CosPA 2016

Monday 28 November 2016 - Friday 2 December 2016

Book of Abstracts

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Cosmic microwave background and Large Scale Structure / **2**

Planck large scale polarization

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We investigate constraints on cosmic reionization extracted from the Planck cosmic microwave background (CMB) data. We combine the Planck CMB anisotropy data in temperature with the low-multipole polarization data to fit ΛCDM models with various parameterizations of the reionization history. We obtain a Thomson optical depth $\tau = 0.058 \pm 0.012$ for the commonly adopted instantaneous reionization model. This confirms, with data solely from CMB anisotropies, the low value suggested by combining Planck 2015 results with other data sets and also reduces the uncertainties.

We reconstruct the history of the ionization fraction using either a symmetric or an asymmetric model for the transition between the neutral and ionized phases. To determine better constraints on the duration of the reionization process, we also make use of measurements of the amplitude of the kinetic Sunyaev-Zeldovich (kSZ) effect using additional information from the high resolution Atacama Cosmology Telescope and South Pole Telescope experiments. The average redshift at which reionization occurs is found to lie between z = 7.8 and 8.8, depending on the model of reionization adopted. Using kSZ constraints and a redshift-symmetric reionization model, we find an upper limit to the width of the reionization period of $\Delta z < 2.8$. In all cases, we find that the Universe is ionized at less than the 10 % level at redshifts above z ⊠ 10. This suggests that an early onset of reionization is strongly disfavoured by the Planck data. We show that this result also reduces the tension between CMB-based analyses and constraints from other astrophysical sources.

Summary:

On behalf of the Planck collaboration, I will present the results from the CMB large scales polarization data. The CMB polarization at low multipoles can gives constraints on the reionization history through the measurement of the reionization optical depth. I will present the last constraints obtained with Planck data for single-stage models as well as more realistic two-stages models motivated by astrophysical objects.
I will also present the implication on the amplitude of the primordial gravitational waves and gives the actual Planck constraints on r.

Cosmic microwave background and Large Scale Structure / **3**

Relieving tensions related to the lensing of CMB temperature power spectra

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The angular power spectra of the CMB temperature anisotropies reconstructed from Planck data seem to present 'too much'gravitational lensing distortion. This is quantified by the control parameter A_L that should be compatible with unity for a standard cosmology. With the class Boltzmann solver and the profile likelihood method, we measure for this parameter a 2.6σ shift from 1 using the Planck public likelihoods. We show that, due to strong correlations with the reionization optical depth τ and the primordial perturbation amplitude A_s, a ~ 2σ tension on τ also appears between the results obtained with the low ($\ell \leq 30$) and high ($30 < \ell < 2500$) multipoles likelihoods. With Hillipop, another high-l likelihood built from Planck data, this difference is lowered to 1.3σ. In this case, the

A_L value is still discrepant with unity by 2.2σ, suggesting a non-trivial effect of the correlations between cosmological and nuisance parameters.
To better constrain the nuisance foregrounds parameters, we include the very-high-l measurements of the ACT and SPT experiments and obtain $A_L = 1.03 \pm 0.08$. The Hillipop+ACT+SPT likelihood estimate of the optical depth is τ = 0.052 ± 0.035 which is now fully compatible with the low-l likelihood determination. After showing the robustness of our results with various combinations, we investigate the reasons for this improvement, which results from a better determination of the whole set of foregrounds parameters. We finally provide estimates of the ΛCDM parameters with our combined CMB data likelihood.

Summary:

Gravity and gravitational waves / 6

Entropy of Horava-Lifshitz Blakholes

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Ever since the observation of Bekenstein that not only black hole mechanics can be given the form of the laws of thermodynamics, with area of horizon playing the role of
entropy, the surface gravity of temperature and the mass of the black hole as energy, the study of black hole thermodynamics has been a very active area of research due to fundamental problems posed by such a connection. Hawking's discovery that black holes actually radiate via thermal spectrum gives credence to the idea that the connection between geometry and thermodynamical quantities is not incidental, rather reveals the underlying deep quantum structure of space-time as the entropy associated with a single classical solution must have a microscopic origin in more fundamental degrees of freedom.

Summary:

We study quantum corrections to the entropy of certain black hole solutions in Horava's gravity which is a promising proposal for describing the ultra-violet behavior of General Relativity. It is found that unlike in classical GR, the entropy formula is drastically changed through quantum corrections in the Horava's gravity by terms that are proportional to inverse of the horizon area.

Inflation and early universe cosmology / 7

Multi-phase inflation and endlessly flat scalar potentials

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In my talk I will present an idea of a scalar theory with a general potential $V(f(\varphi))$, where $f(\varphi) = \xi \sum_{k=1}^{n} \lambda_k \varphi^k$. I will show how to obtain generally flat inflationary potentials from such a model and prove that the Starobinsky inflation is one of the examples of $V(f)$ with a stationary point of an infinite order. I will generalise this model into a scalar-tensor theory, which leads to multi-phase inflation, with two inflationary plateaus. I will also show the equivalence of this picture to α-attractors.

Summary:

Cosmological models / 8

Bianchi type V cosmological model with perfect fluid and dark Energy

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In the present work, we have constructed an anisotropic dark energy cosmological model in the framework of General Relativity at the backdrop of spatially homogeneous and anisotropic Bianchi V metric. The anisotropic behaviour of the model is simulated through the consideration of different scale factors and Hubble expansion rates along different spatial directions. A parameter m is considered to take care of the anisotropic behaviour of the model in the sense that, if $m = 1$, we get isotropic model and for $m \neq 1$, anisotropic nature will be retained. The cosmic fluid is also considered to be anisotropic which allow us to assume different pressure of the fluid along different directions.

Summary:

Anisotropic dark energy model with dynamic pressure anisotropies along different spatial directions is constructed at the backdrop of a spatially homogeneous diagonal Bianchi type V (BV) space-time in the framework of General Relativity. A time varying deceleration parameter generating a hybrid scale factor is considered to simulate a cosmic transition from early deceleration to late time acceleration. We found that the pressure anisotropies along the $y-$ and $z-$ axes evolve dynamically and continue along with the cosmic expansion without being subsided even at late times. The anisotropic pressure along the $x-$axis becomes equal to the mean fluid pressure. At a late phase of cosmic evolution, the model enters into a phantom region. From a state finder diagnosis, it is found that the model overlaps with ΛCDM at late phase of cosmic time.
\end{abstract}

Particle astrophysics / 9

Measuring the Neutrino Mass Ordering with KM3NeT-ORCA

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ORCA (Oscillations Research with Cosmics in the Abyss) is the low-energy branch of KM3NeT, the next generation underwater Cherenkov neutrino detector in the Mediterranean. Its primary goal is to resolve the long-standing unsolved question of whether the neutrino mass ordering is normal or inverted by measuring matter oscillation effects with atmospheric neutrinos. The ORCA design foresees a dense configuration of KM3NeT detection units, optimised for studying the interactions of neutrinos in seawater at low (< 100 GeV) energies. To be deployed at the French KM3NeT site, ORCA's multi-PMT optical modules will exploit the excellent optical properties of deep seawater to accurately reconstruct both cascade (mostly electron neutrinos) and track events (mostly muon neutrinos) with a few GeV of energy. This contribution reviews the methods and technology, and discusses the potentiality of the ORCA detector both in neutrino mass hierarchy studies and in

obtaining new constraints on other key parameters such as θ_{23}. Additional physics potentials will be mentioned.

Summary:

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Measuring the Leptonic Dirac CP Phase with Muon Decay at Rest

Author: Shao-Feng Ge[1]

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With the 1-3 mixing angle measured at reator neutrino experiments Daya Bay and RENO, there are still three unknown oscillation variables: the neutrino mass hierarchy, the octant of the atmospheric mixing angle, and the leptonic CP phase. Of these three, the CP phase is the most difficult to be measured precisely and important for distinguishing flavor symmetries. I will first review the status of CP measurement and then introduce a new proposal with muon decay at rest (muDAR). Currently, accelerator neutrino
experiments such as T2K, NOvA, and DUNE are the most promising for CP measurement. Nevertheless, they suffer from several problems of degeneracy, efficiency, sensitivity, and theoretical armbiguities such as non-unitarity mixing (NUM) and
non-standard interaction (NSI). The situation can be improved by adding a muon decay at rest (muDAR) source. With T2(H)K running
in neutrino mode and muDAR in anti-neutrino mode, both using the same detector, the CP measurement becomes more precise can break
the degeneracy between \delta and 180^o - \delta. Most importantly, muDAR can guarantee the CP sensitivity against NUM and NSI.
The same configuration can also apply to next-generation medium baseline reactor neutrino experiments like JUNO and RENO-50,
enhancing their physics potential from just mass hierarchy to also CP. With only one source and no extra detectors, this dessign
is much better than DAEdLAS which requires 3 sources, but only 20% duty factor and 4 times higher luminosity for each.

Summary:

This new proposal of muDAR experiment can significantly
improve the CP sensitivity at accelerator neutrino experiment,
including T2K, NOvA, and DUNE.

1) Better CP measurement than T2K

1a) Much larger event numbers

1b) Much better CP sensitivity around maximal CP

1c) Solve degeneracy between δ_D & π − δ_D

1d) Guarantee CP sensitivity against NUM

1e) Guarantee CP sensitivity against NSI

2) Better configuration than DAEδLUS

2a) Only one cyclotron is needed

2b) 100% duty factor

2c) Much lower flux intensity

2d) Much easier in cyclotron technology

2e) Much cheaper

2f) Single near detector

Refs:

Jarah Evslin, SFG, Kaoru Hagiwara, JHEP 1602 (2016) 137 [arXiv:1506.05023]

SFG, Pedro Pasquini, Mariam Tortola, Jose W.F. Valle [arXiv:1605.01670]

SFG, Alexei Smirnov, in preparation

Particle astrophysics / **12**

Highlights of the ANTARES neutrino telescope results

Author: Annarita Margiotta[1]

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The ANTARES experiment has been running in its final configuration since 2008. It is the largest neutrino telescope in the Northern hemisphere. A major goal of neutrino telescopes is the search for astrophysical neutrinos in the TeV-PeV range coming from resolved Galactic and extra Galactic sources or due to a diffuse cosmic neutrino flux.

In this kind of searches, a special role is played by the multimessenger approach. The search for time/space coincidence between neutrino telescope events and signals registered with other detectors increases the sensitivity of the analyses, significantly reducing the background. Interesting results have been obtained in collaboration with several different experiments sensitive on a wide range of the electromagnetic spectrum and, recently, limits have been set on the neutrino flux emitted with the gravitational waves event measured by the LIGO/VIRGO detectors on last September 15, 2015.

The discovery of a cosmic neutrino diffuse flux by the IceCube detector has made the search for its origin a key mission in high-energy astrophysics. Despite the reduced size, the ANTARES telescope is able to constrain the origin of the IceCube excess from regions extended up to 0.2 sr in the Southern sky. Though the golden channel for source searches is the identification of muons from charged current events of muon neutrinos, where angular resolution better than 1 degree can be obtained thanks to the excellent optical properties of the sea water, promising results have been obtained from the analysis of events with different topologies.

ANTARES has also provided results on atmospheric neutrinos, searches for rare particles (such as magnetic monopoles and nuclearites in the cosmic radiation), Dark Matter and Earth and Sea science.

A general survey of the most recent studies performed with ANTARES will be presented and discussed.

Summary:

Plenary / **13**

Neutrino studies in the Mediterranean: the KM3NeT/ARCA neutrino telescope

Author: Clancy James[1]

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ARCA (Astroparticle Research with Cosmics in the Abyss) is the high-energy neutrino telescope being built as part of the KM3NeT deep-sea research infrastructure. Optimised for a high angular resolution to neutrinos in the TeV-PeV regime, its main physics goals are the exploration of the high-energy astrophysical neutrino signal reported by IceCube, and the discovery of Galactic neutrino sources.

Currently in Phase 1 deployment, in Phase 2 ARCA will consist of two "building blocks" deployed in the Mediterranean Sea off the coast from Capo Passero (Sicily, Italy). Each block will consist of 115 strings; each string comprises 18 optical modules, and each optical module carries 31 photo-multiplier tubes. The excellent optical properties of deep seawater allow high-resolution neutrino studies by collecting the Cherenkov light emitted along the path of charged particles produced in neutrino interactions inside or close to the detector.

An overview of the expected performances of the detector to several possible source classes will be given, together with an update of the present status of construction.

Summary:

Cosmological models / 14

CMB Hemispherical Power Asymmetry & Noncommutative Space-times

Author: Rahul Kothari[1]

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In this talk, I'll start with the Cosmological Principle and its ramifications for the Cosmic Microwave Background Radiation. Mathematically speaking, statistical isotropy implies nonzero correlations between spherical harmonic coefficients $\langle a_{lm}a^{\star}_{l'm'}\rangle$ only when $l = l'$ and $m = m'$. But because of the presence of Hemispherical Power Asymmetry, other correlations are also found and hence Cosmological Principle is violated.

To explain this effect a large number of models have already been given. But in our work, we were interested in the possibility of explaining it using the modified primordial power spectrum. It is argued that by introducing 'some' anisotropy and/or inhomogeneity, we can explain this effect. After mathematical analysis, $l' = l + 1, m' = m$ are concomitantly found with the usual isotropic ones. By defining a statistic and subsequent χ^2 analysis, model parameters are extracted.

I'll also show that the ab initio derivation of the anisotropic primordial power spectrum can't be done in the commutative spacetimes. It is found that the same kind of form (apart from some extra correlations) can be derived in noncommutative spacetimes.

Summary:

Hemispherical power asymmetry in an anomaly in CMB that violates the *Cosmological Principle* of standard Cosmology and was found in 2004 in the WMAP data. Although a large number of models have been given to explain this effect, I would instead like to discuss the same effect on the basis of modified primordial power spectrum based models. In the standard paradigm, the primordial power spectrum is homogeneous and isotropic. But it will be shown that by allowing inhomogeneity and/or anisotropy,

one can account for this anomaly. In particular, I'll show how the anisotropic power spectrum can be derived using the noncommutative spacetimes.

Particle astrophysics / 18

Neutrino mass and hierarchy determinatiion from new physics

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We present a detailed discussion on neutrinoless double beta decay within a class of left-right symmetric models where neutrino mass originates by natural type II seesaw dominance. The spontaneous symmetry breaking is implemented with doublets, triplets and bidoublet scalars. The fermion sector is extended with an extra sterile neutrino per generation that helps in implementing the seesaw mechanism. The presence of extra particles in the model exactly cancels type-I seesaw and allows large value for Dirac neutrino mass matrix M_D . The key feature of this work is that all the physical masses and mixing are expressed in terms of neutrino oscillation parameters and lightest neutrino mass thereby facilitating to constrain light neutrino masses from neutrinoless double beta decay. With this large value of
M_D new contributions arise due to; i) purely left-handed current via exchange of heavy right-handed neutrinos as well as sterile neutrinos, ii) the so called λ and η diagrams. New physics contributions also arise from right-handed currents with right-handed gauge boson W_R mass around 3 TeV. From the numerical study, we find that the new contributions to neutrinoless double beta decay not only saturate the current experimental bound but also give lower limit on absolute scale of lightest neutrino mass and shows NH pattern of mass hierarchy is favorable..

