hi

Lecture 29, 04.25.2017

Particle Physics 4, Cosmology 5

housekeeping

Question about anything?

I'll make a movie for you:

Poster selection:

how you doin'?

Final: Thursday, May 4…in here…and yes, 0745h. I'll bring bagels.

1. Before Final day: second midterm available Friday midnight…closes midnight, Monday. ***MasteringAstronomy***

2. Final day: first poster session…about 30 minutes or so

3. Final day: Feynman diagram part…random partner, sit anywhere in atrium or lecture room

4. Final day: return anonymous survey which will be available after Thursday's class

Homework #14…available last Saturday:

10 points-worth in MasteringPhysics + 20 points-worth on paper

walks you through some of the Feynman Diagram parts of the actual Finals-day FD part…a video is involved

http://www.pa.msu.edu/~brock/file_sharing/QSandBB/2017homework/

Homework #15

will be assigned after Thursday's class and cover this week's subjects and content of a couple of movies… MasteringAstronomy, closes midnight, Thursday, May 4

now hear this

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: 4/17/2017 - 5/17/2017
ISP 220 002: 4/17/2017 - 5/17/2017

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 5/17/2017 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).

also:

I'll have an optional anonymous course review with points

Honors Project

Data were due April 22. Paper due on May 4 (final day).

upload instructions:

http://www.pa.msu.edu/~brock/file_sharing/QSandBB/2017homework/honors_project_2017/UploadInstructions

particle physics

where we are

Quarks

- model confirmed
- held in hadrons by the gluon field…which forms bulk of mass
- masses of hadrons - insulting. masses of quarks - bizarre

Messenger particles

- photon (electromagnetic), gluon (strong), W(weak), ?(gravity)

the modern picture

of the elementary particle patterns

circa 2000

and still current

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 2000

the quark families...quark "doublets"

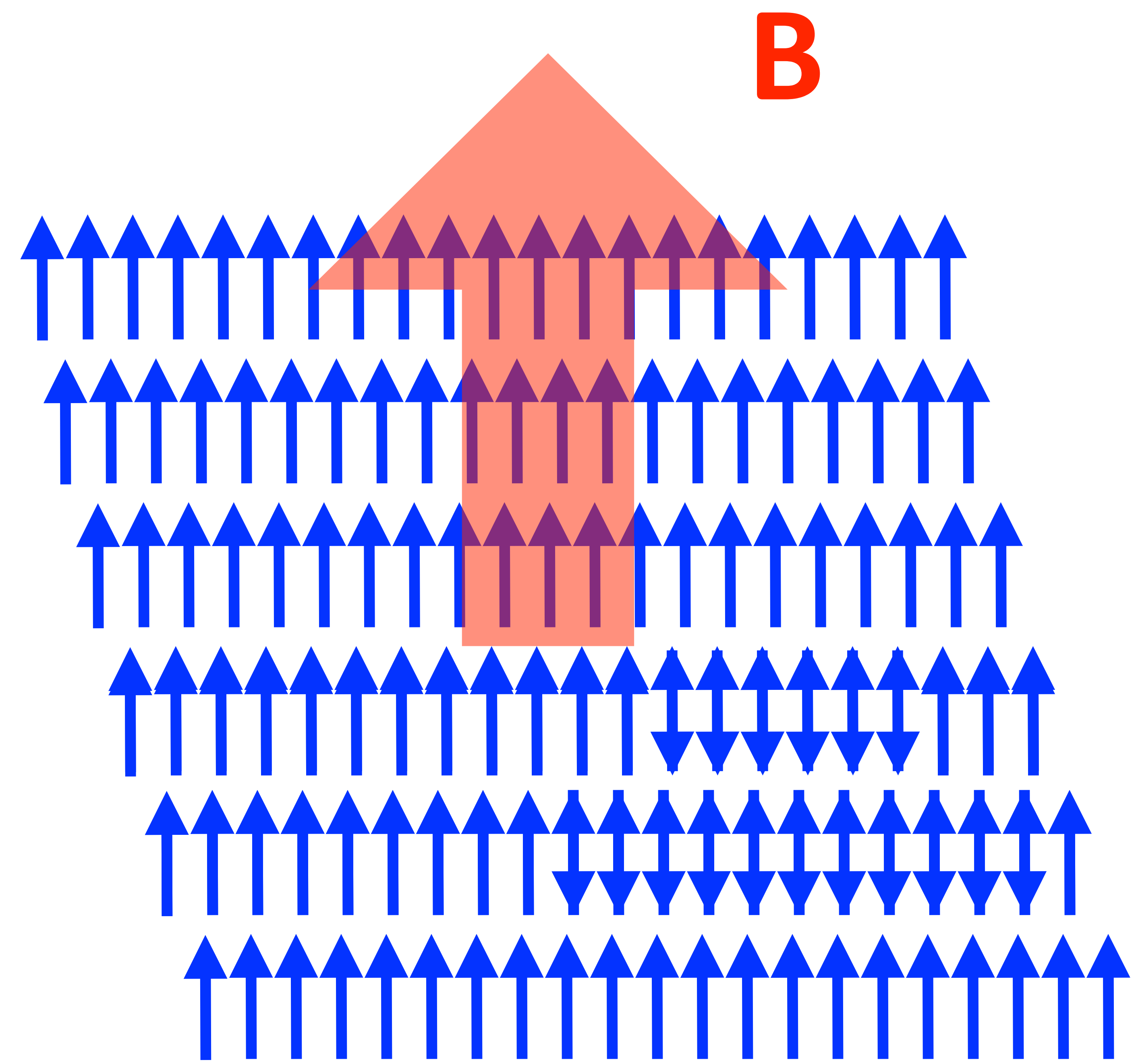
$$\begin{pmatrix} u \\ d \end{pmatrix} \quad \begin{pmatrix} c \\ s \end{pmatrix} \quad \begin{pmatrix} t \\ b \end{pmatrix}$$

and their interactions: ✘ no, ✔ yes.

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

why

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



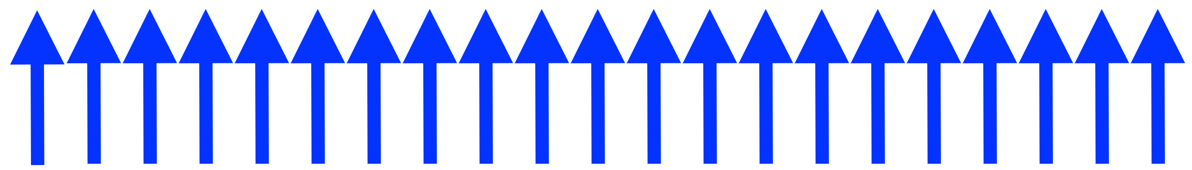
4.2 K - liquifies

2.17 K - superfluid

a little model of an *ideal* ferromagnet

in one - dimension

At a low temperature – like room temperature:



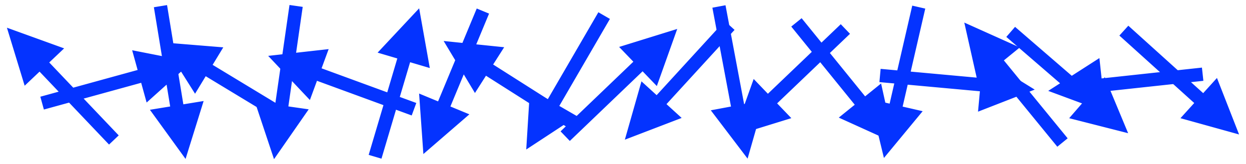
M is maximum

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

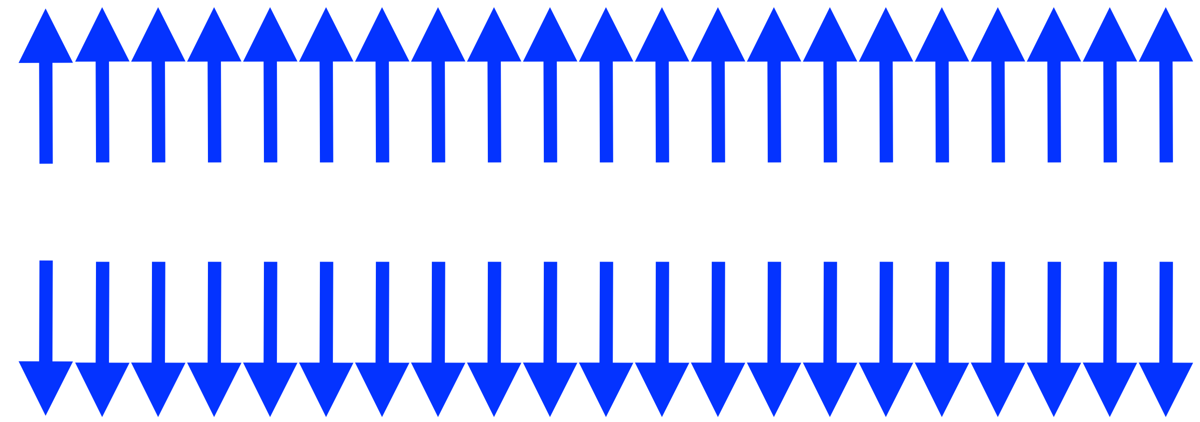
M becomes zero

an important difference

between these two situations

H  M = 0

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

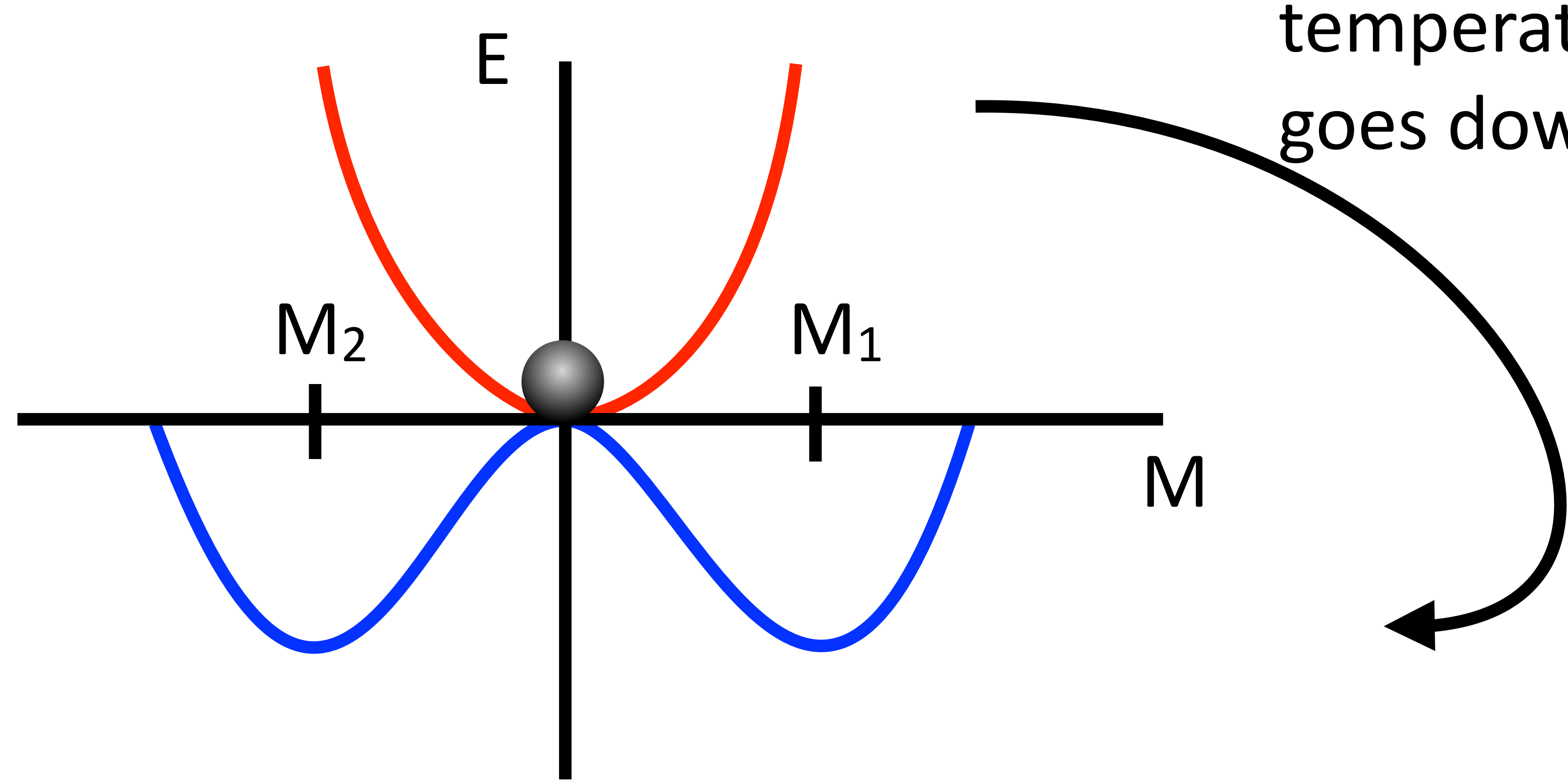
C 

$M_1 \neq 0$

$M_2 \neq 0$

we say that the symmetry is "broken"

when temperature goes down



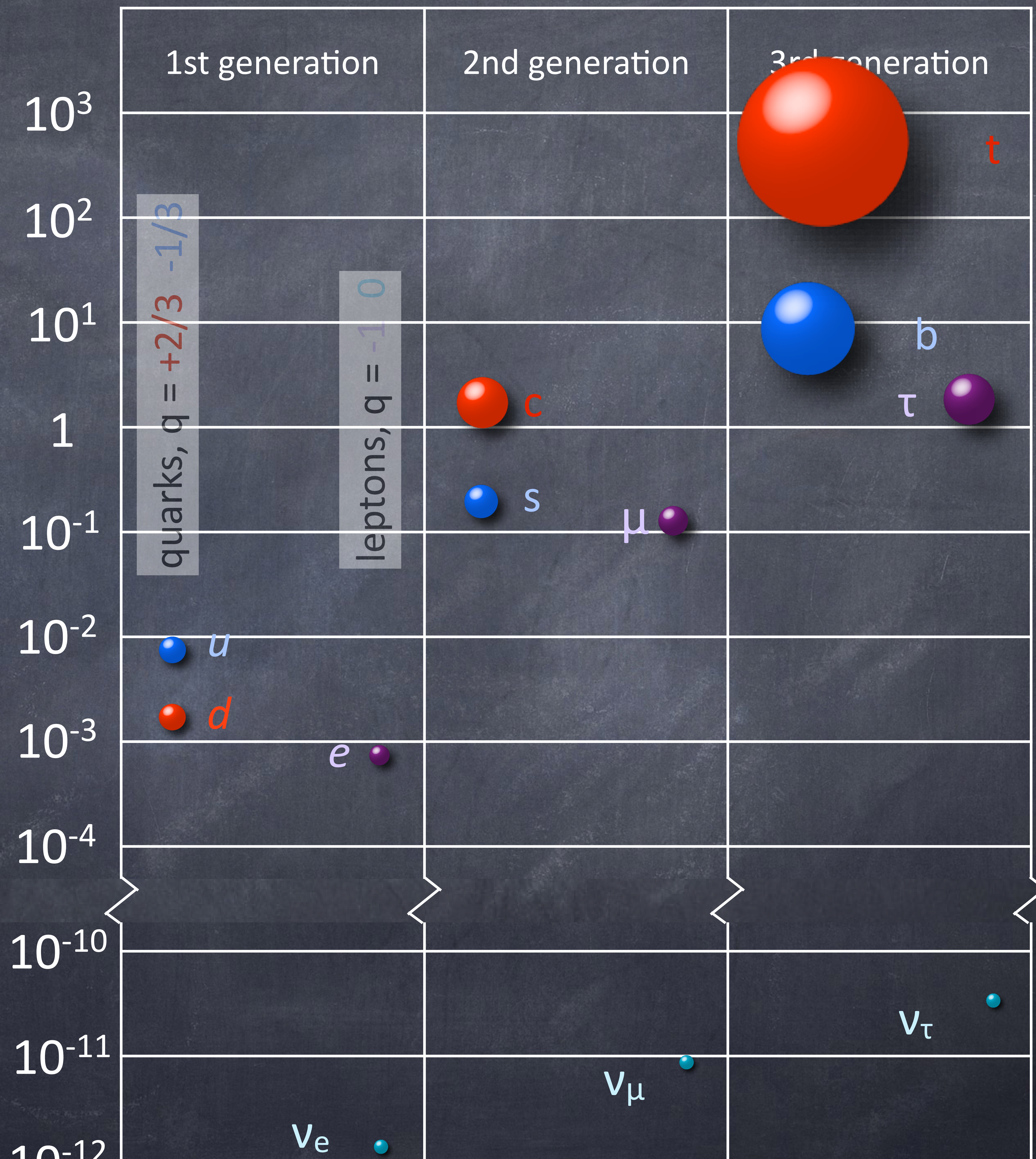
the energy level of the **hot ground state** is higher than the energy level of the **cold ground state**

this often-told magnet story

evolves into the new story of MASS

quarks & leptons

proton masses



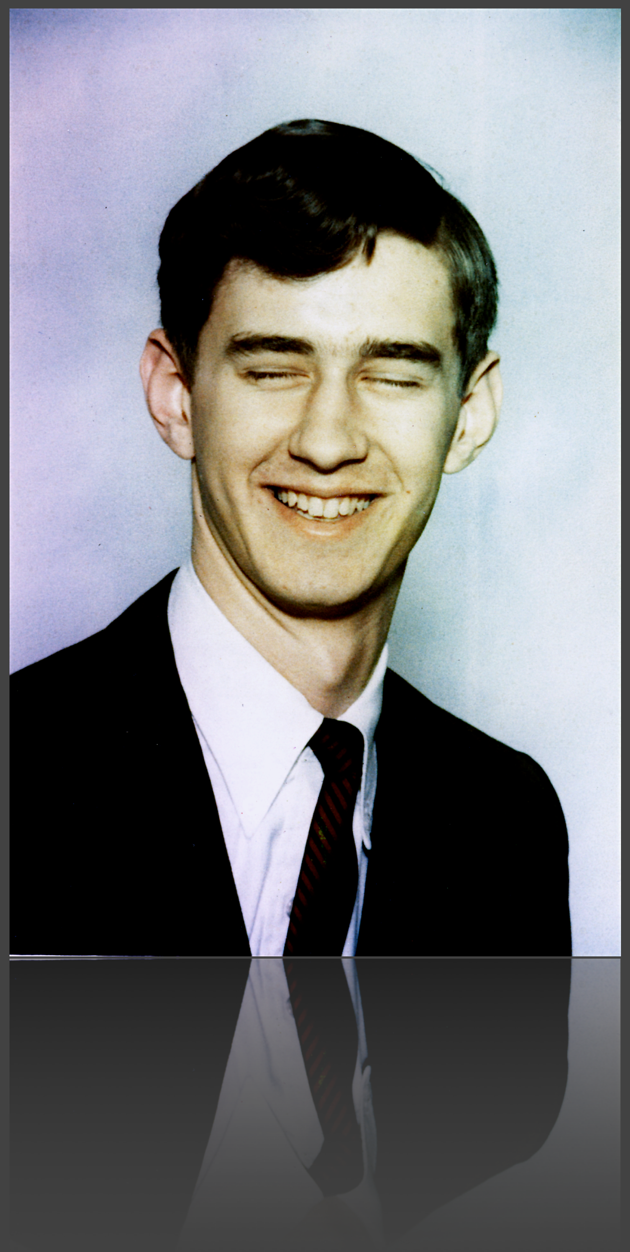
the only mathematical solution that made sense:

