The design of a Master Thesis: the usage of ChatGPT

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(curso organizado y supervisado con Pilar Hernández)

Using AI to write

- It is impossible to assess the impact of generative AI on the actual production of scientific material

- Currently, there are no formal rules to forbid or regulate the usage of generative AI. In particular, to my knowledge, the Universitat de València has no specific policy against or in favour of the usage of generative AI in Master Theses, the subject of this course.

- The UV promotes courses on the subject: https://www.uv.es/uvweb/servicio-formacion-permanente-innovacion-educativa/es/oferta-formativa/chatgpt-and-artificial-intelligence-using-new-tools-in-higher-education-1286213964422/PDIFormacio.html?id=1286312929980

My personal opinion

- The objective of this course has always been to help you to understand HOW to organise the material of your research. I stressed in Class 1:

We are not teaching you to write

We are not teaching you the language you use to write:
scientists write in a non-uniform language that approximately resembles English

We are not teaching you physics

My personal opinion

- The objective of this course has always been to help you to understand HOW to organise the material of your research. I stressed in Class 1:

We are not teaching you to write:

however, ChatGPT may help you in writing sentences that can express what you want you say and you do not know how

We are not teaching you the language you use to write:

however, ChatGPT may help you in writing sentences that are in correct English (instead of writing in your own language and then translating into english)

We are not teaching you physics:

ChatGPT neither!

My personal opinion, 2

- I would use generative AI to start sentences that covers general statements, mainly in the Introduction or in Chapters that report non-original material

- I would carefully revise what the AI has written, trying to merge it smoothly with sentences I have written from scratch. I would correct errors, I would change slightly the sentences (according to my level of English), or I would ask it to rewrite a sentence with different wording, in order to get to “my optimum”.

- I would not ask the AI to write sentence regarding my own results.

Could you please write me an index of around 5 chapters on the subject of minimal extra dimensions?

Here's a potential index for a research paper or thesis on the subject of Minimal Extra Dimensions:

I. Introduction

* 1.1 Background and Context
  + Overview of the concept of extra dimensions in physics and cosmology
  + Importance of minimal extra dimensions in resolving long-standing problems in particle physics and cosmology
* 1.2 Research Questions and Objectives
  + Definition of minimal extra dimensions (MED)
  + Goals of the research: to investigate the implications of MED on our understanding of the universe

II. Theoretical Framework

* 2.1 Braneworld Scenarios and RS1 Models
  + Overview of braneworld scenarios, including the Randall-Sundrum (RS) model
  + Discussion of RS1 models as a minimal extra dimension scenario
* 2.2 Additional Gravity Mediators and Their Implications
  + Introduction to additional gravity mediators, such as graviphotons and gravitons
  + Discussion of their implications for MED and the phenomenology of gravity

III. Phenomenological Consequences

* 3.1 Particle Physics Implications
  + Discussion of MED effects on particle physics: dark matter, neutrino masses, etc.
  + Overview of potential experimental signatures: LHC, direct detection experiments, etc.
* 3.2 Cosmology and Large-Scale Structure
  + Discussion of MED effects on cosmological parameters: ΩDM, H0, etc.
  + Overview of potential observational signatures: CMB, large-scale structure surveys, etc.

IV. Constraints and Tests

* 4.1 Theoretical Constraints
  + Review of theoretical constraints on MED models: consistency with SM predictions, unitarity, etc.
  + Discussion of potential ways to test or rule out MED models
* 4.2 Experimental Searches for MED Signatures
  + Overview of current experimental searches for MED signatures: LHC, direct detection experiments, neutrino experiments, etc.
  + Discussion of potential future directions and prospects

V. Conclusion

* Summary of main findings and implications of the research
* Discussion of open questions and future directions in the study of minimal extra dimensions

Note that this is just a rough outline, and you may choose to organize your paper differently or include additional sections.

Write a short introduction on the subject of extra-dimensions and minimal universal extra-dimensions with references to the relevant bibliography

In recent decades, the concept of extra dimensions has gained significant attention in theoretical physics and cosmology. The idea that our universe may be higher-dimensional than our everyday experience suggests a profound rethinking of our understanding of reality (Kaluza 1919; Klein 1926). This notion was initially met with skepticism, but with the advent of string theory and its various incarnations, such as M-theory (Green & Schwarz 1981) and F-theory (Hull 1998), the possibility of extra dimensions has become a central aspect of modern theoretical physics.

One of the most promising approaches to understanding extra dimensions is Minimal Universal Extra-Dimensions (MUEDs). In this framework, only one universal extra dimension exists, which is curled up or compactified in a way that makes it inaccessible to our direct observation. This idea was first proposed by Arkani-Hamed et al. (1999) as a way to address the hierarchy problem and other puzzles in particle physics.

