EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

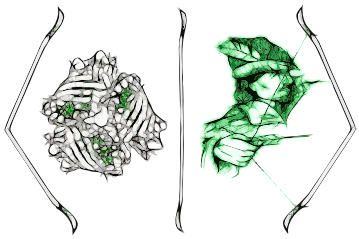
Exploratory Workshop Scheme

Standing Committee for Physical and Engineering Sciences (PESC)

ESF PESC Strategic Workshop on

Signatures of Quantumness in Complex Systems

Nottingham (United Kingdom), 29 June – 3 July 2011



Convened by:

Gerardo Adesso

School of Mathematical Sciences, University of Nottingham, United Kingdom

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SCIENTIFIC REPORT

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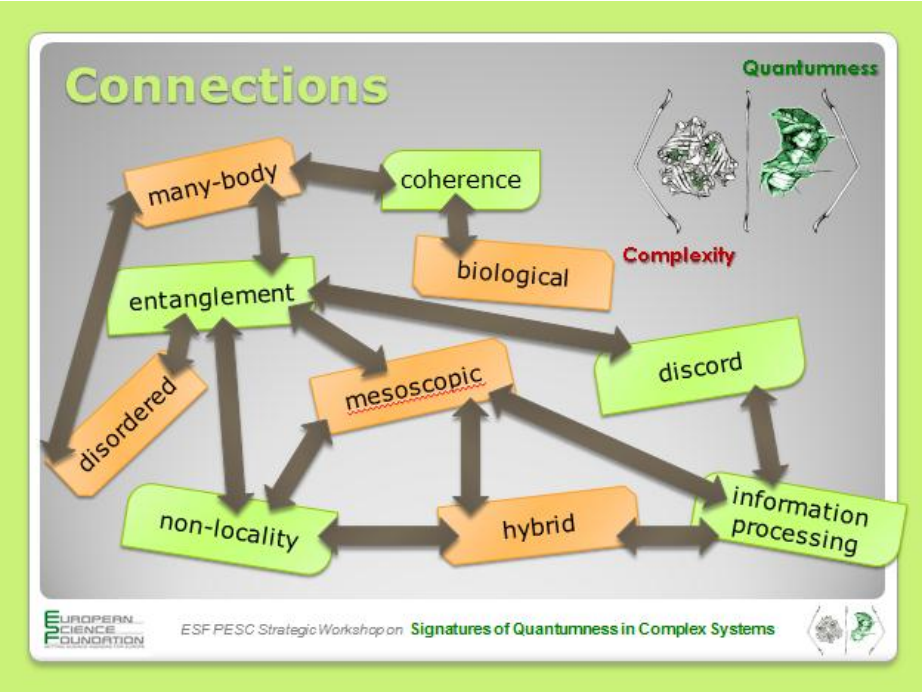
1. Executive summary

The meeting took place at the *Westminster Hotel (Best Western)* in Nottingham from Wednesday June 20, 2011 (arrival & registration day) to Sunday July 03, 2011 (departure day). It featured 30 participants (29 invited speakers + 1 convener) from 11 countries, plus the ESF rapporteur and a local organising team of 4 postgraduate staff members of the University of Nottingham. All the participants were lodged in the same hotel, where we had our meals and coffee breaks as well. The meeting room (Cromwell meeting room) was equipped with a projector and several round tables arranged "cabaret-style". The participants found the atmosphere particularly pleasant and favouring discussions. Each speaker was allowed 30+5 minutes for the talk+questions. The convener gave a short introductive presentation at the beginning of the workshop, and the PESC rapporteur Prof. Aizenman introduced ESF and its activities later on the same day.

The interaction among the participants was fervent, and many lively discussions arose during the talks and continued over coffee breaks and post-dinner discussions in the hotel or at a nearby pub. On the afternoon of July 1 we had a social trip to Newstead Abbey, where we enjoyed a guided tour in the home of Lord Byron, and a nice walk in the beautiful surrounding gardens. This was followed by a conference dinner at the Riverbank restaurant in Nottingham city centre. All these events contributed to building strong feelings of fruitful scientific and personal interaction among the participants, enforcing existing links and giving rise to new connections between different communities, in particular quantum information scientists and researchers in bio/complex systems. The workshop was concluded by an interactive strategic session where summary and follow-ups were discussed. Most of the participants found the idea of an exploratory workshop, and this one in particular, a much more valid experience compared to some conventional large-scale conferences where the interaction is sensibly more limited. We then agreed that a community has been created at the workshop, and we plan to sustain it with further activities, as detailed in Section 3.

