Cosmic-rays and

diffuse galactic gamma-ray emission

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Topics

- Postdoc still waiting in Taiwan for his visa (11 months)!

Postponed

- Deconvolve gas line spectra to give 3D distribution of ISM
- Devise method to account for uncertainties in diffuse model in likelihood fits
- Produce software to adapt model to LAT data (A LAT task?)

In the pipeline

- Derive model of interstellar radiation field including anisotropy
- Derive hadronic gamma-ray emissivities based on Monte-Carlo code DPMJET.

Publication accepted

- Work out time-dependent cosmic-ray nucleon propagation in the Galaxy

Standard indicators for cosmic-ray propagation may be flawed!

Scientific objectives

In case of an SNR origin the CR electron spectrum would vary in space and time throughout the Galaxy.

- **would a SNR origin of CR nucleons also lead to significant fluctuations of the CR density in the Galaxy, which then would modify secondary-to-primary ratios from their steady-state values?**

- **are there any signatures in the CR distribution in the Galaxy, that might permit to infer a SNR origin of CR nucleons on the grounds of locally observed CR spectra and the diffuse Galactic gamma-ray emission?**

The model

The transport equation:

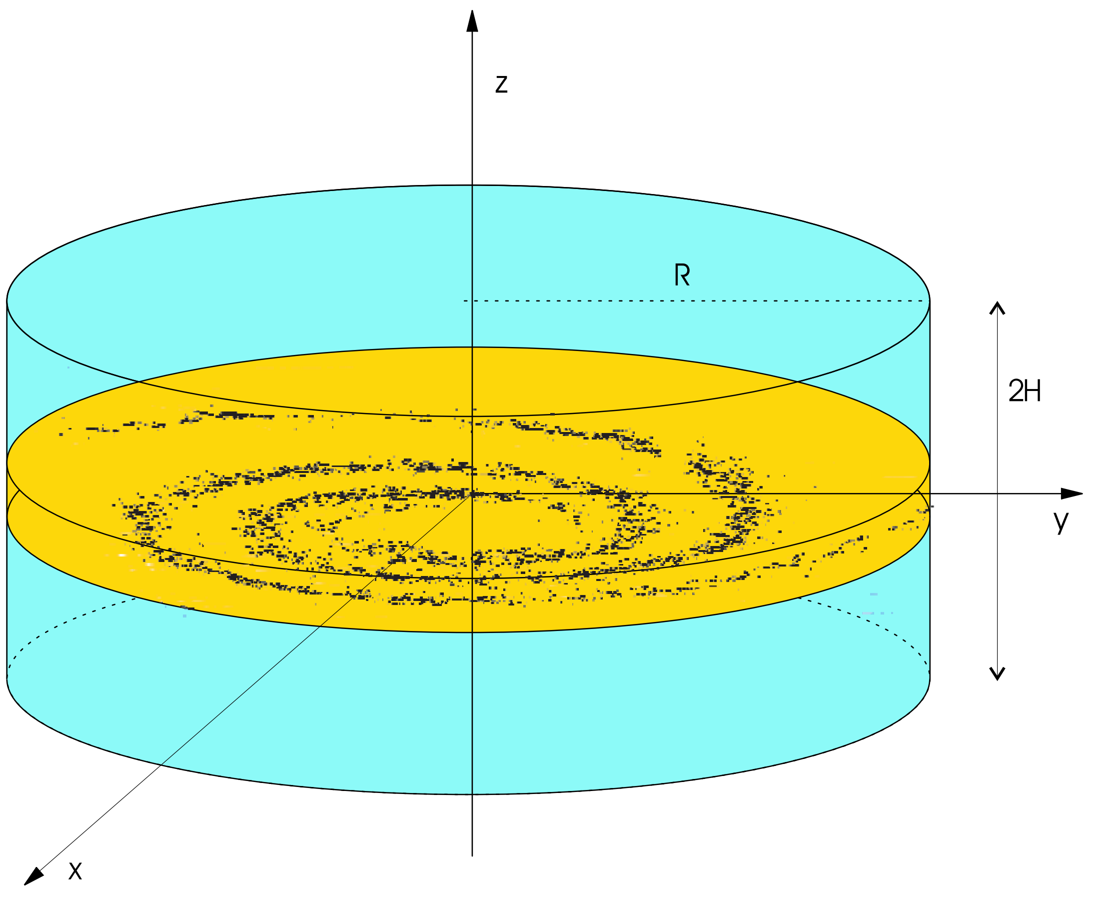
$$\frac{\partial N}{\partial t} - S = \nabla\left(k\nabla N\right) - \Omega v \sigma N$$

