7th MEFT Workshop

Wednesday 29 June 2022 - Wednesday 29 June 2022

Book of Abstracts

Contents

15

Applications to biological networks of adaptive Hagen-Poiseuille flow on graphs

Author: Ana Filipa Valente[1]

[1] *Instituto Superior Técnico*

Corresponding Author: anasquintern@gmail.com

Transport networks are some of the many dynamical systems that can be described using networks and graphs, and key aspects of these networks can be described using hydrodynamical equations. Specifically, some can be described using the Hagen-Poiseuille law, like blood network models or network models that describe Physarum polycephalum, an acellular protist that grows in a network-like pattern, and whose networks are efficient, robust and cheap.
This work intends to analyse the dynamics of such network models, based on the Hagen-Poiseuille adaptive formalism for viscous incompressible flows proposed by R. Almeida & R. Dilão in Phys. D: Nonlinear Phenom. 436 (2022), p. 133322. More explicitly, the goals of the project are to analyse: phase transitions on graph structures, the effect of saturation on the elasticity functions characterising veins, the topological changes of vein networks to time-dependent sources, the dynamic characterisation of Murray's law and models of Physarum's periodic processes (peristalsis and shuttle streaming) in vein networks.

17

Measurement of the number of muons near the shower core using MARTA engineering array

Author: Milton Freitas[None]

Corresponding Author: miltonfreits@gmail.com

As particles coming from space with center-of-mass energies up to 400 TeV (well above the limits of current man-made accelerators), the Ultra High Energy Cosmic Rays detected at the Pierre Auger Observatory are currently one of the most important research objects in Astroparticle physics.

In recent works, it has been demonstrated that the muon number distribution at the ground can be used to probe the first few, very high energy interactions of a shower, which would allow us to obtain information on the primary's source and acceleration mechanisms. Yet, currently most cosmic ray experiments don't directly measure the muon content in an Extensive Air Shower (EAS), but rather estimate through shower features due to the incapability of the detectors to distinguish the muon content from the electromagnetic component of the shower.

The Muon Array with RPCs for Tagging Air Showers (MARTA) is a hybrid detector design with the purpose measuring the muon content in an EAS. The main idea is to place a Resistive Plate Chamber (RPC) under a water-Cherenkov Detector (WCD) in order to shield it from the showers' electromagnetic content.

An implementation of MARTA has already been installed at the Pierre Auger observatory and is currently being used as an R&D project to test MARTA's viability to directly measure the muon content in a shower.

The purpose of my thesis project is then to use the MARTA simulation framework to test the possibility of measuring the number of muons near the shower core, where the contamination due to the electromagnetic component is at its highest making it so that current studies with this engineering array cannot probe this region. I will then develop a new RPC configuration mode based on linking the total charge in a pad to the number of particles crossing it at a given time which, combined with other strategies such as defining fiducial areas, may allow us to recover the important shower region.

A successful implementation would allow us to study the important shower core region for the first time.

27

Algorithms for energy communities management

Author: António Rodrigues[None]

Corresponding Author: rafinha.couras@gmail.com

Energy, in particular renewable energy, is one of the areas whose development will have a very significant impact on our way of life. Today we are looking for the solution to global warming and other problems of our planet in it. Intelligent and planned management of these types of resources is also necessary to obtain the best possible use. One idea that has been developed in some countries around the world, but not yet very widespread in Portugal, is the creation of "Energy Communities".
Local Energy Communities can play a crucial role in the energy transition, providing flexibility services and orchestrating decentralized energy resources for a safe and cost-efficient electricity supply and ensuring a stable grid, while simultaneously moving energy consumption and empowering local assets, thus increasing the social impact and cohesion of communities.
In line with the uncertainties found in the Portuguese panorama, the biggest gap in Portuguese ambition is the lack of concrete programs dedicated to the development of REC. Similarly, the absence of specific implementation targets does not support its development.
Thus, the main goal of this thesis is to facilitate the transition to Energy communities, by focusing on the Development of a complete review of the current state of the art in academic articles and develop algorithms for the design and operation of energy community management.

