

Diffuse Gamma-ray emission in galaxy clusters using LHAASO-WCDA

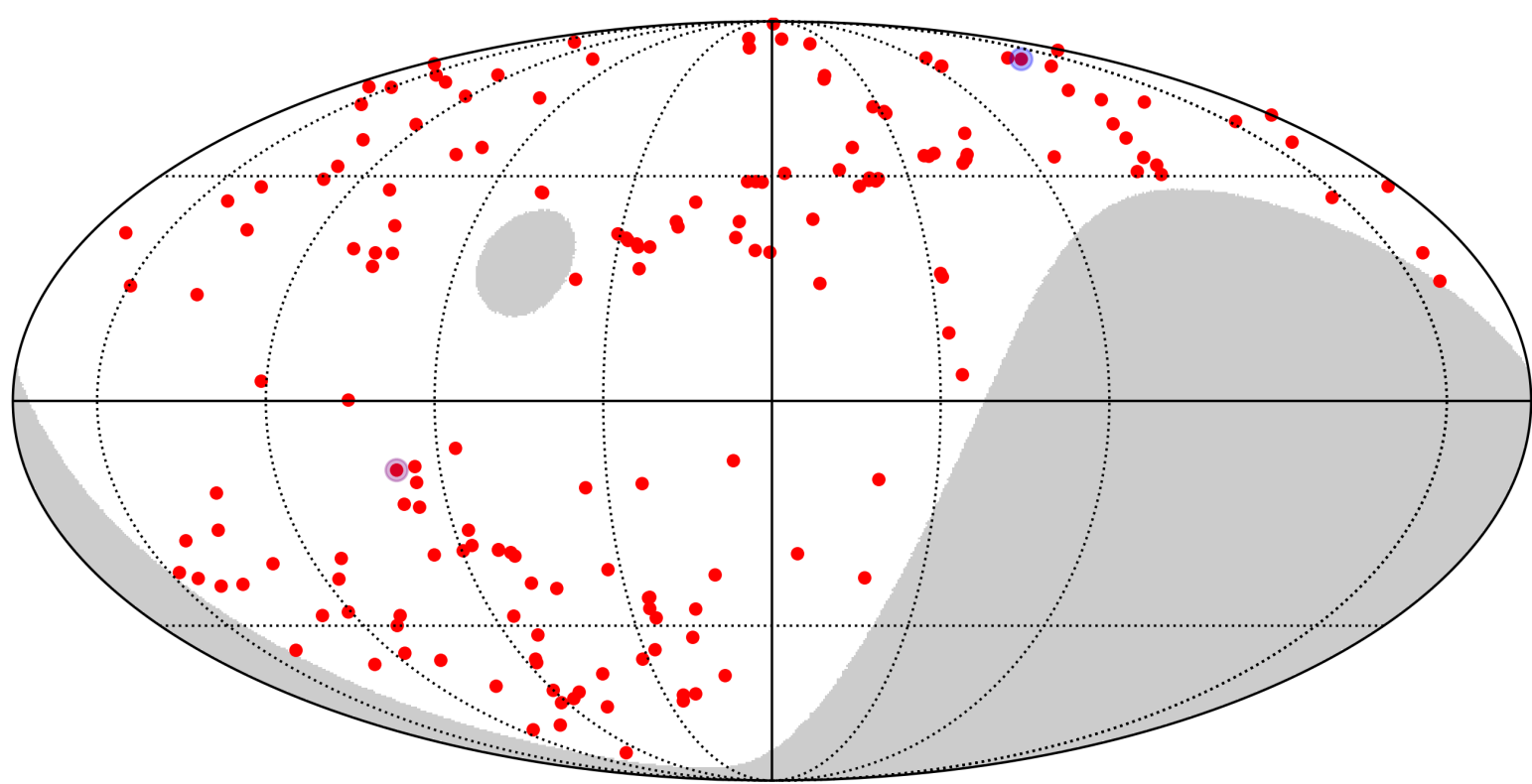
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ABSTRACT

Galaxy clusters are the largest gravitationally bounded systems in the universe. Almost 80% of their content is dark matter (DM), while 15% is in the form of hot gas permeating the Intra Cluster Medium (ICM). It is believed that a relativistic population of protons have been accumulated through the formation history of the galaxy clusters. This component should interact with ambient protons and photons producing charged and neutral pions leading to production of secondary electrons and gamma-rays. Here we show the analysis using LHAASO WCDA to search for a diffuse signal in a sample of nearby galaxy clusters.

