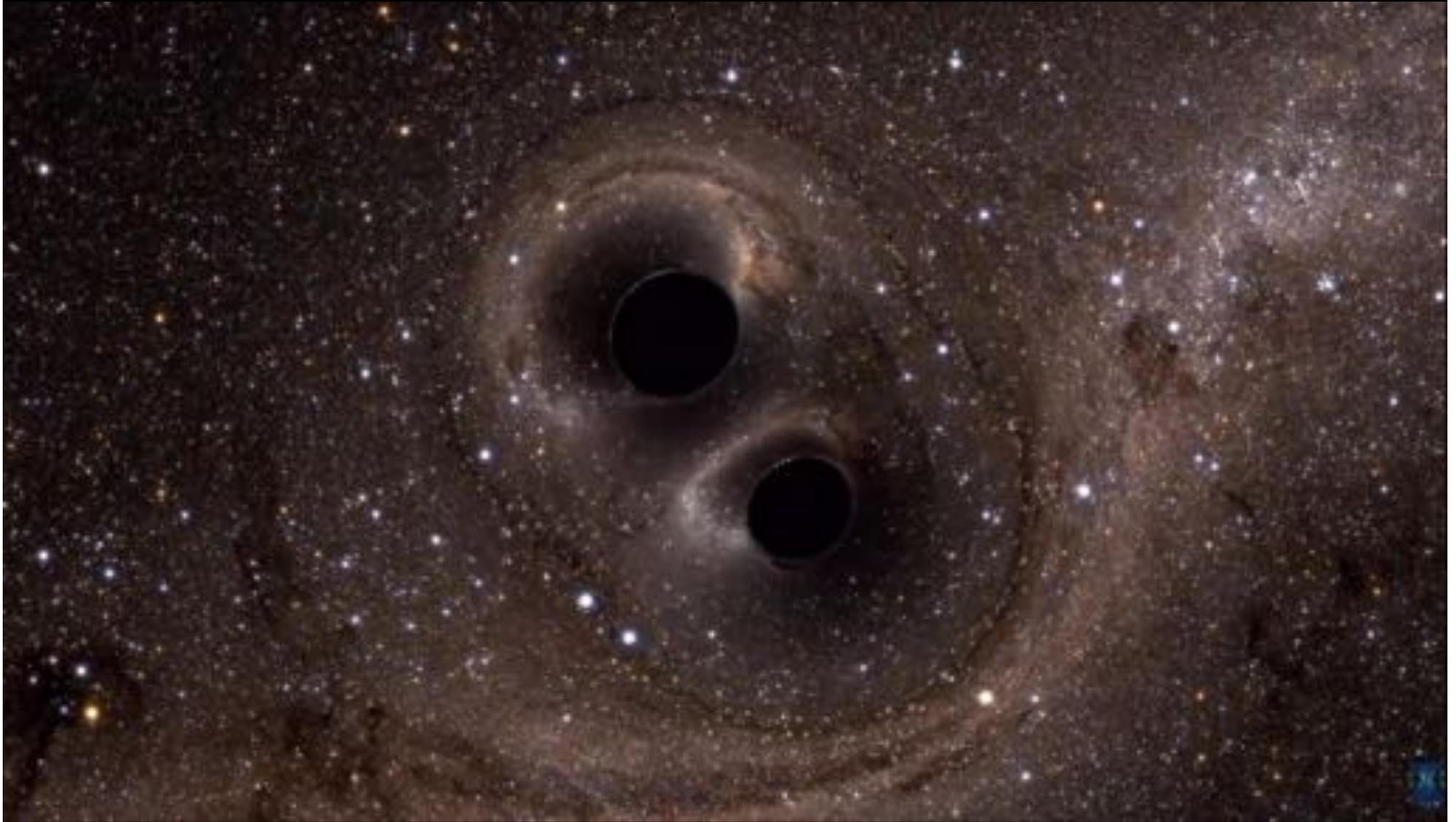


Un miliardo di anni fa in una galassia
lontana, lontana . . .

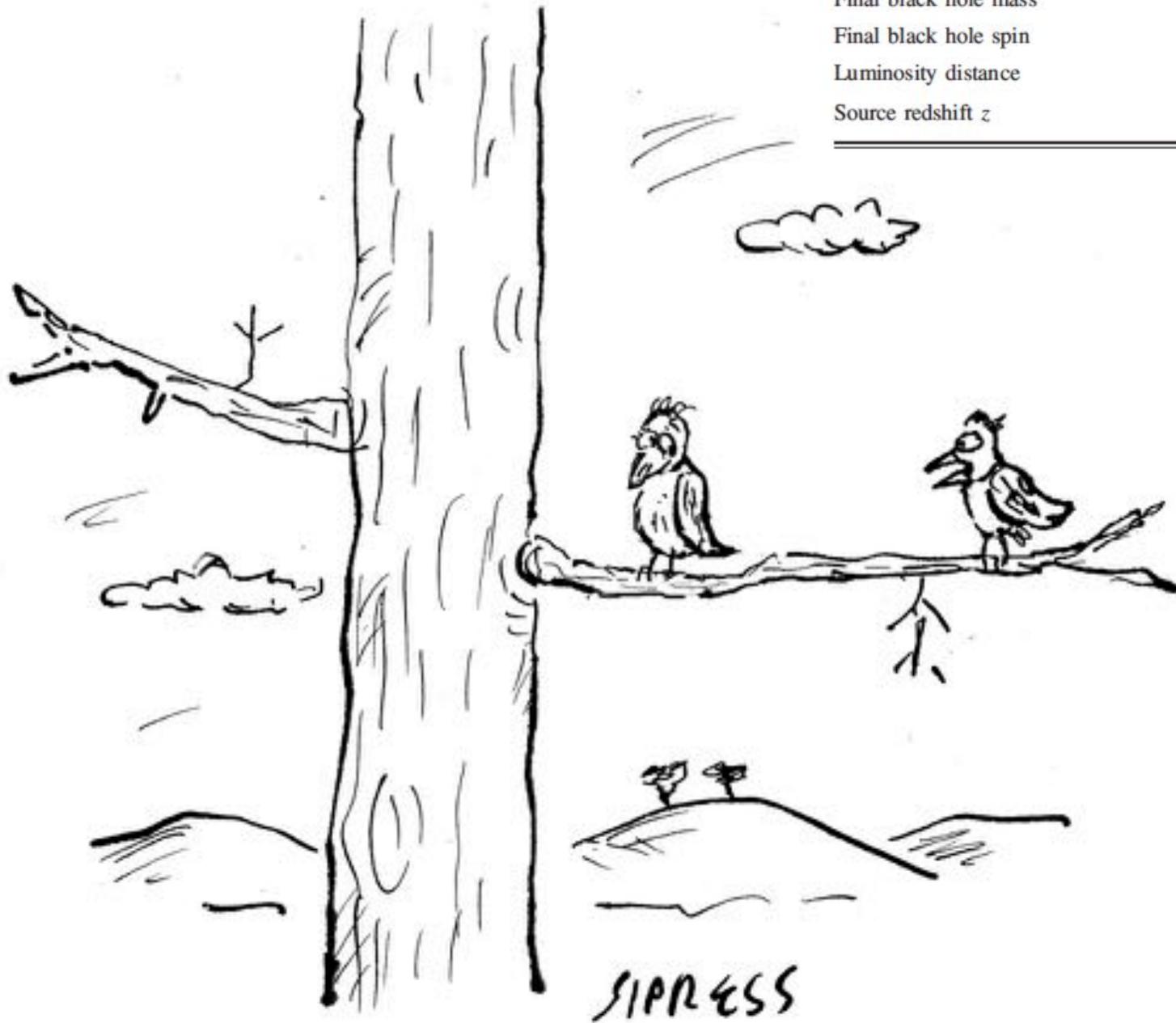
Open Labs 2016

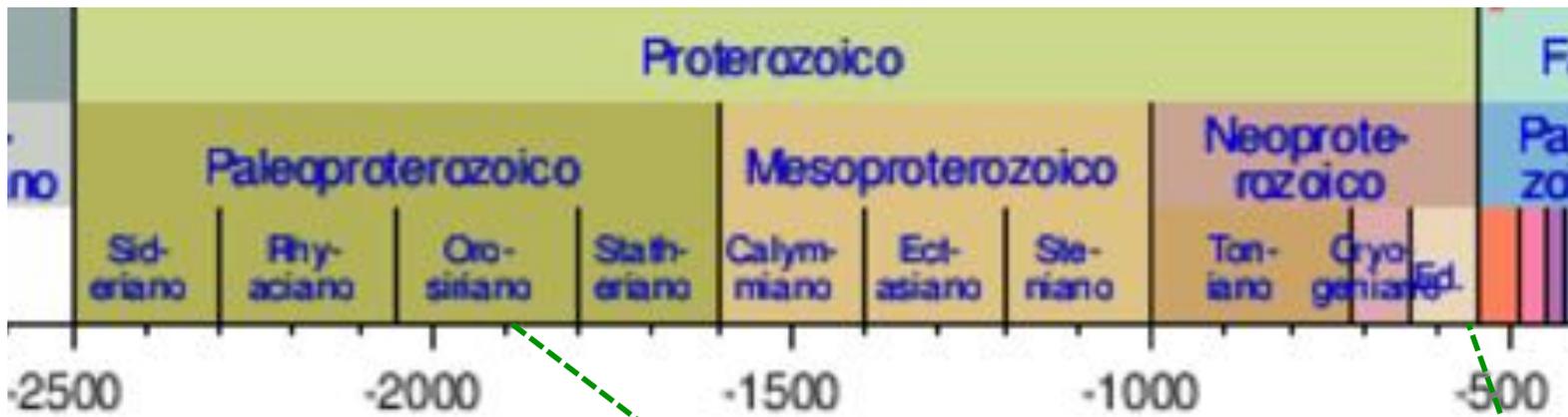
*Barbara Sciascia (INFN)
Laboratori Nazionali di Frascati*

*Poco più di un miliardo di anni fa
due buchi neri si sono scontrati
producendo un'onda gravitazionale
che ha viaggiato fino a noi ed è
stata rivelata il 14 settembre 2015
dall'esperimento Virgo-Ligo...*

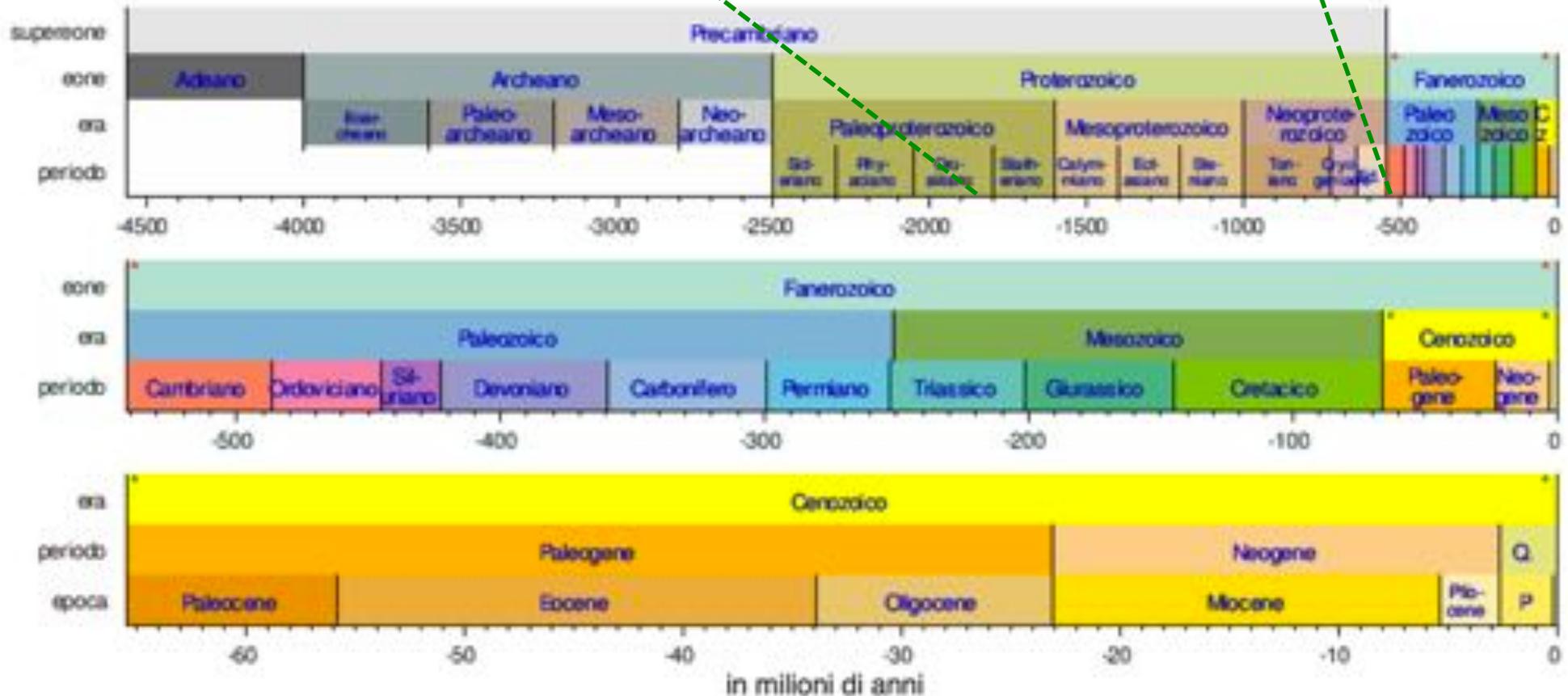


Primary black hole mass	$36_{-4}^{+5} M_{\odot}$
Secondary black hole mass	$29_{-4}^{+4} M_{\odot}$
Final black hole mass	$62_{-4}^{+4} M_{\odot}$
Final black hole spin	$0.67_{-0.07}^{+0.05}$
Luminosity distance	410_{-180}^{+160} Mpc
Source redshift z	$0.09_{-0.04}^{+0.03}$



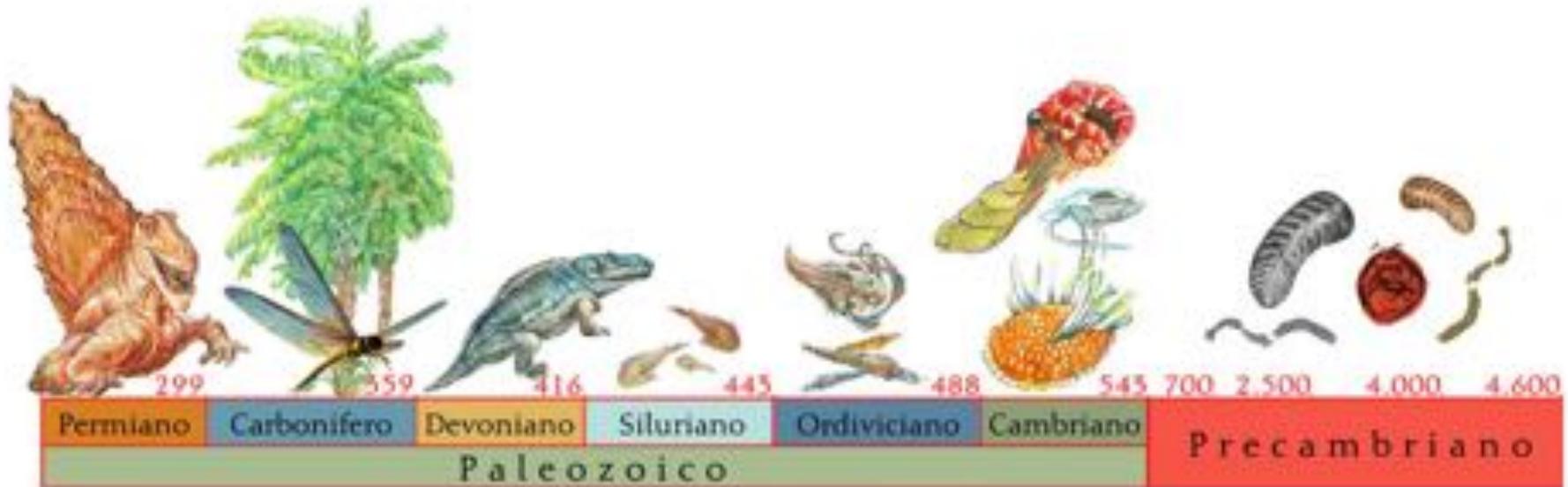
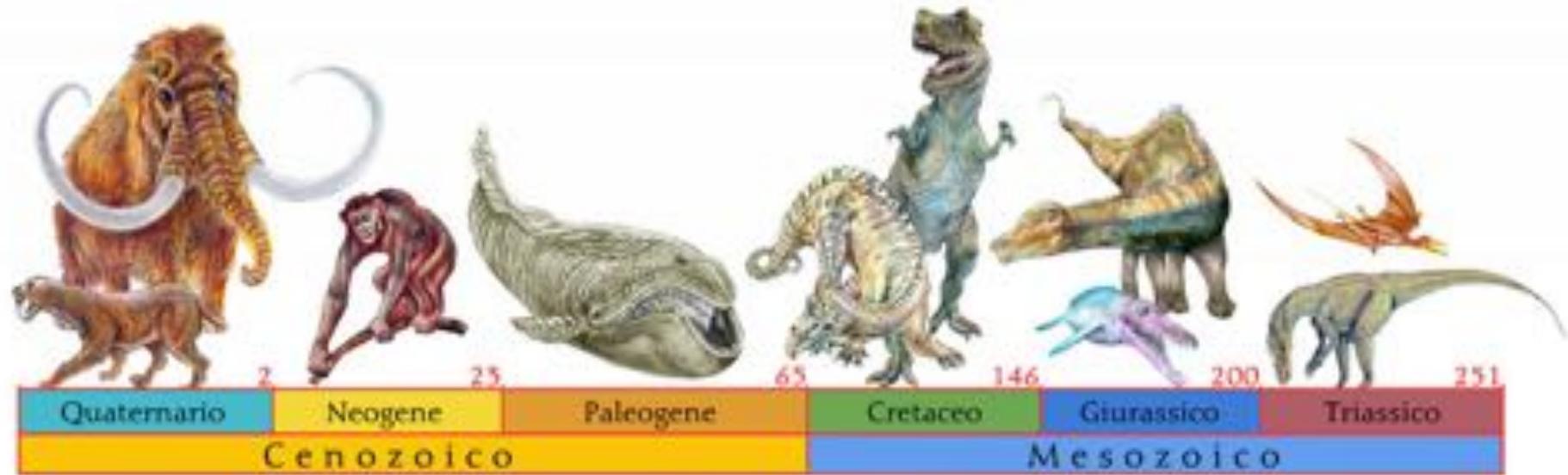


[https://it.wikipedia.org/wiki/Scala_dei_tempi_geologici]



