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THE GRAVITATIONAL VOICE

number 22

JULY 2012

An Astronomy Park around Virgo!

News from EGO and VIRGO

CONTENTS

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The content of this newsletter does not necessarily represent the opinion of the management.

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EDITORIAL

While reading the following two articles on wind turbines in the April issue of Europhysics News:
C. le Pair, F. Udo and K. de Groot: Wind turbines as yet unsuitable as electricity providers. http://dx.doi.org/10.1051/epn/2012204
and
P.J. Eecen, H.A. Bijleveld and B. Sanderse: Wind energy research - development of advanced design tools. http://dx.doi.org/10.1051/epn/2012203

I was surprised to read such sharp opinions in such a widely diffused and normally "soft" magazine. Hence, I thought it would be interesting to hear the reactions of the EGO and Virgo folk and, as such, I advertised the two articles by e-mail.

We publish in this issue of ***h***, in the column "Letters to the Editor", a subsequent exchange of letters and we mention the fact, upon the suggestion of Andrea Vicere', that EPS and SIF are organising a school dedicated to the theme: http://en.sif.it/activities/energy_school/2012 with 'energy storage' being one of the central topics. We will be happy to receive and publish further comments on this hot subject.

C. BRADASCHIA
Editor-in-Chief

Squeezing light to catch gravitational waves

That the expected amplitude of a gravitational wave is quite small is a fact familiar to readers of h. So it should not come as a surprise that catching a gravitational wave is a difficult task. It is mainly a struggle against various noises which do their best to mask the expected effect, a distance change between two suspended mirrors.

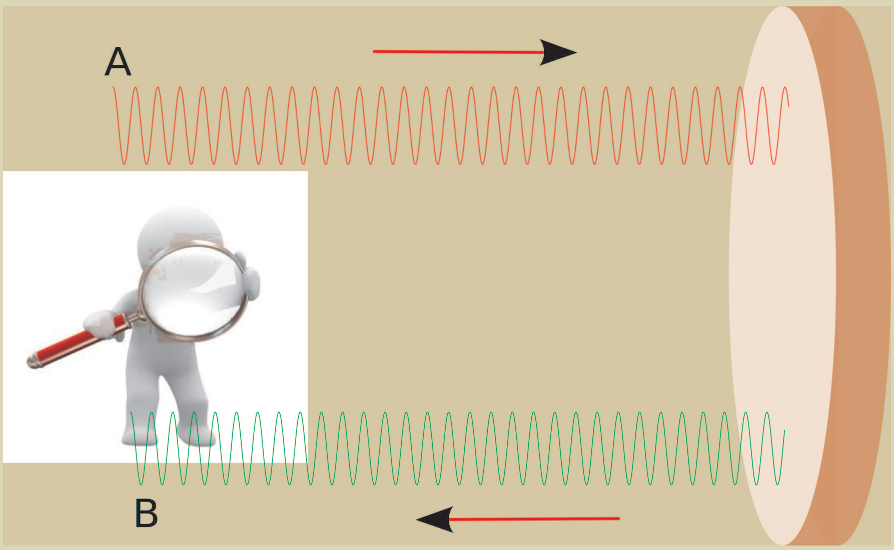
Due to the smallness of the quantities involved, measuring the position of a mirror with a ruler is out of question and the VIRGO way to do that is by using interference. In a nutshell, a light wave (the laser beam) is sent to a far away mirror, and the reflected wave is observed. The information about the mirror's position is contained in how many times the wave oscillates before coming back.

Obviously the mirror moves for a lot of reasons unrelated to the presence of gravitational waves, and currently the fundamental limitation for the VIRGO sensitivity is thermal motion. But let us suppose that in a not too far future thermal noise will be reduced by a large factor. Then we will find that there is a kind of noise which is linked in a very intimate way with the measurement procedure used. We can call it optical noise or, for reasons that will be discussed in the following, quantum noise.

The surprising point about quantum noise is that it could seem that it gives a limit to the sensitivity that cannot be evaded for fundamental reasons, no matter how smart we are. This is called Standard Quantum Limit (SQL).

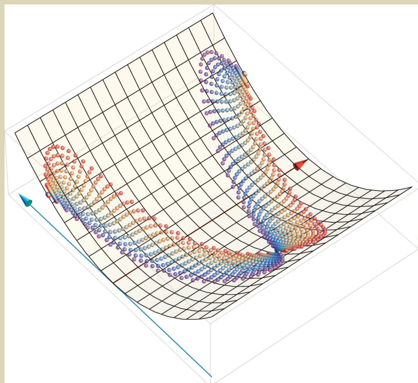
When we think about a wave, we imagine something which is similar to the picture sketched in Figure 1. There is something which can oscillate, such as a guitar string, and the "position" and the "velocity" of a given piece of the string is well defined at any time. The trouble with this picture is that it is a classical one. It does not take into account the fact that guitar strings (or the electromagnetic field constituting a laser light wave) follow the rules of quantum mechanics.

Figure 1. The VIRGO way to measure the position of a mirror. The light sent to the mirror (in red) is reflected back (in green) to the observer.



A quantum oscillator behaves in a quite peculiar way. We cannot determine exactly its "position" and its "velocity" at the same time: accordingly with the so-called Heisenberg uncertainty relation the product of the indeterminacy of these two quantities cannot be smaller than a value proportional to a fundamental physical constant called *h*. This has interesting consequences that I will try to illustrate with some examples.

Figure 2 – The behavior of a quantum ball oscillating at the bottom of a valley. The oscillation is along the blue axis, while time increases along the red one. Each color corresponds to a possible classical motion which starts at the same position with a different initial velocity.



In Figure 2 I represented the possible positions of a small "quantum ball" oscillating inside a valley as a function of time. In drawing the picture I supposed that initially the ball was found with pretty good accuracy displaced in the positive direction from the bottom of the valley. The initial ball velocity is thus uncertain, this uncertainty becoming larger and larger with the precision of our knowledge of the initial position. Several initial velocities will be possible, and for each of them the position of the ball will change in the following in a different way. The uncertainty about the position will grow reaching a maximum after a quarter of the oscillation period, and then it will start to decrease and so on, continuously oscillating between a maximum and a minimum.

This "quantum ball" behaves quite strangely, but maybe I set it up in the wrong way. If we want to obtain a more "classical" ball it is better to avoid a too accurate initial position measurement, which unavoidably triggers a large increase of the uncertainty afterwards.

The knowledge about the position of a classical oscillator can be perfect in principle and it does not change with time. The most similar quantum oscillation we can construct is the so-called *coherent state*, which is actually a quite accurate model for a laser beam. In this case the position indeterminacy is not zero, but at least it is time independent. This is showed pictorially in Figure 3: in the case we are interested in, the plot could represent the value of the laser field at a given point as a function of the time. The two colors correspond to two waves with different amplitudes, and at a given time the indeterminacy is represented by the thickness of the curve.

We should keep in mind that there is no such thing as a "real" classical trajectory followed by the oscillator but hidden by our ignorance: at a given time the oscillator is in a quantum superposition of positions. I will not discuss here the fascinating subject of the meaning of this quantum superposition concept, which is a severe challenge for the common sense (1).

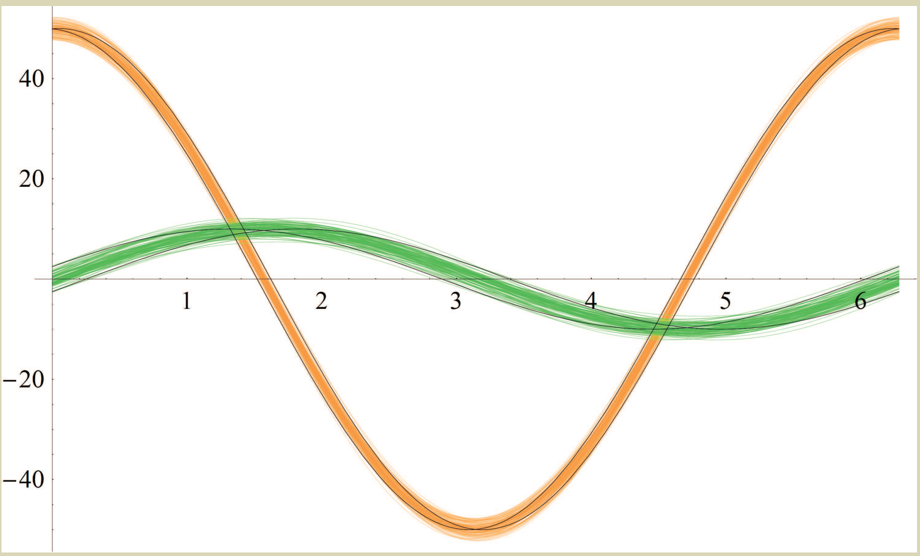
From our point of view we can see a quantum superposition as a noise source: when we measure something about the oscillator we will find a result selected randomly among all the possibilities. As we are interested in measuring the displacement of the wave (that is, its phase), a measurement will select one of the classical oscillations compatible with the given indeterminacy. By looking at Figure 2 we see that there are several different phases which can come out after the measurement, evidenced as classical curves with different colors. In other words we have a quite large phase indeterminacy.

For the coherent states in Figure 3 things go somewhat better. Once again the phase is not completely determined, but its indeterminacy is much less than before. I plotted two extreme possibilities for each wave (thin gray lines): this is an estimate of the limit on the sensitivity to the position of the mirror.

By looking carefully at Figure 3 we realize an important point: the phase indeterminacy of the orange curve is lower than the green curve's one. This seems to suggest a simple way to reduce phase noise: we could simply increase the field amplitude, by buying a more powerful laser. Up to some extent this certainly works. However increasing the laser power is not a painless option, as it leads to several issues which are not easy to deal with. But let us suppose that these could be solved: still we find that quantum noise cannot be reduced arbitrarily in this way.

The reason is simple to understand: as it is clear from Figure 3, a coherent oscillator fluctuates both in phase and in amplitude. When the laser is reflected by the mirror it acts on it with a pressure proportional to the square of its amplitude. If the amplitude fluctuates the pressure will also and the mirror will be displaced from its original position in an unpredictable way, changing the phase of the reflected beam anyway. When the laser power is low this effect will be small, but the intrinsic phase indeterminacy of the coherent state will be large. On the other hand when the laser power is increased the intrinsic phase indeterminacy will decrease, but the phase indeterminacy induced by the shaken mirror will increase. There will be an optimal intermediate power that will give the lower phase indeterminacy obtainable, which is the Standard Quantum Limit mentioned before.

