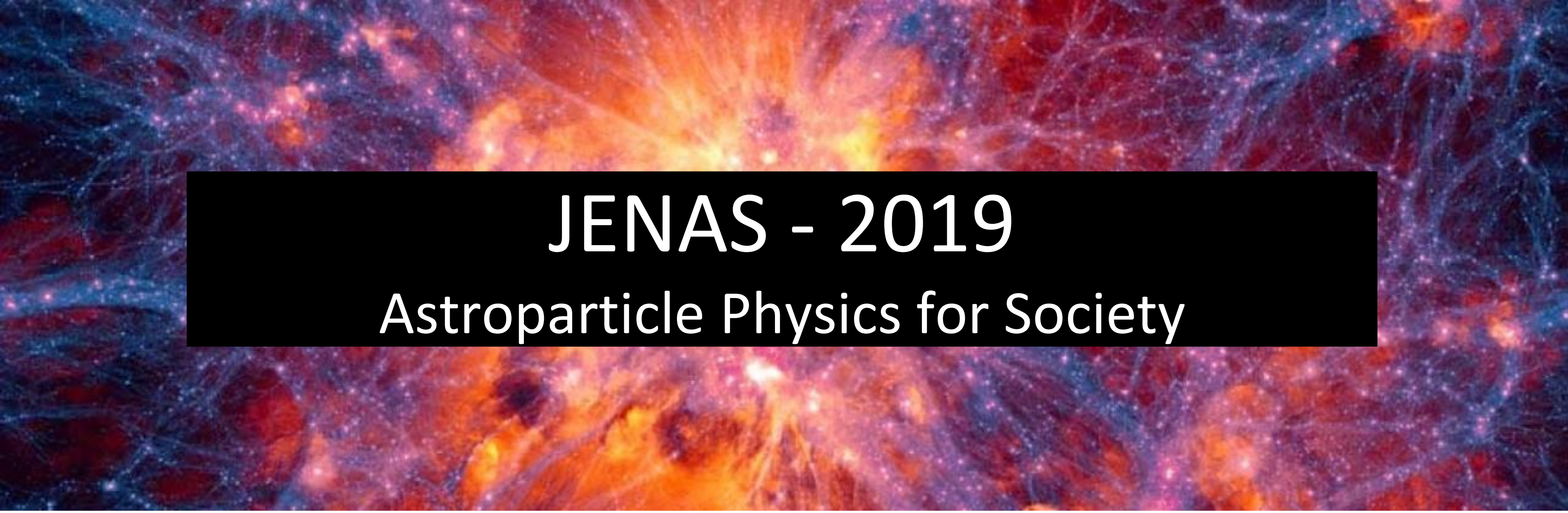


JENAS - 2019

Astroparticle Physics for Society

Jo van den Brand
Spokesperson of the Virgo Collaboration
Nikhef

Benefits of Astroparticle Physics to Society

APPEC and societal issues

Case Studies

- Tomography with Cosmic Ray Muons
- SENSE coordinates R&D in academia and industry in low light level sensing

Example: gravitational waves

- Philosophy and Sociology
- Innovations, Industry, and Spin-off

ApPEC Considerations

- What is provided now?
- Your input!

What can ApPEC do for you?

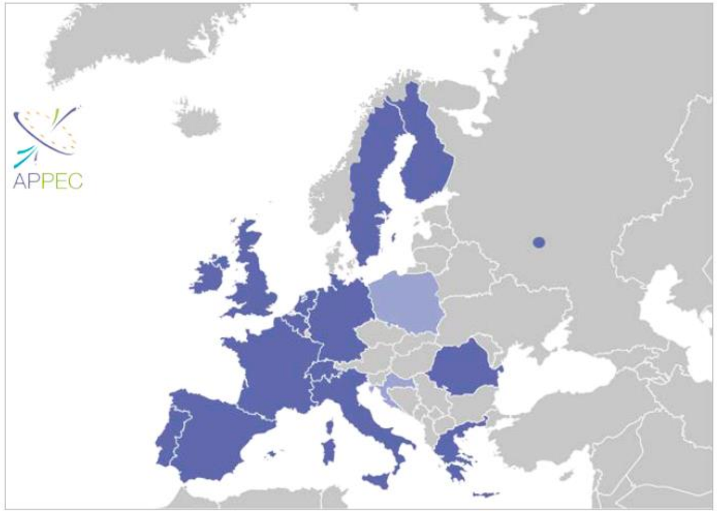
European Astroparticle Physics Strategy 2017-2026

Societal issues are addressed in the Roadmap (https://www.appec.org/roadmap)

Astronomy and particle physics communities

APPEC's field of interest naturally touches astronomy and particle physics. ESO and CERN are already long-term observers at APPEC meetings and events. In the context of possible future space-based projects such as Euclid, COrE and LISA, ESA is becoming another important partner.

APPEC will enhance its interactions with its present observers ESO and CERN in areas of mutual interest and will seek to engage with ESA in view of upcoming astroparticle-physics-oriented space missions. This will ensure scientific complementarity, where appropriate, and allow closer collaboration with our colleagues in the astronomy and particle physics communities. APPEC therefore welcomes ASTERICS, which serves as a platform for closer collaboration between the ESFRI-listed projects SKA, CTA, KM3NeT and E-ELT.



APPEC member states

Interdisciplinary opportunities

Some of our infrastructures offer unique opportunities for other research disciplines or for industry. Cabled deep-sea and deep-ice neutrino telescopes, for example, are of great interest to marine biologists and geologists, while deep-underground laboratories offer test facilities ideal for biologists studying the evolution of life in low-radioactivity environments and microbial life under extreme conditions.

APPEC will further develop interdisciplinary workshops and will promote to the outside world – including both academia and industry – interdisciplinary access to its full research infrastructure.

European Astroparticle Physics Strategy 2017-2026

Societal issues

Curiosity-driven research

Astroparticle physics is a perfect example of curiosity-driven research. A combination of excitement about the mysteries of the Universe and spectacular discoveries easily spark public interest, giving rise to a surge of outreach activities that in turn capture the imagination of all kinds of people and increase the skills base for the future. The inherent high-tech aspects of instrumentation in our field provide ample opportunity for industrial collaboration, not only in terms of delivering the technologies required for astroparticle physics projects but also in applying these technologies to other challenges. In this way, pure science generates significant economic growth.

Gender balance

APPEC is fully committed to promoting an inclusive, gender-neutral working environment. Historically, physics is a field with low representation of female researchers, especially in leading positions. Despite prominent role models, women still remain underrepresented in our field of research.

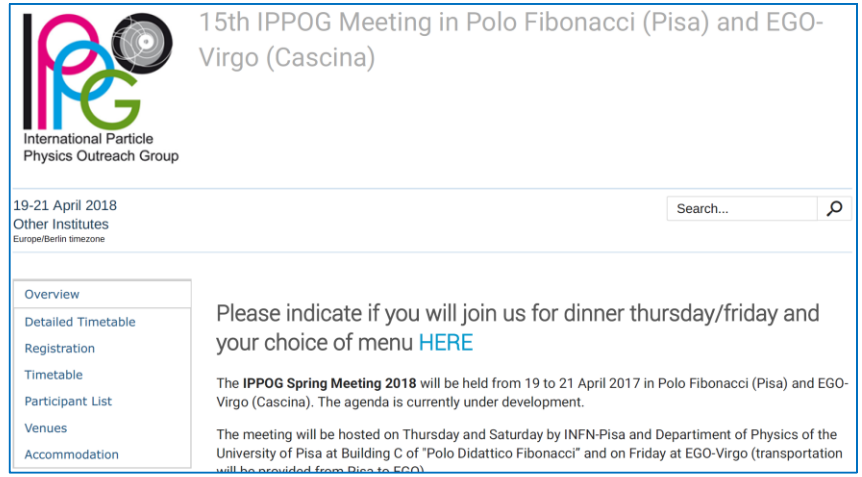
Inspired by the H2020 project GENERA, APPEC will develop a gender balance policy for all of its activities and will urge projects to develop and implement Gender Equality Plans.

European Astroparticle Physics Strategy 2017-2026

Societal issues

Education and outreach

Astroparticle physics research attracts strong interest from students and the general public alike, as demonstrated recently by the huge publicity surrounding the discovery of gravitational waves.



Given the rapid expansion of the field of astroparticle physics, APPEC encourages (e.g. in cooperation with the IPPOG) the exchange of best practice in the sphere of outreach. At its frontier research facilities, APPEC will implement more structured organisation of dedicated astroparticle physics summer schools and studentships. APPEC will also enhance its presence on the web and social media.

Industry

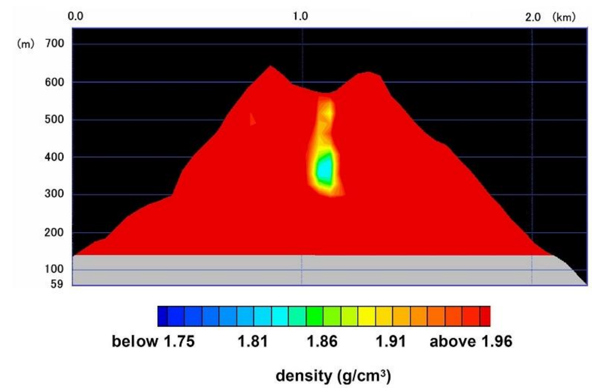
Astroparticle physics creates and uses advanced technologies. As a result, close cooperation with high-tech industry is vital. This interplay between basic research and innovation generates knowledge and technology with potential societal benefits. For example, cosmic-ray muon tomography is used to image volcanos, nuclear material, burial sites and blast furnaces; largescale networks of seismic sensors, capitalising on experiences gained in gravitational-wave research, have been developed for oil exploration and perimeter security.

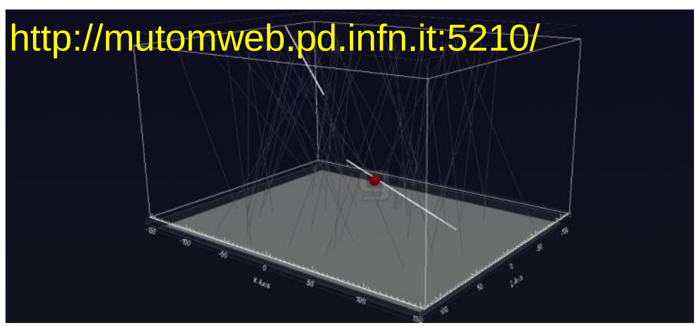
APPEC will increase its efforts to identify potential applications of astroparticle physics expertise for societal benefit. In parallel, APPEC will continue to organise its successful technology fora on targeted technologies and use these as a platform for discussion and collaboration involving industry and academia

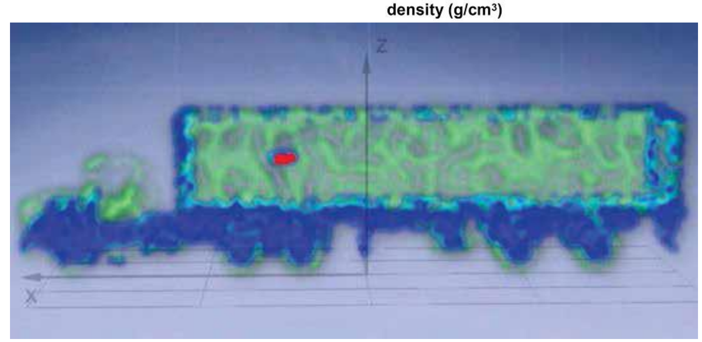
Case study 1: Tomography with Cosmic Ray Muons

Muongraphy: cosmic rays are used to image the inside of an active volcano in Japan
Cosmic rays can also be used to screen trucks for high-Z materials

- What is going on inside an active volcano?
  - Mt. Asama in Japan is monitored by Center for High Energy gEophysics Research (CHEER) of UTokyo
  - Muographic images showing the interior of Mt. Asama
  - Solid red indicates magma that has cooled after extrusion
  - http://www.u-tokyo.ac.jp/en/whyutokyo/wj_001.html
  - Mu-Ray project to image Mount Vesuvius
- Mapping glaciers
  - http://www.naturalsciences.ch/service/news/57678-eiger-muon-glacier-tomography
- Industrial applications
  - Imaging of blast furnaces
- National Security
  - Identification of high-Z material; monitoring fuel in Fukoshima Daiichi plant
  - Screening trucks for nuclear material at Cosmic Muon Tomography CMT by INFN
- Neutrinos
  - Image Earth's core
- Buildings
  - Monitor integrity of buildings





