Rapporteur talk:

Acceleration and Propagation of CR

Sections OG 1.3, OG 1.4, HE 1.2 (theory)

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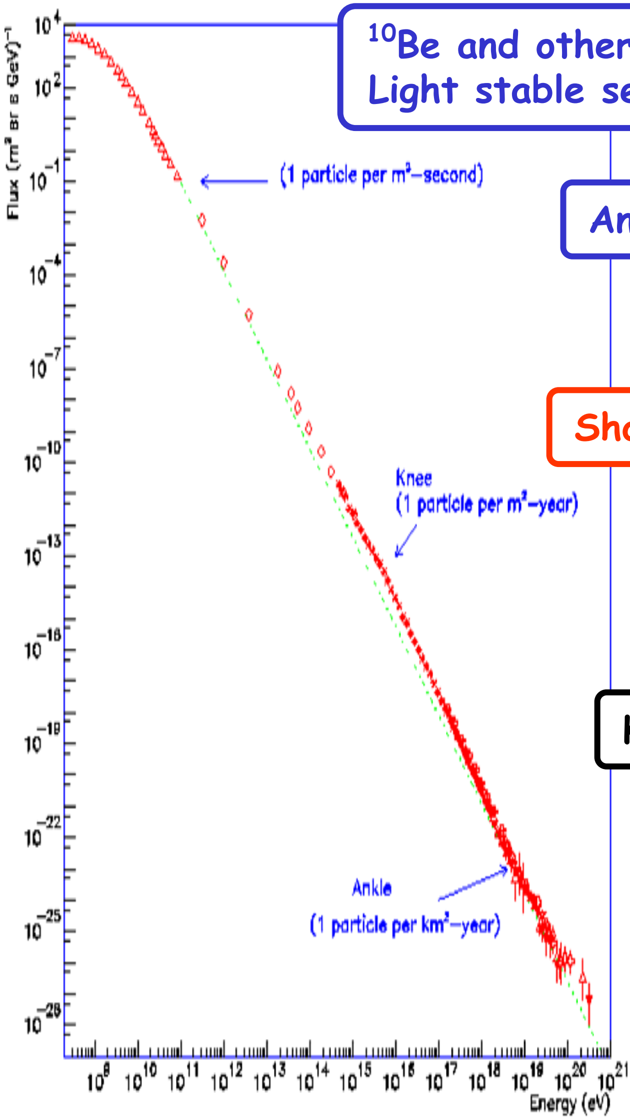
Covered Topics



OG1.3

- ^{10}Be and other radioactive secondaries
- Light stable secondaries (d, ^{3}He, LiBeB)
- LiBeB production cross sections
- Antiprotons, anti- d, t, ^{3}He, ^{4}He
- TeV electrons
- New effects in CR propagation
- Propagation models/codes

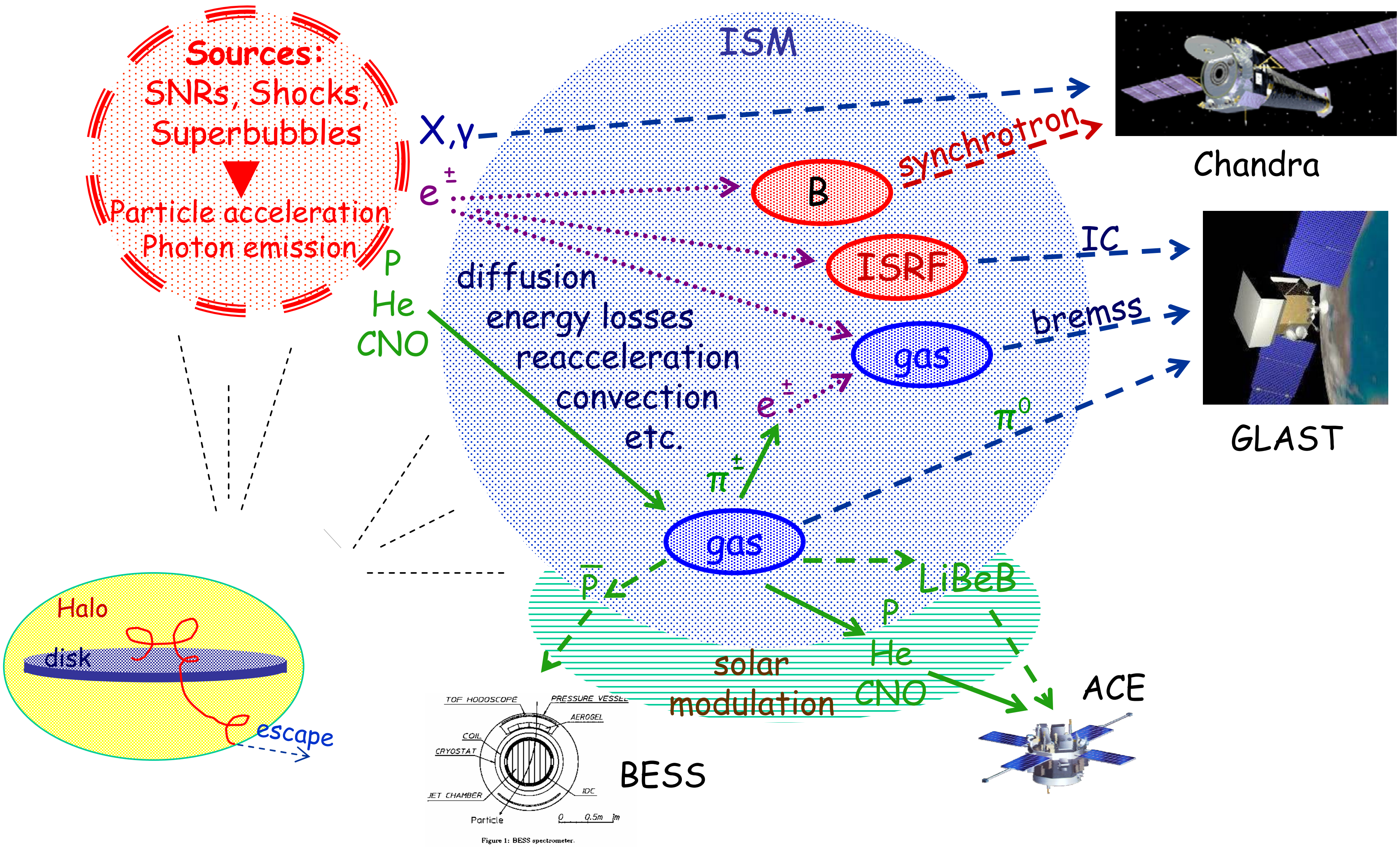
OG1.4

- Shocks in SNR
- Shocks in the Galactic wind
- Shocks in the galaxy clusters
- Relativistic shocks/jets, pair plasma

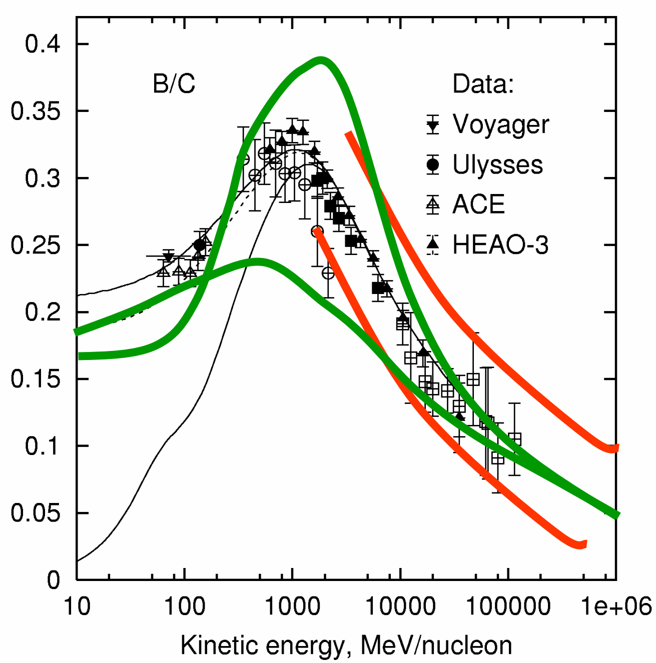
HE1.2

- Knee: Diffusion
- Knee: Sources
- More in the rapporteur talk by Prof. Takita

CR Interactions in the Interstellar Medium



Fixing Propagation Parameters: Standard Way

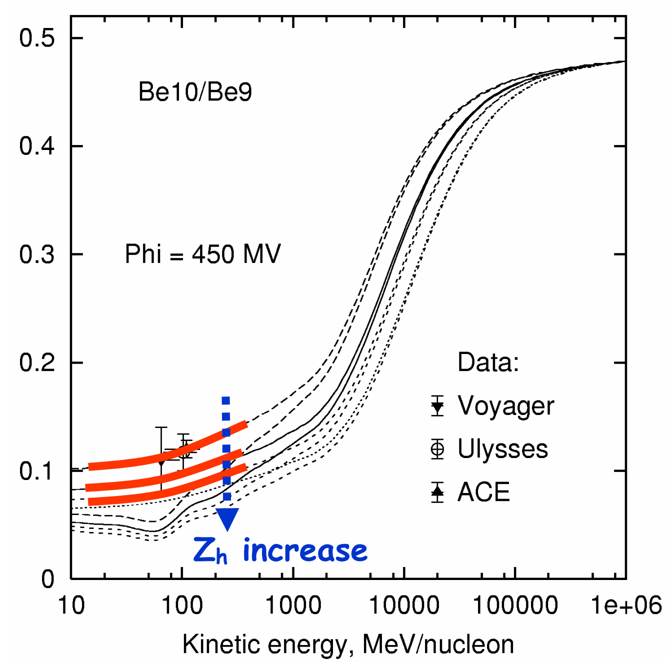


Using secondary/primary nuclei ratio:

- Diffusion coefficient and its index
- Propagation mode and its parameters (e.g., reacceleration V_A, convection V_z)

Radiactive isotopes:

Galactic halo size Z_h



Radioactive Secondaries @ 1 GeV/nucleon

28th International Cosmic Ray Conference — 1937

A new Thought on the Energy Dependence of the $^{10}Be/^{9}Be$ Ratio

Alexander Molnar and Manfred Simon
University of Siegen, 57072 Siegen, Germany

Uncertainties in the production cross section

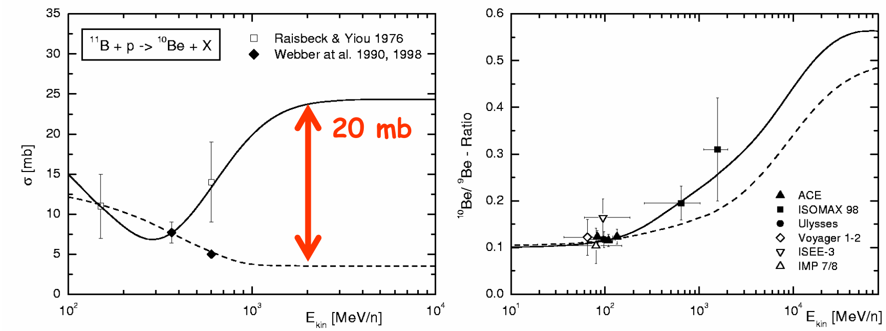


Fig. 2. The $^{10}Be/^{9}Be$ ratio (right) calculated with different cross sections (left). For cross section data see [4,7,8]. $^{10}Be/^{9}Be$ ratio data as in fig. 1.

Two reasons for the discrepancy with ISOMAX data

The energy dependence the halo size

NO wind	↑ Energy	↓ Z_h, halo size
Convection (Voelk)	↑ Energy	↑ Z_h, halo size

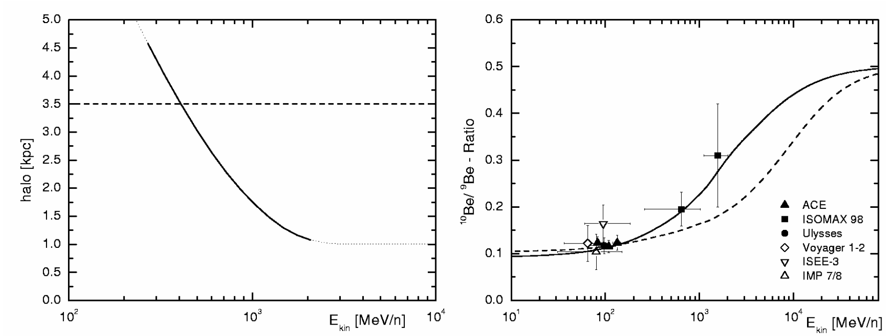
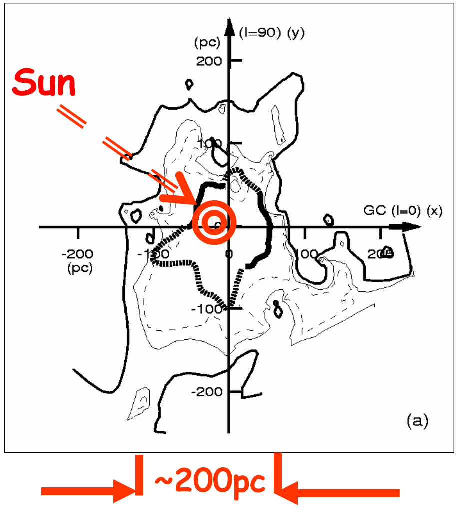


Fig. 3. The $^{10}Be/^{9}Be$ ratio (right) calculated with a constant and an energy dependent halo size (left). Data as in fig. 1.

Non-trivial energy dependence of the diffusion coefficient

Effect of Local Environment



Local Bubble:

- A hole in the interstellar gas is formed in a series of SN explosions; some shocks may still exist there…
- May be important for radioactive CR species, but $D_{xx}(\mathrm{local}) \neq D_{xx}(\mathrm{average})$?

ICRC 2003 Tsukuba, Japan

Radioactive Secondaries: Effect of the LB

Two-zones diffusion model includes the "local hole".

The effect on radioactive secondaries:

- ^{10}Be (2.17 Myr)
- ^{36}Cl (0.443 Myr)

Data "prefer" $R_{hole}>0$:
B/C, ^{10}Be/^{9}Be, ^{36}Cl/Cl

^{26}Al (1.31 Myr)
^{26}Al/^{27}Al – difficulty:
Errors in CS or astrophysical data

Stable and Radioactive Nuclei in a Diffusion Model

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(2) Service d'Astrophysique, SAp CEA-Saclay, 91191 Gif-sur-Yvette, France
(3) LAPTH and Université de Savoie, 74941 Annecy-le-Vieux, France

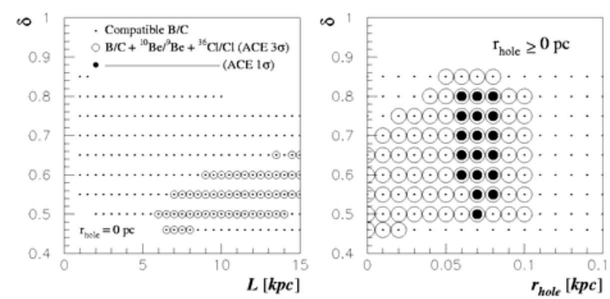

Fig. 2. Representation of the models compatible with B/C plus both ^{10}Be/^{9}Be and ^{36}Cl/Cl ACE 3-σ (open circles) and 1-σ (filled circles) [7]. Left panel displays homogeneous models ($r_{\rm hole}=0$) in the plane $L-\delta$. Right panel displays inhomogeneous models ($r_{\rm hole}\geq 0$) in the plane $r_{\rm hole}-\delta$.

Anisotropy problem ?

Radioactive Secondaries: Effect of the LB

Calculation of Elemental and Isotopic Abundance of Cosmic Rays Using Markov Stochastic Theory: The Effect of Local Superbubble

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(1) Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901, USA
(2) Department of Physics, University of New Hampshire, Durham, NH 03824, USA

Weighted slab calculations:

Local Bubble affects radioactive secondaries

^{26}Al/^{27}Al

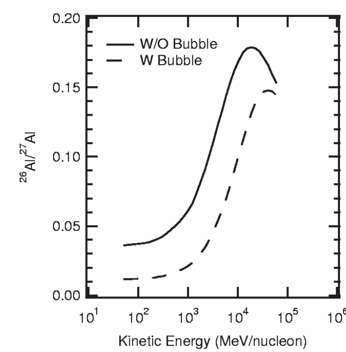

Fig. 4. $^{26}Al/^{27}Al$ ratio for diffusion model without a break in the diffusion coefficient, dv/dz=0kms^{-1}kpc^{-1}, z_h = 3kpc with and without the existance of the local bubble.

Stable Secondaries: ^{3}He, LiBeB

Study of propagation of light secondaries using GALPROP model.

Problem:

Reacceleration model gives too few antiprotons in CR

Test:

"Standard" reacceleration model vs. reacceleration model with LB component

He/Si=100 (GCRS)
vs. 220 (LBS)

28th International Cosmic Ray Conference — 1917

Propagation of Light Elements in the Galaxy

Igor V. Moskalenko,[1,2] Andrew W. Strong,[3] Stepan G. Mashnik,[4] Frank C. Jones[1]
(1) NASA/Goddard Space Flight Center, Code 661, Greenbelt, MD 20771, USA
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(3) MPI für extraterrestrische Physik, Postfach 1312, 85741 Garching, Germany
(4) Los Alamos National Laboratory, Los Alamos, NM 87545, USA

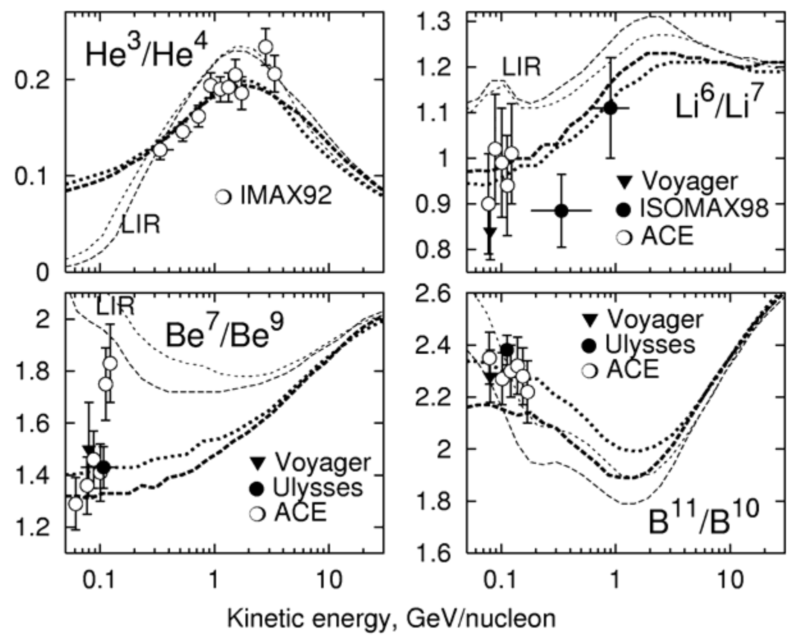

Fig. 3. Isotopic ratios as calculated in two propagation models. Lines are coded as in Fig. 2. Data: IMAX92 [13], ISOMAX98 [5] (with statistical errors only), Voyager [7], Ulysses [1], ACE [3].