The workshop aimed at establishing an all-European platform to explore the interplay between quantumness and complexity, and more broadly the border between the classical and the quantum world. By complex systems we classified biological, many-body, hybrid, disordered, and meso/macroscopic systems. By manifestations of quantumness we instead identified coherence, entanglement, non-classical correlations (quantum discord), non-locality, and information processing applications. The selection of speakers was made in such a way that each participant's recent research was identifiable with one or more crossroads among the above topics. A number of fundamental questions with technological impact were raised: What is the most essential signature of quantumness? Is quantum theory the only one able to explain experiments at the microscopic scale? To what extent quantum effects are manifest and play central roles in complex, many-body and macroscopic systems? What still unexplored possibilities are allowed by quantum laws and general types of quantum correlations for empowered quantum information processing and communication?

The goal of the workshop was to gather a top-notch community of theorists and experimentalists to define the state of the art and the future directions in this emerging area.



Some of the main scientific conclusions emerging from the workshop can be summarised as follows.

- Fundamental quantum effects are now detectable and testable in macroscopic setups that involve up to living complex systems as detectors and processors. On the other hand, unambiguous mathematical criteria for the verification and quantification of general quantum correlations are still to be developed.

- The applications of such general correlations for quantum computation and quantum information processing are being explored beyond the first generation of protocols. There is a clear potential for novel primitives to be developed that could trigger a second quantum revolution, as general quantum correlations beyond entanglement are more robust to mixedness and may survive in realistically noisy environments.

- On parallel grounds, the role of quantum coherence in presence of noise has proven crucial for the efficiency and the survival of light-harvesting bacteria, and for more complex biological mechanisms such as the avian compass. The study of these systems is sparking progress in the description of open quantum systems, and new insight on locating the boundary between the classical and the quantum world.

Combining the above observations, we reached the conclusion that natural systems and tailored hybrid devices might be a source of robust quantum correlations apt to enable disruptive quantum information processing machines. Exploring the role of noise and developing new quantum theory tools for quantum technology, applicable beyond the traditional microscopic world, is the new frontier for the merged areas of quantum information and complexity. The workshop allowed us to form a core coordinated European team to pioneer these developments in the near future.

2. Scientific content of the event

The workshop opened on 30 June with a brief introduction and presentation by the convener **Dr Gerardo Adesso**, in which the main scope and aims of the workshop were reviewed.

The first session featured two high-profile talks discussing the boundaries of the quantum world. **Professor Vlatko Vedral** gave an inspiring flipchart seminar in which all the main themes of the workshop were featured, ranging from evidences for quantum effects in photosynthesis, bird orientation, and possibly human cells, to quantum computation in noisy systems as enabled by quantum discord. The quest for quantumness in all these scenarios emerged as timely and meaningful, and both the speaker and the audience reached the conclusion that much more can be in stock than currently unveiled, about the essential resources needed for quantum technology to outperform the classical one in the mainstream. **Professor Nicolas Gisin** then presented intriguing theoretical and experimental advances concerning the possibility of detecting quantum correlations in optical setups by using a naked human eye instead of engineered photon counters. He employed his own PhD students in the experiments, which were successful to establish non-locality of the observed systems at the microscopic scale, but lacked the necessary sensitivity to resolve quantum effects between macroscopic systems (ensembles of thousands of photons).

