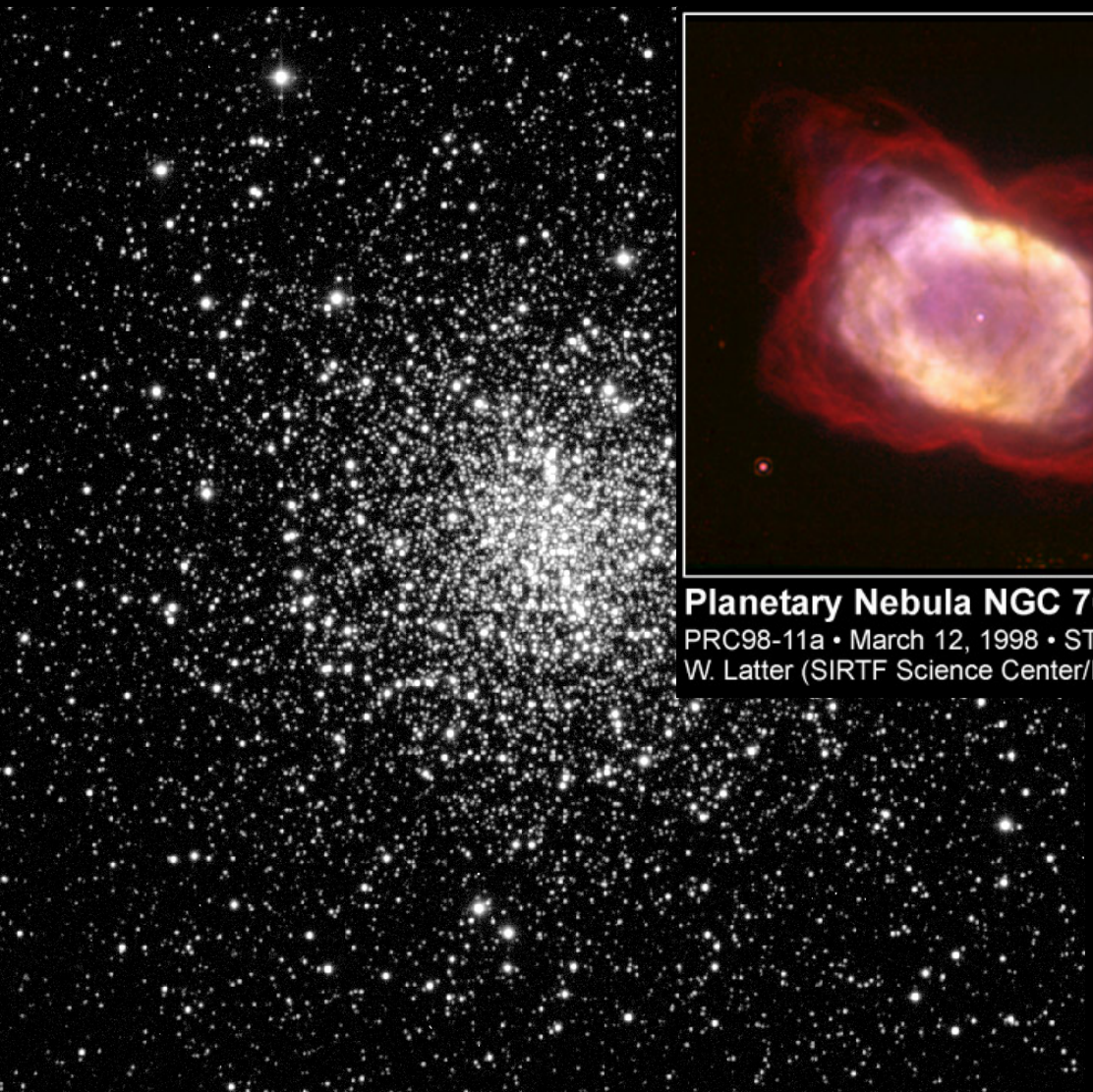
The Universe Speaks

LIGO & the attempt to detect Gravitational Waves

With funding from the National Science Foundation PHY-0757058
Document: **LIGO-G1601300**

