Primordial heavy elements in composite dark matter models

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Outlines

- Cosmological effects of particle physics
- Nonequilibrium cosmological nucleosynthesis
- Physical reasons for new (meta)stable quarks and/or leptons
- Exotic forms of composite dark matter, their cosmological evolution and effects in nucleosynthesis
- Experimental search for composite dark matter and its charged constituents

Basic ideas of cosmoparticle physics in studies of New Physics, underlying Modern Cosmology

- Physics beyond the Standard model can be studied in combination of indirect physical, astrophysical and cosmological effects
- New symmetries imply new conserved charges. Strictly conserved charge implies stability of the lightest particle, possessing it.
- New **stable particles** should be present in the Universe. Breaking of new symmetries implies cosmological **phase transitions**. Cosmological and astrophysical constraints are supplementary to direct experimental search and probe the fundamental structure of particle theory
- Combination of physical, cosmological and astrophysical effects provide an over-determined system of equations for parameters of particle theory

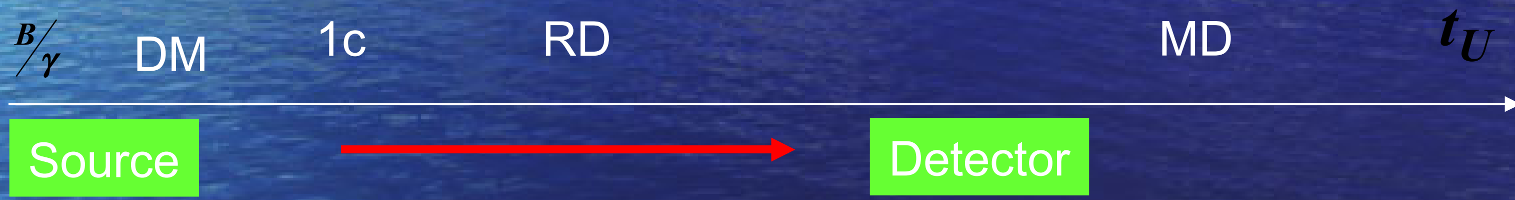
COSMOlogy PARTICLE PHYSICS

Physical scale

New physics

Extremes of physical knowledge converge in the mystical Uhrohboros wrong circle of problems, which can be resolved by methods of Cosmoparticle physics

Cosmological effects of new physics must include with necessity inflation, baryosynthesis and dark matter/energy.
Various other model-dependent cosmological consequences of particle physics maintain cosmophenomenology of new physics



Gedanken Experiment, in which cosmophenomenology of new physics is considered as the source, while its effects on later stages of expansion are considered as detector, fixing the signatures for these effects in the astrophysical data, provides astyrophysical test for new physics and cosmological scenarios, based on it.

Non-equilibrium particles

- Decays of unstable particles, antimatter domain annihilation, PBH evaporation… are the source of particles with energy E>>T or of such particles, which are absent in equilibrium at this temperature T (e.g. antiprotons in baryon asymmetrical Universe after the first microsecond of expansion).
- Late sources of non-equilibrium particles directly contribute in fluxes of cosmic rays.
- If the source of particles acts sufficiently early, interaction of non-equilibrium particles with plasma and radiation can lead to observable effect

Nuclear cosmoarcheology

- **After BBN primordial chemical composition is created in the Universe: 75% H, 25% He-4 with a small fraction of other elements:**

$$X_D = 2.5 \cdot 10^{-5}; X_{^3He} = 4.2 \cdot 10^{-5}; X_{^7Li} = 2 \cdot 10^{-9}$$

- **Destruction by non-equilibrium particles of even small fracion (<1%) of primordial He-4 can lead to excessive abundance of light elements (D and He-3). Antinucleons in the Universe after BBN (from sources of nucleon-antinucleon pairs or survived in antimatter domains) are a profound example of non-equilibrium particles:**

$$\bar{p} + {}^4He \Rightarrow n + \ldots; n + p \Rightarrow D + \gamma; \bar{p} + {}^4He \Rightarrow D + N + pions$$

$$\bar{p} + {}^4He \Rightarrow {}^3H + pions; \bar{p} + {}^4He \Rightarrow {}^3He + pions$$

Experimental nuclear cosmoarcheology

- There was an incomplete link in the cosmoarcheoLOGICAL chain between comophenomenology of new physics and observed light element abundance. The yield of D,T and He-3 was not known in reactions

$$\bar{p} + {}^4He \Rightarrow D + N + pions$$

$$\bar{p} + {}^4He \Rightarrow {}^3H + pions$$

$$\bar{p} + {}^4He \Rightarrow {}^3He + pions$$

This information was obtained in special experiment PS179 at Low Energy Antiproton Ring (LEAR) in CERN. The measured yield of He-3 (20%) provided a set of severe constraints on the sources of nonequilibrium particles after BBN.