Deuterium in CR

Simplified models:
- Leaky-Box
- Convection
- Reacceleration

The uncertainties:
- Cross sections
- Modulation for He & d

The Flux of Cosmic-ray Deuterons in Simplified Propagation Models

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(2) Institute for Terrestrial Magnetism, IZMIRAN, Troitsk, Moscow Region 142092, Russia

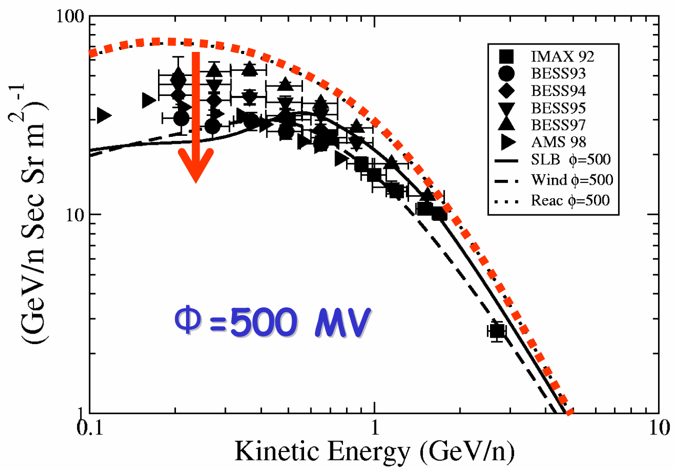
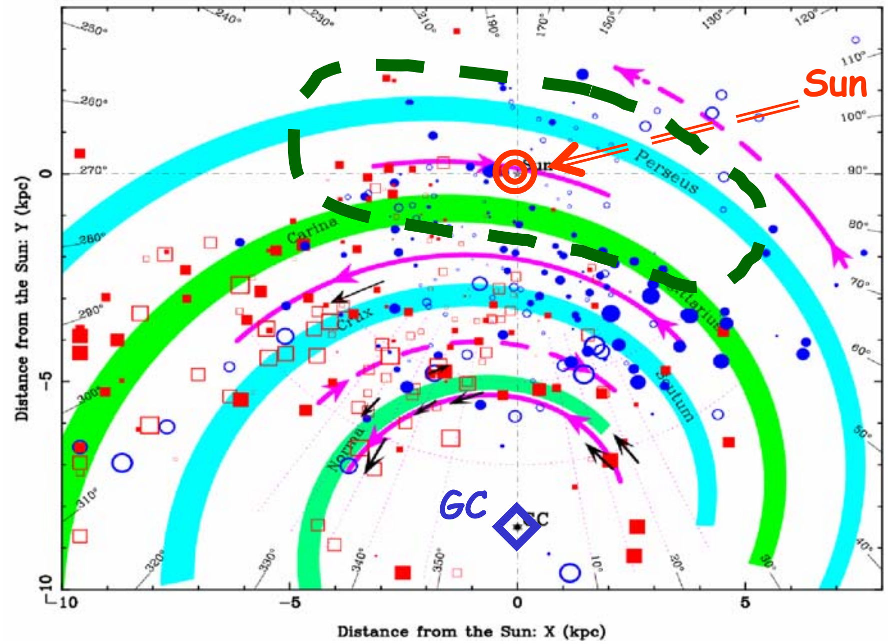


Fig. 1. Comparison of observed (IMAX [3], BESS [18,19], AMS [10]) and calculated deuteron spectrum.

Effect of Local Environment

Regular Galactic magnetic field may establish preferential directions of CR propagation



Collecting Regions

28th International Cosmic Ray Conference — 1977

The size of collecting regions in the galactic disk for proton, Beryllium, Carbon and Iron cosmic rays

Antonio Codino,[1] and Francois Plouin[2]

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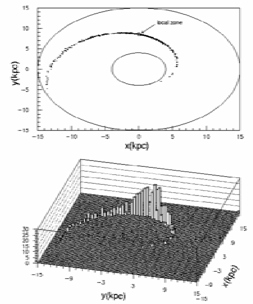

Fig. 2. Iron source distribution in the galactic disk with constant energy of 1 GeV/u feeding the local galactic zone. Sources are predominantly located around the principal field line.

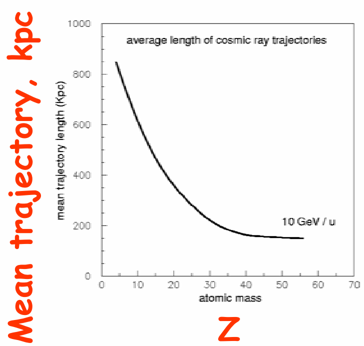

Fig. 3. Mean trajectory length of cosmic rays reaching the solar cavity versus atomic mass at the energy of 10 GeV/u.

Regular magnetic field in the Galaxy affects the diffusion:

The importance of sources depends on their position relatively to the magnetic field line.

Mean trajectory length for CR is a function of Z: different grammage for different species (compare with leaky-box)

Production Cross Sections of LiBeB

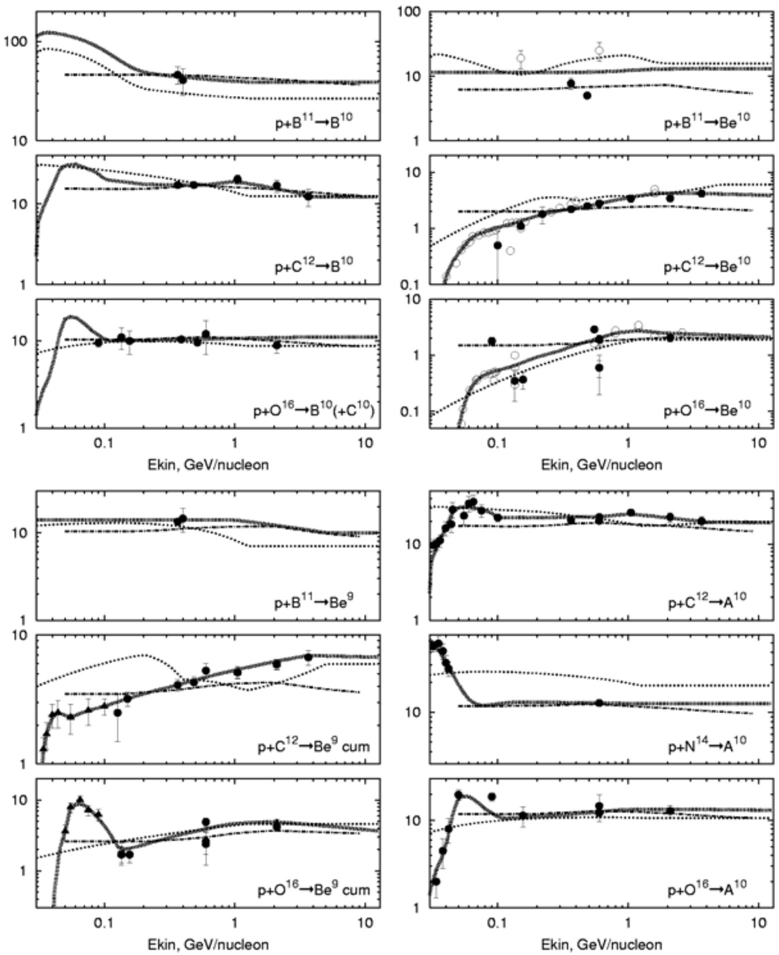

Fig. 2. The production cross sections (mbarn) of B^{10}, $Be^{9,10}$, and isobaric cross section A^{10}=C^{10}+B^{10}+Be^{10}. Lines and data symbols are coded as in Fig. 1.

Evaluation of Production Cross Sections of Li, Be, B in CR

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(3) Los Alamos National Laboratory, Los Alamos, NM 87545, USA

Semi-empirical systematics are not always correct.

Results obtained by different groups are <u>often inconsistent</u> and <u>hard to test</u>.

Very limited number of nuclear measurements:

Evaluating the cross section is very laborious and can't be done without modern nuclear codes.

Use LANL nuclear database and modern computer codes.

Antimatter: Secondary Antiprotons in CR

28th International Cosmic Ray Conference — 1921

Antiprotons in CR: What Do They Tell Us?

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(2) JCA/University of Maryland, Baltimore County, Baltimore, MD 21250, USA
(3) MPI für extraterrestrische Physik, Postfach 1312, 85741 Garching, Germany
(4) Los Alamos National Laboratory, Los Alamos, NM 87545, USA

Uncertainties in the models:

- Propagation models and parameters
  - Gas distribution in the Galaxy
  - Ambient spectrum of CR (solar modulation, GeV excess in γ's !)
  - Current knowledge of CR diffusion
- Production cross sections of isotopes and pbars
  - Typical errors 20%
  - Fitting to B/C ratio may introduce errors in D_{xx}, D_{pp}
- Heliospheric modulation
  - Depends on rigidity
  - Similar for all nuclei A/Z~ +2
  - Different for protons A/Z=+1 and pbars A/Z=-1
- Systematic errors of measurements
  - Difficult to account for

OR Astrophysical Reasons:

- Change in propagation mode at LE
  - E.g., propagation of LE particles aligned to magnetic field lines
- Local environment (e.g. Local Bubble)
  - Fresh "unprocessed" nuclei component at LE
- Sources of LE protons (<20 GeV)
  - Required by diffuse gamma rays and pbars
- Population of hard-nucleon-spectrum sources with matter nearby
  - Required by diffuse gamma rays and pbars

Antimatter: Light Secondary Anti-Nuclei in CR

Predictions for CR fluxes of secondary anti- d, t, ^{3,4}He, using the coalescence model for production of the anti-nuclei and leaky-box and diffusion propagation models.

