hi

Day 28, 24.04.2018

Particle Physics 3 & Cosmology 5

housekeeping

The end game: next slide

Particle Physics:

Readings: Oerter, Cosmic Horizons, and Hobson

Hobson_quantum_fields.pdf is chapter 17

Homework #13 is: partly from MasteringPhysics - normal due date

partly on paper…see the blog

Feynman Diagram rules

3 movies in the lecture slide directory - you'll need them for homework and the final

they are: primitiveDiagrams_X. mp4 where X = 0,1,2

last ~~2~~ 1 week~~s~~ & final

Homework #13 will be assigned 4/21 and due 4/28 - normal rotation

On-line final exam will be assigned Sunday, 4/29 and due Tuesday night, May 1

will cover material since midterm plus the last week of class

There is 1 more 10 point quiz (stay tuned)…

~~only the shadow knows when~~…actually, watch the blog. Quiz up tomorrow, return Thursday in class.

Remember when I was sick?

been trying to catch up, but not going to make it. Hence:

Final Exam day:

1. You'll arrive at 0745 on May 4, here. I know.
2. I'll provide bagels. You supply liquids.
3. We'll have a quiz.
4. I'll finish with about a 1 hour grand finale, lalapalooza, mind-bending lecture
5. You'll do your Feynman Diagram Project
6. There will be no poster project this year

I'm did rethink this, do it by May 4th midnight, but no presentation

now hear this:

sirs@msu.edu <sirs@msu.edu>

SIRS Online Forms

To: brockr@msu.edu <brockr@msu.edu>

Inbox - Exchange   April 16, 2018 at 7:34 AM

To: RAYMOND L BROCK

From: sirs@msu.edu

Student Instruction Rating System (SIRS Online) collects student feedback on courses and instruction at MSU. Student Instructional Rating System (SIRS Online) forms will be available for your students to submit feedback during the dates indicated:

ISP 220 001: 4/16/2018 - 5/16/2018
ISP 220 002: 4/16/2018 - 5/16/2018

Direct students to https://sirsonline.msu.edu.

Students are required to complete the SIRS Online form OR indicate within that form that they decline to participate. Otherwise, final grades (for courses using SIRS Online) will be sequestered for seven days following the course grade submission deadline for this semester.

SIRS Online rating summaries are available to instructors and department chairs after 5/16/2018 at https://sirsonline.msu.edu. Instructors should provide copies of the rating summaries to graduate assistants who assisted in teaching their course(s). Rating information collected by SIRS Online is reported in summary form only and cannot be linked to individual student responses. Student anonymity is carefully protected.

If you have any questions, please contact Michelle Carlson, (mcarlson@msu.edu, (517)432-5936).

honors project began

https://qstbb.pa.msu.edu/storage/Homework_Projects/honors_project_2018/

contains:

- the first instructions: the plan & tutorial
- the second instructions – v2 uploaded, added a missing student
- the data, assigned by name in the second instructions - see next

dates:

- complete first part, March 16
- analyze data by April 24 and hand in complete writeup at the final exam

I ~~need~~ have a Section 2

to test the Z-path uploading machinery and instructions

working on it. I'll be in touch via email.

here's what we've learned

There are three kinds of fields: messenger fields, quark fields, and lepton fields

- oscillations - the particles - of quark fields are the constituents of protons and neutrons, but also hundreds of other "particles" that nature will produce

- oscillations of lepton fields - electrons and the electron neutrino and the other two lepton pairs, round out "matter"

- Messenger fields carry the four known forces from one particle to another

now the jargon

gets a little more straightforward

now defined:

Hadrons: particles made of quarks.

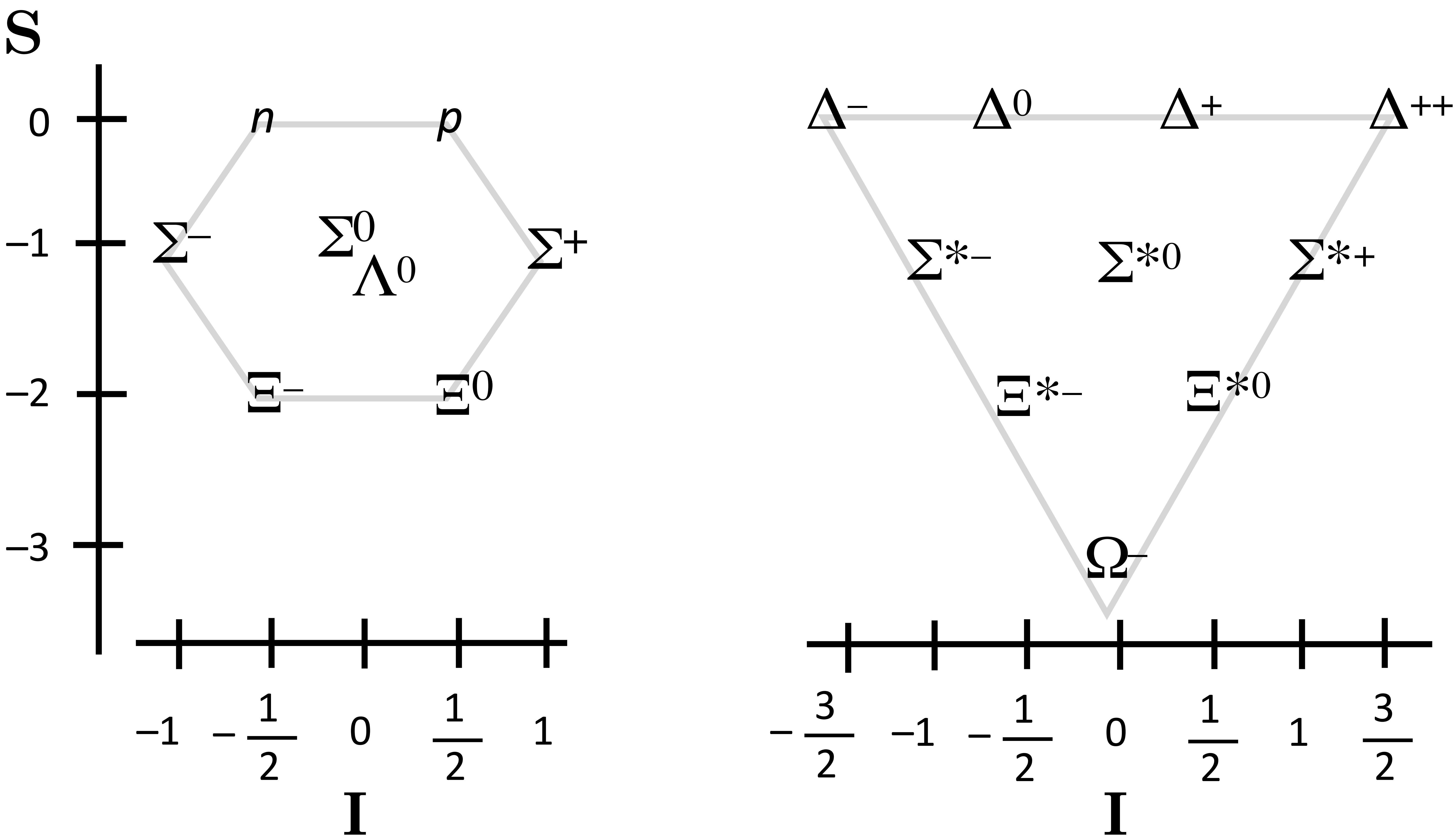
now defined:

Baryons: particles made of 3 quarks.

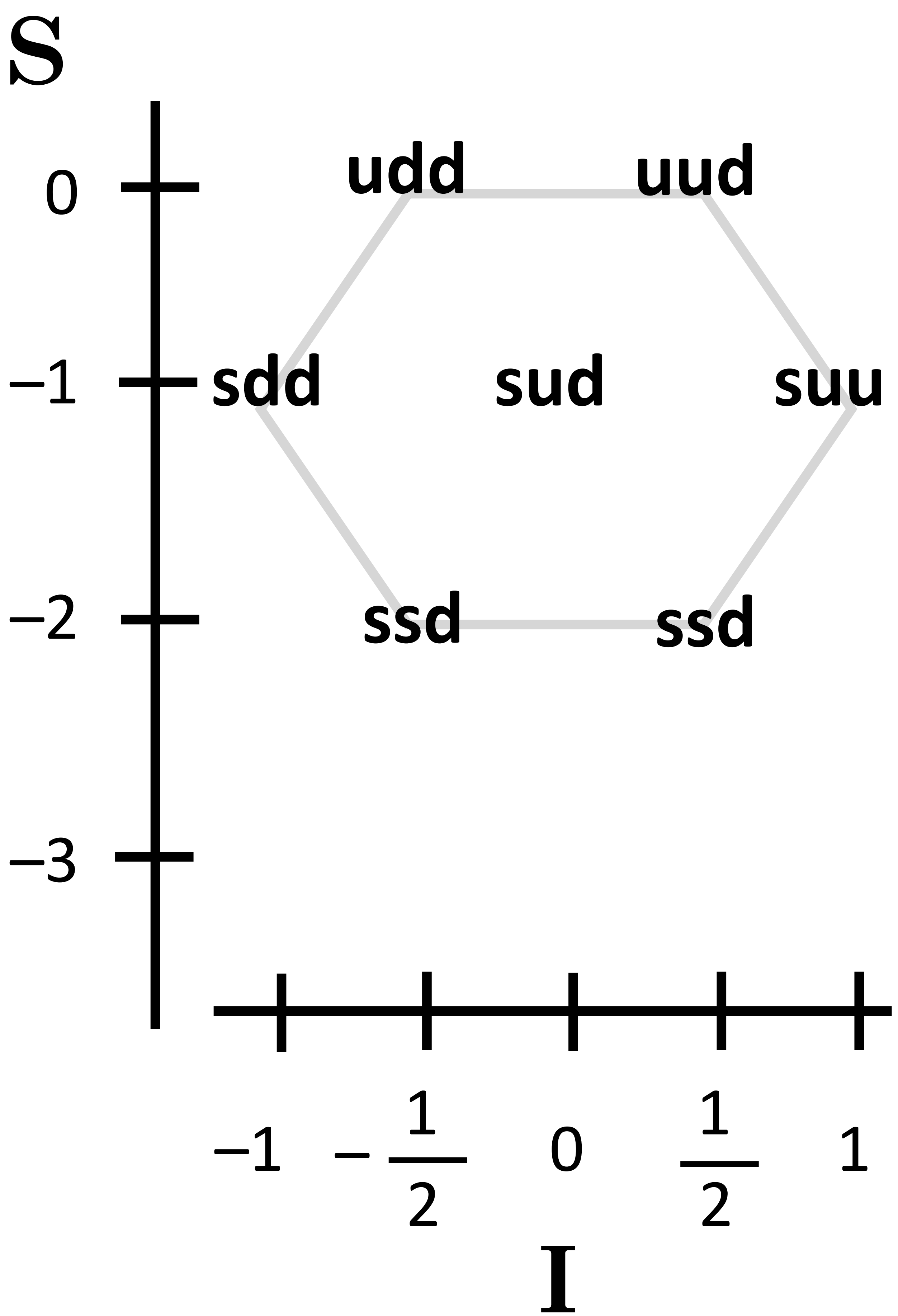
now defined:

Mesons: particles made of 1 quark and 1 antiquark.

the primary baryons



like a glove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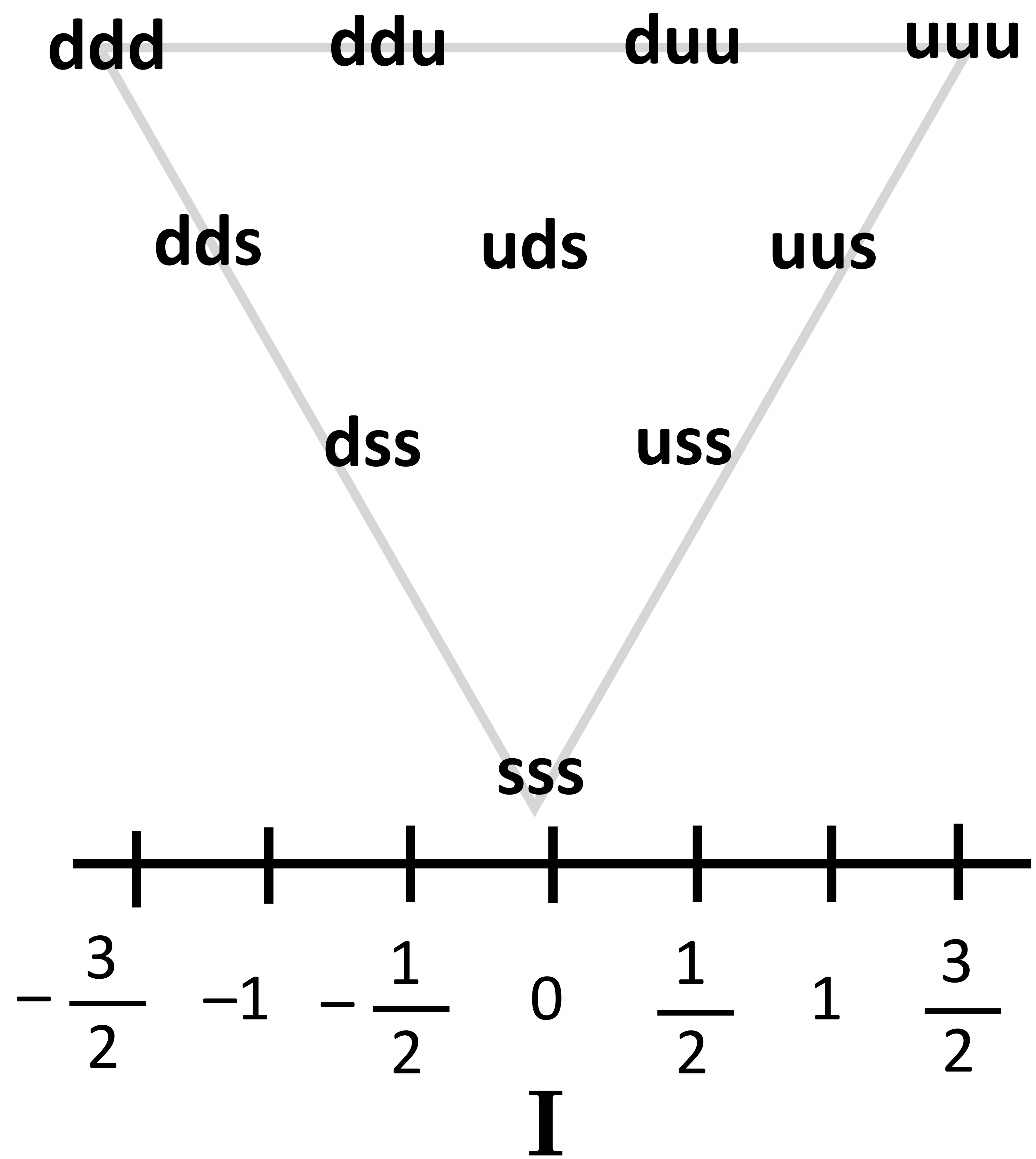
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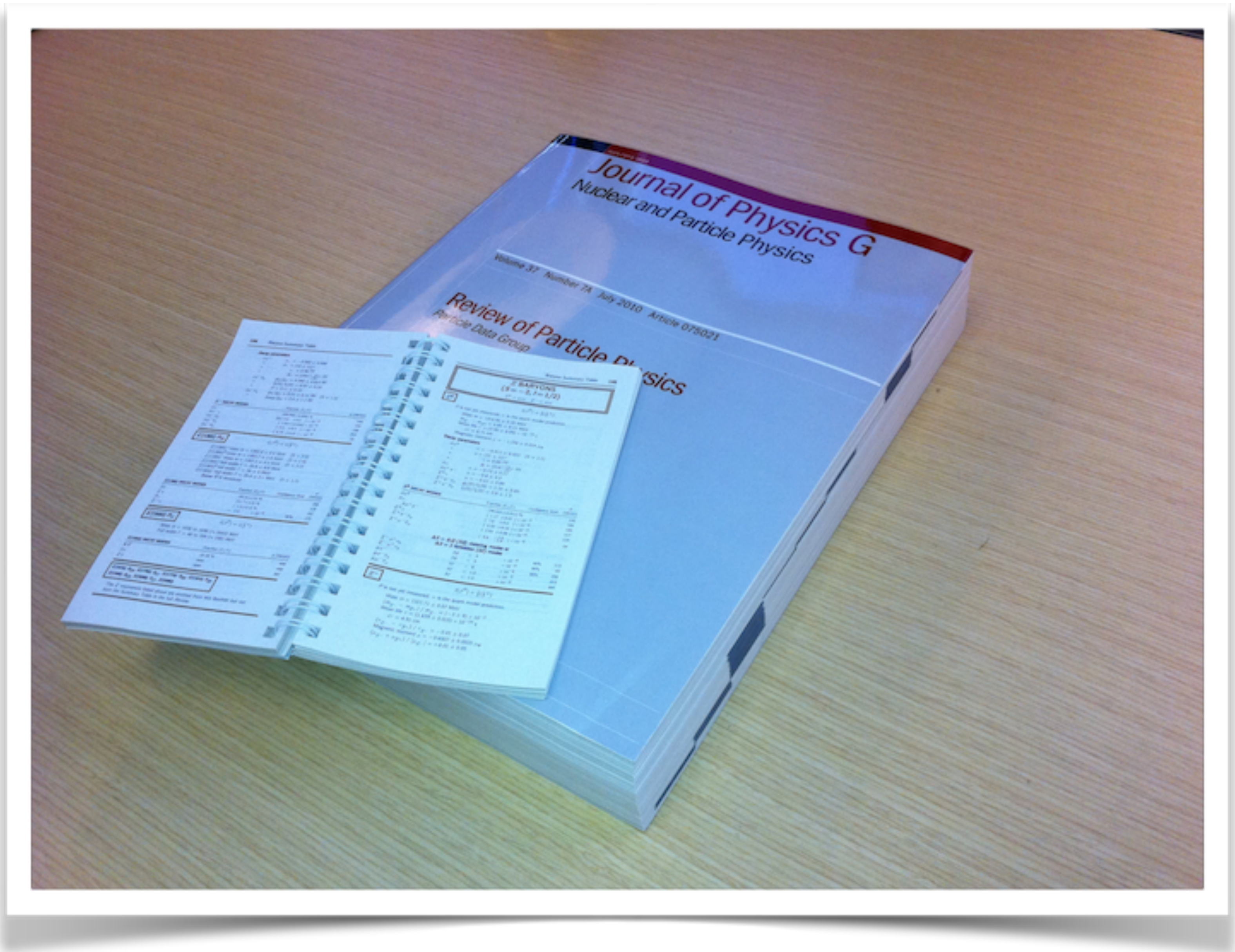
the dominant Baryons

Particle	Symbol	Rest Mass MeV/c^2	spin	Q	B	S	Lifetime	dominant decay modes	quark content
proton	p	938.3	1/2	+1	+1	0	> 10^{31} y		uud
neutron	n	939.6	1/2	0	+1	0	920	$pe^-\bar{\nu}_e$	ddu
Lambda	Λ^0	1115.6	1/2	0	+1	–1	2.6 x 10^{-10}	$p\pi^-,\ n\pi^0$	uds
Sigma	Σ^+	1189.4	1/2	+1	+1	–1	0.8 x 10^{-10}	$p\pi^0,\ n\pi^+$	uus
Sigma	Σ^0	1192.5	1/2	0	+1	–1	6 x 10^{-20}	$\Lambda^0\gamma$	uds
Sigma	Σ^-	1197.3	1/2	–1	+1	–1	1.5 x 10^{-10}	$n\pi^-$	dds
Delta	Δ^{++}	1232	3/2	+2	+1	0	0.6 x 10^{-23}	$p\pi^+$	uuu
Delta	Δ^+	1232	3/2	+1	+1	0	0.6 x 10^{-23}	$n\pi^+,\ p\pi^0$	uud
Delta	Δ^0	1232	3/2	0	+1	0	0.6 x 10^{-23}	$n\pi^0$	udd
Delta	Δ^-	1232	3/2	–1	+1	0	0.6 x 10^{-23}	$n\pi^-$	ddd
Xi	Ξ^0	1315	1/2	0	+1	–2	2.9 x 10^{-10}	$\Lambda^0\pi^0$	uss
Xi	Ξ^-	1321	1/2	–1	+1	–2	1.64 x 10^{-10}	$\Lambda^0\pi^-$	dss
Omega	Ω^-	1672	3/2	–1	+1	–3	0.82 x 10^{-10}	$\Xi^0\pi^-,\ \Lambda^0K^-$	sss

the dominant Mesons

Particle	Symbol	anti-particle	Rest Mass MeV/c²	spin	Q	B	S	Lifetime	dominant decay modes	quark content
Pion	π^+	π^-	139.6	0	+1	0	0	2.6×10^{-8}	$\mu^+\nu_\mu$	$u\bar{d}$
Pi-zero	π^0	π^0	135	0	0	0	0	920	2γ	$\frac{1}{\sqrt{2}}(u\bar{u}+d\bar{d})$
Kaon	K^+	K^-	493.7	0	+1	0	+1	1.24×10^{-8}	$\mu^+\nu_\mu, \pi^+\pi^0$	$u\bar{s}$
K-short	K^0_S	K^0_S	497.7	0	0	0	+1	0.89×10^{-10}	$\pi^+\pi^-, 2\pi^0$	$d\bar{s}, s\bar{d}$
K-long	K^0_L	K^0_L	497.7	0	0	0	+1	5.2×10^{-8}	$\pi^\pm\ell^\mp\nu_\ell$	$d\bar{s}, s\bar{d}$
Eta	η^0	η^0	548.8	0	0	0	0	$< 10^{-18}$	$2\gamma, \pi^+\pi^-\pi^0$	$u\bar{u}, d\bar{d}, s\bar{s}$
Eta-prime	$\eta^{0\prime}$	$\eta^{0\prime}$	958	1	0	0	0	...	$\pi^+\pi^-\eta$	$u\bar{u}, d\bar{d}, s\bar{s}$
Rho	ρ^+	ρ^-	770	1	+1	0	0	$0.4 \times 10^{--23}$	$\pi^+\pi^-, 2\pi^0$	$u\bar{d}$
Rho-naught	ρ^0	ρ^0	770	1	0	0	0	$0.4 \times 10^{--23}$	$\pi^+\pi^-$	$u\bar{u}, d\bar{d}$
Omega	ω^0	ω^0	782	1	0	0	0	$0.8 \times 10^{--22}$	$\pi^+\pi^-\pi^0$	$u\bar{u}, d\bar{d}$
Phi	ϕ	ϕ	1020	1	0	0	0	20×10^{-23}	$K^+K^-, K^0\bar{K}^0$	$s\bar{s}$

6 bits of matter:



$$\begin{pmatrix} u \\ d \end{pmatrix} \qquad \begin{pmatrix} c \\ s \end{pmatrix} \qquad \begin{pmatrix} t \\ b \end{pmatrix}$$

