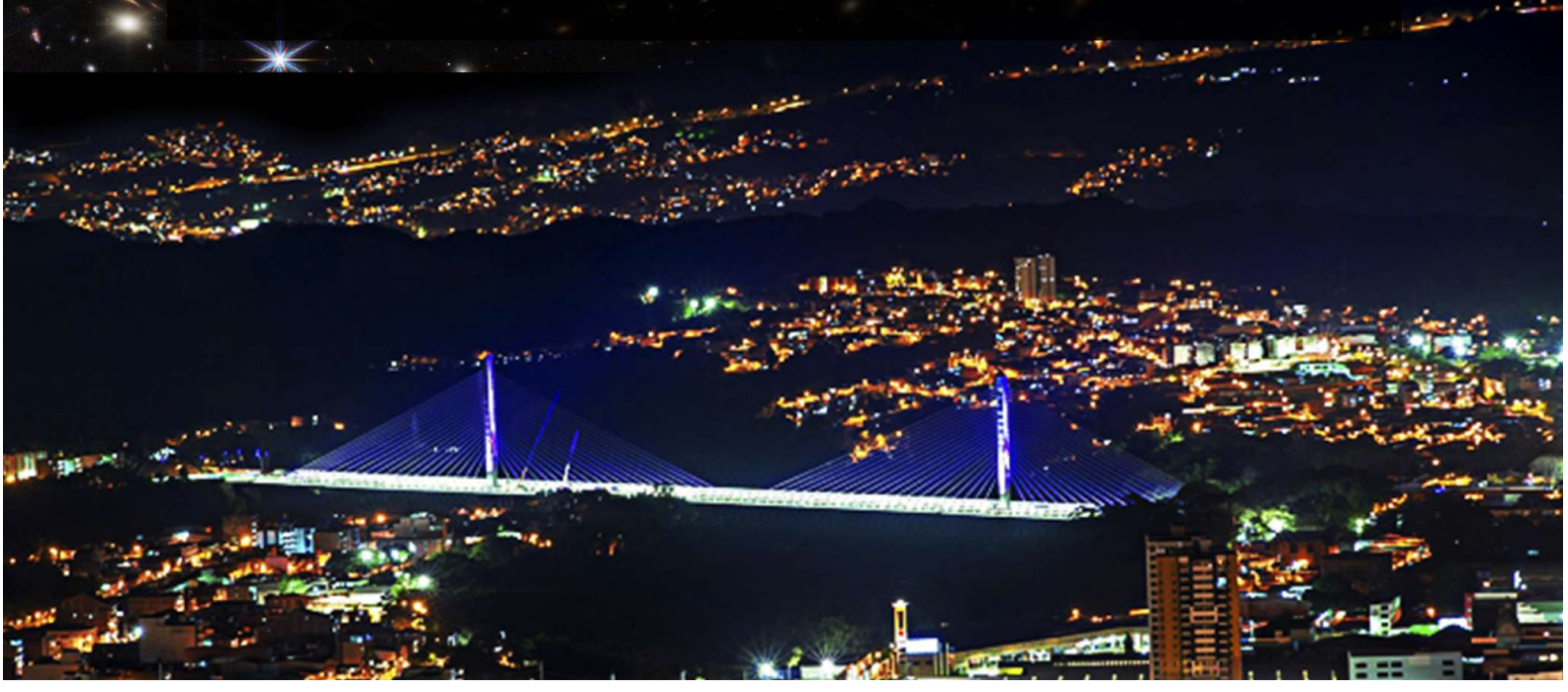
Third Workshop on

Current Challenges in Cosmology

October 23–27, 2023

Bucaramanga - Colombia (UIS Central Campus)

Book of Abstracts



UAN Universidad Antonio Nariño · Universidad del Valle · Universidad Industrial de Santander · UIS · Universidad Nacional de Colombia · Universidad ECCI · Colombia Potencia de la Vida · Ciencias

Contents

Overview

The main objective of this third edition of a workshop on current challenges in cosmology is to discuss several topics in Cosmology, from both theoretical and numerical approaches. Roughly speaking, the topics of discussion can be classified in the following subjects:

- Inflation and the early Universe; gravitational waves,
- Statistics, Weak Lensing and Large-Scale Structure,
- Dark energy and modified gravity.

The workshop is intended to facilitate communication and discussion among researchers, to promote future collaborations and to boost the work of local research groups in theoretical and data-driven cosmology. Along with plenary talks, there will also be discussion sessions aimed to provoke debate and stimulate collaborative work among the participants. The list of invited speakers was designed with the purpose of bringing together a group of researchers with a well known long term trajectory, jointly with a group of young authors with an important progression in their careers during the latest years and with a remarkable academic production in the interest subjects of the workshop.

