CoCo 2019: Cosmología en Colombia

Thursday 30 May 2019 - Friday 31 May 2019

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Book of Abstracts

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Primordial Gravitational Waves in Non-Standard Cosmologies

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Assuming that inflation is followed by a phase where the energy density of the Universe is dominated by a component with a general equation of state, we evaluate the spectrum of primordial gravitational waves induced in the post-inflationary Universe. We show that if the energy density of the Universe is dominated by a component ϕ before Big Bang nucleosynthesis, its equation of state could be constrained by gravitational wave experiments depending on the ratio of energy densities of ϕ and radiation, and also the temperature at the end of the ϕ dominated era. Also, we discuss the impact of scale dependence of tensor modes on the primordial gravitational wave spectrum during the ϕ-domination. These models are motivated by beyond Standard Model physics and scenarios for non-thermal production of dark matter in the early Universe. We also constrain the parameter space of the tensor spectral index and the tensor-to-scalar ratio, using the experimental limits from gravitational wave experiments.

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Bayesian treatment of distance errors in the cosmic distance ladder

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We propose two methods for robustly estimating extragalactic distance errors thopughout the cosmic distance ladder. Frequentist methods they fail to explain both the scatter between different measurements and the effects of skewness in the metric distance probability distribution. We compare the performance of frequentist methods versus our proposed measures for estimating the true variance of redshift-independent extragalactic distances. We also develop a predictive Bayesian model for distance errors for Tully-Fisher relation (TF) derived distances. We are then able to predict distance errors for almost 900 galaxies in the NED-D catalog and 200 galaxies in the HyperLEDA catalog which do not report TF distance modulus errors. Our goal is that our pre-computed errors are used in catalog-wide applications that require acknowledging the true variance of extragalactic distance measurements.

Cosmology / **4**

Supercluster characterization in cosmological simulations

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when the velocities of a group of galaxies converge to a single structure, they are
said to be part of the same supercluster. This structure has quantifiable properties

such as mass, volume, density and inertia, among others. Here we compare cosmological simulations of N-bodies with the results obtained by Tully et al. (2014) when determining these characteristics in Laniakea, our local supercluster. Given the position, velocity and mass data for each body of a simulation, the three-dimensional space is discretized in order to obtain a vector map with the velocity of the center of mass of each voxel. Taking into account the Gaussian behavior of the primordial perturbations in the field of gravity that gave rise to the formation of structure on a large scale, the velocity field in the three axes is smoothed with a Gaussian filter of a certain width σ-vox. To determine the structure formation, the accretion for each voxel is quantified and a scalar field with this information is created. We implemented the watershed algorithm in the scalar field to reconstruct and segregate the superclusters present in the simulation. Evaluating geometric and physical properties we find that Laniakea is an atypical event in terms of form, volume and mass within the framework of cosmological simulations

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Understanding the large scale dark matter distribution with machine learning algorithms.

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Understanding the large scale dark matter distributions in the local Universe is one of the main goals in physical cosmology. However, this distribution is not directly observable and must be inferred from the observed galaxy distribution from large redshift surveys such as the Sloan Digital Sky Survey (SDSS) data or the upcoming of the Dark Energy Spectroscopic Instrument (DESI). In this talk we will show on how machine learning methods can help us to reconstruct the large scale dark matter distribution from observational data. As training data-sets we use different cosmological simulations, both hydrodynamical and semi-analytic. We present preliminary results for our reconstruction algorithms based on SDSS data and comment on its implications and strategies for improvement.