The second morning session was about quantum complexity. The first two talks of the session were close in spirit and concerned the interplay between quantum entanglement and frustration in many-body systems. **Professor Fabrizio Illuminati** described his group's progress in tackling the ground state properties of non-analytically-solvable many-body quantum systems (e.g. spin chains) by using tools from quantum information theory, such as the entanglement spectrum. His methods allowed him to define a universal measure of frustration in classical and quantum systems, and to relate it precisely to ground state entanglement in quantum models where the geometric component of frustration is absent. A philosophical introduction to frustration was then provided by **Professor Saverio Pascazio**, who focused on frustration arising between different bipartitions of a many-body system, which cannot be in general all simultaneously maximally entangled, a feature with implications for error correcting codes in quantum computation. He then showed an interesting approach based on random matrix theory to study the statistical distribution of entanglement in bipartite quantum states of varying dimension. This bridged seamlessly with the subsequent talk, given by **Professor Andreas Buchleitner**. He gave a very rich talk in which he convincingly provided varied motivation to pursue the field of "quantum complexity". He detailed important issues and open questions ranging from quantum optics and quantum control, to complex open system dynamics and the quantum to classical transition.
The ESF rapporteur **Professor Morris Aizenman** gave then a short speech introducing the ESF and its activities, in particular within PESC; he was keen on remarking how quantum information systems constitute a current topic of attention for the Foundation.

Overall the opening morning was of extremely high quality on the scientific side, and the seeds were planted for discussions and actions that were developed during the rest of the workshop.

The first afternoon session collected a mix of theory and experiments aimed at exploring and detecting hybrid signatures of non-classicality. **Dr Fabio Sciarrino** presented his

experimental advances in the engineering and verification of quantum correlations between a single photon and a macroscopic ensemble of 10^4 photons, a micro-macro setup that had already inspired the human-eye experiments presented previously by Gisin. There was significant discussion about the experimental figures and the proper methods to certify quantum non-locality. **Dr Sabrina Maniscalco** then gave a visually appealing talk about quantum dynamics in many-body systems. She presented powerful tools to assess the Markovianity of quantum evolutions, and related these methods to the dynamics of general quantum correlations, such as the quantum discord. The set switched to experiments again as **Dr Rainer Kaltenbaek** presented first results and futuristic plans for a set of experiments aimed at the study of quantum correlations between massive detectors orbiting in space. These experiments are aimed at testing the ultimate limits of quantum theory and its interplay with general relativity as well as with alternate theories. Such a focus was ideally shared with the last talk of the session, by **Dr Ivette Fuentes**. She gave a thought-provoking account of the emerging field of relativistic quantum information, ranging from the effect of acceleration on entangled fields, to potential implementation of quantum communication protocols in space-time adopting suitable point-like detectors and optical cavities.

The final session of the first day was intended to be fully dedicated to quantum biology. However, due to health-related last-minute cancellations by Professor Susana Huelga (who recommended her colleague Dr Javier Prior as her replacement) and by Dr Alexandra Olaya-Castro (replaced by Dr Lucia Hackermueller from the Nottingham cold atoms group), the scope was adjusted to quantum transport in many-body and biological systems.
The session was opened by **Dr Elisabetta Collini**, an “outsider” from chemistry, who presented her ground-breaking experiments demonstrating coherent quantum dynamical effects in the energy transport of living systems at room temperature. She reported noise-enhanced coherent energy transfer in both natural light-harvesting bacteria and artificial polymers, revealed by means of an advanced two-dimensional spectroscopy technique. **Dr Lucia Hackermueller** then introduced ultra-cold fermionic systems as ideal candidates for tuneable many-body quantum simulators. She presented her experiments where the dynamics of a fermionic cloud was studied in and out of equilibrium by tuning the trapping potentials. Sitting ideally between the two previous talks, **Dr Javier Prior** then talked about theoretical progress in the characterisation of many-body open quantum systems. His studies resulted in more faithful models for light-harvesting complexes in realistically non-Markovian noisy environments, allowing him to develop quantitative predictions for the phenomenon of noise-assisted transport beyond a perturbative regime. This concluded the pretty intense first day of the workshop.

