Our Dark Matter, Stopping in Earth, etc.

Our Dark Matter Stopping in Earth

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[2]Speaker at the Work Shop "What comes beyond the Standard Models" in Bled.

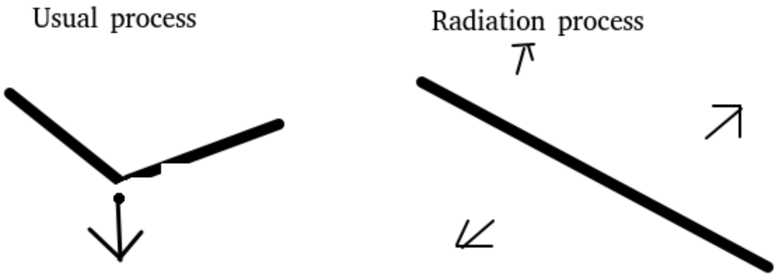
Especially we look for the property: Dark Matter Radiates, say Elctrons, more importantly than Colliding with Nuclei

We have long cosidered a model for dark matter in which the dark matter radiates,

- first of all the X-ray line 3.5 keV, which has been observed, but is not predited from the usually assumed amounts of ionized atoms.
- If there is a level for X-rays it might well be it can also emit electrons with same energy (release).

It could a priori happen that such emission gave a greater potential for detection than the nuclei hit by the dark matter, especially if the dark matter gets stopped in the shielding - the air or the mounteen or earth above the experiments.

If Somehow Excited a Dark Matter Particle could Radiate ?



The Ingenious Seasonal Variation Method Fails for Perfect Dominant Radiation

If WIMPs were radiating causing the detection instead of by collissions and radiation dominated, then the **Seasonal variation method would not work,** because it would be the time spent near the detector that would count, and the shorter time spent with higher speed would **exactly** compensate for the higher number of passing particles per time $\times$ area unit would be just compensated by the shorter passage time.

Table 3 Annual modulation amplitudes from various experiments. From: An induced annual modulation signature in COSINE-100 data by DAMA/LIBRA's analysis method

Counts/kg/keV/day	1–6 keV	2–6 keV
This work	- 0.0441 $\pm$ 0.0057	- 0.0456 $\pm$ 0.0056
DAMA/LIBRA	0.0105 $\pm$ 0.0011	0.0095 $\pm$ 0.0008
COSINE-100	0.0067 $\pm$ 0.0042	0.0050 $\pm$ 0.0047
ANAIS-112	- 0.0034 $\pm$ 0.0042	0.0003 $\pm$ 0.0037

The amplitudes of the annual modulation fits using the DAMA-like method to the COSINE-100 3 years data (this work) are compared with results from DAMA/LIBRA15,16, COSINE-1008, and ANAIS-1129 in both 1–6 keV and 2–6 keV regions.

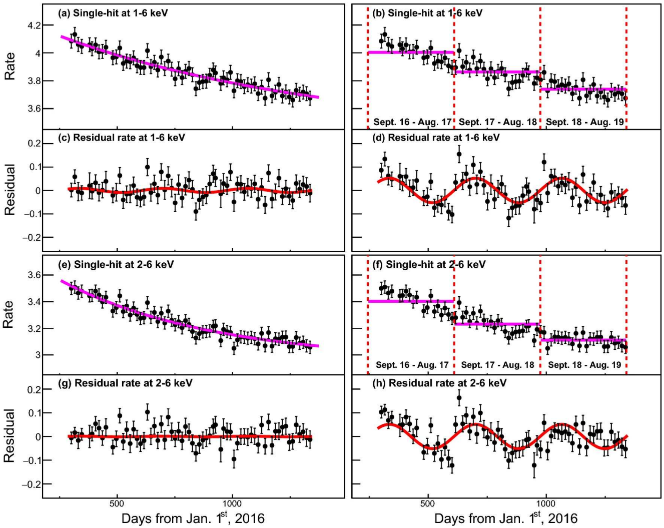

(a) Single-hit at 1-6 keV
(b) Single-hit at 1-6 keV
Sept. 16 - Aug. 17
Sept. 17 - Aug. 18
Sept. 18 - Aug. 19
(c) Residual rate at 1-6 keV
(d) Residual rate at 1-6 keV
(e) Single-hit at 2-6 keV
(f) Single-hit at 2-6 keV
Sept. 16 - Aug. 17
Sept. 17 - Aug. 18
Sept. 18 - Aug. 19
(g) Residual rate at 2-6 keV
(h) Residual rate at 2-6 keV
Rate
Residual
Rate
Residual
4.2
4
3.8
3.6
0.2
0.1
0
−0.1
−0.2
3.6
3.4
3.2
3
0.2
0.1
0
−0.1
−0.2
500
1000
500
1000
Days from Jan. 1st, 2016
Days from Jan. 1st, 2016

Figure text:

Single-hit event rates in the unit of counts/keV/kg/day as a function of time. The top four panels present time-dependent event rates and the residual rates in the single-hit 1–6 keV regions with 15 days bin. Here, the event rates are averaged for the five crystals with weights from uncertainties in each 15-day bin. Purple solid lines present background modeling with the single exponential (a) and the yearly averaged DAMA-like method (b). Residual spectra for the single exponential model (c) and the DAMA-like model (d) are fitted with the sinusoidal function (red solid lines). Same for 2–6 keV in the bottom four panels. Strong annual modulations are observed using the DAMA-like method while the result using the single-exponential models are consistent with no observed modulation.

