Final Report: CERN/FP/116398/2010

1 Overview

Proceeding earlier work developed separately by the members of the present group, this is a research project where we join efforts and which is aimed at further investigating the issues that we have put forward. Since this is a theoretical project we have utilised in our investigations a blend of analytical techniques and numerical simulations. In what follows we present a brief overview of the various approaches followed, and their inherent methods and models, and results obtained. In the following section, we outline a detailed description of the research carried out, and the papers produced throughout the effective duration of the project.

From the very start of the project, and especially during the first half of the project's duration, we have perform a detailed theoretical and phenomenological analysis of the relation between the 'effective' field yielding dark energy and non-canonical Lagrangians and non-linear gauge kinetic functions. Note that generalizations of the action functional can be approached in several ways. For instance, prescriptions consist in replacing the linear scalar curvature term in the Einstein-Hilbert action by a function of the scalar curvature, $f(R)$, or by more general scalar invariants of the theory, a class of theories often termed higher-order gravity theories. Another prescription consists in considering one (or more) scalar fields coupled to the geometry and playing a gravitational role. These theories are denoted scalar-tensor theories, or alternatively, non-minimal coupling theories.

In this context, throughout the duration of the project, infra-red modifications of General Relativity were extensively explored, where the consistency of various candidate models, including 4-dimensional modifications to the Einstein-Hilbert action, especially Guass-Bonnet modifications with a scalar field coupling, were be analyzed. All modified gravity theories induce observational signatures at the post-Newtonian level, which are translated by the parameterized post-Newtonian (PPN) metric coefficients arising from these extensions of GR. We refer the reader to the following section for a detailed description of all the models that were developed.

We have also analysed, in great detail, an interesting possibility that has passed unnoticed till quite recently which is to include a non-minimal coupling between the scalar curvature and the matter Lagrangian density. This produces an extra force with respect to the GR motion, as well as the non-conservation of the matter energy-momentum tensor. We have tested these models from modified gravity against astrophysical and laboratory measurements of the fine-structure constant, as well as laboratory and space-based Equivalence Principle experiments.

In the context of inflation in String Theory:

(i) In this topic we studied theories based on the large volume mechanism of Kahler moduli stabilisation in IIB flux compactifications on Calabi-Yau manifolds. The scalar field sector of the theory consists of many dynamical fields, however, it is common to find oversimplifications in the literature where it is assumed that all the fields but one (associated with the inflaton) are fixed at their minimum. It is of course desirable to go beyond this simplification and study the full dynamics. In particular, because the fields have non-canonical kinetic terms and therefore evolve along curved directions, we have verified whether this models can lead to large non-gaussianities in the CMB.

(ii) Previous studies of these models have focused on the flat directions of the potential. However, different realisations of inflation may arise in different regions of the potential. In particular, assisted inflation (where inflation is supported by the evolution of a large number of fields) may take place in regions where the potential is very steep. We have analysed if this mechanism can be implemented in these models, to establish the region of parameter space where it is valid and to estimate the number of fields that are required for assisted inflation to start off.

In the following section, we present a detailed description of the research carried out, and the papers produced throughout the effective duration of the project.

2 Detailed Report of Research and Publications

2.1 Hořava gravity

Recently, Hořava proposed a power counting renormalizable theory for (3+1)-dimensional quantum gravity, which reduces to Einstein gravity with a non-vanishing cosmological constant in IR, but possesses improved UV behaviors. The spherically symmetric black hole solutions for an arbitrary cosmological constant, which represent the generalization of the standard Schwarzschild-(A)dS solution, has also been obtained for the Hořava-Lifshitz theory. The exact asymptotically flat Schwarzschild type solution of the gravitational field equations in Hořava gravity contains a quadratic increasing term, as well as the square root of a fourth order polynomial in the radial coordinate, and it depends on one arbitrary integration constant. The IR modified Hořava gravity seems to be consistent with the current observational data, but in order to test its viability more observational constraints are necessary.

In [1], we considered the possibility of observationally testing Hořava gravity at the scale of the Solar System, by considering the classical tests of general relativity (perihelion precession of the planet Mercury, deflection of light by the Sun and the radar echo delay) for the spherically symmetric black hole solution of Hořava-Lifshitz gravity. All these gravitational effects can be fully explained in the framework of the vacuum solution of the gravity. Moreover, the study of the classical general relativistic tests also constrain the free parameter of the solution.

