TAsP Meeting

Thursday, 18 January 2024 - Friday, 19 January 2024

Dip. Fisica

Book of Abstracts

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Recent Advances in pre Big Bang String Cosmology

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This presentation delves into recent developments in string cosmology, specifically focusing on the refinement of the Hohm-Zwiebach approach through an Hamiltonian reformulation. A general criterion is established to have $O(d, d)$ invariant actions to all orders in α' connecting T-duality related perturbative solutions of string cosmology equations. Assuming a timely approach to the perturbative string vacuum with zero curvature and string coupling, our solutions demonstrate dilaton stabilization at later times. The result converges dynamically towards a matter-dominated FLRW cosmology or a De-Sitter-like inflationary phase, dependent on the initial conditions and the characteristics of the dilation potential. As a remarkable feature, for the same class of initial conditions, this scenario also provides a mechanism to wash out (arbitrarly large) anisotropic initial conditions. This work explores Hamiltonian reformulations, non-perturbative effects, and the emergence of late time attractors in string cosmology.
The presentation will be based on arXiv:2308.16076

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Getting the most on Supernova axions

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In this talk I will discuss how Supernovae (SN) can be exploited to severely constrain the parameter space of axion-like-particles (ALPs) coupled to nucleons. In particular, I will provide a continuous extension of the ALP emission rates to the case of strong nuclear couplings, in which they could enter the trapping regime. This approach allowed us to extend the usual cooling bound on nucleonphilic ALPs from the case of weak coupling regime to the case of strong nuclear couplings. Furthermore, strongly coupled ALPs would have given rise to a signal in the Kamiokande II water Cherenkov detector. The non observation of this signal allows the introduction of a complementary constraints. Thus, the combination of this two arguments prevents the possibility for future cosmological surveys to detect any signatures of the QCD axion mass.

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Anatomy of astrophysical echoes from axion dark matter

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If the dark matter in the Universe is made of μeV axion-like particles (ALPs), then a rich phenomenology can emerge in connection to their stimulated decay into two photons. We discuss the ALP stimulated decay induced by astrophysical beams of Galactic radio sources. Three signatures, made by two echoes and one collinear emission, are associated with the decay, and can be simultaneously detected, offering a unique opportunity for a clear ALP identification. We derive the formalism associated with such signatures starting from first principles, and providing the relevant equations to be applied to study the ALP phenomenology.
We then focus on the case of Galactic pulsars as stimulating sources and derive forecasts for future observations, which will be complementary to helioscopes and haloscopes results.

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Galactic Archaeology: decoding the fossil record of Galaxy formation and evolution

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One of most important issue in Astrophysics is the achievement of a robust understanding of the sequence of processes that contributed to the building up of the Milky Way. This is obviously important not only "on a local scale" in order to recover the history of formation and evolution of the Galaxy, but also, more in general, for understanding
the formation process of spiral galaxies. In the last decade, the advent of high precision photometric and spectroscopic surveys as well as the possibility to estimate, thanks to the ESA Gaia mission, accurate distance for a huge number of field stars, combined with the development of an accurate theoretical framework, is actually opening a new era for this kind of investigations.
We will present some recent results - obtained by using this updated observational and theoretical framework - about the formation and early evolution of the Milky Way.

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Neutrino decoupling in standard and non-standard scenarios

Author: Stefano Gariazzo[1]

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We discuss the phenomenology of neutrino decoupling in the early universe, by summarising the details of the calculation in standard and non-standard scenarios. We quickly present the state-of-the-art calculation of the effective number of neutrino species in the early universe (Neff) in the

three-neutrino case, which gives Neff=3.044, and show how the result can change when additional particles (such as sterile neutrinos or decoupled scalar fields) are considered. Implications for Big Bang Nucleosynthesis are also briefly discussed.