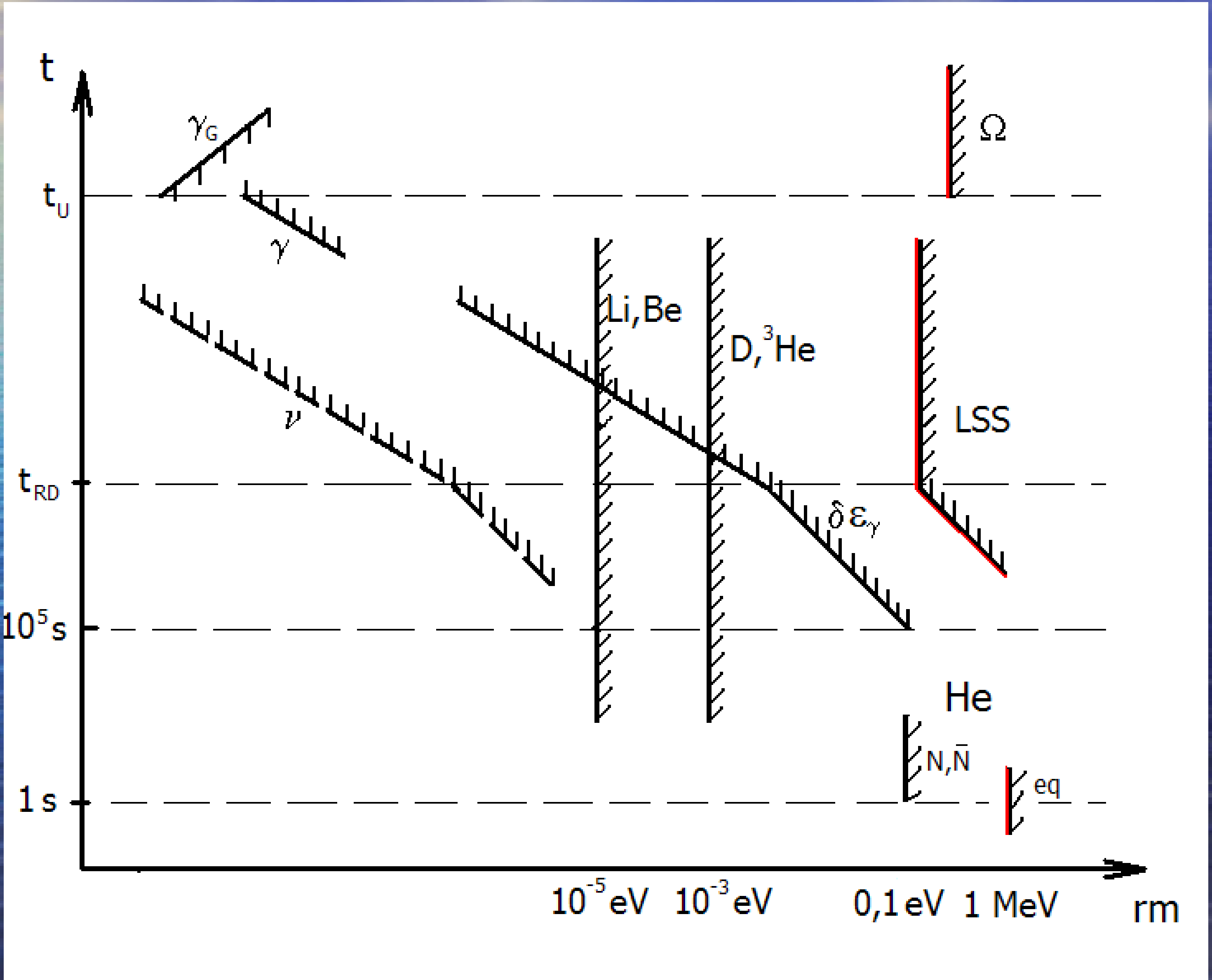
- Analysis of Li and Be formation by nonequilibrium nuclear fragments (D, He-3, T) strengthened these constraints by 2 orders of magnitude. The progress was achieved in the result of Astro-nuclear experiment ASTROBELIX

$$\bar{p} + {}^4He \Rightarrow D + ...; D + {}^4He \Rightarrow {}^6Li + \gamma$$

$$\bar{p} + {}^4He \Rightarrow {}^3H + ...; {}^3H + {}^4He \Rightarrow {}^6Li + n$$

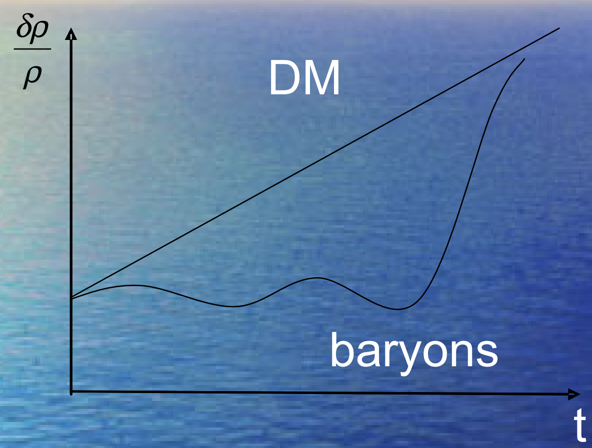
$$\bar{p} + {}^4He \Rightarrow {}^3He + ...; {}^3He + {}^4He \Rightarrow {}^7Be + \gamma$$

Laboratory of the Universe



$$r \equiv \frac{n_X}{n_\gamma}$$

Cosmological Dark Matter



$$\frac{\delta\rho}{\rho} \Rightarrow \frac{\delta T}{T}$$

Cosmological Dark Matter explains:

- **virial paradox in galaxy clusters,**
- **rotation curves of galaxies**
- **dark halos of galaxies**
- **effects of macro-lensing**

But first of all it provides formation of galaxies from small density fluctuations, corresponding to the observed fluctuations of CMB

To fulfil these duties Dark Matter should interact sufficiently weakly with baryonic matter and radiation and it should be sufficiently stable on cosmological timescale

Dark Matter Candidates

- Massive neutrinos (m<1eV, M>46 GeV) probably exist but they can be only a subdominant DM component
- LSSP, mostly neutralino, though even stop is possible (SUSY – solution for divergence of Higgs mass)
- Invisible axion (Solution for strong CP violation in QCD)
- Mirror matter (Solution for equivalence of L and R coordinate systems) – strictly symmetric to ordinary particles, and Shadow matter in more general asymmetric case
- Topological defects, Q-balls, PBHs, …

They follow from different extentions of Standard Model and, in general, from physical viewpoint should co-exist.

Therefore from physical viewpoint Dark Matter is most probably multi-component

Dark Matter from Charged Particles?

By definition Dark Matter is non-luminous, while charged particles are the source of electromagnetic radiation. Therefore, neutral weakly interacting elementary particles are usually considered as Dark Matter candidates. If such neutral particles with mass m are stable, they freeze out in early Universe and form structure of inhomogeneities with the minimal characterstic scale

$$M = m_{Pl} \left(\frac{m_{Pl}}{m} \right)^2$$

- However, if charged particels are heavy, stable and bound within neutral « atomic » states they can play the role of composite Dark matter.
- Physical models, underlying such scenarios, their problems and nontrivial solutions as well as the possibilities for their test are the subject of the present talk.

Sinister model solving Sea saw and Dark Matter Problems

A Sinister Extension of the Standard Model to $SU(3) \times SU(2) \times SU(2) \times U(1)$

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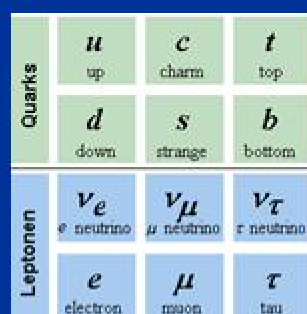
This paper describes work done in collaboration with Andy Cohen. In our model, ordinary fermions are accompanied by an equal number 'terafermions.' These particles are linked to ordinary quarks and leptons by an unconventional CP' operation, whose soft breaking in the Higgs mass sector results in their acquiring large masses. The model leads to no detectable strong CP violating effects, produces small Dirac masses for neutrinos, and offers a novel alternative for dark matter as electromagnetically bound systems made of terafermions.