Keynote Speakers

- Alejandro Jiménez Cano - *Tartu University*
- Alma González - *Universidad de Guanajuato*
- Andrés Plazas - *Standford University*
- Antonio Enea Romano - *Universidad de Antioquia*
- Darío Bettoni - *León University*
- Domenico Sapone - *Universidad de Chile*
- Elena Giusarma - *Michigan Technological University*
- José Beltrán Jimenez - *Universidad de Salamanca*

- Konstantinos Dimopoulos - *Lancaster University*
- Miguel Quartin - *Universidade Federal do Rio de Janeiro*
- Natalia Porqueres - *Oxford University*
- Sebastián Bahamonde - *Tokyo Institute of Technology*
- Sultan Hassan - *New York University*
- Tomi Koivisto - *Tartu University*
- Verónica Errasti Díez - *Ludwig-Maximilians-Universität München (LMU Munich) & Excellence Cluster ORIGINS*

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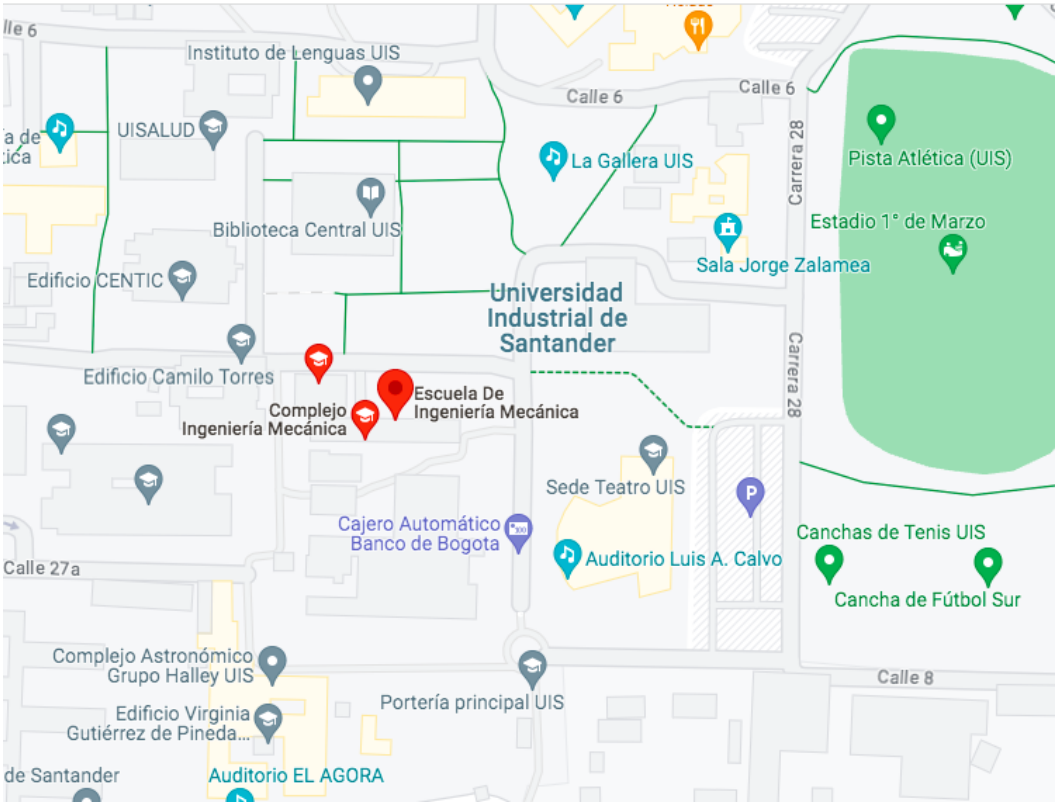
Venue

Aula Máxima de la Escuela de Ingeniería Mecánica (Campus Central UIS, Carrera 27 Calle 9, Bucaramanga - Colombia)



Practical Information

Internet Connection: Free internet connection is available at the conference venue. Use the following wifi network:

Wifi: **Invitados_UIS**
User: **invfisica@uis.co**
Password: **892767**

VISA: Citizens from a limited number of countries only are required to obtain a VISA to enter Colombia. Please check at http://www.cancilleria.gov.co/en/procedures_services/visas if you require a visa before arranging your trip.

Currency: The local currency is the Colombian peso (COP). Use the on-line currency Converter for more accurate conversion: http://www.xe.com/

Weather: Bucaramanga's weather is mostly warm. Over the year temperature can typically vary from 20 °C to 28 °C. On-line weather information can be found here.

