Primary electrons and positrons from nearby supernova remnants and pulsars.

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Based on arXiv:1002.1910

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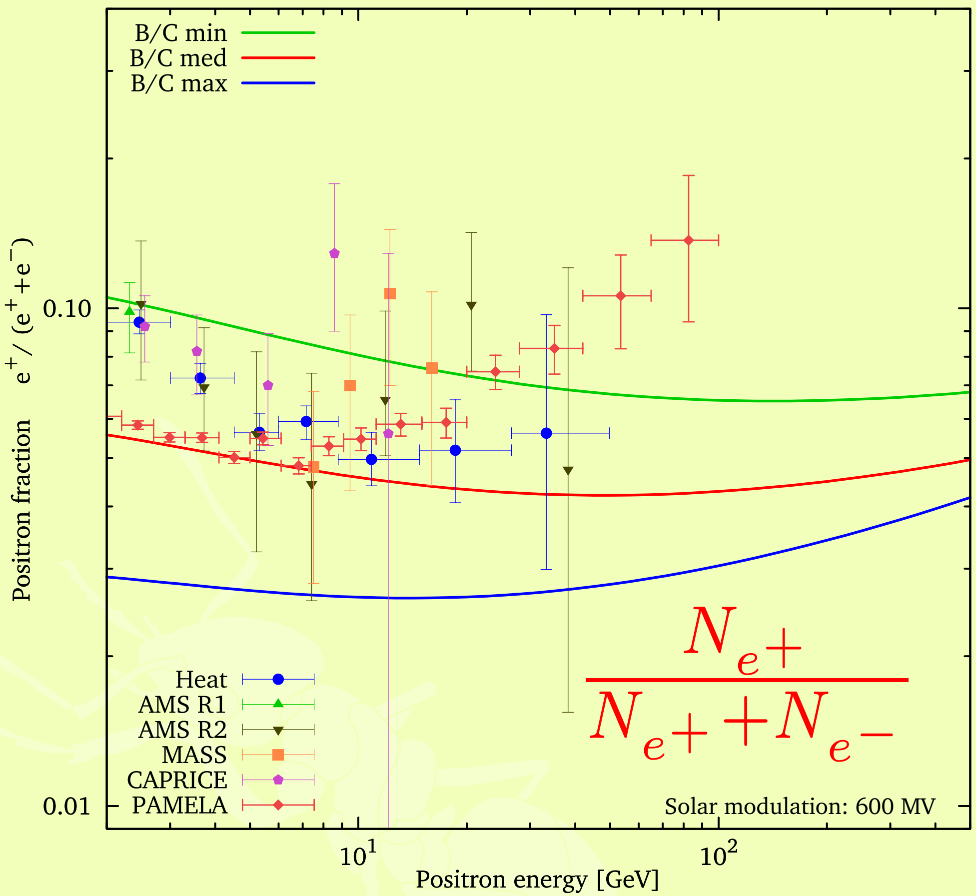
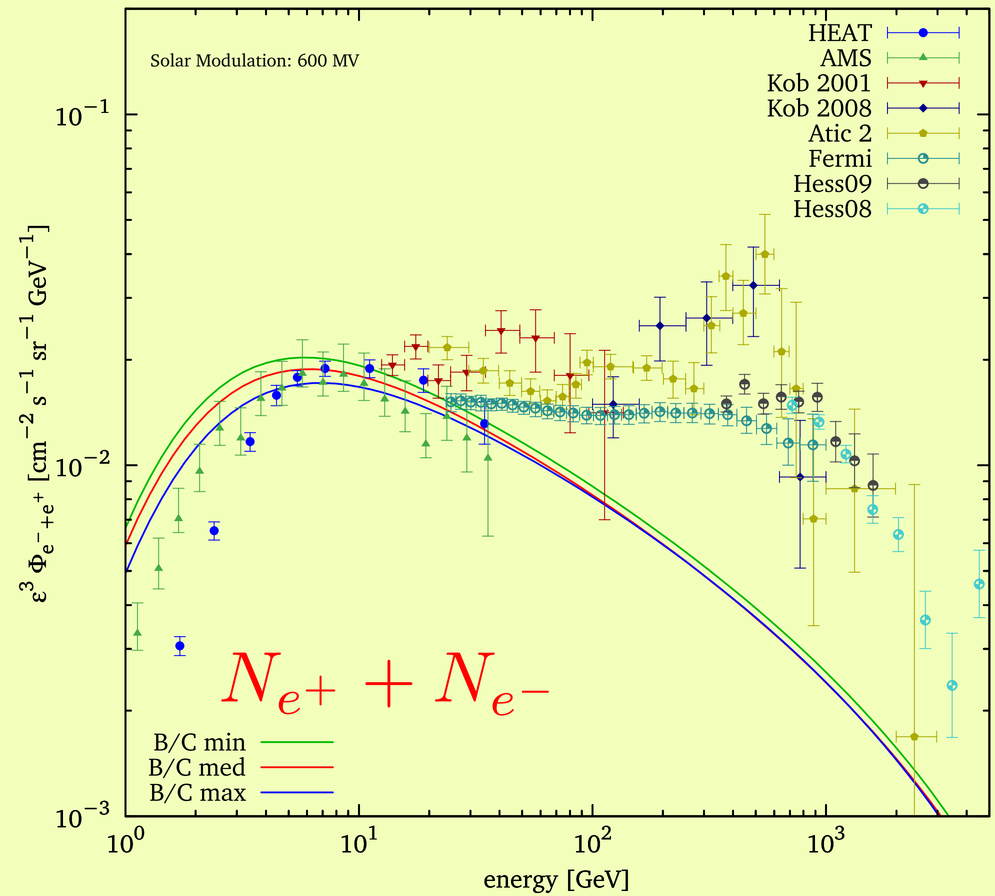
Motivation:

