Fermi-LAT observations of Hydra A

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Abstract

Galaxy clusters are the largest virialized structures in the Universe. The detection of diffuse-radio emission from galaxy clusters indicates populations of relativistic leptons interacting with the intracluster medium. Gamma-ray emission from galaxy clusters, arising from these energetic leptons and the decay of neutral pions produced in hadronic interactions, may be detectable with the Fermi-LAT. Using data from the Fermi-LAT, we will present upper limits on gamma-ray emission from Hydra A, which hosts a cluster scale AGN outburst with extraordinary energetics. These upper limits are then used to constrain the energetics of hadronic cosmic rays in Hydra A.

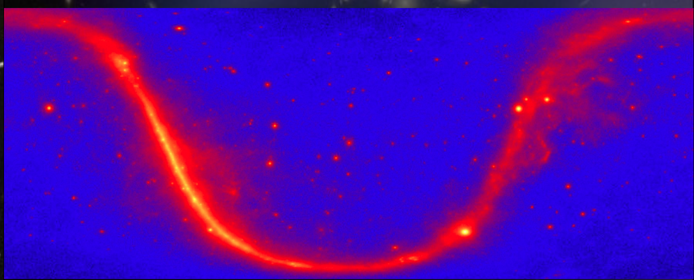
The Fermi-LAT Satellite

The Large Area Telescope (LAT) is the primary instrument on the Fermi Gamma-ray Space Telescope (Fermi). It is an imaging, wide field of view, high energy telescope, covering the energy regime from 20 MeV to 300 GeV with an angular resolution of approximately 5° at 100 MeV and narrowing to 0.14° at 10 GeV.

Image of the Fermi Satellite in orbit.

Credit: NASA E/PO, Sonoma State University, Aurore Simonnet

An all sky map of the gamma-ray Universe produced using the Fermi-LAT satellite is shown below. The image shows how the sky appears at energies more than 100 million times greater than that of visible light. The bright band across the image is the combination of diffuse gamma-ray emission from our galaxy and point sources embedded within.



Fermi-LAT all sky map of the gamma-ray Universe above 100 MeV.

Cosmic Rays in Galaxy Clusters

Large scale shock waves caused by hierarchical structure formation may accelerate particles to non-thermal energies. Additionally supernovae and galactic winds from galaxies can populate galaxy clusters with non-thermal particles. Finally, powerful AGNs are believed to be prominent injectors of CRs into the ICM.

For an assumed magnetic field of B ≈ 30 μG (Tayler & Perley 1993), electrons with energies greater than a GeV cannot accumulate within the cluster volume. This is due to synchrotron and inverse Compton cooling ($\tau_{cool} \leq 10^7$ years, Hinton et al 2007).

However, hadronic CRs with energies of less than 10^{15} eV accumulate within the cluster volume. This CR component will interact with the hot intra-cluster medium and produce high energy γ-ray via inelastic proton-proton collisions and subsequent π^0 decay, and is predicted to be detectable with Fermi (Hinton et al 2007).

Conclusion

From our upper limits, it is clear that the current generation of gamma-ray observatories are able to constrain the most favorable scenarios of hadronic cosmic ray content in Hydra A. However, it is still not possible to completely exclude hadronic cosmic rays as the energetically most important feedback agent in cluster-scale AGN outbursts.

Hydra A

Hydra A is the closest (at a redshift of 0.054) known galaxy cluster which hosts a cluster-scale AGN outburst.

It features low frequency radio lobes extending to 4 arcmin from the cluster centre.

These radio lobes are surrounded by shocks in the intra-cluster medium.

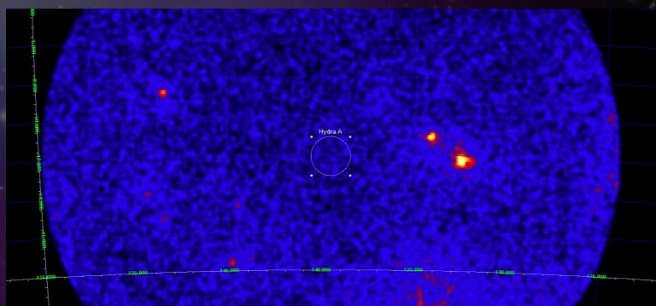
Properties of Hydra A:

- d = 260 Mpc
- $T_{ICM} \approx 10^7 - 10^8$ K
- $\rho \sim 5 \times 10^{-3}$ cm^{-3}

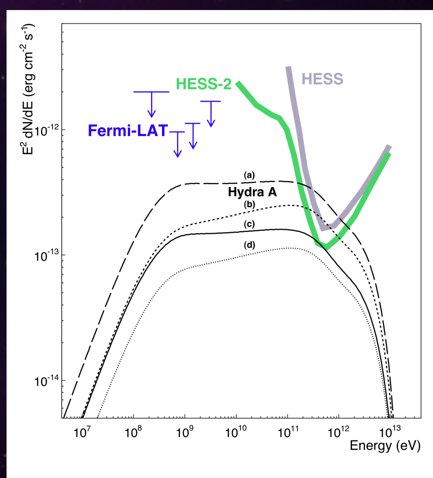
Composite image of Hydra A showing the intracluster medium as observed by Chandra in blue and jets of radio emission observed by the Very Large Array in red.
Image credit: Nasa/CXC/U Waterloo/C Kirkpatrick et al.

Results

Data presented here comprises 2 years of Fermi-LAT observations. Events with energies between 100 MeV and 300 GeV and within a circular region of 15° radius have been considered in the analysis. A counts map of this region produced using standard Fermi analysis tools is shown below (where the counts range from 0 to 11 per bin).



There was no detection of Hydra A with the Fermi-LAT and here we present the upper limits.



The black curves (labeled as a, b, c and d) represent different model predictions for the production of gamma-rays within Hydra A as calculated by Hinton et al. (2007). The blue lines represent the 3σ upper limits within the energy bands for Hydra A as observed with Fermi for two years (from launch up to June 2010).