Figure 3. In a coherent state the knowledge we have about the amplitude of the laser field does not change with time, and it is the better we can get with this constraint. This is the best approximation we can have of our intuitive (classical) concept of a wave.



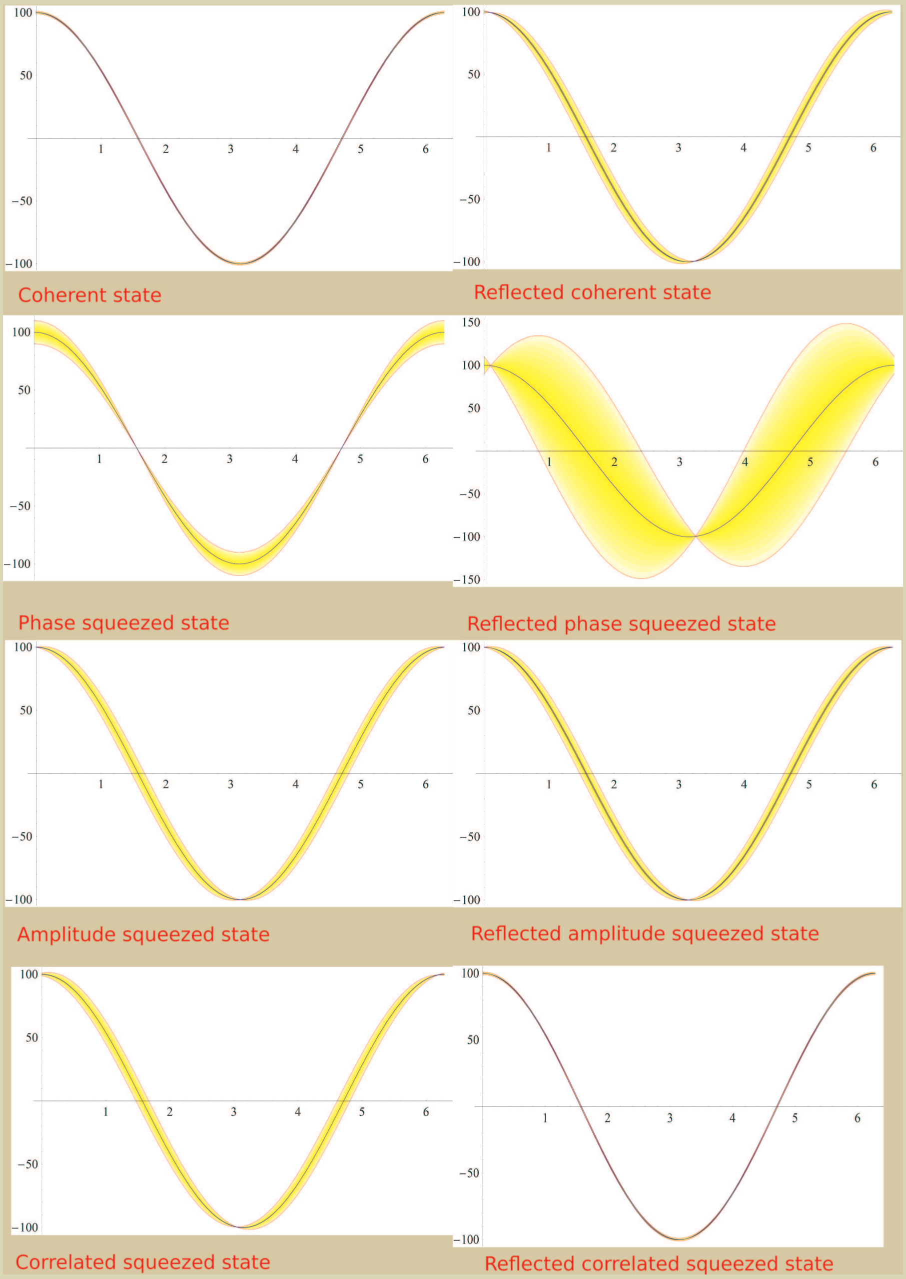


Figure 4 - The state of a quantum oscillator can be changed. On the left side four different states for an incoming laser beam are depicted. The beams reflected by a suspended mirror are described by new states, which are represented on the right side. Some classical oscillations compatible with the indeterminacy are superimposed in each case.

It seems that there is no way to escape from this, but this is not true. A hint about a possible way out comes from the "strange" quantum oscillation we saw in Figure 2, which is a member of a family called "squeezed states". This particular "squeezed state" is no better than a coherent one as its phase noise is larger, but maybe with some exploration it is possible to find something useful.

The first option could be to use a squeezed state with less phase noise compared with the one of a coherent state. An object of this kind in fact exists; it is appropriately called a "phase squeezed" state and is represented in the second row of Figure 4, above.

But this solution does not work. As there's no such thing as a free lunch, we see that together with a reduced phase noise there is an increased amplitude one (2). When a laser beam in this "phase squeezed state" is reflected on a mirror, it shakes it a lot, and the reflected beam (on the right side in Figure 4) is in a state with an increased phase noise. This is the same effect that leads to the Standard Quantum Limit (see the first row of Figure 4) but worsened.

On the other hand if we try to use an "amplitude squeezed state" like the one which is represented in the third row of Figure 4, this will be reflected by the mirror without shaking it a lot. However a large phase noise will be present in the beam since the beginning: this is not a good option either.

The simplest options do not seem to work well, but there is a large class of possible "squeezed states". In the "phase squeezed" and "amplitude squeezed" states I described so far the probability of having a phase fluctuations is independent from the probability of having an amplitude one. In the general case we can introduce correlations between the two.

And it turns out that doing this in a clever way we can obtain a "squeezed state" that, after being reflected by the mirror, has a phase noise reduced compared with the one of a "coherent state". An example is represented in the last row of Figure 4.

This opens the door to several interesting possibilities of evading the Standard Quantum Limit. In the last decade these have been extensively studied theoretically and tested experimentally. The level of noise reduction is continuously increasing, and the key issue here is the ability of generating laser beams with large squeezing (3).

Squeezed light will be applied in the next generation of advanced gravitational waves detectors. It will become in the future a more and more important aspect in the design of gravitational wave observatories.

G. CELLA, Pisa Group

(1) For those who are interested to a non technical but careful introduction I cannot resist the temptation of suggesting a book: G. Ghirardi, Sneaking a Look at God's Cards, Princeton University (2007). It requires some effort, but it is worth of it.

(2) This is a general consequence of the Heisenberg uncertainty relation, which can be rephrased by saying that the product of the position error at a given time and after a quarter of period is constant, so if we reduce the first we should increase the second. I encourage you to verify this on all the oscillations in Figure 4.

(3) I will not discuss here in detail how a squeezed beam can be generated. This is done routinely today in optical laboratories. I want only to remark that when we reflect a coherent state on a mirror, the reflected beam will be in a squeezed state, as shown in the first row of Figure 4.

The Japanese Large-scale Gravitational Wave Telescope: KAGRA

After long and arduous efforts the Japanese Large-scale Gravitational wave Telescope (LCGT) was finally approved by the Ministry of Education, Culture, Sports, Science and Technology in June of 2010. Although a significant amount of delay was caused by the Tohoku Earthquake and its aftermath, the excavation of the tunnel at the Kamioka mine was finally started on May 22, 2012. Meanwhile, KAGRA was selected as the new nickname for LCGT, which is associated with the Kamioka Gravitational wave detector, and a new logo (see Fig. 1) was chosen subsequently. In Japanese, the word kagura means music and dance in honor of Japanese gods. In this article I will briefly explain the objectives, design, preparation, schedule, and organization of KAGRA.

The objectives of KAGRA are to detect gravitational waves and to establish a new astronomy - gravitational wave astronomy - together with Virgo, LIGO, and GEO in the context of the worldwide network. We are especially interested in detecting gravitational waves coming from neutron star binary coalescences. These detections together with simultaneous gamma-ray observations will, for instance, allow us to determine whether neutron star binary coalescences are truly an engine of short gamma-ray bursts. We also expect to detect gravitational waves coming from black hole binary coalescences, supernovae, pulsars, etc., although the expected detection rate for such events is not well established.

KAGRA consists of a 3km long Resonant Sideband Extraction (RSE) interferometer with the cryogenic mirrors suspended from the Seismic Attenuation System (SAS). The detector will be built underground in the Kamioka mine, 200m below the surface, as illustrated in Fig. 2. The vibration level at the site is a factor of 100 smaller than the surface, which together with the SAS, reduces the seismically-originated mirror motion drastically. The SAS was developed based on the Virgo Super-attenuator technologies, and in collaboration with LIGO. As shown in Fig. 3, the SAS consists of an inverted pendulum and a multi-stage pendulum. Each stage also acts as a very low-resonant-frequency vertical isolator with the help of geometric anti-spring effect, invented by Riccardo DeSalvo. The mirrors of the arm cavities are cooled to 20K in order to reduce the thermal noise. For this purpose, sapphire substrates and fibers will be used because of the material's excellent mechanical and thermal properties. The lower stages of the SAS are set up in a cryostat (see Fig. 4), and are cooled by a pulse tube cryocooler via soft heat links to the intermediate masses. The cryogenic thermal shield around the masses and inside the beam tube (up to 20 meters from the masses) prevents the masses from being exposed to the thermal radiation from the room temperature vacuum chamber and beam tubes. The topology of a power-recycled Fabry-Perot Michelson interferometer, which is used for most of the 1st-generation detectors, such as Virgo, LIGO and TAMA300, will be enhanced by an RSE configuration, for which an additional mirror is placed at the anti-symmetric port.

