Cosmic Rays from Multifrequency Observations of the Interstellar Emission

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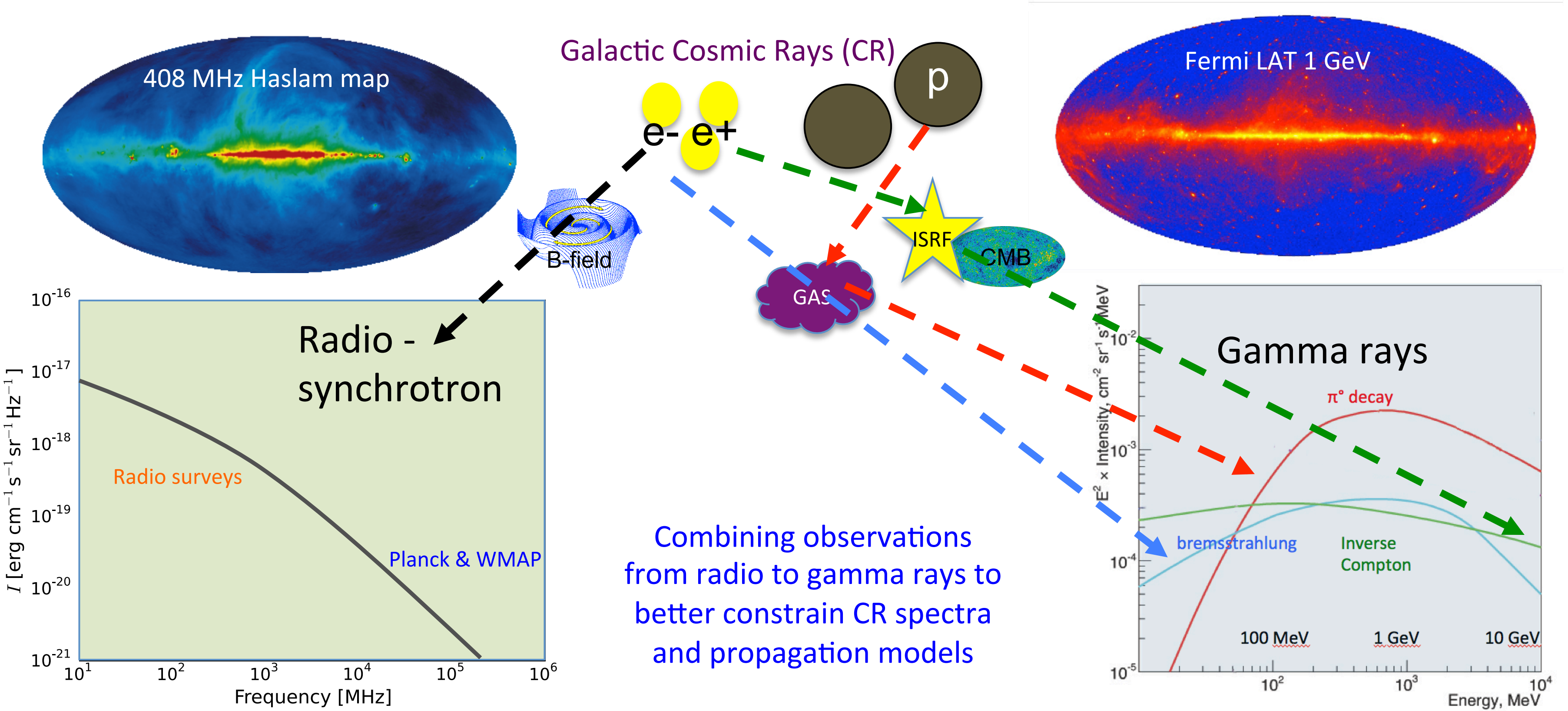
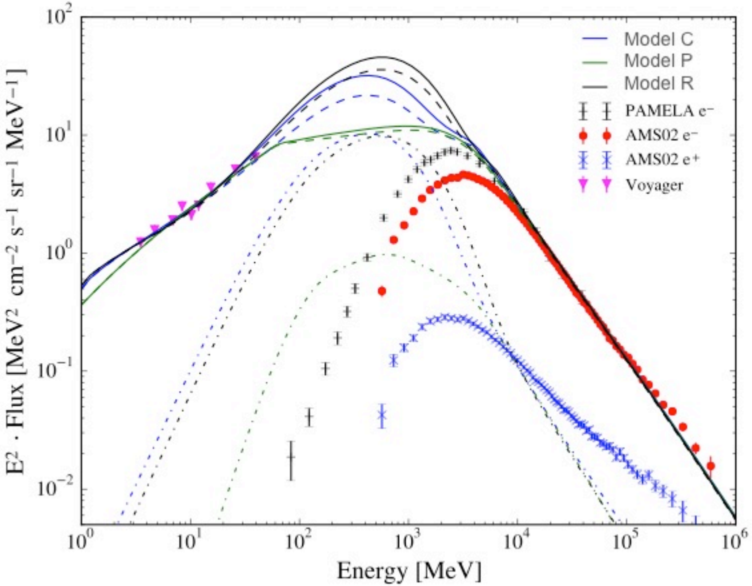


