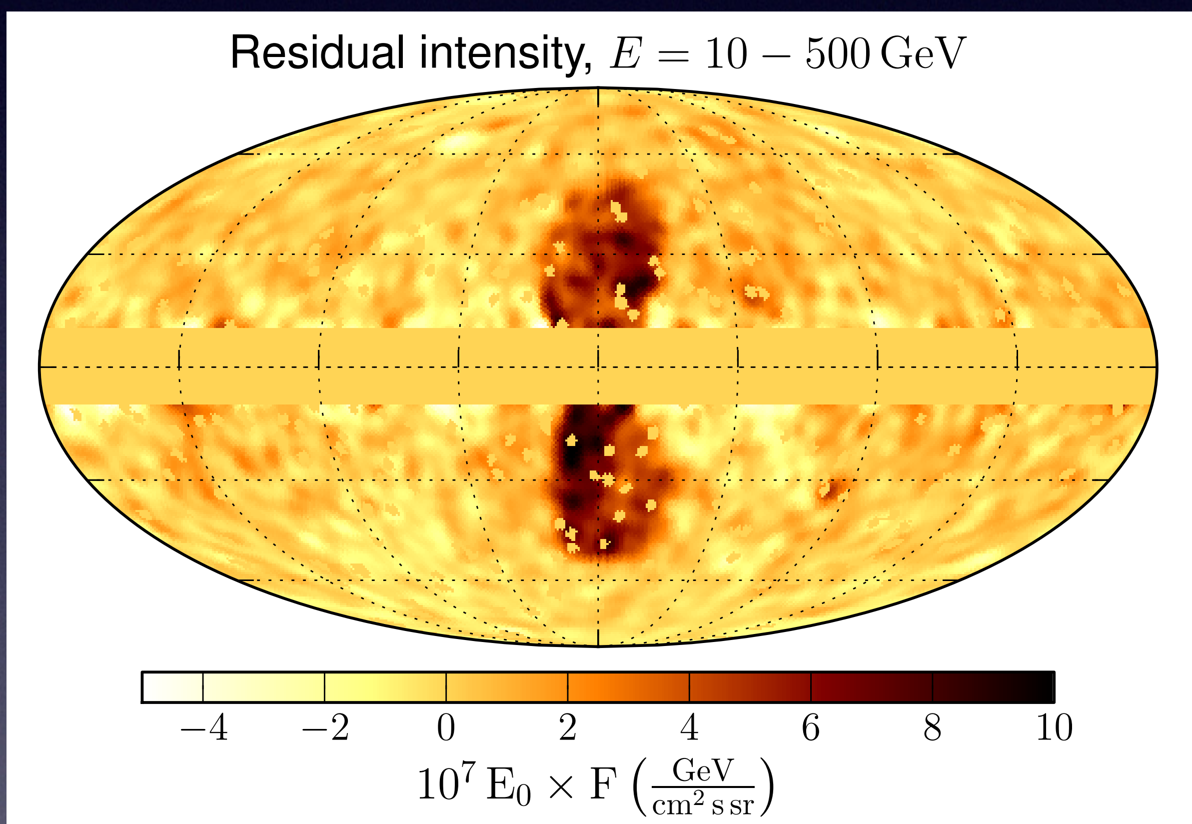
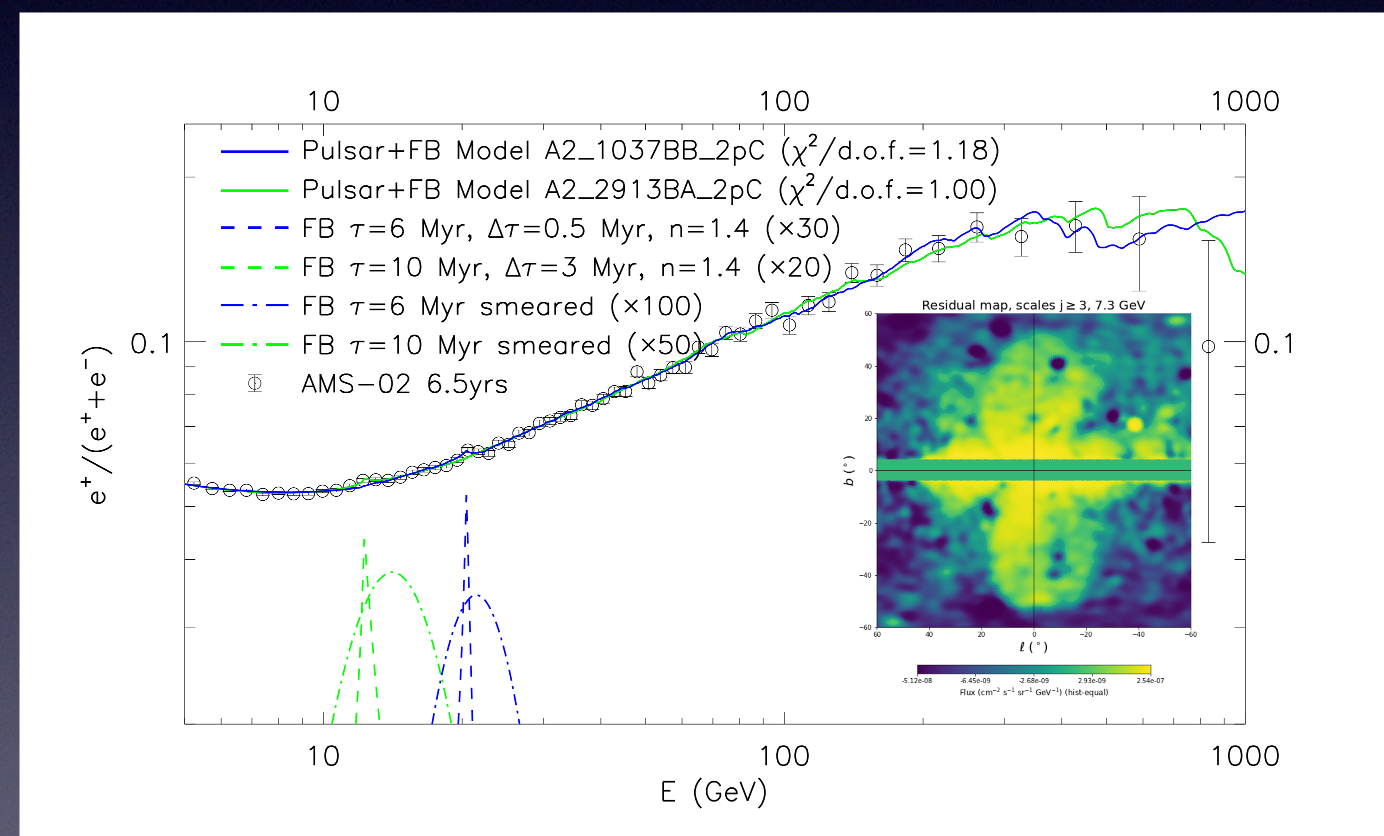
Have we found the counterpart signal of the Fermi bubbles at the cosmic-ray positrons?





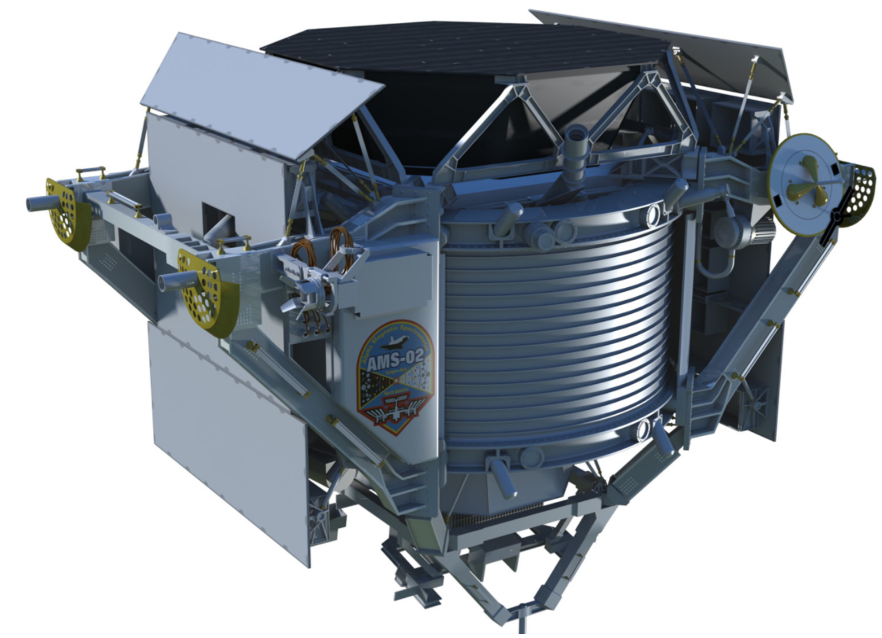
Iason Krommydas @ Rice University

*Cholis, Krommydas, PRD **105** 023015 (2022)*

Cholis , Krommydas arXiv:2208.07880 (ApJ 2023)

