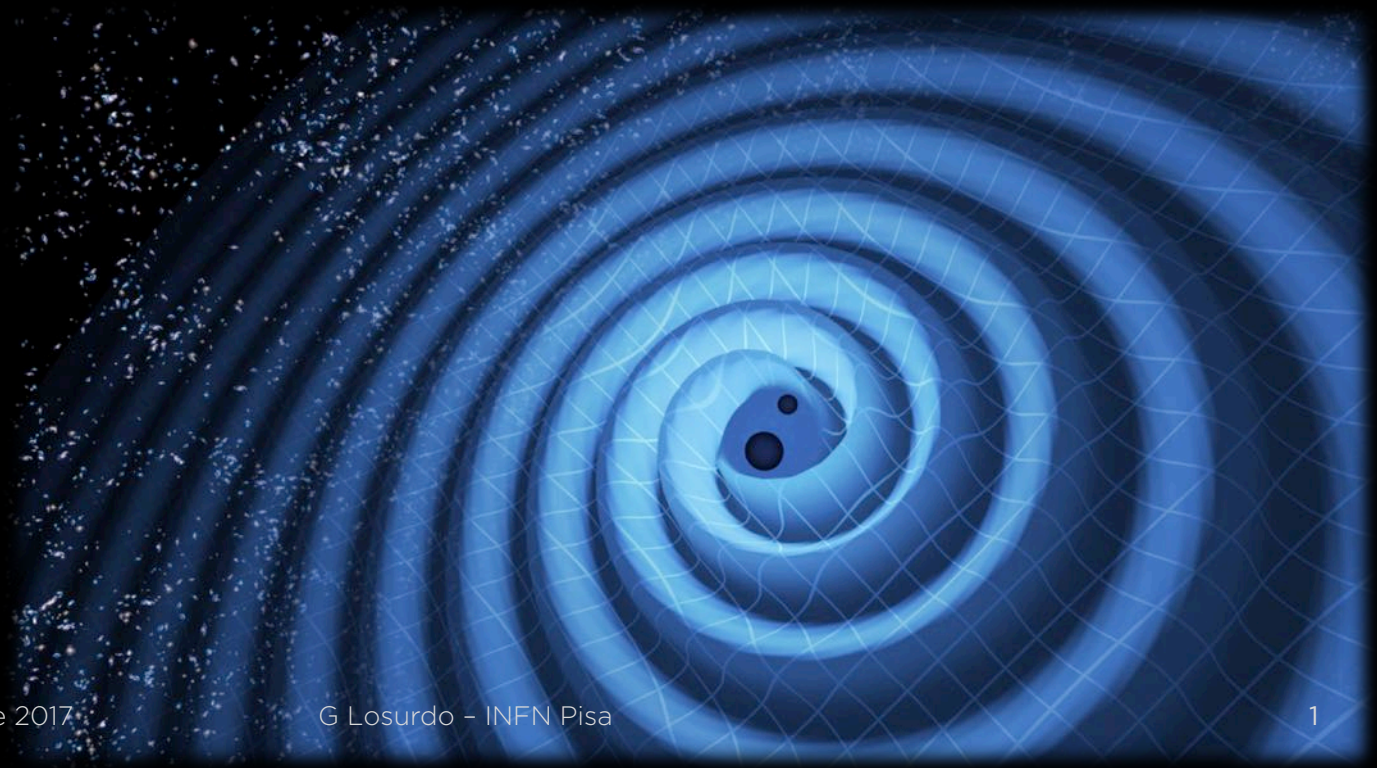
ONDE GRAVITAZIONALI

una NUOVA

FINESTRA

sull'UNIVERSO

Giovanni Losurdo - INFN Pisa



2015
CENTENARIO DELLA RELATIVITA' GENERALE

NASCITA DELL'ASTRONOMIA GRAVITAZIONALE?

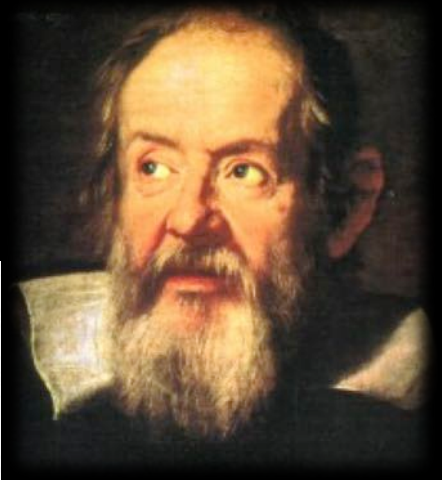
I Cieli di Brera
16 novembre 2011

17 AGOSTO...130 MILIONI DI ANNI FA

Credit: NASA Astrophysics

IL CONTESTO

SIDEREUS NUNCIUS (1610)



SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, ſuſpiciendaque proponens
vnicuique, præſertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnaſij Publico Mathematico
PERSPICILLI
Nuper à ſe reperti beneficio ſunt obſeruata in LVNÆ FACIE, FIXIS IN-NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam diſparibus interuallis, atque periodis, celeritate mirabili circumuolutis; quos, nemini in hanc vſque diem cognitos, nouiſſimè Author deprehendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.

VENETIIS, Apud Thomam Baglionum. M D C X.
Superiorum Permiſſu, & Priuilegio.

OBSERVAT. SIDEREAE

Ori. * *○ * Occ.

Stella occidentaliori maior, ambæ tamen valdè conſpicuæ, ac ſplendidæ: vtra quæ diſtabat à Ioue ſcrupulis primis duobus; tertia quoque Stellula apparere cępit hora tertia prius minimè conſpecta, quæ ex parte orientali Iouem ferè tangebat, eratque admodum exigua. Omnes fuerunt in eadem recta, & ſecundum Eclypticæ longitudinem coordinatæ.

Die decimatertia primum à me quatuor conſpectæ fuerunt Stellulæ in hac ad Iouem conſtitutione. Erant tres occidentales, & vna orientalis; lineam proximè

Ori. * ○ * * * Occ.

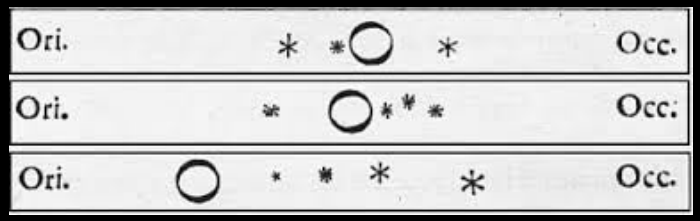
rectam conſtituebant; media enim occidẽtalium paululum à recta Septentrionem verſus deflectebat: Aberat orientalior à Ioue minuta duo: reliquarum, & Iouis intercapedines erant ſingulæ vnius tantum minuti. Stellæ omnes eandem præ ſe ferebant magnitudinem; ac licet exiguam, lucidiſſimæ tamen erant, ac fixis eiuſdem magnitudinis longe ſplendidiores.

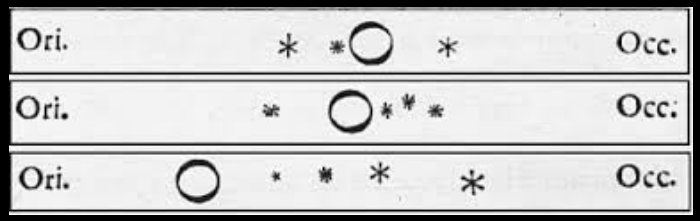
Die decimaquarta nubiloſa fuit tempeſtas.

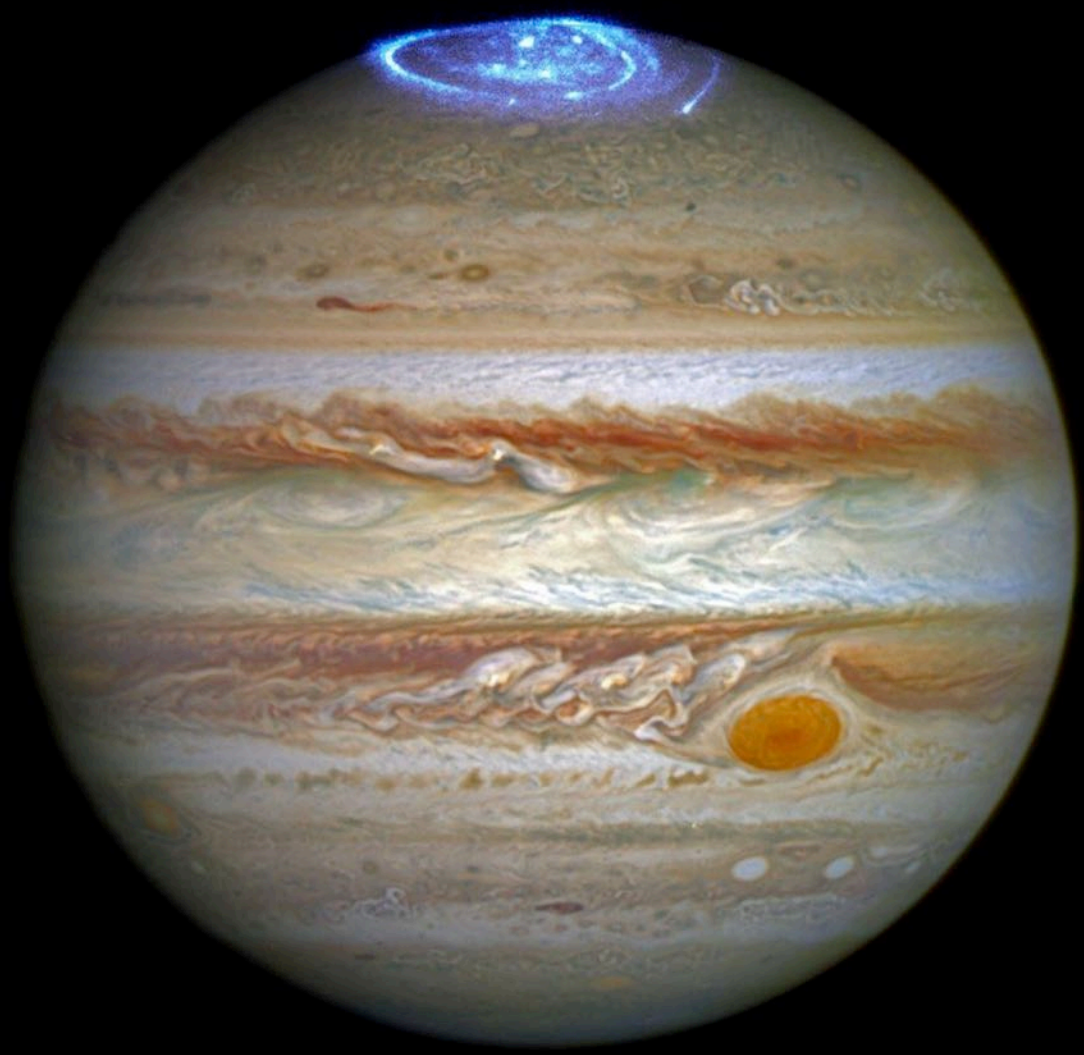
Die decimaquinta, hora noctis tertia in proximè depicta fuerunt habitudine quatuor Stellæ ad Iouem;

Ori. ○ * * * * Occ.

400 ANNI


Ori.
Occ.
Ori.
Occ.
Ori.
Occ.





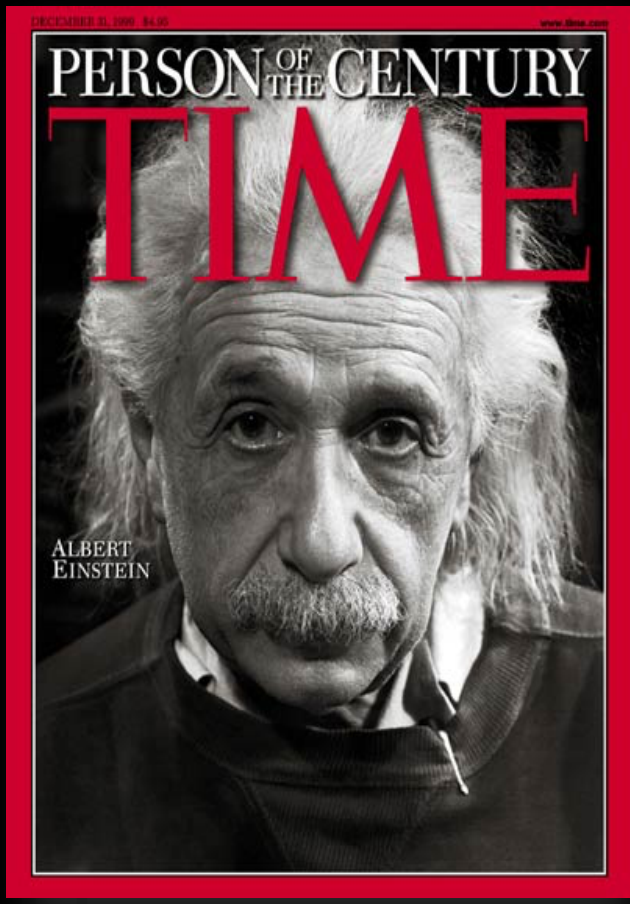
Credit: NASA/Hubble

RELATIVITA' GENERALE (1915)

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

GEOMETRIA SPAZIO-TEMPO

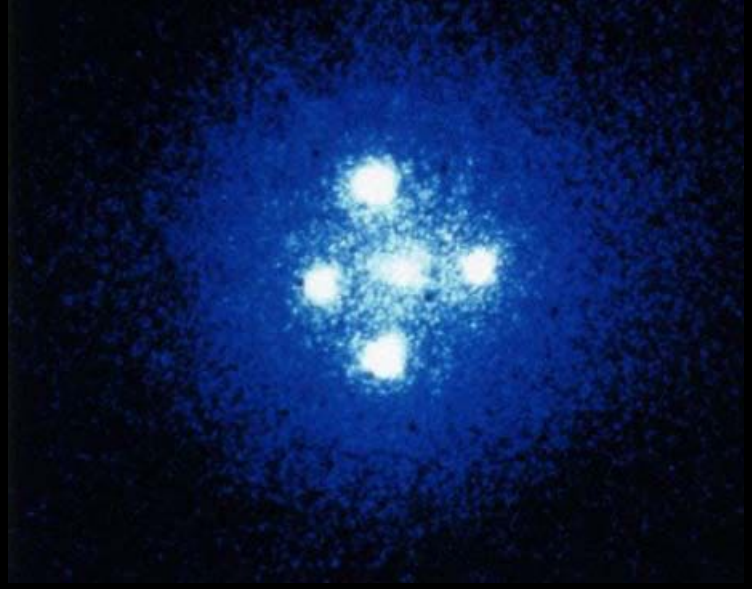
MASSA-ENERGIA



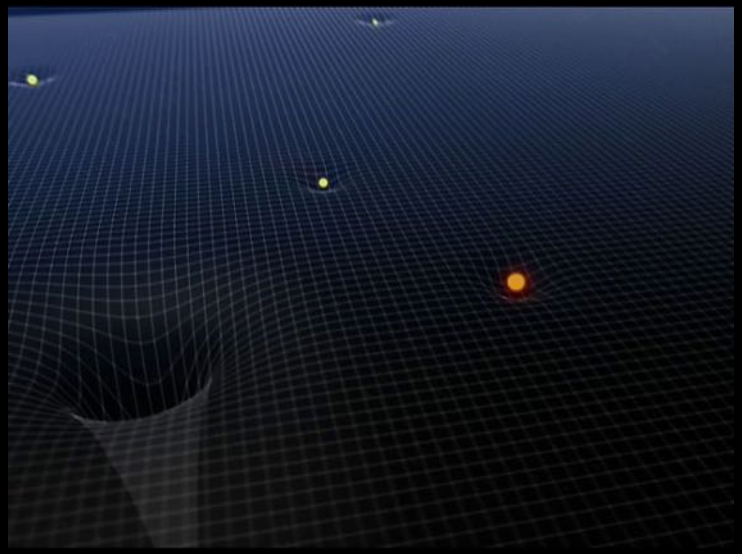
LA MATERIA DICE ALLO SPAZIOTEMPO COME INCURVARSI;
LO SPAZIOTEMPO DICE ALLA MATERIA COME MUOVERSI.
(J.A. WHEELER)

Credit: LIGO

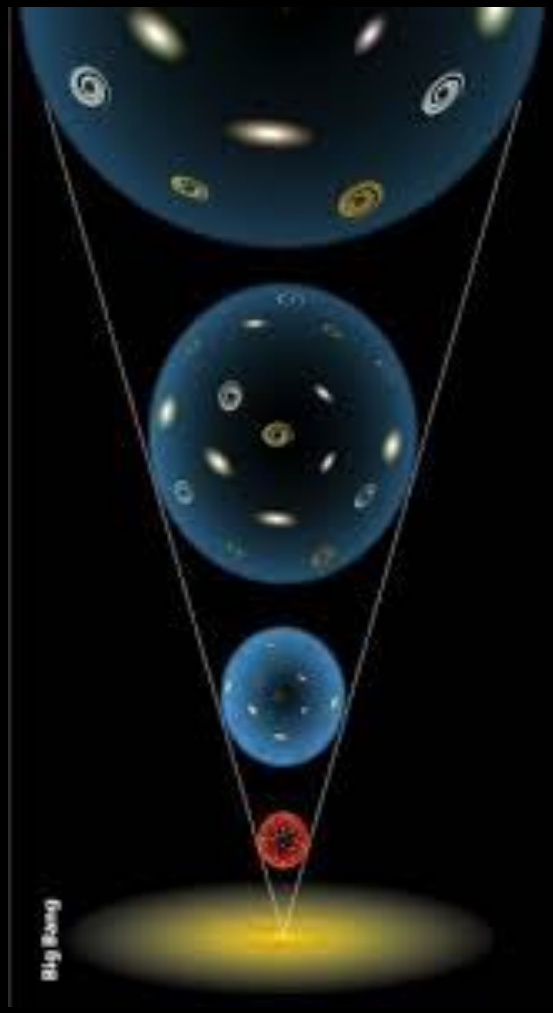
PREVISIONI



DEFLESSIONE DELLA LUCE



ESISTENZA DEI BUCHI NERI



ESPANSIONE DELL'UNIVERSO (BIG BANG)

ONDE GRAVITAZIONALI (1916)

Sitzung der physikalisch-mathematischen Klasse vom 22. Juni 1916

Näherungsweise Integration der Feldgleichungen der Gravitation.

Von A. Einstein.

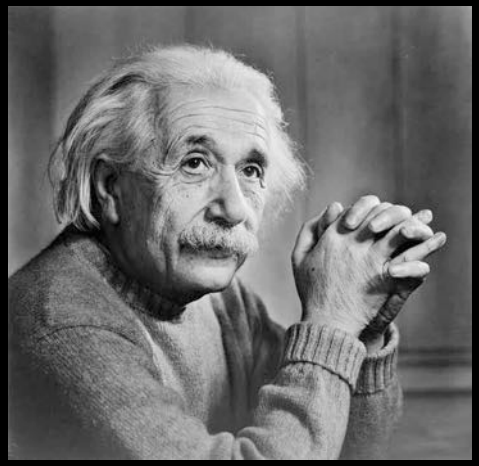
Daraus folgt dann zunächst, daß sich die Gravitationsfelder mit Lichtgeschwindigkeit ausbreiten. Wir werden im Anschluß an diese all-

§ 2. Ebene Gravitationswellen.

Aus den Gleichungen (6) und (9) folgt, daß sich Gravitationsfelder stets mit der Geschwindigkeit 1, d. h. mit Lichtgeschwindigkeit, fortpflanzen. Ebene, nach der positiven x-Achse fortschreitende Gravitationswellen sind daher durch den Ansatz zu finden

$$\gamma'_{\mu\nu} = \alpha_{\mu\nu} f(x_1 + i x_4) = \alpha_{\mu\nu} f(x - t). \qquad (15)$$

Nachtrag. Das seltsame Ergebnis, daß Gravitationswellen existieren sollen, welche keine Energie transportieren (Typen a, b, c), klärt sich in einfacher Weise auf. Es handelt sich nämlich dabei nicht um »reale« Wellen, sondern um »scheinbare« Wellen, die darauf beruhen, daß als Bezugssystem ein wellenartig zitterndes Koordinatensystem benutzt wird. Dies sieht man bequem in folgender Weise ein.



Piccole increspature dello spazio-tempo che si propagano alla velocità della luce

Generate da grandi masse che si muovono a grande velocità

ONDE GRAVITAZIONALI

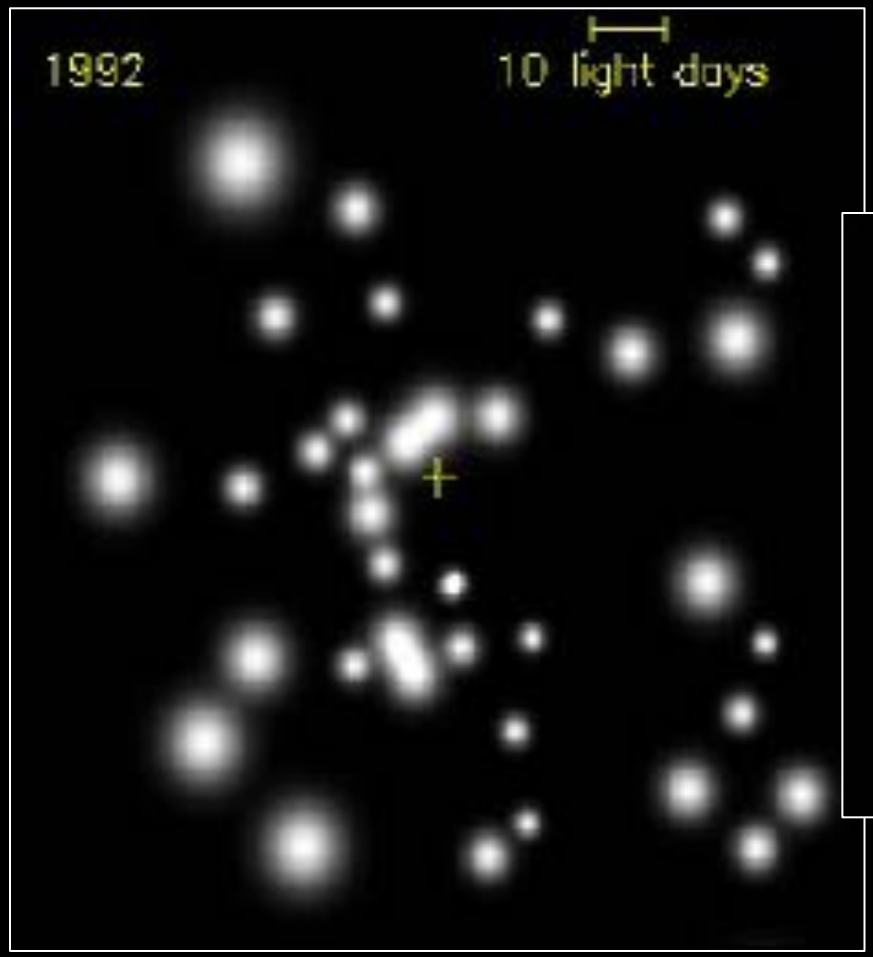
INTERAGISCONO MOLTO DEBOLMENTE CON LA MATERIA

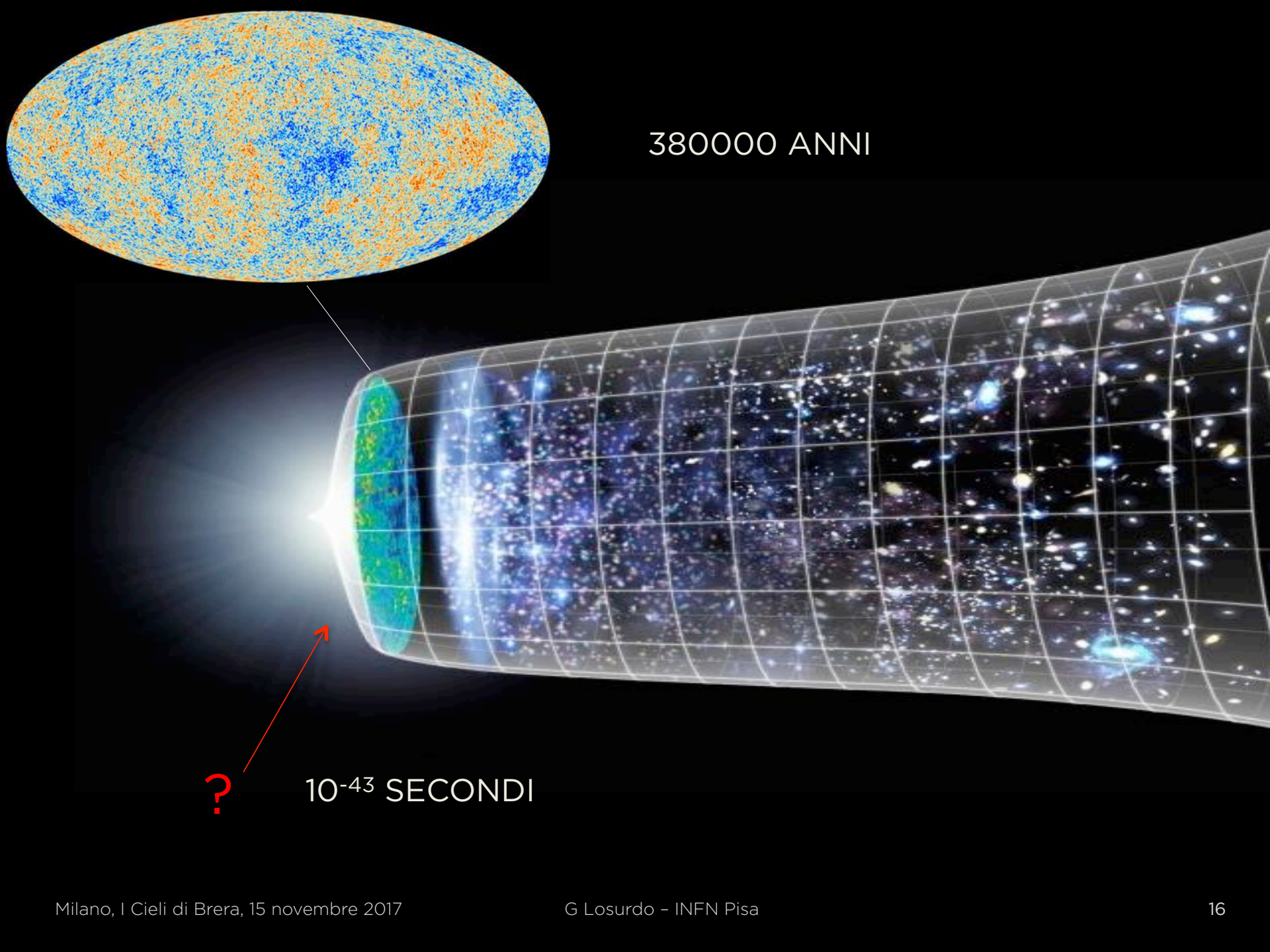
ATTRAVERSANO L'UNIVERSO INDISTURBATE

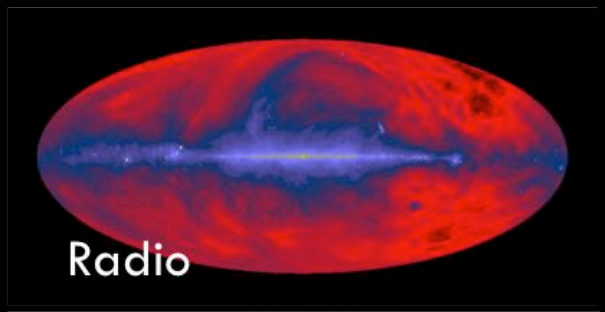
E' MOLTO DIFFICILE "CATTURARLE"

