Cosmic rays and magnetic fields constrained by synchrotron and gamma rays

We combine synchrotron and gamma-ray data to put constraints on Galactic cosmic ray electrons and magnetic fields, using GALPROP

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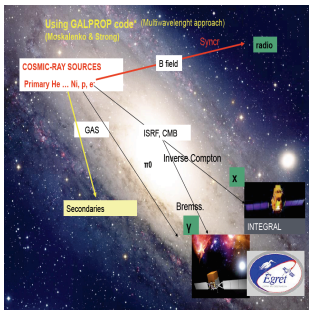
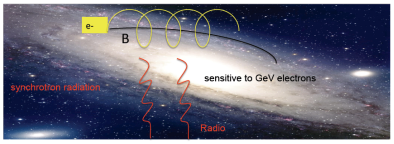
Abstract. By combining synchrotron and gamma-ray data we can put better constraints on Galactic cosmic ray electrons and magnetic fields than possible when considering these data separately. The GALPROP code includes 3D magnetic field models, and these can be used to make self-consistent predictions of the synchrotron and gamma-ray sky. We present the current state of this study.





Galactic magnetic field (B) is very uncertain, many models in the literature!
-> Synchrotron radiation (radio band) -> constrain B models

synchrotron frequency ~ γ^2 B

1-30 GeV electrons + few μG => 10 MHz -10 GHz

- Synchrotron spectral Index ➔ e- spectral index (~ 2+(p-1)/2 after propagation)
- Synchrotron Intensity ➔ B intensity

B field knowledge

Measurements of the Zeeman spectral-line splitting, optical polarization of starlight, Faraday rotation measurements of pulsar and extra-galactic sources -> 2 components of B:

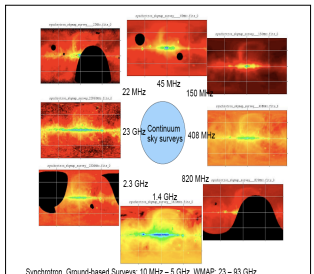
1) Regular field -> polarized synchrotron emission and total synchrotron emission
2) Randomly oriented field -> total synchrotron emission

Evidence of different components:

- Disk
- Halo
- Dipole
- Toroidal

Procedure with GALPROP

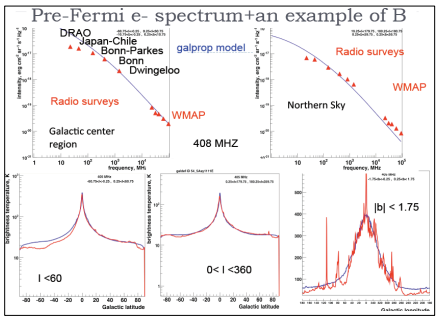
- Used CR sources distribution, and e- that fits the FERMI intermediate latitude spectrum.
- 3D models of the regular field and random field component in GALPROP
- Adjusting the value of total magnetic field to fit the synchrotron intensity at the 408 MHz map
- Comparing synchrotron latitude and longitude profiles with the available radio surveys.



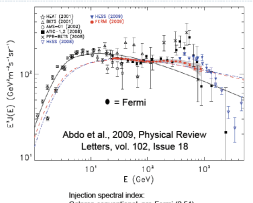
Synchrotron Ground-based Surveys: 10 MHz – 5 GHz WMAP: 23 – 93 GHz
Planck: 30 - 800 GHz

- ✓ Many models of the B implemented in GALPROP (Han and Qiao 1994, Tinyakov & Tkachev 2002, Prouza & Smida 2003, Miville-Deschenes et al. 2008, Sun et al. 2008)
- ✓ Spectra, latitude and longitude profiles have been obtained, but none is in agreement with the data.
- ✓ Tuning parameters to fit the data

Pre-Fermi e- spectrum+an example of B



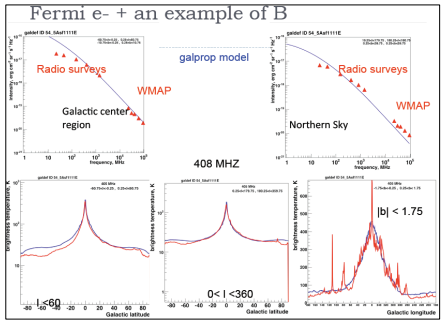
Fermi electron spectrum



Abdo et al., 2009, Physical Review Letters, vol. 102, Issue 18

Injection spectral index:
Galprop conventional, pre-Fermi (2.54)
->Fermi (2.43)

Fermi e- + an example of B



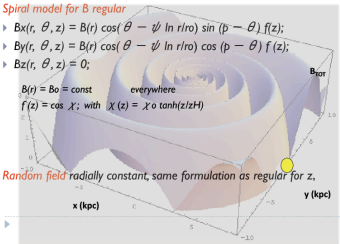
Example of GALPROP magnetic field model

Spiral model for B regular

- $Bx(r, \theta, z) = B(r) \cos(\theta - \psi \ln r/r_0) \sin(p - \theta) f(z)$;
- $By(r, \theta, z) = B(r) \cos(\theta - \psi \ln r/r_0) \cos(p - \theta) f(z)$;
- $Bz(r, \theta, z) = 0$;

$B(r) = B_0 = \text{const}$ everywhere

$f(z) = \cos \chi$; with $\chi(z) = \chi_0 \tanh(z/zH)$



Random field radially constant, same formulation as regular for z,

Conclusions

- Many B models from the literature were tested -> none is reproducing the spectra, latitude and longitude profiles
- One of the best models for galprop was defined that fits well
- To be investigated: B intensity higher than previously thought
- Combining gamma-ray, synchrotron and direct CR measurements -> better model of B
- Upcoming: Planck data
- Future: including polarisation in GALPROP