MI12: Gauge and String Theories

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1 Research Activity

The topics covered in 2010 are related to current issues in the theory of elementary particle interactions and of the theory of the gravitational force and interrelations among them. The main research activities in this period focused along different directions, within the broad field of High-Energy Theoretical Physics: study of the intriguing, recently established black-hole/qubit correspondence; study of algebraic and group-theoretical aspects of the Attractor Mechanism, with particular emphasis on the multi-center solutions and their split flow dynamics and marginal stability phenomena; study of general, group-theoretical and mathematical issues in the (extended) supersymmetric theories of supergravity; study of the embedding of inflationary cosmological dynamics into N=1 supergravity, with special emphasis on the recently proposed Higgs inflation within the NMSSM. We studied black hole entropy, flat directions and higher derivatives, as well as Quantum Special Kaehler Geometry. We studied also N=4 supersymmetric mechanics in multi dimensions.

Most of the ongoing research deals with supersymmetric field theories and supergravity, the latter as a low energy approximation of quantum gravity (superstrings or M theory). Emerging aspects in the physics of extremal black holes are flow equations for scalar fields in single-center and double-center solutions and relative attractor and split attractor flows. Stability and decays of BH composites depend on wall crossing through walls of marginal stability. These issues are studied extending the marginal stability formulae to N=8 supergravity. A generalized mirror symmetry for seven-manifolds has been introduced. Self-mirror theories correspond to theories with vanishing on shell trace anomalies and enjoy milder quantum corrections. Different aspects in the classifications of classical and quantum (discrete) charge orbits for extremal black holes (in 4 and 5 dimensions) have been studied, together with the description of the fake superpotential for small black holes. General fake superpotentials connecting 4D spherical to 5D spinning BH have been investigated. Inflationary cosmological supergravity models with Higgs generated inflation have been also studied. In these models, an important role is played by superconformal symmetry.

Furthermore, we studied thermodynamic geometric methods and State-space Manifold to describe rotating black holes, Black Strings, Black Rings and Hawking radiation. We discussed further the properties of Black Branes in string theory and M-Theory, and thereby took an account of the microscopic viewpoint and statistical correlations for the spherical and non-spherical horizon configurations in D=5. We studied statistical correlations, quark number susceptibilities for the hot Quantum chromodynamics and extended our examinations for the stability of quarkonium bound states. The former investigation was communicated to the Conference on Quark confinement and the hadron spectrum QCHS IX, Madrid last summer, whereas the latter one has been accepted as an oral presentation which was given at The Symposium on Prospects in the Physics of Discrete Symmetries organized by the Physics Department of "Sapienza" University of Rome, and by INFN (Istituto Nazionale di Fisica Nucleare) in December 2010. Apart from the latter work in the High Energy Physics, our contribution in 2010 has been extended towards the low energy scientific applications of Riemannian geometry.

In the past year we have also studied a class of supersymmetric spinning particle models derived from the radial quantization of stationary, spherically symmetric black holes of four dimensional N=2 supergravities. These spinning particles move in quaternionic Kahler manifolds and the quantized models are gauge invariant field theories with fields equaling sections of special

quaternionic vector bundles. Moreover we have also proposed a new approach to study four dimensional gravity recasting it in terms of six dimensional quantum mechanics by melding the two times and "tractor" approaches. In the past year we have also computed the transition amplitude for a relativistic O(N) extended fermionic particle in curved space, and we computed the counterterm by using different renormalization schemes.

In the future we intend to extend the results obtained in the past year in many directions. First of all, noting that a quaternionic Kahler space can be thought as the base manifold on a hyper Kahler cone, we would like to reinterpret ghost coordinates of the quaternionic Kähler spinning particles as the extra coordinates one needs to uplift the model from the 4d dimensional base to the 4(d+1) dimensional cone; we intend also to analyze the reduction from the hyper Kähler cone to the 4d+2 dimensional twistor space. Another interesting project we are developing, is related to the well known AdS/CFT correspondence. We are trying, in fact, to use tractor technique to calculate holographic anomalies as well as partially massless higher spin fields in ADS manifold.

