Sulla natura e l' origine del ginocchio e della caviglia nello spettro dei raggi cosmici

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Sommaire

- Le genou et la cheville dans le spectre différentiel en énergie de la radiation cosmique.
- Phénomèns et parametres qui forgent les propriétés des rayons cosmiques dans la Galaxie.
- Trajectoires des le rayons cosmique et calcul de l' intensité.
- Qu' est-ce que le genou et la cheville ?
- Comparaison des genoux calculés de l' Helium, du Fer et des protons avec les données expérimentales.
- Comparaison du spectre calculé entre 10^14 et 10^20 eV avec les données expérimentales.
- Caractéristiques de cette solution du problem du genou et de la cheville.
- Commentaires.

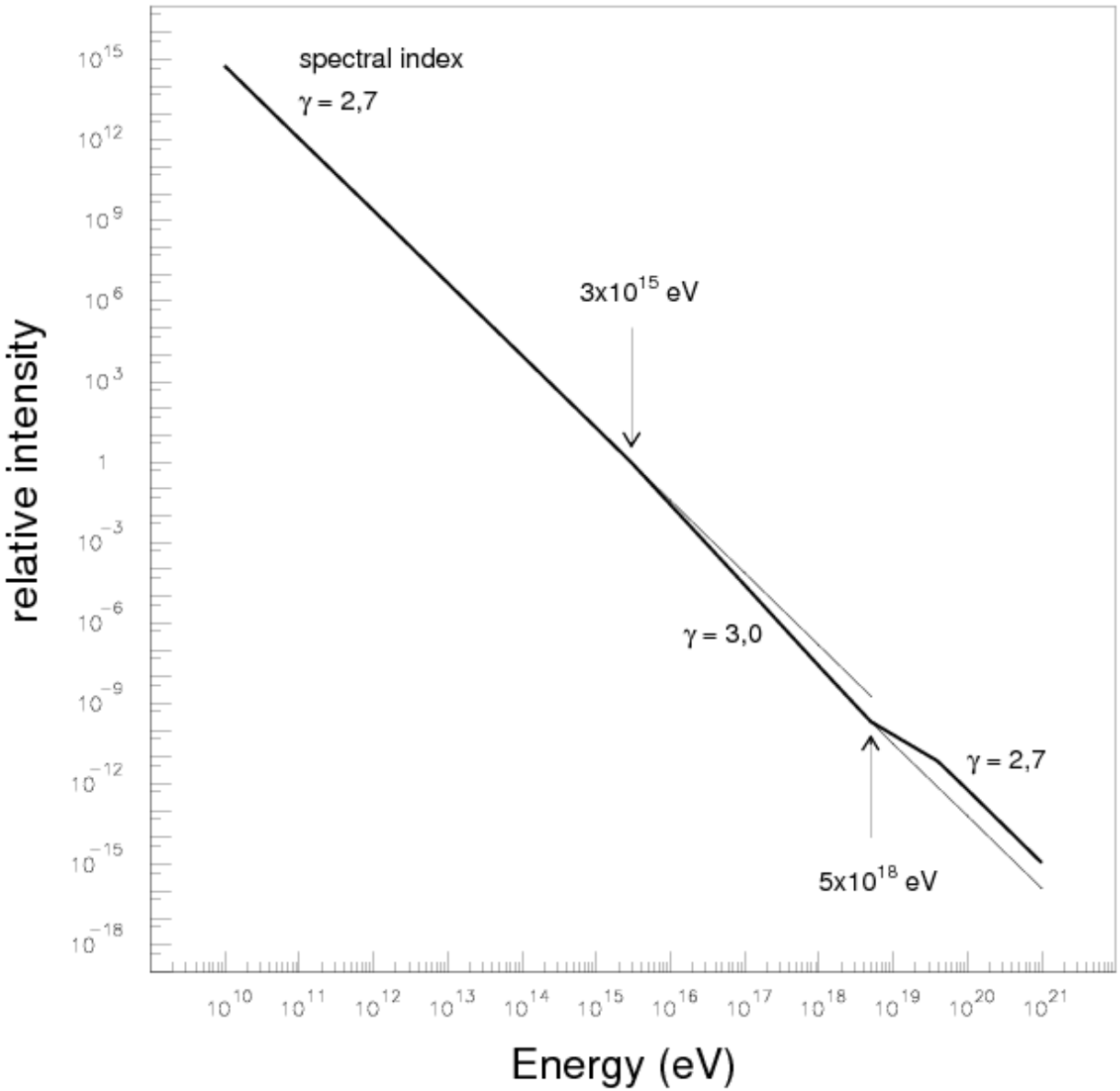
Tema del seminario è descritto nei seguenti lavori in collaborazione con Francois Plouin

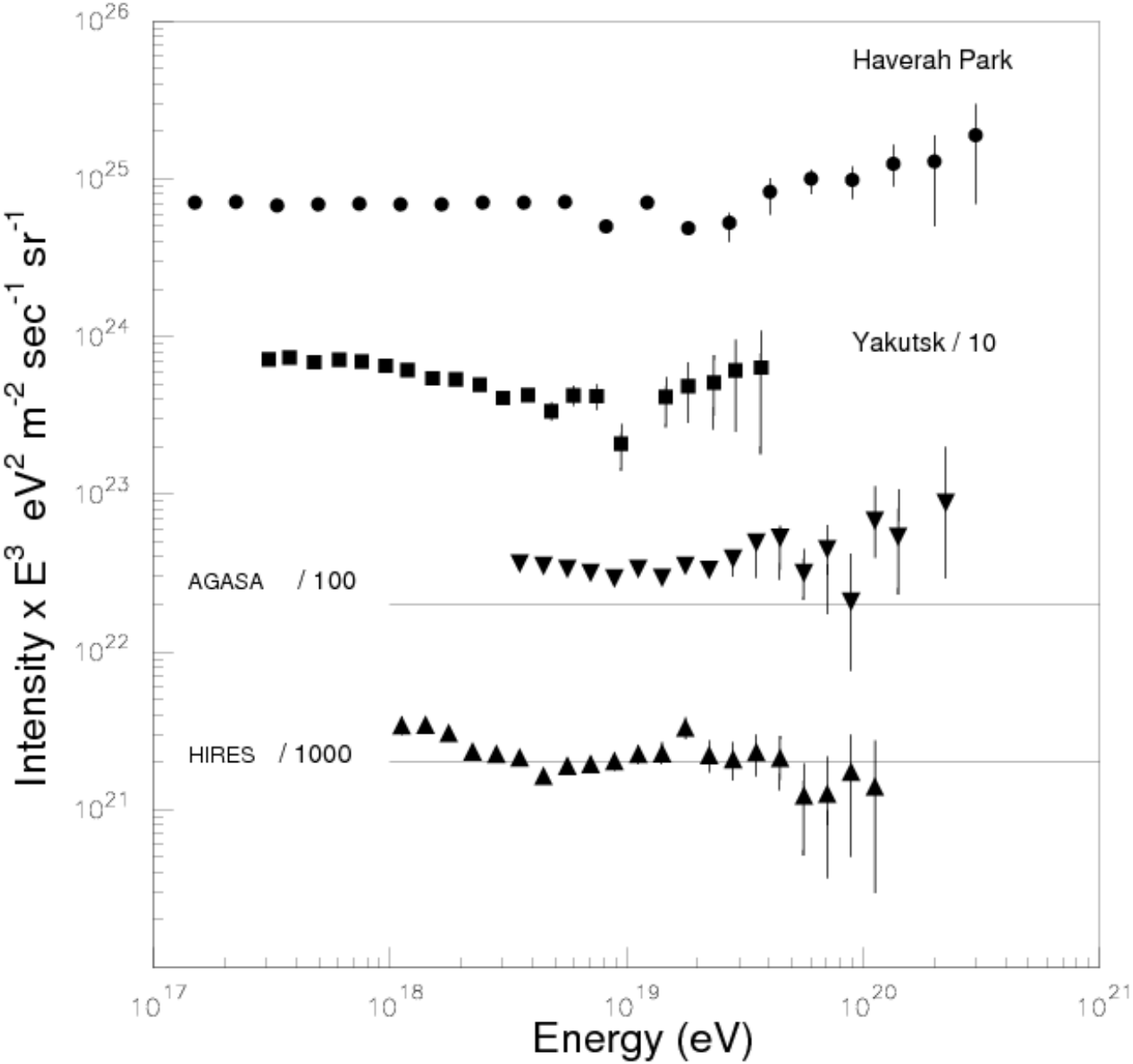
L' origine della caviglia

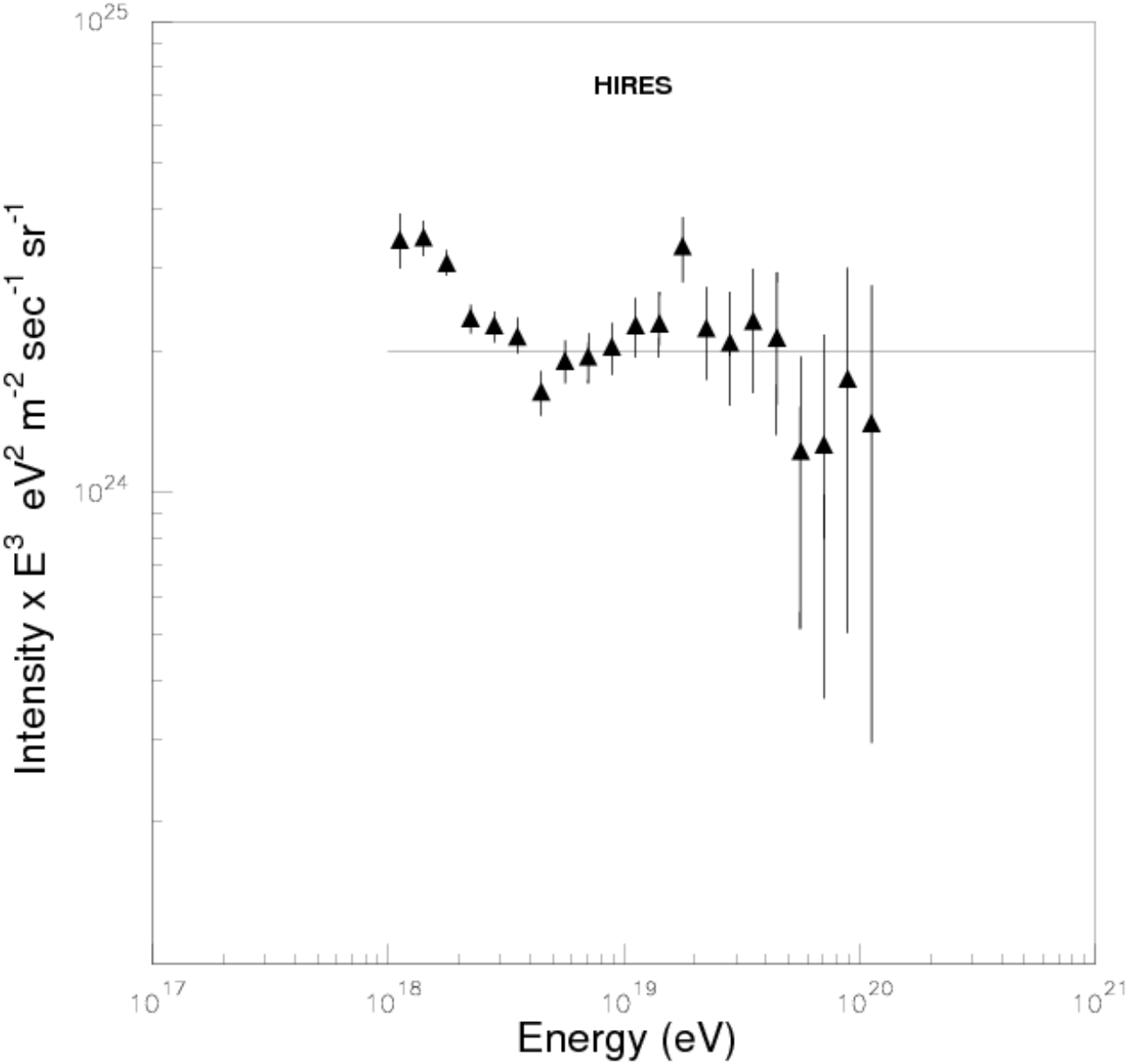
L' unico meccanismo che genera il ginocchio e la caviglia nella zona galattica locale

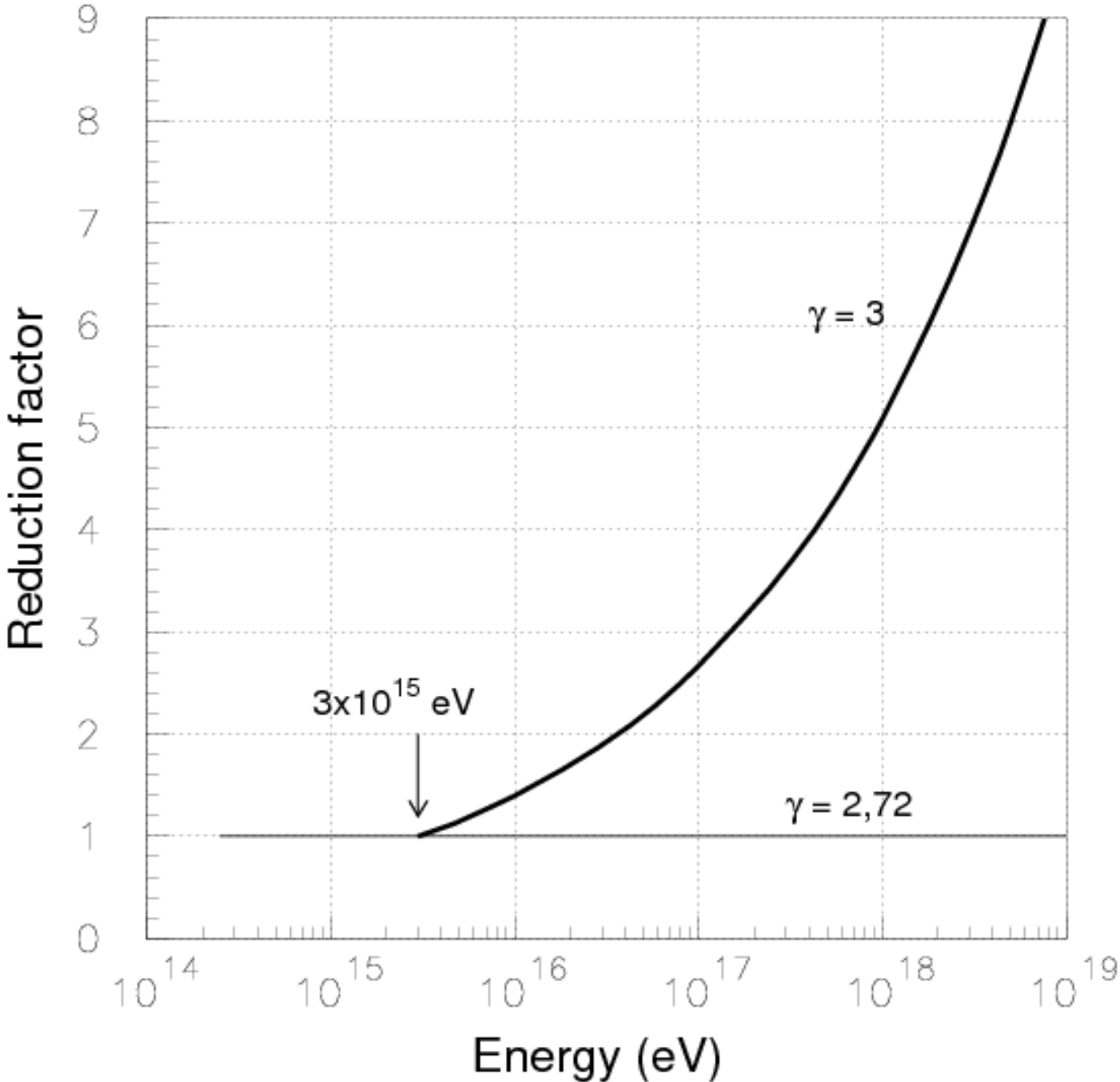
Bacini galattici di elio e ferro intorno alle energie del ginocchio

Sono stati diffusi sulla rete informatica di astrofisica circa due mesi fa


spectral index
γ = 2,7
3x10^15 eV
γ = 3,0
γ = 2,7
5x10^18 eV
relative intensity
Energy (eV)
10^15
10^12
10^9
10^6
10^3
1
10^-3
10^-6
10^-9
10^-12
10^-15
10^-18
10^10
10^11
10^12
10^13
10^14
10^15
10^16
10^17
10^18
10^19
10^20
10^21


Haverah Park
Yakutsk / 10
AGASA / 100
HIRES / 1000
Intensity x E^3 eV^2 m^-2 sec^-1 sr^-1
Energy (eV)
10^26
10^25
10^24
10^23
10^22
10^21
10^17
10^18
10^19
10^20
10^21


HIRES
10^{25}
10^{24}
Intensity x E^3 eV^2 m^{-2} sec^{-1} sr^{-1}
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}
Energy (eV)


Reduction factor
9
8
7
6
5
4
3
2
1
0
γ = 3
3x10^15 eV
γ = 2,72
10^14
10^15
10^16
10^17
10^18
10^19
Energy (eV)

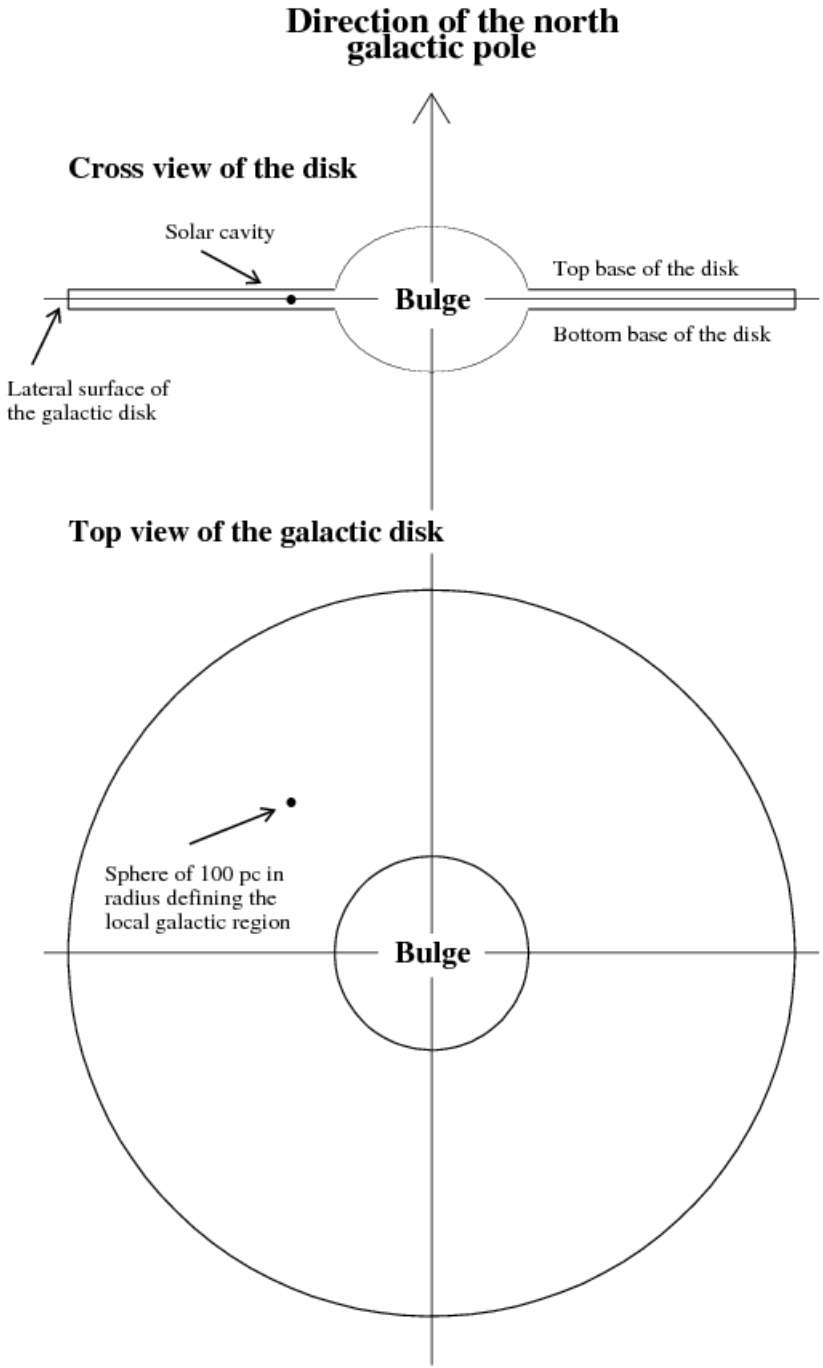
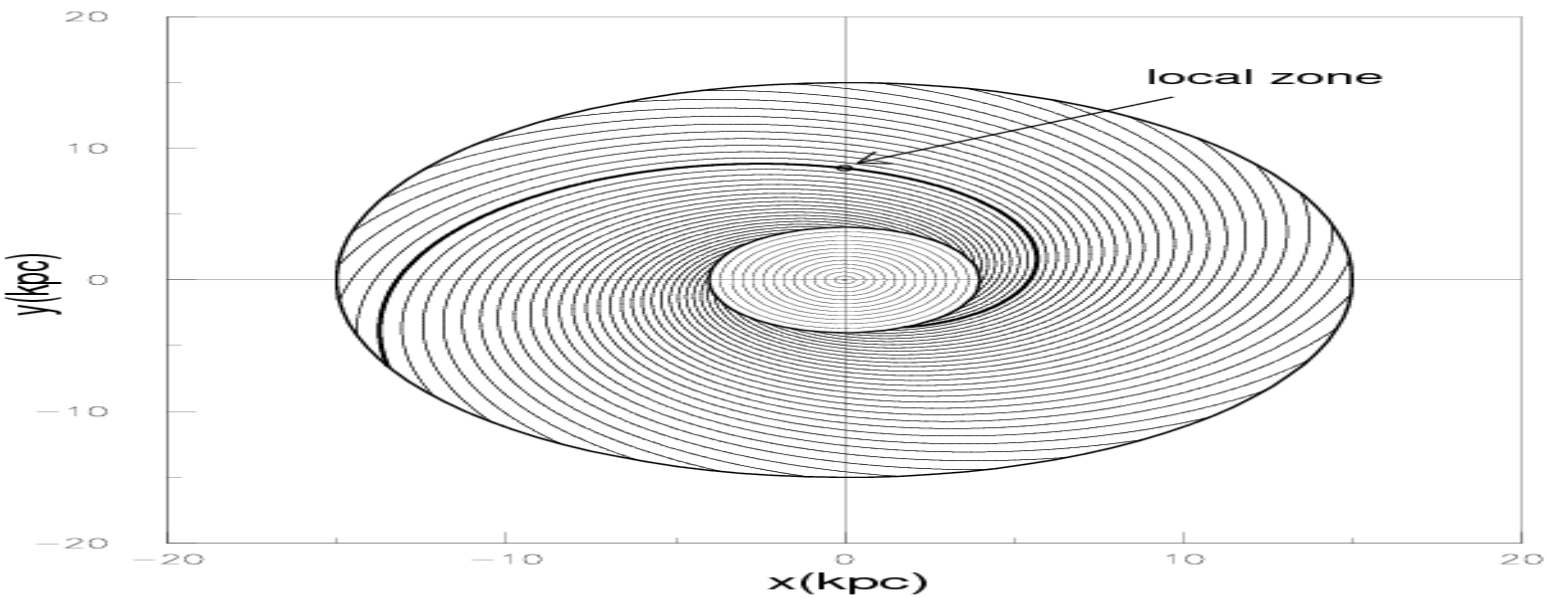
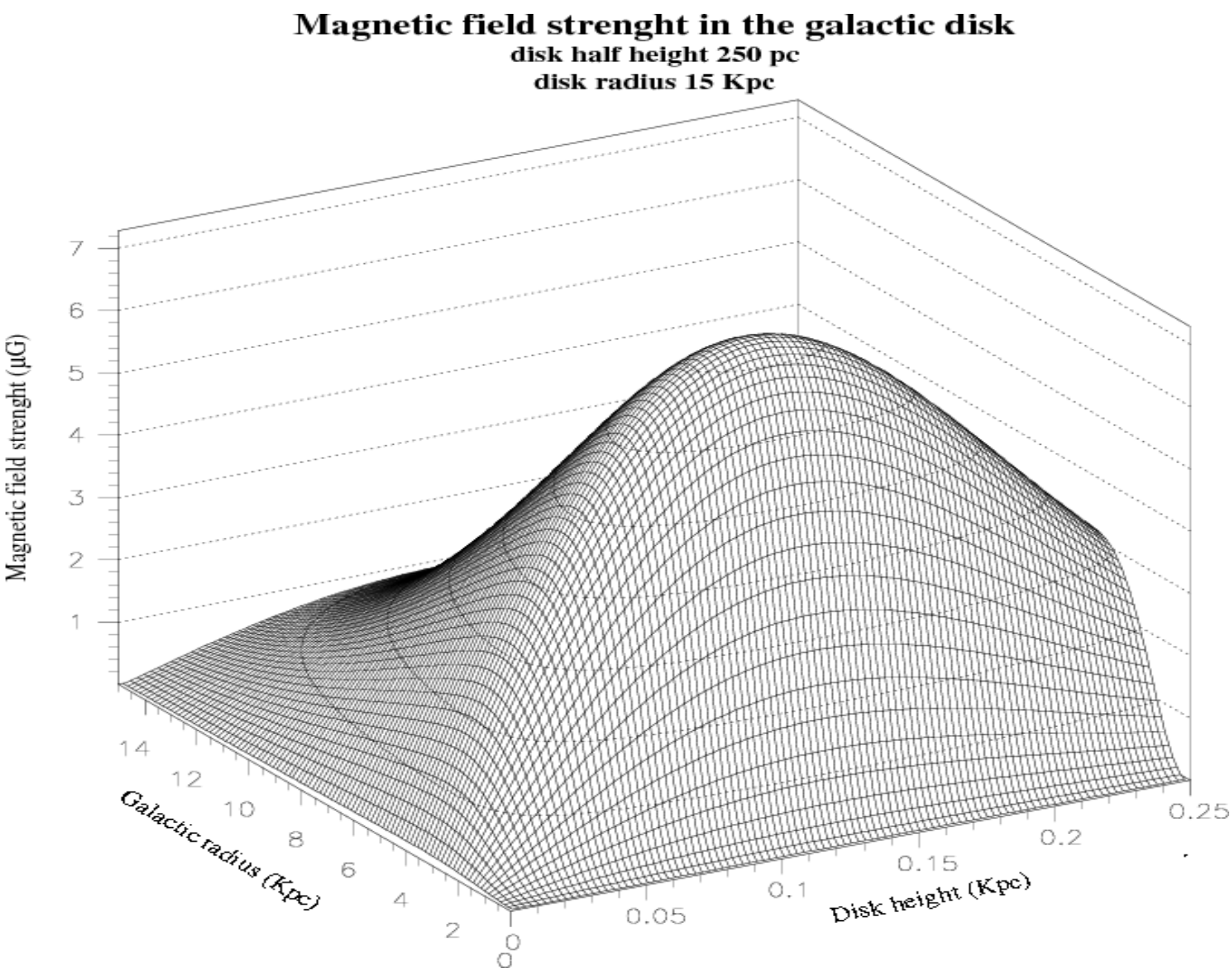

Direction of the north galactic pole
Cross view of the disk
Solar cavity
Top base of the disk
Bulge
Bottom base of the disk
Lateral surface of the galactic disk
Top view of the galactic disk
Sphere of 100 pc in radius defining the local galactic region
Bulge

Table 1: *Shapes and field strenghts of the regular magnetic fields in spiral galaxies determined by radio observations.*

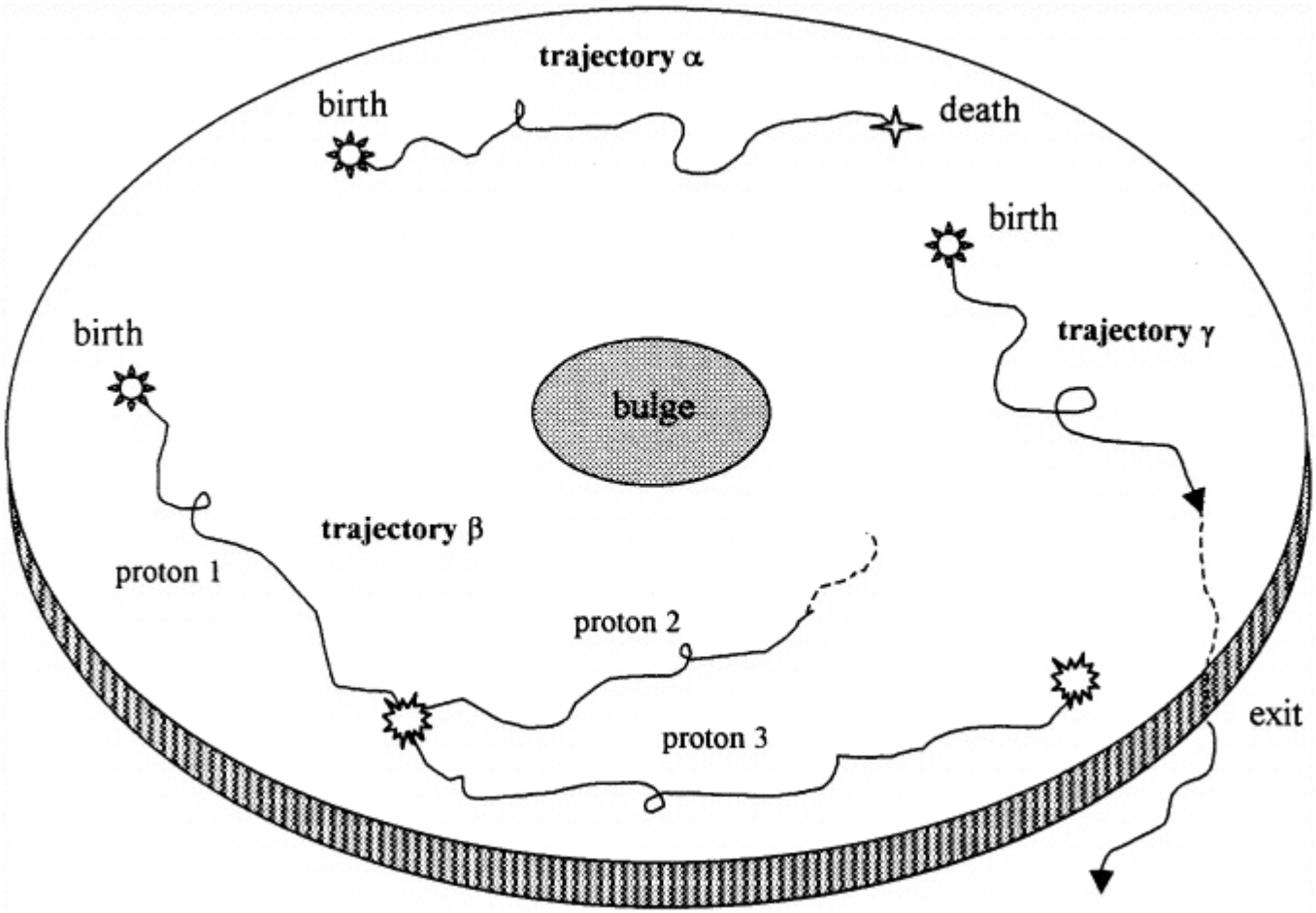
Galaxy	Regular field shape	Field strenght (μG)	References
M33	spiral	3±1	Sofue et al. 1981
M51	spiral	10	Mathewson et al. 1972
NGC 6946	spiral	12±4	Klein et al. 1982
M81	spiral	8±3	Sofue et al. 1980
M83	spiral	not given	Ondrechen 1985
M31	circular	3-4	Beck 1981
IC 342	circular	7±2	Graeve et al. 1986
NGC 253	probably spiral	a few μG	Klein et al. 1983
NGC 2903	spiral	not given	Sofue et al. 1985
NGC 5055	probably spiral	not given	Sofue et al. 1985
NGC 4631	not given	a few μG	Golla et al. 1988
NGC 891	parallel to the galactic plane	a few μG	Sukumar et al. 1991
NGC 4565	parallel to the galactic plane	not given	Sukumar et al. 1991

Champ magnetique spirale



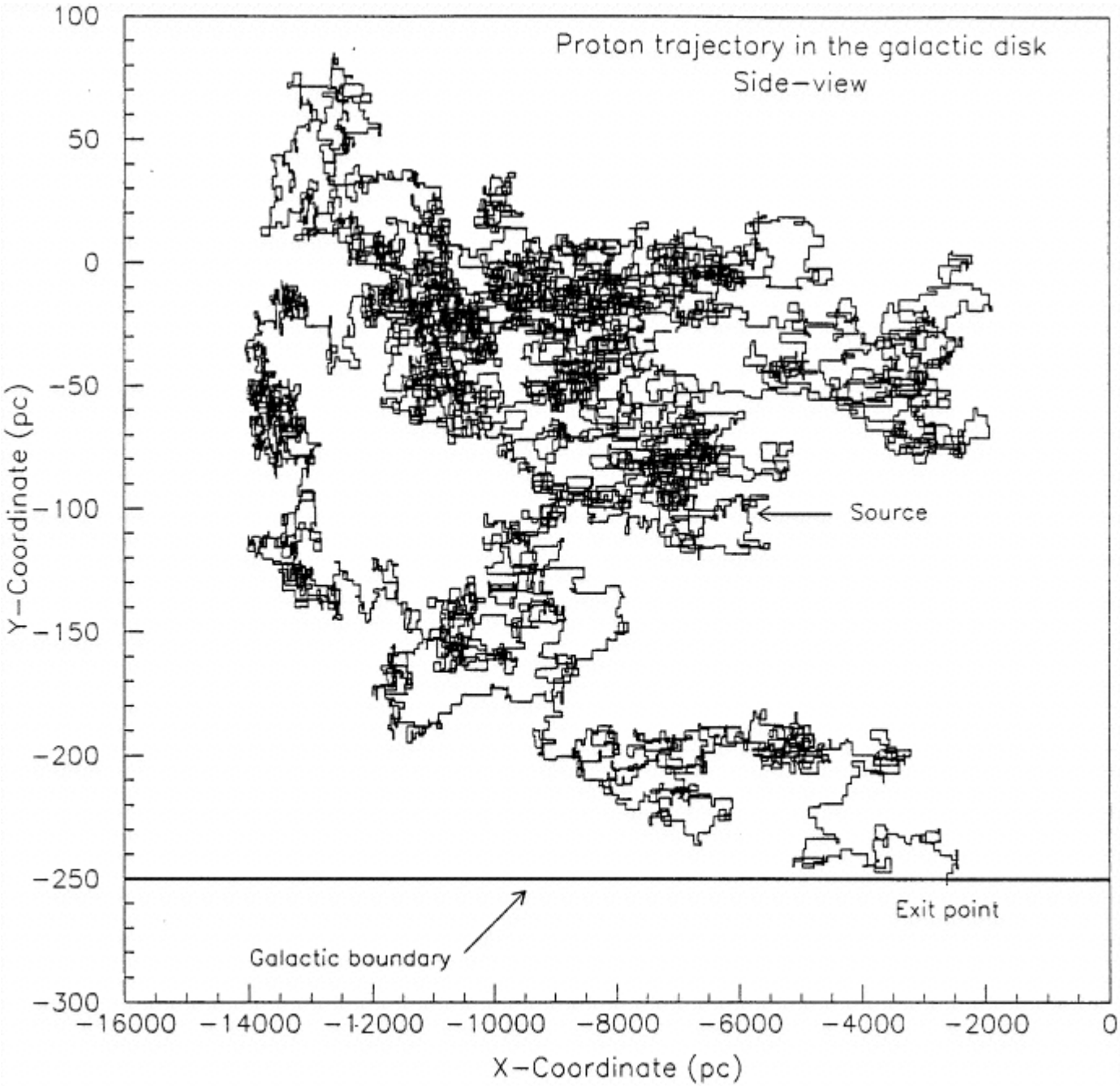

Magnetic field strenght in the galactic disk
disk half height 250 pc
disk radius 15 Kpc
Magnetic field strenght (μG)
7
6
5
4
3
2
1
Galactic radius (Kpc)
14
12
10
8
6
4
2
0
0
0.05
0.1
0.15
0.2
0.25
Disk height (Kpc)