The second day, Friday July 1st, was devoted to mathematical and foundational aspects of quantum (information) theory. The opening was delivered by **Professor Andreas Winter**, who gave for the first time a rigorous definition and classification of the ubiquitous class of local operations and classical communication. His findings, despite the technical presentation, were actively followed, and there was consensus on the usefulness of his technique even beyond the specific result of the talk. **Professor Caslav Brukner** then gave an exhaustive introduction to quantum discord and presented his definition of a geometric measure of general quantum correlations. He then focused on the central topic of potential applications and operational interpretations for such correlations in quantum information and communication, mentioning the case of the remote state preparation protocol. **Professor Nicolas Cerf** devoted himself to reporting some recent progress on a longstanding conjecture in quantum information, namely the additivity of the capacity of bosonic Gaussian

channels, which in layman terms amounts to prove that, even quantumly, there is nothing emptier than the vacuum. As obvious as it may seem, this statement is surprisingly hard to prove, and he offered his fresh updates based on the majorisation tool. After coffee, it was the turn of **Professor Antonio Acin**, who followed along A. Winter's steps and delivered a pleasant, interactive talk about non-locality in multipartite systems. He showed that the violation of the Svetlichny inequality does not constitute in general an evidence of genuine multipartite non-locality, and more complicate definitions need to be adopted, following the paradigm of device-independence. **Dr Marcin Pawlowski** then gave a talk, enriched by historical metaphors, on "the simplicity as an axiom". Adopting a measure of complexity based on the Occam's razor, he constructed an example to show that quantum mechanics can provide an exponentially less complex description of a system compared to classical mechanics, thus concluding that the quantum one has to be the right theory. **Professor Adan Cabello** then presented a graph formalism for non-locality and non-contextuality inequality. Several graph parameters were related to the maximal violation of these inequalities as allowed by different theories (classical, quantum, and post-quantum).
The last talk of the day was by the experimentalist **Dr Marco Barbieri**. He reported on his recent experiment on Hardy's paradox to test quantum correlations in time. Timelike quantum correlations were found to be stronger than conventional spacelike quantum correlations. With this the second day was concluded on the official scientific side, and we moved the interaction over to the social events.

The last day of the workshop, Saturday July 2nd, opened with two talks about entanglement in multiparticle systems. **Professor Anna Sanpera** reported novel work on quantum correlations in proximity of a topological phase. She found a quantitative connection between the gap in the entanglement spectrum and the universal critical exponents of the considered models. **Professor Chiara Macchiavello** then reported evidence for multipartite entanglement arising in several quantum algorithms. The dynamics of multipartite entanglement was analysed in detail in the case of Grover's search algorithm.

The second morning session was the ideal continuation of the corresponding "hybrid" one two days before, and contained the state of the art in mesoscopic and macroscopic manifestations and demonstrations of quantum effects.
Dr Oriol Romero-Isart reported a detailed, experimentally feasible proposal to prepare and verify spatial quantum superposition of massive nanospheres in an optomechanical setup. These systems could be ideal test beds to test for collapse theory beyond quantum mechanics. Optomechanics was also the central theme in the rich talk by **Dr Mauro Paternostro**. He showed how non-classicality of a mechanical mode can be engineered by photon-subtraction from a reflected optical beam, how cold-atom probes help in detecting it, and how to build quantum networks by pouring quantum correlations onto the vibrational modes of movable mirrors. **Dr Magdalena Stobinska** then reported a proposal for loophole-free Bell inequality violation using macroscopically populated states of light generated by optimal quantum cloning. She introduced a new optical filter and detailed its effectiveness for the proposed experiments. **Dr Tobias Donner** finally presented two astonishing experiments in which quantum behaviour is revealed at meso/macroscopic sizes. The first experiment concerned the realisation of a mechanical analogue of Schrödinger's cat; in the second experiment he demonstrated a quantum drum obtained by cooling a mechanical mode to its ground state by means of strong light-matter interaction.

The final talk session of the workshop was entirely devoted to quantum correlations, including and beyond entanglement. **Dr Animesh Datta** gave a detailed review of the use of quantum discord in quantum computation, and went further by showing that even the "mother" protocol of quantum communication provides suitable operational interpretations for quantum discord and related measures. His talk raised some open issues and made direct links with the opening talk by V. Vedral and the one by C. Brukner the day after. This was followed by **Professor Matteo Paris** talking about entanglement generated between two Gaussian beams interfering at a beam splitter. He derived rigorous conditions relating the entanglement production to the distinguishability of the beams before the optical interaction. The last two talks were specifically focused on the interplay between entanglement and general quantum correlations. **Professor Dagmar Bruss** explained how quantum discord is equivalent to entanglement created between a system and an apparatus in a partial quantum measurement. She further remarked how local operations can generate quantum correlations, and provided some conditions for any bona fide measure of such correlations. Finally, **Dr Marco Piani** moved along complementary lines by introducing a general activation protocol to map any multipartite quantum correlation into distillable entanglement with an ancillary system. Interpreting the ancilla as an apparatus, the framework by Bruss is recovered and extended, to provide insight about the generation and evolution of quantum correlations in the Von Neumann chain of measurements.