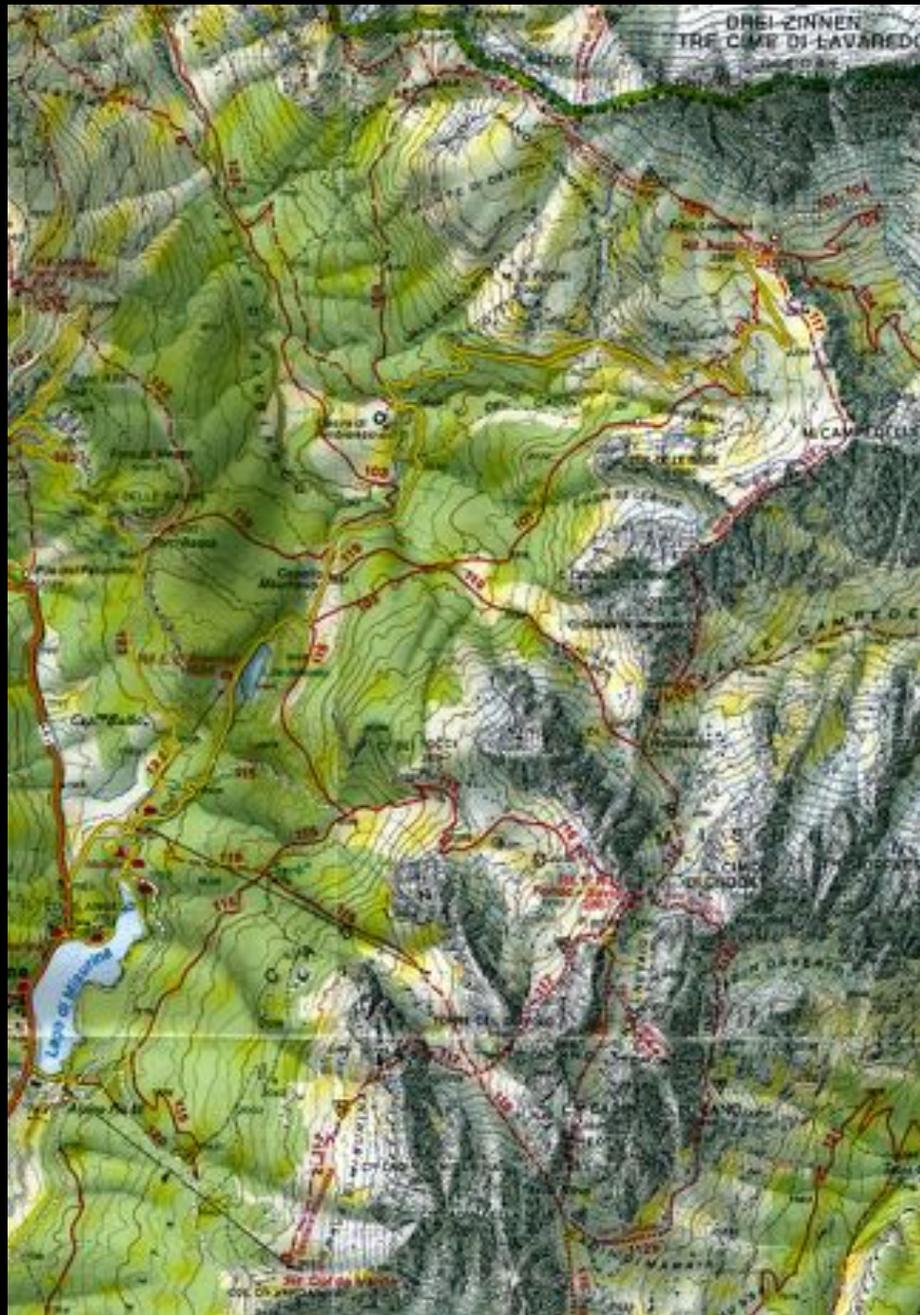
LA SCALA DEL TEMPO GEOLOGICO IN MILIONI DI ANNI

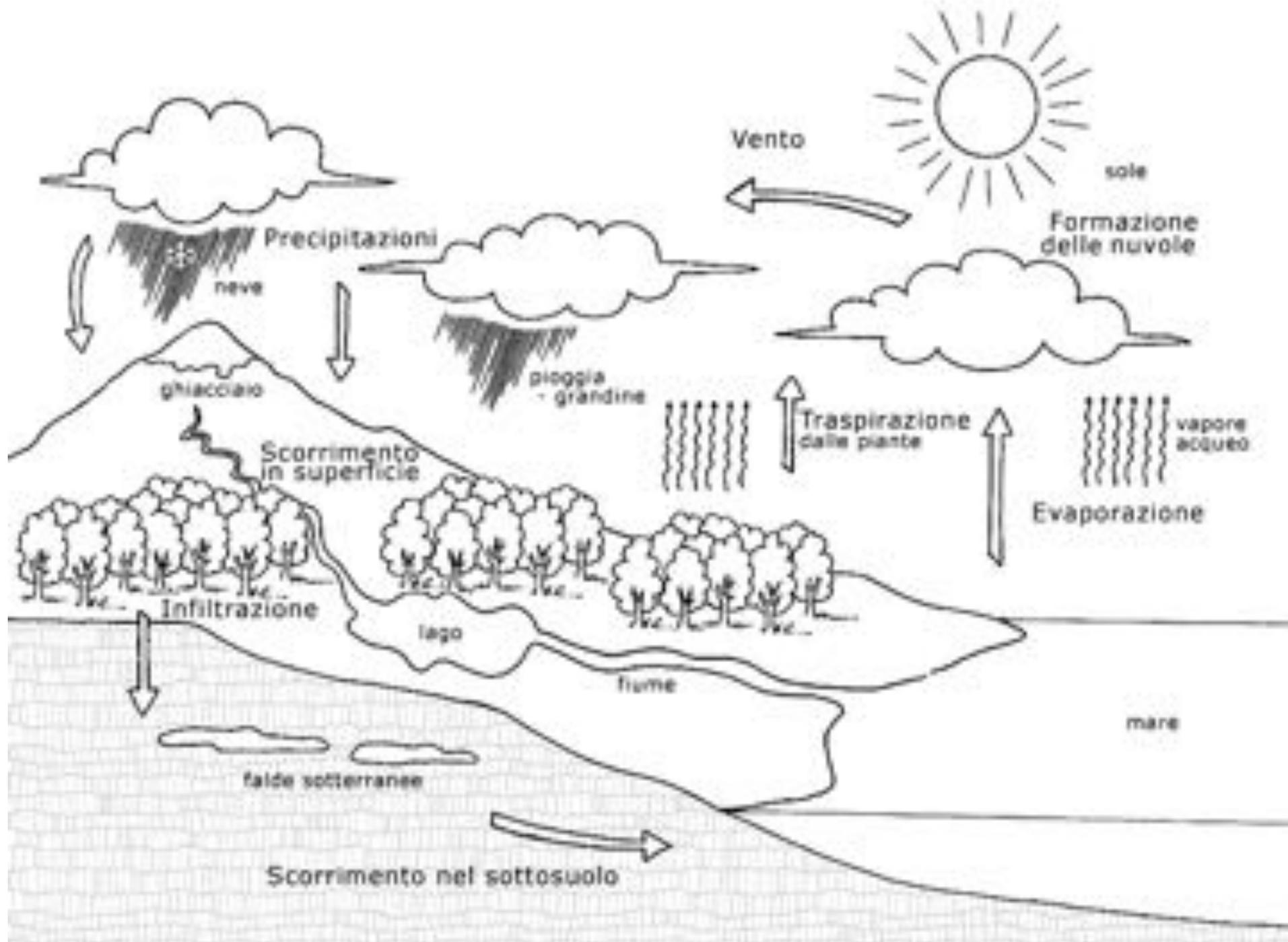
RAPPRESENTA L'EVOLUZIONE DELLA VITA SUL PIANETA TERRA CON LA SUA MIRABILE VARIETA' DI FORME, PERIODO PER PERIODO



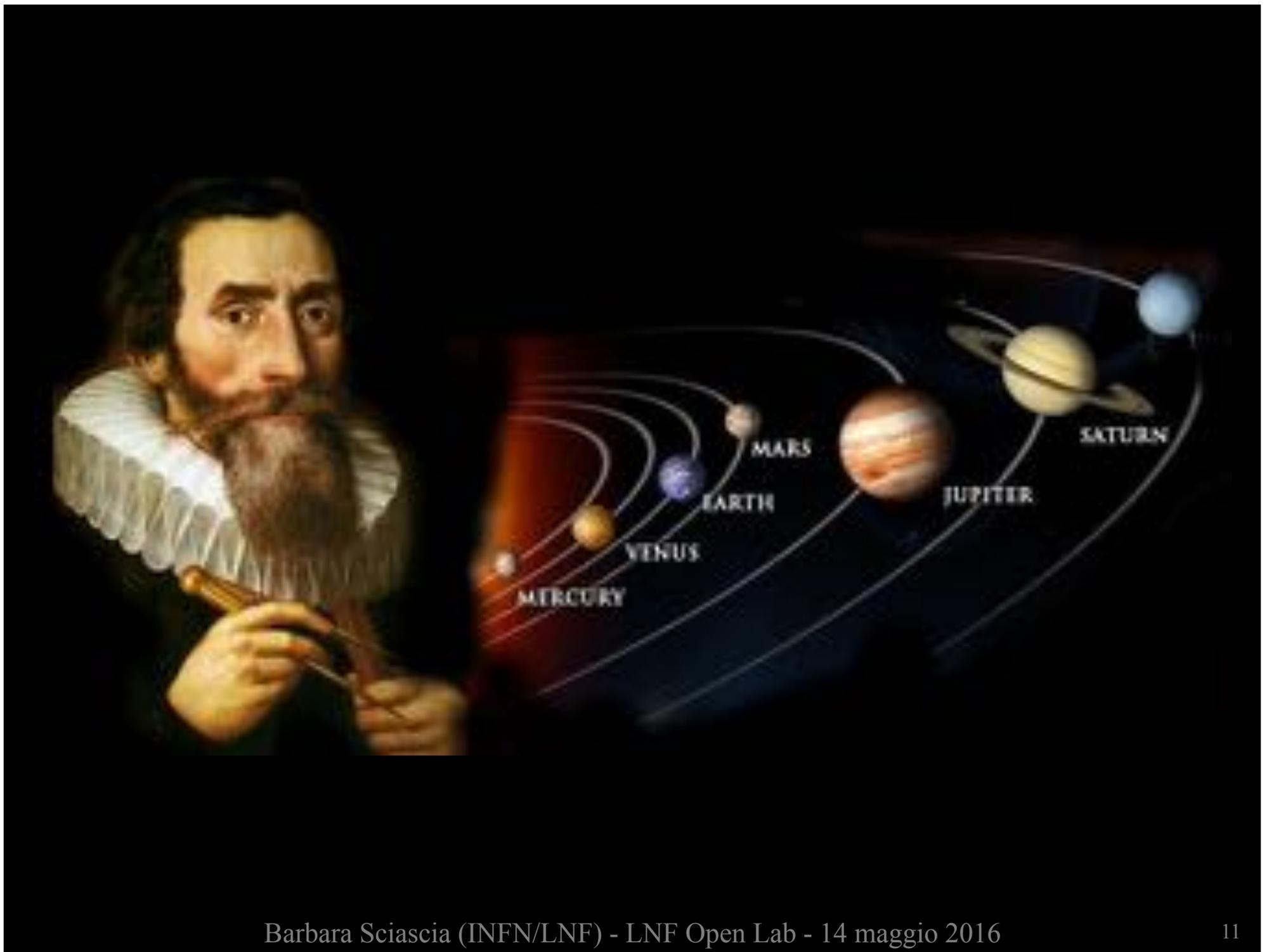
[<http://www.museocapellini.it/sites/default/files/Storia%20della%20Terra...jpg>]



