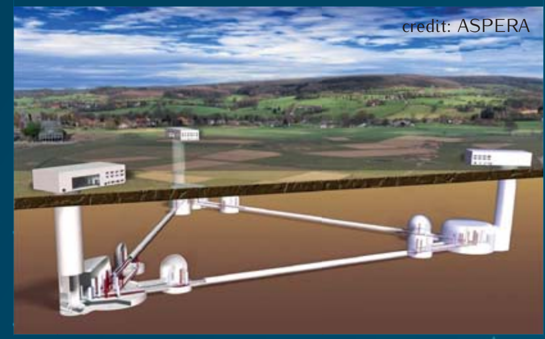
Observatories Cover Entire Spectrum of Gravitational Waves

2025-2035



First **underground laser interferometric gravitational wave detectors** (3rd generation) like KAGRA (Japan) or the Einstein Telescope (EU) will cover the entire **kHz frequency gravitational wave** range with unprecedented sensitivity.

A **space based laser interferometric gravitational wave detector** following the **LISA mission** concept will observe **low mHz frequency gravitational waves** to address ESA's Cosmic Vision L3 science theme "The Gravitational Universe". **Launch in the 2030s.**

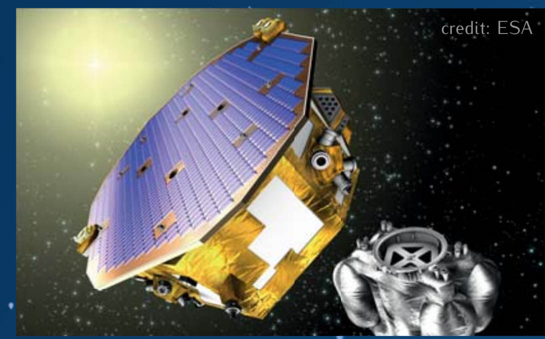
The future **Square Kilometre Array will** allow very high precision pulsar timing and significantly enhance **nHz frequency gravitational wave** observations.

By 2035, gravitational wave detectors will **cover the entire frequency range** and will observe black hole mergers, extreme mass ratio inspirals and compact binary star systems on a daily basis. Among others we will learn about the **evolution of the Universe and the event horizon of black holes.** Also electromagnetically dark and yet unknown sources of gravitational waves might be detected.

First Advanced Gravitational Wave Detectors Online

2015-2025

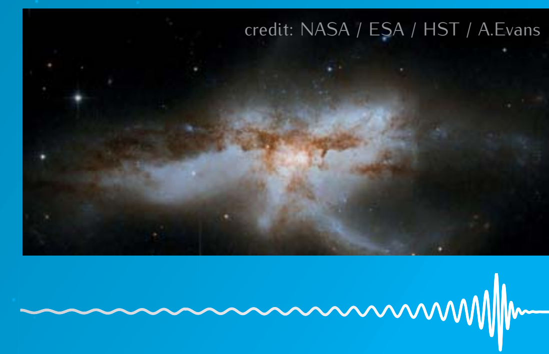
First **advanced laser interferometric gravitational wave detectors** like Advanced LIGO and Advanced Virgo become fully operational. **First direct detection of gravitational waves expected soon after.** GEO600 continues **technology development for future detectors.**



LISA Pathfinder (ESA) will test technologies for space based gravitational wave observatories. **Launch in 2015.**

Pulsar Timing Arrays observe **very low frequency gravitational waves** and complement the laser interferometric detectors.

The first direct detection of gravitational waves is expected soon after the advanced laser interferometric detectors become operational. These will be able to observe strong high frequency signals from spinning neutron stars, neutron star mergers and supernovae, and **start the field of gravitational wave astronomy.** Work on future detectors (underground and in space) will continue.



