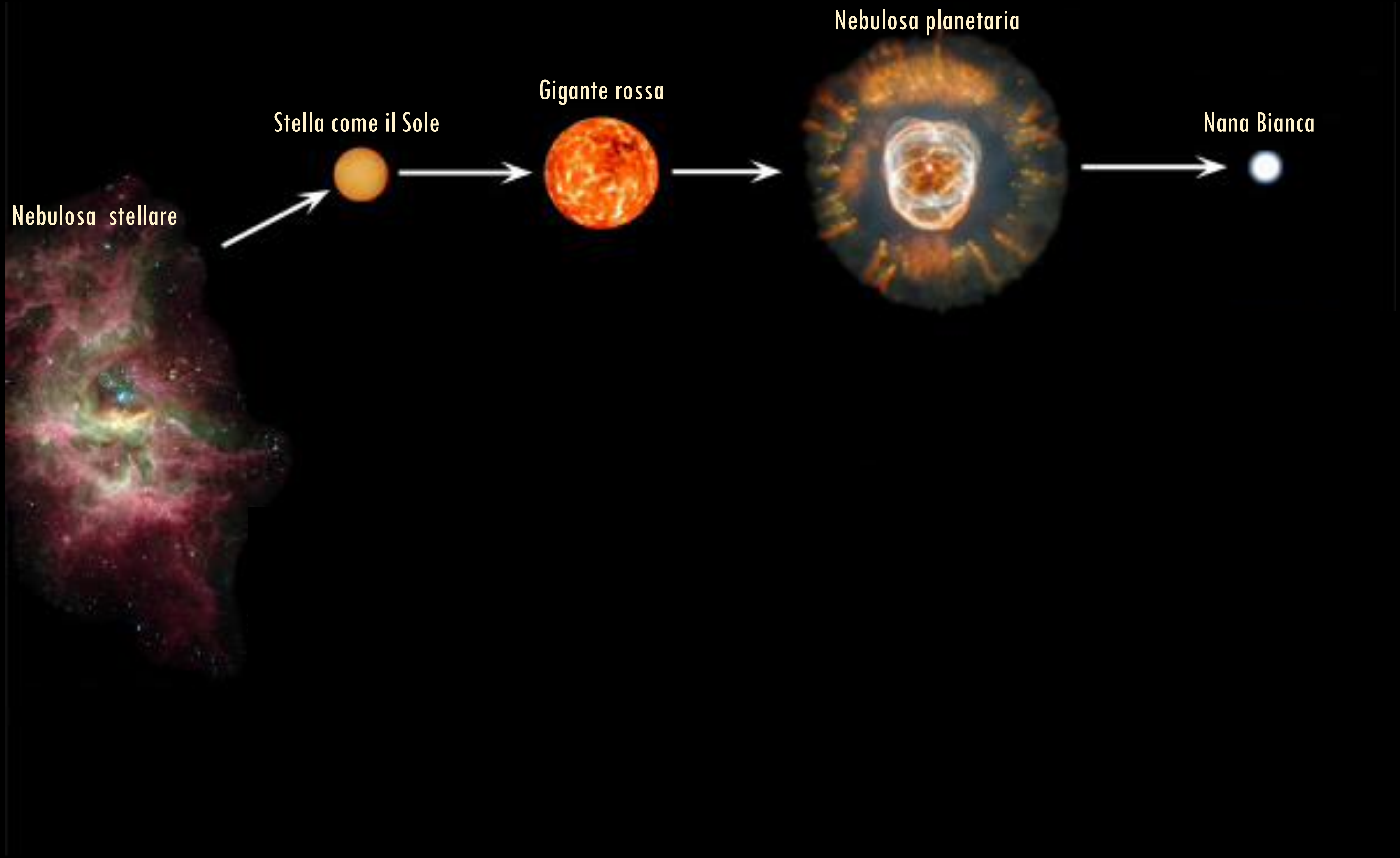
Danza, luci e suoni dal cosmo

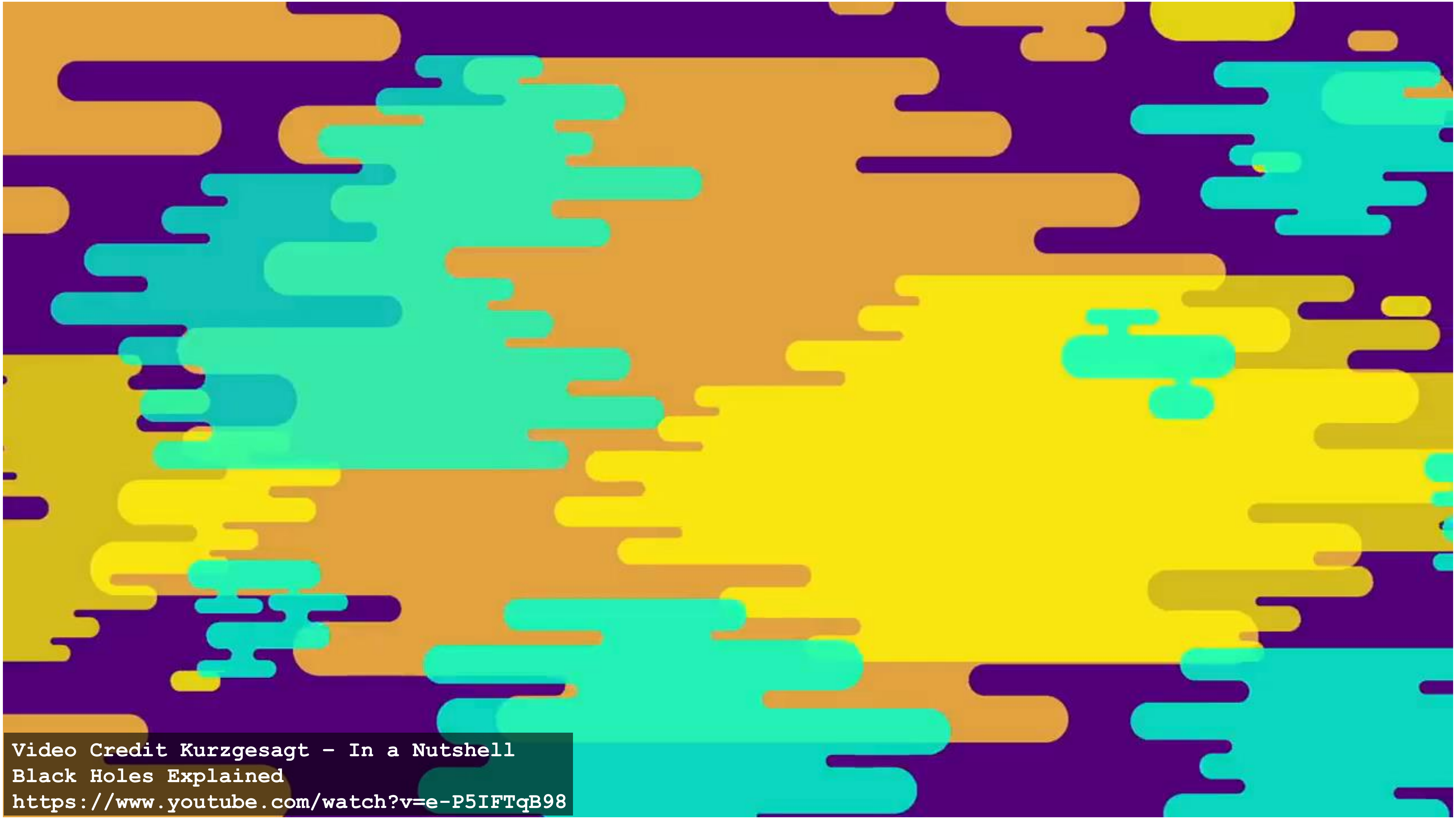
Dott.ssa Elisabetta Bissaldi

Dipartimento Interateneo di Fisica – Politecnico e INFN Bari

Art & Science ACROSS ITALY



Credit: starcycleesunley.weebly.com



Video Credit Kurzgesagt – In a Nutshell
Black Holes Explained
https://www.youtube.com/watch?v=e-P5IFTqB98

Credit: NASA/GSFC/CI Lab/ESA/Hubble/Hurt,Pile/IPAC

Black hole 101

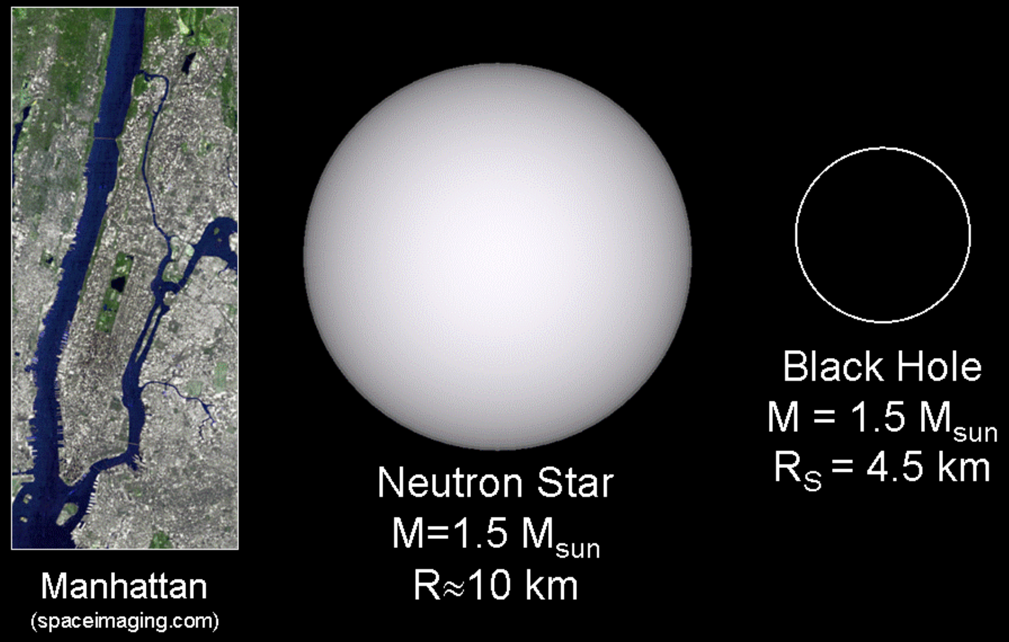
Video Credit: NASA Goddard
https://www.youtube.com/watch?v=aMTwtb3TVIk

Black hole 101

Video Credit: NASA Goddard
https://www.youtube.com/watch?v=aMTwtb3TVIk


PARTE LONTANA DEL DISCO DI ACCRESCIMENTO
ORBITA DEI FOTONI
OMBRA DEL BUCO NERO
BEAMING DOPPLER
DISCO DI ACCRESCIMENTO
PARTE LONTANA DEL DISCO DI ACCRESCIMENTO
Credit: NASA GSFC/Jeremy Schnitman

