EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

Exploratory Workshops Scheme

Standing Committee for Physical and Engineering Sciences (PESC)

Scientific Report

ESF Exploratory Workshop on

Astrophysical Tests Of Fundamental Physics

Porto, Portugal, 26-30 March 2008

Convened by:
Carlos Martins

Centro de Astrofisica, Universidade do Porto

Co-sponsored by:

Centro de Astrofísica da Universidade do Porto

Centro de Física do Porto

U.PORTO

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

ESF Exploratory Workshop Report

Astrophysical Tests of Fundamental Physics

26-30 March 2008, CAUP, Porto, Portugal

Convenor: Carlos Martins (Carlos.Martins@astro.up.pt)

Executive Summary

Basic Logistics

The workshop was locally hosted by two research centres of the University of Porto, the Centre for Astrophysics (CAUP) and the Centre for Physics (CFP). The talks and formal discussion sessions took place in CAUP's main auditorium. CAUP staff also dealt with the local admin, including the booking of flights and hotels, the refund of participants' expenses, and the creation of wireless and/or wired internet access for all participants.

All non-local participants stayed in the same hotel (Residencial Vice-Rei), and were given a per diem in accordance with the rules of the Portuguese research council (FCT). This per diem covered the cost of hotel (which the participants paid on check-out), the meals during the workshop (except the workshop dinner, which was part of the workshop's budget) and small transportation expenses like buses or metro tickets. In most cases, flights were booked by the CAUP staff according to the participants' instructions. In a few cases where the participants had special travel arrangements (eg, the trip to Porto was part of a longer trip, so the origin and destination airports were different) they booked the flights themselves, and were subsequently refunded up to a previously agreed amount. In one case (A. Challinor) the travel was covered by the participant's own grant.

Both the per diems and (where applicable) the flight refunds were paid by bank transfer to a bank account specified by each participant. According to FCT and local rules, transfers were made during the month of April, and all participants have now confirmed (through signing a receipt and returning it to CAUP) that they have received the due amount.

Participants

As soon as the proposal was approved, the prospective participants named in the application were invited to attend, and about half of these ended up doing so. For those unable to attend, a replacement was eventually found that could cover an equal or similar area, while maintaining the balance of geographical, age and gender distribution. In fact, the final list of participants is somewhat more diverse than the original one. This is despite the fact that all 3 US participants named in the workshop proposal were unable to attend. These were not replaced since, as was pointed out in the proposal, they work on specific topics in which there is relatively less European expertise; nevertheless, care was put into including these topics in the workshop discussions.

In addition to senior participants that were invited ab initio, we also invited expressions of interest from outstanding young participants (which we defined as being born after 1979). We then selected 6 of these (C. Burrage, E. Fernandez-Martinez, D. Garcia-Figueroa, L. Joukovskaya, C. Pahud, J. Rocher) who were then invited to attend under the same conditions as the more senior ones. Of these 6, 3 are post-doctoral researchers and the other 3 (Burrage, Garcia-Figueroa, Pahud) are PhD students about to finish their thesis.

Last-minute Changes

One of the participants (J. Garcia-Bellido) had to cancel his attendance at the last minute, due to family reasons. Since his flights had already been booked by us and were non-refundable, this expense is still included in the budget. Attempts were made to replace him with another participant from the same institution (who could still use his flights, upon re-issue of the tickets under a different name). However, finding a replacement proved impossible, since the cancellation occurred at the beginning of Easter week, and the 2 or 3 scientists who could justifiably be brought in as replacements were away from work and out of contact.

Since one of CAUP's unique features is that it shares its space with an astronomy outreach unit, which among other things runs a planetarium, the slot corresponding to J. Garcia-Bellido's talk was replaced by a session at the planetarium for the workshop participants, together with their spouses and children. The planetarium staff provided a brief demonstration of the planetarium's capabilities, and answered several questions from the workshop participants, both on the planetarium itself and on other outreach activities they coordinate. This subsequently generated some interesting informal discussions on the role of outreach in our research area.

A second participant (A. Achucarro) attended the workshop, despite being ill with flu. She participated in the workshop's activities in the first two days but, her condition not improving, decided to return home early, without presenting her talk that was scheduled for the last day. Her flight was therefore changed at the last minute, with the cost of the change being covered by local sources. In this case, the remaining program was shifted forward, leaving more time for the final discussion.

