

ORIGIN OF MASSES IN THE EARLY UNIVERSE

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FROM UNIVERSE TO QUARKS

1 CONCEPTS:

- ✠ conformal action,
- ✠ frame of reference, and
- ✠ normal ordering (Casimir energy & condensate)

2 LOW-ENERGY QCD

3 MINIMAL STANDARD MODEL

4 COSMOLOGY and GENERAL RELATIVITY

NORMAL ORDERING

Oscillator

$$:\sum_n \frac{p_n^2 + \omega_n^2 q_n^2}{2} \rightrightarrows \sum_n \omega_n \frac{a_n^+ a_n^- + a_n^- a_n^+}{2} \rightrightarrows \sum_n \omega_n \left(a_n^+ a_n^- + \frac{1}{2} \right)$$

quark condensate

$$\bar{d}d = \langle \bar{d}d \rangle + : \bar{d}d :$$

Numerical results for the isospin symmetric case

[Yu.Kalinovsky, L.Kaschluhn, V.Pervushin, A new QCD inspired version of the Nambu-Jona-Lasinio model, Phys.Lett. B 231 (1989) pp. 288–292]

GMOR:

$$-\frac{\langle \bar{d}d \rangle}{M_d^3} = \frac{M_\pi^2 F_\pi^2}{2m_d M_d^3} \simeq 0.41 \pm 0.08$$

PDG 2007

CONCEPTS: CONFORMAL SYMMETRY AND NORMAL ORDERING

THEORIES

- 1 LOW-ENERGY QCD: GMOR - relation Λ_{QCD}
- 2 CONFORMAL invariant STANDARD MODEL (CSM)?
- 3 CONFORMAL version of GENERAL RELATIVITY (CGR)?

INPUT: the largest mass t-quark condensate and GMOR-rel.

$$\mathcal{H}_{\text{int}}^{\text{CSM}} = \lambda \varphi^4 / 4 + \varphi g_t \bar{t} t \rightarrow V_{\text{eff}}(v) = \lambda v^4 / 4 - v g_t \langle \bar{t} t \rangle$$

$$\bar{t} t =: \bar{t} t : - \langle \bar{t} t \rangle, \text{ where } \frac{\langle \bar{t} t \rangle}{M_t^3} \sim \frac{\langle d\bar{d} \rangle}{M_d^3} \simeq 0.41 \pm 0.08,$$

$$M_t = g_t v = 174 \text{ GeV}, g_t \simeq 1/\sqrt{2}, \text{ and}$$

$$v = 246 \text{ GeV} \text{ is the constant part of the Higgs field } \varphi = v + h$$

OUTPUT: λ and e-w boson masses

$$V'_{\text{eff}}(v) = 0 \rightarrow \lambda v^3 = g_t \langle \bar{t} t \rangle \rightarrow \lambda = \frac{\langle \bar{t} t \rangle}{4M_t^3} = \frac{0.41 \pm 0.08}{4},$$

$$m_{\text{higgs}}^{\text{tree}} = \sqrt{3g_t \langle \bar{t} t \rangle} / v = 131 \pm 8 \text{ GeV}$$

Other condensate contributions $\langle hh \rangle$, $\langle W^+ W^- \rangle$, $\langle ZZ \rangle$:

$$m_{\text{higgs}} \simeq m_{\text{higgs}}^{\text{tree}} \left[1 + \frac{\Delta m_{\text{higgs}}^2}{m_{\text{higgs}}^2} \right]^{1/2} = m_{\text{higgs}}^{\text{tree}} [1 + 0.014]$$

CONCEPTS: CONFORMAL SYMMETRY AND CONFORMAL ANOMALIES

THEORIES

- 1 LOW-ENERGY QCD!
- 2 CONFORMAL invariant STANDARD MODEL (CSM)!
- 3 CONFORMAL version of GENERAL RELATIVITY (CGR)?

$$W_{\text{H-E}} = -(1/6) \int d^4x \sqrt{-g} R^{(4)}; \quad ds^2 = g_{\mu\nu} dx^\mu dx^\nu$$

