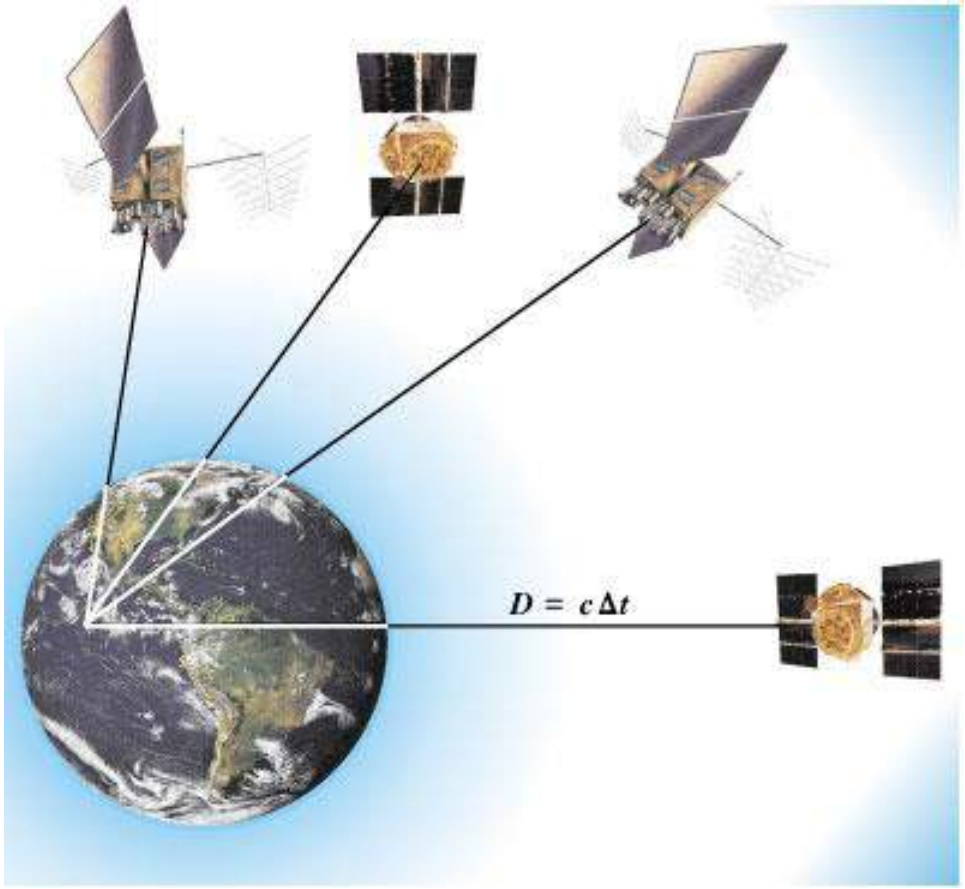




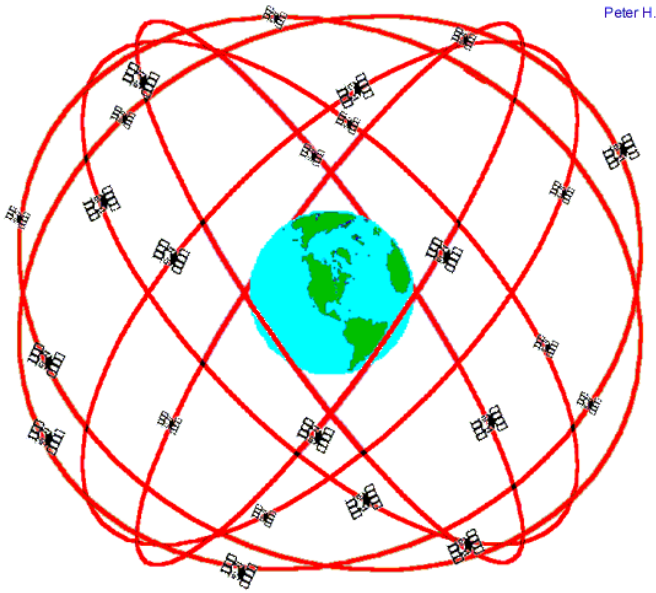
The Global Position System (GPS)



The Global Position System (GPS)



The Global Position System (GPS) e la relativita'!



GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

v = 3.87 Km/s

$t_{01} - t_{01}' = (1 - \gamma)\, t_{01}$

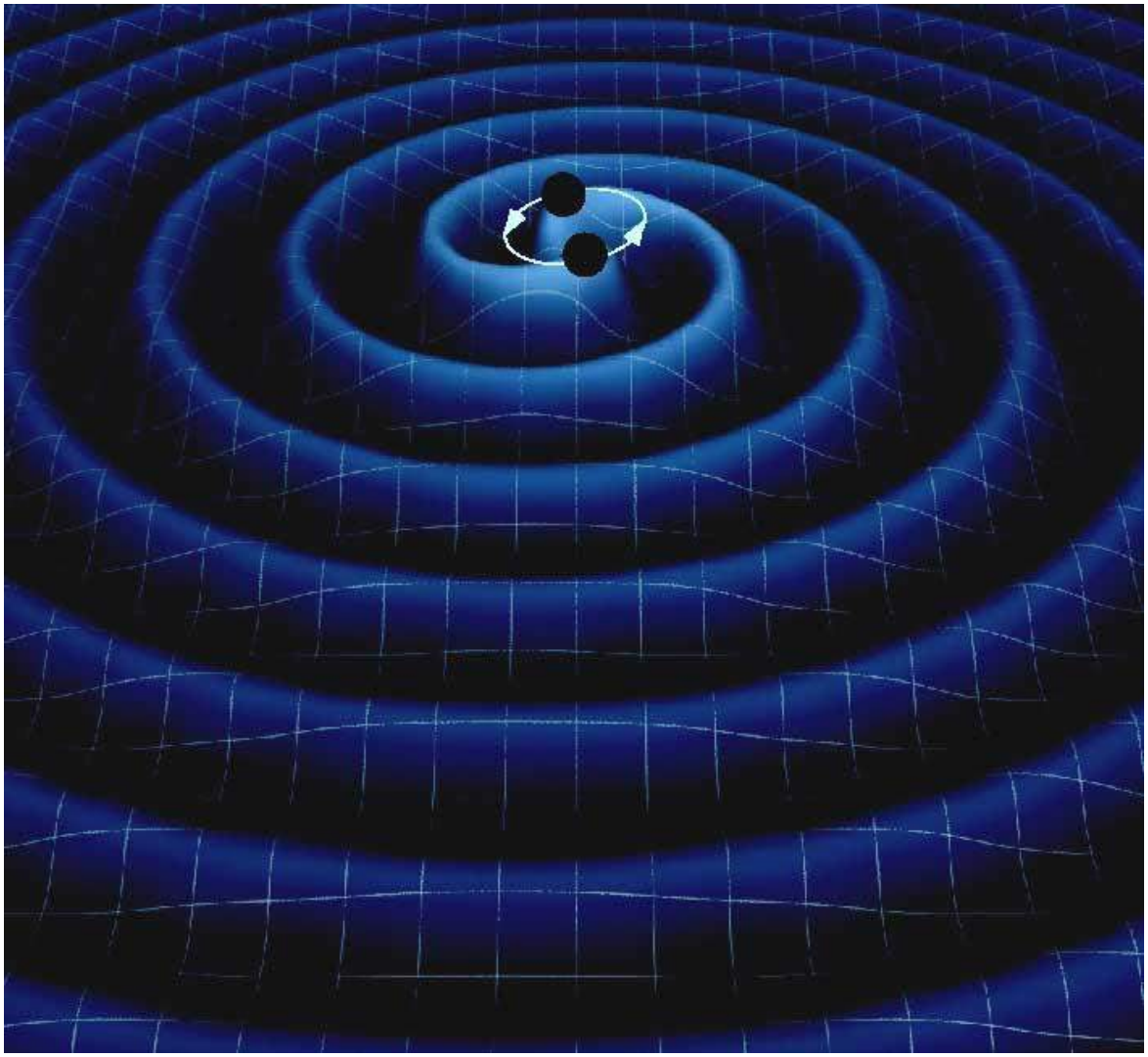
1 orbit ~ 12 hours

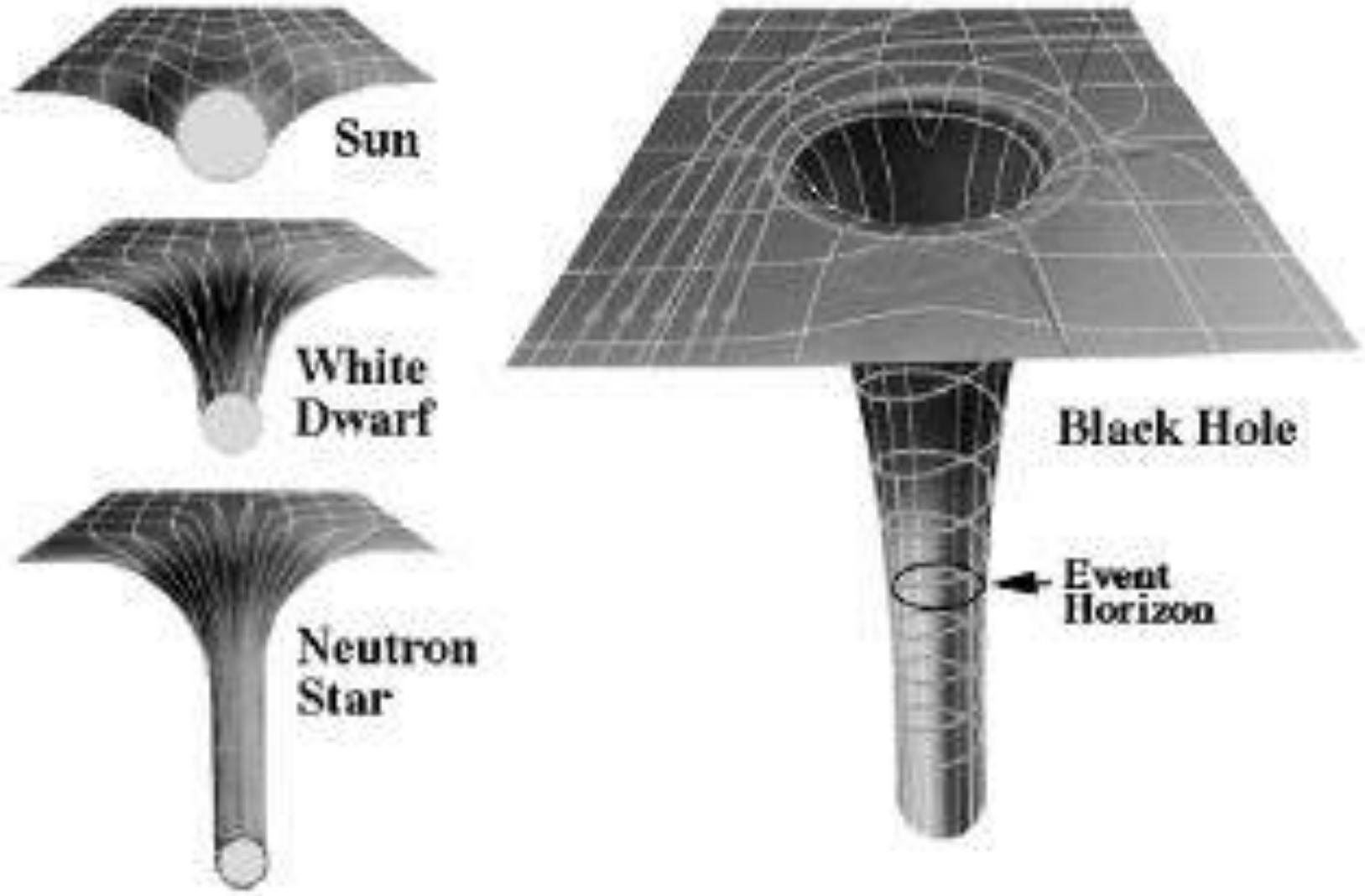
➔ $t_{01} - t_{01}' \sim 6\ 10^{-8}$ s

➔ $\Delta D \sim 18$ m

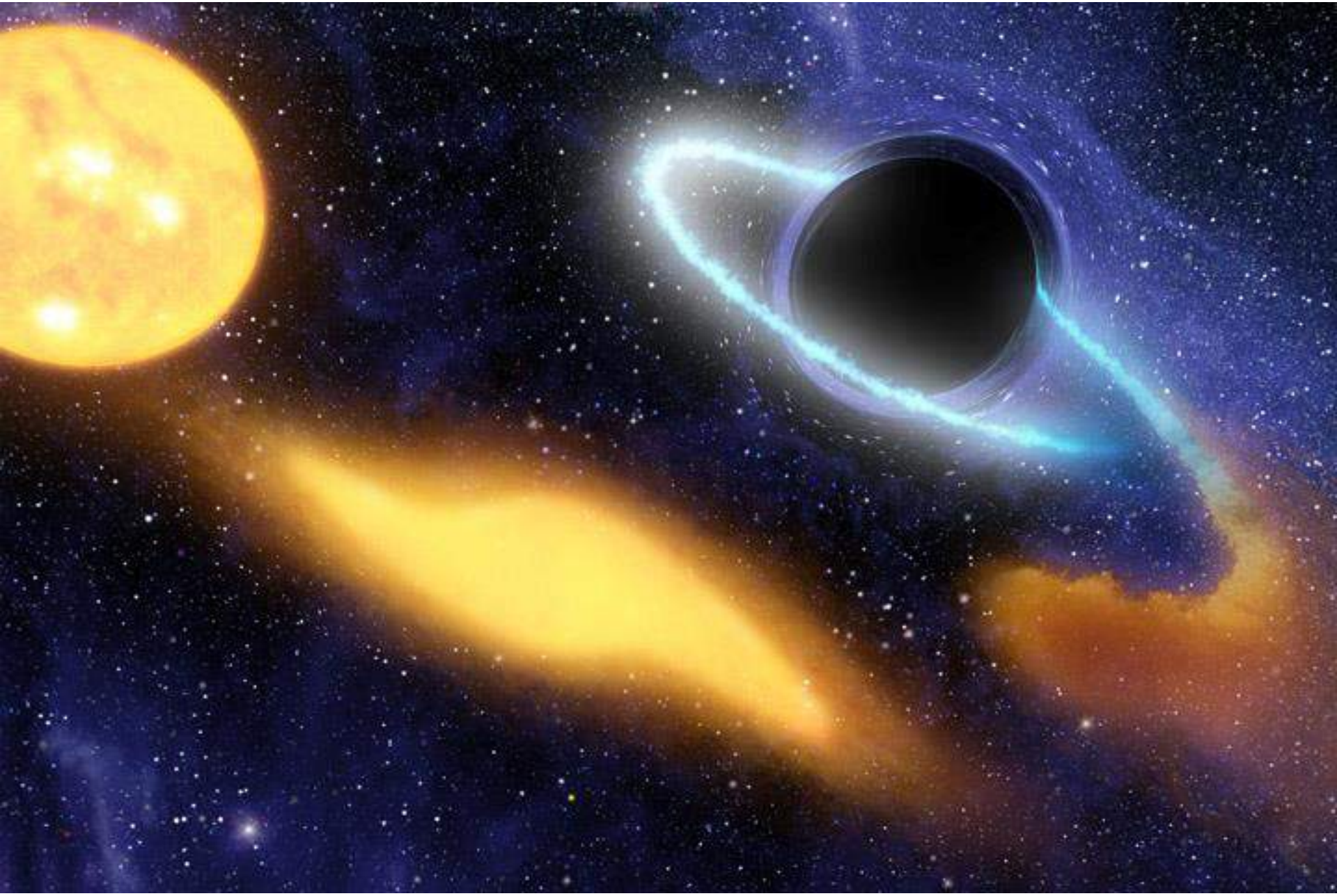
Due to other effects connected to general relativity $\Delta D \sim 100$ m