Fig. 1. Logo of KAGRA

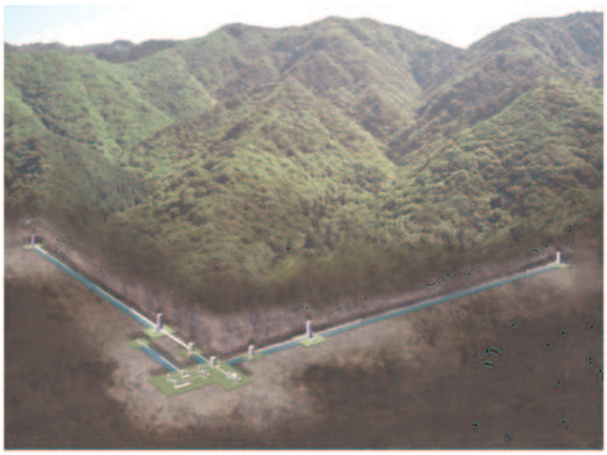


Fig. 2. Illustration of KAGRA located underground in the Kamioka mine.

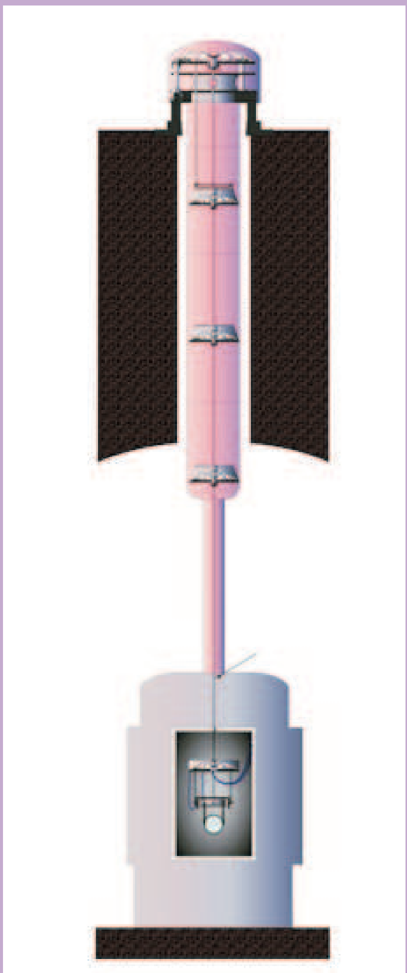


Fig. 3. Seismic Attenuation System for KAGRA. The upper and the lower parts are separated by solid rock.

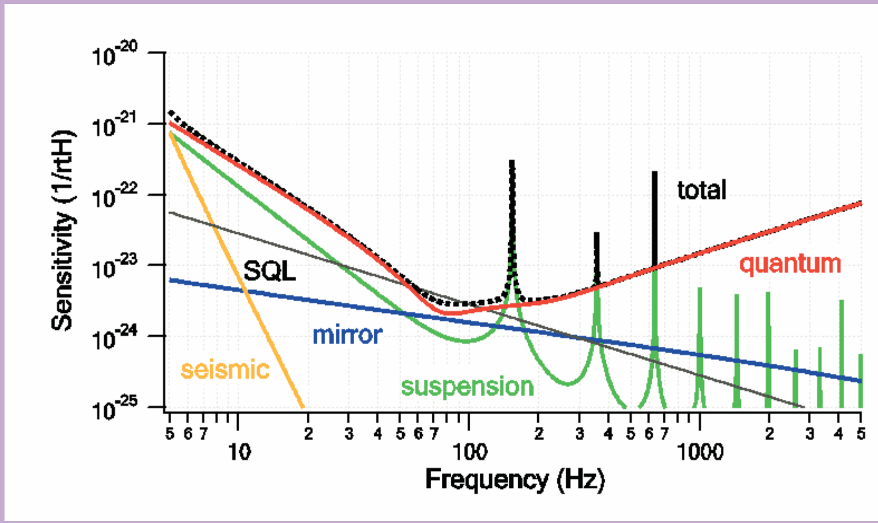
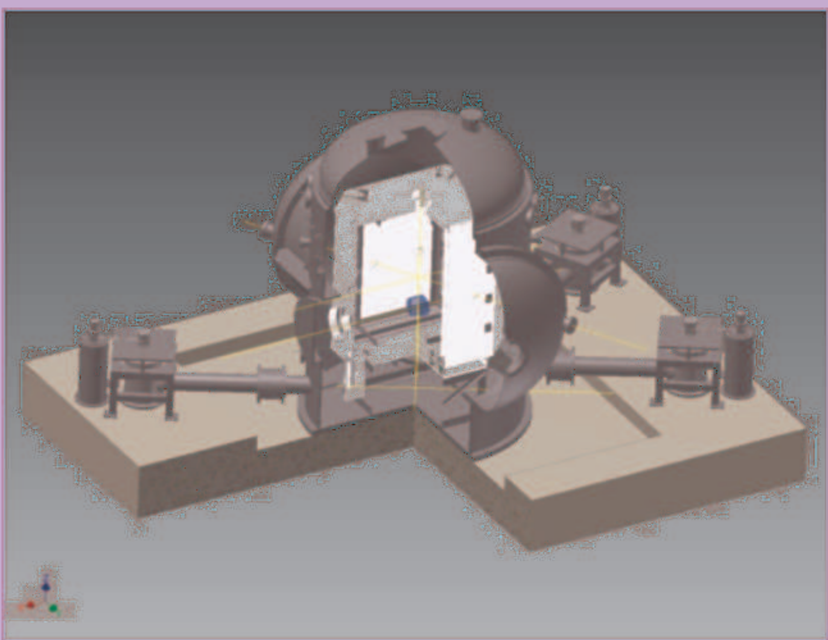


Fig. 5. Sensitivity limit of KAGRA.

This configuration allows us to optimize the quantum noise, that is composed of shot noise and radiation pressure noise, with regard to the chirp signal expected from a compact-star binary coalescence.

KAGRA is required to detect gravitational waves coming from neutron star binary coalescences more than once a year with probability of higher than 90%. To satisfy this requirement, the duty factor of KAGRA must exceed 80% and the observation range must be larger than ~180 Mpc. Here, a signal-to-noise ratio of 8 for gravitational waves incident normal onto the detector is assumed. The spectrum of the sensitivity limit of KAGRA is shown in Fig. 5, which gives an observation range of ~280 Mpc. In reality, however, we anticipate that various practical deviations from the ideal design could impair this sensitivity limit.

Fig. 4. Sketch of the cryostat and cryocoolers designed for KAGRA.



In Japan we started research and development for the detection of gravitational waves with a laser interferometer around 25 years ago with the 10m and, later, the 100m delay-line prototypes at Institute of Space and Astronautical Science (ISAS), and then with the 20m Fabry-Perot prototype at National Astronomical Observatory of Japan (NAOJ). Encouraged by the successful results on those prototypes, we proceeded to realize TAMA300 at NAOJ and CLIO at the Kamioka mine facility of the Institute for Cosmic Ray Research (ICRR), University of Tokyo. TAMA300 is a power-recycled Fabry-Perot Michelson interferometer, where a simpler version of SAS was installed and its performances were successfully verified. CLIO, the 100m cryogenic prototype interferometer, was built to demonstrate the cryogenic technologies required for KAGRA. At room temperature CLIO has achieved a sensitivity limited by both the suspension thermal noise and the mirror thermal noise. By cooling of the two front mirrors a reduction of thermal noise could successfully be demonstrated (see Fig. 6). This was a crucial milestone for the success of KAGRA.

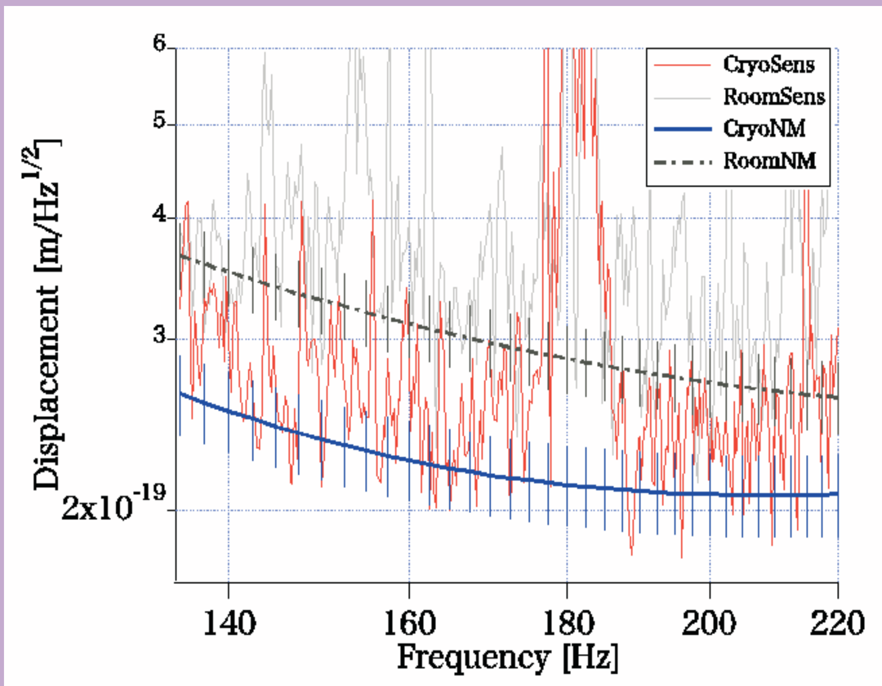


Fig. 6. Sensitivity of CLIO operated with the two front mirrors at room (grey trace) and cryogenic (red trace) temperature. (Takashi Uchiyama, et al., Phys. Rev. Lett. 108 (2012) 141101)

After the tunnel is completed, which is expected to happen in March of 2014, we plan to build KAGRA in two stages: initial KAGRA (iKAGRA) and baseline KAGRA (bKAGRA). iKAGRA is a simple Fabry-Perot Michelson interferometer with a modest vibration isolation system and fused silica test masses at room temperature. We decided to start with iKAGRA to gain some useful experience for a km-class interferometer and also to learn technical challenges for bKAGRA. We plan to conduct a short observation run in 2015 to check the data acquisition system and analyze the obtained data. We hope that we can achieve a sensitivity good enough to join the worldwide network of gravitational wave detection. Then we will proceed to bKAGRA. It is an RSE interferometer with a full SAS and sapphire mirrors at cryogenic temperature. We hope to finish the installation and commissioning to start an observation run around 2017 - 2018.