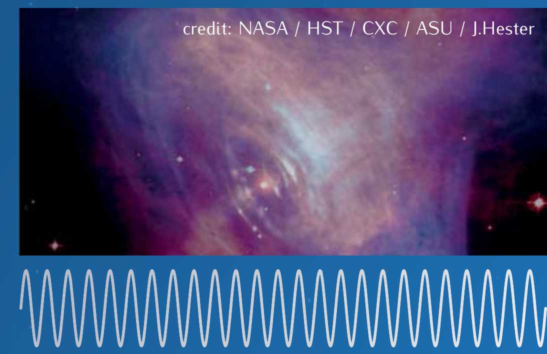
Galaxy mergers – the coalescence of two supermassive black holes – produce a gravitational wave signal with inspiral, merger and ringdown.

A First Step Towards Gravitational Wave Astronomy?

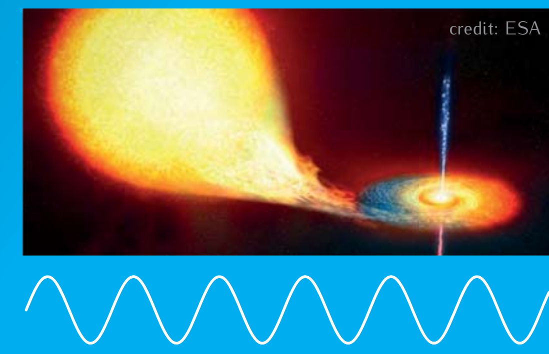
March 17 2014

Researchers found evidence for the cosmic inflation. After independent confirmation, this would be the very first time that gravitational waves extend our knowledge about the otherwise invisible Universe.

There is strong evidence that data of the **cosmic microwave background polarization** by the BICEP2 telescope holds information about **gravitational waves produced during the first tiny fraction of a second after the Big Bang.** If confirmed by other experiments, this is a validation of cosmic inflation and marks the beginning of a new astronomy where we observe the effects of gravitational waves on matter and radiation.



Spinning neutron stars with small (sub-centimeter) surface imperfection produce high frequency gravitational waves.



Compact binaries that consist of a neutron star or a black hole and a companion in very close orbit produce low frequency sine waves.

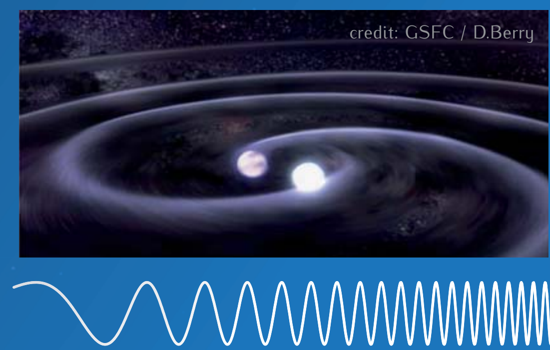
Indirect Proof for Gravitational Waves (1993 Nobel Prize)

1974

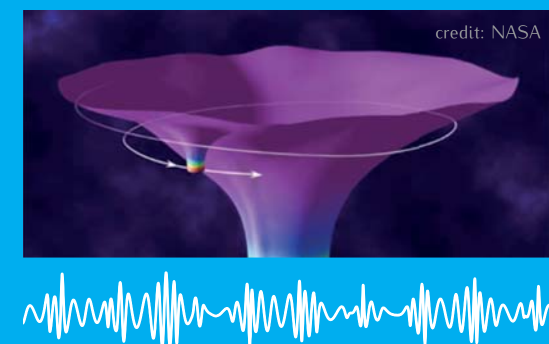
Russell Hulse and Joseph Taylor were awarded the Nobel Price for the first indirect observation of gravitational waves. They proved that the predictions of General Relativity are correct.

Two radio astronomers (Russell Hulse and Joseph Taylor) detected a **binary pulsar** in 1974 and were able to determine that **the orbital period decreases by about 77 millionth of a second per year.** This is in **excellent agreement with the general relativistic prediction** that the orbit should decay **by losing orbital energy in the form of gravitational waves.** The discovery was awarded the Nobel Prize in 1993.

