Progressing beyond the Standard Models

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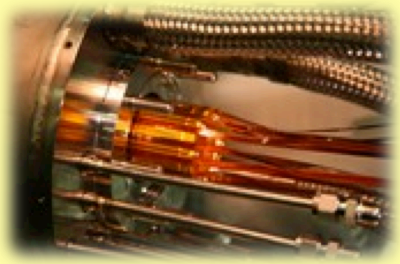

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…..to solve any problem that has never been solved before, you have to leave the door to the unknown ajar.

You have to permit the possibility that you do not have it exactly right.

Otherwise, if you have made up your mind already, you might not solve it.

(Richard Feynman)

Outline of Talk

(1) Standard Model (SM) of particle physics

- shortcomings, need for improved model GM

(2) Generation Model (GM) 2002 → 2011

- elementary particles of SM have substructure

(3) Composite Generation Model (CGM)

- new paradigms for mass and gravity
- understanding dark matter and dark energy
- solves matter-antimatter asymmetry problem

Standard Model (SM) of Particle Physics

The Standard Model is so complex that it would be hard to put it on a T-shirt – though not impossible; you'd just have to write kind of small

(Steven Weinberg)

Weinberg says that the Standard Model of particle physics is too complicated, with the ultimate goal being a theory that is much simpler

Particle Physics Standard Model

- **SM** provides excellent account of the **experimental data** involving **interactions** of **leptons** and **hadrons** (baryons and mesons) with each other and also the **decay modes** of **unstable leptons** and **hadrons**
- Achieved by **assuming** 12 **elementary** particles (6 leptons and 6 quarks) and 3 **fundamental** interactions (electromagnetic, strong and weak interactions)
  - very successful but considered **incomplete**

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Shortcomings of SM

SM provides **no understanding** of several **empirical observations**, e.g.

- Does not explain occurrence of **3 generations** of 12 elementary particles:
  (i) u, d, ν_e, e^- (ii) c, s, ν_μ, μ^- (iii) t, b, ν_τ, τ^-
  each generation behaves similarly (except mass)

- Does not provide **unified description** of **origin of mass** nor describe **mass hierarchy** of leptons and quarks

- Nature of **gravity**, **dark matter, dark energy** or the **matter-antimatter asymmetry problem**

3 Dubious Assumptions of SM

1. Diverse complicated scheme of additive quantum numbers to classify elementary particles
2. Weak isospin doublets in quark sector to accommodate the universality of charge-changing (CC) weak interactions
3. Weak interactions are fundamental inter-actions described by a local gauge theory

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A1. SM additive quantum numbers

Leptons

	Q	L	L_μ	L_τ
ν_e	0	1	0	0
e^-	-1	1	0	0
ν_μ	0	1	1	0
μ^-	-1	1	1	0
ν_τ	0	1	0	1
τ^-	-1	1	0	1

Quarks

	Q	A	S	C	B	T
u	$+\frac{2}{3}$	$\frac{1}{3}$	0	0	0	0
d	$-\frac{1}{3}$	$\frac{1}{3}$	0	0	0	0
c	$+\frac{2}{3}$	$\frac{1}{3}$	0	1	0	0
s	$-\frac{1}{3}$	$\frac{1}{3}$	-1	0	0	0
t	$+\frac{2}{3}$	$\frac{1}{3}$	0	0	0	1
b	$-\frac{1}{3}$	$\frac{1}{3}$	0	0	-1	0

- Antiparticles have **opposite** quantum numbers
- Leptons and quarks have **different** quantum numbers
- Quantum numbers **conserved** except S, C, B, T

A1. SM: BASIC PROBLEM

CLASSIFICATION OF ELEMENTARY PARTICLES

- Diverse complicated scheme
- Some not conserved in weak interactions
- Fails to provide any physical basis

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A2. SM: UNIVERSALITY OF CC WEAK INTERACTIONS - LEPTON SECTOR

CC weak interactions mediated by W bosons

Mass eigenstate leptons form weak isospin doublets : (ν_e , e^-) , (ν_μ , μ^-) $i = ½$, $Q = i_3 - ½L$