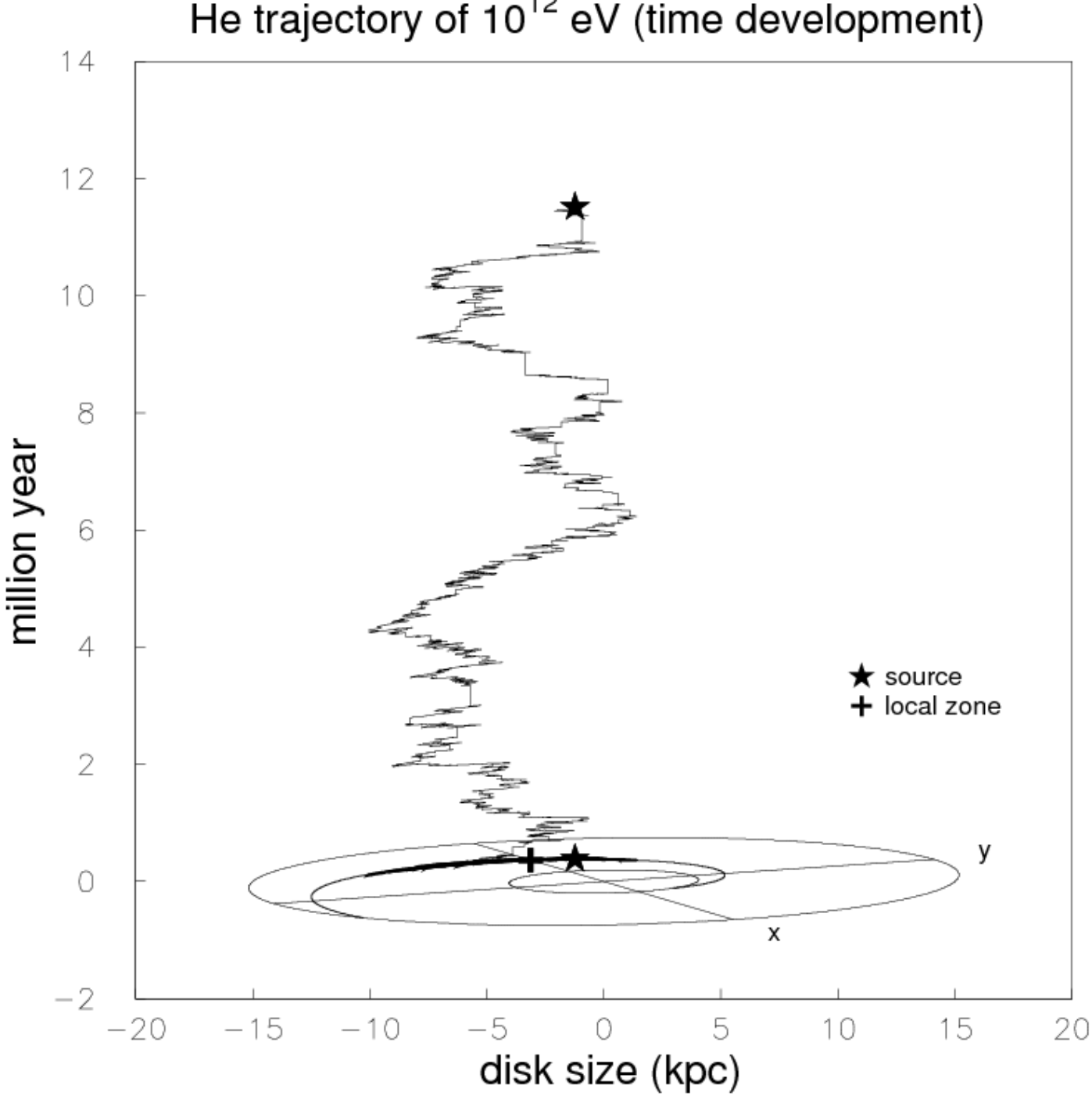
Trajectoires des rayons cosmiques dans le disque

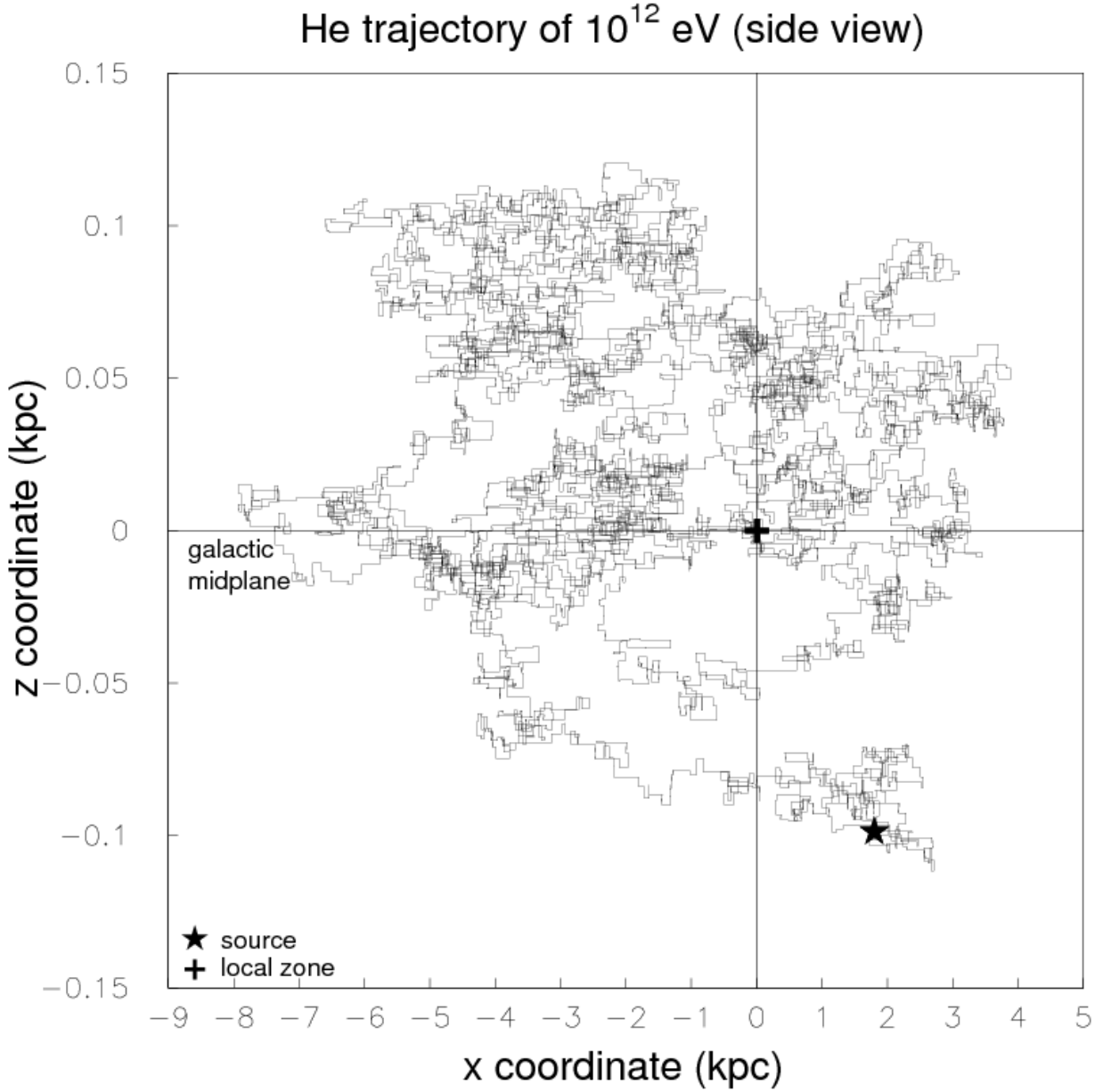


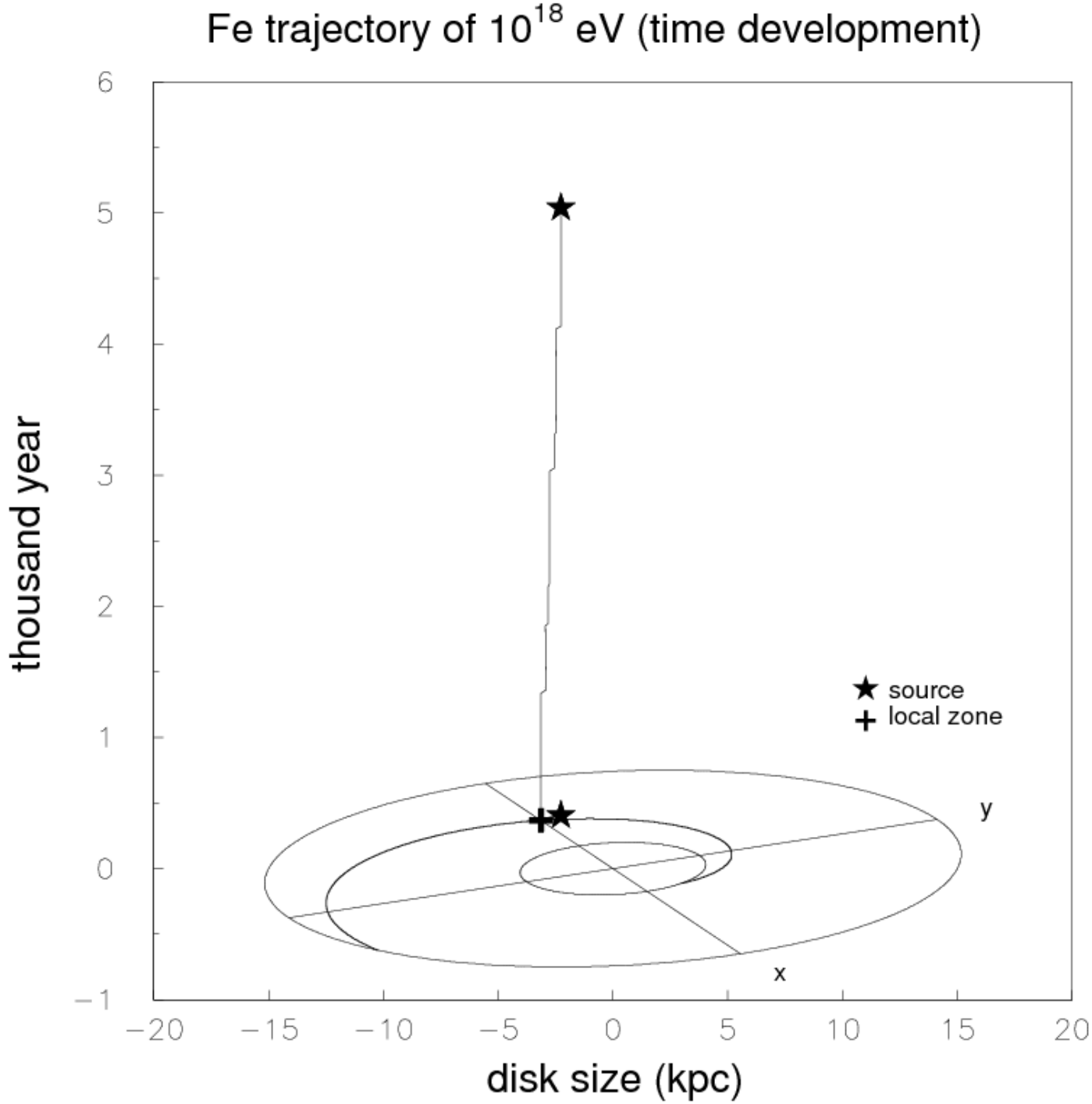
Brunetti & Codino, ApJ, 2000, 528, 789

Brunetti & Codino, ApJ, 2000, 528, 789




He trajectory of 10^{12} eV (time development)
million year
disk size (kpc)
source
local zone
x
y
14
12
10
8
6
4
2
0
−2
−20
−15
−10
−5
0
5
10
15
20


He trajectory of 10^{12} eV (side view)
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
z coordinate (kpc)
galactic
midplane
source
local zone
−9 −8 −7 −6 −5 −4 −3 −2 −1 0 1 2 3 4 5
x coordinate (kpc)


Fe trajectory of 10^{18} eV (time development)
thousand year
disk size (kpc)
source
local zone
y
x
6
5
4
3
2
1
0
−1
−20
−15
−10
−5
0
5
10
15
20

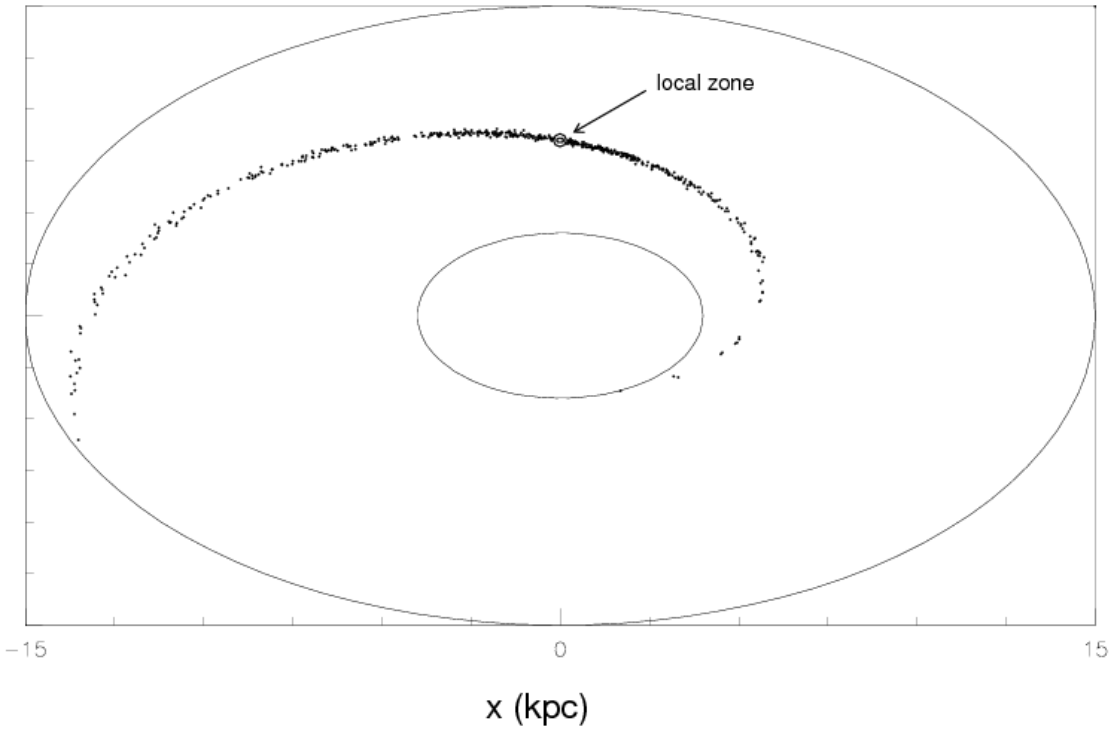
Les trajectoires des rayons cosmiques dans la Galaxie
paramètres additionneles

- La valeur moyenne de la densité de la matière est de un atom d' hydrogène par cm^3 augmenté a 1,24 compte tenu des elements lourds.

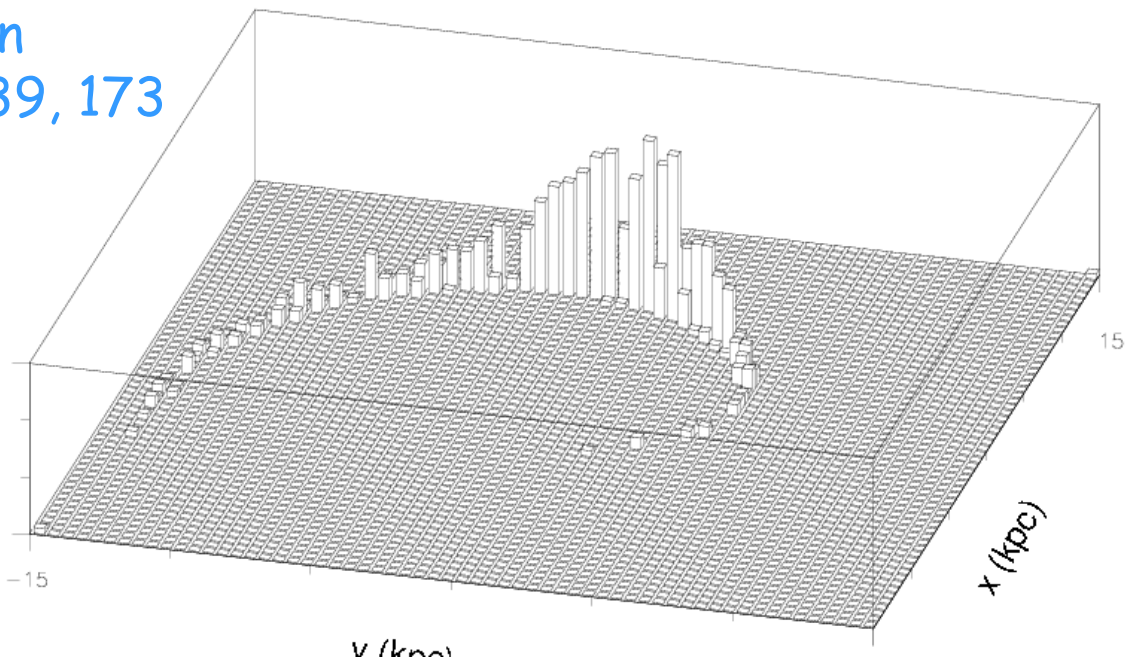
- Les sources sont representées par une distribution uniforme par l' équation

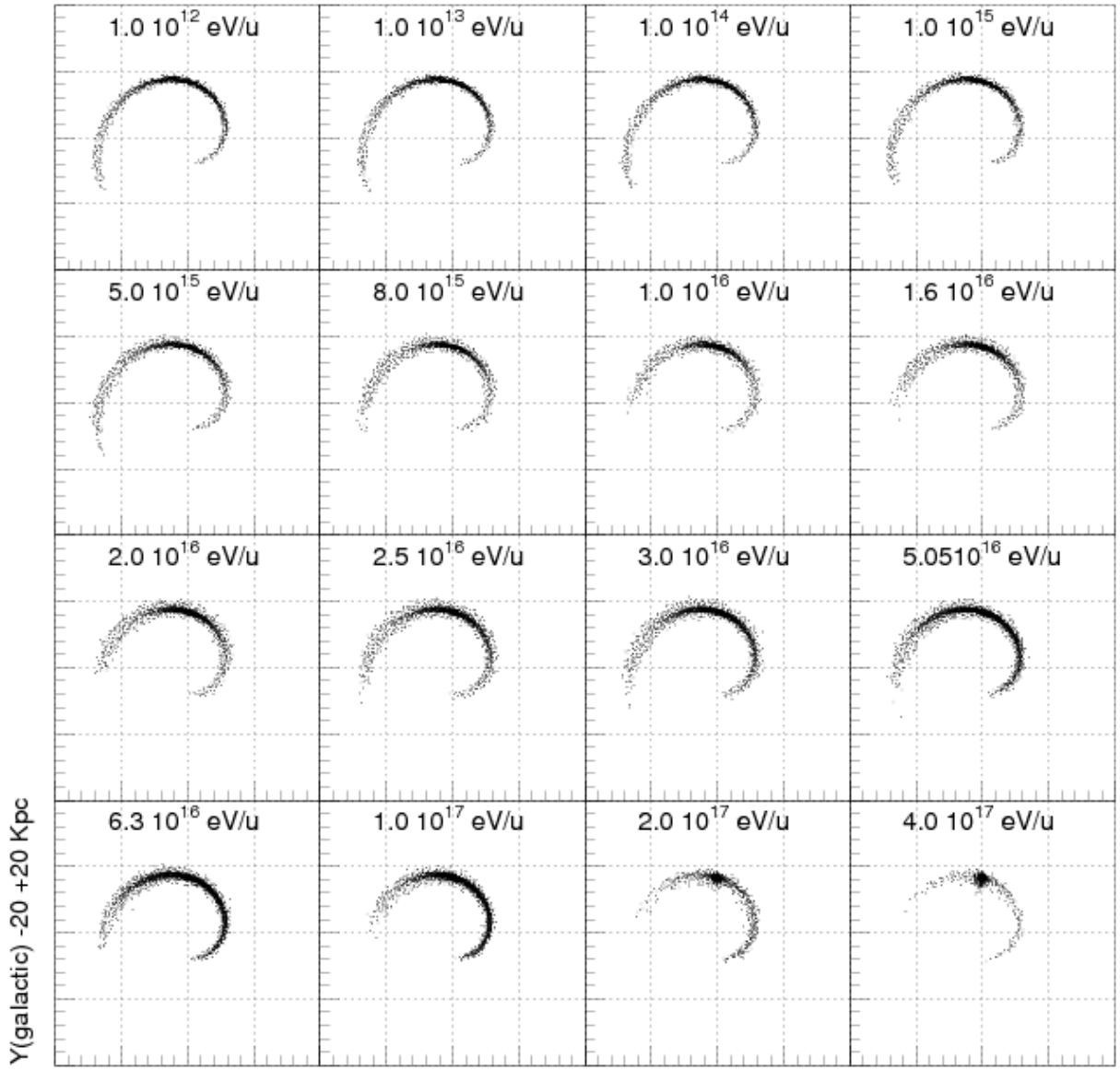
$$Q(r,z,l)=C\Theta(r-R)N(\sigma,z)$$

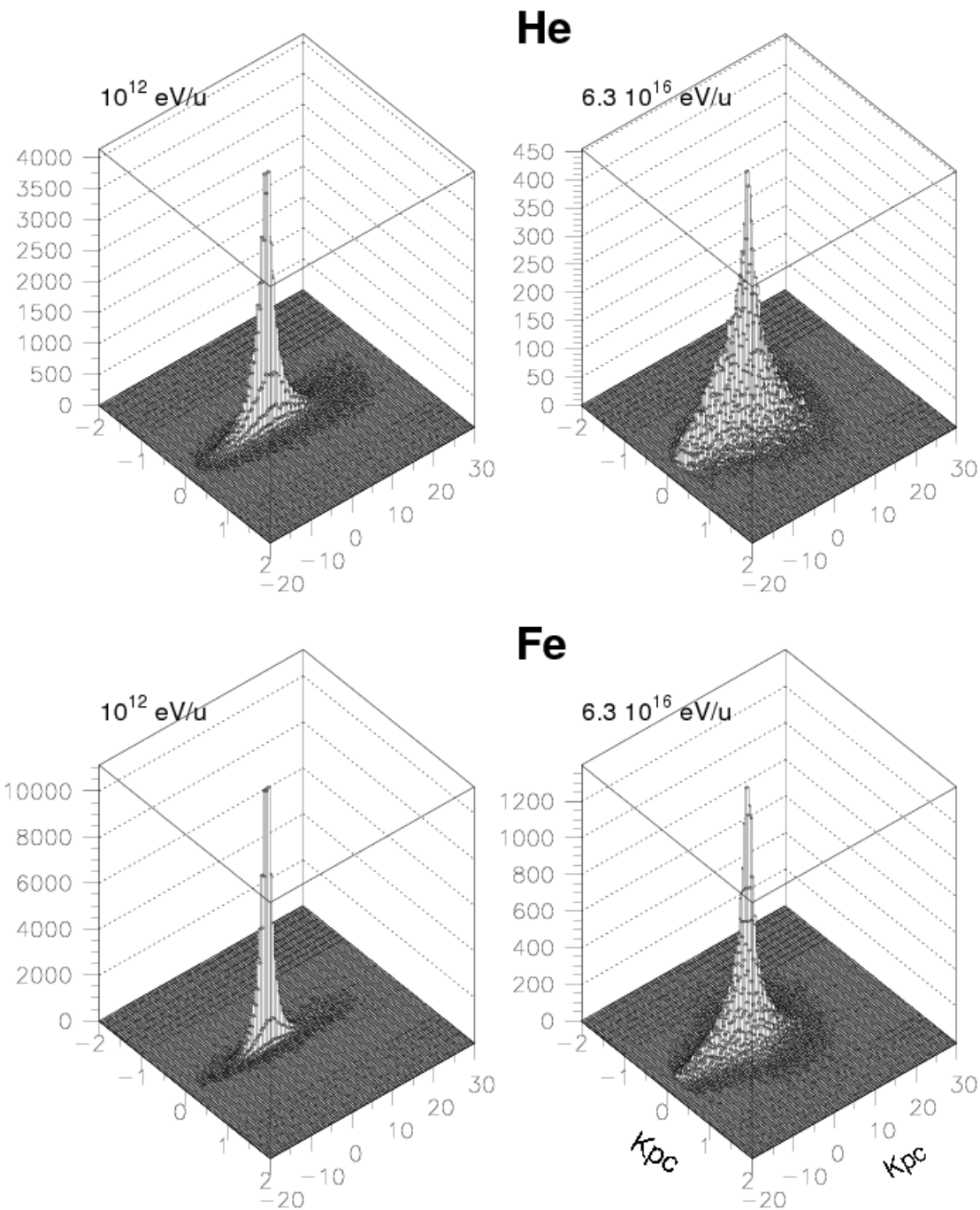
ou $N(\sigma,z)$ est une distribution gaussienne dans la direction z avec une deviation standard σ de 80 parsec.

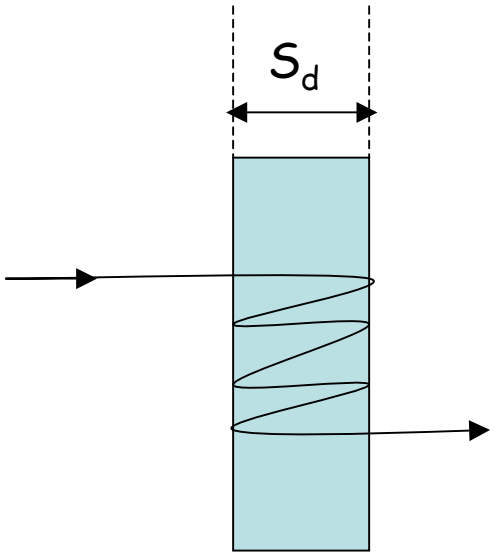


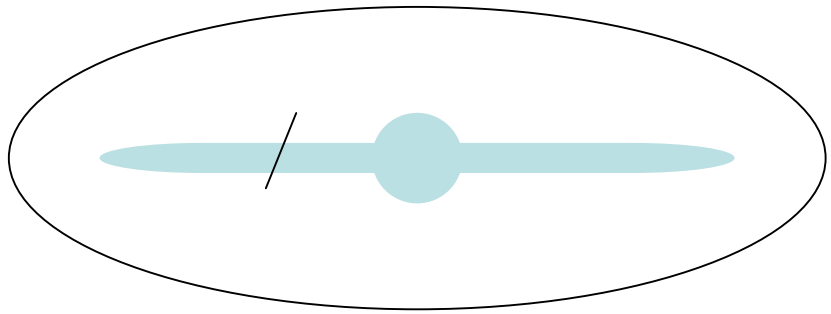
Codino & Plouin
ApJ, 2006, 639, 173




1.0 10^12 eV/u
1.0 10^13 eV/u
1.0 10^14 eV/u
1.0 10^15 eV/u
5.0 10^15 eV/u
8.0 10^15 eV/u
1.0 10^16 eV/u
1.6 10^16 eV/u
2.0 10^16 eV/u
2.5 10^16 eV/u
3.0 10^16 eV/u
5.0510^16 eV/u
6.3 10^16 eV/u
1.0 10^17 eV/u
2.0 10^17 eV/u
4.0 10^17 eV/u
Y(galactic) -20 +20 Kpc
X(galactic) -20 +20 Kpc.


He
10^{12} eV/u
4000
3500
3000
2500
2000
1500
1000
500
0
−2
−1
0
1
2
−20
−10
0
10
20
30
$6.3\ 10^{16}$ eV/u
450
400
350
300
250
200
150
100
50
0
Fe
10^{12} eV/u
10000
8000
6000
4000
2000
0
$6.3\ 10^{16}$ eV/u
1200
1000
800
600
400
200
0
Kpc
Kpc





g grammage (g/cm^2) colonne de gas rencontrée par les rayons cosmiques

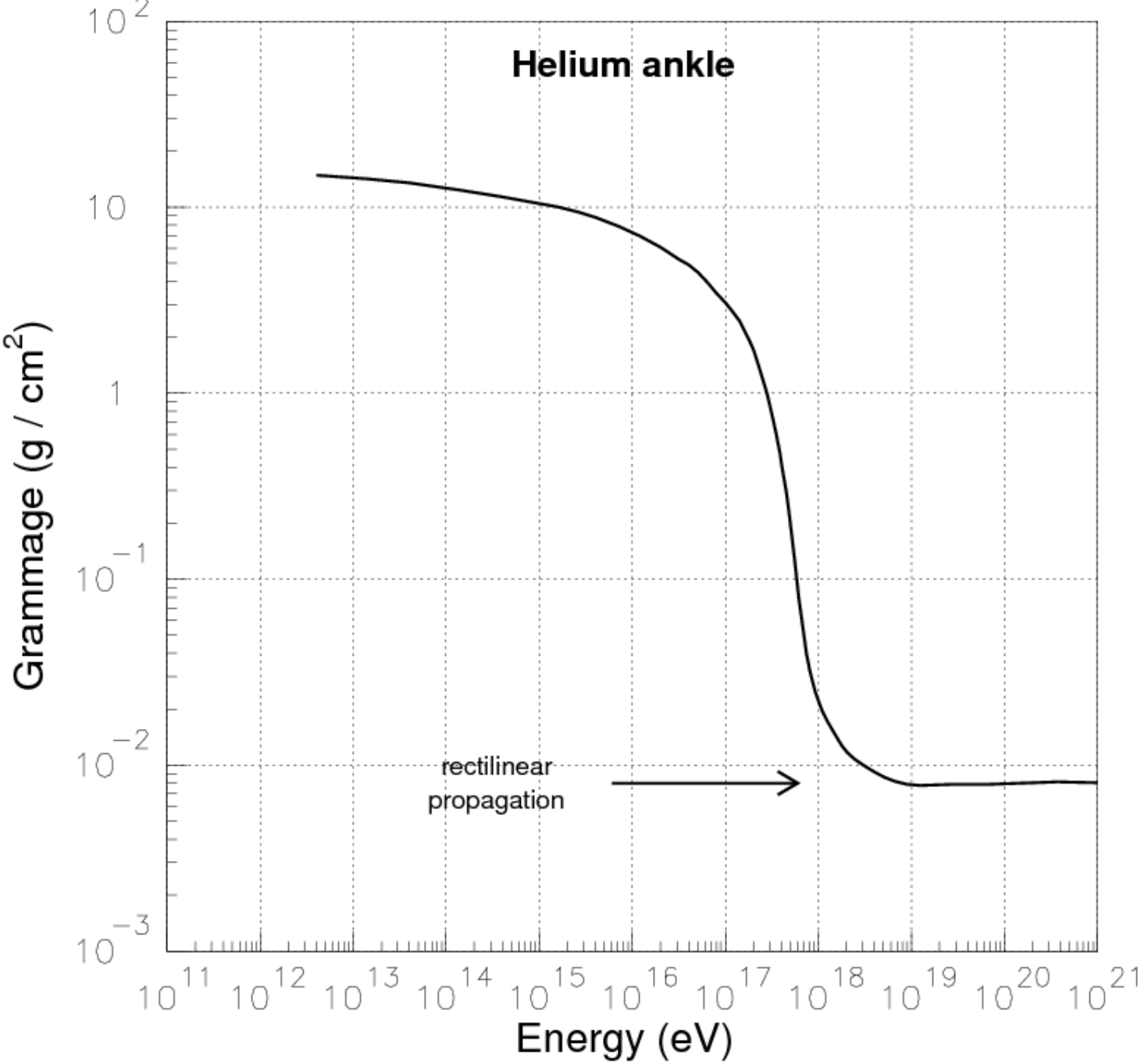
$g = m_H n_H L_D$

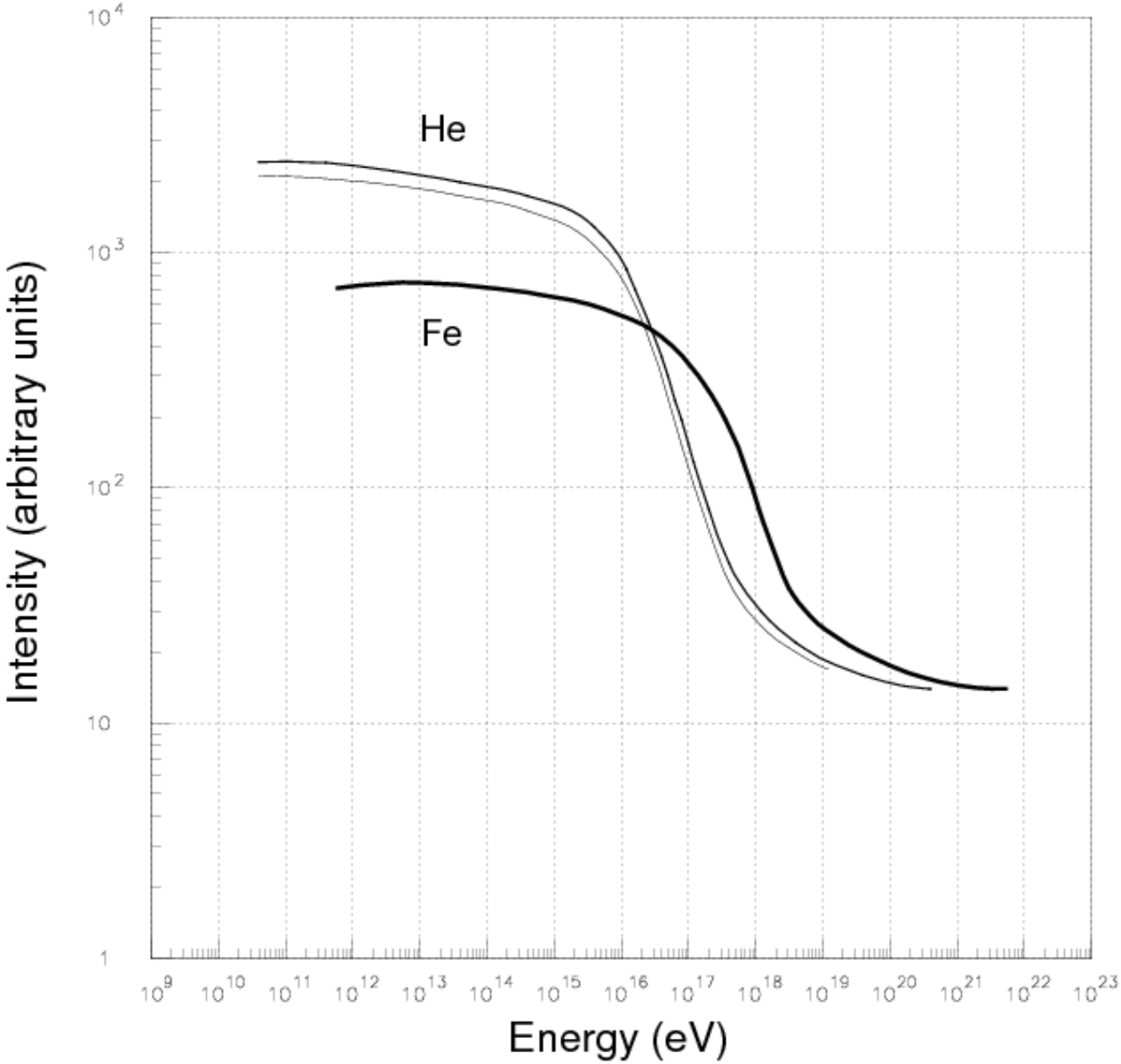
L_D longueur de la trajectoire
n_H nombre d' atoms par centimètre cube
m_H mass de l' hydrogène