Onde gravitazionali



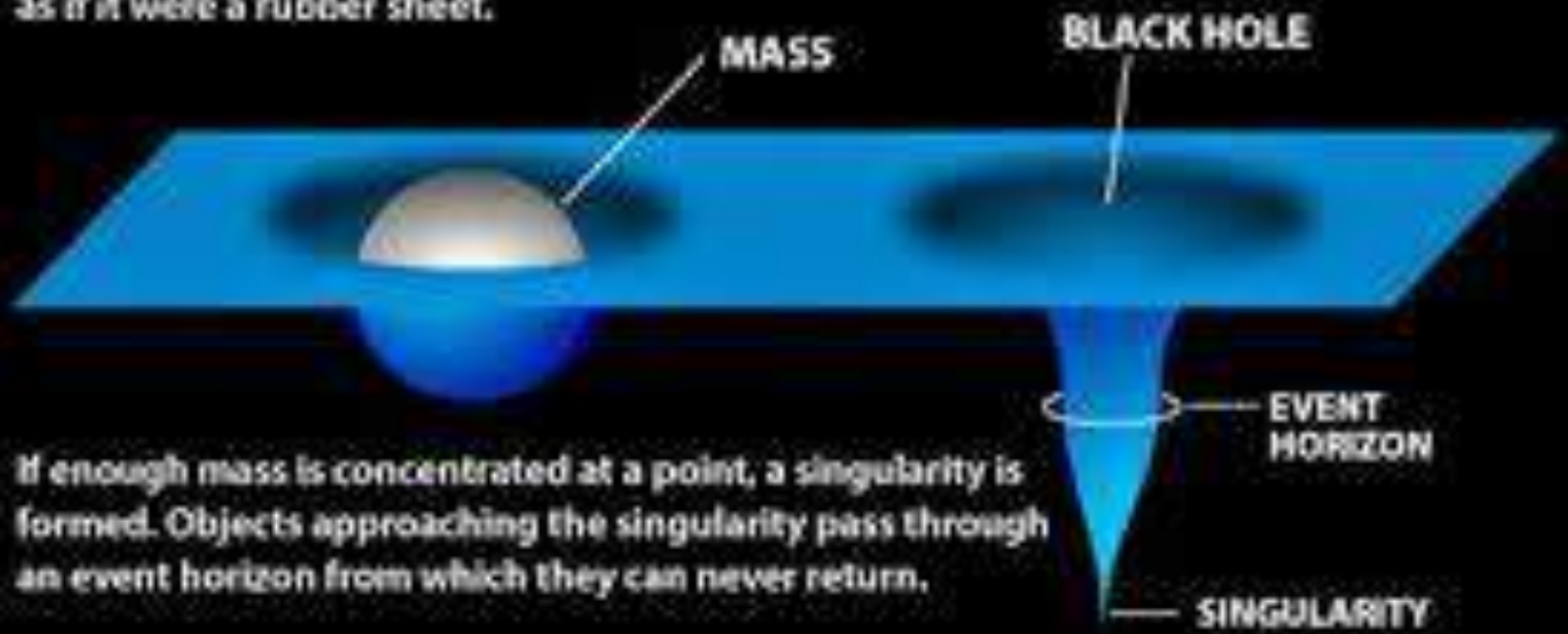


Credit: Adam Apollo

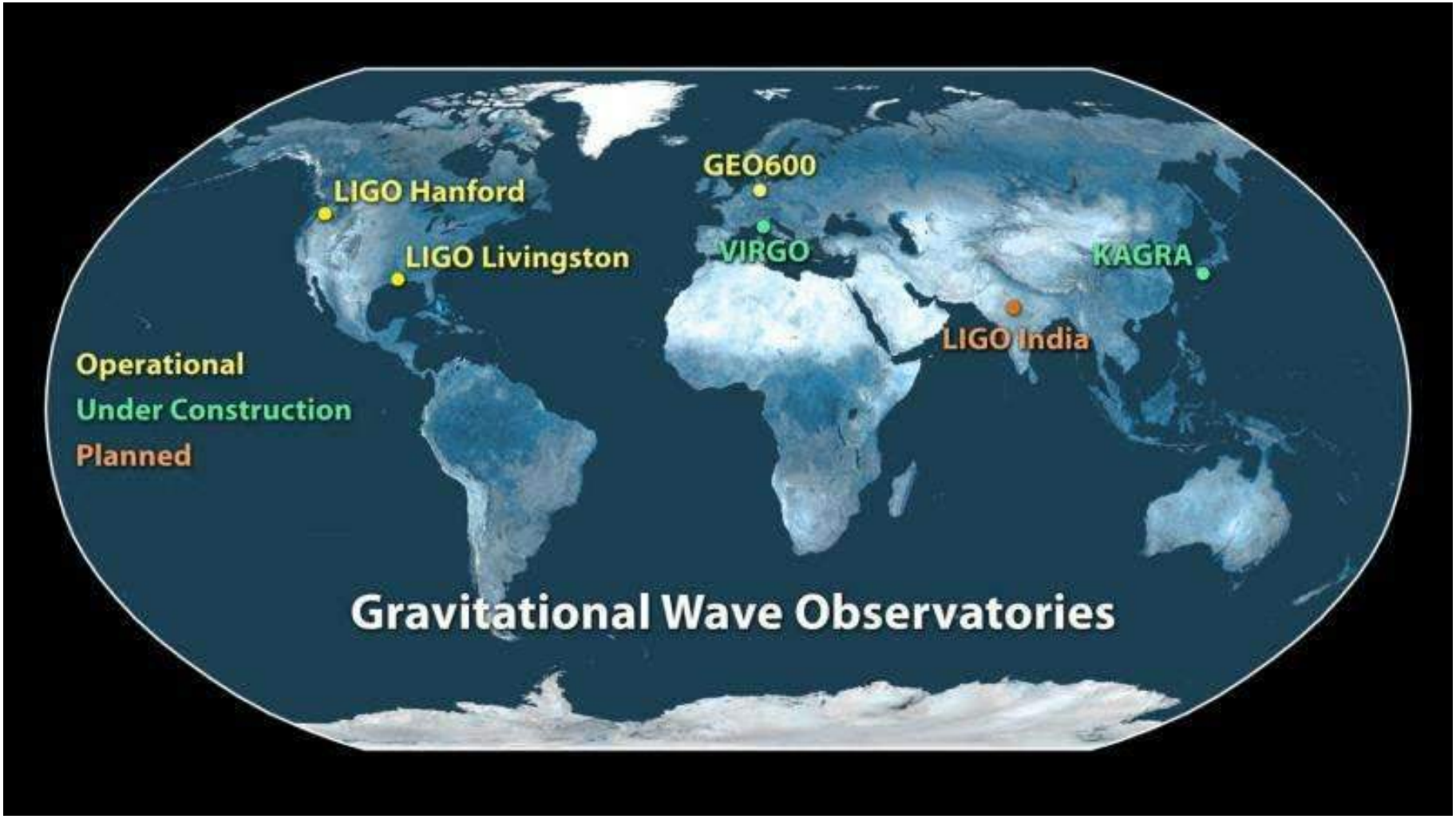


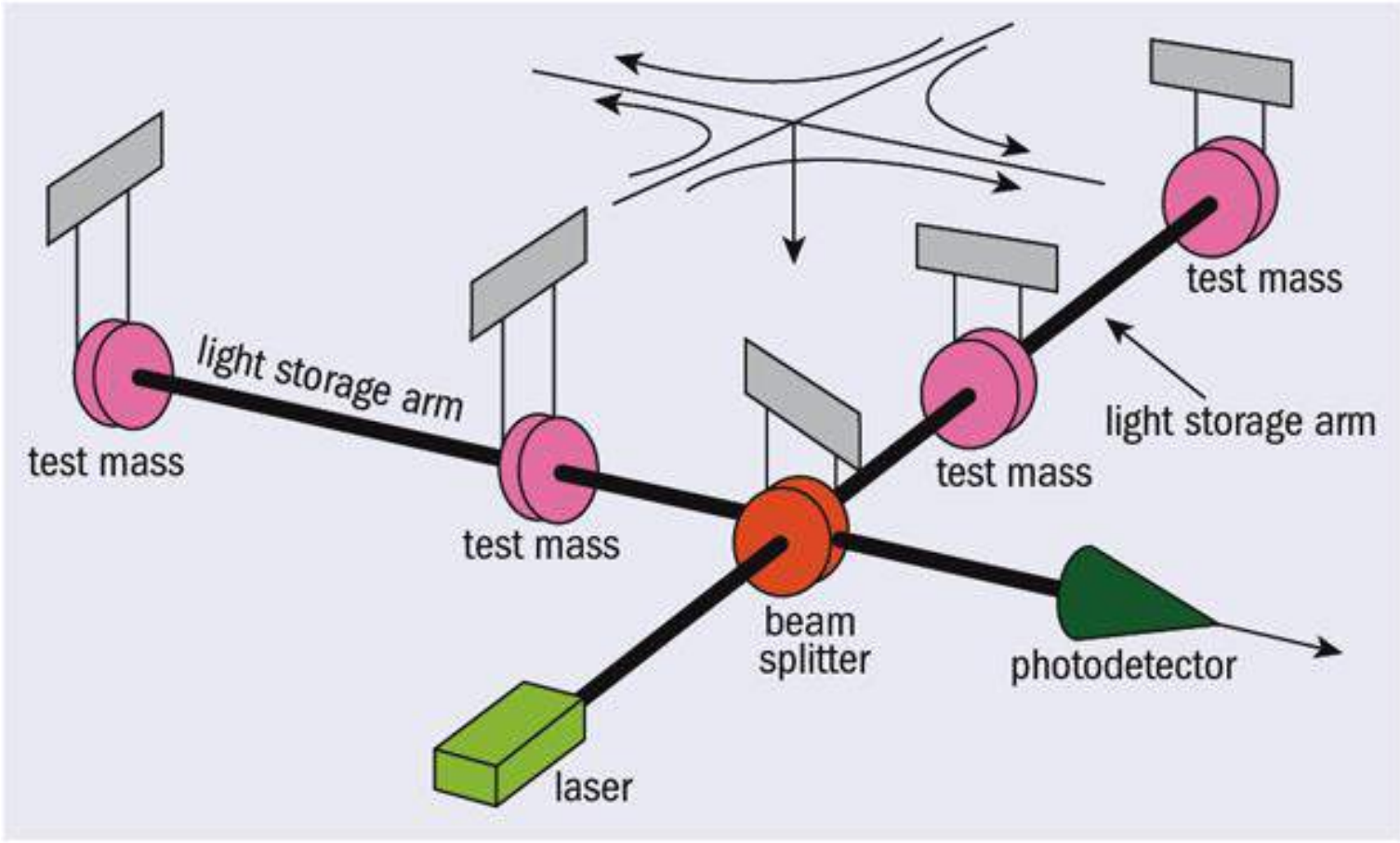
HOW TO MAKE A BLACK HOLE

The presence of mass distorts the local space-time as if it were a rubber sheet.

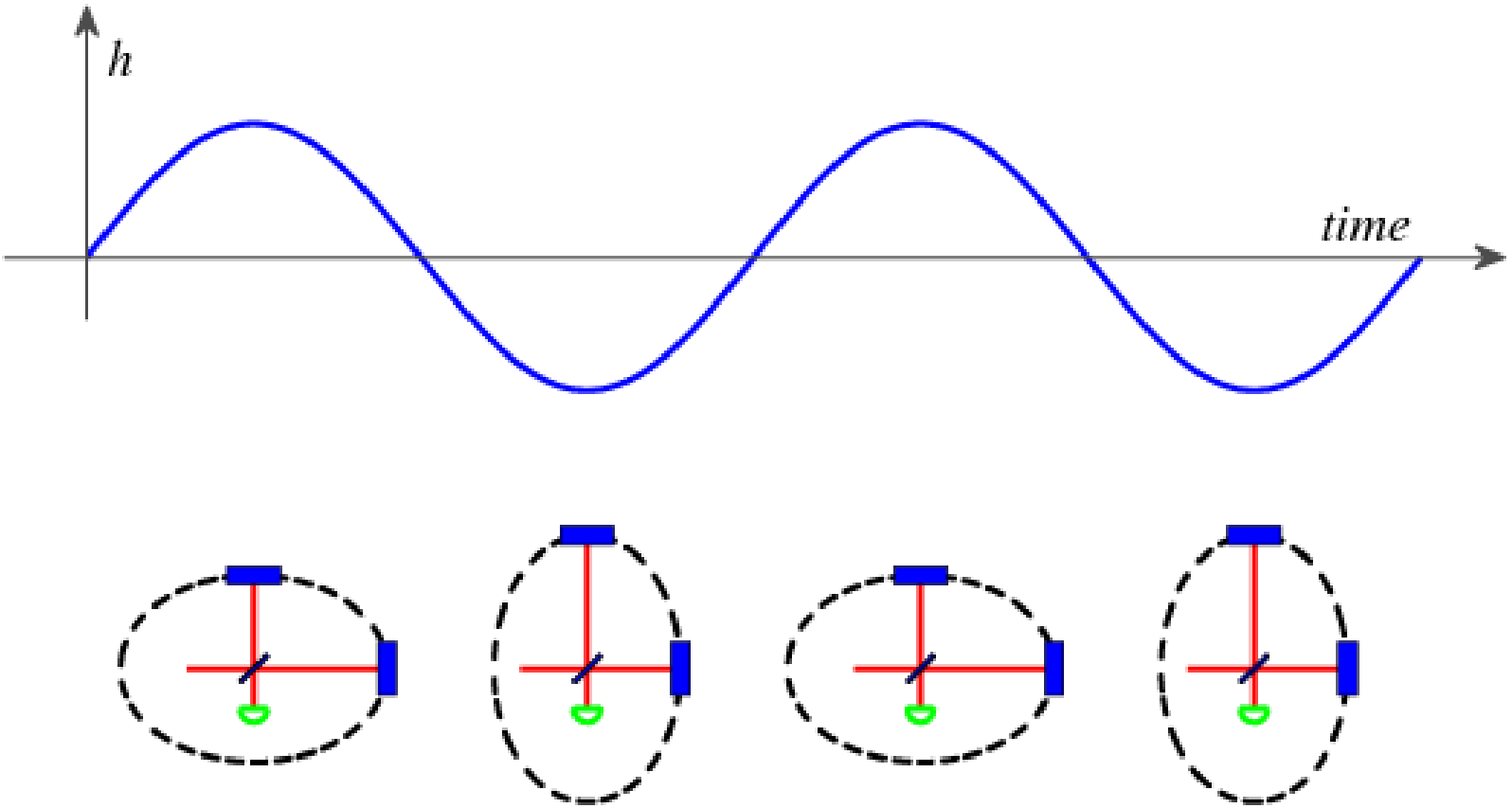


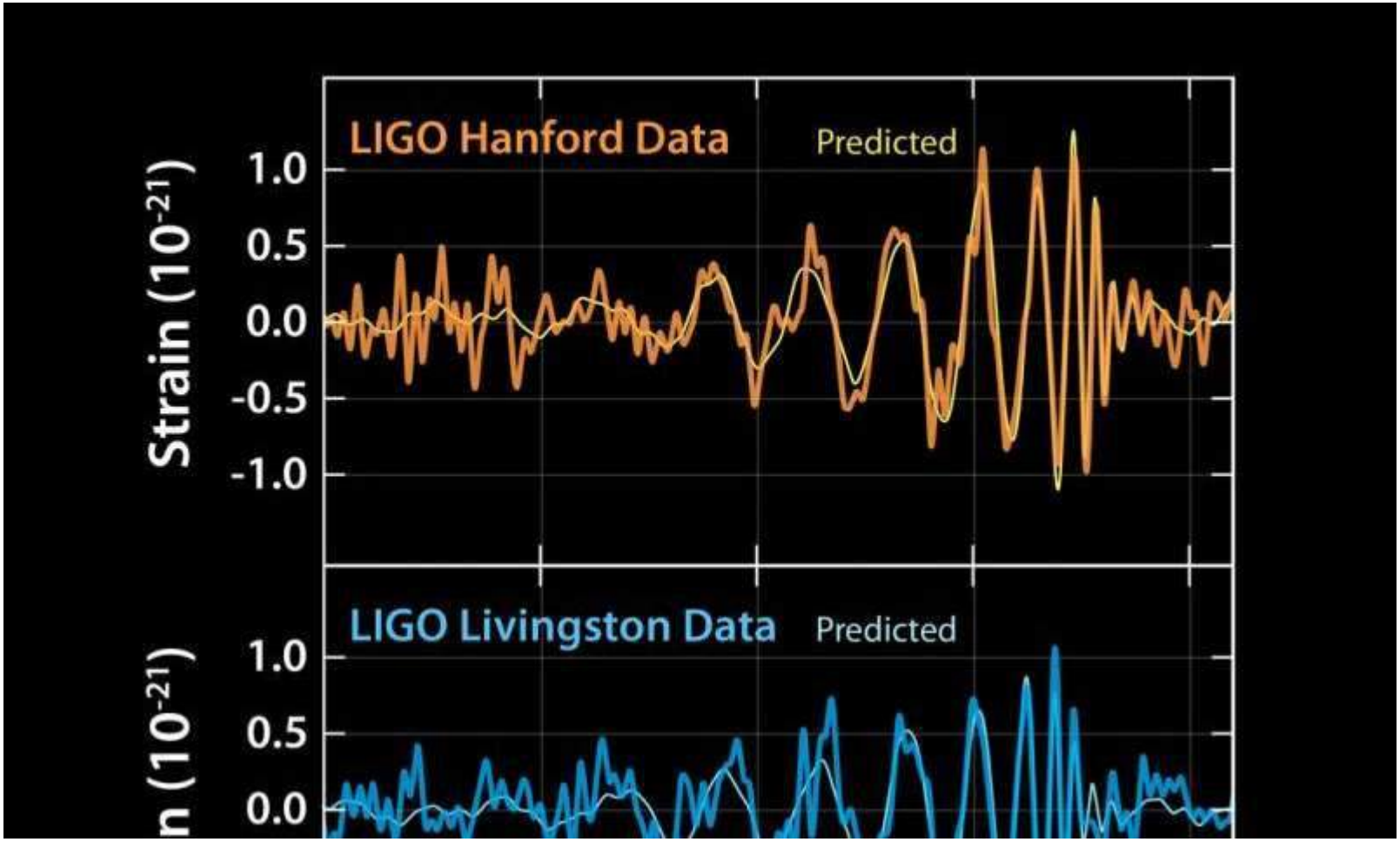
If enough mass is concentrated at a point, a singularity is formed. Objects approaching the singularity pass through an event horizon from which they can never return.

