Grav11

April 11th–15th, 2011, La Cumbre, Argentina

Program (April 8, 2011)

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
9:00-9:50	Registration	J. Pullin	R. Wald	L. Lehner	M. Reiris
10:00-10:30	Coffee				
10:30-11:20	H. Friedrich	F. Beyer	M. Díaz	D. Sudarsky	A. Aceña
11:30-12:20	S. Dain	O. Moreschi	O. Reula	C. Kozameh	G. Giribet
12:20-14:00	Lunch				
14:00-14:30	Gutierrez-Piñeres	D. López Nacir	*enjoy*	Landau & Teppa	E. Gallo
14:35-15:05	G. Ávila	D. Kofron	*your*	M. Bilal	A. Del Valle
15:05-15:45	Coffee				
15:45-16:15	L. Kraiselburd	M. Ramírez	*free*	A. Giacomini	J. Oliva
16:20-16:50	M. Astorino	M. Orsaria	*afternoon*	F. Canfora	C. Correa
16:55-17:25	E. Eiroa	L. Escobar		G. Pérez Nadal	S. Willison

Moorning Talks

Monday 11

On conformal structures of asymptotically flat, static vacuum data.
Helmut Friedrich
Albert Einstein Institut, Potsdam, Germany.

The detailed understanding of asymptotically flat solution near the 'critical sets', i.e. in the region where space-like infinity touches null infinity, will allow us to relate analytically physical concepts defined on Cauchy data to physical concepts defined on null infinity. Moreover, it offers possibilities to calculate numerically the entire development in time of Cauchy data, including the asymptotic structure and radiation field, by solving finite Cauchy problems.

In the case of time reflection symmetric vacuum data evidence is increasing that (finite) smoothness at null infinity is related to the data being asymptotically static (up to a given order). We discuss the problem of characterizing in the set of asymptotically flat, time reflection symmetric vacuum data the data which are near space-like infinity asymptotic to conformally static data.

Geometrical inequalities for axially symmetric black holes
Sergio Dain
FaMAF, Universidad Nacional de Córdoba,
Instituto de Física Enrique Gaviola (IFEG), CONICET, Córdoba, Argentina.

A geometrical inequality in General Relativity relates quantities that have both a physical interpretation and a geometrical definition. These kind of inequalities play an important role in the theory, in particular for vacuum black holes. In this talk I will first give an overview on geometrical inequalities in axial symmetry. Then I will present recent results on a quasi-local inequality between horizon area and angular momentum.

Tuesday 12

The problem of time in canonical quantum gravity
Jorge Pullin
Louisiana State University, USA.

We show that if one combines the conditional probabilities interpretation of Page and Wootters with the evolving constants of the motion of Rovelli one obtains in model systems a satisfactory solution to the problem of time, including the construction of the correct propagators. The resulting theories have a fundamental loss of unitarity due to the use of real clocks.

A singular initial value problem and applications in general relativity
Florian Beyer[1] and Philippe LeFloch[2]
[1] Department of Mathematics and Statistics, University of Otago, New Zealand
[2] Universite Pierre et Marie Curie (Paris 6), France

The Fuchsian method applies to certain classes of singular wave equations. Under certain conditions, it allows to construct solutions with a prescribed singular behavior and gives rise to a well-defined notion of a "singular initial value problem". In this talk, I recall the Fuchsian method and a new numerical approximation scheme which was introduced by P. LeFloch and myself. Then I discuss our current results about applying the method to general relativity.

Balanced equations of motion for particles in general relativity
Emanuel Gallo and **Osvaldo M. Moreschi**
FaMAF, Universidad Nacional de Córdoba,
Instituto de Física Enrique Gaviola (IFEG), CONICET, Córdoba, Argentina.

We study the dynamics of compact objects in the relativistic particle paradigm. In this work we present the first order gravitational radiation corrections applied to the equations of motion for a binary system.

Wednesday 13

A New Framework for Treating Small Scale Inhomogeneities in Cosmology
Robert Wald
Universty of Chicago, USA.

We provide a general framework that allows one to analyze—in a mathematically precise manner—solutions to Einstein's equation wherein, a priori, nonlinear effects of small scale inhomogeneities can produce significant effects on the background geometry. This framework is a generalization (to the case where inhomogeneous matter is present) of the "shortwave approximation" that has been used to analyze the back-reaction effects of gravitational radiation. We prove within this framework that, provided that matter satisfies the weak energy condition (i.e. has positive energy density in all frames), the "effective stress energy" produced by small scale inhomogeneities also must satisfy the weak energy condition and must be traceless, so it cannot mimic the effects of dark energy. We also analyze cosmological perturbation theory within this framework and calculate the corrections produced by small scale inhomogeneities to the equations satisfied by long wavelength perturbations.