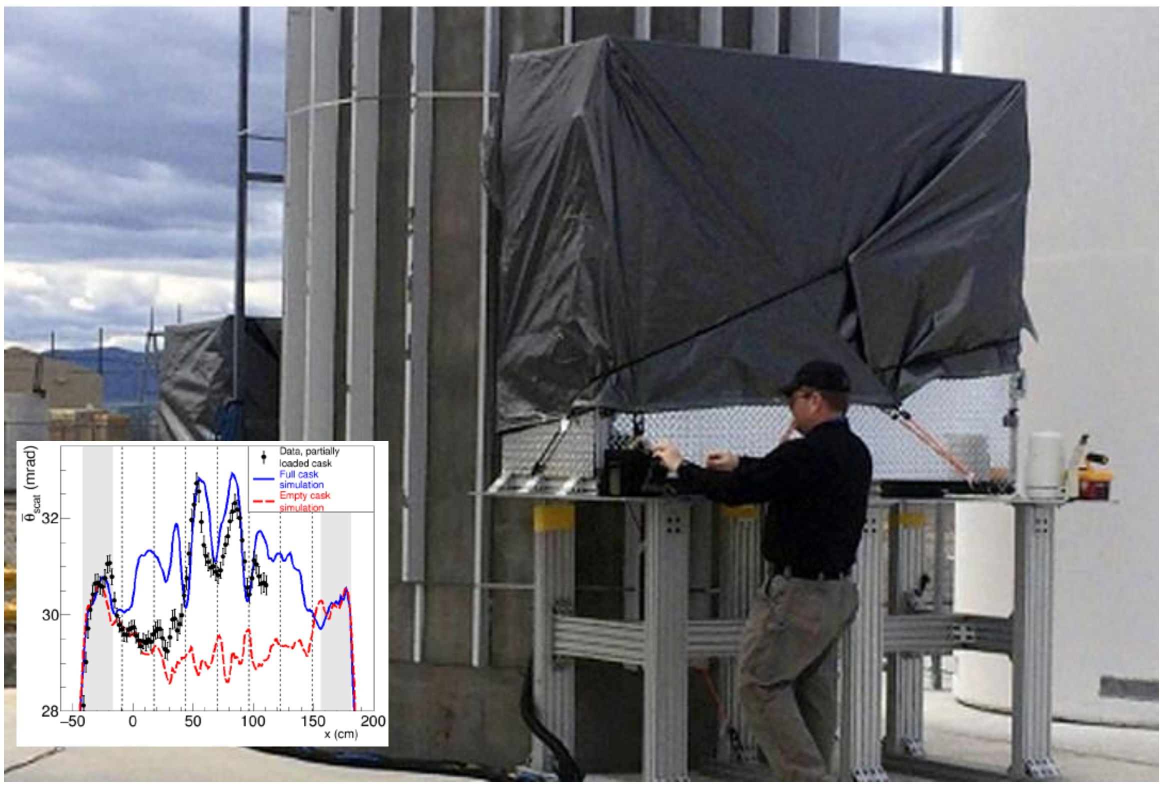


Muon radiography verifies spent nuclear fuel in sealed casks

LANL: Researchers and collaborators have investigated a method to “see” inside sealed casks using naturally occurring cosmic-ray muons

Features of muon radiography for this applications

- Most of the world’s plutonium resides inside spent nuclear reactor fuel rods
- Muons can penetrate the 25 cm thick steel shielding and bring useful information
- Muons are an external probe that are not subject to backgrounds from other casks
- Employ 1.2 x 1.2 sqm detectors and employ about 90 days of measurement time (IAEA goal is 3 months)



Verification of spent nuclear fuel in sealed dry storage casks via measurements of cosmic ray muon scattering

J. M. Durham,[1,*] D. Poulson,[1,2] J. Bacon,[1] D. L. Chichester,[3] E. Guardincerri,[1] C. L. Morris,[1] K. Plaud-Ramos,[1] W. Schwendiman,[3] J. D. Tolman,[3] and P. Winston[3]

[1]*Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA*
[2]*University of New Mexico, Albuquerque, New Mexico 87131, USA*
[3]*Idaho National Laboratory, Idaho Falls, Idaho 83415, USA*

(Dated: March 14, 2018)

Most of the plutonium in the world resides inside spent nuclear reactor fuel rods. This high-level radioactive waste is commonly held in long-term storage within large, heavily shielded casks. Currently, international nuclear safeguards inspectors have no stand-alone method of verifying the amount of reactor fuel stored within a sealed cask. Here we demonstrate experimentally that measurements of the scattering angles of cosmic ray muons which pass through a storage cask can be used to determine if spent fuel assemblies are missing without opening the cask. This application of technology and methods commonly used in high-energy particle physics provides a potential solution to this long-standing problem in international nuclear safeguards.

I. INTRODUCTION

Plutonium is produced in all uranium-fueled nuclear reactors following neutron capture on ^{238}U nuclei and two beta decays, primarily through the reactions

$$^{238}\mathrm{U} + n \longrightarrow {}^{239}\mathrm{U} \xrightarrow{\beta^-} {}^{239}\mathrm{Np} \xrightarrow{\beta^-} {}^{239}\mathrm{Pu}. \quad (1)$$

non-weapon states agree to accept safeguards by the International Atomic Energy Agency (IAEA), which shall be applied on all fissionable material within the state or under its control for the purpose of verifying compliance with the treaty. The IAEA considers member state declarations, analyzes open-source data and information from third parties, and conducts inspections of nuclear facilities to draw conclusions about activities in states under nuclear safeguards.

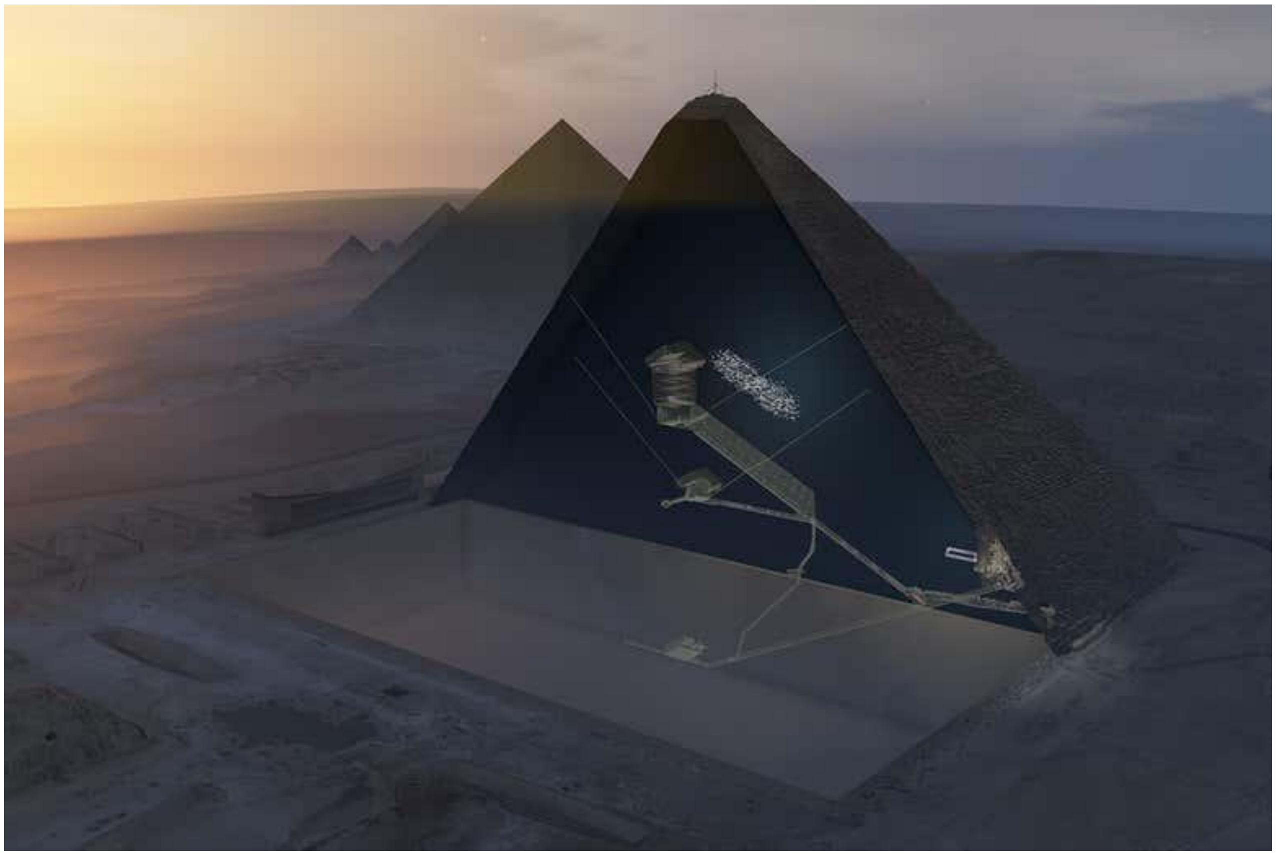
See https://arxiv.org/abs/1710.03098

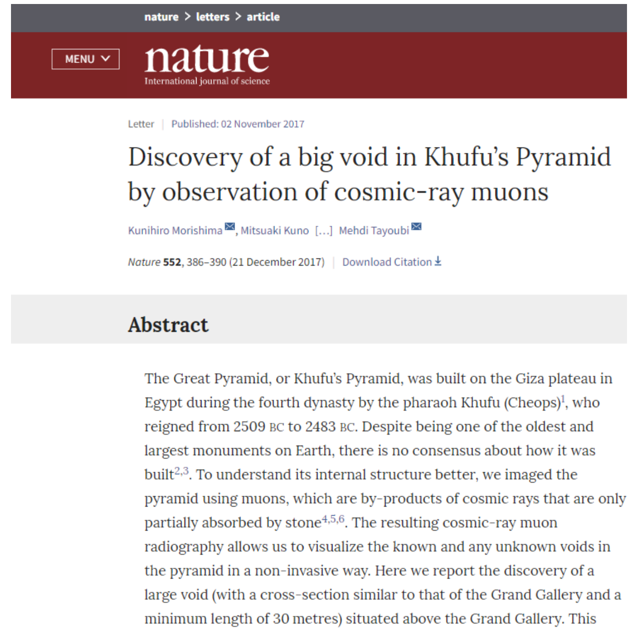
Radiography with Cosmic Ray Muons

Cosmic-ray muon radiography allows us the discovery of a large void (with a cross section similar to the Grand Gallery and a length of 30 m minimum) above the Grand Gallery

First major inner structure found in the Great Pyramid since the 19th century

- First observed with nuclear emulsion films installed in the Queen's chamber (University of Nagoya)
- Confirmed with scintillator hodoscopes set up in the same chamber (KEK)
- Re-confirmed with gas detectors outside of the pyramid (CEA)





nature > letters > article

MENU

nature
International journal of science

Letter | Published: 02 November 2017

Discovery of a big void in Khufu's Pyramid by observation of cosmic-ray muons

Kunihiro Morishima, Mitsuaki Kuno […] Mehdi Tayoubi

Nature **552**, 386–390 (21 December 2017) | Download Citation

Abstract

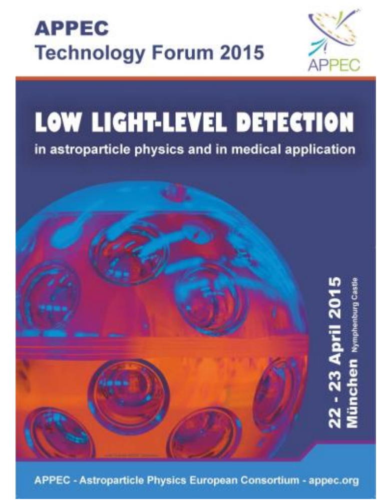
The Great Pyramid, or Khufu's Pyramid, was built on the Giza plateau in Egypt during the fourth dynasty by the pharaoh Khufu (Cheops)[1], who reigned from 2509 BC to 2483 BC. Despite being one of the oldest and largest monuments on Earth, there is no consensus about how it was built[2,3]. To understand its internal structure better, we imaged the pyramid using muons, which are by-products of cosmic rays that are only partially absorbed by stone[4,5,6]. The resulting cosmic-ray muon radiography allows us to visualize the known and any unknown voids in the pyramid in a non-invasive way. Here we report the discovery of a large void (with a cross-section similar to that of the Grand Gallery and a minimum length of 30 metres) situated above the Grand Gallery. This