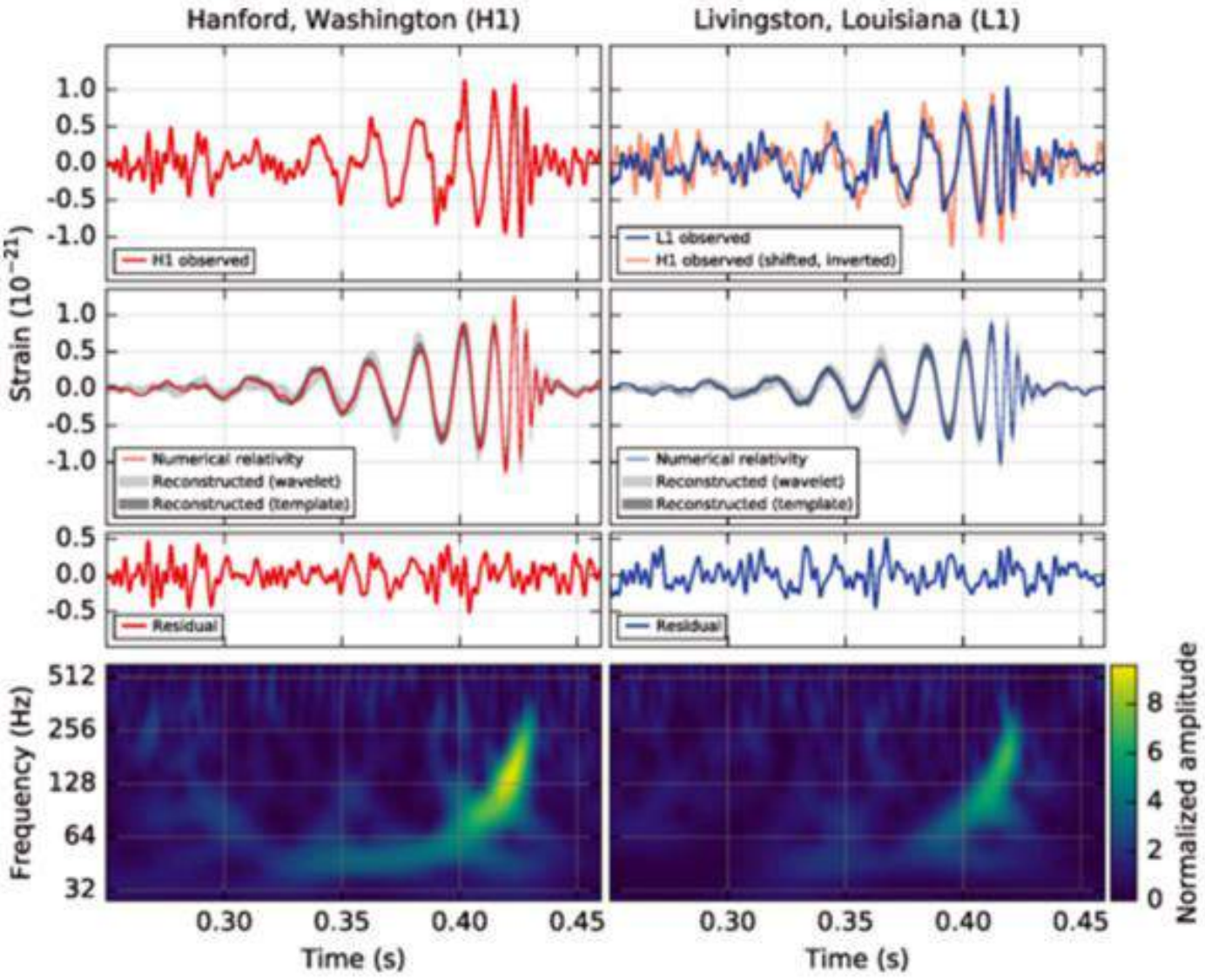

GEO600
LIGO Hanford
VIRGO
KAGRA
LIGO Livingston
LIGO India
Operational
Under Construction
Planned
Gravitational Wave Observatories

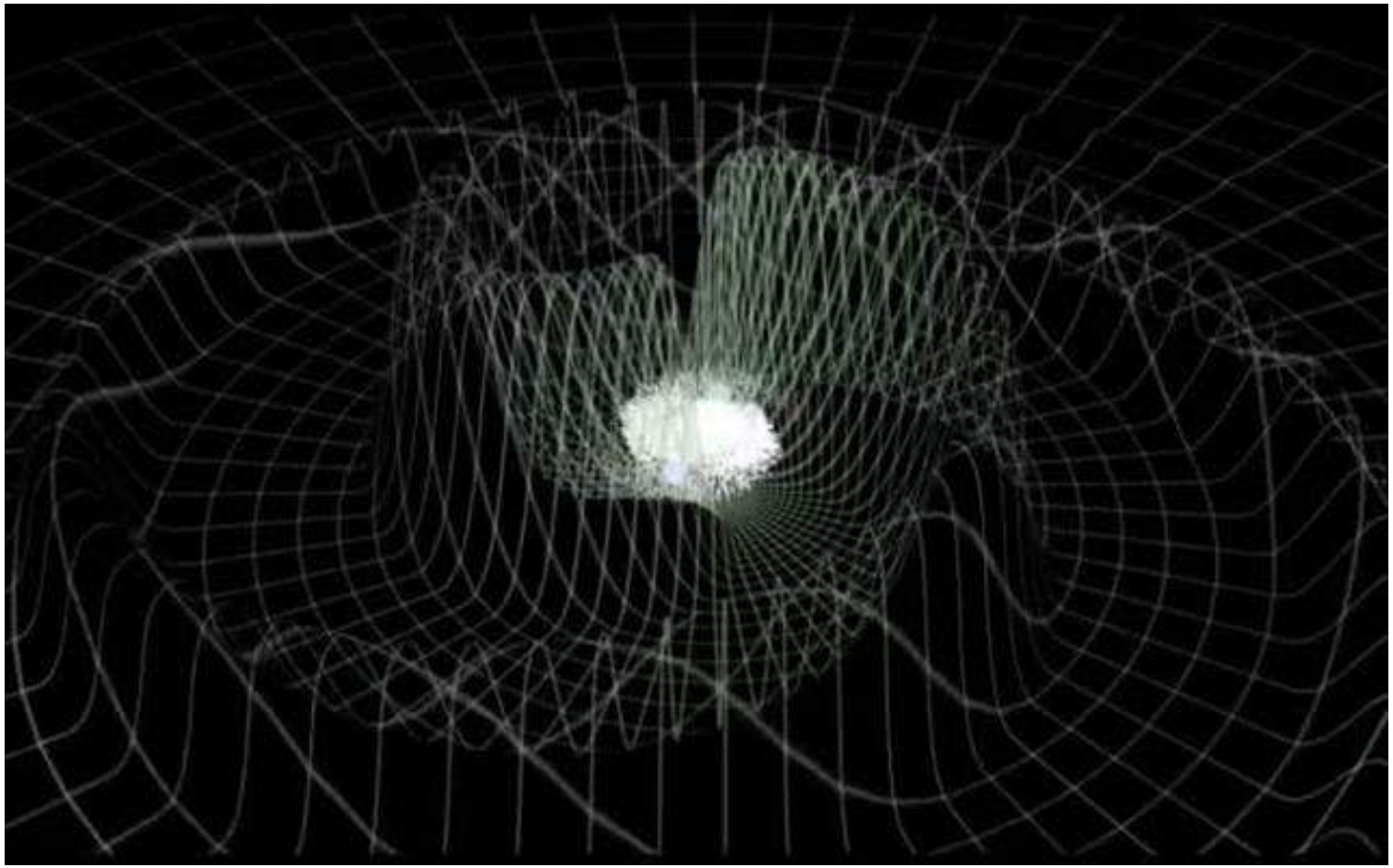

test mass
light storage arm
test mass
test mass
beam
splitter
test mass
light storage arm
test mass
photodetector
laser

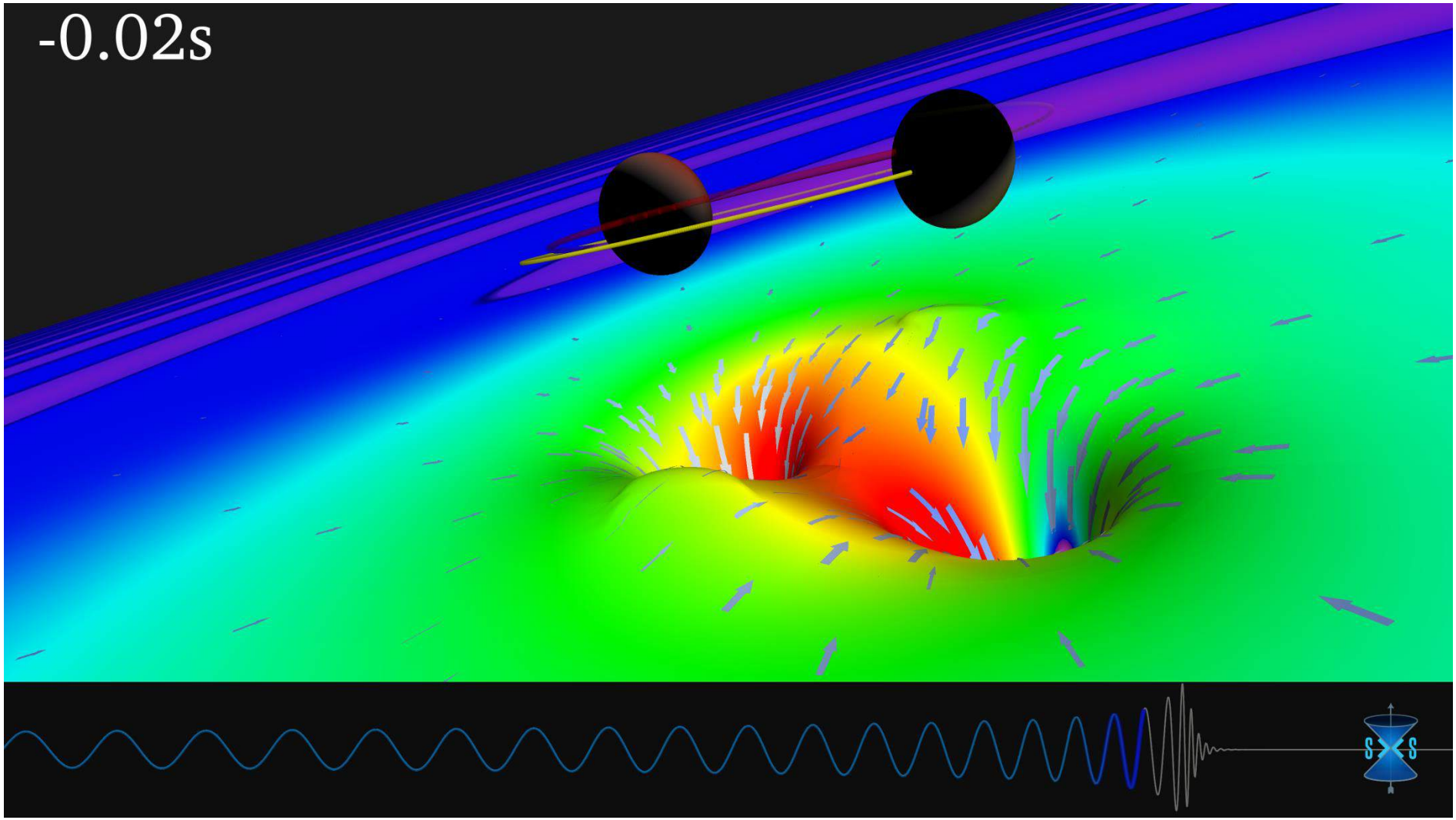

05/20/2012
© REUTERS

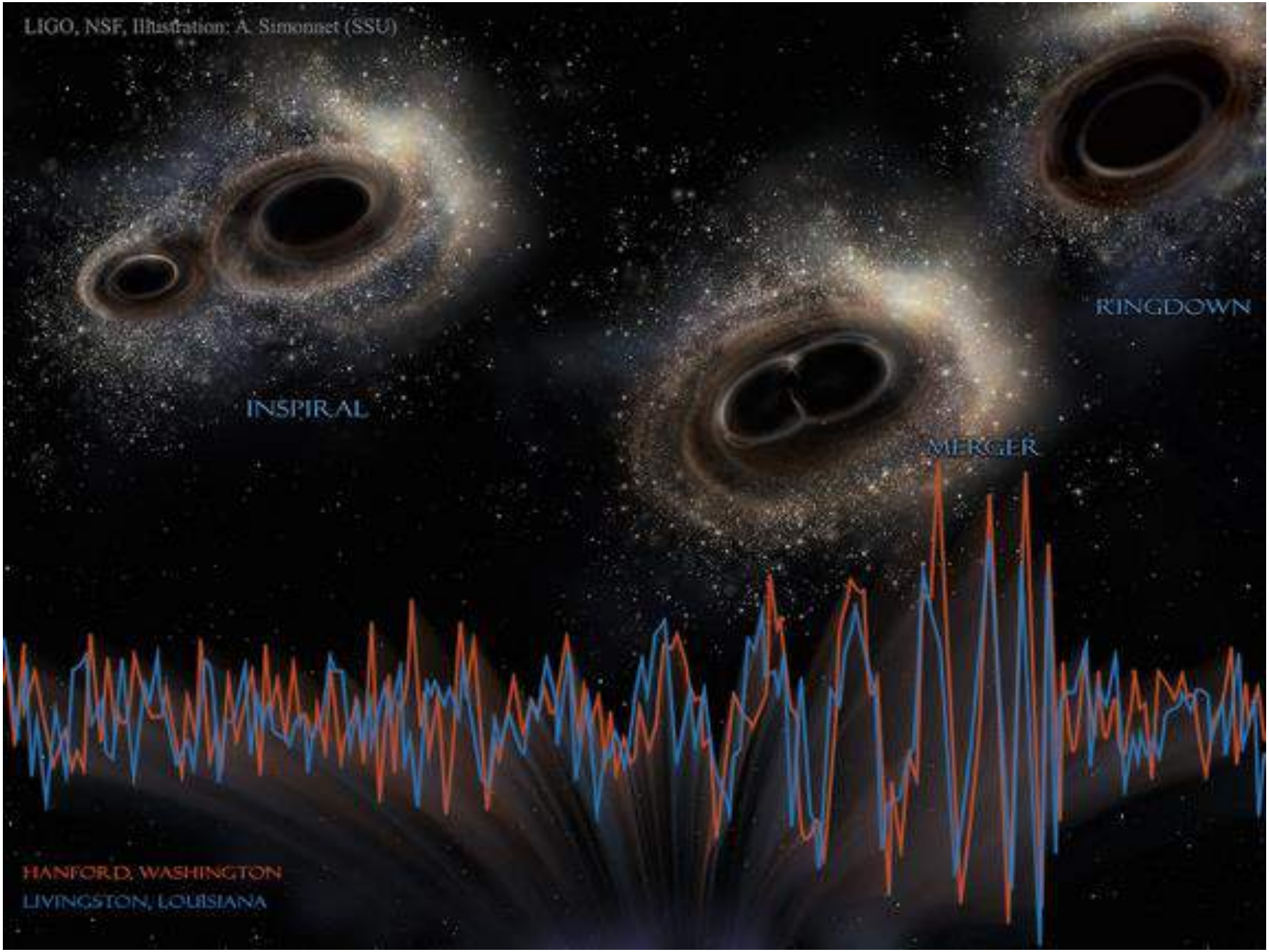

h
time


LIGO Hanford Data
Predicted
Strain (10-21)
1.0
0.5
0.0
-0.5
-1.0
LIGO Livingston Data
Predicted
1.0
0.5
0.0


