The Universe Speaks

LIGO & the attempt to detect Gravitational Waves

With funding from the National Science Foundation PHY-0757058

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By William Katzman, LIGO-SEC Program Leader

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Speaking through light

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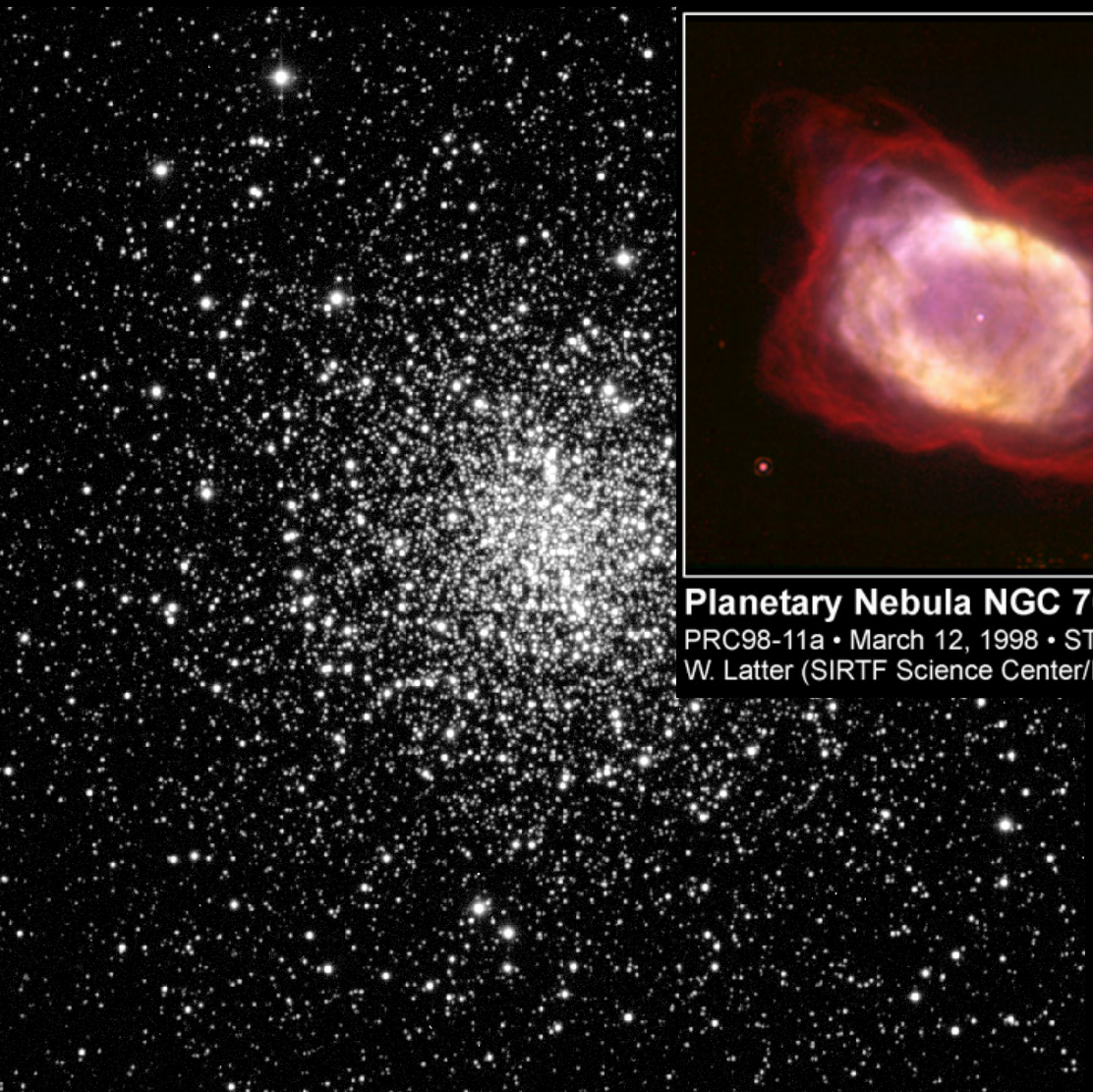
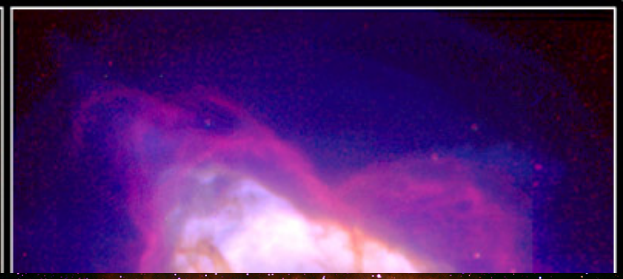


Planetary Nebula NGC 7027
PRC98-11a • March 12, 1998 • ST ScI OPO
W. Latter (SIRTF Science Center/IPAC/Caltech) and NASA