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The Scalar Galileon and its constraints from GW170818 and GRB170817A

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The advanced Laser Interferometer Gravitational Observatory (LIGO) and the VIRGO interferometer announced the detection of gravitational waves (GW170817) from the merger of a binary neutron star, as well as the associated gamma ray burst (GRB170817A), 1.7 s after the gravity wave detection. An immediate consequence of these detections is that gravity waves propagate at light speed in one part to 10^{15}. Modified gravity theories, for example the scalar Galileon one, predict, in general, modifications to the gravity waves speed. We built the action for the scalar Galileon and study the implications of the mentioned detections on this theory. The scalar Galileon is a scalar field whose action leads to field equations that are not higher than second-order. This is a necessary condition to make the Hamiltonian bounded from below, as it is required to avoid tachyonic instabilities. So,

any theory that involves scalar fields and aims to describe nature must belong to the scalar Galileon action.

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Constraining cosmological parameters with the β-skeleton of the cosmic web

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Constraining cosmological parameters from observational data is one of the main challenges in observational cosmology. To address it, we present results based on the β-skeleton, a new technique designed to find a graph describing the underlying web structure in spatial point distributions. From the β-skeleton we define an entropy scalar and show how it can be used a cosmological probe by measuring changes in entropy as a function of the β parameter used to build the skeleton. We test this concept both on simulated and observational data from the Sloan Digital Sky Survey. We finalize by showing how future projects such as the Dark Energy Spectroscopic Instrument can be used to take advantage of this new technique.

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Propagation of waves and eikonal approximation in the Horndeski's vector-tensor theory

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In this talk we use the eikonal approximation to impose constraints on the Horndeski's vector-tensor theory. We explore the modifications imposed by Horndeski's theory on some very basic aspects of geometric optics such as light propagation on null geodesics, the geodesic deviation equation, photon creation, among others. We illustrate our results in Friedmann-Lemaître and Schwarzschild spacetimes and speculate on possible interpretations and observational consequences of our findings.

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Reconstructing Non-standard Cosmologies with Dark Matter

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Assuming the detection of a weakly interacting massive particle (WIMP) of dark matter (DM) occurs, its particle physics properties (mass m_χ, and thermally averaged DM annihilation cross section $\langle\sigma v\rangle$) are known and these disagree with the usual freeze-out mechanism, one can either look for different DM production mechanisms or for alternative cosmological scenarios. Here we consider the production of WIMP DM in scenarios where for some period at early times the expansion of the Universe was governed by a matter-component ϕ. We force the ϕ component to decay to SM radiation before BBN occurs, so radiation effectively dominates at this moment. The decays of ϕ imply a source of entropy production in the thermal bath which alters the Boltzmann equations and impacts the dark matter relic abundance. Using a particle physics model-independent approach, i.e. for given m_χ and $\langle\sigma v\rangle$, we study the reconstruction of the parameters characterizing the non-standard cosmology. We explore 4 different cases distinguished by the freeze-out occurrence with respect to some study points related with ρ_ϕ domination and ρ_ϕ decay (equality, critic, end) and attempt to present an analytic estimation of each regime separately.

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Anisotropic 2-form dark energy

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We study the dynamics of dark energy in the presence of a 2-form field coupled to a canonical scalar field ϕ. We consider the coupling proportional to $e^{-\mu\phi/M_{\rm Pl}}H_{\alpha\beta\gamma}H^{\alpha\beta\gamma}$ and the scalar potential $V(\phi) \propto e^{-\lambda\phi/M_{\rm Pl}}$, where $H_{\alpha\beta\gamma}$ is the 2-form field strength, μ, λ are constants, and $M_{\rm pl}$ is the reduced Planck mass. We show the existence of an anisotropic matter-dominated scaling solution followed by a stable accelerated fixed point with a non-vanishing shear.Even if $\lambda \geq calO(1)$, it is possible to realize the dark energy equation of state $w_{\rm DE}$ close to -1 at low redshifts for $\mu \gg \lambda$. The existence of anisotropic hair and the oscillating behavior of $w_{\rm DE}$ are key features for distinguishing our scenario from other dark energy models like quintessence.