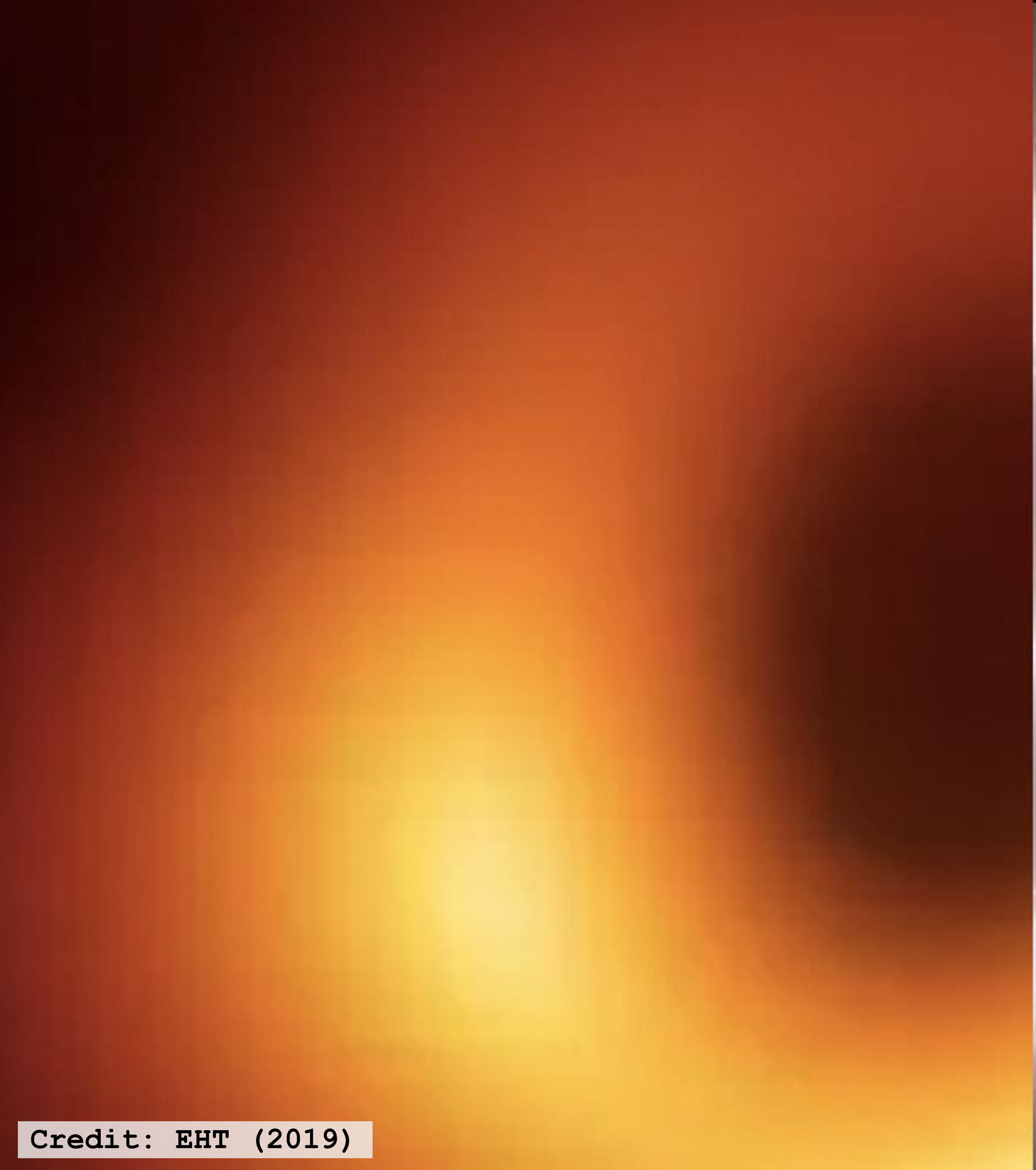
BUCO NERO STELLARE

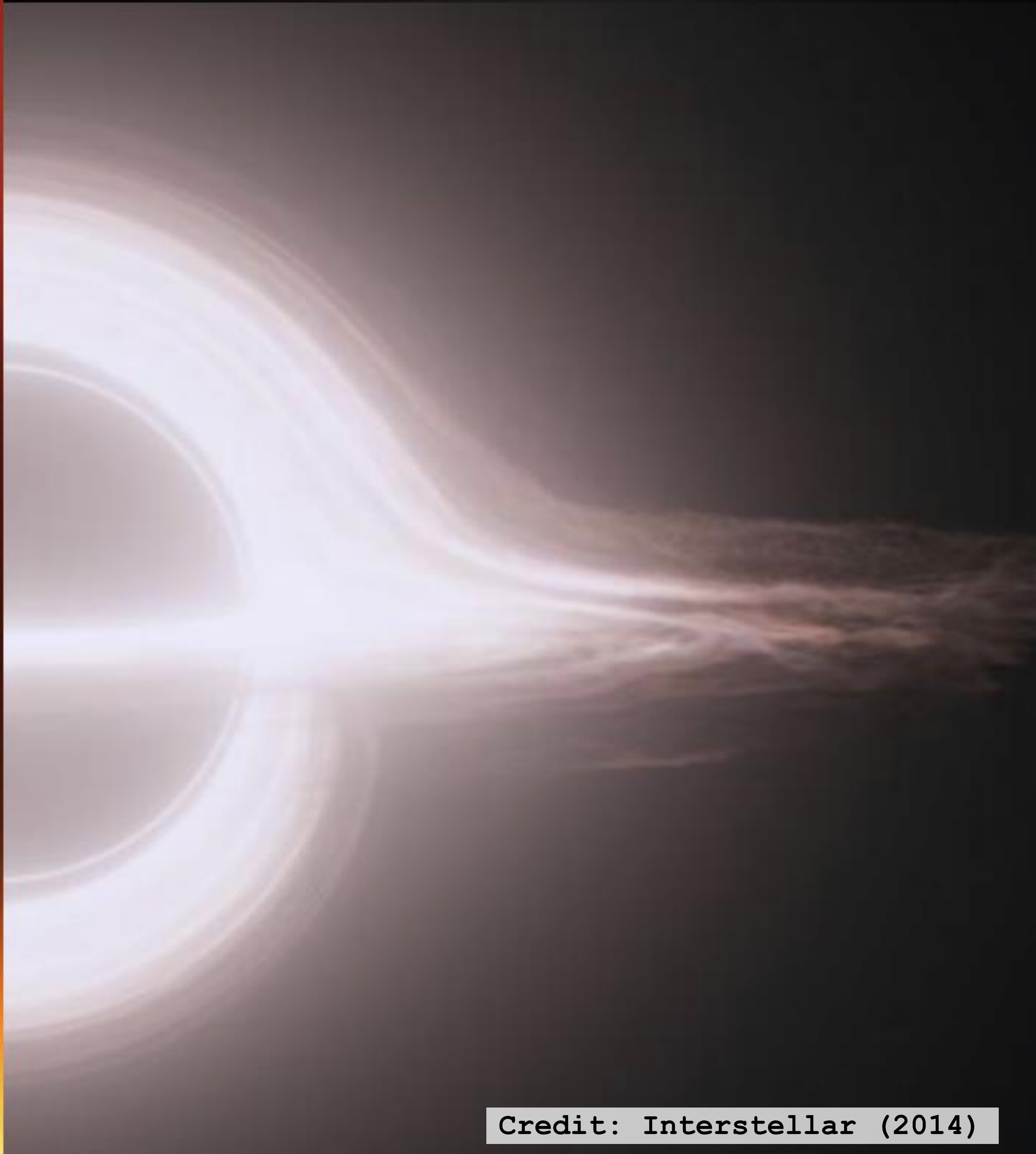


BUCO NERO GALATTICO

3 miliardi di masse solari

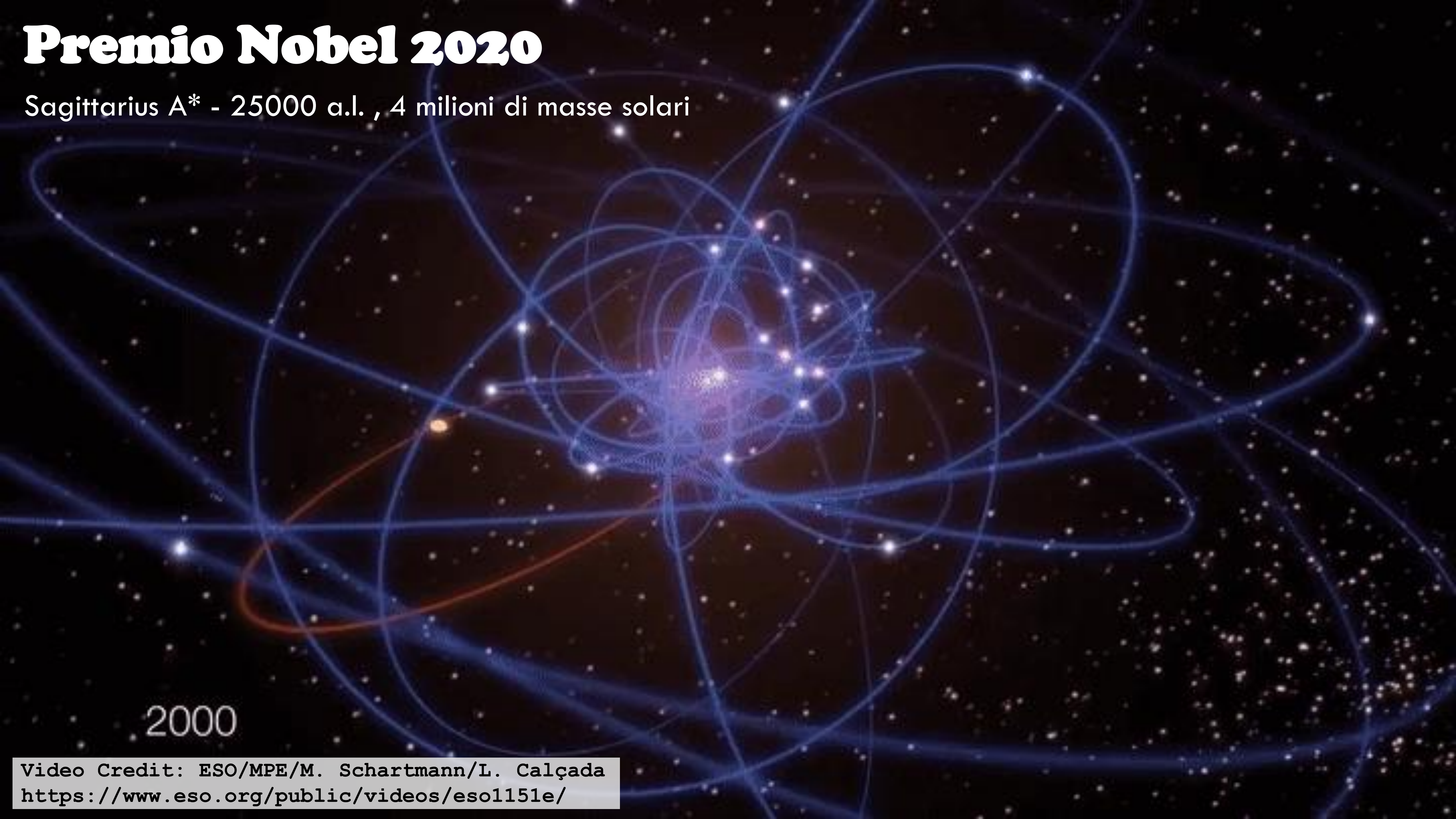
Credit: https://xkcd.com/2135/


Credit: EHT (2019)

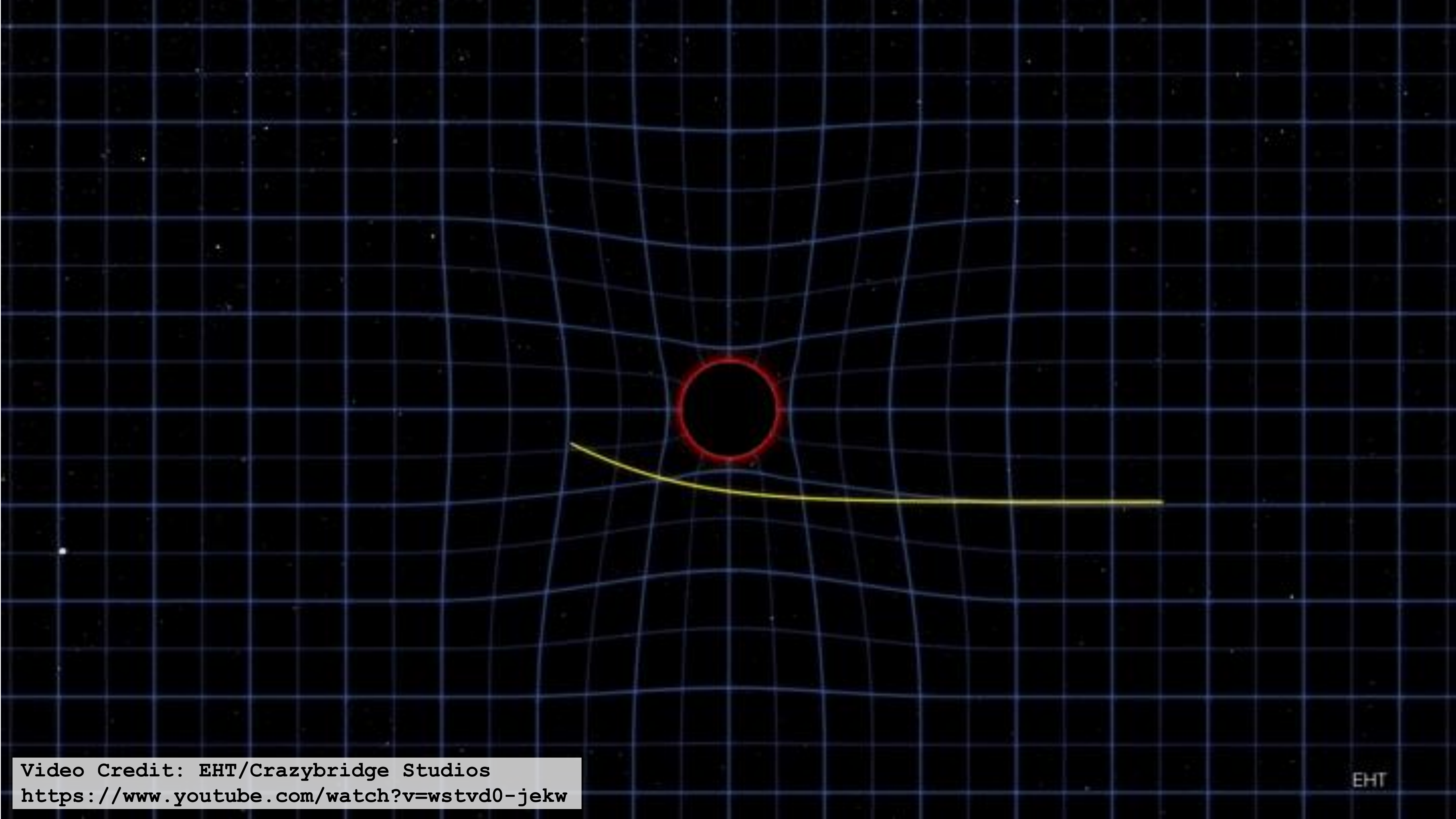

Credit: Interstellar (2014)

