CoCo 2o22: Cosmology in Colombia

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Book of Abstracts

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Dynamical system with anisotropic tachyon field

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We study a dark energy (DE) model based on a tachyon field ϕ coupled to a vector field in a Bianchi-I anisotropic background. We consider that the potential of the tachyon field V and the coupling function f satisfy the differentials equations $\alpha = M_{pl} V_{,\phi}/V^{3/2}$ and $\beta = (M_{pl} f_{,\phi}) / \left(f\sqrt{V}\right)$ respectively, where M_{pl} is the reduced Planck mass, α and β are constants. A dynamical analysis of the differential equations that describe the dynamics of the Universe is performed to identify the parameter window compatible with an anisotropic or isotropic model of dark energy. Due to the complexity of differential equations, it is necessary to employ a numerical approach to find an approximation of the available region of parameters α and β. The field equations and the equations of motion are solved numerically in order to verify that our model reproduces the proper expansion history of the universe. We find that the late anisotropic hair predicted by our model is within the observational bounds.

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Dark energy from vector gauge fields

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In this work, we study a dark energy model solely based on gauge vector fields, coupled to dark matter. We use the dynamical system approach to investigate the stability of this proposal and identify both, scaling and late-time accelerating solutions. Then, we numerically integrate the equations that characterize the dynamics of the model to verify the results of the previous analysis and identify the particular evolution of the universe predicted for this model. The action of the model is

$$S = \int d^4x\sqrt{-g}\left[\frac{1}{2}M_P^2 R - \frac{1}{4}F^a_{\mu\nu}F_a^{\mu\nu} - V(X) + f(X,Y)\mathcal{L}_{mat} + \mathcal{L}_r + \mathcal{L}_b\right],$$

where g is the determinant of the metric $g_{\mu\nu}$, M_P is the reduced Planck mass, R is the Ricci scalar, $F^a_{\mu\nu}$ is the field strength tensor, $V(X)$ is the potential of the field, $f(X,Y)$ is a function that couples the gauge field with the dark matter, $X = A^a_\mu A^\nu_a$ and $Y = F^a_{\mu\nu}F_a^{\mu\nu}$. $\mathcal{L}_{mat}$, $\mathcal{L}_r$, and $\mathcal{L}_b$ are the Lagrangians densities for dark matter, baryonic matter and radiation fluids, respectively.

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Construction of initial data sets for relativistic cosmology

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In this talk, we will present an analytical and numerical approach for constructing initial data sets of inhomogeneous cosmological spacetimes with a spatial topology of $\mathbb{T}^3$. On the one hand, the analytical part is based on a 2+1 decomposition of the so-called constraint equations, which are a set of tensorial equations that determine the initial data in general relativity, to turn them into a certain hyperbolic system. On the other hand, due to the spatial topology and the periodic boundary conditions, the numerical part is built on a Fourier spectral method, which allows to keep a reasonable accuracy in the numerical computations of the initial data components. We test the suitability of our infrastructure against some well-known initial data sets, and we apply it to construct non-linear perturbations of some cosmological spacetimes such as FRW or Gowdy spacetimes.

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Schrödinger-Poisson model for the growth of cosmic structures

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The formation of structures in the universe is studied with the help of a dynamical cold dark matter model addressed as the Schrödinger-Poisson model. The Schrödinger-Poisson equation (SPE) is obtained from the Vlasov-Poisson equation which is derived in a perturbation regime of the fluid equations in the Newtonian regime. The SPE is restricted to one dimension and numerically integrated using a representation in a B-Splines basis and the Crank-Nicolson method, under the Magnus approximation, for the time propagation. Using different dark energy models we obtain the cold dark matter dynamics and the matter power spectrum. We discuss the effects of these models paying special attention to the comparison with the Λ-CDM model.