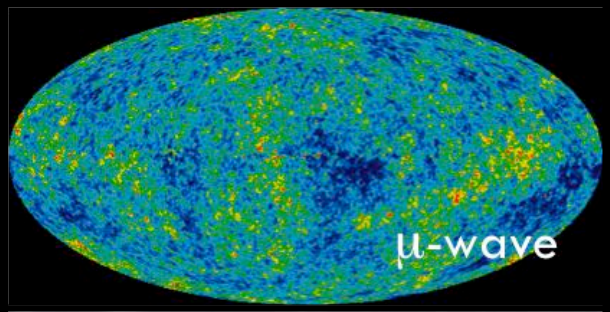

Credit: Hubble

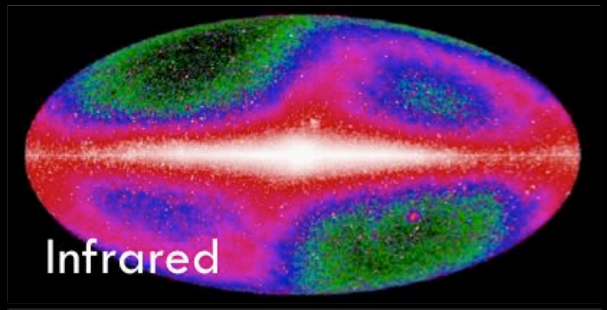
BUCHI NERI



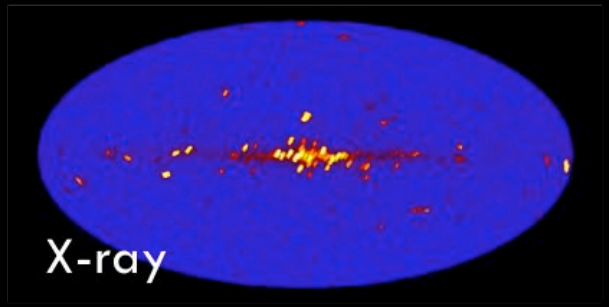

380000 ANNI
?
10-43 SECONDI

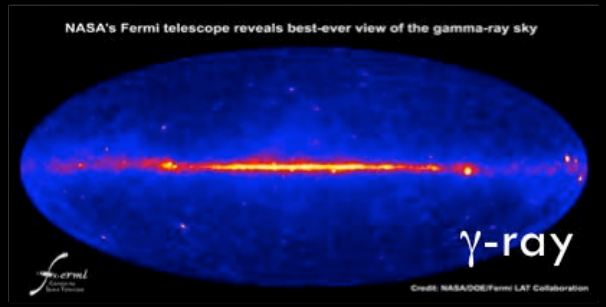

Radio

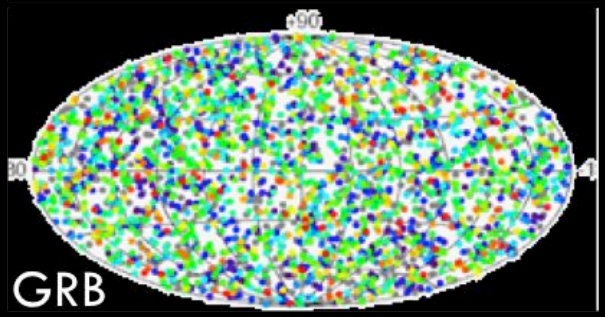

μ-wave


Infrared

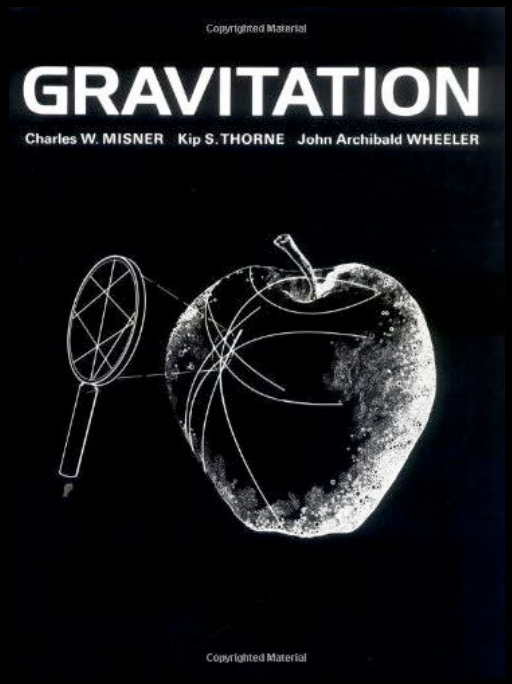

Visible

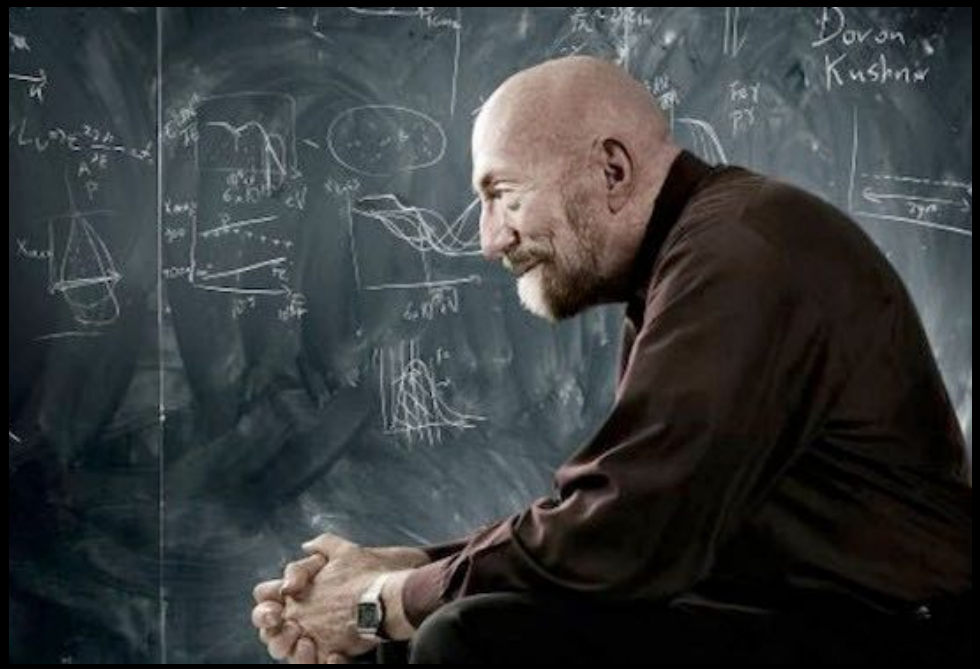

X-ray


NASA's Fermi telescope reveals best-ever view of the gamma-ray sky
γ-ray
Credit: NASA/DOE/Fermi LAT Collaboration


GRB

K.S. Thorne
Feynman Professor of
theoretical physics - Caltech





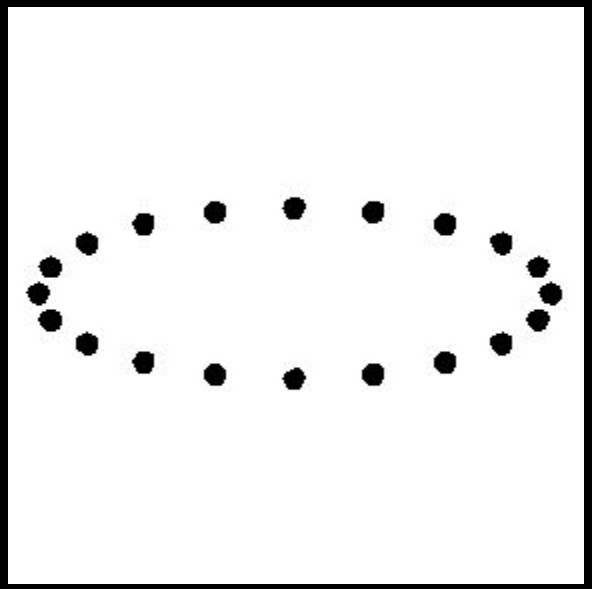
In una intervista di qualche anno fa…

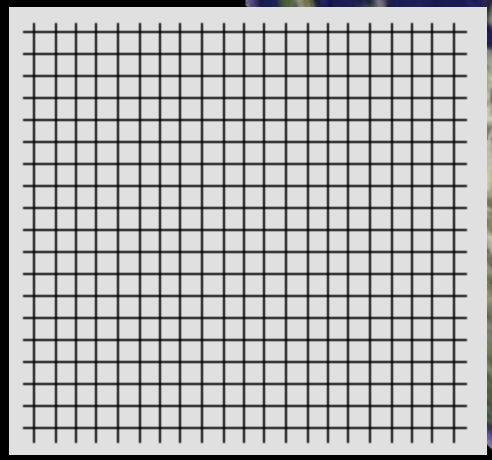
D: Cosa pensi quando guardi il cielo e vedi le stelle?

R: Penso a tutte le cose che non riesco a vedere lassù…

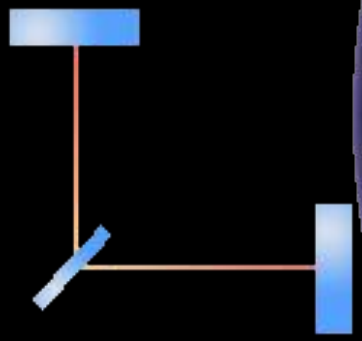
QUALI EFFETTI?

- Le OG deformano lo spazio-tempo
- Effetto su un anello di masse in caduta libera…



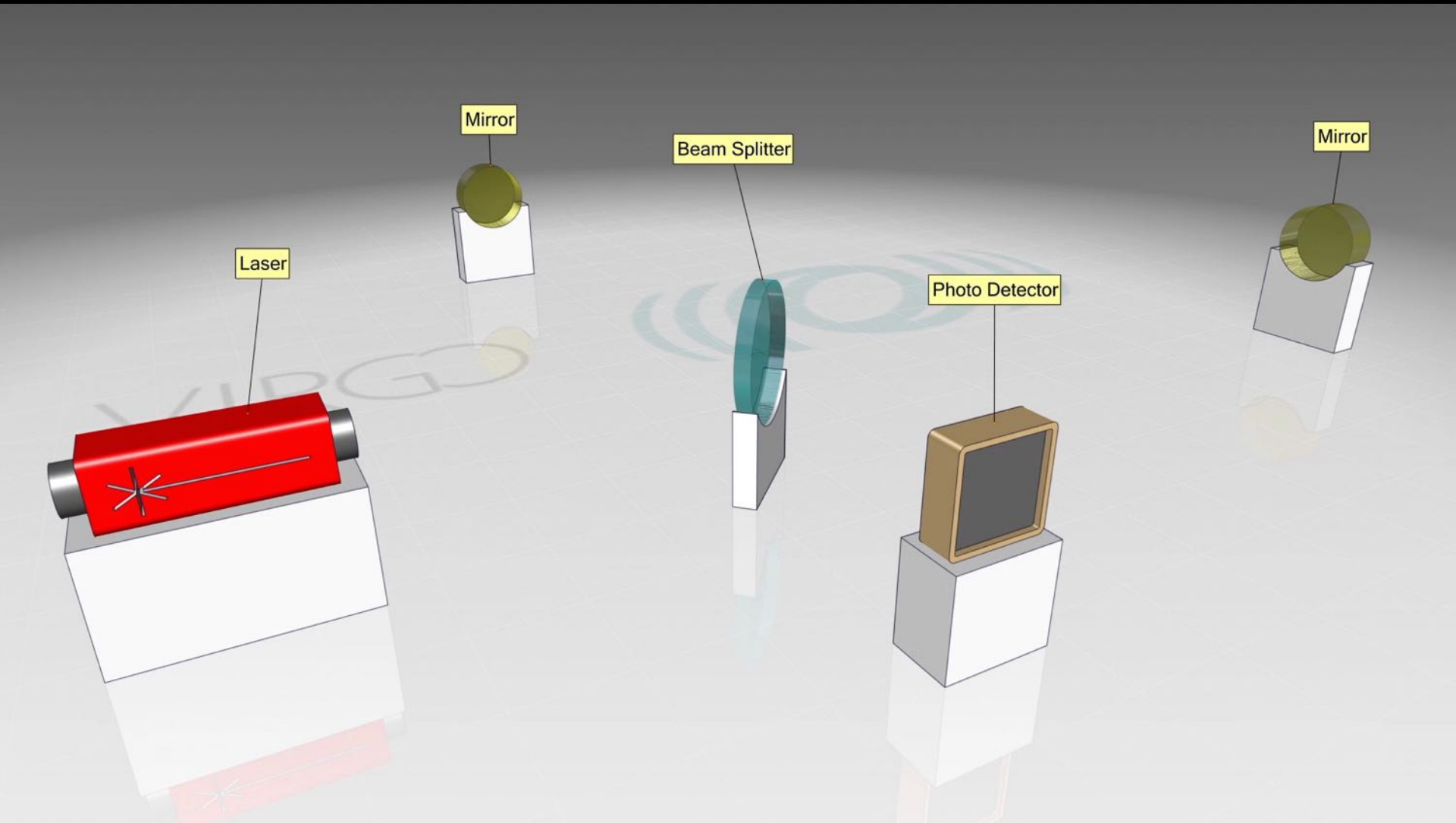


SI POSSONO RIVELARE?



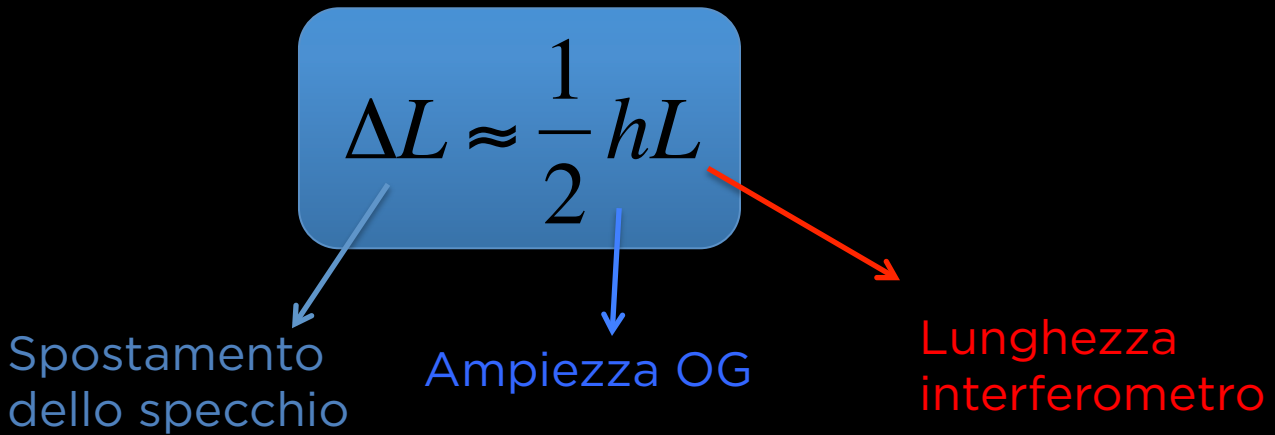
- Idea: sostituire l'anello di masse con specchi
- Misurarne gli spostamenti con un interferometro

L’interferometro di Michelson: misurare piccoli spostamenti usando la luce



SI POSSONO RIVELARE?

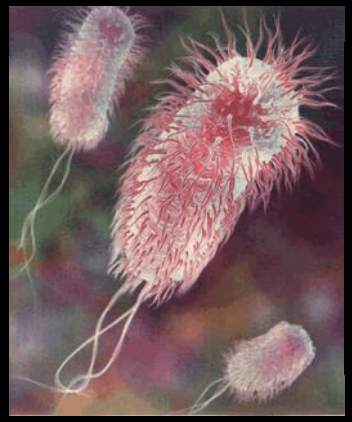
- Di quanto si sposta uno specchio investito da OG?

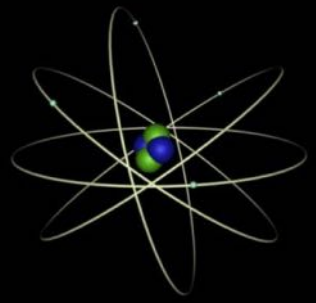


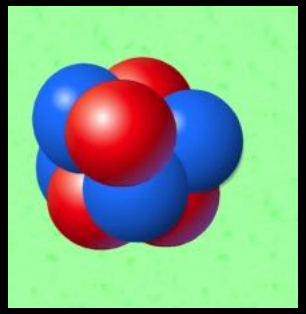
- Per due stelle di neutroni che coalescono a 10 Mpc si ha $h \sim 10^{-21}$
- Sulla Terra si può realizzare L ~ qualche km
- Bisogna perciò essere capaci di misurare $\Delta L \sim 10^{-18}$ metri!

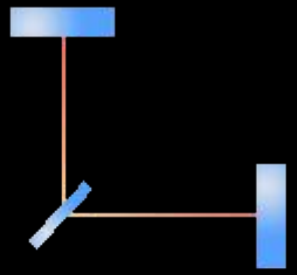
10^{-18} m ?????

QUANTO E' PICCOLO 10^{-18} m?





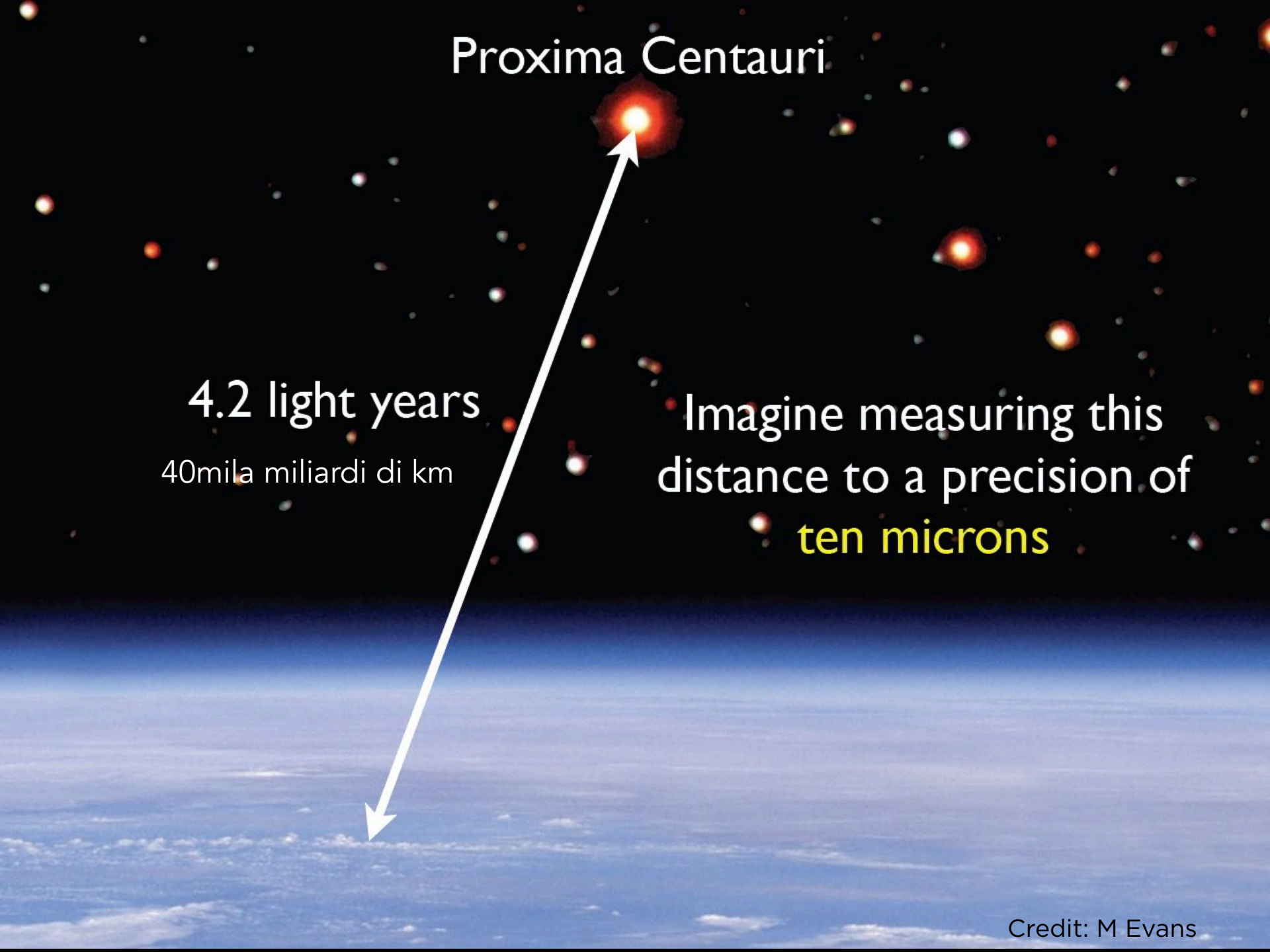




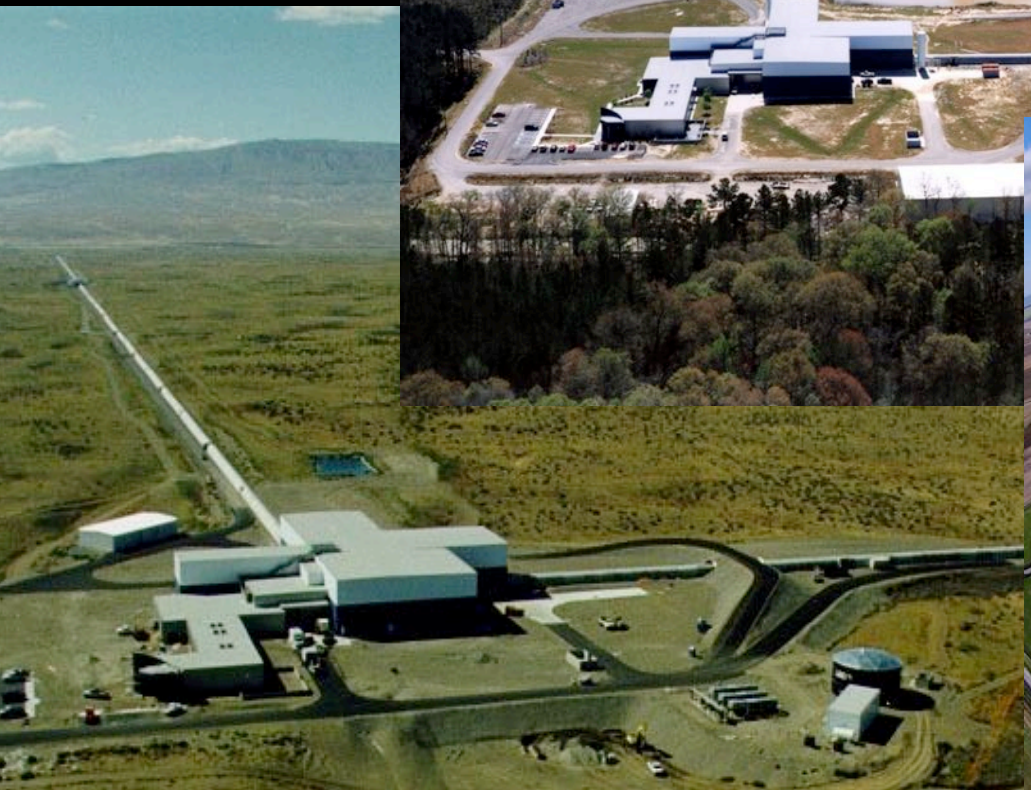
$\approx 10^{-5}$ m $\approx 10^{-10}$ m $\approx 10^{-15}$ m $\approx 10^{-18}$ m

