The Search for the Origin of Cosmic Rays

Anthony Fedorchak, 25 July 2014, Johns Hopkins University

Abstract

The topic I researched this summer was that of cosmic rays, rays of high energy particles composed mainly of Hydrogen nuclei and also the nuclei of other atoms.[1] The collision of these particles with Earth's atmosphere causes a "shower" of particles to rain down on the surface (Figure 1). Cosmic rays can produce a neutron, which then interacts with Nitrogen, forming Carbon 14, an isotope central to the process of carbon dating (Figure 2 / Figure 3).[2] Also, cosmic rays account for 0.39 mSv out of the yearly average of 2.4 mSv of natural radiation that public workers experience, accounting for approx. 15%.[3] I then examined the characteristics of a currently known cosmic ray source, Supernovae Remnants, and examined Pulsars, AGN, and the Sun to try and possibly identify these as additional sources of cosmic rays.

Figure 1: Cosmic ray shower

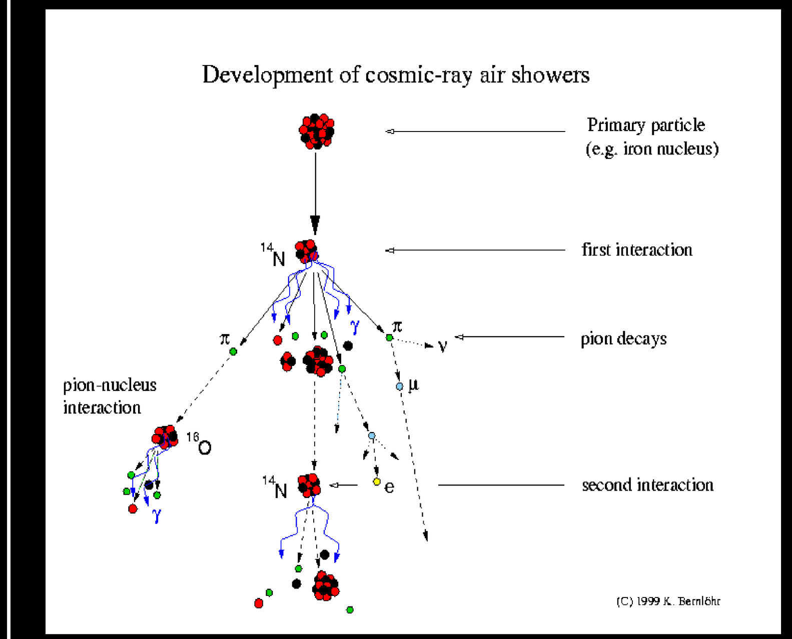


Figure 2: ^{14}C Production

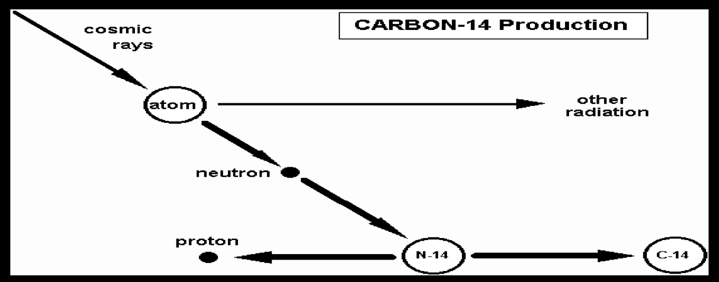
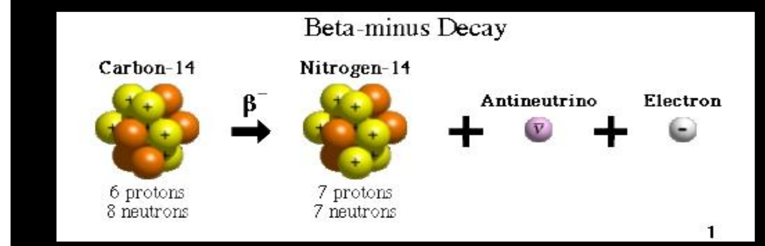


Figure 3: ^{14}C beta decay



Possible Sources

Cosmic rays, put simply, are high energy particles, so anything that has the capability to move these particles to high energy can be classified as exhibiting the behavior of a cosmic ray source.

