Cosmic-Ray propagation with USINE

Collaborators: B. Coste, L. Derome, F. Donato,
A. Putze, P. Salati, R. Taillet...
+ many others.

Basic phenomenology, sample results, and a bit of USINE...

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IDMS2011
DESY, 15/6/2011

~ *Outline* ~

I. Secondary-to-primary ratio

II. Radioactive species

III. Primary species

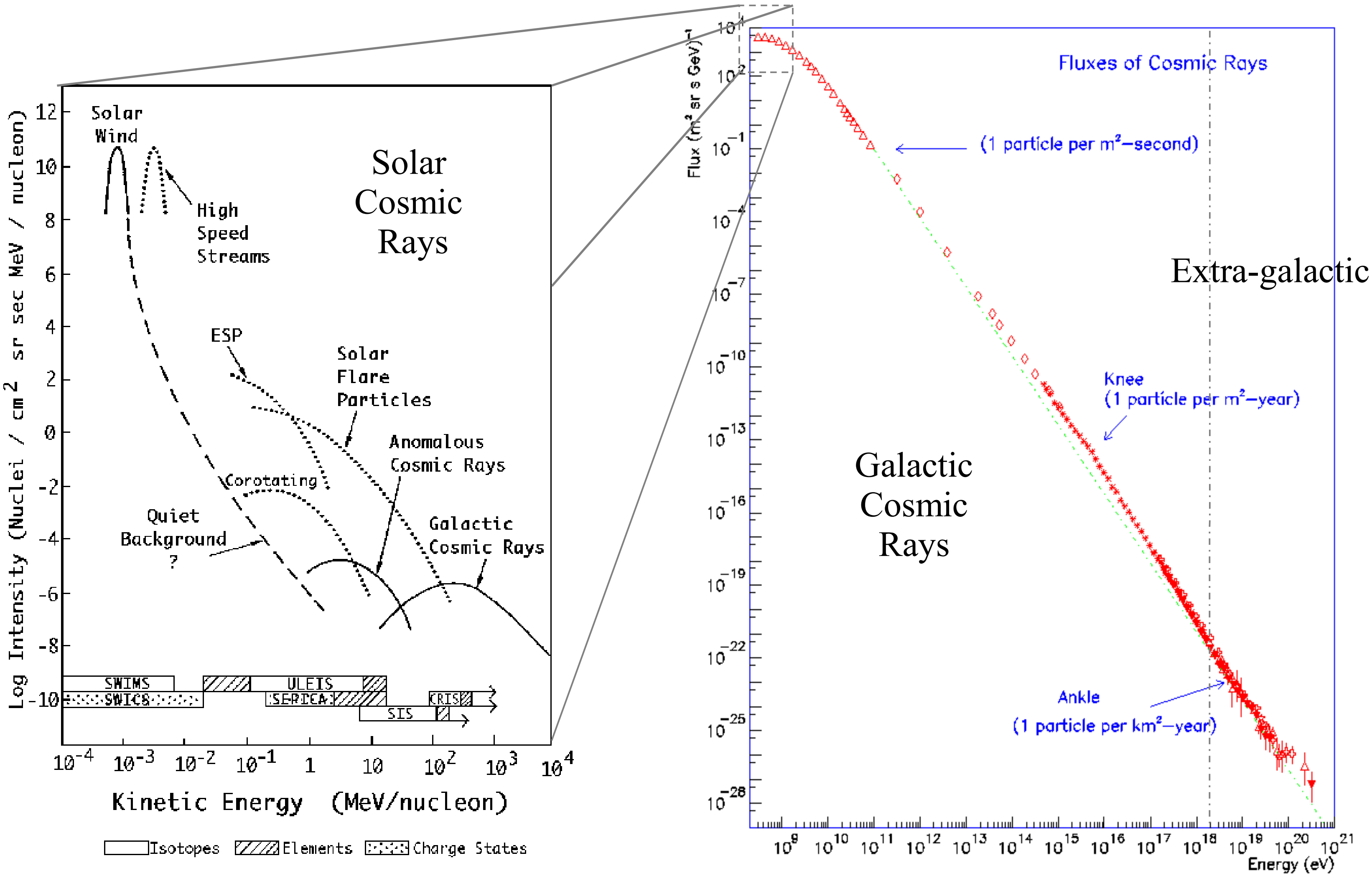
IV. Standard antiprotons and antideuterons

V. Exotic antiprotons and antideuterons

VI. Conclusions and USINE

N.B.: does not cover γ-rays (see Andy Strong's talk), leptons (see Fiorenza Donato's talk), and only briefly antiprotons (see Pierre Salati's talk)

CR spectrum: from Solar to extragalactic origin

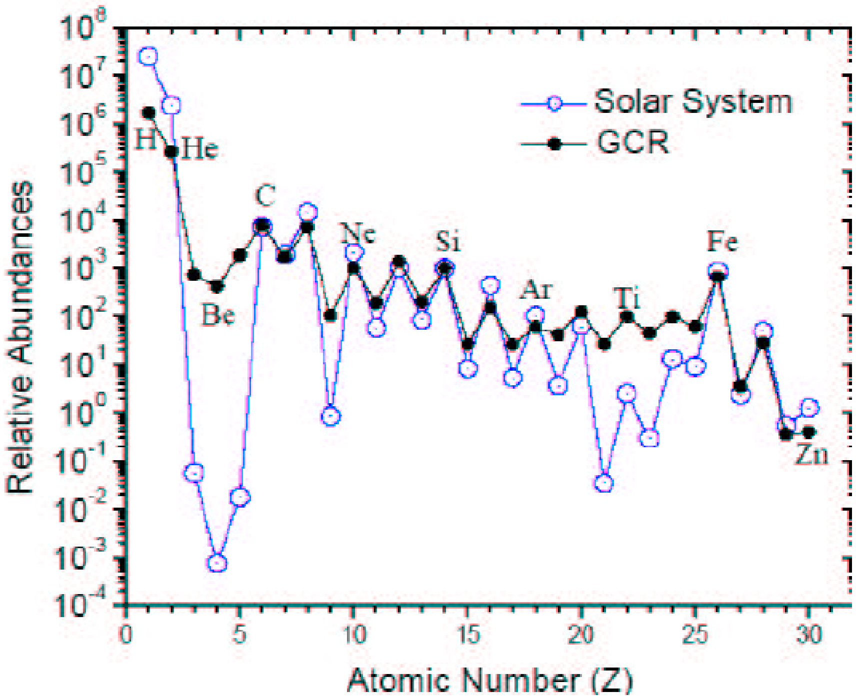


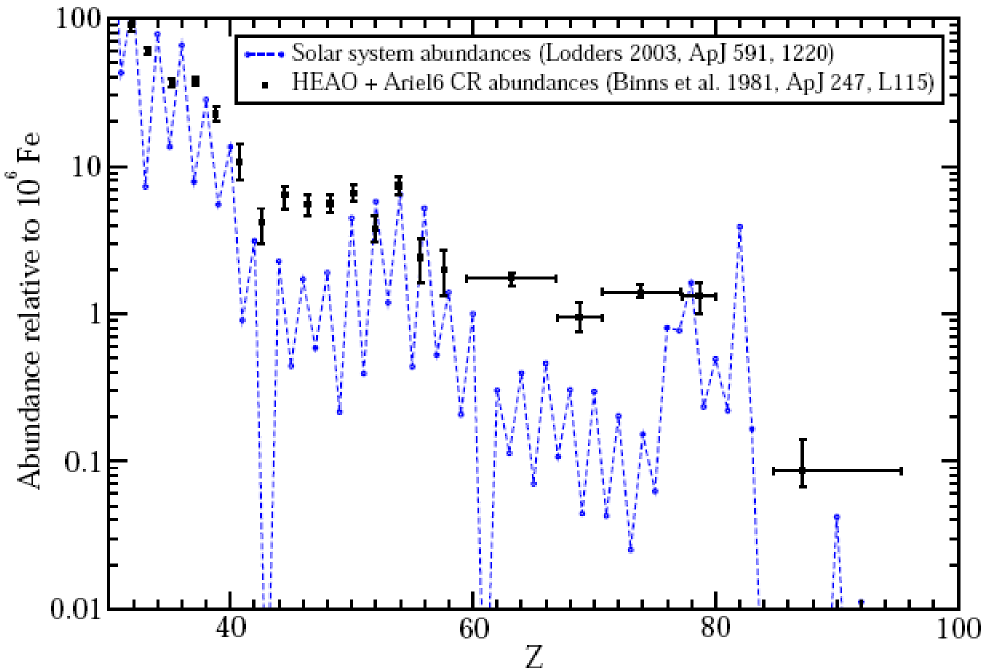
N.B.: Solar modulation of GCRs below GeV/amu energies

→ We focus on the GeV-TeV region: GCRs

Abundances: GCR vs Solar System

(secondary species to "calibrate" propagation)





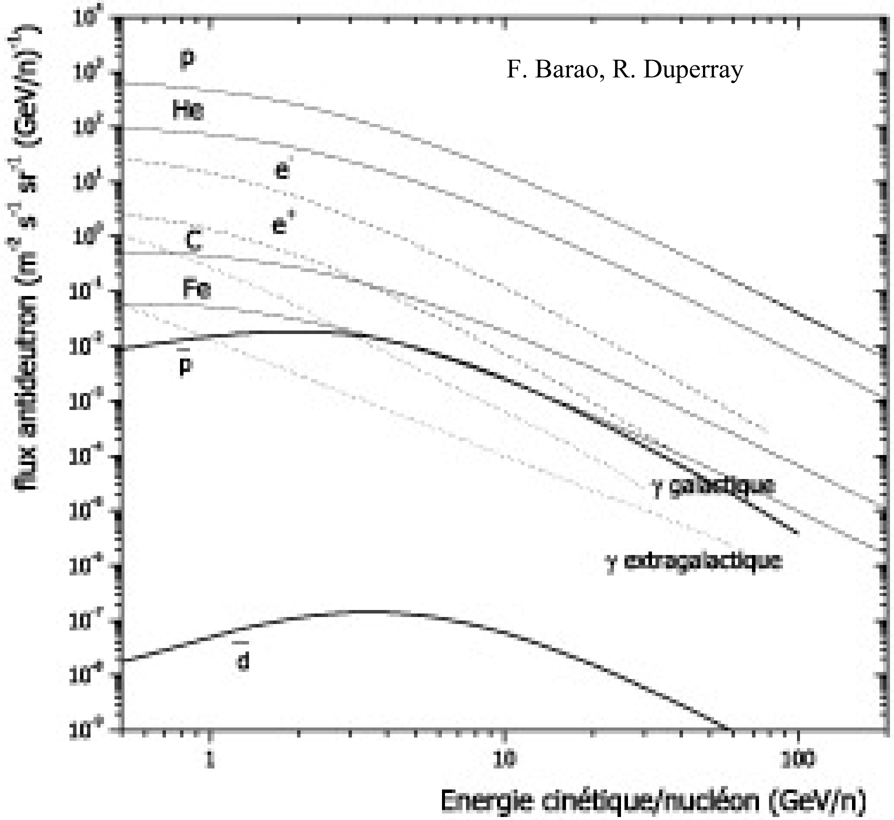
=> Primary species are present in sources (CNO, Fe)