How soon will Gravitational Waves be detected? From initial LIGO to Advanced LIGO
Mario Díaz
The Unversity of Texas at Brownsville, USA.

After a decade of operation the Laser Interferometer Gravitational Wave Observatory's detectors in Hanford, Washington and in Livingston, Louisiana, have been decommissioned. A feverish construction process has started to upgrade the observatories with a new generation of instruments that are expected to operate at much higher sensitivity. In this talk I will review the science developed with initial LIGO, and the observations performed with it and other similar detectors around the world. I will finally describe the technological improvements planned for Advanced LIGO including its expected timeframe, discuss the prospects of a network of several advanced detectors operating around the world and the coming of age of gravitational wave astronomy.

Numerical treatment of interfaces in Quantum Mechanics
Oscar Reula
FaMAF, Universidad Nacional de Córdoba,
Instituto de Física Enrique Gaviola (IFEG), CONICET, Córdoba, Argentina.

In this article we develop a numerical scheme to deal with interfaces between touching numerical grids when solving Schrödinger equation. In order to pass the information among grids we use the values of the fields only at the contact point between them. Surprisingly we obtain a convergent methods which is third order accurate with respect to the spatial resolution. In test cases, at the minimal resolution needed to describe correctly the waves, the error of this approximation is similar to that of a homogeneous (centered differences everywhere) scheme with three points stencil, that is a sixth order finite difference

operator. The semi-discrete approximation preserves the norm and uses standard finite difference operators satisfying summation by parts. For the time integrator we use a semi-implicit IMEX Runge Kutta method.

Thursday 14

Black holes and membranes: From astrophysics to cosmic censorship violation
Luis Lehner
Perimeter Institute / University of Guelph, Canada.

This talk will review two systems where suitble analogies between black holes and membranes helps to shed light on the dynamics of strong gravitating system. In the first case we will discuss how the interaction of black holes with surrounding plasmas can launch energetic jets which could be detected in the electromagnetic spectra. In the second case we will discuss the behavior of a class of unstable black holes in higher dimensions which displays a "cascade" behavior shrinking in regions to zero size given rise to a naked singularity and providing an example of a violation of cosmic censorship without fine tuning. In both cases, analogies with suitably defined membranes would provide a simpler understanding of the system and point to further interesting behaviors.

The case for novel physics provided by the seeds of cosmic structure.
Daniel Sudarsky
Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, México D.F. México.

The observations of the first traces of cosmic structure in the Cosmic Microwave Background are in excellent agreement with the predictions of Inflation. We will argue, however, that, in odder to produce a truly satisfactory account of the origin of the seeds of cosmic structure, we must go beyond the established physical paradigms. We will briefly discuss the shortcoming of some of the most popular accounts of the generation by quantum fluctuations in the inflationary scenario. It might seem very worrisome that no version of quantum theory seems capable of fully addressing the issue, however, as we will show, this situation is in fact an opportunity to explore with some guidance, issues which where thought to be beyond our reach.

Isolated Black Holes
Carlos Kozameh
FaMAF, Universidad Nacional de Córdoba,
Instituto de Física Enrique Gaviola (IFEG), CONICET, Córdoba, Argentina.

We define a family of spacetimes representing isolated black holes exhibiting remarkable universal properties which are natural generalizations from stationary spacetime. They admit a well defined notion of surface gravity k_H. This generalized surface gravity mediates an exponential relation between a regular null coordinate w near the horizon and an asymptotic Bondi null coordinate u defined in the vicinity of future null infinity. Our construction provides a framework for the study of gravitational collapse of an isolated system in its late stage of evolution.

Friday 15

Static solutions from the point of view of comparison geometry
Martín Reiris
Albert Einstein Institut, Potsdam, Germany.

We analyze (the harmonic map representation of) static solutions of the Einstein Equa- tions in dimension three from the point of view of comparison geometry. We find simple monotonic quantities capturing sharply the influence of the Lapse function on the fo- cussing of geodesics. This allows, in particular, a sharp estimation of the Laplacian of the distance function to a given (hyper)-surface. We apply the technique to asymptoti- cally flat solutions with regular and connected horizons and, after a detailed analysis of the distance function to the horizon, we recover the Penrose inequality and the unique- ness of the Schwarzschild solution. The proof of this last result does not require proving conformal flatness at any intermediate step.