Premio Nobel 2020

Sagittarius A* - 25000 a.l. , 4 milioni di masse solari



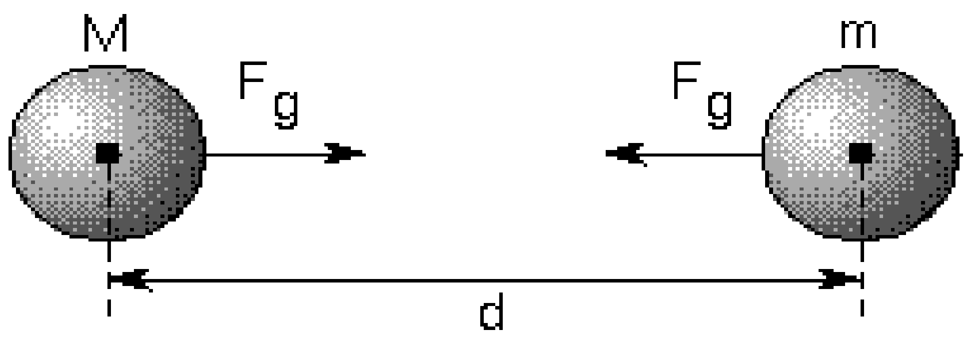
Video Credit: ESO/MPE/M. Schartmann/L. Calçada
https://www.eso.org/public/videos/eso1151e/



Video Credit: EHT/Crazybridge Studios
https://www.youtube.com/watch?v=wstvd0-jekw

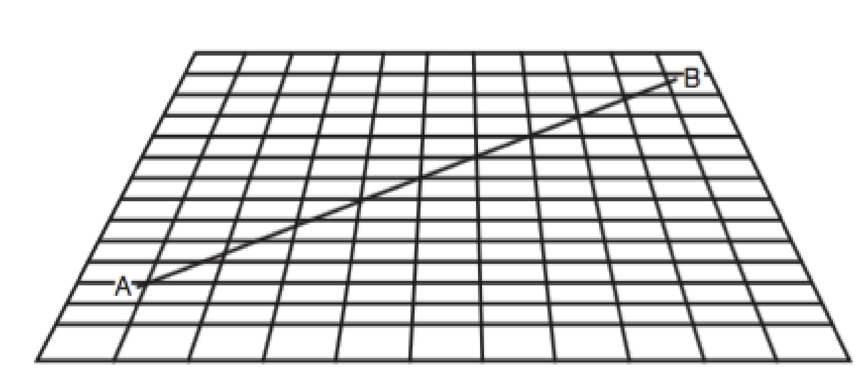
La Gravità

1. **Gravità newtoniana**
   - Forza di gravità = Azione a distanza
   - La legge di Newton descrive l'effetto della gravità, ma non la sua causa!



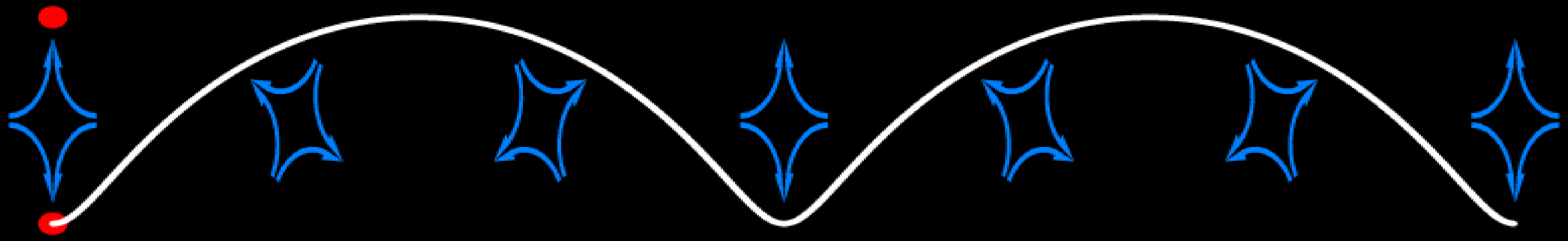
$$F_g = G\frac{Mm}{d^2}$$

2. **Relatività generale di Einstein**
   - Spazio tempo = campo quadridimensionale curvo
   - Forza di gravità = effetto della curvatura dello spazio tempo
     - **Ogni massa/energia curva lo spazio attorno a sé**
   - Gli oggetti in caduta libera seguono semplicemente la curvatura locale dello spazio tempo

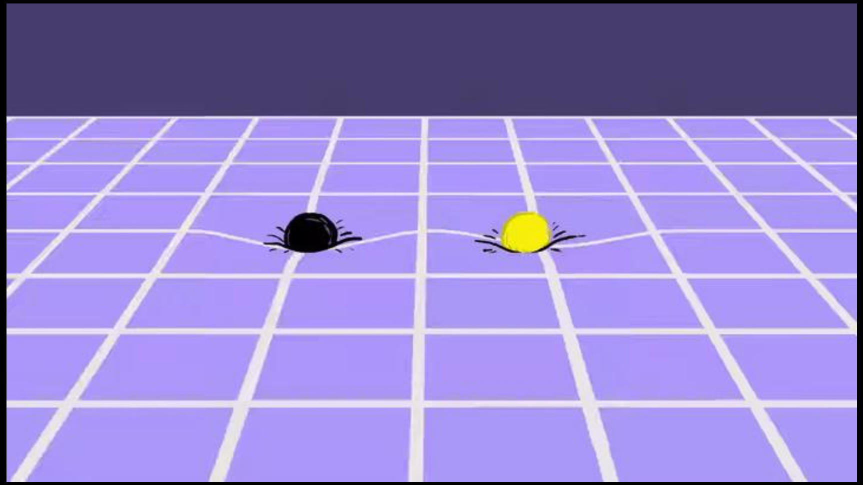


Onde gravitazionali

Brevi perturbazioni del campo gravitazionale
che si propagano alla velocità della luce

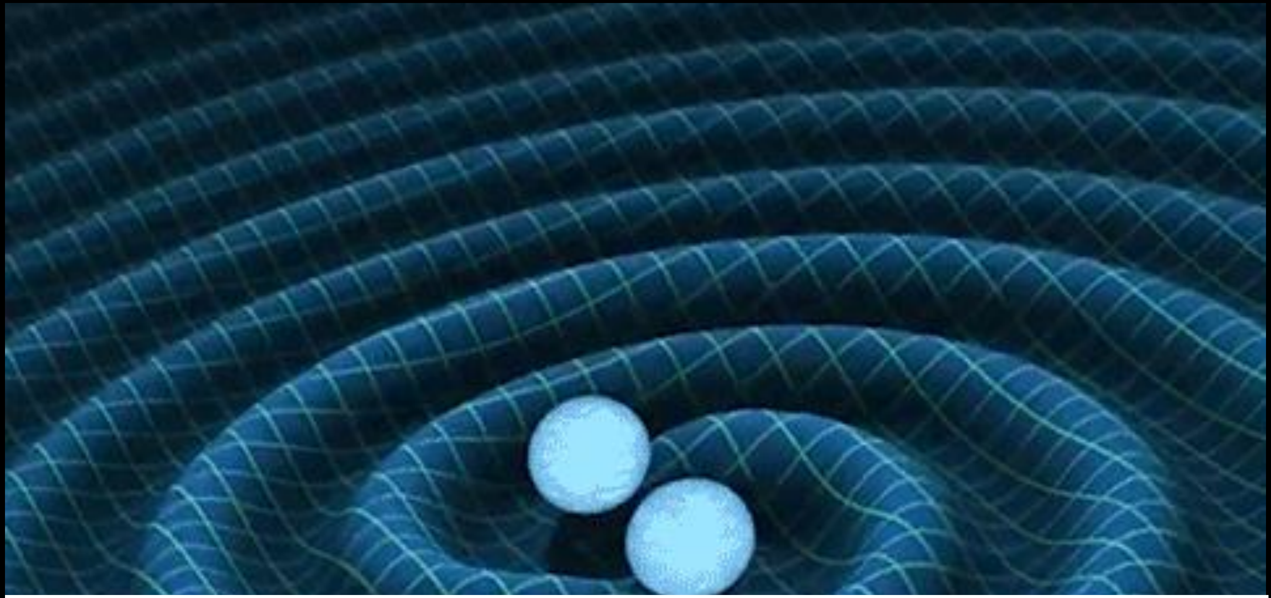


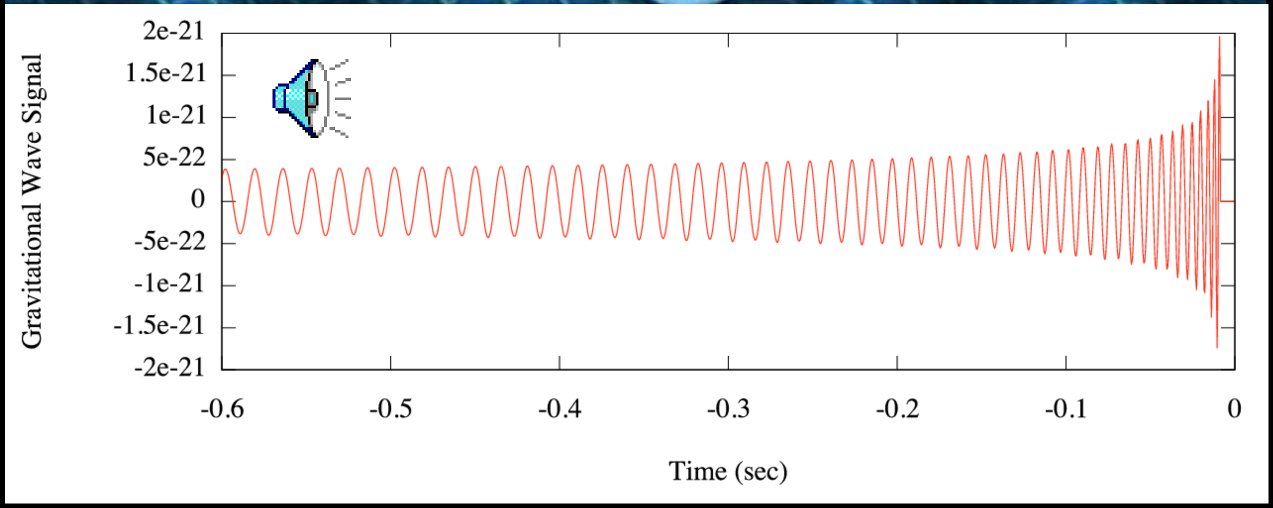
Ogni grande massa o coppia di masse che si muove rapidamente genera fluttuazioni di una scala ridottissima nello spazio tempo



Possibili sorgenti di onde gravitazionali

- Fluttuazioni subito dopo il big bang
- Esplosioni di stelle super massive
- Pulsar
- Sistemi binari di
  - Nane bianche
  - Stelle di neutroni
  - Buchi neri



