Spontaneous Symmetry Breaking, a Memorial Conference for Robert Brout

16 to 19 January 2018
Nanyang Executive Centre, NTU
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Foreword

We would like to welcome all of you to Spontaneous Symmetry Breaking, a Memorial Conference for Robert Brout. Spontaneous Symmetry Breaking is one of the key concepts of modern fundamental physics. It permeates most basic subfields. We know that in quantum physics the dynamics are governed by the symmetries that a particular system has to respect. The more symmetries the better behaved is the system. However, we also know that the quantum systems show a great variety and spontaneous symmetry breaking is a key to understanding this. The dynamical equations need to respect the various symmetries but the ground states need not. This allows for the variety we see in the quantum world.

Robert Brout was a key person in the development of many of the subfields we will discuss during this conference, in particle physics, cosmology, statistical physics and condensed matter physics. He sadly died in 2011, two years before the Nobel Prize was given to François Englert and Peter Higgs for the Brout-Englert-Higgs mechanism. Robert Brout would have been 90 this year and the conference will celebrate his memory as well as being an exposé of the concept of spontaneous symmetry breaking and its importance at the research frontier.

We hope you will actively participate in this exciting conference!

Professor Kok Khoo Phua  
Institute of Advanced Studies  
Nanyang Technological University

Professor Lars Brink  
Chalmers University of Technology

Professor Marc Henneaux  
Université Libre de Bruxelles

Professor François Englert  
Nobel Laureate in Physics 2013
# Organising Committee

## Honorary Chair

<table>
<thead>
<tr>
<th>NAME</th>
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<tr>
<td>François Englert</td>
<td>Université Libre de Bruxelles</td>
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## Co-Chairs

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<tr>
<th>NAME</th>
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<tr>
<td>Lars Brink</td>
<td>Chalmers University of Technology</td>
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<tr>
<td>Marc Henneaux</td>
<td>Université Libre de Bruxelles</td>
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<tr>
<td>Kok Khoo Phua</td>
<td>Institute of Advanced Studies, NTU</td>
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Programme
<table>
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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>08.00 – 09.00</td>
<td>Registration</td>
</tr>
<tr>
<td>09.00 – 09.15</td>
<td>Welcome Address by:</td>
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<tr>
<td></td>
<td><strong>Kok Khoo Phua</strong> (Institute of Advanced Studies, NTU)</td>
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<td></td>
<td><strong>Lars Brink</strong> (Chalmers University of Technology)</td>
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<td><strong>Marc Henneaux</strong> (Université Libre de Bruxelles)</td>
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<tr>
<td>09:15 – 10:15</td>
<td>François Englert (Université Libre de Bruxelles)</td>
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<tr>
<td></td>
<td><em>A Story of Physics and Friendship</em></td>
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<tr>
<td>10:15 – 11:00</td>
<td>Kazuo Fujikawa (RIKEN Nishina Center)</td>
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<td><em>Spontaneous Symmetry Breaking and Bogoliubov Transformation</em></td>
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<tr>
<td>11:00 – 11:45</td>
<td>Group Photo &amp; Coffee Break</td>
</tr>
<tr>
<td>11:45 – 13:15</td>
<td>John Ellis (CERN) &amp; Peter Jenni (CERN and Albert-Ludwigs-University Freiburg)</td>
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<tr>
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<td>John Ellis: <em>BEH Boson in the Standard Model: From Speculation to Characterization</em></td>
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<tr>
<td></td>
<td>Peter Jenni: <em>The Long Journey with the LHC to Demonstrate the Brout-Englert-Higgs Mechanism</em></td>
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<tr>
<td>13:15 – 14:30</td>
<td>Lunch</td>
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### Day 1 – Tuesday, 16 January 2018