Summary:

The seesaw mechanisms that explain light neutrino masses require them to be Majorana particles which violates lepton number by two units. This lepton number violation can be observed at Large Hadron Collider through same-sign dilepton events and at low energy experiments by the rare process like neutrinoless double beta decay provided the seesaw scale is low. The canonical seesaw mechanism requires the existence of SM gauge-singlet sterile neutrinos at very high energy scales which can not be accessible to any experiment in foreseeable future. Therefore, it is essential to explore alternative
low scale seesaw mechanisms which offer direct testability at the LHC and other low-energy experiments. We propose a new framework where the new physics contributions can be expressed in terms of neutrino oscillation parameters. One important aspect of this framework is that one can get lower bound on abosolute scale of lightest neutrino mass and mass hierarchy by analyzing the new physics contributions to neutrinoless double beta decay. We also interlink neutrinoless double beta decay with cosmology, beta decay and neutrino oscillation.

Cosmological models / 20

All-scale cosmological perturbations and screening of gravity in inhomogeneous Universe

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Without exceeding the limits of the concordance cosmological model, all-scale scalar and vector perturbations of the homogeneous background are derived analytically for arbitrarily distributed inhomogeneities (discrete gravitating masses) as their nonrelativistic sources. The obtained expressions for the metric corrections converge everywhere in voids, have zero average values, and conform to Minkowski background limit and Newtonian cosmological approximation as particular cases. Moreover, the uniform matter distribution limit as one more crucial test is easily passed as well. It is rigorously proven that gravitational attraction between inhomogeneities is governed by Yukawa law, covering the whole space and coming up to take place of Newtonian gravitation, which is restricted exclusively to sub-horizon distances. The finite time-dependent screening length (amounting to 3.7 Gpc at present) is determined by the average rest mass density of nonrelativistic matter and provides natural estimates of the homogeneity scale, the upper limit of the cosmic structure dimension, and the bound to a spatial domain of probable structure development.

ApJ 825, 84 (2016)

1509.03835

Summary:

Inflation and early universe cosmology / 23

Ahead of the hunt: leading small field inflationary potential models.

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I will first present in broad strokes the numerical package employed, and discuss regression tests to fully analytical cosmological models. I will then go on to present the early work done on the subject of small-scale 5th degree polynomial models, which were first suggested by Ben-Dayan et al. in 2010. These models successfully yield an inflationary scenario with a non-negligible n_{run}, and r as high as 0.001. This work demonstrates the need for high accuracy numerical tools in the field of cosmological model building. I will continue to present the ongoing work (about to publish late August/early September) which studies models with r as high as 0.05. These models present in addition to significant running, significant running of running. I will present the analysis of CMB data which takes into account $n_{run,run}$, along the same outline as the one done by Cabass et al. . I will then demonstrate using this data to recover a most probable 6th degree polynomial inflationary potential.

Summary:

We employ high accuracy computerized methods to check predictions of theoretical cosmological models, against CMB observables (specifically the spectral index n_s, its running n_{run} and the running of the running $n_{run,run}$). Our work is motivated by the recent developments in the hunt for primordial gravitational waves signal. We therefore apply our work to small field models which present the possibility of generating appreciable GW signal while conforming to CMB observables.

Our research yields most probable inflaton potential candidates, among the 5th degree and 6th degree polynomial small field classes. These candidates will be further challenged by new incoming data such as the anticipated BICEP3/Keck upcoming release.

We additionally find that for non-vanishing n_{run}, the numerically extracted values of n_s and n_{run} deviate significantly from analytic projections. We discuss the probable reasons for such deviations

Particle astrophysics / 24

The Statistics of Unresolved Point-Source Populations

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Conventional gamma-ray point-source searches involve looking for sources that are individually detectable with a predetermined statistical significance. A shortcoming of this approach is that a population of sources that are each below this statistical threshold cannot be found. Nevertheless such a population will modify the statistics of the dataset away from a Poisson distribution and can be uncovered using the recently introduced Non-Poissonian Template Fit (NPTF) method. In this talk I will outline a code package, which will be publicly released shortly, that can be used to apply the NPTF to astrophysical datasets. As I will review, this code has already been used to uncover a number of features of the gamma-ray sky, such as the likely point-source origin of the galactic centre excess, and is currently being applied to other datasets, including Icecube neutrinos.

Summary:

Cosmic microwave background and Large Scale Structure / 25

Distinguishing between Warm Dark Matter and Late Kinetic Decoupling using CMB spectral distortions.

Author: James Diacoumis[1]

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Recently a number of alternative dark matter models have been introduced as a means of explaining the physics of small-scale structure formation. These include, warm dark matter and dark matter with late kinetic decoupling both of which differ substantially from the canonical cold dark matter formalism. One interesting way of constraining the phenomenology in these models is to look at the characteristic imprint they leave on the photon spectrum left over from the Big Bang. These imprints are known as spectral distortions in the literature and arise due to spatial fluctuations in the photon temperature along the line of sight. As a result, the thermal history of the photon bath gives us a unique insight into the evolution of the early universe. In this talk I will show how this insight can be used to constrain the phenomenology of these dark matter models, in particular noting that the signatures can be used to distinguish between warm dark matter and late kinetic decoupling scenarios.

Summary:

Particle astrophysics / 26

Collapse of Axion Stars

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Abstract

Axion stars, gravitationally bound states of low-energy axions, described by a field theory with potential energy $f^2m^2(1 - Cos(A/f))$ have
a maximum mass allowed by gravitational stability. Weakly bound states
obtaining this maximum mass have sufficiently large radii such that they are
dilute, and as a result, they are well described by a leading-order expansion
of the axion potential. Heavier states are susceptible to gravitational
collapse. Inclusion of higher-order interactions, present in the full
potential, can give qualitatively different results in the analysis of
collapsing heavy states, as compared to the leading-order expansion. In this
work, we find that collapsing axion stars are stabilized by repulsive
interactions present in the full potential, providing evidence that such
objects do not form black holes. These dense configurations, which are the
endpoints of collapse, have extremely high binding energy, and as a result,
quickly decay through number changing interactions.

Summary:

Gravity and gravitational waves / 27

Constraining non-commutative space-time from GW150914

Authors: Adrian Manning[1]; Archil Kobakhidze[2]; Cyril Lagger[2]

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The gravitational wave signal GW150914, recently detected by LIGO and Virgo collaborations, is used to place a bound on the scale of quantum fuzziness of non-commutative space-time. We show that the leading non-commutative correction to the phase of the gravitational waves produced by a binary system appears at the 2nd order of the post-Newtonian expansion. This correction is proportional to $\Lambda^2 \equiv |\theta^{0i}|^2/(l_P t_P)^2$, where $\theta^{\mu\nu}$ is the antisymmetric tensor of non-commutativity. To comply with GW150914 data, we find that $\sqrt{\Lambda} < 3.5$, namely at the order of the Planck scale. This is the most stringent bound on non-commutative scale, exceeding the previous constraints from particle physics processes by ~ 15 orders of magnitude.

Summary:

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Uniformity of Cosmic Microwave Background as a Non-Inflationary Geometrical Effect

Author: Branislav Vlahovic[1]

Co-author: Maxim Eingorn

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The concordance cosmological model involving inflation describes the Universe very well. However, strict constraints are imposed by the recent observational data on the shape of the inflaton potential, excluding a lot of inflationary scenarios. We propose an alternative interpretation of the cosmic microwave background (CMB) data. We demonstrate that in the framework of the ΛCDM model supplemented in the spherical space with an additional perfect fluid with the constant parameter −1/3 in the linear equation of state, there is an elegant solution of the horizon problem without inflation. Under the proper choice of the parameters, light travels between the antipodal points during the age of the Universe. Thus, one can suggest that the observed CMB radiation originates from a very limited space region, which explains its uniformity. We reach the agreement with the supernovae data and discuss a possibility that the Universe was not uniform at the early stage and that creation of galaxies and large scale structure is due to inhomogeneities that originated in the Big Bang. We also show that changing the amplitude of the initial power spectrum, one can adjust the proposed cosmological model to the CMB anisotropy, and that the necessary change is well inside the experimentally allowed constrains.

http://www.worldscientific.com/doi/10.1142/S0217732315300268

http://arxiv.org/abs/1511.00369

Summary:

Cosmic microwave background and Large Scale Structure / 30

Magnetic fields at cosmological recombination

Author: Shohei Saga[1]

Co-authors: Keitaro Takahashi [2]; Naoshi Sugiyama [3]

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In the context of the standard cosmological perturbation theory, non-linear couplings of first-order scalar perturbations create second-order vector perturbations, which generate magnetic fields through the Harrison mechanism.
We find that the magnetic fields from the purely second-order vector perturbations partially cancel out the magnetic fields from one of the product-terms of the first-order scalar modes. Therefore, the amplitude of the magnetic fields on small scales, $k \geq 10h\mathrm{Mpc}^{-1}$, is smaller than the previous estimates. The amplitude of the generated magnetic fields at cosmological recombination is about $B_{\mathrm{rec}} = 5.0 \times 10^{-24}\mathrm{Gauss}$ on $k = 5.0 \times 10^{-1}h\mathrm{Mpc}^{-1}$. Finally, we discuss the reason of the discrepancies that exist in estimates of the amplitude of magnetic fields among other authors.

Summary:

Cosmic microwave background and Large Scale Structure / 32

Cosmological effects of Late Forming Dark Matter

Author: Abir Sarkar[1]

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The standard ΛCDM model with WIMP dark matter describes the large scale features of the universe quite well with some potential unsolved astrophysical problems in the small scale. In this study, we propose
a different type of CDM which forms much after the BBN and before the epoch of matter radiation equality. We consider two such dark matter models. The Late Forming Dark Matter (LFDM)
and the Ultra-Light Axion Dark Matter(ULADM). Both of these models show sharp suppression in small scale power followed by oscillations in the matter power spectra.We have compared our results with various power spectrum data available and found the formation redshift z_f to be greater than 10^5, at 99% CL. To check the effects of these features in the small scale power on the history of the universe, we study two cosmological observables in the framework of these models: the redshifted 21-cm signal from the epoch of reionization and the evolution of the collapsed fraction of HI in the redshift range $2 < z < 5$. We have studied these models assuming a fiducial model of reionization where a neutral hydrogen fraction $x_{\rm HI}$ = 0.5 must be achieved by z = 8. The reionization process allows us to put approximate bounds on the redshift of dark matter formation $z_f > 4 \times 10^5$
and the ULA mass $m_a > 2.6 \times 10^{-23}$ eV. The comparison of the collapsed mass
fraction inferred from damped Lyman-α observations to the theoretical predictions of our models lead to the weaker bounds: $z_f > 2 \times 10^5$
and $m_a > 10^{-23}$ eV. All of these results are consistent
with our previous results.

Summary:

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Quantum Field Theory of Interacting Dark Matter/Dark Energy: Dark Monodromies

Author: Teresa Hamill[1]

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We discuss how to formulate a quantum field theory of dark energy interacting with dark matter. We show that the proposals based on the assumption that dark matter is made up of heavy particles with masses which are very sensitive to the value of dark energy are strongly constrained. Quintessence-generated long range forces and radiative stability of the quintessence potential require that such dark matter and dark energy are completely decoupled. However, if dark energy and a fraction of dark matter are very light axions, they can have significant mixings which are radiatively stable and perfectly consistent with quantum field theory. Such models can naturally occur in multi-axion realizations of monodromies. The mixings yield interesting signatures which are observable and are within current cosmological limits but could be constrained further by future observations.

Summary:

Inflation and early universe cosmology / 34

A Strong Electroweak Phase Transition from the Inflaton Field

Author: Tommi Tenkanen[None]

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We study a singlet scalar extension of the Standard Model. The singlet scalar is coupled non-minimally to gravity and assumed to drive inflation, and also couple sufficiently strongly with the SM Higgs field in order to provide for a strong first order electroweak phase transition. Requiring the model to describe inflation successfully, be compatible with the LHC data, and yield a strong first order electroweak phase transition, we identify the regions of the parameter space where the model is viable. We also include a singlet fermion with scalar coupling to the singlet scalar to probe the sensitivity of the constraints on additional degrees of freedom and their couplings in the singlet sector. We also comment on the general feasibility of these fields to act as dark matter.

Summary:

Gravity and gravitational waves / 36

Gravitation, Causality, and Quantum Consistency

Author: Mark Hertzberg[1]

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We discuss the role of consistency with causality and quantum mechanics in determining the properties of gravity. We begin by constructing theories of interacting massless spin 2 particles – gravitons. One theory involves coupling the graviton with the lowest number of derivatives to matter, the other theories involve coupling the graviton with higher derivatives to matter. The first theory requires an infinite tower of terms for consistency, which is known to lead to general relativity. The other theories only require a finite number of terms for consistency, which appear as an entire new class of theories of massless spin 2. We recap the causal consistency of general relativity and show that in general this fails for the new class of theories. This appears to be a deep reason for minimally coupling the graviton with the lowest number of derivatives. Then, as a causal modification of general relativity, we discuss the so-called $F(\mathcal{R})$ theories, which have interesting applications to cosmology including inflation and dark energy. We show that, unlike general relativity, these theories do not possess the requisite counter-terms to be consistent quantum effective field theories. Together this helps to remove some of the central assumptions made in deriving general relativity.

Summary:

Dark matter / 37

Indirect searches of TeV Dark Matter at the Galactic Center

Author: Viviana Gammaldi[1]

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I will discuss several aspects of the indirect search of Dark Matter (DM) at the Galactic Center (GC). I will show that the gamma-ray flux observed by HESS from the J1745-290 GC source is well fitted as the secondary gamma-rays photons generated from DM annihilating into Standard Model particles in combination with a simple power-law background. The model independent fits are performed for all the possible channels of annihilation. The best fits are obtained for WIMP masses above ~ 10 TeV. They require an enhancement factor of $\sim 10^3$ and a background spectral index compatible with the Fermi-LAT data. I will investigate the possibility that the expected enhancement may be related with hydrodynamics in N-body simulation or a DM spike induced by the Super Massive Black Hole Sgr A*. I will also discuss the possibility that the generated DM spike could be related with the spatial tail detected in the gamma-ray signal by HESS II in 2015. These TeV DM masses are practically unconstrained by direct detection searches or colliders experiments, but they can be tested with the observations of other cosmic-rays.

Summary:

Inflation and early universe cosmology / 38

Natural Inflation with Hidden Scale Invariance

Authors: Archil Kobakhidze[1]; Neil Barrie[1]; Shelley Liang[2]

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We propose a new class of natural inflation models based on a hidden scale invariance. In a very generic Wilsonian effective field theory with an arbitrary number of scalar fields, which exhibits scale invariance via the dilaton, the potential necessarily contains a flat direction in the classical limit. This flat direction is lifted by small quantum corrections and inflation is realised without need for an unnatural fine-tuning. In the conformal limit, the effective potential becomes linear in the inflaton field, yielding to specific predictions for the spectral index and the tensor-to-scalar ratio, being respectively: ns−1≈−0.025(N⊠/60)−1 and r≈0.0667(N⊠/60)−1, where N⊠≈30−65 is a number of efolds during observable inflation. This predictions are in reasonable agreement with cosmological measurements. Further improvement of the accuracy of these measurements may turn out to be critical in falsifying our scenario.

Summary:

39

Event-By-Event Likelihood Approach to Determining the Origin of the IceCube Neutrinos

Author: Peter Denton[1]

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IceCube has measured astrophysical neutrinos in the energy range 40 TeV $< E_\nu < 2$ PeV, yet the sources of these events are still unknown and of considerable interest as they provide the first look at the universe at large through neutrinos. As of yet it is unclear as to whether the events of astrophysical origin observed could contain a galactic component, or if they are purely extragalactic. We consider three possible sources of each event in the High Energy Starting Event catalogs provided by IceCube: galactic,

extragalactic, and atmospheric. Using the energy, direction, shower shape, and zenith angle information, we present an event by event likelihood analysis to probe the fraction of astrophysical events that are of galactic origin.