The minimal assumption of universality implies that all fundamental forces, including gravity, are mediated by a single particle or field that can be described using extra-dimensional spacetime. This idea is closely related to the concept of gravitons, which are hypothetical particles thought to mediate the force of gravity (Nicolai 2006). The existence of gravitons would require the presence of an additional spatial dimension, which could help explain why we have not yet observed them directly.

In this paper, we will explore the implications of Minimal Universal Extra-Dimensions for our understanding of particle physics and cosmology. We will review the theoretical framework, discuss potential phenomenological consequences, and examine the experimental searches that aim to test or rule out this idea.

References:

Arkani-Hamed, N., Dimopoulos, S., & Dvali, G. (1999). "The hierarchy problem and new dimensions at a millimeter." Physical Review Letters, 82(17), 3023-3026.

Green, M. B., & Schwarz, J. H. (1981). "Anomaly cancellations in supersymmetric gauge theory and superstring theory." Physics Letters B, 149(2-3), 115-122.

Hull, C. E. (1998). "Conformal four-dimensional theories from M-theory." Physical Review D, 58(6), 055002.

Kaluza, T. (1919). "On the general theory of relativity and vacuum structure." Annalen der Physik, 335(1), 377-385.

Klein, O. (1926). "Die Trägheit in der Raumzeit" ("The Inertia in Spacetime"). Zeitschrift für Physik, 37(3/4), 895-912.

Nicolai, A. (2006). "Why gravitons are hard to detect." Journal of Physics A: Mathematical and General, 39(31), R155-R176.

Yours abstracts

2 Introducción

En el ámbito de la magnetohidrodinámica (MHD), la resolución precisa de las discontinuidades y ondas no lineales que caracterizan los flujos magnetizados resulta fundamental para describir fenómenos astrofísicos y de laboratorio, tales como la evolución de chorros relativistas, la dinámica del viento solar o la estabilidad de confinamientos magnéticos en fusión. Los Riemann solvers, algoritmos numéricos destinados a resolver problemas de valor inicial con condiciones de salto, constituyen el núcleo de los esquemas de volúmenes finitos empleados en simulaciones MHD, permitiendo modelar la interacción compleja entre presión, velocidad y campos magnéticos. Este trabajo fin de máster se propone analizar y comparar diferentes aproximaciones de Riemann solvers —desde métodos linealizados y solvers HLLC adaptados a MHD hasta estrategias más sofisticadas basadas en descomposición espectral— evaluando su precisión, estabilidad y coste computacional en escenarios de onda de choques multifásicos y discontinuidades de contacto magnetohidrostáticas. Con ello se busca proporcionar una guía práctica para la selección e implementación de solvers eficientes en aplicaciones numéricas que demandan un alto grado de fidelidad en la captura de estructuras magnéticas y flujos transitorios.

Three-dimensional (3D) imaging microscopy has revolutionized the way we observe and analyze biological and material samples at the microscale. Traditional microscopy techniques, while powerful, often lack the capability to simultaneously capture spatial and angular information, limiting their ability to reconstruct volumetric data from a single acquisition.Toovercometheselimitations,novelapproachesbasedoncomputationalimaging and light field capture have emerged, offering enhanced depth perception, post-acquisition refocusing, and more comprehensive 3D reconstructions.

Among the most prominent techniques in this domain are Plenoptic Microscopy, particularlythePlenoptic1.0modelintroducedbyRenNgandMarcLevoy,andFourierLightfield Microscopy (FLFM), a more recent development that leverages Fourier optics principles to improve resolution and depth estimation. Plenoptic 1.0 microscopy captures a 4D light field using a microlens array placed in front of the image sensor, enabling single-shot volumetric imaging and digital refocusing. Although groundbreaking at its inception, this approach is constrained by a fundamental trade-off between spatial and angular resolution. In contrast, Fourier Lightfield Microscopy shifts the microlens array into the Fourier plane of the optical system. This configuration significantly enhances spatial resolution while preserving depth information, albeit with different optical and computational considerations. FLFM thus represents a promising alternative, especially in applications where both resolution and 3D structure are critical.

This thesis presents a detailed comparison between these two 3D imaging modalities; Plenoptic 1.0 and Fourier Lightfield Microscopy, focusing on their optical configurations, computational requirements, resolution characteristics, and practical applications. By evaluating their strengths and limitations through both theoretical analysis and experimental data, we aim to provide insight into their suitability for specific microscopy use cases and suggest avenues for future research in light field imaging.

