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Book of Abstracts

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A neural network approach for approximating the local mass in general relativity

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Within the framework of general relativity, the concept of local mass (or quasi-local mass) aims to quantify the amount of mass contained within a particular region of space-time. Nevertheless, the precise definition of such mass in accordance with the theory of general relativity continues to be an unresolved matter. Over the past few decades, numerous proposals have emerged in an attempt to address this issue. One particular proposal that has garnered significant attention from the scientific community in recent years is Bartnik's mass proposal, which builds upon a specific instance of the well-established ADM-mass concept. Unfortunately, performing numerical calculations of this mass for specific situations using conventional numerical methods presents a formidable challenge due to the inherent complexity of the coupled system of partial differential equations that must be solved. Motivated by this challenge, our presentation aims to introduce a deep learning approach for approximating Bartnik's mass for a two-dimensional hypersurface. We will showcase several numerical results and discuss the advantages and disadvantages associated with this method.

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Machine learning unveils the linear matter power spectrum of modified gravity

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The matter power spectrum $P(k)$ is one of the main quantities connecting observational and theoretical cosmology. Although for a fixed redshift this can be numerically computed very efficiently by Boltzmann solvers, an analytical description is always desirable. However, accurate fitting functions for $P(k)$ are only available for the concordance model. Taking into account that forthcoming surveys will further constrain the parameter space of cosmological models, it is also of interest to have analytical formulations for $P(k)$ when alternative models are considered. Here, we use the genetic algorithms, a machine learning technique, to find a parametric function for $P(k)$ considering several possible effects imprinted by modifications of gravity. Our expression for the $P(k)$ of modified gravity shows a mean accuracy of around 1-2% when compared with numerical data obtained via modified versions of the Boltzmann solver CLASS, and thus it represents a competitive formulation given the target accuracy of forthcoming surveys.

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Can we link galaxy assembly times to the assembly times of their host halos?: A perspective from Mutual Information

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The Next Generation Illustris simulations (IllustrisTNG) have shown a remarkable match with the observed clustering properties of galaxies, providing us with a unique opportunity to study the relationship between the assembly times of galaxies, the color $(g-i)$ and the specific Star Formation Rate (sSFR) with the assembly times of their host dark-matter (DM) haloes. To quantify this dependence, we used the Mutual Information (MI) statistic, which assesses the dependence between two continuous or discrete variables. MI is a powerful tool that allows us to capture complex and nonlinear relationships. In our context, MI statistics enable us to identify the subtle correlations for galaxies in the stellar mass range of $10^9 \leq M_\star \leq 10^{11.5}$ \Msunh between the assembly times, the sSFR and color $(g-i)$ with the assembly times of their DM haloes. Our results show that the MI between the assembly times of central galaxies and their host haloes is moderate for galaxies with stellar masses below $M_\star$
$lesssim 10^{10.25}$\Msunh, decreasing for higher stellar masses. Also, we found that the MI between the assembly time of DM haloes and color $(g-i)$ show a weak correllation for central galaxies with stellar masses below $M_\star$
$lesssim 10^{10.5}$ and negligible for galaxies with higher stellar masses. The sSFR for central galaxies shows a negligible correlation with the assembly time of their haloes. For satellite galaxies, the MI is close to zero for all stellar masses and variables. Overall, our study highlighted the nature of these connections and the challenges of uncovering them.

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Reconstruyendo el perfil de masa de cúmulos de galaxias a partir del efecto de lente gravitacional

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En este trabajo presentamos *relensing*, un método que busca modelar cúmulos de galaxias haciendo uso del efecto de lente gravitacional. Hemos implementado un método no paramétrico (o de forma-libre) el cual determina el potencial deflector sobre una red irregular adaptativa. Para poder modelar un cúmulo de galaxias, *relensing* hace uso de sistemas de múltiples imágenes (régimen fuerte), al igual que utiliza la elipticidad de fuentes de fondo que han sido débilmente deformadas (régimen débil). Con *relensing* introducimos un suavizado en el potencial deflector, el cual reduce el ruido presente en la reconstrucción y por tanto, se obtienen perfiles de masa menos irregulares y más cercanos a la distribución real. Esta mejora se extiende a los mapas de magnificación, y con ello, a la estimación de las curvas críticas y cáusticas. Para validar el poder del suavizado, aplicamos *relensing* a Ares y Hera, los cuales son dos cúmulos de galaxias simulados que buscan asemejar las observaciones dadas por el telescopio espacial Hubble. Nuestros resultados muestran una mejora respecto a reconstrucciones realizadas con métodos que se basan en los mismos principios que *relensing*. El suavizado del potencial introduce además un aumentando la estabilidad y una reducción del tiempo de cómputo en nuestra implementación.

