

Emiliano Imeroni - Statement of Research Interests

My research interests lie in string theory and quantum field theory. I have mainly been interested in the *gauge/string theory correspondence*, that holographically relates a higher-dimensional string theory – a theory of gravity – to a lower-dimensional non-gravitational quantum field theory, opening new perspectives on both of them, and in particular on the strong coupling regime of the field theory.

Quantum field theory is at the core of the current understanding of microscopic physics, in the fields of elementary particles and condensed matter systems, and the focus of my research has been the study of quantum field theory making use of different concepts and tools drawn from the arena of string theory, supersymmetry and supergravity, with the ultimate aim of finding applications of the gauge/string correspondence to *experimentally accessible real-world physical systems*.

Most of my early research has been devoted to the study of generalizations of the gauge/string correspondence to *gauge theories of more direct phenomenological interest* with respect to $\mathcal{N} = 4$ Super Yang-Mills theory, the theory involved in the best known example of the duality. Since $\mathcal{N} = 4$ Super Yang-Mills is very far from providing a description of real-world elementary particles, due to its conformal invariance and high degree of supersymmetry, I have studied the duality for less supersymmetric and/or non-conformal gauge theories.¹

In particular, I considered three-dimensional non-conformal gauge theories with eight preserved supercharges via classical solutions describing fractional and wrapped D-branes, recovering the running coupling constant and metric on the moduli space.² Then, I concentrated on $\mathcal{N} = 1$ supersymmetric gauge theories, extracting the the all-loop β -function of pure $\mathcal{N} = 1$ Super Yang-Mills theory from the warped deformed conifold solution by Klebanov and Strassler, including a prediction for non-perturbative contributions,³ and constructing a dual supergravity realization of $\mathcal{N} = 1$ Super QCD by means of fractional branes, deriving its classical moduli space and non-perturbative effective superpotential from a dual geometric perspective.⁴

Moreover, I have been interested in “orientifold field theory”, an $SU(N)$ gauge theory which reduces to ordinary QCD for $N = 3$, but is equivalent to $\mathcal{N} = 1$ Super Yang-Mills theory at large N : mass ratios and the ratio between the domain wall tension and the value of the quark condensate were estimated using a type 0' string theory construction.⁵

I also considered extended objects in the gravity dual of the “ β -deformed” $\mathcal{N} = 1$ superconformal gauge theory, which is obtained as a marginal deformation of $\mathcal{N} = 4$ Super Yang-Mills, finding D-brane probes describing giant gravitons and Wilson loops and identifying new states that appear at special values of the deformation parameter.⁶

More recently, my study of the gauge/string duality has shifted towards *applications to condensed matter physics*. Quantum critical systems, which are relevant for instance to the physics of unconventional superconductors and gases of trapped cold atoms, are described by strongly coupled conformal field theories and are thus amenable to the study by means of holographic methods.

In this context, I have introduced the marginal β -deformation of the three-dimensional $\mathcal{N} = 6$

¹Some of my research in this direction is reviewed in E. Imeroni, *The gauge/string correspondence towards realistic gauge theories*, based on Ph.D. thesis, [hep-th/0312070](#)

²P. Di Vecchia, H. Enger, E. Imeroni and E. Lozano-Tellechea, *Gauge theories from wrapped and fractional branes*, Nuclear Physics B **631**, 95 (2002), [hep-th/0112126](#)

³E. Imeroni, *On the $\mathcal{N} = 1$ β -function from the conifold*, Physics Letters B **541**, 189 (2002), [hep-th/0205216](#)

⁴E. Imeroni and A. Lerda, *Non-perturbative gauge superpotentials from supergravity*, JHEP **0312**, 051 (2003), [hep-th/0310157](#)

⁵A. Armoni and E. Imeroni, *Predictions for orientifold field theories from type 0' string theory*, Physics Letters B **631**, 192 (2005), [hep-th/0508107](#)

⁶E. Imeroni and A. Naqvi, *Giants and loops in β -deformed theories*, JHEP **0703**, 034 (2007), [hep-th/0612032](#)

Chern-Simons-matter theory living on multiple M2-branes on an orbifold of M-theory. I have derived its gravity dual and studied its moduli space by means of brane probes.⁷

I also derived a charged black hole solution with Schrödinger asymptotic symmetry, dual to a non-relativistic theory at finite temperature with an R-charge chemical potential, that admits an extremal limit. Thermodynamic and transport properties of the solution were studied in view of possible applications to the study of Fermi surfaces in non-relativistic conformal field theories.⁸

I have also been interested in extensions of the duality *beyond the supergravity approximation*, through the study of strings in a plane-parallel wave background with a compact space-like circle,⁹ and in the *non-critical $c = 1$ string theory* in two-dimensions, mainly viewed as a useful toy model for a better understanding of the open/closed string duality.¹⁰

My current and future research will be centered on extending the directions presented above, aiming towards the holographic description of experimentally testable physical systems.

1. *Applications of the duality to condensed matter systems.* I plan to use holographic techniques to understand novel regimes of condensed matter systems, in particular of three-dimensional systems that exhibit superfluidity, superconductivity and condensation and have descriptions in terms of conformal field theories. Specific topics I will concentrate on include:

- The holographic study of Fermi surfaces in non-relativistic many body systems at finite $U(1)$ charge density, with the aim of understanding quantum liquids via the careful study of extremal black holes geometries with asymptotic Schrödinger isometry in supergravity.
- The construction of holographic duals of non-relativistic superfluids and superconductors, via black hole solutions including a field whose expectation value encodes the condensate that breaks the $U(1)$ charge symmetry in the superfluid phase, a crucial step towards the description of fermions at unitarity in the gauge/string correspondence.
- A deeper study of the phase structure of non-relativistic field theories, by constructing black hole solutions in the dual geometry that asymptote to Schrödinger space-time written in the global patch of coordinates.
- The holographic study of inhomogenous and crystalline phases of superconductors.

2. *Applications of the duality to elementary particle physics.* The description of QCD, the theory of strong interactions, via string theory is still a hard challenge, mainly because of the inherent difficulty of treating string theory in a Ramond-Ramond background. Recent progress has been made by considering a “hybrid” dual model that combines the expertise acquired through the gauge/string correspondence with more direct inputs coming from phenomenology. I would like to enhance the range of application of such “hybrid” dual model in the following directions:

- The inclusion of flavors of fundamental fermions at a full dynamical level. This will allow to go beyond pure Yang-Mills theory and to achieve a hybrid dual model of QCD.
- The use of the hybrid model to study zero- and finite-temperature properties of QCD with fundamental flavors of quarks, with particular attention to real-time properties such as transport coefficients that are inaccessible to alternative techniques such as lattice QCD.

⁷E. Imeroni, *On deformed gauge theories and their string/M-theory duals*, JHEP **0810**, 026 (2008), [arXiv:0808.1271](#) [[hep-th](#)]

⁸E. Imeroni and A. Sinha, *Nonrelativistic metrics with extremal limits*, JHEP **0909**, 096 (2009), [arXiv:0907.1892](#) [[hep-th](#)]

⁹M. Bertolini, J. de Boer, T. Harmark, E. Imeroni and N. A. Obers, *Gauge theory description of compactified pp-waves*, JHEP **0301**, 016 (2003), [hep-th/0209201](#)

¹⁰S. Alexandrov and E. Imeroni, *$c = 1$ from $c < 1$: Bulk and boundary correlators*, Nuclear Physics B **731**, 242 (2005), [hep-th/0504199](#)