Cosmic Rays Emission and Propagation

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Introduction

Objective: In this work, we are trying to characterize this emission of cosmic rays from pulsars. In more detail, we are exploring if such a population of pulsars can make the cosmic ray (CR) electrons that produces the gamma-ray exceeding emission.

- The Fermi LAT gamma-ray instrument is detecting an emission that exceeds the expectations towards the Galactic center of the Milky Way. In the past years this emission has been attributed by different authors either to dark matter or to a glow of sources that were too faint to be detected by Fermi. Recently, we were able to model the entire gamma-ray excess of the Galactic center with a population of about one thousand pulsars.
- To do that we have investigated the CR electron spectra that can be produced by pulsar wind nebula (PWN). We have characterized the PWN by the age of the pulsar and from its distance from the Earth. As a result we found that as the pulsar furthered away from the earth the gamma rays produced by its CRs were harder to detect as well as the younger pulsars. This will be the basis to describe CR electrons produced by the pulsars in the Galactic center, and eventually the emission seen by Fermi LAT in the same region.

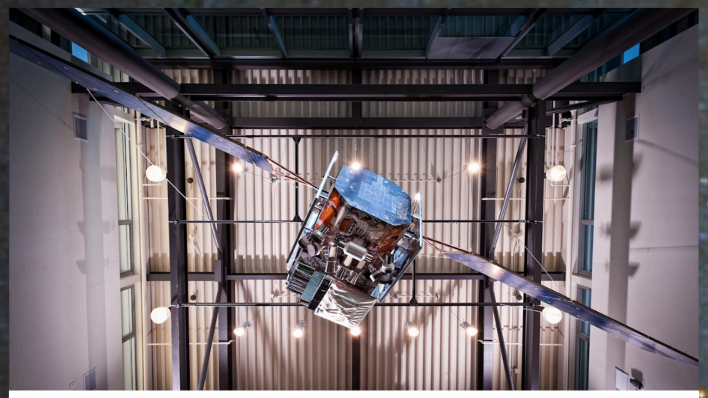

Figure 1: Fermi Telescope replica, half the size of the original, as seen in the Kavli building at SLAC.

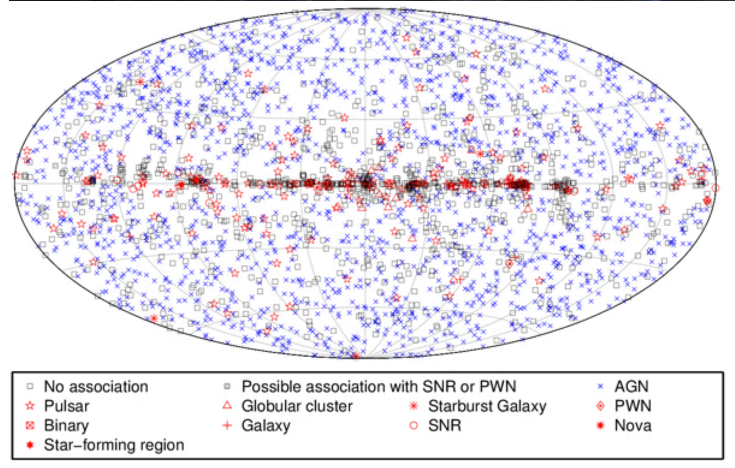

Figure 2: This image is the entire milky way in a 2D plane that shows what has been collected by Fermi essentially showing that Galactic center is made from pulsars.