HST • NICMOS • WFPC2

Speaking through light



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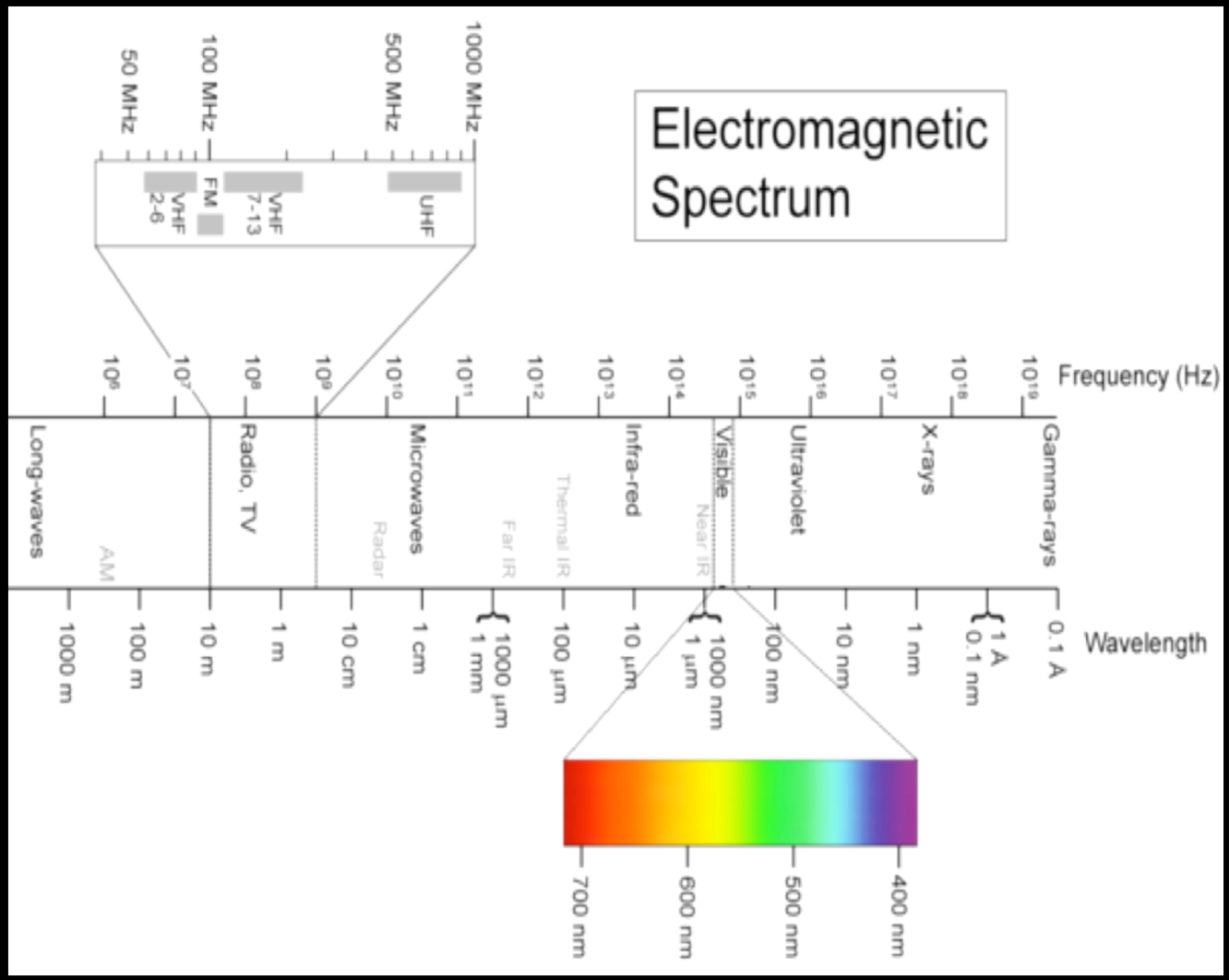
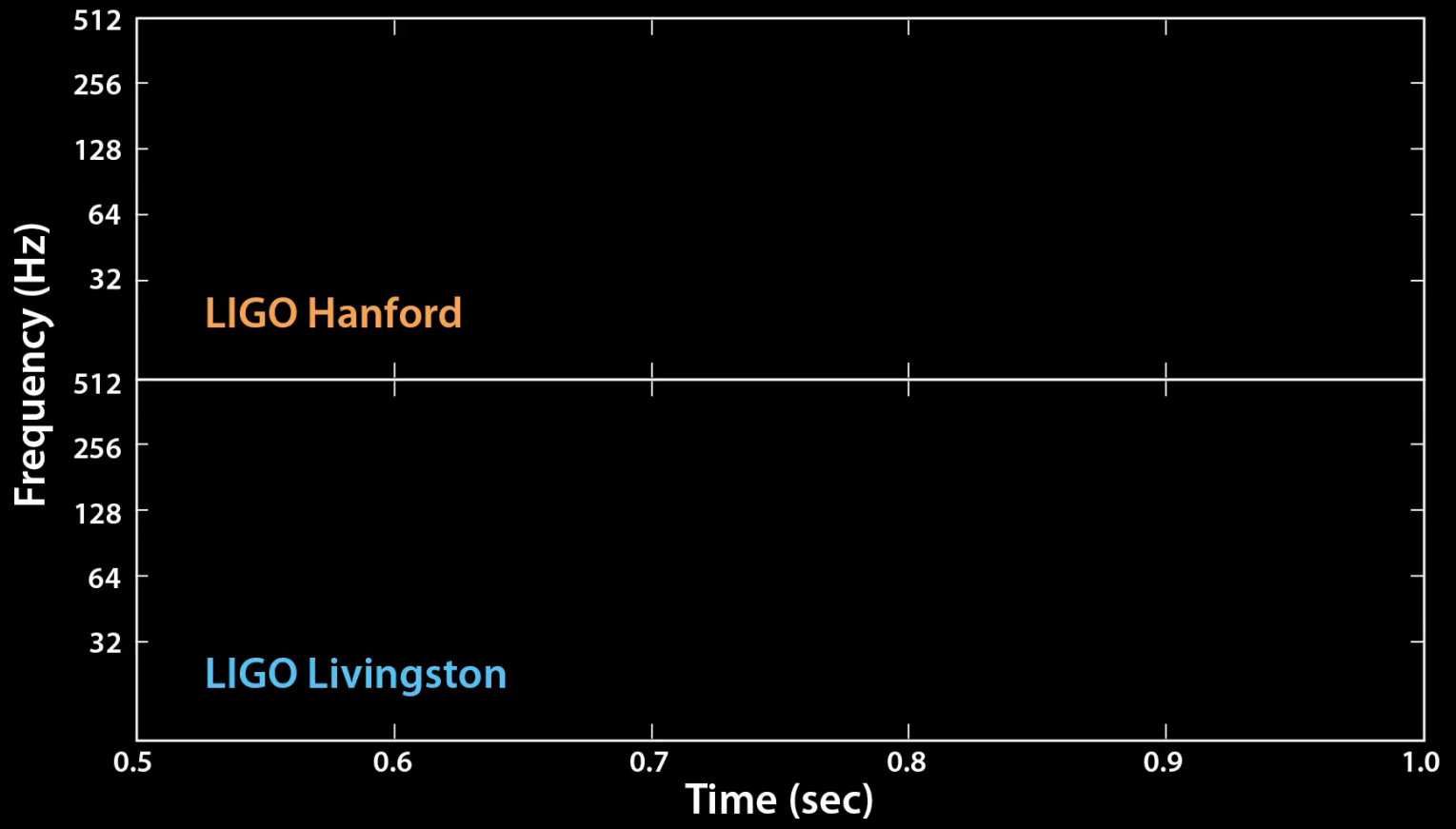
Speaking through light

Spectrum


Electromagnetic Spectrum
Frequency (Hz)
Wavelength
Gamma-rays
X-rays
Ultraviolet
Visible
Infra-red
Microwaves
Radio, TV
Long-waves
Near IR
Thermal IR
Far IR
Radar
AM
UHF
VHF 7-13
FM
VHF 2-6
1000 MHz
500 MHz
100 MHz
50 MHz
0.1 Å
1 Å
1 nm
10 nm
100 nm
1000 nm
1 µm
10 µm
100 µm
1000 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1000 m
