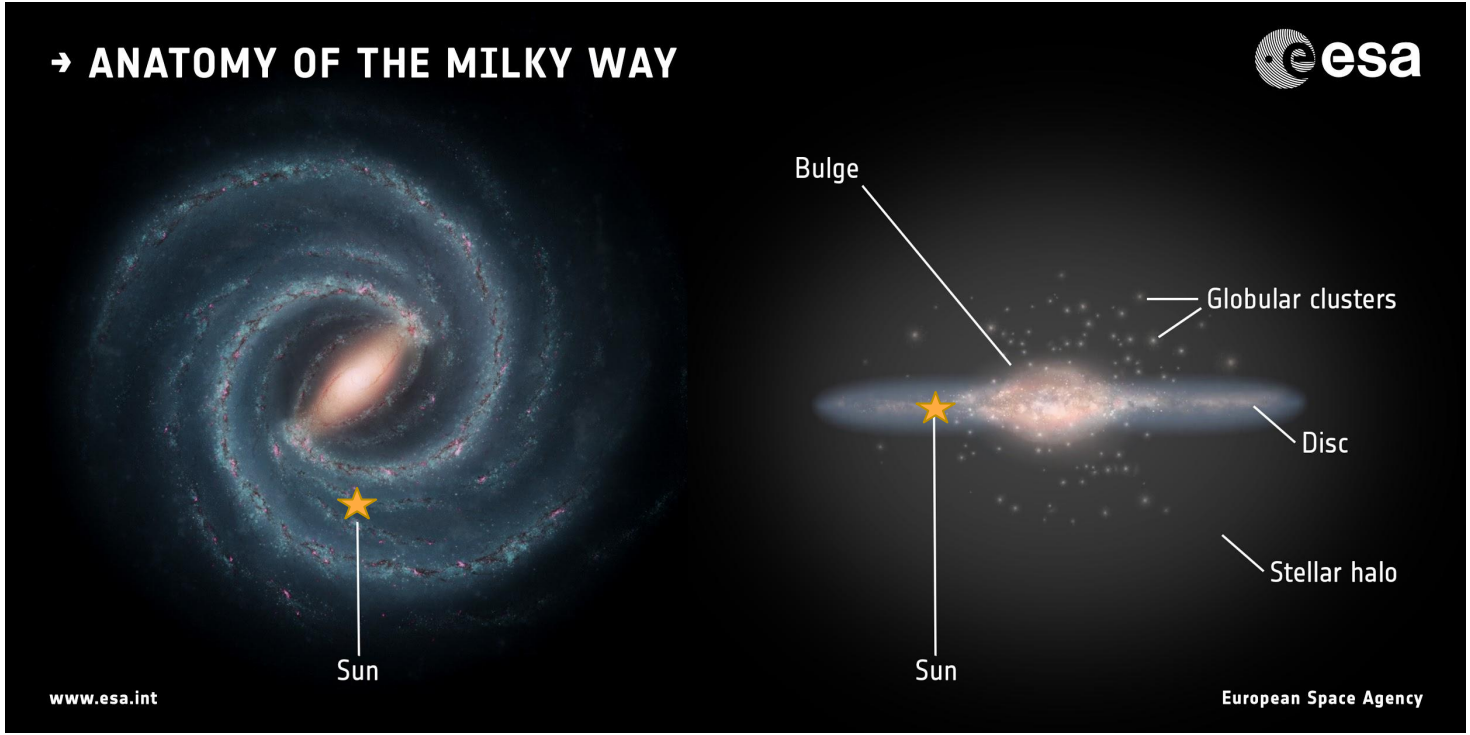
Mapping the sky with Einstein's invisible waves

Astronomy in the City
25th November 2020, Birmingham (UK)

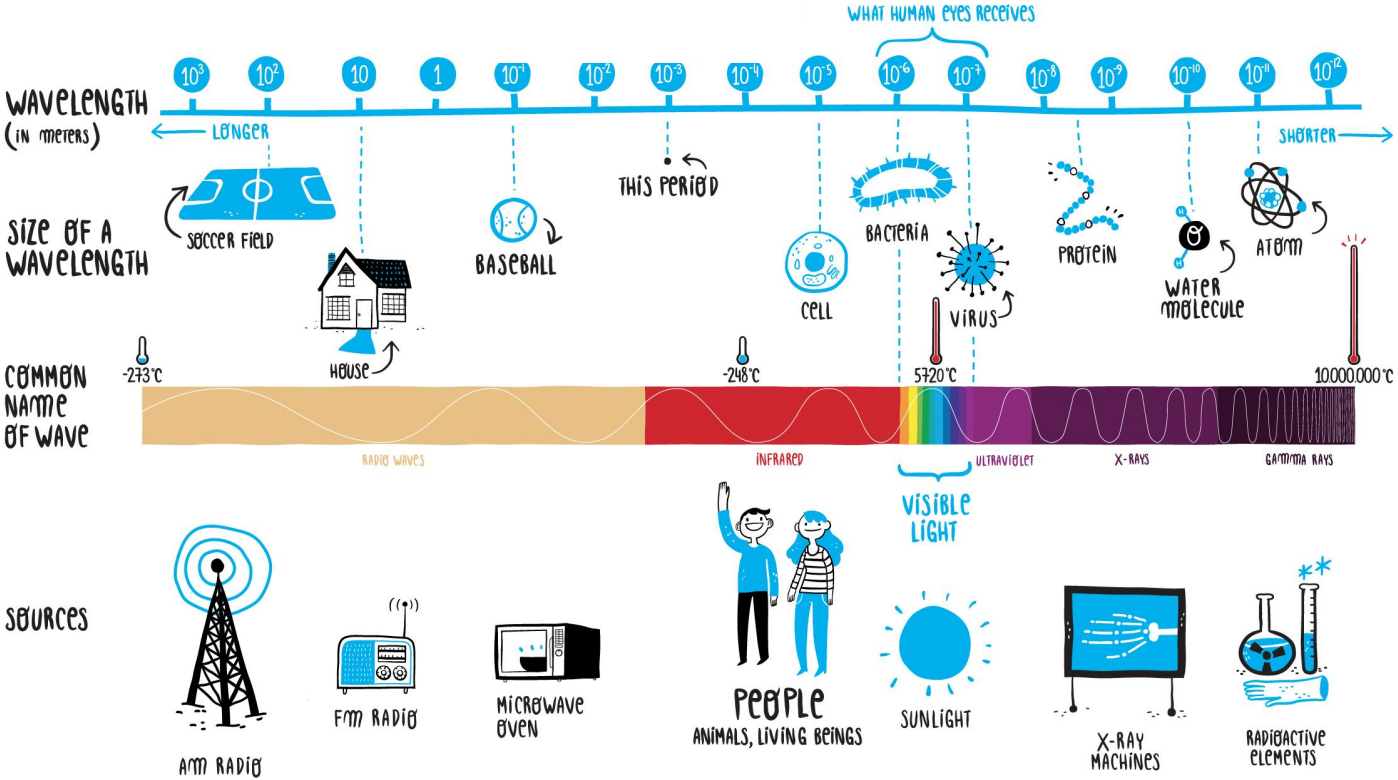
Valeriya Korol
Institute for Gravitational Wave Astronomy
University of Birmingham

The Milky Way seen from Broad Haven, Pembrokeshire. Photograph: Alamy

How does the Milky Way look from outside?