See https://arxiv.org/abs/1711.01576

Case study 2: SENSE

SENSE was funded under H2020-FETOPEN-2015-CSA. See https://www.sense-pro.org/
It builds on the ApPEC Technology FORUM April 2015 on "*Low light-level detection in APP and in medical application*"

- The project's objectives are to coordinate the research and development efforts in academia and industry in low light-level detection
  - The SENSE Detector School, August 1, 2019, https://www.sense-pro.org/news/latest-news/105-the-sense-detector-school
  - Single Photon Detection Workshop, July 31, 2019, https://www.sense-pro.org/news/latest-news/104-single-photon-detection-workshop
  - SENSE: Roadmap of LLL sensors – What comes next?, July 30, 2019, https://www.sense-pro.org/news/latest-news/100-sense-roadmap-of-lllsensors-what-comes-next
- This initiative has emerged from the series of Technology Forums organized within the frame of ASPERA and APPEC
  - About 80 participants from collaborations, industry, and funding agencies
  - ALPS, PAO, CTA, DARWIN, GERDA, IceCube, Jem-Euso, KM3NeT, MAGIC, Xenon
  - Bte Bedampfungstechnik, Entropy, ET EET, FBK, Hamamatsu LC, Ketek, MELZ, SensL
- Three APPEC related partners
  - University of Geneva ➔ Teresa Montaruli, Domenico della Volpe
  - MPI for Physics in Munich ➔ Razmik Mirzoyan
  - DESY (coordinator) ➔ Thomas Berghöfer, Katharina Henjes-Kunst
- SENSE
  - Invite R&D experts to prepare an R&D roadmap for ultimate low light level sensors
  - Coordinate, monitor, and evaluate R&D efforts of groups/industry advancing low light level sensors



Example: gravitational wave research

Example: How can society benefit from GW research?

Gravitational wave research has several aspects that are of benefit to society. Scientific merit will be discussed by **Giovanni Losurdo**

Gravitational waves and fundamental physics: new particles, DM and DE, BHs, quantum gravity, Lorentz invariance

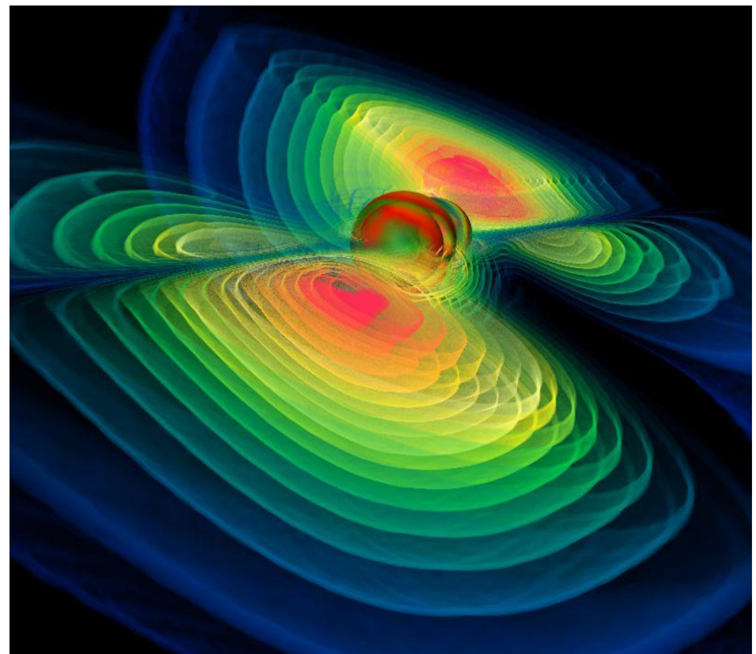
Gravitational waves as tool for astronomy and astrophysics

Spacetime: aspects from philosophy

The quest for gravitational waves: a case study for sociology

International and global experimental infrastructures

Proven impact on technological innovation and spin-offs



Coalescence of black hole binary

© MPI for Gravitational Physics/W.Benger-Zib)

Example: How can society benefit from GW research?

Gravitational wave research has several aspects that are of benefit to society. Scientific merit will be discussed by **Giovanni Losurdo**

Gravitational waves and fundamental physics: new particles, DM and DE, BHs, quantum gravity, Lorentz invariance

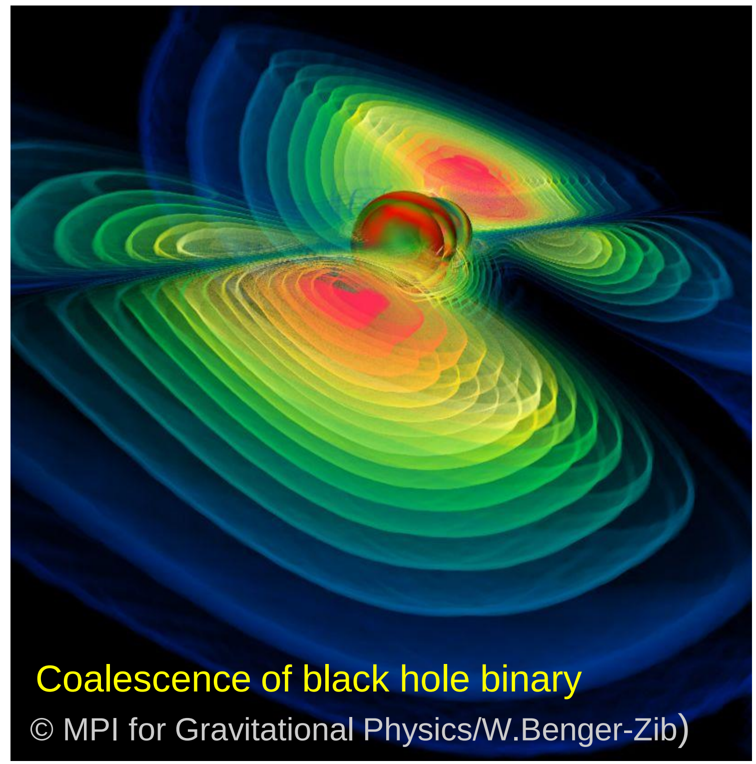
Gravitational waves as tool for astronomy and astrophysics

Spacetime: aspects from philosophy

The quest for gravitational waves: a case study for sociology

International and global experimental infrastructures

Proven impact on technological innovation and spin-offs



Coalescence of black hole binary

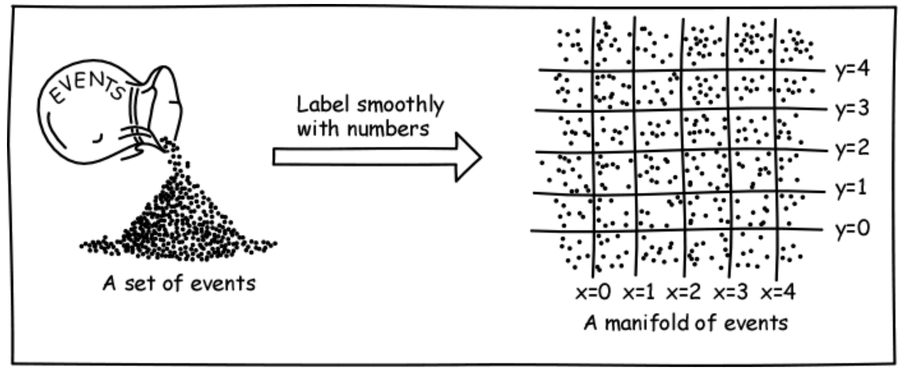
© MPI for Gravitational Physics/W.Benger-Zib)

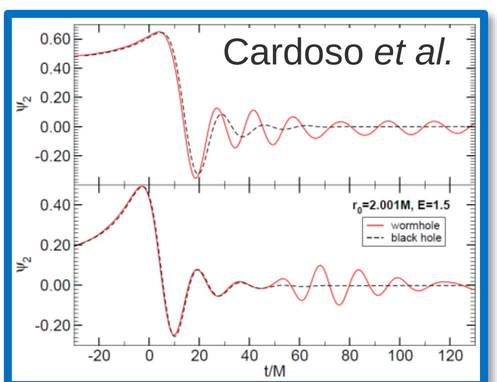
(Mathematical) Philosophy

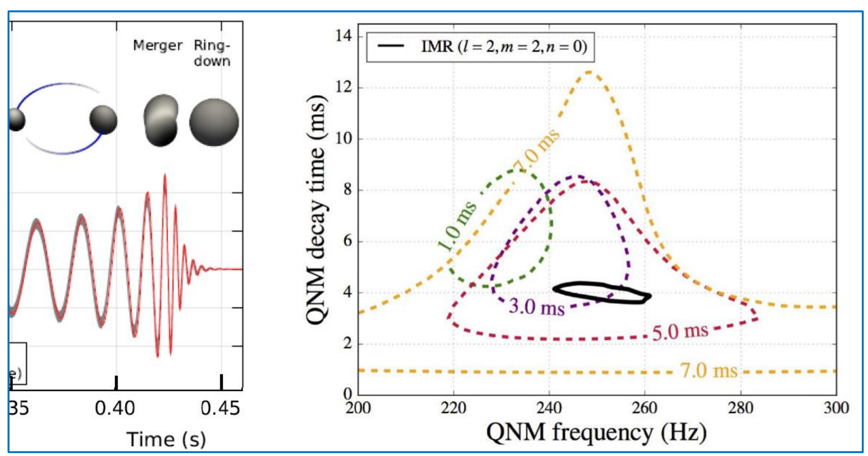
Pure philosophical questions related to the origin of space and time exist for centuries. Now the anwers to such questions maybe within reach of the physical sciences

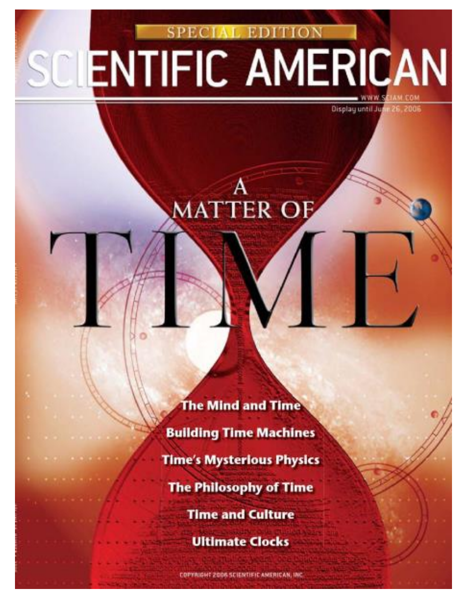
Questions

- What is space? What is time?
- Spacetime and (growing) block universe, eternalism
- Do they exist independently of the things and processes in them? Or is their existence parasitic on these things and processes?
  - Spacetime substantivalism: “The hole argument”
  - http://plato.stanford.edu/entries/spacetime-holearg/
  - No successful theory of quantum gravity can be set against an independent, container spacetime
- Is spacetime emergent?
  - Black hole information paradox
- What can GWs say about this?
  - Black hole: QM meets GR