Esta presentación está basada en nuestro paper titulado “**relensing: Reconstructing the mass profile of galaxy clusters from gravitational lensing**”.

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Discs of satellites in the Illustris-TNG simulations I: identification of flattened systems

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The Local Group, dominated by the main galaxies: the Milky Way and the Andromeda galaxy, presents a scenario where a set of satellite galaxies orbiting around one of these two galaxies is observed. These satellites do not present an isotropic distribution, but rather the majority are located on a plane almost perpendicular to the plane of the galaxy's disk. In the case of the Milky Way, the distribution of dwarf galaxies presents a structure that has a radius ~ 200 kpc, where most of them is found, and a thickness of ~50 kpc, which has been called the disk of satellites or Vast Polar Structure of Satellite Galaxies (VPOS). For the Andromeda satellite disk, the radial extension is like that of the Milky Way, but with a slightly thinner width.
The study of the disks of dwarf satellites is important due to the discrepancy in the way in which dwarf galaxies are distributed around larger galaxies, since theoretically they should have a nearly isotropic distribution around their host galaxies, contrary to observations. Currently there is no theoretical model that correctly explains the spatial distribution of these objects within the Local Group or in other galactic systems.
This paper presents the results of a study on the identification of galaxy satellite disks in IllustrisTNG simulations at z = 0. From a total of 64066 systems made up of a central galaxy and several galaxies that orbit around it, we have detected 5393 flattened systems resembling the VPOS. The method used for detecting flattened distributions of galaxies and some statistics of the found systems are presented.

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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), Generalized Proca theory (GPT) and Generalized SU(2) Proca theory (GSU2P). The last two differ in that while GPT does not have internal simmetries, the GSU2P is invariant under SU(2) group of global transformations. The frame-dragging effect occurs when a rotating compact object distorts spacetime and inertial observers are dragged along when they are in free fall from infinity. James Hartle developed a methodology to study this effect for slowly rotating stars in General Relativity (GR) through a perturbative treatment of the GR's field equations in powers of ^{2} , 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 and GSU2P, we find important deviations from GR which exhibit the role that the vector field plays in the gravitational interaction for both theories. We also find constraints in the relevant modified gravity couplings which could be compared with possible future results from multimessenger astronomy.

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Scalar-Vector Multifield Anisotropic Dark Energy

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We present partial results from a model constructed using conventional components found in string compactification as well as in general supersymmetric theories. The model entails a pair of scalar fields coupled through non-trivial kinetic mixing and incorporates a $U(1)$ vector field with a field dependent gauge kinetic function. The system unveils a novel fixed point within a Bianchi I space-time background, exhibiting characteristics that could potentially describe a late accelerated epoch in the universe. Additionally, we expound on potential ultraviolet (UV) completions that give rise to such a model.

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

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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 $0.06\,h/\mathrm{Mpc}$
$lesssim k$
$lesssim 0.2\,h/\mathrm{Mpc}$, $ii)$ 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.

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

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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.

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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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Broad absorption lines in DESI Y1 QSO spectra

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Accurate quasar classifications and redshift measurements are increasingly important to precision cosmology experiments. Broad absorption line (BAL) features are present in 15-20% of all quasars, and these features can introduce systematic redshift errors, and in extreme cases produce misclassifications. We quantitatively investigate the impact of BAL features on quasar classifications and redshift measurements with synthetic spectra that were designed to match observations by the Dark Energy Spectroscopic Instrument (DESI) survey. Over the course of five years, DESI aims to measure spectra for 40 million galaxies and quasars, including nearly three million quasars. Our synthetic quasar spectra match the signal-to-noise ratio and redshift distributions of the first year of DESI observations and include the same synthetic quasar spectra both with and without BAL features. We demonstrate that masking the locations of the BAL features decreases the redshift errors by about 1% and reduces the number of catastrophic redshift errors by about 80%. We conclude that identifying

and masking BAL troughs should be a standard part of the redshift determination step for DESI and other large-scale spectroscopic surveys of quasars.

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Scaling Solutions in Generalized Proca Theory and its Cosmological Implications

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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.

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

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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.