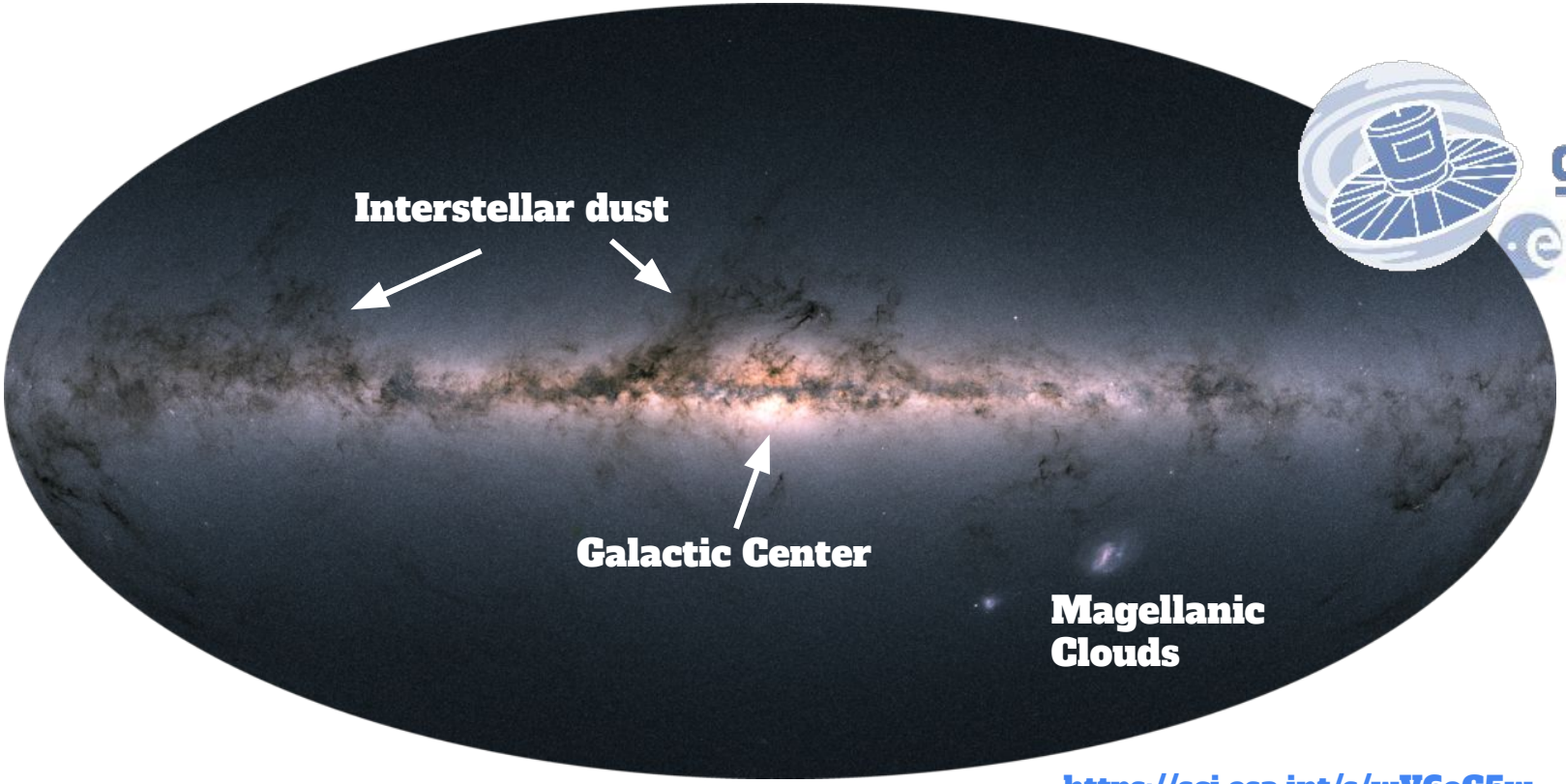


Electromagnetic spectrum



kids.alma.cl/the-electromagnetic-spectrum/

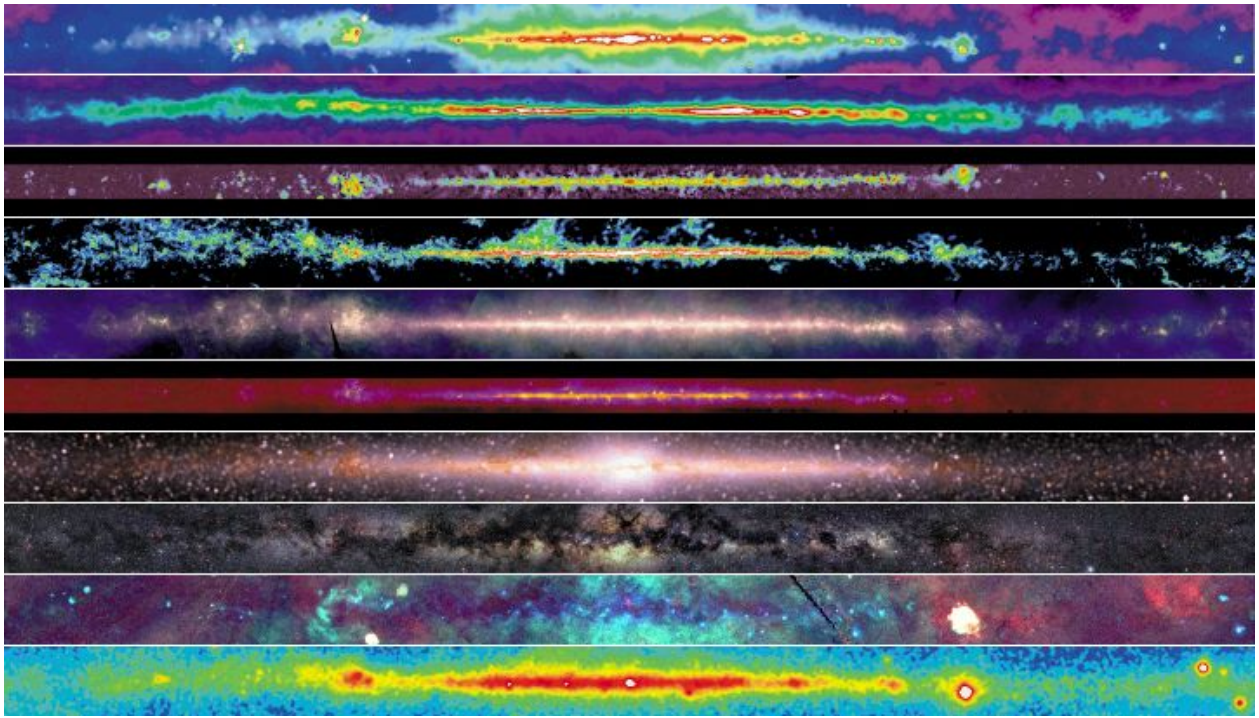
Milky Way at optical wavelengths



gaia
esa

https://sci.esa.int/s/wV6oG5w

Milky Way at different wavelengths



Radio Continuum (408 MHz)

Atomic Hydrogen

Radio Continuum (2.4-2.7 GHz)

Molecular Hydrogen

Infrared

Mid Infrared (6.8 - 10.0 micron)

Near Infrared

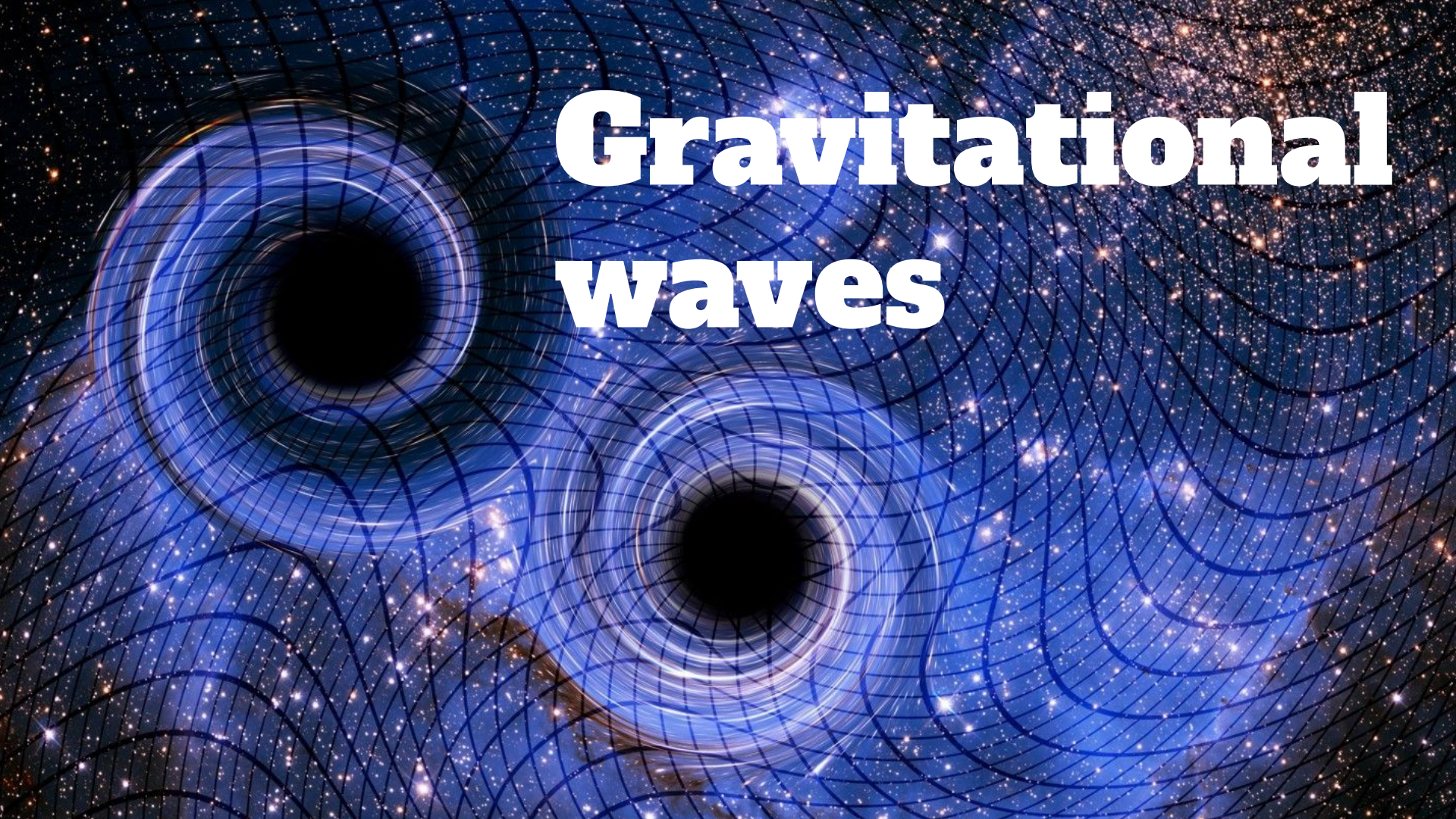
Optical

X-Ray

Gamma Ray

nasa.gov/archive/mwmw/mmw_images

Can we use a different kind of waves to study the Milky Way?