masses of all quarks, leptons, and messenger particles

= 0

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

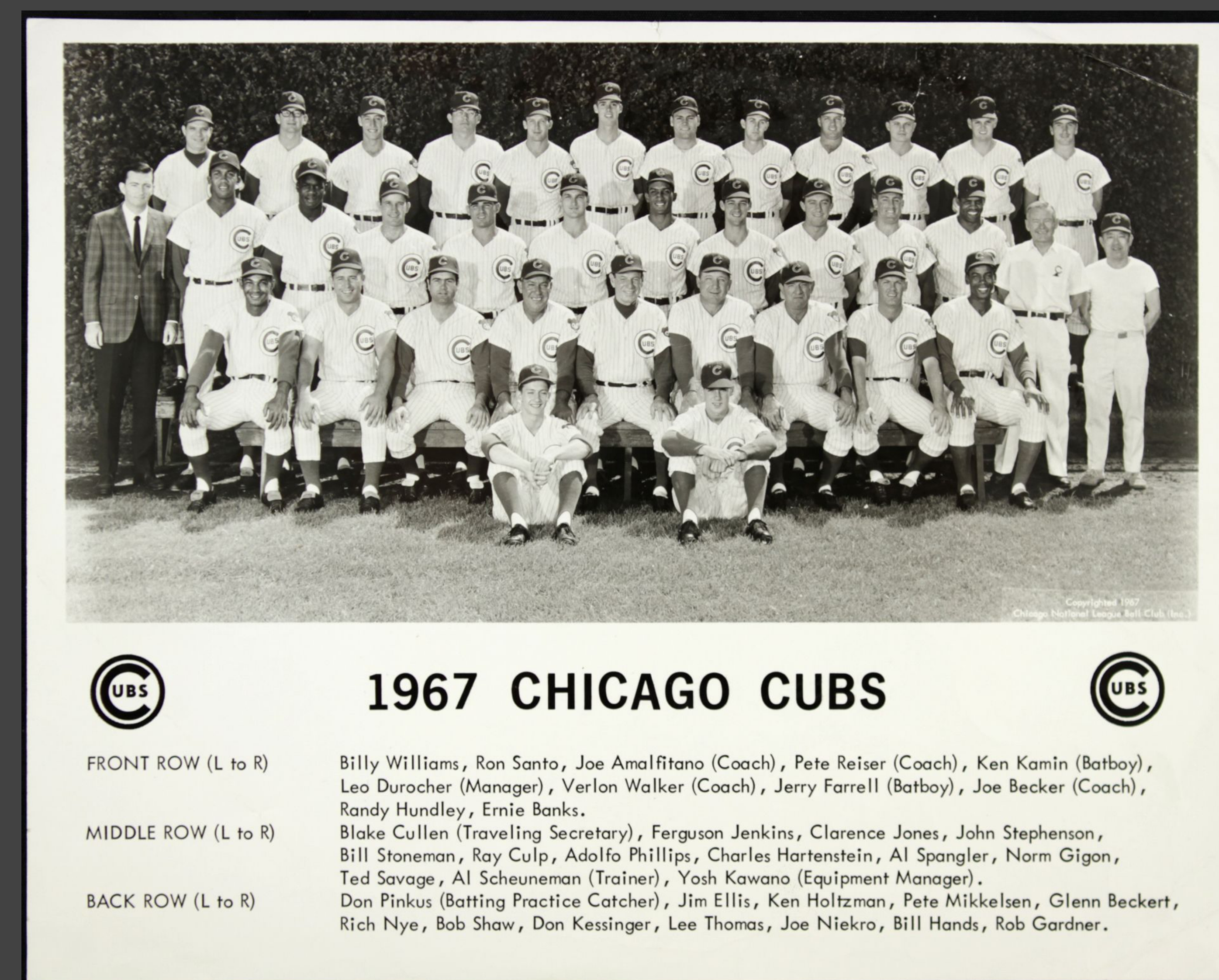
1967



1967

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

1967



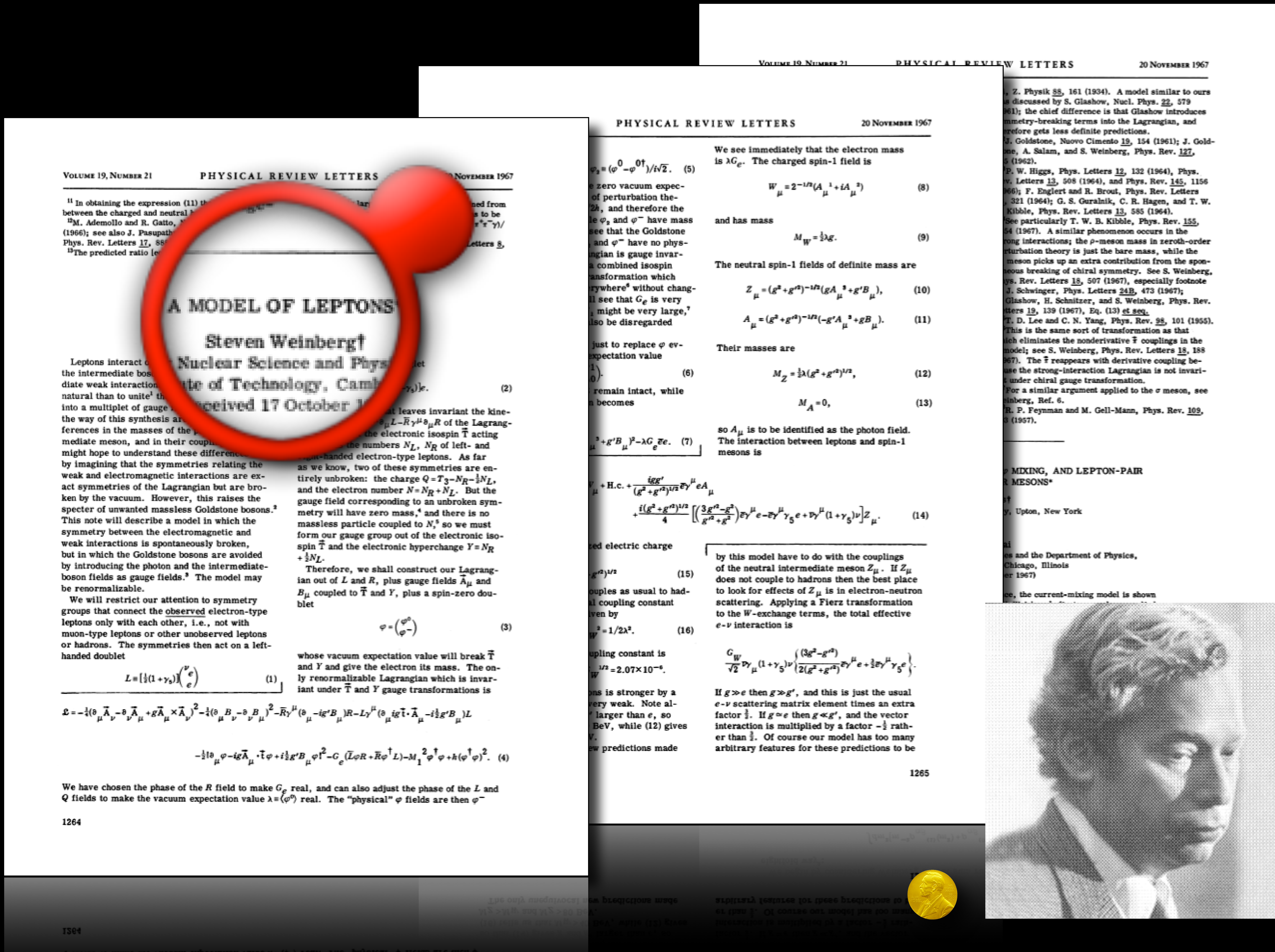
http://www.mustangdreams.com/mdfastback.htm

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



VOLUME 19, NUMBER 21 PHYSICAL REVIEW LETTERS 20 NOVEMBER 1967
A MODEL OF LEPTONS
Steven Weinberg†
Nuclear Science and Phys
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PHYSICAL REVIEW LETTERS 20 NOVEMBER 1967
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?

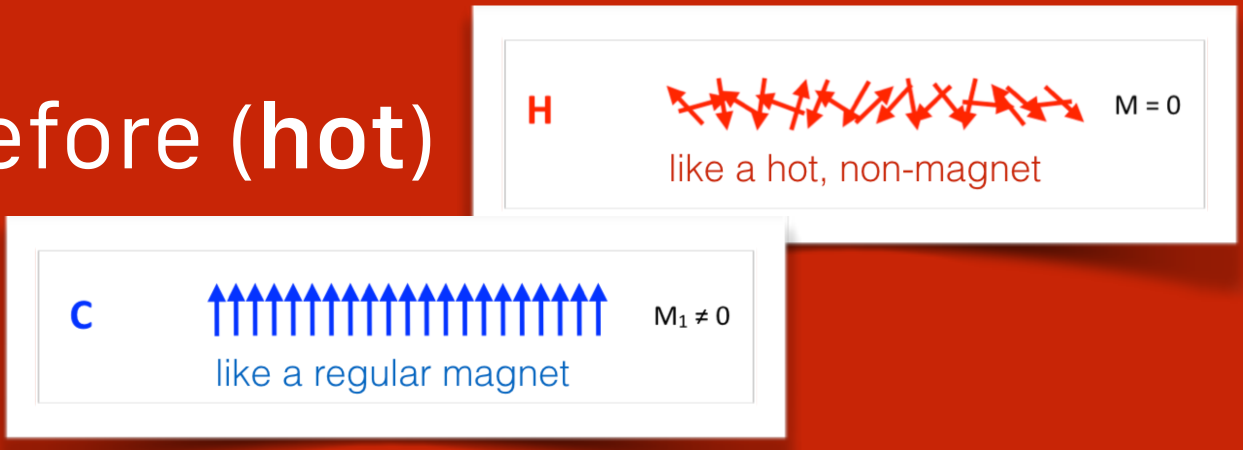
everywhere in the Universe

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**)

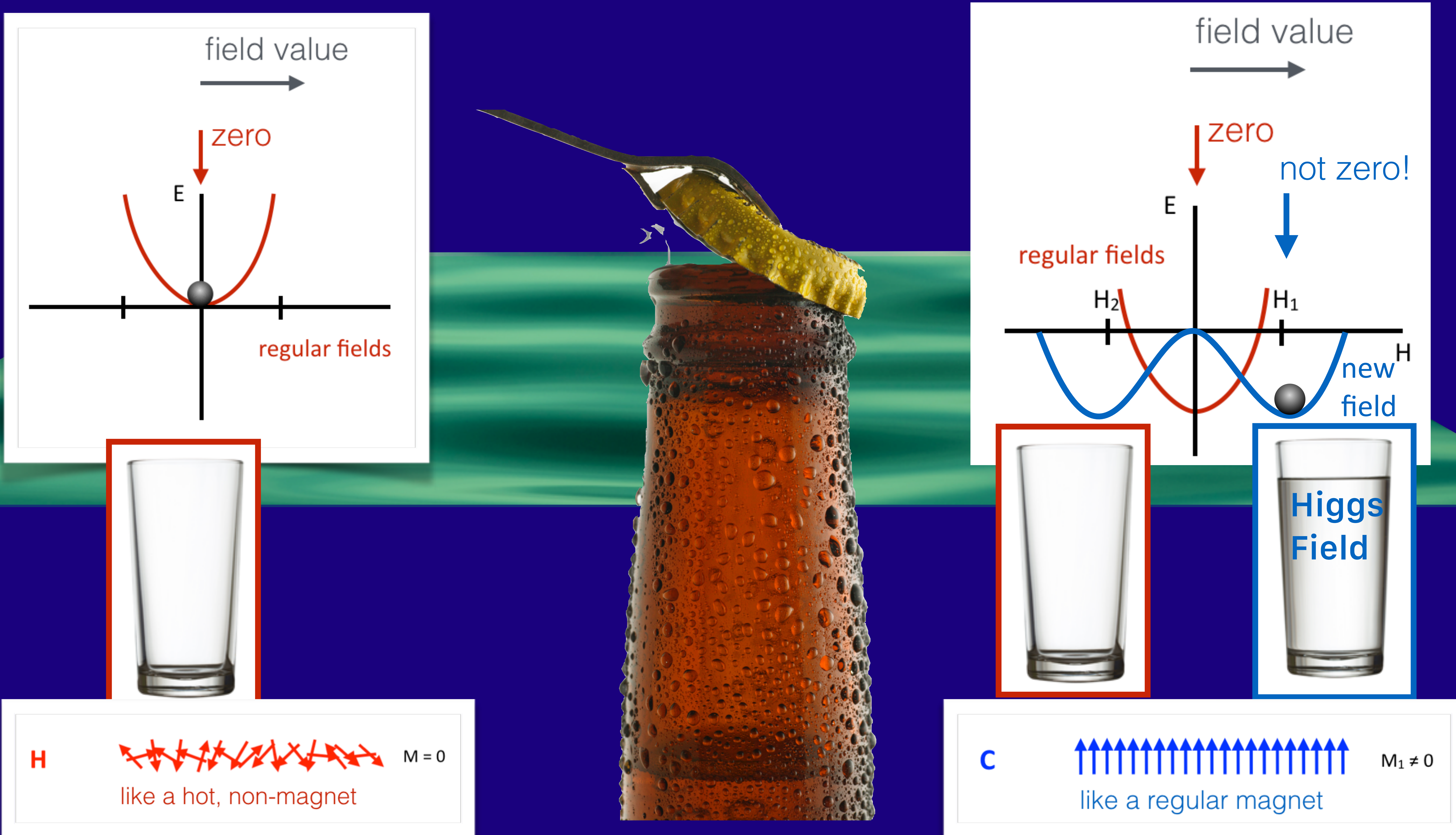
and different fields and particles after (**cold**)



we live in the resulting "cold" universe

10^{-12}s after the big bang

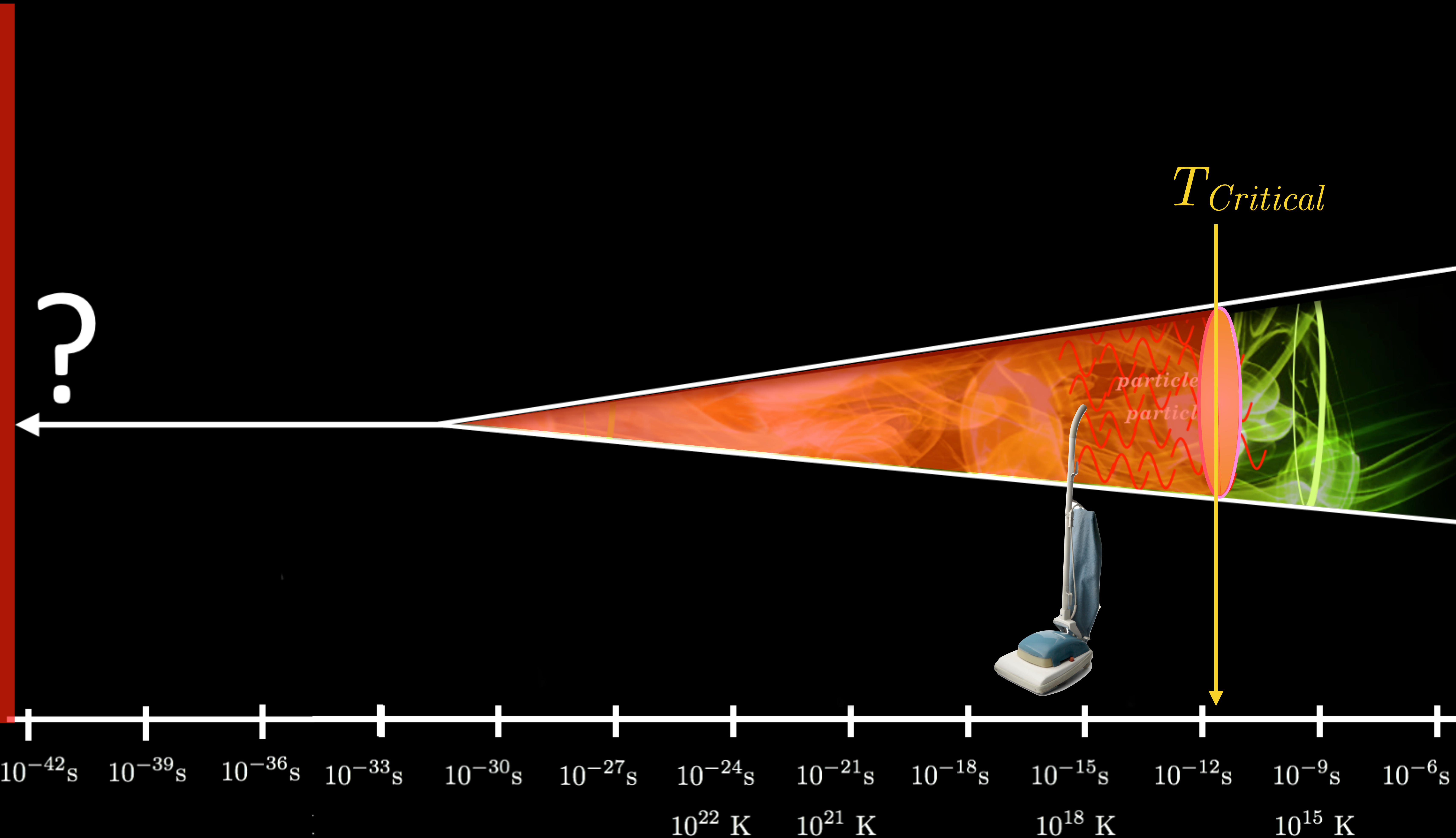
universe condensed: a phase change



the big story of the Standard Model

is the story of mass.

elementary particle epoch



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0	-2	-9	8	9	8	-2	-8	9	7	-9	-8	-8	0	-7	-2	-8	9	-8	0	-7	-9	-2	[illegible]	-8	-9	[illegible]	-9
7	-8	-8	8	9	7	-7	7	8	0	0	0	-7	-9	7	-8	-7	-8	8	9	9	-2	9	[illegible]	9	[illegible]	[illegible]	9
9	-9	-2	-9	-8	9	9	8	7	9	-9	-7	-2	9	-7	9	-8	9	-9	9	-2	-9	-2	[illegible]	9	[illegible]	[illegible]	-8
8	8	-8	9	-7	9	-8	8	9	8	7	8	8	7	-2	-8	-8	-2	9	-7	8	-7	[illegible]	[illegible]	[illegible]	[illegible]	-9	-8
-7	-8	-8	-2	-7	-9	-8	9	-9	-9	-2	-8	9	9	-8	0	-7	-2	0	8	-7	-8	8	-7	9	0	-7	8
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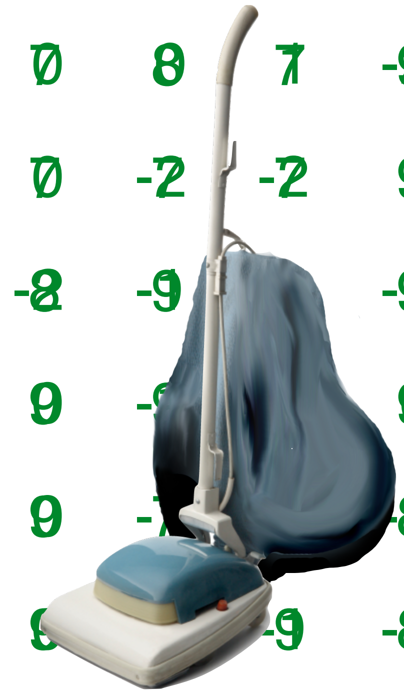
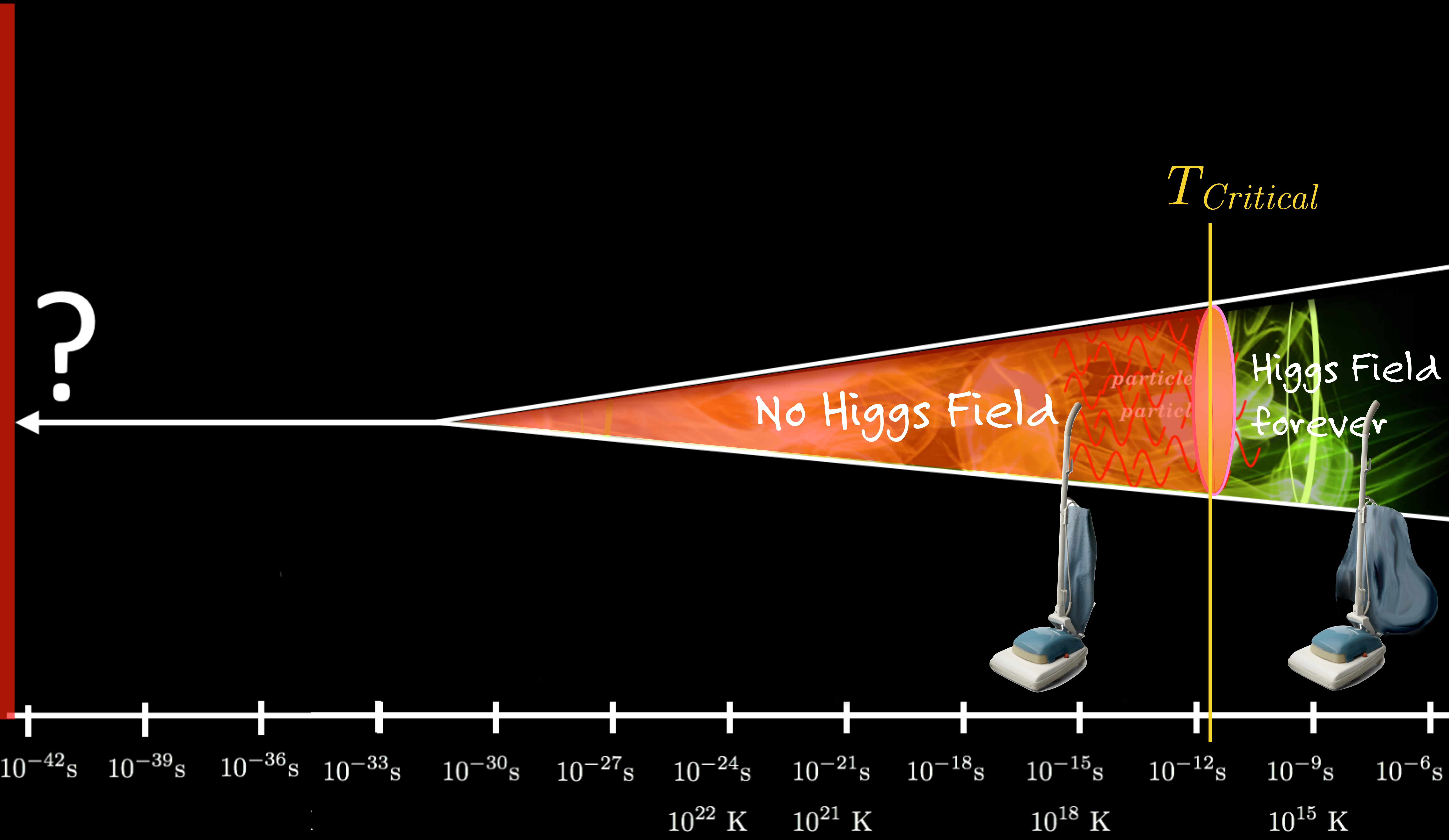
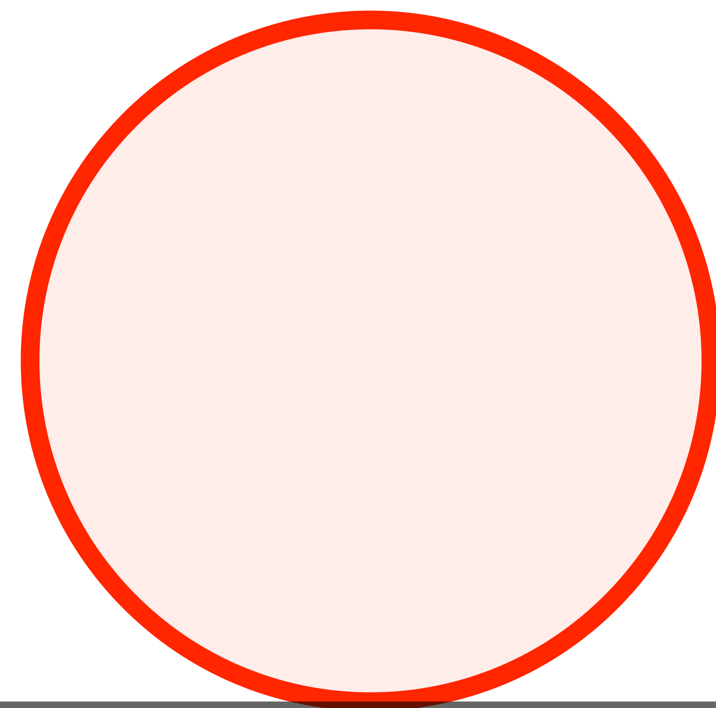


elementary particle epoch

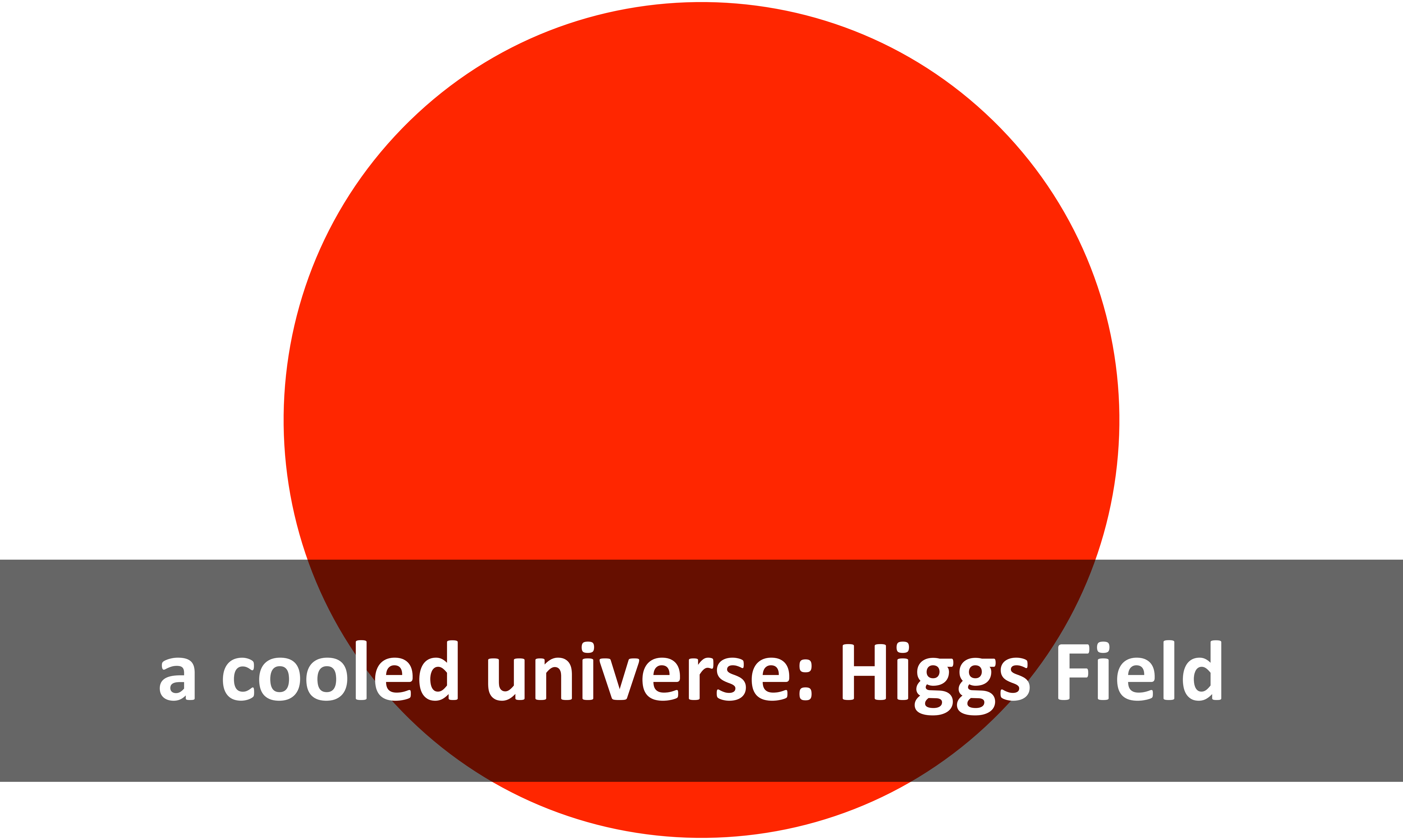


(after David Miller)