Hanford, Washington (H1)
Livingston, Louisiana (L1)
Strain (10^{-21})
H1 observed
L1 observed
H1 observed (shifted, inverted)
Numerical relativity
Reconstructed (wavelet)
Reconstructed (template)
Residual
Frequency (Hz)
512
256
128
64
32
0.30
0.35
0.40
0.45
Time (s)
Normalized amplitude
0
2
4
6
8




-0.02s

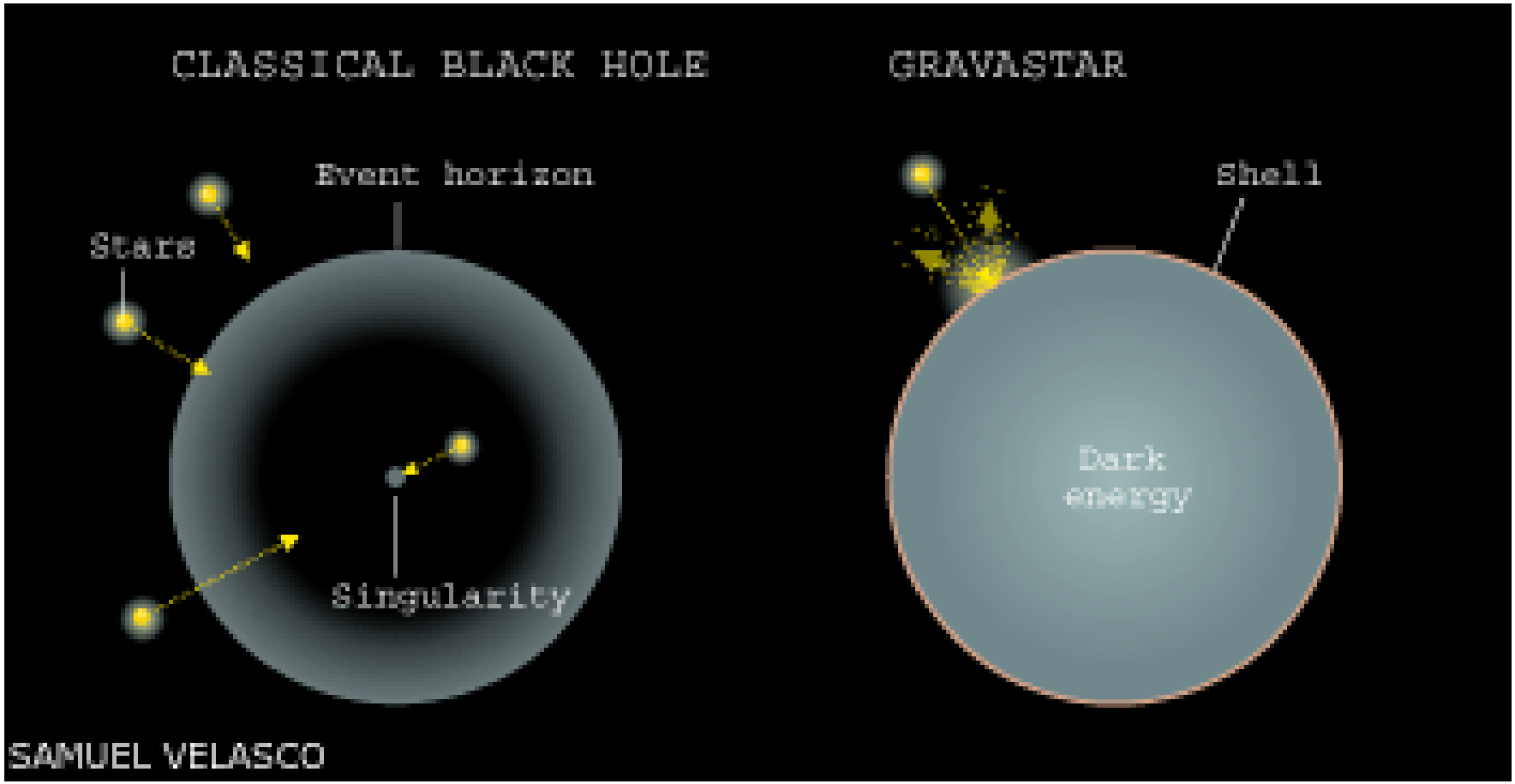

LIGO, NSF, Illustration: A. Simonnet (SSU)
INSPIRAL
MERGER
RINGDOWN
HANFORD, WASHINGTON
LIVINGSTON, LOUISIANA

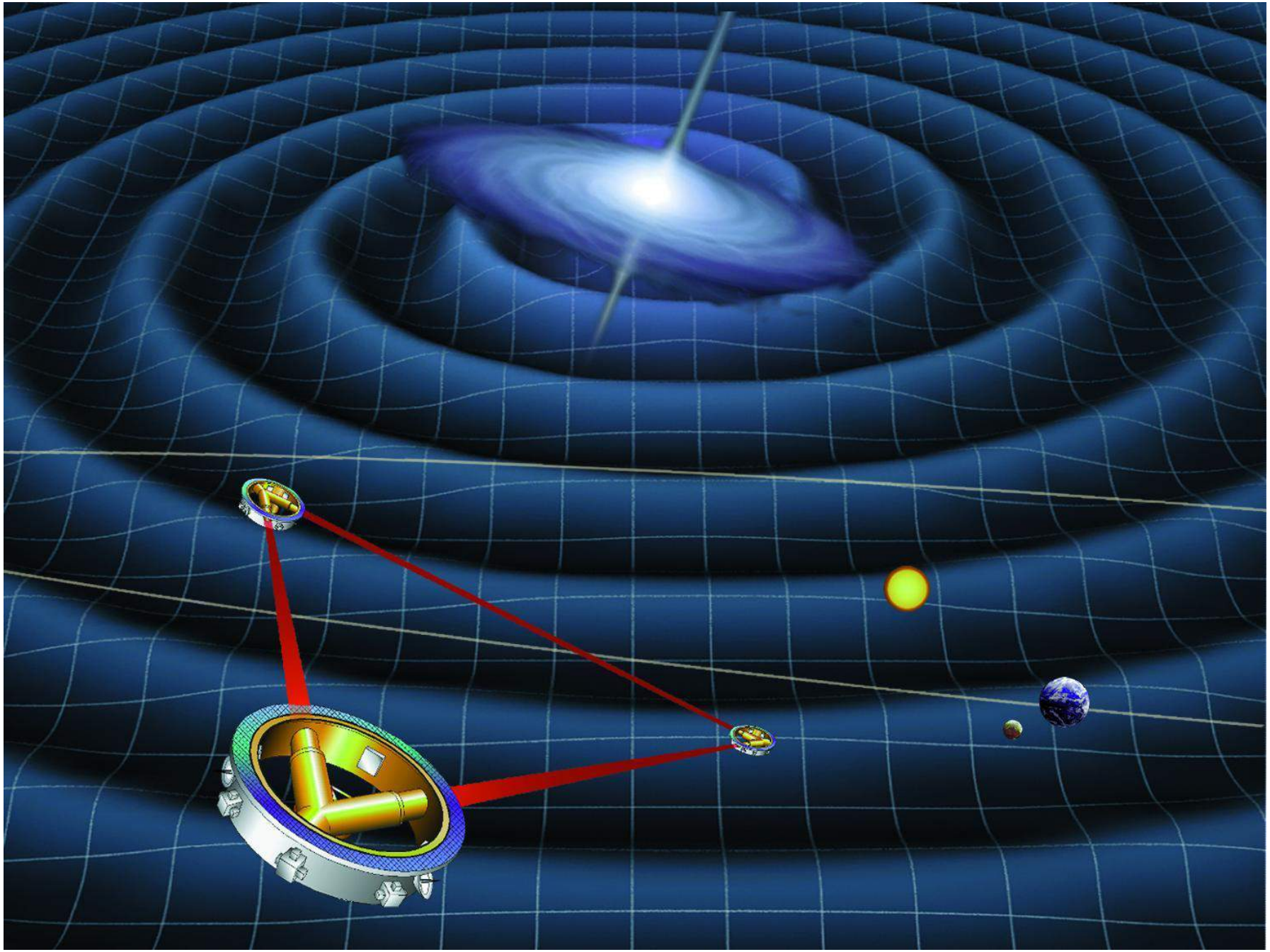
Gravastar???

Una gravastar? Che cos'è?

«Le gravastars e i wormholes fanno parte di quelli che in gergo vengono chiamati "*black-hole mimicker*s", ossia oggetti che possono essere tanto compatti quanto un buco nero ma che non possiedono l'orizzonte degli eventi. Una gravastar è una stella esotica, la cui forza gravitazionale è bilanciata da un nucleo interno fatto di energia oscura: in pratica, di materia con una pressione negativa. I wormholes sono invece una sorta di tunnel spaziotemporale che connette due regioni distanti del nostro universo o addirittura due universi diversi. Il punto più stretto del tunnel, detto "gola", è anch'esso, formato da materia esotica, simile a quella delle gravastar.

Gravastar???

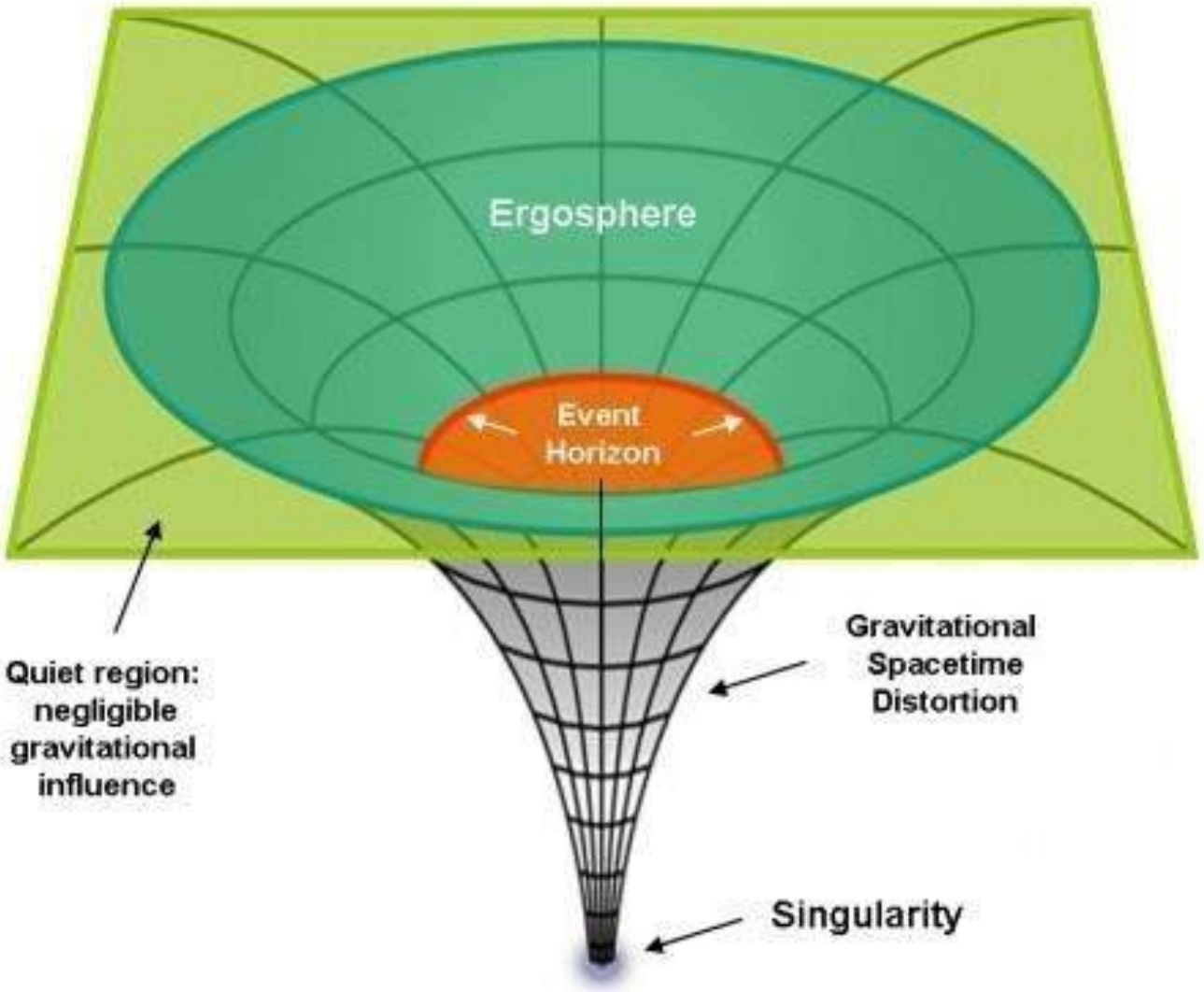

CLASSICAL BLACK HOLE
Event horizon
Stars
Singularity
GRAVASTAR
Shell
Dark energy
SAMUEL VELASCO



Lanciarsi in un buco nero?

Lanciarsi in un buco nero?