Speaking through light

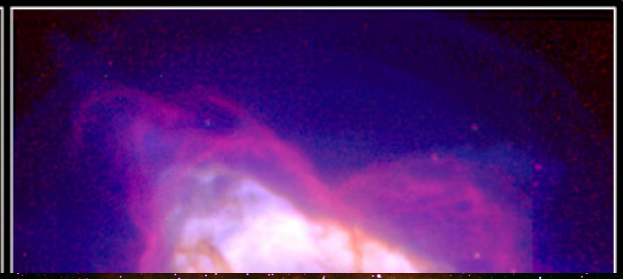
Speaking through light



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

HST • NICMOS • WFPC2

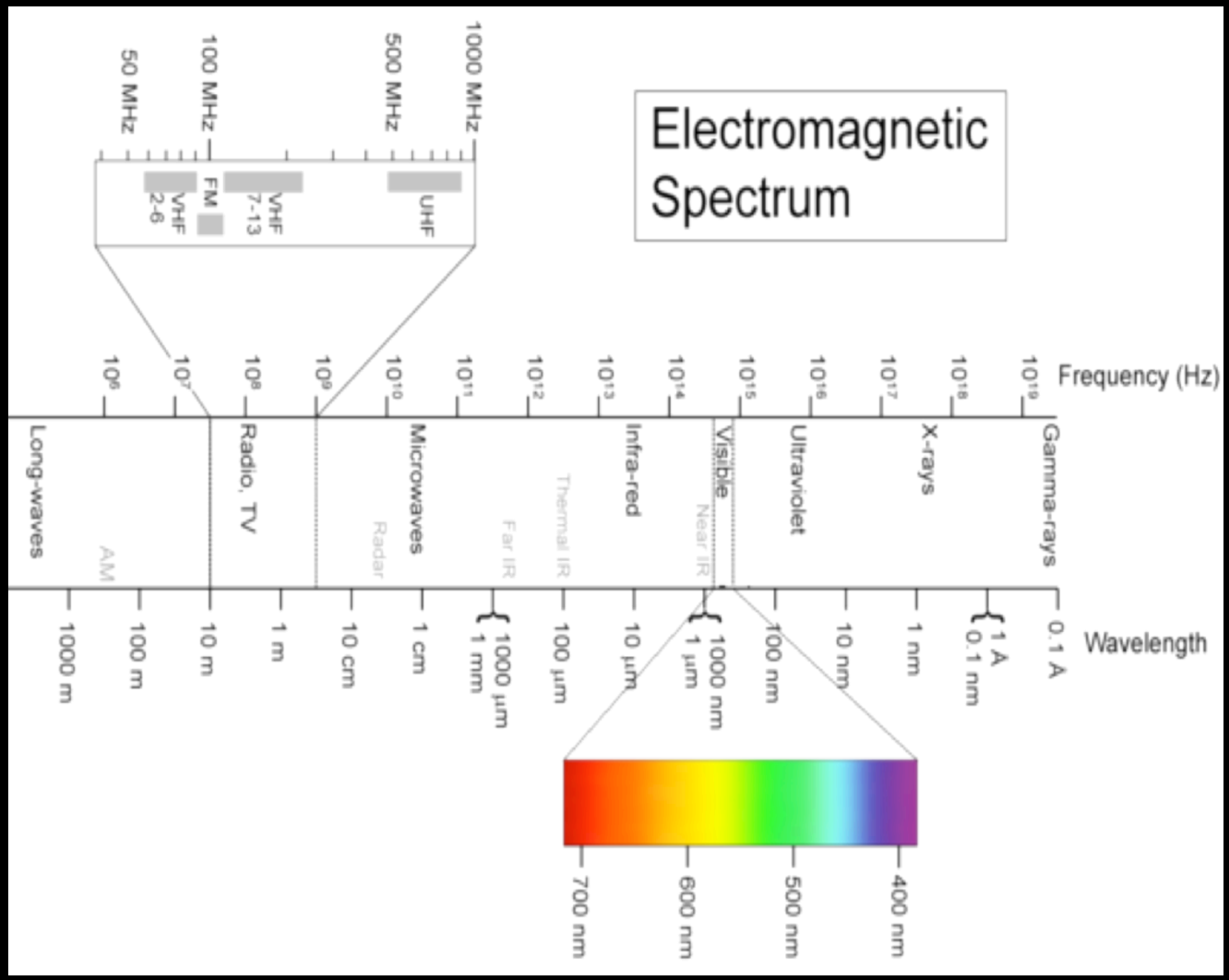
Speaking through light



Planetary Nebula NGC
PRC98-11a • March 12, 1998 •
W. Latter (SIRTF Science Cente

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

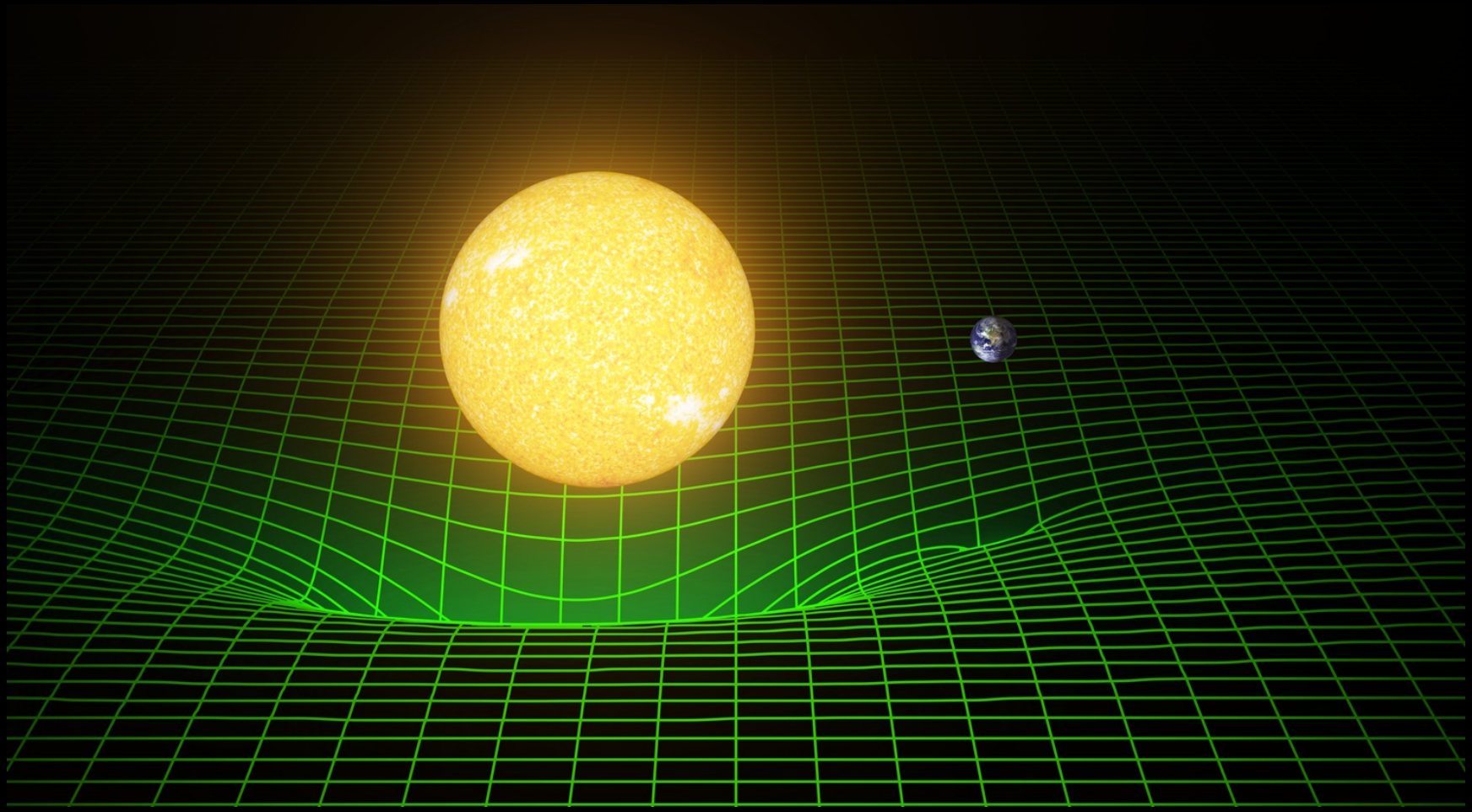
LIGO
Gravitational Wave Observing

- Visible light, radio waves, ultraviolet, infrared, microwaves, gamma rays are all electromagnetic waves – or LIGHT!
- Light can be blocked & scattered…Gravity waves can’t (practically speaking)
- Light travels through space & time – gravity is a change OF space & time

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