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Constrains on Dark Energy with cosmological proxies

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In this talk we consider an effective parametrization for a scalar field that evolves in time, known as K-essence, to describe Dark Energy in the framework of FLRW metric. In the past, we constrained the free parameters of this model with luminosity distances of supernova Ia up to redshift 1.4. Now, we introduce different cosmological proxies, as BAO and CMB data from Planck, to complete the

evolution of K-essence model at higher redshifts, missed by the supernovae sample. In addition, we discuss the most general family of solutions that can be considered to fulfil the dynamical system that arises from the K-essence equation of motion.

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The spin of primordial black holes

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I will briefly discuss the simplest scenarios for primordial black hole formation, and the reason behind the recent interest in these objects. I will then show that one of the predictions in these scenarios is that primordial black hole spin is small, in the sense that the spin parameter is of the order of a percent.

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Correlation functions of sourced gravitational waves in inflationary scalar vector models. A symmetry based approach

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We use conformal symmetry to constrain the shape of inflationary correlators in the presence of long-lived vector field perturbations. Applying conformal Ward identities, we derive general expressions, up to amplitudes and normalization factors, for the two and three point correlators in the presence of vector fields mediated by the interaction f()
⊠
FµFµ + ˜ FµFµ

, where f()
is a suitable coupling function between the scalar and the vector field. The previous interaction allows for isotropy and parity symmetry breaking and is consistent with super horizon conformal symmetry. As an application of the conformal field theory techniques followed here, we evaluate the mixed tensor-scalar h
i and tensor-scalar-scalar h
i correlators which are interesting to look
for parity violating effects related with chiral gravitational waves. Finally, we derive consistency relations for the three point correlators obtained.

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The cosmic web as a cosmological probe in the Dark Energy Spectroscopic Instrument

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Large galaxy redshift surveys have become a standard tool in observational cosmology in the last three decades. The correlation function of the galaxy distribution inferred from those surveys is widely recognized as a strong cosmological probe. This has motivated new surveys such as the Dark Energy Spectroscopic Instrument (DESI) to increase by an order of magnitude the number of mapped galaxies in current catalogs. In this talk I will explain how the cosmic web defined by galaxies in those kind of surveys can serve as cosmological tool complementary to the correlation function, for instance via the Alcock-Paczynski test on the galaxy gradient field derived. I will also show the new beta-skeleton method used to define the cosmic web from galaxy survey data, emphasizing its possibilities as a new cosmological tool that can be applied to data from the DESI.

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Applying the Compressed Sensing Protocol on Cosmological Signals

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Large scale galaxy surveys have shown its ability to constraint cosmological parameters mostly through the analysis of the correlation function and the power spectrum.
The Nyquist criterion underlies the design of these large surveys by imposing a condition on the minimal number density of tracers required to recover the matter density signal corresponding to a given wave-number.
Here, we illustrate how the compressed sensing (CS) protocol can help to by pass the limitations imposed by this criterion.
CS establishes that, if a signal is sparse in some suitable domain, it can be reconstructed perfectly from a small number of random measurements, overcoming the limitations in the well-known Nyquist criterion.
CS has already played a pivotal role in magnetic resonance imaging (MRI), applied mathematics, physics and more recently in machine learning.
Here we will show preliminary results on simulations to demonstrate how CS can make an impact on the interpretation of data from large experiments such as the Dark Energy Spectroscopic Instrument.

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Dark matter phase transitions and gravitational waves

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A rather minimal possibility is that dark matter consists of the gauge bosons of a spontaneously broken symmetry. I will discuss the possibility of detecting the gravitational waves produced by the phase transition associated with such breaking. Concretely, I will focus on the scenario based on an

☒☒(2)_D group and argue that it is a case study for the sensitivity of future gravitational wave observatories to phase transitions associated with dark matter. This is because there are few parameters and those fixing the relic density also determine the effective potential establishing the strength of the phase transition. Particularly promising for LISA is the super-cool dark matter regime, with DM masses above 100 TeV, for which the gravitational wave signal is notably strong

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Regular black holes with exotic topologies

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In this talk we will show that one can construct regular black holes solutions by reversing the Penrose singularity theorem and by tuning the null energy condition appropriately. In particular, we will show the existence of spherically symmetric regular black hole solutions with exotic topologies and we will classify them by using some kind of charge related to the trace of the energy momentum tensor computed at spatial infinity. Finally, possible links with Petrov changes and phase transitions will be briefly commented.

