Multiple Point Principle, Three Mass-estimates of Bound State of $6t + 6\bar{t}$ Agree

"Multiple Point Principle" is the name given to our proposal for a **new law of nature**, saying that the coupling constants are fine tuned to be at a **critical point** rather analogously to say a mixture of ice and water (slush) neccesarily being at temperature 0^0 Celsius.

Collaborators: **D. Bennett, C.D. Froggatt, L.V. Laperashvili, C. Das**

The ideas go also back to work involving also Niels Brene, I. Picek, ...

Dark Matter Pearls

L. Laperashvili(ITEP), H.B. Nielsen(Copenhagen), and C. D. Froggatt, C. Das, Takanishi

Toyama , March, 2017

[3] *ITEP,*
National Research Center "Kurchatov Institute", Moscow
[4] *The Niels Bohr Institute, Copenhagen*
H.B. Nielsen presents the talk.

Main ideas

- Strongly Bound State: We speculate that mainly due to exchange of Higgs bosons a system of 6 top plus 6 anti top quarks bind so strongly as to make a **bound state** with appreciably lower mass than that of 12 seperate quarks and anti quarks.
- Multiple Point Principle: We propose a **new law of nature(MPP)** saying, that - somewhat mysteriously may be - the **coupling constants** and other parameters, such as the Higgs mass square, **get adjusted** so as to guarantee that there are *several vacua all with very small energy density(=cosmological constant).*

Plan of talk:

- Heading F(750), We miss you!
- Introduction "New" Law of Nature, and a Bound State
- MPP The New law, "Multiple Point (Criticallity) Principle".
- Bound Bound state of 6 top and 6 anti top.
- Reasons Attempts to explain why MPP.
- High The mass of the bound state that could arrange the stability of our vacuum to be just boarderline stable w.r.t. the Higgs field.
- Condensate The mass of the bound state making the "condensate vacuum" degenerate in energy density to the "present vacuum"
- Bag Bag model estimation of the mass of the bound state.
- Dark Dark Matter as Pearls of the "condesate vacuum".
- Conclusion Telling that you should now believe our MPP law!


F(750),
WE MISS YOU
γγ


650
↓
ZZ
F(750),
WE MISS YOU
γγ

Multipel Point Principle(=MPP):

Our proposal for a “new” law of nature - Multiple Point Principle(=MPP) - (first by Don Bennett and myself) means that **there shall exist several vacua with very small energy density.**

Three Vacua in Standard Model:

For simplicity and **trustability** we in this talk restrict ourselves to **pure Standard Model** and only the following **three** vacua:

- Present The vacuum, in which we live, in the sense, that, if we in practice find a place with zero density of material, then that region is in the state of the "present vacuum".
- High (Higgs) field vacuum This vacuum is a state, in which the Higgs field is at a minimum in the Higgs-effective potential $V_{eff}(\phi_H)$ having a value of the Higgs field near $\phi_H \sim 10^{18}$ GeV. It is known, that with pure Standard Model it seems, that the energy density of this vacuum is slightly negative (with 3 standard deviations from being just zero).
- Condensate vacuum This third vacuum is a very speculative possible state inside the pure Standard Model, which contains a lot of strongly bound states, each bound from 6 top + 6 anti top quarks.

Can use Multiple Point Principle together with Any Model (side-remark)

In the present talk I shall concentrate on the version "several vacua, that all have very **small energy densities**" = MPP.
But older version had it: "Several vacua all have the **same energy density** (with some accuracy, that can be discussed)" = MPP.
Also one does not need to assume just Standard Model as I shall do in the present talk. For instance with Roman Nevzorov some of us (Froggatt and me) assumed a supersymmetry only broken tinily in one vacuum, but much stronger broken in e.g. the present vacuum.

The with Roman Nevzorov works extend Standard Model with Susy etc.

(Otherwise in the present talk I only keep Standard Model.)
Assuming some of the vacua to have only tinily broken susy, a tiny **cosmological constant** in the almost susy unbroken vacuum could be **transfered - by means of MPP** - to the present vacuum, and a rather successfull fitting/derivation of the astronomically determined cosmological constant could be achieved!
Also the original idea that we - Don Bennett and I - should invent the "multiple point principle" was based on a model called AntiGUT, which extends the Standard Model, although first having new physics only rather close to the Planck scale, actually by letting each family of fermions have its own system of gauge groups. The gauge bosons also in families!

Also Application in Extensions of Standard Model by Kawana et al.

Multiple Point Principle of the Standard Model with Scalar Singlet Dark Matter and Right Handed Neutrinos Kiyoharu Kawana
Prog. Theor. Exp. Phys. (2015) 023B04

Finetuning of Parameters, Couplings

Our "multiple point principle" is really just an assumption about the coupling constants - in the Standard Model, if we, as in this talk, take the model to be pure Standard Model - being **finetuned** so as to make the three vacua proposed have just zero energy density $V_{present}, V_{condensate}, V_{high\ field}=0$ (with say the accuracy of the order of the astronomically found energy density in the "present vacuum" ~ 75 % of the total energy density in the present universe.)

I.e. MPP provides 3 restrictions between the parameters of the model in question, here the Standard Model, from which the $\sim$ zero energy densities in all three vacua follows.

Multiple Point Principle means Relations between the couplings and other parameters:

$$V_{present}(\Lambda_{CC}, g_t, m_H^2, \Lambda_{QCD}, ...) = 0 \quad (1)$$
$$V_{condensate}(\Lambda_{CC}, g_t, m_H^2, \Lambda_{QCD}, ...) = 0 \quad (2)$$
$$V_{high\ field}(\Lambda_{CC}, g_t, m_H^2, \Lambda_{QCD}, ...) = 0 \quad (3)$$

Here we wrote explictely the following parameters of the Standard Model:

$$\Lambda_{CC} \; : \; \text{The cosmoligal constant} \quad (4)$$
$$g_t \; : \; \text{The top Yukawa coupling} \quad (5)$$
$$m_H^2 \; : \; \text{Higgs mass squared} \quad (6)$$
$$\Lambda_{QCD} \; : \; \text{The scale parameter of QCD} \quad (7)$$

Whether these parameters are renormalized or bare does not matter so much here.
$V_{present}$, $V_{cindensate}$, $V_{high\ field}$ are the vacuum energy densities for the three speculated vacua.

Use of Multiple Point Principle:

Taking the experimental values for all the Standard Model parameters except for say $\Lambda_{CC}, m_H^2,$ and g_t we could look at it, that e.g. $V_{present} = 0$ fixes the cosmological costant Λ_{CC} to essentailly zero. (It is very small indeed). Then $V_{high\ field} = 0$ (meaning the energy density of the vacuum having the very high Higgs field $\phi_H \approx 10^{18} GeV$) could be taken to predict the Higgs mass, and the $V_{condensate} = 0$ to predict, say, the g_t Yukawa coupling. In fact Colin Froggatt and I (H.B.N.) PREdicted the Higgs mass many years ago to 135 GeV $\pm$ 10 GeV from such an MPP-assumption.

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

Lars Andersen

Historiemaler Portrætmaler Provokunstner Om Lars Andersen CV/omtale Kontakt

Other PREdictions of Higgs Mass: Kane et al., bound...