In [2], we analyzed the stability of the Einstein static universe by considering linear homogeneous perturbations in the context of an IR modification of Horava gravity, which implies a 'soft' breaking of the 'detailed balance' condition. The stability regions of the Einstein static universe were parameterized by the linear equation of state parameter $w = p/\rho$ and the parameters appearing in the Horava theory, and it was shown that a large class of stable solutions exists in the respective parameter space.

2.2 $f(R, L_m)$ gravity

In [3], we generalized the $f(R)$ type gravity models by assuming that the gravitational Lagrangian is given by an arbitrary function of the Ricci scalar R and of the matter Lagrangian

L_m. We obtained the gravitational field equations in the metric formalism, as well as the equations of motion for test particles, which follow from the covariant divergence of the energy-momentum tensor. The equations of motion for test particles can also be derived from a variational principle in the particular case in which the Lagrangian density of the matter is an arbitrary function of the energy-density of the matter only. Generally, the motion is non-geodesic, and takes place in the presence of an extra force orthogonal to the four-velocity. The Newtonian limit of the equation of motion was also considered, and a procedure for obtaining the energy-momentum tensor of the matter was presented. The gravitational field equations and the equations of motion for a particular model in which the action of the gravitational field has an exponential dependence on the standard general relativistic Hilbert–Einstein Lagrange density were also derived.

2.3 Braneworlds

In [4], the classical tests of general relativity (perihelion precession, deflection of light, and the radar echo delay) were considered for several spherically symmetric static vacuum solutions in brane world models. Generally, the spherically symmetric vacuum solutions of the brane gravitational field equations have properties quite distinct as compared to the standard black hole solutions of general relativity. As a first step a general formalism that facilitates the analysis of general relativistic Solar System tests for any given spherically symmetric metric was developed. It was shown that the existing observational Solar System data on the perihelion shift of Mercury, on the light bending around the Sun (obtained using long-baseline radio interferometry), and ranging to Mars using the Viking lander, constrain the numerical values of the parameters of the specific models.

2.4 Chern-Simons modified gravity

A promising extension of general relativity is Chern-Simons (CS) modified gravity, in which the Einstein-Hilbert action is modified by adding a parity-violating CS term, which couples to gravity via a scalar field.

In [5], we considered the interesting, yet relatively unexplored, dynamical formulation of CS modified gravity, where the CS coupling field is treated as a dynamical field, endowed with its own stress-energy tensor and evolution equation. We considered the possibility of observationally testing dynamical CS modified gravity by using the accretion disk properties around slowly-rotating black holes. The energy flux, temperature distribution, the emission spectrum as well as the energy conversion efficiency were obtained, and compared to the standard general relativistic Kerr solution. It was shown that the Kerr black hole provide a more efficient engine for the transformation of the energy of the accreting mass into radiation than their slowly-rotating counterparts in CS modified gravity. Specific signatures appear in the electromagnetic spectrum, thus leading to the possibility of directly testing CS modified gravity by using astrophysical observations of the emission spectra from accretion disks.

2.5 Dark spinor models in gravitation and cosmology

In [6], we introduced and carefully defined an entire class of field theories based on non-standard spinors. Their dominant interaction is via the gravitational field which makes them naturally dark; we refer to them as Dark Spinors. We provided a critical analysis of previous proposals for dark spinors noting that they violate Lorentz invariance. As a working assumption we restricted our analysis to non-standard spinors which preserve Lorentz invariance, whilst being non-local and explicitly construct such a theory. We constructed the complete energy-momentum tensor and derive its components explicitly by assuming a specific projection operator. It is natural to next consider dark spinors in a cosmological setting. We found various interesting solutions where the spinor field leads to slow roll and fast roll de Sitter solutions. We also analysed models where the spinor is coupled conformally to gravity, and considered the perturbations and stability of the spinor.

2.6 Chameleon Fields

Certain scalar-tensor theories exhibit the so-called chameleon mechanism, whereby observational signatures of scalar fields are hidden by a combination of self-interactions and interactions with ambient matter. Not all scalar-tensor theories exhibit such a chameleon mechanism, which has been originally found in models with inverse power run-away potentials and field independent couplings to matter.

