# SURF@IFISC 2021 Proposals

**1. Twitter as a proxy for sociolinguistic variation**
Advisor: David Sánchez and Jose J. Ramasco

Online microblogging platforms such as Twitter generate massive amounts of data that contain a wealth of information on language usage. It is well known that spelling, lexical and syntactic variation of this usage is correlated with the speakers' socioeconomic status. Our aim is to employ a database of UK geolocated tweets to quantify, with statistical methods, the influence of income and educational levels on standard and non-standard spoken English. The SURF fellow will benefit from learning big data techniques to analyze human behavior phenomena in today's society.

**2. Role of dissipation in quantum reservoir computing**
Advisors: Gian Luca Giorgi and Roberta Zambrini

Quantum reservoir computing (QRC) is an unconventional approach that aims to exploit the complex and rich dynamics of quantum systems for machine learning purposes. QRC is especially suited for temporal tasks and offers the advantage, with respect to more conventional machine learning paradigms, of low training cost and fast learning. A fundamental ingredient for QRC to be effective is represented by need of energy dissipation in the dynamical map. Goal of this project is to introduce the student to the general framework of QRC assessing the performance depending on the way dissipation is added, namely (i) by adding and measuring an ancilla system or (ii) putting the reservoir in contact with a thermal bath.

**3. Thermodynamic Uncertainty Relation in the presence of a Maxwell demon at the nanoscale**
Advisor: Rosa López

In this project we are interested in the thermodynamic uncertainty (TUR) relation when a Maxwell demon Is present in the quantum regime. When a Maxwell demon acts the entropy production must include the entropy associated to the information flow that the demon acquires and in this manner a system can perform useful work or can be cooled. The second law is then preserved by the action of the demon when the information is erased and then energy is dissipated in an irreversible fashion. The TUR relates the entropy production with the fluctuations of the flows generated in a system. It is a bound for the precision (for a current measurement) for a given entropy production. In the presence of the demon the entropy production must account for the information flow and this will be the main goal of the project, i.e., to determine the TUR in the presence of a demon. Additionally, we will propose a quantum system in which the TUR can be explicitly computed. The system consists in two two-terminal nanoconductors that interacts electrostatically that are driven by thermal gradients and biased voltages.

**4. Evolution of air transport fares during the COVID-19 pandemic**
Advisor: Massimiliano Zanin

One of the best ways for understanding a (free market) transportation system is to study the prices assigned to each route and their evolution through time. This is because prices include information about both the offer and the demand; the expected (by the operator) and perceived (by the passenger) value of each trip; and they are frequently updated, thus incorporating events and information about the market as a whole. In this project we will study a data set of prices, updated daily, of the most important intra-European routes in air transport, starting from September 2020. The objective will be to describe how the COVID-19 pandemic impacted the market, and specifically how the expectations of recovering a normal situation evolved through time. This, in turn, will give us a unique look at the evolution of the air transport - not just what it did, but also what was expected to do. The student must have a good knowledge of Python and of its standard libraries; previous experience in modelling and data analysis will also be positively evaluated.

**5. Power grid stability in scenarios of large renewable penetration**
Advisors: Pere Colet and Damià Gomila

The power grid is, arguably, the largest socio-technical system in the world. Stable operation requires the synchronization of the power plants and a precise balance between generation and consumption. The balance is not easy to achieve due to the random character of (part of) the load and the increasing use of renewable sources which are subject to uncontrollable factors, such as wind or sunlight. In this project we will study the synchronization and stability of a prototypical power grid when a large fraction of the generation comes from renewable sources, as well as the effect of including battery storage systems.

**6. Game theory and the evolution of cancer**
Advisor: Tobias Galla

Populations of cancerous cells can be described using ideas from evolutionary game theory. For example, mutants may emerge and compete with ‘wild type’ (normal) cells for resources. This determines the fitness of the different types of cells, and how quickly they reproduce. In game theory one is interested in the interaction between co-operators (who contribute to a common resource) and defectors (who use the resource but do not contribute). The dynamics of such systems can be described mathematically by stochastic models of so-called birth-death processes. In this project you will use ideas from non-equilibrium statistical physics to investigate evolutionary games (e.g. public good games) and/or populations of cells in the context of cancer modelling. For example, we might focus on the probability with which mutants can invade and take over an existing population. Ideally the project will combine computational work and analytical calculations. Interested students will need to be proficient in a computer language such as C++ or Fortran (Matlab will not be sufficient), and they need to have a solid interest in the theory of stochastic processes. Prior knowledge of techniques from statistical physics (e.g. master equations, stochastic differential equations) would be welcome.

**7. Particle motion in a Bose-Einstein condensate**
Advisor: Emilio Hernandez-Garcia

Ultra-cold gases can condensate into a fascinating state of matter known as Bose-Einstein condensate. They present surprising quantum properties such as superfluidity. In the framework of a mean-field approximation, such condensates can be described with variations of the Gross-Pitaevskii, or Nonlinear Schrödinger, equation. This model can be rewritten in a form related to the Euler equations for an inviscid and compressible classical fluid, which opens the possibility of studying the hydrodynamics of the condensate in terms of classical fluid dynamics. The aim of this work is to explore the hydrodynamic forces acting on an impurity immersed in the condensate in relatively simple situations, such as the effect of gravity and buoyancy, or the motion driven by a sound-wave field.