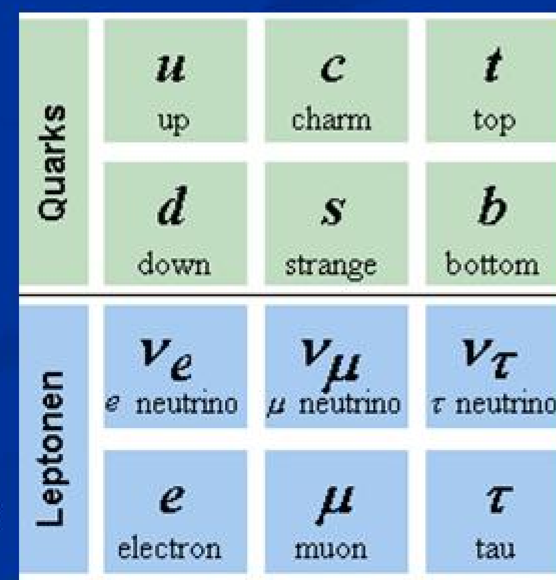
Abstract

- *The role of Sinister Heavy Fermions in recent Glashow's SU(3)*SU(2)*SU(2)'*U(1) model is to offer in a unique frame relic Helium-like products (an ingenious candidate to the dark matter puzzle), a solution to the See-Saw mechanism for light neutrino masses as well as to strong CP violation problem in QCD. Their mass are million times larger than common ones*
- *The Sinister model requires a three additional families of leptons and quarks, but only the lightest of them Heavy U-quark and E-"electron" are stable.*



U

E



Glashow's tera-fermions

SU(3)xSU(2)xSU(2)xU(1)

Tera-fermions (*N,E,U,D*) ⇔ W', Z', H', γ and g

\+ problem of CP-violation in QCD

\+ problem of neutrino mass

\+ (?) DM as [(*UUU*)*EE*] tera-helium **(NO!)**

$$\begin{pmatrix} N \\ E \end{pmatrix}$$

N: Very heavy and unstable

E: m~500 GeV, stable

$$\frac{m_E}{m_e} = \frac{m_U}{m_u} = \frac{m_D}{m_d} = \frac{\text{vev}'}{\text{vev}} = S_6\, 10^6$$

$$\begin{pmatrix} U \\ D \end{pmatrix}$$

U: m~3 TeV, (meta)stable

D: m~5 TeV, *D* → *U* +…

Why Tera-helium is a good Dark Matter gas?

- Teraparticles do not have normal W and Z interactions and do not contribute into SM parameters, so they can not be excluded by precision measurements of SM parameters
- CP' symmetry of Glashow's model helps to solve strong CP violation problem in QCD.
- Tera-neutrino is unstable, because it gives Dirac see-saw mass to normal neutrino.
- UUU as the new form of hadron - bound by ChromoCoulomb forces. It's size is about 1/alpha_QCD m_U about 10^-16 cm and it weakly interacts with hadrons.

Cosmological tera-fermion asymmetry

$$\Omega_{(UUUEE)} \equiv \Omega_{CDM} = 0.224$$

$$\Omega_b = 0.044$$

- To saturate the observed dark matter of the Universe Glashow assumed tera-U-quark and tera-electron excess generated in the early Universe.
- The model assumes tera-fermion asymmetry of the Universe, which should be generated together with the observed baryon (and lepton) asymmetry

However, this asymmetry can not suppress primordial antiparticles, as it is the case for antibaryons due to baryon asymmetry

(Ep) catalyzer

- In the expanding Universe no binding or annihilation is complete. Significant fraction of products of incomplete burning remains. In Sinister model they are: (UUU), (UUu), (Uud), [(UUU)E], [(UUu)E], [(Uud)E], as well as tera-positrons and tera-antibaryons
- Glashow's hope was that at T<25keV all free E bind with protons and (Ep) « atom » plays the role of catalyzer, eliminating all these free species, in reactions like

$$[(UUU)E] + (Ep) \to [(UUU)EE] + p$$

$$E^+ + (Ep) \to (E^+E) + p$$

But this hope can not be realized, since much earlier all the free E are trapped by He

Tera Leptons in Glashow's Sinister Universe

- Moreover, in opposition to almost effective pair Tera-Quark U annihilations (like common proton-anti-proton), there is no such an early or late Tera-Lepton pairs suppressions, because:
- a) electromagnetic interactions are "weaker" than nuclear ones because their coupling is smaller and mainly because the cross sections is proportional to inverse square Tera-Lepton Mass
- b) helium ion 4He++ is able

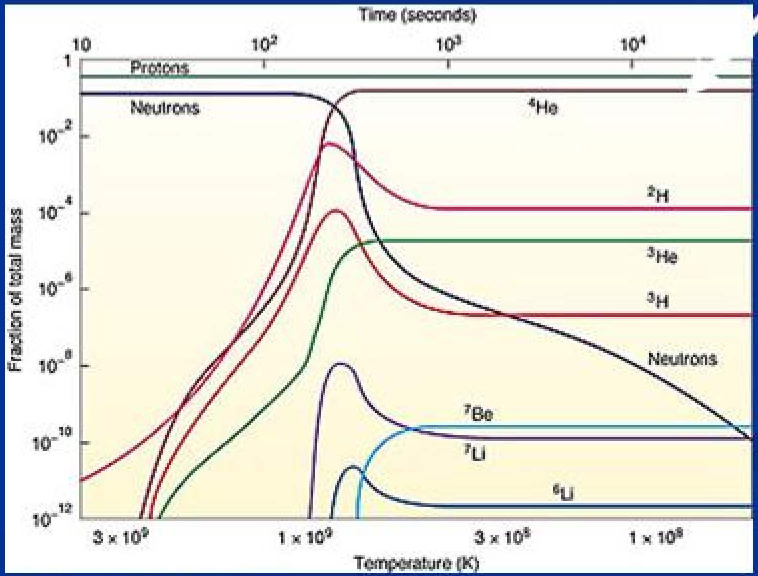
to attract and capture,

E-, fixing it into a hybrid

tera helium "ion" trap.

This takes place during the first

few minutes of the Universe



Why Grave Shadows over the Sinister universe?