COSINE-100 mearsurements, methodology dependence

- [2] : When they analyse with the method like the **way of DAMA** the strange **negative amplitude** comes up.
- [1] : When they analyse their own way, the result (which inside uncertainty) is **both cosistent with DAMA and with no oscillation with season** (after three years)

The different Depths of the Experiments Simulating DAMA:

The detector of **Cosine-100** is located underground at a depth of **700m**, approximately **1600m.w.e**, in the Yangyang Underground Laboratory in Yangyang,. South Korea.

DAMA is located **1400 m** ($\sim$ **4200 m.w.e.**) in GranSasso.

The hut housing the **Anais** experiment is placed at the hall B of LSC (under **2450 m.w.e.** ($\sim$ **800 m**) of overburden).

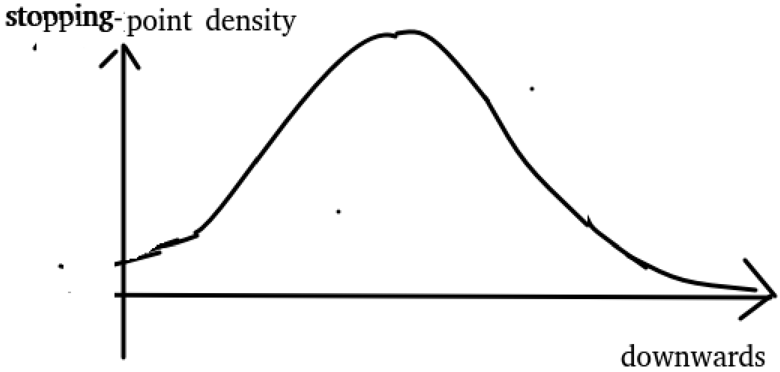
Simple Properties of Our Model:

- The main signal for observation is **radiation** of electrons or photons say
- (Likely) the main observational effect comes thus from dark matter particles, which essentially **stopped**.
- The dark matter particles interact so strongly that they get **slowed down** in the earth shielding.

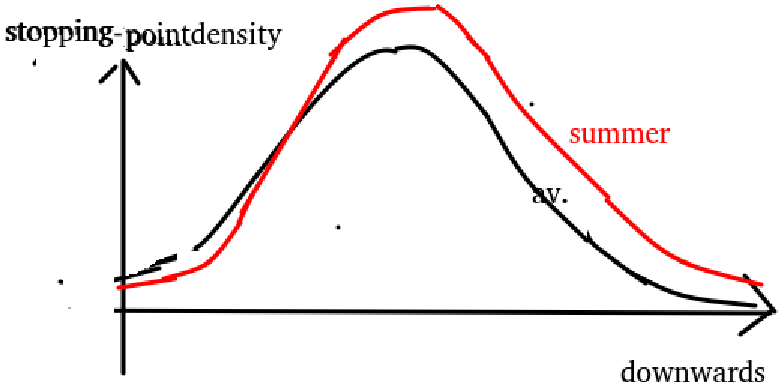
Ignore for simplicity but the moton in one direction down

The depth into which a dark matter particle will penetrate before (effectively) stopping, will be a smooth function of its velocity relative to the Earth. So "topologically" the **distribution of stopping-depths** will repflect the **initially velocity spectrum** in the down direction.

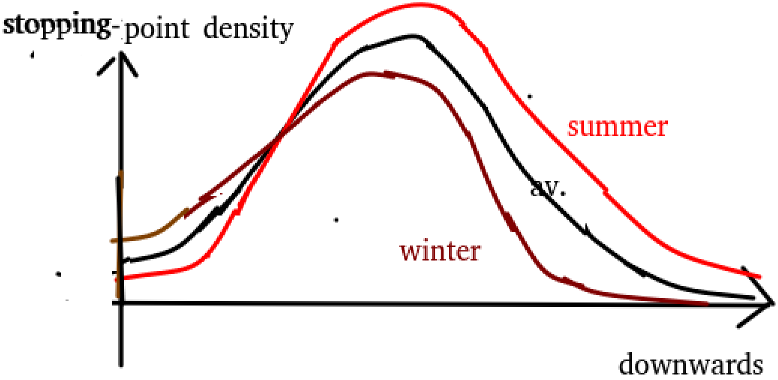
Velocity Distribution gets Transformed to Stopping Position Depth



