Cosmic Ray Charged Nuclei propagation in the Galaxy

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Plan

I – Links with _-rays

II – Reminder about propagation models

III – « Local » effective propagation parameters

IV – Shortcomings of standard models

V – Conclusions and perspectives

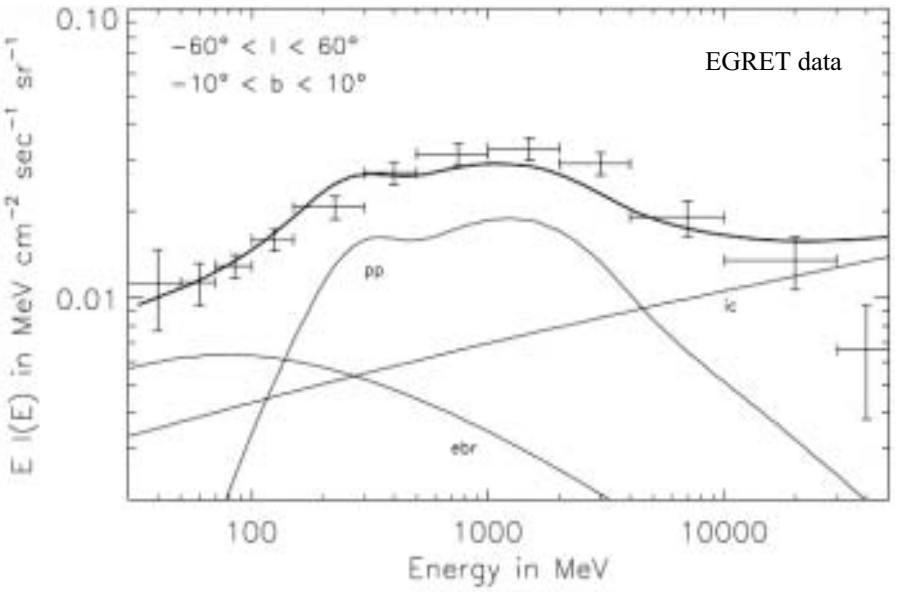
From protons and electrons to diffuse _-rays

Contributions:

i) p+p via π° (dominant ~ GeV)

ii) e- (bremsstrahlung, inverse Compton)

Pohl & Esposito, ApJ **507**, 327 (1998)

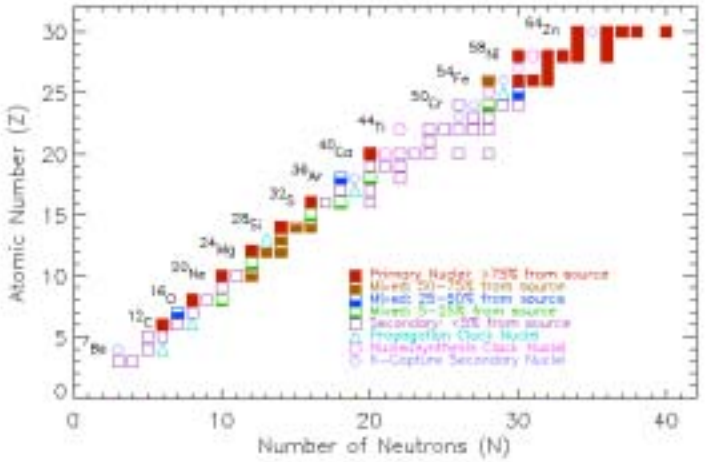


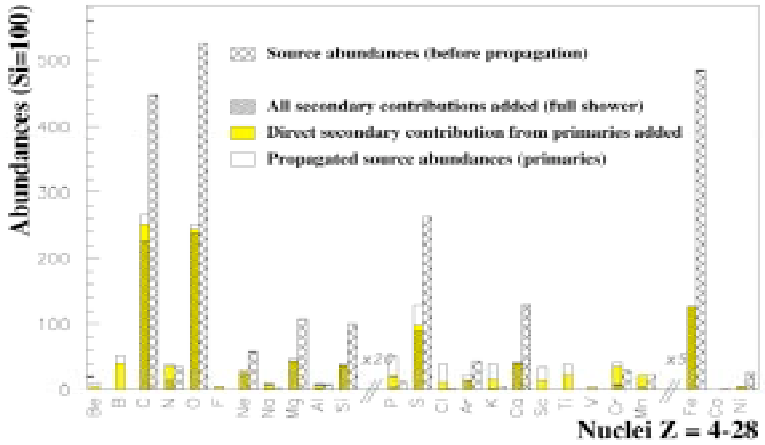
→ Evaluation of the equilibrium spectra in the whole Galaxy!

1. Sources: discreteness, time evolution and spectra
2. Gas distribution: in the galactic plane, around the sources
3. Propagation parameters: # of param., spatial dependence?

A Leaky Box to understand many data, save what really happens in the Galaxy…

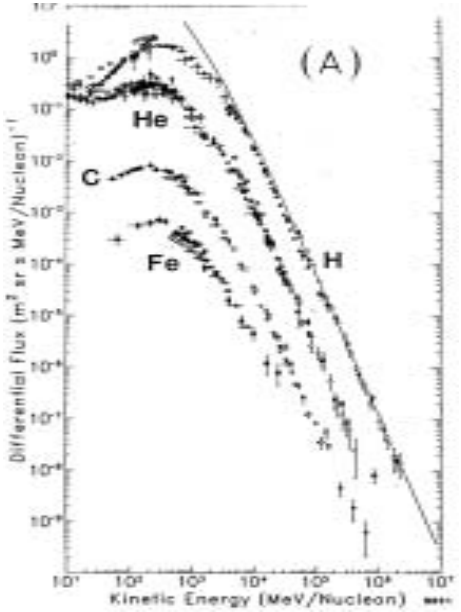
(http://www.srl.caltech.edu/ACE/CRIS_SIS/cris.html)





Simpson, Ann. Rev. Nuc. Part. Sci. **33**, 323 (1983).

