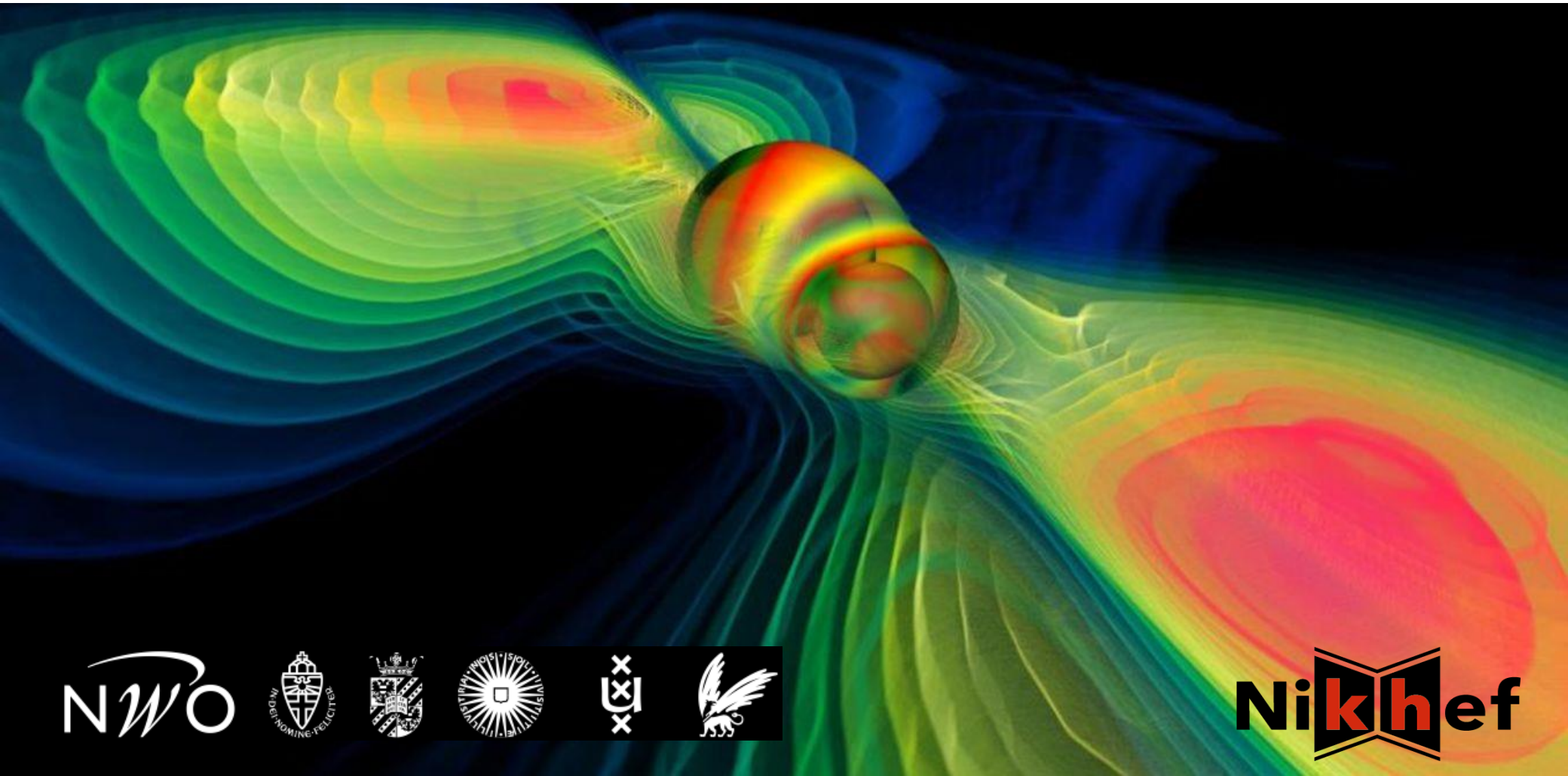
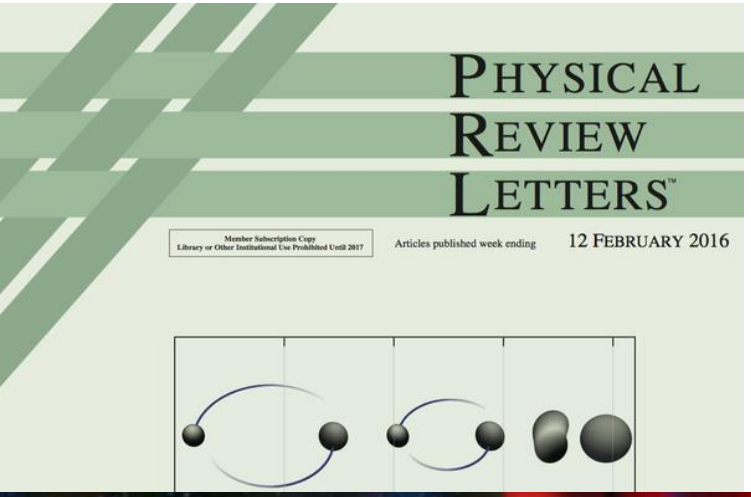
Einstein Telescope makes Europe greater

Jo van den Brand
Nikhef and VU Amsterdam



February 2016: discovery of gravitational waves

The discovery was world news. For the first time we can observe vibrations in space itself and employ this to study cosmological events, such as colliding black holes



"All the News That's Fit to Print"

The New York Times

Late Edition

Today, some sunshine giving way to times of clouds, cold, high 28. Tonight, a flurry or heavier squall late, low 15. Tomorrow, windy, frigid, high 21. Weather map, Page A19.