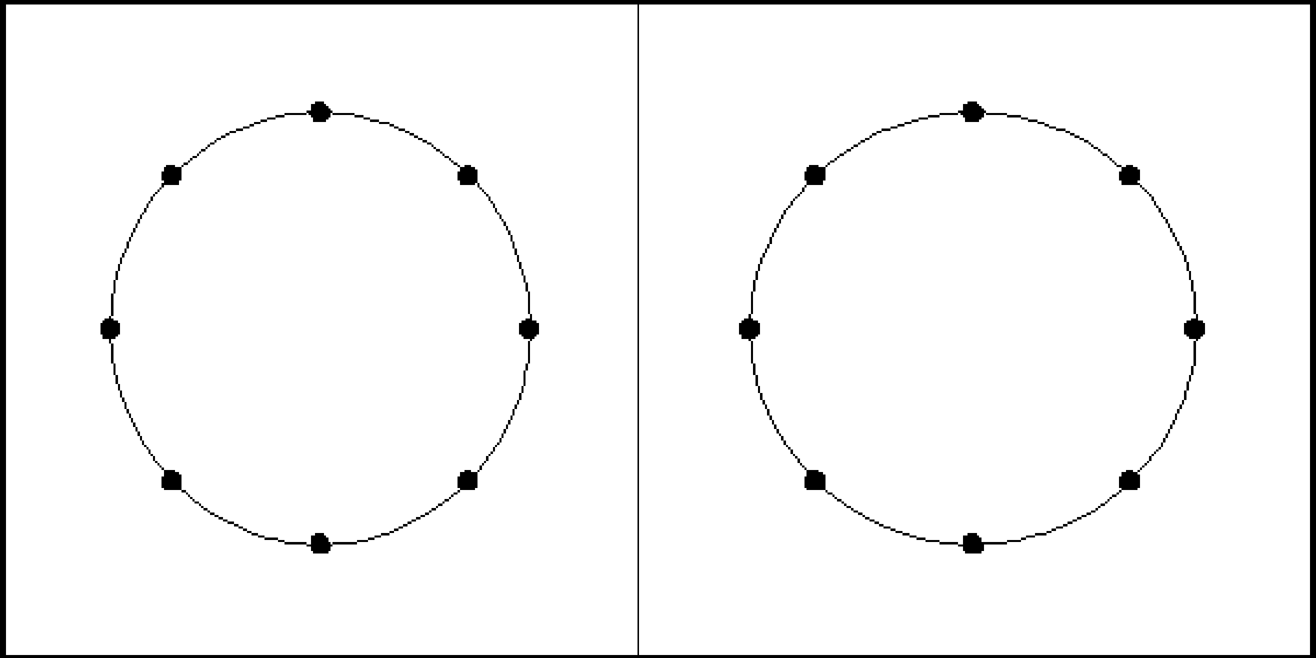


I sistemi binari perdono energia emettendo onde gravitazionali e la loro distanza reciproca si riduce

- La frequenza delle onde gravitazionali aumenta e si definisce «chirp» (cinguettio)

Effetti delle onde gravitazionali

- Al passaggio di un'onda gravitazionale, **lo spazio è stirato e schiacciato**
  - Effetto opposto in direzioni perpendicolari
  - È difficile osservarle perché tutti gli atomi sono affetti dallo stesso spostamento
  - Effetto su un sistema di particelle dovuto ad un'onda gravitazionale:



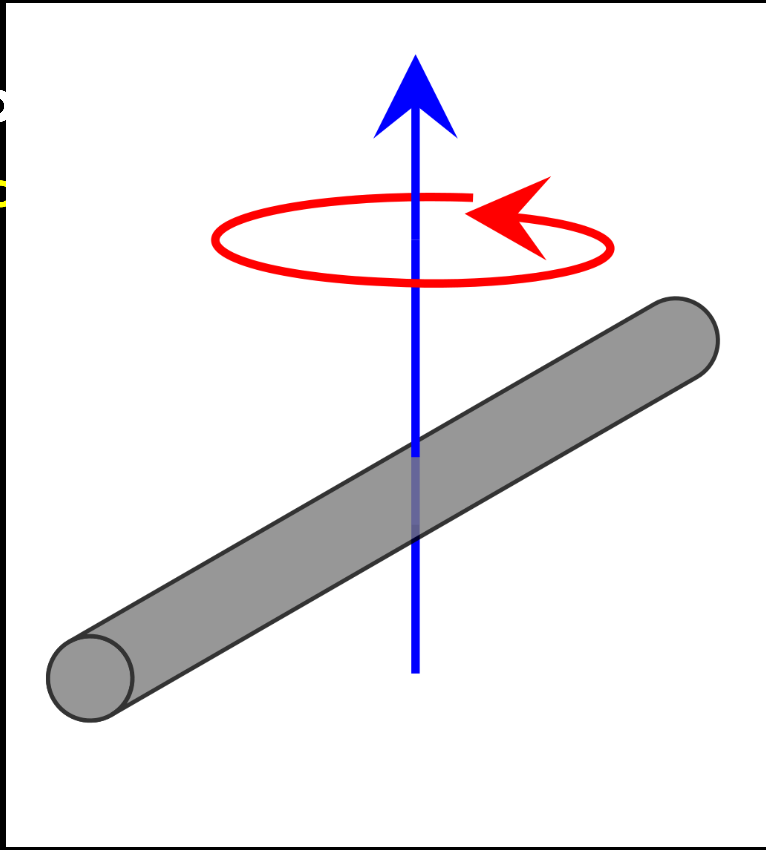
Potenza di un'onda gravitazionale

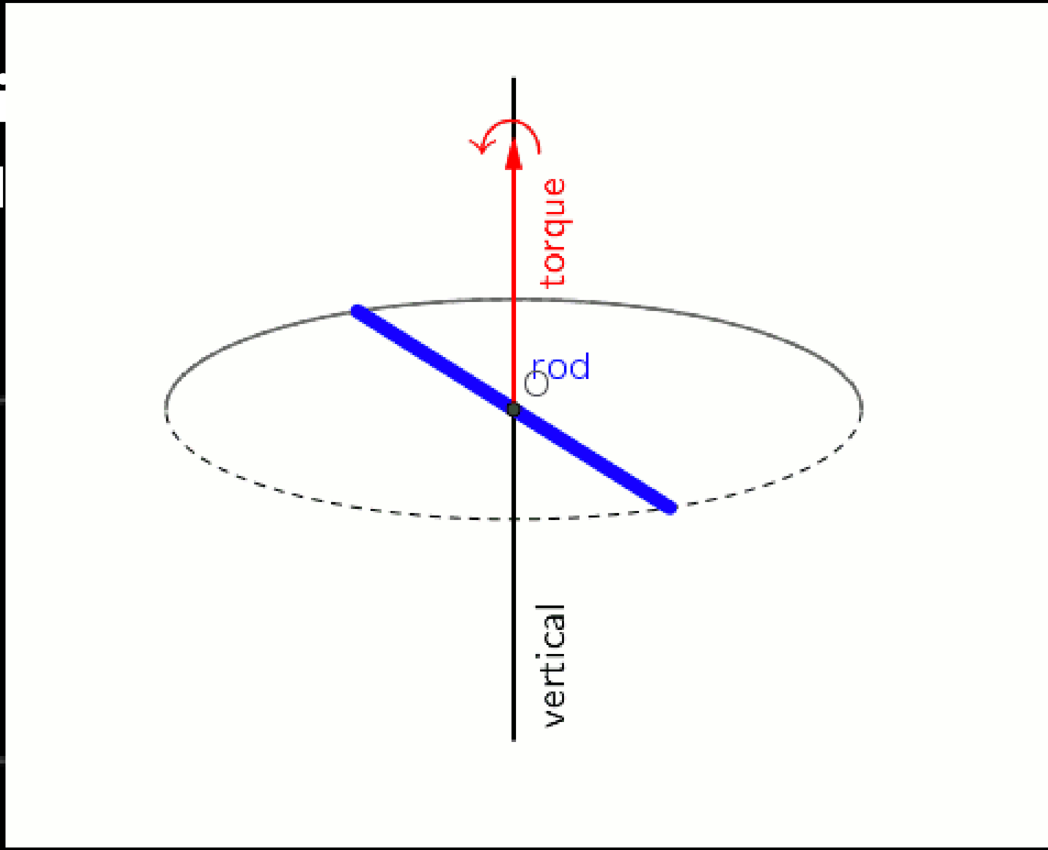
Possiamo creare le onde gravitazionali in laboratorio?

- Se facciamo **ruotare un asta sottile** lunga 1 metro e di massa 1 kg con velocità angolare 1 rad/s attorno al suo centro, la potenza emessa in onde gravitazionali è pari a **10^{-54} W**

Possiamo … zi

- Nel mo … , l … è **~200 W**





uscole
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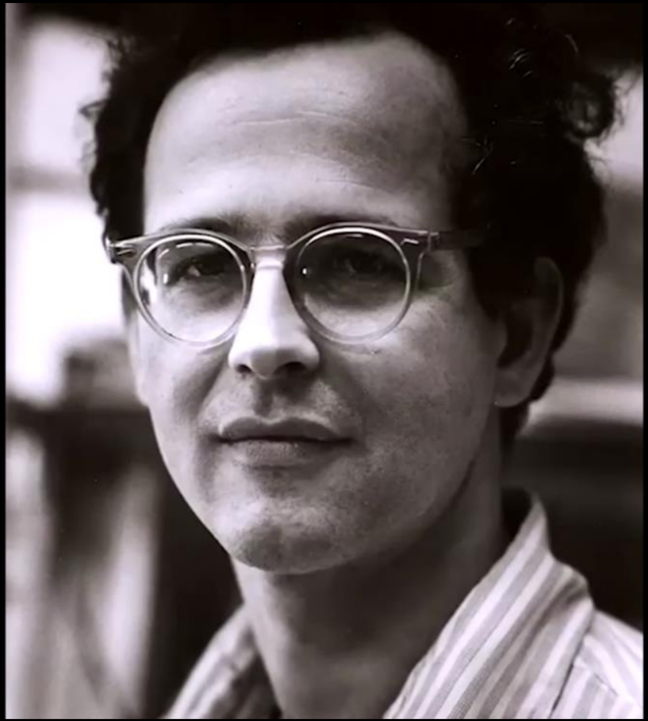
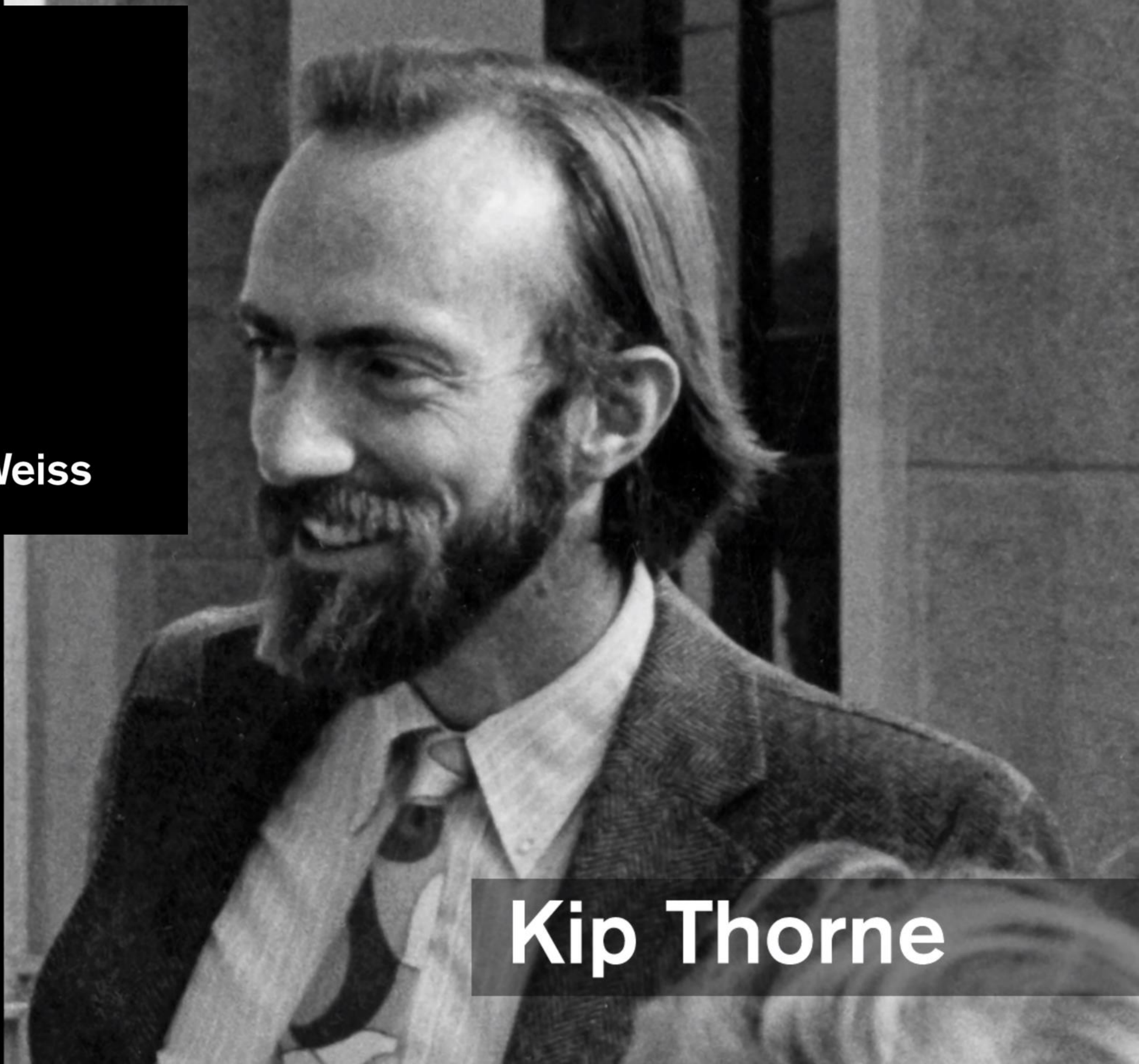
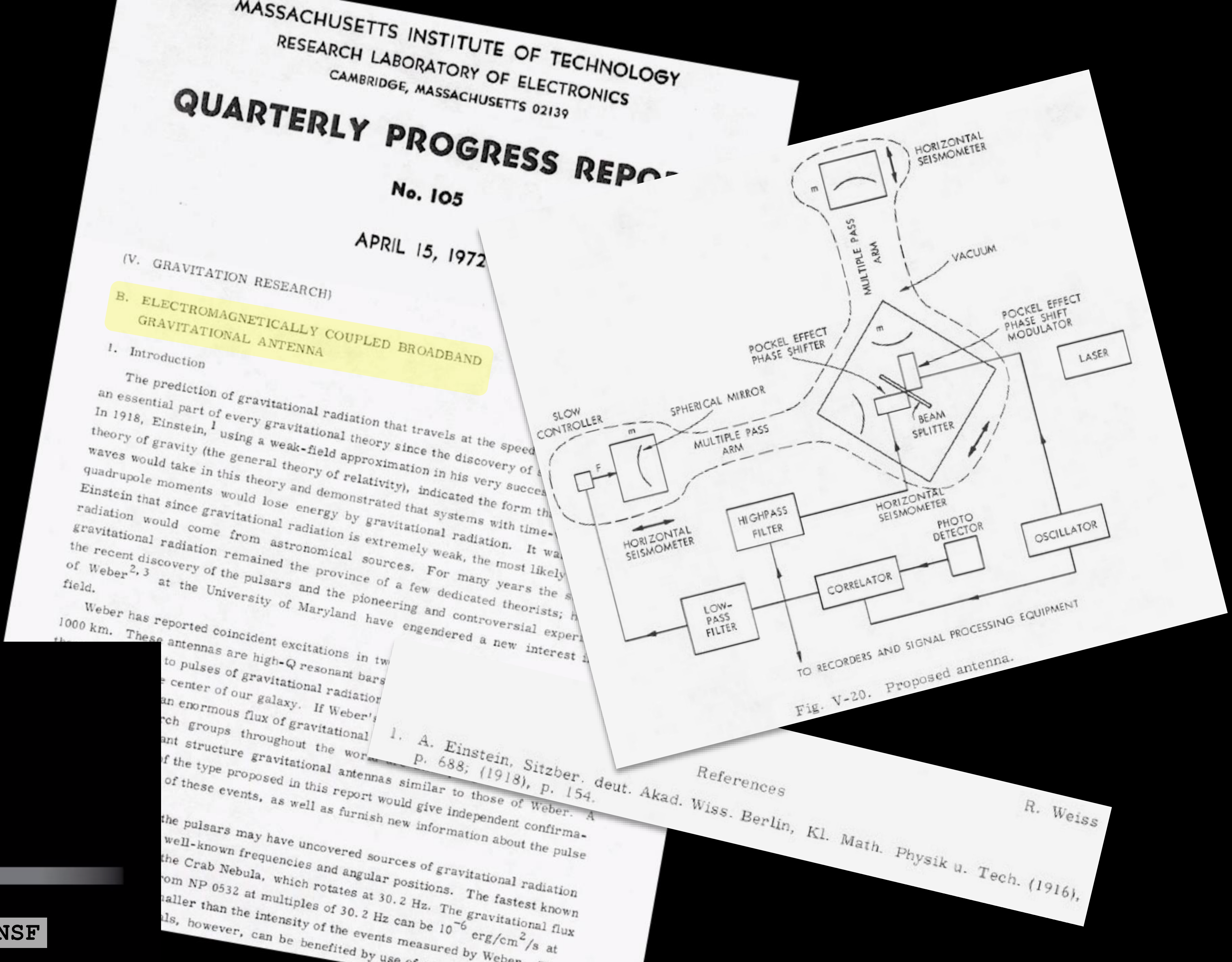