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An effective fluid description of scalar-vector-tensor theories under the sub-horizon and quasi-static approximations

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In general, modified gravity theories can be seen as dark energy theories using the effective fluid approach. In this work, we apply this formalism to the most general second-order scalar-vector-tensor (SVT) theory of gravity. This will allow us to encompass all the free functions of the theory in terms of the equation of state, speed of sound, velocity, and anisotropic stress of a very general dark energy fluid. We show that under the quasi-static and sub-horizon approximations it is possible to obtain analytical expressions for the fields and the gravitational potentials, and thus fairly condensed expressions for the perturbations of the fluid. Using these analytical results, we reproduce some well-known computations in cosmological models within the SVT framework, such as quintessence, kinetic gravity braiding, f(R), and others, in order to test the accuracy of our approach. Furthermore, we propose a designer dark energy model whose background evolution is identical to that of the standard cosmological model, but different at the linear perturbative level. For this designer model, we compute some cosmological observables, such as the growth factor, the angular power spectrum, and the matter power spectrum, and compare them with the predictions given by the standard cosmological model.

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Frame dragging effect around slowly rotating stars in modified gravity theories

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We study the frame-dragging effect in the context of slowly rotating stars in Horndeski theory (HT) and Generalized Proca theory (GPT). The frame-dragging effect occurs when a rotating compact object distorts spacetime and inertial observers are dragged along when they are infree fall from infinity. James Hartle developed a methodology to study this effect for slowly rotating stars in the context of General Relativity (GR) through a perturbative treatment of the GR's field equations in powers of Ω^2 , Ω being the angular velocity of the star. Applying the same methodology, we find that deviations from GR are very tiny in HT; these results holds for both the interior and exterior regions of the star. For the GPT, we find constraints in the relevant modified gravity coupling; moreover, deviations from GR play an important role for the predictions regarding frame dragging. These deviations, which make the GPT quite distinguishable from GR, depend on both the vector field configuration and the value of the coupling constant.

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Decoupling-limit consistency of the generalized SU(2) Proca theory

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We study the consistency of the decoupling limit of the generalized SU(2) Proca theory (GSU2P). Namely, we study the healthiness of those terms whose analysis in the scalar limit was not originally established in the reconstruction of the full theory (see the work by Gallego Cadavid et al. [Phys. Rev. D 102, 104066 (2020)]). Those terms are the parity-violating $\tilde{\mathcal{L}}^1_{4,2}$ and the parity-conserving beyond SU(2) Proca terms $\mathcal{L}^3_{4,2}$ and $\mathcal{L}^4_{4,2}$. Using the 3+1 Arnowitt-Deser-Misner formalism, we write down the kinetic Lagrangian of these terms in the decoupling limit and show that their corresponding kinetic matrices are degenerate. This degeneracy is a necessary condition for the propagation of the right number of degrees of freedom, as required by the primary constraint-enforcing relation. Interestingly, the $\tilde{\mathcal{L}}^1_{4,2}$ term, which is purely non-Abelian, does not contribute to the kinetic Lagrangian of the theory, so its contribution is trivially degenerate. Similarly, but not trivially in these cases, the contributions of the $\mathcal{L}^3_{4,2}$ and $\mathcal{L}^4_{4,2}$ terms to the kinetic Lagrangian turn out to be degenerate as well. The results presented in this paper represent progress in the construction of the fully healthy GSU2P.

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Stability Criteria in f(R) Gravity from Thermodynamics Analogy

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In this work we analyze the stability criteria in f(R) theories of gravity in the metric formalism under the approach of a thermodynamics analogy proposed in [C.D. Peralta and S.E. Jorás JCAP06(2020)053] for ϕˆ4 and double well inflationary potentials. We starting from the mentioned potentials in the Einstein frame, and obtain a parametric form of f(R) in the corresponding Jordan frame. Such approach yields plenty of new pieces of information, namely a self-terminating inflationary solution with a linear Lagrangian, a robust criterion for stability of such theories, and a dynamical effective potential for the Ricci scalar R.