The KAGRA project is hosted by ICRR with strong support from the High Energy Accelerator Research Organization (KEK) and NAOJ, as well as from more than twenty domestic and more than ten international institutes/universities. KAGRA is led by Principal Investigator, Takaaki Kajita, who is also the director of ICRR and the Executive Office (EO). The EO manages fourteen subsystem groups with the help of the Project Management Support (PMS) group and mostly through the Systems Engineering Office (SEO). KAGRA council consisting of the directors of ICRR, KEK, and NAOJ and other important members determines critical issues on the project. KAGRA also has Program Advisory Board (PAB) and External Review Board (ERB). PAB consisting of senior members in the GW and neighboring field (including European members: Benoit Mours and Bernard Schutz) reviews mainly the management aspects of KAGRA, while ERB consisting of researchers with high expertise in the GW field (including European members: currently Raffaele Flaminio, Andreas Freise, Roberto Passaquieti, and Benno Willke, and formerly Alessandro Bertolini) reviews mainly the technical aspects of KAGRA.

KAGRA employs the underground location and cryogenic mirrors, which are key technologies for the 3rd-generation gravitational wave detectors, such as the Einstein Telescope (ET). Therefore, KAGRA is not only one of the 2nd-generation detectors, aiming for the first direct detection of gravitational waves, but also plays an important role for future generations to further develop gravitational wave astronomy. Hence, we are naturally collaborating with the ET project by exchanging young scientists with the ET-LCGT interferometric Telescope Exchange of Scientists (ELiTES) program led by Michele Punturo on the ET side and with the student fellowships on the KAGRA side (we also plan to submit a proposal equivalent to ELiTES).

KAGRA is still in the initial stage of the project, but we truly hope that we can achieve a good sensitivity as soon as possible to join the world network of gravitational wave detection.

Professor Seiji Kawamura
Institute for Cosmic Ray Research
University of Tokyo
Subproject manager of KAGRA
Member of GWIC

LISA Pathfinder: achieving near-perfect free-fall for gravitational wave astronomy

Free-fall and gravitational wave detection

A gravitational wave is "felt" as a tidal effect, a position-dependent acceleration that stretches and contracts, just as the gravitational field of the sun and moon is observed in the swelling of the ocean at opposite sides of the Earth. A gravitational wave detector's simple, but difficult, task is that of measuring the minute tidal deformation that a passing gravitational wave produces on a constellation of free-falling test particles.

In terrestrial laser interferometer detectors like VIRGO and LIGO, aimed at sensitivity in the range of 10 Hz to audio frequencies, the test particles are suspended end mirrors several km apart, which are in free-fall except for calibrated suspension and control forces. For ultra-low frequencies, from nano to microHz, several dozen neutron star pulsars scattered across the Milky Way can serve as test masses, with gravitational wave strain detectable in the Doppler-shifted arrival of their radio beacon "clock" pulses at earthbound radio telescopes. For gravitational wave detection in the intermediate 0.1 to 100 mHz band, the LISA – Laser Interferometer Space Antenna – mission concept foresees roughly-kg test masses orbiting around the sun in a nearly equilateral triangle with several million km side length.

These detection techniques are all forms of differential accelerometry. The gravitationally-induced relative acceleration of the free-falling test bodies is measurable, but it is in direct competition with two main noise sources: first, the fake effective acceleration caused by noise of the detector as a displacement sensor, and, second, any true residual acceleration of the test particles caused by spurious forces unrelated to the gravitational wave. For this second reason, the free-falling test particles are also known as "geodesic reference" test masses, as they ideally serve as references of purely gravitational orbits.

For LISA, the maximum tolerable deviation from perfect free-fall is quantified by a residual acceleration noise with a noise power spectral density below $3\ 10^{-15}/s^2/Hz^{1/2}$. This translates to a background of spurious acceleration low enough to allow, in several hours time, resolution of a gravitational differential acceleration with amplitude $10^{-17}\ g$ – where $g = 9.81\ m/s^2$ is the well known acceleration due to gravity at the Earth's surface – with oscillation periods from 5 minutes to several hours. Coincidentally, this requirement for low acceleration noise is similar to that needed, around 10 Hz, for Advanced VIRGO.

LISA will observe binary systems of compact objects – solar mass black holes, neutron stars, and white dwarfs – at a point in their evolution millions of years before their orbital frequency reaches the audio frequencies range detectable by VIRGO, minutes before their final merger. More unique to LISA are gravitational waves from compact objects falling into the massive black holes at the centers of galaxies and coalescences of the massive black holes themselves, binary systems with millions of solar masses that merge at frequencies far below the terrestrial observation band. Achieving – or not achieving – the target acceleration noise floor determines the LISA resolution at and below several mHz, and thus also the number of astrophysical sources that we can observe, to what distance, for what length of observation time, and how well we will know their sky positions.

Given the impact that free-fall will have on gravitational wave science, it is reasonable to ask … can we really use an apple-sized test mass as a reference of pure free-fall with such precision, well below a femto-*g* ("femto" means 10^{-15})? Probably yes, according to analysis and earth-based measurements of the small forces that can perturb the test mass orbit. However, a complete answer to this question awaits the results of LISA Pathfinder, the "Einstein geodesic explorer" mission.

LISA Pathfinder

LISA Pathfinder (LPF) is a European Space Agency (ESA)-led mission aimed at achieving, and measuring, sub-femto-*g* free-fall with the core hardware that will be used for LISA. It will launch in 2014, from French Guyana, into the 1st Lagrange point roughly 1.5 million km toward the sun, with the aim of guaranteeing the differential accelerometry resolution that is needed to open the window of space-based gravitational wave astrophysical observation in the next decade.

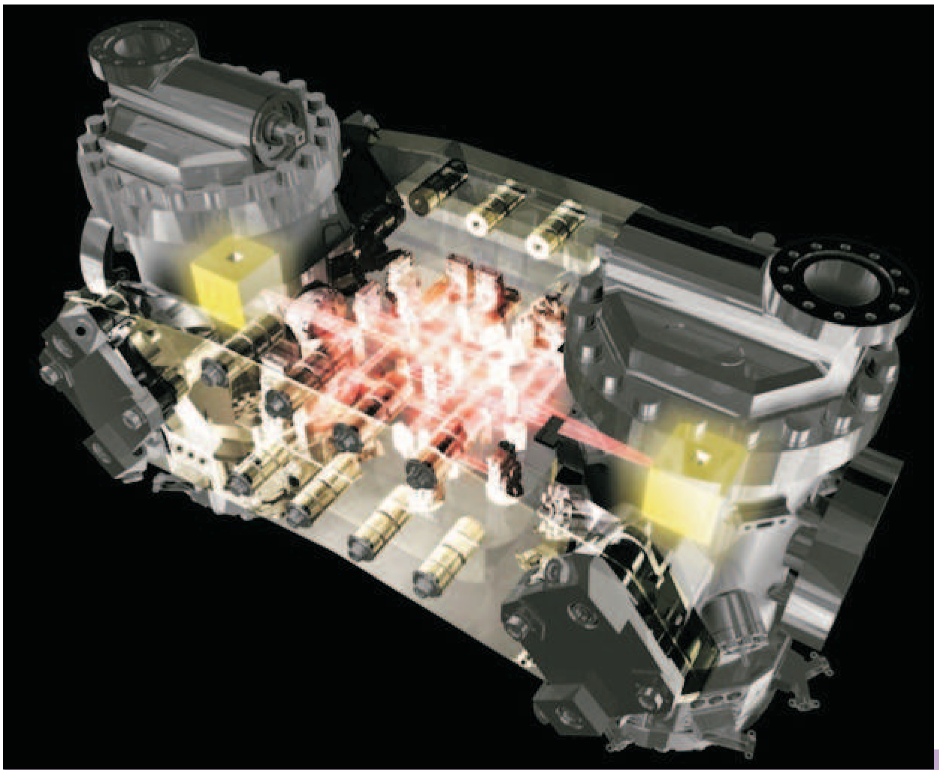


Figure 1 Illustration of the LISA Pathfinder science payload, featuring the two 2-kg Au/Pt test masses, separated by a Zerodur optical bench with interferometry hardware to allow a relative acceleration measurement.

Space allows much larger test particle separation than the km-sized interferometry arms possible on earth. It eliminates the force noise introduced by suspending the test mass in 1 *g* – indeed it eliminates the need to touch the test mass at all – and radically extends the time scale over which the test mass can be considered in free-fall. It also allows us to safely distance the test masses from the Earth's locally noisy gravitational field from moving water, rock, air, and life. These are the reasons why we need to go into space to detect gravitational waves at frequencies below 1 Hz.

Space does not remove, however, the residual interaction with the co-orbiting satellite and the local environment around the test mass. Additionally, the LISA acceleration noise goals are three orders of magnitude beyond what is currently achieved by the best space differential accelerometry experiments, such as the GOCE mission, which measures spatial and temporal variations in the Earth's gravity. As both the sensitivity level and low frequencies required are difficult to reach in an Earthbound laboratory, an in-orbit experiment like LPF is necessary to convincingly demonstrate the measurement science needed for space-based gravitational wave astrophysics.

The idea of LPF is to drastically shrink a single LISA arm to fit into a single spacecraft, with two free-falling test masses separated by 40 cm, and then perform a laser interferometer measurement of the residual relative acceleration between the two test masses. The sensitivity to gravitational waves is lost in the factor 10^9 reduction of the test particle separation, but the relevant noise sources for the stray TM acceleration remain and will be detected at the femto-m/s^2-level.

The co-orbiting satellite, in addition to housing interferometry hardware, shields a LISA or LISA Pathfinder test mass from the fluctuating solar radiation pressure that would otherwise dominate its residual acceleration. The remaining sources of force noise relevant at the femto-g level include cosmic ray charging of the test mass and stray electrostatic fields; test mass magnetic impurities and the interplanetary and spacecraft magnetic fields; Brownian motion from residual gas impacts; fluctuations in nanoNewton-level applied electrostatic control forces; spacecraft self-gravity fluctuations.