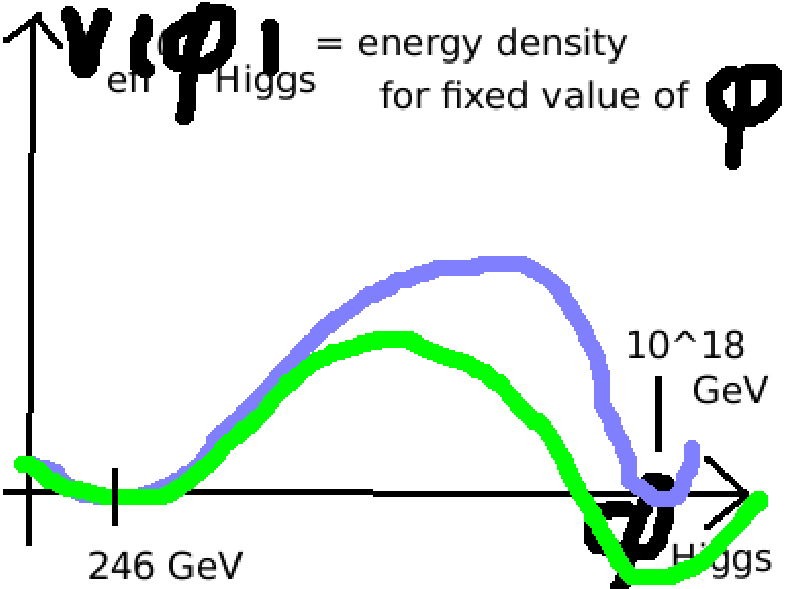
Higgs mass prediction for realistic string/M theory vacua Gordon Kane, Piyush Kumar, Ran Lu, and Bob Zheng Phys. Rev. D 85, 075026 Published 30 April 2012

SUSY theories put an uper bound on the Higgs mass:

Very close to the found mass actually:

D. Abbaneo et al. [ALEPH Collaboration], arXiv:hep-ex/0112021.

Y. Okada, M. Yamaguchi and T. Yanagida, Prog. Theor. Phys. 85, 1 (1991); M. Carena, M. Quiros, and C. E. M. Wagner, Nucl. Phys. B 461, 407 (1996) [arXiv:hep-ph/9508343];


= energy density
for fixed value of
eff
Higgs
10^18
GeV
246 GeV
Higgs

A Remarkable Side-Point:

The second minimum in the Higgs effective potential corresponding to what, we call the "High field" vacuum, has an expectation value for the Higgs field ϕ_H, which is **remarkably close** (order of magnitudewise) **to the Plankc energy scale**! This should not be an accident, but rather explained: Planck energy scale is the "fundamental physics scale" for both energy and Higgs fields; they have the same dimension.

Two of the vacua, which we discuss to day, have for some reason exceptionally small, say, Higgs field, while the "high field" vacuum has the "normal" order of unity in Plack units value for *its* Higgs expectation value. So rather ask the question:

Why do the two vacua, "present vacuum" and "condensate vacuum", not have Planck scale, say, Higgs fields? (Let me for the moment postpone, that indeed we have an explanation from "multiple point principle", that these two vacua have exceptionally small Higgs expectation values scale.)

But Why should we believe in the postulate of "Multiple Point Principle" ?

- **Need Coupling Explanations** Even with great effort e.g. Graham Ross could not get the factor Δ with which the Higgs is too light further down than about $1/20$. Cosmological constant ?...
- "Derivations" In models which allow somehow influence from the future to adjust coupling constants one may make some "derivations" of MPP.
- Empirical But really it is the main point of todays talk to deliver some empirical support (our PREdiction of Higgs mass, and two derivations of same bound state mass).

Universe does Finetune; Multilocal Action

Natural solution to the naturalness problem Universe does fine-tuning Yuta Hamada , Hikaru Kawai and Kiyoharu Kawana

1. Reason:“ Plural of Cosmological Constant”

- 1 We have to assume that the energy density in the “present vacuum” is very small compared say to Planck energy density, because it has been well known to be small long before the measurements with supernovae A1 setlled it to be non-zero.
- 2 This assumption does not become essentially less bautiful or more complicated by “putting it in plural”: **Several vacua have very small energy density/cosmological constant** compared to say the Planck energy density or the Higgs energy density or most high energy physics contributions.

(Private conversation with L. Susskind.)

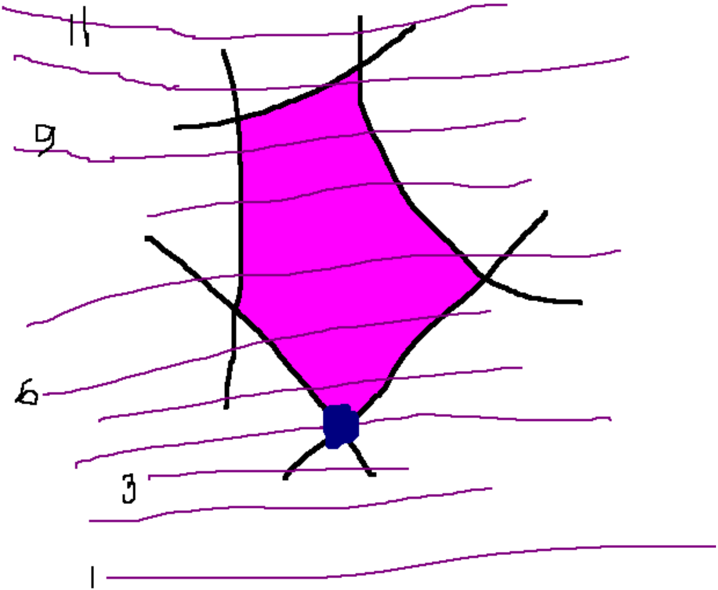
But each time you fix the energy of one more vacuum energy density you get one more relation between the parameters couplings of the theory.

It may even be more beautiful to talk about several/all vacua than

2. Reason: Extremizing Something, Positive Energy

- A. Assume that energy-density should be positive or zero. i.e. bottom in hamiltonian density is at least zero. This will restrict the coupling constants and other parameters - e.g. Higgs mass - to some polyhedron-like figure with curved sides, where the sides correspond to one possible vacuum or another one having just zero energy density.
- B. Assume that the couplings and parameters inside the positivity restriction are selected by **minimizing something / some function of these couplngs and parameters**(a generic or “random” function).
  Using antropic principle the function could suggestively be the number of human beings in the universe resulting with the couplings etc. in the point in parameter-space considered.

On the figure I have drawn the cote curves -really cote surfaces-.



11
9
6
3
1

Very offen Minimum of Function occurs in Corners

The crucial point is, that - especially in a high dimensional coupling-constant and parameter space - will very offen the minmimum fall in a **corner** (where several sides cross) of the polyhedron-like region with curved sides (violet).
But the “sides” correspond to different vacua having zero energy density. So a corner corresponds to several vacua all having zero energy density $\rightarrow$ “Multiple Point Principle”!

3. Reason; Our Bennett's and Mine Original Explanation

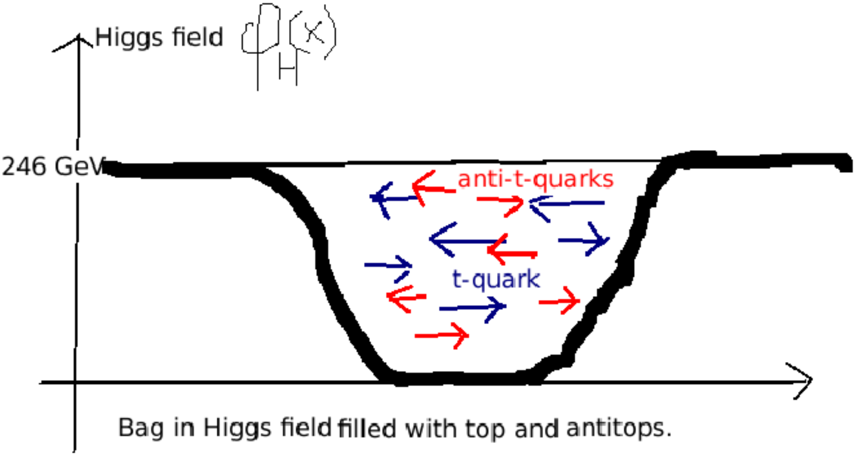
One assume that some **extensive quantities / commodities** i.e. some integrals over space time of say fields raised to some powers etc. - say Higgs field squared - are **fixed** by "God"/ some law, rather than as I think we would usually think, it is the couplings themselves, that are selected by "God".


VAPOR
ICE
WATER
EXTENSIVE Q's: E, V, N

The Difficulty of the Bound State

When we - as we now want - want to check if the "multiple point principle" is true/valid law of nature, we have the difficulty, that an important role is played by a bound state, with which the vacuum, which we call "condensate vacuum", is filed.