**Session Chair: Marc Henneaux (Université Libre de Bruxelles)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
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<tbody>
<tr>
<td>14:30 – 15:15</td>
<td>Édouard Brezin (École Normale Supérieure) via skype</td>
<td><em>Historical Survey of the Interplay Between Phase Transitions and Spontaneous Symmetry Breaking</em></td>
</tr>
<tr>
<td>15:15 – 16:00</td>
<td>Robin Stinchcombe (University of Oxford)</td>
<td><em>Symmetry-Breaking in Statistical Physics</em></td>
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<tr>
<td>16:00 – 16:30</td>
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<td>Coffee Break</td>
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<tr>
<td>16:30 – 17:15</td>
<td>Willy Fischler (University of Texas)</td>
<td><em>Theta QCD, Theta QED and some connection to Spontaneous Symmetry Breaking</em></td>
</tr>
<tr>
<td>18:00</td>
<td>Dinner at Peach Garden @ NTU (by invitation only)</td>
<td><strong>Dinner at Peach Garden @ NTU</strong></td>
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**Dinner at Peach Garden @ NTU**

Two-way transportation will be provided.

Please assemble at the NEC Guest Wing Lobby (Level 1) by 5.45pm.
### Day 2 – Wednesday, 17 January 2018

**Session Chair: Edward Teo (National University of Singapore)**

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<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Topic</th>
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<tbody>
<tr>
<td>09:00 – 09:45</td>
<td>Malcolm J. Perry (University of Cambridge)</td>
<td>BMS Symmetry, Scattering and Black Holes</td>
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<tr>
<td>09:45 – 10:30</td>
<td>Renata Kallosh (Stanford University)</td>
<td>Maximal Supersymmetry and Applications in Cosmology</td>
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<td>10:30 – 11:00</td>
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<td>Coffee Break</td>
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**Session Chair: Jean Orloff (Laboratoire de Physique de Clermont)**

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<tr>
<th>Time</th>
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<tr>
<td>11:00 – 11:45</td>
<td>Viacheslav Mukhanov (Ludwig Maximilian University of Munich)</td>
<td>Broken Symmetries in Cosmology</td>
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<tr>
<td>11:45 – 12:30</td>
<td>Jean-Marie Frère (Université Libre de Bruxelles)</td>
<td>The Interaction We Did Not Expect</td>
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<tr>
<td>12:30 – 13:45</td>
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<td>Lunch</td>
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**Session Chair: Serge Massar (Université Libre de Bruxelles)**

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<tr>
<th>Time</th>
<th>Speaker</th>
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<tbody>
<tr>
<td>13:45 – 14:30</td>
<td>Sidney Nagel (University of Chicago)</td>
<td>Jamming: Rigidity Between the Mechanical Extremes of Order and Disorder</td>
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<tr>
<td>15:15 – 15:45</td>
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<td>Coffee Break</td>
</tr>
<tr>
<td>15:45 – 16:30</td>
<td>Eliezer Rabinovici (The Hebrew University of Jerusalem) via skype</td>
<td>On the Phases of Gauge Theory and Gravity</td>
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<tr>
<td>17:10</td>
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<td><strong>Depart for Conference Banquet</strong></td>
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<tr>
<td>18:00</td>
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<td>Conference Banquet (by invitation only)</td>
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**Banquet at Tanglin Club**  
Two-way transportation will be provided. Please assemble at the NEC Guest Wing Lobby (Level 1) by 5.00pm.
**Day 3 – Thursday, 18 January 2018**

**Session Chair: Riccardo Argurio (Université Libre de Bruxelles)**

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<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Topic</th>
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<tbody>
<tr>
<td>09:30 – 10:15</td>
<td>Gerard 't Hooft (Universiteit Utrecht)</td>
<td><em>BEH Mechanisms for the Four Forces</em></td>
</tr>
<tr>
<td>10:15 – 11:00</td>
<td>Jean Iliopoulos (École Normale Supérieure)</td>
<td><em>SSB and the Brout-Englert-Higgs Mechanism Beyond the Standard Model</em></td>
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<tr>
<td>11:00 – 11:30</td>
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<td>Coffee Break</td>
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**Session Chair: Louis Chen (National University of Singapore)**

