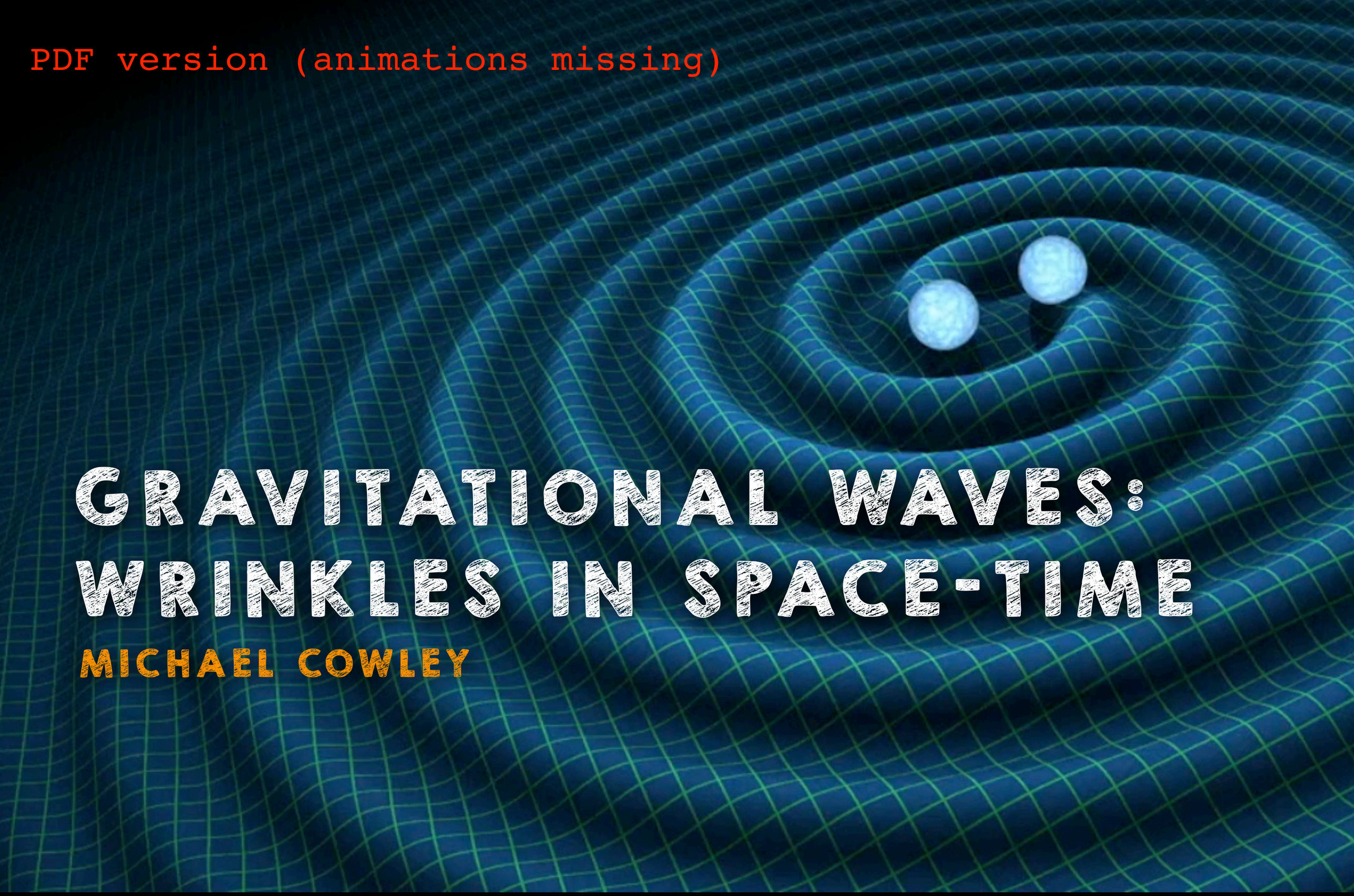
PDF version (animations missing)