ν_e , ν_μ interact with e^- , μ^- , respectively, with **full** strength of CC weak interaction

ν_e , ν_μ do **not** interact with μ^- , e^- , respectively - by conservation of lepton numbers

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A2. SM: UNIVERSALITY OF CC WEAK INTERACTIONS - QUARK SECTOR

Weak isospin doublets : (u , d') , (c , s') $Q = i_3 + A/2$

$d' = d \cos\theta + s \sin\theta$, $s' = -d \sin\theta + s \cos\theta$

(weak eigenstate quarks)

θ is Cabibbo angle (1963)

u , c interact with d' , s' , respectively, with

full strength of CC weak interaction

u , c do **not** interact with s' , d' , respectively

- no conservation of any quantum numbers.

A3. Origin of Mass in SM

(1) Masses of hadrons arise mainly from the energy content of their constituent quarks and gluons, in agreement with Einstein

(2) Masses of fundamental particles, leptons, quarks and W and Z weak bosons are interpreted differently, arising from the existence of the so-called Higgs field

A3. MASSES of ELEMENTARY PARTICLES in SM (leptons, quarks, W and Z bosons)

Arise from existence of the so-called Higgs field

Higgs field was introduced to spontaneously break the U(1) x SU(2) local gauge symmetry of the electro-weak interaction to generate the masses of the W and Z bosons

Higgs field also cured the associated fermion mass problem: by coupling, with appropriate strength, originally massless fermions to the scalar Higgs field, it is possible to produce the observed fermion masses and maintain local gauge invariance

A3. SM MASS PROBLEMS

(1) No clear evidence of hypothetical Higgs field

(2) No **unified** origin of mass

(3) Fermion-Higgs coupling strength dependent upon mass of fermion – new parameter for each fermion (14 in total, including two more parameters to describe masses of W and Higgs particle)

(4) Higgs mechanism does **not provide any physical explanation** for origin of the masses of the fundamental particles

A3. SM MASS PROBLEMS 2

Dubious assumption:

Weak interactions are fundamental arising from a local gauge theory is at variance with the experimental facts – W and Z bosons are **not** massless as required for gauge invariance

More Problems:

How does the Higgs boson get its mass?

How does SSB occur within EW theory?

What principle determines masses of leptons and quarks?

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3 Simpler Assumptions of GM

1. **Simpler** and **unified** classification of leptons and quarks

2. **Mass eigenstate quarks** form weak isospin doublets and hadrons composed of **weak eigenstate quarks**

3. **Weak interactions** are **not** fundamental interactions

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A1. GM ADDITIVE QUANTUM NUMBERS

particle	Q	p	g	particle	Q	p	g
ν_e	0	-1	0	u	$+\frac{2}{3}$	$\frac{1}{3}$	0
e^-	-1	-1	0	d	$-\frac{1}{3}$	$\frac{1}{3}$	0
ν_μ	0	-1	±1	c	$+\frac{2}{3}$	$\frac{1}{3}$	±1
μ^-	-1	-1	±1	s	$-\frac{1}{3}$	$\frac{1}{3}$	±1
ν_τ	0	-1	0, ±2	t	$+\frac{2}{3}$	$\frac{1}{3}$	0, ±2
τ^-	-1	-1	0, ±2	b	$-\frac{1}{3}$	$\frac{1}{3}$	0, ±2

- **Simpler unified** classification scheme
- Quantum numbers **conserved** in **all interactions**

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A2. CONSERVATION OF GENERATION QUANTUM NUMBER

POSTULATE 1:

Mass eigenstate quarks of **same** generation form weak isospin doublets : (u , d) , (c , s)

u , c interact with d , s , respectively, with **full** strength of CC weak interaction

u , c do **not** interact with s , d , respectively

- **conservation** of generation quantum number

A2. CONSERVATION OF GENERATION QUANTUM NUMBER 2

POSTULATE 2:

Hadrons composed of weak eigenstate quarks: d' , s'
not mass eigenstate quarks: d , s