2.6.1 Chameleons with Field Dependent Couplings

In [7], we investigated field-theories with field-dependent couplings and a power-law potential for the scalar field. We showed that the theory indeed is a chameleon field theory. We found the thin-shell solution for a spherical body and investigated the consequences for Eöt-Wash experiments, fifth-force searches and Casimir force experiments. Requiring that the scalar-field evades gravitational tests, we found that the coupling is sensitive to a mass-scale which is of order of the Hubble scale today.

2.6.2 Chameleon dark energy models with characteristic signatures

In chameleon dark energy models, local gravity constraints tend to rule out parameters in which observable cosmological signatures can be found. In [8], we studied viable chameleon potentials consistent with a number of recent observational and experimental bounds. A novel chameleon field potential, motivated by $f(R)$ gravity, is constructed where observable cosmological signatures are present both at the background evolution and in the growth-rate of the perturbations. We studied the evolution of matter density perturbations on low redshifts for this potential and showed that the growth index today γ_0 can have significant dispersion on scales relevant for large scale structures. The values of γ_0 can be even smaller than 0.2 with large variations of *gamma* on very low redshifts for the model parameters constrained by local gravity tests. This gives a possibility to clearly distinguish these chameleon models from the Lambda-Cold-Dark-Matter model in future high-precision observations.

2.7 Varying alpha from N-body Simulations

In [9], we studied the Bekenstein-Sandvik-Barrow-Magueijo (BSBM) model for the spatial and temporal variations of the fine structure constant, alpha, with the aid of full N-body simulations which explicitly and self-consistently solved for the scalar field driving the alpha-evolution. We focussed on the scalar field (or equivalently alpha) inside the dark matter halos and find that the profile of the scalar field is essentially independent of the BSBM model parameter. This means that given the density profile of an isolated halo and the background value of the scalar field, we can accurately determine the scalar field perturbation in that halo. We also derived an analytic expression for the scalar-field perturbation using the Navarro-Frenk-White halo profile, and showed that it agrees well with numerical results, at least for isolated halos; for non-isolated halos this prediction differs from numerical result by a (nearly) constant offset which depends on the environment of the halo.

2.8 ISW-LSS cross-correlation in coupled Dark Energy models with massive neutrinos

In [10], we provided an exhaustive analysis of the Integrated Sach–Wolfe effect (ISW) in the context of coupled Dark Energy cosmologies where a component of massive neutrinos is also presented. We focussed on the effects of both the coupling between Dark Matter and Dark Energy and of the neutrino mass on the cross-correlation between galaxy/quasar distributions and ISW effect. Theoretical predictions of the cross–correlation function were then compared with observational data. We found that, while it is not possible to distinguish among the models at low redshifts, discrepancies between coupled models and ΛCDM increase with z. In spite of this, current data alone seems not able to distinguish between coupled models and ΛCDM. However, we show that upcoming galaxy surveys will permit tomographic analysis which allow to better discriminate among the models. We compared three different tomographic schemes and investigate how the expected signal to noise ratio of the ISW–LSS cross–correlation changes when increasing the number of tomographic bins. We found that, by increasing the number of the bins from five to ten, practically no improvement is achieved in discriminating the different models.

2.9 CMB statistics in noncommutative inflation

Noncommutative geometry can provide effective description of physics at very short distances taking into account generic effects of quantum gravity. Inflation amplifies tiny quantum fluctuations in the early universe to macroscopic scales and may thus imprint high energy physics signatures in the cosmological perturbations that could be detected in the CMB.

It was shown in [11] that this can give rise to parity-violating modulations of the primordial spectrum and odd non-Gaussian signatures. The breaking of rotational invariance of the CMB provides constraints on the scale of noncommutativity that are competitive with the existing noncosmological bounds, and could explain the curious hemispherical asymmetry that has been claimed to be observed in the sky. This introduces also non-Gaussianity with peculiar shape- and scale-dependence, which in principle allows an independent cross-check of the presence of noncommutativity at inflation.

2.10 Constraining Entropic Cosmology

It has been recently proposed that the interpretation of gravity as an emergent, entropic force might have nontrivial implications to cosmology. In [12], two approaches were investigated: in one, the Friedman equation receives entropic contributions from the usually neglected surface terms, and in another, the extra terms are derived from quantum corrections to the entropy formula. UV terms may drive inflation, avoiding a recently derived no-go theorem, though in some cases leading to a graceful exit problem. IR terms can generate dark energy, alleviating the cosmological constant problem. The quantum corrections are bounded by their implications to the BBN, and the surface terms are constrained in addition by their effect upon the behavior of matter. Likelihood analyses are performed to constrain the modifications by the SNeIa, BAO and CMB data. It is found that a monomial correction to the area-entropy formula results in late acceleration in very good agreement with observations, which then turn out to be compatible with positive curvature. The evolution of perturbations is deduced by assuming the Jebsen-Birkhoff theorem. Distinct signatures can then be identified in the large scale structure formation. Furthermore, it is shown that the visible universe satisfies the Bekenstein bound.