- Stellar nucleosynthesis
- Acceleration in SN shocks ($\geq 10^4$ yr after nucleosynthesis, from radioactive primary Co/Ni)

=> Secondary species are absent of sources (LiBeB, SubFe)

- Produced during propagation of primaries (cross ~10 g cm^{-2} @ GeV/amu)
- Propagation timescale (confinement) ~ 10 Myr from ^{10}Be flux

Also γ, ν, antimatter…



<u>GCR content</u>

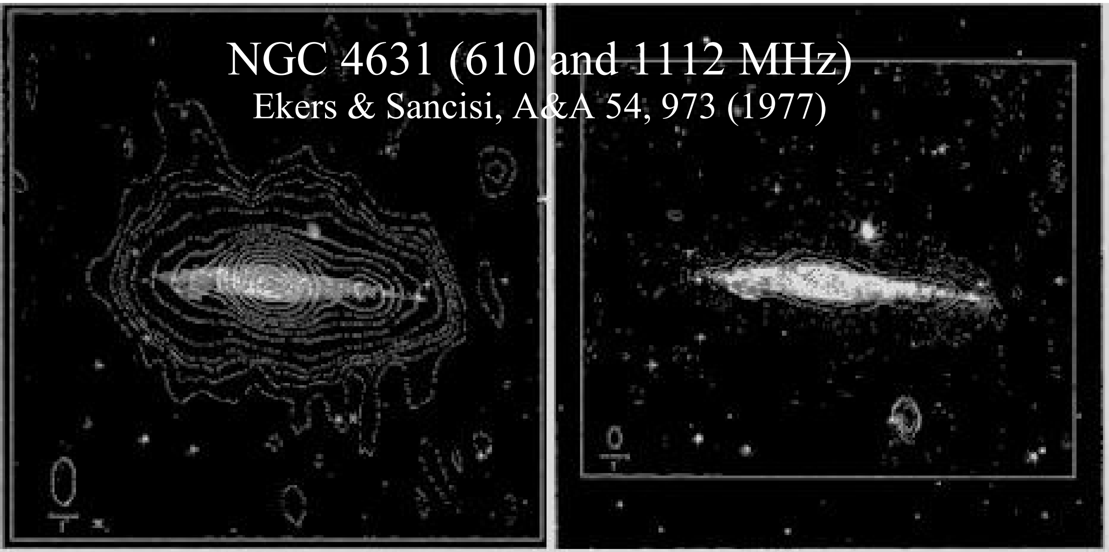
Nuclei: H, He, CNO, Fe… - Light, heavy, VH and UH - Stable, β and EC rad. **Electons** *[e/p ~ 1% @ GeV]*	<u>Matter</u>
Anti-nuclei: pbar, dbar… **Positrons** *[e^+/e^- ~ 10%]*	<u>Anti-Matter</u>
γ and ν	<u>Neutral</u>

N.B.: Information carried by neutral or charged particles is different!

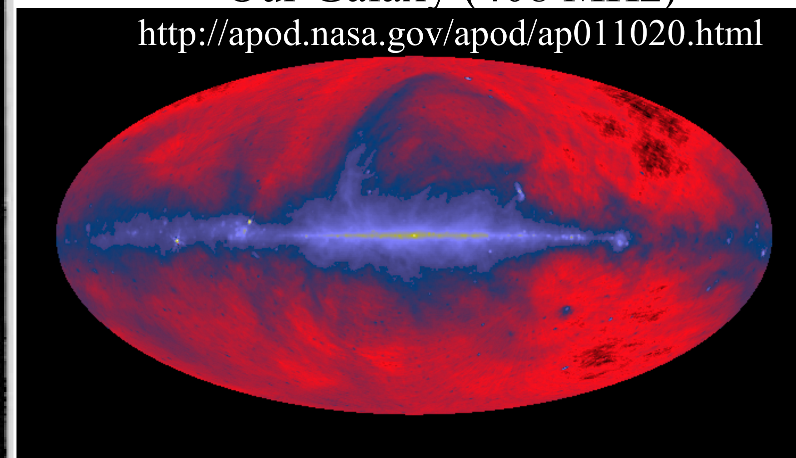
=> gamma-rays are measured along a line of sight

=> Charged particles diffuse: only a local measurement

Spatial distribution of GCRs



Our Galaxy (408 MHz)



Cosmic radio waves are generated by high energy electrons spiralling along magnetic fields. In the Milky Way, many of the bright sources near the plane are distant pulsars, star forming regions, and SN remnants. The grand looping structures are pieces of bubbles blown by local stellar activity.

=> Proof that cosmic rays (at least electrons)
pervade a larger zone (~ few kpc) than the disc thickness

Open questions

1. Do we understand the "standard" galactic fluxes?

- **Sources (SN, pulsars, SB...)**
- **Nucleosynthesis (r and s-process for heavy nuclei)**
- **Acceleration mechanisms (injection, B amplification)**
- **Propagation mechanisms (link to turbulence, spatial dependence, isotropy)**
- **Magneto-cosmico-gaseo properties of the Galaxy (MHD description)**
    - i) GCRs here/in the whole Galaxy (linked to diffuse emissions)
    - ii) GCRs now/in the past/future (linked with massive extinctions?)

2. Do we understand Solar Modulation?

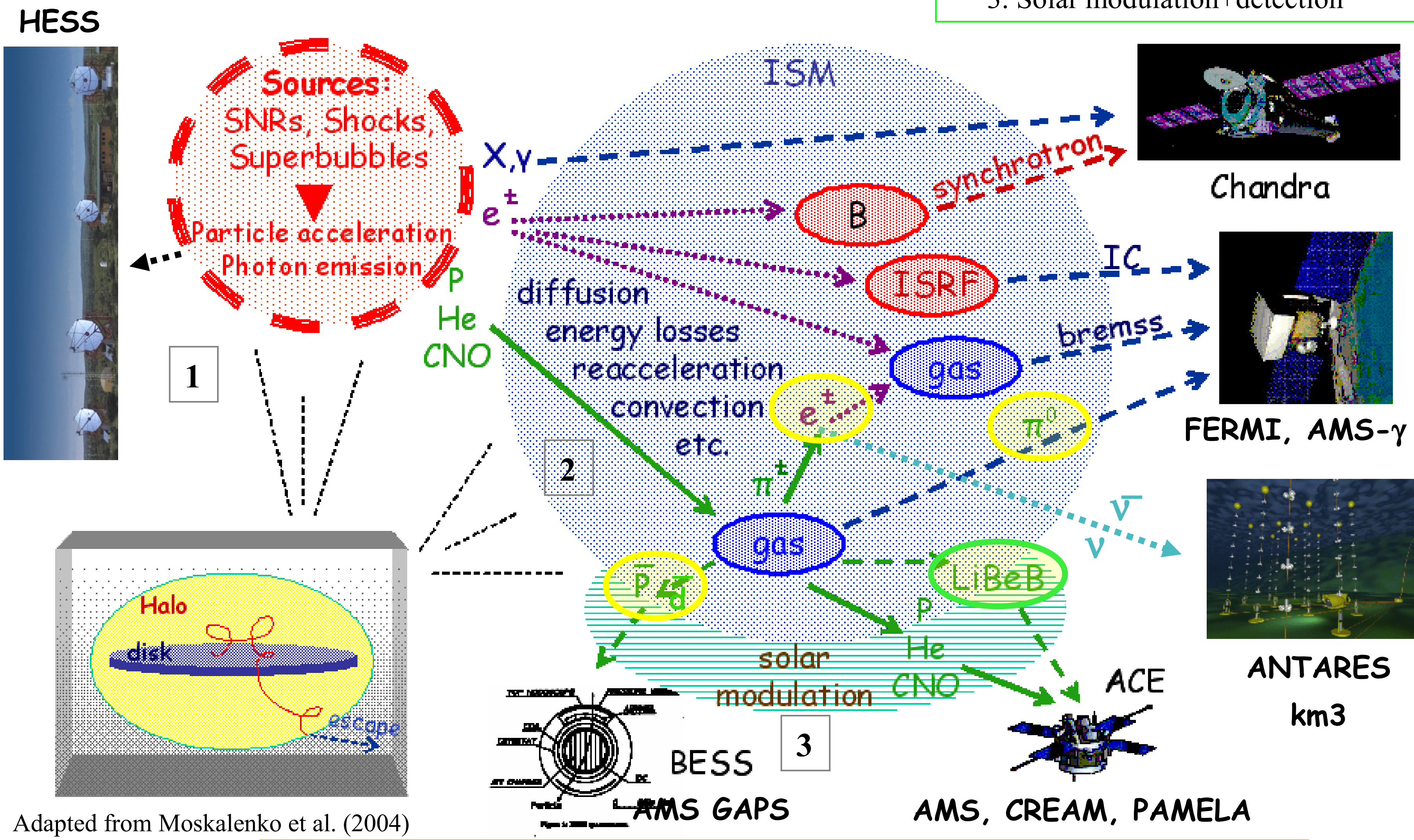
3. Are GCRs a good laboratory to search for new physics?

- **Dark matter/new physics ?**
- **Just standard astrophysics?**

From sources to detection: modelling the astrophysical 'backgrounds'

Cosmic Ray journey in 3 steps:

1. Synthesis and acceleration
2. Transport (diffusion & interactions)
3. Solar modulation+detection



Adapted from Moskalenko et al. (2004)

=> Search for DM where “standard” production is rare (secondary)

=> Use LiBeB to calibrate the transport coefficients

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Basics of transport: equation

$$\frac{\partial \psi}{\partial t} = q(\mathbf{r}, p) + \nabla \cdot (D_{xx} \nabla \psi - \mathbf{V} \psi) + \frac{\partial}{\partial p} p^2 D_{pp} \frac{\partial}{\partial p} \frac{1}{p^2} \psi - \frac{\partial}{\partial p} \left[\dot{p} \psi - \frac{p}{3} (\nabla \cdot \mathbf{V}) \psi \right] - \frac{1}{\tau_f} \psi - \frac{1}{\tau_r} \psi$$

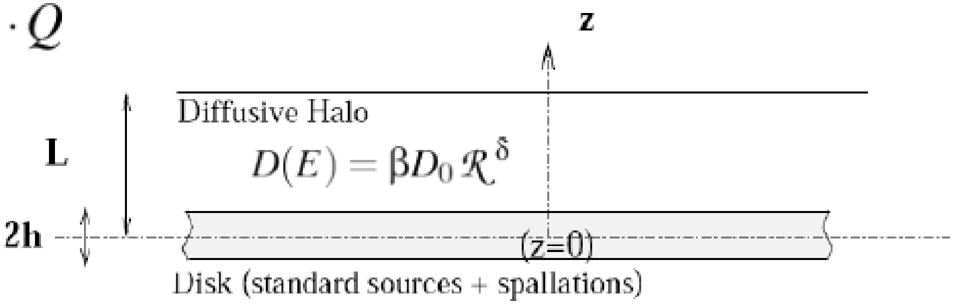
Basics of transport: simplifying assumptions

$$\frac{\partial \psi}{\partial t} = q(\mathbf{r}, p) + \nabla \cdot (D_{xx} \nabla \psi - \mathbf{V}\psi) + \frac{\partial}{\partial p} p^2 D_{pp} \frac{\partial}{\partial p} \frac{1}{p^2} \psi - \frac{\partial}{\partial p} \left[\dot{p}\psi - \frac{p}{3} (\nabla \cdot \mathbf{V})\psi \right] - \frac{1}{\tau_f} \psi - \frac{1}{\tau_r} \psi$$