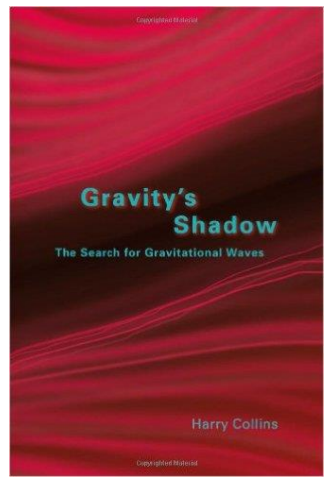


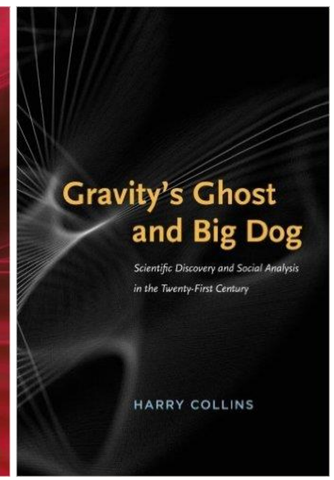
Sociology of gravitational wave physics

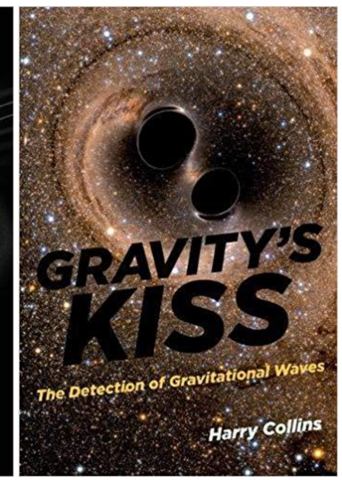
Harry Collins (University of Bath) has followed the GW field since 1972

Books

- Harry Collins published 3 books
  - *"Gravity's Shadow the Search for Gravitational Waves“ (2004),* Chicago: University of Chicago Press ISBN 9780226113784
  - *"Gravity's Ghost: Scientific Discovery in the Twenty-First Century“ (2010),* Chicago: The University of Chicago Press ISBN 9780226113562
  - *“Gravity's Kiss: The Detection of Gravitational Waves” (2015),* The MIT Press, ISBN 978-0262036184
  - See http://www.iphysnet.com/wp/2017/04/12/the-sociology-of-gravitational-waves-an-interview-with-harry-collins/
- Central topics
  - Definitive account of the controversy surrounding Weber’s claims
  - Provide insight in the way big science projects evolve
- Essential (as opposed to derivative) values of science
  - Integrity in the search for evidence and honesty in declaring results
  - Willingness to listen to anyone’s theories
  - Readiness to expose one’s findings to criticism and debate
  - Specify the means by with theories can be shown to be wrong
- Social engineering
  - Hardware injections: Equinox event and Big Dog event







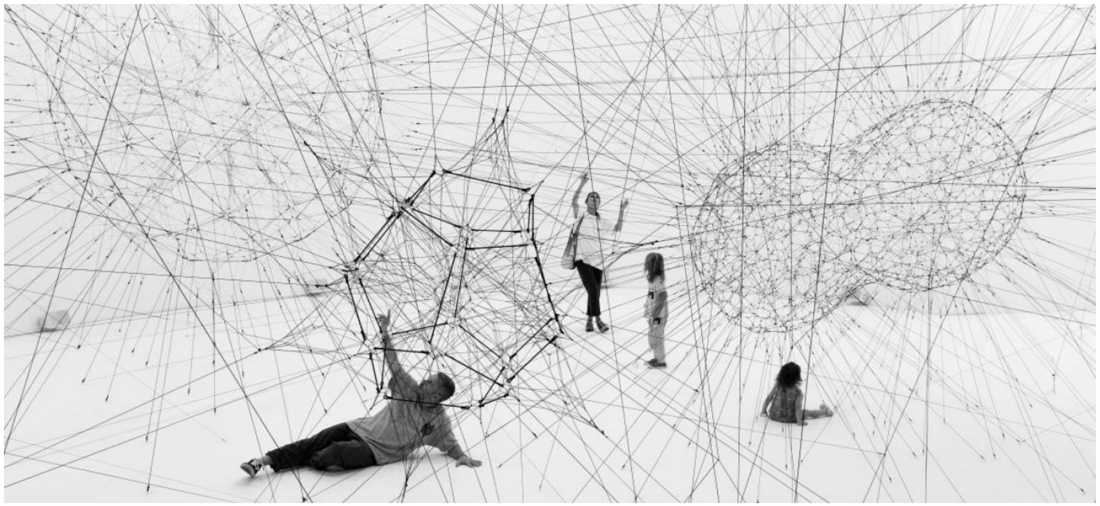
Outreach

- Einstein@home (See https://einsteinathome.org/)
  - Developed by LSC and MPG. Supported by APS, NSF, and MPG

einstein@home

Contemporary art and gravitational waves

Astroparticle physics is intellectually appealing to artists. Various exhibitions show artists connecting to our science. Note that these event attract a large audience



Carte Blanche to Tomás Saraceno PALAIS DE TOKYO

Paris, 17/10/2018 to 06/01/2019

https://www.artsy.net/article/artsy-editorial-influential-artists-2018

Contemporary art and Vantablack

Vantablack is used in LIGO and Virgo. Artist Anish Kapoor has the exclusive rights to “Vantablack”

Man hospitalised after falling in Anish Kapoor installation

The work at the Serralves museum, which includes a gaping hole, is part of the artist's first institutional show in Portugal

JOSÉ DA SILVA
17th August 2018 17:40 BST

INTERNATIONAL EDITION
THE ART NEWSPAPER

http://stuartsemple.com/project/worlds-pinkest-pink-50g-powdered-paint-stuart-semple/

Gravitational waves and popular culture

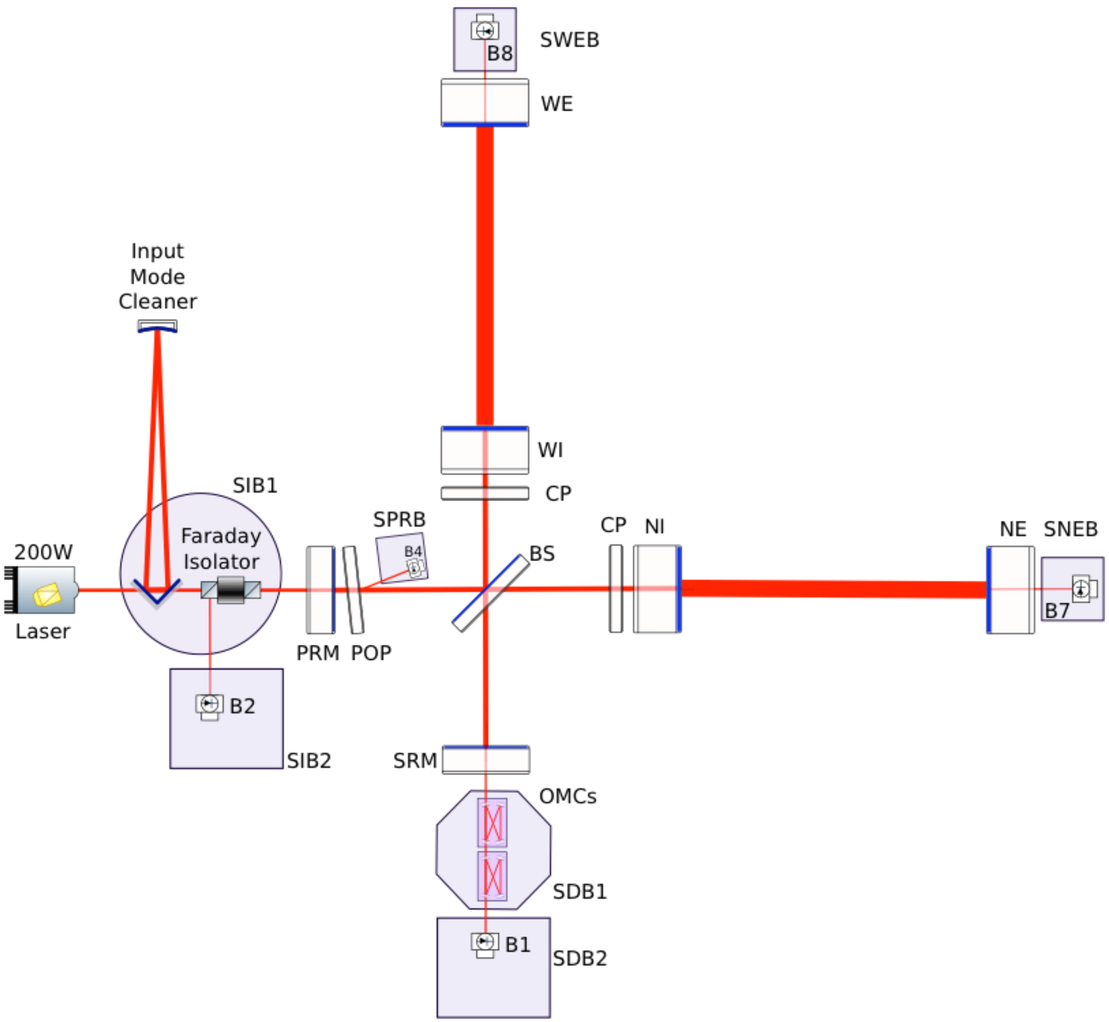
Gravitational waves and black holes now have become part of pop culture. Below a brief overview of some of the manifestations

https://shenovafashion.com/products/gravitational-waves-dress

Virgo and the International Gravitational Wave Network

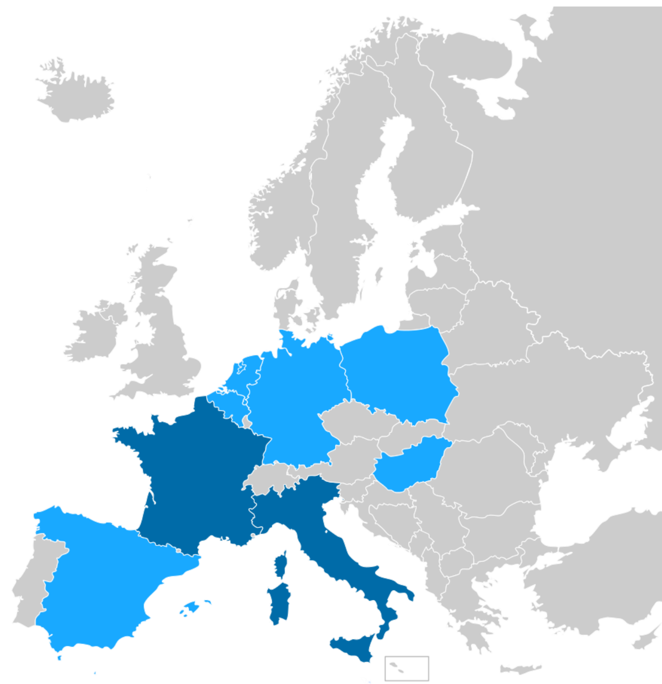
Advanced Virgo

Advanced Virgo started operation on August 1, 2017. It features many improvements with respect to Virgo and Virgo+. Significant and innovative technology has been developed



The Virgo Collaboration consists of 482 members (360 authors) from 96 institutes and from 8 European countries

Many groups come from particle physics



Virgo interferometer

Global GW Detector Network

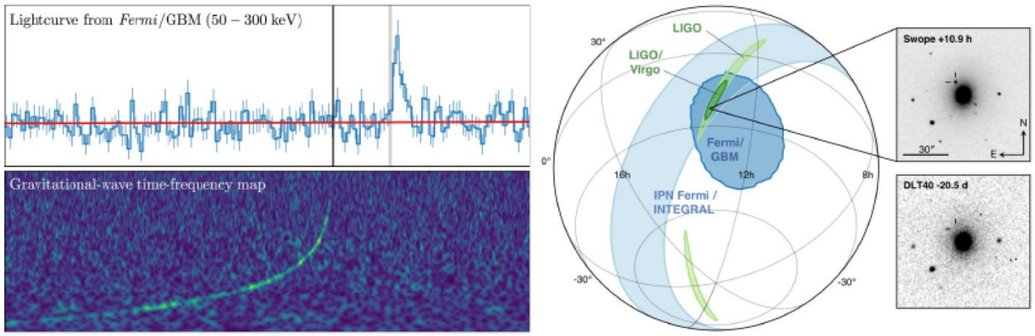
- Current state-of-the-art: Second-generation ("advanced") laser interferometers

GW Open Data and Open Public Alerts

Virgo led the release to the public of all LIGO Virgo data obtained in O2
See https://www.gw-openscience.org/static/workshop2/

LIGO and Virgo alerts are public: https://emfollow.docs.ligo.org/userguide/

LIGO/Virgo Public Alerts User Guide



Welcome to the LIGO/Virgo Public Alerts User Guide! This document is intended for both professional astronomers and science enthusiasts who are interested in receiving alerts and real-time data products related to gravitational-wave (GW) events.