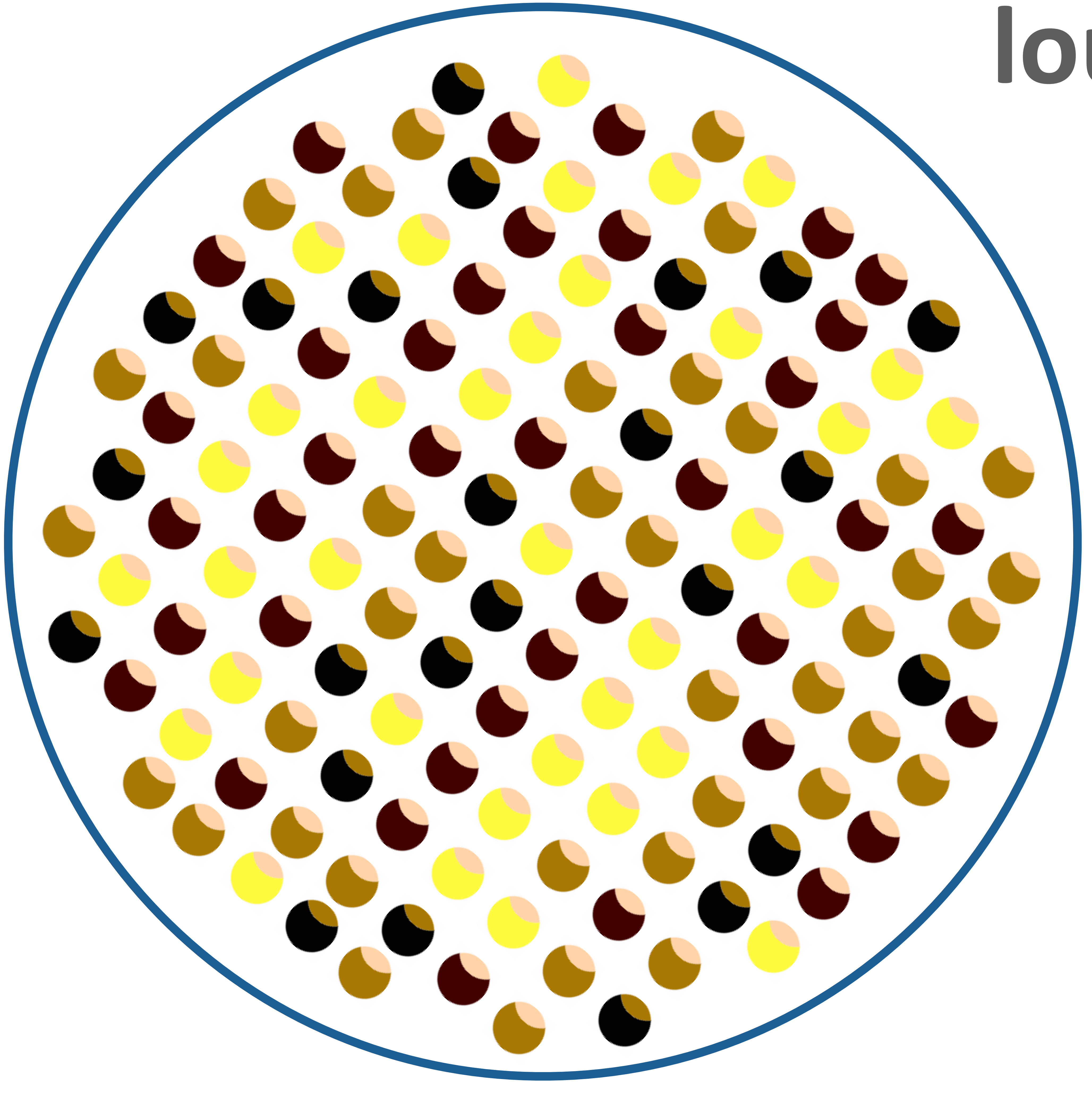


the hot universe: no Higgs Field

(after David Miller)

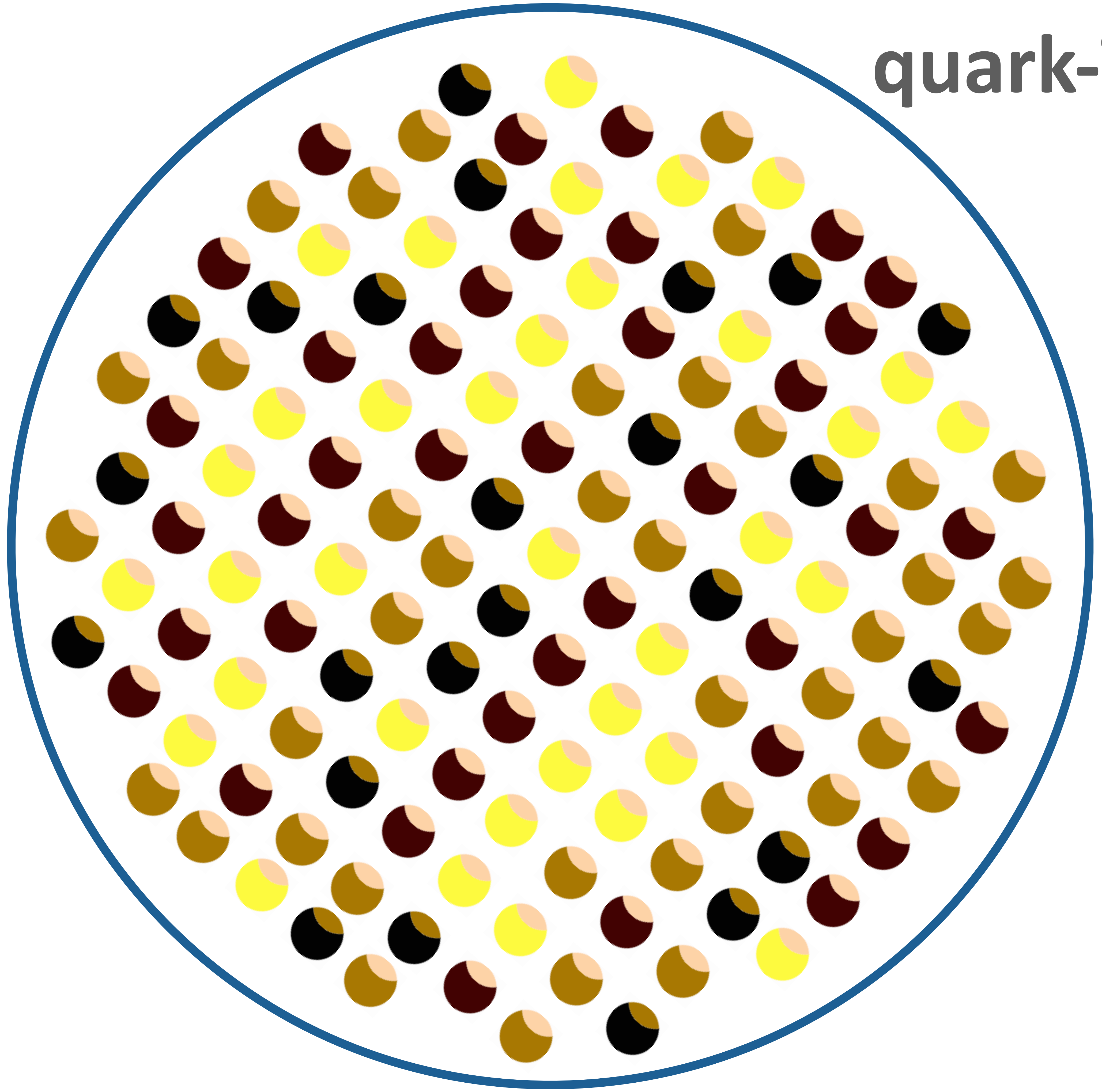


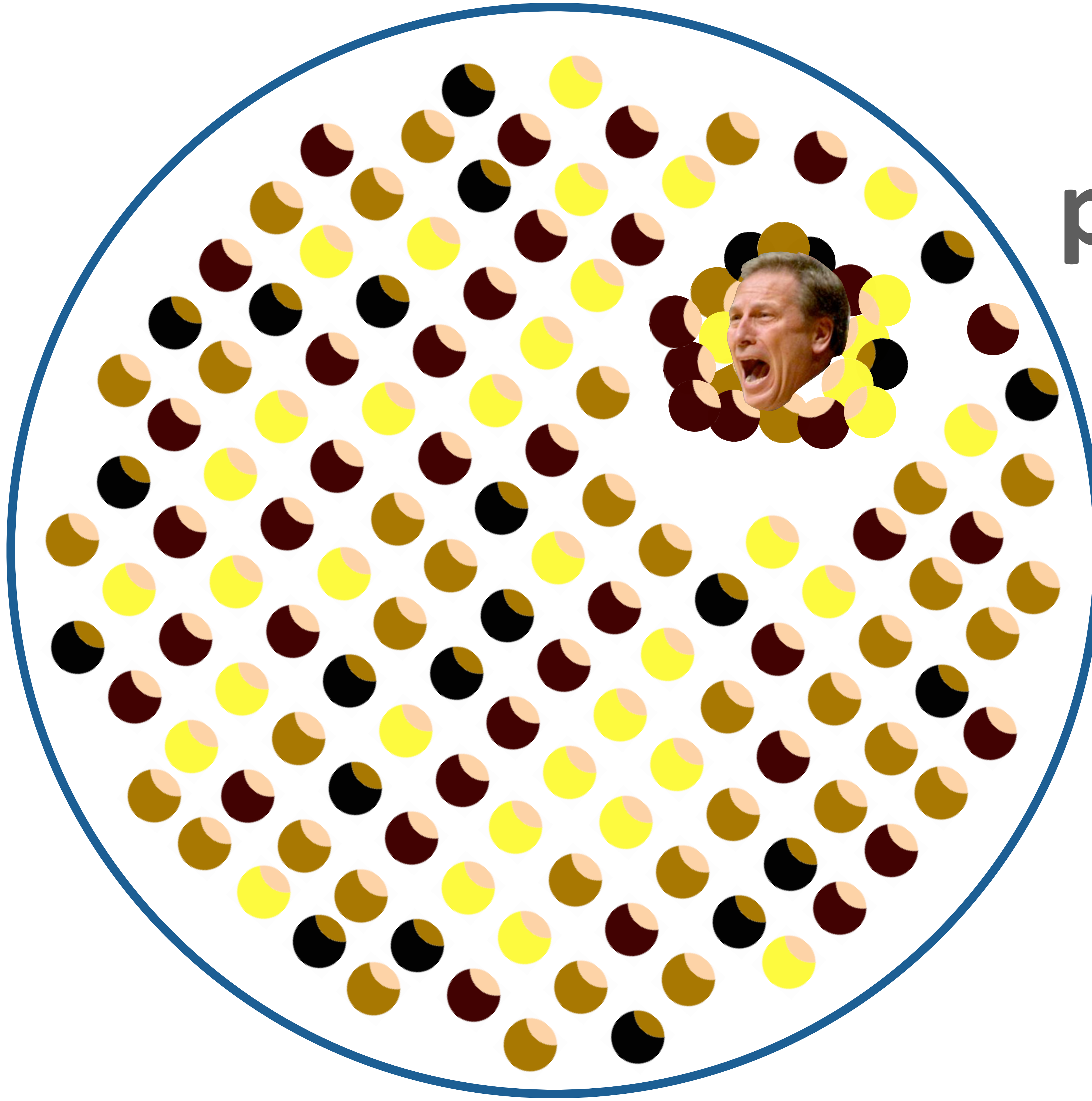
(after David Miller)