Steady-state: 1D Diffusion Model *vs* LeakyBox Model

$$1\mathrm{D}: \quad -D\, N'' + 2h\delta(z) \cdot nv\sigma \times N = 2h\delta(z) \cdot Q$$

$$\begin{cases} N(z) = N(0) \cdot \dfrac{L - z}{L} \\ \dfrac{2D}{2hL} \cdot N(0) + nv\sigma N(0) = Q \end{cases}$$



Basics of transport: Do/L degeneracy

$$\frac{\partial \psi}{\partial t} = q(\mathbf{r}, p) + \nabla \cdot (D_{xx} \nabla \psi - \mathbf{V}\psi) + \frac{\partial}{\partial p} p^2 D_{pp} \frac{\partial}{\partial p} \frac{1}{p^2} \psi - \frac{\partial}{\partial p}\left[\dot{p}\psi - \frac{p}{3}(\nabla \cdot \mathbf{V})\psi\right] - \frac{1}{\tau_f}\psi - \frac{1}{\tau_r}\psi$$

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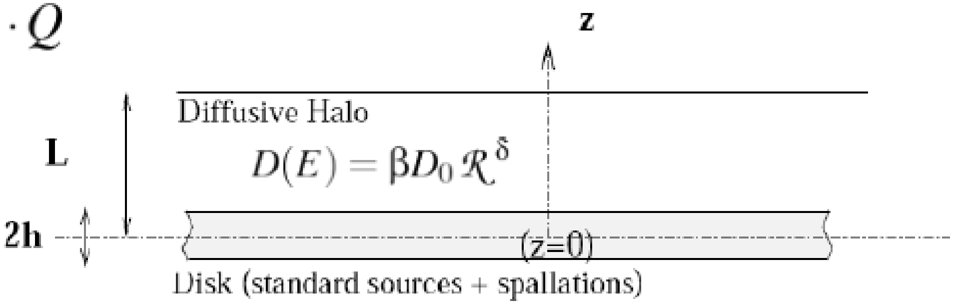

LB equation : $\dfrac{N}{\tau_{esc}} + \bar{n}v\sigma N = Q$ => Link between LBM and diffusion models

Degeneracy: Models with the same D_0/L are equivalent (secondary-to-primary production)
=> referred to as *"the degeneracy"* in the following

Basics of transport: diffusion and source slope

$$\frac{\partial\psi}{\partial t} = q(\mathbf{r}, p) + \nabla\cdot(D_{xx}\nabla\psi - \mathbf{V}\psi) + \frac{\partial}{\partial p}p^2 D_{pp}\frac{\partial}{\partial p}\frac{1}{p^2}\psi - \frac{\partial}{\partial p}\left[\dot{p}\psi - \frac{p}{3}(\nabla\cdot\mathbf{V})\psi\right] - \frac{1}{\tau_f}\psi - \frac{1}{\tau_r}\psi$$

Steady-state: 1D Diffusion Model *vs* LeakyBox Model

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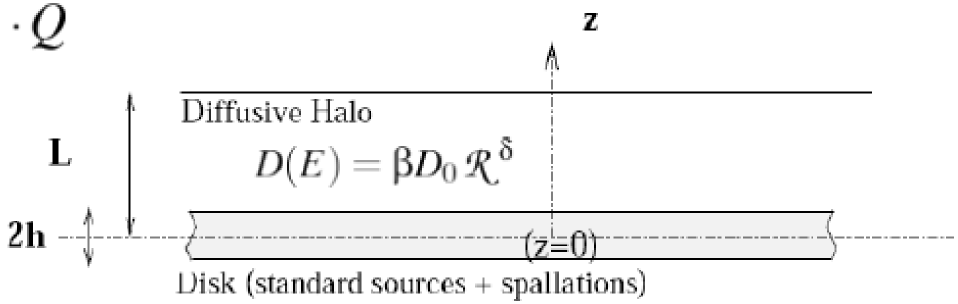

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Simple case: secondary-to-primary ratio

High energy: $N^p \propto \dfrac{Q}{D} \propto \dfrac{E^{-\alpha}}{E^\delta}$, and $N^s \propto \dfrac{N^p}{D}$ $\Rightarrow$ $\dfrac{N^s}{N^p}(e.g.\ B/C) \propto D^{-1} \propto E^{-\delta}$

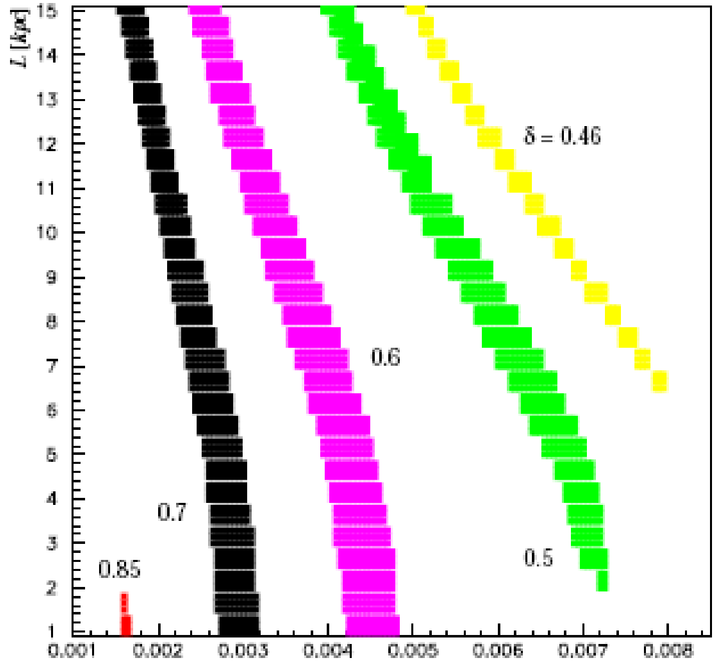
I. Sec. to prim. ratio

Illustration

- fit B/C and SubFe-Fe only
- D0, L, δ, Vc, Va free parameters

The 'degeneracy': for a given D0, all L allowed

L



Maurin *et al.*, Apj **555**, 585 (2001) ***D_0/L***

=> convection and reacceleration required
=> large value of the diffusion slope δ favoured

Illustration

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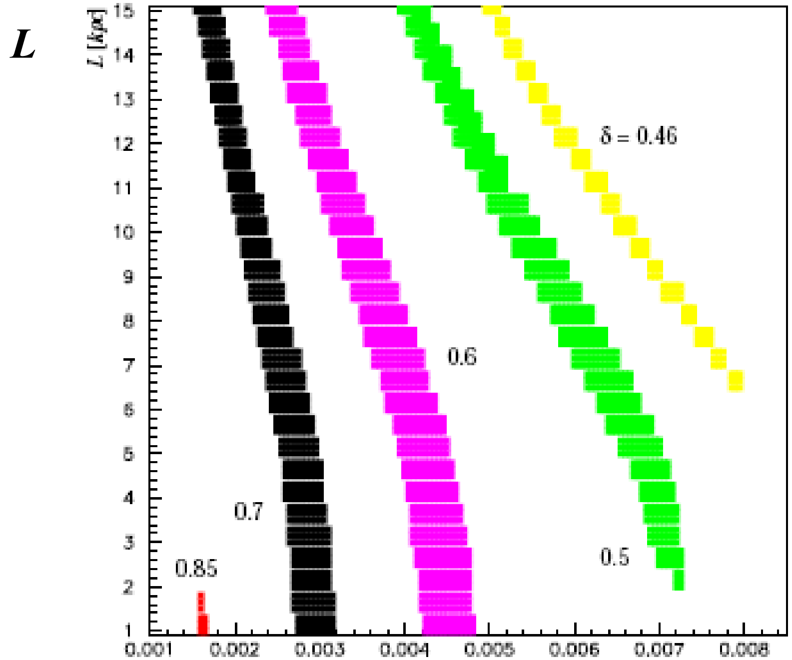

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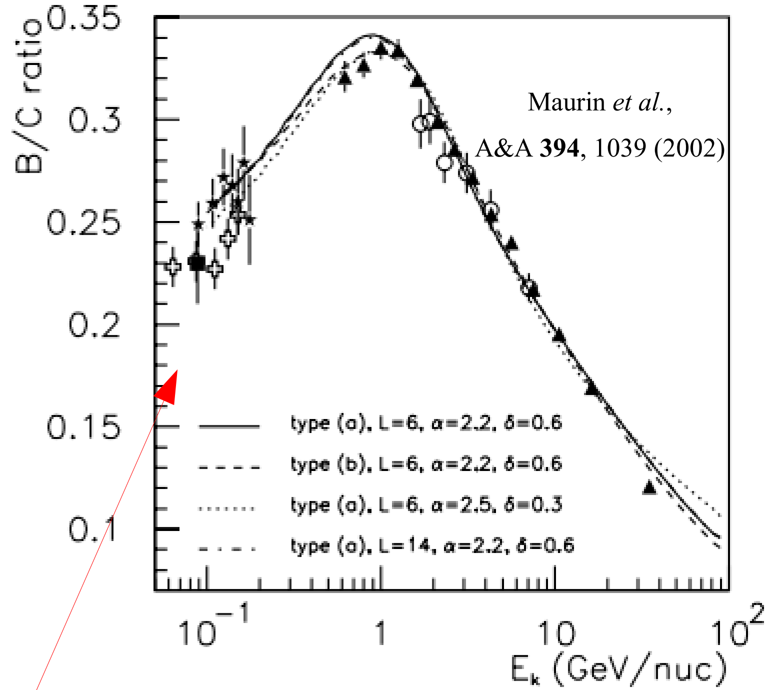
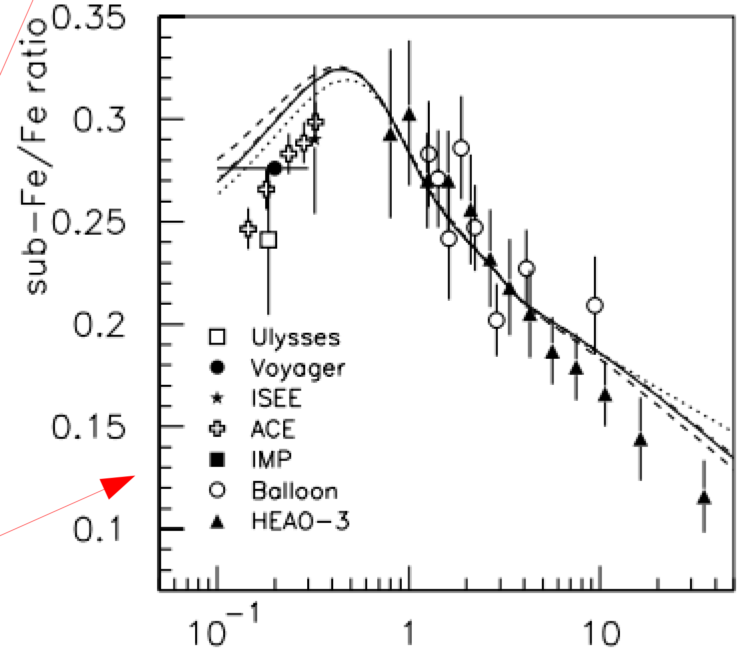




=> convection and reacceleration required
=> large value of the diffusion slope δ favoured

=> 'simple enough' to fit secondary to primary ratio, but...