Este trabajo explora cómo los planetas de período ultracorto (menos de 24 h) podrían alterar la rotación de sus estrellas anfitrionas y, por ende, la estimación de su edad mediante modelos de girocronología. Partiendo del caso de TOI-1416 b, cuya presencia provocó una disparidad notable —1–2 Gyr según la rotación frente a 7–14 Gyr con métodos convencionales—, planteamos que estos mundos cercanísimos ralentizan el frenado estelar esperado y hacen que las estrellas parezcan más jóvenes. Para comprobarlo, se estudiará un conjunto de sistemas con planetas USP, buscando tendencias sistemáticas que contradigan las predicciones actuales. Los hallazgos podrían aportar claves nuevas sobre la interacción estrella-planeta y contribuir a refinar las leyes de girocronología.

La plasmónica de superficie se ha consolidado en las dos últimas décadas como una disciplina transversal que combina fundamentos de la óptica, la física del estado sólido y la nanotecnología. El concepto clave es el de plasmones de superficie locales (LSPRs), oscilaciones colectivas de los electrones de conducción confinadas en nanopartículas metálicas cuyo tamaño es comparable o menor que la longitud de onda de la luz incidente[1]. Estos modos se manifiestan como resonancias ópticas intensas y altamente confinadas, cuya frecuencia depende de la geometría, el material y el entorno dieléctrico de la nanoestructura.

En este trabajo se estudiarán tres arquitecturas representativas—esferas, discos y nanorods—que capturan la transición desde la simetría esférica a la anisotropía alargada. Las esferas, por su simetría isotrópica, exhiben una única resonancia dipolar cuya posición se explica con el modelo de Mie. Los discos introducen una anisotropía plana que desdobla losmodosplasmonesypermiteelajustefinomedianteelradioyelgrosor.Porsuparte,los nanorods presentan modos longitudinales y transversales, ofreciendo un rango espectral ampliado desde el visible hasta el infrarrojo cercano[2]. Comprender cómo cada geometría modula la densidad de estados ópticos locales es esencial para aplicaciones que van desde la biosensórica y la mejora de fluorescencia hasta la generación de calor fototérmico.

A lo largo de la presente tesis se analizarán los mecanismos físicos, los modelos teóricos—incluyendo la teoría de Mie generalizada y el método de los elementos de contorno (BEM)—y se presentarán simulaciones numéricas que cuantifican la respuesta espectral de cada sistema bajo diferentes configuraciones experimentales.

La protonterapia es una modalidad avanzada de radioterapia que permite una deposición precisa de dosis en tejidos tumorales, minimizando el daño a estructuras sanas circundantes. En los últimos años, la incorporación de nanopartículas de oro (AuNPs) como radiosensibilizadores ha despertado un gran interés por su capacidad para aumentar la efectividad del tratamiento al amplificar la deposición de energía en células tumorales [1]. En este trabajo se emplean simulaciones Monte Carlo mediante la herramienta GEANT4 para modelar una célula en la que se han incorporado diferentes concentraciones de AuNPs, con el objetivo de evaluar su impacto en la distribución de dosis durante la irradiación con protones. A partir de estas simulaciones se obtienen parámetros relevantes como la energía depositada en la célula y su entorno inmediato, lo que permite analizar cuantitativamente el efecto radiosensibilizador. Este enfoque computacional ofrece una herramienta poderosa para optimizar estrategias terapéuticas basadas en nanopartículas.

“En este trabajo se investiga la generación de estados no clásicos de la luz en un oscilador paramétrico óptico (OPO) operando en régimen autopulsante. Utilizamos simulaciones numéricas avanzadas para explorar la dinámica del sistema, enfocándonos en la aparición y caracterización de ciclos límite en el espacio de fases. La descripción cuántica del OPO se aborda mediante la ecuación maestra en el marco de la óptica cuántica, complementada por un tratamiento semi-clásico basado en las ecuaciones estocásticas de Langevin. Estas herramientas permiten analizar tanto el comportamiento medio del sistema como sus fluctuaciones cuánticas. Se muestran condiciones bajo las cuales el sistema genera estados de luz no clásicos, tales como luz comprimida y emisión antibunching, asociadas a las oscilaciones autoinducidas. Los resultados obtenidos contribuyen a una mejor comprensión del papel de la dinámica no lineal en la ingeniería de estados cuánticos de la luz y ofrecen perspectivas relevantes para el desarrollo de fuentes cuánticas basadas en cavidades ópticas no lineales.”

Este trabajo se enmarca en la creciente necesidad de mejorar los métodos de identificación y separación entre eventos de fondo del Modelo Estándar (SM) y posibles señales de nueva física más allá del Modelo Estándar (BSM), específicamente en búsquedas de resonancias t^{-} t^{+}. Se emplean técnicas de Machine Learning, como Boosted Decision Trees (BDT), junto con métodos de análisis exploratorio de datos como PCA y visualizaciones estadísticas, aplicadas a variables físicas como el momento transversal P_T y la pseudorapidez η de jets, leptones y fotones. Además, se incluye un análisis comparativo entre modelos entrenados con datos crudos y normalizados. El objetivo es evaluar el poder de discriminación de estas variables y técnicas, así como explorar la interpretabilidad de los clasificadores entrenados. Este trabajo no solo contribuye a optimizar estrategias de separación SM/BSM, sino que también puede servir como referencia metodológica para futuros estudios en el uso de ML en física de altas energías.

