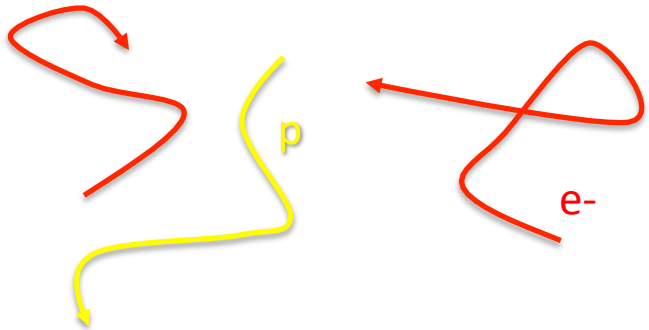
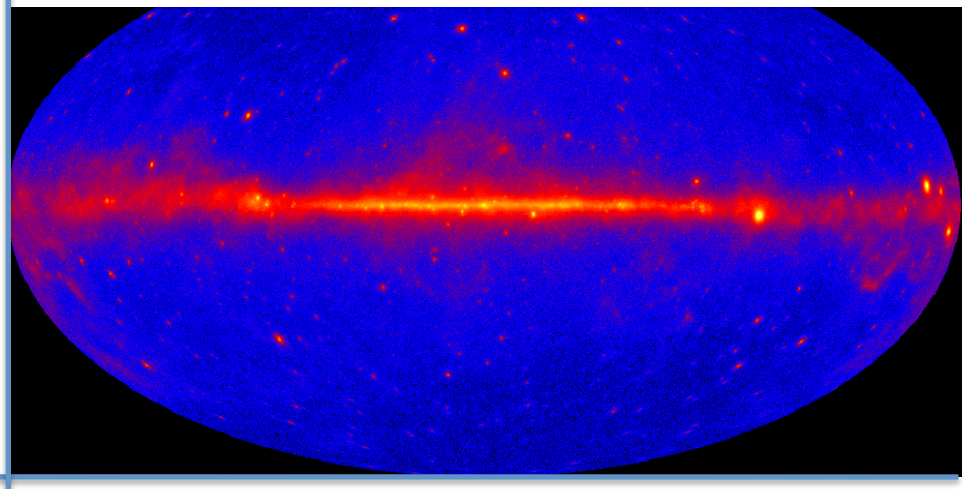
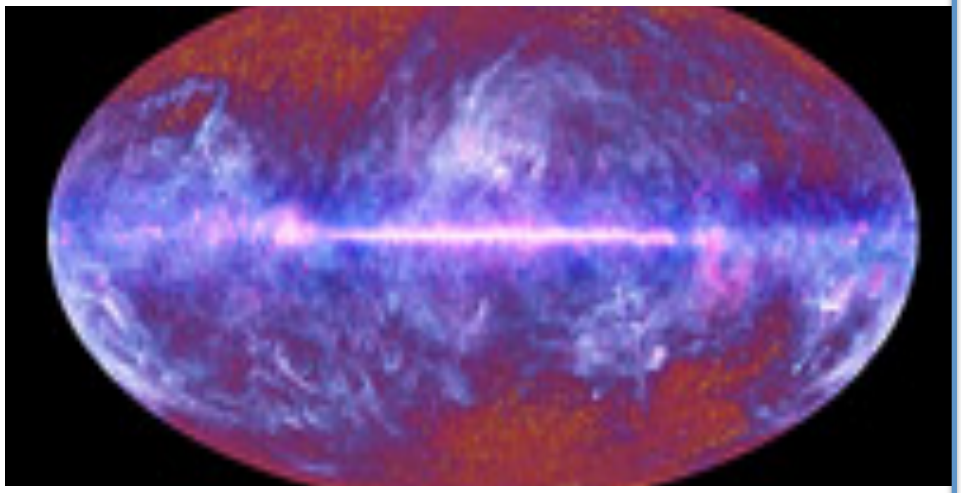
Cosmic rays



