Winter Mini Workshop on Gravity and Cosmology

Monday, January 21, 2019 - Wednesday, January 23, 2019

Faculty of Physics, University of Warsaw

Book of Abstracts

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Light Particles with Spin in Inflation

The existence of light particles with spin during inflation is prohibited by the Higuchi bound. This conclusion can be evaded if one considers states with a sizeable coupling with the inflaton foliation, since this breaks the de Sitter isometries. The action for these states can be constructed within the Effective Field Theory of Inflation, or using a CCWZ procedure. Light particles with spin have prescribed couplings with soft inflaton perturbations, which are encoded in consistency relations. I will talk about the phenomenology of light states with spin 2. These mix with the graviton changing the tensor power spectrum and can lead to sizeable tensor non-Gaussianities. They also give rise to a scalar bispectrum and trispectrum with a characteristic angle-dependent non-Gaussianity.

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To B or not to B: Primordial magnetic fields from Weyl anomaly

For more than twenty years, it has been argued that the Weyl anomaly of quantum electrodynamics sources cosmological magnetic fields in the early universe. If true, this would be a natural way to produce the seed magnetic fields of our universe within the Standard Model. In this talk, I will examine this long-standing claim and show that there is actually no production of coherent magnetic fields from the Weyl anomaly, irrespective of the number of massless charged particles in the early universe.

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On Lorentz-invariant massive spin-2 theories

In this talk, we construct Lorentz-invariant massive spin-2
theories in a flat space-time. Starting from the most general action of a massive spin-2 field whose Lagrangian contains up to quadratic in first derivatives of a field, we investigate new possibilities by using the Hamiltonian analysis. By imposing degeneracy of the kinetic matrix and the existence of subsequent constraints, we classify theories based on the number of degrees of freedom and constraint structures and obtain a wider class of Fierz-Pauli theory as well as (partially) massless theories, whose vector and/or scalar degrees of freedom are absent. We also discuss the relation between our theories and known massive/massless spin-2 theories.

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Is GR Unique?

Probably not. I will introduce some different gravity theories which are as good as GR in the sense that all of constraints are first class and therefore a graviton has only 2 polarisations and the structure of the theory at low energies is thus expected to be stable against quantum corrections.

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Dirac analysis of cosmological perturbation theory.

I will talk about the Dirac procedure for constrained systems applied to the Arnowitt-Deser-Misner formalism linearized around the Friedmann-Lemaitre universe. I will employ some basic concepts such as Dirac observables, Dirac brackets, gauge-fixing conditions, reduced phase space, physical Hamiltonian and physical dynamics, and the canonical isomorphism between different gauge-fixed surfaces. The formalism is developed for the universe with a single fluid and then straightforwardly extended to the multi-fluid case. The obtained result is a starting point for future quantization of the cosmological perturbations and the cosmological background [arXiv:1810.11621].

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Gravitational waves and their footprints from primordial interactions

Detection of tensor mode fluctuations at the largest cosmological scales is often expected to provide a robust evidence of inflation and to fix the inflationary energy scale. Such direct connection is however applicable only when gravitational waves (GWs), the source of tensor perturbations, are effectively decoupled from other energy contents. However, spin-1 particles can be produced efficiently during inflation due to interactions, and their energy is then transferred to GWs already during inflation, giving a new source of GWs. Moreover, such GWs can have non-trivial correlations with curvature perturbations, which would otherwise be absent. I demonstrate detectable GW signals and discuss potentially observable correlations between tensor and scalar perturbations.

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Astrophysical Probes of Dark Matter

In this talk, I will introduce a novel model to explain the small structure observations of galaxies. This model contains ultralight bosonic fields and heavy fermionic particles as dark matter. The second part of talk will revisit the idea of femtolensing of gamma ray bursts, which has been put forward as an exciting possibility to probe exotic astrophysical objects with masses below 10^−13 solar masses such as small primordial black holes or ultra-compact dark matter minihalos.

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Probing the Dark Universe with Compact inspiraling Binaries

Abstract: Gravitational wave (GW) astronomy provides us a unique chance to probe invisible matter in the universe. In this talk we introduce several ways of probing dark ambient matter of compact binaries through GWs. We first present some analytical understanding of the distribution of binaries' orbital parameters and its relation to binaries' formation channels. Then, we describe how the barycenter motion of a binary, potentially visible to space GW telescopes, can serve as a direct probe of the ambient density. Finally, we show how the GWs from compact binaries can be used to probe/constrain dark matter with a long range force.