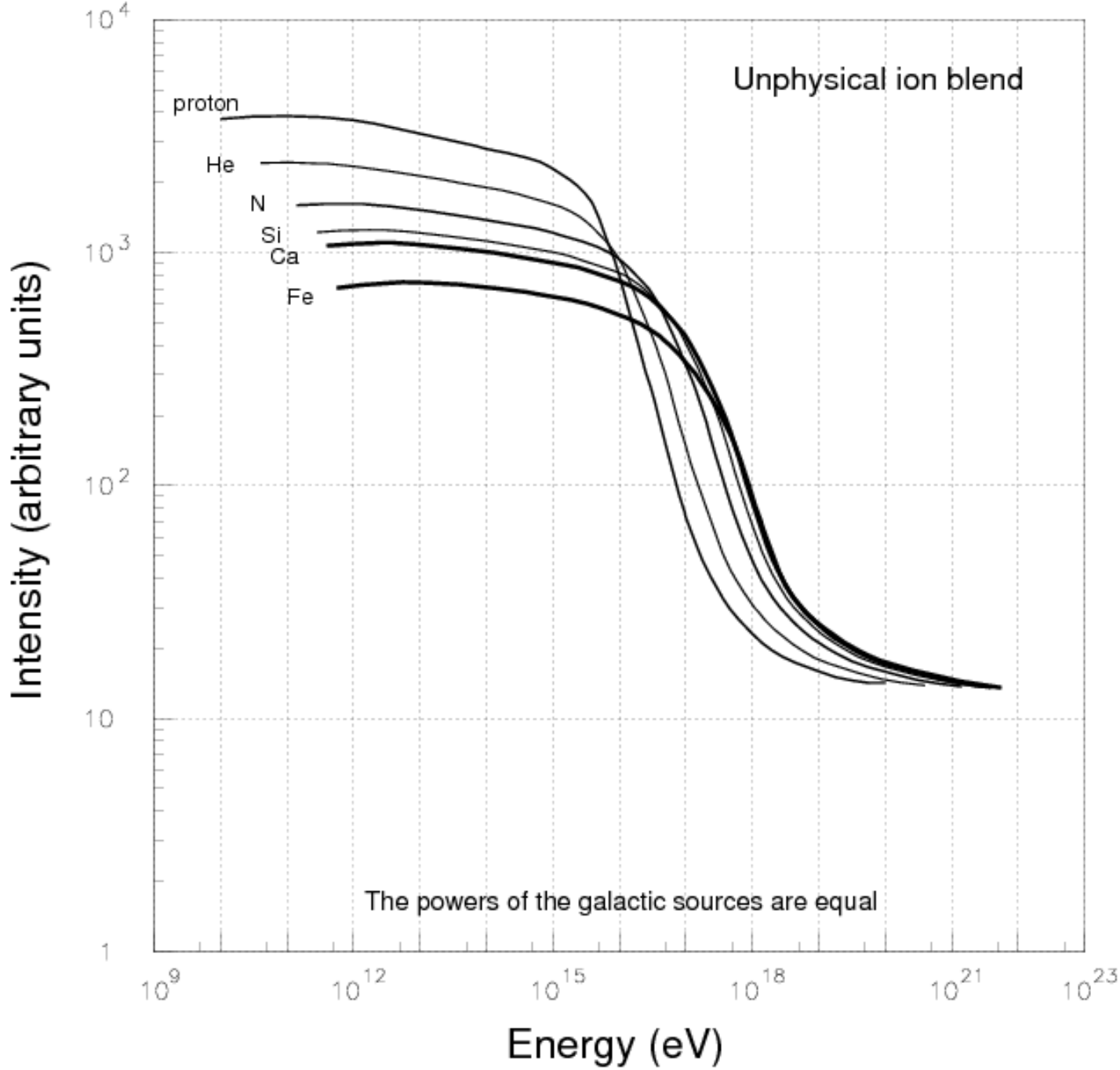
$L_D = v_d\, s_d$

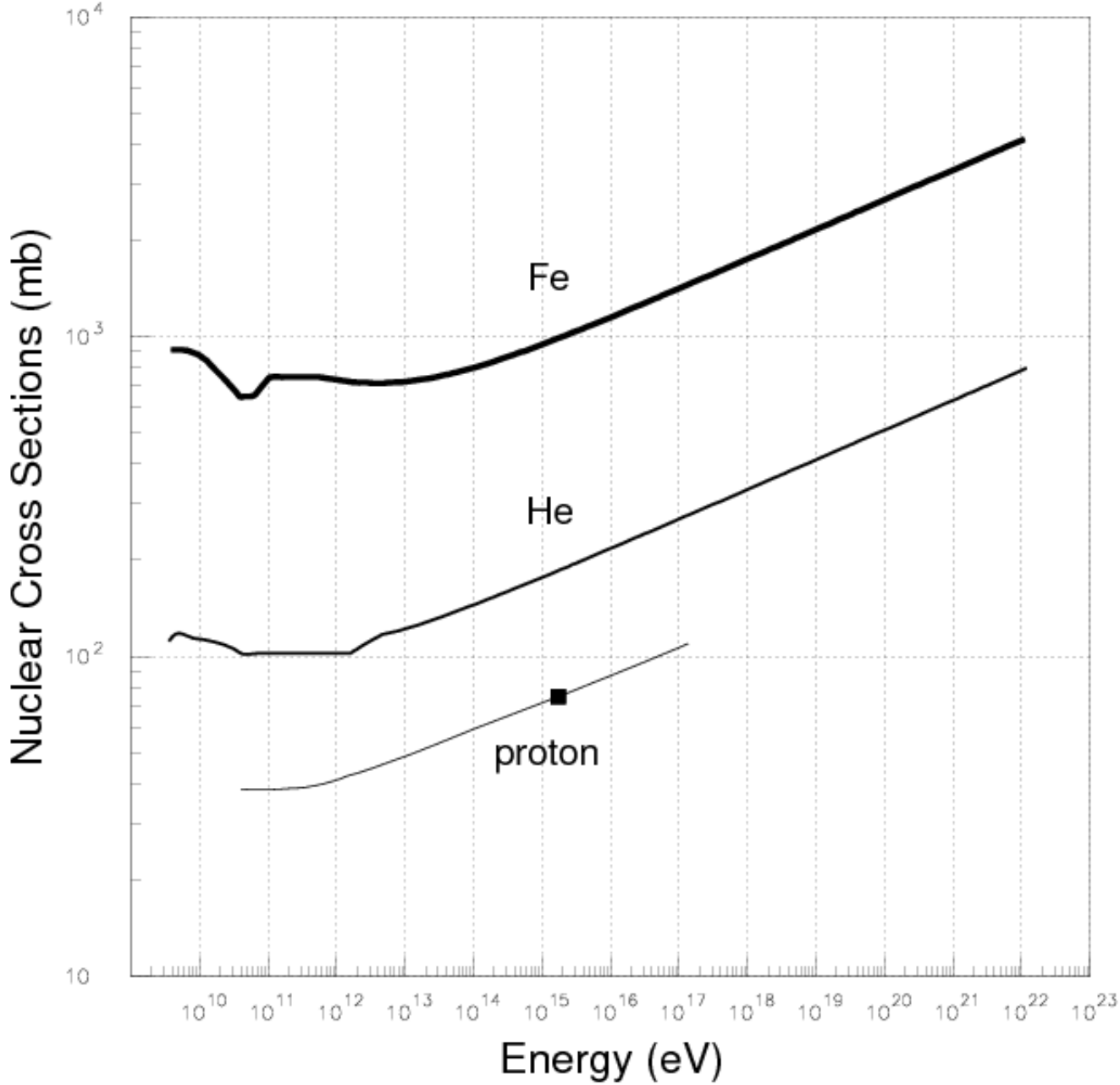
V_d nombre d' inversions du mouvement
S_d épaisseur physique du disque

$\lambda = A / (\sigma\ g\ N_A)$ longueur de collision nucléaire

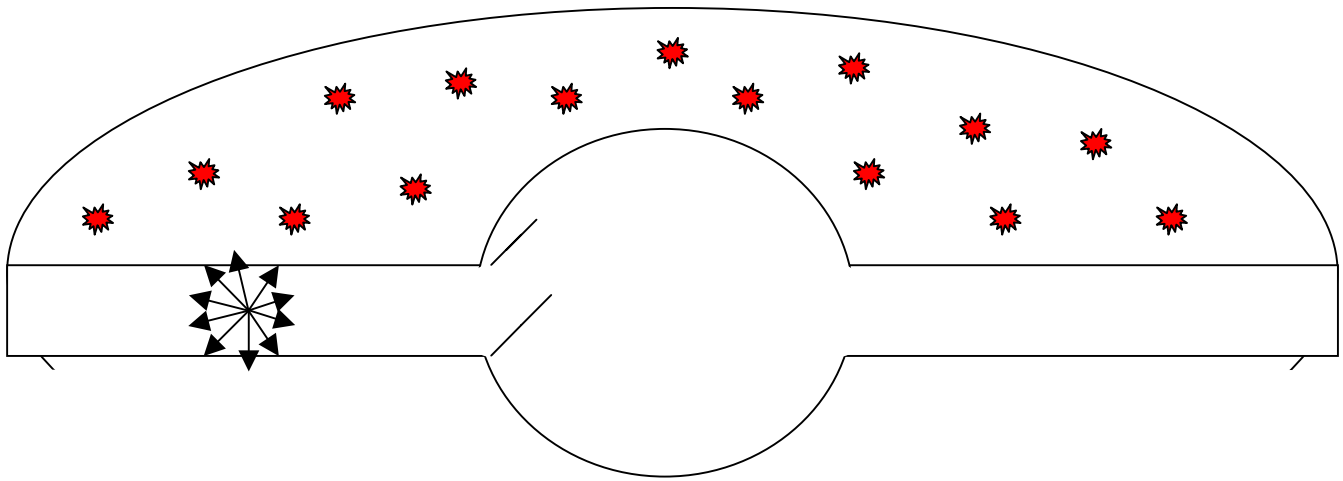

Helium ankle
Grammage (g / cm^2)
Energy (eV)
rectilinear
propagation
10^{2}
10
1
10^{-1}
10^{-2}
10^{-3}
10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21}


He
Fe
Intensity (arbitrary units)
Energy (eV)
10^4
10^3
10^2
10
1
10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21} 10^{22} 10^{23}

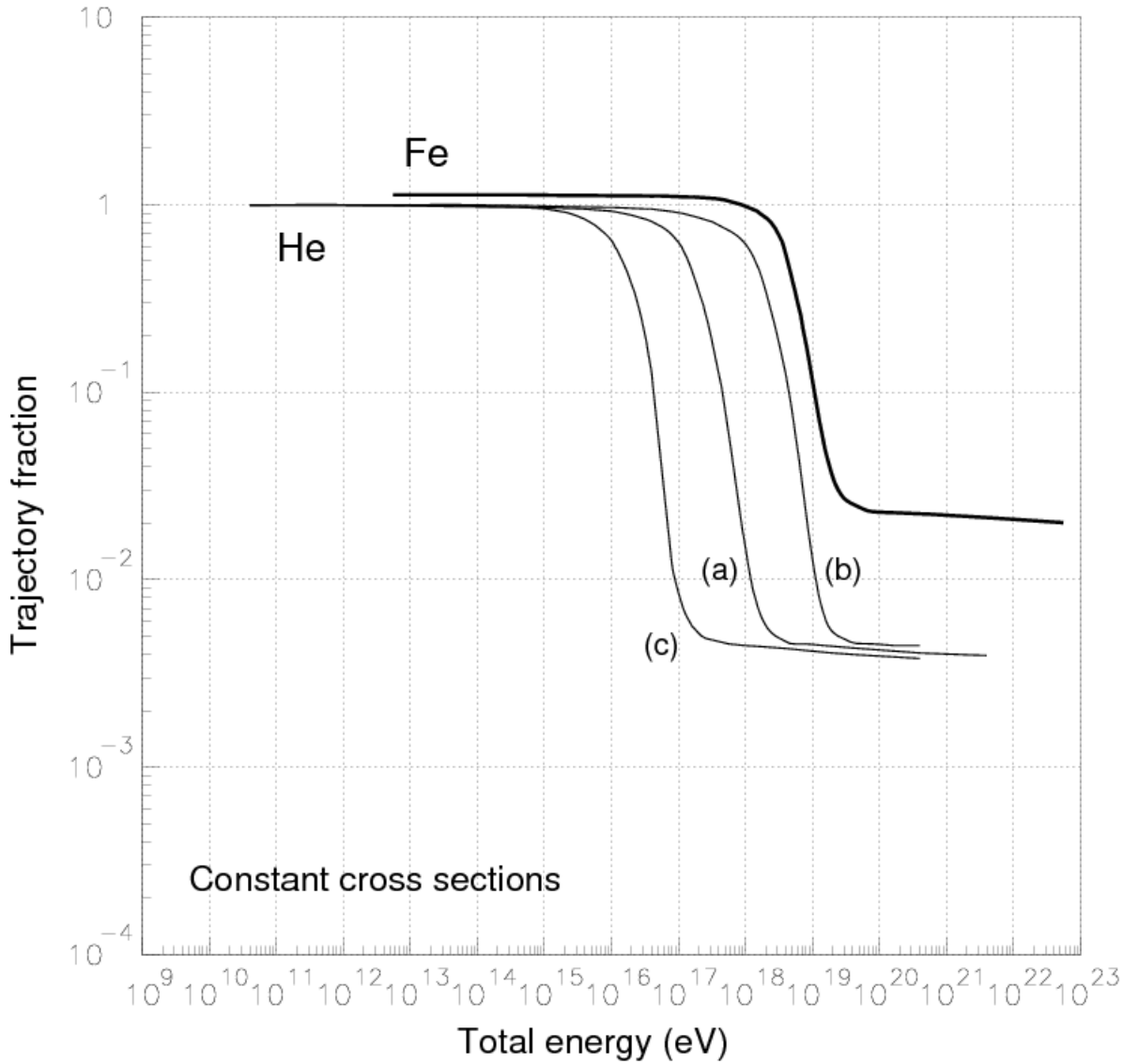

Unphysical ion blend
proton
He
N
Si
Ca
Fe
The powers of the galactic sources are equal
Intensity (arbitrary units)
Energy (eV)
10^4
10^3
10^2
10
1
10^9
10^12
10^15
10^18
10^21
10^23

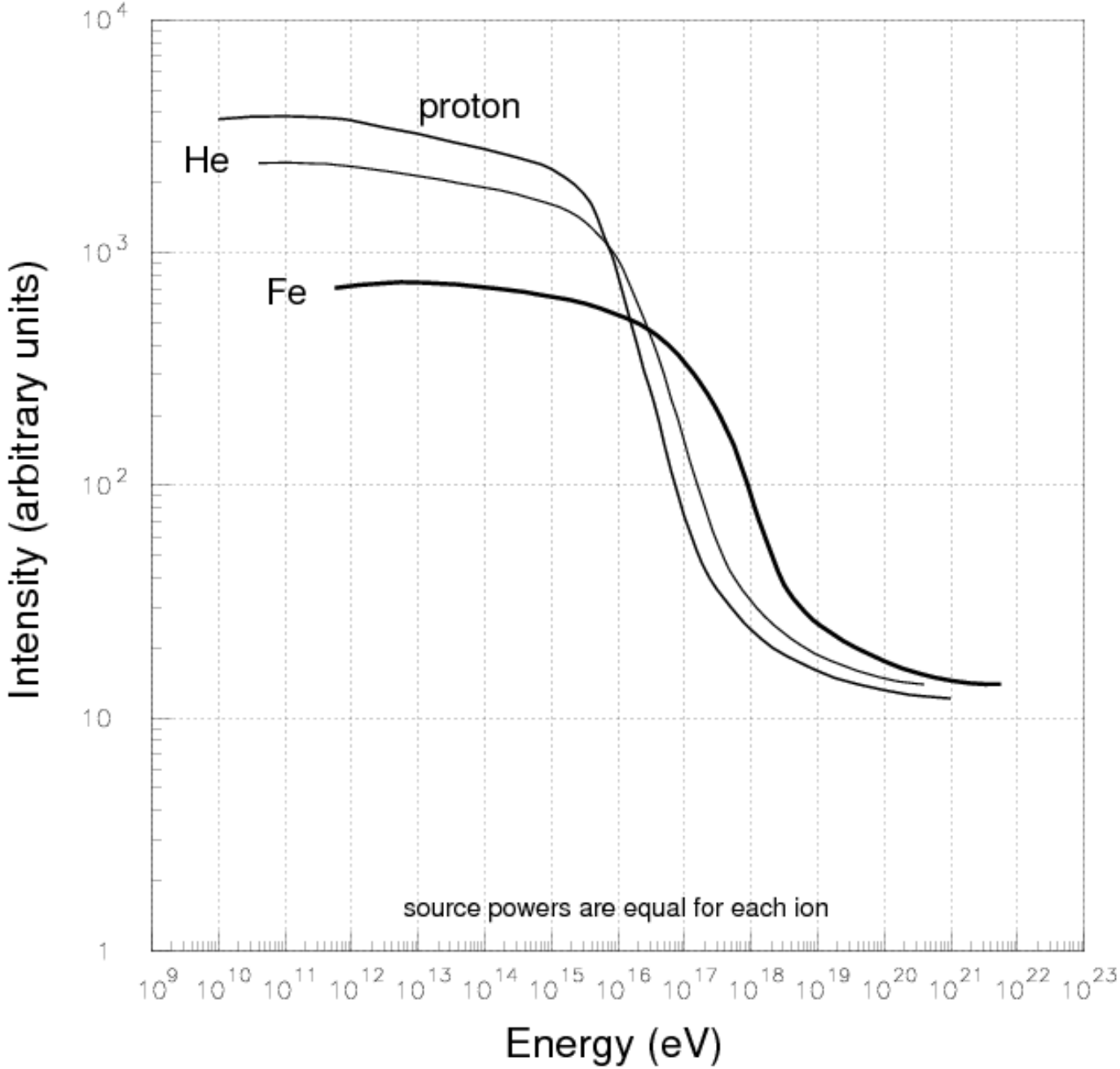

Nuclear Cross Sections (mb)
10^4
10^3
10^2
10
Fe
He
proton
10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21} 10^{22} 10^{23}
Energy (eV)

Illuminating the Galaxy by an ion beam emitted from the Earth and counting the number of nuclear collisions in the disk



nuclear collisions


Fe
He
(a)
(b)
(c)
Constant cross sections
Trajectory fraction
Total energy (eV)
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{9} 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21} 10^{22} 10^{23}


proton
He
Fe
source powers are equal for each ion
Intensity (arbitrary units)
Energy (eV)
10^4
10^3
10^2
10
1
10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20 10^21 10^22 10^23

Abondances des ions cosmiques et indices spectraux

Dans les figures précédentes, les sources galactiques des ions individuels avaient toutes la me^me puissance, ce qui, évidemment n'est pas la réalité.

Nous devons prendre en compte les abondances des rayons cosmiques et les indices spectraux de chaque ion cosmique.

Abondances relatives de ions cosmiques à basses energies

(bien au-dessous du genou)

Energie = 10^{12} eV

Ions	Composition (%)	Indices Spectraux	Intensité (ions/m^2 s sr GeV)	Reference
H	41	2.75 ± 0.02	10.91 ± 0.32	Wiebel-Sooth
He	26	2.62 ± 0.02	6.60 ± 0.15	
CNO	11	2.67 ± 0.02	2.86 ± 0.06	
Ne-S	10	2.64 ± 0.03	2.43 ± 0.07	
Fe-Ni (17-26)	10	2.60 ± 0.03	2.52 ± 0.05	
Other heavy ions	0.5	2.60 ± 0.03	0.02 ± 0.02	

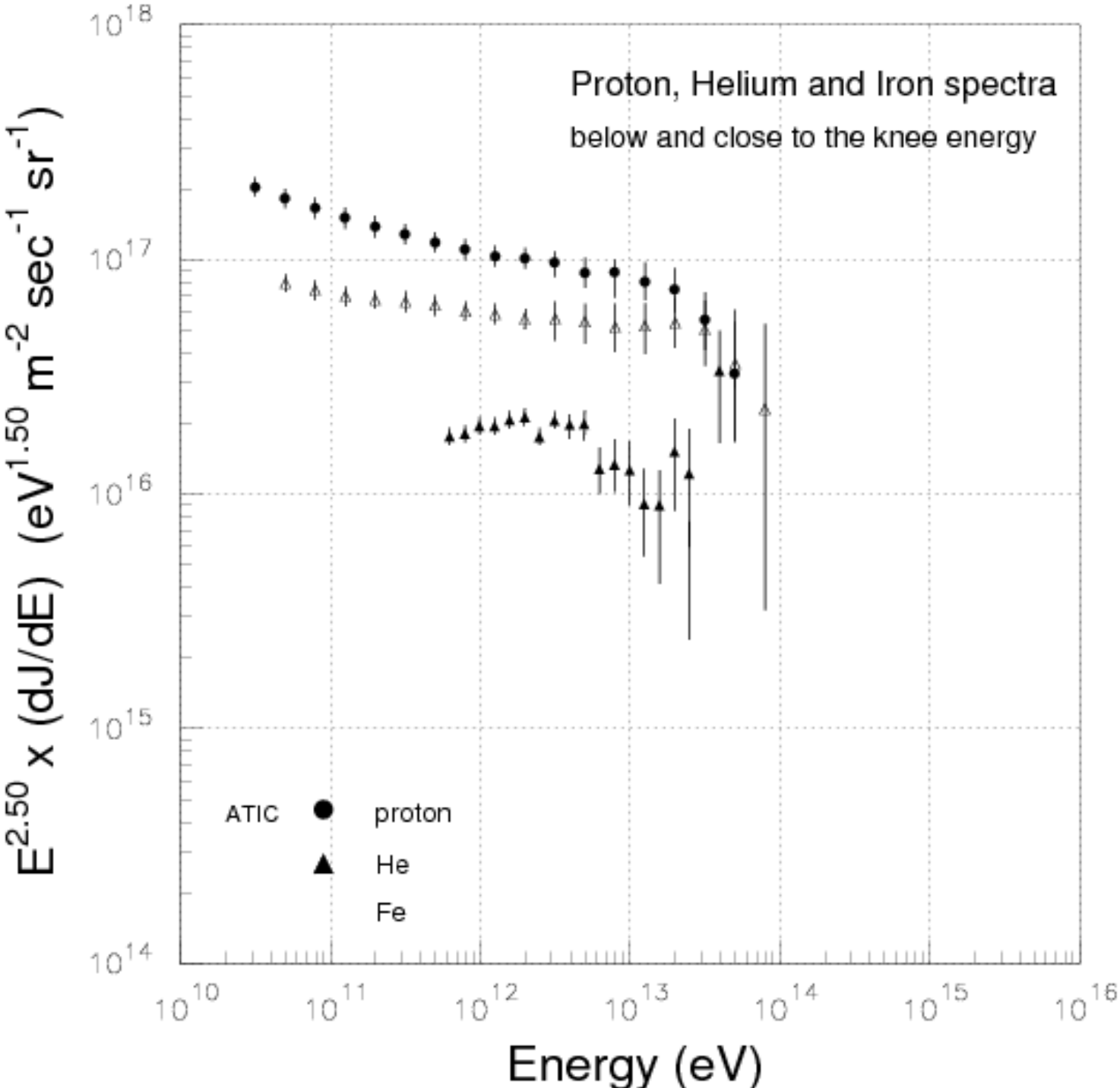
Hypothèse sur les indices spectraux de la rayons cosmiques

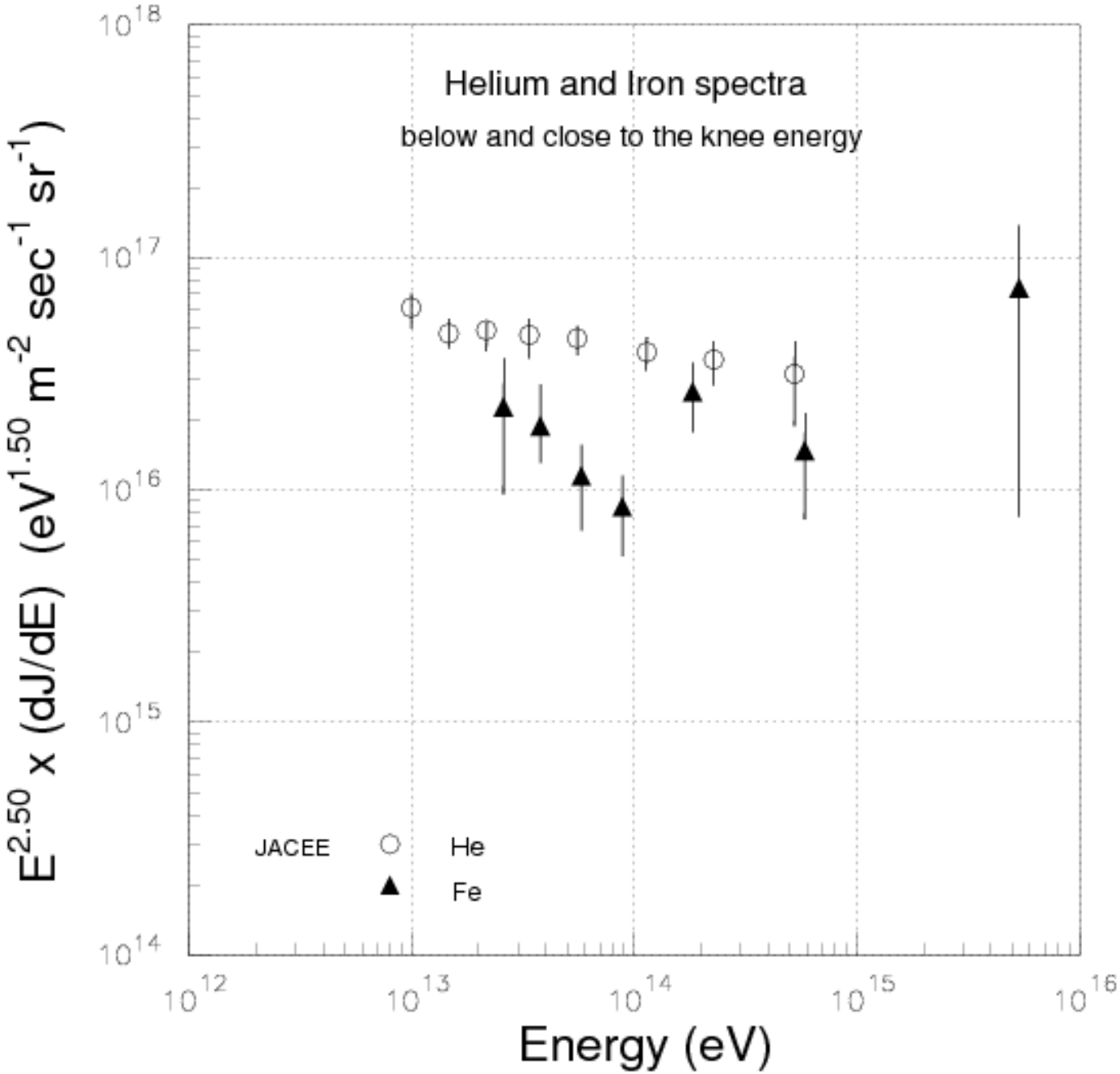
Les indices spectraux mesurés dans les expériences et aussi
les abondances des ions dans la band d' energie au-desous du genou
sont des paramètres importants qui contribuent à l' évaluation des
spectres cosmiques.

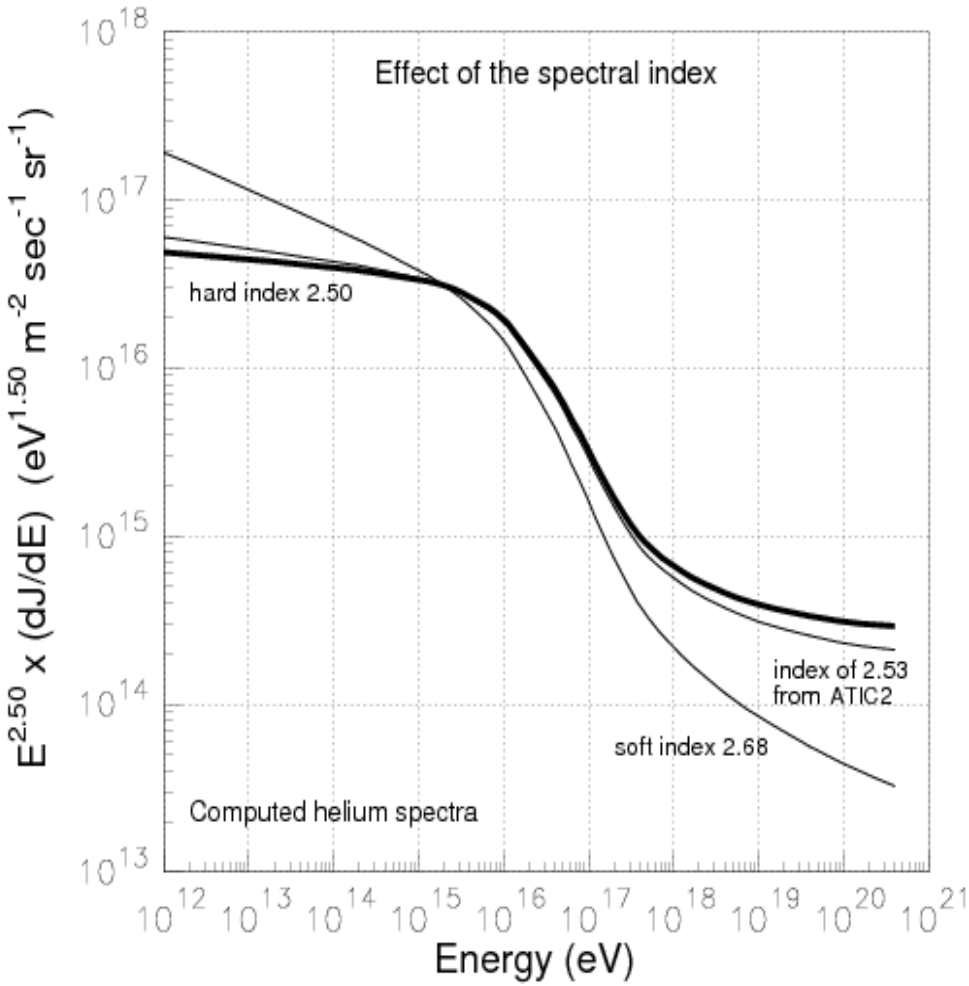
Les valeurs des indices spectraux utilisées dans le calcul
sont supposée (et donc adoptées) constantes dans toute la bande d' energie
pour chaque ion cosmique (entre quelques GeV jusqu' à 10^21 eV).

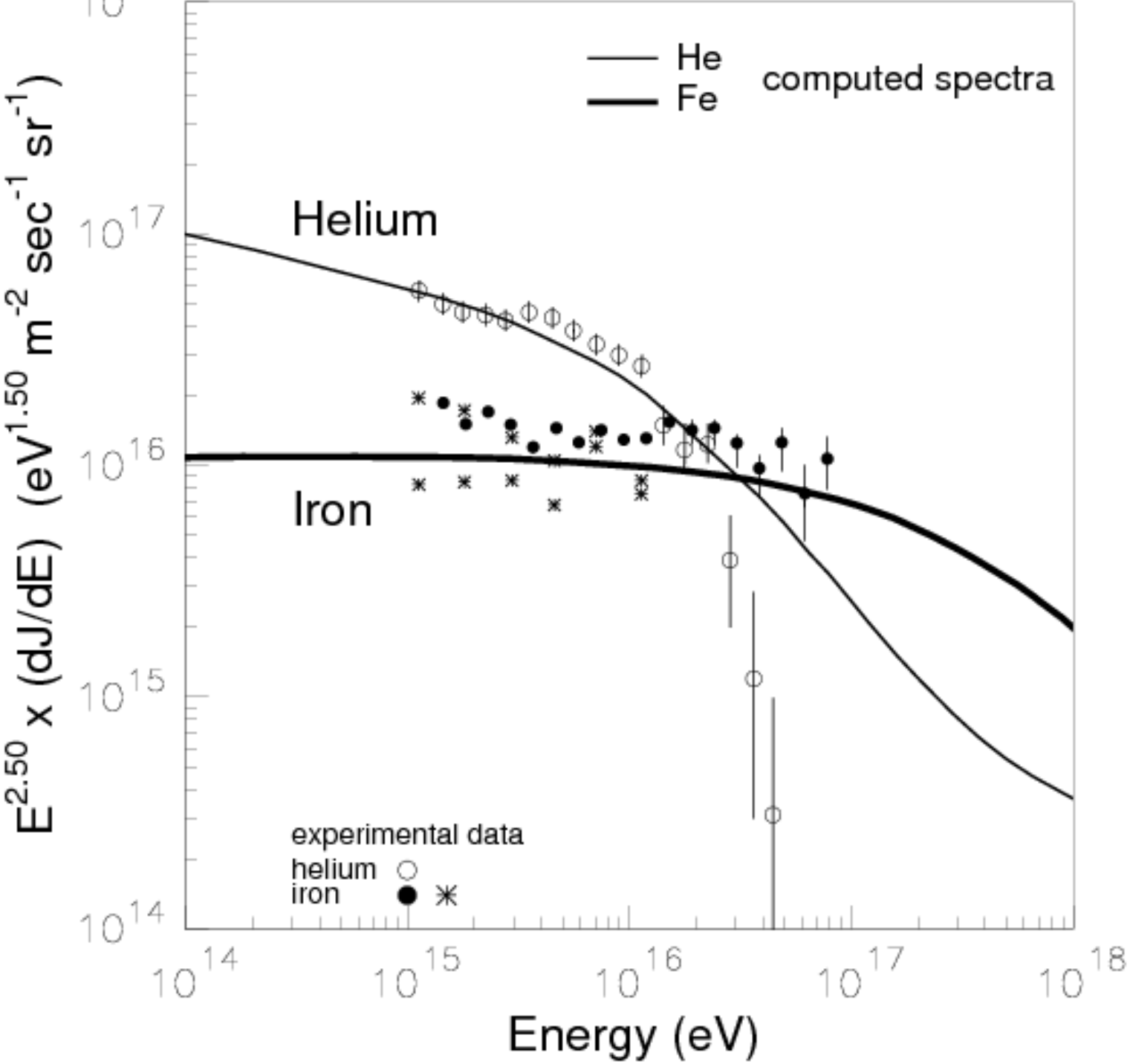
Il n' y a donc pas d'adjustements arbitraires dans le calcul.

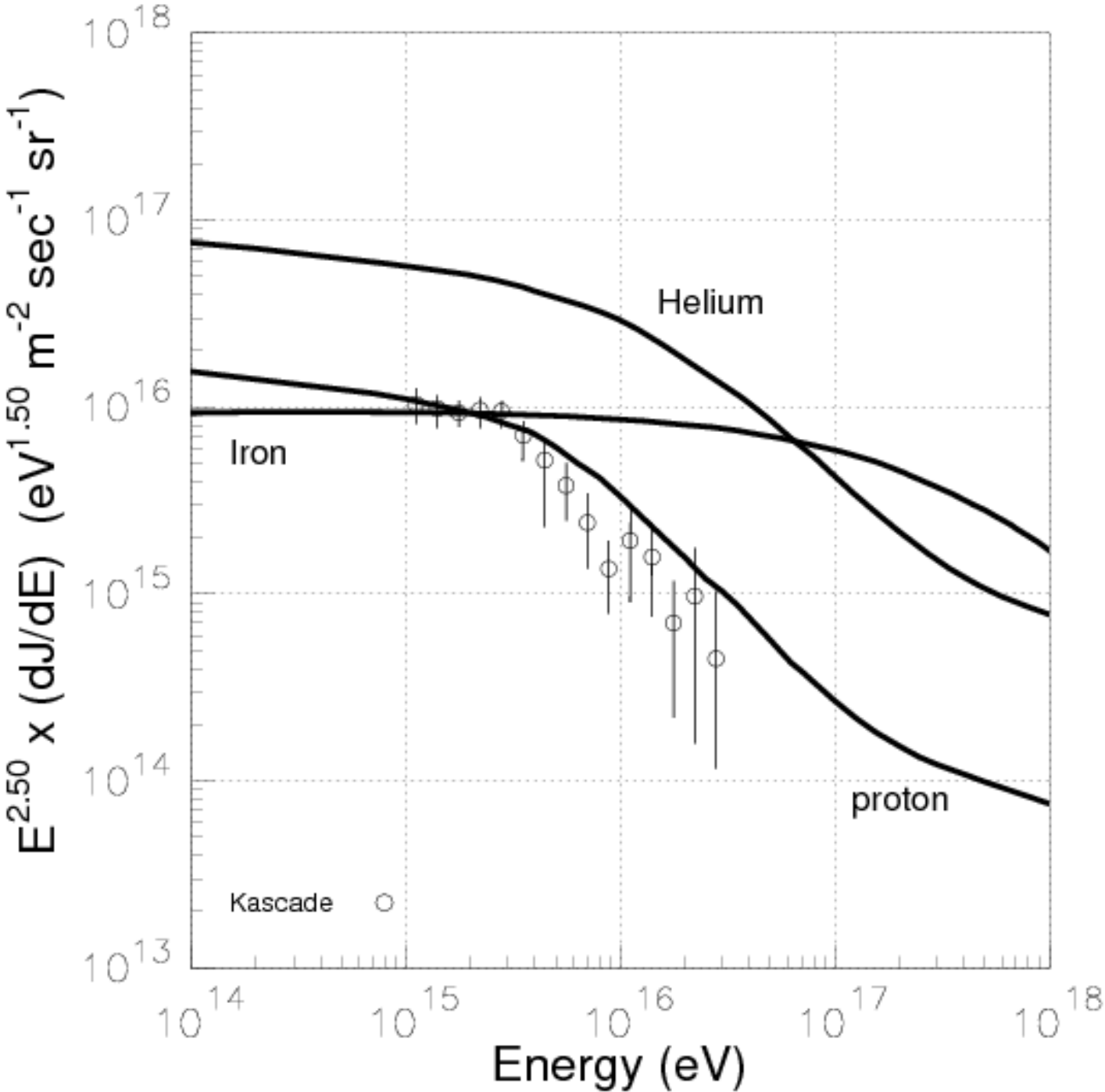
Il n' y a pas non plus de distinction entre les indices aux sources
et les indices mesurés par les èxperiences autour de la Terra (zone locale).

