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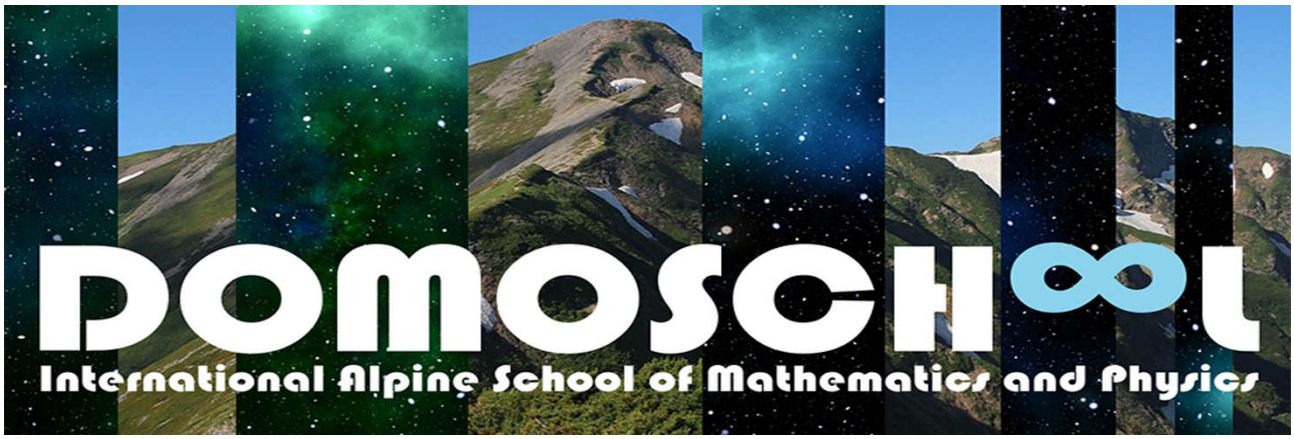
DOMOSCHOOL
International Alpine School of Mathematics and Physics

15 – 19 JULY 2019 - Domodossola -Italy

EINSTEIN EQUATIONS: PHYSICAL AND MATHEMATICAL ASPECTS OF GENERAL RELATIVITY



DOMOSCHOOL BOOKLET

2019 EDITION

SCIENTIFIC BOARD

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VIA ANTONIO ROSMINI, 24
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PROGRAMME

MONDAY 15th July

09:00 -- 10:00 Reception and Registration

10:00 - 10:20 **Introduction to the Domoschool 2019 Edition**

10:25 -- 11:20 **Alexei A. Starobinsky**

Inflation and pre-inflation: the present status and expected discoveries

11:25 -- 12:25 **Lars Andersson**

Geometry and analysis in black hole spacetimes

12:30 -- 12:50 Vladimir Toussaint (Short Talk 1 – ST1)

Massive Bosonic conformal zero-mode in the spatially compactified FLRW spacetimes and its detection

13:00 -- 14:30 **lunch break**

14:35 -- 15:30 **Pengzi Miao**

Quasi-local energy and isometric embedding of spacelike 2-surfaces

15:35 -- 16:30 **Donato Bini**

The self-force problem in black hole spacetimes. I: Scalar perturbations in a Schwarzschild spacetime (part I)

16:35 -- 17:05 **coffee break**

17:10 -- 18:05 **Donato Bini**

The self-force problem in black hole spacetimes. I: Scalar perturbations in a Schwarzschild spacetime (part II)

TUESDAY 16th July

09:00 -- 9:55 **Lars Andersson**

Geometry and analysis in black hole spacetimes

10:00 -- 10:55 **Donato Bini**

The self-force problem in black hole spacetimes. II: Gravitational perturbations in a Schwarzschild spacetime (part I)

11:00 - 11:30 **coffee break**

11:35 - 12:30 **Donato Bini**

The self-force problem in black hole spacetimes. II: Gravitational perturbations in a Schwarzschild spacetime (part II)

12:35 -- 12:55 Adamantia Zampeli (ST2)