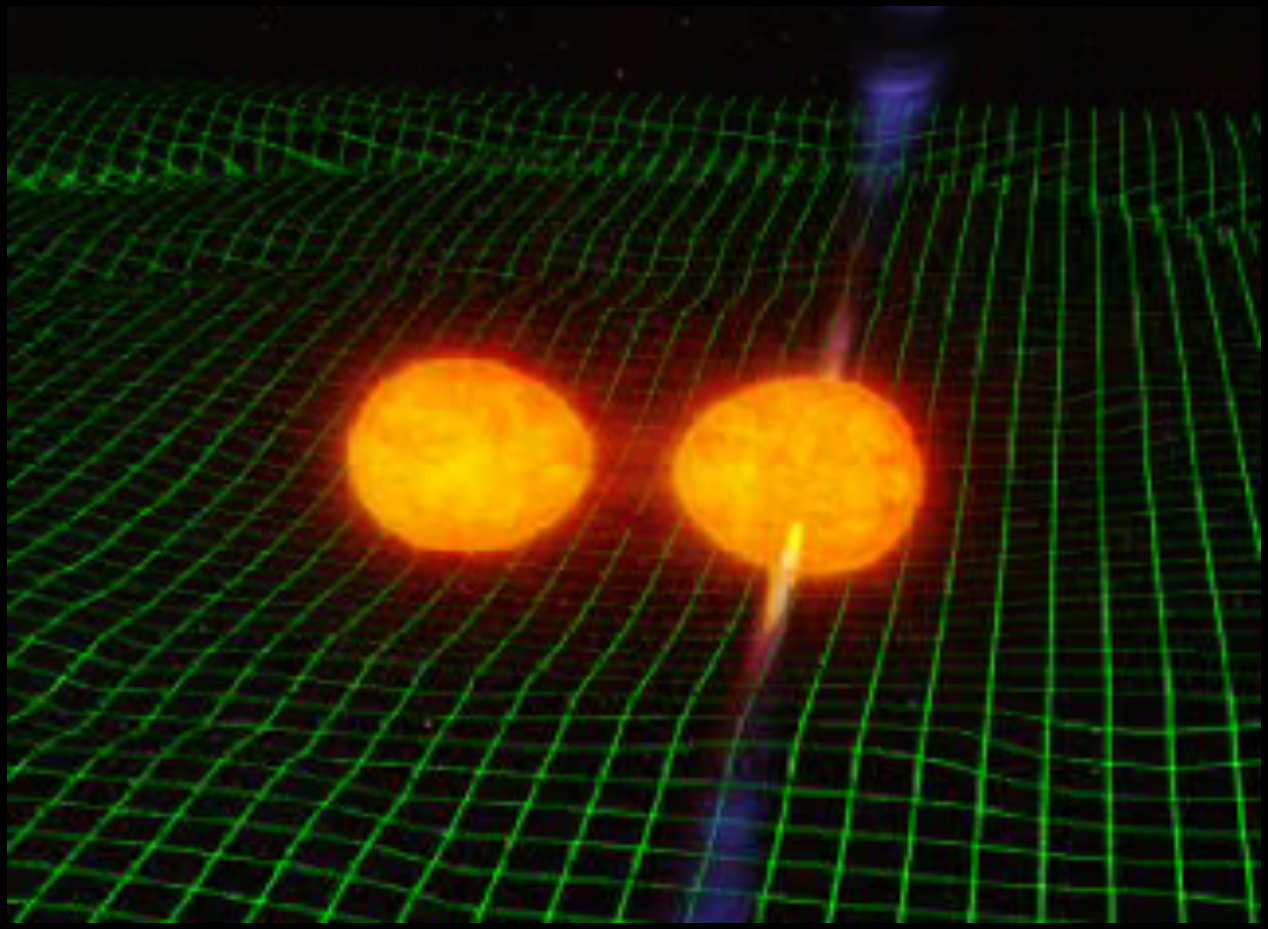
Warped Spacetime – Gravity Fields

- Here we use Lycra/Spandex on embroidery hoops to model spacetime & a metal sphere as a star.
- Roll a ball across fabric while on the table.
- Lift it up – how is it different? Now roll a ball…
- What happens when you just let go of a ball?
- What happens if you send a heavy ball around the light ball?
- This is a model – what are its strengths and weaknesses?

Warped Spacetime – Gravity Fields 2

- Get 2 balls orbiting each other (if you can)
- Does the distance change from flat space to curved space? How?
- If 2 balls lay next to each other does the distance change the same in each direction?
- This is a model – what are its strengths and weaknesses?