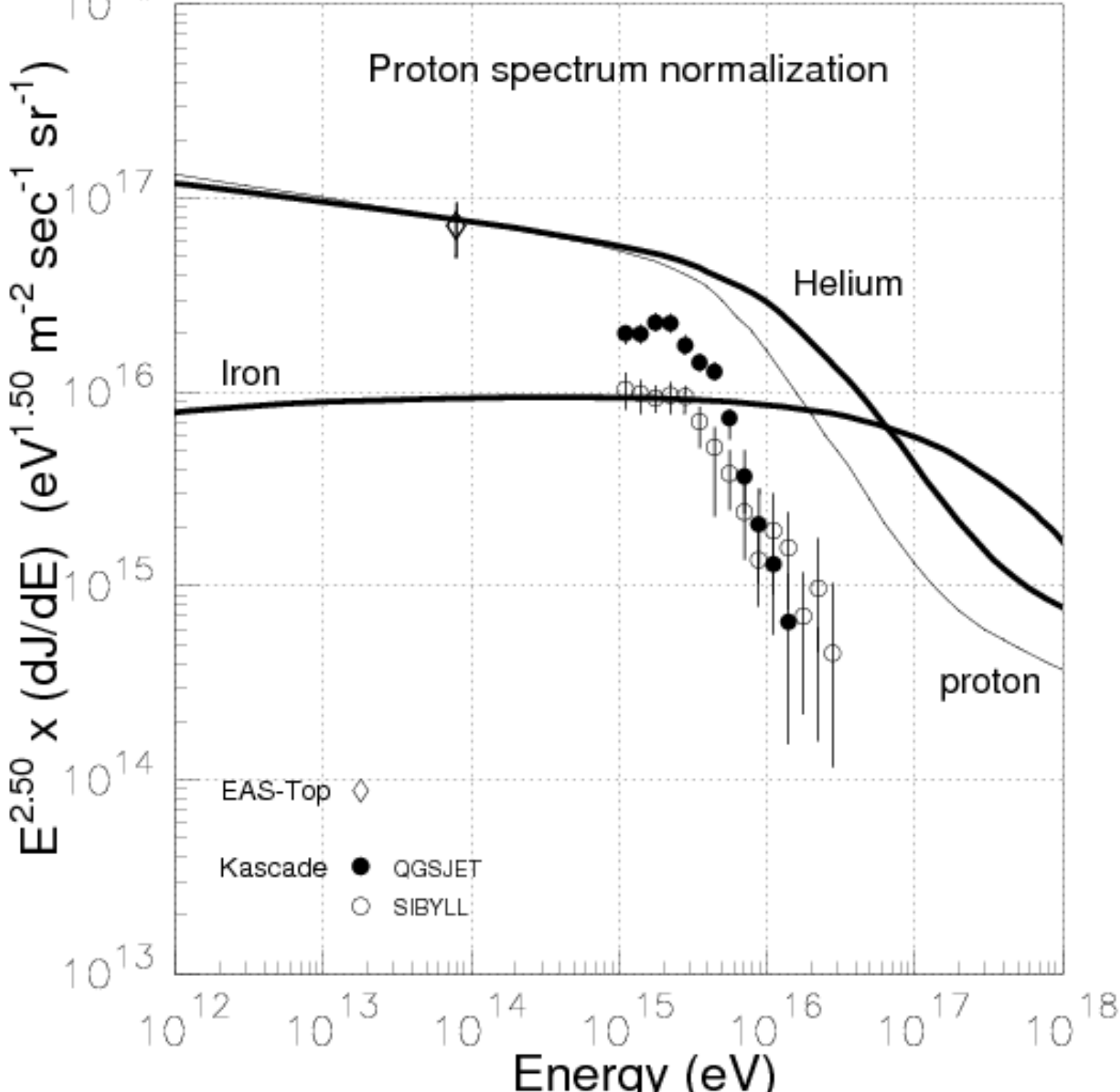

Proton, Helium and Iron spectra
below and close to the knee energy
ATIC
proton
He
Fe
$E^{2.50}$ x (dJ/dE) (eV$^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}

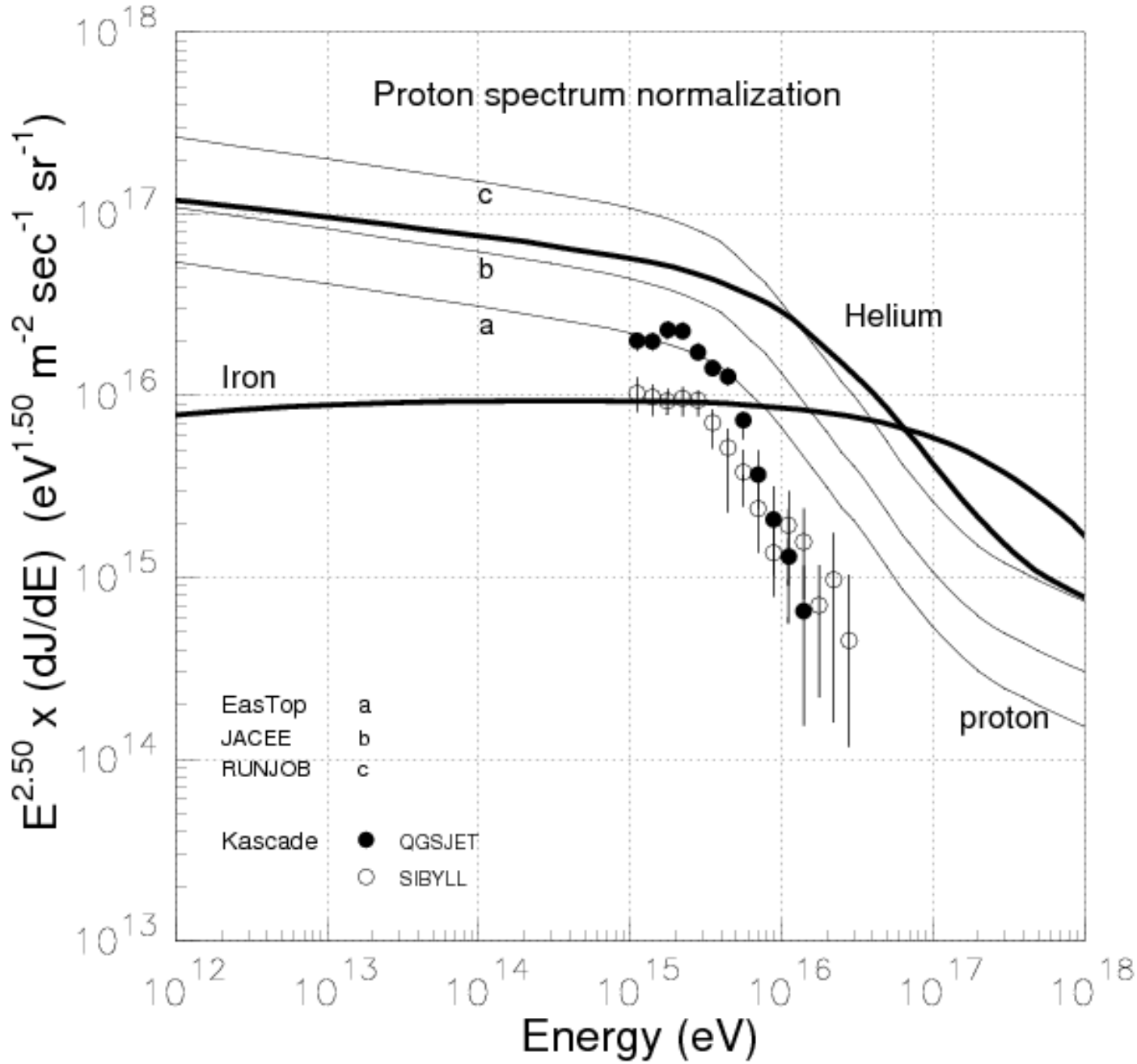

Helium and Iron spectra
below and close to the knee energy
$E^{2.50}$ x (dJ/dE) ($eV^{1.50}$ m^{-2} sec^{-1} sr^{-1})
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}
Energy (eV)
JACEE
He
Fe

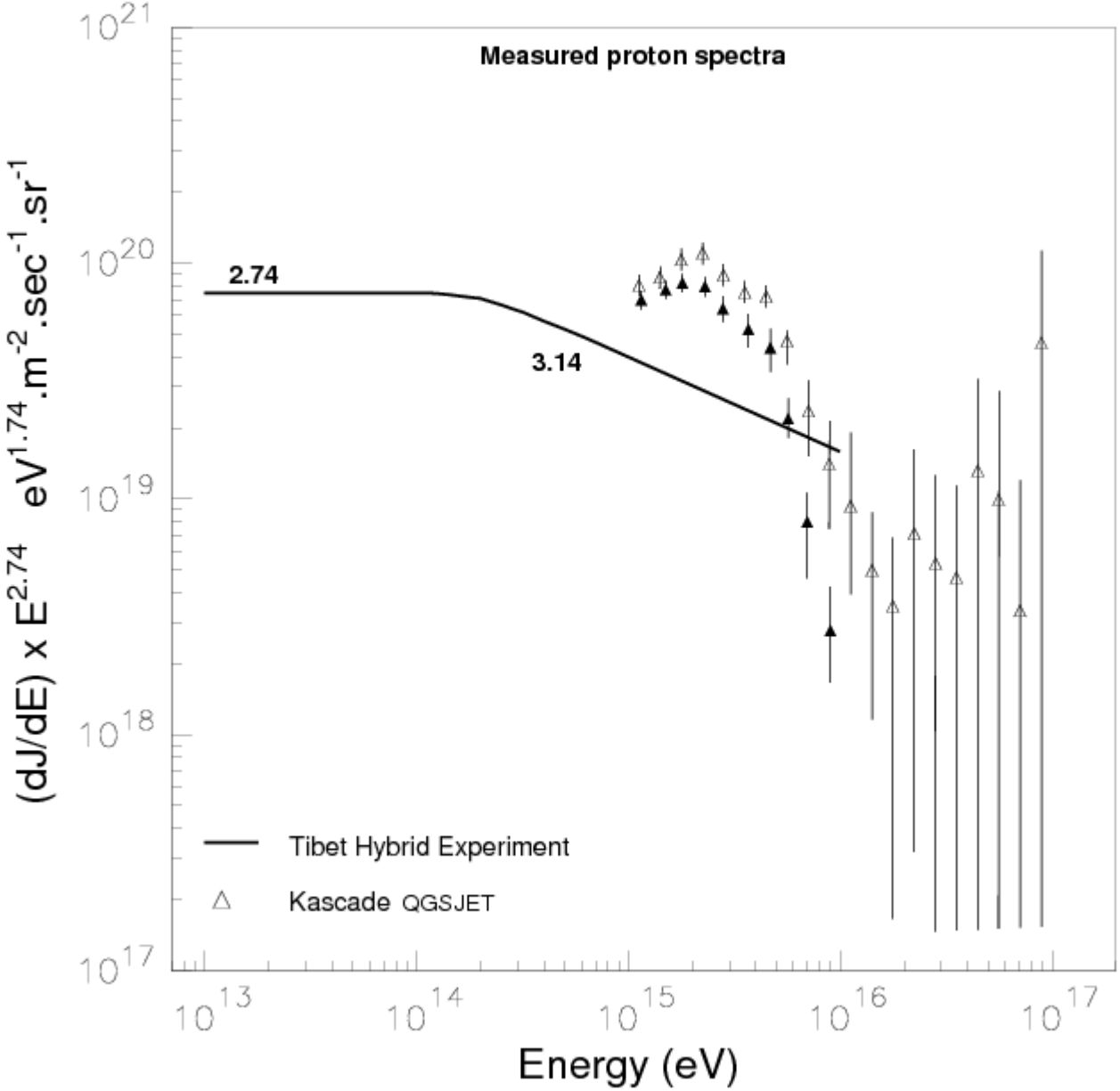

Effect of the spectral index
hard index 2.50
index of 2.53
from ATIC2
soft index 2.68
Computed helium spectra
$E^{2.50}$ x (dJ/dE) (eV$^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21}

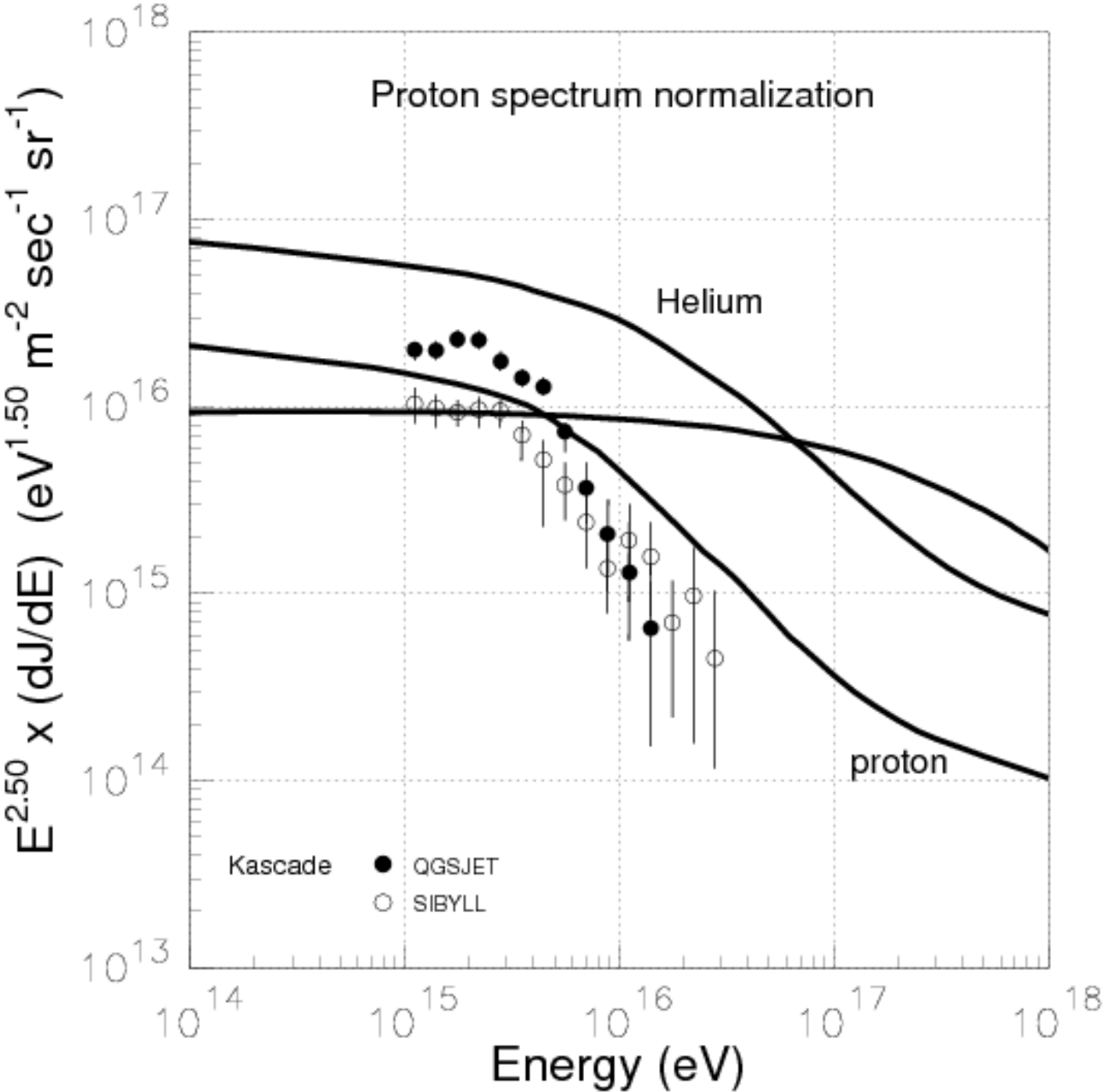

He
Fe
computed spectra
Helium
Iron
experimental data
helium
iron
$E^{2.50}$ x (dJ/dE) (eV$^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}


10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
$E^{2.50}$ x (dJ/dE) (eV$^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Helium
Iron
proton
Kascade
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
Energy (eV)


Proton spectrum normalization
Helium
Iron
proton
EAS-Top
Kascade
QGSJET
SIBYLL
$E^{2.50}$ x (dJ/dE) ($eV^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}


Proton spectrum normalization
c
b
a
Helium
Iron
proton
EasTop a
JACEE b
RUNJOB c
Kascade
QGSJET
SIBYLL
$E^{2.50}$ x (dJ/dE) ($eV^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}


Measured proton spectra
2.74
3.14
Tibet Hybrid Experiment
Kascade QGSJET
(dJ/dE) x E^2.74 eV^1.74.m^-2.sec^-1.sr^-1
Energy (eV)
10^21
10^20
10^19
10^18
10^17
10^13
10^14
10^15
10^16
10^17


Proton spectrum normalization
Helium
proton
Kascade
QGSJET
SIBYLL
$E^{2.50}$ x (dJ/dE) (eV$^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}

Spectre des toutes les particules
C' est à dire le spectre complet

Le spectre des toutes les particules peut ètre calculé pour un ensemble spécifié d' indices et d' abondances des ions.

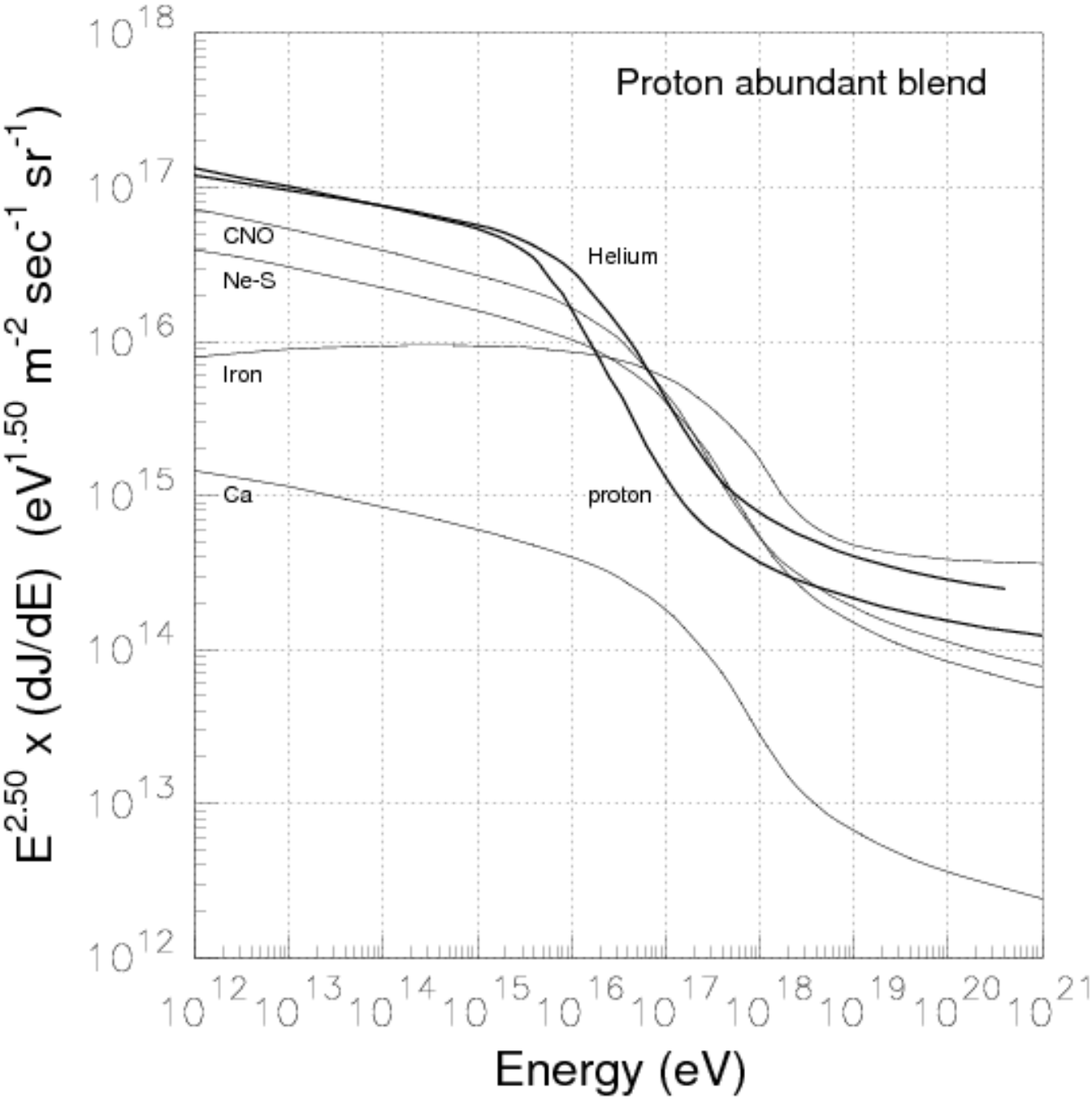
Il faut faire simplement la somme des spectres de chaque ion.

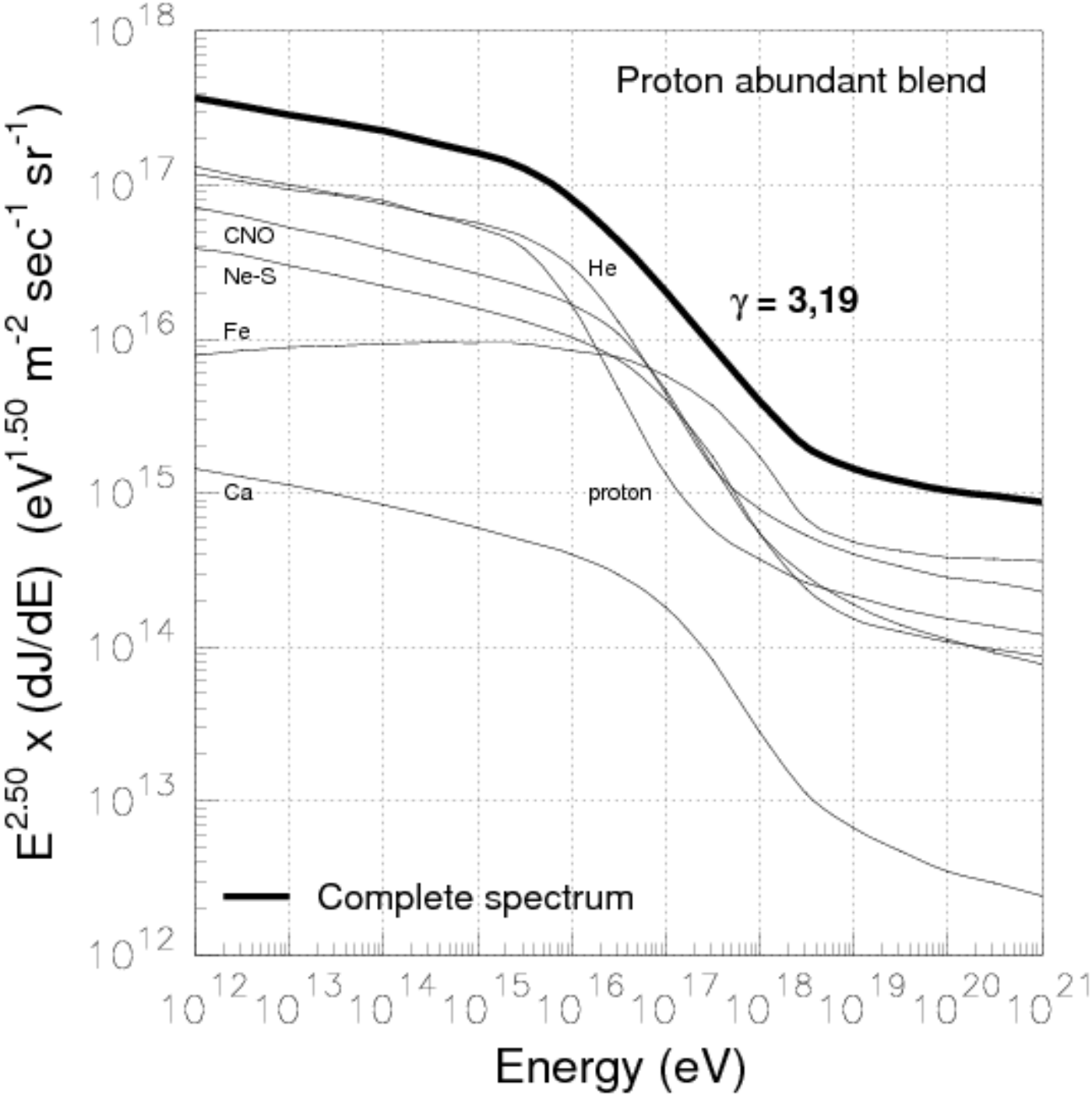
Abondances relatives des ions cosmiques à basses energies

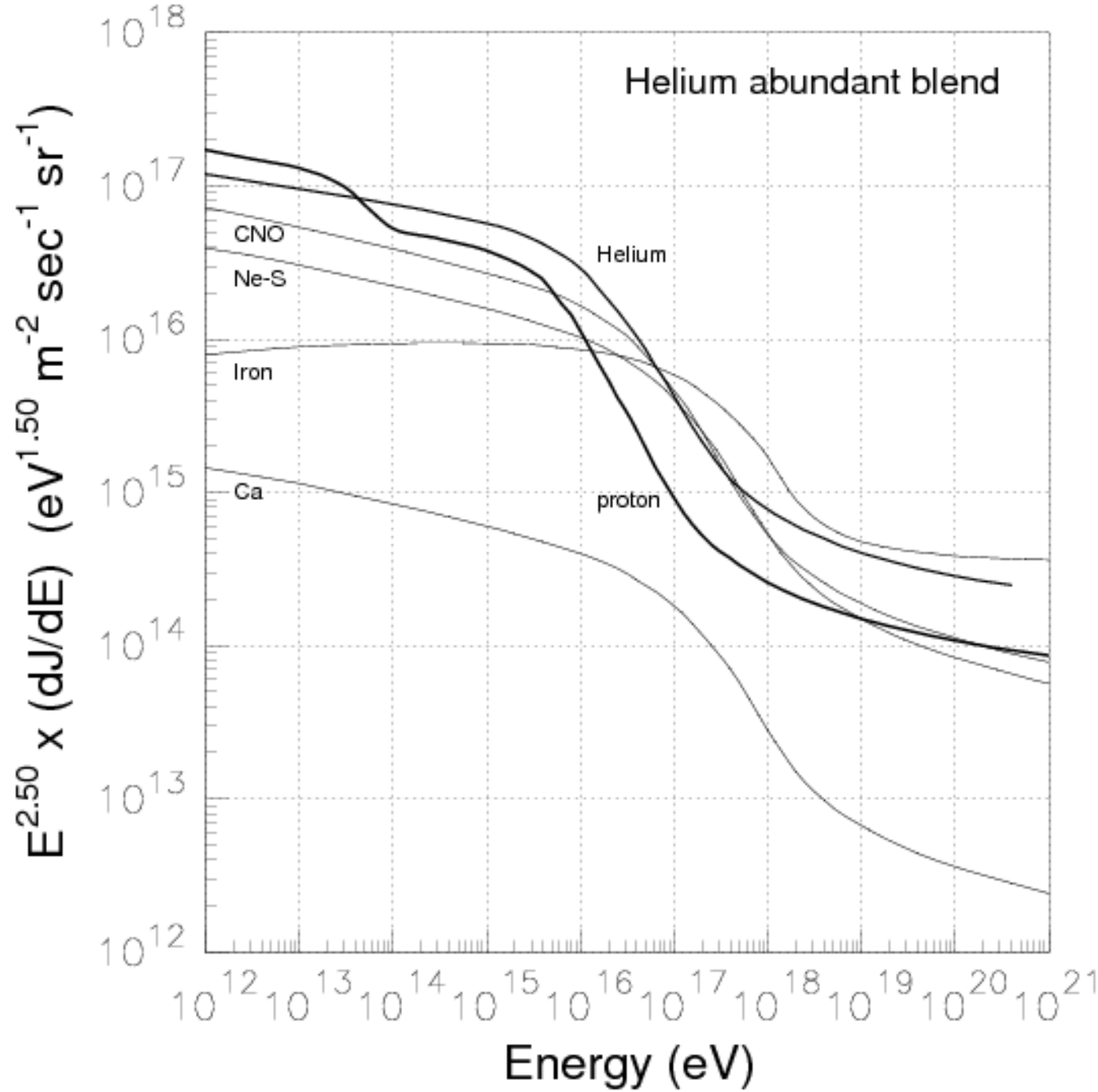
(energie au-dessous du genou)

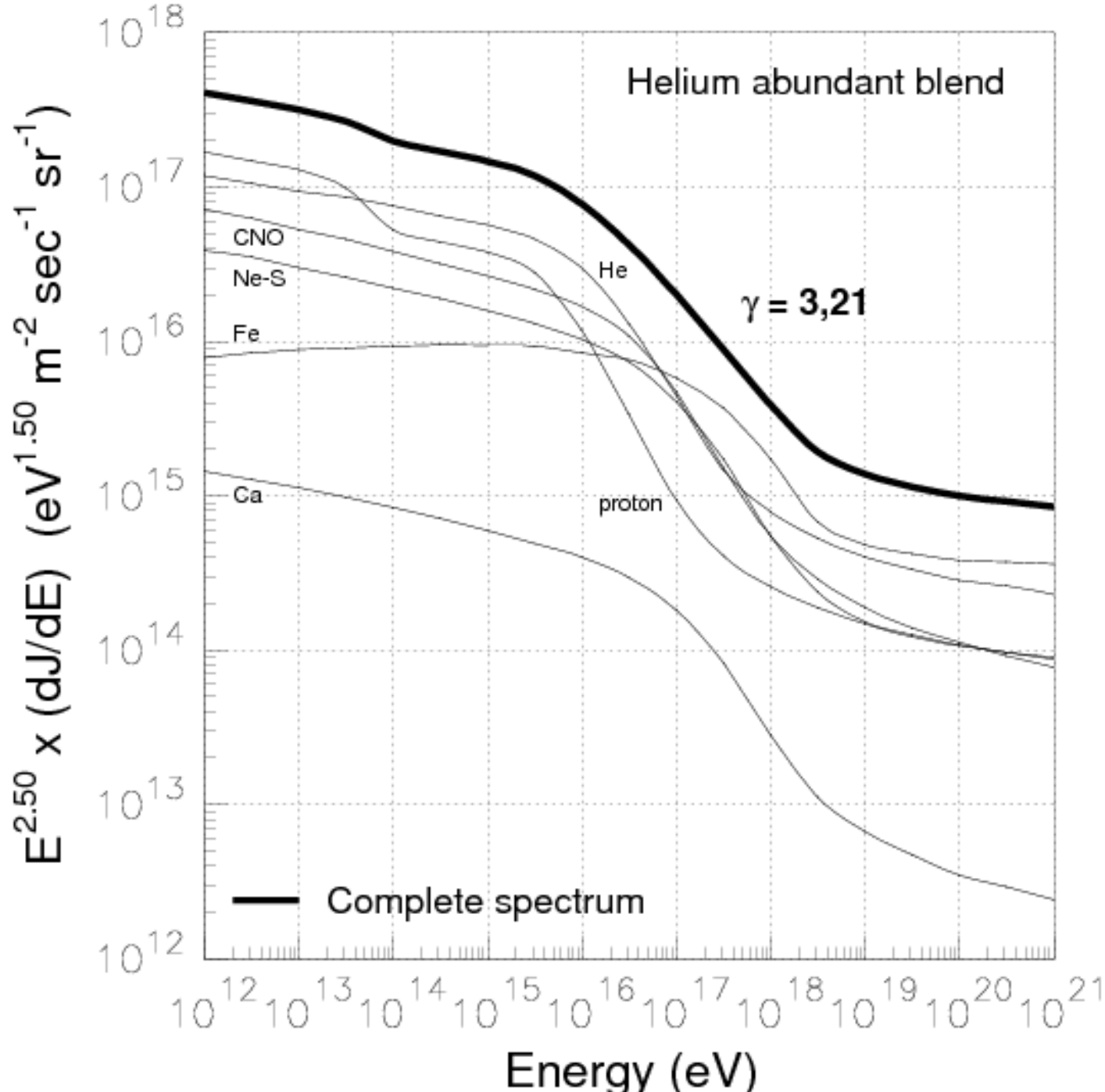
Melange des ions inspiré par l' expérience Atic

Ion	Composition (%)	Indices Spectraux
H	35,6	2.608
He	33,1	2.527
CNO	15,5	2.60
Ne-S	9,2	2.60
Fe (17-26)	6,2	2.50
Ca	0.1	2.60


Proton abundant blend
CNO
Ne-S
Iron
Ca
Helium
proton
$E^{2.50}$ x (dJ/dE) (eV$^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21}


Proton abundant blend
γ = 3,19
CNO
Ne-S
Fe
Ca
He
proton
Complete spectrum
E^2.50 x (dJ/dE) (eV^1.50 m^-2 sec^-1 sr^-1)
Energy (eV)
10^18
10^17
10^16
10^15
10^14
10^13
10^12
10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20 10^21


Helium abundant blend
CNO
Ne-S
Iron
Ca
Helium
proton
$E^{2.50}$ x (dJ/dE) ($eV^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21}

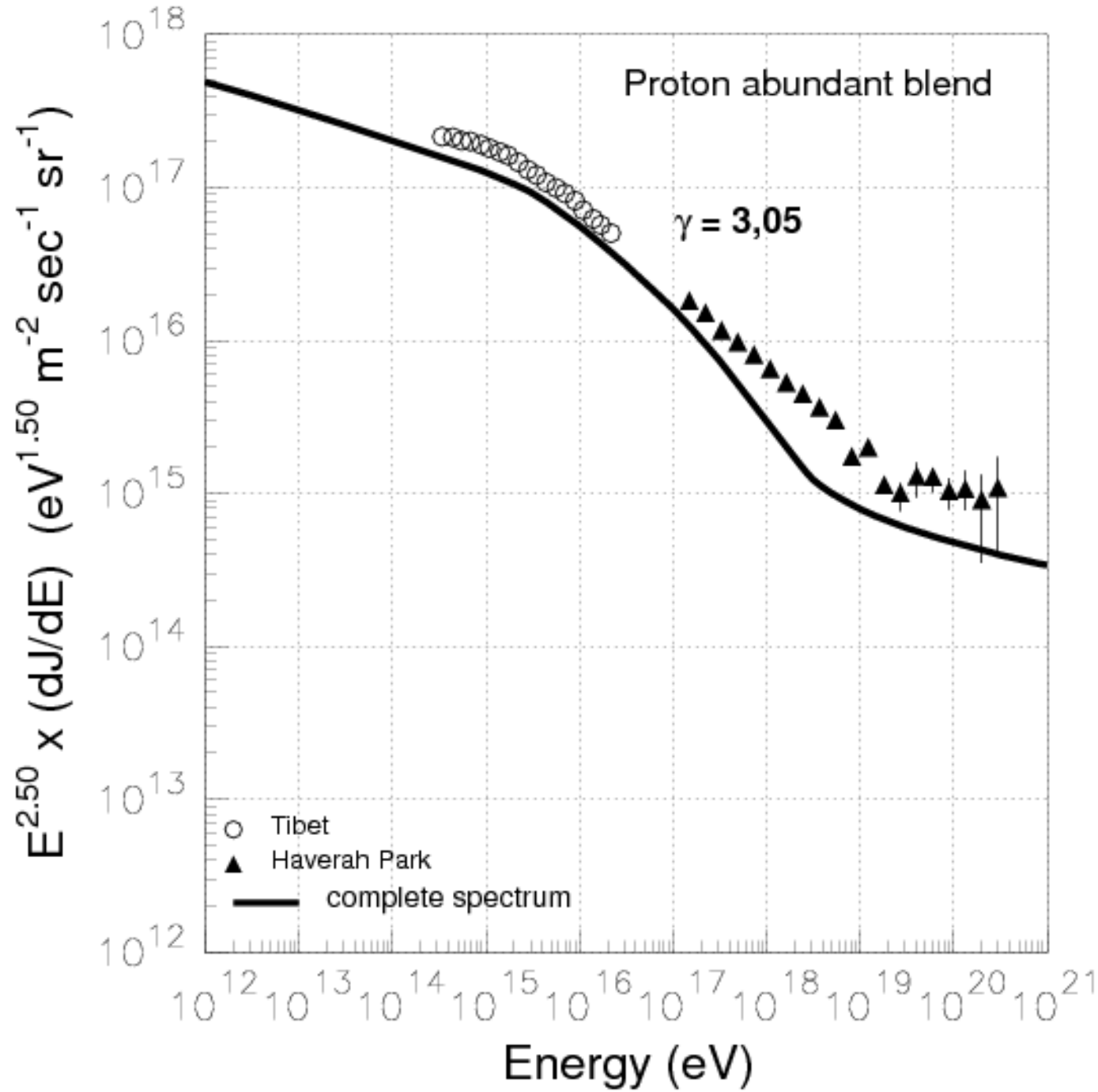

Helium abundant blend
γ = 3,21
CNO
Ne-S
Fe
Ca
He
proton
Complete spectrum
E^2.50 x (dJ/dE) (eV^1.50 m^-2 sec^-1 sr^-1)
Energy (eV)
10^18
10^17
10^16
10^15
10^14
10^13
10^12
10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20 10^21

Abondances relatives des ions cosmiques à basses energies

(energie au-dessous du genou)

RICHE EN PROTONS (melange 1, forte chute) – Energy = 2×10^{15} eV

Ion	Composition (%)	Spectral index
H	32,8	2.72
He	29,7	2.72
CNO	11,7	2.65
Ne-S	10,0	2.65
Fe (17-26)	15,0	2.60
Ca	0.8	2.60