It was nice to get some answers in the last session to the open questions posed in the opening talk, namely about the operational interpretation and usefulness of general quantum correlations in quantum information theory. Clearly, the answers were just a first step and further coordinated research is in progress at the moment, which is an indicator of the success of the workshop.

Before closing, we ran a two-hour strategic session, moderated by the convener and by the ESF rapporteur, whose conclusions are detailed in the next section.

It should be emphasised that essentially every talk generated a discussion and raised questions from the audience both during and after the talk itself. Plus, there were many crosslinks during the talks, with speakers often citing other participant's work and relating to it. This testifies the effectiveness of the blend of selected participants.

3. Assessment of the results, contribution to the future direction of the field, outcome

The workshop was quite successful, in the opinion of the convener and based on feedback from the participants.

The workshop answered some questions and raised many more open issues. It clearly emerged that there is much more in scope for quantum technology beyond conventional protocols based on entanglement and pure states. Quantum correlations such as the quantum discord, surviving in mixed multipartite states, potentially allow for better-than-classical computation and robust quantum communication tasks. In this respect, an outlook for the near future concerns on one side the identification of suitable mathematical criteria to formulate a comprehensive theory and quantification of such correlations. On the other side, the need arises to devise experimentally friendly methods to detect and bound such

correlations in practical demonstrations, and more broadly the quest for novel protocols to take full advantage of non-classicality in separable states stands as a primary issue for further investigation. There was consensus on the fact that the quantum world extends far beyond the conventional microscopic scale. Theoretical predictions and ground-breaking experimental demonstrations, allowed by the unprecedented degree of quantum control on mesoscopic and hybrid systems, are opening the way for verification of quantum effects in natural and engineered complex and macroscopic systems. This included living systems such as light-harvesting systems, who are now believed to survive thanks to quantum coherence assisted by environmental noise. The conventional limitations of first-generation quantum technology, in which the need to achieve isolation from the environment and high degrees of purity was crucial, do not need to apply as far as more general and robust quantum correlations and more complex information carriers are concerned. There is a clear potential for quantum technology to make the leap out from the lab into the real world. We were in the unique position to reach this vision from different perspectives, bridging quantum information theory, quantum foundations, optics and many-body systems, quantum biochemistry and informatics.

The main relevant conclusions and open questions for future coordinated investigation can be summarised as follows.

✓ **Quantum information and quantum correlations: fundamentals and applications**

Take-home messages:

- Quantum discord and general non-classical correlations beyond entanglement are ubiquitous and robust types of quantum correlations whose usefulness is only beginning to become apparent;
- they admit operational interpretation in terms of specific quantum communication and computation protocols and survive up to high level of mixedness;
- they arise naturally in the measurement process and can be prerequisites to the formation of directly usable entanglement.

Open questions:

- to develop a complete mathematical formalism to characterise qualitatively and quantitatively the quantumness of correlations in bipartite and multipartite systems
- to explore the interplay and hierarchical relationships between general quantum correlations and entanglement
- to understand the emergence of classicality and pin down the role of correlations in general quantum measurements
- to devise feasible detection schemes and measurable lower bounds for general quantum correlations
- to clarify the role of quantum correlations in mixed-state quantum computation and to provide novel protocols for the harnessing and operational exploitation of general quantum correlations

✓ **Fundamental tests of quantum theory**

Take-home messages:

- Recent progress in quantum optics, optomechanics and ultra-cold atom systems allows us to devise and potentially demonstrate tests of non-locality and contextuality violation to verify quantum mechanics at meso/macroscopic level, and even test for more general predictions in the context of post-quantum, relativistic or collapse theories;
- some basic notions e.g. multipartite non-locality and in general the class of local operations and quantum communication are only now being rigorously defined despite having been studied and employed extensively in the past decade;
- the assumptions on the verification of quantum mechanics have dropped significantly in the device-independent paradigm and new tools are available to allow potentially loop-hole free verifications.