quarks are a part of reality

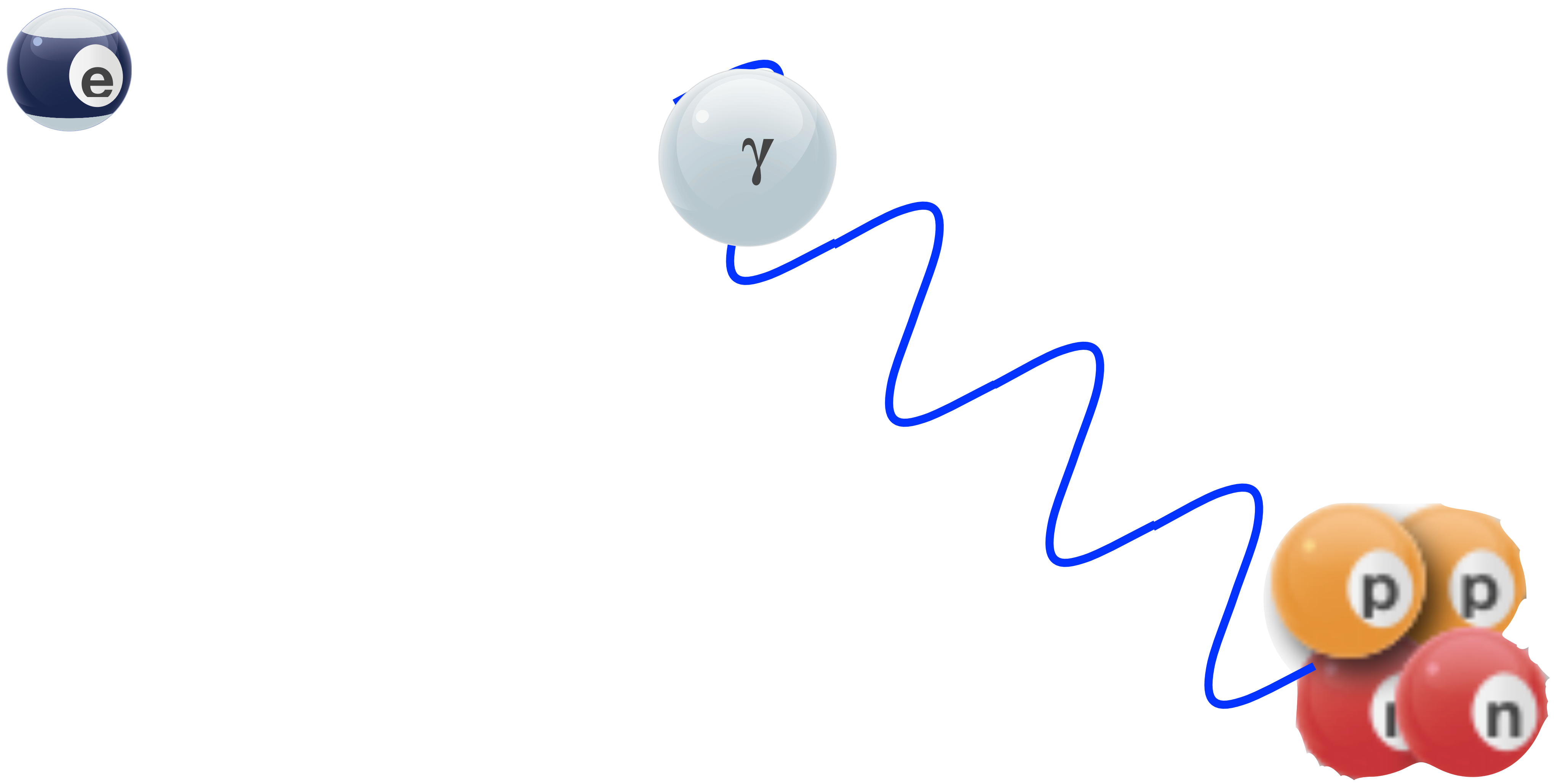
because we can

hit them individually

measure many properties of interactions and particles that are bang-on

scattering of an electron from a nucleus

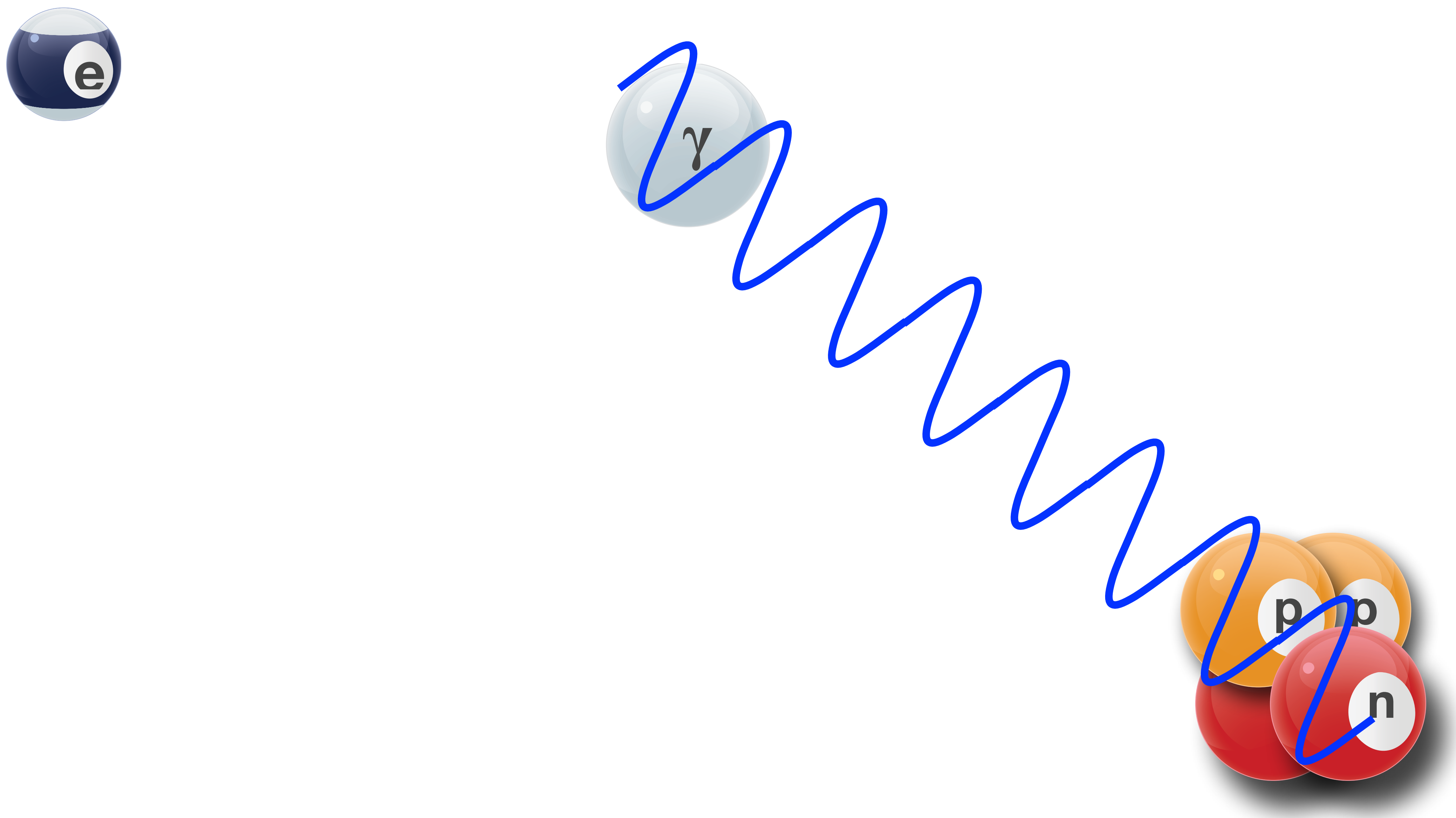
slow electron, long wavelength photon



"sees" the whole nucleus

scattering of an electron from a nucleus

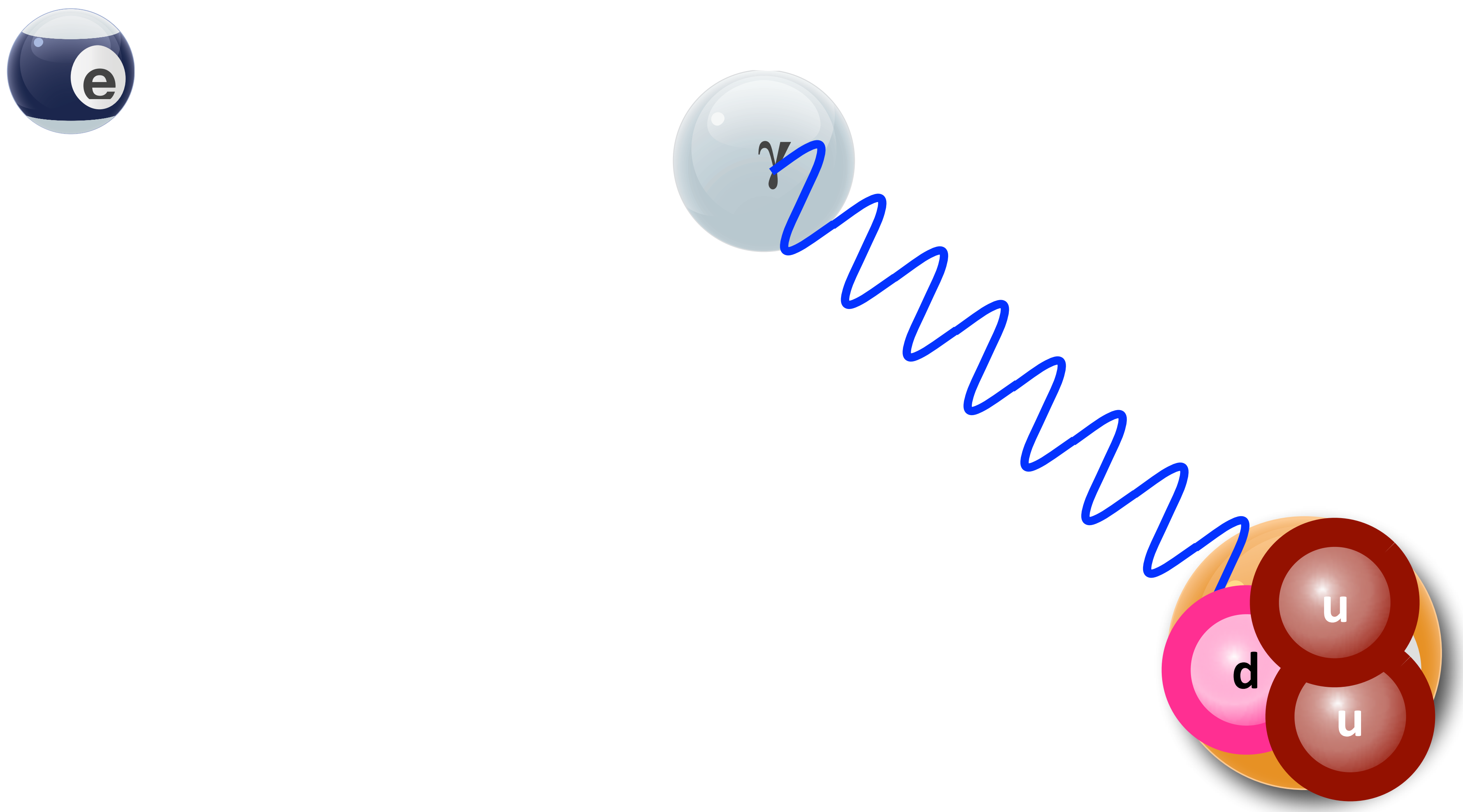
fast electron, **medium-short** wavelength photon



“sees” an individual proton in the nucleus

scattering of an electron from a nucleus

very fast electron, **very-short** wavelength photon



“sees” an individual quark in a proton or neutron

That’s how we became convinced in 1969 –

the same sort of backwards scattering as Rutherford’s

the messenger of the strong interaction

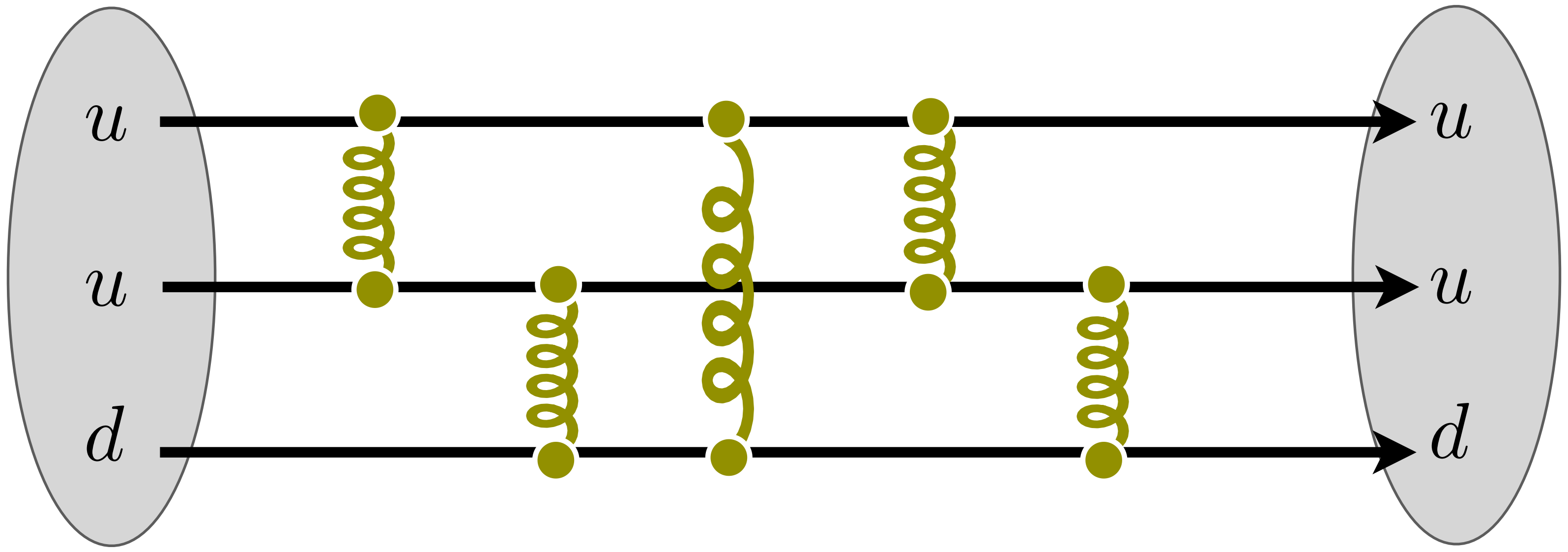
the Gluon

the glue that holds everything together

Predicted the existence of the Strong Messenger Particle:

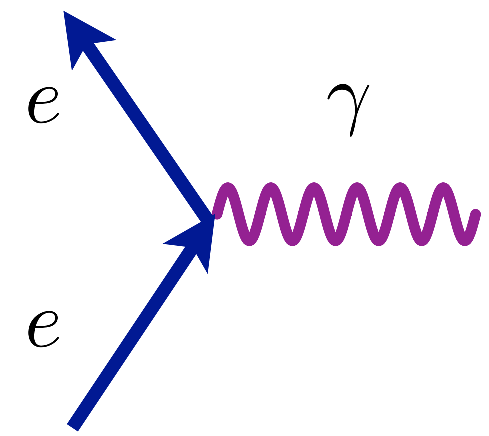
the Gluon

my gluon

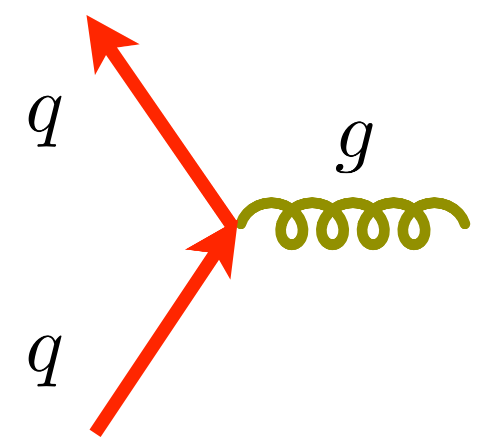


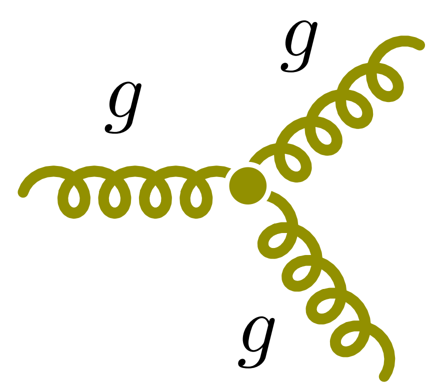
thing 1

they self-interact

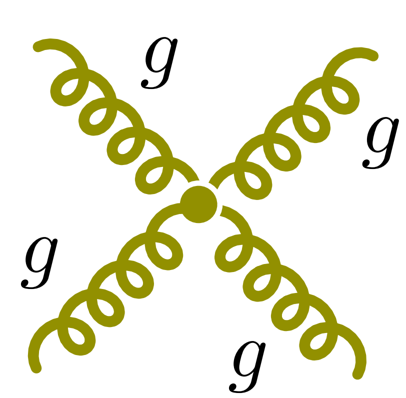


a photon propagates the electromagnetic force...but it does not have an electric charge



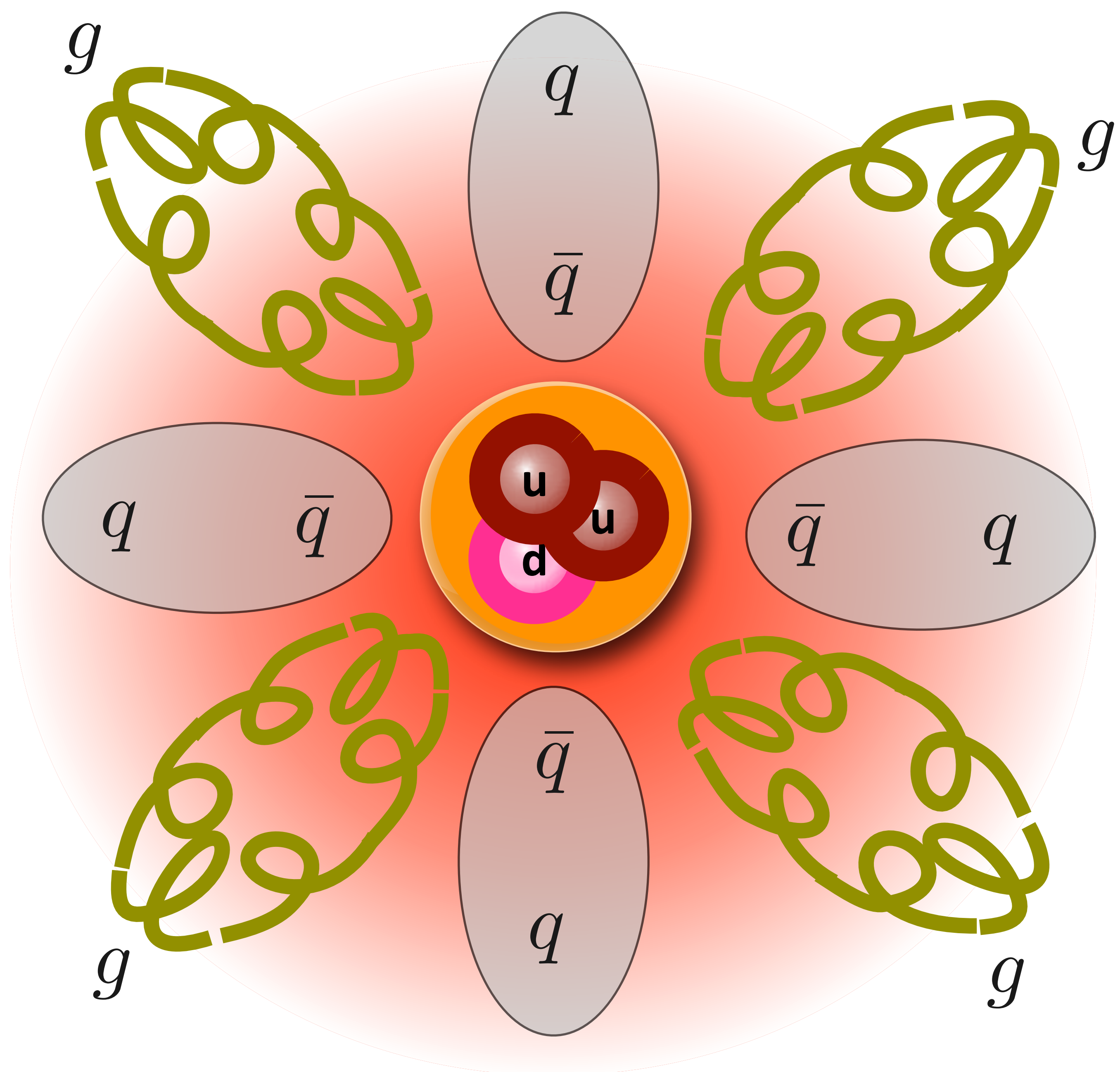


the gluon propagates the strong force...and it DOES have a "strong charge"

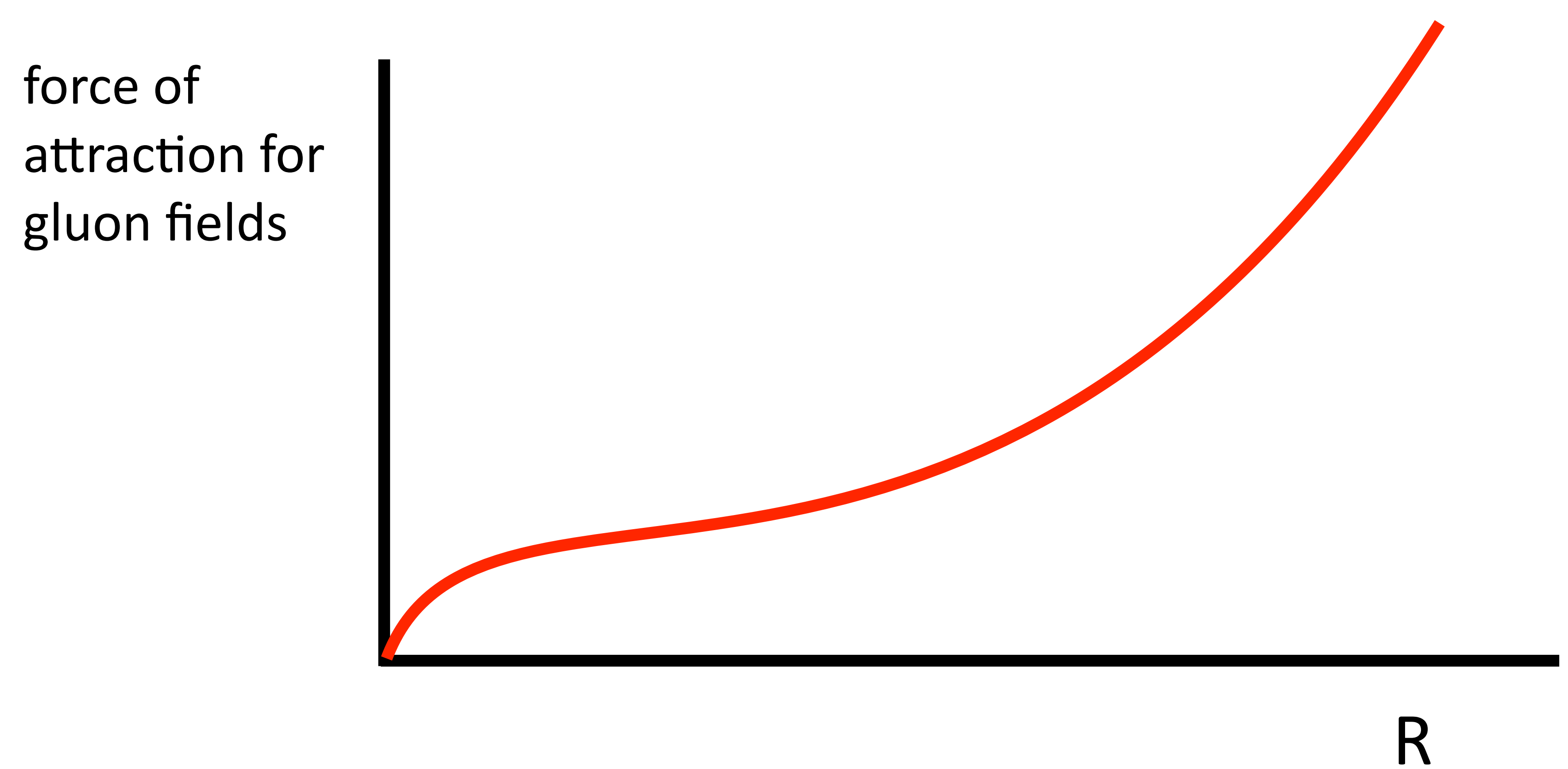


This has significant consequences...almost magical

ah, but the gluon is odd

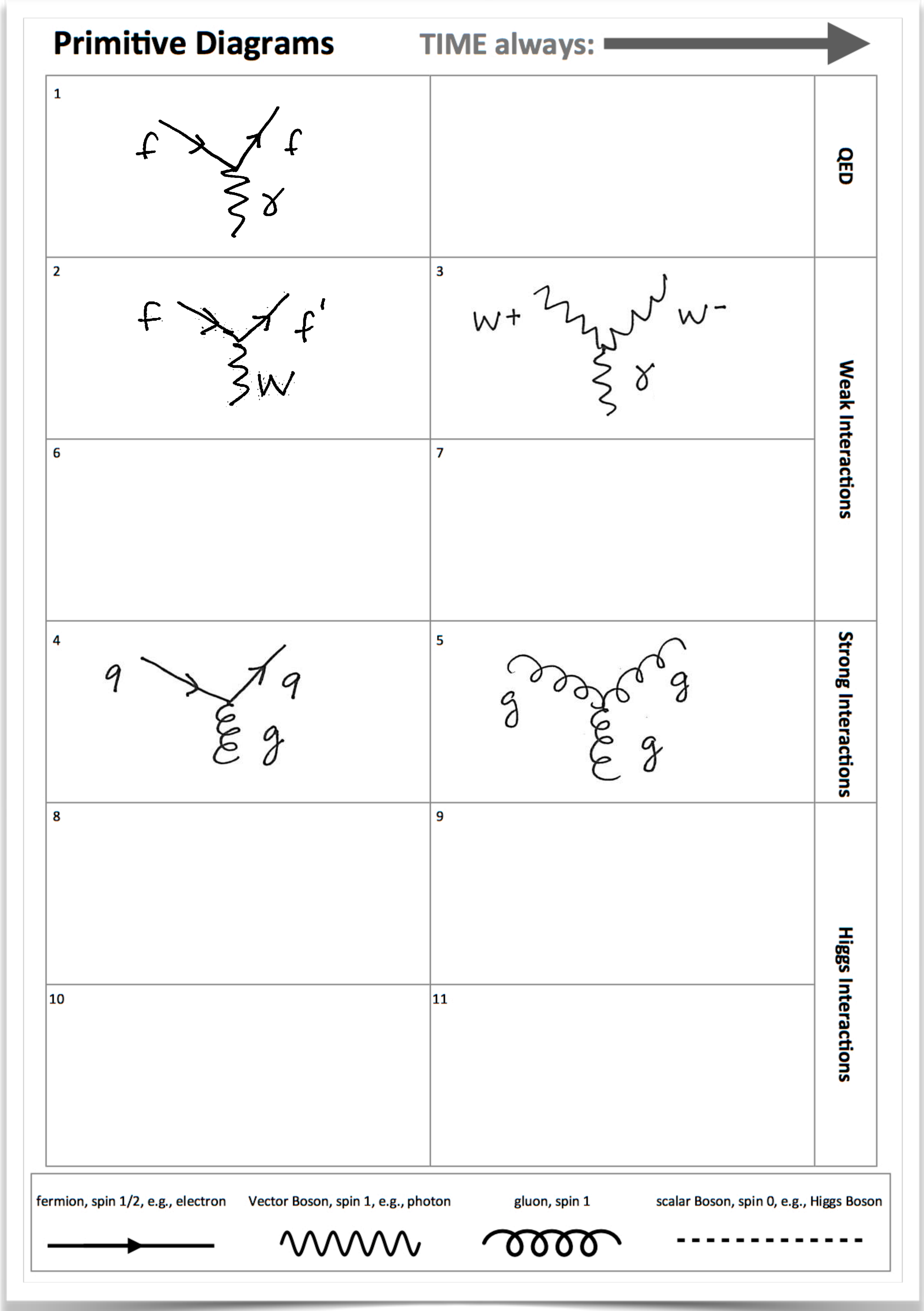


the further away you get, the **STRONGER** the quark-quark attraction is!



fourth and fifth entries into your

table of primitive diagrams



the modern picture

of the elementary particle patterns

circa now

the lepton families...lepton “doublets”

$$\begin{pmatrix}\nu_e \\ e^-\end{pmatrix} \quad \begin{pmatrix}\nu_\mu \\ \mu^-\end{pmatrix} \quad \begin{pmatrix}\nu_\tau \\ \tau^-\end{pmatrix}$$

and their interactions: ✗ no, ✓ yes.

leptons	ν_e	e	ν_μ	μ	ν_τ	τ
strong g	✗	✗	✗	✗	✗	✗
electromagnetic γ	✗	✓	✗	✓	✗	✓
weak W	✓	✓	✓	✓	✓	✓
gravitational	✓	✓	✓	✓	✓	✓

the modern picture

of the elementary particle patterns

circa now

the quark families...quark "doublets"

$$\begin{pmatrix} u \\ d \end{pmatrix} \quad \begin{pmatrix} c \\ s \end{pmatrix} \quad \begin{pmatrix} t \\ b \end{pmatrix}$$

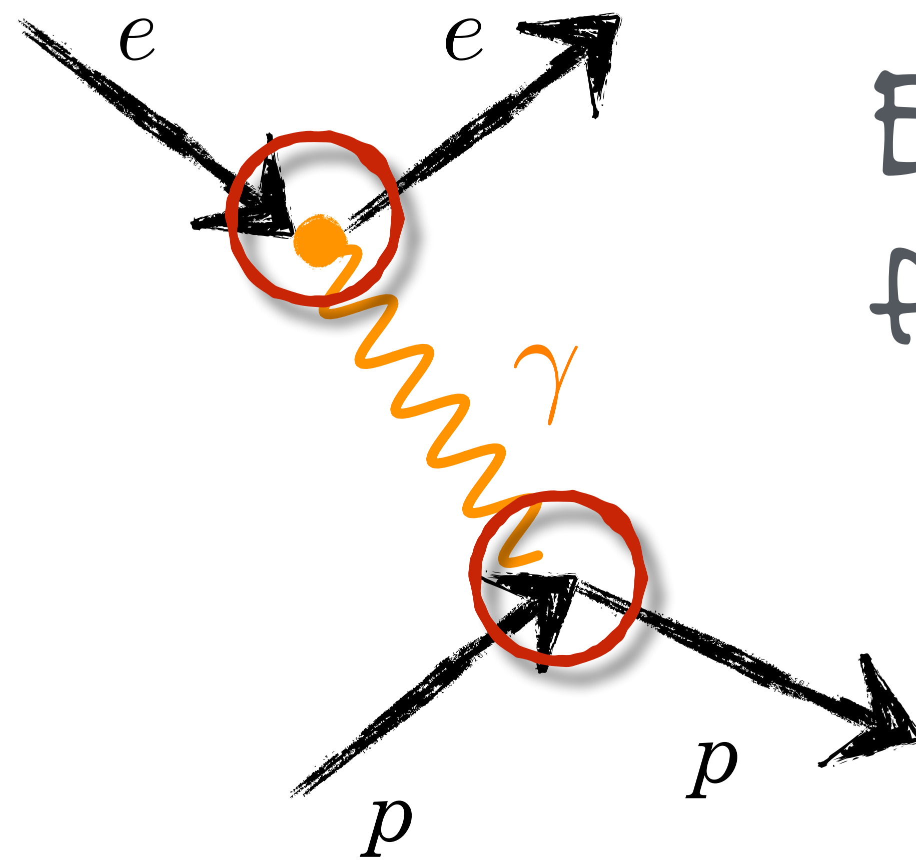
and their interactions: ✘ no, ✔ yes.

quarks	u	d	c	s	t	b
strong g	✔	✔	✔	✔	✔	✔
electromagnetic γ	✔	✔	✔	✔	✔	✔
weak W	✔	✔	✔	✔	✔	✔
gravitational	✔	✔	✔	✔	✔	✔

three forces now

of vastly different strengths

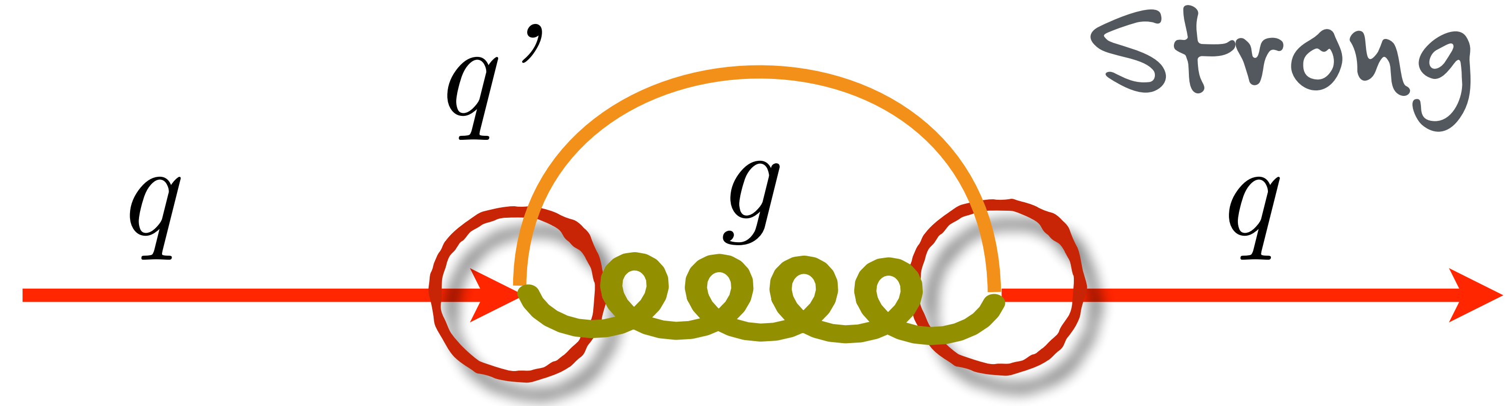
Electromagnetic force 0.007



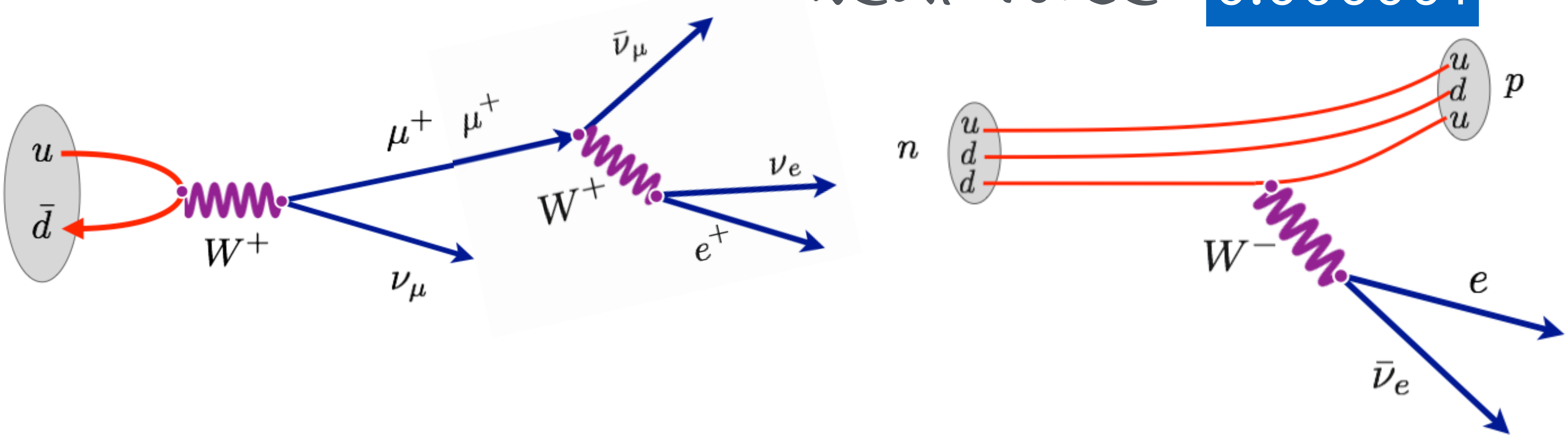
Gravitational force?

