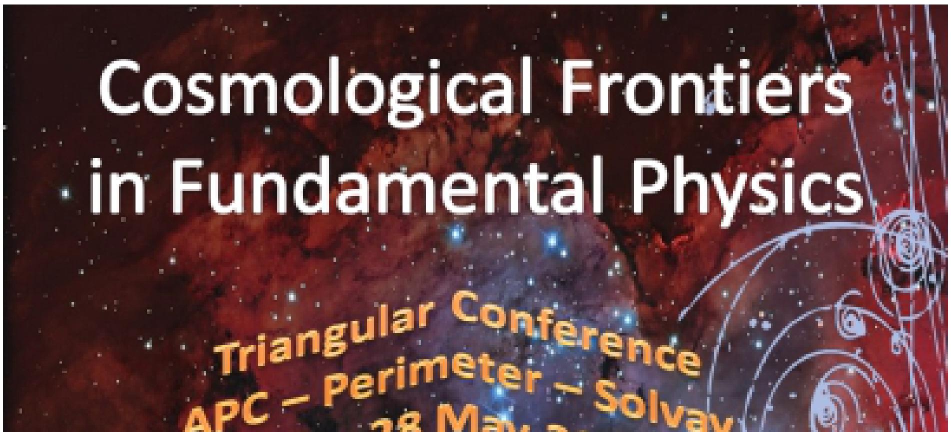
Cosmological Frontiers in Fundamental Physics Triangular Conference : APC - Perimeter - Solvay 2021

mardi 25 mai 2021 - vendredi 28 mai 2021



Recueil des résumés

Contents

First Session, Tuesday / 2

Hubble troubles

The distance ladder relying on supernovae yields higher values of the Hubble constant H0 than those inferred from the inverse distance ladder, calibrated on early-time physics and relying on observations typically involving cosmic microwave background (CMB) in combination with galaxy surveys. Such discrepancy has come to be known as the 'Hubble tension'. This has motivated the exploration of extensions to the standard cosmological model in which higher values of H0 can be obtained from CMB measurements and galaxy surveys. The trouble, however, goes beyond H0; such modifications affect other quantities too, such as cosmic times, age of the Universe and the matter density. Any Hubble trouble has implications well beyond H0 itself. I will recap some recent results and try to look at the tension in both a model-dependent and model independent way.

First Session, Tuesday / 3

A classification of Scalar-Tensor theories: applications to cosmology and astrophysics

The last few years have witnessed a great enthusiasm for modified theories of gravity and particularly for scalar-tensor theories. The motivations to modify gravity are to test the limits of general relativity on the one hand and also to propose "answers" to open questions of cosmology and astrophysics (for e.g. dark energy). In this context, many theories have emerged and a very complex landscape of theories has appeared in the literature. In this talk, I will show how we can clarify this landscape, classify some of these theories and how we can construct the most general tensor-scalar theories (aka DHOST theories) that are physically viable (in a precise sense that I will give). Finally, we will show how these modified theories can be applied to cosmology (to account for dark energy) and in astrophysics. We will also review their status in view of recent GW and other cosmological data.

First Session, Tuesday / 4

From scattering amplitudes to gravitational waves observables

The observation of gravitational waves by the LIGO/Virgo collaborations and the promise of future experiments underscores the need for increasingly more precise theoretical predictions. It has recently been demonstrated that scattering-amplitude techniques, originally developed for QCD calculations, can push the state of the art and provide results that are difficult to obtain by more standard means.
In this talk we will review aspects of scattering amplitudes that are relevant for gravitational wave physics and summarize the results for effective two-body Hamiltonians and for gravitational wave observables obtained through these methods.

Second Session, Tuesday / 5

Overview of LIGO and Virgo observations during the science run O3a

Advanced LIGO and advanced Virgo conducted their third science run O3 between April 2019 and March 2020. So far, the observations of the first six months of O3 have been reported and published with the catalog GWTC-2.
We will provide an overview of the contents of GWTC-2, which includes 39 candidate gravitational wave events associated with compact binary mergers.
These observations give new insights into the population compact stars (black holes or neutron stars)in the Universe.