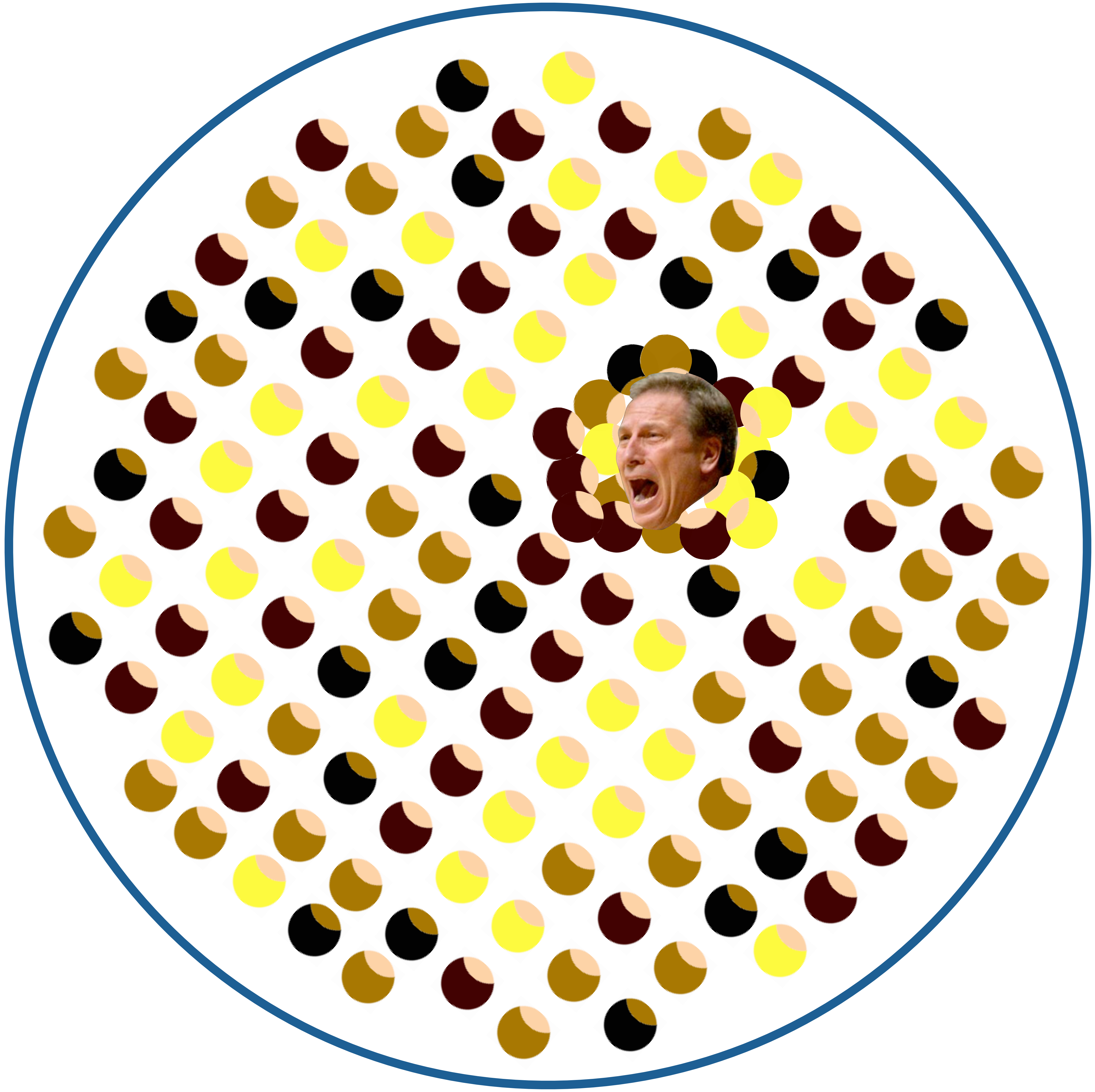
loud

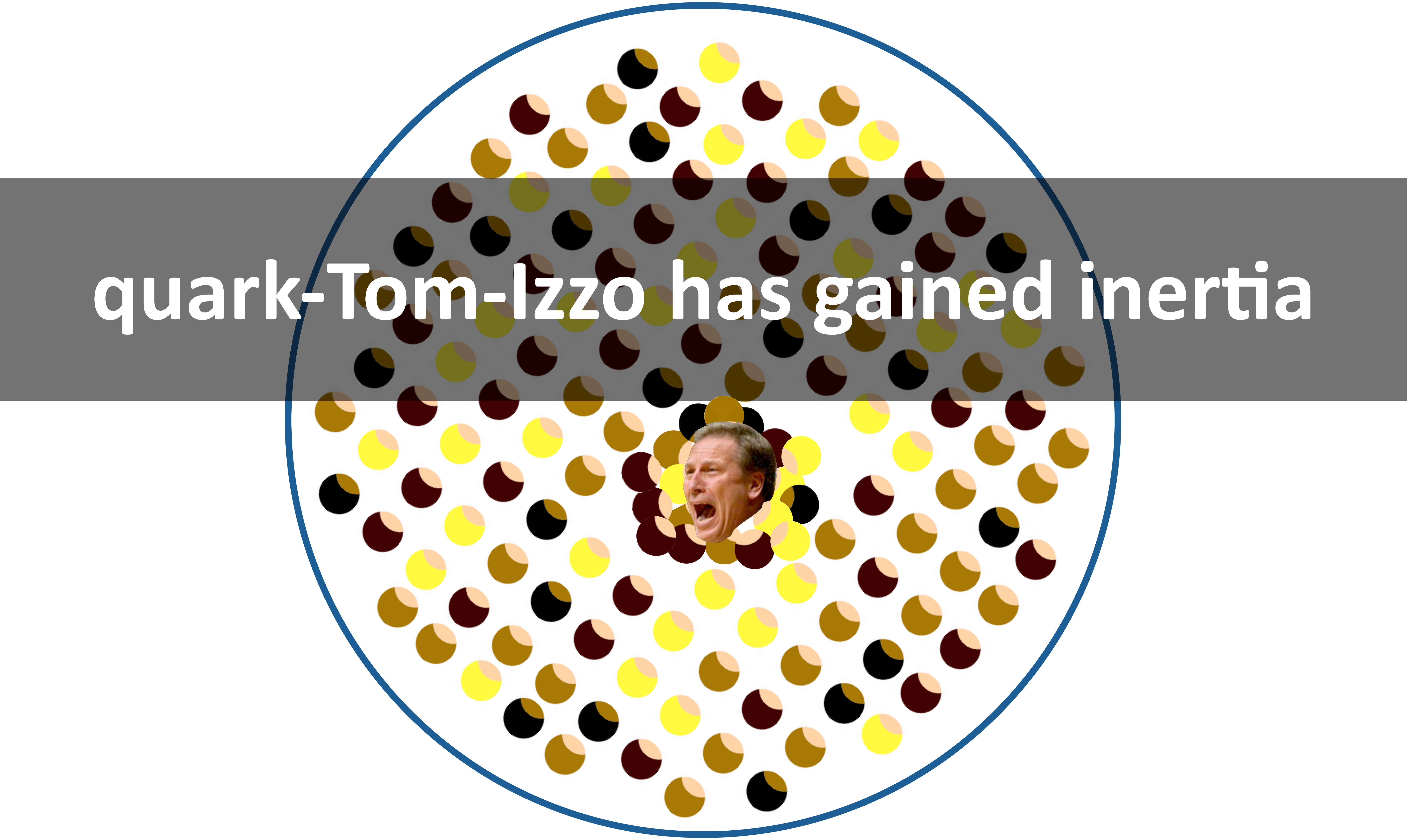
quark-Tom-Izzo





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

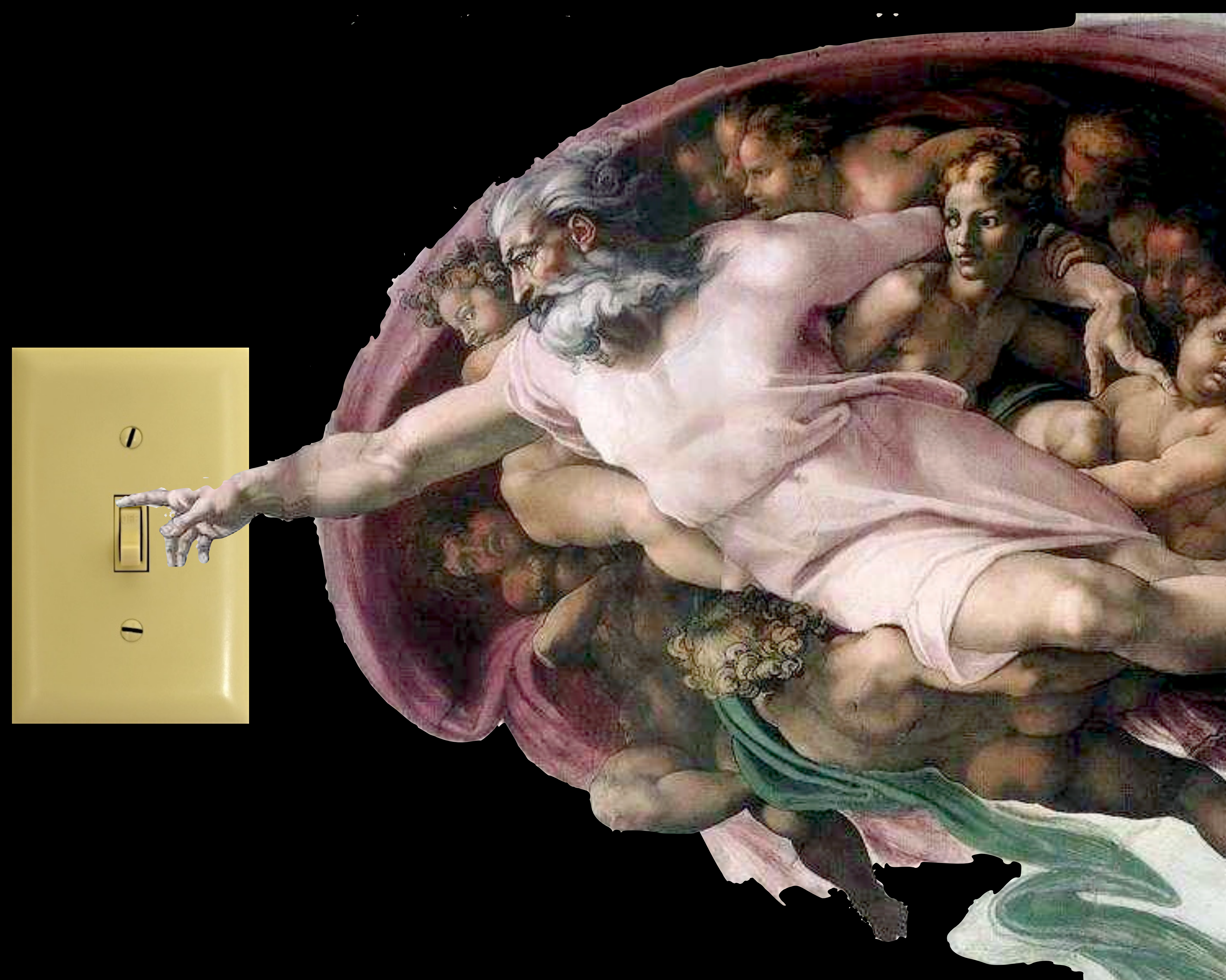
the story of the Weak and Electromagnetic Fields

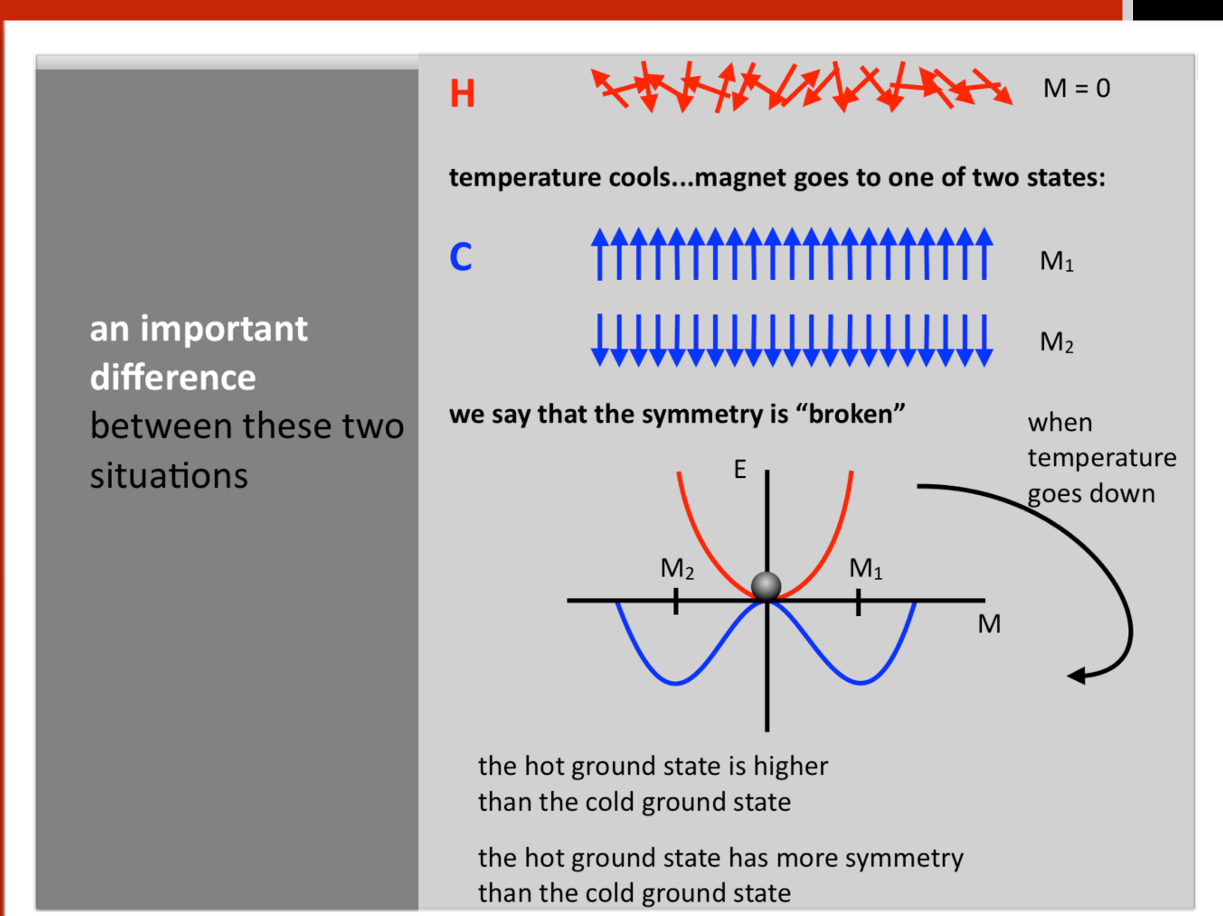
the unification of forces

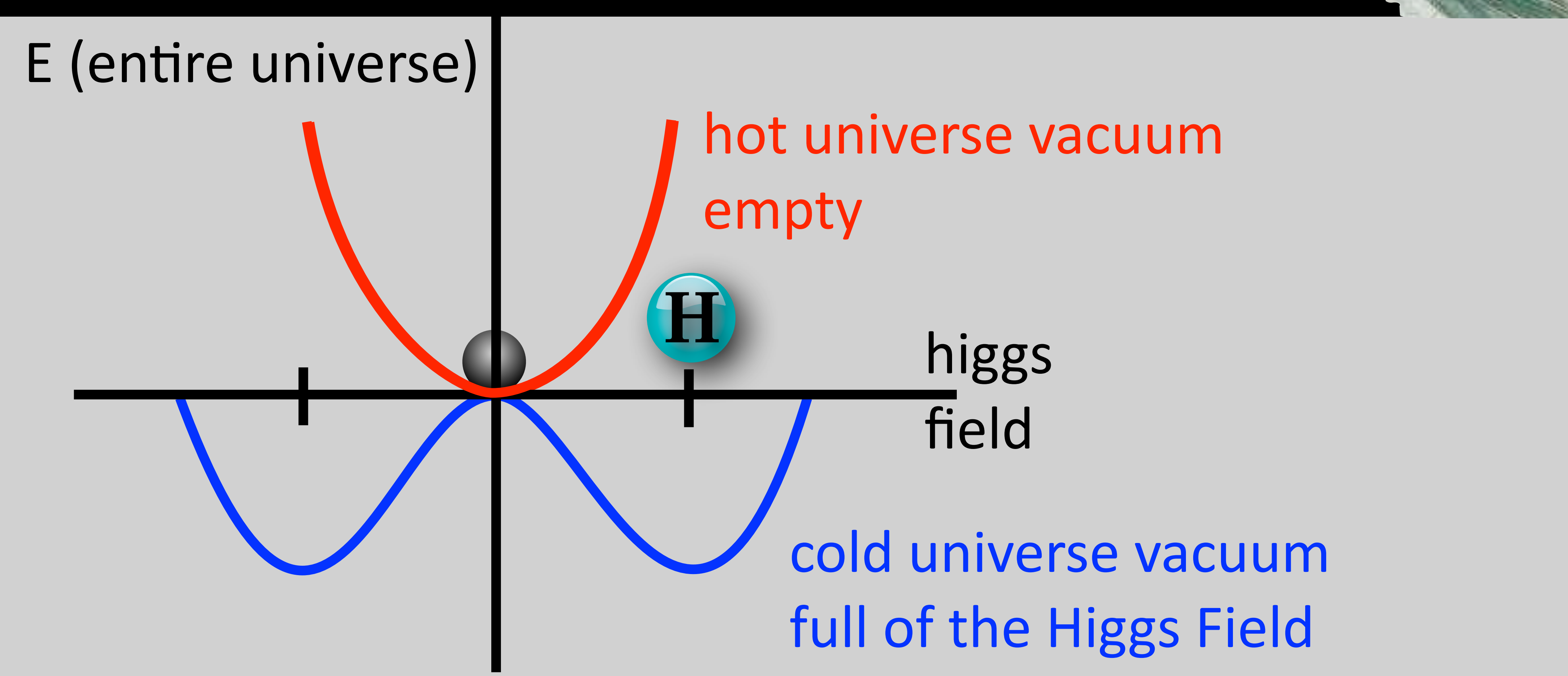
from a hot phase in the universe

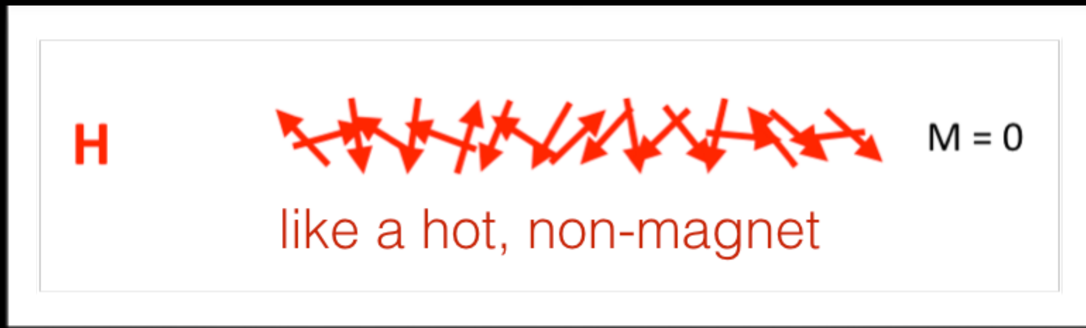
cool it all at once

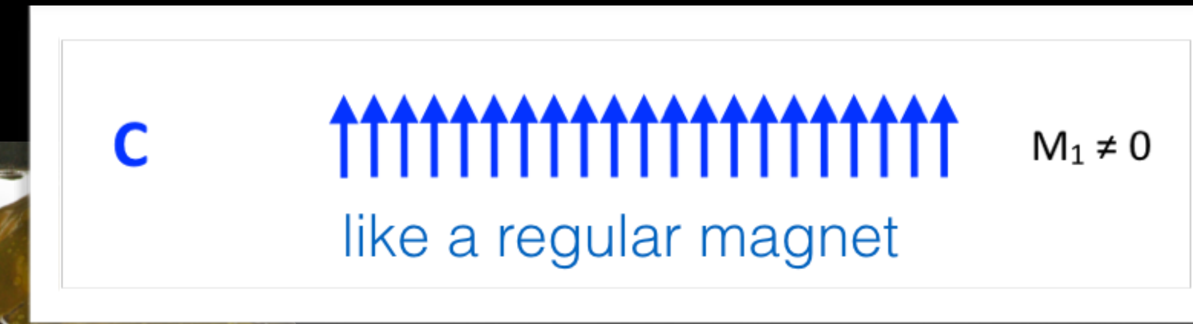
@ 10^{-12} seconds after the BB











a^0 — 0 〰

B^0 — 0 〰

B^+ — + 〰

B^- — - 〰

$\phi \begin{pmatrix} + \text{ - - - - - - -} \\ 0 \text{ - - - - - - -} \end{pmatrix}$

$\phi^* \begin{pmatrix} - \text{ - - - - - - -} \\ 0 \text{ - - - - - - -} \end{pmatrix}$

γ

Z

$W^\pm$

H^0

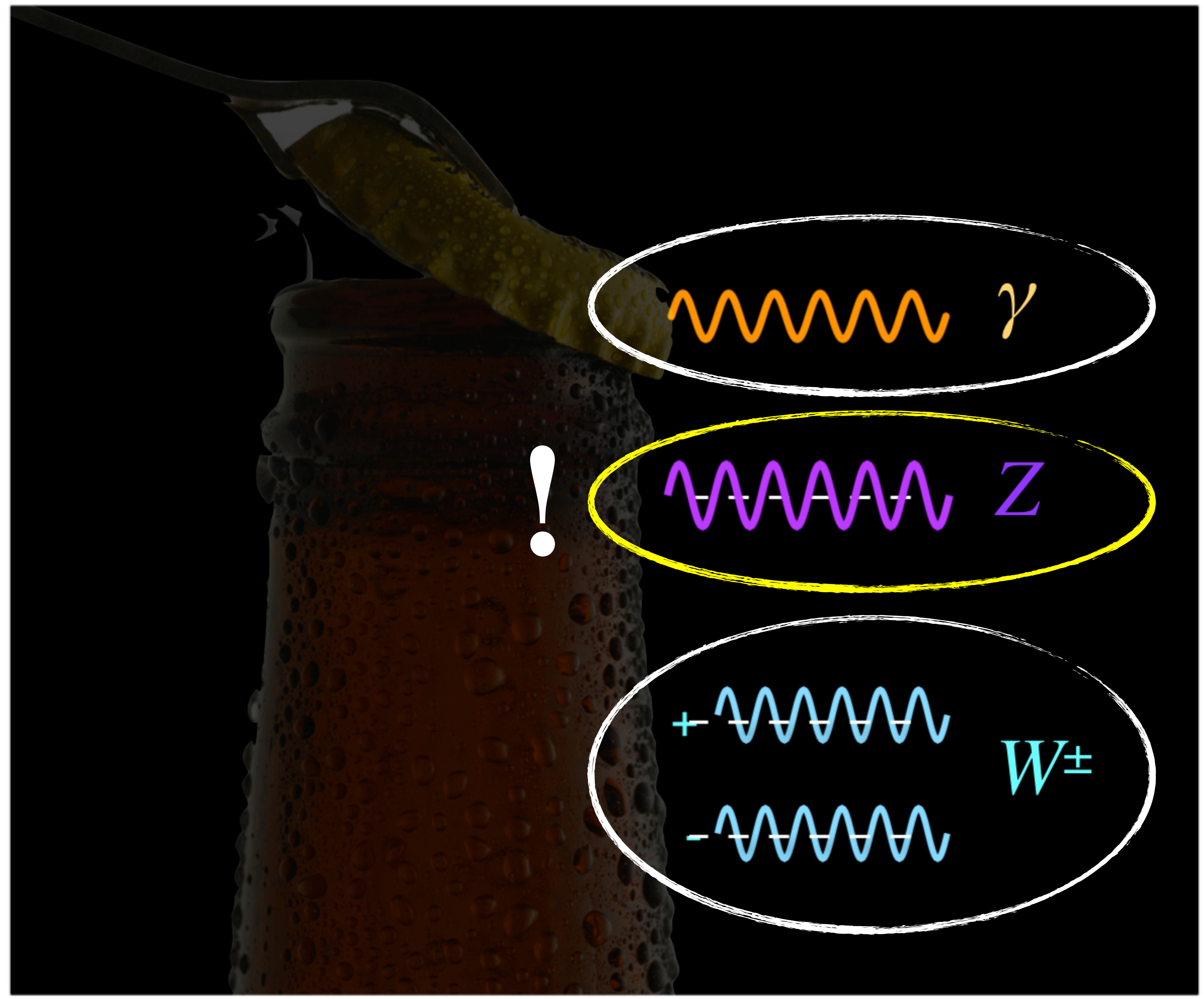
The remaining primordial scalar is the Higgs Field.

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:

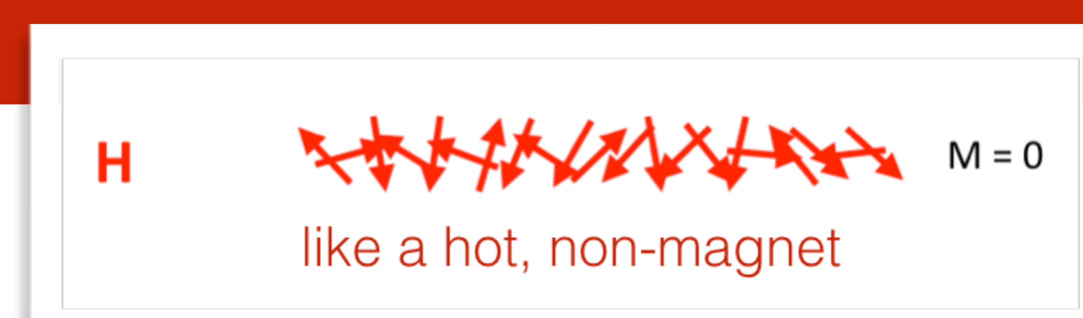
the electromagnetic and weak forces

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:	±1*e*
mass:	80.399 ± 0.023 GeV/c^2 = 80.4 p
spin:	1
category:	weak Vector Boson

particle: **Z Boson**

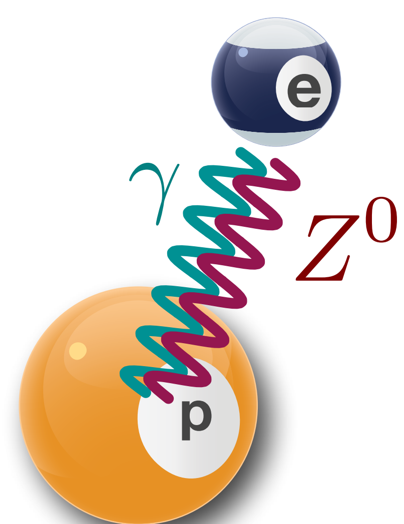
symbol:	Z
charge:	0
mass:	91.1876 ± 0.0021 GeV/c^2 = 91.2 p
spin:	1
category:	weak Vector Boson