In summer the heading on speed is on average Larger, $\Rightarrow$ Goes deeper



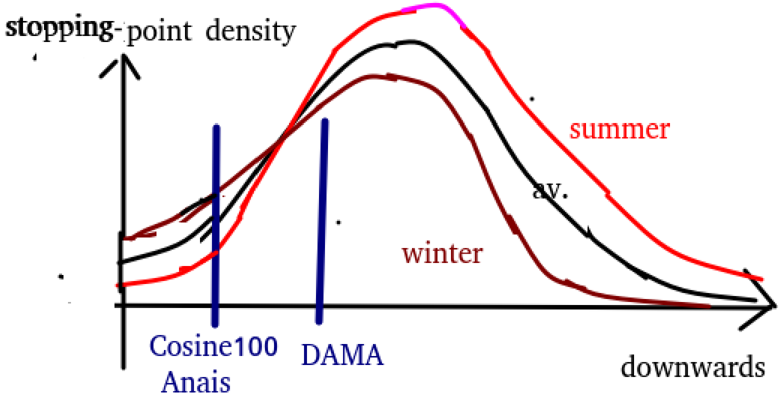
In Winter Speed Relative to Earth of dark Matter is Lower



Stopping ⇒ Huge Dayly variation, Unless Slow Decay

If the dark matter only can penetrate on the time of the **day night** on which the site of observation turns towards the flux of the dark matter, then a large variation with the time on the day or night is expected! This may though be avoided, if the dark matter particles radiate their electrons or whatever with a **life time long compared to a day**. Then it will wash out such an effect of day-night variation.

DAMA is about Twise as Deep Down as Anais and Cosine-100



Fitting of the (Mysterious line) 3.5 keV presumably from Dark Matter

By various X-ray spectroscopes, mostly from sattelites, one has seen a line at 3.5 keV (in the restframe, so to be corrected for redshift), not matching with lines from ions expected in the plasmas looked at; so it is suggestively from dark matter.
In our model dark matter is ordinary matter under high pressure, so that the Fermi energy of the electrons in the compressed material is $E_f \approx 3.3MeV$.
Corresponding to high denstity or fermi-energy E_f we estimate by "dimensional argument" (and calculation for the $\sqrt{2}$) the **Homo-lumo-gap** E_H as

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

Homo-lumo-gap Supposed a general Phnomenon

The formula

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

we supposed a genaral one for the gap between highest filled HOMO level and the lowest unfilled LUMO (H=highest, O=occupied, MO= molecular orbit, L= lowest). Here α is the finestructure constant conceived of as a velocity for our dimensional argument, in an in pracsis nonrelativistic atomic physics theory, while E_f is the Fermi-energy; we have though in mind a theory with relativistic electrons.

The compressed material suggested a favourite emission line E_H, the homo-lumo-gap value, which thus should be

$$E_H = 3.5 keV. \quad (3)$$

Using our Model since long for the 3.5 keV line Observed fix Density of Our Pearls New Vacuum Part

We fitted a parameter cobination

$$\frac{\xi_{fS}^{1/4}}{\Delta V} = 0.6MeV^{-1} \quad (4)$$

$$\text{by identifying} \text{``}homo - lumo - gap'' = E_H = 3.5keV \quad (5)$$

$$\text{essentially fermimomentum } p_f = 2/\frac{\xi_{fS}^{1/4}}{\Delta V} = \frac{2}{0.6MeV^{-1}}$$

$$= 3.3MeV \quad (6)$$

$$\text{Density of inside pearl } \rho_B = 2m_N * \frac{1}{3\pi^2} * p_f^3 \quad (7)$$

$$= 5.2 * 10^{11} kg/m^3. \quad (8)$$

Getting a Nucleon Potential Difference ΔV between the Sides of the Wall:

Believing we could estimate the ratio of the typical radius R of our dark matter pearls (ignoring possibly huge ones of astronomic sizes) to the critical size R_{crit} at which the contracting wall arround the pearl would press the nuclei out and the pearl thus could not be stable if smaller, to be

$$\xi_{fS} = \frac{R}{R_{crit}} \approx 5, \tag{9}$$

we get from $\frac{\xi_{fS}^{1/4}}{\Delta V} = 0.6 MeV^{-1}$ that **the difference in potential ΔV for a nucleon between the inside and outside of the central part of the pearl is**

$$\Delta V = \frac{\sqrt[4]{\xi_{fS}}}{0.6 MeV^{-1}} = 2.5 MeV. \tag{10}$$

Tension of Domain Wall around Pearl Needed

The pressure of the relativistic electron fermi-sea supposed in the new vacuum inside the pearl

$$P = < E_e > n_e/3 \approx \frac{1}{12\pi^2} * p_f^4 \quad (11)$$

$$\text{where we fit } p_f \approx E_f = 2/(0.6MeV^{-1}) = 3.3MeV$$

$$\text{using "}\textit{line energy}\text{"} = E_H = 3.5keV = \sqrt{2}\left(\frac{\alpha}{c}\right)^{3/2} * E_f \quad (12)$$

$$\text{and thus } P = \frac{(3.3MeV)^4}{12\pi^2} = 1.0MeV^4.$$

Now a tension of the surface wall S is required to obey

$$\frac{2S}{R} = P = 1.0MeV^4. \quad (13)$$

Parameters as function of R for given the 3.5 keV or Rather $E_f = 3.3 MeV$

$$\text{Tension } S = \frac{1}{2} P * R \tag{14}$$

$$= 0.5 MeV^4 * R \tag{15}$$

$$= 0.5 MeV^3 / (0.2 * 10^{-12} m) * R \tag{16}$$

$$= 2.5 * 10^{12} MeV^3 / m * R \tag{17}$$

$$\text{or } S^{1/3} = 1.36 * 10^4 MeV / m^{1/3} * \sqrt[3]{R} \tag{18}$$

(The third root of the tension, i.e. $S^{1/3}$ has dimension of energy.)