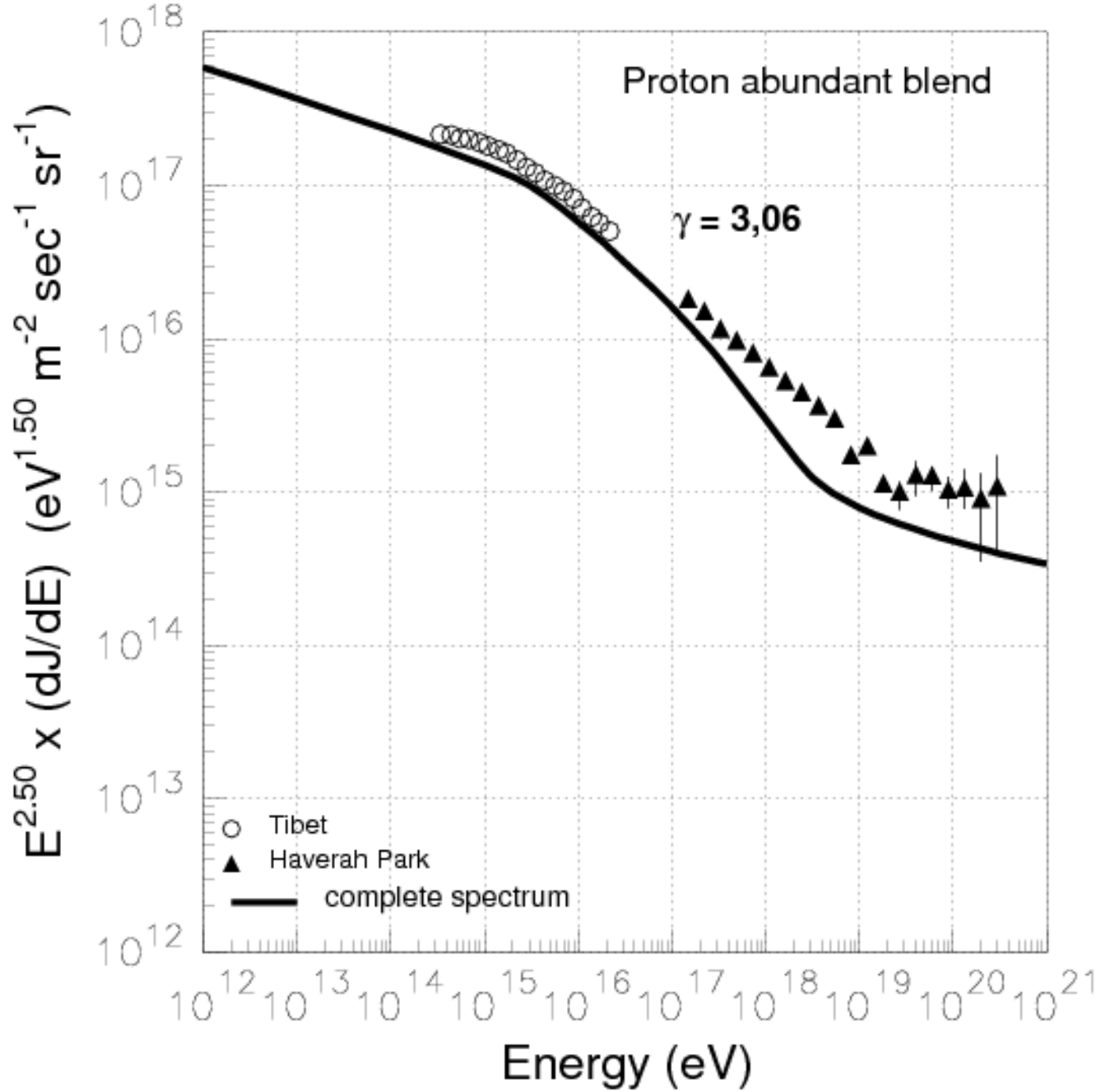

Proton abundant blend
γ = 3,05
Tibet
Haverah Park
complete spectrum
$E^{2.50}$ x (dJ/dE) (eV$^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21}

Relative abundances of cosmic ions at low energies

(below the knee energy)

RICHISSIME EN PROTON – Energy = 2×10^{15} eV

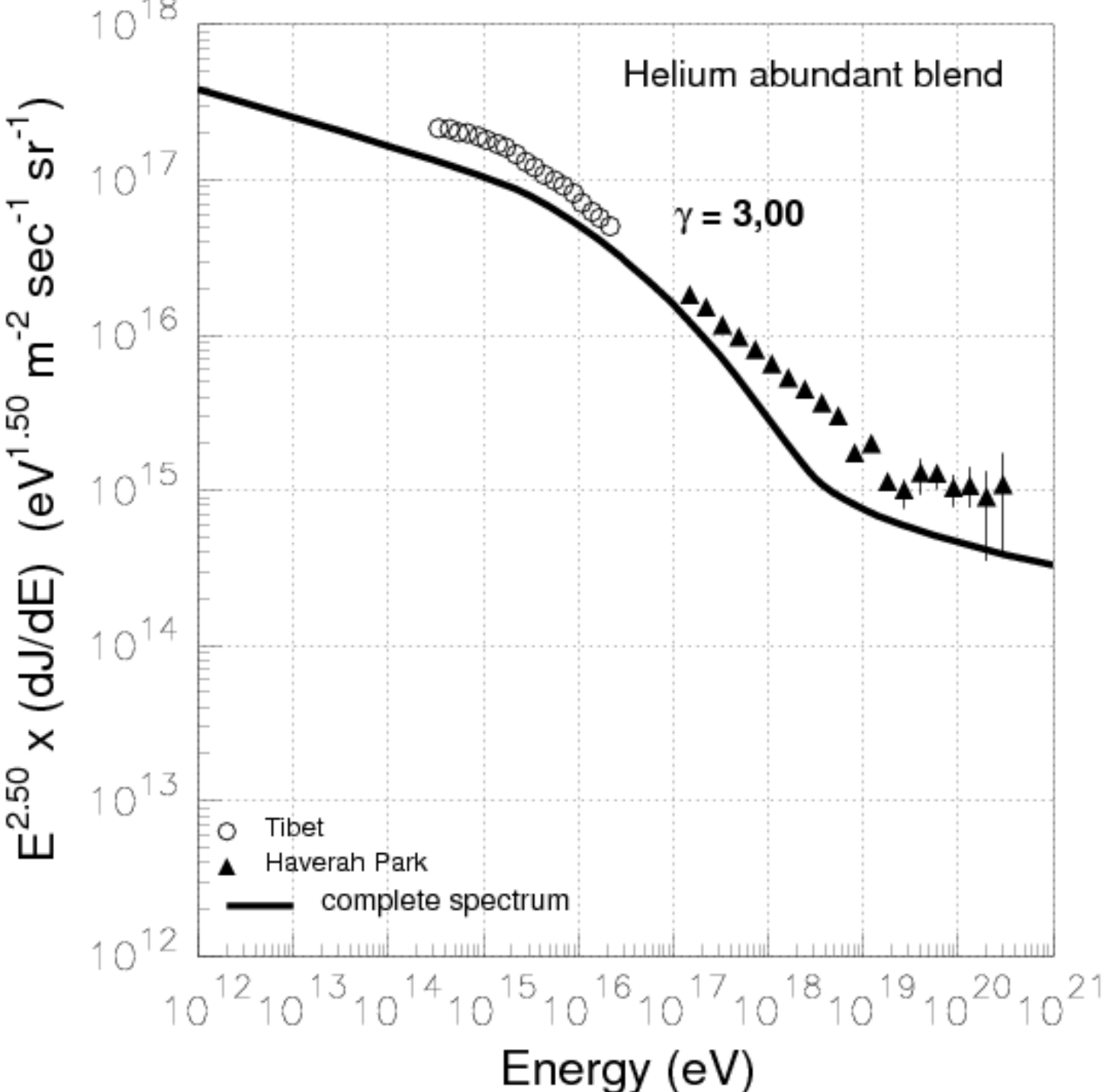
Ion	Composition (%)	Spectral index
H	41,0	2.72
He	25,5	2.72
CNO	10,0	2.65
Ne-S	8,60	2.65
Fe (17-26)	12,8	2.60
Ca	0.74	2.60


Proton abundant blend
γ = 3,06
Tibet
Haverah Park
complete spectrum
E^2.50 x (dJ/dE) (eV^1.50 m^-2 sec^-1 sr^-1)
Energy (eV)
10^18
10^17
10^16
10^15
10^14
10^13
10^12
10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20 10^21

Abondances relatives des ions cosmiques à basses energies

Riche en He (melange 3) - Energy = 2×10^{15} eV

Ion	Composition (%)	Spectral index
H	19,6	2.72
He	35,5	2.72
CNO	14,0	2.65
Ne-S	12,0	2.65
Fe (17-26)	17,8	2.50
Ca	0.1	2.60


Helium abundant blend
γ = 3,00
Tibet
Haverah Park
complete spectrum
$E^{2.50}$ x (dJ/dE) (eV$^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21}

La cheville

La composant extragalactique

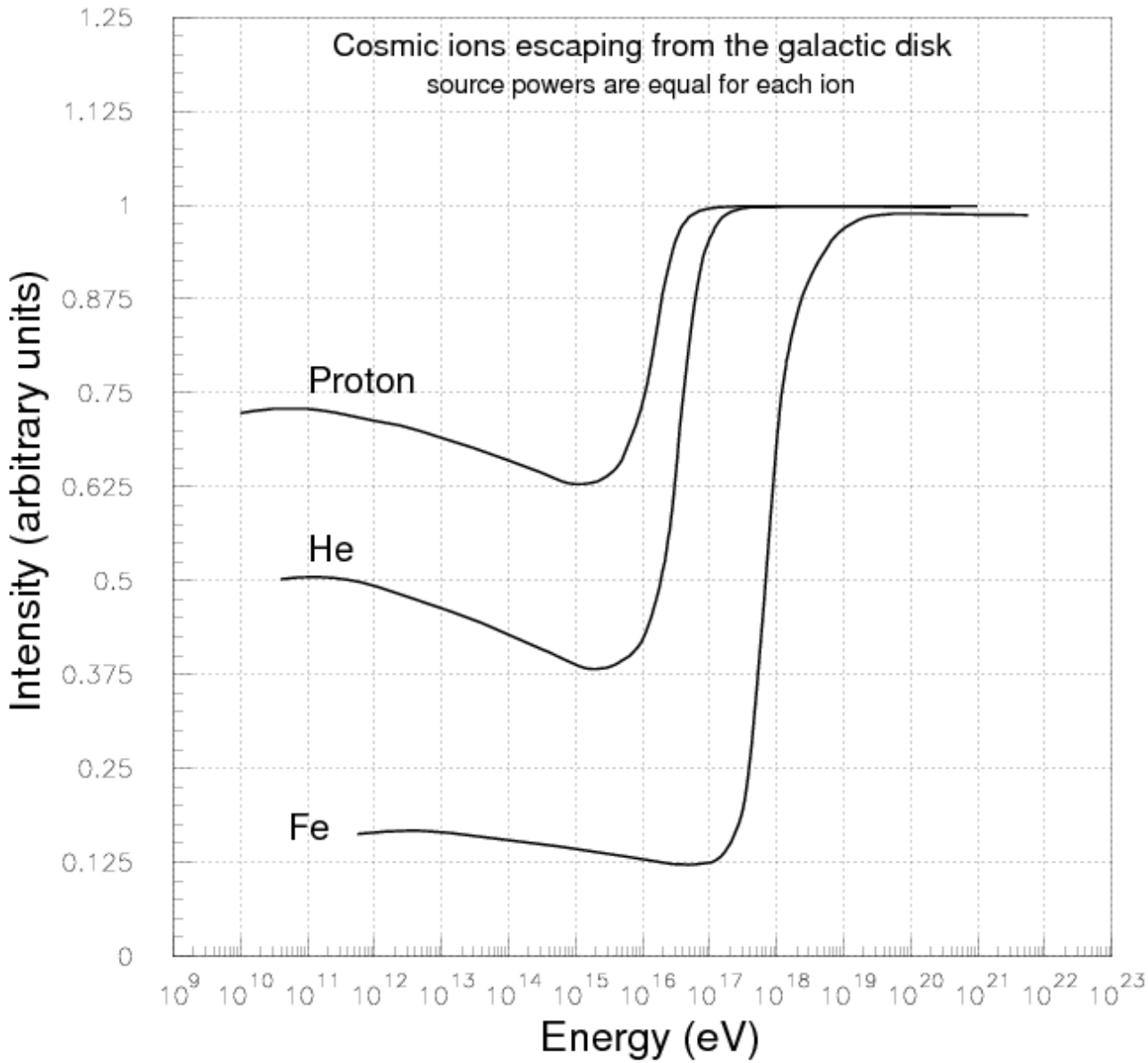
rayons cosmiques s'echappant de la Voie Lactée

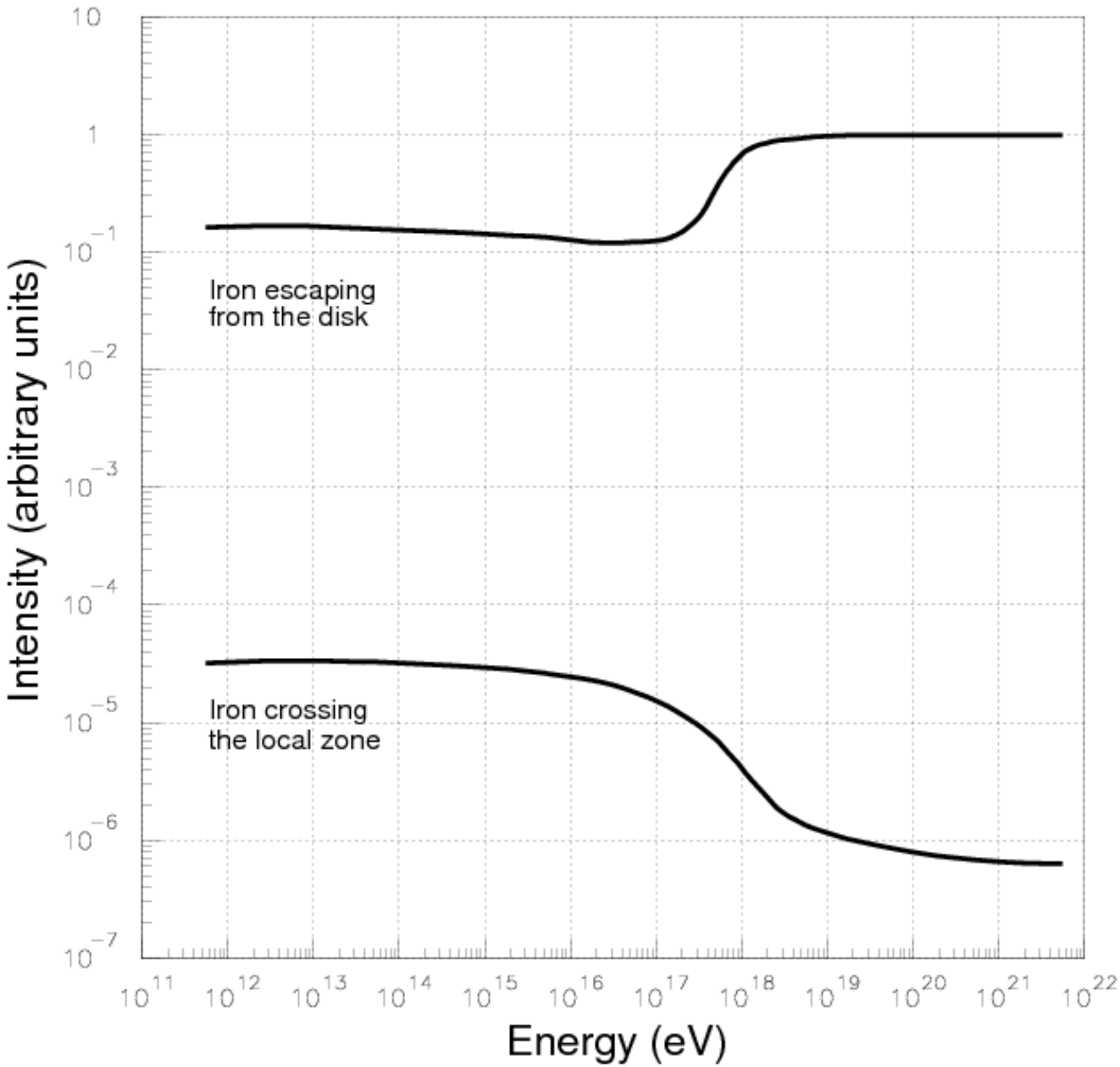
rayons cosmiques entrant dans la Voie Lactée

On admet qu' une composant extragalactique atteint la Terre. On suppose exactement:

- Les abondances relatives des ions extragalactiques dans l' espace intergalactique sont identiques à celles des rayons cosmiques qui s' echappent de la Voie Lactée;

- Les rayons cosmiques extragalactiques entrant dans la Voie Lactée rencontrent la méme structure de champs magnetiques et la mème quantité de matière que les rayons cosmiques galactiques.


Cosmic ions escaping from the galactic disk
source powers are equal for each ion
Proton
He
Fe
Intensity (arbitrary units)
Energy (eV)
1.25
1.125
1
0.875
0.75
0.625
0.5
0.375
0.25
0.125
0
10^{9} 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21} 10^{22} 10^{23}

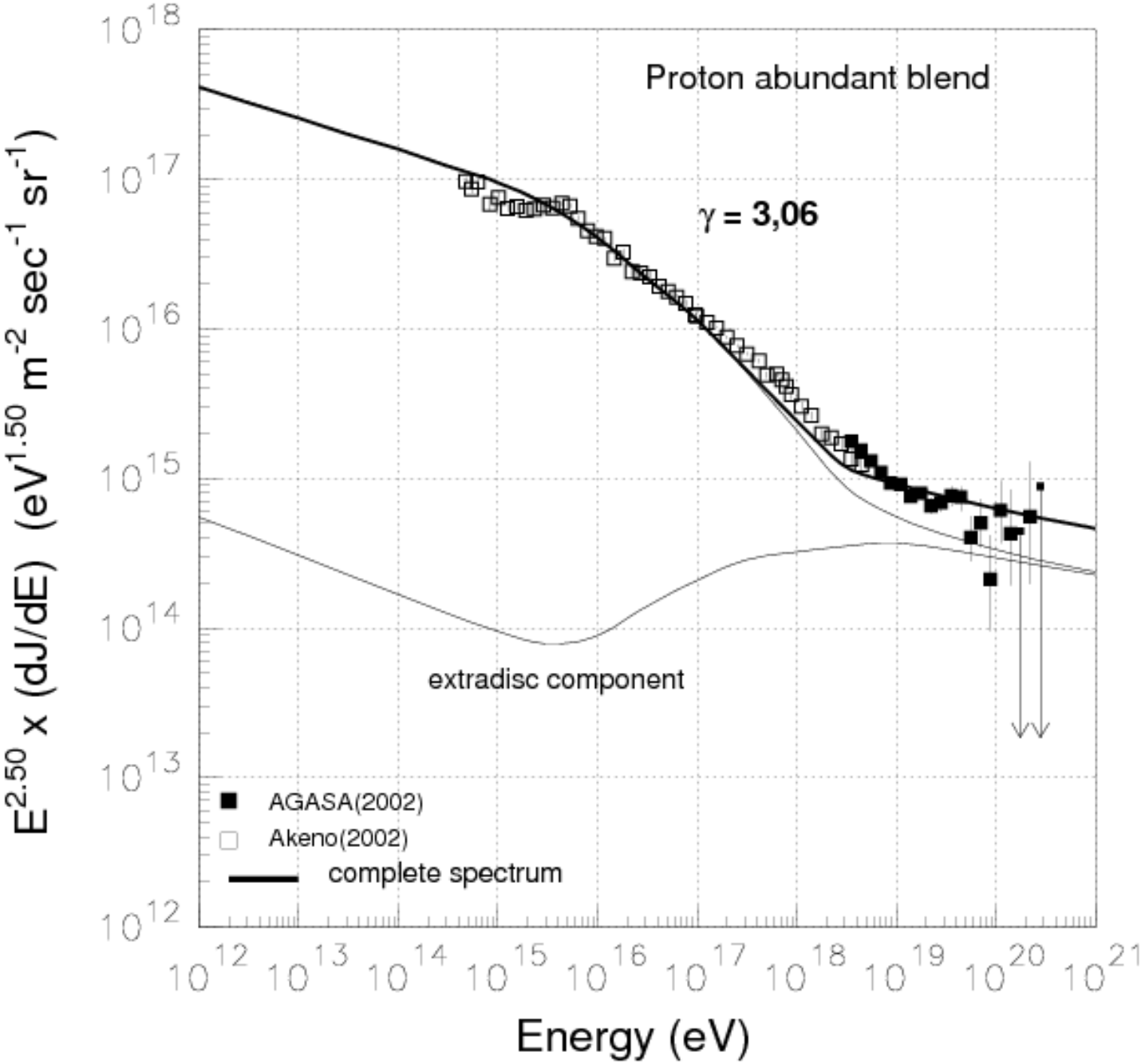

Intensity (arbitrary units)
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
Iron escaping
from the disk
Iron crossing
the local zone
10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21} 10^{22}
Energy (eV)

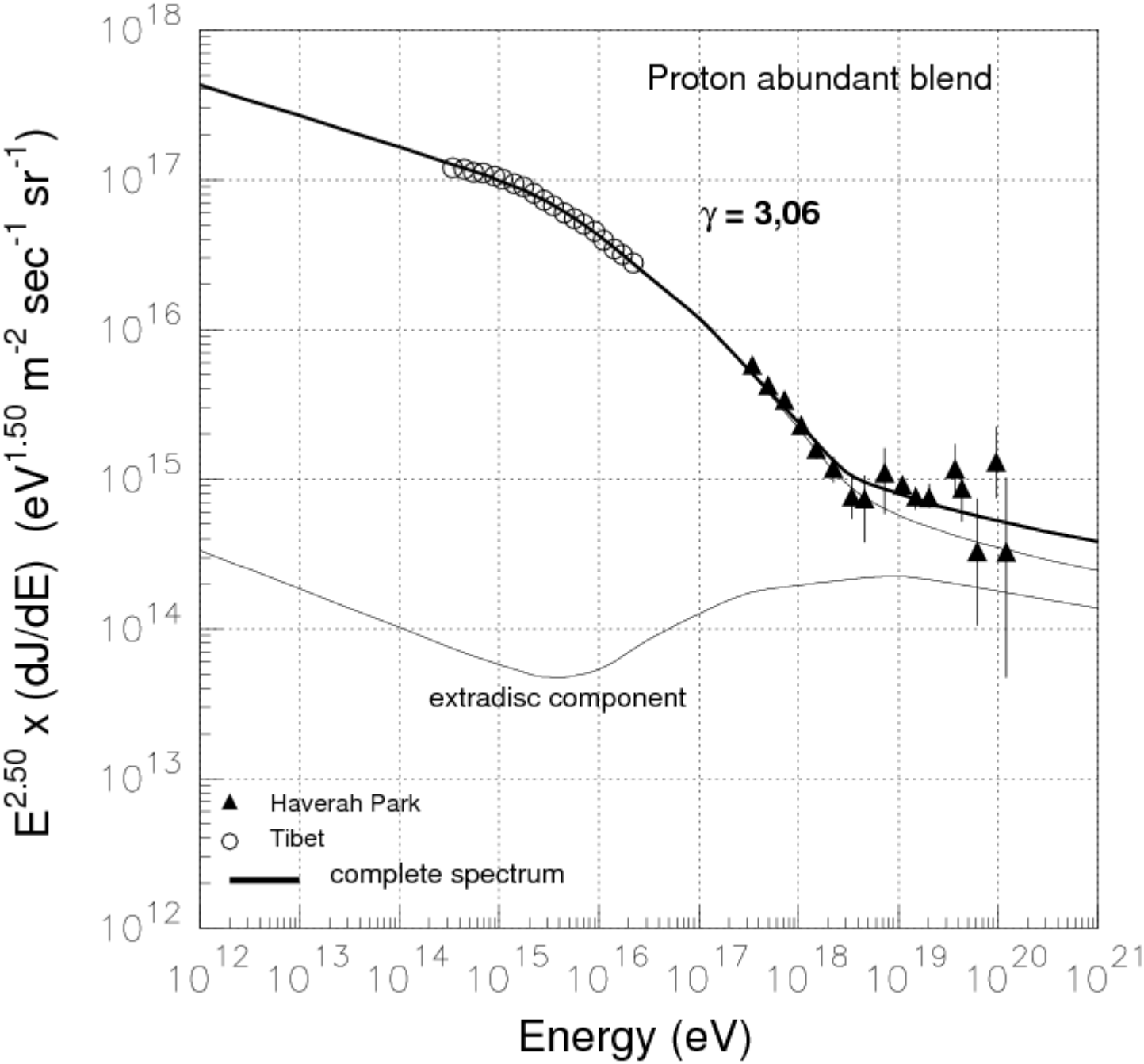
Abondances relatives des ions cosmiques à basses energies

(energie au-dessous du genou)

Plus de PROTONS que de He (melange 2) - Energy = 2×10^{15} eV

Ion	Composition (%)	indice spectral
H	37.9	2.74
He	27,4	2.72
CNO	10,8	2.65
Ne-S	9,3	2.65
Fe (17-26)	13,8	2.50
Ca	0.8	2.60


Proton abundant blend
γ = 3,06
extradisc component
AGASA(2002)
Akeno(2002)
complete spectrum
E^2.50 x (dJ/dE) (eV^1.50 m^-2 sec^-1 sr^-1)
Energy (eV)
10^18
10^17
10^16
10^15
10^14
10^13
10^12
10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20 10^21

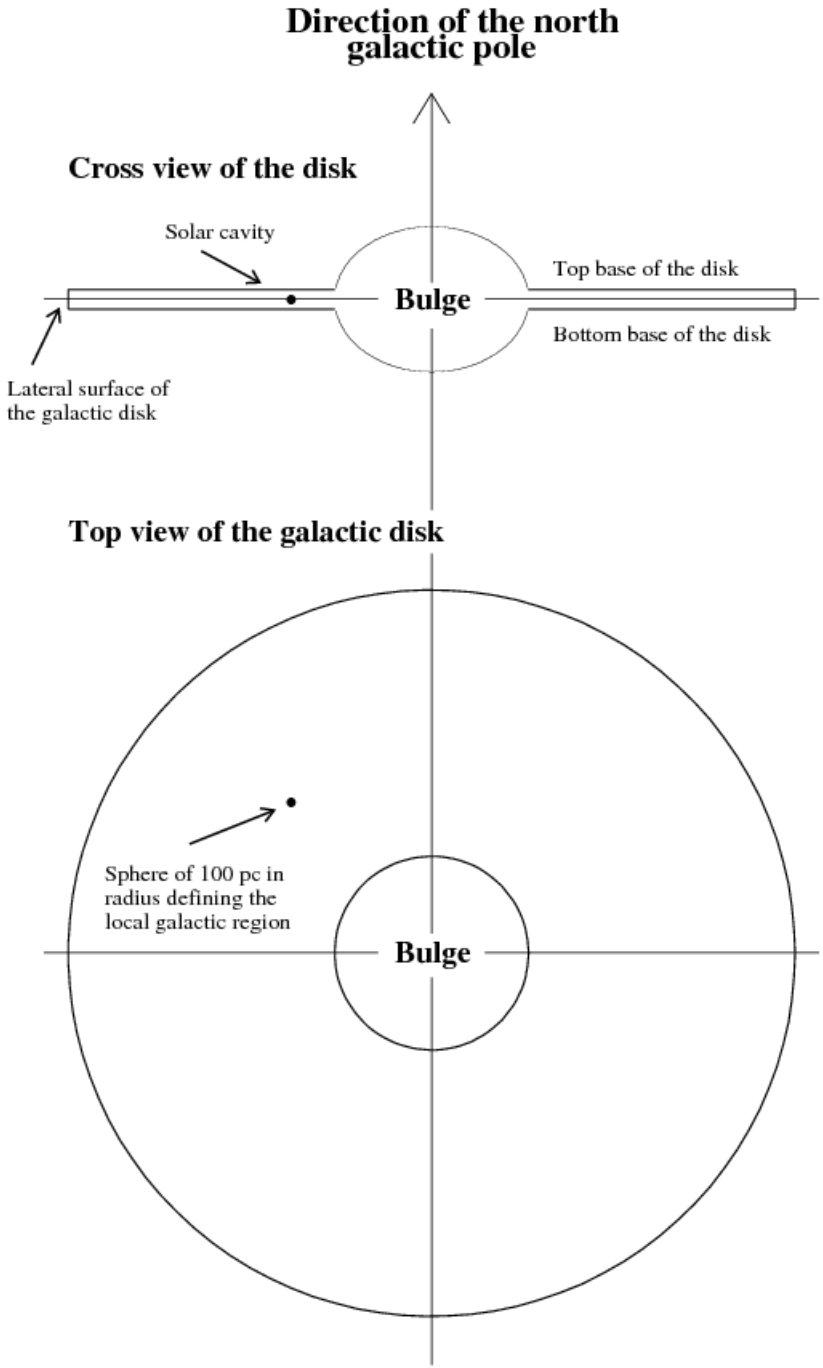

Proton abundant blend
γ = 3,06
extradisc component
Haverah Park
Tibet
complete spectrum
$E^{2.50}$ x (dJ/dE) (eV$^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21}

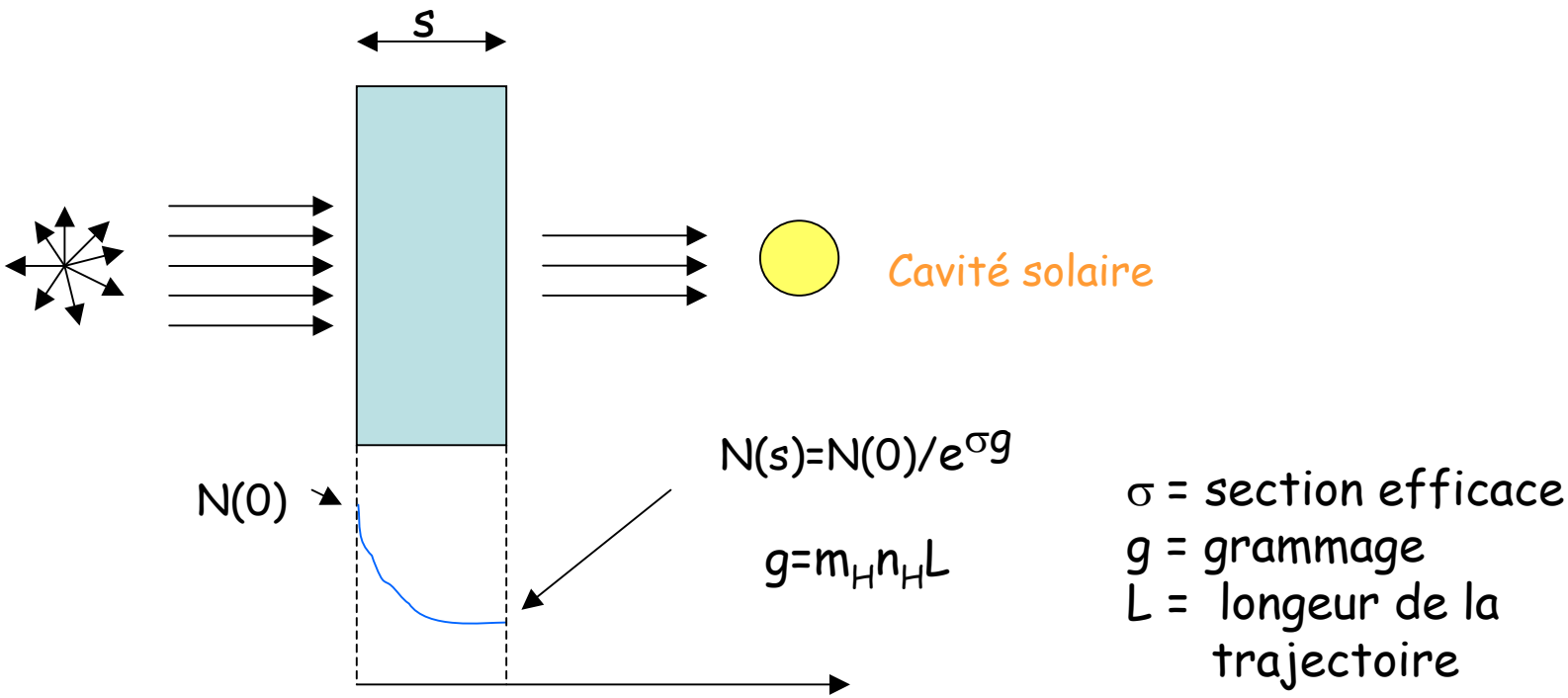
La cheville est indissociable du genou

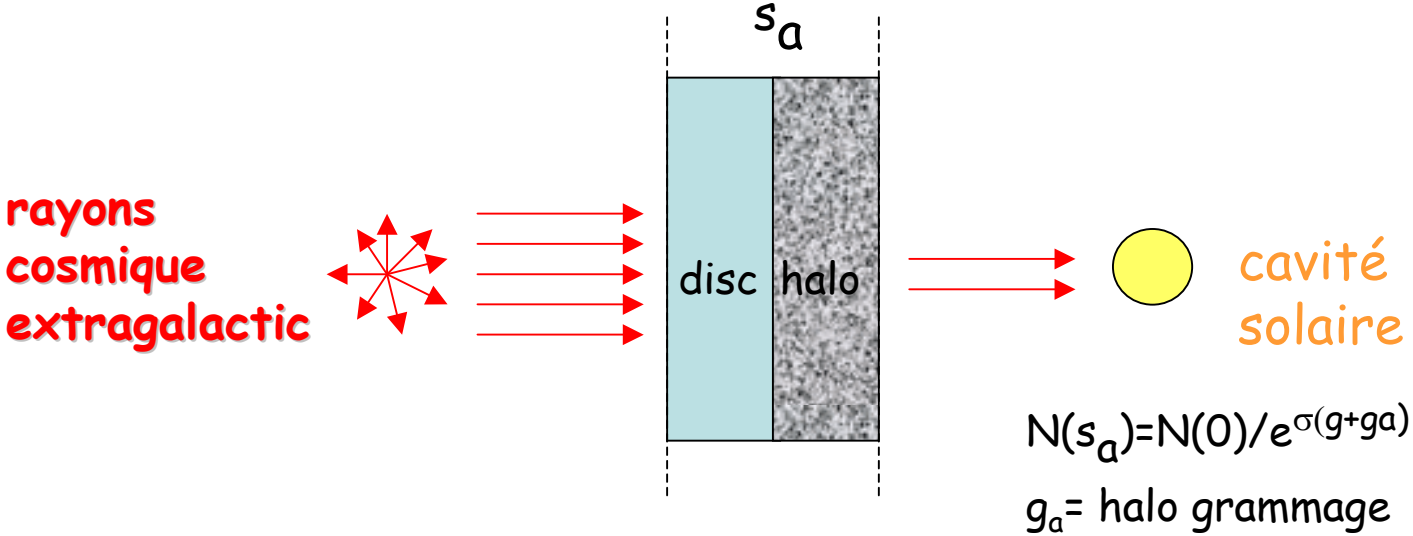
La position de la cheville le long de l' axe des energies est reliée sans ambiguité avec l' energie du genou pour le mème ion cosmique.

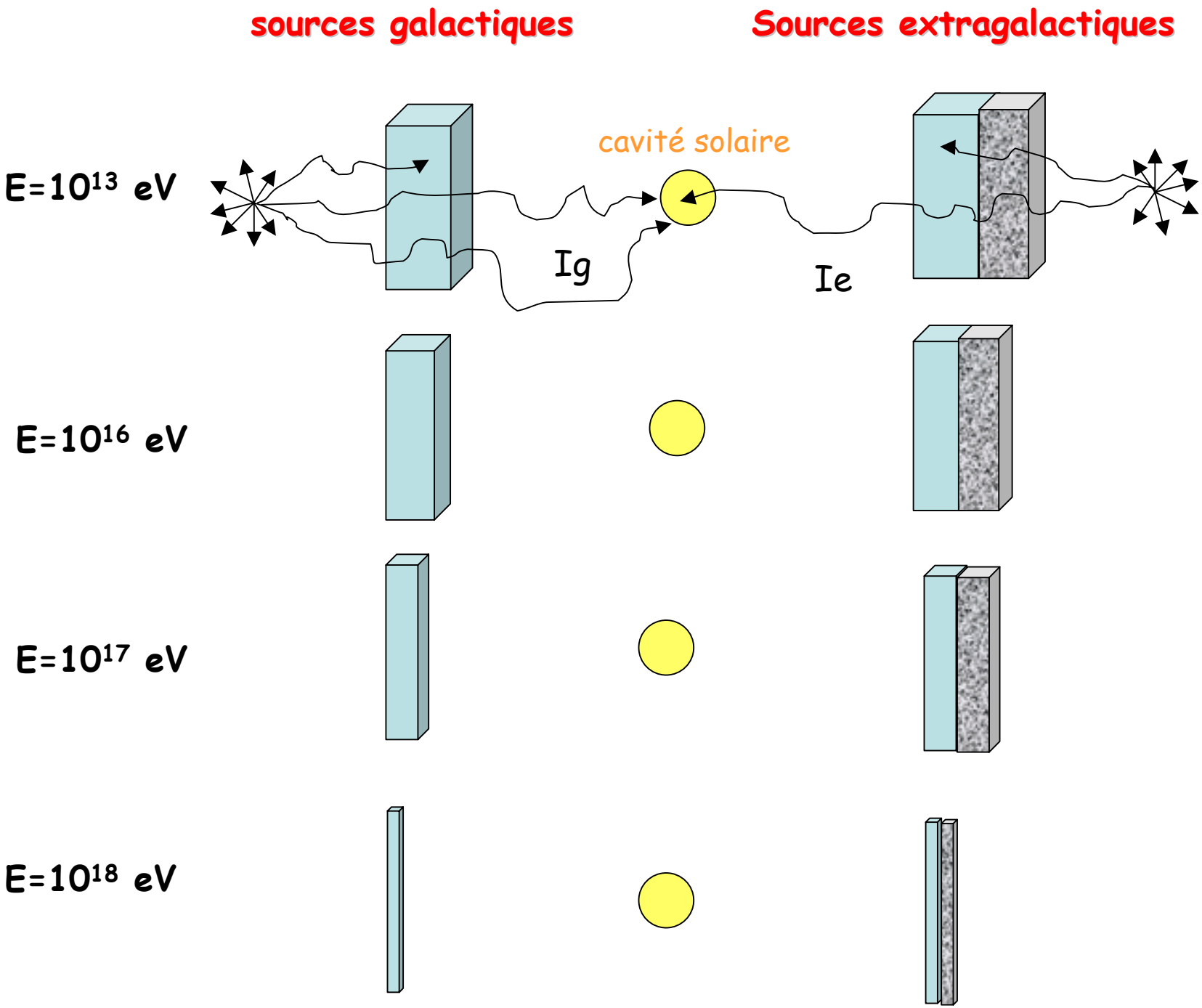
Cette affirmation est la conclusion nécessaire qui résulte de notre explication des genoux des ions individuels et de celle du genou du spectre complet.