Rainer Weiss



1966

Credit: LIGO/Caltech/MIT/LSC/NSF



MASSACHUSETTS INSTITUTE OF TECHNOLOGY
RESEARCH LABORATORY OF ELECTRONICS
CAMBRIDGE, MASSACHUSETTS 02139

QUARTERLY PROGRESS REPO

No. 105

APRIL 15, 1972

(V. GRAVITATION RESEARCH)

B. ELECTROMAGNETICALLY COUPLED BROADBAND GRAVITATIONAL ANTENNA

1. Introduction

The prediction of gravitational radiation that travels at the speed
an essential part of every gravitational theory since the discovery of
In 1918, Einstein,[1] using a weak-field approximation in his very succes
theory of gravity (the general theory of relativity), indicated the form th
waves would take in this theory and demonstrated that systems with time-
quadrupole moments would lose energy by gravitational radiation. It wa
Einstein that since gravitational radiation is extremely weak, the most likely
radiation would come from astronomical sources. For many years the s
gravitational radiation remained the province of a few dedicated theorists; h
the recent discovery of the pulsars and the pioneering and controversial experi
of Weber[2,3] at the University of Maryland have engendered a new interest i
field.

Weber has reported coincident excitations in tw
1000 km. These antennas are high-Q resonant bars
to pulses of gravitational radiatio
center of our galaxy. If Weber's
an enormous flux of gravitational
rch groups throughout the wor
ant structure gravitational antennas similar to those of Weber. A
f the type proposed in this report would give independent confirma-
of these events, as well as furnish new information about the pulse

the pulsars may have uncovered sources of gravitational radiation
well-known frequencies and angular positions. The fastest known
the Crab Nebula, which rotates at 30.2 Hz. The gravitational flux
om NP 0532 at multiples of 30.2 Hz can be 10^{-6} erg/cm^2/s at
aller than the intensity of the events measured by Weber.
ls, however, can be benefited by use of

Fig. V-20. Proposed antenna.

R. Weiss

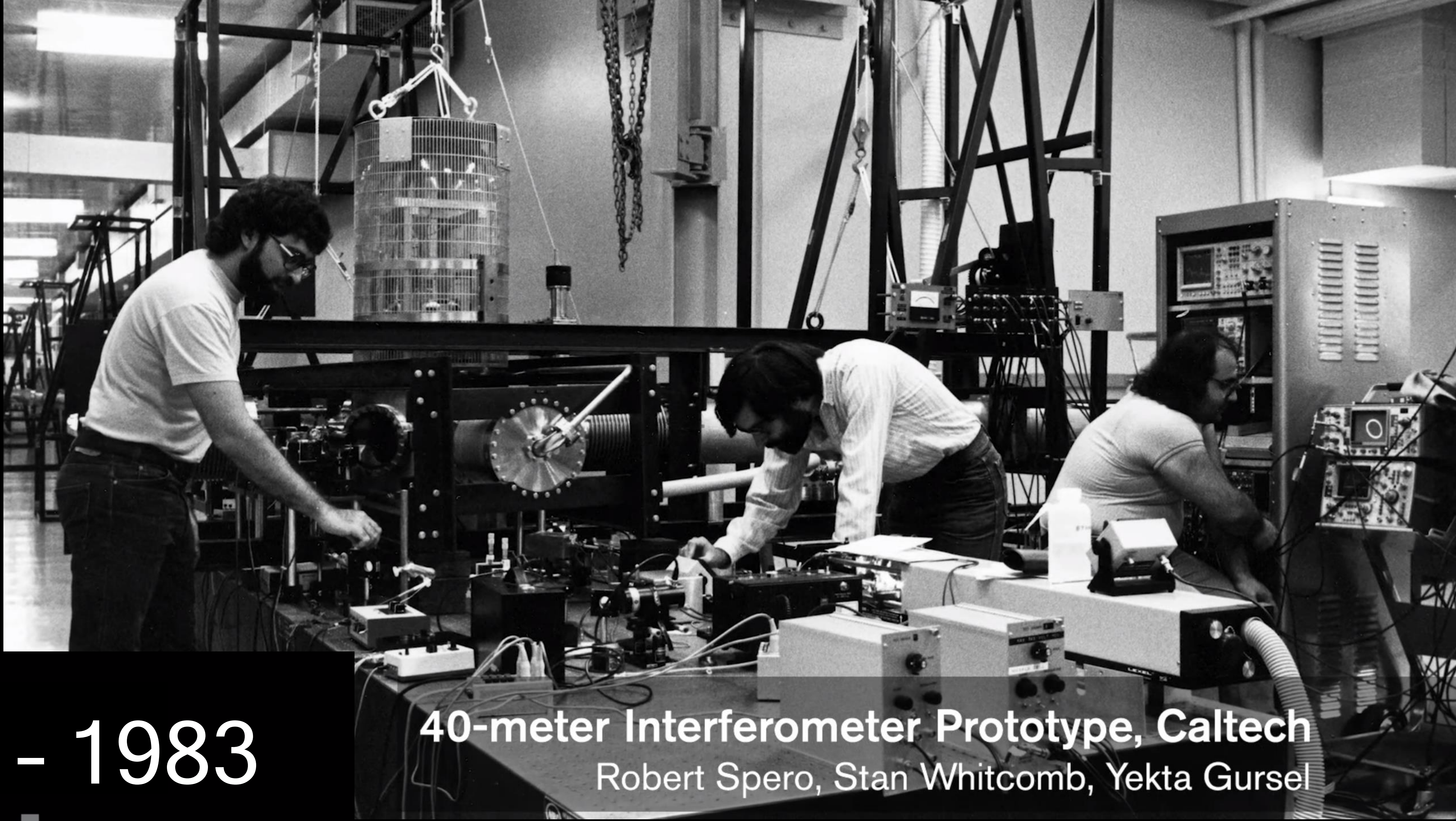
References

1. A. Einstein, Sitzber. deut. Akad. Wiss. Berlin, Kl. Math. Physik u. Tech. (1916), p. 688; (1918), p. 154.

1972

Credit: LIGO/Caltech/MIT/LSC/NSF

1980 - 1983



40-meter Interferometer Prototype, Caltech

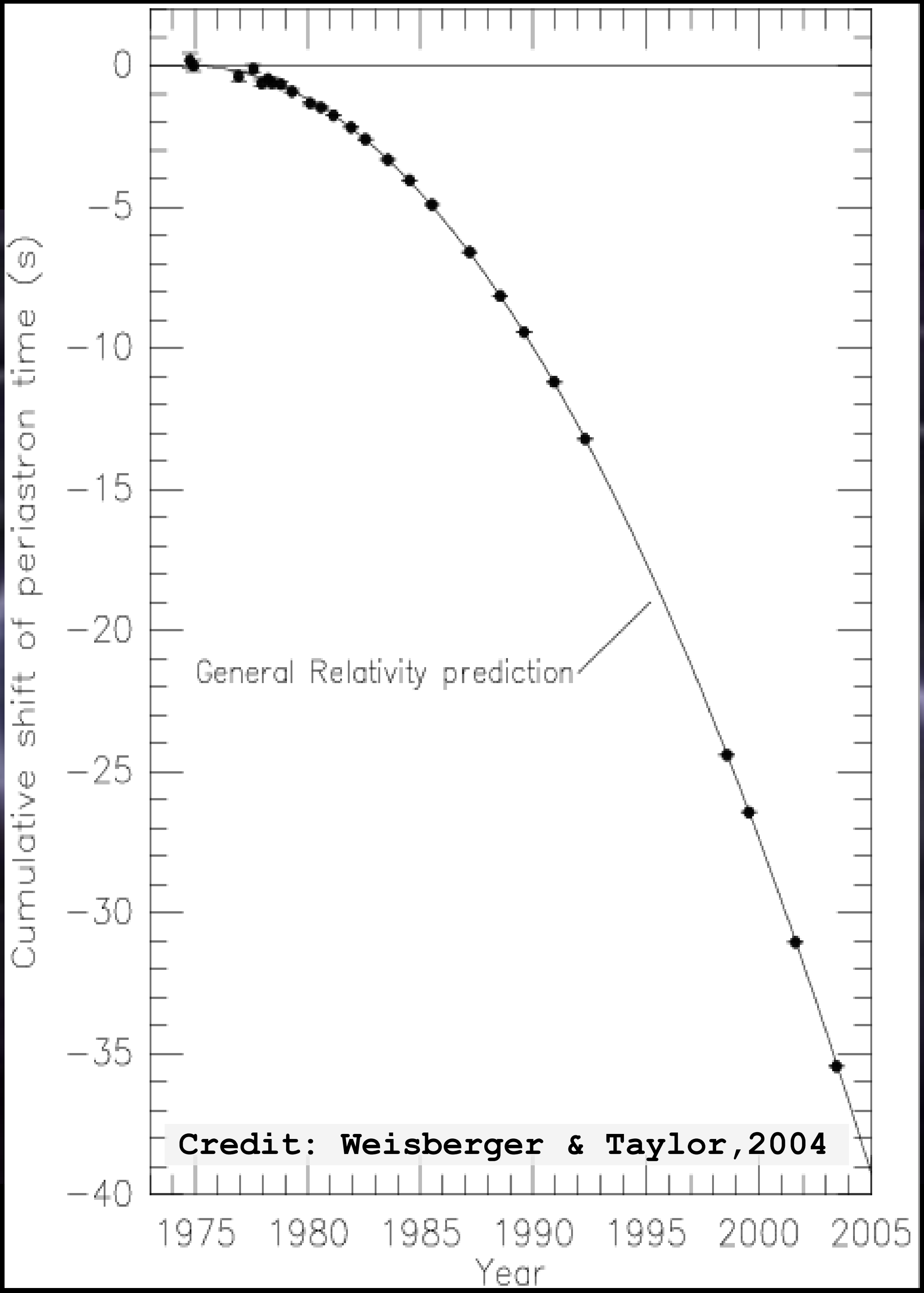
Robert Spero, Stan Whitcomb, Yekta Gursel