Gravitational
waves

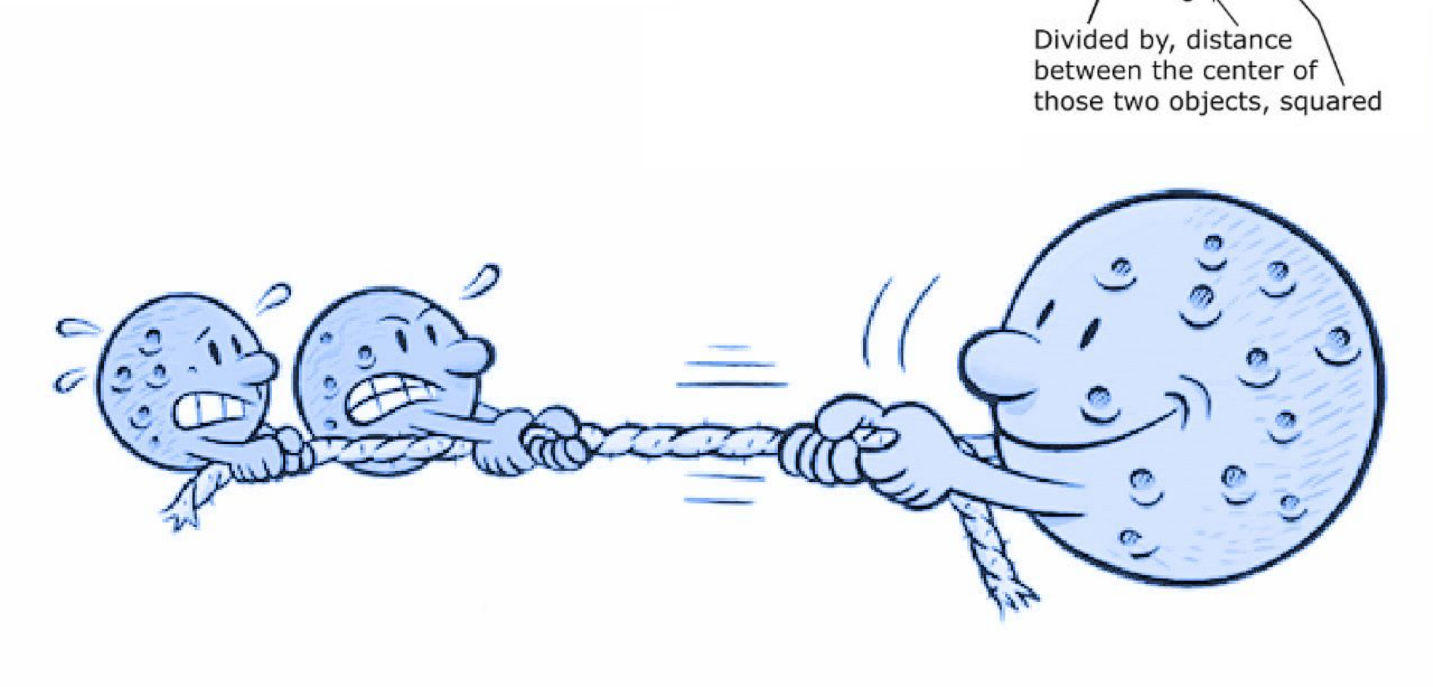
Newton's Gravity

$$F = G\frac{m_1 m_2}{r^2}$$

Mass of object 1 times, Mass of object 2

Force, equals, Gravity times

Divided by, distance between the center of those two objects, squared



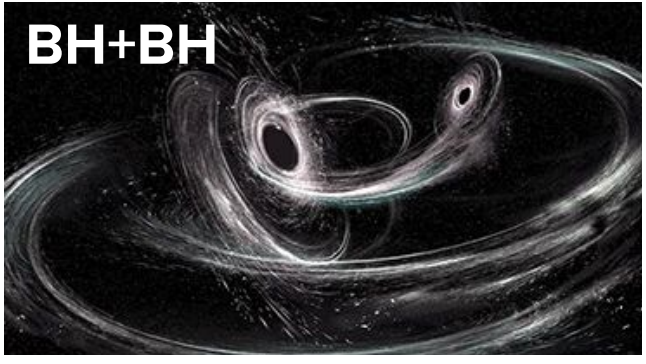
Einstein's Gravity

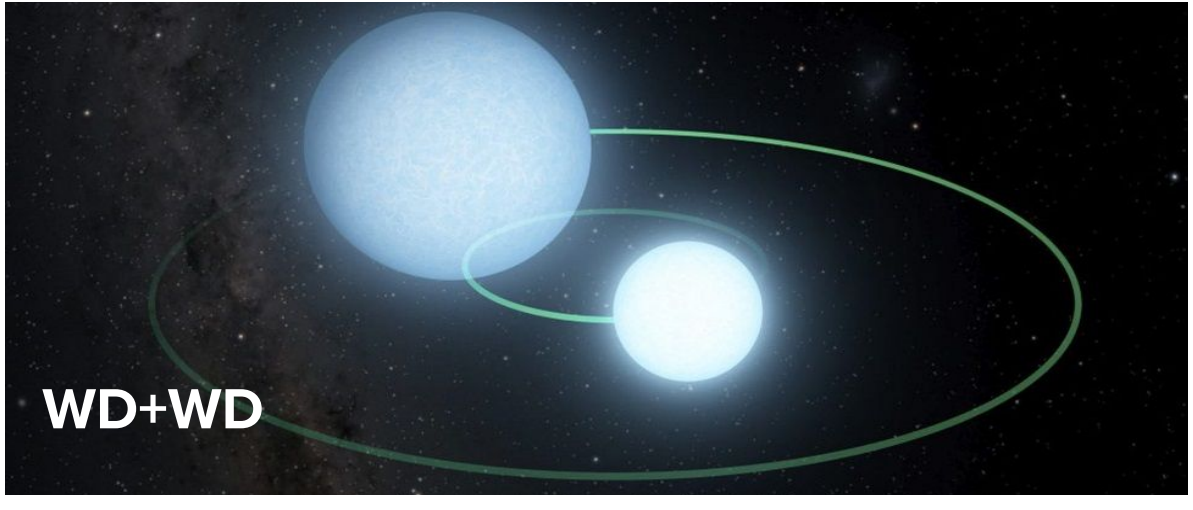
$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

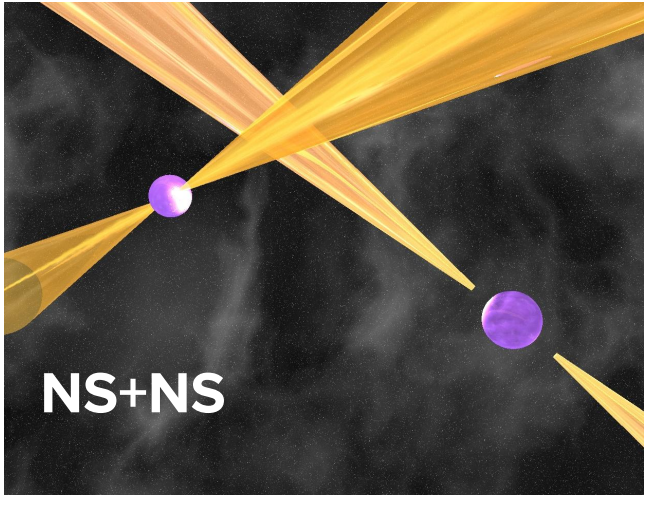
Matter tells spacetime how to curve
Spacetime tells matter how to move
- John Wheeler