Abundances/spectra: primaries *vs* secondaries



« Standard » ingredients

→ Nuc. charts/cross sections (catastrophic losses)

→ Energy losses and gains

→ $dQ/dp = p^{-}\_^{a}$

Plug 'in a LB

(no geometry, no spatial dependence)

→Average sources q^a.Q(E) in the box

→Average density of gas in the box

Output

- **All abundances q^a**
- **Slope of primaries $\_^a$**
- **A leakage time $\_esc(R)$**

(balance between nuclear time and escape to produce secondaries)

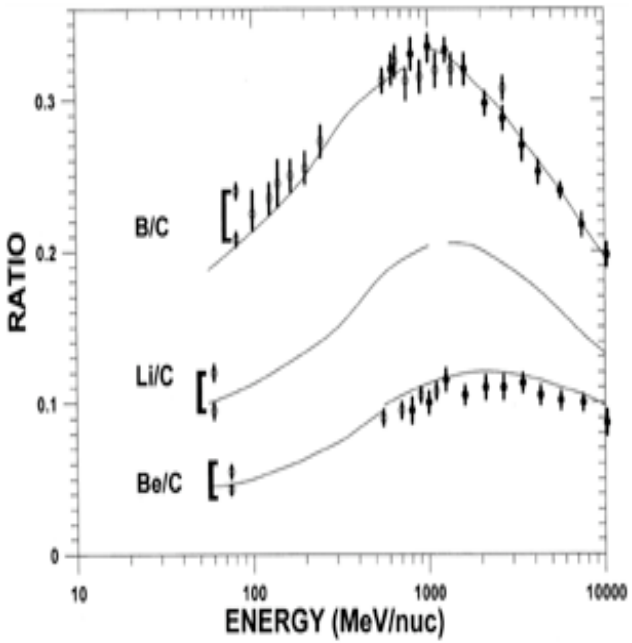
II – Propagation models…

Leaky Box *vs* Diffusion Model

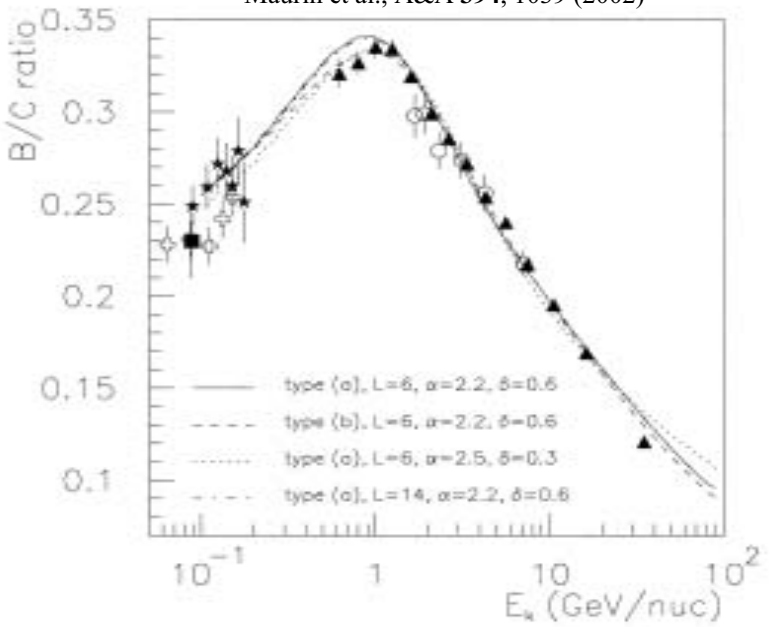
Effective parameter _esc(R) *vs* True (?) parameters

+ geometry + source/gas distribution

Webber et al., ApJ **568**, 210 (2002)