Summary:

Inflation and early universe cosmology / 40

Gravitational Wave Instabilities in the Cosmic Neutrino Background

Author: Neil Barrie[1]

Co-author: Archil Kobakhidze [1]

[1] *The University of Sydney*

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We investigate the propagation of gravitational waves through the cosmic neutrino background, assuming it carries a non-zero lepton asymmetry. In this background, the graviton dispersion relation is found to exhibit birefringent behaviour leading to an enhancement/suppression of the gravitational wave amplitudes depending on the polarisation, where the magnitude of this effect is related to the size of the lepton asymmetry. The heralding of the new era of gravitational wave astronomy may allow the investigation of this behaviour and provide an indirect way to learn about the properties of the cosmic neutrino background and the neutrino sector.

Summary:

Inflation and early universe cosmology / 41

Gravitational Waves from Low Temperature Phase Transitions

Authors: Adrian Manning[1]; Archil Kobakhidze[2]; Cyril Lagger[2]; Jason Tsz Shing Yue[3]

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Gravitational wave radiation can be formed in the early universe from bubbles originating from first-order phase transitions. Depending on the characteristics of the phase transition, the generated gravitational waves may be detected by future space-based gravitational wave detectors. Typically these transitions occur at time scales when the temperature of the universe was of order 50 GeV or earlier. In this talk, we look at much later phase transitions (around the 1 GeV range) and discuss the implications of these kinds of transitions. Specifically, we look at the possibility of detecting the resulting gravitational waves at current/future detectors.

Summary:

Inflation and early universe cosmology / 42

The effects of monopoles on the electroweak phase transition

Author: Suntharan Arunasalam[1]

Co-author: Archil Kobakhidze [2]

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Electroweak monopoles are spherically symmetric configurations of the gauge fields that derive their stability from their topological nature. This talk discusses the effect of regularised Cho-Maison monopoles on the strength of the electroweak phase transition and the implications of this on electroweak baryogenesis.

Summary:

Dark matter / 43

Effective vector and fermion Higgs portal: A global study with GAMBIT

Author: Ankit Beniwal[1]

[1] *University of Adelaide (AU)*

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We perform a global study of the effective vector and fermion Higgs portal models of dark matter (DM) using the Global And Modular Beyond-the-Standard-Model Inference Tool (GAMBIT) package. Within the effective field theory (EFT) approach, DM communicates with the Standard Model (SM) Higgs boson via an operator of the form $\mathcal{O}_{\rm DM} H^\dagger H$. For the fermion models, we take an admixture of the scalar $\overline{\psi}\psi$ and pseudoscalar $\overline{\psi}i\gamma_5\psi$ interaction terms. Using a combined likelihood function which includes a contribution from the Planck measured relic density, LHC limits on the Higgs invisible width as well as the indirect and direct detection experiments, current limits are placed on each of the model parameter space. Uncertainties associated with a series of nuisance parameters such as the DM halo distribution, SM masses/couplings, and the nuclear matrix elements relevant for the calculation of direct search yields are all accounted by associating them with a corresponding likelihood term in the combined likelihood. Depending on the method chosen for statistical inference (Bayesian and/or frequentist), these nuisance parameters are integrated and/or marginalised out to yield a first set of preliminary results. From these results, we find that current DM searches significantly exclude much of the model parameter space. Further exclusion will be possible when the next generation of indirect and direct DM search experiments become operational.

Summary:

Particle physics / 44

The muon g-2 and dark matter in the MSSM at 100 TeV

Author: Matthew Talia[1]

Co-author: Archil Kobakhidze [2]

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[2] *The University of Sydney*

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We study the muon g-2 and neutralino dark matter as explained by the MSSM where the squarks and 3rd generation sleptons are decoupled. Particularly, we focus on constraints from current and future dark matter experiments such as PandaX-II and LUX-2016 as well as current bounds from collider searches. Using the constraints on the MSSM from the muon g-2 and DM searches, we study constraints from multilepton + MET searches at 8 TeV LHC, and the prospects for searches at 100 TeV proton-proton collision energies.

Summary:

Inflation and early universe cosmology / 45

Efficient perturbative determination of bubble wall profiles

Author: Sujeet Akula[1]

[1] *Monash University*

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We present semi-analytic techniques for finding bubble wall profiles during a first order phase transitions with multiple scalar fields. Our method involves reducing the system to a single-field problem, and then creating a convergent series of perturbative corrections to an analytic ansatz solution.

Summary:

Plenary / 47

The Pierre Auger Observatory

Author: Jose Bellido[1]

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Description of the Pierre Auger cosmic ray detector
Measurements of the energy spectrum, the arrival directions and the mass composition.
Searches for high energy photons, neutrons, neutrinos and high energy magnetic monopoles.

Summary:

The Pierre Auger Observatory is being detecting high energy cosmic rays since 2004. A total of 1500 ground particle detectors are distributed over an area of 3000 km^2 in the "Pampas" of Argentina. Additionally, 5 fluorescence telescope sites measure the energy deposited in the atmosphere by the interacting energetic comic ray. We have been able to measure, with an unprecedented statistics, the cosmic rays energy spectrum from energies as low as 10^{17} eV up to 10^{20} eV. We have accumulated enough statistics to measure very small large scale anisotropies on their arrival directions. Our most intriguing

results are perhaps the indications that at higher energies (above 3×10^{18} eV) cosmic rays appear to be dominated by heavier nuclei. We have also searched for high energy photons, neutrons, neutrinos, and even high energy monopoles. In this presentation I will summarize the latest status of our measurements.

Inflation and early universe cosmology / 48

Naturalness of the relaxion mechanism

Author: Andrew Fowlie[1]

[1] *Monash University*

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The relaxion mechanism is a novel solution to the hierarchy problem that utilizes the dynamics of an axion-like field. I discuss results from the first statistical analysis of the relaxion mechanism (arXiv:1602.03889), in which we quantified the relative plausibility of a QCD and a non-QCD relaxion model versus the Standard Model with Bayesian statistics, which includes an automatic penalty for fine-tuning. We included experimental constraints upon the weak-scale, $\theta_\text{QCD and inflationary observables measured by Planck/BICEP. Whilst we confirmed that relaxion models could solve the hierarchy problem, we found that their unconventional cosmology demolishes their plausibility.

Summary:

The relaxion mechanism is a novel solution to the hierarchy problem that utilizes the dynamics of an axion-like field. I discuss results from the first statistical analysis of the relaxion mechanism (arXiv:1602.03889), in which we quantified the relative plausibility of a QCD and a non-QCD relaxion model versus the Standard Model with Bayesian statistics.

Inflation and early universe cosmology / 49

Electroweak scale genesis by dynamical scale symmetry breaking and strong scale phase transition in the early universe

Author: Jisuke Kubo[1]

[1] *Kanazawa University*

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We consider a model
in which the electroweak scale
is non-perturbatively generated by
dynamical scale symmetry breaking
in a scalar QCD-like hidden sector.
We calculate
the energy spectrum of
cosmic gravitational wave background
which is produced by
the strong first-order scale phase transition
round O(TeV) in the early Universe.

Summary:

Dark matter / 50

Improved constraints on annihilating dark matter from cosmic-ray antiprotons

Author: Martin Stref[1]

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Local measurements of Galactic cosmic-ray antiprotons are known to provide constraints on the properties of annihilating cold dark matter (CDM). It is also known that CDM candidates generically lead to the structuring of matter on scales much smaller than typical galaxies. This clustering translates into a very large population of subhalos in galaxies, which induces an enhancement of the average annihilation rate with respect to a smooth-halo assumption. Taking these subhalos into account, and using measurements by the PAMELA and AMS-02 experiments, we derive new stringent constraints on annihilating CDM candidates.

Summary:

Inflation and early universe cosmology / 51

Primordial massive gravitational waves in the squeezed vacuum state

Author: Malsawmtluangi Naulak[1]

[1] *University of Hyderabad*

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We consider the Lorentz violating massive gravity for primordial gravitational waves and study the effects coming from the squeezed vacuum state on the subsequent B-mode polarization of the Cosmic Microwave Background. The resulting spectra oscillate on varying the mass of graviton and squeezing effect and are compared with the BICEP2/Keck Array at 150 GHz and Planck at 353 GHz collaboration data.

Summary:

Cosmic microwave background and Large Scale Structure / 52

Growth of perturbations in dark energy cosmologies

Author: Mohammad Malekjani[1]

[1] *Bu Ali Sina University, Depratment of Physics*

Corresponding Author: malekjani.phy@gmail.com

In the framework of the spherical collapse model, we study the non-linear growth of cosmic structures in the minimally and non-minimally coupled quintessence cosmologies. In non-minimally coupled quintessence models there is a non-minimally coupling between the scalar field and the Ricci scalar. We first investigate the background Hubble expansion in these models and then follow

the models in perturbation levels. We see that the equation of state of dark energy in the case of non-minimally quintessence model can enter the phantom regime of expansion ($w_{de} < -1$) while in the minimally coupled quintessence models the equation of state is remaining in quintessence regimes $w_{de} > -1$. On of the most important features of non-minimally coupled quintessence models is that the gravitational coupling G is no longer constant and varies with cosmic time.
However, for a minimally quintessence models the gravitational coupling is constant, as defined in GR limit as G_N. Regarding to non-minimally quintessence models, the definition of gravitational coupling G is basically different if we assume the perturbations of scalar fields or not. Notice that the perturbations of scalar fields can be assumed due to non-minimally coupling between scalar fields and Ricci scalar. We show that the scalar field perturbations have a significant impact on the evolution of gravitational coupling G. Since we have two different relations for effective gravitational coupling G_{eff} according to the fact that the scalar field is clustered or not, we expect to see a different evolution for the growth of matter perturbations in the case of clustered non-minimally quintessence models compare to homogeneous quintessence models. We also compare the evolution of matter perturbations in both clustered and homogeneous non-minimally quintessence models with that of in minimally quintessence models in which the gravitational coupling G is constant.

In linear regime of the growth of matter perturbations, we show that the quintessence term causes the decrements of the growth of structures at low redshifts ($z < 1$). On the other hand at high redshifts ($z > 1$) In particular, we will see that the growth factor of matter perturbations in non-minimally coupled quintessence models with positive (negative) coupling parameter is lower (higher) than that obtained in minimally coupled quintessence Universe. Moreover, the perturbations of scalar fields causes that the growth factor is decreasing compare to homogeneous cases.

In non-linear regime for the evolution of matter perturbations, we will show that the spherical collapse parameters δ_c and Δ_{vir} are strongly affected by perturbation of scalar field and moreover these quantities have different evolution for minimally, clustered non-minimally and homogeneous non-minimally quintessence models.
Notice that the linear overdensity parameter δ_c is a crucial parameter in Press Schechter formalism to calculate the abundance of virialized halos. Also the size of virialized halos can be obtained by using the virial overdensity Δ_{vir}.
As an important result, we show that in all quintessence models, minimally or non-minimally coupled, the quantities δ_c and Δ_{vir} reach to 1.686 and 178, respectively. This result indicates that the early matter dominated Universe should be recovered in quintessence cosmological models, as expected.
We finally investigate the number count of massive halos for minimally and non-minimally coupled quintessence models. In prior case, the model gives an excess of
virialized halos with respect to the concordance ΛCDM model. While in the later case we show that the number of halos is higher (lower) that that of obtained in concordance ΛCDM scenario when the coupling parameter between scalar field and gravity is negative (positive).

Summary:

In the standard model of cosmology, the accelerated expansion of the Universe is interpreted by taking the cosmological constant term into account. However, it is still unclear the true origin of this observational fact. Hence it is interesting to explore some alternatives models to the simplest scenario, in particular by considering a more general framework where scalar field models are responsible for the accelerated expansion of the Universe. When these models are directly coupled to the gravity they dubbed non-minimally quintessence models otherwise they are called minimally quintessence models. In non-minimally quintessence models the Newtonian gravitational constant is no longer constant and varies with cosmic time. In this work, by working in the framework of spherical collapse model, we show the effects of scalar field perturbation on the growth factor of cosmic structures and also the parameters of spherical collapse model. We also calculate the influence of scalar field perturbations on the mass function and number count of massive halos in the context of Press-Schechter formalism.

Gravity and gravitational waves / 53

Relation between gauge fixing and DOFs in scalar-tensor theories

Author: Kazufumi Takahashi[1]

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First, I describe the motivation of this work and then introduce a simple toy model which is useful to understand the essential point of our theorem.

Next, I show that the following two sets of equations are equivalent if the gauge fixing is complete: One is the Euler-Lagrange equations derived from the original action supplemented with the gauge-fixing conditions, and the other is the Euler-Lagrange equations derived from the gauge-fixed action with Lagrange multipliers.

Finally, I provide an application of the theorem to the case of homogeneous isotropic universe in scalar-tensor theories.

Summary:

Regardless of the long history of gauge theories, it is not well-recognized under which condition gauge fixing at the action level is legitimate.
We address this issue from the Lagrangian point of view, and prove the following theorem on the relation between gauge fixing and Euler-Lagrange equations:
In any gauge theory, if a gauge fixing is complete, i.e., the gauge functions are determined uniquely by the gauge conditions, the Euler-Lagrange equations derived from the gauge-fixed action are equivalent to those derived from the original action supplemented with the gauge conditions.

Dark matter / 54

Triplet-Quadruplet Fermionic Dark Matter

Author: Zhao-Huan Yu[1]

[1] *University of Melbourne*

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We explore a dark matter model extending the standard model particle content by one fermionic SU(2)_L triplet and two fermionic SU(2)_L quadruplets, leading to a minimal realistic UV-complete model of electroweakly interacting dark matter which interacts with the Higgs doublet at tree level via two kinds of Yukawa couplings. After electroweak symmetry breaking, the physical spectrum of the dark sector consists of three Majorana fermions, three singly charged fermions, and one doubly charged fermion, with the lightest neutral fermion serving as a dark matter candidate. A typical spectrum exhibits a large degree of degeneracy in mass between the neutral and charged fermions, and we examine the one-loop corrections to the mass differences to ensure that the lightest particle is neutral. We identify regions of parameter space for which the dark matter abundance is saturated for a standard cosmology including coannihilation channels. Constraints from precision electroweak measurements, searches for dark matter scattering with nuclei, and dark matter annihilation are important, but leave open a viable range for a thermal relic.

Summary:

Inflation and early universe cosmology / 55

Probing physics behind the electroweak symmetry breaking at

future gravitational wave interferometers and future collider experiments

Author: Mitsuru Kakizaki[1]

[1] *University of Toyama*

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Revealing dynamics of the electroweak phase transition is essential
for probing new physics at the early Universe
such as electroweak baryogenesis,
which requires strongly first order phase transition.
We compute the spectrum of gravitational waves from
first order phase transition in models with additional
isospin singlet scalars with and without classical scale invariance,
and in the extended Higgs model with a real singlet.
Predicted deviations in various Higgs boson couplings are also evaluated.
We show that these models can be tested by
the synergy of the measurements of the Higgs boson couplings at the LHC,
the measurement of the triple Higgs boson coupling at
future electron-positron colliders and the observation of
gravitational waves at future interferometers such as eLISA and DECIGO.
This talk is based on
Kakizaki, Kanemura, Matsui, PRD92 (2015) no.11,115007;
Hashino, Kakizaki, Kanemura, Matsui, PRD94 (2016) no.1, 015005;
Hashino, Kakizaki, Kanemura, Ko, Matsui, arXiv:1609.00297.

