Mercoledì 13 dicembre 2023 ore 15:00

Seminario

Come le cariche negative trattenute dagli ammassi di galassie causano il moto di recessione dell' universo osservato

Antonio Codino

Università di Perugia e associato scientifico INFN

Just to avoid vagueness, by nearby universe is meant:

1 - Material bodies and radiation in a stretch of 3×10^{26} meters, or 10 Gigaparsec from the Earth.

2 - Global mass of about 10^{56} grams corresponding to some 2×10^{11} galaxies.

3 - Galaxy clusters are redshifted as established by a plethora of data since a century.

For these numerical figures see, for example, J. C. Cavalho, 1996, Int. Jour. Theor. Phys. pages 2507-2509 and N. J. Cornish et al., 2004, Phys. Rev. Lett. 92 :201302-201305.

None of these three parameters are critical in this talk.

Two research books recently published :

The ubiquitous mechanism accelerating cosmic rays at all the energies (2021).

This book demonstrates that the acceleration of cosmic rays in the Galaxy is accomplished by an electrostatic field. The book is a collection of 35 original papers and its elaboration took 20 years.

How electrostatic fields generated by cosmic rays cause the expansion of the nearby universe (2022).

The second book explores in diverse astrophysical areas some consequences of the electrostatic fields acting in galaxies and galaxy clusters. The expansion of the nearby universe is one of this area, the theme of this presentation.

Some elementary questions :

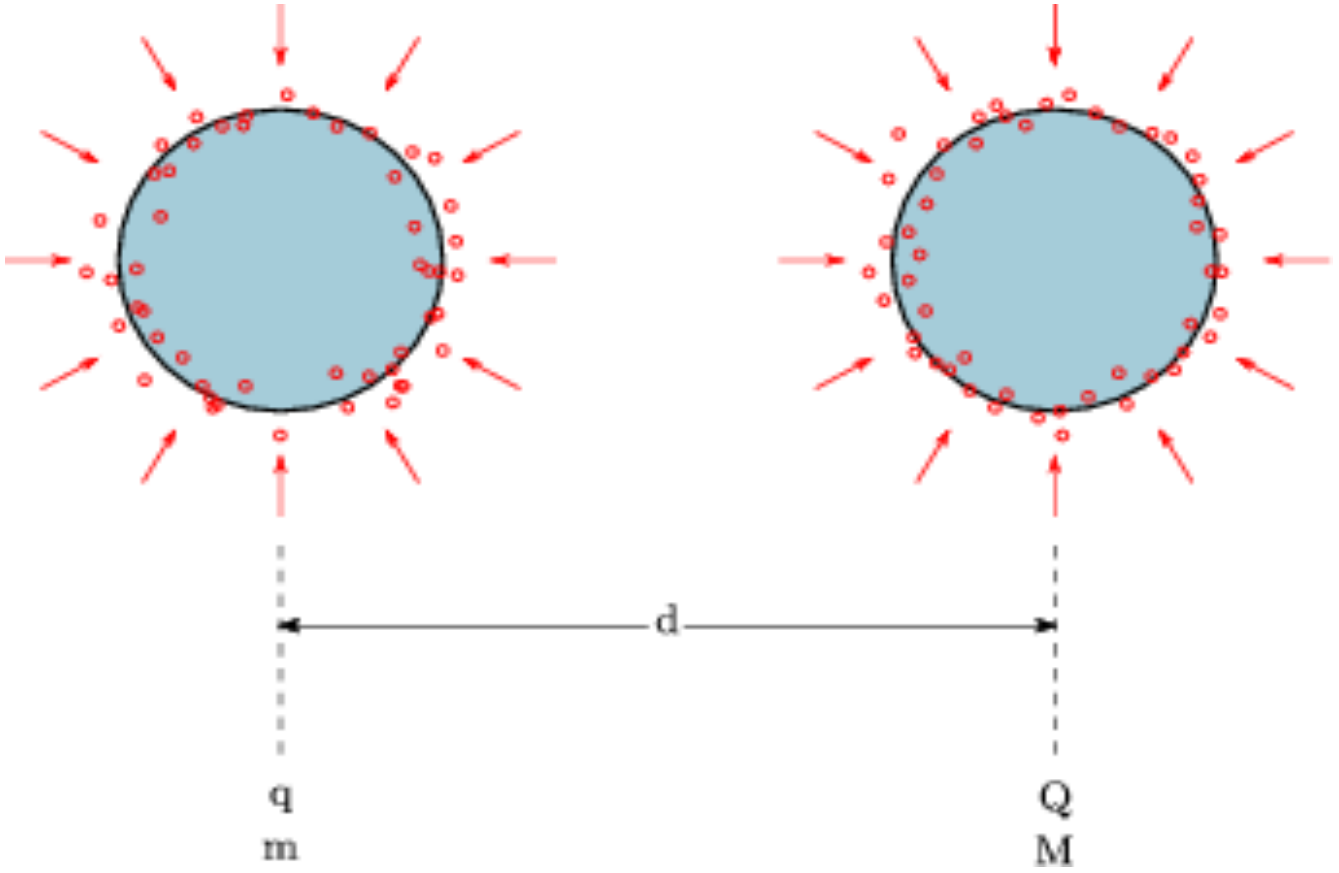
(1) How much electric charge do we need to observe galaxy clusters running away at the dizzying velocities they exhibit ?

(2) And, how cosmic rays are meddled with these incredible velocities ?

The chief reason why cosmic rays come to play the dominant, pivotable role in the expansion of the nearby universe is purely empirical : the charge transported by cosmic rays is highly imbalanced.

Above the energy of about 100 MeV, 98.5 per cent of the charge is positive, transported by cosmic nuclei, and only 1.5 per cent is negative, transported by cosmic-ray electrons.

I raggi cosmici globalmente trasportano carica elettrica positiva (oltre 10 GeV il 98.5 % della carica è positiva e solo l' 1.5 % negativa).



- **The equilibrium between gravitational pull and electrostatic repulsion of equal sign charges**

There is a unique ratio of the electric charges q and Q trapped on two objects of masses m and M preserving the mechanical equilibrium. This turns out simply by equating the gravitational law and Coulomb law :

$$GmM/r^2 = q\,Q\,/(4\,\pi\,\varepsilon_0\,r^2)$$

- **For simplicity, setting q = Q and m = M the balance condition is :**

$$(q/m) = (4\,\pi\,\varepsilon_0\,G)^{1/2} = 8.617508 \times 10^{-11}$$

C/Kg

This is a mere definition, devoid of any subtlety.

For example, the electric charge producing the balance condition for two masses equal to the nominal mass of the Milky Way Galaxy of 3×10^{41} Kg is : 2.585252×10^{31} Coulomb (hereafter C)

- **Invece , il rapporto carica-massa dei raggi cosmici $(q/m)_{cr}$ è incredibilmente elevato. Ad esempio, per i protoni**

$$(q/m)_{cr} = 1.602 \times 10^{19}\ C / 1.6726 \times 10^{-27}\ Kg = 0.9578 \times 10^{8}\ C/Kg.$$

Questo significa che tutte le volte che i raggi cosmici si arrestano, vengono assorbiti o generati oppure fuoriescono da una regione, la carica elettrica dell' ambiente rimane fortemente sbilanciata.

- **In breve, occorre un solo atomo ionizzato su 10^{18} atomi neutri per soddisfare la condizione di bilanciamento tra forza di gravità e forza elettrostatica :**

$$8.617 \times 10^{-11} / 0.9578 \times 10^{8} = 1.1 \times 10^{18}$$

Tutto ciò non è sorprendente come è ben noto.

Questo numero esiguo di atomi è conforme alla nozione comune che in molti sistemi fisici la forza di gravità

Consider now an impressive, fundamental result obtained by studying cosmic rays :

For the first time, it is calculated the electric charge transported by cosmic rays and that stored in the disk of the Milky Way Galaxy at the cosmic-ray sources, Q_w. It is : $Q_{cr} = -Q_w$. A. Codino, 2021, paper 450, ICRC, Berlin, Germany ; and chapter 2 of : *The ubiquitous mechanism accelerating cosmic rays at all the energies.*

This charge turns out to be $Q_{cr} = 1.09 \times 10^{32}$ C, the same order of magnitude of the balancing charge of 2.58×10^{31} just defined (Sic ! Yes !).

The result is obtained by applying the Virial Theorem to the population of cosmic rays (charged particles) disseminated in the Galaxy in the electrostatic potential V(r) generated both by the same cosmic-ray protons and the negative charges (quiescent electrons) at the cosmic-ray sources in the thin Galactic disk.

Mean energy density of the cosmic radiation quite close to 1 eV per cubic centimeter.

(see, for example, A. C. Cunning et al., 2016, ApJ, 831, 18)

(Virial Theorem) $U = -2\ T_{cr}$

U is the mean electrostatic energy of a system of charged particles (cosmic rays).

T_{cr} is the mean kinetic energy of the same system of particles.

E_e electrostatic energy, r_g disk radius = 15 kpc, cosmic-nuclei propagation region R,

$E_e = Q_w^2\ r_g / (16\ \pi\ \varepsilon_0\ R^2)$ in the standard condition $r_g << R$, (for example $R = 10\ r_g$=150 kpc). Then, it results :

$q_g = \pi\ r_g\ R\ [(128/3)\ \varepsilon_0\ T_{cr}]\ ½ = 1.09 \times 10^{32}$ C, valid as order of magnitude.

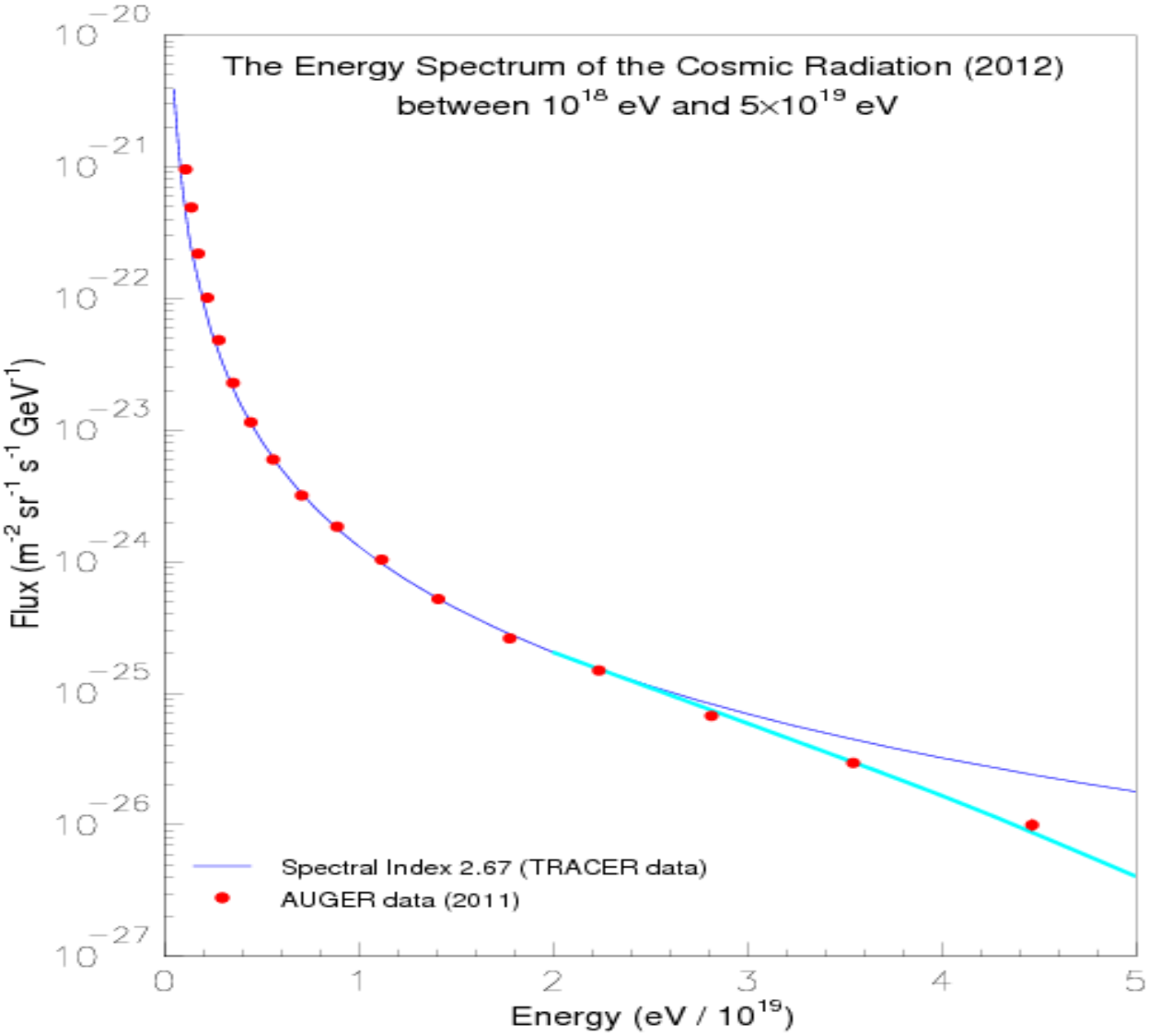
(2) Si consideri ora questa seconda verifica incrociata :

Poiché questa carica necessariamente ruota con il disco galattico alle velocità tipiche di nubi e stelle di 240 Km/s, è inevitabile che generi un campo magnetico. Quanto è l' intensità del campo magnetico generato da questa carica ruotante di 1.09 x 10^{32} C ?

