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The nature of dark matter in the context of Zeldovich's legacy in cosmoparticle physics

SAI, 14 March 2019

Seminar dedicated to 105 Anniversary of Ya. B. Zeldovich

Outlines

- Cosmological impact of new stable particles.
- Puzzles of direct and indirect searches for dark matter

The bedrocks of modern cosmology

Our current understanding of structure and evolution of the Universe implies three necessary elements of Big Bang cosmology that can not find physical grounds in the standard model of electroweak and strong interactions. They are:

- Inflation
- Baryosynthesis
- Dark matter/energy

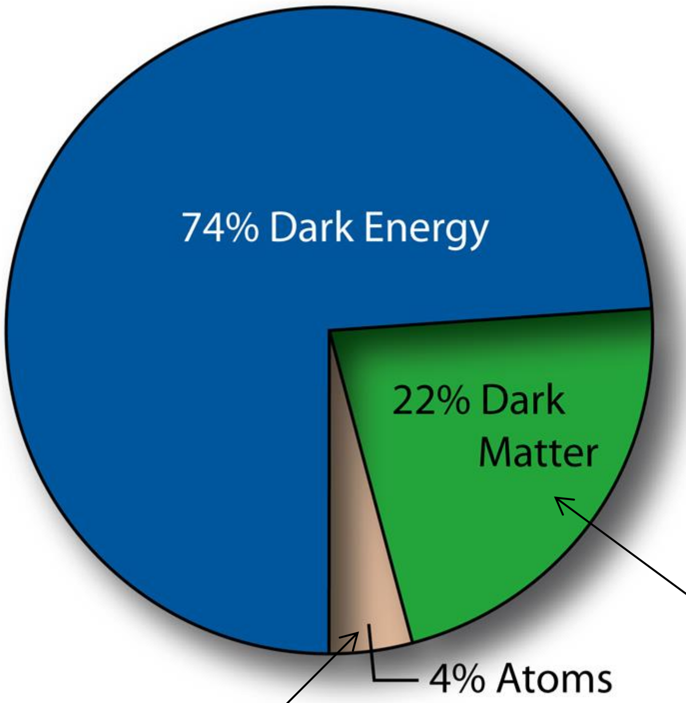
All these phenomena imply extension of the Standard Model of Strong (QCD) and Electroweak Interactions. On the other hand, studies of physics Beyond the Standard Model involve Cosmology for their probe.

COSMOPARTICLE PHYSICS studies the fundamental relationship of

COSMOlogy and PARTICLE PHYSICS

in the complex cross-disciplinary physical and astronomical research

Composition of the Universe



$$\Omega \equiv \frac{\rho}{\rho_{cr}}$$

$$\Omega_b \approx 0.044 \qquad \Omega_{CMB} \approx 0.5 \cdot 10^{-4}$$

$$\Omega_{DM} \approx 0.20$$

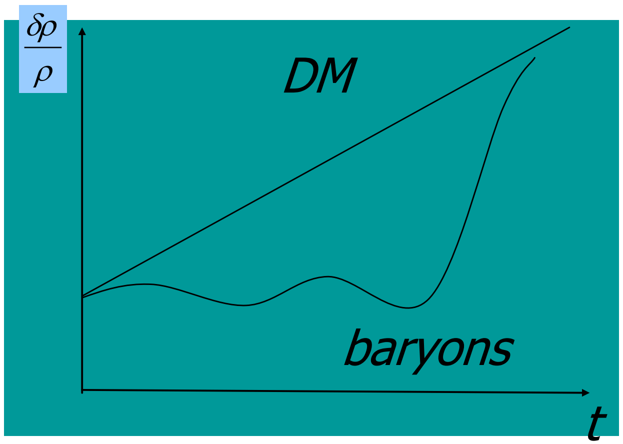
$$\Omega_\Lambda \approx 0.7$$

$$\Omega_{tot} \approx 1.0$$

Baryonic matter consists of atoms

Can dark Matter consist of Dark atoms?

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 – Cosmological Reflection of Microworld Structure

Dark Matter should be present in the modern Universe, and thus is stable on cosmological scale.

This stabilty reflects some Conservation Law, which prohibits DM decay.

Following Noether’s theorem this conservation law should correspond to a (nearly) strict symmetry of microworld.

Dark matter and the mass of neutrino

Astrophysical implications of the neutrino rest mass. III. Nonlinear growth of perturbations and the missing mass

A. G. Doroshkevich, Ya. B. Zel'dovich, R. A. Syunyaev, and M. Yu. Khlopov

Keldysh Institute of Applied Mathematics, USSR Academy of Sciences, Moscow, and Institute for Space Research, USSR Academy of Sciences, Moscow

(Submitted May 28, 1980)

Pis'ma Astron. Zh. **6**, 465–469 (August 1980)

A discussion is given of the influence that a finite rest mass for the neutrino would have on the phenomenon of "missing mass" in galaxies and clusters of galaxies, on the nonlinear stage in the evolution of primordial irregularities, and on the problem of observing neutral hydrogen in the spectrum of distant quasars.

In 1980 the experimental claims on the existence of the mass of electron neutrino about 30 eV lead to immediate cosmological consequence of the neutrino dominated Universe, In which massive neutrinos play the role of dark matter.

Axion

Some astrophysical limitations on the axion mass

M. I. Vysotsskii, Ya. B. Zel'dovich, M. Yu. Khlopov, and V. M. Chechetkin

Institute of Applied Mathematics, USSR Academy of Sciences

(Submitted 27 March 1978)
Pis'ma Zh. Eksp. Teor. Fiz. **27**, No. 9, 533–536 (5 May 1978)

A comparison of the axion luminosity of the sun with the observed photon luminosity leads to the lower bound $\mu_a >$ 25 keV. This bound can be raised to $\mu_a > 200$ keV by resorting to modern ideas concerning the structure of supergiants.

Stable DM models

For weakly interacting particles that were in equilibrium, the scale of structure is in the inverse dependence on mass of particles:

- Hot Dark Matter (HDM) – particles with mass of tens eV (scale of superclusters)
- Cold Dark Matter (CDM) – particles with mass, exceeding GeVs (planet scale – biasing)
- Warm Dark Matter (WDM) – particles with mass few keV (scale of galaxies)

Unstable DM models

For metastable particles the necessary condition to form the structure is to have lifetime, exceeding the time of structure formation :

- Unstable Dark Matter (UDM) – particles with lifetime, less than the age of the Universe. Modern dark matter is explained by primordial particles and/or their decay products.
- Decaying Dark Matter (DDM) – particles with lifetime, exceeding the age of the Universe. Their decays can be a source of CR anomalies.