I. Sec. to prim. ratio

Transport parameter determination: status

Automated parameter scan
Maurin et al., ApJ **555**, 596 (2001)
Maurin, Taillet & Donato, A&A **394**, 1039 (2002)

Markov Chain Monte Carlo scan
[+ local bubble (determination of L)]
Donato, Maurin & Taillet, A&A **381**, 539 (2002)
Putze *et al.,* A&A **497**, 991 (2009)
Putze, Derome & Maurin, A&A **516**, A66 (2010)

Systematic uncertainties
Maurin, Putze & Derome, A&A **516**, A67 (2010)

=> $\delta \in$ [0.3-0.5-0.8]

=> L $\in$ [1-50] kpc

=> ingredients yield Sys.Unc.>Stat.Unc.

...see also
Jones et al., ApJ **547**, 264 (2001)
Lionetto et al., JCAP **9**, 10 (2005)
Di Bernardo et al., arXiv:0909.4548

=> already tricky in a given “configuration”

Systematic uncertainties: production cross-sections

Maurin, Putze & Derome, **arXiv:1001.0553** (2010)

GALPROP 09, Webber 03, or energy biased X-sections

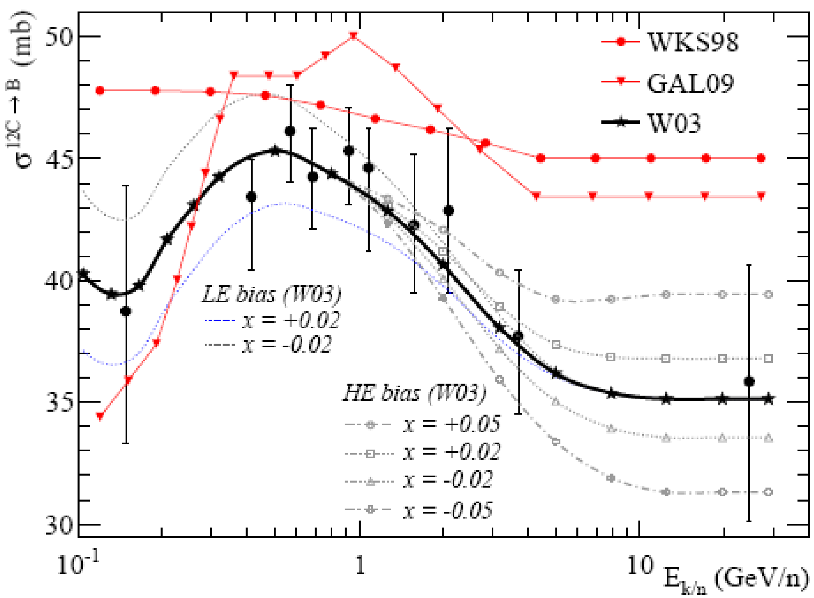
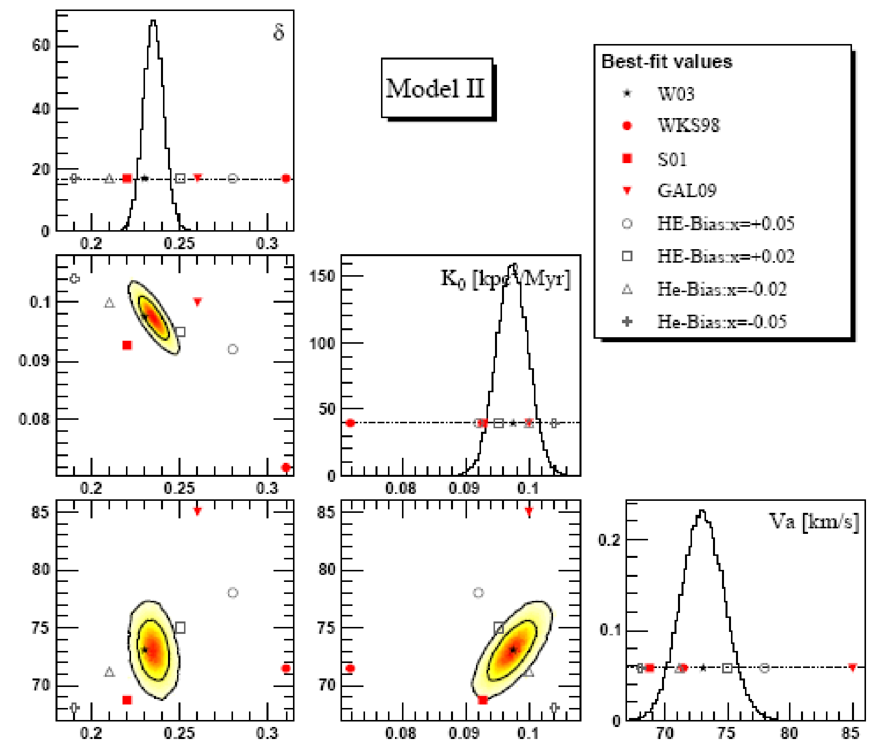


Fig. 3. Production cross-section for $^{12}C+H \to ^{10,11}B$ (adapted from Webber et al. 2003). The standard sets are shown as solid lines (WKS98: red dots; GAL09: red down triangles; W03: black stars), and the biased sets in dotted ($|x| = 0.02$) and dashed ($|x| = 0.05$) lines.



=> Systematics uncertainties > "statistical uncertainties" (fit from data)

Illustration of the difficulties with δ

Using <100 GeV B/C data

[Maurin, Putze & Derome, A&A **516**, A67 (2010)]

Standard: $D(E) = \beta K_0 \mathcal{R}^\delta$

→ reacceleration only => **δ~ 0.3**
[Strong et al., ApJ **509**, 212 (1998)]

→ reacceleration+convection => **δ~ 0.7**

Leaky-box inspired: $D(E) = K_0 \mathcal{R}^\delta$ → **δ~ 0.5**

[Webber *et al.*, ApJS **144**, 153 (2003)]

Upturn: $D(E) = \beta^{\eta_T} \cdot K_0 \mathcal{R}^\delta$ with $\eta_T \sim -2$ → almost any value...

[Ptuskin *et al.*, ApJ **642**, 902 (2006)]

=> and yet, many refinements
of the model may be required!

Sample of models proposed in the literature...

Bloemen *et al.* A&A **267**, 372 (1993)	=> Semi-analytical (homogeneous D, linear wind)
Erlykin & Wolfendale, J. Phys. G **28**, 2329 (2002)	=> Semi-analytical (use δ(r), linked to turbulence level)
Jones *et al.,* ApJ **547**, 264 (2001)	=> Semi-analytical (homogeneous D, constant wind)
Ptuskin & Soutoul, A&A **337**, 859 (1998)	=> Semi-analytical (radioactive nuc. and LISM)
Shibata *et al.*, ApJ **642**, 882 (2006)	=> Semi-analytical (inhomog. D, no V)
Berezhko *et al.,* A&A **410**, 189 (2003)	=> Secondary production in source
Breitschwerdt *et al.*, A&A **385**, 216 (2002)	=> Numerical (homog. D, but V(r,z))
Evoli *et al.* JCAP **10**, 18 (2008)	=> Numerical (inhomogeneous D, no V, no E losses)
Farahat *et al.*, ApJ **681**, 1334 (2008)	=> Numerical (backward Markov stochastic processes)
Strong & Moskalenko, ApJ **509**, 212 (1998)	=> Numerical (cst + linear wind)

\+ anisotropic diffusion (e.g., to explain the knee)...
\+ time-dependent effects (HE leptons, nuclei?)...
\+ MHD couplings of magnetic fields, CRs and gas...

=> Definitively no standard propagation model yet...
=> barely value of parameters from various 'effective' models

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Local origin for low-energy radioactive species

$l_{max} \sim \sqrt{Dt}$ => limited distance travelled in a finite time

Limited lifetime: $t_{rad} = \gamma \cdot \tau_0 = \gamma \cdot \ln 2 \cdot t_{1/2}$

$$\text{Below GeV/n energy}: D \sim 10^{28}\ \text{cm}^2\ \text{s}^{-1}, t^{^{10}\text{Be}} = 1.51\ \text{Myr} \Rightarrow l_{rad} \sim 100\ \text{pc}$$

Low-energy radioactive nuclei only sensitive to *D*
=> breaks the *D0/L* degeneracy, allows the determination of *L*

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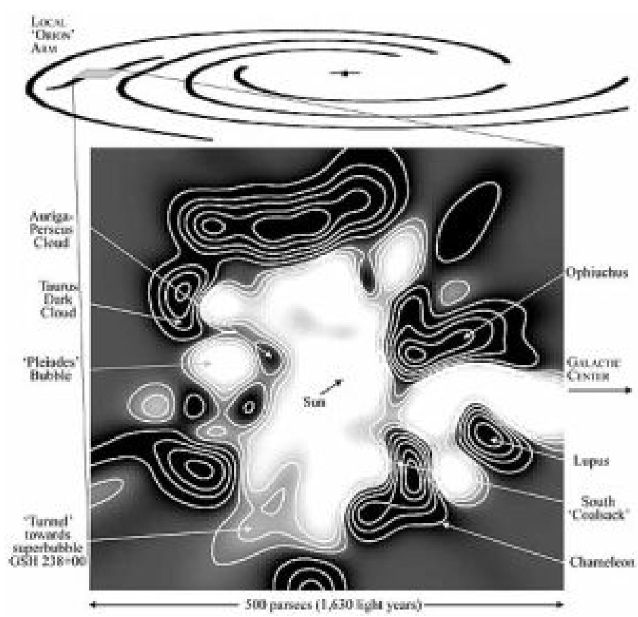
Low-energy radioactive nuclei only sensitive to *D*
=> breaks the *D0/L* degeneracy, allows the determination of *L*

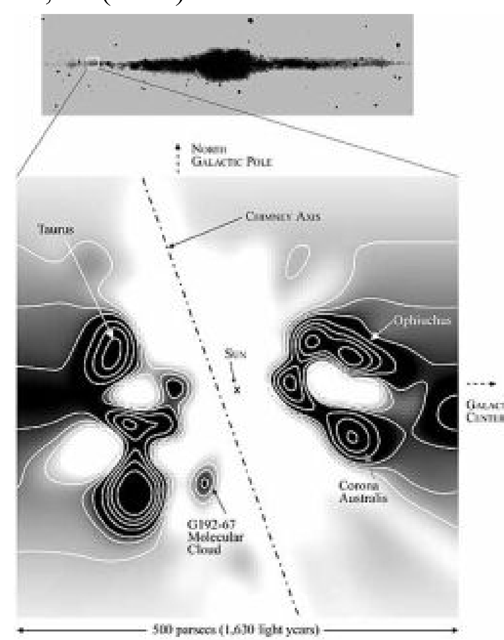
+ local underdensity (~100 pc around the sun)