0.000000000000000000000000000000000001

Strong force 1



Weak force 0.000001



shifting gears

the weak and electromagnetic forces are one.

“phase transitions”

not a subject of Particle Physics

we thought

but we stole a theory from materials scientists

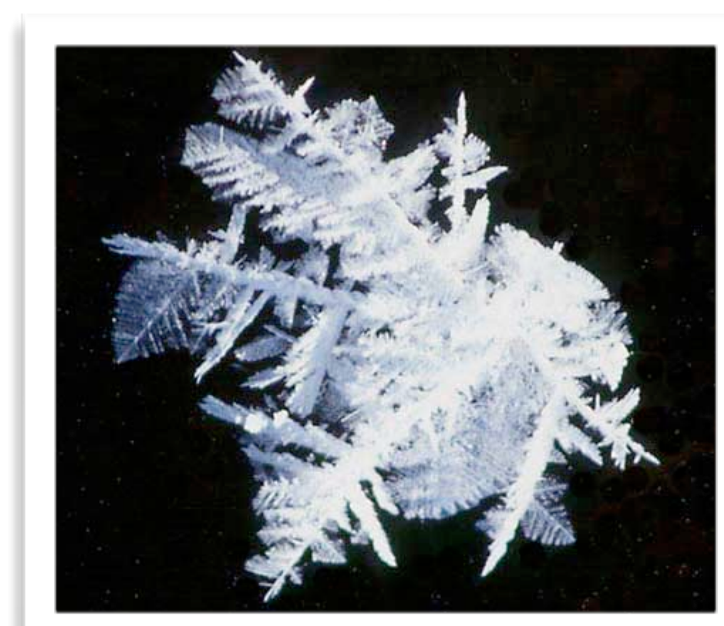
think about a phase transition

what a physicist sees

is a change of symmetry

before: every direction is identical

when there has been a symmetry change, that’s essentially the definition of a phase change: Pierre Curie



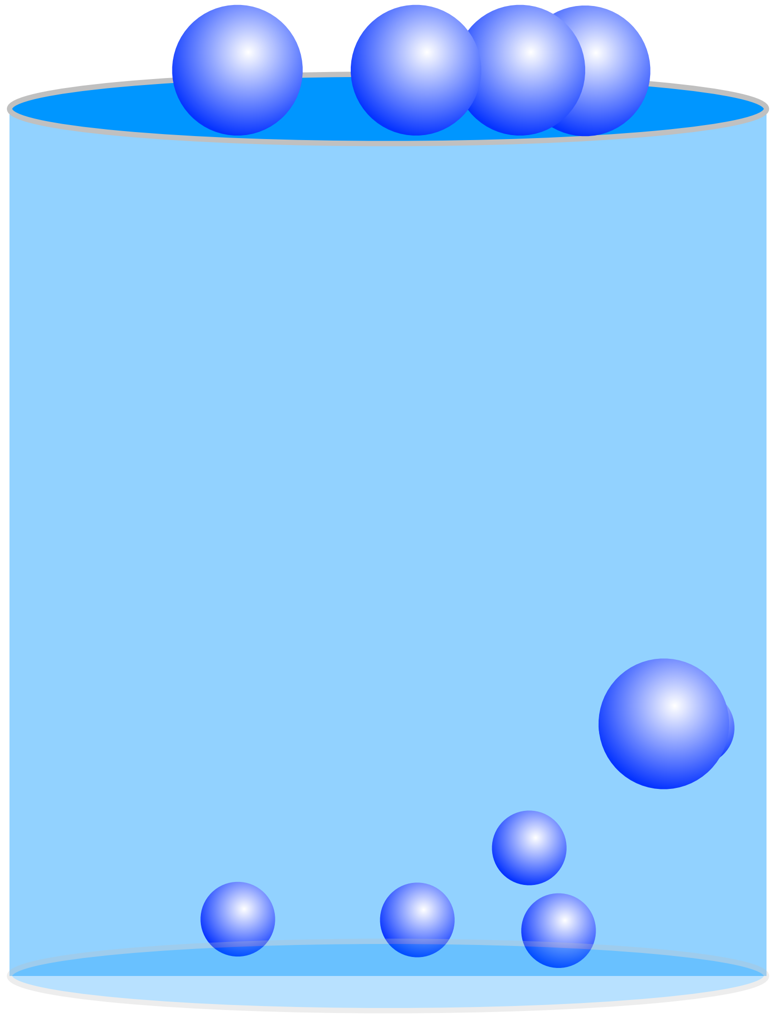
after: now there are special directions

http://www.youtube.com/watch?v=hGmC0W6ejFg&feature=related

there are basically 2 kinds

1st Order - nucleation

2d Order - continuous



Boiling starts in various locations inside of liquid water

Other kinds of phase transitions happen uniformly throughout the substance.

you probably are mostly familiar with:

freezing

melting

boiling

These "2nd Order," phase transitions are continuous-everywhere:

crystallization
changes of density
magnetism
superconductivity
superfluidity
plasma transition
electron gases
Bose gases

a ferromagnet

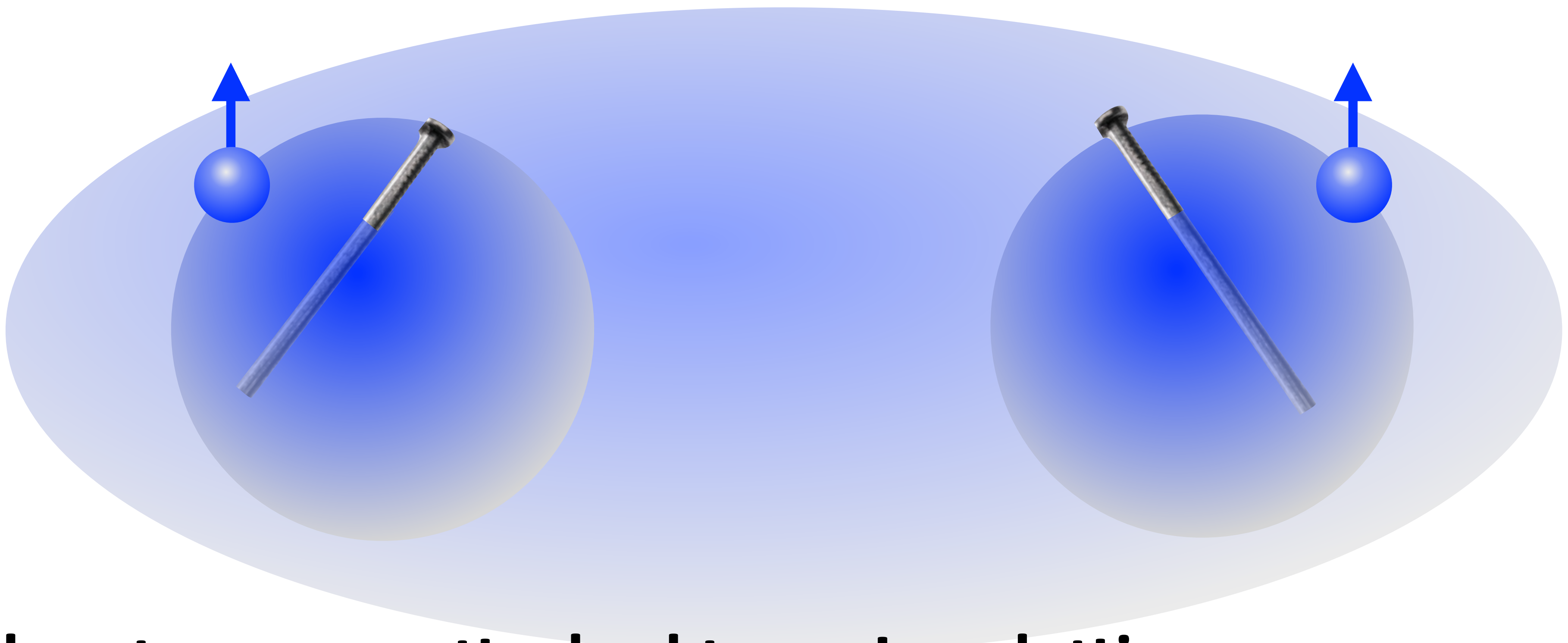
most familiarly:

iron

also:Co, Ni, Li gas

many compounds

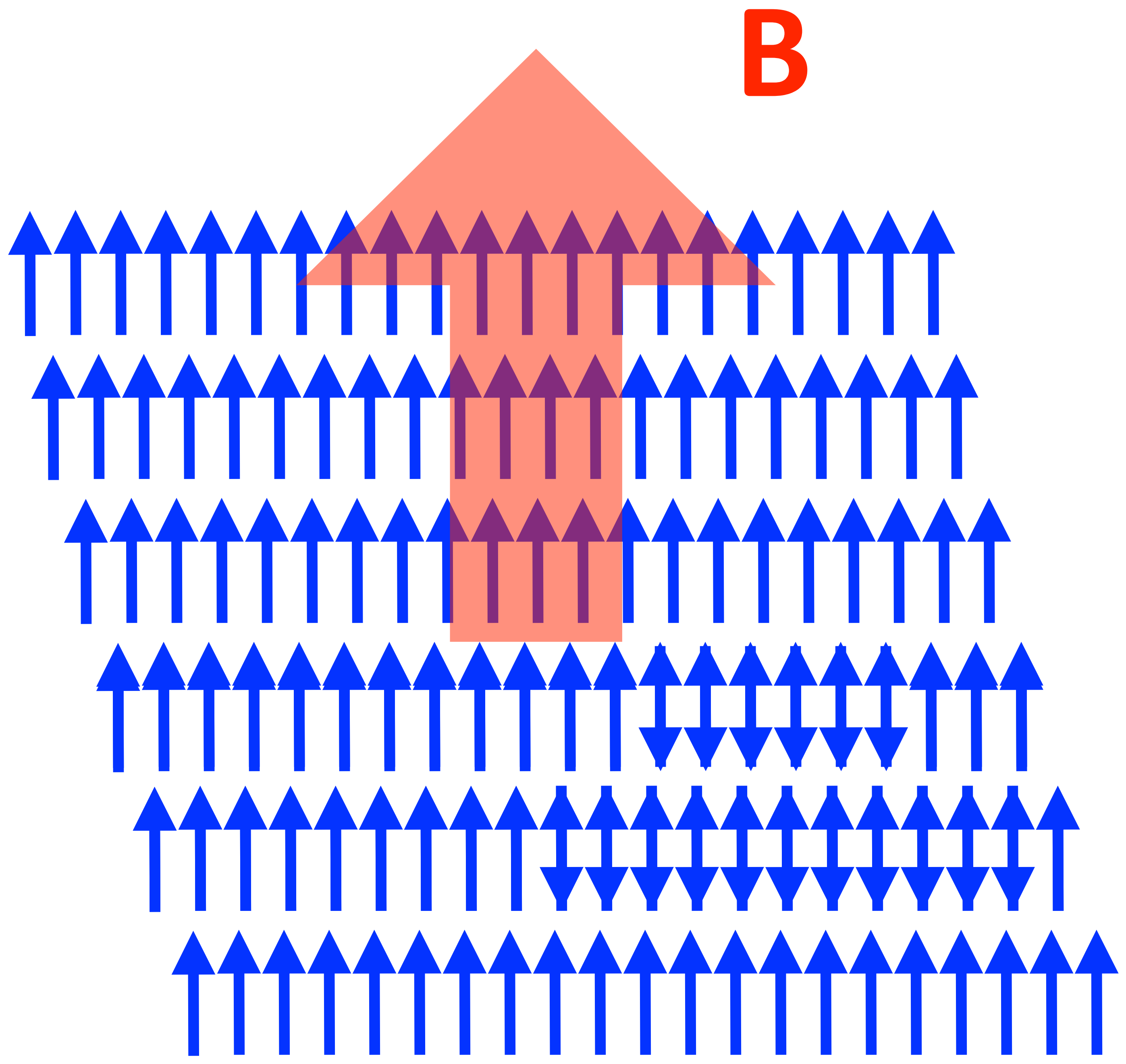
If atoms are far apart...a quantum mechanical effect keeps the spins aligned, minimizing the electrostatic energy



if the atoms are attached to an Iron lattice...
the spins can add up

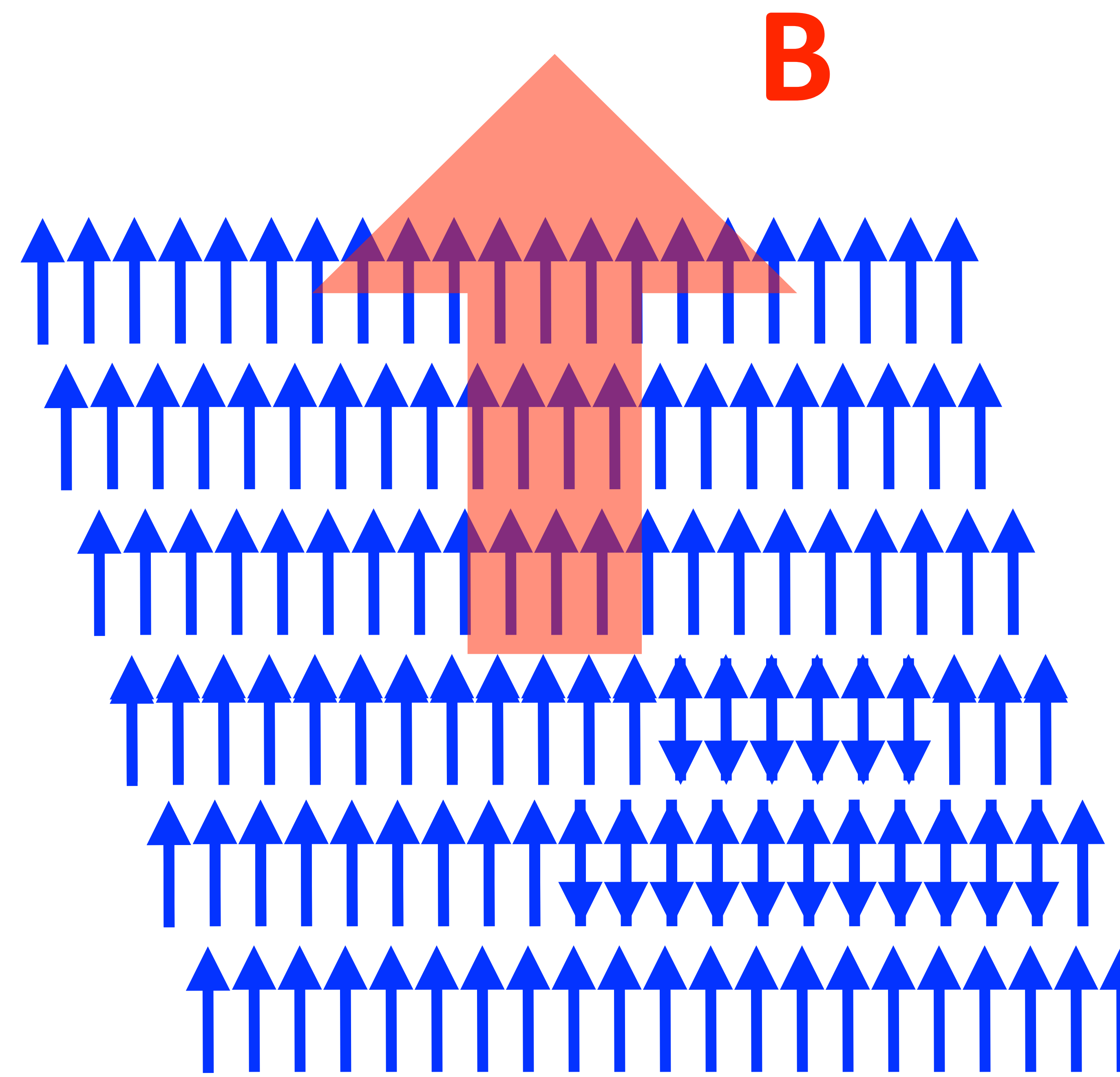
that's a permanent ferromagnet

in 2 - dimensions



why

is he talking about phase transitions you’re asking yourself?



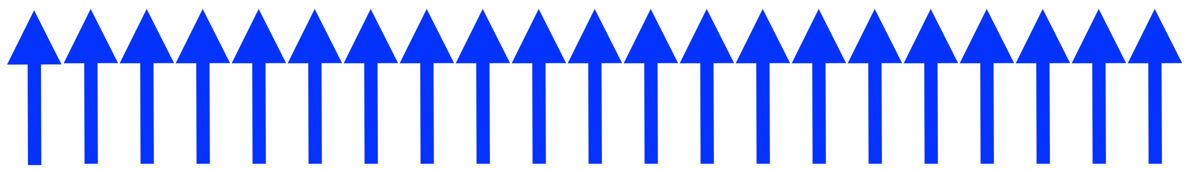
4.2 K - liquifies

2.17 K - superfluid

a little model of an *ideal* ferromagnet

in one - dimension

At a low temperature – like room temperature:



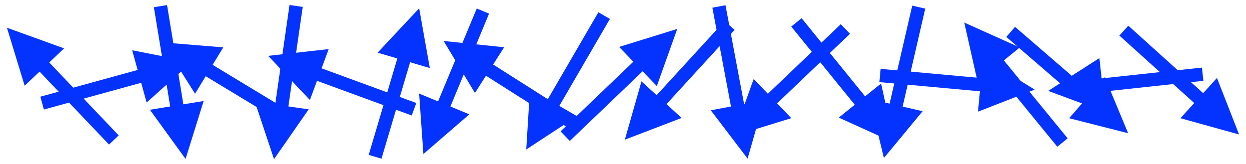
M is maximum

M, "magnetization": a measure of how magnetized

"ground state" – state of lowest energy –

when all electronic magnets are aligned

There is a high temperature – the "Curie Point":



then the "ground state" – state of lowest energy –

when all electronic magnets are random

M becomes zero

an important difference

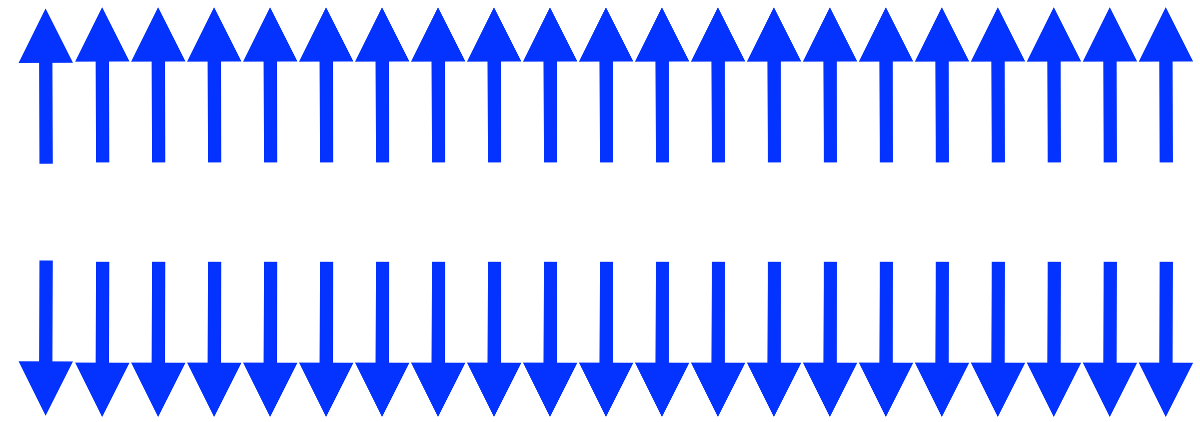
between these two situations

H

M = 0

temperature cools...magnet goes to one of two states:

C

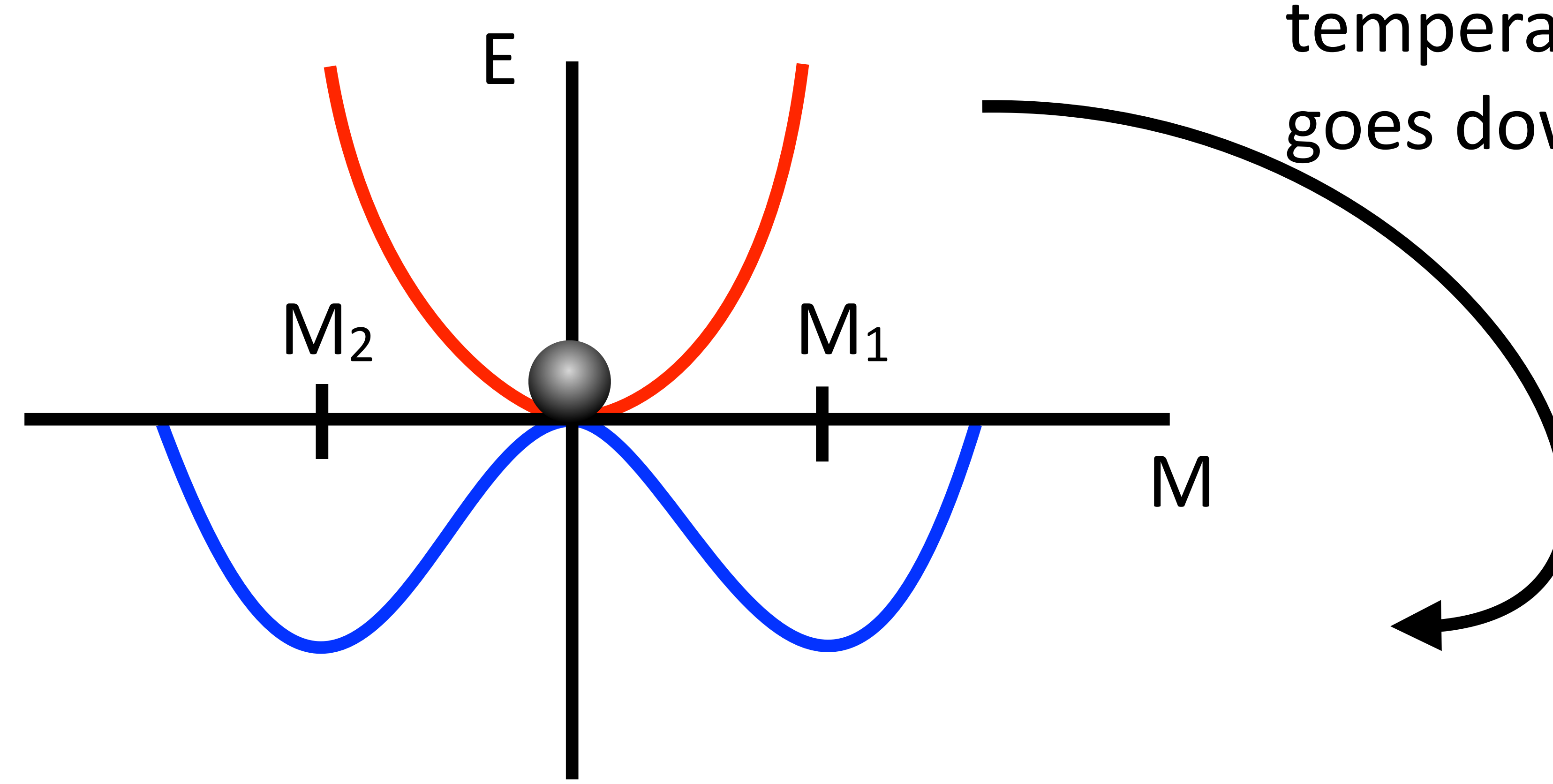


$M_1 \neq 0$

$M_2 \neq 0$

we say that the symmetry is “broken”

when temperature goes down



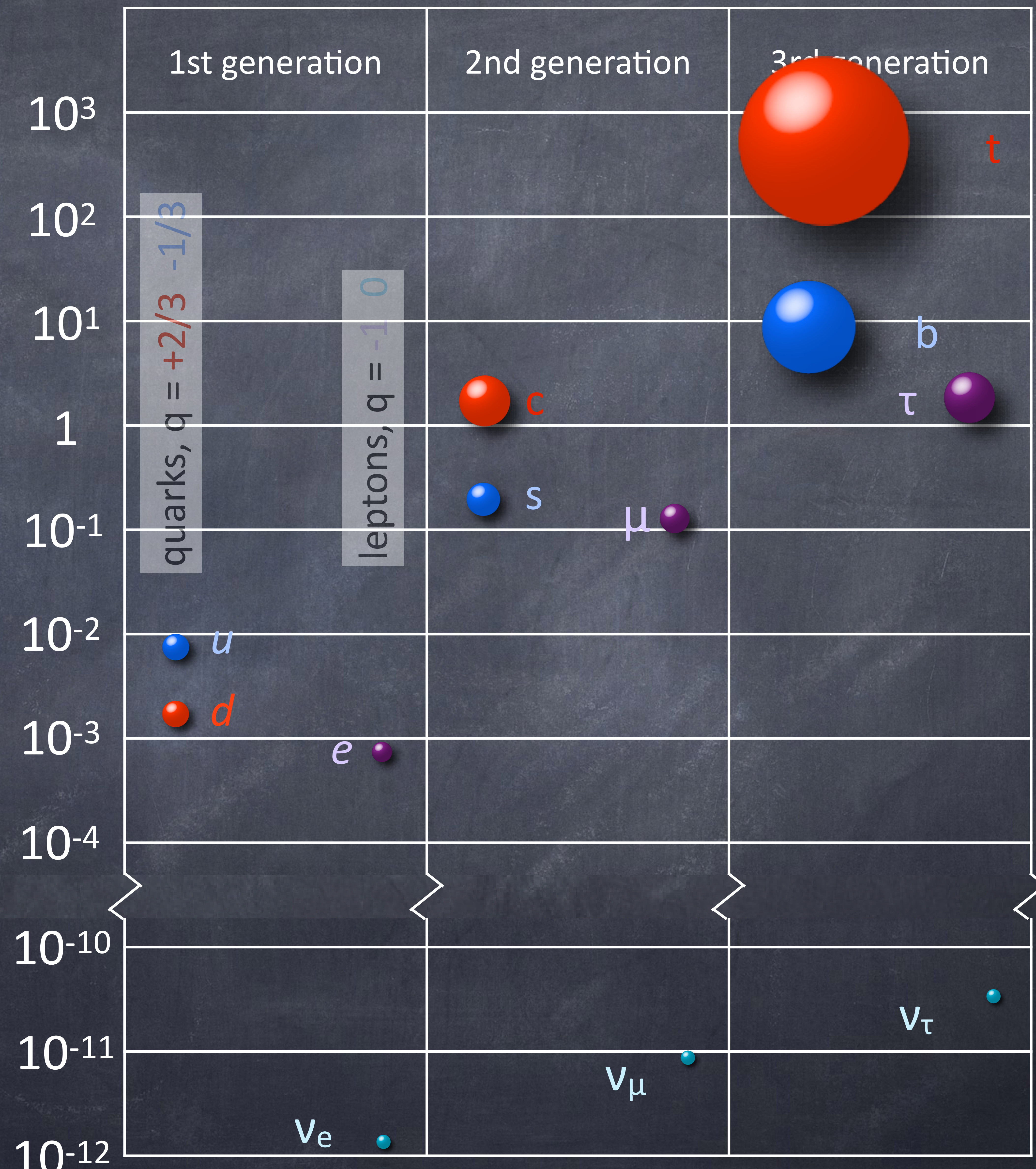
the energy level of the **hot ground state** is higher than the energy level of the **cold ground state**

this often-told magnet story

evolves into the new story of MASS

quarks & leptons

proton masses



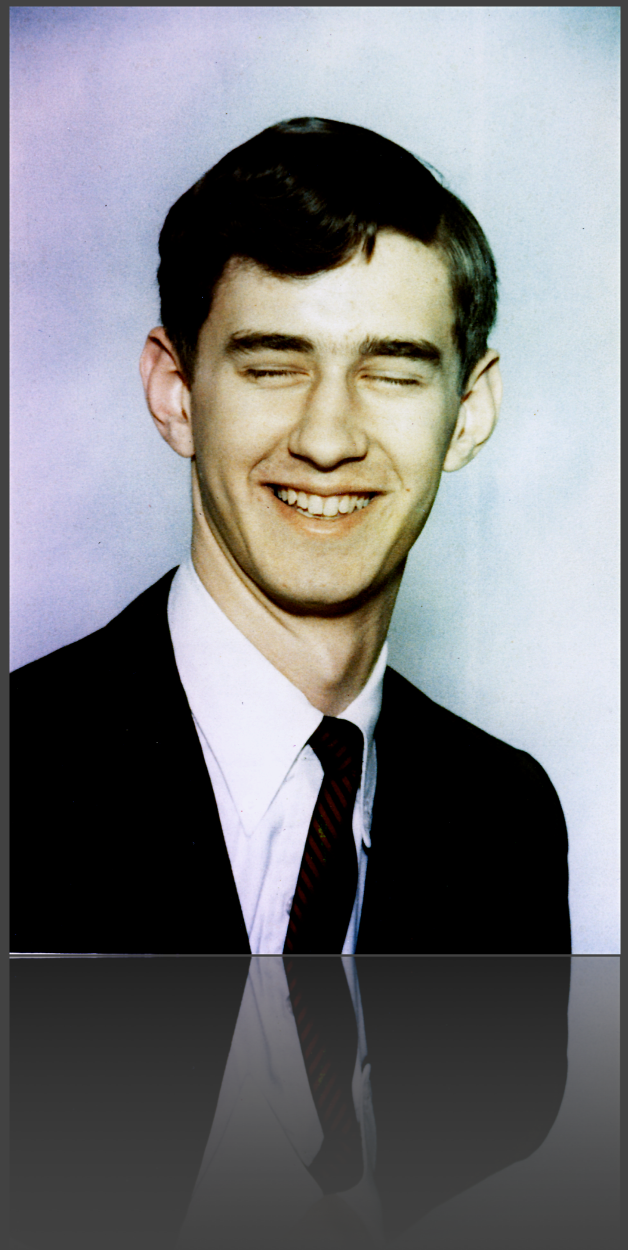
the only mathematical solution that made sense:

masses of all quarks, leptons, and messenger particles

= 0

until we stole the magnet story and rewrote it into our book

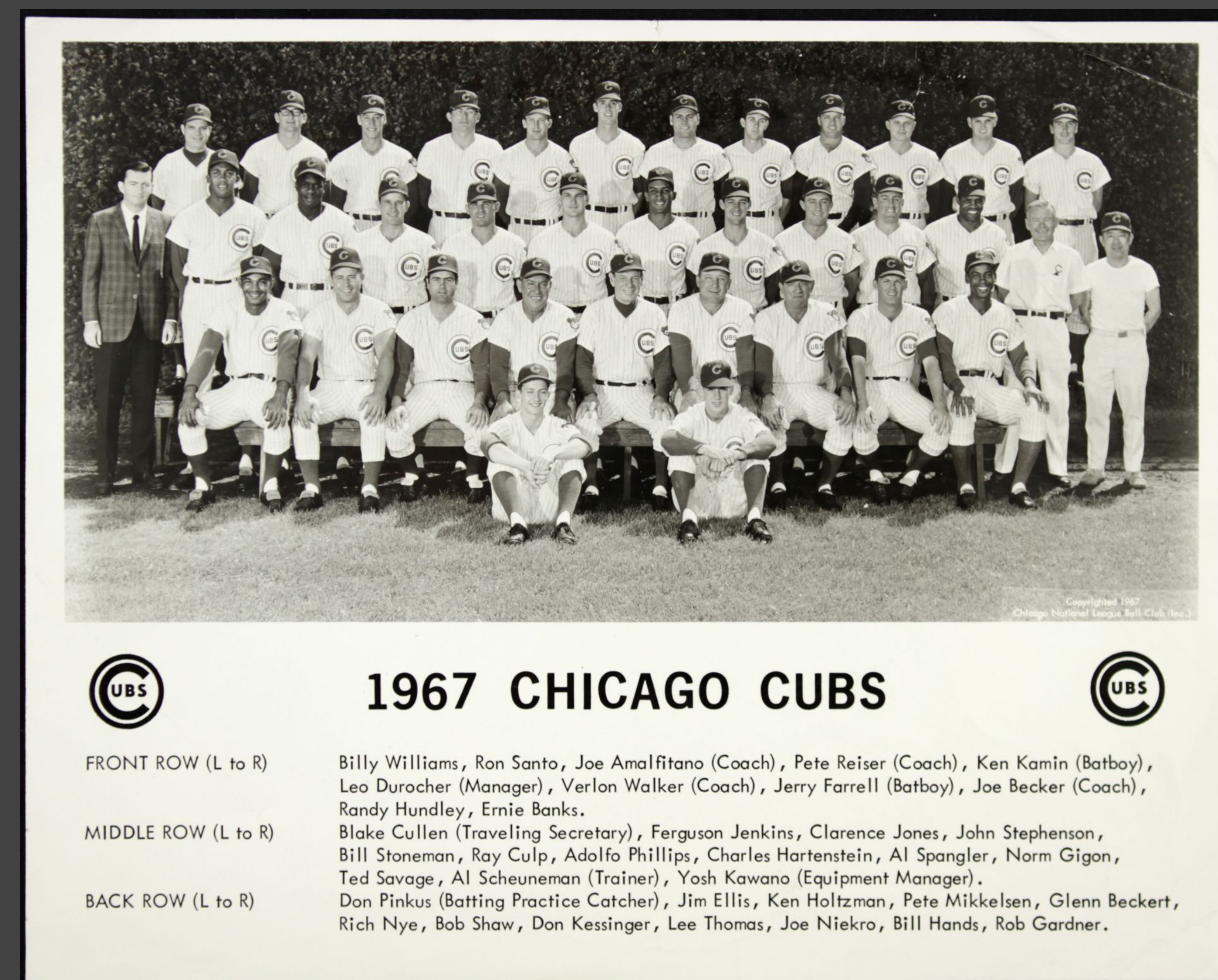
1967



1967

http://www.mustangdreams.com/mdfastback.htm

1967



http://www.mustangdreams.com/mdfastback.htm

1967

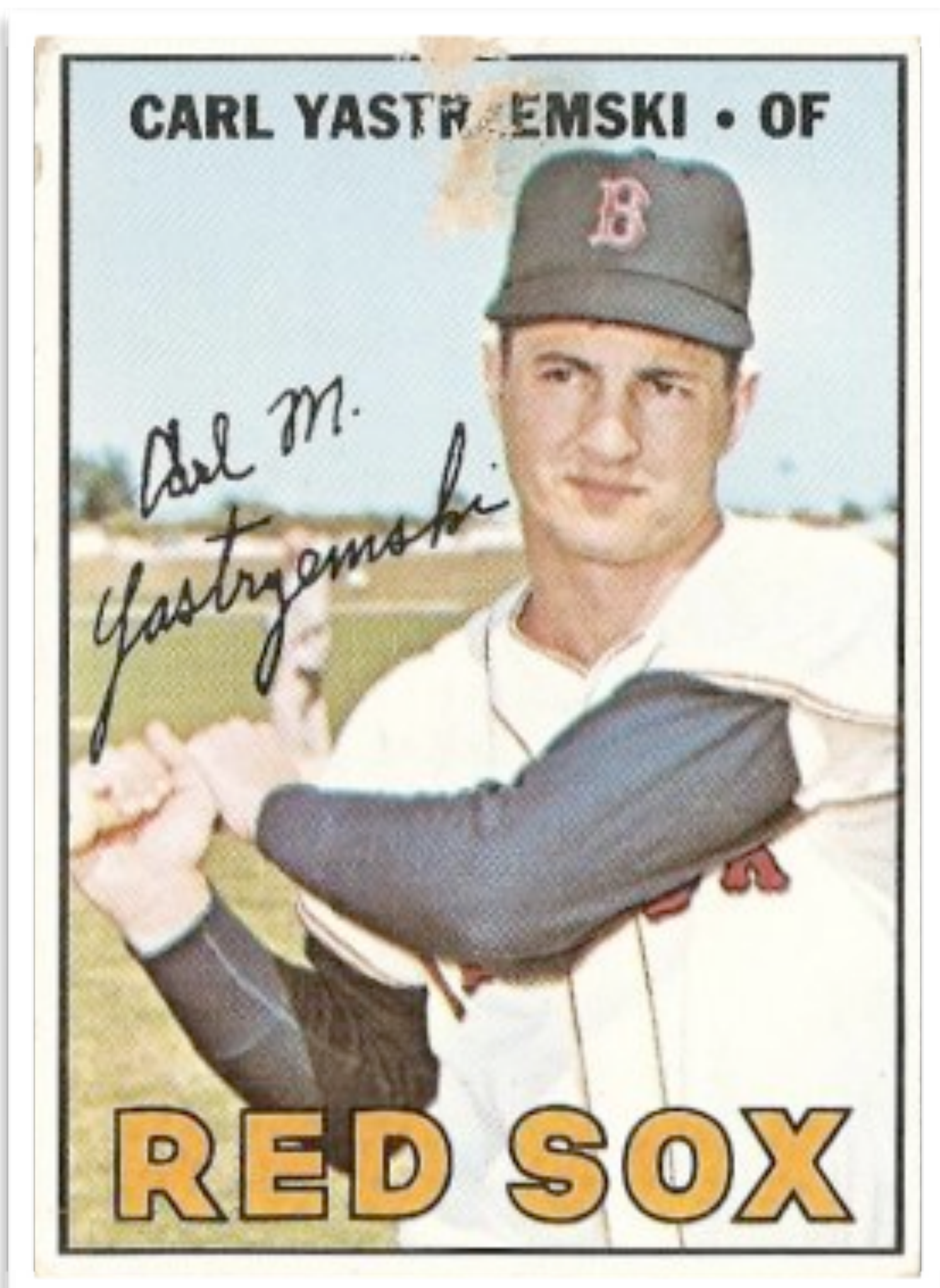
http://www.mustangdreams.com/mdfastback.htm

http://nobelprize.org/nobel_prizes/physics/laureates/1979/weinberg-autobio.html

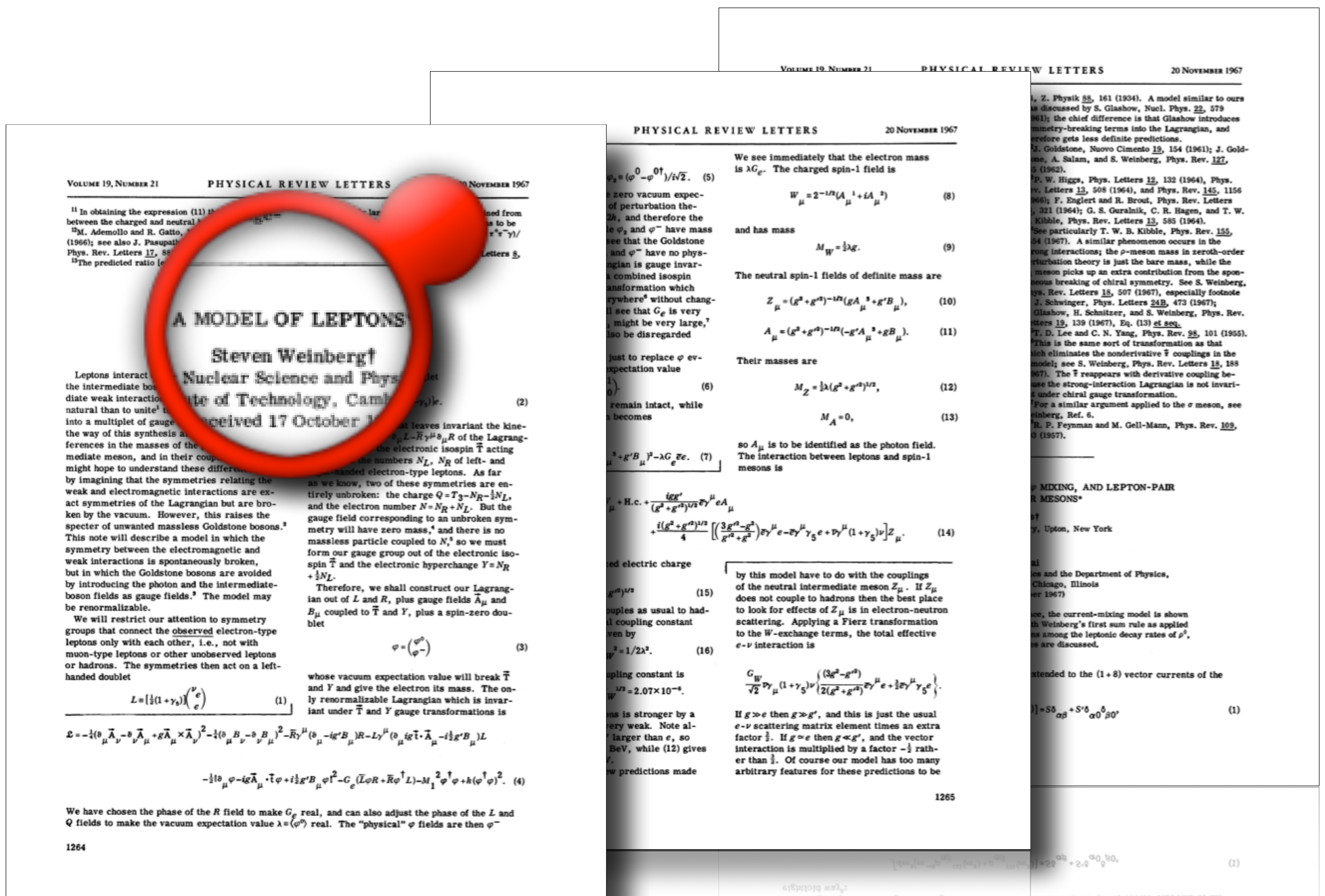
http://hacks.mit.edu/Hacks/by_year/2006

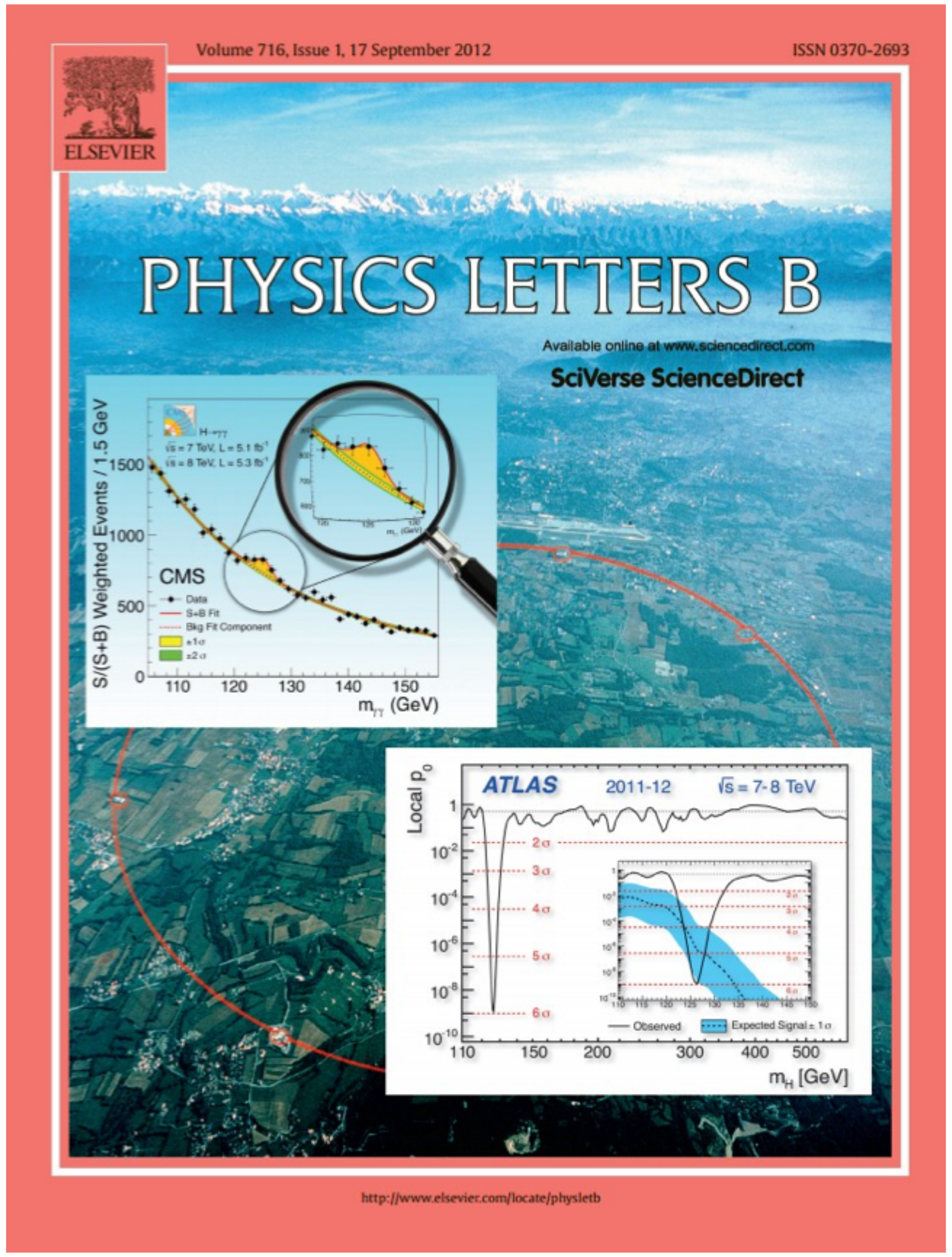
between **1967 - 2012**

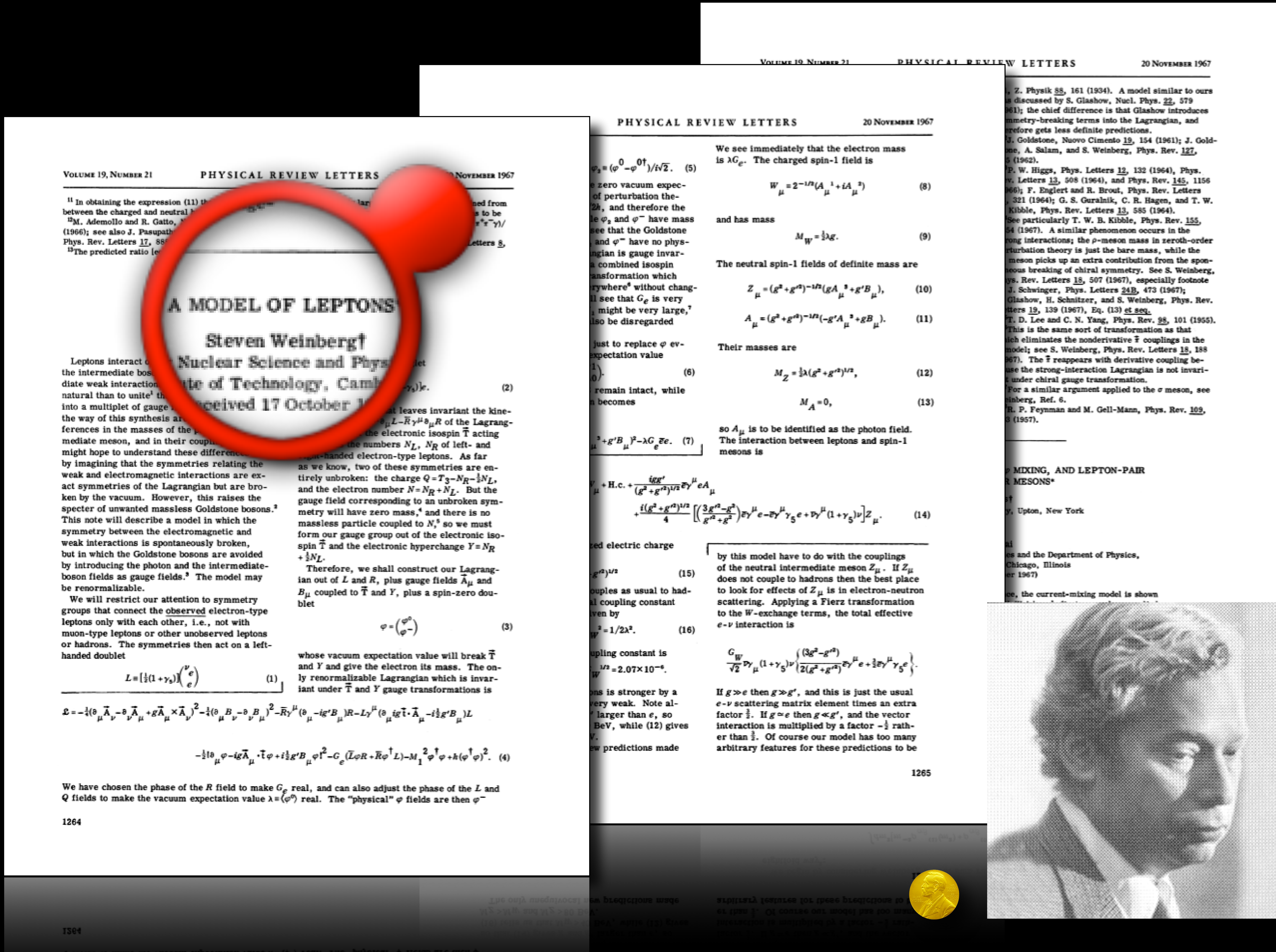
- history was made



between **1967 - 2012**



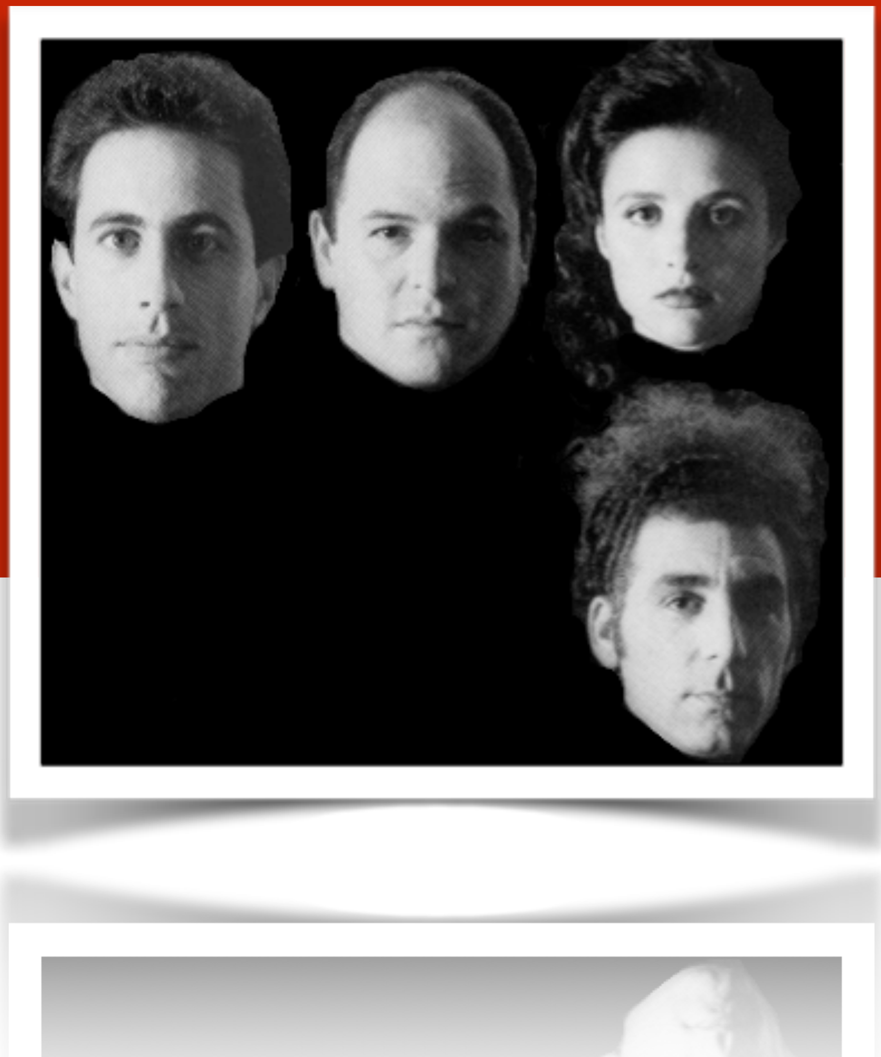


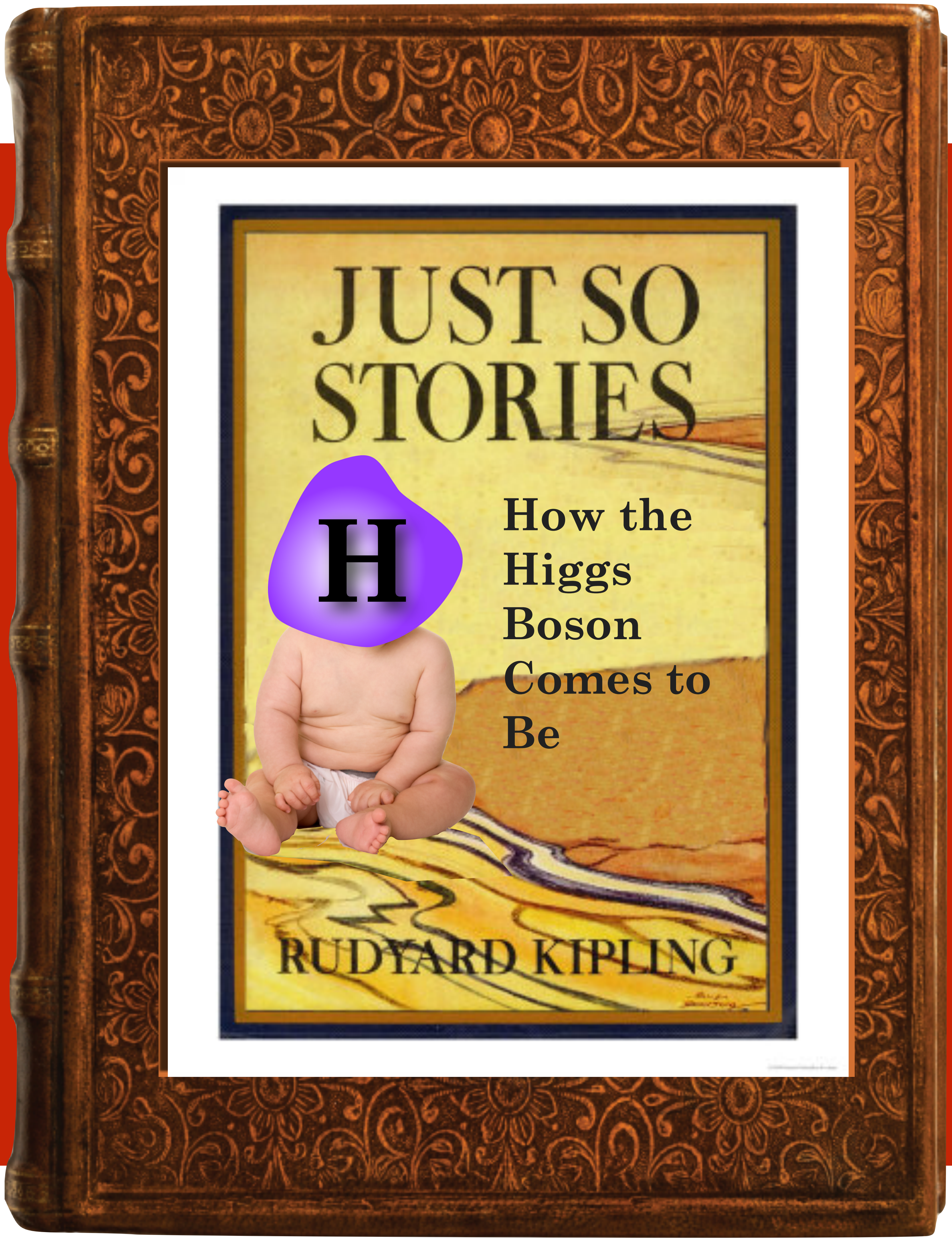

Volume 19, Number 21
PHYSICAL REVIEW LETTERS
20 November 1967
A MODEL OF LEPTONS
Steven Weinberg†
1264
1265

of particle physics

the story of the Higgs Boson

a story about nothing.