Objectives and Main Conclusions

The deepest enigma of modern physics is whether or not there are any fundamental scalar fields in nature: although there are widely accepted theories in particle physics and cosmology which rely on them (cf. the Higgs in the standard model of particle physics, the dilaton and moduli in string theory, or the inflation and quintessence fields in cosmology), neither has so far produced any definitive evidence for them. This workshop brought together Europe's best experts in the various approaches to this and related topics, to identify and characterise key observational probes of fundamental physics.

The main conclusion of the workshop was a better appreciation of the existing divide between theory and observation (or, to put it broadly, between the physics and the astronomy). This is particularly crucial at a time when large-scale observational projects (many of which space-based) are being built or planned. These often involve teams of hundreds of people, with many years of planning, design and fund-seeking, and budgets that are only available to large international research organisations.

In these circumstances, it is crucial to have a solid theoretical underpinning to justify the large-scale observational efforts. This will not only put the community in a better position to identify the key astrophysical and cosmological tests of fundamental physics, that might be carried out in the coming decades but also, as far as this is possible, allow it to estimate the potential of each experiment for serendipitous discovery. Both of these are crucial not only for the research community itself but also for funding agencies, who will be faced with increasing competition for limited resources, and must make funding decisions that will affect not only individual experiments but also the field as a whole many years in advance.

It is this theoretical underpinning that the community represented by the workshop's participants is ideally placed to provide, and this should be our key goal in the coming years. In preparation for this exciting but also demanding future, it is also crucial to train a new generation of 'bilingual' researchers, that are fluent both in the language of observational astronomy and cosmology and in that of fundamental physics, and therefore will be in an ideal position to exploit the opportunities ahead.

Proceedings and Future Actions

All the workshop's seminars and discussion sessions have been recorded in audio and video format, and are now available, together with pdf files of the seminar's slides, on the workshop webpage at CAUP.

It was agreed that more organised mechanisms for the community to interact are needed, although it wasn't clear which kind of mechanism is the right one for us. In addition to the standard type of networks (such as provided by ESF or the EU-FP7), there were also suggestions for a kind of virtual European Cosmology Institute (possibly with travel funded under FP7 or ESF), which could be the basis for the 'theoretical underpinning' work discussed above. On the other hand, it also wasn't clear what should be the exact focus of such a network (eg, what should be our relation to forthcoming observational consortia).

Discussions of these issues are ongoing at the time of writing this report. On the other hand, some 'follow-up' scientific events on the topics of this workshop are being organised in European countries by several of the workshop's participants in 2008 and 2009, which will provide further opportunities for the community to interact and become involved.

Scientific Content

Overview

Scalar fields have long been part of the standard model of particle physics, most notably in the form of the the Higgs particle, which is supposed to give mass to all other particles (in addition to making the theory gauge-invariant). In this context it's remarkable that Einstein gravity has a single gravitating field (the metric, a 2-tensor and does not use any scalar field, because almost any consistent gravitational theory one can think of will have one or several scalar fields. Indeed, the fact that there is no scalar field is, to some extent, what defines Einstein gravity. The search for cosmological scalar fields is therefore the optimal way of testing Einstein gravity, in addition to probing fundamental physics as a whole (Martins).

There are three firmly established facts that the standard model of particle physics can't explain. Evidence for neutrino masses is the most important recent result in particle physics, and requires anew ad-hoc conservation law or phenomena beyond current framework. No object in the standard model can account for the amount of dark matter required by observations (and baryons or massive neutrinos can't do it). A mechanism for generating the Baryon Asymmetry of the Universe does exist, but fails quantitatively given the measured values of the parameters controlling it. It's precisely our confidence in the standard model that leads us to the expectation that there must be new physics beyond it. On the other hand, it is manifest that all of these have obvious astrophysical and cosmological implications, and so progress in fundamental particle physics increasingly depends on progress in cosmology.

Recent developments suggest that scalar fields could be equally important in astrophysics and cosmology, but neither side has so far produced definitive experimental or observational evidence for them. Scalar fields play a key role in most paradigms of modern cosmology, including the exponential expansion of the early universe (inflation), as relics of cosmological phase transitions (cosmic defects), as dynamical dark energy powering current acceleration phase (being an alternative to the cosmological constant) and in driving the variation of nature's fundamental couplings and mass ratios. Even more important than each of these paradigms is the fact that they usually don't occur alone---this will be crucial for future consistency tests. An example is the possibility of using astrophysical measurements of fundamental constants as a function of redshift to reconstruct the equation of state of dark energy, thus looking for any dynamics which would signal the breakdown of Einstein's gravity (Martins).