The list of some physical candidates for DM

- Sterile neutrinos – physics of neutrino mass
- Axions – problem of CP violation in QCD
- Axinos - SUSY
- Gravitinos - SUGRA
- Neutralinos - SUSY
- KK-particles: B_{KK1}
- Anomalous hadrons, O-helium
- Supermassive particles…
- Mirror and shadow particles, PBHs…

WIMP

(weakly interacting massive particles)

SIMP

(strongly interacting massive particles)

THE PUZZLES
OF DARK MATTER SEARCH

Direct seaches for Dark Matter

Possibility of detecting relict massive neutrinos

V. F. Shvartsman, V. B. Braginskiĭ, S. S. Gershteĭn, Ya. B. Zel'dovich, and M. Yu. Khlopov
M. V. Keldysh Institute of Applied Mathematics, Academy of Sciences of the USSR

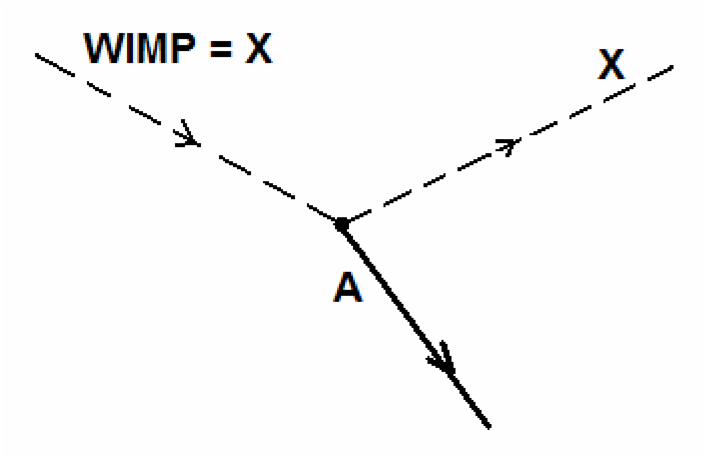
(Submitted 18 August 1982)
Pis'ma Zh. Eksp. Teor. Fiz. **36**, No. 6, 224–226 (20 September 1982)

The coherent intensification of the interaction of relict massive neutrinos with grains of matter with a size on the order of the neutrino wavelength suggests that it might be possible to detect a galactic neutrino sea by virtue of the mechanical pressure which it exerts in the direction opposite that in which the solar system is moving in the galaxy.

WIMP-nucleus interaction

CDM can consist of Weakly Interacting Massive Particles (WIMPs).

Such particles can be searched by effects of WIMP-nucleus interactions.



$$\Delta T = 0 \div \Delta T_{\max} = \frac{q_{\max}^2}{2m_A} = \frac{2\mu^2 v^2}{m_A} \xrightarrow[m_X >> m_A]{} 2 m_A v^2$$

$$v \sim 300 \frac{\text{km}}{\text{s}}, \qquad \Delta T \sim 10 \text{keV}$$

$\Delta T_{\max} < E_A^* \Rightarrow$ *elastic scattering*

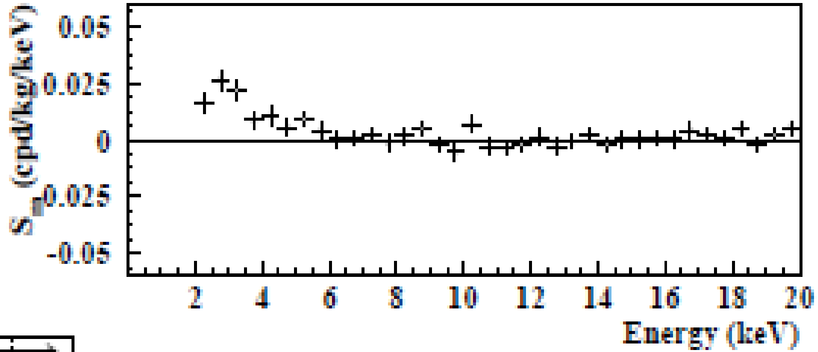
$q_{(\max)} R_A > 1 \Rightarrow$ *non-pointlike nucleus*

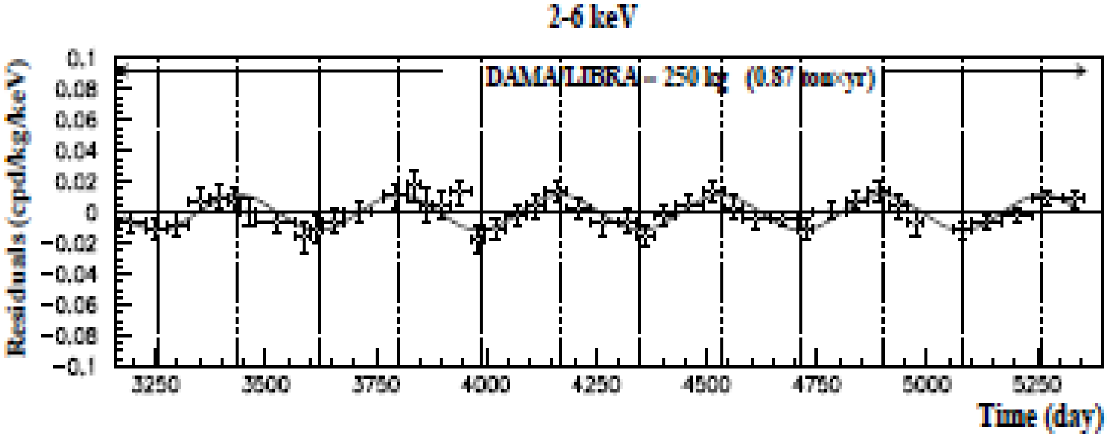
$$Interaction\ amplitude \equiv A_{AX} = A_{AX}^{\text{point}} \cdot F_A(q^2)$$

Direct search for DM (WIMPs)