Canonical quantization of the Szekeres spacetime

13:00 – 14:30 **lunch break**

14:35 -- 15:30 **Alexei Starobinsky**

Inflation and pre-inflation: the present status and expected discoveries

15:35 -- 16:30 **Pengzi Miao**

Quasi-local energy and isometric embedding of spacelike 2-surfaces

16:35 -- 17:05 **coffee break**

17:10 -- 17:30 Francesco Cremona (ST3)

On the linear instability of the wormhole of Ellis-Bronnikov-Morris-Thorne

WEDNESDAY 17th July

FREE DAY – Guided tour *(optional)*

THE TRONTANO TALES

DOMODOSSOLA AND ITS SORROUNDINGS

PROGRAMME:

9.25 AM: meeting point at Rosmini College

10.00 AM: train to Trontano from Domodossola railway station

10.25 AM: arrive at VERIGO and descending in a beautiful walk in the woods up to the Mulini del Graglia, then:

- visit of the mills
- glass of wine by the wine press
- lunch together from 1pm to 2pm with local products
- after lunch walk around the typical alpine village

3.43 PM: train to Domodossola

4.10 P.M. arrival at Domodossola railway station

the Journey will be held also in case of bad weather conditions

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THURSDAY 18th July

09:00 -- 9:55 **Lars Andersson**

Geometry and analysis in black hole spacetimes

10:00 -- 10:20 Jiri Ryzner (ST4)

Exact solutions od Einstein-Maxwell(-dilation) equations with discrete translational symmetry

10:25 -- 10:55 Lennart Brocki (ST5)

Quantum Ergosphere and Brick Wall Entropy

10:50 - 11:20 **coffee break**

11:25 - 12:20 **Pengzi Miao**

Quasi-local energy and isometric embedding of spacelike 2-surfaces

12:25 -- 12:55 Mario Luis Gutierrez (ST6)

A Numerical Approach to General Relativity

12:50 – 14:30 **lunch break**

14:35 -- 15:30 **Alexei Starobinsky**

Inflation and pre-inflation: the present status and expected discoveries

15:35 -- 16:30 **Marco Giammarchi**

The search for antimatter gravity

16:35 -- 17:05 **coffee break**

17:05 -- 17:25 Andrew Miller (ST7)

Using machine learning to detect gravitational waves from young neutron stars

17:30 -- 17:50 Colin MacLaurin (ST8)

Spatial measurement in curved spacetime

FRIDAY 19th July

09:00 -- 9:55 **Marco Giammarchi**

The search for antimatter gravity

10:00 -- 10:20 Tereza Vardanyan (ST11)

Exact Solutions of the Einstein Equations for an Infinite Slab with Constant Energy Density

10:25 -- 10:45 Syed Naqvi (ST12)

Gravitational wave Memory Effect

10:50 - 11:20 **coffee break**

11:25 - 12:20 **Pengzi Miao**

Quasi-local energy and isometric embedding of spacelike 2-surfaces

12:25 -- 12:45 Elias Arawi Sol Megier (ST13)

Square-Torsion Gravity: a geometric candidate for dark matter

12:50 – 14:30 **lunch break**

14:35 -- 15:30 **Lars Andersson**

Geometry and analysis in black hole spacetimes

15:35 -- 16:30 **Alexei Starobinsky**

Inflation and pre-inflation: the present status and expected discoveries

16:30 -- 17:00 **coffee break**

17:00 **Conclusion**

SATURDAY 20th July

21.00 – 23.00 **public conference for citizenship open to all**

(optional - free - italian language)

COLLOQUI sull'UNIVERSO

It is a public event, free and free, open to the population, created within Domoschool 2019, the International Alpine School of Mathematics and Physics, and will be held in Piazza Rovereto in Domodossola /Cappella Mellerio
For the 2019 edition, moderated by Cinzia Attinà of La Stampa VCO, and by prof. Sergio Cacciatori we will have as guests:

ANDREA ACCOMAZZO
Italian scientist based in Germany, where he directs the missions of the ESA - European Space Agency.
He was flight director of the Rosetta Mission, which allowed the study of cometa 67P Churyumov-Gerasimenko.
In 2014 he was named scientist of the year by the journal Nature. Today he leads the mission that will lead the BepiColombo probe to Mercurio
It will lead us to discover the European space exploration program.

