Campus UAB, c. Can Magrans s/n, 08193, Bellaterra, Barcelona
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*These conferences are organised in the framework of the Maria de Maeztu Thematic Cores, obtained this year by Prof. S. Nojiri*

# 10 Oct. Program

## 10:00-11:15 Alberto Lobo room

S. Nojiri

Department of Physics, Nagoya University, Nagoya, Japan, Kobayashi-Maskawa Institute for the Origin of Particles and the Universe, Nagoya University, Nagoya, Japan

**Modified Gravity Theories -Reconstruction and More - I**

Einstein's general relativity has been verified very accurately at the scale of the solar system and is consistent at the galactic and galaxy cluster scales, apart from the dark matter problem. Even on smaller scales, the inverse square law of force derived from general relativity has been verified to an accuracy of about 1/10,000 on the cm scale. Thus, general relativity describes nature very well, but when viewed as a quantum theory, general relativity cannot be regarded as the final theory of gravity due to the problems of non-renormalizability and loss of information due to black holes.

Discrepancies with quantum theory generally occur on the microscopic scale, but phenomena have been found on large scales that are difficult to explain with general relativity, such as the accelerated expansion of the current universe found at the end of the last century.

The unknown fluid that causes this accelerated expansion of the universe has been named "dark energy", and its elucidation is considered the biggest problem in physics this century.

In these lectures, I will introduce various modified gravity theories and explain how these theories can reproduce the expansion of the universe and how a spherically symmetric space-time like a black hole can be constructed as a verification of the modified gravity theory.

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## Lectures 1, 2.

**1. Introduction -- motivation and inevitability of modified gravity**

(a) Why modified gravity?

b) Scalar-Einstein gravity

(c) F(R)-gravity

(d) Scalar-Einstein-Gauss-Bonnet gravity

(e) Einstein-F(G) gravity

(f) Other modified gravity theories

**2. Universe evolution from modified gravity**

(a) Generalized Equation of State

(b) Scalar-Einstein gravity I

(c) Scalar-Einstein gravity II

(d) Scalar-Einstein-Gauss-Bonnet gravity

(e) Einstein-F(G) gravity

(f) F(R)-gravity I

(g) F(R)-gravity II

(h) F(R), F(G) v.s. $P(\phi)R + Q(\phi)$, $-V(\phi) + \xi(\phi)G$

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11.15-11:45 Alberto Lobo room

Martiros Khurshudyan, ICE-CSIC

**Learning new physics from the $H_0$ tension problem**

It is thought that the $H_0$ tension problem can be an indicator of new physics. This may seem to be an easy task to do. However, this is not the case, being one that strongly depends on the assumptions used to craft a theoretical model. In this talk, we will discuss some of our results on searching for a solution to this problem, using Machine Learning tools.

# 19 Oct. Workshop Program

10:00-13:00 – Conference hall of the Artificial Intelligence Research Institute (IIIA-CSIC). Campus UAB Carrer de Can Planas, Zona 2, 08193 Bellaterra

S.D. Odintsov, ICREA, ICE-CSIC, IEEC - **Presentation**

S. Nojiri

Department of Physics, Nagoya University, Nagoya, Japan, Kobayashi-Maskawa Institute for the Origin of Particles and the Universe, Nagoya University, Nagoya, Japan

**Modified Gravity Theories -Reconstruction and More – II**

Continued: Lectures 3,4.

**3. Novel black holes in modified gravity**

(a) Scalar-Tensor Theory

(b) Scalar-Einstein-Gauss-Bonnet gravity

(c) F(R) gravity

**4. Other topics**

(a) Gravitational waves

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(b) Compact stars

(c) Entropic structures

(d) Other topics

(e) Summary and discussion for future works

## J. Haro, UPC

**Reheating in non-oscillating backgrounds**

We present, for smooth non-oscillating backgrounds, an analytic formula which calculates the energy density of massive and massless particles created via gravitational particle production, thus giving the corresponding reheating temperature. It can be applied to models of quintessential inflation such as $\alpha$-attractors, and shows that for masses larger than the Hubble rate at the end of inflation, namely HEND, the reheating temperature is exponentially suppressed. On the contrary, for masses of the order of HEND one obtains a maximum reheating temperature of the order of 107 GeV. Finally, we present a way to overcome the constraints coming from the overproduction of gravitational waves in quintessential inflation.

## D. Sáez-Gómez, University of Valladolid

**Singularities in cosmology: a way to dodge them**

Space-time singularities arise naturally in General Relativity under very natural assumptions and show up the limits of GR, which is known to be not a complete theory at the UV regime. In cosmology, some new singularities have been found over the last decades, awakening the interest again on the way they occur. In this talk, I will give an overview on cosmological singularities and then will show how under some assumptions, some space-time observers might not feel any singularity versus others they do.

## E. Elizalde, ICE-CSIC, IEEC - **Closing remarks**