Title: Cherenkov Telescope Array: Development of a calibration system for NectarCAM and study of Supernova Remnants as PeVatron candidates.

Keywords: high-energy gamma observation, supernova remnant, Cherenkov Telescope Array, Galactic cosmic rays, radiative models, multiwavelenth analysis, NectarCAM camera, single photoelectron calibration

Abstract:

Cherenkov Telescope Array (CTA) promises to see the high-energy Universe with unprecedented sensitivity and angular resolution covering the multi-TeV domain. The first part of the thesis concerns the development of a single photoelectron calibration system for the NectarCAM camera. The second part aims to understand the origin of Cosmic Rays (CRs) by performing a multiwavelength (MWL) analysis of existing data of Galactic Supernova Remnants (SNRs). Finally, the third part studies CTA's role in detecting SNRs in search for PeVatrons by simulating fluxes using Gammapy.

A focal plane single photoelectron (SPE) calibration system has been specially designed by IJCLab for the NectarCAM camera of the MST telescopes. The system consists of a white painted screen, a fishtail light guide, and a flasher. The flashes mimic the Cherenkov radiation and illuminate the focal plane under the screen homogeneously. Then, through the XY motorization, the screen is moved across the entire focal plane of the NectarCAM camera. This thesis work concerns the development of the calibration system. In particular, the design of the calibration screen was optimized, and an algorithm to scan the focal plane was written. Finally, the data from the MST calibration runs were analyzed, and the results show a good performance of the calibration system.

SNRs are promising candidate sources for Galactic CRs. The charged CRs can be detected indirectly by the γ-ray observations through the π^0 production and consequent decay to high-energy γ-rays. In this thesis work, we study the trends in favor of lepto-hadronic scenarios and search for SNRs which show signs of hadron acceleration up to the highest energies. We have performed an MWL study on nine SNRs using data from different instruments different. The data were fitted with radiative models to evaluate the hadronic contribution. The fit results were analyzed using three different methods: likelihood comparison, BIC criterion, and the estimation of the hadronic contribution as a function of energy bins. The results showed that all the studied SNRs favor the lepto-hadronic model over a pure leptonic one. We identified four SNRs, RX J1713, Cassiopeia A, HESS J1731, and HAWC J2227, which showed important hadronic contributions up to a few TeV, thus making them promising PeVatron candidates. Additionally, for some SNRs, excess flux was observed at high energies.

The last part of the thesis is dedicated to assessing CTA's capability to detect SNRs. This involves answering if CTA can 1) improve the observations of the potential PeVatron sources previously identified, 2) detect different proton cutoff energy values, and 3) identify the contribution of heavier elements to the excess flux at high-energy observed before. To do so, CTA fluxes are simulated by Gammapy using physically motivated models taken from the results of the MWL study performed earlier. CTA has provided flux covering a wide energy range with less uncertainty compared to current instruments. For source RX J1713, a contribution of heavy elements was introduced. The result showed that by using a combination of hydrogen and nitrogen-like elements, a better fit was obtained compared to the fit using only protons.
In addition to the previous simulation study, we also analyzed the results of the Galactic Plane Survey simulated by the Galactic group of CTA. The study showed that CTA would increase the number of detected SNRs by a factor of 2. Additionally, SNRs covering a large distance (up to 20 kpcs), with flux as low as $\sim 10^{-14}$ photons cm^{-2}s^{-1} would be easily detected by CTA.