- The helium ion $^4He^{++}$ capture of E^- leads to a pile up of relic $(^4HeE)^+$ traces, a lethal compound for any Sinister Universe.
- This capture leaves no Tera-Lepton frozen in Ep relic (otherwise an ideal catalyzer to achieve effective late E^+E^- annihilations possibly saving the model).
- The $(^4HeE)^+$ Coulomb screening is also avoiding the synthesis of the desired UUUEE hidden dark matter gas. The $e(^4HeE)^+$ behave chemically like an anomalous hydrogen isotope.
- Also tera-positronium (eE^+) relics are over-abundant and they behave like an anomalous hydrogen atom:

HE-cage for negatively charged components of composite dark matter – No go theorem for -1 charge components

- If composite dark matter particles are « atoms », binding positive P and negative E charges, all the free primordial negative charges E bind with He-4, as soon as helium is created in SBBN.
- Particles E with electric charge -1 form +1 ion [E He].
- This ion is a form of anomalous hydrogen.
- Its Coulomb barrier prevents effective binding of positively charged particles P with E. These positively charged particles, bound with electrons, become atoms of anomalous istotopes
- Positively charged ion is not formed, if negatively charged particles E have electric charge -2.

4-th family

$\begin{pmatrix} N \\ E \end{pmatrix}$ m~50 GeV, (quasi)stable

100 GeV <m<~1 TeV, *E ->N lν,…* unstable

$\begin{pmatrix} U \\ D \end{pmatrix}$ 220 GeV <m<~1 TeV, *U -> N + light fermions* Long-living wihout mixing with light generations

220 GeV <m<~1 TeV, *D -> U lν,…* unstable

Precision measurements of SM parameters admit existence of 4th family, if 4th neutrino has mass around 50 GeV and masses of E, U and D are near their experimental bounds.

If U-quark has lifetime, exceeding the age of the Universe, and in the early Universe excess of anti-U quarks is generated, primordial U-matter in the form of **AN**ti-**U**-**T**ripple-**I**ons of **U**nknown **M**atter (anutium).

$\Delta_{\bar{U}\bar{U}\bar{U}} \equiv (\overline{UUU})$ can become a -2 charge constituent of composite dark matter

4th neutrino with mass 50 GeV can not be dominant form of dark matter. But even its sparse dark matter component can help to resolve the puzzles of direct and indirect WIMP searches.

Dominant forms of dark matter

Example 1: Heavy quarks

O-Helium formation

$$I_o = Z_{He}^2 Z_\Delta^2 \alpha^2 m_{He} = 1.6 MeV$$

$$T < I_o$$

$$\left(\bar{U}\bar{U}\bar{U}\right) + {}^4He \Rightarrow \left[\left(\bar{U}\bar{U}\bar{U}\right) He\right] + \gamma$$

But it goes only after He is formed at T ~100 keV

The size of O-helium is

$$R_o = 1/\left(ZZ_{He}\alpha m_{He}\right) = 2 \cdot 10^{-13} cm$$

It catalyzes exponential suppression of all the remaining U-baryons with positive charge and causes new types of nuclear transformations

O-Helium: alpha particle with zero charge

- O-helium looks like an alpha particle with shielded electric charge. It can closely approach nuclei due to the absence of a Coulomb barrier. For this reason, in the presence of O-helium, the character of SBBN processes can change drastically.

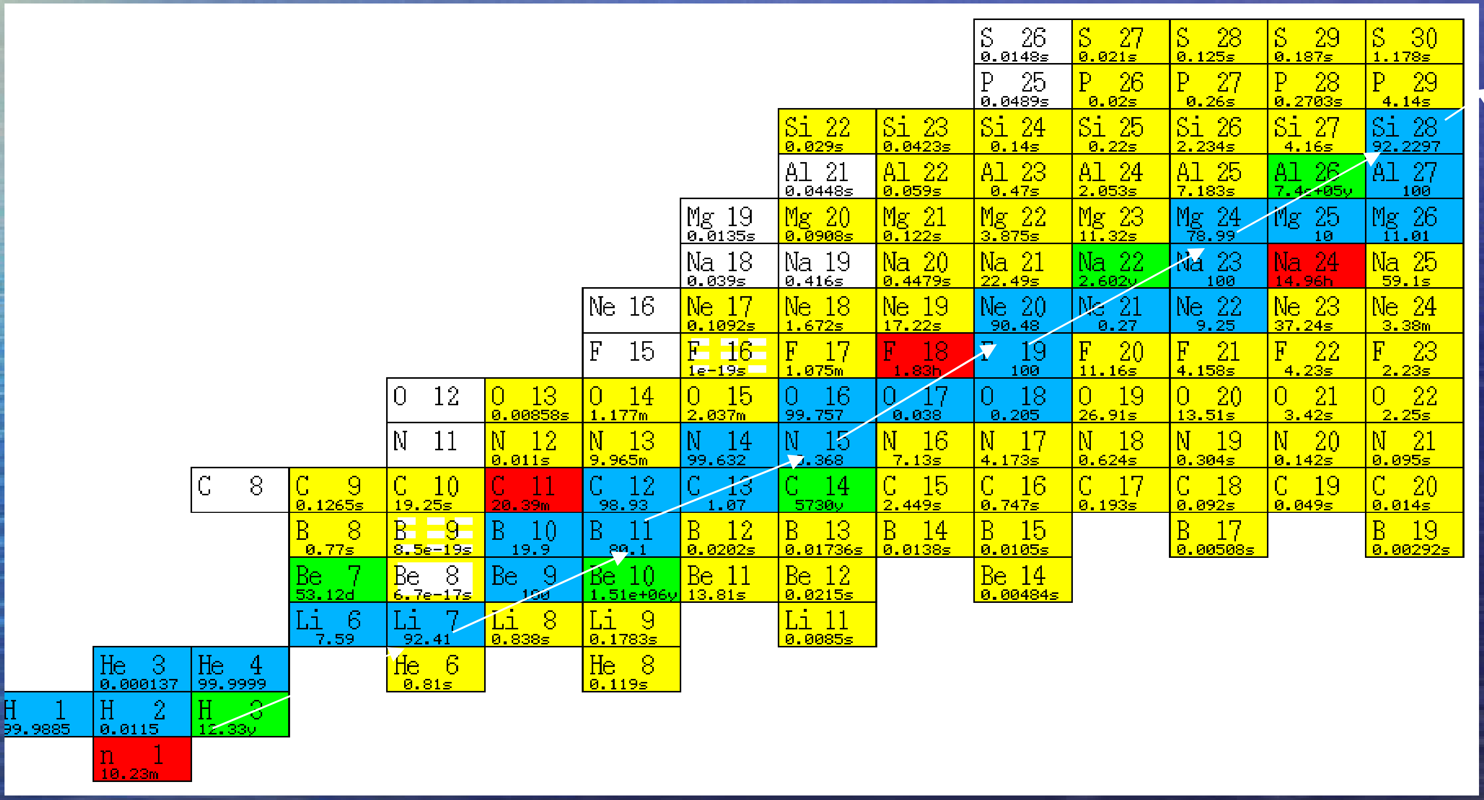
$$\left(A,Z\right)+\left[\left(\bar{U}\bar{U}\bar{U}\right)He\right]\rightarrow\left(A+4,Z+2\right)+\left(\bar{U}\bar{U}\bar{U}\right)$$

- This transformation can take place if

$$M\left(A,Z\right)+m_{He}-I_{o}>M\left(A+4,Z+2\right)$$

This condition is not valid for stable nuclids, participating in SBBN processes, but unstable tritium gives rise to a chain of O-helium catalyzed nuclear reactions towards heavy nuclides.