The vertical profile of gas:

$$\Omega(z) = \frac{n_0}{\cosh(z\, h_g)}$$

The diffusion coefficient:

$$k = \begin{cases} k_0\left(\frac{\zeta}{\zeta_0}\right)^{0.6} & \text{for } \zeta \geq \zeta_0 = 4 \text{ GV/c} \\ k_0\left(\frac{\zeta}{\zeta_0}\right)^{-0.48} & \text{for } \zeta < \zeta_0 \end{cases}$$



The sources : $S = \sum q_j\, \delta(\vec{r} - \vec{r}_j)$ $\quad q_j\left(\zeta, t\right) = q_{j_0}\left(t - t_j\right) \exp\left(-\frac{t - t_j}{20\,\text{kyr}}\right) \Theta\left(t - t_j\right) \left(\frac{\zeta}{\zeta_0}\right)^{-s}$

Parameters are chosen to reproduce B/C and the Be isotope ratio in the steady-state.

The method

- we need to get the physics right on small scales $\rightarrow$ no finite-difference algorithm!
- Assume gas distribution Ω and diffusion coefficient independent of r and ϕ.

$$\frac{\partial N}{\partial t} - S = k(p)\left\{\frac{1}{r}\frac{\partial N}{\partial r} + \frac{\partial^2 N}{\partial r^2} + \frac{1}{r^2}\frac{\partial^2 N}{\partial \varphi^2} + \frac{\partial^2 N}{\partial z^2}\right\} - \Omega(z) v \sigma N$$

- Expand desired solution in a Fourier-Bessel series.

$$N = \frac{1}{\pi}\sum_n \sum_m \left(A_{nm}\cdot\cos\left(n\varphi\right) + B_{nm}\cdot\sin\left(n\varphi\right)\right)\frac{\jmath_n\left(\alpha_{nm} r\right)}{\left(\jmath_n'\left(\alpha_{nm} R\right)\right)^2}$$