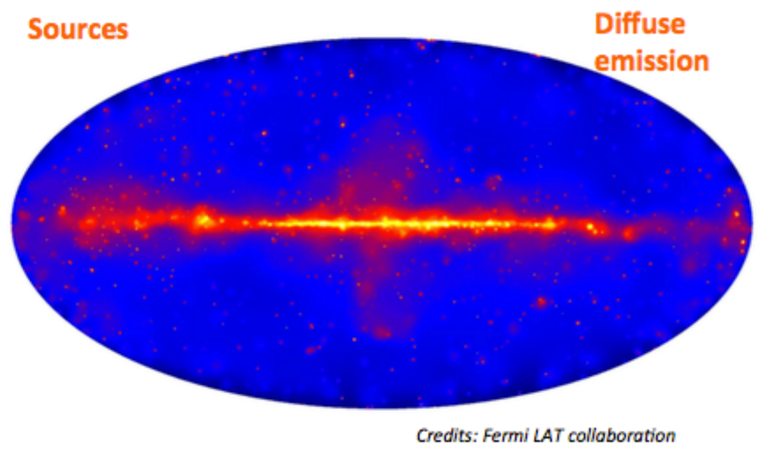

Figure 3: This is also an image of the milky way in a 2D plane that demonstrates the sources and diffusion emission of gamma rays.

Methods

- **First, I had learn how gamma rays are produced and how Fermi is able to detect them in order to understand the reason for using Fermi and gamma rays to detect the emission of CRs.**
- **Secondly, I learned about Inverse Compton so that I would be able to understand how gamma rays are produced from CRs and the diffusion of the CR electrons.**
- **Lastly, we used python to construct a program that resulted in graphs and predictions of the emission and propagation of CR electrons. The graphs were used to compare the distance and age of the pulsars to analyze the flux of the CRs emitted.**

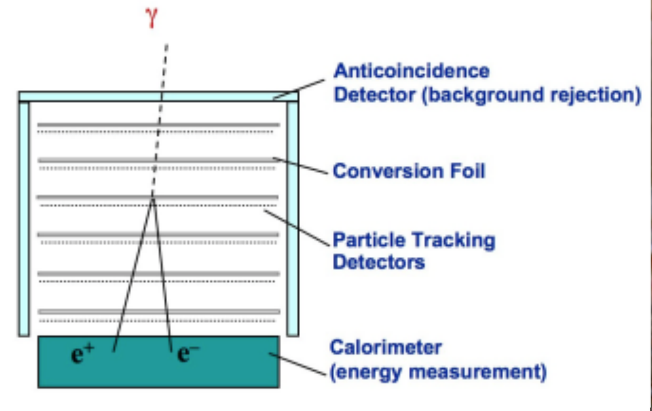

Figure 4: This is an image of the Fermi LAT and describes how the telescope detects the pair conversion.

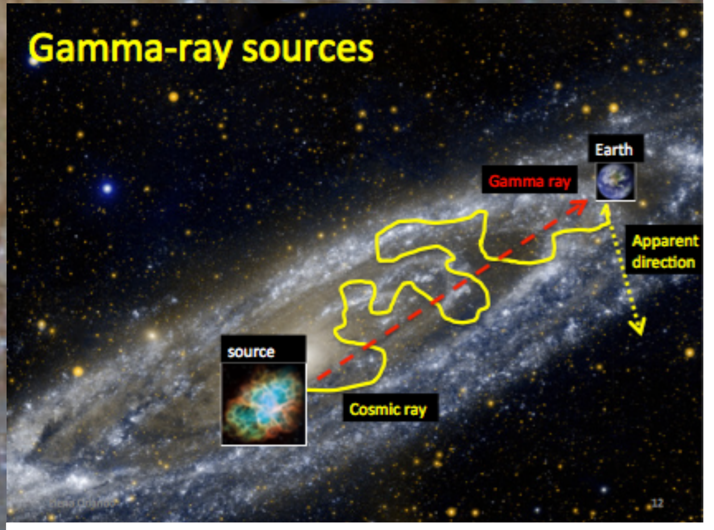

Figure 5: This image is a good visual aid to explain the emission of a gamma rays and how gamma rays help pin down the source of the cosmic rays.