Restaurants: There are plenty of restaurants near the campus with variety of tastes. Also, there are some restaurants inside the campus. We recommend to walk around Calle 9 and Carrera 27.

Transport: *Metrolinea* is the main bus system in Bucaramanga. Notice however that not all the main streets are covered by this system. The closest station to the campus is **Parque Estación UIS**. A complete tool could be found in https://www.metrolinea.gov.co/v3.0/.

Activities in Bucaramanga: there are several interesting places that can be visited during the stay in Bucarmanga (also in nearby towns):

1. **Parque Nacional de Chicamocha**
   Website
2. **Catedral de la Sagrada Familia**
   Website
3. **Puente del Bicentenario**
   Wikipedia
4. **Parque del Agua**
   Website
5. **Centro Comercial Cacique**
   Website
6. **Parque San Pio**
   TripAdvisor
7. **Universidad Industrial de Santander (UIS)**
   Website

Take a look also in these suggestions for the best restaurants, bars and pubs in Bucaramanga.

Be safe: A number of precautions are advisable for you to enjoy a safe stay in Bucaramanga. Please, remember to:

- Do not leave your electronic devices: smart phones, tablets, laptops, etc... in plain sight.
- Do not order any taxi at random: ask for help to order one. Apps like *Uber* and *Cabify* work pretty well in the whole country

Useful contacts :

- Emergencies (police and medical): Line **123**. This number can be called from any phone, including mobile phones without a SIM card.
- Taxis: please be aware, try to get taxis only in authorized sites. You can also use these numbers to get a safe option:
  Taxis Libres: (607) 633 3333 - 310 2111111

  Online applications: Cabify `https://cabify.com/es`, Uber `https://www.uber.com/co/es/`
- Ordering food online. We recommend the online application `https://rappi.com.co/`. Depending on your location, it shows the near options to you.

Workshop Program

Registration: **Monday 23th, 8:20 am - 8:50 am**
Opening and welcome speech: **Monday 23th, 8:50 am**

	Monday 23	**Tuesday 24**	**Wednesday 25**	**Thursday 26**	**Friday 27**
09:00 10:00	Miguel Quartin	Alma González	Tomi Koivisto	Alejandro Jimenez Cano	Natalia Porqueres (Remote)
10:00 10:15	Coffee Break				
10:15 11:15	Elena Giusarma (Remote)	Konstantinos Dimopoulos (Remote)	José Beltrán Jimenez	Verónica Errasti Díez	Dario Bettoni
11:15 12:15	Discussion session	Discussion session	Discussion session	Discussion session	Discussion session
12:15 14:00	Lunch				
14:00 15:00	Domenico Sapone	Andrés Plazas (Remote)	Antonio Enea Romano	Sebastian Bahamonde	Sultan Hassan (Remote)
15:00 15:15	Coffee Break				
15:15 16:15	Discussion session	Discussion session	Discussion session	Discussion session	Discussion session
16:15 18:15		Short Course		Short Course	Short Talks
18:15 19:00					
19:00 20:00			Public Lecture		

MONDAY 23th October

Miguel Quartin: Improving LSS analysis with velocities and model-independence
Elena Giusarma: Unveiling the Universe with Machine Learning: A Cosmological Perspective
Domenico Sapone: Behind the scenes of an experiment

TUESDAY 24th October

Alma González: An overview of DESI Lyman alpha forest data and science
Konstantinos Dimopoulos: Cosmic Inflation and Dark Energy and Gravitational Waves Andrés Plazas: The Vera C. Rubin Observatory, the LSSTCam, and the Legacy Survey of Space and Time

Short Course

16:15-18:15 Alma González: Exploring the public DESI data early release

WEDNESDAY 25th October

Tomi Koivisto: Teleparallel Relativity
José Beltrán Jiménez: Robustness of the Geometrical Trinity of Gravity
Antonio Enea Romano: The mirage of luminal modified gravitational-wave propagation

Public Lecture

19:00-20:00 Verónica Errasti Díez: Lo que la física (no) sabe explicarnos

THURSDAY 26th October

Alejandro Jiménez Cano: Teleparallel Relativity
Verónica Errasti Díez: Rethinking stability
Sebastian Bahamonde: Metric-Affine Gravity: From theory to applications in black holes and cosmology

Short Course

16:15-18:15 Alma González: Exploring the public DESI data early release

FRIDAY 27th October

Natalia Porqueres: Lifting the weak lensing degeneracy with a field-based likelihood
Dario Bettoni: Hubble-induced phase transitions: Ricci-reheating, Cosmic Defects and Gravitational Waves
Sultan Hassan: Optimal methods for retrieving information from upcoming surveys