The problem is thus reduced to numerically solving many simple equations

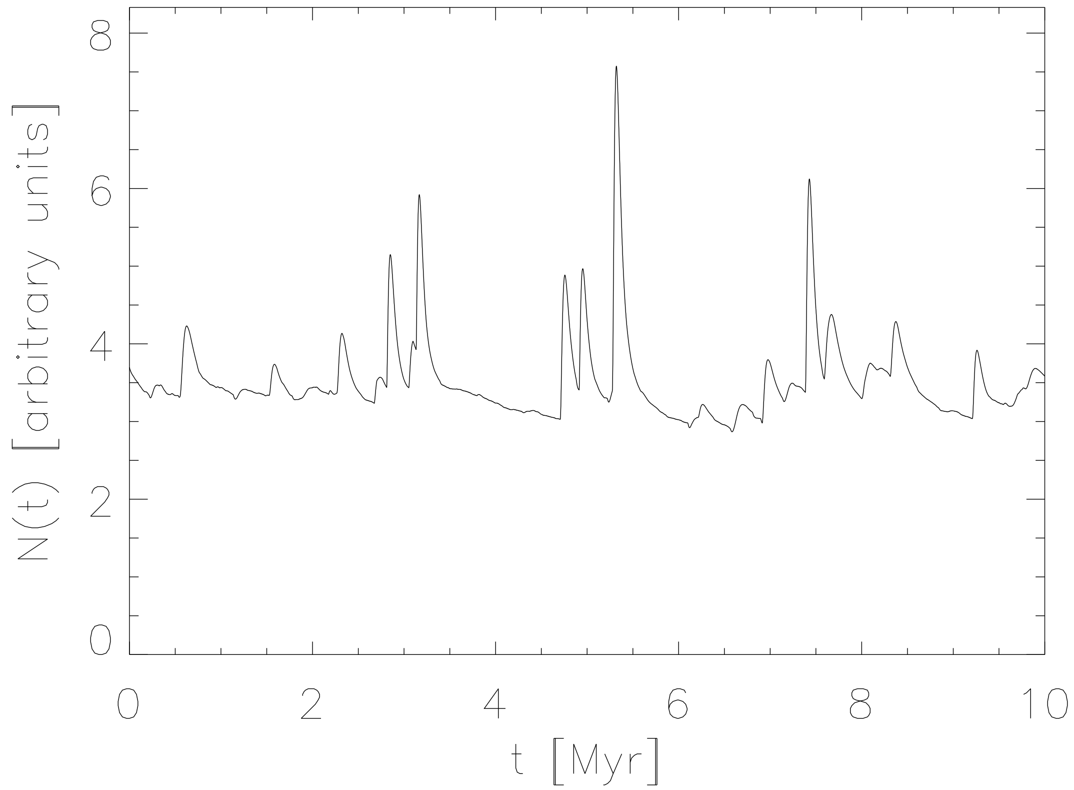
$$\frac{\partial A_{nm}}{\partial t} - S^A_{nm} = k(p)\left[-\alpha^2_{nm} A_{nm} + \frac{\partial^2 A_{nm}}{\partial z^2}\right] - \Omega(z) v \sigma A_{nm}\ , \qquad S^A_{nm} = \sum_i q_i(p,t)\cos\left(n\,\varphi_i\right)\frac{\jmath_n\left(\alpha_{nm} r_i\right)}{\left(\jmath_n'\left(\alpha_{nm} a\right)\right)^2}$$

and similar equations for B_{nm}

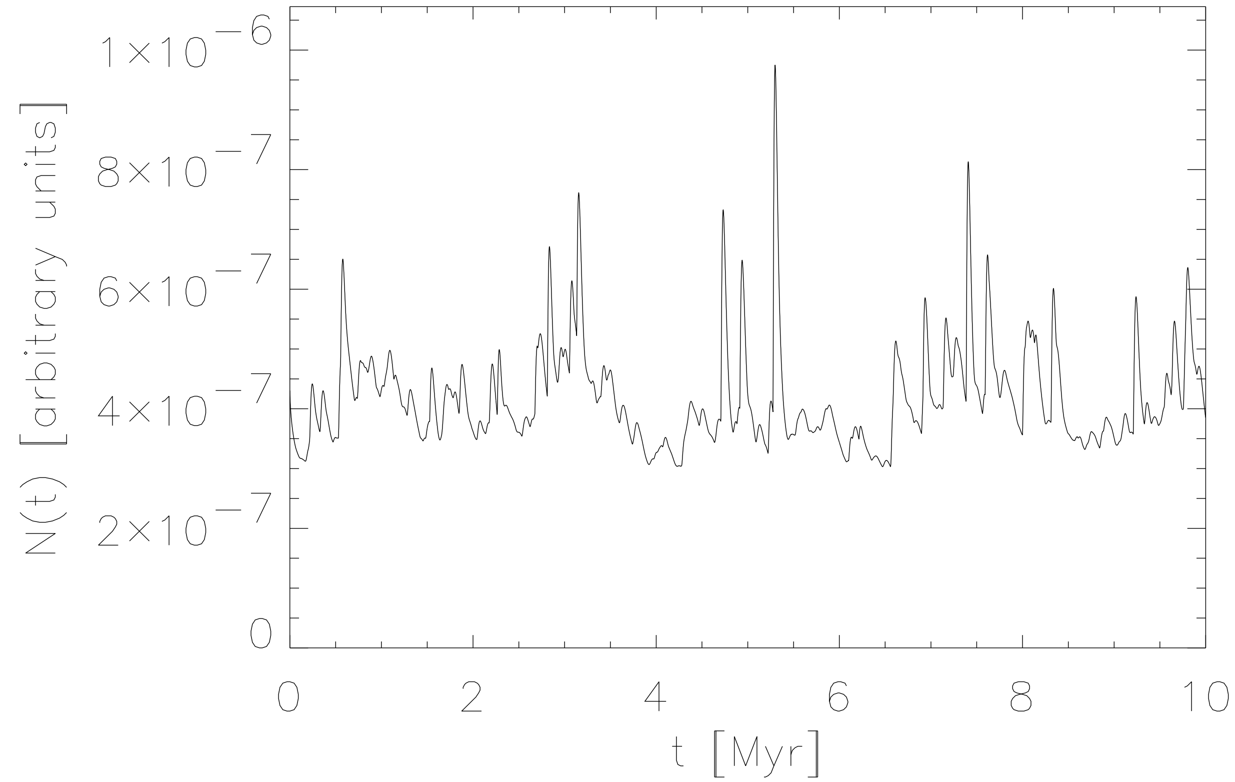
$$\frac{\partial B_{nm}}{\partial t} - S^B_{nm} = k(p)\left[-\alpha^2_{nm} B_{nm} + \frac{\partial^2 B_{nm}}{\partial z^2}\right] - \Omega(z) v \sigma B_{nm}\ , \qquad S^B_{nm} = \sum_i q_i(p,t)\sin\left(n\,\varphi_i\right)\frac{\jmath_n\left(\alpha_{nm} r_i\right)}{\left(\jmath_n'\left(\alpha_{nm} a\right)\right)^2}$$