Parameters as function of R given the 3.5 keV or Rather $E_f = 3.3 MeV$

$$S = 2.5 * 10^{12} MeV^3/m * R \quad (19)$$

$$S^{1/3} = 1.46 * 10^4 MeV/m^{1/3} * \sqrt[3]{R} \quad (20)$$

$$M = \rho_B * 4/3 * \pi * R^3 \quad (21)$$

$$= 2.2 * 10^{12} kg/m^3 * R^3 \quad (22)$$

$$\sigma = \pi * R^2 \quad (23)$$

$$\frac{\sigma}{M} = \rho_B^{-1} * 4/3 * R^{-1} \quad (24)$$

$$= 2.6 * 10^{-12} m^3/kg * R^{-1} \quad (25)$$

Parameters for Stopping, using $E_f = 3.3MeV$

$$\frac{M}{\sigma} = \rho_B * 3/4 * R \quad (26)$$

$$= 3.9 * 10^{11} kg/m^3 * R \quad (27)$$

$$\frac{M}{\sigma \rho_{water}} = 3.9 * 10^8 * R \quad (28)$$

$$\frac{M}{\sigma \rho_{stone}} = 1.3 * 10^8 * R \quad (29)$$

For e.g. getting the pearl stop of order of magnitude after penetrating 1 km stone it takes about $R = 1km/(1.3 * 10^8) = 0.8 * 10^{-5} m$ and that would give about $M = 1.1g$.

Some Densities

$$\begin{aligned}
\text{Density inside DM: } \rho_B &= 5.2 * 10^{11} kg/m^3 (\text{using } E_f = 3.3 MeV) \\
\text{DM-density near Sun; } D_{sun} &= 0.43 GeV/cm^3 && (30) \\
&= 1.78 * 10^{-27} kg/Gev * 0.43 GeV/cm^3 \\
&= 0.77 * 10^{-21} kg/m^3 && (31) \\
\text{DM in whole world:} D_{world} &= 2.2 * 10^{-27} kg/m^3 && (32) \\
\text{giving ratio } \frac{\rho_B}{D_{sun}} &= \frac{5.2 * 10^{11} kg/m^3}{0.77 * 10^{-21} kg/m^3} && (33) \\
&= 6.8 * 10^{32} (\text{using } E_f = 3.3 MeV) \\
\text{giving } \frac{dist_{pearls}}{R_{pearls}} &= \sqrt[3]{6.8 * 10^{32}} && (34) \\
&= 0.89 * 10^{11}. (\text{us. } E_f = 3.3 MeV)
\end{aligned}$$

,

$$\text{or } dist_{pearls} = 0.89 * 10^{11} R_{pearls} \quad (35)$$

E.g. $R_{pearls} = 10^{-5}m$ will give a typical distance of $1000km$, near the sun.
away from galaxies it would rather 100 times longer, i.e. for $R_{pearls} = 10^{-5}m$ a distance about 100000km.

Tensile Strength of Human skin Tissue $21.6 \pm 8.4 MPa$

Desparately looking for how much the pressure can be before a solid yields to e.g. a dark matter pearl lying on it, I noted down: The average ultimate tensile strength $21.6 \pm 8.6 MPa$, and the elastic modulus $83.3 \pm 34.9 MPa$.
Taking this for estimating the stopping of a pearl with dragging force at first

$$F_D = \frac{C}{2}\rho\sigma v^2 \quad (36)$$

$$\text{and then breaking force } F_{ts} = \sigma * 21 MPa \quad (37)$$

$$\text{breaking at } 21 MPa = C/2 * \rho v^2 \quad (38)$$

$$\text{with say stone } \rho = 3000 kg/m^3 \ C/2 v^2 = 7 * 10^3 Pa\ m^3/kg \quad (39)$$

$$= 7 * 10^3 m^2/s^2 \quad (40)$$

$$\text{giving } v = 167 m/s \text{ (with } C/2 = 1/4)$$

A bit better the Stopping Length

The drag equation with the drag coefficient C taken to 1/2 gives

$$\text{Drag force } F_D = \frac{1}{4}\rho * \sigma * v^2 \quad (41)$$

$$\text{with Newton } M\dot{v} = \frac{1}{4}\rho * \sigma * v^2 \quad (42)$$

$$\text{giving } \frac{d}{dt}\left(\frac{1}{v}\right) = -\frac{\sigma}{4M} * \rho \quad (43)$$

$$\text{Integrates to } v = -\frac{1}{t} * \frac{4M}{\sigma * \rho}(\text{counting } t < 0) \quad (44)$$

$$(45)$$

Calculating Stopping Length a Bit Better

$$\text{Again integrating, length } L = \int_{beg}^{stop} v dt \quad (46)$$

$$= \frac{4M}{\sigma * \rho} * \ln(t - t_{beg}) \quad (47)$$

Formally we have a logarithmic divergence, but in reallity, it is between the start velocity say 200km/s and the velocity at the stopping, say $167 m/s$. So the logarithm is $\ln(200000/167) = 7.0$. So the stopping length a bit better is

$$L = \frac{4M}{\sigma * \rho} * 7.0 \quad (48)$$

$$= 28 * \frac{M}{\sigma * \rho} \quad (49)$$

Or might the Pearls Cotinue Like Snow Falling Through the Earth ??