This quickly became a story

of a particular epoch in the early Universe

which itself underwent a phase transition

Not in your average hunk of iron

the “system”?

that’s right. the whole enchilada

the entire Universe

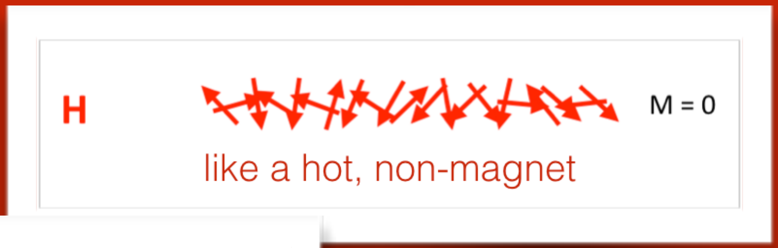
the phase transition?

everywhere in the Universe

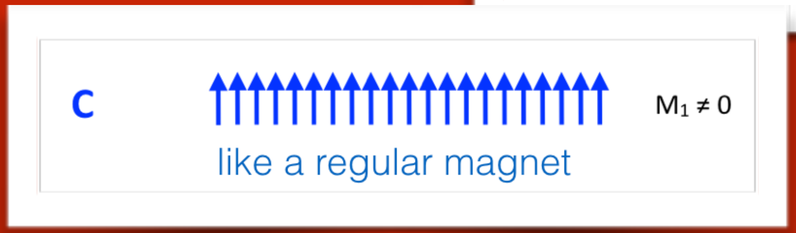
there was a phase change in the entire Universe

at about 1 picosecond after the big bang

there were PRIMORDIAL fields and particles before (**hot**)



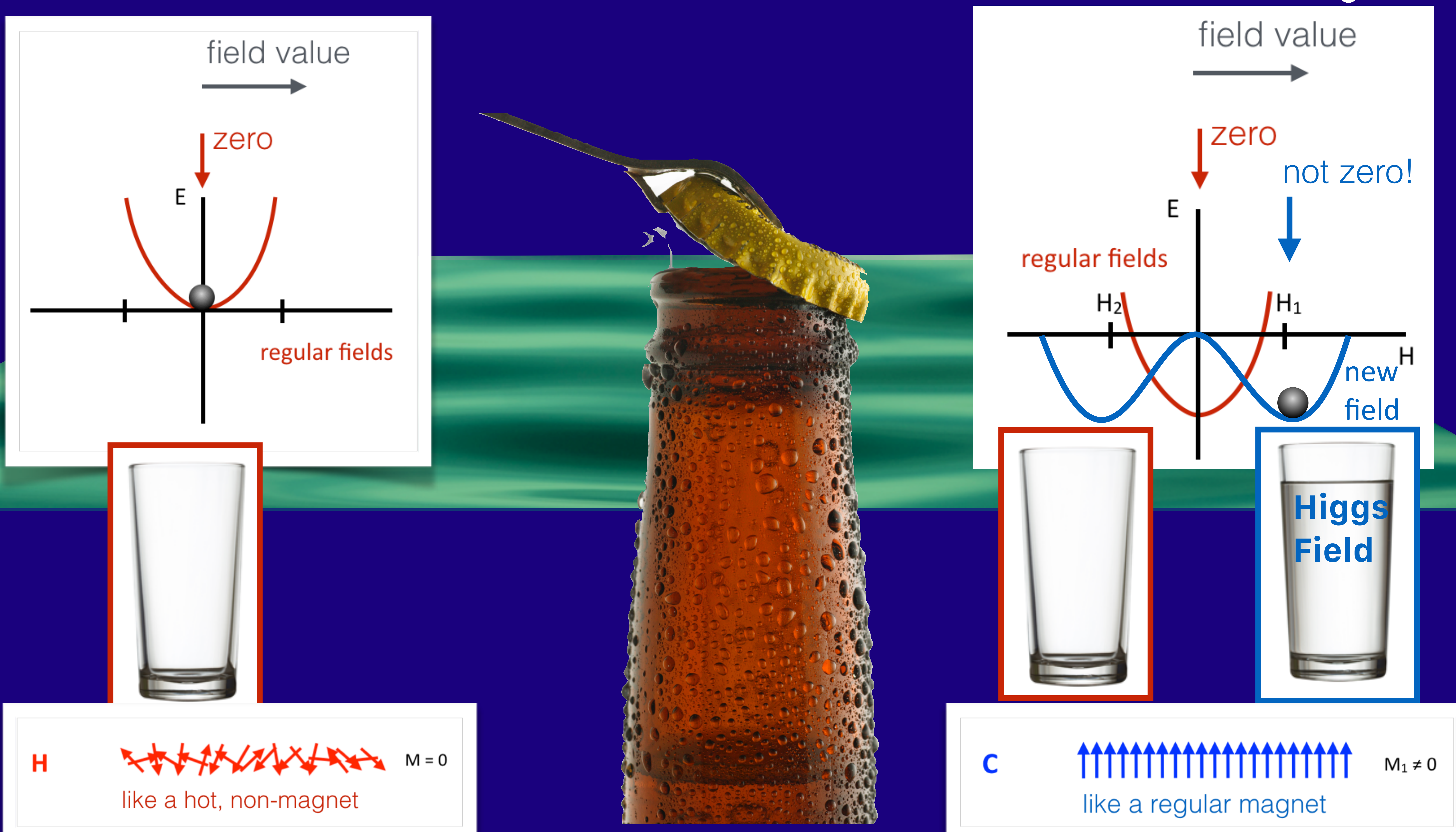
and different fields and particles after (**cold**)



we live in the resulting "cold" universe

10^{-12}s after the big bang

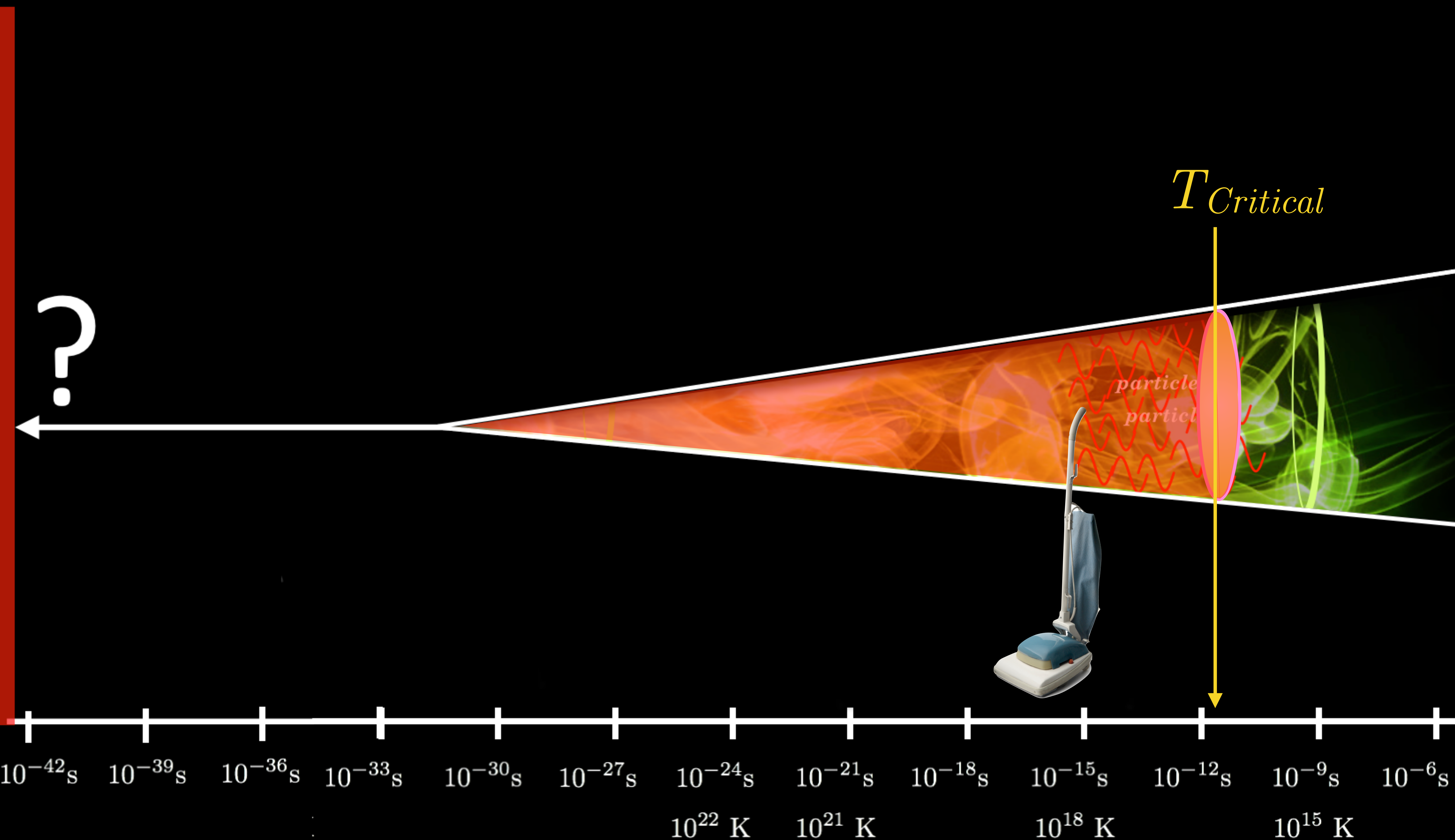
universe condensed: a phase change



the big story of the Standard Model

is the story of mass.

elementary particle epoch



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-2	-2	8	7	-9	8	-2	9	0	-2	-2	-8	0	8	8	7	-2	-2	-9	0	7	9	7	8	-8	7	-8	-7
-2	-2	-2	8	9	9	-8	8	8	-2	-9	0	9	-8	8	8	7	8	9	-8	0	0	-8	9	8	9	8	-2
-2	9	9	-2	8	0	7	7	8	-9	-9	8	7	8	-2	9	-7	-2	-2	9	-9	9	-2		-2	-9		-2
-2	9	-8	-8	9	0	7	8	-9	9	8	-8	8	9	-2	-7	-2	7	8	-8	-2	-7	-7		-2			-2
8	8	-2	7	9	7	9	-2	-2	-2	8	-2	9	-8	7	-2	-2	9	-2	0	-2	7	9		-2			8
-2	-9	-9	0	-2	-9	-2	9	-2	9	0	-2	7	8	8	8	8	-2	8	9	-2	8					-8	9
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7	8	7	9	-2	-9	9	8	-8	-9	7	-2	-2	8	-9	7	-2	9	-2	-2	-2	-2	8	8	-2	8	8	-2
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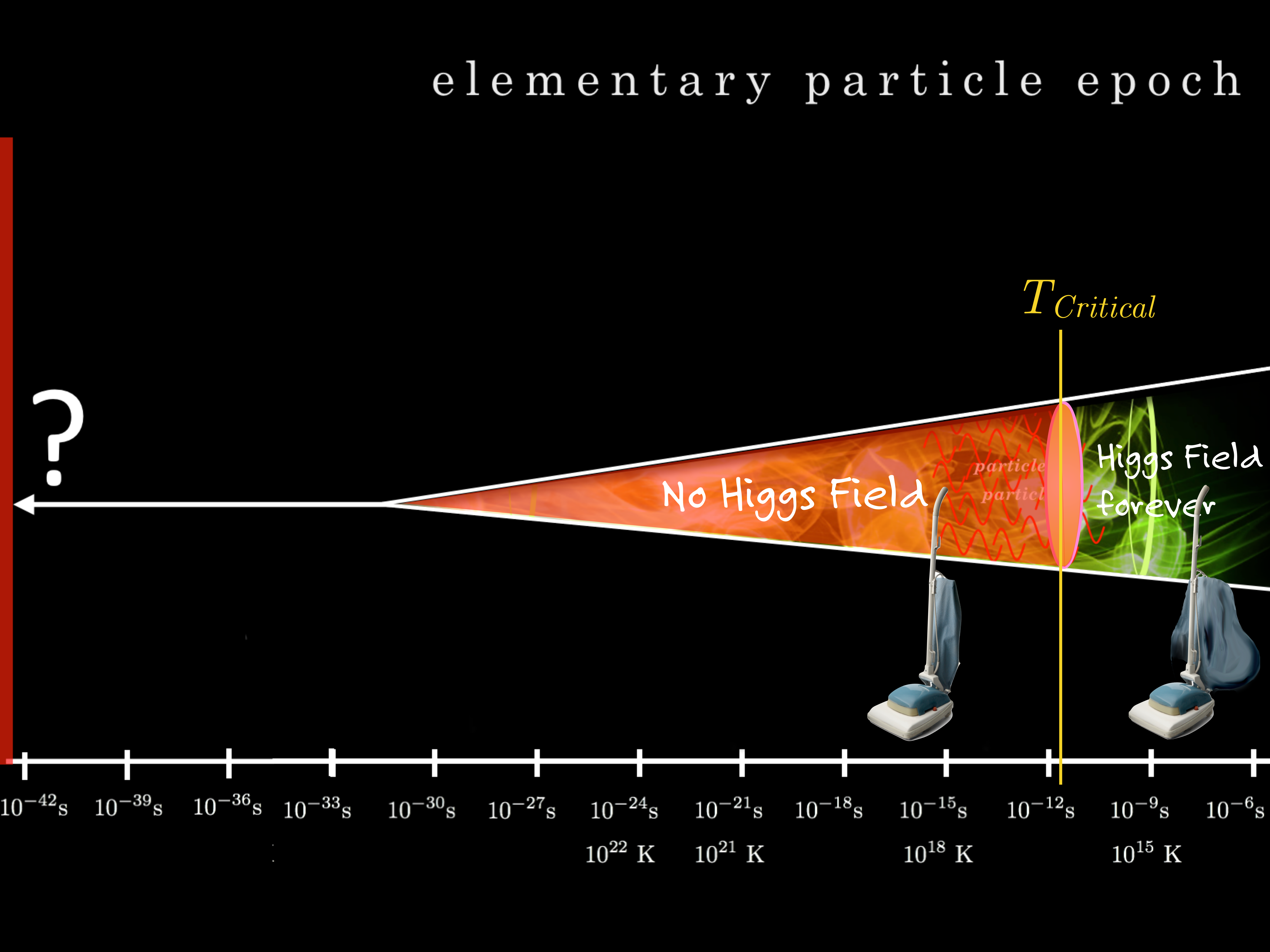
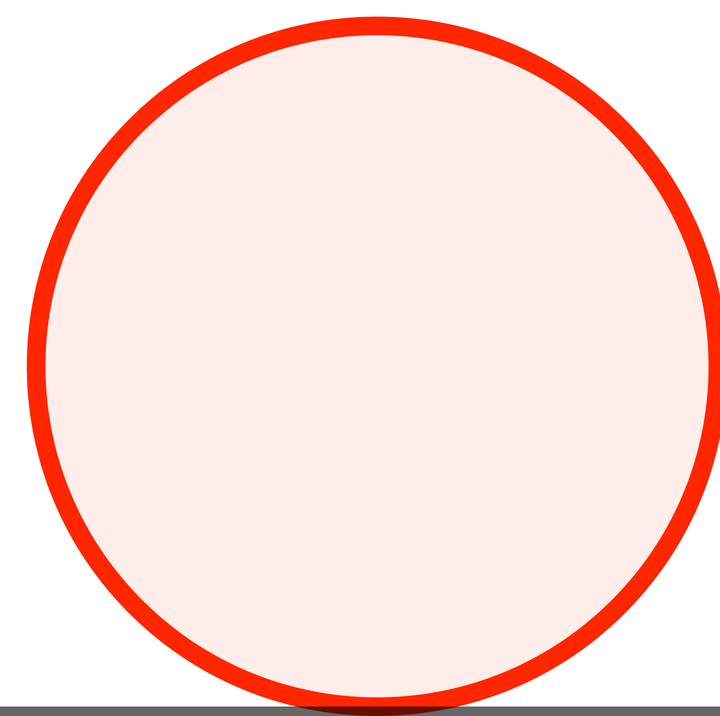

elementary particle epoch
?
$T_{Critical}$
No Higgs Field
particle
particl
Higgs Field
forever
10^{-42}s
10^{-39}s
10^{-36}s
10^{-33}s
10^{-30}s
10^{-27}s
10^{-24}s
10^{-21}s
10^{-18}s
10^{-15}s
10^{-12}s
10^{-9}s
10^{-6}s
10^{22} K
10^{21} K
10^{18} K
10^{15} K

(after David Miller)

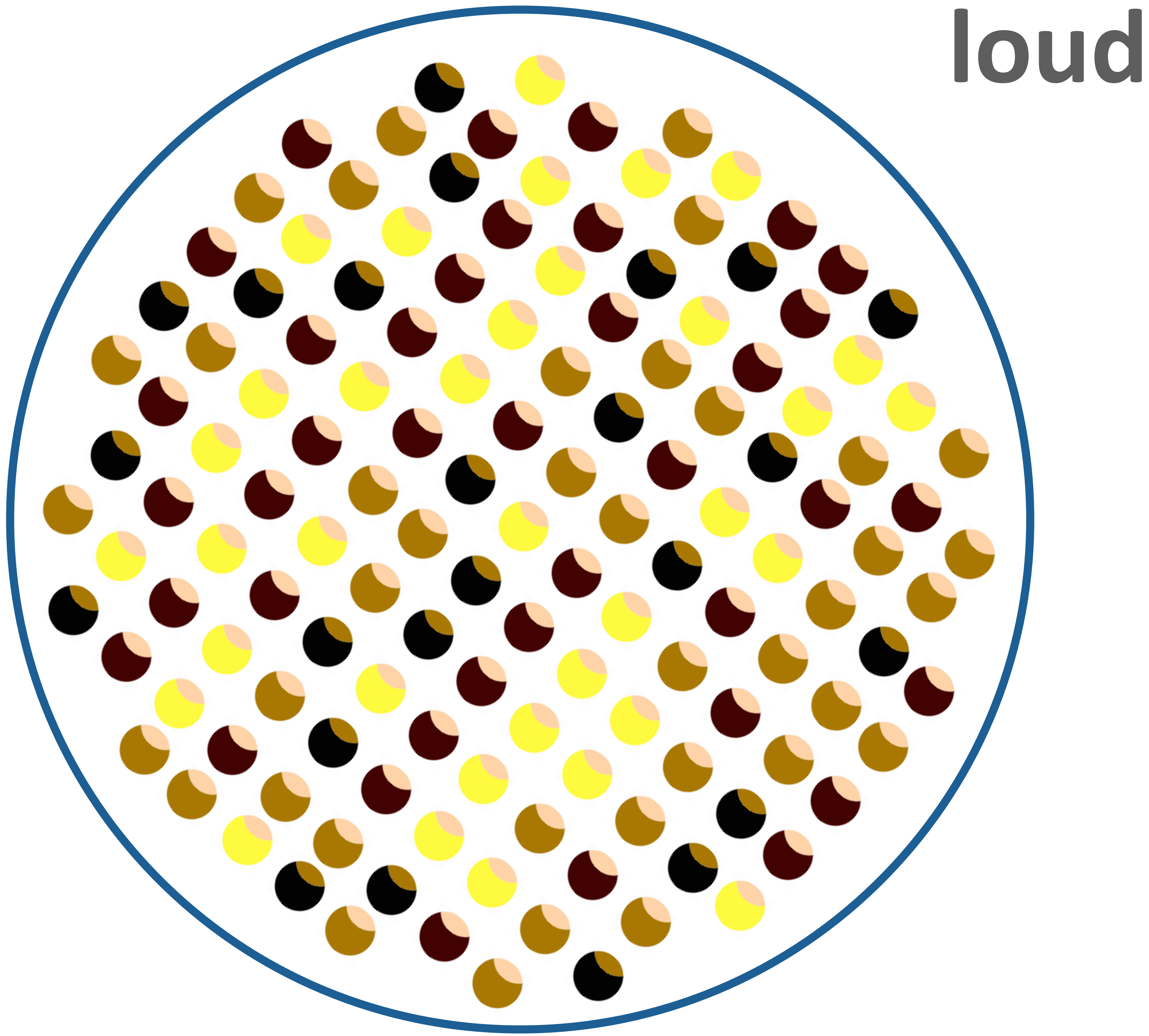


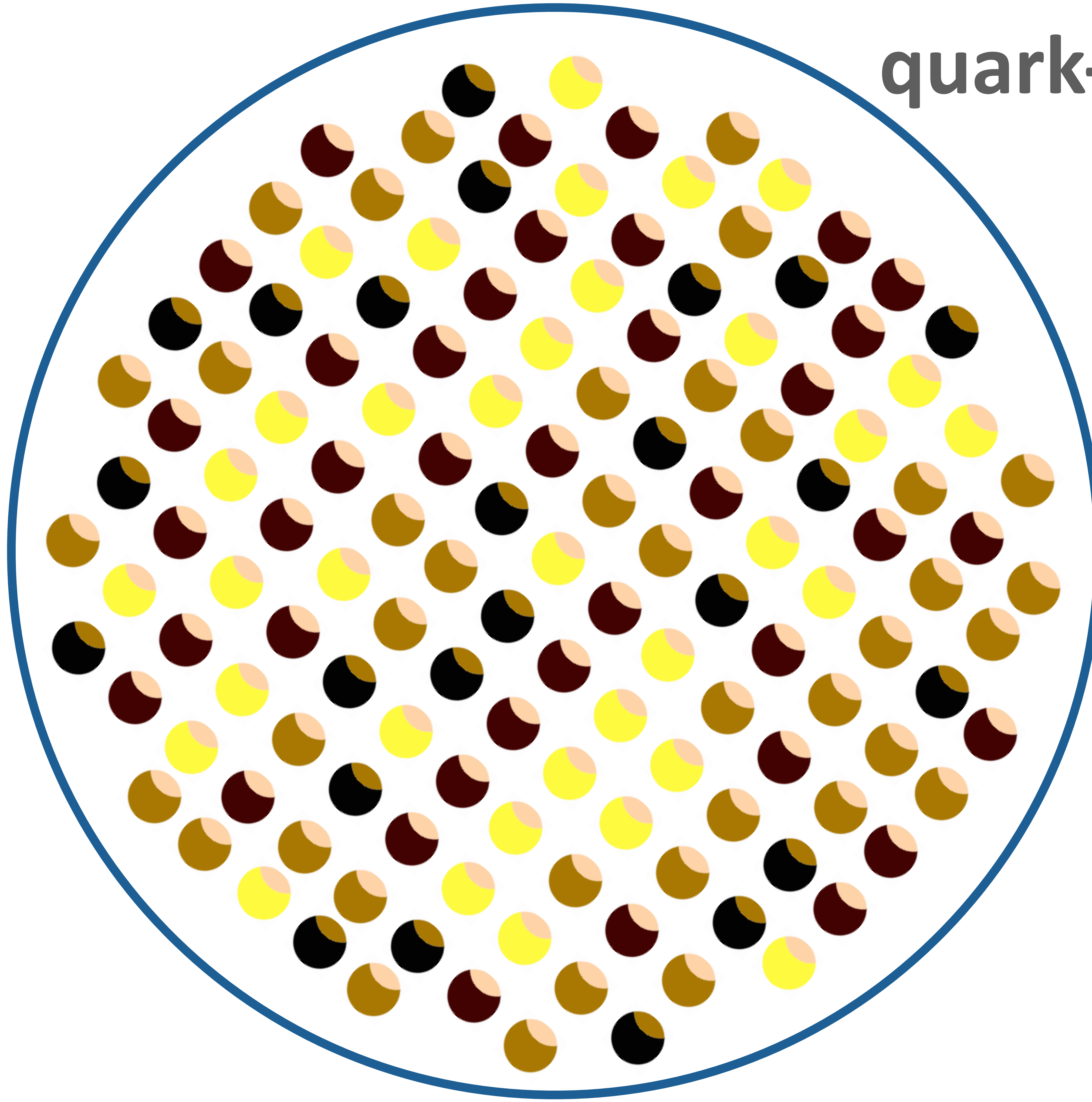
the hot universe: no Higgs Field

(after David Miller)

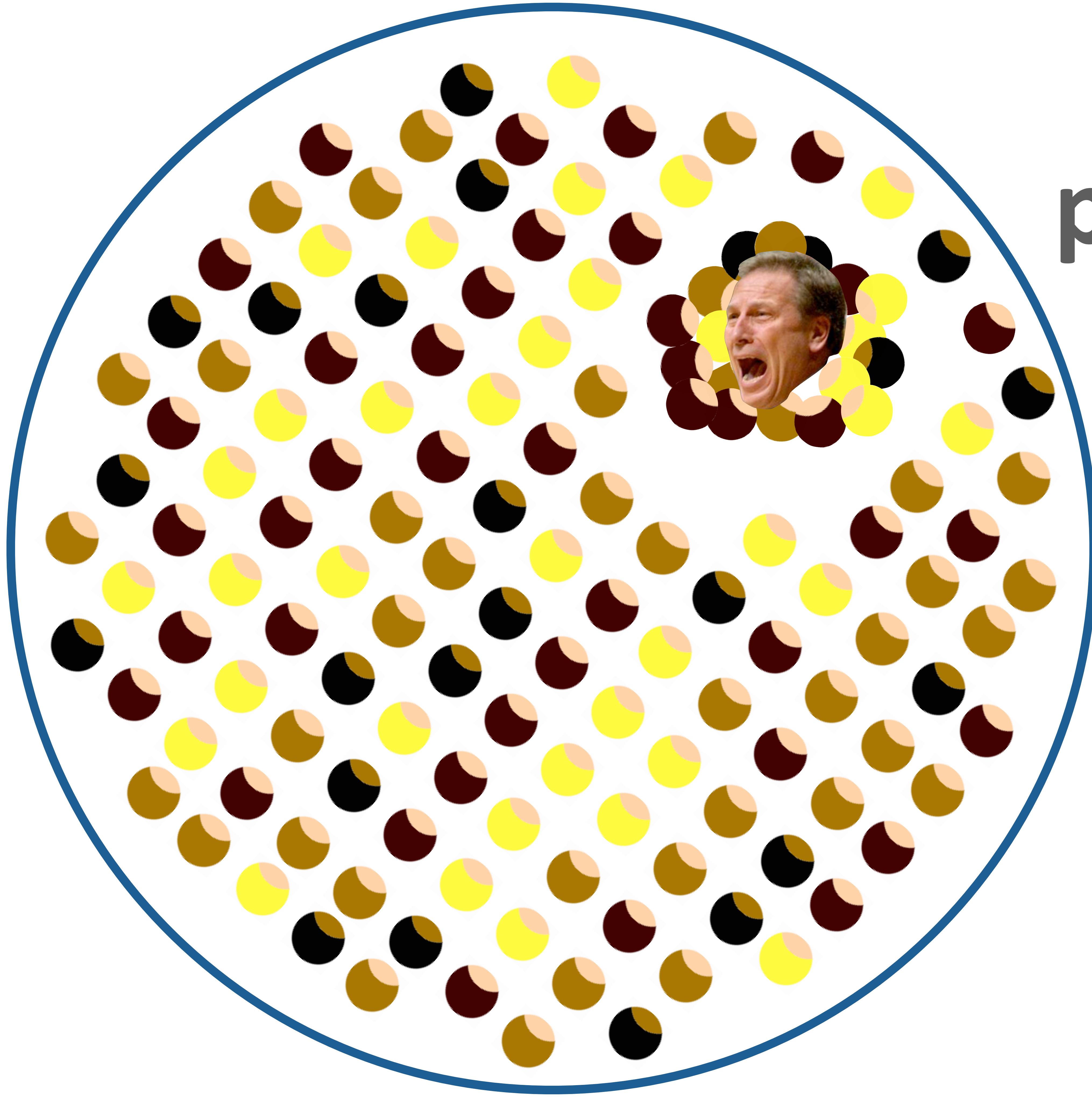
a cooled universe: Higgs Field

(after David Miller)

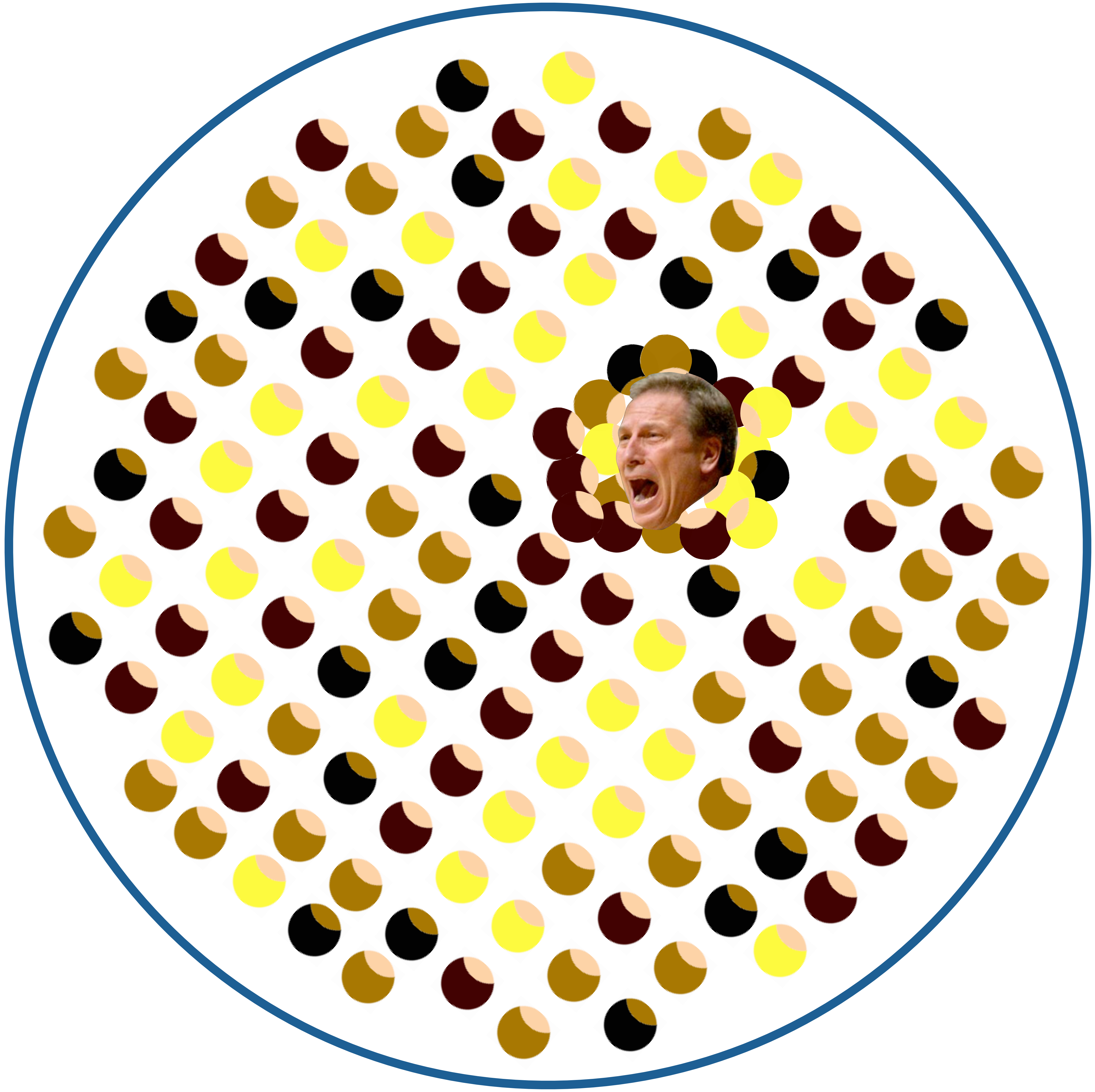

loud



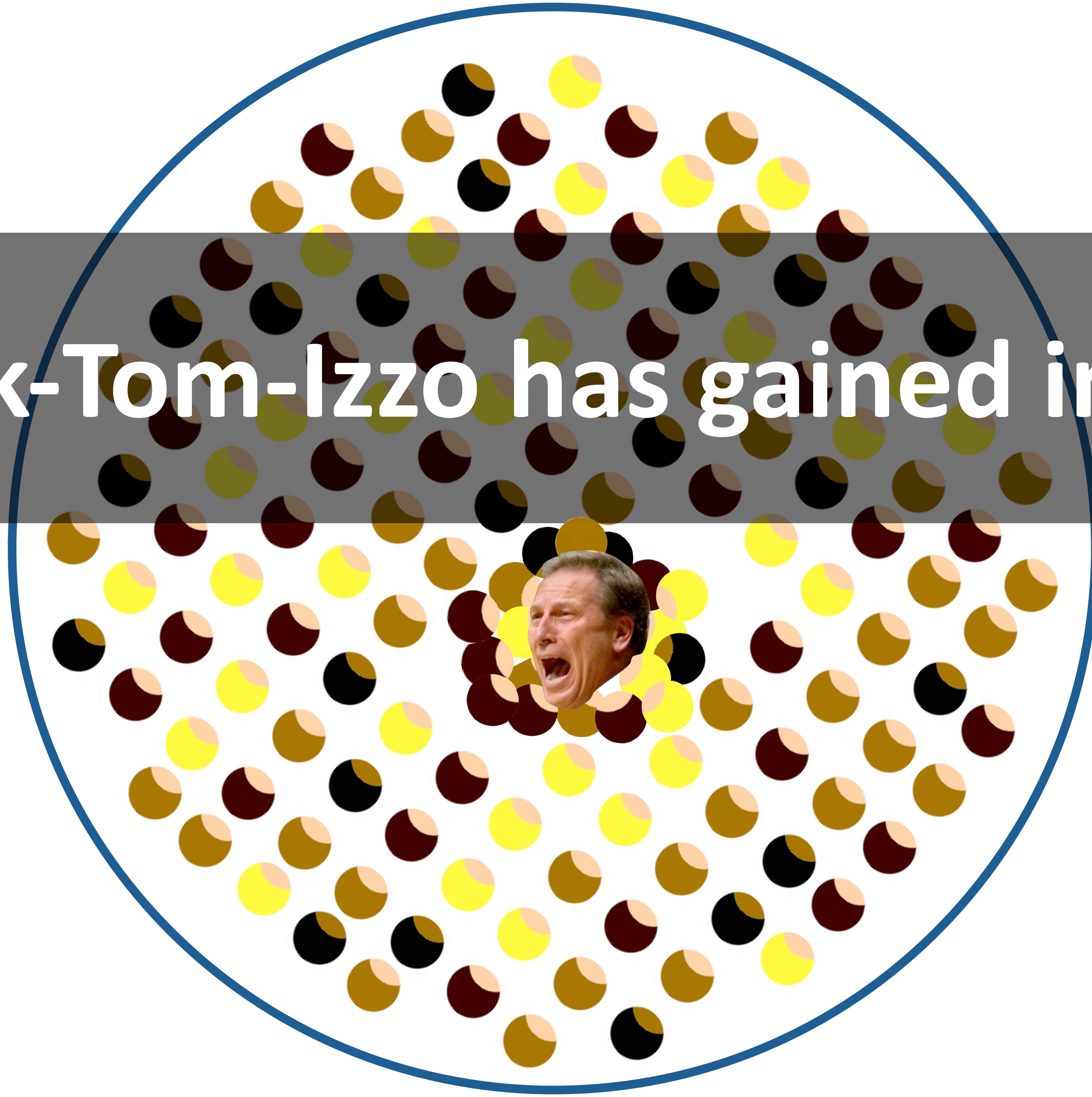
quark-Tom-Izzo



popular



quark-Tom-Izzo has gained inertia




quark-Tom-Izzo has mass.