gamma rays

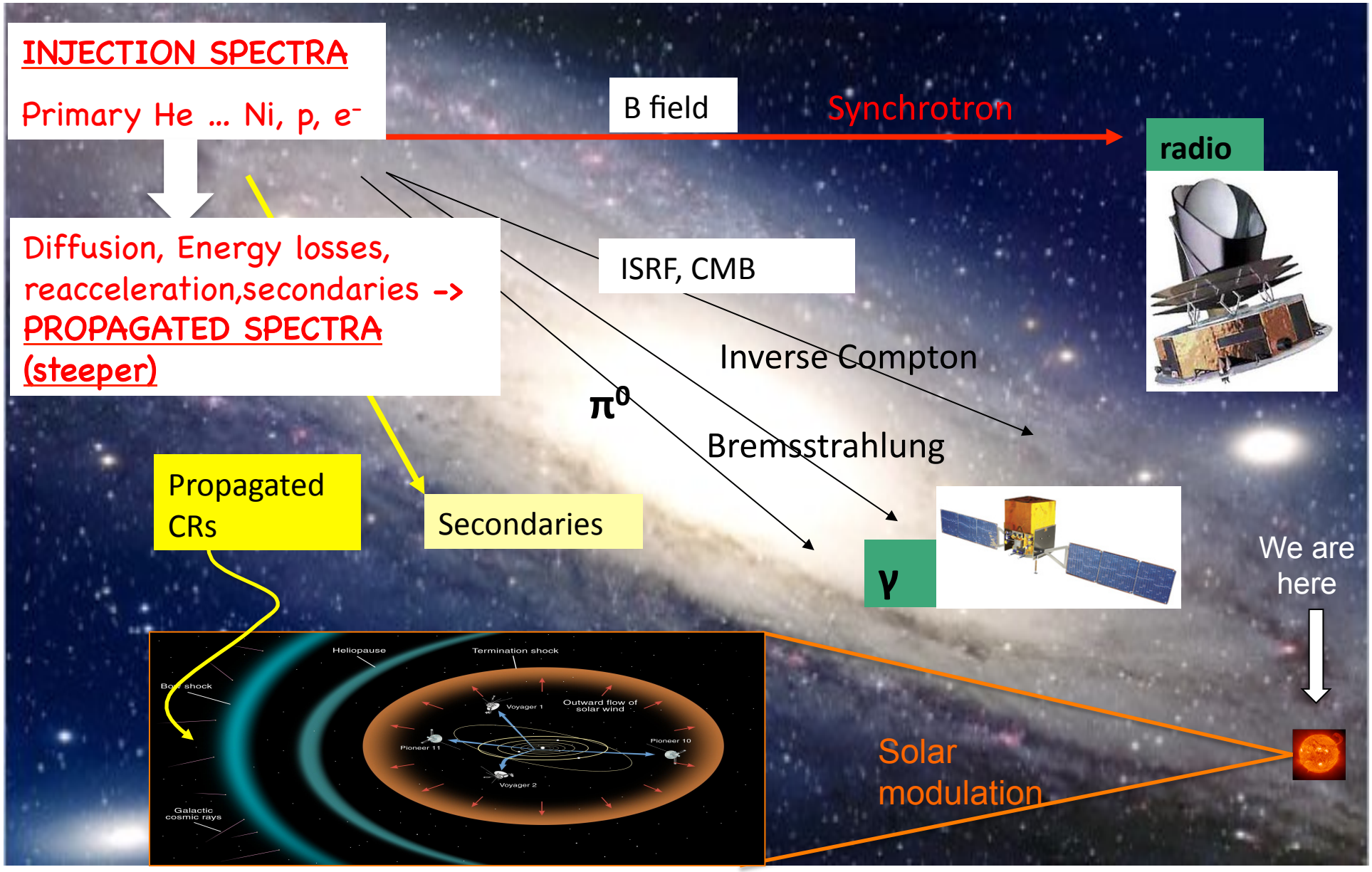


Synchrotron



from the Galaxy

Cosmic-ray propagation in the Galaxy



Overview: Modeling the diffuse emission with GALPROP

THE TEAM:
I. Moskalenko and A. Strong (original creators),
S. Digel, G. Johannesson, T. Porter, A. Vladimirov and me

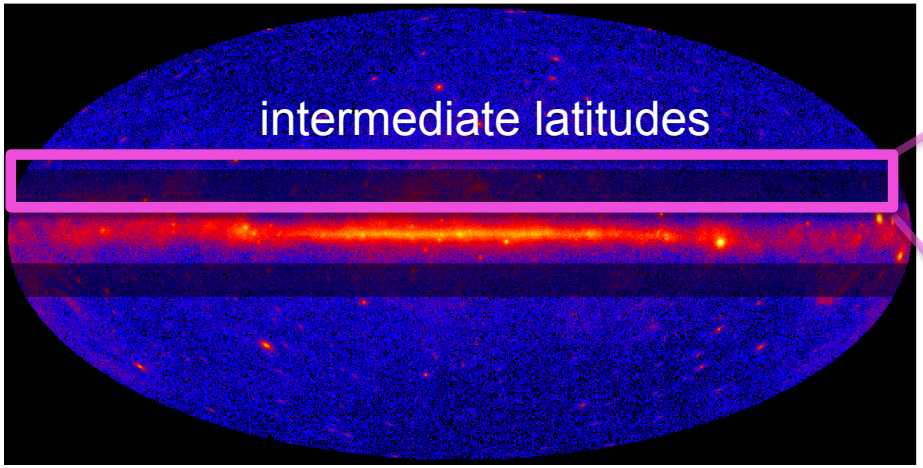
Dedicated website http://*galprop.stanford.edu – webrun and references therein*

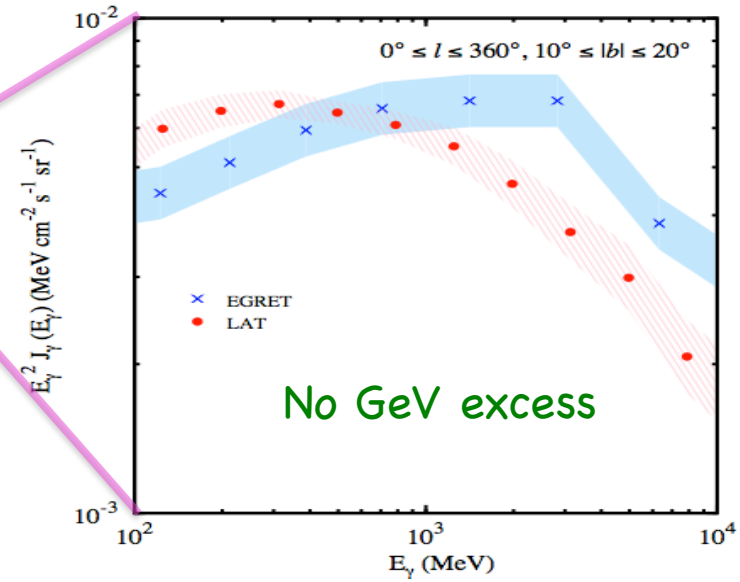
Recipe:

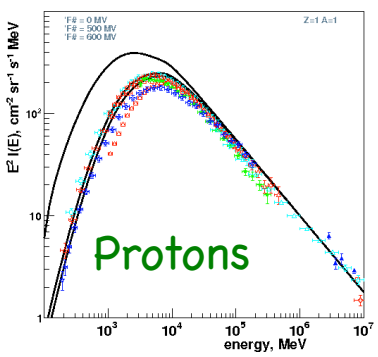
- cosmic-ray spectra p , He , e- , e+ (including secondaries)
(NB recently using Fermi-measured electrons)
- cosmic-ray source distribution follows SNR/pulsars
- Interstellar radiation field
- HI, CO surveys
- B/C etc for propagation parameters
- Galactic magnetic field

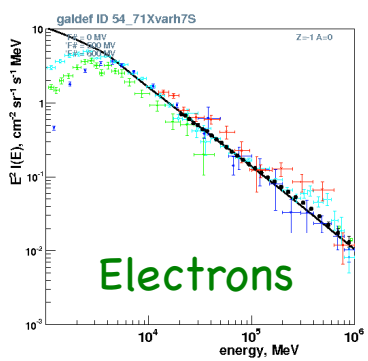
Solve transport equation (energy losses, diffusion acceleration, convection, fragmentation, radioactive decay) for all CR species

Review: Diffuse γ rays with Fermi/LAT

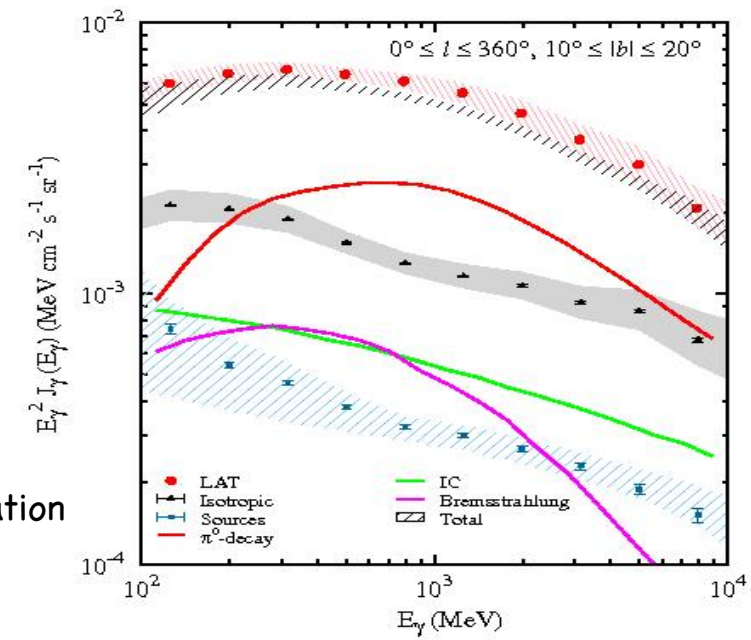








GALPROP Model based on local cosmic-ray spectra agrees with Fermi !

