Searching for Quantum Gravity in the Sky

a Bad Honnef Physics School

Book of Abstracts

Quantum gravity phenomenology - The past, the now and the future 2
Theory and observables within deformed relativity 3
The search for time delays in GRB and AGN observations 4
Quantum gravity effects on astroparticle propagation: interaction threshold effects 5
Data analysis for anomalous threshold reactions 6
Reaching the boundaries of general relativity - Tensions in Cosmology 7
Searching for quantum gravity in the lab, instead of the sky 8

Quantum gravity phenomenology - The past, the now and the future

Christian Pfeifer (University of Bremen)

Theory and observables within deformed relativity

Giacomo Rosati (University of Wrocław)

I will review the basic ideas behind the deformation of relativistic symmetries (DSR approach), give some practical examples, and compare this approach with the one in which relativistic symmetries are broken at the Planck scale, i.e. the so-called Lorentz Invariance Violation (LIV) scenario.
I will then focus on how some particular observables, like time delays in the propagation of ultra-high energy astrophysical particles, are obtained in the DSR scenario

The search for time delays in GRB and AGN observations

Jelena Strišković (Josip Juraj Strossmayer University of Osijek)

Quantum gravity effects on astroparticle propagation: interaction threshold effects

Rafael Alves Batista (Sorbonne Université)

This lecture series explores the search for quantum gravity (QG) effects using astroparticle probes. The first lecture provides a comprehensive introduction, detailing how to model the transport of astroparticles in various astrophysical environments. It will cover fundamental concepts such as cross sections, mean free paths, and key interaction processes that influence gamma rays, cosmic rays, and neutrinos. The second lecture focuses on deviations from the standard picture presented in the first lecture, illustrating how QG effects alter the propagation of astroparticles. Special emphasis will be placed on how interaction thresholds are modified due to QG effects. The final lecture deals with advanced modelling techniques that can be employed for this type of study, specifically transport equations and Monte Carlo methods, and presents several astrophysical scenarios as case studies for detecting potential QG signals.

- Lecture 1: Introduction and the Basics
    - Overview of the lecture series and objectives
    - Importance of studying quantum gravity effects on astroparticle propagation
    - Modelling the propagation of astroparticles
        - relevant ingredients for model-building
    - Review of particle interactions
        - cross sections
    - mean free paths
    - Interaction processes relevant for astroparticle propagation
        - threshold computations
        - examples of threshold calculations
        - examples of interactions (pair production, Compton scattering, photopion production, etc)
    - Importance of these interactions in the context of astroparticle propagation
- Lecture 2: Particle interactions and QG phenomenology
    - Departing from the standard picture: QG effects
        - Lorentz invariance violation (LIV)
        - deformed special relativity (DSR)
    - (Re-)computing interaction thresholds
    - Revisiting relevant interactions
    - Expected observational signatures:
        - high-energy gamma rays
        - ultra-high-energy cosmic rays
        - high-energy neutrinos
- Lecture 3: Modelling astroparticle propagation with QG effects
    - Numerical methods
        - transport equations
        - Monte Carlo methods
    - Case studies
        - gamma-gamma pair production
        - photodisintegration of cosmic rays
    - Confronting models and observations
        - expected signals

        - uncertainties
    - Summary and conclusions

Data analysis for anomalous threshold reactions

Caterina Trimarelli (University of Geneva)

The analysis of data related to anomalous threshold reactions is a crucial tool for investigating potential signals of new physics in the context of quantum gravity phenomenology. These reactions, which manifest as deviations from expected behavior in the energy threshold for certain particle interactions, can provide key insights into modifications of dispersion relations for various cosmic messengers, including photons, neutrinos, gravitational waves, and cosmic rays. This lecture will focus on models based on modified dispersion relations and how these models are compared with observational data to test their consistency and constrain possible new physics. The methodologies for identifying and quantifying deviations from standard predictions will be discussed, with an emphasis on how data analysis can refine or challenge these theoretical models.

Reaching the boundaries of general relativity - Tensions in Cosmology

Jackson Levi Said (University of Malta)

Searching for quantum gravity in the lab, instead of the sky

Flaminia Giacomini (ETH Zürich)

This lecture offers a complementary perspective on where we may observe quantum effects in gravity. In particular, we will focus on the study of gravitating quantum systems, for instance a massive quantum system prepared in a quantum superposition of positions and sourcing a gravitational field.
This scenario has recently attracted a lot of attention: experiments are working towards realising macroscopic quantum superpositions of gravitational sources in the laboratory, and it is expected that measuring the gravitational field associated to a quantum source will give information about some quantum aspects of gravity. However, there are still open questions concerning the precise conclusions that these experiments could draw on the nature of gravity, such as whether experiments in this regime will be able to test more than the Newtonian part of the gravitational field.
In my lecture, I will first give a broad introduction to the field and present the most discussed physical situations. Then, I will argue that quantum information tools, such as theorems and communication protocols, can play an important role in identifying these effects and clarifying in which sense they are quantum. Finally, I will provide a personal perspective on why a theoretical study is needed to plan a new generation of experiments testing quantum aspects of gravity in a broader sense than what proposed so far.