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Time Travel Paradoxes and Entangled Timelines

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It seems that if time travel is possible, it is inevitable to encounter paradoxes. These paradoxes include consistency paradoxes, such as the famous grandfather paradox, and bootstrap paradoxes, in which something is created out of nothing. The concept of parallel timelines is suggested to address these paradoxes, and a model called "Entangled Timelines" or E-CTCs is proposed to explain the mechanism by which timelines can be created. This mechanism is based on the Everett or "many-worlds" interpretation. In this research, we endeavor to expand upon the existing model by exploring various scenarios, including multiple time machines, an infinite number of timelines, non-cyclical timelines. Additionally, we investigate the consequences of a part of an entangled system and particles in superposition accessing the time machine.

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Las teorías gravitacionales en el contexto de geometrías no Riemannianas al filo de la navaja de Ockham

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La teoría newtoniana de la gravedad puede ser reformulada en el lenguaje de geometría diferencial como una teoría no relativista en espaciotiempo curvo, en donde la fuente de la curvatura está asociada con el potencial gravitacional newtoniano estándar. Ésta es conocida como la teoría de Newton-Cartan (NC), y aunque a nivel dinámico es absolutamente equivalente a la teoría newtoniana estándar, la interpretación de los objetos geométricos y de la estructura misma del espaciotiempo newtoniano es diferente. Un factor determinante de esta reformulación es que permite hacer una comparación en paralelo, y en el mismo lenguaje geométrico, de los postulados necesarios para construir la teoría de NC y la teoría de la Relatividad General (RG) de Einstein. Se concluye que la teoría de RG es más simple que la teoría de NC ya que requiere menos postulados para su construcción. Con base en estas conclusión y adhiriéndose al principio de la navaja de Ockham, es razonable pensar que la RG sea la mejor opción que ha tenido la naturaleza para describir la gravedad. No obstante, se ha mostrado que, a nivel dinámico, la RG es indistinguible de sus versiones teleparalela y simétrica teleparalela en el contexto de geometrías no Riemannianas. Por lo anterior, en este trabajo se plantea la pregunta ¿cuál teoría gravitacional sería la preferida por la Naturaleza teniendo como base su simplicidad y el número de postulados requeridos para su construcción?

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Spherical collapse model for a non-Abelian Gauge-field cosmology

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In this talk, we investigate the spherical collapse model within the framework of dynamical dark energy cosmologies. We present a versatile code that allows for the implementation of various dark energy models, providing a powerful tool for studying their effects on structure formation. To demonstrate the capabilities of our code, we focus on a cosmology where a non-abelian gauge SU(2) vector field is the sole source of dark energy. This choice allows us to explore the unique characteristics of this model and investigate its implications for the formation of cosmic structures. By incorporating the dynamics of the non-abelian gauge field into the spherical collapse model, we analyze the growth of density perturbations and the formation of collapsed objects in this cosmological scenario. We observe distinct deviations from the LCDM result, highlighting the importance of considering alternative sources of dark energy in cosmological investigations of structure formation.

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DARK AND BARYONIC MATTER IN EULERIAN COSMOLOGICAL PERTURBATION THEORY TO FIRST ORDER

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In modern cosmology, the problem of large-scale structure formation has been studied through various analytical and computational methods and has become a cornerstone of astrophysics. The complexity of the equations that describe the evolution of small fluctuations in the matter field, with respect to the Friedmann - Lemaître - Robertson - Walker (FLRW) universe, commonly known as the theory linearized gravitational perturbations, makes it a valuable framework for describing the problem. Specifically, the approximation of sub-horizon scale allows us to explore scenarios where semi-analytical tools play a significant role in gaining a better understanding of how significant structures in our universe have evolved and how the cosmic web structure is formed. In this sense, these types of techniques have allowed for comparisons with extensive simulations and have provided a basis for contrasting with high-precision observations in this context. Therefore, in this lecture, we present a semi-analytical description of the evolution of contrast density in cold dark matter (CDM), including baryonic matter, in a linear regime in Fourier space. We achieve this by using the Jeans filtering function (JFF), considering only proportional solutions, and then comparing them with the numerical solutions calculated for the JFF equations to zero and first order. Finally, we discuss and elaborate upon some of the results obtained for various initial conditions in redshift.

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Energía oscura y campos vectoriales inhomogéneos

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Con frecuencia, se ha recurrido a campos escalares como potenciales fuentes de inflación y energía oscura, dado que son capaces de generar presiones negativas requeridas para este tipo de fenómenos. Sin embargo, en esta ocasión, se ha explorado un enfoque diferente al considerar campos vectoriales no homogéneos como posibles fuentes de energía oscura.