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<tr>
<th>Time</th>
<th>Speaker</th>
<th>Topic</th>
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<tbody>
<tr>
<td>11:30 – 12:15</td>
<td>Michael Atiyah (University of Edinburgh)</td>
<td><em>A Mathematician Takes a Radical Look at Physics</em></td>
</tr>
<tr>
<td>12:15 – 13:00</td>
<td>Yaron Oz (Tel Aviv University)</td>
<td><em>Spontaneous Symmetry Breaking, Conformal Anomaly and Incompressible Fluid Turbulence</em></td>
</tr>
<tr>
<td>13:00 – 13:45</td>
<td>Hiroshi Ooguri (Caltech)</td>
<td><em>Symmetry of Quantum Gravity</em></td>
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<tr>
<td>13:45 – 14:45</td>
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<td>Lunch</td>
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<tr>
<td>15:00</td>
<td></td>
<td><strong>Depart for Gardens By the Bay</strong></td>
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<tr>
<td>15:00 – 21:00</td>
<td>Excursion to Gardens by the Bay</td>
<td><em>Dinner @ Lau Pa Sat (free and easy)</em></td>
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The grande dame of hawker centres in Singapore, Lau Pa Sat blends history, striking architecture and scrumptious local food into one heady experience.

**Excursion to Gardens by the Bay**

Two-way transportation will be provided. Please assemble at the NEC Guest Wing Lobby (Level 1) by 2.55pm.
Day 4 – Friday, 19 January 2018

**Session Chair:** Pinaki Sengupta (School of Physical and Mathematical Science, NTU)

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<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
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<tbody>
<tr>
<td>09:30 – 10:15</td>
<td>Mikhail Shaposhnikov (École Polytechnique Fédérale de Lausanne)</td>
<td>Spontaneous Versus Explicit Breaking of Scale Invariance</td>
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<tr>
<td>10:15 – 11:00</td>
<td>Bert Halperin (Harvard University)</td>
<td>Particle-Hole Symmetry in a Partially Full Landau Level</td>
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<tr>
<td>11:00 – 11:45</td>
<td>F. Duncan M. Haldane (Princeton University)</td>
<td>Topological Order vs Broken Symmetry: A New Paradigm</td>
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<tr>
<td>11:45 – 13:00</td>
<td>Lunch</td>
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**Session Chair:** Leong Chuan Kwek (Institute of Advanced Studies, NTU)

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<th>Time</th>
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<tr>
<td>13:00 – 13:45</td>
<td>Mats Larsson (Stockholm University)</td>
<td>Symmetry Breaking and Chirality in Molecular Physics and Biology</td>
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<tr>
<td>13:45 – 14:30</td>
<td>Yun-Feng Xiao (Peking University)</td>
<td>Spontaneous Symmetry Breaking in an Ultrahigh-Q Microcavity</td>
</tr>
<tr>
<td>14:30 – 15:15</td>
<td>Philippe Spindel (Université Libre de Bruxelles &amp; Université de Mons)</td>
<td>Quantum Supersymmetric Cosmological Billiards and their Hidden Kac-Moody Structure</td>
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<tr>
<td>15:15 – 17:00</td>
<td>Light refreshments</td>
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End of Conference

*Note: All talks include 5 minutes of Question and Answers.*
Abstracts | Invited Talks
Abstract
In sufficiently low dimensions, the addition of quenched disorder to a translation invariant Hamiltonian of a system with a first order phase transition results in the elimination of the related discontinuity. This Imry-Ma phenomenon is exemplified by the random field Ising model for which the rounding occurs in two dimensions. For continuous symmetry breaking, as in the O(N) models, the rounding effect persists up to and including four dimensions. The talk will focus on the question of a possible existence at the critical dimensions of another transition, reached by varying the disorder's strength. Its manifestation would be in the decay rate of the correlation between quenched expectations, which could conceivably transition from exponential decay at high disorder to a power law at low disorder.
(The talk is based on a joint work with R. Peled).
I will ask some radical questions, which are old but should be re-visited. I will start by distinguishing between Mathematics which is in the mind, and Physics which is in the outside world.

