h

THE GRAVITATIONAL VOICE

number 24

JULY 2013

Biathlon 2013 at EGO site

SCIENCE ON SITE
Tachyons at EGO
Archimedes Mysteries

LIFE IN CASCINA
EGO and the Comune together for Cascina

News from EGO and VIRGO

CONTENTS

"h - The Gravitational Voice" is an internal publication of the European Gravitational Observatory (EGO) and the Virgo Collaboration.

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

Editor: Carlo Bradaschia

Editorial Staff:
Henrich Heitmann
Gary Hemming
Martin Mohan
Séverine Perus
Frédéric Richard

Production:
Séverine Perus

Published in electronic format on the EGO Web:
www.ego-gw.it

EDITORIAL

This 24th issue of *h* is a very tough one, requiring an effort by our readers to digest the articles on Casimir effect and on tachyons and quantum entanglement. Both deal with phenomena which contradict the two cornerstone theories of modern physics, Quantum Mechanics and Relativity. In addition, in two other columns, we unveil two worrying natural phenomena here at EGO: genetic mutations and weight disappearance ("Archimedes Mysteries"). This last article, in addition, is "entangled" with that of the Casimir effect which deals with problems with Archimedes principle. Archimedes himself is, in turn, "entangled" with 2013 which is the 2300th anniversary of his birth, in 287 BC.

In order to mitigate the efforts of our readers with the articles on tachyons and on Casimir effect, we suggest "sneaking" a look at a very helpful book about all the challenges of modern physics: Giancarlo Ghirardi "Sneaking a Look at God's Cards", Revised Edition: Unraveling the Mysteries of Quantum Mechanics – Princeton University Press, 2004.

Besides the many other interesting columns, I would invite readers to focus on "Wind and overshoes". This is based on a careful experimental study carried out by the *h* team, which reached important technical conclusions.

C. BRADASCHIA
Editor-in-Chief

Photo credit of the front page: Massimo D'Andrea, EGO

GWADW 2013 at Elba

The GWADW is one of the most exciting conferences in our field. It is focused on instrument science and aims to improve gravitational wave detectors. When the GWADW is in Elba, as it was this year, the excitement about interesting science and new technology constructively interferes with the breath taking sunsets in La Biodola and the incredible food that this island offers. The result is an overwhelming success which makes you wish the workshop could last at least a week longer!

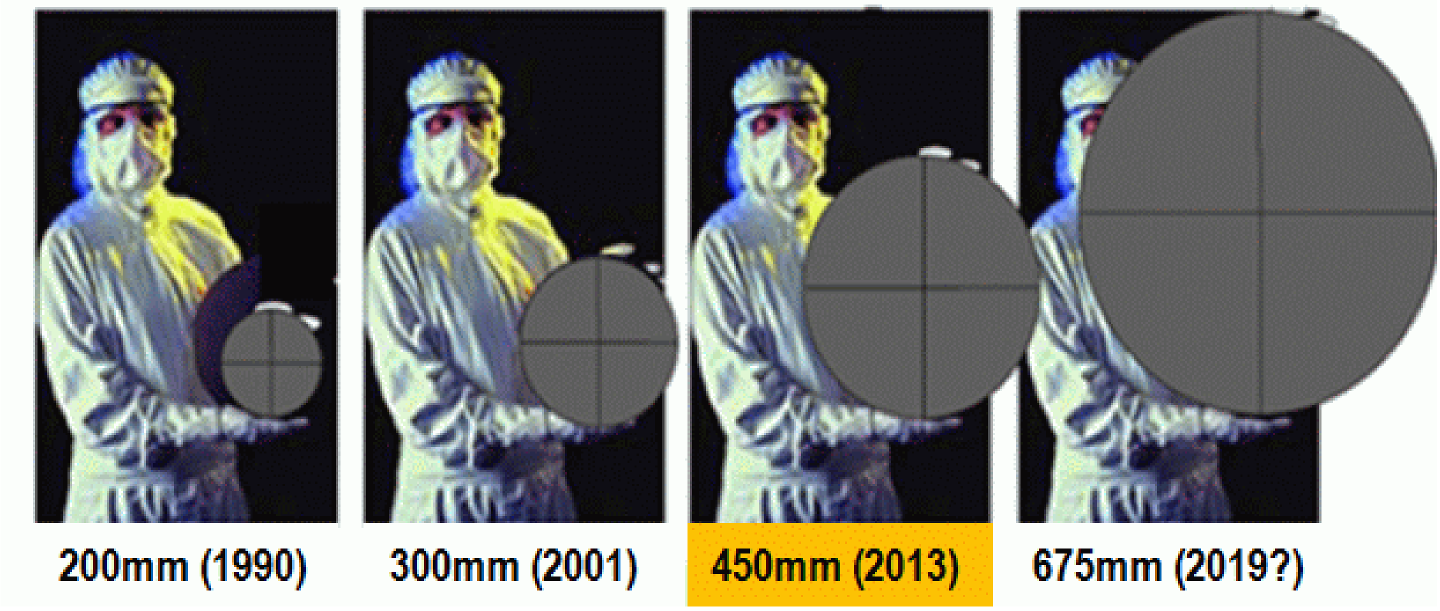
This GWADW2013 took place between May 19 and May 25 and brought to the Hotel Hermitage in La Biodola 110 participants from all around the world. The goal of this workshop is to bring people together to shape the future of gravitational wave detection. One funny implication of this ambitious objective is that ground based interferometric advanced detectors currently being installed, Advanced LIGO, Advanced VIRGO and Kagra, are essentially taken for granted, even if they are still works in progress!

Garrett Cole presenting his latest measurements on crystalline coatings.

After several years in which quantum noise reduction was the hot topic of the GWADW, this year the focus shifted to thermal noise. Several workshop sessions were dedicated to beating what appears to be the most difficult noise source to overcome, in order to increase the sensitivity of advanced detectors where it counts the most. Thermal noise results from the Brownian motion of atoms in the test mass materials and it can be completely extinguished only by cooling the test mass temperature to absolute zero. Many experiments are currently in progress with the aim of understanding, measuring and characterizing thermal noise. Several directions are being explored: “regular” amorphous coatings, new coating materials, new optical techniques, and cryogenic temperatures. This effort is remarkably spread all around the world, within groups at Kagra, Virgo and the LIGO Scientific Collaboration. Kagra, in particular, is the only advanced detector which plans to operate at cryogenic temperatures and it is leading the effort on exploring how the interferometer test masses can be cooled down effectively.