19

Tunneling Magnetoresistance Sensors for Low Intensity Fields

Author: Luís Martins[1]

[1] *Instituto Superior Técnico*

Corresponding Author: luisfmartins@tecnico.ulisboa.pt

Unpatterned magnetic tunnel junctions using compound free layers based on CoFeB, along with NiFe or CoFeBTa were studied magnetically to compare their behaviour in a linear region, with the goal of identifying which would be more adequate for magnetic sensors. These materials were selected with the prospect of obtaining lower coercivity in this linear region while minimizing electrical noise. Similar magnetic behaviour was observed for both, for the same thickness values and more elaborate results would be drawn from an electrical study of these structures after patterning.

21

Towards end-to-end speech-to-text summarisation

Author: Raul Pombo Monteiro[None]

Corresponding Author: raul.monteiro@tecnico.ulisboa.pt

Deep neural networks research has thrived since AlexNet (Krizhevsky et al., 2012) outperformed classical computer vision techniques in the ImageNet Large Scale Visual Recognition Challenge in 2012. The latter used tailored feature extraction algorithms, whereas AlexNet only resorted to the depth of the model to achieve such high performance. Since then, deep neural networks have been broadly used in Natural Language Processing (NLP), from which transformers and language models account for some of its most recent developments. Under a paradigm-changing title, "Attention Is All We Need", the transformer architecture was initially introduced by Vaswani et al. (2017) to implement end-to-end translation and relies on a mechanism of self-attention to encode each input word considering its global context. The transformer architecture then became prevalent in most NLP tasks: machine translation, parsing, text summarisation, to name a few. Unsurprisingly, the same methodologies have been applied to speech processing (Dong et al., 2018), particularly Automatic Speech Recognition (ASR). Motivated by this progress, more advanced methods that implement end-to-end speech-to-text translation have arisen (Vila et al., 2018), in opposition to cascade models, which require an intermediate step for transcription. Following the same reasoning, the goal of this master thesis is to develop a model that implements end-to-end speech-to-text summarisation. The model will be based on the transformers architecture and shall use the speech audio as input to directly produce a summary of its content without a transcription step.

12

Machine learning in cardiac electrophysiology: localization of accessory pathways in Wolff-Parkinson-White syndrome patients with 12-lead electrocardiographic analysis

Author: Diana Sofia De Oliveira Bernardo[None]

Corresponding Author: diana.sofia@tecnico.ulisboa.pt

Wolff-Parkinson-White (WPW) syndrome is a rare congenital heart disease characterized by the presence of an accessory pathway (AP) between the atria and the ventricles, causing abnormal conduction of electric signals in the heart and eventually episodes of tachyarrhythmias. The treatment of choice for people with this syndrome is radiofrequency catheter ablation of the AP. The success of this procedure depends on the prior localization of the APs. The AP location influences the direction of conduction and electrocardiogram (ECG) features will vary depending on it. Therefore, the alterations observed in the 12-lead ECG pattern can be used to localize the correct sites of the AP. So far, a non-invasive accurate automated method using artificial neural networks (ANNs) to localize AP sites is not available. Therefore, the primary goals of this thesis are to create a new model for the diagnosis of AP localization in WPW syndrome and to make this model more accurate than the conventional methods and algorithms that already exist. An ANN will learn the characteristics of ECG waves for each AP site using cases of patients with a known AP location. Such method method using an automate ECG classification to accurately identify AP sites non-invasively in WPW syndrome patients will become very useful in clinical practice and can even eventually be adapted to other arrhythmia conditions of the heart.