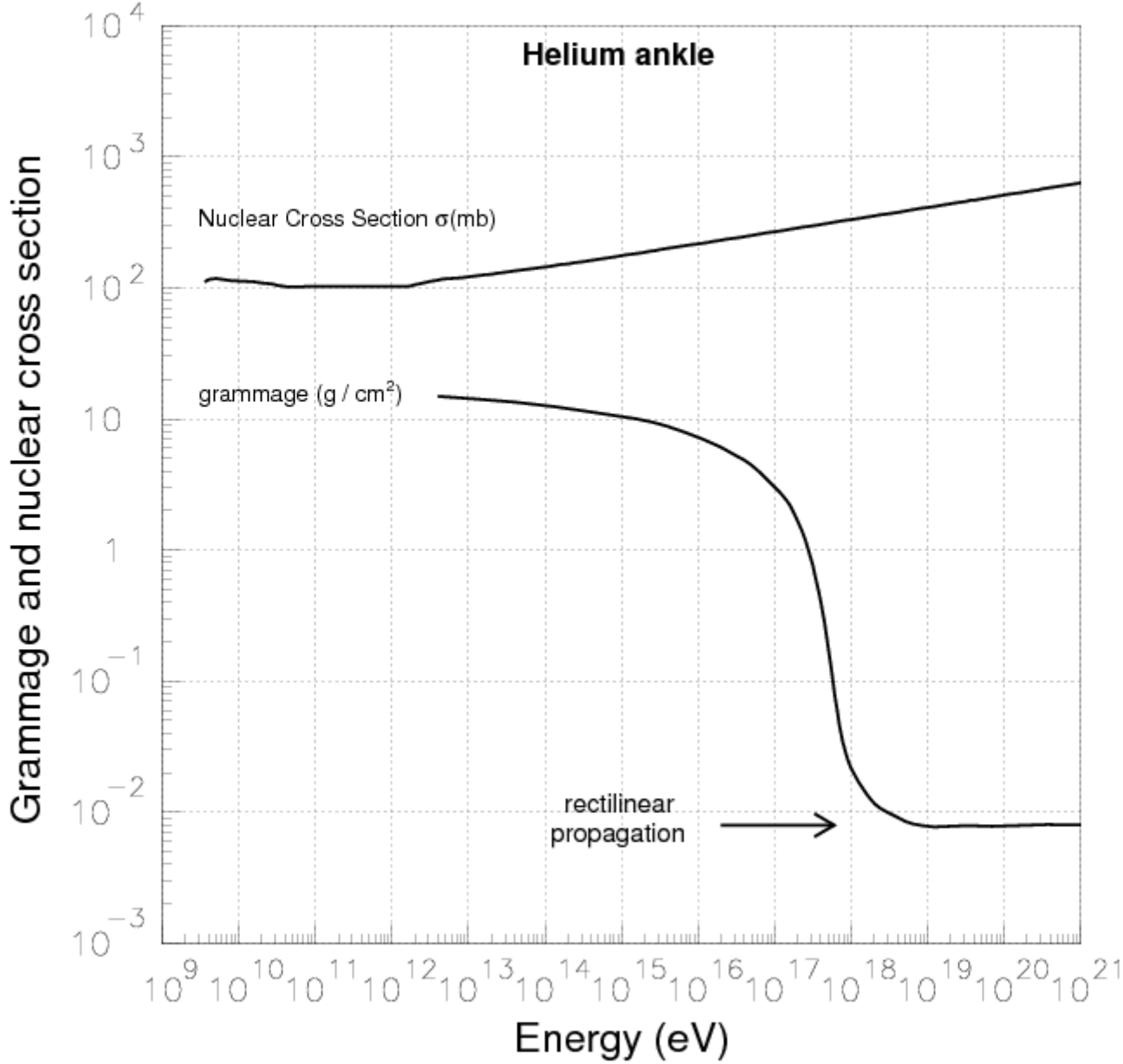
C' est aussi, à notre avis, un test croisé supplémentaire de ce que l' explication du genou est correcte.

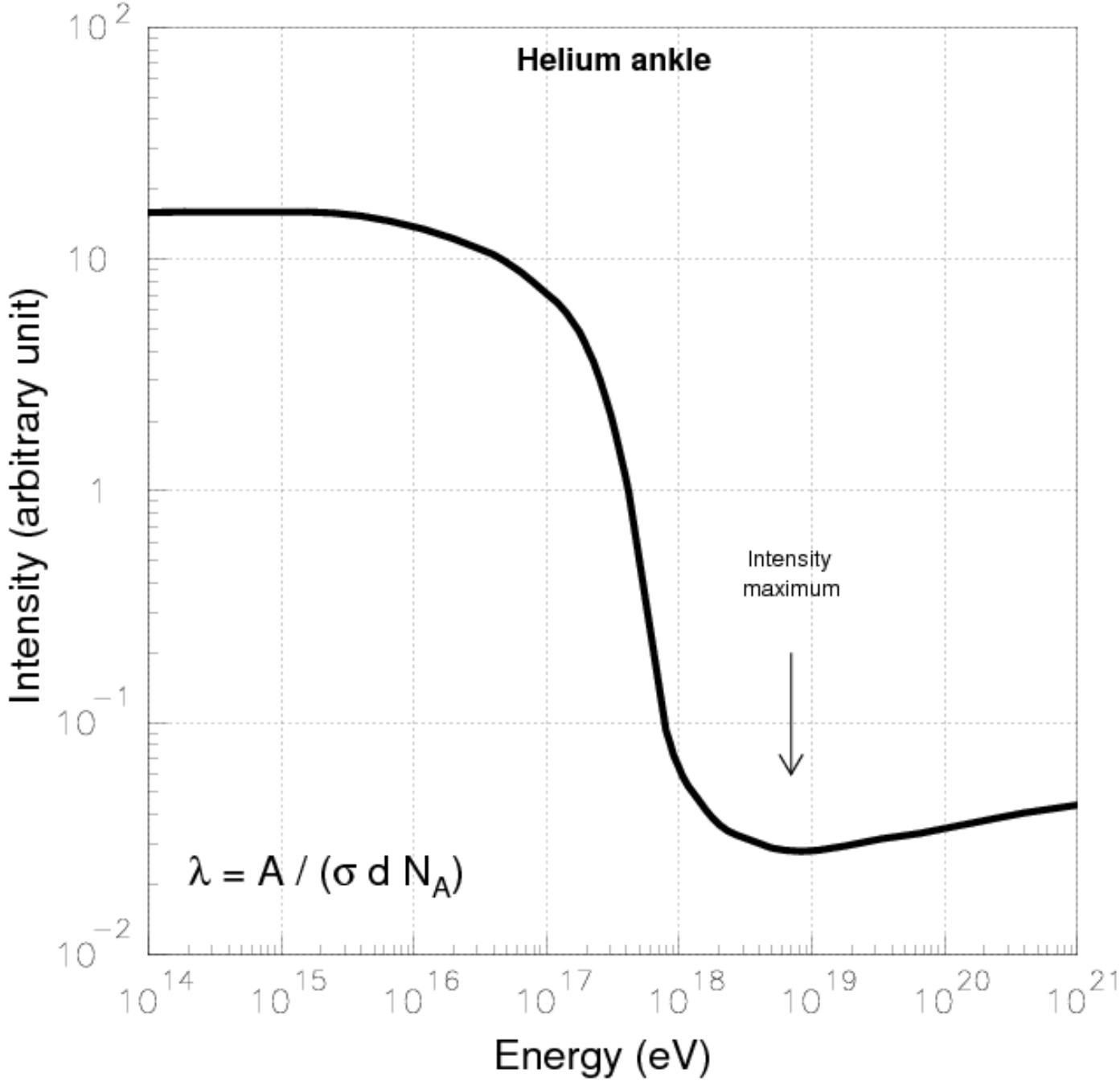

Direction of the north galactic pole
Cross view of the disk
Solar cavity
Top base of the disk
Bulge
Bottom base of the disk
Lateral surface of the galactic disk
Top view of the galactic disk
Sphere of 100 pc in radius defining the local galactic region
Bulge


s
rayons cosmiques galactiques
Cavité solaire
N(0)
N(s)=N(0)/e^σg
g=m_H n_H L
σ = section efficace
g = grammage
L = longeur de la trajectoire

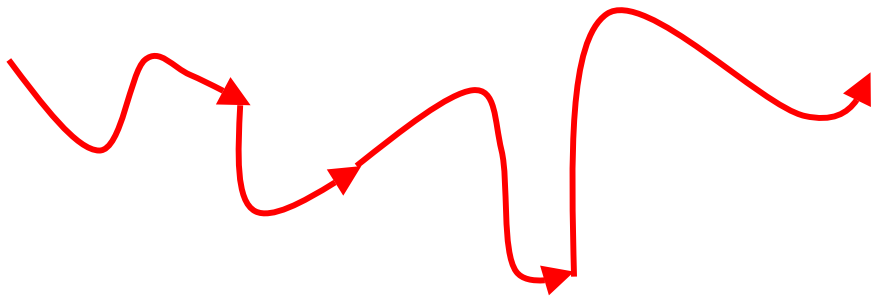

s_a
rayons cosmique extragalactic
disc
halo
cavité solaire
N(s_a)=N(0)/e^σ(g+ga)
g_a= halo grammage


sources galactiques
Sources extragalactiques
cavité solaire
Ig
Ie
E=10¹³ eV
E=10¹⁶ eV
E=10¹⁷ eV
E=10¹⁸ eV


Helium ankle
Nuclear Cross Section σ(mb)
grammage (g / cm²)
rectilinear
propagation
Grammage and nuclear cross section
Energy (eV)
10⁴
10³
10²
10
1
10⁻¹
10⁻²
10⁻³
10⁹ 10¹⁰ 10¹¹ 10¹² 10¹³ 10¹⁴ 10¹⁵ 10¹⁶ 10¹⁷ 10¹⁸ 10¹⁹ 10²⁰ 10²¹


Helium ankle
Intensity (arbitrary unit)
10^2
10
1
10^{-1}
10^{-2}
Intensity
maximum
$\lambda = A / (\sigma d N_A)$
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}
Energy (eV)

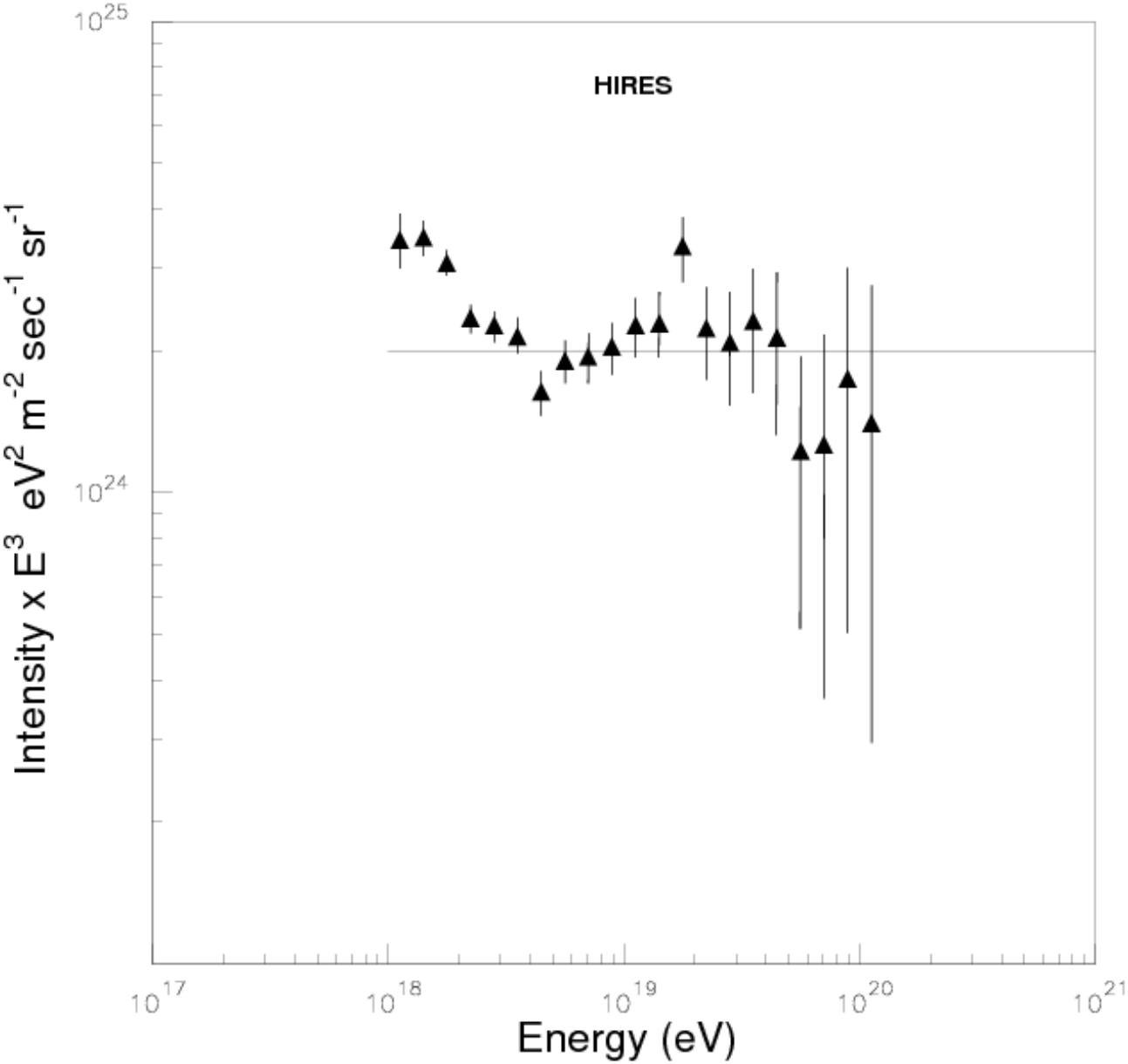
Propagation rectilineaire

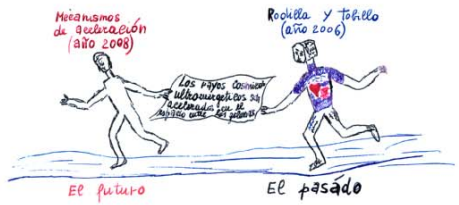


Les rayons cosmiques, dans la propagation rectilineaire, penètre le milieu insterstellaire en segments de ligne droite.

L' energie dans laquelle la propagation rectilineare s' instaure, constitue un signe clair pour la cheville, une référence depourvue de toute ambiguité, parce que l' intensité moyenne du champ magnetique est bien connue (3 microgauss, en moyenne).

Pour l' helium cette energie est 4×10^{18} eV et pour le fer 3×10^{19} eV .


HIRES
10^{25}
10^{24}
Intensity x E^3 eV^2 m^{-2} sec^{-1} sr^{-1}
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}
Energy (eV)



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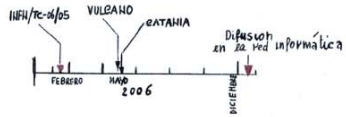

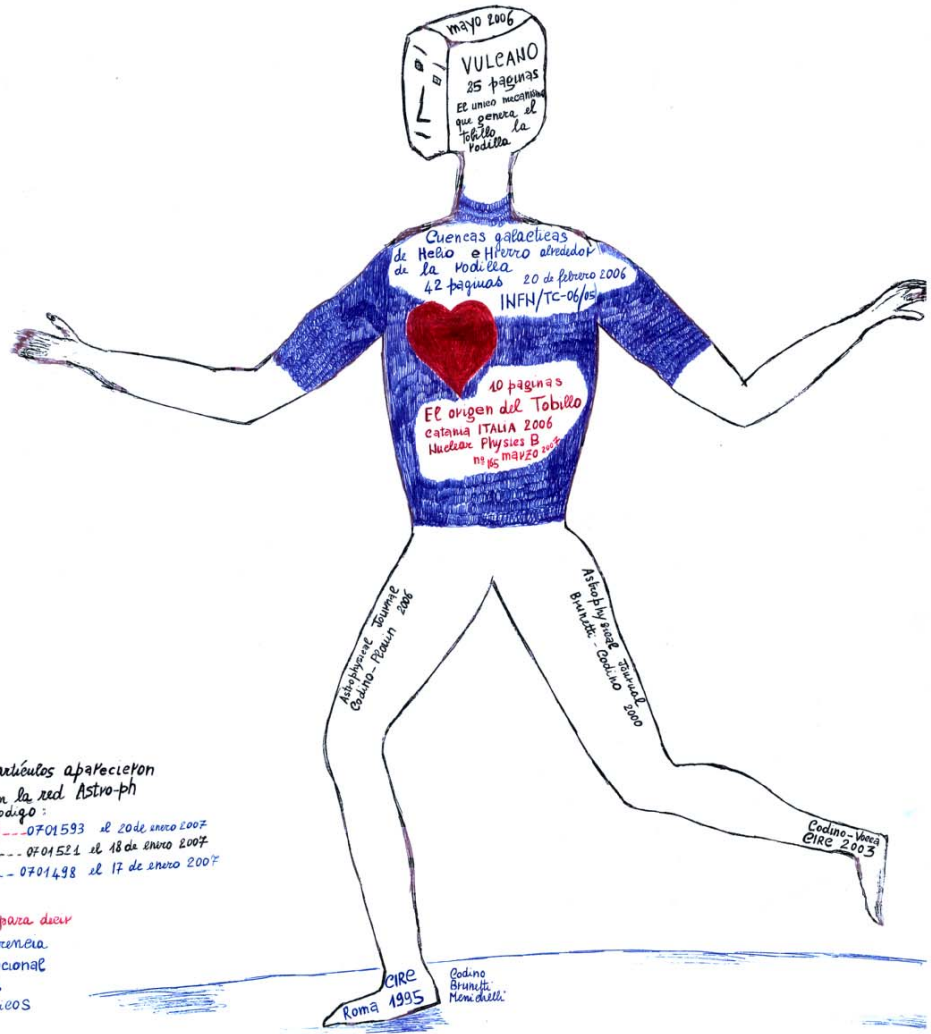

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El unico ... 0701521 el 18 de enero 2007

Cuencas ... 0701498 el 17 de enero 2007

CIRE para decir
Conferencia
Internacional
Rayos
Cósmicos

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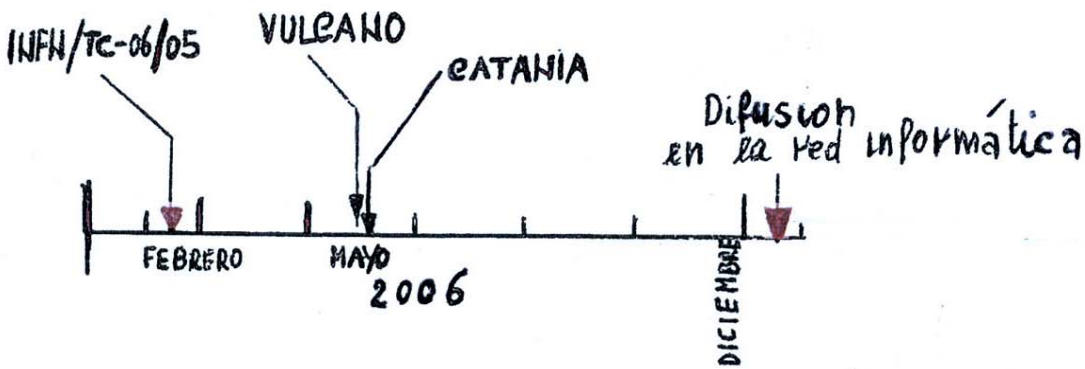
Estos artículos fueron realizados durante el año 2006



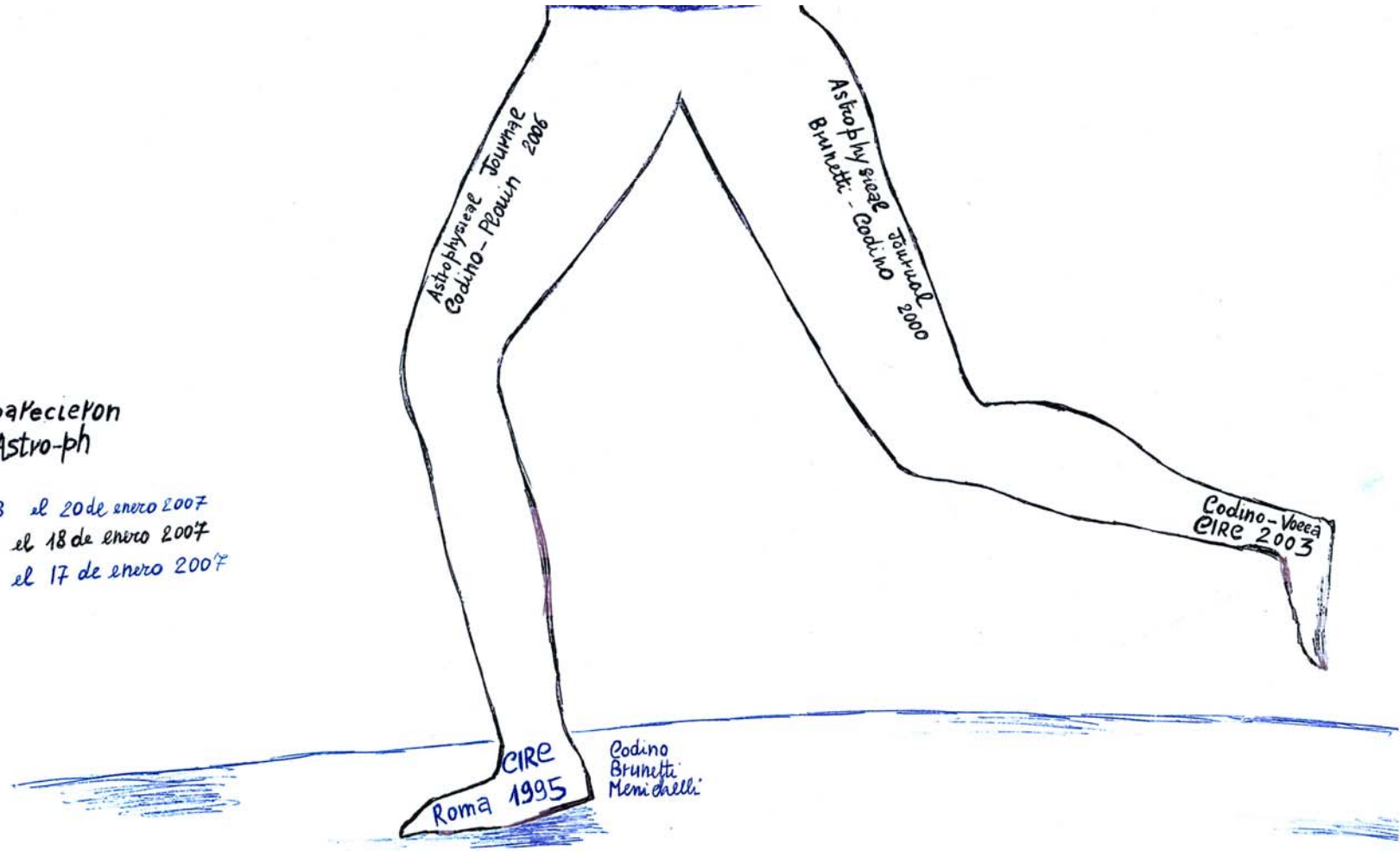
Estos artículos aparecieron en la red Astro-ph con el codigo:

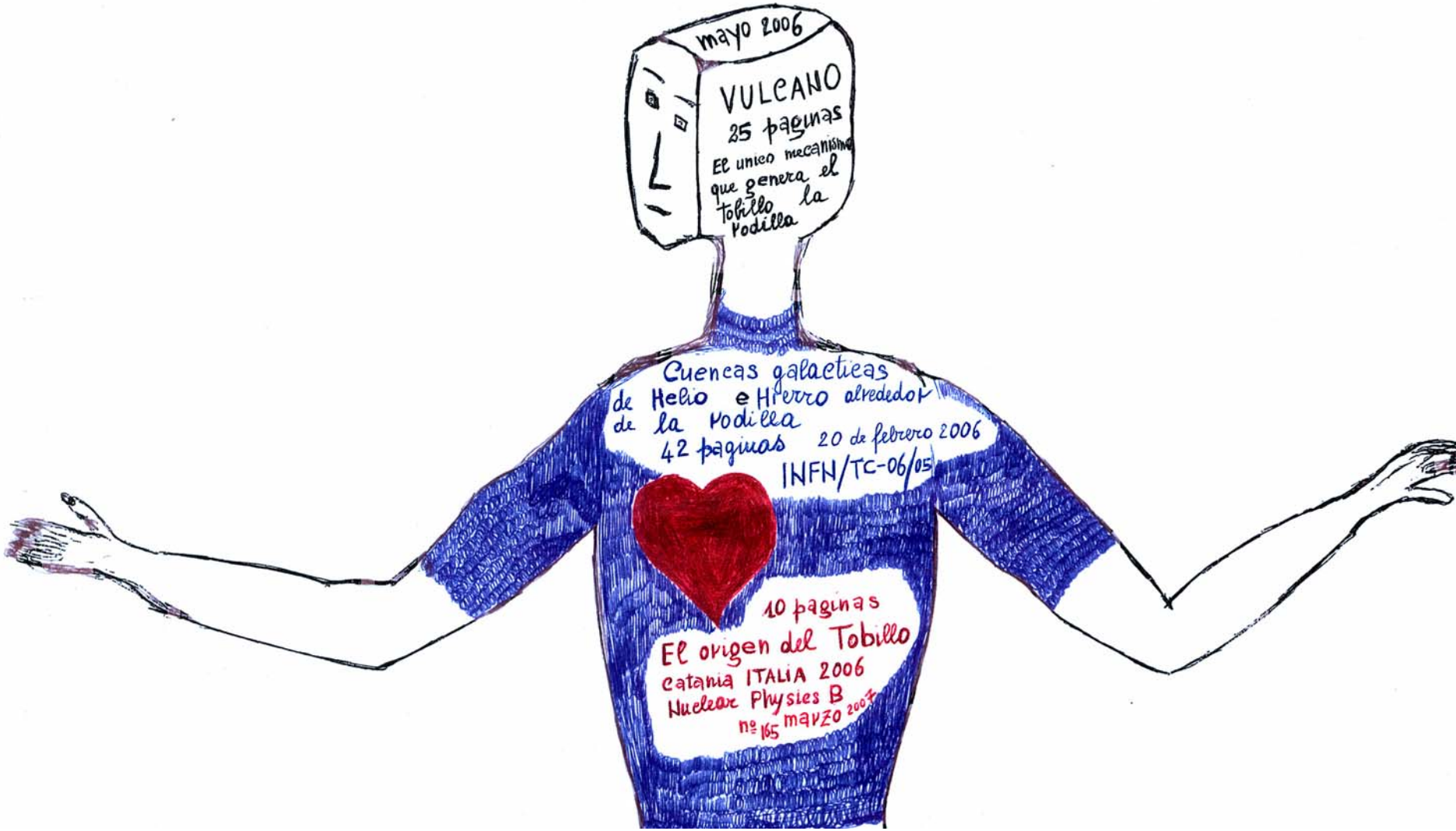
El origen---0701593 el 20 de enero 2007

El unico---0701521 el 18 de enero 2007

Cuneos---0701498 el 17 de enero 2007

CIRC para decir
Conferencia
Internacional
Rayos
Cósmicos




mayo 2006
VULCANO
25 paginas
El unico mecanismo que genera el Tobillo la rodilla
Cuencas galacticas de Helio e Hierro alrededor de la rodilla
42 paginas
20 de febrero 2006
INFN/TC-06/05
10 paginas
El origen del Tobillo
catania ITALIA 2006
Nuclear Physics B
nº 165 marzo 2007

L' accord avec le données se réfère:

- Le genou du proton (Kascade).
- Le genou de l' helium (Kascade).
- Le spectre du fer entre 10^{15} et 10^{17} eV (Kascade et Eas-top).
- La relation entre l' energie du genou et l' energie de la cheville.

- La pente (environ 3) du spectre complet de la radiation cosmique entre 10^{15} and 5 10^{18} eV

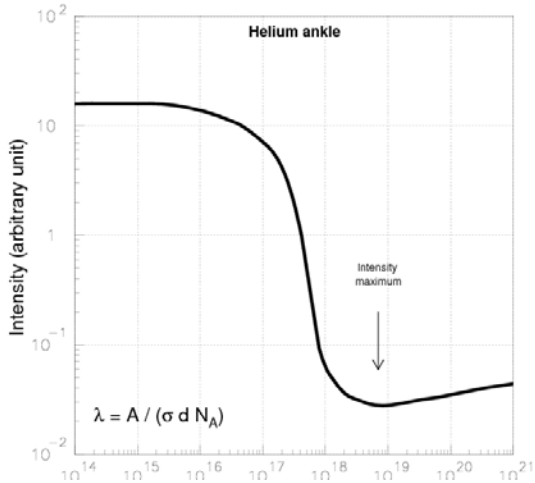
- La bosse dans le spectre complet entre 5 10^{18} eV

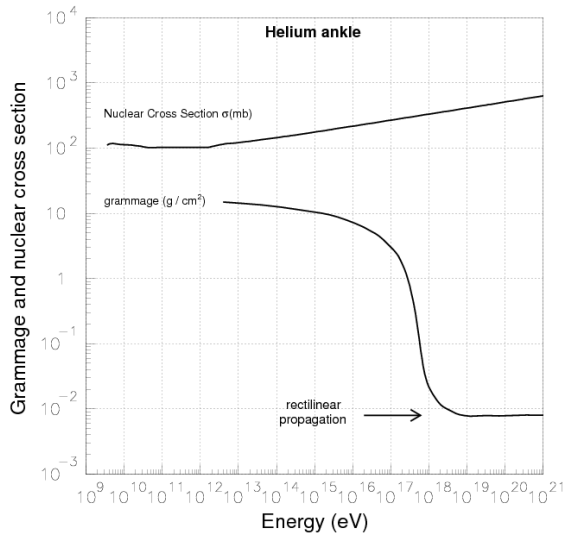
  et 5 10^{19} eV.

Cheville et ions extragalactiques

Les positions de la cheville et du genoux le long de l' axe des energies sont determinées et liées de facon unique par l' intensité moyenne du champ magnetique galactique, qui determine le grammage, and par la pente des sections efficaces inelastiques qui montent avec l' energie, comme on le voit dans le grafique a coté.

Ce resultat est fondamental parce que, pour la première fois, le genou et la cheville sont liés l' un avec l' autre.





Fin du seminaire

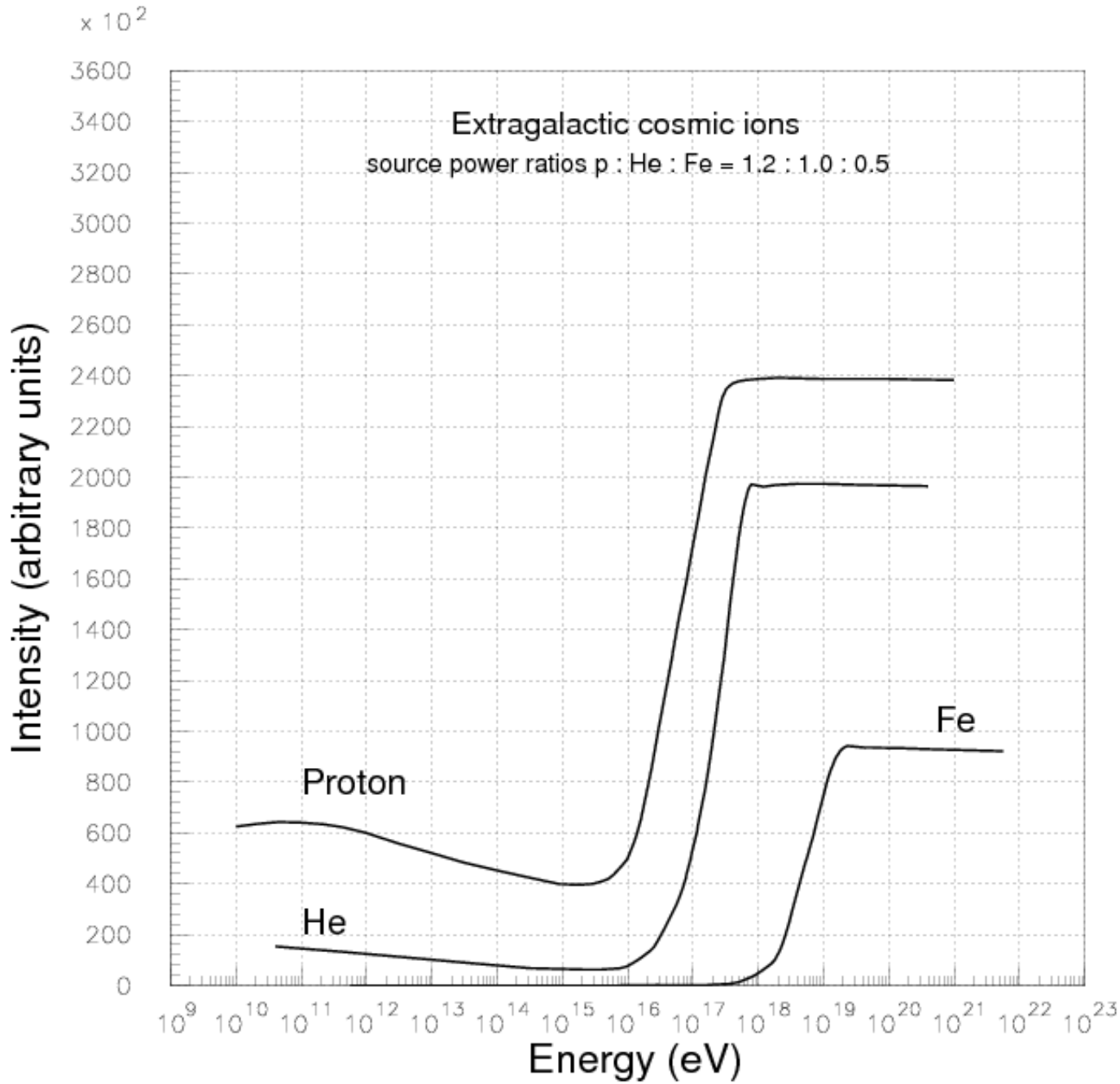
Cheville et ions extragalactiques

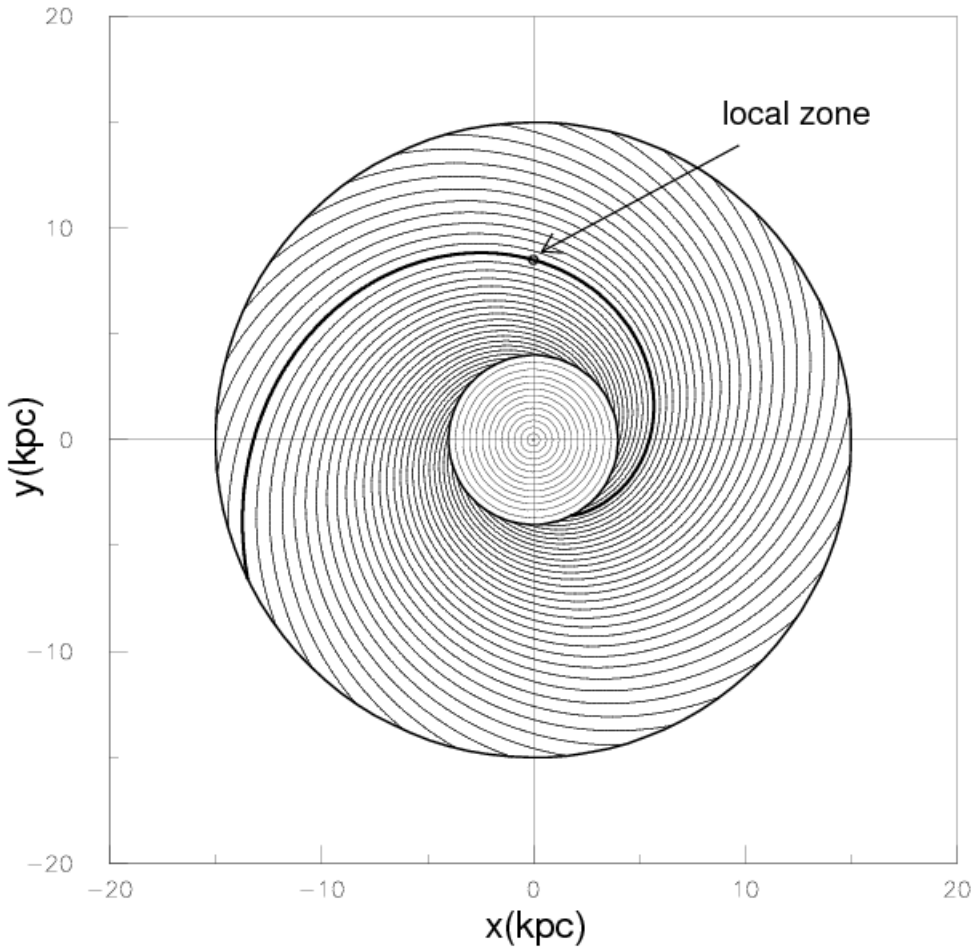
S' il existe une composant extragalactique dans l' espace autour de la Voie Lactée, il est intéressant de déterminer l' intensité à la Terre.

