Autumn workshop on gravity and cosmology

Tuesday 12 November 2019 - Thursday 14 November 2019

Book of Abstracts

Contents

Reconstruct the history of the universe in f(T) gravity through observational data 1

On the uniqueness of general relativity 1

Cuscuton Gravity as a Classically Stable Limiting Curvature Theory 1

Thin shell wormhole associated with black holes and early universe 2

TBA 2

String Regge trajectory on de Sitter space and implications to inflation 2

Free discussion 2

Cosmology with compact phase space 2

Precision constraints for dark energy in the gravitational wave era 3

free discussion 3

The cosmological inconstant and Cartan's spiral staircase 3

novel matter coupling in Einstein gravity 4

2

Reconstruct the history of the universe in f(T) gravity through observational data

Describing the accelerating expansion of the universe and understanding its causes is an important part of modern cosmology. In order to better understand the evolution form and physical nature of accelerated expansion, it is necessary to combine observation with theory to constrain various dark energy models and modified gravity models. We reconstruct the f(T) gravity model with the latest observation data in order to find a suitable f(T) model which can relieve the tension of different cosmological observations. We will use the effective field theory approach to investigate the evolution equations on particular model that satisfies the observational constraints at the background and perturbation level.

3

On the uniqueness of general relativity

It is frequently quoted in the literature that general relativity is the only nonlinear theory that can be obtained from massless particles of spin 2. Anyway the technical assumptions behind this statement are not often scrutinized. I will discuss what happen when one of these assumptions is relaxed and I will argue that modern on-shell methods provide a convenient mathematical framework for the analysis of this problem. Finally, I will also discuss the role that soft theorems can play in this context.

4

Cuscuton Gravity as a Classically Stable Limiting Curvature Theory

Finding effective theories of modified gravity that can resolve cosmological singularities and avoid other physical pathologies such as ghost and gradient instabilities has turned out to be a rather difficult task. The concept of limiting curvature, where one bounds a finite number of curvature-invariant functions thanks to constraint equations, is a promising avenue in that direction, but its implementation has only led to mixed results. Cuscuton gravity, which can be defined as a special subclass of k-essence theory for instance, is a minimal modification of gravity since it does not introduce any new degree of freedom on a cosmological background. Importantly, it naturally incorporates the idea of limiting curvature as we will present. Accordingly, we show how models of cuscuton gravity possess non-singular cosmological solutions and how those appear stable at first sight. Yet, various subtleties arise in the perturbations such as apparent divergences, e.g., when the Hubble parameter crosses zero. We revisit the cosmological perturbations in various gauges and demonstrate that the stability results are robust even at those crossing points, although certain gauges are better suited to analyze the perturbations. We comment on the validity of the different gauges and present the behavior of the perturbations both in the ultraviolet and infrared. Finally, perturbations for a model of extended cuscuton (as a subclass of Horndeski theory) are also presented.

5

Thin shell wormhole associated with black holes and early universe

Using ideas of perturbation theories of brane cosmology, we first introduce a new method to judge the stabilities of a type of travelable wormholes, namely the thin-shell wormholes constructed by cutting-and-pasting two building-block spacetimes at arbitrary joining shell radius. Then, we will introduce some phenomenological aspects about the wormhole cosmology, especially focus on the scenario of thin-shell wormholes in inflating FLRW spacetimes.

6

TBA

7

String Regge trajectory on de Sitter space and implications to inflation

We study the spectrum of semiclassical rotating strings on de Sitter space and its consistency. Even though a naive extrapolation of the linear Regge trajectory on flat space implies a violation of the Higuchi bound (a unitarity bound on the mass of higher-spin particles in de Sitter space), the curved space effects turn out to modify the trajectory to respect the bound. Interestingly, there exists a maximum spin for each Regge trajectory as a consequence of accelerated expansion, which is helpful to make the spectrum consistent with the Higuchi bound, but at the same time it could be an obstruction to stringy UV completion based on an infinite higher-spin tower. By pushing further this observation, we demonstrate that the vacuum energy V inflating the universe has to be bounded by the string scale Ms as $V < M_s^4$, if UV completion is achieved by the leading Regge trajectory with higher spin states up to the 4D Planck scale. Its application to inflation at the early universe implies an upper bound on the tensor-to-scalar ratio, $r < 0.01 \times (M_s/10^{16} GeV)^4$, which is within the scope of the near future CMB experiments. We also discuss another possibility that UV completion is achieved by multiple Regge trajectories.

8

Free discussion

9

Cosmology with compact phase space

The kinematical phase space of classical gravitational field is flat (affine) and unbounded. In consequence, field variables may tend to infinity leading to appearance of singularities, which plague Einstein's theory of gravity. During the talk the idea of generalizing the theory of gravity by compactification of the phase space will be discussed. We investigate the procedure of compactification of the phase space on a minisuperspace gravitational model with two dimensional phase space. In the affine limit, the model reduces to the flat de Sitter cosmology. The phase space is generalized to the spherical case, and the case of loop quantum cosmology is recovered in the cylindrical phase space limit. Analysis of the dynamics reveals that the compactness of the phase space leads to both UV and IR effects. In particular, the phase of re-collapse appears, preventing the universe from expanding to infinite volume. Furthermore, the quantum version of the model is investigated and the quantum constraint is solved. An exemplary transition amplitude between initial and final state of the classical trajectory is determined

10

Precision constraints for dark energy in the gravitational wave era

In this talk I will sketch how combining new constraints from gravitational wave measurements, traditional observational bounds from cosmology and insights from theoretical particle physics allows us to test gravity with unprecedented precision, in particular zooming in on the nature of dark energy. As an explicit example, I will highlight the interplay between gravitational wave constraints from the neutron star merger GW170817, data constraints from cosmic microwave background and galaxy clustering measurements, and theoretical priors on dark energy theories from requiring them to be well-behaved and consistent at all energies.

11

free discussion

12

The cosmological inconstant and Cartan's spiral staircase

We review recent efforts to turn the cosmological constant into a dynamical variable without an ungainly proliferation of free parameters. In a cosmological setting where parity invariance is imposed (along with homogeneity and isotropy) this leads to phenomenological disaster. However, in this theory it is possible to construct parity violating Friedman models due to torsion, a re-enactment of "Cartan's spiral staircase". We examine the Hamiltonian structure of the 2 branches (parity compliant and parity violating) and conclude that they must correspond to different theories, with different numbers of degrees of freedom. Parity violation may save these models phenomenologically, giving observational relevance to the Pontryagin invariant (and possibly the Immirzi parameter) in cosmology. Preliminary work on gravity waves in these theories is briefly discussed.

13

novel matter coupling in Einstein gravity

The old school knowledge tells us that the matter can couple to Einstein gravity in either minimal or Brans-Dicke manner. Recently we discovered a novel type of matter coupling in Einstein gravity. This type of matter coupling is theoretically self-consistent in the sense that all constraints in the Hamiltonian are preserved to be first class. At low energy scale it recovers the classic standard predictions of Einstein gravity + minimal coupling, including the gravitational potential, equivalence principle and so on, while at the high energy scale much richer phenomenology is granted. We predict a universal lower bound on the cross section between dark matter particle and Standard Model particles in this framework. The novel matter coupling may provide a resolution to the cosmological singularity problem.

Ref: for Hamiltonian analysis, see P. A. M. Dirac, "Lectures on Quantum Mechanics" (Yeshiva University, New York 1964).