The recently measured performance of a new type of coatings, “crystalline”, has been unanimously declared the most exciting result of the workshop. Garrett Cole (University of Vienna) and collaborators recently published measurements that are consistent with the idea that AlGaAs crystalline coatings have a thermal noise level that is at least a factor of 3 lower than “regular” amorphous coatings, such as the ones currently used to coat advanced detector test masses. Even if there are still several key steps to be done to make these coatings suitable for kilometric scale interferometric detectors, (first of all making them large enough), the possible implications for the field are remarkable.

State-of the art amorphous coatings adopted to coat the advanced detectors test masses seemed to have reached their best possible performance and the only other ideas to reduce coating thermal noise at room temperature relied on (more complicated, and mostly unexplored) optical techniques, not immediately applicable in advanced detectors.



Sheila Rowan talked about the "scaling" problem: increasing the size of the test masses (and learning how to make coatings large enough) takes time.

With crystalline coating, there is now the hope of reducing coating thermal noise by "just" changing the test mass coatings. Moreover, these new coatings are expected to have good performance also at cryogenic temperatures.

Conceptual designs for third generation detectors, or "beyond advanced" detectors, are also getting a more defined shape. A couple of years after the release of the design study for a new European interferometer, the Einstein Telescope, the LIGO community is also converging on a conceptual design for building a new detector more sensitive than Advanced LIGO. One of the options considered is to change the material used to make the interferometer test masses from fused silica to silicon and take advantage of the thermal properties of silicon at 120 K. Silicon at 120K, together with heavier test masses, lower power and the injection of squeezed light would give a sensitivity up to a factor of about 5 better than Advanced LIGO. This is not quite the factor of 10 improvement targeted by ET. However, this new LIGO detector could be built within the current LIGO vacuum envelope, thus largely reducing the overall cost of the project.

GWADW is not only about interferometric ground based detectors. Several talks have been dedicated to present the latest news in pulsar timing, atom interferometers and space based gravitational wave detectors, all aiming to extend the gravitational wave detection band to frequencies below those of ground based detectors.

This edition of the GWADW saw also a very successful poster session, made even more interesting by aleatico, the sweet red wine typical of Elba, a pleasant surprise for most of the participants.

On a less positive note, the weather this year has not been as fantastic as it was two years ago. This is probably the only thing left for the organizers to improve!

See you in Japan for GWADW 2014!

Lisa BARSOTTI
MIT Kavli Institute / LIGO Laboratory

One of the fabulous sunsets in La Biodola

Fresh News:

GR20/Amaldi10 in Warsaw

This short note, subsequent to my participation in Amaldi10, in Warsaw, last week, is not intended as a summary of all of the very interesting subjects that were addressed. The aim is to express my appreciation of two sessions that were held for the first time.

The "EPO (Education and Public Outreach) on Gravitational Wave Astronomy" session was co-chaired by Martin Hendry and myself, but we deserve no merit for its success, given that we accepted all seven of the excellent submitted abstracts, which we had obtained following repeated solicitation for proposals to the GW/GR community. All of the talks were interesting, very well prepared and, what is probably most relevant, given by people involved in the matter on a volunteer basis. I quote as examples the "Einstein at Home" project, using more than 100,000 idle PCs all over the world in astrophysics analysis (they have already discovered a few tens of new pulsars) and the fully "hands-on" GW summer school in Birmingham, where students and teachers have been working together on equal ground, both on analysis and experiment, even up to the point of soldering electronic components on a printed board.

The other session I mention is the "Q&A Everything you wanted to know about GWs but were afraid to ask", which was very well organised by Viviana Fafone and Patrick Sutton. The peculiarity of the session was the high vivacity of the debate between almost all speakers and the audience: the direct interaction between answerers and questioners lead to reciprocal comprehension. The interaction between a GW Old Man (MC) and a young theorist (RS) discussing the power transported by GWs was particularly animated. By the way, the discussion took place in response to a question proposed by me: I was not questioning whether energy is transported by GWs, rather where this energy is absorbed.

A short word on the other GW sessions, all of which were interesting - the message was that aLIGO, thanks to their early start and with the impressive firepower of the LSC, is about one year ahead of Advanced Virgo. Maybe the Americans are optimist, expecting to start data taking after a too rapid commissioning; but I cannot refrain from thinking that our funding agencies, instead of being so frugal with their budgets, might have been wiser saying: here are more people, here is more money, please do not miss the first detection. Not being there will be a shame for us researchers, but much more so for our institutions.

Abstracts of all sessions can be read in the Book of Abstracts (http://gr20-amaldi10.edu.pl/userfiles/book_07_07_2013.pdf)

C. BRADASCHIA
Co-chair of the EPO
GW Astronomy session

The beautiful venue of the GR20-Amaldi10 conference: the "Old Library" of the University of Warsaw.

The Stefano Braccini Prize 2012

Competition was once again very tough in the second edition of the thesis prize dedicated to Stefano Braccini and the prize board has been set a tough task in choosing a winner. The three members of the board: A. Giazotto (chair), A. Brillet and S. Shore, unanimously requested to exceptionally award two prizes, as they were unable to choose between Kiwamu Izumi and Vivien Raymond, in spite of the completely different subjects.

Kiwamu Izumi (LIGO Observatory, Hanford) submitted the thesis: “Multi-Color Interferometry for Lock Acquisition of Laser Interferometric Gravitational Wave Detectors” and Vivien Raymond (LIGO Laboratory, Caltech) the thesis: “Parameter Estimation Using Markov Chain Monte Carlo Methods for Gravitational Waves from Spinning Inspirals of Compact Objects”. The motivations of the board are explained herewith:

For Kiwamu Izumi: Years of experience accumulated from operating large interferometric gravitational wave observatories, LIGO and Virgo, have shown how complex it is to disentangle the nested optical cavities of the interferometer’s structure. In particular, locking the interferometer has been a continuing challenge because of the nonlinear couplings between them. In this thesis, Kiwamu Izumi has shown in a study conducted at the 40 m Caltech test interferometer, that locking can be facilitated by injecting multicolor laser beams. The Braccini Prize committee finds Izumi's experimental results to be a substantial, promising advance that will simplify operational procedures of future large interferometers for gravitational wave detection.