E' un microGauss, 10^{-10} Tesla. Orbene questa è l' intensità del campo magnetico galattico misurata da molti astronomi ottici e radio astronomi nel corso di 70 anni.

(3) Si consideri questa terza sorprendente verifica incrociata :

il campo elettrico generato dalla carica di 1.09 x 10^{32} C nella Galassia accelera i protoni cosmici sino ad energie massime di (2-3)x10^{19} eV. Queste energie sono esattamente quelle osservate nel 2007 dall' esperimento Auger, il più preciso e grande esperimento di raggi cosmici al mondo dislocato in Argentina su un' area di 3000 km^2 e in presa dati da due decenni


The Energy Spectrum of the Cosmic Radiation (2012)
between 10^18 eV and 5×10^19 eV
Flux (m^-2 sr^-1 s^-1 GeV^-1)
Energy (eV / 10^19)
Spectral Index 2.67 (TRACER data)
AUGER data (2011)

In concreto negli anni 2013-2018, prima della pubblicazione dei due libri gemelli 2022-2023, sono intervenuto per avvertire la comunità scientifica dei raggi cosmici di alte energie su questi temi con diversi lavori :

1 - Sulle scale dell' energia degli esperimenti Auger (Argentina) e Telescope Array (Utah, Nord America)

A. Codino, 2017, About the consistency of energy scales etc, arXiV: 1710.06659v1, Astrop-ph.HE, 18 ottobre 2017

2 - Sull' interpretazione della depressione dello spettro dei raggi cosmici a (2-3) x 10^{19} eV. Non sono i protoni extragalattici che generano il GZK ma il campo elettrostatico galattico.

A. Codino, 2013, The absence of GZK depression in the energy spectrum etc., ICRC (2013) Rio de Janeiro, Brasil.

A. Codino, 2017, About the energy interval etc, JAMP, 5, 225-237.

3 La composizione chimica pesante della radiazione cosmica : A. Codino, 2017, The energy spectrum of ultraheavy nuclei etc. JAMP, 5, 1540-1550.

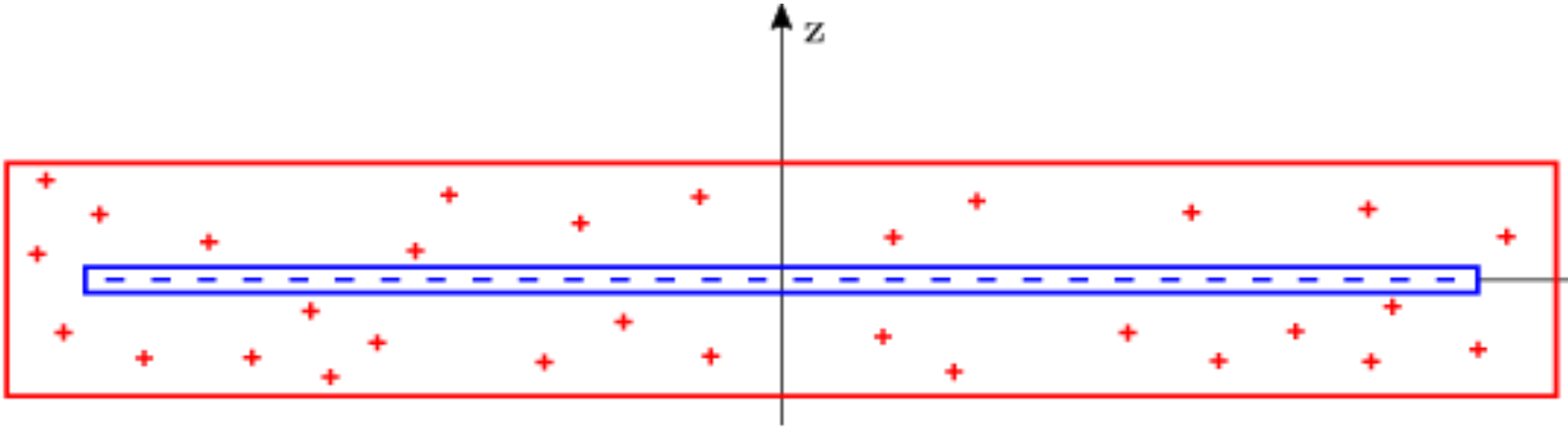
Another essential result, useful in this presentation.

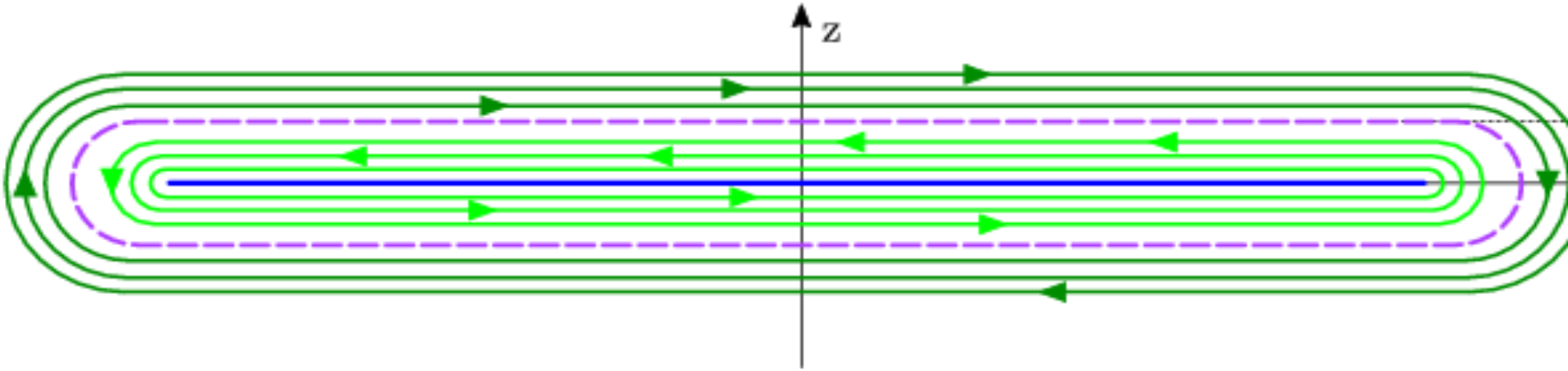
It is derived, debated and consolidated in :

The ubiquitous mechanism accelerating cosmic rays at all the energies **(Chapter 3) :**

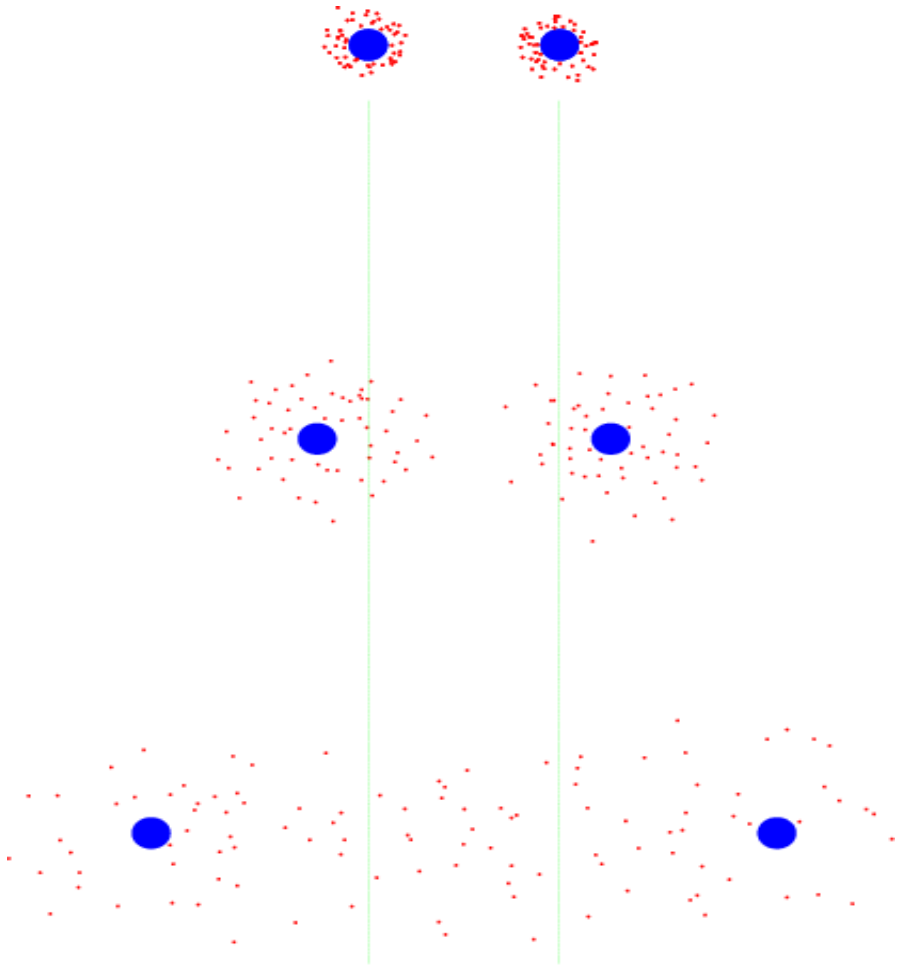
Cosmic-ray sources retain a negative charge (electrons) while the halo of cosmic-ray protons residing in the galactic outskirts retain a positive electric charge.

Negative charge designated by Q_w mostly resides in the thin Galactic disk while the positive charge designated by Q_{cr} being $Q_w = -Q_{cr}$.


z


z

Gran parte dei protoni cosmici (puntini rossi, cariche positive) fuoriescono dagli ammassi di galassie lasciandovi cariche elettriche negative (cerchi blu).



Cosmic-ray protons while propagating from a source obey this radial law :

$$\rho(r) = k/r \quad \text{where} \quad 0 < r < R_c$$

where R_c is the maximum distance travelled by cosmic-ray protons and r the distance from the cluster center.

Cosmic-proton diffusing region : R_c = 150 Mpc
Average intercluster distance : d_c = 60 Mpc
Average cluster radii : r_c = 3 Mpc

- **The function $\rho(r)$ also describes the positive charge density per unit volume of cosmic-ray protons, as they are positively charged particles. In the spherical volume of radius R_c the constant k is : $k = N_g Q_{cr}/4\pi\varepsilon_0 R_c^2$ where $N_g Q_{cr} = Q_c$ is the positive electric charge of the cluster composed of N_g galaxies and Q_{cr} the cosmic-ray charge.**

For example, for N_g = 2000 and $Q_{cr} = 2.58 \times 10^{31}$ C the cluster charge is : (2000) (2.58 x 10^{31} C) = 5.17 x 10^{34} C.