If the dragging force is

$$F_D = \frac{C}{2} * \sigma * \rho * v^2 \quad (50)$$

$$\text{then the balance} \quad \text{velocity } v \quad (51)$$

$$\text{is given by } gM = \frac{C}{2}\sigma * \rho * v^2 \quad (52)$$

$$\text{meaning } v|_{balance} = \sqrt{\frac{g}{\rho} * \frac{M}{\sigma}} = \sqrt{9.8m/s^2 * 1km}$$

$$= 99m/s(\text{for } \frac{M}{\sigma * \rho} = 1km)$$

$$\text{while } v_{balance} = \sqrt{9.8m/s^2 1km/28} = 19m/s(\text{for } \frac{M}{\sigma * \rho} = 1km/28)$$

"Formally" our Pearls should Stop at Some Level in Earth, depending on incomming velocity.

Formally, since the 167 m/s for breaking and stopping is a higher velocity than the 99 m/s we shall expect the pearls to stop and not to continue slowly sinking like snow. But it is really so tight, that we do not know what would really happen even believing our model and fits.

(Better) Fitting (i.e. $L = 4\ln(\frac{300km/s}{167m/s}) * \frac{M}{\sigma * \rho}$):

To now make stopping leng $L = 1km$ we need

$$\frac{M}{\sigma * \rho} = 1km/28 = 36m \quad (53$$

$$\frac{M}{\sigma} = 36m * 3000kg/m^3 = 1.08 * 10^5 kg/m$$

$$\frac{\sigma}{M} = 9 * 10^{-6} m^2/kg \quad (54$$

$$\text{Pearl radius } R = 36m/1.3 * 10^8 = 2.7 * 10^{-7} m \quad (55$$

$$\text{distance between pearls ``}dist\text{''} = 0.89 * 10^{11} * 2.7 * 10^{-7} m$$

$$= 2.4 * 10^4 m = 24km \quad (56$$

Better fitting w. $L = 4\ln(\frac{300km/s}{167m/s})\frac{M}{\sigma*\rho}$ continued:

$$\begin{aligned}
\text{Distance between the DM-pearls `}dist'' &= 24km \\
\text{means ``}densityofpearls''_{number} &= 7.2*10^{-15}m^{-3} \\
\text{giving } 7.2*10^{-15}m^{-3}*3*10^5 m/s &= 2.2*10^{-9}m^{-2}s^{-1} \\
\text{or for } 1/4\ m^2\ \text{``}Rate\ on\ 1/4'' &= 5.5*10^{-10}s^{-1} \\
\text{In a day (24 hours) ``}Rate\ on\ 1/4'' &= 5.5*10^{-10}s^{-1}*60*60*24 \\
&= 4.0*10^{-5} pearls\ per\ day \\
\text{If DAMA counts } 50cpd & \\
\text{then each pearl must give} & \\
hbox\text{``}Onepearlscounts'' &= 50cpd/(4.0*10^{-5}pearls\ per \\
&= 1.3*10^6 counts\ per\ pearl
\end{aligned}$$

You, DAMA, Need a Pearl in Every Season Roughtly

The pearls are "macroscopic" and can have many exitations, so for that it may be o.k., but if DAMA shall look at the same pearl for 4000 years?
We have to claim that by the uncertainties in our estimates we can squeeze a bit the numbers and then say that inside our only order of magnitude accuracy:
We could mannage to have pearls sufficiently heavy compared to their cross section to reach down 1 km or a bit less, and still their would be enogh of them that DAMA/Libra would see a few new pearls every season, then each pearl might lie there for a week say and emmit electrons of 3.5 keV but there is a tension in the fit.

How Much to Correct Our First Estimate ?

- To meaningfully "see" a seasonal variation there should preferably come an independent event every season, meaning say $10^{-2}cpd$, so that 3 to 4 in a year. If one sees say $50cpd$ (including stationary mode and in DAMA/LIBRA) then each pearl should send 5000 electrons in this at least needed limit.
- No reason to assume not at least one emission of electron from each pearl once it stopped in DAMA, so we should at most correct our HOMO-LUMO-gap estimate by the $\sqrt[3]{1.3 * 10^6} = 110$ in which case each pearl on average should send 1 electron.