OHe catalysis of heavy element production in SBBN



OHe induced tree of transitions

		Sc 36 0.0162s	Sc 37 0.0294s	Sc 38 0.0522s	Sc 39 0.0921s	Sc 40 0.1823s	Sc 41 0.5963s	Sc 42 1.028m	Sc 43 3.891h	Sc 44 2.442d	Sc 45 100	Sc 46 83.79d	Sc 4 3.349
	Ca 34 0.0172s	Ca 35 0.0257s	Ca 36 0.102s	Ca 37 0.1811s	Ca 38 0.44s	Ca 39 0.8596s	Ca 40 96.941	Ca 41 1.03e+05y	Ca 42 0.647	Ca 43 0.135	Ca 44 2.086	Ca 45 162.6d	Ca 4 0.00
	K 33 0.031s	K 34 0.067s	K 35 0.19s	K 36 0.342s	K 37 1.226s	K 38 7.636m	K 39 93.2581	K 40 0.0117	K 41 6.7302	K 42 12.36h	K 43 22.3h	K 44 22.13m	K 4 17.3
Ar 31 0.0141s	Ar 32 0.098s	Ar 33 0.173s	Ar 34 0.8445s	Ar 35 1.775s	Ar 36 0.3365	Ar 37 34.95d	Ar 38 0.0632	Ar 39 269y	Ar 40 99.6003	Ar 41 1.822h	Ar 42 32.9y	Ar 43 5.37m	Ar 4 11.87
Cl 30 0.0474s	Cl 31 0.15s	Cl 32 0.298s	Cl 33 2.511s	Cl 34 32m	Cl 35 75.78	Cl 36 3.01e+05y	Cl 37 24.22	Cl 38 37.24m	Cl 39 55.6m	Cl 40 1.35m	Cl 41 38.4s	Cl 42 6.8s	Cl 4 3.3
S 29 0.187s	S 30 1.178s	S 31 2.572s	S 32 94.93	S 33 0.76	S 34 4.29	S 35 87.51d	S 36 0.02	S 37 5.05m	S 38 2.838h	S 39 11.5s	S 40 8.8s	S 41 2.6s	S 4 0.56
P 28 0.2703s	P 29 4.14s	P 30 2.498m	P 31 100	P 32 14.26d	P 33 25.34d	P 34 12.43s	P 35 47.3s	P 36 5.6s	P 37 2.31s	P 38 0.64s	P 39 0.16s	P 40 0.26s	P 4 0.12
Si 27 4.16s	Si 28 92.2297	Si 29 4.6832	Si 30 3.0872	Si 31 2.622h	Si 32 172y	Si 33 6.18s	Si 34 2.77s	Si 35 0.78s	Si 36 0.45s	Si 37 0.116s	Si 38 0.0688s	Si 39 0.0351s	Si 4 0.017
Al 26 7.4e+05y	Al 27 100	Al 28 2.241m	Al 29 6.56m	Al 30 3.6s	Al 31 0.644s	Al 32 0.033s	Al 33 0.2s	Al 34 0.0563s	Al 35 0.0386s	Al 36 0.09s	Al 37 0.022s	Al 38 0.016s	Al 3 0.009

After K-39 the chain of transformations starts to create unstable isotopes and gives rise to an extensive tree of transitions along the table of nuclides

Complicated set of problems

- Successive works by Pospelov (2006) and Kohri, Takayama (2006) revealed the uncertainties even in the roots of this tree.
- The « Bohr orbit » $I_o = Z_{He}^2 Z_\Delta^2 \alpha^2 m_{He} = 1.6 MeV$ value is claimed as good approximation by Kohri, Takayama, while Pospelov offers reduced value for this binding energy. Then the tree, starting from D is possible.
- The self-consistent treatment assumes the framework, much more complicated, than in SBBN.

O-helium warm dark matter

$$T < T_{od} = 1keV$$

$$n_b \langle \sigma v \rangle \left(m_p / m_o \right) t < 1$$

$$T_{RM} = 1eV$$

$$M_{od} = \frac{T_{RM}}{T_{od}} m_{Pl} \left(\frac{m_{Pl}}{T_{od}} \right)^2 = 10^9 M_{e}$$