In **GM**: roles of **mass** eigenstate quarks and **weak** eigenstate quarks **interchanged** from that in SM

- Overcomes **dubious** assumption (2) of SM involving weak eigenstate doublets (u, d') and (c, s') which are not supported by any **conserved** quantum number

A3. Evidence for Compositeness of Leptons and Quarks

- electrical charges of electron and proton are opposite in sign but **exactly** equal in magnitude: atoms are **neutral**

- protons consist of quarks so their charges are intimately **related** to that of electron: u-quark has charge +2/3 and d-quark has charge -1/3 if electron has charge -1

- these relations comprehensible if leptons and quarks composed of **same kinds** of particles

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A3. Evidence for Compositeness of Leptons and Quarks 2

- all leptons and quarks seem to have **mass**

- known that most of the **mass** of nucleons arises from **internal energy** of constituents
  > suggests leptons and quarks are composite

- **3 generations** of leptons and quarks
  > also suggests members are composites (cf. Mendeleev table of elements)

A3. Non-Fundamental Weak Interactions

GM assumes: leptons, quarks, W and Z bosons are **composites**

- Weak interactions are **not** fundamental
- They are residual interactions of strong **color** force binding constituents together
- This color force similar to that of **QCD** in SM
- Overcomes **dubious** assumption (3) of SM involving **fundamental** weak interactions

COMPOSITE GM

2005 → construction of GM with **composite** leptons and quarks – based on **unified** classification scheme and early **1979** model of **Harari** and **Shupe**

Current composite GM proposed in **2011**

Chapter 1 *Particle Physics*, InTech, Rijeka, 2012
Adv. in High Energy Physics Art.ID 341738 2013

COMPOSITE GM 2

In CGM elementary particles of SM have a **substructure** consisting of massless "rishons" bound together by strong color interactions, mediated by massless hypergluons**.** Each rishon carries a color charge, red, green or blue (cf quark in SM)

This model is very similar to SM in which hadrons have a **substructure** consisting of quarks bound together by strong color interactions, mediated by massless gluons

Harari-Shupe Model (1979)

Leptons and quarks are composites of **two** kinds of spin-1/2 particles (rishons):

T-rishon Q = +1/3 and V-rishon Q = 0

also their anti-particles:

T-rishon Q = -1/3 and V-rishon Q = 0

Harari-Shupe Model (HSM) of First Generation

Particle	Structure	Q
e^+	TTT	+1
u	TTV, TVT, VTT	+2/3
d	TVV, VTV, VVT	+1/3
ν_e	VVV	0
ν_e	VVV	0
d	TVV, VTV, VVT	-1/3
u	TTV, TVT, VTT	-2/3
e^-	TTT	-1

Composite GM 3

CGM is a major extension of HSM :

- Introduced **third** kind of rishon U
- Allotted three additive quantum numbers of GM
- Leads to modification of HSM for 1^{st} Generation

Quantum numbers of rishons in CGM:

Rishon	Q	p	g
T	+1/3	+1/3	0
V	0	+1/3	0
U	0	+1/3	-1

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First Generation of Leptons and Quarks in CGM

Particle	Structure	Q	p	g
e^+	TTT	+1	+1	0
u	TTV	+2/3	+1/3	0
d	TVV	+1/3	-1/3	0
ν_e	VVV	0	-1	0
ν_e	VVV	0	+1	0
d	TVV	-1/3	+1/3	0
u	TTV	-2/3	-1/3	0
e^-	TTT	-1	-1	0

Summary: Three Generations

- lepton of 1st generation is **colorless**, composed of 3 rishons carrying **different** colors
- quark of 1st generation is **colored**, composed of 1 rishon and 1 **colorless** rishon-antirishon pair
- 1st generation of particles built out of T and V or T and V so all have g = 0
- 2nd & 3rd generations: 1st generation plus 1 & 2 **colorless** rishon-antirishon pair(s) UV or VU with Q = p = 0 but g = +/-1 so g= +/-1 and g = 0, +/-2, respectively → **three repeating patterns**

A3. NEW PARADIGM for MASS

Since the mass of a hadron arises mainly from the energy of its constituents, CGM suggests that mass of lepton, quark or vector boson arises from a characteristic energy *E* associated with its constituent rishons and hypergluons according to $m = E/c^2$

Thus, CGM provides **new paradigm** and a **unified** description for origin of **all** mass: the mass of a body arises from the energy content *E* of its constituents. The mass is given by $m = E/c^2$ in agreement with Einstein's 1905 conclusion and there is no requirement for a Higgs field.