Short Talks

16:15-16:35 Guillermo Palma: Analyzing Running Vacuum Energy and Viscous Dark Matter Models

16:35-16:55 John Byron Orjuela-Quintana: Tracking the validity of the quasi-static and sub-horizon approximations in modified gravity

16:55-17:15 Gabriel Gomez: Generalized Coupled Vector Dark Energy Models

17:15-17:25 Santiago Garcia Serna: Scaling Solutions in Generalized Proca Theory and its Cosmological Implications

17:25-17:35 Gabriela Alejandra Valencia Zuñiga: Structure formation in an anisotropic universe

17:35-17:45 Jhan Nicolás Martínez Lobo: Particle-like solutions in the generalized SU(2) Proca theory

17:45-17:55 Jose Rodríguez: Some astrophysical properties of compact object solutions in the Generalized SU(2) Proca theory

17:55-18:05 William Jaimes: Frame dragging effect around slowly rotating stars in modified gravity theories

Invited Talks

Monday 23th October

Improving LSS analysis with velocities and model-independence 09:00

Miguel Quartin

Universidade Federal do Rio de Janeiro, Rio de Janeiro - Brasil

The large upcoming spectroscopic surveys like DESI and Euclid will enable a very precise measurement of the matter power spectrum and bispectrum on a vast range of scales. I will discuss how this precision can be improved with the combined use of galaxies and standard candles as tracers of the matter and velocity fields. I will show the benefits of using either supernovae or bright standard sirens as standard candles for this purpose. I will also discuss how this increase in precision can come hand-in-hand with improved accuracy by using a methodology which analyzes the mildly non-linear scales of the LSS data without the need to make any model assumptions on the nature of dark energy. Finally, I will forecast the achievable precision with this methodology for the most relevant cosmological parameters and discuss how this could resolve the issue of the cosmological tensions.

Unveiling the Universe with Machine Learning: A Cosmological Perspective 10:15

Elena Giusarma

Michigan Technological University, Michigan - United States

In the near future, forthcoming Large-Scale Structure (LSS) missions such as the DESI, eROSITA, Euclid, WFIRST , and LSST are poised to survey extensive cosmological volumes, collecting terabytes of data that promise to enhance our understanding of cosmological parameters with unprecedented precision. To achieve this ambitious objective, it is crucial to extract the maximum amount of information from data. However, we must tackle two primary challenges to conduct optimal cosmological analyses: the development of precise theoretical models in the non-linear regime and the creation of novel computational techniques to surmount the computational bottlenecks inherent in traditional simulation methods. In this presentation, I will introduce an innovative machine learning (ML) approach designed to construct a deep learning emulator at the field level for cosmological simulations, with a primary focus on neutrino particles. I will demonstrate that the deep learning methodology offers a highly accurate alternative to conventional techniques by directly mapping non-standard cosmological simulations, including those involving neutrinos, from standard simulations. This approach has the potential to generate precise predictions for cosmological fields across

a range of input parameters, facilitating faster and more efficient exploration of non-standard cosmological scenarios.

Behind the scenes of an experiment

14:00

Domenico Sapone
Universidad de Chile, Santiago de Chile - Chile

Understanding the expansion of the universe is the top priority of all space agencies. In this talk, we will discuss the primary cosmological observables capable of shedding light on these mysterious phenomena. We will also focus on the intense efforts that the European Space Agency is undertaking to understand the nature of accelerated expansion. In particular, we will present the Euclid Satellite.

Tuesday 24th October

An overview of DESI Lyman alpha forest data and science

09:00

Alma González
Universidad de Guanajuato, Guanajuato - México

The Lyman alpha forest measured from the spectra of high-redshift quasars observed with DESI will provide a wealth of information for cosmology. It will allow us to unveil the expansion history with great precision by measuring the BAO scale at redshift above 2, through the measurement of the forest absorptions auto-correlation and cross-correlations with quasars. Furthermore, it will provide information on scales of about tens of Mpc, allowing to set strong constraints to massive neutrinos and dark matter with small scale suppression, such as warm and scalar field dark matter. In this talk I will give an overview of the Lyman alpha DESI early data and science as well as prospects for the first year analysis.

Cosmic Inflation and Dark Energy and Gravitational Waves

10:15

Konstantinos Dimopoulos
Lancaster University, Lancaster - United Kingdom

I will briefly introduce cosmic inflation and dark energy and combine them in quintessential inflation. A stochastic spectrum of primordial gravitational waves (PGWs) is expected from inflation, but it is unobservable in the near future. I will discuss some ways to boost the inflation generated PGWs, in quintessential inflation and beyond, which may result in characteristic observable spectra. If indeed observed, such PGWs can shed light on the background theory.

