IWDMS2018 - International Workshop on Dark Matter and Stars

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Center for Astrophysics and Gravitation, Instituto Superior Técnico, University of Lisbon

Book of Abstracts

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21-cm observations and warm dark matter models

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The recent report of 21-cm absorption signal by EDGES experiment has raised considerable interest in the dark matter (DM) community. Taking the reported EDGES result at face value, a number of forthcoming papers constrained masses of DM particles and their interaction strengths with Standard Model particles.

However, the connection between the formation of structures and 21-cm EDGES signal requires knowledge of parameters that describe star formation and radiation production during the Dark Ages.

We demonstrate that it is impossible to robustly constrain the dark matter model using only the EDGES signal. In particular, we show that resonantly produced 7~keV sterile neutrino dark matter model is consistent with recent 21-cm EDGES measurements.

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3.5 keV line in the Galactic bulge region

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The 3.5 keV line, discovered in early 2014 in the spectra of different cosmic objects, draws large attention as being the dark matter signal candidate. Much effort was performed since then to determine it's nature. The one conclusion to point out is that the dark matter signal is by now the only explanation consistent with all the observational data available.
We are presenting the detection of the 3.5 keV line in the stacked spectra of the XMM-Newton observation of the Galactic bulge region. The line was detected significantly in the several annulus regions around Galactic center. Being interpreted as dark matter decay line, this allows us to determine the inner halo profile slope.
We also briefly discuss the perspectives of the planned experiments in frames of our restrictions on signal parameters.

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An experiment to measure the speed of gravity: optimization of the rotating quadrupole mass

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The authors have experience with the SCHENBERG Gravitation Wave detector which is a resonant-mass developed by the Brazilian GRAVITON. Its spherical antenna weighs 1150 kg and it is monitored by six ultralow noise parametric transducers and is connected to the outer environment by a suspension system designed to attenuate local noise, both seismic and non-seismic, operating in a

temperature of 4 K. With all the acknowledgment acquired the idea of making an experiment to measure the speed of gravity took form. Using monocrystalline sapphire with very high mechanical and electrical Q´s, ultralow phase noise microwave sources, Finite Element Modelling designed suspensions, parametric microwave transducers, excellent properties of noise filtering of the resonant-mass detectors and the development of high-speed rotation machines guided the authors to the design of the experiment. The experiment will measure oscillations caused by gravitational interaction with an amplitude of the order of 0.1 am (10-19m). The main feature is a rotating mass that will generate a periodic tide signal at a very high frequency. in this work the optimization of such mass to reach the highest tide signal is shown.

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Asteroseismology constraints on dark photons

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TBA

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Astrophysical constraints on dark matter

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I will overview what astrophysical observations tell us about the properties of dark matter with particular focus on Primordial Black Holes (PBHs), black holes formed in the early Universe. The recent discovery of gravitational waves from mergers of ~10 Solar mass black hole binaries has (along with the lack of signal in WIMP detection experiments) led to increased interest in PBHs as a dark matter candidate. I will discuss the limits on their abundance, with particular emphasis on microlensing and dynamical constraints in the Solar mass region.

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Axion-Plasmon Polaritons in Strongly Magnetized Plasmas

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Axions are hypothetical particles related to the violation of the charge-parity symmetry within the strong sector of the standard model, being one of the most prone candidates for dark matter. Multiple attempts to prove their existence are currently performed in different physical systems. Here, we predict that axions may couple to the electrostatic (Langmuir) modes of a strongly magnetized plasma, and show that a new quasiparticle can be defined, the axion-plasmon polariton. The excitation of axions can be inferred from the pronounced modification of the dispersion relation of the Langmuir waves, a feature that we estimate to be accessible in state-of-the-art plasma-based experiments.

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Dark matter & compact stars

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I will discuss ways that compact star observations can set constraints on different dark matter candidates. In addition, I will entertain the possibility of asymmetric dark matter forming its own compact objects and I will argue that such objects could be detected and identified using a variety of techniques.