The addition of an ad-hoc Cosmological Constant in the Einstein frame leads to a Thermodynamical interpretation of this physical system described by a Van der Waals like behavior, which allows whole thermodynamics picture then follows: a equation of state, binodal and spinodal curves, phase transition, critical quantities (pressure, volume and temperature), entropy jumps, specific-heat divergence (and the corresponding critical exponent).

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THE PRIMORDIAL CURVATURE PERTURBATION IN THE GENERALIZED SU(2) PROCA THEORY

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We apply the δN formalism to study the spectrum and bispectrum of the primordial curvature perturbation ζ for the constant-roll inflation scenario where ζ is generated by vector field perturbations of a cosmic triad background field configuration. This is studied in the Friedmann-Lemaître-Robertson-Walker space-time background and in the framework of the generalized $SU(2)$ Proca theory. The latter is a variant of the generalized Proca theory where the vector field belongs to the Lie algebra of the $SU(2)$ group of global transformations under which the action is made invariant. This configuration naturally leads to consider the cosmic triad as a scalar field, the latter being the norm of the physical three-dimensional vector fields. Under this assumption, the predictions in the tensor to scalar ratio vs. spectral index plane are obtained as well as those for the level of non-gaussianity in the bispectrum, revealing the scenario would be in good agreement with the observations.

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Cosmología Observacional desde Colombia: DESI y la red cósmica

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El Dark Energy Spectroscopic Instrument (DESI) es a la fecha es el único experimento activo de medición de energía oscura de Etapa IV utilizando oscilaciones acústicas bariónicas y otras técnicas que se basan en mediciones espectroscópicas. Se espera que el proyecto tome datos hasta el año 2026.
A través de la Universidad de los Andes, Colombia es uno de los países que cuentan con participación en DESI junto a cerca de otras 70 instituciones en el mundo. Esto hace posible que estudiantes e investigadores en Colombia participen en un experimento de frontera en cosmología observacional, marcando un hito para Colombia en la historia del estudio de esta área de la ciencia.
DESI empezó a tomar datos en el 2021 y ya ha tomado más espectros de galaxias que los que se han tomado en todos los experimentos anteriores como SDSS o BOSS.
En esta charla presentaré a DESI, sus primeros resultados preliminares y la estructura de los Data Releases públicos que empezarán en el 2023. También presentaré resultados preliminares de estudios que pretenden utilizar la red cósmica como una nueva herramienta para acotar parámetros cosmológicos.

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Modified Chaplygin gas as early dark energy

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We introduce an effective parametrization of an early dark energy model that mimics radiation at early times and governs the present acceleration of the Universe. We show that such a parametrization can be modeled by a Chaplygin gas and investigate the cosmological viability of the model. We use a Bayesian method and the modular software \textsc{CosmoSIS} to find the best values for the free parameters of the model and some relevant cosmological parameters associated with the evolution of this matter-energy contribution. Our results predict an earlier formation of the structure and a shorter age of the Universe compared with the ΛCDM model. We also explore the likelihood that this kind of dark energy model could alleviate the ongoing tensions in cosmology, the Hubble tension, and the so-called σ_8 tension. Early dark energy models are quite promising for understanding the evolution of the early Universe and add dynamics to this dark component, which is still undetected yet predominant at this stage of the Universe.

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Colapso esférico en diversos modelos de energía oscura

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Se presentará un estudio del proceso de formación de estructuras a gran escala en el Universo, en el marco del modelo del colapso esférico, para diferentes escenarios de energía oscura. Se consideran modelos de energía oscura con ecuaciones de estado dinámicas construidas a partir del análisis fenomenológico y otras construidas a partir de campos, con el objetivo de evaluar los efectos del componente de energía oscura en el proceso de formación de estructuras. Primero se mostrará la evolución de las perturbaciones de materia tanto en el régimen no lineal como en el régimen lineal. Luego, se mostrará el cálculo de los parámetros que caracterizan el modelo del colapso esférico, es decir, la sobredensidad crítica δ_c, el parámetro de sobredensidad virial Δ_v y el factor de crecimiento D_+. Finalmente, mediante el formalismo Press-Schecter, se mostrará cómo la energía oscura afecta el proceso de formación de estructuras a gran escala.