MARCO GIAMMARCHI
Italian scientist, First Researcher at INFN - National Institute of Nuclear Physics, headquarters of Milano
He participated in experiments in particle physics at Fermilab Natural Areas, in the Gran Sasso and in Argentina.
He currently coordinates the Antimatter group of Milan and is Infn referee of the Virgo and CUORE experiments.

LECTURES

Titles and Abstracts

Alexei A. Starobinsky

Inflation and pre-inflation: the present status and expected discoveries

Lars Andersson

Geometry and analysis in black hole spacetimes

Pengzi Miao

Quasi-local energy and isometric embedding of spacelike 2-surfaces

Donato Bini

The self-force problem in black hole spacetimes. I: Scalar perturbations in a Schwarzschild spacetime - II: Gravitational perturbations in a Schwarzschild spacetime

Marco Giammarchi

The search for antimatter gravity

LECTURE

Alexei A. Starobinsky
Member of the Russian Academy of Science.
Landau Institute for Theoretical Physics RAS.
Moscow-Chernogolovka, Russia

Inflation and pre-inflation: the present status and expected discoveries

4 lessons of one hour each

I shall outline the two simplest classes of phenomenological models of slow-roll inflation in the early Universe based either on scalar fields in General Relativity or on modified f(R) gravity, their relation and basic assumptions necessary for their realization. At the present state-of-the-art, the simplest inflationary models from these classes producing the best fit to all existing astronomical data requires one, maximum two dimensionless parameters taken from observations only. The main discoveries expected for these models in future are discussed, too. Among them the most fundamental are primordial quantum gravitational waves generated during inflation. It is argued that the measured value of the slope n_s-1 of the primordial scalar power spectrum, under the additional assumption of the absence of new fundamental scales both during and after inflation, implies small, but not too small tensor-to-scalar ratio r~3(1- n_s)^2 ~ 0.004 or even more, similar to that in the original f(R) = R+R^2 inflationary model (Starobinsky, 1980). Another possible discovery is related to small local features in the CMB temperature anisotropy power spectrum in the multipole range l=(20-40) beyond which new physics during inflation may be hidden. Also new physics acted during the last stage of inflation could show itself would primordial black holes be found, in particular, through direct observations of their coalescence in binary systems at present. Since inflation, as a metastable quantum state, had finite life-time (and we can measure difference in its duration in terms of the number of e-folds between different points of space with remarkable accuracy), it is well possible to think what might be before it. In the models considered, the most generic predecessor of inflation is an anisotropic and inhomogeneous space-time near a generic space-like singularity. Conditions needed for the onset of inflation from such a state will be discussed. Since this process is generic, too, for inflation to begin inside a patch including the observable part of the Universe, causal connection inside the whole patch is not necessary. However, it becomes obligatory for a graceful exit from inflation in order to have practically the same number of e-folds during inflation inside this patch.

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LECTURE

Pengzi Miao
University of Miami,
Miami, Florida (USA)

Quasi-local energy and isometric embedding of spacelike 2-surfaces

4 lessons of one hour each

The notion of quasi-local energy is a basic subject of study in general relativity. In this course, we will discuss ways of defining the quasi-local energy for a spacelike, closed twosurface, with a focus on the surface Hamiltonian approach.
This approach is naturally tied to the classic problem of isometric embeddings in differential geometry, which we will also discuss.

LECTURE

Lars Andersson
Albert Einstein Institute
(Max-Planck Institute for Gravitational Physics),
Potsdam, Germany

Geometry and analysis in black hole spacetimes

4 lessons of one hour each

Black holes play a central role in general relativity and astrophysics. The problem of proving the dynamical stability of the Kerr black hole spacetime, which is describes a rotating black hole in vacuum, is one of the most important open problems in general relativity. Following a brief introduction to the evolution problem for the Einstein equations, I will discuss the main features of the geometry of the Kerr spacetime, including its algebraically special nature and consequences thereof. I will then present some aspects of the black hole stability problem, and present the main steps in the recent proof of linearized stability of the Kerr black hole spacetime, see arXiv:1903.03859.

