Multi-wavelength Signatures of Cosmic Rays in the Milky Way

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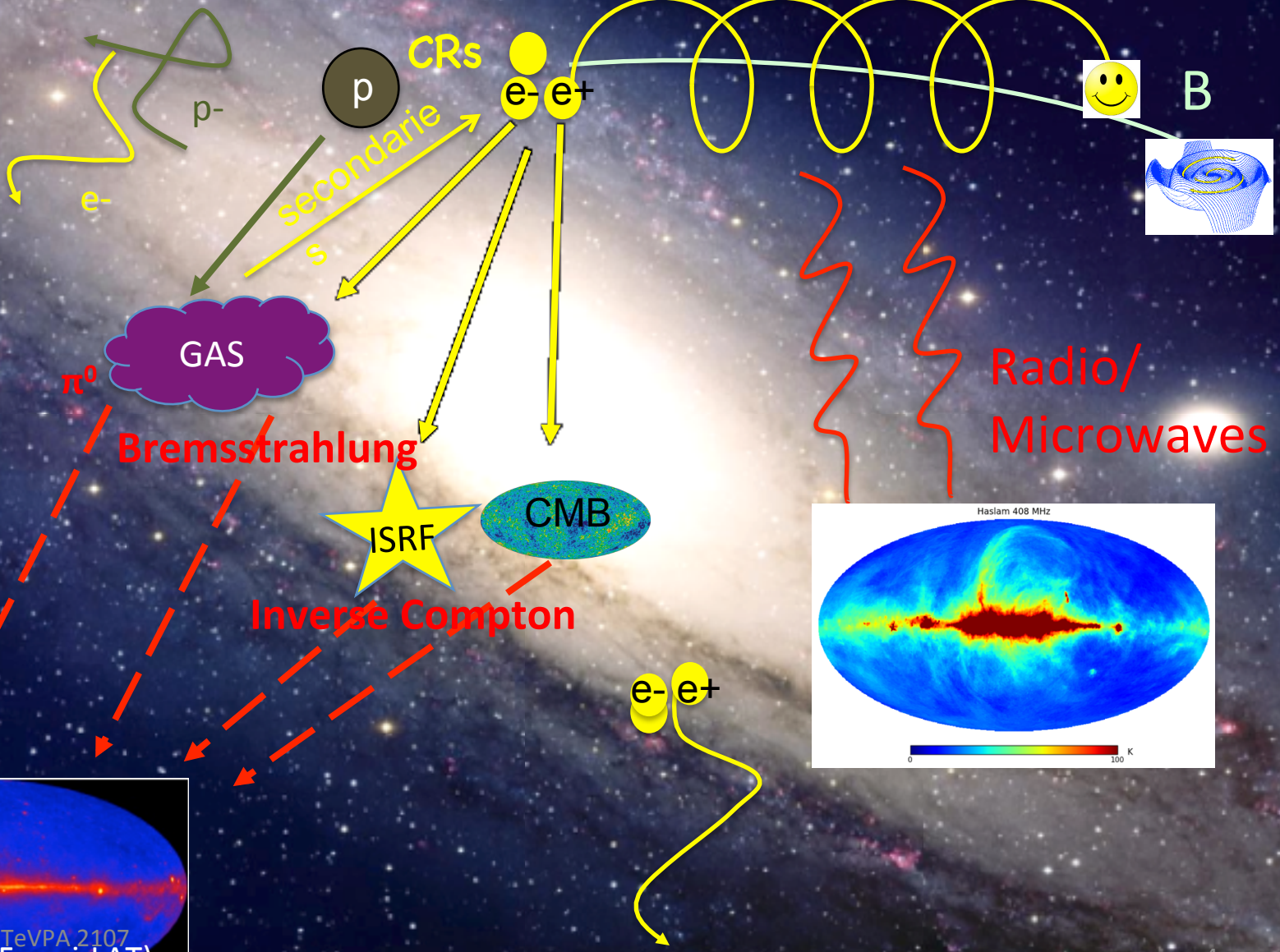
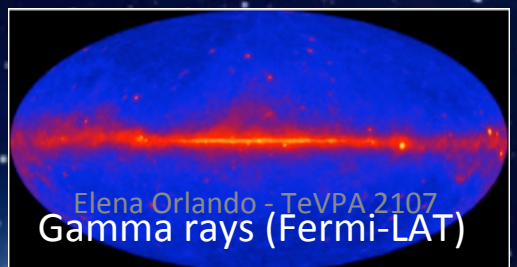
CRs and associated interstellar emission