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Improving dark matter halo catalogs for large scale structure using machine learning

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Our understanding of the Universe in its largest scales relies on our ability to accurately simulate the complexities of gravitational evolution, thus allowing us to test various cosmological models. Moreover, the increasing volume of the observations of our Universe and the nature of the targeted galaxies impose strong conditions on the size and mass resolution of these N-body simulations, thereby largely increasing the computational requirements past the tractability threshold. In order to mitigate the computational burden linked to large high-resolution (HR) simulations, we have developed a machine learning model that is able to increase the resolution of a low-resolution (LR) halo catalog by correcting the halo masses based on the relation of LR halos and their HR counterparts. The cost of our machine learning model is negligible compared to the cost of a real HR simulation; meaning the cost of obtaining a HR-like simulation is cut by a factor of ˜8.

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Coupled Proca vector dark energy

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We investigate the cosmic effects of a Proca-type vector field coupled to cold dark matter (CDM). We compute the cosmological perturbations and the background evolution of the model by implementing it in the Boltzmann code CLASS. The interaction term was chosen as a $Qf(X)\rho_{cdm}$, where Q is a coupling constant, $f(X)$ is a polynomial function of the vector field A_μ, and $\rho_{\rm cdm}$ is the CDM energy density. Our code reproduced the previous result at background level showed in \textit{JCAP 12 (2019) 032} and the solution of matter power spectrum (P_k) and angular power spectrum (C_{ll})

described in \textit{JCAP 03 (2021) 032}. Additionally, we studied how the interaction affect the P_k and C_{ll}.

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Galaxy orientation with the cosmic web filaments

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In this work, we study the correlation between galaxy orientations and filaments of the cosmic web using observational measurements. We used bright galaxies observations from the Dark Energy Spectroscopic Instrument (DESI). The cosmic web filaments were computed using the Discrete Persistent Source Extractor (DisPerSE) algorithm. We found the closest filament segment to each galaxy. These segments were projected in the RA-Dec plane to compute their tilt. Compared with the galaxy orientation in the same plane, we found a high alignment between the galaxies' direction and the tilt of their nearest filament segment. This alignment evidence will allow us to understand the effect of the galaxies' properties on the filamentary structure.

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Numerical study of the 1D Schrödinger-Poison equation for Ultralight Cold Dark Matter

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The large scale structures on the universe are best described by the cold dark matter model which only fails on sub-galaxy scales known as the small scale crisis. There has been a recently proposed model of dark matter, where cold dark matter is modeled by a complex scalar field, which follows a Schrödinger equation with a non-linear potential which satisfies a Poisson equation. This Schrödinger-Poisson equation (SP-equation) approximates the results of the standard cold dark matter model on large scales and, on small scales, exhibits some properties that could help to solve some problems on the small scale crisis. We propose an approach for the numerical integration of the SP equation in 1D, where we combine a matrix representation in a B-splines basis with the a Crank-Nicholson time-evolution integrator. As preliminary results we present the Husimi distributions obtained with in this approach. We also performed evolution of cosmological initial conditions under different box sizes where we found a good agreement with linear perturbation theory.

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Mass reconstruction in disc like galaxies using strong lensing and rotation curves: The Gallenspy package

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Two methods for mass profiles reconstruction in disc-like galaxies are presented in this work, the first is done with the fit of the rotation curve based on the data of circular velocity which are obtained observationally in a stars system, while the other method is focused in the Gravitational Lensed Effect (GLE). For these mass reconstructions, two routines developed in the language of programming python were used: one of them is Galrotpy, which was built by members of the Galaxies, Gravitation and Cosmology group from the Observatorio Astronómico Nacional of the Universidad Nacional de Colombia and whose funtionality is applied in the rotation curves, the other routine is Gallenspy which was created in the development of this work and it is focused in the GLE. It should be noted that both routines perform a parametric estimation from the Bayesian statistics, which allows obtaining the uncertainties of the estimated values. Finally is shown the great power of combining galactic dynamics and GLE, for this purpose the mass profiles of the galaxies SDSSJ2141-001 and SDSSJ1331+3628 were reconstructed with Galrotpy and Gallenspy where these results obtained are compared with those reported by other authors regarding these systems.