Anti-^{4}He provides the smallest background for DM signal, but…

-The signal (also coalescence) is weak

-Annihilation cs is large @ LE

-Heliospheric modulation

Atmospheric and Galactic Production and Propagation of Light Antimatter Nuclei

Baret B.[1], Duperray R.[1], Boudoul G.[1], Barrau A.[1], Derome L.[1], Maurin D.[2], Protasov K.[1], and Buénerd M.[1]
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4.2. In the Galaxy

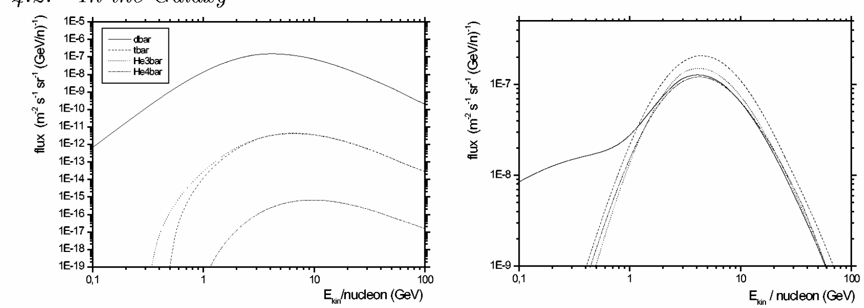

Fig. 2. *Left: Calculated Galactic flux for $\overline{d}$ (solid line), $\overline{t}$ (dashed line), $\overline{^3He}$ (dotted line), and $\overline{^4He}$ (dash-dotted line) using production cross sections from the standard coalescence model and the LBM for the propagation. Similar results are obtained with the microscopic coalescence model. Right: Same as left for $\overline{d}$ (solid line) and with contribution of non-annihilating rescattering of the particles (dashed line), showing the dramatic increase of the flux at low energy expected from this effect. The dot-dashed and dashed lines correspond to the minimum and maximum flux respectively, constrained by the nuclear CR data [6], calculated in the Diffusion Model.*

Effect of IS Turbulence on CR Transport

Dissipation of Hydromagnetic Waves on Energetic Particles: Impact on Interstellar Turbulence and Cosmic Ray Transport

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spectrum and the determination of the mean free path, which is

$$l(p) = l_{Ko}(p)\left[1 - 2\pi^{3/2} V_a p^{1/3} l_{Ko}^{1/2}(p)\left(3C_A B^2 r_g^{1/2}\right)^{-1}\int_p^{p_L} dp_2\, p_2^{2/3}\int_{p_2}^{\infty} \frac{dp_1}{p_1}\Psi(p_1)\right]^{-2}. \qquad (4)$$

Here l_{Ko} is the diffusion mean free path calculated for a Kolmogorov spectrum without regard of wave damping, and $p_L = p_{res}(k_L)$. The second term in brackets describes the modification of the mean free path due to the damping of short waves.

B. Iroshnikov-Kraichnan cascade. The simplified equation for waves reads simular to eq. (3) but with the different l.h.s.: $\frac{\partial}{\partial k}\left(C_M k^3 (\rho V_a)^{-1} W^2(k)\right)$, where approximately $C_M = 1$. At $\Gamma_{cr} = 0$, this gives the spectrum $W(k) \propto k^{-3/2}$ first found in [4,6]. Using the same procedure as in the case A, one can obtain:

$$l(p) = l_{Kr}(p)\left[1 - \pi V_a p^{1/2} l_{Kr}(p)\left(2C_M B^2 r_g\right)^{-1}\int_p^{p_L} dp_2\, p_2^{1/2}\int_{p_2}^{\infty} \frac{dp_1}{p_1}\Psi(p_1)\right]^{-1}. \qquad (5)$$

Here l_{Kr} is the diffusion mean free path calculated for a power law Kraichnan spectrum without regard of wave damping on CR.

GALPROP: New Developments in CR Propagation Code

I.V. Moskalenko,[1,2] F.C. Jones,[1] S.G. Mashnik,[3] V.S. Ptuskin,[4,5] A.W. Strong[6]
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(4) IZMIRAN, Russian Academy of Sci., Troitsk, Moscow Region 142190, Russia
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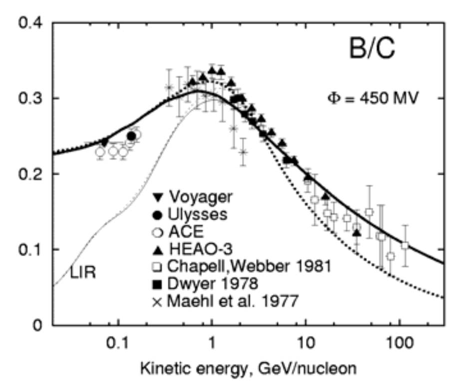


Fig. 1. B/C ratio. Calculations: ••• – Kraichnan cascade, solid line – Kolmogorov cascade. Thick lines – modulated, thin lines – interstellar (LIR). Data: for references see [7].

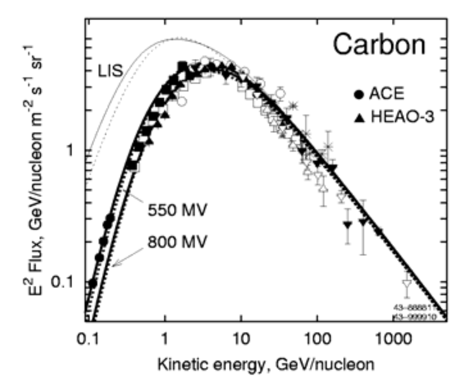
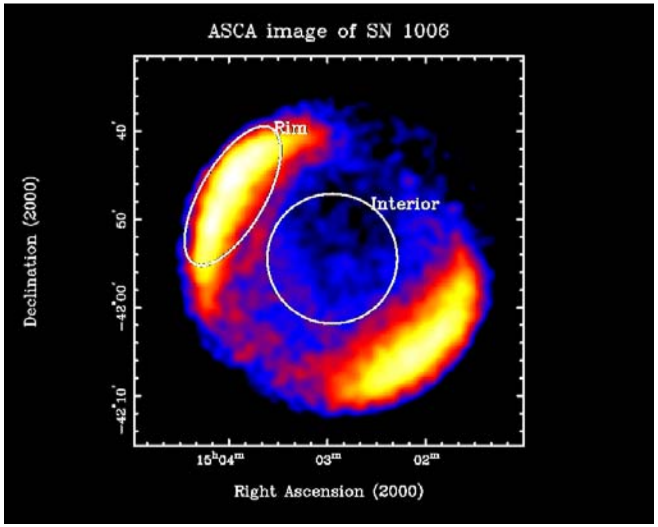


Fig. 2. Spectrum of carbon. Lines are coded as in Fig. 1. Thick lines – modulated ($\Phi = 550$, 800 MV), thin lines – interstellar (LIS). Data: for references see [7].

Effect of Local Sources

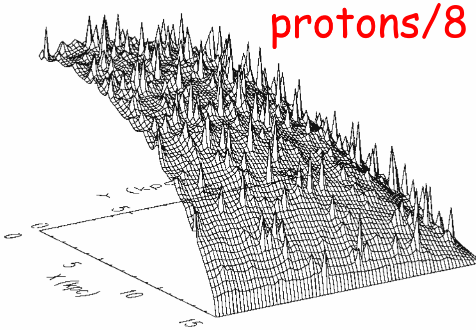


SNR are believed to be the sources of CR because of strong shocks waves and suitable energetics

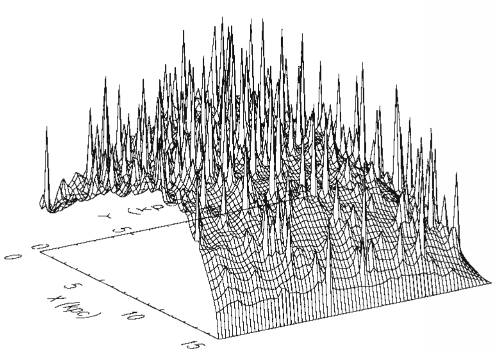
<u>Modeling stochastic SNR events:</u>

Protons – relatively small fluctuations

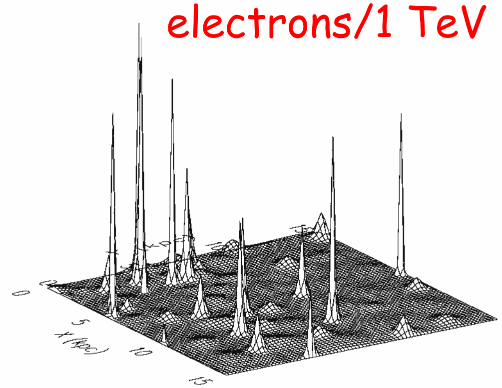
protons/8 GeV



electrons/16 GeV



electrons/1 TeV



Electrons – large fluctuations, increase with energy

CR Fluctuations

Fluctuations of 1-1000 TeV protons and effect of close SNRs on CR anisotropy in reacceleration model and plain diffusion.

SNRs included: SN 185, RX J1713-3946, S 147, Cygnus Loop, Vela, G65.3+5.7, HB21

Excluded: RX J0852-4622 too young, inclusion will give 100 times larger anisotropy.