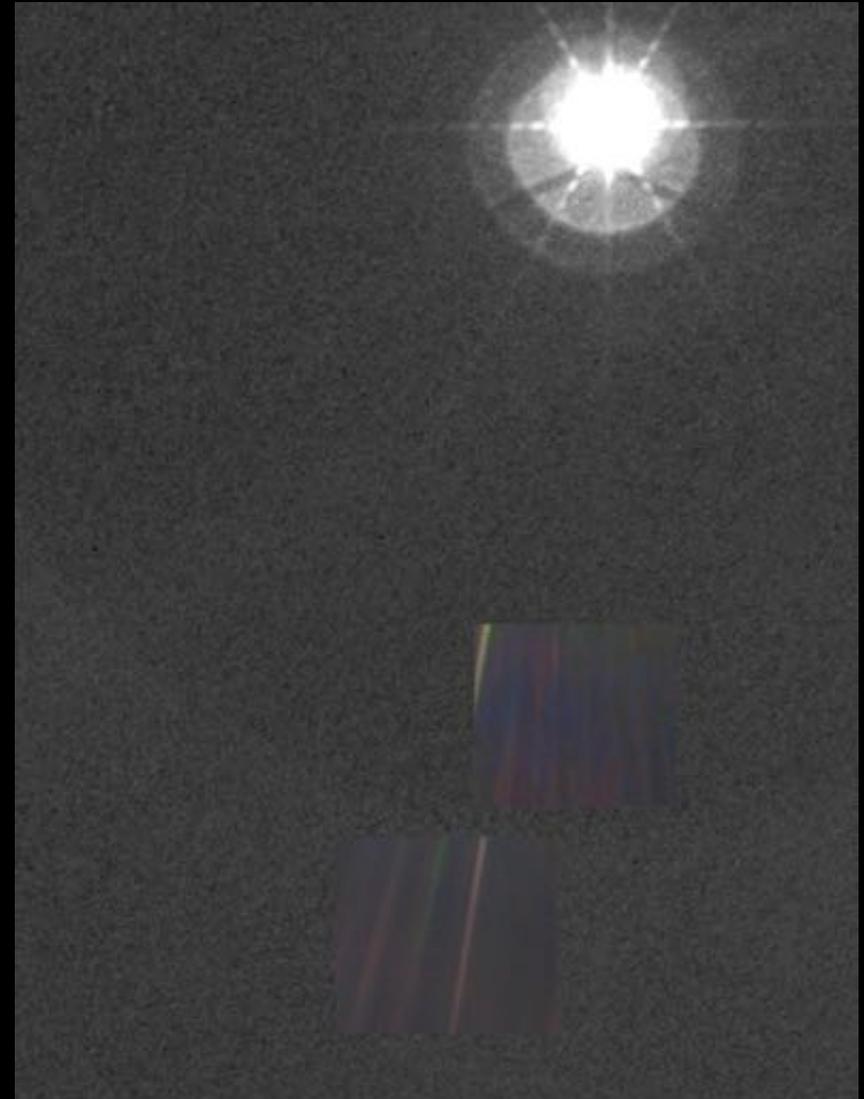












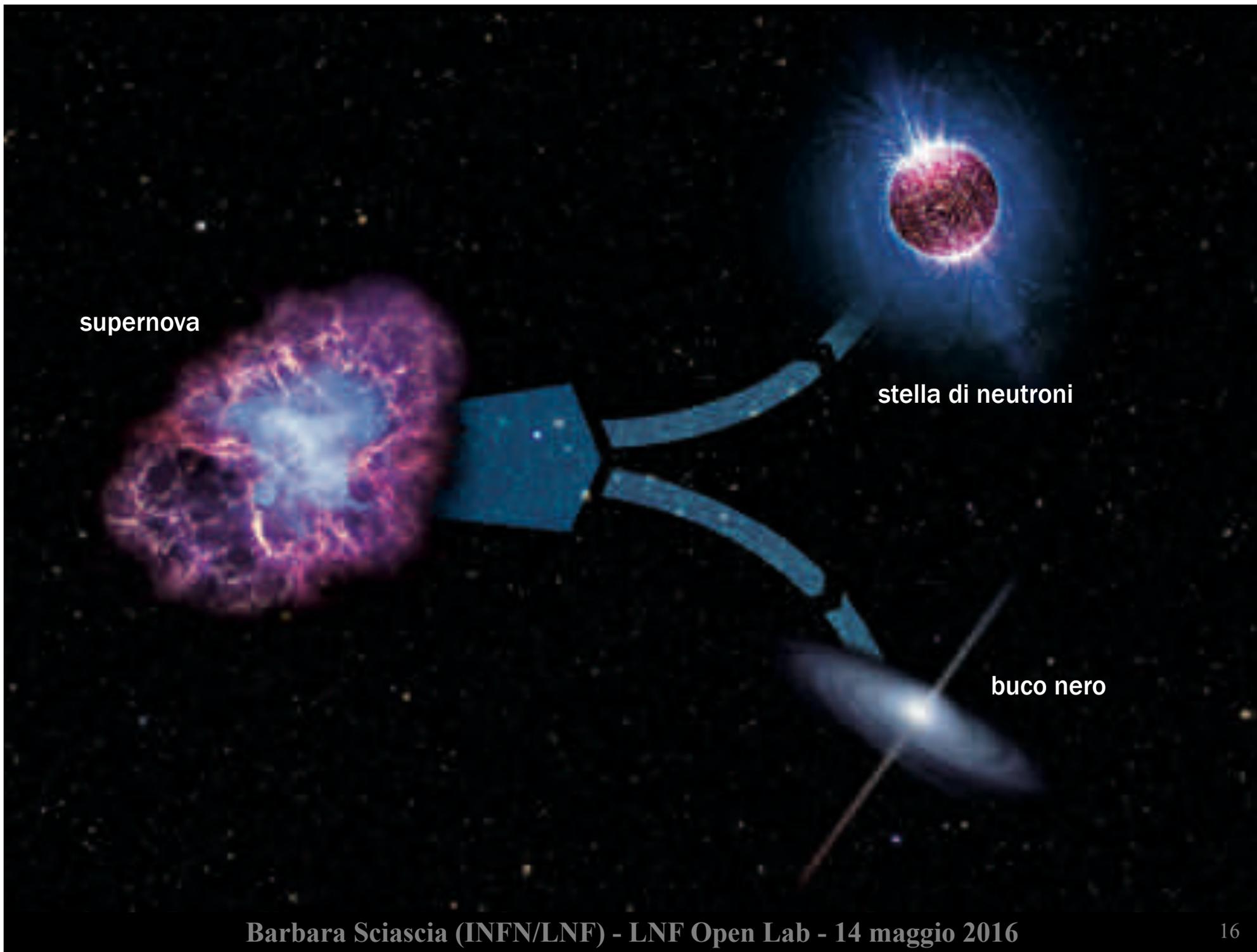


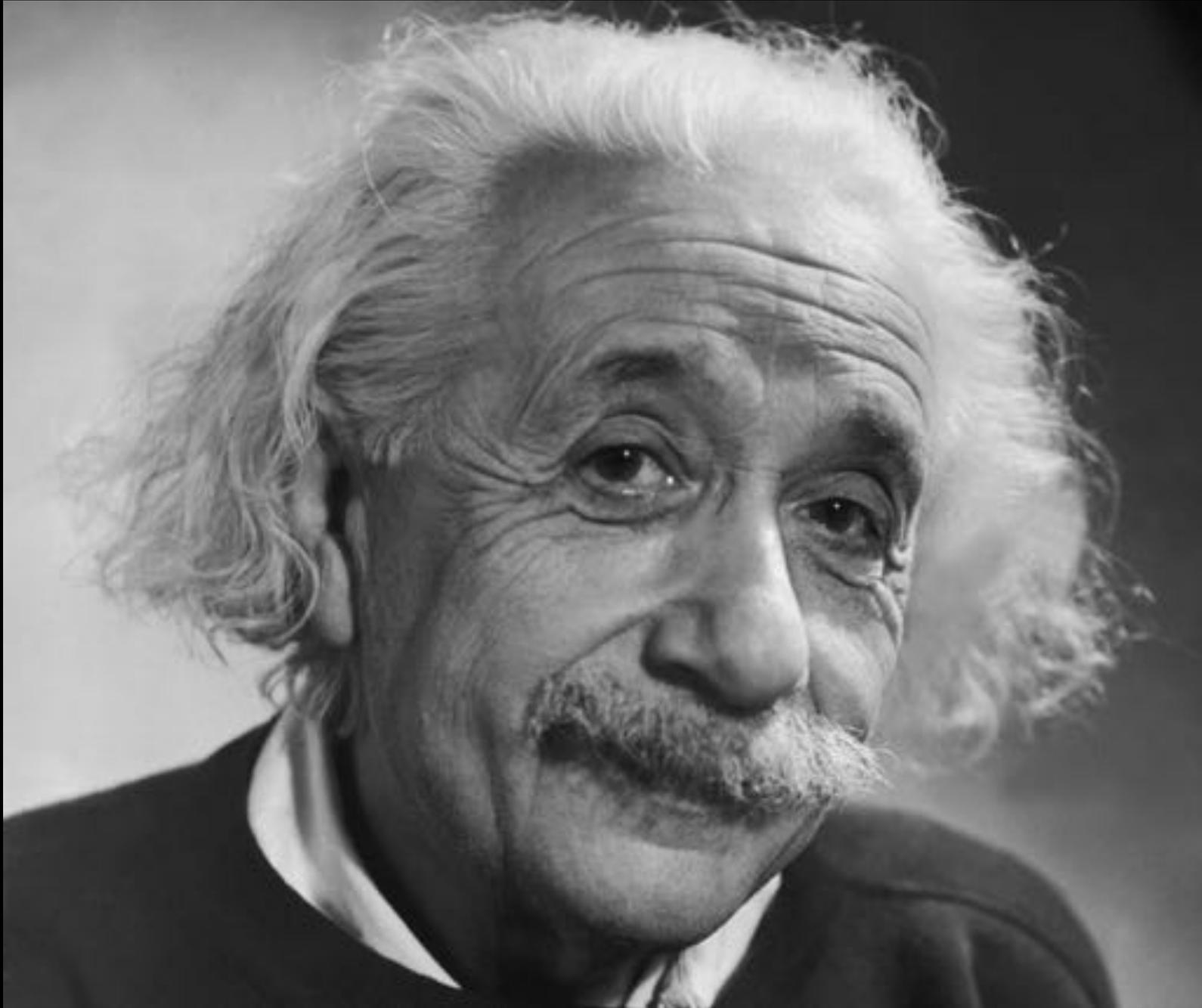


supernova

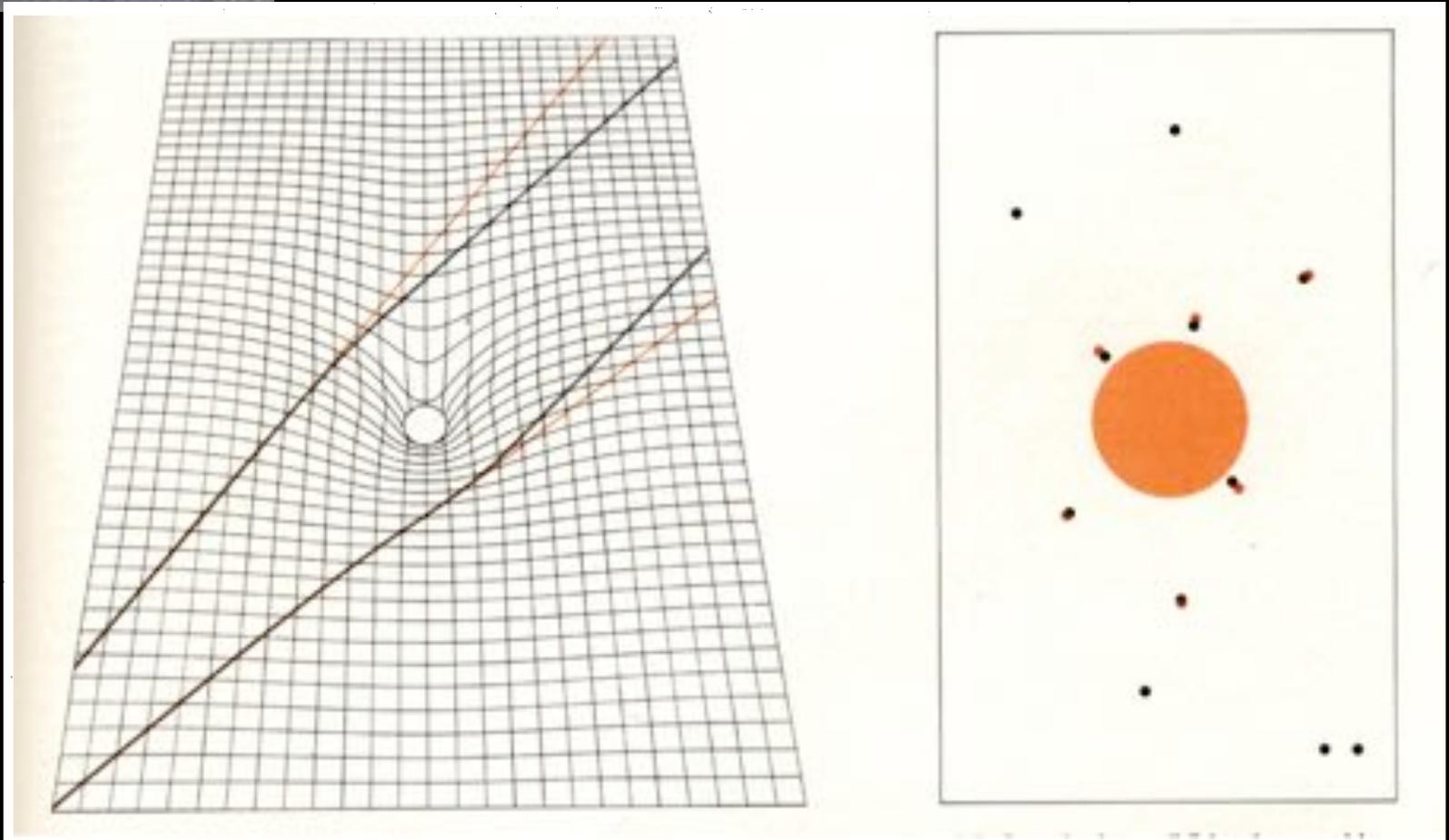
stella di neutroni

buco nero



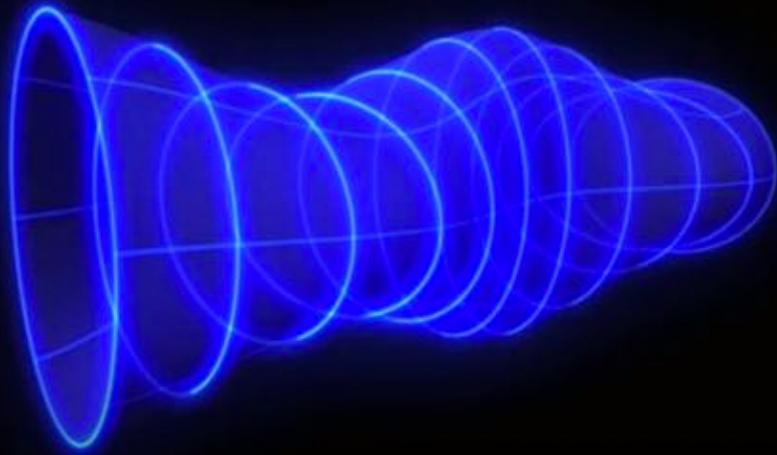
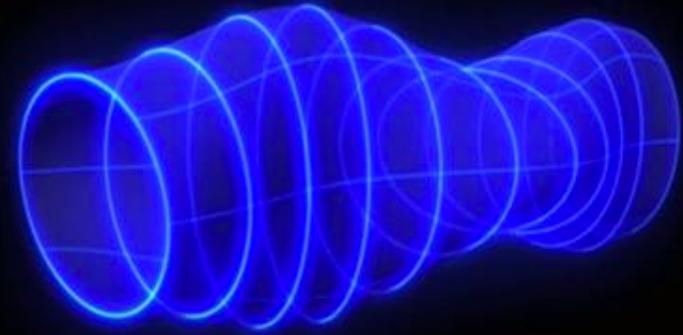


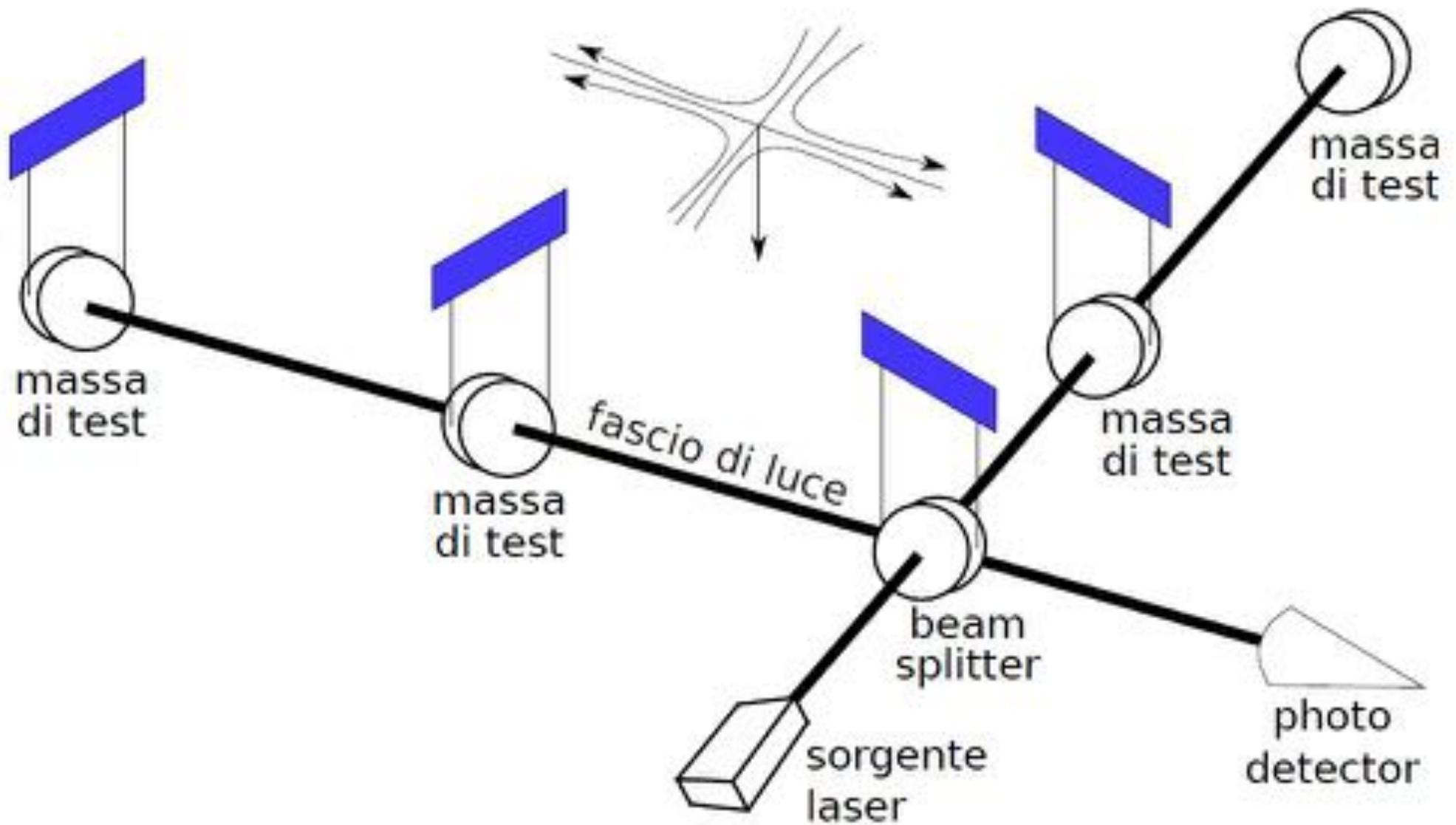


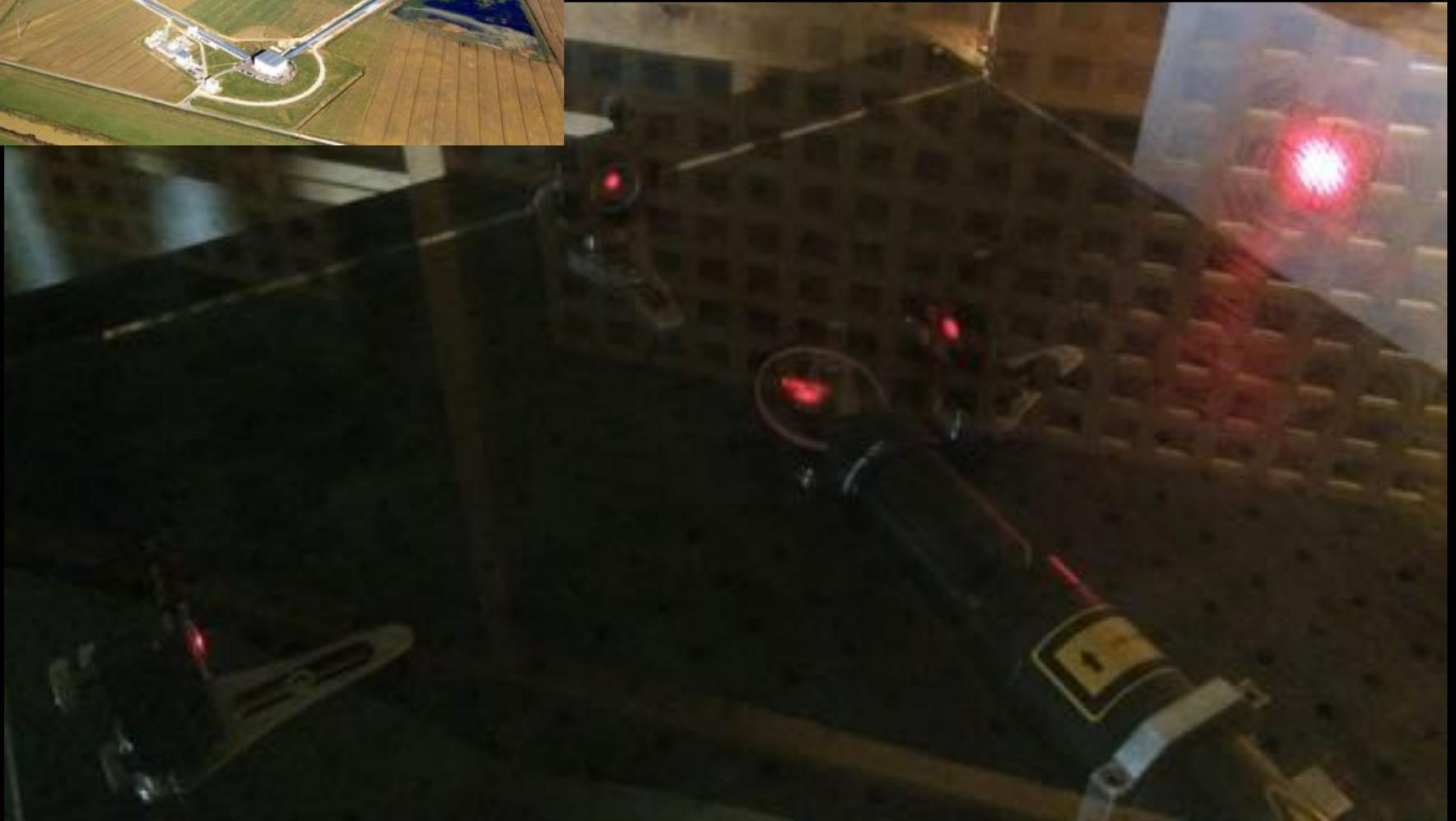












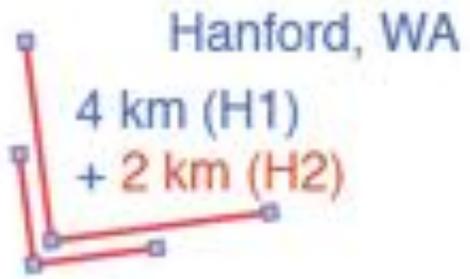
Barbara Sciascia (INFN/LNF) - LNF Open Lab - 14 maggio 2016



LIGO: Laser Interferometer Gravitational-wave Observatory



LHO



Hanford, WA

4 km (H1)

+ 2 km (H2)



LLO

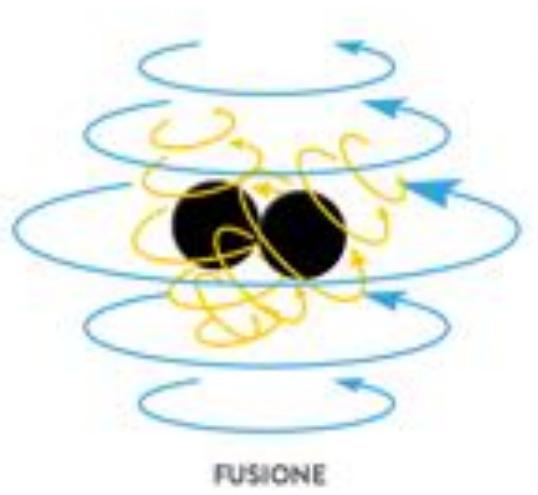
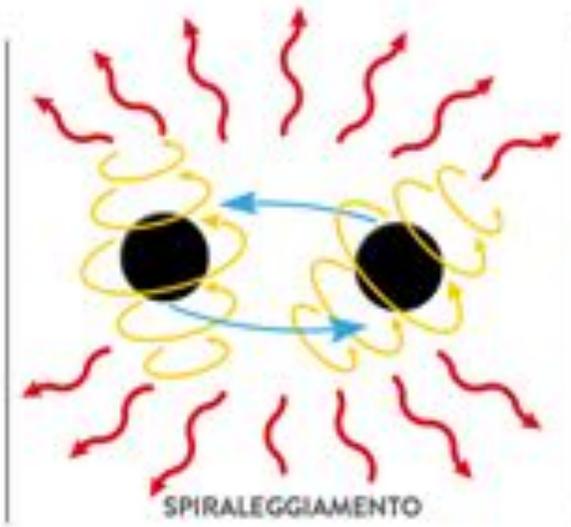
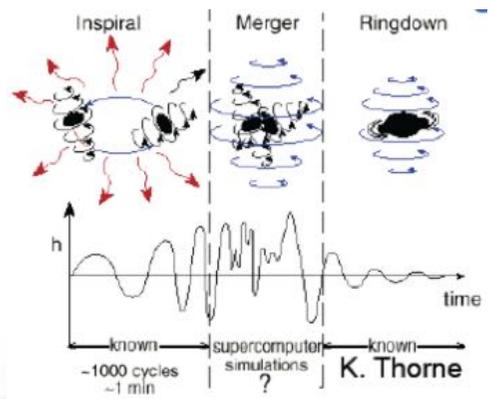
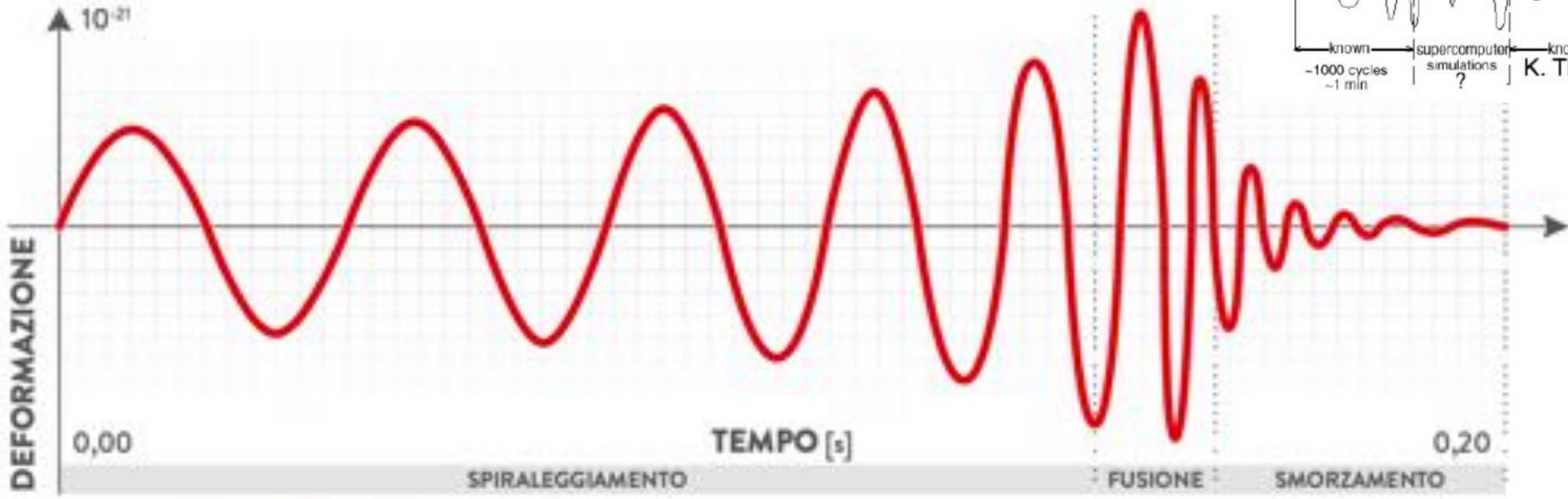