Temporal variation of the oxygen flux

^{16}O at 10 GeV/nuc



^{16}O at 5 TeV/nuc



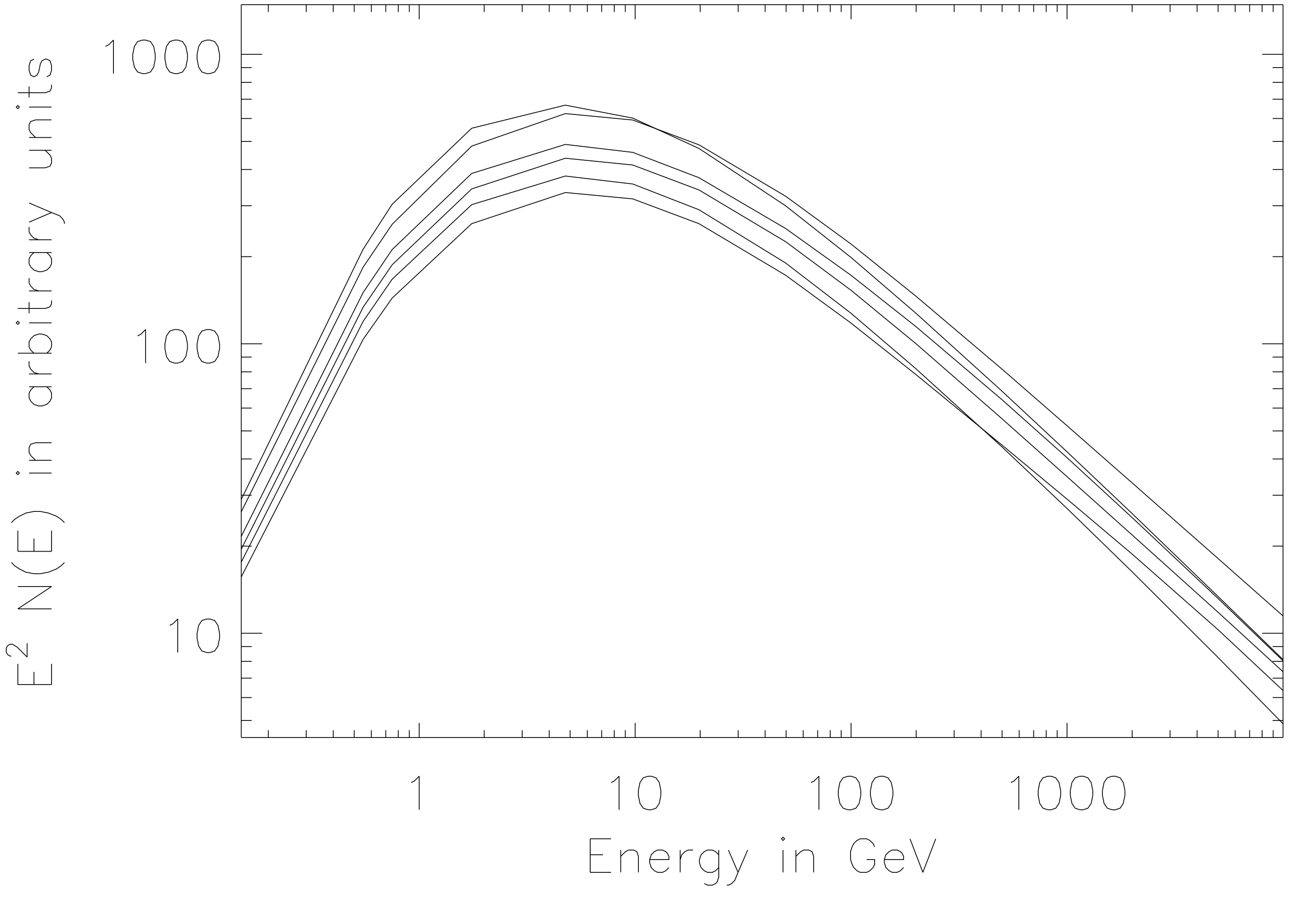
Variations by typically 20% with high amplitude spikes!