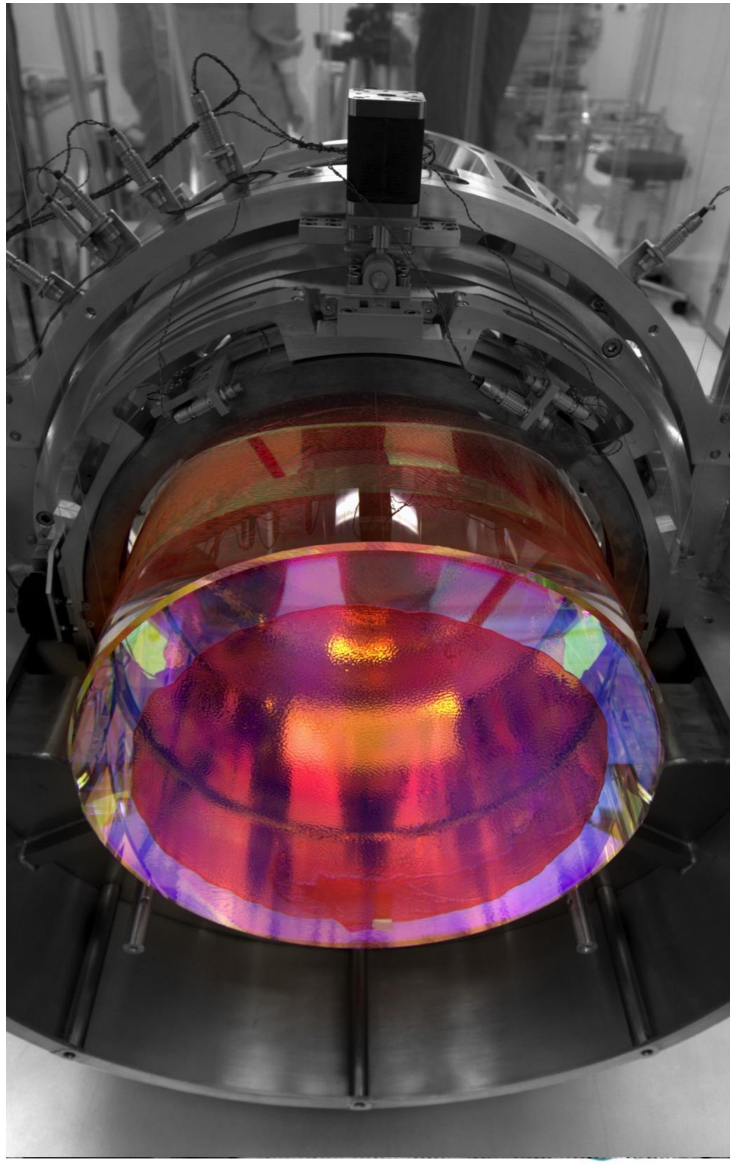
Three sites (LHO, LLO, Virgo) together form a global network of ground-based GW detectors. T
Scientific Collaboration and the Virgo Collaboration jointly analyze the data in real time to detec
localize transients from compact binary mergers and other sources. When a signal candidate is f
alert is sent to astronomers in order to search for counterparts (electromagnetic waves or neutri

Advanced LIGO and Advanced Virgo began their third observing run (O3) on April 1, 2019. For
time, **LIGO/Virgo alerts are public**. Alerts are distributed through NASA's Gamma-ray Coor
Network (GCN). There are two types of alerts: human-readable GCN Circulars and machine-rea
Notices. This document provides a brief overview of the procedures for vetting and sending GW
describes their contents and format, and includes instructions and sample code for receiving GC
and decoding GW sky maps.

Hands-on workshop to learn how to access and analyze LIGO and Virgo data

Extreme mirror technology

Laboratoire des Matériaux Avancés LMA at Lyon produced the coatings used on the main mirrors of the two working gravitational wave detectors: Advanced LIGO and Virgo. These coatings feature low losses, low absorption, and low scattering properties



Features

- Flatness < 0.5 nm rms over central 160 mm of mirrors by using ion beam polishing (robotic silica deposition was investigated)
- Ti:Ta_2O_5 and SiO_2 stacks with optical absorption about 0.3 ppm

Expand LMA capabilities for next generation

LMA is the only coating group known to be capable of scaling up

Quantum optics: injection of squeezed light

Injection of frequency dependent squeezed light will allow the reduction of quantum noise at both low frequency (radiation pressure noise) and at high frequency (shot noise)

Spin-off to society

Vibration isolation for advanced instrumentation

VLBAI - Very Long Baseline Atom Interferometry

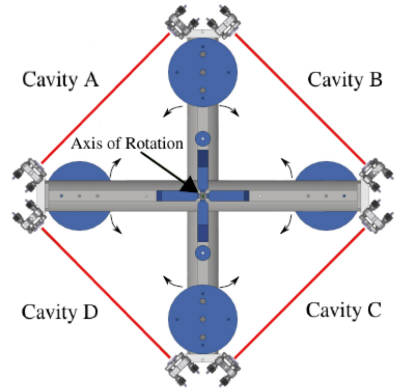
Hannover Institut für Technology – HITec

- New class of experiments in atom optics with applications in high-accuracy absolute gravimetry, gravity-gradiometry and tests of fundamental physics
- Extending the baseline of gravimeters from tens of centimeters to several meters opens the way for competition with state of the art superconducting gravimeters and [quantum tests of the universality of free fall (UFF)] at an unprecedented level
- See https://www.iqo.uni-hannover.de/de/arbeitsgruppen/quantum-sensing/research-projects/vlbai-very-long-baseline-atom-interferometry/

Low frequency gravitational force sensing

Department of Quantum Science, Australian National University,
Building 38a, Science Road, Acton, ACT 0200, Australia

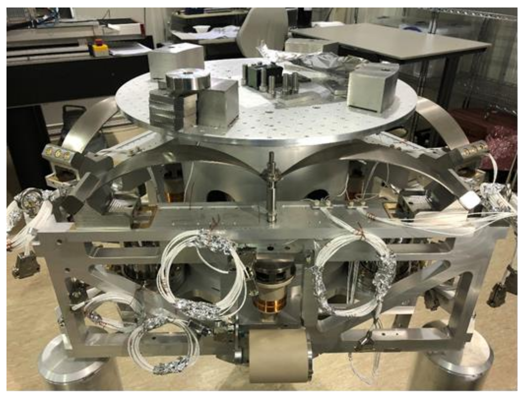
- Dual torsion-beam gravimeter
- Measure local gravitational forces to high precision
- Allows prompt gravitational transients from earthquakes
- See: https://arxiv.org/pdf/1809.04787.pdf

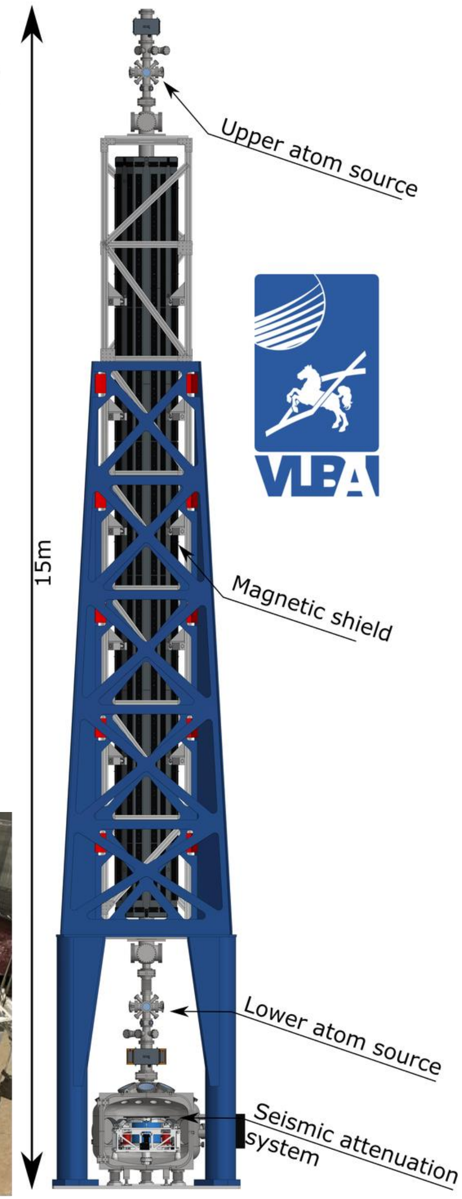


Force sensor for chameleon and Casimir force experiments

Department of Physics & Astronomy and LaserLaB,
VU University Amsterdam

- Search for non-Newtonian forces (chameleon fields)
- See http://www.few.vu.nl/~aai930/PhysRevD.91.102002.pdf





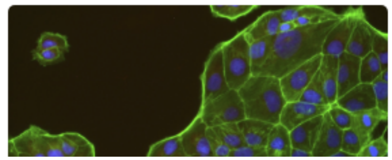
Examples of spin-off from gravitational wave research

Growing human bones using gravitational wave technology

12 September 2017

Technology originally developed to witness black holes colliding is now being used to grow human bone in a laboratory, which could revolutionise the treatment of bone injuries.

The research team used measurement technology, based on the sophisticated laser interferometer systems designed in the UK for gravitational wave detection, to turn stem cells into bone cells.



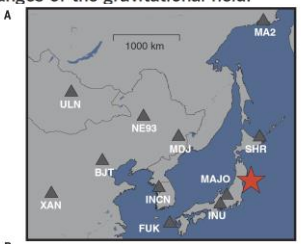
GEOPHYSICS

Observations and modeling of the elastogravity signals preceding direct seismic waves

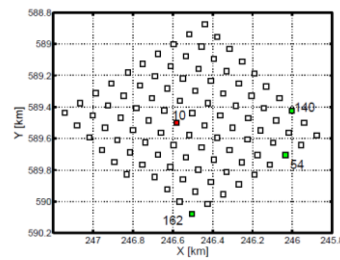
Martin Vallée,[1*] Jean Paul Ampuero,[2] Kévin Juhel,[1] Pascal Bernard,[1] Jean-Paul Montagner,[1] Matteo Barsuglia[3]

After an earthquake, the earliest deformation signals are not expected to be carried by the fastest (*P*) elastic waves but by the speed-of-light changes of the gravitational field. However, these perturbations are weak and, so far, th
enough to fully understand their origins and to use th
estimate of the earthquake magnitude. We show that
well observed with broadband seismometers at distance
from the source of the 2011, moment magnitude 9.1, Toh
model them by a new formalism, taking into account bo
gravity-induced motion. These prompt elastogravity s
time-scale magnitude determination for great earthq

A

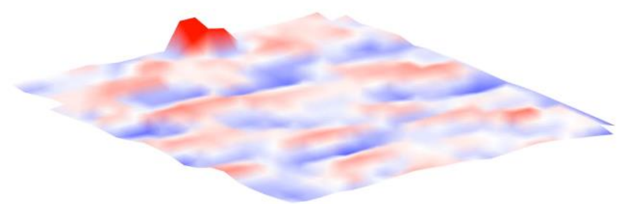


B



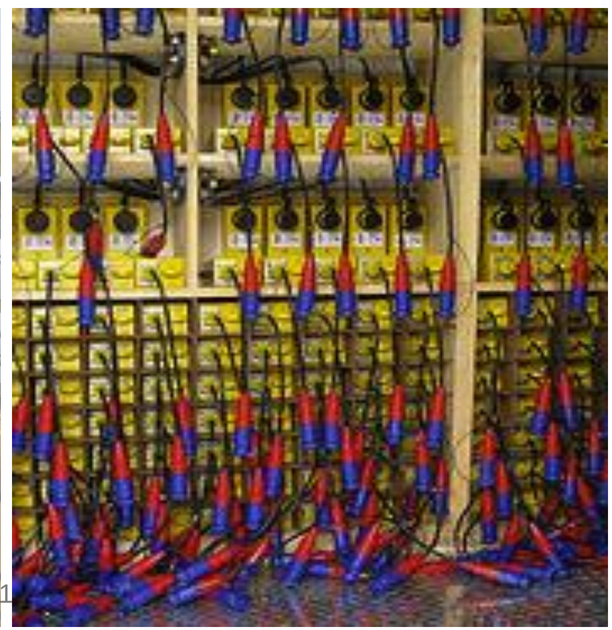
Smart seismic sensor networks (www.innoseis.com)