So we should correct

$$p_f = 3.3MeV \quad \rightarrow \quad 3.3MeV * 50 \leq p_f \leq 3.3MeV * 110 \quad (66)$$

In DAMA/LIBRA presumably 50 cpd, if stationary included

DAMA/LIBRA counts $S_m = 0.0103 cpd/kg/keV$ for the oscillating contribution, and has

- DAMA 100 kg NaI, so 1 cpd/keV
- DAMA/LIBRA 250kg NaI, so 2.5 cpd/keV

With 2keV to 6 keV this means in DAMA 4 event per day, and in DAMA/LIBRA 10 events per day in the oscillary mode.
If we expect of the order of 5 times as many events in the staionart mode, this would be 20 and 50 respectively per day.

Size 5×5 counters of $10.2 \times 10.2 \times 25, 4cm$, say $1/4\ m^2$

The NaI(TI) DAMA/LIBRA apparatus uses 25 NaI(TI) highly radiopure detectors with 9.70 kg mass each one ($10.2 \times 10.2 \times 25.4cm$) placed in five rows by five columns. The granularity of the apparatus is an interesting feature for Dark Matter particle investigations since Dark Matter particles can just contribute to events where only one of the 25 detectors fires (single-hit events) and not to whose where more than one detector fire in coincidence (multiple-hit events).

Luckily Our Bad Fit is in the Rate Going as 3rd power in Fermi Momentum

We had in our first numbers assumed we could calculate the HOMO-LUMO-Gap in the material under high pressure filling the new vacuum inside the pearl from **dimensional arguments** and get the Fermi energy to be $E_f = 3.3MeV$ from knowing the frequency of the $E_H = 3.5keV$ radiation presumably comming from dark matter.
Let us to fit better by adjusting this estimate to give an acceptable value for the number of pearls hitting at DAMA/Libra per season: **At east one per season**.
Reasonable fit:

$$\text{Fermi energy in DM-pearl} E_f = p_f \quad = \quad 70 * 3.3MeV = 23MeV.$$

Excuse: Lot of Irregularities in “Crystal” bring Electron States Inbetween

The very uncertain - only order of magnitude dimensional argument - for the Fermimomentum needed for getting the by sattelites etc. observed line $3.5keV$ should be changed to reasonable number of pearls per season in DAMA/LIBRA:

$$E_f = p_f = 3.3Mev \quad \rightarrow \quad E_f = p_f = 23MeV. \tag{67}$$

Each pearl should still deliver $(\frac{110}{70})^3 = 4$ of the $3.5keV$-electrons.

Adjusting Parameters from $p_f = 3.3 MeV \rightarrow p_f = 23 MeV$

$$
\begin{aligned}
S &= 2.5 * 10^{12} MeV^3/m * R \rightarrow 6.0 * 10^{19} MeV^3/m * R \quad (68)\\
S^{1/3} &= 1.46 * 10^4 MeV/m^{1/3} * \sqrt[3]{R} \rightarrow 3.9 * 10^6 MeV/m^{1/3} \sqrt[3]{R}\\
M &= \rho_B * 4/3 * \pi * R^3 \quad (69)\\
&= 2.2 * 10^{12} kg/m^3 * R^3 \rightarrow 7.2 * 10^{19} * R^3 \quad (70)\\
\sigma &= \pi * R^2 \quad (71)\\
\frac{\sigma}{M} &= \rho_B^{-1} * 4/3 * R^{-1} \quad (72)\\
&= 2.6 * 10^{-12} m^3/kg * R^{-1} \rightarrow 3.7 * 10^{-14} m^3/kg * R^{-1}
\end{aligned}
$$

Parameters for Stopping, using $E_f = 3.3 MeV \rightarrow E_f = 23 MeV$

$$\frac{M}{\sigma} = \rho_B * 3/4 * R \tag{73}$$

$$= 3.9 * 10^{11} kg/m^3 * R \rightarrow 1.3 * 10^{17} kg/m^3 * R$$

$$\frac{M}{\sigma \rho_{water}} = \tag{74}$$

$$3.9 * 10^8 * R \rightarrow 1.3 * 10^{14} * R$$

$$\frac{M}{\sigma \rho_{stone}} = \tag{75}$$

$$1.3 * 10^8 * R \rightarrow 4.5 * 10^{13} R \tag{76}$$

"Fittig" of R, the radius, after settling on $p_f = 23MeV$

$$\text{Stopping length } L = 28\frac{M}{\sigma * \rho_{stone}} = 1km \quad (77)$$

$$\text{gives } \frac{M}{\sigma * \rho_{stone}} = 36m \quad (78)$$

$$\Rightarrow \frac{M}{\sigma} = 1.1 * 10^5 kg/m^2 \quad (79)$$

$$\text{Require } \frac{M}{\sigma} = 1.3 * 10^{17} kg/m^3 * R \quad (80)$$

$$\Rightarrow R = 8 * 10^{-13} m \quad (81)$$

$$\Rightarrow M = 7.2 * 10^{19} kg/m^3 * R^3 \quad (82)$$

$$= 4 * 10^{-17} kg = 4 * 10^{-14} g \quad (83)$$

“Inverse Darkness”, Dust

$$\frac{M}{\sigma * \rho_{stone}} = 36m \quad (84)$$

$$\Rightarrow \frac{M}{\sigma} = 1.1 * 10^5 kg/m^2 \quad (85)$$

$$\Rightarrow \text{Invers darkness } \frac{\sigma}{M} = 9 * 10^{-6} m^2/kg \quad (86)$$

$$\text{To compare Correa } \frac{\sigma}{M} = 15m^2/kg \text{ at } v \to 0 \quad (87)$$

$$(88)$$

Then we must imagine a dust grain surrounding the genuine pearl extending about $\sqrt{15/(9 * 10^{-6})} = 1.3 * 10^3$ times longer out on a linear scale.