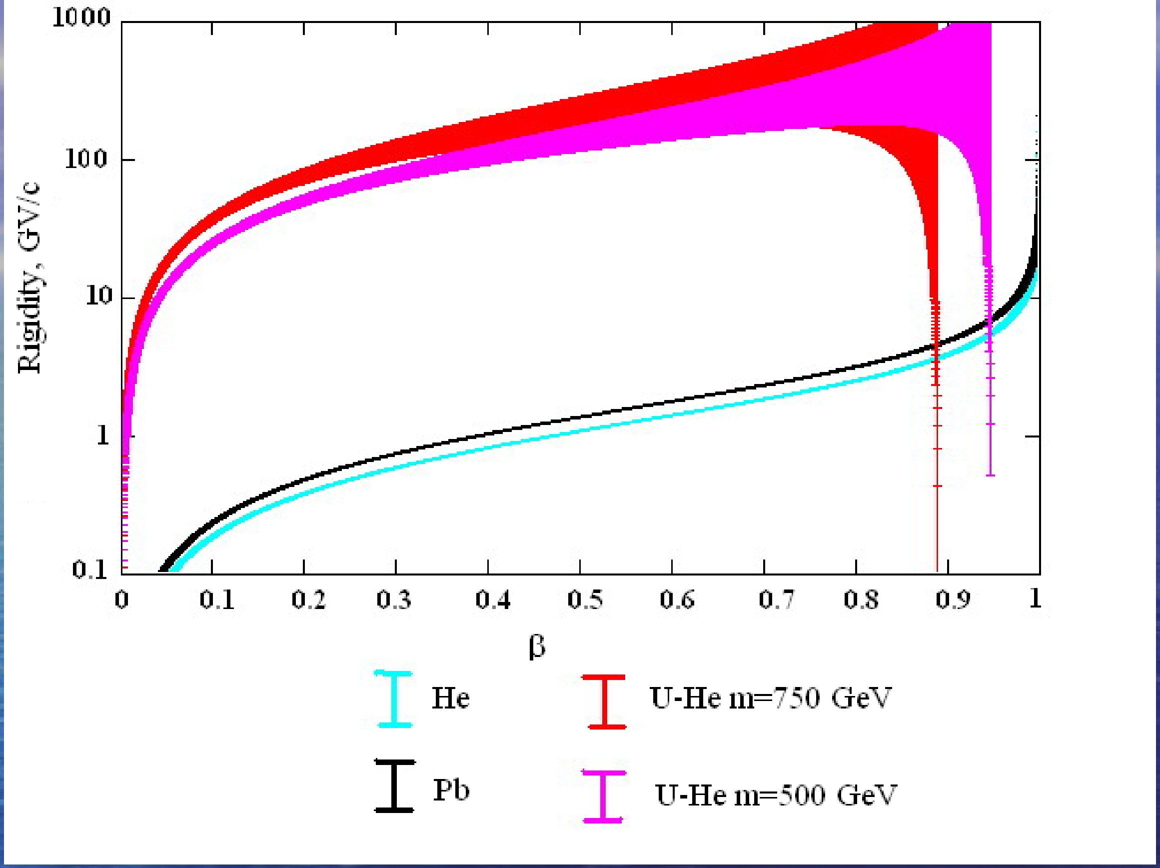
- Energy and momentum transfer from baryons to O-helium is not effective and O-helium gas decouples from plasma and radiation
- O-helium dark matter starts to dominate
- On scales, smaller than this scale composite nature of O-helium results in suppression of density fluctuations, making O-helium gas more close to warm dark matter

Anutium component of cosmic rays

$$\frac{(\bar{U}\bar{U}\bar{U})}{{}^{4}He} < 10^{-7}$$

- Galactic cosmic rays destroy O-helium. This can lead to appearance of a free anutium component in cosmic rays.

Such flux can be accessible to PAMELA and AMS-02 experiments



Rigidity of anutiium component of cosmic rays

Difference in rigidity provides discrimination of anutium and ordinary nuclear components

O-helium in Earth

- In the reaction

$$(A,Z) + \left[(\bar{U}\bar{U}\bar{U})\,He\right] \rightarrow (A+4, Z+2) + (\bar{U}\bar{U}\bar{U})$$

The final nucleus is formed in the excited [He, M(A, Z)] state, which can rapidly experience αlpha decay, giving rise to (OHe) regeneration and to effective quasi-elastic process of (OHe)-nucleus scattering.

If quasi-elastic channel dominates the in-falling flux sinks down the center of Earth and there should be no more than

$$r_o < 5 \cdot 10^{-23}$$

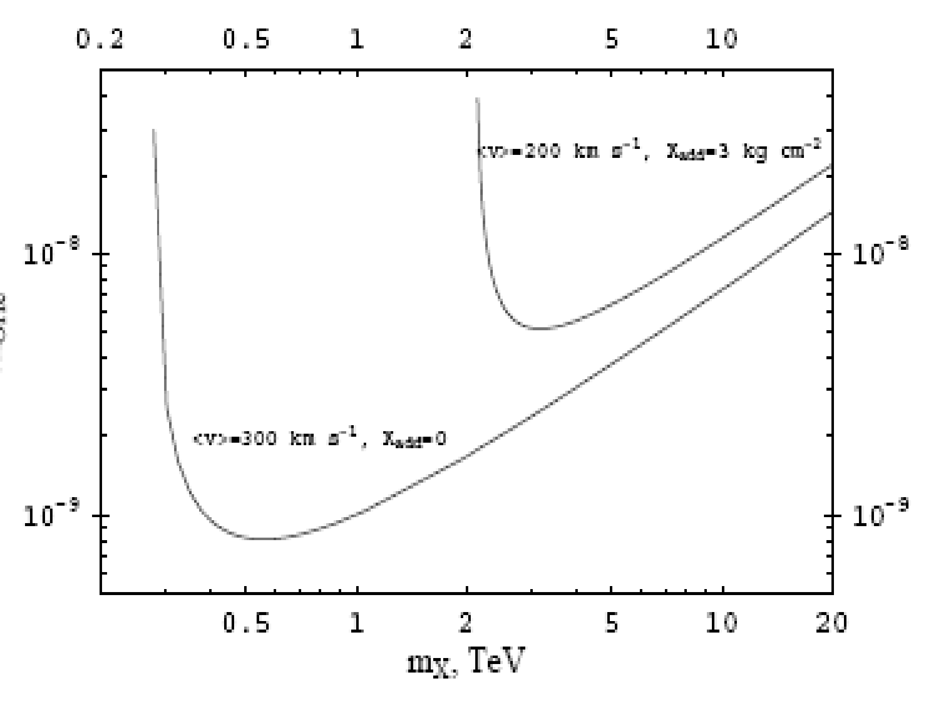
of anomalous isotopes around us, being below the experimental upper limits for elements with Z ≥ 2.

O-helium experimental search?

- In underground detectors, (OHe) “atoms” are slowed down to thermal energies far below the threshold for direct dark matter detection. However, (OHe) destruction can result in observable effects.
- O-helium gives rise to less than 0.1 of expected background events in XQC experiment, thus avoiding severe constraints on Strongly Interacting Massive Particles (SIMPs), obtained from the results of this experiment.

It implies development of specific strategy for direct experimental search for O-helium.

Superfluid He-3 search for O-helium



- Superfluid He-3 detectors are sensitive to energy release above 1 keV. If not slowed down in atmosphere O-helium from halo, falling down the Earth, causes energy release of 6 keV.
- Even a few g existing device in CRTBT-Grenoble can be sensitive and exclude heavy O-helium, leaving an allowed range of U-quark masses, accessible to search in cosmic rays and at LHC and Tevatron

O-helium Universe?

- The proposed scenario is the minimal for composite dark matter. It assumes only the existence of a heavy stable U-quark and of an anti-U excess generated in the early Universe to saturate the modern dark matter density. Most of its signatures are determined by the nontrivial application of known physics. It might be too simple and too pronounced to be real. With respect to nuclear transformations, O-helium looks like the “philosopher’s stone,” the alchemist’s dream. That might be the main reason why it cannot exist.
- However, its exciting properties put us in mind of Voltaire: “Se O-helium n’existai pas, il faudrai l’inventer.”