For Vivien Raymond: In this thesis Vivien Raymond introduces new analysis techniques using templates to extract the gravitational wave signals from NS or BH coalescing binary systems in which one or both of the components has spin. As shown in this thesis, knowing how to include the spin can be the critical difference in detection. The thesis presents extensive Monte Carlo simulations mimicking astrophysically relevant parameter spaces and shows applications under realistic assumptions for next generation instruments. The Braccini Prize committee finds Raymond’s work extremely relevant for the success of the future advanced gravitational wave detectors.

The authors of the other six theses submitted for the prize received the congratulations of the board, with all of them being of very high quality.

C.BRADASCHIA
on behalf of the Prize Committee

The Archimedes force of vacuum

One of the most striking implications of quantum mechanics is that a vacuum is not simply an "empty space" where bodies move. It is a very "particular physical state" where the uncertainty principle dominates and imposes that we cannot simply say "nothing" is there. On the contrary, the vacuum is a sea of virtual photons (now for simplicity we are considering only the electromagnetic field). They cannot be directly detected by photodiodes, or by our eyes, or any other detector of electromagnetic waves, but they possess their energy, the so called vacuum fluctuation energy. The most anti-intuitive property of the vacuum so conceived is that the energy density, i.e. the vacuum energy contained in a unit volume, is massive, the highest energy that we can image, and can be assumed as infinite for most of the problems of quantum mechanics.

Notice that quantum mechanics survives comfortably with this point of view with a fundamental consideration: whatever measurement we could conceive, it will always be a result of a change in this energy, which is always finite. Unfortunately this fundamental statement of quantum mechanics is in complete contrast with General Relativity, the other main theory of physics. Following General Relativity each energy corresponds to a mass, via the world famous equation $E = mc^2$.

And again, following General Relativity, each mass deforms the space, and curves it: if the energy density of vacuum would be really massive, as quantum mechanics foresees, the space around us would be curved in on itself, forming a small closed spherical universe. Pauli, almost one hundred years ago, calculated the radius of such theoretical universe, indeed our universe, and the result was 31 km! Fortunately our universe is "a bit bigger": 42 billion light-years.

Thus the two most important theories of last century were, and ARE, in fundamental striking contrast.

Since the first calculations by Pauli many extensive theoretical attempts have been made to solve the contrast. Some theories started by accepting that the virtual photons (and the other vacuum fields) do gravitate and tried to prove that the contribution to the gravitational field is cancelled by other virtual fields, like in the case of Supersymmetry. Unfortunately none of these theories resulted in a success. Other theories, on the contrary, tried to prove that virtual photons do not gravitate and thus our universe can again be bigger than 31 km. Unfortunately none of these theories has been completely convincing, always encountering important fundamental problems.

From an experimental point of view, however, not even a single experiment has tried to disentangle at least this first hypothesis, clarifying if virtual photons do gravitate or not.

In this spirit we have proposed, some years ago, a road-map for an experiment capable of testing this hypothesis. The main idea of the experiment is simple: if we really live in a sea of virtual photons, we have two possibilities. If the virtual photons do gravitate then there will be an equilibrium around the earth such that if we imagine to remove part of them from a certain volume, creating a bubble, there will be a lack of weight in that volume and the bubble will be pushed upwards, like a bubble in the water. Otherwise, if they do not gravitate, the bubble will remain in equilibrium, floating in the vacuum.

The first question that could occur to the reader is whether such a bubble can be created. Fortunately the answer is yes. Indeed if we consider two metallic plates, placed one in front of the other at a short distance, the space between the two is filled with less virtual photons with respect to the free space. This is called a Casimir cavity: indeed, the virtual photons that have too large a wavelength cannot survive inside the cavity and are expelled. As a consequence, the virtual photons that surround the plates exert a force that it is no longer compensated by the virtual photons inside the cavity, so that the two plates are pushed towards each other. This is known as the Casimir effect and the force is well measured and confirms the quantum mechanics interpretation of vacuum.

Stated that a bubble can be created, the idea to test if the virtual photons do gravitate is quite simple: if they gravitate the bubble will receive an upward force whose magnitude is equal to the weight of the virtual photons that exited the cavity. A sort of Archimedes force of vacuum.

Several papers have been published on this item, to show that theoretically this force should exist and with the expected amplitude: when placed in the gravitational field of the earth the cavity will be pushed upwards with a force equal to the energy of vacuum expelled from the cavity, divided by c^2 so to obtain the mass, times g, the gravitational acceleration. Thus the measurement can in principle be done.

How could such an experiment be realized? The force is extremely tiny, so that the measurement cannot be performed in DC, it must be modulated and performed at a frequency where noise is small and present days detectors of small forces can work.

How to modulate the force? Of course by modulating the vacuum energy contained in the cavity. But how can this energy be modulated? Again in principle it is not a real issue: it is sufficient to modulate the reflectivity of the plates. When the plates are transparent, the vacuum virtual photons can enter inside the cavity and the weight will be higher. Then, when the plates are more reflective, virtual photons will be expelled from the cavity and the weight will be less. Now, next question: how to modulate the reflectivity of a plate? Here, a consideration must be made: this modulation must be done without giving the plate "a lot of energy"; otherwise we will measure just the weight of the energy that we have given to the system.

We must find a way to change reflectivity using a minimal amount of energy, at most comparable with the change of vacuum energy. After careful analysis a possible solution seems to be a superconductive transition bringing the material from some transparency to some reflectivity and vice versa. Indeed in this case, for particular superconductors, particular temperatures and Casimir cavity parameters, the magnetic energy to be supplied to the superconductor plates to make the transition, the so called condensation energy, is of the same order of magnitude as the change of Casimir energy. All of this, up to now, is the theory. To make the first experimental step it is then necessary to prove that indeed, by using a superconducting transition, it is possible to change the vacuum energy of the Casimir cavity. Noticeable, due to the fact that during the transition the Casimir energy changes, the transition itself is influenced by the Casimir energy: in particular the external magnetic field necessary to destroy superconductivity is different in case of a single metallic plate or in case of a plate that is part of a Casimir cavity.

Thus a measurement of the external field is the way to prove that the energy is indeed modulated and, at the same time and for the first time, that virtual photons can influence a phase transition (the superconductive transition).