<u>Reacceleration model with close SNRs is better.</u>

28th International Cosmic Ray Conference — 1933

On Fluctuations of Cosmic Rays in the Galaxy with Random Supernova Outbursts

V.S. Ptuskin,[1,2] F.C. Jones,[3] E.S. Seo,[2] and R. Sina[2]
(1) IZMIRAN, Troitsk, Moscow region 142190, Russia
(2) IPST, University of Maryland, College Park, MD 20742, USA
(3) NASA/Goddard Space Flight Center, Greenbelt, MD 20771, USA

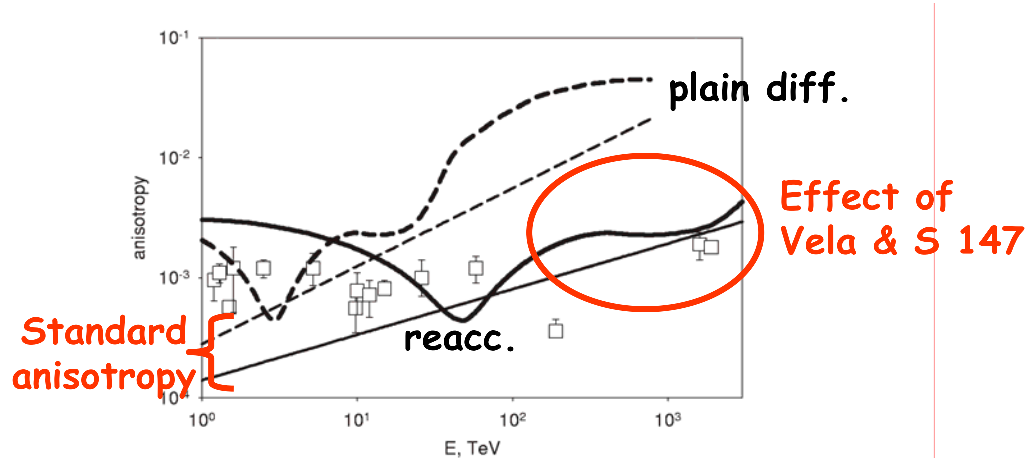


Fig. 1. The CR anisotropy produced by local supernovae (thick curves) and the expected fluctuation anisotropy (thin straight lines) in the reacceleration (solid curves) and the plain diffusion (dashed curves) models. The data on CR anisotropy are taken from [1].

TeV Electrons

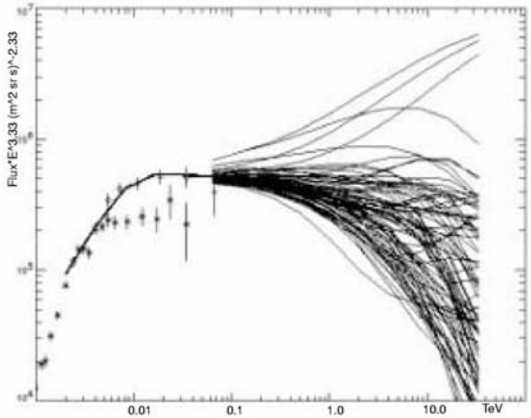


Fig. 1. High energy electron spectra observed in a numerical model of the Galaxy at a ring distant 8kpc from the Galactic center - described in text.

28th International Cosmic Ray Conference —— 1989

Stochastic Effects on the Electron Spectrum above TeV Energies

Simon Swordy
Enrico Fermi Institute, University of Chicago, Chicago, IL 60637, USA

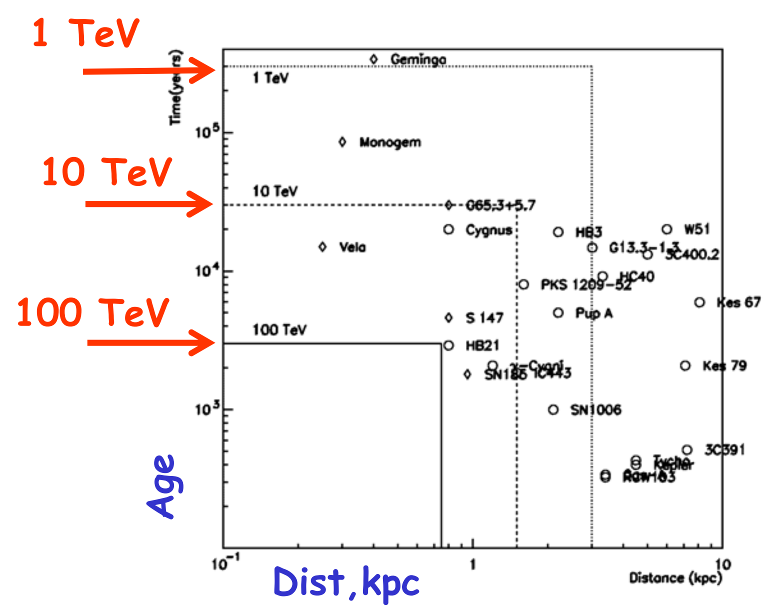


Fig. 2. Compilation of nearby shell-type and plerion SNR distances and ages. Line boxes represent limiting energies for electrons to reach Earth - see text.

"GZK effect" for electrons:

Sharp cutoff in the primary electron spectrum above 100 TeV (30 TeV ?).

VHE electron measurements is a direct test of SNR origin of CR, but also a test of our local environment

Structure in the VHE Electron Spectrum

28th International Cosmic Ray Conference — 1993

The Origin of High Energy Cosmic-Ray Electrons and Nearby Supernova Remnants

Kenji Yoshida,[1] Tadashi Kobayashi,[2] Yoshiko Komori,[3] and Jun Nishimura[4]
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(3) Kanagawa Prefectural College, Yokohama 241-0815, Japan
(4) The Institute of Space and Astronautical Science, Sagamihara 229-8510, Japan

Table 1. List of nearby SNRs [5].

SNR	R(kpc)	T(yr)
SN185	0.95	1.8×10^3
S147	0.80	4.6×10^3
HB 21	0.80	1.9×10^4
G65.3+5.7	0.80	2.0×10^4
Cygnus Loop	0.44	2.0×10^4
Vela	0.30	1.1×10^4
Monogem	0.30	8.6×10^4
Loop1	0.17	2.0×10^5
Geminga	0.4	3.4×10^5

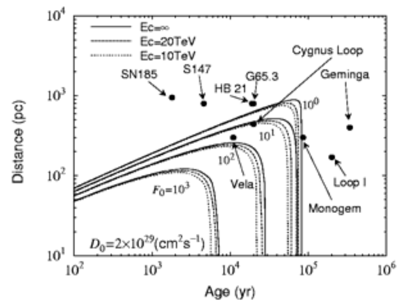

Fig. 1. Contours of the electron flux E^3J at 3TeV between T and R.

Figure 2 shows the calculated energy spectra of electrons without a cut-off and with a cut-off of E_c = 20 TeV in the injected electron spectrum from the remnant, assuming the promptly release after the explosion. We can find that these spectra are similar with each other, in spite of the cut-off energies.

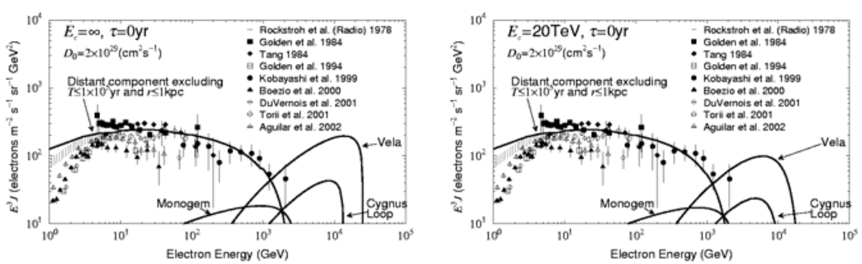

Fig. 2. Calculated Spectra without a cut-off (left) and with a cut-off of E_c = 20TeV (right) in the promptly release of electrons after the explosion ($\tau = 0$), comparing with presently available data (references in [5]).

Some nearby SNRs should exhibit unique identifiable features in the electron spectrum in the range 1-10 TeV.

The most promising sources are Vela, Cygnus Loop, and Monogem.

Estimates of IC gamma-ray flux from these sources would be interesting

Models: Exponential Galaxy Model

Cosmic-ray Propagation and the Energy Spectra Observed on Earth

Makoto Hareyama, M. Nakazawa, C. Saito, R. Suzuki, and T. Shibata
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$$D(\boldsymbol{r}) = D_0 \exp[+(r/r_D + |z|/z_D)], \qquad (1a)$$

$$n(\boldsymbol{r}) = n_0 \exp[-(r/r_n + |z|/z_n)], \qquad (1b)$$

$$Q(\boldsymbol{r}) = Q_0 \exp[-(r/r_Q + |z|/z_Q)], \qquad (1c)$$

where D_0, n_0 and Q_0 correspond to diffusion coefficient, gas density and the source density of CR at the Galactic center $(0, 0)$, respectively.

$$[\nabla \cdot D(\boldsymbol{r})\nabla - n(\boldsymbol{r})v\sigma_p]\,\Phi_p(\boldsymbol{r};\boldsymbol{r}_0) = -\delta(\boldsymbol{r}-\boldsymbol{r}_0)/2\pi r_0, \qquad (4)$$

$$\text{with} \quad \Phi_p(r, \pm\infty; r_0, z_0) = 0, \qquad \Phi_p(\infty, z; r_0, z_0) = 0, \qquad (5)$$

where v is the particle velocity, and σ_p the inelastic collision cross section with nuclei of the interstellar gas.

$$\left[\nabla \cdot D(\boldsymbol{r})\nabla - n(\boldsymbol{r})v\sigma_\tau - \frac{1}{\tau_0 \Gamma}\right]\Phi_\tau(\boldsymbol{r};\boldsymbol{r}_0) = -\frac{\delta(\boldsymbol{r}-\boldsymbol{r}_0)}{2\pi r_0}, \qquad (1)$$

where σ_τ and τ_0 are the inelastic cross section and the life time of the unstable nucleus, respectively, and Γ its Lorentz factor. All variables used in the present

$$N_{p\to\tau}(\boldsymbol{r}) = \iint d\boldsymbol{r}_0 [N_p(\boldsymbol{r}_0) n(\boldsymbol{r}_0) v\sigma_{p\to\tau}]\,\Phi_\tau(\boldsymbol{r};\boldsymbol{r}_0), \qquad (3)$$

where $\sigma_{p\to\tau}$ is the production cross section of the unstable nucleus due to the interaction of the primary nucleus p with the interstellar gas. Here we omit the rigidity term R_0 $(= R)$ for the simplicity.