GRAVITATIONAL WAVES: WRINKLES IN SPACE-TIME

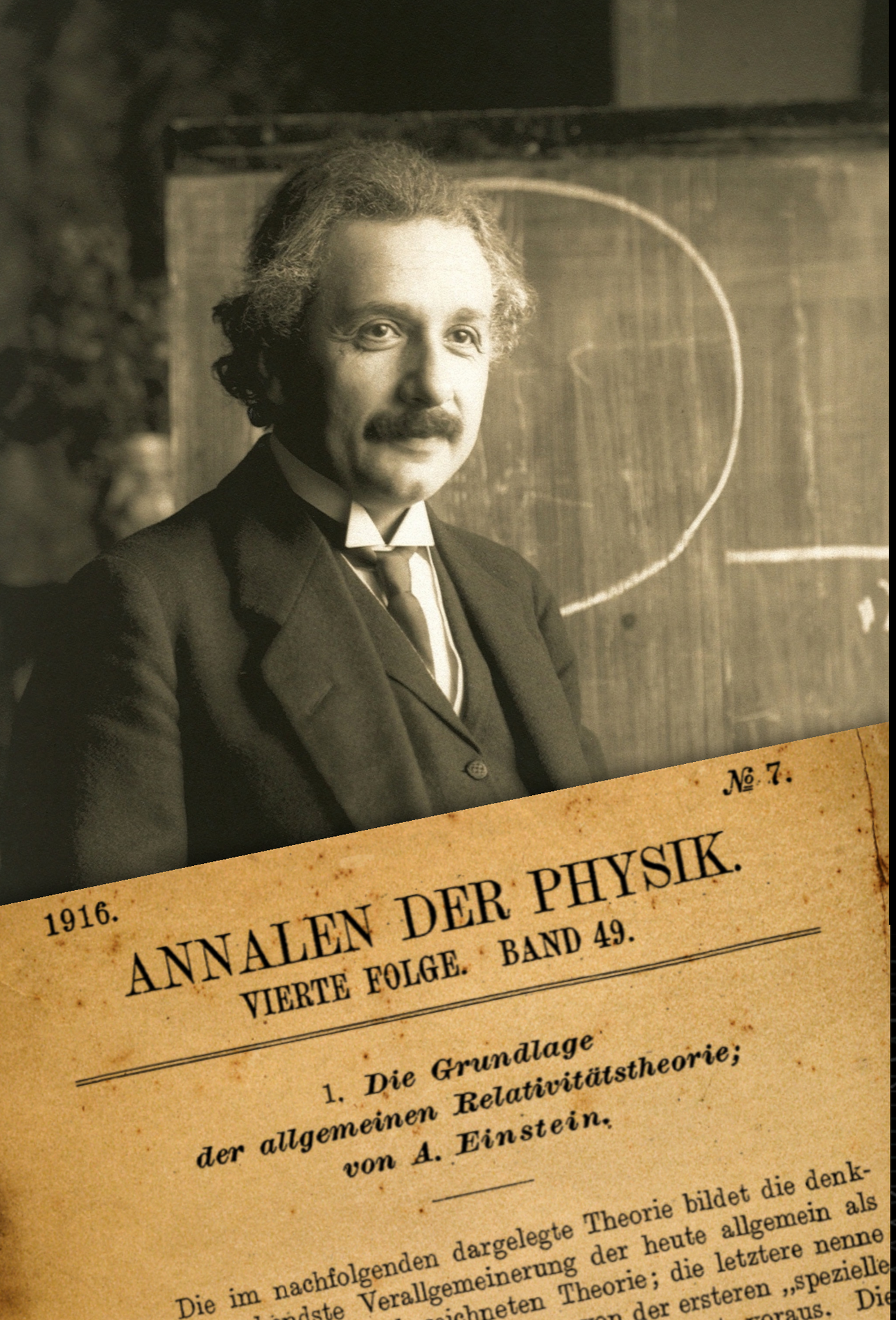
MICHAEL COWLEY

Australian Government
Department of Industry and Science

AAO

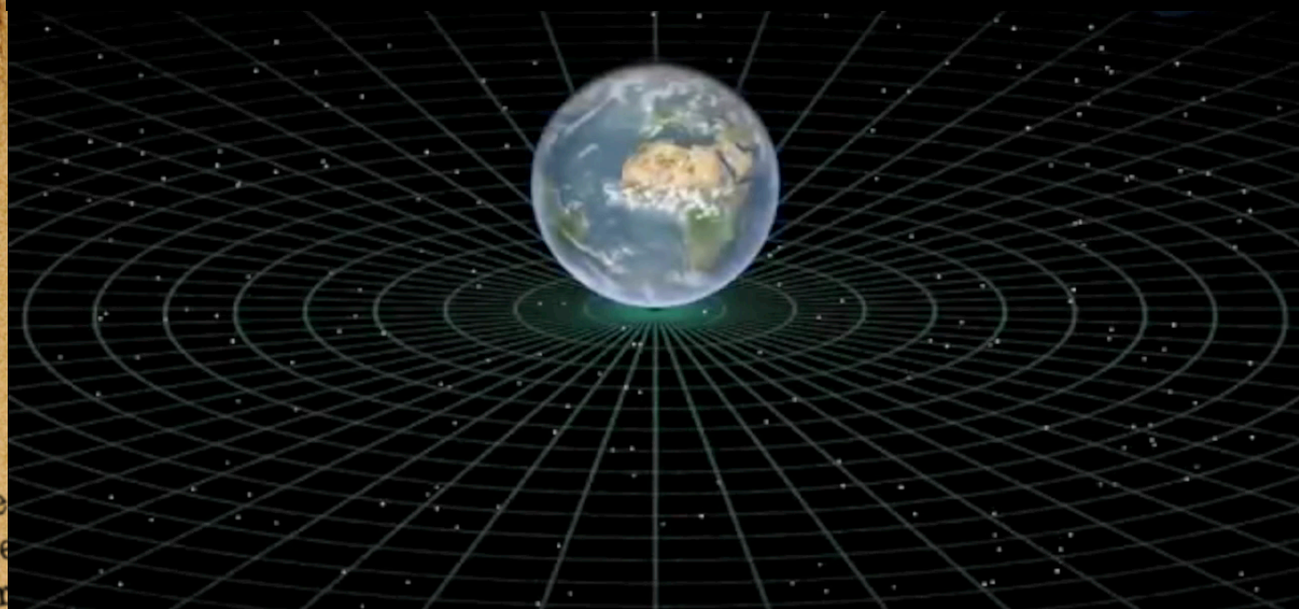
MACQUARIE University
SYDNEY·AUSTRALIA

CSIRO Scientists in schools



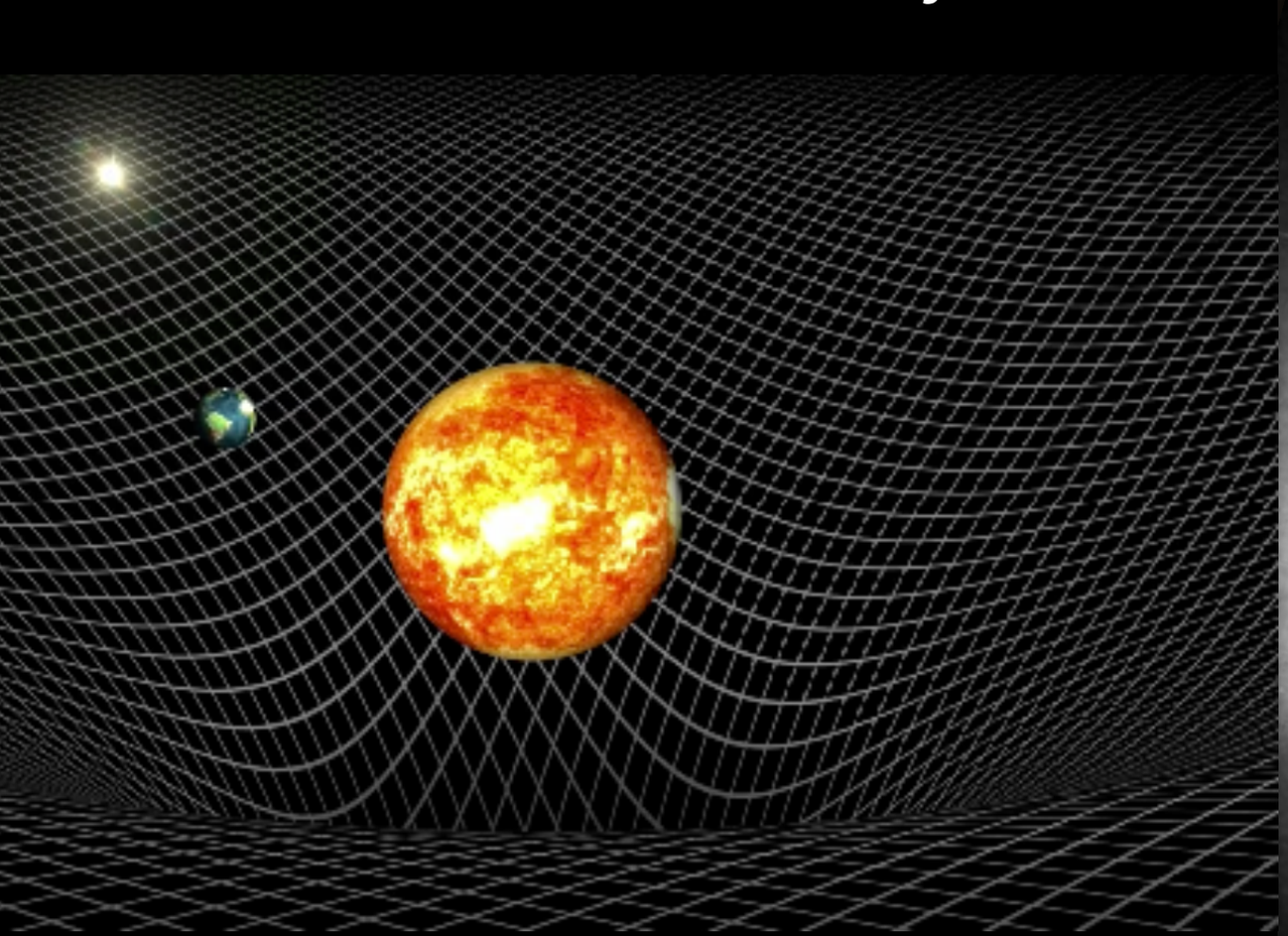
What is Gravity?

Albert Einstein's general theory of relativity describes the interaction of gravity as a result of **space being curved** by massive objects



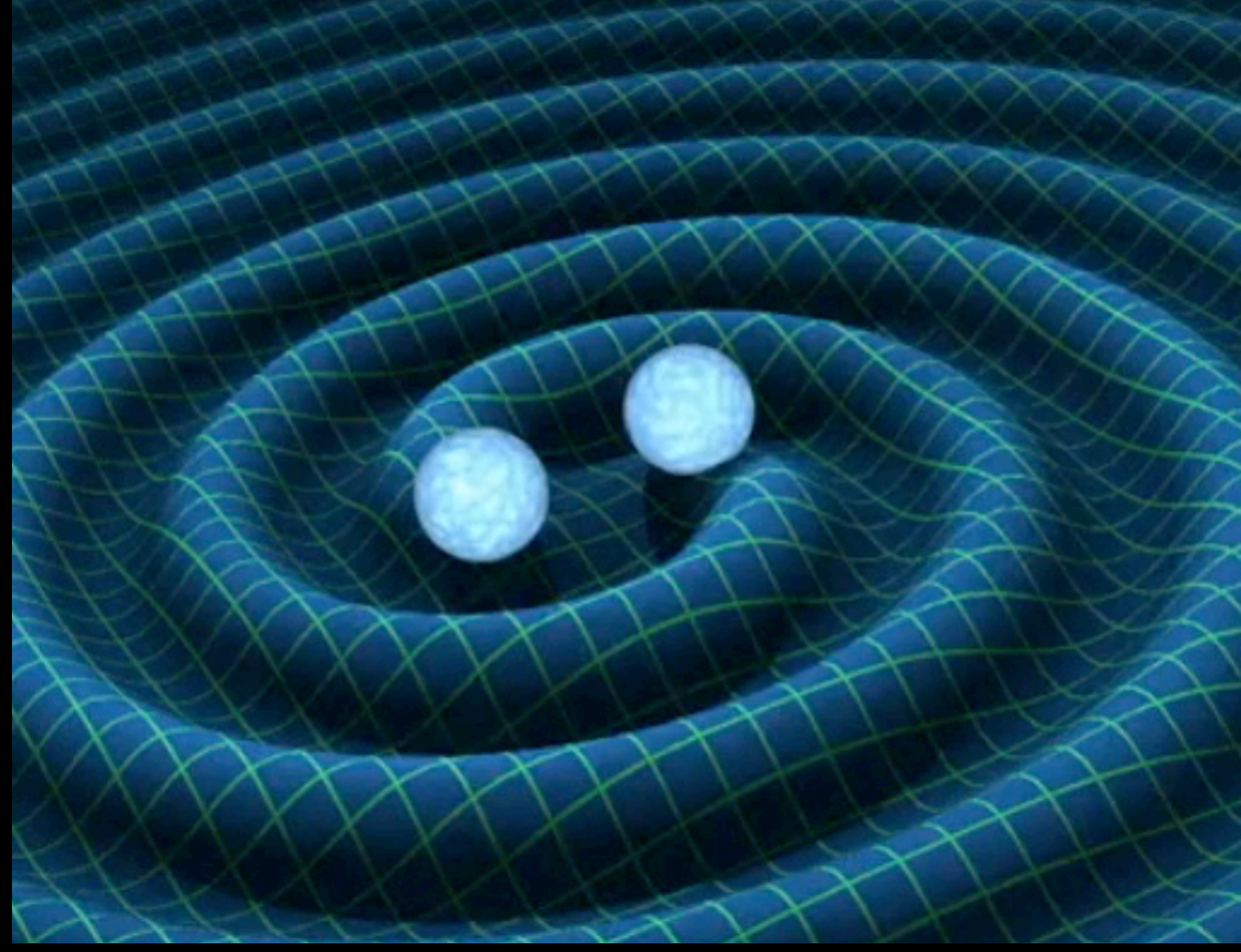
Testing General Relativity

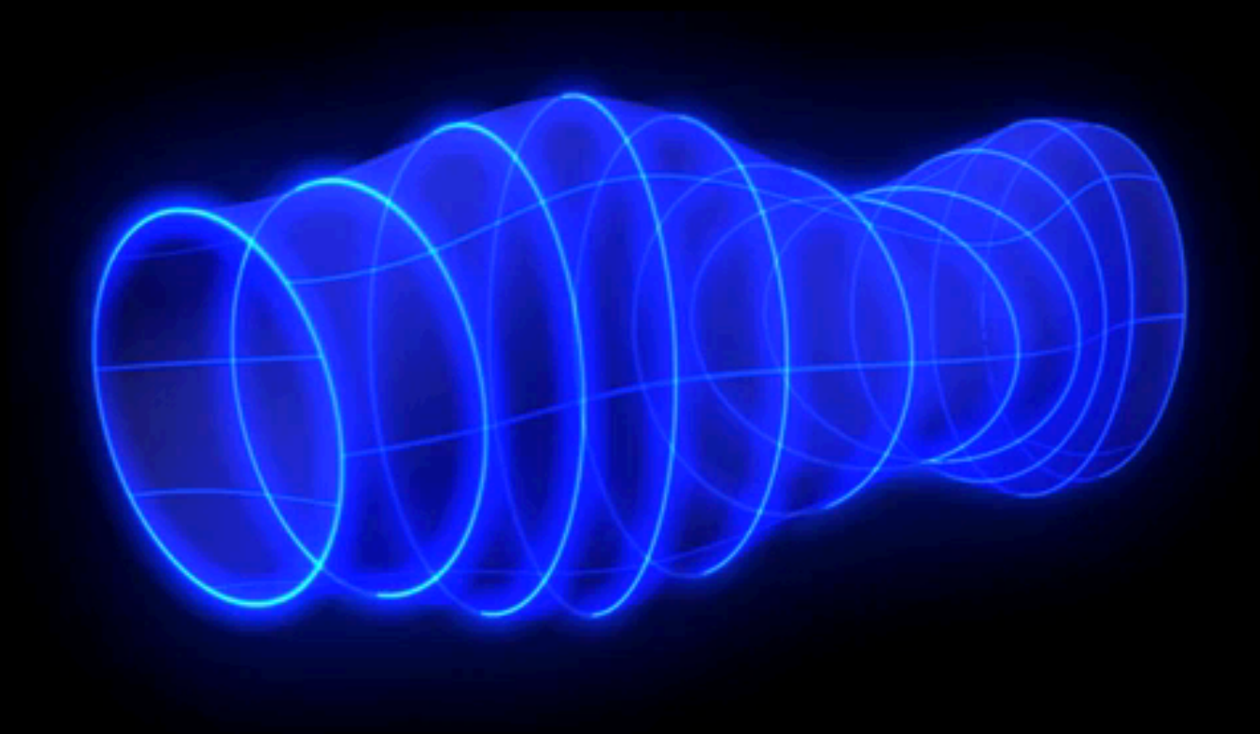
Eddington photographed positions of stars near the Sun to **test Einstein's prediction** of warped space around massive objects



What are Gravitational Waves?