This has been the goal of the Aladin experiment, funded by INFN and performed in the years 2005-2010. Various papers have been published on these items, showing the theoretical calculations following different approaches; the experimental results are reported in figure 1 (next page). The results are encouraging, an anomalous behavior of the superconducting plate is found at the expected energy. It leads to the next steps.

What are the next steps to be done to understand if it is possible to perform the gravity experiment?

The situation is extremely difficult, but not without hope. There are three fields where large, but not impossible, progresses must be performed to meet the challenge.

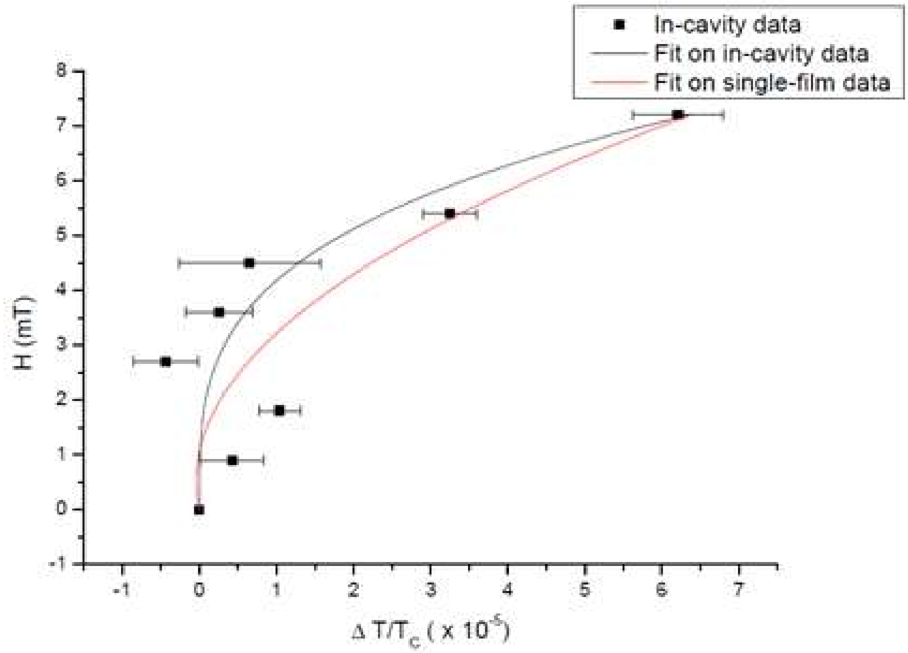


Figure1: Critical Magnetic field of a film being part of a Casimir cavity. In the figure is reported on y-axis the critical field (necessary to destroy superconductivity) and on x-axis the relative shift in superconducting transition temperature. If the film was not be part of a Casimir cavity the theoretical red curve would be expected, a very well known and tested root function curve. The experimental points are reported in black, with a fitting curve. As it is seen the points tend to not lie on the red curve for low magnetic field and low shift-temperatures - as expected from our theory - and recover the simple film red curve for higher field and shift temperatures, as expected. (Points for higher field and shift- temperatures are not reported for simplicity).

The first key point is the modulation of the force. Even if the use of a simple metal was important to make a proof of principle that the vacuum fluctuations do influence the phase transition and contribute to the free energy, in order to reach a good modulation depth the use of simple metal must be abandoned and replaced with High Tc superconductors. These compounds perform transitions from semiconducting to superconducting state. In this case the modulation of reflectivity of the plate, and hence of the Casimir energy, is much higher with respect to a metal-to-superconductor transition. The study of use of these materials will be one of the next steps of this research.

The second key point is the number of layers that can be stacked one over the other to constitute a series of many cavities that multiply the effect. A very high number of layers are needed to reach an effect that could be detected by a macroscopic apparatus.

The third key point is the sensitivity of the detector to small forces. In this respect progress has been impressive. The interferometers for gravitational wave detectors have reached the project sensitivities and many promising up-grades are foreseen for ET or other third generation detectors, taking advantage of huge, rapidly evolving experimental activity. An apparatus based on the same technologies could be employed to measure the Casimir gravity effect.

We can conclude that if the effort in these three research fields progress as expected, in a not too distant future the proof of Archimedes force of vacuum can become an experimental reality.

E. CALLONI, Naples Group

Tachyons at EGO

by Sandro Faetti
and Leone Fronzoni

An experiment of fundamental physics entitled "Superluminal Quantum Communications" will be performed inside the EGO tunnels between September 2013 and June 2016, in order to test a superluminal model of Quantum Mechanics *(QM)*. The new *QM*-model has been proposed to bypass an unsatisfactory aspect of orthodox Quantum Mechanics: *QM is a non-local theory*. The non-locality of *QM* appears evident if one considers some exotic states that are allowed by *QM*: the *entangled* quantum states.

See the box on Newton's classical Physics at the end of the article.

1 - Introduction for pedestrians (but acquainted with the "bra-ket" representation |*A*> of a quantum state A and with the concept of superposition of quantum states)