The spectra of cosmic rays

Sample of possible ^{12}C spectra

given at top-of-atmosphere

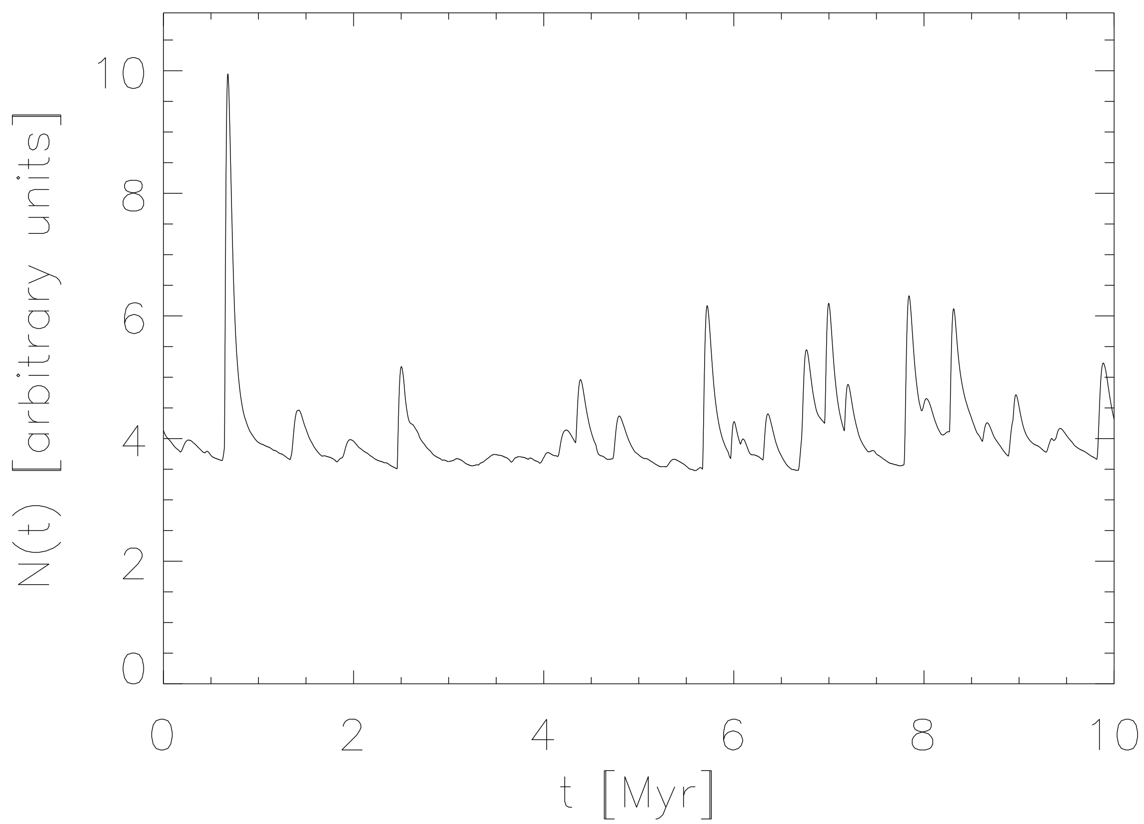
assuming $\Phi = 500$ MV.



