Dark Matter Macroscopic Pearls, 3.55 keV X-ray line, How big ?

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Bled , July , 2020

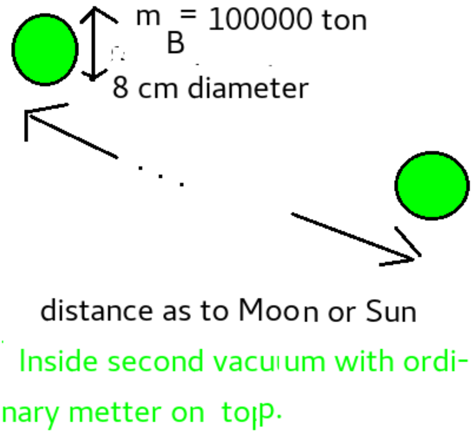
Shall stress small macroscopic pearls

- **Our Old Model:** We develop our model of dark matter being cm-size pearls with masses of 10^8 kg under the attempt to identify the X-ray radiation seen by sattelites and supposed to originate from dark matter with the energy per photon 3.55 keV, and discuss the possibility of some dark matter pearls being much smaller but still macroscopic.
- **Observational Discussion:** If they interact several times through an experimental apparatus they will be **disqualified** as dark matter, which is usually assumed to have so small cross section that they only interact **once** in the detector.

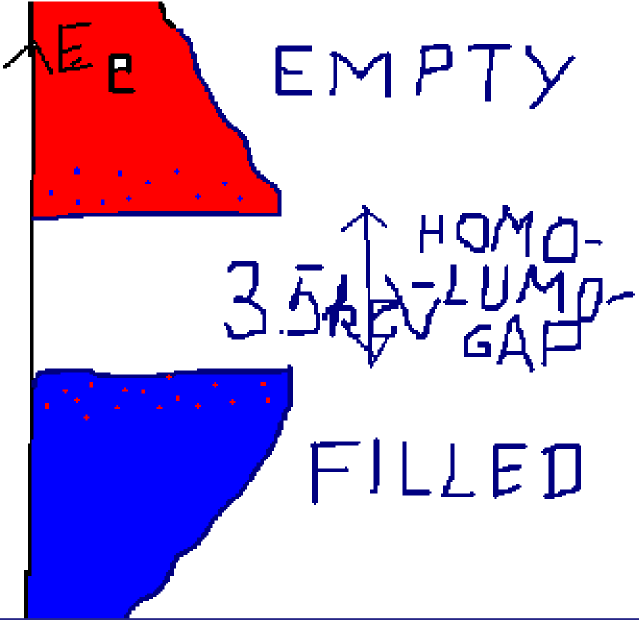
Our Model for Dark Matter ?

Ingredients in our - since long - macroscopic pearl model for dark matter:

- **Multiple Point Principle:** Several vacua with **same energy density** seperated by high tension "walls"(surfaces much like the surface of a buble of water).
- **also ordniary matter inside the buble:** just under abnormously high pressure due to the tension of the bubble seperation surface. (Surface tension S).
- **Homolumo** In the inside matter the electron state energy spectrum has a very generally occuring gap **homolumo gap**.
- **Non-gravitational:**Some **non-gravity dark matter signs:**
  - The **3.5 keV X-ray** radiation. (Related to Homolumo gap).
  - **positrons** relative to gamma-rays from dark matter (problem)


m_B = 100000 ton
8 cm diameter
. . .
distance as to Moon or Sun
Inside second vacuum with ordi-
nary metter on top.

EMPTY
HOMO-LUMO-GAP
3.5 KEV
FILLED


EMPTY
HOMO-
-LUMO-
GAP
3.5 keV
FILLED

We "Calculated" the Homolumo gap in the pearls interior ordinary matter

The homolumo gap ends up being just

$$E_H = \sqrt{2} \left(\frac{\alpha}{c} \right)^{3/2} E_f. \quad (1)$$

Here E_f is the fermi-energy of the electrons in the material (inside the pearls of dark matter in the model), a few MeV.
The homolumo gap E_H is supposed to be approximately the energy of the emitted photons and thus we hope that our E_H becomes equal to 3.55 keV. (Exciton decay).

Plan for Dark Matter:

- **Intro** Introduction.
- **Model** Our model of dark matter pearls,
- **Collide** Picturing colliding pearls, heat spreading.
- **DAMA** Can we interprete DAMA-effect as due to small macroscopic pearls ?

Dark Matter in Only Standard Model (except MPP)

Contrary to everybody else, except for the poeple with primordial black holes for dark matter, we want to propose a dark matter model **inside Standard Model**, only with a certain assumption about the coupling constants in the Standard Model, that there are several vacua with finetuned same energy density. So:

- We assume a law of nature - of a bit unusual kind- "Multiple Point Principle" saying: there are **several** different **vacuum phases**, and they all have the **same energy density** (or we can include that they have ~ 0 energy density.)
- Apart then from me mentioning some attempt mainly with Yasutaka Takanishi of explaining the baryon excess, we shall use **only Standard Model**, even for dark matter!

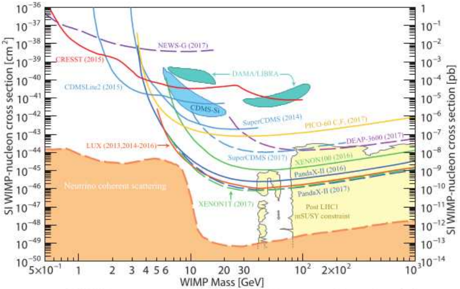


Figure 26.1: WIMP cross sections (normalized to a single nucleon) for spin-independent coupling versus mass. The DAMA/LIBRA [72], and CDMS-Si enclosed areas are regions of interest from possible signal events. References to the experimental results are given in the text. For context, the black contour shows a scan of the parameter space of 4 typical SUSY models, CMSSM, NUHM1, NUHM2, pMSSM10 [73], which integrates constraints set by ATLAS Run 1.

Argon for example).

In summary, the confused situation at low WIMP mass has largely been cleared up (with the notable exception of the DAMA claim). Liquid noble gas detectors have achieved large progress in sensitivity to spin independent coupling WIMPs without seeing any hint of a signal. A lot of progress has also been achieved by the PICO experiment for spin dependent couplings. Many new projects focus on the very low mass range of 0.1-10 GeV. Sensitivities down to $\sigma_{\chi p}$ of 10^{-13} pb, as needed to probe nearly all of the MSSM parameter space [39] at WIMP masses above 10 GeV and to saturate the limit

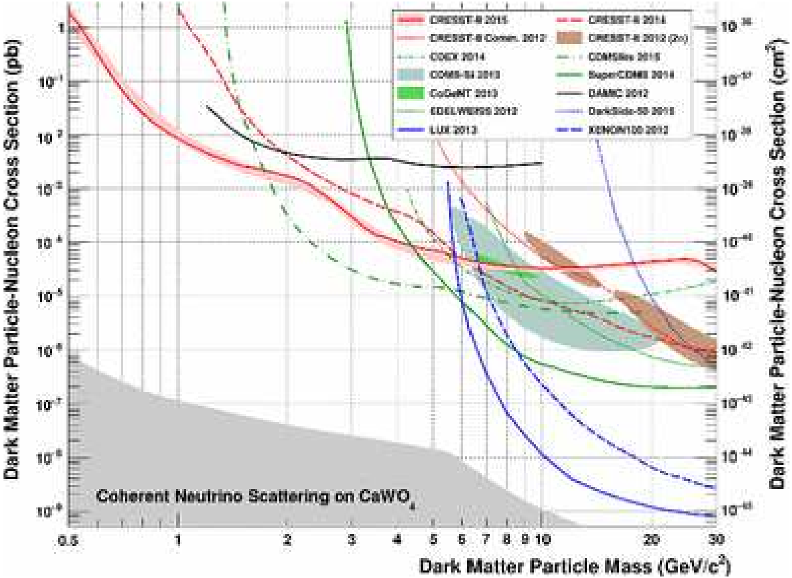
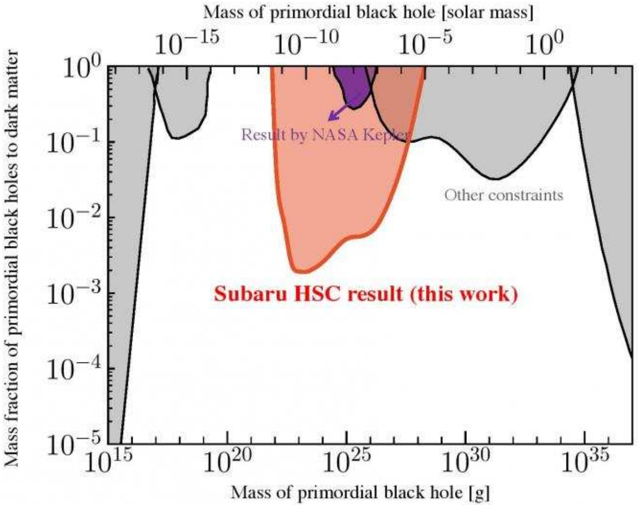

CRESST-II 2015
CRESST-II 2014
CRESST-II Comm. 2012
CRESST-II 2012 (2σ)
CDEX 2014
CDMSlite 2015
CDMS-Si 2013
SuperCDMS 2014
CoGeNT 2013
DAMIC 2012
EDELWEISS 2012
DarkSide-50 2015
LUX 2013
XENON100 2012
Coherent Neutrino Scattering on CaWO$_4$
Dark Matter Particle-Nucleon Cross Section (pb)
Dark Matter Particle-Nucleon Cross Section (cm^2)
Dark Matter Particle Mass (GeV/c^2)

Figure caption on Dark matter mass: Parameter space for elastic spin-independent dark matter-nucleon scattering. The result from the analysis presented in [5] is drawn in solid red together with the expected sensitivity (1σ confidence level (C.L.)) from a data-driven background-only model (light red band). The remaining red lines correspond to previous CRESST-II limits [4, 10]. The favored parameter space reported by CRESST-II phase 1 [11], CDMS-Si [12] and CoGeNT [13] are drawn as shaded regions. For comparison, exclusion limits (90 % C.L.) of the liquid noble gas experiments [14, 15, 16] are depicted in blue, from germanium and silicon based experiments in green [17, 18, 19, 20, 21]. In the gray area coherent neutrino nucleus scattering, dominantly from solar neutrinos, will be an irreducible background for a CaWO 4 -based dark matter search experiment [22].


Mass of primordial black hole [solar mass]
10^−15
10^−10
10^−5
10^0
Mass fraction of primordial black holes to dark matter
10^0
10^−1
10^−2
10^−3
10^−4
10^−5
Result by NASA Kepler
Other constraints
Subaru HSC result (this work)
10^15
10^20
10^25
10^30
10^35
Mass of primordial black hole [g]

Motivation for Our Mouse size dark matter model:

- Remarkably: **No sign of deviations from Standard Model** except neutrino oscillations and cosmological and fine tuning problems,and then ca. 5 almost not significant **anomalies** e.g violation of lepton flavour universality in B-decay (which I last year suggested to be due to **non-perturbative effects**, so that still Standard Model).
- Remarkably: **No** experiment looking for **dark matter impacts found** any, **except for DAMA**, which seemingly is in contradiction with the other experiments inside conventional models.