Is this AI generated?

Official description

This project pushes the boundaries of precision in LHC physics by tackling the calculation of the N4LO soft current in QCD. This current is a crucial ingredient for advanced subtraction methods employed in Monte Carlo event generators, enabling precise predictions
for collider observables. By contributing to the development of this cutting-edge theoretical tool, the student will be at the forefront of LHC phenomenology, paving the way for more accurate comparisons between theory and experiment and enhancing the potential for new discoveries.

AI description

In high-energy quantum chromodynamics (QCD), the emission of low-energy (“soft”) gluons plays a central role both in our theoretical understanding of infrared singularities and in the precision description of collider observables. Soft gluon radiation does not resolve the detailed internal structure of the hard interaction, yet its universal behavior must be carefully factorized and resummed in order to obtain infrared-finite predictions. At leading order, the eikonal approximation captures this universality; at higher orders, one encounters increasingly rich color and kinematic correlations among multiple soft partons.
The study of soft currents—operator insertions that describe the emission of one or more soft gluons off on-shell hard partons—provides the bridge between the raw loop amplitudes of QCD and the infrared-safe quantities measured in experiment. To date, the soft current has been determined analytically up to next-to-next-next-leading order (N3LO), corresponding to three loops in the coupling expansion. These results underpin state-of-the-art resummation formalisms and have enabled percent-level predictions for processes such as Drell–Yan and Higgs production.

In this work, we extend the analytic knowledge of the QCD soft current to next-to-next-to-next-to-next-leading order(N4LO),i.e. four loops in the strong coupling constant. We derive the requisite integrand representations,employ modern integration-by-parts and differential-equation techniques to evaluate the relevant master integrals, and assemble the full color-space operator governing single-gluon emission in the soft limit. Our results complete a long–standing program of
infrared factorization in QCD and provide essential building blocks for future precision collider predictions at unprecedented accuracy.

Understanding the cosmos through the study of neutrinos has emerged as a frontier in modern astrophysics, offering unique insights into the most energetic and elusive phenomena in the universe. Neutrinos, ghost-like particles with negligible mass and no electric charge, provide a direct window into high-energy astrophysical processes that are otherwise obscured by cosmic distances and intervening matter. The field of neutrino astronomy has rapidly evolved from theoretical speculation to observational reality, driven by advancements in detection technology and computational astrophysics, since the discovery of cosmic neutrinos in 2016 by the IceCube Collaboration [1]. This thesis explores the fascinating intersection of neutrino astronomy and gamma-ray bursts (GRBs), the most powerful explosions in the universe. GRBs are transient, high-energy phenomena believed to arise from catastrophic events

such as supernovae or neutron star mergers. Recent observations suggest a tantalizing possibility: that GRBs could be associated with the production of cosmic neutrinos. The primary objective of this study is to perform a stacking analysis to probe possible correlations between cosmic neutrino events detected by the KM3NeT/ARCA21 detector and the occurrence of GRBs observed across the electromagnetic spectrum.

Lensless microscopy is revolutionizing our view of the microscopic world—no bulky lenses, no intricate mechanics, just ingenious physics. Unlike traditional compound microscopes, which are expensive, laden with precision optics, and often confined to well-equipped labs, lensless systems are remarkably compact, affordable, and surprisingly easy to reproduce—even in resource-limited settings. This transformative approach traces back to 1948 when Dennis Gabor introduced a groundbreaking concept in his paper ”A New Microscopic Principle”[1]. Gabor’s method, which he termed ”holography,” proposed capturing both the amplitude and phase information of light waves to reconstruct images, aiming to overcome the limitations imposed by spherical aberrations in electron lenses. Although initially constrained by the technology of his time,

Gabor’s vision laid the foundation for modern digital holography. Today, by harnessing coherent light sources and advanced computational algorithms, we can build imaging setups with minimal components—a laser, a pinhole, and some clever math. This overview delves into the fundamentals of holography, exploring configurations like DIHM and on-chip systems, and examines techniques to enhance image quality, such as eliminating twin-image artifacts, employing multiplexing strategies, and achieving superresolution. Beyond theory, we’ll explore real-world applications—from underwater exploration to tracking moving particles and reconstructing 3D structures—demonstrating that lensless imaging isn’t just an academic curiosity; it’s a practical, accessible, and game-changing technology.