Fundamentally one cannot calculate completely perturbatively, when one calculates on a bound state!


Higgs field
246 GeV
anti-t-quarks
t-quark
Bag in Higgs field filled with top and antitops.

Lucky Overdetermined Situation

Luckily we are with "multiple point principle"(to be tested) in the very good situation calculationally, that in addition to know already from experiment all the parameters of the Standard Model to day, we have the ca. three extra equations, if MPP assumed, and so we can use this information to help us through the caculational problems with the bound state.

Checking MPP by Calculating Mass of the Bound State in Several Ways

Since it is non-perturbative and thus either difficult or very crude only, that we can compute say the mass of the bound state, it is suggestive to take it as a parameter. Then we may formulate testing the "multiple point principle" as evaluating by *different* assumptions inside MPP the mass of the bound state.

Really Check Bound State Mass Obtained from Degeneracy of Vacuum Pairs

Our technique - to day - is to estimate/calculate the value of the mass of the bound state of 6 top and 6 anti top quarks speculated to exist in our picture/model. (Since we have two relative energy density predictions - ignoring the absolute smallness of cosmological constant - we get two such bound state mass fits.) In addition we can seek to obtain the bound state mass by building a bag-model-like ansatz for the bound state and estimates its mass. Thus we get using our mutiple point principle two a priori different mass predictions for the 6top + 6 anti top bound state.

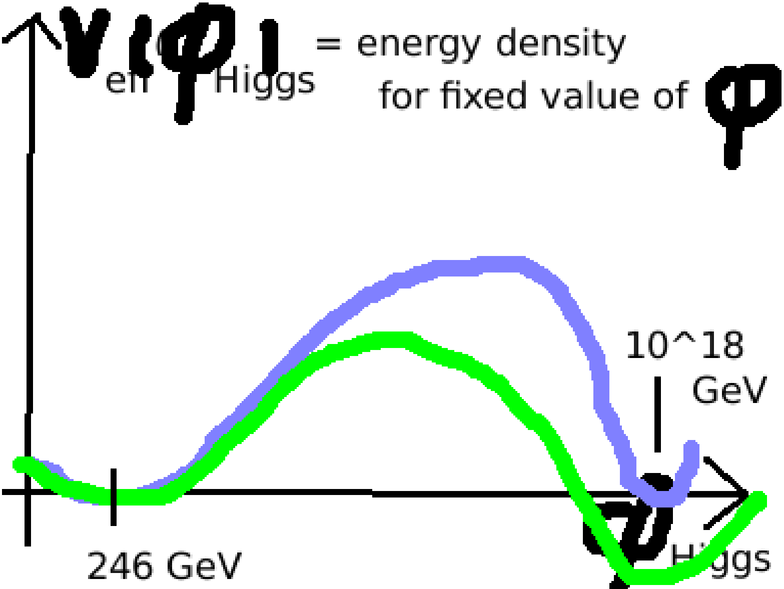
Our Three Bound State Mass Fits:

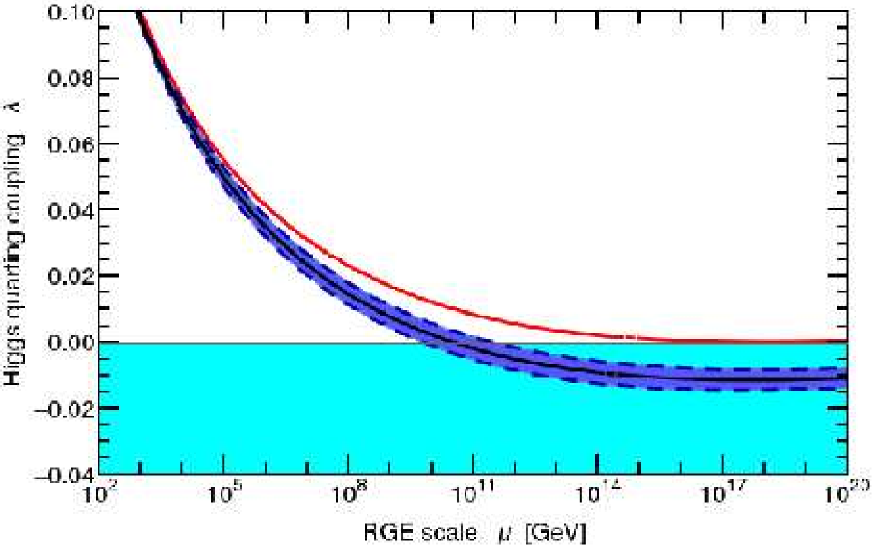
- high field fit We fit to get a tiny correction to the Higgs mass relative to the running selfcoupling so as to ensure the MPP-requirement, that the "present vacuum" be degenerate with the "high field vacuum": Fitting mass $m_{from\ high\ field\ fit} \approx 700 GeV$ to $800 GeV$.
- condensate vacuum fit We fit the mass to the binding between the bound states in a region filled with such particles to lowest energy density just gets zero/same energy density as the present vacuum. With a simple but accidentally almost true assumption we fit the mass to $m_{from\ condensate\ fit} \approx 4m_t = 692 GeV \pm 100 GeV$, say.
- Ansatz calculation We make a bag-model-like crude ansatz for the bound state of the 6 top + 6 anti top and seek the minimum energy/mass by varying bag radius R. With very crude inclusion of various corrections we reach the mass estimate $m_{bag-model} \approx 5m_t = 865 GeV \pm 200 GeV$, say.

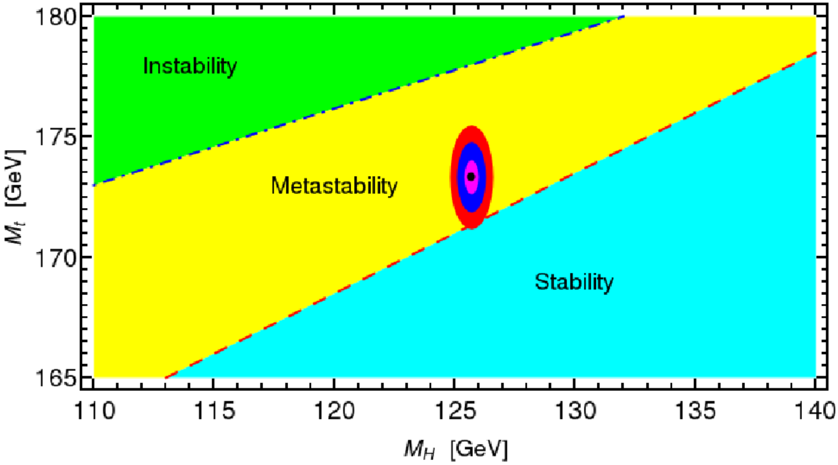
Small Correction by Laperashvili, Das, and me to "High field Vacuum" Energy Density

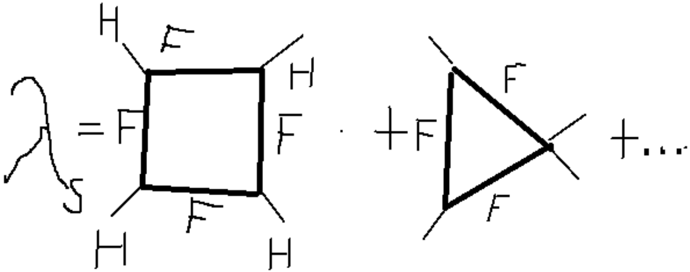
From De Grassi et al.'s calculation of the effective Higgs field potential $V_{eff}(\phi_H)$ there is a minimum in this potential, but it goes **slightly** under 0 so that the present vacuum is **unstable** for the experimental Higgsmass 125.09 ± 0.24, while the value, that would have made the second minimum just degenerate with the present vacuum energy density would be rather $m_H|_{from\ MPP\ De\ Grassi...} = 129.4$ GeV.