1. What are the best mathematical models of Physics: discrete or continuous? {Plato}
2. Is there an Ether? {Maxwell}
3. Are the “Constants of Nature” constant in extreme conditions? {Dirac}

The ultimate aim of the mathematician is to fit mathematical beauty to experimental evidence {Weyl}

The ultimate aim of the physicist is to predict experimental evidence from simple mathematical models {Newton, Einstein}
Abstract
Although the competition between order and disorder was inscribed in the Boltzmann-Gibbs principles of statistical mechanics, it took many decades before it was established that they could provide an actual description of a phase transition. An underlying spontaneous symmetry breaking is not always obvious a priori. Several kinds of symmetry breaking manifest themselves according to the nature of symmetry, the presence of disorder, topological excitations, etc.
Abstract
This talk will contain two parts. The first part will review the early days of BEH phenomenology before the LHC. The second part will describe efforts to understand what ATLAS and CMS have discovered, and look for possible accompanying physics in the TeV range.
In the fall of 1959, I came to the U.S. at the invitation of Robert Brout, a professor at Cornell University (Ithaca, NY), to work with him for two years as a Research Associate. At Cornell University we sow the seeds of our lasting collaboration and of our lifelong friendship. Two years later, as I was scheduled to return to Belgium I was offered a full professorship position at Cornell University. I did not accept it and after discussions with Robert, we finally all left the U.S., Robert, his family and I, towards a permanent stay in Belgium. I will tell these adventures and how we worked together in Belgium at the Université Libre de Bruxelles (ULB). I shall show, in particular, how we were led to the discovery of the mass generation for elementary matter constituents and how we conceived a mechanism for the creation of our universe through an exponential primordial expansion, later called inflation.
Author : Willy Fischler

Affiliation : University of Texas

Title : Theta QCD, Theta QED and some connection to Spontaneous Symmetry Breaking.

Email : fischler@physics.utexas.edu

Abstract
Some of the effects produced by these parameters will be discussed.
Abstract
The unification of so-called "weak" and electromagnetic interactions, through the Brout-Englert-Higgs mechanism has shown that there was nothing "weak" there, with the W and Z couplings in fact larger than the electric one.

Meanwhile, the Scalar boson, whether fundamental or composite, has appeared as a reality, way beyond the simple auxiliary in providing gauge boson masses. Its further importance is due to the chiral structure of the Standard model, where a non-trivial agent is required to provide fermion masses. Masses have changed status, from a "fact of life" to a type of interaction. The mass sector is associated to the instability of most weakly interacting particles, and in fact what appears (as of now) as a new, really feeble, interaction orders of magnitude smaller than gauge forces.

Of its nature, we know very little, except that its couplings appear arbitrary, escaping gauge constraints.

Just as significant is the fact that the Scalar couplings break the archetypal symmetry of gauge interactions (CP or T in 4 dimensions). Such breaking is both observed at our scale, and needed at a larger level to explain the defeat of antimatter, but makes the nature of the Scalar interactions even more enigmatic in their relation to fundamental gauge theories.
Abstract
I will briefly mention a paper on the spontaneous deformation of nuclei in analogy to Higgs mechanism [1]. Personally, I have received a rare good comment from Nambu on this work. I will then discuss a nice idea of the general field theoretical formulation of the Bogoliubov transformation by Nambu and Jona-Lasinio [2], which they did not call Bogoliubov transformation explicitly. People used to think of the Bogoliubov transformation only in terms of creation and annihilation operators; and it is true that we need them, but only at the final stage. Their field theoretical formulation, although not manifestly relativistic, allows us to analyze a general class of problems and, in some cases, acts as a criterion of possible spontaneous symmetry breaking. It is also compared to a relativistic analogue of Bogoliubov transformation, which we recently used to define Majorana neutrinos in the seesaw mechanism in a consistent manner. Some details of our works on Majorana neutrinos will be discussed [3].