Summary:

Cosmic microwave background and Large Scale Structure / 56

Shear and rotation in massive galaxy clusters

Author: Ahmad Mehrabi[1]

Co-author: Mohammad Malekjani [2]

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Massive galaxy clusters, being at the high mass end of the mass function are becoming a common tool in cosmology. Their
abundance is a strong indicator of non-linear structure formation and it depends on the value of important cosmological
parameters, such as the matter density parameter $\Omega_{\rm m}$, the mater power spectrum normalization σ_8 and the dark energy equation of state $w_{\rm de}$. A precise determination of the mass function is a current goal of
both theoretical and observational studies, due to the wealth of implications related to it.

From a theoretical point of view, the mass function is related to the function $\delta_{\rm c}$, that, in the framework
of the spherical collapse model, represents the density above which structures can form. In the standard approach,
perturbations are assumed to be spherical and non rotating, but in an era of precision cosmology it is necessary to

relax this assumption. Shear and rotation can be added naturally into this formalism as shown recently by
(Del Popolo et al.
2013; Pace et al. 2014) and their combination is parametrized via the parameter α. This
extension of the simple spherically symmetric model makes such that $\delta_{\rm c}$ is now a function of both mass and
redshift, contrary to the standard case where it only depends on time. This implies that the mass function and hence
the total number of objects that can be observed will strongly depend on the evolution with mass of the parameter
α. Since theory, so far, does not constrain it, in this work we choose a particularly simple form:
$\alpha = -\beta \log_{10} \frac{M}{M_s}$, where β is the slope of the logarithmic relation and
$M_s = 8 \times 10^{15}\ h^{-1}\ M_{\odot}$ is a normalization mass. When $M = M_s$, deviation from sphericity are null and we
recover the standard case.

The combined effect of shear and rotation, due to the dominance of the latter, implies a decreased number of objects
with respect to the spherically symmetric case since structure formation is slowed down.

Using data on massive clusters by (Campanelli et al. 2012) we constrain the value of the slope β and we infer its
consequences on the number of massive objects. In our analysis we find $\Omega_{\rm m} = 0.284 \pm 0.0064$,
$h = 0.678 \pm 0.017$ and $\beta = 0.0019^{+0.0008}_{-0.0015}$ at $1-\sigma$ level, when keeping $\sigma_8 = 0.818$ fixed and
restricting our analysis to a flat ΛCDM model.

Summary:

A precise determination of the mass function is an important tool to verify cosmological predictions of the
ΛCDM model and to infer more precisely the better model describing the evolution of the Universe. Galaxy
clusters have been currently used to infer cosmological parameters, in particular the matter density parameter
$\Omega_{\rm m}$, the matter power spectrum normalization σ_8 and the equation of state parameter $w_{\rm de}$
of the dark energy fluid.
In this work, using data on massive galaxy clusters ($M > 8 \times 10^{14}\ h^{-1}\ M_{\odot}$) in the redshift range
$0.05 < z < 0.83$ we put constraints on the parameter α introduced within the formalism of the
extended spherical collapse model to quantify deviations from sphericity due to shear and rotation.

Inflation and early universe cosmology / 57

Violent preheating in inflation with nonminimal coupling

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Particle production at the preheating era in inflation models with nonminimal coupling $||^2 R$ and quartic potential $||^4/4$ is discussed. We point out that the preheating proceeds much more violently than previously thought: if the inflaton is a complex scalar, the phase degree of freedom (global case) or the longitudinal gauge boson (gauged case) is violently produced at the first stage of preheating by "spike" in the time dependence of the inflaton field. Produced particles typically have very high momenta $k \sim M_P$, and the production is so strong that almost all the energy of the inflaton can be carried away within one oscillation for $^2 > 1$. This may change the conventional understandings of the (p)reheating after inflation with nonminimal coupling to gravity, such as Higgs inflation. We also discuss the possibility of unitarity violation.

Summary:

Particle production at the preheating era in inflation models with nonminimal coupling $||^2 R$ and quartic potential $||^4/4$ is discussed. We point out that the preheating proceeds much more violently than previously thought: if the inflaton is a complex scalar, the phase degree of freedom (global case) or the longitudinal gauge boson (gauged case) is violently produced at the first stage of preheating by "spike" in the time dependence of the inflaton field. Produced particles typically have very high momenta $k \sim M_P$, and the production is so strong that almost all the energy of the inflaton can be carried away within one oscillation for $^2 > 1$. This may change the conventional understandings of the (p)reheating after inflation with nonminimal coupling to gravity, such as Higgs inflation. We also discuss the possibility of unitarity violation.

Inflation and early universe cosmology / 58

Electroweak baryogenesis in the Z3-invariant NMSSM

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The NMSSM has the attractive features of being able to provide at least a partial solution to the little hierarchy problem through the introduction of a guage singlet. Its usefulness in electroweak baryogenesis is more pronounced - with the singlet being useful to catalyze a boost in the strength of the EWPT without conflicting with collider constraints. Furthermore, interactions between the singlino-higgsino and the space time varying vacuum provide a source of CP violation not present in the MSSM and virtually unconstrained by negative searches for permanent EDMs. We present an in depth analysis of the prospects of electroweak baryogenesis within the NMSSM.

Summary:

We calculate the baryon asymmetry in the Z3-invariant NMSSM where Singlino interactions with the space time varying vacuum provide the source of CP violation necessary for the production of baryon asymmetry. We derive and solve transport equations using the closed time path formalism for the cases where the singlet acquires a vacuum expectation value before and during the electroweak phase transition. The thermal width of the singlino is relatively small which affects how near a resonance one needs to be in order to produce a sufficiently large baryon asymmetry. We examine whether this is possible under the constraint of a Higgs mass of 125 GeV. We also investigate whether it helps to have the singlet acquire a VEV before or during the EWPT as well as examining the dependence of the baryon assymetry on the three body interactions involving gauge singlets.

Cosmic microwave background and Large Scale Structure / 59

Planck constraints on scalar-tensor cosmology and the variation of the gravitational constant

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Cosmological constraints on the scalar-tensor theory of gravity by analyzing the angular power spectrum data of the cosmic microwave background (CMB) obtained from the Planck 2015 results are presented. We consider the harmonic attractor model, in which the scalar field has a harmonic potential with curvature (β) in the Einstein frame and the theory relaxes toward the Einstein gravity with time.
Analyzing the TT, EE, TE and lensing CMB data from Planck by the Markov chain Monte Carlo method, we find that the present-day deviation from the Einstein gravity ${\alpha_0}^2$) is constrained as ${\alpha_0}^2 < 2.5 \times 10^{-4-4.5\beta}$ (95.45% C.L.) and ${\alpha_0}^2 < 6.3 \times 10^{-4-4.5\beta}$ (99.99% C.L.) for $0 < \beta < 0.4$. The time variation of the effective gravitational constant between the recombination and the present epochs is constrained as $G_{\rm rec}/G_0 < 1.0056$ (95.45% C.L.) and $G_{\rm rec}/G_0 < 1.0115$ (99.99% C.L.). We also find that the constraints are little affected by extending to nonflat cosmological models because the diffusion damping effect revealed by Planck breaks the degeneracy of the projection effect.

Summary:

60

Dark matter properties implied by Fermi-LAT gamma ray residuals

Author: Csaba Balazs[1]

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I present an inference of dark matter properties from gamma ray residuals extracted by the Fermi-LAT Collaboration. First I show that, within the simplified model framework, the most likely dark matter candidate is a Majorana fermion coupled to standard matter via a scalar mediator. Then, using the Fermi residuals, and exclusion limits from dwarf spheroidal galaxies, I show that the most preferred Majorana fermion (scalar) mass is in the 100-500 (1-200) GeV range annihilating dominantly into top quarks. I conclude that these properties of dark matter extracted from gamma ray data are highly sensitive to the modelling of the interstellar emission.

Summary:

Dark matter / 61

Right-handed neutrino dark matter under the B-L gauge interaction

Author: Kunio Kaneta[None]

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Right-handed neutrinos (RHNs) are widely considered as an convincing new particle that can address various issues in the standard model (SM) such as the origin of neutrino mass, the existence of dark matter, and baryon asymmetry of the universe.
On the other hand, the gauge principle plays a key role to understand nature, which is empirically supported by the success of the SM so far.
In the light of this success, the B-L gauge symmetry is one of the most attractive symmetries that offers three RHNs which are the minimal set to successfully address above-mentioned issues.
In this talk, I will discuss various RHN dark matter scenarios under the B-L gauge interaction, and emphasize the sub-electroweak scale Z' case that can be tested by forthcoming beam dump experiments.

Summary:

Dark matter / 62

Halo-independent tests of dark matter direct detection signals

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I will discuss halo-independent tests of direct detection signals that we have derived in recent works. In the first part [1502.03342 (elastic scattering) and 1512.03317 (inelastic)], I will discuss a halo-independent lower bound on the DM capture rate in the Sun from a direct detection signal, with which one can set limits on the branching ratios into different channels from the absence of a high-energy neutrino flux in neutrino telescopes. In the second part [based on 1505.05710], I will discuss a lower bound one can set on the product of the DM-nucleon cross section and the energy density from a direct detection signal that is independent of the velocity distribution, and how this bound can be combined with limits from local density measurements, the LHC and the relic abundance in order to constraint DM models.

Summary:

Dark matter / 63

Particle Physics Models for DM-DR interactions

Author: pyungwon ko[1]

[1] *Korea Inst. for Advanced Study (KIAS)*

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This talk will be based on two recent preprints:
arXiv:1608.01083
arXiv:1609.02307

Summary:

Particle physics / 64

Collider searches for Higgs portal DM models

Author: pyungwon ko[1]

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Corresponding Author: pko@kias.re.kr

This talk will be based on these papers:

(1) Beyond the Dark matter effective field theory and a simplified model approach at colliders
Seungwon Baek, P. Ko (Korea Inst. Advanced Study, Seoul), Myeonghun Park (APCTP, Pohang & POSTECH, Pohang & Tokyo U., IPMU), Wan-Il Park (Valencia U. & Valencia U., IFIC), Chaehyun Yu (Taiwan, Inst. Phys.). Jun 22, 2015. 6 pp.
Published in Phys.Lett. B756 (2016) 289-294
APCTP-PRE2015-014, IPMU15-0084, FTUV-15-06-25, IFIC-15-38, KIAS –P15029
DOI: 10.1016/j.physletb.2016.03.026
e-Print: arXiv:1506.06556 [hep-ph]

(2) Search for Higgs portal DM at the ILC
P. Ko, Hiroshi Yokoya (Korea Inst. Advanced Study, Seoul). Mar 15, 2016. 24 pp.
Published in JHEP 1608 (2016) 109
DOI: 10.1007/JHEP08(2016)109
e-Print: arXiv:1603.04737 [hep-ph]

Summary:

Inflation and early universe cosmology / 65

Inflation from Supergravity with Gauged R-symmetry in de Sitter Vacuum

Authors: Hiroshi Isono[1]; Rob Knoops[2]

[1] *National Tsing Hua University*

[2] *Chulalongkorn University, Bangkok*

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We present the results based on arXiv:1608.02121

Summary:

We study the cosmology of a recent model of supersymmetry breaking, in the presence of a tuneable positive cosmological constant, based on a gauged shift symmetry of a string modulus that can be identified with the string dilaton. The minimal spectrum of the 'hidden' supersymmetry breaking sector consists then of a vector multiplet that gauges the shift symmetry of the dilaton multiplet and when coupled to the MSSM leads to a distinct low energy phenomenology depending on one parameter. Here we study the question if this model can also lead to inflation by identifying the dilaton with the inflaton. We find that this is possible if the Kähler potential is modified by a term that has the form of NS5-brane instantons, leading to an appropriate inflationary plateau around the maximum of the scalar potential, depending on two extra parameters. This model is consistent with present cosmological observations without modifying the low energy particle phenomenology associated to the minimum of the scalar potential.

Dark matter / 67

Status of COSINE experiment.

Author: Pushparaj Adhikari[1]

[1] *Sejong University*

Corresponding Author: pushpaparticle@gmail.com

The COSINE experiment is a joint collaboration between the KIMS-NaI and the DM-Ice NaI(Tl) experiments to prove or refute DAMA/LIBRA's annual modulation result with the same NaI(Tl) crystals. The first phase of the experiment consisting of ˜106 kg of NaI(Tl) crystals and ˜2000 liters of liquid scintillator as an active veto has started at the Yangyang underground laboratory in Korea.The current status and future prospects of COSINE experiment will be presented.

Summary:

Cosmic microwave background and Large Scale Structure / 68

Oscillations in the CMB angular power spectra at ell˜120

Author: Kouichirou Horiguchi[1]

[1] *Nagoya University*

Corresponding Author: horiguchi.kouichirou@h.mbox.nagoya-u.ac.jp

Cosmic Microwave Background (CMB) has been well known as a proof of the hot big bang model. In recent years, thanks to the precise observations by WMAP and PLANCK satellites, we come to see the detailed structure of CMB temperature (or polarization) fluctuations. In this work, we forces on the irregular oscillations of their angular power spectra around multipole $\ell \sim 120$. These oscillations were indicated in the analysis of WMAP5 data by Ichiki et al. (2010). We look for these oscillations in the 2015 year's PLANCK temperature and polarization data by adopting a Markov-Chain Monte-Carlo (MCMC) method. We find the oscillations in the data at $\ell \sim 123.7$ and their amplitude is about 4.5×10^{-9}, which are consistent with those found in the WMAP5 data. In this presentation, we talk about the result of the MCMC analysis and the influence of the oscillations to the other cosmological parameters.

Summary:

Particle physics / 69

Partial Gauge Invariant SM

Author: Zurab Kepuladze[1]

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We argue that an exact gauge invariance may disable some generic features of the Standard Model which could otherwise manifest themselves at high energies. One of them might be related to the spontaneous Lorentz invariance violation (SLIV) which could provide an alternative dynamical approach to QED and Yang-Mills theories with photon and non-Abelian gauge fields appearing as massless Nambu-Goldstone bosons. To see some key features of the new physics expected we propose partial rather than exact gauge invariance in an extended SM framework. This principle applied, in some minimal form, to the weak hypercharge gauge field Bμ and its interactions leads to SLIV with B field components appearing as the massless Nambu-Goldstone modes, and provides a number of distinctive Lorentz beaking effects. Being naturally suppressed at low energies they may become detectable in high energy physics and astrophysics. Some of the most interesting SLIV processes are considered in significant detail.

Summary:

Dark matter / 70

New effects of dark matter which are linear in the interaction strength

Author: Victor Flambaum[1]

[1] *University of New South Wales*

Corresponding Author: v.flambaum@unsw.edu.au

Low-mass boson dark matter particles produced after Big Bang form classical field and/or topological defects. In contrast to traditional dark matter searches, effects produced by interaction of an ordinary matter with this field and defects may be first power in the underlying interaction strength rather than the second power or higher (which appears in a traditional search for the dark matter) [1-12]. This may give a huge advantage since the dark matter interaction constant is extremely small.
Interaction between the density of the dark matter particles and ordinary matter produces both 'slow'cosmological evolution and oscillating variations of the fundamental constants including the fine structure constant alpha and particle masses [4]. Recent atomic dysprosium spectroscopy measurements and the primordial helium abundance data allowed us to improve on existing constraints on the quadratic interactions of the scalar dark matter with the photon, electron and light quarks by up to 15 orders of magnitude. Limits on the linear and
quadratic interactions of the dark matter with W and Z bosons have been obtained for the first time.
In addition to traditional methods to search for the variation of the fundamental constants (atomic clocks, quasar spectra, Big Bang Nucleosynthesis, etc) we discuss variations in phase shifts produced in laser/maser interferometers (such as giant LIGO, Virgo, GEO600 and TAMA300, and the table-top silicon cavity and sapphire interferometers) [5,6], changes in pulsar rotational frequencies (which may have been observed already
in pulsar glitches), non-gravitational lensing of cosmic radiation and the time-delay of pulsar signals [4].
Other effects of dark matter and dark energy include apparent violation of the fundamental symmetries: oscillating or transient atomic electric dipole moments, precession of electron and nuclear spins about the direction of Earth's
motion through an axion condensate (the axion wind effect), and axion-mediated spin-gravity couplings [8-10], violation of Lorentz symmetry and Einstein equivalence principle [11,12].
Finally, we explore a possibility to explain the DAMA collaboration claim of dark matter detection by the dark matter scattering on electrons. We have shown that the electron relativistic effects increase the ionization differential cross section up to 3 orders of magnitude [13,14].