We claimed that with a bound state e.g. with the mass 750 GeV we would get corrected the De Grassi et al. calcuation so as to be consistent with exact MPP.
Basically we claim: The leading diagrams treating the bound state as an "elementary particle"(i.e. with formal Feynmann rules) though modified by including estimated form-factors, we can fit the mass of the bound state, so that the diagrams just cancel the instability and make the energy density of the high Higgs field minimum exactly zero, $V_{eff}(\phi_H \sim 10^{18} GeV) = 0$. That comes for a mass $\sim$ 700 to 800 GeV.


V_eff(φ_Higgs)
= energy density
for fixed value of φ
10^18
GeV
246 GeV
φ_Higgs


0.10
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
10^2
10^5
10^8
10^{11}
10^{14}
10^{17}
10^{20}
Higgs quartic coupling λ
RGE scale μ [GeV]


Instability
Metastability
Stability
180
175
170
165
M_t [GeV]
110
115
120
125
130
135
140
M_H [GeV]



Correction to Higgs-self coupling

The Small Instabily, Negative Self-coupling at the High field Minimum:

Extrapolated using DeGrassi et al. without our correction one gets the following value of the running self coupling $\lambda_{run}(10^{18} GeV)$:

$$\lambda(\phi_{\text{“high field”}}) = -0.01 \pm 0.002. \tag{8}$$

at the high field scale $\phi_{\text{“high field”}}$. However, a value very accurately zero is requied by Multiple Point Principle(=MPP).
Since bound state F is an extended object we must include a formfactor, when using it in Feynman diagrams.
Defining a quantity b denoting the radius of the bound state measured with top quark Compton wave length $1/m_t$ as unit by:

$$< \vec{r}^2 > = 3r_0^2, \tag{9}$$

$$r_0 = \frac{b}{m_t}, \tag{10}$$

Approximating the Bound State as were it an Elementary Particle, since so Strongly Bound

The dominant diagram/correction - the first and quadratic of the diagrams on the figure just above - is

$$\lambda_S \approx \frac{1}{\pi^2}\left(\frac{6g_t}{b}\frac{m_t}{m_S}\right)^4$$

where we have the estimated or measured values

$$g_t = 0.935;\ m_t = 173 GeV;\ b \approx 2.34 \text{or} 2.43$$

Using the after all rather small deviation from perfect MPP

$$\lambda_{\text{high field}} = -0.01 \pm 0.002$$

and requiring it to be cancelled by the correction from the bound state we get the requirement

$$\lambda_S = \frac{1}{\pi^2}\left(\frac{6g_t}{b} * \frac{m_t}{m_F}\right)^4 * (\sim 2) \approx 0.01 \pm 0.002, \qquad (12)$$

where $g_t = .935$, $m_t = 173 GeV$, $b \approx 2.43$ and the factor "(~ 2)" were taken in to approximate some neglected diagrams.

If a nearer study should show that the next diagrams add up to roughly as much as the first one should include the factor ~ 2 to take into account the neglected Feynman diagrams correcting the Higgs self coupling.
The solution w.r.t. the mass of the bound state m_F gives

$$\begin{aligned} m_F &\approx \frac{6 g_t m_t}{b} \left(\frac{\sim 2}{\pi^2 * 0.01 \pm 0.002} \right)^{1/4} \\ \approx 2.31 * 173 GeV * 2.1 &= 4.9 * 173 GeV = 850 GeV \pm 20\% \\ \text{or without the } \sim 2: & \\ m_F = 2.31 * 173 GeV * 1.8 &= 4.1 * 173 GeV = 710 GeV \pm 20\% \end{aligned} \tag{13}$$

Three Agreeing Fits of the Bound State Mass:

In this way we got even two calculations for the bound state mass - using in addition crude estimation -

$$m_F(\text{from ``high field vacuum''}) \approx 850\,GeV \pm 30\%\text{with} \sim 2 \quad (14)$$

$$m_F(\text{from ``high field vacuum''}) \approx 710\,GeV \pm 30\%\text{without} \sim 2 \quad (15)$$

$$m_F(\text{``condensate vac.''}) \approx 692\,GeV \pm 40\% \quad (16)$$

$$m_F(\text{``bag estimate''}) \approx 5m_t = 865\,GeV(veryuncertain) \quad (17)$$

The agreement of the value "692 GeV" with the estimate(s) from the completly different vacuum with the high Higgs field "850GeV" or "710 GeV" and with the mass by estimating how strong the top and anti tops can bind $m_F(\text{``}bagestimate''\text{''}) \approx 865 GeV$ is encourraging and a support of our "Multiple Point Principle"!

Fitting Bound State Mass to the "Condensate Vacuum" having Same Energy Density as the "Present" one.

For calculational purpose we approximate the "condensate vacuum" with a chrystal (but it should at least be a fluid, but that may not matter much for our crude energy density estimate) made from the bound states sitting each with 4 neighbors, the top and anti tops of which are in approximate main quantum numbers n=2 seen from the bound state considered.

The MPP-requirement may be written

$$
\begin{aligned}
0 &= m_F - \text{“binding per F''} && (18)\\
&= m_F - \frac{\#\text{neighbors}}{2} * \text{“binding to neighbor F''} && (19)\\
&\approx m_S - \frac{4}{2} * \text{“binding of F in n=2 arround another F''} && (20)\\
&\approx m_F - \frac{4}{2} * \text{“binding of F''} * \frac{1/2^2}{1/1^2} && (21)\\
&= m_F - \frac{1}{2} * \text{“binding of F''} && (22)\\
&= m_F - \frac{1}{2} * (12 m_t - m_F) && (23)\\
&= \frac{3}{2} m_F - 6 m_t && (24)
\end{aligned}
$$

We shall indeed follow an appendix of our earlier work[?] and assume, that the structure of the condensate can be approximated

We made then the approximation, that we can effectively consider it, that the neighboring top quarks and anti topquarks contained in an F neighboring to another one are *in effect in the n=2 orbit* of the latter. Thus we can take the binding energy of a neighboring F to a given one "binding to neighbor F(750)" to be as, if the top and anti tops were in an n=2 orbit or some superposition thereof. Thus the binding of the neighbors occur with binding energy "binding of F in n=2 around another F".
As long as we can take the effective Higgs mass for the two lowest orbits n = 1 and 2 to be zero, we can count, that the binding energy, for top say, in the orbit n=2 is just one quarter of that in the n=1 orbit, provided we can use the same potential of the form $\propto 1/r$. But now that were, what our above discussion "accidental cancellation" in section **??** should ensure, and so even for an F-particle, which consists of tops and anti tops the ratio of the binding energies should be $1/2^2 = 1/4$.

From the last step in (24) we easily derive of course

$$m_F = \frac{2}{3} * 6 m_t = 4 m_t = 173 GeV * 4 = 692 GeV \text{ agreeing well with } 710 GeV \quad (25)$$

Excusing the Simplifying Accident

Basically the accidental cancellation, that simplifies the calculation so much that we get the mass of bound state F needed to make the “condensate vacuum” degenerate with the “present one” to be $m_F = \frac{12 m_t}{3} = 4 m_t = 692 GeV$ is the following: Realistically the top and antitop do not bind to an ideal point Higgs coupling object, but rather to all the other 11 top or anti tops, and these form a smeared out group of particles, not surrounded by an ideal Yukawa potential but a field emiited from a smeared out source! Very crudely this means that a accidental top or anti feels the field from only about half the other 11 or 12 constituents. **But the mistake by ignoring this reduction by a factor 2 due to the smear out is rather well compensated for by the following two then also to be ignored corrections:**

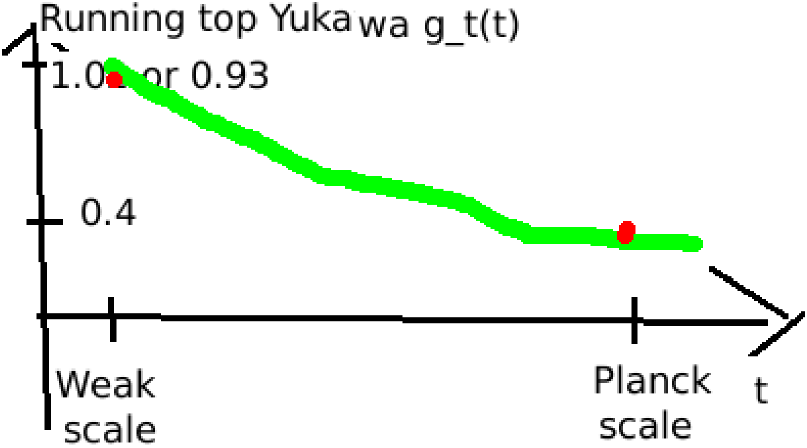
- The exchange of W and Z.
- The gluon exchange only active for quarks inside the F's.