- **The electric charges of the two generic clusters A and B are designated by** Q_e^A and Q_e^B. **For simplicity :** $Q_e^A = Q_e^B$. **The positive charge in the volume of the cluster** A is :

$$Q^A_{cr}(r_c) = N_g Q_{cr}(r_c/R_c)^2 = N_g\ 2.58\times10^{31}\ (3/150)^2\ C$$

- **It is useful to subdivide the charge in two parts :**

  ξ_A positive electric charge fraction contained in the cluster volume of radius r_c (cluster radius).

  $(1-\xi_A)$ rest of the positive charge outside r_c and within **the volume of radius** R_c, **namely, within the spherical shell,** $r_c < r < R_c$

- Charge conservation in the cluster volume $(4/3)\pi r_c^3$ implies :

$$Q^A_e = Q^A_{cr}\,(1-\xi_A)$$

In the spherical volume of the cluster A of radius r_c **it is :**

$$Q_e^A = Q_w^A + Q^A_{cr}(r_c) = -Q^A_{rc} + Q^A_{cr}(r_c) = -6.460546\times10^{34}\ C$$

Numerically, it is : $\xi_A = 4.0\times10^{-4}$ **and** $(1-\xi_A) = 99.9599 \times 10^{-2}$

Only 4 cosmic-ray protons out of 10 000 inhabit the cluster, the vast majority , 9996 cosmic-ray protons evaded or evade from the cluster volume.

- **The electric charges of the two generic clusters A and B are designated by** Q_e^A and Q_e^B

  For simplicity : $Q_e^A = Q_e^B$

- **Let ' s divide the electric field in two components :**

  $E^A(r) = E_-^A(r) + E_+^A(r)$

  $E_-^A(r)$ **electric field of the negative charge,** $r > r_c$

  $E_+^A(r)$ **electric field of the positive charge,** $r_c < r < R_c$

  $\zeta_c = Q_c/Q^b_c$ **= cluster charge/cluster balancing charge**

- $E_-^A(r) = \zeta_c Q_e^A/(4 \pi \varepsilon_0 r^2) = 5.808 \times 10^{44} \zeta_c / r^2 =$

  $= 0.610 \zeta_c / r^2$**(Mpc) V/m**

  $E^A_+(r) = (k/2\varepsilon_0) \zeta_c/(1.-r_c^2/r^2) = (2.704 \times 10^{-5})\zeta_c/(1.-r_c^2/r^2)$ (Mpc) V/m.

- **In the non relativistic approximation the acceleration a_c** acquired by a cluster B subject to the electric field $E^A(d_c)$ of the cluster A is :

$$a_c = (Q_e^B/M^B_c)\ \zeta_c\ E^A(d_c) = (4\ \pi\ \varepsilon_0 G)^{1/2}\ \zeta_c\ E^A(d_c) =$$

$$= 2.7 \times 10^{-10}\ ms^{-2}$$

- **Intercluster distance : d_c = 60 Mpc**
  electric field : $E^A(d_c)$ = 2.135×10^{-2} V/m
  N_g number of galaxies of the cluster: N_g = 2500.
  Average galaxy mass : 3×10^{41} Kg.
  ζ_c = 150 electric charge relative to the balancing charge.
  Cluster mass : $M_c^B = N_g \times 3 \times 10^{41} = 7.5 \times 10^{44}$ Kg.

The velocity gained by this generic cluster in the arbitrary time interval t, for example, one billion years, is :

$v(t) = v(1 \text{ billion years}) = a_c t =$

$= 2.7 \times 10^{-10} \text{ m/s}^2 \times 3.155 \times 10^{16} \text{ s} = 8\,700 \text{ Km/s}$

and the corresponding straight line segment travelled in this time interval L(t) is :

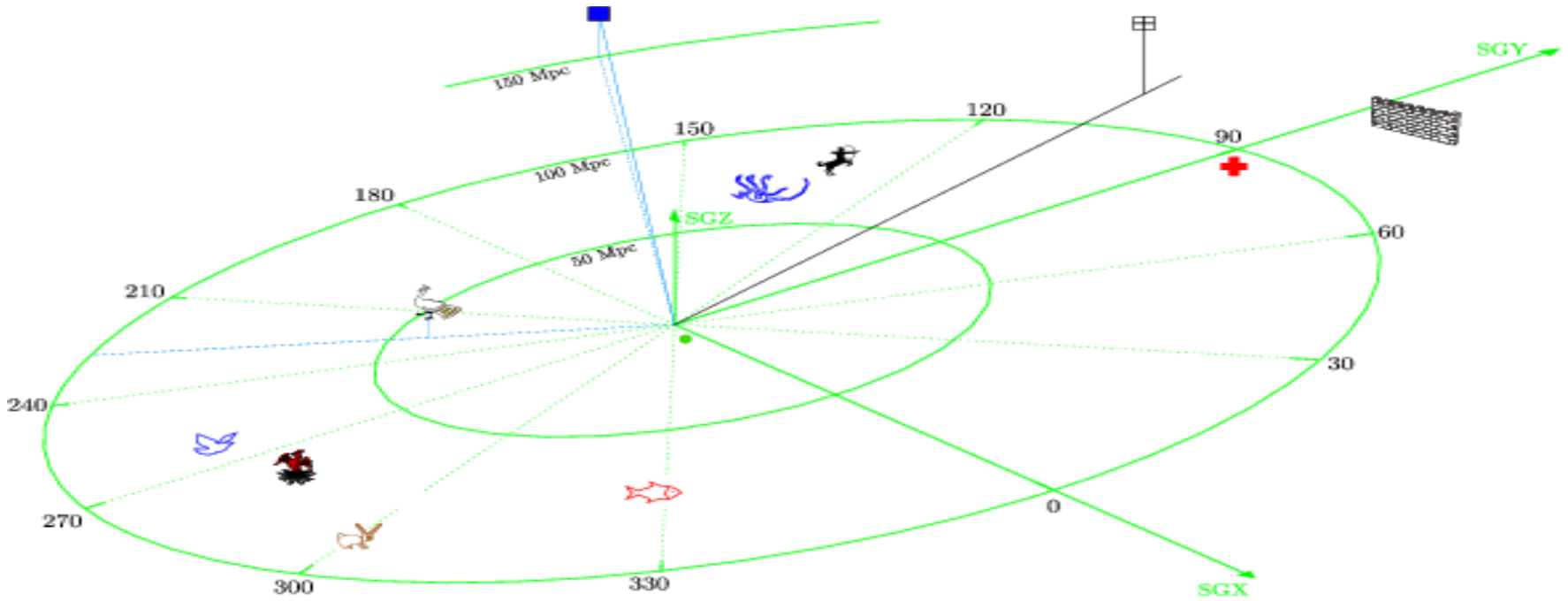
$L(t) = L(1 \text{ billion years}) = (1/2)\ (a_c\ t^2) = 4.2 \text{ Mpc}$

