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Book of Abstracts

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Business Model and his viability - CAPSTONE PROJECT

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In this document we can look at a CAPSTONE project between IST and the company unbabel with emphasis in the part of the project that I'm responsible for.

The WOK Project is a Capstone type of project, developed between Lisbon University's Instituto Superior Técnico (IST) and Faculty of Fine-Arts (FBAUL) Master Degree's final year, resulting in a final project report and master thesis. In this project students from different areas - Computer Engineering, Physics Engineering and Communication Design - collaborate to develop an interface that embeds all their capacities, creating a business opportunity based on a company's needs. The project intends to give students a first hand experience of how to work in multidisciplinary teams and a base for their research for their master thesis.
The idea is creating a microtask service using crowdsourcing, where the channel to interact with the crowd will be the web social application, Facebook, where a chatbot will communicate to interact with the users. The document will start with a introduction of this type of project model, followed by a general idea of the project , the objectives and the future work.

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Customization and Performance Assessment of a Standalone Solar Power System

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Solar energy is gaining a lot of traction in recent years and is one of the main candidates for the substitution of fossil fuel energy sources. In this work, it will be built a standalone photovoltaic system associated to a single axis solar tracker. A performance evaluation of the system will be done to assess the economical viability of such a system, and whether it can produce a larger power than the commercial alternatives available.

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Evolutionary Dynamics of Signaling Games

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The evolutionary origins of information transfer and honest signaling remains an open challenge for a vast plethora of research areas, from Philosophy and Theoretical Biology to the Physics of Complex Systems. An approach on this topic will be done, resorting to a combination of analytical tools. The first is game theory, with particular emphasis on signaling games for both costly and cost-free signaling. The second is stochastic evolutionary dynamics in finite populations. Here, the small mutation limit will be essential for enabling a reduction on the large number of states accessible to this complex system. Finally, the third tool to be used will be the dynamics of adaptive interaction networks, that should have an interesting role when overlapped with the previous ones. Based on

this approach, the development of a rather extensible framework will be done, that should shed some light on the problems behind the emergence of honest signaling.

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Tackling the Qubit Mapping Problem

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Quantum computers promise a framework to efficiently tackle problems that are intractable even to modern day supercomputers. This new type of computers harnesses properties of quantum of quantum physics, like access to a bigger computational space (thanks to the Hilbert space used to describe quantum phenomena), quantum entanglement and interference. These provide na unprecedented level of parallelism and the ability to tackle problems whose computational complexity is beyond the reach of any classical computer.

Quantum computers based on the 'Quantum circuit model'are considered the most viable hosts for universal quantum computation. However, in general, quantum algorithms (in the form of quantum circuits) usually assume complete connectivity between the qubits, and don't take into account the engineering limitations of the diferente implementations: usually qubits are connected in a Nearest Neighbors (NN) fashion, which means that each qubit is only connected with a limited number of adjacente qubits. Performing quantum algorithms requires then the emulation of a complete graph of connectivity between the 'virtual qubits'in the Nearest Neighbor connected graphs in usual implementations.

Such a transformation is called the Qubit Mapping problem. Such a problem is known to be NP-complete, and new tecniques are required to tackle this problema in a scalable way, while providing high-quality mapping, with minimum overhead. Reducing this overhead is especially importante in near-future quantum devices, since imperfect quantum gates and limited coherence time of qubits prevents too long (time-wise) and big (envolving a large number of gates) circuits to be simulated without errors.

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Scalar Fields, Black Holes and Spherical Coordinates

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Black holes (BH) are the fundamental particles of gravity, in the framework of General Relativity. They are extremely simple objects and can host several fascinating phenomena. Amongst these is superradiance, a mechanism through which rotational energy can be extracted from BHs by bosonic fields. Such mechanisms can be used to explore our universe, looking for new types of matter beyond the predictions of the Standard Model.
We explore the concepts of superradiance and superradiant instability of bosonic fields around BHs, as well as novel ways to study these phenomena numerically.

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A novel energy reconstruction for high-energy gamma-ray wide field of view observatories

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Very-high-energy (VHE) cosmic gamma-rays are messengers of violent processes in the Universe. At lower energies, this radiation can be detected by satellites experiments. However, as the energy increases the flux becomes too scarce, and one must rely on ground-based observatories to detect gamma-rays, taking advantage of the large electromagnetic showers that are created when it enters the Earth atmosphere.

In order to study transient phenomena, it is necessary to cover large portions of the sky, which can be achieved by placing arrays at high-altitude. However, as these arrays sample only the shower secondary particles that reach the ground, the determination of the primary gamma-ray energy, while proportional to the number of detected particles, is deteriorated by the stochastic fluctuations of the interactions in the shower. In fact, at low energies, the uncertainty on the shower stage is the main responsible for an energy reconstruction resolution of the order of 100%.