To understand the unusual properties of entangled states let us first consider the description of a single photon *a* propagating in space. According to *QM*, any single photon always has a well defined polarisation, and its quantum state |*A*> can be written $|A\rangle = \cos^2\alpha\,|+\rangle + \sin^2\alpha\, e^{i\phi}|-\rangle$, where α and ϕ are real coefficients and |+> and |−> are two orthogonal polarised states. Different values of coefficients α and ϕ correspond to different photon polarisations (linear, circular or elliptical). If such a photon meets a polarising filter that passes the |*A*> polarisation, the probability that the photon passes through the filter will be, obviously 100%. Now, imagine having two photons *a* and *b* both of which have well-defined polarisations and which are moving away from one another. Let |ψ> = |*A*,*B*> be the quantum state of the two-photon system. This form indicates that photon *a* is in the quantum state |*A*> and photon *b* is in the quantum state |*B*>. Therefore, photons *a* and *b* have well-defined polarisations. Each photon behaves independently and the polarisation of photon *a* does not depend on what happens to photon *b*. This quantum state is consistent with a "classical" description of two polarised photons that propagate independently in space. However, *QM* also predicts the existence of more exotic "*entangled*" states, which do not allow for a classical description. Consider, for instance, two photons, *a* and *b*, moving back to back away from the origin, prepared in the entangled quantum state |ψ>=(|*V,V*> + |*H,H*>) / S2 where *V* and *H* denote vertical and horizontal linear polarisation, respectively. This entangled state cannot be reduced to the simplest form |ψ>=|*A*,*B*> where |*A*> and |*B*> represent the state of polarised single photons *a* and *b*, respectively. If photon *a* (or *b*) meets whatever polarising filter (linear, circular or elliptical), the probability of passage is predicted to be always 50%. Furthermore, the two photons *a* and *b* are strictly related to one another (*entangled* particles): the behaviour of photon *a* depends of what happens to photon *b* and vice-versa. For instance, if photon *a* passes through a vertically-oriented linear polarising filter, *QM* predicts that *b* also passes through a vertical filter; this means that the entangled state |ψ>=(|*V,V*> + |*H,H*>) / S2 collapses *instantaneously* to |*V,V*> where both photons *a* and *b* have vertical polarisations. Note that, according to *QM*, the collapse of the two photons occurs simultaneously, independent of the actual distance between the photons (they could be at astronomical distances); the question is: "how is the information of the fate of *a* transported instantaneously to *b*?" This behaviour could be explained by the existence of *tachyons*, i.e. messengers moving faster than light, but only if the distance d_A from the origin, where photon *a* polarisation is measured, is shorter than d_B, the distance where photon *b* is measured. In this hypothesis, in the time interval $\Delta_t = (d_B - d_A)/c$ between the measurements of *a* and *b*, a tachyon running at a velocity $v_T > (d_{AB})/\Delta_t = c\,(d_{AB})/(d_B - d_A) > c$ could reach *b* and force it to have the same polarisation as *a* (d_{AB} = distance between points *A* and *B*). If $d_B = d_A$, v_T would be infinite and also the tachyon speed should be infinite! The existence of tachyons is considered by the majority of scientists to be in contrast with Relativity, while *QM*, in the absence of tachyons, contrasts with the principle of locality. The proposed experiment is devoted to test the tachyon model of *QM*.

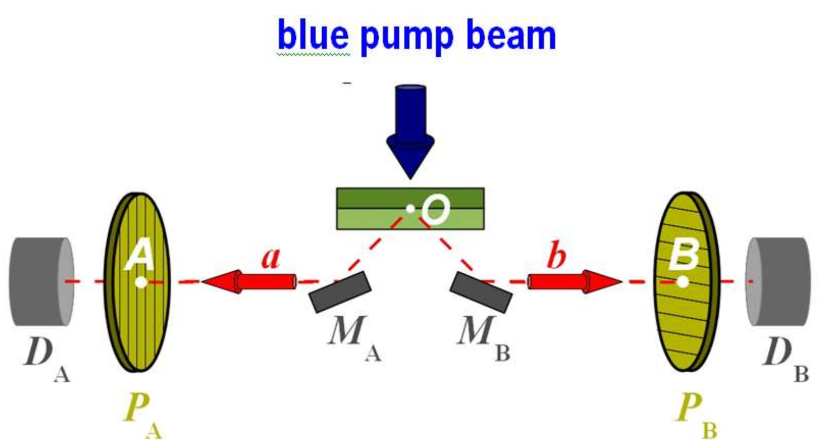
2 - Let us now discuss more deeply the physics problem and the planned experiment.

Einstein and other physicists consider unsatisfactory the non-local character of *QM* and alternative local models have been proposed. In Classical Physics, correlations between events occurring at far points of space are often due to *communications*. However, starting from the famous Aspect experiment in 1982, many experiments ruled out the possibility that subluminal communications can explain quantum correlations between entangled particles. For this reason, it has been proposed that superluminal communications (transported by tachyons) could be responsible for *QM* correlations: when photon *a* (or *b*) collapses to the *V*-polarised state a superluminal signal would be sent to photon *b* (or *a*) and would induce its successive collapse to the *V*-state. Then, the collapses of photons *a* and *b* would not be simultaneous. To avoid casual paradoxes, tachyons must travel isotropically in a preferred frame (*PF*). Here we denote by $v_t = \beta_t c$ ($\beta_t > 1$) the velocity of the tachyons in the *PF* and by $V = \beta c$ ($\beta < 1$) the velocity vector of the *PF* with respect to the Earth.

In our experiment, two 810 nm entangled photons (*a* and *b*) are produced at point *O* in the quantum state |ψ>=(|*V,V*> + |*H,H*>) / S2 by the down conversion of a 405 nm pump laser beam impinging on two adjacent *BBO* (beta-barium borate) non-linear crystals. After reflection on two suitable mirrors, the photons travel in opposite directions meeting two polarising filters P_A and P_B at equal optical paths d_A and d_B from *O* (see Fig. 1). Then, photons are collected by single photons counters (D_A and D_B) and the coincidences are measured.

The main features of the experiment can easily be understood by looking at an ideal experiment performed in

Fig. 1: Schematic view of the experiment.



the *PF*. *QM* predicts zero coincidences for any value of distances d_A and d_B if polarisers P_A and P_B are set vertical and horizontal, respectively. Consider, now, the prediction of the tachyon model for the case $d_A < d_B$. In this case, if photon *a* passes through polariser P_A, it collapses to the vertical polarisation before photon *b* meets polariser P_B. If the consequently emitted tachyon does not reach photon *b* before it meets polariser P_B, then photon *b* passes through the polariser with a 50% probability leading to a non-vanishing number of coincidences in contrast with the predictions of *QM* (0% probability, 0 coincidences). This condition occurs if the reduced tachyon velocity $\beta_t = v_t/c$ is small enough to satisfy the condition $\beta_t < \beta_{t,min} = d_{AB}/|d_A - d_B|$ where d_{AB} is the distance between points *A* and *B*. If $d_A = d_B$, the condition above would always be satisfied and the measured coincidences should always differ from 0 (the prediction of *QM*). However, due to the experimental uncertainty, the equalisation of the photon paths d_A and d_B can be obtained only within a given uncertainty Δ. Then, discrepancies with *QM* might be observed, but only if the tachyon velocity is smaller than the critical value $\beta_{t,min} = d_{AB}/\Delta$. Quantity $\rho = \Delta/d_{AB}$ represents the leading parameter of the experiment.