Ilias Cholis, 4/18/2023

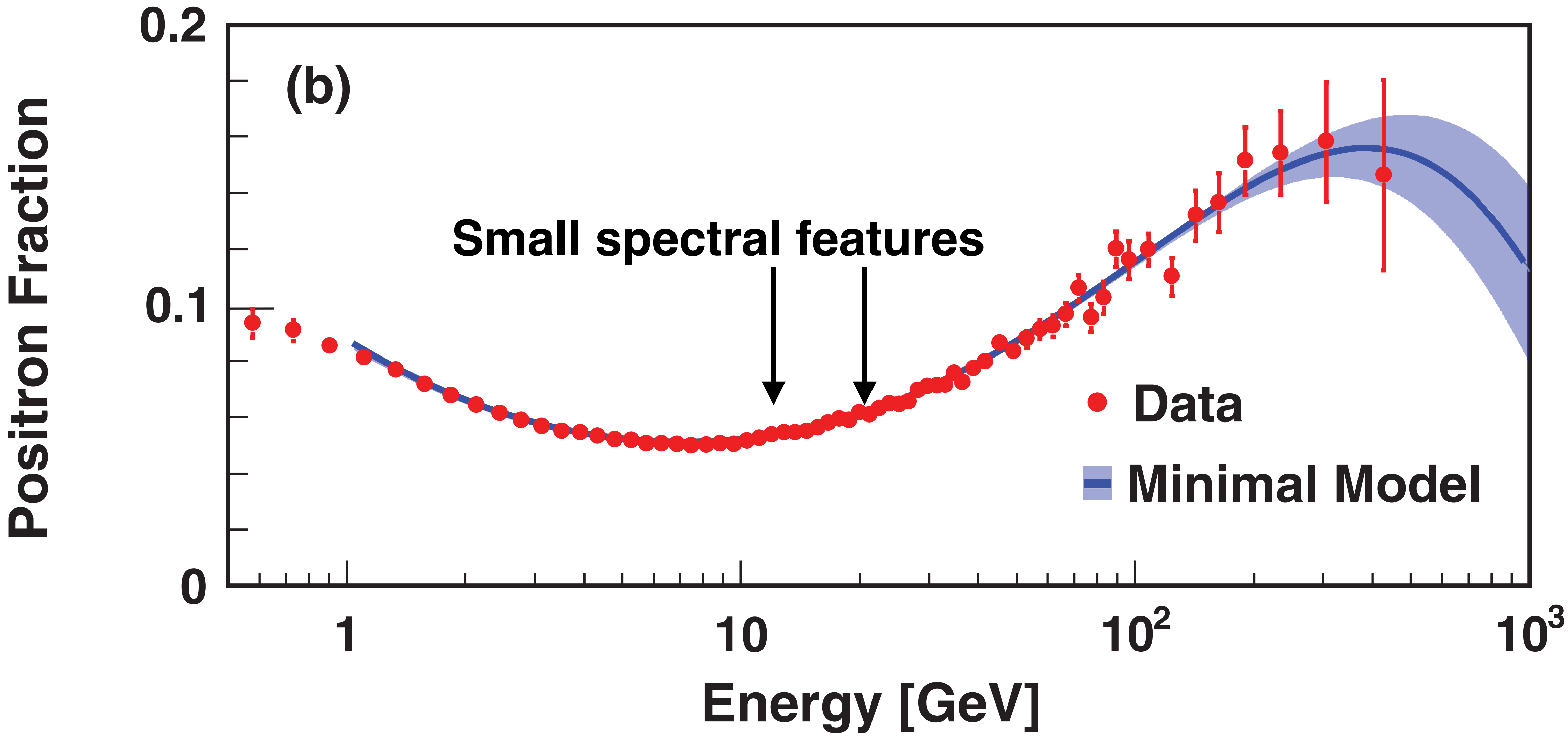
The Cosmic-Ray positron fraction



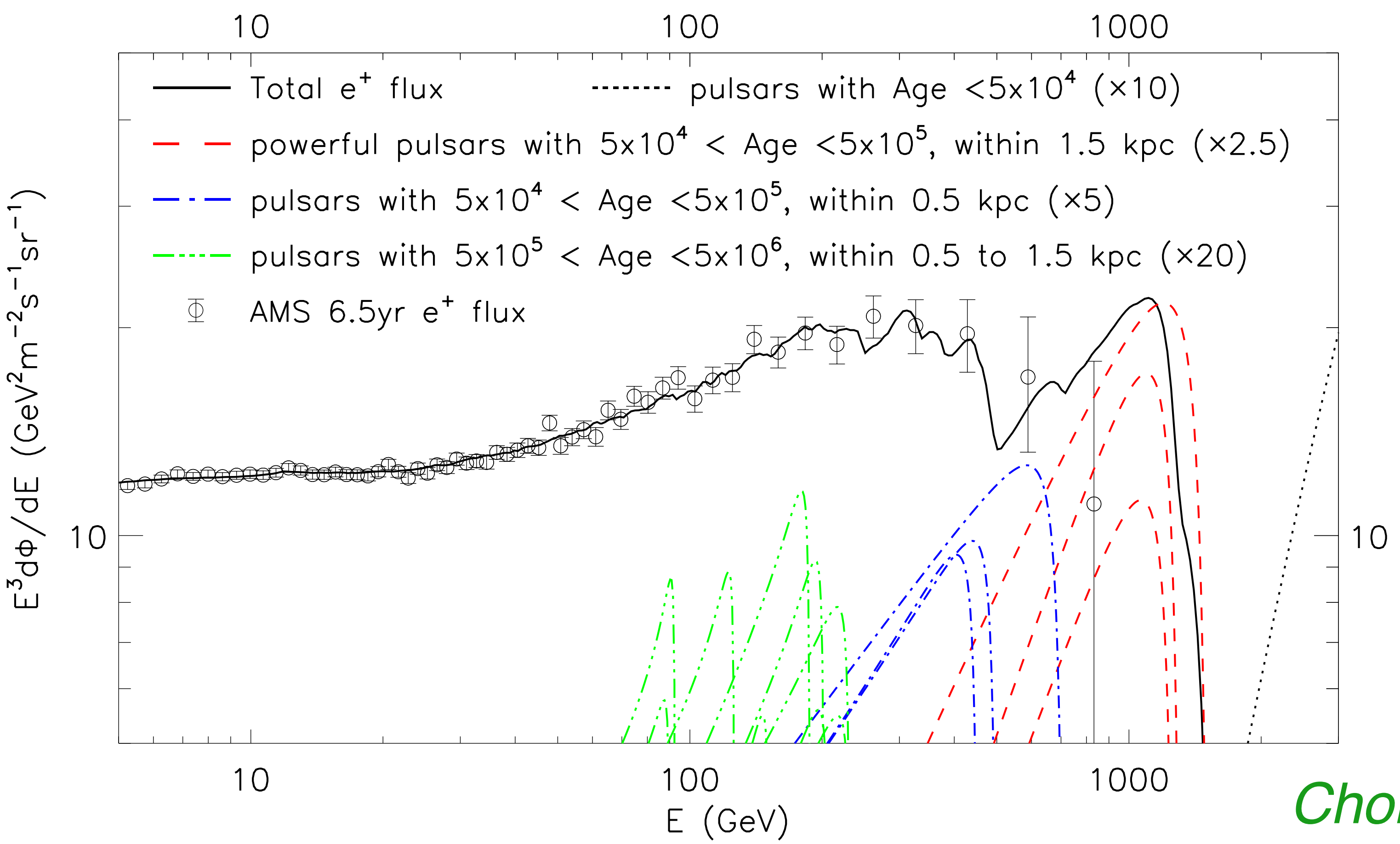
Positron Fraction:

$$e^+/(e^+ + e^-)$$

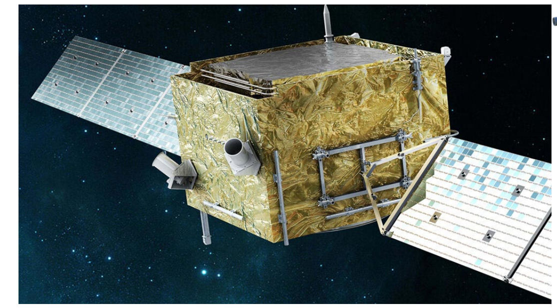
AMS-02 Coll. PRL 2016

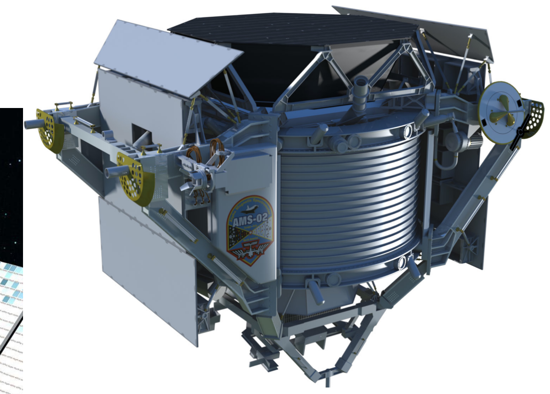


We Account for pulsars and other cosmic-ray sources and Comparing to Observations