1 metro 10 micron 1 Angstrom 1 femtometro 1 attometro

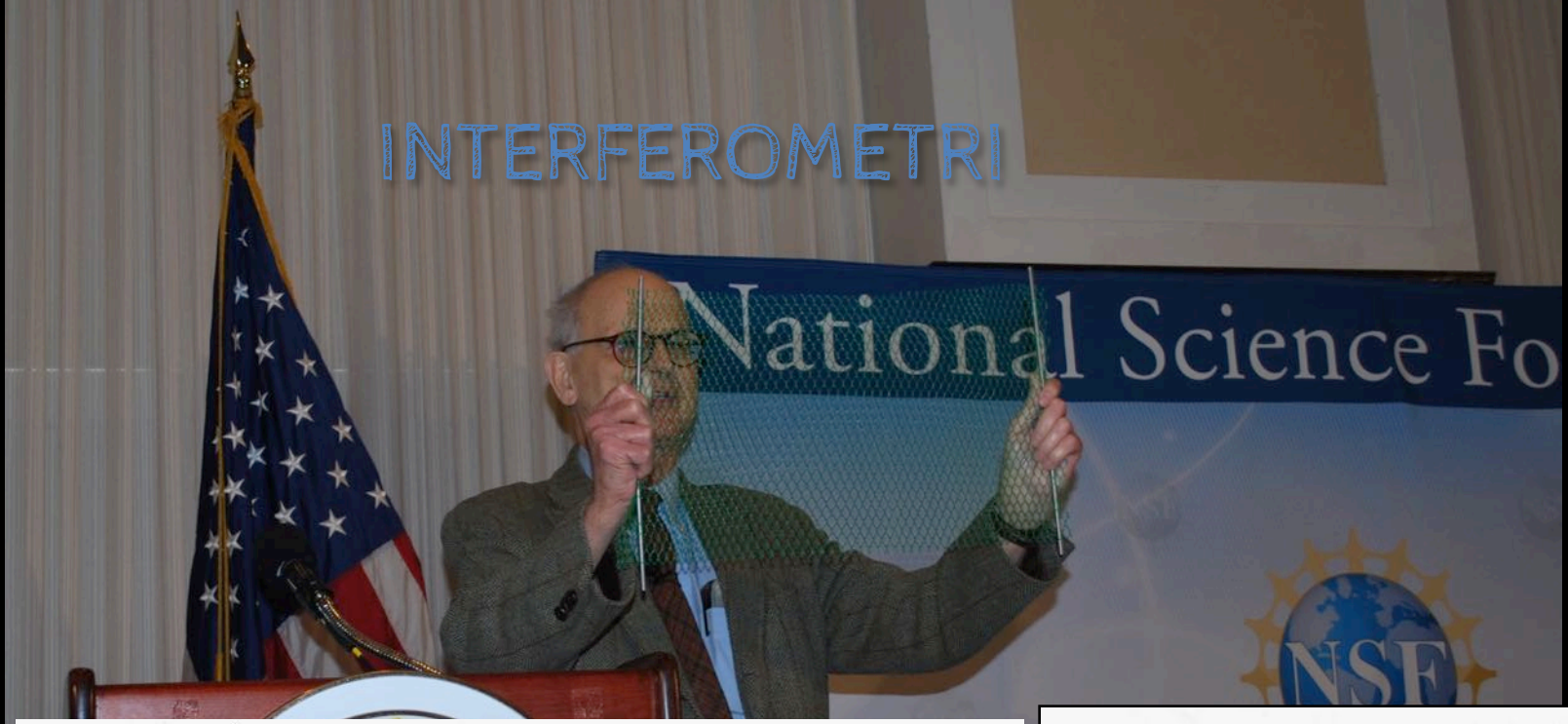
÷100.000 ÷100.000 ÷100.000 ÷1.000


Proxima Centauri
4.2 light years
40mila miliardi di km
Imagine measuring this distance to a precision of ten microns
Credit: M Evans

COME SI MISURA 10^{-18} m?



INTERFEROMETRI



QUARTERLY PROGRESS REPORT

No. 105

APRIL 15, 1972

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

RESEARCH LABORATORY OF ELECTRONICS

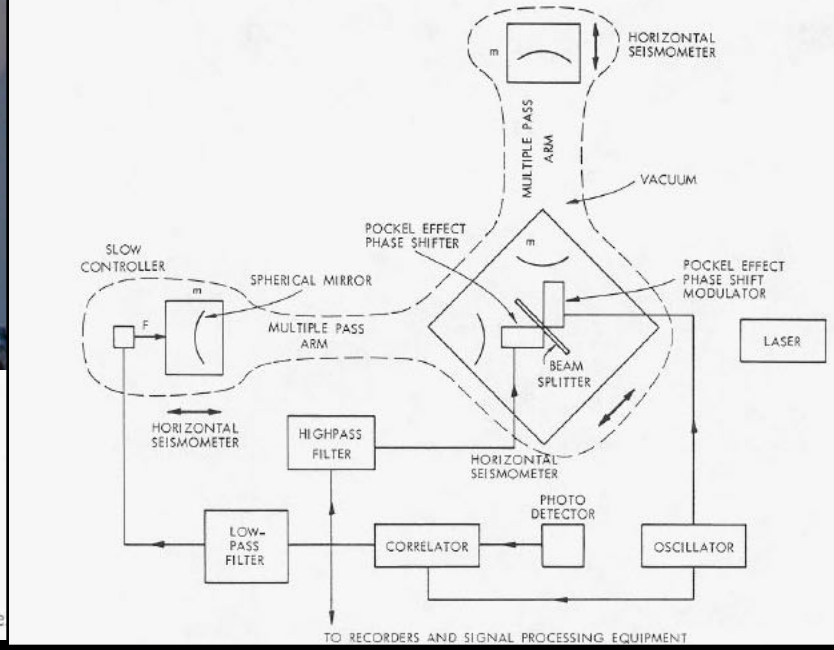
CAMBRIDGE, MASSACHUSETTS 02139

(V. GRAVITATION RESEARCH)

B. ELECTROMAGNETICALLY COUPLED BROADBAND GRAVITATIONAL ANTENNA

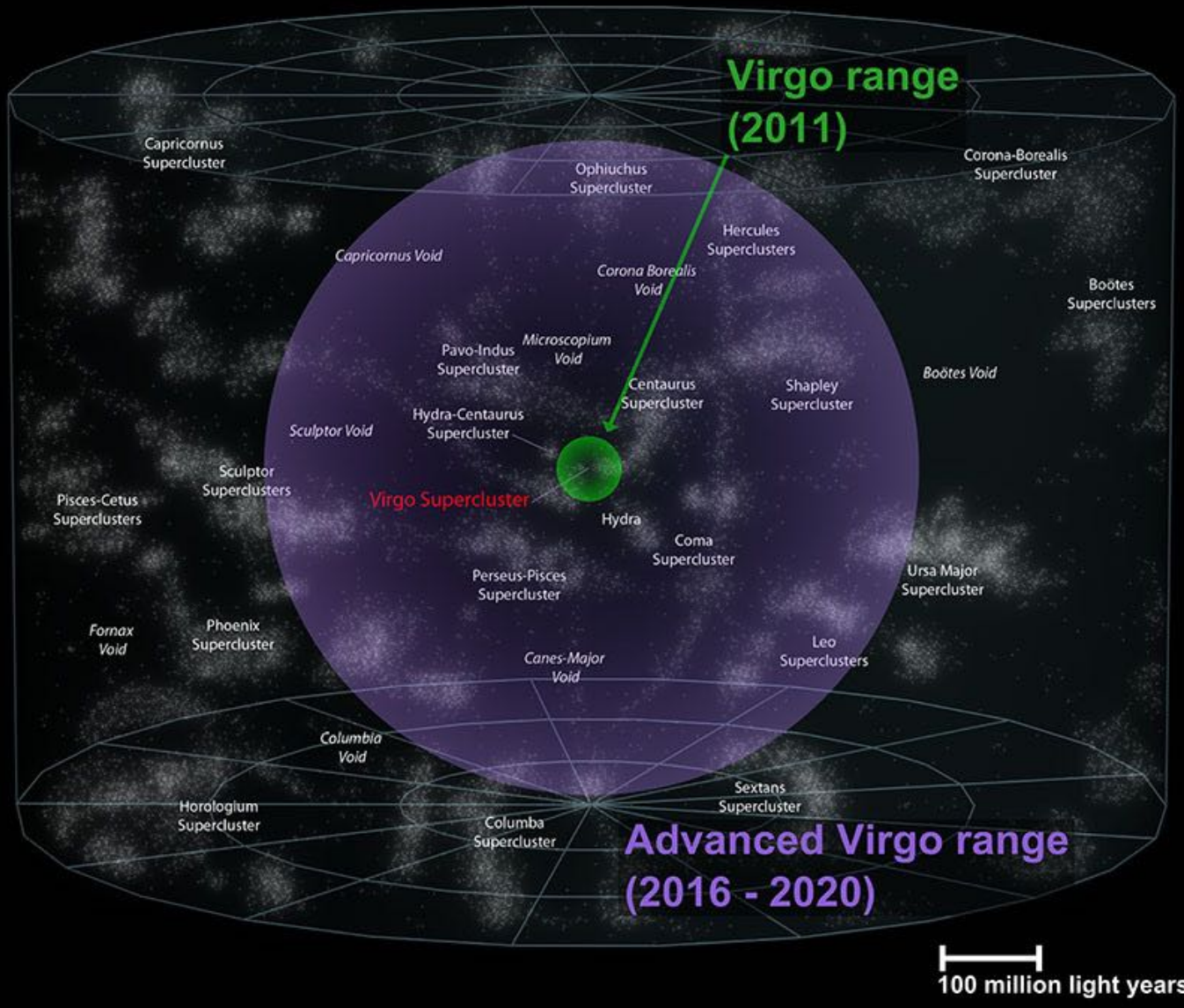
1. Introduction

The prediction of gravitational radiation that travels at the speed of light has bee



LIGO e VIRGO HANNO OSSERVATO L'UNIVERSO FINO AD UNA DISTANZA DI CIRCA 50 MILIONI DI ANNI LUCE. NON E' BASTATO PER RIVELARE LE ONDE GRAVITAZIONALI

ADVANCED LIGO/VIRGO: OSSERVARE 10 VOLTE PIU' LONTANO



ADVANCED LIGO

- Due interferometri. (+1) Finanziato ad aprile 2008 (~230 M$)
- Costruzione completata nel 2014
- Inizia presa dati: settembre 2015

ADVANCED VIRGO

6 Paesi europei,
21 laboratori, ~280 autori

- Finanziato nel 2009 da INFN, CNRS, Nikhef (23.8 ME)
- Costruzione iniziata nel 2012, completataad agosto 2016
- Il 1 agosto 2017 si è unito a LIGO nell'osservazione dell'universo

APC Paris
ARTEMIS Nice
EGO Cascina
INFN Firenze-Urbino
INFN Genova
INFN Napoli
INFN Perugia
INFN Pisa
INFN Roma La Sapienza
INFN Roma Tor Vergata
INFN Padova
INFN TIFPA Trento
LAL Orsay – ESPCI Paris
LAPP Annecy
LKB Paris
LMA Lyon
NIKHEF Amsterdam
POLGRAW
RADBOUD Uni. Nijmegen
RMKI Budapest
University of Valencia

…e altri si sono uniti da poco:
GSSI, Milano Bicocca, Torino, UniSalerno

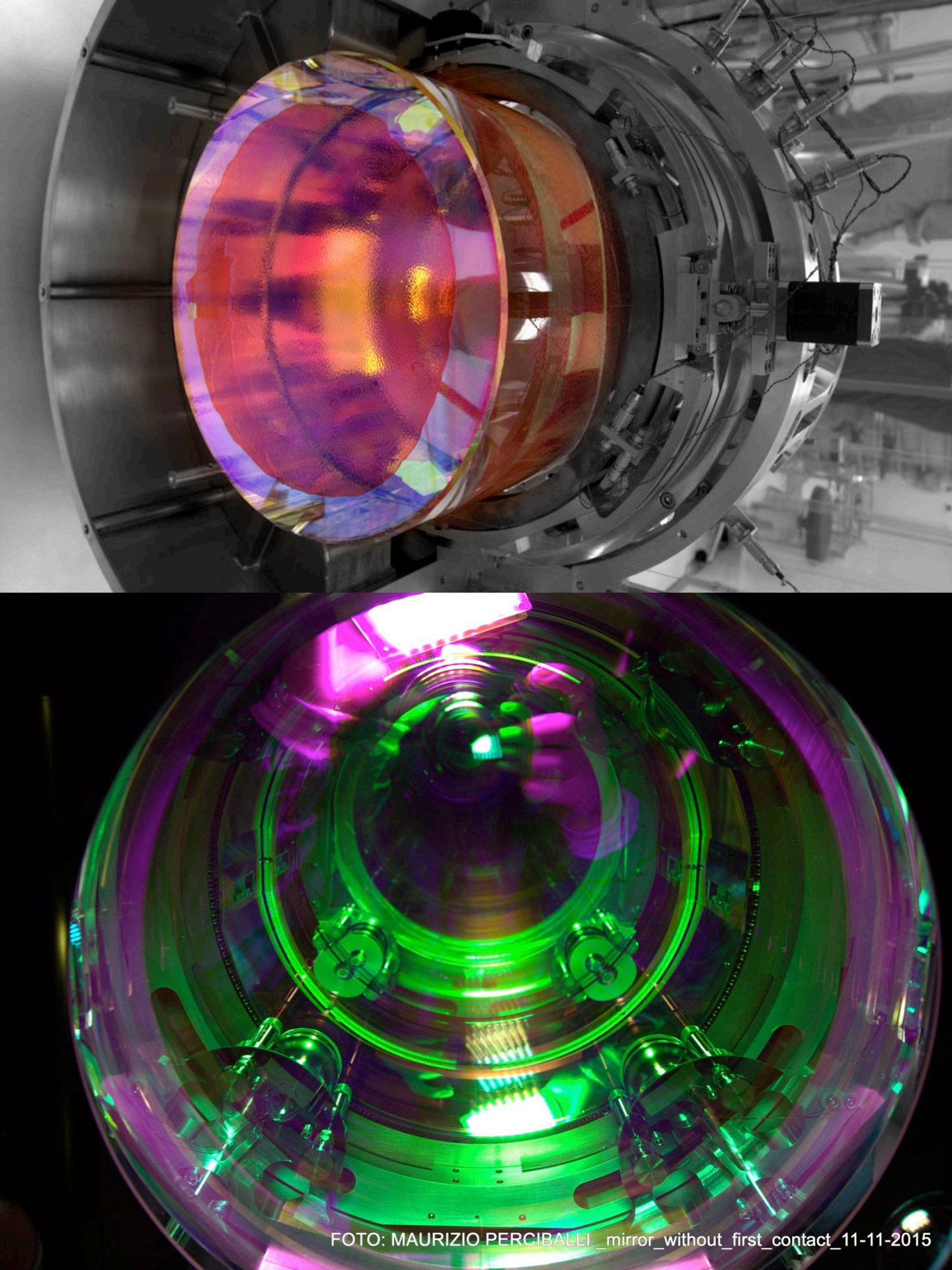
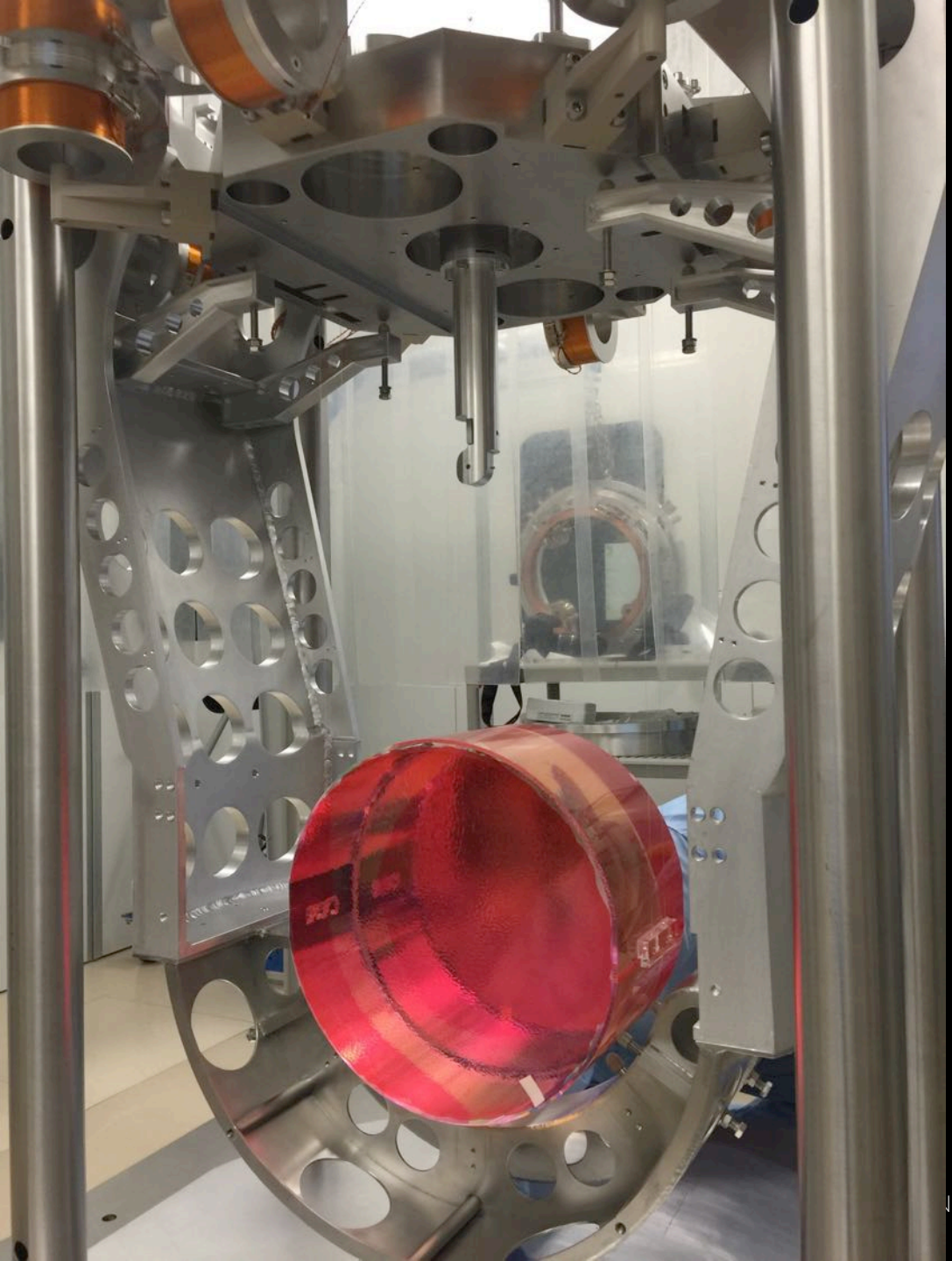
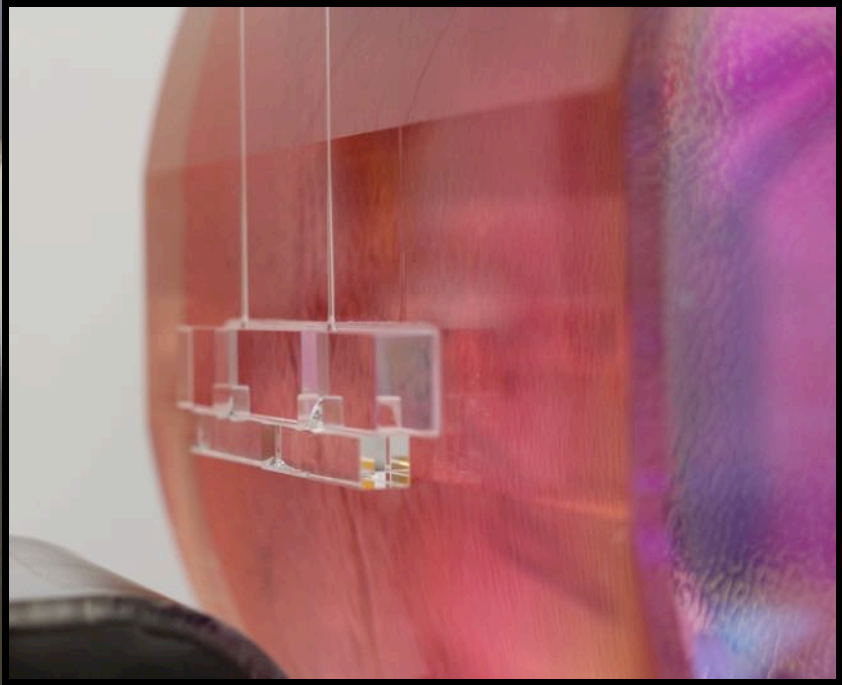
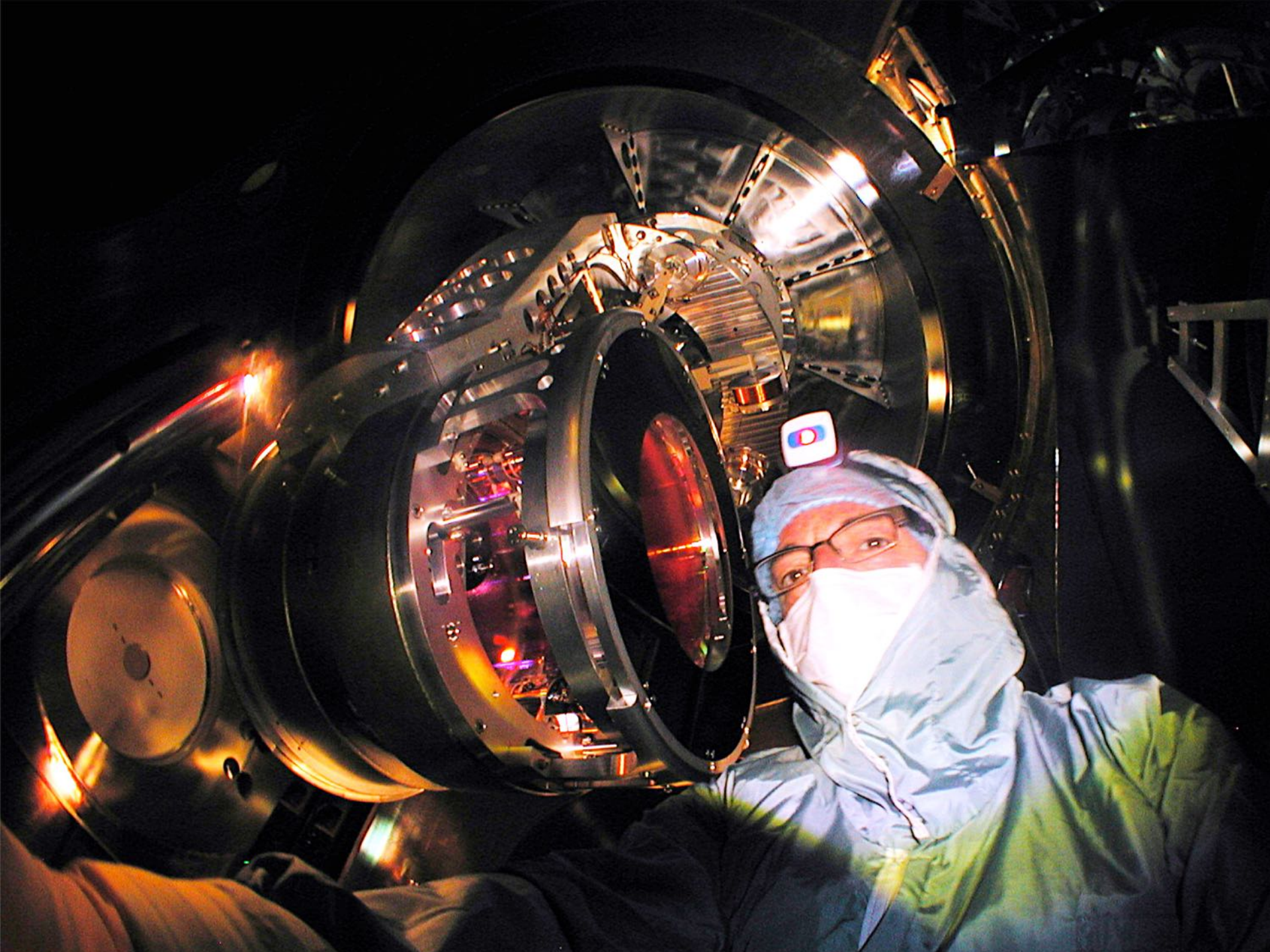
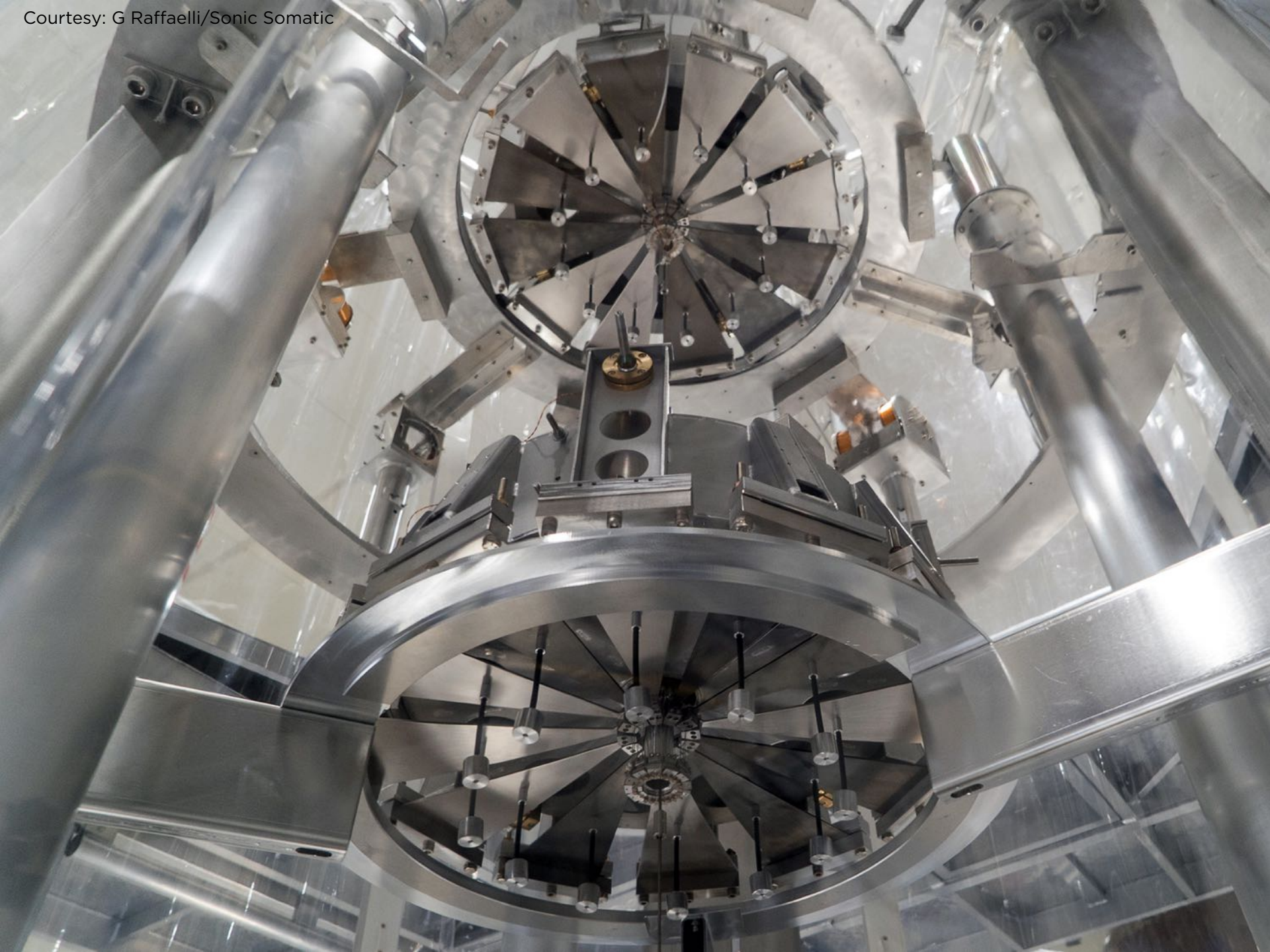