Einstein's theory suggested massive accelerating objects would disrupt space such that 'waves' of **distorted space would radiate from the source**

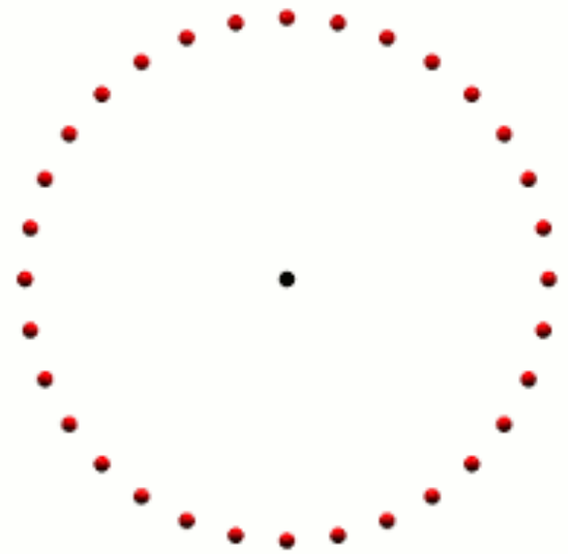




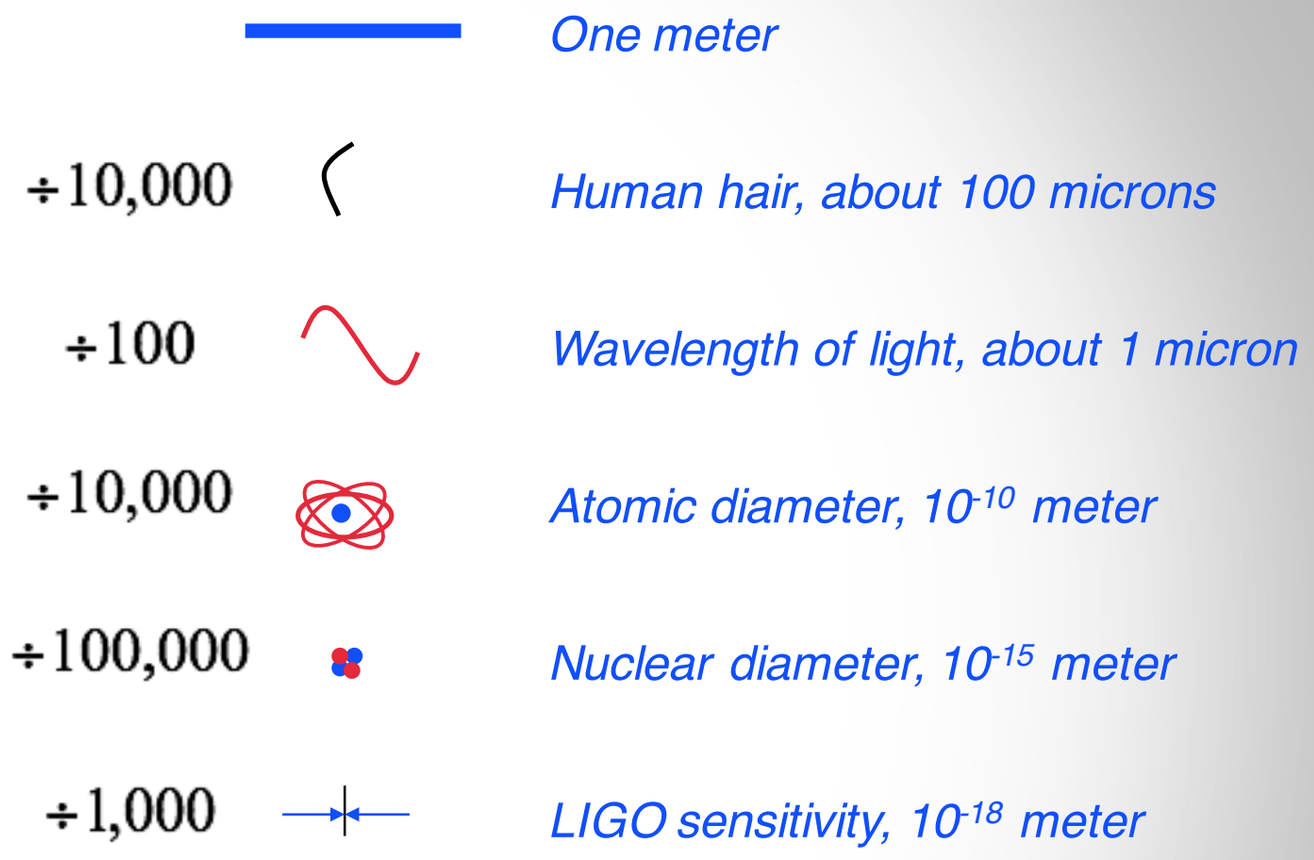
These ripples travel at the **speed of light**, carrying information about their cataclysmic origins. When they pass through space, they **compress in one direction and stretch in another**

Hunting for Gravitational Waves

Weber builds the first instrument designed to detect gravitational waves. Known as a Weber Bar, the instrument is an aluminium cylinder, 2 meters in length and 1 meter in diameter

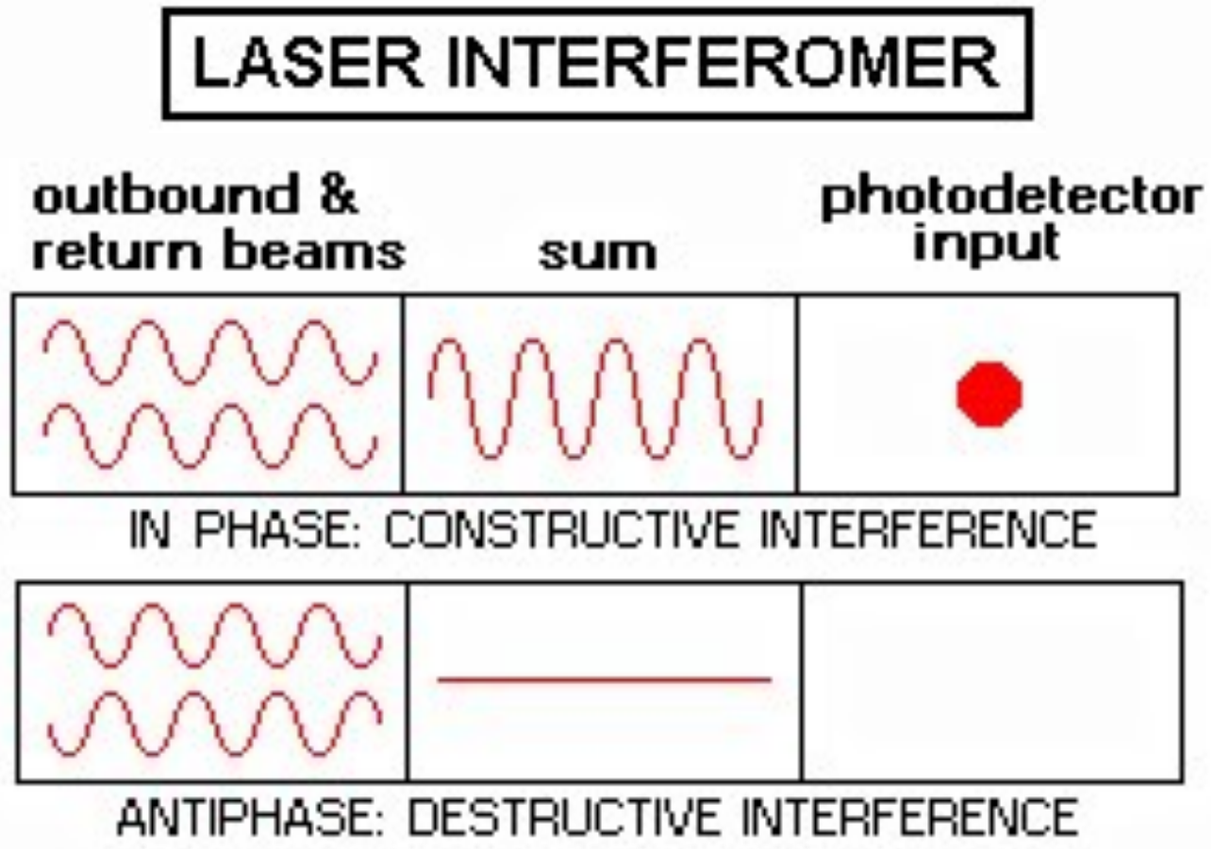


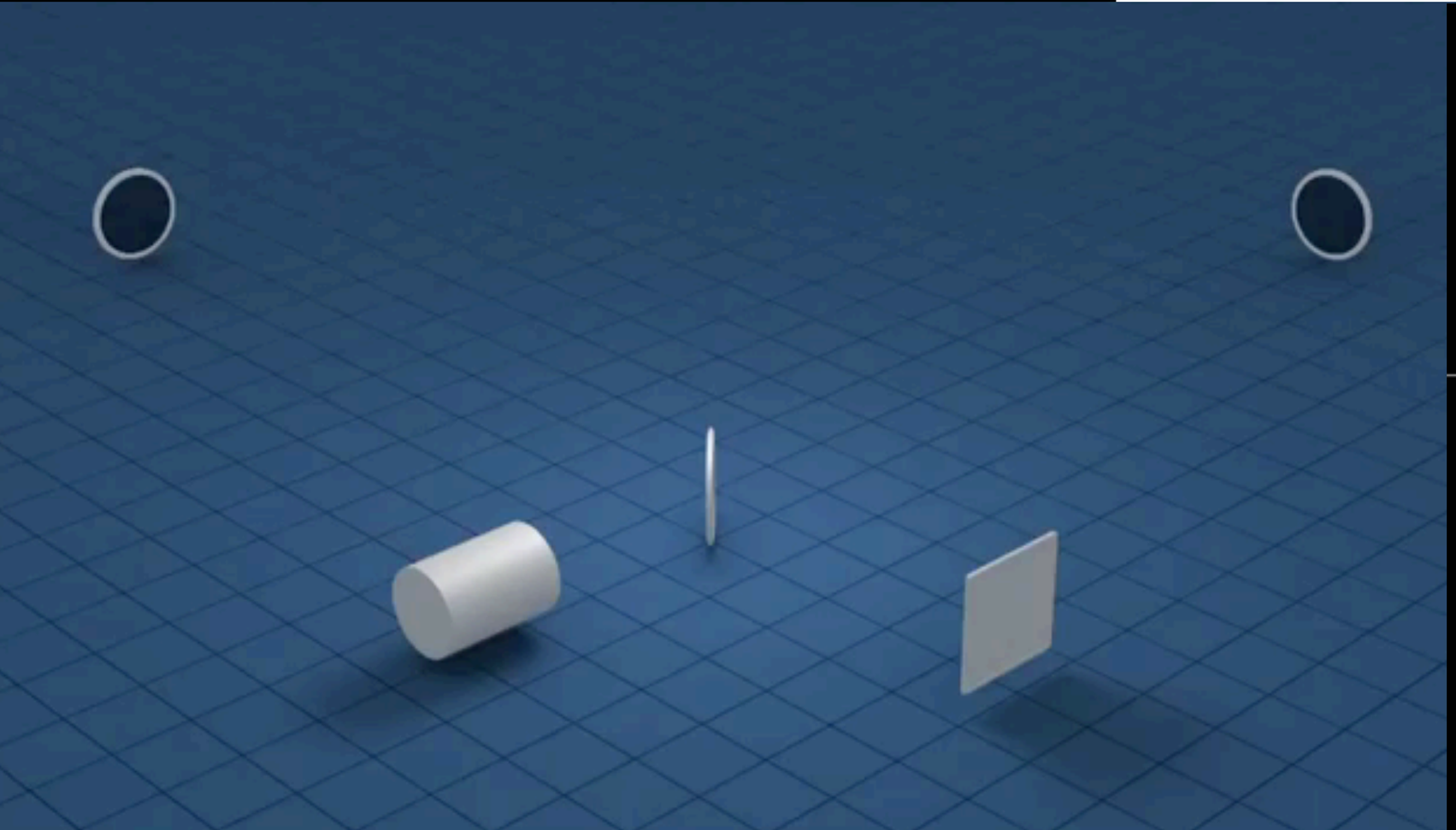
Two neutron stars (weighing a collective total of 1 million Earth masses) orbiting each other 1000 times a second only generate a gravitational wave signal that displaces distance by 1/1,000th of the diameter of an atomic nucleus (10^{-18} meters)