23

Launching the Radiation Hard Electron Monitor aboard the ESA JUICE mission

Author: Francisca Santos[None]

Corresponding Author: francfsantos2000@gmail.com

After the Galileo mission, launched in 1989, provided strong evidence of the existence of oceans beneath the icy crust of Jupiter's moons, Europa, Ganymede and Callisto, these icy worlds were hypothesised to be habitable. As a result, on April 2023, ESA will launch the JUICE mission to explore the icy moons of Jupiter and the gas giant itself.

In my Master thesis project, one of the main challenges that space exploration faces will be approached, the radiation environment. Specifically, in the Jovian System, composed of Jupiter, its moons and rings, the radiation environment is extremely harsh, with much larger electron fluxes

and larger energies than the ones present on Earth. Aboard the JUICE spacecraft will be RADEM (RADiation hard Electron Monitor) and, both as an housekeeping instrument and a charged particle spectrometer, it will provide valuable information about the particle population. This instrument and its role in the JUICE expedition will be the focus of my project.

18

Radiosensitizers for Cancer Radiation Therapy

Author: Sofia Cardoso[None]

Radiotherapy is one of the most effective techniques used to fight cancer and one of the most chosen options. It uses high doses of ionizing radiation to damage cancer cells. However, some cancer types are radioresistant. In this context, radiosensitizers may play a crucial role to improve therapeutic outcomes. G-quadruplex DNA ligands have emerged as good candidates. The aim of the thesis is to evaluate the ability of a small family of G4-DNA ligands to act as radiosensitizers, by studying the effects induced by gamma-radiation in prostate cancer cells. All in all, the study should unravel the benefit of combining radiation treatment with G4-DNA ligands.

22

Investigation of edge instabilities in fusion plasmas using reflectometry

Author: Rafael Valente[None]

Corresponding Author: rafafvalente@gmail.com

With ITER's first full power fusion operation scheduled for 2035, it is essential to perfect and understand the mechanisms of some promising operational regimes, as well as understand their scalability to future reactors.
The EDA H-mode regime, originally discovered at MIT's Alcator C-mod tokamak and recently at the ASDEX Upgrade tokamak at the Max-Plank institute for plasma physics, has proven to be a promising regime for future fusion reactors. This unique operating regime, which possesses a desirable set of characteristics not present in any other regime to date, has the potential to be a valuable tool in the attempt to attain economically viable fusion in next-generation reactors, but there is still a lot to be learned about the regime.
The principal aim of this project is to localize an edge instability whose presence is essential for the achievement of the regime, with the objective of testing its scalability to future reactors.

13

Stellar flare spectroscopy with ESPRESSO

Author: José Manuel Leiria Amoreira[None]

Corresponding Author: jose.amoreira@tecnico.ulisboa.pt

Understanding the stellar magnetic activity phenomena (such as spots, faculae, plages, flares) is very important for different fields of stellar and exoplanetary astrophysics, and for planetary climate studies. Studying magnetic activity on stars of different stellar parameters and activity levels provides an opportunity for detailed tests of stellar/solar dynamo models. From the exoplanetary side, it is well known that stellar active regions combined with the stellar rotation can induce signals in high-precision photometric and radial velocity (RV) observations. These activity-induced signals may lead to masking or mimicking an exoplanet signal. Moreover, these signals are one of the main limitations for the detection and the precise characterization of low mass/small radii planets, which

is the major goal of future instruments.
Late-type stars commonly show flaring activities - unpredictable releases of energy. It is demonstrated that strong flares can significantly affect the properties (profile, flux, wavelength) of strong lines that appear in emission in the chromospheres. These energetic flares can also produce a significant,measurable RV shift for M dwarf stars. As a consequence, the spectra affected by flares are usually discarded in the RV observations. The number of discarded spectra can be significant for active M dwarfs, which is an obvious issue. Another, perhaps more important, issue related to flaring activity in exoplanet research is that the impact of weak flares on RV measurements is not quantified and is typically ignored. This, obviously, increases the level of 'noise'in the RV time-series.
The large number of ESPRESSO ultra-high quality observations should allow us to study the impact of flares (of different energies) on the line-profile variations even for relatively weak lines. The aim of this project is to first identify the signatures of flares in spectral lines and then to study their impact on the RV shift measured from lines with different properties (intensity, excitation potential etc).

