# Probing the early Universe with Gravity

# Rapport sur les contributions

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# Gravitational Birefrigence

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## Summary

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ID de Contribution: **1** Type: **Absracts**

# Measuring gravity using the CMB

We will discuss the effects that a modified sector tensor can produce on the polarisation CMB power spectra. Alternative theories of gravity can give the graviton a mass but also modify the dispersion relation of the gravitational waves. by A mass for the graviton can affect the large angular scales and in general a modified dispersion relation could change the position of the acoustic peaks. These effect modifies either the CMB power spectrum and bispectrum, with respect to the canonical case. Thus given the precision of the CMB experiments, if detected, primordial gravitational waves can help to constraint gravity at a much higher accuracy.

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ID de Contribution: **3** Type: **Absracts**

# The Geometrical Destabilization of Inflation

I will describe the consequences of a recently discovered instability at play in the early universe. The so-called Geometrical Destabilization of inflation is a general mechanism by which the curvature of the field space of inflationary models can dominate the stabilizing forces from the potential and destabilize inflationary trajectories. This instability is present in lots of concrete inflationary models in high-energy physics, although it is often overlooked, and potentially affects all of them. This phenomenon can prematurely end inflation, thereby leading to important observational consequences and sometimes excluding models that would otherwise perfectly fit the data. More generally, it radically modifies the interpretation of cosmological observations in terms of fundamental physics. I will also explain how the Geometrical Destabilization can lead to powerful selection criteria on the internal geometry of high-energy physics models.

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ID de Contribution: **4** Type: **Absracts**

# Gravitational birefringence of light at cosmological scales

The trajectory of light in a flat Robertson-Walker universe is presented taking due account of its spin. The off-set between the trajectories of positive and negative helicity states (birefringence) is of the order of a wave length and depends on the acceleration parameter. In 2008, using techniques of weak quantum measurement, an analogous birefringence in reflection, the Federov-Imbert effect, was observed for the first time. Observation of gravitational birefringence could offer an independent measurement of the acceleration of our universe.

Birefringence might also be induced by gravitational waves and allow for new detection techniques of these waves.

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ID de Contribution: **5** Type: **Absracts**

# Gravitational waves from oscillons after inflation

I will talk about the production of gravitational waves during preheating after inflation in the common case of field potentials that are asymmetric around the minimum. In particular, I will present a study of the impact of oscillons, comparatively long lived and spatially localized regions where a scalar field (e.g. the inflaton) oscillates with large amplitude. Oscillons in asymmetric potentials associated with a phase transition can generate a pronounced peak in the spectrum of gravitational waves, that largely exceeds the linear preheating spectrum. I will discuss the possible implications of this enhanced amplitude of gravitational waves. For instance, for low scale inflation models, the contribution from the oscillons can strongly enhance the observation prospects at current and future gravitational wave detectors.

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ID de Contribution: **6** Type: **Absracts**

# Primordial gravitational waves in supersolid inflation

Supersolid inflation corresponds a class of inflationary theories which spontaneously break both time and space reparameterization invariance during inflation. I will
discuss cosmological fluctuations in such scenarios, focussing on the dynamics of inflationary tensor modes, and including tensor
non Gaussianities. Tensor modes can have a blue spectrum, and primordial tensor non Gaussianities can be parametrically enhanced in the squeezed limit with respect to standard scenarios. At leading order in certain perturbative quantities, the tensor to scalar ratio depends on the parameter controlling the breaking of space reparameterization in de Sitter space: it is indepedent on the slow roll parameter $\epsilon$ which characterizes deviations from pure de Sitter space time. I will discuss observational consequences of these findings, and speculate on possible implications for detection of primordial gravitational waves.

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ID de Contribution: **7** Type: **Absracts**

# Cosmological perturbations and primordial black hole formation

Cosmological perturbations could collapse after horizon crossing giving rise to primordial black holes (PBHs) in the early universe if the perturbation amplitude is large enough to overcome a critical threshold depending on the equation of state and the density profile. In this talk I will present results coming from numerical simulations of PBH formation, where a time independent curvature profile has been used to generate initial conditions describing supra-horizon scale perturbations of a type which could have come from inflation. The connection between the abundance of PBHs constrained by the observations, and the critical amplitude calculated numerically, allows to understand more about the history of the early universe and the possible structures that could have been formed. The simulations shows that PBHs are characterised by critical collapse, with the mass spectrum described by a characteristic feature as a scaling law. I will show examples of simulations describing the collapse of perturbations, also when it is specified on top of a second perturbation with a larger scale.

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ID de Contribution: **8** Type: **Absracts**

# Gravitational waves in a bouncing cosmology from gauge field production

We calculate the gravitational waves (GW) spectrum produced in various Early Universe scenarios from gauge field sources, thus generalizing earlier inflationary calculations to bouncing cosmologies. We consider generic couplings between the gauge fields and the scalar field dominating the energy density of the Universe. Due to this coupling a sourced GW spectrum is generated. For certain coupling, the spectrum can be arbitrarily close to scale invariant (still slightly blue), that is distinguishable form the slightly red inflationary one. Hence we have a proof of concept of observable GW on CMB scales in a bouncing cosmology.