2.11 Embedding DBI inflation in scalar-tensor theory

The Dirac-Born-Infeld (DBI) action has been widely studied as an interesting example of a model of k-inflation in which the sound speed of the cosmological perturbations differs from unity. In [13] article we consider a scalar-tensor theory in which the matter component is a field with a DBI action. Transforming to the Einstein frame, we explore the effect of the resulting coupling on the background dynamics of the fields and the first-order perturbations. We find that the coupling forces the scalar field into the minimum of its effective potential. While the additional scalar field contributes significantly to the energy density during inflation, the dynamics are determined by the DBI field, which has the interesting effect of increasing the number of efolds of inflation and decreasing the boost factor of the DBI field. Focusing on this case, we show, with the benefit of numerical examples, that the power spectrum of the primordial perturbations is determined by the behaviour of the perturbations of the modified DBI field.

2.12 Testing feasibility of scalar-tensor gravity by scale dependent mass and coupling to matter

In [14], we investigate whether there are any cosmological evidences for a scalar field with a mass and coupling to matter which change accordingly to the properties of the astrophysical system it "lives in", without directly focusing on the underlying mechanism that drives the scalar field scale-dependent- properties. We assume a Yukawa type of coupling between the field and matter and also that the scalar field mass grows with density, in order to overcome all gravity constraints within the solar system. We analyse three different gravitational systems assumed as "cosmological indicators": supernovae type Ia, low surface brightness spiral galaxies and clusters of galaxies. Results show that: a. a quite good fit to the rotation curves of low surface brightness galaxies only using visible stellar and gas mass components is obtained; b. a scalar field can fairly well reproduce the matter profile in clusters of galaxies, estimated by

X-ray observations and without the need of any additional dark matter; c. there is an intrinsic difficulty in extracting information about the possibility of a scale-dependent massive scalar field (or more generally about a varying gravitational constant) from supernovae type Ia.

2.13 Traversable wormhole geometries in modified theories of gravity

Traversable wormhole are primarily useful as "gedanken-experiments" and as a theoretician's probe of the foundations of general relativity. We also analyzed in great detail several classes of wormhole geometries in modified theories of gravity.

2.13.1 Wormhole geometries supported by a nonminimal curvature-matter coupling

Wormhole geometries in curvature-matter coupled modified gravity were explored in [15], by considering an explicit nonminimal coupling between an arbitrary function of the scalar curvature, R, and the Lagrangian density of matter. It is the effective stress-energy tensor containing the coupling between matter and the higher order curvature derivatives that is responsible for the null energy condition violation, and consequently for supporting the respective wormhole geometries. The general restrictions imposed by the null energy condition violation were presented in the presence of a nonminimal R-matter coupling. Furthermore, obtaining exact solutions to the gravitational field equations is extremely difficult due to the nonlinearity of the equations, although the problem is mathematically well-defined. Thus, we outlined several approaches for finding wormhole solutions, and deduce an exact solution by considering a linear R nonmiminal curvature-matter coupling and by considering an explicit monotonically decreasing function for the energy density. Although it is difficult to find exact solutions of matter threading the wormhole satisfying the energy conditions at the throat, an exact solution was found where the nonminimal coupling does indeed minimize the violation of the null energy condition of normal matter at the throat.

In [16], we also presented a solution where normal matter satisfies the energy conditions at the throat and it is the higher order curvature derivatives of the nonminimal coupling that is responsible for the null energy condition violation, and consequently for supporting the respective wormhole geometries. For simplicity, we considered a linear R nonmiminal curvature-matter coupling and an explicit monotonically increasing function for the energy density. Thus, the solution found is not asymptotically flat, but may in principle be matched to an exterior vacuum solution.