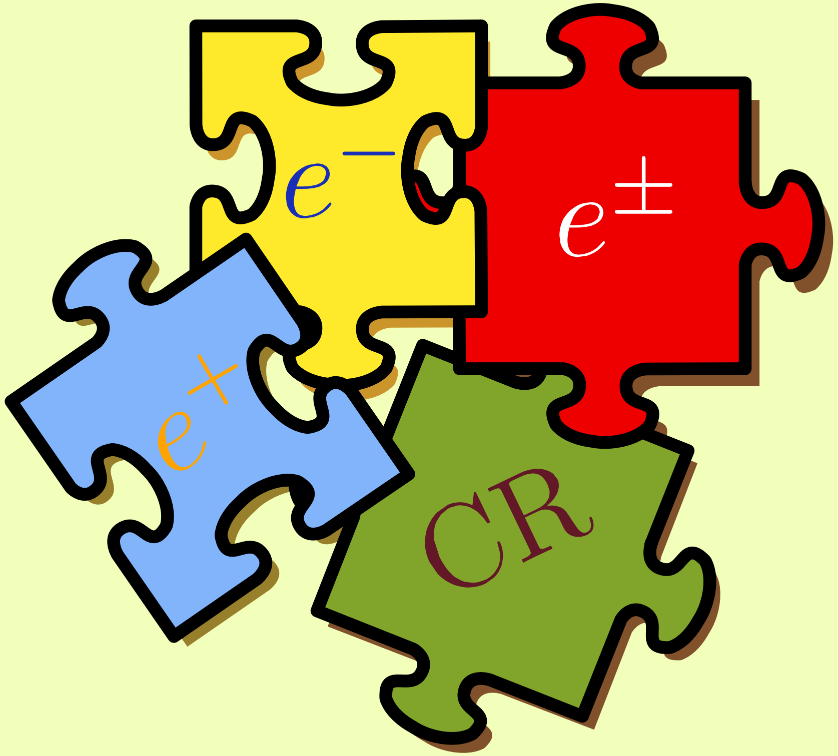




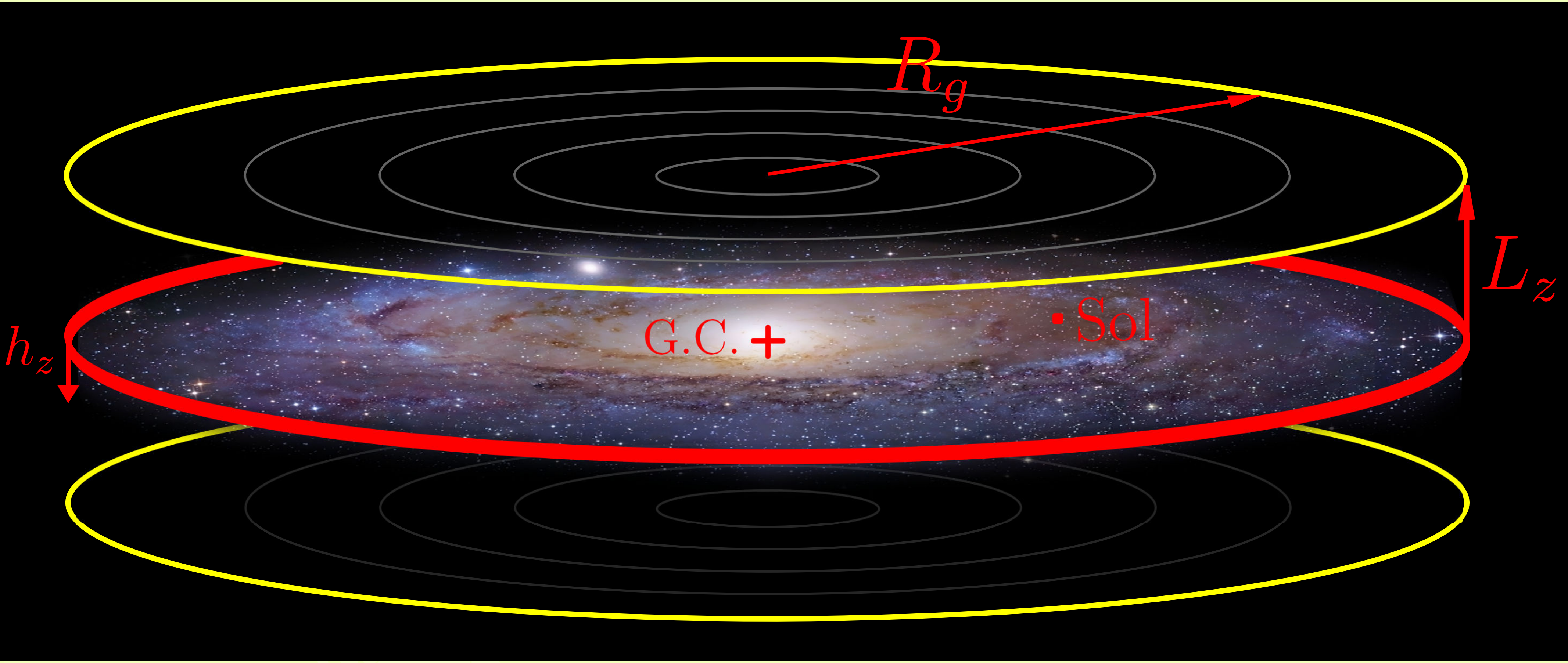
Deviations from *standard* expectations: astrophysical or new physics?

Outline

- **Propagation in the Galaxy**
  - Two–Zone Propagation Model
  - Transport Equation
- **Production of $e^{\pm}$**
  - Supernova remnants
  - Pulsars
  - Results
- **Conclusions**