Unfortunately, the tachyon preferred frame is unknown and the real experiment must be performed in the Earth frame, but this difficulty can be partially bypassed if points *A* and *B* are aligned along the East-West axis. Indeed, due to the rotation of Earth around its polar axis, the local East-West axis becomes periodically orthogonal to *V* on two occasions, t_1 and t_2, each sidereal day, whatever the orientation of the velocity vector *V* of the preferred frame (see Fig. 2). According to Lorentz transformations, at these special times the equality of the optical paths d_A and d_B in the Earth frame implies the equality of the corresponding paths in the *PF*. The measurement of photon coincidences are not instantaneous but require a finite acquisition time Δ*t* that introduces a further uncertainty to the equalisation of the optical paths in the *PF*. Using the Lorentz transformations it can be shown that the coincidences measured at the time intervals $[t_1-\Delta t/2, t_1+\Delta t/2]$ and $[t_2-\Delta t/2, t_2+\Delta t/2]$ differ from the *QM* predictions only if:

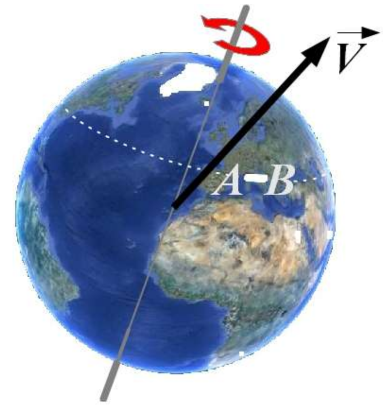


Fig. 2: the velocity vector V of the PF becomes orthogonal to AB twice each day.

$$\beta_t < \beta_{t,\min} = \sqrt{1+\frac{(1-\beta^2)(1-\rho^2)}{\left(\rho+\beta\sin\frac{\pi\Delta t}{T}\right)^2}}$$

where β is the unknown velocity of the *PF*, $\rho = \Delta/d_{AB}$, Δ*t* is the acquisition time and *T* is the sidereal day. A very sensitive experiment ($\beta_{t,min}$ i h) would require ρ i 0 and Δ*t* i 0.

In the EGO experiment, polarisers P_A and P_B will be aligned along the East-West axis (see Fig. 3) and the photon optical paths d_A and d_B will be equalised by means of interferometric methods. Experimental details and exhaustive references can be found in arXiv:1304.2282. The distance between polarisers P_A and P_B is 1.5 km leading to $\rho = 1.5\ 10^{-7}$ and a small enough acquisition time Δ*t* (< 0.1 s) will be obtained developing a very high brightness source of entangled photons.

Fig. 4 shows the predicted values of $\beta_{t,min}$ versus velocity β of the *PF* together with the results obtained in previous experiments. The grey area represents the new region of tachyon velocities that should become accessible.

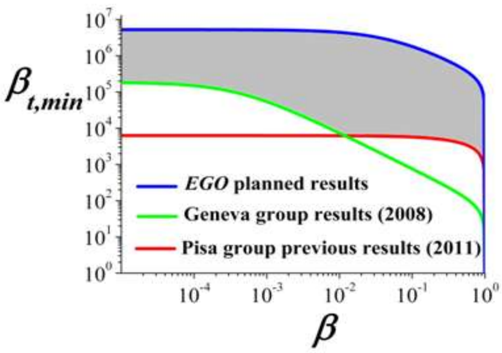


Fig. 4:Lower bound $\beta_{t,min}$ for the reduced tachyon velocity versus the PF reduced velocity β.

If super-luminal communications are responsible for quantum correlations and if the velocity of tachyons lies in the grey region, a periodical sharp variation of coincidences must be observed twice, t_1 and t_2, each sidereal day. Such a result would be of very important relevance from the fundamental

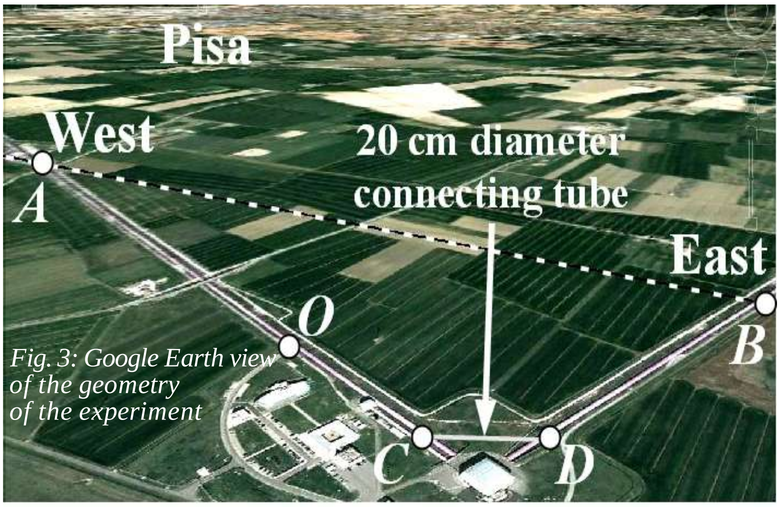


Fig. 3: Google Earth view of the geometry of the experiment

point of view and also have very important consequences in the field of communications. If no losses of *QM* correlations are found, the experiment will increase the actual lower limit for superluminal transfer of information by about two orders of magnitude.

Newton

In physics, the principle of locality states that an object is influenced directly only by its immediate surroundings. Nevertheless, in the 17th Century Newton formulated his Law of Universal Gravitation in terms of "action at a distance", thereby violating the principle of locality.

Newton himself was deeply troubled: “It is inconceivable that inanimate Matter should, without the Mediation of something else, which is not material, operate upon, and affect other matter without mutual Contact…That Gravity should be innate, inherent and essential to Matter, so that one body may act upon another at a distance thro' a Vacuum, without the Mediation of anything else, by and through which their Action and Force may be conveyed from one to another, is to me so great an Absurdity that I believe no Man who has in philosophical Matters a competent Faculty of thinking can ever fall into it. Gravity must be caused by an Agent acting constantly according to certain laws; but whether this Agent be material or immaterial, I have left to the Consideration of my readers.”

—Isaac Newton, *Letters to Bentley*, 1692/3

Tones of a turning glass

Following the *h*23 article by Nicolò Grilli on the HRG (Hemispherical Resonator Gyroscope) inclinometer, we were inspired to reproduce the Bryan effect, discovered in 1890 by G.H. Bryan, it being the foundation of HRG instruments.