Gravitational waves are ripples in the fabric of spacetime

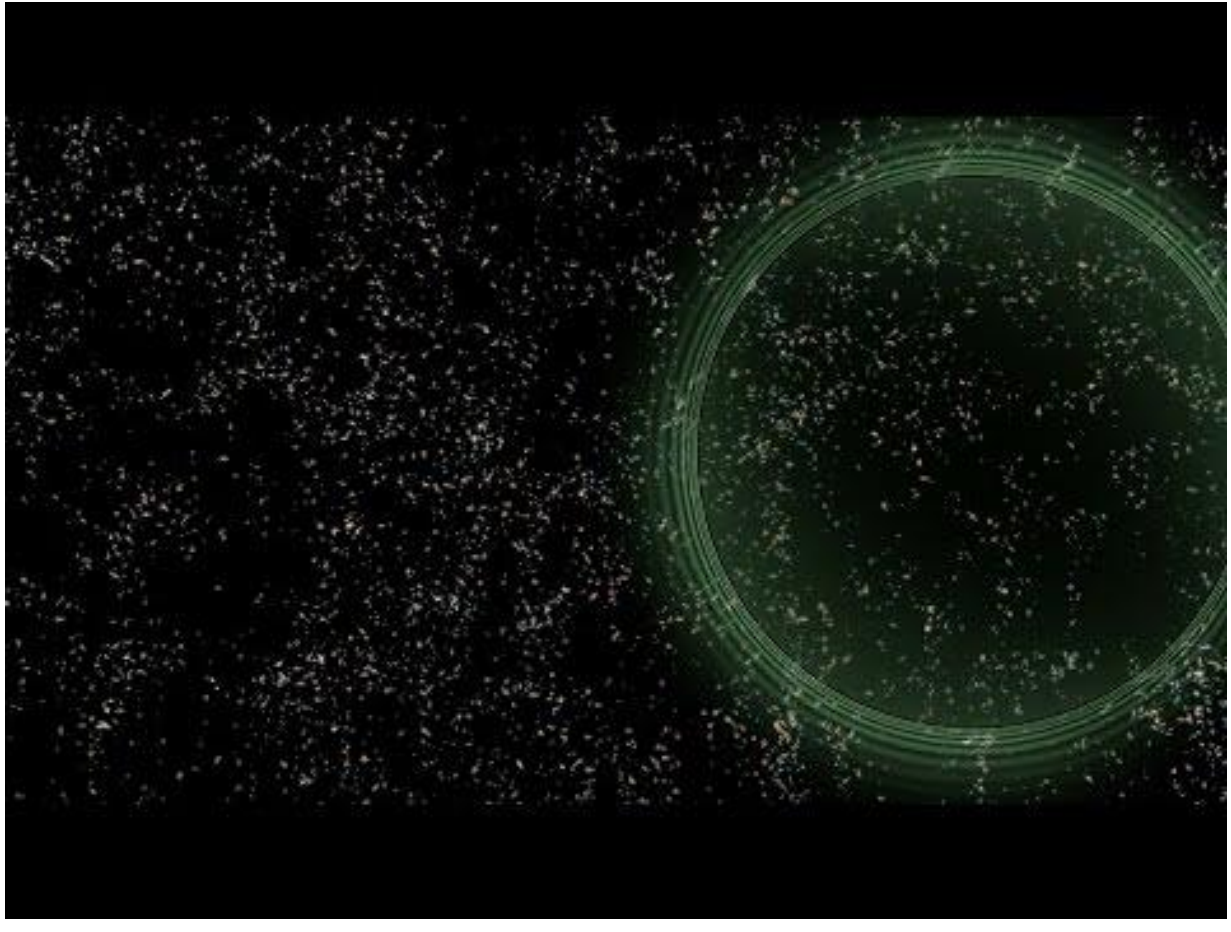
They can be produced by something very massive and compact moving very fast. Binary systems composed of white dwarfs, neutron stars and black holes are the most common gravitational wave emitters.



