A Pulsar Description of the WMAP Haze

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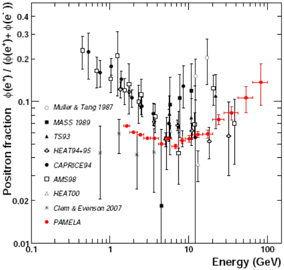
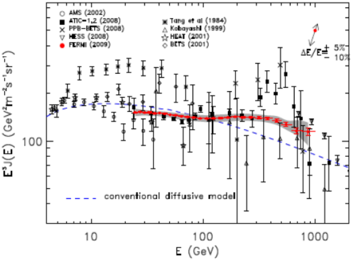
Outline

Cosmic Ray Anomalies

1. There has been a renewed interest in Dark matter as a result of recent cosmic ray experiments



PAMELA Collaboration 0810.4495



Fermi Collaboration 0905.0025

DM interpretation

1. Dark matter interpretation of these anomalies is getting stretched.
2. Cross section is required to be large, tension with CMB data.
3. No excess seen in $\overline{p}$, or γ-rays from the Galactic center and Galactic Ridge regions (Cirelli et al., Meade et al.)
4. There is a possible astrophysical interpretation.

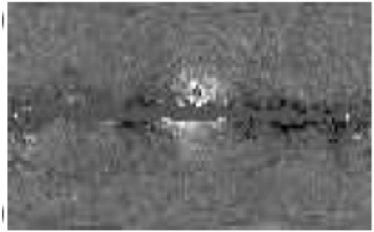
Pulsar interpretation

1. These anomalies could come from pulsar sources.
2. PAMELA was fit using pulsars in three papers
   - Using a galactic pulsar distribution (Hooper 0810.1527)
   - Using discrete pulsars (Profumo 0812.4457 and Malyshev 0903.1310)
3. Fermi Collaboration has fit the anomaly by adding an extra primary source of electrons and positrons

$$J(E) \propto E^{-\gamma} exp(-E/E_{cut}) \tag{1}$$

WMAP Haze

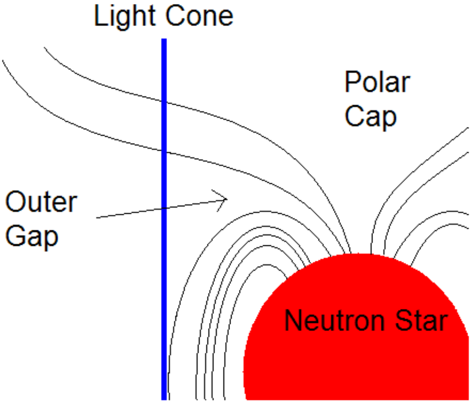
1. There are other anomalies, such as the WMAP Haze.
2. Found by Finkbeiner by analyzing the WMAP data after subtracting off known foregrounds.
3. Approximately radially symmetric signal consistent with synchrotron radiation off of a hard electron population.



Pulsar Models

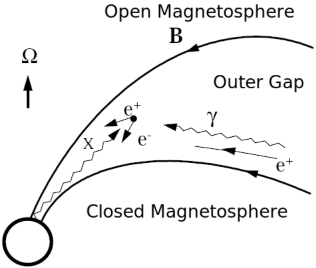
1. Only a few pulsars could contribute to the local cosmic ray anomalies, a larger contribution could contribute to the haze.
2. We will examine the results based on mature γ-ray pulsars.
3. Follow Model of Zhang and Cheng (1997).
4. Based on Outer Gap production.

Pulsar



Pulsar

- Accelerated $e^{\pm}$ in the outer gap radiate synchrocurvature γ-rays.
- Then they collide with the neutron star, produce X-rays.
- X-rays and γ-rays pair produce $e^{\pm}$.



From Zhang and Cheng ApJ 487:370(1997)

Source Function

1. This entire process goes to produce a single energy distribution

$$Q(E) = \dot{N}_{100} Q_0 f_e \left(\frac{E}{\mathrm{GeV}}\right)^{-\alpha} e^{-E/E_{cut}} , \qquad (2)$$

where

$$Q_0 \approx 10^{41}\mathrm{GeV}^{-1}\mathrm{s}^{-1}\frac{100^{\alpha-1.6}\Gamma(0.4)}{\Gamma(2-\alpha)}\left(\frac{100\mathrm{GeV}}{E_{cut}}\right)^{2-\alpha} \qquad (3)$$