Bryan noticed that by striking a glass when it is turning, beats can be heard instead of the pure note produced by a standing glass, as was explained in *h*23.

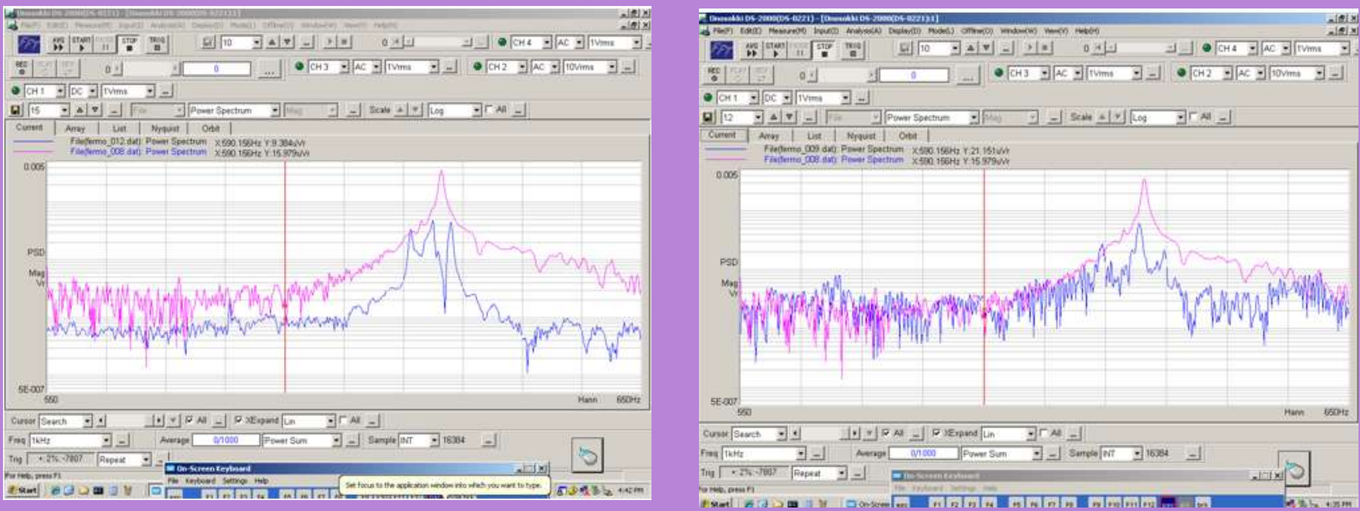
We set up a simple apparatus, consisting of a crystal glass and a turntable capable of 33/45 revolutions per minute. After several trials, we were not able to sense any difference between the standing and the turning glass, hence we decided to upgrade the apparatus.

A larger pulley was provided for the turntable, reaching up to about 90 revolutions per minute, and human ears were replaced by a microphone connected to a spectrum analyser. With this fine equipment (Figs. 1 and 2) we produced several sound spectra that clearly showed the expected effect (Fig. 3 on next page). Encouraged by the instrumental results, some fine-eared colleagues admitted (more likely imagined) that they were able to distinguish a tiny but clear difference between the standing and the turning glass. You can see for yourself by playing the video available at:
http://outreach.ego-gw.it/index.php?option=com_webplayer&view=default&Itemid=89&lang=en .

C. BRADASCHIA

Fig. 1: The experimental set up.

Fig. 2: The glass on the turntable.



(a) (b)

Fig. 3: The standing glass sound spectrum (pink curve) and the turning glass sound spectra (blue curve) at about 45 revolutions per minute (a) and 90 revolutions per minute (b).

Archimedes Mysteries

We would like to have your help in solving a little mystery.

Listening to what happened one morning, while working in the lab, you might ask why we did what we did, but what matters is the surprising result.

We started with an ordinary empty plastic mineral water bottle, with a 1.5 litre nominal capacity and real inner volume of 1.6 litres.

We made a hole in the cork into which we tightly mounted a bicycle tyre valve. We put the cork back on the empty bottle and weighed the bottle: 44.4 g.

With a foot pump we then pumped the bottle up to about 2.24 bars above atmosphere and then tightened the valve. We weighed the inflated bottle: 48.7 g. Fine! We added 1.6 l of air at 2.24 bar; 1 litre of atmospheric air is 1.2 g, while 1.6 l at 2.24 bar is about 1.6x2.24x1.2=4.3 g : 44.4 g + 4.3 g = 48.7 g.

We put the inflated bottle in a plastic bag and tightened it with a classic plastic-covered steel wire. We

weighed the assembly: 64.1 g. Fine! The plastic bag + closing wire, weighed together, are 15.4 g. To summarise: the inflated bottle is 48.7 g, the bag and wire is 15.4 g; the overall total is precisely 64.1 g.

Keeping the bag tightened, we unscrewed the bottle cork: the pressure in the bottle went back to 1 bar releasing 1.6 l of air at 2.24 bar, i.e. 3.58 l of air at atmospheric pressure, which remained in the closing bag, whose volume increased correspondingly. We weighed the assembly, but we refrain from telling you the result, since it is unbelievable, even allowing for a ± 0.2 g exprimental incertitude. in a series of several repeated experiments the result was confirmed.

We ask our readers to guess the result and would be very grateful for an explanation. The first of you proposing an acceptable answer will be awarded with a free subscription to one full year of the *h* newsletter.

C. BRADASCHIA

EGO and the Comune together for Cascina

Cooperation between EGO and the Council of Cascina is becoming ever closer and more fruitful. Besides the usual almost-weekly visits, often undertaken using the Cascina school bus, we have also had a few special ones.

On the afternoon of Friday, May 17 we illustrated our activities to the Communal Youth Council: a group of youngsters aged between 10 and 13 years old, set up in order to help the real County Council to be more sensitive to issues affecting young people.

About 150 visitors came on the following day, it being the “Open Doors Day”, organised in the framework of the “*Agenda della Cultura Scientifica 2013*” (for more information, visit the website of the *Comune di Cascina*, www.comune.cascina.pi.it/).

As announced in the agenda, we also organised a special visit for the fifth classes of a elementary school, where our very own Franco Carbognani showed how he, as a member of the Mars Society, participates in training periods in view of the exploration of Mars. The “show” will be repeated later in July.