400 nm
500 nm
600 nm
700 nm

What if we could hear the universe?



LIGO
Gravitational Wave Observing

- Visible light, radio waves, ultraviolet, infrared, microwaves, gamma rays are all electromagnetic waves – or LIGHT!

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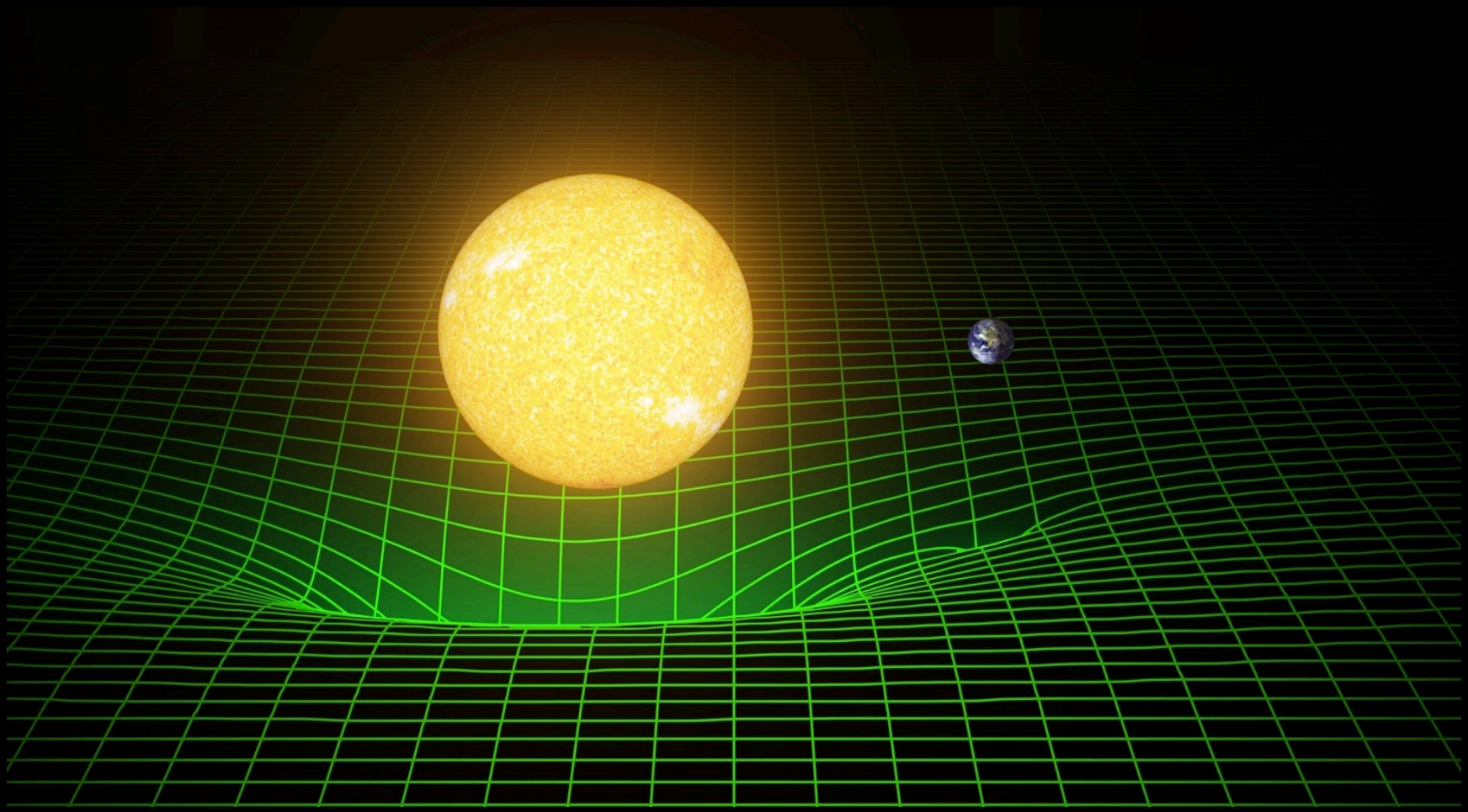
- Light can be blocked & scattered…Gravity waves can’t (practically speaking)
- Light travels through space & time – gravity is a change OF space-time
- Shake a charge you get light.
- Shake a mass you get a gravitational wave.