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Clasificación y determinación de redshift de espectros astrofísicos mediante Redes Neuronales Convolucionales.

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Los avances en cosmología observacional dependen en gran medida de la interpretación de grandes levantamientos (surveys) espectrométricos. Los continuos avances tecnológicos ahora permiten que decenas de miles de espectros sean registrados en una noche de observación. Gracias a esta situación, es necesario abordar el problema de clasificación espectral de una manera mas eficiente que la tradicional. En la ultima década, el uso de técnicas de Machine Learning a demostrado ser eficiente para resolver problemas de clasificación y regresión en diversos campos de la ciencia. Con el animo de abordar la clasificación de espectros eficientemente presentaremos resultados preliminares sobre la implementación de una red neuronal para clasificación y predicción del redshift de espectro astronómicos. Mediante esta implementación se busca crear un modelo que permita clasificar y determinar redshift espectros futuros obtenidos por el proyectos como el Dark Energy Spectroscopic Instrument (DESI)

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GENERALIZED SU(2) PROCA INFLATION

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The generalized SU(2) Proca theory is the only modified gravity theory, nowadays, able to accommodate in a natural way a configuration of vector fields which is compatible with the homogeneous and isotropic nature of our Universe. In a previous work, and employing just one of the three pieces that conform the L_4 Lagrangian, we were able to uncover a self-tuning mechanism that drives an eternal inflationary period for an ample spectrum of initial conditions. We have now included all the three pieces plus a purely curvature term proportional to the double dual Riemann tensor. A novel primordial inflationary mechanism with a graceful exit is unveiled where the mentioned self-tuning mechanism is preserved and has, again, a protagonist role. The inflationary period is long enough to solve the classical problems of the standard Cosmology. For some region of the parameter space, the action is free of tachyonic, ghost, and Laplacian instabilities. The usual naturalness problem of the primordial inflation in this scenario is, therefore, essentially absent.

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Slow-roll Inflation with non-minimal kinetic coupling

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Inflation driven by a scalar tensor model with non-minimal derivative coupling to the Einstein tensor is considered. The power spectra for primordial scalar and tensor fluctuations is analyzed. For the analyzed potentials it is shown that the models can be made compatible with the current observational data.

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Constraining the Generalized SU(2) Proca theory at minimal cost

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Under the same spirit of the Galileon-Horndeski theories, the generalized SU(2) Proca theory was built by demanding that its action is, by construction, free of the Ostrogradski instability. Moreover, it still requires a more exhaustive analysis to guarantee its stability, and therefore to ensure its viability from the theoretical point of view. As a first approach to address this issue, we investigate the general conditions for the absence of ghost and gradient instabilities in the tensor sector. Furthermore, we evaluate the conditions under which the speed of gravitational waves is consistent with recent LIGO/Virgo observations. Thus, in order to fulfill all these restrictions simultaneously, we seek for a suitable parameter space for different combinations of pieces of the SU(2) Lagrangian. From here we determine concrete relations between the coupling constants of the theory and conditions for the gauge field in terms of such constants. Thereby we conclude that, analysis only of the tensor sector constrain this theory without resolving the dynamical cosmological background. The

phenomenological interest of these results lies on the possibility of building models driven by solely non-Abelian vector fields.