DAMA/NaI (7 years) + DAMA/LIBRA (6 years) total exposure: 1.17 ton×yr

$$R(t) = S_0 + S_m \cos[\omega(t - t_0)]$$



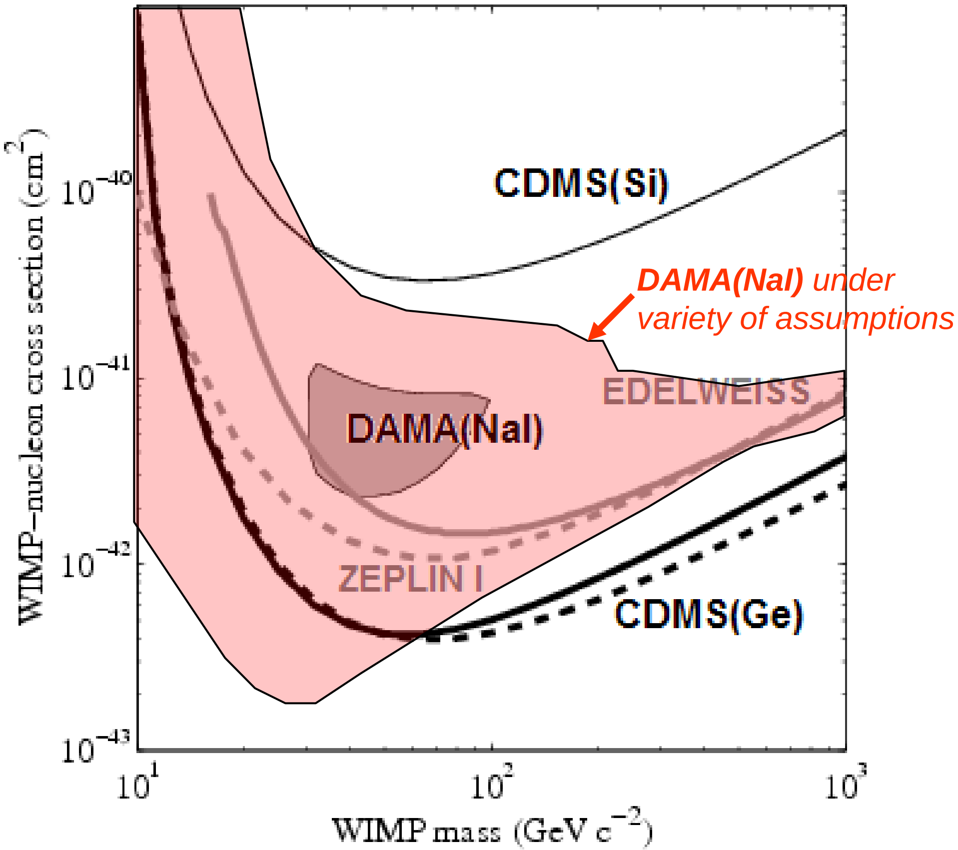


Confidence level 8.9

R.Bernabei et al, arXiv: 1007.0595, 4 July 2010

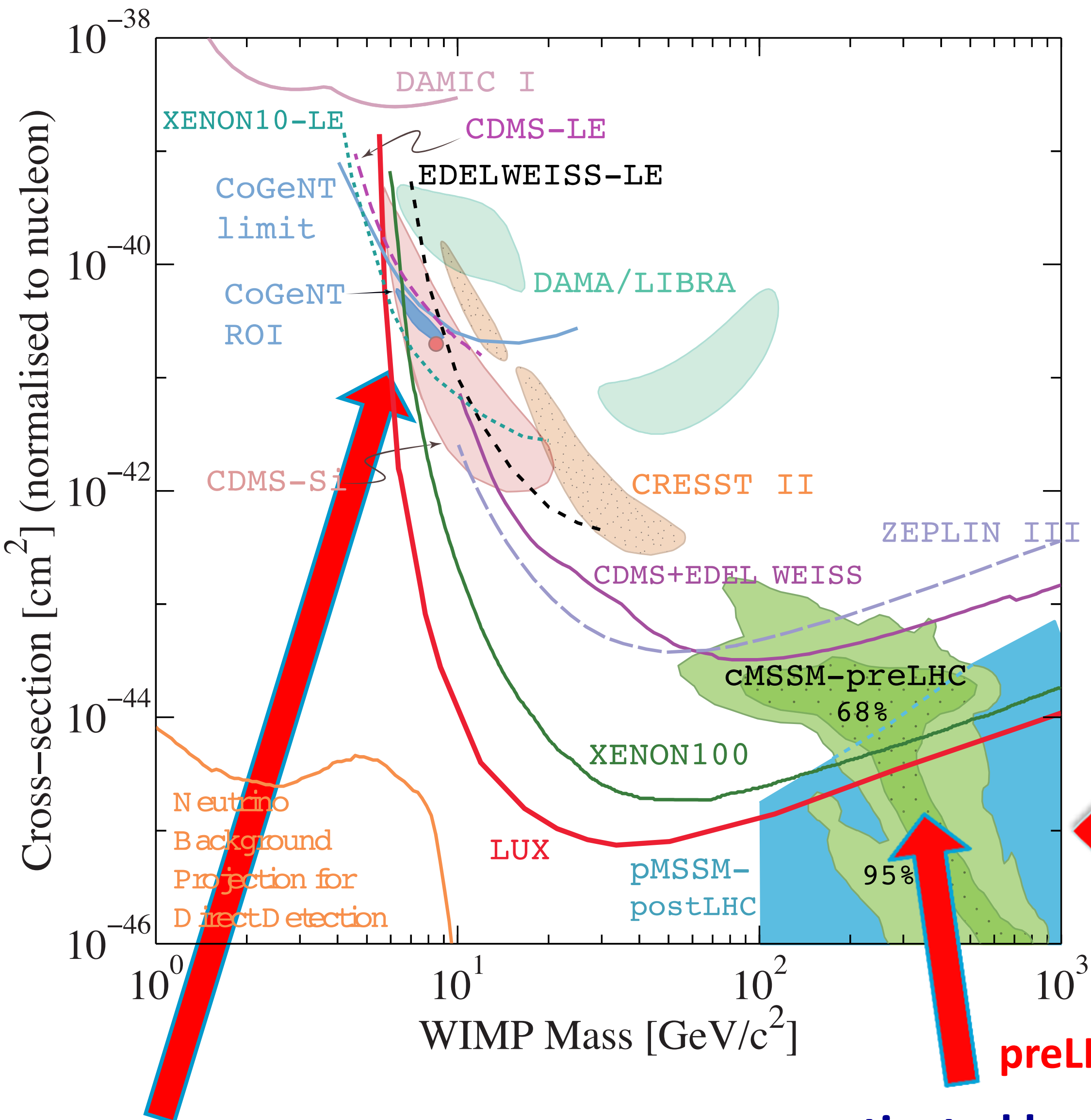
Direct search for WIMPs

Experiment DAMA (*NaI*) vs other underground experiments:
Interpretation in terms of ***scalar*** *AX*-interaction.



Analysis depends essentially on assumption about distribution of DM in vicinity of Solar system. On this picture a quite simplified assumption was adopted.

Direct Detection Nov. 2013



PDG update 2013 (1204.2373)

LHC: theory region has moved down and right

in a very specific way

Smoking gun of SUSY?

preLHC!

motivated by theory (SUSY)

MasterCode, BayesFITS

Confusion region gone

DARK MATTER FROM CHARGED PARTICLES?

Baryonic Matter – atoms of stable quarks and charged lepton (electron)

- Ordinary matter consists of atoms
- Atoms consist of nuclei and electrons.
- Electrons are lightest charged particles – their stability is protected by the conservation of electric charge.
- Nuclei consist of nucleons, whose stability reflects baryon charge conservation.

In ordinary matter stable elementary particles are electrically charged, but bound in neutral atoms.

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 particles 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.

« 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.*

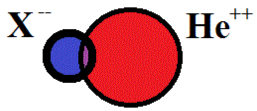
Nuclear-interacting composite dark matter: O-helium « atoms »

If we have a stable double charged particle X^{--} *in excess over its partner* X^{++} *it may create* *Helium like neutral atom (O-helium) at temperature* $T > I_o$

Where:

^{4}He is formed at T ~100 keV (t~100 s)
This means that it would rapidly create a neutral atom, in which all X^{--} are bound

$$X^{--} + {}^4He => (X\ He) + \gamma$$



The Bohr orbit of O-helium « atom » is of the order of radius of helium nucleus.

References

1. M.Yu. Khlopov, *JETP Lett.* 83 (2006) 1;
2. D. Fargion, M.Khlopov, C.Stephan, *Class. Quantum Grav.* 23 (2006) 7305;
2. M. Y. Khlopov and C. Kouvaris, *Phys. Rev.* D 77 (2008) 065002]

Constituents of composite dark matter

Few possible candidates for -2 charges:

Stable doubly charged "leptons" with mass >100 GeV (~1 TeV range):

- *AC « leptons » from almost commutative geometry*

D. Fargion, M.Khlopov, C.Stephan, Class. Quantum Grav. 23 (206) 7305

- *Technibaryons and technileptons from Walking Technicolor (WTC)*

M. Y. Khlopov and C. Kouvaris, Phys. Rev. D 77 (2008) 065002; M. Y. Khlopov and C. Kouvaris, Phys. Rev. D 78 (2008) 065040

Hadron-like bound states of:

- *Stable U-quark of 4-th family in Heterotic string phenomenology*

M.Yu. Khlopov, *JETP Lett.* 83 (2006) 1

- *Stable U-quarks of 5th family in the approach, unifying spins and charges*

N.S. Mankoc Borstnik, Mod. Phys. Lett. A 10 (1995) 587

M.Yu.Khlopov, A.G.Mayorov, E.Yu.Soldatov (2010), arXiv:1003.1144

O-HELIUM DARK MATTER

O-helium dark matter

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

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

$$T_{RM} = 1eV$$

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

- 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

O-helium in Earth

- Elastic scattering dominates in the (OHe)-nucleus interaction. After they fall down terrestrial surface the in-falling OHe particles are effectively slowed down due to elastic collisions with the matter. Then they drift, sinking down towards the center of the Earth with velocity

$$V = \frac{g}{n\sigma v} \approx 80 S_3 A_{med}^{1/2} \mathrm{cm/s}.$$

Here $A_{med} \sim 30$ is the average atomic weight in terrestrial surface matter, $n = 2.4 \cdot 10^{24}/A_{med}$ is the number of terrestrial atomic nuclei, σv is the rate of nuclear collisions and $g = 980\ \mathrm{cm/s^2}$.

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) nuclear reactions 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.

O-HELIUM DARK MATTER IN UNDERGROUND DETECTORS

O-helium concentration in Earth

The O-helium abundance the Earth is determined by the equilibrium between the in-falling and down-drifting fluxes.