Credit: LIGO/Caltech/MIT/LSC/NSF

Premio Nobel 1993

Attribuito a Hulse e Taylor per
un'osservazione indiretta
di onde gravitazionali

- Nel 1974 avevano scoperto la prima pulsar binaria (PSR B1913+16)
- Per 20 anni osservarono che la distanza tra le due stelle di neutroni in rapida rotazione si riduce proprio come previsto dalla relatività generale, assumendo che parte della loro energia viene **emessa in onde gravitazionali**



Credit: LIGO/Caltech/MIT/LSC/NSF

Credit: LIGO/Caltech/MIT/LSC/NSF

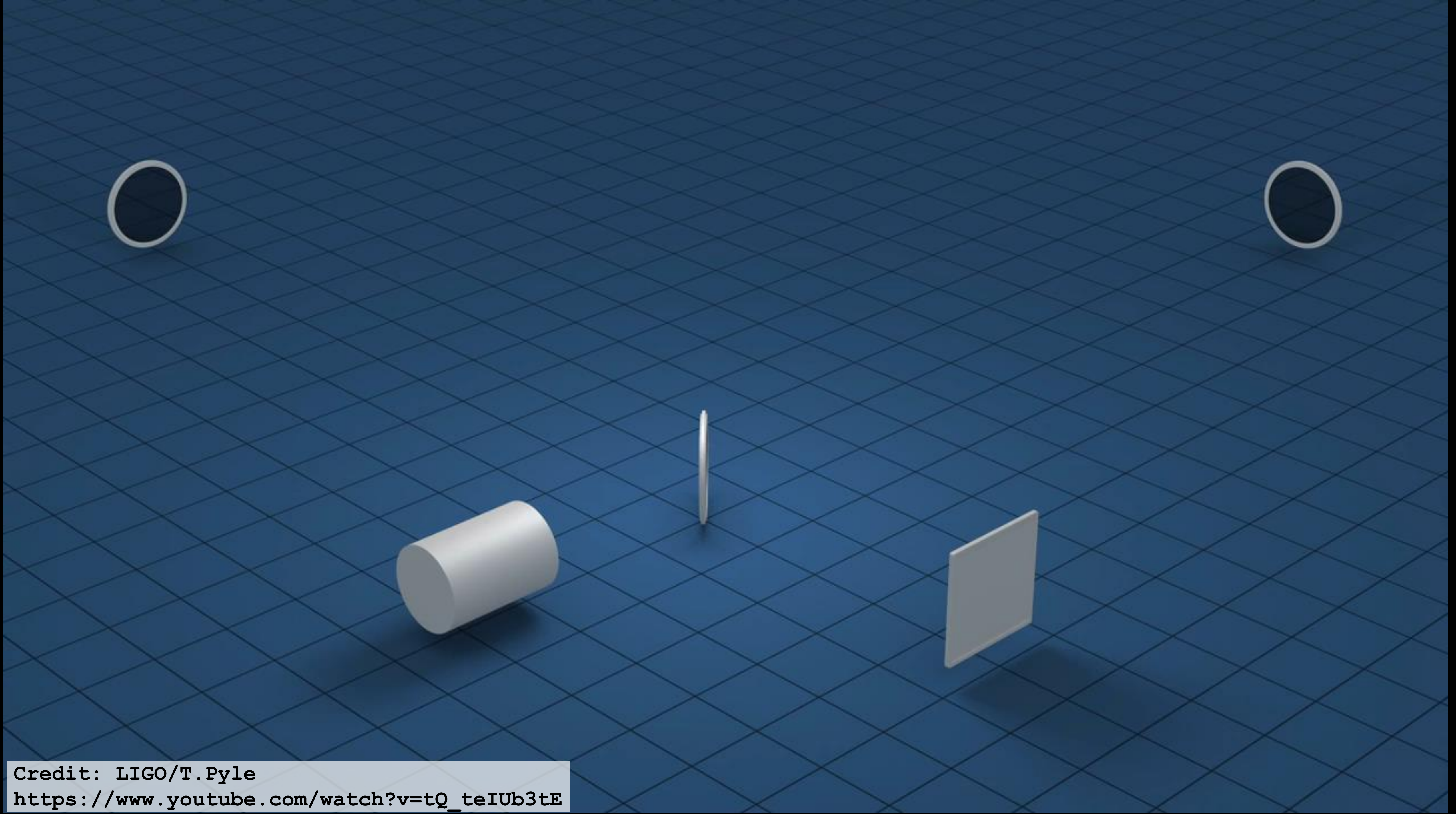
2002 - 2010

Credit: LIGO/Caltech/MIT/LSC/NSF

Credit: LIGO/Caltech/MIT/LSC/NSF

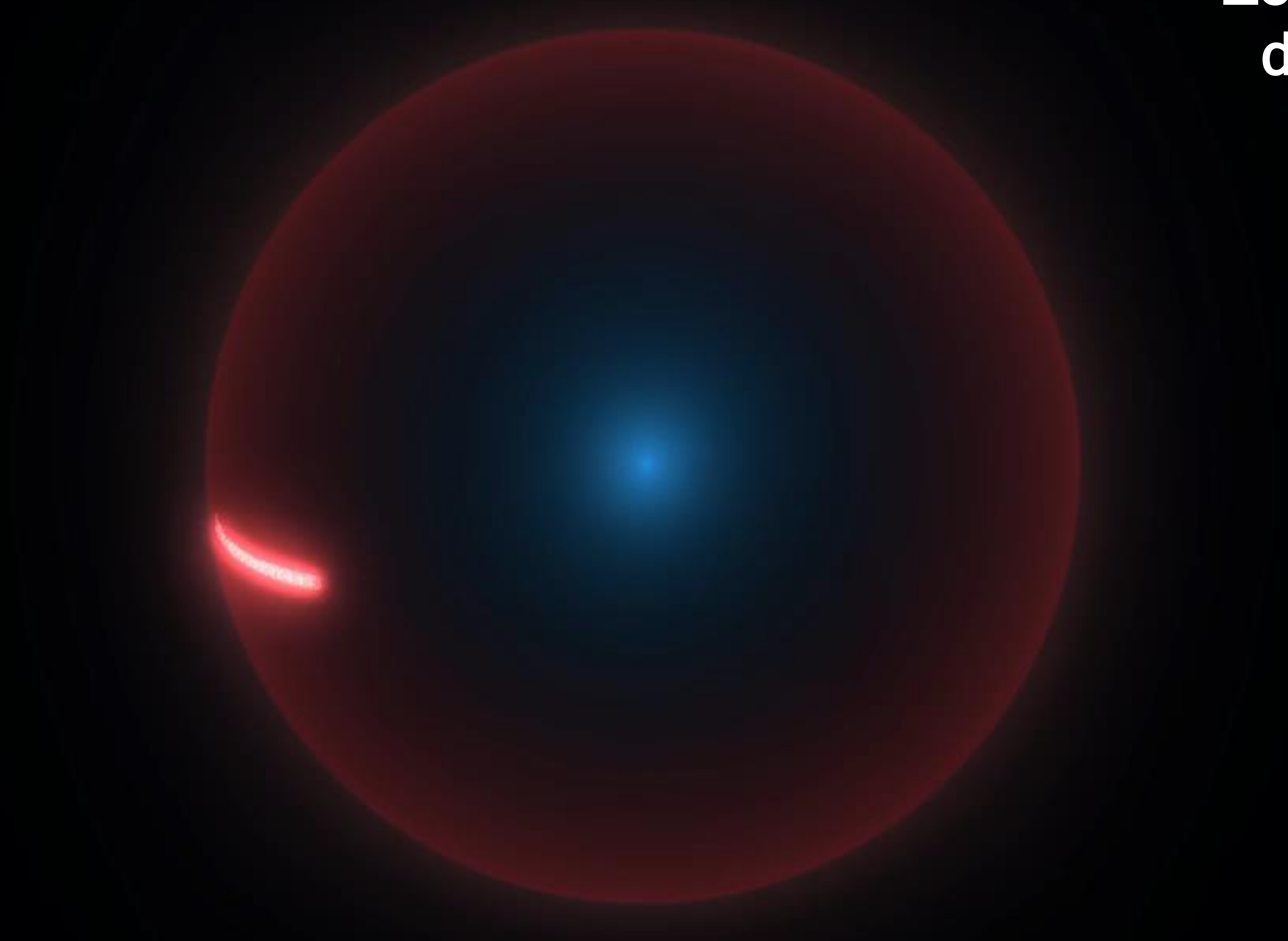

ADVANCED LIGO
2008 - 2015
Livingston, Louisiana
Credit: LIGO/Caltech/MIT/LSC/NSF

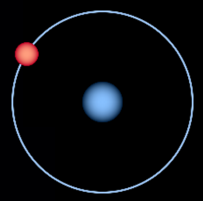

ADVANCED VIRGO
2011 - 2017
Cascina (PI)
Credit: Virgo



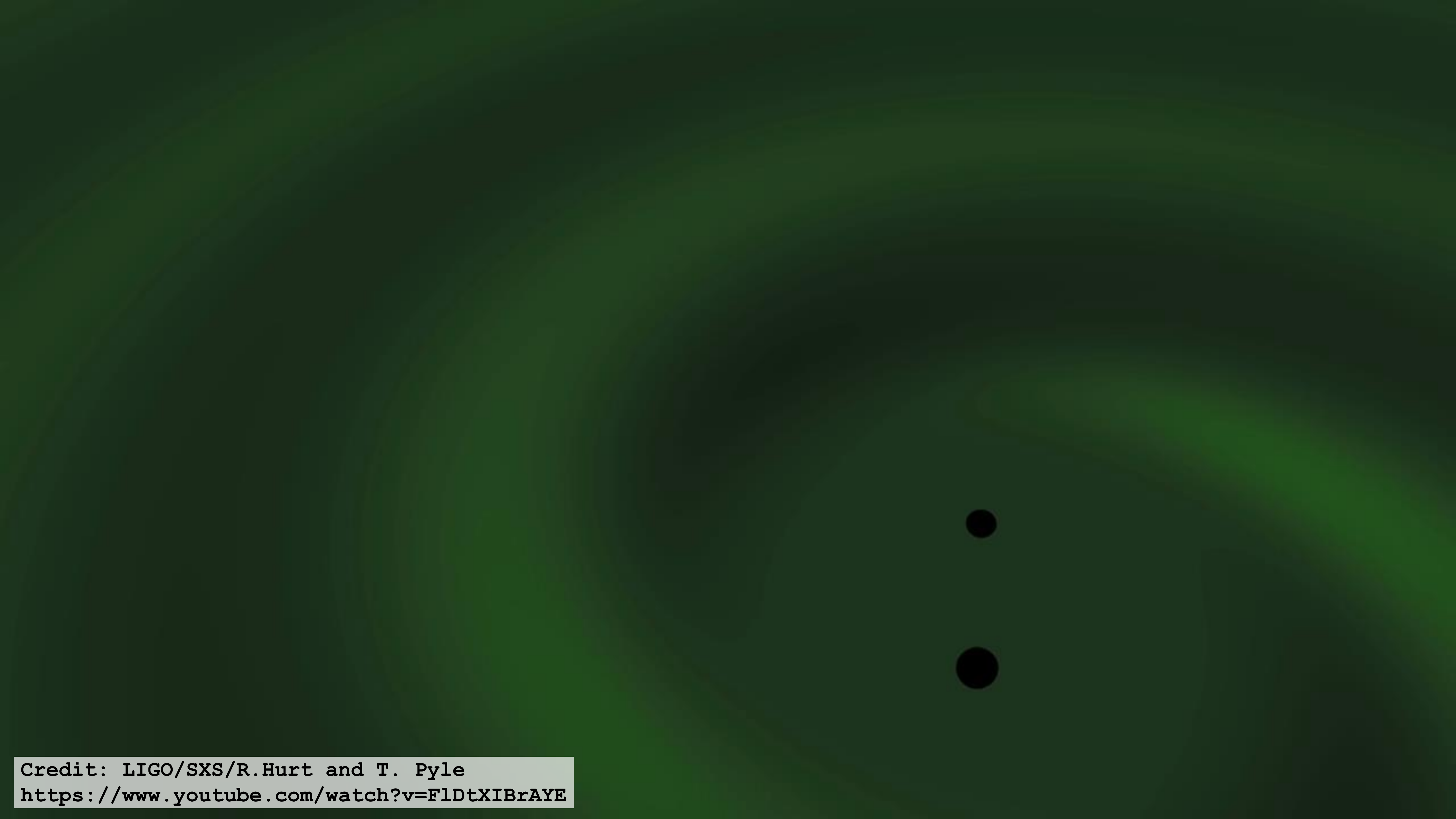
Credit: LIGO/T.Pyle
https://www.youtube.com/watch?v=tQ_teIUb3tE