References:
Abstract
The classification of states of matter by broken symmetry has been enriched by the new understanding that trivial and non-trivial ground states of quantum matter may exhibit fundamental differences that can only change at (zero-temperature) transitions that do not involve any symmetry breaking. Ideas from symmetry have been blended with the classification of topological states in the notion of “symmetry-protected topological states”. Some examples will be reviewed during the talk.
Quantum Hall systems are interacting two-dimensional electron systems in a strong magnetic field. In the limit where one can neglect Landau-level mixing, there is an exact particle-hole symmetry between systems with fractional Landau-level filling fractions $f$ and $1-f$. Based on numerical calculations, it has long been believed that this symmetry is spontaneously broken in the quantized Hall state at total filling $\nu=5/2$, which is $f=1/2$ in the second Landau level. The proposed particle-hole-conjugate ground states, commonly described as the “Pfaffian” and “Anti-Pfaffian”, are topologically distinct, with edge states that have chiral central charges $K=7/2$ and $K=3/2$, respectively. However, recent measurements of the quantized thermal Hall conductance point to a value $K=5/2$, which one might expect for a particle-hole symmetric ground state, in disagreement with previous expectations. By contrast, for total filling $\nu=1/2$, which is $f=1/2$ in the lowest Landau level, no quantized Hall state is observed, and one does not expect to find broken particle-hole symmetry. However, the traditional description based on non-relativistic “composite fermions” interacting with a Chern-Simons gauge field is not explicitly particle-hole symmetric. The question, here, is how particle-hole symmetry is restored in the theory.
Author : Jean Iliopoulos

Affiliation : École Normale Supérieure

Title : SSB and the Brout-Englert-Higgs Mechanism Beyond the Standard Model

Email : Jean.Iliopoulos@lpt.ens.fr

Abstract
The phenomenon of spontaneous symmetry breaking in the presence of gauge interactions is one of the basic ingredients of the standard model in particle physics. However, the same mechanism, under various forms, appears in practically all attempts to go beyond the standard model. In this talk we shall review some of these applications with particular emphasis to supersymmetry as well as to the formulation of gauge theories in spaces with non-commutative geometry.
Abstract
Since 2010 the experiments at the Large Hadron Collider (LHC) at CERN investigate particle physics at the highest collision energies ever achieved in a laboratory. The highly mediated discovery of the scalar boson H predicted by the Brout-Englert-Higgs mechanism, announced in July 2012, was the result of a long and fascinating story at the LHC. Building up the experimental programme with this unique high-energy collider, and developing the very sophisticated detectors built and operated by world-wide collaborations, meant an incredible scientific and human adventure, spanning more than three decades. The first part of this talk will recall the history of this project and illustrate some of the many milestones that finally led to the H discovery by the ATLAS and CMS collaborations 5 years ago with data collected at 7 and 8 TeV proton-proton collision energies. In the second part, the focus of the talk will shift to new results, including also very recent analyses from the ongoing 13 TeV run of the LHC. These concern both improved measurements of the fundamental properties of the H boson as well as examples of searches for physics beyond the Standard Model.
Abstract
We will discuss fundamental theories with maximal supersymmetry: M-theory, Superstring theory and maximally extended supergravity and their symmetries. Some of these symmetries play an important role in improved ultraviolet behaviour of extended supergravities. When maximal supersymmetry is spontaneously broken to minimal supersymmetry we deduce phenomenological models interesting for observational cosmology. These models, called alpha-attractor models, are in good agreement with CMB observations, and provide targets for future satellite missions designed for detection of primordial gravitational waves.
Abstract
The discovery in 1848 of molecular chirality by a young Louis Pasteur was one of his most important but maybe least well-known discoveries. A molecule is said to have chirality if it cannot be superimposed on its mirror image. The concept of chirality was instrumental in establishing the tetrahedral valencies of the carbon atom, and plays a key role in chemistry and biology (and to an increasing degree in physics in different circumstances). The breaking of mirror symmetry in the molecular basis of life (left-handed amino acids, right-handed sugars) was attributed by Pasteur to “dissymmetry of cosmic forces”. Instead of being an exhausted topic, the origin of homochirality remains one of the principal unsolved problems in the natural sciences.