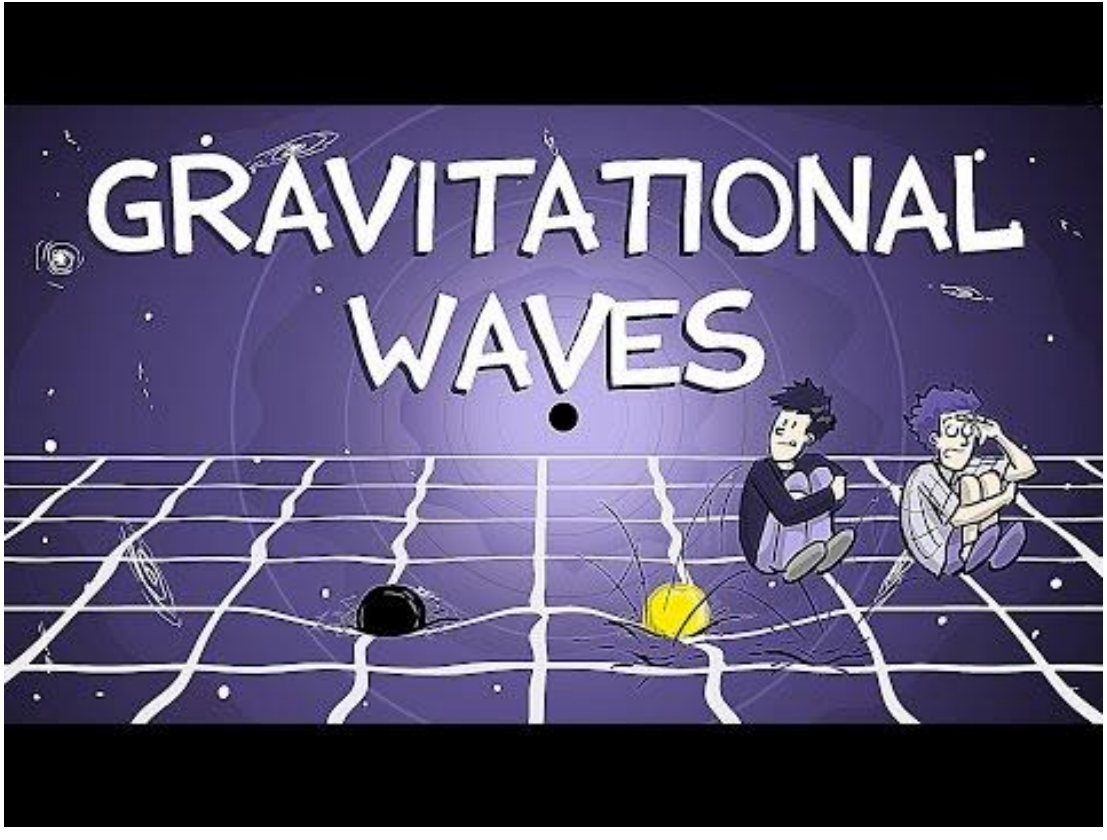




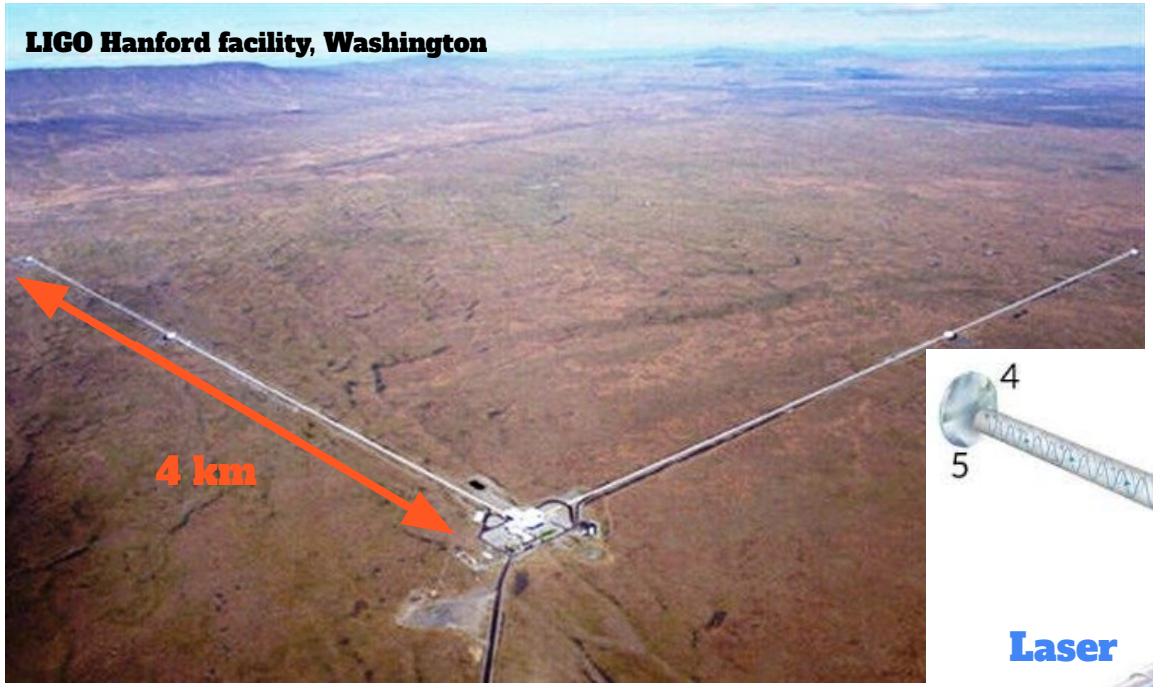
Effect of gravitational waves

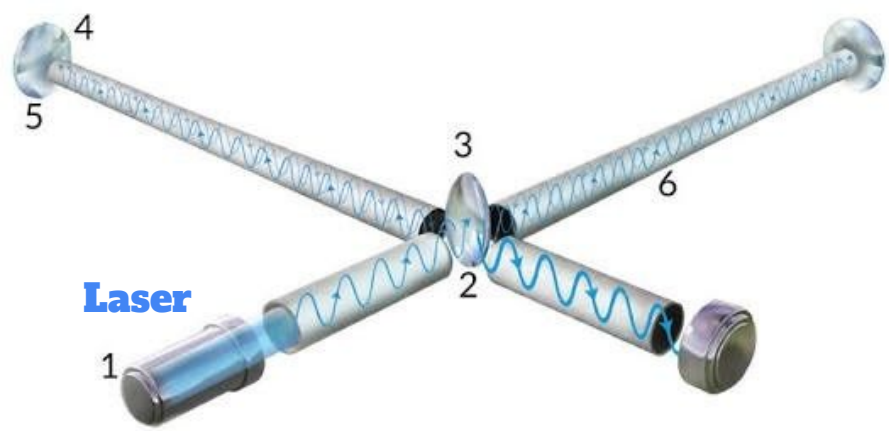


How would you measure wripples of the spacetime?

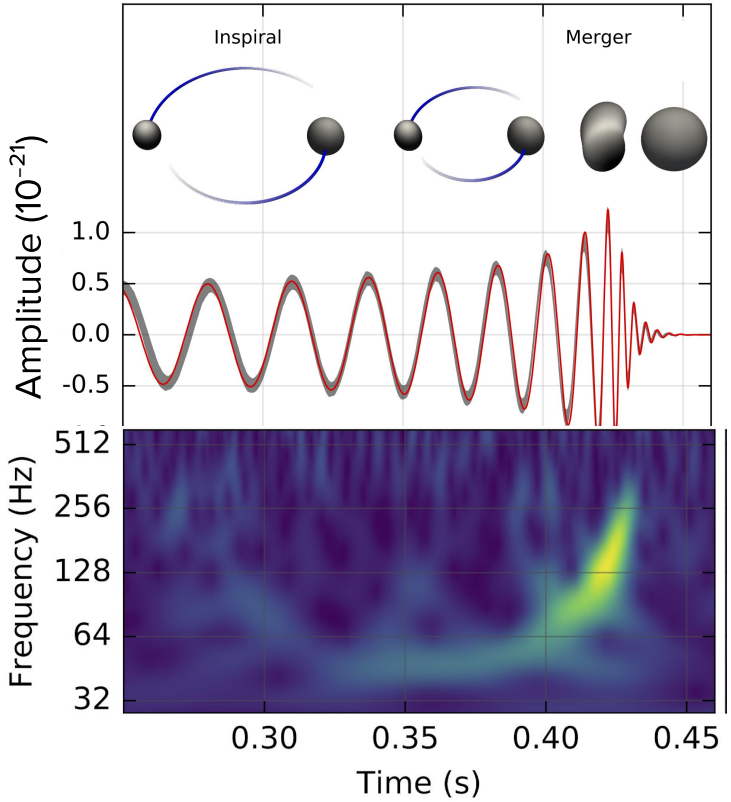


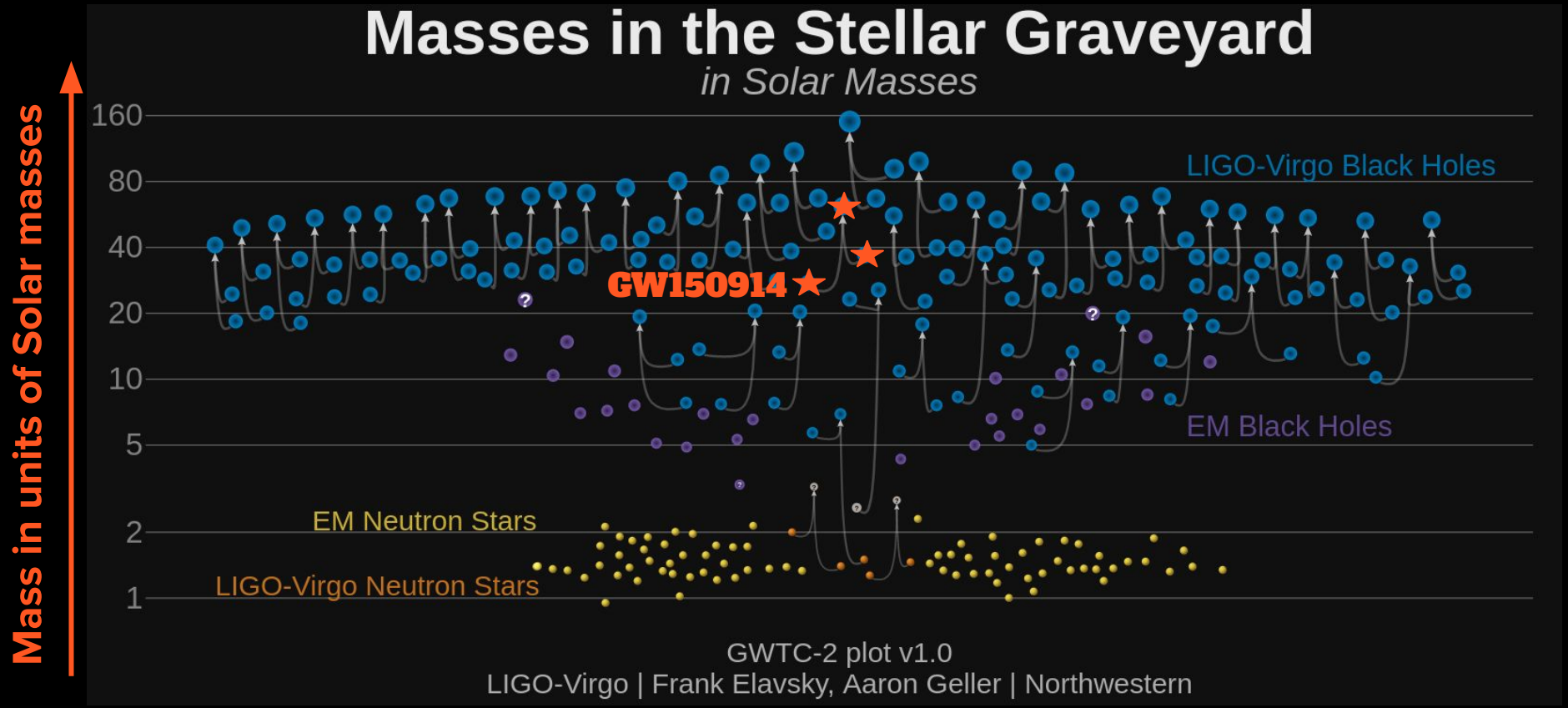
LIGO = Laser Interferometer Gravitational wave Observatory





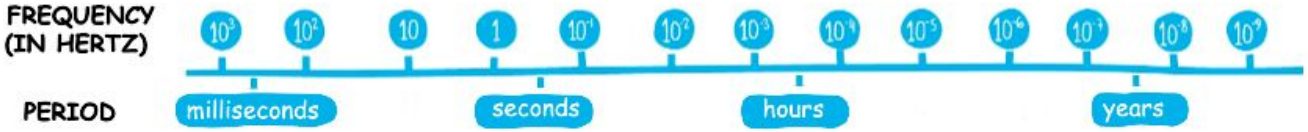
GW150914 first ever detected gravitational wave!




Masses in the Stellar Graveyard
in Solar Masses
Mass in units of Solar masses
160
80
40
20
10
5
2
1
LIGO-Virgo Black Holes
GW150914
EM Black Holes
EM Neutron Stars
LIGO-Virgo Neutron Stars
GWTC-2 plot v1.0
LIGO-Virgo | Frank Elavsky, Aaron Geller | Northwestern

What’s next?