En esta investigación, se ha empleado un lagrangiano que se origina a partir de una triada de campos vectoriales no homogéneos donde, en este caso en particular, se ha adoptado una configuración de campo conocida como configuración magnética. A partir de esta formulación lagrangiana se ha derivado el tensor momento-energía con el cual se describe la dinámica del sistema y, de esta manera,

se encontró un conjunto de ecuaciones autónomas fundamentales para hacer un debido análisis de la estabilidad del sistema, centrado en sus puntos críticos.

Finalmente, se encontró que los resultados obtenidos son consistentes con las observaciones relacionadas con la expansión del universo.

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Evaluation of Dynamic Dark Energy Model

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In this work we reviewed parametrizations of Dark Energy (DE) models focusing on potential late-time physics effects that could alleviate the Hubble Tension. We present a preliminary evaluation of the DE models proposed by Pan et. al. 2019, which consist of phenomenological parametrizations of the DE equation of state, $w = P/\rho$, in terms of the current value, w_0. In addition, we include in this evaluation a proposed DE model consisting of a sigmoid function of FLRW scale factor, a, and w_0.

Our analysis indicates that the Pan et. al. 2019 DE models yield H_0 values that are all within 0.6σ from each other, which renders them effectively equivalent,
and highlights the weak discriminatory power of these DE parametrizations.
These result are in part due to the shape of the functions proposed for $w(a)$, which in all cases define the dynamic variation of DE spread smoothly across redshift space.
In contrast, our sigmoid model provides a stronger constraining of redshift and w_0 parameter space, by explicitly localizing the transition redshift point where the equation of state changes values from the past, $w = -1$ (consistent with CMB), to the present value w_0.
Using the recent (Scolnic et. al., 2022) Pantheon+ SN Ia data, our sigmoid-DE model (Rueda-Blanco, et al., 2023)
gives a best fit value for H_0 of $73^{+0.2}_{-0.6}$ km s^{-1} Mpc^{-1} (\emph{statistical}).
Later on, we analyzed the issue of parameter degeneracy and discuss strategies to lessen their impact in our analysis.
Finally, our findings indicate that the results depend critically on the treatment of the Ω_M parameter in the fits.
Due to the known parameter degeneracy between H_0 and Ω_M, if the Ω_M parameter is left as a floating parameter in the fit, then
the values for w_0 resulting from the fit tend towards the phantom sector ($w_0 < -1$). However, when the Ω_M parameter is held fix
during the fit (which we claim should be the case in order to leave early CMB physics unperturbed) then the values of w_0 delivered by the fits
tend towards values greater than -1. This work is part of a more extensive study of late-time physics models in the context of the Hubble Tension.

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LATE ACCELERATED EXPANSION OF THE UNIVERSE IN DIFFUSIVE SCENARIOS

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En este trabajo, presentamos un modelo de difusión en un marco cosmológico para describir la expansión acelerada del Universo en la época actual. Primero exploramos la introducción un campo escalar en las ecuaciones de campo de Einstein para explicar el efecto de la difusión como el generador de la expansión actual. Una vez que se forman las galaxias, el campo escalar entrega energía al fluido de materia a través del proceso de difusión. Encontramos las soluciones exactas para dos casos: coeficiente de difusión [illegible] constante y coeficiente de difusión dependiente del corrimiento al rojo y establecimos restricciones para que este escenario sea viable.
Adicionalmente, exploramos una segunda opción como fuente para la difusión: un fluido perfecto con una ecuación de estado barotrópica [illegible] = [illegible]. Establecemos las ecuaciones que relacionan la evolución del fluido con la distribución cósmica y encontramos soluciones de las ecuaciones de campo para diferentes posibilidades en los coeficientes de difusión: constante, dependiente del corrimiento al rojo y [illegible] proporcional al parámetro de Hubble normalizado [illegible]([illegible]). El principal hallazgo de este trabajo es que procesos de difusión en el Universo son escenarios viables para describir la dinámica de expansión de manera efectiva una vez que los parámetros libres del modelo son calibrados. La elección del coeficiente de difusión con corrimiento al rojo y la ecuación de estado del fluido cósmico determina fuertemente la forma de las soluciones de las fracciones de densidad y la transición a una expansión acelerada del Universo en la actualidad.