Newton's Gravity

Two Masses attract at a distance.
If the sun were to disappear the planets fly off in a straight line immediately.

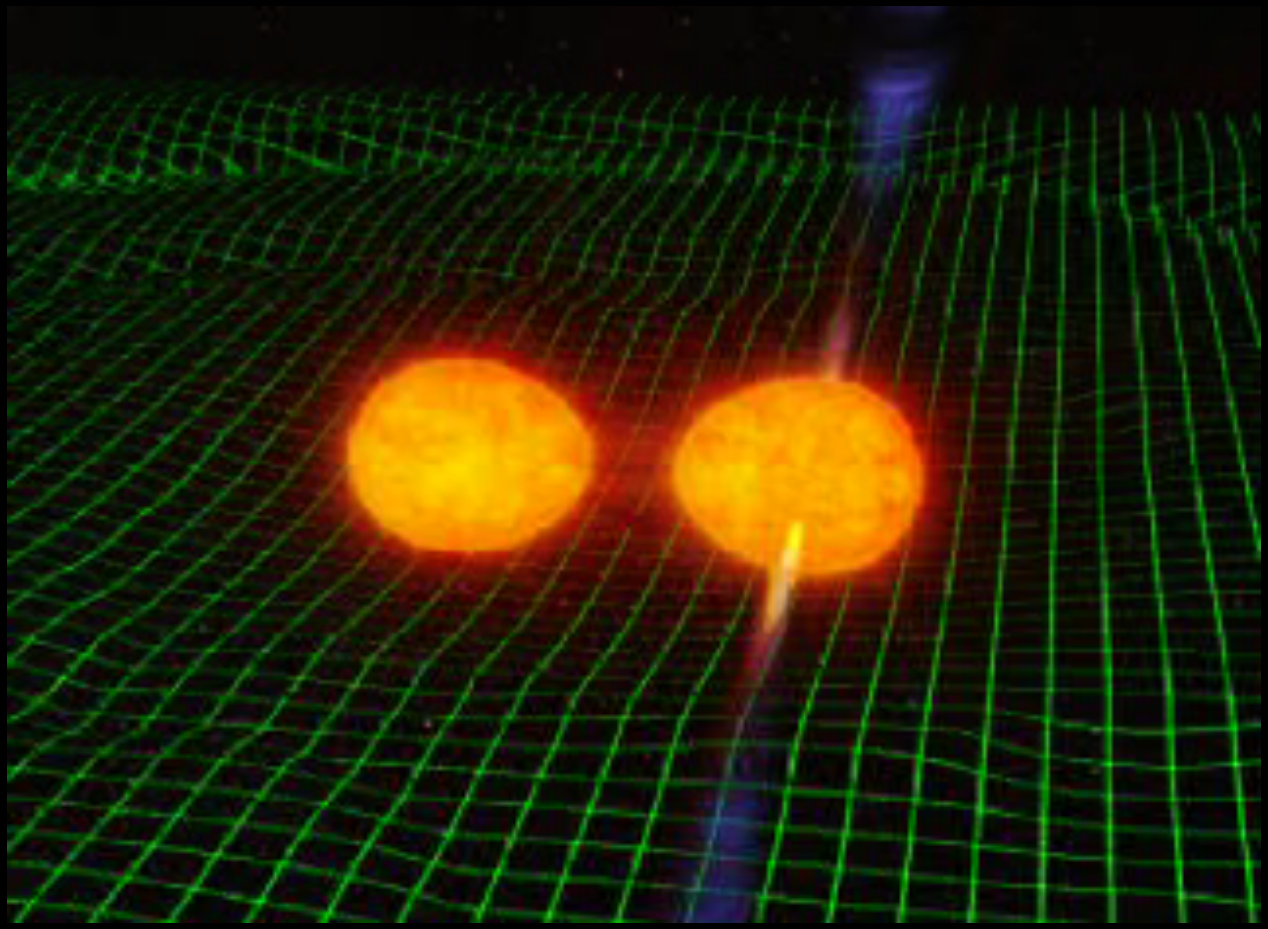
Einstein's Gravity



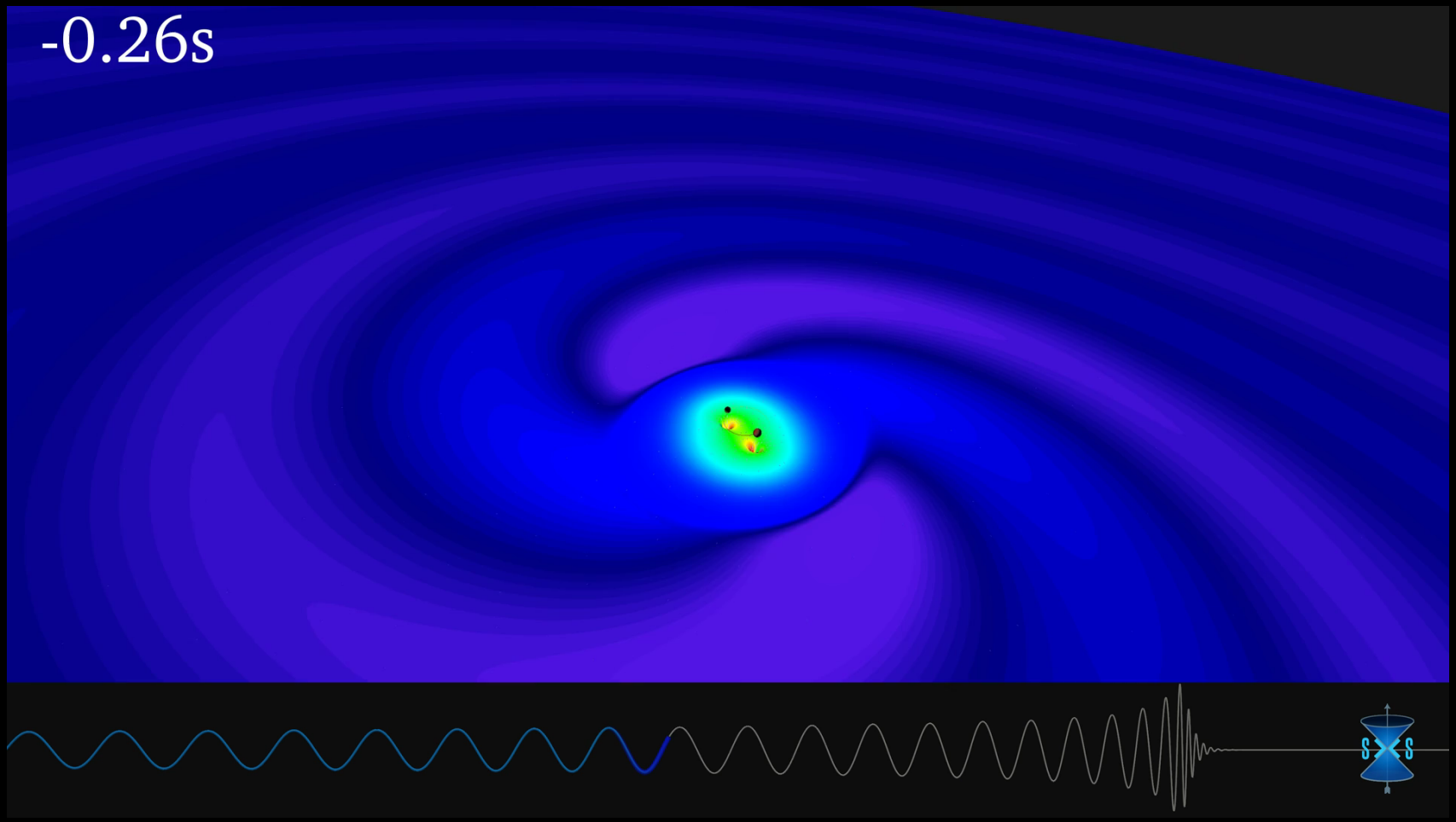
Warped Spacetime – Gravity Fields

- We can use Lycra/Spandex on embroidery hoops to model spacetime & a metal sphere as a star.
- A wave in that fabric is the analogue to a gravitational wave.