mass

was born

in the Higgs Field

“rumor” travels: Higgs Particle

So:

The Higgs Boson is not just another particle.

more details now

what's really in the model

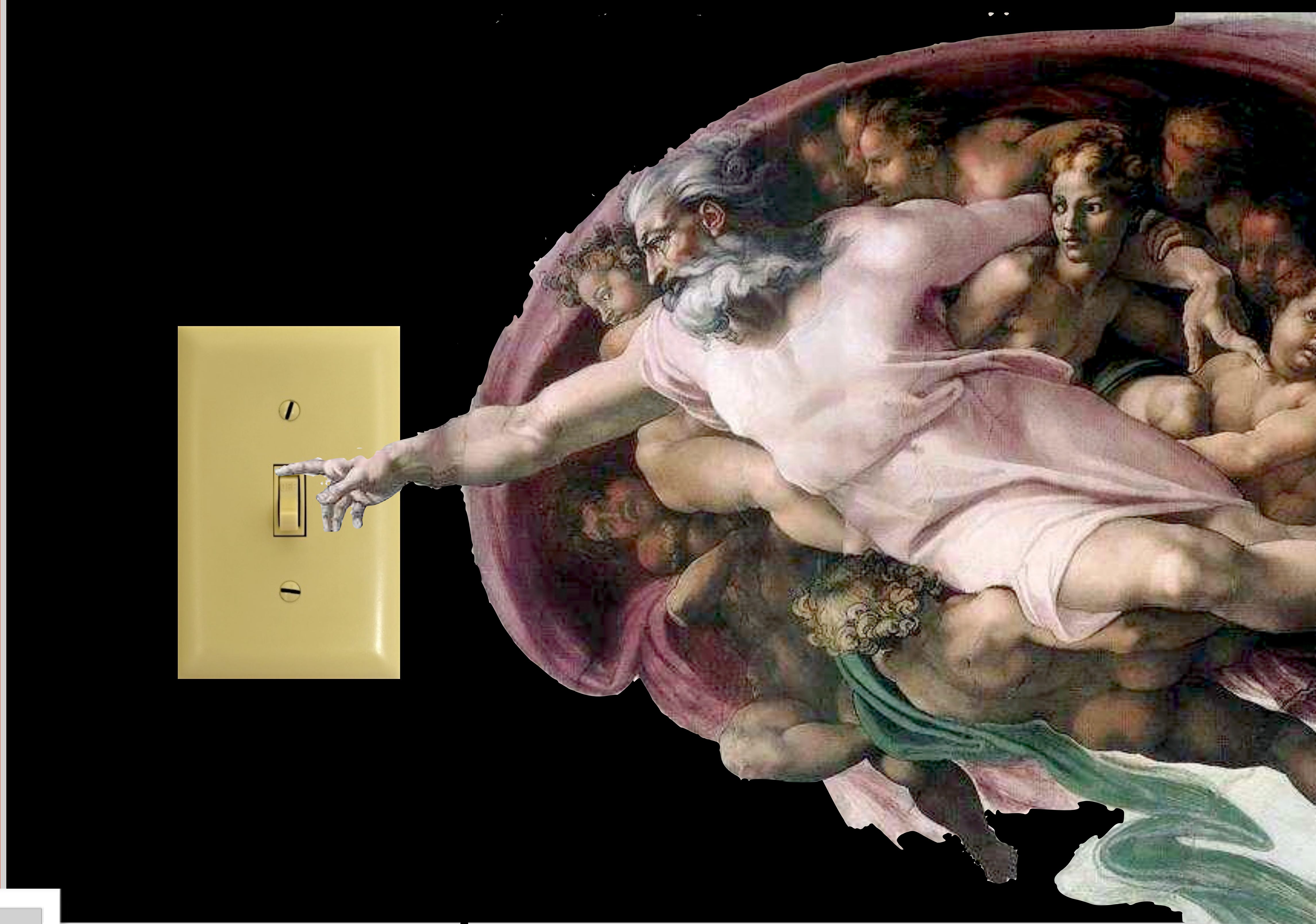
the story of the Weak and Electromagnetic Fields

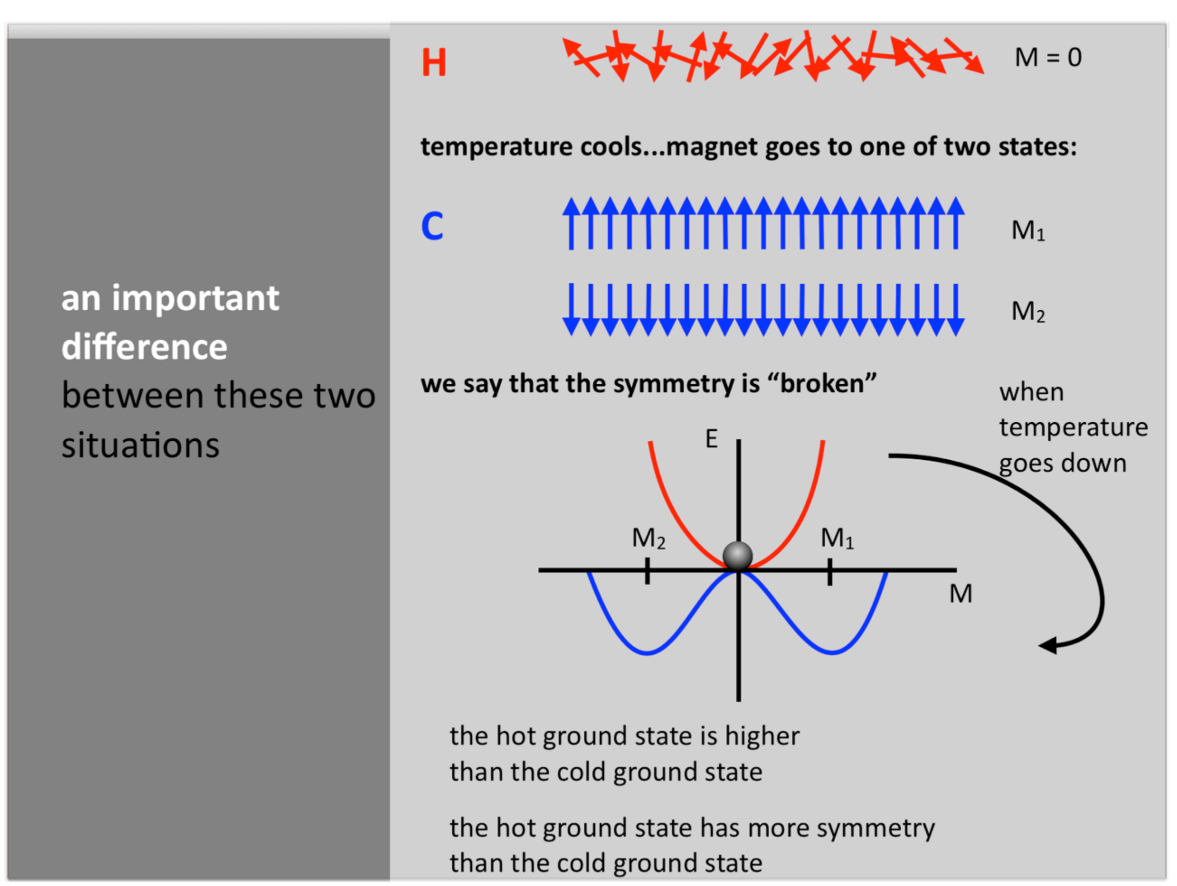
the unification of forces

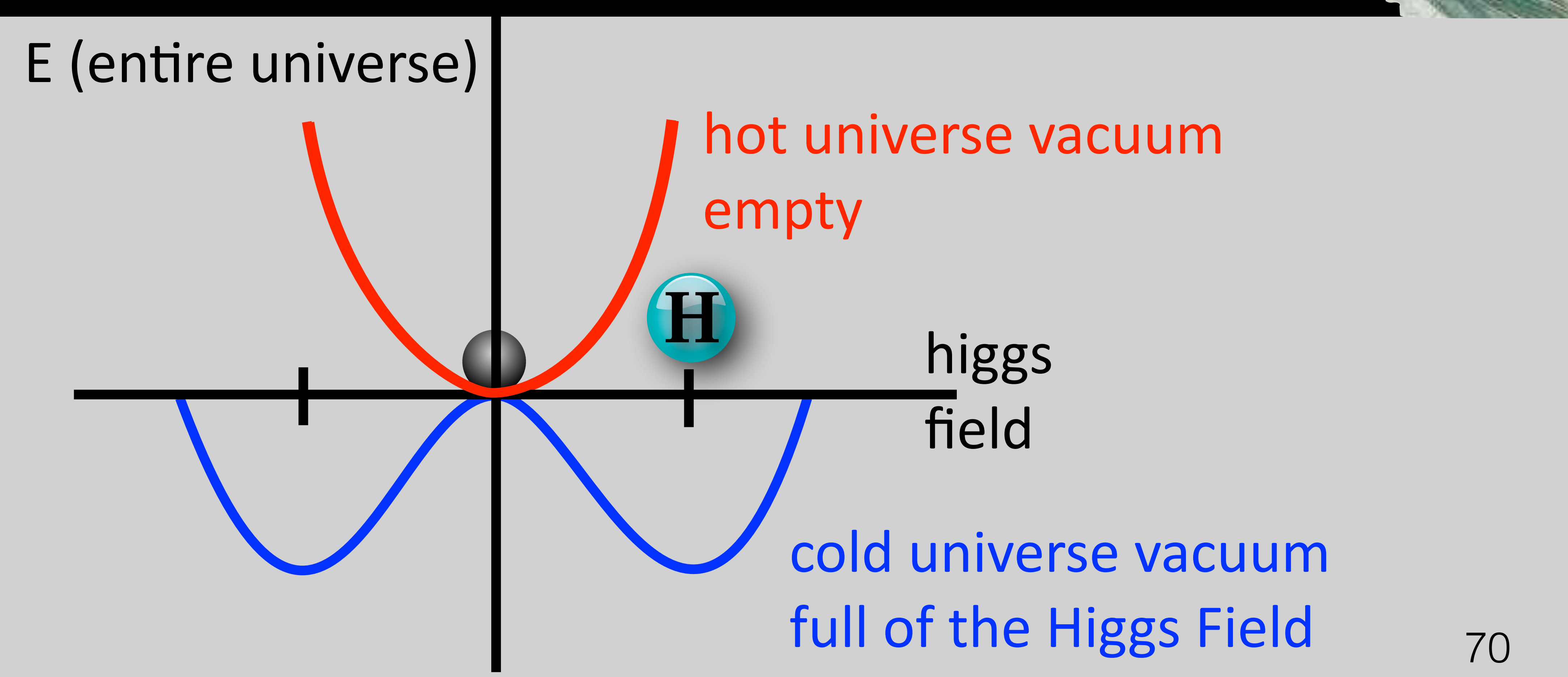
from a hot phase in the universe

cool it all at once

@ 10^{-12} seconds after the BB







H  M = 0

like a hot, non-magnet

C  $M_1 \neq 0$

like a regular magnet

a^0 0

B^0 0

B^+ +

B^- -

ϕ (+ - - - - - - - ; 0 - - - - - - -)

ϕ^* (- - - - - - - - ; 0 - - - - - - -)

γ

Z

$W^\pm$

The remaining primordial scalar is the Higgs Field.

H^0

t = the beginning 0 s

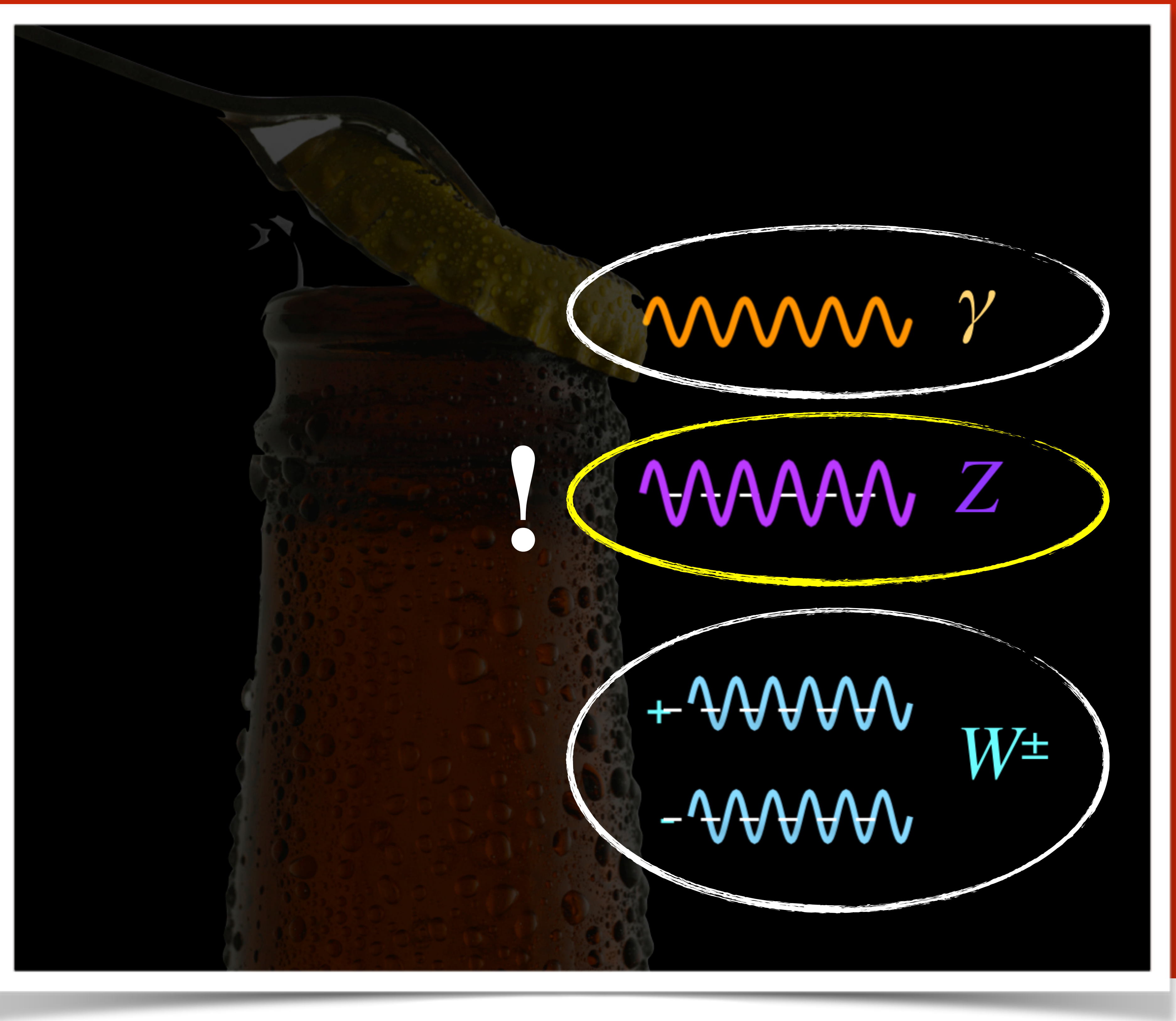
t = 10^{-12} s

t = 10^{+18}s

3 of the primordial Higgs fields combine with 2 of the primordial messengers - and that gives them mass in the mathematics

what's this about?

messengers got fat



this is quite remarkable

If the idea is right:

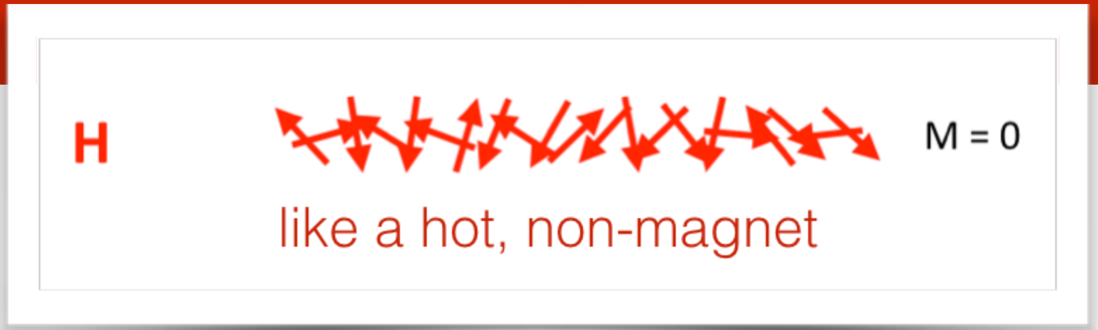
the electromagnetic and weak forces

that are so different today

are actually a "cold-phase" of a single, unified force

"Electroweak Force"

that existed only when the Universe was very, very hot



definite predictions

of Weinberg's model

0. The weak and electromagnetic interactions are two aspects of the same force

1. The W Boson should exist

2. An additional "Z Boson" should exist

   Many physics reactions relate M_W to M_Z

3. This Z Boson and the γ are intimately related

   any reaction with a photon, must also happen with a Z^0

4. The Higgs Boson should exist

particle:

W Boson

symbol:	W
charge:	$\pm 1e$
mass:	80.399 ± 0.023 GeV/c^2 = 80.4 p
spin:	1
category:	weak Vector Boson

particle:

Z Boson

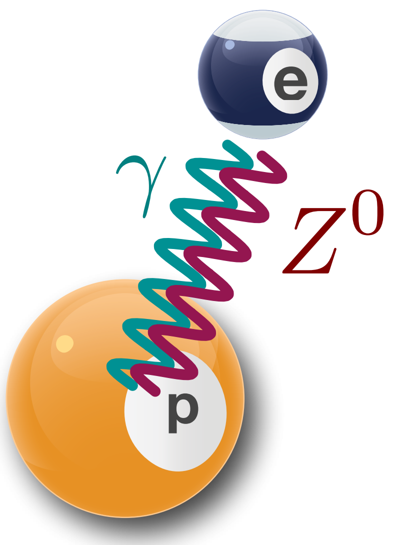
symbol:	*Z*
charge:	0
mass:	91.1876 ± 0.0021 GeV/c^2 = 91.2 p
spin:	1
category:	weak Vector Boson

Photon and Z always mix

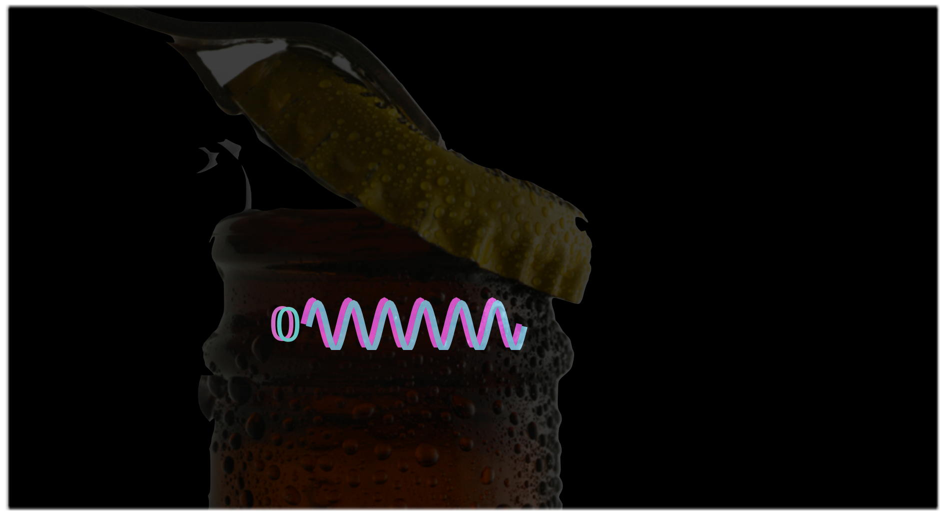
Z, very weakly

3. The *Z* Boson and the γ are intimately related

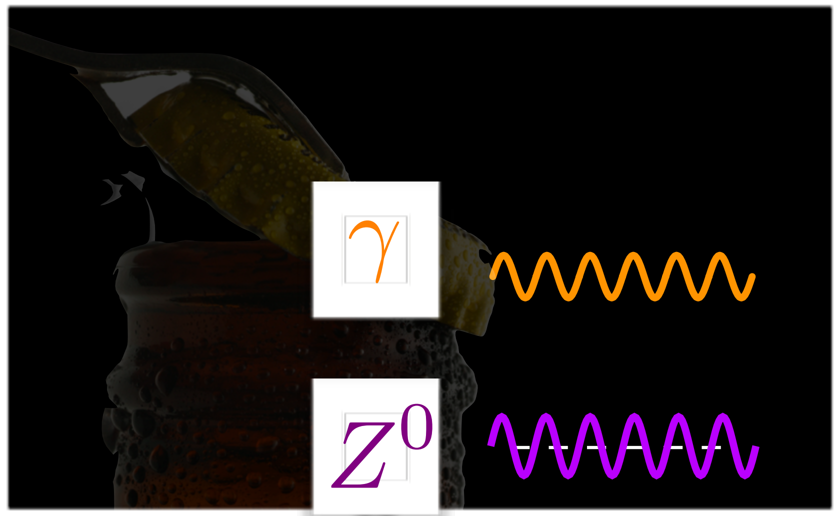
any reaction with a photon, must also happen with a Z^0