Estimating How 6 Top + 6 Anto top Bind

Imganining that the top-Yukawa-coupling g_t were gradually screwed up, the Higgs field inside an ansatz bound state of 6 top + 6 anti tops at say the typical distance of the quarks themselves from the center, would gradually be lowered compared to the usual vacuum expectation value.

"Solve" Hierarchy problem

Having made a fine-tuning theory/model/rule we have at least the chance to have our fine-tuning theory MPP give the experimentally observed order of magnitude for the Higgs mass say. And indeed we predict the right order for the logarithm of the scale range over which μ has to run to get the running top-yukawa-coupling $g_{t\ run}(\mu)$ go from 0.4 at the 10^{18} GeV to the 0.935 needed at the weaak scale from the requirement of the "condensate vacuum " being degenerate with the 'present one".



Scale ratio of the Planck scale to weak scale must be so as to allow g_t to go from 1.0 to 0.4 !

Dark Matter Pearls

Work mainly by

Colin D. Fraggatt and Holger Bech Nielsen

but also other as Bennett, Laperashvili,...Takanishi have been very important mainly in the ideas behind the dark matter itself.

This Dark Matter contribution is a continuation of my talk about "Multiple Point Principle" recently presented in Toyama.

Short review of "Multiple Point Principle"

- Postulate "A new law of Nature", Multiple Point Principle (MPP) saying: There are several different vacua, all having very small energy densities (= cosmological constants), i.e. coupling constants, parameters, adjust themselves so as to achieve this degeneracy.
- If one just uses pure Standard Model, there are just three such small energy density vacua:
  - Present vacuum,
  - High field vacuum,
  - F(750)-condensate vacuum.
- Arranging especially the "F(750)-condensate vacuum" requires that 6 top quark plus 6 anti-top bind themselves together under exchange of (Standard Model) Higgs and helped by other exchanges, gluons, weak gauge bosons,...to form a very strongly bound bound state, F(750) say.

Different Versions of Multiple Point Principle Formulations:

- Meta-formulation Instead of requiring just the energy density small or degenerate, you require that realistically a series of successive vacua could be railized in nature. With Yasutaka Takanishe and Froggatt we considered such meta-stability $\rightarrow$ $m_{Higgs} = 121 GeV$.
- Inclusion or not of Present Cosmological constant one can formulate MPP in two slightly different ways even after having chosen meta- or just energy density reuirements:
  - There are several vacua and they have the same energy density, or
  - There are several vacua and they all have very small energy density, of the order say of the 3/4 of the present total energy density (including the normal matter etc.).

Three Agreeing Fits of the Bound State Mass:

In this way we got even two calculations for the bound state mass - using in addition crude estimation -

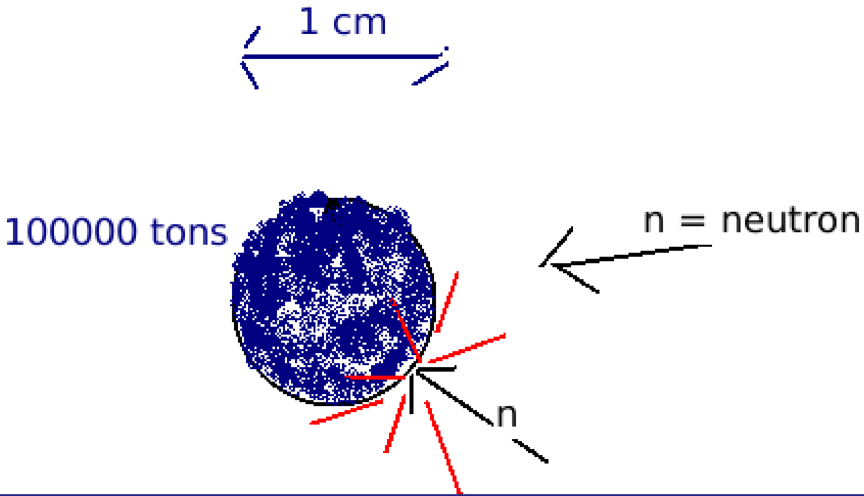
$$m_F(\text{from ``high field vacuum''}) \approx 780 GeV \pm 40\% \quad (26)$$

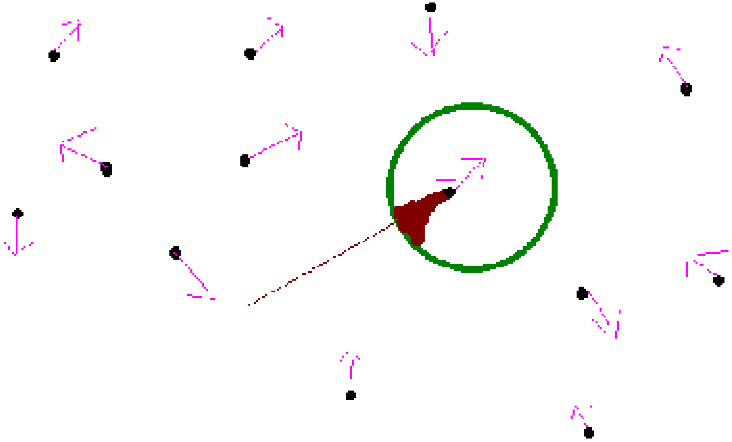
$$m_F(\text{``condensate vac.''}) \approx 692 GeV \pm 40\% \quad (27)$$

$$m_F(\text{``bag estimate''}) \approx 5m_t = 865 GeV (veryuncertain) \quad (28)$$

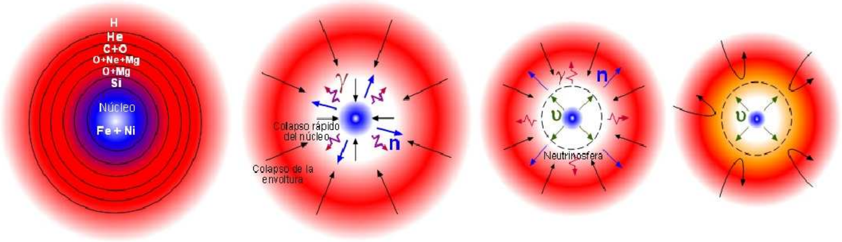
Dark Matter in pure Standard Model with our MPP and bound state:

- The "condensate vacuum" can be used for a model for dark matter as pearl size balls of the "condensate vacuum" surrounded necessarily by a skin - the transition surface - that is then pumped up by ordinary matter, carbon say, to a pressure of the order of that in a white dwarf star. Such pearls may be useful for
  - Dark matter
  - making supernovae explode so as to throw sufficient material out so that we can observe it.
  - Explaing the two bursts of neutrinoes observed with $\sim$ 5 hours time difference in SN1989A in the Big Maggelanic Cloud.
  - helps r-process fit ?
  - explain ratio of dark to normal matter being of order 6.
  - the 3.5 keV X-ray line (from dark matter?)