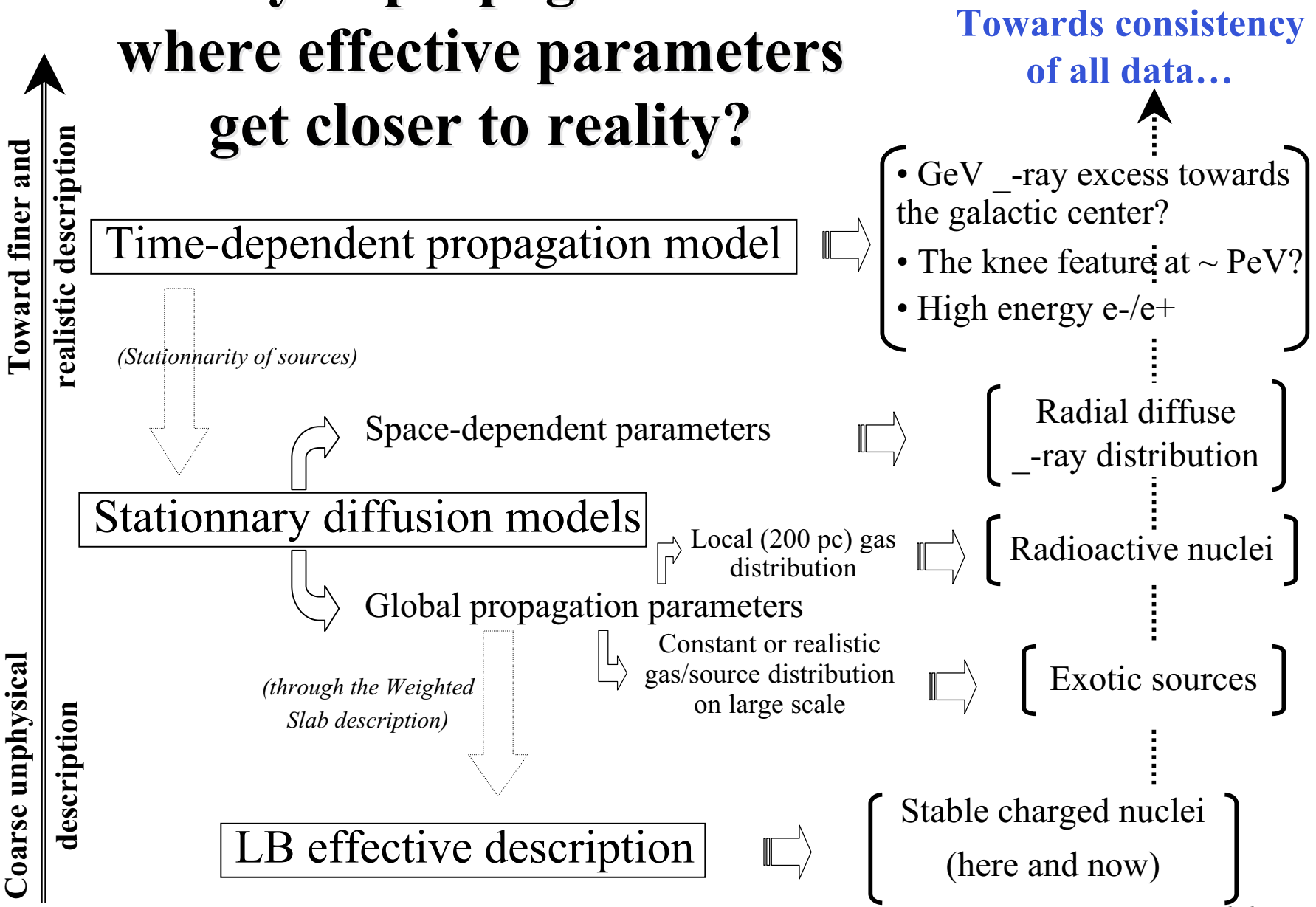
Maurin et al., A&A **394**, 1039 (2002)



→ Both fit equally… but the leakage lifetime approach fails to describe:

1. Radioactive nuclei (e.g. _^{9}Be)
2. Electrons and positrons
3. Exotic sources in the halo (DM, PBH)
4. … what really happens!

Hierarchy of propagation models: where effective parameters get closer to reality?



Ask an expert!

« Such quantities as the density of secondary nuclei and its fluctuations and also the age distribution of the particles […] on the local conditions, are typical of the Galaxy as a whole. […] The fact that the density fluctuations of Cosmic Rays are small justifies the approximation of a source distribution which is continuous in space. »