Photon and Z always mix

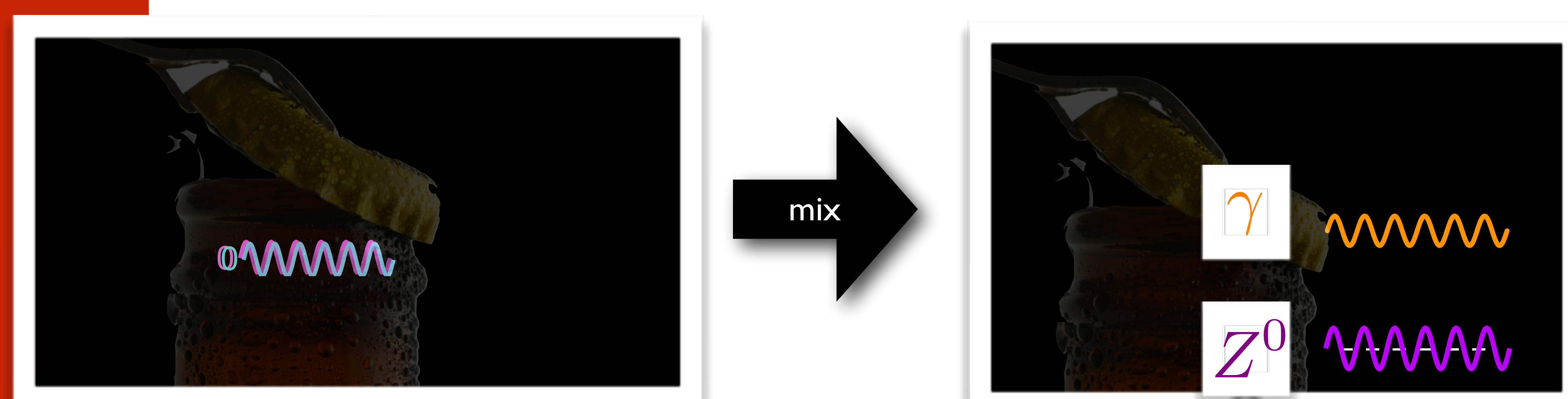
Z, very weakly

3. The Z Boson and the γ are intimately related

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

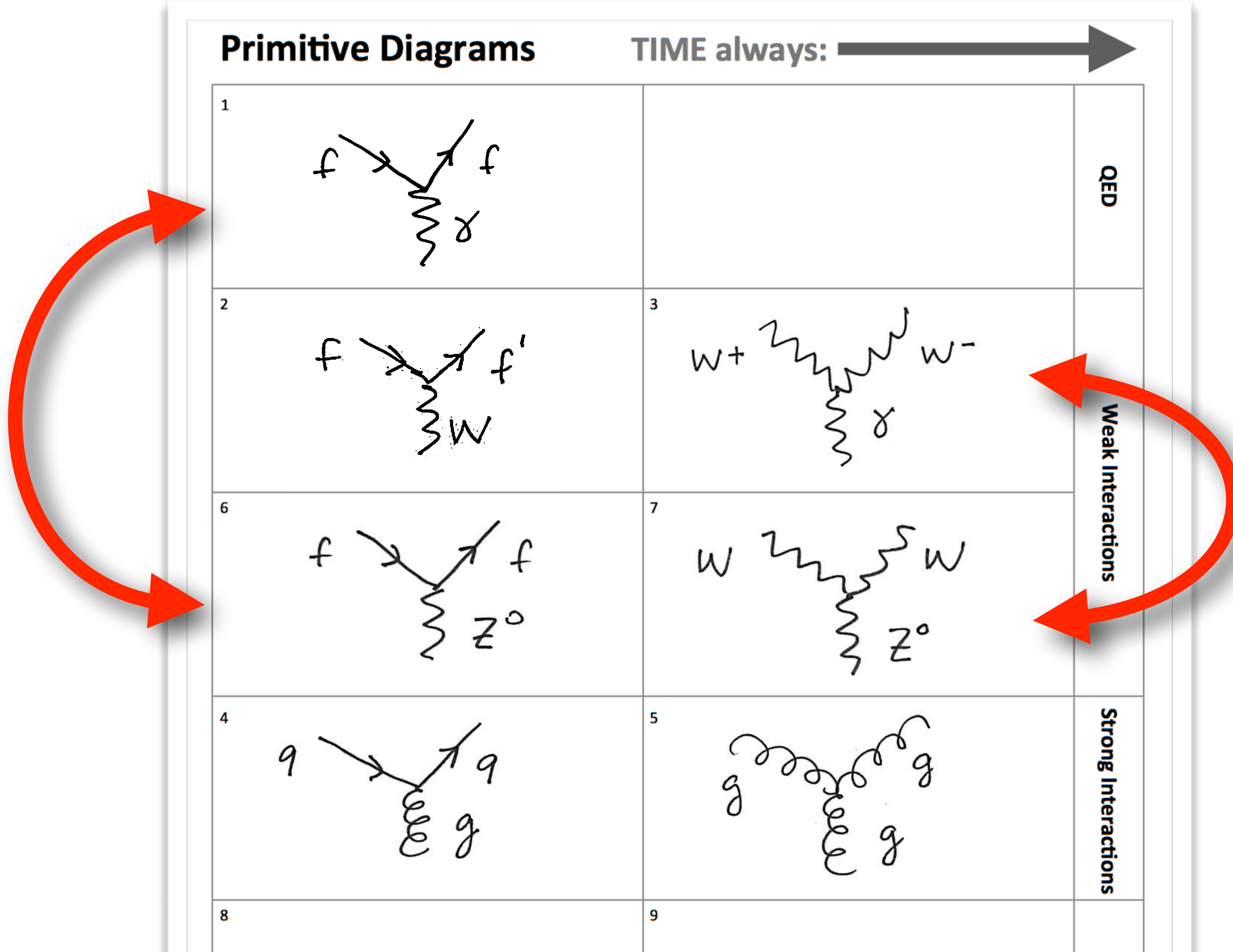


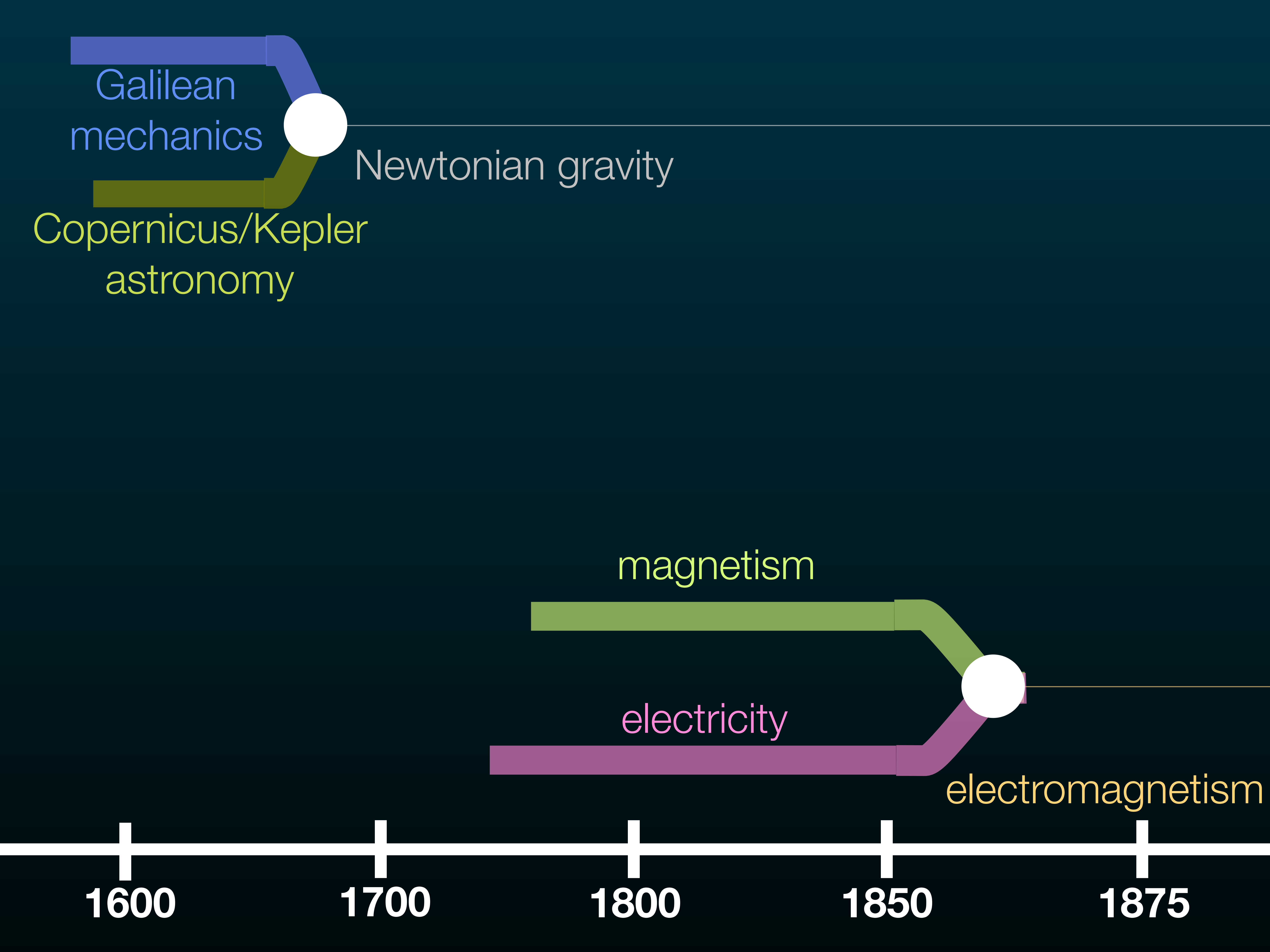
very delicate effects observed in atomic systems due to the Z Boson

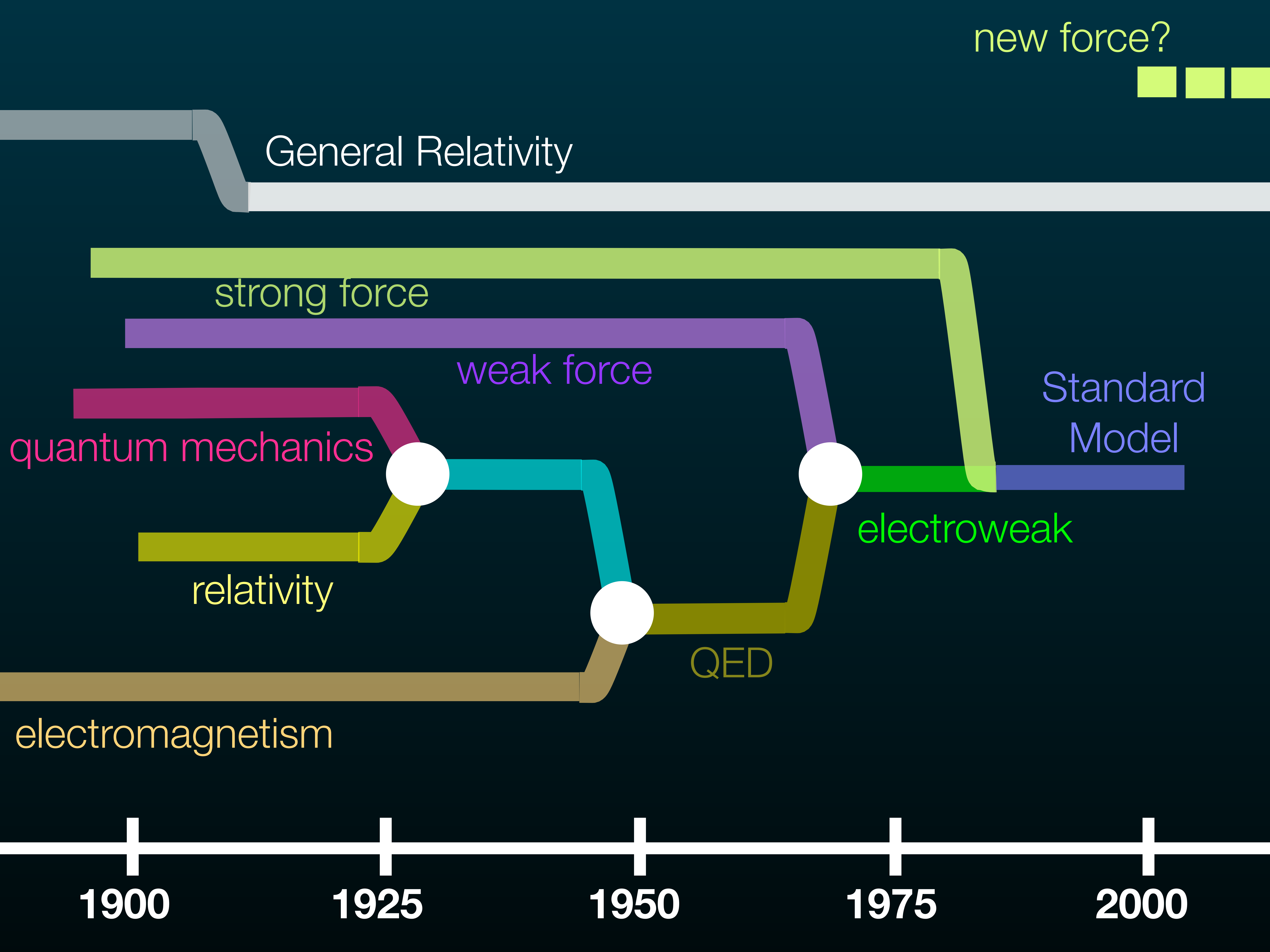


sixth and seventh entries into your

table of primitive diagrams




Galilean mechanics
Copernicus/Kepler astronomy
Newtonian gravity
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?

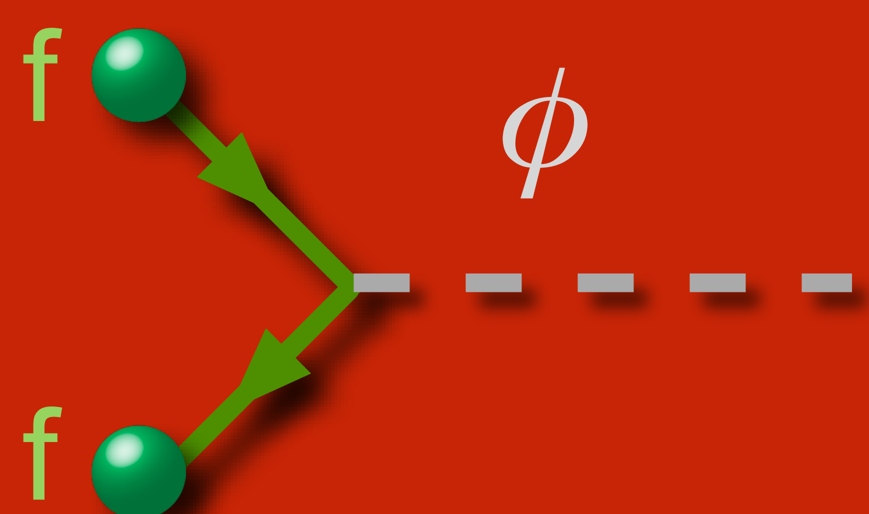
Is “mass” an intrinsic attribute? “nature”?

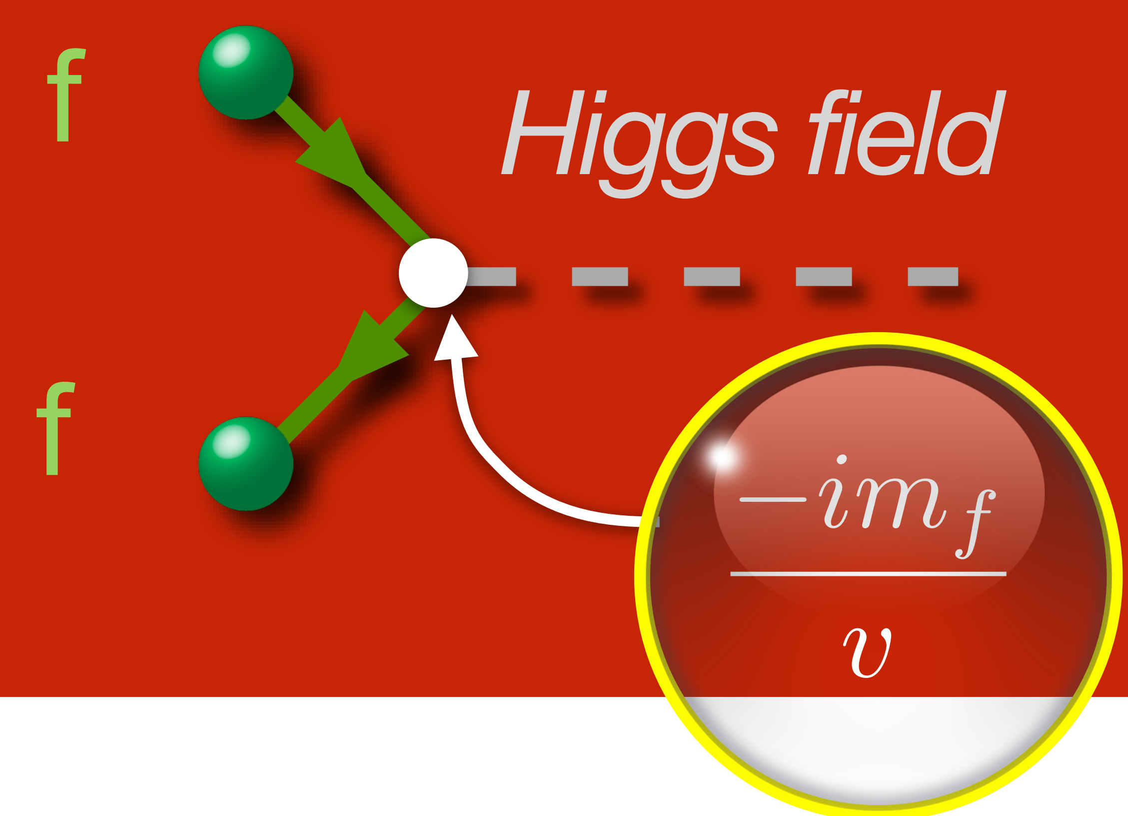
or

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
Nº5
PARTICLE
PHYSICIST
FABIOLA
GIANOTTI



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The New York Times

Wednesday, July 4, 2012 Last Update: 4:00 AM ET

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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

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

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%

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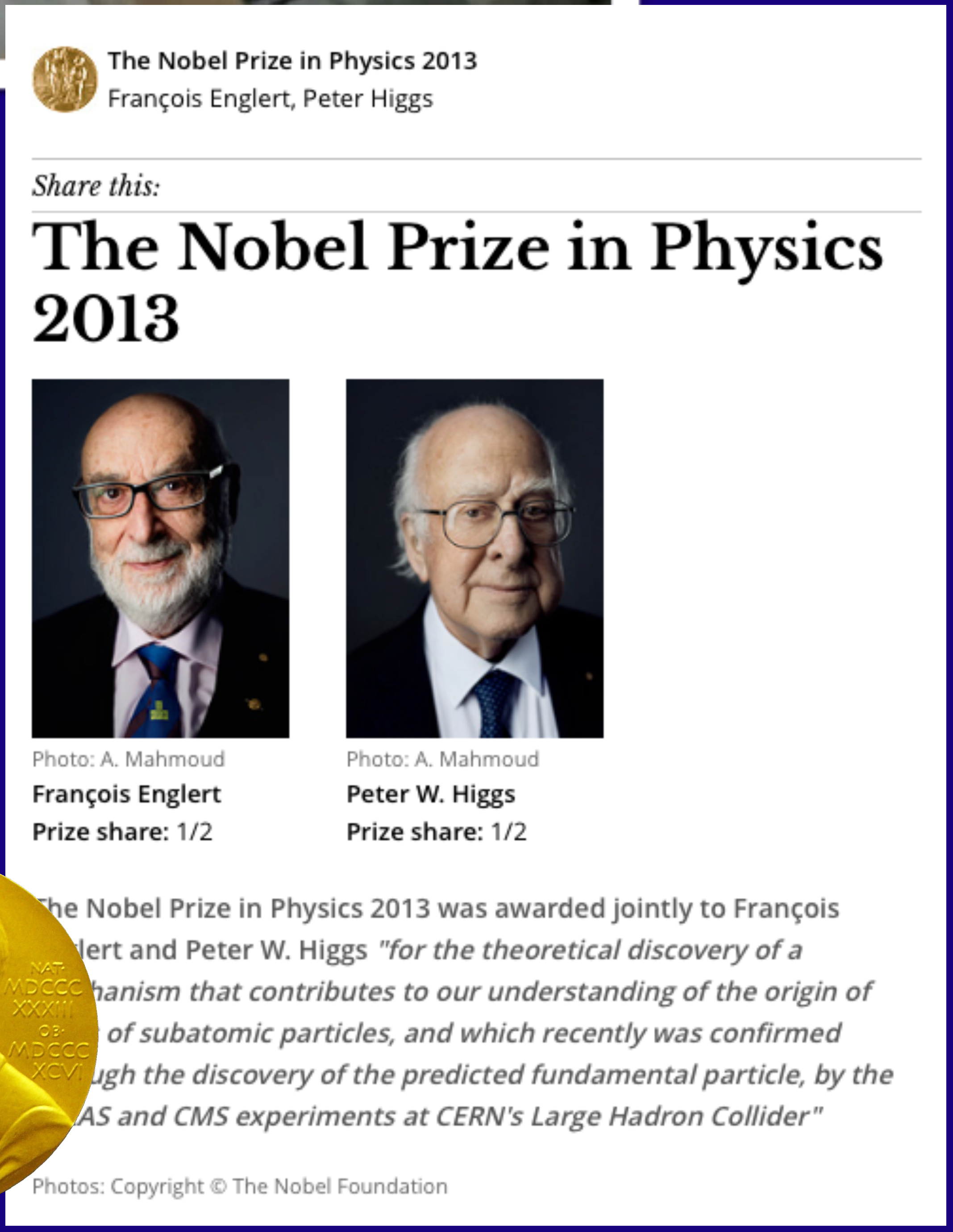
From insight comes inspiration.


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

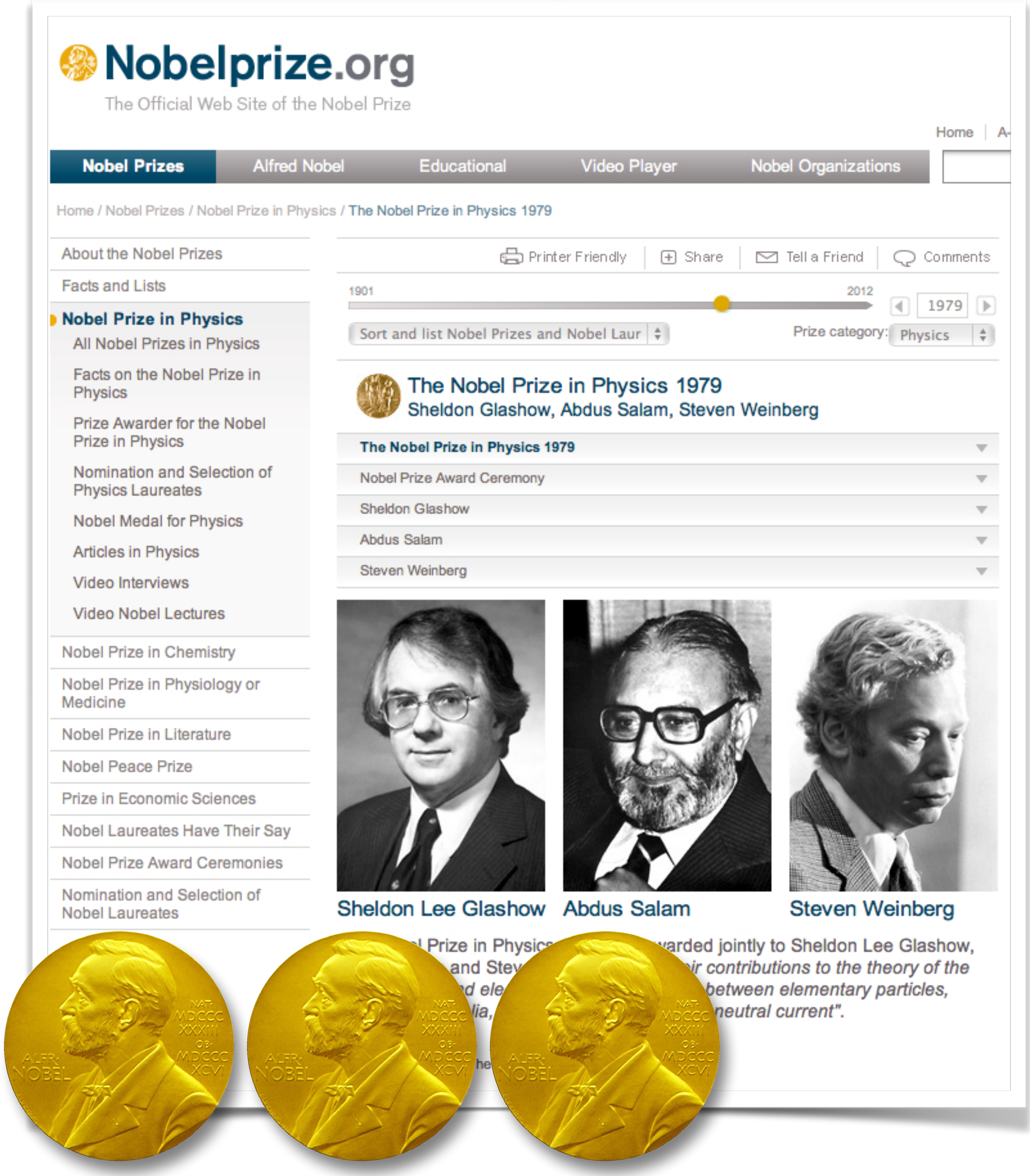
✔ 3. This *Z* Boson and the γ are intimately related