Gamma rays (Fermi-LAT)

Our approach

Interpreting all observations simultaneously with the help of propagation models:

- CR direct measurements
- Gamma-ray interstellar emission
- Radio and microwave interstellar emission

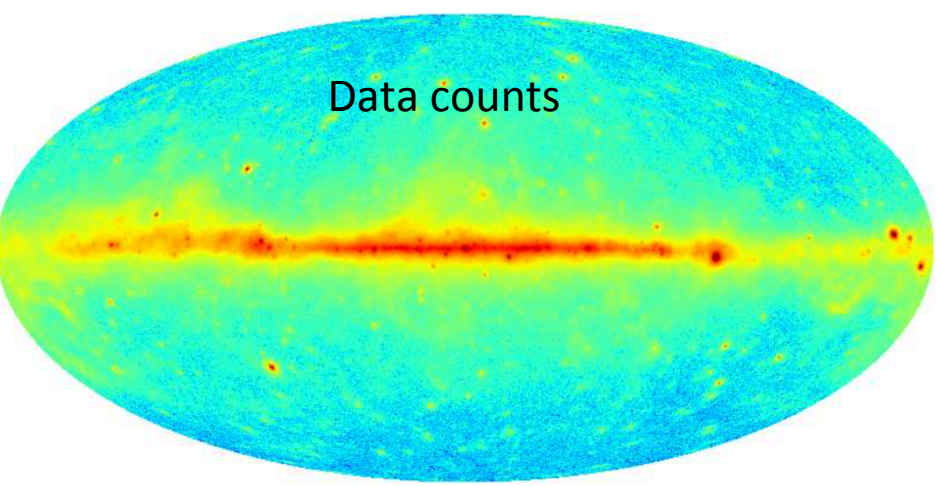
GALPROP (http://*galprop.stanford.edu*)

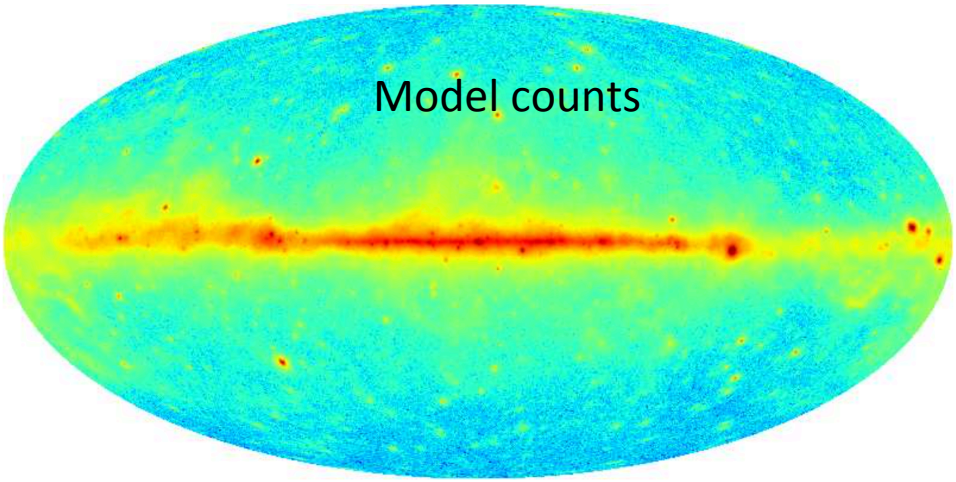
THE TEAM:

Moskalenko, Strong (original developers),
Johannesson, Orlando, Porter, (Vladimirov)

Propagation models with gamma rays

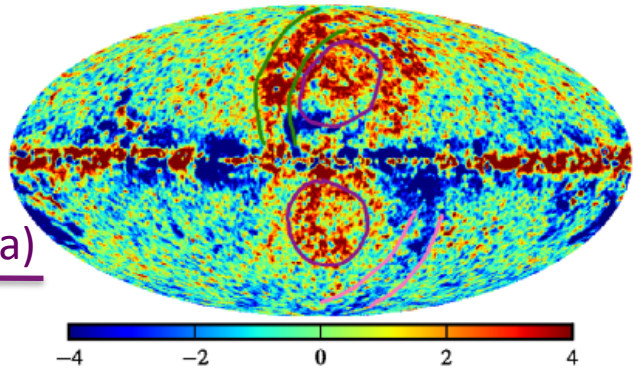
Ackerman et al. 2012 ApJ 750, 3





With CRs consistent with CR local measurements at that time

$$\frac{\text{(model-data)}}{\text{model}}$$



Excess:
- Outer Galaxy
- Fermi Bubbles?
- Inner Galaxy

Models used for gamma-ray analyses

Standard reacceleration models to fit B/C.