Results

- **Based on the data collected by Fermi the main hypothesis was that the Galactic center is made up of pulsars so my objective was to use a python program that simulated the emission and diffusion of the CR electrons using a couple mathematical equations and plot the data produced by this simulation in order to understand more about the sources of the CR electrons.**
- **As a result I was able to plot two graphs shown in figures 6 and 7. From these graphs I was able to analyze the type of electrons that were being detected by the Fermi telescope according to the distance of the pulsar from the Earth and the age of the pulsar.**
- **In figure 6 we took the hypothetical distance of 0.5kpc and compared the different ages of the pulsar and we found that a young pulsar emits a spectrum of very high energetic electrons seen from Earth that result in low flux while a very old pulsar emits a wide spectrum of low and high energetic electrons seen from Earth and the graph demonstrates that the low energy electrons have a higher flux and as the energy of electrons increase the flux reduces.**
- **In figure 7 we took the hypothetical age of 11kyr of the pulsar and compared the different distances of the pulsar with respect to the Earth. We found that if the pulsar is really close to the Earth then Fermi is able to detect a very wide spectrum of low and high energy electrons and the flux is also higher for the low energy electrons and as the energy increases the flux decreases. In comparison to a pulsar at a large distance away from the Earth has a very small spectrum of high energy electrons, but it also has very low flux.**

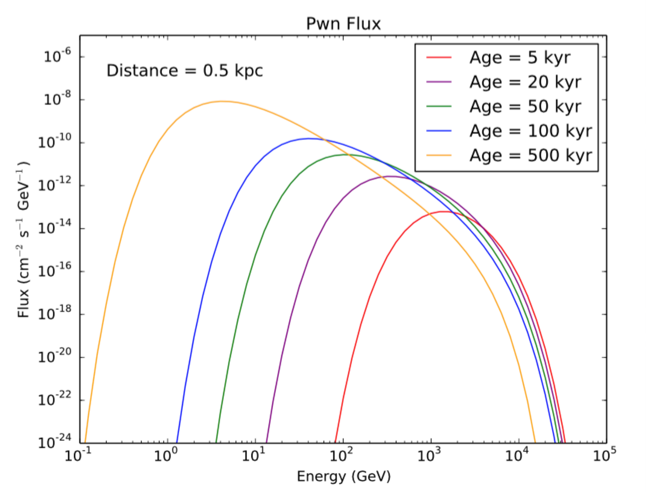

Figure 6: This graph was produced by the python program to compare the flux of the electrons depending on electron energy at a fixed distance of the pulsar from the Earth and different ages of the pulsar.

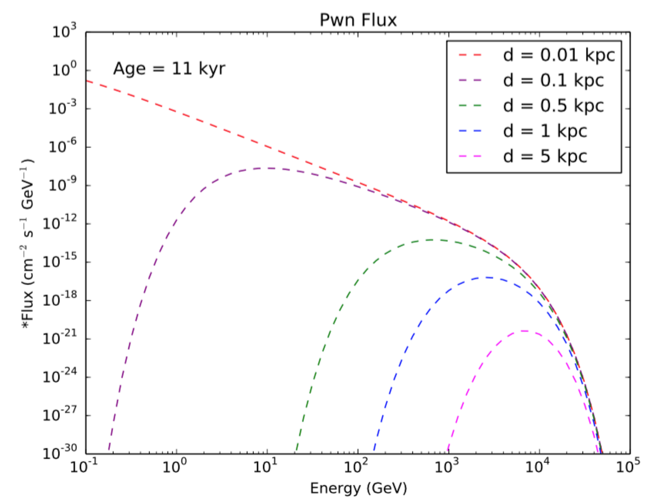

Figure 7: This graph was produced by the python program to compare the flux of the electrons depending on electron energy at a fixed age of the pulsar and the different distances of the pulsar from the Earth.

Conclusions

- I was able to learn a lot of particle physics and cosmology. It was very helpful to learn about the emission of gamma rays and how Fermi is able to detect them and help predict a source for CRs
- I was able to practice and learn a lot of new python commands and use packages I would not usually use. It showed me that astrophysists use programming very often to perform simulations.
- The graphs I produced were a visual certification of the behavior and propagation of high and low energy electrons emitted by pulsars.
- Provided more time I would have construct a program that graphed multiple pulsars and their effects on the propagation of the gamma rays to further our knowledge on these mysterious particles.

Bibliography

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