Chiral molecules possess identical properties unless when interacting with a chiral system, such as circularly polarized light or other chiral systems in the gas or condensed phase. The interaction with circularly polarized light is well understood, whereas the interaction of chiral molecules with other chiral molecules are based on a phenomenological three-point rule, marginally more sophisticated than playing with left-handed and right-handed fingers. Our attempts to address chiral-chiral interaction in simple physics experiments will be described in the talk.
Author: Viatcheslav Mukhanov

Affiliation: Ludwig Maximilian University of Munich

Title: Broken Symmetries in Cosmology

Email: Viatcheslav.Mukhanov@physik.uni-muenchen.de

Abstract

To be announced.
Abstract

Solids are typically described in terms of perturbations about perfect crystalline order. Such an approach takes us only so far: a glass, another ubiquitous form of rigid matter, cannot be described in any meaningful sense as a defected crystal. Is there an opposite extreme to a crystal – a solid with complete disorder – that forms an alternative starting point for understanding rigidity in matter? Jamming is a transition into a solid that is the epitome of disorder and thus offers an alternate limit from which one can attempt to describe solids. At the jamming transition, there is no lengthscale on which the system can be averaged to regain elasticity. Moreover, the physics at the jamming transition dominates the behavior of solids with surprisingly high order. This transition represents an opposite, disordered, pole from the perfect ordered crystal and provides an organizing structure for understanding the mechanical properties of solids over the entire spectrum of disorder.
Abstract
Although predictions of quantum gravity are typically at extremely high energy, consistency in high energy can lead to non-trivial constraints on its low energy effective theory. Because of the unusual ultraviolet behavior of gravitational theory, the standard argument for separation of scales may not work. In this talk, I will focus on the constraints on symmetry in consistent quantum theory of gravity – in particular, the type of allowed symmetry and its representations in the spectrum. I will also discuss the weak gravity conjecture, which gives a lower bound on Coulomb-type forces relative to the gravitational force, and consequences of the conjecture. I will demonstrate the uses of the holographic principle and information theoretical techniques in deriving these results.
Abstract
We propose an effective CFT description of steady state incompressible fluid turbulence at the inertial range of scales in any number of spatial dimensions. We derive a KPZ-type equation for the anomalous scaling of the longitudinal velocity structure functions and relate the intermittency parameter to the boundary Euler conformal anomaly coefficient. The proposed theory consists of a mean field scale invariant theory that exhibits Kolmogorov linear scaling (K41 theory) coupled to a dilaton CFT. The dilaton is a Nambu-Goldstone gapless mode that arises from a spontaneous breaking due to the energy flux of the separate scale and time symmetries of the inviscid Navier-Stokes equations to a K41 scaling with a dynamical exponent $z=2/3$. The dilaton acts as a random measure that dresses the K41 theory and introduces intermittency. We discuss the two, three and large number of space dimensions cases and how entanglement entropy can be used to characterize the intermittency strength.
Abstract
BMS (Bondi-Metzner-Sachs) symmetry is a gravitational symmetry to be found in asymptotically flat spacetimes. It has analogues in electromagnetism and Yang-Mills theories. It has been realised that these symmetries lead to an infinite number of conservation laws in scattering processes. BMS symmetry is broken by these charges resulting in the photon and the graviton as the Goldstone bosons of this broken symmetry. These charges also can be defined on the horizons of black holes and give hints as how one might go about resolving the black hole information paradox.
Abstract