2.13.2 Possibility of hyperbolic tunneling

In [17], we analysed the possibility of having tunnels in a hyperbolic spacetime. We obtained exact solutions of static and pseudo-spherically symmetric spacetime tunnels by adding exotic matter to a vacuum solution referred to as a degenerate solution of class A. The physical properties and characteristics of these intriguing solutions were explored, and through the mathematics of embedding it was shown that particular constraints are placed on the shape function, that differ significantly from the Morris-Thorne wormhole. In particular, it was shown that the energy density is always negative and the radial pressure is positive, at the throat, contrary to the Morris-Thorne counterpart. Specific solutions were also presented by considering several equations of state, and by imposing restricted choices for the shape function or the redshift function.

2.13.3 General class of vacuum Brans-Dicke wormholes

Recently, traversable wormhole geometries were constructed in the context of $f(R)$ gravity. The latter is equivalent to a Brans-Dicke theory with a coupling parameter $w = 0$, which is apparently excluded from the narrow interval, $-3/2 < w < -4/3$, extensively considered in the literature of static wormhole solutions in vacuum Brans-Dicke theory. However, this latter interval is only valid for a specific choice of an integration constant of the field equations derived on the basis of a post-Newtonian weak field approximation, and there is no reason for it to hold in the presence of compact objects with strong gravitational fields.

In this context, in [18] we constructed a general class of vacuum Brans-Dicke wormholes that include the value of $w = 0$. Furthermore, we presented the general condition for the existence of vacuum Brans-Dicke wormhole geometries, and showed that the presence of effective negative energy densities is a generic feature of these vacuum solutions.

2.14 Nature of time and closed timelike curves

The conceptual definition and understanding of time, both quantitatively and qualitatively is of the utmost difficulty and importance. As time is incorporated into the proper structure of the fabric of spacetime, it is interesting to note that General Relativity is contaminated with non-trivial geometries which generate closed timelike curves. A closed timelike curve (CTC) allows time travel, in the sense that an observer that travels on a trajectory in spacetime along this curve, may return to an event before his departure. This fact apparently violates causality, therefore time travel and it's associated paradoxes have to be treated with great caution. The paradoxes fall into two broad groups, namely the consistency paradoxes and the causal loops. A great variety of solutions to the Einstein field equations containing CTCs exist and it seems that two particularly notorious features stand out. Solutions with a tipping over of the light cones due to a rotation about a cylindrically symmetric axis and solutions that violate the energy conditions. All these aspects are analyzed in this review paper [2.2.1].

2.15 The role of shell crossing on the existence and stability of trapped matter shells in spherical inhomogeneous Lambda-CDM models

In [19], we analysed the dynamics of trapped matter shells in spherically symmetric inhomogeneous Λ-CDM models. The investigation uses a Generalised Lemaître-Tolman-Bondi description with initial conditions subject to the constraints of having spatially asymptotic cosmological expansion, initial Hubble-type flow and a regular initial density distribution. We discuss the effects of shell crossing and use a qualitative description of the local trapped matter shells to explore global properties of the models. Once shell crossing occurs, we found a splitting of the global shells separating expansion from collapse into, at most, two global shells:

an inner and an outer limit trapped matter shell. In the case of expanding models, the outer limit trapped matter shell necessarily exists. We also studied the role of shear in this process, compare our analysis with the Newtonian framework and give concrete examples using density profile models of structure formation in cosmology.

2.16 Separating expansion from contraction in spherically symmetric models with a perfect-fluid

In [20], we investigated spherically symmetric perfect-fluid spacetimes and discussed the existence and stability of a dividing shell separating expanding and collapsing regions. We performed a $3+1$ splitting and obtained gauge invariant conditions relating the intrinsic spatial curvature of the shells to the Misner-Sharp mass and to a function of the pressure that we introduce and that generalizes the Tolman-Oppenheimer-Volkoff equilibrium condition. We found that surfaces fulfilling those two conditions fit, locally, the requirements of a dividing shell and we argued that cosmological initial conditions should allow its global validity. We analyzed the particular cases of the Lemaître-Tolman-Bondi dust models with a cosmological constant as an example of a cold dark matter model with a cosmological constant (Λ- CDM) and its generalization to contain a central perfect-fluid core. These models provide simple, but physically interesting illustrations of our results.