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Quasilocal Smarr relations for static black holes

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Smarr relations in terms of thermodynamical quasilocal variables are obtained for Schwarzschild and Reissner-Nordström black holes. Our treatment is based on Brown and York's Euclidean path integral approach for gravitational thermodynamics. The resulting expressions allow us to construct the relation between the quasilocal energy obtained in this setting and the Komar and Misner-Sharp energies, which are regarded as thermodynamical internal energy in other approaches. By considering some properties of the metric, it is shown that the obtained quasilocal Smarr relations can be regarded as thermodynamical realizations of Einstein equations. Extensions of these results to cosmological spacetimes are discussed.

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An exact solution to the gravity of Bakry-Émery-Ricci

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Theories based on metric measure spaces generalize the Ricci tensor by adding a scalar function coupled to the metric through second derivatives. An example is the Bakry-Émery-Ricci (BER) tensor, which has been intensively studied from the mathematical point view and, in minor form, with relation to gravitational theories. In particular, it has been shown that generalized energy conditions give place to extended singularity theorems. Interestingly, certain gravitational theories beyond general relativity, such as Brans-Dicke, f(r) and scalar-tensor, among others, can be written in terms of the BER. In this talk we will solve the vacuum BER-generalized Einstein field equations with spherical symmetry and we will compare the solution with the Schwarzschild and gravitational global monopole spacetimes. Finally, an action principle will be proposed for these generalized field equations.

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Galaxy Bias in Illustris Simulations

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The galaxy distribution on large scales is not uniform, it follows a web-like pattern known as the cosmic-web. This pattern can be completely explained by the galaxies forming inside of dark matter halos. Therefore, the galaxy distribution can be related to the underlying dark matter distribution. This relationship, known as galaxy bias, can be used to understand the varied physics process of galaxy formation and probe the Dark Matter distribution. The purpose of this work is to understand how the cosmic web influences the galaxy bias. To this end, we use data from state-of-the-art hydrodynamical simulations (Illustris and Illustris-TNG). To perform and analysis on a wide range of galaxies masses spanning a mass range from $10^8\ M_\odot/h$ to $10^{13}\ M_\odot/h$. Our preliminary results show that, at fixed mass, galaxies that form early tend to be located in cosmic-web environments with higher anisotropy than its late-forming counterparts, thus demonstrating the influence of the cosmic web on the galaxy formation bias.

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Einstein Yang-Mills Higgs dark energy revisited

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Inspired in the Standard Model of Elementary Particles, the Einstein Yang-Mills Higgs action with the Higgs field in the SU(2) representation was proposed in Class. Quantum Grav. 32 (2015) 045002 as the element responsible for the dark energy phenomenon. We revisit this action emphasizing in a very important aspect not sufficiently explored in the original work and that substantially changes its conclusions. This aspect is the role that the Yang-Mills Higgs interaction plays at fixing the gauge for the Higgs field, in order to sustain a homogeneous and isotropic background, and at driving the late accelerated expansion of the Universe by moving the Higgs field away of the minimum of its potential and holding it towards an asymptotic finite value. We analyse the dynamical behaviour of this system and supplement this analysis with a numerical solution whose initial conditions are in agreement with the current observed values for the density parameters. This scenario represents a step towards a successful merging of cosmology and well-tested particle physics phenomenology.

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A systematic procedure to build the beyond generalized Proca field theory

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To date, different alternative theories of gravity involving Proca fields have been proposed. Unfortunately, the procedure to obtain the relevant terms in some formulations has not been systematic or exhaustive, thus resulting in some missing terms or ambiguity in the process carried out. In this paper, we propose a systematic procedure to build the beyond generalized theory for a Proca field in four dimensions containing only the field itself and its first-order derivatives. In our approach, we employ all the possible Lorentz-invariant Lagrangian pieces made of the Proca field and its first-order derivatives, including those that violate parity, and find the relevant combination that propagates only three degrees of freedom and has healthy dynamics for the longitudinal mode. The key step in our procedure is to retain the flat space-time divergences of the currents in the theory during the covariantization process. In the curved space-time theory, some of the retained terms are not current divergences anymore so that they induce the new terms that identify the beyond generalized Proca field theory. The procedure constitutes a systematic method to build general theories for multiple vector fields with or without internal symmetries. We also comment on the possibility of obtaining the beyond generalized SU(2) Proca field theory from our procedure.