Primary spectra:

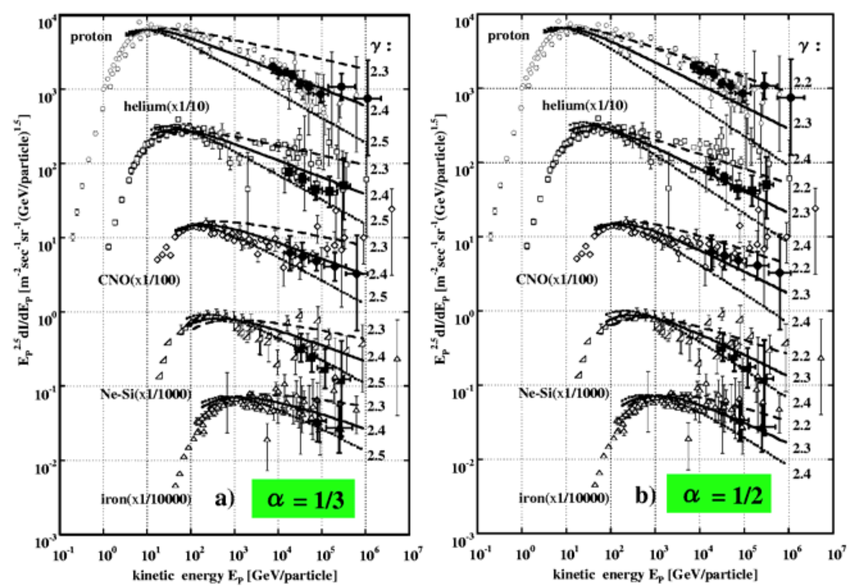


Fig. 1. Energy spectra for individual elements (filled symbols: RUNJOB data[9]).

Models: Exponential Galaxy Model

28th International Cosmic Ray Conference — 1945

Abundance Ratio of Secondary to Primary Expected from the Boundaryless Galaxy Model

Makoto Hareyama, M. Nakazawa, C. Saito, R. Suzuki, and T. Shibata
Department of Physics, Aoyama-Gakuin University, Sagamihara, Kanagawa 229-8558, Japan

28th International Cosmic Ray Conference — 1949

Propagation of Radioactive Secondaries in Cosmic Rays

T. Shibata, Makoto Hareyama, Ito K., M. Nakazawa, C. Saito, and R. Suzuki
Department of Physics, Aoyama-Gakuin University, Sagamihara, Kanagawa 229-8558, Japan

LiBeB/CNO

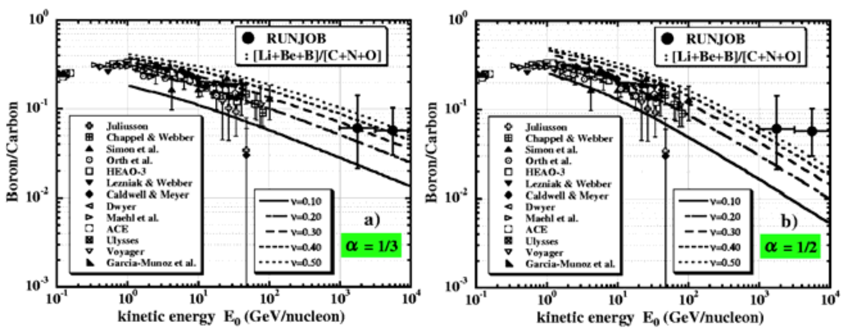


Fig. 1. Boron-carbon ratio with two curve-fittings, a) $\alpha = 1/3$ and b) $\alpha = 1/2$.

$^{10}Be/^{9}Be$

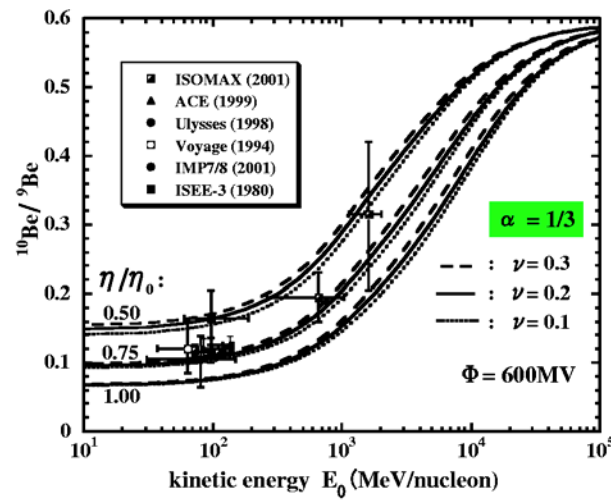


Fig. 1. Abundance ratio of ^{10}Be to ^{9}Be.

Models: Development of a New Propagation Code

Try to solve a plain diffusion equation by the method of series expansion:
Bessel functions in R, and trigonometrical functions in ϕ

28th International Cosmic Ray Conference — 1985

A New Propagation Code For Cosmic Ray Nucleons

Ingo Büsching,[1] Andreas Kopp,[2,1] Martin Pohl[1] and Reinhard Schlickeiser[1]
(1) Institut für Weltraum- und Astrophysik, Ruhr-Universität Bochum, Bochum, Germany
(2) MPI für Aeronomie, Katlenburg-Lindau, Germany

Reduce the 3D equation to the time dependent 1-D propagation:

$$\frac{\partial N}{\partial t} = a\frac{\partial^2 N}{\partial z^2} + b\frac{\partial N}{\partial z} + cN + d$$

28th International Cosmic Ray Conference — 1981

First Results Of A New Cosmic Ray Propagation Code

Ingo Büsching,[1] Andreas Kopp,[2,1] Martin Pohl[1] and Reinhard Schlickeiser[1]
(1) Institut für Weltraum- und Astrophysik, Ruhr-Universität Bochum, Germany
(2) MPI für Aeronomie, Katlenburg-Lindau, Germany

But, no distinctive results yet

Models: GALPROP: Web-Based Interface

Simple forms on the Web to obtain (tables & plots):

- Spectra of any isotope or element Z≤28 or any combination (can choose units and scale)
- Arbitrary isotopic ratios vs. energy
- Isotopic distributions for any Z
- Elemental or isotopic abundances @ arbitrary energy
- Antiprotons
- Electrons & positrons

Modulated & interstellar – first only for the solar vicinity and later for the whole Galaxy.

28th International Cosmic Ray Conference — 1925

GALPROP: New Developments in CR Propagation Code

I.V. Moskalenko,[1,2] F.C. Jones,[1] S.G. Mashnik,[3] V.S. Ptuskin,[4,5] A.W. Strong[6]
(1) NASA/Goddard Space Flight Center, Code 661, Greenbelt, MD 20771, USA
(2) JCA/University of Maryland, Baltimore County, Baltimore, MD 21250, USA
(3) Los Alamos National Laboratory, Los Alamos, NM 87545, USA
(4) IZMIRAN, Russian Academy of Sci., Troitsk, Moscow Region 142190, Russia
(5) IPST/University of Maryland, College Park, MD 20742, USA
(6) MPI für extraterrestrische Physik, Postfach 1312, 85741 Garching, Germany

http://lhea.gsfc.nasa.gov/~imos/galprop.html

Not ready yet, but check back this fall !

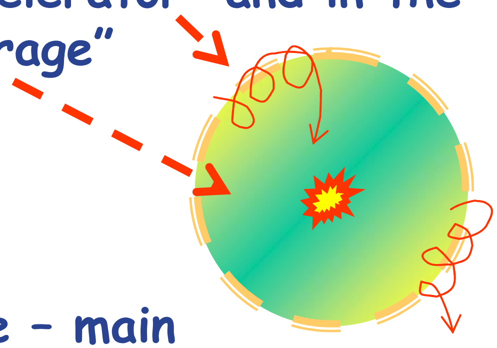
Shocks:

- SNRs
- Galactic wind
- Galaxy clusters

OG1.4: Acceleration of Electrons & Protons in SNR

Young SNR:

- Proton index -2
- Two populations of electrons: in the "accelerator" and in the "storage"



Storage – main contributor to IC.

Needs a strong & turbulent magnetic field to confine relativistic electrons

Electron And Proton Acceleration In SNR

Paolo Lipari[1] and Giovanni Morlino,[1]
INFN sez. Roma I, & Dipartimento di Fisica, Università di Roma "La Sapienza"

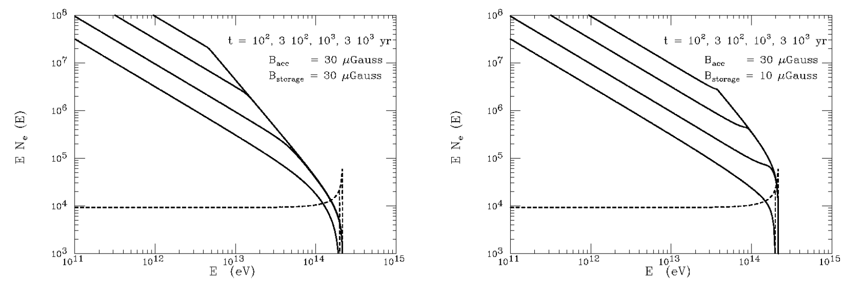


Fig. 1. Relativistic electron population in the "accelerator" (dashed lines) and "storage" volumes (solid lines) of a SNR of age t(years) $= 10^2$, 3×10^2, 10^3 and 3×10^3 The calculation is performed assuming a constant injection rate. In the left (right) panel the magnetic field is chosen as $B = 30$ μGauss in the acceleration region, and 30 (10) μGauss in the storage region.