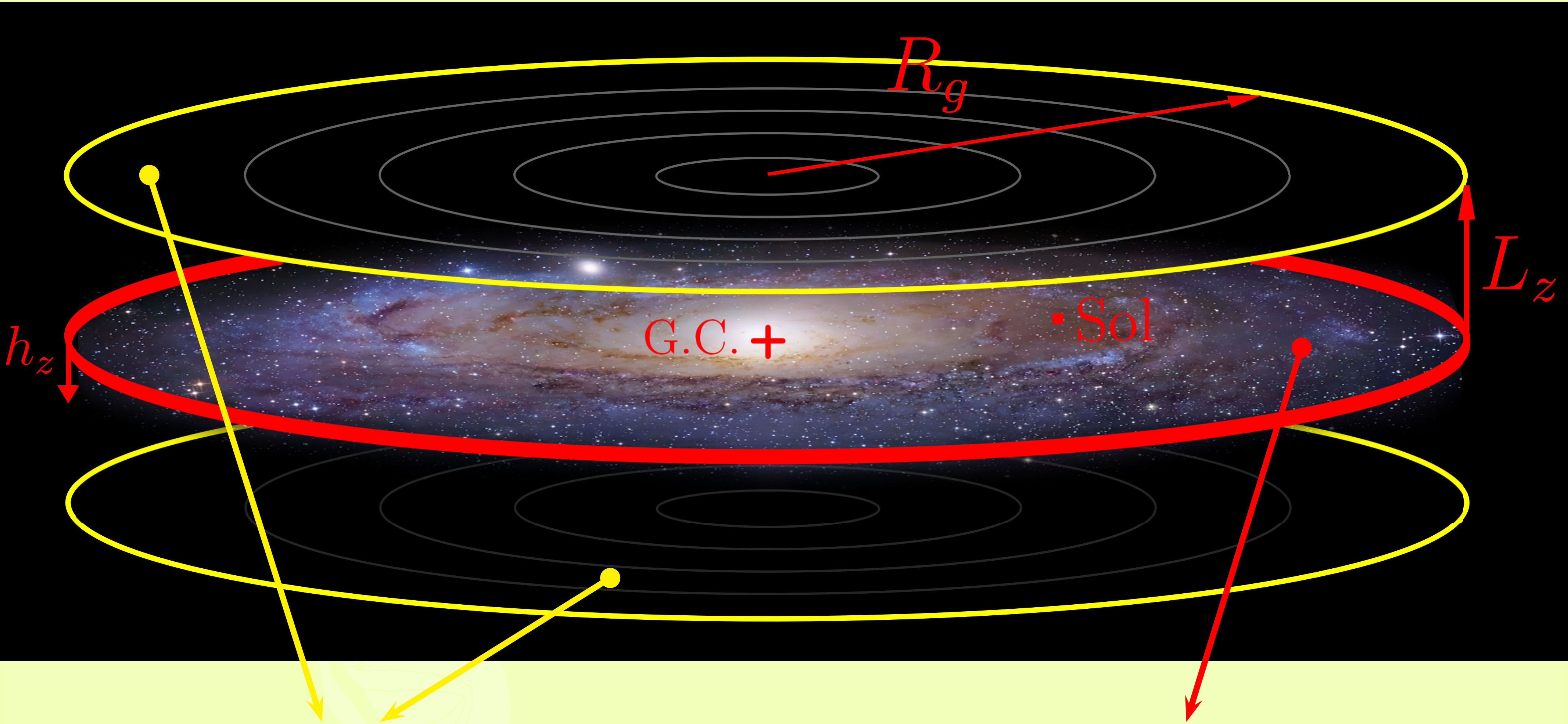
Two–Zone Propagation Model



The CR propagation is modeled in a cylinder where many physical processes take place (Ginzburg and Syrovatskii. Macmillan, 1964).

$$R_g = 20\,\mathrm{kpc}\ ,\ h_z \sim 100\,\mathrm{pc}\ ,\ L_z = 1\text{–}20\,\mathrm{kpc}$$

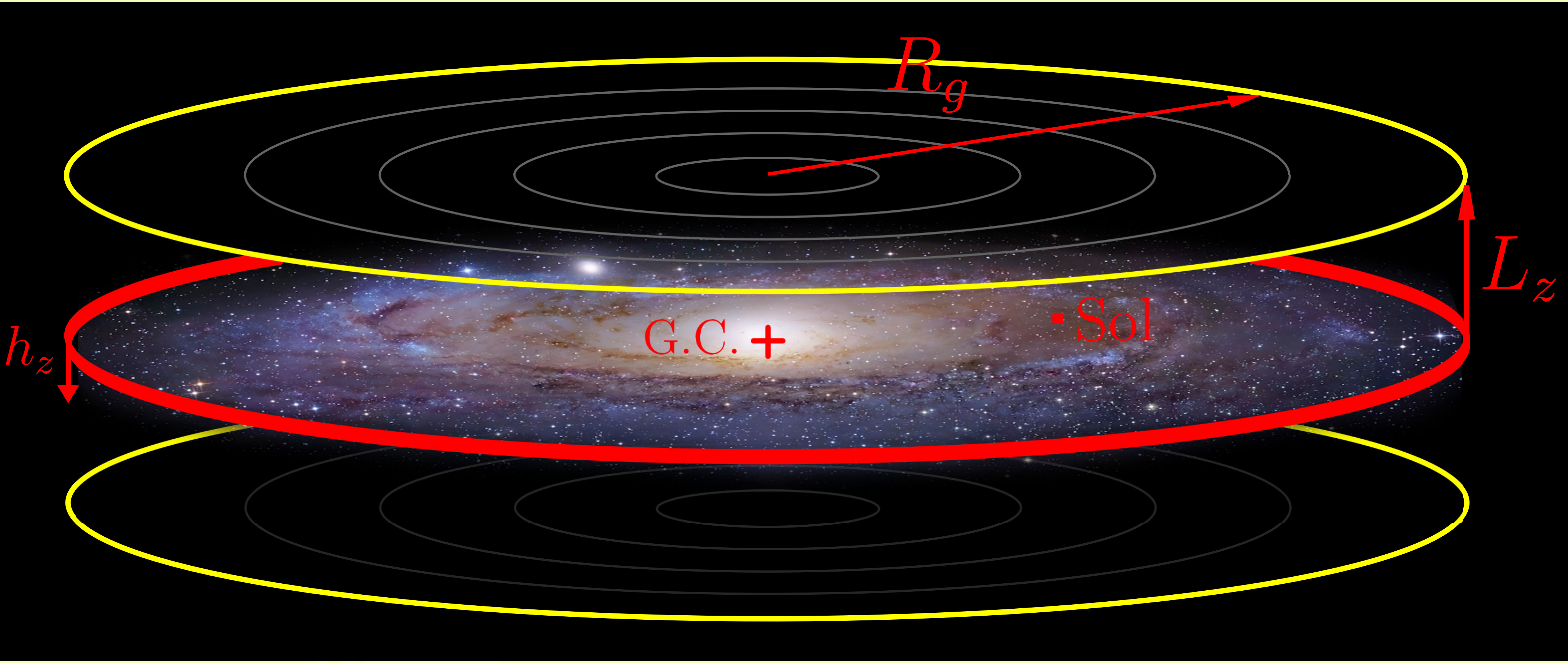
Two–Zone Propagation Model



A *cylinder–L_z* defines the zone where random magnetic fields are located.

A *thin–disk* models the galactic plane, sources and interactions between CR and ISM.

Two–Zone Propagation Model



... but the physics of the CR propagation is contained in the transport equation.

Transport Equation

The physics is described by a continuity equation for the number density per units of energy:

$$\frac{\partial \psi}{\partial t} + \nabla \cdot \vec{J}_x + \frac{\partial J_E}{\partial E} = Q$$

- $\vec{J}_x$ takes into account effects as diffusion, advection and convection:

$$\vec{J}_x = -K_0 \mathcal{R}^\delta \nabla \psi + \vec{V}_c \psi$$

- J_E is related to energy evolution: energy losses and reacceleration.

$$J_E = -\frac{\nabla \cdot \vec{V}_c}{3} \frac{p^2}{E} \psi - b(E)\psi + \ldots$$

- Q is the injection rate (cosmic ray production).