The Sun- The sun emits enormous amounts of energy every second, and in addition to this, events such as solar flares as well as coronal mass ejections provide an even higher level of energy and/or shockwaves that ripple through space, events considered to be solar proton events. Machines such as the GOES Satellite track the flux of protons, and indicate when the sun is more or less active (Figure 4 / Figure 5).[4] [5]

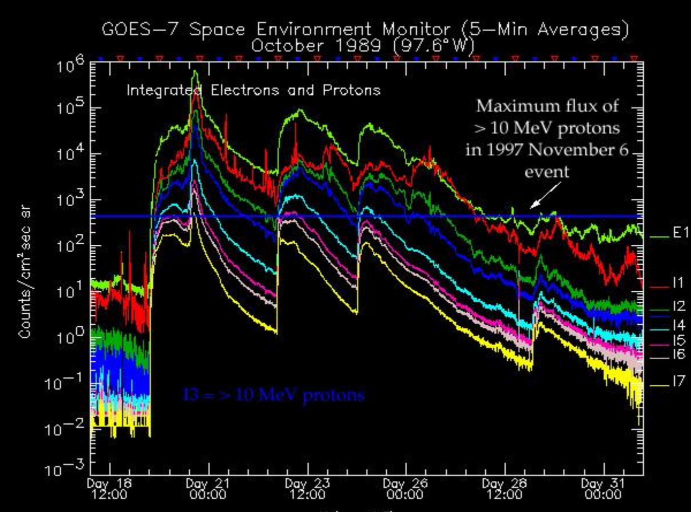


Figure 4: Above is the Proton Flux chart, plotting the proton flux as a function of time, acquired by the GOES Space Telescope. The spike of protons on all energy levels is attributed to a Solar Proton Event.

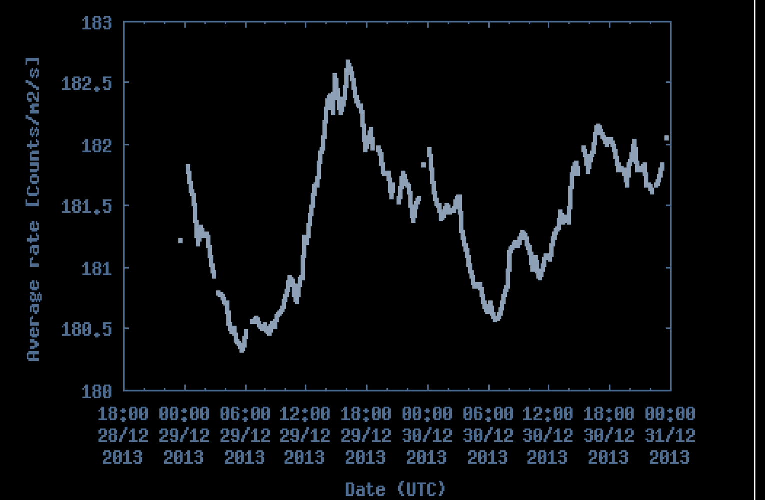


Figure 5: Scientists are still researching the cause of occurrences such as the one pictured above, where there are shown to be variations in the plot of flux of low energy particles as a function of time.

Active Galactic Nuclei- Some galaxies, with extremely luminous centers and high levels of radiation, have been named Active Galaxies, containing an Active Galactic Nucleus (AGN) at the center.[6] These AGN have, at times, been shown to emit radiation at high levels in the form of Gamma Rays (Figure 6).

Figure 6: Active Galaxy M87, one of the first galaxies found with a visible jet of radiation, indicating the presence of an Active Galactic Nucleus.

Pulsars- Pulsars are Neutron Stars that are rotating at immensely high speeds due to the disparity between the magnetic field associated with the Neutron Star and the axis of rotation of the Neutron Star, which results in a spray of radiation out of the poles (Figure 7). The cause of the disparity between the emissions is still being studied today.[7] [8]