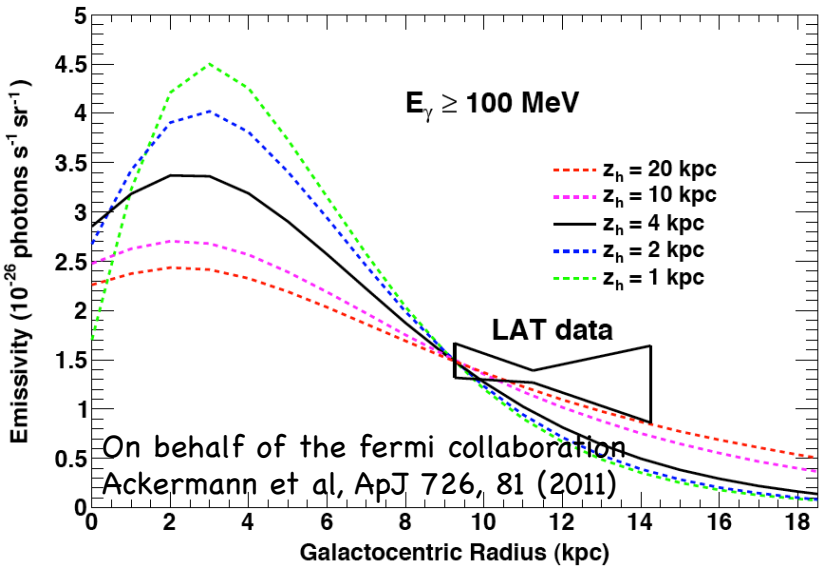


On behalf of the fermi collaboration
Abdo et al. PhRevLett.103.251101

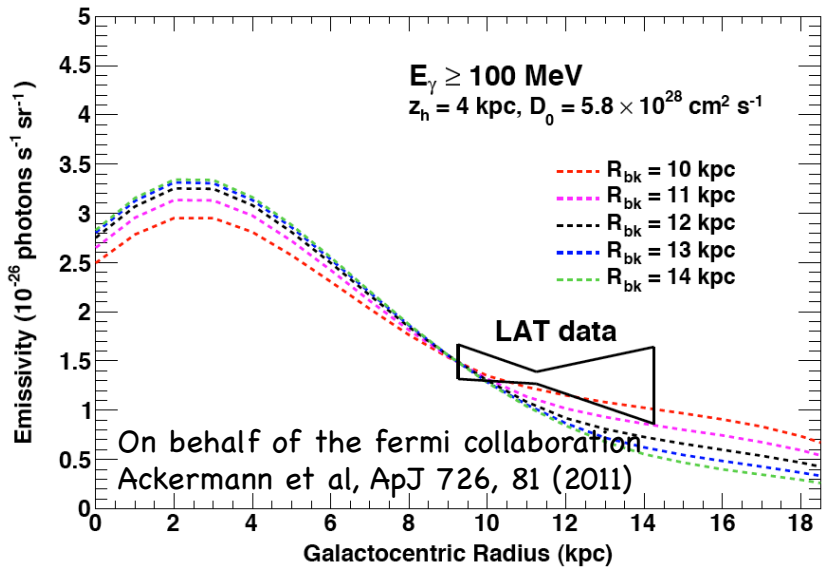
Review: Diffuse γ rays with Fermi/LAT

Gamma-ray emissivity distribution in outer Galaxy

Varying halo size



Varying CR source distribution



Models underpredict gamma rays in outer Galaxy !

Other possibilities:
missing gas, non uniform diffusion coefficient and propagation parameters or sources

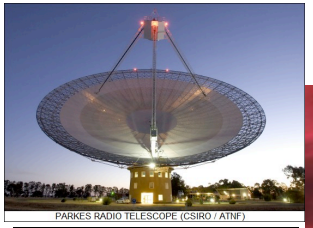
Radio and microwaves parallel study can put more constraints!