4 km

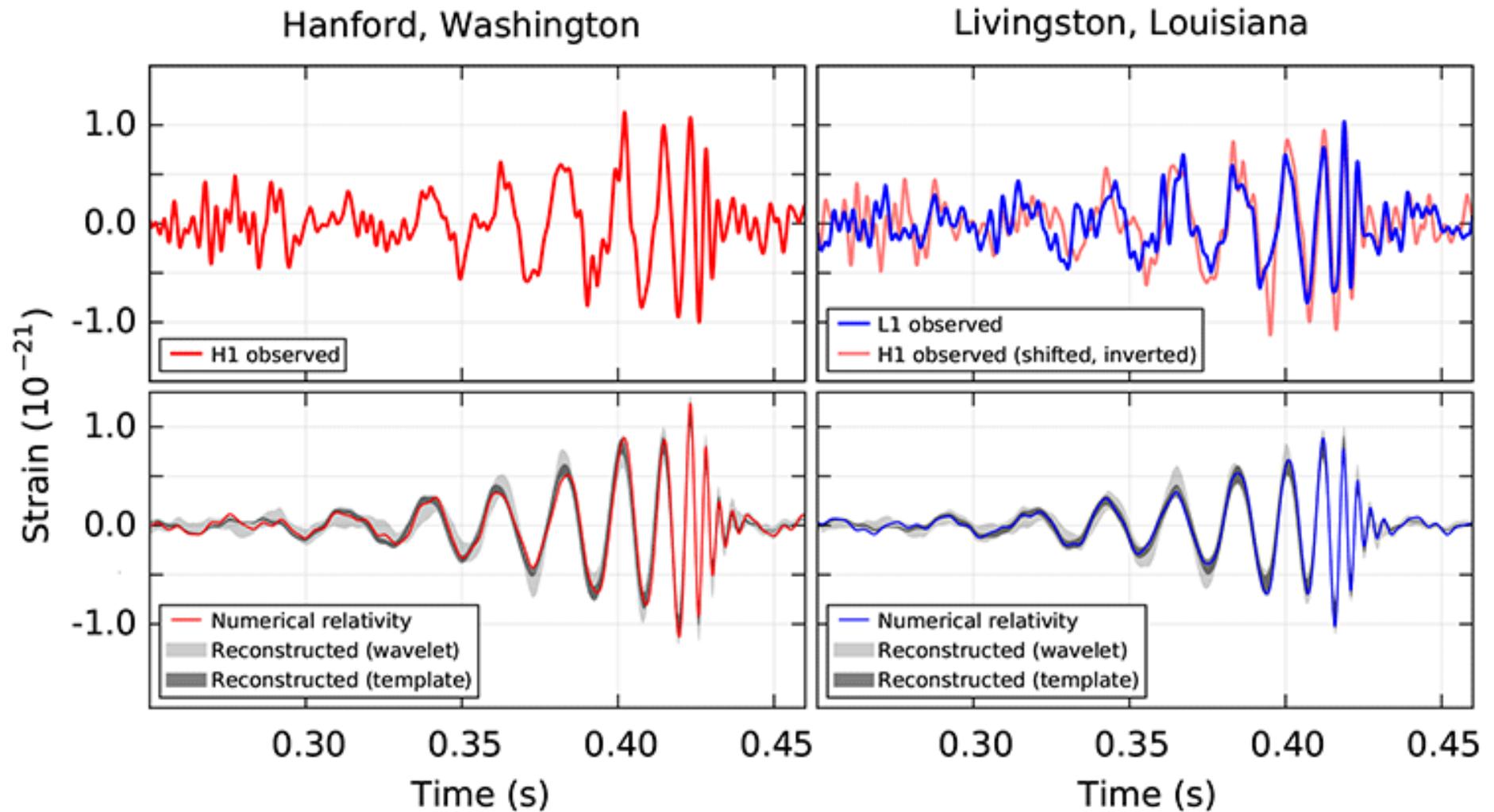
L1

Livingston, LA

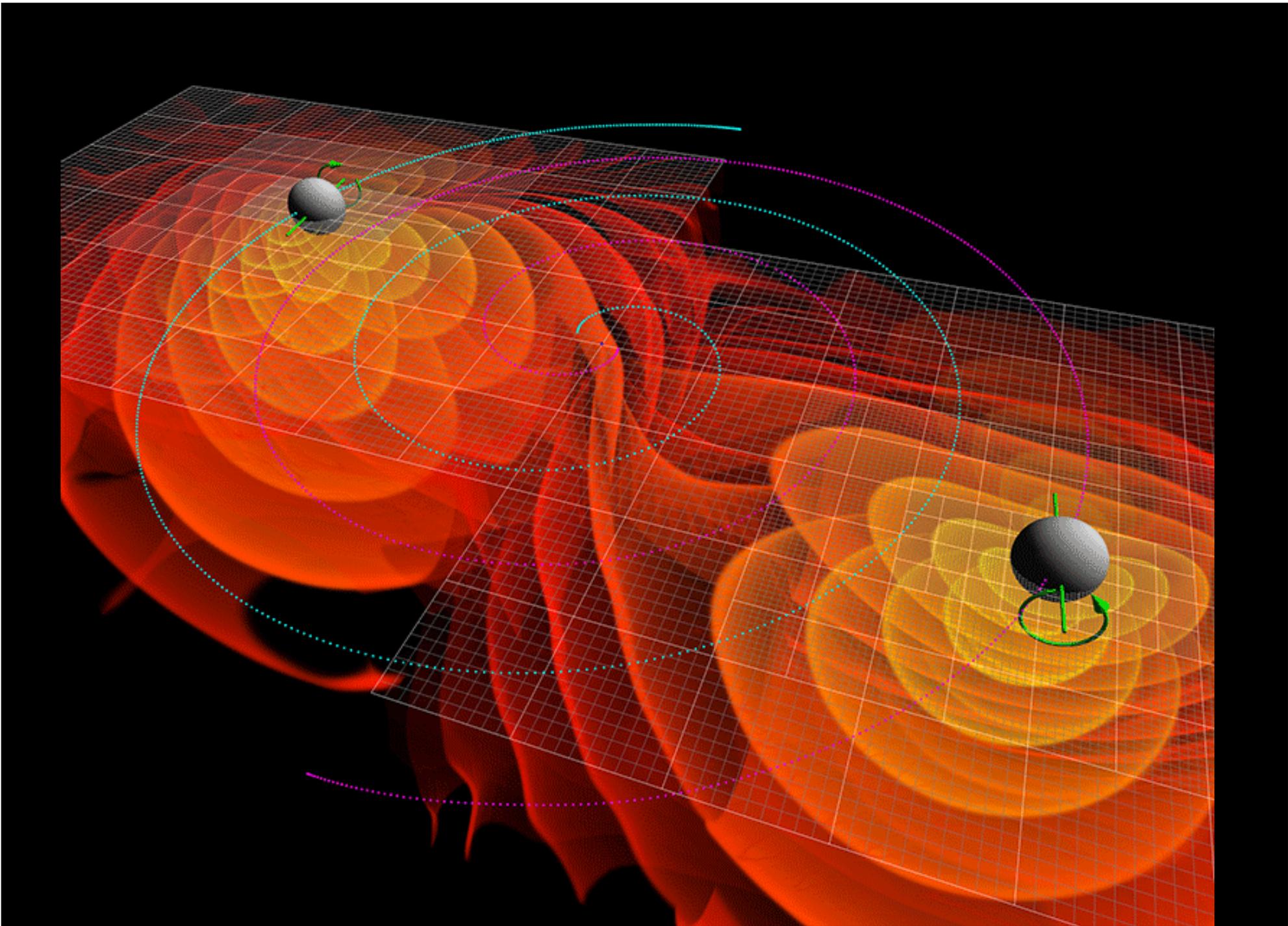




GW150914



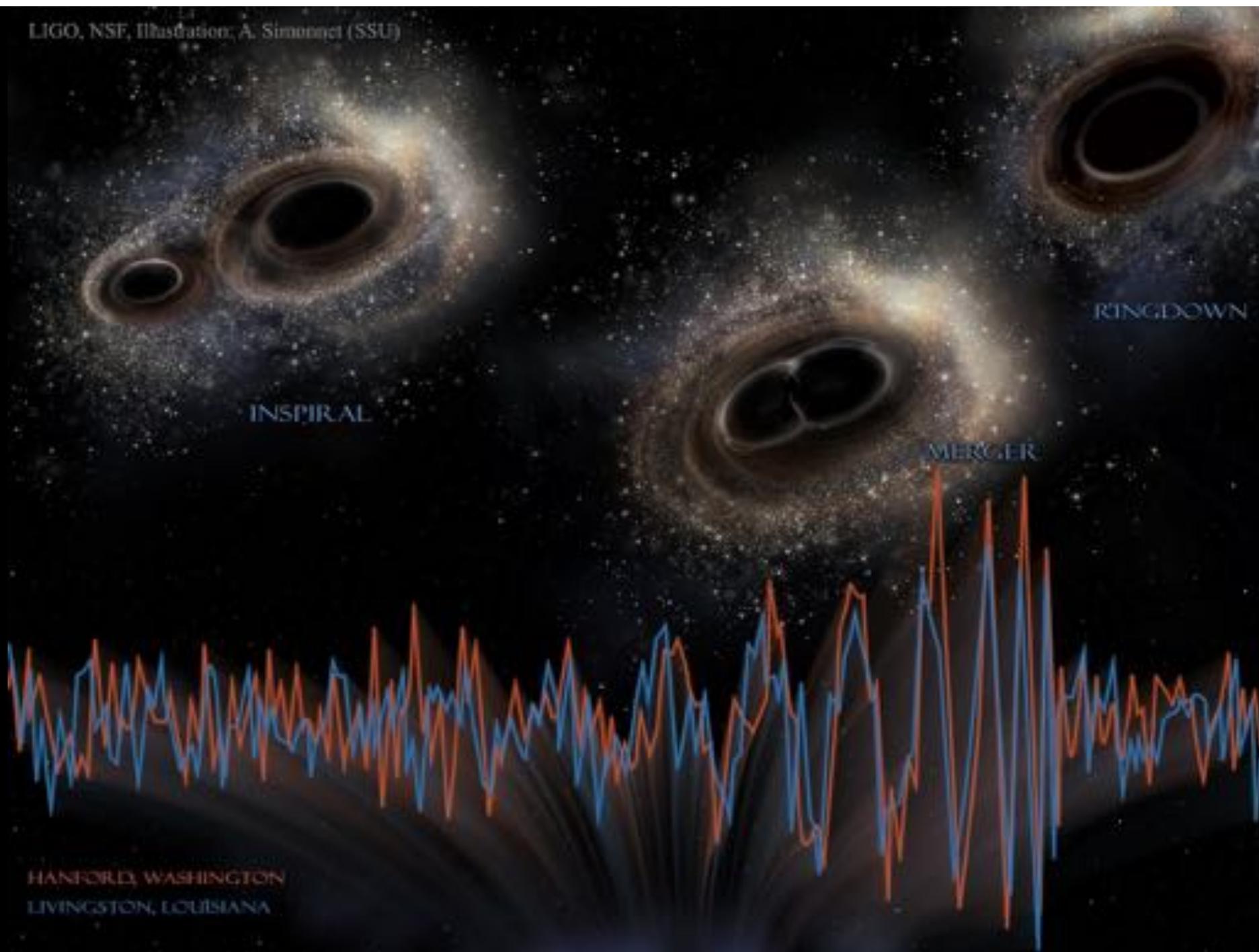
[Physical Review Letter 116, 061102 (2016)]



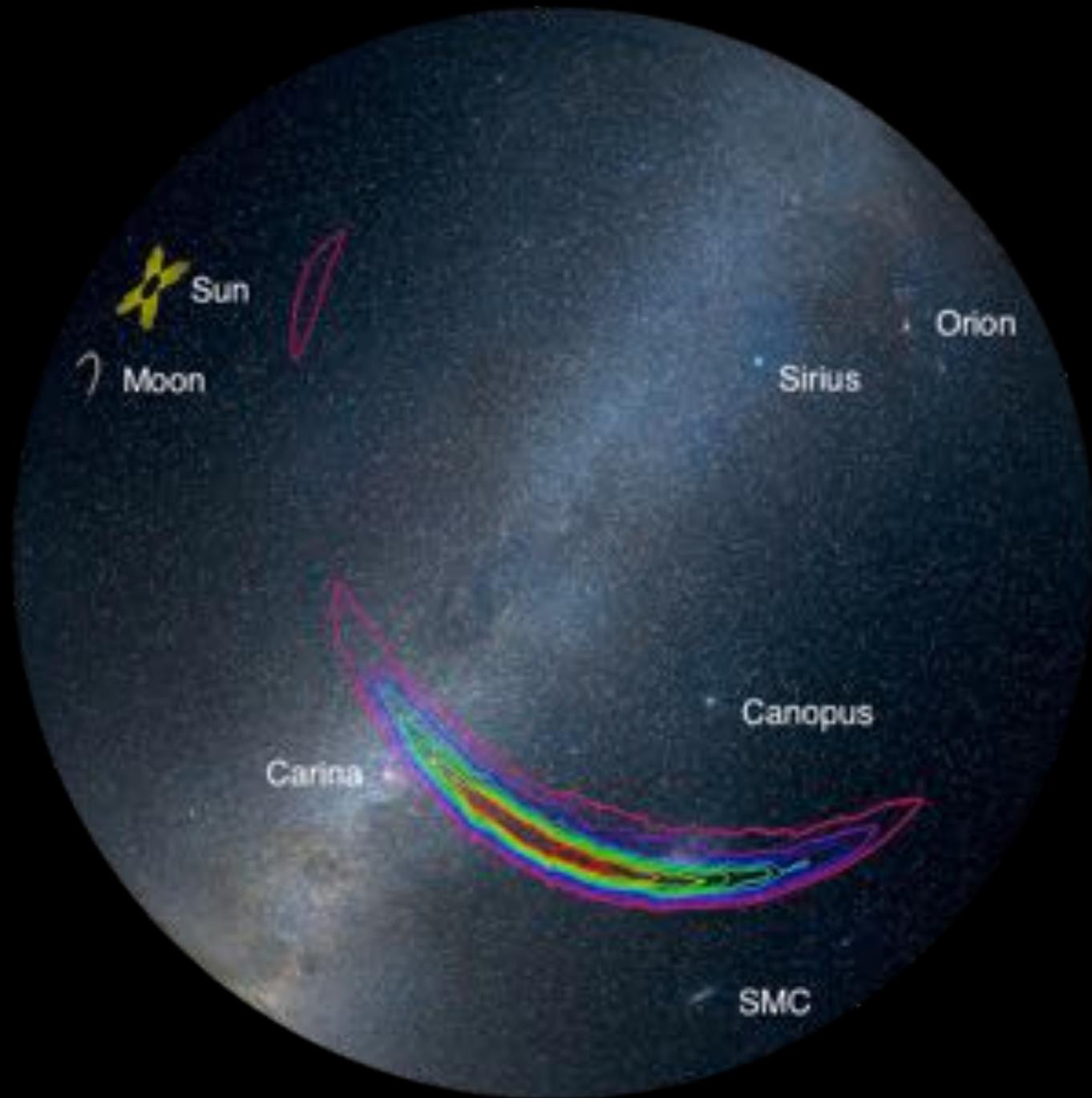


Primary black hole mass	$36^{+5}_{-4} M_{\odot}$
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Final black hole mass	$62^{+4}_{-4} M_{\odot}$
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Source redshift z	$0.09^{+0.03}_{-0.04}$



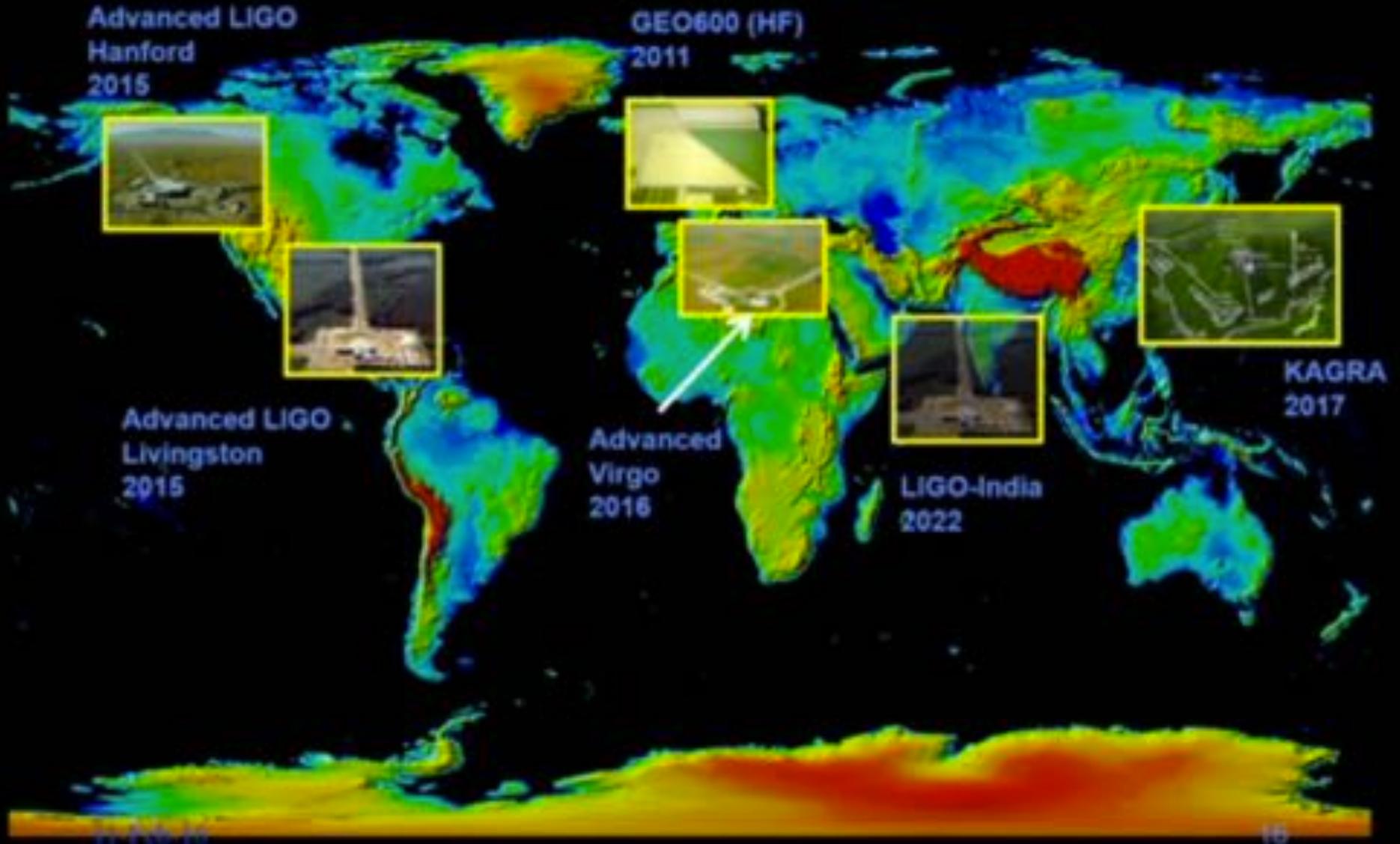


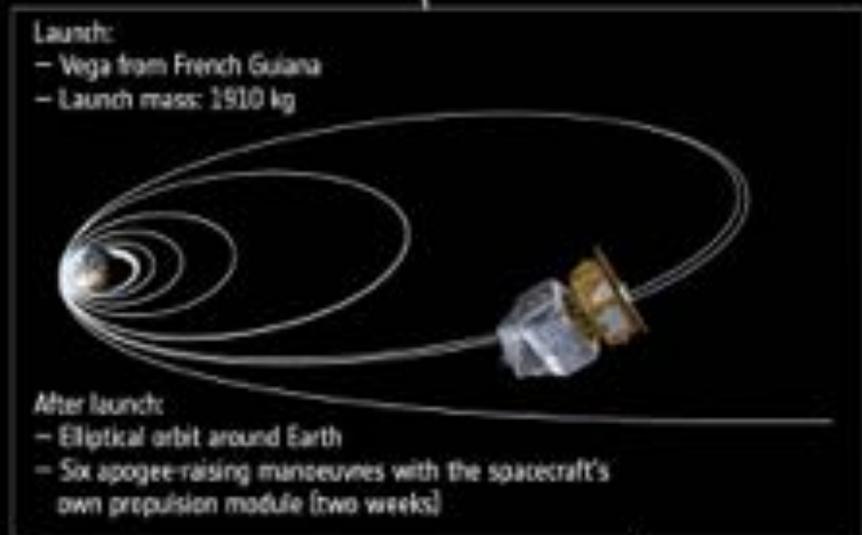
HANFORD, WASHINGTON
LIVINGSTON, LOUISIANA





The advanced GW detector network: 2015-2025





Ground station:

- Cebreros (Spain) 35 m-diameter antenna

Operations:

