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Position: Post-Doc ICRA-br, CBPF, Brasil
Period covered: 25/10/2010 – 19/11/2010

I. Scientific Work

At this moment I am specially interested in the connection between effective metrics and Newtonian mechanics. As was shown by W. R. Hamilton - when he was trying to formalize optics in the same way that Lagrange formalized mechanics - it is possible to map a given mechanical system in an optical one by means of the optical-mechanical analogy. According to this analogy, there exist a formula that relates a given potential in the mechanics of point particles to an index of refraction in geometrical optics. In this way the trajectory of light rays inside a material can be univocally mapped in the trajectory of particles in Newton's mechanics. I am studying how a geometrization procedure of these trajectories can be made in terms of effective geometries and effective null geodesics. The correlation between this study and the study of analogue models of gravitation is being made in this period in ICRAnet Pescara.

Furthermore, I have interests in the study of propagation properties in the context of nonlinear classical field theory. As in the last year, the problem is being investigated from the differential, and algebraic points of view. The mechanism of the effective metric correlates all these properties in a very powerfull and elegant framework that I am formalizing and studying in details. This is because in a nonlinear context the causal structure of the field does not coincide with the Minkowskian one anymore i.e. the rays of radiation cannot be identified with the geodesics of Minkowski space-time. Neverthless, it is possible to show, from the study of the characteristics of the equations, that exists an effective Riemannian manifold in wich the null geodesics coincide with the trajectories of the nonlinear excitations.

Special emphasis is being given to the causal structure of nonlinear electrodynamics theories. This is because it is exactly the linear nature of Maxwell´s electrodynamics that determines the causal structure of the relativistic spacetime we think we know well. In nonlinear electrodynamics the situation is not so simple. These theories, although clearly formulated in a Lorentz covariant fashion do not admit, in general, a special velocity associated to the excitations that has an invariant meaning. In general the velocity of the high energy perturbations depends on the direction, magnitude and nature of the external electromagnetic field in which it propagates. Our studies show, for instance, that the propagation of the waves in a null electromagnetic background is entirely different from the propagation in backgrounds where the electromagnetic invariants do not vanish. Furthermore, because the orientation of the characteristics in spacetime is field dependent, we do not have the same light cone for all points, i.e. the propagation is not isotropic in general. To understand such features i developed a classification of propagation properties of nonlinear electrodynamics based on local properties of the effective metric (class. Quantum Grav. 26 (2009) 135015). I am studying some of its consequences and its relation with the polarization.

My next objectives are to apply the method of classification to investigate in details the electromagnetic propagation properties of high energy excitations in astrophysical situations and in cosmolgy. Beside of this, because nonlinear electrodynamics presents many interesting formal properties that may be geometrized, it can be used as tool to understand better processes associated to gravitation, such as gravitational waves, Lorentz invariance and the geometrization of the interaction itself.

II. Service activities

Within ICRANet

I am writing a review with prof. Novello and S. Bergliaffa on the fundamentals of nonlinear field theory and wave propagation in this context. We are focusing on the propagation of shocks and discontinuities in nonlinear electrodynamics and how these features can be understood in terms of effective metrics. Many interesting special solutions are treated and the adequate analogies with the gravitational field are being made. These last aspects ranges from the causal structure of the field, differential aspects of the equations of motion, classification of the energy momentum tensor and effective metric, nonlinear properties of materials, exotic solutions for photon trajectories, analogue black-holes, nonlinear electrodynamics coupled to general relativity to cosmological solutions and magnetic fields in the large. Most of the review is been discussed and written in the very pleasant building of ICRA-net in Pescara.

2010 List of Publications

M. Novello and E. Goulart – Eletrodinâmica Não-Linear: Causalidade e Efeitos Cosmológicos, editora livraria da fisica, 2010 (book in portuguese);

Érico Goulart and Felipe Tovar Falciano –Geometrical properties of electromagnetic tidal forces– accepted for publication in Int. J. Mod. Phys. A;