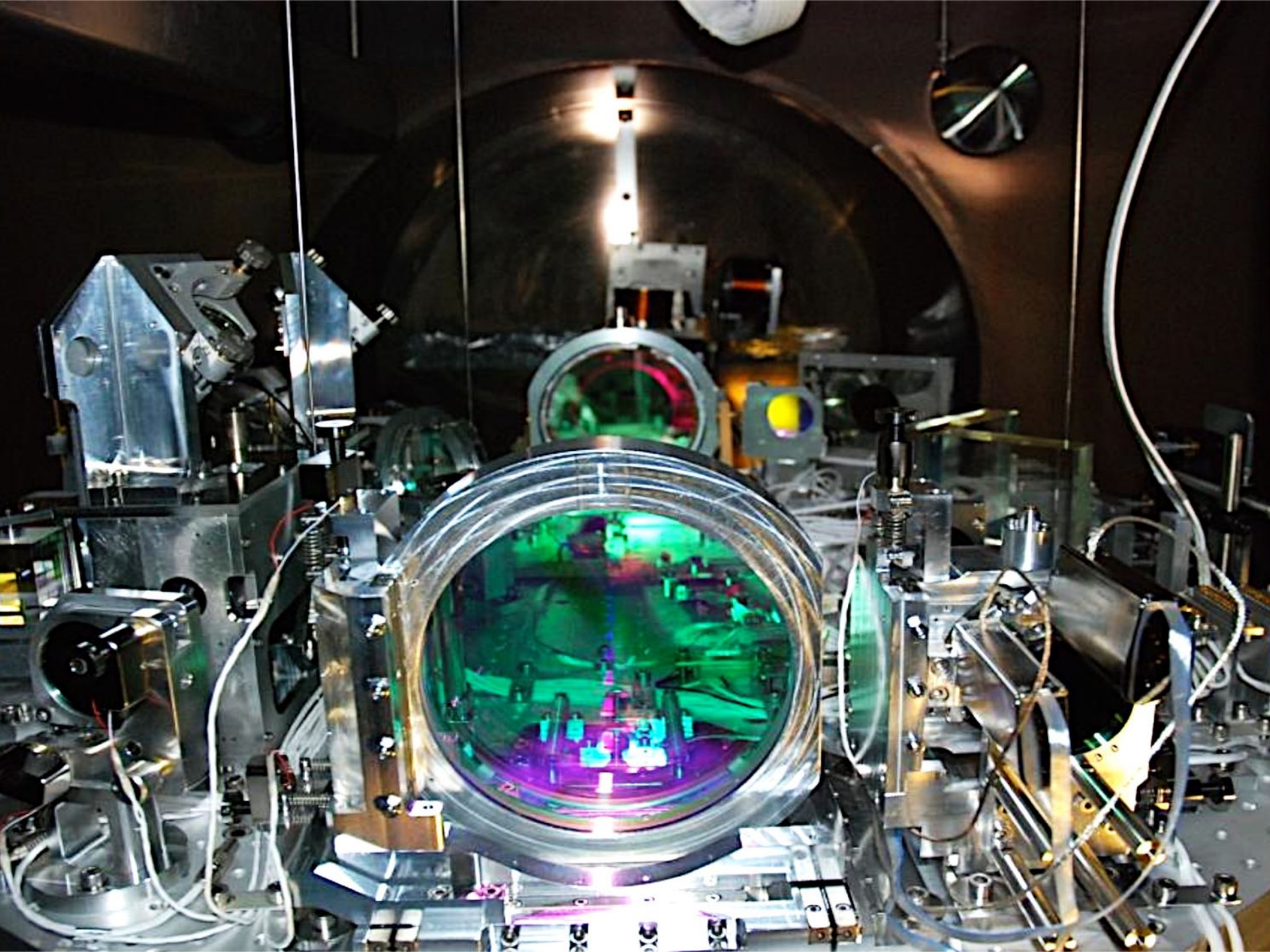
FOTO: MAURIZIO PERCIBALLI _mirror_without_first_contact_11-11-2015

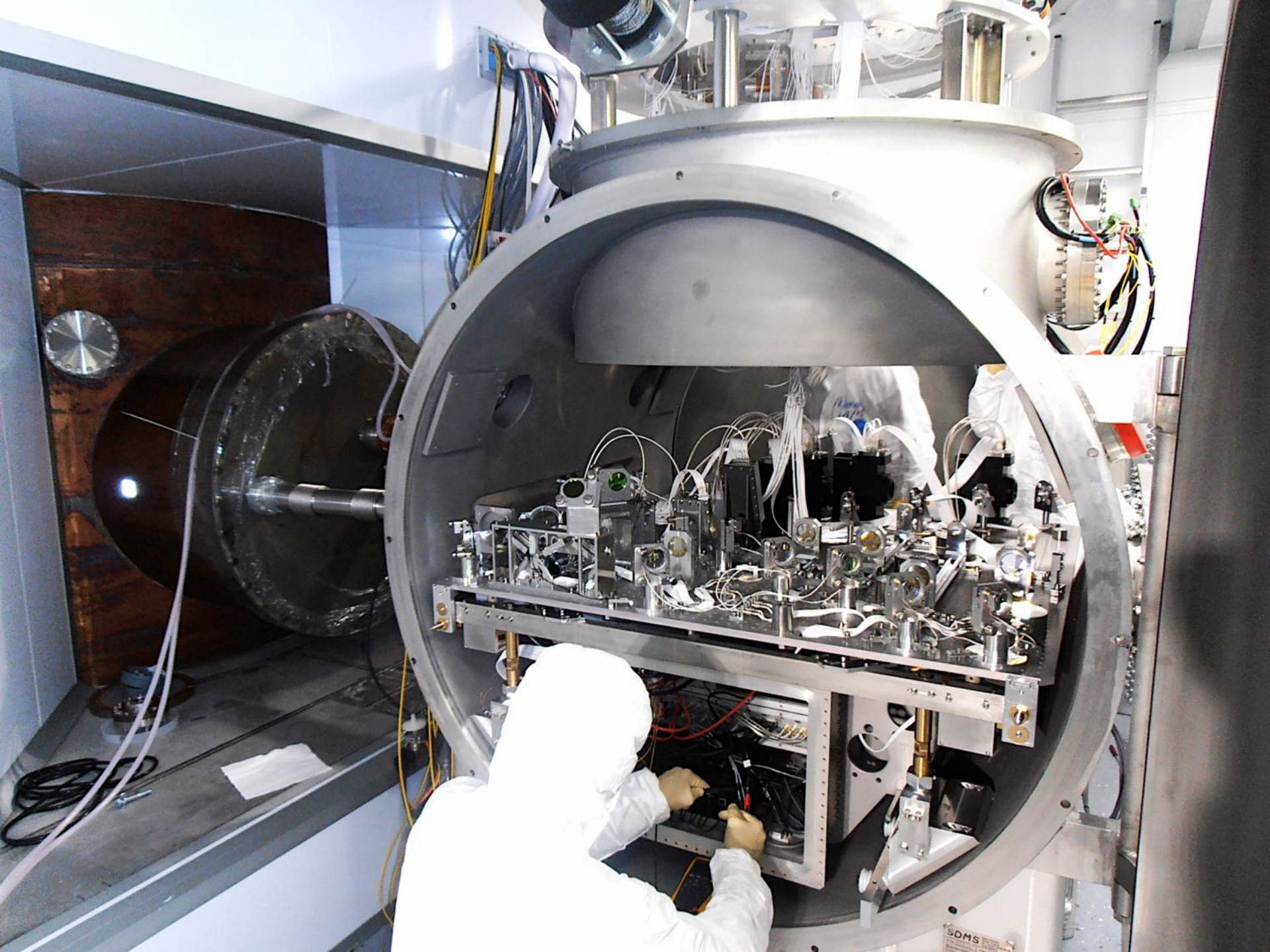







Courtesy: G Raffaelli/Sonic Somatic




SDMS

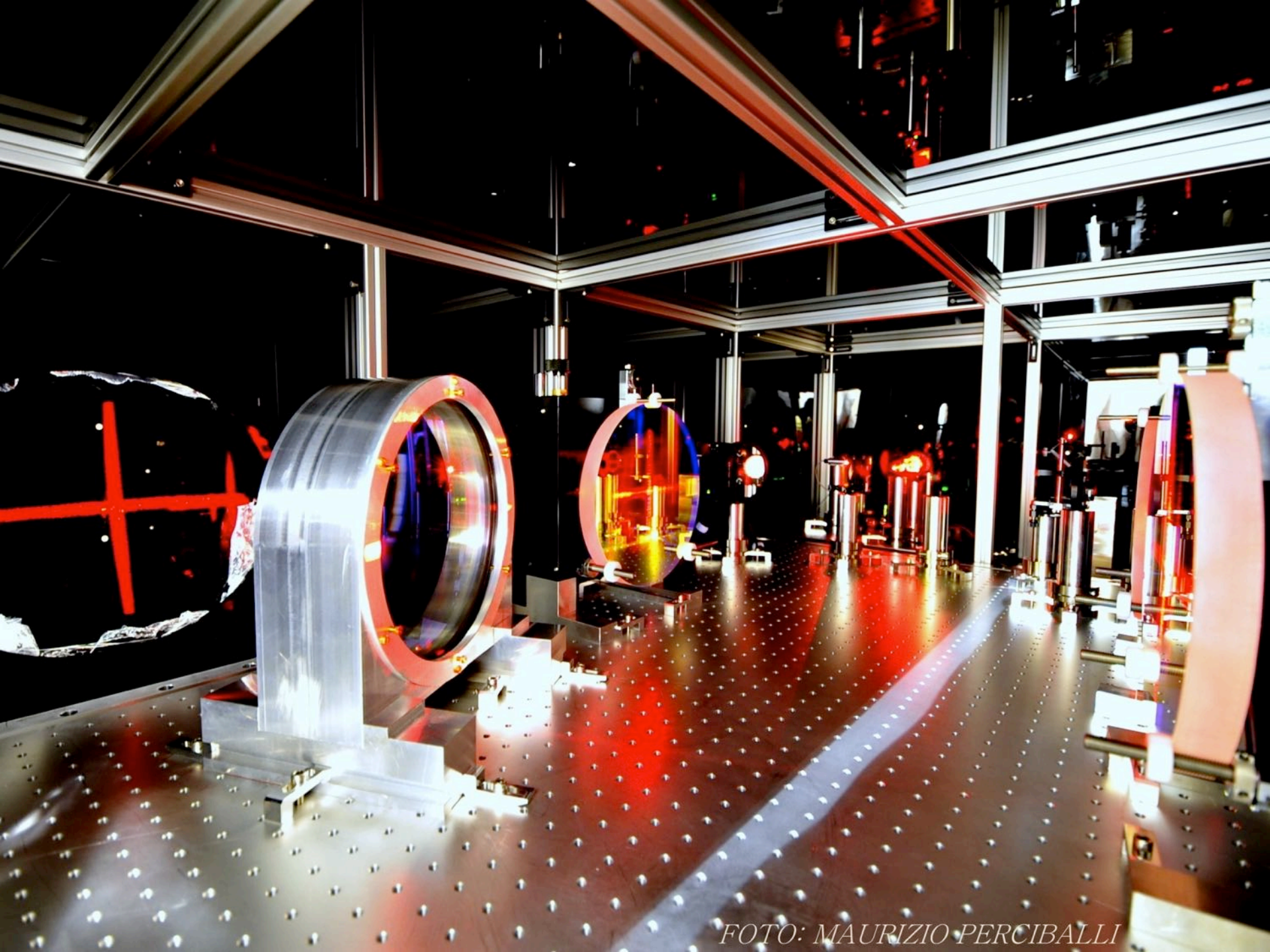


FOTO: MAURIZIO PERCIBALLI

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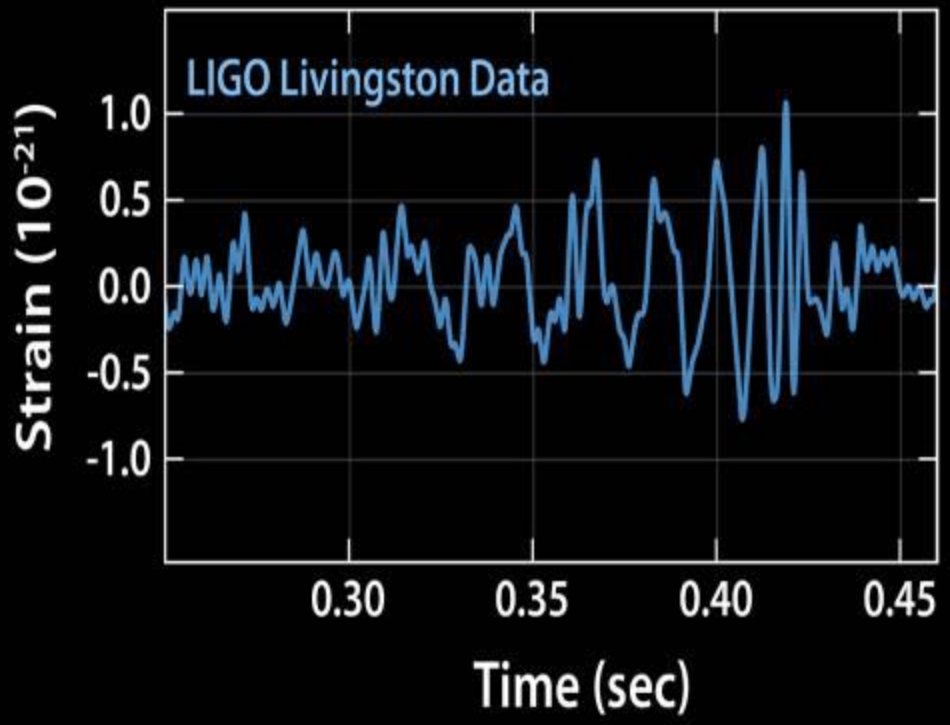
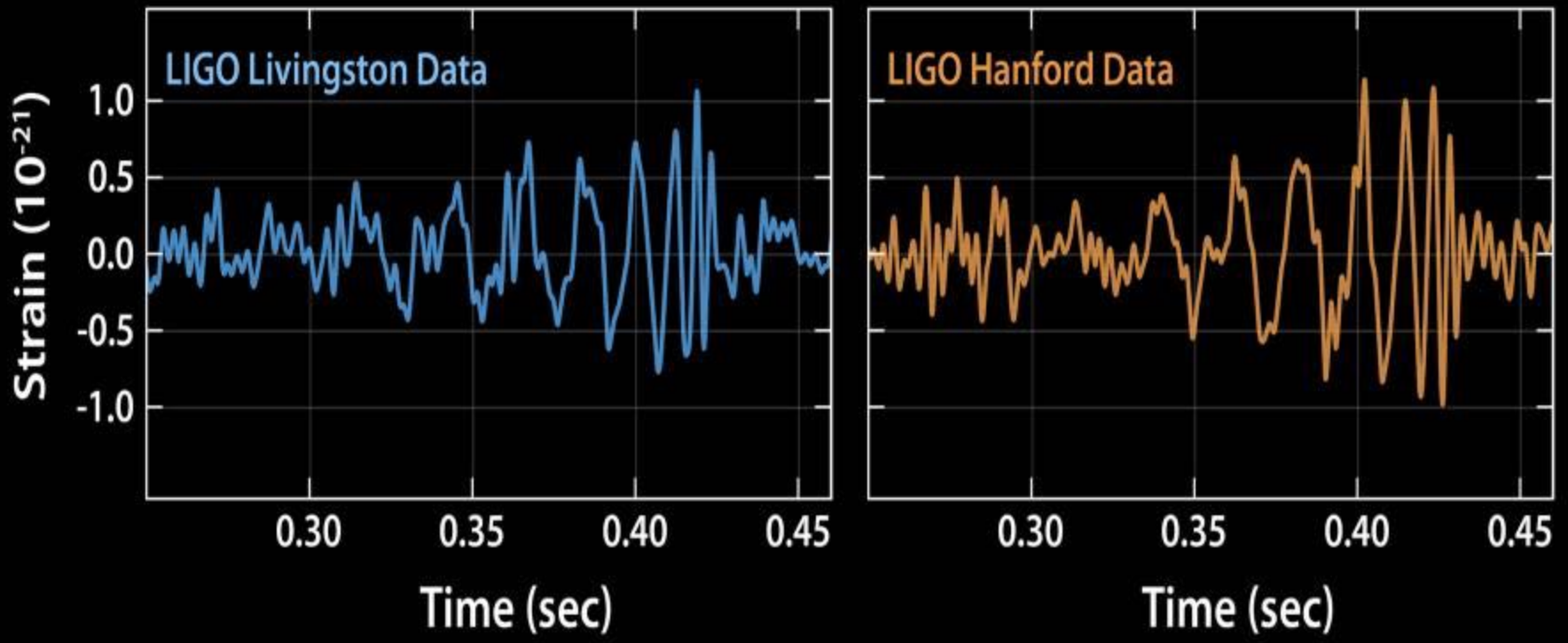
Observation of Gravitational Waves from a Binary Black Hole Merger

B. P. Abbott *et al.* (LIGO Scientific Collaboration and Virgo Collaboration)
Phys. Rev. Lett. **116**, 061102 – Published 11 February 2016

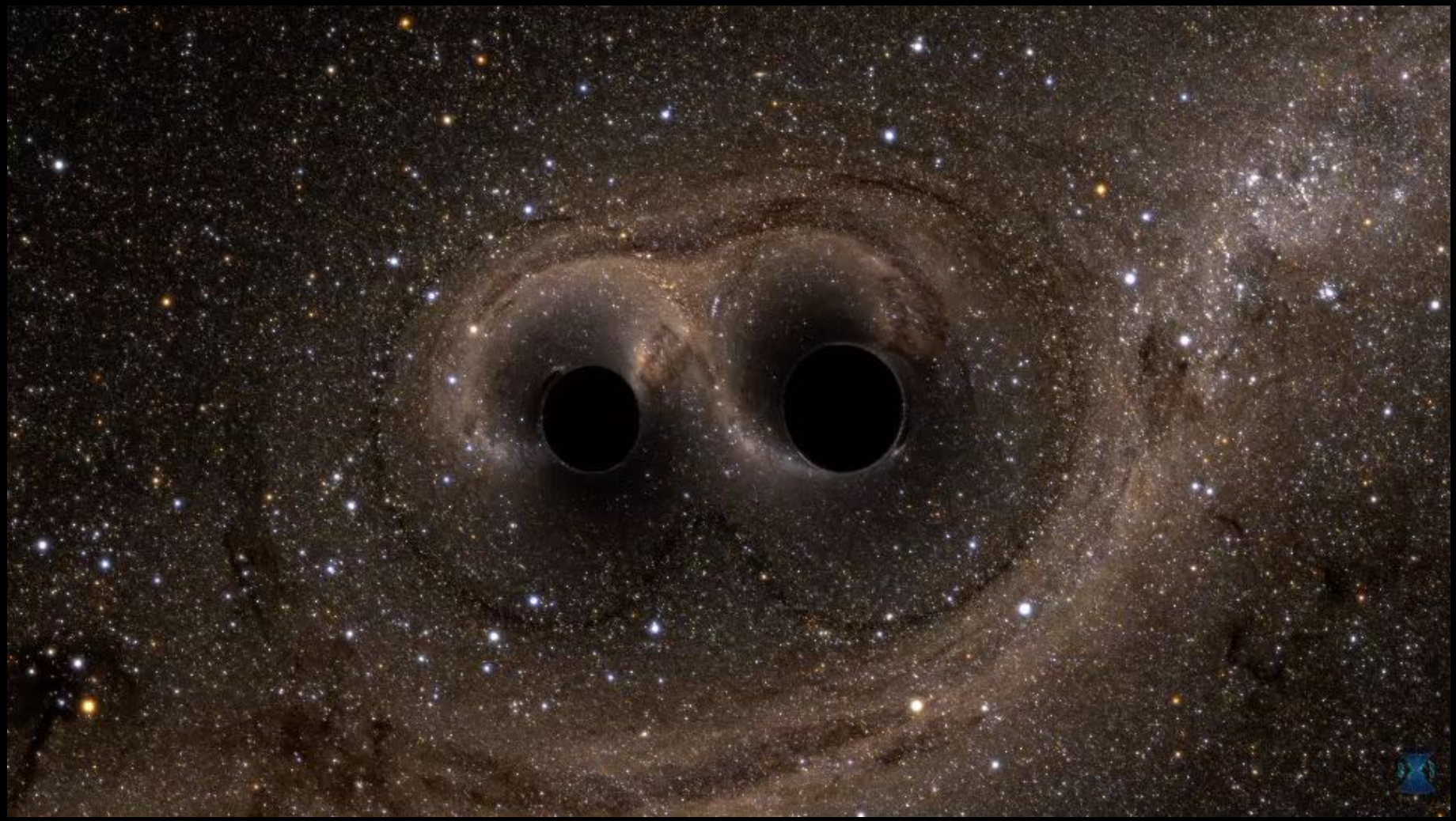
14 SETTEMBRE 2015
LA SCOPERTA

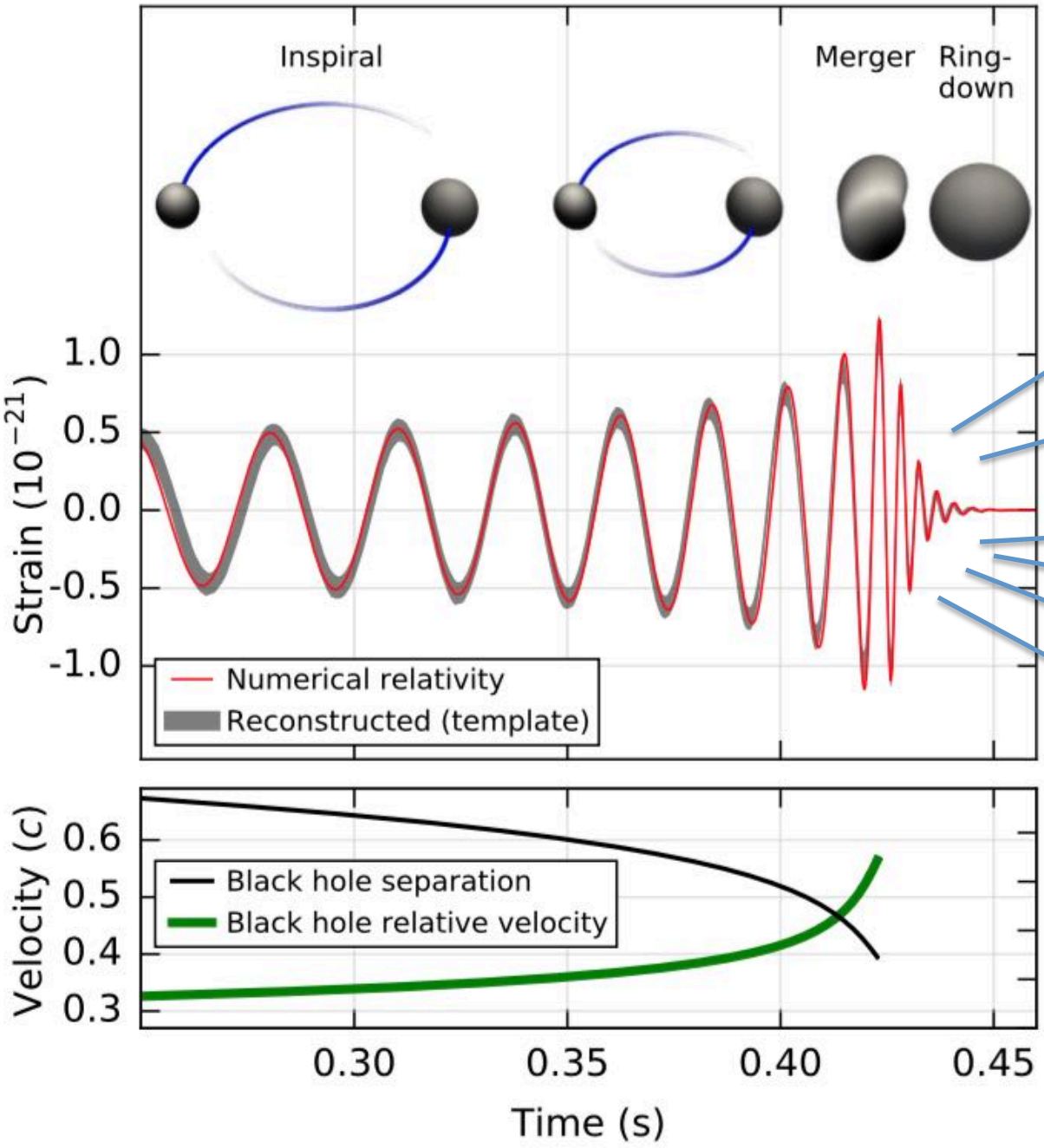

LIGO Livingston Data
Strain (10^{-21})
1.0
0.5
0.0
-0.5
-1.0
0.30
0.35
0.40
0.45
Time (sec)


LIGO Livingston Data
LIGO Hanford Data
Strain (10-21)
1.0
0.5
0.0
-0.5
-1.0
0.30
0.35
0.40
0.45
Time (sec)
0.30
0.35
0.40
0.45
Time (sec)

COSA SI E' VISTO

Credit: SXS





MASSE INIZIALI

MASSA FINALE

DISTANZA

VELOCITA'

SPIN

DIMENSIONI

PRL, 116

1.3 MILIARDI DI ANNI FA

A 10^{22} km DALLA TERRA

DUE BUCHI NERI DA 29 E 36 MASSE SOLARI...

SI FONDONO A VELOCITA' ~c/2

FORMANDO UN BUCO NERO DA 62 MASSE SOLARI

3 MASSE SOLARI VENGONO "TRASFORMATE" IN ONDE GRAVITAZIONALI

IL RAGGIO DEI BUCHI NERI E' ~200 KM

ENERGIA EMESSA IN UN SECONDO:
$5\ 10^{47}$ JOULE

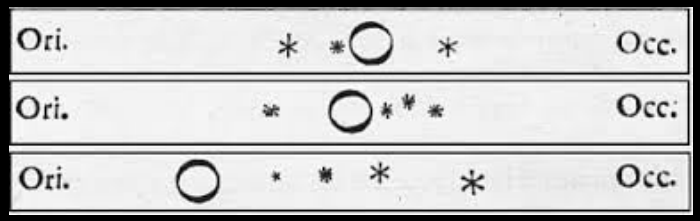
5 000000000000000000000000000...
...000000000000000000000 J

L'EVENTO PIU' "LUMINOSO" MAI OSSERVATO

EFFETTO SUGLI SPECCHI DEL RIVELATORE:

SPOSTAMENTO DI 10^{-18} m =

0.0000000000000001 m


Ori.
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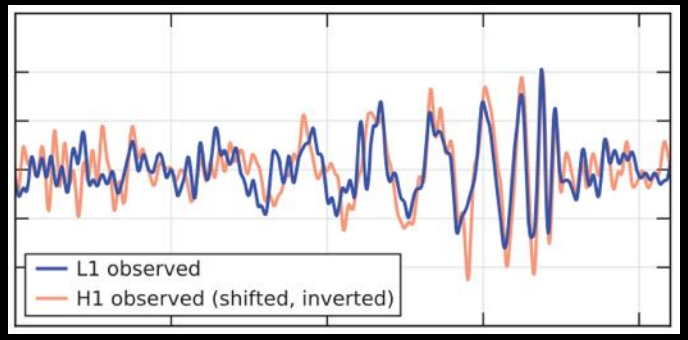

L1 observed
H1 observed (shifted, inverted)

"All the News That's Fit to Print"

The New York Times

Late Edition

Today, some sunshine giving way to times of clouds, cold, high 28. Tonight, a flurry or heavier squall late, low 15. Tomorrow, windy, frigid, high 21. Weather map, Page A19.

VOL. CLXV . . . No. 57,140 © 2016 The New York Times NEW YORK, FRIDAY, FEBRUARY 12, 2016 $2.50

Clinton Paints Sanders Plans As Unrealistic

New Lines of Attack at Milwaukee Debate

By AMY CHOZICK and PATRICK HEALY

MILWAUKEE — Hillary Clinton, scrambling to recover from her double-digit defeat in the New Hampshire primary, repeatedly challenged the trillion-dollar policy plans of Bernie Sanders at their presidential debate on Thursday night and portrayed him as a big talker who needed to "level" with voters about the difficulty of accomplishing his agenda.

Foreign affairs also took on unusual prominence as Mrs. Clinton sought to underscore her experience and Mr. Sanders excoriated her judgment on Libya and Iraq, as well as her previous praise of former Secretary of State Henry A. Kissinger. But Mrs. Clinton was frequently on the offensive as well, seizing an opportunity to talk about leaders she admired and turning it against Mr. Sanders by bashing his past criticism of President Obama — a remark that Mr. Sanders called a "low blow."

With tensions between the two Democrats becoming increasingly obvious, the debate was full of new lines of attack from Mrs. Clinton, who faces pressure to puncture Mr. Sanders's growing popularity before the next nominating contests in Nevada and South Carolina.

She is wagering that even voters excited by Mr. Sanders's inspiring message will reconsider their support when they learn of his lack of experience in foreign policy and his vague explanations for how he will pay for his expansive government programs.

Mrs. Clinton pounced from the start, after Mr. Sanders demurred in saying how much his proposals would increase the size of the federal government. She stepped in and said that by economists' estimates, the government would grow 40 percent under Mr. Sanders.

And rather than bashing him as she did at their debate last Thursday, she appeared to try to get under his skin by implying that he had not been transparent about the cost of his programs, such as his proposed expansion of government health care.

"This is not about math. This is

Continued on Page A16

Going Back to Trenton

Gov. Chris Christie has returned to New Jersey to tend to a state he at times abandoned in his run for president. Page A21.

CALTECH-M.I.T.-LIGO LABORATORY

A worker installed a baffle in 2010 to control light in the Laser Interferometer Gravitational-Wave Observatory in Hanford, Wash.

WITH FAINT CHIRP, SCIENTISTS PROVE EINSTEIN CORRECT

A RIPPLE IN SPACE-TIME

An Echo of Black Holes Colliding a Billion Light-Years Away

By DENNIS OVERBYE

A team of scientists announced on Thursday that they had heard and recorded the sound of two black holes colliding a billion light-years away, a fleeting chirp that fulfilled the last prediction of Einstein's general theory of relativity.

That faint rising tone, physicists say, is the first direct evidence of gravitational waves, the ripples in the fabric of space-time that Einstein predicted a century ago. It completes his vision of a universe in which space and time are interwoven and dynamic, able to stretch, shrink and jiggle. And it is a ringing confirmation of the nature of black holes, the bottomless gravitational pits from which not even light can escape, which were the most foreboding (and unwelcome) part of his theory.

More generally, it means that a century of innovation, testing, questioning and plain hard work after Einstein imagined it on paper, scientists have tapped into the deepest register of physical reality, where the weirdest and wildest implications of Einstein's universe become manifest.

Conveyed by these gravitational waves, power 50 times greater than the output of all the stars in the universe combined vibrated a pair of L-shaped antennas in Washington State and Louisiana known as LIGO on Sept. 14.

If replicated by future experiments, that simple chirp, which rose to the note of middle C before abruptly stopping, seems destined to take its place among the great sound bites of science, ranking with Alexander Graham Bell's "Mr. Watson — come here" and Sputnik's first beeps from orbit.

"We are all over the moon and back," said Gabriela González of Louisiana State University, a spokeswoman for the LIGO Scientific Collaboration, short for Laser Interferometer Gravitational-Wave Observatory. "Einstein would be very happy, I think."

Members of the LIGO group, a

Continued on Page A12

Long in Clinton's Corner, Blacks Notice Sanders

Courted Hard in South Carolina, Loyalists Listen Closely

By RICHARD FAUSSET

ORANGEBURG, S.C. — When Helen Duley was asked whom she would vote for in the South Carolina primary, she answered as if the very question were absurd.

"What I'm seeing is a bunch of confusion, hearsay and foolishness," said Ms. Duley, 60, a retired nursing assistant who is African-American, shortly after finishing breakfast at the downtown McDonald's. "What I also see is a veteran who's already been in the White House eight years. A veteran: Hillary Clinton."

But that was late January. Interviewed again Tuesday as Mrs. Clinton's rival, Senator Bernie Sanders of Vermont, was surging toward an overwhelming victory in the New Hampshire Democratic primary, Ms. Duley found herself suddenly intrigued by a candidate she barely knew. "It makes me feel good," she said, chuckling, "that young people are listening to the elderly people." She now said she was an undecided voter and planned to do some homework on Mr. Sanders.

Mrs. Clinton has long looked forward to the Feb. 27 Democratic contest in South Carolina, the first state where blacks will make up a dominant part of the primary vote. African-Americans accounted for more than half the voters in the 2008 Democratic primary, and she has been counting on them as a bulwark, not just

Continued on Page A18

LOGAN R. CYRUS FOR THE NEW YORK TIMES

Reginald Abraham, left, an organizer for Hillary Clinton, at a barbershop in Orangeburg, S.C.

Last Occupier In Rural Oregon Is Coaxed Out

This article is by Dave Seminara, Richard Pérez-Peña and Kirk Johnson.

PRINCETON, Ore. — They implored the last holdout in the armed occupation of a wildlife refuge here to think about the Holy Spirit. They explained that the First Amendment was about freedom of speech and the Second was about the right to bear arms, and said that they were in that order for a reason. They asked him what he thought Jesus would have done in his situation.

He, in turn, asked for pizza and marijuana, criticized a government that condoned abortion and drone strikes, and talked about U.F.O.s and dying rather than going to prison.

In the final moments, a standoff fed by big ideas about the role of government came down Thursday morning to the grievances and fears of one troubled young man, and the tense but successful efforts of his sympathizers and F.B.I. agents to coax him to surrender, ending the occupation of Malheur National Wildlife Refuge in southeastern Oregon.

"I'm actually feeling suicidal right now," said David Fry, 27, of Blanchester, Ohio, the last of the

Continued on Page A11

President Obama ✓
@POTUS

Einstein was right! Congrats to @NSF and @LIGO on detecting gravitational waves - a huge breakthrough in how we understand the universe.

3:43 PM - 11 Feb 2016

5,740 RETWEETS **12.1K** LIKES

Mark Zuckerberg ✓ Follow
February 11 · Palo Alto, CA, United States ·

Scientists just confirmed the detection of gravitational waves. This is one of the biggest discoveries of modern science.

Albert Einstein is one of my heroes, so I've been following this announcement closely. Einstein first predicted gravitational waves 100 years ago in his Theory of General Relativity. Gravitational waves are ripples in the fabric of space-time created by the movement of mass. These are mostly too small to be detected, so we need to look for waves that begin with massive events like the Big Bang, the collapse of stars and the collision of black holes.

By analyzing the information contained in gravitational waves, we can now open up an entirely new view of the cosmos -- potentially shedding light on the very earliest moments of the universe, as well as the creation and growth of black holes.

It's inspiring to think about all the lives and effort, generation after generation, that have gone into uncovering this insight about our universe. Today's breakthrough depended on the talent of brilliant scientists and engineers from many nations, but also advances in computing that only recently became possible. Congratulations to everyone who helped make this happen. You've made Einstein proud.

PRESS RELEASE

3 October 2017

The Nobel Prize in Physics 2017

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2017

with one half to

Rainer Weiss
LIGO/VIRGO Collaboration

and the other half jointly to

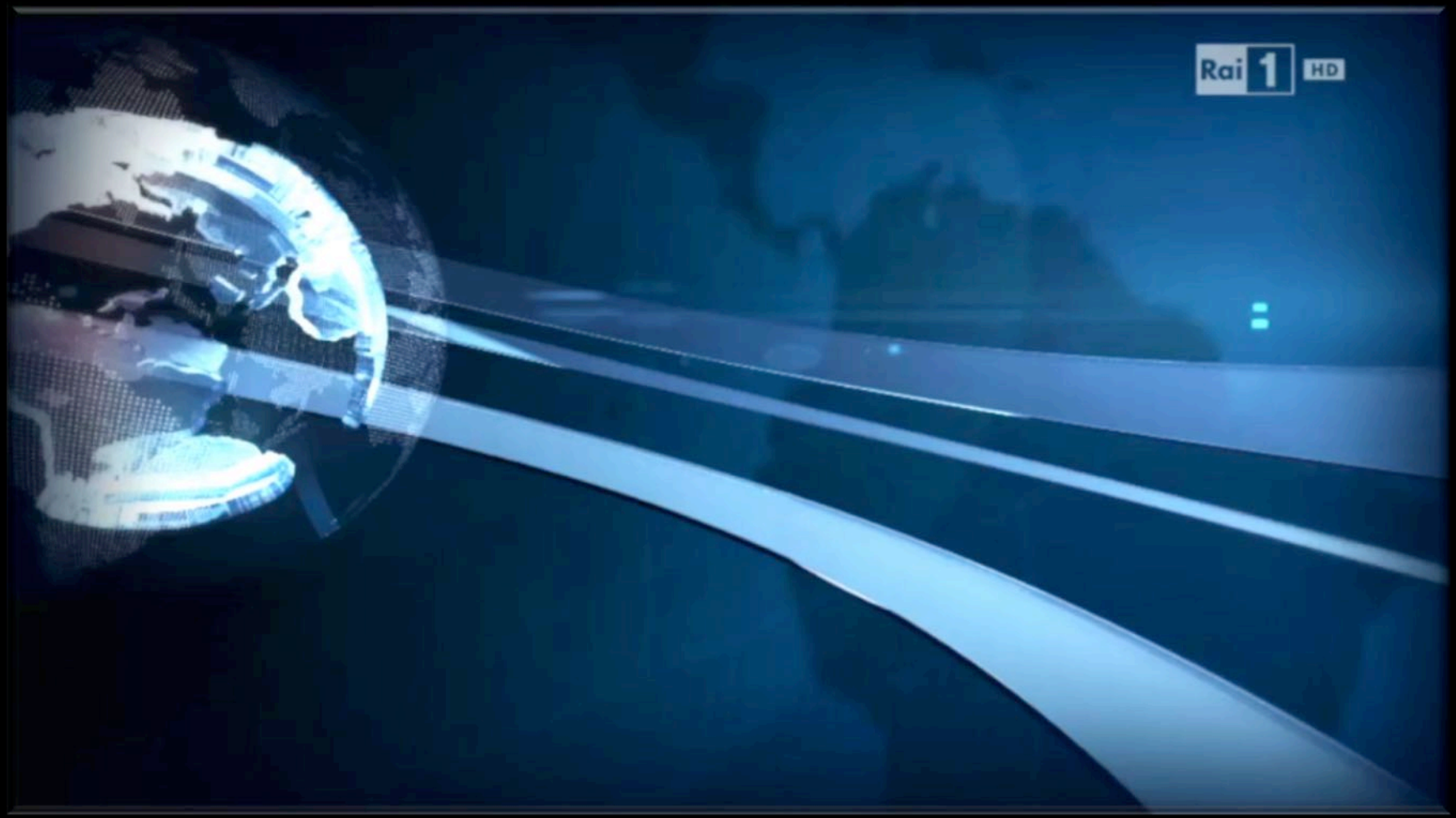
Barry C. Barish
LIGO/VIRGO Collaboration

and

Kip S. Thorne
LIGO/VIRGO Collaboration

"for decisive contributions to the LIGO detector and the observation of gravitational waves"

11 FEBBRAIO 2016



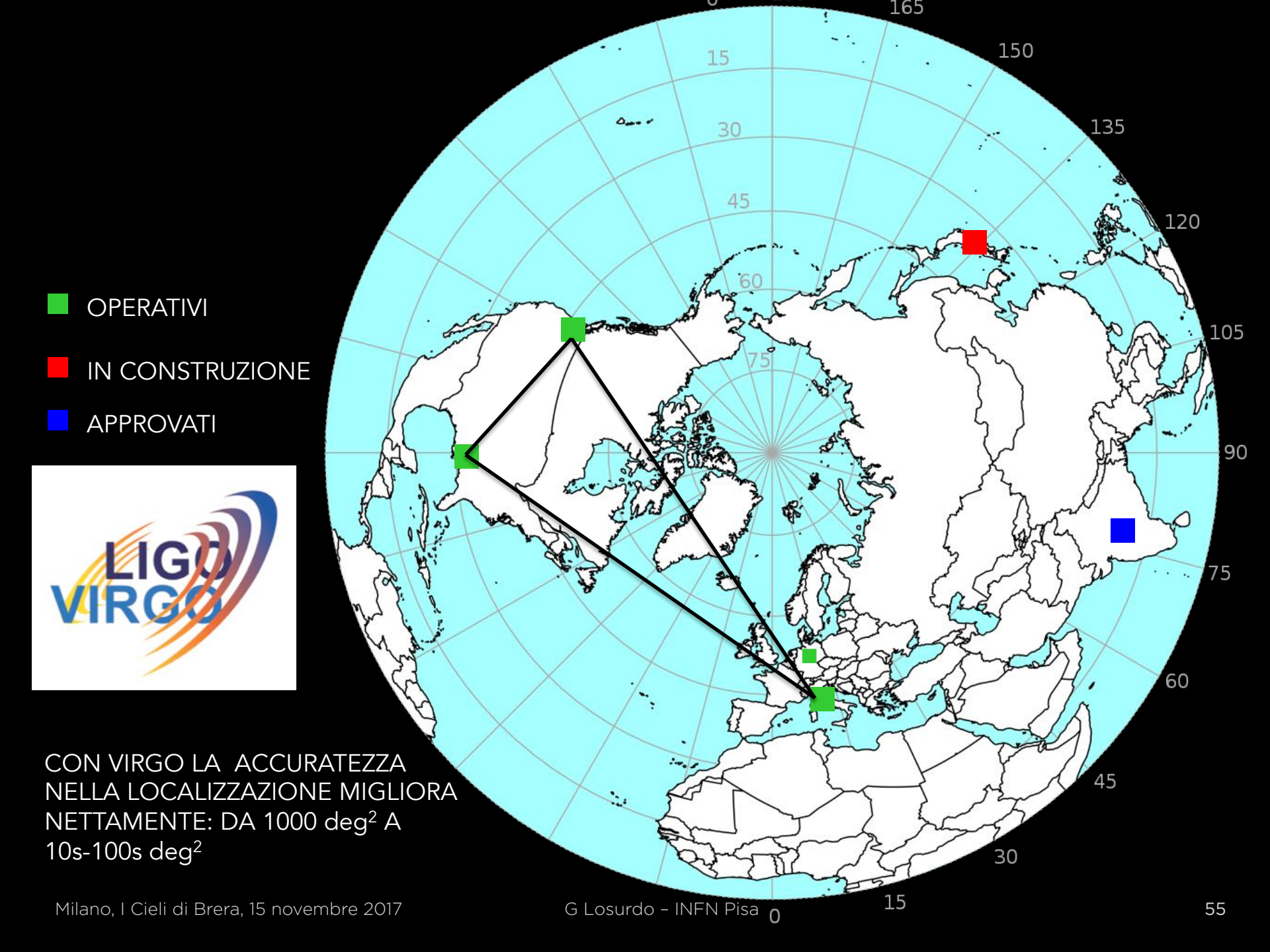

20 Febbraio 2017
Inaugurazione di Advanced Virgo
Losurdo - AdV Project Leader
Fulvio RICCI
Giovanni LOSURDO
Adalberto GIAZOTTO
Alain BRILLET

LA RIVOLUZIONE D'AGOSTO

August 1st, 2017

VIRGO SI UNISCE A LIGO NELLA PRESA DATI

UNA RETE DI 3 RIVELATORI 2G FUNZIONA COME “SINGLE MACHINE”


OPERATIVI
IN CONSTRUZIONE
APPROVATI
LIGO
VIRGO
CON VIRGO LA ACCURATEZZA NELLA LOCALIZZAZIONE MIGLIORA NETTAMENTE: DA 1000 deg^2 A 10s-100s deg^2
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150
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120
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90
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30
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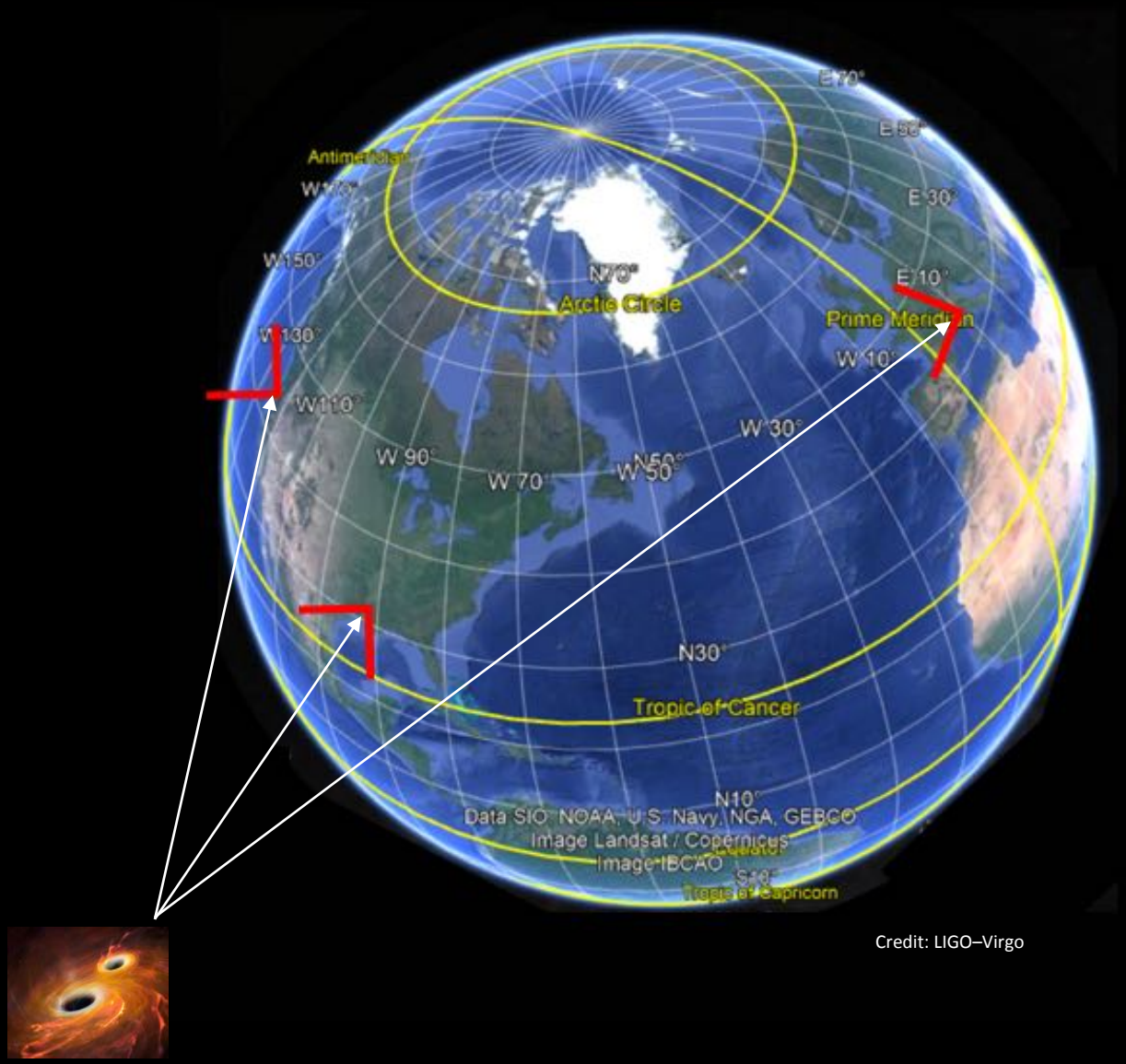
75



Credit: LIGO–Virgo

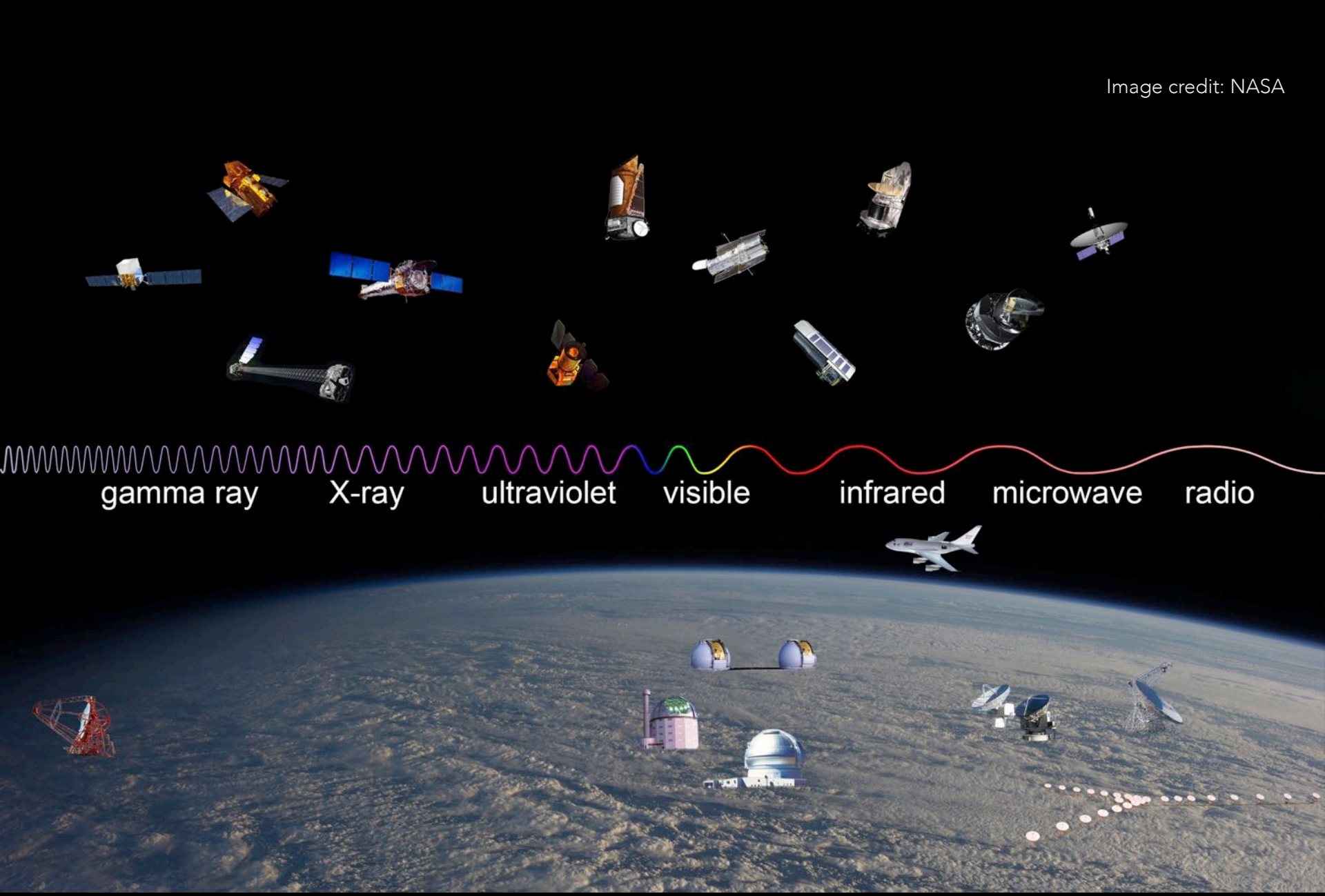
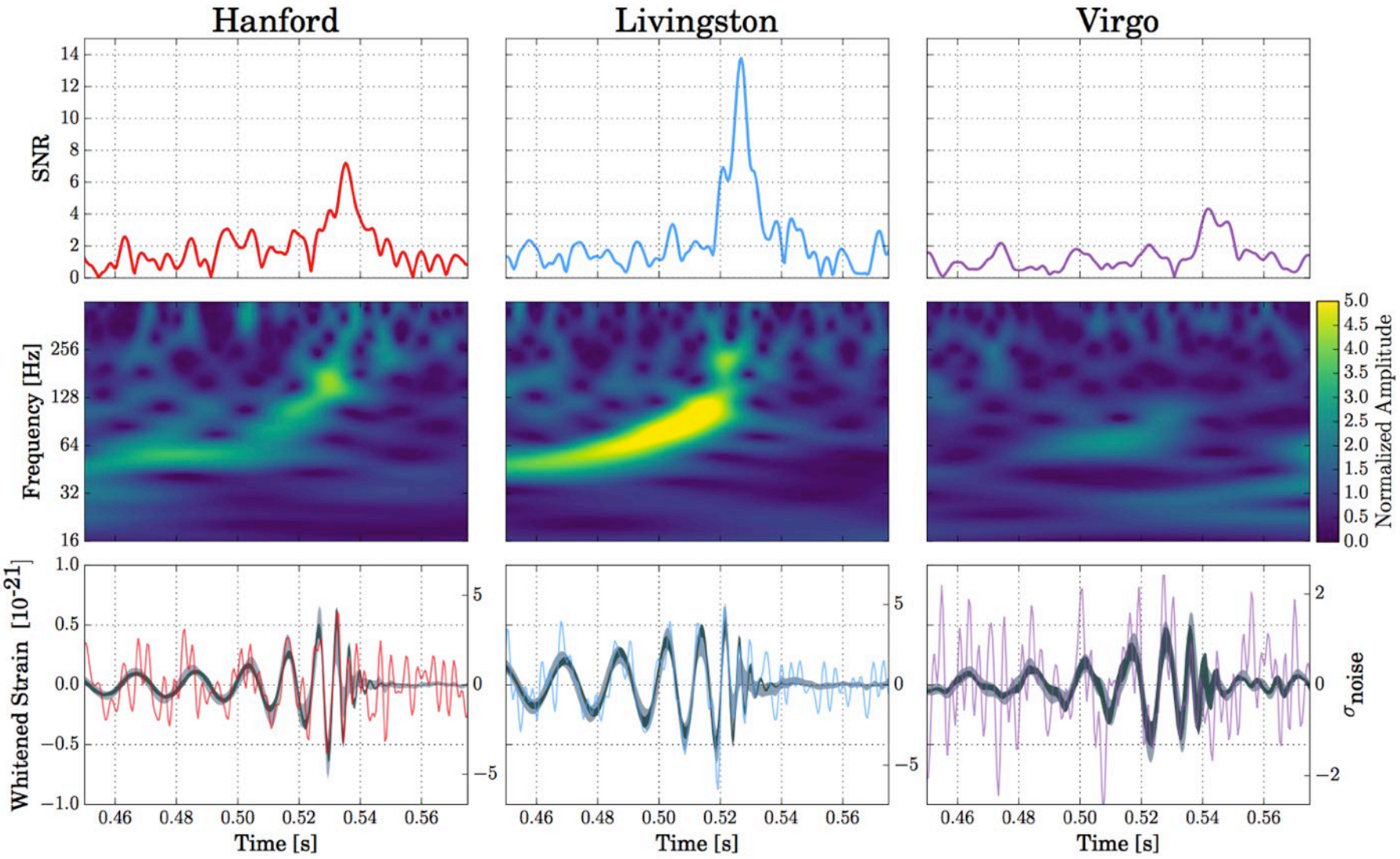
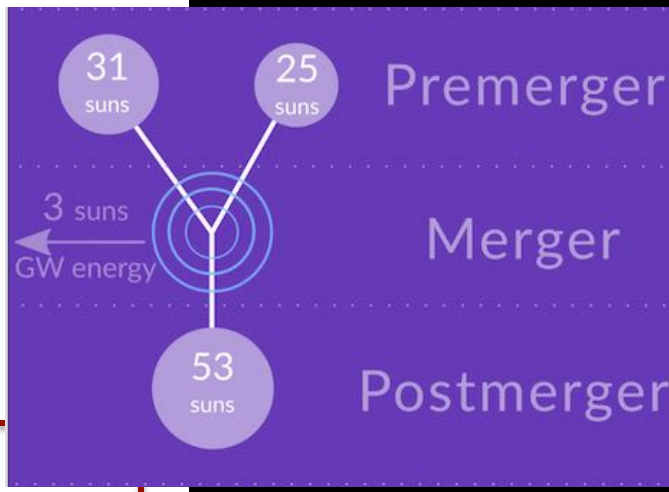


Image credit: NASA
gamma ray
X-ray
ultraviolet
visible
infrared
microwave
radio

14 AGOSTO 2017

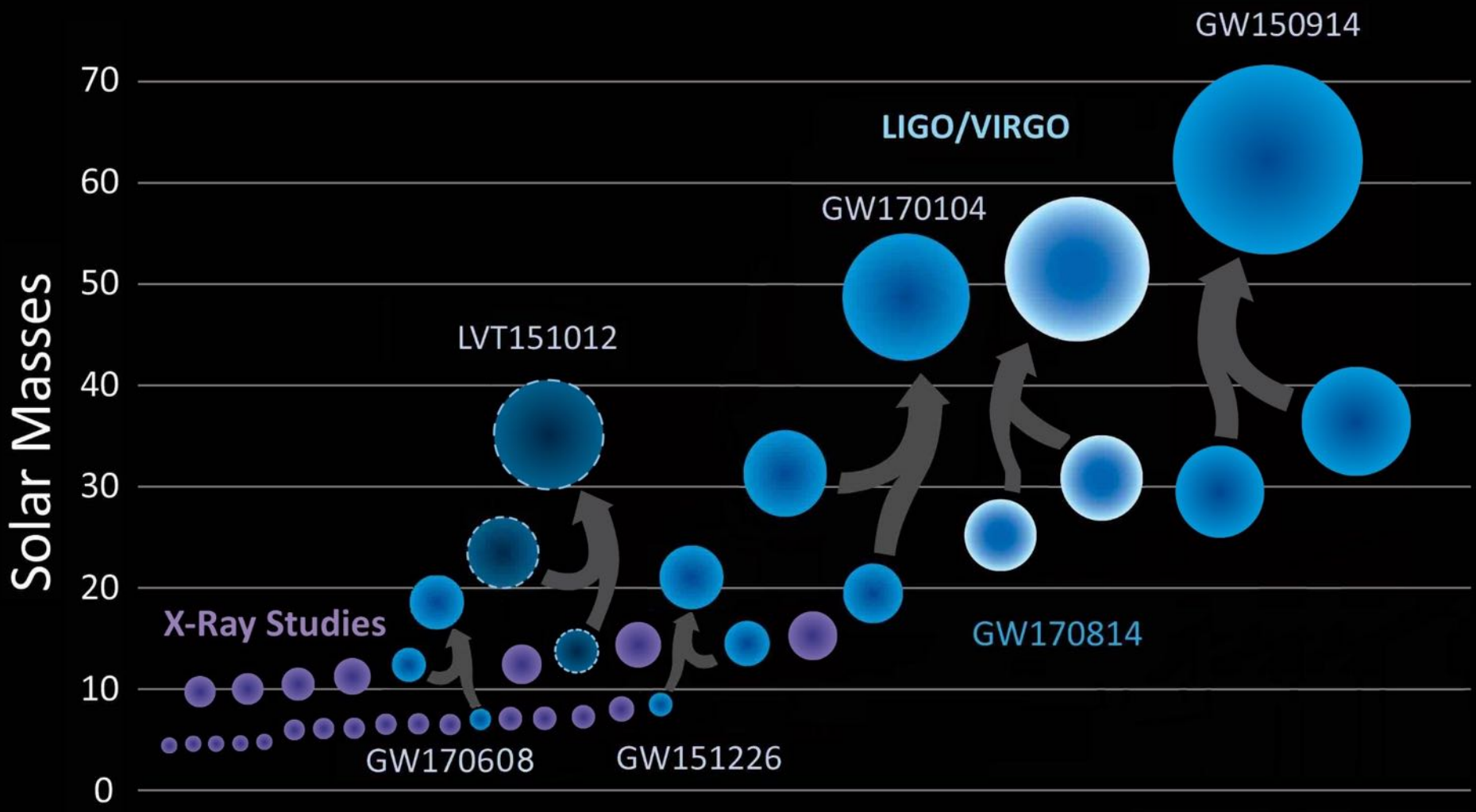


Primary black hole mass m_1	$30.5^{+5.7}_{-3.0}\,\mathrm{M}_\odot$
Secondary black hole mass m_2	$25.3^{+2.8}_{-4.2}\,\mathrm{M}_\odot$
Chirp mass $\mathcal{M}$	$24.1^{+1.4}_{-1.1}\,\mathrm{M}_\odot$
Total mass M	$55.9^{+3.4}_{-2.7}\,\mathrm{M}_\odot$
Final black hole mass M_f	$53.2^{+3.2}_{-2.5}\,\mathrm{M}_\odot$
Radiated energy E_rad	$2.7^{+0.4}_{-0.3}\,\mathrm{M}_\odot\mathrm{c}^2$
Peak luminosity ℓ_peak	$3.7^{+0.5}_{-0.5}\times10^{56}\,\mathrm{erg\,s}^{-1}$
Effective inspiral spin parameter χ_eff	$0.06^{+0.12}_{-0.12}$
Final black hole spin a_f	$0.70^{+0.07}_{-0.05}$
Luminosity distance D_L	$540^{+130}_{-210}\,\mathrm{Mpc}$
Source redshift z	$0.11^{+0.03}_{-0.04}$



PRL,

BUCHI NERI


GW150914
LIGO/VIRGO
GW170104
LVT151012
Solar Masses
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40
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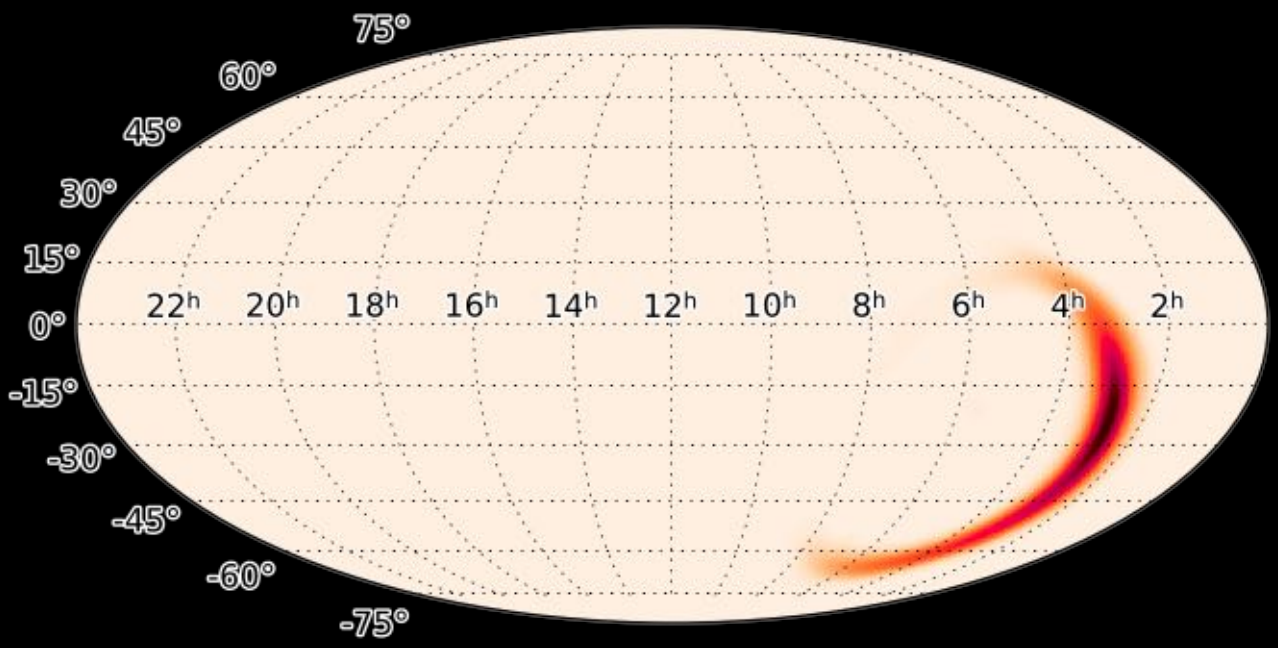
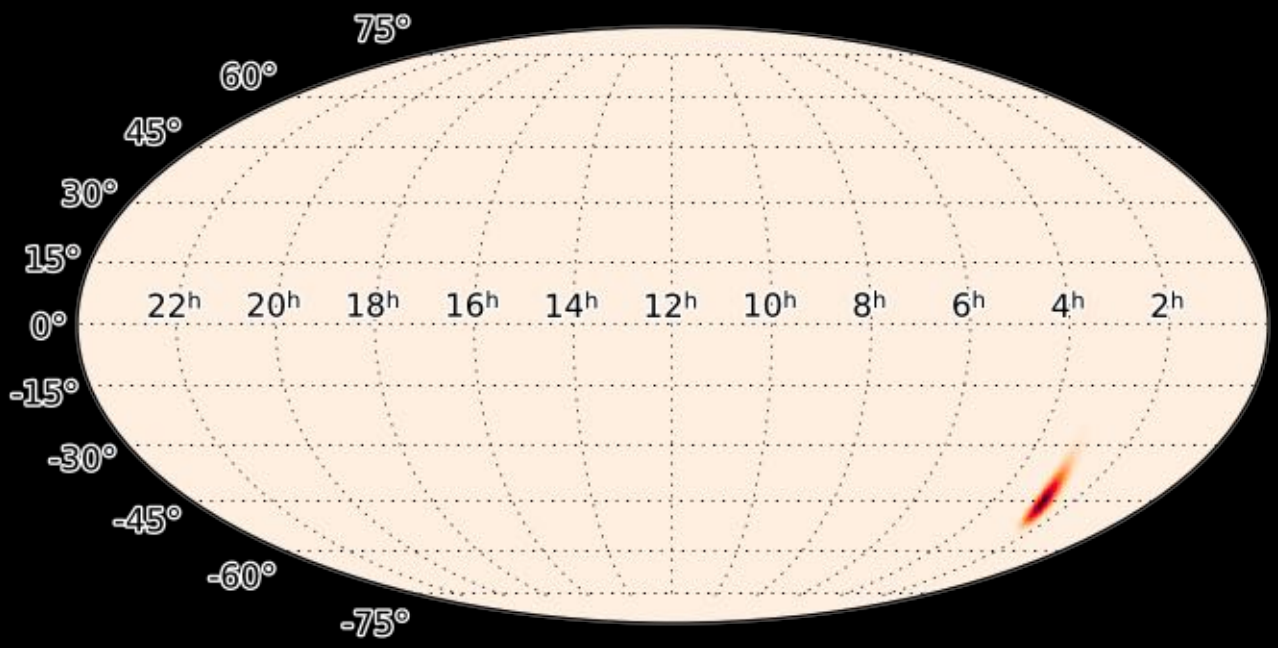
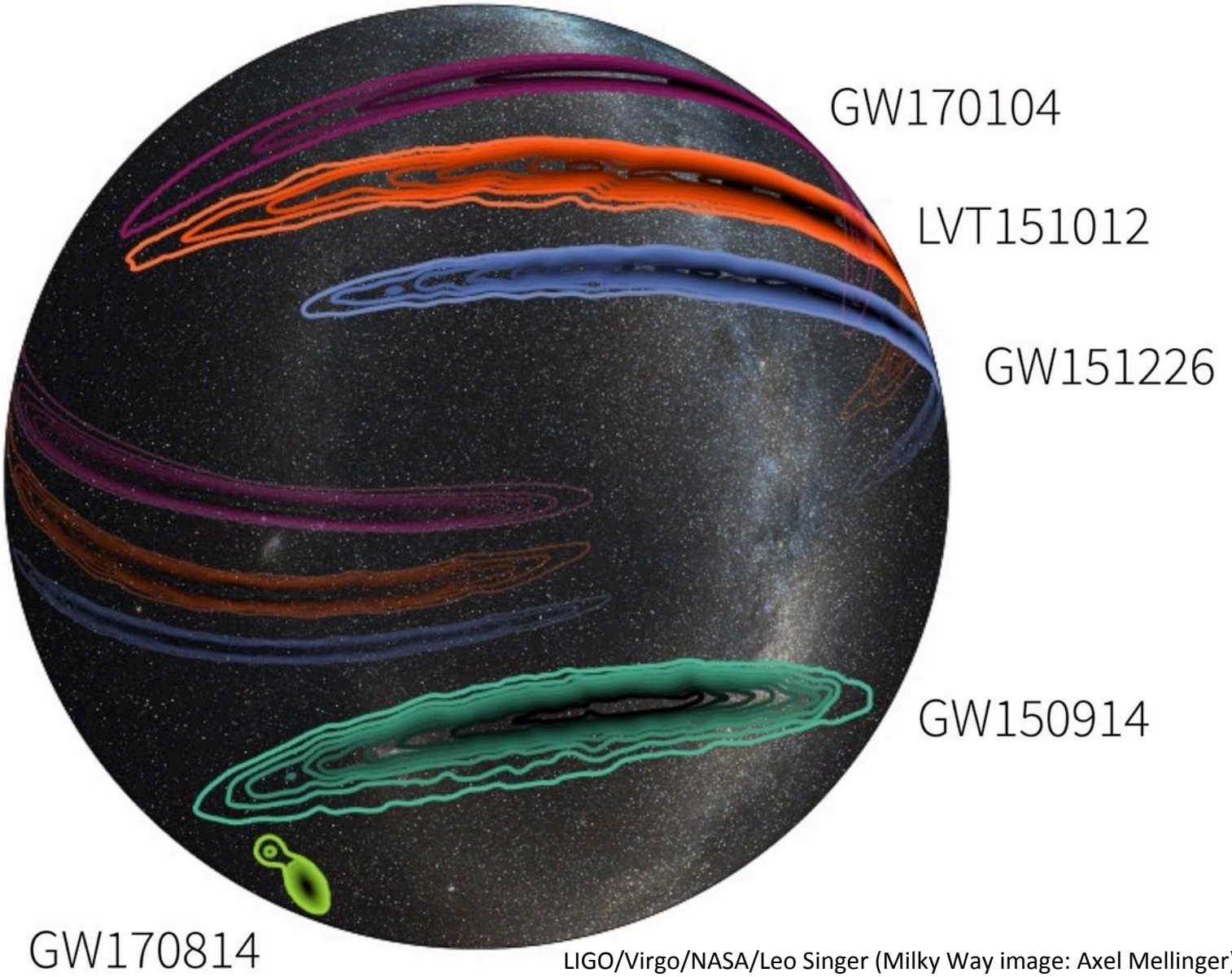
X-Ray Studies
GW170814
GW170608
GW151226

LOCALIZZAZIONE



LOCALIZZAZIONE

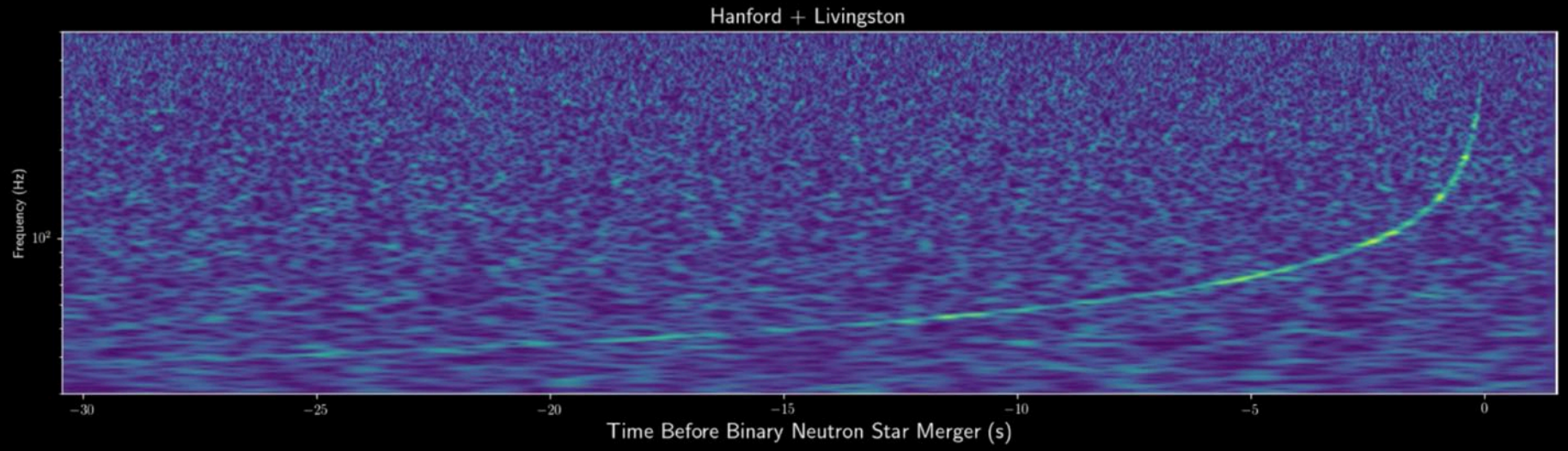




LIGO/Virgo/NASA/Leo Singer (Milky Way image: Axel Mellinger)

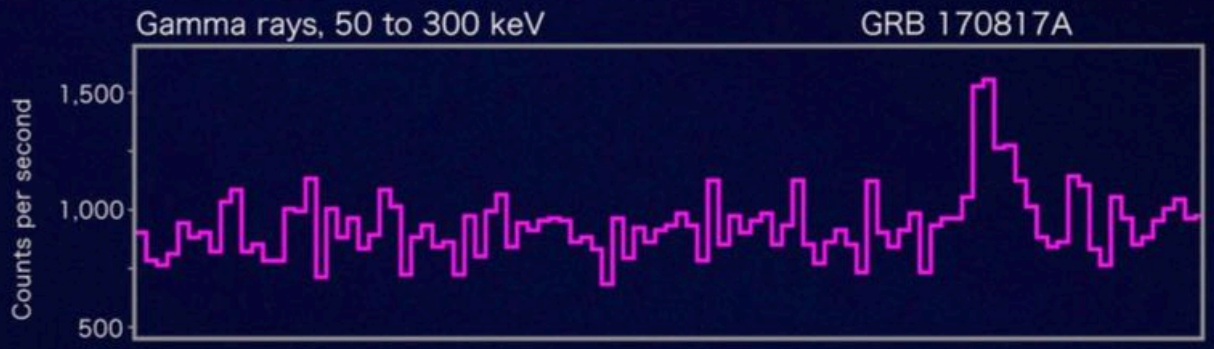
17 AGOSTO 2017

NEMMENO IL TEMPO DI FESTEGGIARE…

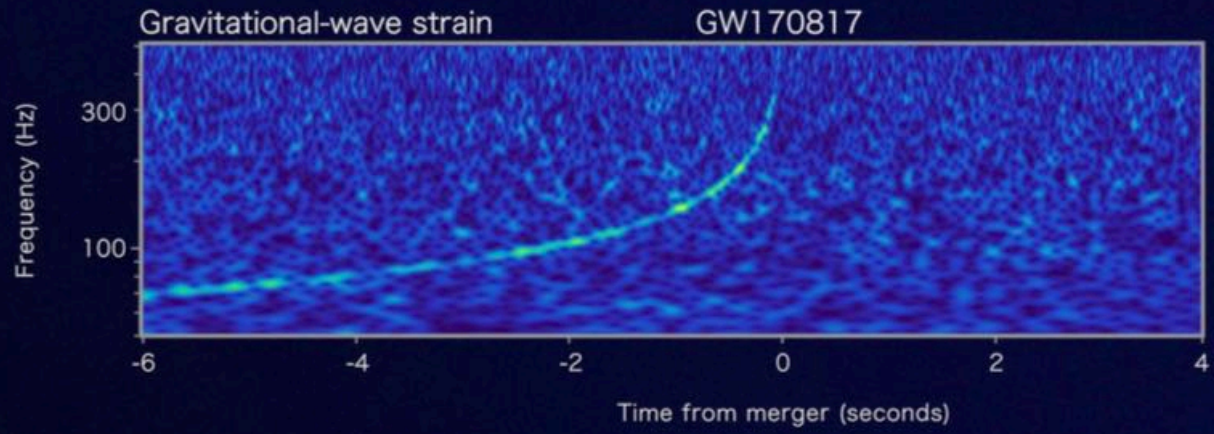


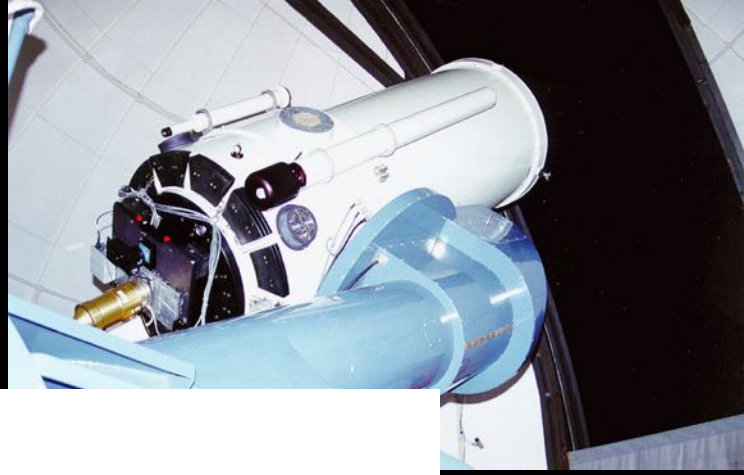
17 AGOSTO...130 MILIONI DI ANNI FA

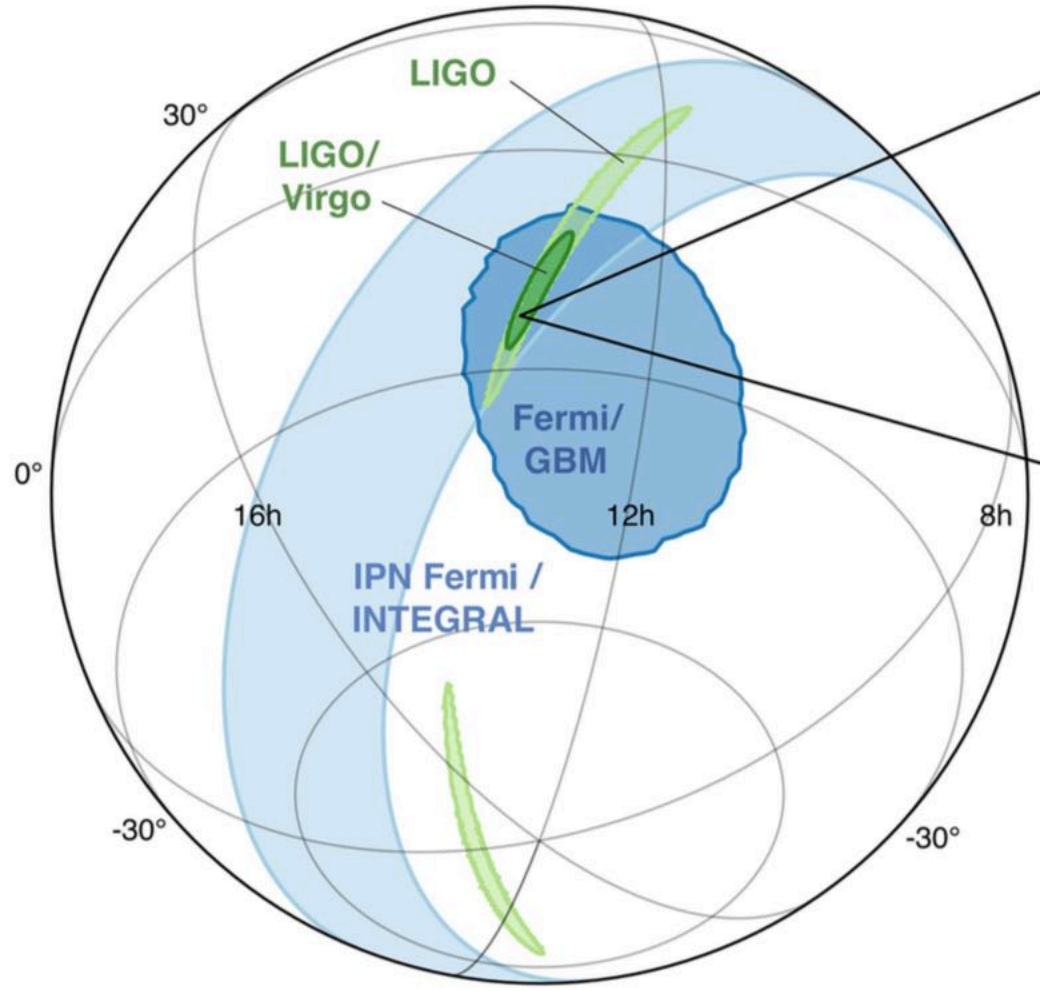
Fermi



LIGO






LIGO
LIGO/
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30°
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-30°
16h
12h
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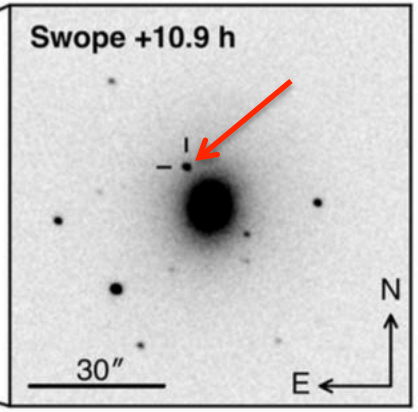
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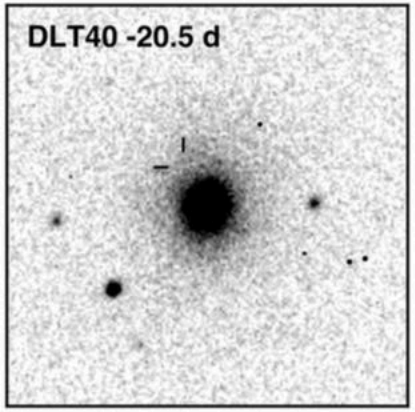
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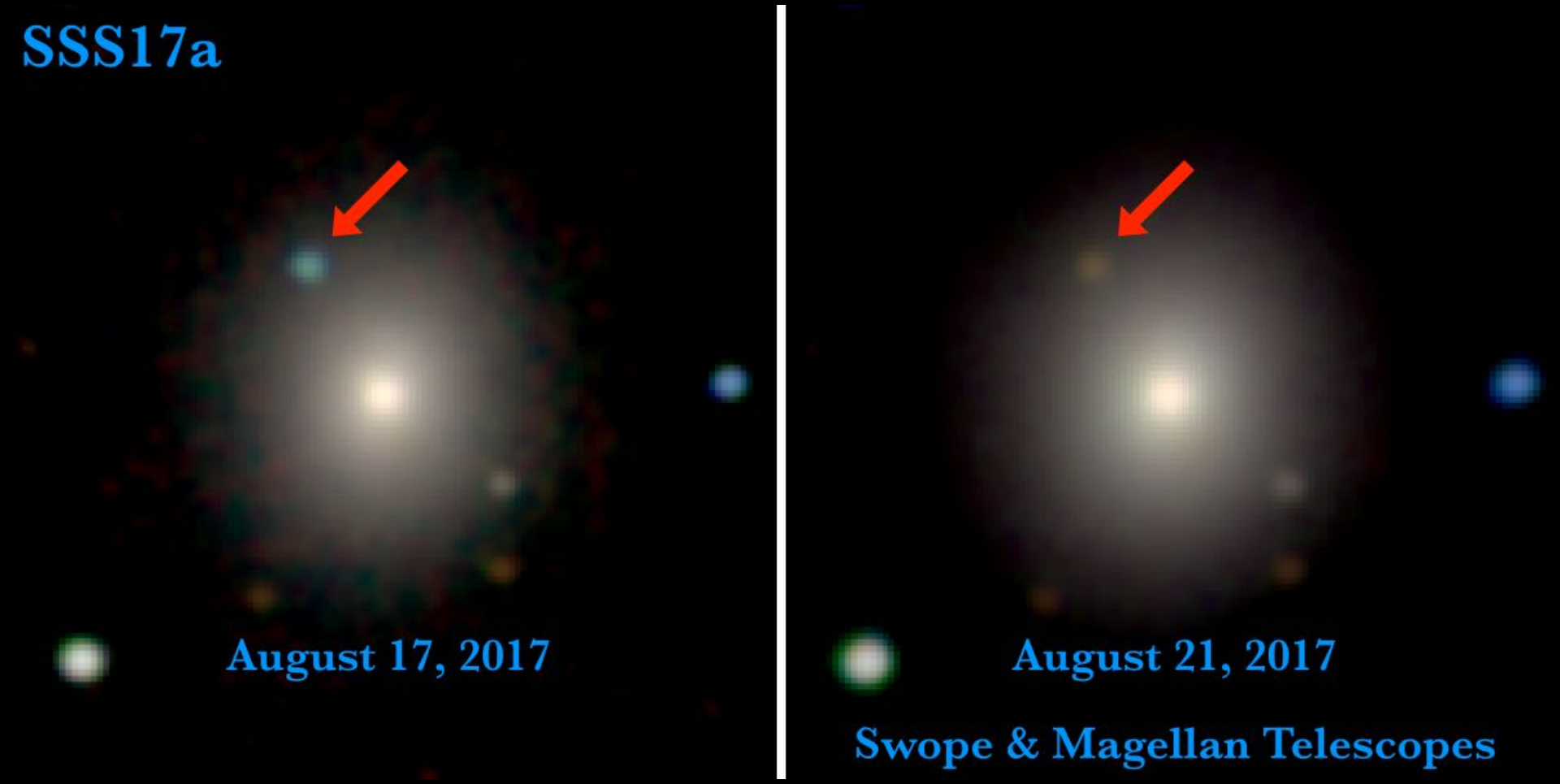
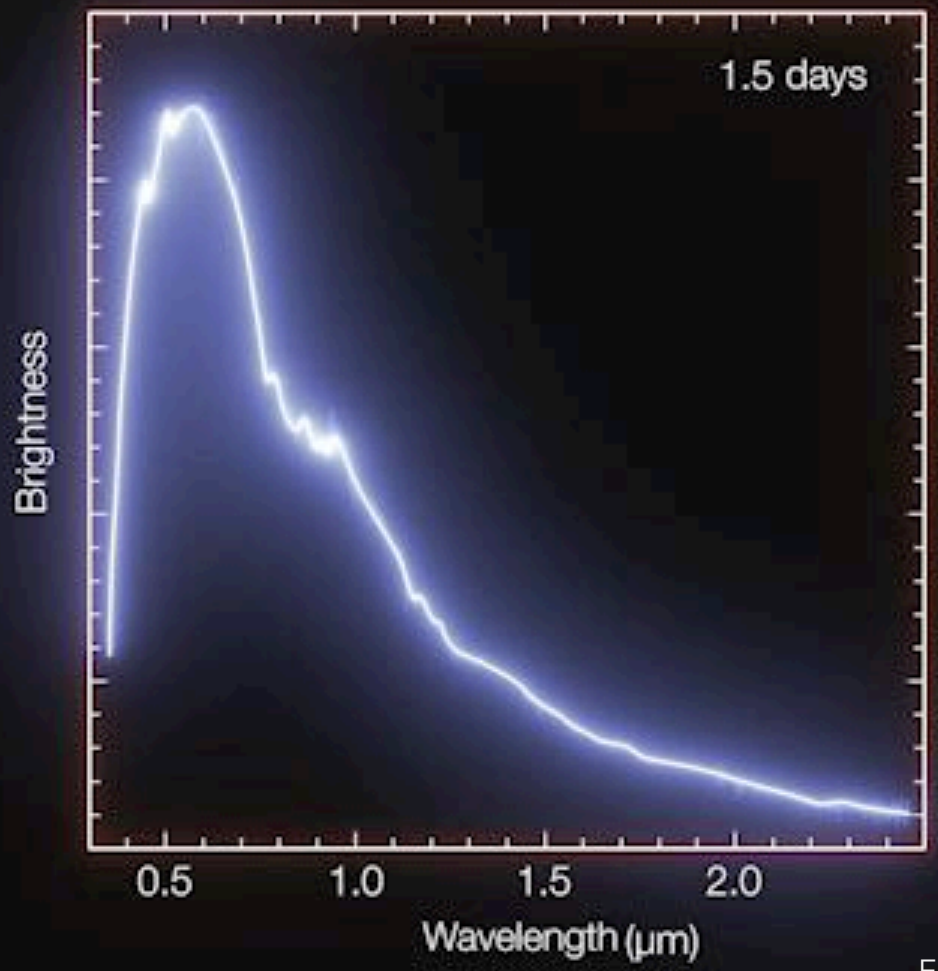


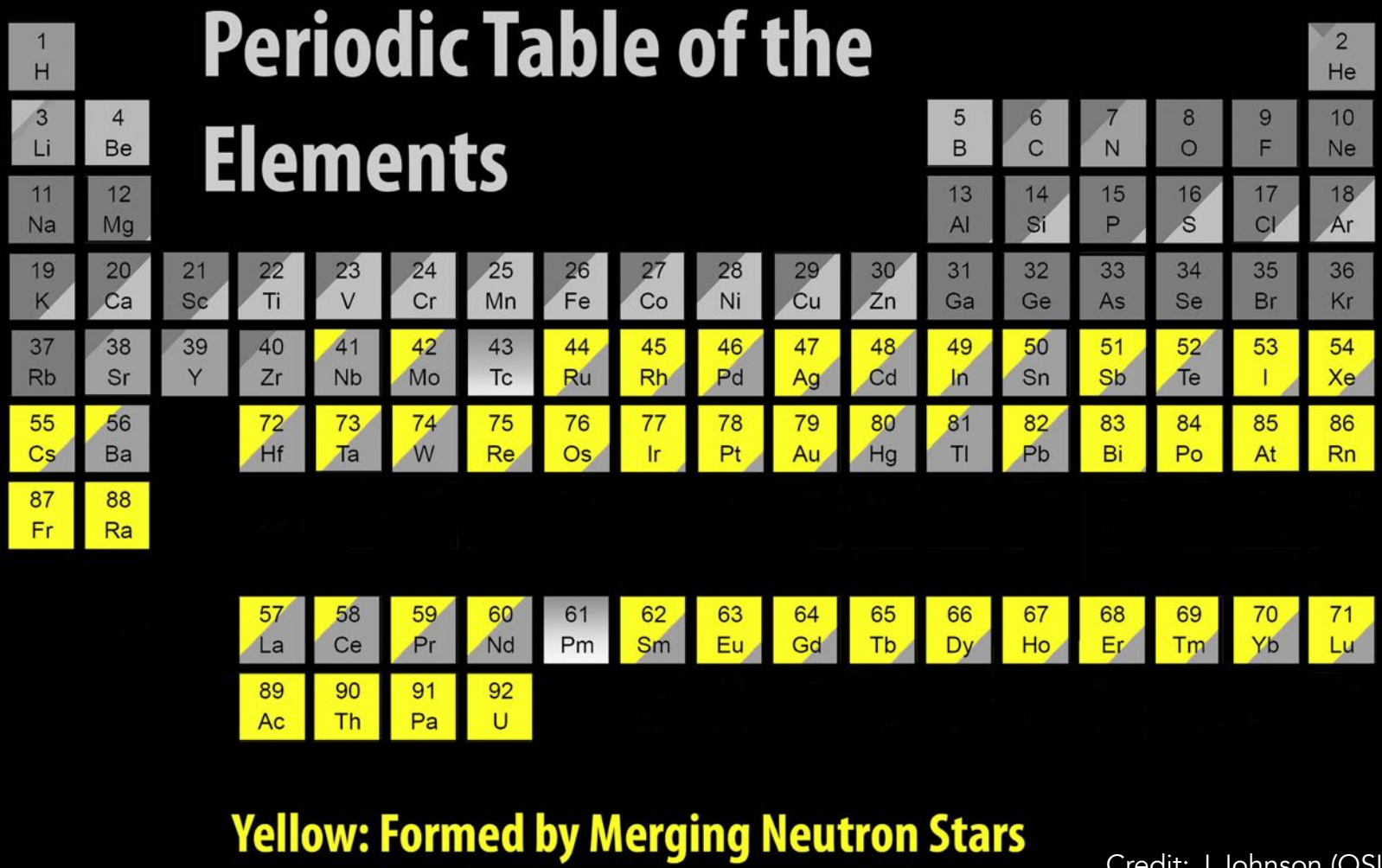
CREDIT: 1M2H_UC Santa Cruz and Carnegie Observatories