All of these noise sources, and others, will be tested on LISA Pathfinder. The most threatening sources are those acting on the test mass surface due to the surrounding electrostatic, magnetic, vacuum, and thermal environment; these sources can be well-characterized on ground with torsion pendulum measurements of small forces with suspended LISA-like test masses inside of the relevant flight hardware. Finally, Brownian noise, stray electrostatic fields, noisy control forces and other sources targeted by LPF are relevant to a broad class of experiments with reference test masses, including Virgo. Thus, the LPF investigations build a physical model of the limits to achieving perfect geodesic motion for experimental gravitation.

Figure 2 shows a conservative prediction for the LPF acceleration noise performance, based on extensive ground testing of both the interferometry sensitivity and force noise sources. In addition to improving upon the official mission goal, the expected performance meets the LISA acceleration noise goal at all frequencies above 1 mHz. In so doing, LPF should guarantee the core LISA scientific return, including high precision observation of gravitational waves from a number of known white dwarf binary systems in our galaxy. Also shown are current upper limits to surface forces acting on the test masses, based on torsion pendulum measurements with prototype flight hardware, indicating that LISA would allow gravitational wave observation, even if the flight performance were no better than that already demonstrated with our more modest ground instruments.

Challenging economic times and evolving science programs inside both ESA and NASA have increased the error bars relevant to the launch date of LISA and have reopened discussion of many aspects of the mission – including the orbits, the optimal size and number of laser links for the available budget, the nature of the collaboration between different agencies, even the use of the name "LISA" itself. The astrophysical science case and performance requirements remain unchanged, however, as does the measurement technique and key hardware. LISA Pathfinder is financed to fly, and it represents, in Virgo terminology, the commissioning phase for the final space gravitational wave observatory, whether or not it is named LISA. We hope to provide an update, with data from the orbiting LPF spacecraft, in just a couple of years!

William Joseph Weber
Università di Trento
19 June 2012

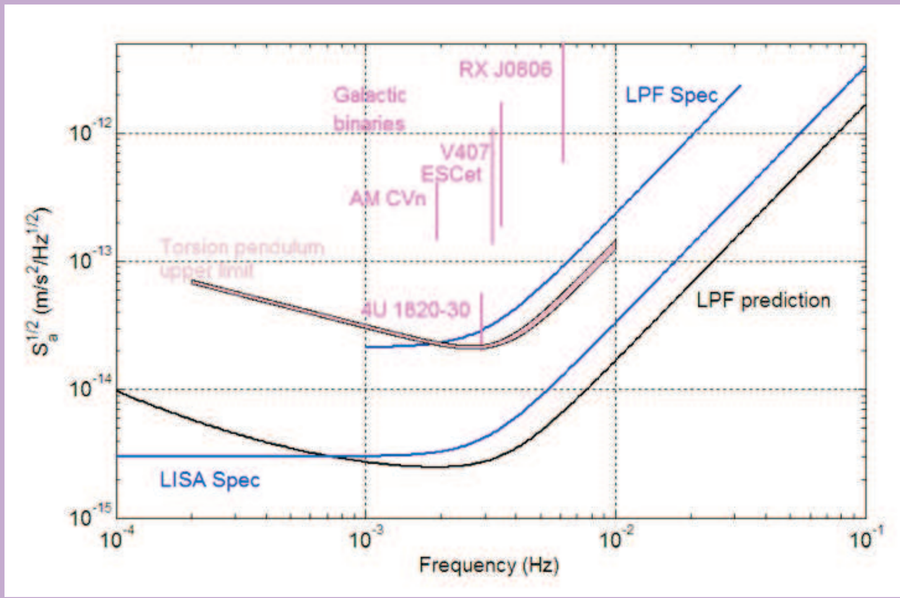


Figure 2 Expected performance for the LPF acceleration noise upper limit (black) compared with the LPF and LISA mission specifications. Also shown are the acceleration noise levels required to observe gravitational waves from a number of known galactic white dwarf binary systems and torsion pendulum upper limits on the contribution from test mass surface forces. [Presented at the Marcel Grossmann 12 Conference in July, 2012]

For more information on LISA Pathfinder, see:
http://www.rssd.esa.int/index.php?project=LISAPATHFINDER&page=Index
and
http://www.esa.int/esaSC/120397_index_0_m.html.

For the evolving LISA concept, see: http://elisa-ngo.org/.

An Astronomy Park

by Sara Baglini

I live in Santo Stefano a Macerata, in the vicinity of EGO. My thesis to obtain the "architect" degree at the University of Florence was inspired by two outstanding structures in the territory. One is EGO and the other is the remaining structure of Decoindustria. We already know about EGO but what about Decoindustria? Decoindustria, which is situated between Chiesanova and the Virgo North End Building, was a plant devoted to the treatment of contaminated liquids. It was closed by the Italian magistracy for illegal

management of poisonous waste.

The idea took shape of converting the industrial plant to something nice and useful for the community. Virgo was the inspiration for the proposal to create a national Science Park dedicated mainly to astronomy. Virgo would play a strong role in attracting people while the attendance would be enhanced by the location along the linear metropolitan area, which is expected in the future to connect Pisa with Florence.

The idea has been endorsed by the Cascina County Council which is already engaged in the challenging decontamination of the Decoindustria site. It has become a real design by the architects Sara Baglini and Danilo Gentili. For the realization it will be necessary to obtain funds at regional, national and European level.

Designing the Park "Gira.sole Luoghi di Scienza"

The original landscape was characterized by the horizontal lines of fields, interrupted by cypress rows and a few farm houses. The new landscape will be dominated by the existence of the EGO observatory and by the large industrial complexes converted for public use.
The needs of students, researchers and tourists will be taken into account within the framework of a science oriented development stimulated by local universities, research institutions and high technology spin off industries.

In addition to a Planetarium and an Astronomy Museum the Astronomy Park will include a Hostel for visiting classes and a Guest House for researchers temporarily working at EGO.
The Hostel and the Guest House will be designed reproducing the architecture of old country houses with common wide yards to be used by students and researchers. At ground level all the common utilities: kitchen, library, reading hall, pub. On the upper floor rooms and small apartments will be available for longer stays.

The Planetarium and the Museum will preserve the size and the shape of the two largest tanks of the old industrial plant. Their pure geometrical shape corresponds very well with the new safe technology which replaces the dangerous original. In the Planetarium, equipped with I-Max technology, there will be room for projections and science inspired shows. In the Museum there will be laboratories for hand-on experimental activity. The large instrument prototypes and the free fall demonstrator presently hosted at EGO will be moved to the garden outside.

The four natural elements can be discerned in this natural science site:
• Fire: the stars projected in

the Planetarium cupola

- Air: the central open space in the Museum building
- Earth: the garden soil and the lining coating the cylindrical buildings
- Water: the fountain basin in the central court.

The Planetarium

The entrance is through a classical dromos (entrance to ancient Greek tombs) slowly descending underground. The visitor will be guided from the obscurity of ignorance to the virtue of wisdom along a spiral slope surrounding the 75 seat Planetarium. The outside of the cupola, a full sphere, will reproduce the Earth's surface, transforming the walk to the entrance of the Planetarium into a "journey around the world".

The Astronomy Museum

The wide central space is partly occupied by a large crystal sphere containing a tree sprouting from a water basin. It is a symbol of nature penetrating the building, an outside symbol contained inside a shell. At ground level there will be a book shop, a media center, a bar and other services. Astronomical exhibits, sky pictures and videos will be exhibited on the two upper floors.

The 2012 VESF School

In the week of June the 18th to the 22nd, EGO hosted the first VESF School on Gravitational Wave (GW) Advanced Detectors.

In the year when work on Advanced Virgo and Advanced LIGO has kicked off, the VESF Executive Board has proposed a topical school, for the first time focused on experimental issues related to the design and construction of Advanced Interferometers: this has turned out to be good intuition, as the numbers confirmed: we had 18 participants, mostly PhD students (and some post-docs). They represented 9 different nationalities over two continents (France, Germany, Great Britain, Greece, India, Italy, Poland, Spain and Ukraine), and they arrived from 13 different institutions, from 7 countries and 2 continents: Siena, Camerino, Pisa, Roma 1 and 2, AEI, Glasgow, IEES, Artemis, LAL, Leiden, Warsaw and MIT.

One striking feature was the high number of women participating: 7, a record for any VESF School! All the students were well prepared and motivated: many of them are already active in the Virgo collaboration, some might join in the future, others are involved with GEO or even with LISA.

The course was held by 14 lecturers of high profile, recruited in 5 different countries (+ EGO). Most of them are actively working on Advanced Virgo, but we also had 2 representatives from the LSC. The lectures, spread over 5 days, ranged over topics from sources to suspensions, from lasers to cavities, from controls to diffuse light and thermal noise, covering most of the issues that characterise the upgrade to Advanced interferometer. Overall, the students were subjected to an amazing 996 slides in 27 hours! Also for this reason, the guided tour of the Virgo facilities was particularly appreciated, and raised a lot of interest and curiosity.

A nice dinner topped the social programme and strengthened friendship ties: rumour has it that the after dinner socialisation lasted till late into the night (or should we say early morning?!). Logistics was, as usual, quite efficient and effective, despite the concurrent meeting of the EGO Council that absorbed most of the energies and time of the EGO staff. Our thanks to EGO and its Director, to the computing people and to the secretariat, for a smooth and trouble-free school!

In summary, an experimental school, both in the sense of a new programme and of a syllabus focused on the experiment, which turned out to be a success!

M. BASSAN

Picture below: school participants with Massimo Bassan (school co-director) and Stefan Hild (lecturer).

The new EGO optics laboratory

The "old" EGO Optics Lab was created in September 2007 in the new building to cope with the growing needs of on-site testing and prototyping of new optical systems for the maintenance and upgrade of Virgo.

The main part of the lab was specifically dedicated to the completion of the R&D for the High Power Input Optics (HPIO) to prepare for AdV. Figure 1 shows the enclosure hosting the 200W laser source and the dedicated high power optical setup. In addition to R&D studies, the setup was intensively used to develop recent Virgo+ upgrades such as improvement of the SIB Faraday isolator, realisation of high power in-vacuum beam dumps for the detection system, study of high power diaphragms…

Figure 1: High power room of the "old" optics lab

A second part of the lab (see Figure 2) was used for all other activities with setups dedicated to measurements such as diffusion, reflectivity, absorption, polarisation …and some more exotic activities such as the development of a new adaptive optics system for GW detectors, the TDM. (Thermally Deformable Mirror). Since its creation, the amount of activities in the lab has constantly increased, reaching complete saturation. In addition to the permanent optical setups installed in the facility, the 43 m2 of the lab were also used to store various optical materials, devices and spares, leaving no room for new setups or space for mounting, cleaning and inspection of optics.