9

Quark Gluon Plasma Effects on Hadronization

Author: Henrique Legoinha[1]

[1] *LIP - Laboratorio de Instrumentação e Física Experimental de Partículas (PT)*

Corresponding Author: h.legoinha@cern.ch

The quark-gluon plasma, a very exotic state of matter usually referred to as QGP, is expected to form under extreme conditions of temperature and pressure, just like the ones in the primordial universe or those at the core of a neutron star. Although Earth conditions are very different, here, Ultra Relativistic Heavy Ion Collisions allow to recreate such medium. Using the CMS detector at the LHC, its remnants can be observed and studied. A key signature of its presence relates to the relative abundance of different B mesons that result from the hadronization of the beauty quark. By studying the production of B mesons in Lead-Lead and proton-proton collisions, we measure the nuclear modification factors for the different B mesons.

10

Higher-Rank Gauge Theories - A quantum Monte-Carlo Study

Author: José Maria Cruz[None]

Corresponding Author: ze.cruz11@gmail.com

Condensed matter physics is the study of collective emergent states of matter. The field is enormously rich ranging over solid state physics including superconductivity and magnetism, quantum liquids, and topological states of matter.
Certain interacting quantum systems can be described at low energies in terms of emergent gauge theory.
Such effective theories can range from the familiar quantum electrodynamics to more exotic field theories that have no parallel in the theory of fundamental particles.
Recently, condensed matter theorists stumbled upon models harboring what are now called fracton phases. These quantum states of matter are characterized by the presence of "charges" that cannot propagate freely in the three dimensions of space but instead are restricted in some way. In trying to understand these phases better people realized that certain tensor gauge theories capture some features of fracton phases.
The principal goal of this project is to investigate the properties of tensor gauge theories coupled to matter including their phases and the nature of the excitations in these different phases.
Specific goals are: (i) obtain a discretized action of the tensor gauge theory; (ii) devise an effective

algorithm to simulate the discretized theory with quantum Monte Carlo; (ii) implement large-scale simulations; (iii) study the phase diagram and the physical properties of the different phase.

8

Energy Extraction from Black Holes

Author: João Sieiro dos Santos[1]

Co-authors: José Natário [2]; Vitor Cardoso [1]

[1] *Centro de Astrofísica e Gravitação-CENTRA, Departamento de Física, Instituto Superior Técnico-IST, Universidade de Lisboa-UL, Avenida Rovisco Pais 1, 1049-001 Lisboa, Portugal*

[2] *Center for Mathematical Analysis, Geometry and Dynamical Systems, Instituto Superior Técnico-IST, Universidade de Lisboa-UL, Avenida Rovisco Pais 1, 1049 Lisboa, Portugal*

Corresponding Author: joaosieirosantos@tecnico.ulisboa.pt

Detection of cosmic rays with very high energies, up to 10^{20} eV, has been present in the literature for a long time [1]. Many processes have been proposed as sources for these high energy particles but no fully satisfactory explanation has been provided. The Penrose process [2,3] makes use of the possibility to have negative energy particles in the ergoregion of a rotating black hole to extract energy from the latter. This mechanism was suggested as a possible source for high energy jets of particles, however, since the process is unlikely to take place from an astrophysical point of view, this gives no solution to the problem of ultra high energy cosmic rays [4]. Still, other variants of the Penrose process which also rely on the possibility of extracting rotational energy from spinning black holes may be more plausible and hence contribute to the explanation of how these particles are being produced. A particular case we want to study is that of the radiative Penrose process [5]. If a black hole is immersed in an asymptotically uniform magnetic field, which has been observed experimentally, and a charged particle is moving in the black hole's ergoregion then it could radiate negative energy photons, which are absorbed by the black hole. The particle will in turn gain energy and be accelerated by the radiation reaction force, contrary to what happens in flat space. For this masters thesis we aim to understand if the radiative Penrose process is a viable candidate to solve the problem at hand, as well as investigate other mechanisms of energy extraction from black holes.

