ILANCE Internships Spring / Summer 2024

The Franco-Japanese laboratory, dedicated to the physics of the two infinities, benefits from an exceptional scientific and cultural environment.

An on-site laboratory in Japan, ILANCE brings together researchers, students, post-docs, engineers and technicians from CNRS and Japanese institutions. The laboratory is made up of French scientists for long-term stays in Japan and Japanese physicists. The laboratory will also aim to welcome and support French scientists for temporary stays in Japan. Based on the Kashiwa campus in the northeast of the city of Tokyo, the ILANCE laboratory permanently hosts scientists from CNRS laboratories and from four departments of the University of Tokyo namely, ICRR, Kavli IPMU, ICEPP and the School of Science.

Development of jet reconstruction ML algorithm for Higgs Bosons factories

Higgs factories, including ILC in Japan, are next-generation electron-positron collider projects to explore fundamental questions of the universe. One of the key characteristics of detectors for Higgs factories is highly-granular calorimetry for precise jet measurement. The "particle flow" algorithm to analysis big data from highly-granular sensors is critical for the jet reconstruction, and we are working on improvement of the algorithm using modern deep-learning techniques. The main part of this internship program is a simulation study of the algorithm, including implementing and improving track-cluster matching algorithm, investigation of effect of precise timing measurement, and investigate detector configuration giving maximal performance. Based on intention of the applicant, related hardware studies on silicon sensors and readout electronics of the highly-granular silicon calorimeter can be included

Can modified gravity explain the accelerated expansion of the Universe ?

The study of new probes for analyzing modified gravity simulations of the large-scale structure of the Universe. Modified gravity (MG) theories of the type of f(R) gravity can explain the accelerated expansion of the Universe without invoking the cosmological constant. Such models require introducing a new scalar field that naturally predicts rich gravitational effects in a different way from general relativity (GR). These modifications lead to changes in the environment of large-scale structures that could be used to distinguish this model from GR. The goal of this project is to provide critical tools to study modified gravity, and help to answer the key scientific question: Does modified gravity successfully explain the accelerated expansion of the Universe?

Looking for radio signals from ultra-high energy cosmic particles.

The GRAND (Giant Radio Array for Neutrino Detection) project aims at detecting ultra-high energy messengers (atomic nuclei, neutrinos, gamma-rays) coming from the most powerful sources in the Universe, with a 200'000 radio antenna array. Two prototypes have been deployed in 2023 in desert areas in China and Argentina, and the first dataset is currently being analyzed. In this internship, the candidate(s) will take part in this exciting phase of pioneering data analysis.

Two possible axes of research will be proposed, based on the collected data at both sites or based on simulations, for a prospective study on the China prototype.

a) the identification of specific signatures in the radio signals from cosmic particles. This will be used to discriminate efficiently against the background radio noise.

b) simulations to assess the performances of a hybrid detector (radio antennas + scintillators) at the China site, to detect cosmic particles.

High Energy Gamma-Ray Astronomy (neutron stars, black holes)

The proposed project is a deep follow-up study on the gamma-ray binary LS I +61 303 at GeV energies. It could either be a neutron star or a low-mass black hole. It is one of the best studied binary systems at high energies showing a very particular behavior: On top of the orbital period of about one month, it shows a super-orbital modulation of about 4 years in several wavelengths. Since the discovery of this phenomenon at GeV energies, the dataset taken by the satellite Fermi has doubled. I propose to analyze the latest Fermi-LAT dataset on the source, prove or falsify the findings done 10 years ago and perform a deep study on the orbital behavior of the source. These findings will be of great interest for the community.

Statistical Study of Giant Molecular Clouds in Galaxies

In this topic, we will utilize extensive imaging spectroscopy datasets of galaxies in the local universe, such as M83, to study a large number of giant molecular clouds (GMCs). GMCs are considered the birthplace of massive stars within galaxies. Our investigation will focus on the physical and chemical properties of GMCs using rich ALMA imaging spectroscopy data sets of various molecular lines to understand the underlying physical processes that govern their evolution. This, in turn, will provide insights into the regulatory mechanisms affecting the overall evolution of galaxies.

Uncovering new radio-loud active galactic nuclei

A fraction of growing supermassive black holes are known to be luminous in radio wavelengths, which are referred to as radio-loud active galactic nuclei (AGNs). These radio-loud AGNs are expected to play important roles in the formation of massive galaxies by controlling the growth of galaxies via negative feedback from AGNs. In this topic, we will search for new radio-loud AGNs by combining large datasets in the optical (from Subaru HSC SSP) and radio (from JVLA, etc.) wavelengths, and the physical properties of these galaxies will be investigated via spectral energy distribution modeling.

Properties of distant galaxies via ALMA and James Webb Space Telescopes data.

In this topic, we will investigate the physical properties of dust-enshrouded high-redshift galaxies uncovered by recent ALMA and/or JWST observations. We will focus on spatially-resolved properties of galaxies using high-spatial resolution data and energy-balance codes to model the observed spectral energy distributions and understand the roles of cosmic dust in the early universe.