very delicate effects observed in atomic systems due to the Z Boson

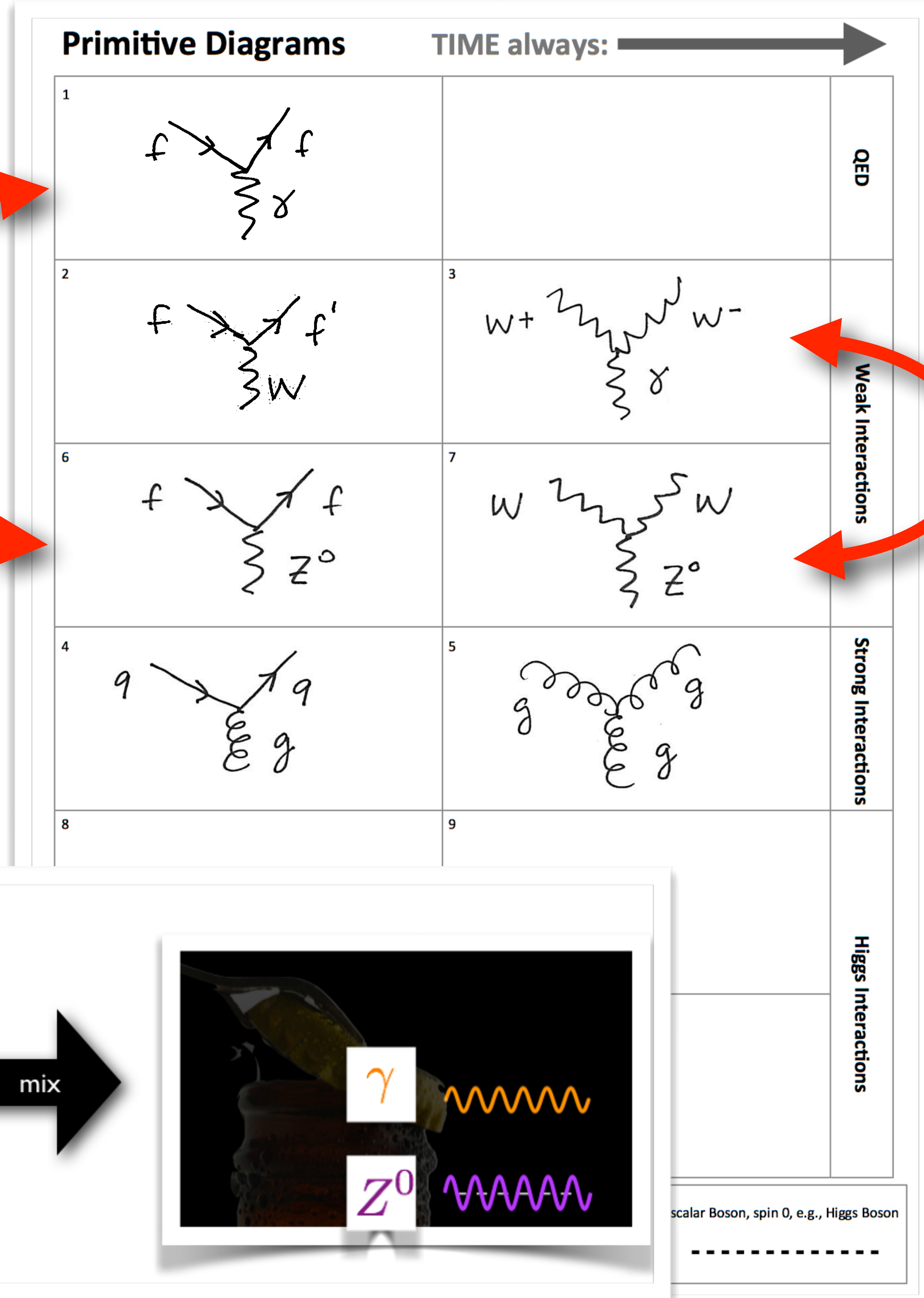


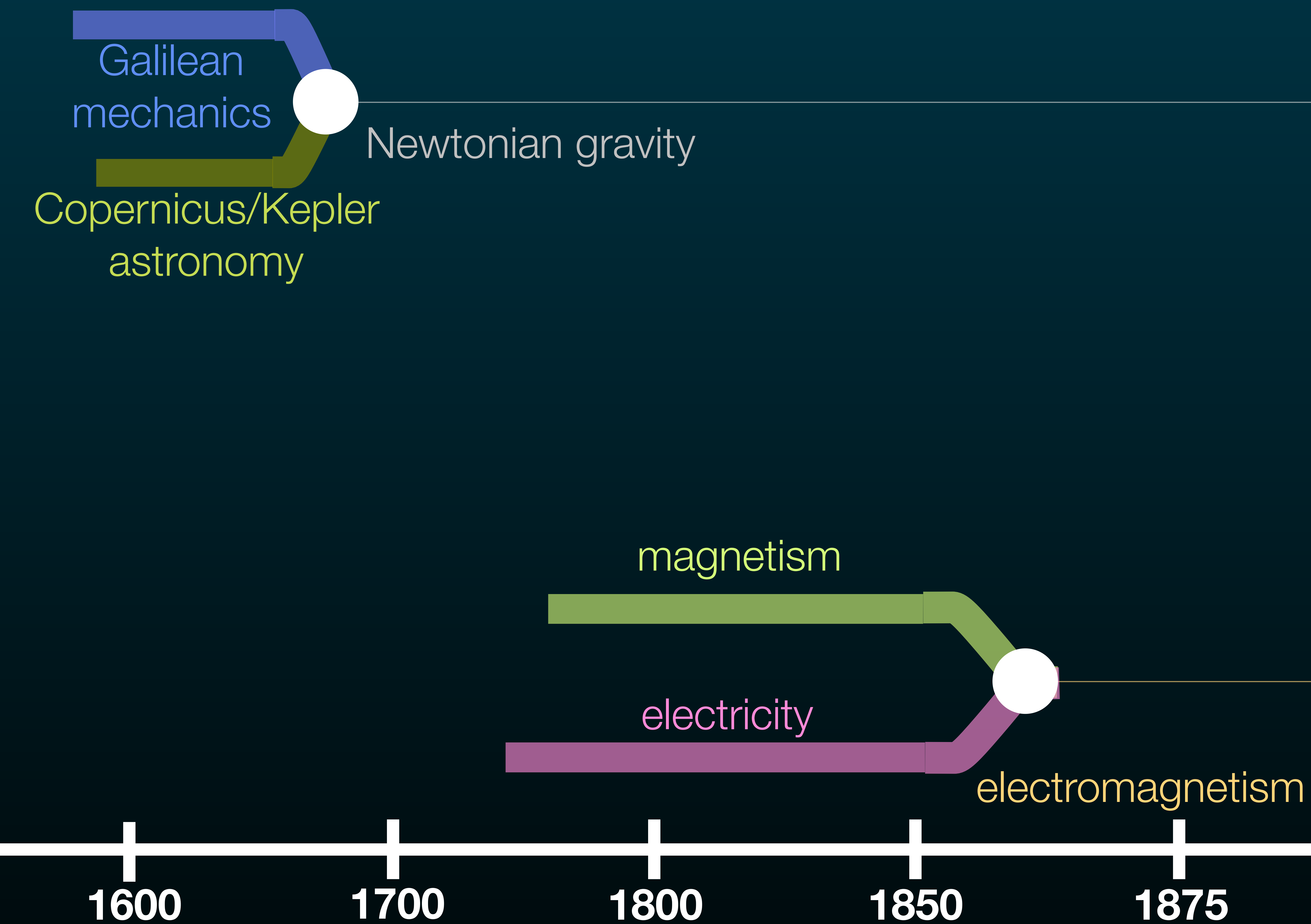
mix

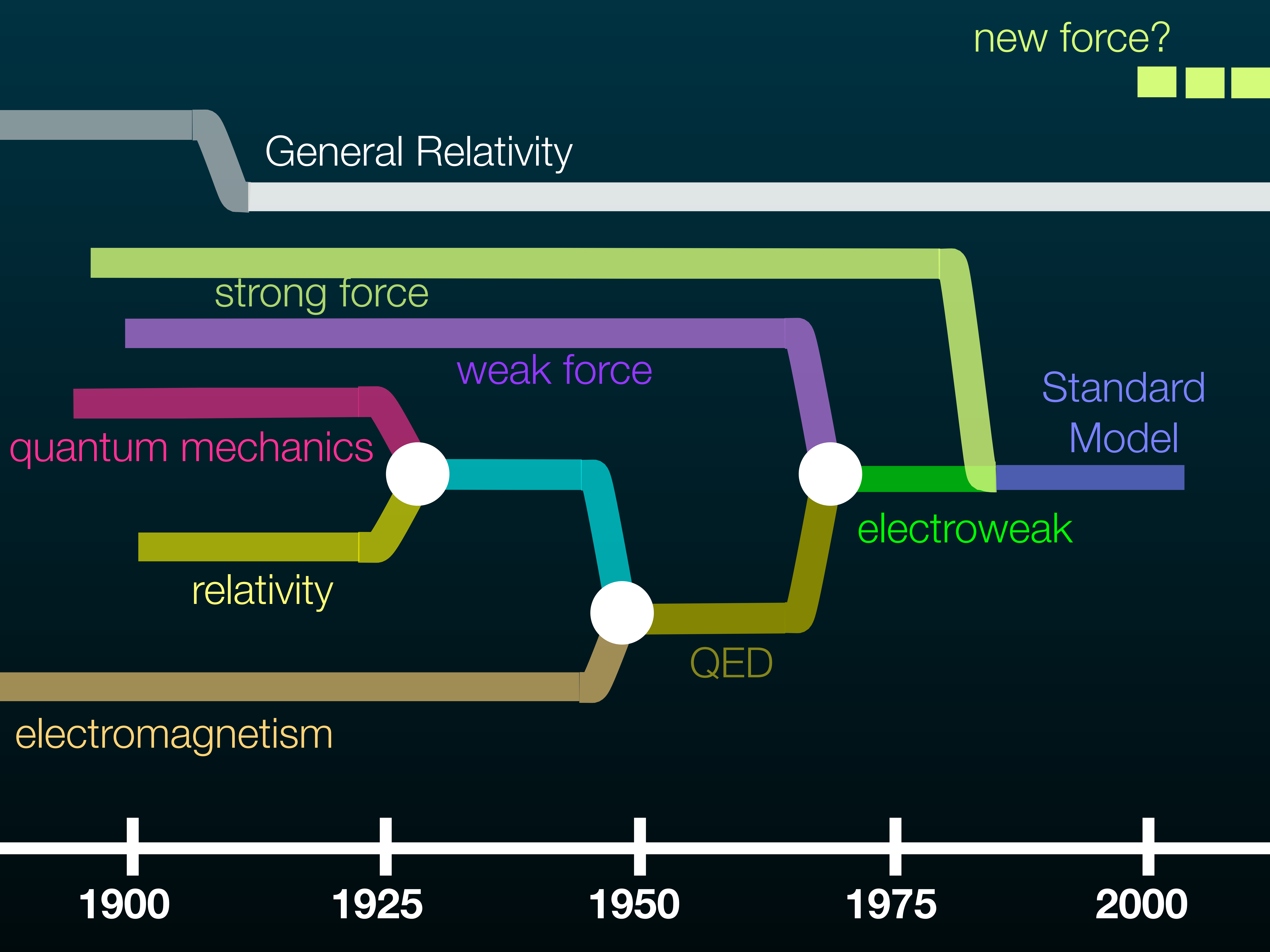


sixth and seventh entries into your

table of primitive diagrams




Galilean mechanics
Newtonian gravity
Copernicus/Kepler astronomy
magnetism
electricity
electromagnetism
1600
1700
1800
1850
1875


new force?
General Relativity
strong force
weak force
Standard
Model
quantum mechanics
electroweak
relativity
QED
electromagnetism
1900
1925
1950
1975
2000

we now think in terms of

epochs in the stages of the early universe

distinguished by phase transitions - stay tuned

‘‘mass generation’’

the holy grail of physics since Newton

what is mass?

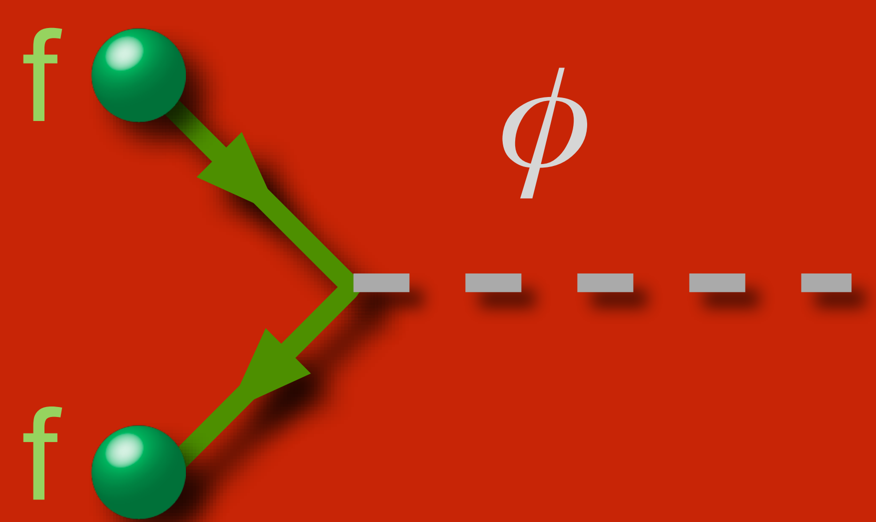
Is “mass” an intrinsic attribute? “nature”?

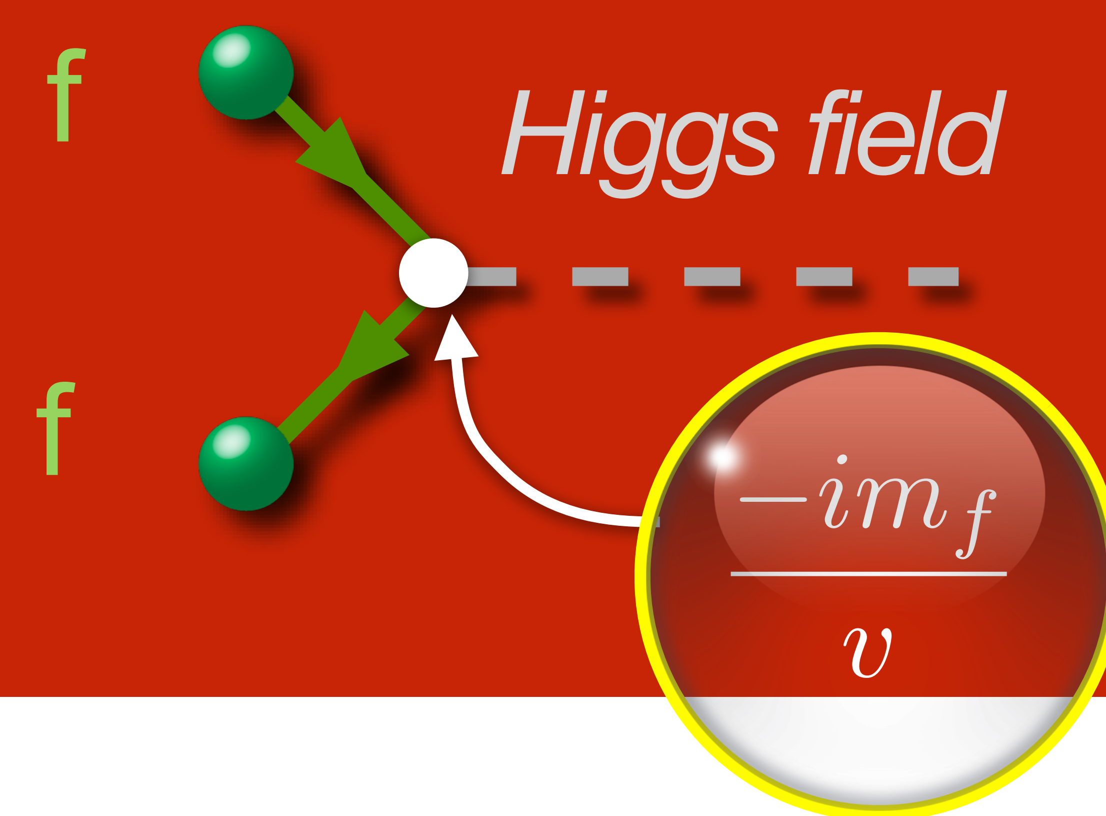
or

Is “mass” an acquired trait? “nurture”?

mass couplings? mass comes from the Higgs FIELD

SM predicts from the hot phase:





find the Higgs particle

confirmation of the process

Big Discovery

July 4, 2012

watch the off-line movie:

https://qstbb.pa.msu.edu/storage/Extras_2017/HiggsDiscovery/

how to find the Higgs?

look for him!


TIME
№5
PARTICLE PHYSICIST
FABIOLA GIANOTTI

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Rapid H.I.V. Home Test Wins Federal Approval

By DONALD G. McNEIL Jr.

The OraQuick test, which uses a cheek swab and gives results in 20 to 40 minutes, is the first chance for Americans to learn in the privacy of their own homes whether they are infected.

DEALBOOK

As Bank Frames a Defense, Barclays' C.E.O. Resigns

By BEN PROTESS and MARK SCOTT

Ahead of a British parliamentary hearing, senior Barclays executives said they thought they had implicit approval from regulators to manipulate interest rates.

• A Chief With Flair Falls

Top Judge Helped

Pool photo by Denis Balibouse

New Particle Could Be Physics' Holy Grail

By DENNIS OVERBYE 4 minutes ago

If confirmed to be the elusive Higgs boson, a newly discovered particle named for the physicist Peter Higgs, above in Geneva, could explain the universe's origin.

Fears of Fires Take Fireworks Out of July 4th Celebrations

By DAN FROSCH

Many U.S. cities and towns across the country have decided to scrap their displays, driven by parched

As Symbols Clash, Fireworks Lose Out to a Hamlet's Bald Eagles

By AARON EDWARDS

The Fire Department in Narrowsburg, N.Y., canceled its annual display after planned fireworks were said to

OPINION »

EDITORIAL

Too Quiet, Again, on Health Care

The Obama campaign has not forcefully countered Republican misinformation on the reform law.

• Dowd: Gaelic Guerrilla
• Friedman: Morsi, Israel
• Douthat: Books for Obama
• Fixes: Rwanda's Miracle
• Kurt Andersen: The Downside of Liberty
• Op-Ed: Anderson Cooper

MARKETS » At 4:02 AM ET

Britain	Germany	France
FTSE 100	DAX	CAC 40
5,673.04	6,553.19	3,248.93
−14.69	−25.02	−22.27
−0.26%	−0.38%	−0.68%

Data delayed at least 15 minutes

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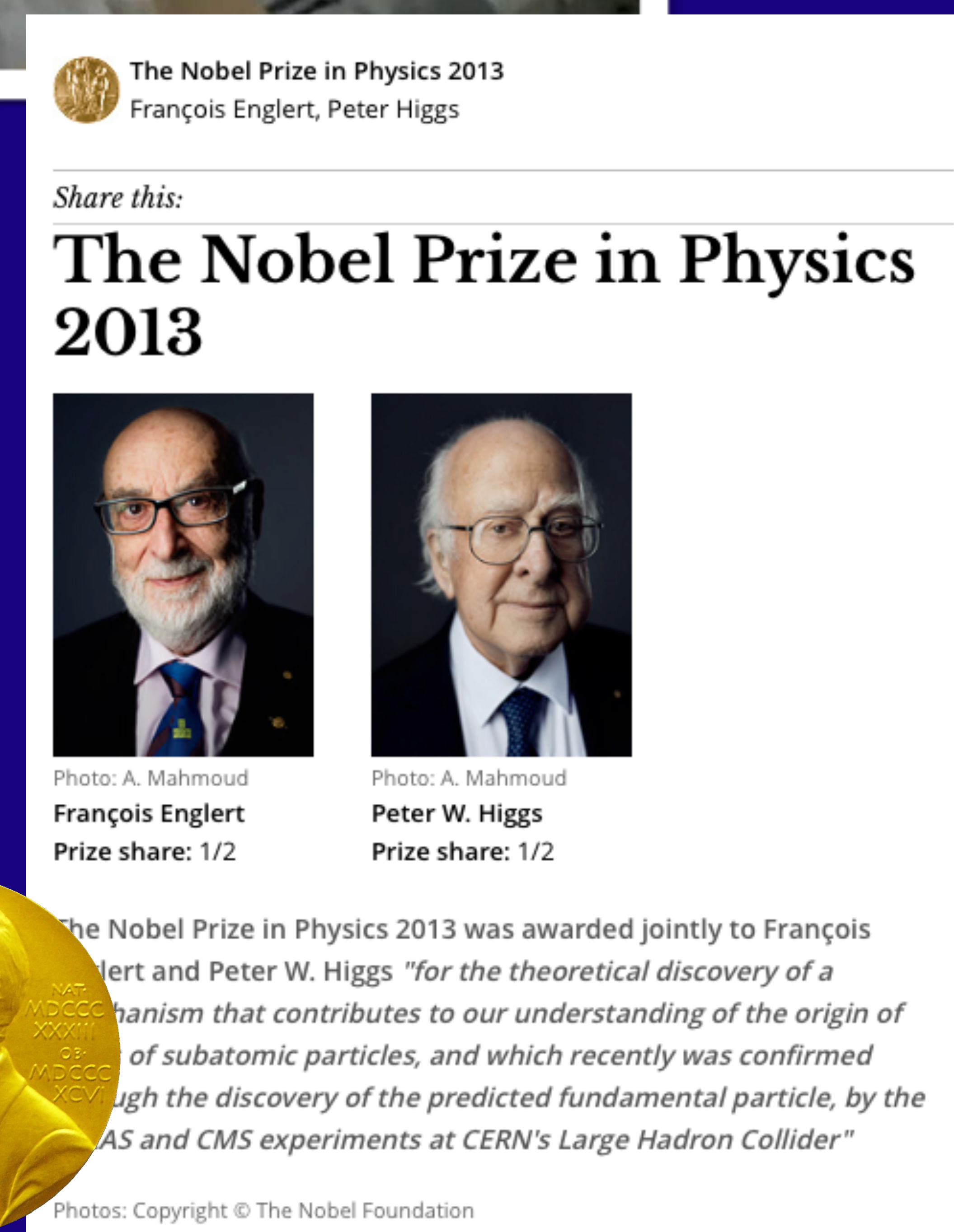
From insight comes inspiration.



The Nobel Prize in Physics 2013

François Englert, Peter Higgs

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The Nobel Prize in Physics 2013

Photo: A. Mahmoud

François Englert

Prize share: 1/2

Photo: A. Mahmoud

Peter W. Higgs

Prize share: 1/2

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"*

Photos: Copyright © The Nobel Foundation

of particle physics

definite predictions

of Weinberg's model

✓ 0. The weak and electromagnetic interactions are two aspects of the same force

✓ 1. The *W* Boson should exist

✓ 2. An additional "*Z* Boson" should exist

Many physics reactions relate M_W to M_Z

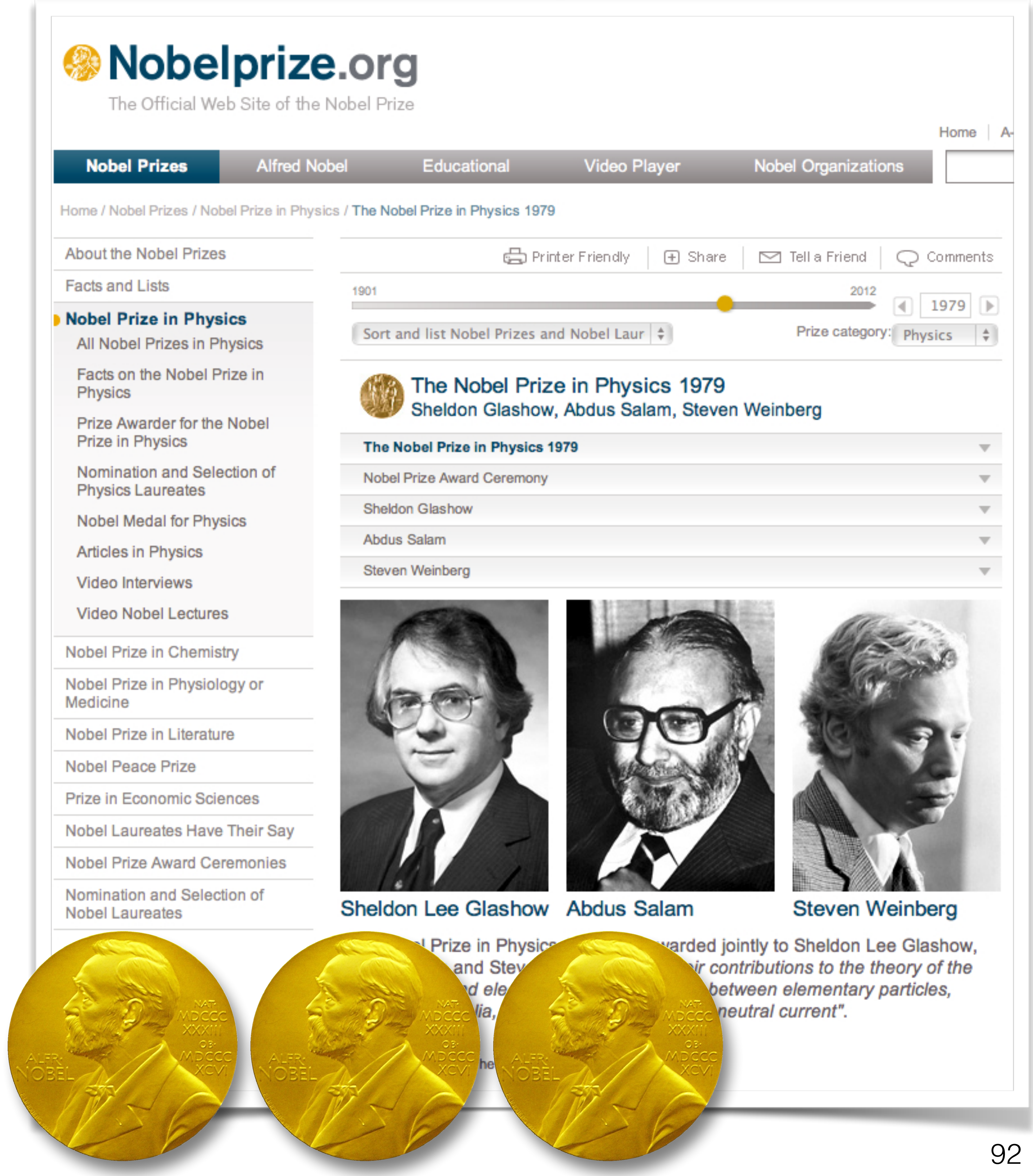
✓ 3. This *Z* Boson and the γ are intimately related

any reaction with a photon, must also happen with a Z^0

✓ 4. The Higgs Boson should exist

Weinberg, Salam, and Glashow

1979

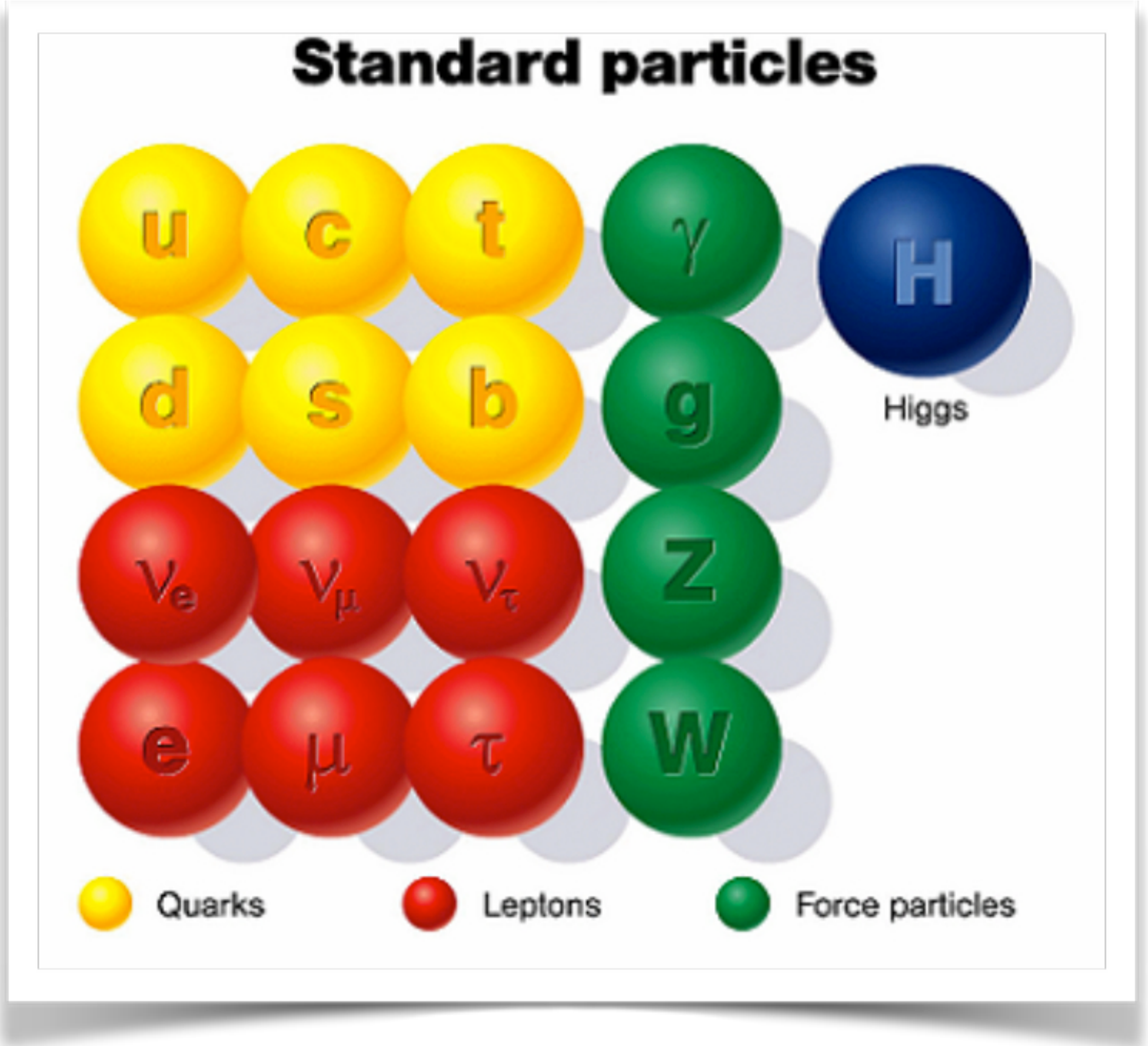


the particle players

and

the "substrate"

Our "Periodic Table"

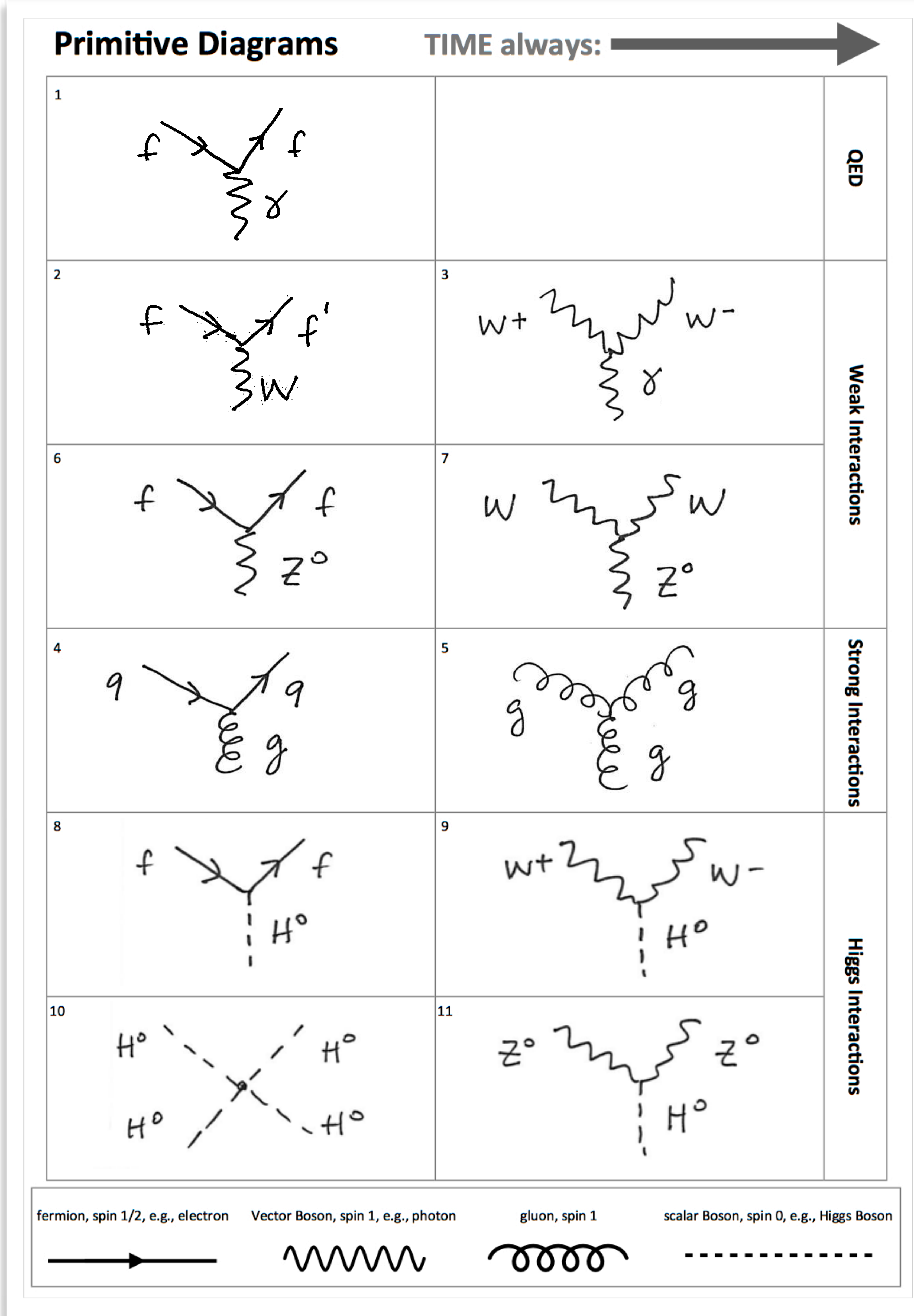


like any particle,

we predict and then search for its manifestation

through its decays

Your final entries into the Primitive Diagram collection



there are two other "issues"

where’s

the antimatter?

what the heck

is dark matter?

watch the off-line movie:

https://qstbb.pa.msu.edu/storage/Extras_2017/DarkMatter/

the more pleasing

extension of the Standard Model

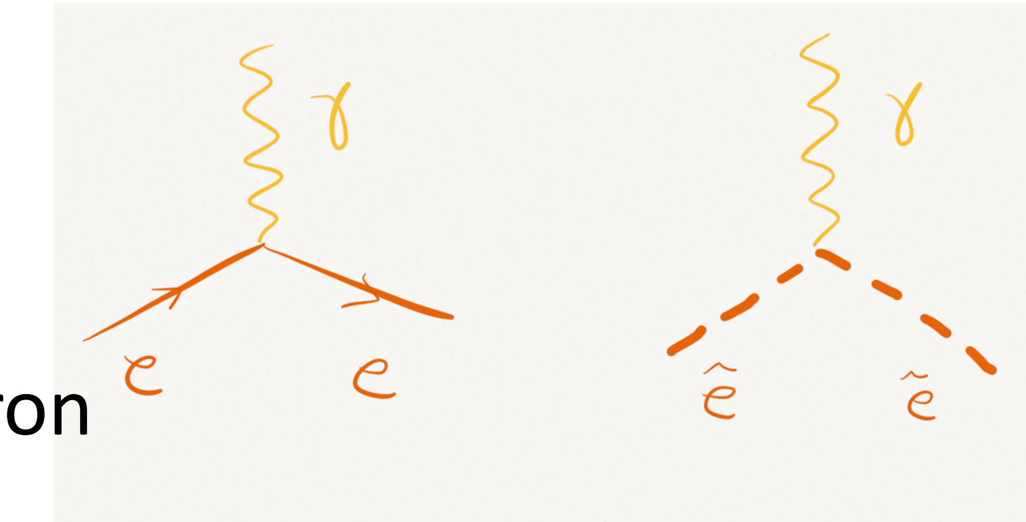
"supersymmetry"

every "Standard Model Particle"