So seemingly dark matter with masses in the LHC and Lux, ... etc. range seem to be more and more excluded. Our model is built on ONLY Standard Model (except for MPP).

More motivation for our macroscopic size dark matter pearl model:

- Dark matter seems to emit both positrons **(the positron excess from PAMELA)** and γ-rays, but **not** in the **ratio** $\#\gamma/\#e^+$ suggested by a **WIMP decaying** model. rather a slower acceleration like in a macroscopic electric field is called for.

Our model has colliding pearls surrounded by an extended electron and positron remnant plasma.

Motivation for our dark matter model further:

- “In the long run” (= in principle) we only use Standard Model but calculate **non-perturbatively**, so there should be no need for fitting parmeters; but in pracsis we cannot calculate non-perturbatively, so we have to **fit a bit**. (If time, I shall tell how we fit a little bit.)
- Only using fitting to the Tunguska event, and improving our theoretical guesses we **fit or rather predict** the **order of magnitudes** of the **frequency 3.5 keV and the intensity** of the 3.5 keV X-ray radiation suspected to be connected with dark matter.

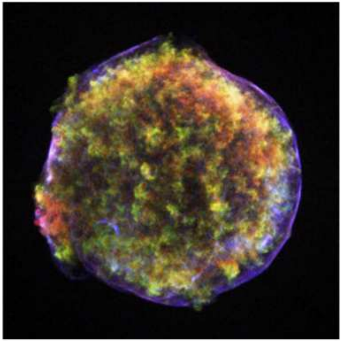
Motivation yet continued:

- Very strangely: If 3.5 keV radiation should come from big clusters of dark matter, it should NOT come **from a supernova-remnant**; but it wa seen from the Thyco Brahes super nova remnant!

In our model this may be explained by the cosmic **radiation** from the remnant of the supernova provides the pearls of ours with energy and then they radiate that out by the for excitons formed in their interior **characteristic** radiation **frequency 3.5 keV.**

Systematics?

Tycho Supernova Remnant



Credit: NASA/CXC/Rutgers/Warren, Hughes et al.

175 ksec XMM observations

Line at 3.55 keV detected:

- potassium with high abundance?
- systematics in line flux?
- *NOT dark matter*

Jeltema & Profumo 2015

Propaganda for "Multiple Point (Criticallity) Principle"(=MPP).

- PREdiction We - CDF and HBN - **PREdicted** the mass of the Higgs boson, before it were found form **MPP**.
- Phenomenology In some models we have **success** phenomelogically: E.g. PREdited the number of families. The top-yukawa coupling $g_t = 1.02 \pm 14\%$ agrees $g_t = 0.935$. Scale problem: Why Higgs mass $<<$ say Planck scale?
- Theory In global time perspective **theretical predictions**.

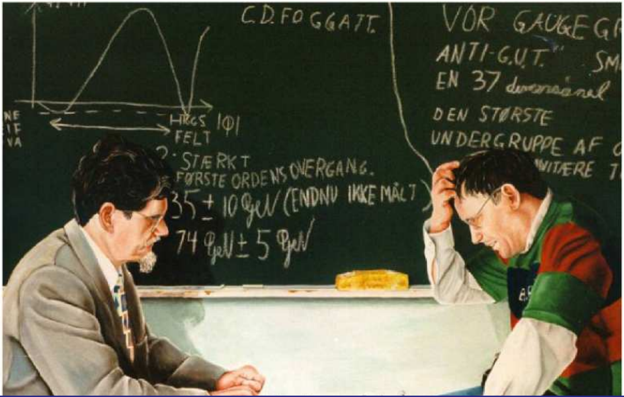
Our Multiple Point Principle Symbolized by Sluch (Ice and water together)

PREdicted Higgs mass

kunstmaler lars andersen http://www.23.dk/skak.htm

Lars Andersen

Historiemaler Portrætmaler Provokunstner Om Lars Andersen CV/omtale Kontakt



Gia Dvali proves that vacua of different energy density forbidden!

Dvali's abstract:
We give a simple argument suggesting that in a consistent quantum field theory tunneling **from Minkowski to a lower energy vacuum must be impossible.** Theories that allow for such a tunneling also allow for localized states of **negative mass**, and therefore, should be **inconsistent**.

Gia Dvali, "Safety of Minkowski Vacuum" arXiv:1107.0956v1 [hep-th] 5 Jul 2011

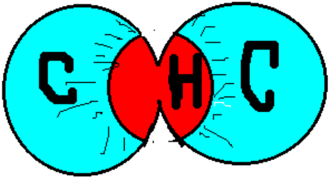
Don Bennett, Froggatt and I started with fixing Extensive quantities(say energy)

That gives microcanonical ensemble and often there will be two phases, and therefore equilibrium only at the phase transition point in say temperature (if we fixed the energy of the whole sample). This where the sklush comes in. If slush, the temperature must be zero.

But truly to get the fourdimensional model we must fix some space time integrals of Lagrangelike field expressions $\mathcal{L}_i(x)$,

$$\begin{aligned} \int \mathcal{L}_1(x) d^4x &= fixed_1 \\ \int \mathcal{L}_2(x) d^4x &= fixed_2 \\ &\vdots \end{aligned}$$

3.5 keV generation



3.5 keV X-ray radiates from the edge of the hot region through the cold one C out in the outer space arround the two having collided pearls.

Fitting 3.55 keV Radiation

We plot the predictions for the ratio $\frac{\xi * 10MeV}{\Delta V}$ from four quantities in the Figure with logarithmic uncertainties estimated crudely as seen in the Table

Name	$\frac{\xi * 10MeV}{\Delta V}$	$\ln \frac{\xi * 10MeV}{\Delta V}$	Uncertainty	
Frequency "3.5keV"	5.0	1.61	100%	
Intensity $\frac{N\sigma}{M^2}$	3.8	1.3	90%	
$S^{1/3}$ theory 1)	0.28	-1.3	40%	
$S^{1/3}$ theory 2)	1	0	40%	
Combined theory ξ, ΔV	0.18	-1.7	100%	
Ratio $\frac{t_{spread}}{t_{radiation}} = 1$	2.4	0.88	80%	l.b.

Table : Table of four theoretical predictions of the parameter $\frac{\xi * 10MeV}{\Delta V}$ on which the quantities happen to mainly depend. The first column denotes the quantities for which we can provide a theoretical or experimental value to be expected for our fit to that quantity. The next column gives what these expected values need the parameter combination $\frac{\xi * 10MeV}{\Delta V}$ to be. The third column is the natural logarithm of that required value for the ratio $\frac{\xi * 10MeV}{\Delta V}$, i.e. $\ln \frac{\xi * 10MeV}{\Delta V}$. The fourth column contains crudely estimated uncertainties of the parameter thus fitted counted in this natural logarithm. In the last column we just marked the ratio $\frac{t_{spread}}{t_{radiation}}$ with l.b. to stress that it is only a lower bound and shall not be

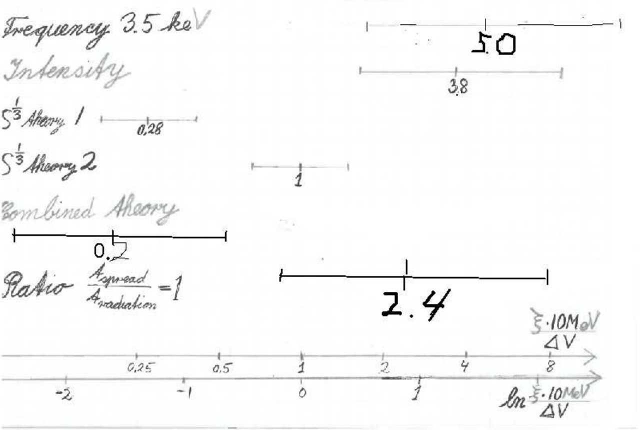


Figure : The values of the ratio $\frac{\xi * 10\ MeV}{\Delta V}$ as needed for four constraints. There are two experimental constraints from the frequency and intensity of the 3.5 keV radiation respectively and two theoretical constraints in two versions corresponding to taking theory 1 or theory 2 for the tension.

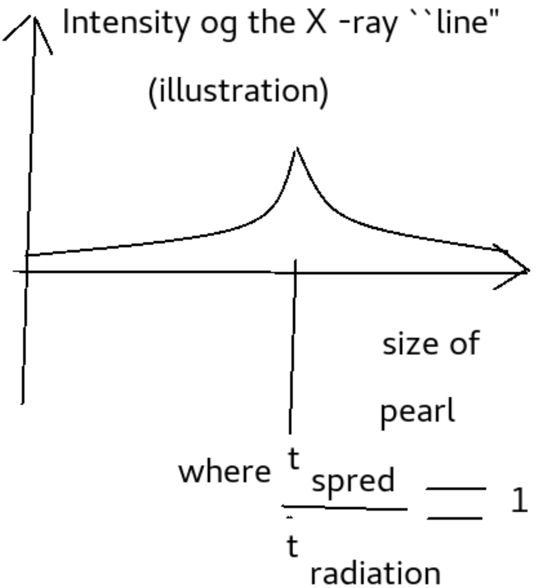

Intensity og the X -ray ``line"
(illustration)
size of
pearl
where t spred
t radiation
1

Table : This table is based on the table 1 in Frey and Cline

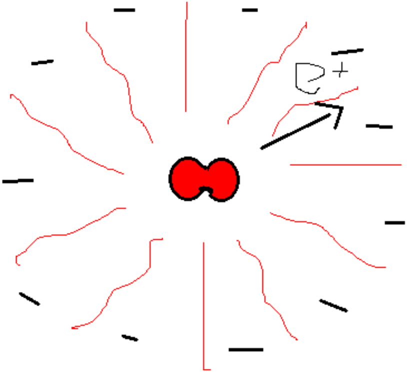
Name	$N < \sigma_{CF} v > * \left(\frac{10GeV}{M}\right)^2$	v	boost	$\left(\frac{N<\sigma_{CF} v>}{v*boost}\right)* \left(\frac{10GeV}{M}\right)^2$	R
Units	$10^{-22} cm^3 s^{-1}$	km/s		$10^{-27} cm^2$	
Clusters[?]	480 ± 250	975	30	0.016 ± 0.008	
Perseus[?]	1400 - 3400	1280	30	0.037 - 0.09	
Perseus[?]	(1 - 2) $*10^5$	1280	30	2.7 - 5.3	ig
Perseus[?]	2600 - 4100	1280	30	0.07 - 0.11	
CCO[?]	1200 - 2000	926	30	0.04 - 0.07	
M31[?]	10 - 30(NFW)	116	10	0.0086 - 0.026	
	30 -50 (Burkert)			0.026 -0.043	
MW[?]	0.1 -0.7 (NFW)	118	5	0.00017 - 0,0012	ig
	50 -550 (Burkert)			0.084 - 0.93	in a
Average				0.032 ± 0.006	

Qualitatively about the positrons and γ-rays from Dark matter.

- When two of our dark matter pearls collide and the skin/ the domain wall arround them contract with high tension a spot is heated to about MeV temperatures, and the in the pearl degenerate **electrons** are in large amounts **spit out**.
- Some of the electrons may run out to long distnce from the two having united pearls and they will create an electic field able to accelerate positrons, at first estimate up to a few MeV energies, but a few will get much more.