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One hundred years of studies of rotation curves of Spiral Galaxies

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The standard analysis of the rotation curves of spiral galaxies suggested the presence of a dark matter component in those galaxies, however there are other models that suggest other explanations to explain the Non-Keplerian behavior.
In this work we studied the rotation curves of spiral galaxies by using different models of diverse physical nature that give us an understanding of them under the gaze of recent observations, including the respective analysis of the rotation curve of the Milky Way from the Gaia Data Data Release 3 (DR3).

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Ecuación de dínamo cosmológico bajo perturbaciones cosmológicas a primer orden

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En los últimos años las simulaciones numéricas han jugado un papel muy importante como complemento a las pruebas a las cuales es sometida constantemente la Relatividad General. Un caso particular es la Relatividad Numérica, con la cual se dificultaría la comprensión de
fenómenos astrofísicos como la colisión de agujeros negros. Desde la astrofísica también se puede estudiar como planetas y estrellas pueden mantener un campo magnético dado un campo magnético semilla, este problema se puede extender a campos encontrados en galaxias y en los vacíos de la estructura a gran escala del universo. Esto lleva a un fenómeno cosmológico de interés, la evolución de

campos magnéticos a lo largo de la historia del universo, los cuales se han estudiado ampliamente, tanto analítica como numéricamente. Un punto importante es que los campos alivian la actual tensión de Hubble, luego su estudio desde el punto de vista de las perturbaciones cosmológicas hace que su evolución sea de gran
interés, su importancia en distintas épocas del universo y cómo a través del mecanismo de dínamo estos campos se han podido mantener desde el universo temprano hasta el día de hoy. En este trabajo se pretende dar una introducción a los campos magnéticos primordiales tomando como referencia la cosmología y la Relatividad Numérica, se mostrarán las perturbaciones cosmológicas a primer orden sobre la solución espacialmente plana de Friedman-Lemaitre-Robertson-Walker (FLRW) haciendo énfasis en el formalismo 3+1 de la relatividad Numérica, esto con miras a obtener la ecuación de dínamo cosmológico desde el punto de vista de las perturbaciones para poder estudiar la evolución de los campos magnéticos primordiales y su amplificación. También se mostrarán avances en el estudio computacional de perturbaciones cosmológicas a partir de la Relatividad Numérica y haciendo uso del software Einstein Toolkit haciendo énfasis en FLRWSolver para la solución numérica en problemas cosmológicos, esto se hace bajo la aproximación de dínamo cinemático.

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Teoría de perturbaciones cosmológicas invariante gauge en teorías de gravedad modificada f(R)

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Argumentos teóricos y observacionales sugieren que la Relatividad General (RG) quizás no sea el modelo gravitacional definitivo. Por ende, se han propuesto una serie de extensiones a la RG, en las cuales es complejo encontrar soluciones exactas a las ecuaciones propuestas. Las técnicas perturbativas desarrolladas en RG son importantes para poder encontrar descripciones físicas y matemáticas de desviaciones a soluciones exactas conocidas, y también para poder comparar los modelos gravitacionales modificados con la RG y poder discriminar entre estas teorías extendidas. En este trabajo, usando una base matemática formal bien definida de la teoría de perturbaciones, desde el formalismo de teoría de perturbaciones invariante gauge de Nakamura [1], se encuentran las ecuaciones perturbadas a primer y segundo orden y se usan en cosmología a primer orden en f(R). Posteriormente, se encuentran cantidades invariantes gauge y se comparan con resultados particulares encontrados en la literatura, en el gauge Newtoniano y gauge síncrono.
[1] Nakamura K 2019 arXiv preprint arXiv:1912.12805

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Papapetrou fields in boosted Kerr black holes

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The spacetime of a boosted Bondi-Sachs rotating black hole is considered as a proper background to examine electromagnetic configurations connected to analytic solutions of Maxwell equations.