VOL. CLXV . . . No. 57,140 + © 2016 The New York Times NEW YORK, FRIDAY, FEBRUARY 12, 2016 $2.50

Clinton Paints Sanders Plans As Unrealistic

New Lines of Attack at Milwaukee Debate

By AMY CHOZICK and PATRICK HEALY

MILWAUKEE — Hillary Clin-

CALTECH-M.I.T.-LIGO LABORATORY

alled a baffle in 2010 to control light in the Laser Interferometer Gravitational-Wave Observatory in Hanford, Wash.

WITH FAINT CHIRP, SCIENTISTS PROVE EINSTEIN CORRECT

A RIPPLE IN SPACE-TIME

An Echo of Black Holes Colliding a Billion Light-Years Away

By DENNIS OVERBYE

A team of scientists announced on Thursday that they had heard and recorded the sound of two black holes colliding a billion light-years away, a fleeting chirp that fulfilled the last prediction of Einstein's general theory of relativity.

That faint rising tone, physicists say, is the first direct evidence of gravitational waves, the ripples in the fabric of space-time that Einstein predicted a century ago. It completes his vision of a universe in which space and time are interwoven and dynamic, able to stretch, shrink and jiggle. And it is a ringing confirmation of the nature of black holes, the bottomless gravitational pits

n Clinton's Corner, Blacks Notice Sanders

Last Occupier

SCIENCE

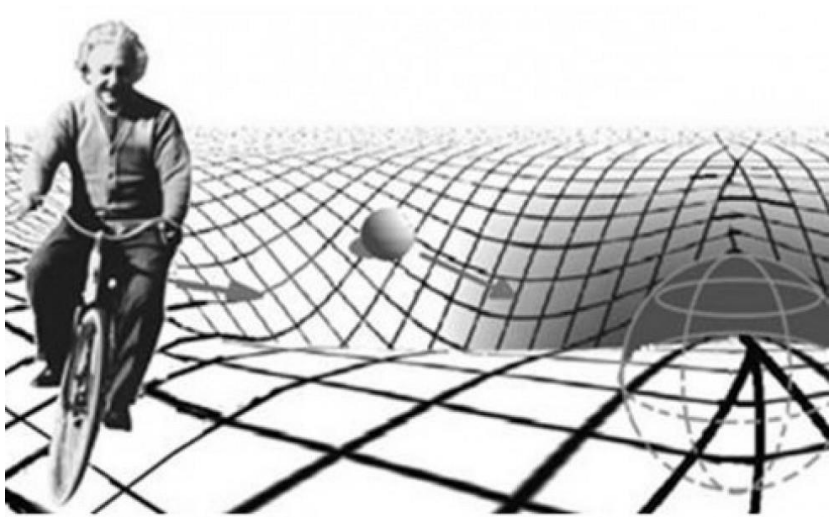
Gravitational Waves Detected, Confirming Einstein's Theory

Einstein’s theory of general relativity

Einstein discovers deep connections between space, time, light, and gravity

Einstein’s Gravity

- Space and time are physical objects
- Gravity as a geometry



Predictions

- Gravitation is curvature of spacetime
- Light bends around the Sun
- Expansion of the Universe
- Black holes, wormholes, structure formation, …
- Gravitational waves

LIGHTS ALL ASKEW IN THE HEAVENS

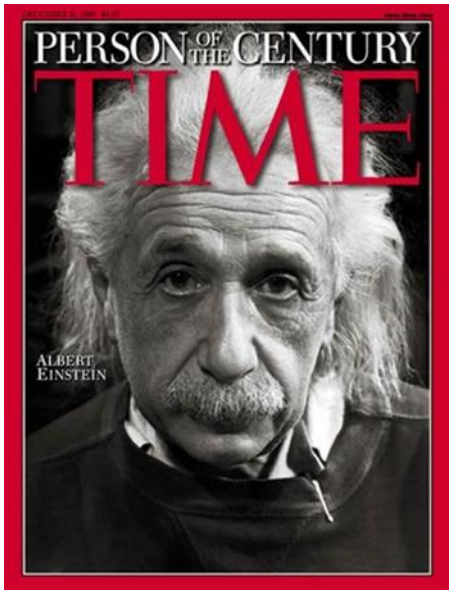
Men of Science More or Less Agog Over Results of Eclipse Observations.

EINSTEIN THEORY TRIUMPHS

Stars Not Where They Seemed or Were Calculated to be, but Nobody Need Worry.