The Vera C. Rubin Observatory, the LSSTCam, and the Legacy Survey of Space and Time

14:00

Andrés Plazas

Standford University, Stanford - United States

The Vera C. Rubin Observatory, currently under construction on Cerro Pachón in Chile, will feature an 8.4-meter telescope, the largest digital camera in the world for astronomy (3200 megapixels), an automated data processing system, and an online public engagement platform. Rubin will conduct the Legacy Survey of Space and Time (LSST), and it will operate on an automated cadence, capturing an area the size of 40 full moons and returning to the same area of sky approximately every three nights after imaging the full sky. The Rubin Observatory was the top-ranked large ground-based project in the US 2010 Astrophysics Decadal Survey, and it will advance science in four main areas: the nature of dark matter and understanding dark energy, cataloging the Solar System, exploring the changing sky, and Milky Way structure and formation. Engineering and then science first light is expected in 2023 and full operations for the ten-year survey commencing in the second half of 2024. In this talk, I will introduce the Rubin Observatory, the LSST, and how to get involved via the Data Preview 0 in preparation for the survey. I will additionally focus on the LSSTCam and its detectors, and discuss the impacts of detector and other systematics on weak lensing —a fundamental probe that will be used by LSST and other stage IV surveys—for cosmological investigations.

Wednesday 25th October

Teleparallel Relativity

09:00

Tomi Koivisto

Tartu University, Tartu - Estonia

The principle of relativity is the requirement that the equations describing the laws of physics have the same form in all admissible frames of reference. To complete realisation of the principle required the recent refinement of Einstein's theories of gravity, since they did not distinguish the admissible reference frames (but confused reference frames with coordinate systems). The new canonical theory is presented as a unification of the "geometrical trinity of gravity", a triad of alternative geometrical formulations and the corresponding alternative interpretations of the gravitational interaction. Applications to black holes and cosmology will be discussed. The canonical theory provides the unique consistent definition of relativistic energy, thus resolving a long-standing foundational problem in physics and paving the way for general-relativistic quantum mechanics.

Robustness of the Geometrical Trinity of Gravity 10:15

José Beltrán Jiménez

Departamento de Física Fundamental, Universidad de Salamanca, Salamanca - Spain

The equivalence principle naturally provides gravity with a geometrical character. However, the precise geometry we employ to describe it admits a certain flexibility. In particular, within a metric-affine framework, Einstein's gravity can be equivalently ascribed to the three independent objects that characterise a connection, i.e., curvature, torsion and non-metricity. After reviewing these three alternative descriptions of gravity, I will uncover a general teleparallel description of GR and how pathologies generally arise beyond the GR equivalents. Finally, I will discuss the inclusion of matter couplings within these frameworks.

The mirage of luminal modified gravitational-wave propagation 14:00

Antonio Enea Romano

Universidad de Antioquia, Medellín - Colombia

Using conformal invariance of gravitational waves, we show that for a luminal modified gravity theory, the gravitational-wave propagation and luminosity distance are the same as in general relativity. The relation between the gravitational-wave and electromagnetic-wave luminosity distance gets however modified for electromagnetism minimally coupled to the Jordan frame metric. Using effective field theory we show that the modified relation obtained for luminal theories is also valid for non-luminal theories with Jordan frame matter-gravity coupling. We generalise our analysis to a time-dependent speed of gravitational waves with matter minimally coupled to either the Jordan or Einstein frame metrics.

Thursday 26th October

Quadratic metric-affine gravity and stability of the vector sector 09:00

Alejandro Jiménez Cano

Tartu University, Tartu - Estonia

In this talk, we will start by reviewing the geometrical entities that constitute the basis of metric-affine gravity: the metric and the connection, as well as the decomposition of the latter. Then the quadratic theory will be presented and we will show how strong the stability conditions for the four vector irreducible pieces of the torsion and the nonmetricity tensors are. These will reduce the number of parameters in the curvature-square sector from 16 to 5. We will also present the case of Weyl-Cartan gravity, proving that the stability of the vector sector completely fixes the dynamics of the full Lagrangian to just an Einstein-Proca theory or pure General Relativity.