Earthquake monitoring



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**



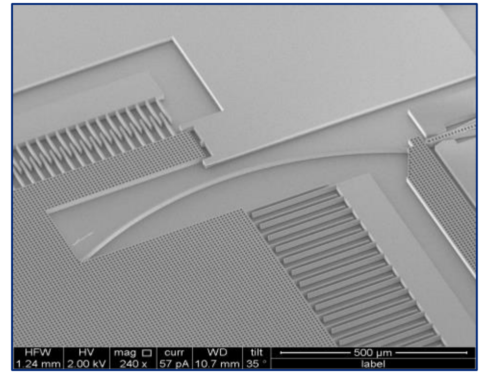
(Wireless) sensor development

In collaboration with industry sensors were developed for both gravity gradient noise suppression, and for oil & gas exploration. This involves MEMS and ASIC development within NL Topsector HTSM

PPS activity Shell, Nikhef, Innoseis

- Results of first field trial under evaluation
  - Earthquake monitoring, exploration
- Collaboration with geologists
  - KNMI in the Netherlands
  - Matra mountains, Wigner, Hungary
  - Istituto Nazionale di Geofisica e Vulcanologia (INGV)

  - Field trials in stringent environmental conditions (arctic / desert)
  - Large-scale field trials in Middle East
  - Seismic study of Virgo site



Large-scale field trials

In collaboration with Shell, PDO and Vodafone

- Long range QC with LoRa and NB-IOT
- Drones for QC and deployment

MEMS sensor development

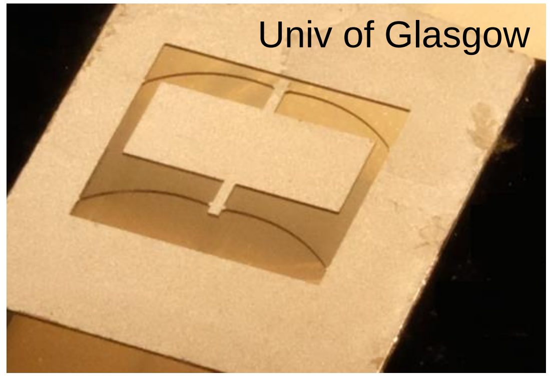
Technology developed for gravitational wave research is now implemented into new types of MEMS sensors: graviometers and accelerometers. This will allow more effective targeting of natural resources

Challenges in MEMS accelerometer development

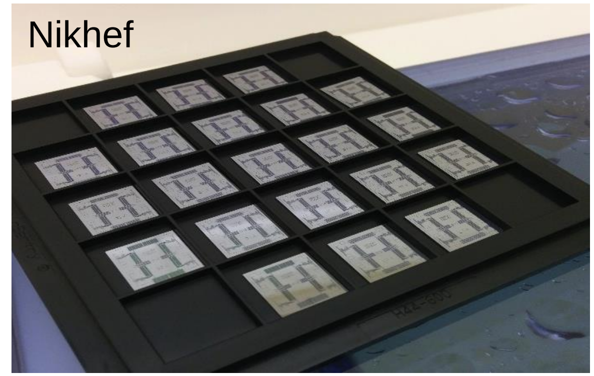
- Thermo-mechanical noise
- This can be reduced by
  - Increasing proof mass mass
  - Decreasing resonance frequency
  - Increasing quality factor

Features of Nikhef MEMS

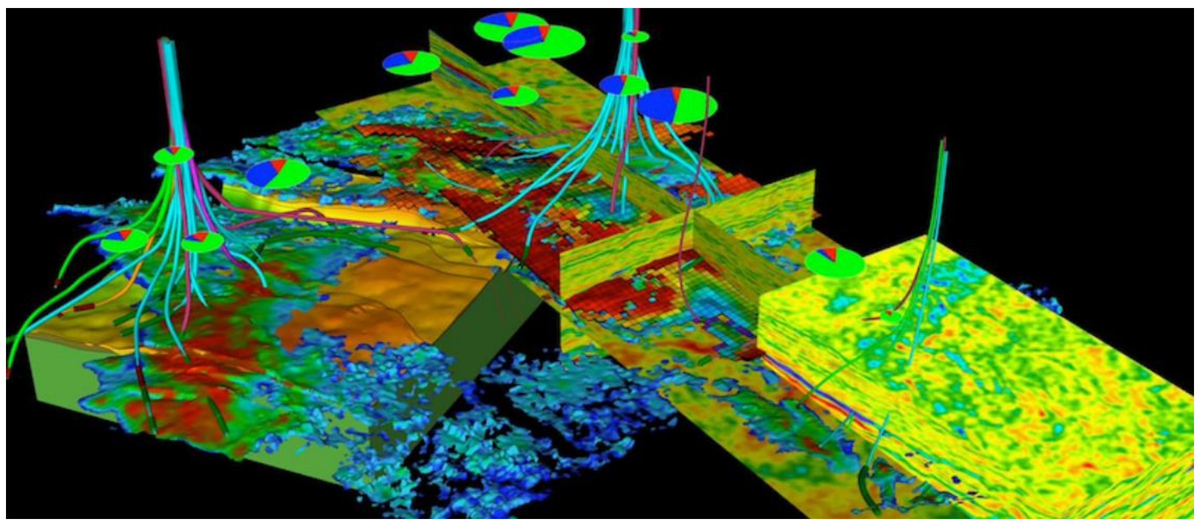
- Simple production techniques
- Single wafer design
- Integrated ASIC electronics for cost reduction during large scale production
- High precision: 1 ng / sqrt(Hz)
- High off-axis stiffness
- Broadband sensitivity: 0.5 – 200 Hz
- Integration in ultra-low power seismic sensing system



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



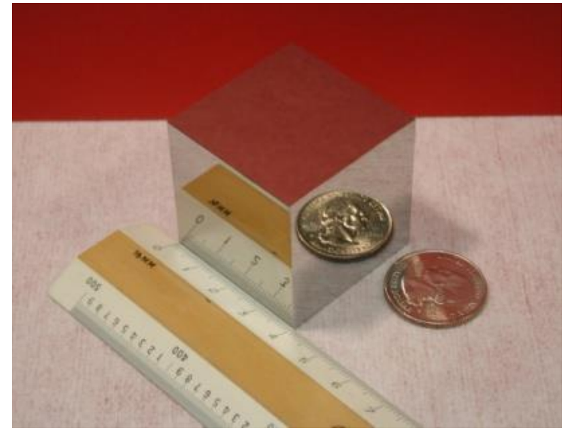
MEMS accelerometer: low-cost production technology yields robust sensors with unprecedented low frequency sensitivity

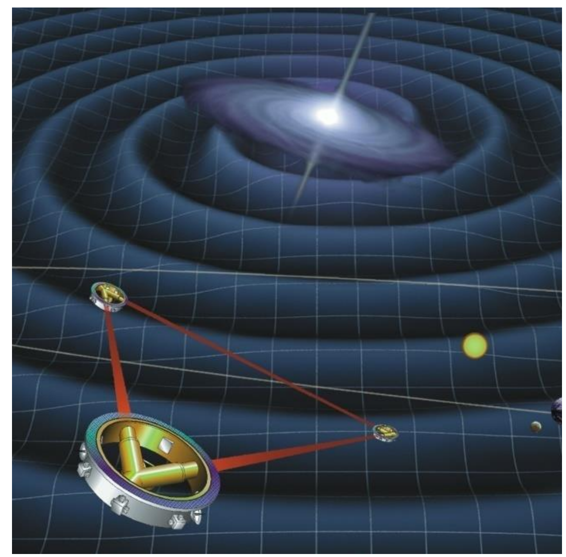


Future gravitational wave experiments

LISA

The Laser Interferometer Space Antenna (LISA) will be the first space-based gravitational wave observatory. Selected to be ESA's third large-class mission, it will address the science theme of the Gravitational Universe. LISA will consist of three spacecraft separated by 2.5 million km in a triangular formation, following Earth in its orbit around the Sun. Launch is expected in 2034

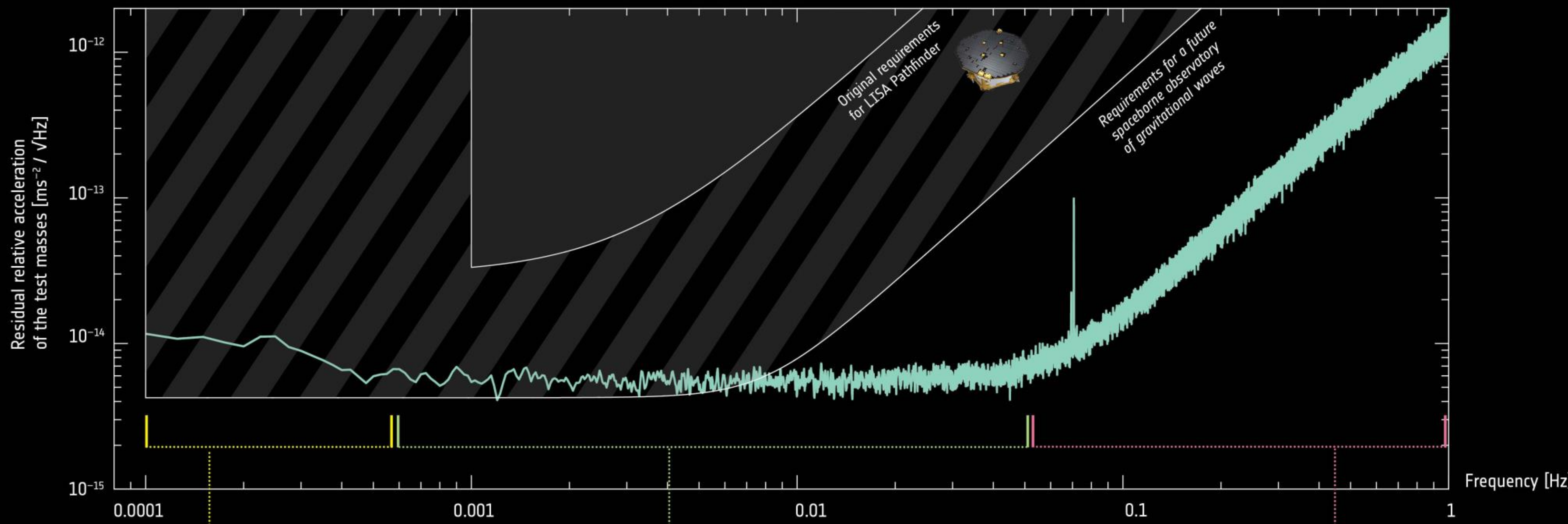


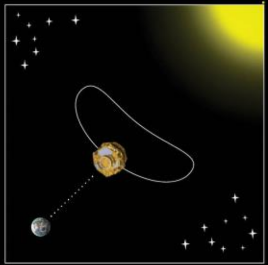


LISA-Pathfinder

LISA Pathfinder is an ESA technology mission that was successfully launched on December 3, 2015.
It uses time-delay interferometry to track the distance between two free-falling test masses

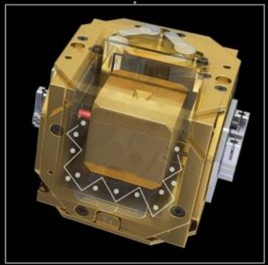
→ LISA PATHFINDER EXCEEDS EXPECTATIONS





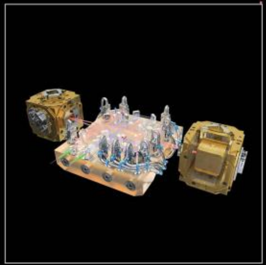
Centrifugal force

The rotation of the spacecraft required to keep the solar array pointed at the Sun and the antenna pointed towards Earth, coupled with the noise of the startrackers produces a noisy centrifugal force on the test masses. This noise term has been subtracted, and the source of the residual noise after subtraction is still being investigated.