Lallement et al., A&A **411**, 447 (2003)
Welsh *et al*, A&A **510**, 54 (2010)

=> no target for local production

=> additional complication for a clear determination of *L*





Local bubble & secondary rad. nuclei: toy model

Donato, Maurin & Taillet, A&A **381**, 539 (2002)
Putze *et al.*, A&A **516**, A66 (2010)

Propagator for a decaying species:

$$-D\triangle_r G + G/(\gamma\tau_0) = \delta(r)$$

$$\Rightarrow \quad G_O(r') \propto \frac{\exp(-l_{\rm rad} r')}{r'}, \quad l_{\rm rad} = \sqrt{D\gamma\tau_0}$$

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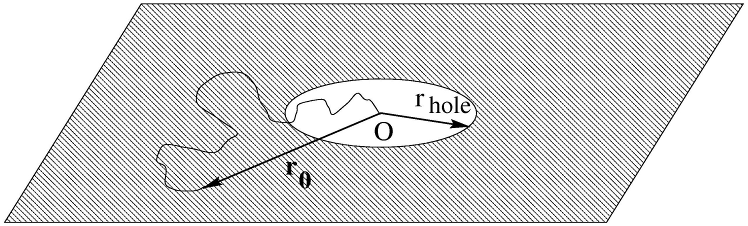
Differential number density w/wo a hole:
(production everywhere in the plane, but in the hole)

$$N(r=z=0) \propto \int_0^{\infty} \int_{-\infty}^{+\infty} G(\sqrt{r'^2+z'^2})\, Q(r',z')\, r'\, dr'\, dz'$$



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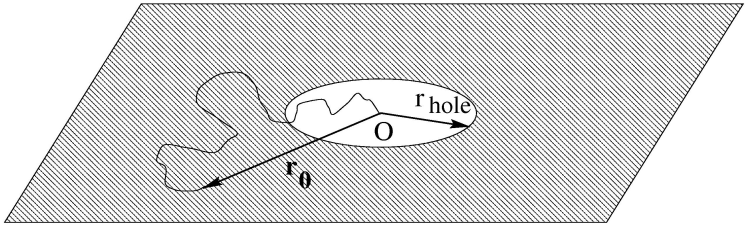

Attenuation w.r.t. the 'no hole' case: With $Q(r,z) \propto \Theta(r-r_h)\delta(z) \Rightarrow \frac{N_{r_h\neq 0}}{N_{r_h=0}} = \exp\left(\frac{-r_h}{l_{\rm rad}}\right) \equiv \kappa$ %

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
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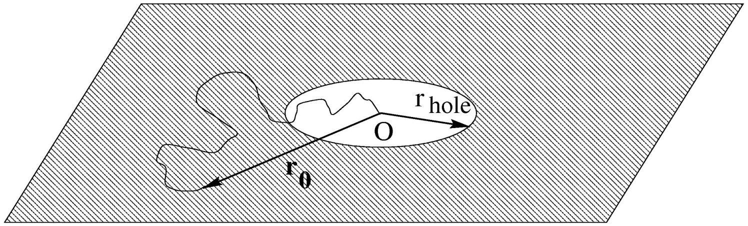

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Consequences for parameter determination:

=> from 10Be/9Be, find r_h~80 pc consistent with gas observations

[see Antje Putze's talk for the impact on L]


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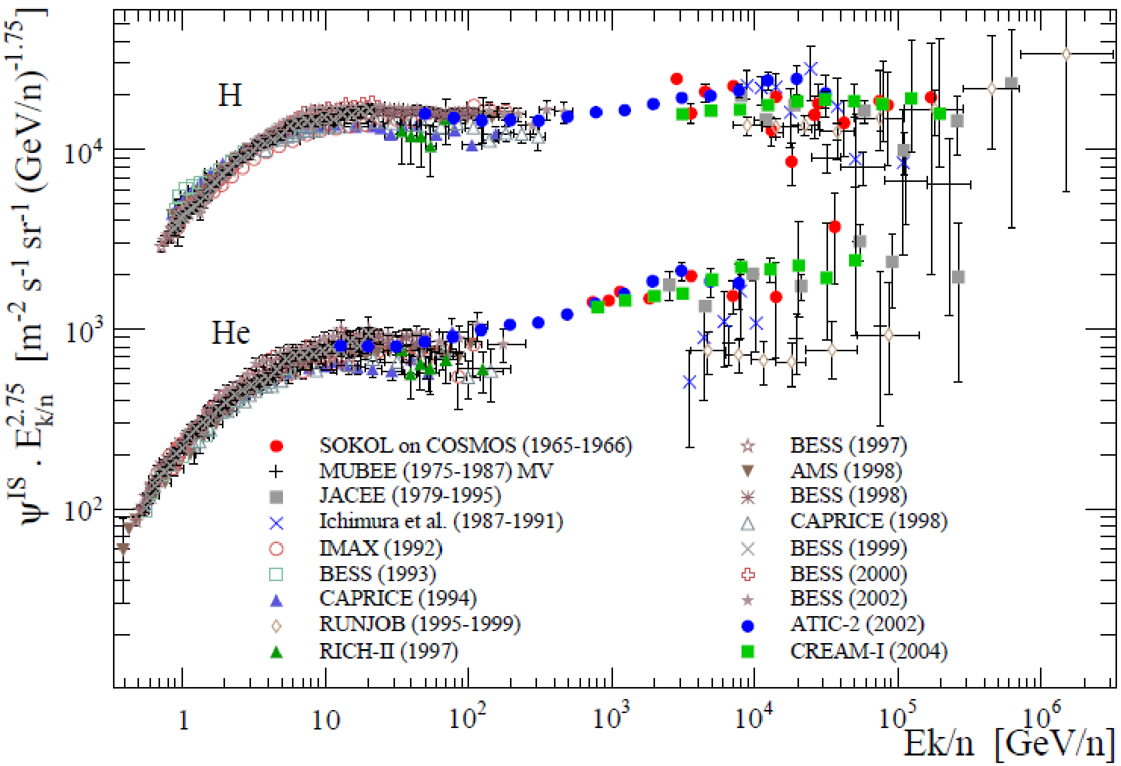
Fitting primary fluxes in diffusion models

Putze, Maurin, Donato, A&A **526**, A101 (2011)
[see also Antje Putze's talk]

Demodulated data (compilation)



<u>First-order degeneracy:</u>

$$\psi(E) \propto \frac{Q(E)}{K(E)} \propto \frac{q}{K_0} \cdot E^{-(\alpha+\delta)}$$

- Normalisation q/K0
- Total slope $\alpha+\delta$

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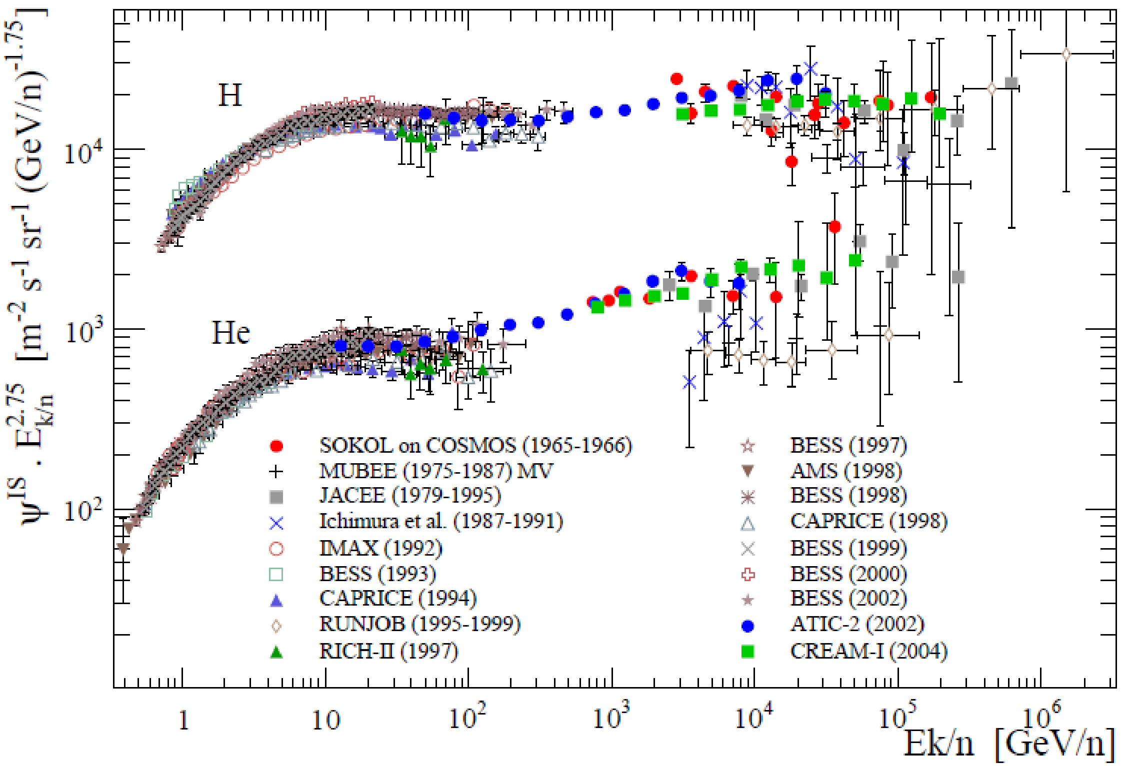

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- Normalisation q/K0
- Total slope α+δ

Second-order correlation:

$$\psi(E) = \frac{v}{4\pi} \cdot \frac{Q(E)}{\frac{K(E)}{hL} + n_{\rm ISM}\sigma v}$$

- α+δ and K0 coupled

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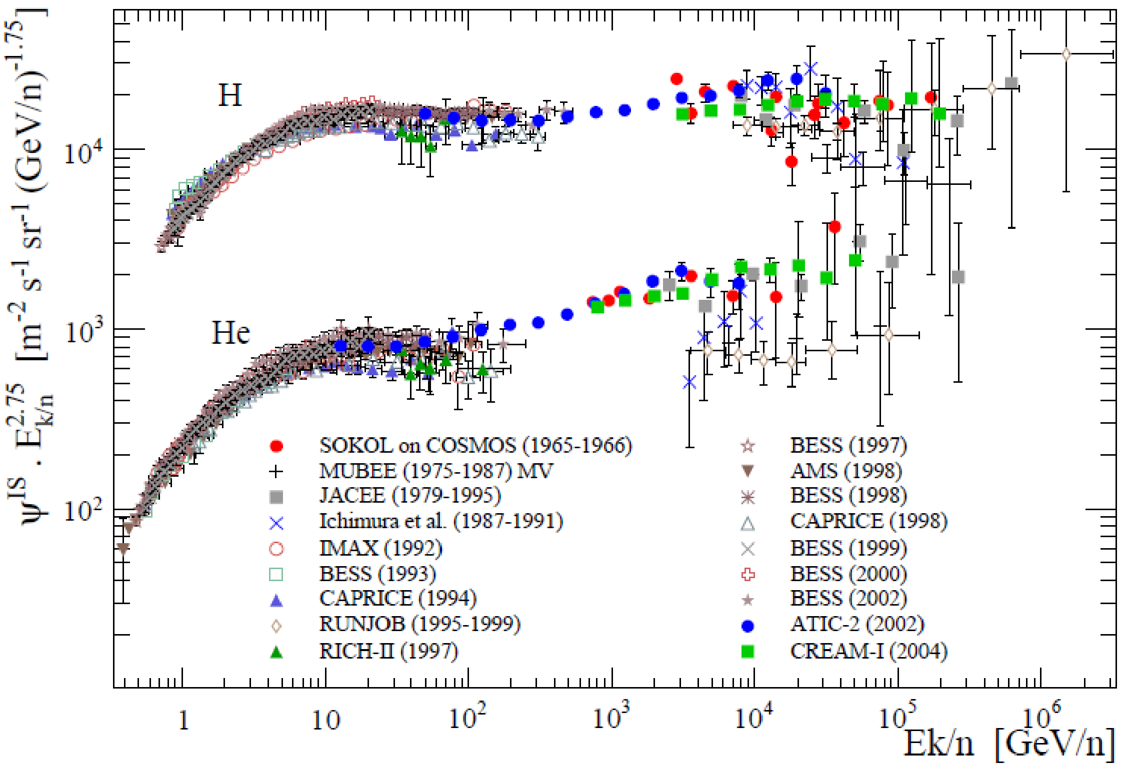