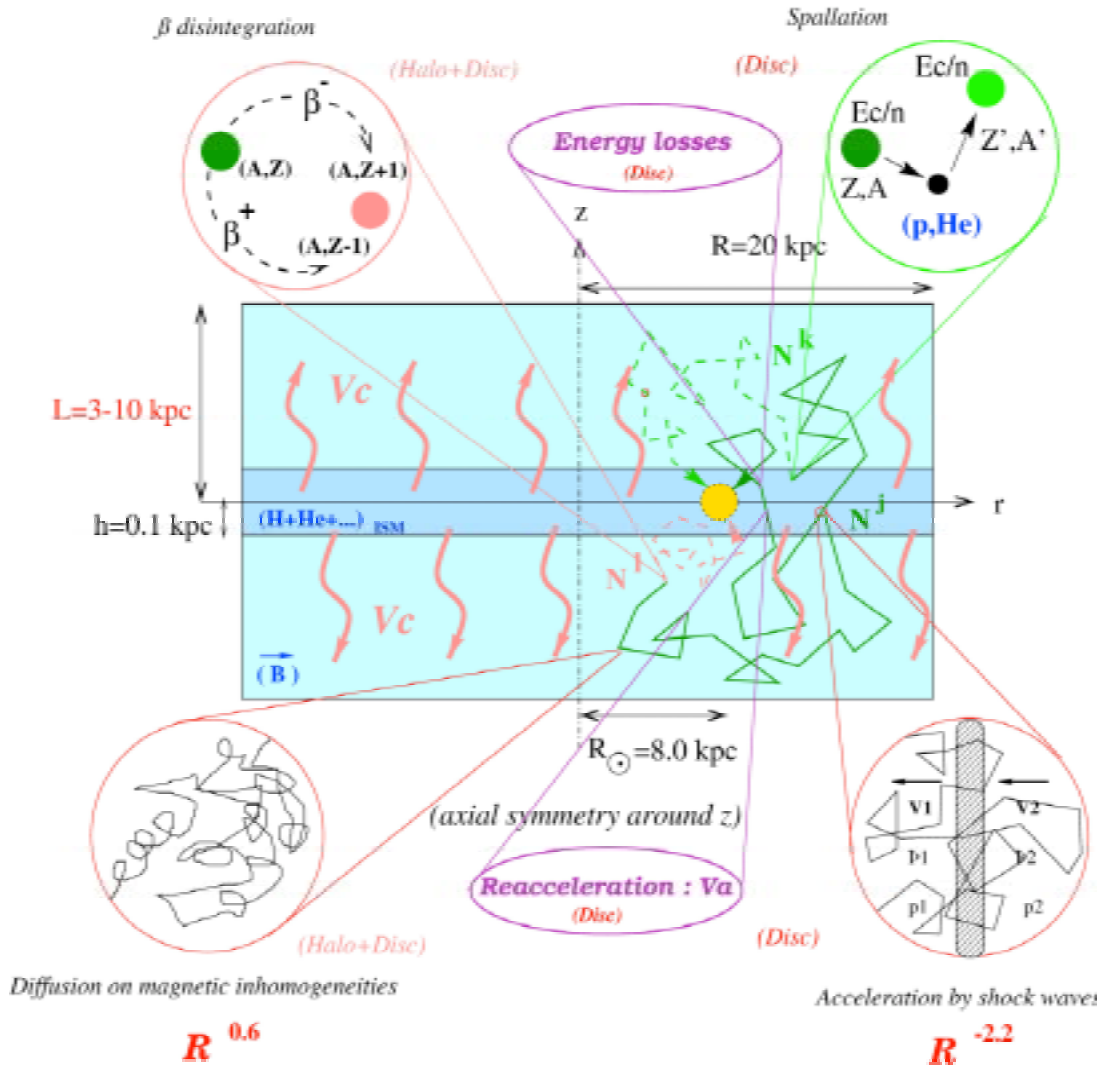
_____ et al., 1990

1. Continuous sources
2. Stationnary propagation models
3. Constant propagation parameters throughout the Galaxy

… but spectra should differ far from or near a source

Where is « near », especially for _-rays?

A « classical » semi-analytical diffusion model



Theoretical/observationnal prior knowledge

(spiral arm structures discarded + isotropic diffusion tensor)

SOURCES

• dQ/dp = R^{-}– with _ ~ 1.8-2.2

• SN remnants radial distribution

/

GEOMETRY

• Diffusive halo: L ~ 3-15 kpc

• Sources and gas: thin disk (~200 pc)

DIFFUSION

Spatial diffusion:

• K(R) = Ko . _ . R– with _ ~ 1/3

Diffusion in energy:

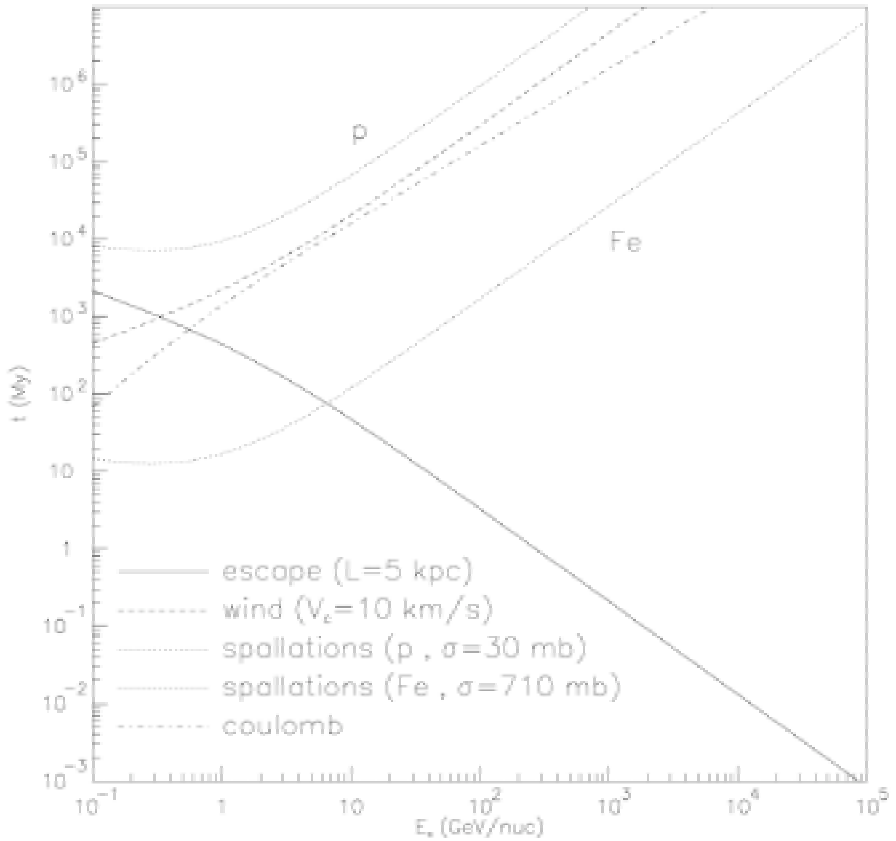
Minimal reacceleration (quasi-linear theory)

• Kpp(R) = 4p_V_a/[3_(4- __)(4- _) K(R)]