Gas damping

Inside their housings, the test masses collide with some of the few gas molecules still present. This noise term becomes smaller with time, as more gas molecules are vented to space.



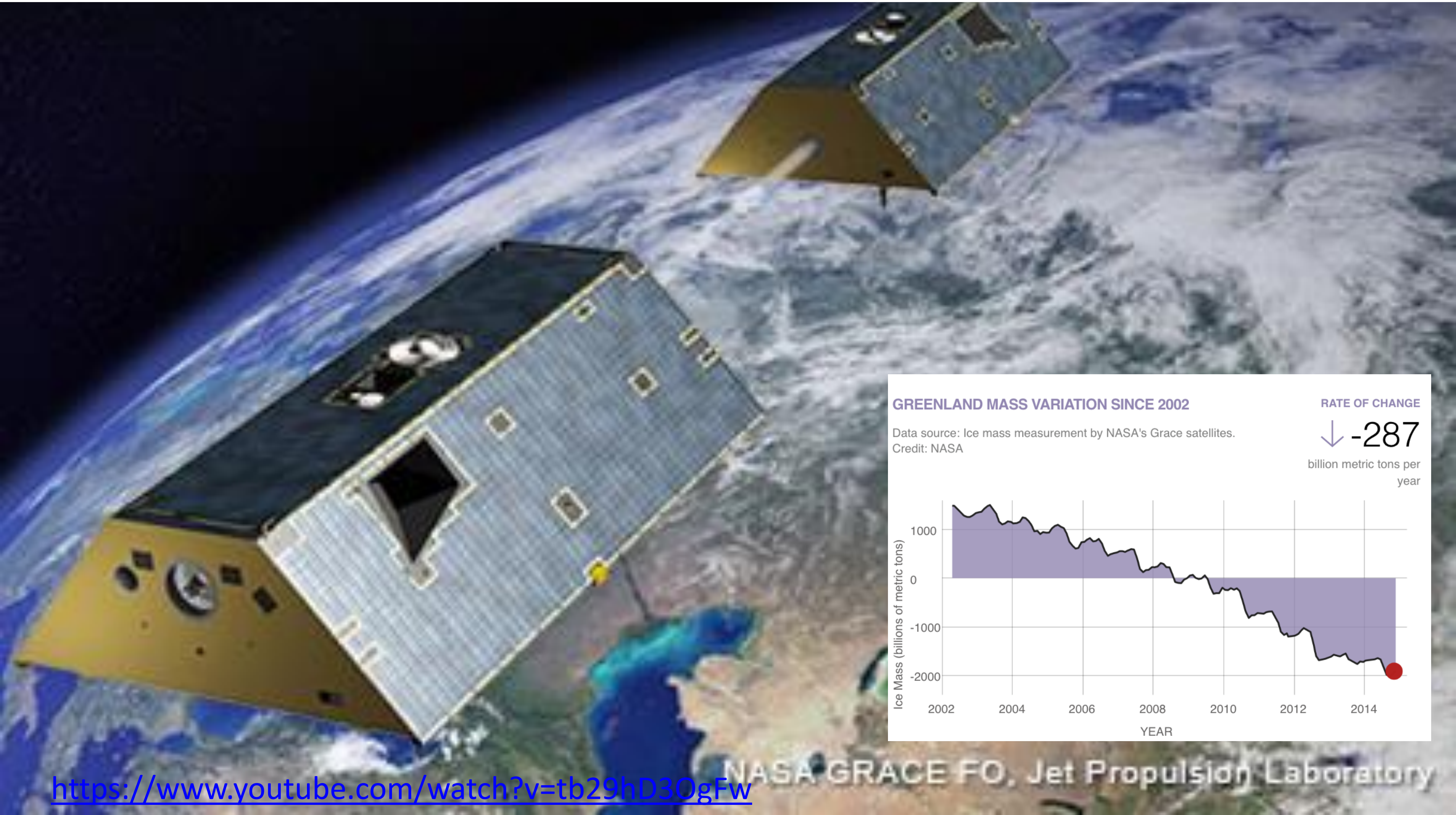
Sensing noise

The sensing noise of the optical metrology system used to monitor the position and orientation of the test masses, at a level of 35 fm / √Hz, has already surpassed the level of precision required by a future gravitational-wave observatory by a factor of more than 100.

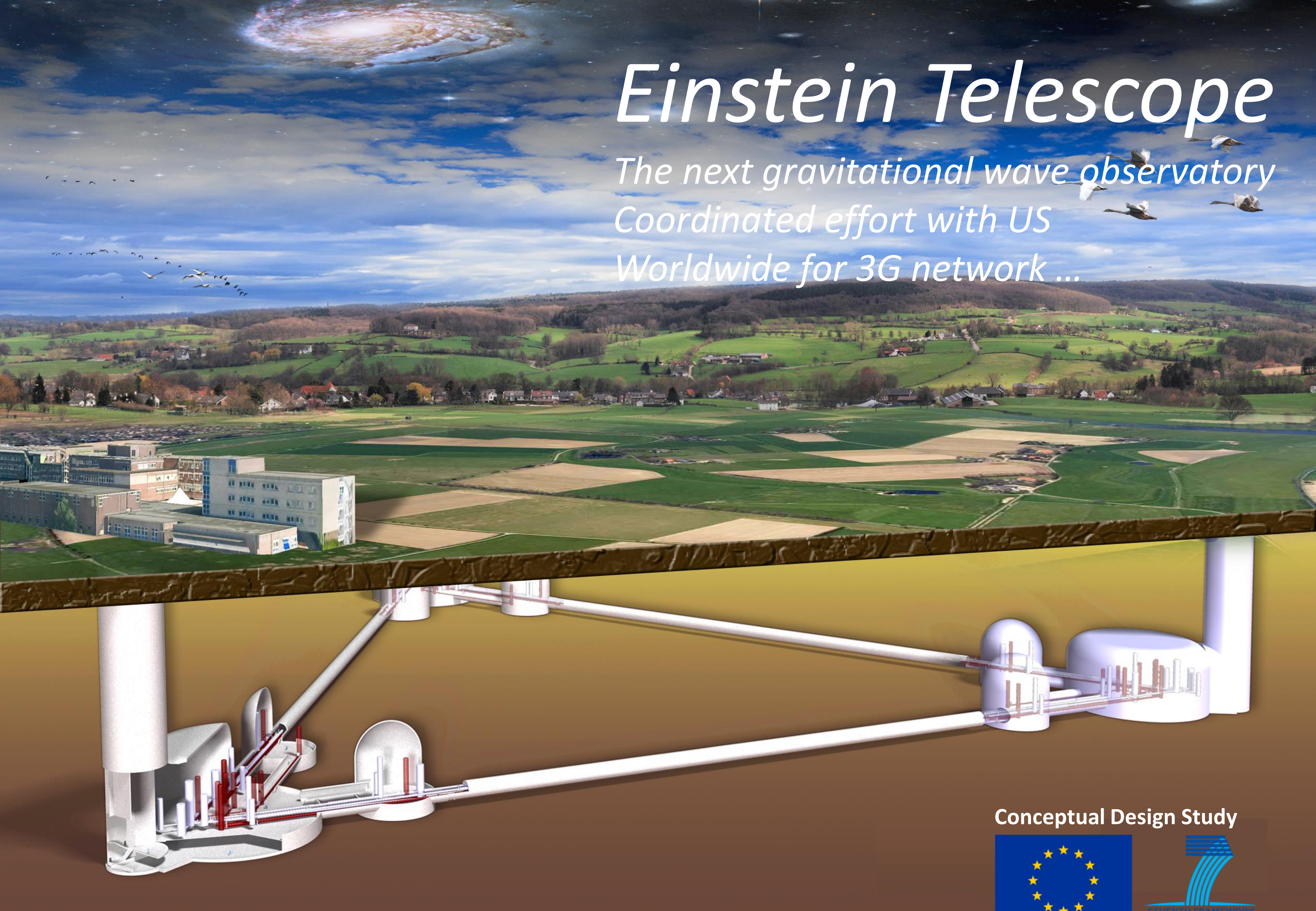
Spacecraft: ESA/ATG medialab; data: ESA/LISA Pathfinder Collaboration

Grace Follow-On mission

LISA technology (laser ranging interferometer) was used in the Gravity Recovery and Climate Experiment Follow-on (GRACE-FO) mission: ground-water balance, ice-sheet thickness, …



https://www.youtube.com/watch?v=tb29hD3OgFw


Einstein Telescope
The next gravitational wave observatory
Coordinated effort with US
Worldwide for 3G network …
Conceptual Design Study

Observe the entire GW sky with high pointing precision

We want to constantly observe the entire sky and this requires multiple 3G observatories

We require a network of 3G detectors spread over the globe

- Correlate high statistics GW data with other (e.g. EM) observations (SKA-II, LSST, Theseus, …)
- Realize multi-messenger exploration of the Universe

Key technologies of Einstein Telescope

ET requires many of the technologies developed for particle physics: underground construction, vacuum and cryogenic technology, advanced controls

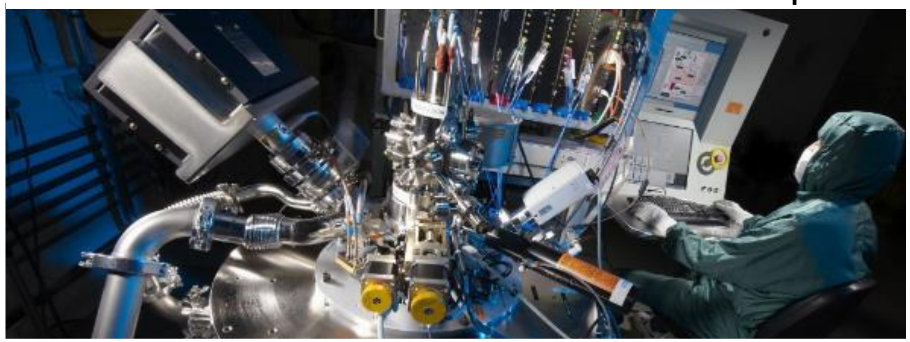
The particle physics community (e.g. CERN) has build up vast expertise in governance and implementation of big science projects. ET should build on this

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

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

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

Cryogenic systems: ET's low frequency interferometer will feature cooled silicon optics



Einstein Telescope and CERN

Interesting would be a CERN role in our quest for Einstein Telescope. There is strong scientific overlap, and we should take advantage of existing expertise and resources