Synergy radio/gamma rays

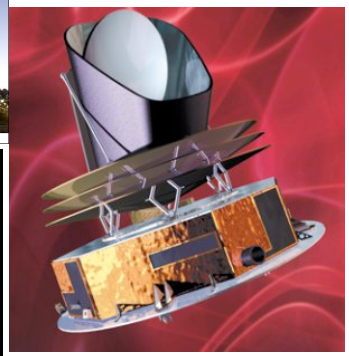
CR e+e-

B field

Synchrotron



PLANCK

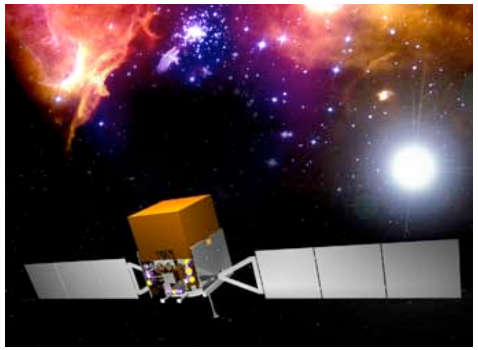


PAMELA, FERMI, AMS, HEAT, HESS, ATIC, MAGIC

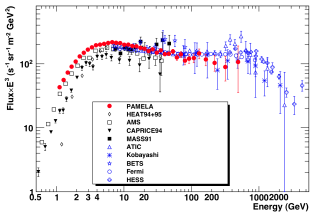
Interstellar radiation field, CMB, gas

Gamma rays

FERMI

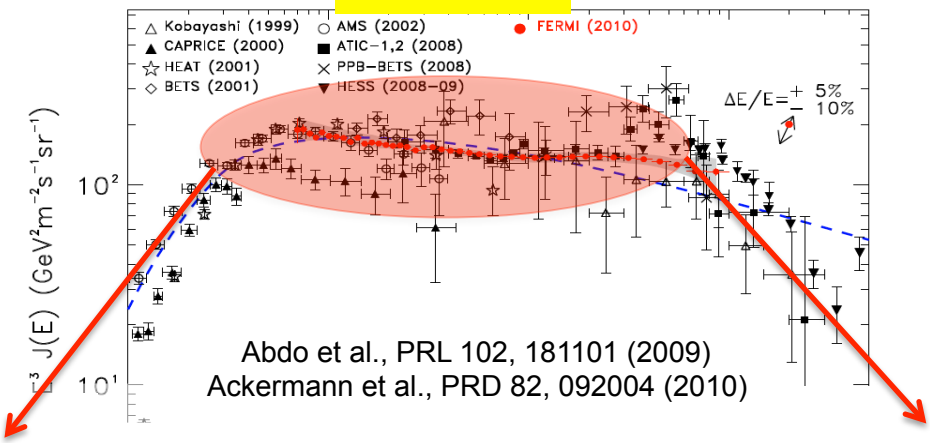


Synergy radio/gamma rays

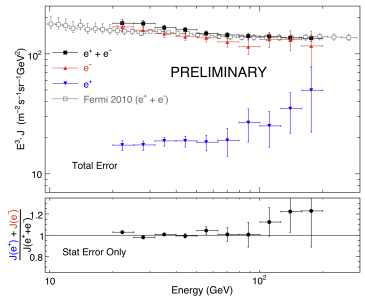


Adriani et al. PRL 106, 201101
Talk by Ricci yersterday

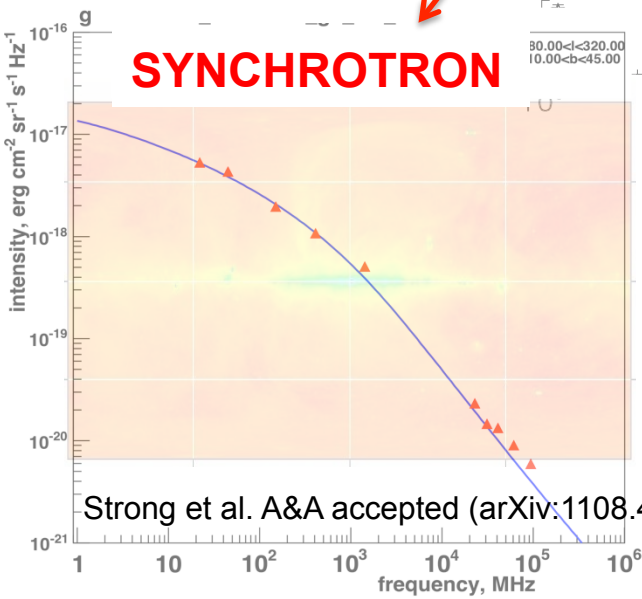
CR e+e-



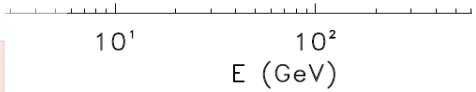
Abdo et al., PRL 102, 181101 (2009)
Ackermann et al., PRD 82, 092004 (2010)



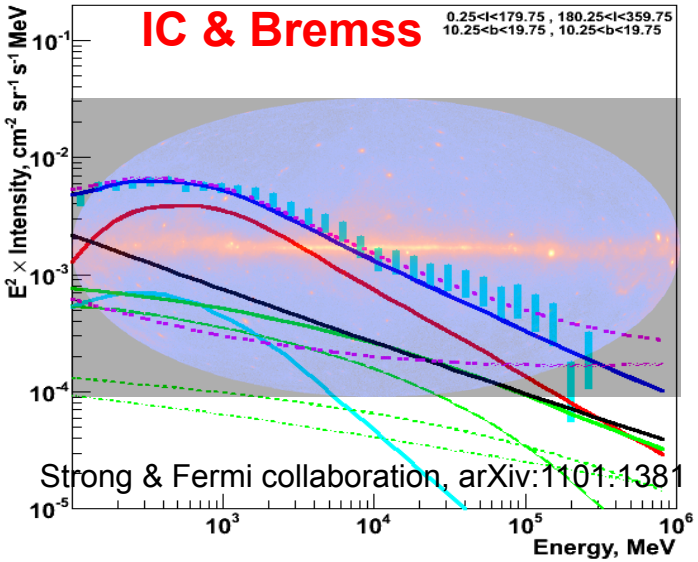
Vandenbrouke,
ICRC 2011 Fermi collaboration



Strong et al. A&A accepted (arXiv:1108.4822)



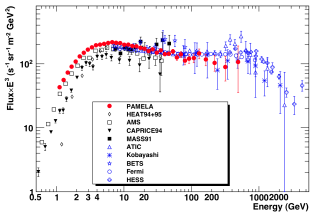
SPECTRA



Strong & Fermi collaboration, arXiv:1101.1381

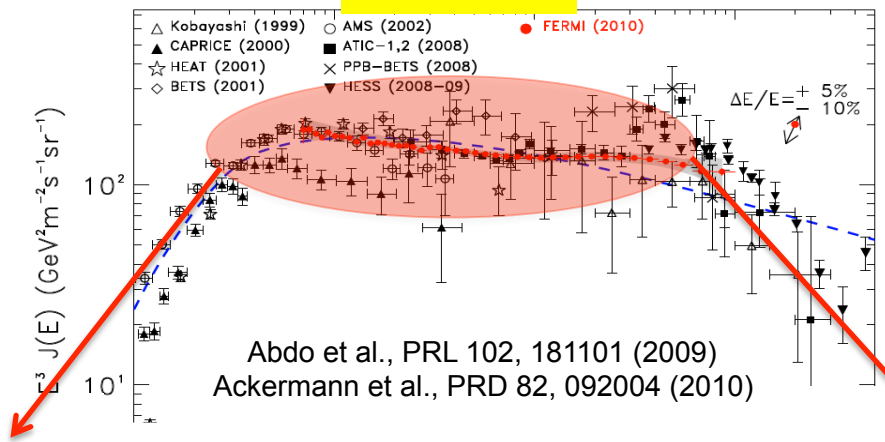
Leptons (and not only) are better constrained by radio and microwaves!

Synergy radio/gamma rays



Adriani et al. PRL 106, 201101
Talk by Ricci yersterday

CR e+e-



Abdo et al., PRL 102, 181101 (2009)
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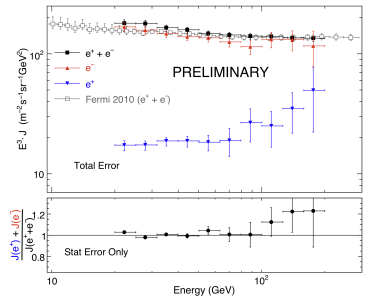
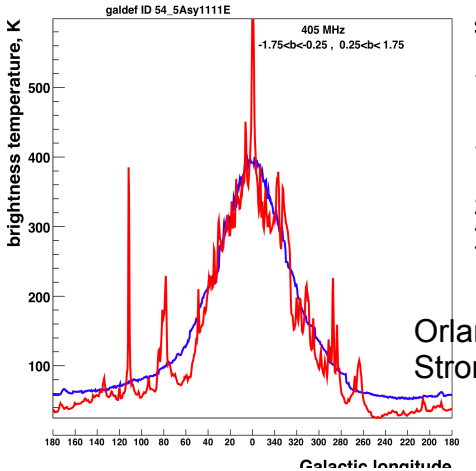