1 cm
100000 tons
n = neutron
n



Supernova development

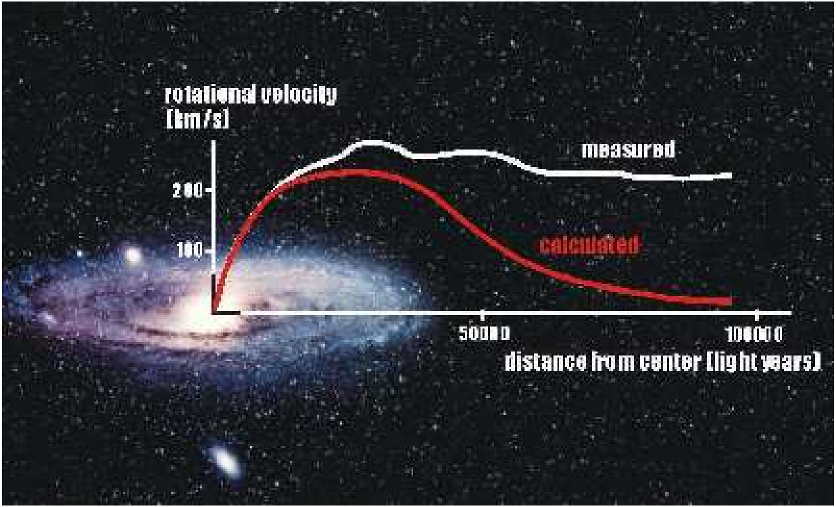


Achievements yet via dark matter as bubles of "condensate vacuum":

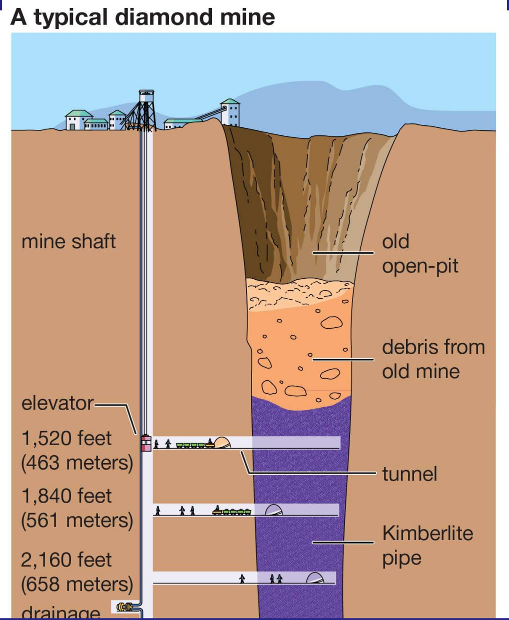
Dark matter pearls in the mass range best fitting our picture of them as bubles of alternative vacuum will hit with time intervals of 100 years the earth and cause significant volcanoes, and they will reach so deep that such volcanoes will bring up the only in the deep stable diamonds. It will be Kimberlite pipes. Could also be the Tunguska event.

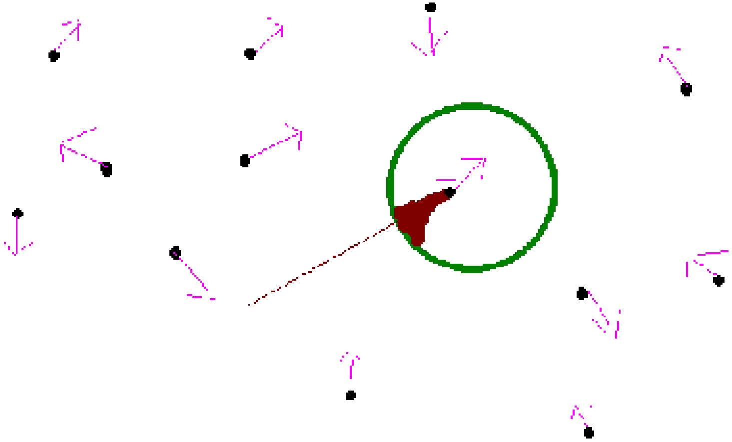
Det Kolde Mørke/sorte stof ude i rummet mellem stjernerne

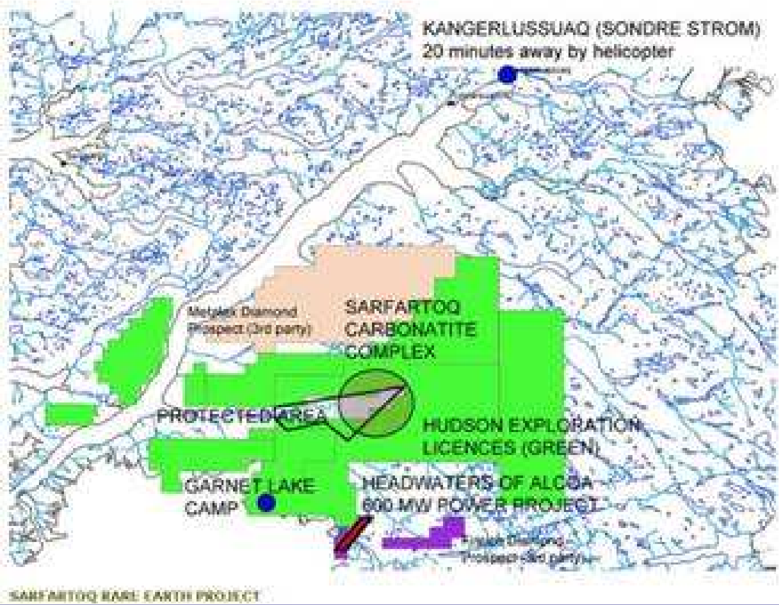
Mine kollegaer mener, at det sorte stof, som er nødvendigt at have mellem stjernerne, for at disse kan løbe så hurtigt rundt om galaksen, som de måles at løbe, ikke kan fås, hvis Standard Modellen er den endelige teori. Man har brug for mindst en anden slags partikel, som kan udgøre det sorte stof! Kun Colin Froggatt og jeg har en teori, efter hvilken, det er muligt - om end lidt kompliceret - at få det sorte stof ud af Standard Modellen alene! Lad mig dog tilstå at *vi* dog har brug for et særligt finindstillingss-princip, som sørger for at koblings-konstanterne i Standard Modellen tager værdier, som sørger for at der bliver flere vacua/tomrumstilstande med samme energitæthed. Koblingerne har altså meget specielle værdier, eller rettere relationer mellem deres værdier.

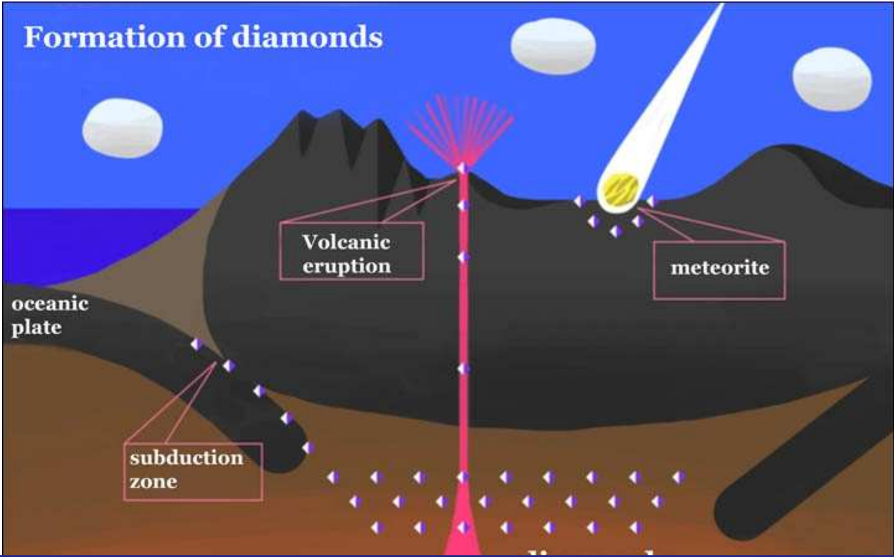

rotational velocity
[km/s]
200
100
measured
calculated
50000
100000
distance from center [light years]