Corollary :

If a particle has mass, then it is composite

Mass Hierarchy of 3 Generations

CGM suggests **mass hierarchy** of 3 generations arises from **substructures** of leptons & quarks

Mass of composite particle expected to be **greater** if constituents on average more widely spaced: consequence of nature of strong color interactions (stronger for larger separations) and higher generations more massive than lower generations

Particles with two or more charged rishons have **larger** structures due to **electric repulsion**

Mass Hierarchy of 3 Generations

Qualitatively (for same generation)

- charged lepton mass > neutral lepton mass
- Q = +2/3 quark mass > Q = -1/3 quark mass

  t mass (175 Gev) > b mass (4.5 GeV)

  c mass (1.3 GeV) > s mass (200 MeV)

  u mass (5 MeV) < d’ mass (10 MeV)

N.B. d mass expected to be < 5 MeV since d’ contains 5% s mass so that proton mass < neutron mass

GRAVITY

Rishons of each **colorless** (total color charge 0) lepton are very strongly localized

- no direct evidence for any substructure
- rishons distributed according to wave functions
- product wave function significant for only an ***extremely small*** volume of space so that color fields are ***almost cancelled*** (N.B. quantum mechanics prevents complete cancellation)

Question: *What is residual interaction arising from the incomplete cancellation of the strong interactions?*

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Gravity 2

Between any two colorless leptons (electrons) there will be a **very weak attractive residual interaction** arising from color interactions acting between the rishons of one lepton and the rishons of the other lepton

Suggest this **residual interaction** gives rise to the usual **gravitational interaction**

[Int. J. Mod. Phys. E ***18*** *(2009) 1773]*

[Int. J. Mod. Phys. E ***20*** *(2011) 733]*

Similar residual interaction between two colorless hadrons (neutrons and/or protons)

Gravity 3

- **Gravity** acts between bodies with **mass**
- **Mass** of a body (ordinary matter) is total mass of **constituent** electrons, neutrons and protons

  - each **composite** and **colourless**
- **Constituents** in 3-colour antisymmetric state

  - **same behaviour** w.r.t. colour interactions
- **Residual colour interactions** have several properties associated with usual gravitational interaction: **universality**, **very weak strength** and **attraction**

New Law of Gravity

GM: **gravity** arises from **residual colour forces** between all electrons, neutrons and protons – leading to new law of gravity

Residual Colour Interaction between **any** two bodies of masses $\boldsymbol{m_1}$ and $\boldsymbol{m_2}$ separated by distance $\boldsymbol{r}$ is of general form:

$$F = H(r)\, m_1 m_2 / r^2$$

where Newton's constant ($\boldsymbol{G}$) is replaced by a function of $\boldsymbol{r}$, $\boldsymbol{H(r)}$

New Law of Gravity 2

- Based on **residual colour interactions** between **electrons, neutrons** and **protons**

- **GM** assumes **residual colour interactions** have **same characteristics** as **strong colour interactions** of **SM** :

  (i) **asymptotic freedom**

  (ii) **colour confinement**

  these determine ***H(r)***

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Asymptotic Freedom and *H(r)*

- **Misnomer** – better term is **antiscreening**
- **Antiscreening** arises from **self-interactions** of **hypergluons** mediating **colour interactions**
- **Antiscreening effects** lead to **increase** in the **strength** of **residual colour interactions** so that ***H*** becomes an increasing function of (*r*)