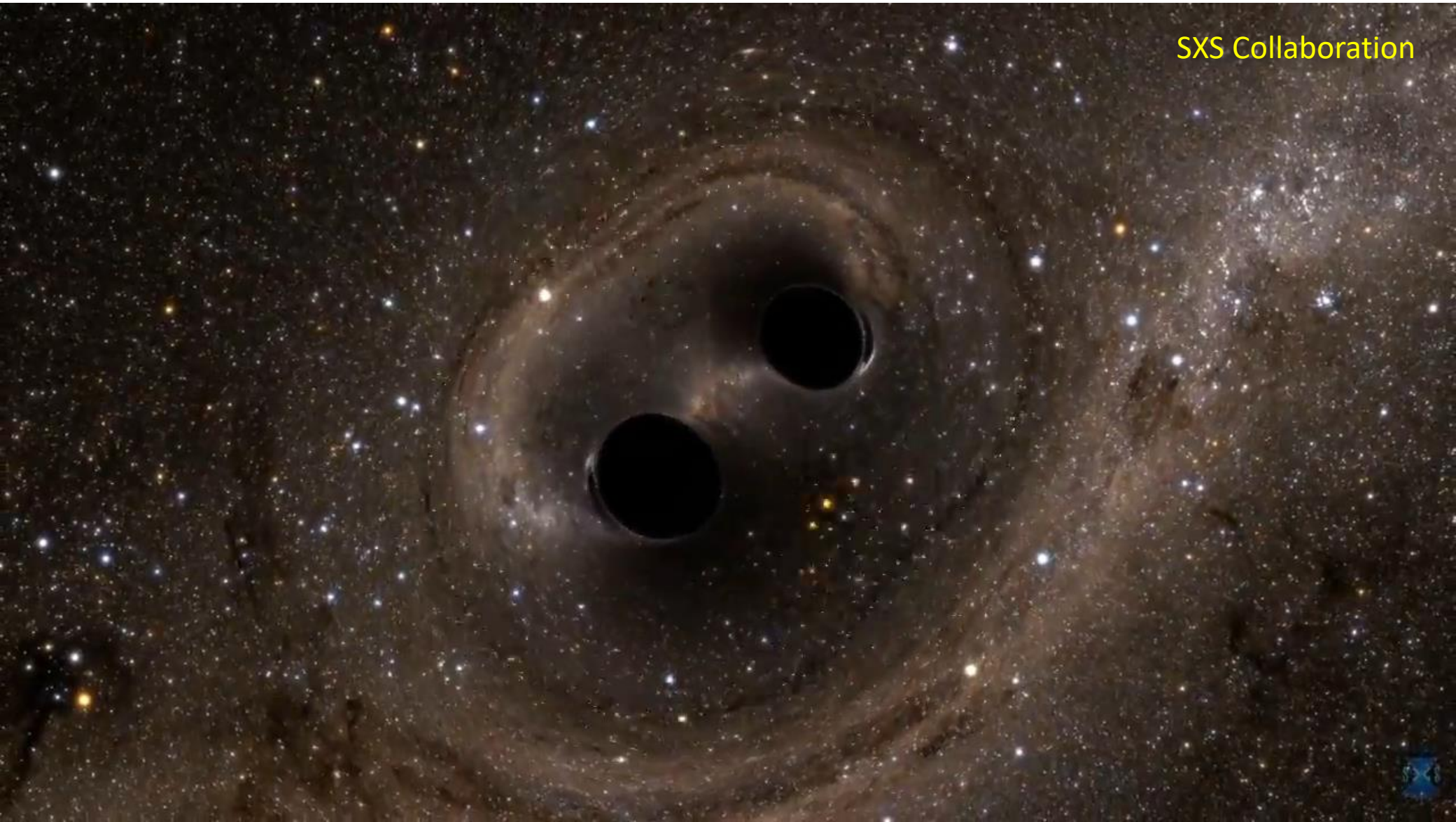
A BOOK FOR 12 WISE MEN

No More in All the World Could Comprehend It, Said Einstein When His Daring Publishers Accepted It.