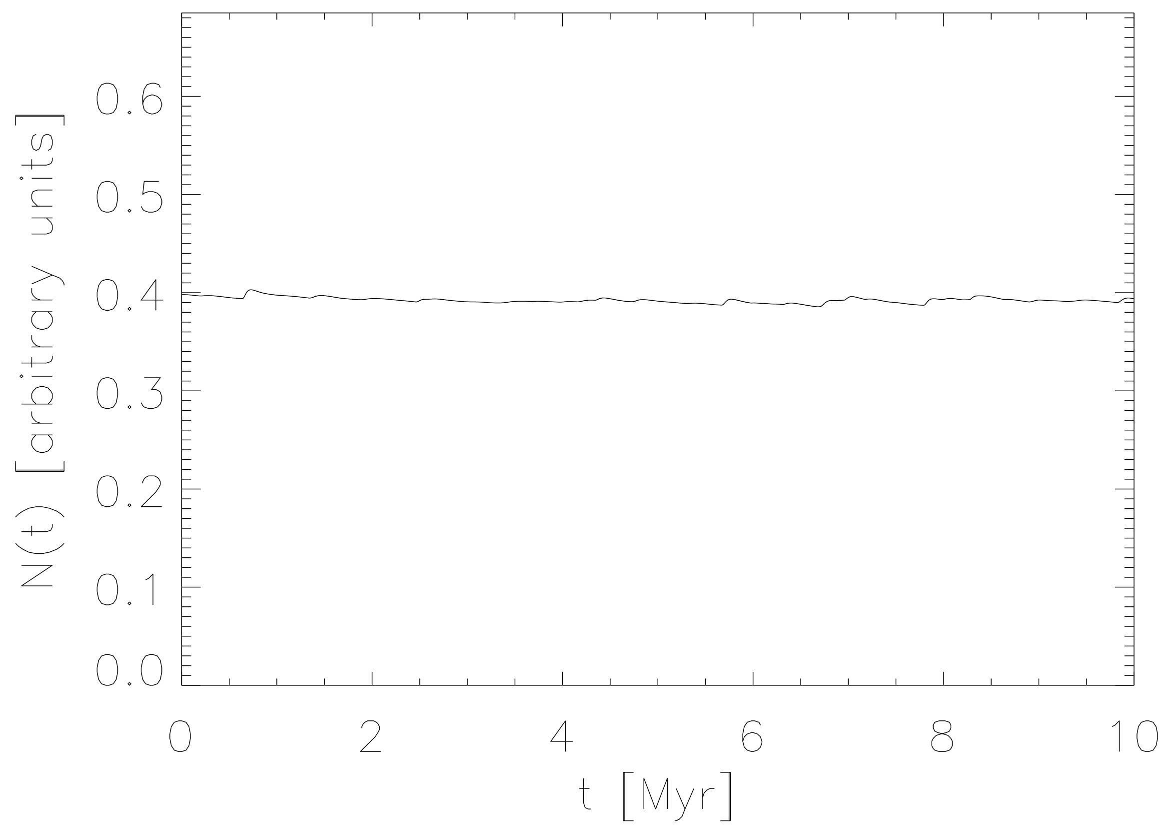
Only the flux varies, not the spectra!

Primary cosmic rays vs. secondaries

^{12}C at 10 GeV/nuc



^{11}B at 10 GeV/nuc



Only primary cosmic rays are affected by flux variations!

The B/C ratio varies!