Cosmic Ray Electron Science with GLAST

J.F. Ormes[1] and Alexander Moiseev[2]

[1] *University of Denver*
[2] *CRESST/USRA/GSFC*

Abstract. Cosmic ray electrons at high energy carry information about their sources, their diffusion in local magnetic fields and their interactions with the photon fields through which they travel. The spectrum of the particles is affected by inverse Compton losses and synchrotron losses, the rates of which are proportional to the square of the particle's energy making the spectra very steep. However, GLAST will be able to make unique and very high statistics measurements of electrons from ~20 to ~700 GeV that will allow us to search for anisotropies in arrival direction and spectral features associated with some dark matter candidates. Complementary information on electrons of still higher energy will be required to see effects of possible individual cosmic ray sources.

Overview

There are several outstanding questions regarding the origin and propagation of cosmic rays with energies from GeV to TeV in the galaxy. While the energy source for these particles is widely believed to come from supernova and their remnants, the details are unknown. Individual supernova remnants may dominate, or their acceleration may require clusters of supernova that drive the formation of superbubbles. We describe the motion of cosmic rays through the interstellar medium by a diffusive process based on the scattering of particles off waves and magnetic irregularities in the galactic magnetic field. What is the effective diffusion coefficient? How uniform is that coefficient across the galaxy? Is there a correlation of this coefficient with galactic spiral structure? How well do cosmic rays penetrate into clouds? Accurate measurements of the local electron spectrum by the Large Area Telescope on GLAST can address some of these questions.

In an accompanying paper (Moiseev, Ormes and Funk, these Proceedings) we demonstrate that the LAT will be capable of high precision measurements of cosmic ray electrons over the energy range ~20 to ~700 GeV. These measurements will be unique and contribute to the understanding of cosmic ray electrons and their production of photons by inverse Compton and synchrotron processes in the local environment. It is in this energy band that the spectral steepening is expected from these processes. With its large field of view and collecting power LAT will be able to measure the dipole anisotropy in electron arrival directions, to study their diffusion and to search for effects of electron streaming in the local galactic magnetic fields (Earl and Lenchek, 1969). Finally, we will be able to search for the spectral feature (a sharp upper edge) that might be produced by the decay of dark matter candidates such as Kaluza Klein dark matter particles (Baltz and Hooper, 2004).

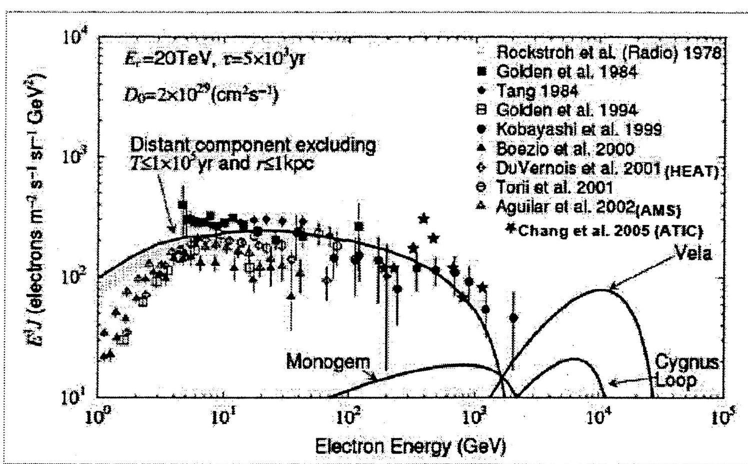

FIGURE 1 E^3×Flux for electrons. This compendium (Kobayashi 2004, Sapinski 2005) of electron measurements shows our poor understanding of the very steep electron spectrum in the range from a few GeV to 100 GeV and the paucity of measurements up to 1 TeV (adopted from Kobayashi et al. 2004).

What can GLAST contribute to electron science?

We outline three specific science areas in which GLAST/LAT electron measurements can contribute to our scientific understanding.

1) Precise measurement of electron spectrum from 10 to 800 GeV.

The change of slope seen at 7 GeV in the data shown in Figure 1 probably represents the change in slope expected due to the change from a region in which the spectral slope is determined by diffusion from the galaxy to one dominated by energy losses due to the electrons interacting with the photon and magnetic fields in the interstellar medium. In this same energy range, solar modulation plays a role in shaping the electron spectrum. The measurements proposed here can be used to sort these processes out and determine which ones dominate and in which energy ranges.

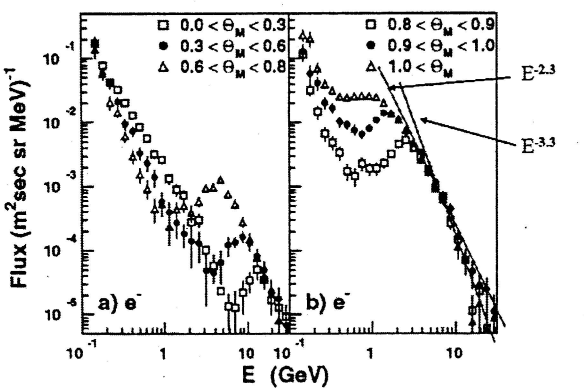

FIGURE 2. AMS electron spectra (Alcarez et al. 2000, Aguilar et al., 2002. The break in spectral slope at ~ 7 GeV corresponds to change between energy regions where diffusion and synchrotron losses dominate. Above this energy, the spectrum will continue with a constant slope until effects of nearby sources and diffusion in local magnetic fields become interesting above 1 TeV

2) Search for Kaluza-Klein dark matter particles in the GLAST energy band.

The electron signature for the direct annihilations of 300 and 600 GeV mass KKDM particles is given by Baltz and Hooper (2005). They show that the spectrum would be characterized by a sharp spectral upper bound at the particle mass. Preliminary results on the electron spectrum at the top of the atmosphere as measured by ATIC-2 show a suggestive feature that begs further investigation (J. Chang et al., 2005). Their data, shows a bump when compared with expectations from a model calculated with a diffusion coefficient of $D=2.0\times10^{29}(E/TeV)^{0.3}$ cm^2 s^{-1} and a power index for the injection spectrum of 2.4.

3) Measurement of electron anisotropy

Below 100 GeV, GLAST should observe anisotropies in the arrival direction of electrons due to diurnal variations and due to the motion of the Earth around the sun and be able to see the large scale effects of the solar magnetic field. Above 100 GeV we should become sensitive to the local interstellar magnetic fields. When located within the diffusing zone of particles coming from a single source (Ptuskin and Ormes, 1995), the expected anisotropy can be related to the gradient in the particle density as follows:

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