Transport Equation: for *electrons*

For *electrons* at GeV–TeV scale:

$$\frac{\partial \psi}{\partial t} - D(\epsilon)\nabla^2\psi - \frac{\partial}{\partial \epsilon}\left(b(\epsilon)\psi\right) = Q(t, \vec{x}, \epsilon)$$

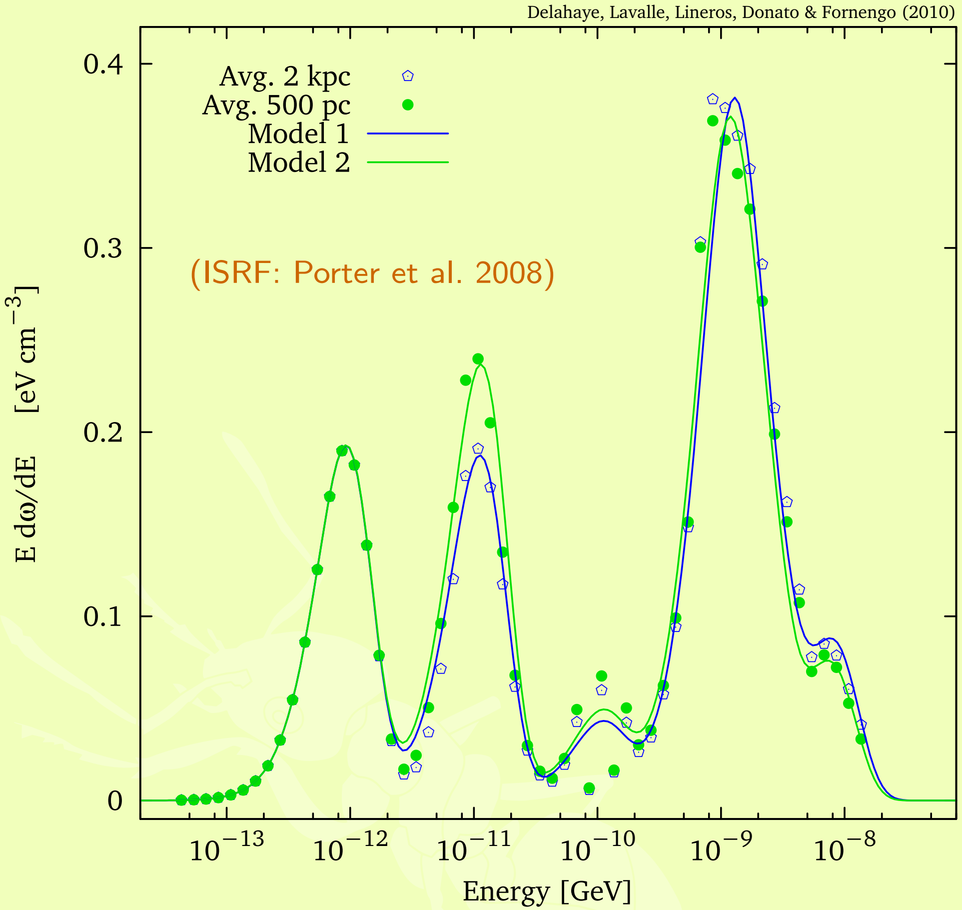
Naturally emerge the diffusion scale and the cooling time:

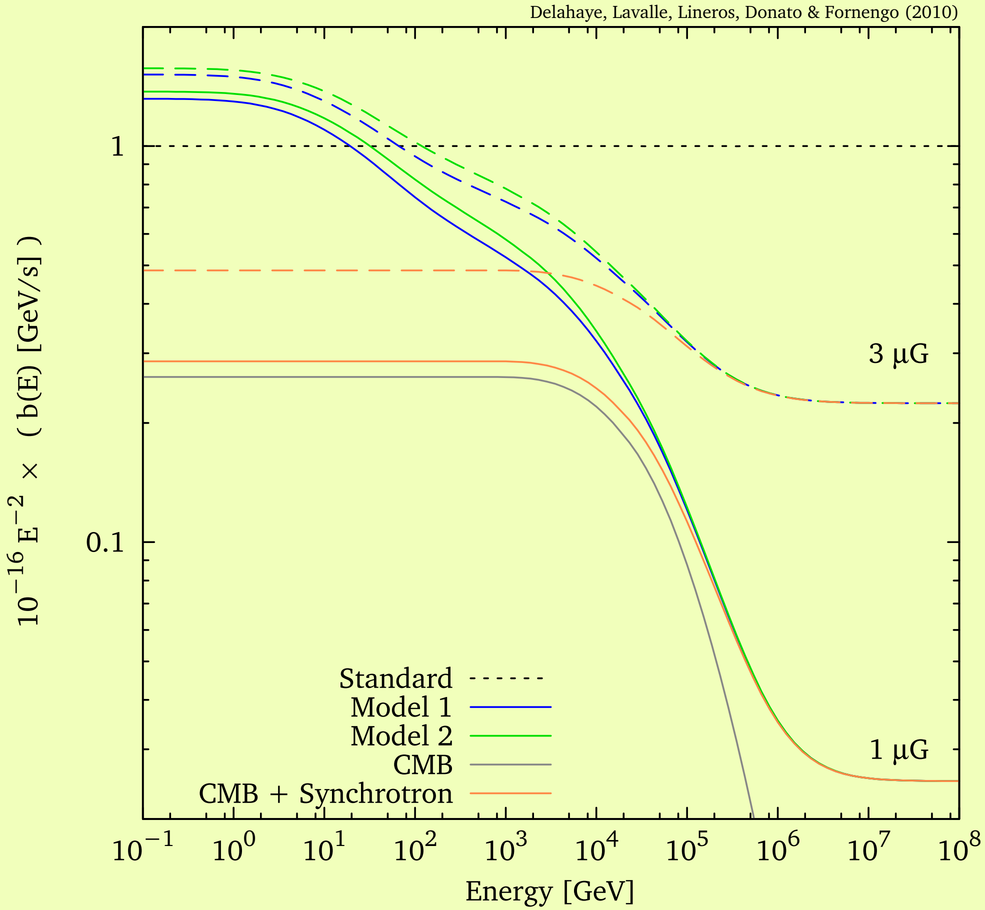
$$\lambda_d^2(\epsilon, \epsilon_0) = 4\int_\epsilon^{\epsilon_0} d\varepsilon \frac{D(\varepsilon)}{b(\varepsilon)} \quad ; \quad \tau_c(\epsilon, \epsilon_0) = \int_\epsilon^{\epsilon_0} d\varepsilon \frac{1}{b(\varepsilon)}$$

that makes easier to solve the transport equation (via the green function).

$$G(t, r, \epsilon, \epsilon_0) = \frac{\delta(t - \tau_c)}{b(\epsilon)} \times \frac{\exp\left(-\frac{r^2}{\lambda^2}\right)}{\pi^{3/2}\lambda_d^3}$$