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Probing Dark Matter-Proton Interactions with Cosmic Reservoirs

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Although Dark matter (DM) is one of the cornerstones of fundamental physics and cosmology, so far it has evaded all the attempts to unveil its nature. A standard way to directly probe DM particles is to search for their scatterings with nucleons in underground detectors. However, in case of DM particles with sub-GeV masses, the direct-detection technique is hampered by the low nucleon recoil energies which are typically below the experimental sensitivity. In this talk, I will discuss a novel idea to probe sub-GeV DM particles. In particular, I will investigate the effects of the possible scatterings between cosmic-ray protons and sub-GeV DM particles in star-forming and starburst galaxies, which are well-motivated astrophysical emitters of high-energy neutrinos and gamma-rays through hadronic collisions. For this scenario, I will explore the phenomenological implications and discuss new constraints on the DM parameter space.

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The interplay between Primordial Black Holes and Leptogenesis

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Primordial Black holes with mass of 10^15 g should have been evaporated by now giving potentially access to the physics of the Early Universe.
In particular, the presence of PBH could have impacted the process of leptogenesis in different ways depending on the mass and so on the temperature of the PBHs. We present the impact of the non-standard cosmology driven by the presence and the evaporation of light primordial black holes on the production of the baryon asymmetry of the Universe in different scenarios of leptogenesis.

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Dark Matter in galaxies: learning with machines

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The (in)famous method of "Rotation Curves" has informed us for decades about the mass structure of disk galaxies. Does modern technology allow us to hope for a more informative method? I will describe some recent work that hints towards a positive answer.

https://arxiv.org/abs/2111.08725

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CosmiXs: Cosmic messenger spectra for indirect dark matter searches

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The energy spectra of particles produced from dark matter (DM) annihilation or decay are one of the fundamental ingredients to calculate the predicted fluxes of cosmic rays and radiation searched for in indirect DM detection. We revisit the calculation of the source spectra for annihilating and decaying DM using the Vincia shower algorithm in Pythia to include QED and QCD final state radiation and diagrams for the EW corrections with massive bosons, not present in the default Pythia shower model. We take into account the spin information of the particles during the entire EW shower and the off-shell contributions from massive gauge bosons. Furthermore, we perform a dedicated tuning of the Vincia and Pythia parameters to LEP data on the production of pions, photons, and hyperons at the Z resonance and discuss the underlying uncertainties. To enable the use of our results in DM studies, we provide the tabulated source spectra for the most relevant cosmic messenger particles, namely antiprotons, positrons, gamma rays and the three neutrino flavors, for all the fermionic and bosonic channels and DM masses between 5 GeV and 100 TeV, on \href{https://github.com/ajueid/CosmiXs.git}{github}.

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PEANUTS: automatic computation of solar neutrino propagation

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I will present PEANUTS (Propagation and Evolution of Active NeUTrinoS), an open-source Python package for the automatic computation of solar neutrino spectra and active neutrino propagation through Earth. PEANUTS is designed to be fast, by employing analytic formulae for the neutrino propagation through varying matter density, and flexible, by allowing the user to input arbitrary solar models, custom Earth density profiles and general detector locations. It provides functionalities for a fully automated simulation of solar neutrino fluxes at a detector, as well as access to individual routines to perform more specialised computations. The software has been extensively tested against the results of the SNO experiment, providing excellent agreement with their results.

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Hunting for dark matter with its high-energy fluxes

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When Sub-GeV dark matter (DM) scatters off nuclei it makes them recoil too faintly to be seen by leading detectors. The community addressed this challenge mainly by proposing novel detection technologies: most of them are still in the conception phase, a few became experiments but are not yet testing motivated DM models. However, relativistic fluxes of light DM necessarily reach us on Earth, and open completely new possibilities to search for DM today, in existing experiments. I will review our proposal to observe sub-GeV Dark Matter upscattered by cosmic rays at large neutrino detectors like Super- and Hyper-Kamiokande, DUNE, KamLAND and JUNO. I will then present novel strong constraints and sensitivities, from the same experiments, that rely on the high-energy flux of DM produced in atmospheric showers. These techniques allow to probe genuinely new parameter space, allowed both by theoretical consistency and by other direct detection experiments, cosmology, meson decays and the LHC.