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Dark matter in the stars: axions and asymmetric dark matter

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I will discuss recent progress in the hunt for axions and asymmetric dark matter using the Sun and other stars. First, I will present the results of global fits to axion and axion-like particle models, including constraints from horizontal branch stars, searches for solar axions, and white dwarf cooling. I will then present some preliminary results of explicit Monte Carlo simulation of energy transport in the Sun by dark matter with velocity- and momentum-dependent interactions with nucleons.

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Dark matter, general relativity and the rotation curve of UGC 128

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General relativity can be used to fit the rotation curves of galaxies with less dark matter than it is necessary when other theories of gravitation are applied. In this approach a galaxy is modelled as low density baryonic dust in stationary, axially-symmetric rotation, in which case it has already been shown that non-linear gravitational effects play a significant role in the overall motion of matter. The fits can be used to determine mass densities as functions of galactocentric distances and heights, therefore yielding galactic masses. As a first approximation to their morphologies, we discovered that new information about the galaxies can be obtained from their mass-density functions. Our pproach is applied here to the galaxy UGC 128, whose results are compared to those previously obtained for NGC 2403. Studies comparing these two galaxies were published before, either assuming the existence of dark matter or using MOND. These two galaxies are at identical positions on the Tully-Fisher relation, having almost identical luminosities. As well, they have almost identical rotation velocities and they are morphologically very similar. However, they display large differences in surface brightness. Despite their almost identical rotational velocity profile, using our approach we found that their mass density profiles may be significantly different. In this poster we will display our results and highlight their implications for the understanding of the nature of dark matter.

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Indirect detection of dark matter and constraints on the first stars

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The first stars formed from pristine hydrogen and helium at high redshift and were much more massive than typical stars of subsequent generations. If these stars formed near the centers of their dark matter minihalos, the dark matter would have contracted around the compact baryonic object. The most massive stars would have ended their lives by collapsing to black holes, leaving a black hole remnant surrounded by a dark matter spike. Furthermore, if the first stage of stellar evolution is a Dark Star phase during which the star is powered by dark matter annihilations, the first stars would have grown to be even larger, possibly even becoming supermassive, and leaving correspondingly larger black hole remnants. In this talk I'll discuss potential signatures of the first stars via indirect detection of annihilation in their dark matter spikes, as well as existing constraints from various experiments.

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Influence of the tetraneutron condensate on properties of neutron stars

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Based on recent experimental and theoretical hints on possible formation of a resonant four-neutron system we study effects of appearance of such a cluster in neutron rich baryon matter inside neutron stars. For this purpose we employ a relativistic mean field approach which includes nucleons, Δ-baryons as well as light nuclear clusters. The Pauli blocking which suppresses tetraneutrons and stable clusters is explicitly included to the model as well. Our analysis demonstrates that tetraneutrons are able to exist as the Bose-Einstein condensate. Such a condensate weakens the nucleon Cooper pairing and significantly suppresses formation of the superfluid phase inside neutron stars. Tetraneutrons are also found to strongly feed vector meson fields and suppress Δ-baryons leading to stiffening of equation of state.

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Interaction of Primordial Black Holes with Stars

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TBA

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Machine learning technique for morphological classification of galaxies

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We checked classifiers as Naive Bayes, Random Forest, and Support Vector Classifier on sample of galaxies from SDSS DR9 (N=60561, 0.02<z<0.06). We used the absolute magnitudes Mu, Mg, Mr, Mi, and Mz, all the color indices, and inverse concentration indexes R50/R90 to the center as the attributes of galaxy. To define an accuracy of the mentioned above classifiers we applied the 5-folds validation technique. It turned out that the Random Forest method provides the highest accuracy, namely 91 % of galaxies from the sample were correctly classified (96 % for E and 80 % for L types). The accuracy of other classifiers was from 85 % to 90 %. We were able to classify 60561 galaxies from the SDSS DR9 with unknown morphologies with a good accuracy onto two clasees (47 % E and 53 % L types of galaxies). Finaly, we found 28 199 E and 32 362 L types among them. We able to classify low-redshift galaxies from the SDSS with unknown morphologies with a good accuracy.