Gravitational Waves



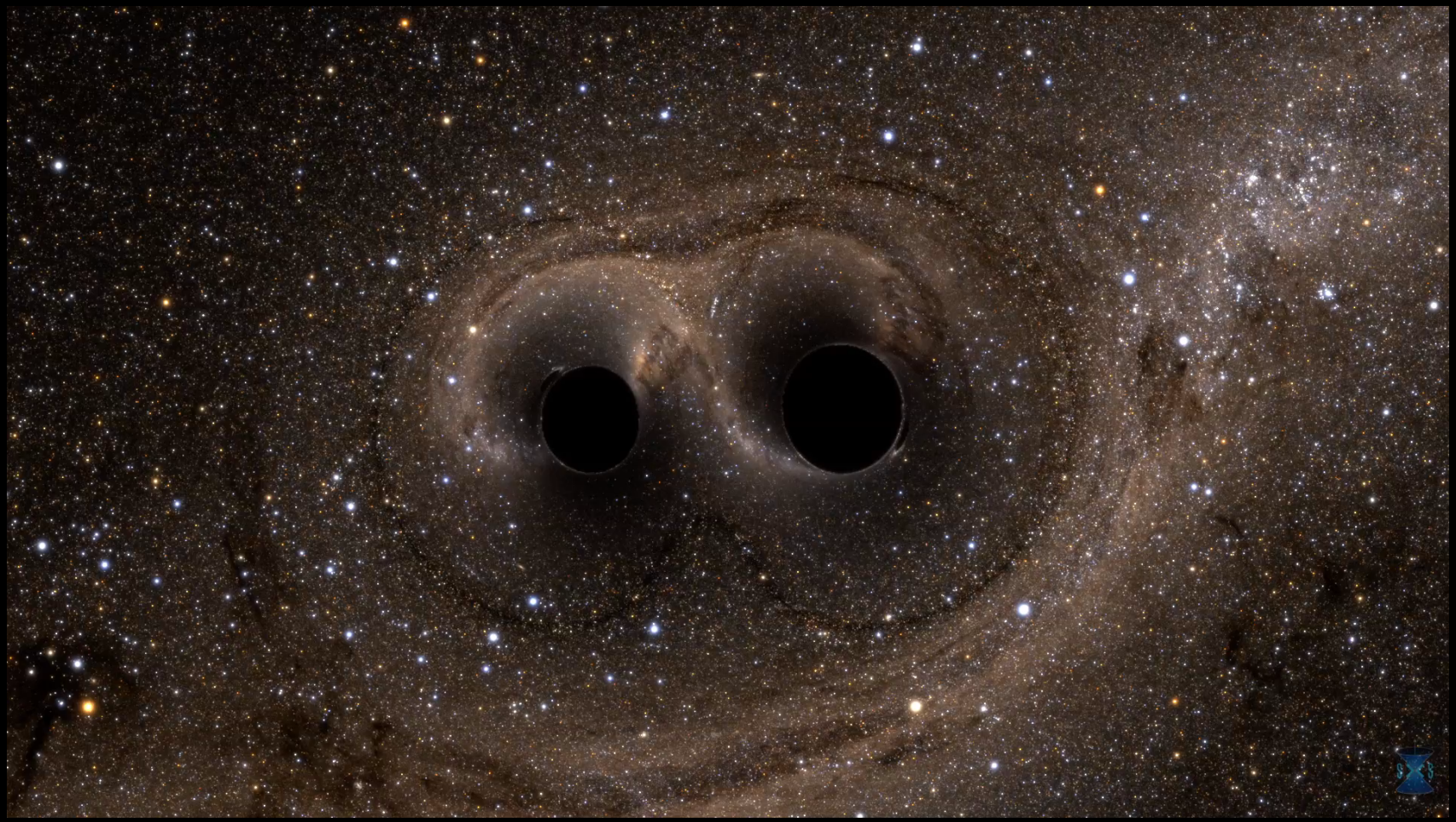
Warped Spacetime & Lensing

- Lay the fabric hoop on the table with a big metal sphere on it. Now lay down 2 parallel pieces of tape – without wrinkling the tape – is it possible?
- Pick up the fabric hoop – what happens to the tape? Re-lay down the tape keeping the tape absolutely flat – what happens?