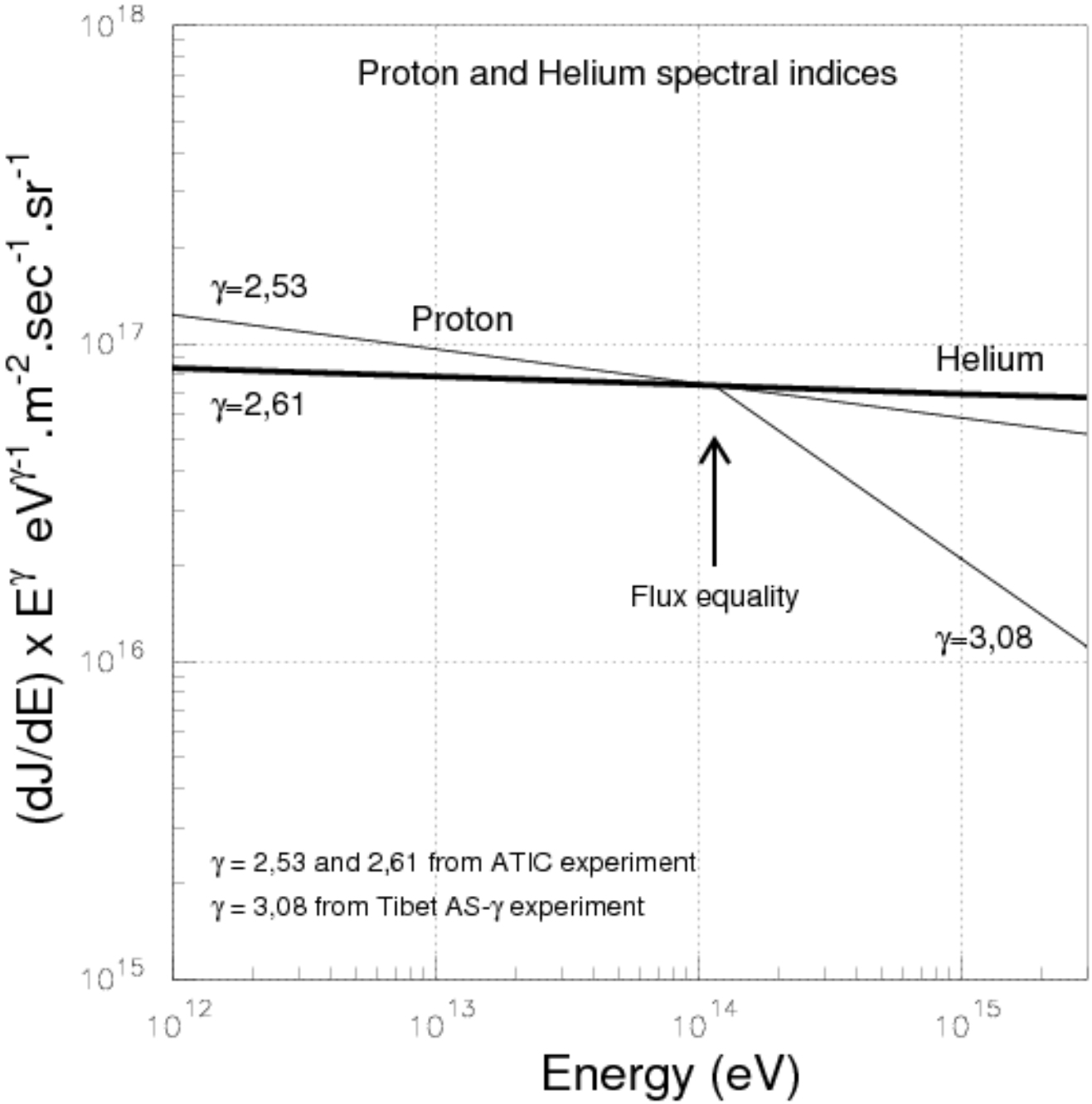
Cette composante extragalactique pourrait e^tre concue de plusieurs facons comme par example :

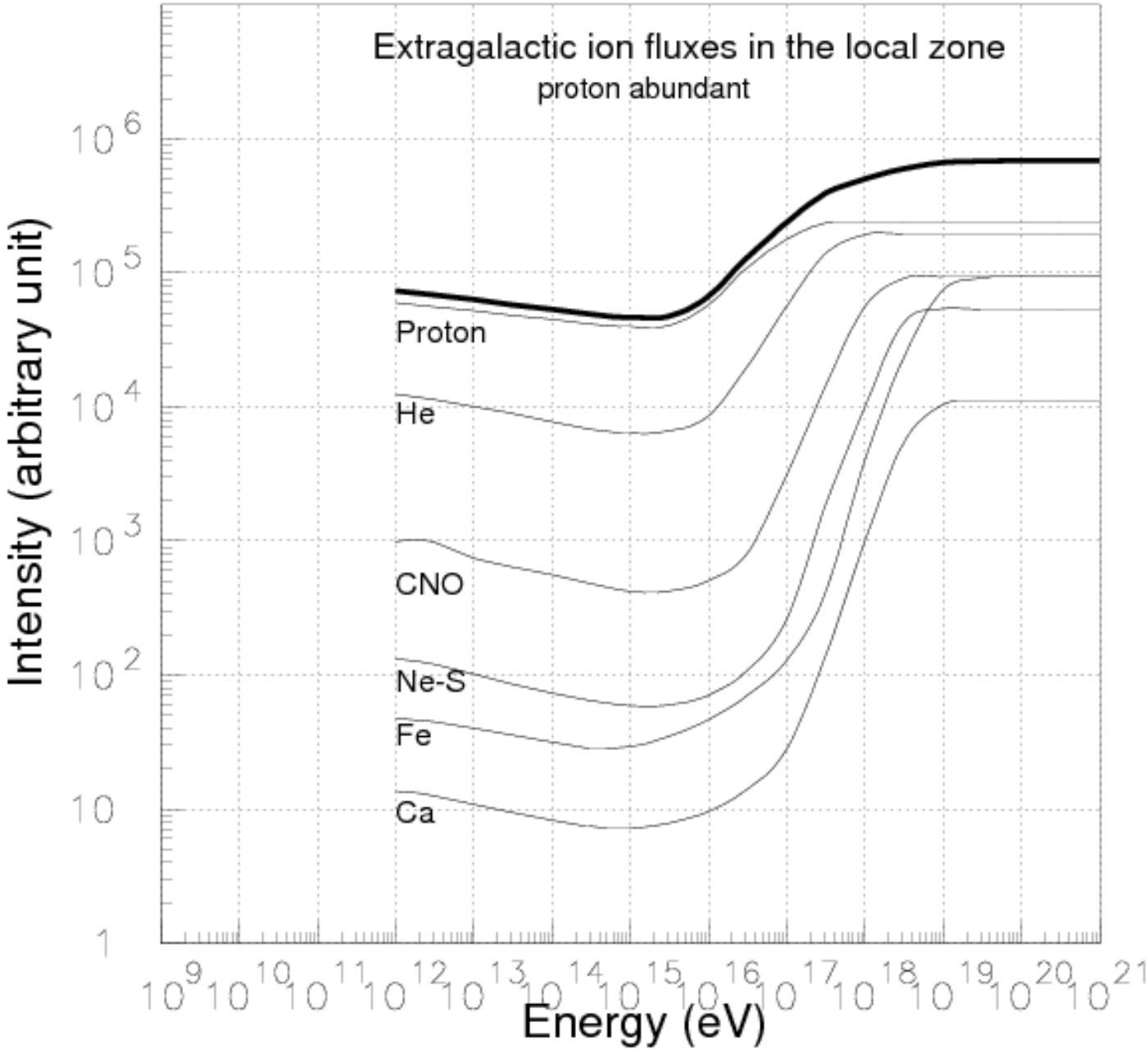
(a) Debris de galaxies normales dans le voisinage cosmique (e.g. 40 Mpc)
(b) Debris de galaxies exceptionelles
(c) Particles qui revient dans la Voie Lactée après s'en ètre echappées.
(d) Populations particulières des rayons cosmiques re-accelerées dans l' espace intergalactique.

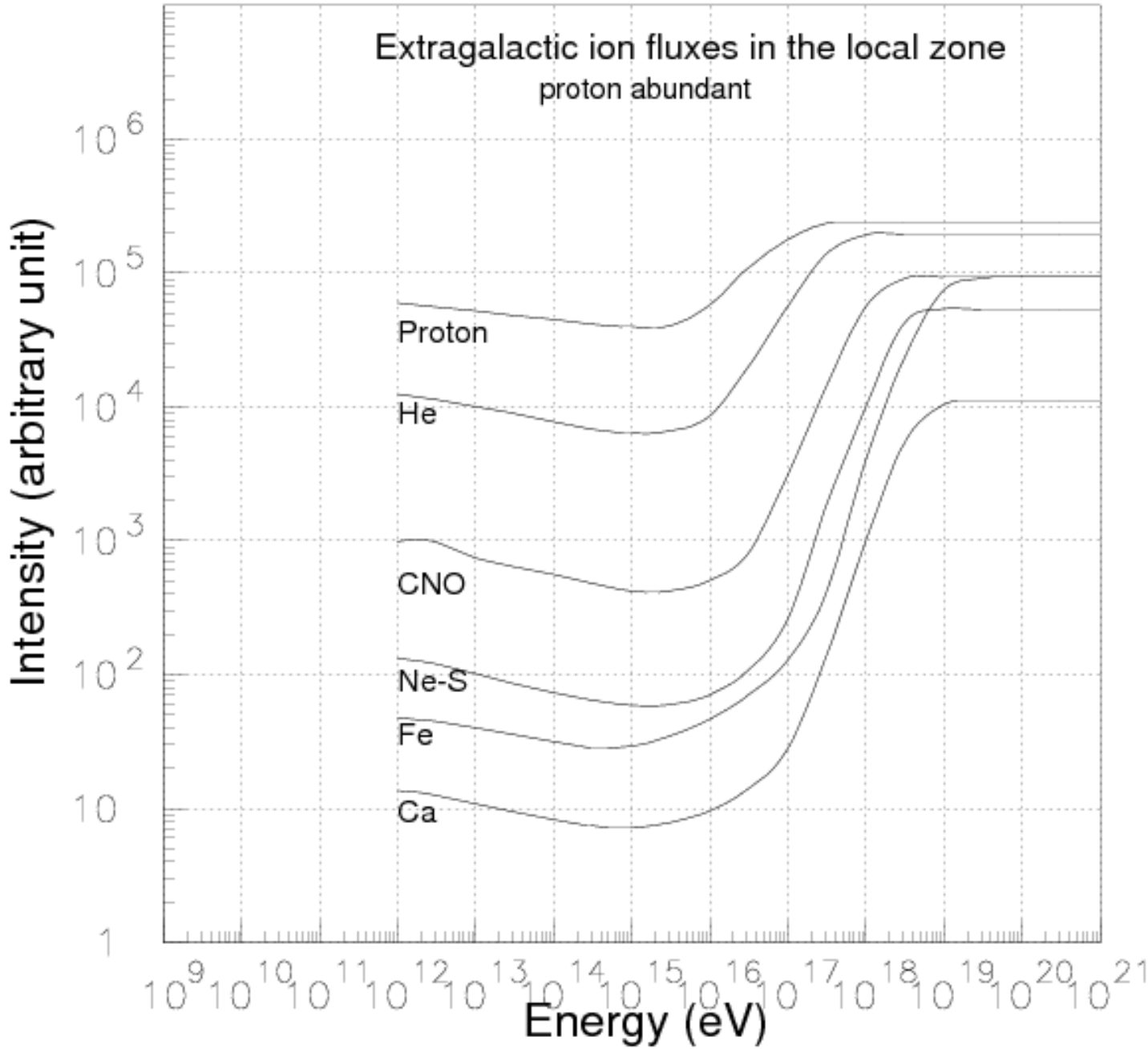
Quelque soit les abundances des ions peuplant l' espace intergalactique (compris entre de bornes plausibles liées à les données experimentels), il existe un point unique le long de l' axe de l' energie dont la composant extragalactique doit posseder un maximum d' intensité. Cette caracteristique est quasiment independent du melange des ions individuels et des indices spectraux .


x 10^2
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Intensity (arbitrary units)
Extragalactic cosmic ions
source power ratios p : He : Fe = 1.2 : 1.0 : 0.5
Proton
He
Fe
10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20 10^21 10^22 10^23
Energy (eV)

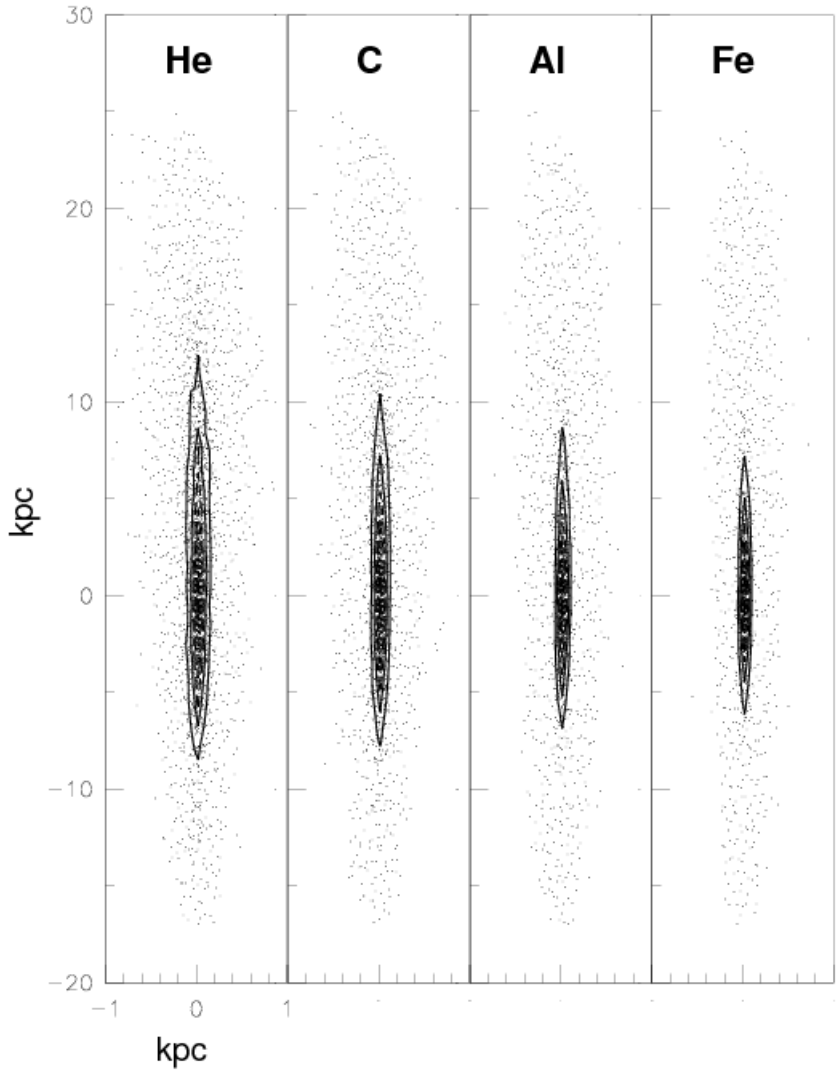

local zone
20
10
0
−10
−20
y(kpc)
−20
−10
0
10
20
x(kpc)

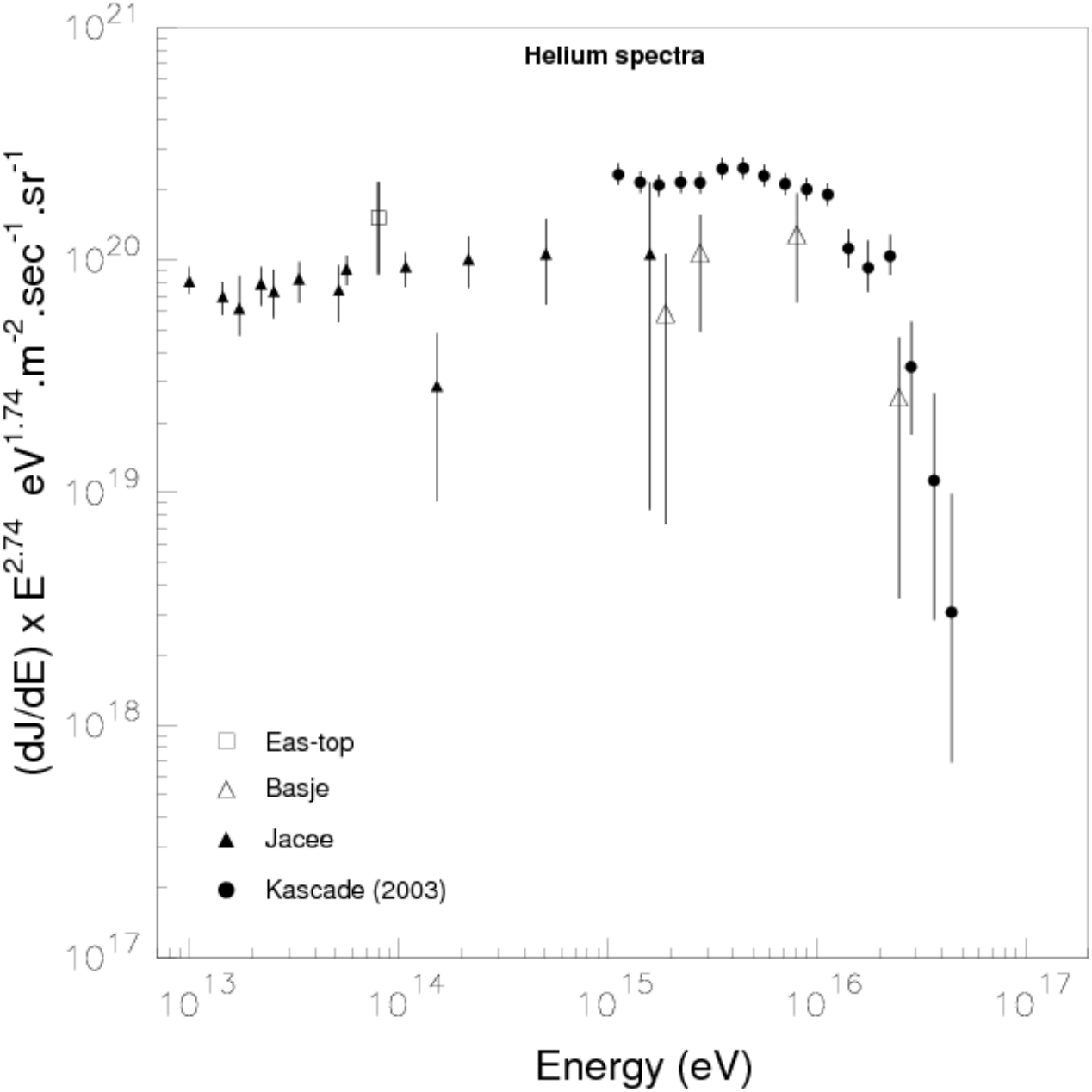

Proton and Helium spectral indices
(dJ/dE) x E^γ eV^(γ-1).m^-2.sec^-1.sr^-1
10^18
10^17
10^16
10^15
10^12
10^13
10^14
10^15
Energy (eV)
γ=2,53
Proton
Helium
γ=2,61
Flux equality
γ=3,08
γ = 2,53 and 2,61 from ATIC experiment
γ = 3,08 from Tibet AS-γ experiment


Extragalactic ion fluxes in the local zone
proton abundant
Intensity (arbitrary unit)
Energy (eV)
Proton
He
CNO
Ne-S
Fe
Ca


Extragalactic ion fluxes in the local zone
proton abundant
Intensity (arbitrary unit)
Energy (eV)
Proton
He
CNO
Ne-S
Fe
Ca

Contour levels for helium, carbon, aluminium and iron illustrating the distribution of cosmic ray sources feeding the local galactic zone




Helium spectra
(dJ/dE) x E^2.74 eV^1.74 .m^-2 .sec^-1 .sr^-1
10^21
10^20
10^19
10^18
10^17
10^13
10^14
10^15
10^16
10^17
Energy (eV)
Eas-top
Basje
Jacee
Kascade (2003)

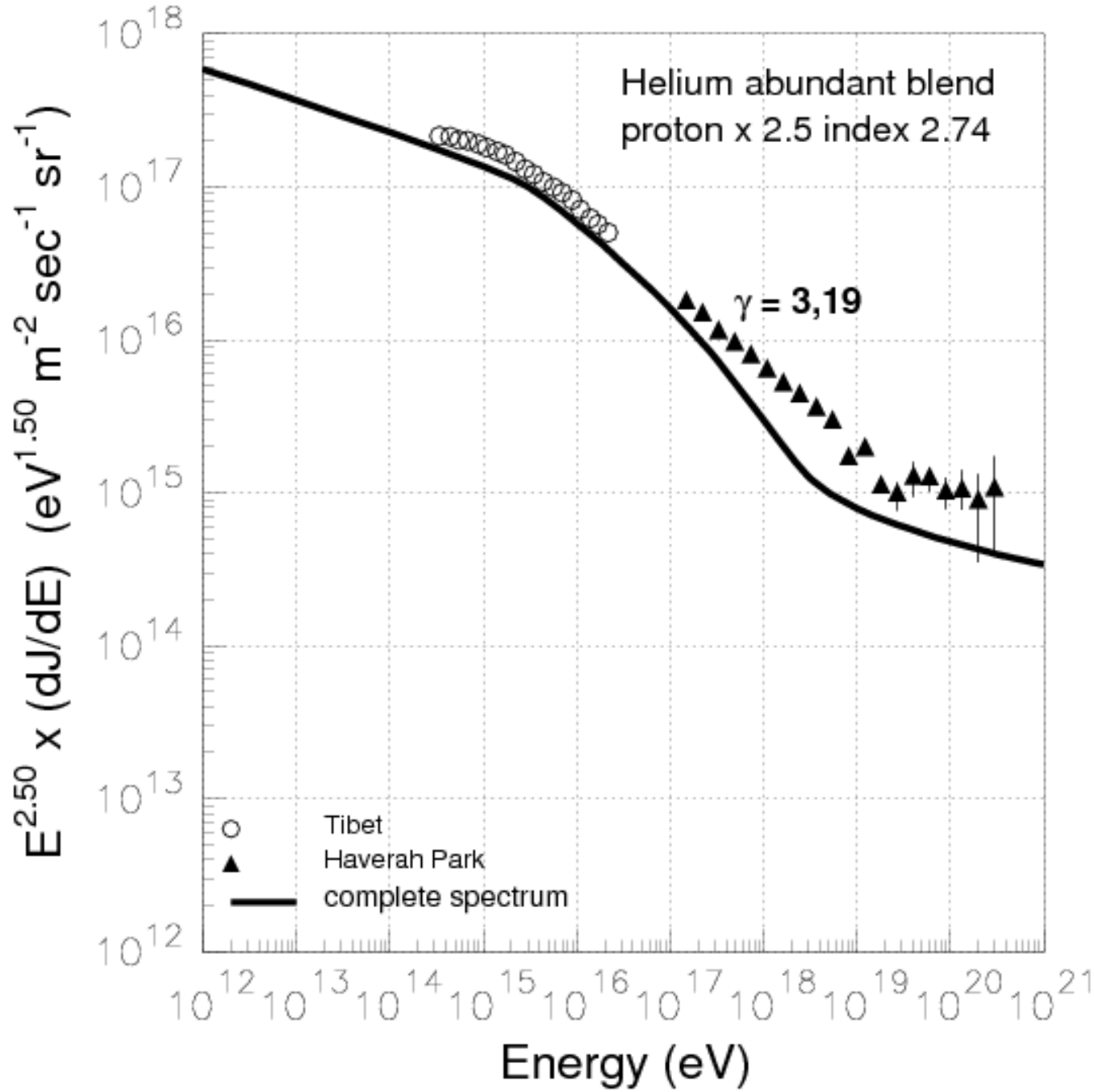
La componente extragalattica

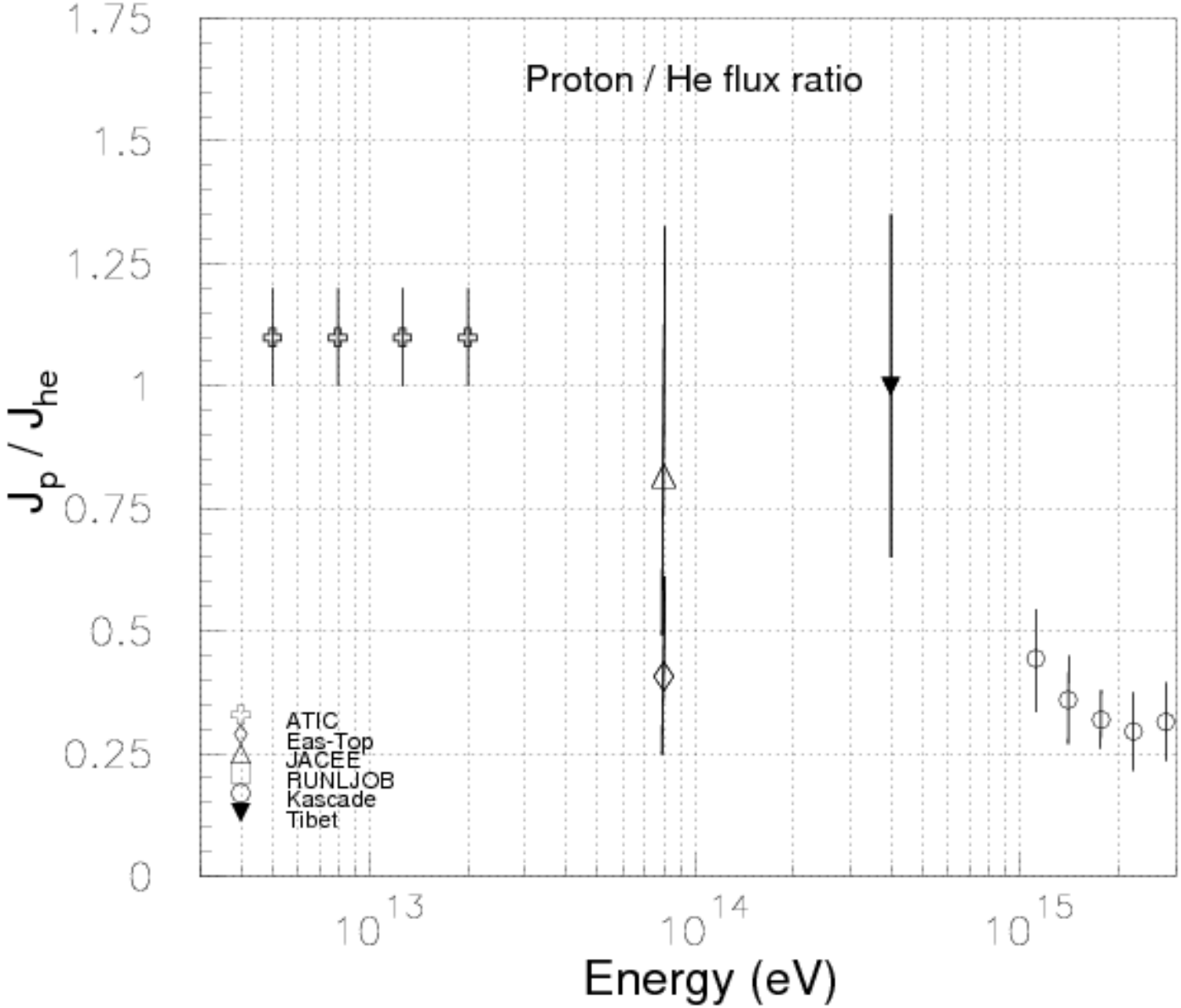
Cosmici in uscita

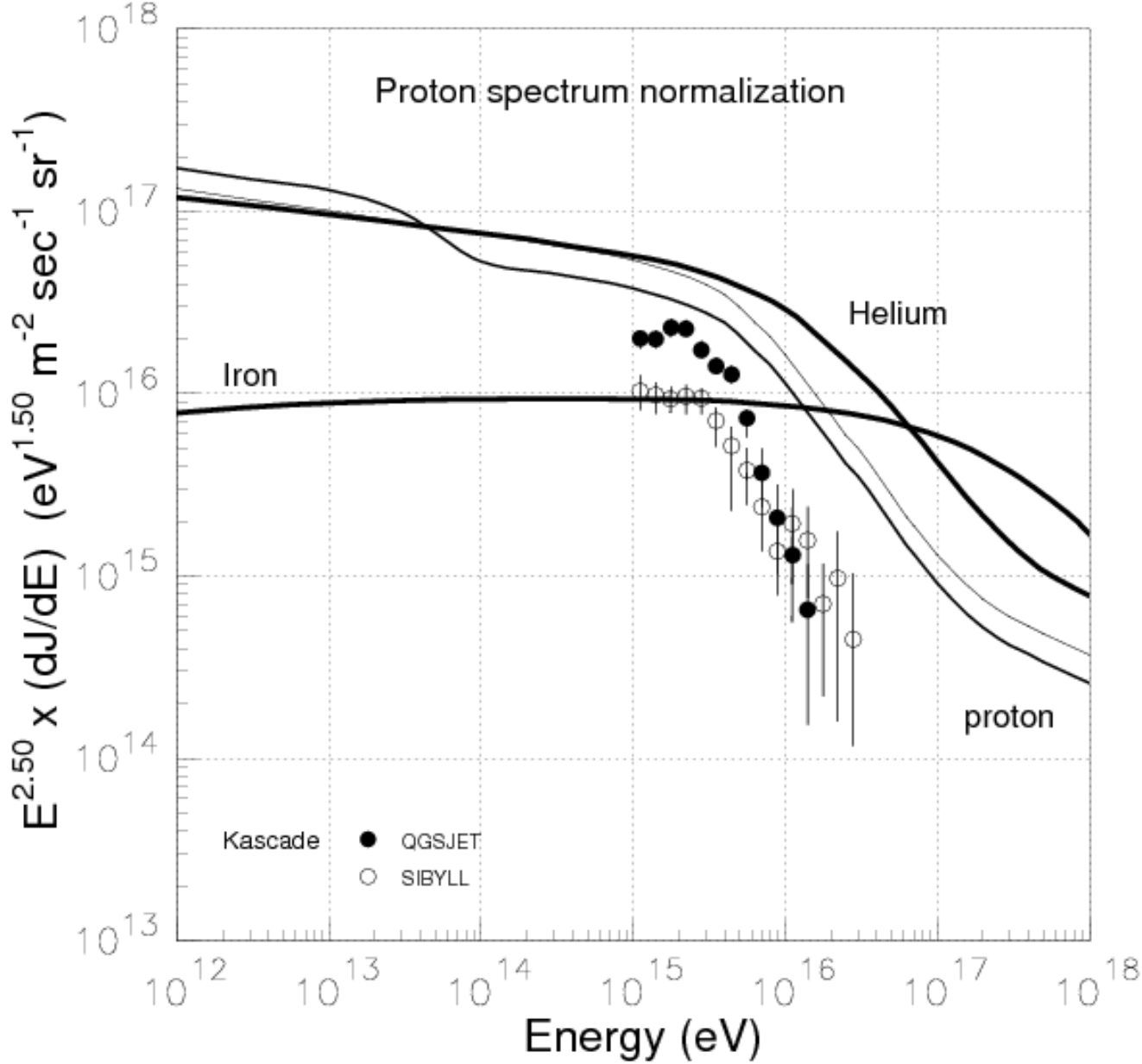
Cosmici in entrata alla Via Lattea

Ammettiamo per semplicità che esista una componente extragalattica della radiazione cosmica che raggiunga la zona locale. Quindi supponiamo che:

- le abbondanze relative degli ioni cosmici extragalattici siano le stesse dei raggi cosmici in uscita dalla Via Lattea
- la componente extragalattica in ingresso alla Via Lattea incontri la medesima struttura di campi magnetici e di materia interstellare intercettate dai raggi cosmici galattici.


Helium abundant blend
proton x 2.5 index 2.74
γ = 3,19
Tibet
Haverah Park
complete spectrum
E^2.50 x (dJ/dE) (eV^1.50 m^-2 sec^-1 sr^-1)
Energy (eV)
10^18
10^17
10^16
10^15
10^14
10^13
10^12
10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20 10^21


Proton / He flux ratio
J_p / J_{he}
1.75
1.5
1.25
1
0.75
0.5
0.25
0
ATIC
Eas-Top
JACEE
RUNLJOB
Kascade
Tibet
10^{13}
10^{14}
10^{15}
Energy (eV)


Proton spectrum normalization
Helium
Iron
proton
Kascade
QGSJET
SIBYLL
$E^{2.50}$ x (dJ/dE) ($eV^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}

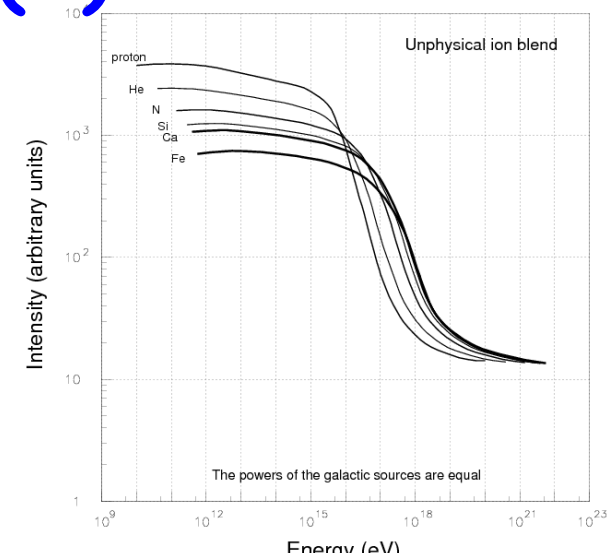
Conclusions (1)

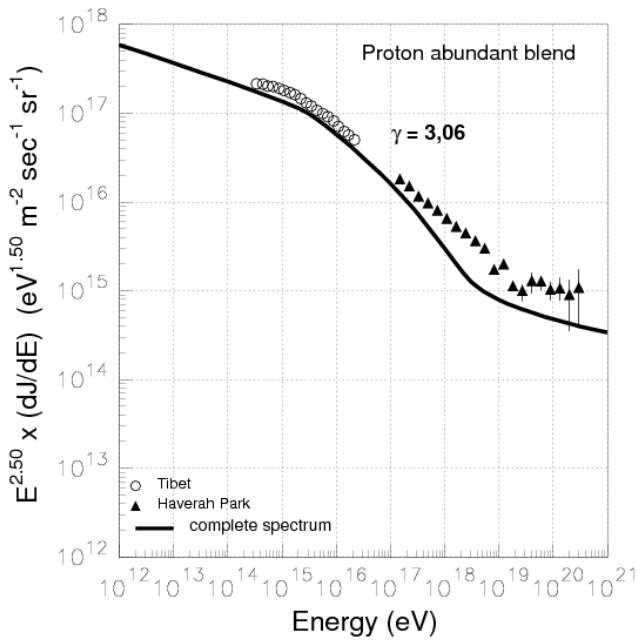
The computed spectra of individual ions (Protons, Helium and Iron) are in good agreement with the experimental data (only the shapes of the spectra) of the Kaskade experiment.