- **For comparison, in 5 billion years :**

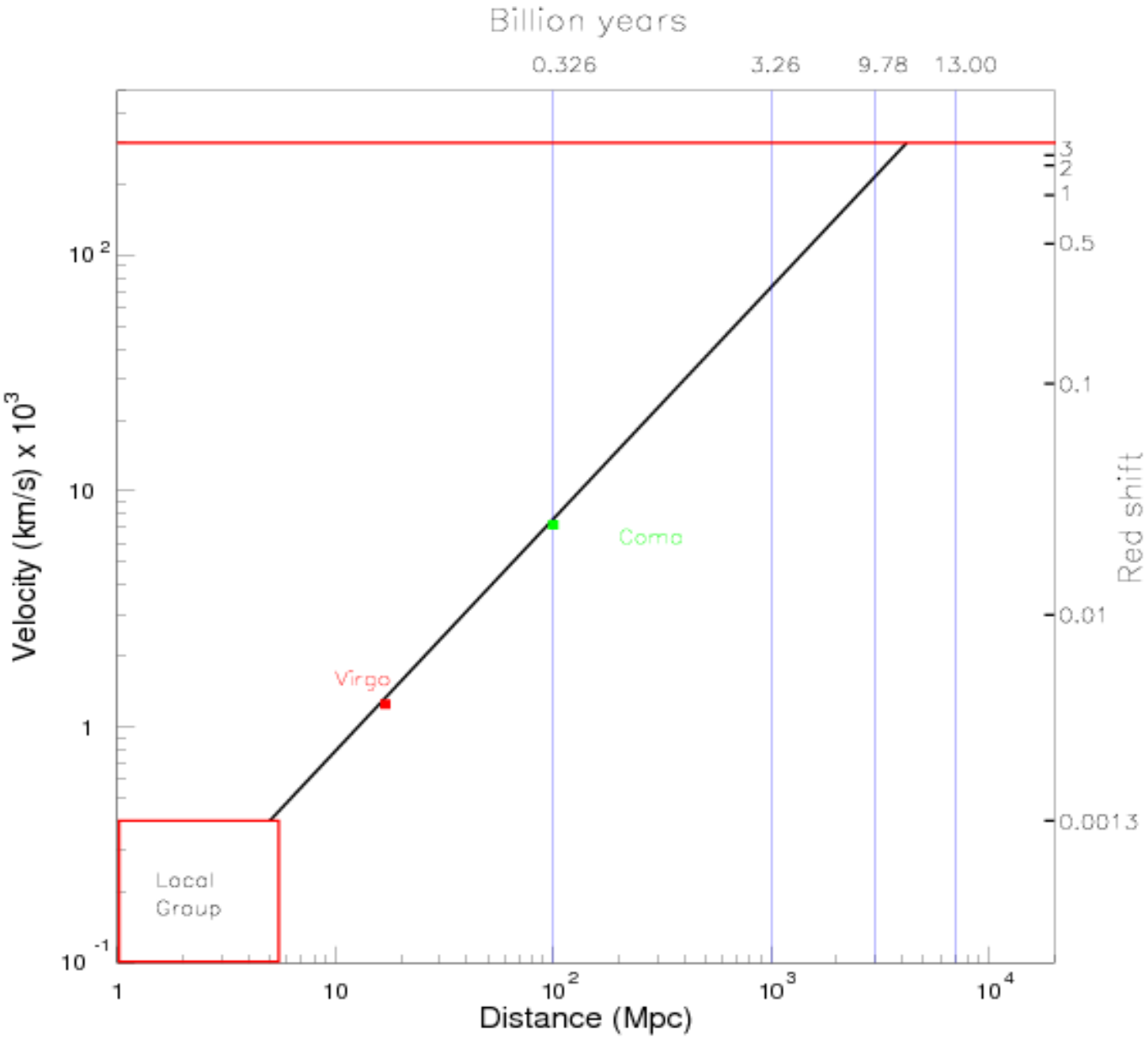
$v(t) = a_c t = 43\,500 \text{ Km/s}$

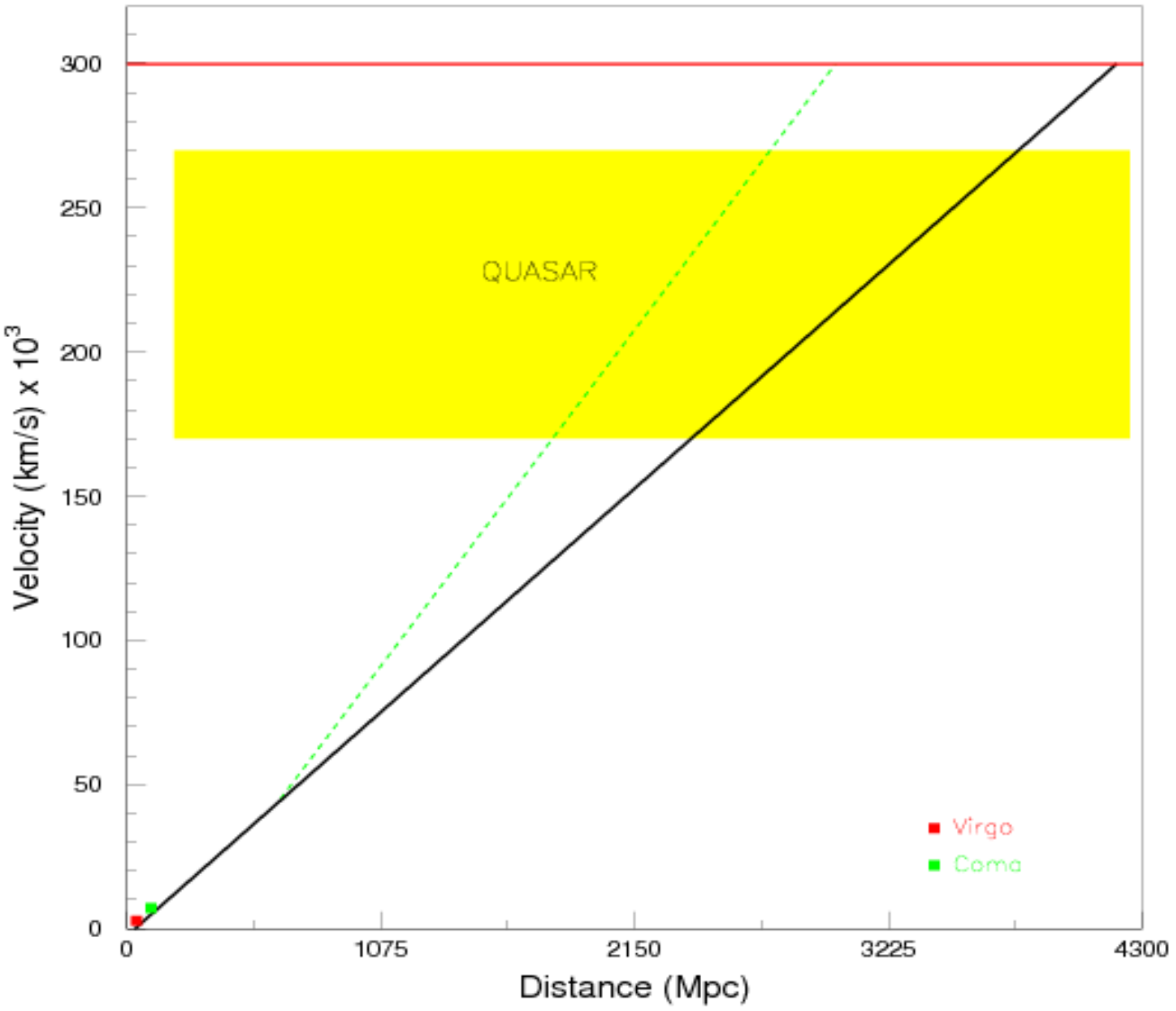
and :

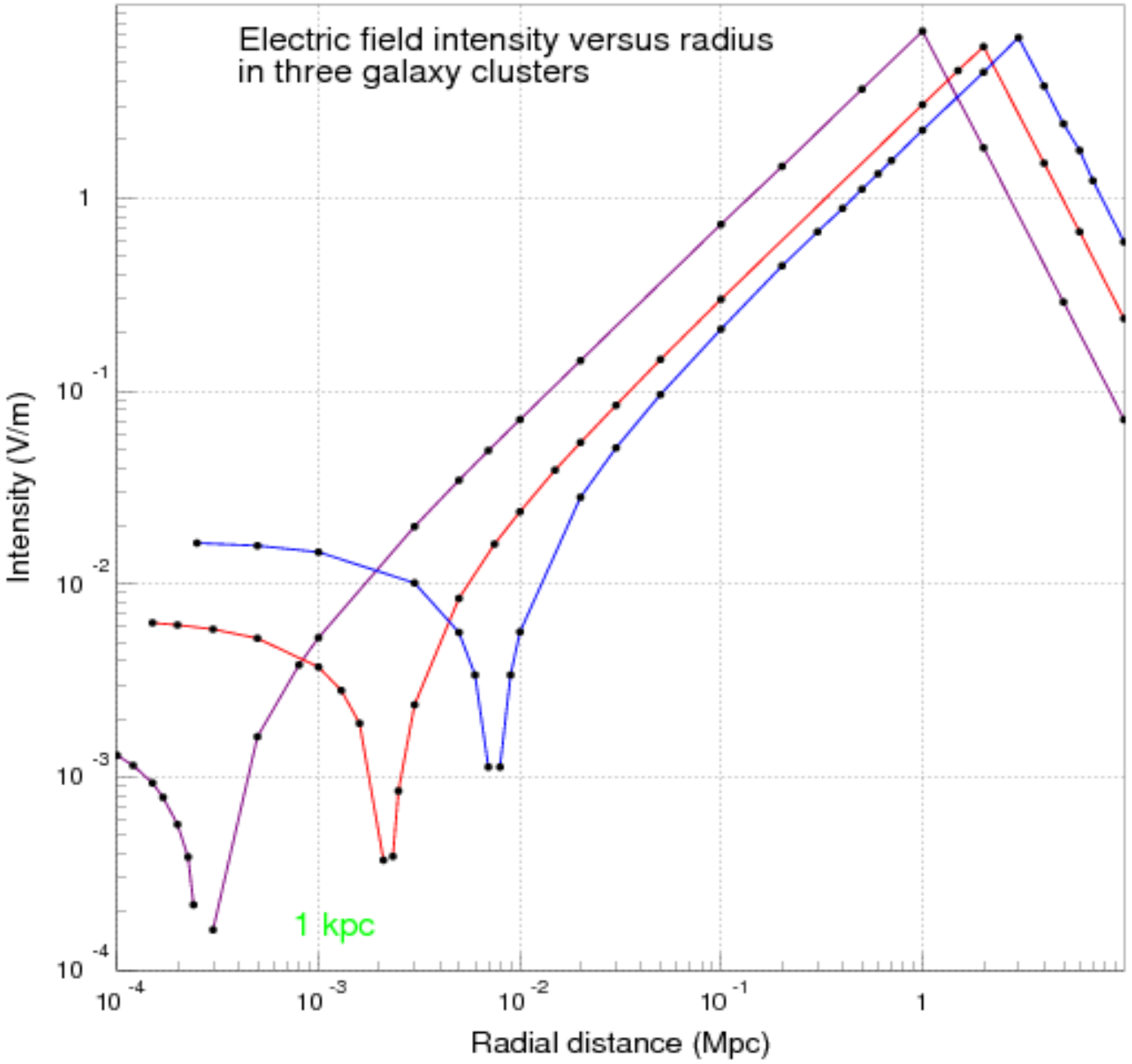
$L(t) = L(5 \text{ billion years}) = (1/2)\ (a_c\ t^2) = 111 \text{ Mpc.}$



Virgo (104, -2) 17
Coma (92.2, -10.5) 100.2
Phoenix (251, -13.5) 95
Perseus Pisces (335.0, -2.0) 64.1
Colomba (222.1, -67.4) 135.2
Centaurus (147.6, +8.3) 92
Pavo-Indus (229.7, +20.5) 45
Hercules (107.3, +49.4) 149
Lepus (300, -4.5) 185
Hydra (139.4, -37.5) 48.4
Shapley (156, +0.2) 149
North Wall (105, +10) 125


Billion years
0.326
3.26
9.78
13.00
Velocity (km/s) x 10^3
10^2
10
1
10^-1
Coma
Virgo
Local
Group
1
10
10^2
10^3
10^4
Distance (Mpc)
Red shift
2
1
0.5
0.1
0.01
0.0013

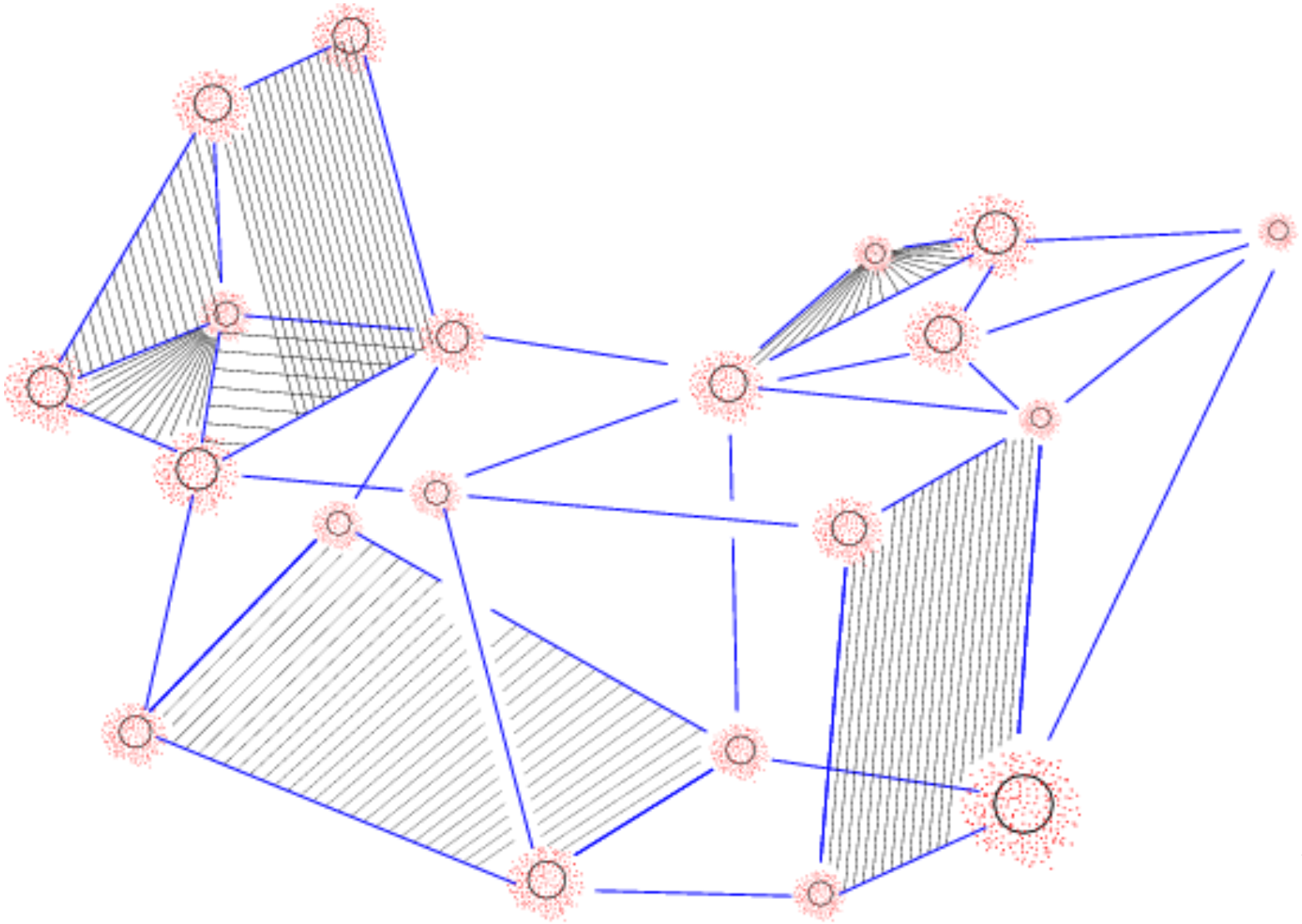

300
250
200
150
100
50
0
Velocity (km/s) x 10^3
QUASAR
Virgo
Coma
0
1075
2150
3225
4300
Distance (Mpc)


Electric field intensity versus radius
in three galaxy clusters
Intensity (V/m)
1
10 -1
10 -2
10 -3
10 -4
1 kpc
10 -4
10 -3
10 -2
10 -1
1
Radial distance (Mpc)

Visualization of 20 galaxy clusters (arbitrary number) prior to electrostatic repulsion develops