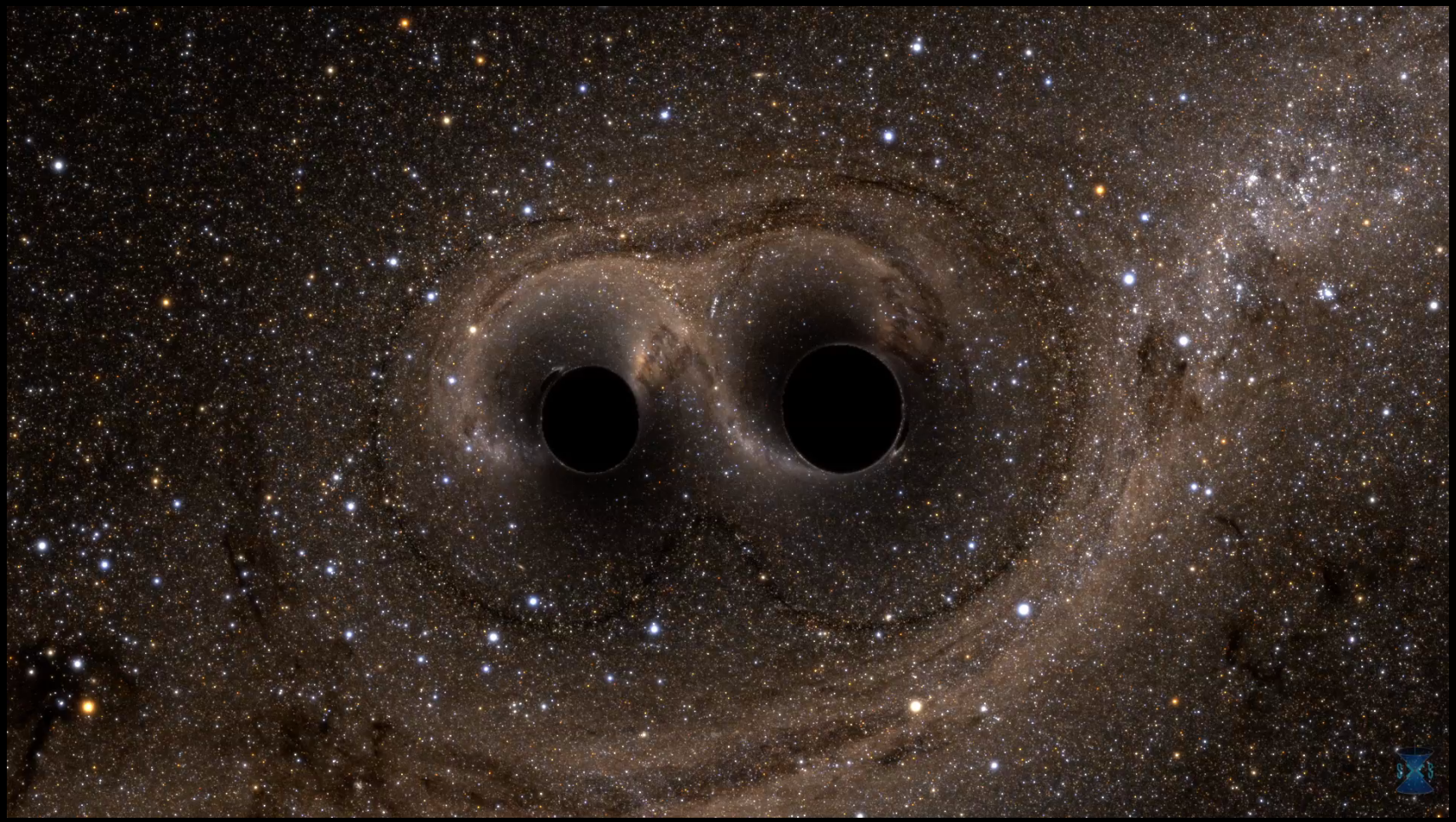
Gravitational Waves



If we could see space-time…



What if we were there?

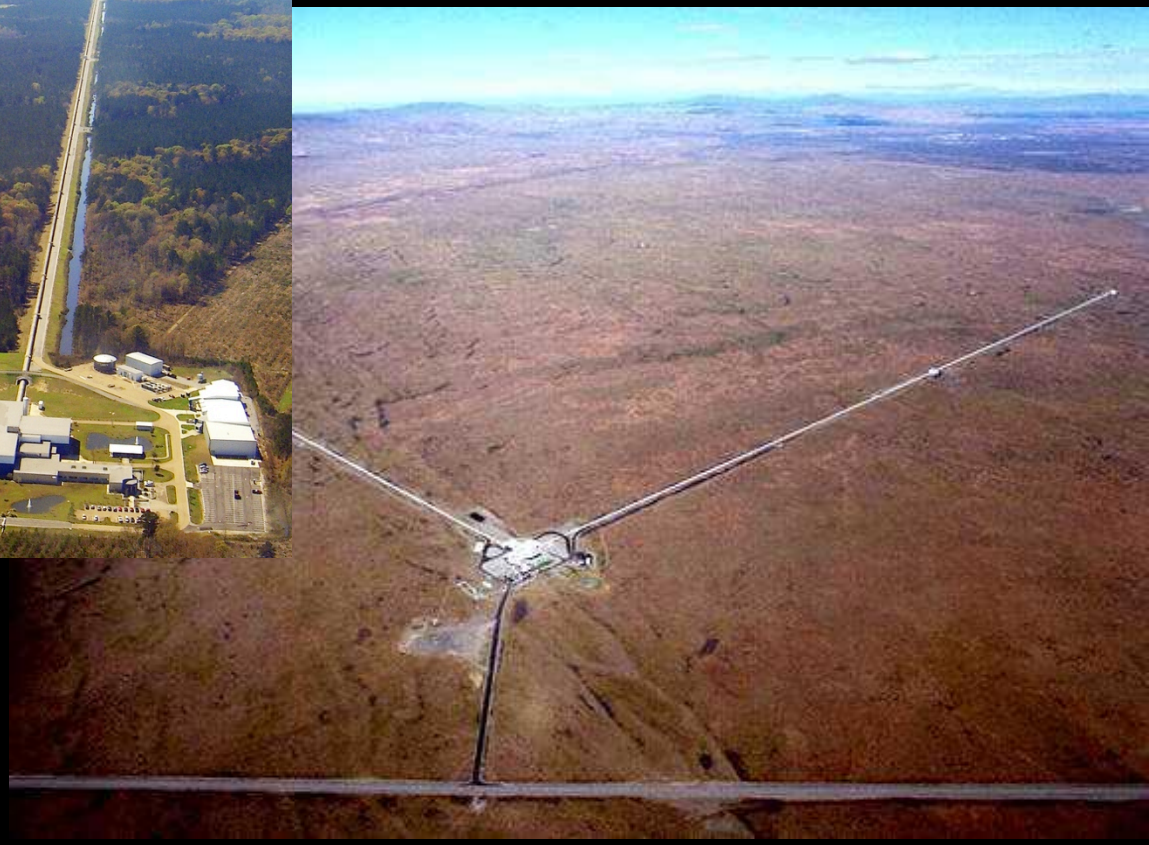


What is a black hole?