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

✔ 4. The Higgs Boson should exist

Weinberg, Salam, and Glashow

1979

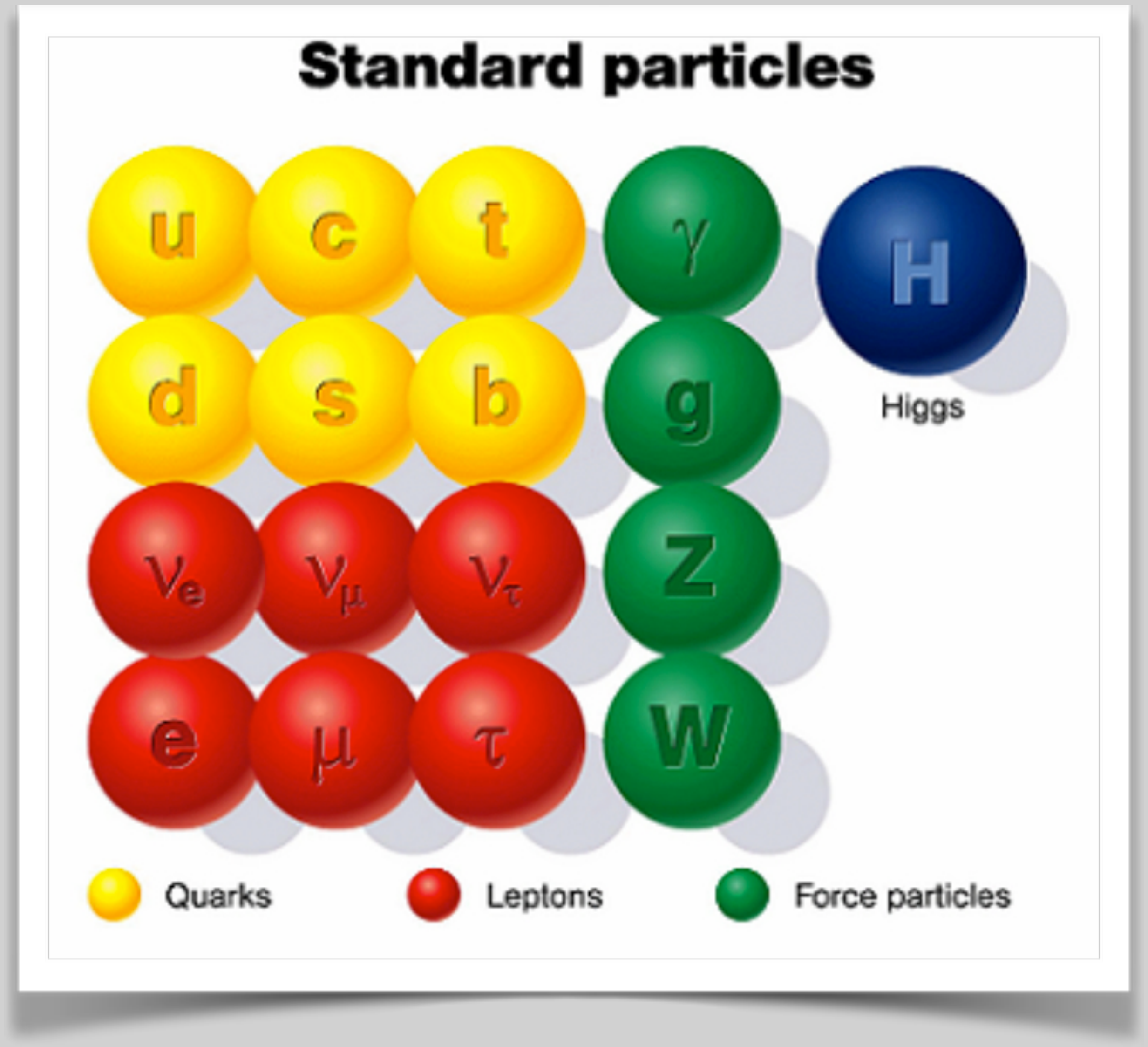


the particle players

and

the "substrate"

Our "Periodic Table"

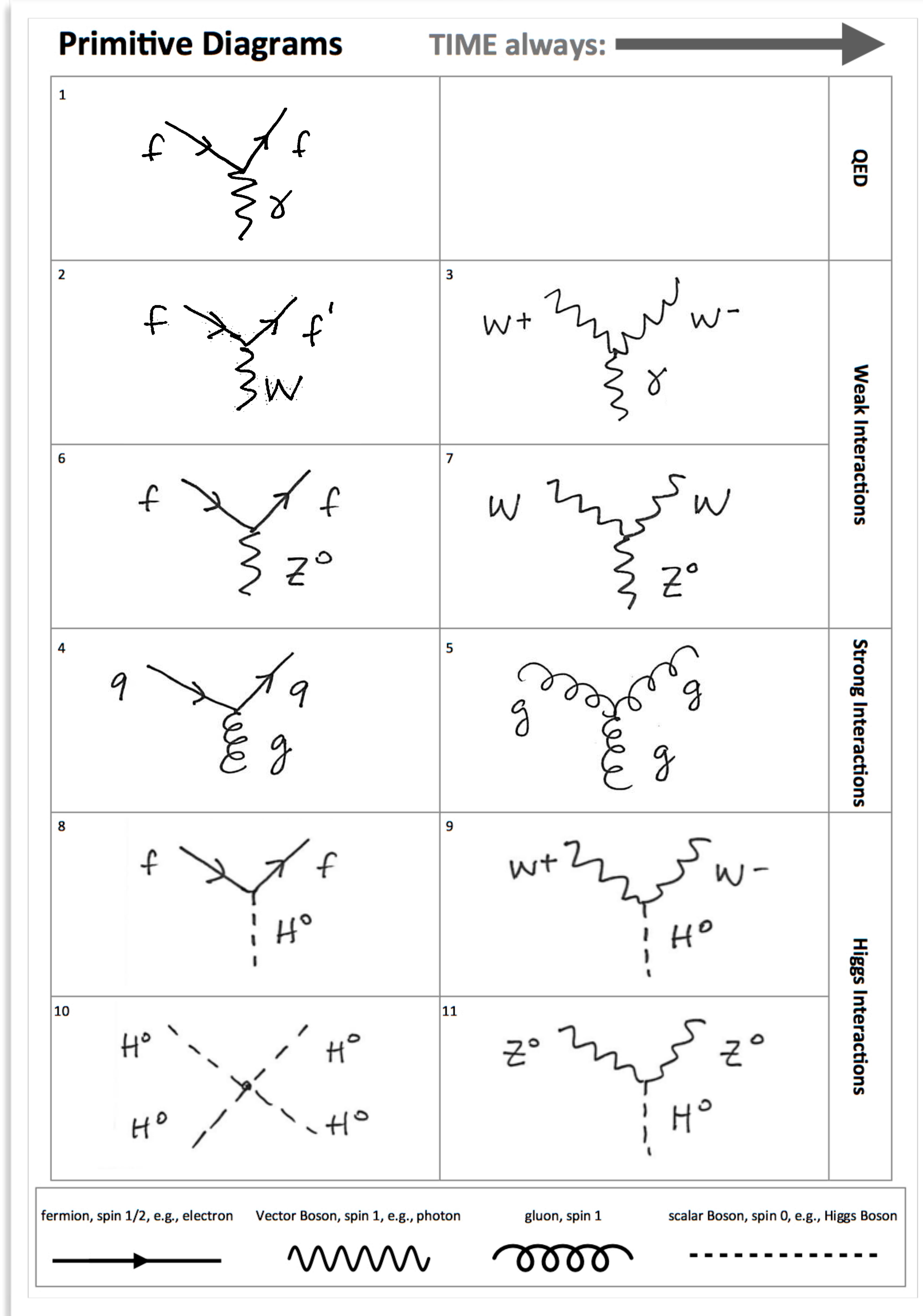


like any particle,

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?

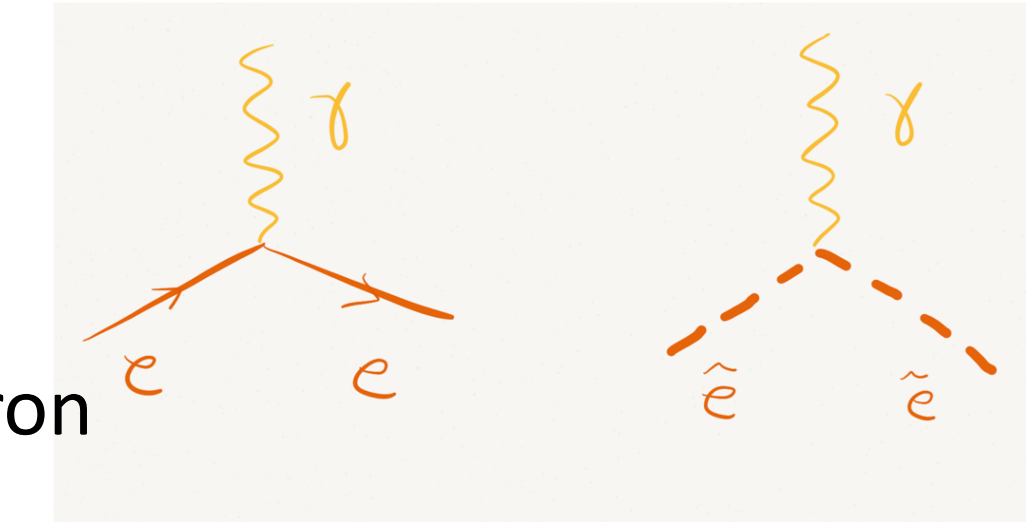
what the heck

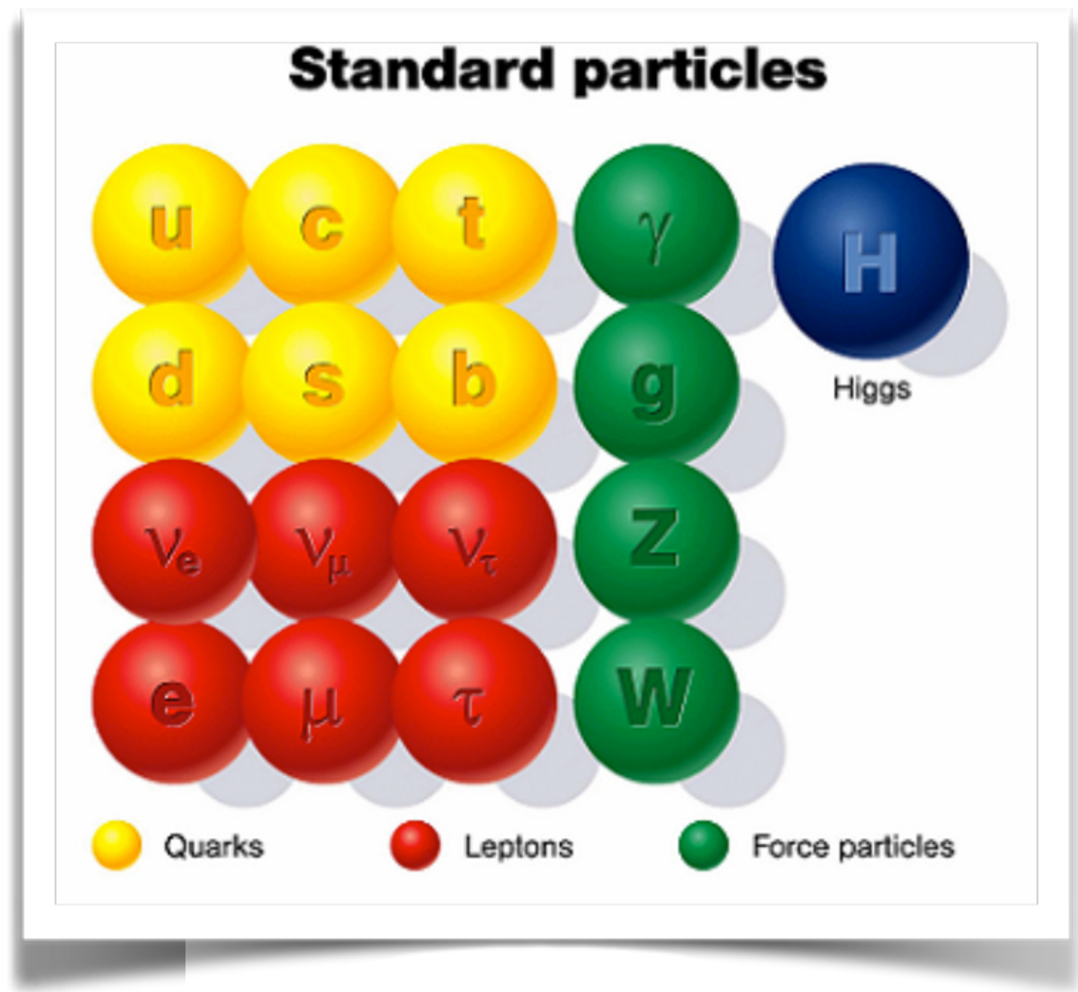
is dark matter?

watch the off-line movie:

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

the more pleasing

electron  "selectron"



extension of the Standard Model

"supersymmetry"

every "Standard Model Particle"

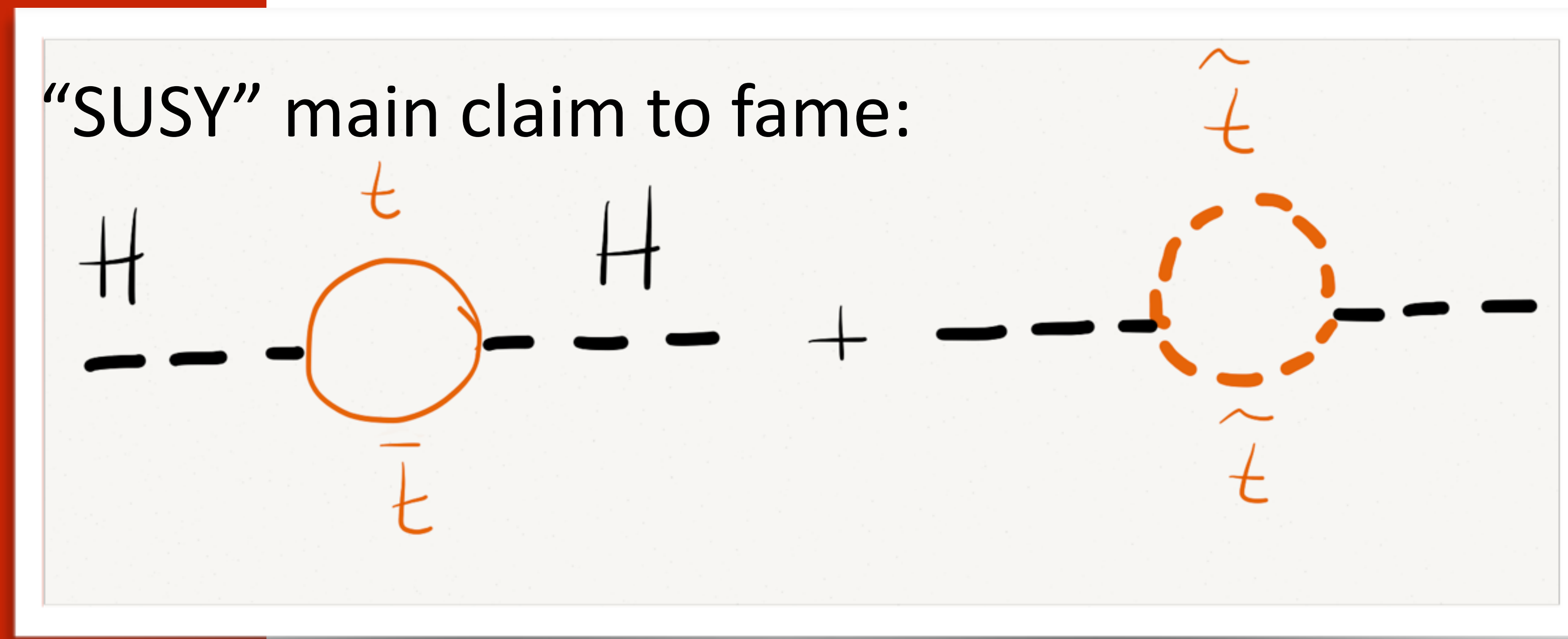
has a super-partner

presumably much heavier

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

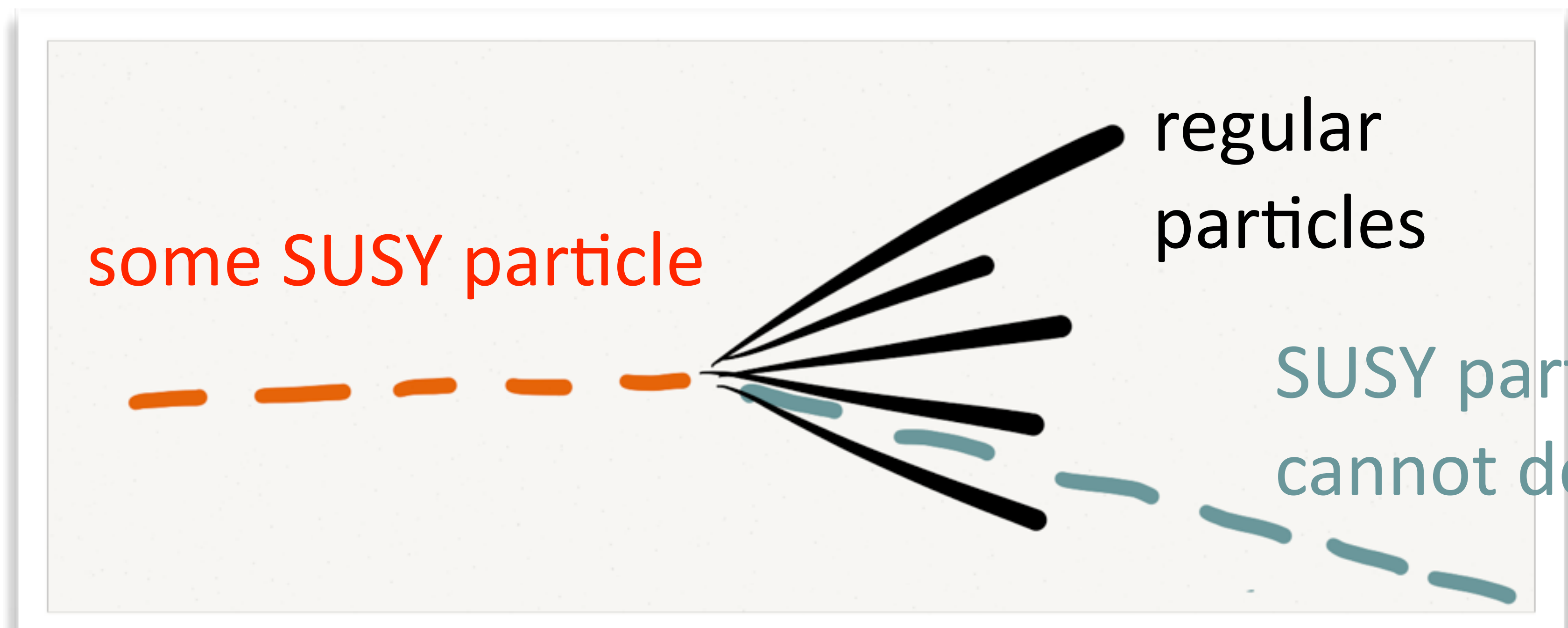
intriguing

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

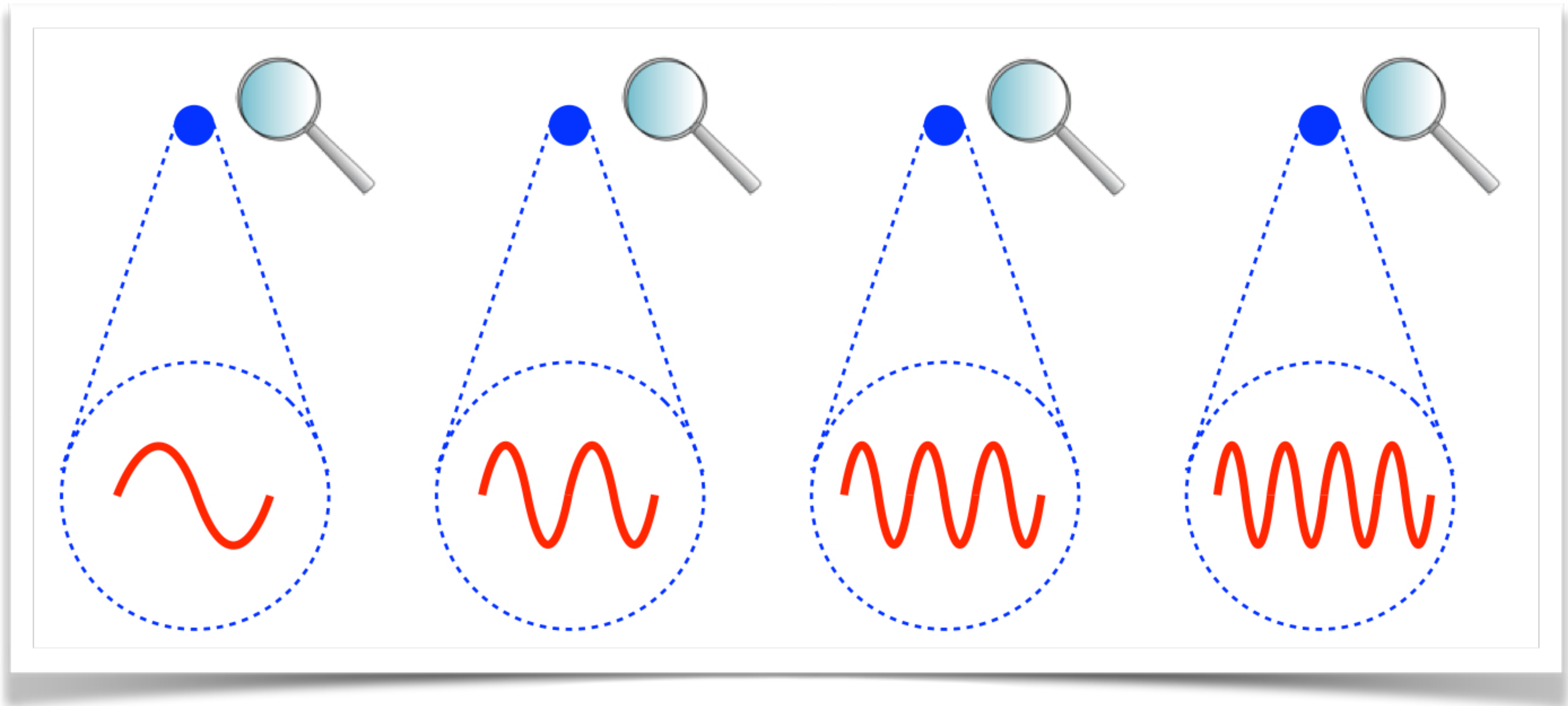
composite Higgs

composite quarks and leptons

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

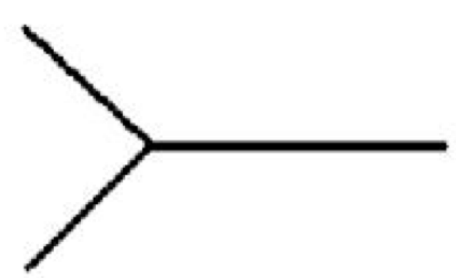
The "infinities" in Relativistic Quantum Field Theory are related to extrapolation in spacetime to zero, x, y, z, = 0

Suppose there is a minimum length in Nature?