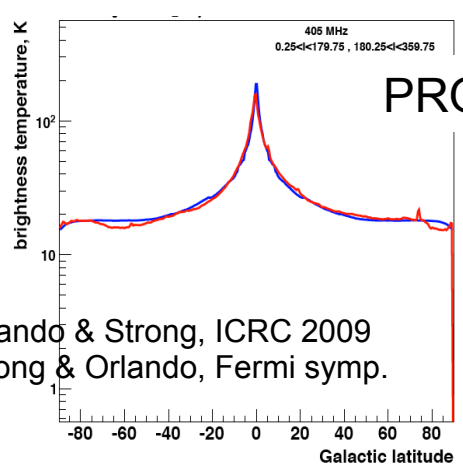
Vandenbrouke,
ICRC 2011 Fermi collaboration

SYNCHROTRON

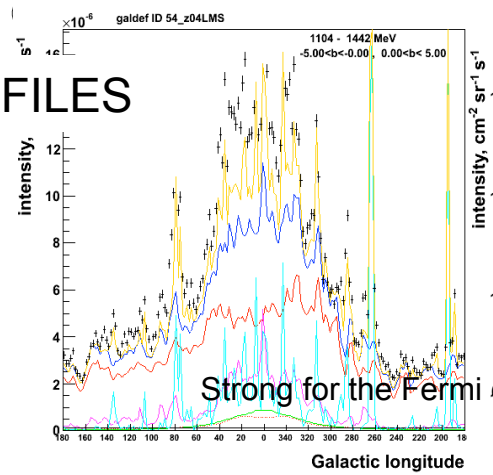
IC & Bremss

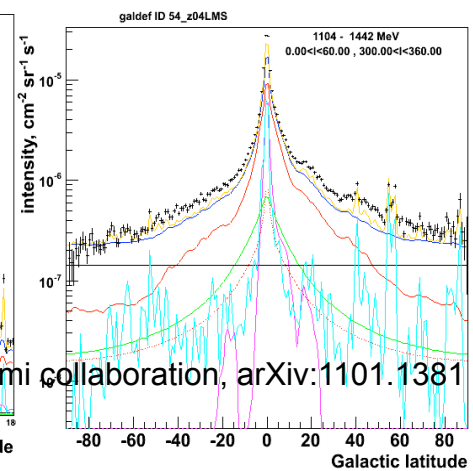
PROFILES





Orlando & Strong, ICRC 2009
Strong & Orlando, Fermi symp.





Strong for the Fermi collaboration, arXiv:1101.1381

Leptons (and not only) are better constrained by radio and microwaves!

Diffuse Synchrotron emission

- Synchrotron spectral Index -> e^- spectral index
- Synchrotron Intensity -> B intensity and electron flux
- e^- 0.5 - 20 GeV -> 20 MHz - 100 GHz

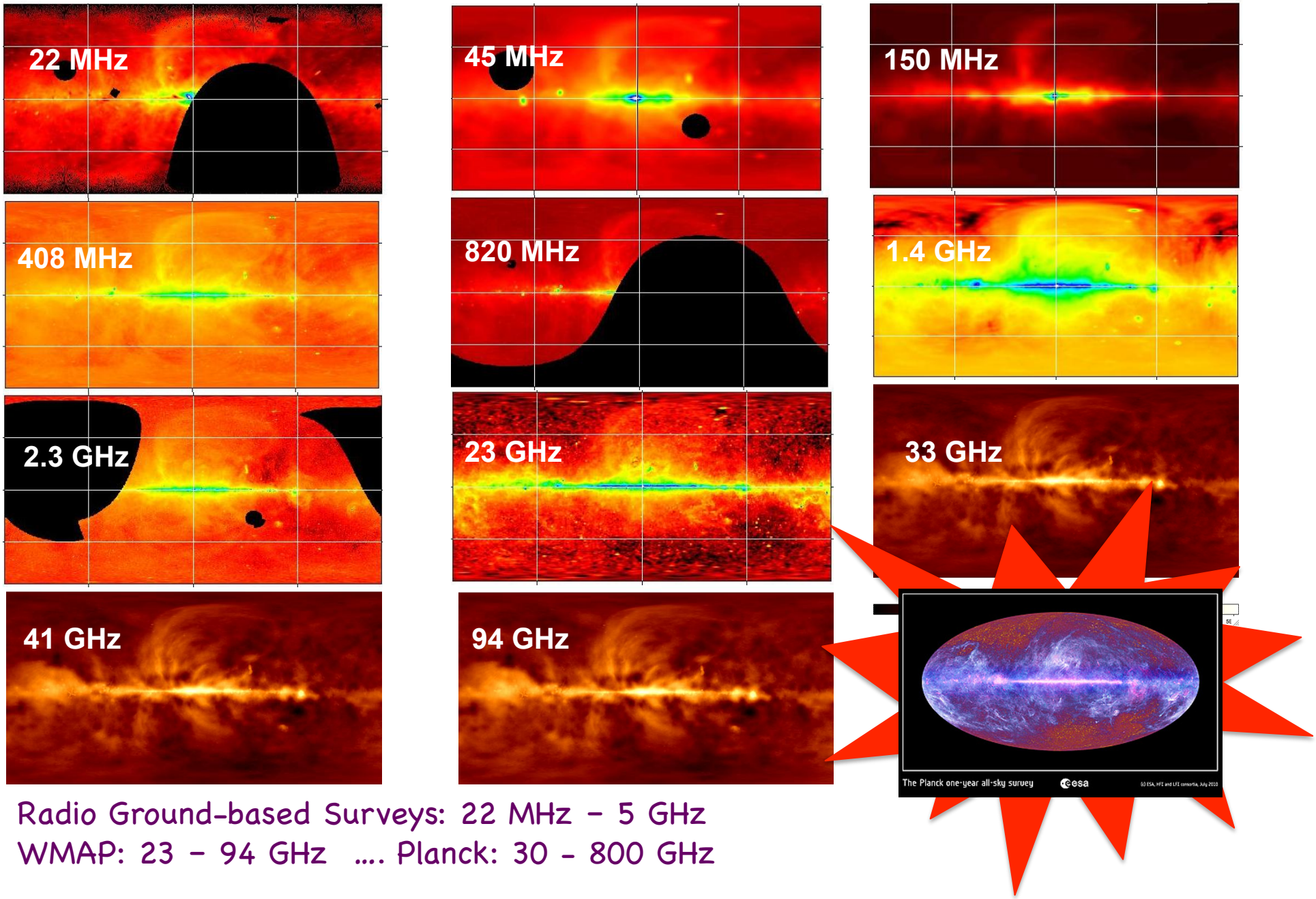
TOGETHER WITH GAMMA RAYS PUTS CONSTRAINTS ON:

- Galatic magnetic fields
- CR eletron spectrum (local and injected)
- Propagation models
- CR source distribution
- Halo size
- Free-free emission and absorption
- ... separation template for CMB studies, Dark Matter searches, anisotropies ...