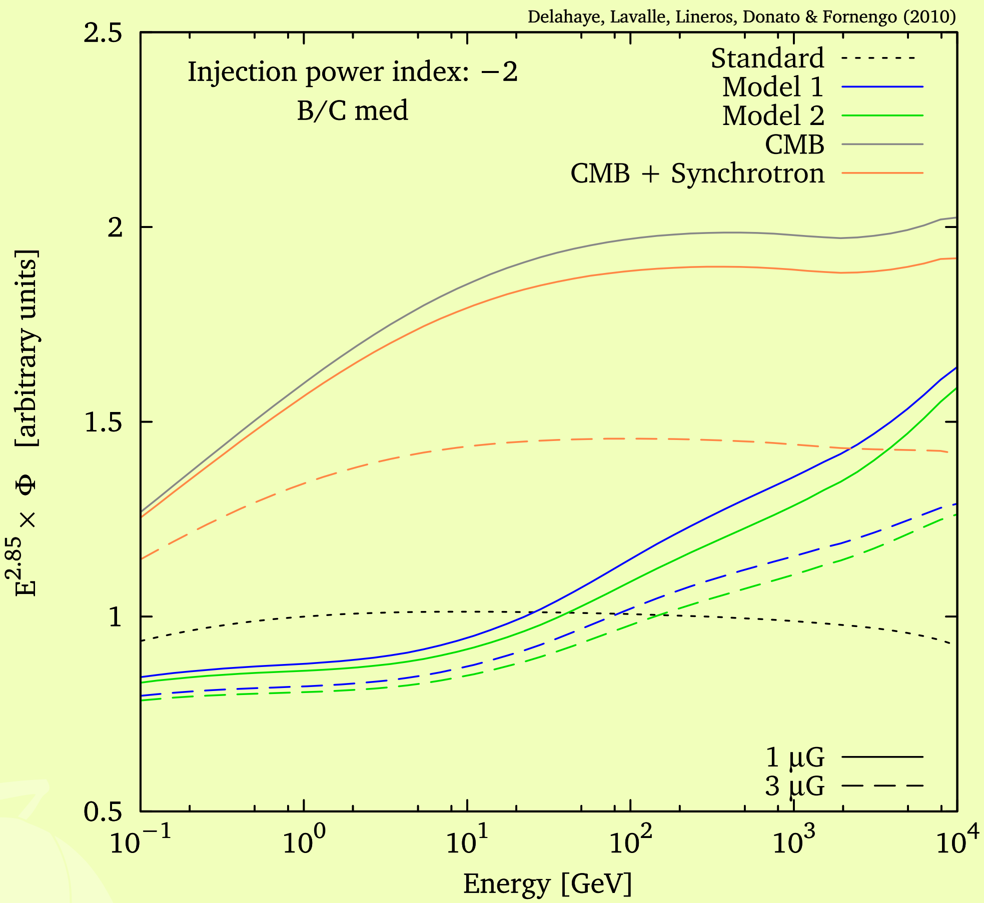
Transport Equation: energy losses





The interstellar radiation field plays an essential role in the energy losses.
After a certain threshold in energy each radiation field component goes to Klein–Nishina limit.

Transport Equation: energy losses



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Production of galactic electrons and positrons

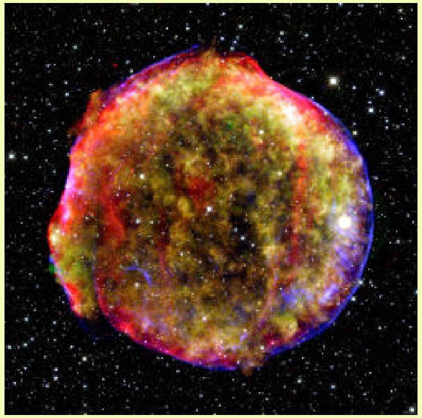
Sources

Many astrophysical phenomena are related to cosmic ray production.
Let's classify them by:

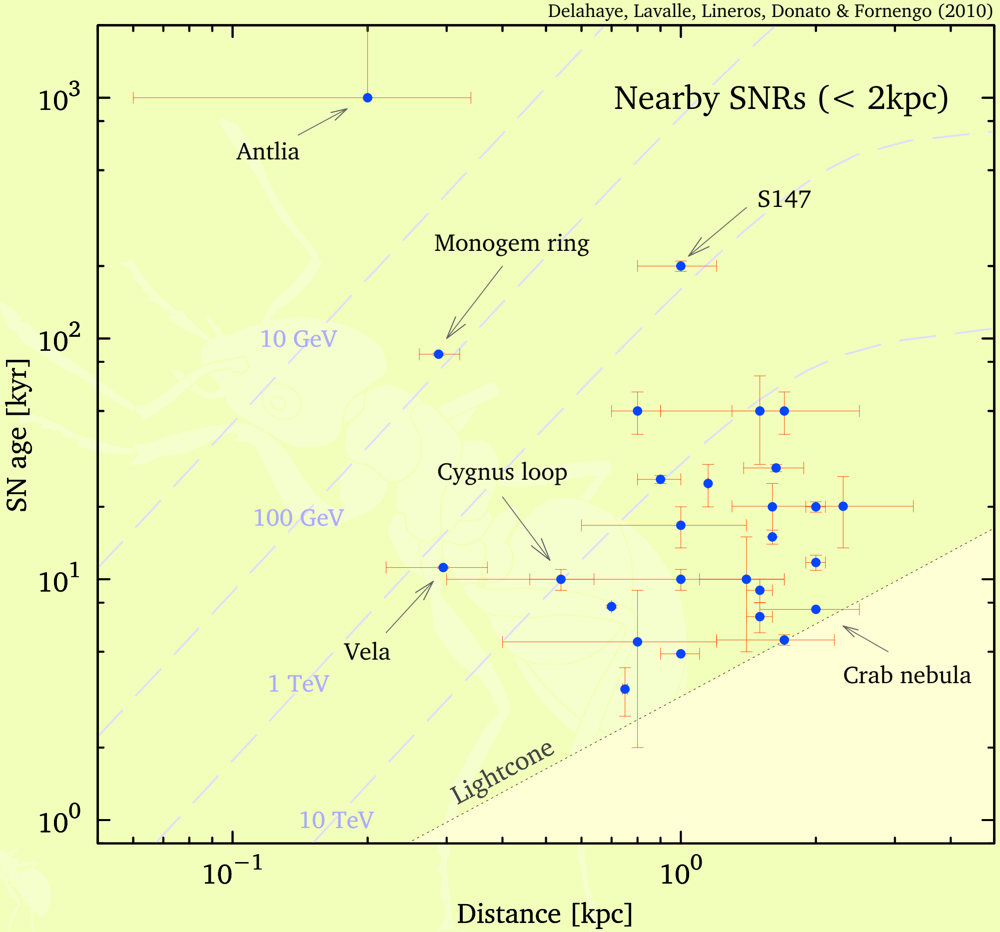
- Astrophysical origin: Supernovae, pulsars
  (This work), (Grasso et al. 2009), (Profumo 2008), (Boulares et al. 1998), and others
- Secondary production: Interaction of CR with IS gas.
  (Delahaye et al. A&A 2009), (Strong et al. 1998)
- New physics: Dark Matter annihiliation
  (Delahaye et al. PRD 2008), (Baltz et al. 1998) and many others

Depending on their nature, sources produce matter or antimatter in different amounts

Production of cosmic rays: supernovae and pulsars



Supernovae provide a important fraction of cosmic rays. Those are directly injected into the galactic medium.