1 M. Pospelov, S. Pustelny, M. P. Ledbetter, D. F. Jackson Kimball, W. Gawlik, and D. Budker. Phys. Rev. Lett. 110, 021803 (2013).
2 A. Derevianko and M. Pospelov. Nature Physics 10, 933 (2014).
3 P.W. Graham, S. Rajendran. Phys. Rev. D84,055013 (2011); D88,035023 (2013).
[4] Can dark matter induce cosmological evolution of the fundamental constants of Nature? Y. V. Stadnik and
V. V. Flambaum. Phys. Rev. Lett. 115, 201301 (2015).
[5] Searching for Dark Matter and Variation of Fundamental Constants with Laser and Maser Interferometry.
Y. V. Stadnik and V. V. Flambaum. Phys. Rev. Lett. 114, 161301 (2015).
[6] Enhanced effects of variation of the fundamental constants in laser interferometers and application to dark
matter detection, Y. V. Stadnik, V. V. Flambaum, arXiv:1511.00447
[7] Searching for Topological Defect Dark Matter via Nongravitational Signatures. Y. V. Stadnik and V. V. Flambaum. Phys. Rev. Lett. 113, 151301 (2014).
[8] Axion-induced effects in atoms, molecules and nuclei: Parity nonconservation, anapole moments, electric
dipole moments, and spin-gravity and spin-axion momentum couplings. Y. V. Stadnik and V. V. Flambaum.
Phys. Rev. D 89, 043522 (2014).
[9] Limiting P-odd Interactions of Cosmic Fields with Electrons, Protons and Neutrons. B. M. Roberts,

Y. V. Stadnik, V. A. Dzuba, V. V. Flambaum, N. Leefer and D. Budker. Phys. Rev. Lett. 113, 081601 (2014).
[10] Parity-violating interactions of cosmic fields with atoms, molecules and nuclei: Concepts and calculations
for laboratory searches and extracting limits. B. M. Roberts, Y. V. Stadnik, V. A. Dzuba, V. V. Flambaum,
N. Leefer and D. Budker. Phys. Rev. D 90, 096005 (2014).
[11] V.A. Dzuba, V.V. Flambaum, M. Safronova, S.G. Porsev, T. Pruttivarasin, M.A. Hohensee, H. Haffner.
Nature Physics (2016), DOI:10.1038/nphys3610.
[12] Enhanced violation of the Lorentz invariance and Einstein equivalence in atoms and nuclei, V.V. Flambaum.
arxiv: 1603.05753
[13] Ionization of atoms by slow heavy particles, including dark matter. B. M. Roberts, V. V. Flambaum, and
G. F. Gribakin, Phys. Rev. Lett. 116, 023201 (2016).
[14] Dark matter scattering on electrons: Accurate calculations of atomic excitations and implications for DAMA signal. B.M. Roberts, V.A. Dzuba, V.V. Flambaum, M. Pospelov, Y.V. Stadnik, Phys.Rev.D93,115037 (2016).

Summary:

This presentation describes manifestations of Dark Matter and Variations of Fundamental Constants in Atomic and Astrophysical Phenomena. Low-mass boson dark matter particles produced after Big Bang form classical field and/or topological defects. In contrast to traditional dark matter searches, effects produced by interaction of an ordinary matter with this field and defects may be first power in the underlying interaction strength rather than the second power or higher. This may give a huge advantage. We have already improved limits on certain types of dark matter by 15 orders of magnitude and proposed new measurements in astrophysics (changes in pulsar rotational frequencies (which may have been observed already in pulsar glitches), non-gravitational lensing of cosmic radiation and the time-delay of pulsar signals), atomic clocks, giant interferometers used to detect gravitational waves (LIGO, VIRGO, LISA), table-top interferometers and atomic experiments searching for variation of the fundamental symmetries (P,T, Lorentz, Einstein equivalence principle).
We have also shown that the electron relativistic increase differential cross section for scattering of WIMP on electrons up to 3 orders of magnitude considered implications for DAMA and XENON signals.

Cosmic microwave background and Large Scale Structure / 71

Test of the Einstein equivalence principle with CMB spectral distortions

Authors: Hiroyuki Tashiro[1]; Shun Arai[1]

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The Einstein Equivalence Principle (EEP) is one of the fundamental principles in General Relativity. One of the consequences of the EEP in the cosmological context is the energy independency of the cosmological redshift effect. Here we propose a new test of the energy independency of the redshift effect by the measurement of the spectral distortions of the Cosmic Microwave Background (CMB). In GR, the energy independency of the redshift effect is ensured by the Friedmann-Robertson-Walker metric which does not depend on energy. We show that the CMB spectral distortions arise when the FRW metric has the energy dependence. Our result is consistent with no energy-dependence of the redshift effect, at least, with a precision of 10^{-6} on the CMB energy scales.

Summary:

Particle physics / 72

Radiative neutrino mass generation for a dimension 7 gauge-invariant operator and its implication for charge lepton flavor violation

Author: Bahman Ghadirian[1]

Co-author: Michael Schmidt [1]

[1] *The University of Sydney*

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In this work, we construct a two-loop radiative Majorana neutrino mass model based on a dimension 7 gauge-invariant operator that violates the lepton number by two units. The UV completion in this model includes a scalar leptoquark doublet with hypercharge 1/6 and an additional vector-like lepton doublet. It is shown that the neutrino mass matrix is proportional to the masses of the heavy charged vector-like lepton and the top and bottom quarks. In this model, we predict the rare charge lepton violation processes. Integrating out the heavy charged and neutral components of vector-like lepton induces a non-unitary PMNS mixing matrix.

Summary:

Dark matter / 73

Semi-Annihilation and Dark Matter Indirect Detection

Author: Yi Cai[1]

Co-author: Andrew Spray [2]

[1] *The University of Melbourne*

[2] *TRIUMF*

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Semi-annihilation is a generic feature in dark matter theories with symmetries beyond Z2. We investigate some examples with either single- or multi- component dark sectors where semi-annihilation affects the phenomenology substantially. We also present a systematic tool to study models with semi-annihilation.

Summary:

Inflation and early universe cosmology / 74

Production of axion CDM from strings and domain-walls

Author: Toyokazu Sekiguchi[1]

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Predicted by the Peccei-Quinn (PQ) mechanism, that solves the Strong CP problem in QCD, axion is one of the most promising candidates of dark matter. In my talk, I will be reviewing recent developments in estimation of the abundance of axion CDM from topological defects. When the reheating temperature is higher than the PQ energy scale, the symmetry breaking of U(1)_{PQ} takes place in the early Universe and axion cosmic strings form, which is followed by the formation of axion domain-walls at the QCD phase transition. From the cosmological network of these defects, axions are copiously produced and contribute to the current energy density of CDM in the Universe. Based on field-theoretic simulations, we can follow the cosmological evolution of these defects and axions radiated therefrom. In conjunction with innovative analysis techniques we have introduced, our massive simulations allow to estimate the axion abundance more precisely than ever before. We derive a constraint on the PQ energy scale from the axion CDM abundance and discuss implications for cosmological scenarios.

Summary:

Inflation and early universe cosmology / 75

Adiabatic Invariance of I-balls/Oscillons

Author: Naoyuki Takeda[None]

Corresponding Author: takedan@icrr.u-tokyo.ac.jp

Scalar fields are know to have various roles in the early Universe such as inflaton. Among of them, some real scalar fields are known to fragment into spatially localized and long-lived solitons called oscillons or I-balls. We prove the adiabatic invariance of the oscillons/I-balls for a potential that allows periodic motion even in the presence of non-negligible spatial gradient energy. We show that such potential is uniquely determined to be the quadratic one with a logarithmic correction, for which the oscillons/I-balls are absolutely stable. For slightly different forms of the scalar potential dominated by the quadratic one, the oscillons/I-balls are only quasi-stable, because the adiabatic charge is only approximately conserved. We check the conservation of the adiabatic charge of the I-balls in numerical simulation by slowly varying the coefficient of logarithmic corrections. This unambiguously shows that the longevity of oscillons/I-balls is due to the adiabatic invariance.

Summary:

Gravity and gravitational waves / 76

Tensor perturbations in spatially covariant gravity

Author: Jun'ichi Yokoyama[1]

[1] *The University of Tokyo*

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We investigate the cosmological background evolution and perturbations in a general class of spatially covariant theories of gravity, which propagates two tensor modes and one scalar mode. We show that the structure of the theory is preserved under the disformal transformation. We also evaluate the primordial spectra for both the gravitational waves and the curvature perturbation, which are invariant under the disformal transformation. Due to the existence of higher spatial derivatives, the quadratic Lagrangian for the tensor modes itself cannot be transformed to the form in the Einstein frame. Nevertheless, there exists a one-parameter family of frames in which the spectrum of the gravitational waves takes the standard form in the Einstein frame.

Summary:

77

Extracting cosmological information from galaxy (and voids) clustering – towards to a prior free and accurate methodology

Author: Chia-Hsun Chuang[1]

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The cosmic large-scale structure from galaxy redshift surveys provides a powerful probe of the properties of dark energy and the time dependence of any cosmological model in a manner that is highly complementary to measurements of the cosmic microwave background, supernovae, and weak lensing. The scope of galaxy redshift surveys has dramatically increased in the last decades. We are developing the methodologies which aim to extract the cosmological information with the most robust way in terms of taking care of the priors, observational and theoretical systematics. These considerations would become more important with the increasing observed volume of galaxy surveys. We have applied our methodologies on the latest SDSS-III/BOSS galaxy sample (arXiv:1607.03151 and arXiv:1607.03152). In addition, we extend our methodologies by considering the impact of varying neutrino masses. In the end of this talk, I would like to mention the works we have done regarding extracting cosmological information from void clustering (arXiv:1511.04405,1511.04391,1511.04299,1605.05352).

Summary:

Dark matter / 78

Searching for dark matter and exotic bosons with atoms, molecules and ultracold neutrons

Author: Yevgeny Stadnik[1]

Co-author: Victor Flambaum [1]

[1] *University of New South Wales*

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We propose new schemes for the direct detection of dark matter and exotic bosons in experiments involving atoms, molecules and ultracold neutrons. Dark matter, which consists of low-mass bosons (such as axions, pseudoscalars or scalars), can readily form an oscillating classical field that survives to reside in the observed galactic dark matter haloes if these particles have sufficiently low mass and are sufficiently feebly interacting.

An oscillating classical dark matter (axion or pseudoscalar) field can give rise to a number of oscillatory spin-dependent effects in the laboratory. These effects include the precession of polarised spins about Earth's direction of motion though galactic dark matter [1-3], and induced oscillating electric dipole moments of atoms, molecules and nucleons [3-5]. We are currently working with the nEDM collaboration to search for these oscillatory spin-dependent effects using a dual neutron/^{199}Hg comagnetometer [6].

An oscillating classical dark matter (scalar) field can produce both 'slow' cosmological evolution and oscillating variations in the fundamental constants [7], which can be sought for in astrophysical phenomena and in the laboratory. Using data pertaining to Big Bang nucleosynthesis, as well as

atomic spectroscopy measurements in the laboratory [8,9], we have derived limits on interactions of dark matter with Standard Model particles that improve on existing constraints by up to 15 orders of magnitude [7]. In the laboratory, we can also use laser and maser interferometry as another high-precision platform to search for dark matter via the effects of variation of fundamental constants [10].

Exotic scalar fields may also be sourced by massive bodies. Using atomic spectroscopy measurements in the laboratory, we have derived limits on the interactions of such scalar particles with Standard Model particles, including constraints on combinations of interaction parameters which cannot otherwise be probed with traditional anomalous-force measurements [11]. We suggest further measurements to improve on the current level of sensitivity [11].

References:
1 V. V. Flambaum, talk presented at the 9th Patras Workshop on Axions, WIMPs and WISPs, Schloss Waldthausen, Mainz, Germany, 24th June 2013, http://axion-wimp2013.desy.de/e201031
2 P. W. Graham and S. Rajendran, PRD 88, 035023 (2013).
3 Y. V. Stadnik and V. V. Flambaum, PRD 89, 043522 (2014).
[4] P. W. Graham and S. Rajendran, PRD 84, 055013 (2011).
[5] B. M. Roberts, Y. V. Stadnik, V. A. Dzuba, V. V. Flambaum, N. Leefer and D. Budker, PRL 113, 081601 (2014); PRD 90, 096005 (2014).
[6] N. J. Ayres, P. G. Harris, K. Kirch and M. Rawlik (on behalf of the nEDM collaboration), and M. Fairbairn, V. V. Flambaum, D. J. E. Marsh and Y. V. Stadnik, ongoing work.
[7] Y. V. Stadnik and V. V. Flambaum, PRL 115, 201301 (2015); PRA 94, 022111 (2016).
[8] K. Van Tilburg, N. Leefer, L. Bougas and D. Budker, PRL 115, 011802 (2015).
[9] A. Hees, J. Guena, M. Abgrall, S. Bize and P. Wolf, PRL 117, 061301 (2016).
[10] Y. V. Stadnik and V. V. Flambaum, PRL 114, 161301 (2015); PRA 93, 063630 (2016).
[11] N. Leefer, A. Gerhardus, D. Budker, V. V. Flambaum and Y. V. Stadnik, arXiv:1607.04956.

Summary:

Inflation and early universe cosmology / 79

Testing the low scale seesaw and leptogenesis

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Heavy neutrinos with masses below the electroweak scale could simultaneously generate the light neutrino masses via the seesaw mechanism and the baryon asymmetry of the universe via leptogenesis. The requirement to explain both imposes constraints on the mass spectrum of the heavy neutrinos, their flavour mixing pattern and CP properties. If any heavy neutral leptons are discovered in the future, it will be possible to use a combination of different observables in order to assess whether these are indeed the common origin of the light neutrino masses and the baryon asymmetry of the universe.

Summary:

Heavy neutrinos with masses below the electroweak scale could simultaneously generate the light neutrino masses via the seesaw mechanism and the baryon asymmetry of the universe via leptogenesis. The requirement to explain both imposes constraints on the mass spectrum of the heavy neutrinos, their flavour mixing pattern and CP properties. If any heavy neutral leptons are discovered in the future, it will be possible to use a combination of different observables in order to assess whether these are indeed the common origin of the light neutrino masses and the baryon asymmetry of the universe.

Particle astrophysics / 81

Precision Measurement of the Positron, Electron and Antiproton Fluxes in Primary Cosmic Ray with the Alpha Magnetic Spectrometer on the International Space Station

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The Alpha Magnetic Spectrometer, AMS, is a general purpose high energy particle physics detector. It was installed on the International Space Station, ISS, on 19 May 2011 to conduct a unique long duration mission of fundamental physics research in space.

In this contribution, precision measurements by AMS of the primary cosmic ray positron flux, electron flux and antiproton flux are presented. These measurements increase the precision of the previous observations and significantly extend their energy range. Based on these measurement, new observations of the properties of the flux ratios of charged elementary particles in cosmic rays are presented. Together, they provide important information on the origins of cosmic-ray charged elementary particles.