CONVECTION

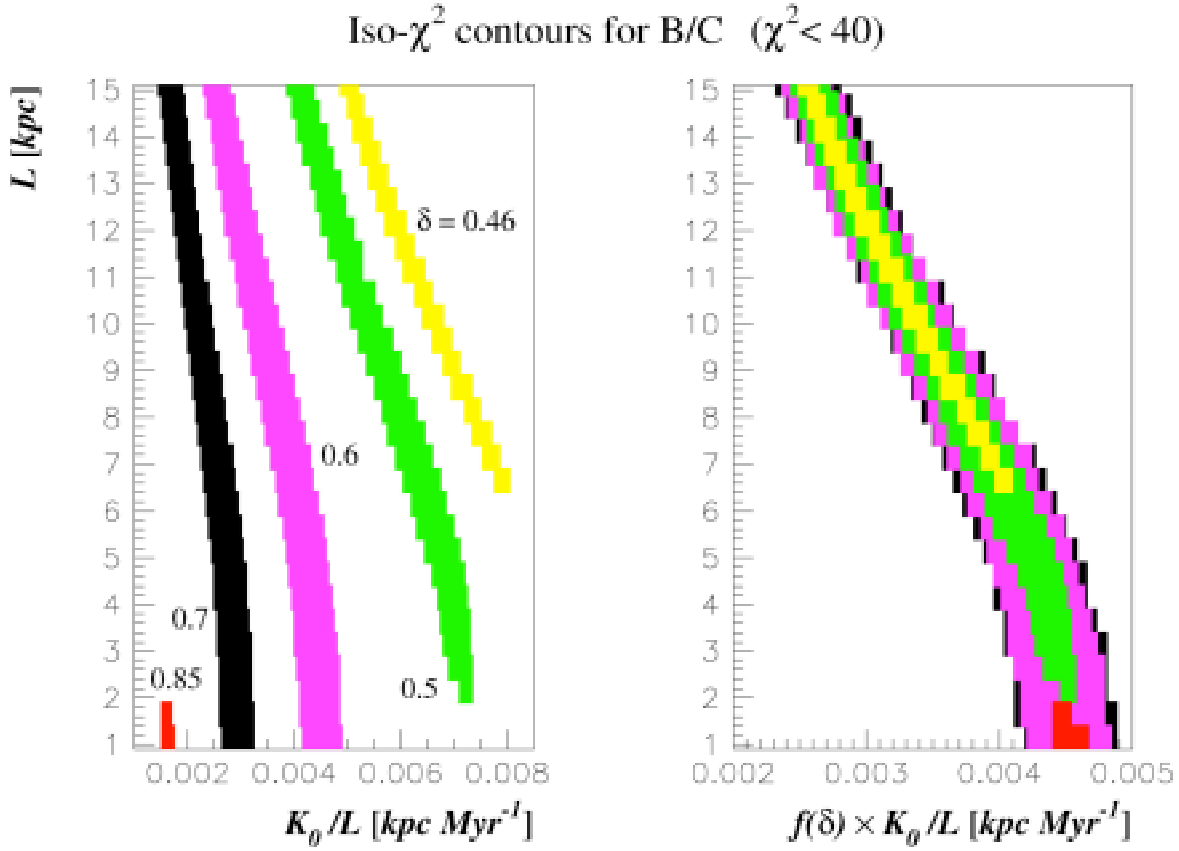
→ seems to be demanded to best fit CRs data

Relative strength of various effects



→ All models turn into pure diffusion models at high energy

Degeneracy of parameters



Maurin et al., ApJ **555**, 585 (2001)

Ko ≡ diffusion norm.

δ ≡ diffusion slope

L ≡ Halo size

(best __ = 25.5 for 26 data and 5 free parameters)

→ _ = 1/3 excluded

◊ Vc = 0 excluded

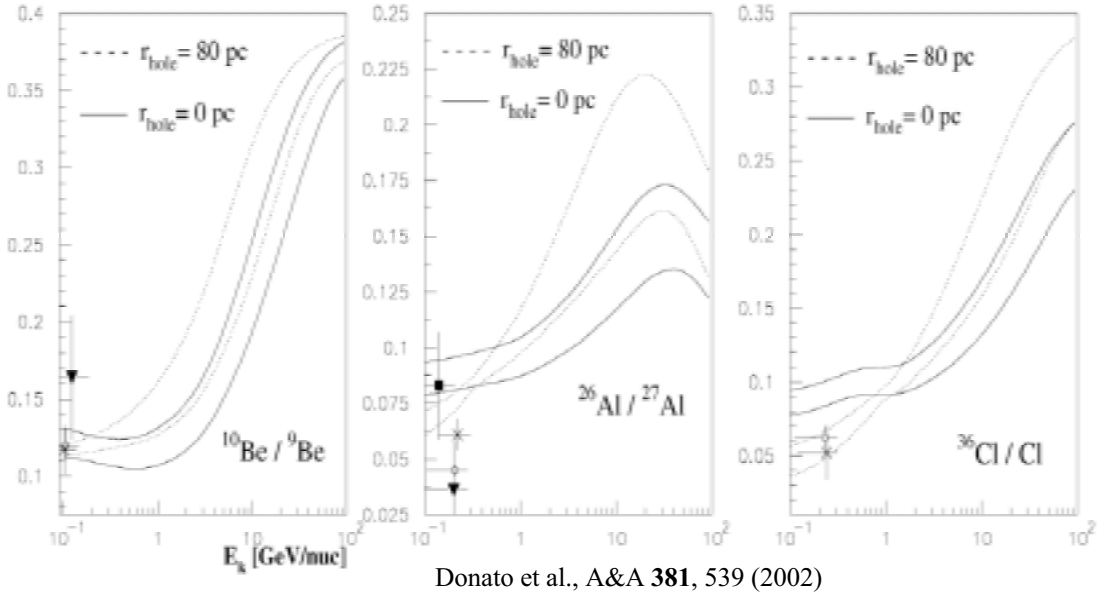
→ radioactive nuclei (e.g. _^{9}Be) should break degeneracy and give L (halo size)…

Why the result L = 4 kpc from GalProp is disputable…

→ The local underdensity (a ≈ 100-200 pc, no gas) affects the unstables

- Typical length before decay: $l_{\rm rad} = \sqrt{D(\mathcal{R})\gamma\tau_0}$
- Attenuation factor: $\kappa \approx \exp\left(-a/l_{\rm rad}\right)$

Envelopes generated by constraining ^{10}Be/^{9}Be ratio (1σ ACE data)



Donato et al., A&A **381**, 539 (2002)