Zoom atomo di idrogeno



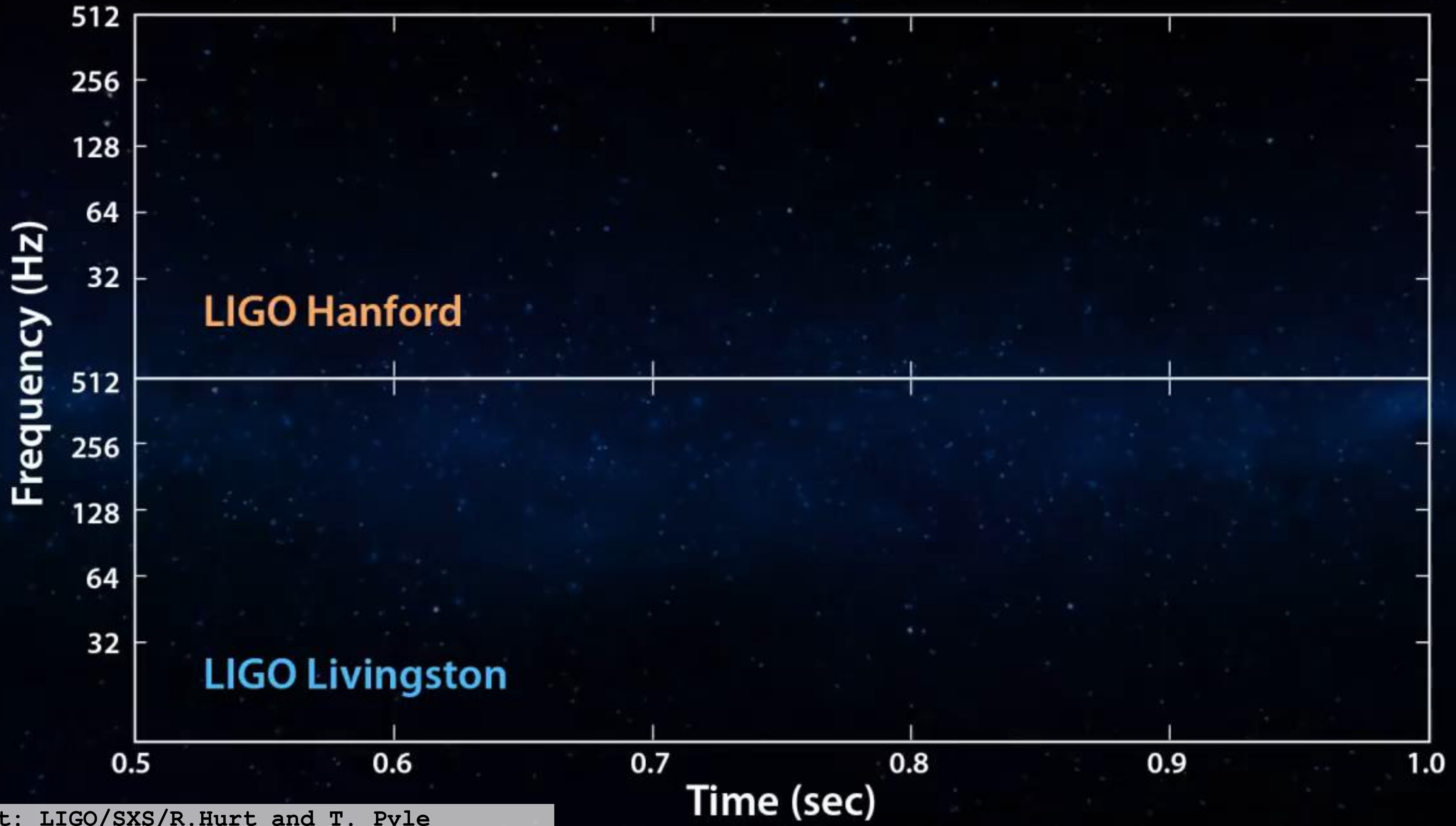


Credit: LIGO/SXS/R.Hurt and T. Pyle
https://www.youtube.com/watch?v=FlDtXIBrAYE

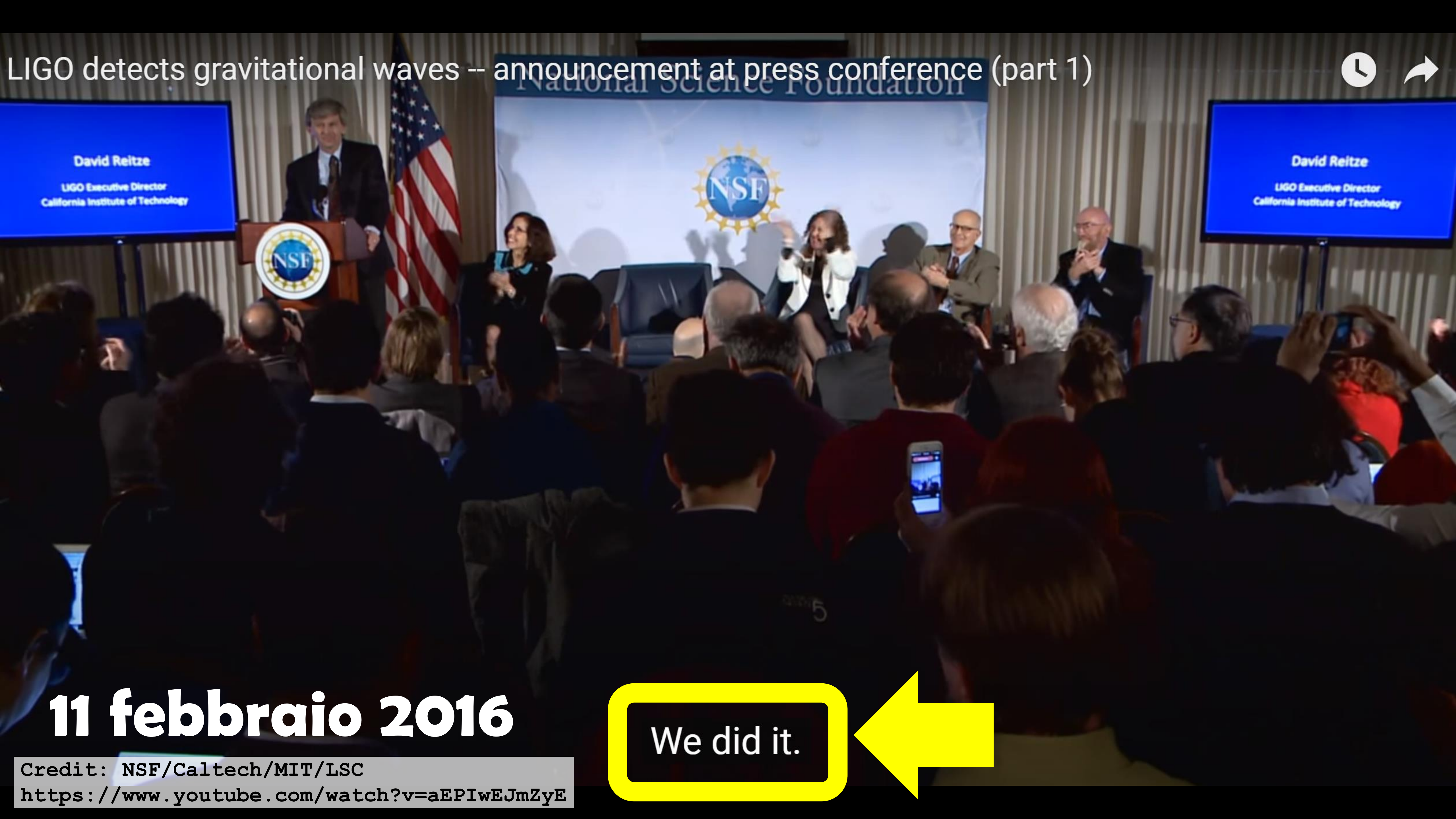


Credit: LIGO/SXS/R.Hurt and T. Pyle
https://www.youtube.com/watch?v=FlDtXIBrAYE

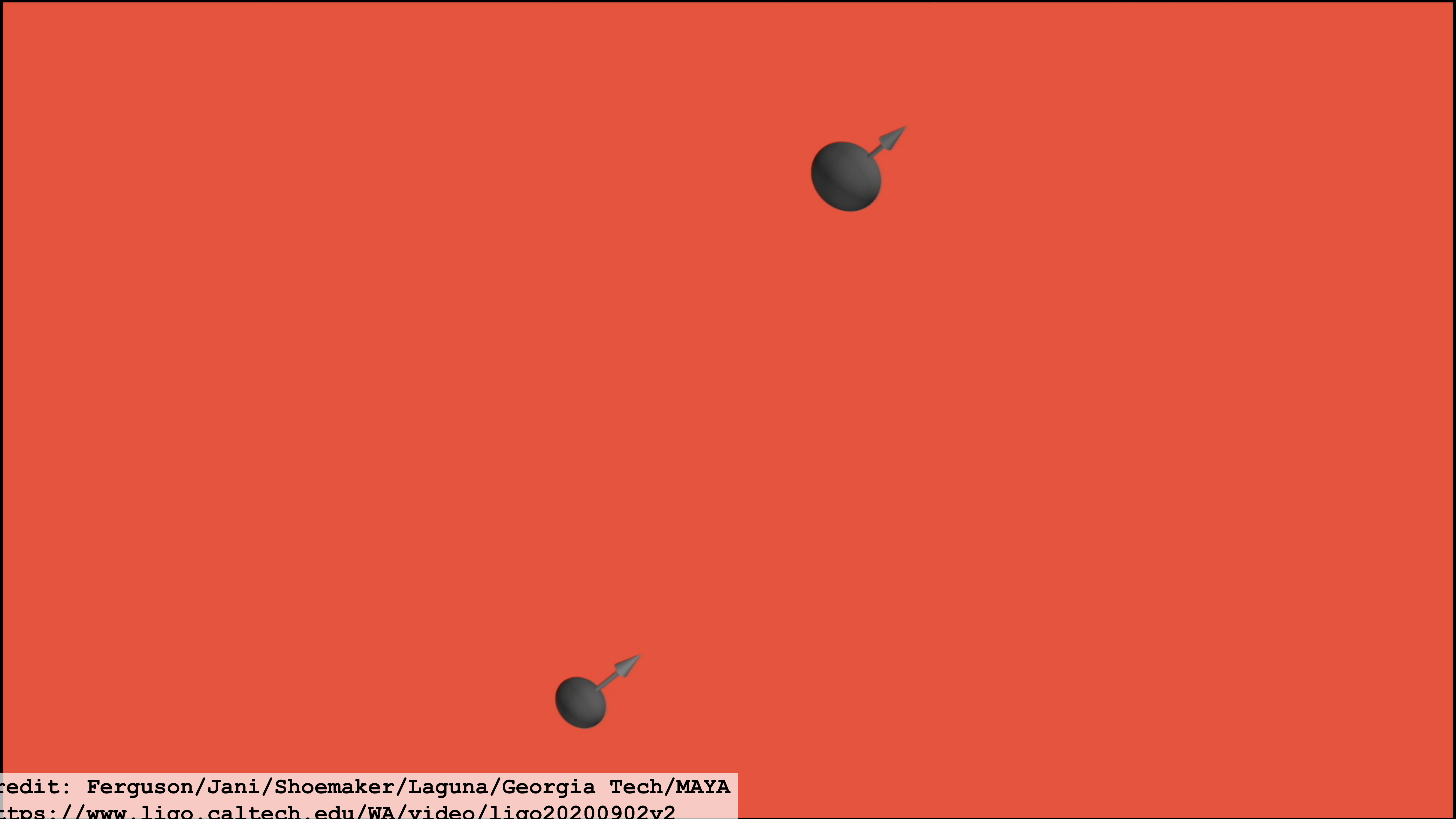
Il 14 settembre 2015...