In our analysis, we first use the Bondi-Sachs transformations in order to bring the boosted rotating black hole metric into the Kerr-Schild form, from which zero angular momentum observers (ZAMOs) are constructed via the ADM formalism. In Kerr-Schild coordinates, we obtain the Killing fields as sources of Maxwell electrodynamics, and we fix a ZAMO in order to evaluate the components of the electric and magnetic fields, from which we obtain nonsingular patterns of an eventual momentum-energy emission of a boosted Kerr-Schild black hole. Distinct patterns are examined and discussed in the case of variations of the boost parameter γ. We extend our analysis by considering the non-singular electromagnetic emission in the framework of a boosted Bondi-Sachs rotating black hole, as it moves at relativistic speeds. We also discuss possible mechanisms that may resemble magnetospheres of rotating boosted black holes and give rise to hydromagnetic flows from accretion discs and to the production of jets.

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Numerical Cosmology State of the Art

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In order to get a better understanding of the Large Scale Structure, physics must find a way to account for the observable universe components, given the fact that in order to build a theory of the LSS, it needs to include many of the known phenomena such as hydrodynamics, electrodynamics, spacetime curvature, the behavior of baryonic matter, quantum particle dynamics as well as models for the yet to be explained behavior of dark matter and the accelerated expansion of the universe, to mention some of them. The construction of such theory is a difficult task, here is where the numerical cosmology arises, along with the historical computational advances such as machine learning nowadays, more accurate numerical techniques with the increased precision of the data surveys (LSST, CHIME, CMB-S, the 21 cm IM experiments), as a viable and efficient way to keep progressing towards the understanding of the cosmological models. Therefore, it is worth checking the historical progress, a brief recompilation of the numerical cosmological models starting with the BSSN formalism to the up-to-date concepts, techniques, and approaches are shown to summarize the current state of art of numerical cosmology.

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Solid Dark Energy with a time dependent function

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En este trabajo se analiza la dinámica cosmológica de un sólido; es decir, una tríada de campos escalares no-homogéneos que en conjunto preservan la isotropía y homogeneidad del universo de fondo. Utilizando la técnica de sistemas dinámicos, encontramos que este sistema no posee atractores acelerados. Este análisis se complementa con soluciones numéricas. Estas soluciones particulares muestran que aunque las soluciones aceleradas no son atractores, su duración es lo suficientemente larga como para asegurar un dominio total de energía oscura. De posible interés, se encuentra que este sólido puede comportarse similar a un modelo wCDM a pesar de que su dinámica está dada por campos escalares. Por lo cual, este modelo podría representar una razón fundamental, y no fenomenológica, de considerar energía oscura con ecuación de estado constante.

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Thermal leptogenesis in the type-I Dirac seesaw extension to the DFSZ axion model for dark matter

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The type-I Dirac seesaw extension is made to the DFSZ axion model, where light active neutrinos are Dirac particles and acquire mass through the
canonical seesaw mechanism after the Peccei-Quinn and electroweak symmetry breaking, finding that neutrino mass is given by m_{\nu} ≈ ⊠⊠{⊠}/Λ{⊠⊠},
result which relates the three energy scales involved in the model: the mass of the heavy sterile Dirac fermions introduced (Λ{⊠⊠}), Peccei-Quinn scale
(⊠{⊠}), and electroweak scale (⊠). As a consequence, it was found that 10ˆ(3)*⊠{⊠}
˜Λ{⊠⊠}, hence neutrino Yukawa coupling associated to the QCD axion,
candidate to dark matter, is highly (up to 10ˆ(−10)) suppressed in comparison to the Higgs. Dirac neutrino effective mass matrix is computed explicitly,
whose components depend on active-sterile mixing parameters, the latter being new sources of CP violation. Therefore, the CP asymmetry factor
and the baryon-antibaryon density are computed for the unflavoured leptogenesis, linking neutrino physics, QCD axion, and cosmological
parameters into a same physical framework.

