On the SNR contribution to the spectra of secondary nuclei

Sergey Ostapchenko (NTNU)

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in collaboration with M. Kachelriess & R. Tòmas

Outline

- PAMELA positron excess & SNR mechanism
- SNR mechanism: further studies
- Time-dependent MC approach
- Results: production of secondary nuclei by SNRs
- Galactic propagation
- Predictions for primary/secondary nuclear ratios
- Outlook

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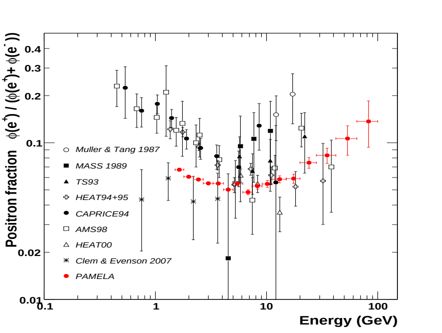

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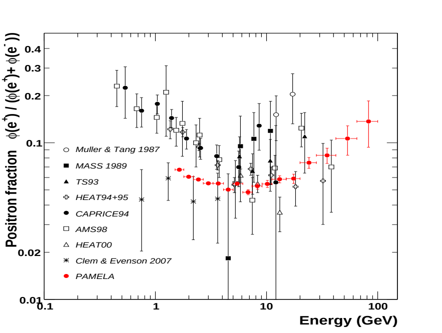

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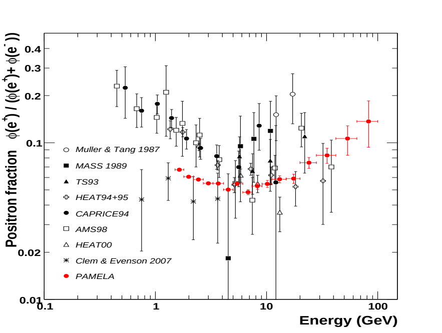

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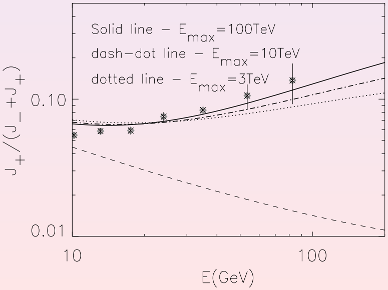

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- alternative explanation: production & reacceleration of $e^{\pm}$ in SNRs *[Blasi, 2009]* - steep rise of e^+/e^- ratio predicted!

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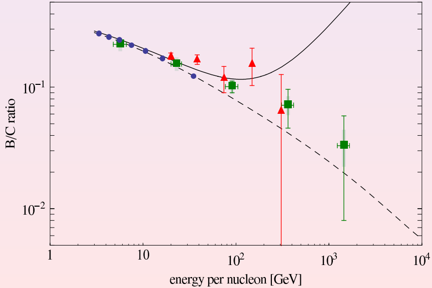

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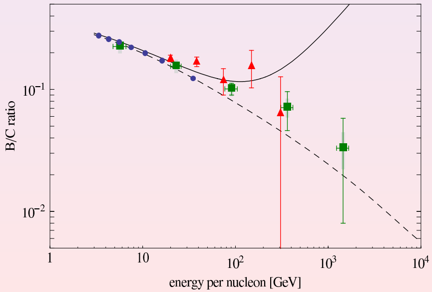

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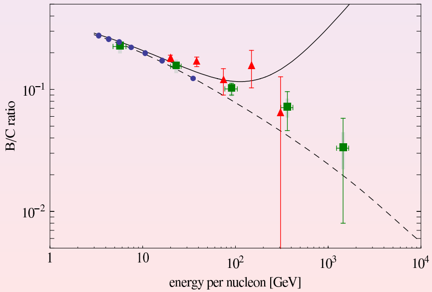

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Testing the SNR mechanism with a MC approach

- MC treatment of production / reacceleration of e^+, $\bar{p}$ in SNRs *[Kachelriess, SO & Tòmas, 2010]*
  - transparent implementation of hadronic interactions / decays
  - time dependence of relevant parameters due to SNR evolution (e.g., $v_{\rm sh}$, D)
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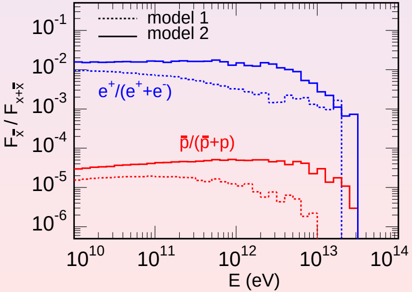

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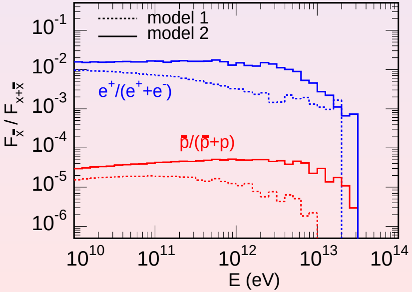