- Mission operations from ESOC
- Science operations from ESAC

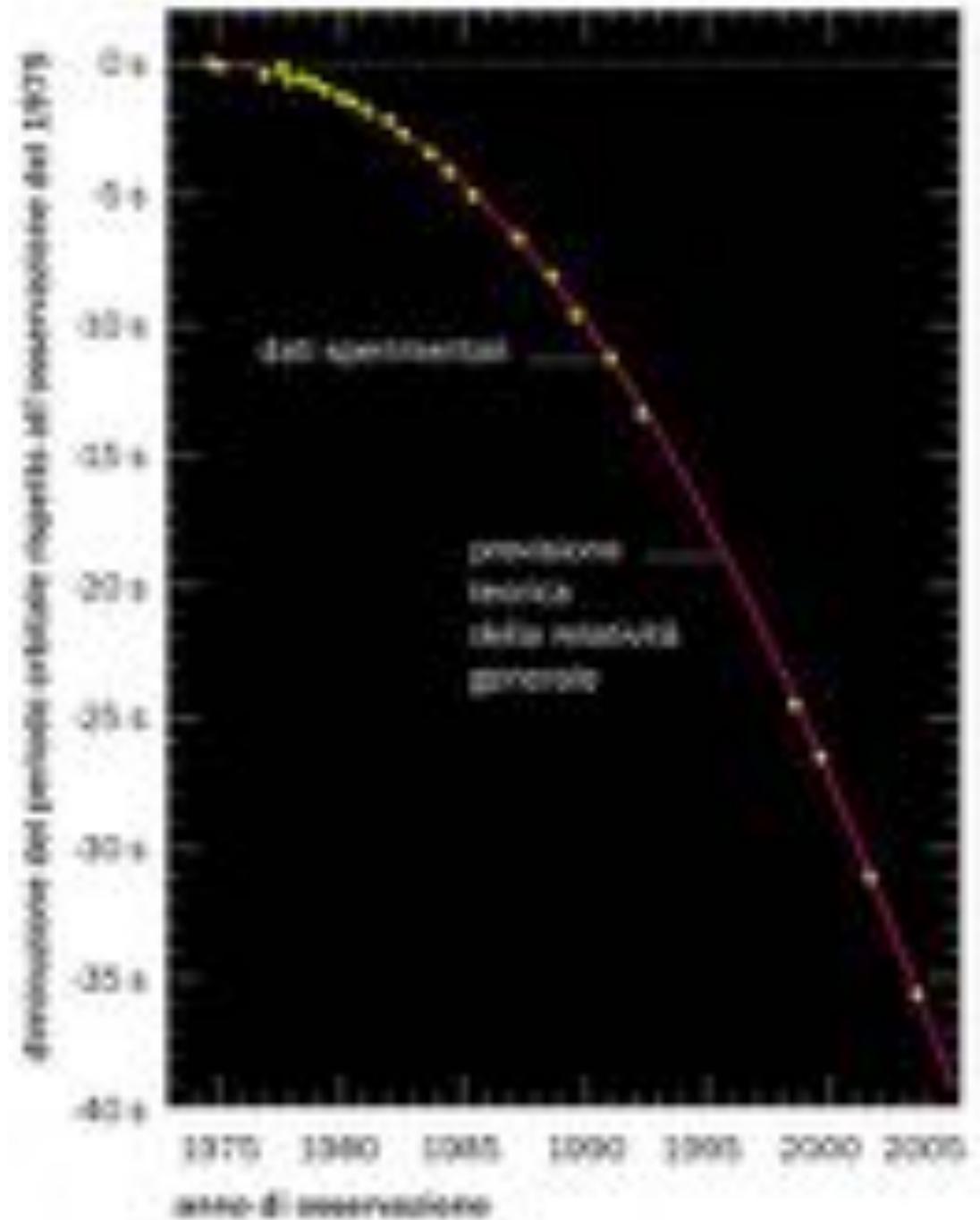
Duration of cruise to L1 after last burn: six weeks