Example 2: AC-model

Extension of Standard model by two new doubly charged « leptons » $(A^{--} \text{ and } C^{++})$

Form neutral atoms (AC, O-helium,….)-> composite dark matter candidates!

They are leptons, since they possess only γ and Z (and new, y-) interactions

+ follows from unification of General Relativity and gauge symmetries on the basis of almost commutative (AC) geometry (Alain Connes)

+ DM (AC) "atoms"

Mass of AC-leptons has « geometric origin ». Experimental constraint $m_A = m_C = m > 100GeV$

We take m=100GeV S_2

Their charge is not fixed and is chosen +-2 from the above cosmological arguments.

Their absolute stability can be protected by a strictly conserved new U(1) charge, which they possess.

In the early Universe formation of AC-atoms is inevitably accompanied by a fraction of charged leptons, remaining free.

Exotic primordial forms of A and C matter

AC-matter is dominantly in the form of (AC) atoms. Their size is

$$R_{AC} = 1/\left(Z_A Z_C \alpha m\right) = 1.37 \cdot 10^{-14} S_2 cm$$

and they weakly interact with matter.

However, there inevitably remains a fraction of the order of $\frac{n}{n_b} = 10^{-7}$

of

- Anion-type (-2 charge) leptons A, bound in the first three minutes with He in neutral Ole-helium.
- Cathion-type (+2 charge) leptons C in a form of anomalous helium, which should be suppressed in Earth down to

$$r < 10^{-19}$$

Mechanisms of suppression of anomalous helium imply OLe helium catalysis of (AC) binding in dense matter objects. This catalysis is effective, if AC-leptons possess a U(1) gauge charge.

Dense AC-matter bodies inside stars and planets?

Inside a dense matter body (OHe) catalyzes C aggregation into (AC)-atoms in the reaction

$$(eeC^{++}) + (A^{--}He) \to (AC) + He + 2e.$$

In the result of this reaction (OHe), interacting with matter with a nuclear cross section given by

$$\sigma_{trAb} = \pi R_{OHe}^2 \frac{m_p}{m_A} \approx 10^{-27}/S_2\,\mathrm{cm}^2,$$

and (eeC^{++}), having a nearly atomic cross section of that interaction

$$\sigma_{tra} = \sigma_a (m_p/m_C) \approx 10^{-18} S_2\,\mathrm{cm}^2,$$

bind into weakly interacting (AC)-atom, which decouples from the surrounding matter.

In this process "products of incomplete AC-matter combustion" (OLe-helium and anomalous helium), which were coupled to the ordinary matter by hadronic and atomic interactions, convert into (AC) atoms, which immediately sinks down to the center of the body.

Growth and evolution of (*AC*)-atomic conglomeration inside the matter body may lead to the formation of a dense self-gravitating (*AC*)-matter object, which can survive after the star, inside which it was formed, exploded.

Example 3: WTC-model

Charged techniparticles

- Technibaryon UU is the lightest. It has charge +2, while its stable antiparticle has charge -2.
- If TB is conserved, $\bar{U}\bar{U}$ is main constituent of composite dark matter.
- If L’ is conserved, composite dark matter is provided by technilepton ζ with charge -2.
- Their mixture contributes composite dark matter, if both the technilepton number L’ and are TB conserved.

Techniparticle excess

- The advantage of WTC framework is that it provides definite relationship between baryon asymmetry and techniparticle excess.

$$\frac{TB}{B} = -\sigma_{UU}\left(\frac{L'}{B}\frac{1}{3\sigma_\zeta} + 1 + \frac{L}{3B}\right)$$

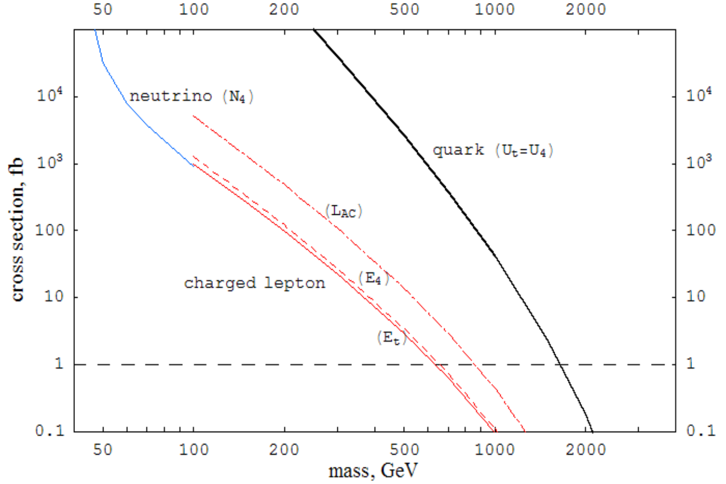
Here $\sigma_i \; (i = UU, \zeta)$ are statistical factors in equilibrium relationship between, TB, B, L and L'

For reasonable choice of parameters observed baryon asymmetry corresponds to techniparticle excess, saturating observed DM density.

A WTC Universe?

- Even minimal, WTC model gives a wide variety of possibilities for composite dark matter scenario.
- It provides relationship between baryon asymmetry and dark matter.
- It makes possible nearly WDM (techni-O-helium) or mixed WDM+CDM scenarios
- Techni-O-helium is necessary (and even dominant) element of such scenarios

LHC discovery potential for components of composite dark matter



- In the context of composite dark matter search for new (meta)stable quarks and leptons acquires the meaning of crucial test for its basic constituents
- The level of abscissa axis corresponds to the minimal level of LHC sensitivity during 1year of operation

Conclusions

- Composite dark matter and its basic constituents are not excluded either by experimental, or by cosmological arguments and are the challenge for cosmic ray and accelerator search

- Small fraction or even dominant part of composite dark matter can be in the form of O-helium, catalyzing new form of nuclear transformation

- The program of test for composite dark matter in cosmoparticle physics analysis of its signatures and experimental search for stable charged particles in cosmic rays and at accelerators is available

Virtual Institute on Astroparticle physics (VIA) -

A possible regular interactive form of collaboration in cross-disciplinary study of fundamental relationship between micro- and macro-worlds

Gravitino in SUSY models

- Local SUSY models predict SUSY partner of graviton with spin 3/2 – gravitino, having semi-gravitational interaction $\propto 1/m_{Pl}$
- In a wide variety of models gravitino mass is determined by SUSY breaking scale (~100 GeV)
- In such models gravitino is unstable with lifetime

$$\tau = a\left(\frac{m_{Pl}}{m_G}\right)^3 \frac{1}{m_{Pl}} \approx 10^8 s\left(\frac{100GeV}{m_G}\right)^3$$