$$R_{dust\ grain} = R * 1.3 * 10^3 = 10^{-9}m = 1nm. \quad (89)$$

The Tension in the Domain Wall arround the Pearl

$$\text{Cubic Root of Tension } S^{1/3} = 3.9 * 10^6 MeV/m^{1/3} \sqrt[3]{R} \quad (89)$$

$$= 3.9 * 10^6 MeV/m^{1/3} * \sqrt[3]{8 * 10^{-13} m} \quad (90)$$

$$= 3.6 * 10^2 MeV = 360 MeV \quad (91)$$

This is the energy scale of **pion or hadron physics** indicating that the **Phases of vacuum we speculate are to be distiguished by some pion or hadron physics!**

What tells the Energy Scale of the Tension S ?

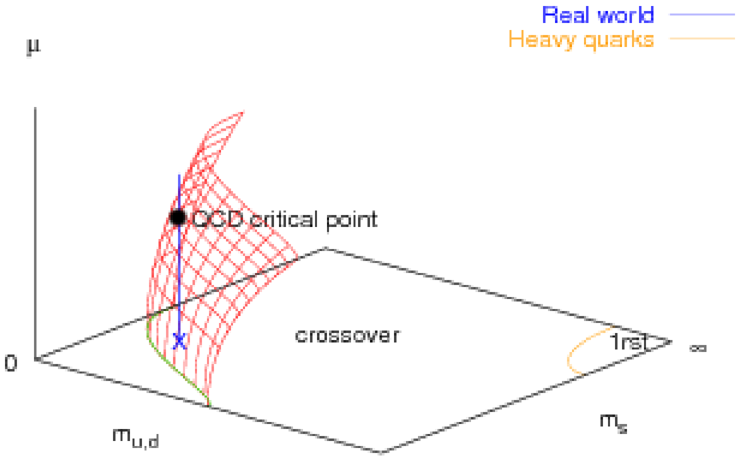
The cubic root of the tension S in the wall surrounding the pearls

$$\sqrt[3]{S} = 360 MeV \quad (92)$$

suggests:

- The physics behind should be **Pion or Hadron Physics**: In fact we have found that there is a possibility for there being a phase transition in vacuum, on the one side of which the Nambu Jonalasinio spontaneous breaking is really a spontaneous breaking, while in the other vacuum the quark masses have rather just broken this symmetry.
- If we speculated that the domain walls **surrounded the voids** seen in between the galaxy rich regions with extensions of order of 30 to 300 Mpc, then the **energy density of the walls could replace the dark energy density.**

Phase Diagram, QCD with Quark masses



Columbia plot, just quark masses ($m_u = m_d$)

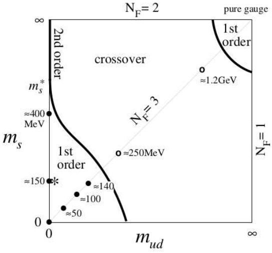


Figure 23: Order of the finite temperature QCD transition in the (m_{ud}, m_s) plane. First order signals are observed at the points marked with filled circle, while no clear two state signals are found at the points with open circle. The second order transition line is suggested [42] to deviate from the vertical axis as $m_{ud} \propto (m_s^* - m_s)^{5/2}$ below m_s^*. The values of quark mass in physical units are computed using a^{-1} determined from m_ρ: $a^{-1} \sim 0.8$ GeV for $\beta \leq 4.7$ and $\sim 1.0(1.8)$ GeV for $\beta = 5.0(5.5)$. See Sec. 8 for more detailed discussion on the values of the quark mass in physical units. The real world determined by the value of m_ϕ/m_ρ and m_π/m_ρ corresponds to the point marked with star.

To support us: what side experimental point ?

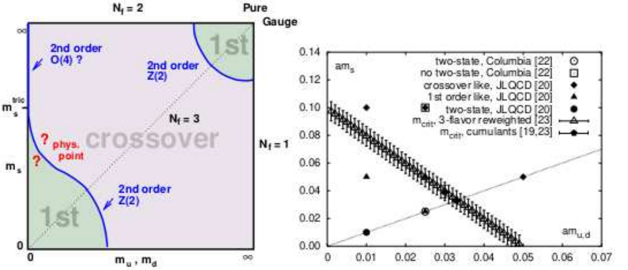


Figure 1: The phase diagram, expected (left) and lattice data (right), in the plane of strange and degenerate u,d quark masses.