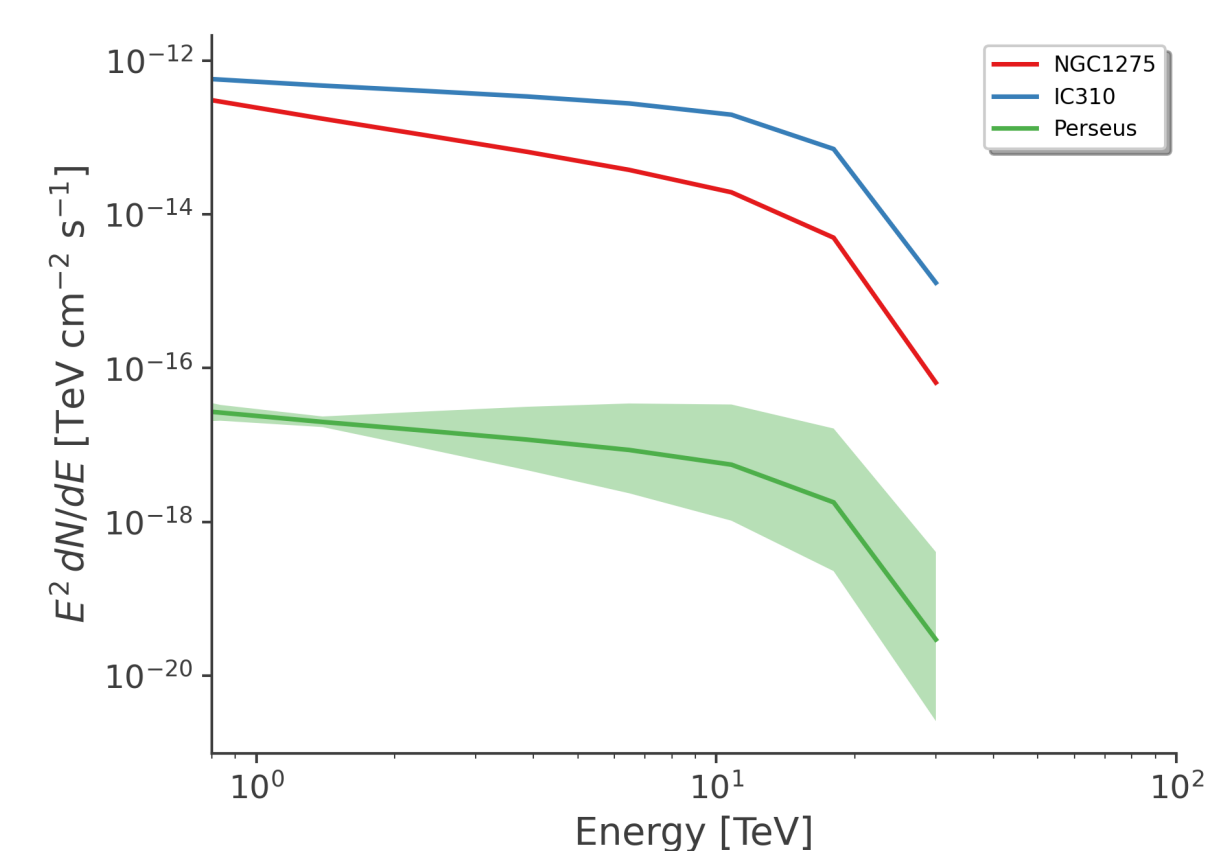