(see talk by Taoso yesterday)

Strong, Orlando & Jaffe A&A accepted (arXiv:1108.4822)

Radio surveys & WMAP

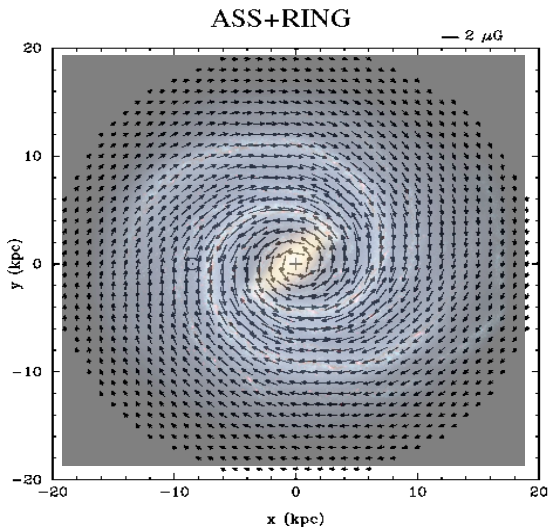


Radio Ground-based Surveys: 22 MHz – 5 GHz
WMAP: 23 – 94 GHz .... Planck: 30 - 800 GHz

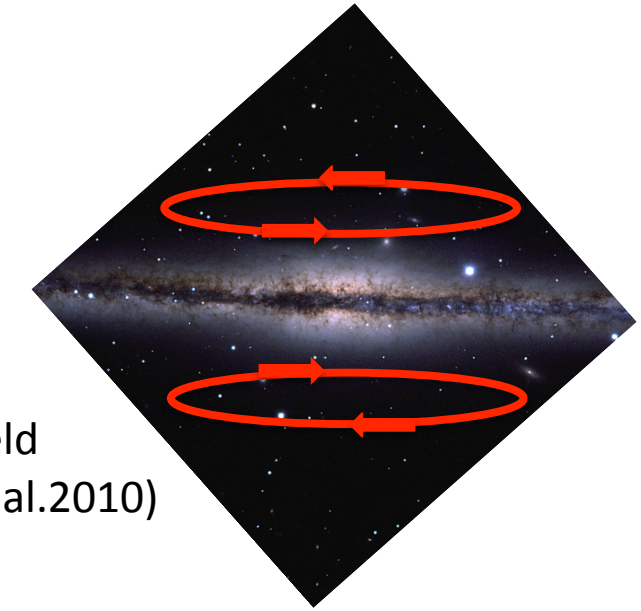
1. Probing Galactic Magnetic fields

REGULAR COMPONENTS:

Disc field
(Sun et al.2008)

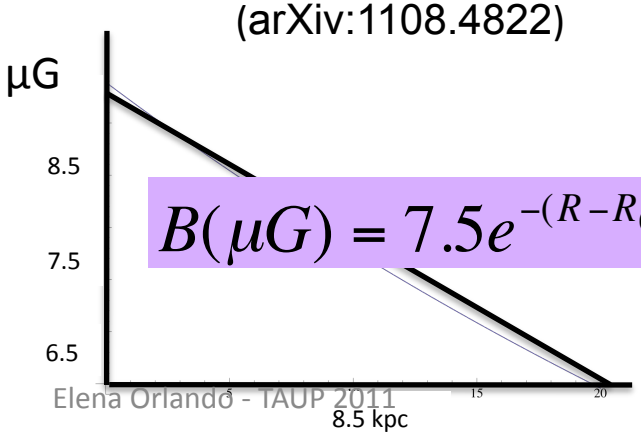


Halo field
(Sun et al.2010)

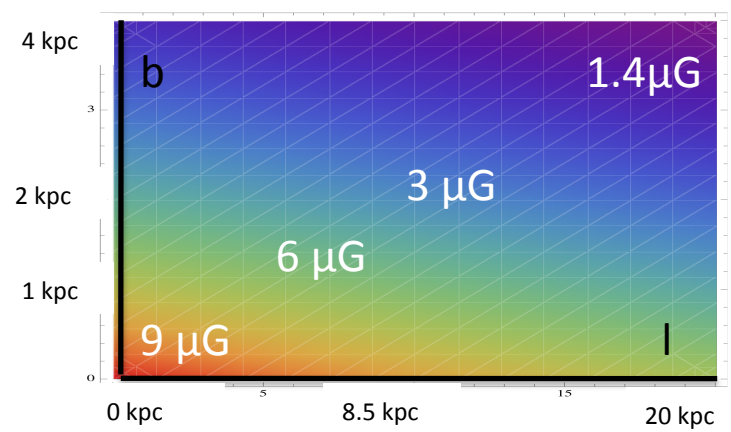


RANDOM COMPONENT (from our work):

Strong et al. A&A accepted
(arXiv:1108.4822)

