# Doctoral INPhINIT - INCOMING Fellowship Programme
# 2020 Call for applications

**Position**: QCD matter at extreme temperatures and in neutron stars

**Leader**: Néstor Armesto (nestor.armesto@usc.es)

## Centre description

The Galician Institute for High Energy Physics (Instituto Galego de Física de Altas Enerxías, IGFAE) is a joint research institute of the University of Santiago de Compostela and Xunta de Galicia (the Galician Autonomous Government). It was officially created on July 2, 1999. The main goal of the Institute is to coordinate and foster the scientific and technical research in the field of High Energy Physics, Particle and Nuclear Physics and related areas as Astrophysics, Medical Physics and Instrumentation. Of primary importance is the planning and promotion of the relation with large experimental facilities, especially with CERN, GSI/FAIR and the Pierre Auger Observatory at present.

The experimental groups at IGFAE coordinate the Spanish participation in the LHCb Collaboration at CERN, the Spanish participation in the Pierre Auger Observatory, as well as the Spanish participation in the GSI/FAIR nuclear facility. Members of the Institute have a relevant participation in the LHCb upgrade planning, in the LHeC project development and planning, etc. In the last couple of years a new line has also been open with the building of a new facility (LaserPet) at the University of Santiago de Compostela aiming to produce radioisotopes for medical use by a laser-induced plasma accelerator. Moreover, the theory section of the Institute holds an excellent international reputation, with participation in different international committees, invitations to plenary talks and large-impact publications.

## Research project and research line description

Recent data on small collision systems, pp and pPb, at the LHC at CERN show many of the characteristics observed in PbPb, suggesting that collectivity is already attained in these systems. Both initial and final state explanations have been proposed. If the former, these phenomena shed light on the hadronic wave function and the large energy and parton density behaviour of Quantum Chromodynamics (QCD). If the latter, they would illuminate the problem of isotropisation and equilibration, and the emergence of a macroscopic description from the far-from-equilibrium microscopic dynamics. The project focuses on theoretical and phenomenological studies aimed to clarify the origin of collectivity. Both initial and final state explanations will be pursued, based on perturbative QCD and non-perturbative models.

Another key source of information about high density but lower temperature strongly interacting matter is provided by neutron stars (NS). Observations from both traditional astrophysics and gravitational wave (GW) signals emitted by NS binaries strongly constrain the equation of state of baryonic matter. Here non-perturbative effective field theories will be used to describe the NS and the GW and compare with available observational data.

IGFAE's Particle Physics Phenomenology Group consists of six professors plus two emeritus, three postdocs and seven PhD. students. The group, in very close relationship with experimental collaborations at the LHC, is a world leader in the field of heavy-ion collisions, on both initial state explanations within weak (Color Glass Condensate, CGC) and strong coupling QCD (string models and AdS/CFT), and final state ones (radiative energy loss for energetic partons and rescattering models for quarkonium). Also, in non-linear field theories, solitons and their applications to strong interaction physics. It is strongly implicated in organisation and development of main conferences in the field, and in future projects like HL-LHC, FCC,...

## Job description

The candidate will be supervised to work on one of the following topics:

- Initial state explanations of the collectivity observed in pp and pPb within the CGC, a weak coupling non-perturbative effective field theory (EFT) that allows first principle calculations of hadron wave functions and of production and correlations of particles. Radiative corrections for observables to be measured at the LHC and the evolution with energy of correlations and the density matrix of the system will be computed.
- Final state explanations for quarkonium production in small systems like the transport model realisation by comovers. Excited states of charmonium and bottomonium will be analysed, pursuing a unified explanation that considers initial and final state effects, and the relation and interplay with the effective temperature and the different time scales in the process.
- The phenomena of radiative energy loss and its effects on the yields of high-energy particles and jets in small systems. High-energy particle and jet suppression - jet quenching - is apparently absent in small systems, being the only characteristic observed exclusively in heavy-ion collisions. The origin of such smallness and the possibilities that energy loss phenomena offer to study the different times in the process will be analysed.
- EFTs like generalizations of the Skyrme model applied to the description of strongly interacting matter, NS and NS binaries and to a numerical determination of the most relevant observational signatures, both for structural NS properties and for the expected GW signals.

The candidate will acquire a deep theoretical and phenomenological knowledge of the respective problems. Both analytical and numerical skills will be developed, including modern techniques for jet studies or numerical techniques for NS and GW simulation involving pattern recognition and machine learning. Publications in top peer-reviewed journals and presentations in international conferences will follow.