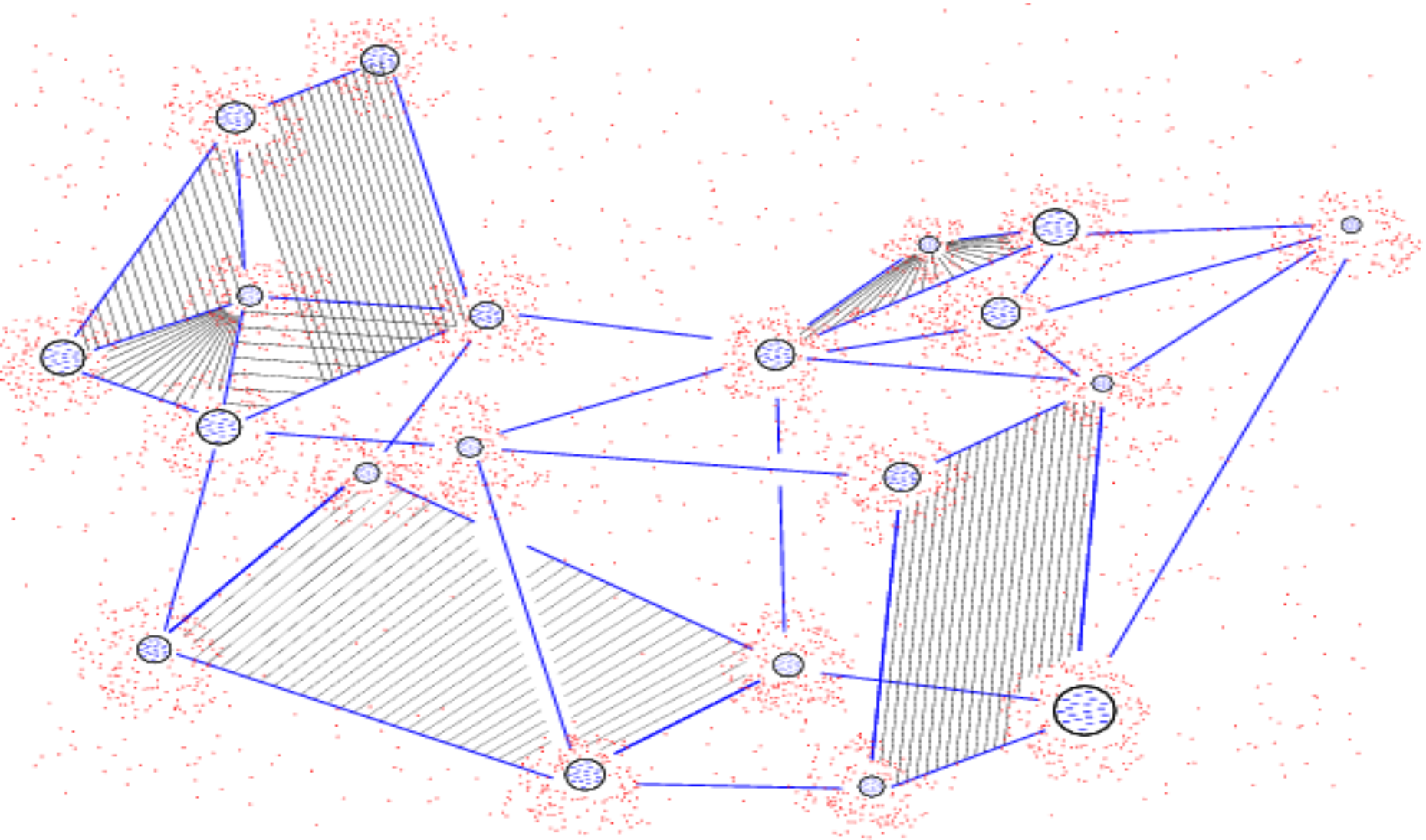
red dots : positively charged cosmic-ray protons while propagating

black circles represent cluster volumes while blue straight lines cluster distances

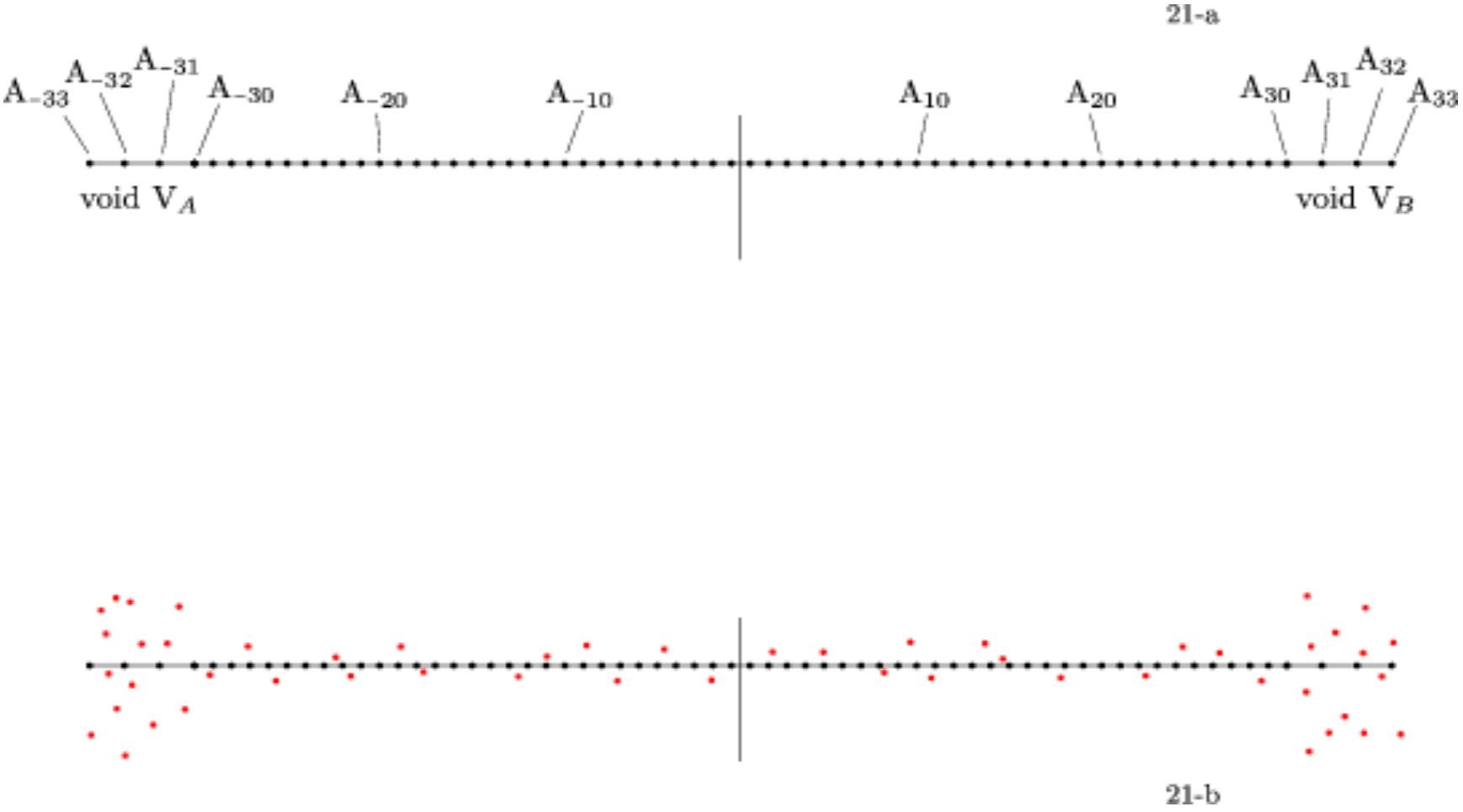


Cosmic-ray protons (red dots) while overflowing from cluster volumes

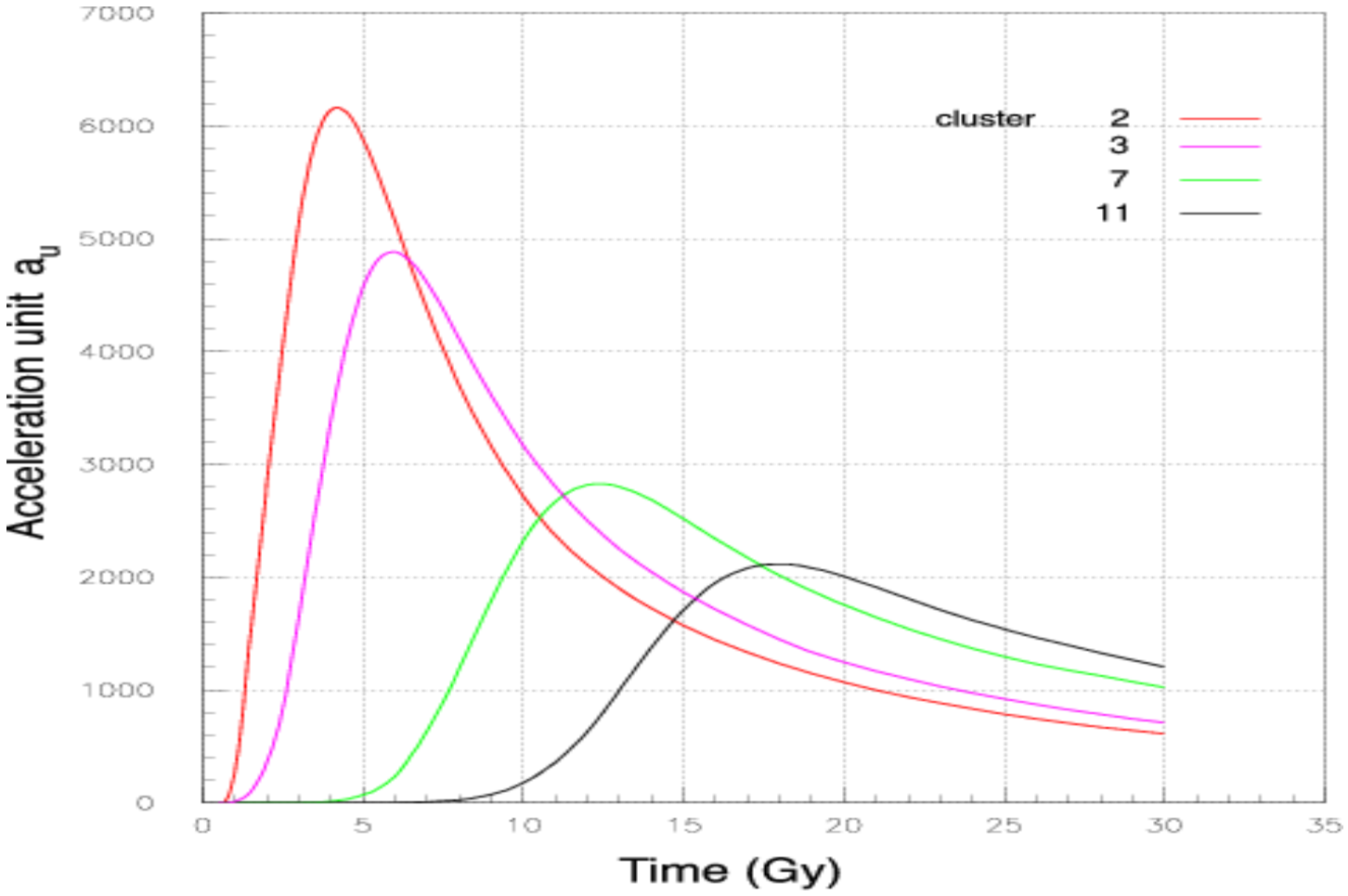
leave negative charges (blue minus signs) inside cluster volumes.