- The escape velocity is greater than the speed of light.
- Light is the universe's speed limit.
- Radius of a black hole (non-spinning):
  $r = (2MG)/ c^2$ where r is radius M is the mass, G is a constant c is the constant of the speed of light
- radius = Mass x 1.5 x 10^{-27} meters/kg

The Observatory

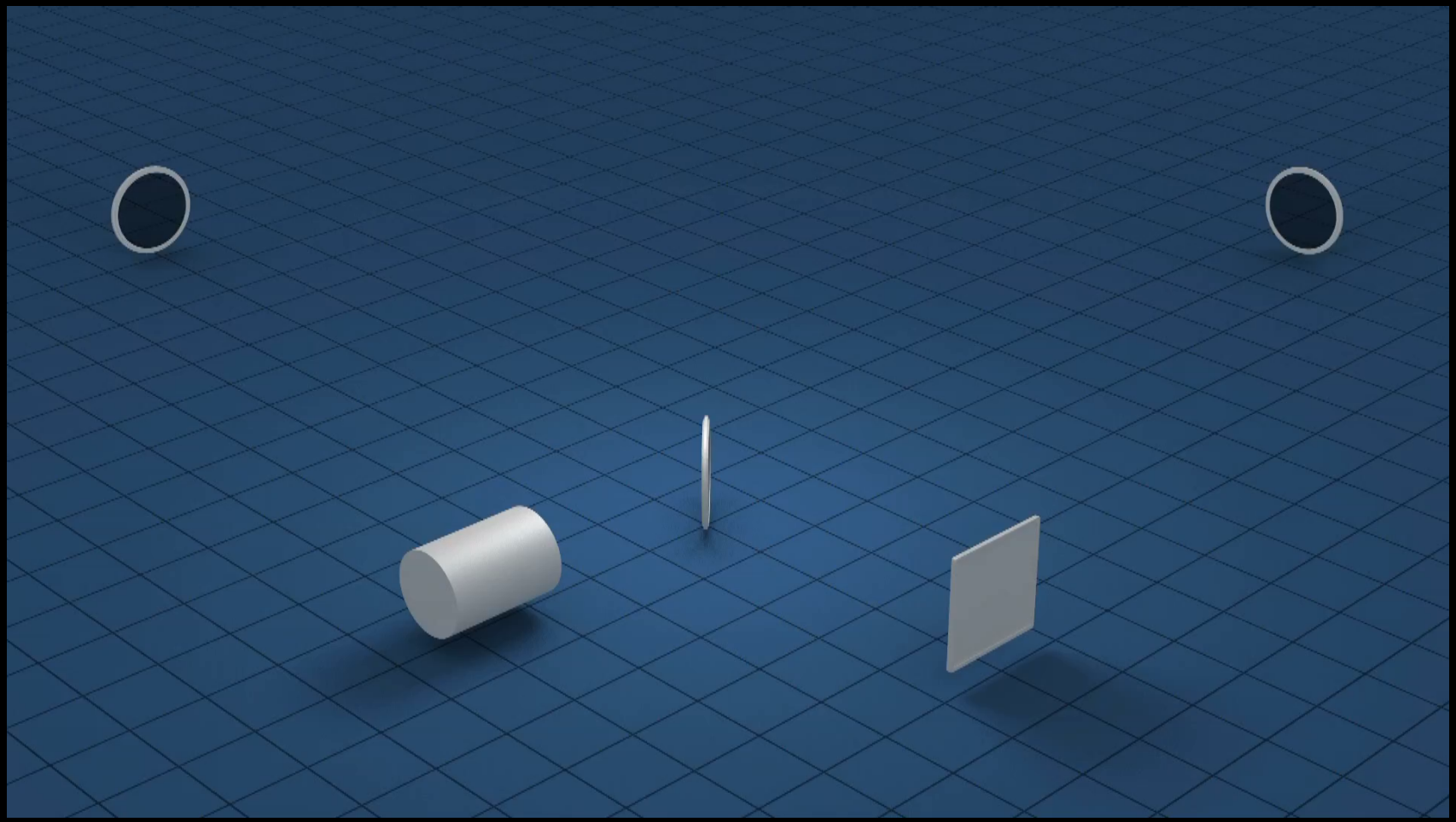
← Livingston, Louisiana



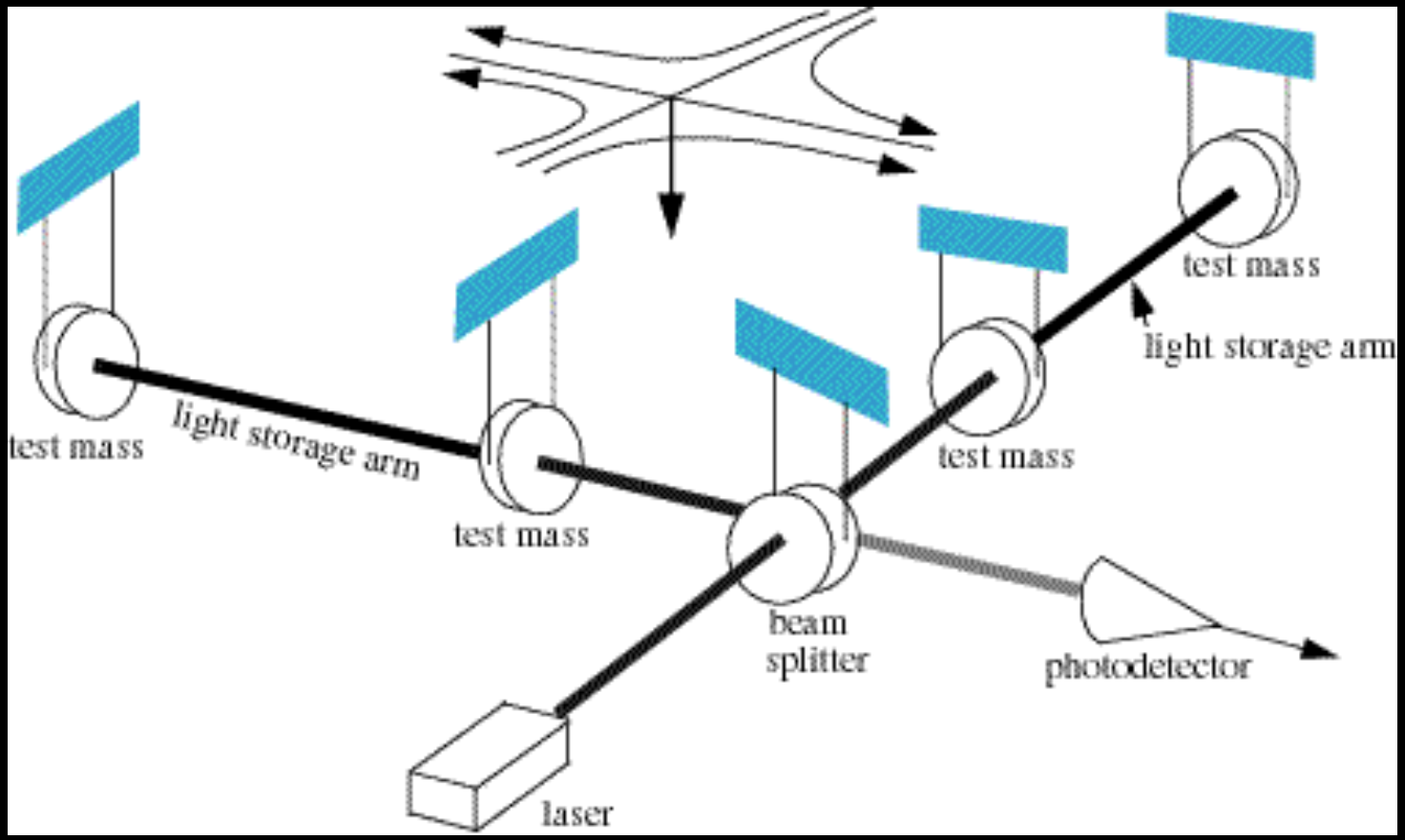
Hanford, Washington →

Supported by NSF grants PHY-0917587, PHY-1506037, PHY-0757058

Laser Interferometer



The improved laser interferometer



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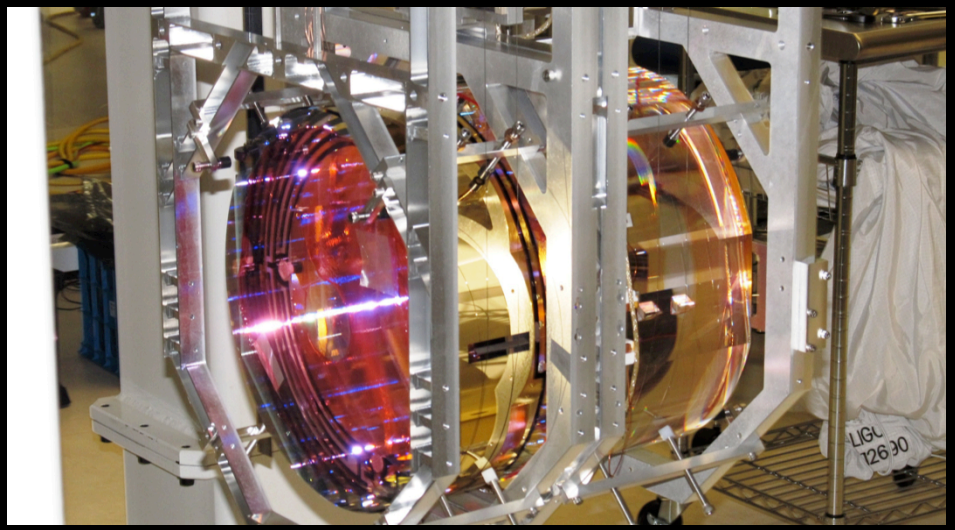