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Novel Ways to Hunt Axion Dark Matter: Observation and Experiment

Identification of dark matter has been an outstanding problem in
physics for decades, and axion (or axion like partciles) is its
candidate with great motivations. A number of observations and experiments have tried to detect axion by using the axion-photon conversion by assuming the axion is coupled to photon, while no signal yet to be found. In this talk, I will discuss new techniques to search for axion dark matter (ADM) by focusing on
another phenomena, birefringence, which is caused by the same coupling. The polarimetry observation of protoplanetary disks puts the best constraint on ADM for fuzzy dark matter mass ($m = 10^{-22}$eV). I also propose a laser-cavity experiment which can improve the constraint by several orders of magnitude in the intermidiate mass range (10^{-17}eV < m < 10^{-12}eV).

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New Weyl-invariant vector-tensor theory for the cosmological constant

In arXiv:1811.09547 we introduced an interesting new Weyl-invariant and generally-covariant vector-tensor theory with higher derivatives. This theory can be induced by extending the mimetic construction to vector fields of conformal weight four. We demonstrated that in gauge-invariant variables this novel theory reduces to the Henneaux–Teitelboim description of the unimodular gravity. Hence, compared with the standard general relativity, our new higher derivative vector-tensor theory has only one new global degree of freedom - the cosmological constant. Finally I will discuss potential extensions of this vector-tensor theory.

GWs, CMB, LLS… / 11

Dark energy, modified gravity in light of LIGO

I will review the problem of the acceleration of the expansion of the universe at late times and discuss how models of modifications of gravity can provide an alternative mechanism to the cosmological constant. I will discuss the space of models, how to best think about the generic effects these models have on structure formation and therefore how they can be constrained through observations. Finally, I will touch on the connection between cosmology, modified gravity and the predictions for gravitational waves and how the measurement of their speed has severely reduced the theory space.

GWs, CMB, LLS… / 12

On the Maximal Strength of a First-Order Electroweak Phase Transition and its Gravitational Wave Signal

What is the maximum possible strength of a first-order electroweak phase transition and the resulting gravitational wave signal? While naively one might expect that supercooling could increase the strength of the transition to very high values, for strong supercooling the Universe is no longer radiation-dominated and the vacuum energy of the unstable minimum of the potential dominates the expansion, which can jeopardize the successful completion of the phase transition. After providing a general treatment for the nucleation, growth and percolation of broken phase bubbles during a first-order phase transition that encompasses the case of significant supercooling, we study the conditions for successful bubble percolation and completion of the electroweak phase transition in various theories beyond the Standard Model. These conditions set a lower bound on the temperature of the transition, which in turn bounds the peak frequency of the GW signal from the phase transition to be f \gtrsim 10^{-4} Hz. Since the plasma cannot be significantly diluted, the resulting GW signal originates mostly from sound waves and turbulence in the plasma, rather than bubble collisions. We also study the condition for GW production by sound waves to be long-lasting (GW source active for approximately a Hubble time), showing it is generally not fulfilled in concrete scenarios. Because of this the sound wave GW signal could be weakened, with turbulence setting in earlier, resulting in a smaller overall GW signal as compared to current literature predictions.

GWs, CMB, LLS… / 13

Firewall controversy and the Euclidean path integral approach

The information loss problem in black hole physics is a very important but unresolved problem. I will review the issue including the recent discussion with the firewall controversy. Instead of the firewall conjecture or other candidates of resolutions, I will suggest that the Euclidean path integral sheds some lights to the problem.

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Charge fluctuations in SQED in power-law inflation

The rapid expansion of inflationary universe amplifies microscopic linear quantum fluctuations of non-conformally coupled fields such as the minimally coupled massless scalar, and generates large superhorizon correlators. On the other hand, conformally coupled fields such as the photon are insensitive to the expansion itself. However, if the photon couples to the complex scalar the effect of the rapid expansion can be mediated to the photon: Expansion induces large superhorizon correlators of charge currents of the scalar, which in turn induce correlators of electric and magnetic fields much larger than their tree level values. I will present recent results in scalar electrodynamics in power-law inflation.

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On spontaneous breaking of Weyl conformal geometry to Einstein gravity and its applications

We investigate the spontaneous breaking of Weyl conformal geometry to Einstein gravity in the presence/absence of matter with non-minimal couplings and possible applications to model building beyond SM.

GWs, CMB, LLS… / 18

On square roots of matrices in massive and bimetric gravity

The modern theory of ghost-free massive gravity hinges upon the notion of a square root of a matrix. This is non-trivial and not unique. It makes the standard perturbation theory in terms of matrices problematic, and in some cases even impossible. I will describe the mathematics behind these issues, and also discuss a method of dealing with perturbation theory around a given solution in terms of eigenvalues instead of matrices.