Second Session, Tuesday / 6

Detecting Gravitational Waves Using the public LIGO-VIRGO data: Doubling the sample of Binary Black Hole Mergers

The LIGO-VIRGO data presents a magnificent opportunity for exploring the uncharted territory of binary compact objects.
We have developed an independent analysis pipeline for analyzing the public LIGO-VIRGO data from the first two observing runs. We have developed several novel techniques, and revisited all the choices essential for such an analysis. The resulting improvement (comparing to the LIGO-VIRGO official analysis) amounts to doubling the probed volume for binary black holes, and as a result, doubled the sample of detected events.
Among the newly discovered events are:
An event (GW170121) with substantial negative effective spin,
An event (GW151216) with maximal effective spin, inconsistent with dynamical formation.
An event (GW170817A) with source frame total mass of about a hundred solar masses, constraining the existence of any potential upper mass cutoffs.
I will also discuss the prospects for detecting systems of lensed GW events, what we learn from them, and present an intriguing candidate.
Last, I will briefly mention current and future projects including some future directions in GW astrophysics.

First session, Wednesday / 8

LiteBIRD: testing cosmic inflation from L2

The LiteBIRD satellite is a CMB mission targeting the B-mode polarization and the primordial gravitational waves signal that it is expected to carry. Scheduled for flight in the late 2020s, LiteBIRD will complement ground-based efforts by mapping angular scales and observational frequencies unreachable from the ground. In particular, LiteBIRD will constrain both the reionization and the recombination bump of the B-mode power spectrum, using its 15 frequency bands—ranging from 34 to 448 GHz—to reject the emission from the Galactic thermal dust and synchrotron. In this talk, I will give a status update on LiteBIRD, its potential to constrain inflation and the challenges it will have to face, with particular attention to the problem of Galactic foregrounds.

First session, Wednesday / 9

Through the veil of dust to inflation

An inflation-probing B-mode signal in the polarization of the cosmic microwave background (CMB) would be a discovery of utmost importance in physics. While recent BICEP results hinting upon the detection of such a signal rallied enthusiasm, Planck showed that this breakthrough is still out of reach, because of contamination from Galactic dust. To get to the primordial B-modes, we need to subtract polarized emission of magnetized interstellar dust with high accuracy. A critical piece of this puzzle is the 3-d structure of the magnetic field threading dust clouds, which cannot be accessed through microwave observations alone, since they record integrated emission along the line of sight. Instead, observations of a large number of stars at known distances in optical polarization, tracing the same CMB-obscuring dust, can map the magnetic field between them. The Polar Area Stellar Imaging in Polarization High Accuracy Experiment (PASIPHAE) will deliver such a map combining novel-technology wide-field-optimized optical polarimeters and an extraordinary commitment of observing time by the Skinakas observatory in Crete and the South African Astronomical Observatory. Such a map would not only boost CMB polarization foreground removal, but it would also have a profound impact in a wide range of astrophysical research, including interstellar medium physics, high-energy astrophysics, and galactic evolution.

First session, Wednesday / 10

Gauge fields in Inflation & Origin of Matter in the Universe

Modern cosmology profoundly involves particle theory beyond the Standard Model to explain long-standing puzzles: the origin of the observed matter asymmetry, nature of dark matter, massive neutrinos, and cosmic inflation. In this talk, I will explain that a new setup based on embedding axion-inflation in the gauge extensions of the SM can possibly solve and relate these seemingly unrelated mysteries of modern particle physics and cosmology. The baryon asymmetry and dark matter today may be remnants of a pure quantum effect (chiral anomaly) in inflation which is the source of CP violation in inflation. As a smoking gun, this setup has robust observable signatures for the GW background to be probed by future CMB missions and laser interferometer detectors.