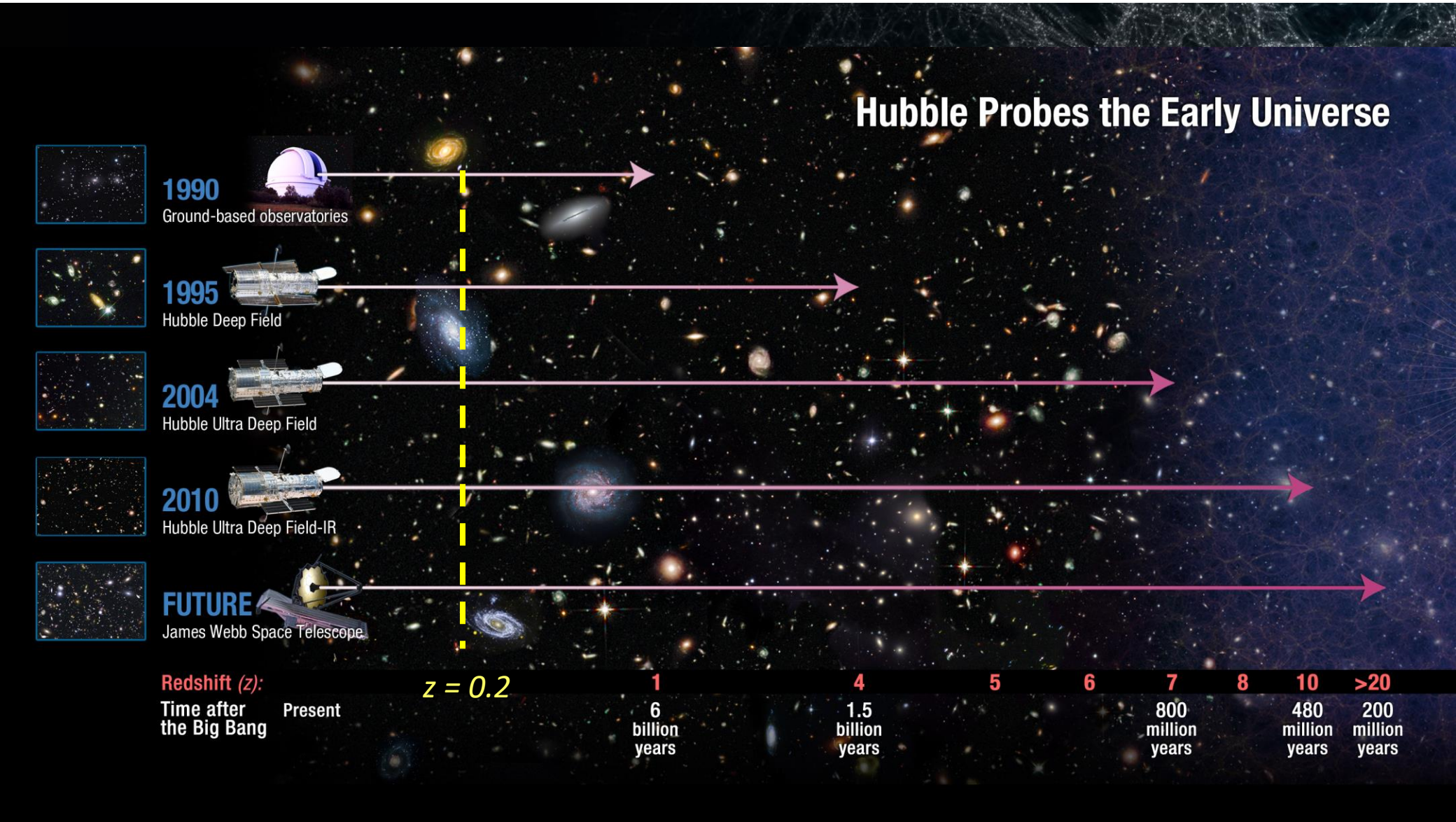
Event GW150914

Chirp-signal from gravitational waves from two coalescing black holes were observed with the LIGO detectors by the LIGO-Virgo Consortium on September 14, 2015



A view on the entire Universe

We want to study the early Universe, including the “dark ages”, before formation of the first stars



Einstein Telescope provides access to the *dark ages*

Einstein Telescope can detect merging black holes up to a redshift of 20. Cosmography and studies of primordial black holes become possible. Up to hundred throusand BBH events per year

Einstein Telescope provides access to the *dark ages*

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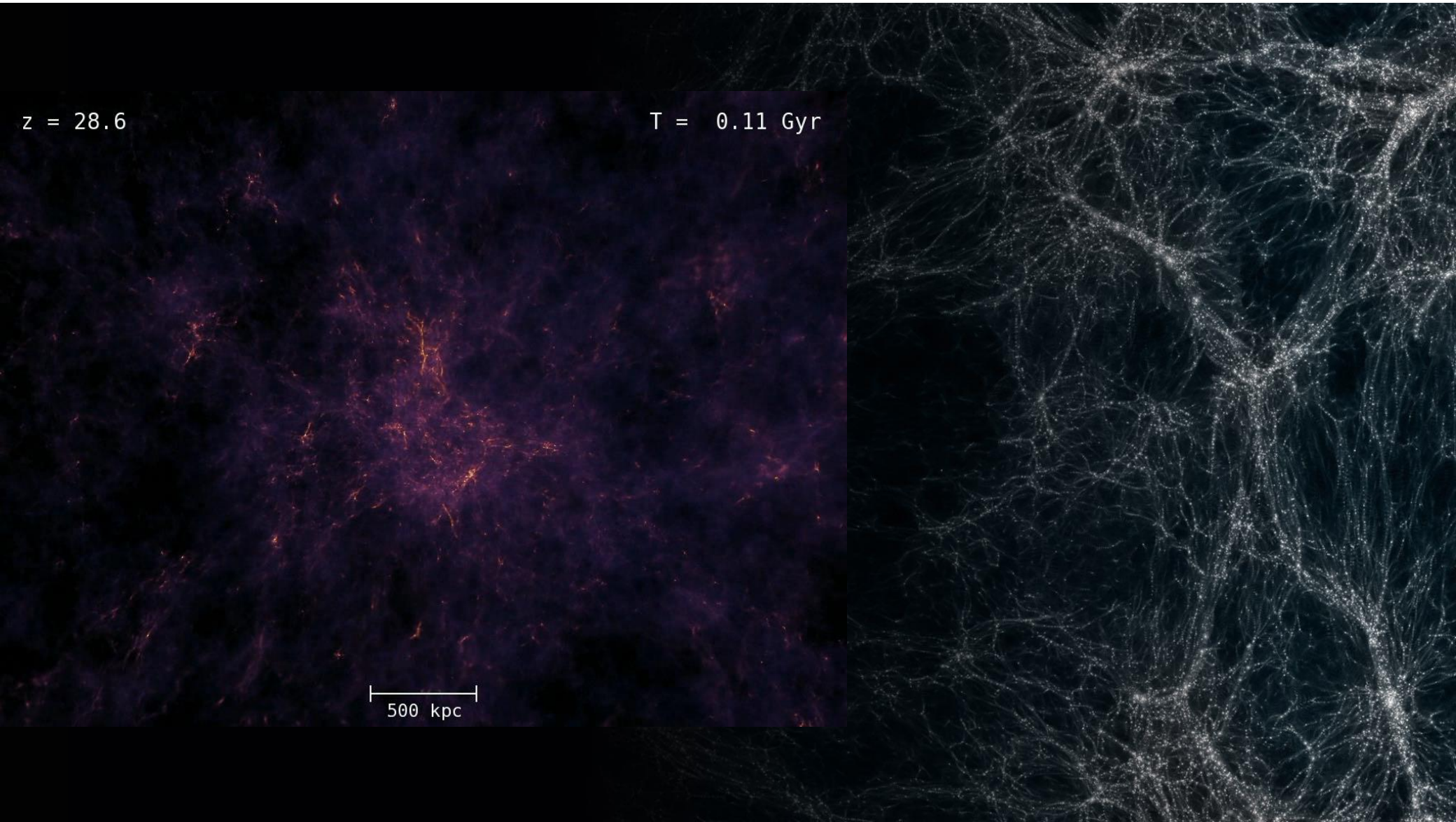
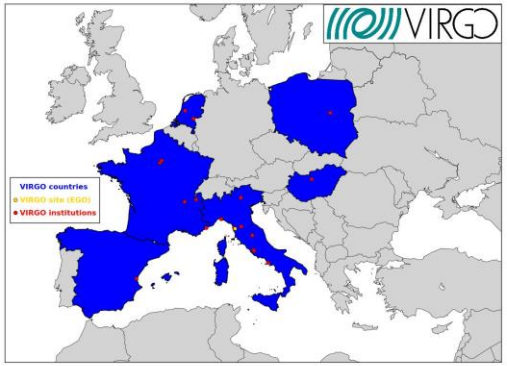