Conformal extensions for stationary spacetimes

Andrés E. Aceña[1] and Juan A. Valiente Kroon[2]
[1] Albert Einstein Institut, Potsdam, Germany
[2] School of Mathematical Sciences, Queen Mary, University of London, London, UK.

In this talk I will present recent work done in collaboration with Juan A. Valiente Kroon regarding the asymptotic structure of asymptotically flat and stationary spacetimes.

The main result is that the construction of the cylinder at spatial infinity and the regular finite initial value problem, introduced for the general case by Friedrich, for stationary initial data sets are, in a precise sense, as regular as they could be.

I will present the basics of the construction of the cylinder at spatial infinity and the regular finite initial value problem, together with the specific features of asymptotically flat stationary spacetimes. Then I will discuss the necessary steps to obtain our result.

On asymptotically (A)dS solutions in three-dimensional massive gravity

G. Giribet[1] and M. Leston [2]
[1] Universidad de Buenos Aires, Argentina.
[2] IAFE, Buenos Aires, Argentina.

The thermodynamics and conserved charges in three-dimensional massive gravity will be discussed in the context of (A)dS/CFT correspondence.

Afternoon Talks

Monday 11

An infinite family of new exact solutions: Charged relativistic annular static thin disks around a central black hole

A.C. Gutiérrez-Piñeres[1], G.A. González[2]
[1] Facultad de Ciencias Básicas, Universidad Tecnológica de Bolívar, Cartagena de Indias, Colombia
[2] Escuela de Física, Universidad Industrial de Santander, Bucaramanga, Colombia

A new family of exact solutions of the Einstein-Maxwell equations for static axially symmetric spacetimes is presented. The metric functions of the solutions are explicitly computed and are simply written in terms of the oblate spheroidal coordinates. The solutions, obtained by applying the Ernst method of complex potentials, describe an infinite family of static charged dust disks with an inner edge around a Schwarzschild black hole. The energy density, pressure and charge density of all the disks of the family are everywhere well behaved, in such a way that the energy-momentum tensor fully agrees with all the energy conditions.

Tensor decompositions with fast decay conditions at space-like infinity

G. Ávila
AEI, Potsdam, Germany

Corvino, Corvino and Schoen, Chruściel and Delay have shown the existence of a large class of asymptotically flat vacuum initial data for Einstein's field equations which are static or stationary in a neighborhood of space-like infinity, yet quite general in the interior.

We present a quasilinear elliptic system of equations of which we expect that can be used to construct vacuum initial data which are asymptotically flat and time-reflection symmetric and asymptotic to static data up to a prescribed order at space-like infinity. We present an existence result which is valid when the order at which the solutions approach staticity is restricted to a given range.

Difficulties appear when trying to improve this result to show existence of solutions asymptotically static to higher order. The problems arise from the lack of surjectivity of certain operator.

Certain tensor decompositions in asymptotically flat manifolds exhibit some of the difficulties encountered above. The Helmholtz decomposition will be discussed as a model problem. A method to circumvent the difficulties that come up when fast decay rates are required will be shown. This is done in a way that might open the possibility to numerical computation, an aspect in which we are also interested for the initial data of Corvino et al. Finally the lessons learned from this model are used to get a better understanding the issues concerning the possible improvement to the existence result.

Digging in through the Equivalence Principle

L. Kraiselburd[1] and H.Vucetich[1]
[1]Grupo de Gravitación, Astrofísica y Cosmología,FCAGLP,Universidad Nacional de La Plata, La Plata, Argentina.

A. Einstein claimed the Equivalence Principle (EP) in his book, *"How I Constructed the Theory of Relativity"* such that,

"A little reflection will show that the law of the equality of the inertial and gravitational mass is equivalent to the assertion that the acceleration imparted to a body by a gravitational field is independent of the nature of the body ...

...It is only when there is numerical equality between the inertial and gravitational mass that the acceleration is independent of the nature of the body."

From this principle follows both the Universality of Free Fall (UFF) and Local Lorentz Invariance (LLI), thus fulfilling the equality between inertial mass, passive mass and rest mass. Another profound consequence is that all forms of non-gravitational energy, which contribute to the inertial mass, should couple in the same way to the gravitational field. Any violation of the UFF can be described with a non-zero difference between inertial mass and passive mass, which can be expressed via nuclear binding energies and phenomenological parameters specific to each type of interaction reflecting its degree of violation to the EP. Since these parameters are measured in Eötvös-like experiments, then these last ones can set an upper limit on the difference of acceleration in a gravitational field for different materials and so impose upper bounds on the "violation parameters".

