International workshop on

CPT and Lorentz Symmetry in Field Theory

Program & Abstracts

UAlg FCT
UNIVERSIDADE DO ALGARVE
FACULDADE DE CIÊNCIAS E TECNOLOGIA

FCT
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Program day 1:

8:45 - 9:15	Registration
9:15 - 9:30	Welcome

Session 1

9:30 - 10:00	Ian Drummond: *Lorentz Symmetry Breaking and Causality*
10:00 - 10:30	Diego Blas: *Horava gravity: motivation and status*
10:30 - 11:00	Coffee break

Session 2

11:00 - 11:30	Frans Klinkhamer: *On an anomalous origin of Lorentz and CPT violation*
11:30 - 12:00	Jay Tasson: *Gravity Lorentz Violation and Effective Field Theory*
12:00 - 12:30	Mauro Cambiaso: *Structural aspects of Lorentz-violating quantum field theory*
12:30 - 14:30	Lunch break

Session 3

14:30 - 15:00	Nikolaos Mavromatos: *Matter-antimatter asymmetry in the Universe via string-inspired CPT Violation at early eras*
15:00 - 15:30	Jorge Páramos: *Inflation with a massive vector field nonminimally coupled to Gravity*
15:30 - 16:00	Ralf Lehnert: *Constraining Lorentz Violation in Electroweak Physics*
16:00 - 16:30	Coffee break

Session 4

16:30 - 17:00	Jorge Alfaro: *Electroweak standard model with very special relativity*
17:00 - 17:30	Carlos Escobar: *Casimir effect within the Standard Model Extension framework*
19:00 - 21:00	Cocktail

Program day 2:

Session 5

9:30 - 10:00	Don Colladay: *Quantization of Space-like States in Lorentz-Violating Theories*
10:00 - 10:30	Jean Alexandre: *Symmetries in models containing non-Hermitian mass terms*
10:30 - 11:00	Coffee break

Session 6

11:00 - 11:30	Luís Urrutia: *Nambu models and their generalization*
11:30 - 12:00	Zhi Xiao: *Utilizing Lorentz violation Method to Constrain Nonmetricity*
12:00 - 12:30	Kevin Grosvenor: *Horava Gravity in 2+1 Dimensions*
12:30 - 14:30	Lunch break

Session 7

14:30 - 15:00	Orfeu Bertolami: *Recent developments on Phase-Space Noncommutative Quantum Mechanics*
15:00 - 15:30	Carlos Reyes: *Lorentz symmetry violation with higher-order operators*
15:30 - 16:00	Marco Schreck: *Vacuum Cherenkov radiation for Lorentz-violating fermions*
16:00 - 16:30	Coffee break

Session 8

16:30 - 17:00	Manoel Ferreira: *Proposing and Constraining Lorentz-violating and CPT-odd nonminimal couplings in the Electroweak sector*
17:00 - 17:30	Jacob Noordmans: *Tests of Lorentz and CPT symmetry with hadrons and nuclei*
17:30 - 18:00	Robertus Potting: *Cherenkov-like emisssion of weak gauge bosons in the SME*

ABSTRACTS:

Ian Drummond
Lorentz Symmetry Breaking and Causality
Session 1, 9:30-10:00

We consider the constraints imposed on Lorentz symmetry breaking by the requirements of causality in quantum field theory. We present the ideas in terms of scalar field theory and QED.

Diego Blas
Horava gravity: motivation and status
Session 1, 10:00-10:30

I'll review why Horava gravity may be a UV complete theory of gravity in 3+1 dimensions. My emphasis will be on where do we stand in the theoretical challenges and phenomenological bounds.

Frans Klinkhamer
On an anomalous origin of Lorentz and CPT violation
Session 2, 11:00-11:30

If there is Lorentz and CPT violation in Nature, then it is crucial to discover and understand the underlying mechanism. In this talk, we will discuss one such mechanism which relies on four-dimensional chiral gauge theories defined over a spacetime manifold with the topology R^3 x S^1. It can be shown that the effective gauge-field action contains a local Chern-Simons-like term which violates Lorentz and CPT invariance. This result is established perturbatively with a generalized Pauli-Villars regularization and nonperturbatively with a lattice regularization based on Ginsparg-Wilson fermions.