Science

Gravity is a fundamental interaction with most important open scientific issues

GWs are the dynamical part of gravity

Strong scientific interest from HEP

Governance

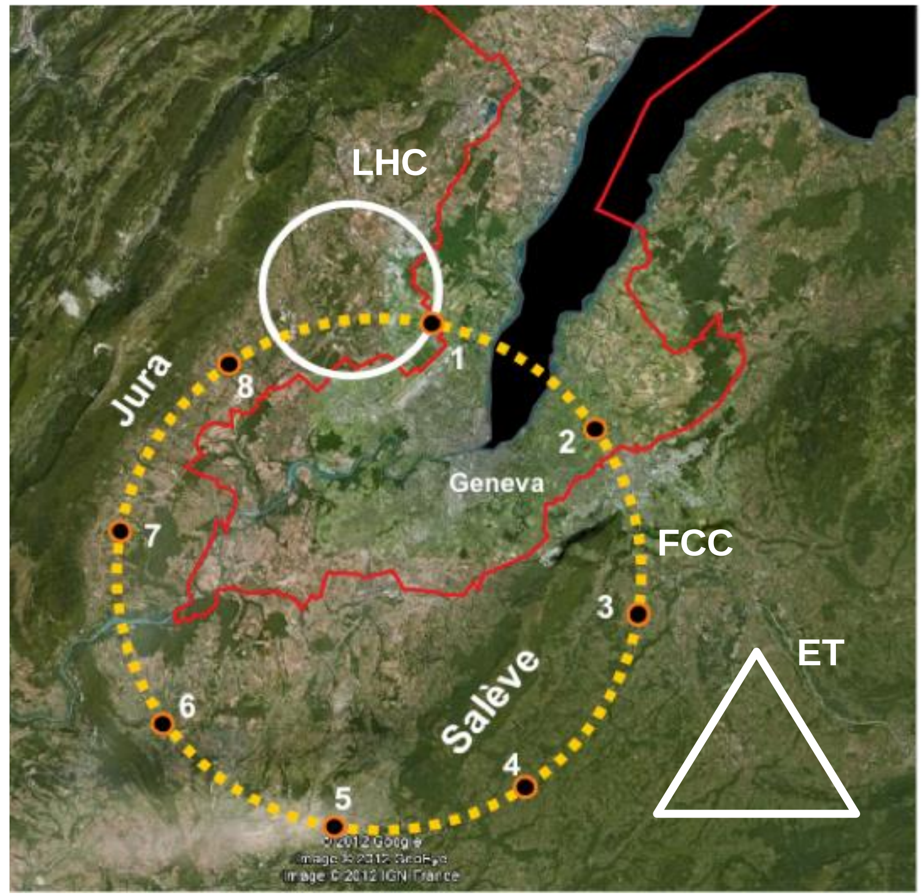
Financial and project management

Excellent, robust and proven organization

Technical

Vacuum infrastructure, underground construction

Cryogenics, controls

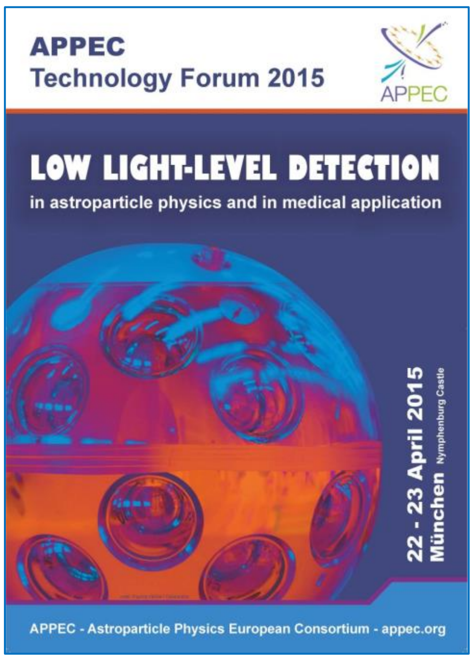


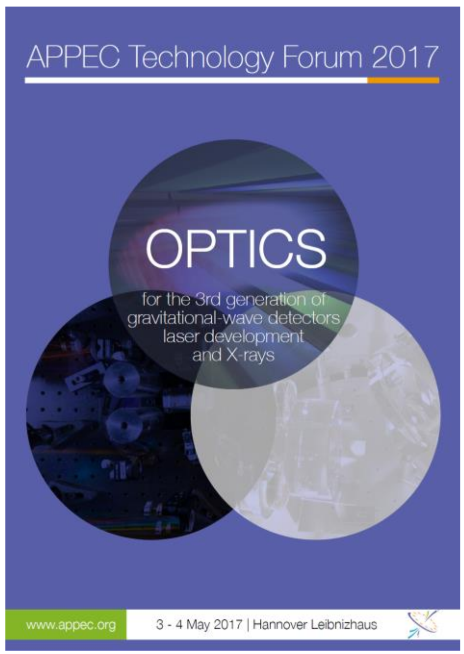
Tasks for APPEC

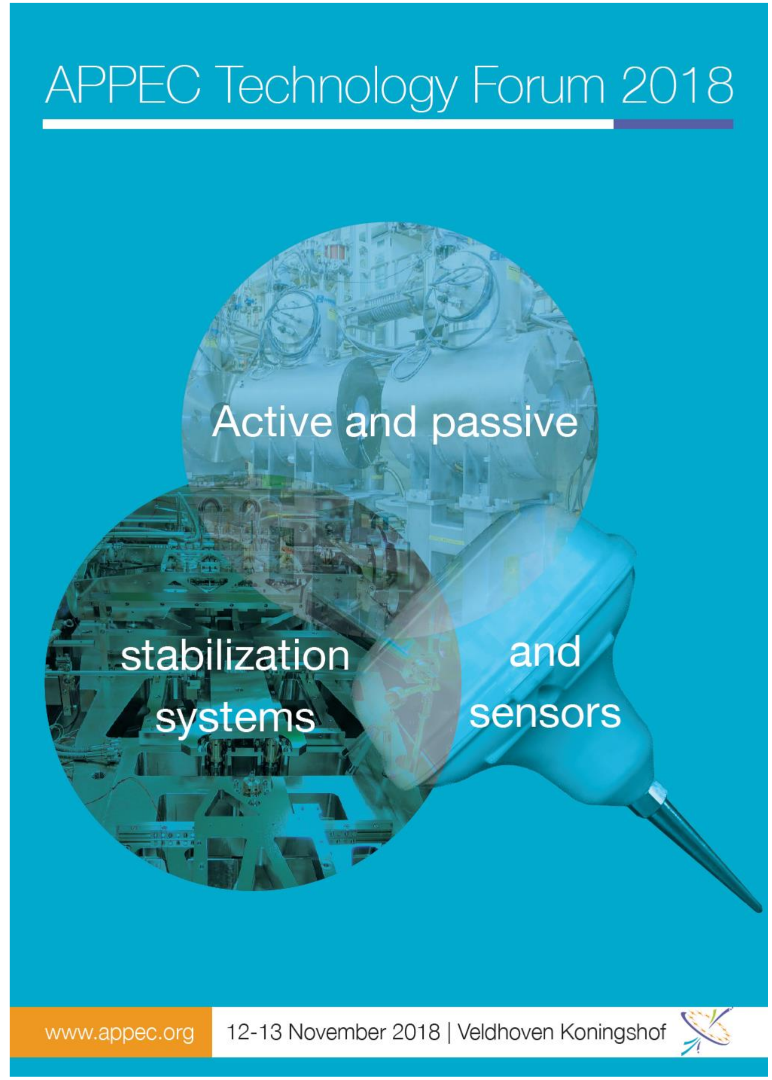
ApPEC Technology Forums

The Astroparticle Physics European Consortium APPEC invites technology experts from industry, project scientists and funding agencies representatives for the APPEC Technology Forum

- APPEC Technology Forum 2018, "Active and passive stabilization systems and sensors", Timetable and presentations, Brochure
- APPEC Technology Forum 2017, "Optics for the 3rd generation of gravitational-wave detectors laser development and X-rays", Timetable and presentations, Brochure
- APPEC Technology Forum 2015, "Low light-level detection in astroparticle physics and in medical application", Timetable and presentations, Brochure







ApPEC Knowledge Translation and Transfer

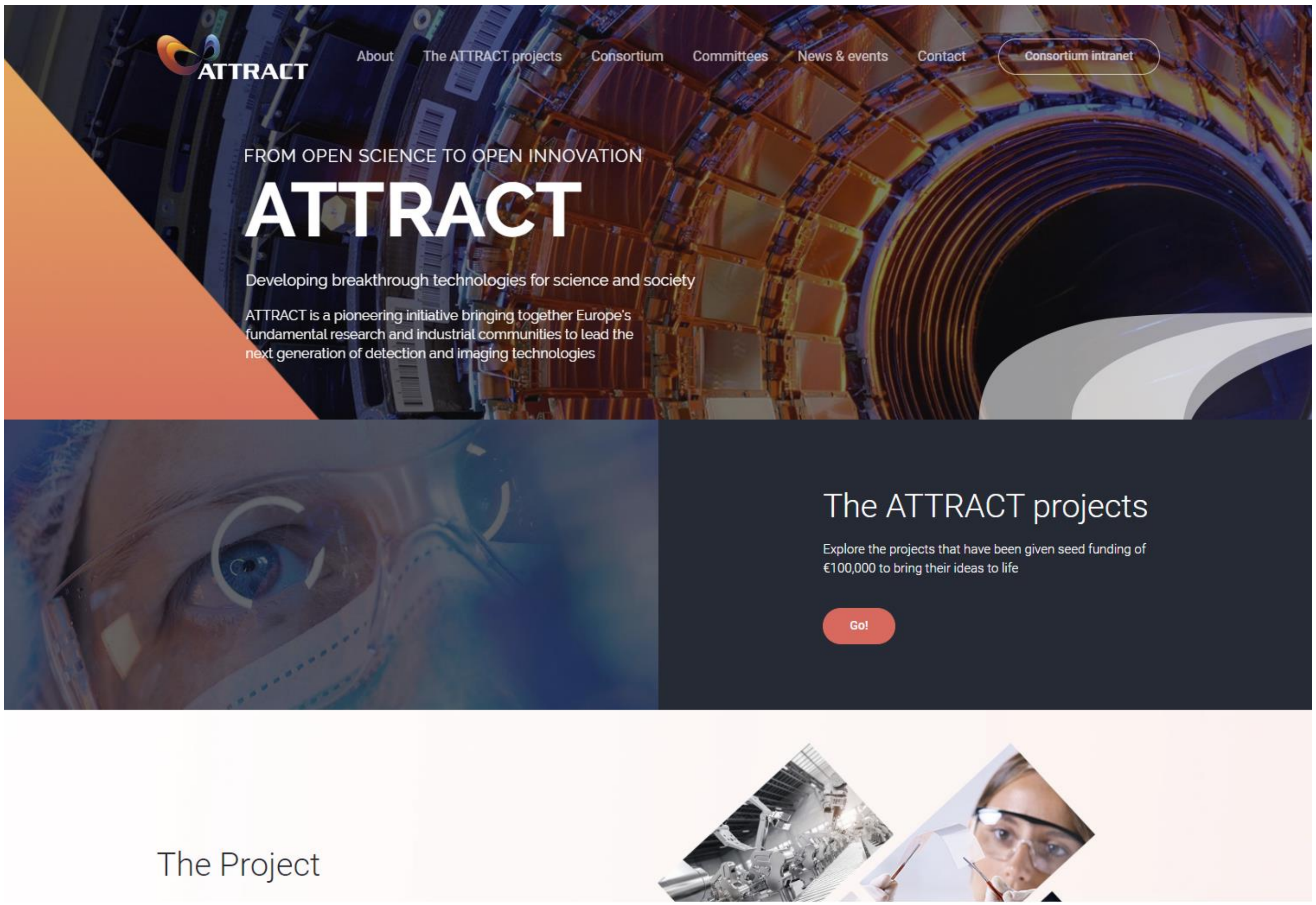
What should APPEC do to encourage the use of astroparticle physics technology and concepts for direct societal benefit?

- Continue to focus on fundamental research, but always keeping an eye open for possible applications
  - Funding of R&D initiatives
- Improve the education of our scientists on the possibility of extracting value from fundamental research
  - Organization of KTT courses and workshops
- Stimulate networking with industry
  - Increase the opportunities for networking of our researchers with industry (continue Technology Forums)
- Help researchers, technology transfer staff, and research users
  - Act as knowledge broker who understands both “worlds”; communicate with stakeholders
- Lay down a clear Intellectual Property policy that is generous with the scientists and encourages KTT

The ATTRACT Initiative

From open science to open innovation. See https://attract-eu.com/
Create a co-innovation ecosystem between fundamental research and industrial communities to develop breakthrough detection and imaging technologies for scientific and commercial uses

- Europe's scientific leaders join forces to create new products, companies and jobs, by taking detector and imaging technologies, and with PPS partners convert them to commercial use
  - A bigger return on Europe's scientific investment that will benefit both the economy and society at large



ATTRACT Consortium

Aalto University
CERN
EMBL
eirma
ESO
European XFEL
ESRF The European Synchrotron
ESADE Business School RAMON LLULL UNIVERSITY
ILL NEUTRONS FOR SOCIETY

Summary

APPEC must continue to encourage the use of astroparticle physics technology and concepts for direct societal benefit

Shouldn’t we collaborate with the ECFA R&D detector panel (APPEC representative Federica Petricca) with the scope to survey innovation useful for society?

APPEC is promoting Technology Forum and right now would be a good time to promote a new open call especially given that around ET there are many agencies

APPEC should continue organizing the Technology Forums. How can this be organized?

What European resources are there to bring our R&D to higher TRLs?