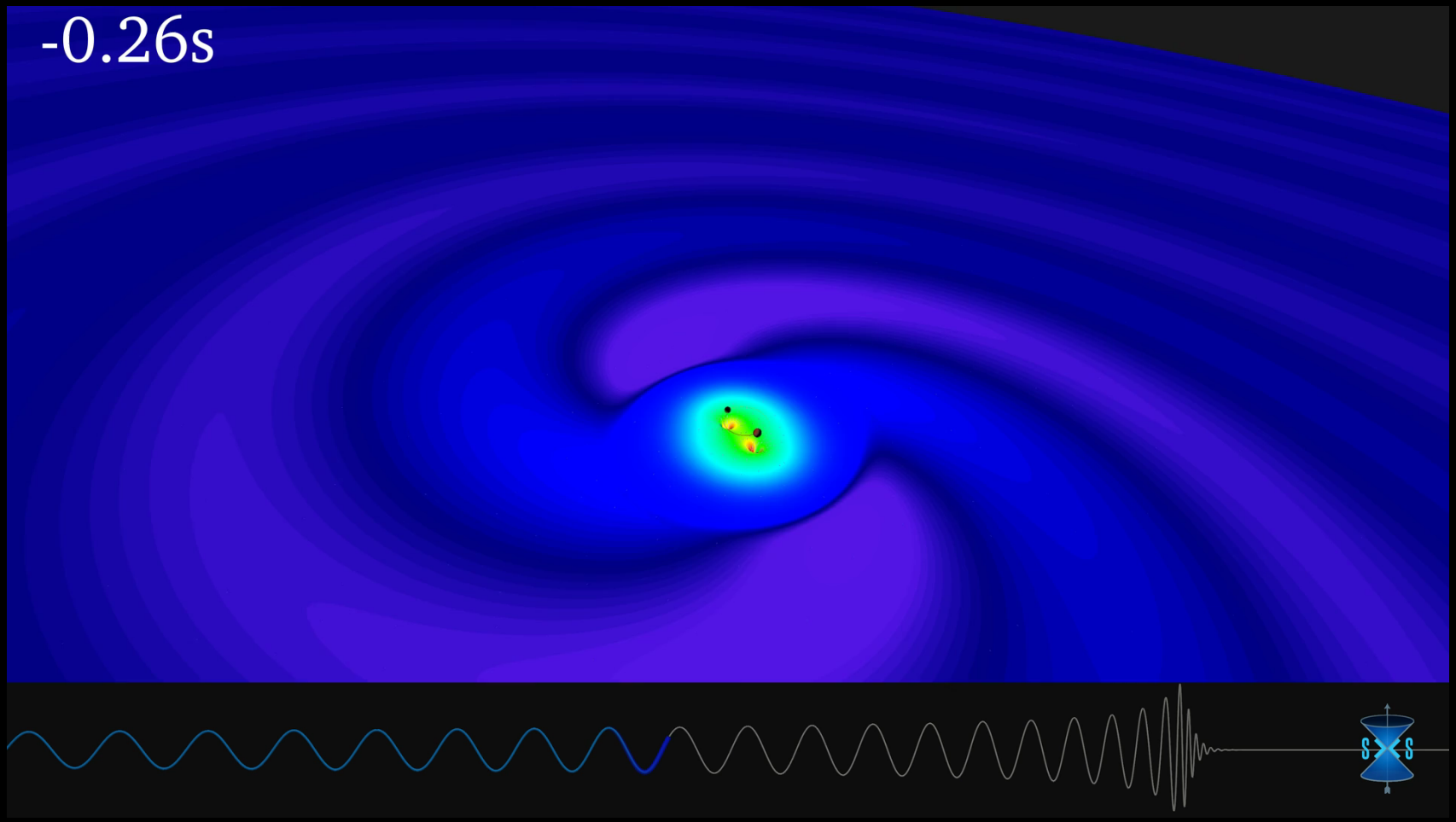
Gravitational Lensing

- Look through the base of a wine glass on top of graph paper – notice the distortions.
- Aim the wine glass at a Maglite bulb, and see if you can get a ring a the base of the wine glass.

What if we were there?



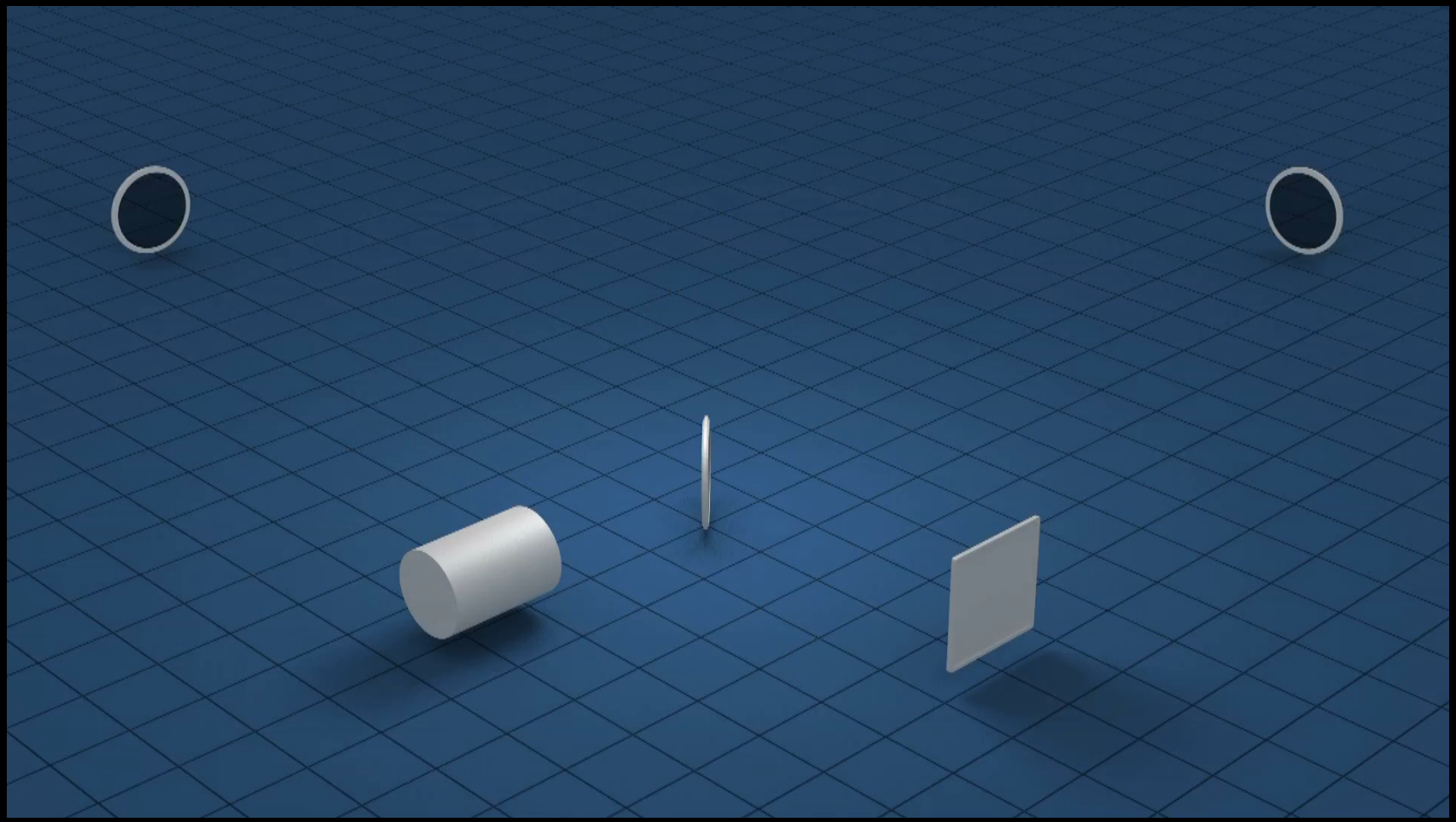
If we could see space-time…



What is a black hole?