The standard cosmological model is almost a decade old and extremely successful. In this decade, cosmology has made the transition from a data starved science to a data driven science. The standard cosmological model has survived almost unscathed through this avalanche of cosmological data that has brought about 'precision cosmology'. The model, with only a handful of parameters, describes observations of the Universe from 380000 years after the big bang to the present day, and many of the parameters are constrained at the percent level. Despite its successes, it has two outstanding questions, dark energy and inflation: nothing weighs something and gives accelerated expansion, but not as much as naively expected (Verde). This raises the key issue of what could we reasonably learn from a dark energy experiment (or in other words, what is the criterion for success of an experiment).

Current Observational Probes

A range of astrophysical and cosmological probes are thus being actively pursued in order to probe the dark side of the universe. Weak gravitational lensing (Taylor) has rapidly developed over the last few years to become one of the major probes of cosmology. On the scale of galaxy clusters gravitational lensing can be used to map the dark matter distribution in 2D and 3D, and can be compared with the galaxy and gas distribution. On larger scales the statistics of the cosmic lensing shear signal are being used to pin-down the cosmological parameters and help determine the nature of the dark matter. Baryon Acoustic Oscillations (Fernandez-Martinez) in the early universe provide us with a standard ruler, the sound horizon at recombination, which can be very accurately calibrated through the cosmic microwave background. This characteristic length is imprinted in the matter distribution of the Universe and it can be studied through tracers of the matter distribution such as galaxy surveys. Measuring this standard ruler at different redshifts is then a direct probe of the rate of expansion of the Universe. The cosmic microwave background itself is currently the most precision probe of fundamental physics in the early universe (Challinor). In addition to the temperature anisotropy measurements that are by now common, polarisation is proving to be an exciting new window for constraining fundamental physics scenarios, including the character and statistics of the primordial curvature perturbation, primordial gravitational waves, cosmic (super-)strings and absolute neutrino masses.

Indeed, over the last decade a wealth of cosmological observations has revolutionised cosmology, which in only a few years has become a data-driven field. Many ambitious proposals for new and larger cosmological surveys will deliver increasingly vast and complex data sets in the future. A central role in exploiting future data will be played by our ability to perform sound and efficient statistical analyses and model inferences (Trotta). The future will bring important statistical challenges, and Bayesian inference techniques seem well suited to cope with upcoming massive data sets, including the Planck Satellite, VSA/VISTA/DES, DUNE and others.

Constraining New Phenomenological Models

Scalar fields have been used to model inflation, to generate dark energy and to act as dark matter. Their puzzling ubiquity is all the more intriguing that no fundamental scalar particle has ever been observed. On the other hand, there are obstacles to building well-motivated quintessence models of dark energy (Brax). A possible alternative is the chameleon mechanism (Burrage), which among other things predicts that the scalar field (known in this context as the Chameleon) mixes with photons in the presence of a magnetic field. The strong magnetic fields in the interior of a supernova mean that there could be a large flux of Chameleons at the surface of the supernova. Mixing between photons and Chameleons in the intergalactic medium would then explain the observed discrepancy between measurements of angular diameter distances and luminosity distances. Another alternative are the so-called brane world scenarios (Binetruy). At this stage, more than predictions, the brane world idea provides a framework for new cosmological models, and cosmological observations are one of the many arenas where such models could show up.

The quest for dark energy is shedding light on aspects of gravity that only a few years ago were out of observational reach, including scalar-tensor models, $f(R)$ Lagrangians, models that violate the equivalence principle and extra-dimensional models. Current and future experiments, especially weak lensing from space, can constrain tightly their parameters (Amendola). A related issue is also the need for two periods of accelerations, in the early and in the late universe; some of these models may provide a partial answer to this problem. The residual of an incomplete decay of the inflaton field may play the role of Dark Matter, and in an anthropic string landscape sense, the inflaton field can act as Dark Energy as well (Pahud).