Open questions:

- to realise the proposed experiments with massive objects on earth and in space
- to achieve the first loophole-free demonstration of Bell inequality violations
- to implement relativistic protocols in space-time
- to refine detection of micro-macro and macro-macro quantum correlations by means of optical elements or living detectors
- to explore the connection between genuine multipartite non-locality, multipartite quantum correlations and the performance of quantum algorithms

✓ **Quantum complex, many-body and biological systems**

Take-home messages:

- Quantum coherence effects take place in living organisms, e.g. in light-harvesting processes or in the avian compass; noise typically assists the efficiency of such processes;
- measures for Markovianity of quantum evolutions and tools to simulate the dynamics of complex quantum systems in non-Markovian evolutions are now available, opening the way to a more realistic description of the above phenomena and beyond;
- quantum correlations in many-body systems and statistical concepts such as frustration share an intimate relationship, and a crossbreed of techniques can be useful for a better understanding of both fields

Open questions:

- to develop a more detailed description of the light-harvesting bacteria and their interaction with a realistically non-Markovian environment
- to explore connections between non-Markovianity of quantum evolutions and non-classicality of quantum states
- to propose and test novel hybrid setups for scalable implementation of quantum networking, tailored to be tolerant and optimised by the presence of external noise

- to apply indicators based on quantum correlations in order to tackle open issues in statistical and condensed matter physics, e.g. ground state solutions, dynamics, and phase transitions
- to test for quantumness in more biological mechanisms, e.g. in DNA, mitochondria, human brain, etc.

Beyond the scientific value, one main aim of the workshop was that of establishing strategic connections at the European level. The venue was particularly suitable for this purpose and the first steps in such a direction have been already undertaken. Having gathered experts in otherwise distant areas, the workshop inspired a strong interest, if not an actual necessity, to reach beyond the traditional discipline boundaries and develop a common vocabulary to understand the subject from a broader perspective. This triggered new collaborations formed during the workshop, and a reinforcement of existing ones.

Concerning specific actions, we agreed in the strategic session that the successful experience arising from the exploratory (strategic) workshop had to be pursued forward to follow-up activities. The first step was agreed to be an application for an **ESF Research Conference**, to be submitted in September 2011 (currently in preparation). Several participants offered to help as co-chairs. The conference will feature tutorials towards the above mentioned objective of deploying a common language and introducing attendants to the different aspects of quantum and complexity. Then standard talks and poster presentations will be featured, leaving ample time for discussions. On parallel grounds, some subgroups of participants are being involved in FP7 STREP proposal applications which were conceived in fact during the discussions at the workshop in Nottingham. At a later stage, after the ESF restructuring is complete and calls are available again, we plan to apply for a Research Networking Programme.
We plan to add all the presentation links to the workshop website and to start from there to establish a web group to coordinate our action.