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Neutron stars meet constraints from astrophysics, gravitation, high and low energy nuclear physics

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We apply the novel equation of state, which includes the surface tension contribution induced by the interparticle interaction and the asymmetry between neutrons and protons, to the study of neutron star properties. This equation of state is obtained from the virial expansion for the multicomponent particle mixtures that takes into account the hard-core repulsion between them. The considered model is in full concordance with all the known properties of normal nuclear matter, provides a high quality description of the proton flow constraints, hadron multiplicities created during the nuclear-nuclear collision experiments and equally is consistent with astrophysical data coming from neutron star observations and GW170817 merger. The found mass-radius relation for neutron stars computed with this equation of state is consistent with astrophysical observations. This talk will show how the induced surface tension (IST) equation of state opens an elegant way to describe the properties of matter across a very wide range of densities and temperatures.

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On the relevance of polarimetry of astronomical objects and the importance of the determination of the instrumental polarization in FORS2 at the ESO-VLT

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Polarimetric studies of stars, supernovae, clusters and galaxies are able to provide crucial information about the intrinsic properties of these objects. Polarimetry is also extremely important to understand the properties of the dust that might affect the observations and lead to systematic effects.

In our work we investigate the instrumental polarization in FORS2- the FOcal Reducer and low dispersion Spectrograph at Very Large Telescope, ESO. With optical multiband sky observations in

BVRI during full moon we were able to produced 2D maps of the the instrumental polarization. These maps are particularly relevant in polarimetric studies of extended sources.

This work was supported by FCT- Fundacao para a Ciencia e Tecnologia and by Project PTDC/FIS-AST-31546

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Partial ionization and stellar rotation: a seismic connection in F-type stars

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F-type stars are very diverse concerning magnetic and rotational properties. As it is well know, in these stars magnetism and rotation are intimately linked. Understanding how these macroscopic observable properties relate to the physics of the stellar interiors is a challenging exercise.

We studied the relation between the star's rotation period and partial ionization processes occurring in the outer envelopes of a subset of stars of the Kepler legacy sample. We found a trend, in the form of a power-law dependence, that favors the idea that ionization is acting as an underlying mechanism, which is crucial for understanding the relation between rotation and magnetism and even observational features such as the Kraft break.

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Photon emission from dark mediators in White Dwarfs

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We consider self-annihilation of fermionic sub-GeV dark matter into metastable mediators inside white dwarfs (WDs). We assume these mediators decay into two photons after being produced. We calculate the luminosity of WDs due to these annihilations taking into account theenergy loss of the mediator and its finite lifetime in the dense stellar medium. Finally, using complementary sets of measurements ranging from cold white dwarfs in the M4 globular cluster and direct/indirect searches we discuss constraints on mediator lifetimes.

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Review on the hadronic equation of state for neutron stars

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The equation of state (EoS) of dense hadronic matter is of crucial importance for the description of the static and dynamical properties of neutron stars. In this talk I will review the current status of the hadronic EoS for neutron stars, from the point of both ab-initio many-body approaches and

phenomenological models. The theoretical predictions for the hadronic EoS will be compared to the data coming from both nuclear physics experiments and astrophysical observations, providing insights for future research.

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Rotating clumps of scalar field dark matter

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Low-energy, self-gravitating solutions of a scalar field coupled to gravity, described by the Schrodinger-Poisson system, are good candidates for realistic astrophysical structures, being particularly suited to describe dark matter halos. In this work we study the scenario in which one of these structures is gravitationally perturbed by a point-like mass. We analyse the effects that the body has on the distribution of the scalar field and how it backreacts on the body's motion. We show that an initially static, spherical structure can develop non-spherical clumps with angular momentum, the amplitude of which is directly related to the mass of the orbiting particle.