DAMPE

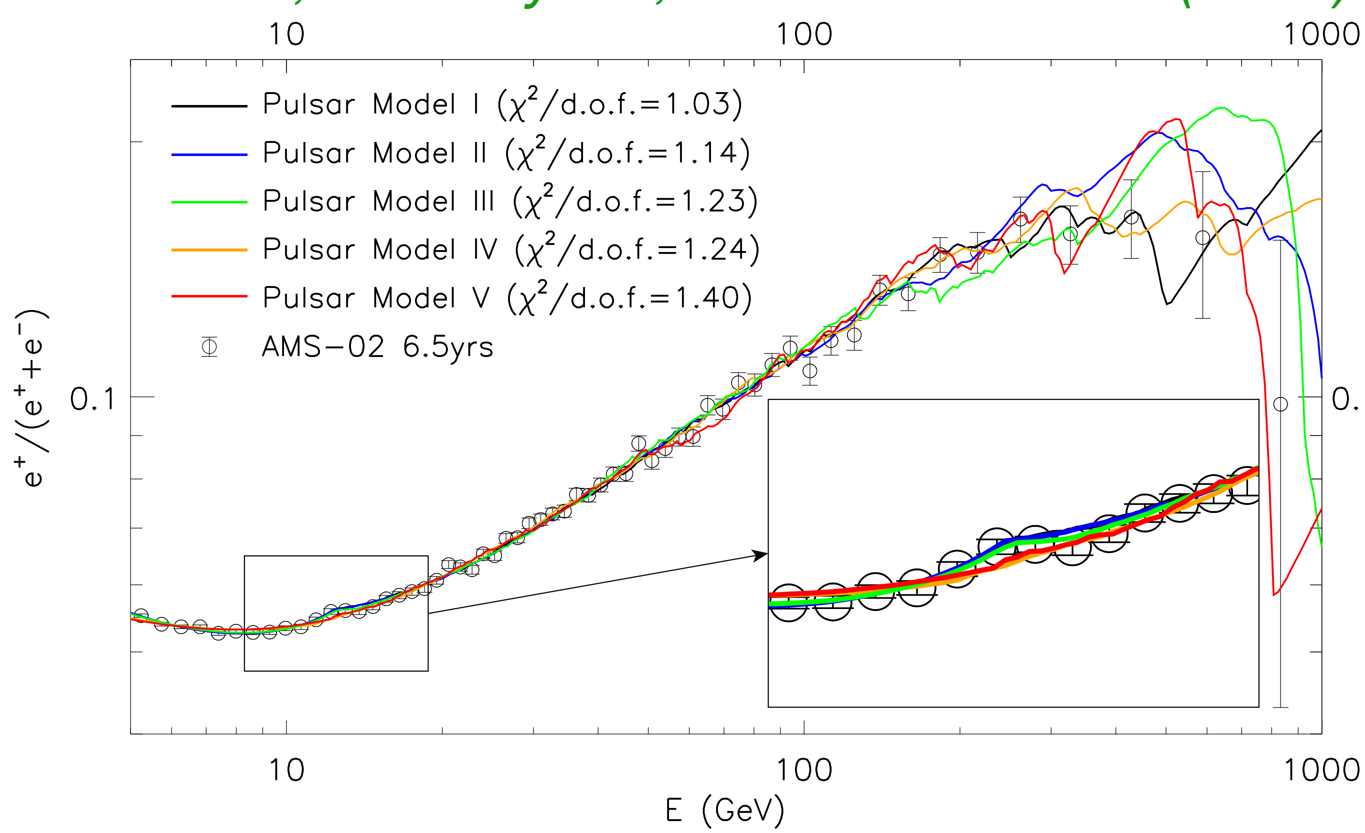




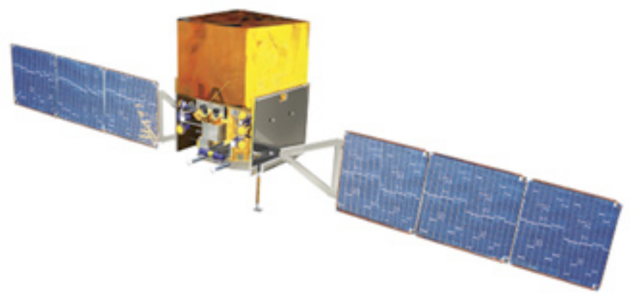
AMS-02

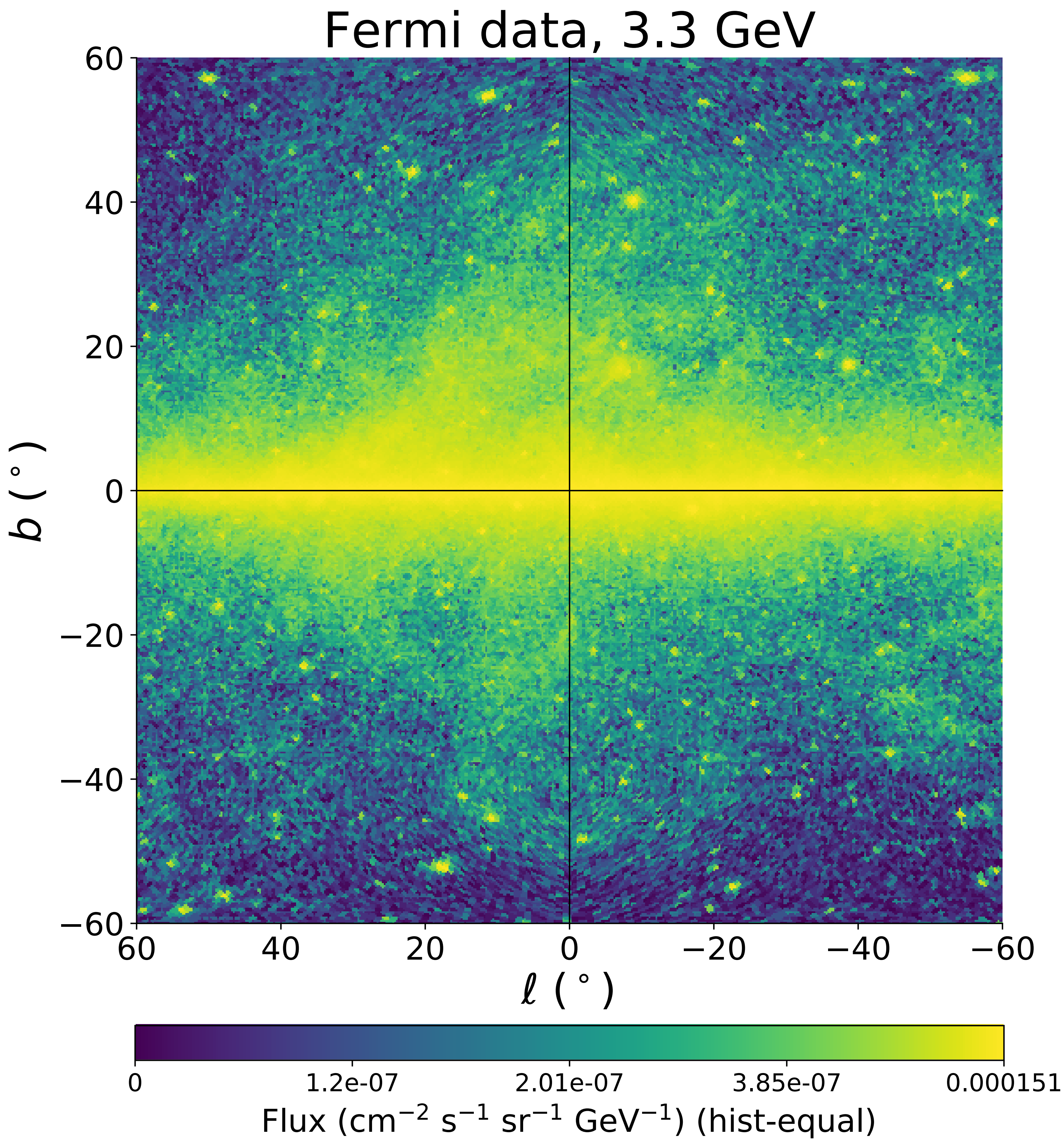
*Cholis, Krommydas, PRD **105** 023015 (2022)*

While pulsars are not the only source of cosmic-ray electrons and positrons, adding their contribution we can test various hypotheses on the properties of Milky Way pulsars using the recently released (2017-2021) cosmic-ray energy spectral measurements.



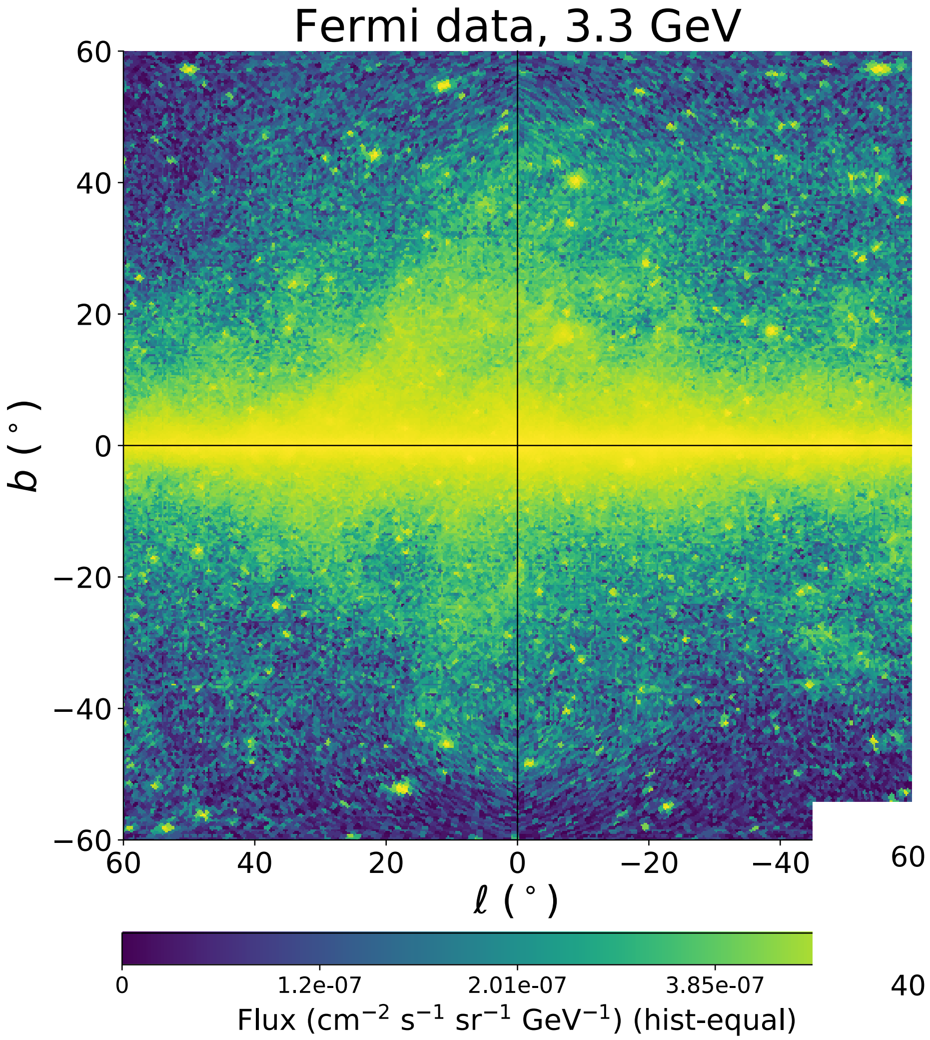
Using the Fermi Data





Using the Fermi Data

collection of ISM models



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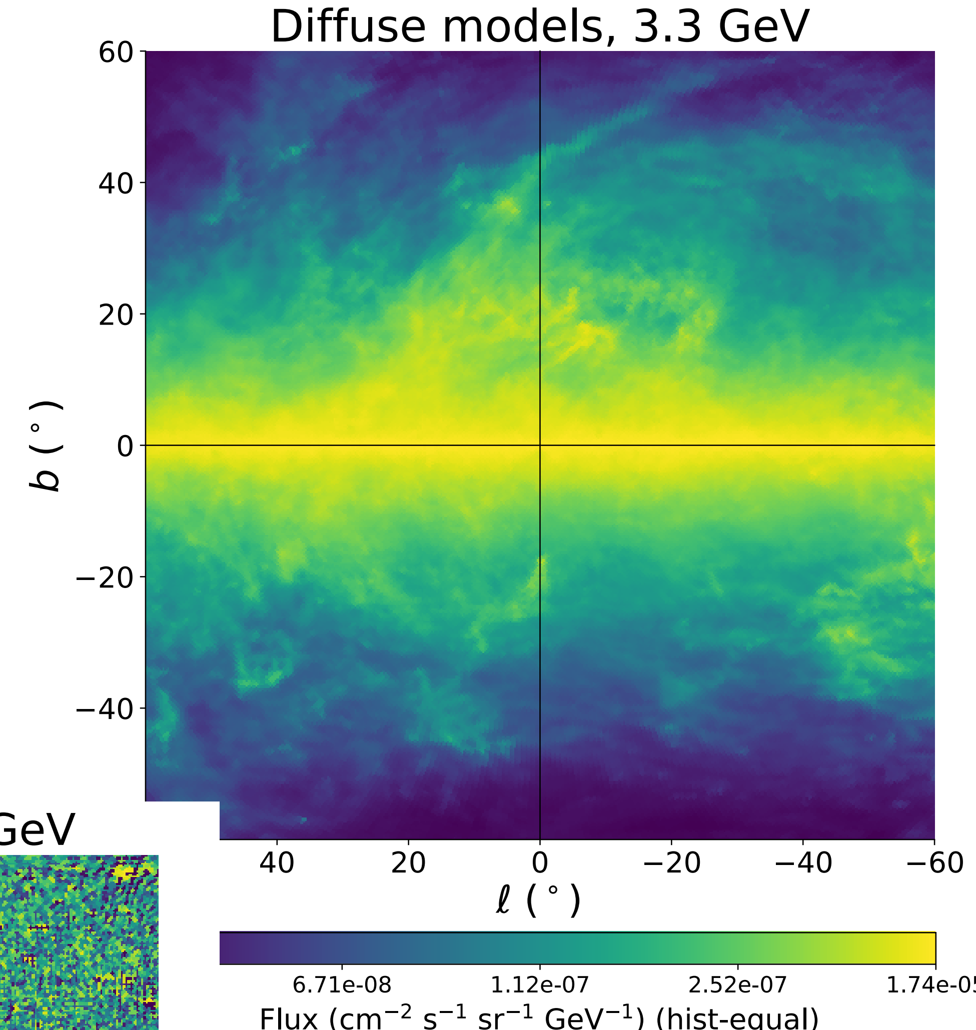
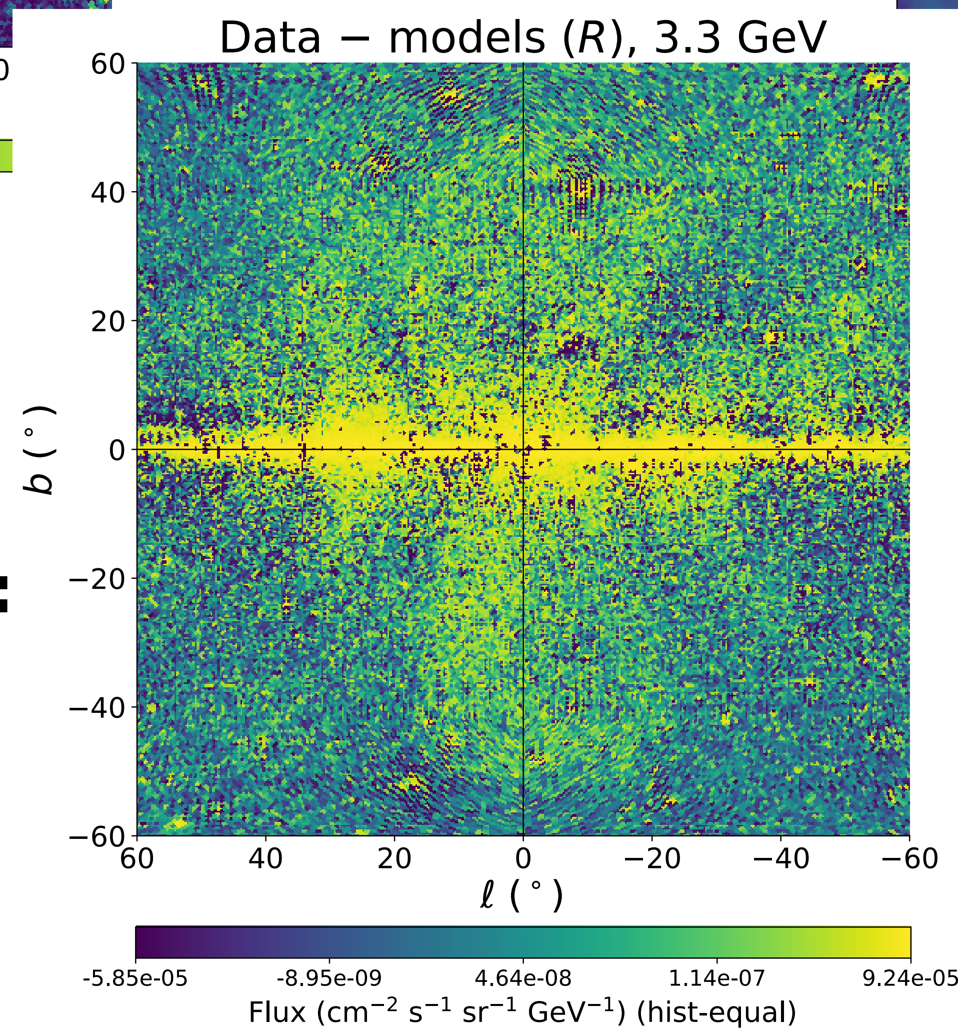
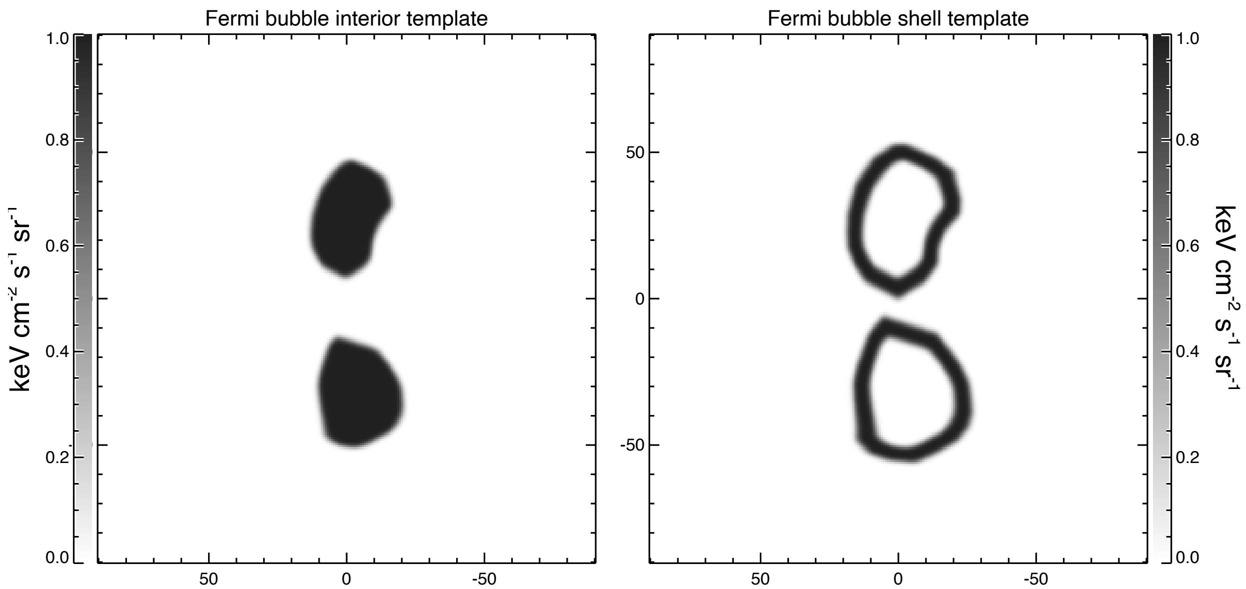