Jay Tasson

Gravity Lorentz Violation and Effective Field Theory

Session 2, 11:30-12:00

The full theory of Lorentz violation in linearized gravity has recently been developed. This presentation will summarize the features of this general framework. Basics of the philosophy and construction of effective field-theory studies of Lorentz violation will also be reviewed. Recent applications to LIGO results, gravitational Cherenkov radiation of cosmic rays, short-range gravity experiments, and post-newtonian tests will be discussed.

Mauro Cambiaso

Structural aspects of Lorentz-violating quantum field theory

Session 2, 12:00 - 12:30

In the last couple of decades the Standard Model Extension (SME) has emerged as a fruitful framework to analyse the empirical and theoretical extent of the validity of cornerstones of modern particle physic, namely, of Special Relativity and the transformation properties under C, P, T (or some combinations of these). Up to date no violation of these symmetry principles has been observed. The SME allows to contrast high-precision experimental tests with posited alterations representing minute Lorentz and/or CPT violations. From such analyses, bounds on the extent of departures from Lorentz and CPT symmetries can be obtained with ever increasing accuracy. These analyses have been mostly focused on tree-level processes. In this presentation I would like
to comment on structural aspects of perturbative Lorentz violating quantum field theory. I will show that some insight coming from radiative corrections demands a careful reassessment of perturbation theory. Specifically I will argue that both the standard renormalization procedure as well as
the Lehmann-Symanzik-Zimmermann reduction formalism need to be adapted given that the asymptotic single-particle states can be receive quantum corrections by Lorentz-violating operators that are not present in the original Lagrangian.

Nikolaos Mavromatos

Matter-antimatter asymmetry in the Universe via string-inspired CPT Violation at early eras

Session 3, 14:30 - 15:00

In four-space-time dimensional string/brane theory (obtained either after compactification, or appropriate restriction to brane worlds with three large spatial dimensions) the rich physics potential associated with the presence of non-trivial Kalb-Ramond (KR) axion-like fields has not been fully explored so far. In this talk, I discuss a scenario whereby such fields produce (spontaneous) Lorentz-violating cosmological backgrounds over which strings propagate, which in the early Universe can lead to baryogenesis through leptogenesis in models with heavy right-handed neutrinos. The latter acquire their masses also through interactions with the KR axions, provided a mixing with ordinary axion fields (that are abundant in string models) occurs in an appropriate manner. Some elementary phenomenology of such class of models is briefly discussed.

Jorge Páramos

Inflation with a massive vector field nonminimally coupled to Gravity

Session 3, 15:00 - 15:30

We assess the possibility that inflation is driven by a massive vector field with SO(3) global symmetry nonminimally coupled to gravity: given an adequate Ansatz for the vector field, we study the behavior of the ensuing dynamical system to find exponential inflationary solutions. As expected, these depend on the mass of the vector field and the strength of its non-minimal coupling with both the Ricci scalar and tensor.

Ralf Lehnert

Constraining Lorentz Violation in Electroweak Physics

Session 3, 15:30 - 16:00

For practical reasons, the majority of past Lorentz test has involved stable or quasistable particles, such as photons, neutrinos, electrons, protons, and neutrons. Similar effort in the electroweak sector have only recently taken shape. Within this context, Lorentz-violation searches in the Standard-Model Extension's Z-Boson sector will be discussed. It is argued that existing precision data on polarized electron-electron scattering can be employed to extract the first conservative two-sided limits on Lorentz breakdown in this sector at the level of 10^{-7}.

Jorge Alfaro

Electroweak standard model with very special relativity

Session 4, 16:30 - 17:00

The very special relativity electroweak Standard Model (VSR EW SM) is a theory with SU(2)_L x U(1)_R symmetry, with the same number of leptons and gauge fields as in the usual Weinberg-Salam model. No new particles are introduced. The model is renormalizable and unitarity is preserved. Besides, neutrino masses are generated. A VSR-invariant term will produce neutrino oscillations and new processes are allowed. In particular, we compute the rate of the decays $\mu \rightarrow e + \gamma$. All these processes, which are forbidden in the electroweak Standard Model, put stringent bounds on the parameters of our model and measure the violation of Lorentz invariance.
Violations of Lorentz invariance have been predicted by several theories of quantum gravity [J. Alfaro, H. Morales-Tecotl, and L. F. Urrutia, Phys. Rev. Lett. 84, 2318 (2000); Phys. Rev. D 65, 103509 (2002)]. It is a remarkable possibility that the low-energy effects of Lorentz violation induced by quantum gravity could be contained in the nonlocal terms of the VSR EW SM.