Figure 2.

Besides, new activities are foreseen in the next few years since the EGO Optics Group is in charge of the INJ subsystem for AdV, which means in particular the development of 2 large optical benches. The HPIO R&D setups have to be maintained over the next 2 years as the final Faraday Isolator and other components will be built and characterised before integration into AdV.

It was therefore decided in 2011 to enlarge the lab by "absorbing" the space dedicated to the electronics laboratory that moved to Building 1. Plans of the new lab can be seen in Figure 3.

The two rooms, Optics Labs 1 and 2, correspond to the old laboratory. The addition of two new rooms doubles the total space of the lab: Optics Lab 3 hosts three new optical tables and will be devoted to the most demanding applications in terms of cleanliness, Optics Lab 4 will be used for storage and some space will be devoted to noise studies with, for example, a setup dedicated to mechanical characterisation of optical mounts.

The most important modifications of the infrastructures are linked to cleanliness issues. Indeed, the "old" laboratory was created in a space that was supposed to host some offices, and the materials used where far from adapted to a clean environment. Despite all efforts to maintain the old lab "as clean as possible", Figure 4 shows the state of an optic exposed for a few days to its hostile conditions.

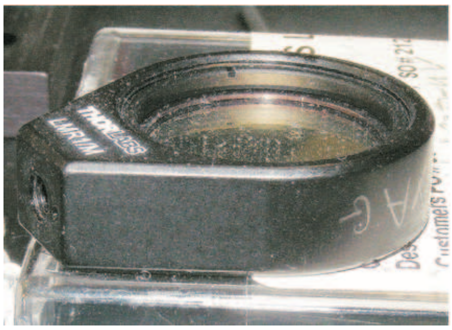


Figure 4: A few days of dust exposition in the old lab.

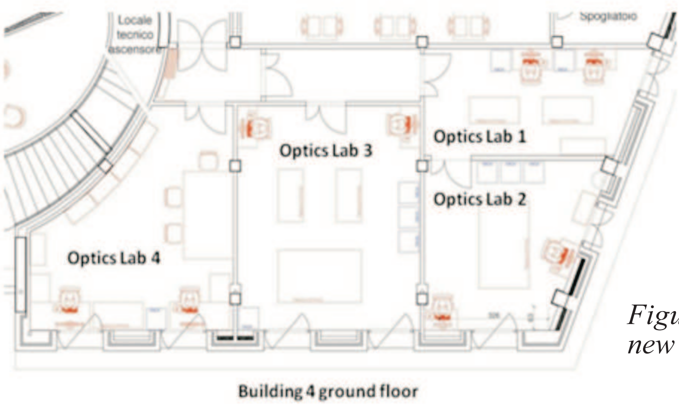


Figure 3: Plan of the new laboratory

Therefore, considerable effort was made to modify rooms 1, 2, 3 in order to limit this issue. More in detail, the ceiling, originally made of plaster, was replaced with plastic plates. Then, the walls were painted with a special paint and a PVC floor was installed. In addition, the existing air conditioning was modified to control the temperature of rooms 1 to 3 and clean filters where installed on different AC outlets.

Figure 5: A view of one of the new rooms, Optics Lab 3.

Infrastructure works started in February 2012 and finished last May. First impressions of the new lab are very good and people find it for the moment a very convenient place to work. Figure 5 shows a view of the new room Optics Lab 3 where some setups for AdV, such as BMS improvement and RFC characterization, were already installed. As one can see from this figure, in only one month, this new room already starts to be crowded...

B. CANUEL
EGO Optics group

The Biathlon 2012

With respect to past years (in 2011 it rained shortly after everybody had moved to the canteen), this year the Biathlon took place during a particularly hot period.

This might have deterred a few potential athletes from participating, but nevertheless four teams were formed, ready to participate in the competition.

The table below shows the measured times after half the Biathlon (athletes returning from the North arm, grey) and the final times (white).

The winning team was the newly created PartenoPisa; but being a blend of the traditionally victorious Napoli (poetic: Partenope) and Locking teams, its victory was not a real surprise. For the second to fourth places, the arrival sequence changed quite a lot between the first half (the athletes coming back from the North Arm) and the final result.

Despite the difficult weather conditions, the winning time was comparable with that of past years (2011: 35’13”; 2010: 36’29”).

H. HEITMANN
h Reporter

Heading for the final leg of the run, after receiving the baton from the cyclist.

Photo courtesy of Marc van der Sluys.

2011	The Flying Dutchmen		LAPP et al.		Black PearlTeam		PartenoPisa	
1km	Kristen Zych		C.N. Colacino		Philippe Benoit		Luciano DiFiore	
2 km	Adriaan ter Braack		P-F Cohadon		Giuseppe DiBiase		Enrico Calloni	
Bike 6km	Mark Beker		Loic Rolland		F. Carbognani		Niccolo' Grilli	
3 km	Mathieu Blom		Bruno Lieunard		Frederic Richard		Gabriele Vajente	
Number	2	4	4	3	3	2	1	1
Time	19:55	41:10	21:06	40:51	20:17	40:16	18:21	36:12

Copenhagen, a drama

In this issue we use the production of the play 'Copenhagen' by Michael Frayn at the Church of San Zeno in Pisa on the 15 of June, which was supported and promoted by EGO, along with the Foundation Pisa and the Comune di Pisa, as a springboard to look at the event on which the play is based, its author and the setting in which the performance was given.

The Bohr-Heisenberg meeting

The play itself is based on a meeting that took place in occupied Denmark in September 1941 between the physicists Niels Bohr (1885-1962) and Werner Heisenberg (1901-1976), while the latter visited Copenhagen with fellow physicist Carl Friedrich von Weizsäcker. What actually took place at that meeting will probably always be lost in the mists of time, but, in subsequent years it has been possible to formulate a general idea – perhaps 'ideas' is a more precise way of putting it – of what was discussed. The issue of the content of the discussion first emerged with the publication of the book 'Brighter than a thousand suns: A personal history of the atomic scientists', which contains the first published account of the Manhattan Project and the German atomic bomb project, by Robert Jungk (1913-1994) in German in 1956. Jungk, who was born into a Jewish family in Berlin and was studying at its university when Hitler came to power, emigrated to Paris and studied at the Sorbonne in 1933, before spending the period 1936-1938 in Prague, publishing an anti-fascist paper. From '38, with the entrance of the Nazis into Prague, he fled to Switzerland, where he remained until the end of the war in 1945 [2]. He described himself as a 'scientific journalist' [1] and produced a considerable volume of literature in relation to the development and production of both nuclear energy and weapons. He was also keenly involved in the themes of peace, the future and anti-nuclear activity, publishing, among numerous other titles, a critique of the nuclear industry with 'The Nuclear State' in 1970 and even standing as Green Party candidate in the Austrian presidential elections of 1992, eventually won by Thomas Klestil. Following the 1956 publication he was contacted directly by Heisenberg, who wished to clarify a handful of points that emerged following the latter's reading of the text during a period of short illness [3]. It is from this exchange of letters, which took place between November of '56 and January of '57, and subsequent events that the dynamic of the affair emerges.

Heisenberg's original letter covers an array of different issues, from the political convictions of a colleague to discussions on the 'Uraniam problem', and the concept of active resistance within a totalitarian dictatorship. He even goes as far as to note that he has actually read almost all of the works by the English novelist Anthony Trollope, rather than Tobias Smollet, as had been reported by Jungk in his text. However, it is his subsequent letter, motivated by a request for further information solicited by Jungk in reply to the original correspondence, that the Copenhagen meeting is addressed.

In his reply, Heisenberg describes how the physicists in, what he terms, their 'Uranium Club' had reached the conclusion that not only would it be possible to produce energy from a uranium and heavy water reactor, but also that a decay product of 239-uranium would be produced which could be used as an explosive in an atomic bomb. However, they perceived the technical resources required to achieve an objective of this kind to be 'enormous'. He continues by explaining how this was actually a useful situation:

“This situation seemed to us to be an especially favorable precondition as it enabled the physicists to influence further developments. For, had the production of atomic bombs been impossible, the problem would not have arisen at all; but had it been easy, then the physicists definitely could not have prevented their production...The actual givens of the situation, however, gave the physicists at that moment in time a decisive amount of influence over the subsequent events..” [3]

In this context, Heisenberg states that they, note the fact that the letter uses 'we', rather than 'I', thought that a discussion with Bohr 'might be of value'. During that meeting Heisenberg states that he asked Bohr whether he thought it justifiable that scientists work on the 'Uranium problem' during war-time, considering the grave consequences such work might imply. He continues by saying that Bohr 'immediately grasped the meaning of the question' and describes his response as being 'startled'. He then says that Bohr immediately demanded:

“Do you really believe one can utilize Uranium fission for the construction of weapons?” [3]

Heisenberg then becomes a little more coy, stating that he 'may' have replied that 'I know' that, at least in principle, it is possible. He then describes how Bohr was so 'shocked' at what he had heard and that the explanation for this reaction must have been that Bohr believed Heisenberg was trying to tell him that Germany had made great strides towards the manufacture of the bomb.
This letter certainly gives rise to a

sense of frustration on the part of Heisenberg; a sense of inconclusiveness; of an unfinished piece of business. He puts this down to the fact that he knew that Bohr was being closely monitored by what he terms 'German political operatives' and as a result, he was forced to be circumspect in his statements:

"I tried to keep the conversation at a level of allusions that would not immediately endanger my life...In my subsequent attempt to correct this false impression I must not have wholly succeeded in winning Bohr's trust, especially because I only dared to speak in very cautious allusions (which definitely was a mistake on my part) out of fear that later on a particular choice of words could be held against me." [3]