THE GRAVITATIONAL WAVE SPECTRUM



THE GRAVITATIONAL WAVE SPECTRUM

FREQUENCY (IN HERTZ)

10^{3} 10^{2} 10 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9}

PERIOD

milliseconds | seconds | hours | years

SIZE OF A WAVELENGTH

RADIUS OF THE EARTH

RADIUS OF THE SUN

RADIUS OF THE MILKY WAY

THE GRAVITATIONAL WAVE SPECTRUM

FREQUENCY (IN HERTZ)

10^{3} 10^{2} 10 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9}

PERIOD

milliseconds | seconds | hours | years

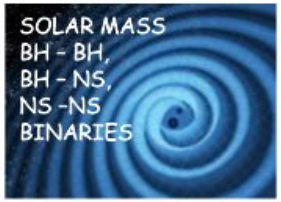
SIZE OF A WAVELENGTH

RADIUS OF THE EARTH

RADIUS OF THE SUN

RADIUS OF THE MILKY WAY

SOURCES



THE GRAVITATIONAL WAVE SPECTRUM

FREQUENCY (IN HERTZ)

10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9}

PERIOD

milliseconds — seconds — hours — years

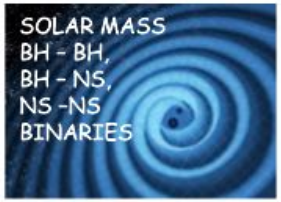
SIZE OF A WAVELENGTH

RADIUS OF THE EARTH

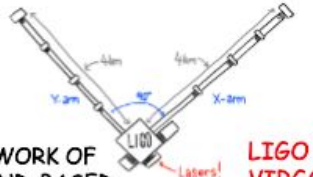
RADIUS OF THE SUN

RADIUS OF THE MILKY WAY

SOURCES



DETECTOR

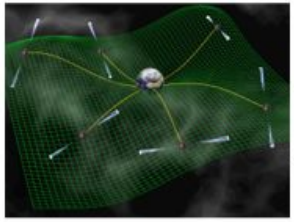


NETWORK OF GROUND-BASED DETECTORS

LIGO & VIRGO

SPACE_BASED DETECTORS

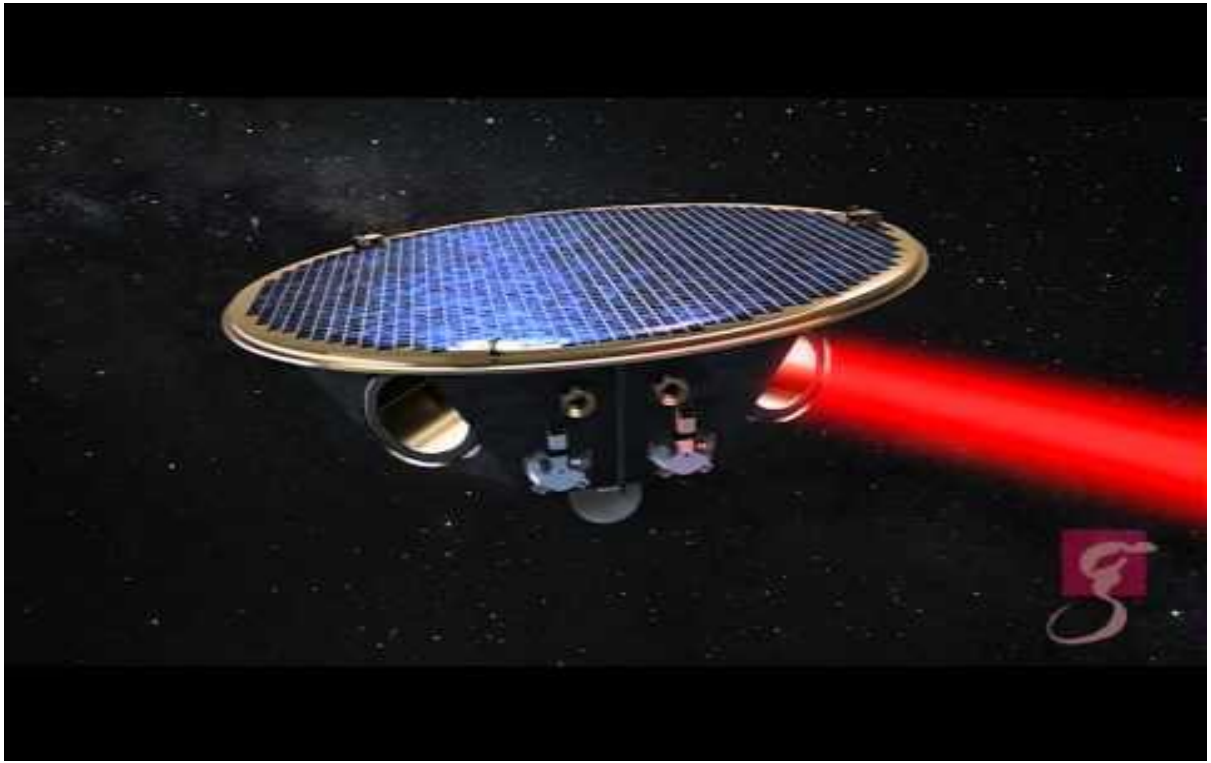
LISA mission



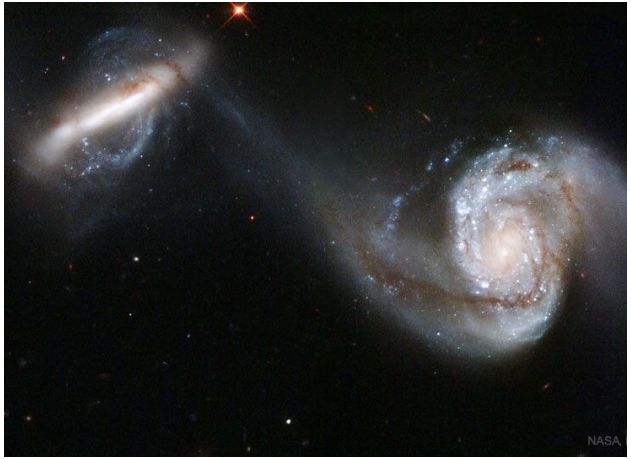
Pulsar Timing Array:

NETWORK OF GALACTIC PULSARS

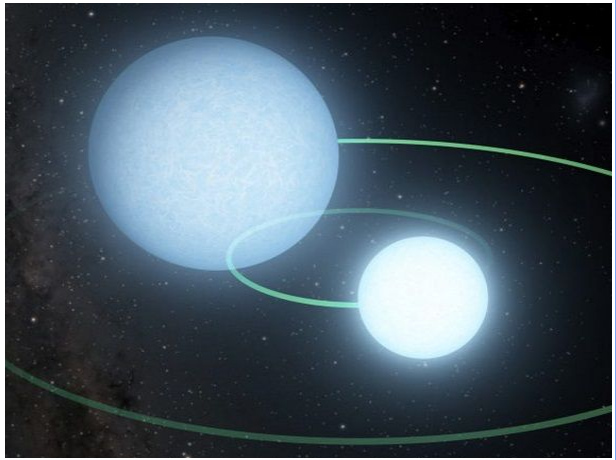
Laser Interferometer Space Antenna, in short LISA



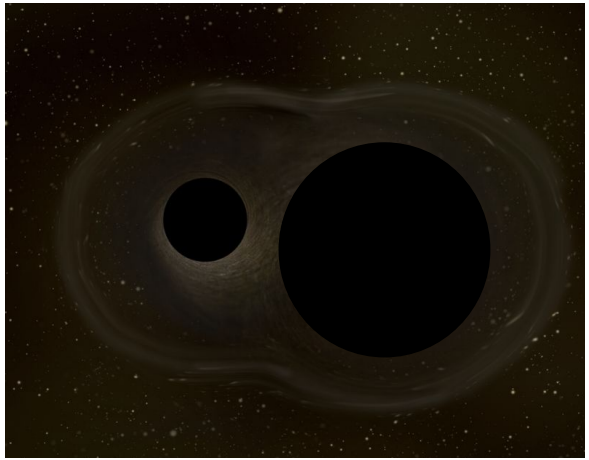
What will LISA observe?