4. Final programme

Wednesday 29 June 2011

Afternoon	*Arrival*
17.00-19.00	*Registration*
19.15	*Dinner*

Thursday 30 June 2011

08.00-08.40	*Registration*
08.45-09.05	**Welcome by Convenor** **Gerardo ADESSO** (University of Nottingham, Nottingham, United Kingdom)
09.05-10.15	**Morning Session: *Boundaries of the Quantum World***
09.05-09.40	***What is "quantum" in quantum information processing?*** **Vlatko VEDRAL** (Centre for Quantum Technologies, Singapore, Singapore)
09.40-10.15	***Can one see entanglement?*** **Nicolas GISIN** (University of Geneva, Geneva, Switzerland)
10.15-10.35	*Coffee / Tea break*
10.35-12.20	**Morning Session: *Quantum Complexity***
10.35-11.10	***Entanglement, frustration, factorization: A quantum informatic perspective on collective quantum effects*** **Fabrizio ILLUMINATI** (Università di Salerno, Salerno, Italy)
11.10-11.45	***Entanglement, frustration and complexity*** **Saverio PASCAZIO** (Università di Bari, Bari, Italy)
11.45-12.20	***What's complex in quantum optics?*** **Andreas BUCHLEITNER** (Albert-Ludwigs University of Freiburg, Freiburg, Germany)
12.20-12.55	**Presentation of the European Science Foundation (ESF)** **Morris AIZENMAN** (ESF Standing Committee for Physical and Engineering Sciences - PESC)
12.55-14.30	*Lunch*
14.30-16.50	**Afternoon Session: *Hybrid Signatures of Quantumness***
14.30-15.05	***Hybrid non-locality test in a microscopic-macroscopic system*** **Fabio SCIARRINO** (Sapienza Università di Roma, Roma, Italy)
15.05-15.40	***Quantifying, characterizing and controlling information flow in ultracold atomic gases*** **Sabrina MANISCALCO** (University of Turku, Turku, Finland)
15.40-16.15	***Macroscopic quantum resonators in space*** **Rainer KALTENBAEK** (University of Vienna, Vienna, Austria)
16.15-16.50	***Cavities and point-like systems for relativistic quantum information processing*** **Ivette FUENTES** (University of Nottingham, Nottingham, United Kingdom)
16.50-17.10	*Coffee / Tea break*
17.10-18.55	**Afternoon Session: *Quantum Transport in Many-Body and Biological Systems***
17.10-17.45	***Coherent dynamics in energy migration: subtle quantum-mechanical strategies for energy transfer optimization*** **Elisabetta COLLINI** (Università di Padova, Padova, Italy)
17.45-18.20	***Interacting ultra cold fermions in optical lattices*** **Lucia HACKERMUELLER** (University of Nottingham, Nottingham, United Kingdom)
18.25-18.55	***Strong system-environment interactions in the non-perturbative regime*** **Javier PRIOR** (Universidad Politécnica de Cartagena, Cartagena, Spain)
18.55-19.15	*Discussion*
19.15	*Dinner*

Friday 1 July 2011

08.30-10.15	**Morning Session: *Quantum Information Theory***
08.30-09.05	***Some observations on LOCC*** **Andreas WINTER** (University of Bristol, Bristol, United Kingdom)
09.05-09.40	***Quantum discord: quantification and operational meaning*** **Caslav BRUKNER** (University of Vienna, Vienna, Austria)
09.40-10.15	***Majorization and the information capacity of Bosonic Gaussian channels*** **Nicolas CERF** (Université Libre de Bruxelles, Bruxelles, Belgium)
10.15-10.35	*Coffee / Tea break*

10.35-12.55	**Morning Session: *Non-Locality and Quantum Foundations***
10.35-11.10	***The structure of multipartite correlations***
	Antonio ACIN (ICFO, Castelldefels, Spain)
11.10-11.45	***The simplicity as an axiom***
	Marcin PAWLOWSKI (University of Bristol, Bristol, United Kingdom)
11.45-12.20	***Contextuality, non-locality and quantum graphs***
	Adan CABELLO (Universidad de Sevilla, Sevilla, Spain)
12.20-12.55	***Quantum correlations "now and then" are weirder than "here and there"***
	Marco BARBIERI (Institut d'Optique, Palaiseau, France)
12.55-14.30	*Lunch*
14.30-15.00	*Discussion*
15.00-18.00	*Social trip to Newstead Abbey*
18.30	*Conference Dinner* (The Riverbank, Nottingham)

Saturday 2 July 2011

09.05-10.15	**Morning Session: *Entanglement in Multiparticle Systems***
09.05-09.40	***Entanglement in critical and topological phases***
	Anna SANPERA (Universitat Autonoma de Barcelona, Bellaterra, Spain)
09.40-10.15	***Multipartite entanglement in quantum algorithms***
	Chiara MACCHIAVELLO (Università di Pavia, Pavia, Italy)
10.15-10.35	*Coffee / Tea break*
10.35-12.55	**Morning Session: *Mesoscopic Quantum Effects***
10.35-11.10	***Large quantum superpositions and interference of massive nanometer-sized objects***
	Oriol ROMERO-ISART (Max-Planck-Institut für Quantenoptik, Garching, Germany)
11.10-11.45	***Mesoscopic non-classicality: atoms, mirrors and all that***
	Mauro PATERNOSTRO (Queen's University Belfast, Belfast, United Kingdom)
11.45-12.20	***Loophole-free Bell inequality test with threshold measurements and macroscopic states of light***
	Magdalena STOBINSKA (Max Planck Institute for the Science of Light, Erlangen, Germany)
12.20-12.55	***Cavity optomechanics in its ground state: the quantum drum***
	Tobias DONNER (ETH, Zurich, Switzerland)
12.55-14.30	*Lunch*
14.30-16.50	**Afternoon Session: *General Quantum Correlations***
14.30-15.05	***Quantum discord in quantum computation***
	Animesh DATTA (University of Oxford, Oxford, United Kingdom)
15.05-15.40	***Looking through a beam splitter to see quantum effects***
	Matteo PARIS (Università di Milano, Milano, Italy)
15.40-16.15	***Linking quantum discord to entanglement in a measurement***
	Dagmar BRUSS (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany)
16.15-16.50	***Characterizing quantumness via entanglement creation***
	Marco PIANI (Institute for Quantum Computing, Waterloo, Canada)
16.50-17.10	*Coffee / Tea break*
17.10-19.10	**Strategic discussion on follow-up activities/networking/collaboration**
19.15	*Dinner*