On an even more engaging level, we have been requested by Professor, and “Councillor”, Mellea to organise two classes called “Physics in English”, in which experimental physics is taught, possibly in the laboratory, using only the English language. We succeeded in providing ten 90 minutes lectures for two classes, thanks to the efforts of Carlo Nicola Colacino and Bas Swinkels, from the Virgo entourage, and Riccardo Stara and Steve Shore from the University of Pisa Physics Department.

From their side, the *Comune* have given us free access to the *Città del Teatro* for the theatre events of the European Researchers’ Night (both in the past and the upcoming one). Finally, very promising steps forward have been announced in the area of obtaining funds from the *Regione Toscana* for the realisation of the “Open Air Museum” here on the EGO site, as discussed in a previous issue of *h*. This could be the first step on the road to the proposed Astronomy Park shown on the poster at the entrance of the EGO Main Building.

C. BRADASCHIA
Outreach Coordinator

How to increase the number of attendees to meetings?

Dear all, let me show you the latest trick tested by our On-site Works Coordinator (F. Carbognani) to increase the number of attendees at the Weekly Coordination Meeting, and it works!

A piece of advice: Each Tuesday in the Meeting Room from 10:00 onwards, come with an empty stomach!

Biathlon 2013

After a long cool and rainy period, the coldest spring ever, this year's biathlon took place during what seemed to be one of the first sunny days of the year. Napoli, LAPP and Nikhef had set up teams, and, for the first time, there was also a team representing the gravitational voice.
After the signal, runners started on the first 1-km leg, followed by their 2-km colleagues. Cyclists then returned along the 6 km of the North and West arms, before passing the baton to the final 3-km runners. In a dramatic final spurt, Daniel Vander-Hyde (*h* team) and Enrico Calloni (Napoli) almost simultaneously approached the red-white finish tape, but finally the *h* team won with half a second to spare.
The will to win must have been unconditional in the *h* team; witnesses report having heard the battle cry "gold or nothing!" in the *h* training camp before the competition; visibly motivating its members considerably…

After the effort everyone was invited by EGO to close the evening with a nice buffet, prepared with great care by the Panini team. Families were invited, too, and many happy children were seen.

H.HEITMANN
h Reporter

The h team succeeded in passing the finish line first in the Biathlon, but not in the buffet! (Photo credit: M. D'Andrea, EGO)

Arrival sequence and the measured times after half the Biathlon (athletes returning from the North arm, grey) and the final numbers (white).

2013	h team		Napoli		LAPP		Nikhef	
1km	S. Perus		F. Garufi		D. Busculic		D. Rabeling	
2 km	F. Richard		S. Capozziello		A. Masserot		A. Conte	
Bike 6km	G. Pillant		L. DiFiore		M. Ducrot		K. Agatsuma	
3 km	D. Vander-Hyde		E. Calloni		L. Rolland		J. van Heijningen	
Number	2	1	1	2	4	4	3	3
Time	20:13	38:43	19:42	38:44	23:24	43:55	20:41	42:39

Genetic Mutations?

Do gravitational waves produce genetic mutations?

It appears that they do in Cascina, at least on cats!

Wind and Overshoes

A long time ago, the ever vigilant *h* team noticed that many fragments of blue overshoes and even some entire ones were appearing in the grass all over the EGO site. The first hypothesis was that someone was trying to produce new overshoes by growing them, planting fragments in the hope of seeing new overshoes sprouting up. After an intense discussion we concluded that this was not possible as overshoes were not made of biological material.

Then came more observational data: we noticed that most of the outside garbage bins have a lot of these blue things. The next hypotheses was that animals, may be magpies, are picking out stuff from the bins or some lazy colleagues are throwing garbage directly into the fields. This theory was excluded by scanning the images recorded by the security cameras. At this point we decided to study the environmental data collected by the many sensors we have all around the site. Temperature, pressure, humidity, seismic activity, wind speed. This last parameter drew our attention. Historical data gathered over many years show, surprisingly, that we have relatively strong winds almost every day.

Proposed conclusion: strong winds scatter the light plastic overshoes from the bins. Intense experimental activity was needed and immediately started. After a few weeks of experiments we showed that wind is responsible for scattering overshoes around, in particular when they are not pushed deep into the bin. Finer experimental data revealed that stronger winds are more effective in the scattering. A FEM aerodynamic model and observation showed that high speed air curls in the cylindrical bins amplify the effect.

Now the proposed solution: We think that putting used overshoes into internal bins only will prevent this pollution. We ask our colleagues to do so and possibly to collect overshoes lying around in the grass.

C. BRADASCHIA

About Daniel Vander-Hyde and Gabriel Pillant

I would like to introduce you to these two gentlemen who kindly accepted to run for the *h*-team.

Firstly, .Daniel (who is already well-known by us as an outstanding athlete) is an undergraduate student in Physics from the Californian State University, Fullerton who currently works on environmental noise studies under Irene Fiori's supervision.

He is not a novice in our field of research as he has already participated in scientific activities for the LIGO Scientific Community during a former internship. The thing he has really appreciated here in Virgo up to now is its scientific community. The community is not large which gives its members the opportunity to interact with colleagues in diverse fields. The community is not restricted to very specific and focused topics. This is on of the Virgo strong points in his opinion.

Gabriel is also well known but more for his superbike (or '*Spigaou*' as they say in his native city Marseille) than for his sports performance. He is doing his graduating internship in the Optics group. He enjoys the studies that he is currently carrying out on the Electro-Optics Modulators a lot and would be happy to have the possibility to work during the optics installation phase. For him the appealing aspect of his studies is the large range of possible applications for Optics in our everyday life. As an example he quotes a stage that he performed in Bordeaux on laser applications for the dental surgery.

Gabriel's Spigaou

A special thanks to them for their motivation and enthusiasm!

F. RICHARD
h interviewer

GOOD NEWS!

Welcome to Matthieu, born on April 9, and congratulations to the Canuel family: Benjamin, Valentina and Sophie.

PERSONNEL MOVEMENTS

Arrivals

Mirko Prijatelj
Optical Engineer in the optics group

Domiziana Mele
Trainee in the electronics group

Departure

Benjamin Canuel
Applied Physicist who left the EGO optics group