  \- **Flat rotation curves** imply ***H(r) = G(1 + kr)***

Galaxy Rotation Problem

Major gravitational problem for **rotation curves** of galaxies:

- found disagreement with Newton's law at large r : stars and gas rotating too fast with constant v

- implied either **Newton's law incorrect** or some **considerable mass was missing**

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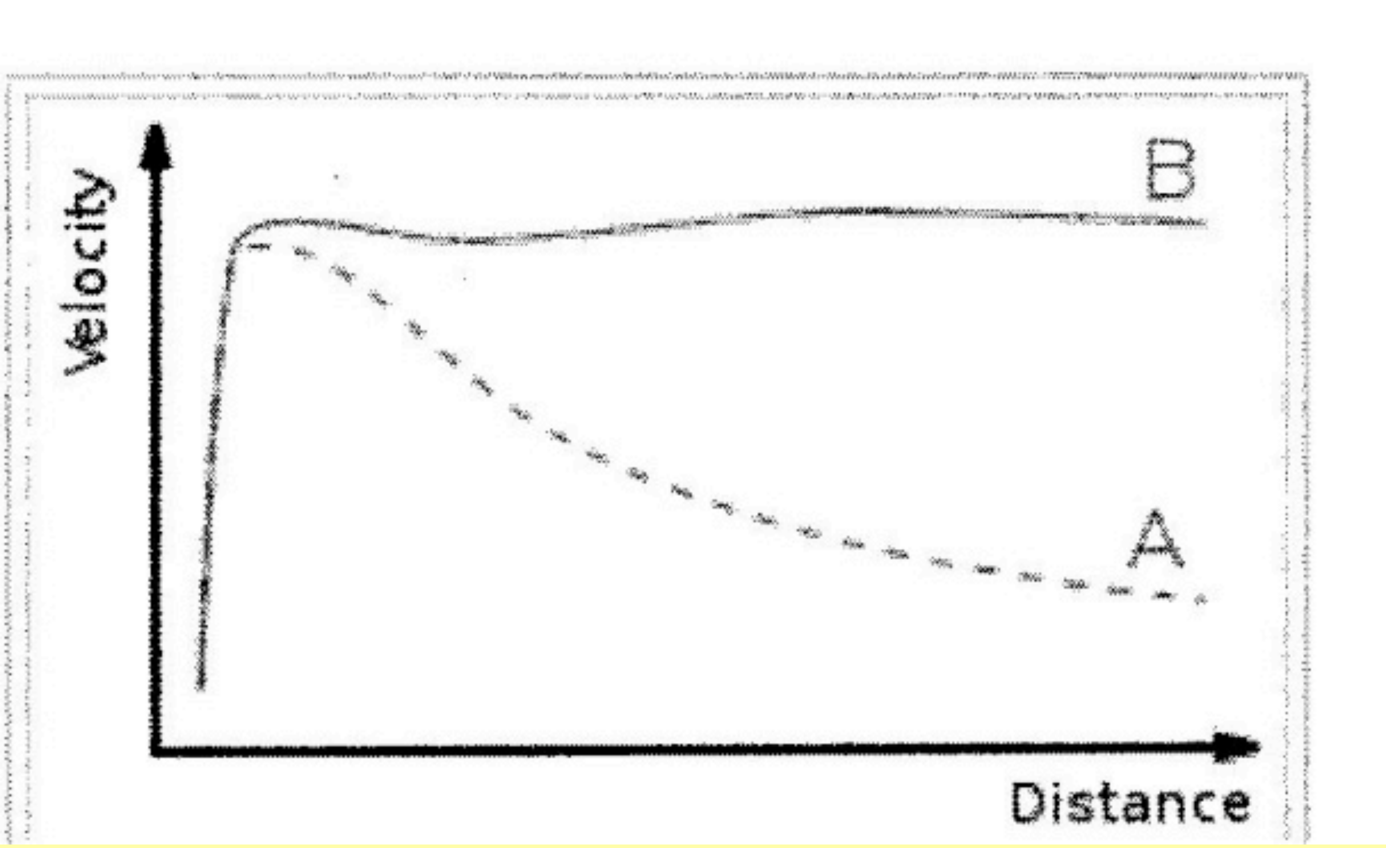
Rotation Curve for Galaxy

