Title and abstract of projects:

1. Supervisor: Van Que Tran (NCTS)

Title: Exploring Gravitational Waves from First-Order Phase Transitions in the Early Universe

Abstract:

In the early Universe, fundamental forces and particles underwent dramatic changes as the cosmos cooled. One key event, called electroweak symmetry breaking, shaped how particles like the Higgs boson interact and gave them mass. In the Standard Model of particle physics, this process is smooth, like water gradually cooling into ice. However, theories beyond the Standard Model suggest it could have been a violent, first-order phase transition--more like water suddenly freezing in a supercooled state. During such a first-order electroweak phase transition (FOEWPT), bubbles of a new vacuum state could form, expand, and collide in the hot, dense early Universe. These collisions would release energy in the form of gravitational waves (GWs)—ripples in spacetime itself. Detecting these GWs could reveal secrets about the Universe's first moments and test new physics beyond the Standard Model. This topic is exciting because it connects particle physics to cosmology. A FOEWPT could be one of three conditions needed to explain why there's more matter than antimatter in the Universe today, a puzzle known as baryogenesis. It also predicts new particles that future experiments, like those at particle colliders, might discover. Most thrillingly, the GWs from these ancient events could be detected by upcoming space-based observatories like LISA, TianQin, or DECIGO, giving us a direct window into the early Universe.

2. Supervisor: Shu-Yu Ho (AS)

Title: Calculating the relic abundance of dark matter with micrOMEGAs

Abstract:

Calculating the correct relic abundance of dark matter is a crucial topic in dark matter research. In this study program, we will focus on several well-known dark matter scenarios, such as weakly interacting massive particles (WIMPs) and feebly interacting massive particles (FIMPs), and estimate their relic densities by using the micrOMEGAs package. In addition, we will compare the calculation results with the analytical formula.

3. Supervisor: Loc Ngo (NCTS)

Title: Pathways for primordial black holes to resolve the dark matter problem

Abstract:

In this summer project, we will explore scenarios for primordial black holes (PBHs) to resolve the dark matter (DM) problem. First, we will study how ultra-light PBHs can produce the observed DM abundance via Hawking evaporation while satisfying cosmological constraints. Second, we will study how heavy PBHs themselves could also be a natural DM candidate. This project aims to help the student develop physical intuition, perform some simple calculations, and most importantly learn how to approach new research problems.

4. Supervisor: Cheng-Wei Chiang (NTU)
Title: AI in collider physics
Abstract:

In this project, the student is asked to master various techniques required for using modern AI in collider physics. This involves the installation of common high-energy physics packages, learning how to use them, the generation of collider events for physical processes, and working on a machine learning project.

5. Supervisor: Po-Yen Tseng (NTHU)
Title: Probing Heavy Dark Matter in Red Giants

Abstract:

We consider the heavy dark matter (DM) being captured by the red giants (RGs), following reference arXiv:2509.03388. Captured DM particles move toward the helium-rich core and accumulate into a compact configuration. As the DM population grows, it gravitationally bounds and then undergoes gravitational collapse. The resulting energy release heats the stellar core and advances helium ignition compared with the standard stellar evolution. This leads to the observational constraint that helium ignition must not occur before the observed luminosity at the tip of the RG branch. The student can learn i) how to compute the DM capture rate by RGs, ii) analysis the condition when the gravitational collapse starts, and iii) estimate trigger mass for helium ignition. If the time is sufficient, we will perform further analysis and translate these conditions into bounds on DM properties.