He felt that this impossibility to communicate fully was at the root of the misunderstanding. Certainly, he was correct in believing that Bohr was under surveillance. At the end of September 1943, Bohr, whose mother was Jewish, received warning of his imminent arrest by the Gestapo as part of a planned deportation of all of the Jews in Denmark. He and his wife subsequently fled to Sweden by sea [4] as part of what has become known as the 'Rescue of the Danish Jews' – an historic event in which the Modstandsbevægelsen (Danish Resistance Movement) with the help of many ordinary Danish citizens, evacuated the vast majority of the country's Jewish population by boats of varying sea-worthiness to Sweden. As a result of these actions, 8,000 people's lives were saved. At the end of the war, 99% of Denmark's Jewish population had survived the Holocaust. [5] Before long he was taken by military aeroplane to Britain, where he was introduced to the secret atomic bomb project, before being transferred to the Los Alomos base in the United States, where he worked on the Manhattan Project under the pseudonym 'Nicholas Baker' for security reasons. [6] Interestingly, Bohr frequently expressed concern about the development of atomic weapons and is even quoted as having later said, "*That is why I went to America. They didn't need my help in making the atom bomb.*" [7] Following a meeting with Oppenheimer, in which it was apparently decided to send Bohr to speak to Roosevelt about the possibility of sharing information with the Russians, in order to speed up work, Roosevelt seemingly proposed that Bohr should discuss the idea with Churchill, to gain British agreement. Churchill, however, of course not renowned for his overtly friendly sentiment towards the communist system, recorded *"It seems to me Bohr ought to be confined or at any rate made to see that he is very near the edge of mortal crimes."* [8]

The remainder of the letter dedicated to the meeting deals with what took place in a less distinct manner, exploring rather issues in relation to the state of developments in Germany and the USA at the time. It is interesting however, to note how Heisenberg goes to considerable lengths to stress that he is uncertain of all that he recalls owing to the passage of time – remember this was 15 years after the event - and to a conscience of an unspoken sub-text to the meeting, which rendered it difficult to clarify precisely what took place:

"Everything I am writing here is in a sense an after the fact analysis of a very complicated psychological situation, where it is unlikely that every point can be accurate. - I myself was very unhappy over this conversation...Even now, as I am writing this conversation down, I have no good feeling, since the wording of the various statements can certainly not be accurate anymore, and it would require all the fine nuances to accurately recount the actual content of the conversation in its psychological shading." [3]

An extract of Heisenberg's letter was included in the Danish language version of the text, also published in 1956, which was apparently taken out of its original context and gave the impression that Heisenberg had used his meeting with Bohr to claim that, for moral reasons, he had sabotaged the German atomic bomb project. [9] Bohr, upon reading the text, took exception to this description of events and, as a result, proceeded to write a series of letters, most of which were never sent, to Heisenberg, in order to express his disagreement. These letters – eleven documents in all – are available via the Niels Bohr Archive, the website of which states that, "The documents supplement and confirm previously published statements of Bohr's recollections of the meeting, especially those of his son, Aage Bohr." and that they were released in their entirety on the 6th of February 2002, "in order to avoid possible misunderstandings". [10] The documents had been subject to a clause proscribing their release until fifty years after the death of Bohr, which means that they should not have been released before 2012. However, this clause was revoked, in agreement with Bohr's family, given the intense interest in the Heisenberg meeting provoked by Frayn's play. [11]

All but one of the eleven documents in the archive are either drafts – sometimes incomplete - or notes and are even sometimes in the hand-writing of Margrethe – Bohr's wife - or Aage Bohr, rather than Bohr himself. The remaining document is in the form of a telegram, sent by Heisenberg in response to 60th birthday greeting from Bohr. The Director of the Niels Bohr Archive, Finn Aaserud, notes in the introduction to the documents that they are to be treated with caution, all being written at least sixteen years after the event. In addition, they have all been translated into English, which means that, "As with any translation, the precise choice of corresponding words and phrases has been difficult"; a difficulty accentuated by the fact that the documents are drafts, notes and often unfinished. [11]

Rather than offer an interpretation of the letters here, which is obviously the axis on which this story pivots, and making a vain attempt to reach a conclusion that is perhaps un-reachable and un-knowable, it is perhaps more advised to simply point the reader in the direction of the documents themselves. They can be found within the pages of the Niels Bohr Archive website and are available here – http://www.nba.nbi.dk/papers/introduction.htm. Regardless of the extent to which the documents actually clarify the issue, they do give the impression of a wish to address or render clearer exactly what happened on that evening back in 1941.

One further piece of interesting information is provided through a summary of events by Bohr's son, Aage, quoted in the book, Niels Bohr: His life and work as seen by his friends and colleagues, edited by Stefan Rozental and released in 1967, in which he addresses the meeting directly:

"In the book "Brighter than a Thousand Suns" by Robert Jungk it is asserted that the German physicists submitted a secret plan to my father, aimed at preventing the development of atomic weapons through a mutual agreement with colleagues in the allied countries. This account has no basis in the actual events, since there was no mention of any such plan either during Heisenberg's visit, or during a later visit to Copenhagen – also mentioned by Jungk – of the German physicist Hans J.D. Jensen. On the contrary, the very scanty contact with the German physicists during the occupation contributed – as already mentioned – to strengthen the impression that the German authorities attributed great military importance to atomic energy." [12]

And with that, we return to the beginning. The evidence has been presented, but the conclusion remains the same – indecisive. Given the lack of conclusive proof, it is possible only to read and re-read the available documents, looking for suggestions, building hypotheses and loading more or less significance onto statements that may or may not really be of any import. This really does seem to be an area of history of which we will never really be able to know precisely what occurred. The issue was, however, further clouded in March 2006, following the intervention of the Croat physicist and philosopher, Ivan Supek (1915-2007), who had been a friend and student of Heisenberg. Supek claimed that Margrethe Bohr had informed him, in confidence, that von Weizsäcker, rather than Heisenberg had actually been the protaganist in the meeting:

"Heisenberg and von Weizsäcker came to Bohr in German army uniforms. Von Weizsäcker's idea, probably originating from his father who was Ribbentrop's deputy, was to persuade Bohr to mediate for peace between Great Britain and Germany." [13]

So, 65 years after the event, yet another alley opens up down which one might potentially lose oneself. Enter Michael Frayn - stage left, one is tempted to say - and the words he puts into the mouth of his Heisenberg:

"*No one understands my trip to Copenhagen. Time and time again I've explained it. To Bohr himself, and Margrethe. To interrogators and intelligence officers, to journalists and historians. The more I've explained, the deeper the uncertainty has become. Well, I shall be happy to make one more attempt."* [14]

G. HEMMING

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Michael Frayn

Michael Frayn was born in Mill Hill, London in 1933, grew up in Ewell, Surrey and was educated at Kingston Grammar School. His father, a deaf asbestos salesman, would bring home samples of the material, with which the young Michael would play, hammering nails into them and so on, completely oblivious of its toxicity. Frayn's sister, Jill, would later prematurely pass away suffering from a lymphoma, probably caused as a result of this early and sustained exposure to asbestos dust. His mother, having survived the War, died of a heart attack in November 1945.

He was idealogical as a schoolboy and, while at school, set up an independent communist cell with a classmate. Following school, he learned Russian, while on a two year military service, and then studied at Cambridge, where he read Moral Sciences (Philosophy) at Emmanuel College. While at the university he, along with a group of Russian-speaking friends, set up what he believes was the first student exchange programme with Moscow, although this brought him into contact with the intelligence services which, as he wished to maintain his independence, caused him to withdraw. His earlier communist tendencies soon wore off, however. He states that he learned Russian to study Russia better, but that “The interest in Russia remained, the communism wore off pretty quickly”.

Upon graduation, he began to work as a reporter for the Manchester Guardian and has since commented that “Newspapers were where I felt most at home”. Having worked for both the Guardian and the Observer, Frayn began to write fiction, which he describes as being not unlike 'industrial management' – citing the need to strike a balance with the characters of a play or book in order to get them to do what the author wants them to do, while still allowing them to have their own lives as well. He has written both drama and prose and been successful in both, while his work ranges from farce - the writing of which he describes as being 'particularly difficult' - to philosophical, often in the same play. His most famous productions have been Noises Off, a farce about a play within a play, Copenhagen and Democracy, a drama about the end of Willy Brandt's chancellorship of West Germany and the unmasking of his secretary, Gunter Guillaume, as a spy.

In relation to Copenhagen, he says that he “worked very hard to find out everything that was known...I've tried to respect the historical record, in so far as it exists, but then what I've tried to do is imagine what was in the heads of the two.” With regard to the potential pitfalls of this approach, he recounts an interesting anecdote in relation to the opening night of the play in New York, in itself a tense evening, following which he met one of the audience - Werner Heisenberg's son - who informed him that his – Frayn's – Heisenberg was nothing like his father, who never expressed feelings for anything other than music, but that, however, he understood how a play requires characters to be more forthcoming in order to function properly.

As well as his own fiction, Frayn has translated work by both Chekhov and Tolstoy into English and says that one of the aspects of Chekhov's work that he most admires is his modesty, in the sense that he is absent from it. In this context, the nearest Frayn has come to writing about himself is in 'My Father's Fortune, A Life', a memoir about the life of his father, written to satisfy the curiosity of his daughter about her antecedents, in which he of course appears as a significant part of his father's life.

So, playwright, novelist, reporter, columnist and screenwriter, the bibliography is considerable. But one thing in particular stands out from the various available sources – interviews, reviews and so on - for an article such as this, and that is the fact that, as he says in his own words, “I very much like laughing”.

The Church of San Zeno, Pisa

The setting for the production of Michael Frayn's Copenhagen was the deconsecrated Church of San Zeno in Pisa. One of the oldest churches in the city, the abbey was re-opened in October of 2000, following a protracted restoration and is now used for exhibitions, concerts and the occasional play. It can be found on Via San Zeno, near to Piazza Santa Caterina and is near to the homonymous doorway to the old town, which gives onto the intersection between Via del Brennero and Via Vittorio Veneto. Dated as far back as 1029, the church was part of a monastery complex and also hosted a hospital until the 15th century. The church passed to the order of the Camaldolese monks in the 12th century.