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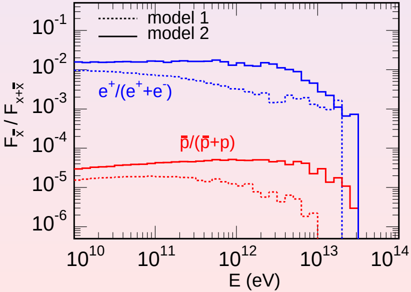

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- thermal leakage injection model *[Malkov & Völk, 1995]*
  - all nuclei injected at 10 GeV/nucleon
  - isotopic abundances from *[Strong & Moskalenko, 2001]*

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- spallation cross sections / decay tables from GALPROP *[Strong & Moskalenko, 1998]*: data-improved parametrization of Silbelberg & Tsao / BNL reaction network

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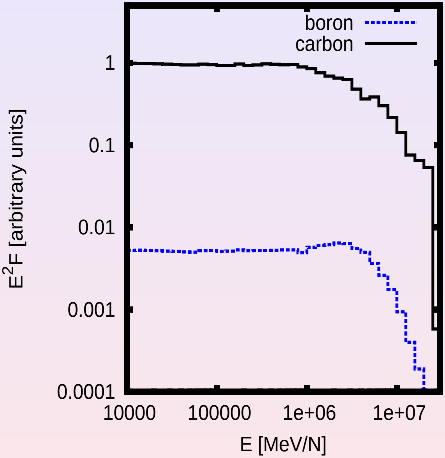
- standard SNR parameters:
  - $M_{\rm ej} = 4 M_\odot$
  - $E_{\rm SNR} = 5 \times 10^{51}$ erg
  - $\tau_{\rm SNR} = 13000$ yr
  - $n_{\rm ISM} = 2\,{\rm cm}^{-3}$
  - $f_B B = 1\,\mu$G

Results: production of secondary nuclei by SNRs



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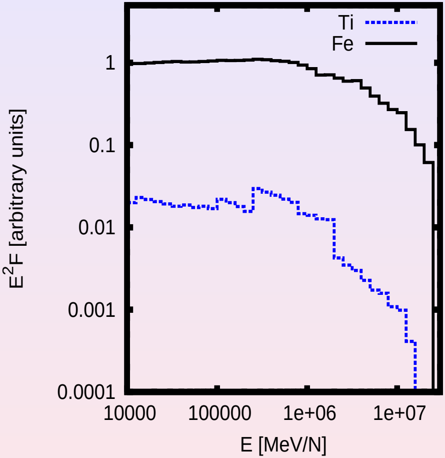

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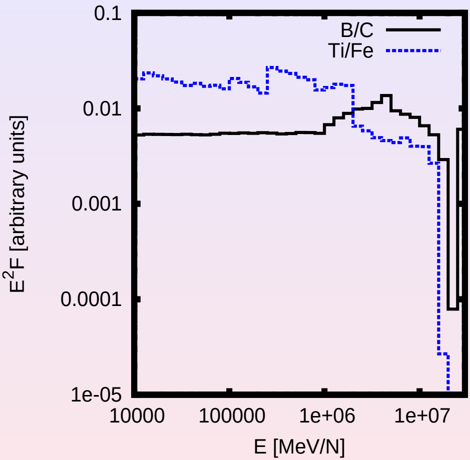

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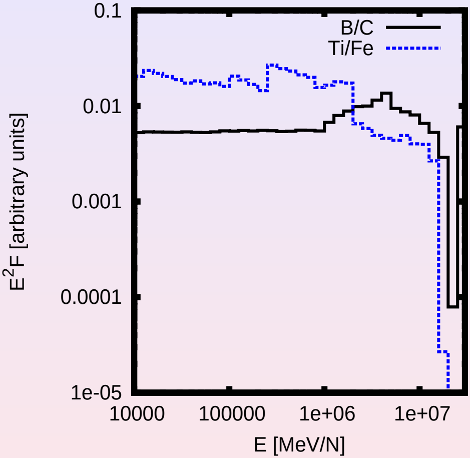

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- why?

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- what happens if it spallates at $t_{\rm s} < t_{\rm acc}$ or $t_{\rm acc} < t_{\rm s} < \tau_{\rm SNR}$?