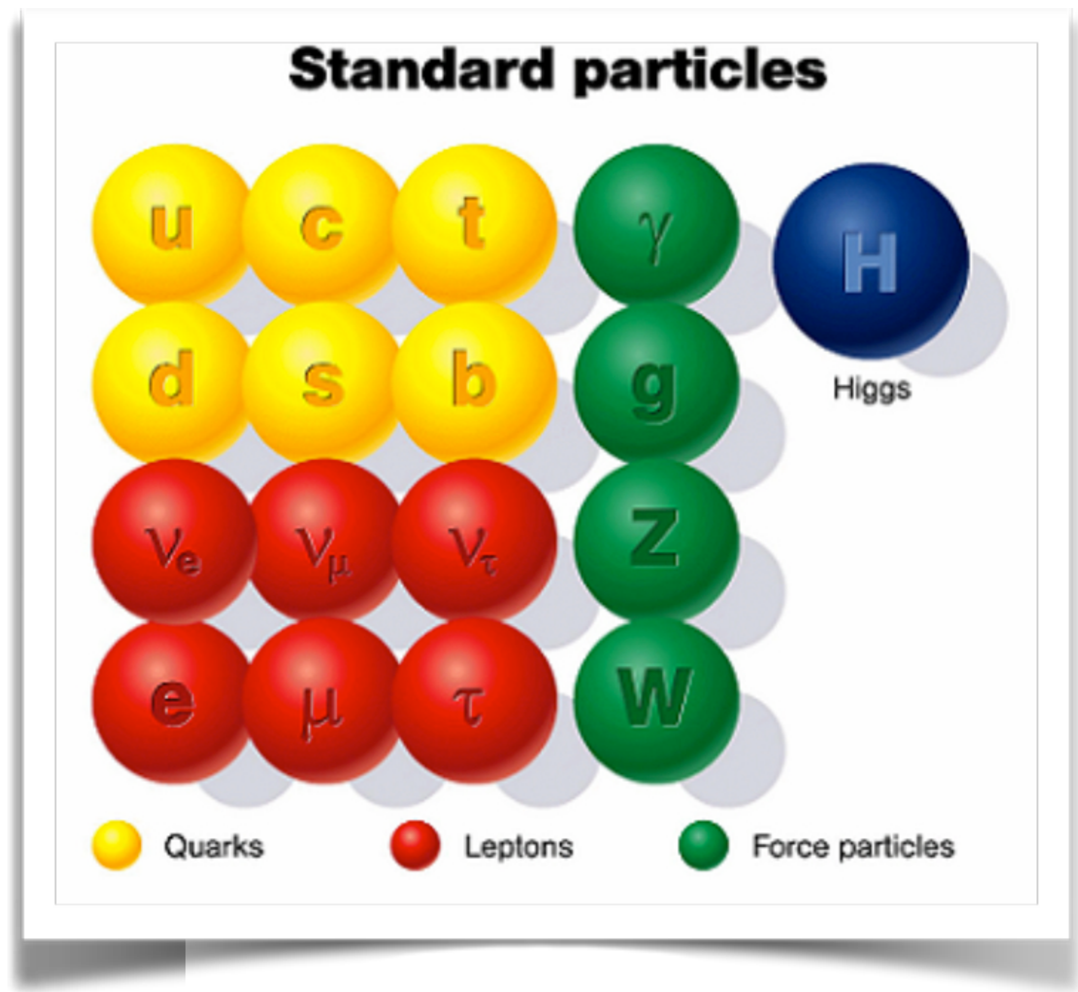
has a super-partner

presumably much heavier

electron



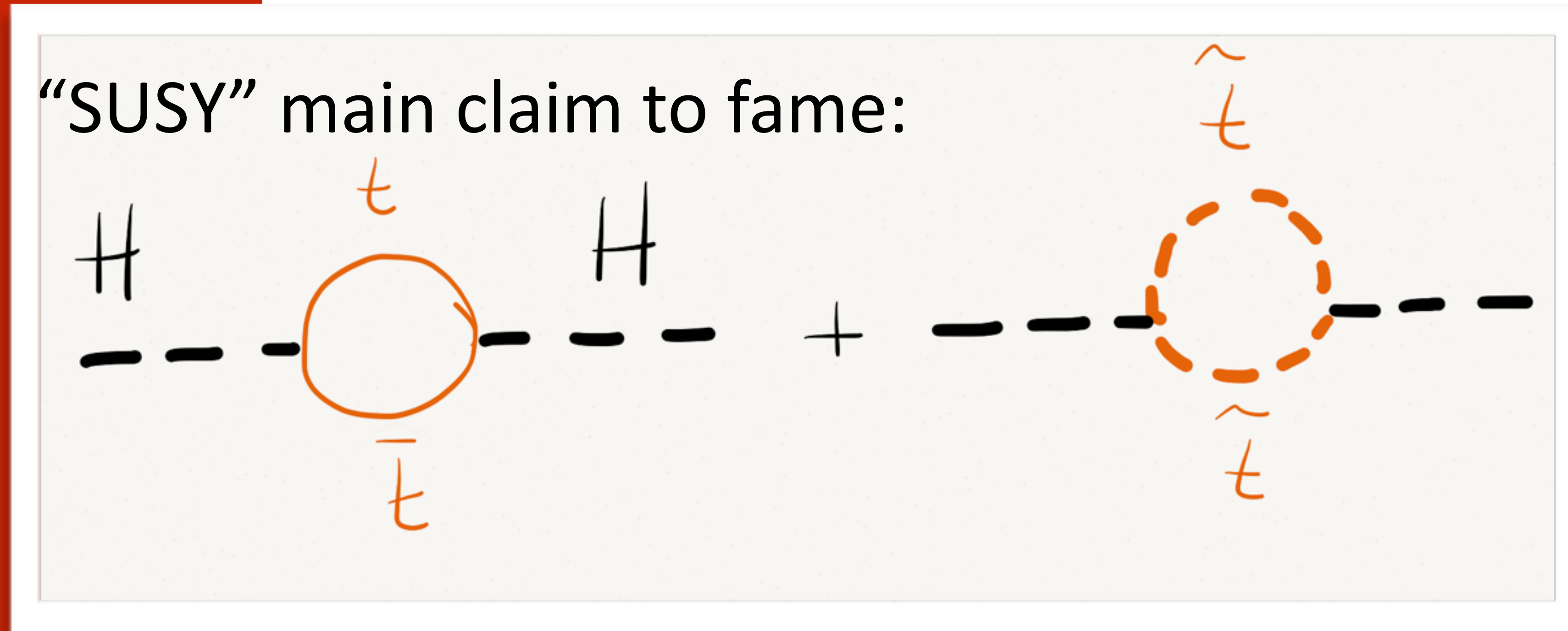
"selectron"



Searching for decades with every incremental increase in energy and luminosity. No evidence so far.

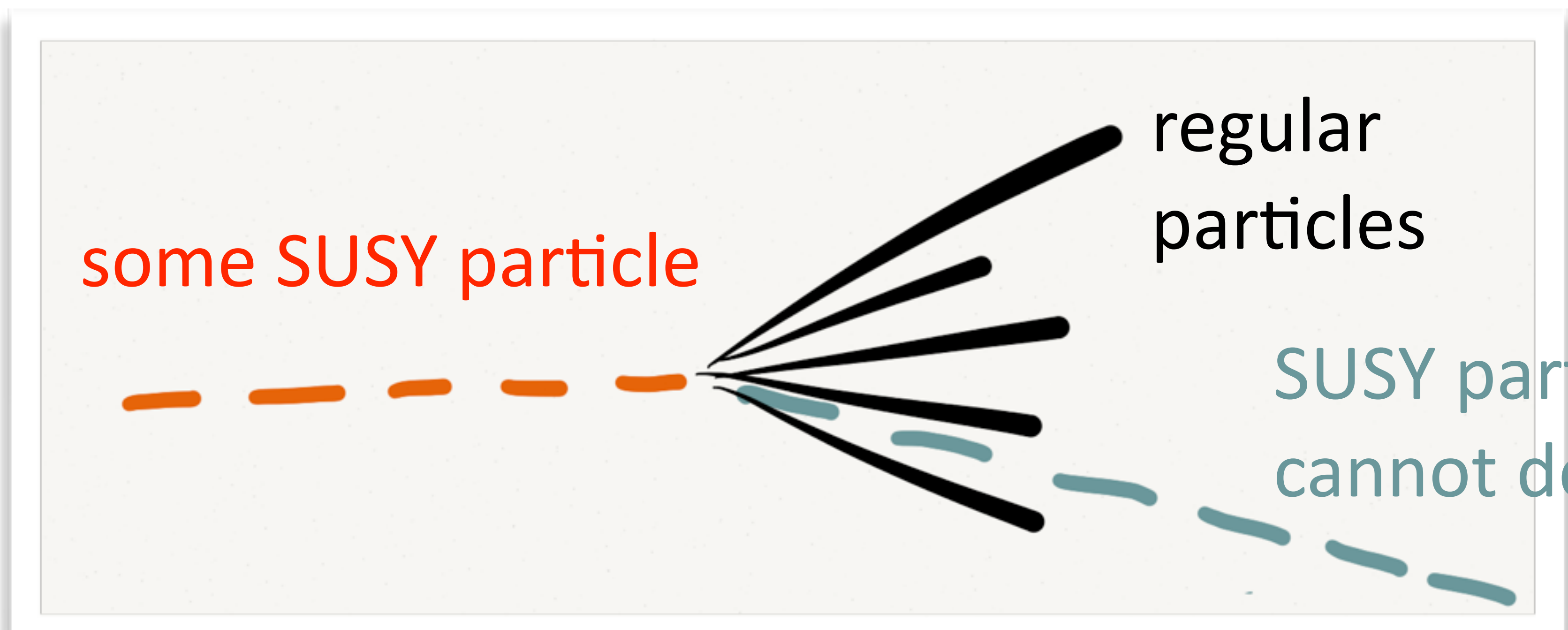
intriguing

for two big reasons



$= 0$

tames a SM Higgs mass problem*, "naturally"



???

*mass should be much higher

many other extensions

which unify forces and fix the infinities

add messenger particles

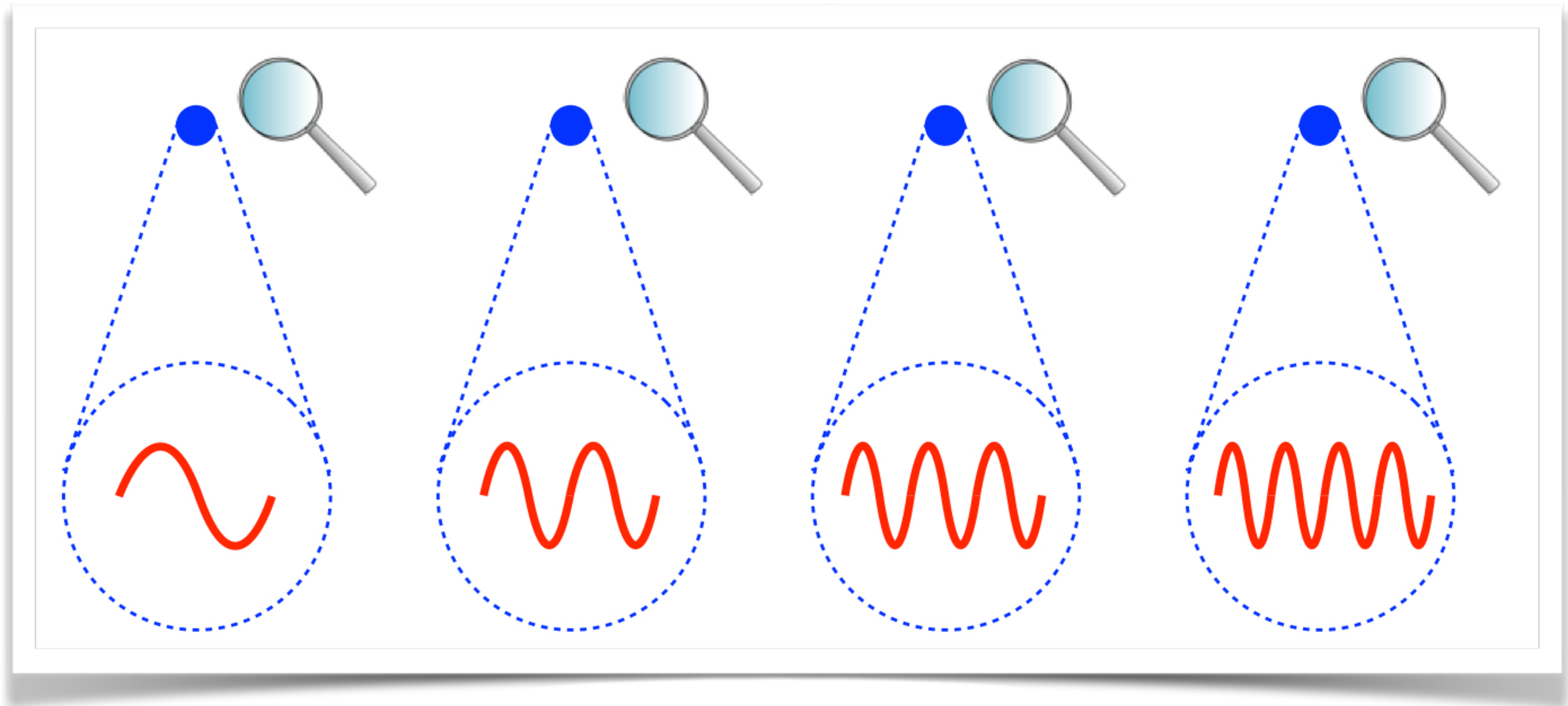
composite Higgs

composite quarks and leptons

"String Theory"...stop and start history in mathematics

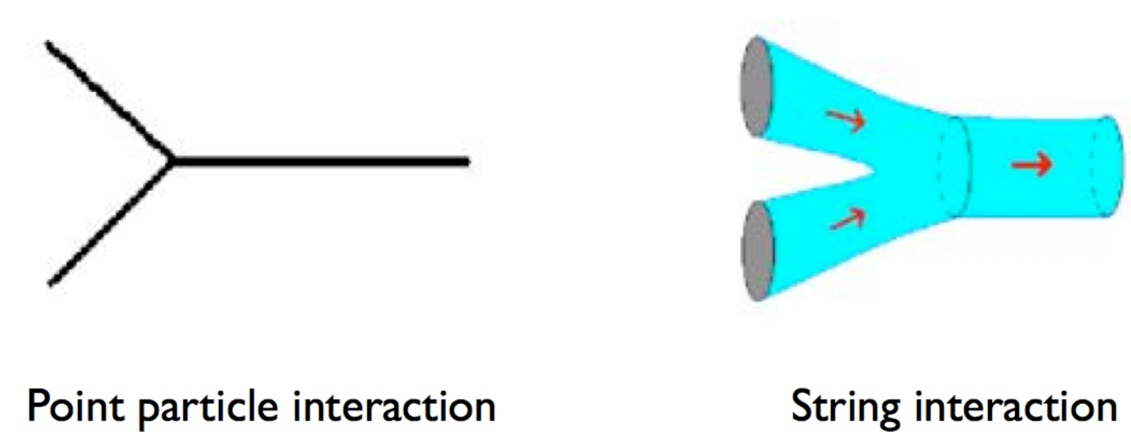
The "infinities" in Relativistic Quantum Field Theory are related to extrapolation in spacetime to zero, x, y, z, = 0

Suppose there is a minimum length in Nature?

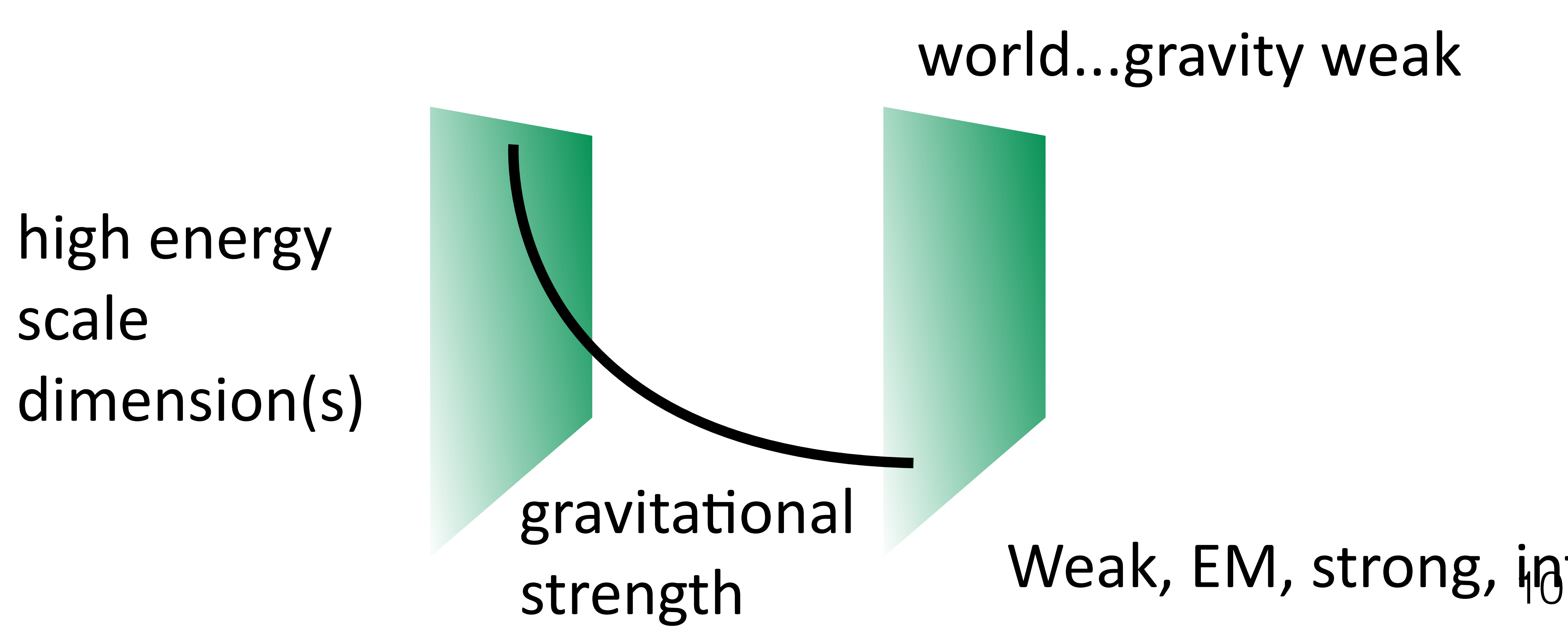


each wavelength...a different – e x t e n d e d – particle.

Plus: get a gravity and the graviton for free!



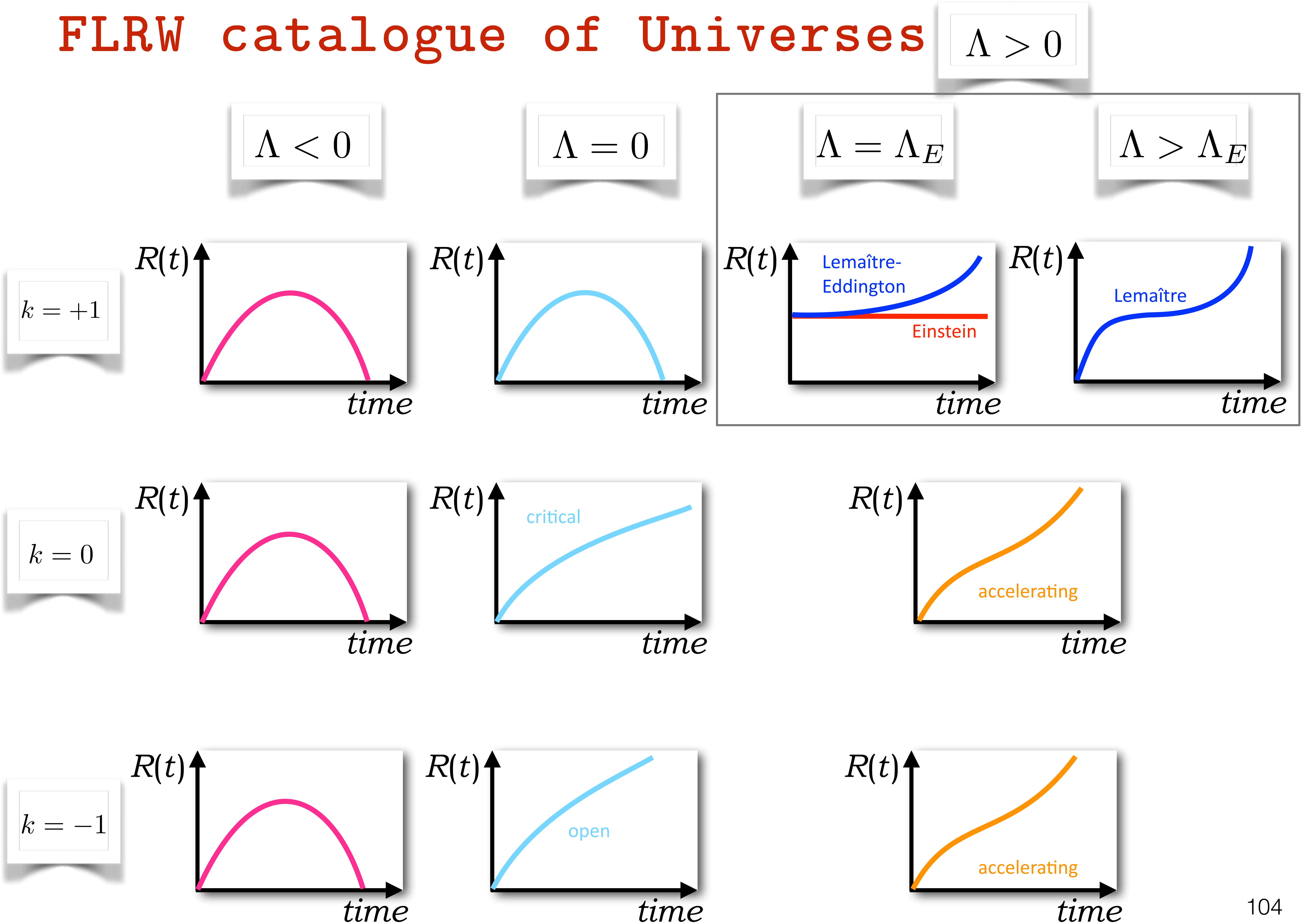
....up to 10 space and 1 time dimensions.



pretty:

Cosmology 5

FLRW catalogue of Universes



three ~~two~~ opposing views

"Steady State Universe"

eternal, matter created out of vacuum to maintain constant energy density...

"Big Bang Universe"

universe began at an instant

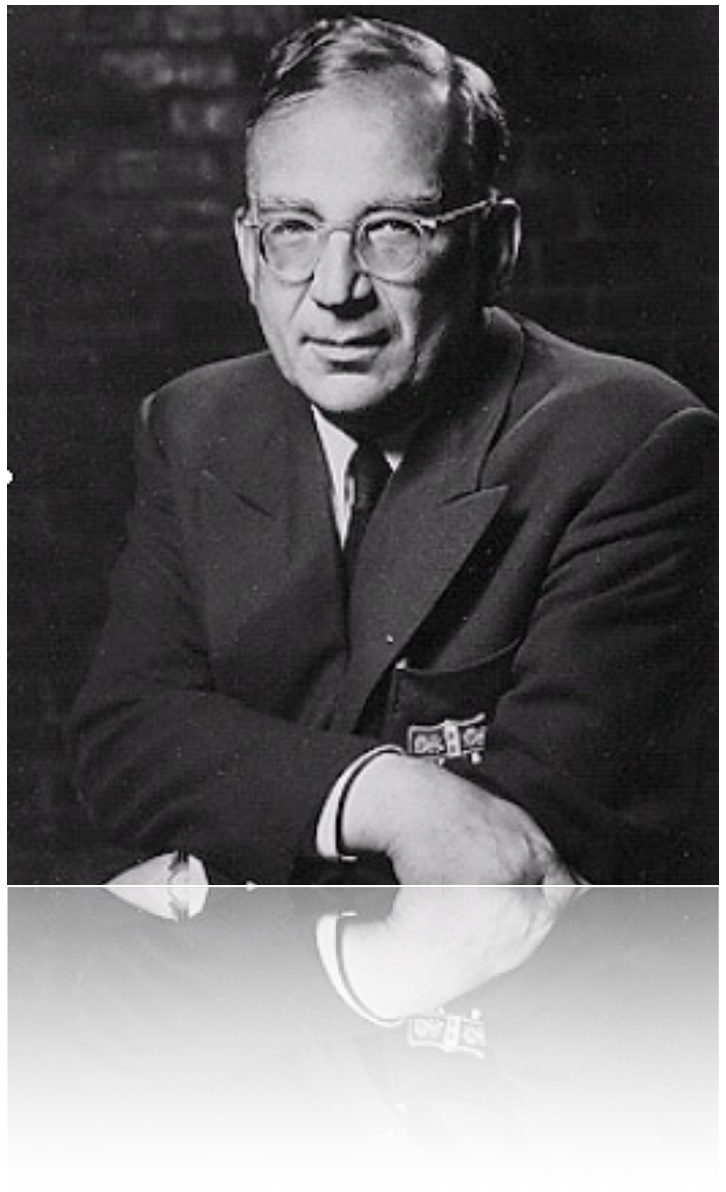
I lied: cyclic universe

over and over...bang and collapse - so eternal and a beginning

George Gamow

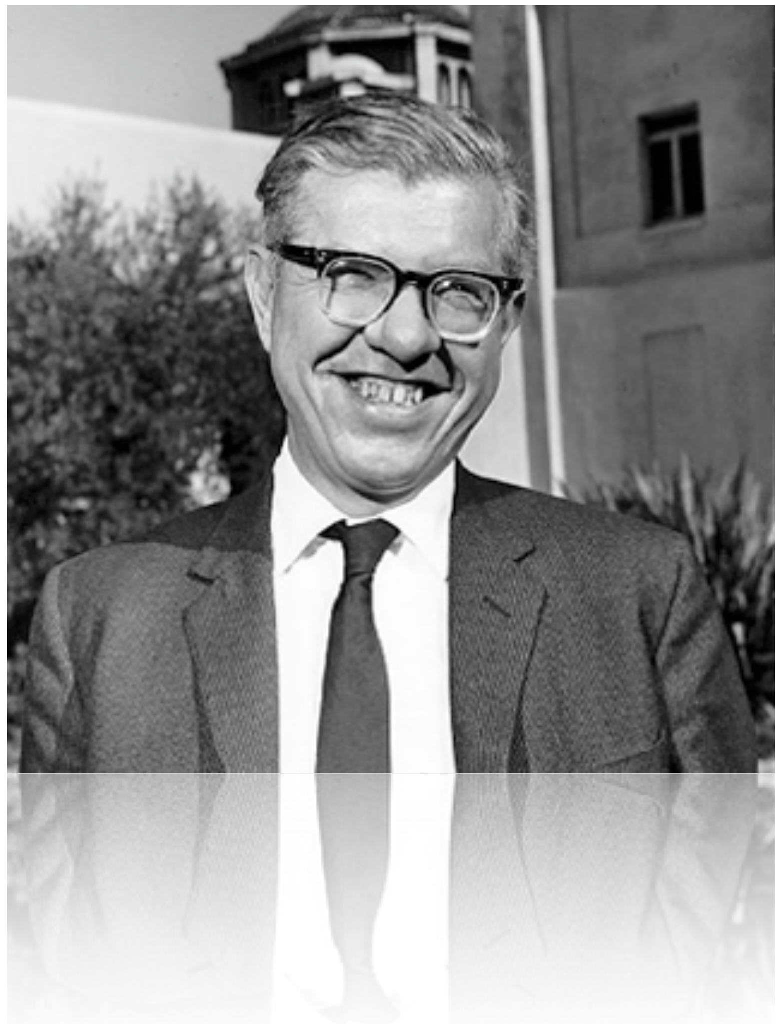
universe born

hot primordial soup



Fred Hoyle

steady state model, continuous creation of matter.



To Hoyle: the Big Bang implied a creator.

“Big Bang” was coined by Fred Hoyle in a

BBC radio broadcast for the general public in 1948

The recession of the galaxies does not give the only observational test that a theory of the expanding universemust satisfy. During the past few years astronomers have developed a number of further requirements. Although I don't wish to go into these in detail, I might mention that it is now possible to determine the ages of our own Galaxy and of several neighbouring galaxies with a substantial degree of accuracy. The result is about five thousand million years. A satisfactory theory must provide for this age, neither more nor less.

We now come to the question of applying the observational tests to earlier theories. These theories were based on the hypothesis that all the matter in the universe was created in one bigh bang at a particular time in the remote past. It now turns out that in some respect or other all such theories are in conflict with the observational requirements. And to a degree that can hardly be ignored. Investigators of this problem are like a party of mountaineers attempting an unclimbed peak. Previously it had seemed as if the main difficulty was to decide between a number of routes, all of which seemed promising lines of ascent. But now we find that each of these routes peters out in seemingly hopeless precipices. A new way must be found. The new xxxx way I am now going to discuss involves the hypothesis that matter is created continously.

How are the difficulties facing former theories overcome by introducing continuous creation of matter?

I cannot deal fully with this question, but perhaps you may like to hear one of many possible examples. According to the majority of the earlier theories the density of the matter which composes the background, the background which I've already described, must in the distant past, have been vastly greater than it is at present. This is an effect arising from the expansion, which in these theories produces a decrease of background density as we go forwards into the future but an

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Big Bang cosmology is a form of religious fundamentalism ...and this is why these peculiar states of mind have flourished so strongly over the past quarter century. It is the nature of fundamentalism that it should contain a powerful streak of irrationality and that it should not relate, in a verifiable, practical way, to the everyday world. ...it would take an eternity of time to distill even one drop of sense...Big bang cosmology refers to an epoch that cannot be reached from any form of astronomy...

Fred Hoyle

Home is Where the Wind Blows 1994.

Sorry, Fred.

Here's the current understanding of the life of a Universe:

evolving in time and temperature.