General relativity is based on two independent assumptions, namely that matter fields are minimally coupled to a unique metric tensor, and that the kinetic term of this metric is given by the (pure spin-2) Einstein-Hilbert action. Both assumptions are generically violated in extra-dimensional theories, which notably predict the existence of scalar partners to the graviton. One may distinguish three qualitatively different classes of constraints that experiment imposes on such theories: (i) solar-system tests, (ii) binary-pulsar observations, and (iii) cosmological data. A complementary class of constraints is provided by the mathematical consistency of the models, notably their stability and the well-posedness of their Cauchy problem. (Esposito-Farese) Standard scalar-tensor theories are consistent and natural, but tightly constrained experimentally; nevertheless they are useful as contrasting alternatives to GR. The best present field theory for MOND has still some mathematical and experimental difficulties. Finally there are simpler models, useful to exhibit the generic difficulties: for example the Pioneer anomaly is mathematically and experimentally OK, but neither MOND nor the Pioneer models are natural.

Inflation and its Consequences

Cosmological inflation is a robust paradigm that has many concrete predictions for the origin of large scale structures of matter and cosmic microwave background anisotropies, all of which are consistent with present observations. Moreover, recently a new window has been opened into the very beginning of the universe via the production of a stochastic background of gravitational waves as well as the generation of the primordial seed for galactic magnetic fields at preheating after inflation (Garcia-Bellido---talk cancelled). Reheating the universe after inflation is an extremely violent process which generates a significant amount of energy in the form of gravitational waves. The different stages of reheating (preheating, bubble collisions and turbulence) determine the time evolution of the power spectrum of this post inflationary background, whose shape and amplitude can be extrapolated till the end of reheating, and redshifted till today. Its energy density ratio to photons today, could be significant for high-scale models, although well beyond the frequency range of observatories like LIGO, LISA or BBO (Garcia-Figueroa). The discovery of such a background would open a new window into the very early universe which could help test inflation.

Some of the flat directions in the Minimal Supersymmetric Standard Model (MSSM) field space can support phenomenologically viable inflation, provided the soft supersymmetry breaking terms satisfy a certain relation. In particular, there is a class of Kahler potentials which naturally provide all the ingredients necessary for MSSM inflation (Enqvist). In such models, the parameters of the inflaton potential (such as the inflaton mass) can in principle be determined in laboratory. However, there are many open questions in these scenarios. Some of these are similar to the (well known) difficulties encountered when trying to generate stable de Sitter states or inflationary trajectories in supergravity models with a stringy origin (Achucarro---talk cancelled).

From Cosmic Strings to String Theory

An interesting feature of high-energy physics models of the early universe based on supersymmetric Grand Unified Theories (SUSY GUTs) is that when a phase of inflation is added to the picture, the formation of stable cosmic strings is highly generic at the end of the phase of inflation (Rocher). The most recent CMB data can then be used to obtain new strong constraints on popular models of inflation. Some orthogonal constraints from CMB can be obtain from the measurement of the statistical properties of the spectrum of primordial fluctuations of density. To be able to confront models of inflation to the current and future data, the predictions need to be as accurate as possible. However for models with inflection points (such as hybrid models), the potential (including radiative loop corrections) cannot be computed very accurately with usual perturbative methods, so improved methods based on renormalisation groups are required.

In fact, it has been noticed that the production of cosmic strings at the end of inflation is even more generic. Recent work in building inflationary models in string theory has led to the conclusion that the final stages of inflation generically produce string remnants of cosmological size. These objects, dubbed cosmic superstrings, have different properties than ordinary cosmic strings, thus providing a potential observational window to high-energy physics (Avgoustidis). Even through there are key issues such as the behaviour of small-scale structure, the number of kinks in loops, the presence of absence of scaling solution in networks with junctions and the detailed non-gaussian properties of this objects, it is clear that they will provide a key discriminant between competing models.

A challenging goal of string theory is to provide a model for the Big-Bang itself or, more accurately, to determine what replaces space-time and gravity near the Big-Bang. This may then lead to an understanding of whether or not space-time existed before the Big Bang: if so, one may ask how did perturbations propagate through the singularity, but if not the issue becomes what determined the initial state of the universe. One can look for answers in a few string theory models. The strategy for this endeavour is twofold (Craps): one starts with a space-time with a space-like (or light-like) singularity, and embeds it string theory to find out whether 'reasonable' extrapolations of usual rules of string theory give sensible and consistent results. A particular case is the analysis of the dynamics of the tachyon scalar field of cubic string in the Friedmann-Robertson-Walker background (Joukovskaya). A rolling tachyon solution interpolates between perturbative and non-perturbative vacua, and this solution can lead to epochs of cosmic acceleration.