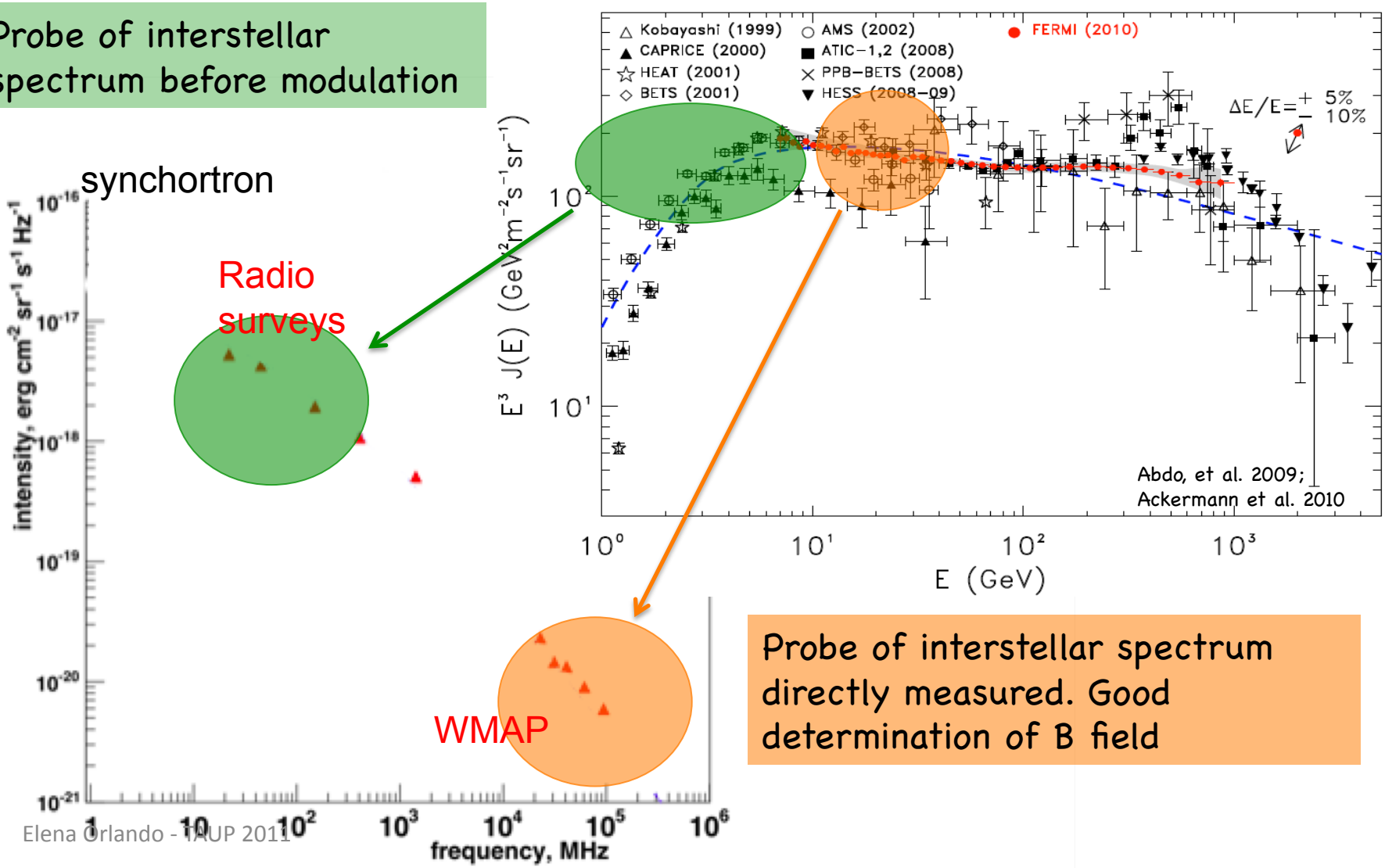


$$B(\mu G) = 7.5 e^{-(R-R_0)/30kpc} e^{-|z|/3kpc}$$



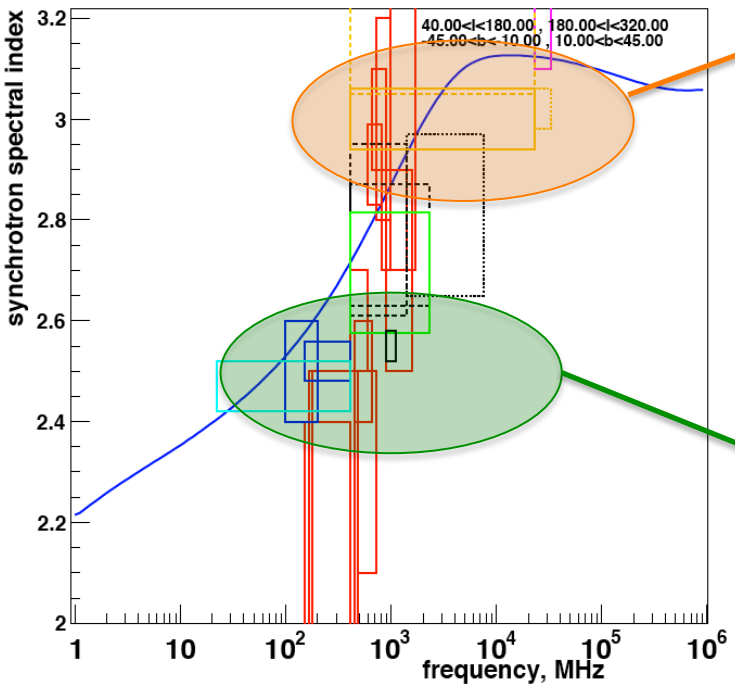
2a. Probing Interstellar electron spectrum

Probe of interstellar spectrum before modulation



Probe of interstellar spectrum directly measured. Good determination of B field

Synchrotron spectral index measurements …



β~3.0 → P~3.0

β=2+(p-1)/2
(p=ambient e- spectrum)

