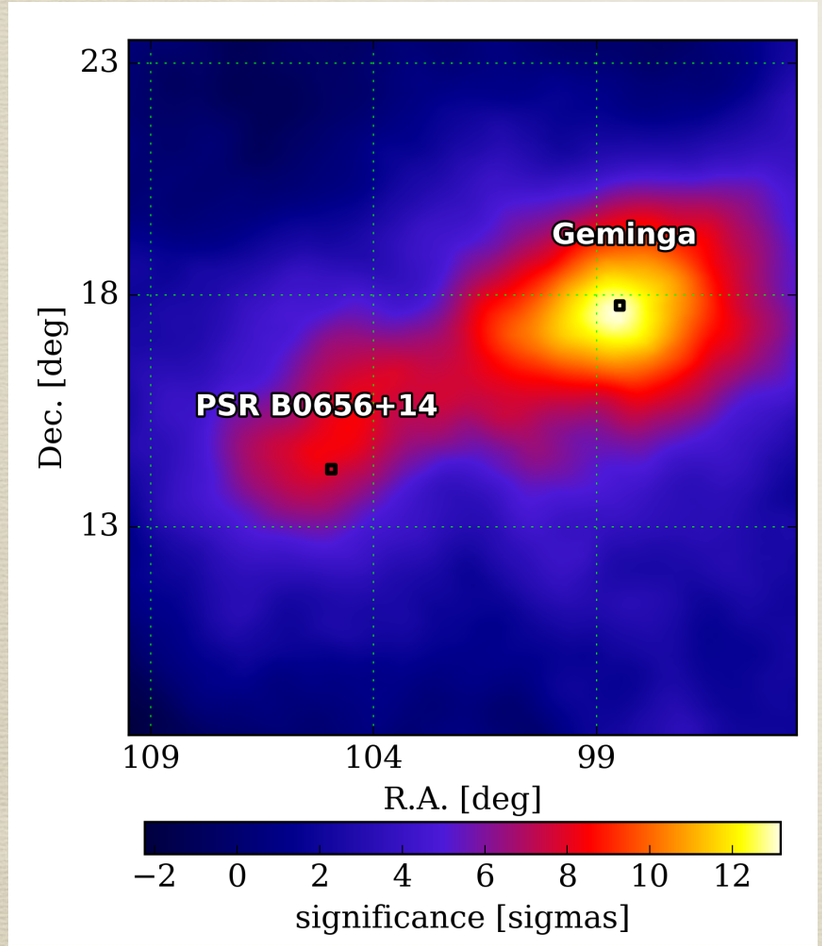
An undiscovered pulsar as the origin of the cosmic ray all-electron spectrum

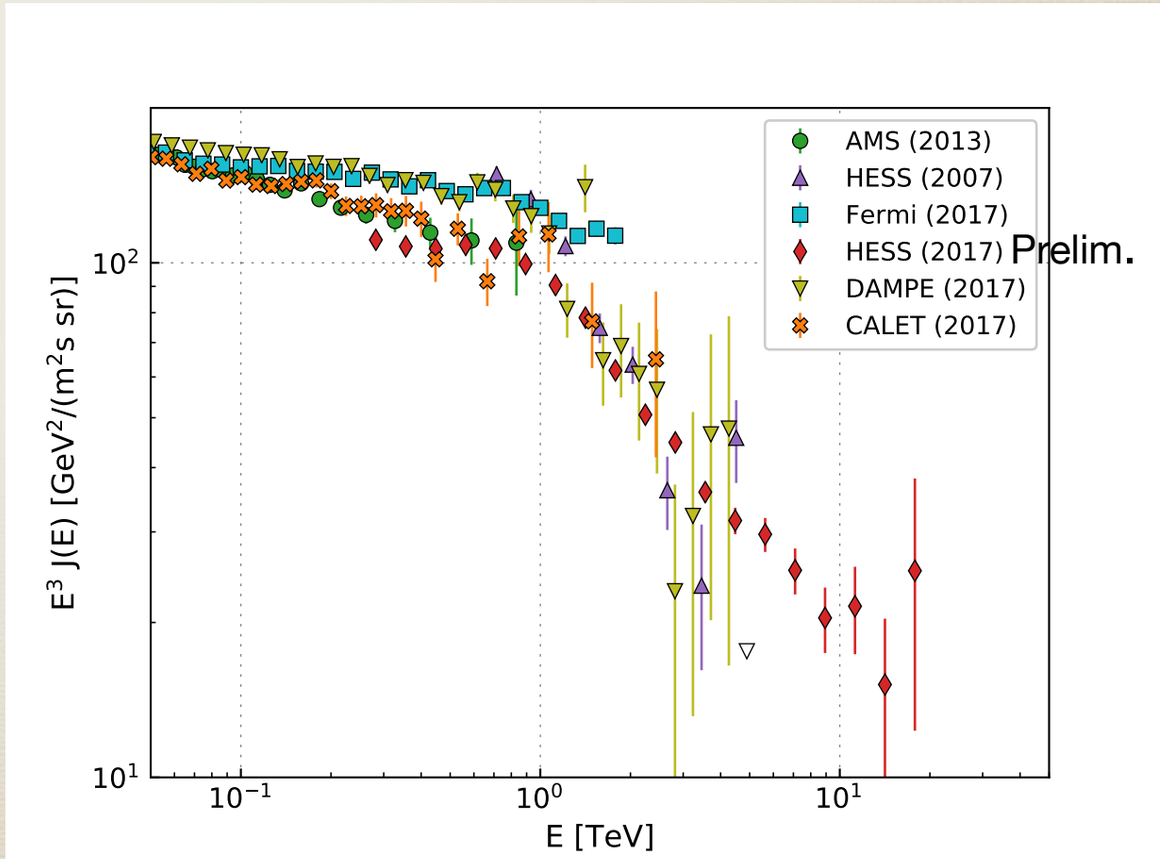
Rubén López-Coto[1], D. Parsons[2], J. Hinton[2], G. Giacinti[2]
[1]Istituto Nazionale di Fisica Nucleare, Sezione di Padova
[2]Max Planck Institut für Kernphysik, Heidelberg, Germany
29/07/19

Funded by H2020 Marie Sklodowska Curie FELLINI - Grant 754496

Recent results on all-electron propagation

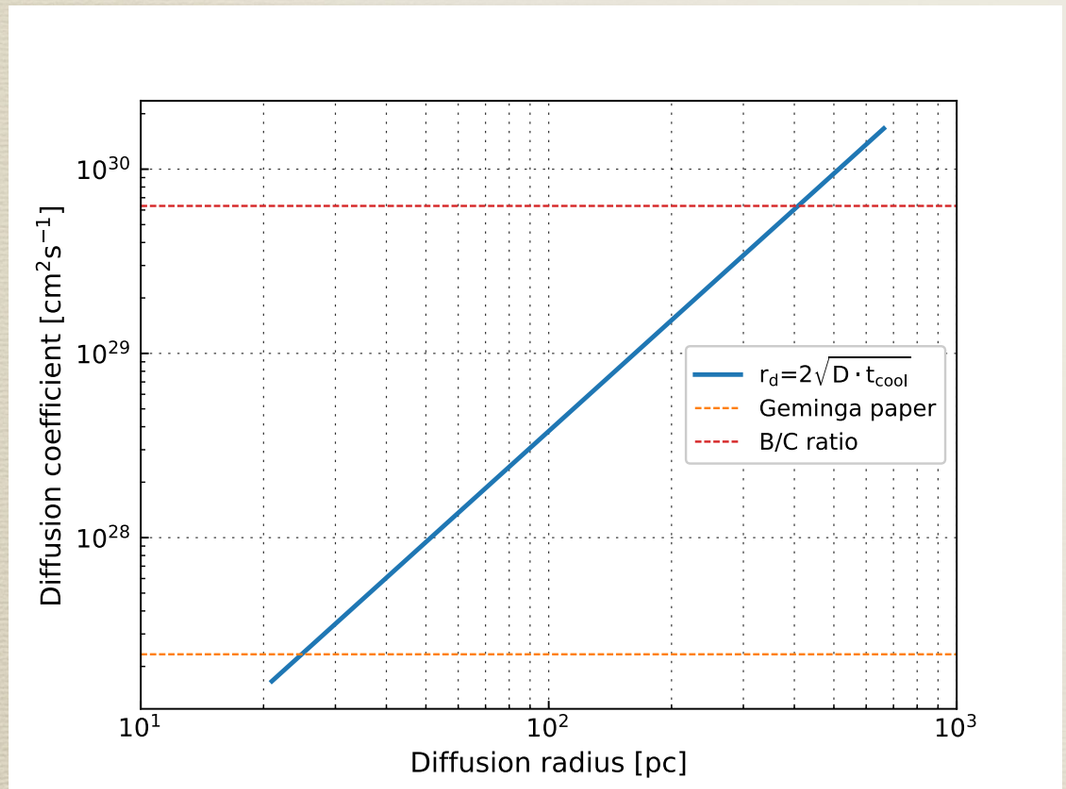
- Measurement by HAWC of a diffusion coefficient two orders of magnitude lower than averages of the ISM around Geminga and Monogem
- Featureless power-law spectrum in the all-electron spectrum measured by HESS between 1-20 TeV with ~3.8 spectral index

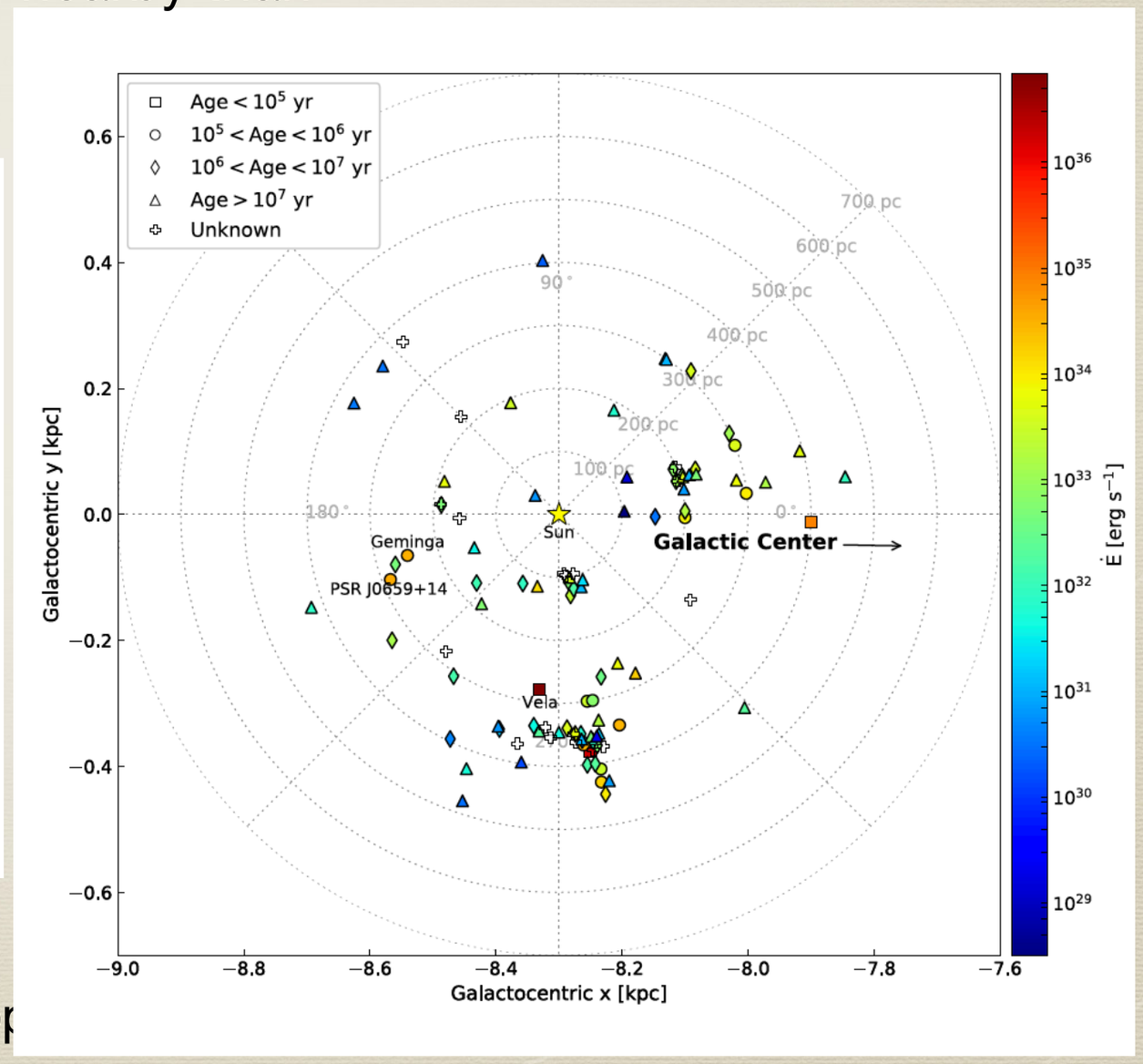




Can pulsars still explain the positron excess?

The diffusion radius,
assuming HAWC's diffusion,
should be ~25 pc ——————> more nearby than
any known pulsar





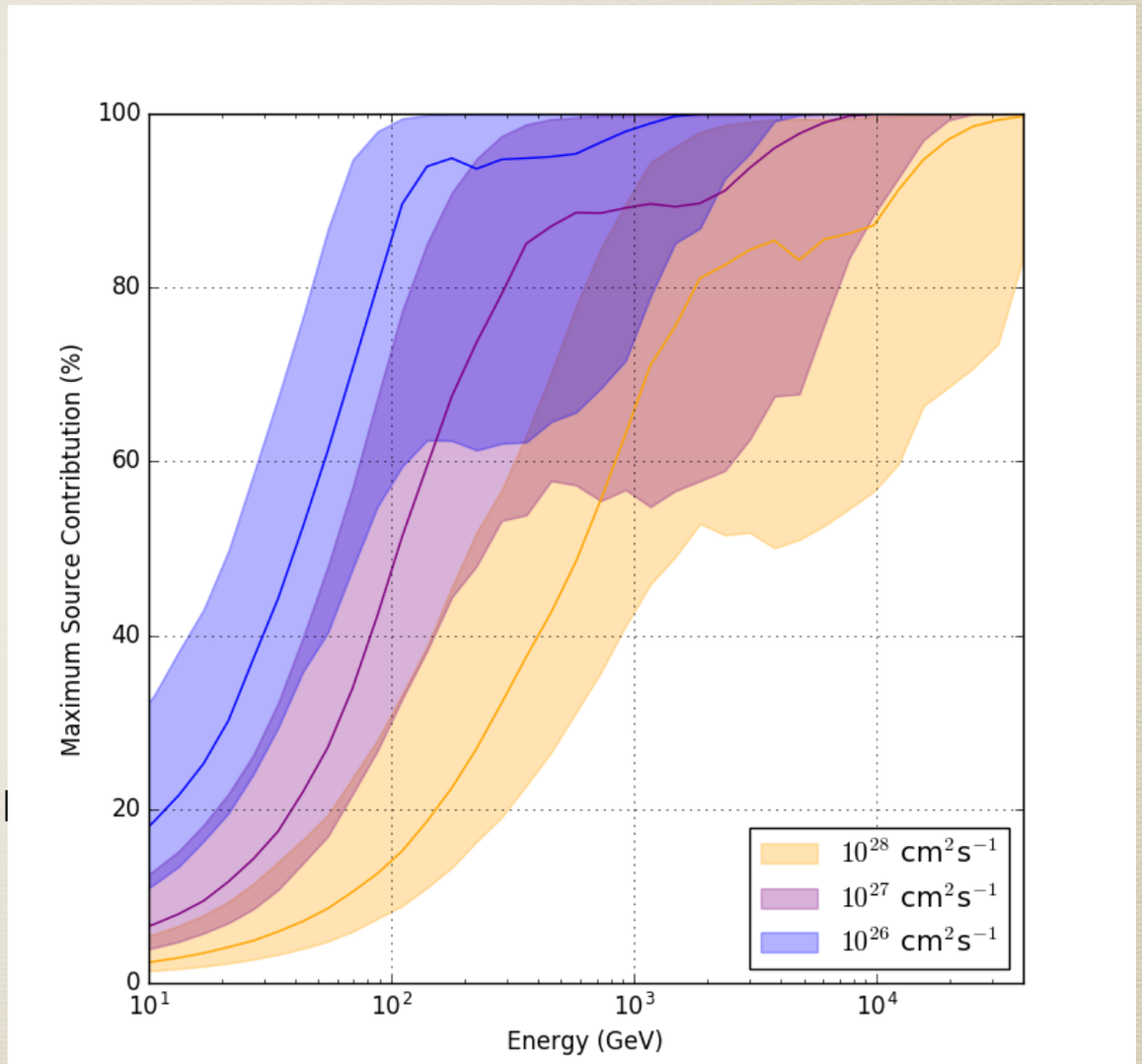
Rubén Lóp

How many pulsars?

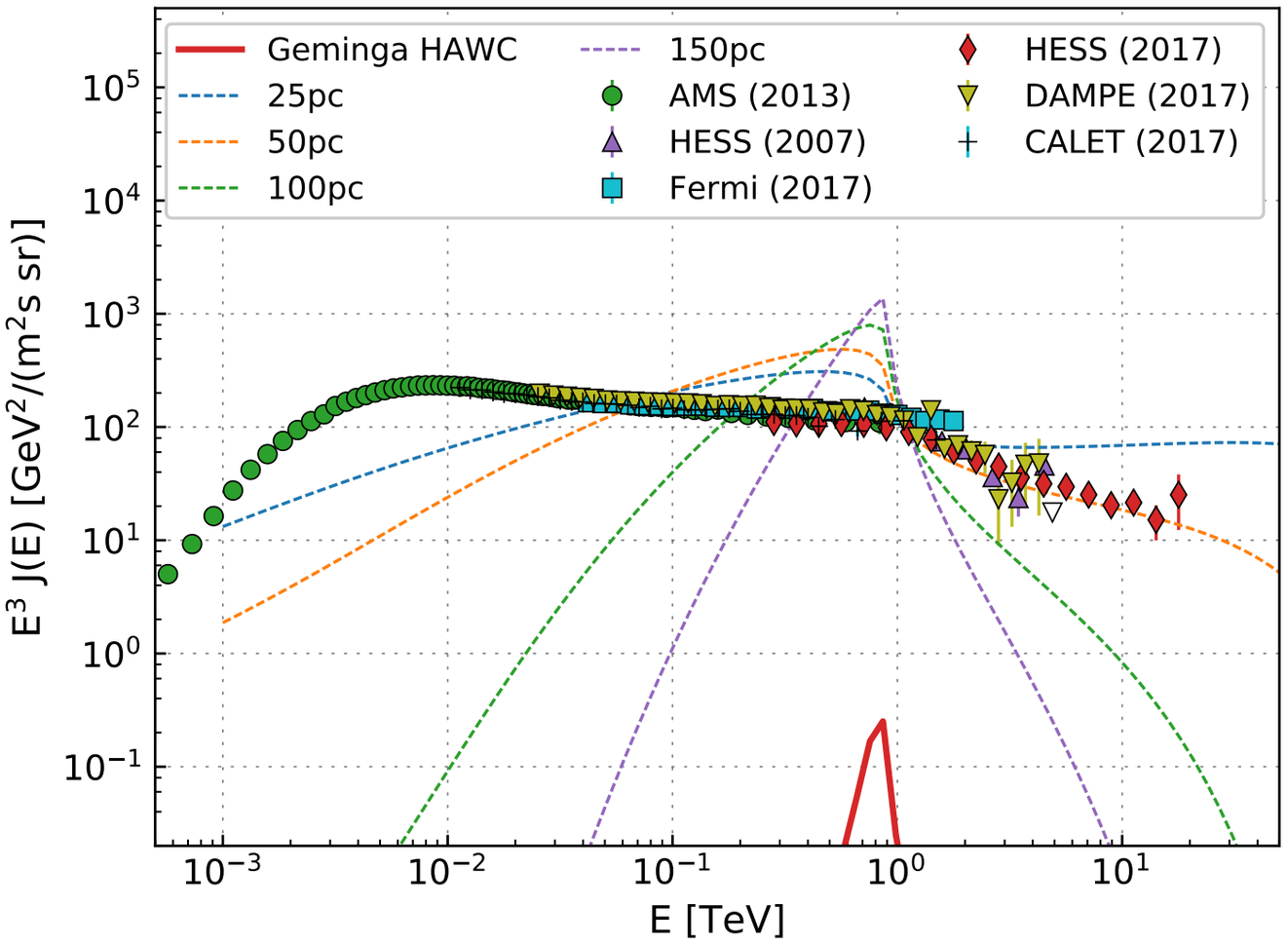
• Pulsars would need to have very particular characteristics to accelerate electrons and significantly contribute to the local all-electron spectrum up to 20 TeV.

• Simulations of pulsars in the Milky Way distributed into spiral arms.
-> Calculate the maximum contribution of a single source

• The maximum contribution of a single pulsar for low diffusion coefficient is almost certain fo E > 1 TeV



All-electron flux (different distances)



Plot normalized at 1 TeV for different distances, same alpha

Important:

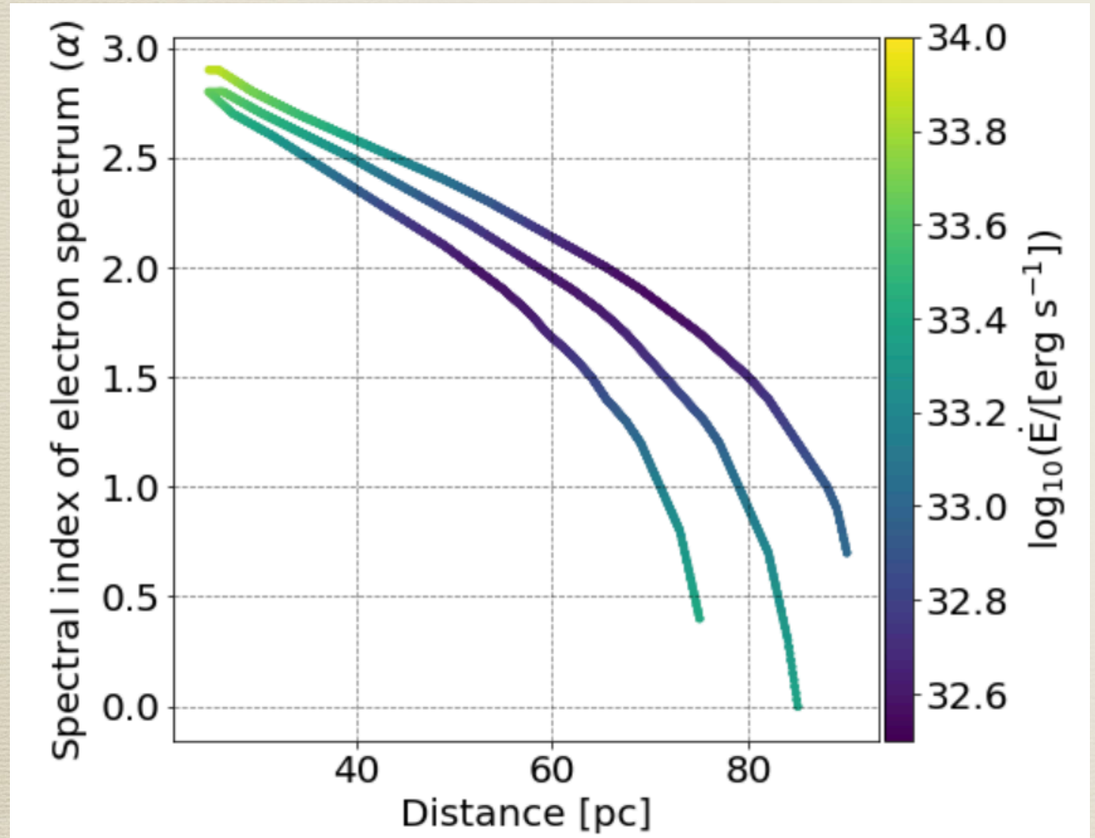
- reproduce the all-$e^{\pm}$ spectral index at E > 1 TeV (Γ=-3.78)
- Injection spectrum of electrons: $dN/dE = f_0 E^{-\alpha}$
- Diffusion coefficient $D(E) = D_0 E^{-\delta}$

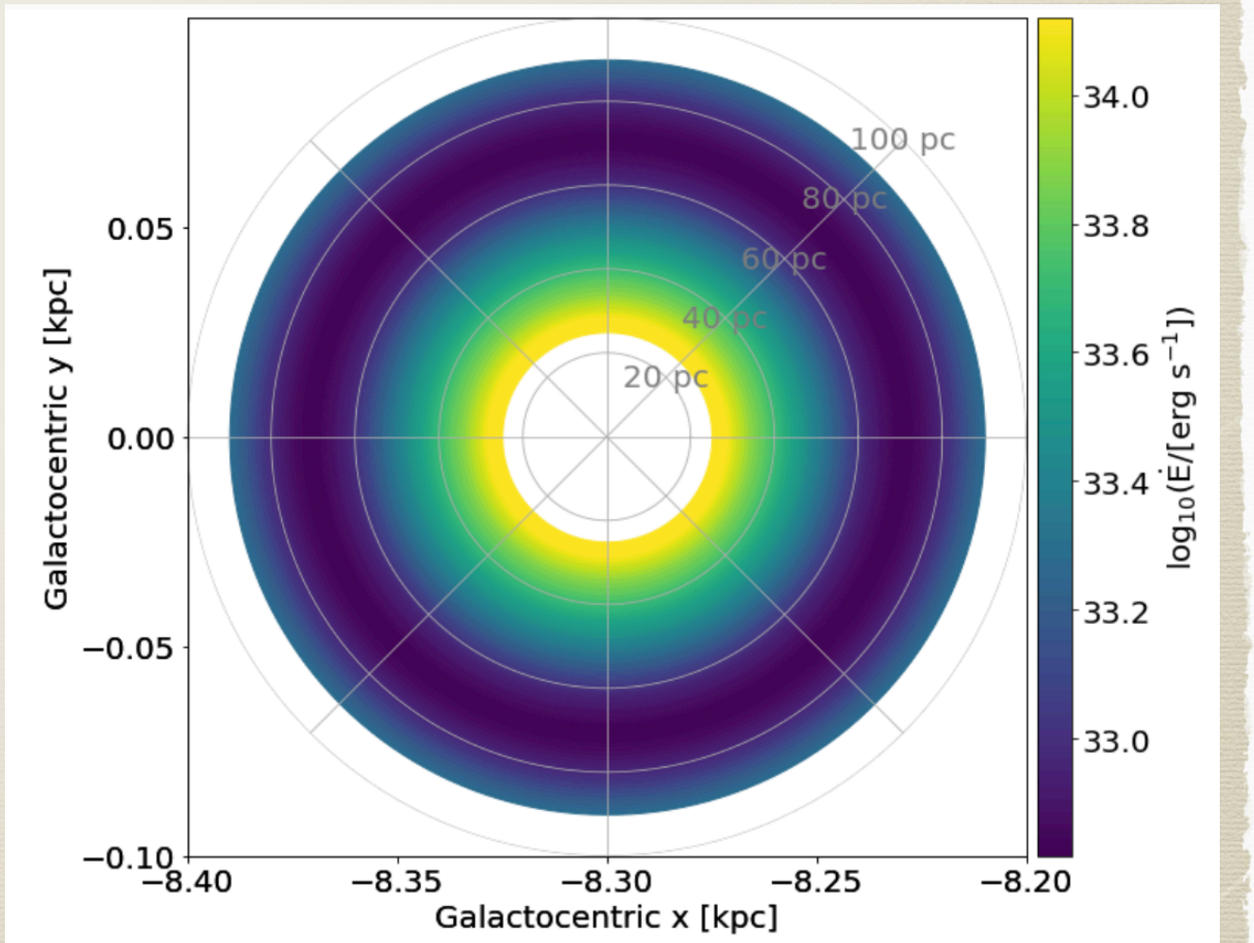
- fixing D (diff coeff), δ (diff index), the spectral index above 1 TeV depends on distance and α (spectral index of electrons)

- Finally, normalize (will give the spin-down power (**Edot)** of the pulsar)

Can pulsars still explain the positron excess?

- Fixing the diffusion coefficient, and delta, for each distance you get the spectral index of the injected electrons and normalize it with the spin-down power.
- Contrary to intuition, you need more power injected at the lowest energies (spectral index effect)





An undiscovered pulsar as an explanation

A pulsar located at < 90 pc would make it.

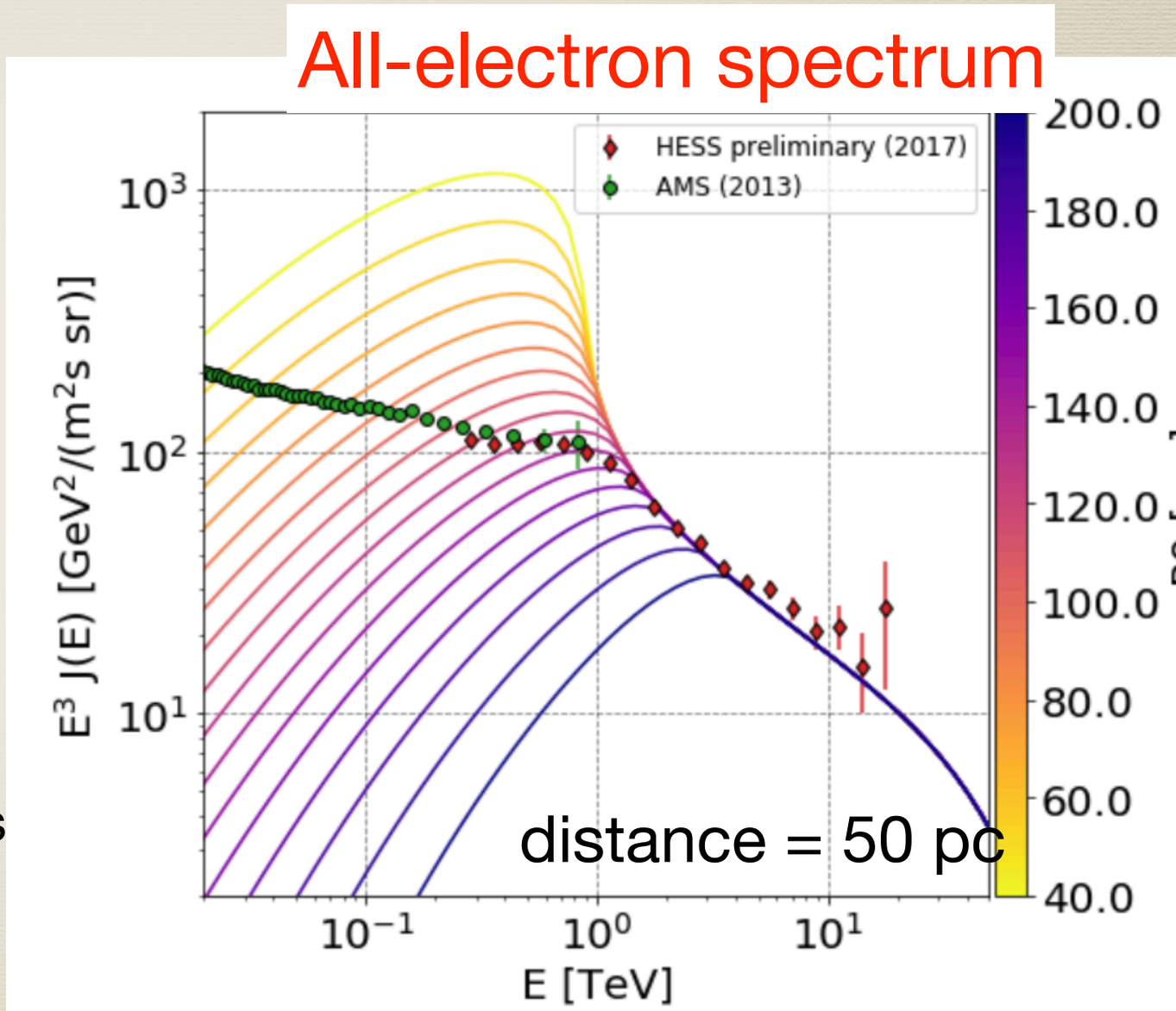
- The general characteristics for this pulsar

are:

- Age > 300 kyr
- Distance < 80-90 pc
- Spin-down power ~10^{33} -10^{34} erg/s

- Probability for this pulsar to exist if it is <1 Myr old is 5-10%

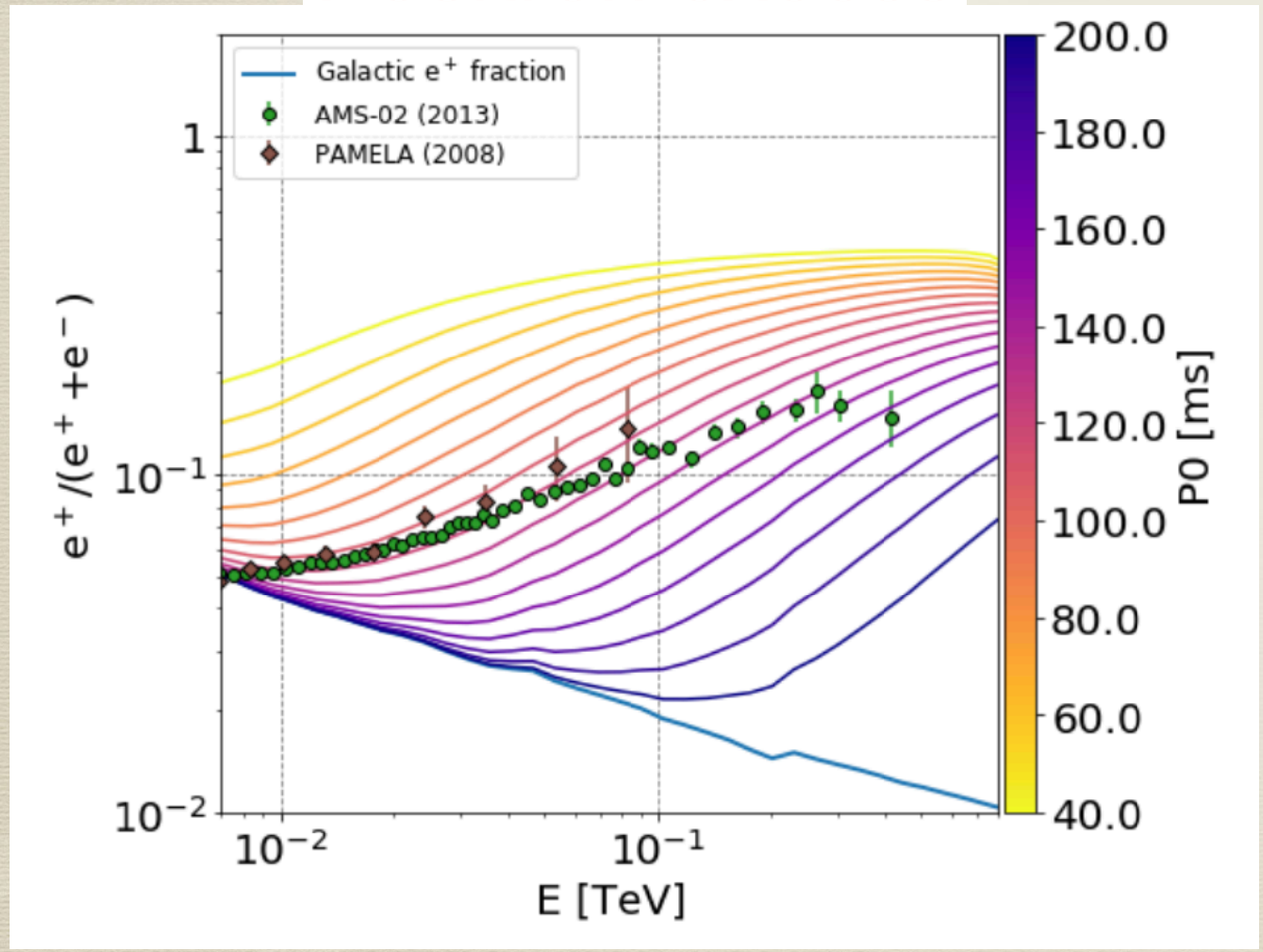
All-electron spectrum



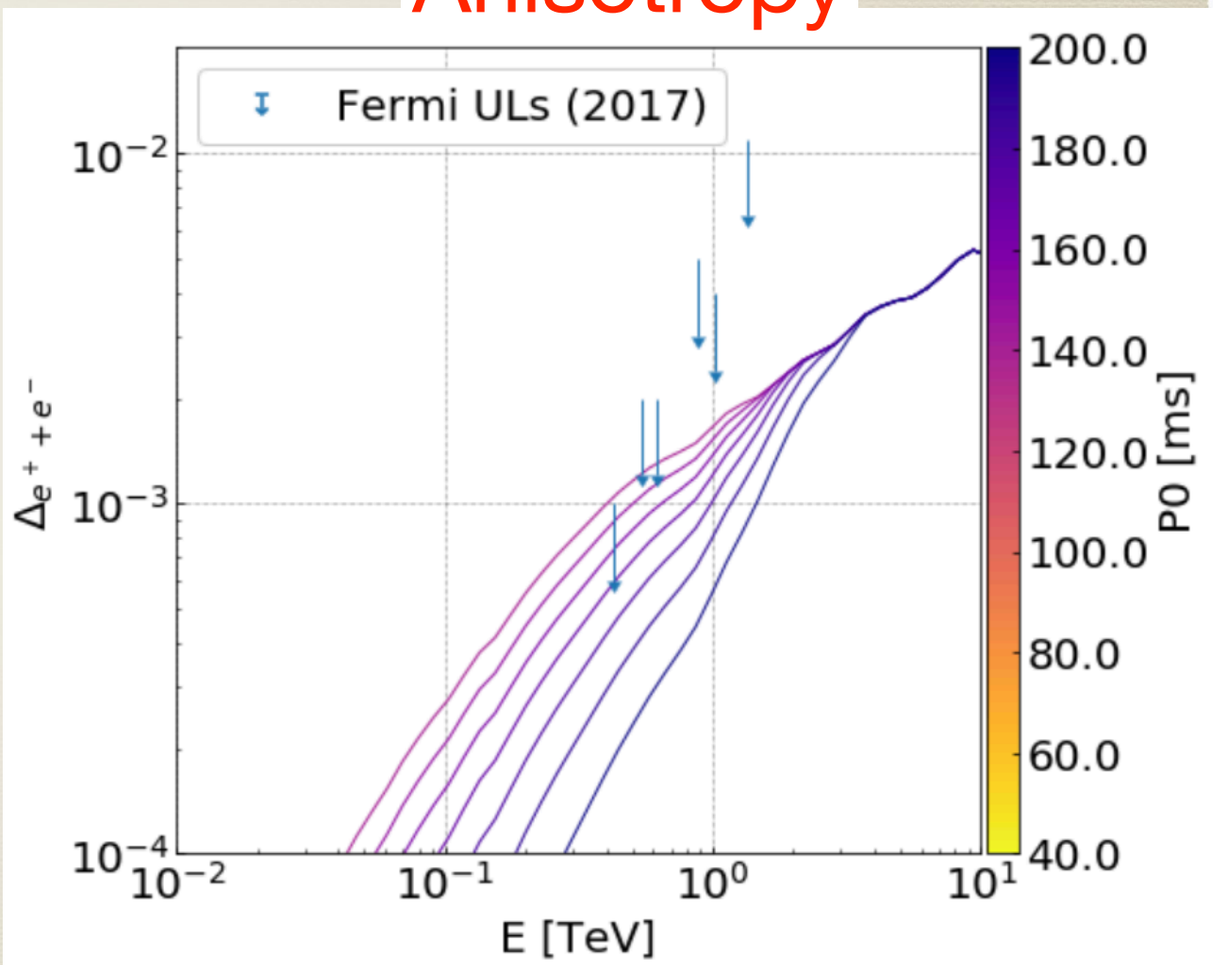
An undiscovered pulsar as an explanation

- It fulfills the experimental constrains for several sets of parameters as:
  - Positron flux
  - Positron excess
  - All-electron anisotropy

Positron excess

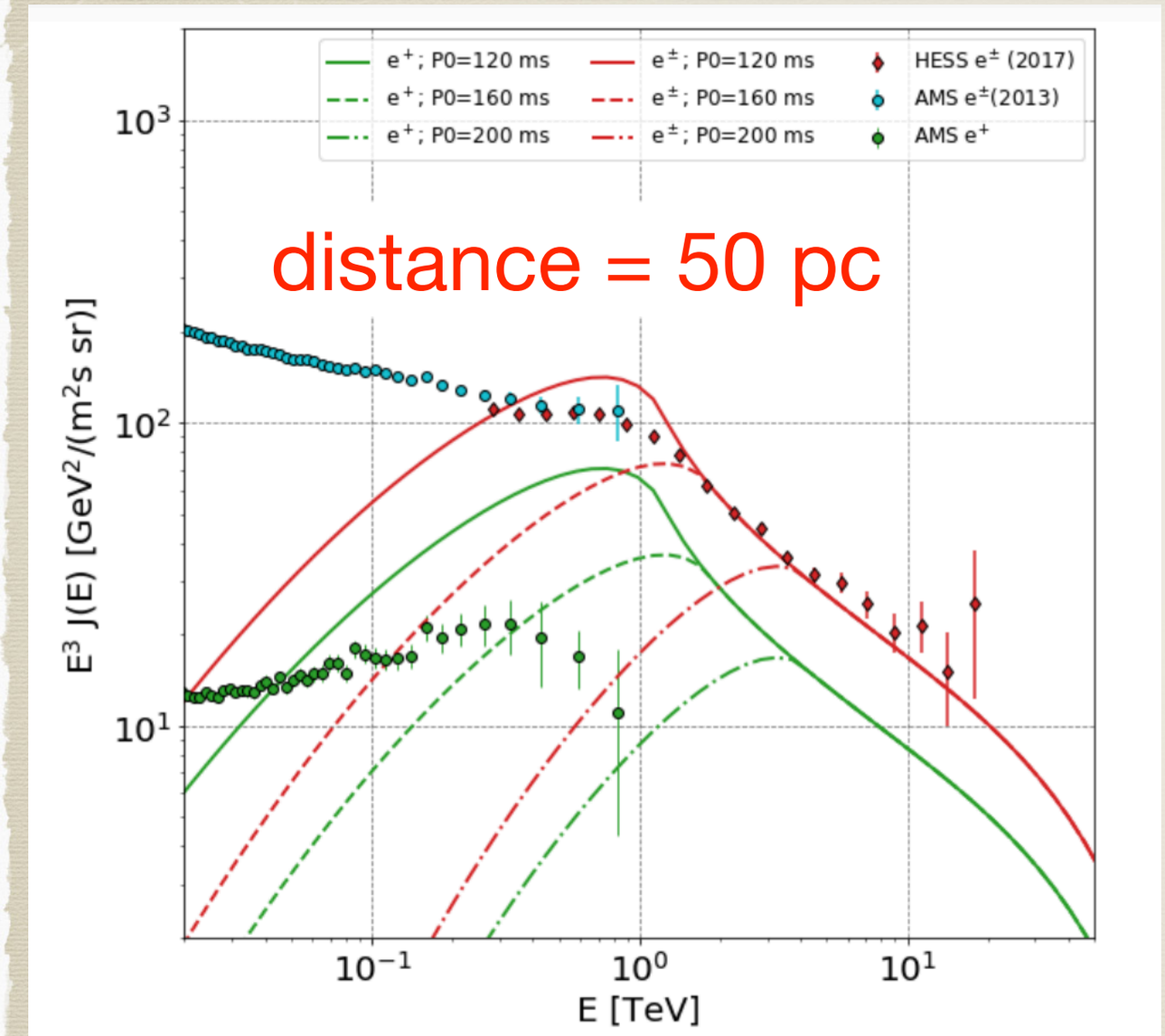


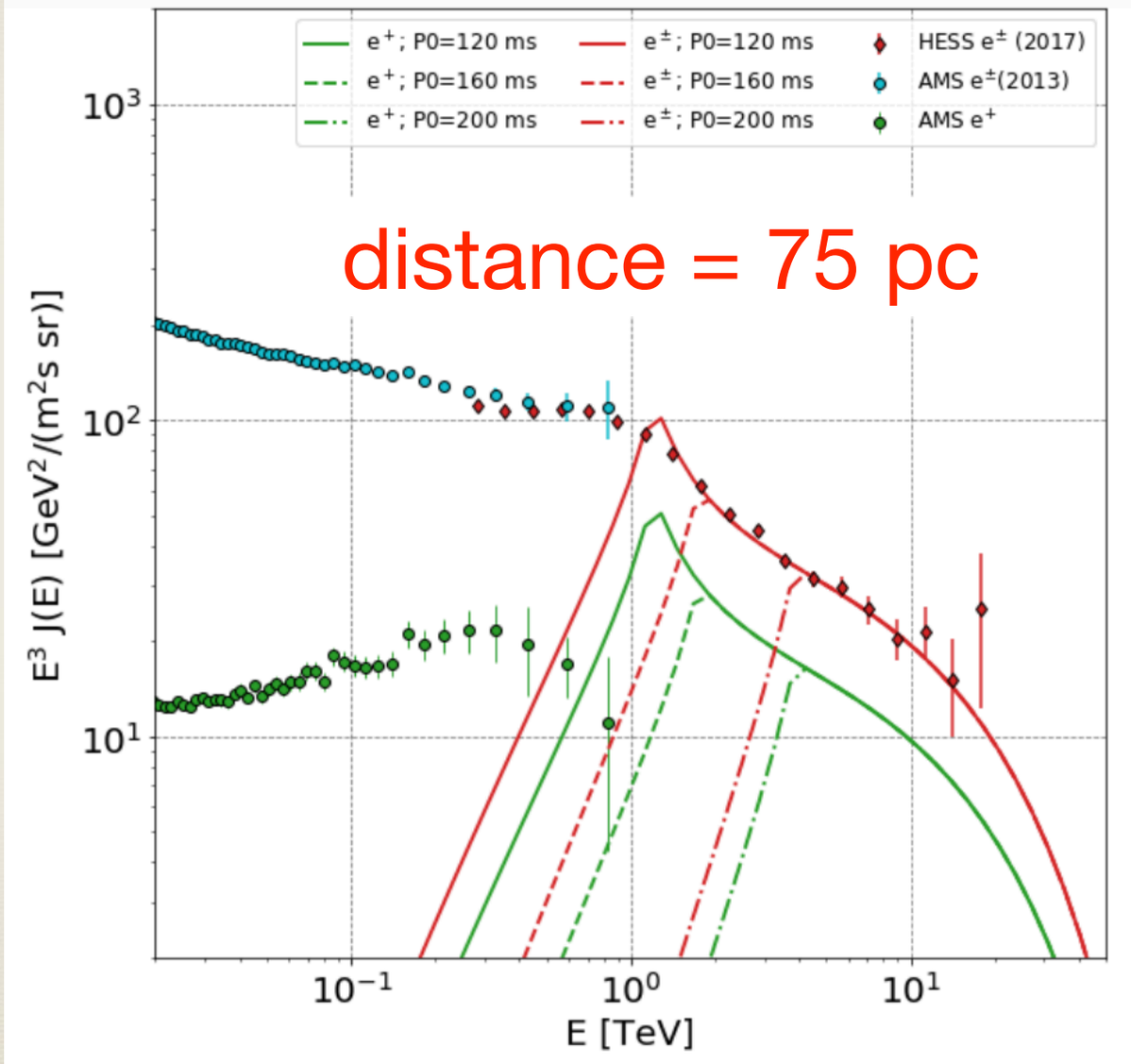
Anisotropy



RLC, Parsons, Hinton & Giacinti, Undiscovered Pulsar in the Local Bubble as an Explanation of the Local High Energy Cosmic Ray All-Electron Spectrum, PRL, 121, 251106 (2018).

An undiscovered pulsar as an explanation





Bonus track

LETTER

doi:10.1038/nature17424

The locations of recent supernovae near the Sun from modelling ^{60}Fe transport

D. Breitschwerdt[1], J. Feige[1], M. M. Schulreich[1], M. A. de. Avillez[1,2], C. Dettbarn[3] & B. Fuchs[3]

Simulations of ^{60}Fe to determine the formation of the Local Bubble point to two nearby SNe:

- Exploded 1.5 and 2.3 Myr ago
- At 90-100 pc

Conclusions

- We show that we can reconcile a low diffusion coefficient with the HESS all-electron spectrum without the need of invoking exotic explanations.

- An undiscovered pulsar inside the Local Bubble could be the answer in case the diffusion inside it is as slow as that measured by HAWC around Geminga.

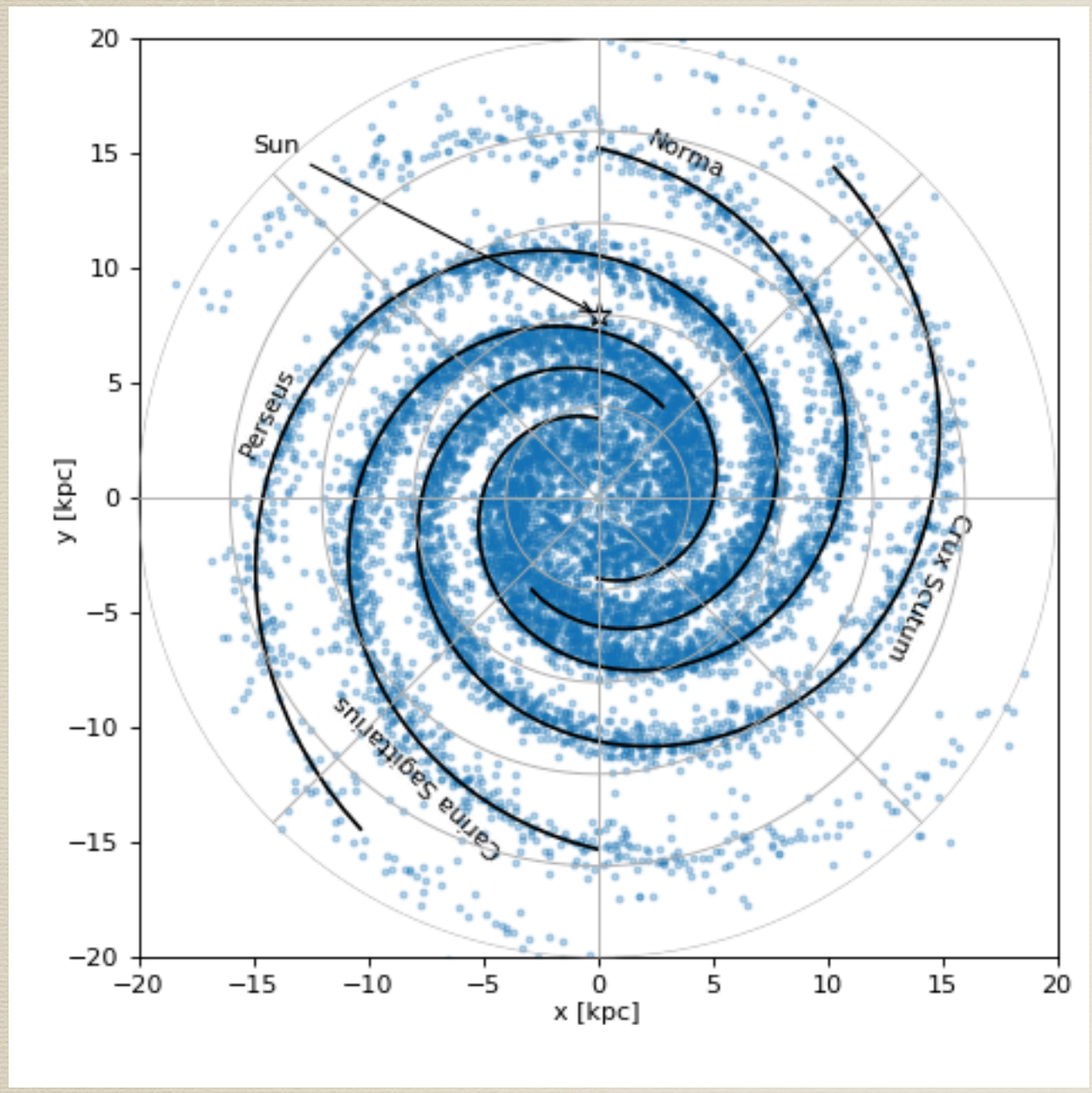
- The characteristics of this pulsar are:
  - Age > 300 kyr
  - Distance < 80-90 pc
  - Spin-down power ~10^{33} -10^{34} erg/s

- Similar characteristics to the latest SNe explosions in the Local Bubble.

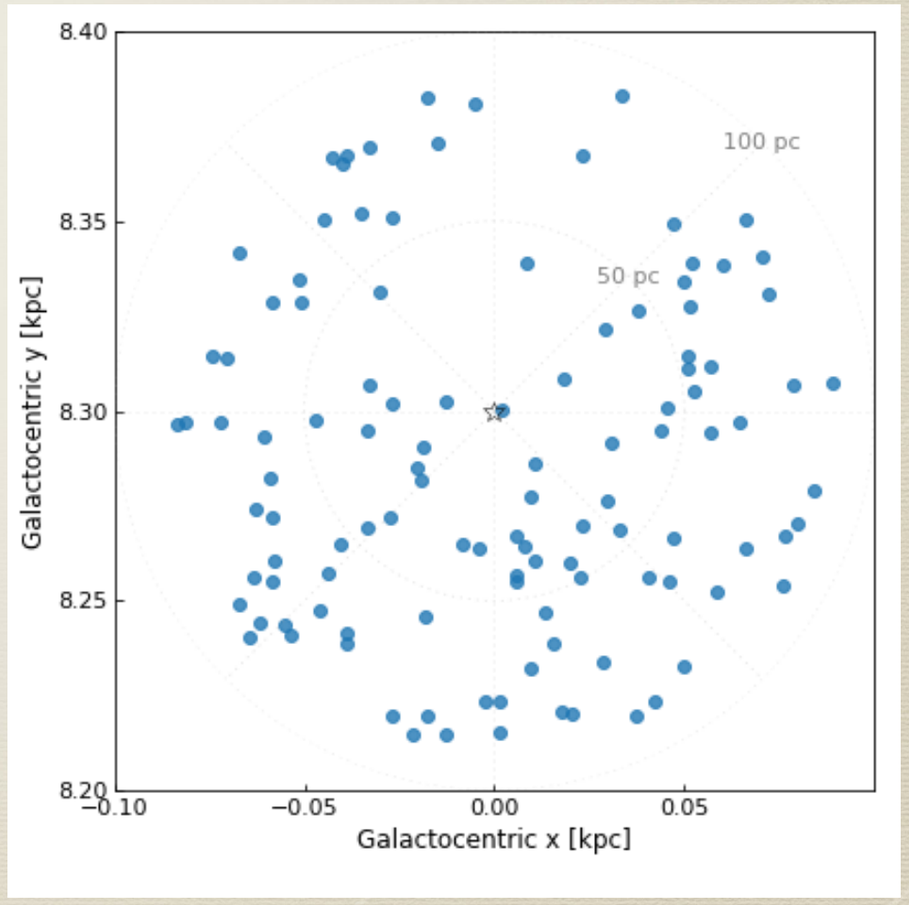
Thanks!

Backup

Pulsar simulation



Using gammapy, spiral arm distribution



Cumulative distribution