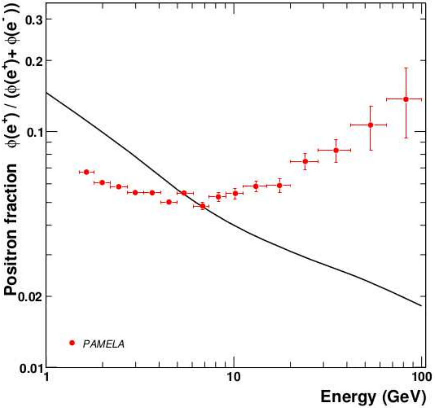
About positron to gamma ray ratio (continued)

- In any model with positrons being produced and accellerated such positrons will shake off γ-rays / light.
- The emission of such light has an intesity proportional to the square of the acceleration of the charged particle, here the positron.
- In "usual" dark matter models - a particle decaying producing the positron - the positron is accelerated over a very short distance, effectively given by the mass of the particle and quantum mechanics.
- In our model the acceleration takes place over a distance given by the extend of the from the explosion made extension of an electron cloud. At least it is "macroscopic"



Positrons accelerat ed over long distance relative to positrons from a decay.

PAMELA positrons versus theory of background



Data on Positrons

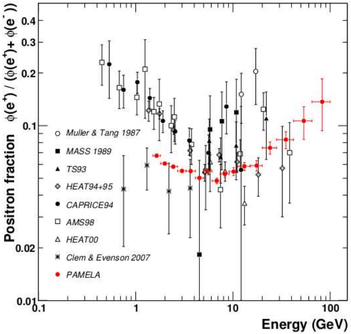


FIG. 3: **PAMELA positron fraction with other experimental data.** The positron fraction measured by the PAMELA experiment compared with other recent experimental data[24, 29, 30, 31, 32, 33, 34, 35]. One standard deviation error bars are shown. If not visible, they lie inside the data points.

- "Production and propagation of cosmic-ray positrons and electrons", I.V. Moskalenko 1 and A.W. Strong
Max-Planck-Institut f ur Extraterrestrische Physik, Postfach 1603, D-85740 Garching, Germany;
arXiv:astro-ph/9710124v1 13 Oct 1997

$I(E)_e = 3.2 * 10^{-8} cm^{-2} s^{-1} sr^{-1} MeV^{-1}$ at 9 GeV.

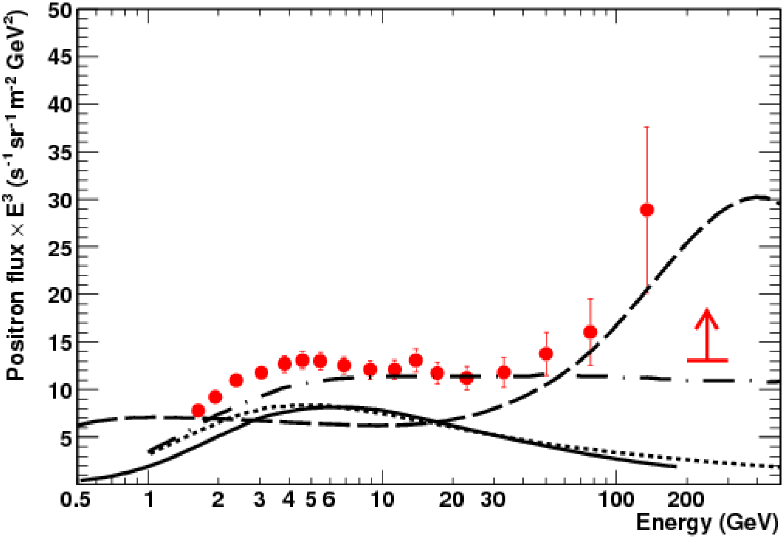
From next figure we see that for $E = 9GeV$ of a positron the

$$\text{“Positron rate”} = I(E = 9GeV)_{e^+} = \frac{12 s^{-1} sr^{-1} m^{-2} GeV^2}{E^3}$$
$$= \frac{12}{729} s^{-1} sr^{-1} m^{-2} GeV^{-1}$$
$$= 1.6 * 10^{-2} s^{-1} sr^{-1} m^{-2} GeV^{-1}$$
$$= 1.6 * 10^{-9} s^{-1} sr^{-1} cm^{-2} MeV^{-1}$$

At $E = 9GeV$ the ratio

$$\frac{I_{e^+}}{I_{e^-} + I_{e^+}} = 0.05$$

$0.05^{-1} * 1.6 * 10^{-9} s^{-1} sr^{-1} cm^{-2} MeV^{-1}$ just matches $3.2 * 10^{-8} s^{-1} sr^{-1} cm^{-2} MeV^{-1}$.


Positron flux × E^3 (s^{-1} sr^{-1} m^{-2} GeV^2)
50
45
40
35
30
25
20
15
10
5
0.5
1
2
3
4 5 6
10
20 30
100
200
Energy (GeV)

Excess of Positrons

To get some numbers let us say that

$$\begin{aligned} \text{In a range:} & \quad 30GeV \text{ to } 150GeV \\ I_{e^+} \text{ is shifted} & \quad 12 \text{ to } 16E^{-3}s^{-1}sr^{-1}m^{-2}GeV^2 \text{by the "excess"}. \\ \text{So:} Excess &= 4E^{-3}s^{-1}sr^{-1}m^{-2}GeV^2, \end{aligned} \tag{2}$$

and at least an excess energy

$$\begin{aligned} \text{"excess energy"} &= \int_{30GeV}^{150GeV} \frac{4s^{-1}sr^{-1}m^{-2}GeV^2 * E}{E^3} dE \\ &= \left[-\frac{4s^{-1}sr^{-1}m^{-2}GeV^2}{E} \right]_{30GeV}^{150GeV} \\ &\approx 0.1s^{-1}sr^{-1}m^{-2}GeV \end{aligned} \tag{3}$$

Energy density of Excess positrons

$0.1 s^{-1} sr^{-1} m^{-2} GeV$ translates for positrons moving with speed of light into an energy density due to excess positrons
$0.03 * 10^{-8} sr^{-1} m^{-3} GeV = 3 * 10^{-10} sr^{-1} m^{-3} GeV$.
This is when integrated over the whole sphere of 4π:
$4 * 10^{-9} m^{-3} GeV = 4 * 10^{-15} cm^{-3} GeV$
And that is 10^{14} times smaller than the density of dark matter
$\rho_{DMsun} = 0.3 GeV/cm^3$ in our neighborhood.

If we have at least an excess of positrons comming from dark matter which is present with an energy density $\sim 10^{14}$ times smaller than the corresponding density of the dark matter itself in the associated region, then the rate of decay or annihilation or effective transformation to positrons over the survivel time for the high energy positrons must be 10^{-14}.

Now rate of collission of one of our pearls with another one is of the order

$$
\begin{aligned}
\text{“Rate of collission” for pearl} &= v * \frac{\rho_{DMsun}\pi(2R)^2}{\rho_B} \\
&= 200km/s \frac{0.3GeV/cm^3\pi(2*3.9cm)^2}{1.4*10^8kg} \\
&= \frac{2*10^7cm/s*0.3GeV/cm^3*200cm^2}{2*10^{35}GeV} \\
&= 6*10^{-27}s^{-1}
\end{aligned}
$$

where we used $1kg = 6*10^{26}GeV$.

Decay rate relative to Einstein energy Mc^2

Believing the the released energy E_S from the surface contraction once a couple of the pearls collide is

$$E_S = 0.065\% \text{ of } M_B c,$$

where M_B is the mass of one pearl a collission rate $6 * 10^{-27} s^{-1}$ means that the decay rate of the Einstein energy effectively is

$$\text{"Eff. Decay rate"} = 6 * 10^{-27} \frac{E_S}{M_B c^2} = 4 * 10^{-30} s^{-1}$$

Time needed for positron production

To have time enough for producing 10^{-14} times as much energy in positrons as the energy of the dark matter itselfwith a transformation rate "Eff. Decay rate" $= 4 * 10^{-30} s^{-1}$ one needs a time $t_{needed} = \frac{10^{-14}}{4*10^{-30}s^{-1}} = \frac{1}{4} * 10^{16} s$.
Luckily for the possibility of our model being able to explain the positrons comming from the dark matter this needed time $t_{needed} = \frac{1}{4} * 10^{16} s$ is 40 times smaller than the age of the universe, which is $10^{17} s$ ($=$ the 13 milliard years).
But this means the survival time for positrons having been produced by the collissions of the dark matter should be at the very least 1/40 of the age of the universe, and if not all energy from the collissions should go into positrons, it should be even longer!

Radiation goes as acceleration squared of the charged object.

So:

- If acceleration of the positron say in our model takes place through a macroscopically big cloud created by strongly expelled electrons from the contraction explosion, then the acceleration is much smaller than
- if the positron is produced in a particle reaction - a decay or annihilation - taking place strictly speaking in a point (but in reality in some region of a size determined from quantum mechanics effects). So in such a particle decay model for the γ-ray radiation you get much more γ-rays relative to the amount of positrons, than in our model.

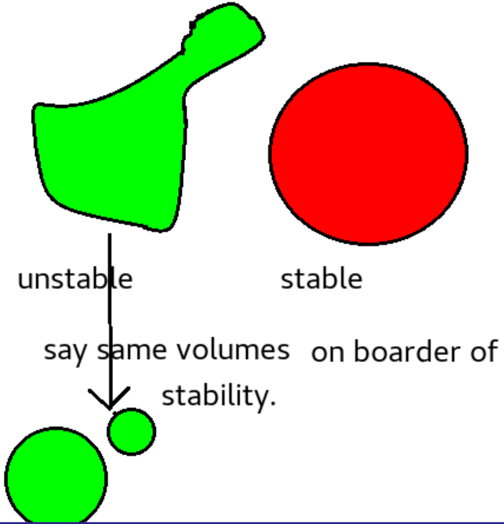
Positron Excess could be realized in Our Model for Dark Matter.

- If the "fraction of energy going to positrons in the collissions" times "the fraction of the universe age the positrons can keep on running arround in the neighborhood" can be bigger than $\sim 1/40$, then the observed positron excess could match our dark matter model.
- Usually a problem: γ-rays from dark matter adjusting to the positron rate gets predicting too high. It may be quite complicated and model dependent to obtain our γ-ray prediction relative to the positron production, but **because the positrons in our model are accelerated over much longer - basically macroscopic distances - distances than in simple WIMPs or the like decaying or annihilating type of models, we get much smaller acceleration square for the positrons than the "usual" type of models.**

Parameters of Our model for Dark Matter

The parameters of our model picture of the Tunguska particle as a ball of a new type of vacuum with a bound state condensate, filled with ordinary white dwarf-like matter and on the borderline of stability.

Fitting inspired correction of theoretical mistake:



Lower limit for stability of a pearl

For a given skin tension S (we have two ways of estimating the third root of the tension of the skin of the pearls From condensate $S^{1/3} \sim 16GeV$ and fitting to among others Tunguska event rate: in old fit $S^{1/3} \sim 28GeV$ and in new $S^{1/3} \sim 4.8GeV$) the pressure from the inside material needed to keep the ballance is

$$P \sim \frac{S}{R}. \tag{4}$$

With a potential step for a nucleon to pass out of the pearl $\Delta V \sim 10MeV$ or after our little correction also $\Delta V \sim 10MeV$ there will be a minimal size of the pearl for it to be stable. We assumed originally that roughly all the pearls had just the radius R equal to this stability bound. **But inspired by the fitting of the intesity of the 3.5 keV line, we found out that most only barely above the bound of stability pearls would decay.** This we made into a theoretical correction by a factor $2^{4/9}\sqrt{4\pi}$.