We will discuss the very different possible Physics manifestations of systems governed by local and space time symmetries. The role of the identification of the possible relevant degrees of freedom in determining the Phases of the system will be highlighted.
I will confront different ways the scale invariance can be broken in quantum field theory and discuss quantum scale invariant effective theories of particle physics and gravity and their relevance to the hierarchy problem.
Abstract
One of the key challenges of gravitational physics is to understand the fate of spacetime at spacelike (cosmological) singularities, such as the big bang singularity that gave birth to our universe. A novel way of attacking this problem has been suggested a few years ago via a conjectured correspondence between various supergravity theories and the dynamics of a spinning massless particle moving on an infinite-dimensional Kac–Moody coset space. Evidence for such a supergravity / Kac–Moody link emerged through the study à la Belinskii–Khalatnikov–Lifshitz of the structure of cosmological singularities in the string theory and supergravity, in various space- time dimensions, up to 11. It was found that, for the bosonic sector of eleven dimensional supergravity most of the degrees of freedom freeze, excepted the diagonal components of the metric which undergo at each point a chaotic billiard motion, in a cell of the hyperbolic space, equivalent to a conical polyhedron in a 10-D Lorentzian space, that can be identified with the Weyl chamber of E(10). During this talk I will discuss D=4 supergravity, and thus pass from E(10) to AE(3). The hidden rôle of E(10) in the dynamics of maximal supergravity was confirmed to higher approximations (up to the third level) in the gradient expansion of its bosonic sector. In addition, the study of the fermionic sector of supergravity theories has exhibited a related rôle of Kac–Moody algebras. At leading order in the gradient expansion of the gravitino field, the fermionic dynamics at each spatial point was found to be given by parallel transport with respect to a (bosonic-induced) connection taking values within the compact sub-algebra of the corresponding bosonic Kac–Moody algebra. However, the latter works considered only the terms linear in the gravitino, and, moreover, treated the fermionic degrees of freedom as a “classical” (i.e. Grassman-valued) fermionic field. The aim of my talk will be to clarify the occurrence of hidden Kac–Moody structures in simple supergravity, within a setting which goes beyond the previous works both by being fully quantum, and by taking completely into account the crucial nonlinearities in the fermions that
allow supergravity to exist. To simplify the cosmological dynamics, we work within a
supersymmetric mini-superspace model, namely a Bianchi IX one. Although the quantum
time of supersymmetric mini-superspace models has attracted the interest of many authors,
it is, in our knowledge, for the first time that a complete description of all the physical states of
the supersymmetric Bianchi IX model. The quantization of the homogeneous gravitino field
leads to a 64-dimensional fermionic Hilbert space. We focus on the 15- and 20-dimensional
subspaces (with fermion numbers NF = 2 and NF = 3) where there exist propagating solutions
of the supersymmetry constraints that carry (in the small-wavelength limit) a chaotic spinorial
dynamics generalizing the Belinskii–Khalatnikov–Lifshitz classical “Öscillatory” dynamics. In
particular, it shows that the quantized contribution of the terms quartic in the Fermions
generically leads to an avoidance of the zero-volume singularity, i.e. to a cosmological bounce
at level NF = 2. On the other hand, by exactly solving the supersymmetry constraints near
each one of the three dominant potential walls underlying the latter chaotic billiard dynamics,
we compute the three operators that describe the corresponding potential-wall reflections of
the spinorial state describing the quantum evolution of the Universe. It is found that the latter,
purely dynamically-defined, reflection operators satisfy generalized Coxeter relations which
define a type of spinorial extension of the Weyl group of the rank-3 hyperbolic Kac–Moody
algebra AE(3).