LECTURE

Donato Bini
Istituto per le Applicazioni del Calcolo "M. Picone",
CNR, Rome - Italy

The self-force problem in black hole spacetimes. I:
Scalar perturbations in a Schwarzschild spacetime
1 lesson of two hours

The self-force program is introduced and discussed, with special attention to the scalar pertubations (zero spin) and to complete analytic calculations in the Schwarzschild spacetime. Related topics: mode sum expansion, regularization techniques, gauge modes,

The self-force problem in black hole spacetimes. II:
Gravitational perturbations in a Schwarzschild spacetime.
1 lesson of two hours

The gravitational perturbation equations (spin 2) in the Schwarzschild background are analyzed in the Regge-Wheeler gauge explicitly performing analytic computation in a Post-Newtonian scheme. It is shown how to evaluate gauge-invariant quantities expressed in turn in terms of gauge invariant variables. Related topics: different parity perturbations, metric reconstruction, regularization, converting information in the Effective-One-Body formalism.

LECTURE

Marco Giammarchi
Istituto Nazionale di Fisica Nucleare
Sezione di Milano - Italy

The search for antimatter gravity
2 lessons of one hour each

Gravitational properties of antimatter are related to both the validity of the CPT theorem in Particle Physics and the Weak Equivalence Principe of General Relativity.
The motivation and techniques of the main approaches to this topic will be presented.

talks

Titles and Abstracts

Vladimir Toussaint (Short Talk 1 – ST1)

Massive Bosonic conformal zero-mode in the spatially compactified FLRW spacetimes and its detection

Adamantia Zampeli (ST2)

Canonical quantization of the Szekeres spacetime

Francesco Cremona (ST3)

On the linear instability of the wormhole of Ellis-Bronnikov-Morris-Thorne

Jiri Ryzner (ST4)

Exact solutions od Einstein-Maxwell(-dilation) equations with discrete translational symmetry

Lennart Brocki (ST5)

Quantum Ergosphere and Brick Wall Entropy

Mario Luis Gutierrez (ST6)

A Numerical Approach to General Relativity

Andrew Miller (ST7)

Using machine learning to detect gravitational waves from young neutron stars

Colin MacLaurin (ST8)

Spatial measurement in curved spacetime

Adnan Maliq (ST9)

Investigating Exact Solutions in f gravity

Vittorio De Falco (ST10)

New trends in the general relativistic Poynting-Robertson effect modelling

Tereza Vardanyan (ST11)

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SHORT TALKS

Vladimir Toussaint
Department of Mathematical and Sciences
University of Nottingham

Massive Bosonic conformal zero-mode
in the spatially compactified FLRW spacetimes and its detection

Abstract

We consider a massive scalar field in the (1 + 1)- dimensional, spatially compactified Friedmann-Robertson-Walker (FRW) cosmological spacetimes. We consider both twisted and untwisted fields. The issue of the massive conformal zero mode arises for the untwisted field whenever the effective mass vanishes at early or late times. More precisely we show that this occurs whenever the zeromomentum mode of the untwisted field reduces to a massive conformal zero-mode in the corresponding asymptotic region(s). To resolve this issue, we develop a new scheme for quantizing the zero-momentum mode. This new quantization scheme introduces a family of two real parameters for every zeromomentum mode with an associated two-real-parameter set of in/out vacua. Moreover, we show that the zero-momentum ground state's wave functional corresponds to a family of two-real parameter Gaussian wave packets. For applications, we examine the finite-time detector's response to a massive scalar field in the (1 + 1)-dimensional, spatially compactified Milne spacetime. Explicit analytic results are obtained for the comoving and inertially non-comoving trajectories. Numerical results are provided for the comoving trajectory. The numerical results suggest that when the in-vacuum is chosen to be very far from the conventional Minkowski vacuum state, then it contains particles. As result, spontaneous excitation of the comoving detector occurs.