The in-falling O-helium flux from dark matter halo is

$$F = \frac{n_0}{8\pi} \cdot |\overline{V_h} + \overline{V_E}|,$$

where $\boldsymbol{V_h}$ is velocity of Solar System relative to DM halo (220 km/s), $\boldsymbol{V_E}$ is velocity of orbital motion of Earth (29.5 km/s) and

$n_0 = 3 \cdot 10^{-4} S_3^{-1}\,\mathrm{cm}^{-3}$ is the local density of O-helium dark matter.

At a depth *L* below the Earth's surface, the drift timescale is ~*L/V.* It means that the change of the incoming flux, caused by the motion of the Earth along its orbit, should lead at the depth L ~ 10^5 cm to the corresponding change in the equilibrium underground concentration of OHe on the timescale

$$t_{dr} \approx 2.5 \cdot 10^2 S_3^{-1}\,\mathrm{s}$$

Annual modulation of O-helium concentration in Earth

The equilibrium concentration, which is established in the matter of underground detectors, is given by

$$n_{oE} = \frac{2\pi \cdot F}{V} = n_{oE}^{(1)} + n_{oE}^{(2)} \cdot sin(\omega(t - t_0)),$$

where $\omega = 2\pi/T$, T=1*yr* and $\boldsymbol{t_o}$ is the phase. The averaged concentration is given by

$$n_{oE}^{(1)} = \frac{n_o}{320 S_3 A_{med}^{1/2}} V_h$$

and the annual modulation of OHe concentration is characterized by

$$n_{oE}^{(2)} = \frac{n_o}{640 S_3 A_{med}^{1/2}} V_E$$

The rate of nuclear reactions of OHe with nuclei is proportional to the local concentration and the energy release in these reactions leads to ionization signal containing both constant part and annual modulation.

OHe solution for puzzles of direct DM search

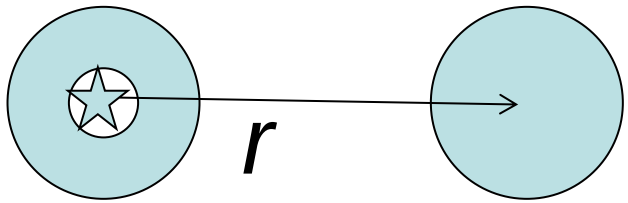
- OHe equilibrium concentration in the matter of DAMA detector is maintained for less than an hour
- The process

$$OHe + (A, Z) \Rightarrow [OHe(A, Z)] + \gamma$$

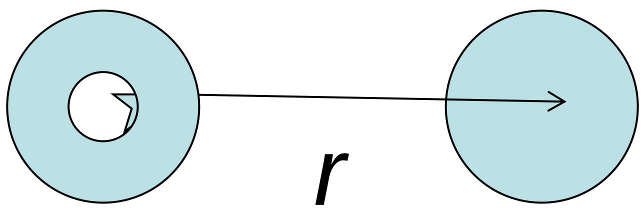
is possible, in which only a few keV energy is released. Other inelastic processes are suppressed

- Annual modulations in inelastic processes, induced by OHe in matter. No signal of WIMP-like recoil
- Signal in DAMA detector is not accompanied by processes with large energy release. This signal corresponds to a formation of anomalous isotopes with binding energy of few keV

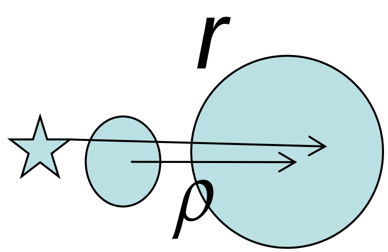
Potential of OHe-nucleus interaction



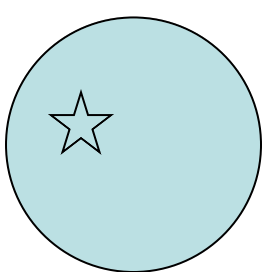
$$U_{Xnuc} = -2Z\alpha\left(\frac{1}{r} + \frac{1}{r_o}\right)\exp\left(-2r/r_o\right)$$



$$U_{Stark} = -\frac{2Z\alpha}{r^4}\frac{9}{2}r_o^3$$

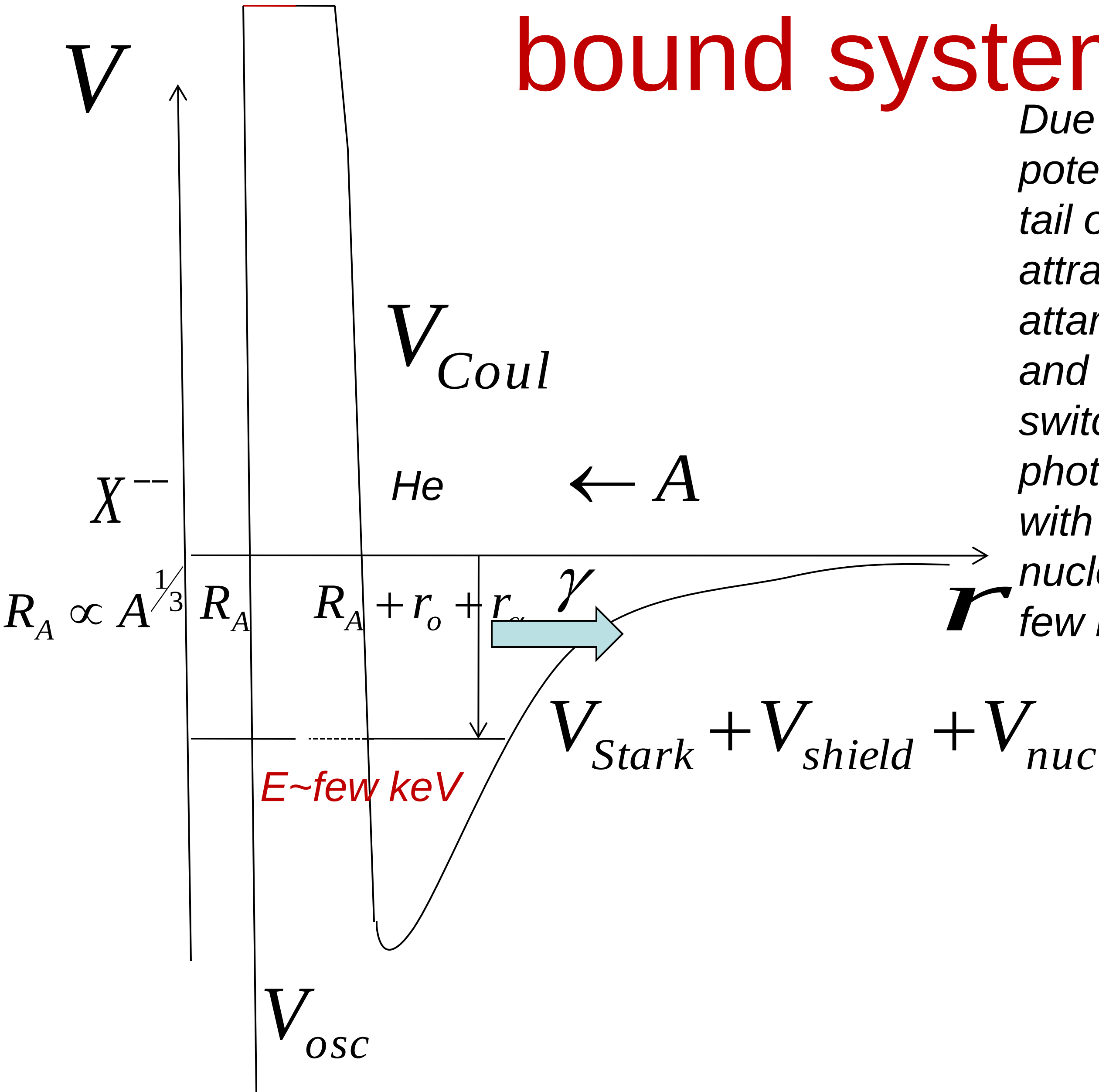


$$U_{Coul} = +\frac{2\alpha Z}{\rho} - \frac{2\alpha Z}{r}$$



$$U_{osc} = -\left[\frac{(Z+2)\alpha}{R}\left(1-\left(\frac{r}{R}\right)^2\right)\right]$$