Merger of supermassive black holes residing at the centers of galaxies across the whole Universe



White dwarf, neutron star and black hole binaries in our Milky Way

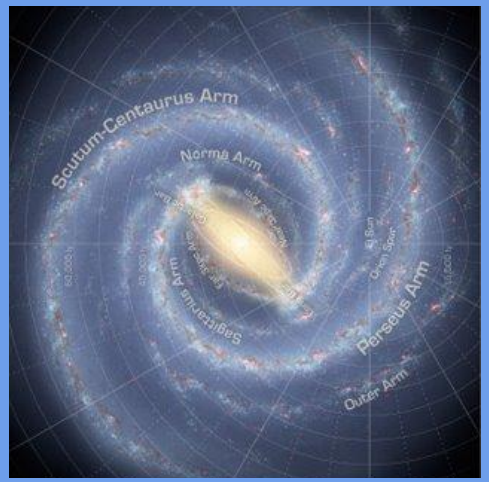


Stellar origin black holes falling into supermassive black holes

What can LISA tell us about our Galaxy?

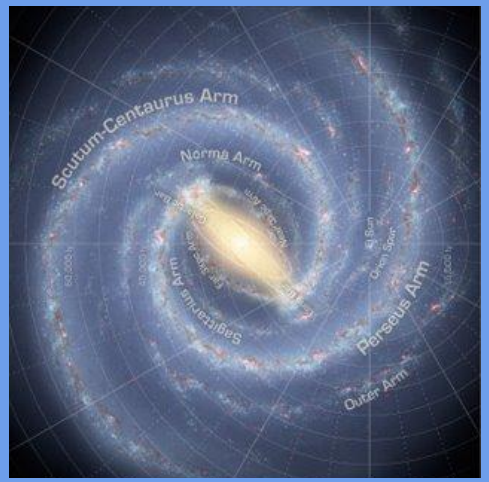
Modelling the Milky Way for LISA

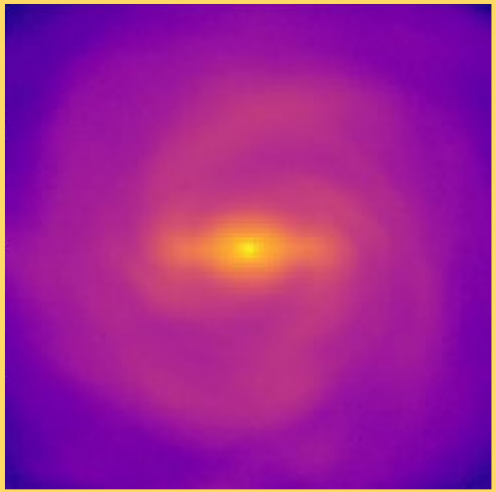
Idea to test



Modelling the Milky Way for LISA

Idea to test

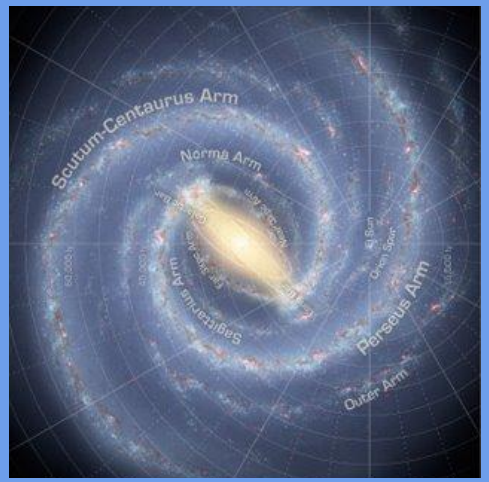


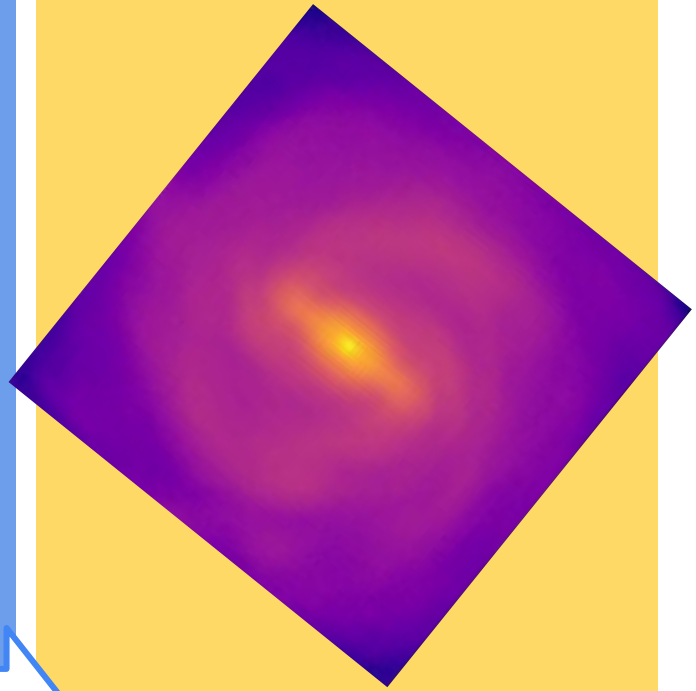


Milky Way simulation

Modelling the Milky Way for LISA