Carlos Escobar

Casimir effect within the Standard Model Extension framework

Session 4, 17:00 - 17:30

In this talk we present a local approach to study the Lorentz violation effects of the minimal standard model extension on the Casimir force between two parallel conducting plates in the vacuum. Using a perturbative method similar to that used for obtaining the Born series for the scattering amplitudes in quantum mechanics, we compute, at leading order in the Lorentz-violating coefficients, the relevant Green's function which satisfies given boundary conditions. Employing standard point-splitting techniques we express the vacuum expectation value of the stress-energy tensor in terms of the Green's function. We discuss its structure in the region between the plates. We compute the renormalized vacuum stress and Casimir force. We also derive the local Casimir energy, which is found to diverge as approaching the plates, and we demonstrate that it does not contribute to the observable force.

Don Colladay
Quantization of Space-like States in Lorentz-Violating Theories
Session 5, 9:30 - 10:00

Lagrangians in Lorentz-violating theories can be related to relativistic extended hamiltonians that yield formulas for the four-velocity of wave packets. These hamiltonians can be used to re-express the field expansions and phase-space factors in terms of observer covariant expressions that remain well-defined even when the energy of the states go negative in certain reference frames. This allows for consistent quantization of certain theories involving space-like momentum states that can yield consistent calculations of processes such as Cherenkov radiation without encountering typical divergent factors normally associated with non-concordant reference frames.

Jean Alexandre
Symmetries in models containing non-Hermitian mass terms
Session 5, 10:00 - 10:30

Discrete and continuous symmetries are essential to understand the consistency of non-Hermitian models. This is shown for two free models involving non-Hernitian mass terms: one model with two coupled complex scalars, and the other with one fermion flavour. An emphasis is given on: (i) the relation between discrete symmetries and the equations of motion; (ii) the existence of conserved current without symmetry for the Lagrangian.

Luís Urrutia
Nambu models and their generalization
Session 6, 11:00 - 11:30

We review some aspects of Lorentz invariant violating theories from the point of view of the spontaneous breaking of the Lorentz symmetry, focusing on the Nambu models. To begin with we consider the abelian Nambu model (ANM). We show how the Lorentz symmetry is recovered from the ANM by imposing current conservation and demanding the Gauss law as an initial condition in the dynamics . In this case we recover Electrodynamics in its gauge invariant version, independently of the constraint which defines de ANM. The procedure and results applies to the Yang- Mills and linearized gravity cases. Finally, we introduce a generalization of the Nambu models (ENM), starting from a very general class of gauge theories and taking also an arbitrary (up to some general regularity conditions) constraint among the coordinates of the gauge theory to define the ENM. We show that the same two previously stated conditions in the U(1) case allow us to recover the initial gauge theory from the ENM.

Zhi Xiao
Utilizing Lorentz violation Method to Constrain Nonmetricity
Session 6, 11:30 - 12:00

In this talk, I will give first constraints on in-matter nonmetricity. I will show how the effective field theory toolbox developed for the study of Lorentz violation (LV) can be employed for investigations of the "effective LV" background caused by nonmetricity, a geometric object extending the notion of a Riemannian manifold. The idea is to probe for the effects of spacetime nonmetricity sourced by liquid ^{4}He with polarized slow neutrons. I present the first constraints on isotropic and parity-odd nonmetricity components. Further constraints on anisotropic nonmetricity components within this EFT framework may be feasible with proper experimental techniques in the near future.

Kevin Grosvenor
Horava Gravity in 2+1 Dimensions
Session 6, 12:00 - 12:30

We study the phases of FLRW solutions of projectable Horava gravity in 2+1 dimensions and the implications of recent RG calculations on the phase diagram.

Orfeu Bertolami
Recent developments on Phase-Space Noncommutative Quantum Mechanics
Session 7, 14:30 - 15:00

In this talk we shall review on the main features of phase-space quantum mechanics, most particularly on issues such as entanglement and uncertainty relations; implications for quantum cosmology and Schwarzschild black holes will also be discussed.