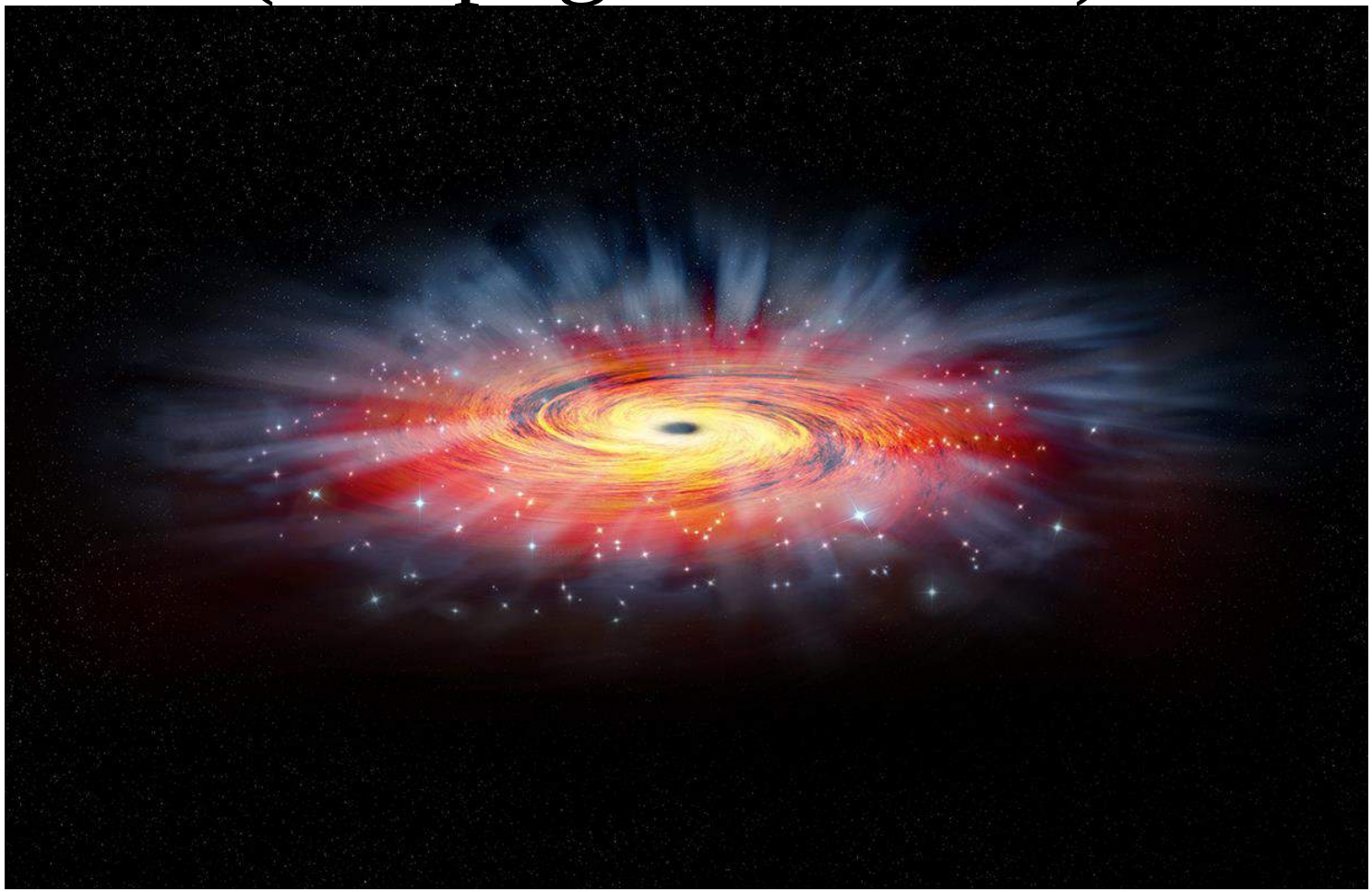
Black Hole Regions



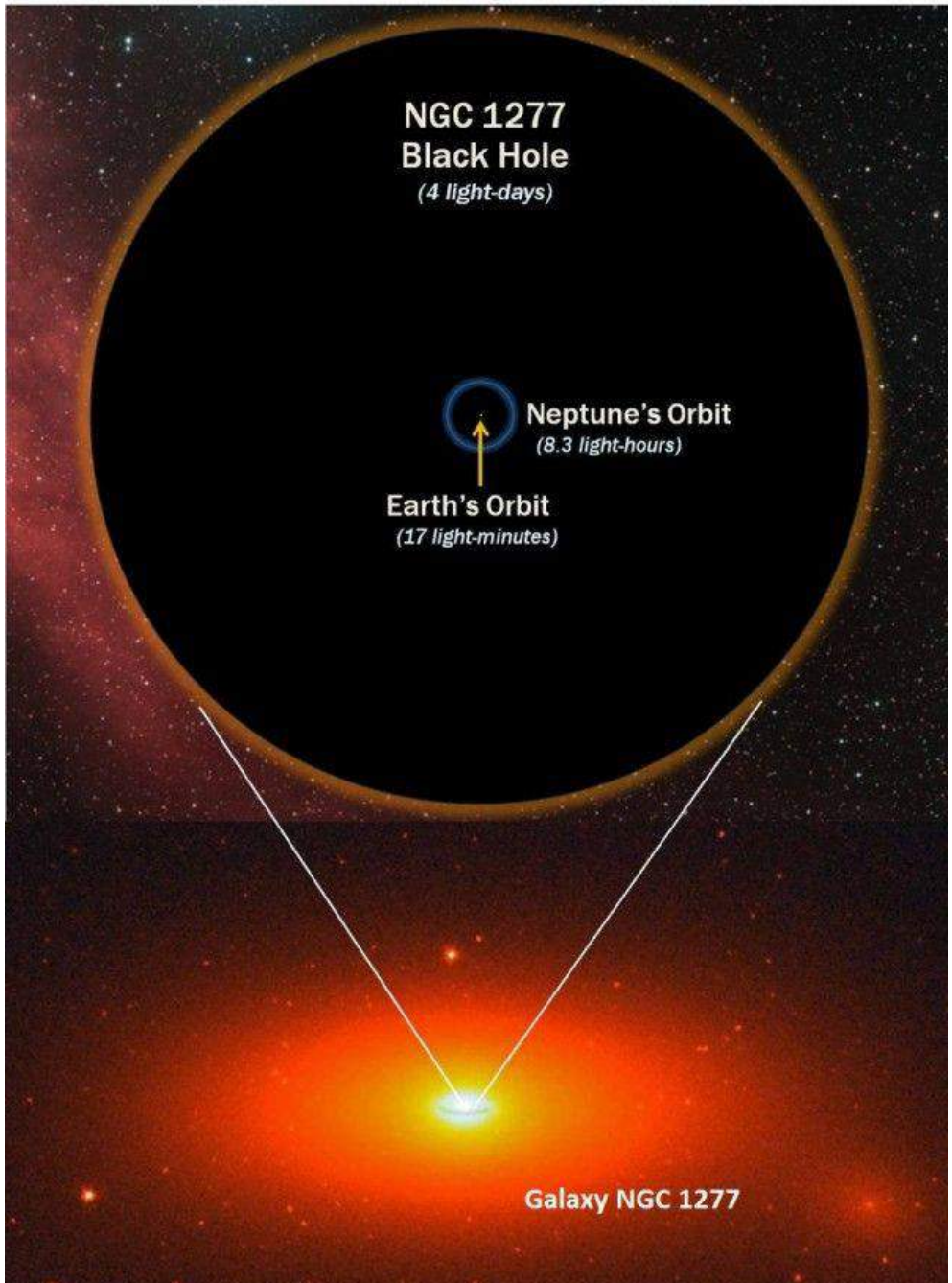
Spaghettification!

To Black Hole

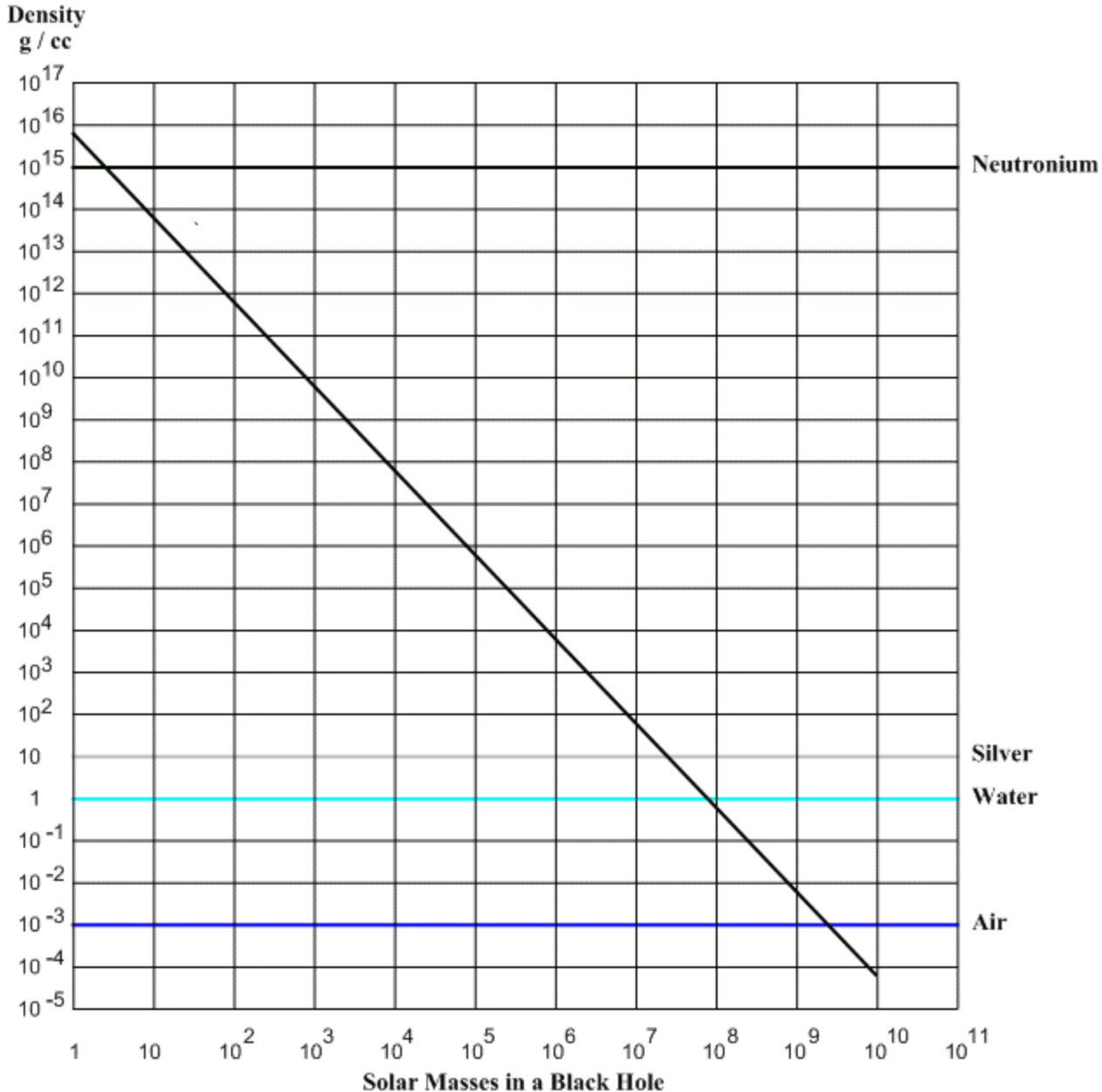
Buchi neri supermassicci densita' bassa (no spaghetificaton)



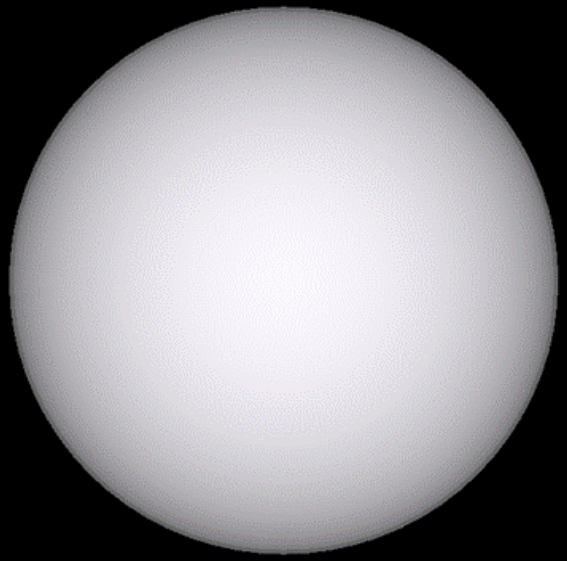
Black Hole – mass about 17 miliarde di volte massa Sole



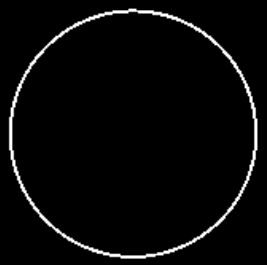
Densita' buchi neri



Manhattan
(spaceimaging.com)



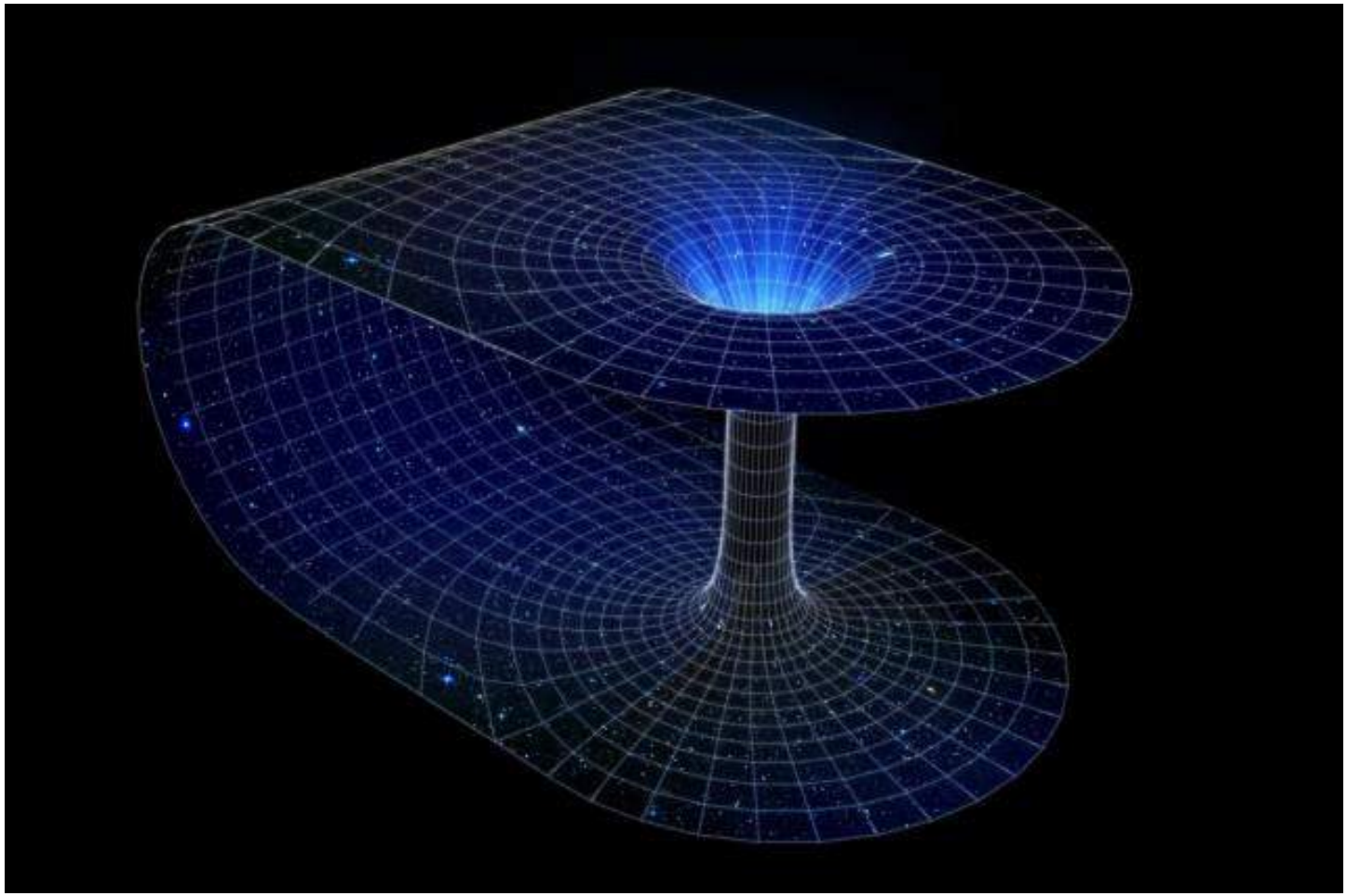
Neutron Star
$M=1.5\ M_{sun}$
$R \approx 10$ km



Black Hole
$M = 1.5\ M_{sun}$
$R_S = 4.5$ km

Viaggi interstellati?