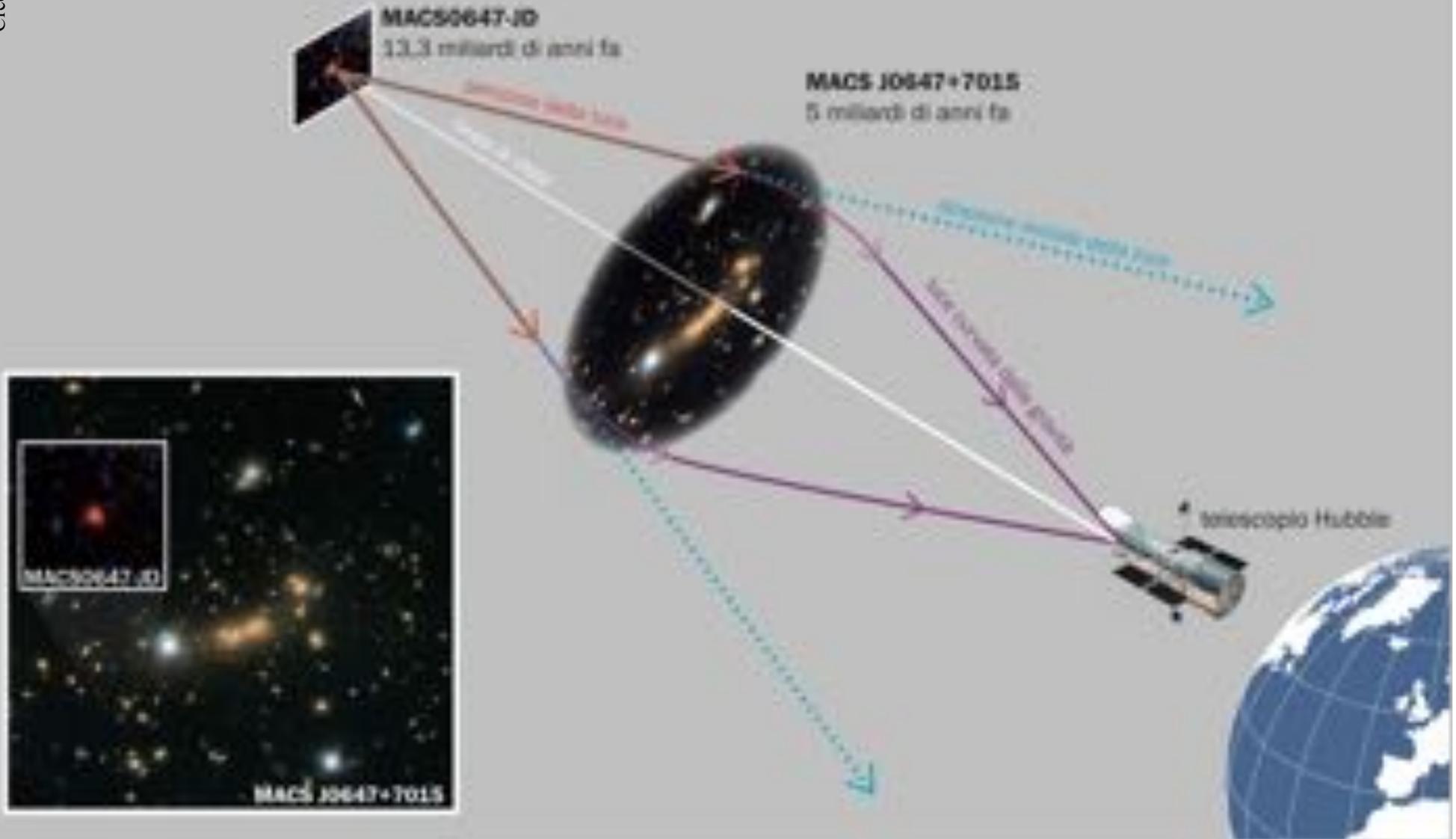


Pulsar PSR1913+16

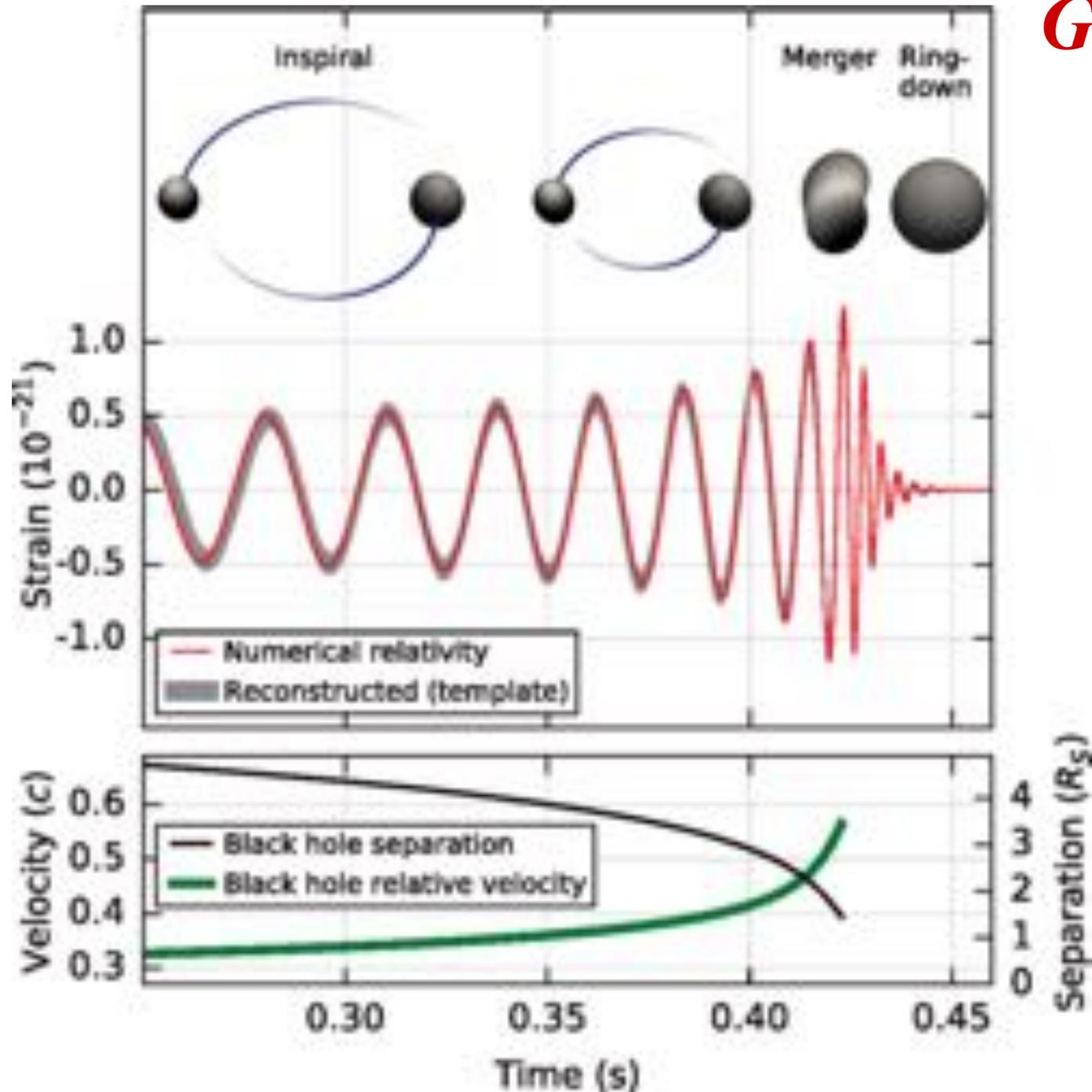
Credits: Asimmetrie



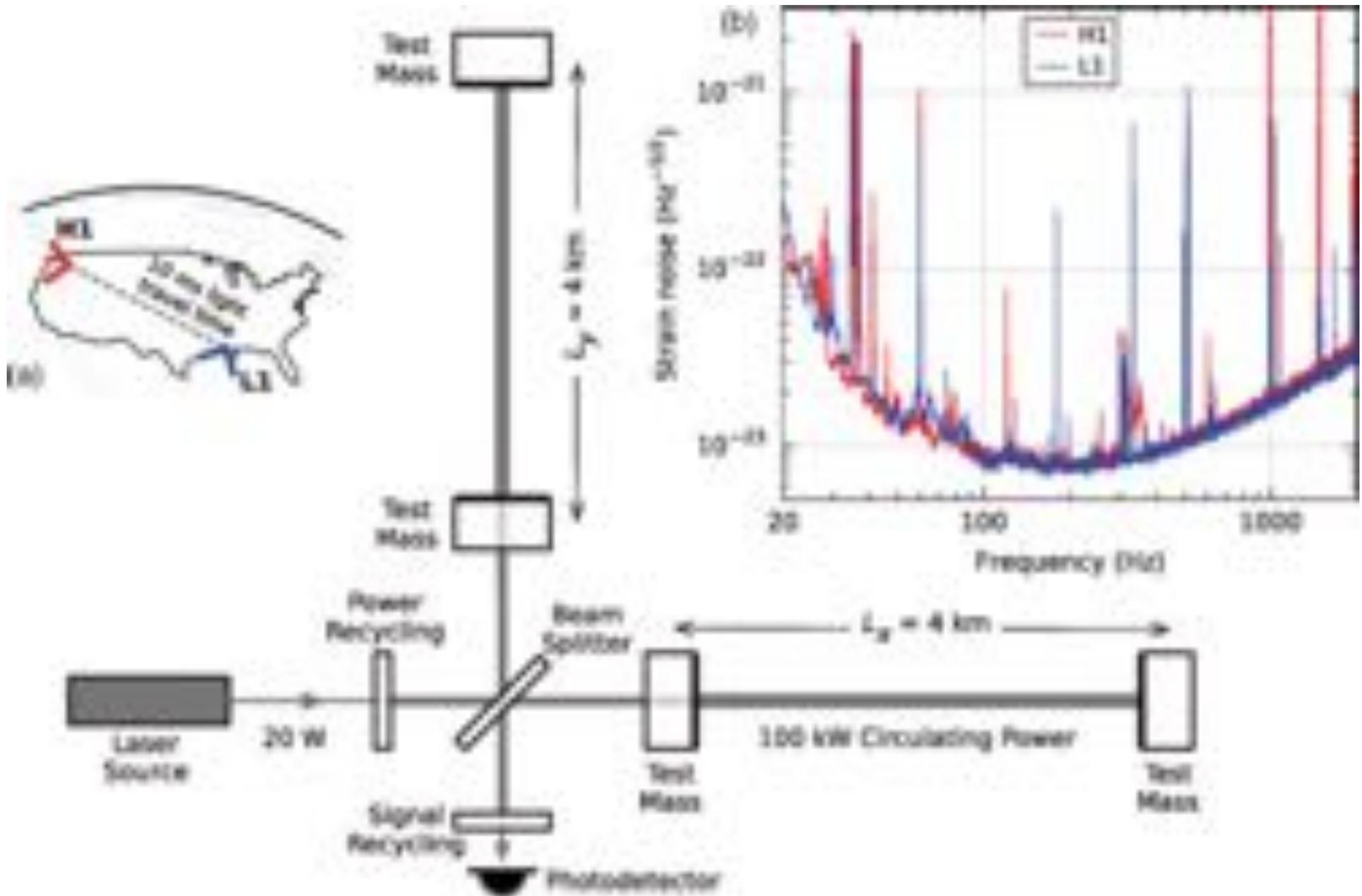
Gravitational lensing



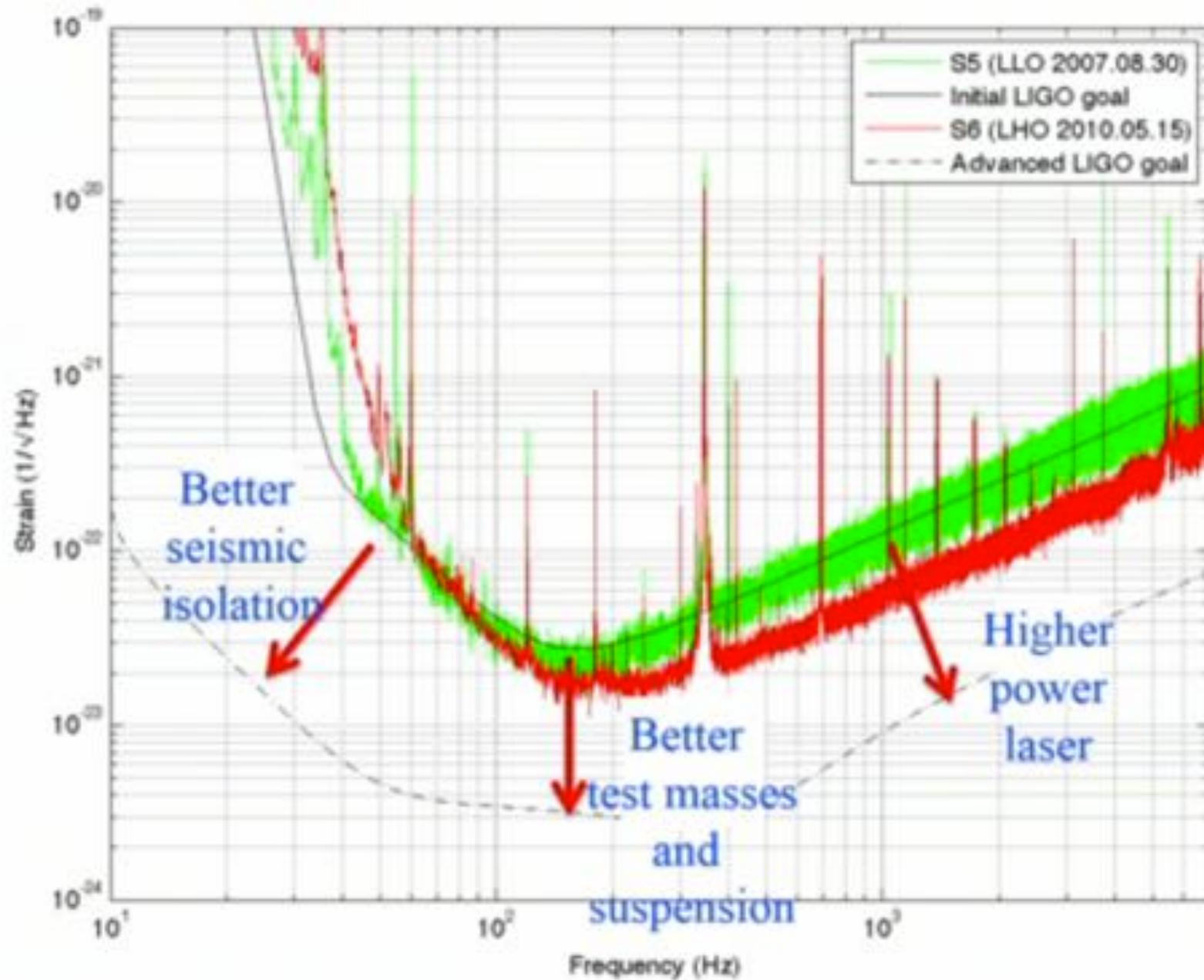
GW150914



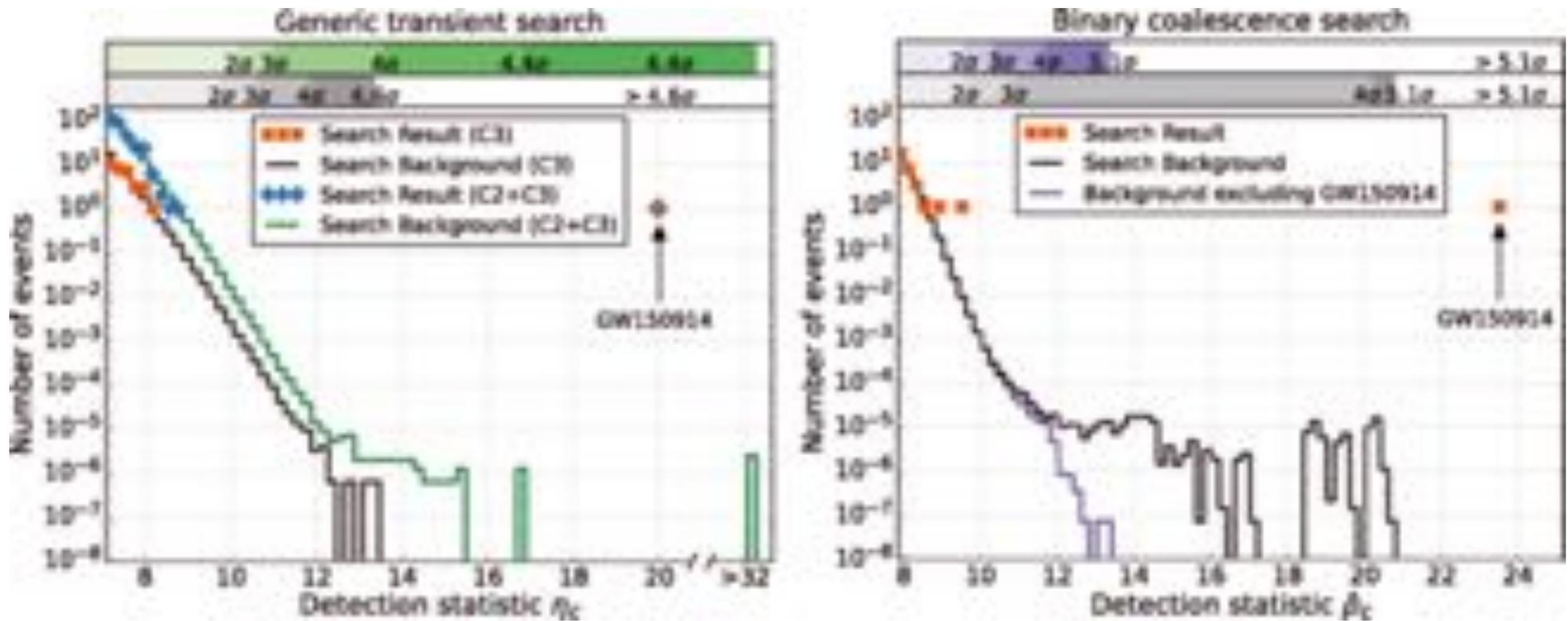
GW150914



GW150914

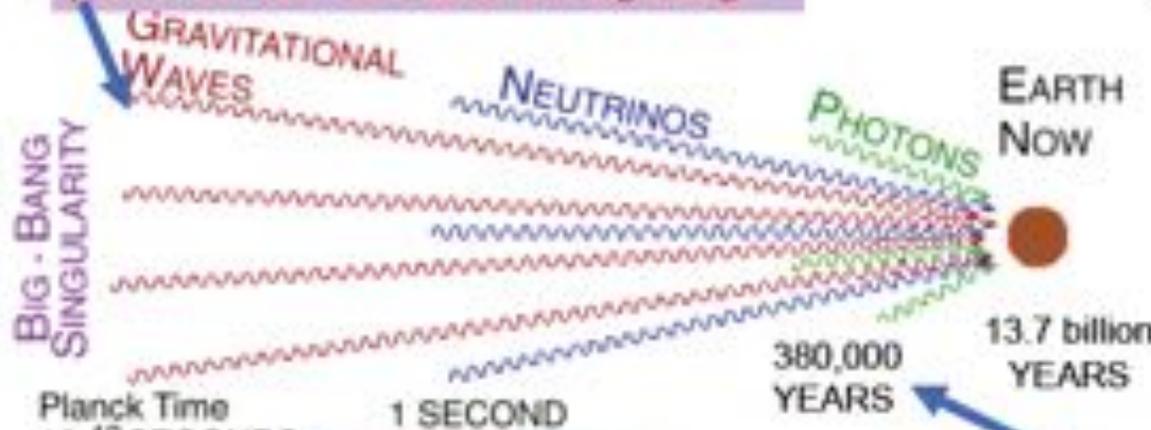


GW150914



Gravitational waves from Big Bang

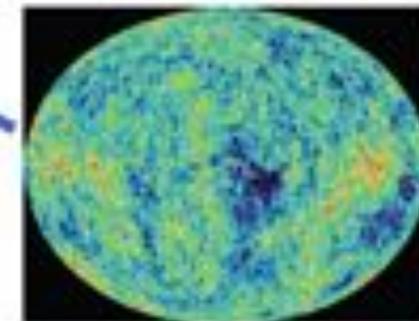
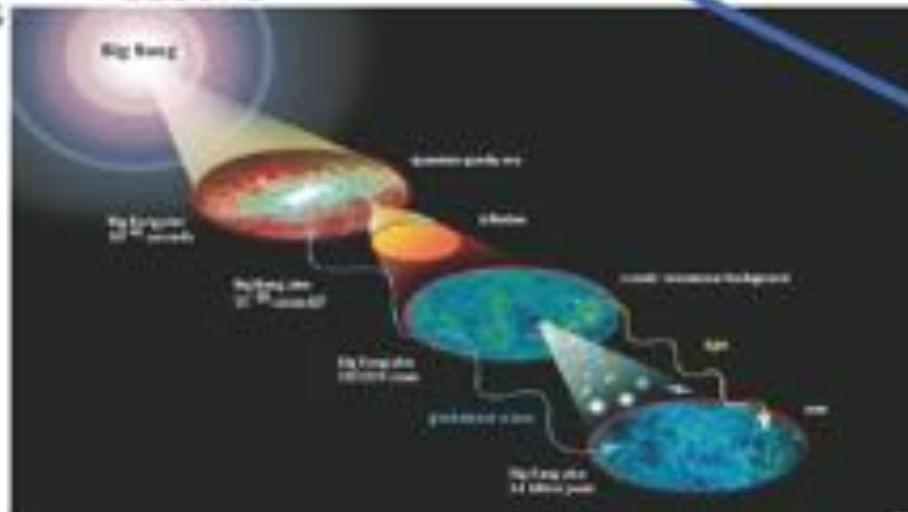
Waves now in the LIGO band were produced 10^{-22} sec after the big bang



$$\Omega_{GW}(f) = \frac{1}{\rho_c} \frac{d\rho_{GW}(f)}{d \ln f}$$

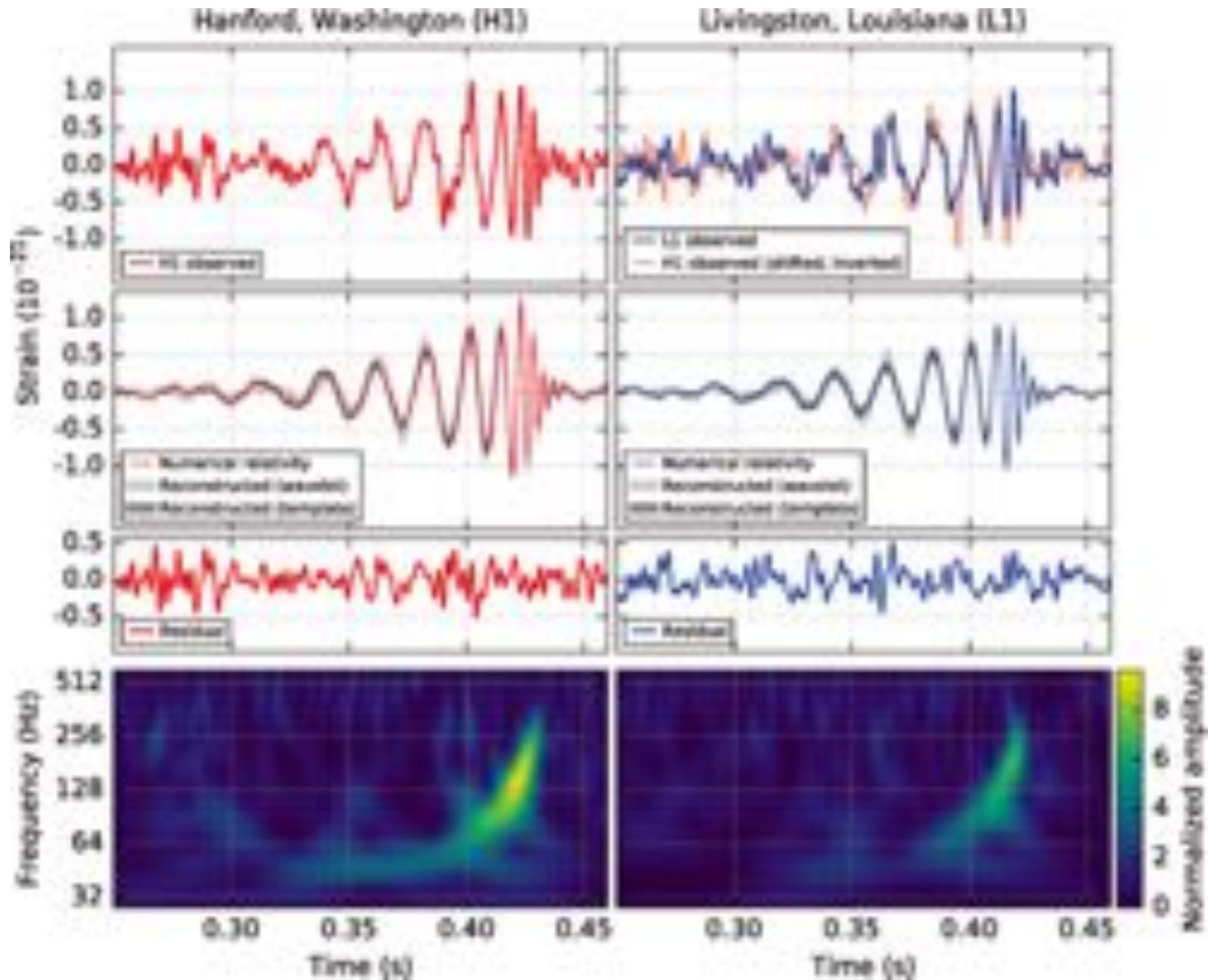
$$\rho_{GW} = \frac{c^2}{32\pi G} \langle \dot{h}_{ab} \dot{h}^{ab} \rangle$$

$$h(f) = 6.3 \times 10^{-22} \sqrt{\Omega_{GW}(f)} \left(\frac{100 \text{ Hz}}{f} \right)^{1/2} \text{ Hz}^{-1/2}$$



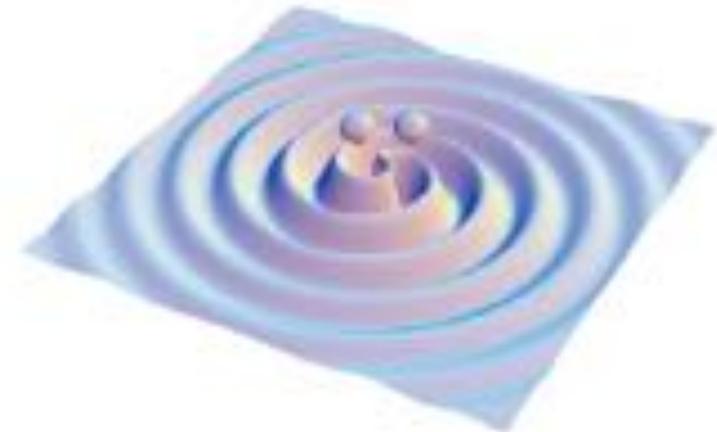
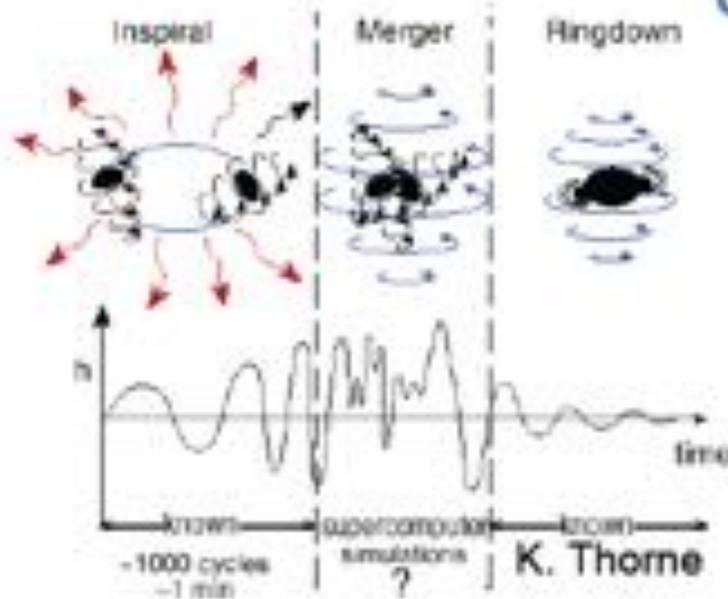
cosmic microwave background — WMAP 2003

GW150914

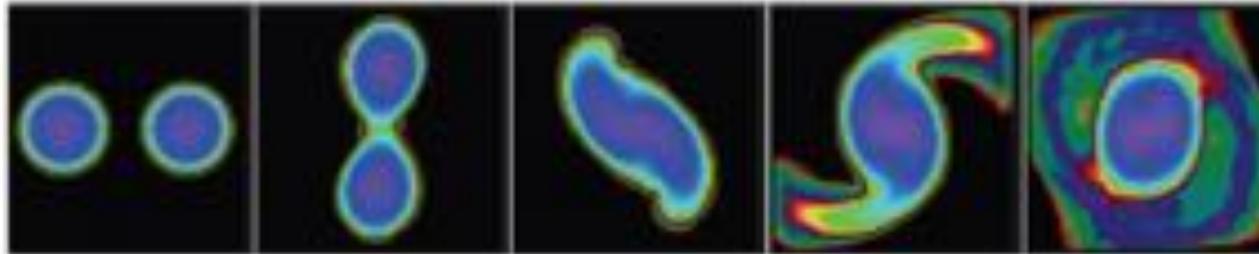


GWs from coalescing compact binaries (NS/NS, BH/BH, NS/BH)

Compact binary mergers

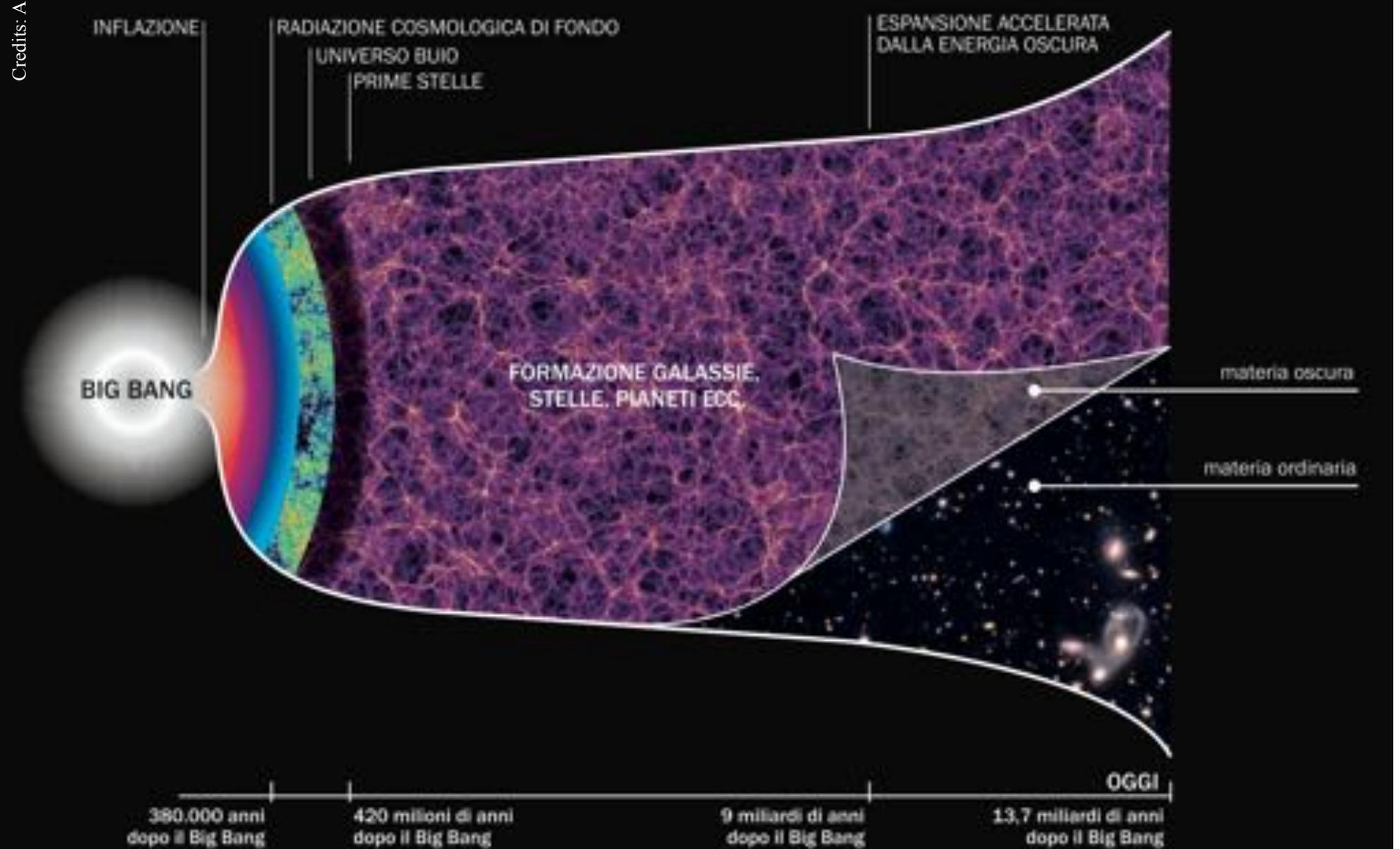


- Neutron star – neutron star (Centrella et al.)