Carlos Reyes

Lorentz symmetry violation with higher-order operators

Session 7, 15:00 - 15:30

The renormalization in a Lorentz-breaking scalar-spinor higher-derivative model involving the Yukawa-like coupling is studied. We explicitly demonstrate that the convergence is improved in comparison with the usual scalar-spinor model. We compute the one-loop corrections to the propagators for the scalar and fermionic fields and show that in the presence of higher-order Lorentz invariance violation, the poles that dominate the physical theory, are driven away from the standard on-shell pole mass due to radiatively induced lower dimensional operators. The new operators change introduce large Lorentz-breaking corrections and lead to modifications in the renormalization conditions of the theory. We found the physical pole mass for the scalar and fermion two-point functions.

Marco Schreck

Vacuum Cherenkov radiation for Lorentz-violating fermions

Session 7, 15:30 - 16:00

Whenever the electromagnetic sector is affected by Lorentz violation, a charged, massive fermion may lose energy in vacuo by radiating photons. The origin of this process can be traced back to the nontrivial refractive index of a Lorentz-violating vacuum, which opens the phase space for this otherwise forbidden decay. Due to its resemblance to ordinary Cherenkov radiation in media, it is referred to as vacuum Cherenkov radiation. This decay has been investigated extensively for modified photons, but it can occur in the presence of Lorentz violation in the fermion sector, too, where an extensive study of this scenario had been missing, so far. To complement our understanding, vacuum Cherenkov radiation has lately been considered for fermions that are subject to Lorentz-violating modifications of the minimal Standard-Model Extension (SME). The current talk focuses on giving a summary of the most significant findings. The process is investigated by computing the decay rates and radiated-energy rates at tree level. Thereby, recent studies of a modified Dirac theory enable a convenient evaluation of the matrix element square. The integration over phase space is carried out numerically, and certain asymptotic regimes are considered analytically. A broad spectrum of Lorentz-violating frameworks is analyzed ranging over all classes of coefficients that the SME fermion sector comprises. The studies involve both processes with and without a spin-flip of the incoming fermion. The talk is concluded on by discussing new constraints on Lorentz violation in the fermion sector based on the obtained theoretical results and experimental data of ultra-high energy cosmic rays detected on Earth.

Manoel Ferreira

Proposing and Constraining Lorentz-violating and CPT-odd nonminimal couplings in the Electroweak sector

Session 8, 16:30 - 17:00

In this talk, we propose two possibilities of CPT-odd and Lorentz-violating (LV) nonminimal couplings in the Electroweak sector. These terms are gauge-invariant and couple a fixed 4-vector to the physical fields of the theory. After determining the LV contributions to the electroweak currents, we reassess the evaluation of the decay rate for the vector mediators W and Z. Using the experimental uncertainty in these decay rates, upper bounds of 10^{-15} $(\text{eV})^{-1}$ and 10^{-14} $(\text{eV})^{-1}$ are imposed on the magnitude of the proposed nonminimal interactions.

Jacob Noordmans

Tests of Lorentz and CPT symmetry with hadrons and nuclei

Session 8, 17:00 - 17:30

Some theories of quantum gravity allow for the possibility of the breakdown of Lorentz and CPT symmetry. At presently attainable energies, the consequences of the (high-energy) breakdown of these fundamental symmetries are best described by an effective field theory approach, called the standard model extension (SME). To explore the breaking of Lorentz and CPT invariance in strong interactions, we apply the machinery of chiral perturbation theory to the SME. We derive the effective chiral Lagrangian with hadronic and electromagnetic interactions in terms of the effective degrees of freedom (pions, photons, and nucleons), corresponding to a selected set of Lorentz and CPT-violating operators. We derive strict limits on some of the tensors that quantify the symmetry breaking. We also point to possible new opportunities for studying Lorentz and CPT violation, using chiral perturbation theory.

Robertus Potting

Cherenkov-like emisssion of weak gauge bosons in the SME

Session 8, 17:30 - 18:00

We investigate possible consequences of CPT and Lorentz violation in the electroweak gauge sector of the Standard Model in the context of the Standard-Model Extension. In particular, we consider the Lorentz-violating and CPT-odd Chern-Simons like parameter for the W boson, which is thus far unbounded by experiment. Any non-zero value of this parameter implies that, for sufficiently large energies, one of the polarization modes of the W boson propagates with spacelike four-momentum. In this scenario, emission of W bosons by ultra-high-energy cosmic rays is possible. We calculate the induced fermion energy-loss rate and we deduce the first limit on the pertinent Lorentz- and CPT-violating parameter that couples to the W boson.