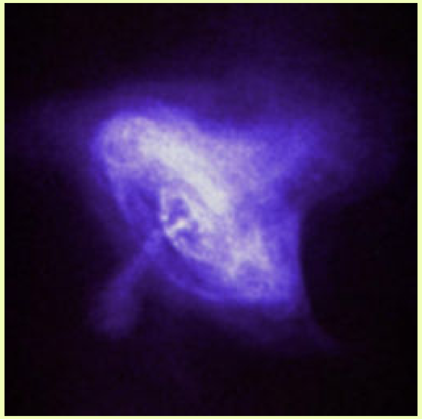


There are ~ 30 nearby SN remnants.

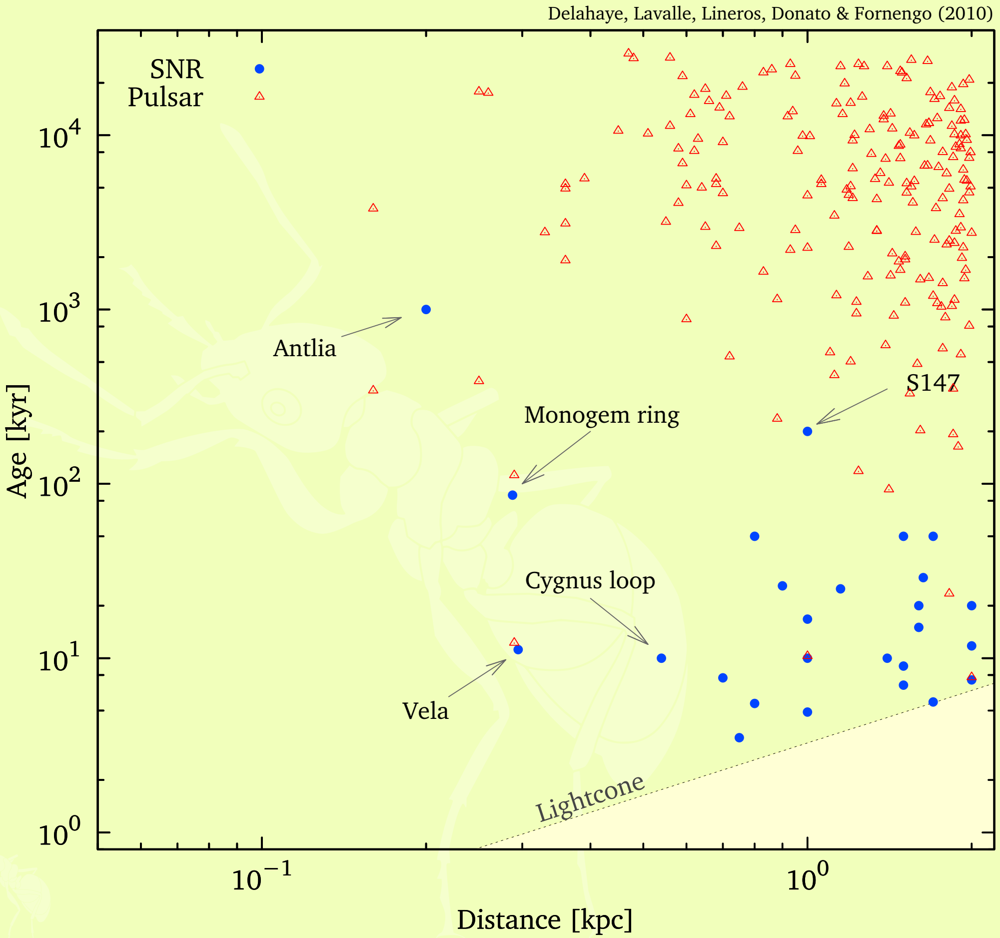
Documented galactic supernovae go up to 200

(Green, arXiv:0905.3699).

Production of cosmic rays: supernovae and pulsars



As result of core–collapse SN, Pulsars produce electrons positrons which gain energy thanks to the Pulsar Wind Nebula (Blondin et al. 2001)

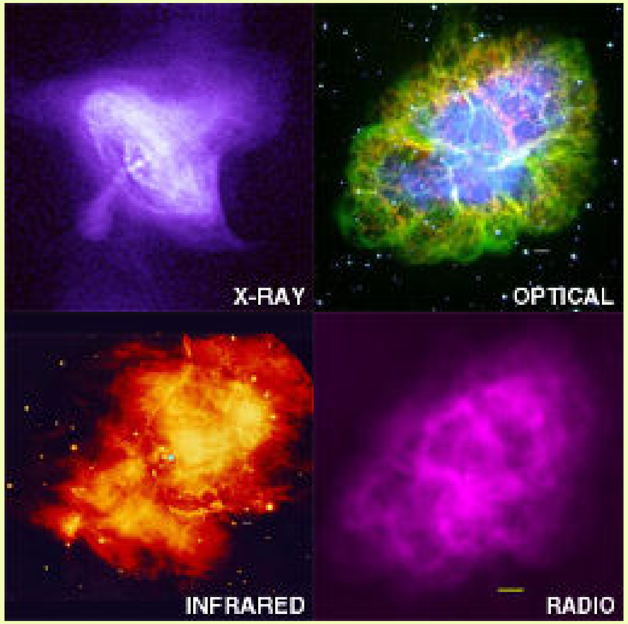


There are $\sim$ 200 nearby pulsars.

(ATNF catalog: Manchester et al. 2005).

Of course, to measure supernovae and pulsars is not easy and standard methods are not free of biases.