The **BICEP2 telescope** (left) located in Antarctica is designed to detect the polarization of the cosmic microwave background.



Two neutron stars in a close orbit that shrinks until merger due to radiation of gravitational waves at increasing frequency.

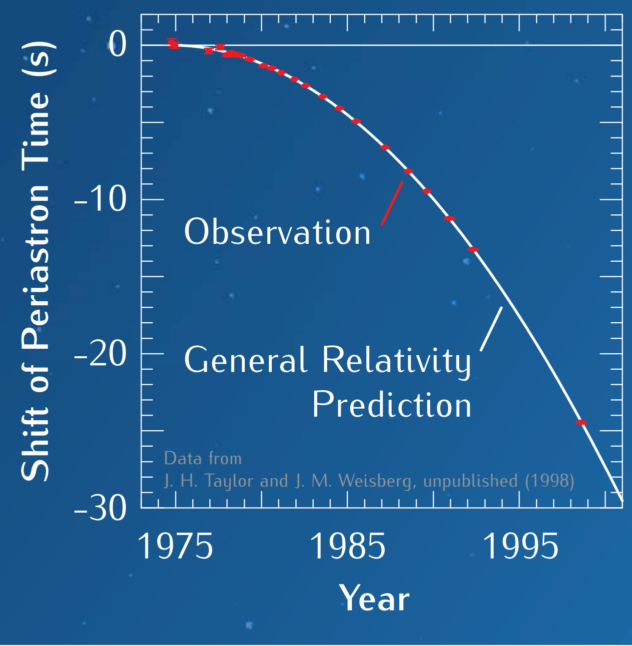


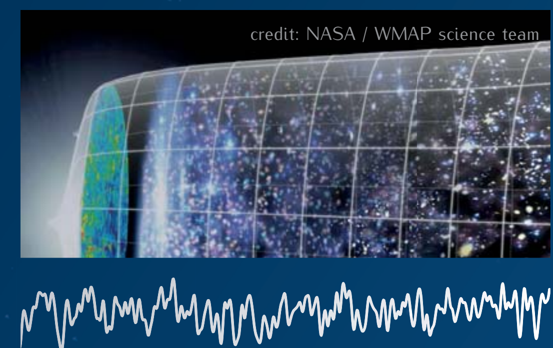
Gravitational waves produced in **extreme mass ratio inspirals** tell us details about the event horizon of massive black holes.

Prediction of Gravitational Waves by Albert Einstein

1916

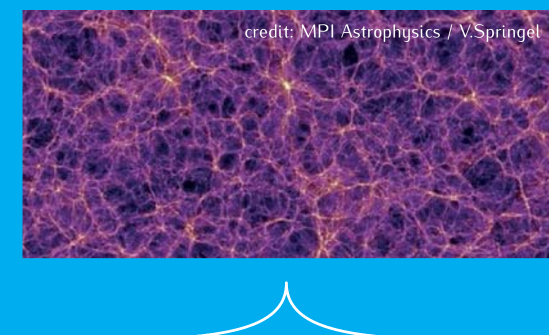
Since nothing can move faster than light, changes in the gravitational field should propagate at a finite speed in the form of **gravitational waves.** Albert Einstein discussed gravitational waves in his 1916 paper, but it was only in 1918 that he published "Über die Gravitationswellen" with a correct exposition of the subject. These waves are emitted by accelerated masses like binary star systems. **The observation of gravitational waves has the potential to revolutionize astronomy** since they can teach us about events not measurable in any other way.





Future detectors will be able to **directly observe the entire gravitational wave spectrum** produced during cosmic inflation.

Core-collapse (Type II) supernovae can produce gravitational waves with distinct characteristics at high frequencies.



Gravitational waves can originate from **cosmic strings** or totally unknown phenomena invisible to electromagnetic observations