"crosover" and "first order" allude to Phase transition as Function of Temperature for the Given Quark masses

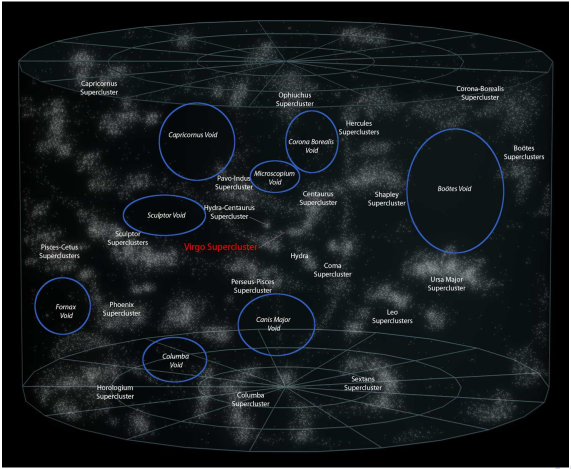
If there is a different behavior of a phase transition as function of temperature, it must mean that the regions in quark mass spacee must be indifferent phases.

This is our hope for a phase transition as function of the quark masses of the vacuum itself, even at zero temperature!

A phase transition of this type would be involved with the Nambu Jonalasionio spontaneous breakdown and have an energy scale of the order of say pion masses. We found that our domain wall had a cubic root of its tension i the energy range about 360 MeV.

Remember : We claim a **principle** that there shall be **many vacuum-phases** with energy density finetuned (as a new physics principle) to have the same energy density.

Three-dimensional perspective Galaxy Distributions, thus Voids



The Idea is: Voids surrounded by Domain Walls crudely

Since the voids have typical sizes of the order of diameters of 100 Mpc, domain walls around the voids would correspond to typical transvers distnce from one wall to the next of 100 Mpc. From that one can estimate the tension S of such walls by requiring that the energy density of the walls should be what one in the standard cosmological model takes as the cosmological constant Λ.
I.e.

$$\frac{S}{100 Mpc} \approx \Omega_\Lambda * \rho_{critical} \qquad (93)$$

$$\rho_{critical} = \frac{3H^2}{8\pi G} = 1.8788 \times 10^{-26} h^2 \mathrm{kg\,m}^{-3} \quad (94)$$

$$= 2.7754 \times 10^{11} h^2 M_\odot \,\mathrm{Mpc}^{-3}, \quad (95)$$

$$\Omega_\Lambda = 74\% \quad (96)$$

$$h = 0.674 \quad (97)$$

$$M_\odot = 1.9891 * 10^{30} kg \quad (98)$$

$$1 Mpc = 3.09 * 10^{22} m \quad (99)$$

$$1 GeV/c^2 = 1.7826619210^{-27} kg \quad (100)$$

$$(101)$$

Determing S, the Tension, to Match Cosmological Constant

$$
\begin{aligned}
S &\approx \Omega_\Lambda * \rho_{critical} * 100 Mpc && (102)\\
&= 0.74 * 2.7754 * 10^{11} * 1.9891 * 10^{30} kg \ldots && (103)\\
&/ \quad (3.09 * 10^{22} m)^2 * 100 * 0.67^2 && (104)\\
&= 1.92 * 10^{-2} kg/m^2 && (105)\\
&= 1.92 * 10^{-2}/(1.78266 * 10^{-27}) * GeV (1.98 * 10^{-16})^2 GeV^2 && (106)\\
&= 4.22 * 10^{-7} GeV^3 && (107)\\
&= 4.22 * 10^{2} MeV^3; && (108)\\
\sqrt[3]{S} &= 7.5 MeV. && (109)
\end{aligned}
$$

Conclusion

Starting from the rather paradoxical results from the underground experiments looking for dark Matter we have extracted some feastures from our model for dark matter as **Small pearls of a new phase of vacuum filled with ordinary matter under high pressure** we presented:

- How the arrangement in our model of the pearls being stopped in the earth/shielding in of the order of one km, could explain that experiments as Anais and Cosine-100, which are **only about 800 m down under ground might not see much - or may be even negative - seasonal varition**, while DAMA/LIBRA, which is 1400 m underground sees much more.

Conclusion (continued)

- The tension in the domain wall betwenn the two vacua needed for the fit to both a sufficient number of pearls arriving at DAMA/LIBRA and the Stopping in the 1 km order of magnitudeturned out of the order of $(40MeV)^3$ indicating that it should arise from physics of pion or hadron type. And we saw, that there is indeed lattice simulations indicating a phase transition as function of the quark masses, that might be the one Nature uses for making our type of dark matter.
- The order of magnitude of the tension S would also be applicable for having the energy density of large scale domain walls replace the in the standard cosmological model dark energy (= cosmological constant).

Outlook: Proposal for Experiment

We propose that one digs out earth from a depth like that of DAMA/LIBRA (1400 m earth), and seek to seperate especially haevy corns from the earth, since the dark matter pearls we proposed are very heavy for their size, and should be seperable by gravity.

J. Va'vra "A new possible way to explain the DAMA results" J. Va'vra Physics Letters B 735 (2014) 181–185, Contents lists available at ScienceDirect Physics Letters B www.elsevier.com/locate/physletb

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