Formation of OHe-nucleus bound system



Due to shielded Coulomb potential of X, Stark effect and tail of nuclear Yukawa force OHe attracts the nucleus. Nuclear attarction causes OHe excitation and Coulomb repulsion is switched on. If the system emits a photon, OHe forms a bound state with nucleus but ***beyond*** *the nucleus with binding energy of few keV.*

Few keV Level in OHe-nucleus system

- The problem is reduced to a quantum mechanical problem of energy level of OHe-nucleus bound state in the potential well, formed by shielded Coulomb, Stark effect and Yukawa tail attraction and dipole-like Coulomb barrier for the nucleus in vicinity of OHe. The internal well is determined by oscillatory potential of X in compound (Z+2) nucleus, in which He is aggregated.
- The numerical solution for this problem is simplified for rectangular wells and walls, giving a few keV level for Na.

Rate of OHe-nucleus radiative capture

As soon as the energy of level is found one can use the analogy with radiative capture of neutron by proton with the account for:

- Absence of M1 transition for OHe-nucleus system (which is dominant for n+p reaction)
- Suppression of E1 transition by factor $f \sim 10^{-3}$, corresponding to isospin symmetry breaking

(in the case of OHe only isoscalar transition is possible, while E1 goes due to isovector transition only)

Reproduction of DAMA/NaI and DAMA/LIBRA events

The rate of OHe radiative capture by nucleus with charge Z and atomic number A to the energy level E in the medium with temperature T is given by

$$\sigma v = \frac{f\pi\alpha}{m_p^2} \frac{3}{\sqrt{2}} \left(\frac{Z}{A}\right)^2 \frac{T}{\sqrt{A m_p E}}.$$

Formation of OHe-nucleus bound system leads to energy release of its binding energy, detected as ionization signal. In the context of our approach the existence of annual modulations of this signal in the range 2-6 keV and absence of such effect at energies above 6 keV means that binding energy of Na-Ohe system in DAMA experiment should not exceed 6 keV, being in the range 2-4 keV.

Annual modulation of signals in DAMA/NaI and DAMA/LIBRA events

The amplitude of annual modulation of ionization signal (measured in counts per day per kg, cpd/kg) is given by

$$\zeta = \frac{3\pi\alpha \cdot n_o N_A V_E t Q}{640\sqrt{2} A_{med}^{1/2}(A_I + A_{Na})} \frac{f}{S_3 m_p^2} (\frac{Z_i}{A_i})^2 \frac{T}{\sqrt{A_i m_p E_i}} = 4.3 \cdot 10^{10} \frac{f}{S_3^2} (\frac{Z_i}{A_i})^2 \frac{T}{\sqrt{A_i m_p E_i}}.$$

This value should be compared with the integrated over energy bins signals in DAMA/NaI and DAMA/LIBRA experiments and the results of these experiments can be reproduced for

$$E_{Na} = 3keV$$

Puzzles of indirect dark matter searches

Indirect searches for Dark Matter

Astrophysical bounds on the mass of heavy stable neutral leptons

Ya. B. Zel'dovich, A. A. Klypin, M. Yu. Khlopov, and V. M. Chechetkin

Institute of Applied Mathematics, USSR Academy of Sciences
(Submitted 29 November 1979)
Yad. Fiz. **31**, 1286–1294 (May 1980)

Analytical and numerical calculations show that heavy neutral stable leptons are carried along by the collapsing matter during the formation of galaxies and possibly stars as well. The condensation in galaxies and stars results in appreciable annihilation of leptons and antileptons. Modern observations of cosmic-ray and γ-ray fluxes establish a limit $m_\nu \gtrsim 100$ GeV for the mass of neutral leptons, since annihilation of neutral leptons produces γ rays and cosmic rays. The obtained bound, in conjunction with ones established earlier, precludes the existence of stable neutral leptons (neutrinos) with $m_\nu > 30$ eV.

Cosmic positron excess from DM?