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- Total slope α+δ

Second-order correlation:

$$\psi(E) = \frac{v}{4\pi} \cdot \frac{Q(E)}{\frac{K(E)}{hL} + n_{\rm ISM}\sigma v}$$

- α+δ and K0 coupled

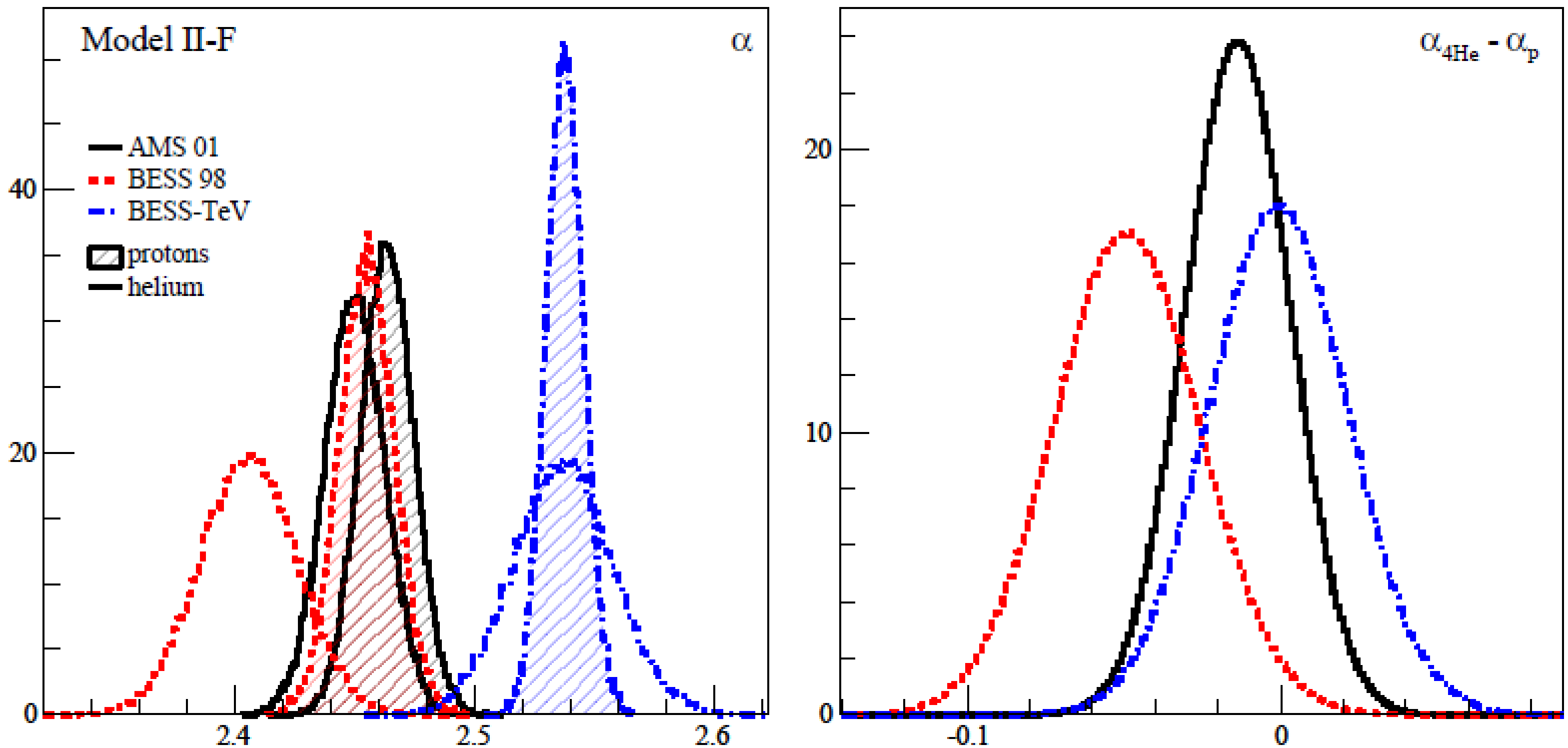
More subtle effects:

- energy redistributions...

=> primary species alone cannot constrain the transport parameters
=> < 100 GeV/n, ~ well-fitted for any config. (w/wo Va, w/wo Vc)

Source spectral index for p and He

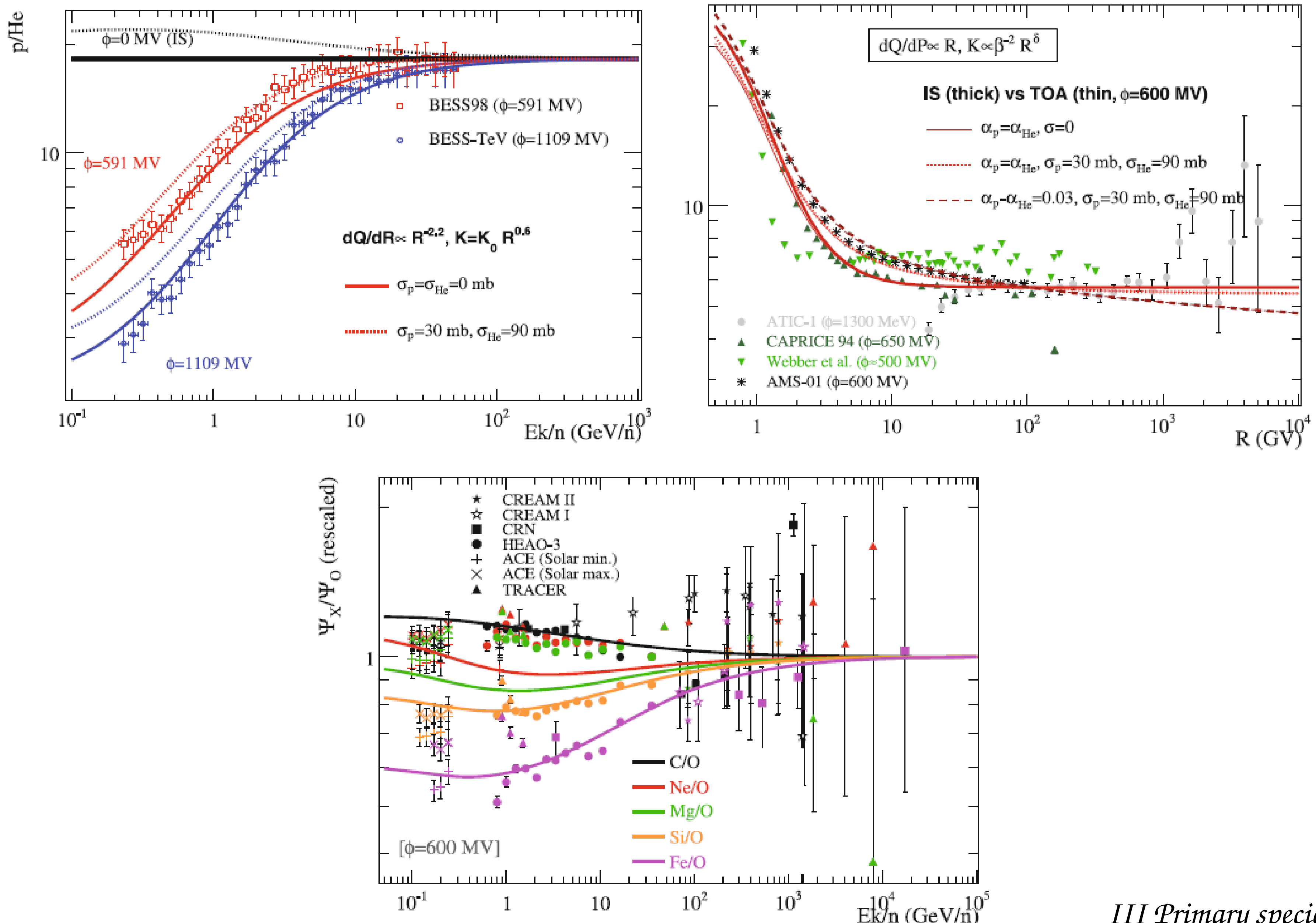
Putze, Maurin, Donato, A&A **526**, A101 (2011)
[see also Antje Putze's talk]



=> Inconsistency between the data (worse for heavier nuclei)
=> p and He ~ same spectral index, but depends on the 'model'
=> α ~ [2.25-2.5] although [δ~0.3-0.8]

[more in Antje Putze's talk]

Ratio of primary species (1D toy model)