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Solar Models, neutrinos and helioseismology

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The exquisite data provided by helioseismology and, more recently, by solar neutrino experiments allow us to determine the physical conditions in the solar interior. Our understanding of solar interior physics, represented by solar models, can then be tested precisely. In this talk, I will review the current status of solar models and the most recent results on solar neutrinos, and discuss some caveats in current models. I will then highlight some open questions for solar physics, stellar and particle physics

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The effects of dark matter on Sun-like stars: neutrinos and helioseismology

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I will introduce the effects of dark matter capture in Sun-like stars, as they pass through the distribution of dark matter known to fill the Milky Way. I will focus on the effects of heat conduction by weakly interacting particles such as asymmetric dark matter: specifically, a reduction of central temperature and thus a significant change in the solar neutrino fluxes, as well as changes in the radius-dependent sound speed, reflected in high-precision helioseismology measurements. Such effects may help solve the solar abundance problem, a > 6-sigma discrepancy between the predicted and observed structure of the Sun in the Standard Solar Model, which has confounded solar physicists for over a decade. I will briefly discuss other effects of dark matter on stars, as well as complementary probes from laboratory experiments.

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The shadow of dark matter as a shadow of sting theory

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We point out that the Kalb-Ramond field of string theory can help to generate a $U_Y(1)$ portal to dark matter. This entails the possibility that the $U_Y(1)$ gauge field is related to a fundamental vector field for open string interactions. The $U_Y(1)$ portal also implies dipole and fluorescent dark matter couplings of the form initially suggested by Profumo and Sigurdson [1], and used by Conlon et al. to explain the anomalies in the 3.5 keV data from Perseus. The requirement to explain the observed dark matter abundance relates the coupling scale M in the corresponding low-energy effective $U_Y(1)$ portal to the dark matter mass m. The corresponding electron recoil cross sections for a dipole coupled dark matter species are below the limits from XENON, SuperCDMS and SENSEI, but above the neutrino floor.

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Trojan Horse mechanism of dark matter inside neutron stars

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In this talk I will present recent progress on the study of dark matter models where gravitationally captured dark matter can self-annihilate inside a dense star (neutron star) and subsequently produce changes in the microscopic matter conditions. Depending on selected dark candidate
mass and interaction cross-section to nucleons this fact could lead to a new mechanism to form even denser stars.

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White dwarf stars as physics laboratories

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White dwarfs are the final remnants of low and intermediate mass main sequence stars. Because of electron degeneracy, their evolution is just a cooling process. The basic ingredients to understand their evolution are well identified (although not all of them completely understood), and there is at present an important observational background that allows to check the different models of cooling.

The majority of white dwarfs can be imagined as a degenerate core made of a mixture of 12C, 16O plus several impurities that contains the bulk of mass and acts as an energy reservoir, surrounded by a semidegenerate envelope that controls the flux of energy from the interior to free space. Since the corresponding cooling rate can be obtained from their luminosity function or the secular drift of their period of pulsation, it is possible to consider them as a calorimeter turning around the center of the Galaxy. Therefore, these properties can be used to detect the existence of additional, unexpected, energy sources or sinks. In this talk I describe how white dwarfs can be used as detectors and I apply them to the case of axions.

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e- e+ plasma-dark electromagnetism similarity establishes a (nearly) weaker-than-gravity bound on long-range dark matter self-interactions

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Dark matter (DM) has been theorized to be charged under its own "dark electromagnetism" (DEM). Under this hypothesis, DM can behave like a cold collisionless plasma of self-interacting DM particles, and exhibit plasma-like instabilities with observational consequences [1,2]. Using PIC simulations [3], the nonlinear evolution of such instabilities driven by the interpenetration of two $e^- \, e^+$ plasma clouds that mimic the "dark plasma" are explored. We show that the clouds slow down due to both oblique and Weibel generated electromagnetic fields, which deflect the particle trajectories, transferring bulk forward momentum into transverse momentum and thermal velocity spread. This process causes the flow velocity to decrease from v_{fl} by a factor of $\sqrt{3}$ in a time interval $\Delta t \omega_p \sim 1/\sqrt{\alpha}(c/v_{fl})$, close to $10 \times$ the instability growth time, where α is the equipartition parameter determined by the non-linear saturation of the instabilities, and ω_p is the plasma frequency. We show that if the typical DM slab length $L > v_{fl}\Delta t$, this slowdown is always expected. Comparison with astronomical observations reveal strong new constraints on DEM with the dark electromagnetic self-interaction $\alpha_D < 4 \times 10^{-25}$.

[1] Heikinheimo et. al PRB 749 7 (2015) [2] Fonseca et al., PPCF 50, 124034 (2008)