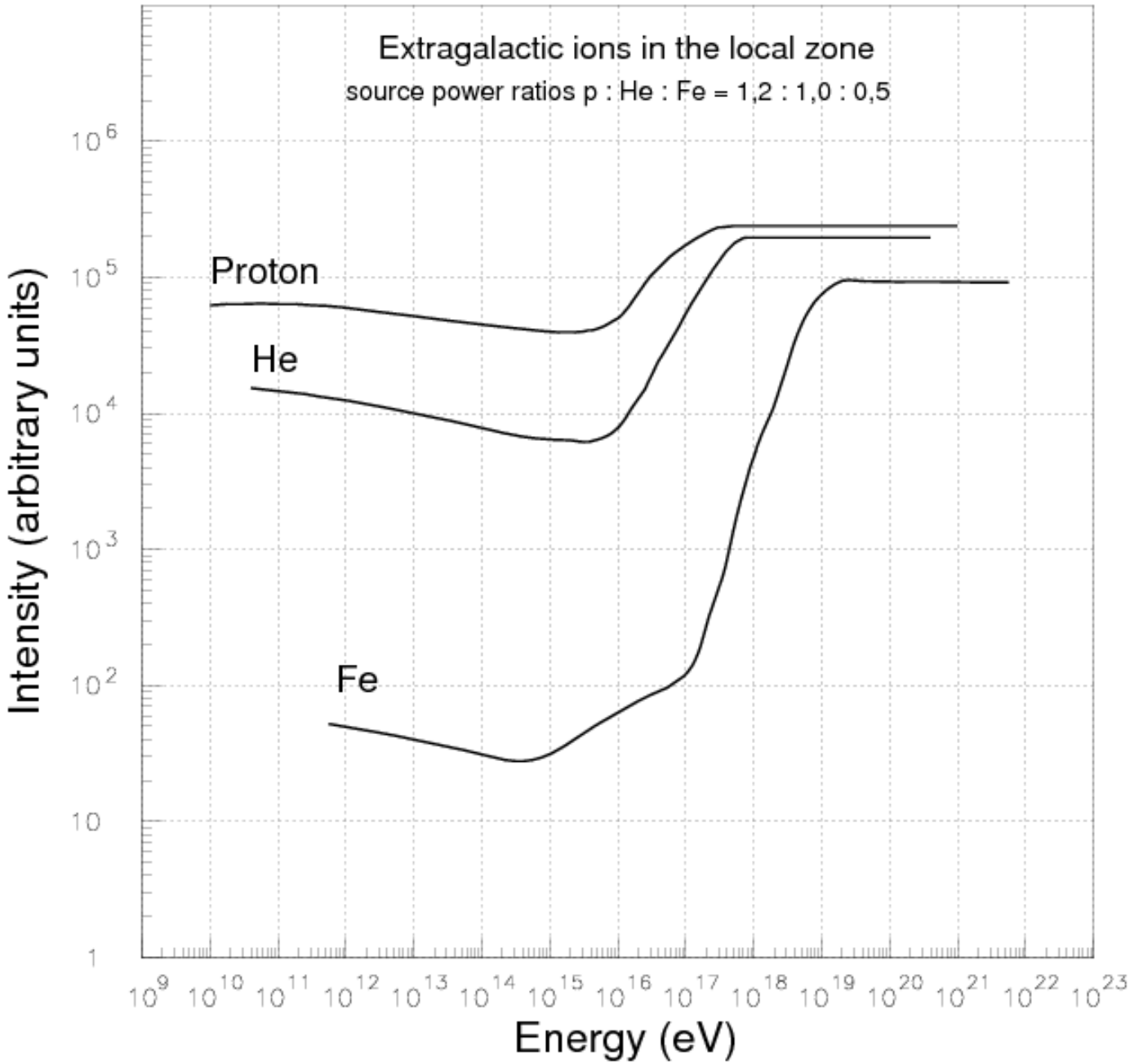
Regardless of the particular ion blend, the computed position along the energy axis of the knee of the all-particle spectrum also matches the results of the experiments.

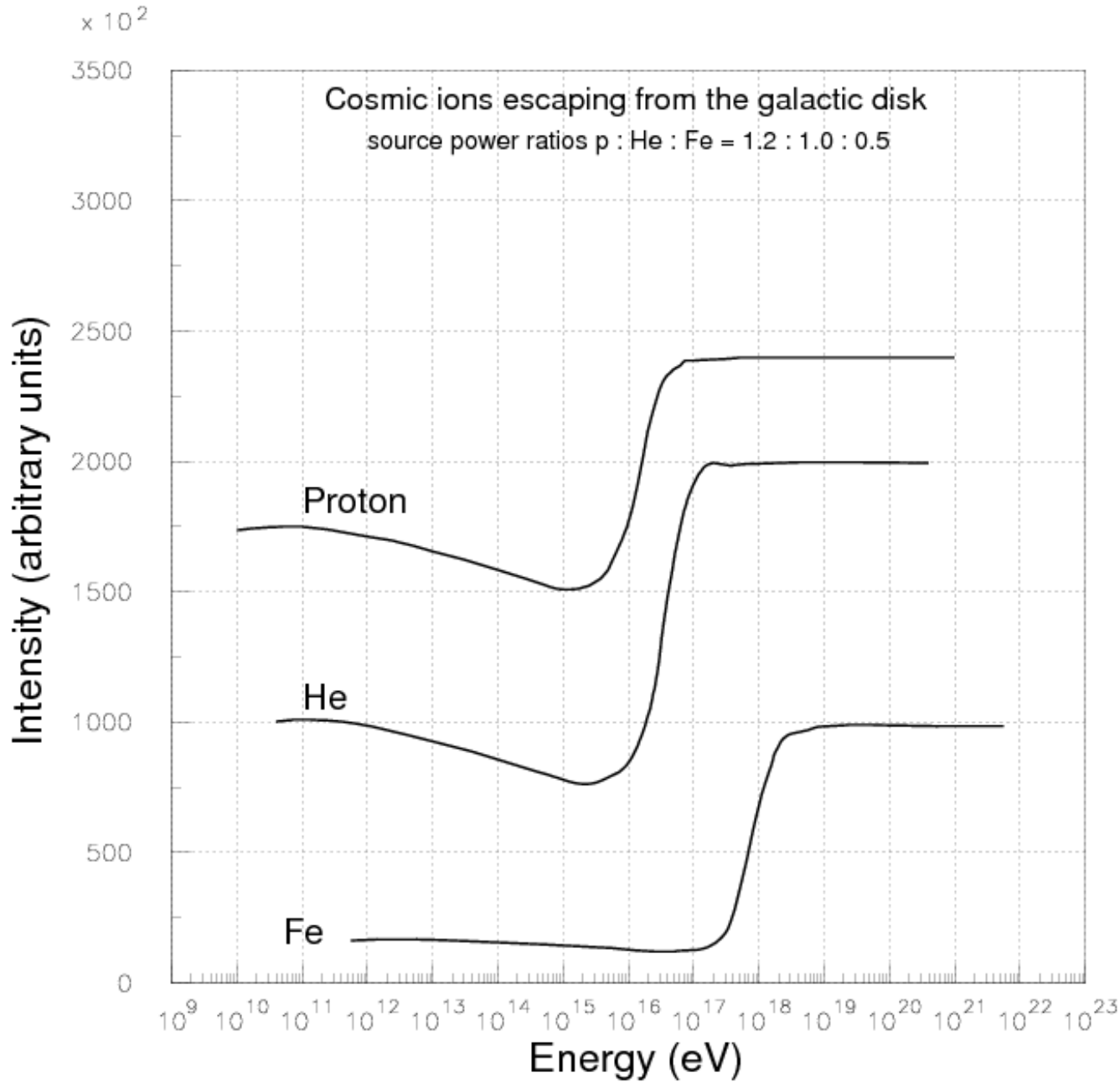
With the above inputs the all-particle energy spectrum between the knee and the ankle is calculated showing a spectral index of 3.05 for a proton abundant blend and 3.06 for an helium abundant blend i.e the spectral index is close to the observed value of 3 in the range 10^{15} and 10^{17} eV.

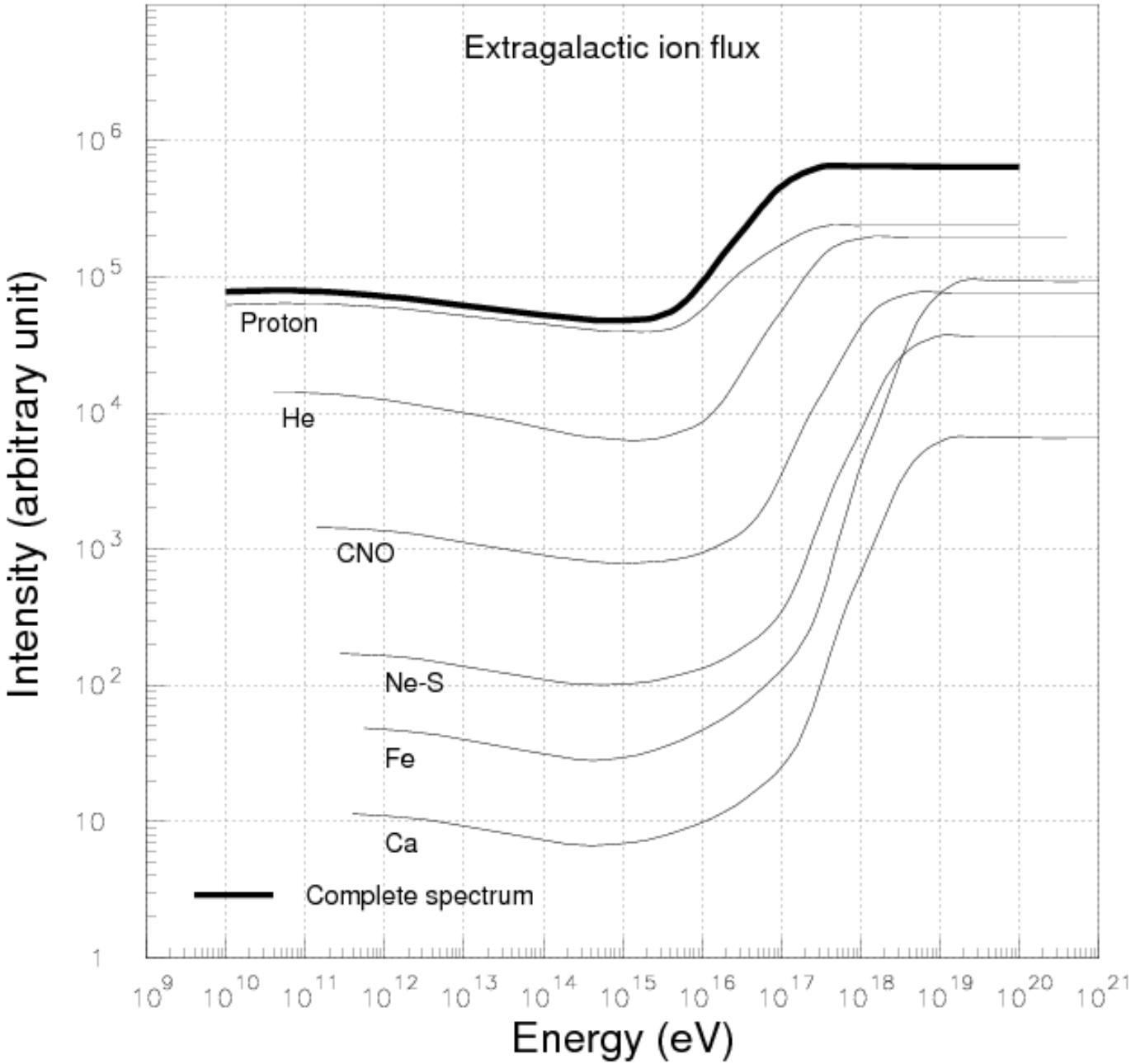
This agreement is particularly meaningful since the energy spectra of individual ions have slopes of 3.38 (Helium) and 3.34 (Fe) in the same energy range. The computed indices of 3.05 and 3.06 between 10^{15}-10^{17} eV are the result of the sum of all the ion spectra as indicated in the figure.

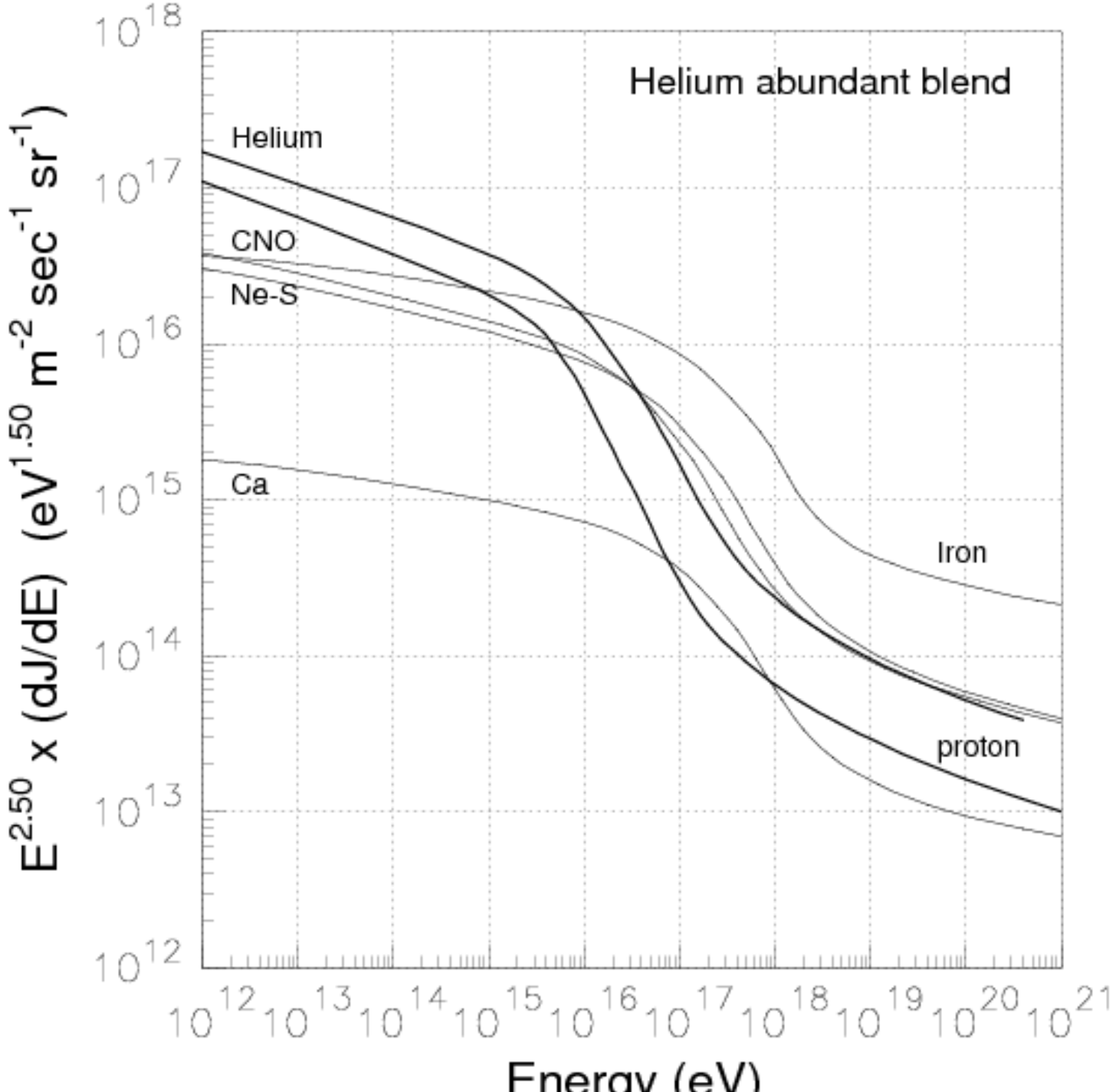


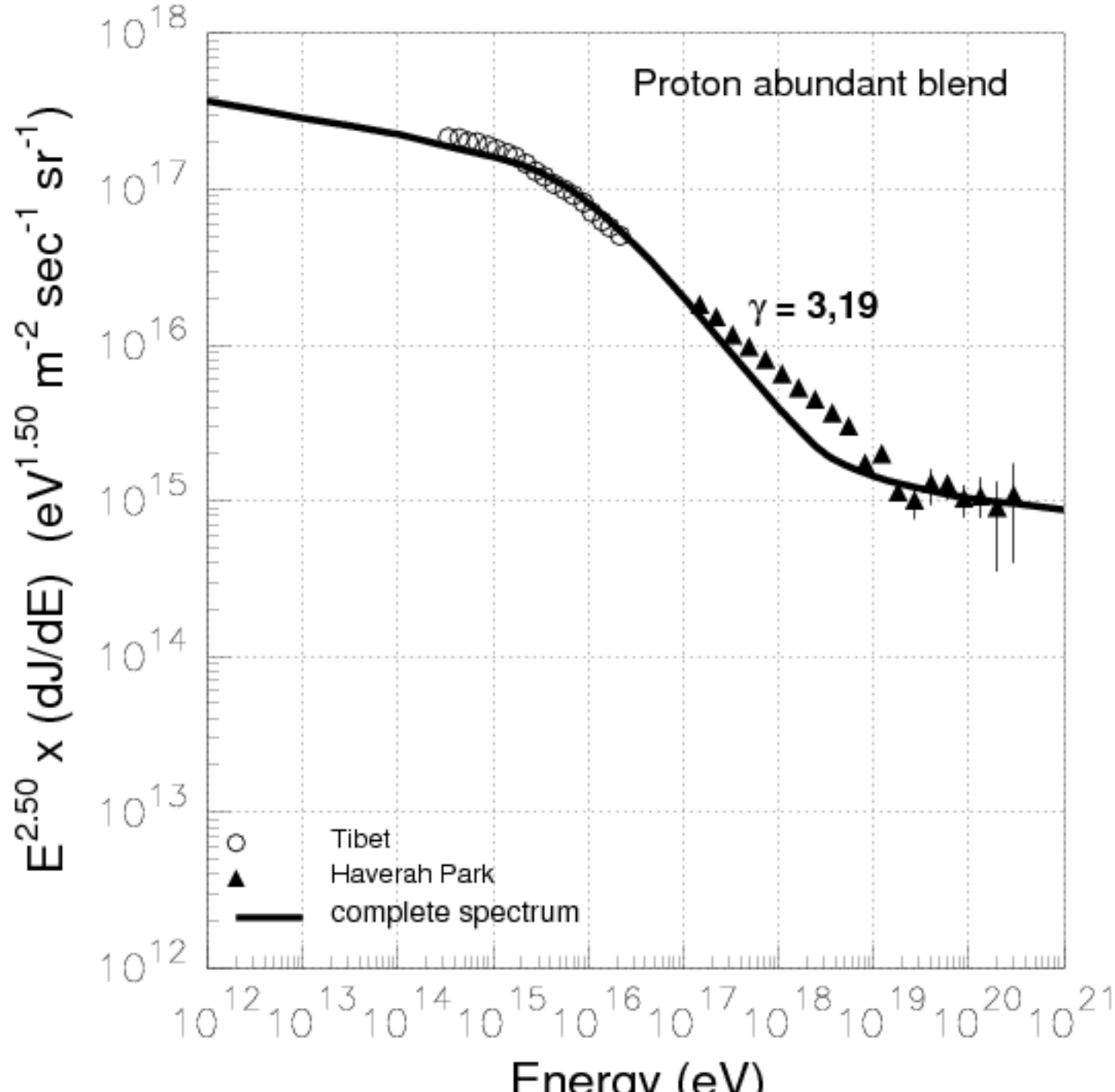


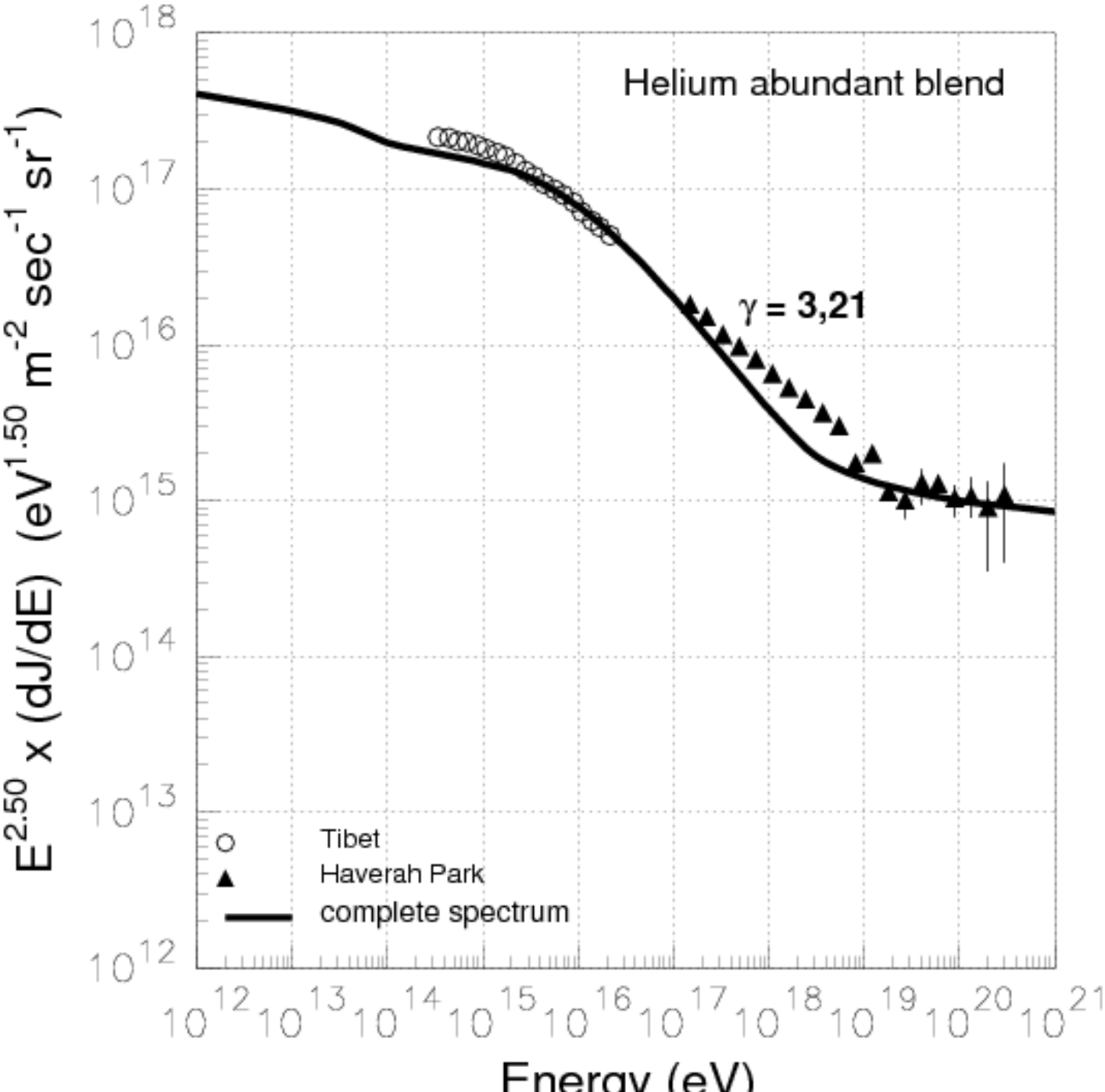

Extragalactic ions in the local zone
source power ratios p : He : Fe = 1,2 : 1,0 : 0,5
Proton
He
Fe
Intensity (arbitrary units)
Energy (eV)
1
10
10^2
10^3
10^4
10^5
10^6
10^9
10^10
10^11
10^12
10^13
10^14
10^15
10^16
10^17
10^18
10^19
10^20
10^21
10^22
10^23

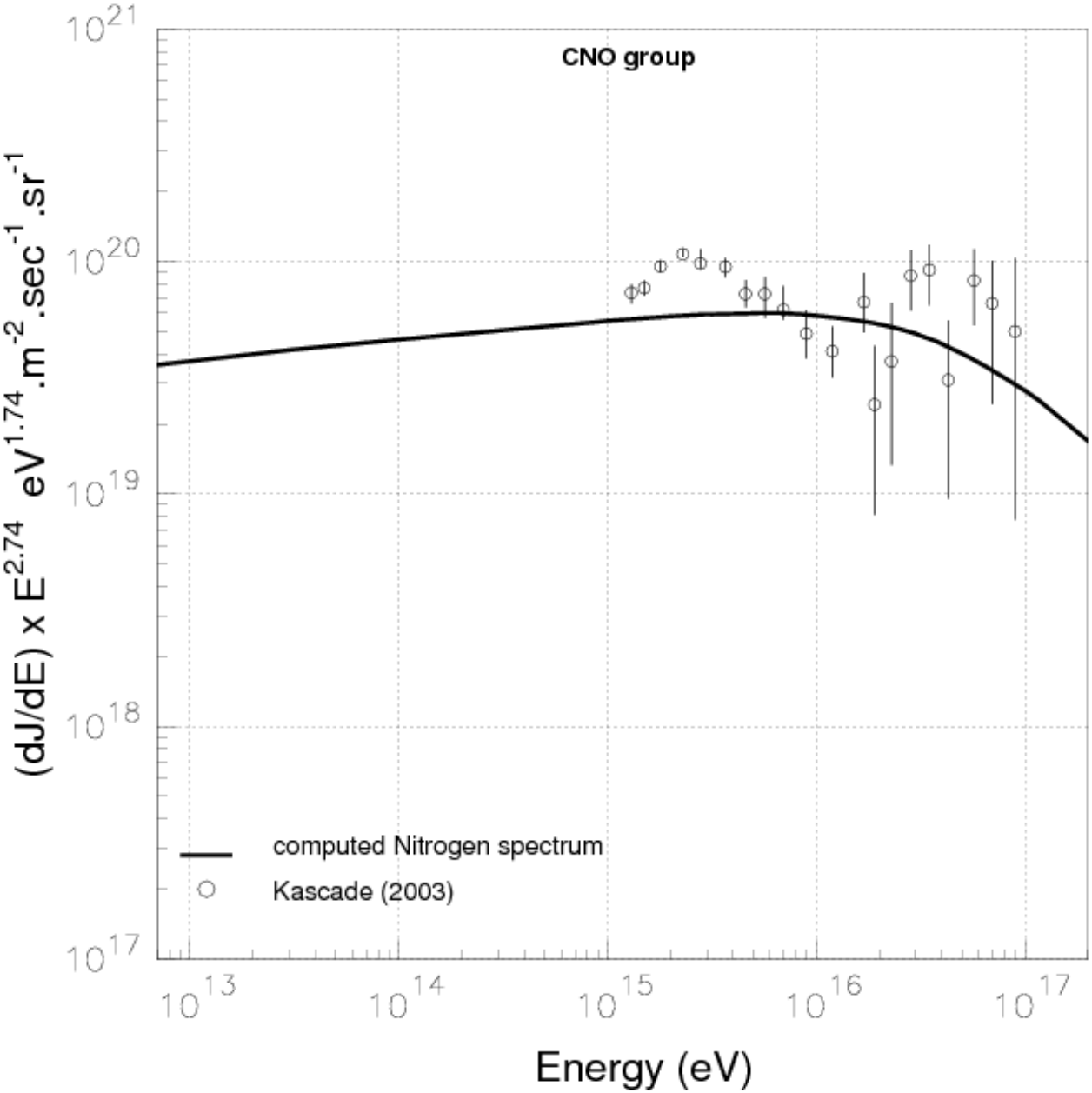

x 10^2
3500
3000
2500
2000
1500
1000
500
0
Intensity (arbitrary units)
Cosmic ions escaping from the galactic disk
source power ratios p : He : Fe = 1.2 : 1.0 : 0.5
Proton
He
Fe
10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20 10^21 10^22 10^23
Energy (eV)

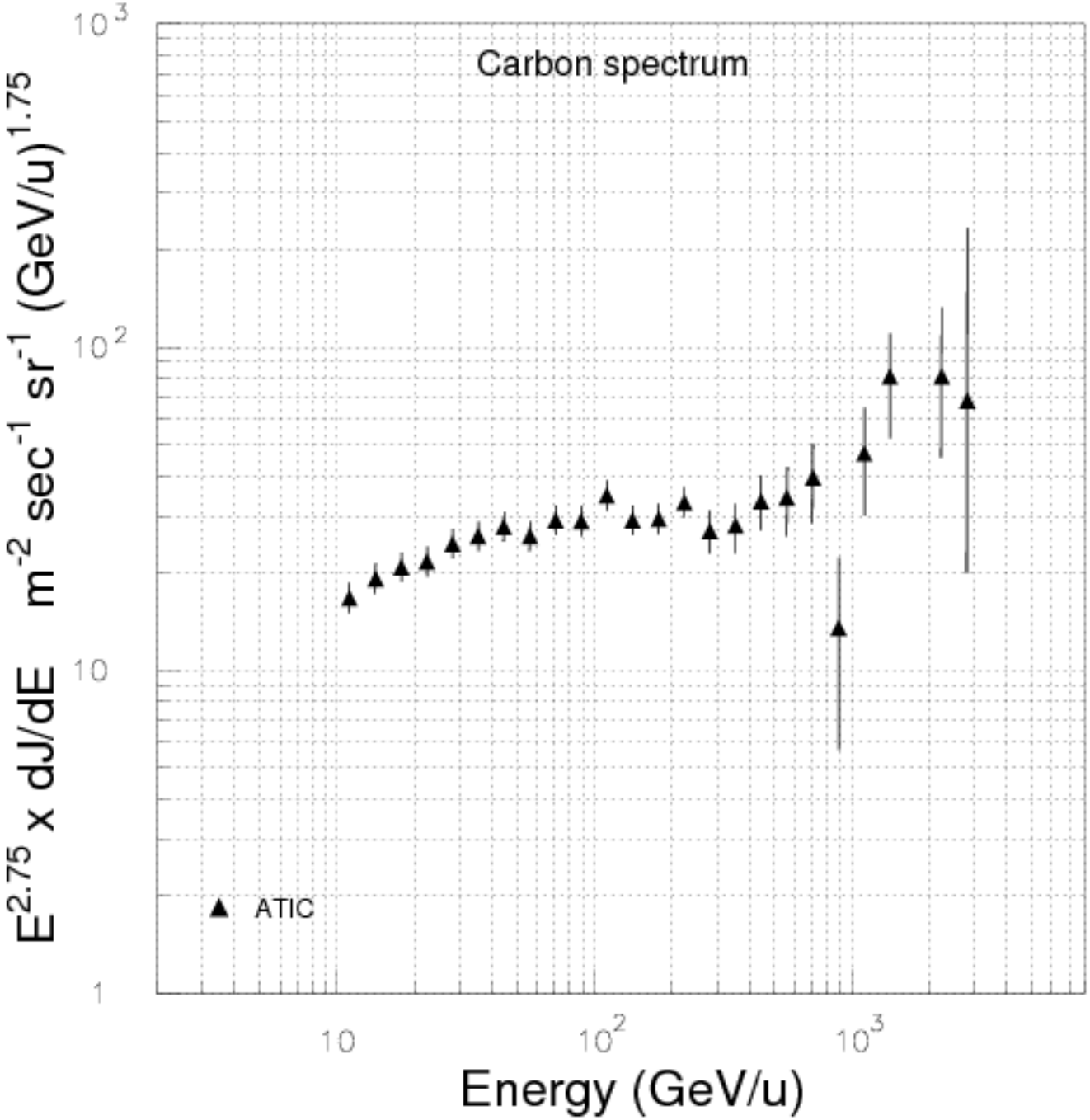

Extragalactic ion flux
Intensity (arbitrary unit)
Energy (eV)
Proton
He
CNO
Ne-S
Fe
Ca
Complete spectrum
1
10
10^2
10^3
10^4
10^5
10^6
10^9
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}

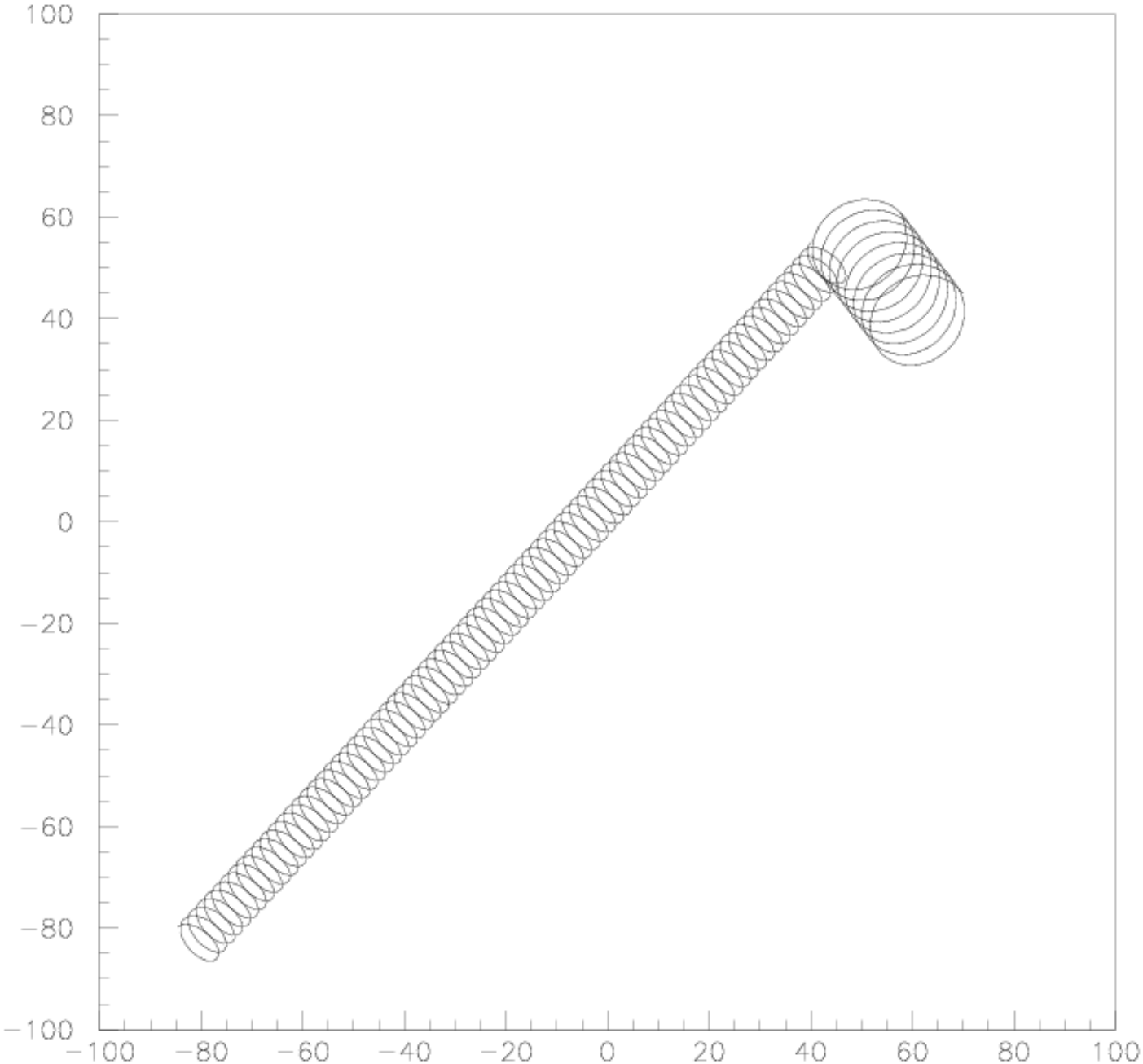

Helium abundant blend
Helium
CNO
Ne-S
Ca
Iron
proton
$E^{2.50}$ x (dJ/dE) (eV$^{1.50}$ m^{-2} sec^{-1} sr^{-1})
Energy (eV)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21}


Proton abundant blend
γ = 3,19
Tibet
Haverah Park
complete spectrum
E^2.50 x (dJ/dE) (eV^1.50 m^-2 sec^-1 sr^-1)
Energy (eV)
10^18
10^17
10^16
10^15
10^14
10^13
10^12
10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20 10^21


Helium abundant blend
γ = 3,21
Tibet
Haverah Park
complete spectrum
E^2.50 x (dJ/dE) (eV^1.50 m^-2 sec^-1 sr^-1)
Energy (eV)
10^18
10^17
10^16
10^15
10^14
10^13
10^12
10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20 10^21


CNO group
10^{21}
10^{20}
10^{19}
10^{18}
10^{17}
$(dJ/dE) \times E^{2.74}$ $eV^{1.74}.m^{-2}.sec^{-1}.sr^{-1}$
computed Nitrogen spectrum
Kascade (2003)
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
Energy (eV)


Carbon spectrum
$E^{2.75}$ x dJ/dE m^{-2} sec^{-1} sr^{-1} $(GeV/u)^{1.75}$
10^3
10^2
10
1
ATIC
10
10^2
10^3
Energy (GeV/u)


100
80
60
40
20
0
−20
−40
−60
−80
−100
−100
−80
−60
−40
−20
0
20
40
60
80
100

Relative abundances of cosmic ions at low energies

(below the knee energy)

PROTON superABUNDANT BLEND – Energy = 2×10^{15} eV

Ion	Composition (%)	Spectral index
H	41,0	2.72
He	25,5	2.72
CNO	10,0	2.65
Ne-S	8,60	2.65
Fe (17-26)	12,8	2.60
Ca	0.74	2.60