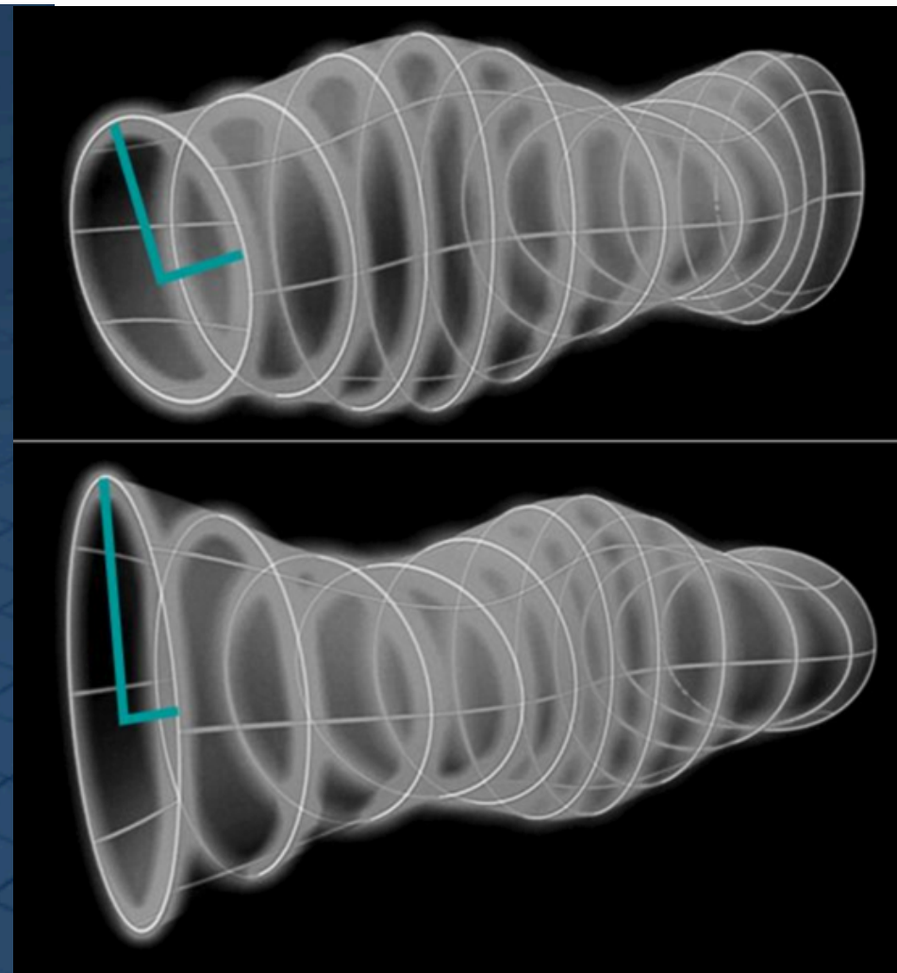


The answer is LASERS!

Laser Interferometry for gravitational wave detection were first conceived by Soviet scientists, Mikhail Gertsenshtein and Vladislav Pustovoit in 1962, and independently several years later by Weber and by Rainer Weiss in the USA







LIGO

After construction, LIGO began detection runs and collected data from 2002 - 2010. The number of Gravitational Wave detected was:

ESTIMATED
THAT EVERY YEAR YOU SHOULD GET SOMEWHERE BETWEEN
1 & 1 / 10,000

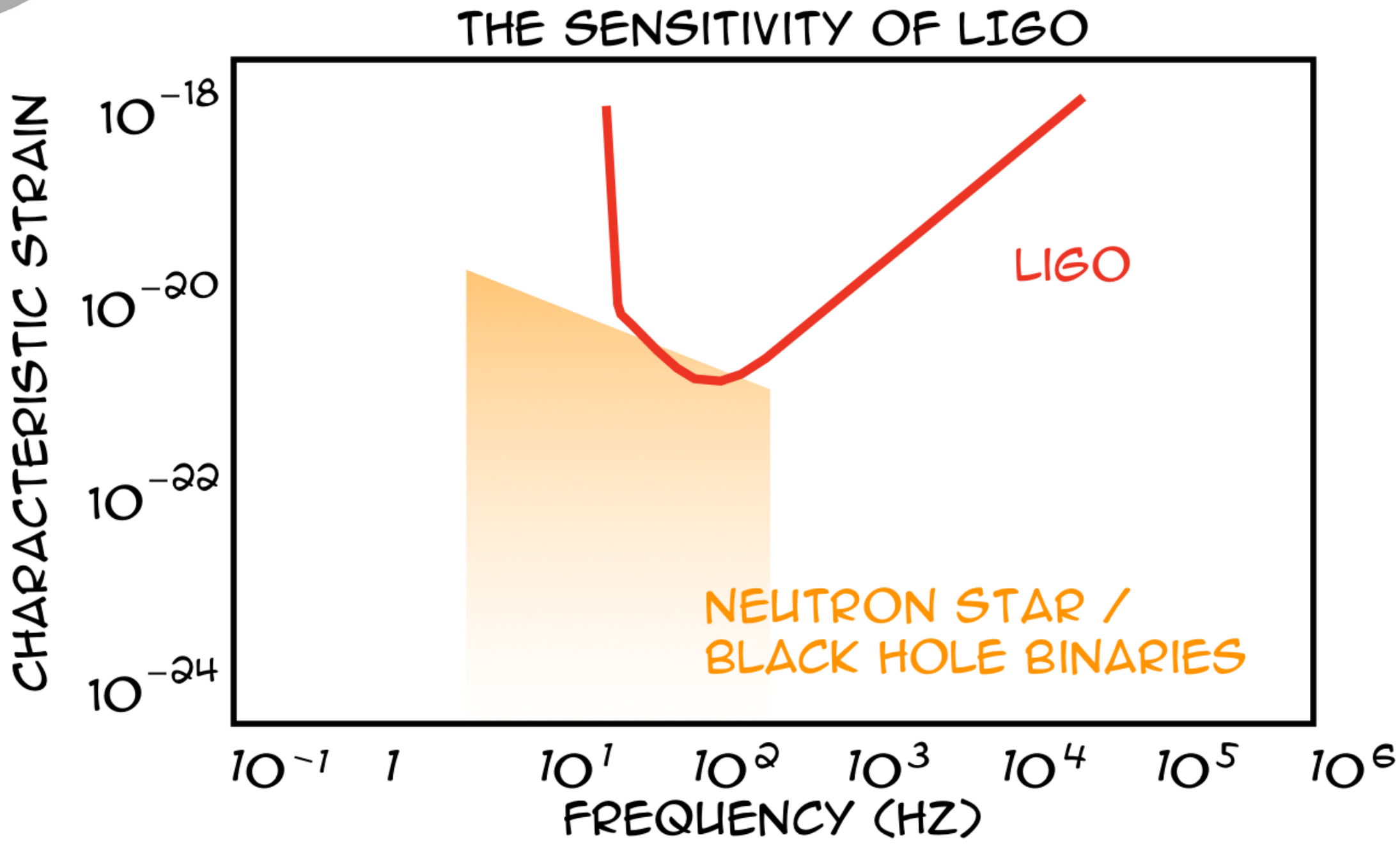
BEST CASE

see 8 in total

WORST CASE

wait 10,000 years for 1

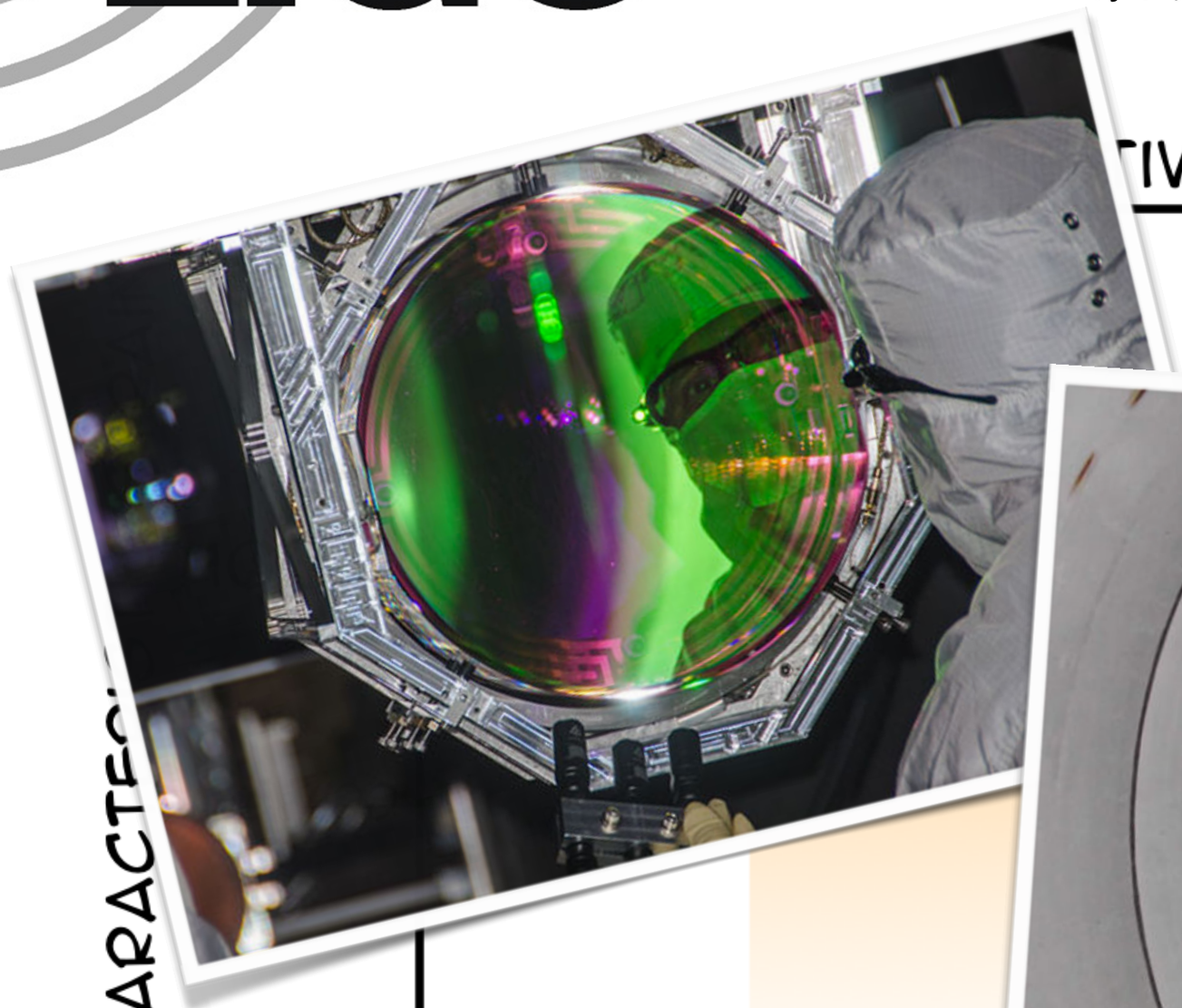
LIGO

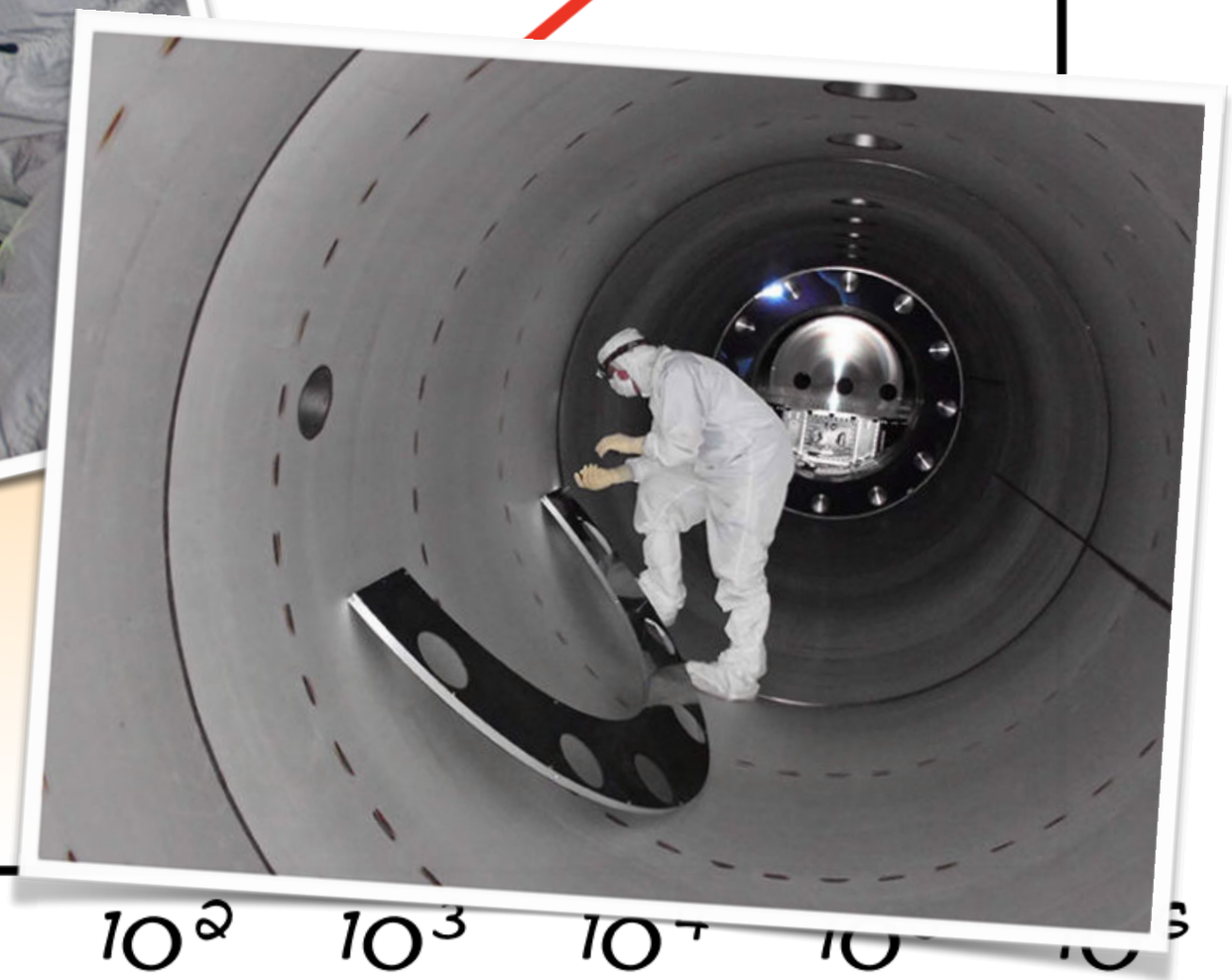

THE SENSITIVITY OF LIGO
CHARACTERISTIC STRAIN
10^{-18}
10^{-20}
10^{-22}
10^{-24}
LIGO
NEUTRON STAR / BLACK HOLE BINARIES
10^{-1}
1
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
FREQUENCY (HZ)