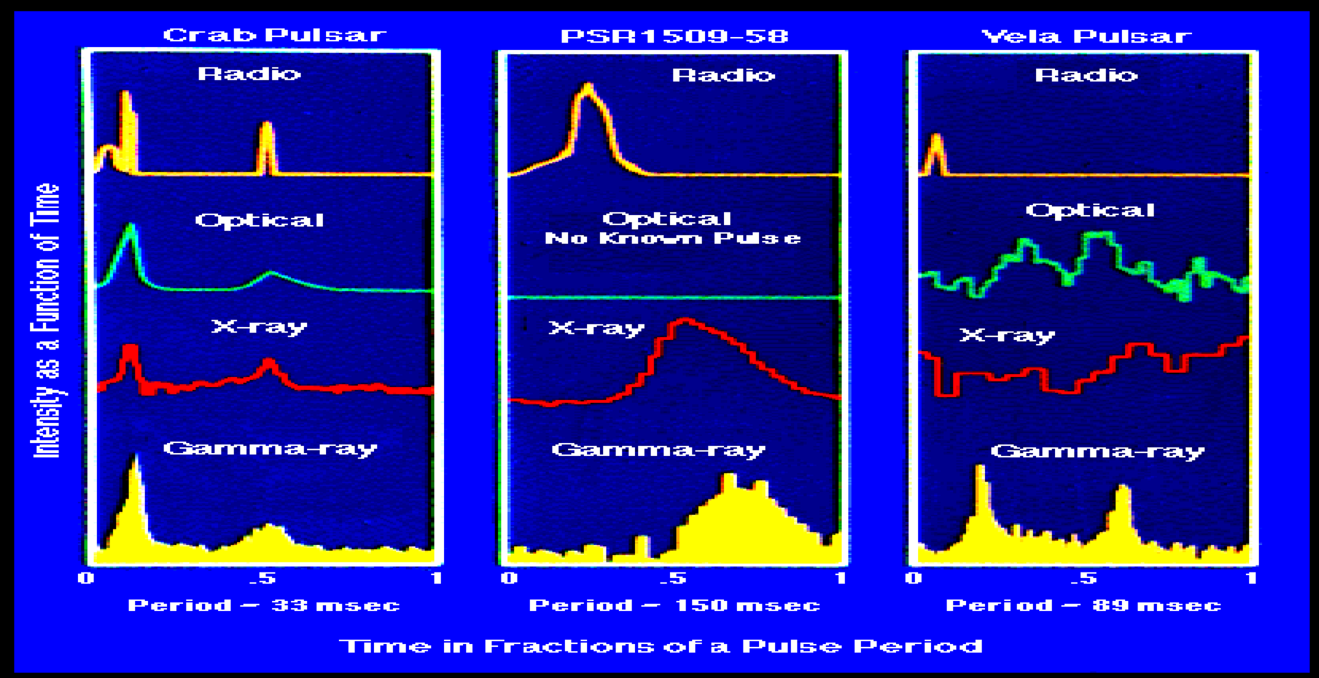
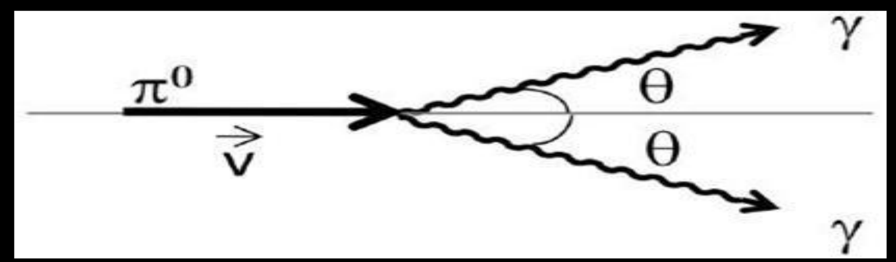


Figure 7- Pictured above is the intensity of varying energies of radiation as a function of time for 3 pulsars. Those with a shorter period are shown to be relatively more active in comparison to those with a longer period.

Fermi Telescope Breakthrough

The π^0 , a possible result of cosmic ray collisions, was the subject of research for scientists at the Kavli Institute. When the π^0 decays, it produces two gamma rays (Figure 8) of a distinct energy level, one that has been measured. [9]

Figure 8: Neutral pion decay into two gammas



By analyzing the radiation emissions from Supernovae remnants IC 443 and W44 (Figure 9), the scientists of the Kavli Institute were able to provide evidence that these Supernovae Remnants were sources of cosmic rays by comparing the π^0 –decay energy levels with the energy levels of gamma rays born from other processes. [10]