International collaboration of institutions

The best institutes in Europe will collaborate with top institutes worldwide. Einstein Telescope will act as a magnet for international top talent

The Virgo Collaboration at the European Gravitational Observatory consists of about 300 scientists from 20 institutes in France, Hungary, Italy, Poland, Spain and The Netherlands

LIGO Virgo Collaboration has about 1500 active researchers in 140 institutes and MOUs with 92 collaborations in astronomy. The best institutes and scientists are involved

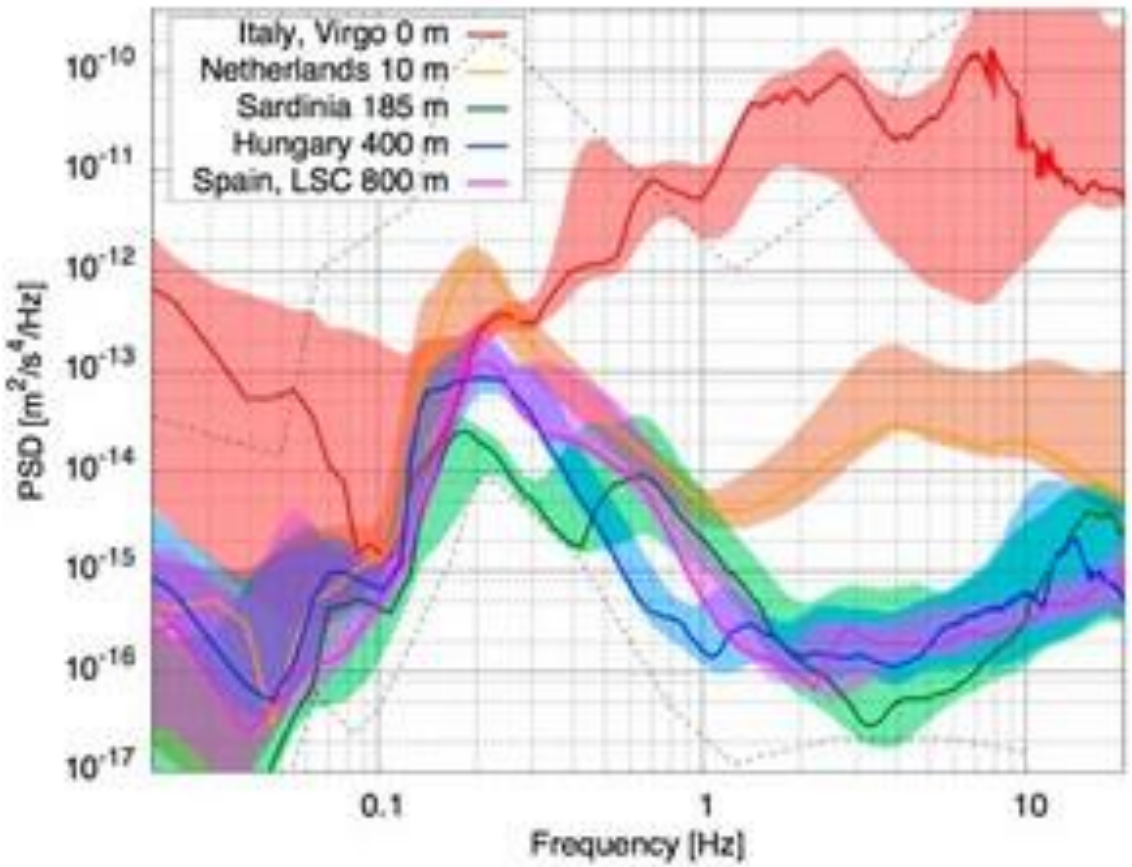


National interest should be fostered

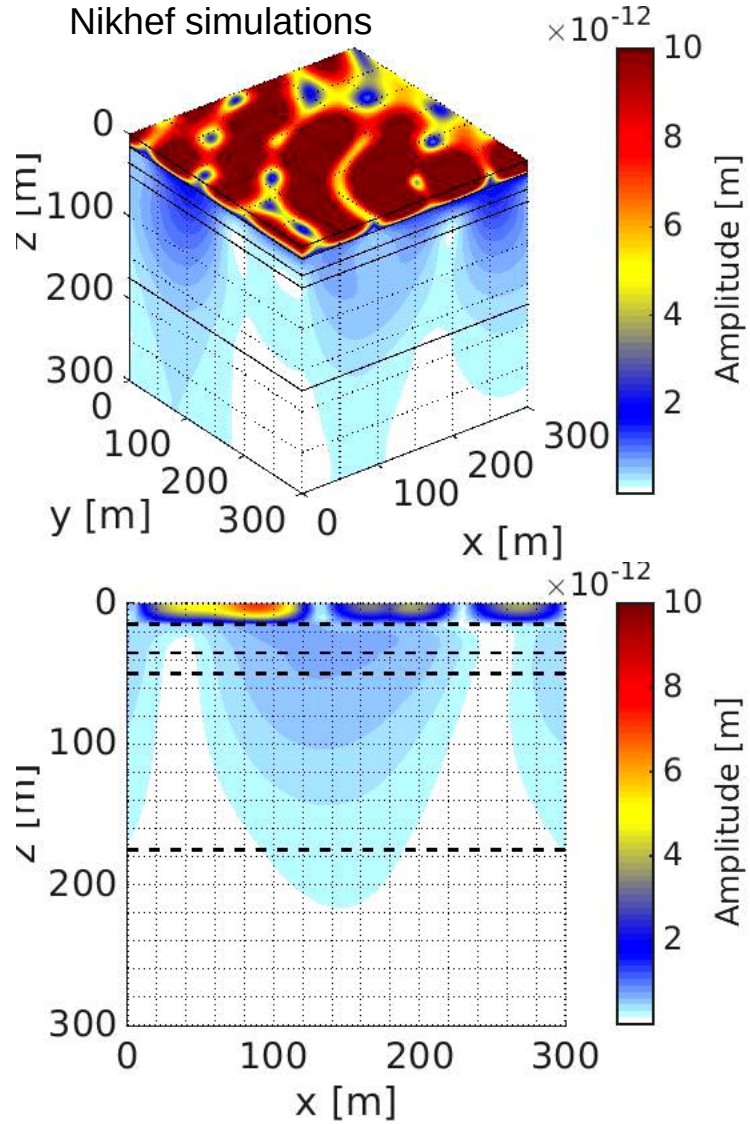
Einstein Telescope receives overwhelming scientific support. What about support from the Academy, local support, national support at the political level. Support from industry, and from the general public

What is unique about the geology?

The geology of the Hungary Matra site is well understood, and features hard rock. Measurements show good seismic results. In addition the region is (partly) free of disturbing (man-made) seismic activities



Nikhef simulations



Choice of site