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The ADER-DG Method for Relativistic Fluids

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Problemas físicos tales como conducción de calor, la ley de Hooke, la conservación de la carga eléctrica, para mencionar unos pocos, están escritos matemáticamente en términos de ecuaciones diferenciales parciales (EDPs). Por lo tanto, es importante y además imperativo entender y desarrollar métodos que lleven a solucionar este tipo de ecuaciones. Además, es vital considerar que las soluciones analíticas a este tipo de problemas son en términos prácticos imposibles de obtener. Dado lo anterior, la implementación de técnicas numéricas que solucionen de forma aproximadas este tipo de EDPs se hace necesaria para poder entender de mejor manera el problema físico que se está estudiando.
En Astrofísica son varios los problemas que se escriben matemáticamente a partir de sistemas de EDPs de tipo hiperbólico, no lineales y acoplados, entre ellos podemos mencionar las ondas de choque interplanetarias debidas a erupciones solares y eyecciones de masa coronaria, ondas de choque que viajan a través de una estrella masiva cuando explota en una supernova, entre otros.
El método de ADER-DG (Adaptive Derivative –Discontinuous Galerkin) es un método numérico con alto orden arbitrario de aproximación en tiempo y espacio el cuál requiere una reconstrucción de celda. Este alto orden arbitrario de aproximación presenta gran ventaja a la hora de buscar soluciones aproximadas a problemas físicos descritos a través de EDPs de tipo hiperbólico, ya que, dadas las condiciones del problema, distintos órdenes de aproximación pueden usarse en un mismo problema, obteniendo así una alta resolución en lugares y momentos clave, como por ejemplo en la discontinuidad de los medios presentada

en una onda de choque.
En esta ponencia se presentarán los conceptos básicos de hidrodinámica e hidrodinámica relativista, así como algunos problemas astrofísicos allí involucrados. Se presentará también el problema de Riemann, así como soluciones numéricas al mismo a partir de esquemas numéricos en el método de Volúmenes Finitos, esquemas WENO (Weighted Essential Non Oscillatory), el método de ADER-DG y las respectivas implementaciones del problema de Riemann desde el problema del tubo de choque de Sod para varios órdenes de aproximación utilizando el software ExaHyPE dentro del marco no relativista.

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Marcos Conformales en Teorías de Gravedad Escalar-Tensor

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Debido a las observaciones del CMB y de las supernovas tipo I se puede concluir que el universo se está expandiendo de manera acelerada. La aceleración del universo se puede explicar mediante el modelo ΛCDM, el cual considera que el universo estaría compuesto en su mayoría por la constante cosmológica Λ, una forma de Energía Oscura, y de Materia Oscura Fría. Sin embargo, este modelo no explica el origen de la energía oscura ni el de la materia oscura y deja sin respuesta a los problemas de la constante cosmológica. Por lo cual, se hace plausible una modificación a esta teoría. Las teorías de gravedad Escalar-Tensor son una modificación de la teoría de la Relatividad General, la cual es la teoría base para el modelo ΛCDM.
Las teorías de gravedad Escalar-Tensor se presentan en dos marcos confórmales diferentes los así llamados Marcos de Jordan y de Einstein, la diferencia matemática entre ellos principalmente radica en la acción, donde en ambos marcos el campo se acopla no minimalmente ya sea o al escalar de curvatura (Marco de Jordan) o al tensor momentum-energía (marco de einstein). La presentación se centra en mostrar ambos marcos y luego se da en un enfoque en magnetogenesis