To further examine the accuracy of present Eötvös experiments, we shall attempt to set up modern independent bounds on violation of the EP by the four known fundamental forces.

Accelerating black hole in 2+1 dimensions and 3+1 black (st)ring
Marco Astorino
CECS, Valdivia, Chile

A C-metric type solution for general relativity with cosmological constant is presented in 2+1 dimensions. It is interpreted as a three-dimensional black hole accelerated by a strut. Positive values of the cosmological constant are admissible too. Some embeddings of this metric in the 3+1 space-time are considered: accelerating BTZ black string and a black ring where the gravitational force is sustained by the acceleration.

Bardeen black holes: some general aspects and gravitational lensing
Ernesto F. Eiroa[1,2] and Carlos M. Sendra[1,2]
[1] IAFE, Buenos Aires, Argentina
[2] Departamento de Física, FCEyN, UBA, Buenos Aires, Argentina.

The Bardeen model belongs to the class of regular black holes, i.e. those without singularities. This type of solutions can be obtained by coupling nonlinear electrodynamics to gravity. In this talk, some general aspects of Bardeen black holes are reviewed and their gravitational lensing effects in the strong deflection limit are discussed.

Tuesday 12

Dissipative effects in the Effective Field Theory of Inflation
Diana López Nacir[1],Rafael Porto[2,3,4], Leonardo Senatore [5,6],and Matias Zaldarriaga[2]
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[6] Kavli Institute for Particle Astrophysics and Cosmology, Menlo Park, CA 94025, USA.

We generalize the effective field theory (EFT) of single field inflation to include dissipative effects. Working in the unitary gauge we couple new degrees of freedom in the effective action that are constrained solely by invariance under spatial diffeomorphisms. We study the case of scalar, vector and tensor operators. The addition of dissipation modifies the dynamics of the perturbations, in particular the appearance of 'friction', i.e. $\gamma\dot{\pi}$, and noise terms. Assuming certain locality properties for the Green's functions of these new degrees of freedom, we show that there is a regime (large friction) in which the ζ-correlators are

dominated by the noise and the power spectrum can be significantly enhanced. As in previous cases, the non-linear realization of time diffeomorphisms imposes restrictions among different observables. We compute the three point functions $\langle\zeta\zeta\zeta\rangle$ for a wide class of models, and discuss under which circumstances a large friction term leads to an increased level of non-gaussianities. We show: 1) locality and scale invariance restricts the value of $f_{\rm NL}$ to be small for terms of the form $f(t)\mathcal{O}$, independently of the size of the friction coefficient; and 2) a scalar coupling of the type $\mathcal{O}g^{00}$ (invariant under shift symmetry) leads to $f_{\rm NL} \sim \frac{\gamma}{c_s^2 H}$, provided it is also responsible for dissipation. On the other hand, vector couplings may produce large friction without any significant increase in $f_{\rm NL}$.

Progress in understanding boost rotation symmetric spacetimes
D. Kofron[1], J. Bicak[1]
[1] IoTP, Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic

The boost-rotation (BR) symmetric solutions describe spatially bounded charged rotating objects undergoing a "uniform acceleration"; they are asymptotically flat in the sense that they admit smooth though not complete null infinity. Moreover, they are radiative (contain gravitational and electromagnetic radiation).

I shall report about four recent advances in the analysis of the BR-symmetric solutions: (i) the Newtonian limit (ii) the accelerating magic field (iii) rotating charged black holes accelerated by an electric field (iv) general charged C-metric in global BR coordinates and it's news function (radiation patterns).

On the dynamics of a shell of collisionless matter in cylindrical symmetry
Reinaldo J. Gleiser, **Marcos A. Ramírez**
FaMAF, Universidad Nacional de Córdoba, Córdoba, Argentina

We consider a thin shell of colisionless particles in cylindrical symmetry and show that, under certain restrictions, the equation of motion of the shell decouples from that of the gravitational field. We also study the linearized field equations around a static configuration and find that at first order the shell can oscilate at any arbitrary frequency in sharp constrast to newtonian expectations. We further discuss the properties of these first order solutions, comment on the initial value problem and compare with previous results.