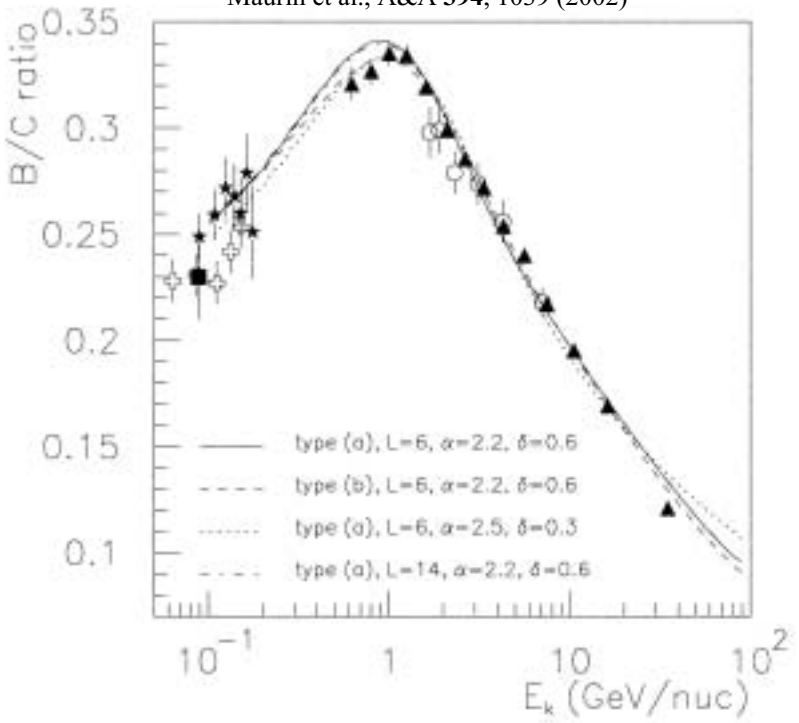
→ **L ≤ 12 kpc** (degeneracy remains)

Unstable nuclei in GalProp, that perfectly fit the data (according to the authors) should be multiplied by _:

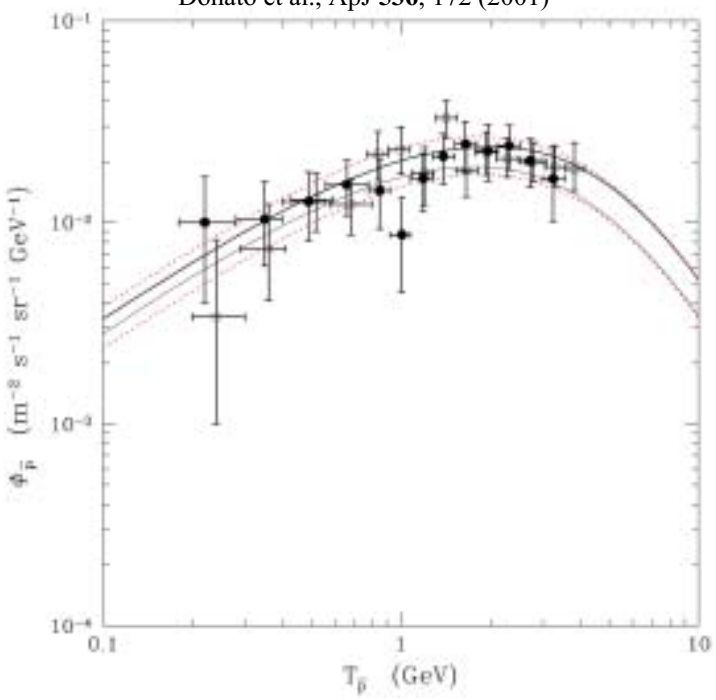
Species	τ_0 (Myr)	$l_{\rm rad}$ (pc)	κ
^{10}Be	2.17	351	0.57
^{26}Al	1.31	273	0.48
^{36}Cl	0.443	159	0.28
^{54}Mn	2.9[a]	406	0.61

… but why B/C + antiprotons are not OK in GalProp?

Maurin et al., A&A **394**, 1039 (2002)



Donato et al., ApJ **536**, 172 (2001)