Sunday 3 July 2011

Morning	*Breakfast and Departure*

5. Final list of participants

1.	**Antonio ACIN**	ICFO-Institut de Ciencies Fotoniques, ES
2.	**Gerardo ADESSO**	*(Convenor)* University of Nottingham, UK
3.	**Morris AIZENMAN**	*(ESF Rapporteur)* National Science Foundation, US
4.	**Marco BARBIERI**	Institut d'Optique, FR
5.	**Caslav BRUKNER**	University of Vienna, AT
6.	**Dagmar BRUSS**	Heinrich-Heine-Universität Düsseldorf, DE
7.	**Andreas BUCHLEITNER**	Albert-Ludwigs University of Freiburg, DE
8.	**Adan CABELLO**	Universidad de Sevilla, ES
9.	**Nicolas CERF**	Université Libre de Bruxelles, BE
10.	**Elisabetta COLLINI**	Università degli Studi di Padova, IT

11.	**Animesh DATTA**	University of Oxford, UK
12.	**Tobias DONNER**	ETH Zurich, CH
13.	**Ivette FUENTES**	University of Nottingham, UK
14.	**Nicolas GISIN**	University of Geneva, CH
15.	**Lucia HACKERMUELLER**	University of Nottingham, UK
16.	**Fabrizio ILLUMINATI**	Università degli Studi di Salerno, IT
17.	**Rainer KALTENBAEK**	University of Vienna, AT
18.	**Chiara MACCHIAVELLO**	Università degli Studi di Pavia, IT
19.	**Sabrina MANISCALCO**	University of Turku, FI
20.	**Matteo PARIS**	Università degli Studi di Milano, IT
21.	**Saverio PASCAZIO**	Università di Bari, IT
22.	**Mauro PATERNOSTRO**	Queen's University Belfast, UK
23.	**Marcin PAWLOWSKI**	University of Bristol, UK
24.	**Marco PIANI**	Institute for Quantum Computing, CA
25.	**Javier PRIOR**	Universidad Politécnica de Cartagena, ES
26.	**Oriol ROMERO-ISART**	Max-Planck-Institut für Quantenoptik, DE
27.	**Anna SANPERA**	Universitat Autònoma de Barcelona, ES
28.	**Fabio SCIARRINO**	Sapienza Università di Roma, IT
29.	**Magdalena STOBINSKA**	Max Planck Institute for the Science of Light, DE
30.	**Vlatko VEDRAL**	Centre for Quantum Technologies, SG
31.	**Andreas WINTER**	University of Bristol, UK

Local organising team: Catalin Catana, Nicolai Friis, Davide Girolami, Beatriz Olmos-Sanchez (Univ. Nottingham, UK); *Admin support:* David Hawker, Jane Mason (Univ. Nottingham, UK)

6. Statistical information on participants

Total participants (excluding the ESF rapporteur): 30; of which 8 female and 22 male.

Age bracket: 30-39 (19 participants), 40-49 (10 participants), >50 (1 participant).

Countries (with number of representatives): United Kingdom (7), Italy (6), Germany (4), Spain (4), Austria (2), Switzerland (2), Belgium (1), France (1), Finland (1); Canada (1), Singapore (1).