Rethinking stability

10:15

Verónica Errasti Díez

Ludwig-Maximilians-Universität München (LMU Munich) & Excellence Cluster ORIGINS

It's long been recognized that higher-order theories generically propagate an excess of degrees of freedom which, to make matters worse, are associated with negative (kinetic) energies. These are known as Ostrogradski instabilities. Until very recently, such instabilities were immediately disregarded as unphysical and methods were developed to construct theories that would avoid them. Indeed, this has been a very active research subject in the context of gravity theories, with a focus on cosmological applications. A trickle of counterexamples, numerical first and analytical shortly afterwards, confront the established understanding. These examples call for a profound reflection on stability, physically viable theories and theory-construction mechanisms.

Metric-Affine Gravity: From theory to applications in black holes and cosmology

14:00

Sebastian Bahamonde

Tokyo Institute of Technology, Tokyo - Japan

Metric-Affine Gravity constitutes a natural extension of General Relativity that incorporates the notions of torsion and nonmetricity in an enriched space-time geometry. In particular, the spin angular momentum of matter turns out to operate as a source of torsion, whereas the so-called dilation and shear currents of matter act as sources of nonmetricity. In this talk, I will introduce the basic concepts of these theories with the aim to present applications in both black holes and cosmology. I will present an exact static and spherically symmetric black hole solution with spin, dilation and shear charges corresponding to the broadest family of black holes found so far. Some rotating black-hole extensions and the corresponding algebraic classification of the gravitational fields will also be presented. In the last part of my talk, I will focus on cosmology and present the formulation of the linear cosmological perturbation theory using the 3+1 and SVT decomposition for the corresponding geometrical quantities involved in the theory. As an interesting example, the cosmological perturbation of the spin-3 field appearing in nonmetricity will be discussed.

Lifting the weak lensing degeneracy with a field-based likelihood

09:00

Natalia Porqueres

Oxford University, Oxford - United Kingdom

With Euclid and the Vera Rubin Observatory starting their observations in the coming years, we need highly precise and accurate data analysis techniques to optimally extract the information from weak lensing data. However, the standard approach based on fitting some summary statistics is inevitably suboptimal and imposes approximations on the statistical and physical modeling. I will present a new method to analyse weak lensing based on a full physics model and field-based statistics. By analysing the data at the pixel level, this method lifts the weak lensing degeneracy and provides uncertainties on the cosmological parameters up to a factor 5 smaller than those from standard techniques on the same data. In addition to a gravity model, the method accounts for intrinsic alignments and baryon feedback. I will discuss the current status and ways to meet the challenges of this approach for its first real data application.

Hubble-induced phase transitions: Ricci-reheating, Cosmic Defects and Gravitational Waves

10:15

Dario Bettoni

León University, León - Spain

A post-inflationary epoch with a stiff equation of state parameter, like it happens in quintessential inflation, leads to an interesting phenomenology in the presence of non-minimally coupled spectator fields with internal symmetries. I will discuss how this scenario can provide an efficient reheating mechanism, the formation of cosmic defects and the production of gravitational waves and how these can be used to test early universe properties.

Optimal methods for retrieving information from upcoming surveys

14:00

Sultan Hassan

New York University, New York - United States

Due to the unprecedented sensitivity and large field of views, extracting the maximum amount of information remains a key challenge in future surveys. In this talk, I will discuss the current challenges in analyzing the expected big data from upcoming large scale surveys, and present several promising techniques to perform high-dimensional likelihood-free inference and emulation using generative models, namely normalizing flows, and diffusion models. I will then focus on my recent attempts to open the black-box of neural networks. In particular, I will show how a similarity measure metric of learning representation may be used to examine the relationship between similarity and performance of pre-trained neural networks on the CAMELS Multifield Dataset. By comparing representations between layers of two randomly-initialized neural network architectures, a correlation between similarity and accuracy in recovering cosmological parameters is observed. This analysis shows that exploring representation similarity against performance offers meaningful insights into complex deep learning models to generalize them to out-of-distribution samples.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Lo que la física (no) sabe explicarnos
La física es un magnífico entramado de ideas que nos permite comprender mejor el universo que habitamos y dónde nos ubicamos en el mismo. A este fin, haremos un breve recorrido por los principales resultados de la física contemporánea, relacionándolos entre sí. El viaje nos llevará hasta las fronteras mismas del conocimiento… ¡y más allá!
No se usarán ecuaciones y no es necesario conocimiento previo alguno. Pero no hay que dejarse en casa ni la curiosidad, ni la imaginación.
Miércoles 25 de Octubre
7:00 p.m.
Auditorio de Ingeniería Mecánica
Verónica Errasti Díez
(Ludwig-Maximilians-Universität München (LMU Munich) & Excellence Cluster ORIGINS)
Foto: https://www.santandercompetitivo.org