Case 1: spallation during acceleration ($t_s < t_{acc}$)

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  - with total probability $w_1 \simeq \sigma_{spall}^{C \to B}\, r\, n_{ISM}\, c\, t_{acc}$
  - always producing boron of the same energy per nucleon E_C^f

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  - always producing boron of the same energy per nucleon E_C^f

Production of secondary nuclei in SNRs: outcome

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- naturally, the discussed correspondence is an approximate one

Galactic propagation

- performed using GALPROP *[Strong & Moskalenko, 1998]*
  - same spallation cross sections used
  - propagation parameters tuned to reproduce secondary/primary ratios for $\gamma = -2$
  - e.g., $D(E) \sim E^{-\delta}$ with $\delta = 0.7$
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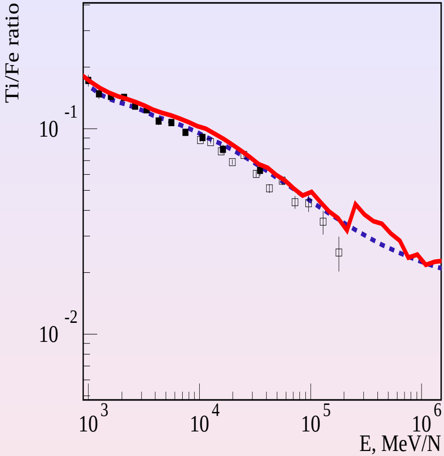
- main aim: investigate corrections to secondary/primary ratios due to the production & reacceleration in SNRs

Secondary/primary ratios after propagation



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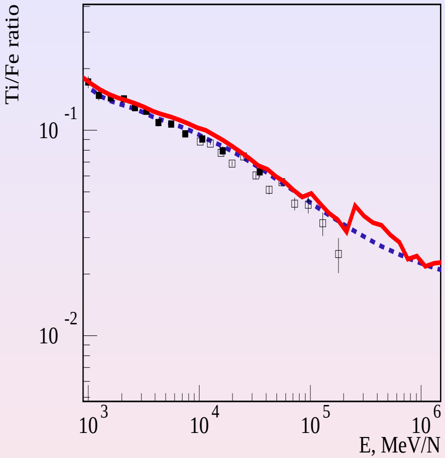

- secondary/primary ratios: no energy rise
- minor corrections for Ti/Fe ratio: masked by $\simeq 2\%$ initial abundance

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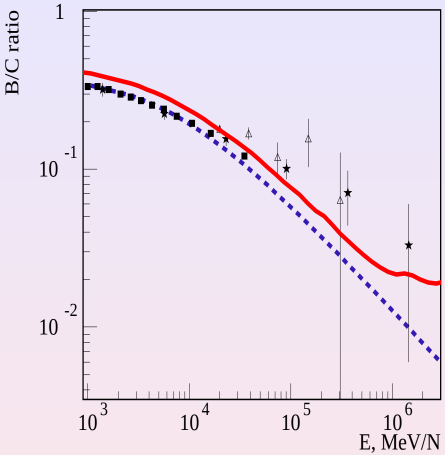

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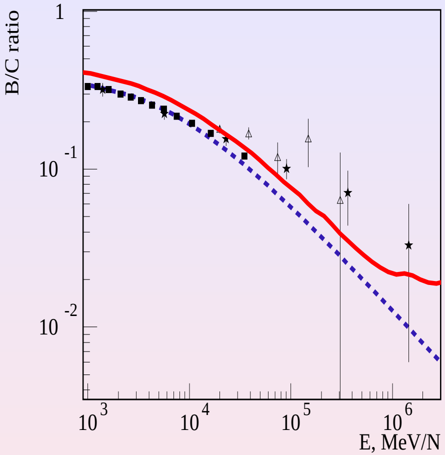

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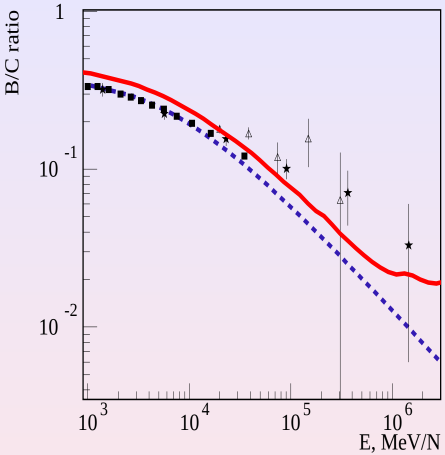

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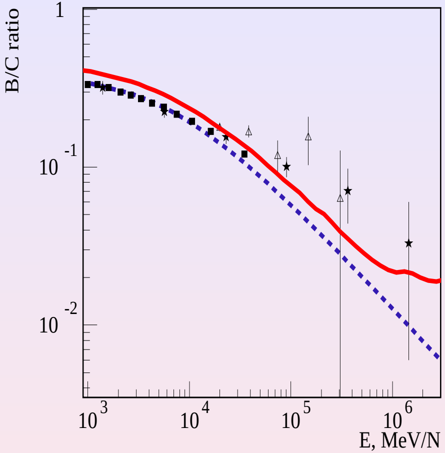

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- AMS measurements of the B/C ratio at TeV energies may provide information on acceleration process / environement

Potential variations

- *B*-field amplification *[Bell & Lucek, 2001; Bell, 2004]*
  - extends CR spectra to higher energies
  - probably modifies spectral shape both for primary and for secondary CRs
  - but: spectral ratio just after the source should stay unchanged
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  - NB: residence time of CRs in SNRs will be reduced
    $\Rightarrow$ so will be the SNR contribution to secondary/primary ratios

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4. precise normalization depends on the properties of acceleration sites / mechanisms