Production of cosmic rays: supernovae and pulsars



Strategies to deal with primary flux:

- Smooth distribution after 2 kpc
- Discrete distribution SNR + Pulsar system
- Injection spectra constrained by radio observation

Both strategies follow same physical constrains:

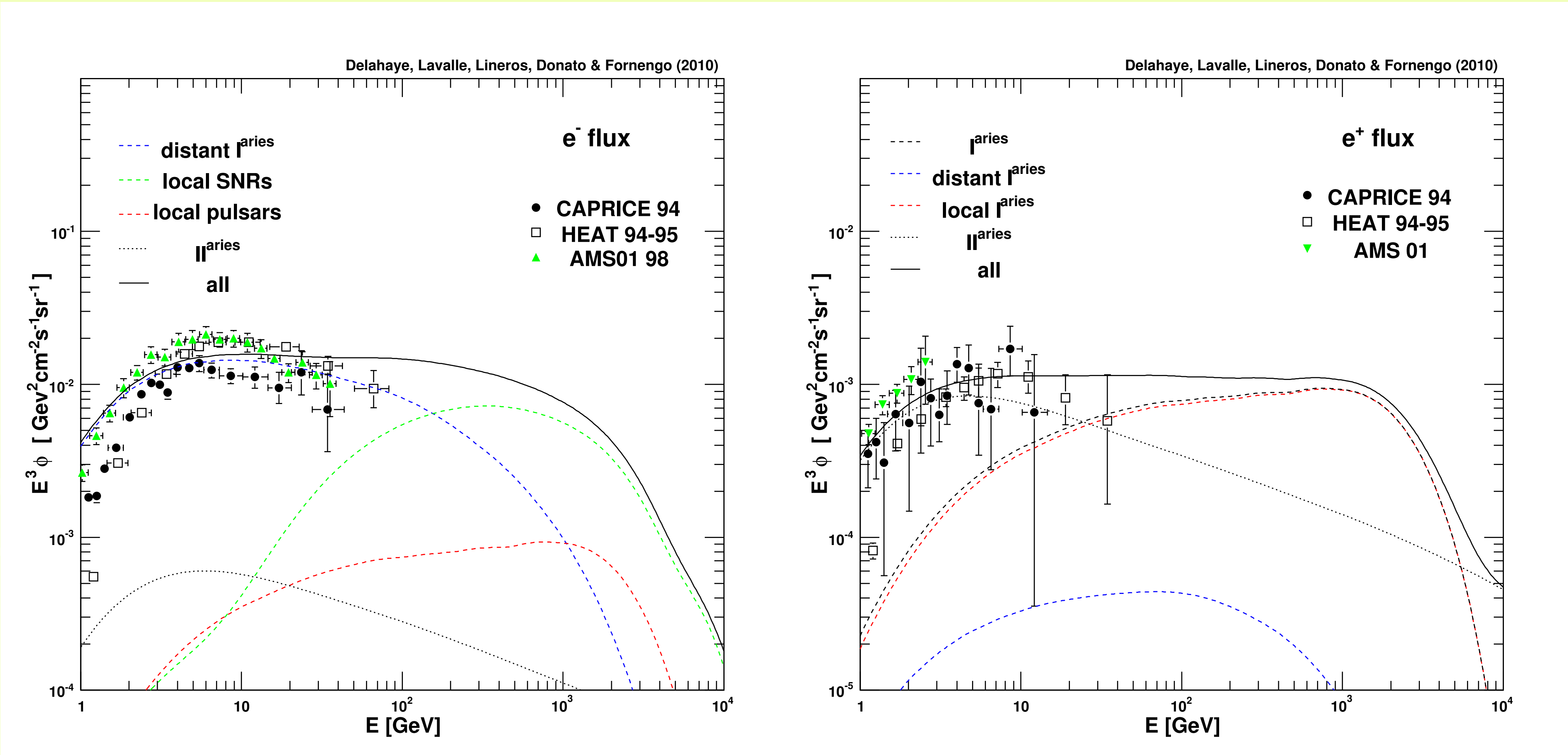
$$Q_{\mathsf{SN/P}} \int d\epsilon \, \epsilon \, \frac{d\tilde{N}}{d\epsilon} = \text{efficiency} \times E^{\star} \frac{\Gamma_{\mathsf{SN}}}{V}$$

For SNRs: $E^{\star} \sim 10^{51}\mathtt{erg}$

For Pulsars: $E^{\star} \sim 10^{49}\mathtt{erg}$

Results: Fluxes

(Delahaye, Lavalle, Lineros, Donato and Fornengo. arXiv:1002.1910)



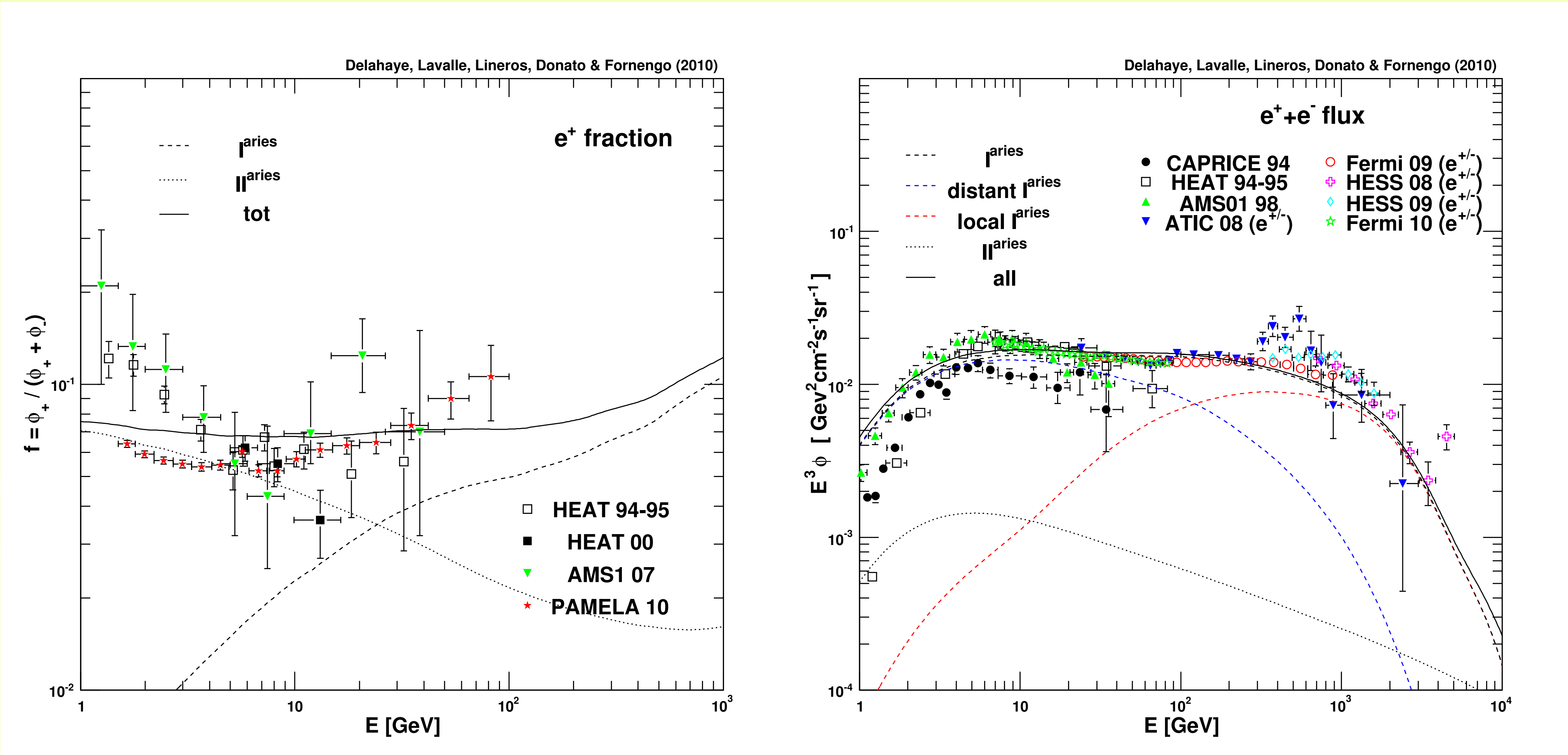
Electron signal is dominated by the SNR component.