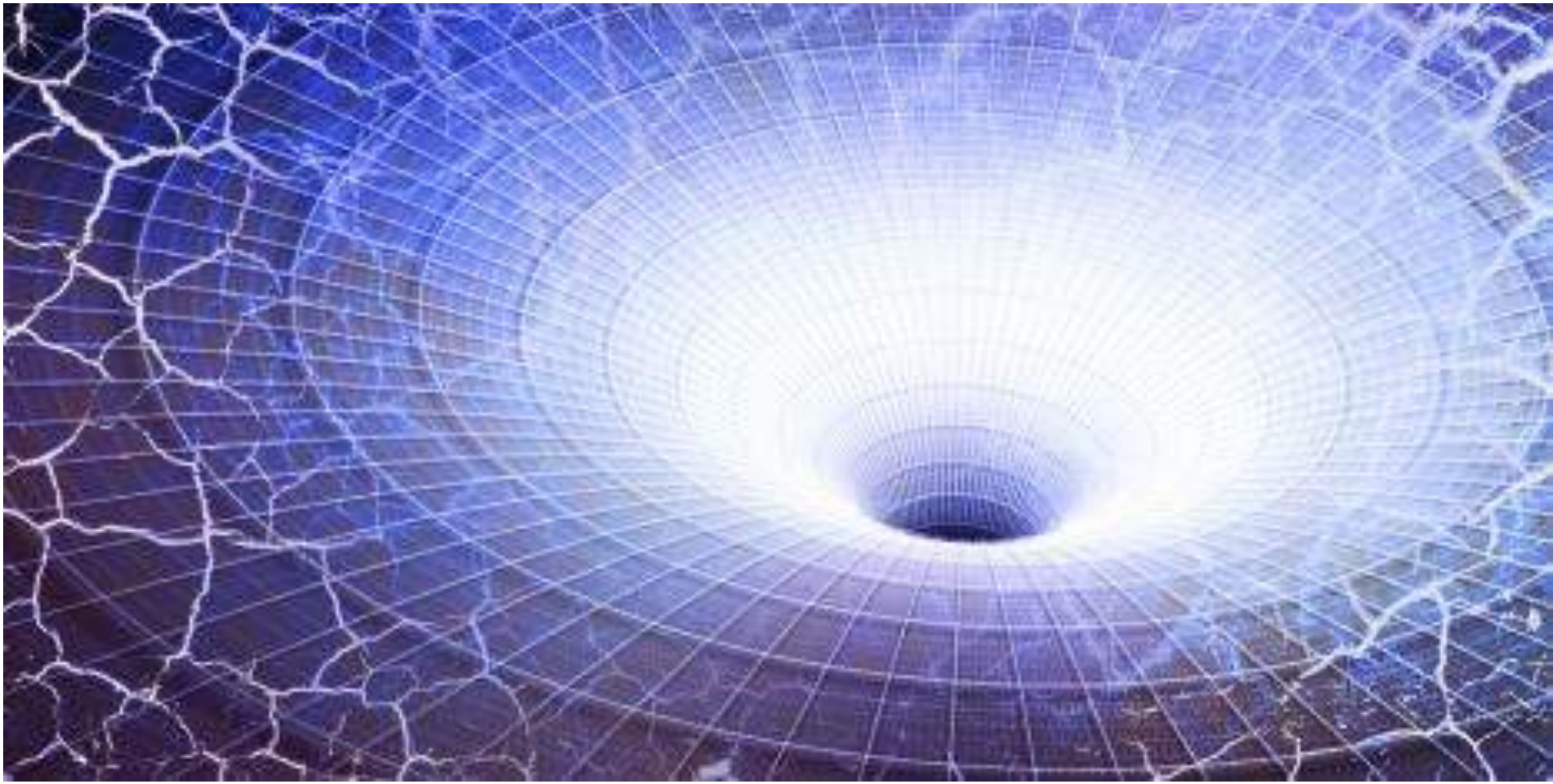
Viaggi interstellati?



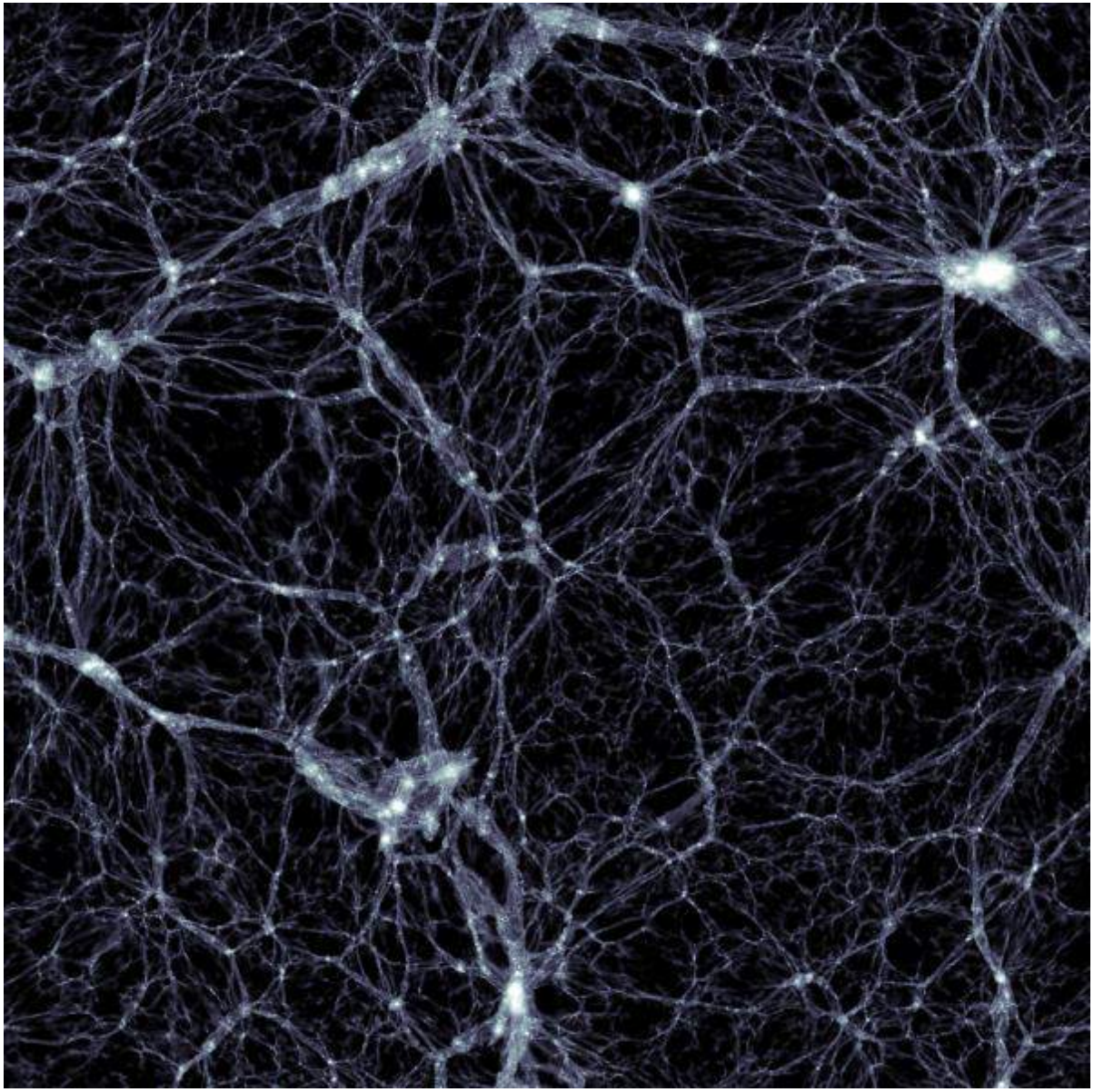
Viaggi in altri Universi?

Viaggi in altri Universi?

Per capire i buchi neri: gravita' quantistica!

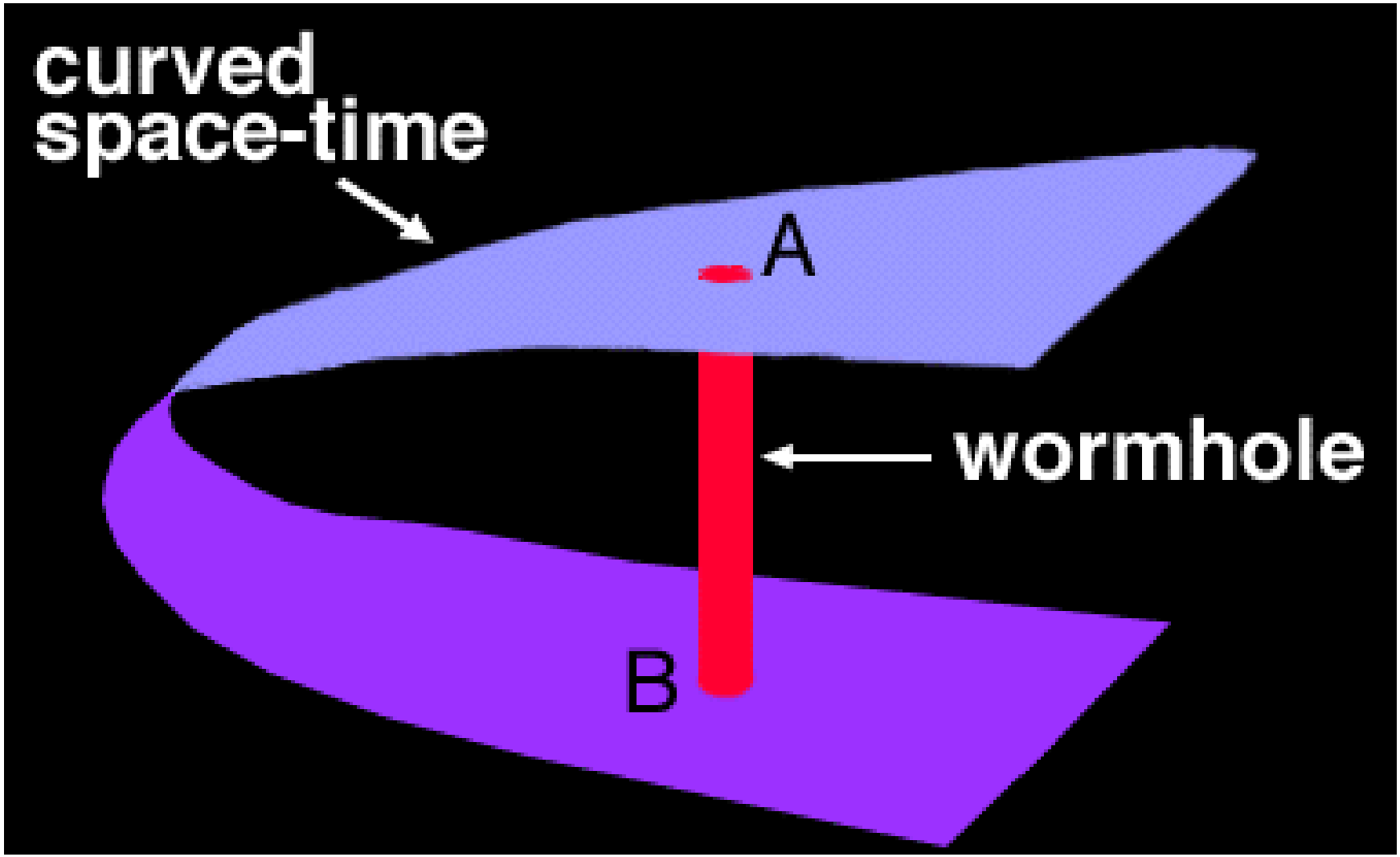


Struttura dello spazio - tempo

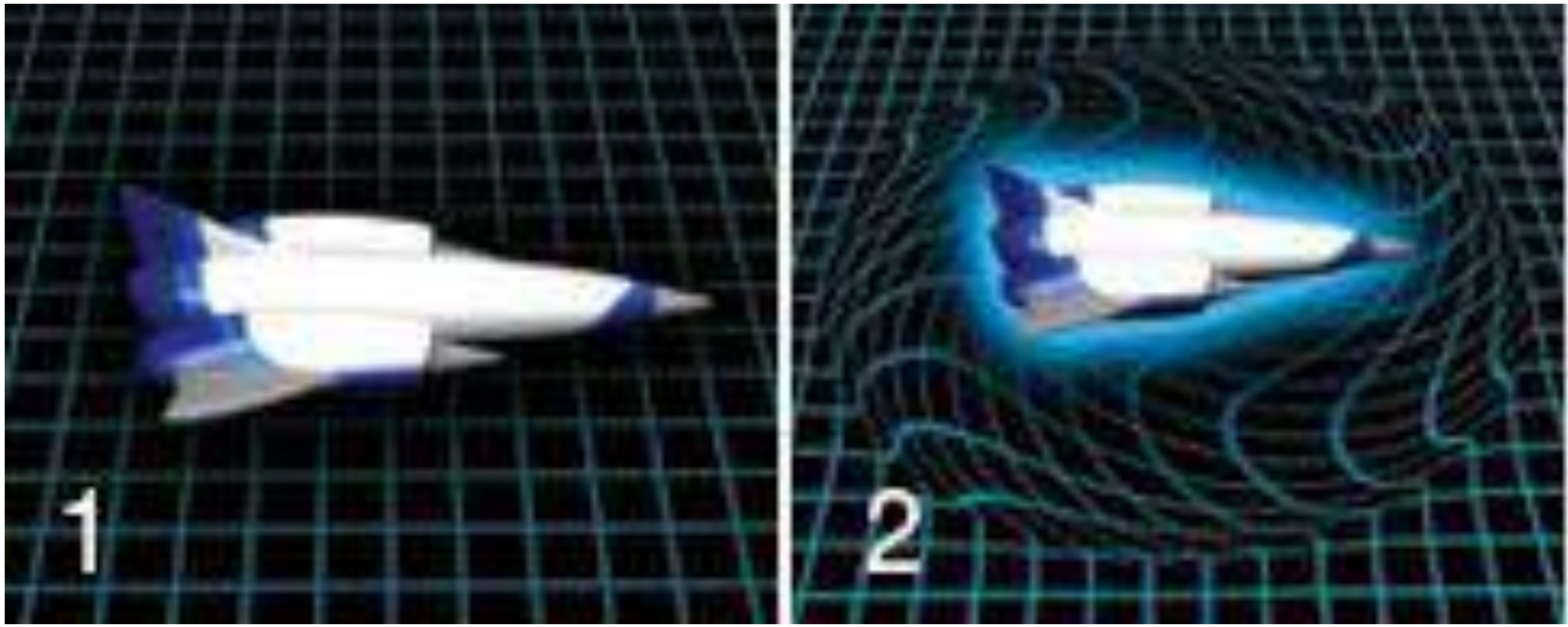


Viaggi interstellati?