*Da un seminario
del 2009*

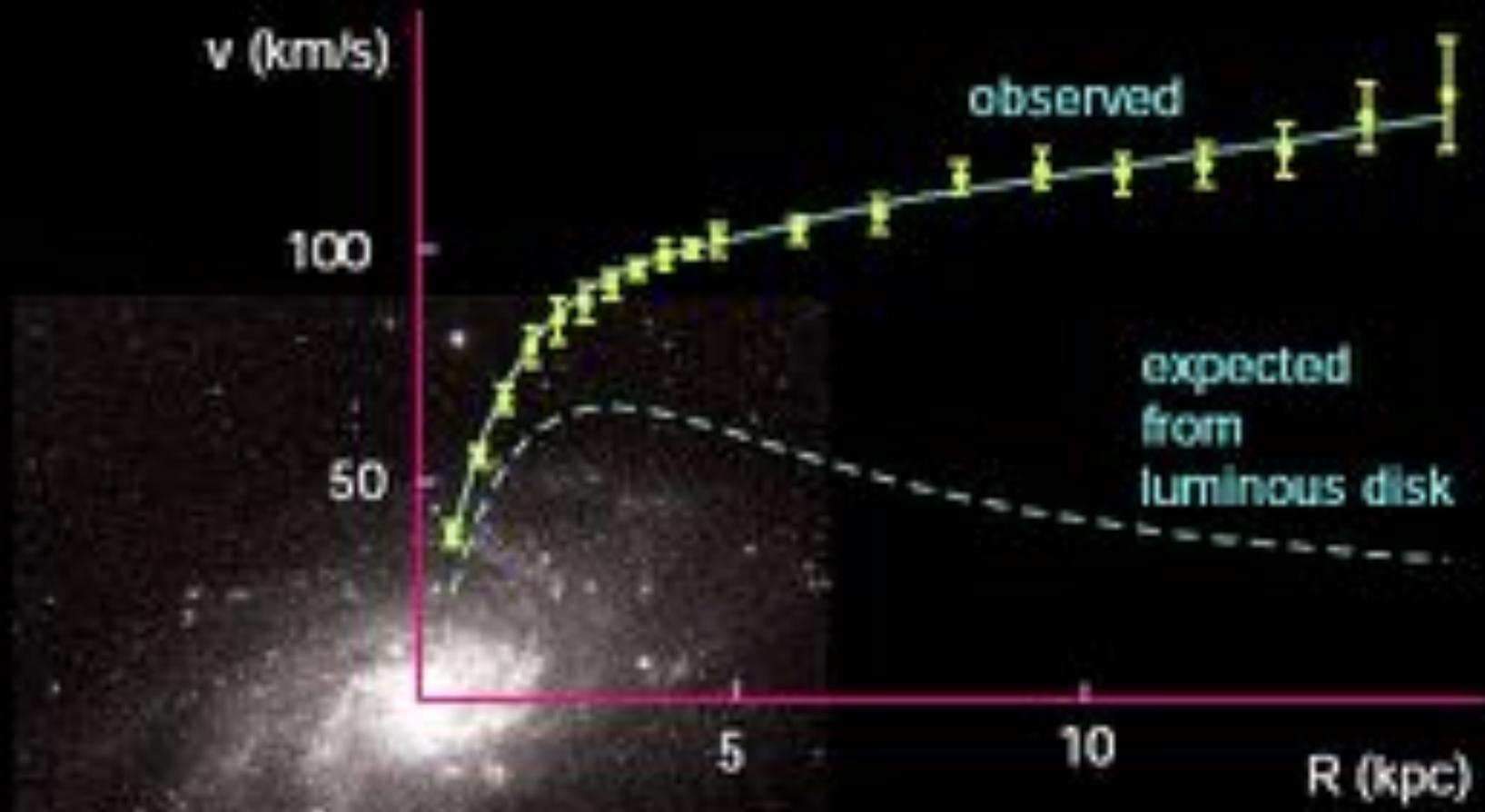
Modello Standard Cosmologico



Materia e Materia Oscura

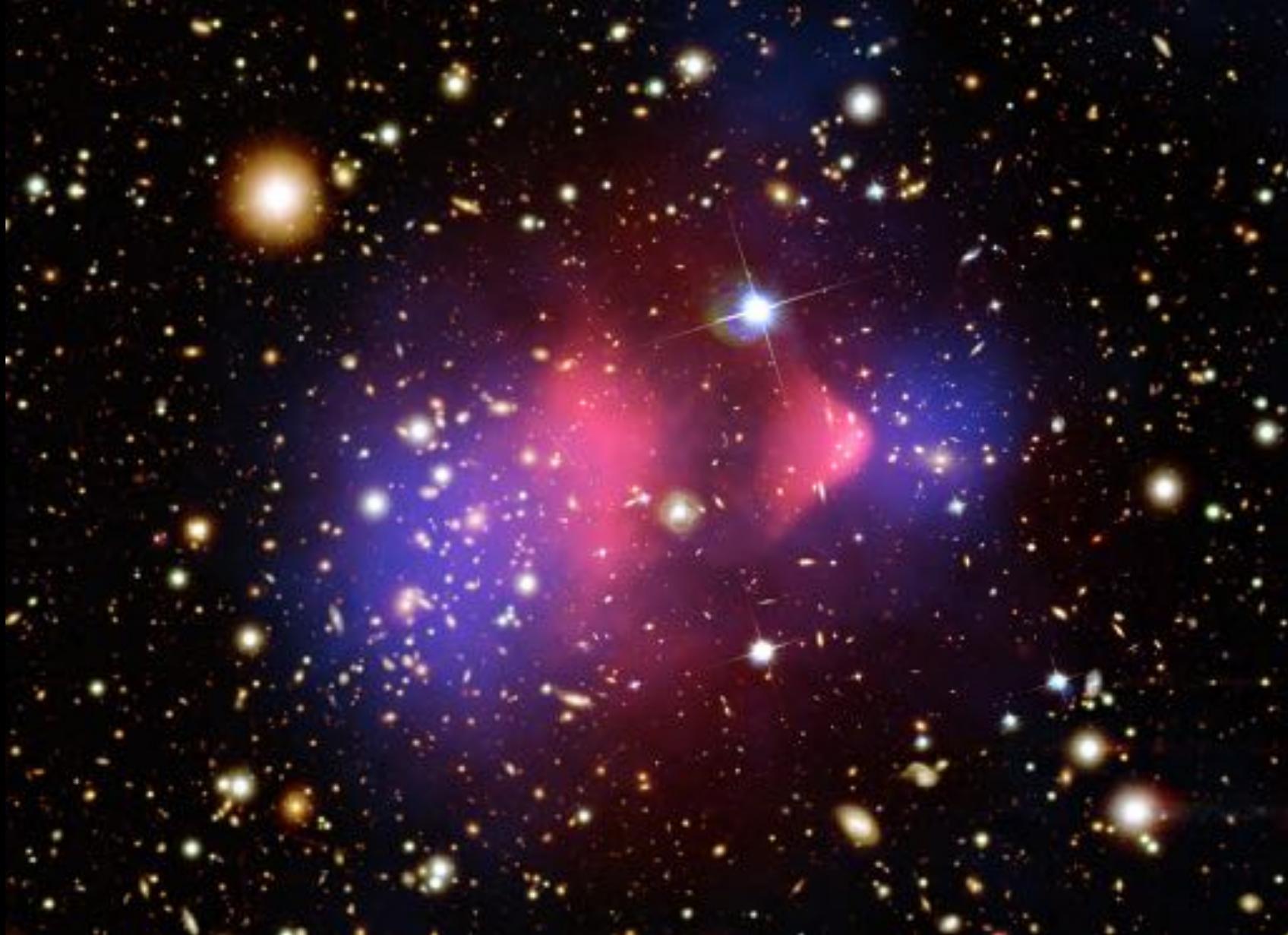


Materia e Materia Oscura

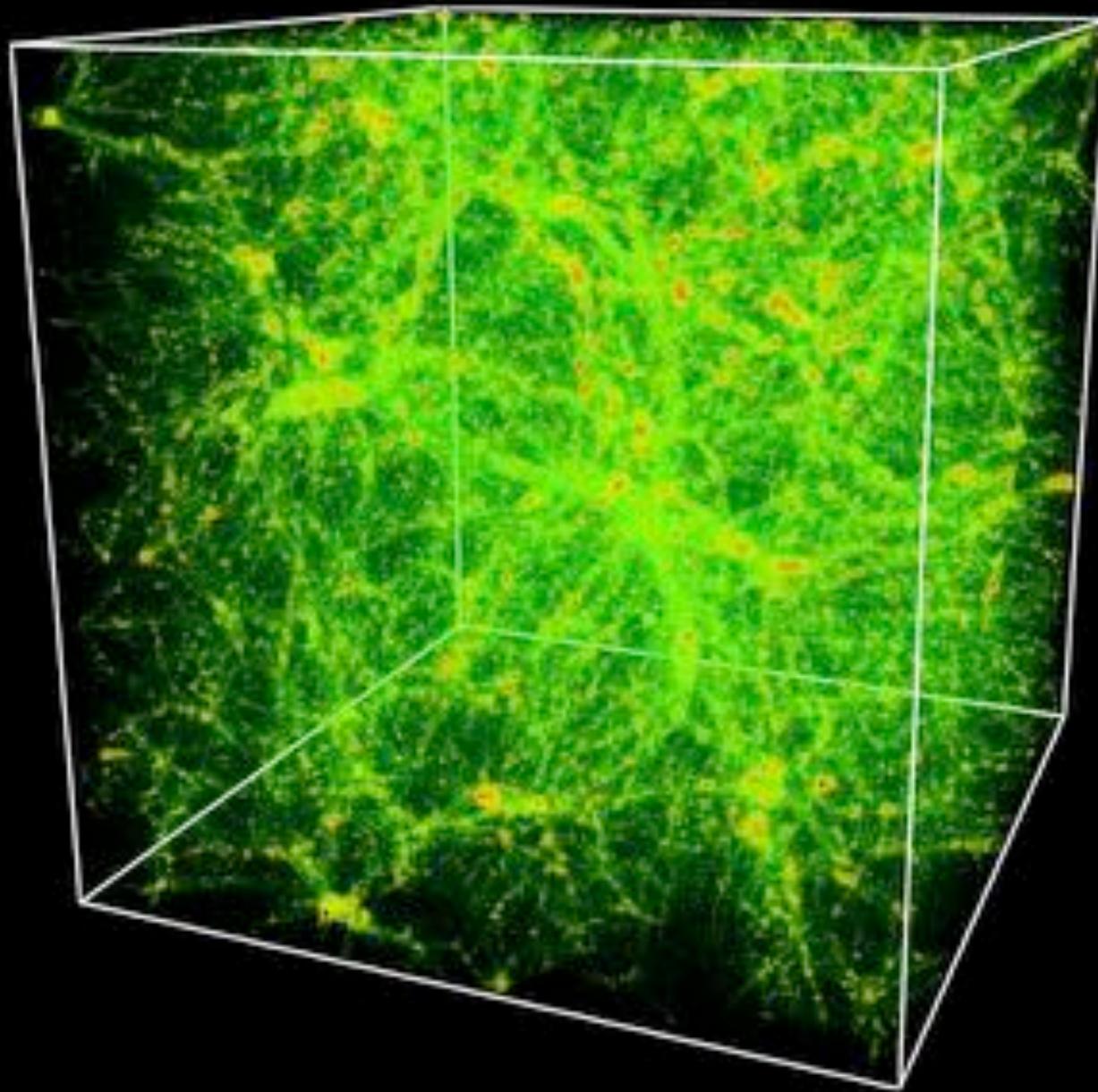


M33 rotation curve

Materia e Materia Oscura



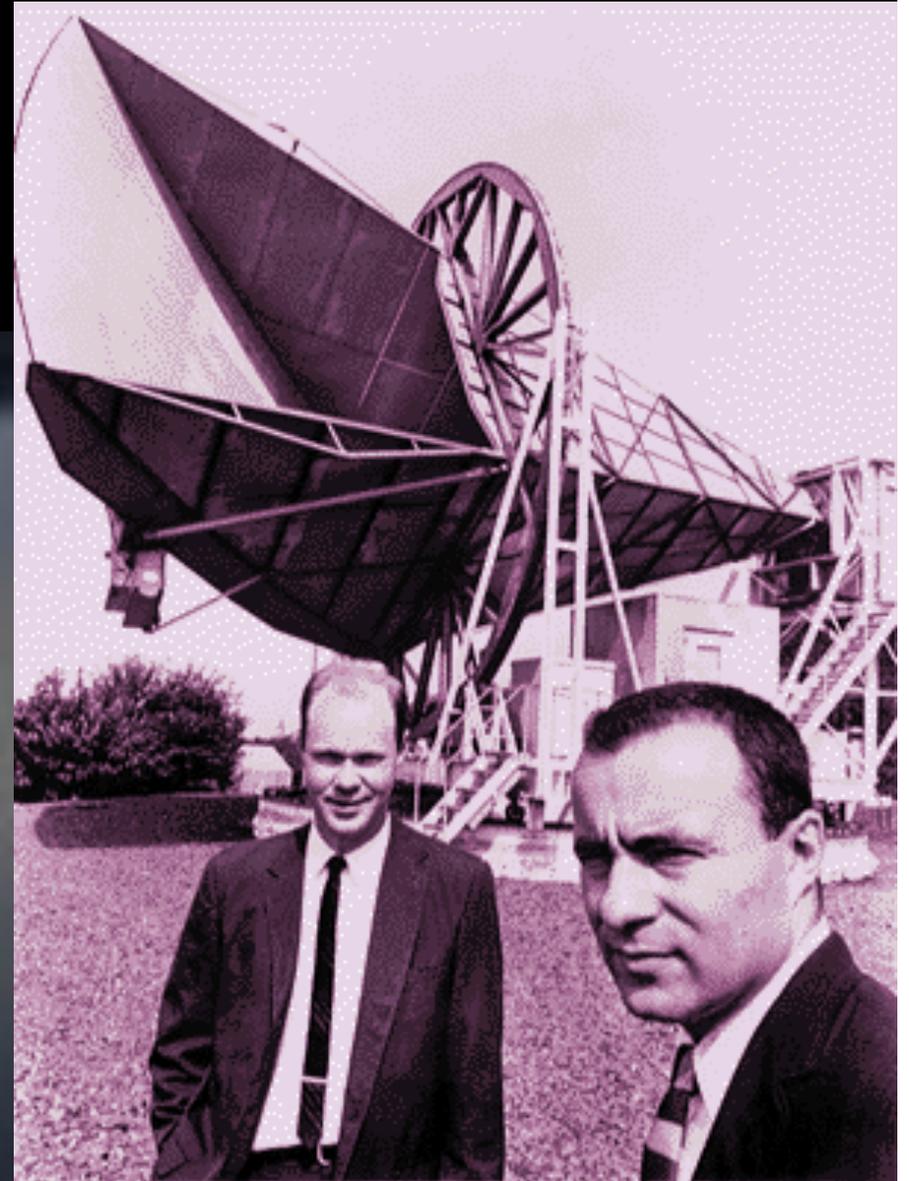
Materia e Materia Oscura

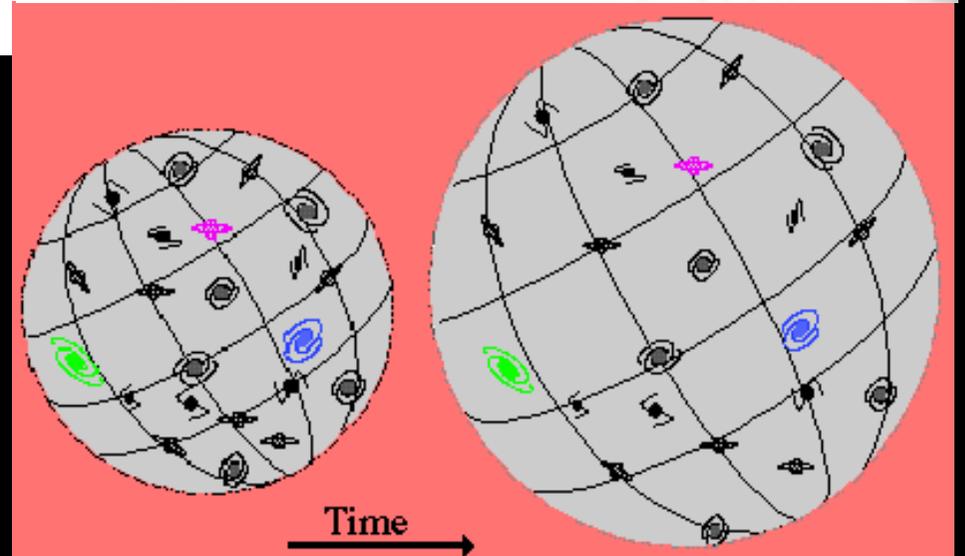
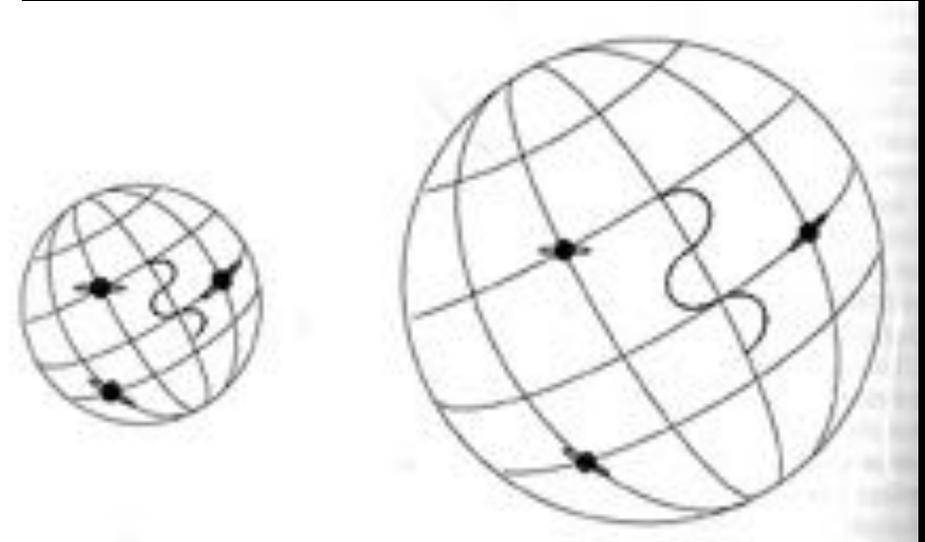
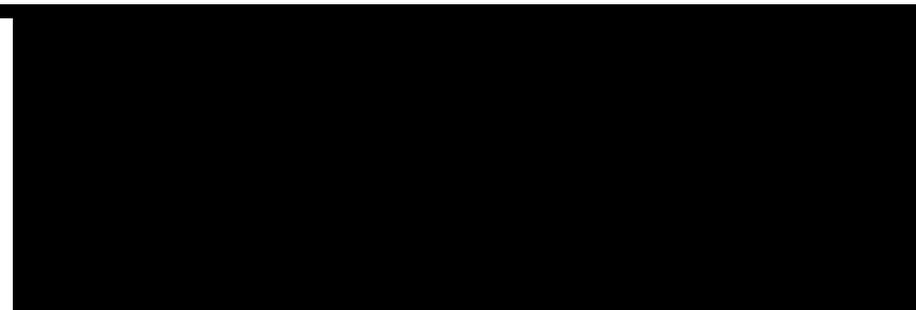
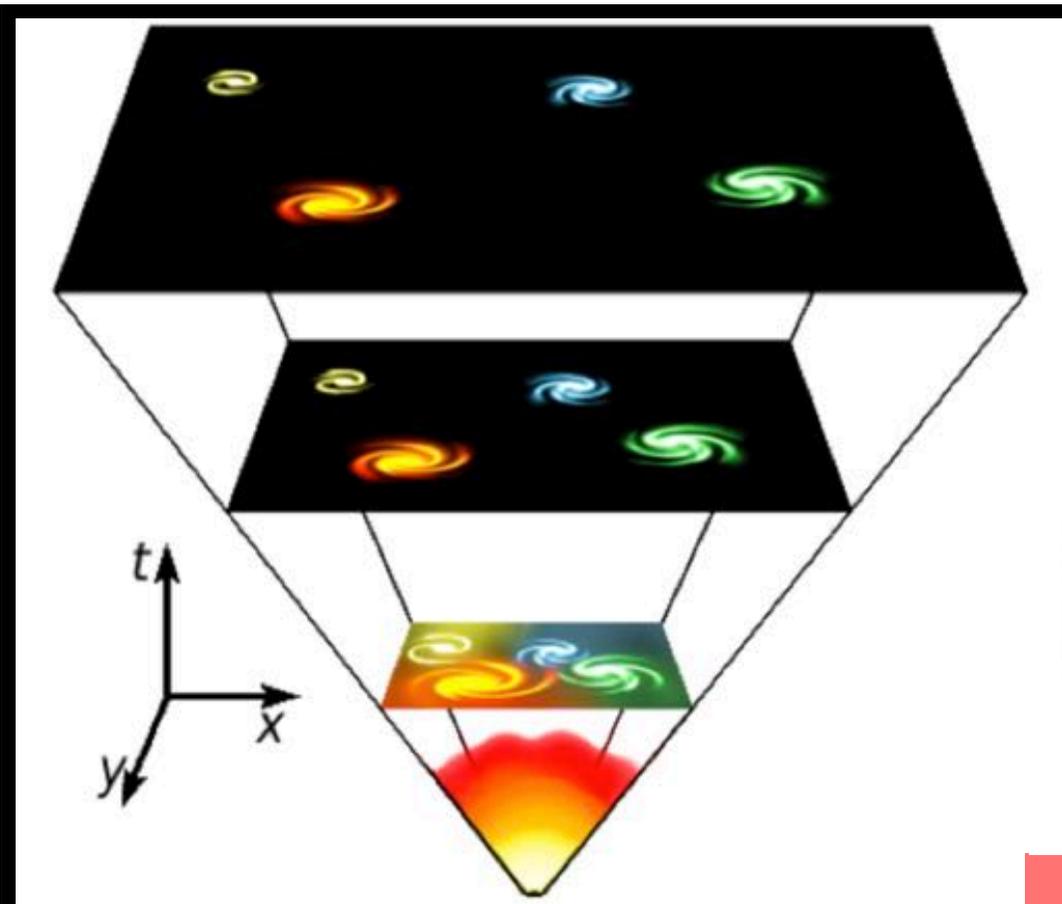