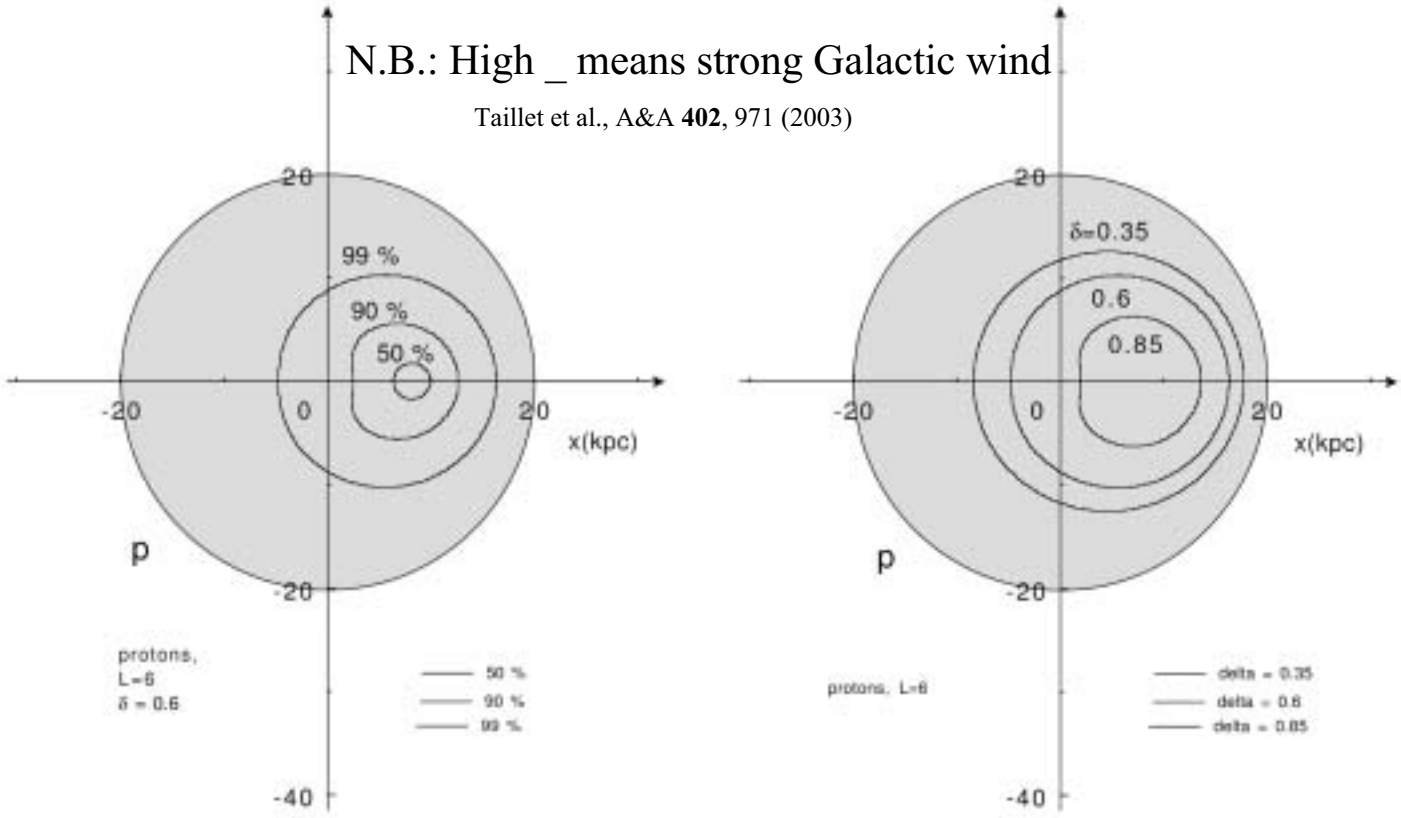
→We disagree with most of GalProp conclusions!

(Where is the failure? None model is correct?)

… anyway, our derived parameters may be only « effective » parameters?

N.B.: High _ means strong Galactic wind

Taillet et al., A&A **402**, 971 (2003)

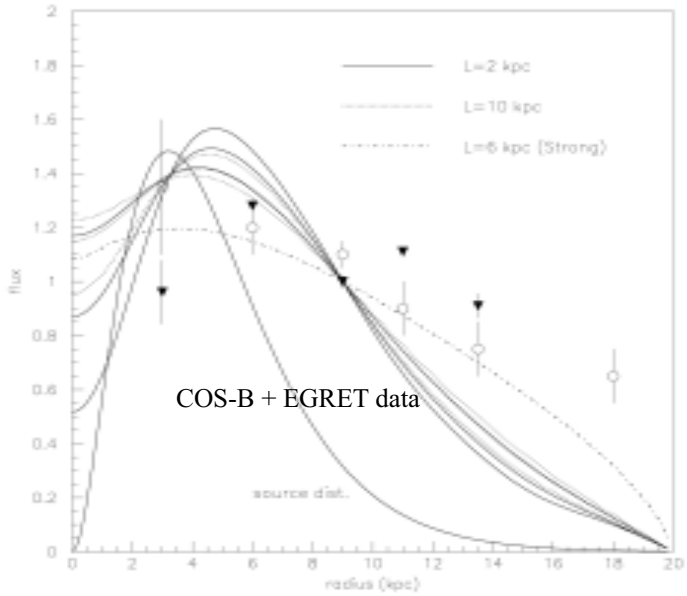


→ A stationnary model if _ is high, cannot be supported by heavy nuclei…

Back to the diffuse emission: two « non »-persistent problems

Radial diffuse emission

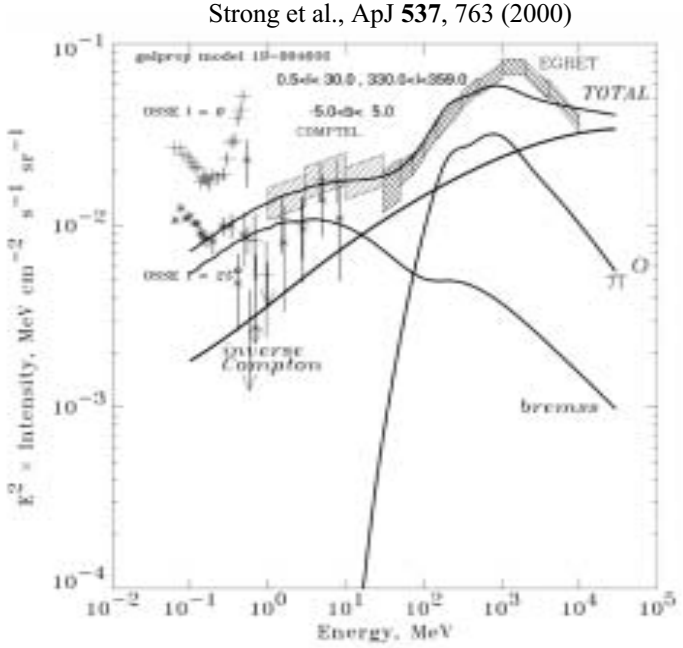
Maurin et al., A&A **394**, 1039 (2002)



1. Change the source distribution?
2. Galactic wind depends on location
3. Abandon the steady state hypothesis?
4. Include the spiral arms structure?
5. Error in the radial diffuse emission estimation?
6. … other ideas?

Excess toward the Galactic center

Strong et al., ApJ **537**, 763 (2000)



1. Change the source spectral indexes?
2. Change the electron spectra?
3. Abandon the steady state hypothesis?
4. Include the spiral arms structure?
5. New physics (WIMPs annihilation)?