The stage at which the shower reaches the ground is connected with the depth at which the cascade reaches its maximum, Xmax. At extreme energy and in cosmic ray showers it has been demonstrated that the analysis of the arrival time structure of the particles at the ground can be used as a reliable estimator of Xmax.

Hence, in this study, we propose to investigate through dedicated simulations the time structure of electromagnetic showers, at the energies relevant for VHE gamma-rays, to create a variable to estimate the value of Xmax, and consequently improve the current energy reconstruction algorithms significantly.

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Optimization of the Selection of Exotic Particles in the SHiP Experiment

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The Search for Hidden Particles experiment is currently being prepared. Amongst other purposes, it will try to detect for the first time the direct decays of Hidden Sector particles to Standard Model ones. Amongst these, are Dark Photons and Heavy Neutral Leptons. I will be talking about the preparation for this experiment, and more specifically, the optimization of the selection of specific branchings of the aforementioned particles.

1

Development of a unilateral Fast-Field Cycling NMR relaxometer

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Nuclear Magnetic Resonance (NMR) relaxometry is a powerful nuclear spectroscopy technique, that has a diverse array of research, clinical and industrial applications. It is used in a broad variety of scientific fields such as, physics, chemistry, materials engineering and medicine.

The aim of this technique is to obtain detailed information about the structure and dynamics of a given molecular sample, from the interaction between the molecular spins and their environment.

The Fast-Field Cycling (FFC) NMR technique originated from the fact that the conventional spectroscopy techniques did not allow to obtain good experimental results for lower magnetic fields (corresponding to lower frequencies).

The evolution of the FFC technique has been made by developing equipment for new industrial applications. For this purpose, the configurations and performances of these equipments have to be in line with the specifications and constraints of the users.

Under this context, with this thesis it is intended to develop and build a first prototype of a FFC magnet for a unilateral NMR relaxometer. The project will require the study of possible magnet designs and also the design of the radio frequency detection system. The main goal is the development of a new, inexpensive, efficient and portable device, that presents some significant advantages compared to the state of the art FFC NMR relaxometers available worldwide, namely the ones being currently used at IST.

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The Wigner function: Quantum Mechanics in phase space

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The Wigner function is one of the main 5 formulations of Quantum Mechanics. In this talk I will review the basics of this formulation and how the work of my Master's thesis fits into this framework.

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Transport through periodically driven systems

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Periodic drives have been receiving renewed attention as the building blocks of new phases of matter such as topological non-trivial states and time crystals. The dynamics of these new non-equilibrium phases is quite different from their equilibrium counterparts. When isolated, the evolution is strongly dependent on its initial condition. Yet, it is hard to imagine that such a regime can be experimentally probed in electronic systems, due to their short decay-times. In practice, it is expected that the state created after a long period of driving will be determined by the system's environment. We will consider electronic systems whose main thermalization mechanism is due to the contact with metallic leads. We will use this setup to probe transport through periodically driven systems in particular when the Floquet band structure acquires a non-trivial topology.

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Bacterial Growth in the Presence of Several Resources

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There are several mathematical models describing bacterial population growth, dependent of one or of several resources. These models apply to communities of single species and in general they describe well the short-term evolution of these communities. However, nature is more complex and species depend on different nutrients for growth. In this context, more complex growth phenomena emerge. In most of these models, it is assumed that each resource is sufficient to ensure the proliferation of species.

We want to analyze and develop models where several nutrients are necessary for growth and to analyze the eventual long-term limitations on the number of species competing for the same pool of resources. We intend to develop a model and to calibrate it with observed data. Then these models could be generalized to include the case where growth is only achieved with different complimentary resources. We also pretend to analyze the case of many resources and species and to study the possibility of emergence of competitive exclusion and/or coexistence.

4

Design and exploitation of a vorticity probe for turbulence studies in fusion devices

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The goal of this work is to understand some turbulence mechanisms through the radial profile analysis of quantities related to *anomalous transport* on plasmas, with special focus on the measure of the *vorticity* at ISTTOK tokamak. The vorticity is a local measure of the velocity field circulation in the plasma fluid, which plays a key role in the transport of energy and particles. The signals acquired will also allow determining the radial poloidal phase velocity profile and the Reynolds stress profile, giving more insight into the plasma transport mechanisms.
The work involves the design of a Langmuir probe array and measurements of floating potentials and ion current saturation signals on different radial positions. These signals are acquired through 'AC' discharges on the plasma.