Second Session, Wednesday / 11

Testing the Cosmological Principle

We study the large-scale anisotropy of the Universe by measuring the dipole in the angular distribution of a flux-limited, all-sky sample of 1.36 million quasars observed by the Wide-field Infrared Survey Explorer (WISE). This sample is derived from the new CatWISE2020 catalog, which contains deep photometric measurements at 3.4 and 4.6 μm from the cryogenic, post-cryogenic, and reactivation phases of the WISE mission. While the direction of the dipole in the quasar sky is similar to that of the cosmic microwave background (CMB), its amplitude is over twice as large as expected, rejecting the canonical, exclusively kinematic interpretation of the CMB dipole with a p-value of $5\times10-7$ (4.9σ for a normal distribution, one-sided), the highest significance achieved to date in such studies. Our results are in conflict with the cosmological principle, a foundational assumption of the concordance ΛCDM model.

Second Session, Wednesday / 12

New Advances with Type Ia Supernovae To Measure The Expansion of the Universe

Type Ia Supernovae (SNe Ia) are critical tools for measuring the current expansion rate of the universe, described by the Hubble Constant, and the accelerating expansion, due to a mysterious dark energy'. As measurements from SNe Ia continue to be important and exciting, there has been widespread interest on strengths and limitations of using SNe Ia in analyses. Here, I review the latest cosmological results using SNe Ia as well as systematic uncertainties and needed improvements for future analyses. I present a new key insight on the physics of SNe that addresses some of the most confounding issues of the last decade. I discuss the state of theHubble Constant Tension' and upcoming measurements of the local cosmic distance ladder. I then will transition to future experiments like LSST and WFIRST, and show forecasts of the amazing constraints on cosmological parameters with 100x the statistics of current samples.

First Session, Thursday / 13

A review of the status of dS vacua in string theory

I shall review the status of dS vacua in string theory in a (hopefully) pedagogical manner. Most of the talk will be about general principles and constraints. But in order to highlight the intricacies of dS model building I will address some details of the particular KKLT scenario.

First Session, Thursday / 14

Holographic routes to de Sitter space

Constructing cosmological solutions in the context of string theory has been notoriously elusive. In this talk I will discuss, from a bottom up point of view, possible ways of obtaining de Sitter/cosmological geometries based on the gauge/gravity duality. These methods are alternative to the standard route (finding a semiclassical vacuum solution of string theory with an effective positive vacuum energy), avoid some common pitfalls and problems, and can potentially be implemented as top-down string theory constructions. These solutions have a field theory dual description as non-vacuum states in (deformed) conformal field theories, and arise due to either non-trivial sources or non-trivial initial conditions.

First Session, Thursday / 15

Fast Radio Burst Physics & Cosmology

The detection of a Fast radio burst (FRB) in 2007 was a major unexpected discovery in astronomy in decades. Hunting for FRBs and measuring their physical properties have become one of the leading scientific goals in astronomy. It is well established that many FRBs are located at a distance of several billion lightyears, and therefore they are the brightest known transients in the universe in the radio band. Using very general arguments, I will show that the radio emission is coherent, and the magnetic field strength associated with the source of these events should be 10^{14}Gauss or more. Recently, an FRB was discovered in the Galaxy and it confirmed that at least some FRBs are associated with magnetars. I will describe my recent work regarding how the FRB radiation is produced and provide a unified picture for the weak Galactic FRB as well as the bright bursts seen at cosmological distances. I will discuss how FRBs can be used as a probe of the baryon distribution in the universe and for investigating the epoch of reionization.

Second Session, Thursday / 16

Enabling kSZ cosmology using Fast Radio Bursts

Sub-percent precision measurements of the kSZ effect – small-scale anisotropies in the CMB due to scattering off clouds of moving ionized gas – will be possible with upcoming CMB and galaxy surveys, so it is timely to ask what science can be extracted with such measurements. I will discuss how recasting kSZ tomography as a bispectrum measurement allows for a unified framework under which the "galaxy optical depth degeneracy" problem becomes clear; the cosmic velocity field and an astrophysical power spectrum involving the electron density appear together. However, these are degenerate only up to an overall amplitude. I will also discuss a way to break the optical depth degeneracy using the dispersion measures of fast radio bursts (FRBs) allowing for strong constraints on the growth of cosmic structure.