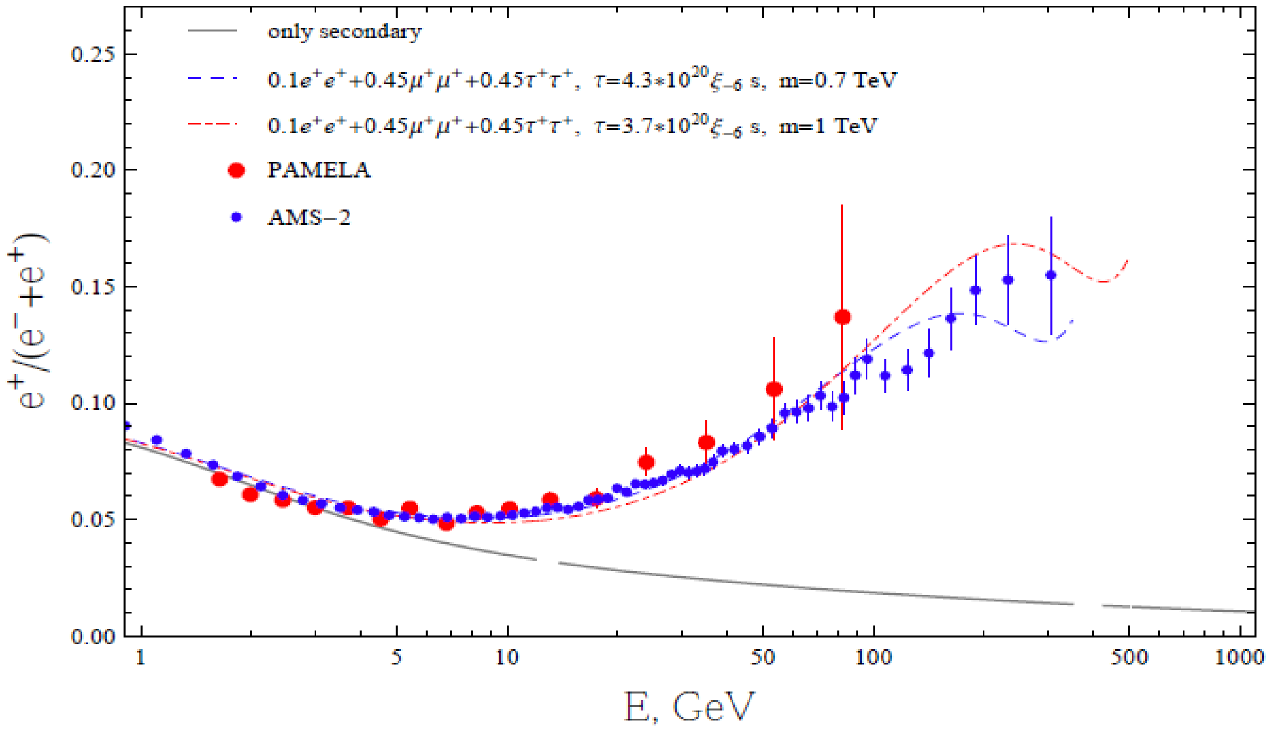
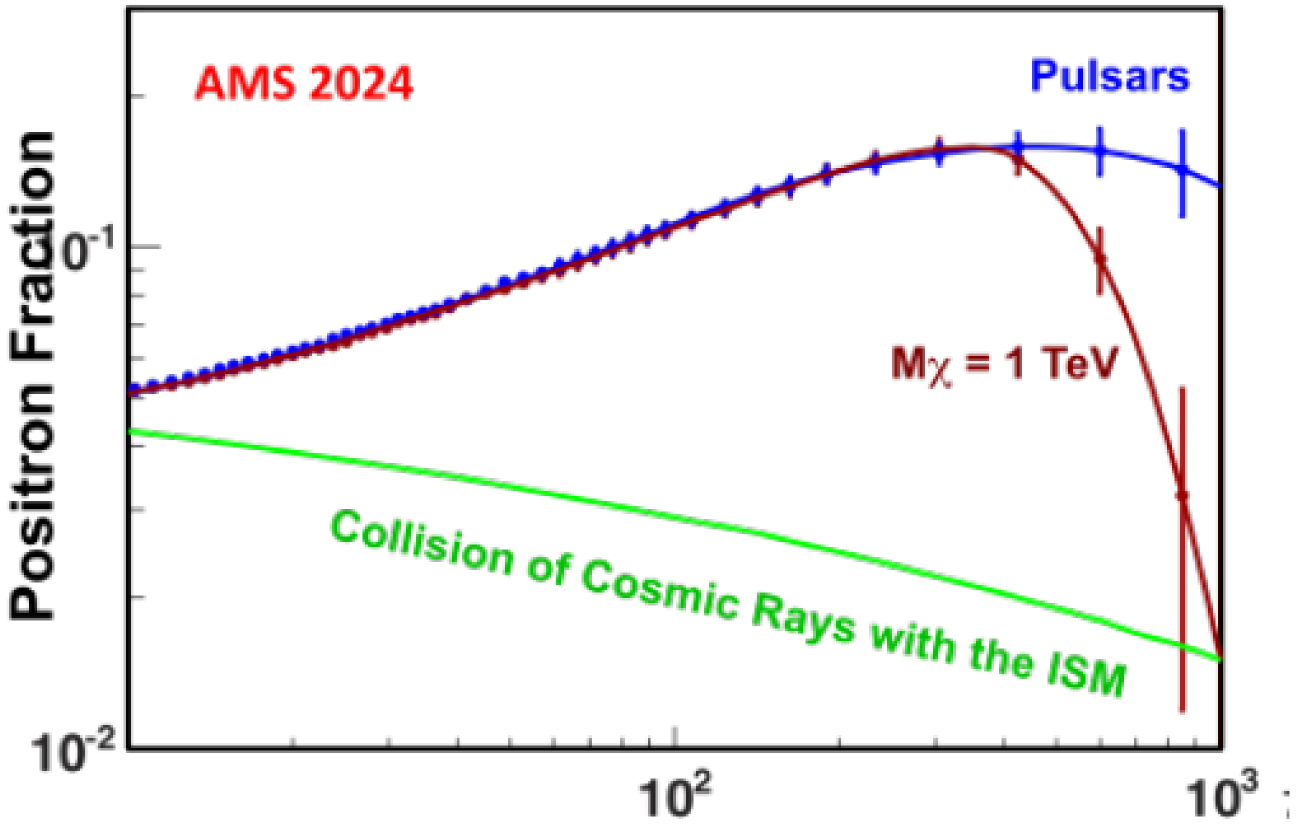


Figure 3: Positron excess due to $UU \to e^+e^+, \mu^+\mu^+, \tau^+\tau^+$ decays compared to PAMELA and AMS-02 data.

Probably such indirect effect is detected in the cosmic positron fluxes.

[figure from K.M.Belotsky et al. arXiv:1403.1212]

AMS02 in the next decade



Presented in CERN on 08.12.2016 by Prof. S.Ting

A solution for cosmic positron excess?

- In WTC: if both technibaryons UU and technileptons ζ are present, CDMS, LUX results constrain WIMP-like ($UU\zeta$) component to contribute no more than 0,0001% of total DM density.
- Decays of positively charged UU->$l^+ l^+$ with a lifetime of about $10^{21} s$ and mass 700-1000 GeV can explain the excess of cosmic positrons, observed by PAMELA and AMS02

Cosmic positron excess from double charged constituents of dark atoms

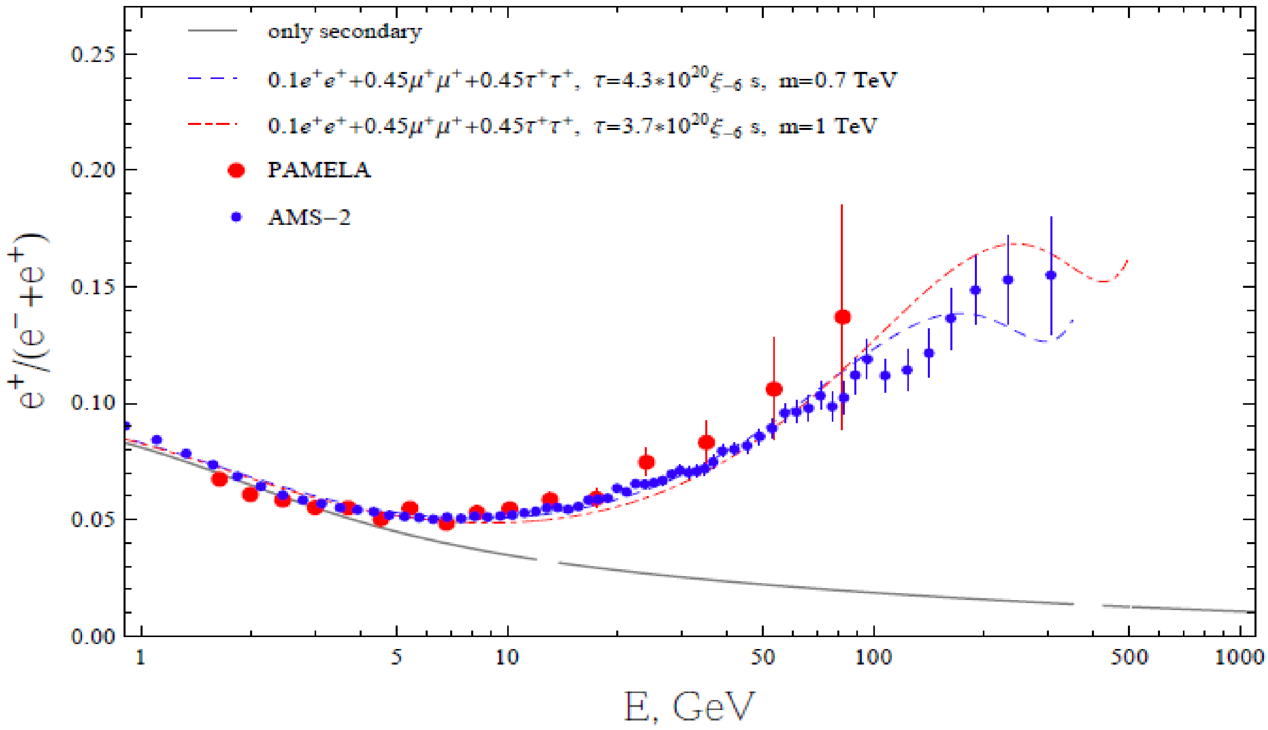


Figure 3: Positron excess due to $UU \to e^+e^+, \mu^+\mu^+, \tau^+\tau^+$ decays compared to PAMELA and AMS-02 data.

