Pulsar contribution to electron/positron cosmic rays

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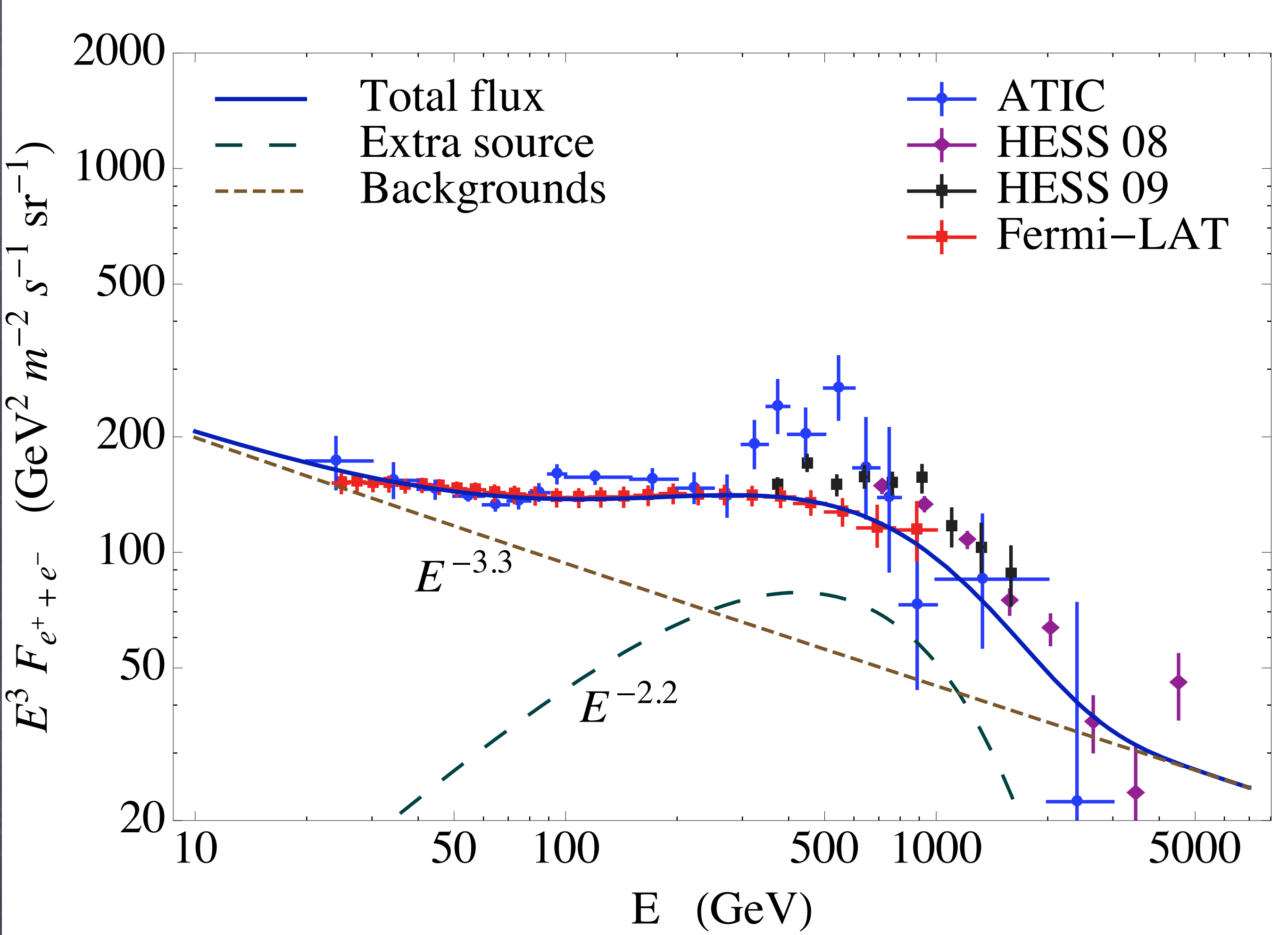
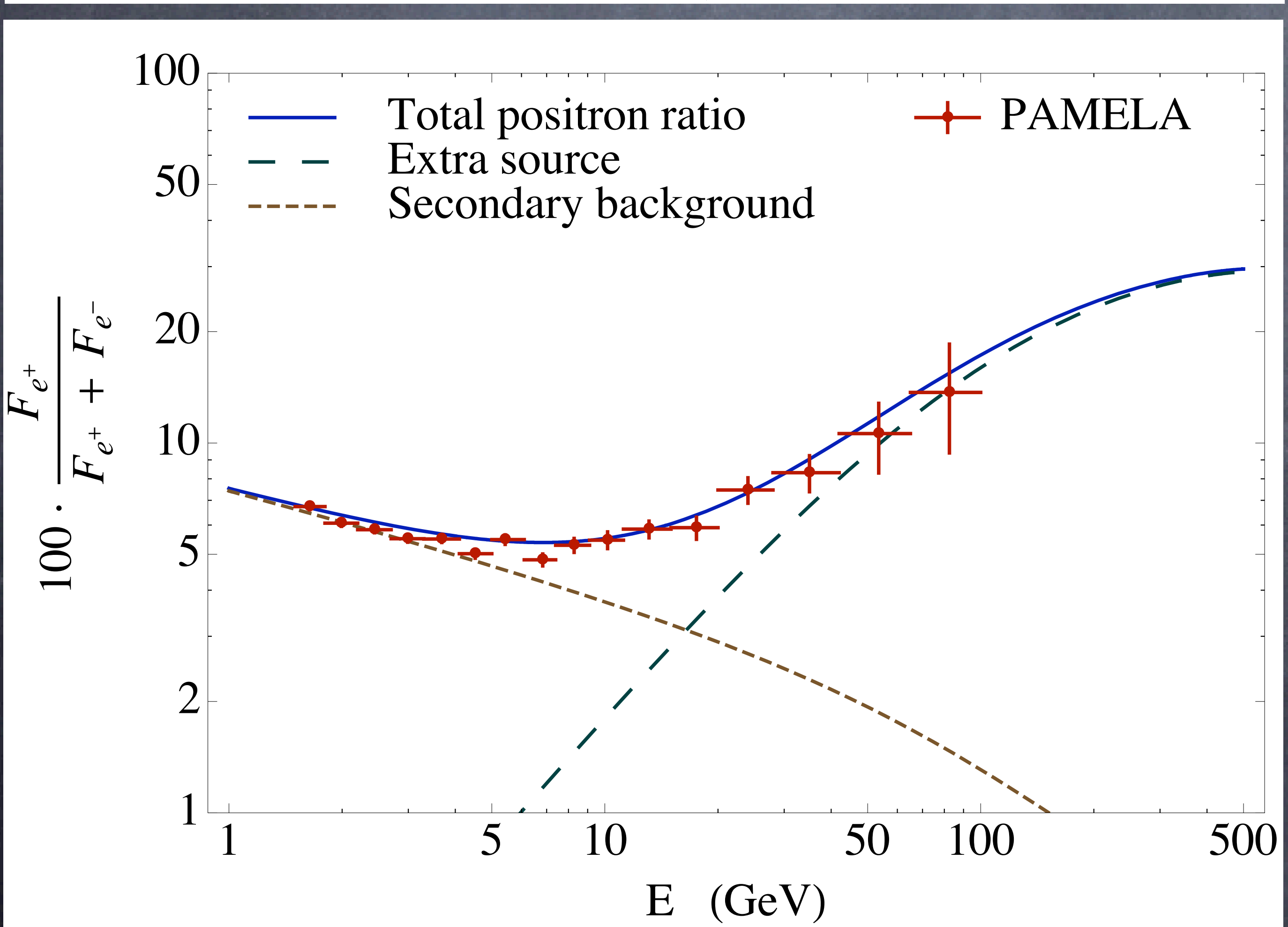
arXiv:0903.1310 PRD80:063005(2009)

Fermi Symposium '09





Anomalous flux:

$$F \sim F_0 E^{-n} e^{-\frac{E}{E_{\rm br}}}$$

$n \sim 2.0 - 2.5$

$E_{\rm br} \sim 100 \text{ GeV} - 1 \text{ TeV}$

Backgrounds:

Primary $\sim E^{-3.3}$

Secondary $\sim E^{-3.6}$

Propagation

Energy loss: $\dot{E} = b_0 E^2$

Characteristic cooling time: $t = \frac{1}{b_0 E}$

For E < 1 TeV the time t > 100 kyr

Diffusion: $D(E) = D_0 E^\delta$ (Moscalenko & Strong)

Characteristic diffusion distnace: $x^2 \sim D(E)t$

For E > 100 GeV the distance x < 2 kpc

Emission 1

Magnetic dipole radiation: $\dot{\mathcal{E}} = \frac{\mathcal{E}_0}{\tau}\left(1 + \frac{t}{\tau}\right)^{-2}$

Pulsar time scale: $\tau < 10\,\mathrm{kyr}$

Crab: $\tau \approx 0.7\,\mathrm{kyr}$ $\mathcal{E}_0 \approx 5 \times 10^{49}\mathrm{erg}$

After escaping the magnetosphere the electrons are trapped for some time in Pulsar Wind Nebula. The lifetime of PWNe << 100 kyr.

For the purposes of e^+e^- observations $\dot{\mathcal{E}} = \mathcal{E}_0\,\delta(t)$

Emission 2

From PWNe synchrotron and Gamma rays:

$$Q \sim \eta \mathcal{E}_0 E^{-n_0} e^{-E/E_{\rm br}} \delta(t)$$

Initial energy: $\mathcal{E}_0 = 10^{48} - 10^{50} {\rm erg}$ $(P = 0.02 - 0.2\,{\rm s})$

Conversion efficiency: $\eta \approx 0.01 - 0.1$

Index: $n_0 \approx 1.0 - 2.0$ (D.A.Green SNR catalog)

Break: $E_{\rm br} \approx 100\,{\rm GeV} - 10\,{\rm TeV}$

Problems

1. PWN lifetime << propagation time:

   The electrons from observed PWNe cannot reach us. The electrons that reach us come from PWNe that can no longer be observed.

2. Degeneracy:

   Thus there are at least 6 unconstrained parameters (single pulsar and ISM) to describe 3 parameters of the anomalous flux.

   For instance, the propagated index of the flux from a disc-like source is

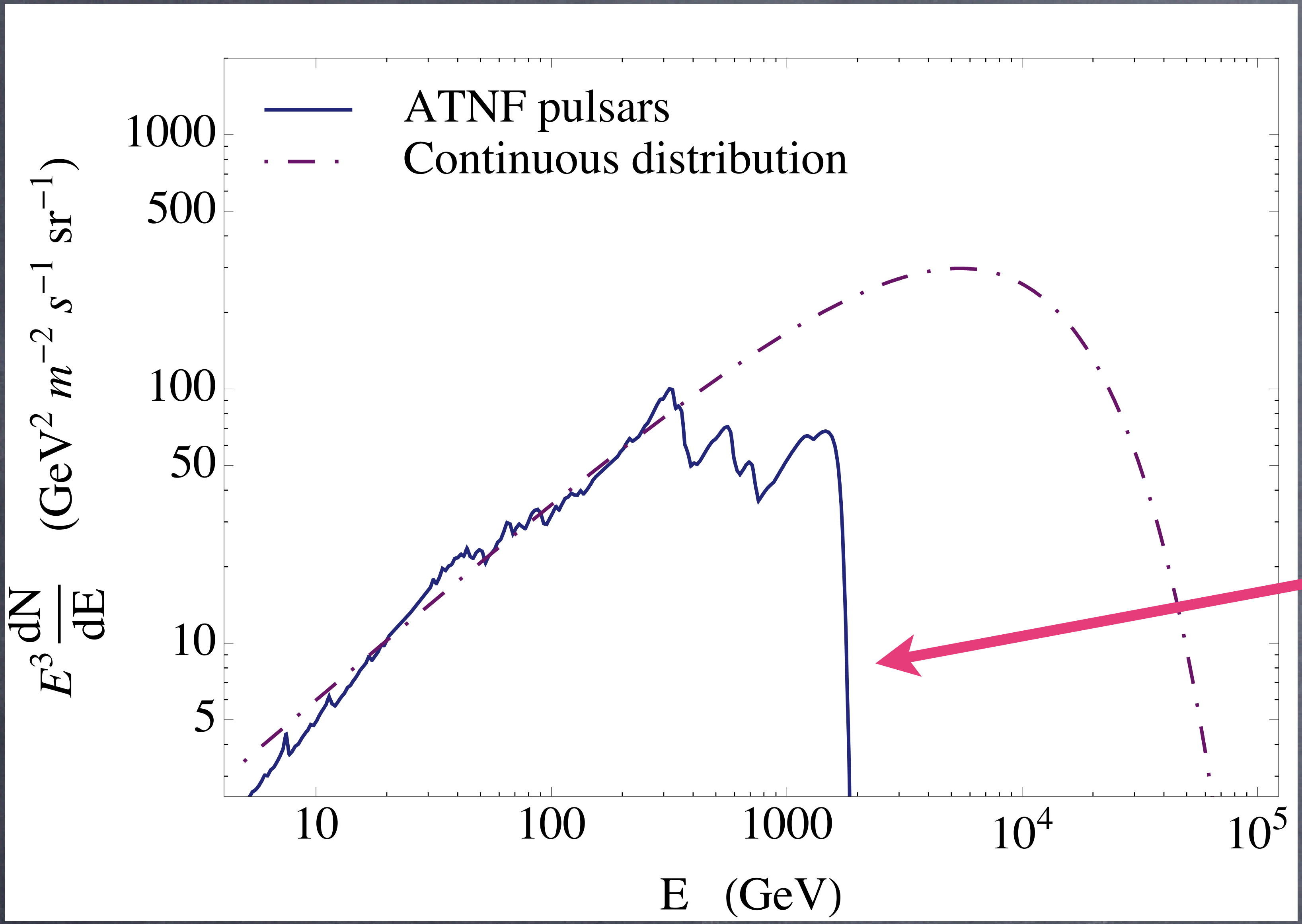
$$n = n_0 + \frac{1+\delta}{2}$$

What we can do?

- Use currently observed PWNe to find the distribution of properties
- Calculate typical spectra
- Constrain the parameters of ISM & pulsars

We will start by comparing the flux from ATNF pulsars and a continuous distribution of pulsars.

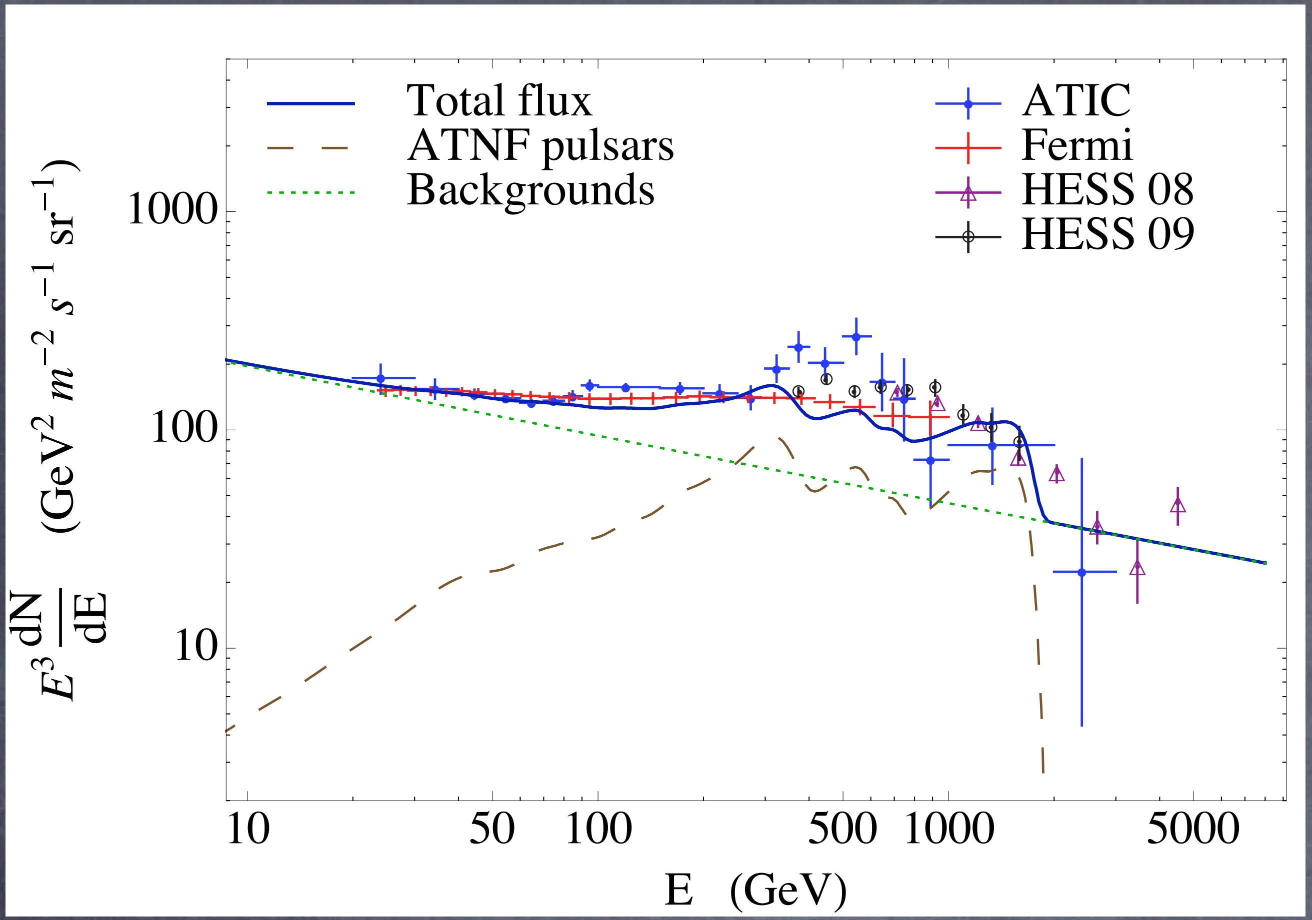
Flux from ATNF pulsars versus continuous disc source



$$n = 1.5$$
$$\eta = 0.065$$
$$\tau = 1\,\text{kyr}$$

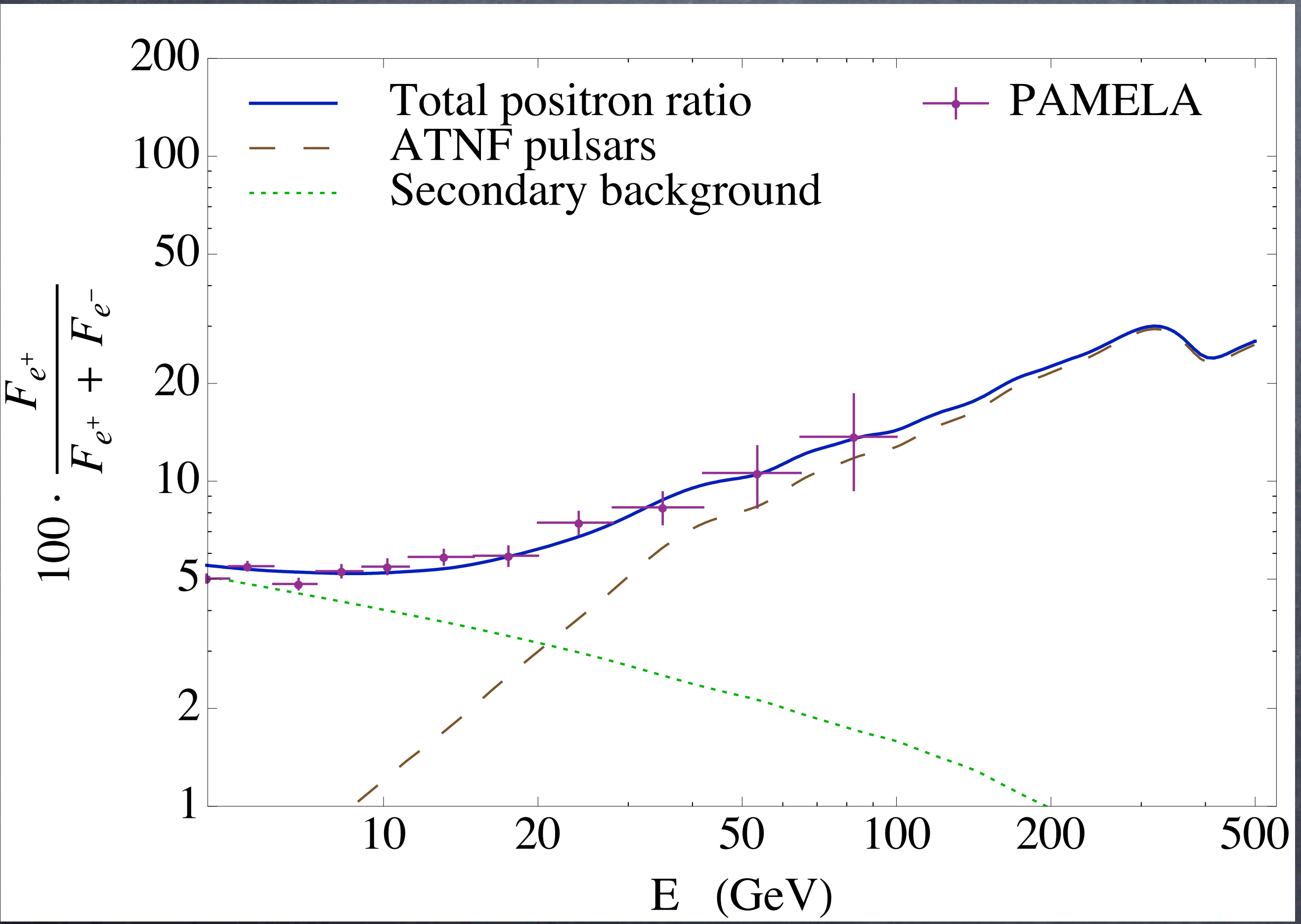
The cutoff is determined by the cooling break from the youngest pulsar within the Earth's diffusion zone.

Fitting the continuous flux to the ATNF pulsars requires the pulsar birth rate $N_b = 1.8\,\text{kyr}^{-1}$



The flux from ATNF pulsars versus Fermi and PAMELA

$$n_0 = 1.5 \qquad \delta = 0.4$$
$$\eta = 0.065$$
$$\tau = 1\ \text{kyr}$$



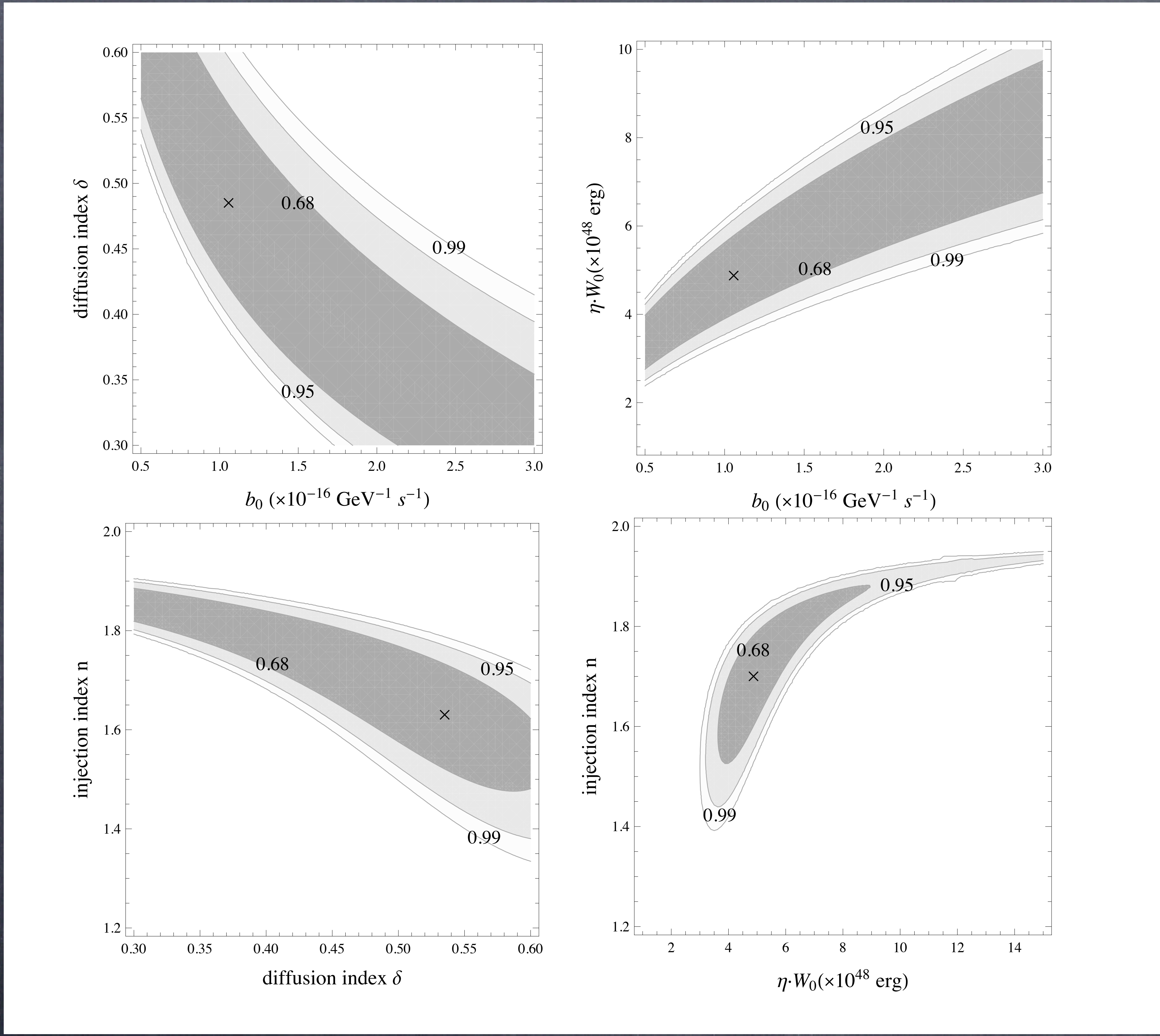
The initial rotational energy for every pulsar is

$$\mathcal{E}_0 = \dot{\mathcal{E}} \frac{t^2}{\tau}$$

where

$\dot{\mathcal{E}}$ - current spin-down

$t = \frac{P}{2\dot{P}}$ - characteristic pulsar age



The crosses and the areas correspond to the best fits of continuous disc distribution to Fermi and PAMELA data.

The best fit parameters are:

$$\delta \approx 0.50 \pm 0.05$$
$$n_0 \approx 1.6 \pm 0.2$$
$$\eta \mathcal{E}_0 \sim 5 \times 10^{48}\ \mathrm{erg}$$

Conclusions

1. It is possible to fit both Fermi and PAMELA with reasonable ISM and pulsar parameters
2. Assuming the pulsar origin of electron/positron fluxes, Fermi&PAMELA can constrain some propagation and pulsar parameters
3. It is impossible to "derive" the flux from the observed properties of pulsars: the corresponding PWNe have disappeared