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SHORT TALK

Adamantia Zampeli
Institute of Theoretical Physics
Charles University

"Canonical quantization of the Szekeres spacetime"

We present the effect of the quantum corrections on the Szekeres spacetime, a system important for the study of the anisotropies of the pre-inflationary era of the universe.
The study is performed in the context of canonical quantisation in the presence of symmetries. We construct an effective classical Lagrangian and impose the quantum version of its classical integrals of motion on the wave function.
The interpretational scheme of the quantum solution is that of Bohmian mechanics, in which one can avoid the unitarity problem of quantum cosmology.
We discuss our results in this context.

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SHORT TALKS

Francesco Cremona
Dipartimento di Matematica
Università degli studi di Milano

On the linear instability of the wormhole of Ellis-Bronnikov-Morris-Thorne

Abstract
In this talk I will present a proof of the linear instability of the wormhole of Ellis, Bronnikov, Morris and Thorne (EBMT), arising from Einstein's equations in presence of a phantom scalar field. After an overview of the geometry of wormholes and phantom scalar fields in the background of general relativity, I will decouple the linearized Einstein's equations for the perturbed EBMT wormhole, reducing them to a wave-type equation for the perturbing function of the wormhole radius: the proof of the linear instability is obtained by showing that the Schrödinger operator that appears in this equation has one negative eigenvalue. A comparison with the previous literature will be made.

SHORT TALKS

Jiři Ryzner
PhD Student
Charles University, Institute of Theoretical Physics

Exact solutions of Einstein-Maxwell(-dilaton) equaitions with discrete translational symmetry

Abstract

We introduce four distinct solutions of Einstein-Maxwell(-dilaton) equations from Majumdar-Papapetrou solutions. In addition to being axially symmetric and static, the solutions are reflection symmetric with respect to some special planes and exhibit a discrete translational symmetry along the axis. The first one is constructed via dimensional reduction and is given in closed form, the others involve infinite series with no closed formula. We investigate the geometry of the solutions, behaviour of invariants, properties of horizons and singularities, the convergence of sums, and conserved quantities.

SHORT TALKS

Lennart Brocki

Istitute of Thaoretical Physics

University of Wroclaw

Quantum Ergosphere and Brick Wall Entropy

Abstract

In this talk we revisit t' Hooft's "brick wall" model for black hole entropy taking into account backreaction effects on the horizon structure. We do so by adopting an evaporating metric in the quasi-static approximation in which departures from the standard Schwarzschild metric are governed by a small luminosity factor.

One of the effects of the backreaction is to create an ergosphere-like region which naturally tames the usual divergence in the calculation of the partition function of the field. The black hole luminosity sets the width of such 'quantum ergosphere'. We find a finite horizon contribution to the entropy which, for the luminosity associated to the Hawking flux, reproduces remarkably well the Bekenstein-Hawking entropy-area law.

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SHORT TALKS

MARIO LUIS GUTIERREZ

Theoretical Cosmology

Newcastle University

A Numerical Approach to General Relativity

Abstract

The Einstein Field Equations (EFE's) are highly nonlinear, coupled, partial differential equations that describe the relation between the geometry of a region of spacetime and its matter content. A severe complication is that, with the exception of a few idealised cases characterised by high degrees of symmetry, the EFE's simply cannot be obtained analytically; we need a computer to do the heavy lifting for us. That being said, computers (for better or worse) lack a sense of humour; they do exactly what you tell them, as you tell them. Therefore, in order to find solutions to realistic (asymmetric) spacetimes, we need to be able to somehow prescribe the right numerical recipe to the machine. In this talk we shall discuss the more widely used such recipe: the 3+1 decomposition of the EFE's.