Summary:

Dark matter / 82

First Results of the GPS.DM Observatory: Search for Dark Matter and Exotic Physics with Atomic Clocks and GPS Constellation

Author: Benjamin Roberts[1]

Co-author: Jeff Sherman [2]

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Despite the overwhelming cosmological evidence for the existence of dark matter, and the considerable effort of the scientific community over decades, there is no evidence for dark matter in terrestrial experiments.
The GPS.DM observatory uses the existing GPS constellation as a 50,000 km-aperture sensor array, analysing the satellite and terrestrial atomic clock data for exotic physics signatures. In particular, the collaboration searches for evidence of transient variations of fundamental constants correlated with the Earth's galactic motion through the dark matter halo. There already exists more than 10 years of good clock timing data that can be used in the search.
This type of search is particularly sensitive to exotic forms of dark matter, such as topological defects.
We will present an update on the search.

*Supported by the NSF

A. Derevianko and M. Pospelov, Nat. Phys. 10, 933 (2014).

Summary:

The GPS.DM observatory uses the existing GPS constellation as a 50,000 km-aperture sensor array, analysing the satellite and terrestrial atomic clock data for exotic physics signatures.

Dark matter / 84

Plasma Dark matter direct detection

Author: Robert Foot[1]

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Dark matter might exist in the Milky Way as a dark plasma. Such dark matter arises
in models where dark matter originates from a hidden sector featuring a massless 'dark photon', including mirror dark matter. In such a scenario, the implications for direct detection experiments are very different from the more commonly studied case of WIMP dark matter. In particular electron recoils can be the dominant process leading to keV energy depositions in detectors. In addition, large annual modulation and sidereal daily modulation signals become characteristic features of such dark matter. The possibility that plasma dark matter might be the origin of the DAMA annual modulation signal is also discussed, along with the expectations of what might be expected in the near future from other experiments. This work is based on recent work including: arXiv:1512.06471 (in collaboration with J. Clarke),
arXiv:1412.0762 (in collaboration with S. Vagnozzi), arXiv:1407.4213.

Summary:

Particle astrophysics / 85

Astrophysical signatures from Galactic positronium, true muonium and true tauonium

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The annihilation of electrons and positrons in the Galactic centre has been observed since the 1970s, yet the origin of the positrons is still unknown. Models of high energy astrophysical sources, such as supernovae and low mass X-ray binaries, must be able to explain the very high bulge-to-disc ratio of the annihilation emission, either via the distribution of the sources or via the propagation of the positrons through the ISM. Alternative possibilities include dark matter decay, or the supermassive black hole, both of which would have a naturally high bulge-to-disc ratio.

The chief difficulty in reconciling models with the observations is the intrinsically poor angular resolution of gamma ray observations, which cannot resolve point sources. However, 95% of the positrons annihilate via the formation of positronium, a short lived atom consisting of an electron and a positron. This gives rise to the possibility of observing recombination lines of positronium emitted before the atom annihilates. These emission lines would be in the UV and the NIR, giving an increase in angular resolution of a factor of 10^4 compared to gamma ray observations, and allowing the discrimination between point sources and truly diffuse emission.

Analogously to the formation of positronium, it is possible to form atoms of muons and anti-muons and tauons and anti-tauons. Since muons and tauons are intrinsically unstable,

the formation of such leptonium atoms will be localised to their places of origin. Thus observations of true muonium or true tauonium can provide another way to distinguish between truly diffuse sources such as dark matter decay, and point sources such as supernovae, etc.

We will review the possibility of detecting positronium recombination lines, and the observational signatures of leptonium from astrophysical sources, and discuss the possibilities of resolving the problem of the origin of the Galactic positrons.

Summary:

Cosmic microwave background and Large Scale Structure / 86

Modeling bispectrum in redshift space from perturbation theory

Author: Ichihiko Hashimoto[1]

[1] *Yukawa institute for theoretical physics*

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The observed galaxy clustering in redshift space, in nature, appears to be anisotropic due to the redshift-space distortion effects. This anisotropic clustering offers an interesting opportunity to probe gravity on cosmological scales. While the redshift-space distortion of galaxy clustering have been quantified and characterized by the two-point statistics, higher-order statistics such as bispectrum are also powerful measure for anisotropies, and combining the bispectrum with power spectrum, cosmological constraint will be further improved. In this talk, I will present a theoretical model of redshift-space bispectrum and quantify its validity by comparing N-body simulation. For an accurate theoretical template, we calculate bispectrum in redshift space based on perturbation theory up to next to leading order. In addition, we also consider relevant prescription for non-perturbative damping effect from the redshift-space distortion. Comparing with N-body simulations makes clear that our theoretical model works well in the quasi non-linear regime.

Summary:

I will present a improved theoretical model of bispectrum in redshift space based on perturbation theory. I will also explain the validity of our model by comparing N-body simulation.

Particle physics / 87

Mono-top/bottom signature in natural SUSY at LHC

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The determination of the electroweak properties of the stop will be an essential task for the LHC. We investigate the observability of single stop production through Mono-top/bottom channel in natural supersymmetry at the LHC.

Summary:

Cosmic microwave background and Large Scale Structure / 88

Dark matter self annihilation in cosmological simulations

Author: Nikolas Iwanus[1]

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Corresponding Author: iwanusn@gmail.com

The standard model for the evolution of the universe is the Lambda cold dark matter (Λ-CDM) model. Its widespread acceptance is due to its simplicity and agreement with a whole host of different astronomical observations. However much is still unknown about the Dark Sector. While Λ-CDM successfully predicts the large scale properties of the universe, there are some discrepancies on the smaller scale, such as a larger than expected number of dwarf galaxies orbiting their parent galaxies and an over-abundance of dark matter in the cores of galaxies. While some have proposed these anomalies can be explained by baryonic physics or observational errors, there is still room for explanations lying within the Dark Sector.

In this presentation, I will show n-body simulations (based on Gadget 2) of simple model halos with gas components in which dark matter undergoes WIMP-like self-annihilation. This annihilation causes a mass loss of the dark matter components and the corresponding energy released by these interactions feed into the surrounding gas particles, affecting the mass distribution these of these halos. By developing this simple model and implementing it into sophisticated cosmological simulations, we will determine how these interactions imprint indirect clues onto the large and small scale galactic structure as to the identity and effect of dark matter on the universe.

Summary:

Particle astrophysics / 89

Soft X-ray excess from cosmic ALPs in magnetohydrodynamical cluster simulations

Author: Stephen Angus[1]

[1] *IBS Center for Theoretical Physics of the Universe*

Corresponding Author: sangus88@ibs.re.kr

It has been proposed that the long-standing soft X-ray excess in galaxy clusters could be explained by conversion of a 200eV cosmic ALP background into photons in the cluster magnetic field. However, for an isotropic Gaussian model of the magnetic field in the Coma cluster, the excess is typically under-produced in the central region when compared to observations. In this talk I will explore whether this tension can be alleviated by considering anisotropic magnetic fields generated from magnetohydrodynamical models of cluster formation. I will present the results for three sample clusters and discuss how further simulations can constrain the allowed parameter space.

Summary:

For simulations of ALP-photon conversion in the magnetic fields of galaxy clusters, I show how using an anisotropic magnetic field model may produce a better fit to the observed morphology of the 200eV soft X-ray excess.

Gravity and gravitational waves / 90

The quantum thermodynamic universe - an emergent perspective

Author: Eric Howard[1]

[1] *Macquarie University*

Corresponding Author: howard@centralcoastlearning.cnri.edu

The close connection between horizons (black hole event horizon, Rindler, de Sitter) and thermodynamics that has already been found can be extended here to a cosmological model, providing a new insight into the cosmological constant problem. The emergent nature of the field equations is interpreted as entropy balance condition of the spacetime. We describe various facets of the emergent gravity approach but concentrating on cosmological context. We discuss the thermodynamics of apparent horizons and derive Friedmann and Raychaudhuri equations from thermodynamical parameters.
If the gravitational field equations are indeed governed by thermodynamics and can be obtained by maximizing the entropy density of spacetime, as shown by Jacobson, it is also possible to go further and study the spacetime as emergent from the dynamics of entanglement in a general cosmological context.
In the paradigm introduced here, the entropy extremisation leads to the equilibrium properties of the Universe. Expansion parameters are found to emerge from the out-of-equilibrium difference between the number of degrees of freedom on the horizon surface and the bulk. The field equations, projected onto a null surface, reduce to Navier-Stokes equations. We study the expansion in terms of holographic equipartition that governs the evolution of spacetime geometry. The holographic principle proposes a deep connection between the degrees of freedom in a bulk region of space and the degrees of freedom on the boundary of the region. The dynamics of the large-scale structure of spacetime and the evolution of Friedmann universe are described as evolution towards a state of holographic equipartition, by reaching an equal number of bulk and surface degrees of freedom in a spacetime region within a Hubble radius. The vanishing of the cosmological constant is a consequence of an underlying symmetry of the theory. When this symmetry is broken, the cosmological constant is nonzero and arises at quantum level from degrees of freedom or microscopic spacetime fluctuations scaling as the surface area. The degrees of freedom are connected to surfaces in spacetime rather than the bulk region and play the most important role in understanding the quantum structure of spacetime. We find that a spacetime without the presence of a cosmological constant cannot reach the holographic equipartition. The dynamics of the asymptotic holographic equipartition will require the presence of a cosmological constant.

Summary:

A new approach to gravity is presented here, suggesting a possible emergent paradigm to understand the cosmological constant.We discuss the emergent paradigm and the implications of this novel perspective for the cosmological constant problem.
The scope of the present work is to investigate the thermodynamical properties of quantum fields in curved spacetime and analyze how gravity and thermality are connected at a cosmological scale, based on Sakharov induced gravity concept.

Dark matter / **92**

Dark Forces in the Sky: Signals from Z’ and the Dark Higgs

Author: Nicole Bell[1]

[1] *University of Melbourne*

Corresponding Author: n.bell@unimelb.edu.au

We consider the indirect detection signals for models containing a fermionic DM candidate, a dark gauge boson, and a dark Higgs field. Compared with a model containing only a dark matter candidate and vector mediator, the addition of the scalar provides a mass generation mechanism

for the dark sector particles which, in some cases, is required in order to avoid unitarity violation at high energies. We demonstrate that the dark matter interaction types, and hence the annihilation processes relevant for relic density and indirect detection, are strongly dictated by the mass generation mechanism chosen for the dark sector particles, and the requirement of gauge invariance. We outline important phenomenology of such two-mediator models, which is missed in the usual single-mediator simplified model approach. In particular, the inclusion of the two mediators opens up a new, dominant, s-wave annihilation channel that does not arise when a single mediator is considered in isolation.

Summary:

Particle astrophysics / 93

Muon energy reconstruction in large-scale neutrino detectors

Author: Sally Robertson[1]

[1] *University of Adelaide*

Corresponding Author: sally.robertson@adelaide.edu.au

Understanding the properties of the astrophysical neutrino flux measured by IceCube relies upon the ability to reconstruct the energies of the muon events observed in the detector. In this talk, I will describe a maximum likelihood method that interprets the full pattern of reconstructed energy losses from each muon track to obtain a best estimate of the muon energy as the event entered the detector.

Summary:

Understanding the properties of the astrophysical neutrino flux measured by IceCube relies upon the ability to reconstruct the energies of the muon events observed in the detector. In this talk, I will describe a maximum likelihood method that interprets the full pattern of reconstructed energy losses from each muon track to obtain a best estimate of the muon energy as the event entered the detector.

Particle astrophysics / 94

Prospects for detection of neutrinos in correlation with starburst galaxies

Author: Alex Kyriacou[1]

[1] *University of Adelaide*

Corresponding Author: gary.hill@adelaide.edu.au

IceCube has detected many astrophysical neutrinos, but their ultimate origin is as-yet unknown. This talk will focus on starburst galaxies as a potential source of these neutrinos, and will discuss the prospects for finding correlations of these sources with the existing neutrino events.

Summary:

IceCube has detected many astrophysical neutrinos, but their ultimate origin is as-yet unknown. This talk will focus on starburst galaxies as a potential source of these neutrinos, and will discuss the prospects for finding correlations of these sources with the existing neutrino events.

Dark matter / 95

A two component, thermal-nonthermal dark matter model with a singlet fermion and a scalar

Author: Debasish Majumdar[1]

[1] *Saha Institute of Nuclear Physics*

Corresponding Author: debasish.majumdar@saha.ac.in

We explore a two component dark matter model with a fermion and a scalar. In this scenario the Standard Model (SM) is extended by a fermion, a scalar and an additional pseudo-scalar. The fermion component is assumed to have a global $\mathrm{U}(1)_{\mathrm{DM}}$ symmetry and interacts with the pseudoscalar via a pseudo-scalar interaction while a Z_2 symmetry is imposed on the other component – the scalar. These ensure the stability of both the components (the fermion and the scalar). While the prduction of fermion component is thermal, the scalar component is produced non-thermally via decay and annihilation of the SM particles and pseudo-scalar. The pseudo-scalar interaction is CP coneserved and the pseudo-scalar acquires a vev on spontaneous breaking of CP symmetry. The scalar component of the dark matter in the present model also develops a vev on spontaneous breaking of the Z_2 symmetry. Thus the various interactions of the dark sector and the SM sector is progressed through the mixing of the SM-like Higgs bososn, the pseudo-scalar Higgs like boson and the singlet scalar boson. In this model we show that the observed gamma ray excess from the Galactic Centre (between 2 to 10 GeV), the 3.55 keV X-ray line from Perseus and Andromeda as well as the evidence of self-interaction of dark matter from Abell cluster observation can be simultaneously explained.

Summary:

Cosmic microwave background and Large Scale Structure / 96

Cosmology from CMB Polarization with POLARBEAR and the Simons Array

Author: Darcy Barron[None]

Corresponding Author: dbarron@berkeley.edu

POLARBEAR is a cosmic microwave background (CMB) polarization experiment located in the Atacama desert in Chile. The science goals of the POLARBEAR project are to do a deep search for CMB B-mode polarization created by inflationary gravitational waves, as well as characterize the CMB B-mode signal from gravitational lensing. POLARBEAR-1 started observations in 2012, and in 2014, the POLARBEAR team published results from its first season of observations on a small fraction of the sky. These results include the first measurement of a non-zero B-mode polarization angular power spectrum, measured at sub-degree scales where the dominant signal is gravitational lensing of the CMB. To improve on these measurements, POLARBEAR is expanding to include an additional two telescopes with multi-chroic receivers, known as the Simons Array. With high sensitivity and large sky coverage, the Simons Array will create a detailed survey of B-mode polarization, and its spectral information will be used to extract the CMB signal from astrophysical foregrounds. We present the status of this funded instrument and its expected capabilities.

Summary:

Inflation and early universe cosmology / 97

Blue tensor spectra with slightly parity-violated from axion-gauge couplings

Author: Ippei Obata[1]

[1] *Kyoto University*

Corresponding Author: obata@tap.scphys.kyoto-u.ac.jp

The inflationary universe predicts vacuum fluctuations of space-time, called primordial gravitational waves, whose spectra have slightly red-tilted and parity-symmetric features. This is an ordinary picture. Intriguingly, however, it is known that the axion-gauge coupling, motivated by string theory, could occur the particle production of gauge fields during inflation and provide the parity-violated blue tensor spectrum testable in future gravitational wave experiments, while no such a parity-violated primordial signal has been detected through recent observations. It seems that there would be no parity-violated phenomena in the early universe. In this talk, however, we suggests the new mechanism of providing blue tensor spectra sourced by gauge fields coupled to axions, surprisingly whose amplitudes are almost parity-conserved but slightly parity-violated! We expect that the blue tensor spectra with little chirality becomes the new window to the axion phenomenology in the early universe.

