Thesis abstract C. Dubos

"Unveiling the origin of Galactic Cosmic-Ray through γ-Ray Observations with the Cherenkov Telescope Array Observatory and development of the calibration system for its NectarCAM Camera"

Nearly a century after their discovery, the misnamed "cosmic rays" remain a major scientific enigma—particularly, one key question persists: what is the origin of these highly energetic particles? Some of these cosmic rays are thought to be accelerated in violent astrophysical environments within our Galaxy, such as supernova remnants or stellar clusters. The composition of the particles themselves may also play a role, with heavier nuclei potentially being more efficiently accelerated than lighter ones. These considerations motivated the work described in this thesis.

In the first part, a multi-messenger astronomy approach is used to identify Galactic cosmic-ray accelerators and to probe the nature of cosmic rays using gamma-ray observations. These gamma-rays, among other processes, are produced via the decay of neutral pions, resulting from interactions between cosmic rays and surrounding matter. By applying various radiative models, a multi-wavelength analysis from radio to gamma-rays of the electromagnetic spectrum of the stellar cluster Cygnus Cocoon was performed, showing high-energy emissions linked to a lepto-hadronic origin, likely involving efficient electron and proton acceleration.

Based on this multi-wavelength study, the second part of this thesis presents simulations conducted for the Cygnus Cocoon, as well as for the two supernova remnants RX J1713.7-3946 and HAWC J2227+610, in the context of the future high-sensitivity ground-based telescope CTAO (Cherenkov Telescope Array Observatory). Using the Gammapy software package, we investigated CTAO's potential to: (1) detect very high-energy cosmic rays and distinguish heavy (CNO, Fe) cosmic rays from lighter ones (protons), and (2) study different cosmic-ray acceleration scenarios through the shape of the gamma-ray spectrum.

In parallel, an instrumental contribution was made to NectarCAM, one of the cameras designed for one of the CTAO telescopes, the Medium-Sized Telescope (MST), which will indirectly detect gamma-rays through Cherenkov astronomy. This work forms the subject of the third part of this thesis. It involved the production and tests of “White Targets” realized at IJCLab, intended for the calibration of the camera sensors, under very low light conditions—at the single photoelectron level—in

preparation for the first NectarCAM observations. Statistical and systematic tools were developed to assess the quality of these targets and enable their selection. Finally, data from camera calibration runs were analyzed, with results showing the good performance of the calibration system.