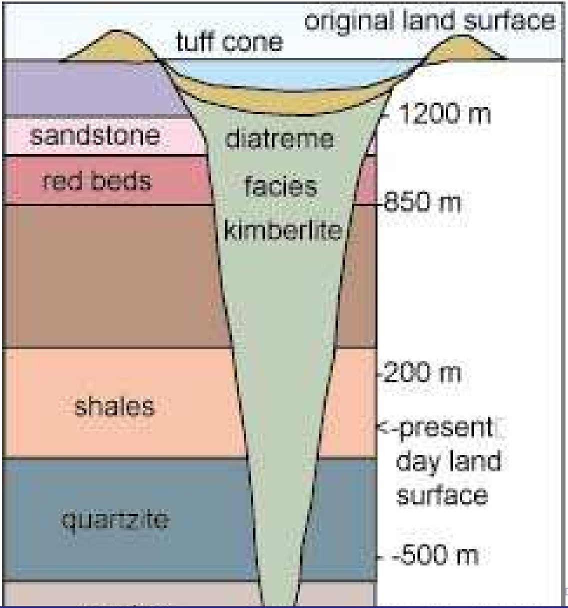
Fritz Zwicky, Opdager af Mørkt Stof


A typical diamond mine
mine shaft
old open-pit
debris from old mine
elevator
1,520 feet (463 meters)
tunnel
1,840 feet (561 meters)
Kimberlite pipe
2,160 feet (658 meters)

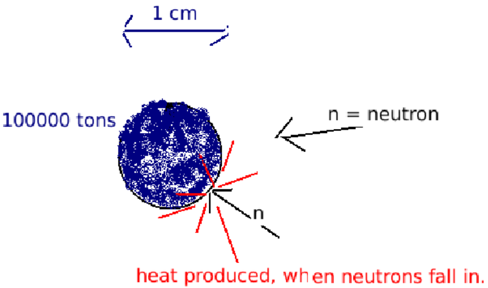



KANGERLUSSUAQ (SONDRE STROM)
20 minutes away by helicopter
SARFARTOQ
CARBONATITE
COMPLEX
PROTECTED AREA
HUDSON EXPLORATION
LICENCES (GREEN)
GARNET LAKE
CAMP
HEADWATERS OF ALCOA
600 MW POWER PROJECT

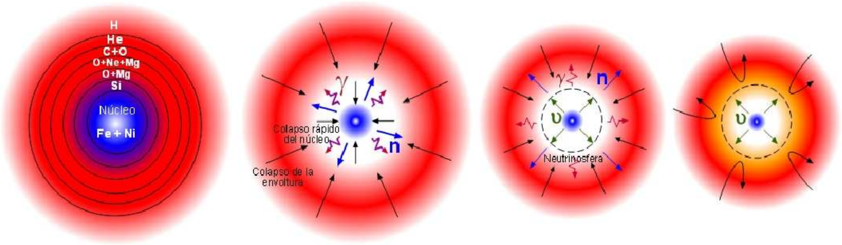

Formation of diamonds
Volcanic eruption
meteorite
oceanic plate
subduction zone

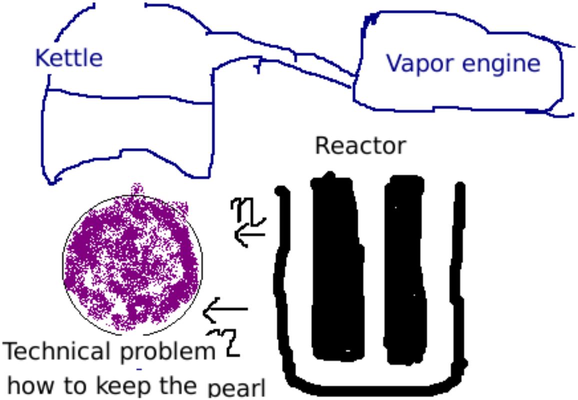

original land surface
tuff cone
sandstone
diatreme
red beds
facies
kimberlite
shales
quartzite
1200 m
850 m
200 m
<-present
day land
surface
-500 m

Pearl produce about 10 MeV energy per neutron caught



Supernova development





Our pearl may be used to get more energy out of a reactor by their property of heating up by 10 MeV per neutron, when hit by neutrons.

The 3.5 keV X-ray line

From the Perseus Cluster and from the Center of Our Milky Way and collecting stattistics from gallaxy clusters... the astronomers have found a hard to identify X-ray line, which correected for the redshift from the supposed cluster of galaxies had the photon energy 3.5 keV.
This 3.5 keV-line is suspected to come from dark matter.

Excitons in our Dark Matter Pearls Correpond to Band Gap agreeing order of magnitudewise with 3.5 keV

We have estimated our dark matter pearls to have a specific density of $10^{14}kg/m^3$ corresponding to pearl with diameter 1 cm and a mass of 10^8kg. So they are compressed reltive to ordinary matter having specific densities rather $10^3$to$10^4kg/m^3$, by a factor 10^{11}to10^{10} in volume or 5000 to 2000 times in length scale.
We shall argue shortly that such a compression dimishing the lattice constant -if it were a lattice - by a factor 2000 to 5000 would lead to an increase in the band gap giving an exciton decay energy by such a factor. Thus e.g. a band gap in say diamond of 5.5 eV or in Germanium 0.67 eV would be scaled up to respectively 10 keV to 28 keV for diamond and 1.3 keV to 3 keV for Germanium.

How does the Band Gap Scale Under Compression?

Let us obtain an idea about how the band gap in an insulator or semiconductor changes with pressure for extremely high pressure (for ordinary "low" pressures one finds somwhat different results in litterature) by the following assumptions/derivations:

- At very high pressure the dispersion relation for the elctrons is dominated by the kinetic energy of the electron.
- If only there were the kinetic energy the band gaps would be zero.
- The smallest thus likely to be where we have in first approximation the zero gap.
- The potential energy providing a level splitting - by level repulsion - is given by the Coulomb potential behaving like $1/r$ and thus for dimensional goes as the inverse of the lattice constant a i.e. as $1/a$.

Derivation of Scaling Behavior for Band gap under compression (continued):

- Thus if the lattice constant a is compressed by a factor being the cubic root of the volume compression factor 10^{11} say, the band gap goes up under the compression by the cubic root of 10^{11}, which is 5000.
- So say 1 eV band gap would scale 5 keV. (Within our crude estimate that could well be the 3.5 keV!)

Fusion Explosion in Pearls to Estmate Isotope Composition of the Ordinary Matter Inside Our Pearls

We suppose that at first the pearl had become filled with Helium, but that then **explosively** a further fusion reaction took place converting this helium into heavier elements. For our hope to understand the 3.5-line hopefully also some uranium and thorium. An understanding from such nuclear explosion may also be helpful for estimating type of ordinary matter under high compression we have got inside the pearl and thereby a bit more accurate estimate of the band gap leading to the 3.5-line radiation.

Importance of the Fusion Explosion

The fusion explosion is important for:

- What is now being the ordinary - from which we are made - was emmitted by the explosion due to the heat development, when helium fused into carnbon and heavier elements.
- The energy of the fusion to higher elements of helium liberates for heat about 1.5 MeV pernucleon in as far as the binding in Helium is 7 MeV while in the heavier elements it is rather 8 to 9 MeV. Thus there is excess energy to emmmit totally out of the pearl one nucleon in 5 when the helium fusions.
- We hope some uranium or thorium is formed (by some neutron capture process, essentially r-process)

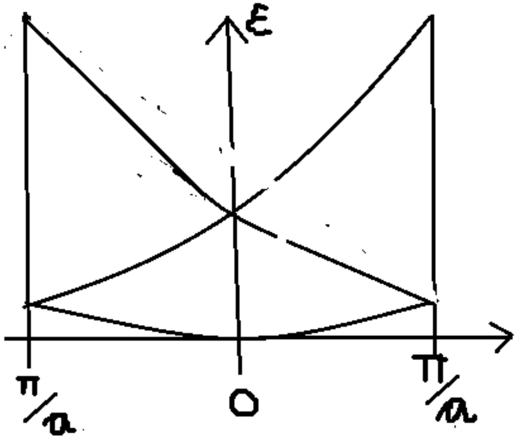
The 3.5keV line is energized by Radioactive thorium or uranium inside the pearls