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The Baryon Asymmetry from Supercooled Confinement

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I will present a new framework for baryogenesis and leptogenesis based on a supercooled confining first order phase transition (PT).
With respect to the case of weakly coupled PTs, the rate asymmetry is enhanced by the decays of hadrons of the strong dynamics after the PT and washout effects from inverse decays are suppressed. Therefore, our setup extends the parameter space of successful generation of the baryon asymmetry down to TeV scale PTs, making it testable with gravity waves at LISA and the Einstein Telescope.
I will discuss two specific realizations of our framework, one of baryogenesis and one of leptogenesis and show how our setup can make their phenomenology partially testable. I will finally comment about the connection between our framework with open SM problems in addition to the generation of the baryon asymmetry.

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A fate of catalyzed first order phase transition -black holes from primordial black holes-

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It has been discussed that primordial black holes (PBHs), as impurities in the early universe, may have played an important role in the cosmological first-order phase transition (FOPT). Assuming that vacuum bubbles nucleate only around the PBHs, we discuss an unique phenomenology of FOPT. If the number of PBHs within one Hubble volume is smaller than unity at the time of bubble nucleation, each true-vacuum bubble catalyzed around them can expand to the Hubble size, and the universe is eventually filled with true vacuum much after nucleation. This super-slow transition predicts enhanced gravitational wave signals from bubble collisions and can be tested in future observations. Moreover, the remaining rare false vacuum patches give birth to baby BHs, which can account for the abundance of dark matter in our universe.

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Discussion

TAsP topics

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Farewell and What Next

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Gravitational waves from holographic phase transitions

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We analyze the phase transition in improved holographic QCD to obtain an estimate of the gravitational wave signal emitted in the confinement transition of a pure SU(N) Yang-Mills dark sector.

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New bounds on monopole abundance from cosmic magnetic fields

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Magnetic monopoles are inevitable predictions of theories like GUTs. They are produced during phase transitions in the early universe, but mechanisms like the Schwinger effect in strong magnetic fields could also contribute to the monopole number density. I will show how from the detection of intergalactic magnetic fields of primordial origin, we can infer additional bounds on the magnetic monopole flux and how even well-established limits, such as Parker bounds and direct search, are affected by intergalactic magnetic fields. I will also discuss the implications of these bounds for minicharged monopoles and magnetic black holes as dark matter candidates, and monopole pair production in primordial magnetic fields.

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Welcome from INFN director

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TasP Iniziativa Specifica

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Extended gravity models for inflation in light of the CMB data

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In this talk, we present different inflationary scenarios based on extended theories of gravity and test their observational viability in light of the most recent CMB data. In the first part, we will analyze the robustness of the standard Starobinsky inflation by inserting it into a generalized framework that is motivated in the braneworld scenario. Following this line, we consider the period of inflation as driven by a supergravity-inspired arctan potential and then study its theoretical and observational predictions, as well as obtain constraints on the reheating phase and its inflationary parameters. Another class of supergravity theories consists of the so-called α-attractors, for which we investigate the observational viability of a model with a double-well inflationary potential. A further class of braneworld-inspired scenarios comes from the generalization of the well-known power law inflation, for which we examine the observational viability for the case of a non-minimal coupling to gravity. Lastly, we present the case of an extended theory of gravity of the type $f(R,\, T)$ plus a scalar field and apply the first-order formalism to find analytical solutions to cosmological scenarios. Using the equivalence between the Jordan and Einstein frames we calculate the theoretical predictions for the inflationary parameters and confront them with the CMB temperature data.

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Black Holes and Dark Matter

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I discuss several connections between black hole phenomenology and dark matter searches. In the first part of the talk, I consider the idea that black holes of primordial origin constitute a portion of the dark matter that permeates the Universe, and explore the consequences of this idea in a cosmological context, discussing the upper limit on their abundance obtained by analyzing the angular power spectrum of the Cosmic Microwave Background. In the second part, I show how dark matter over-densities around black holes can leave a fingerprint on gravitational wave signals, and demonstrate that the upcoming LISA experiment has the potential to discover such signatures and hence indirectly detect dark matter.