We have studied 16 for the large part underground sites, of which 14 in Europe. Besides the site in Hungary, also the sites in Sardinia and in the Netherlands are of good quality

Seismic studies

Total 16 measurements in 11 countries

- Europe
- Kagra, Japan
- Homestake, USA

Permanent underground measurements stations have been set up for Einstein Telescope in Sardinia and in Hungary

Important site constrains:

- Geology of the subsurface
- No disturbing activities in vicinity
- Detailed site studies
- Excellent connections (plane, train, …)
- International collaboration with excellent knowledge institutions
- Expertise of industry

Data collected from these sites

3rd party data obtained and analyzed from these sites

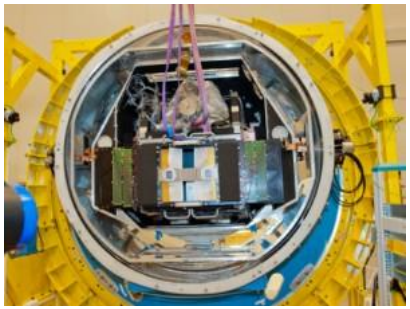
Mark Beker, David Rabeling
Nikhef
KAGRA, Homestake, INFN, Hungary

What is the added value of Einstein Telescope?

The arrival of ET stimulates national and regional innovation power, activity, employment and attractivity for top scientists

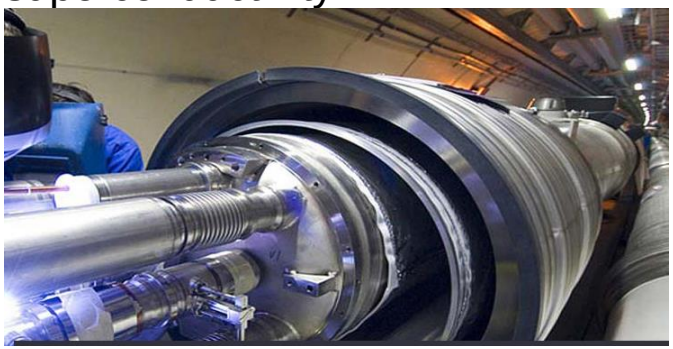
The facility poses extreme technical demands to equipment, that must be development specially for this application. The involvement and expertise of industry is essential