- point sources =

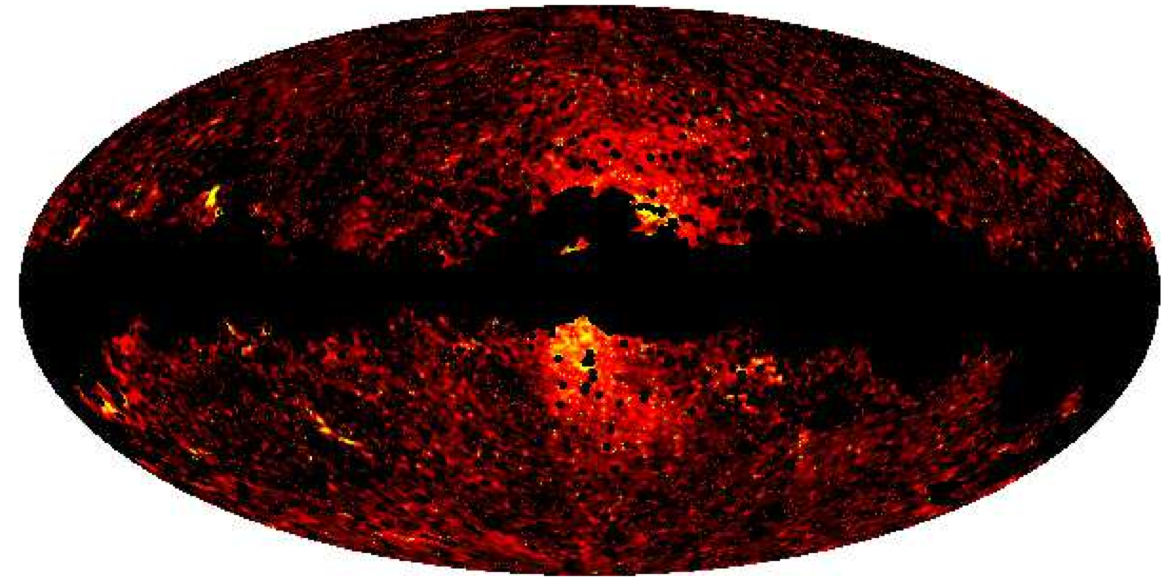


In gamma rays we have discovered the Fermi Bubbles

Su et al. ApJ 724, 1044 (2010)

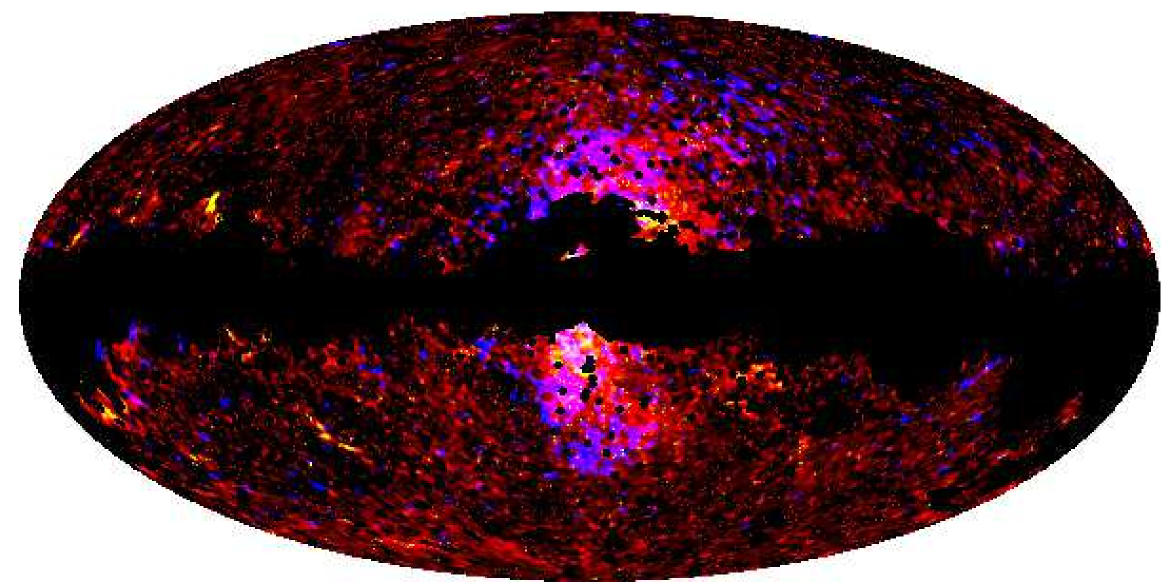


Planck intermediate results. IX. Detection of the Galactic haze with _Planck_



Discovery of edges on the emission.

Planck Coll. A&A 2013



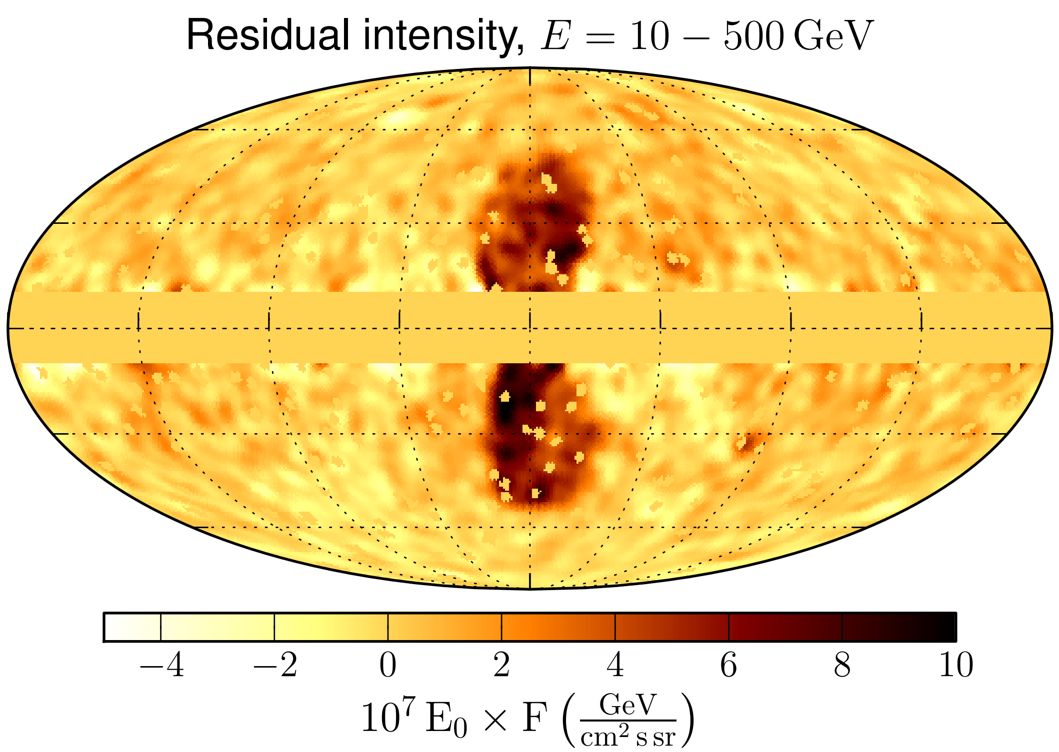
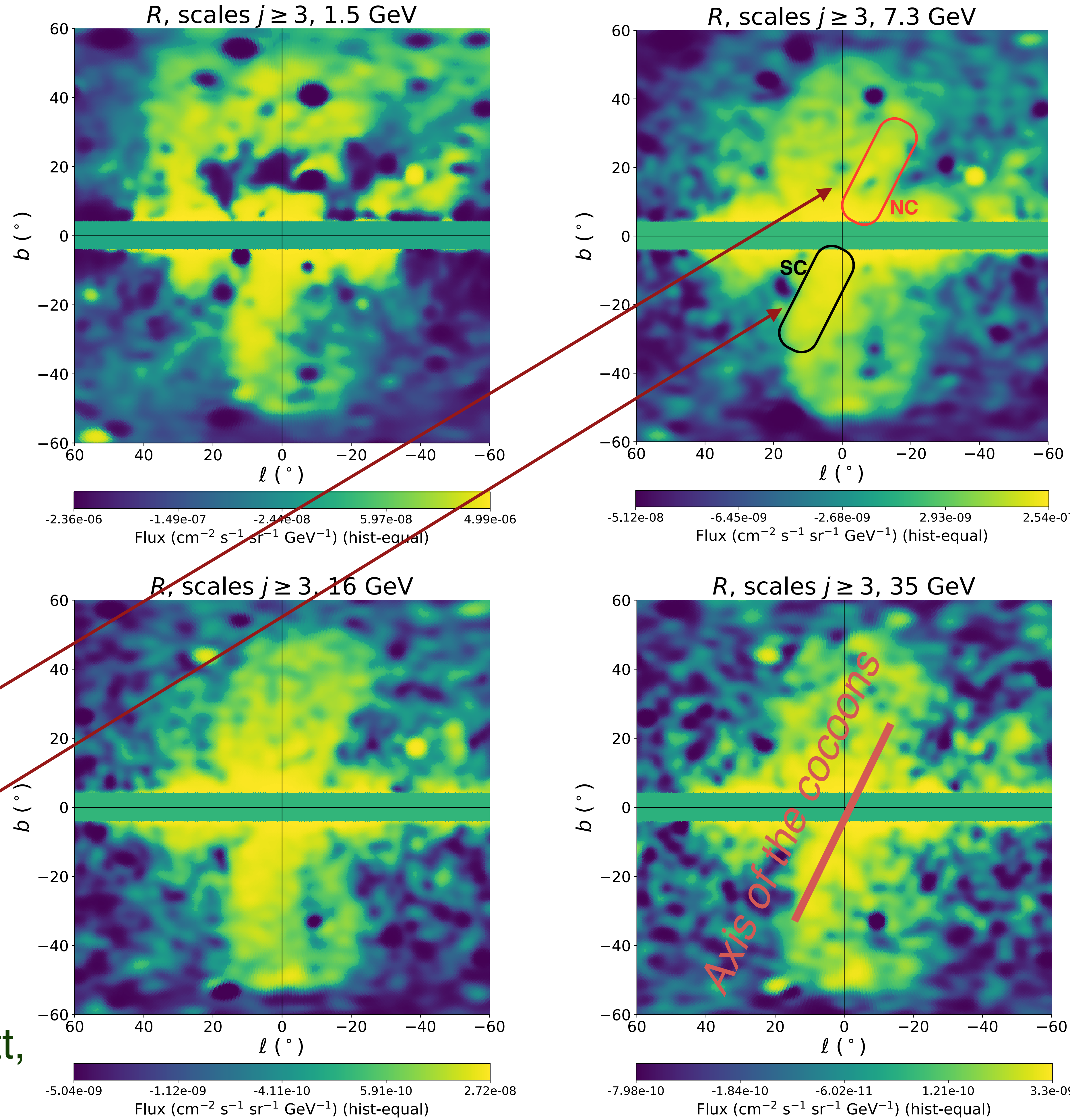