Idea to test

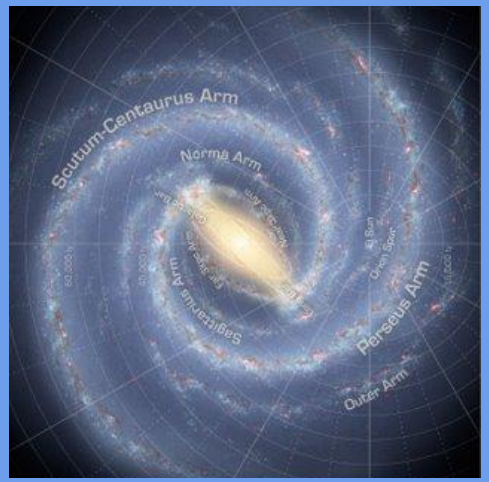


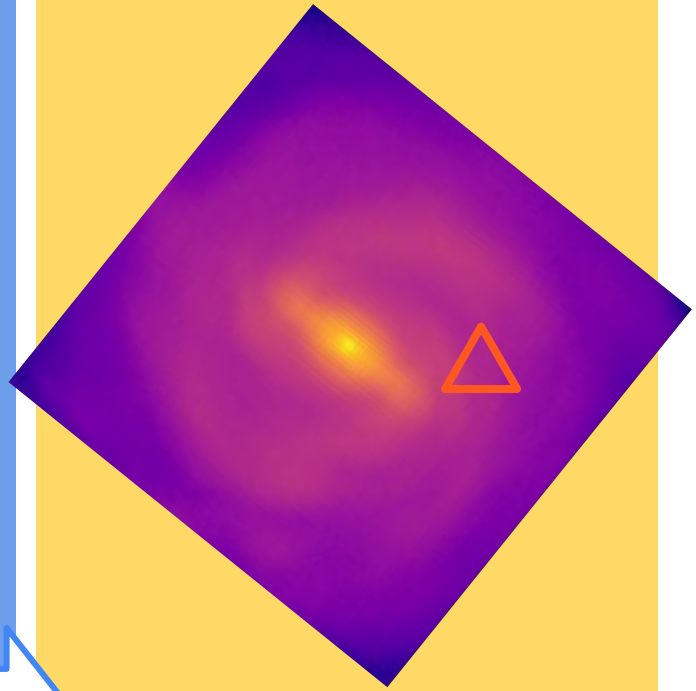


Milky Way simulation

Modelling the Milky Way for LISA

Idea to test

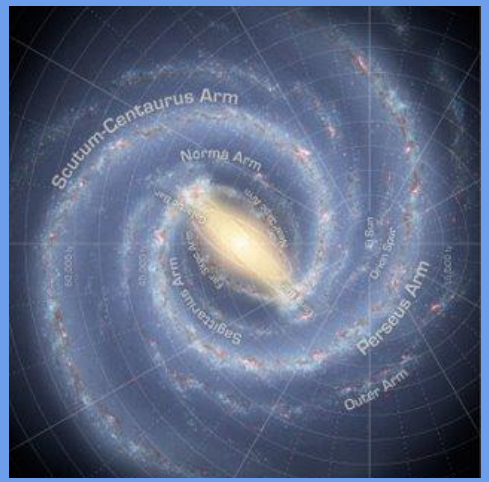


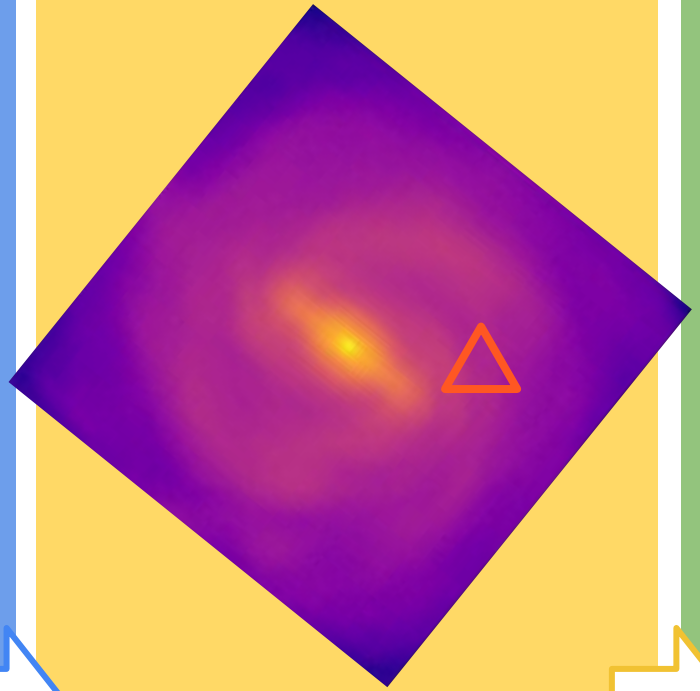


Milky Way simulation

Modelling the Milky Way for LISA

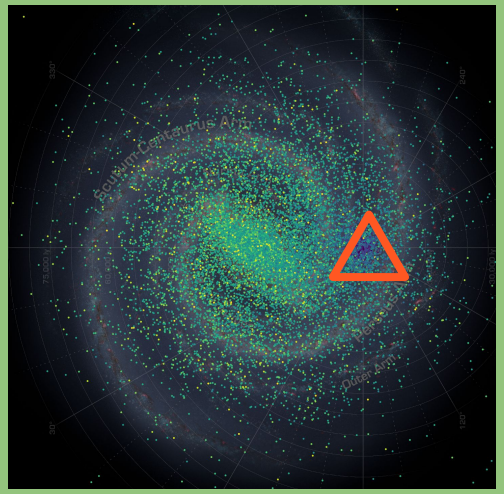
Idea to test



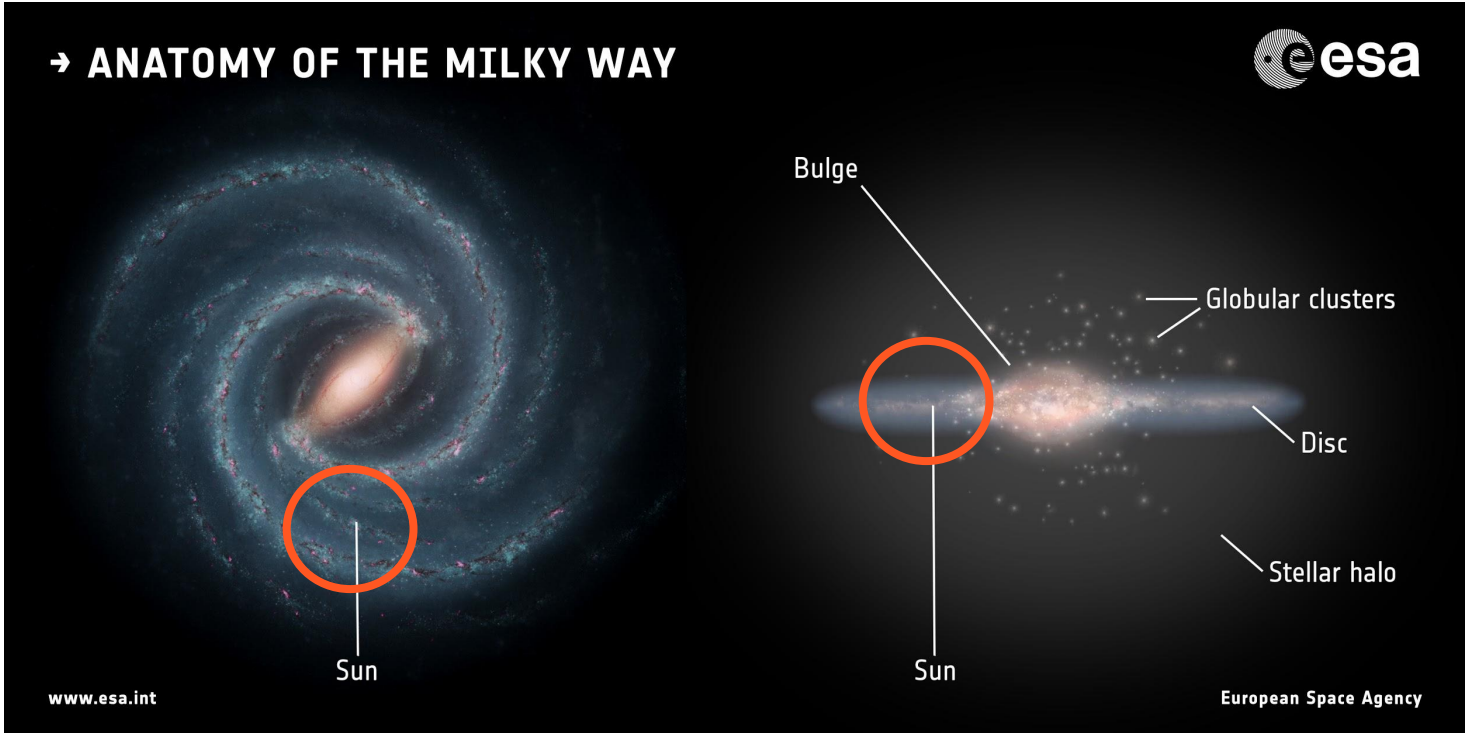


Milky Way simulation

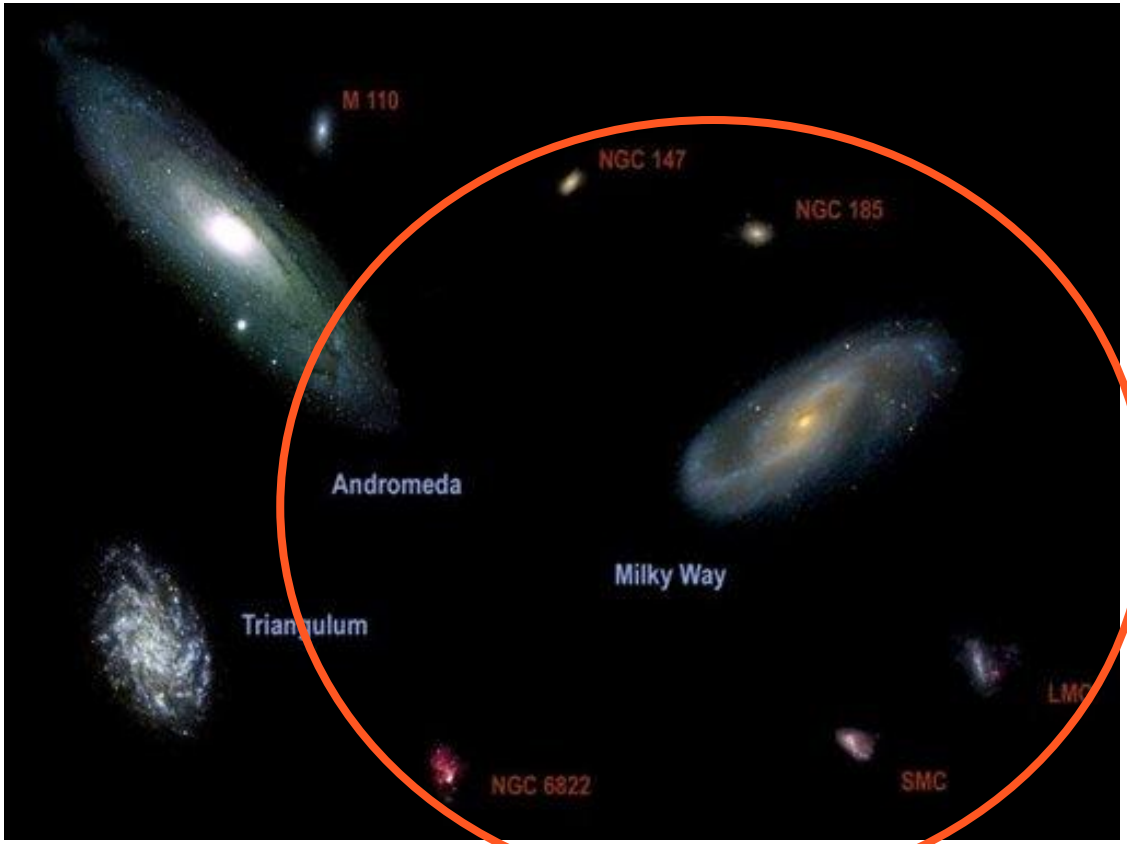
LISA simulation



Range of the optical telescopes for binary white dwarfs



Range of LISA for binary white dwarfs



Milky Way in gravitational waves