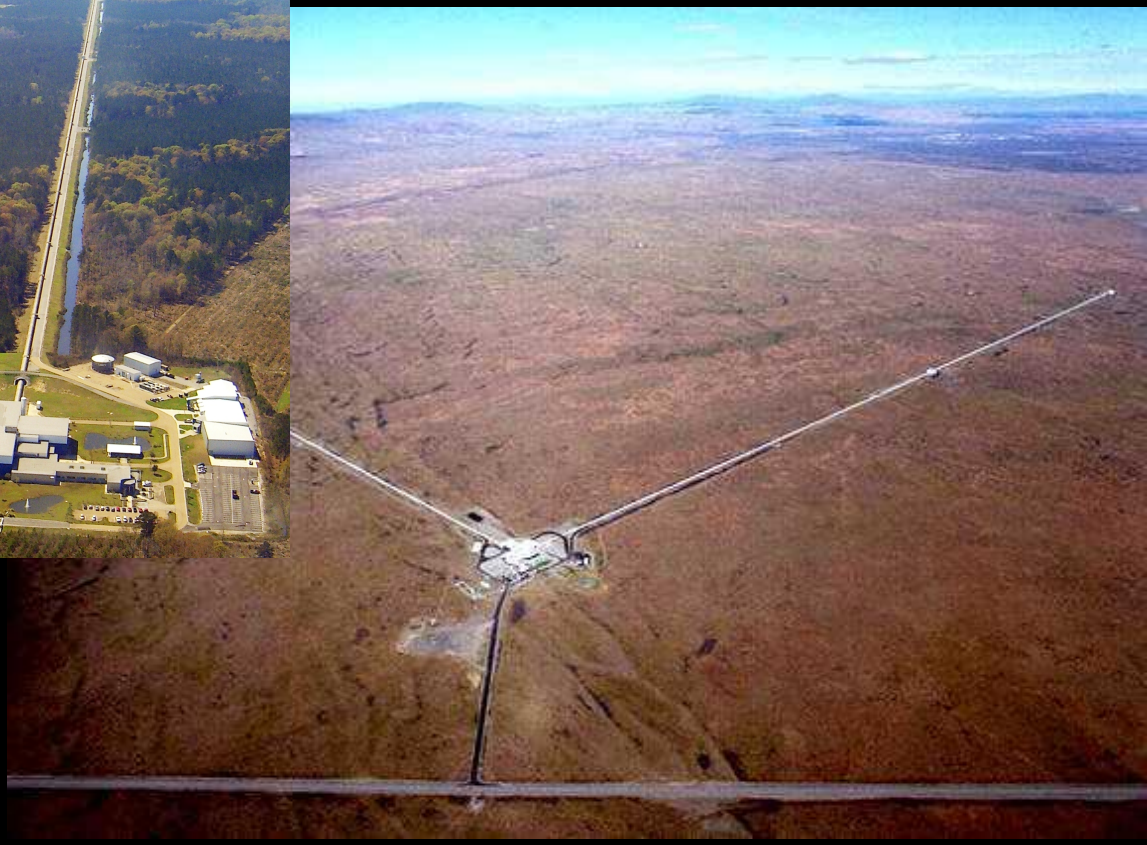
- The escape velocity is greater than the speed of light.
- Light is the universe's speed limit.
- Radius of a black hole (non-spinning):
  $r = (2MG)/ c^2$ where r is radius M is the mass, G is a constant c is the constant of the speed of light
- radius = Mass x 1.5 x 10^{-27} meters/kg