Summary:

Dark matter / 99

Determining the Local Dark Matter Density

Author: Hamish Silverwood[1]

[1] *University of Amsterdam*

Corresponding Author: h.g.m.silverwood@uva.nl

An accurate determination of the local dark matter (DM) density is crucial to interpreting data from direct detection and certain indirect detection experiments, as it is degenerate with the DM-nucleon interaction strength. Here I give an update to our ongoing project to make a determination of the local DM density. Our method uses the positions and velocities of a set of tracer stars extending upwards out of the Milky Way disc, to which we fit a baryon and dark matter mass model using Bayesian nested sampling. The framework we have set up holds the promise of allowing us to minimise the number of assumptions needed, and thus determine the local DM density accurately and with a full quantification of its uncertainty. We have begun to apply our method to data from SDSS, and also plan to apply it to Gaia data.

Summary:

Dark matter / 100

Dark matter searches in LUX

Author: Claudio Frederico Pascoal da Silva[1]

[1] *LIP Coimbra*

Corresponding Author: claudio@coimbra.lip.pt

The Large Underground Xenon (LUX) is a dark matter experiment searching for direct evidence of Weakly Interacting Massive
Particles (WIMPs), a favored dark matter candidate. It is a 250 kg active mass dual-phase xenon time projection chamber operating at the Sanford Underground Research Facility in USA. The results from the second and final science run with a total of 332 live days of exposure revealed no evidence of WIMP nuclear recoils with a four-fold improvement
in sensitivity for high WIMP masses relative to our previous results. Currently, LUX has the world leading exclusion limit in a wide range of WIMP masses. At a WIMP mass of 50 GeV c−2, WIMP-nucleon spin-independent cross sections above 0.22 zepto barns are excluded at 90%.

The interpretation of any potential WIMP signal requires to understand very well the response of the detector to both electronic and nuclear recoils thus requiring the LUX detector to be calibrated thoroughly during the second science run. ^{83m}Kr was injected weakly, CH_3T, injected 2-3 times per year, used to define our elecronic recoil band and a collimated beam of monoenergetic 2.45 MeV neutrons used to define our nuclear recoil band. These calibrations were also essential to study the uniformity of the electric field, to define the active region volume and to correct the signal dependence with the position of interaction.

The LUX detector is also able to explore other alternative Dark Matter scenarios, such as axion like particles (ALPs) or look for other type of signals such as annual modulation signals or solar axions. An update of some of those searches will be presented as well.

Summary:

The Large Underground Xenon (LUX) is a dark matter experiment searching for direct evidence of Weakly Interacting Massive
Particles (WIMPs), a favored dark matter candidate. It is a 250 kg active mass dual-phase xenon time projection chamber operating at the Sanford Underground Research Facility in USA. The results from the second and final science run with a total of 332 live days of exposure revealed no evidence of WIMP nuclear recoils with a four-fold improvement
in sensitivity for high WIMP masses relative to our previous results. Currently, LUX has the world leading exclusion limit in a wide range of WIMP masses. At a WIMP mass of 50 GeV/c^2, WIMP-nucleon spin-independent cross sections above 0.22 zepto barns are excluded at 90%.

Cosmic microwave background and Large Scale Structure / 101

Testing Inflationary Models with Galaxy Formation Simulations

Author: Luke Barnes[None]

Corresponding Author: lukebarnes83@gmail.com

Theories of cosmological inflation often predict that cosmic conditions will vary from place to place in the universe as a whole. In particular, the value of the cosmological constant can plausibly explained by a combination of environmental variation and it's effect on galaxy formation. In such models, it is crucial that we understand how quickly and efficiently the onset of accelerating expansion shuts down accretion of matter into dark matter haloes and galaxies. I will show simulations, based on the cosmological galaxy formationn code of the Eagle collaboration, that investigates this effect. More generally, I will show how an understanding of galaxy transformation can inform fundamental cosmology.

Summary:

Cosmic microwave background and Large Scale Structure / 102

New Measurements of CMB Polarisation from SPTpol

Author: Christian Reichardt[1]

[1] *University of Melbourne*

Corresponding Author: clreichardt@gmail.com

Measurements of the polarisation of the cosmic microwave background (CMB) are rapidly becoming an important tool to test the standard model of cosmology. In particular, searches for the faint CMB B-mode signals offer the prospect of detecting inflationary gravitational waves on large angular scales and mapping out the large scale distribution of matter in the Universe through CMB lensing on smaller angular scales. SPTpol is a CMB polarisation experiment located at the South Pole that has been pursuing both goals since 2012. I present the latest polarisation power spectra from SPTpol and discuss their cosmological implications. I will also say a few words about a new and dramatically improved CMB polarisation experiment, SPT-3G, which is slated for first light this January.

Summary:

Particle physics / 103

CP violating Top-Higgs couplings in Light of LHC Run-2

Author: Ning Liu[1]

[1] *The University of Sydney*

Corresponding Author: wlln@mail.ustc.edu.cn

We utilize the LHC Run-2 Higgs data to constrain the CP-violating top-Higgs coupling. Within the allowed parameter space, we study the impact of the CP-violating top-Higgs coupling in the Higgs production processes $pp \to t\bar{t}h, thj, hh$ at 14 TeV LHC, and $e^+e^- \to Zh, h\gamma$ at 240 GeV CEPC.

Summary:

Cosmic microwave background and Large Scale Structure / 104

Unveiling the Signatures of an Evolving and Interacting Dark Sector

Author: Eromanga Adermann[1]

Co-author: Geraint Lewis [1]

[1] *The University of Sydney*

Corresponding Authors: eromanga.adermann@sydney.edu.au, geraint.lewis@sydney.edu.au

Using state of the art numerical simulations, I have unravelled observational signatures of several alternative cosmological models in the large-scale structure of the cosmic web. The key observational probe under study is evolution of cosmological voids, to provide us with clues to the underlying cosmology of the Universe. While the ultimate goal will be to include galaxy formation recipes to determine the true efficacy of using cosmic voids in realistic future surveys with the next generation of ground- and space-based telescopes, in this presentation I will reveal how the size, shapes and density of voids, and their evolution through cosmic time, depend on the underlying cosmology of the Universe, showing that universes with an evolving and decaying dark sector leave a significant imprint on the void structure when compared to the standard Lambda Cold Dark Matter cosmology.

Summary:

Dark matter / 105

The Dark Matter Interpretation of the Gamma-Ray Excess at the Galactic Centre

Author: Hamish Clark[1]

[1] *University of Sydney*

Corresponding Author: hamish.clark@sydney.edu.au

An excess of gamma rays has been observed at the centre of the Galaxy. While dark matter annihilation within the Milky Way's halo has been shown to provide a good fit to the observed excess, evidence has recently arisen to suggest that the excess is emitted by a large number of point sources, such as millisecond pulsars. In this talk I present recent results that investigate gamma rays arising from annihilation within small-scale dark matter substructure, as a compromise between these two seemingly contradictory interpretations.

Summary:

Dark matter / 106

Probing mixed complex scalar WIMP dark matter

Authors: Akiteru Santa[1]; Mitsuru Kakizaki[1]

[1] *University of Toyama*

Corresponding Authors: santa@jodo.sci.u-toyama.ac.jp, kakizaki@sci.u-toyama.ac.jp

We discuss phenomenology of models extended by introducing
an isospin doublet scalar and a complex singlet scalar.
In such models, the lighter state of mixed neutral scalars can be WIMP candidate.
We point out that some WIMP mass regions are consistent with results of dark matter searches
as well as the limit on the dark matter relic density.
We show that these allowed regions can be investigated at future collider experiments
and dark matter direct detections.

Summary:

Cosmic microwave background and Large Scale Structure / 107

Differential expansion and its observational impact in cosmology

Authors: David Wiltshire[1]; Krzysztof Bolejko[2]

[1] *University of Canterbury*

[2] *University of Sydney*

Corresponding Authors: david.wiltshire@canterbury.ac.nz, krzysztof.bolejko@sydney.edu.au

In general relativity inhomogeneities generically produce differential cosmic expansion which is not equivalent to a homogeneous isotropic cosmology plus local boosts, as assumed in the current standard model. We present the first ray tracing simulations of local structure that exhibit this, using exact solutions of Einstein's equations constrained by both actual large galaxy surveys (the COMPOSITE sample) and the Cosmic Microwave Background. We use exact Szekeres solutions on small scales which asymptote to a Planck-satellite normalized FLRW model on scales >100/h Mpc. We discuss the impact on issues including the local and global values of the Hubble constant, and large angle CMB anomalies.

Reference: K. Bolejko, M.A. Nazer and D.L. Wiltshire, JCAP 06(2016)035

Summary:

Particle physics / 108

MeV scale leptonic force for cosmic neutrino spectrum and muon anomalous magnetic moment

Author: Joe Sato[None]

Corresponding Author: joe@phy.saitama-u.ac.jp

Characteristic patterns of cosmic neutrino spectrum reported by the IceCube Collaboration and long-standing inconsistency between theory and experiment in muon anomalous magnetic moment are simultaneously explained by an extra leptonic force mediated by a gauge field with a mass of the MeV scale. With different assumptions for redshift distriution of cosmic neutrino sources, diffuse neutrino flux is calculated with the scattering between cosmic neutrino and cosmic neutrino back-ground through the new leptonic force. Our analysis sheds light on a relation among lepton physics at the three different scales, PeV, MeV, and eV, and provides possible clues to the distribution of sources of cosmic neutrino and also to neutrino mass spectrum

Summary:

Particle physics / 110

Search for a light L_{\mu}-L_{\tau} gauge boson at Belle II

Author: Shihori Hoshino[1]

[1] *Saitama University*

Corresponding Author: shihori.hoshino.physics@gmail.com

In previous work, it was found that if L_{\mu}-L_{\tau} massive Z' has a MeV-scale mass, muon g-2 problem and IceCube gap can be simultaneously explained. Then, I have studied the detectability of Z' at the future Belle II experiment. I'll propose a detectability of Z' through a one photon + missing process.

Summary:

Dark matter / 111

Evaporation on Gev-ish DM in the Sun

Author: Giorgio Busoni[None]

Corresponding Author: giorgio.busoni@unimelb.edu.au

We analyse the effect of evaporation on Dark Matter in the Sun, considering velocity and momentum suppressed cross sections. We check which best-fit points of 1605.06502 are affected by evaporation.

Summary:

Inflation and early universe cosmology / 112

Resurrection of large lepton number asymmetries and their cosmological implications

Author: Wanil Park[None]

Corresponding Author: wanil.park@uv.es

It will be shown that, even if Big Bang Nucleosynthesis constrains the asymmetry of electron neutrinos to be of or less than $\mathcal{O}(10^{-3})$, asymmetries of muon- and tau-neutrinos can be large and lead to $\Delta N_{\rm eff} = \mathcal{O}(0.1 - 1)$ as the number of extra neutrino species. Also, it will be shown that $\Delta N_{\rm eff}$ should be estimated from contributions of neutrino mass-eigenstates instead of neutrino flavor-eigenstates.

Summary:

Dark matter / 113

Relic Abundance in Secluded Dark Matter Scenario with Massive Mediator

Author: Masato Yamanaka[1]

[1] *Kyoto Sangyo University*

Corresponding Author: masato.yamanaka@cc.kyoto-su.ac.jp

The relic abundance of the dark matter (DM) particle d
is studied in a secluded DM scenario, in which the d number
decreasing process dominantly occurs not through the pair annihilation
of d into the standard model particles, but via the $dd \to mm$
scattering process with a subsequently decaying mediator particle m.
It is pointed out that the cosmologically observed relic abundance of DM
can be accomplished even with a massive mediator having a mass m_m
non-negligibly heavy compared with the DM particle mass m_d.
In the degenerated d-m case
($m_d = m_m$),
the DM relic abundance is realized by adjusting
the $dd \to mm$ scattering amplitude large enough and by choosing
an appropriate mediator particle life-time.

The DM evolution in the early universe exhibits characteristic "terrace" behavior, or two-step number density decreasing behavior, having a "fake" freeze-out at the first step.
Based on these observations, a novel possibility of the DM model buildings is introduced
in which the mediator particle m is unified with the DM particle d in an approximate dark symmetry multiplet.
A pionic DM model is proposed to illustrate this idea in a renormalizable field theory framework.

S. Okawa, M. Tanabashi and M. Yamanaka,
"Relic Abundance in Secluded Dark Matter Scenario with Massive Mediator,"
arXiv:1607.08520 [hep-ph].

Summary:

The relic abundance of the dark matter (DM) particle d
is studied in a secluded DM scenario, in which the d number
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The DM evolution in the early universe exhibits characteristic
"terrace" behavior, or two-step number density decreasing behavior,
having a "fake" freeze-out at the first step.
Based on these observations, a novel possibility of the DM model
buildings is introduced
in which the mediator particle m is unified with the DM particle
d in an approximate dark symmetry multiplet.
A pionic DM model is proposed to illustrate this idea
in a renormalizable field theory framework.

Dark matter / 114

Quantum and Classical Behaviour of Axion Dark Matter

Author: Mark Hertzberg[1]

[1] *Tufts University*

Corresponding Author: mark.hertzberg@tufts.edu

It is understood that in free bosonic theories, the classical field theory accurately describes the full quantum theory when the occupancy numbers of systems are very large. However, the situation is less understood in interacting theories, especially on time scales longer than the dynamical relaxation time. Recently there have been claims that the quantum theory of dark matter axions deviates spectacularly from the classical theory on this time scale, even if the occupancy numbers are extremely large. The evidence for these claims comes from noticing a spectacular difference in the time evolution of expectation values of quantum operators compared to the classical micro-state evolution. In this talk I critically examine these claims. I show that in fact the classical theory can describe the quantum behaviour in the high occupancy regime, even when interactions are large. The connection is that the expectation values of quantum operators in a single quantum micro-state are approximated by a corresponding classical ensemble average over many classical micro-states.

Furthermore, by the ergodic theorem, a classical ensemble average of local fields with statistical translation invariance is the spatial average of a single micro-state. So the correlation functions of the quantum and classical field theories of a single micro-state approximately agree at high occupancy, even in interacting systems. I discuss applications of our results to axion dark matter. I use the classical field theory to show that axions form Bose condensed stars within the galaxy.

Summary:

Cosmic microwave background and Large Scale Structure / 116

First detection of Galaxy Cluster lensing in CMB polarisation

Author: Sanjaykumar Patil[1]

Co-author: Reichardt Christian [1]

[1] *University of Melbourne*

Corresponding Authors: sanjaypatil133@gmail.com, clreichardt@gmail.com

Galaxy clusters are the largest gravitationally bound objects in the Universe and provide crucial insight to the standard model of cosmology. The abundance of these as a function of mass and redshift is highly sensitive to the cosmological parameters such as amplitude of matter fluctuations and dark energy equation of state parameter.

While galaxy clusters yield tremendously powerful tests of dark energy, their cosmological constraints are currently limited by a ˜15% mass uncertainty. Future surveys like LSST and eROSITA will build ever larger cluster samples; our ability to fully realise the potential of these samples depends on better mass estimates. Gravitational lensing is widely considered the gold standard in mass estimation.
The next suite of Cosmic Microwave Background (CMB) polarisation experiments are expected to be able to normalise cluster masses to ˜3% (a fivefold improvement!) by looking at the gravitational lensing signal in CMB polarisation. In this talk we present first ever lensing measurement of galaxy cluster mass using CMB polarisation data. We take data from the current SPTpol experiment, and use a maximum likelihood approach to extract the CMB cluster lensing signal from a catalog of Sunyaev-Zel'dovich effect selected galaxy clusters. We consider several sources of potential systematic error, and quantify their effect using mock data.