Credit: LIGO/SXS/R.Hurt and T. Pyle
https://www.youtube.com/watch?v=FlDtXIBrAYE


LIGO detects gravitational waves -- announcement at press conference (part 1)
National Science Foundation
David Reitze
LIGO Executive Director
California Institute of Technology
NSF
11 febbraio 2016
Credit: NSF/Caltech/MIT/LSC
https://www.youtube.com/watch?v=aEPIwEJmZyE
We did it.

Credit: LIGO/SXS/R.Hurt and T. Pyle
https://www.youtube.com/watch?v=FlDtXIBrAYE



Credit: Ferguson/Jani/Shoemaker/Laguna/Georgia Tech/MAYA
https://www.ligo.caltech.edu/WA/video/ligo20200902v2

Credit: Dana Berry/SkyWorks Digital, Inc./Harvard-Smithsonian Center for Astrophysics

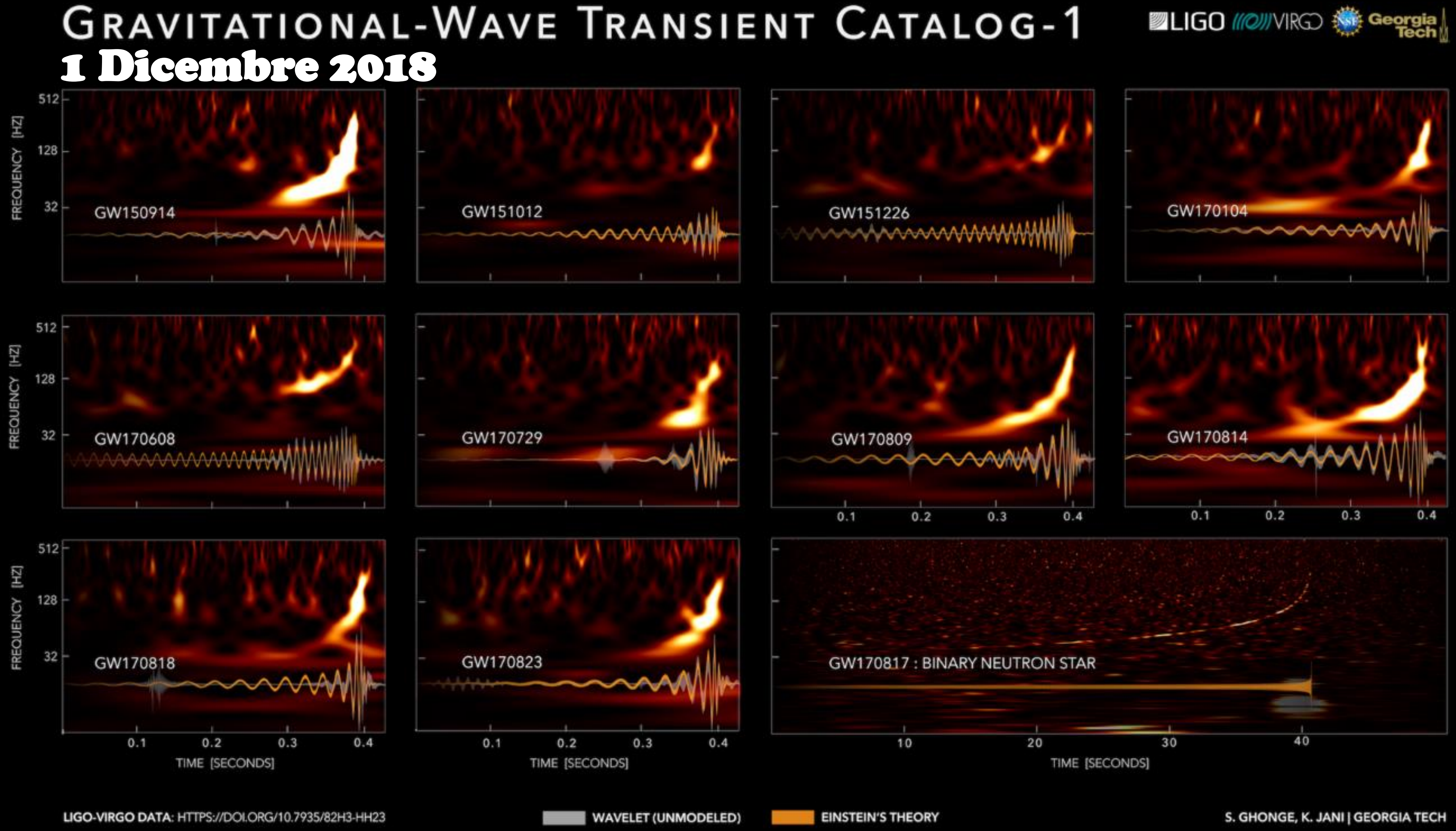
Premio Nobel 2017

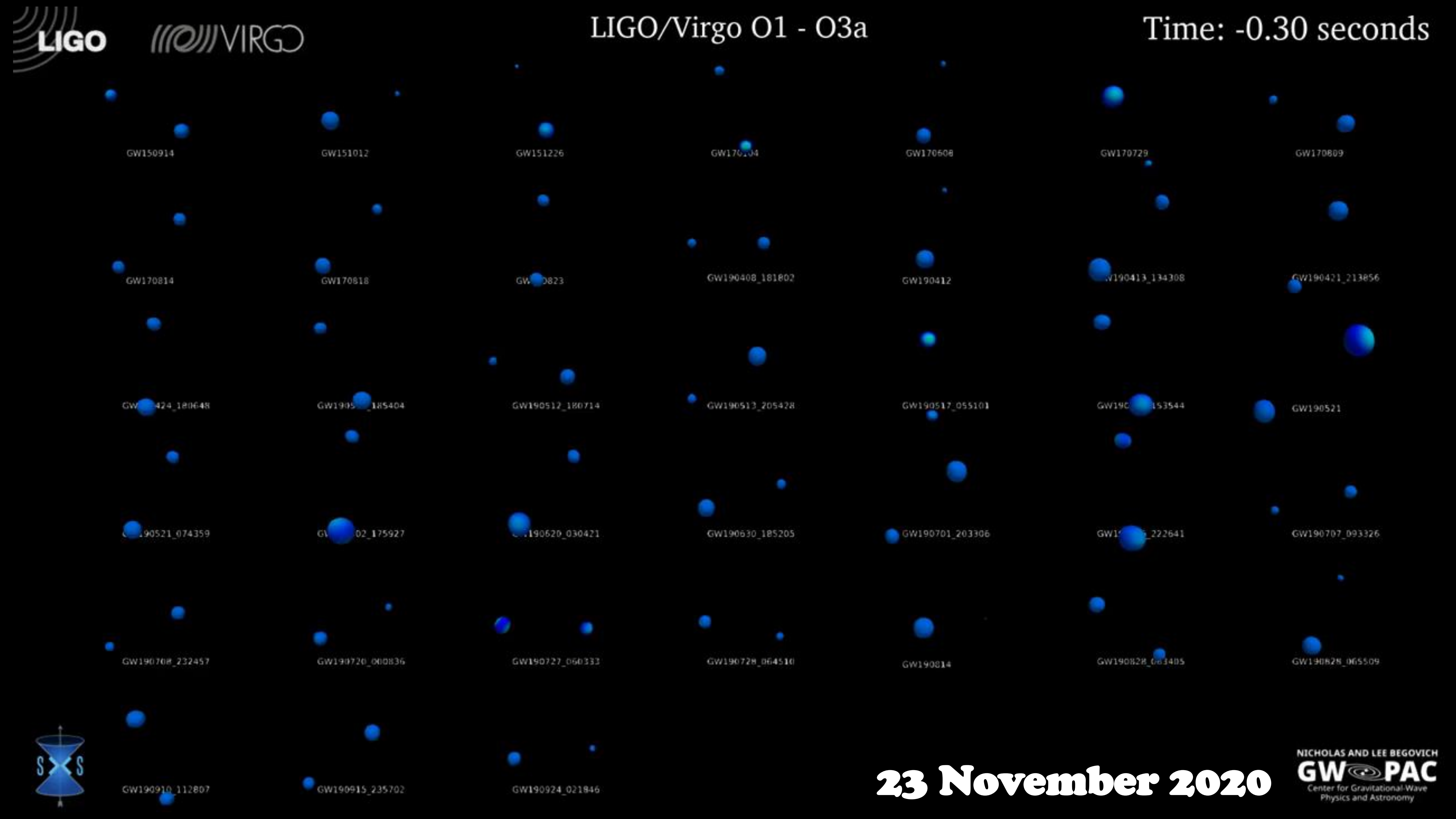
Barry C. Barish – Kip S. Thorne – Rainer Weiss

Credit: JONATHAN NACKSTRAND/AFP/Getty Images/Pi Frisk

GRAVITATIONAL-WAVE TRANSIENT CATALOG-1

1 Dicembre 2018

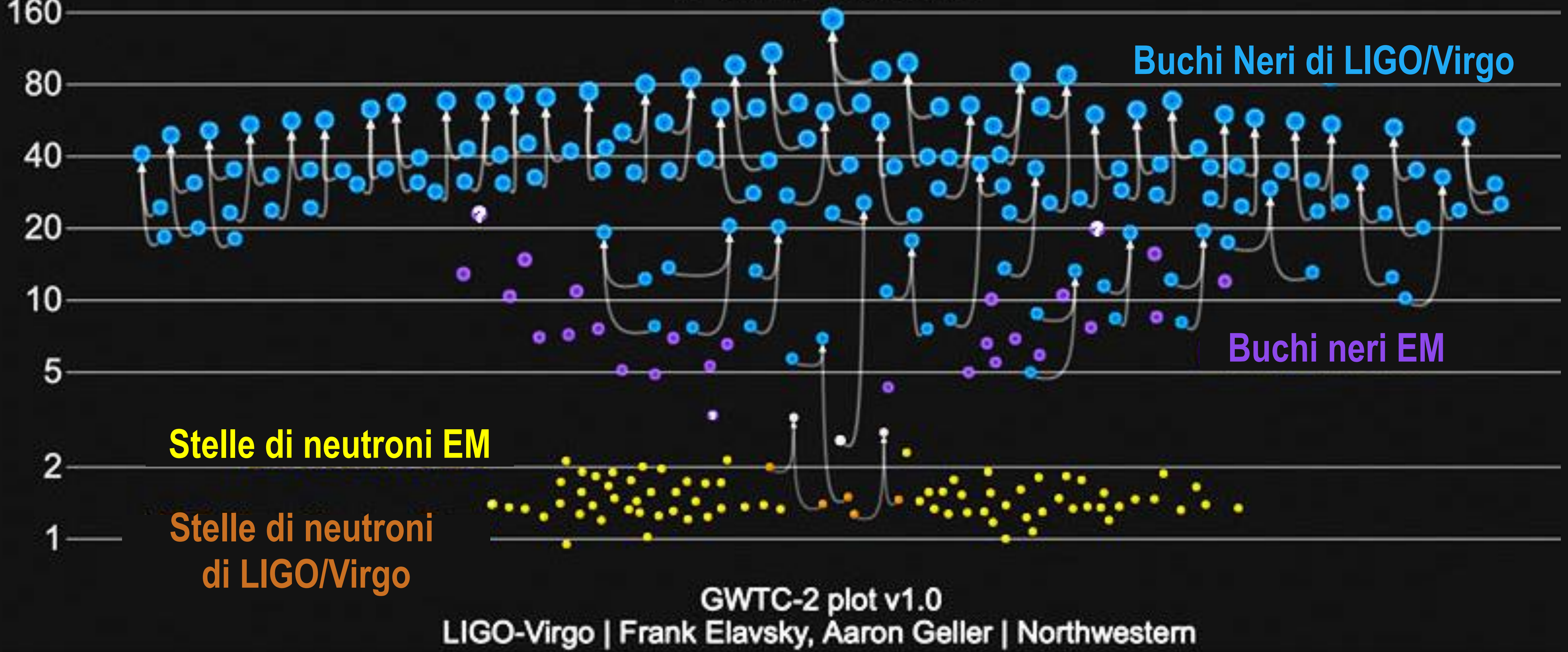




23 November 2020

Masse Nel Cimitero Stellare

In Masse Solari



23 November 2020

Grazie per l'attenzione

Credit: NASA; ESA; G. Illingworth, D. Magee, and P. Oesch, University of California, Santa Cruz; R. Bouwens, Leiden University; and the HUDF09 Team, 2012)