Data Analysis in the Super-Kamiokande Neutrino Experiment

Since their discovery in 1998 we have learnt a lot about the parameters that govern neutrino oscillations, but there are still many questions remaining. Perhaps the most exciting of these is to determine whether neutrino oscillations violate charge-parity symmetry (CPV), and so could potentially explain why we live in a matter-dominated universe. A precise knowledge of the relative positioning of all the photosensors and calibration sources in the detector is necessary to achieve accurate reconstruction. This project involves the analysis of a unique set of photographs captured by a drone underwater in Super-K. Machine learning image segmentation techniques will be explored to accurately identify photosensors in each photo. Then using the photogrammetry technique, the geometry of Super-K can be measured for the first time after being filled with water. The result would be used by all future physics analysis through the detector Monte Carlo simulation.

Machine Learning Event Reconstruction in Neutrino Physics

Event reconstruction algorithms are used to infer the particle properties, such as energy and direction, based on the photosensor information. Traditional likelihood-based algorithms use several approximations in the modeling of the detector that limit its accuracy and speed, which must be improved for Hyper-K. Several algorithms (DNNs; ResNet CNN, GNN, PointNet, UNet) have been adapted to our particular data format and need to be applied to real physics data. Two positions are available for this project:

a) application to CERN particle beam data in the Water Cherenkov Test Experiment,

b) application to Super-K cosmic ray and atmospheric neutrino data.

Optimization of algorithm for low energy events in Cherenkov detector experiments

The domain of low energy neutrinos is at the edge of making important measurements, among which the diffuse supernova neutrino background and the upturn of the electron flavor survival probability of solar neutrinos. In this context, the currently running Super-Kamiokande and the future Hyper-Kamiokande Cherenkov experiments are promising to be the ones to performed these measurements. For that, they need powerful algorithms to reconstruct low energy particle events which, until now, have been based on traditional regression algorithms dating from 15 years ago. During this internship, the student will contribute to the development of a machine learning algorithm based on Graph Neural Network. At first, they will optimize the algorithm to reconstruct low energy events based on electron and positron related signals. In particular, they will investigate if and how this machine learning algorithm could supersede traditional algorithms for solar and relic supernova neutrinos. For that, they will use simulated data and, depending on their results, they could eventually use actual data from Super-Kamiokande to assess how the algorithm impacts current limits on the upturn measurement.

Cosmological Constraints from Lyman Alpha Forest using Hybrid Effective Field Theory

Using small scale information found in Lyman Alpha Forest data for cosmological analysis is difficult due to uncertainties in the underlying hydrodynamical physics. One possible way to include this uncertainty accurately is using perturbation theory, in particular hybrid effective field theory approaches. In this project, students will test the ability for hybrid effective field theory to capture variations in small scale physics and apply the framework to simulated and/or real data.

Data Analysis of a New CERN Neutrinos Experiment

Prior to Hyper-K operation in 2027, a prototype Water Cherenkov Test Experiment (WCTE) will be constructed and operated at CERN in early 2024. The WCTE detector will be installed in the T9 beamline of CERN, instrumented with several beam monitors, to enable the collection of precious ($e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, n, γ) particle beam control sample data, similar to the particles we measure in Super-K and Hyper-K. This project would help develop and validate the general analysis framework and support one of several potential analyses elucidating models of Cherenkov light emission, light propagation in water, pion production and interactions, leptonic scattering, neutron production and tagging.

Search for non-unitarity of the PMNS matrix in the neutrino sector with T2K and Hyper-K

For the very first time, we now have the possibility of measuring the possible violation of CP symmetry in the lepton sector through the oscillation of neutrinos, and through this, of proposing the very first brick explaining the asymmetry between matter and antimatter that we observe in our current universe. In this perspective, the current T2K experiment, and the future Hyper-Kamiokande, are the experiments best placed to realize this fundamental discovery. However, the parameterization (known as PMNS) currently used in neutrino experiments limits the universality of this discovery, as well as possible physics tests beyond the standard model. This subject proposes to rewrite the neutrino oscillation algorithm used in T2K and Hyper-Kamiokande considering a non-unitarity of the PMNS matrix, then to apply the result to the data collected by T2K since 2011 for the first time. This result will constitute a first physics search beyond the standard model by this method in T2K, as well as obtaining universal results on the violation of CP symmetry.

Connecting dark matter and galaxies with machine learning.

Dark matter (DM) is the greatest unsolved mysteries in cosmology and physics, and mostly hidden from the current observations. The DM distribution can be inferred from observed galaxy distributions, but their relation is complex. To learn the spatial correlation between DM and galaxies, we combine hydrodynamic simulations and machine learning techniques. Hydrodynamic simulations can predict the spatial correlation between DM and galaxies, which can be learned by state-of-the-art machine learning technique. This project aims to reveal the DM distribution in the real Universe using the current observation of galaxies