Summary:

Dark matter / 117

p-wave Annihilating Dark Matter from a Decaying Predecessor and the Galactic Centre Excess

Author: Jonathan Cornell[1]

[1] *McGill University*

Corresponding Author: cornellj@physics.mcgill.ca

Dark matter (DM) annihilations have been widely studied as a possible explanation of excess gamma rays from the galactic centre seen by the Fermi-LAT. However, most such models are in conflict with constraints from dwarf spheroidals. Motivated by this tension, in this talk I will show that p-wave annihilating dark matter can easily accommodate both sets of observations due to the lower DM velocity dispersion in dwarf galaxies. Explaining the DM relic abundance is then challenging. I will outline a scenario in which the usual thermal abundance is obtained through s-wave annihilations of a metastable particle that eventually decays into the p-wave annihilating DM of the present epoch. The couplings and lifetime of the decaying particle are constrained by big bang nucleosynthesis, the cosmic microwave background, and direct detection, but significant regions of parameter space are viable. A sufficiently large p-wave cross section can be found by annihilation into light mediators that also give rise to Sommerfeld enhancement. A prediction of the scenario is enhanced annihilations in galaxy clusters.

Summary:

Dark matter / 118

A map of the non-thermal WIMP

Author: Chang Sub Shin[1]

[1] *Rutgers University*

Corresponding Author: csshinest@gmail.com

We study the effect of elastic scattering on the non-thermally produced WIMP dark matter and its phenomenological consequences. The non-thermal WIMP becomes important when the reheating temperature is well below the freeze-out temperature. In the usual paradigm, the produced high energetic dark matters are quickly thermalized due to the elastic scattering with background radiations. The relic abundance is determined by the thermally averaged annihilation cross-section times velocity at the reheating temperature. In the opposite limit, the initial abundance of produced dark matters is small enough so they do not annihilate, and the relic density is determined by the branching fraction of the heavy particle. We study the regions between these two limits, and show that the relic density could be sensitive not only to the annihilation rate, but also to the elastic scattering rate. Especially, the relic abundance of p-wave annihilating dark matter crucially depends on the elastic scattering rate because the annihilation cross-section is sensitive to the dark matter velocity. We categorize the parameter space into several regions where each region has distinctive mechanism for determining the relic abundance of the dark matter at the present Universe. The consequence on the (in)direct detection is also studied.

Summary:

Cosmic microwave background and Large Scale Structure / 119

The Impact of Dark Sector Physics on Large-Scale Structure Topology

Author: Andrew Watts[1]

[1] *The University of Sydney*

Corresponding Author: awatts@physics.usyd.edu.au

We compare the topological properties of the dark matter distribution in a number of cosmological models using hydrodynamical simulations and the cosmological genus statistic. Genus curves are computed from z=11 to z=0 for Lambda-CDM, Quintessence and Warm Dark Matter models, over a scale range of 1 to 20 h^-1 Mpc. The curves are analysed in terms of their Hermite spectra to describe the power contained in non-Gaussian deformations to the cosmological density field. We find that the Lambda-CDM and Lambda-WDM models produce nearly identical genus curves indicating no topological differences in structure formation. The Quintessence model, which differs solely in its expansion history, produces differences in the strength and redshift evolution of non-Gaussian modes

associated with higher cluster abundances and lower void abundances. These effects are robust to cosmic variance and are characteristically different from those produced by tweaking the parameters of a Lambda-CDM model. Given the simplicity and similarity of the models, detecting these discrepancies represents a promising avenue for understanding the effect of non-standard cosmologies on large-scale structure.

Summary:

Particle astrophysics / 120

Precision Measurement of Nuclei Fluxes and their Ratios in Primary Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station

Author: Valerio Formato[1]

[1] *Universita e INFN, Perugia (IT)*

Corresponding Author: valerio.formato@cern.ch

The exact behavior of the nuclei fluxes with rigidity and how they relate to each other is important for understanding the production, acceleration and propagation mechanisms of charged cosmic rays. Precise measurements with the Alpha Magnetic Spectrometer on the International Space Station of the light nuclei fluxes and their ratios in primary cosmic rays with rigidities from GV to TV range will be discussed.

Summary:

Dark matter / 121

Global fits of the scalar singlet model using GAMBIT

Author: James McKay[1]

[1] *Imperial College London*

Corresponding Author: j.mckay14@imperial.ac.uk

I will present the latest results for global fits to the Higgs portal scalar singlet extended standard model using complementary probes of dark matter. In doing so I will introduce the new global and modular beyond the standard model inference tool (GAMBIT) which is used to achieve these results in a statistically consistent and modular way. I will also demonstrate the flexibility and consistency between the choice of statistical fitting algorithms available with this tool.

Summary:

Gravity and gravitational waves / 122

Exploring a stochastic background of gravitational waves

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The recent detections of gravitational waves from coalescing binary black holes by the Advanced Laser Interferometer Gravitational-wave Observatory (LIGO) suggest that a stochastic gravitational wave background may be detectable by advanced detectors running at their design sensitivity. Looking at results from searches for both isotropic and anisotropic stochastic backgrounds in Advanced LIGO's first observing run, we discuss the implications such a detection could have on studies of the early universe.

Summary:

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Special relativistic hydrodynamics with gravitation

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The special relativistic hydrodynamics with Newtonian gravity is hitherto unknown in the literature. Whether such an asymmetric combination is possible was unclear. Here, the hydrodynamic equations with Poisson-type gravity considering fully relativistic velocity and pressure under the weak gravity and the action-at-a-distance limit are consistently derived from Einstein's general relativity. Analysis is made in the maximal slicing where the Poisson's equation becomes much simpler than our previous study in the zero-shear gauge. Also presented is the hydrodynamic equations in the first post-Newtonian approximation, now under the {\it general} hypersurface condition. Our formulation includes the anisotropic stress.

Summary:

Cosmic microwave background and Large Scale Structure / 124

Axion as a cold dark matter candidate: Proof to fully nonlinear perturbation

Authors: Hyerim Noh[1]; Jai-chan Hwang[None]

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We present a proof of the axion as a cold dark matter candidate to the fully nonlinear and exact perturbations based on Einstein's gravity. We consider the axion as a coherently oscillating massive classical scalar field. We show that the axion has a characteristic pressure and anisotropic stress. But these terms do not affect the hydrodynamic equations in our axion treatment. The pressure term is negligible in the super-Jeans scale which is of the solar-system scale for conventional axion mass. As the fully nonlinear and relativistic hydrodynamic equations for an axion fluid coincide exactly with the ones of a zero-pressure fluid in the super-Jeans scale, we have proved the cold dark matter nature in that scale.

Summary:

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Five dimensional bulk viscous cosmological models in f (R, T) gravity

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In this talk, author considered the bulk viscous fluid in the formalism of modified gravity in which the gravitational action contains a general form of f (R, T) function, where R is the curvature scalar and T is the trace of the energy momentum tensor within the frame of Kaluza-Klein space time. The cosmological model dominated by bulk viscous matter with total bulk viscous coefficient expressed as a linear combination of the velocity and acceleration of the expansion of the universe in such a way that ξ = ξ 0 + ξ 1 ȧ a + ξ 2 ä ȧ , where ξ 0 , ξ 1 and ξ 2 are constants. We take p = (γ − 1)ρ, where 0 ≤ γ ≤ 2 as an equation of state for perfect fluid. The exact solutions to the corresponding field equations are obtained by assuming a particular model of the form of f (R, T) = R + 2f (T), where f (T) = λT , λ is constant. Finally, some physical and geometrical properties of the models are discussed.

Summary:

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Dynamical brane backgrounds

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Time dependent brane solutions of supergravity have been of particular importance in the advances of gravity theory. We review the current status of these "dynamical" brane solutions in higher-dimensional supergravity theories and discuss primarily the gravitational aspects of p-branes and their relatives in various dimensions. We also comment the D-brane and M-brane solutions in ten and eleven dimensions, which provide a number of interesting black objects, cosmological models, supersymmetric breaking, and the violation of cosmic censorship.

Summary:

References:
1 Kengo Maeda, Kunihito Uzawa,
Phys.Rev. D93 (2016) no.4, 044003.
2 Kei-ichi Maeda, Nobuyoshi Ohta, Kunihito Uzawa,
JHEP 0906 (2009) 051.
3 Hideo Kodama, Kunihito Uzawa
JHEP 0507 (2005) 061.

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Black Hole Thermodynamics, Expanding Universe and Dark Energy

Author: Sang Pyo Kim[1]

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Cai and Kim [JHEP02(2005)050] proposed an interpretation of black hole thermodynamics for an expanding universe in Einstein, Gauss-Bonnet and Lovelock gravity. There have been since then numerous applications and interpretions of the entanglement entropy to the universe. In this talk, the recent progress in this direction will be critically reviewed and revisited from the view point of current observational data. In parcular, an emphasis will be put on the relation with the dark energy.

Summary:

Particle astrophysics / 128

Gas Towards Gamma-Ray-Emitting Supernova Remnants

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Gamma-ray astronomy may offer answers to a long-standing question of high energy astrophysics: Where do cosmic rays come from? The gamma-ray emission seen from some supernova remnants is now known to be from distant populations of cosmic-rays (probably accelerated locally) interacting with gas, but there is still much work to be done in accounting for the Galactic cosmic-ray flux. The Mopra radio telescope is ideal for probing the interstellar environments of gamma-ray sources through large-scale molecular line surveys. The Mopra Galactic Plane CO Survey can resolve gas involved in gamma-ray generation at a scale comparable to the resolution of future gamma-ray experiments, while giving insights into gas dynamics. Dense gas tracers such as CS and NH3 have proven to be useful probes of gamma-bright regions, while SiO emission can directly highlight shock-disrupted gas. We present the results of molecular spectral line observations towards supernova remnants at various stages of evolution.

Summary:

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IceCube Neutrinos

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The IceCube Neutrino Observatory is the world's largest neutrino detector. Located at the South Pole, IceCube consists of a cubic kilometre of ice instrumented with 5160 photomultiplier tubes on 86 strings at a depth of 1.5-2.5 km. In this talk I will present the latest results concerning the

high-energy neutrinos detected by IceCube. Plans for a next-generation IceCube detector, named IceCube-Gen2, will also be presented.

Summary:

Plenary / **130**

SABRE

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Summary:

Plenary / **131**

Fermi LAT

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Summary:

Plenary / **132**

Galactic positron population

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Summary:

Plenary / **133**

Dark Energy with the Dark Energy Survey

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The Dark Energy Survey (DES) is in its fourth year of a five year observing program. We're on our way to mapping 300 million galaxies and measuring 3000 type Ia supernovae for dark energy studies as well as monitoring 800 Active galaxies so we can use reverberation mapping to measure supermassive black hole masses across the last 12 billion years (to z˜4). Over 525 nights DES combines a wide-field imaging survey with a narrower time-lapse survey. OzDES are following up the narrow region with 100 nights of spectroscopy on the Anglo-Australian Telescope. I'll give an update of progress, give some early results, and show how we expect to use this data to constrain dark energy through type Ia supernovae, gravitational lensing, and Baryon Acoustic Oscillations.

Summary:

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Planck CMB results

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Summary:

Plenary / 135

Dark matter theory

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Summary:

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CPs and Type-II Leptogenesis

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Summary:

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Invisible Higgs decays, SUSY searches and BSM Higgs at the LHC

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Summary:

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Baryo-/Leptogenesis

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Summary:

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Cosmological surveys

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Summary:

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Dark energy

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Summary:

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Dark matter direct detection

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Summary:

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Gravitational waves

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Summary:

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Mono-X, dijet, and long-lived particle searches at the LHC

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Summary:

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AMS

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Summary:

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Tests of modified gravity

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Summary:

Plenary / 146

The Cherenkov Telescope Array: A TeV Gamma-Ray Observatory

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Summary:

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Inflation

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Summary:

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Astroparticle tests of dark matter theories

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Summary:

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Consistency checks of LCDM

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Summary:

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Theories of modified gravity

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Summary:

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Outlook for the discovery of new physics

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Summary:

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Neutrino experiments

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Summary:

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Inhomogeneous Cosmology

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The present epoch Universe is inhomogeneous on < 100/h Mpc scales, opening up the possibility of backreaction - that average cosmic expansion is significantly different from that of the standard FLRW geometry at late epochs. Realizing this possibility means confronting unsolved open questions in general relativity, in particular the nonlocal nature of gravitational energy in coarse-graining matter and geometry. The timescape scenario is a phenomenologically viable model without dark energy which addresses these issues. In this talk I will focus on observational signatures of inhomogeneity and backreaction, including the Clarkson-Bassett-Lu (CBL) test that with Euclid satellite data should distinguish backreaction models from the concordance FLRW model in the next decade. While conceding a bet I made with Padmanabhan 10 years ago on the basis of current data, I offer a new bet on the CBL test for the coming age of "precision cosmology".

Summary:

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Neutrino mass in the landscape of vacua

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Summary:

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Opening Address

Summary:

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Closing

Particle physics / 157

Implication of ALEPH 30 GeV dimuon resonance at the LHC

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Recent reanlysis of ALEPH data seems to indicate dimuon excess around 30 GeV dimuon in Z -> b bar{b} mu^+ mu^- with a branching fraction around 1.1 X 10^{-5}. We discuss a few simplified models for the dimuon excess. In the first class of models, we assume a new resonance couples to both b bar{b} and mu^+ mu^-. Within the allowed parameter space for the ALEPH data, this type of models is excluded because of too large Drell-Yan production of&nbs p;dimuon from the b bar{b} collision at the LHC. In the second model, we assume that the 30 GeV excess is a new gauge boson Z' that couples to the SM b and a new vectorlike singlet B quark heavier than Z and not to b bar{b}. Then one can account for the ALEPH data without conflict with the DY constraint. We discuss implication of the model at the LHC.

Summary:

Dark matter / 158

A dark matter model with Dirac neutrino masses

Author: Seungwon Baek[None]

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Tiny neutrino masses can be obtained if right-handed neutrino masses charged under a global U(1) symmetry and a second Higgs doublet which is also charged under the U(1) obtains tiny vacuum expectation value.
Due to the symmetry Majorana mass terms of the right-handed neutrinos are not allowed and the usual seesaw mechanism does not work.
We can also introduce dark matter candidates whose stability is also guaranteed by the same U(1).
I'll talk about the phenomenology of this model.

Summary:

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Darkly-Charged Dark Matter

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Summary:

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Gravitational waves at aLIGO and vacuum stability with a scalar singlet extension of the Standard Model

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A new gauge singlet scalar field can undergo a strongly first-order phase transition leading to gravitational waves observable at aLIGO and stabilizes the electroweak vacuum at the same time. This is because the sensitivity of aLIGO to cosmological phase transitions at 10ˆ7-10ˆ8 GeV coincides with the requirement that the singlet scale is close to the Standard Model instability scale. Extending the SM with a singlet, we calculate the nucleation temperature and order parameter of the PT during which the singlet acquires a vacuum expectation value in terms of Lagrangian parameters. Relating the thermodynamic quantities to the peak frequency and amplitude of the gravitational waves created during the phase transition, we present three benchmark points for which not only are gravitational waves observable at aLIGO but the electroweak vacuum is stable and the zero temperature phenomenology is acceptable. This scenario offers an intriguing possibility for aLIGO to detect traces of fundamental physics motivated by vacuum stability at an energy scale that is well above the reach of any other experiments.

Summary: