Antimatter from Supernova Remnants

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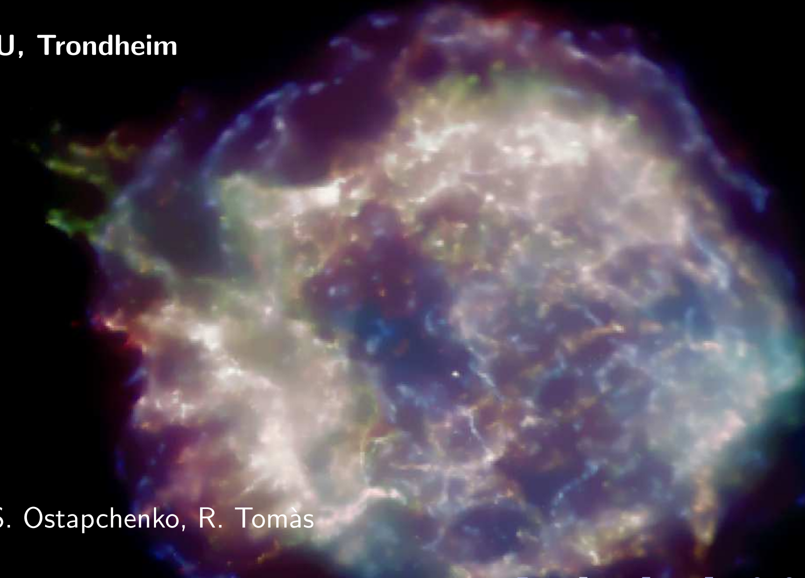
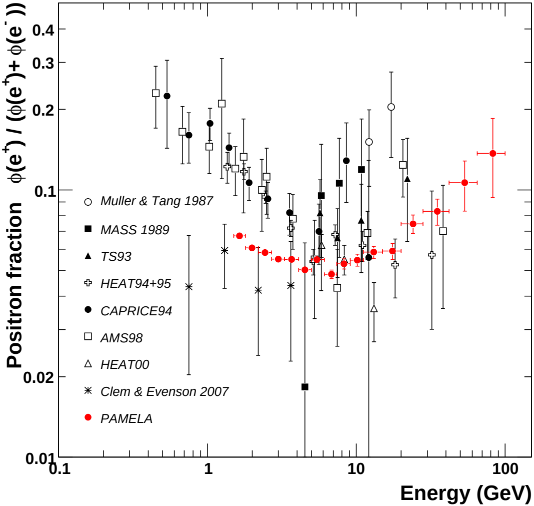


with S. Ostapchenko, R. Tomàs

PAMELA anomaly



Astrophysical sources for anti-matter: CR secondaries

- standard secenario for Galactic CRs:
  - sources are SNRs:
    kinetic energy output of SNe:
    $10M_\odot$ ejected with $v \sim 5 \times 10^8$ cm/s every 30 yr
    $\Rightarrow L_{\rm SN,kin} \sim 3 \times 10^{42}$ erg/s
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$\Rightarrow$ ratio

$$\frac{n_+}{n_-} \propto E^{-\delta}$$

$\Rightarrow$ CR secondaries can not explain increasing positron fraction

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  - requires large boost factors ~ 100
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    - dense, cold clumps
  - "exclusive" coupling to leptons

Astrophysical explanations II: SNR

[P. Blasi '09]

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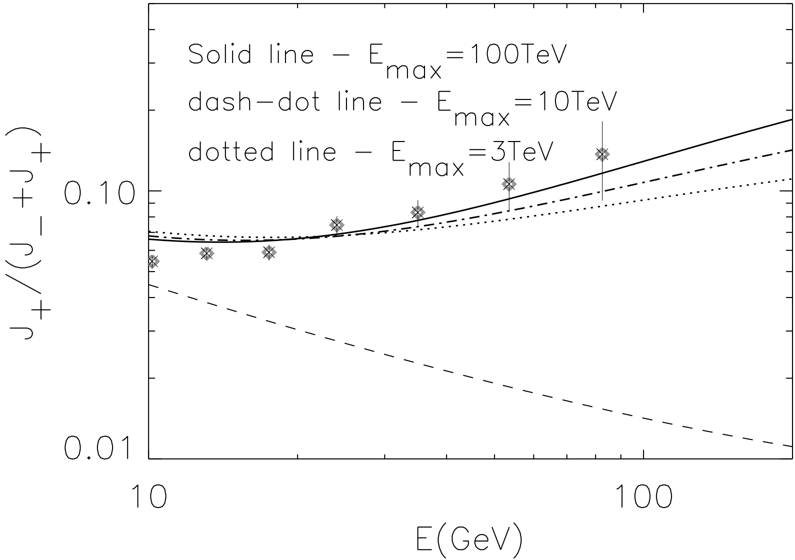
- secondary $e^{\pm}$ are accelerated, spectra becomes harder
- several important implications for CR physics:

$\Rightarrow$ increase of $\bar{p}/p$, B/C, ...

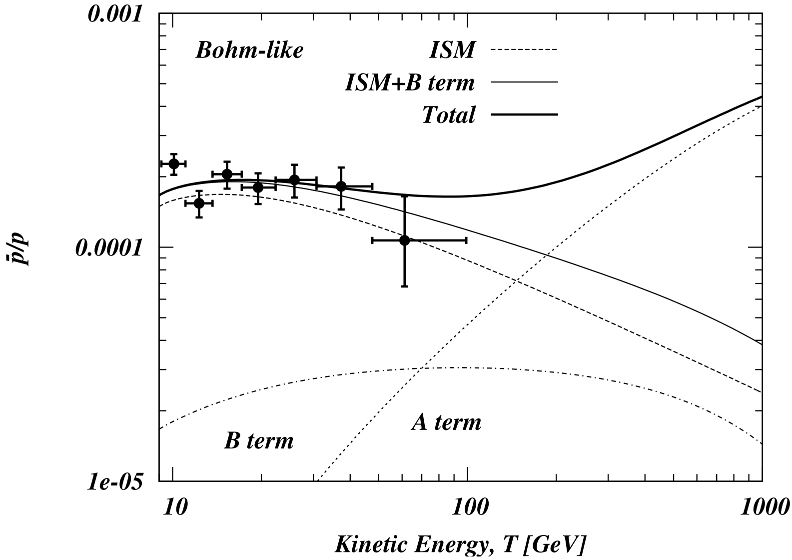
Positron ratio from SNR:

[*Blasi '09*]



Antiproton ratio from SNR:

[Blasi, Serpico '09]



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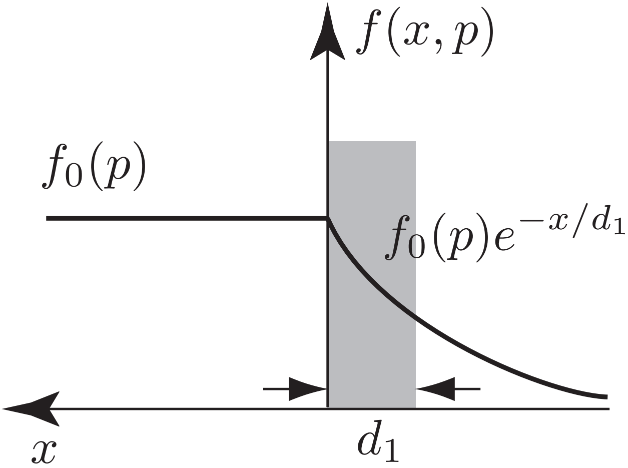

Antiproton ratio from SNR:

[Blasi, Serpico '09]

$$\frac{J_{\bar{p},SNRs}(E)}{J_p(E)} \simeq 2\, n_1\, c\, [\mathcal{A}(E) + \mathcal{B}(E)]$$

where

$$\mathcal{A}(E) = \gamma \left(\frac{1}{\xi} + r^2 \right) \times \int_m^E d\omega\, \omega^{\gamma-3} \frac{D_1(\omega)}{u_1^2} \int_\omega^{E_{\max}} d\mathcal{E}\, \mathcal{E}^{2-\gamma}\, \sigma_{p\bar{p}}(\mathcal{E}, \omega)\,,$$

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- constraints: $t_{\rm acc} \propto D(E)/u^2 \lesssim \tau_{\rm SNR}$ and $D(E)/u_2 \ll u_1 \tau_{\rm SNR}$

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- Example: BS and AMS use as average energy fraction per antiproton/positron:

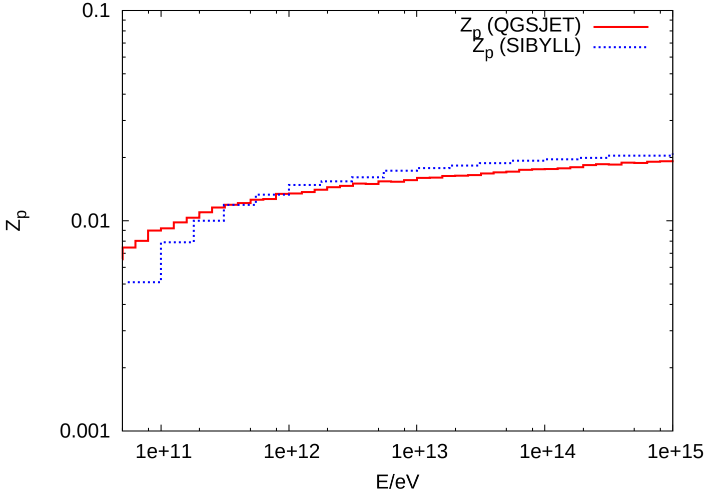
$$\xi_{e^+} = \frac{Z_{e^+}}{n_{e^+}} = 0.05 \qquad , \qquad \xi_{\bar{p}} = \frac{Z_{\bar{p}}}{n_{\bar{p}}} = 0.17$$

where

$$\langle Z_{\bar{p}} \rangle \equiv \frac{1}{\sigma_{pp}^{\rm inel}(E)} \int dE' \, \frac{E'}{E} \, \frac{d\sigma^{p\to\bar{p}}(E,E')}{dE'}$$

Antiproton energy fraction:

- QDC simulations give $Z_{e^+} \sim 0.05 \sim$ const. and $Z_{\bar{p}} \sim 0.02 \sim$ const.



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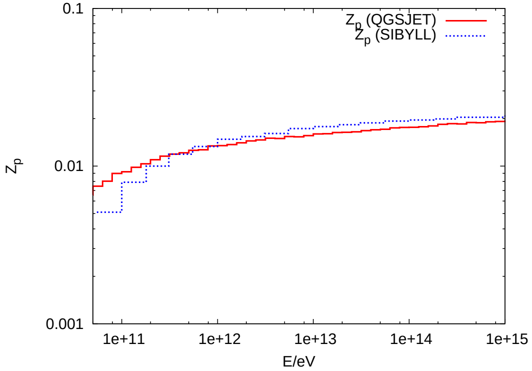

- since multipicity increases fast, $\xi_{e^+} = Z_{e^+}/n_{e^+}$ and $\xi_{\bar{p}} = Z_{\bar{p}}/n_{\bar{p}}$ are strongly energy dependent

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  - acceleration zone $\leq$ SNR [Ahlers, Mertsch, Sarkar, '09]

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- large component $\mathcal{A}$ requires small $v_{\rm sh}$ and large D, giving small $E_{\max}$
- protons accelerate efficiently early, produce secondaries in larger acceleration zone in late phase

Time-dependent framework:

[MK, Ostapchenko, Tomas '10]

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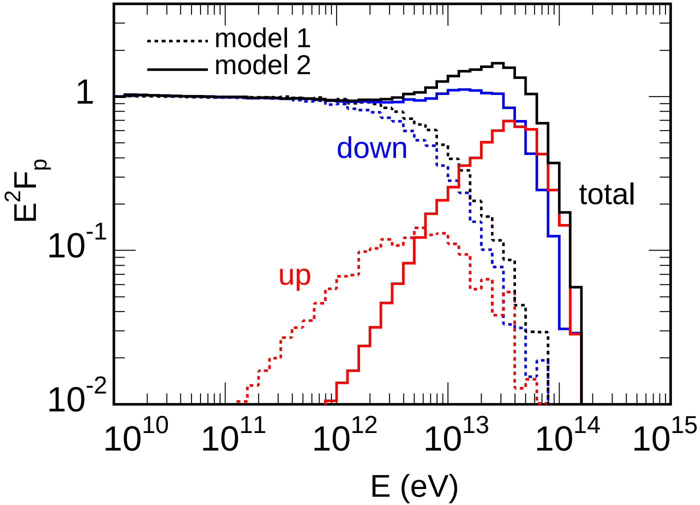
- $E_{\max}$ result of acceleration process
- QGSJET, JETSET for pp interactions, particle decays

Time-dependent framework: results for constant $D(t)$



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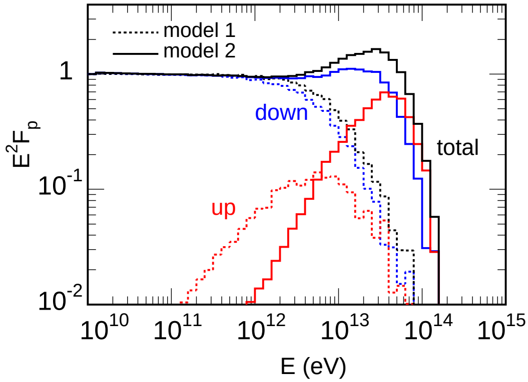

- only downstream spectrum, $E \ll E_{\max}$, is "stationary"
- upstream is always "non-stationary"

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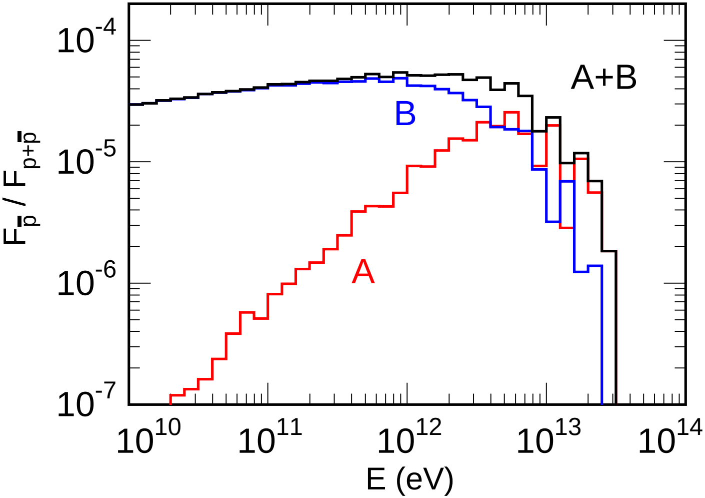

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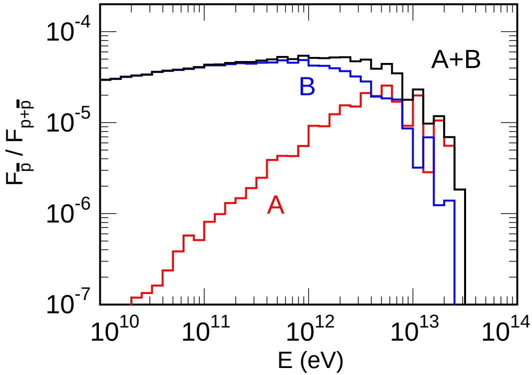

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$$t_{\rm acc} \propto D(E)/u_1^2 \lesssim \tau_{\rm SNR}$$

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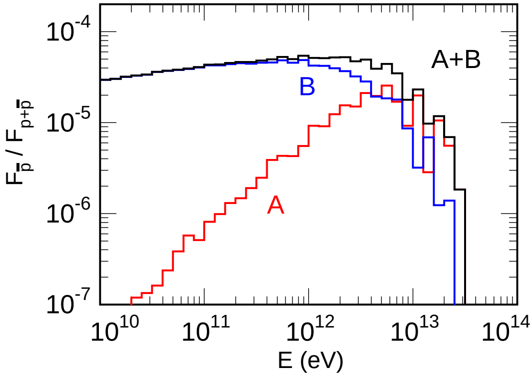

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- reacceleration is a misnamer

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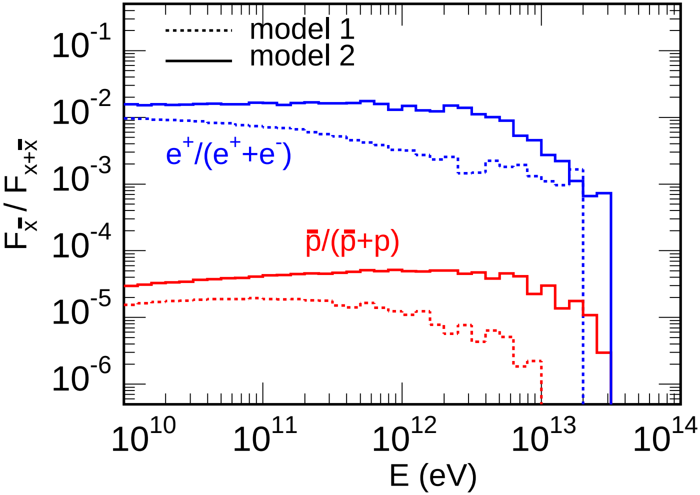

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we model amplification/damping by setting

$$D = \begin{cases} 1/100 \times \frac{cp}{eB}\,, & t < t_* \\ 20 \times \frac{cp}{eB}\,, & t > t_* \end{cases}$$

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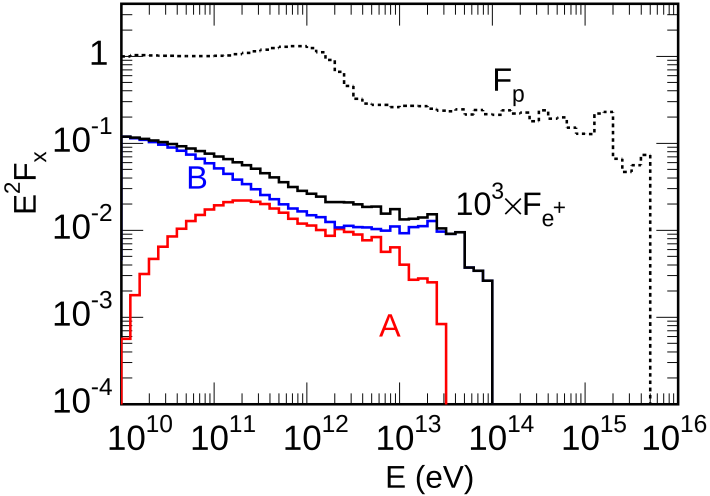

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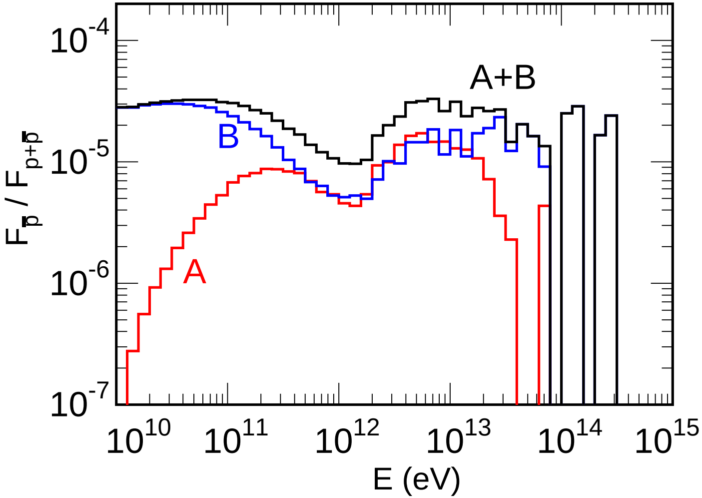

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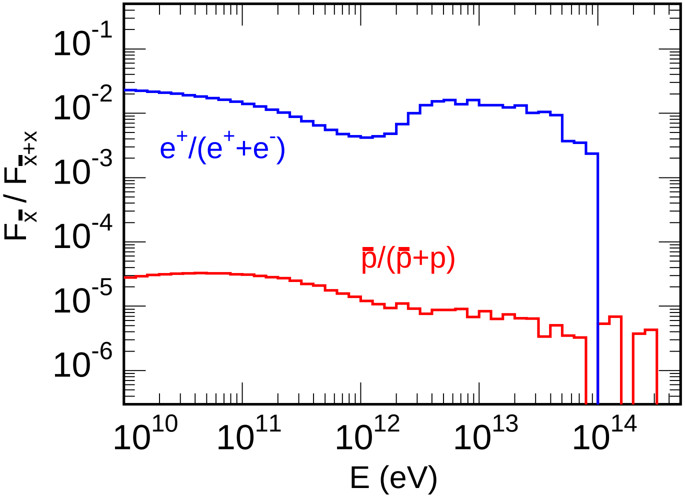

Conclusions

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2. Supernova remnants
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