Table of parameters, Dark Matter Model

Nr.	Name	symbol	old new
1.	Time Interval of impacts	r_B^{-1}	200 years kept
2.	Rate of impacts	r_B	$1.5 * 10^{-8}s^{-1}$ kept
3.	Dark matter density in halo	ρ_{halo}	$0.3\ \text{GeV}/\text{cm}^3$ kept
4.	Dark matter solar system	$\approx 2\rho_{halo}$	$0.6 GeV/cm^3$ kept
5.	Mass of the ball	m_B	$1.4 * 10^8$ kg =140000ton $= 7.9 * 10^{40} \frac{keV}{c^2}$ kept

Parameter table (continued)

Nr.	Name	symbol	old new
6.	Typical speed of ball	v	160 km/s kept
7.	Kinetic energy of ball	T_v	$1.8 * 10^{18}$ J= 430 Mton TNT kept
8.	Energy observed, Tunguska	$E_{Tunguska}$	$(4-13) * 10^{16}$ J= 10 - 30 Mton TNT
9.	Potential shift between vacua	ΔV	10 MeV kept

Parameter table continued

Nr.	Name	symbol	old new
10.	$\sqrt[3]{tension}$(fit)	$S^{1/3}$	28 GeV 4.8 GeV
11.	$\sqrt[3]{tension}$(condensate)	$S^{1/3}$	16 GeV kept
12.	Ball density	ρ_B	$1.0 * 10^{14} \frac{kg}{m^3}$ $5.2 * 10^{11} \frac{kg}{m^3}$
13.	Radius of ball	R	0.67 cm 3.9 cm
14.	homolumo gap	$E_{HW} = E_H$	8.8 ± 6.2keV 1.5 ± 1.1keV

Parameter table continued

Nr.	Name	symbol	old new
15.	Frequency	$3.5 keV$	3.5 keV -
16	Released energy	E_S	$0.38\% Mc^2 =$ $=3.0 * 10^{38} keV$ $0.065\ \%\ Mc^2 =$(**??**) $5.1 * 10^{37} keV$
17.	# 3.5's if all→ 3.5	$N_{\text{all}\rightarrow\ 3.5}$ $= \frac{E_S}{3.5 keV}$	$6 * 10^{37}$ $1.1 * 10^{37}$
18.	# 3.5's	$N = \frac{t_{spread}}{t_{raddiation}} *$ $* N_{\text{all}\rightarrow 3.5}$	$2 * 10^{34}$ $1.0 * 10^{37}$

Parameter table continued

Nr.	Name	symbol	old new
19.	cross section, balls	$\sigma = \pi(2R)^2$	$5.8 cm^2$ $200\ cm^2$
20.	cross section per γ as if all$\rightarrow$ 3.5	$N_{all \rightarrow 3.5}\sigma$	$3._5 * 10^{38} cm^2$ $2.2 * 10^{39} cm^2$
21.	cross section per γ (with time ratio)	$N\sigma$	$1.1 * 10^{35} cm^2$ $4.6 * 10^{39} cm^2$
22.	σ per γ per M^2 (as if all $\rightarrow$ 3.5)	$\frac{N\sigma}{M^2}\vert_{all \rightarrow 3.5}$	$2.6 * 10^{22} \frac{cm^2}{kg^2}$ $1.5 * 10^{23} \frac{cm^2}{kg^2}$
23.	σ per γ per M^2 (with time ratio)	$\frac{N\sigma}{M^2} = \frac{t_{spread} N_{all\ \rightarrow\ 3.5}\sigma}{t_{radiation} M^2}$	$9 * 10^{18} \frac{cm^2}{kg^2}$ $3 * 10^{23} \frac{cm^2}{kg^2}$

Parameter table continued

Nr.	Name	symbol	old new
24.	Spreading time	t_{spread}	$1.4 * 10^{-1}$ s 4.8s
25.	Corrected Spread time for $T \approx 3.5keV$	$t_{cor.spr.} =$ $= t_{spread} * \frac{2}{6.9}$	$4.1 * 10^{-2}$ s 1.4 s
26.	Radiation time	$t_{radiation}$	430 s 2.1 s
27.	Ratio	$\frac{t_{spread}}{t_{radiation}}$	$\frac{1}{3000}$ 2.3
28.	Fit to Cline and Frey (including Boost corr.)	$\frac{N\sigma}{M^2}$	$(1.0 \pm 0.2)10^{23} \frac{cm^2}{kg^2}$ -(**??**, **??**)

Parameter table continued

Nr.	Name	symbol	old new
29.	Radius/critical R (fitted)	$\xi = R/R_{crit}$	1 5.9
30.	Radius/ critical R (speculated)	$\xi = 2^{4/9}\sqrt{4\pi}$	- 4.82
31.	Heat conductivity	$k = \frac{c^2 p_f^2}{85\alpha}$	600 $\frac{MeV^2}{c}$ 25 $\frac{MeV^2}{c}$ (**??-??**)

Explanations of the table

Let us here shortly review the concepts given and explain the table above: First column contains the short name of the quantity given in our model, and the third column is the formula expression for it. The fourth and the fifth columns contain suggested numerical order of magnitude values for the quantity in question: The fourth gives the value obtained with the old numbers from our previous publication [?], so that what could be gotten from these numbers could be considered in some sense "pre"diction.

Explanation of table (continued)

These old numbers were based in some cases on the hypothesis, that the **size of the typical pearl is such that it is just on the borderline of stability towards collapsing by the matter/nuclei inside being spit out under the pressure.** This hypothesis will, however, by nearer thinking be seen not be realistic and the actual radius R_{actual} of a pearl is instead taken to be a fitting parameter ξ times larger than the in the old work used borderline radius.

Table explanation, fitting the radius parameter ξ

Then we fit this scale parameter ξ to deliver the experimentally found intensity of the 3.5 keV X-ray radiation. This of course means that we have given up predicting the intensity of the radiation better than what we got by the old numbers in column four, which give the intensity predicted to be a factor 40000 too low compared to the fit to the Cline and Frey work.

We write the after fitting ξ numbers one line lower.

Under the number of the original numbers we put the numbers as gotten using this fit to the intensity. Predicting though is not fully given up in as far as we in subsection **??** seek to obtain the **theoretical expectation for the average radius adjusting parameter ξ to** $2^{4/9}\sqrt{4\pi} = 4.8$**.** In the sixth column we give a few references to formulas in the text.

Now a short review of the rows in the table:

- 1. The interval r_B^{-1} between successive impacts of our pearls on the earth as estimated from fact that so far only one "Tunguska impact" with the same slightly mysterious properties has been observed, except perhaps the Sodom and Gomorrah event known from the bible.
- 2. Just the inverse of $r_B^{-1} = r_B$.

Dark matter densities as input from astronomi

- 3. The dark matter mass density ρ_{halo} in the halo in the neighborhood of our sun on a kpc scale but away from us on a scale of the order of the solar system, It is such densities, that determine the influence of the dark matter on the motion of the stars and galaxies and it is thus an astronomically measured quantity. We use it together with the rate r_b to determine - after minor corrections using the speed v - to estimate the average or medium mass m_B of the pearls.
- 4. Using the ρ_{halo} as input we estimate / speculate the mass density of dark matter in the solar system near the earth to $\approx 2\rho_{halo}$.

Explanation table, Tunguska ...

- 5. The from the first estimates and data determined mass m_B of a single pearls. (this were already done in our earlier work [**?**].
- 6. Typical speed of the pearl in the region of the earth, where about half the pearls are supposed to be linked to the solar system and thus having lower speed, while about half come from the far out regions of the galactic halo. This speed is of relevance for determining how often a pearl hits the earth and thus for how to get the mass by means of the rate of impacts r_B.
- 7. The kinetic energy $\frac{1}{2}m_B v^2$ of the pearl of importance for the possible energy release by the impact of the pearl in Tunguska.

Table explanation: Tunguska and potential keeping nucleons

- 8. Energy observed as the visible explosion in Tunguska $E_{Tunguska}$, which of course should at least be smaller than the kinetic energy of the pearl available for making explosion, since an appreciable part of th energy will be deposited deeply inside the earth.
- 9. Potential shift for nucleon in passing the skin of the pearl $\Delta V \approx 10 MeV$. We presume that the potential felt by a neutron or a proton inside the pearl is ΔV lower than outside due to a lower Higgs field in the inside the pearl.

Explanation...

- 10. The force per unit length or equivalently the energy per unit area of the pearl surface/skin is denoted S. Then the value has been fitted to the hypothesis that typical pearl size is just on the borderline of stability against the nuclei being spit out, in the column four corresponding to the absolute instability border, whereas the column five, rather is the skin tension corresponding to the fit to the intensity of the 3.5 keV radiation. In both columns it is the third root $S^{1/3}$ of the tension which is given.
- 11. Here we then give the same third root but now estimated from theoretical considerations about the Higgs field and effective field for the bound state of $6t + 6\bar{t}$ speculated in our work. Basically it means that the third root is given by dimensional arguments from top-quark mass. Note that the correction in increasing ξ in going from fourth to fifth column

- 12. Ball density or pearl density ρ_B is the specific density of the bulk of the pearl, i.e. simply the ratio of the mass to the volume.
- 13. The radius R of the ball, mainly thought of as the radius of the skin sphere.
- 14. The homolumo gap calculation is the first main point of the present article and we obtain so good we can the value for the gap between the lowest unoccupied and the highest occupied electronic orbits. It is the main point of the present article that this gaps gives rise to a radiation from the dark matter with the frequency essentially equal to this homolumo gap. Since astronomers have seen a line in X-ray of 3.5 keV it is our first and most important success that this homolumo gap turn out to be order of magnitude-wise equal to 3.5 keV.
- 15. In this line we just note down the supposedly from dark matter emitted X-ray frequency being 3.5 keV.

- 16. The released energy E_S stands for the energy released when two pearls collide and their common surface contracts so as to have one combined pearl in stead of the previous two. This released energy is thus estimated as the fraction of the surface area contracted away multiplied by the surface tension S, and it is written relative to the Einstein energy of the whole pearl $m_B c^2$.
- 17. "# 3.5's as if all $\rightarrow$ 3.5" means the number of photons of energy 3.5 keV, which could be produced from the released energy E_S under the presumably not realistic assumption that all the energy went into such 3.5 keV photons. I.e. it is simply $E_S/(3.5keV)$.
- 18. "# 3.5's" then means the estimate of how many 3.5 keV photons are truly produced in one collision. The main correction relative to the "# 3.5's as if all $\rightarrow$ 3.5" consists in that we expect the emission dominantly into the 3.5 keV line takes place only during the first time t_{spread} after collision

during which period a hot spot created by the released energy E_S spreads out from a supposed very small region to reach the boundary of the pearl. The idea is that until the hot spot reaches the boundary essentially only 3.5 keV X-rays can penetrate from the outskirts of the hot spot out in the free space because the pearl material is supposed to strongly absorb at least radiation with higher frequency than the 3.5 keV line. After the heating up by the spread of the hot spot over the whole pearl and the heating up of the skin of the pearl the emission of radiation will become typically of higher frequency than the 3.5 keV. Thus the energy released gets then lost for emitting radiation in the line 3.5 kev.