Positrons at low energy are mainly secondaries.

At high energy, Pulsar component dominates.

Results: Fraction and total flux

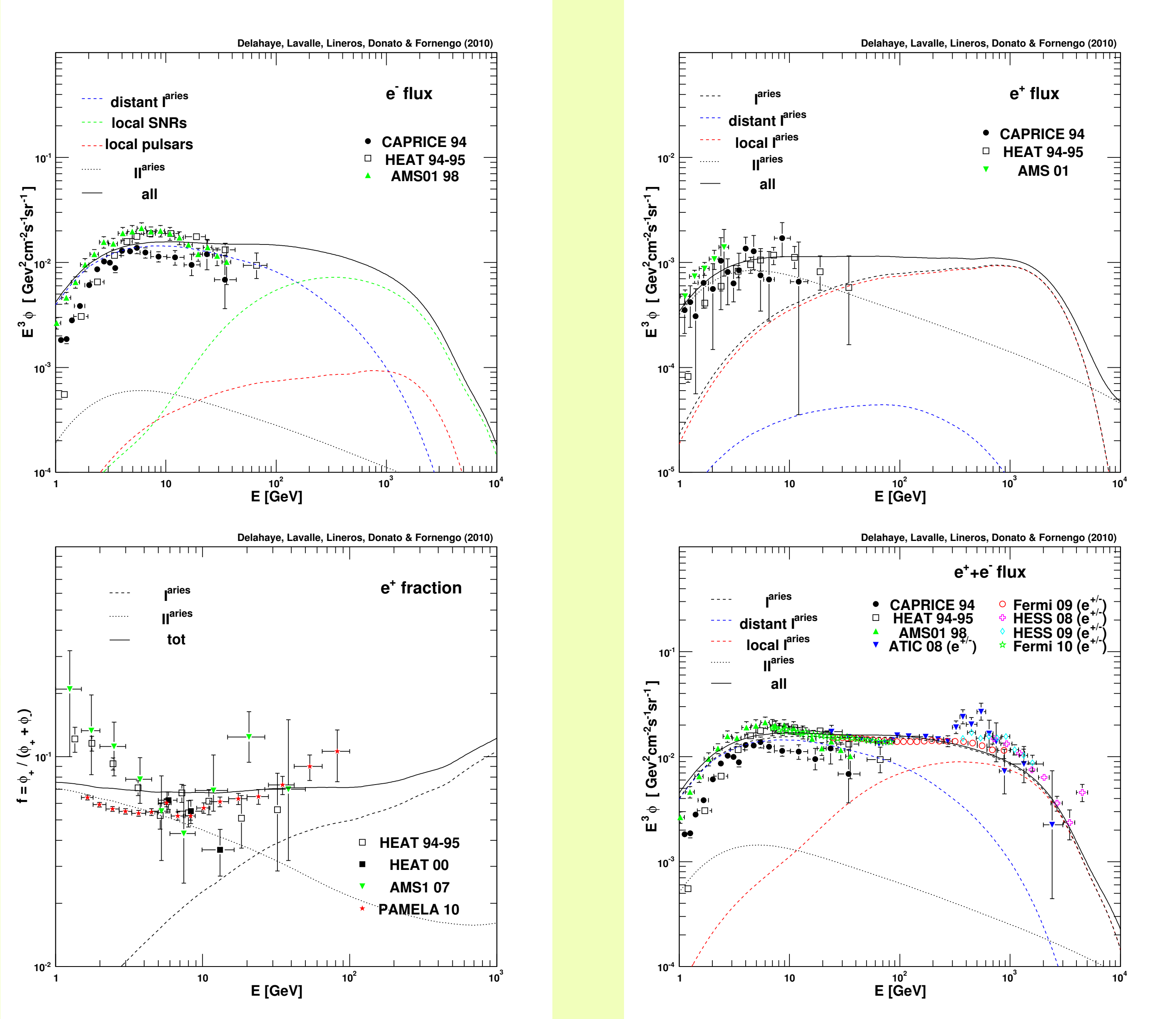
(Delahaye, Lavalle, Lineros, Donato and Fornengo. arXiv:1002.1910)



With conservative assumptions, the SNR+Pulsar hypothesis emcompases the positron fraction and the total flux.

Results: Group picture

(Delahaye, Lavalle, Lineros, Donato and Fornengo. arXiv:1002.1910)



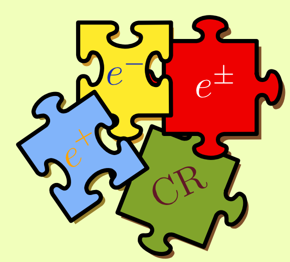
Conclusions

- Supernova remnants and pulsars are objects capable to produce electrons and positrons. We remark that pulsars should associated to SNRs since they are the results of SN explosion.

- Observational constraints are useful to describe/constrain the injection spectra at the source. Uncertainties do not allow to do clean predictions.

- Dark Matter annihilation/decay hypothesis is disfavourable to explain only the electron and positron observations.

- Experiments as PAMELA, FERMI and AMS will give valuable information to complete part of the electron/positron puzzle. For instance, undiscovered pulsars and asymmetries in arrival direction of galactic cosmic rays.



Publicity

PPC 2010

IV INTERNATIONAL WORKSHOP ON THE INTERCONNECTION BETWEEN PARTICLE PHYSICS AND COSMOLOGY

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Thank you