Measuring and attenuating vibrations: nano-technology, medical, defense

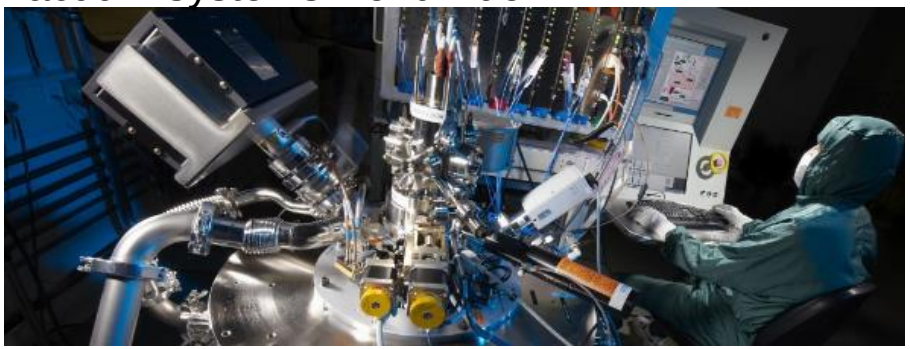


Optics, coatings, special materials, laser technology, semiconductor technology

Cryogenic technology: fusion and superconductivity



Vacuum technology: ET will be one of the biggest vacuum systems worldwide

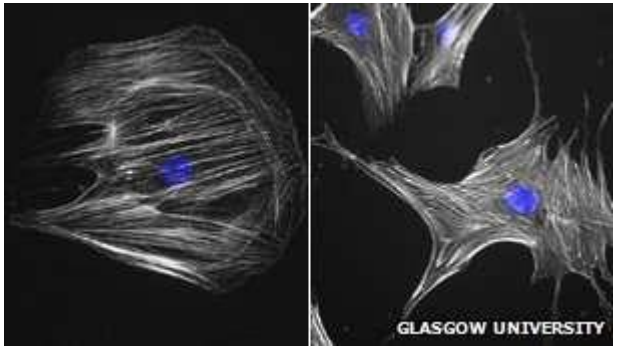


Examples of spin-off from gravitational wave research

Prof Stuart Reid (Univ of West of Scotland)

- Working with cell biologists on adapting sensing techniques from GW technology to control stem cell differentiation for bone healing - spin-off company in progress.

See: http://www.bbc.com/news/uk-scotland-glasgow-west-22035696



Stem cell control: After the stem cells are "nanokicked" they turn into bone cells

Dr Siong Heng (Univ of Glasgow)

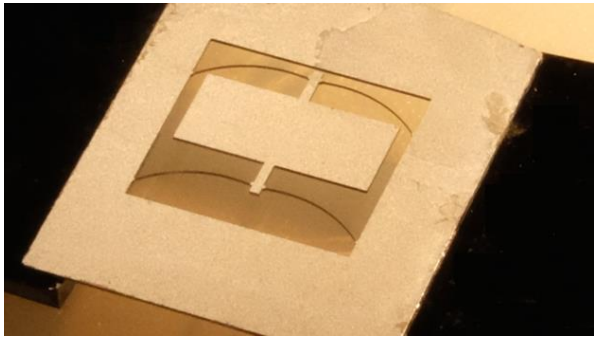
- Working with OPTOS Ltd developing algorithms for automated artefact detection for scanning laser ophthalmoscopes - potential to make significant savings by adopting new automated Quality Assurance processes during the manufacturing process.

See: http://censis.org.uk/censis_projects/optos2_gu/

Dr Giles Hammond, (Univ of Glasgow)

- Working with several industrial partners on utilising spin-offs from core GW technology research to build low frequency ultra-sensitive MEMS gravimeters with applications in the energy, security and geophysics fields. Patent filed (GB Parent Application No: 1415087.4).

See: http://www.bbc.com/news/science-environment-35926147



MEMS gravimetry: Carved from a sheet of silicon, the sensor contains a weight (the central slab) suspended by thin, curved shafts

Dr Stefan Hild (Univ of Glasgow)

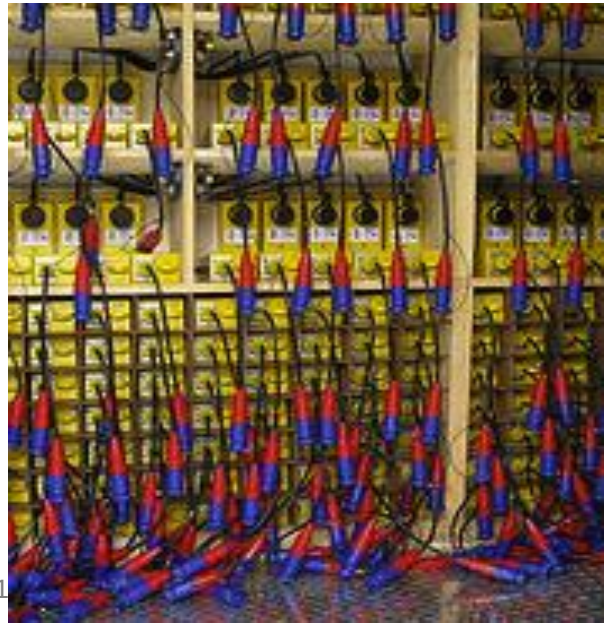
- Working with Historic Scotland in the use of laser interferometry to enable accurate assessment of the climate-change driven decay of historic buildings and monuments

Prof Jim Hough, Prof Sheila Rowan and colleagues (Univ of Glasgow)

- Development of Oxide-bonding (patent granted for bonding silicon carbide) (US2007/0221326 A1), working with Gooch and Housego (UK) on extending this technique for jointing of compound optical systems for use at high laser powers

The problem: land seismic acquisition is limited in scalability due to expensive and inefficient recording systems

Cable-free manufacturers have turned a **cable problem** into a **battery problem**

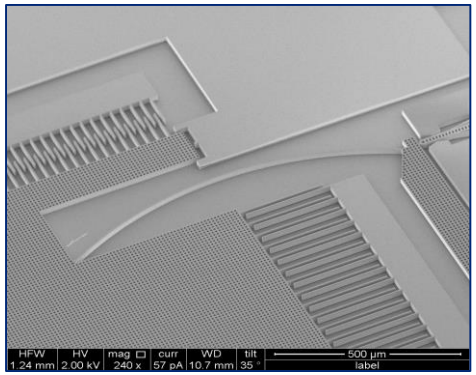


A successful public-private collaboration

Measuring gravitational waves demands seismic quiet sites, such that seismic and Newtonian noise do not limit the measurements