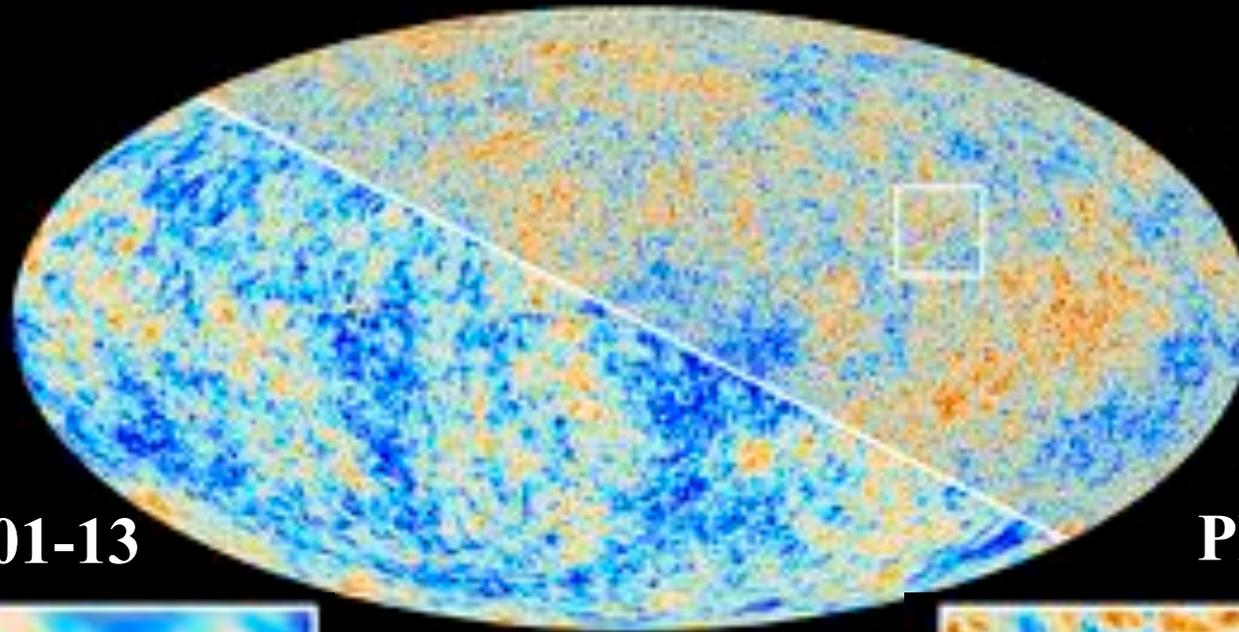
*Henrietta Leavitt
ed Edwin Hubble*

Arno Penzias e Robert Wilson



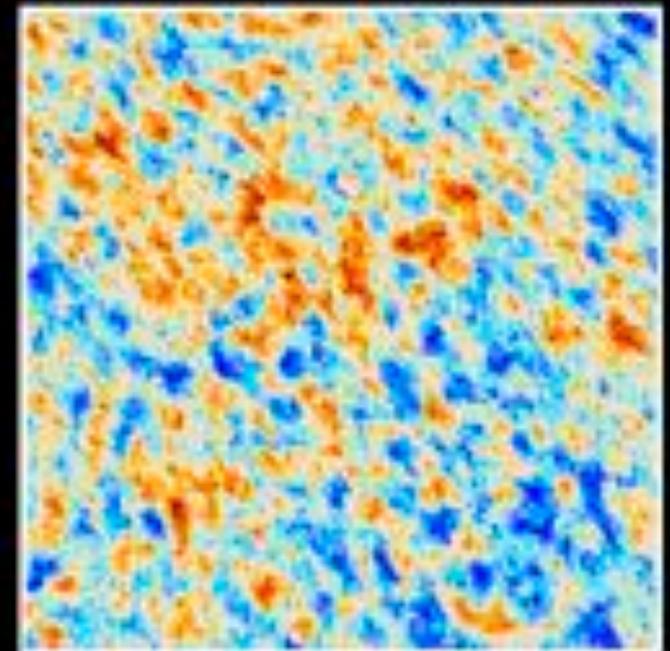
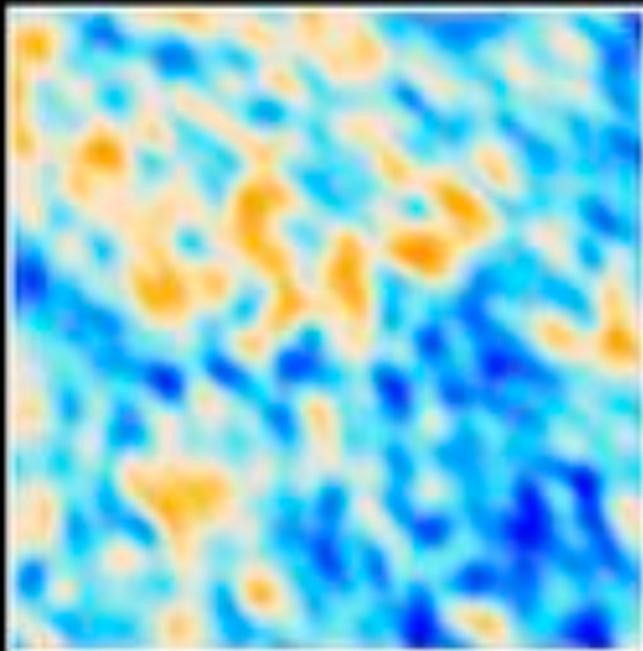


Radiazione cosmica di fondo

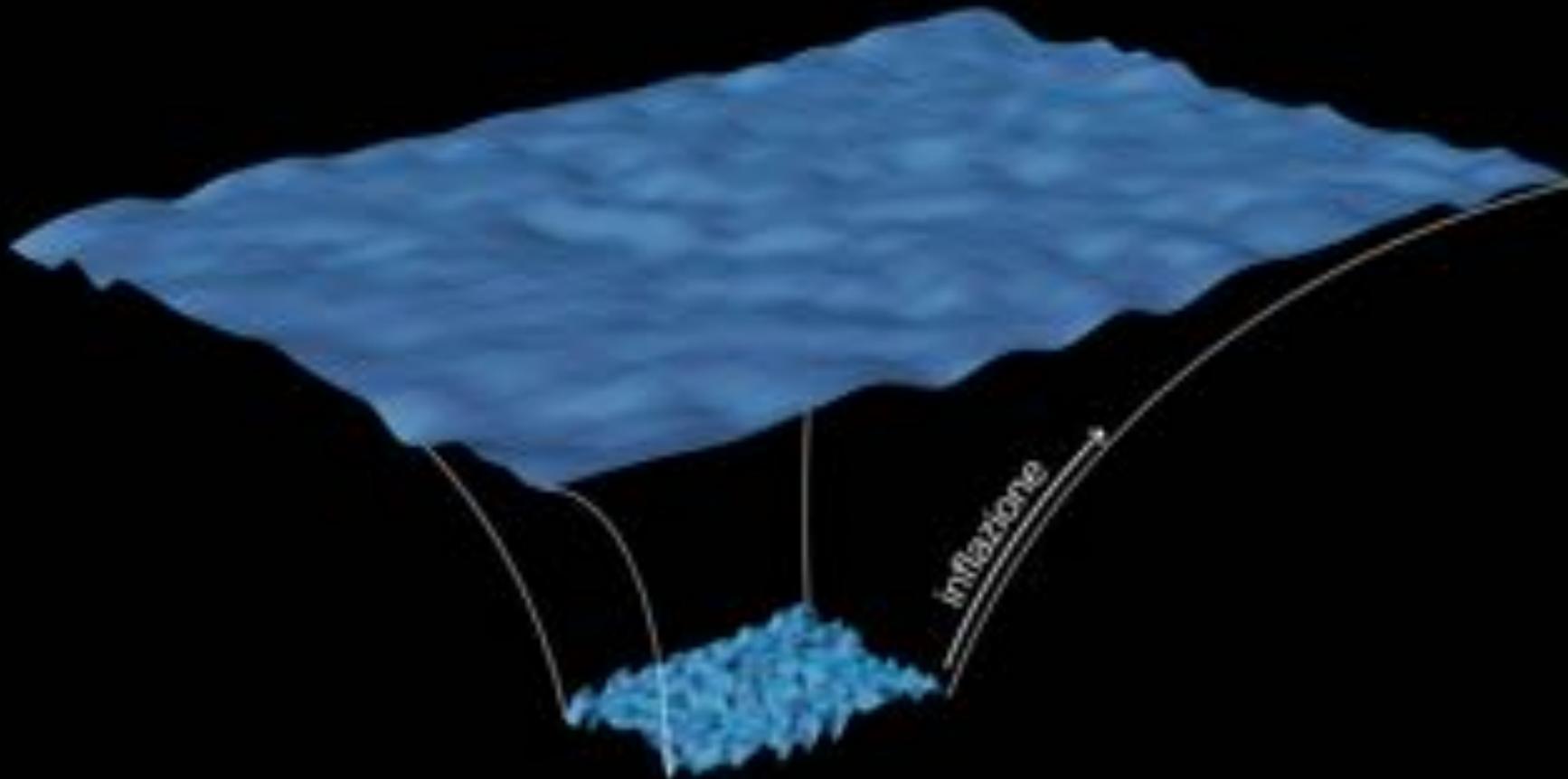


WMAP, 2001-13

Planck, 2013



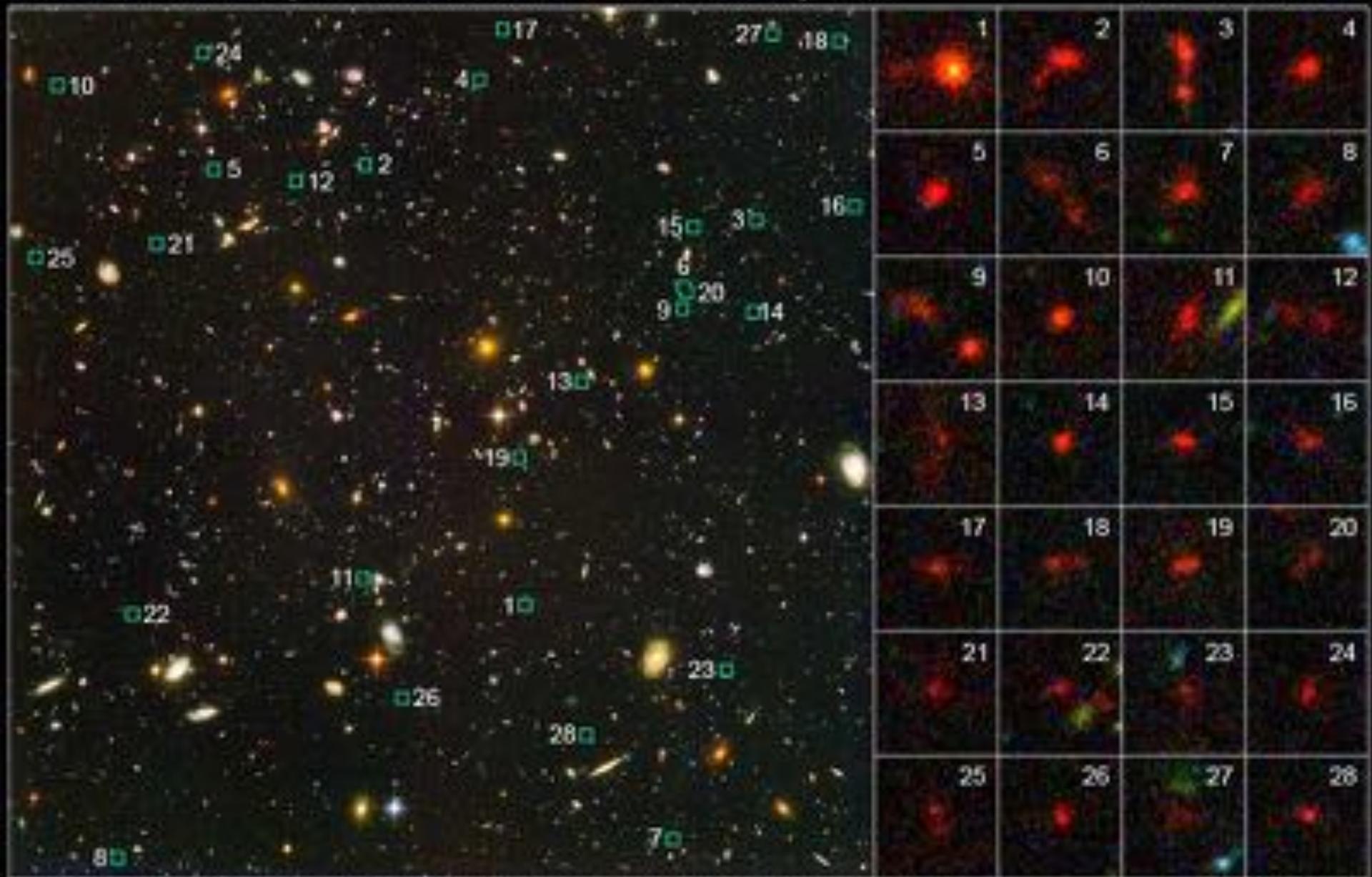
Inflazione



Credits: Asimmetrie

Le nuove Galassie riprese dall'occhio di Hubble Ultra Deep Field

HST = ACS/WFC



NASA, ESA, R. Bouwens and G. Illingworth (University of California, Santa Cruz)

STScI-PRC08-12



Dirac

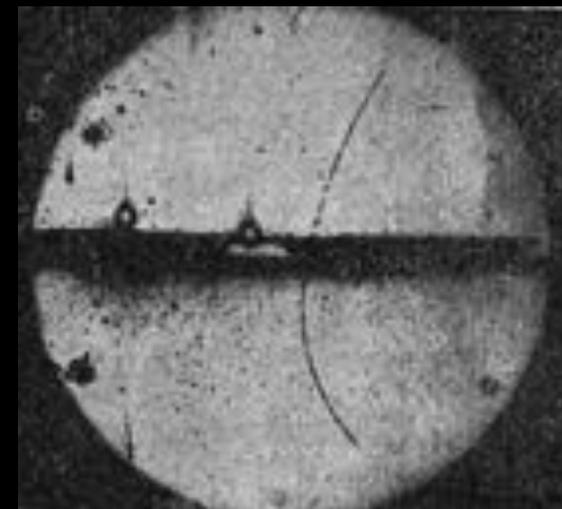
Antimateria



$$(i\gamma^\mu \partial_\mu - m)\psi = 0$$



Anderson



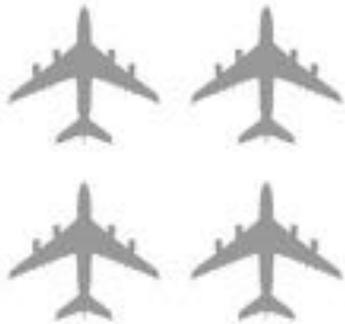
HOW MUCH DOES IT COST TO LAND ON A COMET?

€1.4bn

Rosetta mission
Land on a comet for the first time in human history



...ABOUT THE SAME PRICE AS...



4.2

Airbus A380 aircraft
Cool engineering, but they won't get you into space...

WHO PAID FOR IT?

€3.50

cost per European citizen
(from 1996–2015, so
€0.20/person/year)



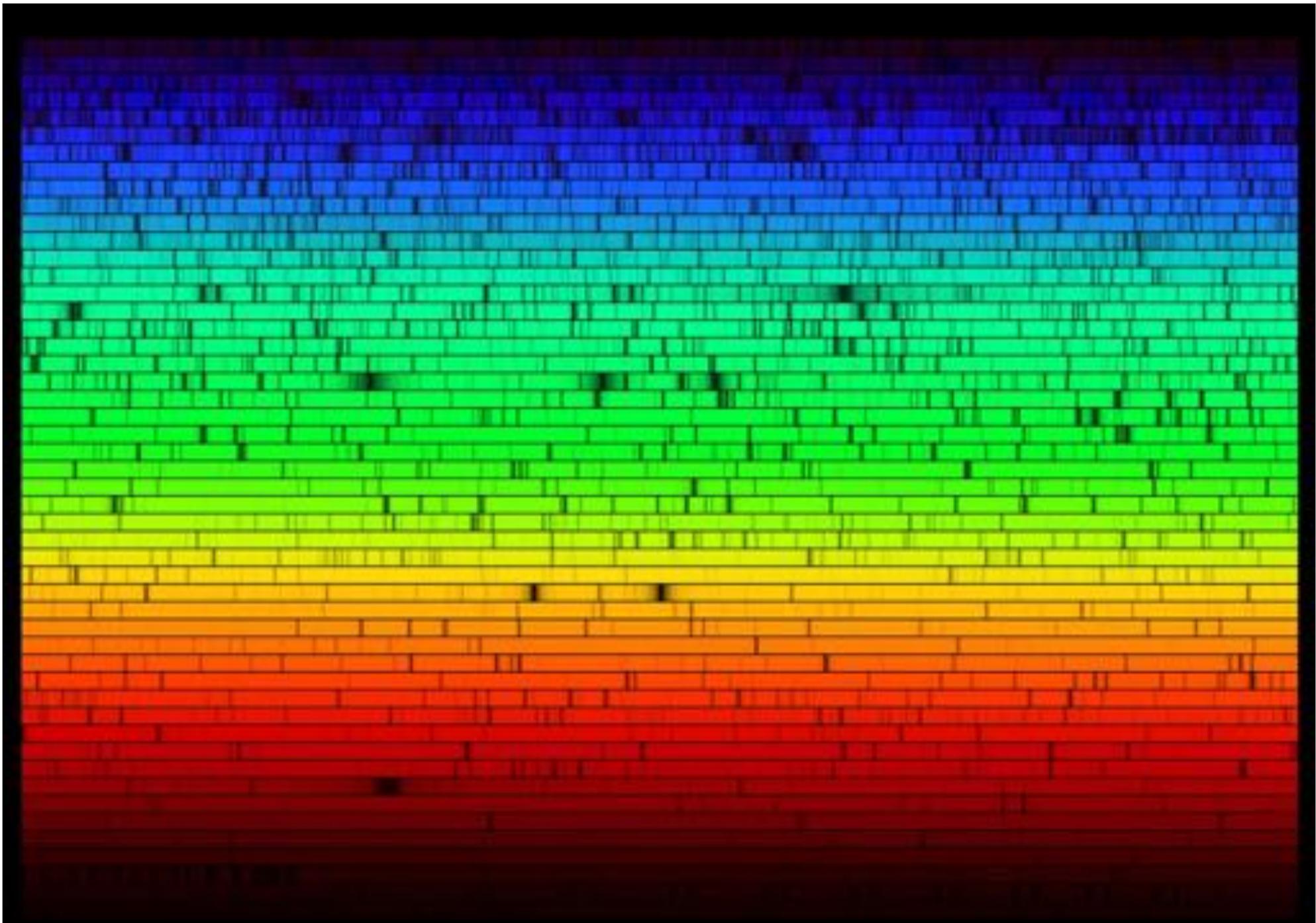
Cost of Rosetta per person **€3.50**

Cost of a cinema ticket to see *Interstellar* **€8.50**

scienceogram.org

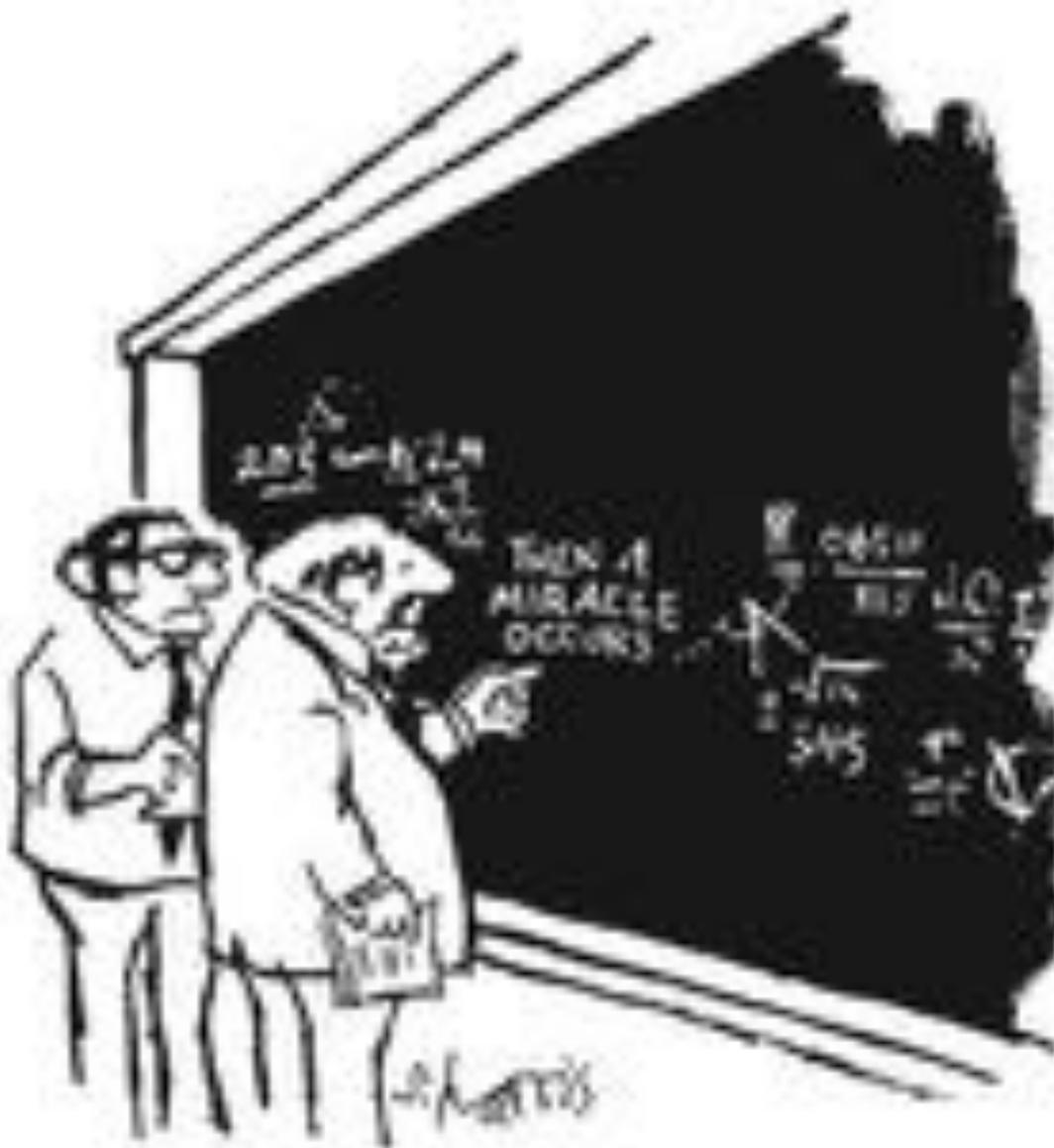
Rosetta/Comet images: ESA; data from ESA, Airbus, UK average cinema ticket price
For full data and sources visit scienceogram.org





“Modello standard della chimica”





"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."