In 2011, particular attention will be devoted to the cross-fertilizing nature of the black-hole/qubit correspondence, at the edge between supergravity Physics and Quantum Information Theory, and the many unsolved issues within the multi-center black p-brane dynamics. The physics of 4D- multicenter black holes is planned to be further studied with special emphasis to a combined horizontal-duality symmetry, introduced recently, which is expected to classify these more general BH solutions with split-attractor flow. Supergravity flux compactifications and supersymmetry breaking in particle physics will be further investigated.

For 2011, we also wish to continue research application of the Riemannian geometry in the directions including (1) black holes in string theory, M-theory and F-theory; (2) hot QCD, quantum field theories, (3) electrical engineering, (4) condensed matter physics and (5) stability properties of topological black holes in arbitrary Yang-Mills theories. At this juncture, we have communicated two papers on black holes physics for their publication and one conference proceeding is to be published in a special volume of Journal of Physics: Conference Series. During the forthcoming period, we shall continue state-space geometry, black hole physics, non-perturbative properties of QCD, non-linear sigma models, gauge theories, moduli space manifolds and their update applications.

Active collaborations include: JINR-Dubna Russia, Imperial College London, Leuven, Annecy, UCLA, UC Berkeley, Stanford University, Univ. Hannover Germany, Turin Polytechnic Italy, CERN, Switzerland Annecy, LAPTH France, Valencia Univ. Spain.

We also organized, between 2005 and 2009, four Schools on topics within MI12, with the participation of fair amount of MI12 collaborators, both as lecturers and as students. We published in 2010 the fourth volume containing the lecture notes of the recently held School on Attractor Mechanism SAM2007, 18 - 22 June 2007 - INFN-Laboratori Nazionali di Frascati, http://www.lnf.infn.it/conference/sam2007, with the title: The Attractor Mechanism, Proceedings of the INFN-Laboratori Nazionali di Frascati School 2007 Series: Springer Proceedings in Physics, Vol. 134, Bellucci, Stefano (Ed.) 2010, X, 346 p., ISBN 978-3-642-10735-1 (print), 978-3-642-10736-8.

2 List of Conference Talks

1. S. Ferrara, invited speaker at the UCLA conference on "Supersymmetry in Mathematics and Physics" (Feb. 2010) delivering a talk on "Black Holes and first order flow in Supergravity".

2. S. Ferrara, invited speaker in the 2010 Erice School for Subnuclear Physics, 48th course (August 2010), lecturing on "Perturbative and non-perturbative aspects of N=8 Supergravity" (contribution to the proceedings by S. Ferrara and A. Marrani in preparation) and at the Singapore Conference (Feb. 2010) in honour of Murray Gell-Mann's 80th birthday with a

speech on "Black Holes and Attractors in Supergravity" arXiv:1009.4175 A. Ceresole and S. Ferrara contribution to the Proceedings.

3. S. Ferrara, invited lecturer at the LACES school (GGI Florence, Dec. 2010), lectures on "Introduction to Black Holes Physics".

4. S. Ferrara, invited speaker at the Abdus Salam Center for Theoretical Physics at the Conference for ICTP's Dirac Medal of 25th Anniversary (November 2010).

5. B.N. Tiwari, Statistical Fluctuation and Black Holes in Strings and M-Theory, INFN, Laboratori Nazionali di Frascati, Roma, Italy (26/10/2010).

6. B.N. Tiwari, Statistical Fluctuation and Black Holes in String Theory, String Theory Group, INFN & Physics Department, University of Rome Tor Vergata, Roma, Italy (11/10/2010).

7. B.N. Tiwari, Correlations, Stabilities and Black Holes in String Theory and M-Theory, Department of Physics, Indian Institute of Technology Kanpur, India (18/05/2010).

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10. State-space Manifold and Rotating Black Holes, Stefano Bellucci, Bhupendra Nath Tiwari, [JHEP 1101:118, 2011]. e-print: arXiv:1010.1427 [hep-th].

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