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2. The distribution of pulsars throughout the galaxy is given by Paczynski, 1990

$$\begin{aligned} \rho(\vec{x}) &= N^{-1} e^{-r/r_0-|z|/z_0}, \quad \text{where} \qquad (4)\\ N &= 4\pi z_0 r_0^2 (1 - e^{-r_{disk}/r_0}(1 + r_{disk}/r_0))\,, \end{aligned}$$

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where $R^2 = r^2 + z^2$, B_0 is the magnetic field at the center of the galaxy and $B_\odot = 5\mu\mathrm{G}$ is the local magnetic field. We choose a characteristic scale $r_b = 10$ kpc and $z_b = 2$ kpc

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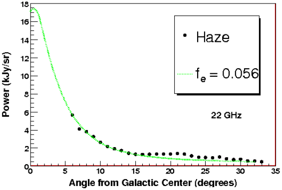
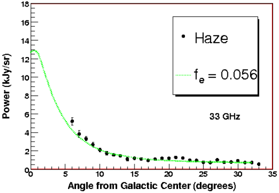
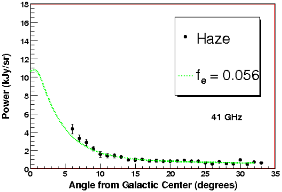
3. The value B_0 and the function $f_C(R)$ encode our ignorance about the magnetic field at the center of the galaxy.
4. Take $B_0 = 30\mu\mathrm{G}$ and $f_C(R) = \exp(-R/R_C)$ and set $R_C = 2$ kpc.

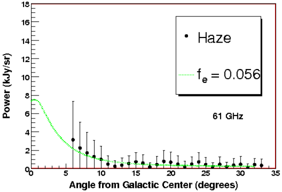
Fits to radial power

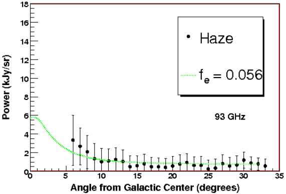
1. The Cheng and Zhang parameters have $E_{cut} = 100$ GeV and $\alpha = 1.6$





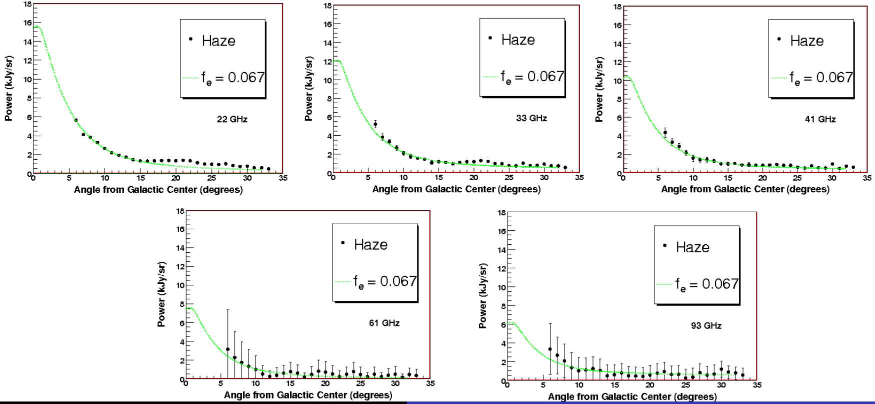






FITS to radial power

1. Changing to a larger cutoff energy results in a better fit: $E_{cut} = 500$ GeV and $\alpha = 1.6$

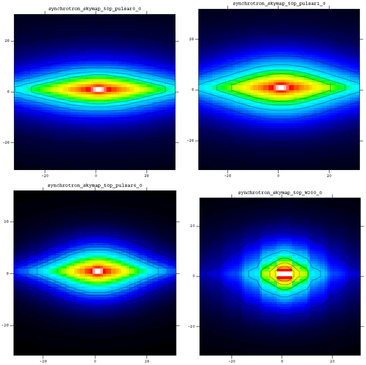


Morphology

1. Earlier stated that the haze was radially symmetric.
2. Pulsar distribution is not spherically symmetric. It traces that density of luminous matter in the galaxy.
3. Morphology of the haze contribution is dependent upon the shape of the B-field.

Morphology

Clockwise from top right: The fiducial parameters, doubling the diffusion coefficient, decreasing the characteristic radius of the pulsar distribution, a sample dark matter contribution.



Outlook

1. The pulsars contribution to the haze would be a necessary ingredient if one is to convince yourself that it is the origin of the cosmic ray anomalies.
2. Need to understand the mask and haze close to the galactic plane since that is where it is the most significant.
3. Planck will give a more accurate determination of the haze.