I. $P_{\text{bar}}/D_{\text{bar}}$ astrophysical uncertainties

II. A multi-purpose 1D toy-model

+ approximate formulae

IHEP - Beijing

2nd Sino-French Workshop on the Dark Universe
Starting point: minute study of propagation of the nuclear component in order to uncover the main astrophysical uncertainties on standard and exotic fluxes.
I. Pbar/Dbar astrophysical uncertainties

1. Determination of the transport coefficients
2. Our « simplified » 2D-model
3. Uncertainties
   - For pbar/dbar “standard” fluxes
   - For exotic sources filling the DM halo
Sources
(acceleration in shock waves)

Propagation (1)
(diffusion on magnetic inhomogeneities)

Interaction
(with interstellar medium)

Propagation (2)

Detection on Earth…

can thus be evaluated…

I. 1. Anti-protons from B/C
The two-zone diffusion/convection model

Diffusion/convection equation:
\[
\frac{\partial N_j}{\partial t} - (K\Delta - V_c)N_j = q(r,z)Q(E) + \sum_k \{ n(r,z)v_\sigma_{\text{prod}} + \Gamma_{\text{rad}} \} N_k
\]

\[\rightarrow \text{Nuclear charts (Z<30)}\]
- 77 nuclei and stable isotopes
- 18 $\beta$ or EC-unstable
(electron attachment and stripping)
- Production and destruction cross sections
(includes ~500 very short half-life nuclei)

i) Simplified geometry (cylindrical symmetry)
- Gas distribution (thin disk)
- Source distribution (thin disk)
- Diffusive halo (L)

ii) Steady-state sources
- Spectrum
- Isotopic abundances

iii) Transport coeff. (independent of the position)
- Diffusion/convection
- Coulomb./Ion./Adiab. losses + reacceleration

Semi-analytical solution

I. 2. Our « simplified » model
Anti-proton « standard » flux

Propagation parameters adjusted to fit the B/C data

→ no free parameters for standard pbar/dbar!!

Note: strong degeneracy between the transport coefficients (not even broken by radioactive species) [Donato, Maurin & Taillet, A&A 381, 539 (2002)]

Standard fluxes: same propagation history (emitted from the disk): not sensitive to this degeneracy

⇒ But what about the exotic contribution?

I. 3. Uncertainties...
Astrophysical uncertainties on exotic sources

=> Two sets of propagation parameters compatible with B/C give different exotic fluxes!

=> Any exotic sources are sensitive to the propagation parameter degeneracy
   Because standard and exotic pbar/dbar do not have the same propagation history!
   (sources in the diffusion halo instead, not in the disk)

=> What really happens in the galactic halo is not well constrained!

I. 3. Uncertainties...
Sources of uncertainty

**Standard physics (bkgd)**

(p,He)CR + (H,He)ISM $\rightarrow$ pbar

- CR p/He spatial distribution
- p/He spectral shape
- ISM spatial distribution
- Nuclear X-sections

**New physics (signal)**

$\chi\chi$ $\rightarrow$ pbar

- DM spatial distribution
- Spectral shape
- NFW MOORE
- SUSY
- clumpiness
- Boost factor: 1-1000 (?)
- Variance: galactic lottery

**Source term**

- pbar effective "source spectrum"

**Propagation**

- Standard pbar
  - i) Nuclear cross-sections: 25%
  - ii) Propagation
    - Low energy (<GeV): <10%
    - High energy: <25%

- Exotic pbar
  - i) DM profile (depends on propag.)
    - Best case: no dependence
    - Worst case (?): $\sim 2$
    - ii) Propagation
      - Low energy (<GeV): $\sim 100$
      - High energy: $\sim 10$

**Note:** same for dbar + uncertainty on dbar production

1.3. Uncertainties...
II. A multi-purpose 1D-model

1. Two types of uncertainties
2. A toy-model to compute $\bar{p}/\bar{d}$
What if... different models give different results?

1) Uncertainties within a given model
   (aka departure from the best fit)

2) Different fluxes from different models
   (aka difference between best fit from two non-equivalent modelling)

=> Reducible if better data on CR nuclei

=> e.g. linear (GALPROP model) vs constant wind (the model we use)

II. 1. Two types of uncertainties
A toy model for exotic anti-protons

\[ L' = 10L \quad \text{and} \quad K' = 10K \]

Standard sources (disk)

\[ -KN'' + (V_{\text{gal}}N)' + 2h\delta(z)N_i\sigma N = 2hq\delta(z) \]

\[ \langle x \rangle_{\text{pure-diffusion}} = \frac{L\mu\nu}{2K} \]

Note: B/C determines the grammage \( \langle x \rangle \)

Exotic sources (DM halo)

\[ -KN'' + (V_{\text{gal}}N)' + 2h\delta(z)N_i\sigma N = q_{\text{Dark}} \]

\[ N_{(\beta, d)}^{\text{pure-DM}}(z = 0) = \frac{q_{\text{Dark}}L^2}{2K} \]

Note: Propagation parameters were fixed by B/C

\[ L' = 10L \quad \text{and} \quad K' = 10K \]

\[ \langle x \rangle' = \langle x \rangle, \]

hence the same pbar secondary flux

\[ N' = 10N \]

hence different primary fluxes!

II. 2. Analytical 1D-model
Simplified formulae for anti-proton and anti-deuteron primary fluxes

Niceties of 1D-models:
- allows to assert and inspect differences when using various transport condition
- nice alternative for quick evaluation of pbar/dbar in some cases (e.g. for SUSY scan)

=> see Maurin, Taillet & Combet (coming soon…)

II. 2. Analytical 1D-model
If you had to retain only one thing...

A) Present status: many set of propagation parameters lead to the same B/C ratio so that
- you end up with the same standard pbar/dbar flux (uncertainties under control),
- but with different fluxes for the exotic contribution!

➔ Exotic theories are difficult to constrain in that case, unless astrophysical parameters are better known (need better data on CR nuclei)!

B) Warnings
- Beware of degeneracies in transport parameters!
- Be aware that successful models might only be effective models!

C) Conclusions
⇒ Study of CRs in their entirety is certainly not an option (such as, e.g., the GALPROP model)
⇒ But don't forget about treacherous astrophysical uncertainties!
⇒ A piece of C++ code distributed to exclusion purpose for CR exotic pbar fluxes.

II. 2. Analytical 1D-model
15 June 2006
PAMELA has been launched from the cosmodrome of Baikonour, in Kazakhstan!

21 June 2006
PAMELA has been switched on

Several tens of thousands of pbar expected in 3 years...