Earth
Space
LIGO Hanford
Virgo
LIGO Livingston

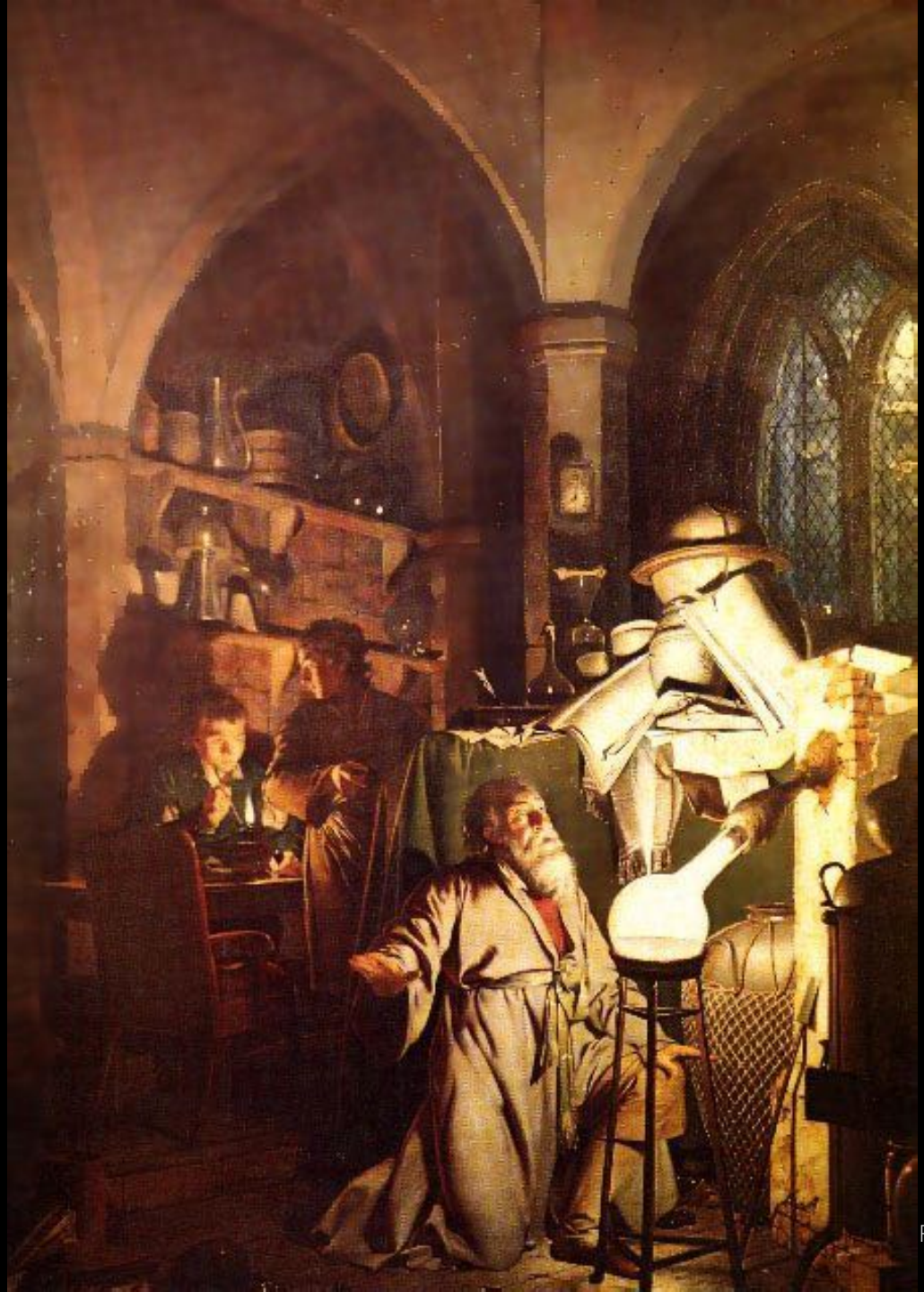


ESO-VLT/X-Shooter

LA FUCINA COSMICA



Credit: J Johnson (OSU)



NELLA COALESCENZA VIENE PRODOTTA UNA MASSA DI ORO PARI A ~10 M_{terra}

ABBIAMO FINALMENTE TROVATO LA “PIETRA FILOSOFALE”

17 AGOSTO...130 MILIONI DI ANNI FA

Credit: NASA Astrophysics

UNA MISURA DI GRANDE PRECISIONE: LA VELOCITA' DELLE ONDE GRAVITAZIONALI E' UGUALE A QUELLA DELLA LUCE ENTRO UNA PARTE SU 10^{15} !!

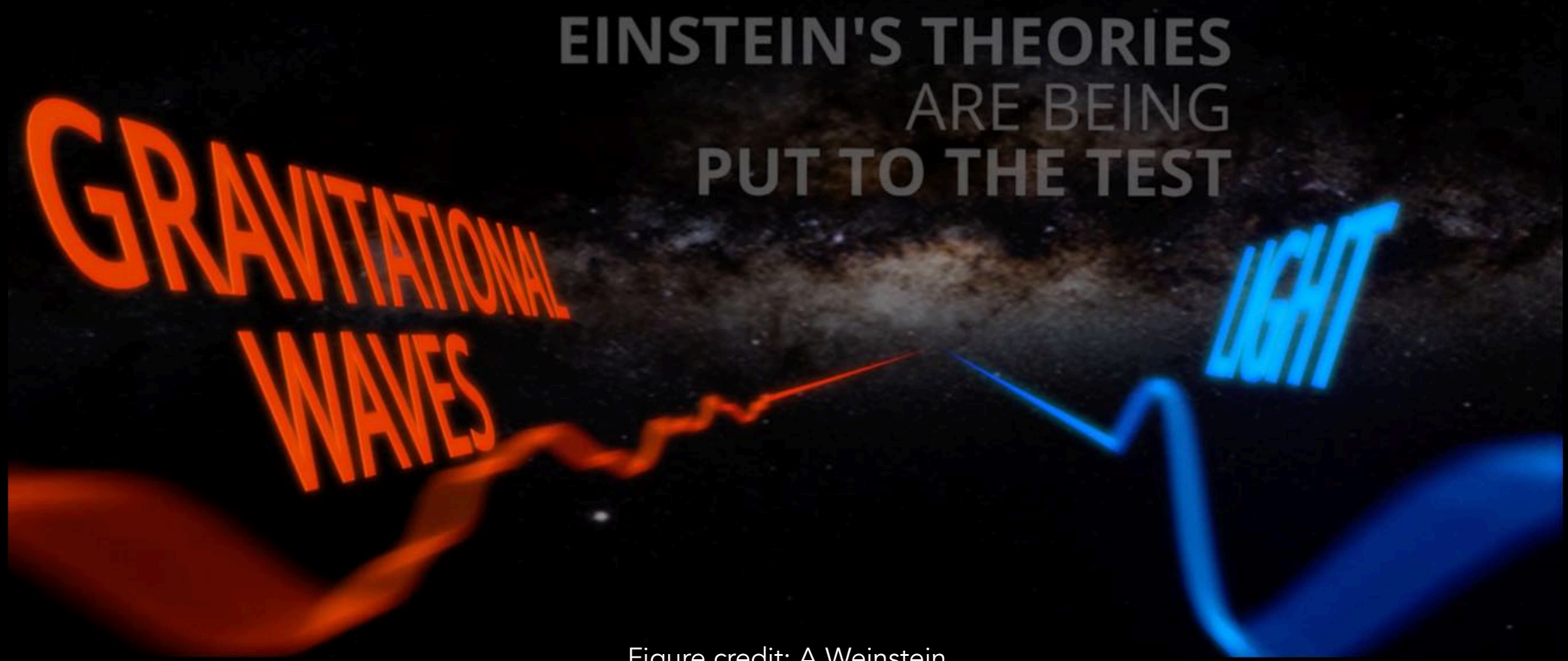
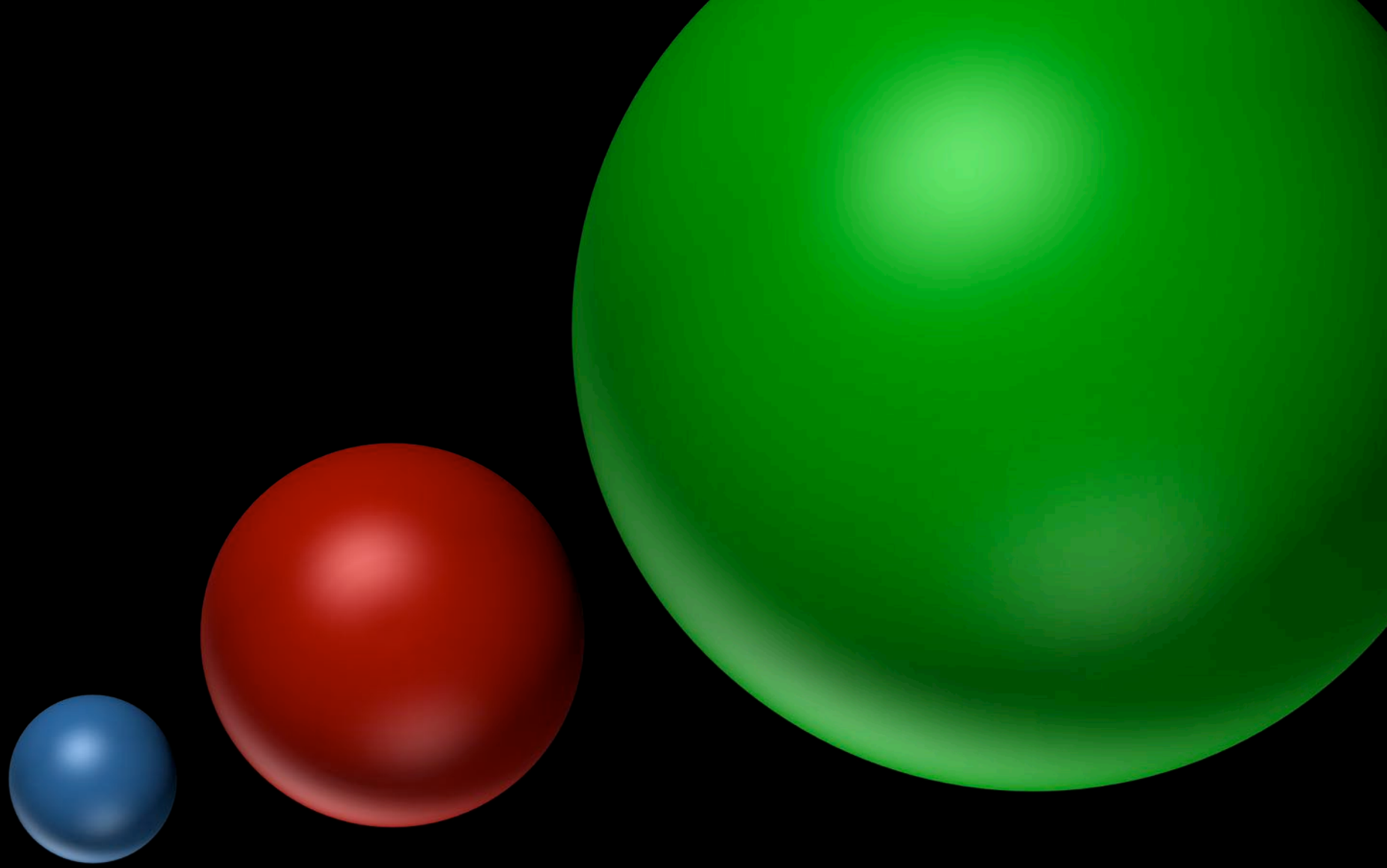


Figure credit: A Weinstein

~3500 scienziati, 45 Paesi, 6 continenti

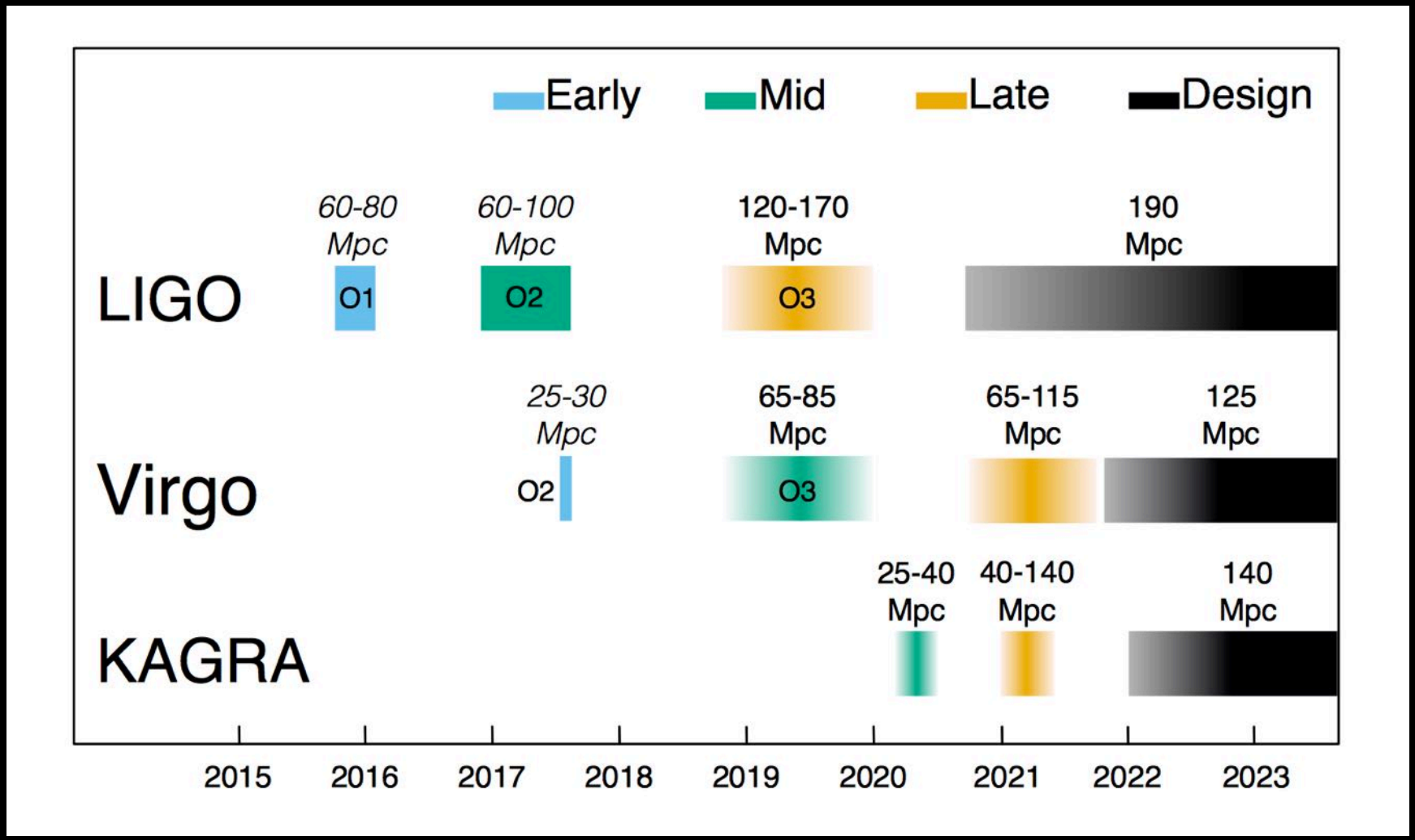
IL FUTURO



VIRGO BEST
(12 Mpc)

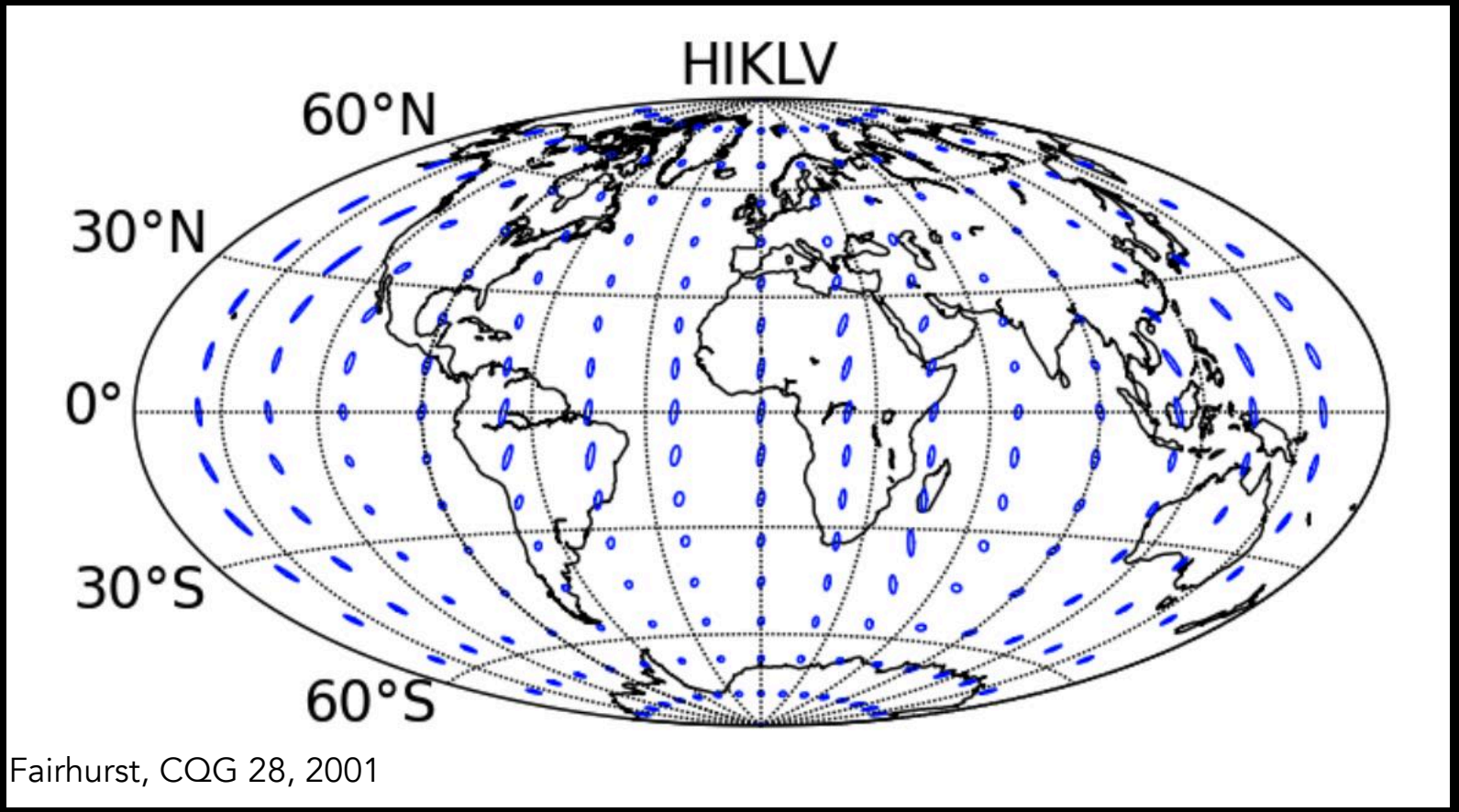
AdV O2
(26 Mpc)

AdV O3 (goal)
(>65 Mpc)



…e dal 2024 si aggiungerà anche LIGO-India

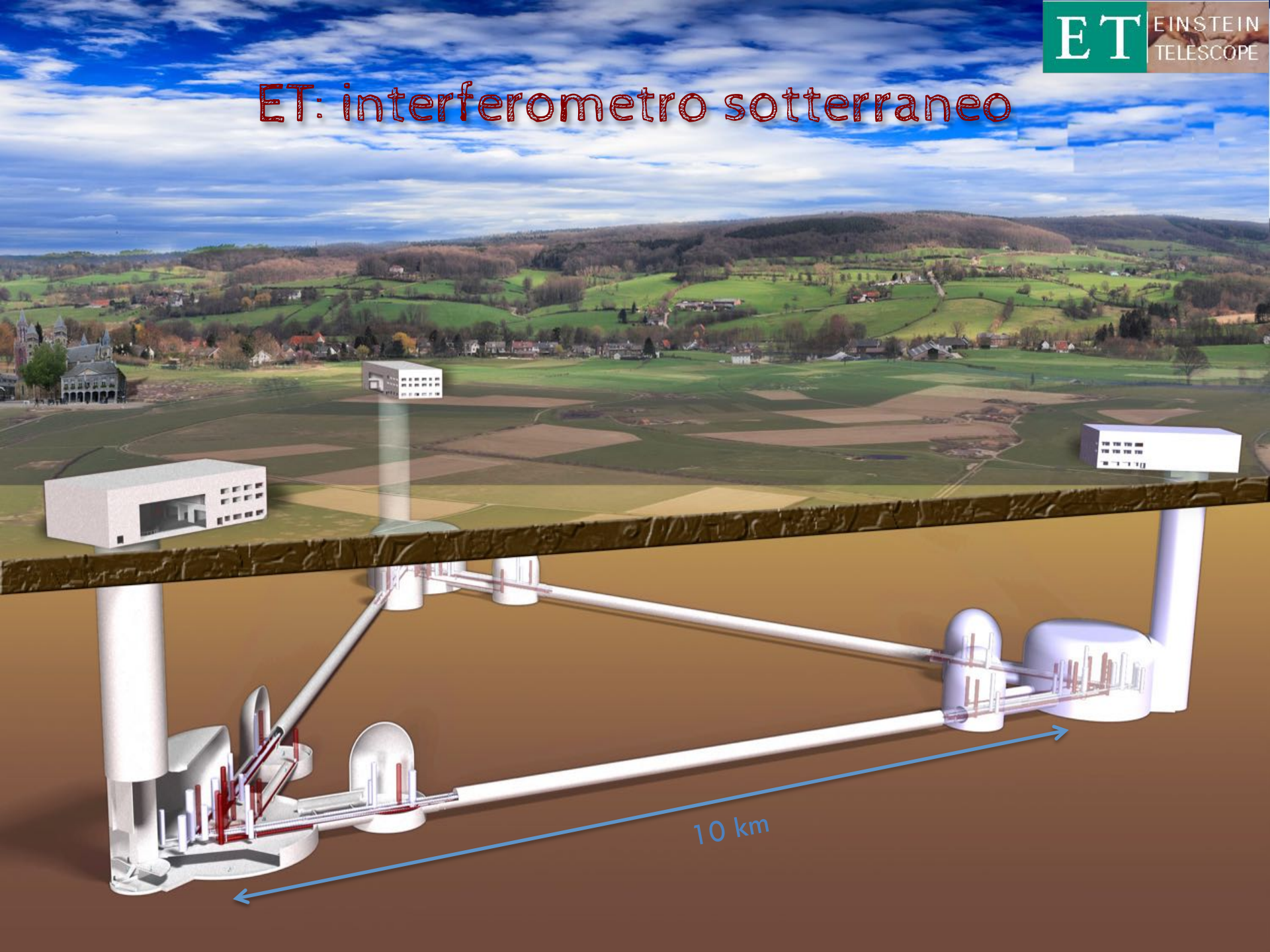
THE MID-TERM GOAL

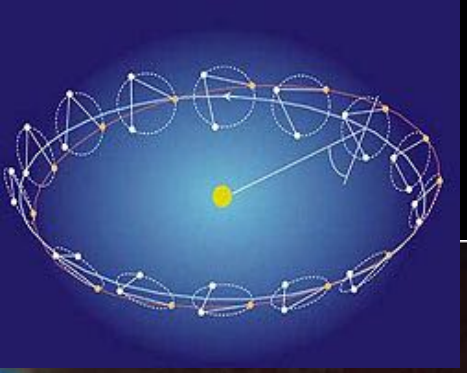


Fairhurst, CQG 28, 2001

Una rete di 5 rivelatori: localizzare la maggior parte delle sorgenti entro 10^{o2}

ET: interferometro sotterraneo





LISA: interferometro spaziale

“RIVELARE LE ONDE GRAVITAZIONALI

NESSUNA IDEA ERA PIU’ FOLLE DI QUESTA”

ADALBERTO GIAZOTTO