- **Rotation curve** is dependence of orbital velocity of visible matter in galaxy on its radial distance (r) from centre of galaxy
- Essentially **'flat'** at extremities of visible matter (stars, hydrogen gas) i.e. large distances
- Implies **gross disagreement** with **Newton's universal law of gravitation** – predicts fall-off as 1/sqrt(r) as in solar system

Galaxy Rotation Curve



Predicted - A   Observed - B

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Galaxy Rotation Problem 2

Two very successful solutions:

1. Dark Matter Hypothesis

Galaxy embedded within a giant halo of **dark matter**: considered non-atomic matter but otherwise **unknown** and **undetected**

2. MOND Hypothesis

1983 Milgrom proposed that gravity varies from Newton's law for **low accelerations**: empirical hypothesis **without physical understanding**

Galaxy Rotation Problem 3

Found that **New Law of Gravity** essentially equivalent to **MOND Hypothesis**

- GM gravitational interaction provides **physical basis** of MOND Hypothesis

- Continuing success of **MOND Hypothesis** is strong argument against the **existence** of undetected **dark matter haloes** consisting of unknown matter embedding galaxies

New Law of Gravity 3

- In GM $H(r) = G(1 + kr)$ arises from the **self-interactions** of the hypergluons mediating the gravitational interaction and explains the **dark matter problem** of the galaxy rotation curves:

  - for **small *r***, $H(r)$ is approximately G and gravity is approximately **Newtonian**

  - for **large *r***, $H(r)$ is approximately Gkr and gravity is approximately $1/r$ rather than $1/r^2$

  - $1/r$ **dependence** gives **flat rotation curves**

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Colour Confinement and *H(r)*

- **Phenomenon** that **colour charged** particles (e.g. quarks in SM, rishons in GM) cannot be **isolated** and consequently form **colourless** composite particles (e.g. mesons and baryons in SM, also leptons in GM)

- **Colour confinement** leads to another phenomenon analogous to **'hadronization process'** (formation of hadrons out of quarks and gluons) in SM and implies ***H(r) = 0*** for sufficiently large ***r*** in GM

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New Law of Gravity 4

- In GM ***H(r) = 0*** arises if the **gravitational field energy** is **sufficient** that it is **energetically favourable** to produce the **mass** of a **particle-antiparticle colorless pair** rather than the colour field to extend further

- Implies **gravity** ceases to exist for sufficiently large cosmological distances

New Law of Gravity 5

- **Strong colour interaction** has finite range of approximately $\mathbf{10^{-15}m}$
- **gravity** is about $\mathbf{10^{-41}}$ times weaker at $\mathbf{10^{-15}m}$ than the **strong colour interaction**
- suggests **'hadronization process'** for **gravity** occurs at about $\mathbf{10^{26}m}$
  - i.e. roughly **10 billion light years**

New Law of Gravity 6

- Implies **gravity** ceases to exist for cosmological distances exceeding several billion light years, resulting in less rapid slowing down of galaxies than expected from Newton's law

- **Result** agrees well with **observations** of distant Type Ia supernovae – indicate **onset** of **accelerating expansion** of universe occurs at about **6 billion light years**

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SUMMARY and CONCLUSION

GM allows progress beyond Standard Models by development of **composite GM model** of the **elementary particles** of **SM**, leading to:

(i) a **unified description of all mass** and an understanding of **mass hierarchy** of three generations of leptons and quarks

(ii) a **new law of gravity** and an understanding of **dark matter** and **dark energy**

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GM Predictions et al

Predictions:

(1) existence of mixed-parity quarks in hadrons

(2) no CP violation in neutral kaon system

(3) 2.5% scalar amplitude in neutral pion

(4) neutron has larger mass than proton

(5) 1.7% strange quarks in proton

and

provides a solution of the matter-antimatter asymmetry problem of the universe

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