- 19. The cross section $\sigma = \pi(2R)^2$ for the pearls colliding is supposed to be the geometrical cross section just given by the radii of the pearls colliding. It is of course π times the square of the sum of the radii of the two pearls.
- 20. "cross section per γ (all $\rightarrow$ 3.5)" means the cross section

that a pearl should have for hitting another pearl if there were only produced one photon (with energy 3.5 keV) per collision and under the assumption that all energy goes to the 3.5 keV.

- 21. "cross section per γ (with time ratio)" means the cross section needed for the collision, if we have to have again one collision for each photon emitted, but this time taking the more realistic amount of photons(3.5 keV) by them only being produced during the time t_{spread}.
- 22. Here we simply divide the "cross section per γ (all $\rightarrow$ 3.5)" by the mass square of the pearl $M^2 = m_B^2$.
- 23. Similarly we divide the number "cross section per γ (with time ratio)" by also $M^2 = m_B^2$. This is now the quantity, which determines the rate of 3.5 keV radiation from various objects, provided one can estimate the square of the density of dark matter in those astronomical objects.
- 24. The spreading time t_{spread} for the hot spot produced in the collision to spread over the whole pearl, so that the wall of

it get heated and energy escapes via higher frequencies than just the 3.5 keV line.

- 25. The same as 24. but taking into account that the 3.5 keV radiation gets replaced by higher frequency radiation as soon as the temperature reaches appreciably above the 3.5 keV; it does not have to get to so high temperature as the main part of the hot spot. Also the correction by a factor 2 takes into account that after the pearl cools off again a period with 3.5 keV radiation will appear.
- 26. The radiation time $t_{radiation}$ is defined as the time it would take for the released energy E_S to get emitted, if the emission goes just via emission of 3.5 keV radiation assumed to be emitted with a rate as given by the black body radiation at the temperature $T = 3.5 keV$. Since this is what is expected to happen during the time interval t_{spread} the fraction of radiation send out as 3.5 keV radiation is estimated as the ratio $\frac{t_{spread}}{t_{radiation}}$.

- 27. This ratio $\frac{t_{spread}}{t_{radiation}}$ relevant for the amount of radiation 3.5 keV emitted.

- 28. The from the work of Cline and Frey extracted quantity $\frac{N\sigma}{M^2}$ for the observations, and this number should thus be considered the experimental value corresponding to the theory in item 23.

- 29. After letting the ratio ξ of the actual radius of the pearl relative to the absolute lower bound from stability free to fit we get the value $\xi = 5.9$.

- 30. But a theoretical estimate of what this ξ ratio should be provides $\xi = 2^{4/9}\sqrt{4\pi}$, which actually should be considered a successful agreement.

- 31. This is our estimated value for the heat conductivity k.

Conclusion

We have persented a - somewhat specific - model for macroscopic dark mater pearls, with the properties:

- The model is in principle built on **only standard model** except for the **Multiple Point principle**.
- We fit both the over all intensity of the 3.55 keV X-ray radiation **and** its frequency (i.e. th enumber 3.55 keV) with one parameter , which actually even is explained and calculated as a peak in the radiation as function of the size of the pearls. (only mildly using the rate of Tunguska-like events).
- There is hope that the model can give positrons which are slowly accelerated to make less gamma rays associated with them.

Conclusion continued

- Small pearls 10^4 GeV mass ? may usually make several hits in earth experiments but especially excite electrons. They would thus except in exceptional cases be disqualified as dark matter in say DAMA/LIBRA and especially in the Xenon experiments even looking for electrons. But seldomly they might only interact once and be counted as dark matter.

Domain walls

In theores with several phases of vacuum, you have at the surfaces where two phases meet:**domain walls**. Such domain walls typically have an energy density and a tension. Usually, e.g. in our model with multiple point principle and standard model otherwise only, the enrgy density along such domain walls is so huge, that even with only one extended wall inside each Hubble volume H^{-3}, the distance scale H^{-1} given by Hubble constant H the universe energy density quickly gets completely dominated by the energy density from such walls; **So such domain walls makes the cosmology a catastrophe!**

Cosmological problem with Domain walls

It was first noted by Zeldovich, Kobzarev and Okun that the restoration of sponta- neously broken discrete symmetries at high temperatures in the early universe poses severe problems for its subsequent evolution.

Ya.B. Zeldovich, I.Y. Kobzarev and L.B. Okun, Sov. Phys. JETP 40, 1 (1975)

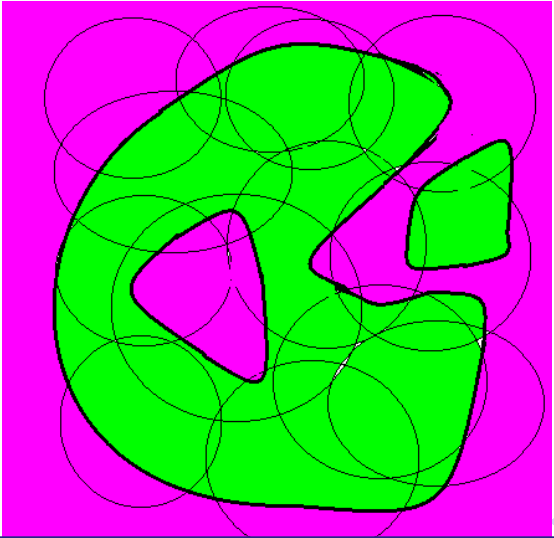
Real Catstrophe in Cosmology for Spontaneously broken discrete symmetry

Breaking some say Z_2 group symmetry leads to real catastrophe! Because of the symmetry there will in different regions not having ever communicated be 50% to 50% chanse for any of the two vacuum-phases. Thus there will over each region of order of length H^{-1} (where H is the Hubble constant at the time considered). If the density of energy over the domain wall per unit area is denoted S, then the energy density in space of the walls must at least be of the order

$$\rho_{walls} \sim \frac{SH^{-2}}{H^{-3}} = SH = \frac{S}{t}, \tag{5}$$

where $t = H^{-1}$ is the time scale given by the Hubble "constant" H, so that there is only communication during the age of the universe inside a region of size t and volume $t^3 = H^{-3}$.

Domain walls and Horizon size balls



Explanation for "Domain walls and Horizon size balls".

- Drawn as if in 2 spatial dimensions.
- The thick black lines symbolize the **domain walls**, they are of course 2-dimensional surfaces in the correct 3-dimensional space.
- These domain walls seperate regions of the two different colors lilac and green, which thus symbolize two phases of vacuum. In the case of a spontaneously broken Z_2 symmetry there is **symmetry** under permutation of green with lilac. (But in our model of MPP there is a (slight) assymmetry: say lilac has no condensate, while green has a condensate of some speculated scalar particle $F(750)$).

Further explanantion of “Domain walls and Horizon size balls”

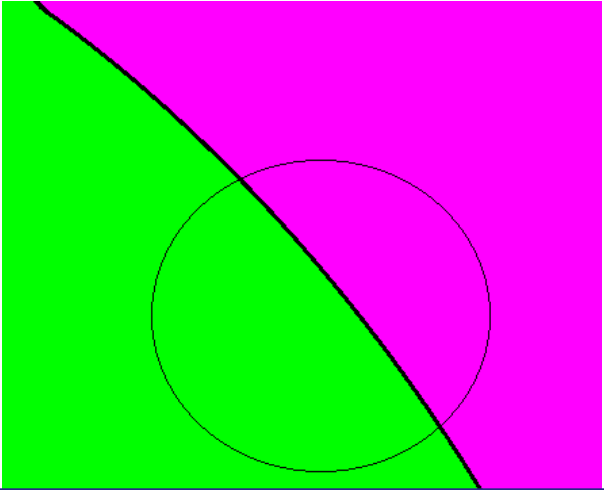
- At a given moment in cosmology we have denoted as thin black lines the surfaces arround regions which are crudely connected causally, so that the points inside such a “ball” drawn with thin line have had causally contact even ignoring inflation.
- For scales longer than the size of these “balls” of size H^{-1} (= the inverse Hubble constant at the time), there was no causal contact - except perhaps in inflation time - and whether one gets the lilac or the geen phase will occur randomly with probability 50 % for each.
- Thus of the order of unity (say 1/2) **domain wall crossing each horizon size ball cannot be prevented in the Z_2-symmetry case.**

Yet further explanation of "Domain walls and Horizon size balls".

- This minimal number of walls per horizon size region puts severe lower limit to the number of walls in the Z_2-symmetric case.
- Denoting the energy density on the domain walls by S the energy of a domain wall piece crossing a (maximal) causally connected region ("ball") of size $\sim H^{-1}$ will be $\sim SH^{-2}$ and thus since the volume of such causal connection region is of the order H^{-3} the density of energy in the walls must be at least

$$\rho_{walls} \geq SH^{-2}/H^{-3} = SH \tag{6}$$

With Z_2-symmetry of order 1 domain wall at least per horizon region.



The dominance at late times of the domain walls energy density.

Over longer distances than $t = H^{-1}$ thus no phase of vacuum correlation possible when there is symmetry unless it were imposed by some rather mysterious initial condition. When two different vacuum-phases thus are likely to be present with only a distance t between them, there must exist domain walls - seperating such vacuum-phases - with distances between them not much longer than $t = H^{-1}$. These must have extensions even of the order of t in distance and thus t^2 in area. Thus the domain wall energy density on average in universe at least:

$$\rho_{walls} \sim \frac{SH^{-2}}{H^{-3}} = SH = \frac{S}{t},$$

where S is the surface tension of the wall.

But What if small deviations from symmetry?

Larson, Sakar, White as well as Hindmarsh, and Coulson et al. calculated:

- "Evading the Cosmological Domain Wall Problem" Sebastian E. Larsson, Subir Sarkar and Peter L. White arXiv:hep-ph/9608319v2 21 Jan 1997 Theoretical Physics, University of Oxford, 1 Keble Road, Oxford OX1 3NP, arXiv:hep-ph/9608319v2 21 Jan 1997
- "Analytic scaling solutions for cosmic domain walls" Mark Hindmarsh May 1996 School of Mathematical and Physical Sciences University of Sussex Brighton BN1 9QH U.K. e-mail: m.b.hindmarsh@sussex.ac.uk, arXiv:hep-ph/9605332v1 16 May 1996, M. Hindmarsh, Phys. Rev. Lett. 77, 4495 (1996).
- D. Coulson, Z. Lalak and B. Ovrut, Phys. Rev. D 53, 4237 (1996).

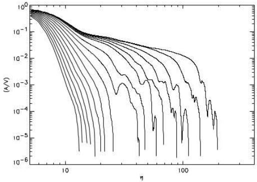


FIG. 5. Comoving area against conformal time in 3 dimensions with the bias ε in the range $0 - 0.03$.

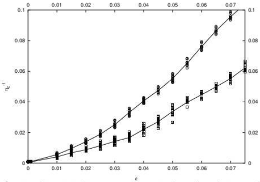


FIG. 6. η_c^{-1} against bias ε in 2 dimensions, where η_c is the conformal time at which the product of η and the comoving area density has fallen by a factor 10 (circles) or 100 (squares). The line connects the mean value of η_c over all the runs.