[1] Y. Tsunesada *et al.*, PoS ICRC2021, 337 (2021).
[2] R. Penrose, Riv. Nuovo Cim. 1, 252 (1969).
[3] R. Brito *et al.*, Superradiance. New Frontiers in Black Hole Physics, 971 (2020).
[4] R. Wald, The Astrophysical Journal 191, 231 (1974).
[5] M. Kološ *et al.*, Phys. Rev. D 103, 024021 (2021).

16

Deciphering jet quenching effects through a quantile ratio

Author: Lénea Luís[1]

[1] *IST*

Corresponding Author: leneasilvaluis@hotmail.com

The Quark-Gluon Plasma (QGP) is predicted to be the predominant state of matter at a few microseconds after the Big Bang, being the earliest stage of the Universe known so far. This state of QCD matter can be produced in ultra-relativistic heavy ion collisions, such as those in the Large Hadron Collider (LHC) or in the Relativistic Heavy-Ion Collider (RHIC). Since this medium is very short-lived, the QGP characteristics can only be infer by the products of heavy ion collisions. One

example of the indirect probes used in this study are the jets –collimated spray of energetic hadrons. These objects propagate in the QGP and interact with it by losing energy. This means that the jet is expected to be modified or absorbed by the QGP, in a phenomena known as jet quenching. By using observables which compare unmodified objects in the QGP with quenched jets, one can study the energy loss in the medium.

14

Decentralized Autonomous Organizations for the life cycle assessment of energy system's management for small-scale infrastructures

Author: Eduardo Bastiana[None]

Corresponding Author: edu.bastiana@gmail.com

Blockchain and Decentralized Autonomous Organizations (DAOs) as concepts have gained increased popularity in the last 15 years, with the use of this structures becoming prominent in the financial industry. Although further uses have been researched and a variety of implementations, from financial to utilities, have been idealized, the use of blockchain and DAOs applied to energy system's management for small-scale infrastructure is a novelty, with little academic references found on the subject. The lack of a full DAO description for any infrastructure life cycle assessment makes the work produced in this sense relevant, given its ability to be used and scaled for other industry-related projects, as well as further diversifying its applications to other industries and utilities.

This project proposes the development of a DAO for managing the life cycle of a energy microgrid infrastructure, focusing mainly on the first three stages of this life cycle: the proposal of new projects and upgrades by members, the selection of the best proposals using voting mechanisms, and the funding of winning proposals using Decentralized Finance. The application of DAOs to the energy industry can ensure the decentralization of service providers, and a grid infrastructure and pricing market oriented for the social benefit of the community, contributing to the sustainability of the industry and our society.

11

Phenomenology of SM extensions with vector-like fermions

Author: Ricardo Amadeu[1]

[1] *IST/CFTP*

Corresponding Author: ricardo.amadeu@tecnico.ulisboa.pt

The Standard Model (SM) of particle physics successfully describes the electroweak (EW) and strong interactions among the elementary particles known to mankind. However, physical phenomena such as the baryon assymetry of the Universe (BAU), the existence of dark matter and neutrino oscillations require Beyond the SM (BSM) theories in order to be explained. Vector-like fermions are hypothetical 1/2 spin particles whose chiral components are in the same representation of the gauge group of the SM. These particles are interesting for several reasons: they provide a new source of CP-violation, necessary to explain the BAU, and constitute a dark matter candidate. The aim of my thesis is to study SM extensions with VLF and verify their compatibility with experimental observations.