FRIDAY 27th October

Analyzing Running Vacuum Energy and Viscous Dark Matter Models

16:15

Guillermo Palma

Universidad de Santiago de Chile, Santiago de Chile - Chile

Running vacuum models and viscous dark matter scenarios beyond perfect fluid idealization are two appealing theoretical strategies that have been separately studied as alternatives to solve some problems rooted in the ΛCDM cosmological model. In this talk, I will explain the cosmological consequences of combining these two notions in a single cosmological setting, paying particular attention in the interplay between these two constituents in different cosmological periods. In particular, I will discuss a well-studied running vacuum model inspired by renormalization group, together with a recently proposed parameterization for the bulk viscosity [Eur. Phys. J. Plus (2023) 138:7381]. Further, by applying dynamical system analysis, I will explain the physical aspects of the new phase space that emerges from the combined models and derive stability conditions that ensure complete cosmological dynamics. It turns out, that four distinct classes of models arise, whose associated critical points are non-trivially renewed compared to the single scenarios. As a complementary strategy to dynamical system analysis, a detailed numerical exploration is performed to quantify the impact of both the running parameter and the bulk viscosity coefficient on the cosmological evolution. Finally, I will present the conclusions including that for some values of the model parameters, the numerical solutions display qualitative differences from the ΛCDM model, which are phenomenologically appealing in light of cosmological observations.

Tracking the validity of the quasi-static and sub-horizon approximations in modified gravity

16:35

John Byron Orjuela-Quintana

Universidad del Valle, Cali - Colombia

Within the framework of modified gravity, the quasi-static and sub-horizon approximations are widely used in analyses aiming to identify departures from the concordance model at late-times. In general, it is assumed that time derivatives are subdominant with respect to spatial derivatives given that the relevant physical modes are those well inside the Hubble radius. In practice, the perturbation equations under these approximations are reduced to a tractable algebraic system in terms of the gravitational potentials and the perturbations of involved matter fields. Here, in the framework of $f(R)$ theories, we revisit standard results when these approximations are invoked using a new parameterization scheme that allows us to track the relevance of each time-derivative term in the perturbation equations. This new approach unveils correction terms which are neglected in the standard procedure. We assess the relevance of these differences by comparing results from both approaches against full numerical solutions for two well-known toy-models: the designer $f(R)$ model and the Hu-Sawicki model. We find that *i)* the sub-horizon approximation can be safely applied to linear perturbation equations for scales $0.06h/Mpc \leq k \leq 0.2h/Mpc$, *ii)* in this "safety region", the quasi-static approximation provides a very accurate description of the late-time cosmological dynamics even when dark energy significantly contribute to the cosmic budget, and *iii)* our new methodology performs better than the standard procedure, even for several orders of magnitude in some cases. Although, the impact of this major improvement on the linear observables is minimal for the studied cases, this does not represent an invalidation for our approach. Instead, our findings indicate that the perturbation expressions derived under these approximations in more general modified gravity theories, such as Horndeski, should be also revisited.

Generalized Coupled Vector Dark Energy Models

16:55

Gabriel Gomez

Universidad de Santiago de Chile, Santiago de Chile - Chile

I will present a detailed approach for building models of interacting dark energy that incorporate vector fields conformally and disformally coupled to dark matter, independent of the underlying gravity theory. This discussion will include a focus on establishing general conditions to prevent the presence of ghost instabilities within the theory. For concreteness, we will consider the standard Proca theory with a vector exponential potential to describe the vector-tensor sector. Additionally, specific coupling functions will be assumed to investigate the dynamics of the cosmological background using dynamical system techniques. To gain a more quantitative understanding of the effects of the coupling parameters on the cosmological background evolution, we will also perform numerical computations. These results shed light on how these couplings can significantly influence the cosmological dynamics during various stages of the Universe's evolution compared to the standard ΛCDM cosmological model.

Scaling Solutions in Generalized Proca Theory and its Cosmological Implications 17:15

Santiago García Serna, John Byron Orjuela Quintana & César A Valenzuela-Toledo
Universidad del Valle, Cali - Colombia

In the framework of the generalized Proca theories, we derive for the first time the most general Lagrangian allowing for scaling solutions between dark energy and cold dark matter. At background level, we highlight two interesting features for this novel model. Firstly, although its equation of state of is exactly -1, the dark energy component has a dynamical behaviour due to its coupling with the cold dark matter. Secondly, the existence of an attractor point where the scaling condition holds and the universe can undergo accelerated expansion. At the perturbative level, we derive the growth equation for cold dark matter under the sub-horizon and quasi-static approximations. The solutions of this equation show that the strength of gravity can vary at late times, where the differences with respect to the concordance model depend on the parameters of the novel model.