The notation of Larsson Sakar and White

These authors perform the computation in a **comoving** e.g. area A, which means it is measured relative to the size parameter a for the universe, and they use a **conformal time** η defined by $d\eta = dt/a(t)$ which measures the comoving distance traversed by light since the big bang.

The bias ϵ:

For concreteness we consider the Z_2 case where there are only two distinct vacuua and we generate the initial configuration with a probability

$$p_+ = 0.5 + \epsilon$$

that each initial domain is in the $+$ phase, where $\epsilon > 0$ is called the bias.

Examples read off from the curves of Larsson, Sakar and White.

The fig 5 have different curves corresponding to different values of the bias ϵ with which the one of the by symmetry equivalent vacua $+$ and $-$ has been overrepresnted to make assymmetry in the initial state. These curves give the comoving A/V (area over volume measured in the universe size a) as function of the conformal time η.

Results for when the domain walls decay away

- For a shift $\delta\rho$ between the energy densities of the two phases the walls will decay away exponentially at a typical size of the walls R reaching a critical limit

$$R_c = \frac{S}{\delta\rho}. \tag{7}$$

- With a bias ϵ in the initial condition probability for radiation dominated universe the critical time for decay is

$$t(R) \sim \epsilon(R)^{-3}. \tag{8}$$

(The varibles R attached denote that it is effective values for averaging over regions of size R).

Lemaitre-Friedmann-Robertson-Walker Equations

$$\left(\frac{\dot{a}}{a}\right)^2 + \frac{kc^2}{a^2} - \frac{\Lambda c^2}{3} = \frac{8\pi G}{3}\rho \tag{9}$$

$$2\frac{\ddot{a}}{a} + \left(\frac{\dot{a}}{a}\right)^2 + \frac{kc^2}{a^2} - \Lambda c^2 = -\frac{8\pi G}{c^2}p. \tag{10}$$

Here a is scale of universe length size, ρ the density and p the pressure (isotropy and homogeneity assumed). Dot denotes derivative w.r.t. time t; k is the curvature index.

Interpretation of LFRW equations

The LFRW-equations are equivalent to the following two equations - wherein though the curvature index k has become an integration constant:

$$\dot{\rho} = -3\frac{\dot{a}}{a}\left(\rho + \frac{p}{c^2}\right) \tag{11}$$

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right) + \frac{\Lambda c^2}{3} \tag{12}$$

The first is the energy conservation equation and the second gives the acceleration of the size if universe a as the gravitational effect of mass/energy and pressure; they both decellerate, while the cosmolgical constant accelelrate the expansion.

In radiation case:

$$\rho_{rad} = 4/c * \int_0^\infty d\nu \int_0^{\frac{\pi}{2}} d\theta \int_0^{2\pi} d\phi\, B_\nu(T)\cos(\theta)\sin(\theta)$$
$$= 4/c * \sigma T^4 \quad (13)$$

where

$$\sigma = \frac{2k_{\rm B}^4\pi^5}{15c^2h^3} \approx 5.670400 \times 10^{-8}\,\mathrm{J\,s^{-1}m^{-2}K^{-4}} \quad (14)$$
$$p = c^2\rho/3 \quad (15)$$

Here the temperature T scales with size a of the universe as

$$T \propto \frac{1}{a} \quad (16)$$

and σ is Stefans constant.

In radiation dominance $a \propto \sqrt{t}$; for walls $a \propto t^2$

One solves the LFRW equations for the radiation case with

$$a(t) \propto \sqrt{t} \tag{17}$$

for t the time and ignoring cosmological constant Λ.

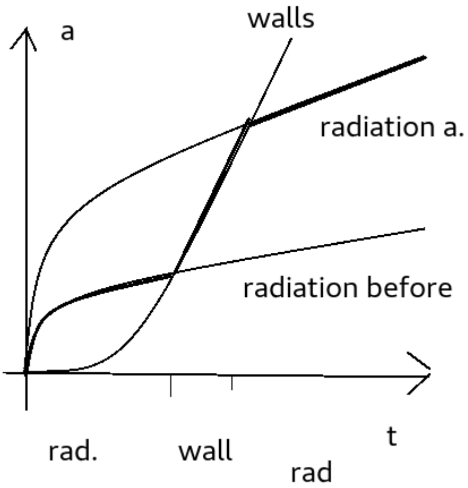
In the wall-dominance case:

$$\rho \propto \sigma * a^2/a^3 = \frac{\sigma}{a} \tag{18}$$

$$p = -\frac{2}{3}\rho \propto 1/a \tag{19}$$

$$a \propto t^2. \tag{20}$$

Universe size with walls intermesso



Reference on Wall cosmology.

- Brazilian Journal of Physics Print version ISSN 0103-9733On-line version ISSN 1678-4448 Braz. J. Phys. vol.33 no.4 So Paulo Dec. 2003 http://dx.doi.org/10.1590/S0103-97332003000400039 “Evolution of perturbations in a domain wall cosmology” Jlio Csar Fabris; Srgio Vitorino de Borba Gonalves

Strongly filtered neutrinos from the domain wall era.

(New idea that may end up making much of the already written stuff of this talk irrelevant or hopeless)

- With the parameters which we have earlier fitted our dark matter pearl theory with for the energy density of the domain wals we hope for, an energy density of the wall being called S with $S^{1/3} \sim 30 GeV$, we expect the domain walls -if they ever become dominant in the cosmology - to do so when universe is about 1 year old.
- Then in a time of that order the walls collide dramatically and release huge amounts of energy into some high energy particles, which we would essentially consider cosmic rays.
- But this happens in an appreciable background plasma with say a temperature of the order of 100 keV. In the - were it not for the walls - otherwise radiation dominace.

Strongly filtered neutrinos (continued)

- Most of the cosmic ray like particles produced from the few year old universe time we expect to be stopped in the plasma and just heat it up, so that we get increased the background radiation, but at first other signs tend to be hitten in the heated plasma, which may get into thermodynamical equilibrium again.
- Except though that very low energy neutrinos will have a low cross section even in such a plasma; so the signal about such a domain wall era might be most importantly the neutrinos that are so low energy that they are not absorbed in the plasma.
- Since the neutrinos as well as other particles to reach us from such an early time as about a one year old universe have to pass a lot of material, especially in the early times when density was much higher, we expect that the neutrino

A sharp energy cut off give close to the cut off energy a strong seasonal effect.

For the seasonal variation seen by the DAMA experiment a very sharp cut off in energy could be very important. If you namely measure the energy to be just above say the cutoff you will see a lot when the earth moves towards the rest frame of the neutrinos while you see nothing for instance with zero relative velocity if you look above and the cut off is sharp.

Is the Hubble constant tension indication of extra radiation

[23] consider changes in the early time physics and reconstruct the late time expansion history using BAO and SN Ia data. They find that dark radiation with an additional effective number of species around 0.4 could relieve the Hubble tension, but note that preliminary Planck CMB polarization data disfavours this solution. At low redshifts ($z \leq 0.6$), the recovered expansion history deviates less than 5 % from the CDM model.

J. L. Bernal, L. Verde, and A. G. Riess. “The trouble with H_0” . JCAP, 10:019, October 2016.

Domain Walls and Bayron Assymmetry

Now we want to look a bit on the possible significance of domain walls on the production of an assymetry so as to get more bayons than antibaryons in the universe:
We see two ways that appearance of walls could influence a typical type of lepton number assymtry and thereby get a baryonnumber assymmetry:

- Energy density: The existence of two phases seperated by walls, which above some temperature melt together to one high temperature phase, can be said to mean that at the high temerature there are a lot of walls arround, basically covering space rather densily.
  This means then effectively an extra contribution to energy density in the high temperature situation, not much different from what an extra term in the cosmological constant gives.

Bayon number and Domain walls (contnued)

- Energy density (continued)
  Such an extra term in cosmological constant would influence the expansion rate in eras wherein it may be important and thus could influence baryon assymmetry creation.
- Hard collissions: If we have a cooling down of a situation with walls, these walls will still collide and move themselves due to their - as temperature gets lower relative to the temperature enormous tension -, and in the clashes of domain wals or when they unite and allow a strong diminishing of their area relative to the temperature at that time very high energy particles might be emitted.
  If appropriate see-saw neutrinos are produced and decay in a cold era sya B-L assymmetry could easily be produced in relatively big amounts.

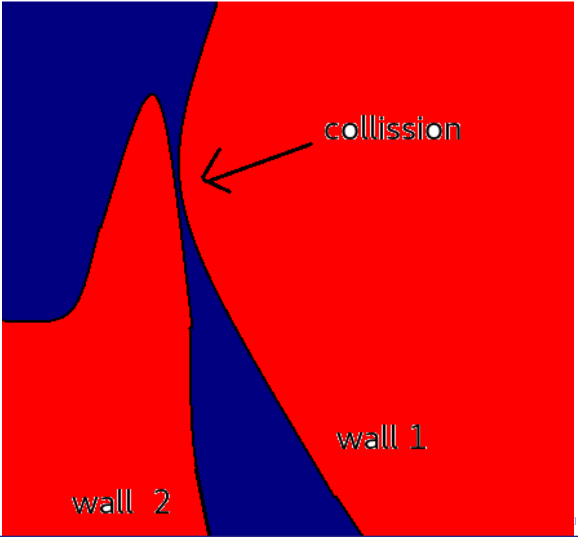
Crude description of Domain walls activity:

- If the walls start in a rather random and chaotic high temperature situation, they will as they get coold down straingt themselves out more and more, and this means releasing energy.
- Under the motion caused for parts of the domain wall(s) we must imagine that they could quickly come to run with speeds comparable to the speed of light unless the radiation or plasma arround them is able stop their motion.
- If they move randomly, they will typically collide.

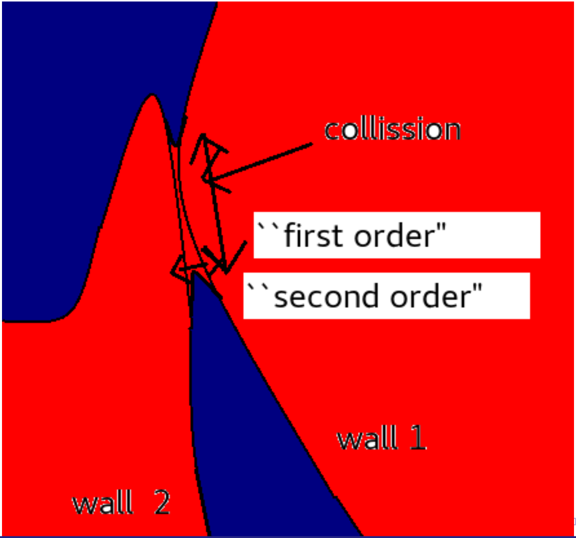
Crude description of domain wall activity (continued)

- When two pieces of domain walls collide at first, they must be touching tangentially at first.
- This leaves to be able to make a partial annihilation of each other in the neighborhood point where they first met.
- By a relatively little disturbance - of "second order" - a little piece of extension of "first order" can be annihilated.
- If by dimensional arguing the tension/energy density along the wall is large compared to say the temperature the energy and heat from the collissions will seem very big.
- In a given cosmolgical temperature era we can with surviving domain walls expect that at collissions particles otherwise only presnt in an earlier and more hot era can be produced.