- If created in early Universe it should decay at $t = \tau$ and give rise to non-equilibrium particles from decay channels

$$G \to g\tilde{g};\gamma\tilde{\gamma} \Rightarrow g \to hadrons$$

Problem of primordial gravitino

- Due to superweak semi-gravitational interaction gravitino could not be in equilibrium in early Universe, but it could be produced in reactions with SUSY particles.
- Abundance of primordial gravitino mass is determined by reheating temperature

$$r_G = \frac{n_G}{n_\gamma} \approx \frac{T_{reheating}}{m_{Pl}}$$

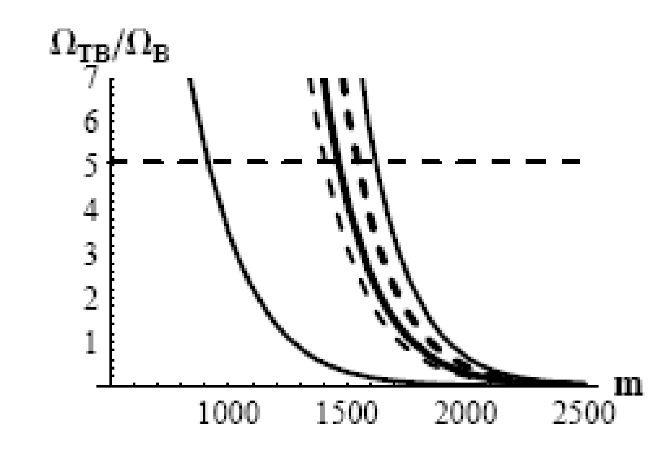
- Hadronic cascades from gravitino decay induce Li production

$$G \to \tilde{g}g \Rightarrow g \to N\overline{N} \Rightarrow \overline{N}\,{}^4He \to T + \ldots \Rightarrow T + {}^4He \to {}^6Li + n$$

- From observed lithium abundance follows $T_{reheating} < 4 \cdot 10^6\,GeV$
- Problem of primordial gravitino (baryogenesis?)

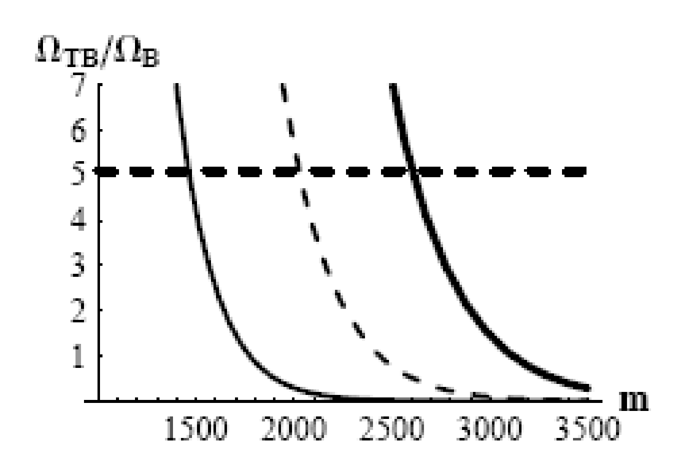
Relationship between TB and B

$$\xi = \frac{L'}{3B\sigma_\zeta} + 1 + \frac{L}{3B}$$



- L'=0, T*=150 GeV

ξ =0.1; 1; 4/3; 2; 3

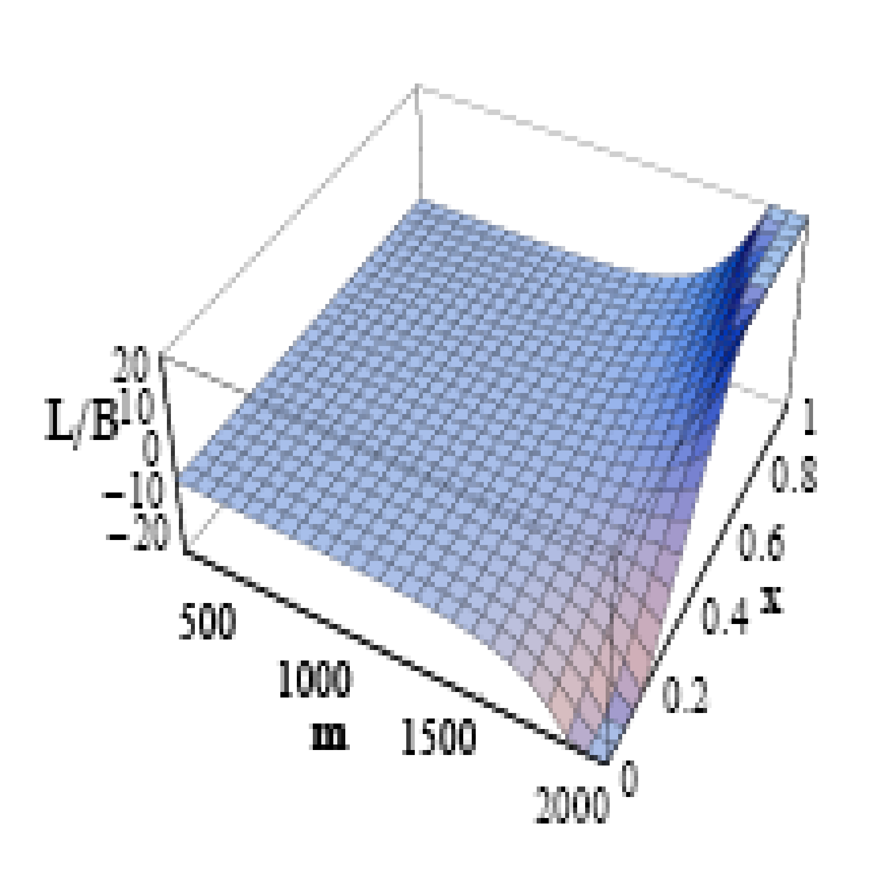


$\xi = 4/3$

- L'=0,

T*=150, 200, 250 GeV

Relationship between TB, L' and B



- x denotes the fraction of dark matter given by the technibaryon
- TB<0, L'>0 – two types of -2 charged techniparticles.

The case TB>0, L'>0 (TB<0, L'<0) gives an interesting possibility of (-2 +2) atom-like WIMPs, similar to AC model. For TB>L' (TB<L') no problem of free +2 charges

Search for anutium in cosmic rays

$$\frac{n_4}{n_p} \sim 10^{-6} \div 10^{-13}$$