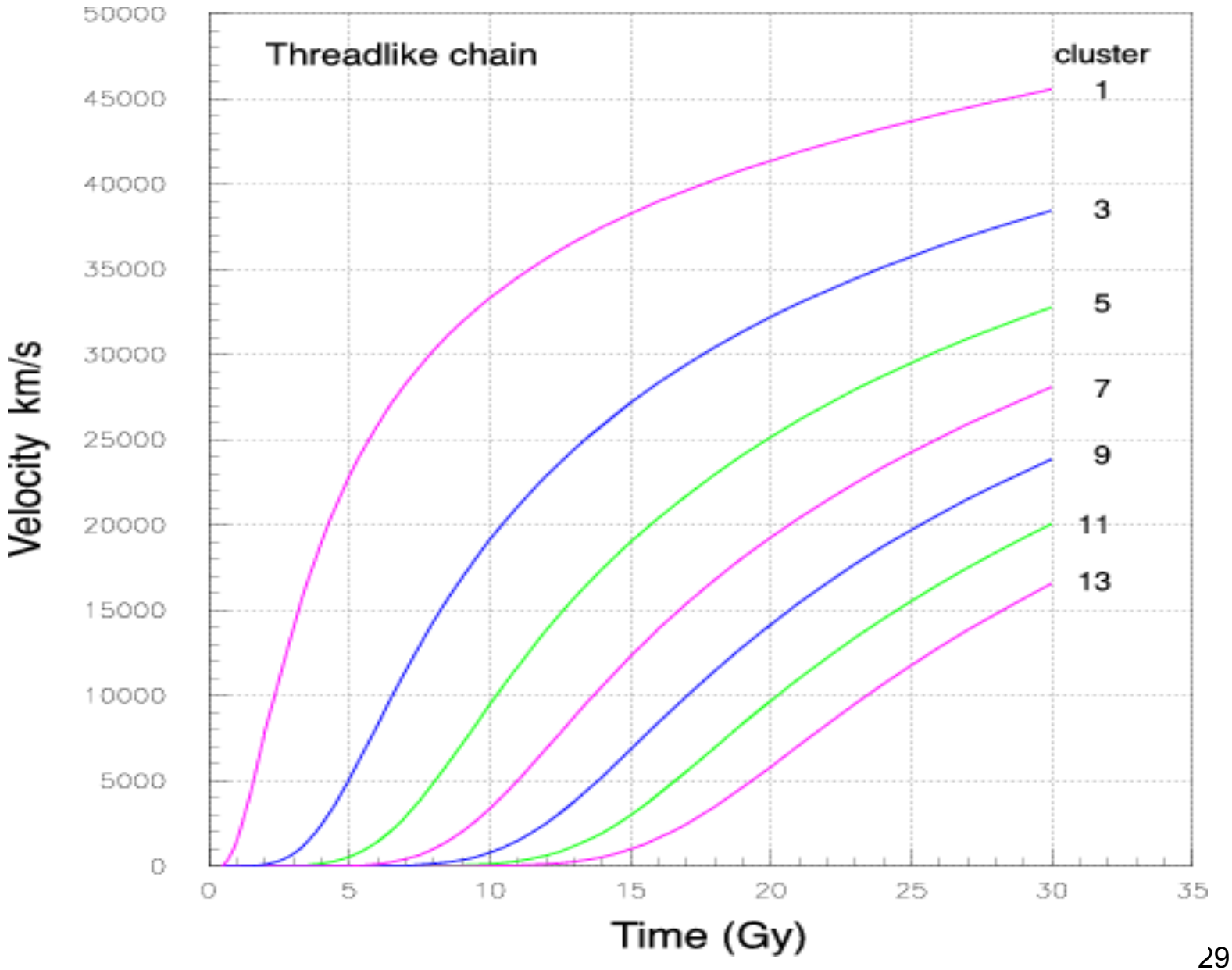


Filiform chain of galaxy clusters 3900 Mpc long from A_{-33} to A_{33} spaced 60 Mpc

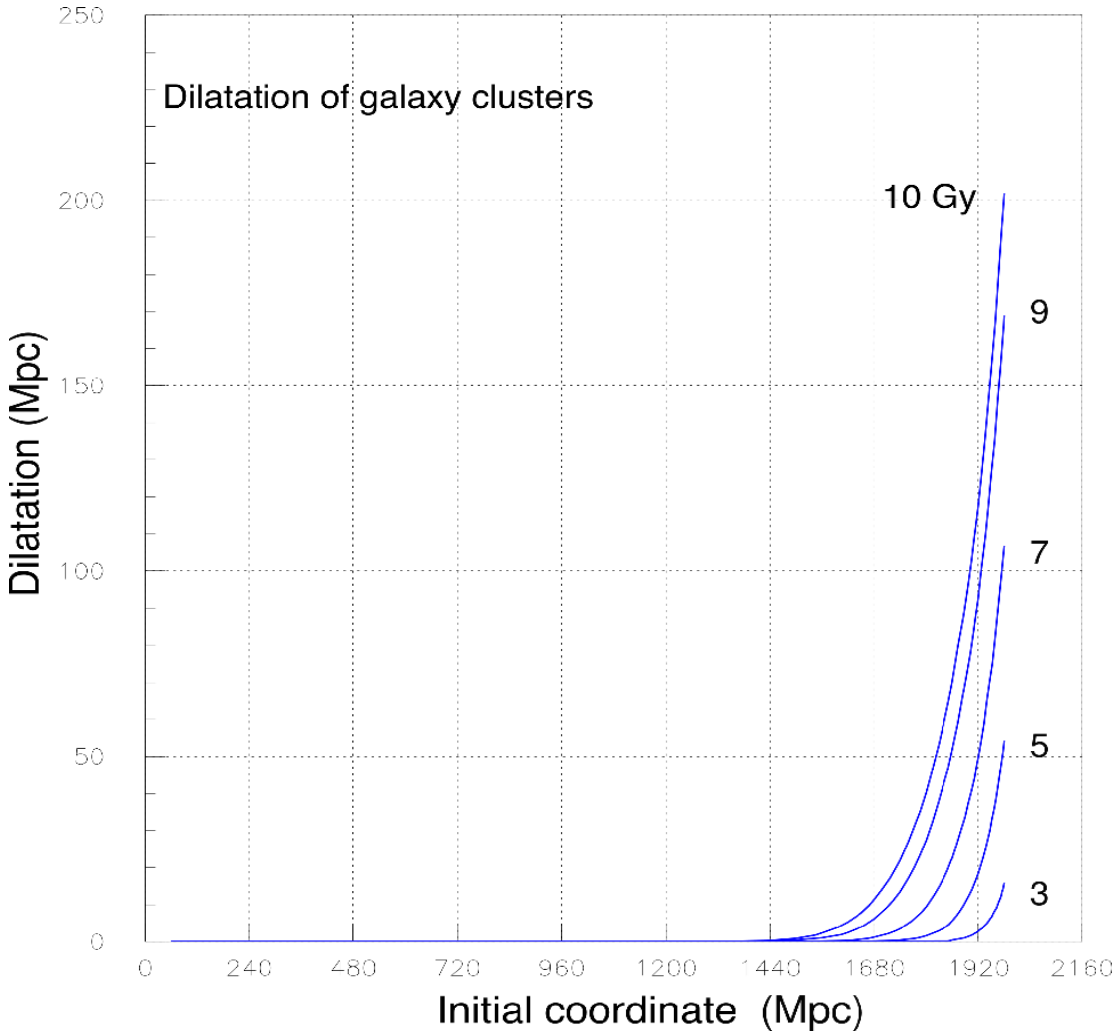


Acceleration experienced by clusters marshalled in a filiform chain
One acceleration unit 10^{-14} m/sec^2




Threadlike chain
cluster
1
3
5
7
9
11
13
Velocity km/s
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
5
10
15
20
25
30
35
Time (Gy)

Expansion of galaxy clusters in a filiform array 1390 Mpc long (arbitrary length)



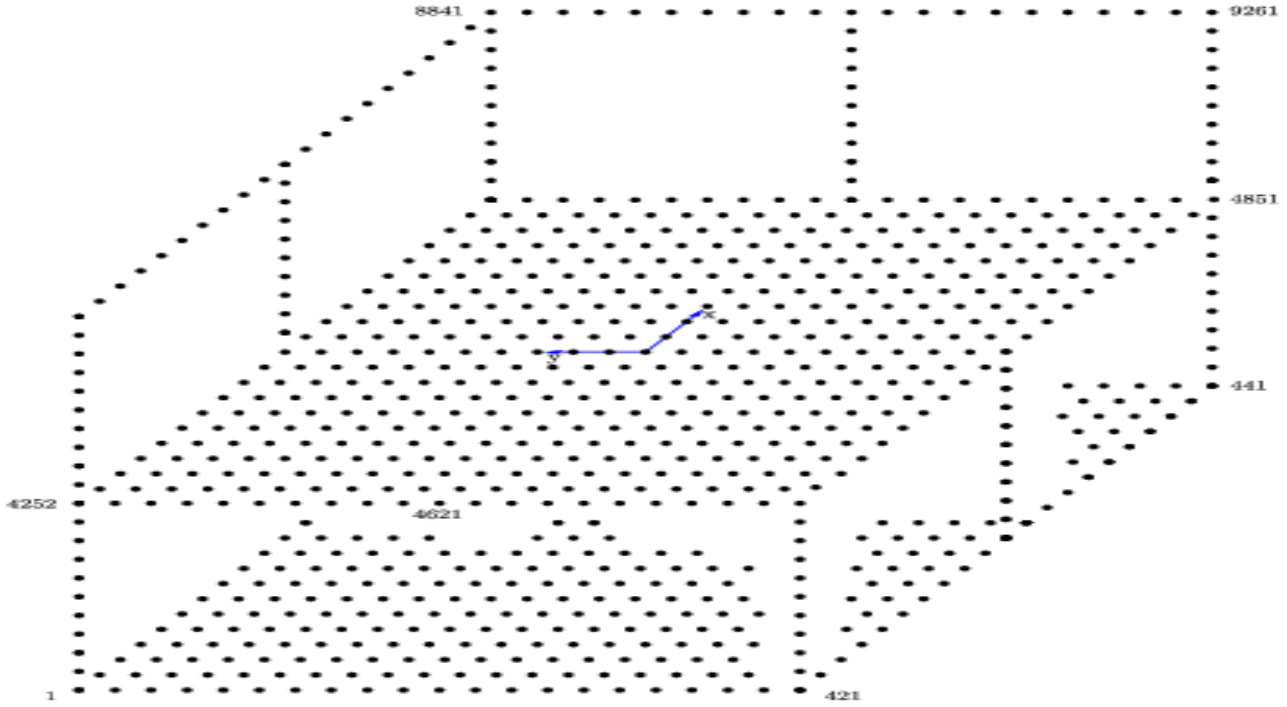
Main features of these results :

(1) Spatial dilatations $d_k(t)$ very modest even for peripheral clusters. For example, the extreme cluster A_{33} during 10 Ga experiences a dilatation of about 200 Mpc passing from the coordinate $x_{33}(0)$ = 1950 Mpc to $x_{33}(10\ Ga)$ = 2150 Mpc being $d_{33}(10\ Ga) = x_{33}(10Ga) - x_{33}(0)$ = 200 Mpc.

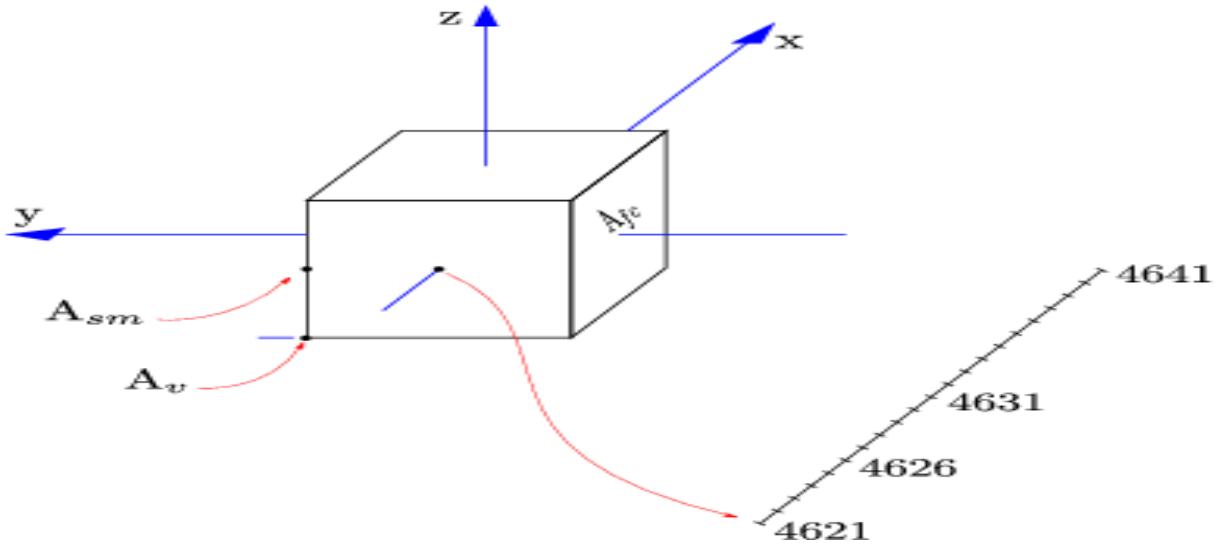
(2) Very high velocities are acquired by the peripheral clusters.
For example, the extreme cluster A_{33} or A_{-33} gain 40 Km/s in 15 Ga.