No constraints from synchrotron were used

(Used for the gamma-ray studies on Galactic center, Fermi bubbles, …)

BUT

- Magnetic field is important for energy losses

- Synchrotron spectrum informs on e-e+ spectrum

Radio and microwave spectral modeling: main results

Strong, A., Orlando, E., Jaffe, T., 2011 A&A, 534, 54

→ Break in LIS from <2 to ~3 @ few GeV

→ Break of injection spectrum < few GeV

→ Standard reacceleration models that fit B/C challenging

Improvements in GALPROP modeling

Orlando & Strong 2013 MNRAS 436, 2127

- 3D B-field configuration: random + regular + anisotropic random components

- polarization

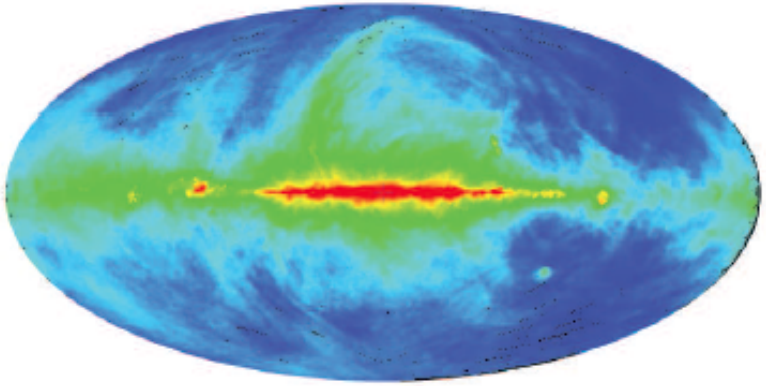
- free-free emission model

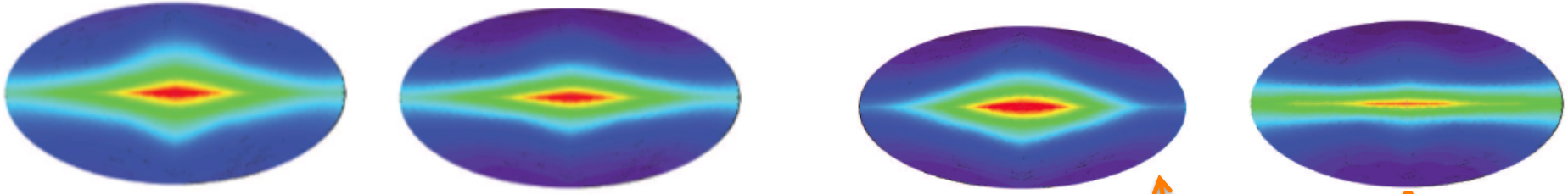
- absorption

Radio and microwave spatial modeling

Orlando & Strong 2013 MNRAS 436, 2127

I @ 408 MHz





Z=10 kpc

Z=4 kpc

Different propagation halo size

Different CR electron distribution

Different CR source distribution

Main results

Based on Orlando & Strong 2013 MNRAS 436,2127

Different spatial models investigated

Preference of:

- Flat CR source distribution in the outer Galaxy
- Halo height > 4 kpc

B-field constrained + Anisotropic component

Pure diffusion models preferred

Best model was used to separate Planck components

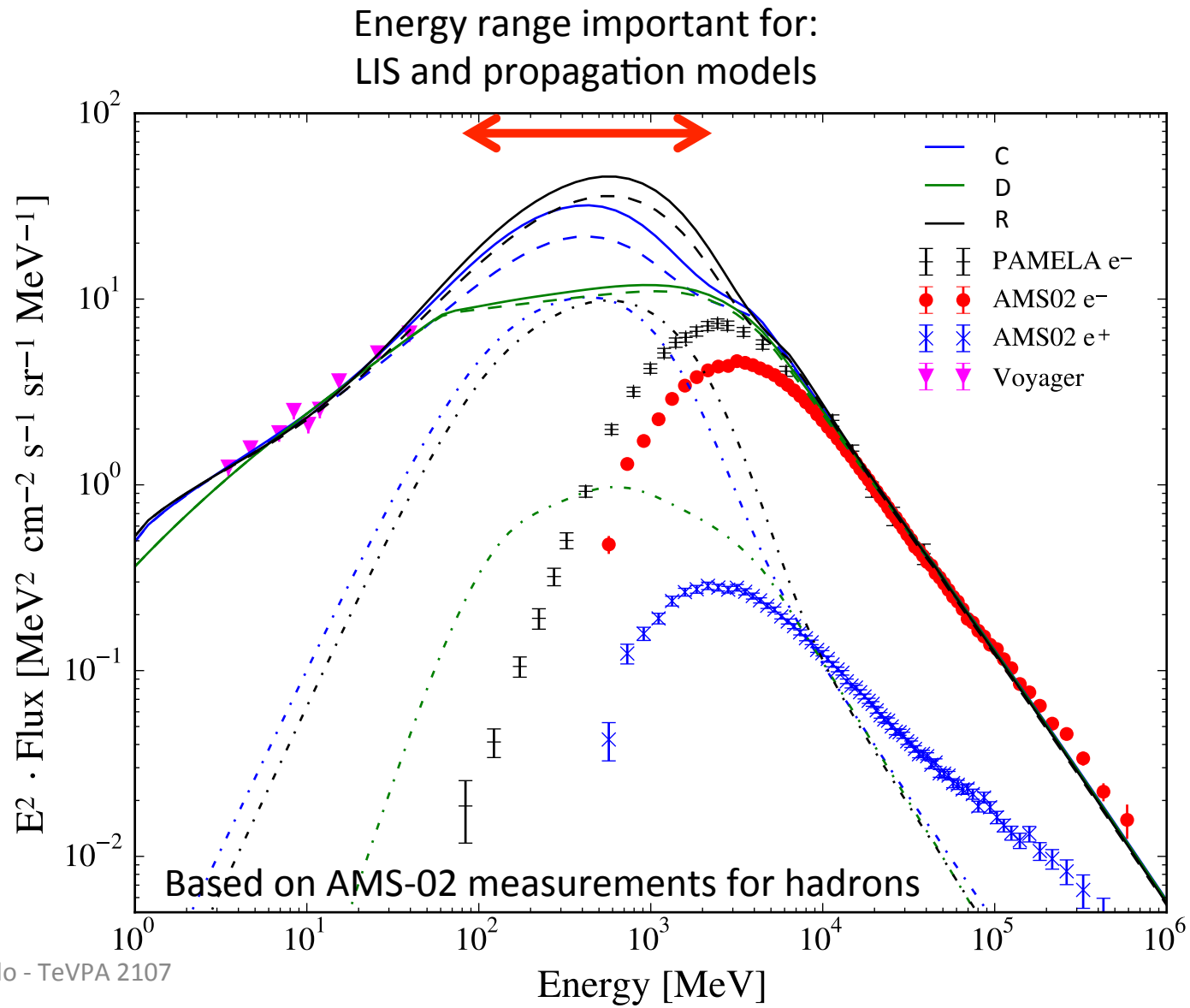
Now – ongoing effort

- electron CR measurements updated (Voyager and AMS-02)