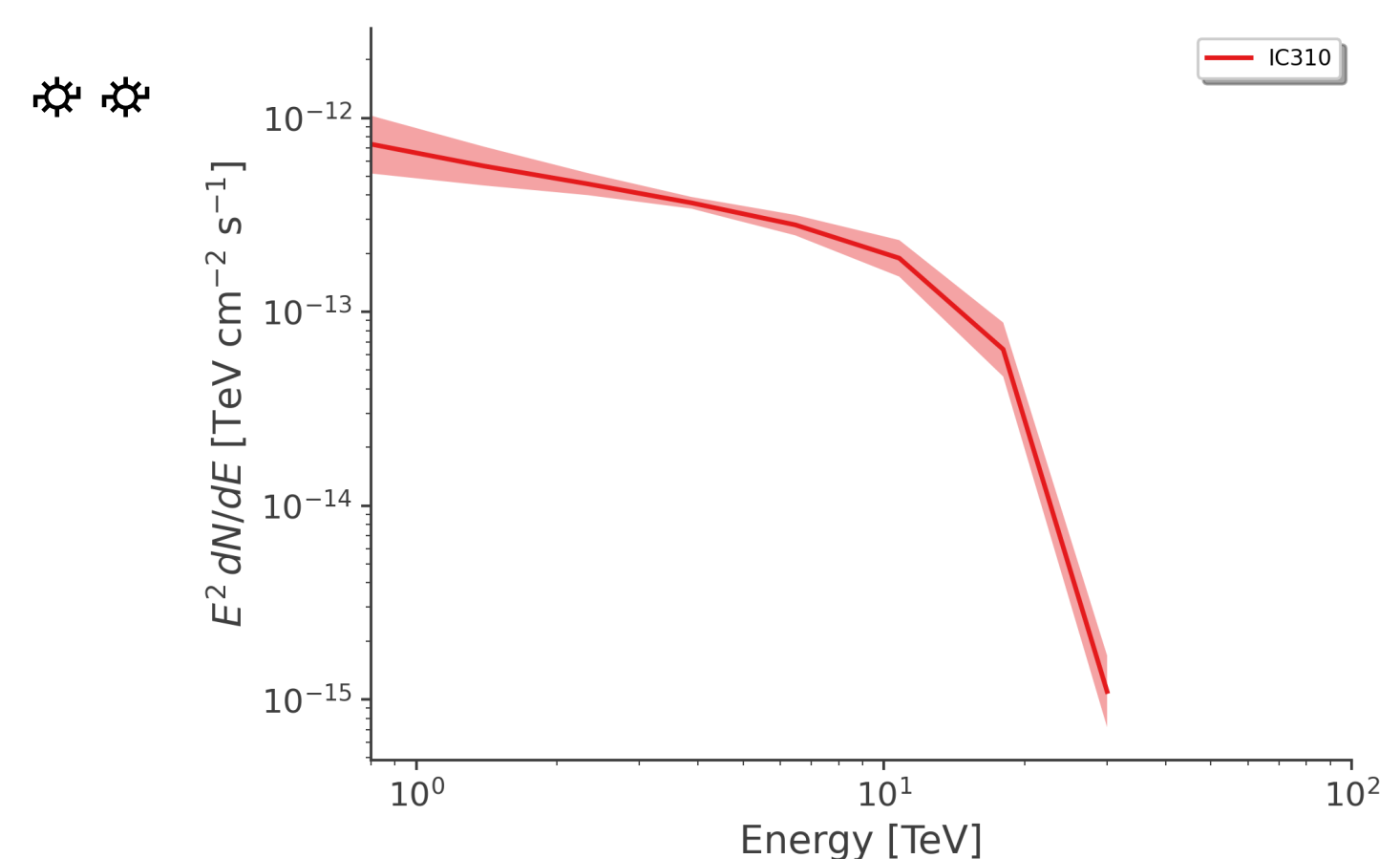
INTRODUCTION