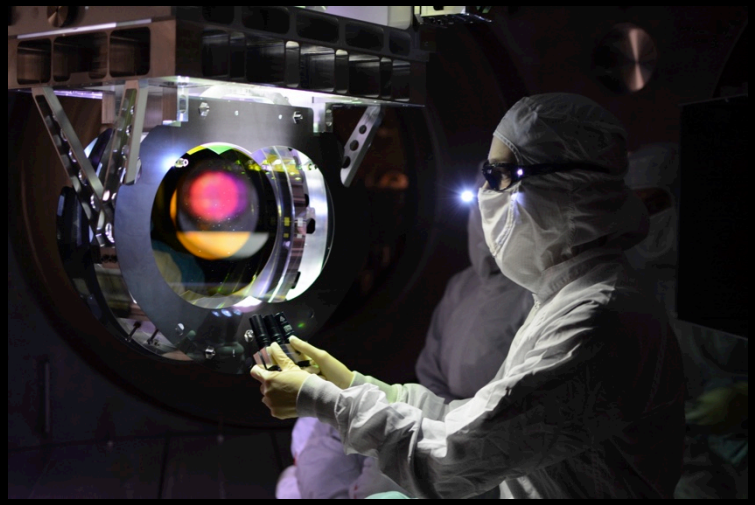

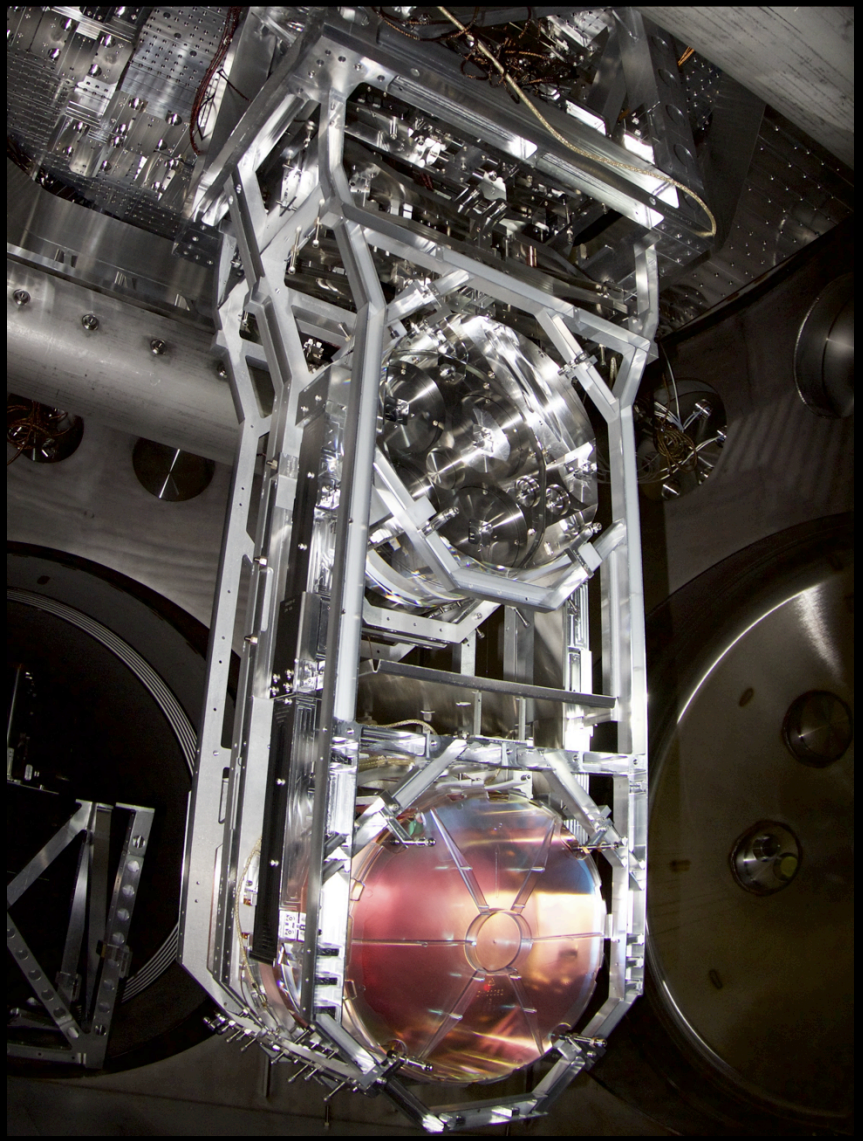

Our Control room

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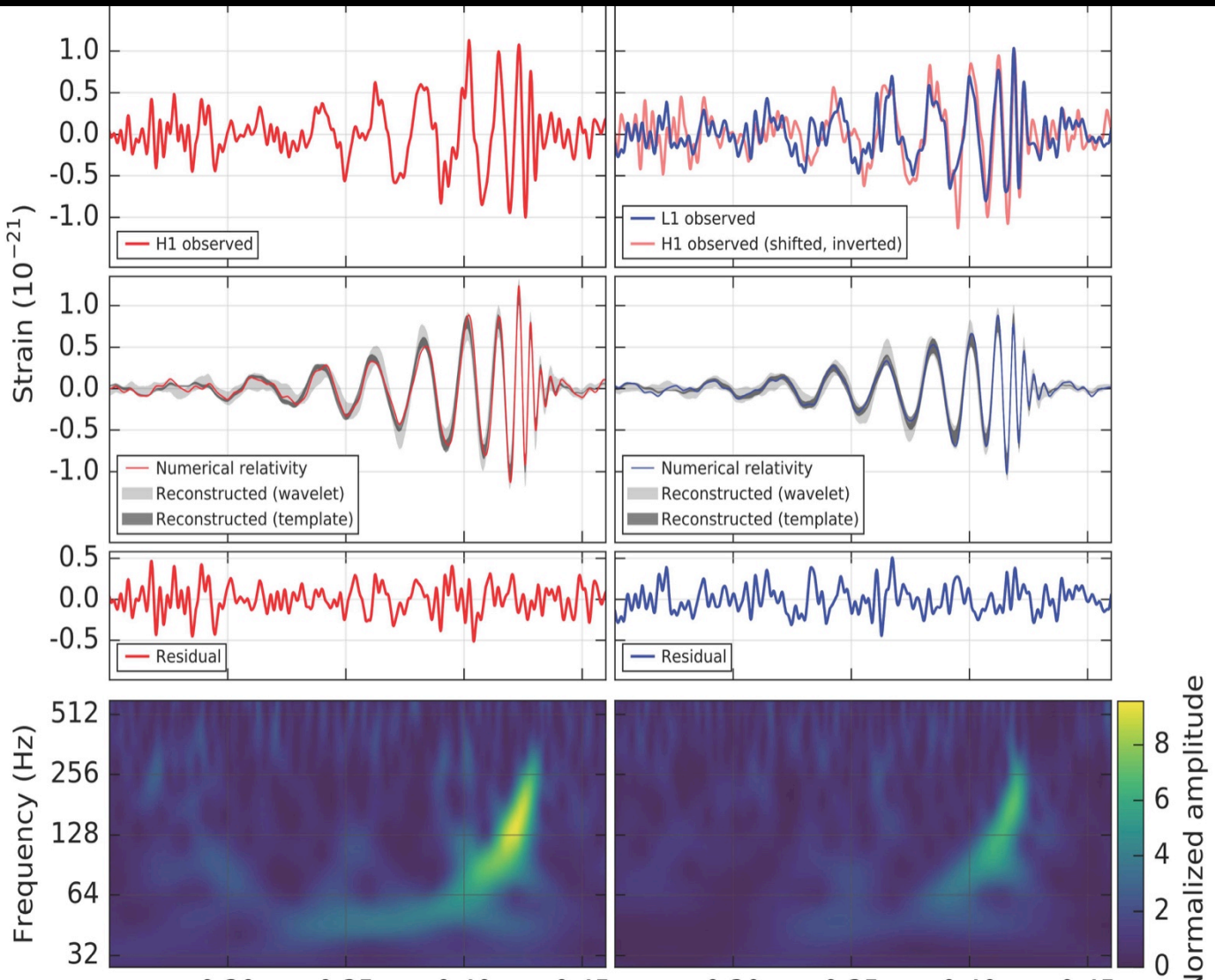
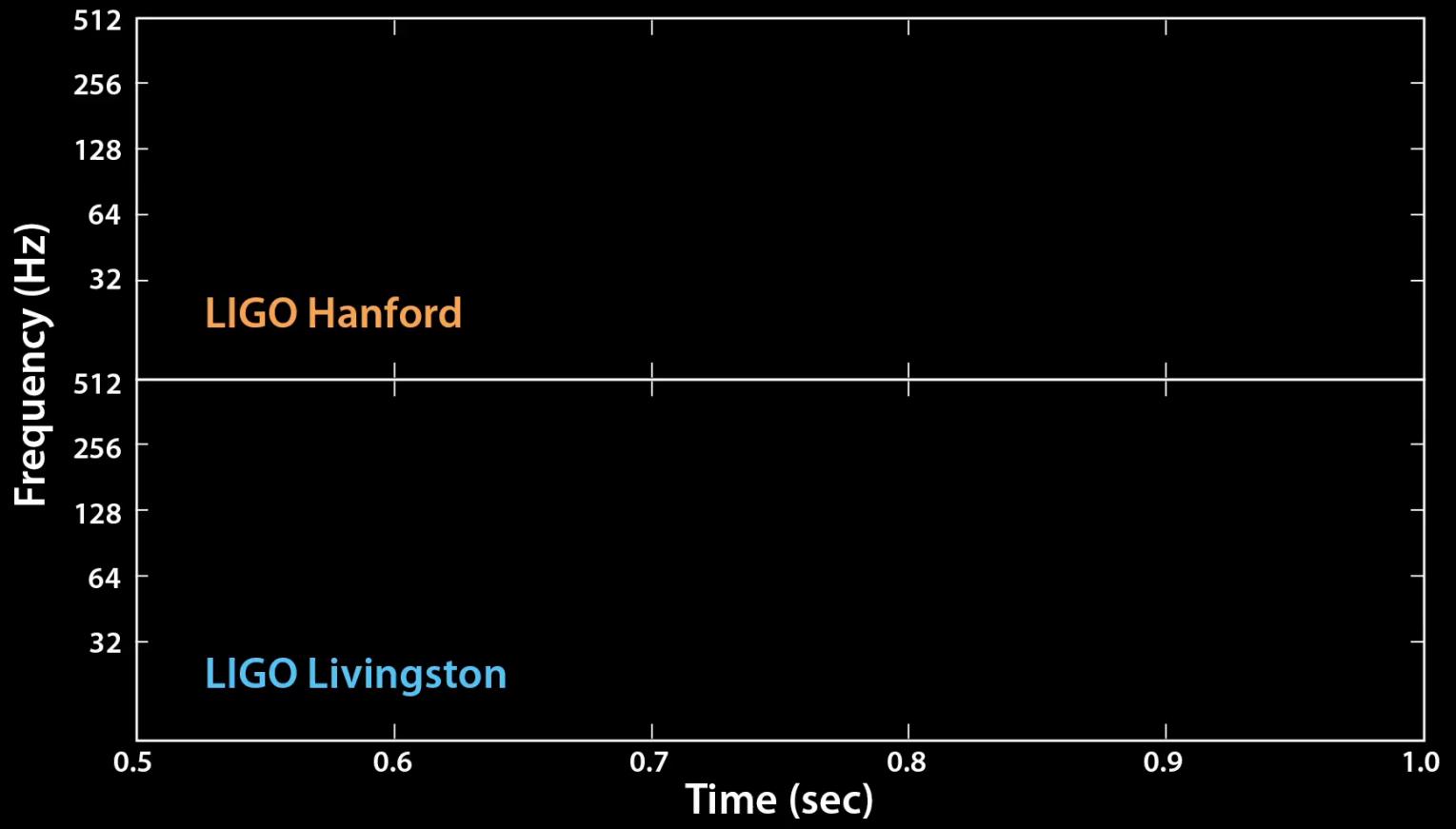
What we saw GW150914