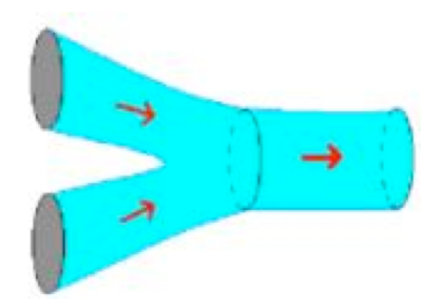


each wavelength...a different – e x t e n d e d – particle.

Plus: get a gravity and the graviton for free!

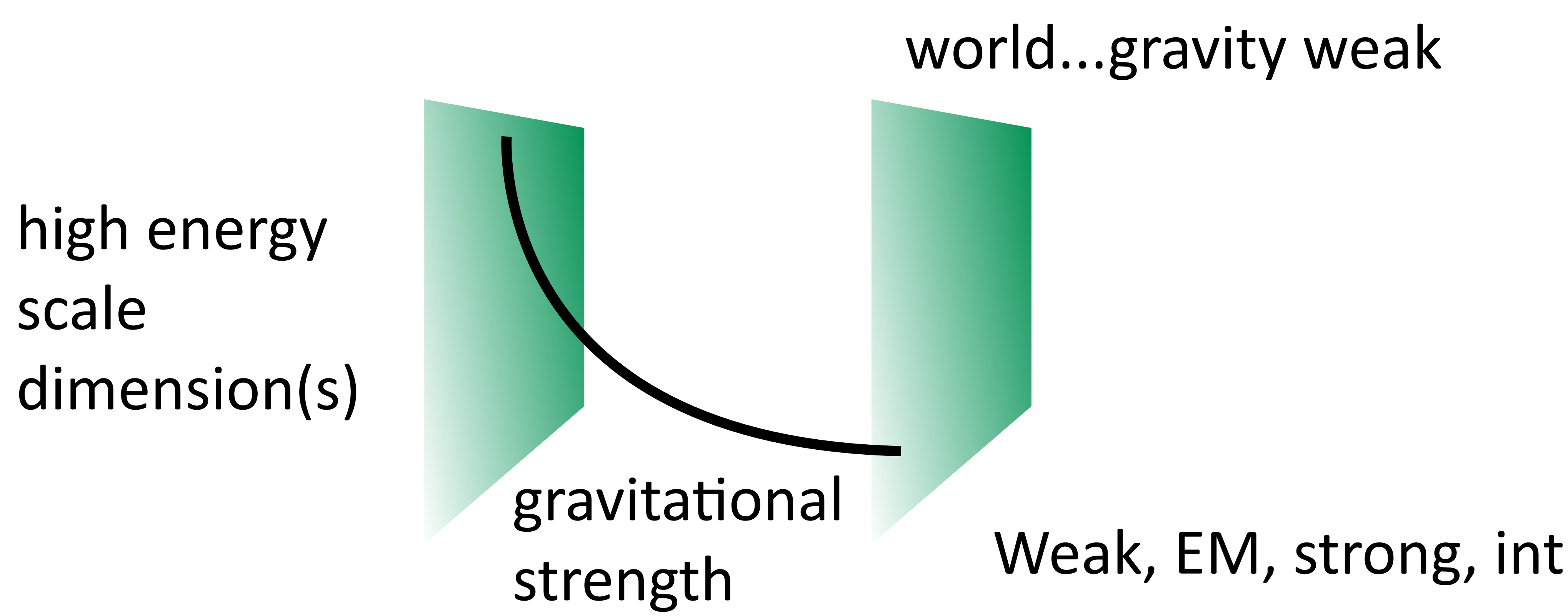


Point particle interaction



String interaction

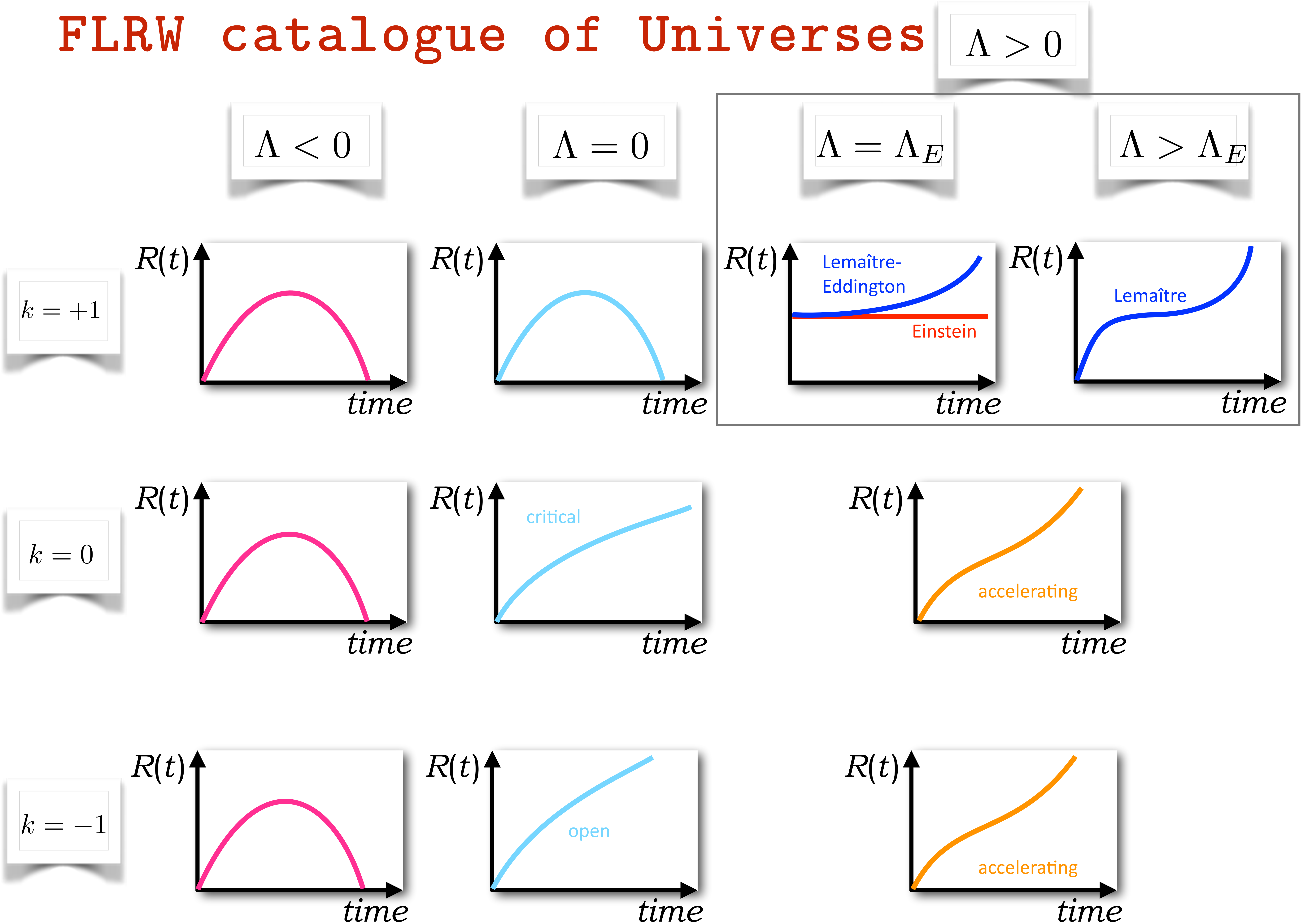
....up to 10 space and 1 time dimensions.



pretty:

Cosmology 5

FLRW catalogue of Universes



~~two~~ three 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

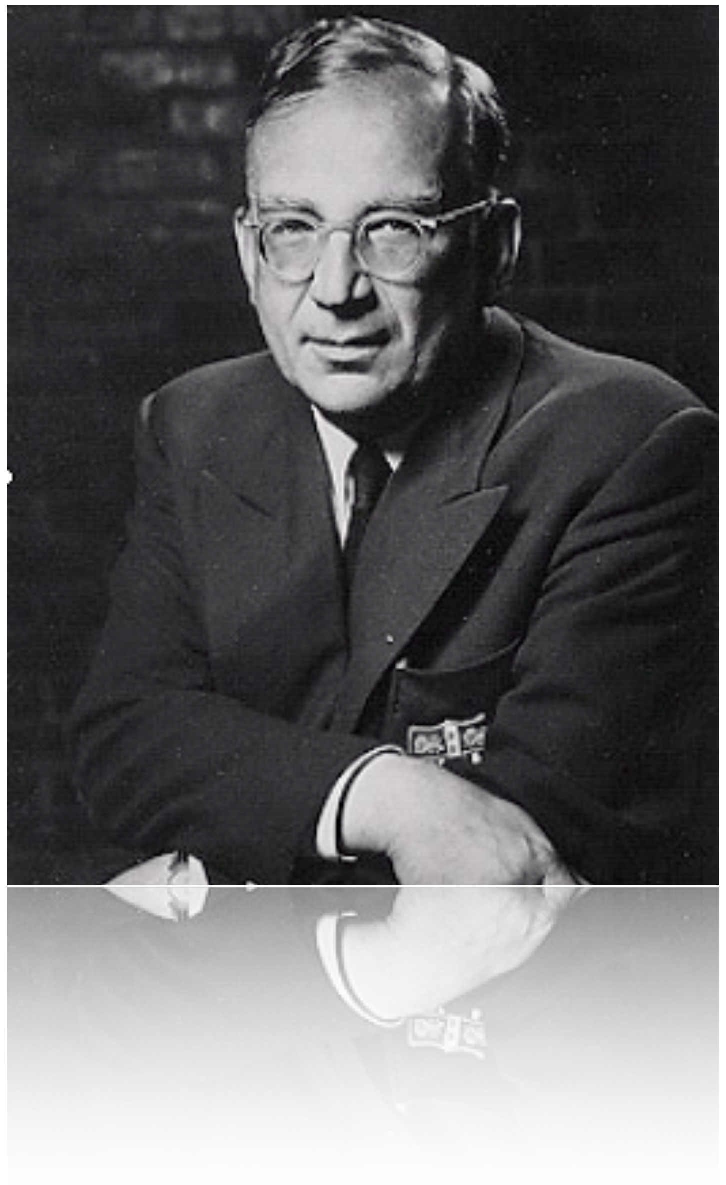
George Gamow

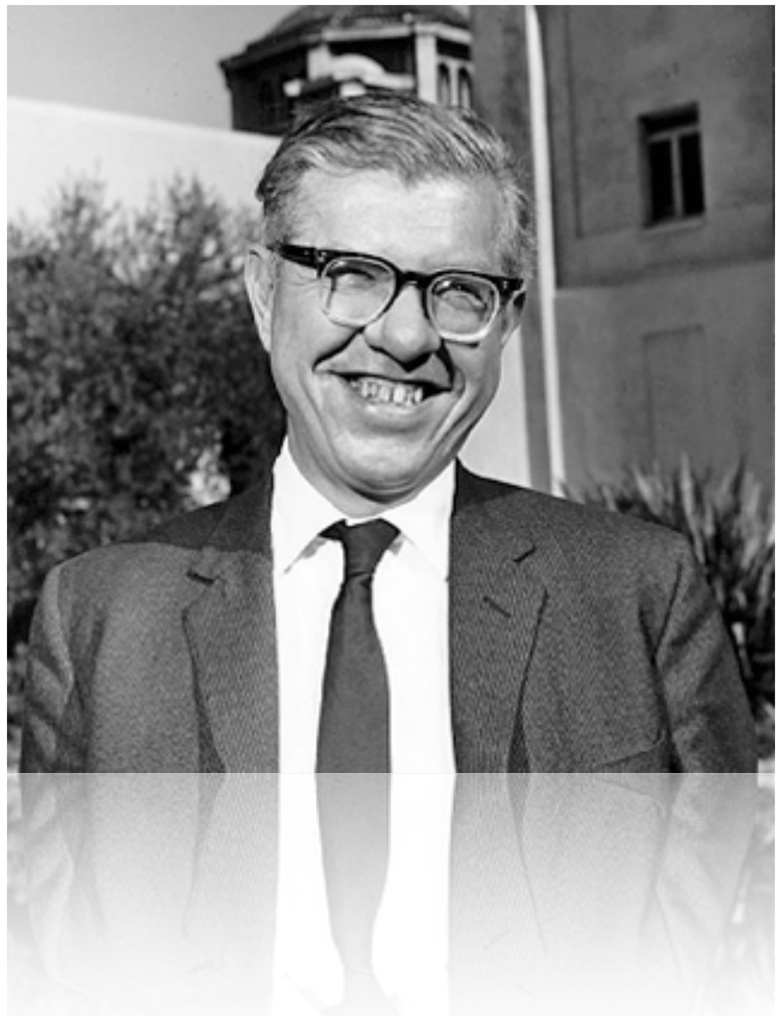
universe born

hot primordial soup

Fred Hoyle

steady state model, continuous creation of matter.

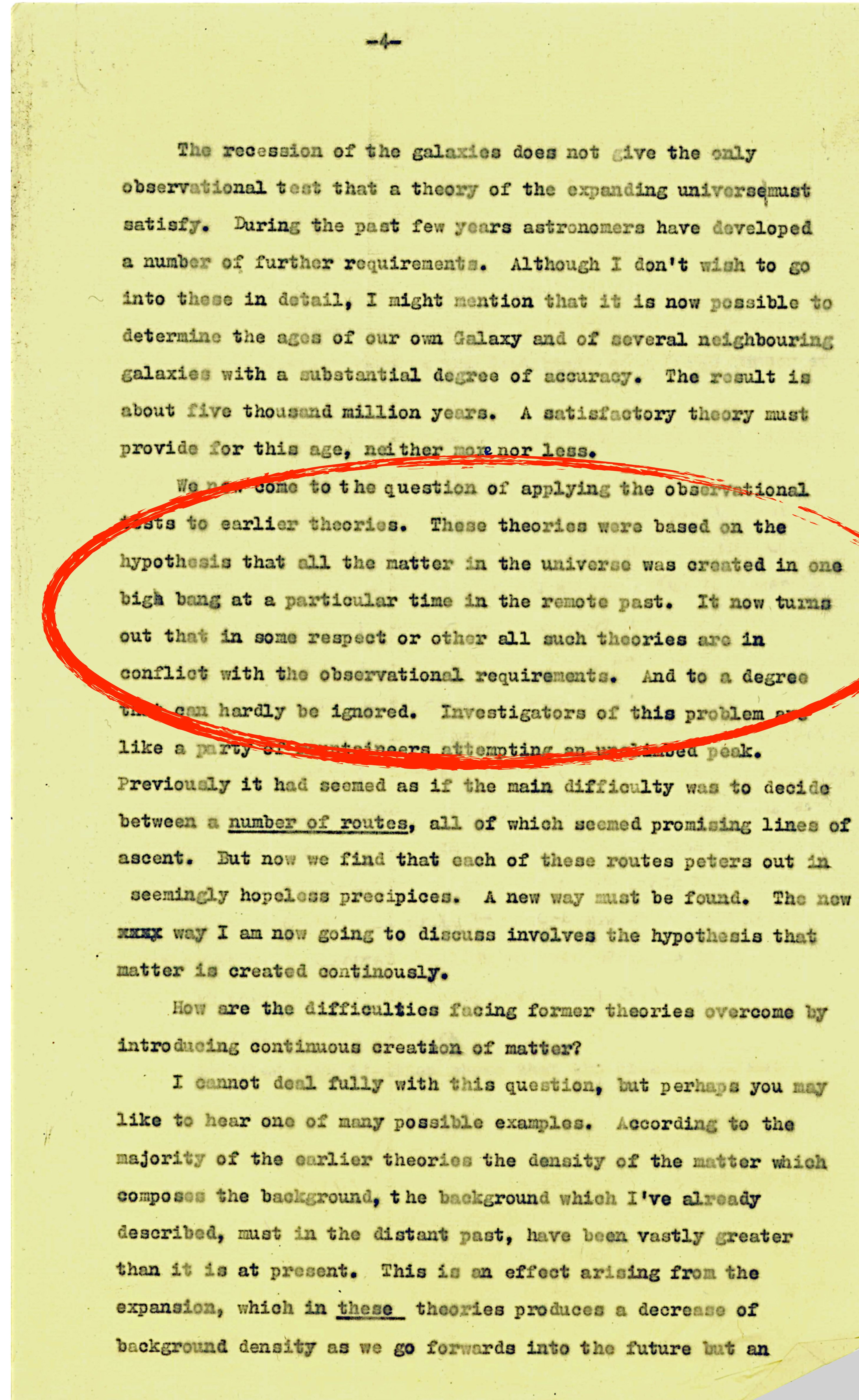




To Hoyle: the Big Bang implied a creator.

"Big Bang" was coined by Fred Hoyle in a

BBC radio broadcast for the general public in 1948



-4-

The recession of the galaxies does not give the only observational test that a theory of the expanding universe must 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 big 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

“

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...

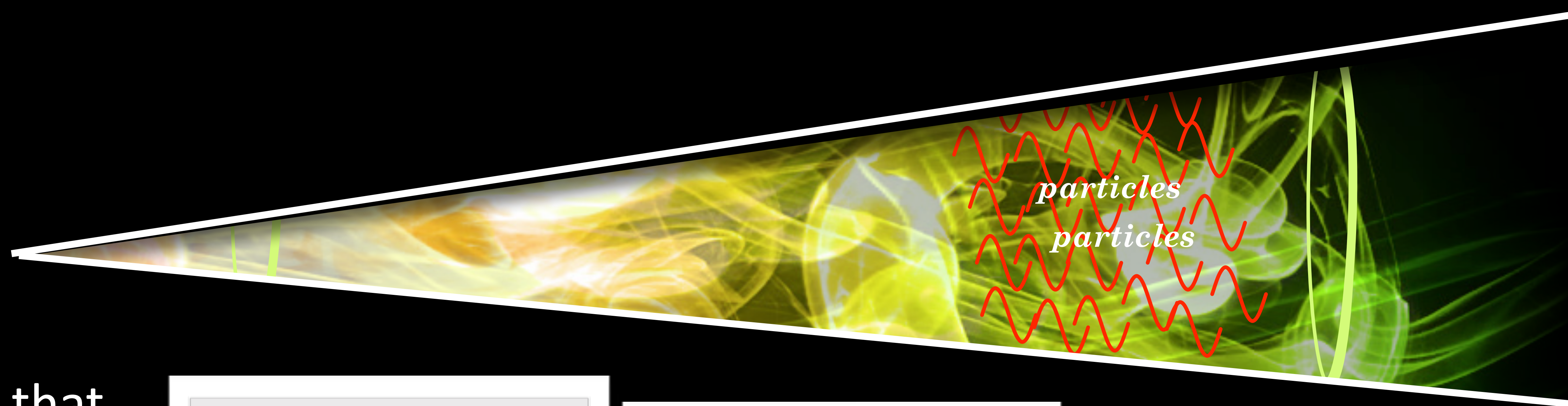
Fred Hoyle
Home is Where the Wind Blows 1994.

Sorry, Fred.

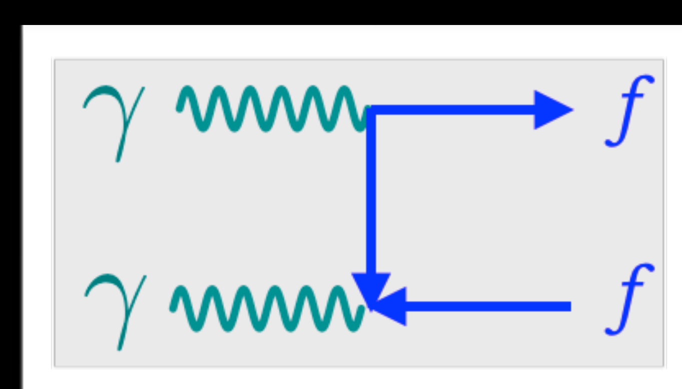
Here’s the current understanding of the life of a Universe:

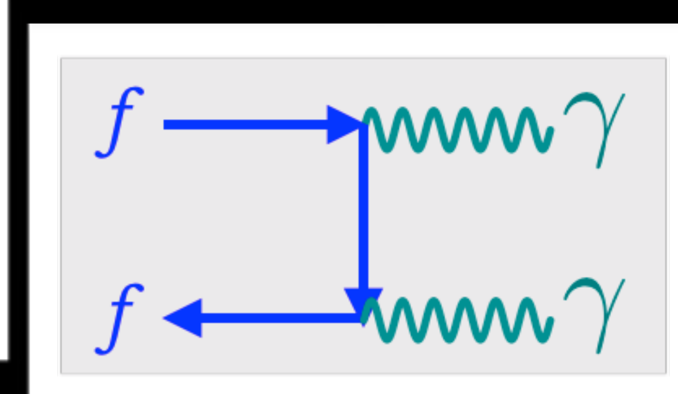
evolving in time and temperature.