2.17 Self-interacting scalar field cosmologies: Unified exact solutions and symmetries

In [21], we investigated a mechanism that generates the exact solutions of scalar field cosmologies in a unified way. The procedure investigated in this work permits to recover almost all known solutions, and allows one to derive new solutions as well. In particular, we derived and discussed one novel solution defined in terms of the Lambert function. The solutions were organized in a classification which depends on the choice of a generating function which we have denoted by $x(\phi)$ that reflects the underlying thermodynamics of the model. We also analysed and discussed the existence of form invariances and dualities between solutions. A general way of defining the latter in an appropriate fashion for scalar fields is put forward.

2.18 Mass freezing in growing neutrino quintessence

Growing neutrino quintessence solves the coincidence problem for dark energy by a growing cosmological value of the neutrino mass which emerges from a cosmon-neutrino interaction stronger than gravity. The cosmon-mediated attraction between neutrinos induces the formation of large scale neutrino lumps in a recent cosmological epoch.

In [22], we argued that the non-linearities in the cosmon field equations stop the further increase of the neutrino mass within sufficiently dense and large lumps. As a result, we found the neutrino induced gravitational potential to be substantially reduced when compared to linear extrapolations. We furthermore demonstrated that inside a lump the possible time variation of fundamental constants is much smaller than their cosmological evolution. This feature may reconcile current geophysical bounds with claimed cosmological variations of the fine structure constant.

3 Publications

3.1 Articles in Research Journals – Published and in Press

1. **"Solar system tests of Hořava-Lifshitz gravity"**
   T. Harko, Z. Kovacs and F. S. N. Lobo
   Proceedings of the Royal Society A (2010), published online 24 Nov. 2010 [arXiv:0908.2874 [gr-qc]]

2. **"Stability of the Einstein static universe in IR modified Hořava gravity"**
   C. G. Boehmer and F. S. N. Lobo
   Eur. Phys. J. C **70**, 1111 (2010) [arXiv:0909.3986 [gr-qc]]

3. **"$f(R, L_m)$ gravity"**
   T. Harko and F. S. N. Lobo
   Eur. Phys. J. C **70**, 373 (2010) [arXiv:1008.4193 [gr-qc]]

4. **"Classical tests of general relativity in brane world models"**
   C. G. Boehmer, G. De Risi, T. Harko and F. S. N. Lobo
   Class. Quant. Grav. **27**, 185013 (2010) [arXiv:0910.3800 [gr-qc]]

5. **"Thin accretion disk signatures in dynamical Chern-Simons modified gravity"**
   T. Harko, Z. Kovacs and F. S. N. Lobo
   Class. Quant. Grav. **27**, 105010 (2010) [arXiv:0909.1267 [gr-qc]]

6. **"Dark spinor models in gravitation and cosmology"**
   C. G. Boehmer, J. Burnett, D. F. Mota and D. J. Shaw
   JHEP **1007**, 053 (2010) [arXiv:1003.3858 [hep-th]]

7. **"Chameleons with Field Dependent Couplings"**
   P. Brax, C. van de Bruck, D. F. Mota, N. J. Nunes and H. A. Winther
   Phys. Rev. D **82**, 083503 (2010) [arXiv:1006.2796 [astro-ph.CO]]

8. **"Chameleon dark energy models with characteristic signatures"**
   R. Gannouji, B. Moraes, D. F. Mota, D. Polarski, S. Tsujikawa and H. A. Winther
   Phys. Rev. D **82**, 124006 (2010) [arXiv:1010.3769 [astro-ph.CO]]

9. **"Varying alpha from N-body Simulations"**
   B. Li, D. F. Mota and J. D. Barrow
   Astrophys. J. **728**, 108 (2011) [arXiv:1009.1396 [astro-ph.CO]]

10. **"ISW-LSS cross-correlation in coupled Dark Energy models with massive neutrinos"**
    R. Mainini and D. F. Mota
    arXiv:1011.0083 [astro-ph.CO]

11. **"CMB statistics in noncommutative inflation"**
T. S. Koivisto and D. F. Mota
JHEP **1102**, 061 (2011) [arXiv:1011.2126 [astro-ph.CO]]

12. **"Constraining Entropic Cosmology"**
T. S. Koivisto, D. F. Mota and M. Zumalacarregui
JCAP **1102**, 027 (2011) [arXiv:1011.2226 [astro-ph.CO]]

13. **"Embedding DBI inflation in scalar-tensor theory"**
C. van de Bruck, D. F. Mota and J. M. Weller
JCAP **1103**, 034 (2011) [arXiv:1012.1567 [astro-ph.CO]]