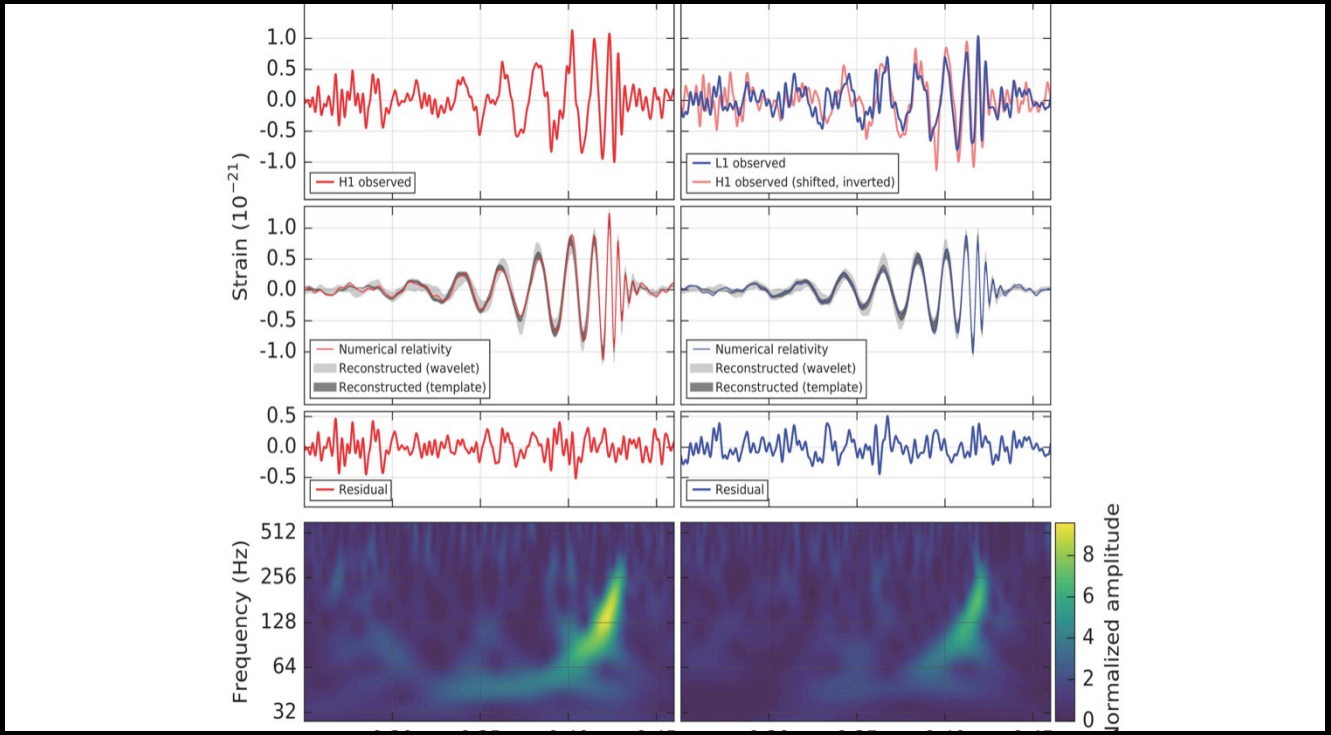


What we “heard” GW150914



Two black holes collide

- Frequency change



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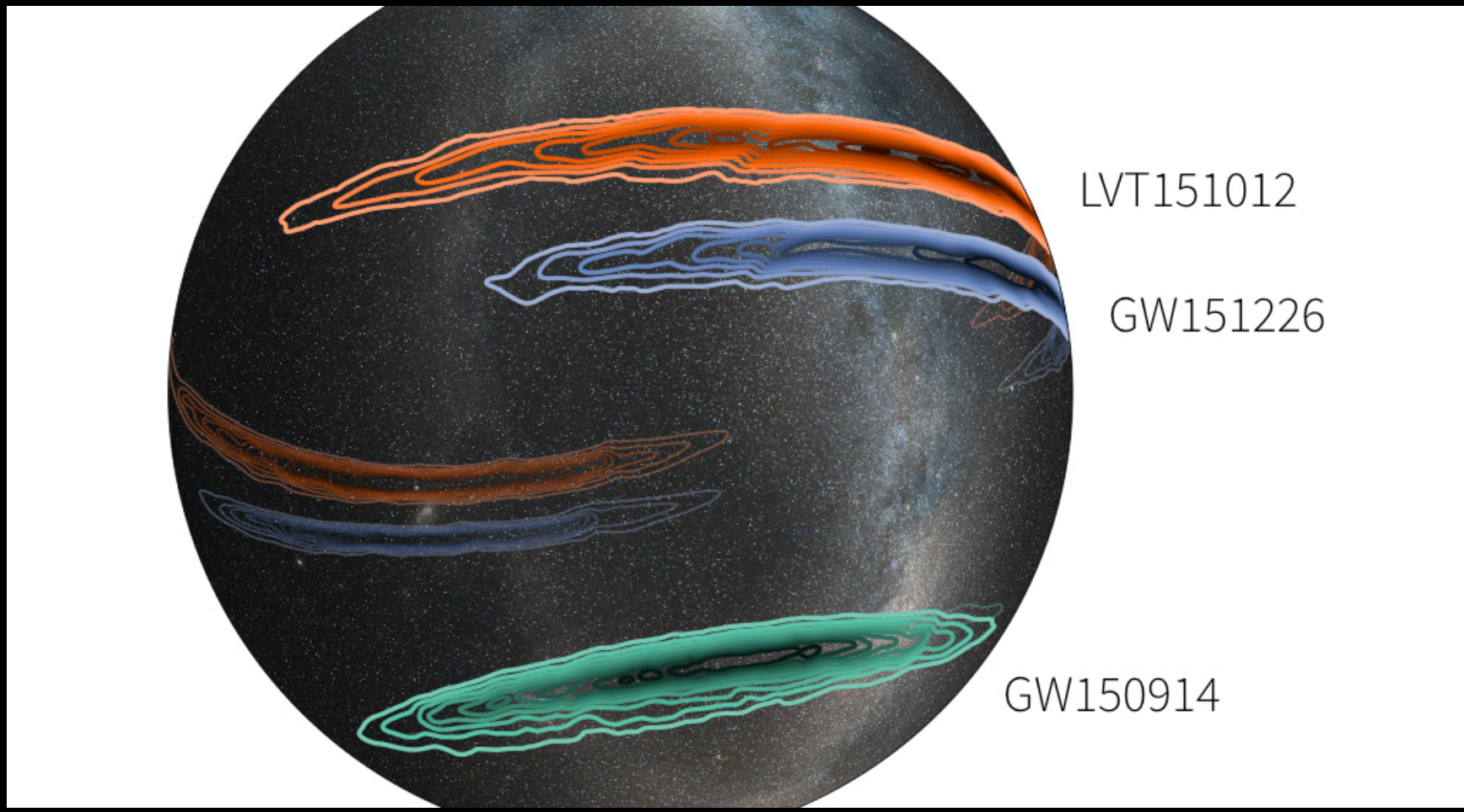
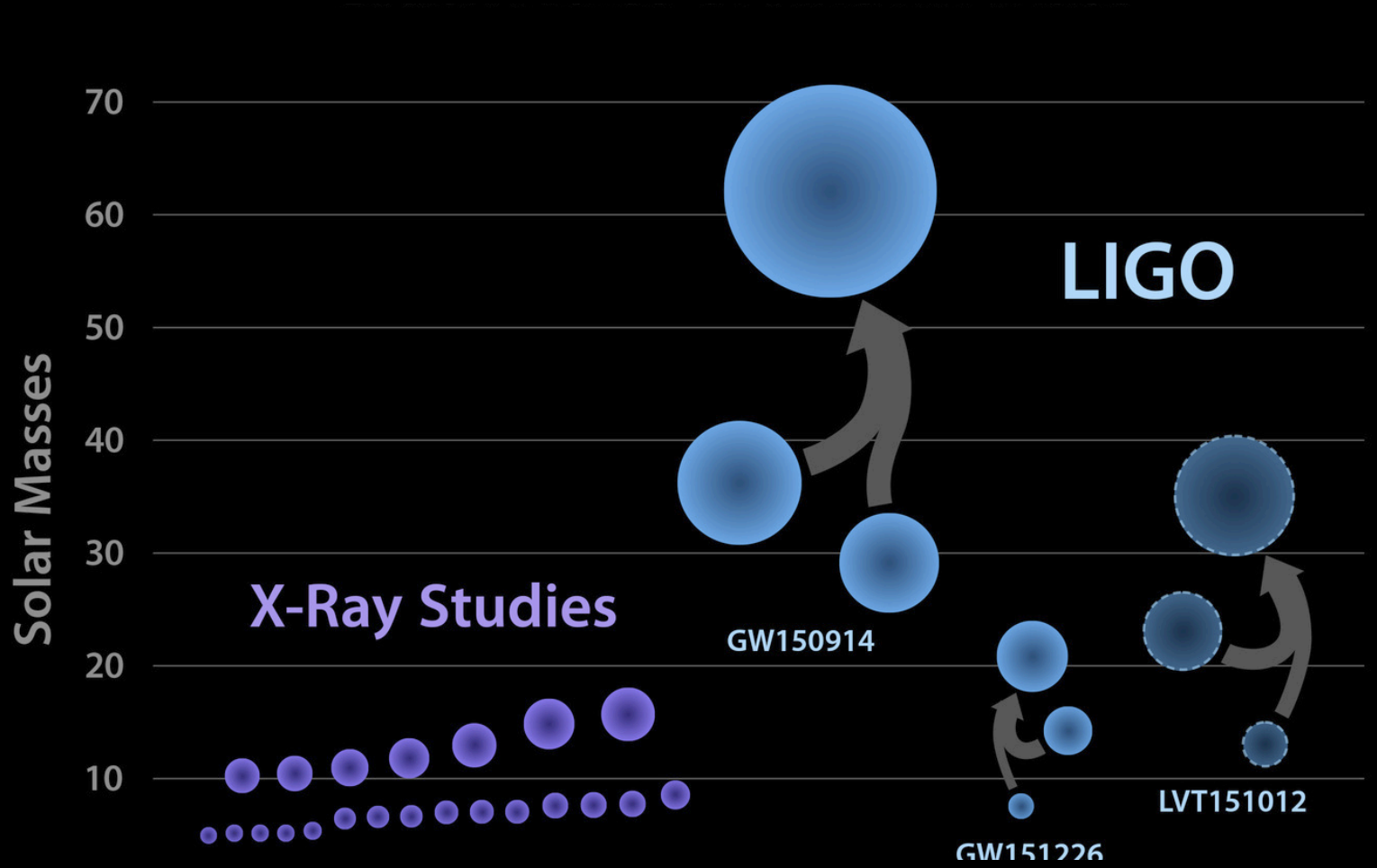
- Just the beginning…other instruments such as LISA and the Pulsar Timing Array

What we've seen so far…



Black Holes currently detected



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- Future results…?

Journey of a G wave

Partially funded by the National Science Foundation