New Observational Probes

Finally, it is clear that a range of new probes is needed to study the dark side of the universe. Some new and recently proposed techniques include the Integrated Sachs Wolfe effect and the so-called Sandage-Loeb test (Melchiorri). Neutrinos have also been playing an increasingly important role, and a range of forthcoming cosmological and local experiments are likely to enhance their importance. Astronomical observations can effectively probe the space-time the variability of the physical dimensionless constants such as the fine structure constant a and proton-to-electron mass ratio which are related to fundamental forces of nature. At the moment there is some controversial evidence for the time variation of both of these quantities (Molaro), which if confirmed will be of revolutionary importance. The proposal for the ESPRESSO (Echelle Spectrograph for Precision Super Stable Observations) spectrograph at the combined incoherent focus of the 4 ESO-VLT units (a potential 16 m equivalent telescope) and its follow up for the European ELT CODEX (COsmic Dynamics EXperiment), if realized, will make possible a significant improvement, in the range of one and two orders of magnitude respectively, thus solving the present controversy and opening a new field of research in case positive results are provided.

These measurements should be complemented by tests of fundamental physical laws using ultra-stable clocks in space and on the ground (Salomon). By comparing clocks of different nature tight limits are obtained for the time variation of the fundamental constants of physics. The ability to compare microwave and optical clocks using the newly developed frequency comb technique opens a wide range of possibilities in clock comparisons. By installing in space ultra-stable cold atom clocks (such as PHARAO/ACES project for flight in 2013), improved tests of general relativity will be performed, such as a measurement of Einstein's gravitational red-shift at the one part per million level. A new kind of relativistic geodesy based on the Einstein effect will also provide information on the Earth geoid.

Future Plans

In addition to extensive informal discussions during the lunch and dinner breaks, the workshop included three organized discussion sessions, moderated by L. Amendola, P. Binetruy and A. Taylor (substituting for A. Achucarro). These were used to assess the current status of European research in this area, identify the main challenges and opportunities in the years ahead, and discuss plans for European-wide actions.

It was agreed that more organised mechanisms for the community to interact are needed, although it wasn't clear which kind of mechanism would be the right one for us. Several participants pointed out that the standard type of networks (such as provided by ESF or the EU-FP7) have a somewhat restrictive scope. For example, FP7 actions focus on training at the PhD level. This may be ideal for countries where PhD grants are scarce, but not for those where they can be obtainable relatively easily. (France was pointed out as an example.)

There were also suggestions for some form of virtual European Cosmology Institute, possibly with travel funds provided under FP7 or ESF. Such an institution could be the focal point for a coordinated 'theoretical underpinning' effort, which has been identified as crucial for the coming years. On the other hand, there was no consensus on what should be the exact focus of such a structure, and particularly how it should relate to forthcoming observational consortia: should it focus on privileged interactions with a few selected experiments that are of interest to its members, or should it be 'orthogonal' to and independent of all of them, but capable of addressing specific issues upon request from any such consortium?

Discussions of these issues are ongoing at the time of writing this report. At the same time, several 'follow-up' scientific events on the topics of this workshop are being organised in European countries by several of the workshop's participants in 2008 and 2009. Noteworthy among these is an 8-week workshop entitled 'New Horizons for Modern Cosmology' (see http://ggi-www.fi.infn.it//index.php?p=events.inc&id=23), which will take place at the Galileo Galilei Institute for Theoretical Physics in Arcetri (Florence, Italy) in early 2009, organised by M. Kamionkowski, C. Martins, A. Melchiorri, A. Polosa and L. Verde. This and other events will provide further opportunities for the community to interact and become involved.