Win-win situation

- Methods developed by Shell will enable measurement of gravitational waves at lower frequencies
- Scientists can then observe merging black holes for a longer period
- And better characterize possible sites for ET
- Shell profits from unique sensor technology



Smart seismic sensors and MEMS accelerometers

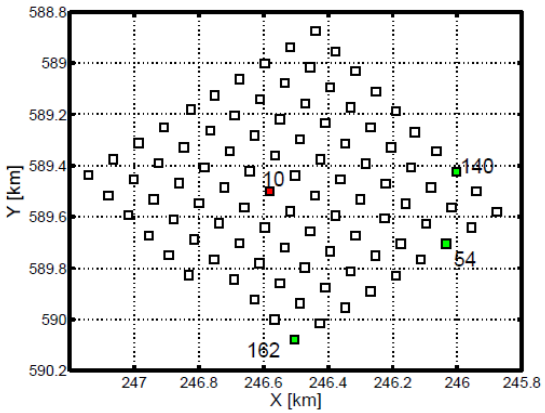
- Innoseis spin-off of this research
- Computing Science Energy Research

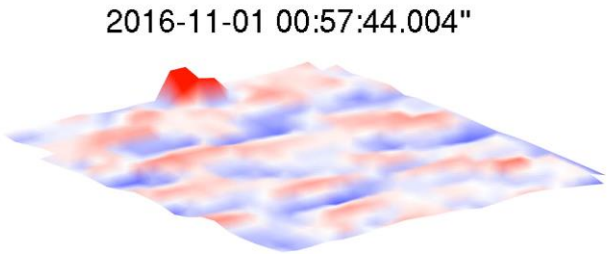
Monitoring of earthquakes

A prototype network of 100 smart seismic sensors was used by Shell to monitor ground motion in Groningen during a three-week period in January 2016. The monitoring of ground motion is required for a better understanding of the earthquake mechanisms and to better know the possible risks of earthquakes

Sensor network at the Earth's surface

- Geophysical techniques such as seismic interferometry are used to study the behavior of the underground
- Shell has an interest in applying these sensors in their worldwide operations for exploration and monitoring of new oil- and gas fields





Detecting a faint earthquake (movie)

Worldwide support for gravitational wave research

LIGO and Virgo are operational. LIGO-India and KAGRA in Japan under construction. ESA launches LISA in 2034. Einstein Telescope CDR financed by EU, support by APPEC

Gravitational wave research

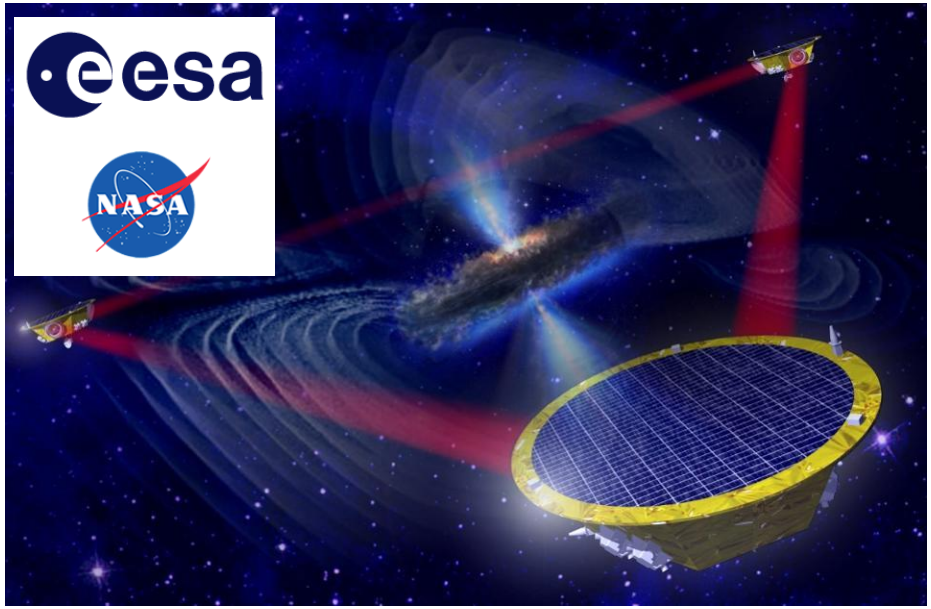
- LIGO and Virgo operational
- LIGO-India and KAGRA under construction
- ESA and NASA select LISA
- Pulsar Timing Arrays, such as EPTA and SKA
- Cosmic Microwave Background radiation

Einstein Telescope

- Design financed by EU in FP7
- APPEC gives GW a prominent place in the new Roadmap and especially the realization of ET

Next steps

- Collaborate Europe wide on all levels
- ESFRI Roadmap



What is needed now?

Einstein Telescope requires that industry, politics and science are acting in consort so that we together can investigate this unique chance on an iconic European project

How can politics and industry help us?

- An innovative R&D program should be defined together with industry
- MOU with most important scientific parties should be established
- Scientists will develop the international science/governance case for ET: GWIC (Summer 2018)
- European research organizations will develop a common strategy that will lead to an ESFRI request backed by various ministries (2019/2021)
- A unique chance for Europe, but support from the ministries of various partner countries is of essential importance

European Strategy Forum on Research Infrastructures

ESFRI