Spacetime Physics

1. Analogue Gravity in Dielectric Media.

Analogue gravity consists in all those approaches whose aim is to reproduce in laboratory, as faithfully as possible, some classical or quantum realisations of nontrivial phenomena involving gravity and that usually cannot tested in the real gravitational situation. Its origin can be identified with a paper by W. Unruh, who in 1981 proved that the linear perturbations of the steady flow of a perfect barotropic fluid are perfectly described by the relativistic wave equation of scalar field on a nontrivial curved spacetime background, whose precise geometry is determined by the exact unperturbed configuration. In particular, event horizons can be generated by allowing the fluid to pass from subluminal to superluminal regimes. Quantising the linearised perturbation one thus expects the analogue of the Hawking radiation phenomenon in presence of horizons. Indeed, Hawking effect is the prototype of object of study in analogue gravity, since it has no hope of being detected in astrophysical observations. This is not however the only one, and a plethora of other possible effects can be considered, including classical and quantum effects in cosmological models. Moreover, from 1981 up to now, several different analogue system have been introduced, for example in BEC, in condensed matter systems, and so on.

Reference papers

[1] F. Belgiorno, S. L. Cacciatori, F. Dalla Piazza and M. Doronzo, *Hopfield-Kerr model and analogue black hole radiation in dielectrics,* Phys. Rev. D **96** (2017) no.9, 096024.

[2] M. Tettamanti, S. L. Cacciatori and A. Parola, "Quantum quenches, sonic horizons and the Hawking radiation in a class of exactly solvable models," Phys. Rev. D **99** (2019) no.4, 045014.

2. Black Holes in Supergravity, Attractors and AdS/CFT.

Black holes in supergravity and in quantum gravity theories represent more than simply particular solutions of the (classical) equations of motion, since, at least as a residual supersymmetry is left unbroken, they provide perturbatively stable solutions around which testing quantum and/or stringy corrections, verifying the AdS/CFT correspondence, holography and so on. In this context we are interested in looking for complete classifications of BPS solutions in $N = 2$, $D = 4$ supergravity theories, as well as studying the attractor mechanism for black holes in supergravity theories, including exceptional (magic) supergravities and gauged supergravities. In particular, we are interested in determining supersymmetric black holes in AdS_4, with non constant scalar fields, for various choices of the scalar potential. This is particularly interesting in relation with the attractor mechanism in gauged supergravity. In this case, indeed, one can show the presence of flat directions in the black hole potential so that, differently from the ungauged case, the moduli on the horizon are not completely specified by the charges. Still, the entropy remains fixed by the charges.

Reference papers

[1] S. L. Cacciatori, D. Klemm, D. S. Mansi, E. Zorzan, "All timelike supersymmetric solutions of N=2, D=4 gauged supergravity coupled to abelian vector multiplets," JHEP 0805:097,2008.

[2] Sergio L. Cacciatori and Dietmar Klemm, "Supersymmetric AdS_4 black holes and attractors," JHEP01(2010)085.

3. String theory.

In Como we consider different mathematical aspects of string theory. A formulation of super string theory based on first principles is still lacking. In particular, after several years of intensive effort, perturbative calculations in string theory have been systematically realised only up to genus two. The reason is that the geometry of the moduli space of super Riemann surfaces (underlying the stringy geometry) is far to be trivial, as it has been shown in a recent paper by R. Donagi and E. Witten. This has originated new ferment in studying super geometry from a rigorous viewpoint. We are interested in this line of research.
A second direction, not unrelated to the first one, regards homological mirror symmetry. A possible way to unify these two questions is the tentative of defining the super analogue of the Calabi-Yau manifolds and to extend the mirror symmetry tools to such new class of manifolds.
Finally, we are interested in some deep mathematical question related to path integral formulation of super string theory.

Reference papers

[1] S. L. Cacciatori, F. Dalla Piazza, B. van Geemen, "Modular Forms and Three Loop Superstring Amplitudes," Nucl.Phys.B800:565-590,2008.

[2] S. L. Cacciatori, M. Compagnoni and S. Guerra, "The Physical Mirror Equivalence for the Local P^2," Commun.Math.Phys. **333** (2015) 1, 367-388.

[3] S. L. Cacciatori, S. Noja and R. Re, *Non Projected Calabi-Yau Supermanifolds over* $\mathbb{P}^2$*,* arXiv:1706.01354 [math.AG].

[4] S. L. Cacciatori and B. Güneysu, *Odd characteristic classes in entire cyclic homology and equivariant loop space homology,* arXiv:1805.07449 [math.KT].

4. Lie Groups and their Applications to Physics.

Unavoidably, Lie algebra and Lie groups play fundamental roles essentially everywhere in physics. In most cases the properties of the algebra are sufficient to what concern the applications of interest. Nevertheless, there are cases where the knowledge of explicit realisations of the group is necessary, including a simple characterisation of the range of parameter for covering the group just once. I started my project on Lie groups as a commission required by people working on lattice QCD numerical simulations, who needed explicit parameterisations of exceptional Lie groups, but met the problem that fixing the correct range of parameters numerically was excessively time and memory consuming for computers, so slowing down the successive application. We developed ways of producing explicit Euler parametrizations of all compact Lie groups suitable for application to gauge theories and gravitational theories.

Reference papers

[1] S. L. Cacciatori, F. Dalla Piazza, A. Scotti, “Compact Lie groups: Euler constructions and generalized Dyson conjecture,” Trans. Am. Math. Soc. 369 (2017), no. 7, 4709-4724