ADVANCED

LIGO

FROM 2010 - 2015, LIGO RECEIVED A $205 MILLION UPGRADE TO ITS INTERFEROMETERS





TIVITY OF LIGO

CHARACTE

10^{-24}

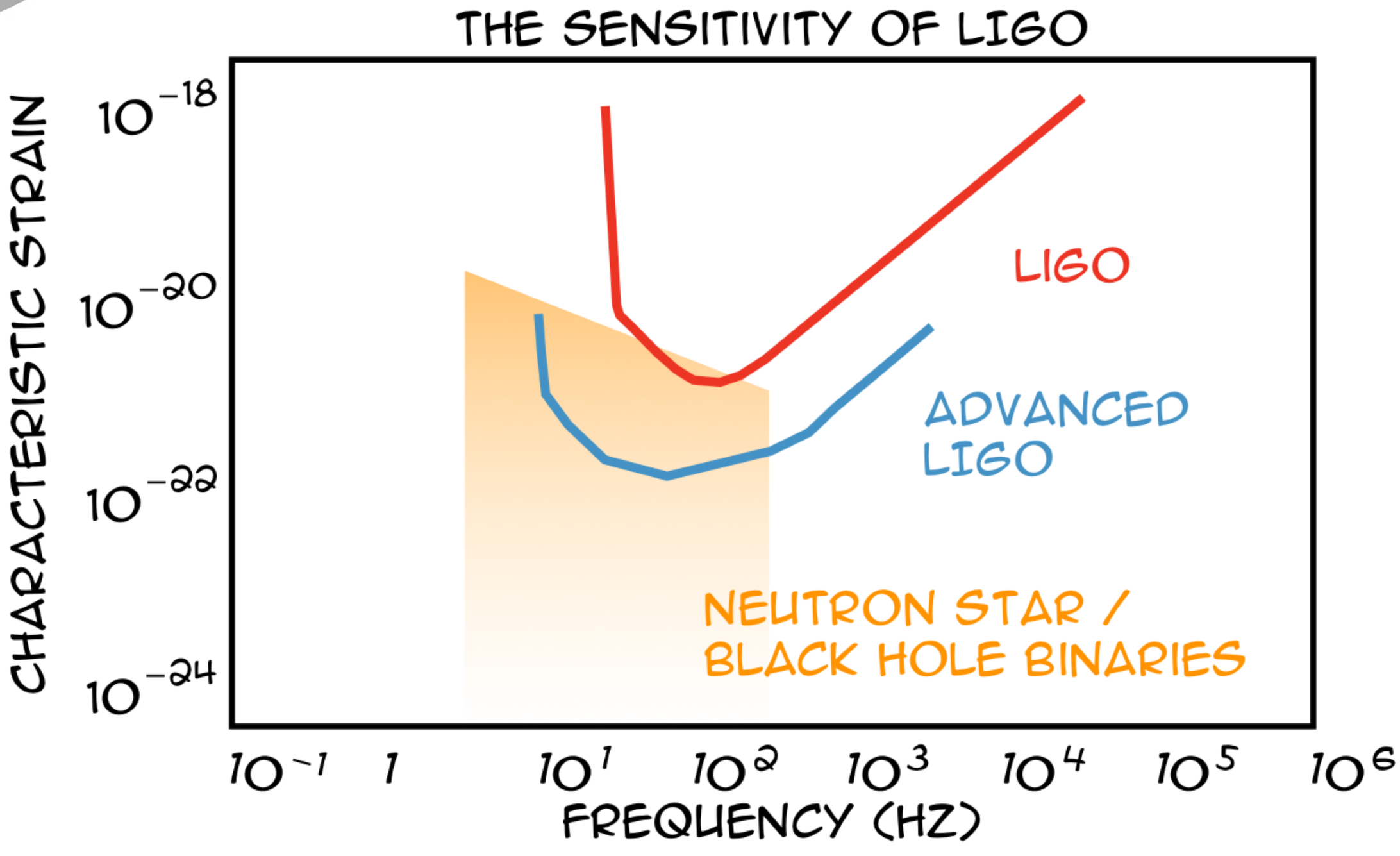
10^{-1} 1 10^{1} 10^{2} 10^{3} 10^{4}

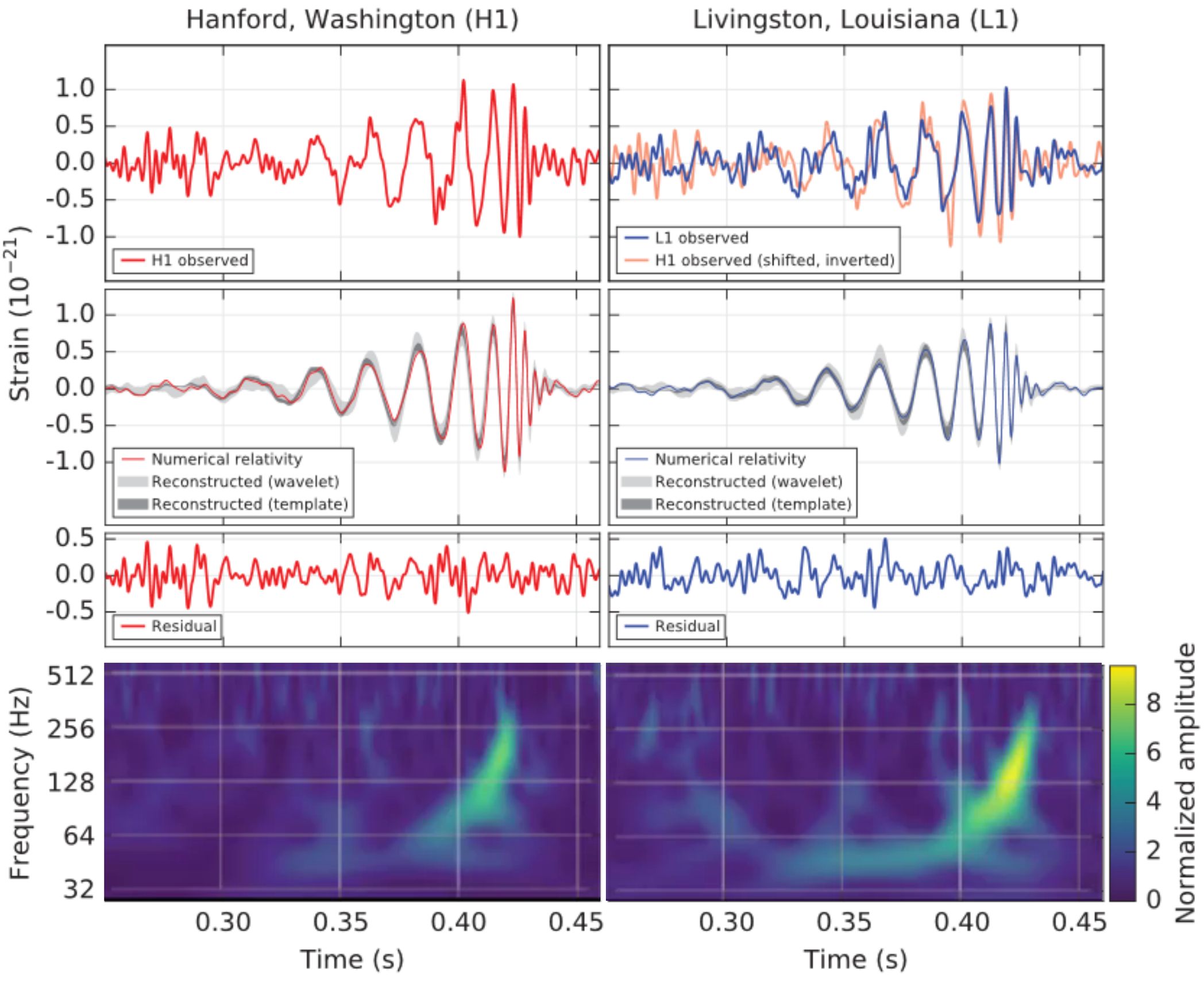
FREQUENCY (HZ)

ADVANCED

LIGO

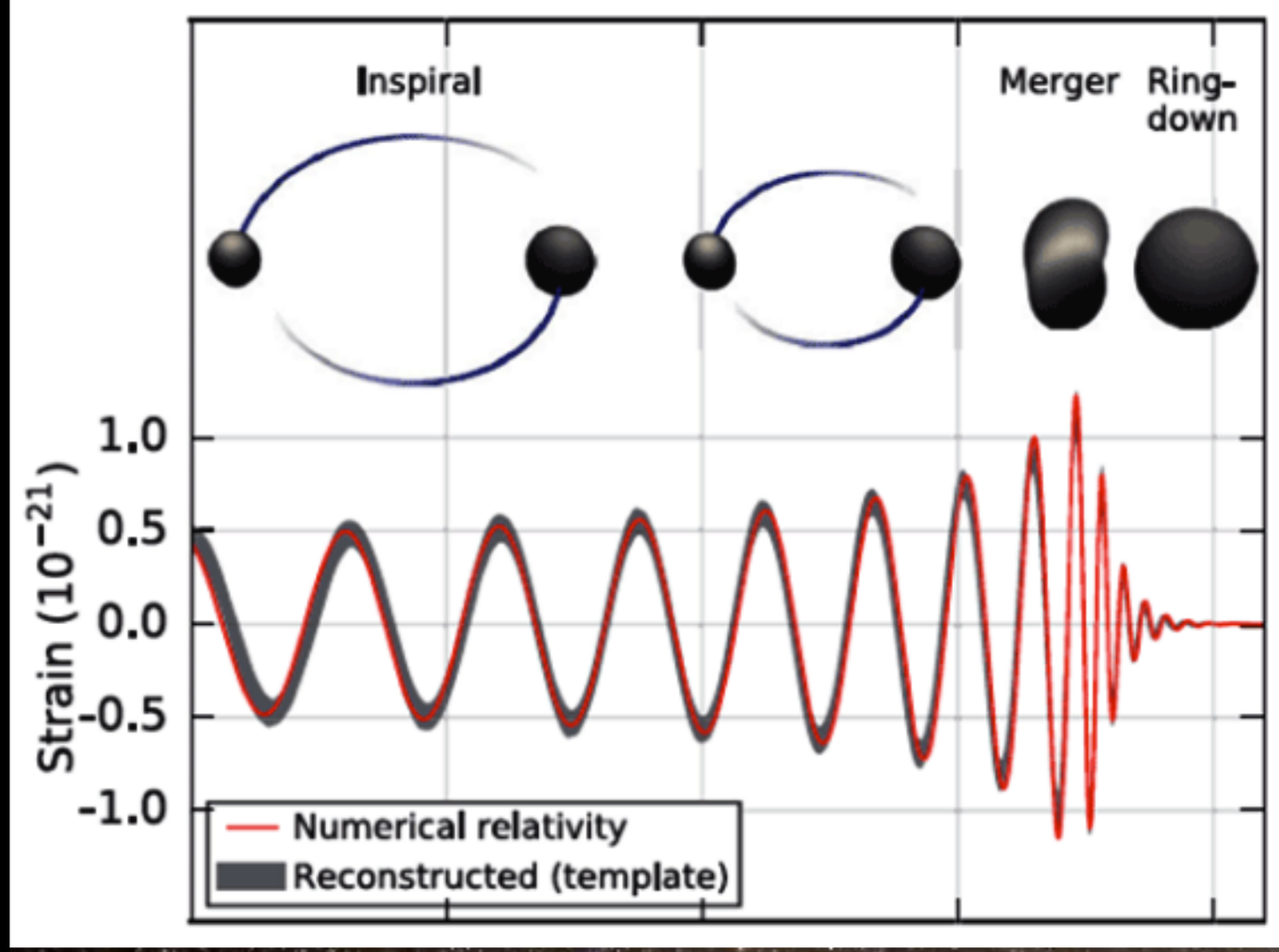
FROM 2010 - 2015, LIGO RECEIVED A $205 MILLION UPGRADE TO ITS INTERFEROMETERS

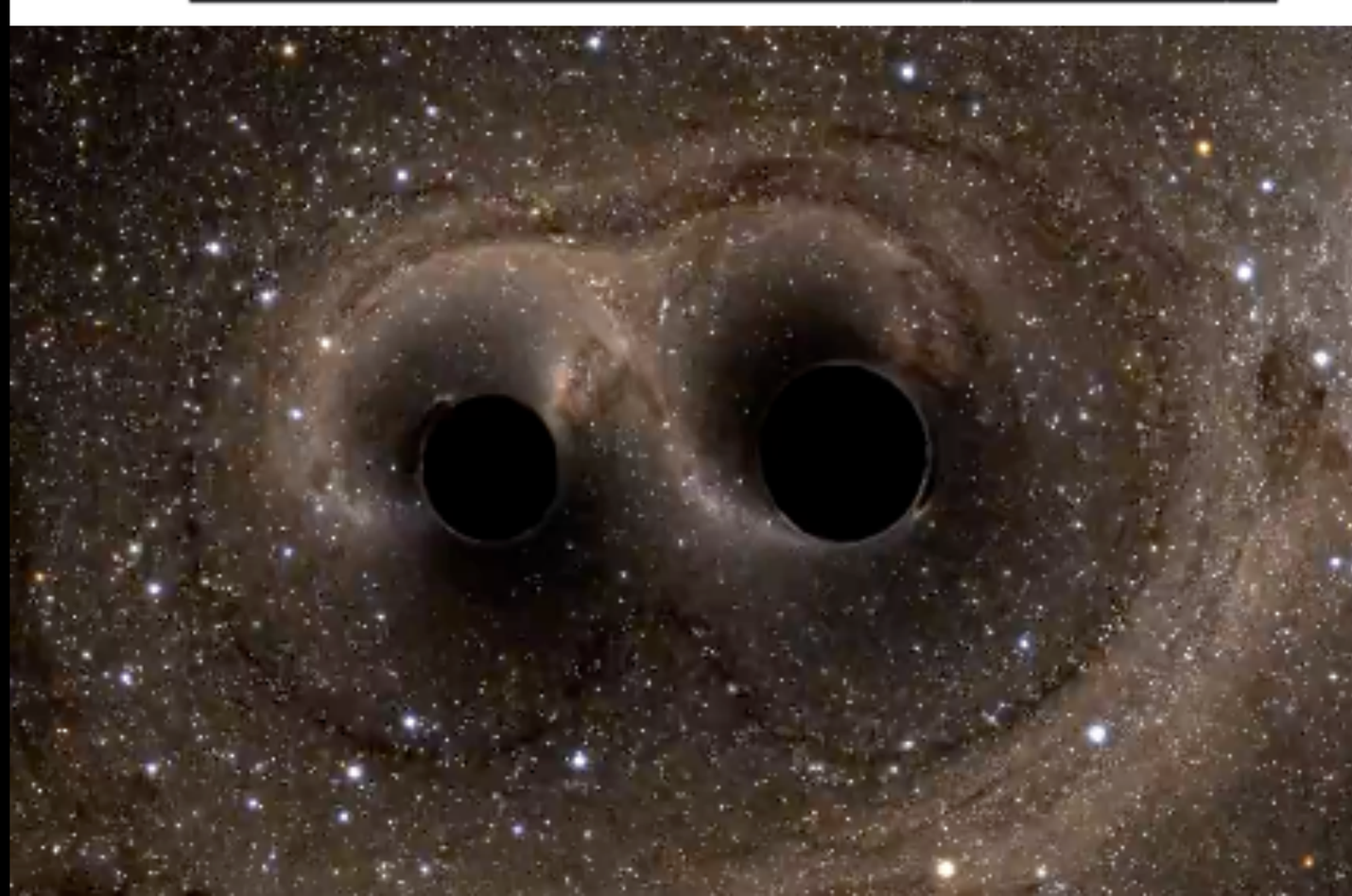



Hanford, Washington (H1)
Livingston, Louisiana (L1)
Strain (10^{-21})
1.0
0.5
0.0
-0.5
-1.0
H1 observed
L1 observed
H1 observed (shifted, inverted)
Numerical relativity
Reconstructed (wavelet)
Reconstructed (template)
Residual
Frequency (Hz)
512
256
128
64
32
0.30
0.35
0.40
0.45
Time (s)
Normalized amplitude
8
6
4
2
0