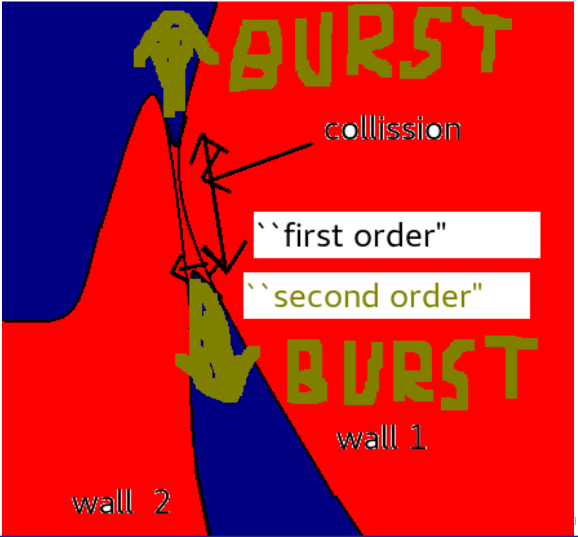
Walls first touch tangentially.



Large piece of walls can be contracted away.



Wall collissions bursts of high energy particles



Restating hope (number 2) for making B-L assymmetry by walls

- 1. At temperatures above say top mass scale, there are walls of the condensate-our phase type, but they are termally fluctuating and even colliding gives only particles of the energy scale of the temperature. (so not so important)
- 2. When temperature comes below the scale of top quark mass assumed to be that of the domain walls we we just now discuss, there are still domain walls although fewer than at the higher temperature; **but now they have tension and energy density along them high compared to surrounding temperature, and thus now they are important.**

Restaing hope for B-L from walls (contniude)

- 3. When in the colder era than the walls-scale temperature the surving domain walls collide, there is released energy of a compared to the temperature arround very high scale.
- 4. In the collissions and associated contractions of pieces of domain walls there will be released so much energy that possibly particles of sorts too heavy to still be arround in the cold era are produced in these collissions anyway.
- 5. For instance see-saw neutrinos may be produced in such collissions **even when surrounding temperature is lower than say top-mass.**

Speculated help for getting more Baryons

- The problem at least for our old model of Y. Takanishi, H.B.N. (and C.D. Froggatt) whith the characteristic of seeking to getting the B-L excess from next to lowest mass see-saw neutrino decaying time-reversal invariance violating, was that it did not produce sufficient excess, because the excess was washed away by essentially the lowest mass see-saw neutrino, which stayed arround in cosmological times too long and allowed B-L violation in approximate equilibrium.
- If we could have got the cooling down faster it would have helped to prevent this wash out.
- If one can get a local warming up in the wall collission in a time when it is already colder, the cooling of the locally heated material will be much faster than if the whole universe is just cooled by the Hubble expansion.

Order of magnitude estimate of energy per particle from Wall collissions

What are the realistic energies per particle obtainable by domain wall collissions from the era wherein the walls are getting of importance but no longer lying so densely in the universe?
Let us estimate:

- A priori A priori the energies per particles are expected to be given by the wall-energy scale E_{wall} , which gives roughly both the thickness of the wall (“thickness” $\sim E_{wall}^{-1}$) and energy density per area of the wall $S \sim E_{wall}^3$.
- γ But now if in the collissions the walls have achieved enormous velocities, so that they have say γ's much bigger than unity then even higher energy per particle seem likely.

Further estimating velocity-γ for wall pieces

- Situation In the cosmological situation in which the typical distance between the domain walls is (already) the Hubble distance $H^{-1} \sim t \propto a$ the walls run in times of the order of magnitude this Hubble time $t \sim H^{-1}$ and accellerate - seen from the average rest frame of the bulk of the plasma whatever arround. During this time a piece of wall of radius r say gets accellerated by a force of the order $r * E_{wall}^3$ and has a rest mass $r^2 * E_{wall}^3$, so that it reaches a time t a momentum of the order $t * r * E_{wall}^3$. Assumming the velocity of order unity, in units with light velocity unity, the relativity theory $\gamma \sim t/r$.
- Max γ It makes no sense to have smaller wall-pieces than of order $r \sim E_{wall}^{-1}$ and thus the biggest typically reached γ is $t * E_{wall}$.

Still estimating energy per particle from wall collissions

- Biggest The biggest typical - there will with exponentially small probability be much higher energy particles produced - particle energy produced in the wall collisions were estimated to $t * E_{wall}$ meaning that it corresponds to an era wherein the temperature were t times larger than in the era with the temperature being the wall scale $T \sim E_{wall}$.
- Era redone The era the particles of which may thus be re-created by wall collissions is thus an era with temperature $T \sim t * E_{wall}$.
- Radiation case In the case that in the times with the walls the dominant material were still radiation so that $T^2 * t \sim conctant$ one would in an era with temperature T say a factor E_{wall}/T lower than the wall-scale E_{wall} have a Hubble scale $t \sim H^{-1}$ being $(E_{wall}/T)^2$ times bigger than the

The DAMA/Libra experiment saw some (Controversial) Dark Matter

Fitting the signal of counting events by the time expression

$$R(t) = S_0 + S_m \cos(\omega(t - t_0)) \quad (21)$$

they find

$$t_0 = 152.5 day \quad (22)$$
$$\text{with } T = \frac{2\pi}{\omega} = 1yr$$

they find in region of energy up till 6 keV an S_m of order 0.01 count/day/kg/keV.

Energy distribution of the modulation amplitudes

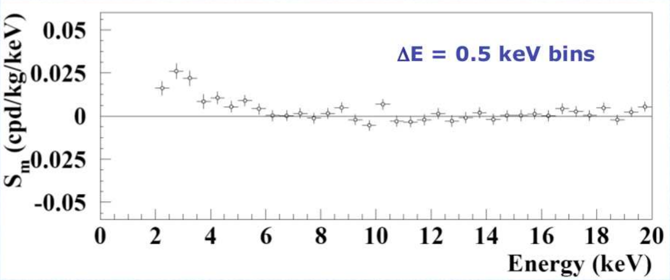
Max lik analysis

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

here $T = 2\pi/\omega = 1$ yr and $t_0 = 152.5$ day

DAMA/NaI (7 years) + DAMA/LIBRA (6 years)

total exposure: 425428 kg×day ≈1.17 ton×yr



A clear modulation is present in the (2-6) keV energy interval, while S_m values compatible with zero are present just above

The S_m values in the (6–20) keV energy interval have random fluctuations around zero with χ^2 equal to 27.5 for 28 degrees of freedom

Our NOT SO SUCCESSFUL speculation for DAMA

- What DAMA "sees" is neutrinoes in an energy range where ONLY electrons are excited. (So nobody else can see it, because background in electrons excited is too high.)
- These neutrinoes should come from collissions of WALLS.
- To have any chanse to come even close to fitting: We need for same density of the inside pearl matter VERY SMALL PEARLS of radius R of nuclear size. (Otherwise they do not collide enough to just come close to the observed rate)

"Neutrinos" solve the conflict with the other experiments

The point proposed that neutrinos interact only with electrons at low energy is actually not true when **neutral current** is included: Neutral currents namely allow **both nuclei and electrons** to have **elastic** scattering with neutrinos.

But if you adjust the energy $\approx$ momentum for the neutrinos to give say a few keV recoils of electrons, then for nuclei it is much less and the latter would not be observed.

With slow heavy particles it is different: The nuclei get the bigger recoil energy than the electrons.

Some ratios: cross section / energy or mass; crudely

$$\text{DAMA:}$$

$$\left(\frac{\sigma}{m}\right)_{DAMA\ 1.} = 10^{-41}\frac{cm^2}{GeV} \tag{23}$$

$$\left(\frac{\sigma}{m}\right)_{DAMA\ 2.} = 5*10^{-42}\frac{cm^2}{GeV} \tag{24}$$

$$\left(\frac{\sigma}{m}\right)_{DAMA\ naive} = 10^{-40}\frac{cm^2}{GeV} \tag{25}$$

$$\text{Neutrino on electron:}$$

$$\frac{\sigma(\nu e)_{CC}}{E_\nu} = 0.4*10^{-41}\frac{cm^2}{GeV} \tag{26}$$

$$\frac{\sigma(\nu\ nucleon)}{E_\nu} = 6*10^{-38}\frac{cm^2}{GeV} \tag{27}$$

$$\tag{28}$$

Some ratios: cross section / energy or mass; crude orientation, continued

Bounds on DM interaction:

$$\left(\frac{\sigma}{m}\right)_{\text{Böehm}} = 10^{-33}\frac{cm^2}{GeV} \quad (29)$$

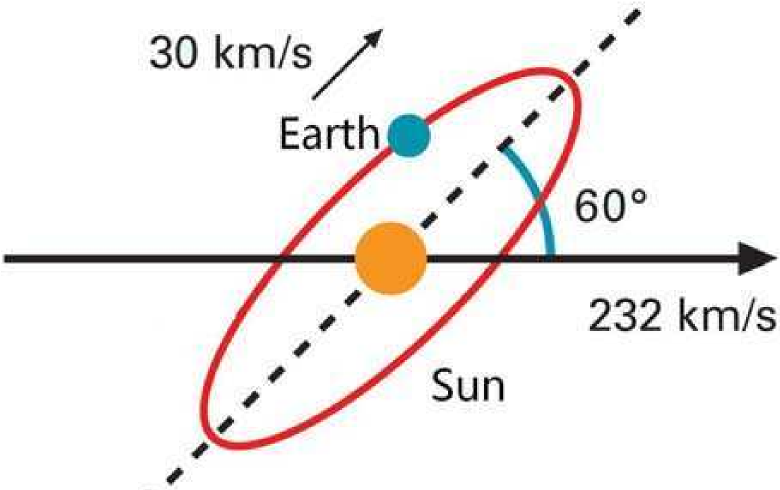
$$\left(\frac{\sigma}{m}\right)_{Cluster-collission...} = 2*10^{-24}\frac{cm^2}{GeV} \quad (30)$$

Our dark matter model:

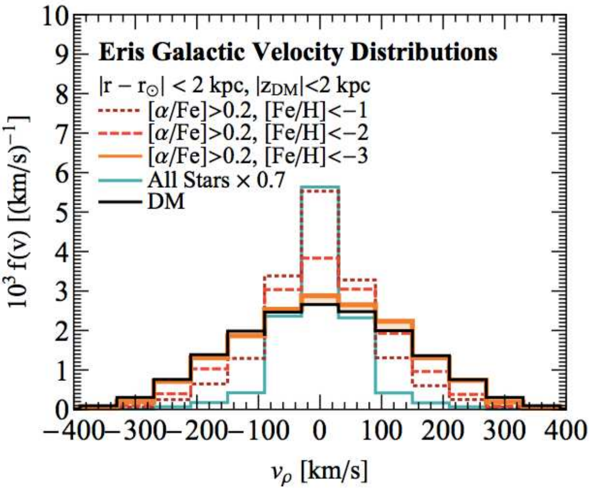
$$\left(\frac{\sigma}{m}\right)_{\text{Our pearls}} = 10^{-33}\frac{cm^2}{GeV} \quad (31)$$

$$(32)$$

Motion relative to Dark Matter



Motion of Dark Matter, stars etc.



Text for the figure “Motion of Dark Matter Stars etc.