(3) Very small variations in the distances of central and intermediate clusters.

Definition of dilatation : $d_k(t) \equiv x_k(t) - x_k(0)$
$X_k(t)$ position of the cluster k at time t.
$X_k(t)$ position of the cluster k at time zero.

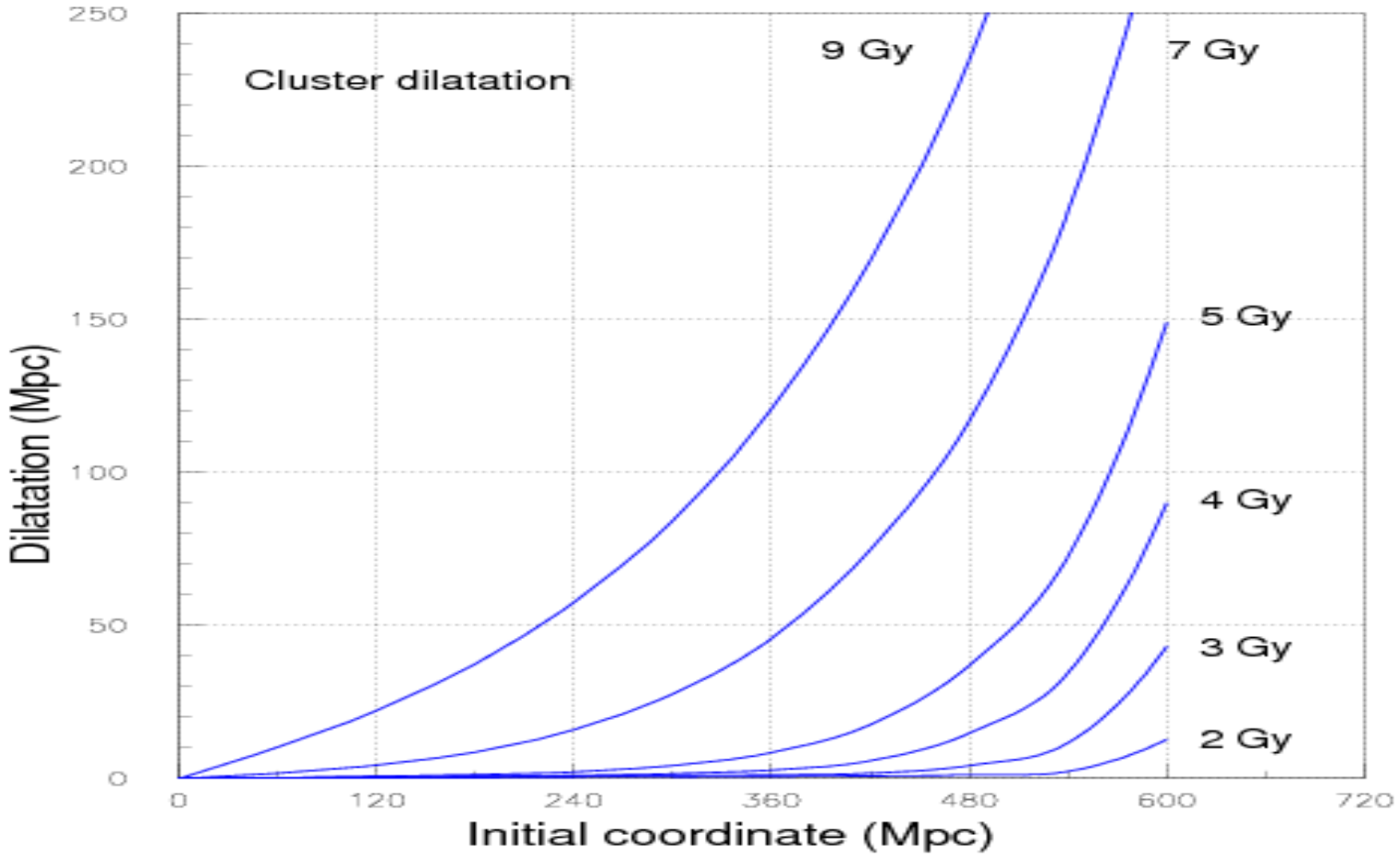

8841
9261
4851
441
4252
4621
1
421

26–a


z
x
y
A_{fc}
A_{sm}
A_v
4641
4631
4626
4621

26–b

Dilatation (Mpc) versus time (Gy) (10^9 years)



Where is the empirical evidence that galaxy clusters store negative charges in the range 10^{34}-10^{36} C ?

Intrinsically, cosmic-ray electrons suffer synchrotron emission and cannot travel away from the sources (some kpc) . On the contrary, cosmic-ray protons propagate faraway from the sources as they rarely collide (once in ten billion years). This spatial asymmetry inevitably condenses negative charge (quiescent electrons) in the cluster volume and positive charge (cosmic-ray nuclei) around the cluster.

Gamma ray data in the range 100 MeV to 500 GeV collected in the last seventy years are consistent with this view :

Cosmic-ray protons in galaxy clusters are surprisingly scarce, as attested by empirical evidence since 70 years.

Diffuse gamma ray fluxes from galaxy clusters and cosmic-ray protons

Rates of the diffuse gamma radiation in clusters have been estimated to be in the range 10^{-8} photons/cm^2 sec.

See, for example, M. Dennison, 1980, ApJ, 239, pages 679-695.

Arnon Dar and N. J. Shaviv, 1995, Phys. Rev. Lett., 75, 3052.

p p –> neutral pions + anything, believed to be the dominant photon source

Upscattering of cosmic microwave photons colliding with TeV cosmic-ray electrons

No empirical evidence of diffuse gamma rays in galaxy clusters has been found to date (2023) in spite of the sensitive quests by SAS-2, EGRET, GLAST, MAGIC, VERITAS experiments.

These searches have produced only upper limits, some 10^{-11} photons/cm^2 sec in the gamma ray flux in the range 100 MeV – 500 GeV.

O. Reimer et al. 2003, ApJ, 588,155; J. Aleksić et al. 2010, ApJ, 541, A99; F. Zandanel et al. 2014, MNRAS, 440,663; M. Ackermann et al., 2016, ApJ, 787, 18; R. D. Griffin et al., 2014, ApJ, 795, L21;

Quite opposite it is the thriving, variegated radio emission from galaxy clusters :

(1)Syncrothron radiation observed in galaxy clusters is emitted by cosmic-ray electrons in the GeV energy range.

See, for example, W. Jaffe, 1980, ApJ, 241, 925-927

(2) Synchrotron radiation takes the form of giant radio halos, minihalos, radio filaments and radio relics. It is detected in all the cluster volume.

See, for example, M. Murgia et al. 2009, Astron. and Astrophys, 499, 679-695.

Simple suggestion: The cluster electric field Ec continuously accelerates and disperse cosmic-ray electrons in all the cluster volume and beyond, due to its centripetal direction.

Unsurprisingly, cosmic-ray electrons are energized everywhere, particularly at the cluster outskirts, where the electric field E_c is more intense than at cluster center.

Conclusions :

The empirical base of the expansion of nearby universe by electrostatic repulsion is anchored to many experimental results on Galactic cosmic rays, particularly, the exact account of intensity, direction and orientation of the Galactic magnetic field.

(1) Adopting electrostatic repulsion among galaxy clusters it turns out that their relative distances increase with time, along with their velocities.

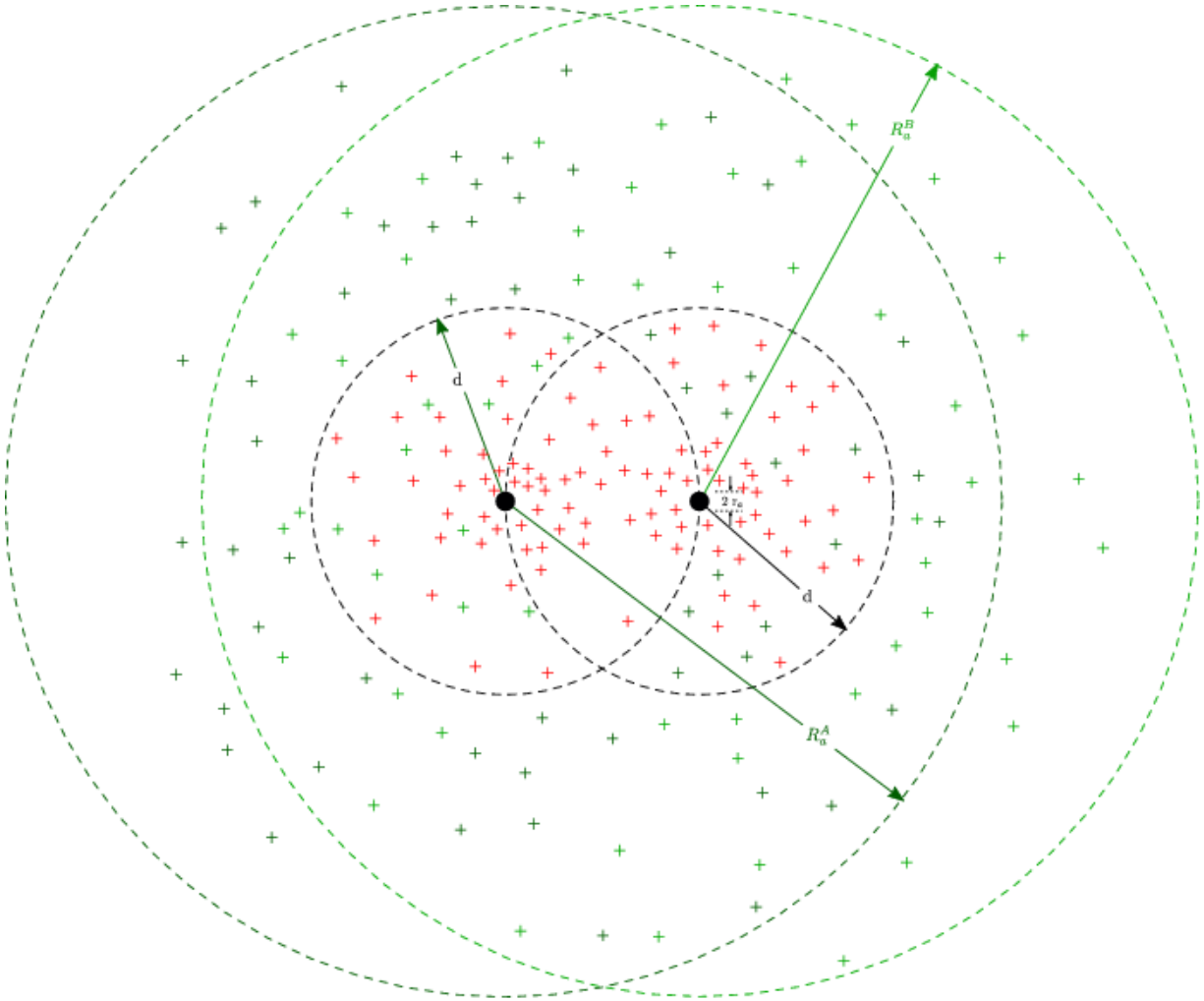
(2) Inevitably, galaxy clusters have to accelerate as their initial dynamic condition is at rest, in a chill universe, as attested by the cosmic microwave black body radiation at 2.72 absolute degrees or below.

