

Master 2 Project

Massive star-forming regions as cosmic accelerators

Research field

High-energy and particle astrophysics

Abstract

Cosmic rays (CRs) are charged energetic particles accelerated in the Universe to enormous energies by processes that are not yet completely understood. Observations indicate that in the Milky Way there are objects capable of accelerating particles up to energies of a few PeV, well beyond typical thermal energies. This non-thermal fluid is suspected of playing a key role in the formation of stars and the evolution of galaxies, by redistributing energy to all components of galactic ecosystems. Building a comprehensive understanding of CRs is therefore of paramount importance to astrophysics at large.

The standard paradigm assumes that Galactic CRs are accelerated in strong shocks in supernova remnants. Yet, both theory and observations suggest that these objects can hardly produce particles beyond 100 TeV, leaving room for another family of accelerators. Star-forming regions could host specific processes capable of accelerating particles up to PeV energies [1], and material from the winds of evolved massive stars is essential to explain the abundances of heavy elements observed in CRs [2].

CRs can be probed through observations of gamma rays produced in their interactions with the rich reservoir of gas and photons in star-forming regions. Gamma-ray emission is indeed observed toward at least a dozen Galactic star-forming regions, and the sample keeps growing [3]. However, detailed studies of some individual regions so far remain compatible with a variety of scenarios for the particle acceleration site and process [4].

In this internship, the student will analyze observations by the **Fermi Gamma-Ray Space Telescope** toward several prominent Galactic star-forming regions. The work will consist of a **morphological and spectral characterization** of the emission associated with the targets, which will later be used to constrain where and how particles are accelerated, and how they merge with the large-scale population of CRs in the Milky Way.

The intern will be welcomed into a small group at **IRAP** with more than two decades of expertise in gamma-ray astronomy and a continued interest in cosmic rays. The group is part of an international collaboration gathered around the Fermi space mission, and the student will have the opportunity to interact with worldwide experts in the field.

References:

- [1] Vieu et al. 2022, *arXiv:2207.01432*
- [2] Tatischeff et al. 2021, *arXiv:2106.15581*
- [3] Tibaldo, Gaggero, Martin 2021, *arXiv:2103.16423*
- [4] Astiasarain, Tibaldo, Martin 2023, *arXiv:2301.04504*

Methodology

Data analysis

Prerequisites

The student should be about to complete a master degree in physics or astrophysics.
Knowledge of programming in Python is an asset.

Hosting institute

IRAP

Research Institute in Astrophysics and Planetology

9, Avenue du Colonel Roche / 14 avenue Édouard Belin

31028 Toulouse Cedex 04, France

Estimated Schedule

Estimated start date: **February 1, 2026**

Proposed duration: **5 months**

Supervisor

Luigi Tibaldo

luigi.tibaldo@irap.omp.eu