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ID de Contribution: **9** Type: **Absracts**

# A large stochastic GW background at interferometer scales from axion inflation

Axion inflation is a natural class of models of inflation, in which the flatness of the inflaton potential is protected
against quantum correction by an approximate shift symmetry. The symmetry highly constrains the couplings of the inflaton to other fields. The allowed coupling to vector fields produces an amplification of these fields, exponentially proportional to thespeed of the inflation. The amplified vector fields source primordial density perturbations and gravitational waves (GW). As the speed of the inflaton generally increases during inflation, these signal are naturally blue, and can grow to an observable amplitudeat interferometer scales. We will discuss under which conditions a visible signal can be obtained at LISA and LIGO scales, without at the same time overproducing primordial black holes. The GW background produced by this mechanism is chiral and highly non-gaussian. These properties may allow us to discriminate this signal against astrophysical backgrounds.

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ID de Contribution: **10** Type: **Absracts**

# Gravitational Waves from Networks of Cosmic Defects

I will discuss the irreducible emission of gravitational waves by any cosmic defect network, and its observational consequences.

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ID de Contribution: **11** Type: **Absracts**

# Can massive primordial black holes be the dark matter?

The recent detection by Advanced-LIGO/VIRGO of gravitational waves (GW) from the merging of binary black hole systems sets new limits on the merging rates of massive primordial black holes (PBH) that could be identified to the dark matter in the Universe. If PBH are regrouped in clusters with a similar density to the one observed in ultra-faint dwarf galaxies, merging rates are comparable to aLIGO expectations. Massive PBH dark matter predicts the existence of thousands of those dwarf galaxies where star formation is unlikely, which would possibly provide a solution to the missing satellite and too-big-to-fail problems. Such PBH could be produced in the early Universe, e.g. due to the collapse of large density fluctuations generated during a phase of hybrid inflation, a model easily embedded in high-energy frameworks such as supersymmetry and GUT. aLIGO and future GW antennas could be able measure the abundance and mass distribution of PBH in the range 5 - 200 solar masses to 10% accuracy, which could help to reveal their nature, with profound implications for cosmology and high energy physics. Moreover, the future LISA space interferometer will be able to detect the stochastic background of gravitational waves induced by PBHs, that could be distinguished from the GW background from stellar BH binaries due to a specific frequency dependance.

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ID de Contribution: **12** Type: **Absracts**

# The Quest for the Gravitational-Wave Stochastic Background

According to various cosmological scenarios, we are bathed in a stochastic background of gravitational waves generated in the first instants after the Big Bang. This background is based on the amplification of vacuum fluctuations during inflation, as well as on additional GW radiation produced in the final stages of inflation (for example in preheating models or models of axion inflation). Detection of this background would have a profound impact on our understanding of the evolution of the Universe, as it represents a unique window on the physical laws that apply at the highest energy scales, potentially up to the Grand Unified Theory (GUT) scale 10^16 GeV. Other models of cosmological GW background include phase transitions, cosmic (super)string models, and pre Big Bang models.
In addition to the cosmological background, an astrophysical background may have resulted from the superposition of a large number of unresolved sources since the beginning of stellar activity. This astrophysical contribution could be a foreground masking the cosmological background, but it can also provide very interesting informations, not only about the physical properties of the respective astrophysical populations, complementing individual GW detections, but also about the evolution of these objects with redshift, the star formation history or the metallicity.
In this talk, I will give an overview of the different sources and present the data analysis methods used in the LIGO/Virgo collaboration to measure the energy density of the GW background. I will also discuss how the future generation of detectors can be used to remove the astrophysical foreground in both earth and space detectors.

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ID de Contribution: **14** Type: **Absracts**

# On Primordial Gravity Waves from String Inflation

I will discuss the status and challenges of string they inflationary models, which can potentially produce detectable primordial gravitational waves. I will illustrate these aspects in terms of axion inflation in string theory models.

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ID de Contribution: **15** Type: **Absracts**

# Generalized Detection Algorithm for a SGWB with non-standard Polarizations

In this talk, we present a generalized algorithm for the detection of a stationary, isotropic and Gaussian SGWB with non-standard polarizations, as predicted by many alternative theories of gravity and cosmological models. We follow a frequentist approach that is suitable when no prior knowledge is available about alternative theories and hitherto unclear production mechanisms. We compute the statistical estimators needed to investigate the presence of the non-standard modes of polarization within this background. Also, we describe a generalized algorithm that allows the reconstruction of the detailed frequency dependence of the SGWB spectral density, improving upon the standard cross-correlation algorithm, which assumes power-law spectral densities. We will provide upper limits on the sensitivity to this background. Moreover, considering the predicted strain sensitivities form the scheduled Advanced detectors upgrades, we will present estimations on the SGWB sensitivities achievable in the near future, and we will compare the results with the predictions of some theoretical models of production.

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ID de Contribution: **16** Type: **Absracts**

# More Gravitational Waves from Axion Monodromy

One common feature of models of axion inflation is the existence of instantonic modulations, which can give rise to a series of local minima in the post-inflationary region of the potential. The inflaton can then populate more than one of these vacua inside a single Hubble patch, which corresponds to a dynamical phase decomposition. In the subsequent process of bubble wall collisions, the lowest-lying axionic minimum eventually takes over all of space. Our main result is that this violent process sources gravitational waves, very much like in the case of a first-order phase transition.

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