Laser Interferometer



The Observatory

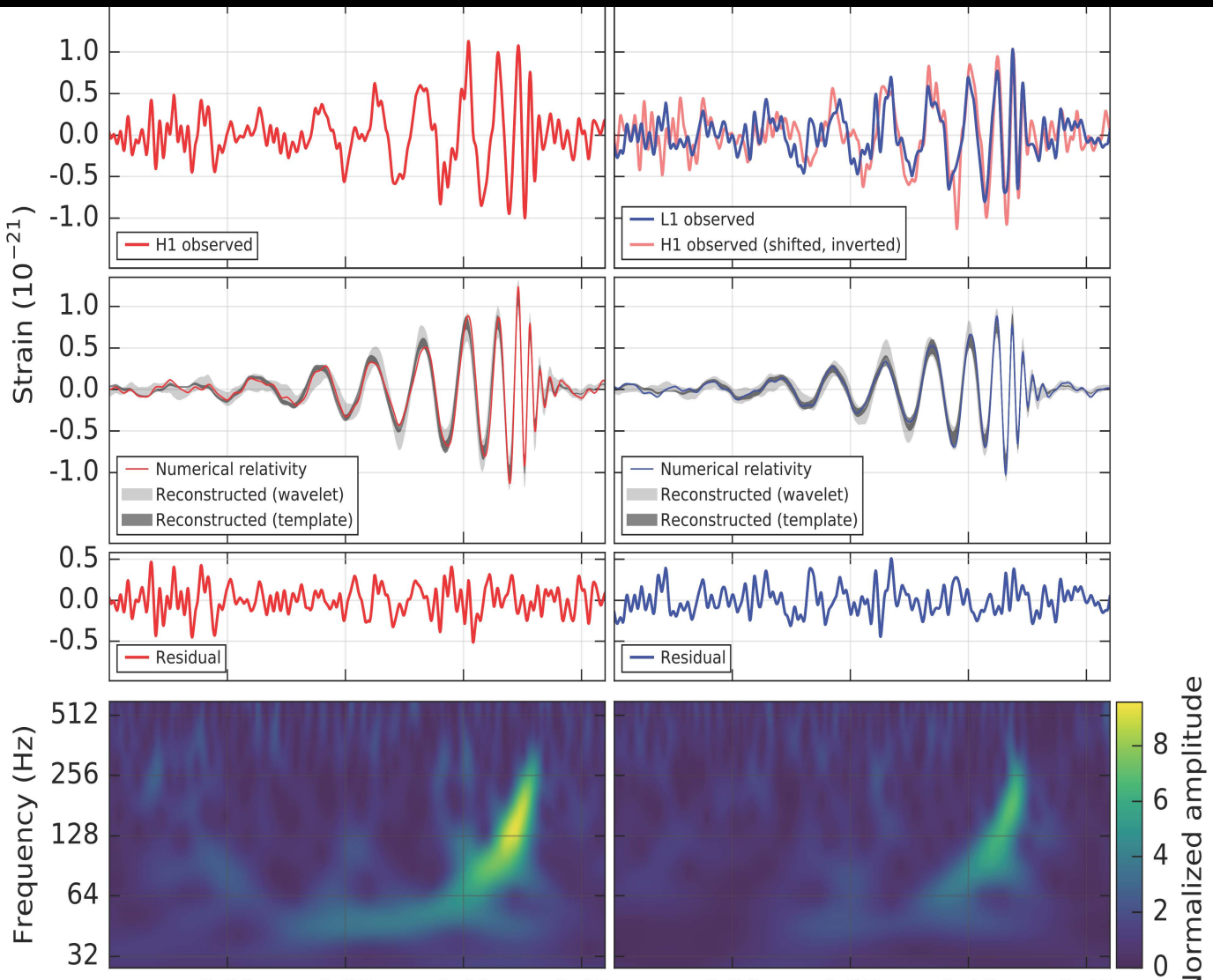
← Livingston, Louisiana



Hanford, Washington →

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

What we saw GW150914



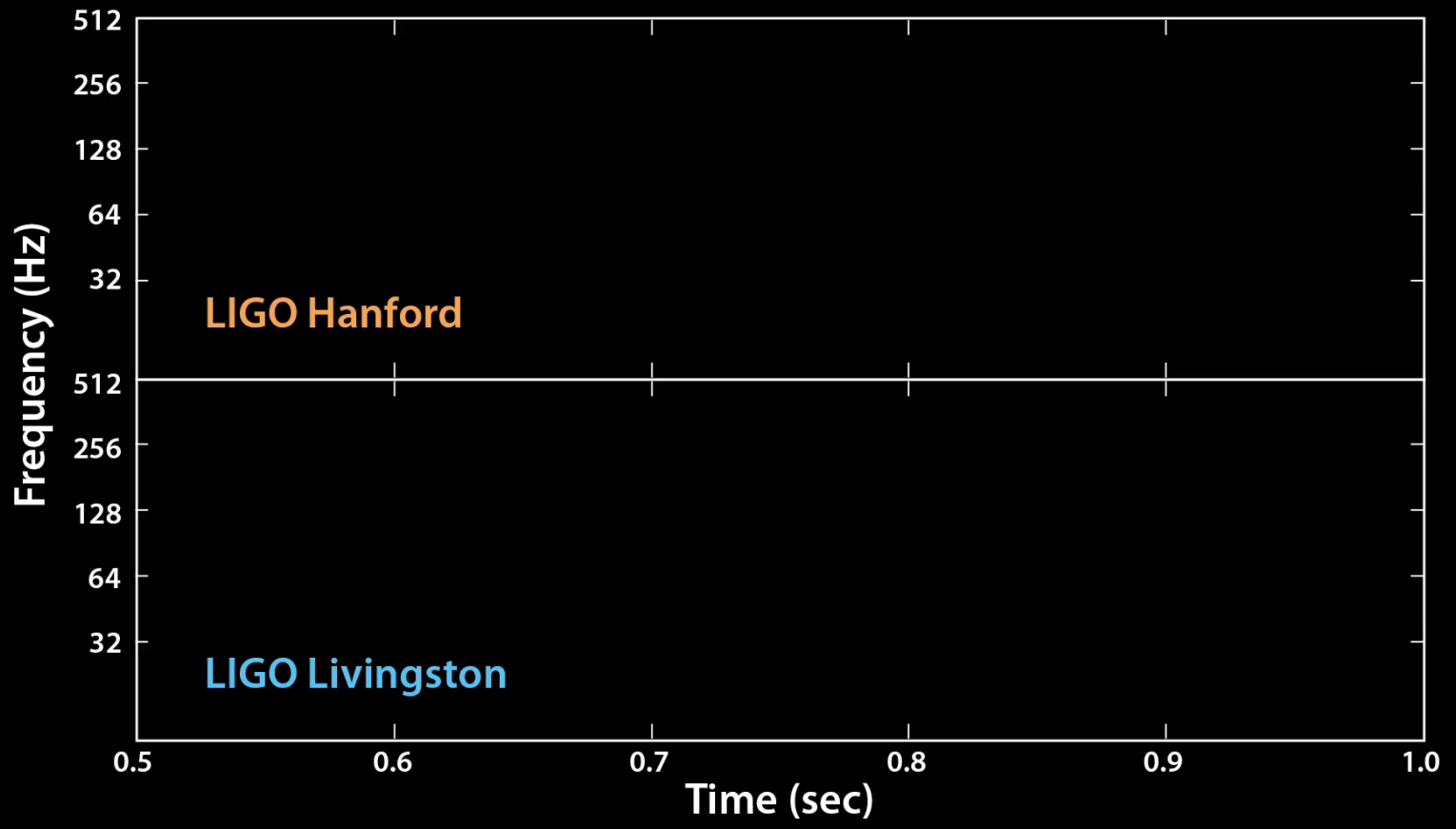
Analyzing the Data activity

- Try to match the “actual data” with a template – which is a theoretical overlay of what we should see.
- Hints: each signal belongs to one class of templates designated by a letter such as “M” Figure out which class first, then figure out the individual template.
- http://cgwp.gravity.psu.edu/outreach/activities/

Binary Inspiral activity

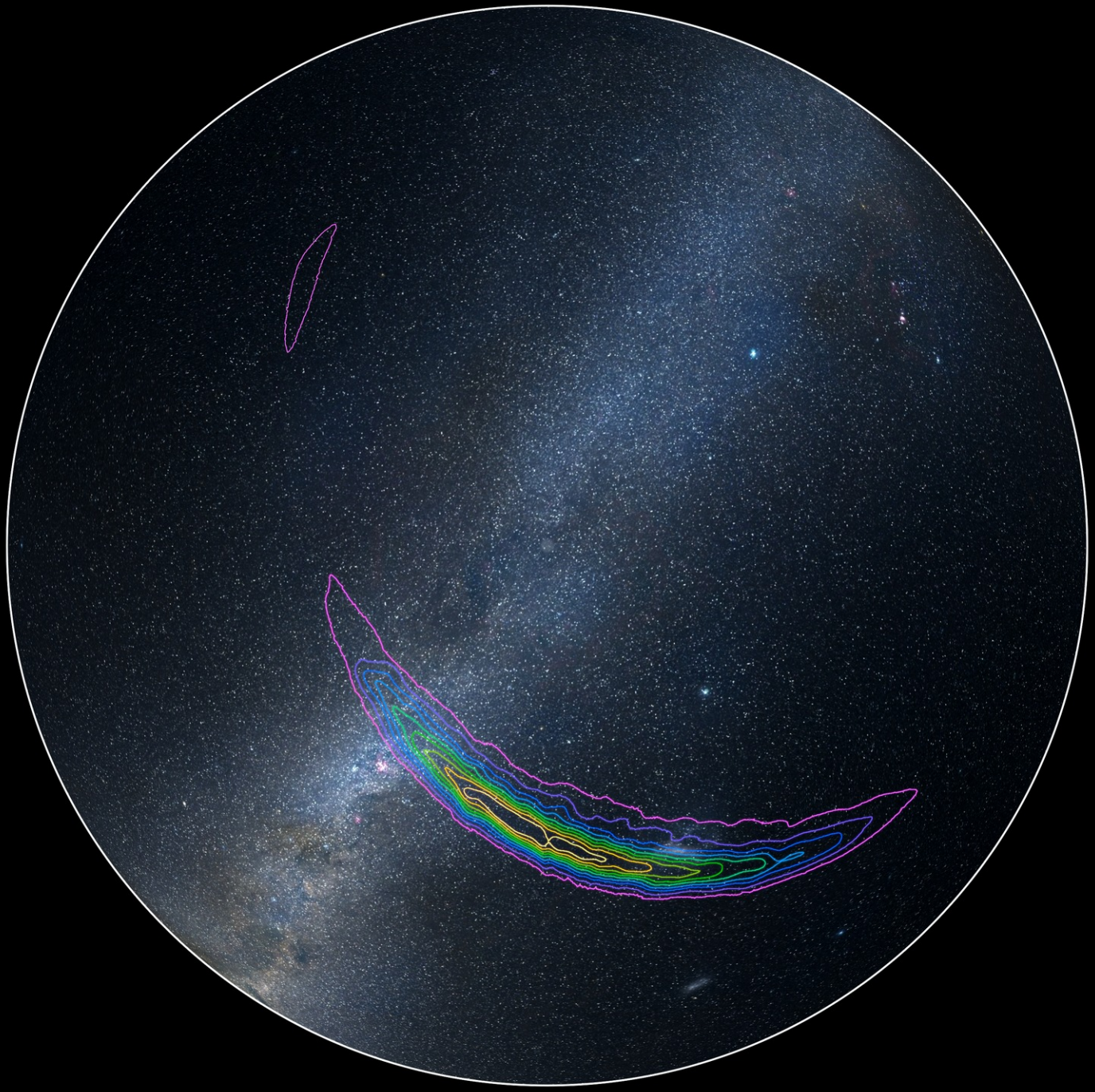
- True binary system: Use 2 tennis balls hung from overhead through a washer or nut. Watch as they come together
- Quicker version – just use a single washer/nut on a string through a straw. As it rotates pull it inwards – what happens?
- Audio version – put a nut in a balloon and spin.

What we “heard” GW150914



Two black holes collide

- Frequency change (mass and straw)
- Over a billion years ago
- 2 black holes (36 solar mass and 29 solar mass)
- 36 + 29 = 62 + 3 solar mass radiated
  - Equivalent to 1 million earth's energy
- More power than all the stars in the universe
- Just the beginning…other instruments such as LISA and the Pulsar Timing Array



Find out more

- https://www.ligo.caltech.edu/LA/page/june-2016-leadership
- ligo.caltech.edu/detection
- ligo.caltech.edu/LA for field trips or info on our detector
- Livingston Observatory open the 3rd Saturday of each month… visit ligo.caltech.edu/LA