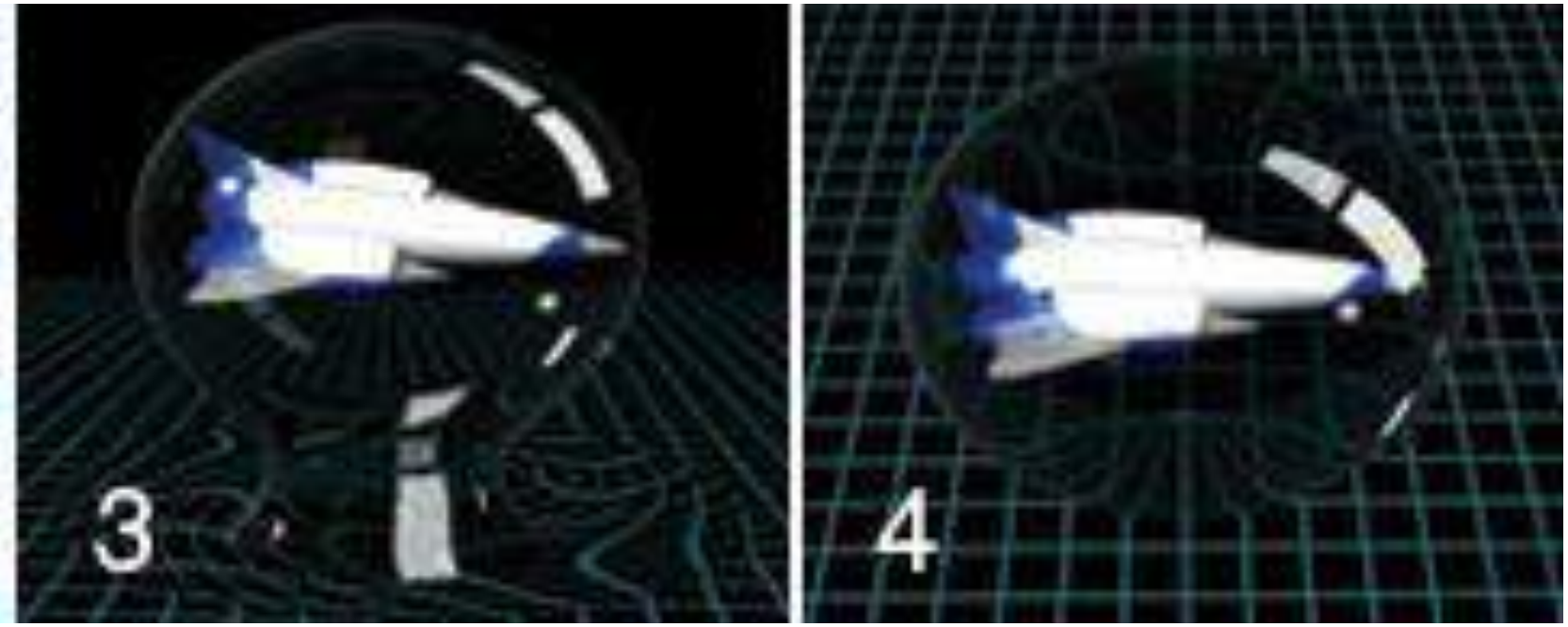
Scorciatoie spazio-temporali



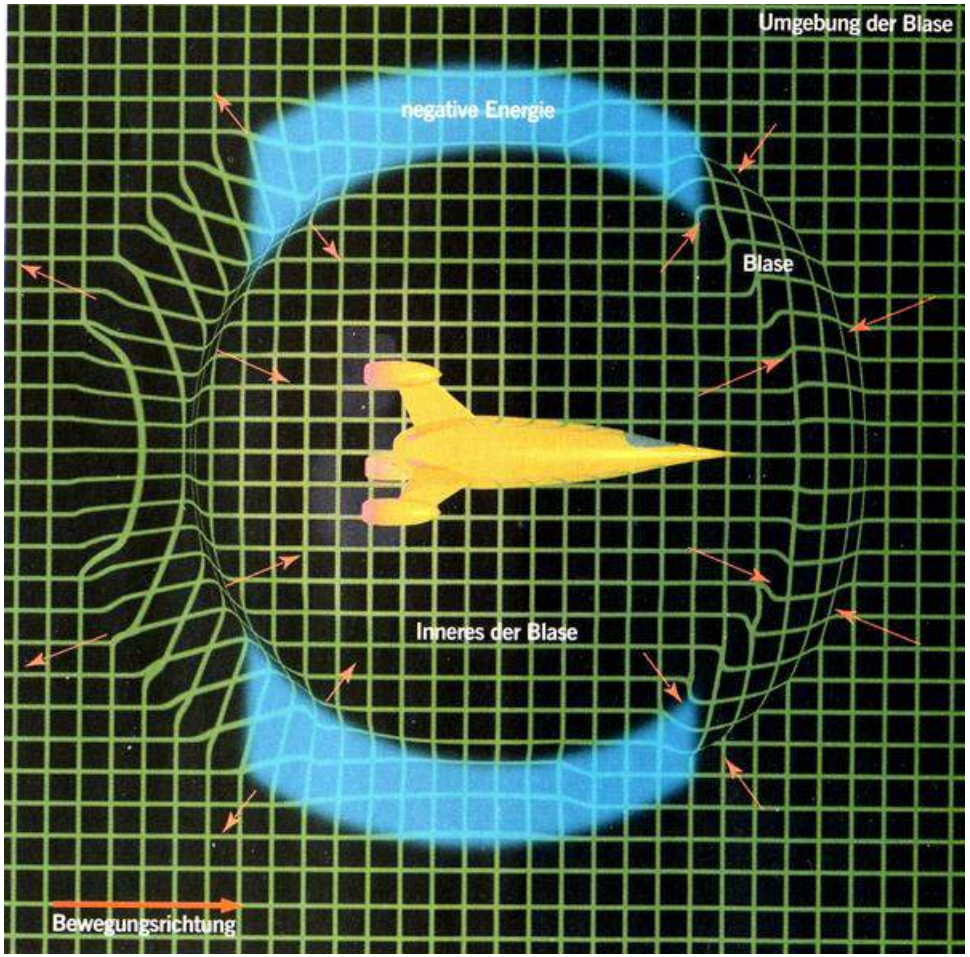
Motori che manipolano lo spazio-tempo



Motori che manipolano lo spazio-tempo

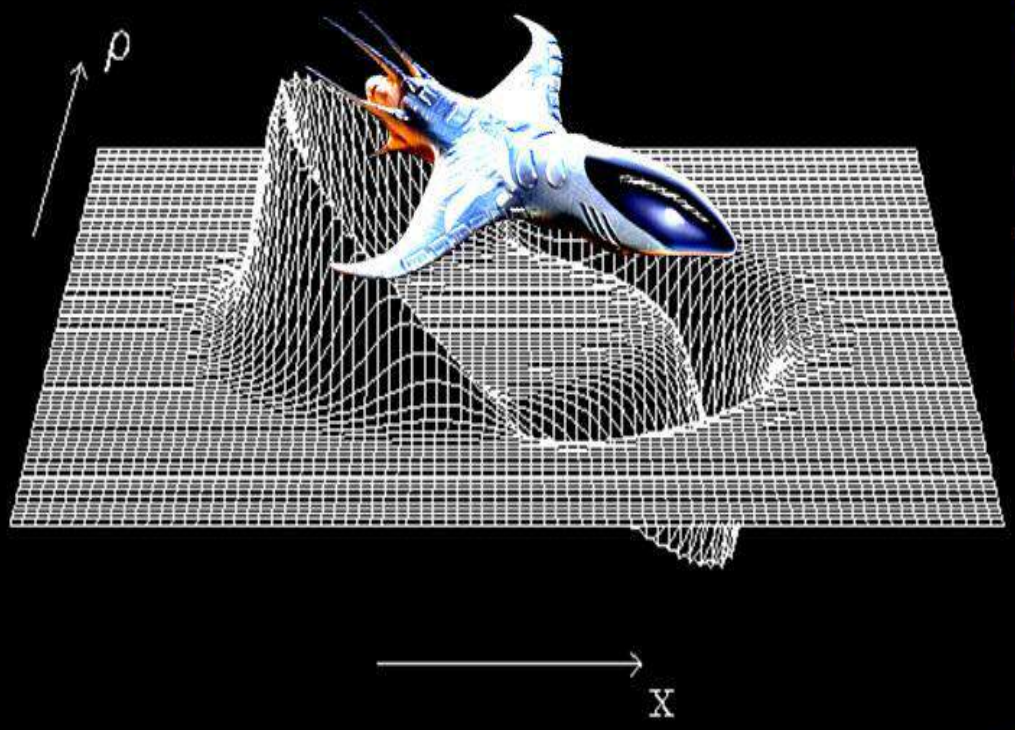


Motori che manipolano lo spazio-tempo: Alcubierre – surf sulle onde spazio-temporali



Alcubierre Warp Drive

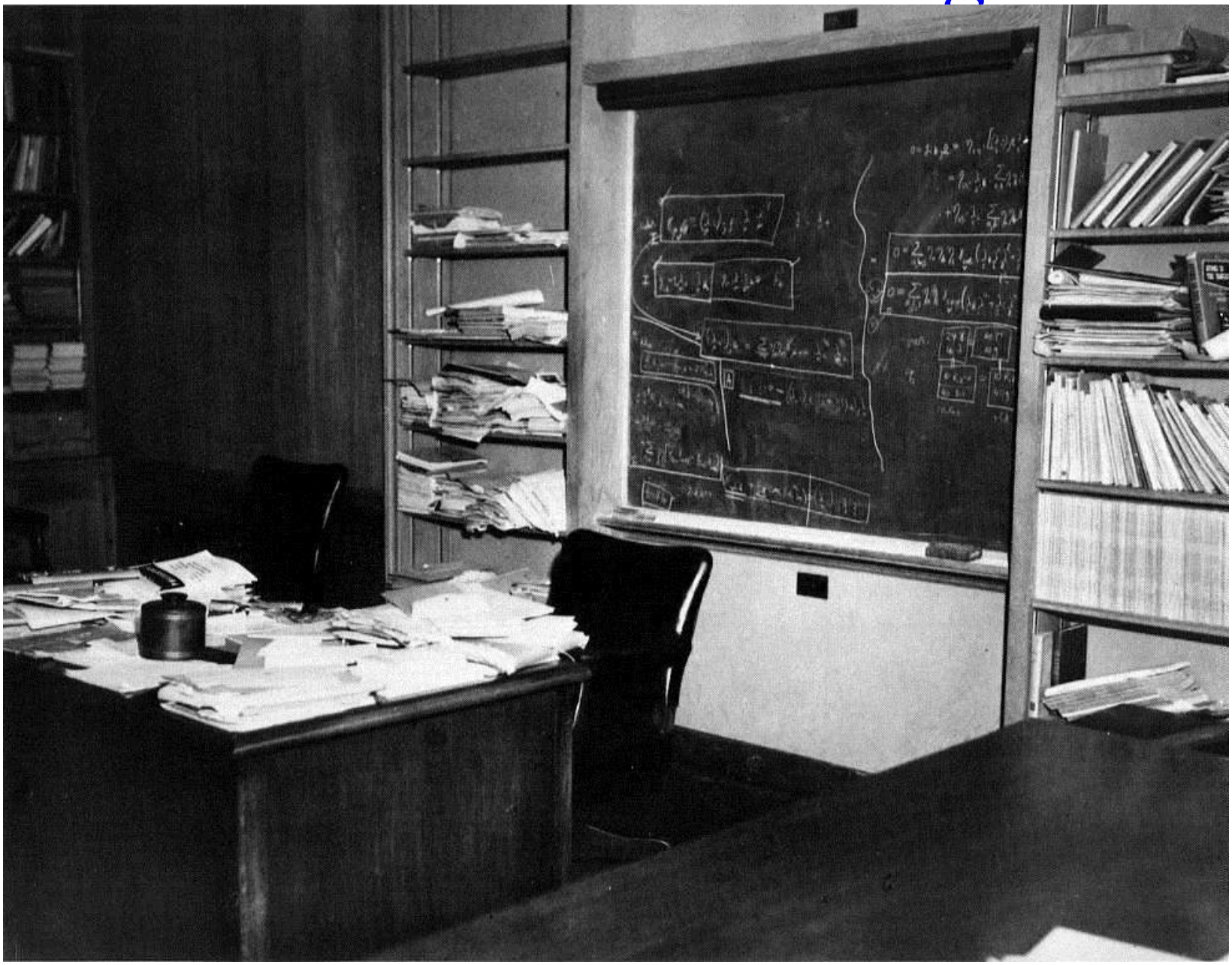
$$\vartheta = - \alpha \ \mathrm{Tr}(\mathrm{K})$$



Alcubierre Warp Drive: stretches spacetime in a wave causing the fabric of space ahead of a spacecraft to contract and the space behind it to expand.

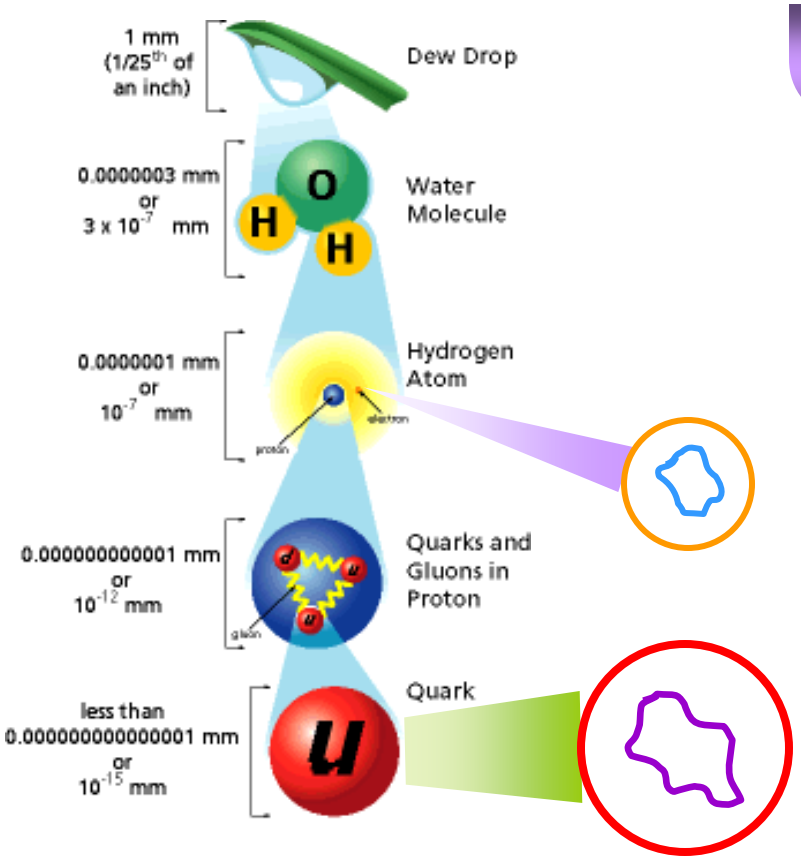
The ship can ride the wave to accelerate to high speeds and time travel.

Einstein – l'ultima lavagna



Questioni Aperte

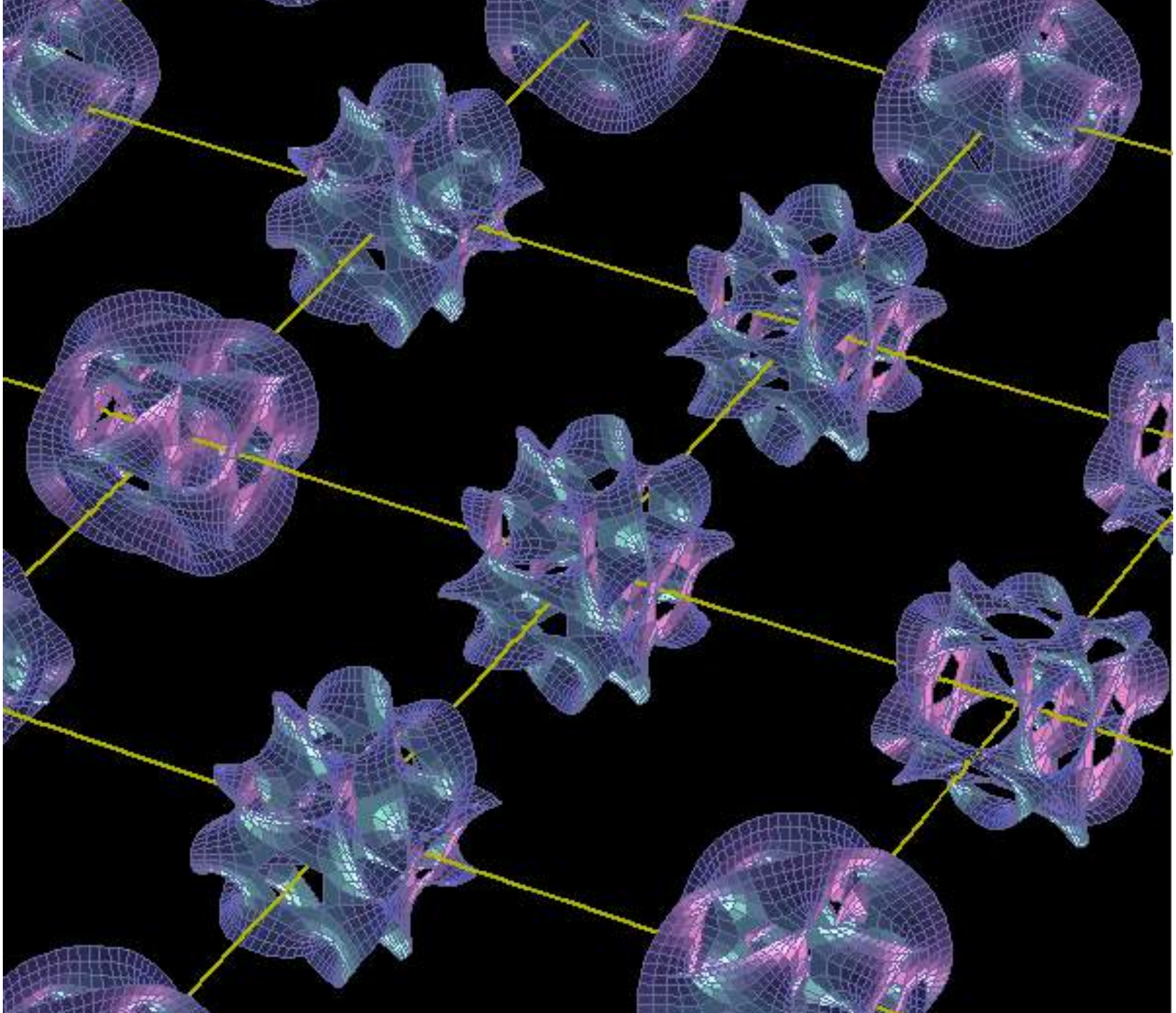
- Le particelle sono veramente puntiformi ?