The pace of the acceleration in the last 10-15 billion years is in the range of 10^{-10}-10^{-11} m/s^2.

Positively charged cosmic ray-protons evaded from clusters leaving negative charges in the cluster volumes. The unpredicted and surprising absence of diffuse gamma rays in the range 100 MeV 500 GeV from galaxy clusters is supportive evidence of the negative charges in galaxy clusters and the concomitant electrostatic repulsion.

Spare slides

Details of the calculation of the electrostatic repulsion between two clusters



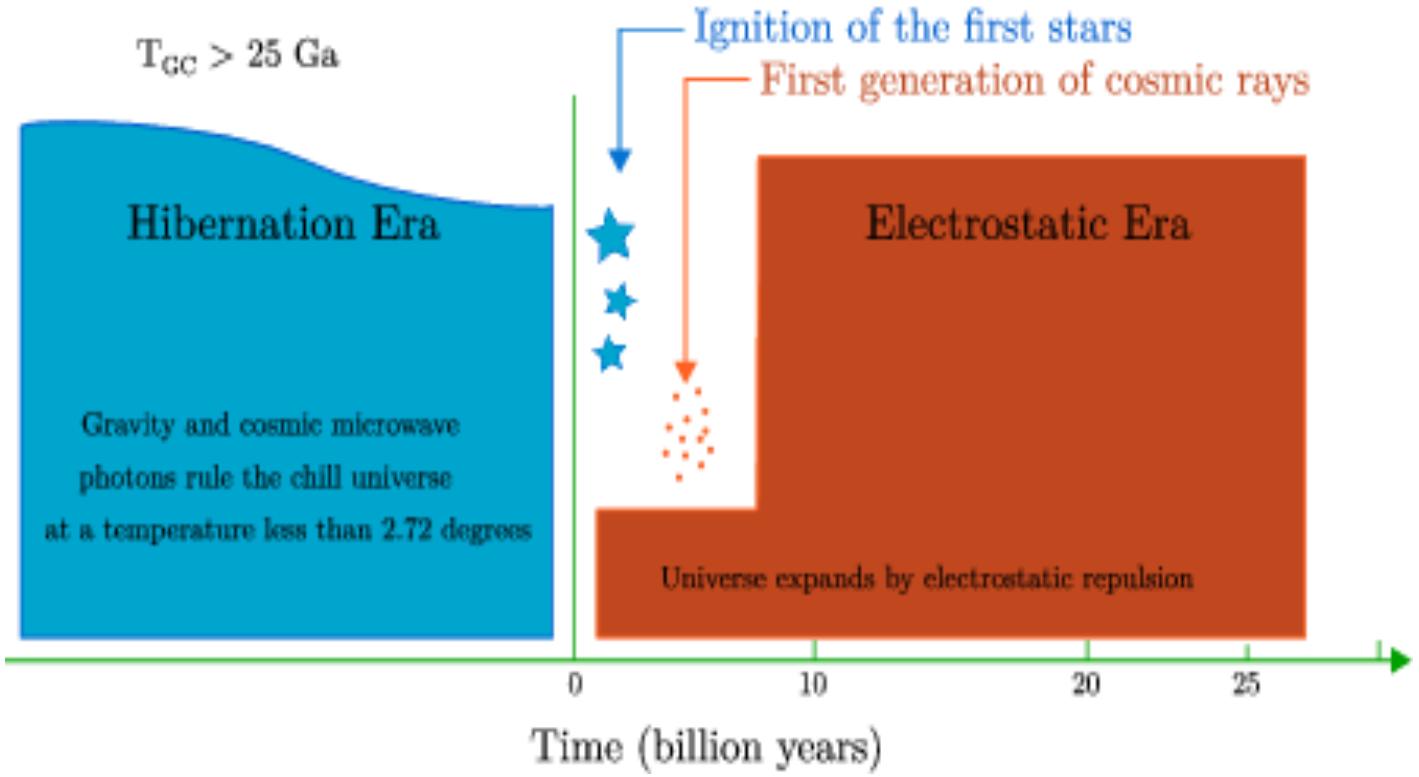
Hibernation Era and Electrostatic Era

T_{GC} cosmic time measured via Globular Cluster age

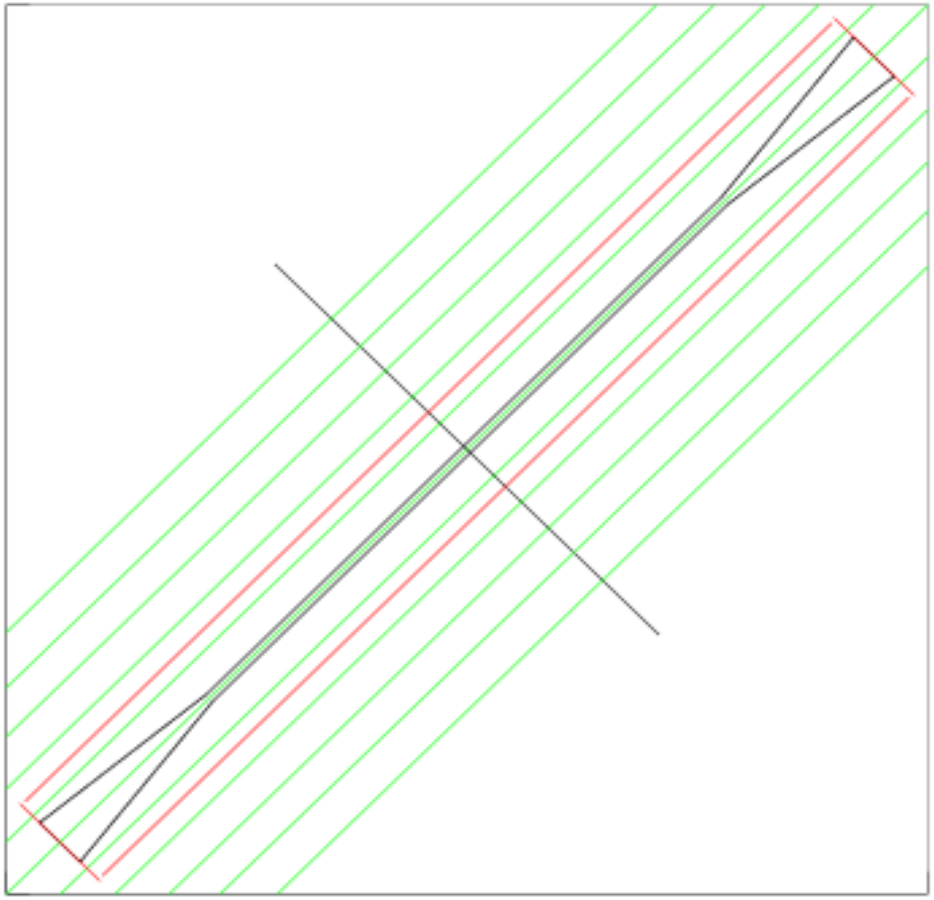
A. Sandage, 1982 ApJ, 252, 553.

E. Bohm-Vitense and P. Szkody, 1973 ApJ, 184, 211.

H. Herjen et al., 2004 Astronomical Journal, 127, 771.



Side view of the Galactic disk (black silouhette) and
halo of positively charged cosmic-ray protons (red rectangle)



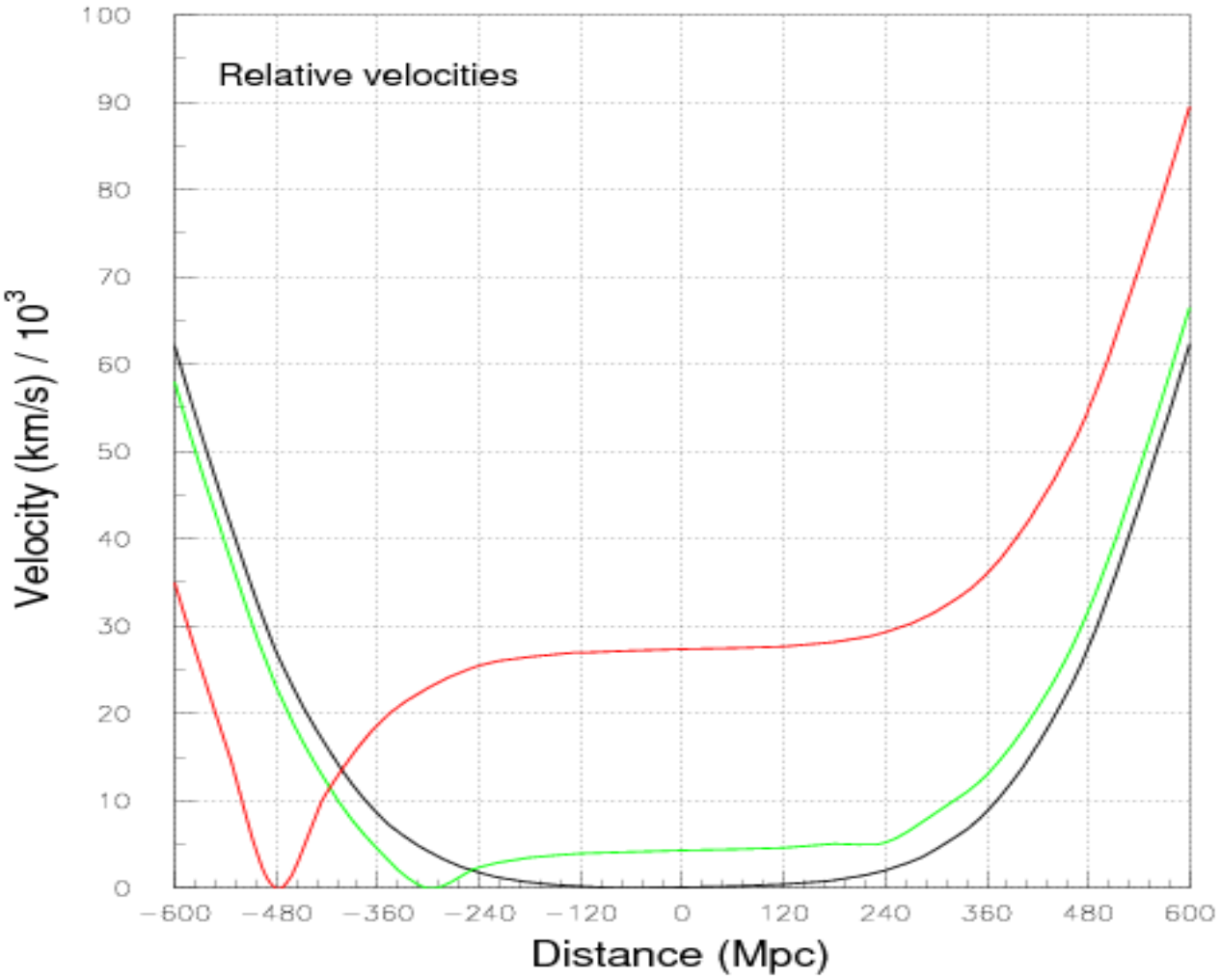
Let us anchor the following two statements to the empirical data:

What is the physical process causing the expansion of material bodies observed around the Earth since a century ?

It is the electrostatic repulsion of negatively charged galaxy clusters.

How do galaxy clusters become negative charged bodies so that they can exert the electric repulsion ?

Cosmic-ray protons, since the ignition of the first stars, massively evaded from cluster volumes and left negative charges in the cluster volume.


Relative velocities
Velocity (km/s) / 10^3
100
90
80
70
60
50
40
30
20
10
0
−600
−480
−360
−240
−120
0
120
240
360
480
600
Distance (Mpc)

Pubblicazioni annunciate nel libro : How the electrostatic fields generated by cosmic rays cause the expansion of the nearby universe, Società Editrice Esculapio, Bologna, Italy :

1 - A. Codino, A simpler explanation of the microwave cosmic radiation with a black body spectrum;

2 - A. Codino, Cosmic electron spectra from the Voyager Probes and the Galactic electrostatic field.