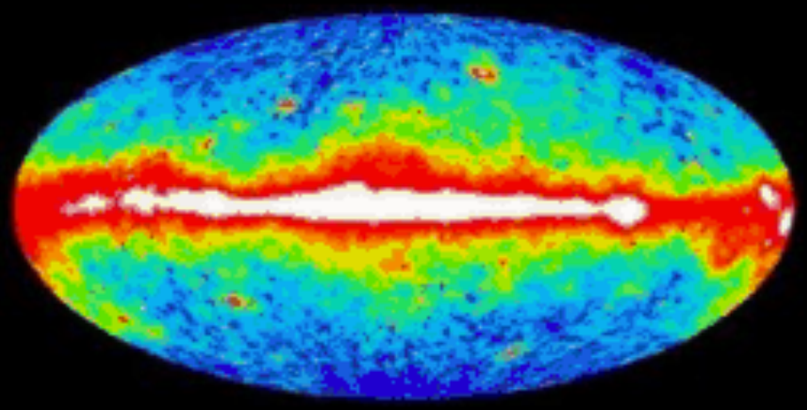
Detection Details

- Two massive black holes merging
- 36 and 28 times the mass of the Sun
- Estimated 1.3 billion light years away
- Combined mass of the final black hole is 62 solar masses
- 3 Suns worth of mass was lost in gravitational wave energy

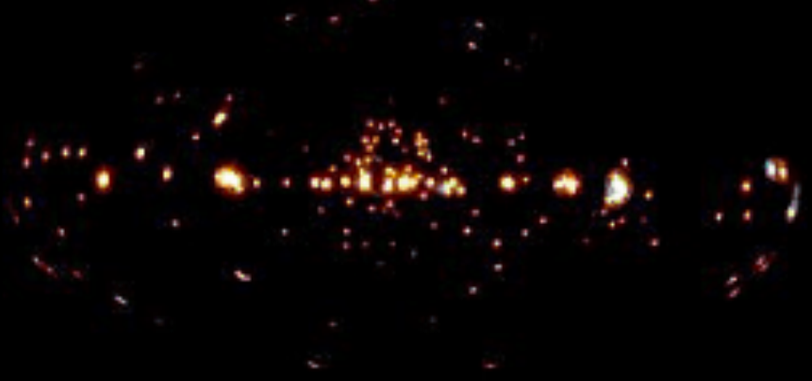




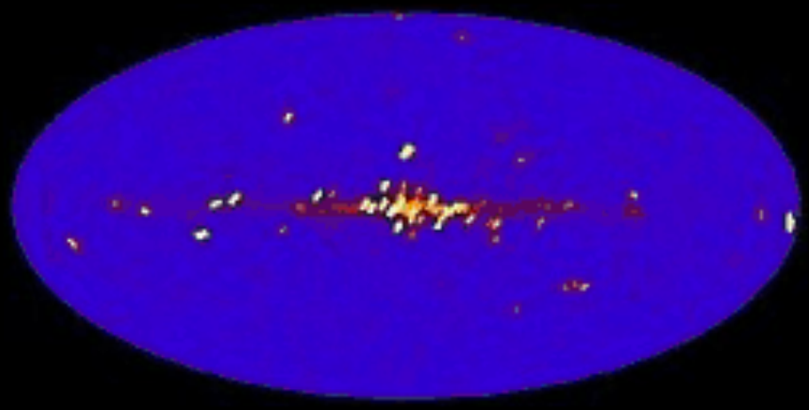
THE ELECTROMAGNETIC SPECTRUM



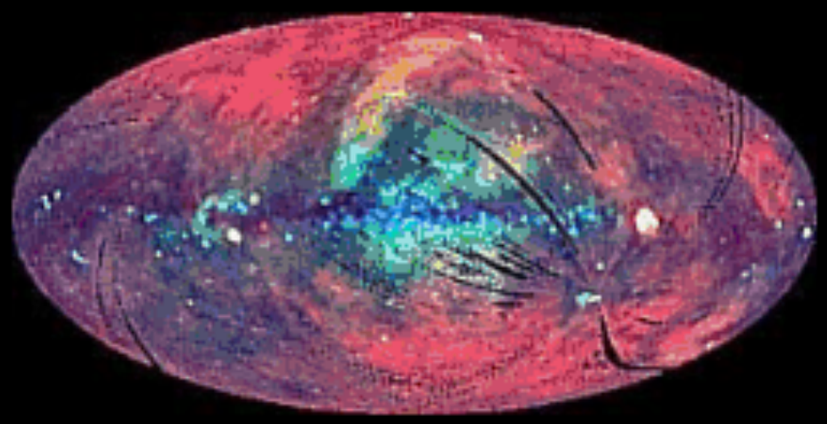
Gamma-Ray >100MeV (CGRO, NASA)



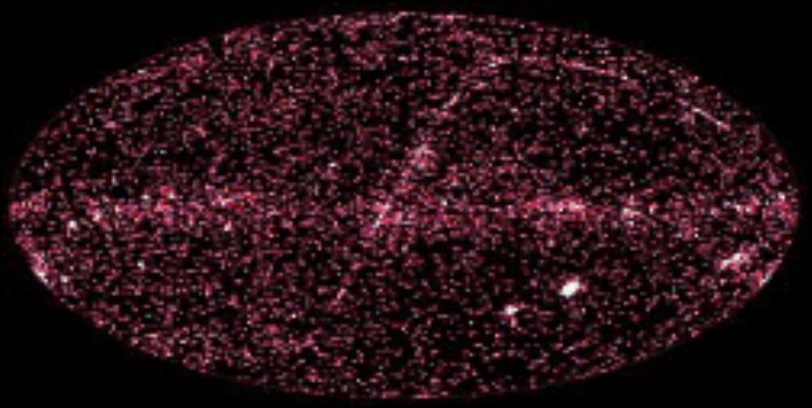
Gamma-Ray (N. Gehrels et.al. GSFC, EGRET, NASA)



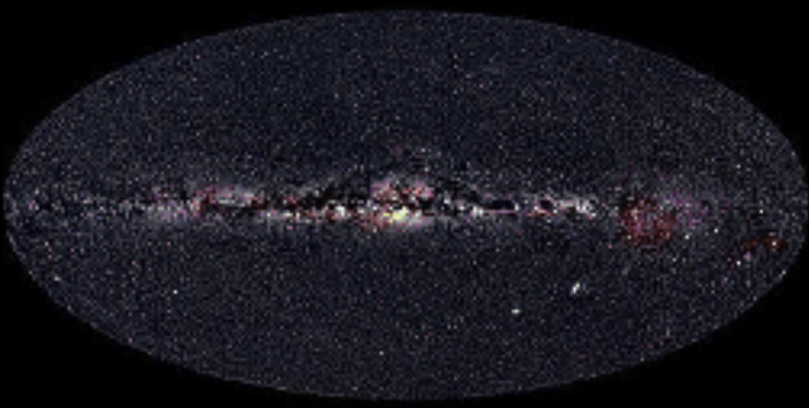
X-Ray 2-10keV (HEAO-1, NASA)



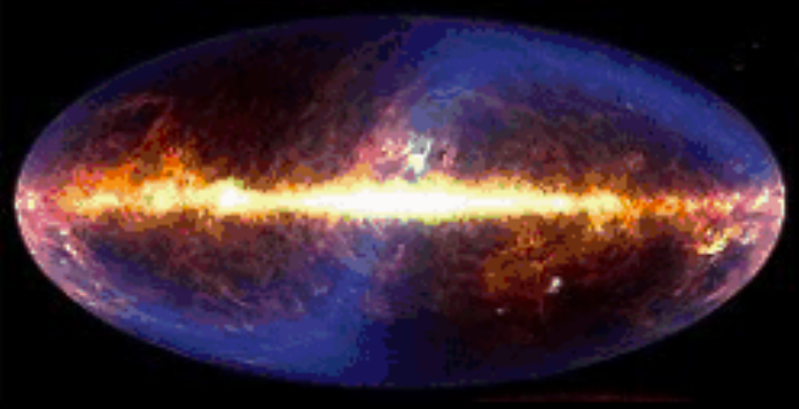
X-Ray 0.25, 0.75, 1.5 keV (S. Digel et. al. GSFC, ROSAT, NASA)



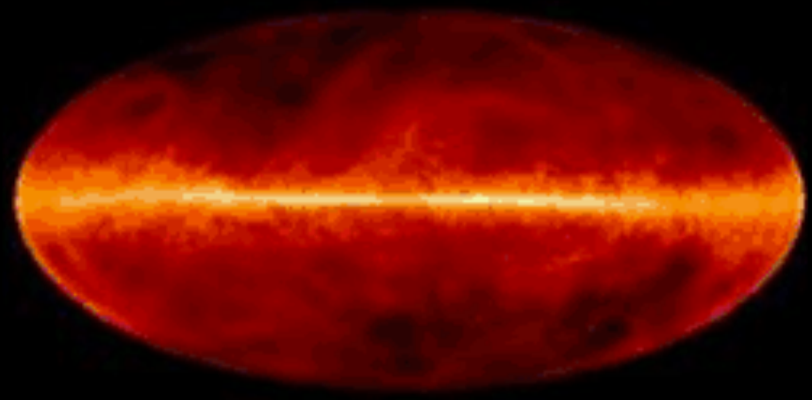
Ultraviolet (J. Bonnell et.al.(GSFC), NASA)