References
[arXiv:1406.1309 [gr-qc]]
[2] Quantum Supersymmetric Cosmological Billiards and their Hidden Kac-Moody Structure, e-
Print: [arXiv:1704.08116 [gr-qc]]
The talk will begin with a brief appreciation on the part of Robert Brout's many pioneering contributions to statistical physics which concern especially phase transitions and symmetry breaking in classical and quantum cooperative thermal systems. The work ranged from pure to disordered generalisations including the spin glass, and provided a basis and stimulus for a vast range of subsequent advances.

The talk will go on to outline a limited and interrelated selection from these, including ones we have worked on.

Among them are quantum models with zero temperature transitions equivalent to classical ones in higher dimension. Another class are geometric models having "cluster" equivalences to thermal ones. The simplest of these, percolation, provides the easiest example of scaling and renormalisation group procedures for critical behaviour.

Finally, non-equilibrium phase transitions will be introduced, starting with a simple driven exclusion model with surprisingly rich behaviour. Its generalisations provide nice examples of symmetry breaking, and have been used to describe a wide range of phenomena from things such as vehicular and other traffic to game theory and financial markets.
Abstract
Besides the electroweak forces, the BEH mechanism also figures in the strong force and in gravity, even in different ways. We will recount about the dual BEH mechanism and the conformal BEH mechanism. Thus an idea, once thought to be esoteric and not really relevant for physics, now finds numerous peculiar applications.
Abstract
Spontaneous symmetry breaking is a ubiquitous property in nature and diverse fields of modern physics. However, such symmetry breaking has been elusive experimentally in the optical systems, which usually demand multiple identical subsystems. We experimentally demonstrate spontaneous symmetry breaking in a single whispering-gallery microcavity without any explicit breaking of parity or time-reversal symmetry. Above a threshold power, the intensities of clockwise and counter clockwise propagating waves in a cavity grow unbalanced, which is induced by the Kerr-nonlinearity-modulated coupling between the counter-propagating waves.
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Conference on The Transient Universe

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Cosmic Fireworks: Supernovae, Gamma-Ray Bursts, Fast Radio Bursts, Tidal Disruption Events and Compact Binary Mergers are at the focus of interest today. These are typically multi-messenger events that emit in various channels, ranging from radio to gamma-rays and from neutrinos to gravitational waves. Our understanding of these transient phenomena has advanced greatly in the last years and great expectations are for the next decade when new-dedicated observatories will get on line.

The conference will discuss observations of these events by different detectors, ranging from LIGO/Virgo to IceCube and Auger, radio and optical telescopes and high-energy satellites. It will also explore their modeling focusing in particular on theoretical interlinks and relations between the mechanism driving the different transient phenomena.

Please click here to register early by 31 January 2018 to enjoy the discount!

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The Conference on Particles and Cosmology will be held at the Nanyang Executive Centre from 5 to 9 March 2018 at NTU, Singapore.

About 14 billion years ago our Universe was created by a big explosion, the “Big Bang”. In this explosion the matter in our Universe as well as space and time were created. The matter was a plasma of quarks, gluons, photons, electrons and neutrinos. The dynamics of those particles is described by the Standard Theory of Particle Physics. Thus Cosmology and Particle Physics are strongly correlated. New discoveries in Particle Physics, e.g. the discovery of the masses of the neutrinos, change Cosmology, and new discoveries in Cosmology, e.g. the dark matter or dark energy in the Universe, will be important for Particle Physics.

The Standard Theory of Particle Physics describes very well the electroweak and the strong interactions, but it is still unclear, how the gravitational interaction can be included.

Important for Cosmology are the dark matter and the dark energy in the Universe. It is still unknown, what is behind the dark matter. It might be provided by a new neutral particle. Also it remains unclear, why there is a dark energy, which generates the acceleration of the expansion of our Universe. Important for Cosmology are in particular the neutrino masses, which might be Majorana masses. Thus far we do not understand the origin of the very small neutrino masses, the pattern of the lepton flavor mixing and the connection between the cosmological matter-antimatter asymmetry and the CP-violation.

These and related problems of Cosmology and Particle Physics will be discussed at the conference.
The world around is very complex with an enormous variety in phenomena. How can we ever dream of finding fundamental laws that describe these phenomena and still be comprehensible?

One important ingredient for this is the concept of spontaneous symmetry breaking, whereby the ground-state of the physical system does not show regularities but the underlying fundamental equations do. Understanding the symmetries of the systems often defines the possible fundamental laws which can then be formulated. The solutions where the symmetry is then spontaneously broken can then show great varieties.

This concept occurs in many of the fundamental fields of physics. In particle physics it is the mechanism by which the fundamental particles gain their masses. In cosmology and in statistical physics it triggers the phase transitions which explains why our universe is so homogeneous and how matter can change phases. In condensed matter it explains for example phenomena like magnetism.

This meeting is a tribute to Robert Brout who would have been 90 this year and who gave significant contributions in all these fields. Unfortunately he passed away just a few years before the Nobel Prize was awarded to his long-time collaborator François Englert with whom he shared so many of these results.

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