The pearls must be arround for the order of the age of the Universe 13.6 milliard years, and thus only the isotopes with life times of this order or longer will still be present in our times. Uranium and can cope with such long times and stil be active to excite electrons inside our pearls. These (quasi)electrons and the holes then form excitons which may go to have just the band gap energy and finally decay under emmission of photons (in the case of the huge gap X-rays). Some line will appear with exciton energy equal to the band gap energy.**3.5 keV ?**

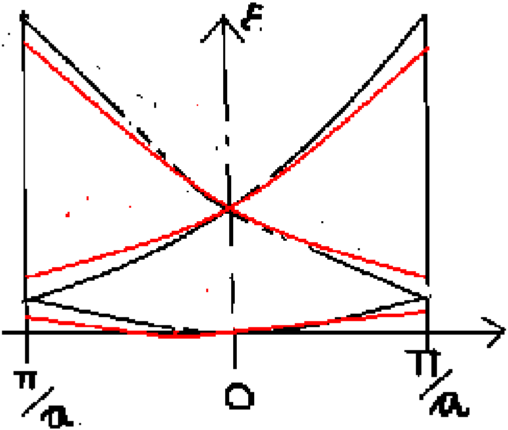
Degenerate Electron states get split by the Potential term treated as a perturbation to the purely kinetic energy

When the first order approximation has two electron states - namely with momenta $p = \pm\frac{\pi}{a}$, where a is the lattice constant - with the same energy $E = \frac{\pi^2}{a^2 2m}$ and the same quasi momentum $p_Q = \frac{\pi}{a}(mod\frac{2\pi}{a})$, the perturbation term, namely the potential term is to be diagonalized in the two-dimensional subspace of the state space for the electron corresponding to these two states. The energy of the states resulting from these two states after the perturbation will be split just as the splitting of the eigenvalues for the perturbation/the potential term.

Dispersionrelation Only with Kinetic Energy in One Dimension



Dispersionrelation Perturbed by Potential Term



Conclusion on Dark Matter Pearls

- Have a Dark Matter Model with **Only Standard Model !**
- Our Dark Matter consists of cm-size pearls of mass 500000 ton, inside which there is some ordinary matter carbon ... uranium sitting on a background of a new vacuum called “condensate vacuum”.
- The pearls should have formed after the time when the temperature passed the weak interaction temperature scale 100 GeV. First they should have formed in random shapes and first after the antibaryons were annihilated away they would have had time to contract. Now they would then stopped from totally contracting - if sufficiently large - by including nucleons carried by a 10 MeV bariere from going out of the pearls.
- First there would form helium inside the pearls,

- but at some moment an **explosion** of helium being fusioned to heavier elements would take place. A so high temperature would arise that by essentially a rapid neutron capture process, r-process, would take place, so that even uran and thorium would be formed.
- After full contraction till the ordinary chemicals inside could stop further contraction of the skin seperating the condensate and the present vacua the pressure inside is so high that the density of the ordinary matter there becomes $10^{14} kg/m^3$.
- The atoms inside are then compressed so that the lattice constant or the distance between the atoms is of the order of 3000 times smaller than in ordinary matter under normal conditions.

- This compression raise the band gap between the filled and empty electronic bands by a factor being the cubic root of the volume compression factor 10^{11}. So an ordinary band gab in the eV range goes up by a factor of the order of 5000.
- An elctron in the empty bound to a hole in the uppermost filled band makes up an exciton, which after relaxation has the energy of the band width meaning 5000 times an "ordinary" band gap of eV order of magnitude.
- We want to identify radiation from the decay of such excitons with the by the astronomers observed 3.5 keV X-ray radiation, suspected to come from dark matter.
- We estimate that cosmic rays as a source of energy to produce the observed 3.5 keV radiation falls short of the observed intensity by a factor 10^5 but that radioactivity from uranium and or thorium inside the pearls themselves might provide sufficient energy for the radiation.

- The line has been seen in the supernova remnant from Keplers supernova. This could be explained in our model as being due to the very high 3.5 keV emmission due to the energy provided by the cosmic radiation, which is of course much stronger in the supernova remnant than at a random place in the dark matter. Very few dark matter models could match that a dark matter line should be seen especially from a supernova remnant.

Conclusion

The remarkable **coincidence**, that our three mass estimations coincide is an evindence in favour of the **truth of our model, with the Multiple Point Principle, and the bound state**!

Some Achievements of our Model MPP and Strongly Bound State of 6 Top + 6 Anti top, (in pure SM)

I must mention the following achievements most of which I did not have time for:

- Hierarchy problem The fine-tuning caused by our MPP requirements combined with the assumption, that the Higgs field in the "high field vacuum" is of the order of the Planck scale (or only a bit under) leads to the scale problem being solved in the sense, that the Higgs mass and weak scale get fixed to be *exponentially* much lower than the Planck scale, and that in fact very closely by the right size for the logarithm.

Achievements of Multiple Point Principle(=MPP)(in pure SM) Continued:

- g_t Froggatt and I estimated the value of the top-Yukawa-coupling g_t needed for MPP in the sense, that it represents a phase transition value between the “condensate vacuum” and the “present vacuum”. We found the phase transition $g_{t\ phase\ transition} = 1.02 \pm 14\%$, agreeing with experiment $g_{t\ exp} = 0.93_5$.
- Stability Explaining the that the Higgs mass just puts our vacuum on the borderline of being meta-satble.
- Correction to Stability ...even very accurately, if we take seriously the very small correction due to the bound state by Laperashvili, Das, and myself.

Acievements Still in pure Standard Model of our MPP and bound sate:

- The “condensate vacuum” can be used for a model for dark matter as pearl size balls of the “condensate vacuum” surrounded necessarily by a skin - the transition surface - that is then pumped up by ordinary matter, carbon say, to a pressure of the order of that in a white dwarf star. Such pearls may be useful for
  - Dark matter
  - making supernovae explode so as to throw sufficient material out so that we can observe it.
  - Explaing the two bursts of neutrinoes observed with ~ 5 hours time difference in SN1989A in the Big Maggelanic Cloud.
  - helps r-process fit ?
  - explain ratio of dark to normal matter being of order 6.

Achievements yet via dark matter as bubles of “condensate vacuum”:

Dark matter pearls in the mass range best fitting our picture of them as bubles of alternative vacuum will hit with time intervals of 100 years the earth and cause significant volcanoes, and they will reach so deep that such volcanoes will bring up the only in the deep stable diamonds. It will be Kimberlite pipes. Could also be the Tunguska event.

Achievements of MPP in Extended Models (i.e. not only SM):

- Value of Cosmological Constant With Roman Nevzorov we got values for the CC using "same version" of MPP and an almost supersymmetric vacuum state.
- Number of families Prior to having formulated MPP we fitted finstructure constants in an extension of the Standard Model "AntiGUT" in which each family of fermions has its own set of gauge bosons. We - including Brene and Don Bennett and me - **pre**dicted the number of families, which was not known yet at that time.

Encouridgement for Theoreticians to Calculate More Accurately This Bound State

At the end I would stress: **Since Our picture is PURE STANDARD MODEL, everything can in principle be CALCULATED!** So it is only a question of better techniques - Bethe Salpeter Equation ? - or better computers and use of them - lattice theory with Higgsfield on the lattice ? - to obtain more solid and accurate checks of MPP and calculation of the bound state mass than my crude estimates.

And this is just a work for the theoreticians (among the students say).

Then there should pop up some peaks - like the joke of Pich's - by themselves, when the experimentalists make the plots.

If not it would mean that Standard Model were not right also nonperturbatively.

Many in the audience should be able to do a better calculation involving our phantasy-bound state:

If you can make lattice calculations on a theory with many scalars in addition to gauge fields, it should be easy to do it for the Standard Model with the Higgs field as the important exchange between top quarks. Or if you have a frame wherein the bound state can be studied by a method ending up mathematically similar to the Schrdinger-equation - just for mass square - it should not be so difficult to add the Higgs-exchange and investigate if our 6 top + 6 anti top will bind as a superexcotic resonance.