- Galaxy clusters are expected to have a large population of relativistic cosmic rays protons (CRs) confined
- CRs can be accelerated up energies above 100 TeV
- Hadronic interactions should induce a diffuse gamma-ray emission through the whole volume of the host cluster
- We use the MCXC-II catalog to select clusters within the field of view of LHAASO and redshift no larger than 0.05. The sample resulting in 176 clusters. ✓✓✓
- An extra selection cut is related to the expected diffuse gamma-ray emission induced by CR interactions. ✨ ✨ ✨



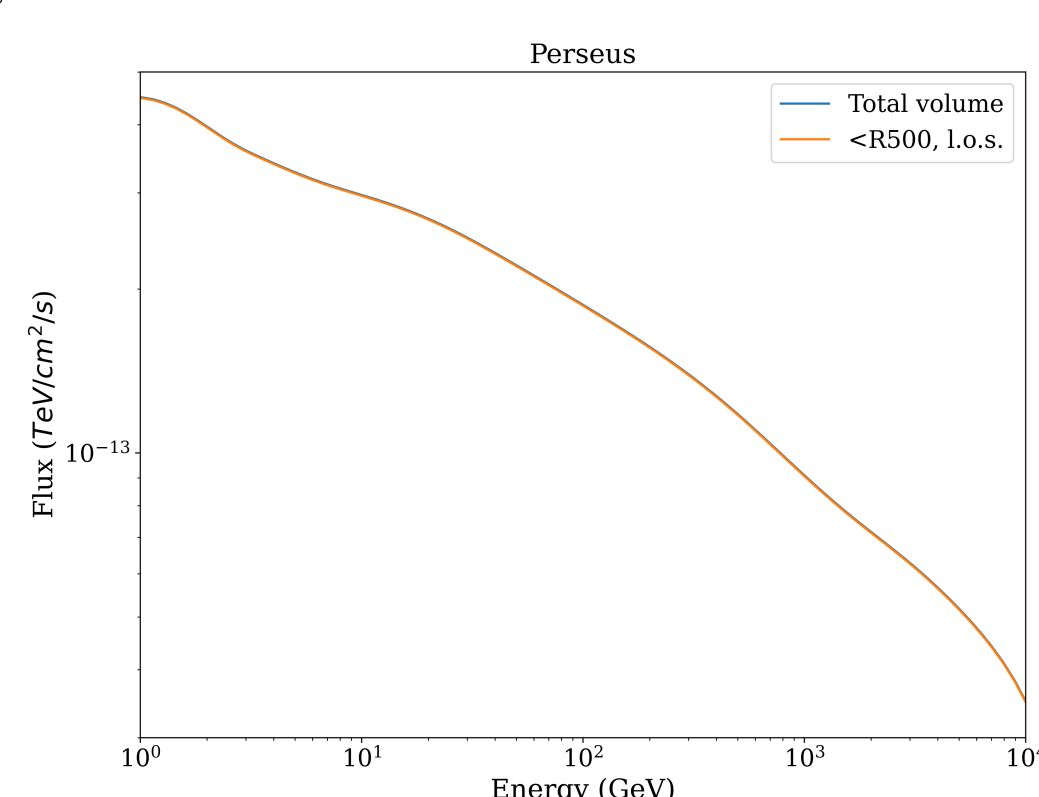
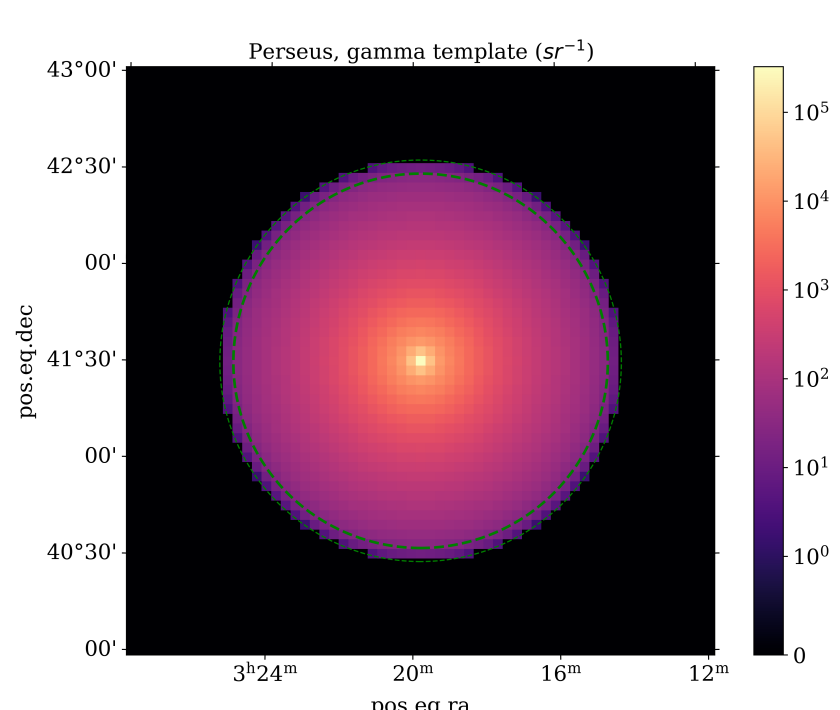
ANALYSIS USING 3ML

- We use WCDA data covering 1484 transits and the corresponding Detector response for declinations larger than 28 degrees
- We include the two AGNS located in the center of the cluster: IC 310 and NGC 1275.
 - NGC 1275 \Rightarrow PowerLaw + PointSource [TS \sim 10]
 - IC 310 \Rightarrow PowerLaw + PointSource [TS \sim 193]
 - EBL Model \Rightarrow Dominguez
 - No clear detection of NGC 1275 [Δ AIC = -6, Δ BIC = 6 with respect to only consider IC 310 contribution]
- SpatialTemplate_2D model for the CRs component. We test for a PowerLaw spectrum (reasonable choice)
 - We fix the spectral indices of the AGNs and only let the normalizations as free parameters
 - The CRs component add other two spectral free parameters
 - No evidence of diffuse emission (TS \approx -10⁻⁴), but the expected peak of the emission is coincident with the position of NGC 1275
 - No improvement with respect to only consider IC 310
 - Test if masking the center of the cluster can improve the fit quality ✨



Modeling: Perseus Cluster

- We use Minot (Remi+; 2019) to model the different populations and parameters to describe the ICM of a cluster.
- As an example, we show the expected spatial and spectral gamma-ray emission for the Perseus Cluster
- From X-ray observations, the ICM gas is described using a double- β model with core radii at 57 and 278 kpc and average gas density of $4.6 \times 10^{-3} \text{ cm}^{-3}$.
- We use a Universal Pressure Profile to describe the gas pressure in the Perseus cluster (Ghirardini+; 2019)
- The magnetic field is a power-law in the gas density: $B(r) \propto n_e^\eta$.



ToDo

- Reduce the sample size to only consider the best targets (based on gamma-ray luminosity)
- Finish estimation of spatial templates (check with existing literature to find magnetic field and gas density parameters)
- Extract upper limits on the CR-to-thermal-pressure ratio from a joint analysis