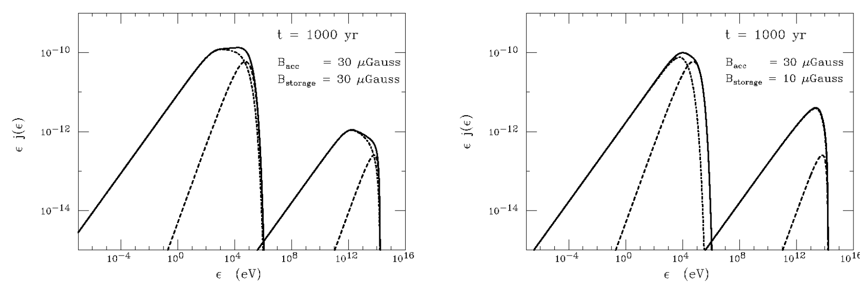


Fig. 2. Emissivity for synchrotron radiation and Inverse Compton scattering on the 2.7K radiation averaged over the entire volume of a SNR of age $t = 10^3$. The calculation is performed assuming a constant injection rate. In the left (right) panel the magnetic field is assumed to be $B = 30$ μGauss in the acceleration region, and 30 (10) μGauss in the "storage region" at the center of the shell. The contributions of electrons in the acceleration (storage) region is shown with dashed (dot–dashed) lines.

Shocks in the Galactic wind: E>10^{15} eV

Cosmic Ray Acceleration by Spiral Shocks in the Galactic Wind

H.J. Völk[1] and V.N. Zirakashvili[2]
(1) Max-Planck-Institut für Kernphysik, D-69029 Heidelberg,Germany
(2) Institute for Terrestrial Magnetism, Ionosphere and Radiowave Propagation, 142190 Troitsk, Moscow Region, Russia

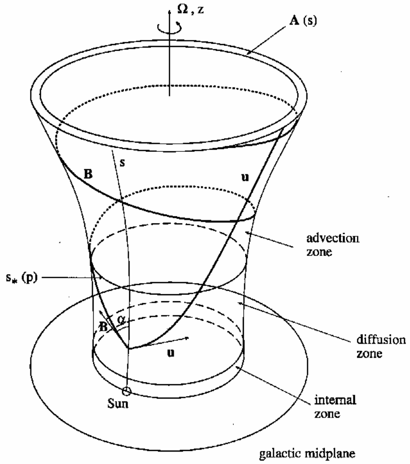


Fig. 1. The structure of the galactic wind flow for a flux tube originating at the position of the Sun. The boundary between the diffusion and advection zones is moving up with energy of the cosmic-ray particle.

Acceleration by shocks at 50-100 kpc from the plane

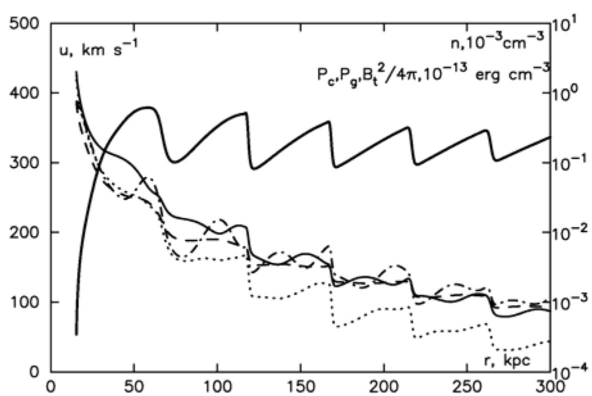
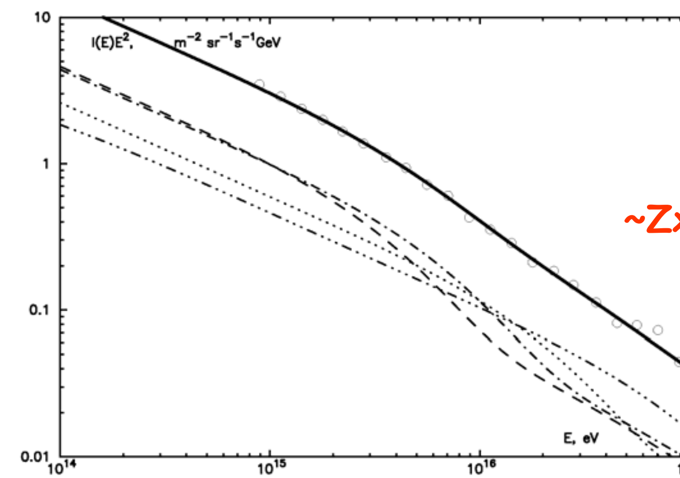


Fig. 1. Radial dependencies, taken at one azimuth angle. The values of the radial gas velocity u (thick solid), the cosmic ray (thin solid) and gas (dotted) pressures P_c and P_g, respectively, the gas number density n (dashed), and the total magnetic field tension $B_t^2/4\pi$ (dash-dotted) are given. Forward SIR shocks form a saw-tooth velocity profile at large distances in the Galactic Wind flow.



~Z×10^{17} eV

Fig. 2. Calculated differential spectral flux $I(E)$ of the CR protons (dashed), helium nuclei (dash-dotted), carbon (dotted), iron (dash-dot-dotted), all-particle (solid) in the Galaxy for the exponential cut-off, and the all-particle spectral flux observed [8] by the KASCADE collaboration (empty circles). The chemical composition has been fixed at $E = 9 \cdot 10^{14}$ eV from Fig.5 of [8].

Low efficiency, but Myrs of time…

Particle Acceleration in the Clusters of Galaxies

28th International Cosmic Ray Conference — 2051

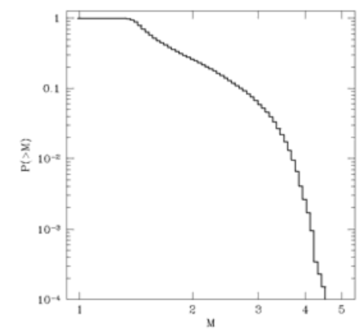
Shock Acceleration and gamma radiation in Clusters of Galaxies

Pasquale Blasi,[1] and Stefano Gabici[2]
(1) INAF, Osservatorio Astrofisico di Arcetri, Florence, Italy
(2) Dipartimento di Astronomia, Università di Firenze, Florence, Italy

Shocks associated with mergers of clusters

GLAST will be able to detect ~50 clusters

Only 10% of total diffuse emission (10 times lower than Loeb-Waxman estimate for strong shocks)



Mergers: Mach number <2

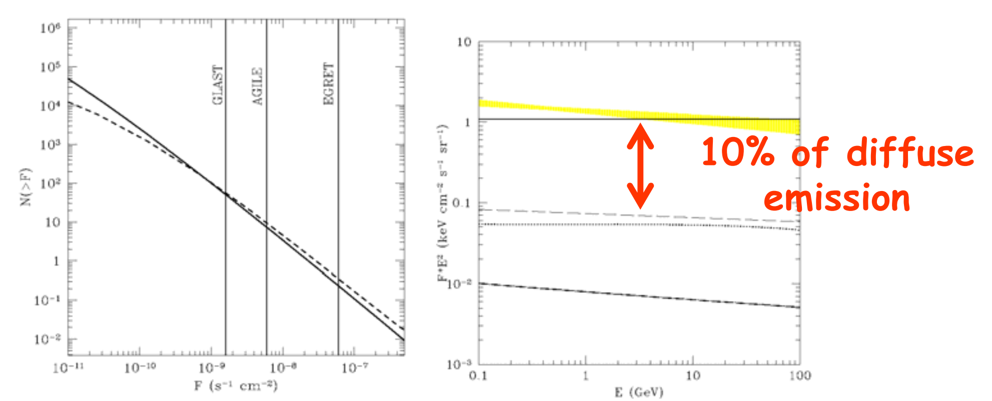


Fig. 2. *a) LogN – LogS* for mergers (dashed line) and for accretion (solid line). *b)* The diffuse gamma ray background from clusters of galaxies. See text for more information.

Electrons in the Galaxy Clusters

N-body + hydrodynamic simulations:

- Shock acceleration due to mergers
- Scattering on Alfven waves (necessary !)

Wave power spectrum is modified presumably due to particle acceleration

28th International Cosmic Ray Conference — 2059

Particle Acceleration in Clusters of Galaxies

Motokazu Takizawa,[1] Tsuguya Naito,[2] Hiroshi Ohno,[3], and Shinpei Shibata[1]
(1) Department of Physics, Yamagata University, Yamagata 990-8560, Japan
(2) Yamanashi Gakuin University, Koufu, Yamanashi, 400-8575, Japan
(3) Yamagata Junior College, Yamagata 990-2316, Japan

Radio emission from Coma cluster

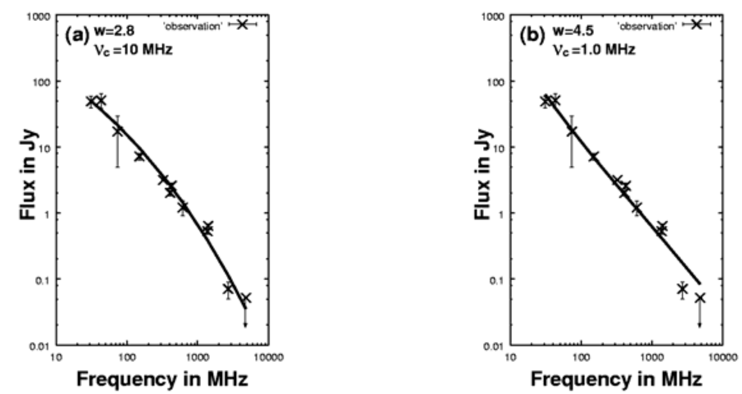


Fig. 2. Two examples reproducing the observed radio spectrum. (a) $w = 2.8$; (b) $w = 4.5$; The observed intensity is drawn from Deiss et al.[2].