Velocity histograms of different components of the Milky Way, as seen in the ERIS simulation. The black histogram shows the velocity distribution of dark matter. The cyan histogram illustrates the velocity of all stars, and has a much larger central peak than the dark matter distribution. The orange histogram, however, which includes only metal-poor stars, is very similar to the dark matter velocity distribution. [Herzog-Arbeitman et al. 2018]

Numbers for Crude Estimates

- **Density of Dark Matter in Solar System Neighborhood:**

$$D = \frac{0.3 GeV}{cm^3} = 5.35 * 10^{-22} \frac{kg}{m^3} \qquad (33)$$

- **Typical Speed (also reletive to each other):**

$$v = 200 km/s = 2 * 10^5 m/s \qquad (34)$$

- **Rate on crossing Area, per m^2:**

$$Rate = vD = 1.07 * 10^{-16} \frac{kg}{m^2 s} \qquad (35)$$

Hitting Rates for some Masses:

With

$$Rate = vD = 1.07 * 10^{-16} \frac{kg}{m^2 s} \quad (36)$$

we have for various masses rates:

mass	m^2 rate	m^2 time	earth rate	earth time
$10^{-16} kg$ $= 5 * 10^{10} GeV$	$1 s^{-1}$	1 s	$5 * 10^{16} s^{-1}$	$2 * 10^{-15} s$
$10^{-8} kg = 10 \mu g$	$10^{-8} s^{-1}$	$10^8 s = 3y.$	$5 * 10^8 s^{-1}$	$2 * 10^{-9} s$
1 kg	$10^{-16} s^{-1}$	$10^{16} s$	$5 s^{-1}$	$0.2 s$
$10^8 kg = 10^5 ton$	$10^{-24} s^{-1}$	$10^{24} s$	$5 * 10^{-10} s^{-1}$	$2 * 10^9 s$ $\sim 100 y$

Compare Imapcts of Ordnary matter

$10^{-2} kg$: 10^5 per year
1 kg : 10^4 per year.
$10^8 kg$: 10^{-3} per year.
Since a year has $3.16 * 10^7$ s this corresponds to a mass density $D_{meteors}$ times the velocity $v_{meteors}$ being of the order

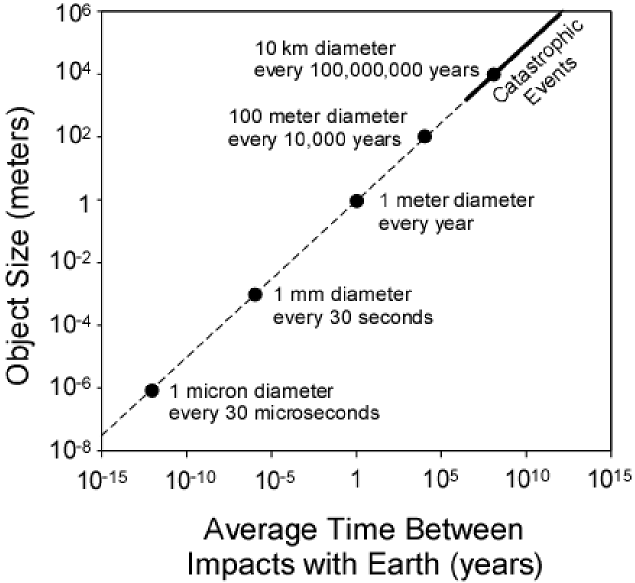
$$v_{metoer} D_{meteor} \sim \frac{10^4 kg/year/eartharea}{3.16 * 10^7 s/year} \quad (37)$$

$$= 3 * 10^{-3} kg/eartharea/s \quad (38)$$

$$= \frac{3 * 10^{-3} kg/eartharea/s}{0.5 * 10^{15} m^2/eartharea} \quad (39)$$

$$= 2 * 10^{-18} kgs^{-1} m^{-2}; \quad (40)$$

formally a **factor 50 smaller** than the dark matter.



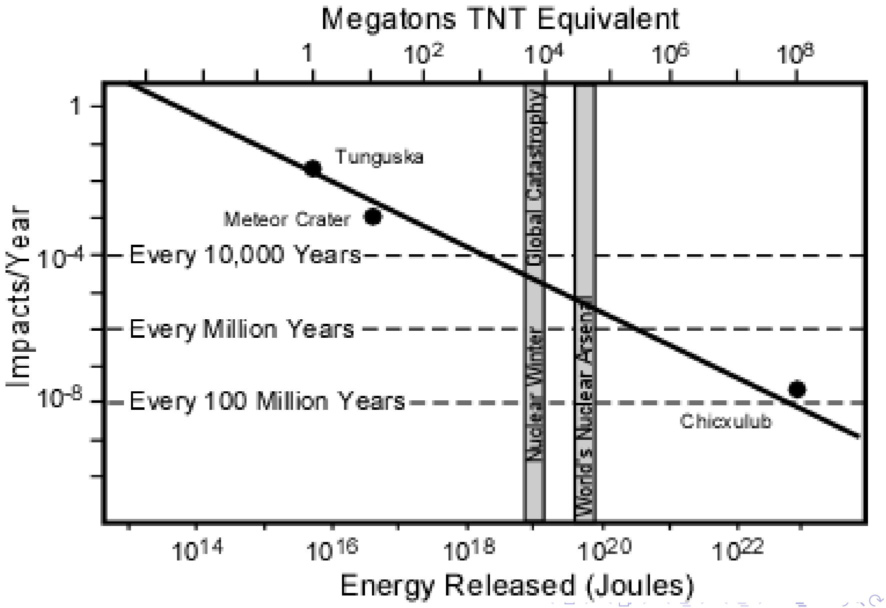
Object Size (meters)
Average Time Between Impacts with Earth (years)
10 km diameter every 100,000,000 years
100 meter diameter every 10,000 years
1 meter diameter every year
1 mm diameter every 30 seconds
1 micron diameter every 30 microseconds
Catastrophic Events
10^6
10^4
10^2
1
10^-2
10^-4
10^-6
10^-8
10^-15
10^-10
10^-5
1
10^5
10^10
10^15

Size of Impact goes square root as "time in between"

A formula easy to remember is:

$$\text{“impact size” in m} = \sqrt{\text{av. “time between” in years}} \quad (41)$$

on earth.


Megatons TNT Equivalent
1
10^2
10^4
10^6
10^8
Impacts/Year
1
10^-4
10^-8
Tunguska
Meteor Crater
Every 10,000 Years
Every Million Years
Every 100 Million Years
Global Catastrophy
Nuclear Winter
World's Nuclear Arsenal
Chicxulub
10^14
10^16
10^18
10^20
10^22
Energy Released (Joules)

Would Macroscopic Dark Matter Dominate Meteors?

-
-

Dark Matter ?

Main points of present talk:

- **Multiple Point Principle:** Several vacua with **same energy density** seperated by high tension "walls"(surfaces much like the surface of a buble of water).
- **Cosmological effects of such Walls**
  - 6 cm and 100000 ton dark matter pearls surrounded by wall. (seen as Tunguska event, kimberlite pipes, supernova extra neutrino bunch ?)
  - High energy particles from wall collissions especially neutrinoes may survive. (Has DAMA seen these neutrinoes ?)
- Some **non-gravity dark matter signs:**
  - The 3.5 keV X-ray radiation.
  - positrons relative to gamma-rays from dark matter (problem)

Plan for Dark Matter:

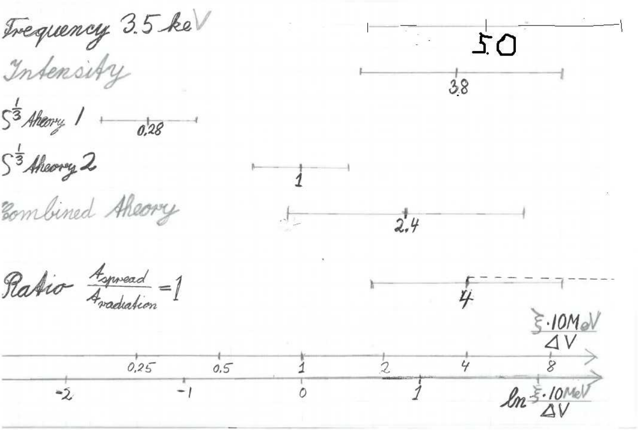
- Intro Introduction.
- Model Our model of dark matter pearls,
- Collide Picturing colliding pearls, heat spreading.
- Walls Walls in cosmology giving neutrinoes etc. and contracting...
- DAMA Can we interprete DAMA-effect as due to neutrinoes from walls ?

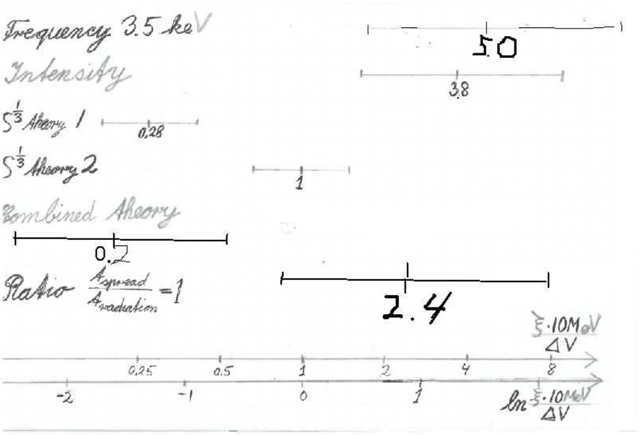
Dark Matter in Only Standard Model (except MPP)

Contrary to everybody else, except for the poeple with primordial black holes for dark matter, we want to propose a dark matter model **inside Standard Model**, only with a certain assumption about the coupling constants in the Standard Model, that there are several vacua with finetuned same energy density. So:

- We assume a law of nature - of a bit unusual kind- "Multiple Point Principle" saying: there are **several** different **vacuum phases**, and they all have the **same energy density** (or we can include that they have ~ 0 energy density.)
- Apart then from me mentioning some attempt mainly with Yasutaka Takanishi of explaining the baryon excess, we shall use **only Standard Model**, even for dark matter!

Figure caption on Dark matter mass: Parameter space for elastic spin-independent dark matter-nucleon scattering. The result from the analysis presented in [5] is drawn in solid red together with the expected sensitivity (1σ confidence level (C.L.)) from a data-driven background-only model (light red band). The remaining red lines correspond to previous CRESST-II limits [4, 10]. The favored parameter space reported by CRESST-II phase 1 [11], CDMS-Si [12] and CoGeNT [13] are drawn as shaded regions. For comparison, exclusion limits (90 % C.L.) of the liquid noble gas experiments [14, 15, 16] are depicted in blue, from germanium and silicon based experiments in green [17, 18, 19, 20, 21]. In the gray area coherent neutrino nucleus scattering, dominantly from solar neutrinos, will be an irreducible background for a CaWO 4 -based dark matter search experiment [22].


Frequency 3.5 keV
5.0
Intensity
3.8
0.28
1
Combined theory
2.4
Ratio
=1
4
0.25
0.5
1
2
4
8
-2
-1
0
1



Frequency 3.5 keV
50
Intensity
3.8
$\xi^{\frac{1}{3}}$ theory 1
0,28
$\xi^{\frac{1}{3}}$ theory 2
1
Combined theory
0.2
Ratio $\frac{A_{spread}}{A_{radiation}}=1$
2.4
$\xi \cdot 10 MeV$
ΔV
0,25
0,5
1
2
4
8
-2
-1
0
1
$\ln \frac{\xi \cdot 10 MeV}{\Delta V}$