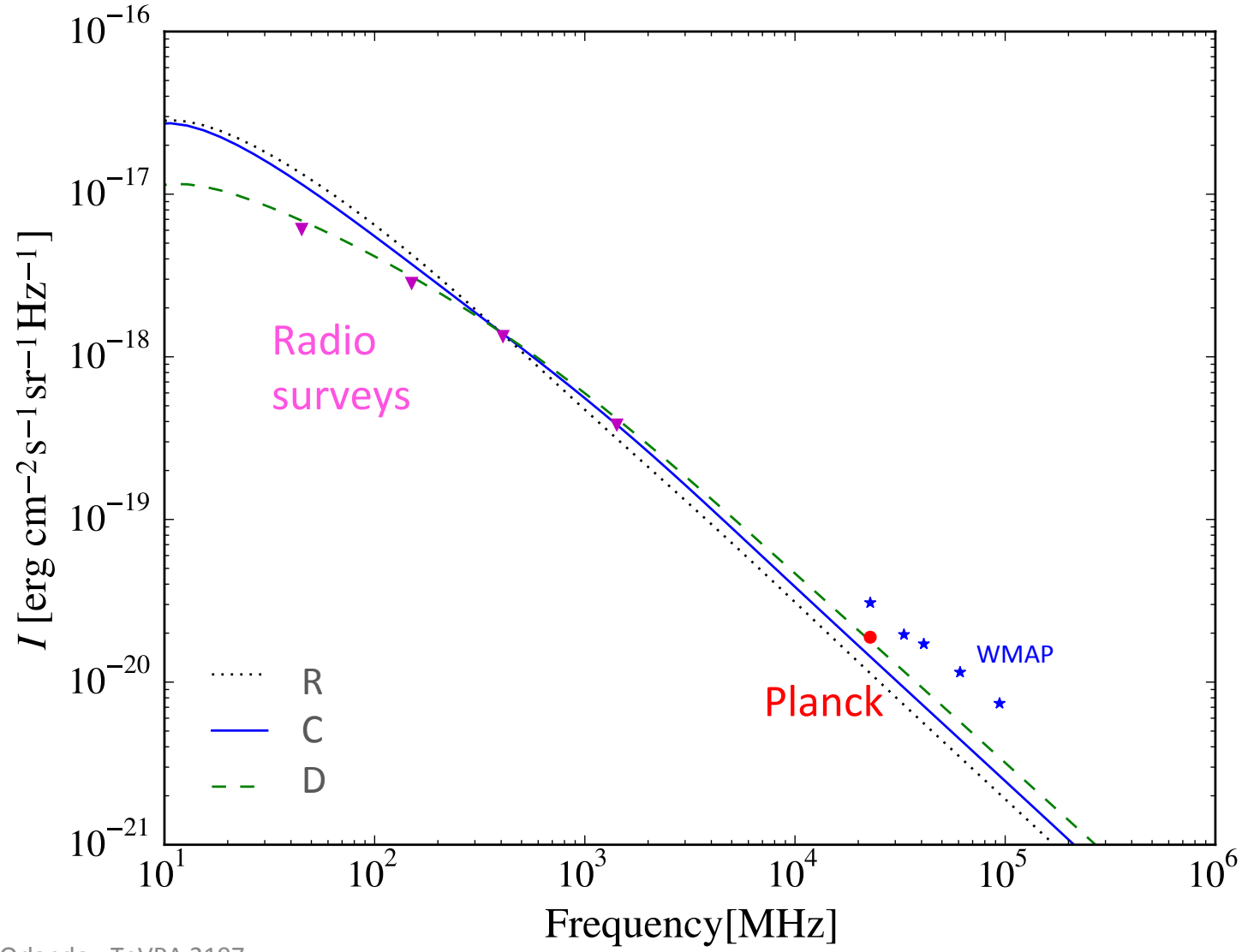
- Updated synchrotron maps

- Fermi-LAT observations

Electron (& positron) local interstellar spectrum

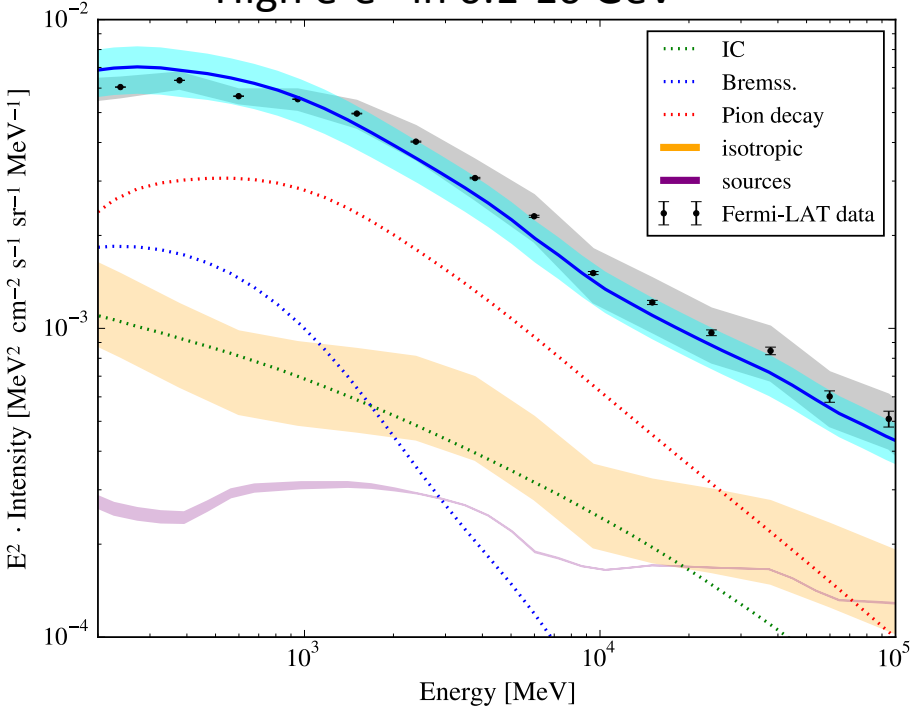


Produced synchrotron emission

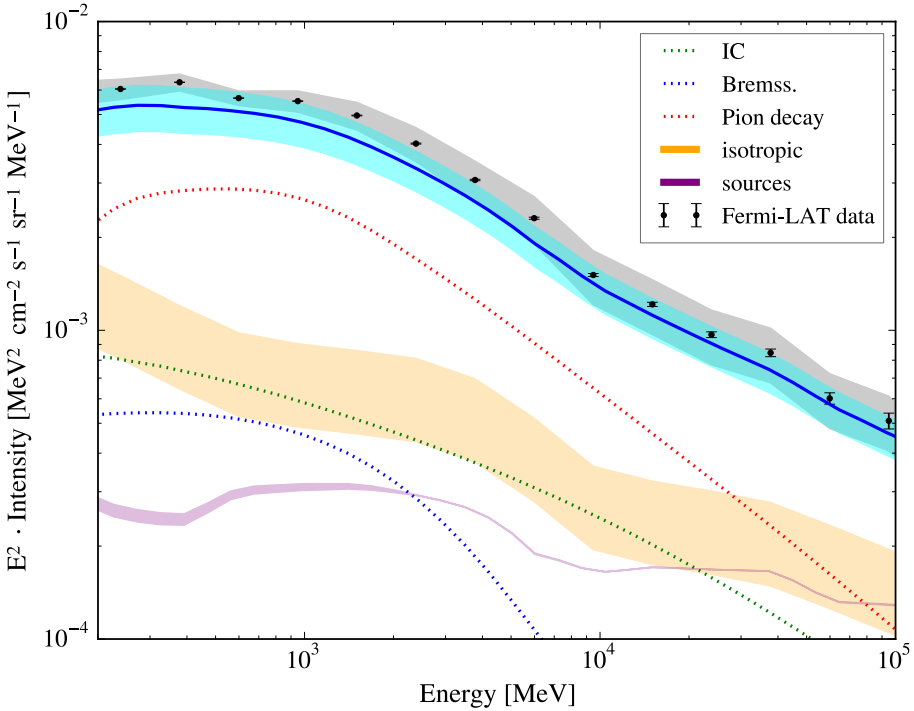