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Dark energy with vector fields in the generalized SU(2) Proca theory

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The cosmological observations are consistent with a homogeneous and isotropic universe at large scales which favours the use of scalar fields as generators of the primordial and late inflationary periods. However, in the Standard Model of Particle Physics, whose action is invariant under SU(3)C × SU(2)L × U(1)Y local transformations, there exist vector fields which are the messengers of the fundamental interactions and that could serve as the driving force behind the cosmological inflationary periods. We have studied the vector-tensor variant of the Horndeski theory, when the action enjoys a global SU(2) symmetry, which is called the generalized SU(2) Proca theory. In particular, we have analyzed the Einstein-Hilbert plus the Yang-Mills Lagrangian plus the Lagrangian piece that contains products of two covariant derivatives of the vector field and that is reduced, in the Abelian case, to products of the S tensor (the symmetric version of the gauge field strength tensor). We have found an asymptotic behaviour, for an ample spectrum of initial conditions, where an eternal inflationary period is generated with an effective equation of state $\omega = -1$, which would represent the current behaviour of dark energy. Unfortunately, this mechanism fails at describing the thermal history of the universe , since the radiation- and matter-dominated periods are, essentially, inexistent.

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Primordial Black Holes and the 21cm Line

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Primordial Black Holes and the 21cm Line

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A Large Scale Structure Void Identifier for Galaxy Surveys Based on the Beta-Skeleton Graph Method

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Large underdense regions in the Large Scale Structure (LSS) of the Universe, also known as voids, are a prominent features of the cosmic web that can also be used as a cosmological probe. In this talk, I will present a new void-finding algorithm that can be applied to both observational and simulated data. The algorithm is based on the β-Skeleton, an algorithm widely used on machine learning, optimization and image recognition; recently it has been introduced as a LSS analysis tool. The analysis we have performed, on observational and simulated data, considers voids as ellipsoids. We study their statistical properties such as volumes and shape finding a good agreement with other void finders. We finalize by exploring possible applications of this void finder to constrain cosmological parameters based on data from the Dark Energy Spectroscopic Instrument.

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Can we use ”climate change” on Neutron Stars to detect dark matter?

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The presence of dark matter has been ascertained through a wealth of astrophysical and cosmological phenomena and its nature is a central puzzle in modern science. Elementary particles stand as the most compelling explanation. They have been intensively searched for at underground laboratories looking for an energy recoil signal and at telescopes sifting for excess events in gamma-ray or cosmic-ray observations. In this talk, we show a detection method based on spectroscopy measurements of neutron stars. We outline the luminosity and age of neutrons stars whose dark matter scattering off neutrons can heat neutron stars up to a measurable level. We show that in this case neutron star spectroscopy could constitute the best probe for dark matter particles over a wide masses and interactions strength.

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Anisotropic inflation with coupled p-forms

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We study the cosmology in the presence of arbitrary couplings between p-forms in 4-dimensional space-time for a general action respecting gauge symmetry and parity invariance. The interaction between 0-form (scalar field ϕ) and 3-form fields gives rise to an effective potential $V_{\rm eff}(\phi)$ for the former after integrating out the contribution of the latter. We explore the dynamics of inflation on an anisotropic cosmological background for a coupled system of 0-, 1-, and 2-forms. In the absence of interactions between 1- and 2-forms, we derive conditions under which the anisotropic shear endowed with nearly constant energy densities of 1- and 2-forms survives during slow-roll inflation for an arbitrary scalar potential $V_{\rm eff}(\phi)$. If 1- and 2-forms are coupled to each other, we show the

existence of a new class of anisotropic inflationary solutions in which the energy density of 2-form is sustained by that of 1-form through their interactions.