[K.M.Belotsky et al. arXiv:1403.1212]

Composite dark matter explanation for high energy positron excess

- Any source of high energy positrons, distributed in galactic halo is simultaneously the source of gamma ray background, measured by FERMI/LAT.
- Not to exceed the measured gamma ray background the mass of decaying double charged particles should not exceed

$$M < 1 \text{ TeV}$$

Excessive positrons in Integral

Taking into account that in the galactic bulge with radius ~ 1 kpc the number density of O-helium can reach the value

$$n_o \approx 3 \cdot 10^{-3}/S_3 \, \mathrm{cm}^{-3}$$

one can estimate the collision rate of O-helium in this central region:

$$dN/dt = n_o^2 \sigma v_h 4\pi r_b^3/3 \approx 3 \cdot 10^{42} S_3^{-2} \, s^{-1}$$

At the velocity of particules in halo, energy transfer in such collisions is E ~ 1MeV. These collisions can lead to excitation of O-helium. If 2S level is excited, pair production dominates over two-photon channel in the de-excitation by E0 transition and positron production with the rate

$$3 \cdot 10^{42} S_3^{-2} \, s^{-1}$$

is not accompanied by strong gamma signal. This rate of positron production is sufficient to explain the excess of positron production in bulge, measured by Integral.

Excessive positrons in Integral from dark atoms– high sensitivity to DM distribution

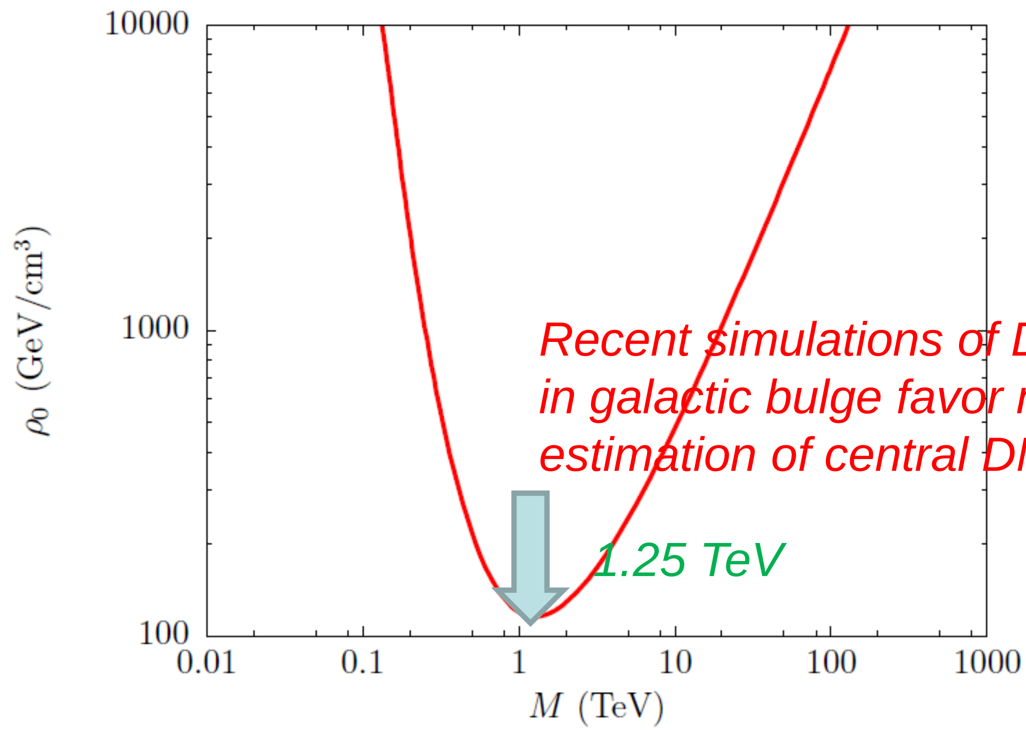


Figure 1: Values of the central dark matter density ρ_0 (GeV/cm^3) and of the OHe mas M (TeV) reproducing the excess of e^+e^- pairs production in the galactic bulge. Belo the red curve, the predicted rate is too low.

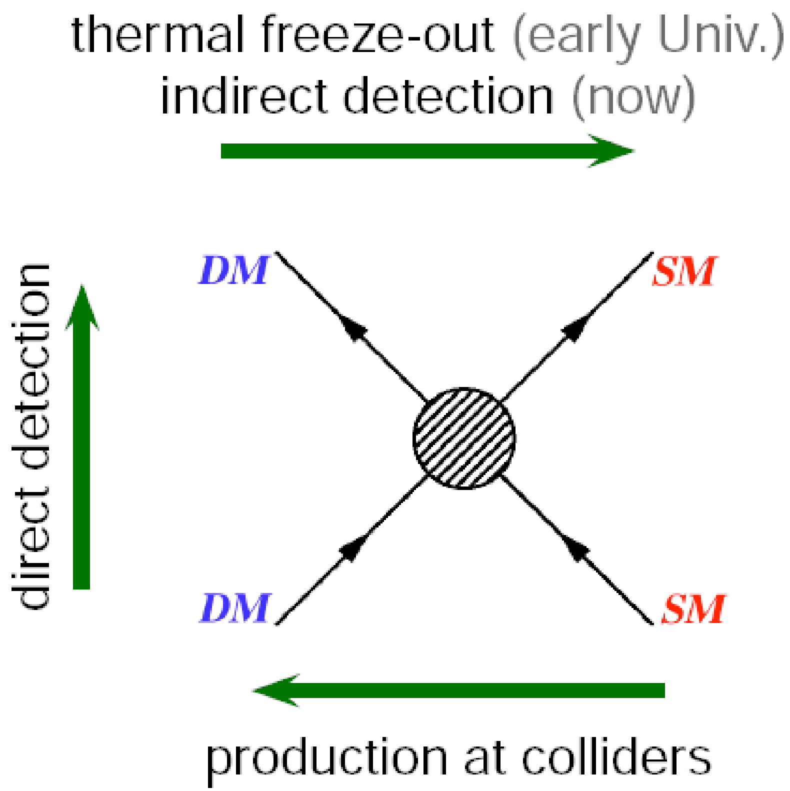
J.-R. Cudell, M.Yu.Khlopov and Q.Wallemacq
Dark atoms and the positron-annihilation-line excess in the galactic bulge.
Advances in High Energy Physics, vol. 2014, Article ID 869425, : arXiv: 1401.5228

Composite dark matter explanation for low energy positron excess

- In spite of large uncertainty of DM distribution in galactic bulge, where baryonic matter dominates and DM dynamical effects are suppressed, realistic simulations favor lower value of DM central density around $\rho_0 \simeq 115$ GeV/cm^3. Then observed excess of positron annihilation line can be reproduced in OHe model only at the mass of its heavy double charged constituent:
- $$M \simeq 1.25 \text{ TeV}$$