Gamma-ray emission and comparison with Fermi-LAT

High e-e+ in 0.1-10 GeV

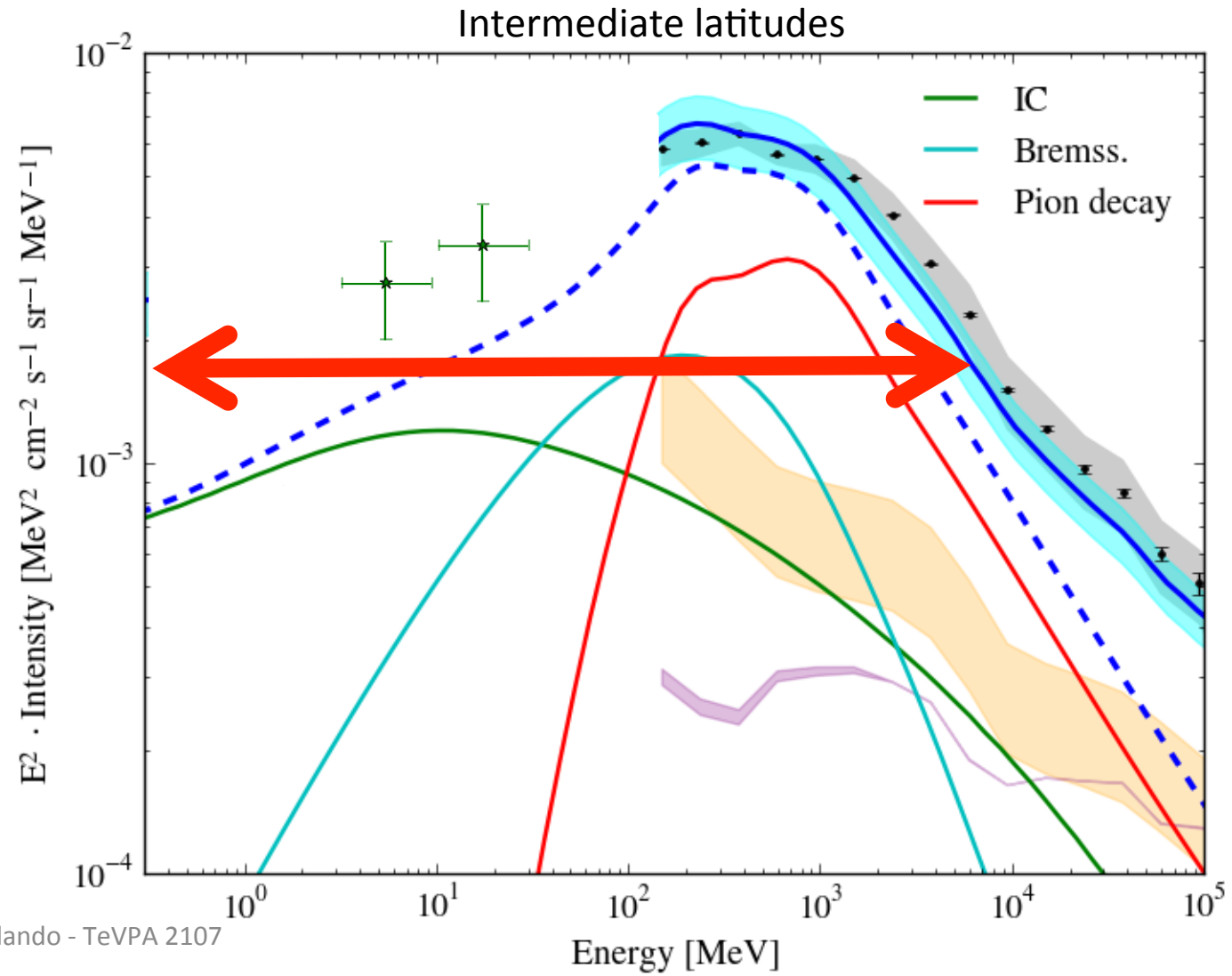


Low e-e+ in 0.1-10 GeV

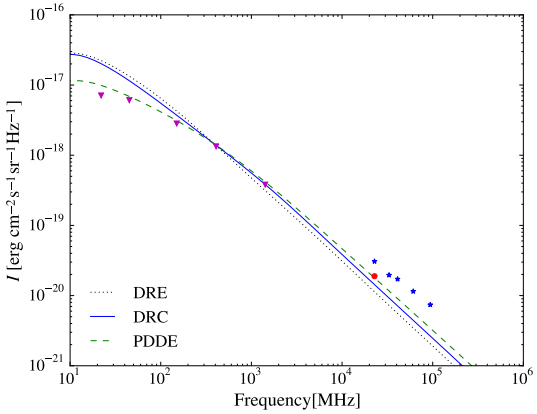


Fermi data are from
Ackermann et al.2012, ApJ,750,3

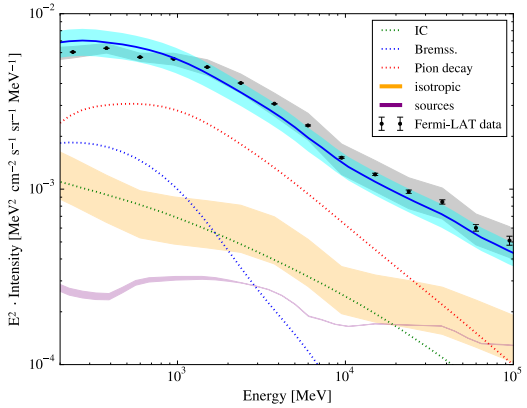
Updated interstellar model, and predictions for AMEGO and e-ASTROGAM



Summary



- Importance of using radio observations to constrain electrons and propagation parameters



- Relevance for the Fermi-LAT specially at lower energies, which can give additional constraints

Thank you for your attention!