Final Programme

Wednesday 26 March 2008

Arrival and Registration

Thursday 27 March 2008

09.00-09.30 Registration
09.30-09.40 Opening Remarks
09.40-10.00 Presentation of the European Science Foundation (ESF)
Walter Gear (Standing Committee for Physical and Engineering Sciences)
10.00-10.20 Astrophysical Tests of Fundamental Physics
Carlos Martins (Centro de Astrofísica, Universidade do Porto - CAUP)
10.20-11.00 Observational Cosmology and Fundamental Physics
Licia Verde (ICE, Barcelona)
11.00-11.30 Coffee Break
11.30-12.10 Probing the Universe with Cosmological Lensing
Andy Taylor (IfA, Edinburgh)
12.10-12.50 Constraining the Dark Energy Potential with BAO Surveys}
Enrique Fernandez-Martinez (MPF, Munich)
12.50-15.00 Lunch break / Informal Discussion
15.00-15.40 CMB Constraints on Fundamental Physics
Anthony Challinor (IoA/DAMTP, Cambridge)
15.40-16.20 Bayes in the Sky - Statistical Challenges in Cosmology
Roberto Trotta (Oxford)
16.20-17.00 Supernova Brightening from Chameleon-Photon Mixing}
Clare Burrage (DAMTP, Cambridge)
17.00-17.30 Coffee Break
17.30-19.00 Discussion session
Where We Are: Current Strengths and Weaknesses of European Research in this Area

Friday 28 March 2008

09.00-09.40 The Ubiquitous Scalar Fields
Philippe Brax (CEA, Saclay)
09.40-10.20 Astrophysical Consequences of Extra Dimensions
Pierre Binetruy (APC, Paris)
10.20-11.00 The Dark Side of Gravity
Luca Amendola (INAF, Roma Obs.)
11.00-11.30 Coffee Break
11.30-12.10 Experimental and Theoretical Constraints on Alternative Gravity Theories
Gilles Esposito-Farese (IAP, Paris)
12.10-12.50 Triple Unification of Inflation, Dark Matter, and Dark Energy Using a Single Field
Cedric Pahud (Sussex)
12.50-15.00 Lunch break / Informal Discussion
15.00-15.40 Planetarium Session
15.40-16.20 Inflation Within Minimally Supersymmetric Standard Model
Kari Enqvist (Helsinki)
16.20-17.00 Constraining the Primordial SSBs and the Inflation Potential with the CMB
Jonathan Rocher (ULB, Brussels)

17.00-17.30 Coffee Break
17.30-19.00 Discussion Session
    Where do We Want to Go: Key Challenges and Opportunities in the Next Decade}
19.30-22.30 Workshop Dinner

Saturday 29 March 2008

09.00-09.40 Fundamental Physics with Space Clocks
    Christophe Salomon (ENS, Paris)
09.40-10.20 Astronomical Measurements and Constraints on the Space-time Variability of ♋ and ❍
    Paolo Molaro (Trieste Obs.)
10.20-11.00 New Constraints on the Cosmological Dark Side
    Alessandro Melchiorri (Roma)
11.00-11.30 Coffee Break
11.30-12.10 Modelling the Big Bang in String Theory
    Ben Craps (VUB, Brussels)
12.10-12.50 Accelerating Universe from Cubic String Field Theory
    Liudmila Joukovskaya (DAMTP, Cambridge)
12.50-15.00 Lunch break / Informal Discussion
15.00-15.40 Supergravity and Cosmolgy – Yet Again
    Achucarro (Inst. Lorentz, Leiden) - cancelled due to illness
15.40-16.20 Cosmic Superstrings and their Astrophysical Consequences
    Anastasios Avgoustidis (Barcelona)
16.20-17.00 Post-inflationary Gravitational Waves from Reheating
    Daniel Garcia-Figueroa (UAM, Madrid)
17.00-17.30 Coffee Break
17.30-19.00 Discussion Session
    How do We Get There: Plans for European-wide Actions
19.00 Workshop closure

Sunday 30 March 2008

Departure

Statistical Information

Total Participants: 26 (Including the ESF representative, but not J. Garcia-Bellido)

Country of Work: Belgium (2), Finland (1), France (4), Germany (1), Holland (1), Italy (3), Portugal (4), Spain (3), United Kingdom (7)

Nationality: Belgium (1), Finland (1), France (5), Greece (1), Italy (5), Portugal (4), Russia (1), Spain (3), Switzerland (1), United Kingdom (4)

Age: Less than 30 (7), 30 to 39 (9), 40 to 49 (7), More than 49 (3)

Gender: Female (4), Male (22)

Final List of Participants

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