SHORT TALKS

Andrew Miller
Sapienza Università di Roma
3rd year Ph.D. student

Using machine learning to detect gravitational waves from young neutron stars

We present a new study on the effectiveness of artificial and convolutional neural networks (ANNs and CNNs) to detect long duration transient gravitational waves, signals lasting for hours-days, from isolated neutron stars.
These signals could come from a remnant of a binary neutron star merger (GW170817) or from a core-collapse supernova, which are likely to be seen in LIGO/Virgo's third observing run. While much work has been done on developing ANNs/CNNs for gravitational wave detection of binary black hole signals, these algorithms have not yet been expanded to long duration transient signals from isolated neutron stars, nor has there been a study on the application of such methods to a real search and the limitations that one would encounter, such as a finite amount of training data and nonstationary noise.
We first quantify how robust the ANNs/CNNs are towards different signal morphologies, specifically showing that they can detect a signal whose frequency evolution follows a different power law than the signals on which the ANNs/CNNs were trained.
Then, we demonstrate that the non-stationary noise decreases the ANNs'/CNNs' detection efficiency and thus the changing noise needs to be considered in a real search.
Additionally we show that an ANN trained on injections in white noise can still achieve decent detection efficiencies when used on real noise, implying that simulated data may be able to supplement limited training data.
We also determine that using an ensemble of ANNs, where each ANN is trained on different portions of the input images, can reduce the false alarm probability, an output of the analysis that in conventional methods is typically easy to control.
Finally we compare the detection efficiencies and false alarm probabilities of the ANNs/CNNs to the Generalized FrequencyHough (GFH), a pattern-recognition technique that can search for signals whose frequencies follow a power-law behavior.
Even though the ANNs/CNNs are less sensitive than the GFH, they are more robust and much faster than the GFH after training.

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SHORT TALKS

Colin MacLaurin

University of Queensland, Australia

Spatial measurement in curved spacetime

Abstract

I examine the observer dependence of length measurement in general relativity. Given a spatial vector $\boldsymbol{\xi}$ representing an unstressed ruler, and a coordinate Φ which serves as an extrinsic reference, the proper length element is

$$dL = \frac{1}{d\Phi(\boldsymbol{\xi})} d\Phi.$$

This situates extended objects, relative to Φ, in their rest frame, generalising length-contraction from special relativity. Given an observer $\mathbf{u}$, the ruler direction which maximises $dL/d\Phi$ is shown to have measurement

$$dL_{\Phi\text{-max}} = \frac{1}{\sqrt{g^{\Phi\Phi} + (u^{\Phi})^2}} d\Phi.$$

As a specific example, consider radial motion in Schwarzschild spacetime, parametrised by the Killing energy per mass e. Then the radial proper length is:

$$dL = \frac{1}{|e|} dr$$

(Gautreau & Hoffmann 1978), which remains valid inside the horizon, and reduces to the familiar quantity $(1 - 2M/r)^{-1/2} dr$ in the case of static observers. Only observers with $dr/d\tau = 0$ can possibly orient their rulers to achieve the usual measurement.

The formalism here is remarkably "post-mature", and is independent of the excellent work by de Felice & Bini (2010), as well as spacetime splitting formalism (Jantzen+ 2013) to which it is related.

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SHORT TALKS

Adnan Malik

University of Management and Technology, Sialkot, Pakistan.

Investigating Exact Solutions in $f(R,\varphi,X)$ Gravity

Abstract

The aim of current work is to investigate modified $f(R,\varphi,X)$ theory of gravity, where *R*, *φ* and *X* represent the Ricci scalar, scalar potential and kinetic term respectively. Specifically, we take the Friedmann-Robertson-Walker space time for finding some exact solutions. We study the acceleration expansion of universe by taking Klein-Gordon equation. Furthermore, power law and exponential law techniques are used during the discussion of solutions. It is concluded that expansion of universe can be justified in $f(R,\varphi,X)$ gravity.