Combining observations from radio to gamma rays to better constrain CR spectra and propagation models

Various models of electrons LIS based on CR measurements

Radio Synchrotron observations of the interstellar emission provide fundamental information on CR electrons, which are also producing the leptonic emission (inverse Compton and bremsstrahlung) in gamma rays seen by Fermi LAT. We describe some updates to the analysis of the interstellar emission from radio to gamma rays and to the modeling of CRs with the GALPROP code (https://galprop.stanford.edu).

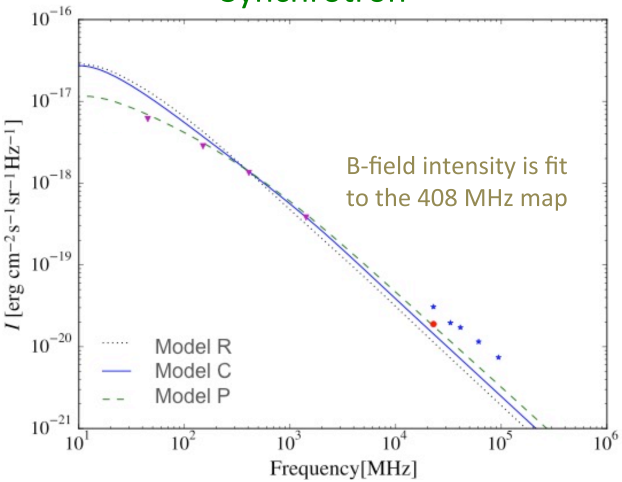
We gain information about electrons in the energy range 10^2 - 10^4 MeV without making any assumptions about solar modulation. In this energy range solar modulation is significant, and there are no interstellar CR direct measurements.



Electron and positron LIS of three baseline models C (blue line), P (green line), and R (black line) for positrons (dashed-dotted line), electrons only (dashed line), and positrons plus electrons (solid line) compared with data: blue crosses: AMS-02 positrons [4]; red points: AMS-02 electrons [5]; black crosses: PAMELA electrons [3]; magenta triangles: Voyager 1 electrons and positrons [6]. Details on the models can be found in [7].

Radio Synchrotron and Gamma Ray interstellar emission

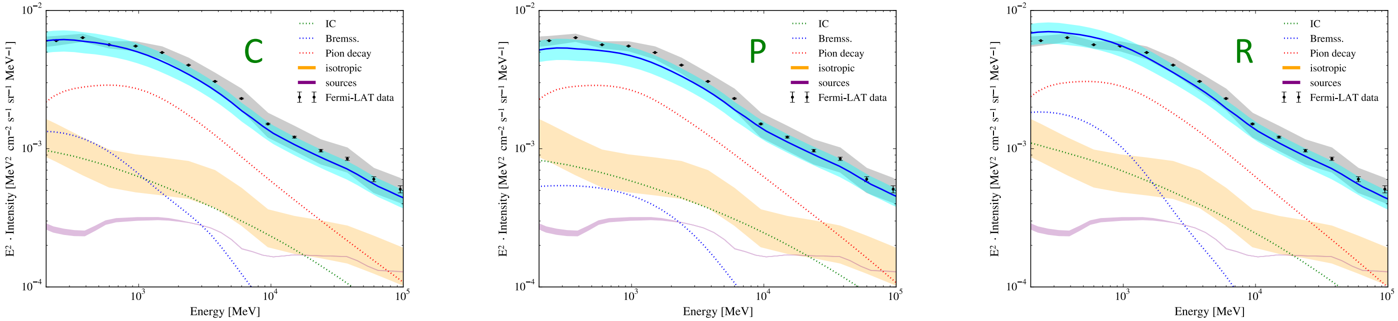
Synchrotron



Synchrotron spectra for the three electron models compared with data for intermediate latitudes (i.e. 10< b< 20). Radio surveys at 45, 150, 408, and 1420 MHz (magenta triangles) are as described in [10]. WMAP [5] (blue stars) and synchrotron temperature map by Planck [8] (red point) are also shown.