I. Secondary-to-primary ratio

II. Radioactive species

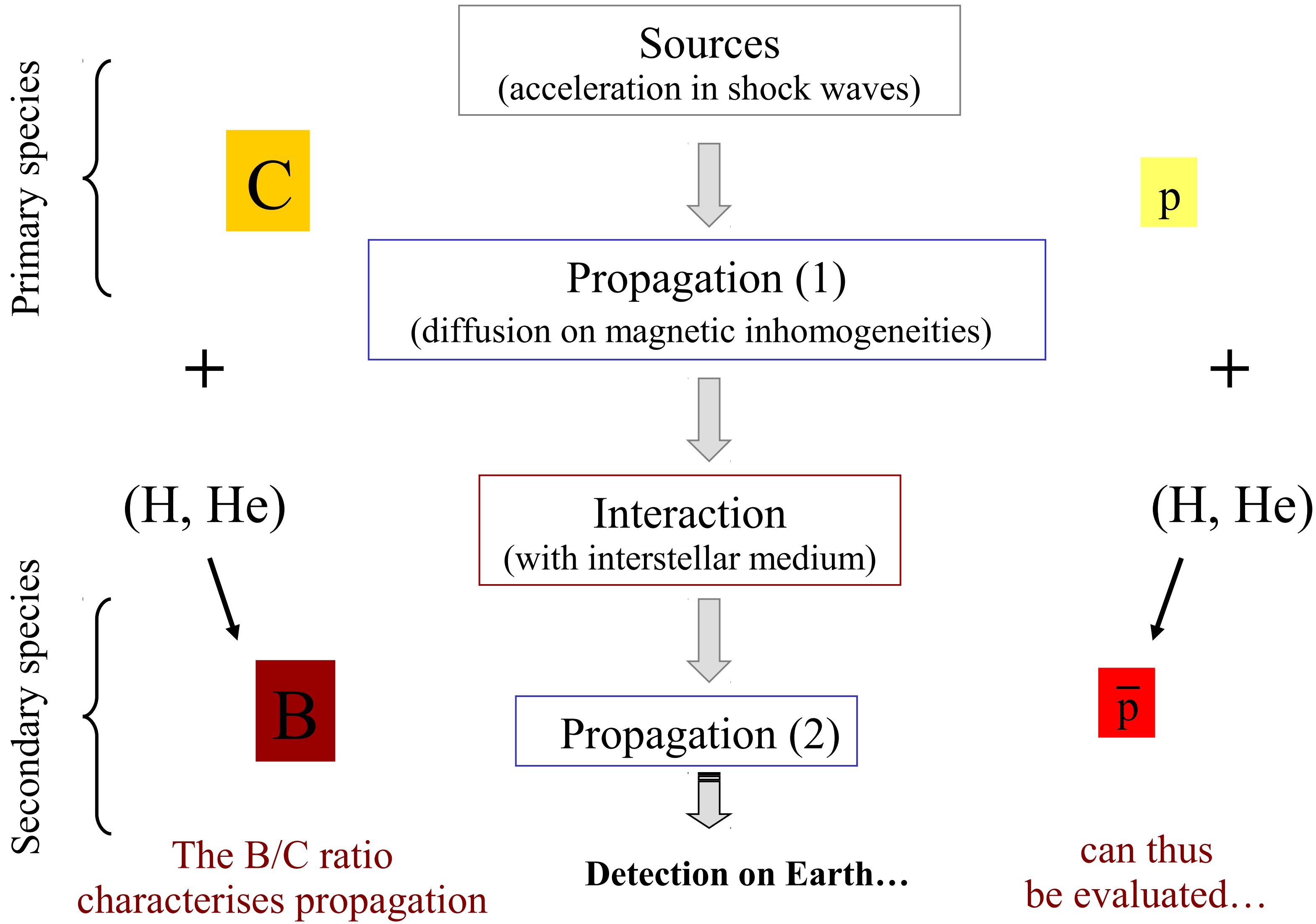
III. Primary species

IV. Standard antiprotons and antideuterons

V. Exotic antiprotons and antideuterons

VI. Conclusions and USINE

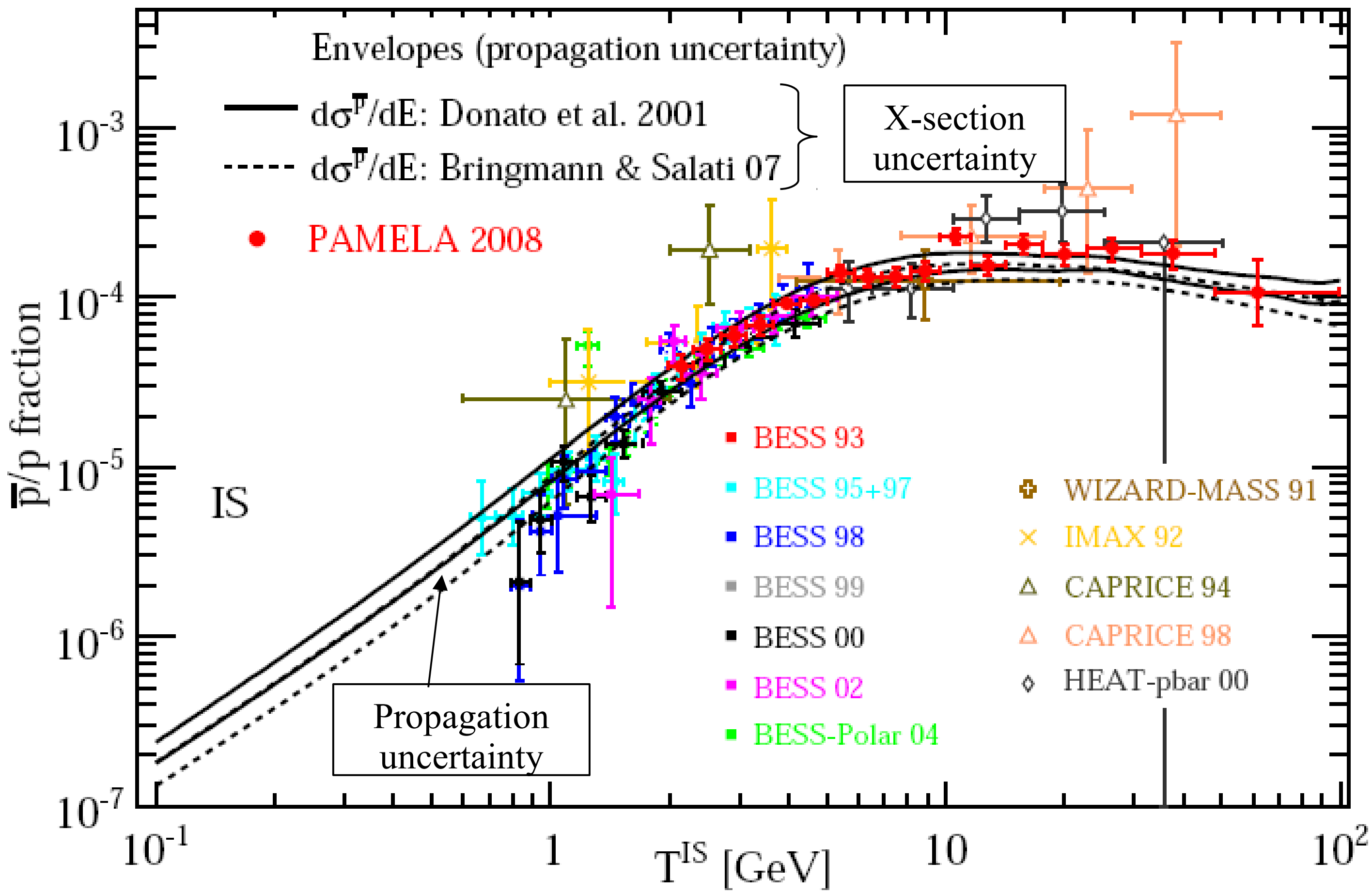
Principle for standard antiprotons and antideuterons



N.B.: valid *if and only if* same propagation history!

Antiprotons

Donato *et al.*, ApJ **563**, 172 (2001), Donato *et al.*, PRL **102**, 071301 (2009)



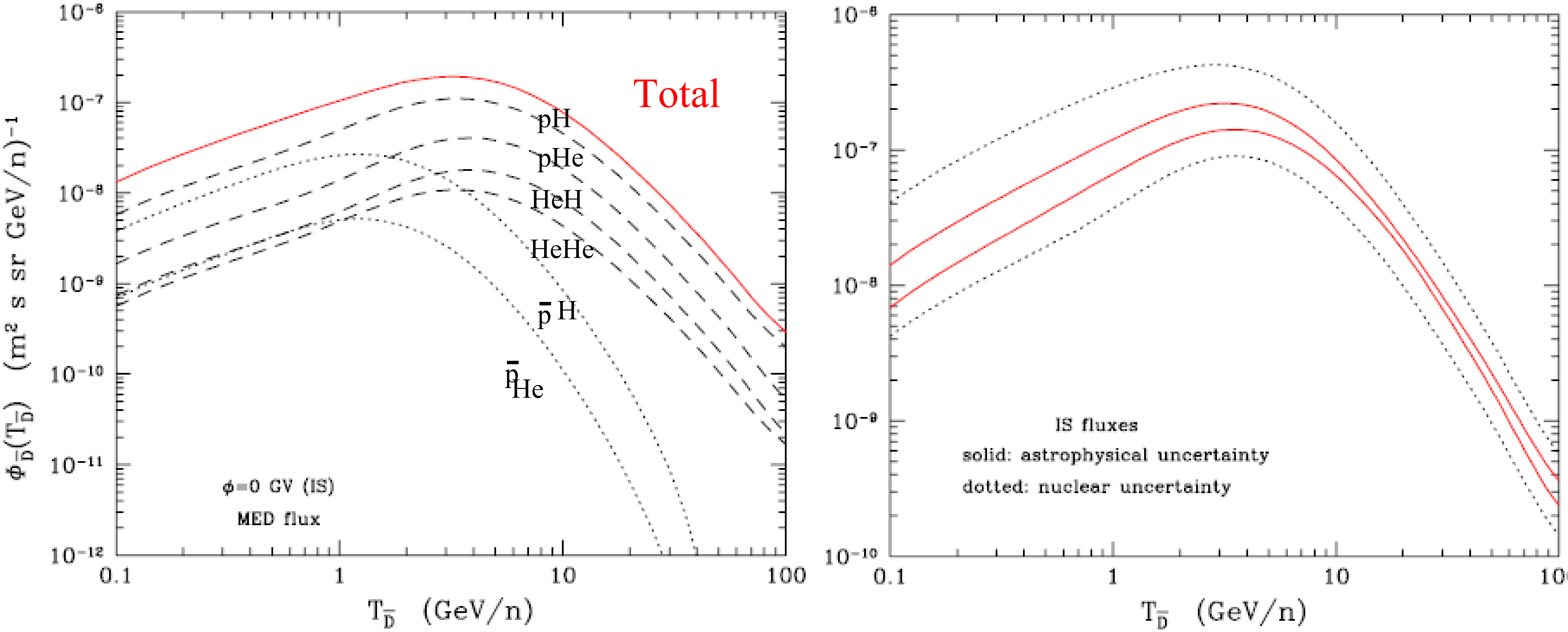
=> excellent agreement with the data

=> small astrophysical uncertainty on the antiproton background

=> dominated by nuclear production cross-section uncertainty

Antideuterons

Donato, Fornengo & Salati, Phys. Rev. D **62**, 043003 (2000)
Duperray *et al.*, Phys. Rev. D **71**, 083013 (2005)
Donato *et al.*, PRD **78**, 043506 (2008)



=> Transport uncertainty (<40%), as for pbar [should decrease soon: PAMELA, AMS]
=> Nuclear uncertainty ~ factor of 10 [more nuclear data required]


I. Secondary-to-primary ratio
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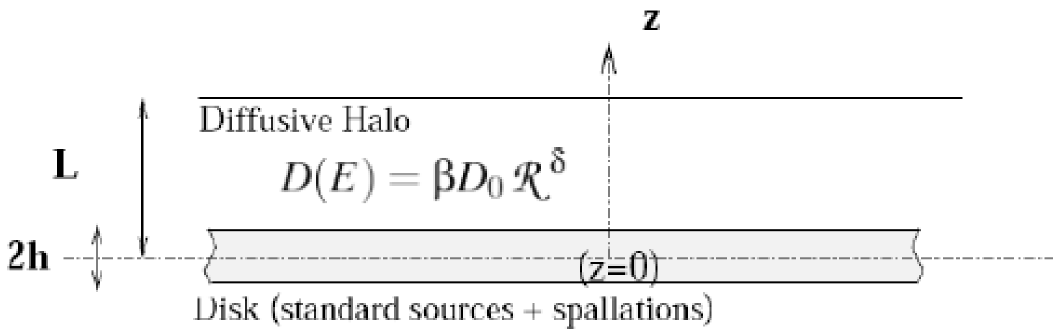
Phenomenology of the DM signal

Maurin *et al.*, 2006a [arXiv:astro-ph/0609522]
Maurin *et al.*, 2006b [arXiv:astro-ph/0612714]



1) Good approximation to neglect: energy losses, spallations

2) In 1D model (only z-dependence): $-D\frac{d^2N}{dz^2} = q_{\rm Dark}$

3) Breaks ***Do/L*** degeneracy: $N_{(\bar{p},\bar{d})}(z=0) = \frac{q_{\rm Dark}L^2}{\mathbf{2D}} = \frac{q_{\rm Dark}\lambda_{\rm esc}L}{\mu v}$

=> 'signal' uncertainty scales as L

… and we remind that L is still not well constrained!