Can magnetars be considered highly magnetized quark stars?
M. Orsaria, Ignacio F. Ranea-Sandoval and H. Vucetich
Facultad de Ciencias Astronómicas y Geofísicas,
Universidad Nacional de La Plata UNLP,
Gravitation, Astrophysics and Cosmology Group.

We present an analytical model of a magnetar as a high density magnetized quark bag. The effect of strong magnetic fields ($B > 5 \times 10^{16} G$) in the equation of state is considered. An analytic expression for the Mass-Radius relationship is found from the energy variational principle in general relativity. Our results are compared with observational evidences of possible quark and/or hybrid stars.

Dynamical analysis of Bianchi cosmologies coupled to scalar fields with various potentials.
Leon Escobar, Florian Beyer
Universidad del Valle, Colombia.
University of Otago, New Zealand.

In this talk, we study the dynamics of homogeneous (but anisotropic) cosmological models (Bianchi

cosmologies) coupled to a scalar field for various potentials. These models are relevant in contemporary cosmology for two reasons. First, they are useful for the analysis of the rate of expansion and the anisotropy of the universe. Secondly, for these models Einsteiń s equations imply a relatively simple autonomous system of nonlinear ordinary differential equations. In this work we use this feature to analyze the dynamics for various potentials by means of numerical experiments.

Thursday 14

Space-time variation of the electron-to-proton mass ratio in a Weyl model
S. J. Landau[1,2], **F. A. Teppa Pannia**[2], Y. Bonder[3] and D. Sudarsky[3,4]
[1] IFIBA, Buenos Aires, Argentina
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[3] ICN, Universidad Nacional Autónoma de México, México D.F., México
[4] IAFE, Buenos Aires, Argentina.

We considered the recent data indicating a space-time variation of the electron-to-proton mass ratio (μ) within the Milky Way (Levshakov et al. 2010), to study a phenomenological model where the effective fermion masses depend on the local value of the Weyl tensor. Furthermore, we contrasted the required value of the model's parameters with the bounds obtained for the same quantity from modern tests on the violation of the Weak Equivalence Principle (WEP). In this work, we deduced the theoretical expression for the variation of μ and for the violation of the WEP as a function of the model parameters and we also performed a least square minimization in order to obtain constraints on the model parameters from bounds on the WEP.The bounds obtained on the model's parameters from the variation of μ are inconsistent with the bounds obtained from constraints on the violation of the WEP. This result indicates that the variation of nucleon and electron masses through the Weyl tensor is not a viable model.

Lanczos Potential for Petrov Type II spacetimes
Zafar Ahsan and **Mohd Bilal**
Aligarh Muslim University, Aligarh, (U.P.)INDIA

During the last two decades the interest in the study of a rank three tensor, known as Lanczos spin tensor, proposed by C. Lanczos, has been revived. In fact, Lanczos used this tensor to create the gravitational field through the Weyl Lanczos equation. In this paper, the Lanczos potential for an arbitrary Petrov type II spacetime has been obtained and Robinson-Trautman family of metrics has been considered as an example. Here we have used the Newman-Penrose and Geroch Held Penrose formalism to carry out the calculaltions.

Gravitationally induced zero modes of the Faddeev-Popov operator in the Coulomb gauge for Abelian gauge theories.
Fabrizio Canfora[1], **Alex Giacomini**[2], Julio Oliva[2]
[1] Centro de Estudios Cientificos, Valdivia, Chile
[2] Universidad Austral de Chile, Valdivia, Chile.

It is shown that on curved backgrounds, the Coulomb gauge Faddeev-Popov operator can have zero modes even in the abelian case. These zero modes cannot be eliminated by restricting the path integral over a certain region in the space of gauge potentials. The conditions for the existence of these zero modes are studied for static spherically symmetric spacetimes in arbitrary dimensions. For this class of metrics, the general analytic expression of the metric components in terms of the zero modes is constructed. Such expression allows to find the asymptotic behavior of background metrics, which induce zero modes in the

Coulomb gauge, an interesting example being the three dimensional Anti de-Sitter spacetime. Some of the implications for quantum field theory on curved spacetimes are discussed.

New features of the gauge-fixing ambiguities on curved space
F. Canfora[1], A. Giacomini[2] and J. Oliva[2]
[1] CECS, Valdivia, Chile
[2] Universidad Austral De Chile (UACH), Valdivia, Chile

In this talk I will present some new results on the gauge fixing ambiguities (discussed for the first time by Gribov on flat space-times) in both gauge theories on curved space and gravity. After a brief review on the known results on flat space, I will present some of the interesting new features of the Gribov ambiguities on curved space in Abelian gauge theories. Then, gauge-fixing ambiguities in gravity theories will be discussed and the possible connection with supersymmetry breaking will be analyzed.