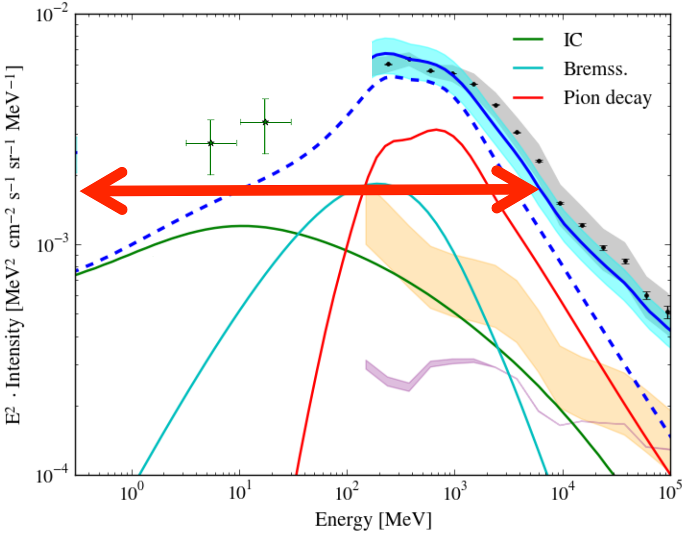
Gamma Rays

Calculated gamma-ray components and spectrum for C, P, and R models (left to right) compared with Fermi LAT data from [1] for intermediate latitudes (10<|b|<20, all longitudes), using the electron LIS as previously reported. Data include statistical (grey area) and systematic errors (black bars). Here components are not fitted to gamma-ray data, so uncertainties in the gas are not accounted for. Spectra for sources and isotropic are taken as in [1], for the most extreme cases reported there. 30% uncertainty is added to the isotropic spectrum, following the study in [2] based on various foreground models. The inverse Compton component has been scaled to better reproduce gamma rays as found in [1].



Fermi data are from [1]

Predictions for the MeV energy range



Predictions for the energy range of e-ASTROGAM and AMEGO, possible future gamma-ray instruments for model R, as an example. The figure shows also the Fermi LAT data intermediate latitudes [1] and COMPTEL data [9] for comparison.

The sky above 100MeV is dominated by emission produced by CRs interacting with the gas and interstellar radiation field via pion-decay, IC, and bremsstrahlung. Disentangling the different components at the LAT energies is challenging and is usually done in a model-dependent approach. Uncertainties in the ISM is the major limitation to our modeling and hence in our knowledge of CRs, e.g. as found in [1]. The situation below 100MeV is still unexplored. Extrapolations of present models to such low energies predict inverse Compton and bremsstrahlung to be the major mechanisms of CR-induced emission, which are of leptonic origin.

CONCLUSIONS: In this work we presented the feasibility and importance of using multi wavelength observations, especially at radio wavelengths, together with CR measurements, to constrain the gamma-ray interstellar spectrum below 1 GeV.

REFERENCES: - **[1]** Ackermann, M., Ajello, M., Atwood, W. B., et al. 2012, ApJ, 750, 3; **[2]** Ackermann, M., Ajello, M., Albert, A., et al. 2015, ApJ, 799, 86; **[3]** Adriani, O., Barbarino, G. C., Bazilevskaya, G. A., et al. 2015, ApJ, 810, 142; **[4]** Aguilar, M., Aisa, D., Alvino, A., et al. 2014, Physical Review Letters, 113, 121102; **[5]** Bennett, C. L., Larson, D., Weiland, J. L., et al. 2013, ApJS, 208, 20; **[6]** Cummings, A. C., Stone, E. C., Heikkila, B. C., et al. 2016, ApJ, 831, 18; **[7]** Orlando et al, submitted; **[8]** Planck Collaboration, Adam, R., Ade, P. A. R., et al. 2016, A&A, 594, A10; **[9]** Strong, A. W., Bloemen, H., Diehl, R., Hermsen, W., & Schönfelder, V. 1999, Astrophysical Letters and Communications, 39, 209; **[10]** Strong, A. W., Orlando, E., & Jaffe, T. R. 2011, A&A, 534, A54;

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