Fig. 9. *Top*: The microwave haze at *Planck* 30 GHz (red, $-12\,\mu$K < $\Delta T_{\rm CMB}$ < 30 μK) and 44 GHz (yellow, 12 μK < $\Delta T_{\rm CMB}$ < 40 μK). *Bottom*: The same but including the *Fermi* 2-5 GeV haze/bubbles of Dobler et al. (2010) (blue, 1.05 < intensity [keV cm^{-2} s^{-1} sr^{-1}] < 1.25; see their Fig. 11). The spatial correspondence between the two is excellent, particularly at low southern Galactic latitude, suggesting that this is a multi-wavelength view of the same underlying physical mechanism.

Fermi-LAT Collaboration Result ApJ 2014

Fermi Bubbles: (we clearly find them)

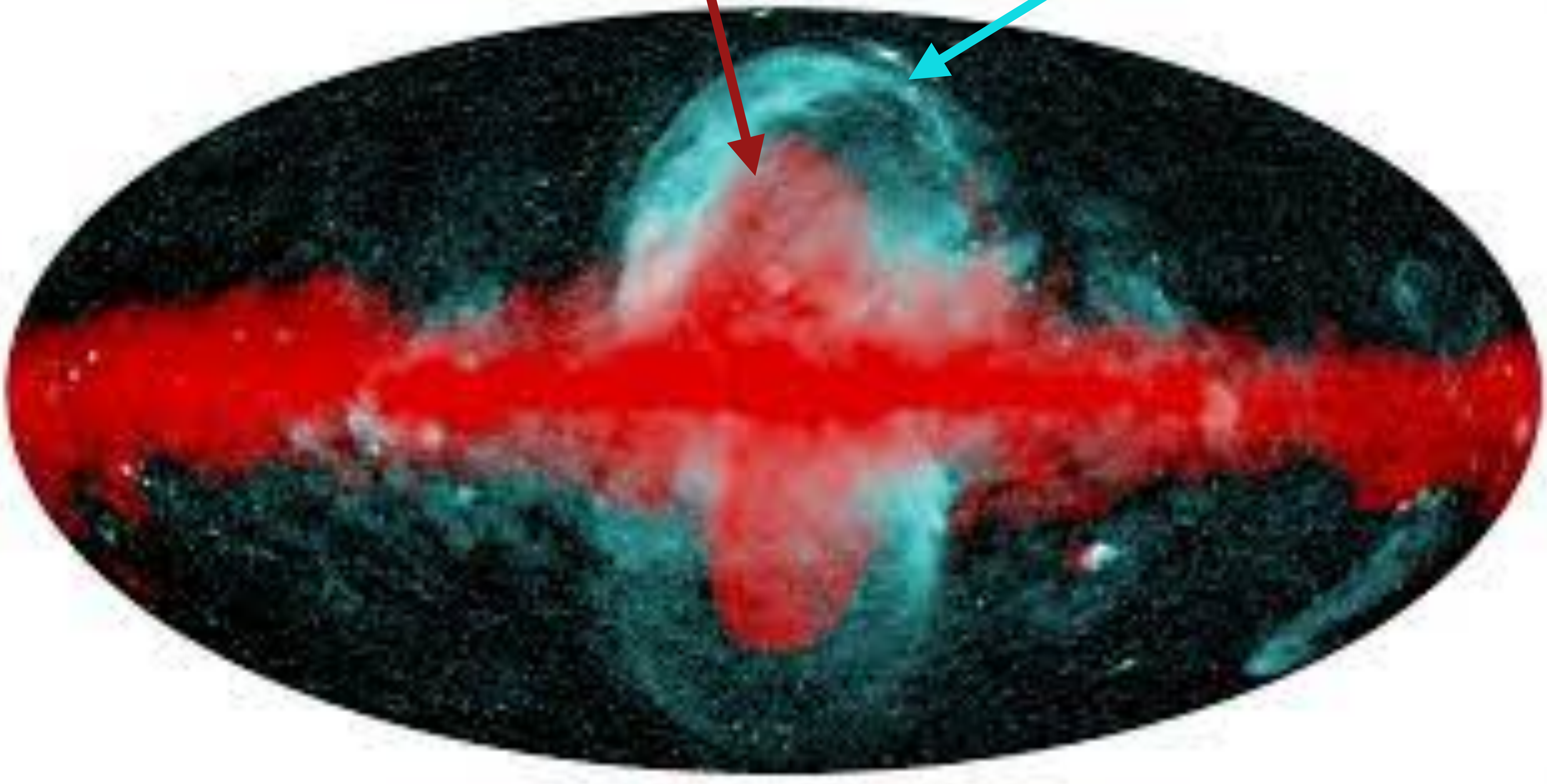


Northern cocoon

Southern cocoon

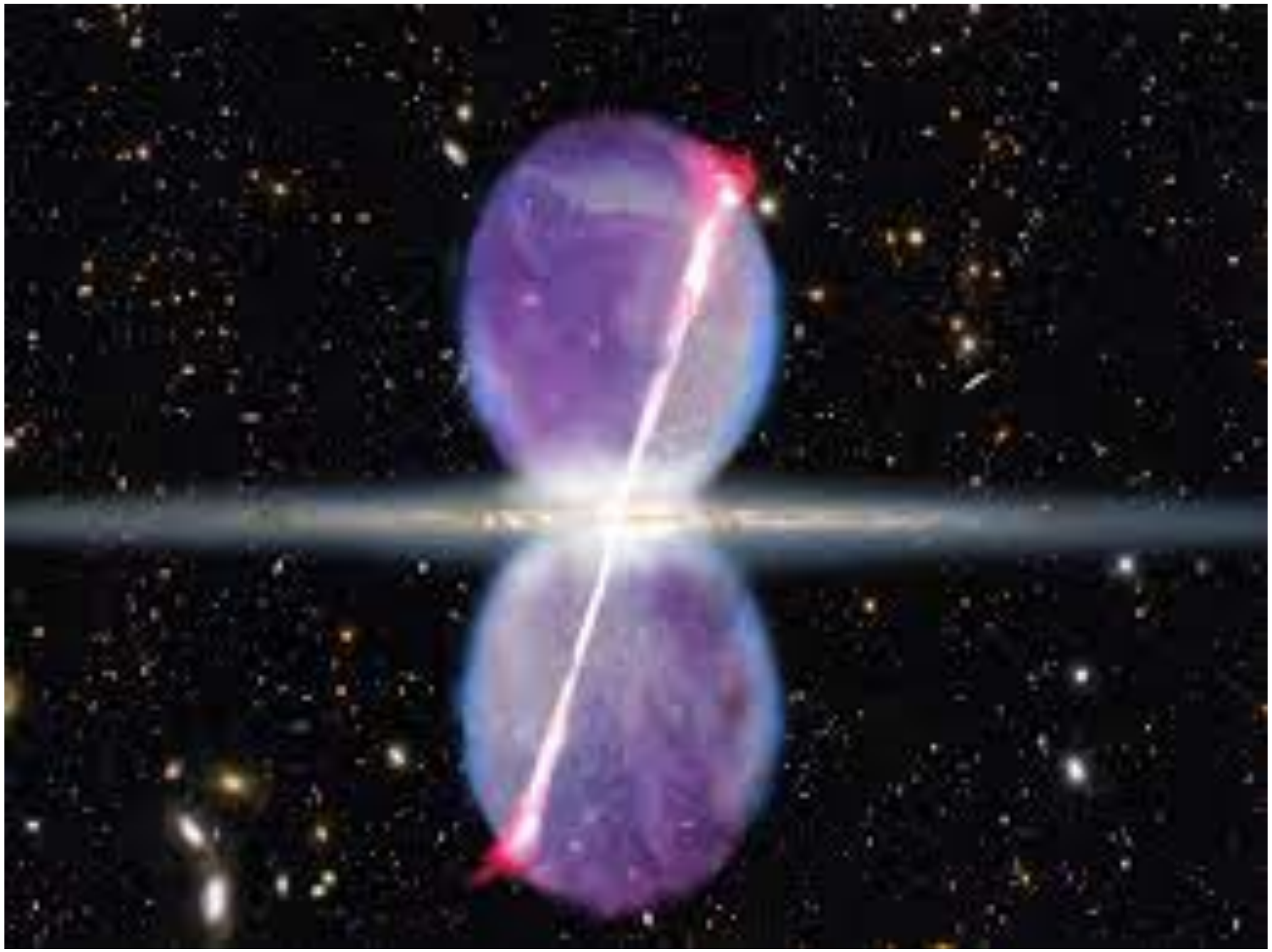
Balaji, **IC**, McDermott, Fox, PRD 2018

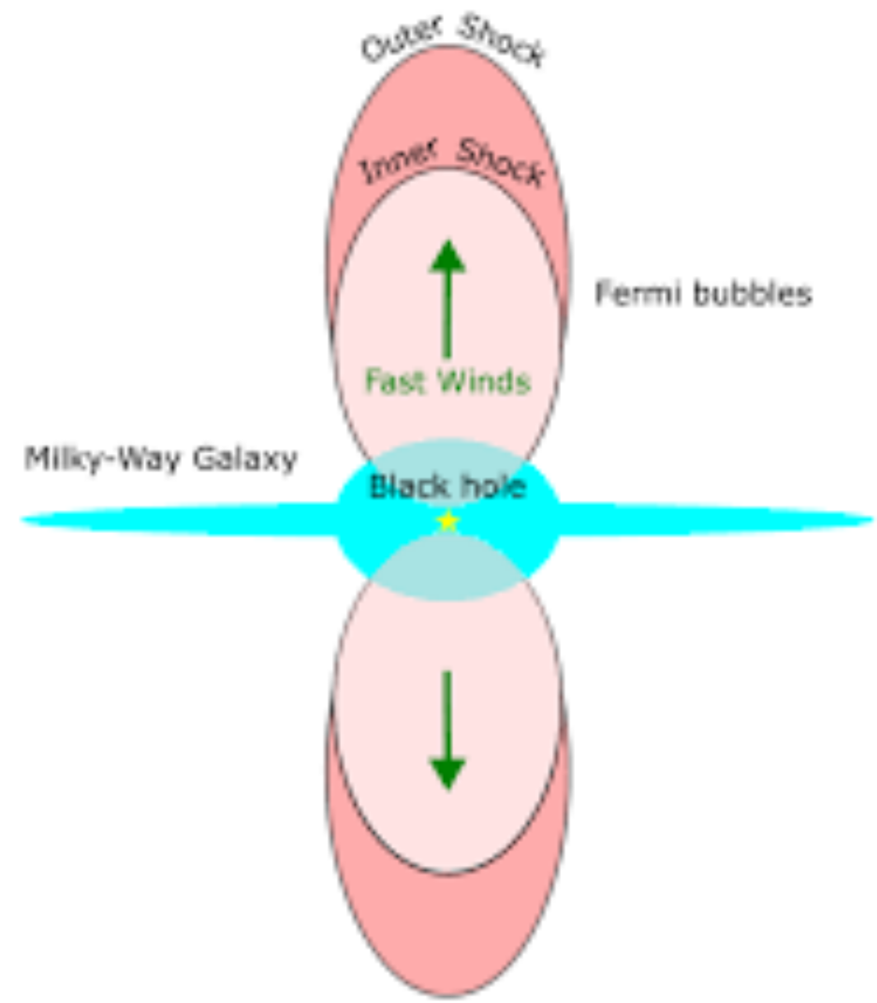
In addition to the Fermi Bubbles, in 2021 the e-ROSITA Bubbles at X rays were discovered



So what are those bubbles a signal of ?

They could be signals of EPISODIC bursts of cosmic-rays originating from the supermassive black hole at the center of our galaxy





…AND maybe the galactic center excess in GeV energy gamma rays is just the result a similar signal from the supermassive black hole.

Connecting to positrons

…the cosmic rays giving these gamma-ray, X-ray and microwave signals would either be protons OR electrons + positrons.

If the Fermi Bubbles are produced by cosmic-ray electrons + positrons, then we can estimate

i) the age of the Fermi Bubbles burst event to be ~5 Myr old. The e-ROSITA signal would come from an older burst event.
ii) the energy output of the Fermi Bubbles to be $10^{56} - 10^{57}$erg. The e-ROSITA energy output is highly uncertain.

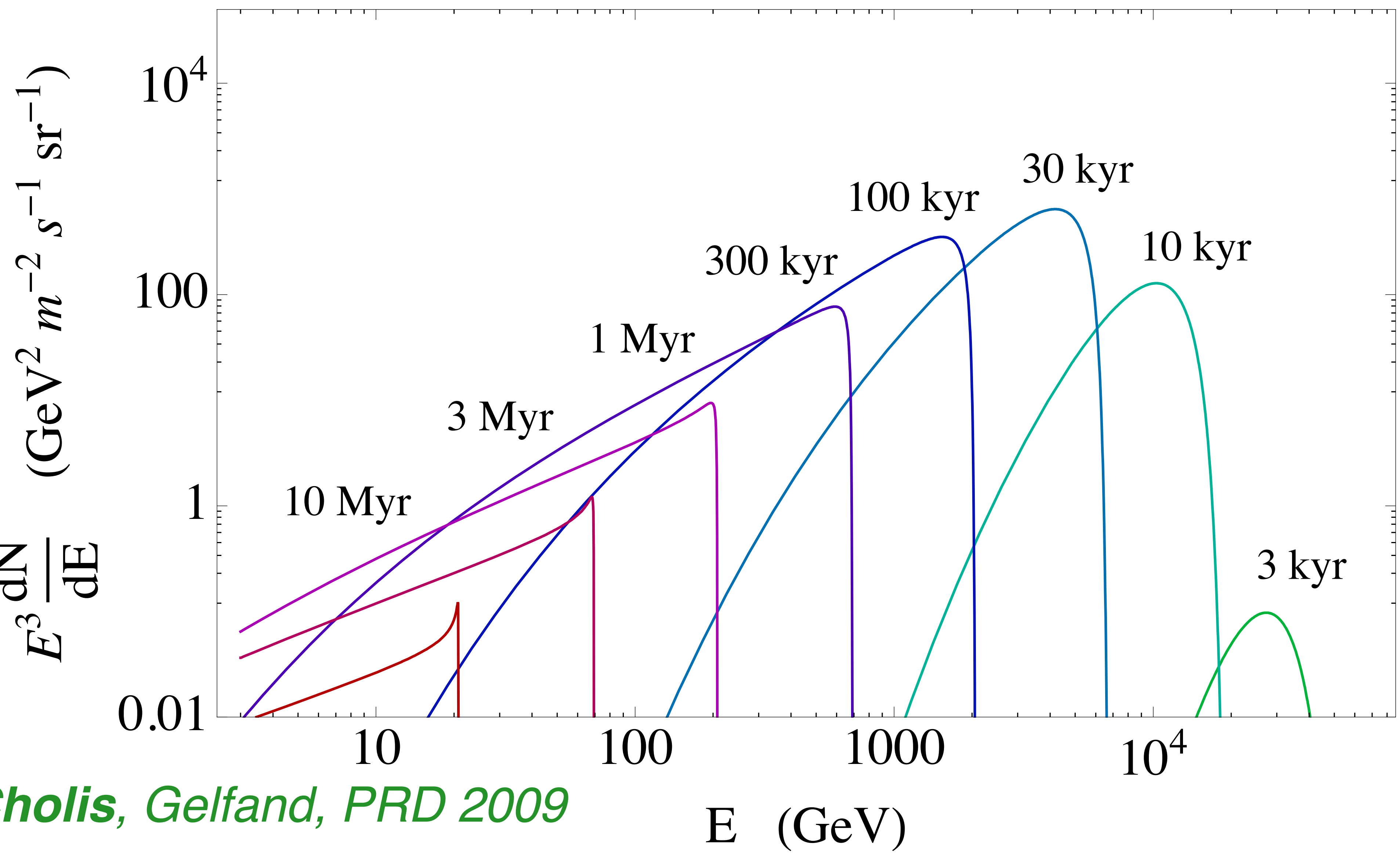
Most of those positrons propagate perpendicular to the disk. However, some fraction will end up propagating along the galactic disk. The highest energy positrons would be reaching us (at the Sun) about now….

Modeling the cosmic ray flux from a burst of positrons, originating from pulsars or from the supermassive black hole

Assuming the injection time is much smaller than the propagation time

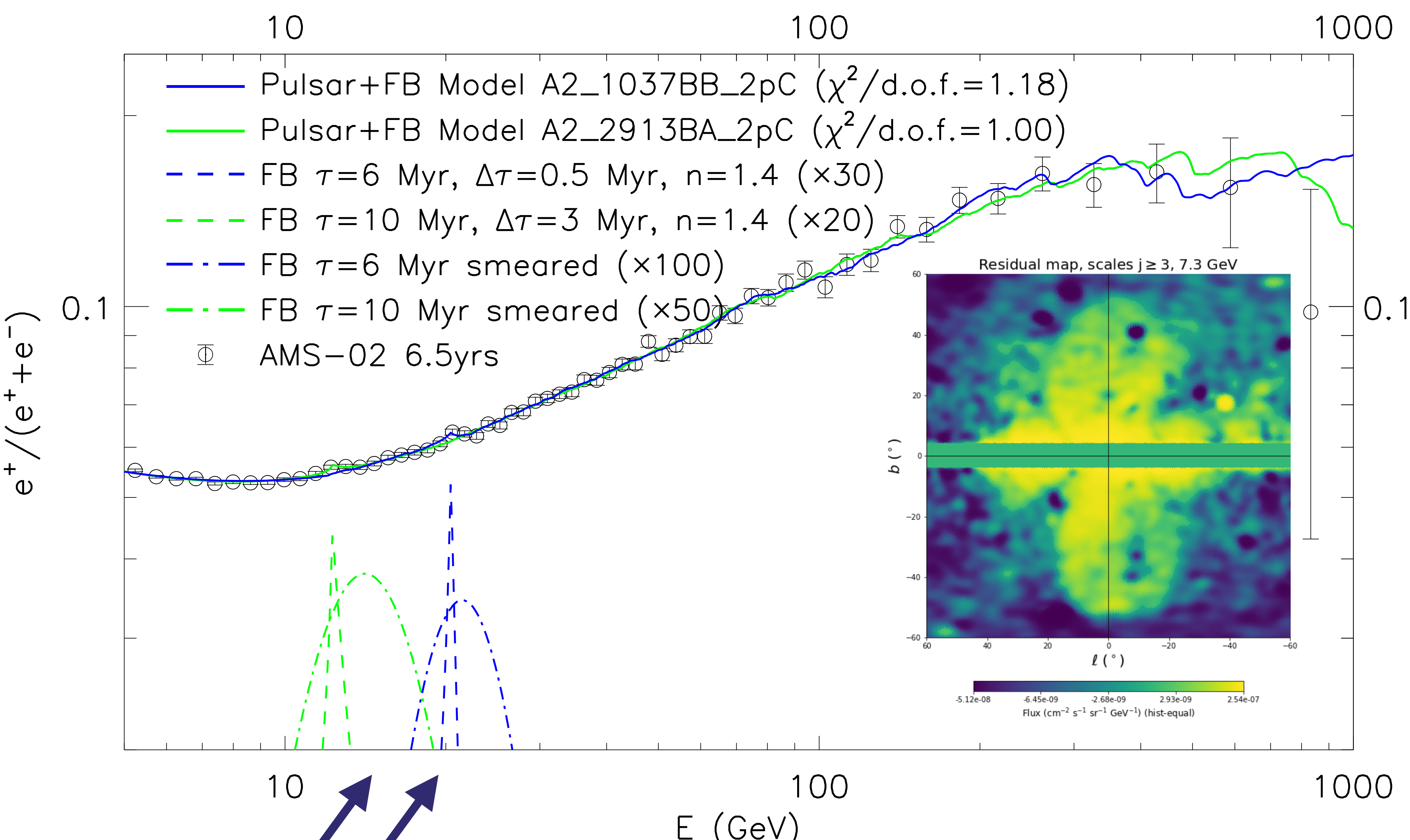
Assuming Time-bombs of Cosmic-Rays

For a Milky Way source the cosmic-ray positron flux evolution with time



*Malyshev, **Cholis**, Gelfand, PRD 2009*

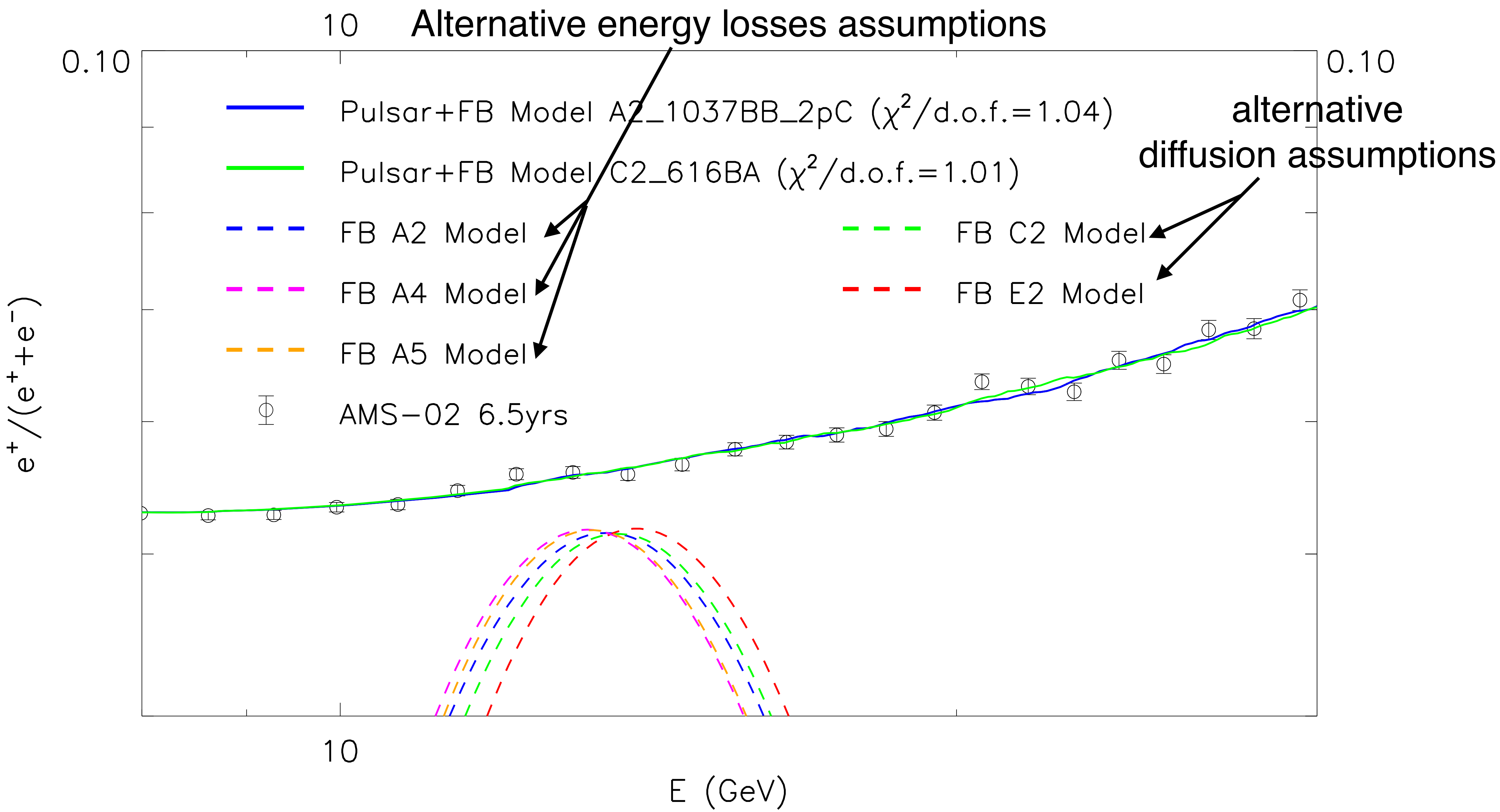
A cosmic-ray burst event from the center of the galaxy can give tiny spectral features at 10-30 GeV positron energies:



Cholis , Krommydas arXiv:2208.07880 (ApJ 2023)

Fermi and/or e-ROSITA Bubbles counterpart signal in positrons?

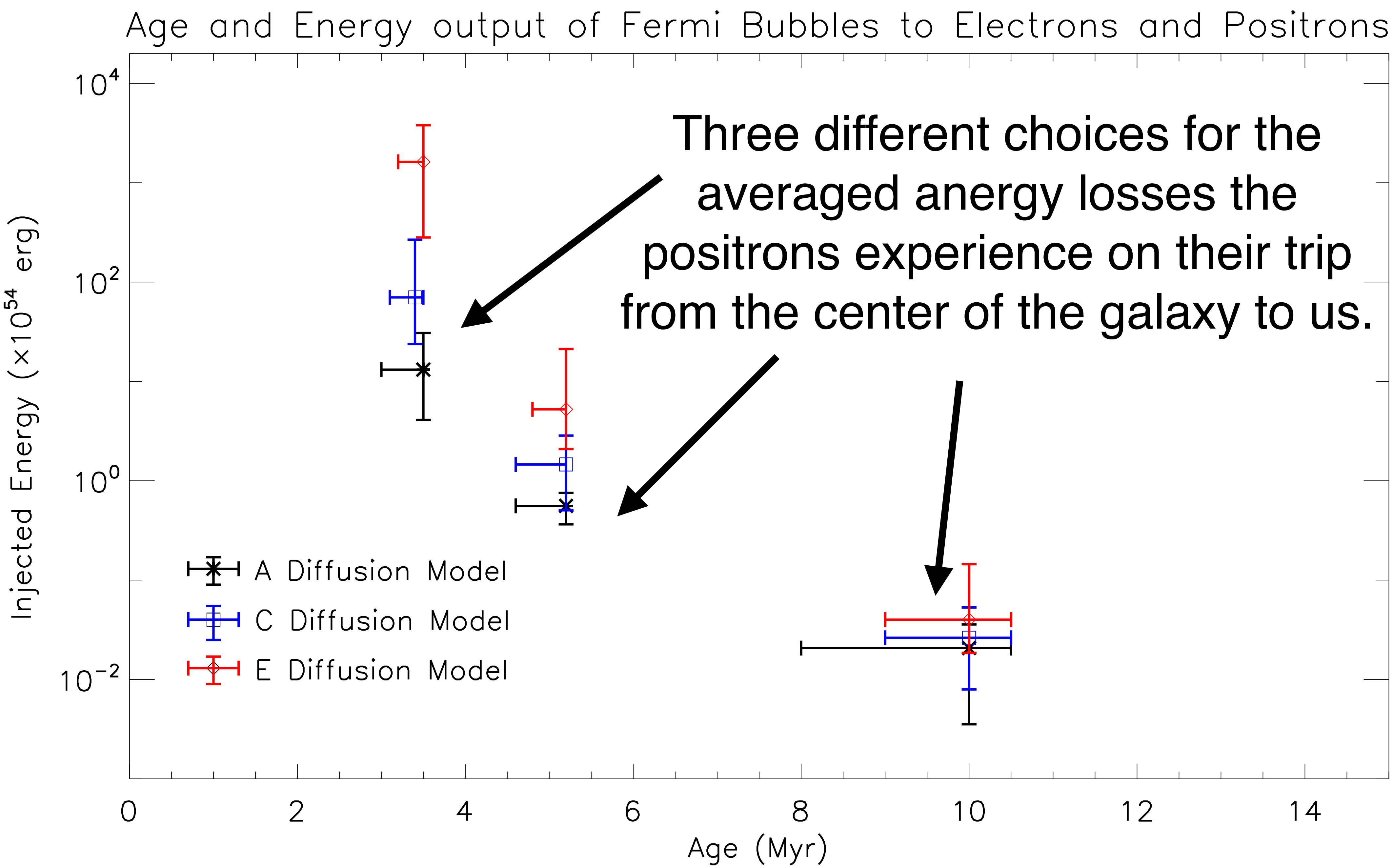
The impact of ISM assumptions on the propagation of cosmic-rays



Cholis , Krommydas arXiv:2208.07880 (ApJ 2023)

DO these positron features have the right properties to be related to the Fermi Bubbles?

…within the uncertainties **YES**. Typically a small fraction of the total energy of the original burst event leaks to positrons that reach us.



Cholis , Krommydas arXiv:2208.07880 (ApJ 2023)

Thank you

Acknowledgements

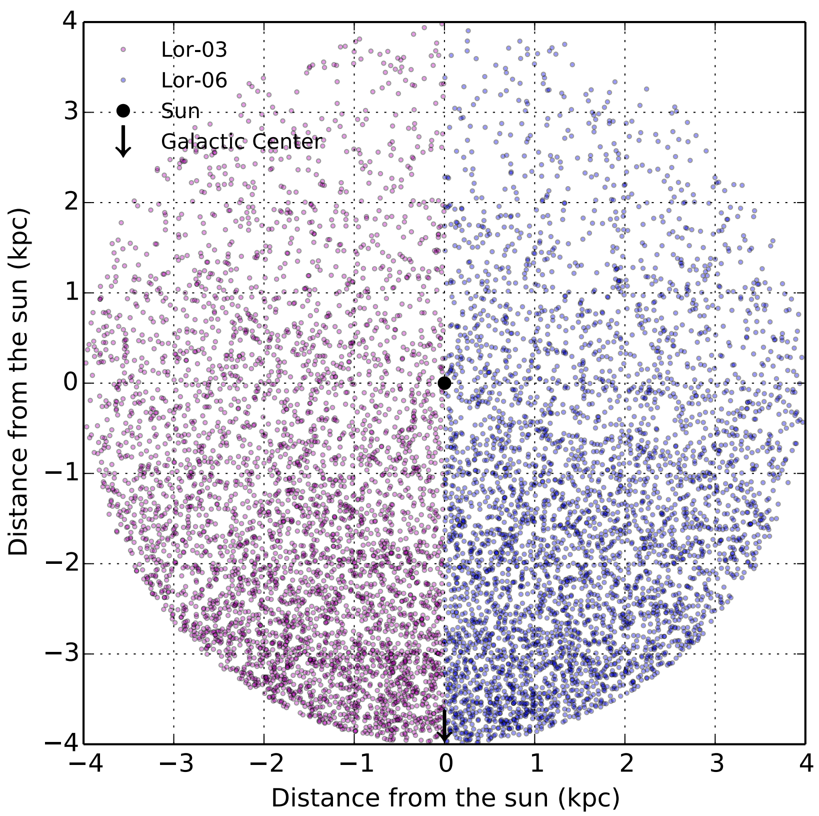
MSGC, NASA No. NNX15AJ20H
MSGC, NASA No. 80NSSC20M0124

Office of High Energy Physics

DE-SC0022352

Additional Slides

Including uncertainties on the Pulsar Properties

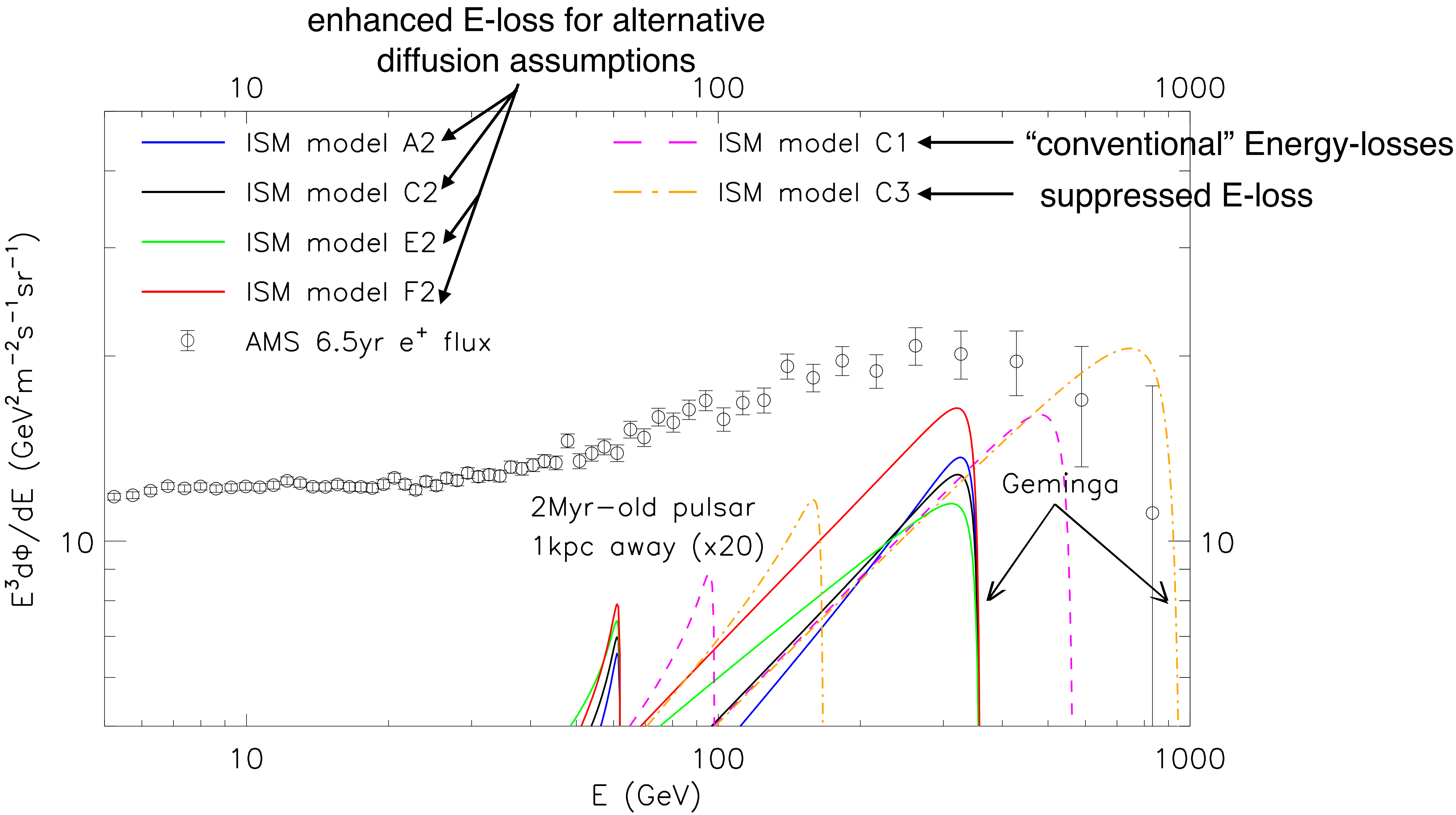


One has to include all uncertainties, pertaining to

- The Neutron Stars distribution in space
- The initial conditions of the Neutron Stars (as a distribution of properties) in terms of their initial spin-down power
- The uncertainties on their time evolution, i.e. κ & τ_0
- How many cosmic-ray electrons and positrons they produce/inject into the interstellar medium and with what spectrum
- How these electrons/positrons propagate from there to us (ISM physics & Heliospheric Physics)

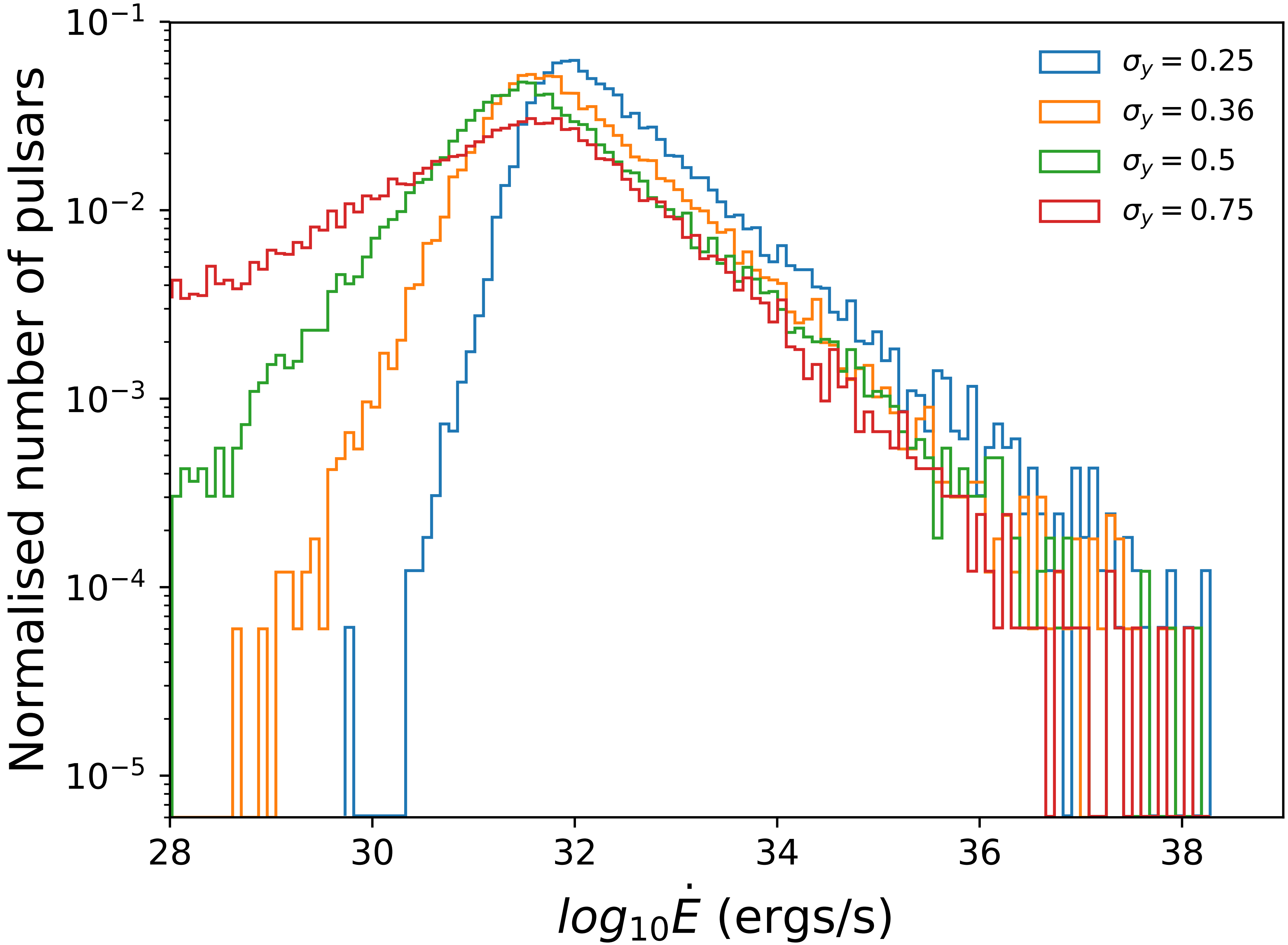
We have produced over 7K unique Milky-Way pulsar simulations. Each simulation contains anywhere between 5K to 18K unique pulsars within 4 kpc from the Sun.

The impact of ISM assumptions on the propagation of cosmic-rays



*Cholis, Krommydas, PRD **105** 023015 (2022)*

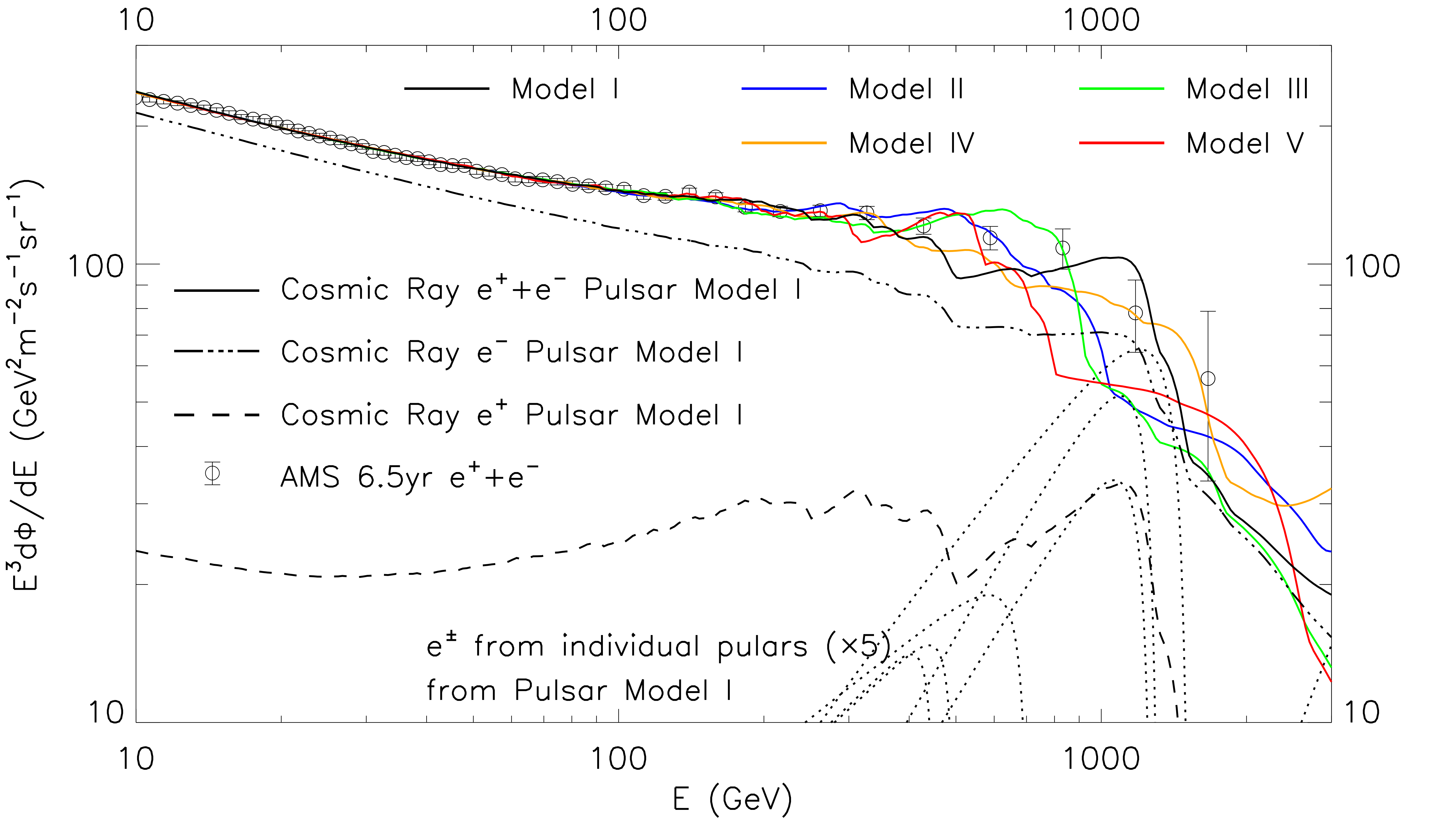
Alternative assumptions on the (i.e. observable) luminosity of pulsars



*Cholis, Karwal, Kamionkowski, PRD **98** 063008 (2018)*

Total Lepton Flux from AMS-02:

*Cholis, Krommydas, PRD **105** 023015 (2022)*



*ALSO relied on work: Cholis, McKinnon, PRD **106** 063021 (2022), to model the impact of the solar wind..*

Total Lepton Flux from DAMPE (probing the youngest pulsars):