Stress tensor fluctuations in de Sitter spacetime
G. Perez-Nadal[1], A. Roura[2] and E. Verdaguer [3]
[1] FCEN, Universidad de Buenos Aires, Buenos Aires, Argentina
[2] AEI, Potsdam, Germany
[3] ICC, Universitat de Barcelona, Barcelona, Spain

In this talk I will describe some properties of the two-point function of the stress tensor operator of a quantum field in de Sitter spacetime, using the formalism of maximally symmetric bitensors. I will also discuss some implications for one-loop perturbative quantum gravity around de Sitter spacetime.

Friday 15

A gauge invariant formulation of gravitational lensing
E. Gallo
FaMAF, Universidad Nacional de Córdoba,
Instituto de Física Enrique Gaviola (IFEG), CONICET, Córdoba, Argentina.

We present new expressions for the optical scalars and the deflection angle in terms of gauge invariants quantities. Our work generalizes standard references in the literature where normally stringent assumptions are made on the sources. We also present a method of approximation for solving the lens equations, that can be applied to any order.

Three-dimensional massive gravity in Lifshitz spaces
Andrea L. Del Valle and Andrés F. Goya
Universidad de Buenos Aires, Argentina.

In this talk we will review a recent proposal for formulating a non-relativistic version of AdS/CFT correspondence. This involves the so-called Lifshitz metrics, which happen to coincide with Anti-de Sitter space only for a particular value of their parameter z, usually called the 'dynamical exponent'. We will focus on the realization of this correspondence within the context of three-dimensional massive gravity, and discuss how to compute correlation functions in the dual theory. The extension to the case of finite temperature, which involves black holes that asymptote Lifshitz space, will be briefly discussed.

A special class of higher derivative theories of gravity
Julio Oliva[1], Sourya Ray[2]
[1] Instituto de Física, Universidad Austral de Chile, Valdivia, Chile

[2] Centro de Estudios Científicos, Valdivia, Chile

We present a new set of higher derivative theories of gravity in arbitrary dimensions, determined by requiring the trace of the field equations to be a second order constraint, in analogy to BHT (Bergshoeff, Hohm and Townsend)new massive gravity. A special subclass of theories within this family is such that for spherically symmetric spacetimes, the whole system reduces to a second order system. The black hole solution is found and the Birkhoffś theorem is proved. For this symmetry, the theory provides a natural extension of a Lovelock theory of order k to dimenion D=2k-1, in which the corresponding Lovelock theory trivializes it self.

Stability Analysis of Regular Black Holes

C. Correa[1], G. Romero[1,2], D. Pérez[2] and S. Perez Bergliaffa[3]
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[2] Instituto Argentino de Radioastronomía (CCT La Plata-CONICET)
[3] Instituto de Física. Universidade do Estado de Rio de Janerio.

A regular black hole is a singularity-free, exact solution to Einstein's field equations. One possible set of regular black holes solutions has the geometry of the space-time described by Schwarschild's solution at large radius and by a de Sitter-like solution at small radius.

Adopting the equation of state suggested by Mbonye and Kanzanas (2005), the model of the interior of the black hole consists of matter fields with sound speed bounded by the speed of light. The interior transits smoothly between normal matter and a core of a "quintessence-like" fluid with an equation of state that approaches $p = -\rho$ when $r \to 0$.

In this work we implement a stability analysis through linearized perturbations around static solutions of the thermodynamics quantities of the matter that constitutes the interior of this non-singular black hole model. We restrict the treatment to spherically symmetric perturbations which have only time and radial coordinate dependence, and in order to identify possible instabilities we study exponential plane-wave solutions of the perturbation equations.

A simple algebraic global isometric embedding is presented for the nonrotating BTZ black hole and its counterpart of Euclidean signature.

Dr S. Willison
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The image of the embedding, in Minkowski space of two extra dimensions, is the interection of two quadric hypersurfaces.

Furthermore an embedding into AdS_4 or H_4 is also obtained, showing that the spacetime is of embedding class one with respect to maximally symmetric space of negative curvature.

The rotating solution of Euclidean signature is also shown to admit a quadratic algebraic embedding, but seemingly requires more than two extra dimensions.