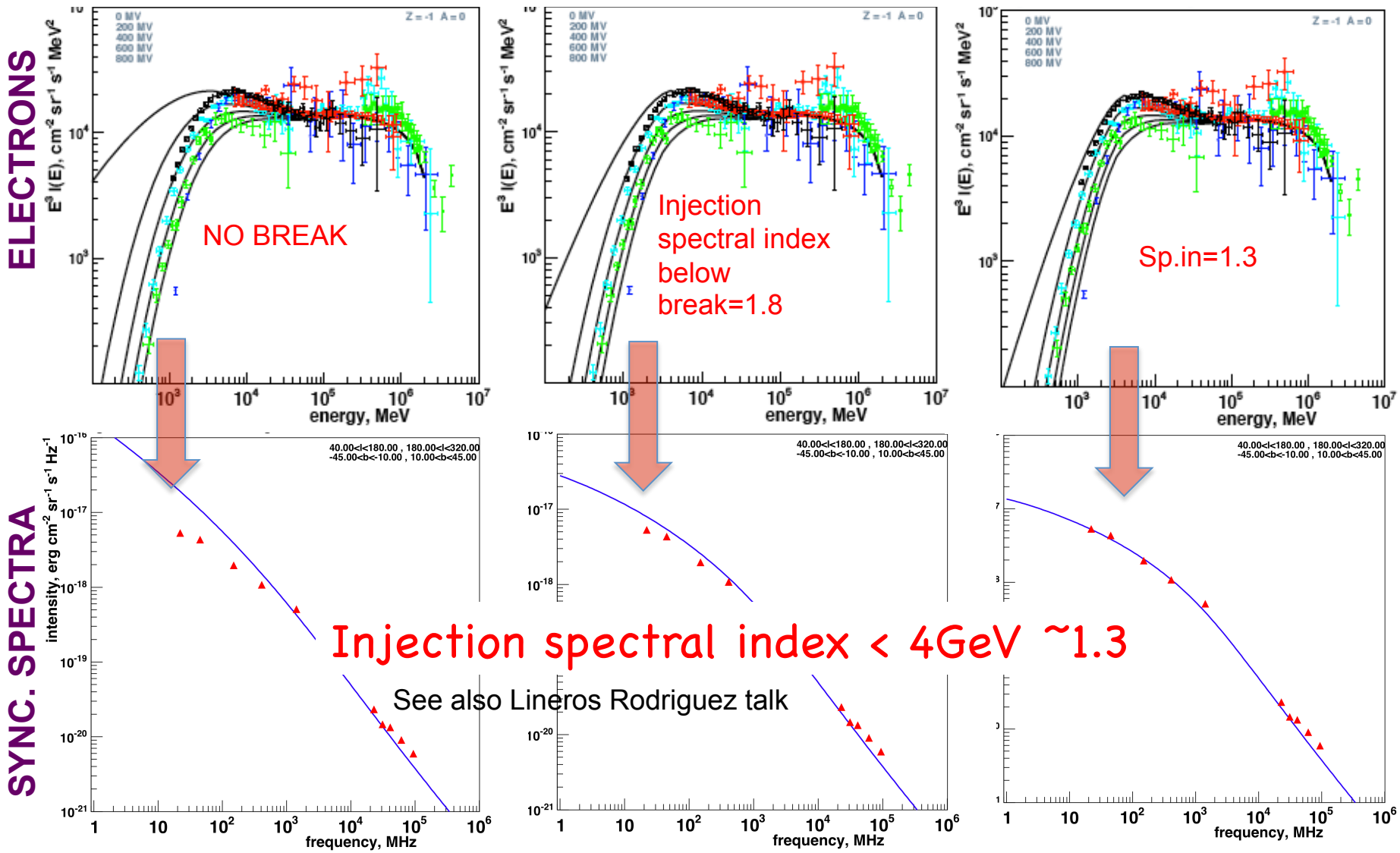
β~2.5 → p~2.0

Strong, Orlando & Jaffe A&A accepted (arXiv:1108.4822)

… need of a break in interstellar e-

2b. Probing injection sp. Index

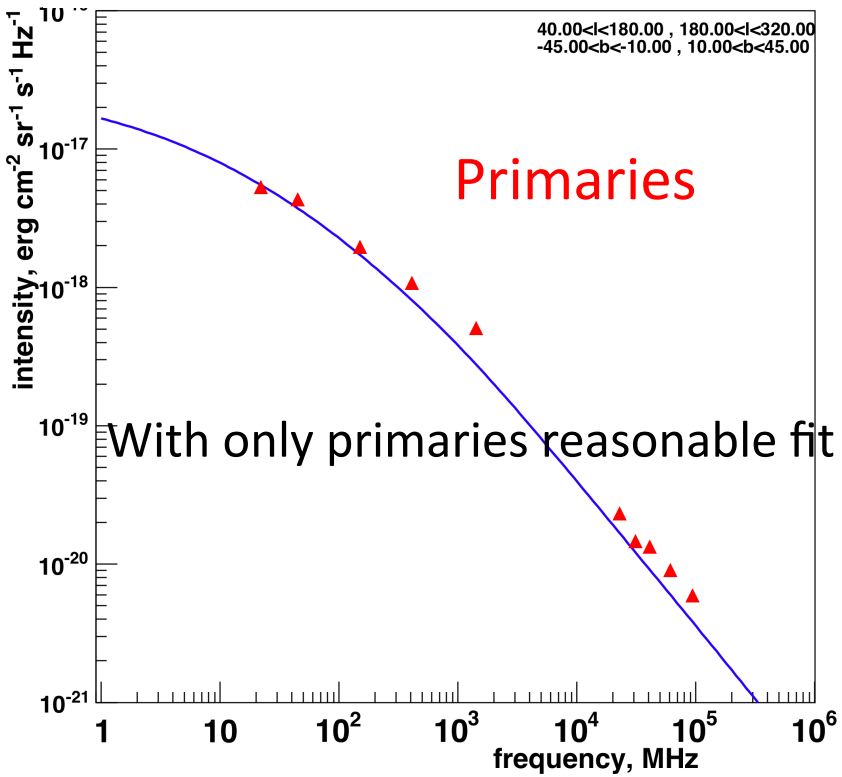
Pure Diffuse model (Strong et al. 2010 ApJ 722L 58) - High latitude

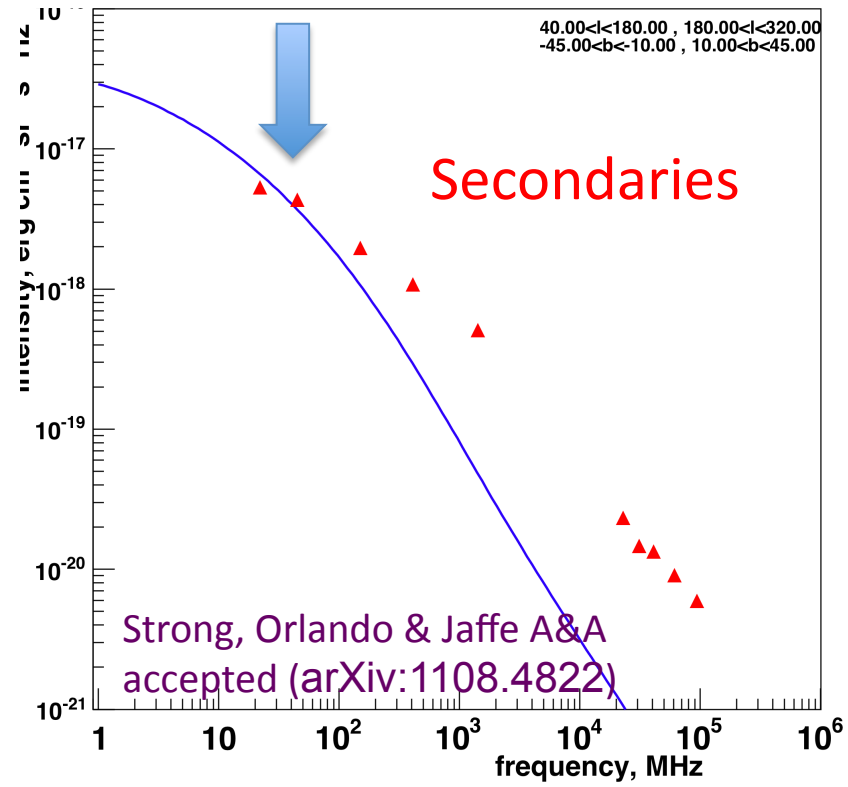


*injection spectral index above 4 GeV = 2.5

3. Testing models of propagation

Reaccelleration model (Strong et al. 2010 ApJ 722L 58)





It poses a challenge for the future!

What synchrotron tells up to now:

1. Break in ambient interstellar e- spectrum from ~2 to ~3 @ few GeV

2. Injection spectrum < few GeV is 1.3-1.6 in pure diffusion models

3. Standard reacceleration models hard to reconcile.

4. Secondary e^+ e^- important for – and constrained by – radio emission

Coming soon

1. Tests on B fields, both random and regular components using polarized and unpolarized WMAP data – producing galactic profiles

2. Constraints on the halo field

5. A polarized/unpolarized 3D MAP OF SYNCHROTRON EMISSION to be used as a template for foreground studies

Next steps

1. Spatially and spectrally constraining Galactic Cosmic rays and sources distribution.

2. Constrain models of propagation

3. Investigate all-sky anisotropies – local emissions