Second Session, Thursday / 17

FRB science results from CHIME

First Session, Friday / 18

A Timeless History of Time

Cosmological observations give us the unique opportunity to probe the fundamental laws of physics at very high energies as well as the perturbative regime of quantum gravity. Unfortunately, due to the creativity of theorists and the paucity of data about the primordial universe, there is a huge number of models compatible with all measurements, featuring a wide variety of mechanisms, symmetries, and spectra of particles.The reason can be traced back to the fact that we don't observe the time evolution during inflation, but only its final outcome. In this talk I will report on the recent progress in developing a completely new "bootstrap" approach to derive predictions from the very early universe that make no reference to time and the un-observable time evolution. The bootstrap approach builds directly upon the fundamental pillars of physics. In particular, I will present the recent breakthroughs in understanding the consequence of unitarity for cosmological correlators to all orders in perturbation theory, as well as the footprint of (bulk) locality. I will show how these principles can be used to derive many classical and new inflationary predictions associated with primordial non-Gaussianity in a way that is both computationally simpler and conceptually more transparent. This includes a reconstruction formula that relates de Sitter correlators to amplitudes for massless particles, cosmological partial-energy recursion relations and a "timeless" differential representation of the perturbative wavefunction. This approach makes no reference to de Sitter boosts, which are broken by a large amount in models that predict primordial non-Gaussianity at an observationally interesting level. Finally I speculate on how these results give us a handle on non-perturbative effects in cosmology either from cosmological positivity relations or from de Sitter holography.

First Session, Friday / 20

Forty years of the no-boundary proposal: a (subjective) status report

I will review the status of the no-boundary proposal, with a particular emphasis on definitions in minisuperspace. This setting allows one to shed light on how to define boundary conditions when the manifolds under consideration are not supposed to have a boundary. A similar situation is encountered for the canonical partition function in asymptotically AdS spaces, and the relation between the two settings will be highlighted. In view of the upcoming anniversary of the no-boundary proposal, I will undertake a comparison between early expectations and the current understanding.

First Session, Friday / 21

Relic neutrino detection through angular correlations in inverse ⊠-decay

Neutrino capture on beta-decaying nuclei is currently the only known potentially viable method of detection of cosmic background neutrinos. It is based on the idea of separation of the spectra of electrons or positrons produced in captures of relic neutrinos on unstable nuclei from those from the usual β-decay and requires very high energy resolution of the detector, comparable to the neutrino mass. In this talk I shall consider an alternative method of discrimination between neutrino capture and β-decay, based on periodic variations of angular correlations in inverse beta decay transitions induced by relic neutrino capture. The time variations are expected to arise due to the peculiar motion of the Sun with respect to the CνB rest frame and the rotation of the Earth about its axis and can be observed in experiments with both polarized and unpolarized nuclear targets. The main advantage of the suggested method is that it does not depend crucially on the energy resolution of detection of the produced β-particles and can be operative even if this resolution exceeds the largest neutrino mass.

Second Session, Friday / 22

Conformal symmetry: towards the link between the Fermi and the Planck scales

If the mass of the Higgs boson is put to zero, the classical Lagrangian of the Standard Model (SM) becomes conformally invariant (CI). Taking into account quantum non-perturbative QCD effects leads to electroweak symmetry breaking with the scale ~100 MeV which is three orders of magnitude less than it is observed experimentally. Depending on the mass of the top quark, the radiative corrections may lead to another minimum of the effective potential for the Higgs field with vev ⊠ MP, where MP is the Planck mass, at least 16 orders of magnitude more than it is observed. We explore yet another source of CI breaking associated with gravity. We suggest a non-perturbative mechanism that can reproduce the observed hierarchy between the Fermi and the Planck scales. The crucial role in this effect is played by a nonminimal coupling of the Higgs field to the Ricci scalar and the Palatini formulation of gravity.

23

Discussion Session. Gravitational wave detection

24

Discussion Session: The cosmological principle and the acceleration of the universe

25

Discussion Session: Cosmological uses of FRBs

26

Discussion Session: Important problems and prospects in Cosmology

27

Openning of the meeting/Welcome

28

First session

Auteur correspondant langlois@apc.univ-paris7.fr

29

Second Session

Auteur correspondant loucatos@apc.univ-paris7.fr