NATURAL UNITS: $M_{\text{Pl}} \sqrt{3/(8\pi)} = c = \hbar = 1.$

CONFORMAL-INVARIANT ACTION

$$W_{\text{CGR}} = - \int d^4x \left[\frac{\sqrt{-\tilde{g}}}{6} R^{(4)}(\tilde{g}) e^{-2D} - e^{-D} \partial_\mu \left(\sqrt{-\tilde{g}} \tilde{g}^{\mu\nu} \partial_\nu e^{-D} \right) \right],$$

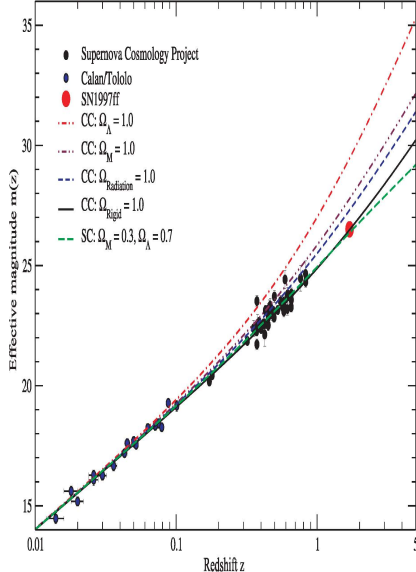
$$\tilde{ds}^2 = \tilde{g}_{\mu\nu} dx^\mu dx^\nu = \tilde{\omega}_{(\alpha)}^{\text{Fock}} \otimes \tilde{\omega}_{(\beta)}^{\text{Fock}} \eta^{(\alpha)(\beta)}$$

Deser S., [Scale invariance and gravitational coupling](#) *Annals Phys.* 59 (1970) 248; Dirac P.A.M, [Long range forces and broken symmetries](#) *Proc. Roy. Soc. Lond. A.* 333 (1973) 403.

FRAME

$$\tilde{\omega}_{(0)}^{\text{Fock}} = e^{-2D} N dx^0, \quad \tilde{\omega}_{(b)}^{\text{Fock}} = \mathbf{e}_{(b)i} dx^i + N_{(b)} dx^0,$$

$D(x^0, x^1, x^2, x^3) = \langle D \rangle(x^0) + \bar{D}(x^0, x^1, x^2, x^3)$ is **DILATON**



dominant Casimir energy

$(\rho = \rho)$ explains long
Supernovae Distances ↑

R_{SNeIa} at z →

$$r_{\text{horizon}}(z) = H_0^{-1} (1+z)^{-2}$$

[SEE BLACK LINE];

Λ CDM model with

short space interval $R = ra$

requires Inflation to explain
long Supernovae Distances

$$R_{\text{SNeIa}} = R_{\Omega_\Lambda=0.7, \Omega_M=0.3},$$

$$\rho \simeq -\rho$$

[SEE GREEN LINE].

D. Behnke, et al. Phys. Lett. B 530 (2002) 20;

A. Zakharov, V. Pervushin, Int. J. Mod. Phys. D19 (2010) No.9

Planck Least Action Postulate in CC

$$W_{\text{Universe}} = \rho_{\text{cr}} V_{\text{hor}}^{(4)}(a_{\text{Pl}}) = \frac{M_{\text{Pl}}^2 (1 + z_{\text{Pl}})^{-8}}{H_0^2 32} = 2\pi$$

$$a_{\text{Pl}}^{-1} = (1 + z_{\text{Pl}}) \simeq 0.62 \cdot 10^{15} \text{ Planck EPOCH!}$$

Conformal Weights of QFT objects are integers

$$\langle \omega_{\mathbf{n}}(a) \rangle = \frac{a^n}{a_{\text{Pl}}^n} H_0$$

$$\omega_{\tau} = a^2 \sqrt{\mathbf{k}^2 + a^2 M_0^2} \quad ; \quad d\tau = d\eta/a^2 = dt/a^3,$$

give scales $\langle \omega_{\mathbf{n}}(a)_{\text{Pl}} \rangle = H_0 a_{\text{Pl}}^n$ for conformal weights
 $n=0,1,2,3,4$ in GeV:

$n=0$	$n=1$	$n=2$	$n=3$	$n=4$
$H_0 \sim 10^{-42}$	$R_{\text{Cel.S.}}^{-1} \sim 10^{-27}$	$T_{\text{CMB}} \sim 10^{-12}$	$M_{\text{EW}} \sim 10^3$	$M_{\text{Pl}} \sim 10^{19}$

Common origin of conformal symmetry breaking in both
 GR & SM

RESULTS: CONFORMAL SCENARIO

✠ EMPTY UNIVERSE → of SNe Ia DATA in CC

✠ Planck Least Action Postulate → Scale Hierarchy $H_0 \alpha_{\text{Pl}}^{-n}$

$$\alpha_{\text{Pl}}^{-1} = (1 + z_{\text{Pl}}) \simeq \left[\frac{M_{\text{Pl}}}{H_0} \right]^{1/4} \simeq 10^{15}$$

✠ Creation of Higgs particles $N_\phi \sim (1 + z_l)^6 \sim 10^{90}$

✠ Scale Hierarchy:

$$\langle t\bar{t} \rangle_{\sigma} = (1 + z_{\text{Pl}})^9 \underbrace{\langle t\bar{t} \rangle}_{\text{BAG}(M=H_0)} = \underbrace{(1 + z_{\text{Pl}})^9 H_0^3}_{M_0^3} \gamma_l = M_0^3 \gamma_l$$

$$\gamma_l \sim 1;$$

✠ t-condensate

$$\langle t\bar{t} \rangle [z] = \frac{(1 + z_{\text{Pl}})^9}{(1 + z)^3} \underbrace{H_0^3 \gamma_l}_{\text{BAG}(M=H_0)}$$

Основная задача авторов - привлечь внимание читателей к интересной и интригующей задаче описания современных экспериментальных и наблюдательных данных в рамках идей и методов, разработанных ещё до 1973-74 гг. основателями современной релятивистской классической и квантовой физики. Отличие нашего подхода от стандартных подходов в том, что всюду, от горизонта Вселенной до кварков, мы будем использовать на классическом уровне масштабно-инвариантные версии современных теорий, с безразмерными константами связи, нарушая эту масштабную инвариантность только на квантовом уровне нормальным упорядочиванием произведений полевых операторов. Метод классификации новых данных, полученных за последние пятнадцать лет в космологии и физике, существенно использует квантовые теории и предствления. Отсюда происходит и название нашей книги "Принципы квантовой Вселенной". Классификация представлена на основе принципов конформной и аффинной симметрий и постулата существования вакуума по аналогии с классификацией элементарных частиц по неприводимым предствлениям группы Пуанкаре.



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Принципы квантовой Вселенной

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The Russian edition of the present book was published in June 2013. It just happened that it was the time between two significant dates: in 2011 the Nobel Prize was awarded "for the discovery of the accelerated expansion of the Universe through observations of distant Supernovae" and in 2012 the Nobel Prize was awarded "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of the mass of subatomic particles". Both these formulations left the questions about the explanations of these phenomena in the framework of the fundamental principles open. Our book is devoted to attempts to explain the observed "long distances to the Supernovae" and "the small value of the Higgs particle mass" by the principles of affine and conformal symmetries and the vacuum postulate. Both these phenomena are described by quantum gravity in the form of joint irreducible unitary representations of the affine and conformal symmetry groups. These representations were used in our book to classify physical processes in the Universe, including its origin from the vacuum.



Victor Pervushin
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Principles of Quantum Universe

Victor Pervushin

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CONCEPTS: CONFORMAL SYMMETRY AND NORMAL ORDERING

THEORIES

- 1 LOW-ENERGY QCD GMOR relation
- 2 CONFORMAL SM Higgs particle mass
- 3 CONFORMAL GR HIERARHY OF SCALES

Thank you for your attention!