Blasi: Alfven waves may be not very effective as energy goes to protons

Main reasons of the steepening:

- Diffusion (2 papers, one idea – to increase the diffusion perpendicular to the plane)
- Source properties

"Many Knees" - Diffusion

$$\frac{d\Phi_Z}{dE}(E) = \Phi_Z^0 E^{\gamma_Z} \left[1 + \left(\frac{E}{E_Z}\right)^{\epsilon_c}\right]^{\frac{-\Delta\gamma}{\epsilon_c}} .$$

e dependence $E_Z = ZE_p$ where E_p is the

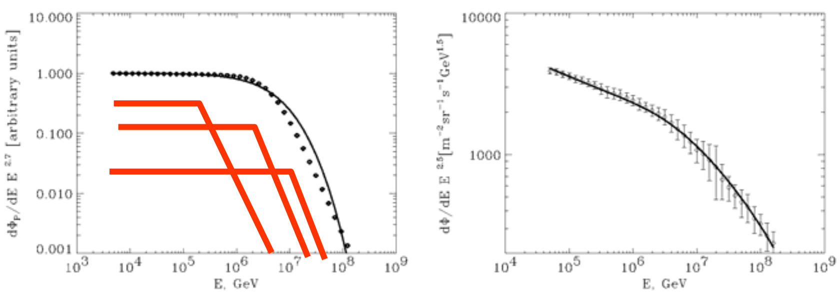


Fig. 1. Left: proton spectrum (◇ – poly-gonato model, solid curve – diffusion model with the radial distribution of sources following the law $Q(r) \sim \delta(r - 4\ \mathrm{kpc})$). Right: ◇ – average all-particle spectrum [2] and diffusion model for elements from H to U according to [2].

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The Knee in the Energy Spectrum of Cosmic Rays in the Framework of the Poly-Gonato and Diffusion Models

J.R. Hörandel[1], N.N. Kalmykov[2], and A.I. Pavlov[3,4]
(1) University of Karlsruhe, PO Box 3640, 76021 Karlsruhe, Germany
(2) Skobeltsyn Institute, Moscow State University, Leninskie Gory 1, 119992, Moscow, Russia
(3) University of Mannheim, D7-27, 68131 Mannheim, Germany
(4) Institute of Astronomy RAS, 48 Pyatnitskaya str., 119017, Moscow, Russia

- Phenomenological model "poly-gonato" reproduces the CR spectrum around the knee.
- Agrees well with simplified diffusion model which includes Hall diffusion.

Problems:

- All sources @ 4 kpc - to obtain the sharp knee
- No disintegration of nuclei
- Importance of the structure of the regular magnetic field

Conclusion:

the origin of the knee is diffusion

Diffusion Perpendicular to the Plane

- $D_\perp$ is too small
- Consider open magnetic lines $\perp$ to the plane (filaments)

  $D_\perp \sim D_\parallel$

Require the Galactic wind ~500 km/s near the plane (check vs. LE CR)

Advective Diffusion Propagation Model for Galactic Cosmic Rays above 10^{12} eV

Shoichi Ogio and Fumio Kakimoto
Department of Physics, Tokyo Institute of Technology, Meguro, Tokyo, 152-8551, Japan

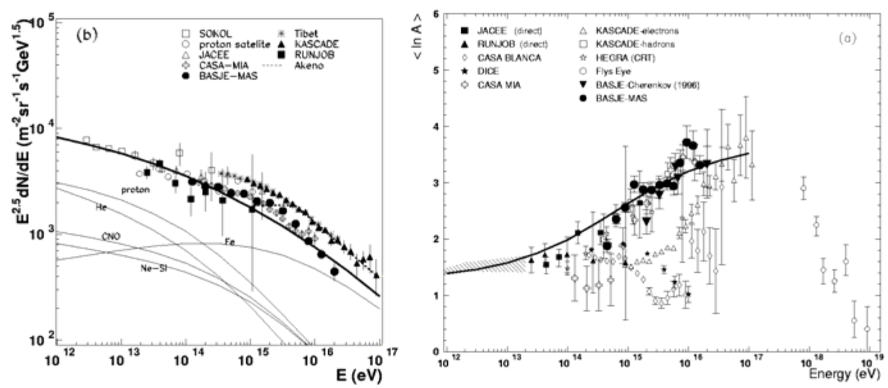


Fig. 2. (a)Calculated all particle spectra with the advective–diffusion model. (b)The averaged mass number, $\langle \ln A \rangle$, calculated with the model. The measured values with various different types of observations are also plotted on this figure. For the references of these measurements, please see the paper by S. Ogio et al.[6].

Young SNRs and Bell-Lucek Mechanism

Young SNRs:

- Bell-Lucek mechanism to increase the turbulent magnetic field ahead of the shock front (Alfven M~1000)
- Bohm diffusion
- Modifications to Sedov-Taylor solution

Acceleration up to
$E \le$ few 10^{17} eV,
steeper spectrum

28th International Cosmic Ray Conference — 299

The Bell-Lucek Mechanism in SNRs and the "Knee" in the Cosmic Ray Spectrum

Luke O'C Drury,[1] Eric van der Swaluw,[1,2] and Olwen Carroll[1,3]
(1) Dublin Institute for Advanced Studies, 5 Merrion Square, Dublin 2, Ireland
(2) FOM-Institute for Plasma Physics Rijnhuizen, P.O. Box 1207, 3430 BE Nieuwegein, The Netherlands
(3) Physics Department, University College Cork, Ireland

the slope is steepened from the canonical value of 4 to

$$4.25 + \frac{3\vartheta}{2}$$

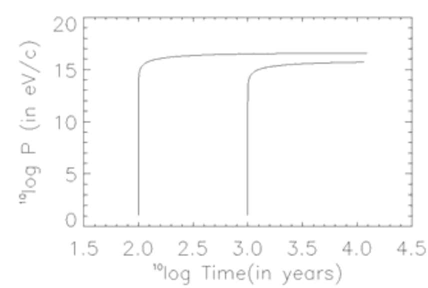


Fig. 1. Example of 2 characteristic curves in the (p, t) plane for a Sedov-Taylor expansion law and a magnetic field which scales with the shock velocity.

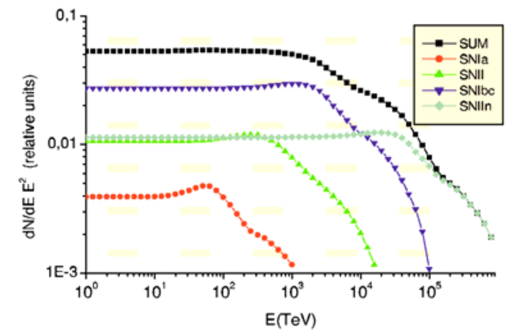
Superposition of Different SNR Types

28th International Cosmic Ray Conference — 307

The Knee in Galactic Cosmic Ray Spectrum and Variety in Supernovae

Lyubov G. Sveshnikova
Skobeltsyn Institute of Nuclear Physics of Moscow State University, 119992, Leninskie Gory, MSU, Moscow, Russsia

SN Ia + SN II + SN Ib/c + SN IIn



Superposition of SNRs of different types:
SN Ia, SN II, SN Ib/c, SN IIn

Different SN rate, power, composition

Knee ~ hypernovae

Predictions for composition

Composition

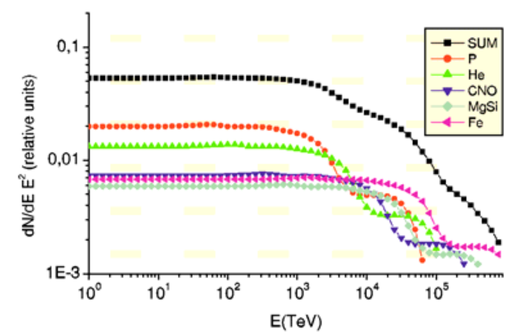


Fig. 2. Spectra of different cosmic ray nuclei.

Historical variations of CR intensity should be essential

Pulsar Origin of the Knee

28th International Cosmic Ray Conference — 303

On the Pulsar Origin of the Knee

Arunava Bhadra
High Energy and Cosmic Ray Research Centre, University of North Bengal, Siliguri 734430 India

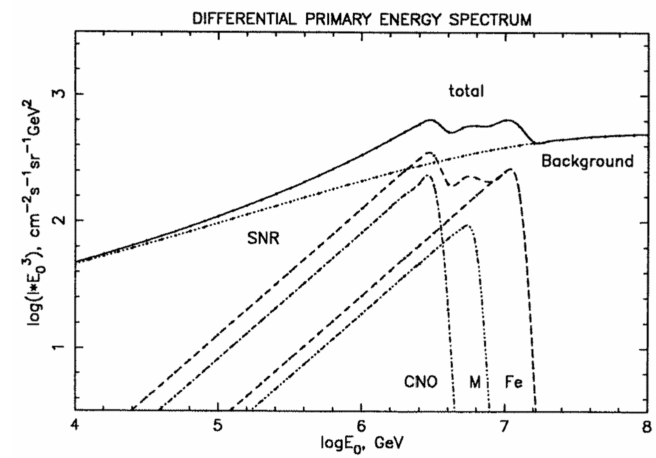
$$E_{max} = 3.4 \times 10^{11} Z B_{12} \Omega^2 \, eV \quad (1)$$

Interestingly for Geminga pulsar ($B_{12} = 1.6, \Omega = 26.29 \; rad \; s^{-1}$), $E_{max} \simeq 3$ PeV for oxygen nuclei as primary (coincidence!) and for Vela Pulsar it is around 5.6 PeV for protons.

J. Phys. G: Nucl. Part. Phys. **23** (1997) 979–989. Printed in the UK

A single source of cosmic rays in the range 10^{15}–10^{16} eV

A D Erlykin† and A W Wolfendale
Department of Physics, University of Durham, Durham, DH1 3LE, UK



Knee structure – a single SNR source, but no gamma rays.

May be pulsar: Geminga or Vela

Conclusions

Thanks to the authors of the reported papers for the education of the rapporteur in the corresponding topics.

Acknowledgments to the LOC for the beautiful organization of the conference.