Structure formation in an anisotropic universe 17:25

Gabriela Alejandra Valencia Zuñiga, Josué Motoa-Manzano & César A Valenzuela-Toledo
Universidad del Valle, Cali - Colombia

In this work, we investigate the growth of cosmological perturbations within a cosmological scenario where the early universe is dominated by dark matter and gradually becomes anisotropic at later times due to the presence of a small shear tensor associated with dark energy. To describe this, we employ the Bianchi I metric, which characterizes a spacetime background that is homogeneous but anisotropic. The equations of motion for a dark matter fluid are derived and solved both at linear and non-linear orders. This study is performed using a constant equation of state for the dark energy component and a time-dependent rate of anisotropic expansion.

Particle-like solutions in the generalized SU(2) Proca theory 17:35

Jhan Nicolás Martínez Lobo[a], Gabriel Gomez[b], Jose Rodríguez[a] & Yeinzon Rodríguez[a,c]
[a] *Universidad Industrial de santander, Bucaramanga - Colombia,* [b] *Universidad de Santiago de Chile, Santiago de Chile - Chile,* [c] *Universidad Antonio Nariño, Bogotá - Colombia*

The generalized SU(2) Proca theory is a vector-tensor modified gravity theory where the action is invariant under both diffeomorphisms and global internal transformations of the SU(2) group. This work constitutes the first approach to investigate the physical properties of the theory at astrophysical scales. We have found solutions that naturally generalize the particle-like solutions of the Einstein-Yang-Mills equations, also known as gauge boson stars. Under the requirement that the solutions must be static, asymptotically flat, and globally regular, the t'Hooft-Polyakov magnetic monopole configuration for the vector field rises as one viable possibility. The solutions have been obtained analytically through asymptotic expansions and numerically by solving the boundary value problem. We have found new features in the solutions such as regions with negative effective energy density and imaginary effective charge. We have also obtained a new kind of globally charged solutions for some region in the parameter space of the theory. Furthermore, we have constructed equilibrium sequences and found turning points in some cases. These results hint towards the existence of stable solutions which are absent in the Einstein-Yang-Mills case.

Some astrophysical properties of compact object solutions in the Generalized SU(2) Proca theory

17:45

Jose Rodríguez

Universidad Industrial de Santander, Bucaramanga - Colombia

In this work, we studied some compact object solutions in the Generalized SU(2) Proca theory. This modified gravity model is a vector-tensor theory whose action is invariant under global transformations of the SU(2) group and includes second-order derivative self-interactions of the vector field beyond the massive Yang-Mills theory. First, we studied two Lagrangian pieces consisting of four gauge fields minimally coupled to metric tensor. These pieces give rise to an exact Reissner-Nordstrom black hole solution endowed with two different non-Abelian effective charges that depend on the free parameters of the theory. We analyzed the spacetime structure and found the parameter space that preserves the weak cosmic censorship conjecture. The joint analysis of observations of the EHT's first images of Sagittarius A* of our Galaxy and the Keck telescope set the first constraint on the free parameters of the theory beyond the theoretical bounds found. Also, we present some numerical solutions in the Generalized SU(2) Proca theory which describes a spherical and static black hole. We constructed equilibrium sequences and studied some thermodynamic properties. Finally, we studied the effective potential of soliton solutions in the Generalized SU(2) Proca theory. These objects are compact enough to generate a photon sphere making them black hole mimickers.

Gravitational theories in the context of non-Riemannian geometries on the edge of Ockham's razor

17:55

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The Newtonian theory of gravity can be reformulated in the language of differential geometry as a non-relativistic theory in curved spacetime, where the source of the curvature is associated with the standard Newtonian gravitational potential. This is known as the Newton-Cartan (NC) theory, and although at a dynamic level it is absolutely equivalent to the standard Newtonian theory, the interpretation of geometric objects and the very structure of Newtonian spacetime is different. A determining factor of this reformulation is that it allows a parallel comparison, and in the same geometric language, of the postulates necessary to construct NC theory and Einstein's theory of General Relativity (GR). It is concluded that the GR theory is simpler than the NC theory since it requires fewer postulates for its construction. Based on these conclusions and adhering to the principle of Ockham's razor, it is reasonable to think that GR is the best option that nature has had to describe gravity. However, it has been shown that, at the dynamical level, GR is indistinguishable from its teleparallel and symmetric teleparallel versions in the context of non-Riemannian geometries. Therefore, in this work the question arises: which gravitational theory would be preferred by Nature based on its simplicity and the number of postulates required for its construction?

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