[see Pierre Salati's talk for more]

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~ Conclusions ~

1. So far, we have just scratched the surface

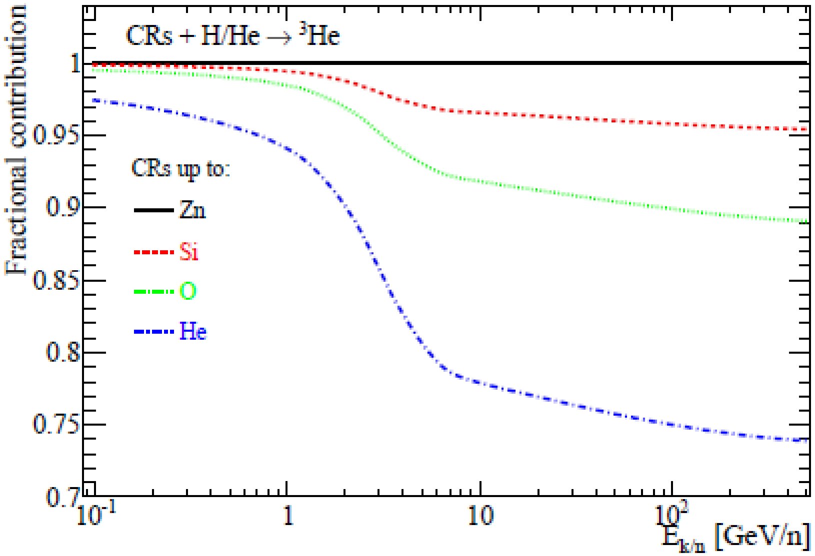
- We deal with phenomenological models
- What you get from depends on what you put in

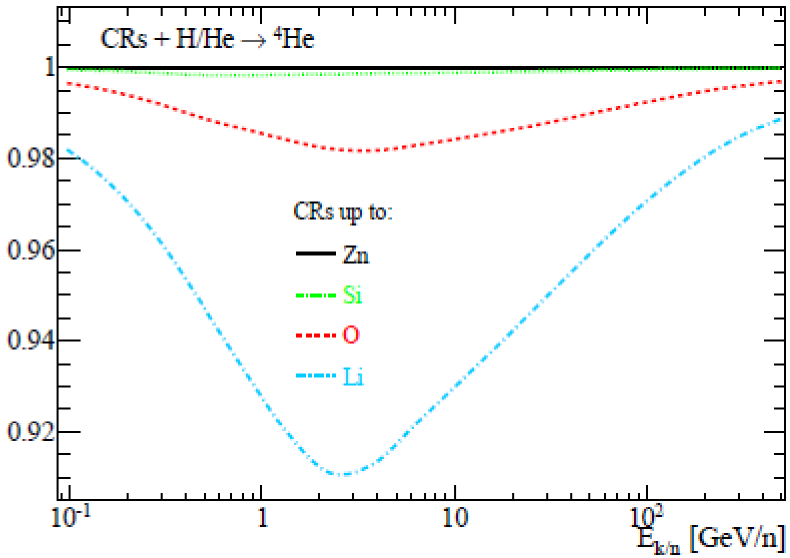
2. What's next?

- AMS-02 data: unprecedented high precision measurements
- The limitations of the steady-state models are already reached

3. And even 'simple' is getting complicated with good enough data

Coste, Derome, Maurin & Putze (in prep.)





N.B.: ^{3}He/^{4}He constraints consistent with B/C
^{3}He/^{4}He as constraining as B/C (in terms of CLs)

USINE

A – Ingredients common to all models

1. Base ingredients
- Nuclear charts (m, A, Z, β and EC-decay channels)
- Atomic properties (FIP, Ek-shell...)
- Nuclear physics (production, inelastic... X-sections)
- Energy losses (Coulomb, ionisation)

2. Solar modulation (IS to TOA)

3. Database (experimental fluxes)

4. Visualization and fitting tools
- Displays
- Fitting tools

Base package, C++/Root interface

Markov Monte Carlo Chain
(MCMC) technique
[GreAT]
=> PDF of parameters

B – Ingredients specific to each model

See Antje Putze's talk

1. Description (Input variables)
- Geometry
- Sources (spatial distribution, spectra)
- Propagation (transport coefficient, equation)

2. Solution of the transport equation
- Standard secondary/primary/tertiary contributions
- Unstable radioactive nuclei (BETA or EC)
- Energy redistributions (energy losses, reacceleration)
- Exotic primary contributions

Models (LB, 1D, 2D const. wind)

USINE

Public release (~December 2010)

- V1.0 public release
- Database (web interfaced MySQL)
- Website (simple model calculation online)

USINE-core (root-like documentation): D.M. (LPSC)
Database: R. Taillet (LAPTh)
GUI: F. Barao (LIP)
MCMC: A. Putze (KTH), L. Derome (LPSC)

… and to improve it

e+/e-: T. Delahaye, F. Donato, J. Lavalle, R. Lineros, P. Salati
γ: T. Delahaye, A. Fiasson, P. Salati...
More statistical tools: A. Putze & L. Derome
N'USINE (N'umerical USINE): others et al...
Better Solar modulation: collaborations welcome...

+ to be thought as a toolbox to implement your own models

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Snapshot: database

1. Direct access (data & references)

[alphabetic sort] [sort by date]

ALICE (Canada) (balloon, 1987) [web]

[data] *elemental fluxes from Ne to Ni* [ref : Esposito *et al.*, Astropart. Phys. **1** (1992) 33]
[data] *isotopes Si, Fe, Ni* [ref : Hesse *et al.*, A&A **314** (1996) 785]

AMS (satellite, 2002) [web]

[data] *B/C ratio* [ref : Tomassetti *et al.*, ICRC (2009)]
[data] *Hbar fluxes* [ref : Aguilar *et al.*, Phys. Rep. **366** (2002) 331]

ATIC (balloon, 2000-2007) [web]

[data] *elemental fluxes* [ref : Panov *et al.*, Bull. Russian Acad. Sci. **73** (2009) 564]
[data] *H fluxes* [ref : Panov *et al.*, Bull. Russian Acad. Sci. **73** (2009) 564]

Ace (CRIS) (satellite, 1997-) [web]

[data] *elemental fluxes from B to Ni at solar max* [ref : George *et al.*, ApJ **698** (2009) 1666]
[data] *radioactive species* [ref : Binns *et al.*, ICRC**26** (1999) 21]

Snapshot: class documentation (1)

ROOT logo

Quick Links:	ROOT Homepage	Class Index	Class Hierarchy	
Source:	header file	source file		
Sections:	class description	function members	data members	class charts

Search documentation | Search

#include "TUsineDiffCoeffEntry.h"

Display options:

Show inherited

Show non-public

[↑ Top] | [? Help]

USINE » INCLUDE » TUsineDiffCoeffEntry

class TUsineDiffCoeffEntry

```
TUsineDiffCoeffEntry
 Scalar spatial Kxx and momentum Kpp diffusion coefficients (dependant on the rigidity) for several parameterisations.
 For details and references, see Putze et al. 2010 and Maurin et al., 2010. The scalar diffusion coefficient
 TUsineDiffCoeffEntry can be used in diffusion models (see e.g. Maurin et al., ApJ 555, 585 (2001)), as used
 in TUsineModelSemiAnalD_VcK. This class can also be used to form a tensor diffusion coefficient (to be done).

 A typical form for the spatial diffusion coefficient is (for standard diffusion fEta=1)
      K(E) = beta^fEta fK0 R^fDelta
 However, a cut-off rigidity can also be added (slope fDeltaBelowR0 below fR0). A key parameter is the wave
 type of the turbulence that affects the form of the momentum diffusion. Allowed forms for fWaveType are:
    - SlabAlfven (standard form where Kpp = 4/3*Va^2*beta^2*etot^2/Kxx/(delta*(4-delta^2)*(4-delta)));
    - IsotropicFastMagnetosonic and MixtureSlabMagnetosonic (see Schlickeiser 2002);
    - LeakyBoxInspired => fEta=0 (to provide a diffusion model equivalent to a Leaky Box Model with lambda_esc=beta R^-delta;
    - FreeEta: required to allow any value of fEta.
 The function OrphanGetGraph() can be used to plot it (see below).
```

Snapshot: class documentation (2)

public:

	TUsineDiffCoeffEntry ()
	TUsineDiffCoeffEntry (const TUsineDiffCoeffEntry&)
	~TUsineDiffCoeffEntry ()
static TClass*	**Class** ()
Double_t	**GetDelta** () const
Double_t	**GetDeltaBelowR0** () const
Double_t	**GetEta** () const
Double_t	**GetK0** () const
Double_t	**GetK0_cm2pers** () const
Double_t	**GetR0** () const
Double_t	**GetVa** () const
Double_t	**GetVa_kpcperMyr** () const
string	**GetWaveType** () const
virtual TClass*	**IsA** () const
Double_t	**Kpp** (Double_t const& etot, Double_t const& rig, Double_t const& beta) const
Double_t	**Kxx** (Double_t const& rig, Double_t const& beta) const
TUsineDiffCoeffEntry&	**operator=** (const TUsineDiffCoeffEntry&)
TGraph*	**OrphanGetGraphKpp** (TUsineCREntry* cr, TUsineAxis* xaxis)
TGraph*	**OrphanGetGraphKxx** (TUsineCREntry* cr, TUsineAxis* xaxis)
void	**Print** () const
void	**SetDelta** (Double_t const& d)
void	**SetDeltaBelowR0** (Double_t const& d)
void	**SetEta** (Double_t const& eta)
void	**SetK0** (Double_t const& ko)
void	**SetR0** (Double_t const& ro)
void	**SetVa** (Double_t const& va)

Data Members

private:

Double_t	**fDelta**	Slope for R > fR0 (always positive)
Double_t	**fDeltaBelowR0**	Slope for R < fR0 (it can be a negative value)
Double_t	**fEta**	beta^fEta factor in K(E): fEta=1 for standard DM
Double_t	**fK0**	Normalisation of the diffusion coeff. (kpc^2/Myr)
Double_t	**fR0**	Rigidity of the break (GV)
Double_t	**fVa**	Alfven velocity for reacceleration (km/s)
string	**fWaveType**	Type of turbulence (case insensitive): for instance SlabAlfven, FreeEta, etc.

Snapshot: Graphic User Interface (GUI)