14. **"Testing feasibility of scalar-tensor gravity by scale dependent mass and coupling to matter"**
D. F. Mota, V. Salzano and S. Capozziello
arXiv:1103.4215 [astro-ph.CO]

15. **"Wormhole geometries supported by a nonminimal curvature-matter coupling"**
N. M. Garcia and F. S. N. Lobo
Phys. Rev. D **82**, 104018 (2010) [arXiv:1007.3040 [gr-qc]]

16. **"Nonminimal curvature-matter coupled wormholes with matter satisfying the null energy condition"**
N. M. Garcia and F. S. N. Lobo
To appear in Classical and Quantum Gravity, arXiv:1012.2443 [gr-qc]

17. **"Possibility of hyperbolic tunneling"**
F. S. N. Lobo and J. P. Mimoso
Phys. Rev. D **82**, 044034 (2010) [arXiv:0907.3811 [gr-qc]]

18. **"General class of vacuum Brans-Dicke wormholes"**
F. S. N. Lobo and M. A. Oliveira
Phys. Rev. D **81**, 067501 (2010) [arXiv:1001.0995 [gr-qc]]

19. **"The role of shell crossing on the existence and stability of trapped matter shells in spherical inhomogeneous Λ-CDM models"**
M. L. Delliou, F. C. Mena and J. P. Mimoso
to appear in Phys. Rev. D, arXiv:1103.0976 [gr-qc]

20. **"Separating expansion from contraction in spherically symmetric models with a perfect-fluid: Generalization of the Tolman-Oppenheimer-Volkoff condition and application to models with a cosmological constant"**
J. P. Mimoso, M. Le Delliou and F. C. Mena
Phys. Rev. D **81**, 123514 (2010) [arXiv:0910.5755 [gr-qc]]

21. **"Self-interacting scalar field cosmologies: Unified exact solutions and symmetries"**
T. Charters and J. P. Mimoso
JCAP **1008**, 022 (2010) [arXiv:0909.2282 [hep-ph]]

22. **“Mass freezing in growing neutrino quintessence”**
N. Nunes, L. Schrempp and C. Wetterich
arXiv:1102.1664 [astro-ph.CO]

3.2 Book Sections

1. **“Closed timelike curves and causality violation”**
F. S. N. Lobo
arXiv:1008.1127 [gr-qc]
Invited chapter to appear in an edited collection ’Classical and Quantum Gravity: Theory, Analysis and Applications’

3.3 Conference Proceedings

1. **“f(G) modified gravity and the energy conditions”**
N. M. Garcia, T. Harko, F. S. N. Lobo and J. P. Mimoso
arXiv:1012.0953 [gr-qc]
Prepared for the proceedings of the Spanish Relativity meeting (ERE2010), Granada, Spain, 6-10 Sep 2010

2. **“Late-time cosmic acceleration: Dark gravity”**
F. S. N. Lobo
arXiv:1011.6176 [gr-qc]
Prepared for the proceedings of the Spanish Relativity meeting (ERE2010), Granada, Spain, 6-10 Sep 2010

3. **“Solar System tests of Hořava-Lifshitz black holes”**
F. S. N. Lobo, T. Harko and Z. Kovacs
arXiv:1001.3517 [gr-qc]
Talk presented at the II Workshop on Black Holes, Instituto Superior Tecnico, Lisbon, 21-22 December 2009

4. **“Unifying exact scalar field cosmologies”**,
J. P. Mimoso and T.Charters
J. Phys. Conf. Ser. 229, 012051 (2010)

5. **“An anti-Schwarzshild solution: wormholes and scalar-tensor solutions”**,
J. P. Mimoso and F. S. N. Lobo,
J. Phys. Conf. Ser. 229, 012078 (2010) [arXiv:1001.2643 [gr-qc]]

6. **“Separating expansion from contraction: generalized TOV condition, LTB models with pressure and Λ-CDM”**,
M. L. Delliou, F. C. Mena and J. P.Mimoso,
AIP Conf. Proc. 1241, 1011 (2010)

7. **“The variation of G in a negatively curved space-time”**
Prepared for the proceedings of the Joint European and National Astronomy Meeting (JENAM) 2010; based on a talk given by JPM in the ”From Varying Couplings to Fundamental Physics” Symposium, Lisbon, Portugal, Sep 2010

J. P. Mimoso and F. S. N. Lobo
arXiv:1101.4405 [gr-qc]