PERSONNEL MOVEMENTS

Departure

Gaelle Parguez

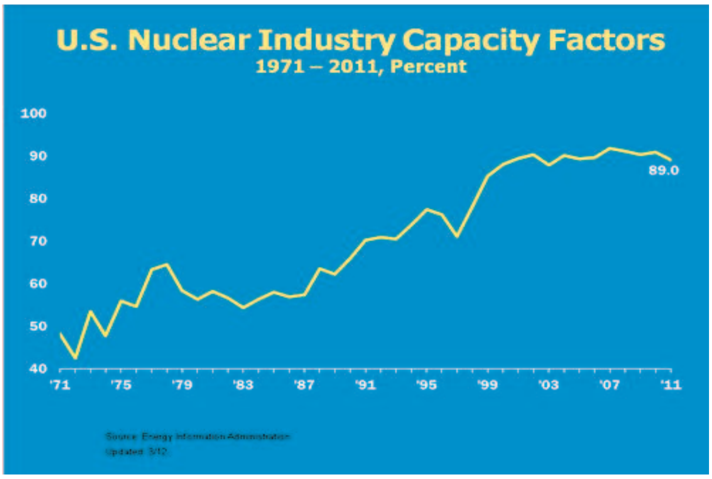
Engineer left the Vacuum team end of June 2012.

The e-mail from Gilles Bogaert
Hi Carlo,
about wind turbines as electricity providers,
http://en.wikipedia.org/wiki/File:Wind_in_Denmark_1977_2011_large.png
Wikipedia explains to me that Danish wind turbines provide already 28% of the 2011 electricity production (and the goal of the Danish government is 50% in 2020).
It is suprising that for the case of Danish wind, the authors of Europhysics News refer to a 2009 report which has been heavily criticized.
Gilles Bogaert, Nice, 8.06.2012

The answer by Michele Punturo
Dear Bogaert, Dear Carlo,
I believe that THE solution for the energy problem doesn't exist, but only components of a global strategy. I found very interesting the reading of a book, freely available on web, written by a physicist: David JC MacKay and titled "Sustainable Energy - without the hot air" (http://www.withouthotair.com).
It is interesting because it makes the attempt to compute an energy budget (consumed energy vs produced energy). As suggested by the title, the author tries to demonstrate how it is possible to use "green" energies, but being a physicist and using numbers and not adjectives, it has a hard job to fill the gap between available "green" energy and the needs of our modern society (the conclusion, if there is a conclusion, is that we have to reduce drastically our energy needs… or, even if it is well hidden in the text, use nuclear energy). There is an interesting evaluation of the energy produced through wind turbines in Ireland (with some reference to the Danish situation); they obviously produce a lot of energy, but to have a relevant role with respect to the needs of a country with the population density of the UK, comparable to the EU average (and not obviously to Denmark), you need to cover a huge fraction (~the entire surface of Wales) of the country with wind turbines plants. Note that the UK has strong winds and this "solution" is not possible for the Mediterranean countries, where the winds are usually weaker than 4m/s (for example see the European wind map in Fig. 49 of the ET design study: https://tds.ego-gw.it/ql/?c=7954). Furthermore, if you see Fig. 26.2 of the above-cited book, the fluctuations of the Energy produced by wind in Ireland aren't mitigated by the country-size plants, and then expensive smart grids are needed to fill the energy holes or to redistribute the peak production. This is mainly done by energy-exchange with neighboring countries (as Denmark does) that produce energy through an easily tunable source (like natural gas, oil, carbon and hydro-electric).
Regards,
Michele Punturo,
Perugia 11.06.2012

A comment from Andrea Vicere'
Hi Michele,
that's right and I believe in fact that nuclear energy is the only source which could allow in the mid term (the next 20 years) to keep the current level of energy supply while reducing dramatically the CO_2 foot print. However, also nuclear energy isn't a solution in the long term because we will run out of cheap uranium sooner or later, and nuclear fusion isn't round the corner. So as you said a mix is necessary, and in the long term one could expect that the storage of energy will be a crucial component of the grid, much more than it is now, in order to increase the capacity factor of wind or solar farms.
Cheers, Andrea
15.06.2012

An answer by Michele Punturo
Let us define "capacity factor" as the ratio between the energy produced by a plant in a period of time and the amount of energy it could have produced at continuous full power operation during the same period. According to the data delivered by the NEI (Nuclear Energy Institute, a policy organization of the nuclear energy and technologies worlds-wide industry, certainly not an independent institution), in a seven year period (2000-2007) the whole nuclear plant system in the USA had a capacity factor of 87%. In the figure the overall trend in the USA in the last 40 years is reported.



One more answer by Michele Punturo
Hi Andrea,
I fully agree that smart grids and energy storage are crucial technologies to be developed in the future. Just to quantify the problem of energy storage, in order to strengthen what was stated at the beginning of the discussion on "wind turbines as a sustainable energy source" let's make a simple computation.
A European citizen consumes, on average, 689W (an American 1363W!!!). Let's consider a country with 60M citizens (like Italy or the UK): the average power consumption is ~41GW. Let's suppose that you want to produce¼ of that energy with wind turbines, without accessing energy produced by other countries in an easily tunable way. Hence about 10GW of the energy is produced with wind turbines (corresponding to 30-40GW of installed power). If you look at wind availability, in a windy country, such as Ireland or the UK, there are periods of 10 days without wind. Let's be optimistic and limit

ourselves to 5 days without wind. Hence you need to store 10GW x 24 x 5 = 1240GWh of energy.
Currently, the only serious way we have to store that energy is using the so called "pumped storage" (hydro-electric plants used in reversed mode). To produce 100 GWh using such a plant you have to store 210M cubic meters of water and let it fall from a height of 200m (considering an efficiency of 90%). This is a lake 10m deep and 21km^2 in surface, about 3 times the lake of Montedoglio, that caused so much trouble to the population in Valtiberina. Then, you need 12 of these (3xMontedoglio) lakes just to cover ¼ of the energy needs for 5 days in Italy! Possible, but quite difficult! Another possibility is using batteries …. Better solution…
Let's jump to Uranium availability. The known conventional reserves in the ground of Uranium are (in the World) 4.7Mtons, the Uranium in the Phosphate deposit (more expensive) are 22Mtons and in the Oceans 4500Mtons (2005 data). Let's use just the easiest and smallest source of Uranium. According to what is stated in the above-cited book, this is enough for about 1000 years of energy production with the (2005) rate of usage. Instead, if each inhabitant of the Earth reaches an energy consumption comparable to the European one, the reserves will be enough for about 160 years. Obviously there could be the usual factor 2 error in the computation, but the once-through nuclear reactor is not the only available technology. Fast breeder reactors could produce a factor 60 more power with the same amount of excavated Uranium; they exist (http://en.wikipedia.org/wiki/Breeder_reactor) but the technology is still not fully under control …or better, is quite risky. But 60x160 years of energy availability is quite appealing.
Finally, there is also Thorium. India has the capability to use Thorium and their reserves are estimated to be enough for 1000 years.

(Andrea found an error in the computation)
Ciao Andrea,
Thanks for your email; it is always useful to cross-check the numbers. I used the numbers and the statements in page 162 of the previously-cited book. I cross-checked the references used in that book and I found a series of interesting info. When economics enters into evaluations, numbers are more difficult and unstable. First of all the global known reserves are increased (2009 data) to 5.5Mtons, but it depends on the extraction cost. An indicative plot is reported here http://www.world-nuclear.org/info/inf75.html.
According to the IAEA there are an additional 5 Mtons available, but it depends on the extraction cost. What remains true (in your email, and wrong in mine) is that the directly available reserves are enough for ~80 years (160 considering the additional reserves stated by the IAEA, but with the current rate of usage!). I found confirmed the increase of performance (x 60) given by fast breeder.
It is always useful to discuss these interesting subjects. Ciao, Michele

A short comment
Hi,
An additional comment, about the authors, De Groot actually,
I am surprised to see he was formerly appointed by the Shell Dutch company:
www.clepair.net/windsecret.html
Gilles Bogaert, 18.06.2012

Jo van den Brand, 24.06.2012:
Windmills in Holland
This contribution was triggered by Carlo Bradaschia, who noticed a paper on wind energy by C. le Pair, F. Udo and K. de Groot in EuroPhysicsNews 43/2 2012. Kees le Pair was director of the Dutch funding agency STW (which supports technical sciences) and Fred Udo was a senior scientist at Nikhef and is now retired. These authors question the rational of placing multi-gigawatt windparks offshore without a good buffer and storage system. I happen to agree with them and recently had the pleasure to explain this on Dutch national television (in a debate with the number one person in the Netherlands active in sustainable energy - this after having left GreenPeace and working with the IPCC). Below I give you a brief impression of the Dutch approach to wind energy.
It is well-known that there is a long tradition of windmills in The Netherlands. The Dutch have been building windmills for centuries and with these windmills part of the country itself was built. Besides land drainage, mills were used for industrial purposes, such as corn milling and sawing. As a nation we have a strong emotional connection to windmills and we are proud to show them to tourists. While 1194 of these historical windmills are still in operation, the vast majority of them has disappeared (the Dutch database lists 15914 of historical windmills). However, recently windmills started a comeback, mainly driven by the quest for sustainable energy. At present there are about 1900 turbines installed on-shore with a capacity of 2.0 GW. Since the power of a wind turbine is given by the kinetic energy of the air incident per unit of time (and thus proportional to $\frac{1}{2} \rho A v^3$), it is quite sensitive to wind speed. It would make sense to place windmills in areas with high wind speed, e.g. along the coast, but in practice they are placed in-land in remote areas. This is motivated by what is called the "perception of the incorporation in the landscape" which is Dutch-speak for "minimizing the number of people complaining". The consequence is that in reality this 2 GW capacity has an efficiency of not more than 18%. To ensure that sufficient energy is available during the other 82% of the time, we are now building 3 large coal-fired power plants. In 2010 the Dutch approach to realizing wind energy became quite aggressive by allocating a subsidy of 5.4 billion Euro (4,395.8 million Euro is already committed) for the construction of offshore wind farms. While this nicely appeals to sentiments on Dutch history of windmills, and the sea, it is worthwhile to question the economic value of such an investment in times of crisis. The promise is a capacity of 700 MW.