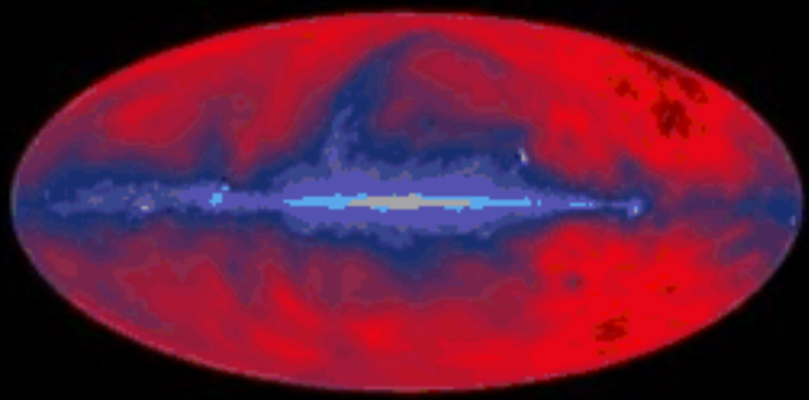
Visible (Axel Mellinger)



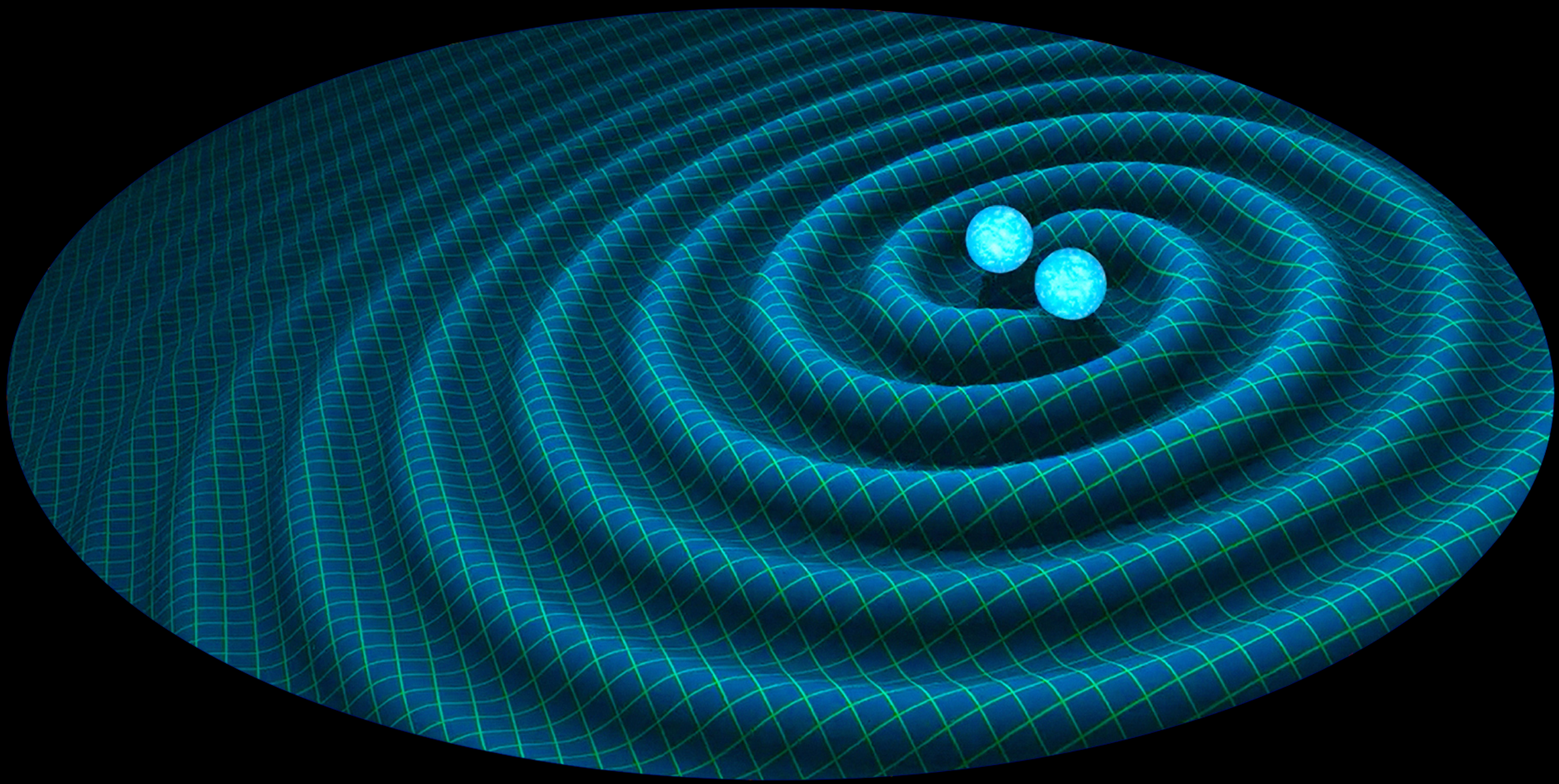
Infrared (DIRBE Team, COBE, NASA)



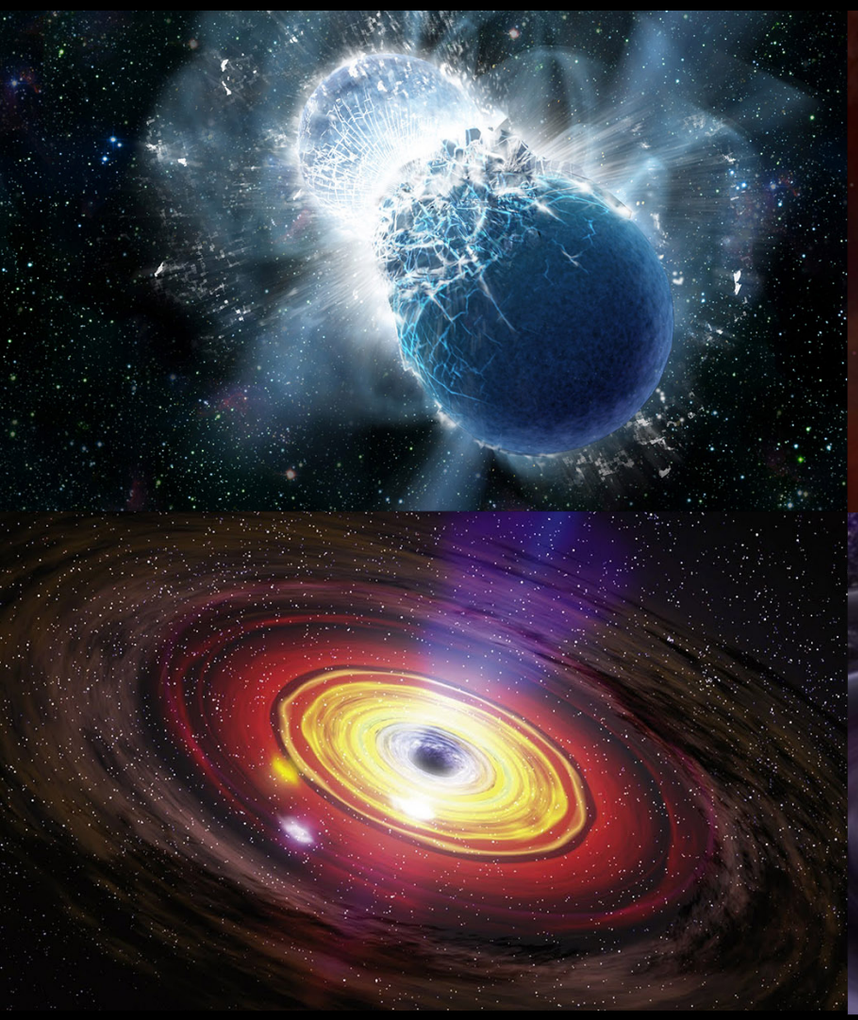
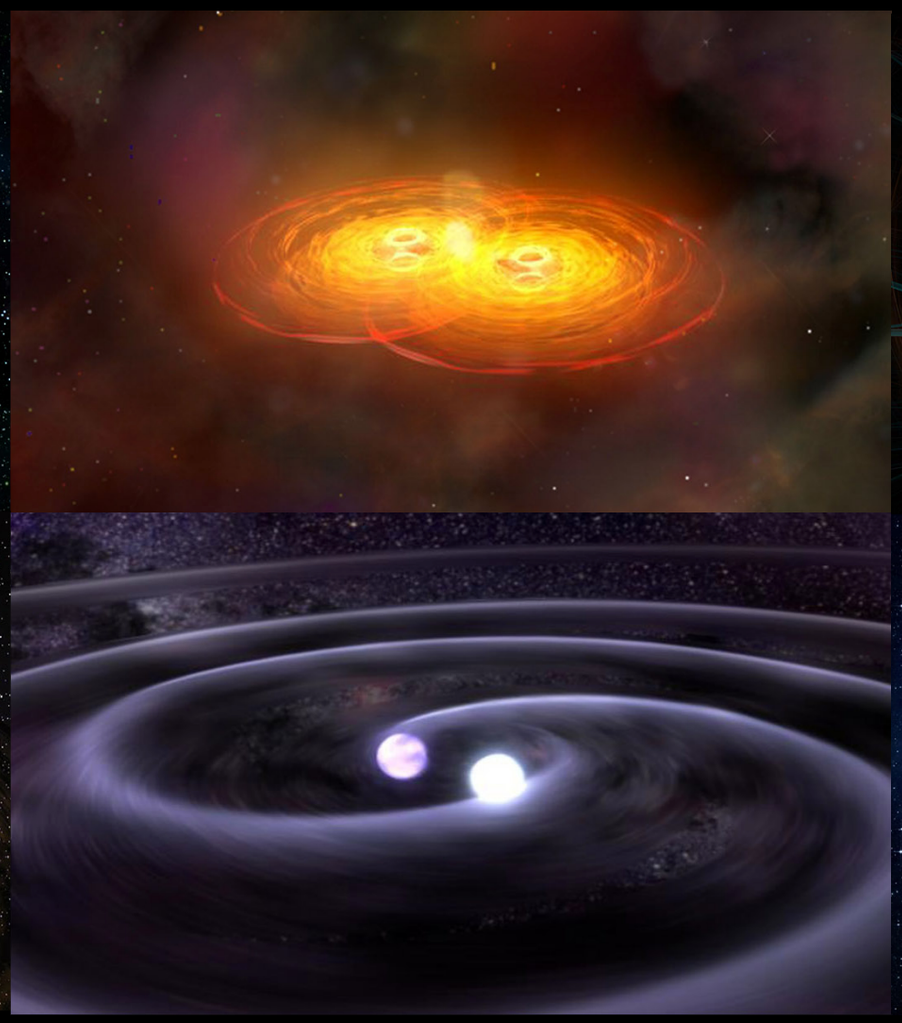
Radio 1420MHz (J. Dickey et.al. UMn. NRAO SkyView)



Radio 408MHz (C. Haslam et al., MPIfR, SkyView)



GRAVITATIONAL WAVES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