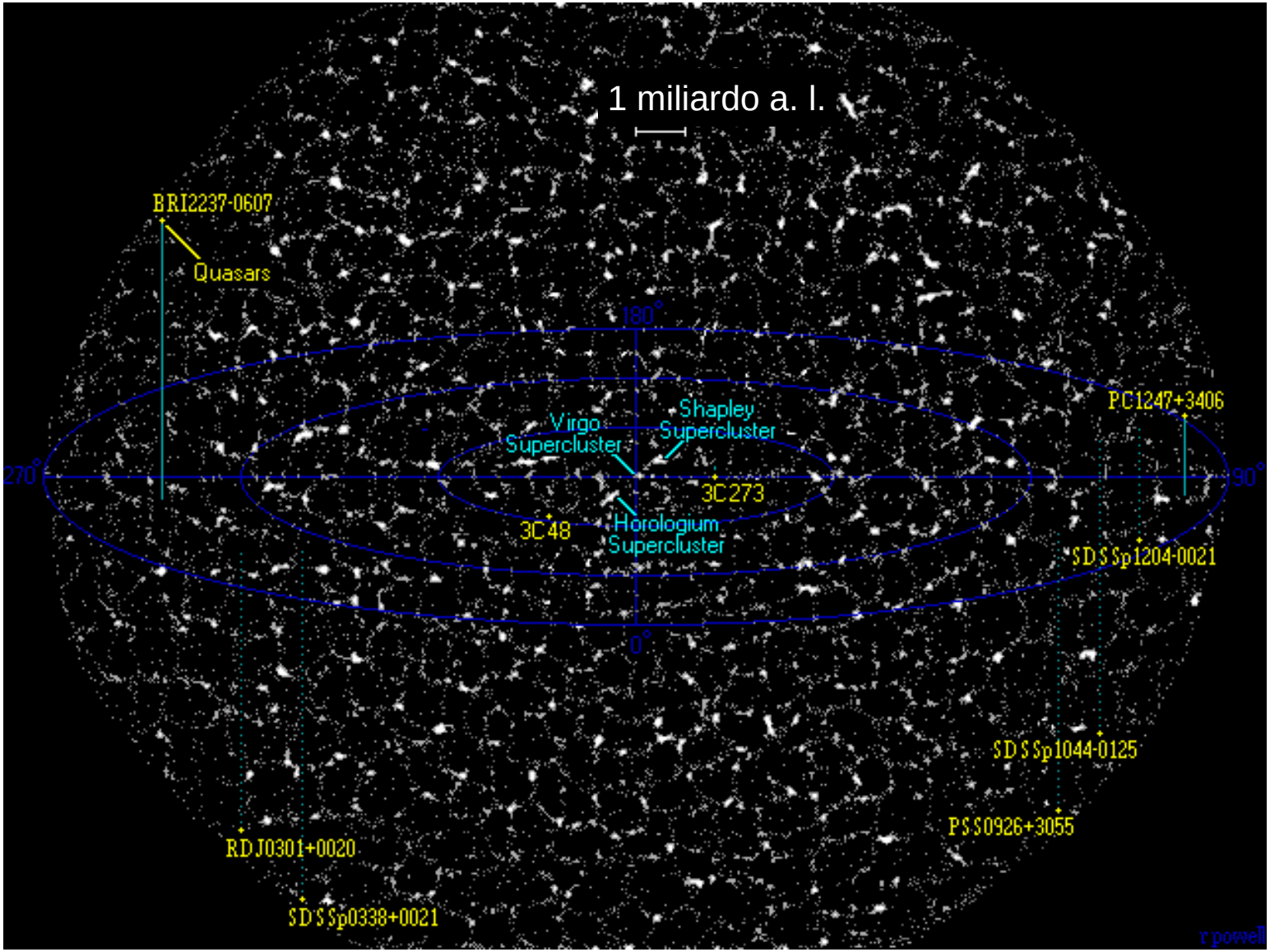


Teoria delle Stringhe

ulteriore livello microscopico: particelle non sono puntiformi, ma piccoli (10^{-33} cm) anelli oscillanti

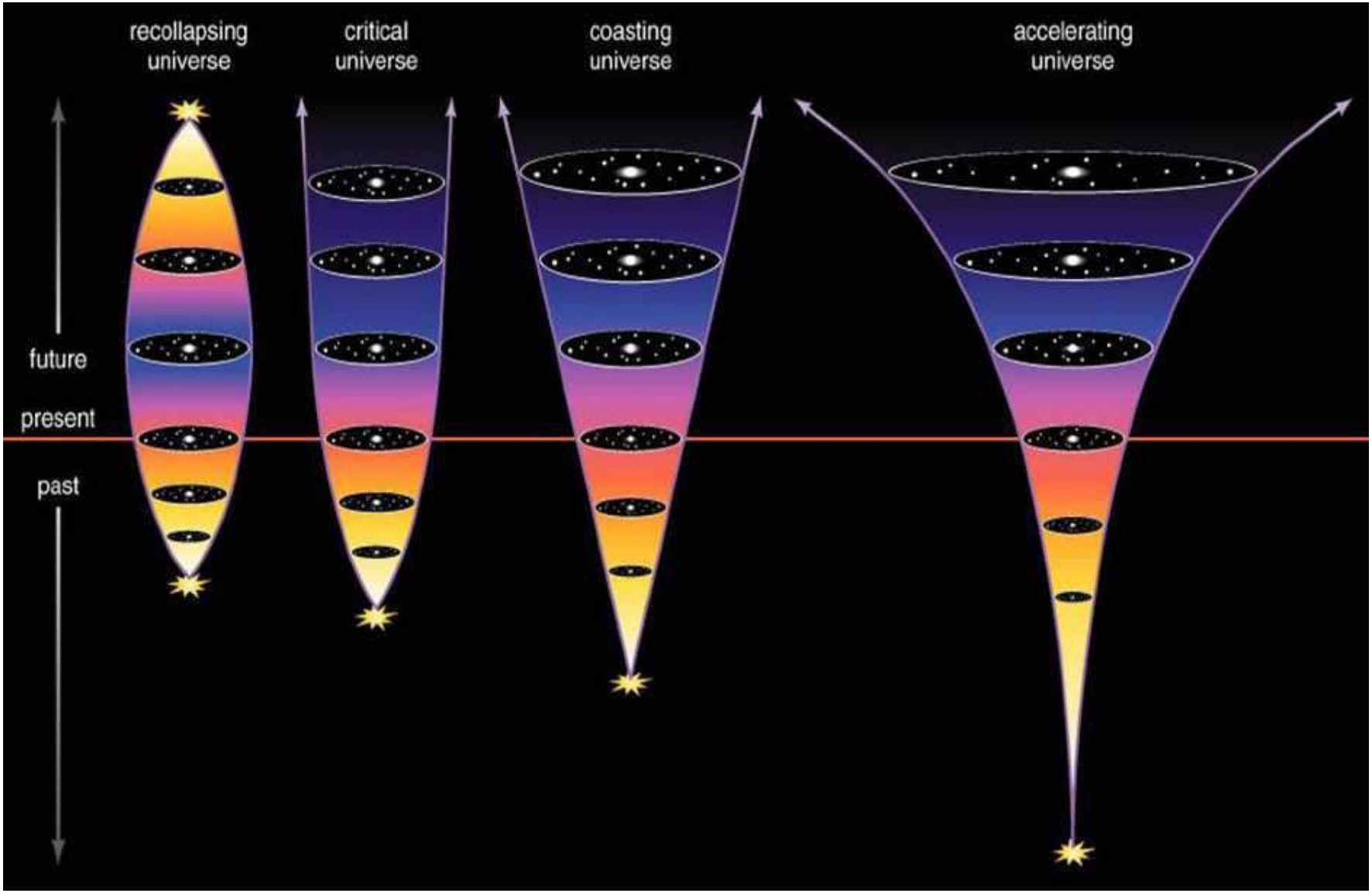
diversi stati di oscillazione della stringa → particelle diverse

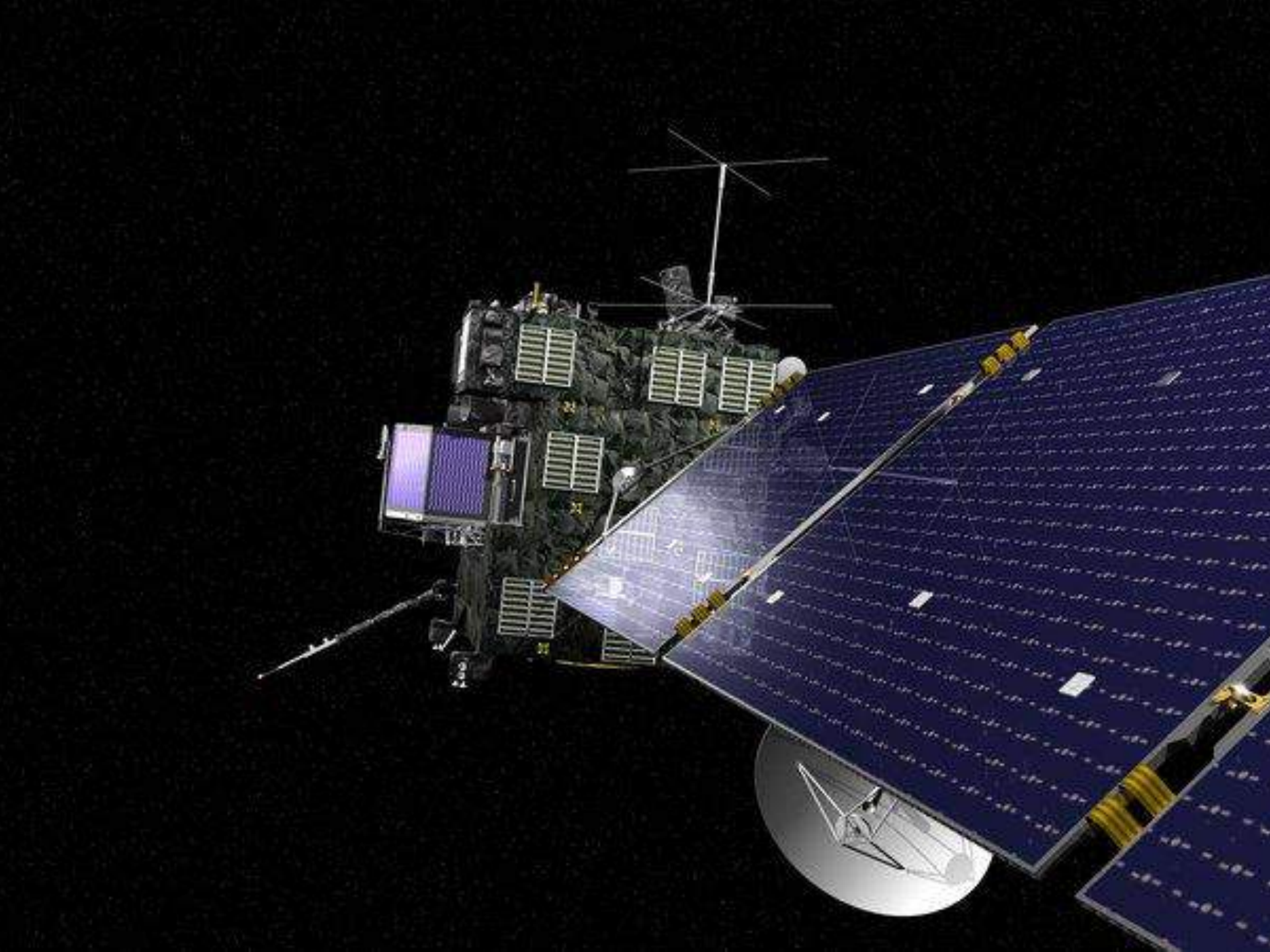



1 miliardo a. l.
BRI2237-0607
Quasars
180°
270°
90°
0°
Virgo
Supercluster
Shapley
Supercluster
3C273
3C48
Horologium
Supercluster
PC1247+3406
SDSSp1204-0021
SDSSp1044-0125
PSS0926+3055
RDJ0301+0020
SDSSp0338+0021
r powell

Zoom In x15

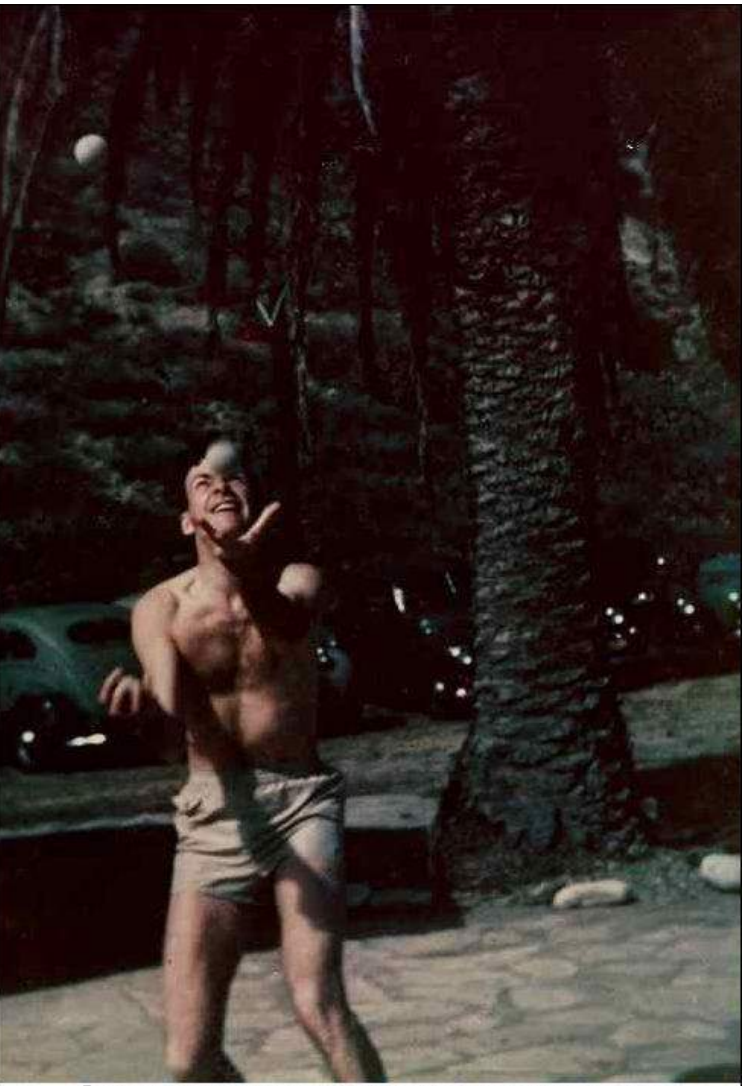
I modelli Cosmologici






Siamo soli nell'Universo?

Feynman – Il valore della scienza



Fuori dalla culla
sulla terra asciutta
eccolo
in piedi:
atomi con la coscienza
materia con la curiosità.
In piedi davanti al mare
meravigliato della propria meraviglia: io
un universo di atomi
un atomo nell'universo

Catalina Oana Curceanu

Dai buchi neri all'adroterapia

Un viaggio nella fisica moderna

Nata in Transilvania (Brasov, Romania) Catalina Oana Curceanu è Primo Ricercatore dell'Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati. Dirige un gruppo di ricercatori che lavorano nel campo della fisica sperimentale adronica e nucleare, conducendo esperimenti sia in Italia sia all'estero, e coordina vari progetti europei. Ha organizzato varie conferenze internazionali ed è autrice di più di 200 pubblicazioni scientifiche in riviste internazionali. Svolge un'intensa attività di formazione e divulgazione scientifica e scrive per vari giornali e riviste italiane e romene. Ha la passione di spiegare a tutti quanto sia bello e affascinante il mondo della scienza.

CURCEANU • DAI BUCHI NERI ALL'ADROTERAPIA