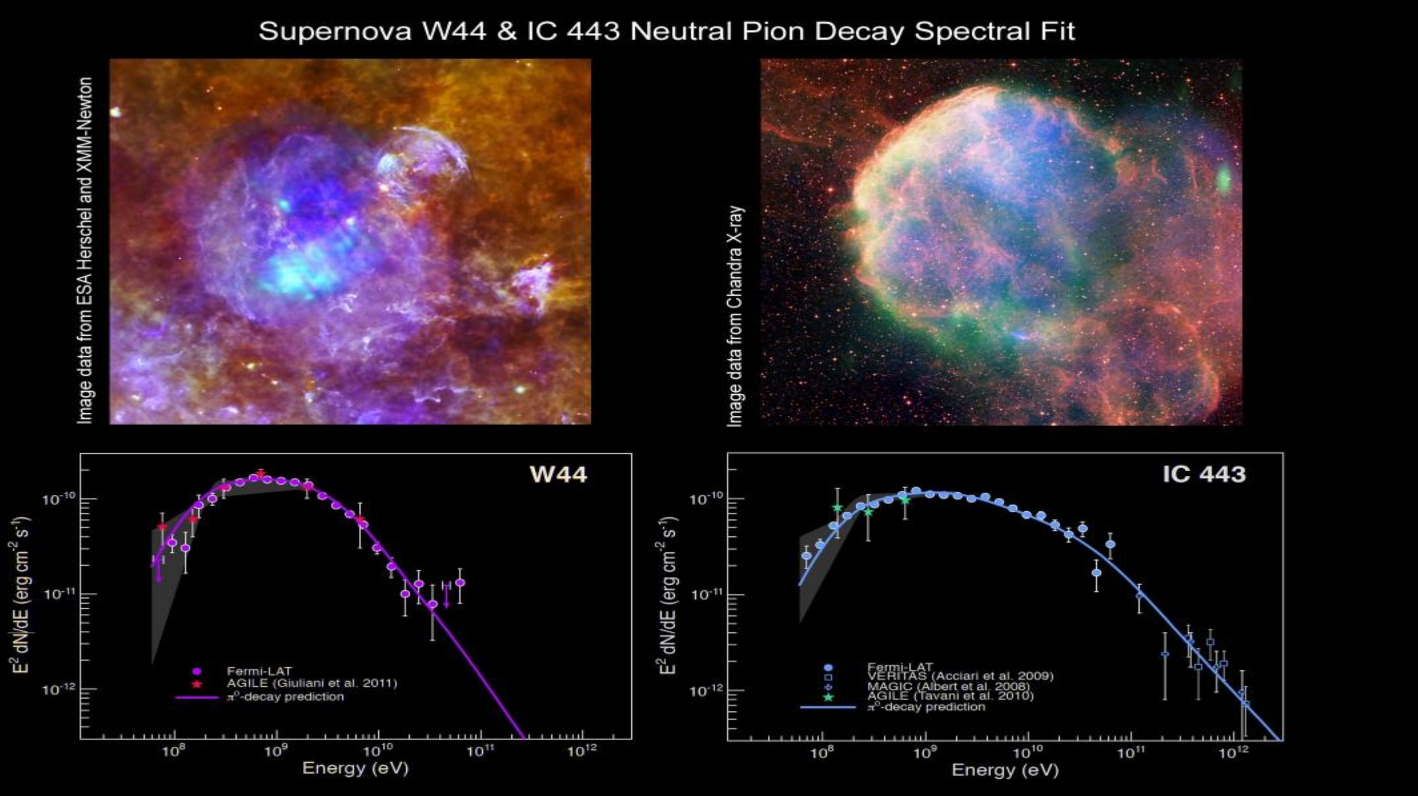
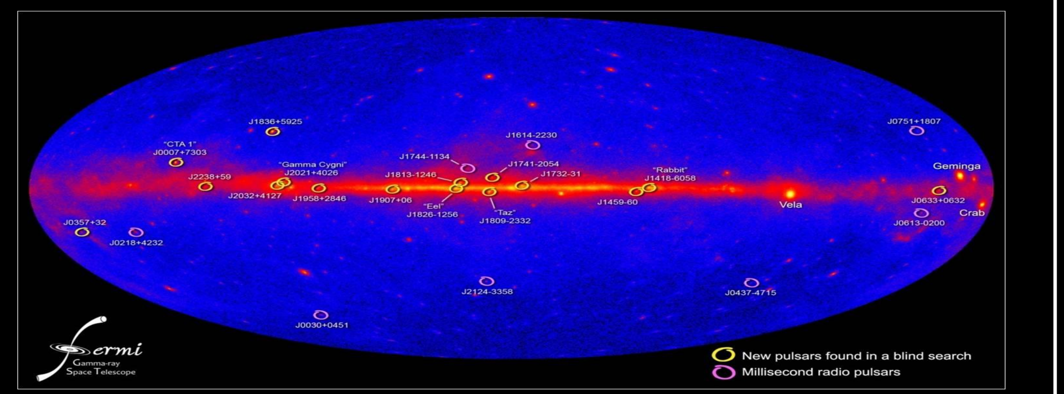


Figure 9- Pictured above is a graph of Gamma Ray flux as a function of energy for Supernovae Remnants W44 and IC 443, as well as images of both W44 and IC 443 in an assortment of spectra. Analysis of graphs similar to the ones above was central to the identification of Supernovae Remnants as a source of cosmic rays.

Continuing Research

I'll continue to look into the effects of cosmic rays, in areas other than the ones mentioned previously. In addition, I'll continue to examine various facets of the mentioned possible sources of cosmic rays, to try and get a more firm understanding of the processes that produce this recorded radiation, including other possible sources of gamma rays discovered by the Fermi telescope, as depicted in figure 10.

Figure 10: Gamma ray sources identified by FGST



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Images

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