COMPOSITE DARK MATTER CONSTITUENTS AT ACCELERATORS

Complementarity in searches for Dark Matter

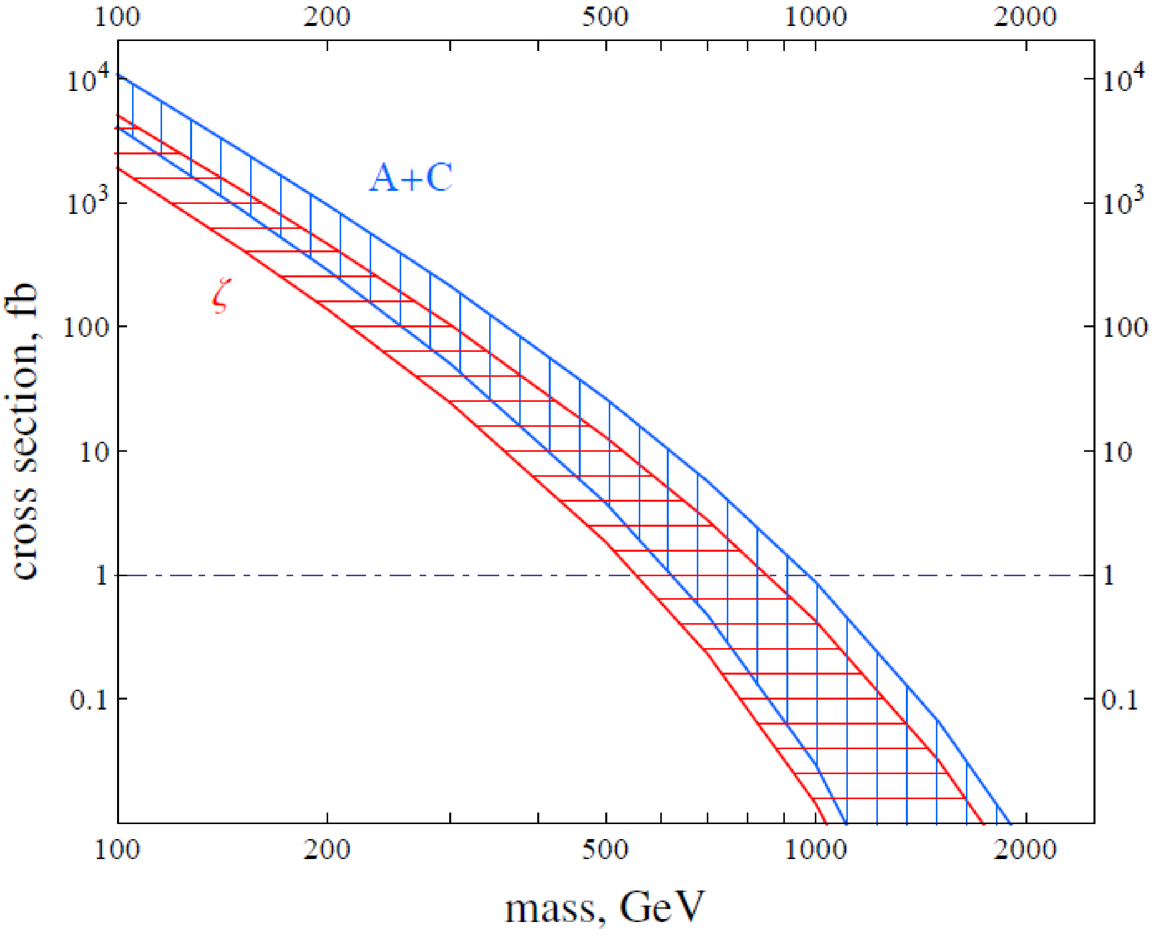


Usually, people use this illustration for complementarity in direct, indirect and accelerator searches for dark matter. However, we see that in the case of composite dark matter the situation is more nontrivial. We need charged particle searches to test dark atom model

Collider test for dark atoms

- Being the simplest dark atom model OHe scenario can not only explain the puzzles of direct dark matter searches, but also explain some possible observed indirect effects of dark matter. Such explanation implies a very narrow range of masses of (meta-) stable double charged particles in vicinity of 1 TeV, what is the challenge for their search at the experiments at the LHC.

LHC discovery potential for charged components of composite dark matter



The shaded strips correspond to production cross sections of technileptons and A,C leptons with Q=2 at 7 teV < $\sqrt{s}$ < 14 TeV

Search for multi-charge particles in the ATLAS experiment

Work is done in a frame of Multi-Charge Analysis Group

Search for Multi-charge Objects in *pp* collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector

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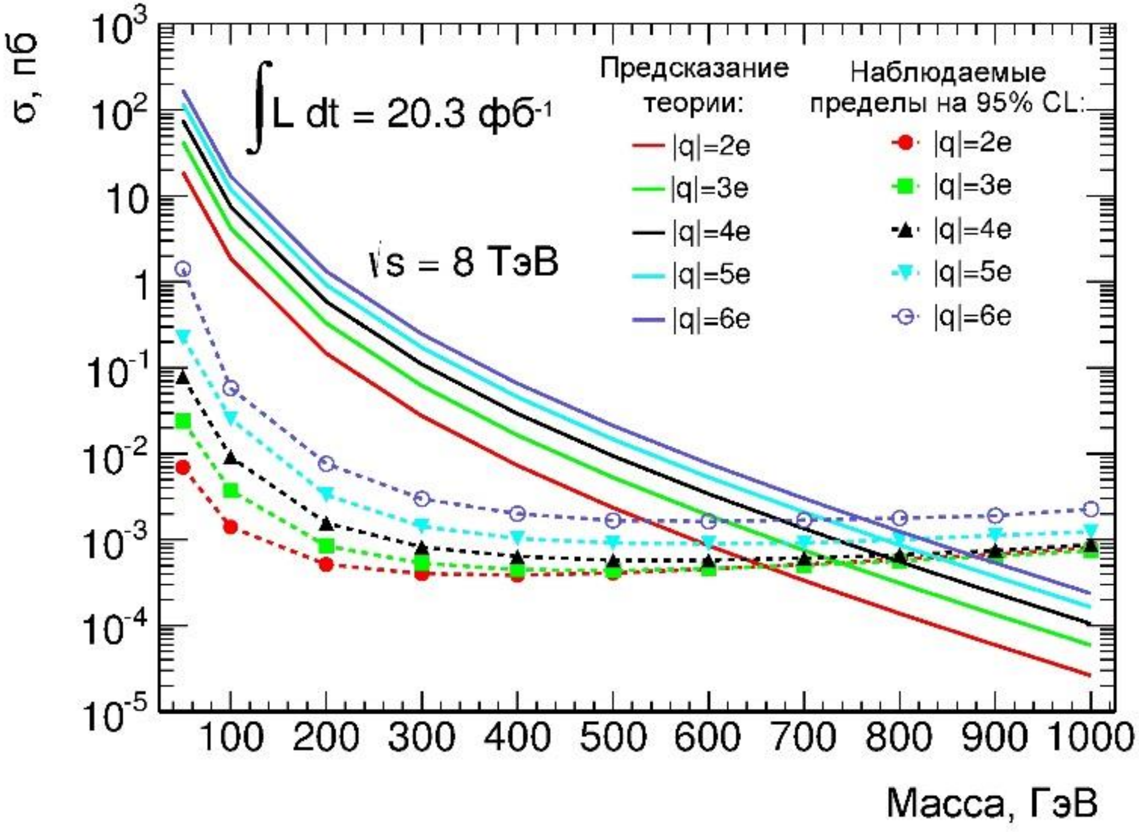
[e]*Indiana University*
[f]*York University*
[g]*University of Bonn*
[h]*University of Paris*

Our studies favor good chances for detection of multi-charge species in ATLAS detector

Searches for multiple charged particles in ATLAS experiment



M>659 GeV for |q|=2e at 95% c.l. [Yu. Smirnov, PhD Thesis]

[ATLAS Collaboration, Search for heavy long-lived multi-charged particles in pp collisions at √s=8 TeV using the ATLAS detector, Eur. Phys. J. C 75 (2015) 362]

Experimentum crucis for composite dark matter at the LHC

Coming analysis of results of double charged particle searches at the LHC can cover all the range of masses, at which composite dark matter can explain excess of slow and high energy positrons, assuming the independent statistics In CMS and ATLAS experiments.

Data period	Estimated lower mass limit, GeV	
	ATLAS or CMS separately	ATLAS and CMS combined
2015–2016	1000	1110
2015–2018	1190	1300

Remind that composite dark matter can explain excess of low energy positrons at M=1.25 TeV and high energy positrons at M<1 TeV.

Conclusion

The puzzle of our origin and existence still retains in the multiverse of cosmological scenarios and particle physical models underlying them.

Zeldovich's dream on the complete cosmological model based on the true particle theory remains the challenge of cosmoparticle physics.

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

International Virtual Institute of Astroparticle Physics (CosmoVIA)

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