…

« Standard » solutions exist!

- _-ray radial distribution and solutions

-Strong et al., A&A **207**, 1 (1998)

-Breitschwerdt, Dogiel & Völk, A&A **385**, 216 (2002)

-Erlykin & Wolfendale, J. Phys. G: **28**, 2329 (2002)

- _-ray excess towards the GC and solutions

-Büsching, Pohl & Schlickeiser, A&A **377**, 1056 (2001)

-Breitschwerdt, Dogiel & Völk, A&A **385**, 216 (2002)

-Erlykin & Wolfendale, J. Phys. G: **28**, 2329 (2002)

→ « old astrophysics » should be pushed one step beyond…

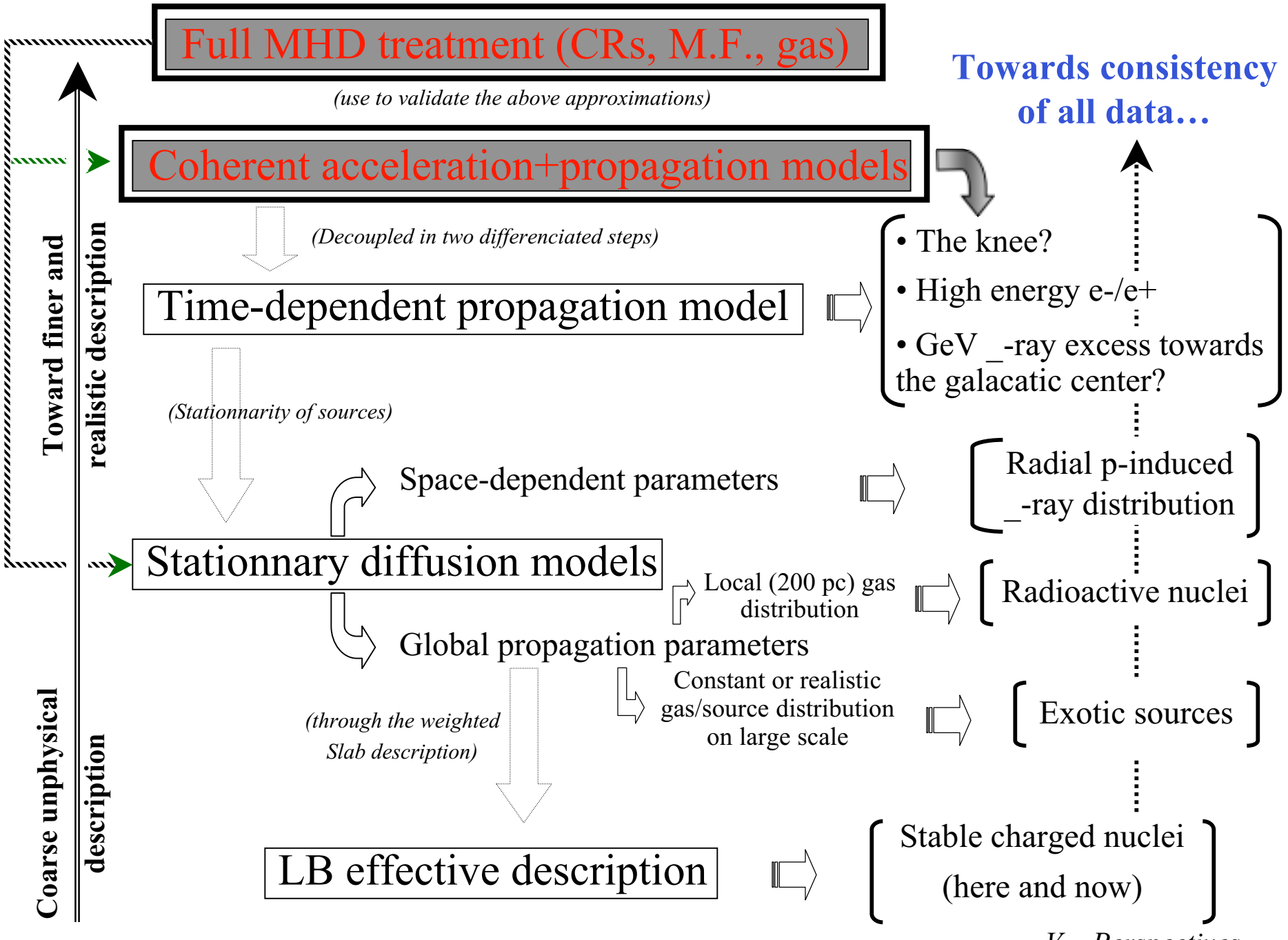
Would there be room for « new physics »?

…a personal point of view

→ Be aware of GalProp shortcomings (as some of its results on nuclei are disputable)

→ Consistency between present data (nuclei, e-e+ and _) is likely to be within reach!

… before GLAST, AMS, PAMELA data bring hundreds of new questions.


Full MHD treatment (CRs, M.F., gas)
(use to validate the above approximations)
Towards consistency of all data…
Coherent acceleration+propagation models
(Decoupled in two differenciated steps)
Time-dependent propagation model
• The knee?
• High energy e-/e+
• GeV _-ray excess towards the galacatic center?
(Stationnarity of sources)
Space-dependent parameters
Radial p-induced _-ray distribution
Stationnary diffusion models
Local (200 pc) gas distribution
Radioactive nuclei
Global propagation parameters
Constant or realistic gas/source distribution on large scale
Exotic sources
(through the weighted Slab description)
LB effective description
Stable charged nuclei (here and now)
Toward finer and realistic description
Coarse unphysical description
V – Perspectives…