SHORT TALKS

Vittorio De Falco

Centre for Computational Physics and Data Processing Faculty of Philosophy & Science Silesian University in Opava

New trends in the general relativistic Poynting-Robertson effect modelling

Abstract

In the radiation processes occurring in high-energy astrophysics around compact ob- jects, it is important to study how the gravitational pull interacts with the radiation field on the surrounding matter. If we consider a small-sized test particle, there is the appearance of the Poynting-Robertson (PR) effect, which is a general relativis- tic viscous phenomenon. I present the actual improvements brought to the general relativistic PR effect model from the results proposed by Bini and collaborators in the two-dimensional (2D) case done in 2009–2011. I show the extension of the 2D model in the three-dimensional (3D) space in the Kerr metric, for a radiation field emitted radially at infinity and from a rigidly rotating spherical source. It is built, as the previous 2D model, upon the ”relativity of observer splitting formalism”, powerful technique in General Relativity (GR). It admits the existence of a critical hypersurface, region where the gravitational and radiation forces balance and the matter tends to end its motion. I explain how to prove with an innovative technique the stability of these critical hypersurfaces. I show also some numerical simulations of selected test particle orbits.

I present how to study the general relativistic PR effect under the Lagrangian for- malism, very peculiar for a viscous system in GR, due to the high-non-linearities of the background metric. I describe how through an innovative mathematical method, termed ”energy formalism”, it is possible to determine the analytical form of the radiation potential and to solve other issues in metric theories of gravity.

I conclude with the discussion about future projects and possible astrophysical applications of the general relativistic PR effect model in high-energy astrophysics.

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SHORT TALKS

Tereza Vardanyan

Postdoctotal Researcher

University of Bologna

Exact Solutions of the Einstein Equations for an Infinite Slab with Constant Energy Density.

Abstract

We find exact static solutions of the Einstein equations in the spacetime with plane symmetry, where an infinite slab with finite thickness and homogeneous energy (mass) density is present. In the first solution the pressure is isotropic, while in the second solution the tangential components of the pressure are equal to zero. In both cases the pressure vanishes at the boundaries of the slab. Outside the slab these solutions are matched with the Rindler spacetime and with the Weyl-Levi-Civita spacetime, which represent special cases of the Kasner solution.

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SHORT TALKS

Syed Naqvi

Jagiellonian Astronomical University, Polski

Gravitational wave Memory Effect

Abstract

Gravitational waves offer a unique window to study the strong-field regime of general relativity. In 1916-18, Einstein showed their existence in linearized approximation which was followed by a period of confusion. Finally cemented theoretically by Bondi, Sachs, Trautman gravitational waves are an important tool to discover new information about fundamental gravity effects.

One of the persistent gravitational wave effect called memory effect forms an interesting proposition theoretically and astrophysically. It is essentially a permanent displacement between particles atier GW passes. It's linear and non-linear form will be important for the future GW detections from compact binary sources. This effect gives information about the asymptotic nature of spacetime and is relevant for a large number of detections by LIGO/VIRGO. The linear part discovered by Zel'dovich & Polnarev and the nonlinear part discovered by Christodoulou help us understand the nature of spacetime and explore further the nonlinear part of general relativity. We plan to study the linear memory effect for different wave profiles under the exact plane wave solution of Einstein's vacuum equations. The displacement and velocity memory effects are studied by analyzing the geodesic equation for test masses under exact plane wave spacetime.

SHORT TALK

Elias Arawi Sol Megier
First year Ph.D. student at
Mathematics Department of
Milan State University

"Square-Torsion Gravity: a geometric candidate for dark matter"

My current research activity is aimed at exploring the possibility that dark matter be described by spacetime geometry. This is achieved using a special instance of the so called square-torsion theories of gravity. Theories in this class extend the Einstein-Hilbert action with terms quadratic in the torsion tensor. The theory I study seems to have hitherto been neglected due to the fact that the torsion tensor is not totally fixed by the equations of motion. Some torsional degrees of freedom remain to be fixed a priori as though they were external sources. I try to use this analogy with matter and show that it becomes mathematically exact for a spacetime with vanishing spin density. The free degrees of freedom then appear in the Einstein equations as a stress-energy tensor due to torsion. This tensor can take the exact form of dust, which is one of the most successful models for dark matter. During my talk I will present the main ideas underpinning these results and sketch my work in progress.

Domodossola (Italy) - July 2019

Edited by

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