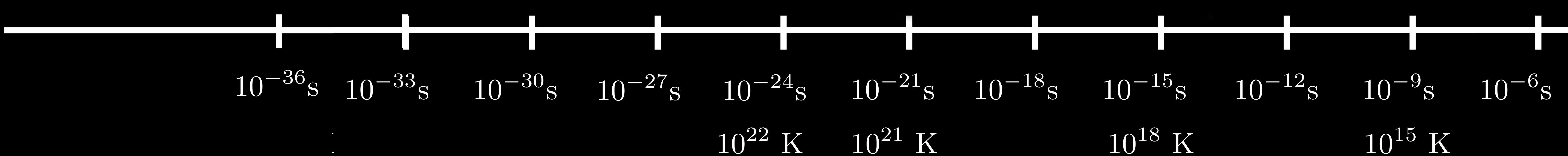
elementary particle epoch



presumed that processes are in equilibrium







There is a limit

Beyond which there is no physics

at the current time

Planck Time = 5.4 x 10^{-44} s

Planck Length = 1.6 x 10^{-35} m

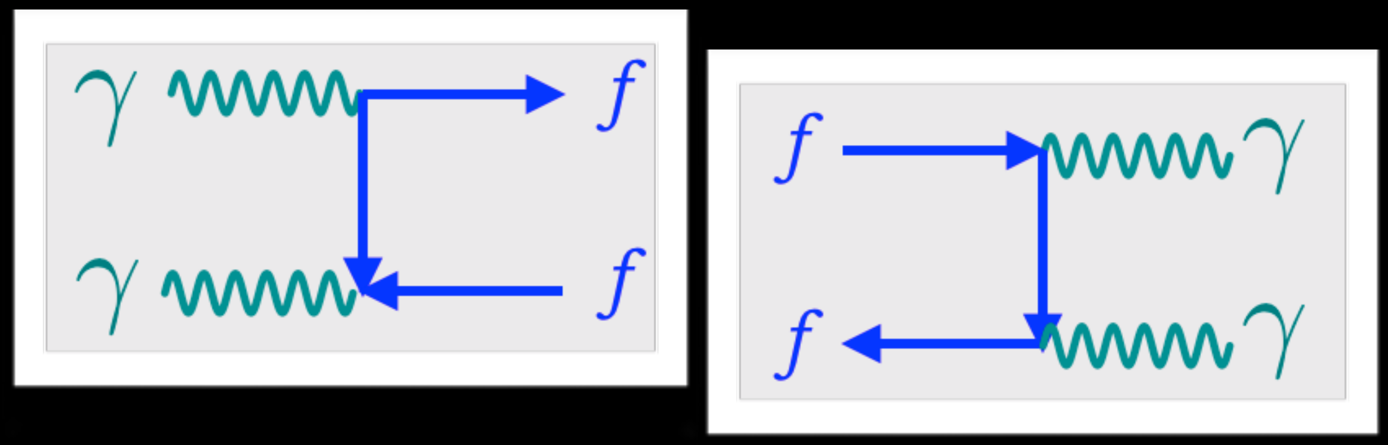
} need a quantum theory of gravity

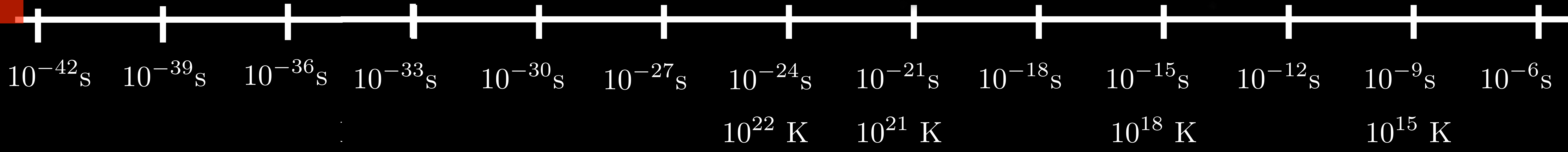
Or a physics with a built-in minimum length in Nature...String Theory.

elementary particle epoch

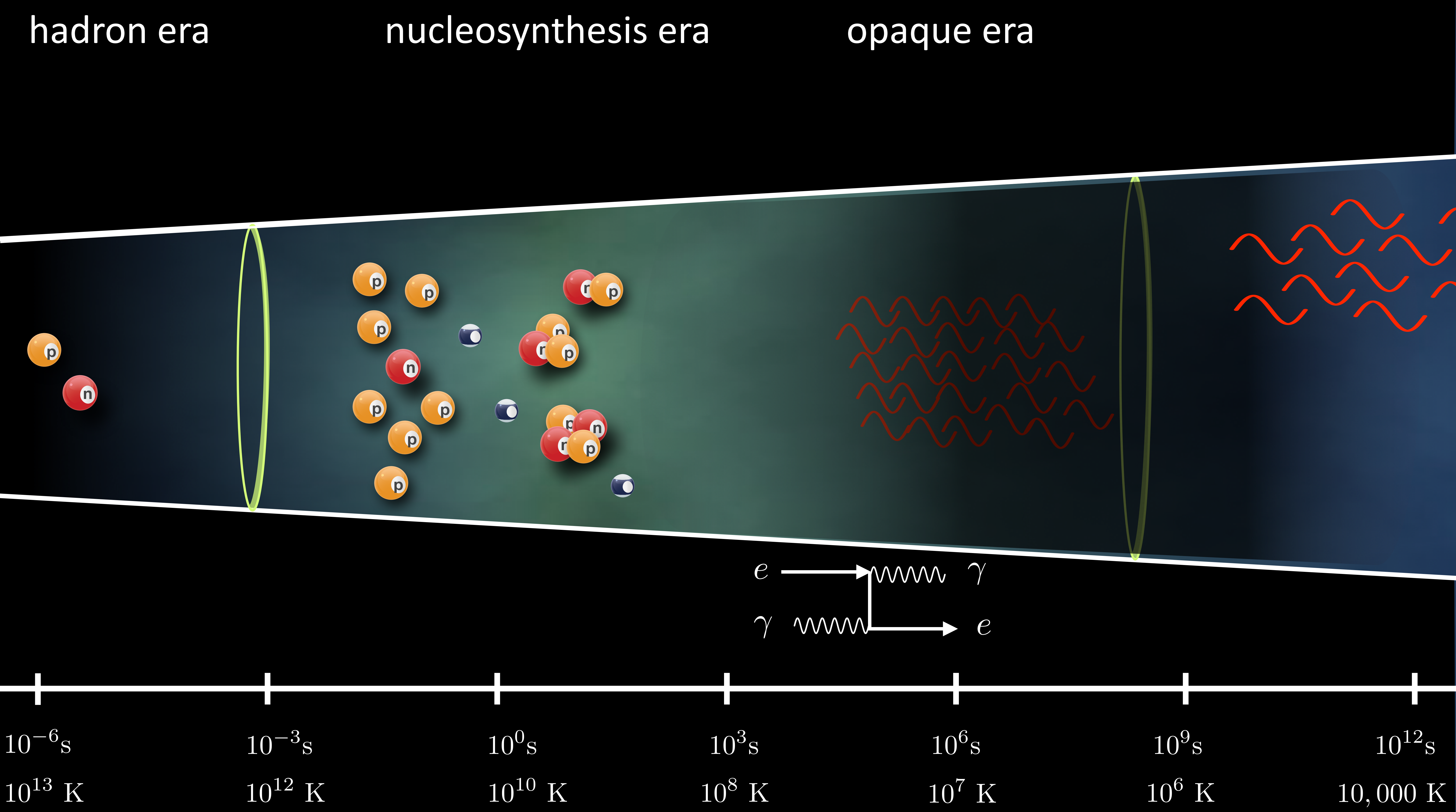
"Quantum Foam"

presumed that processes are in equilibrium

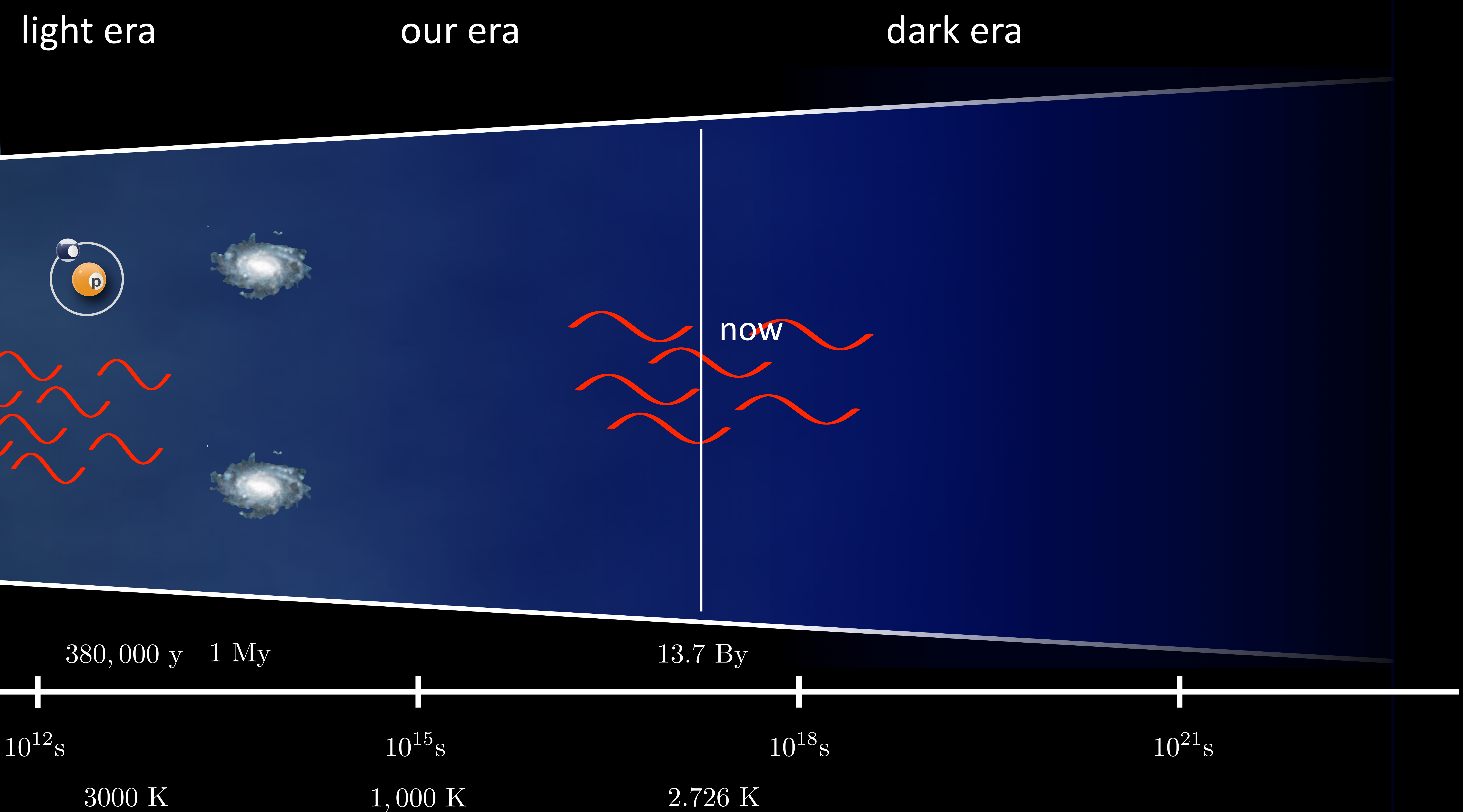




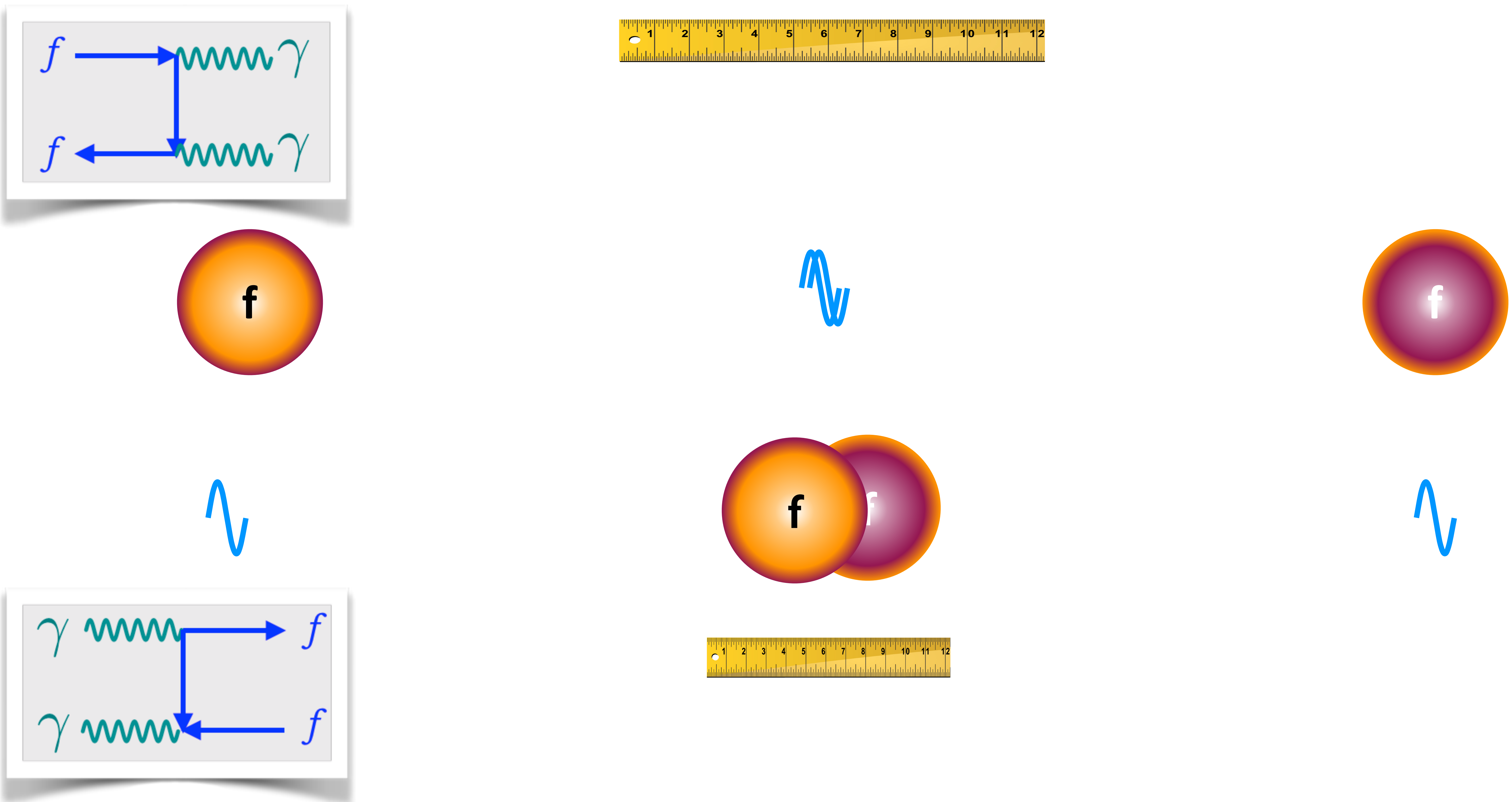
n u c l e o n   e p o c h



g a l a c t i c   e p o c h



prior to 3 minutes: balance between radiation and particles.



Early moments: short wavelength photons = high frequency photons = high energy photons
lots of mc^2 available–can make heavy particles

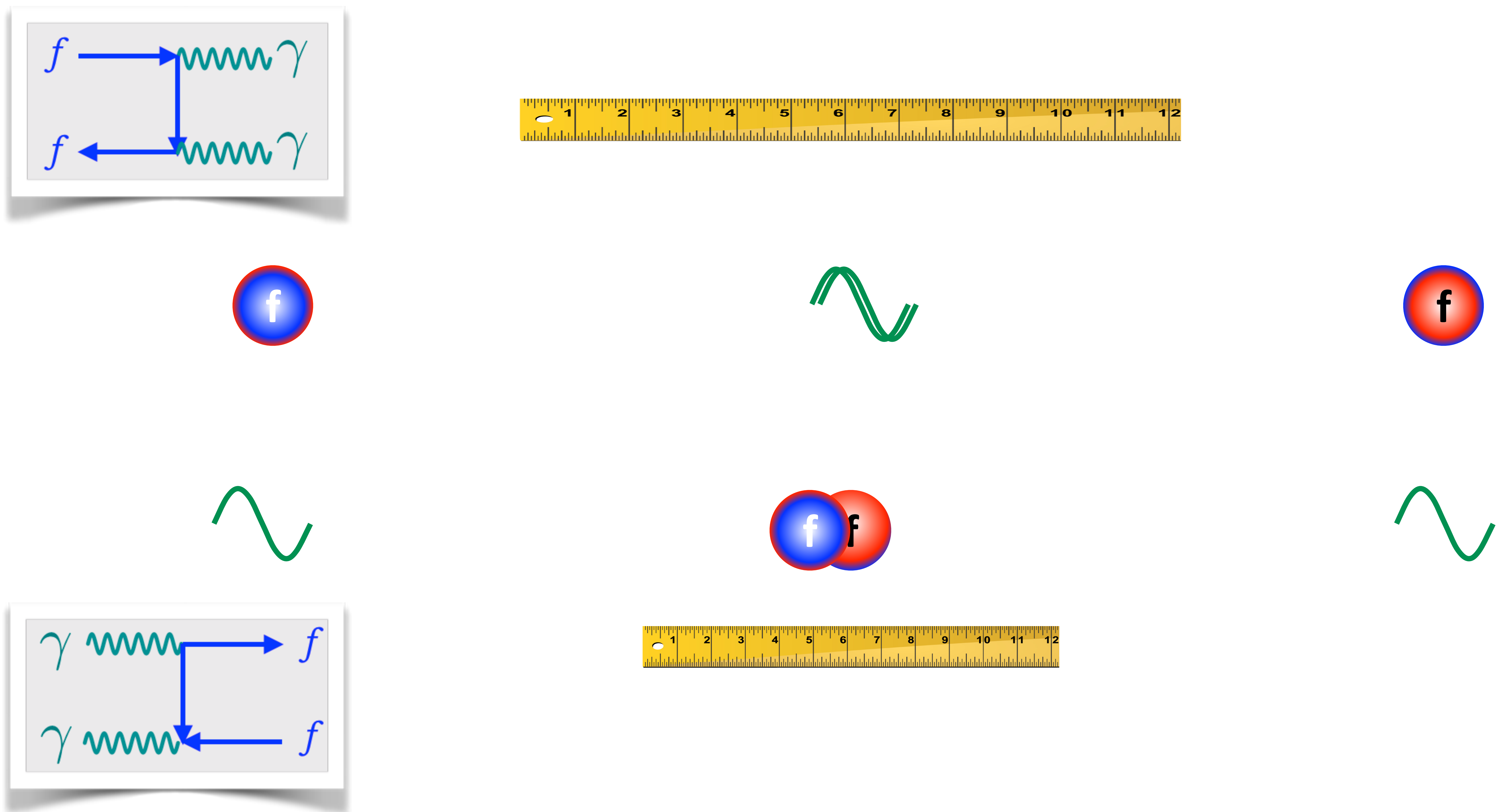
prior to 3 minutes: balance between radiation and particles.

Later moments:

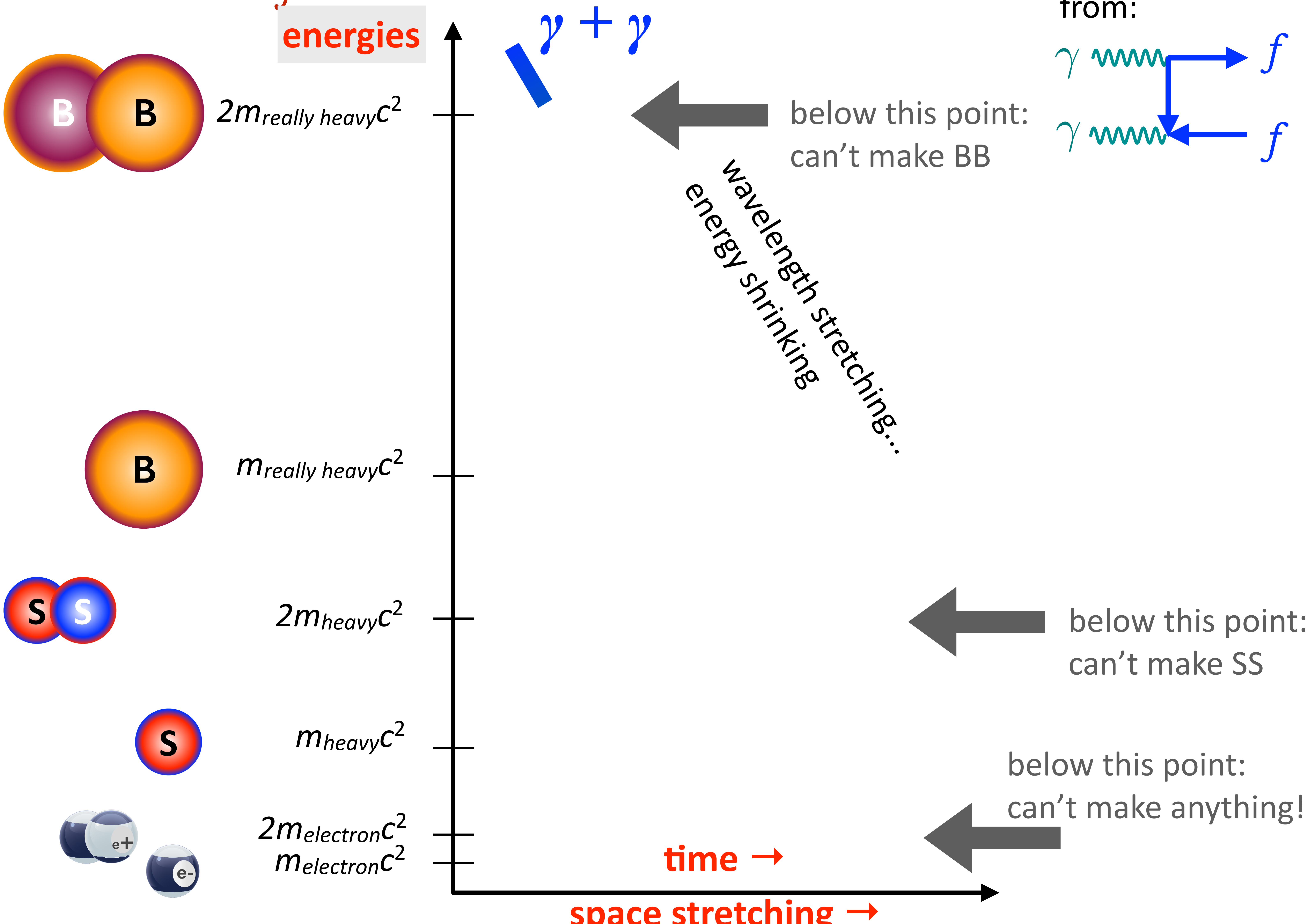
spacetime has stretched!

longer wavelength, lower frequency = less high energy photons

less mc^2 available–can't make heaviest particles

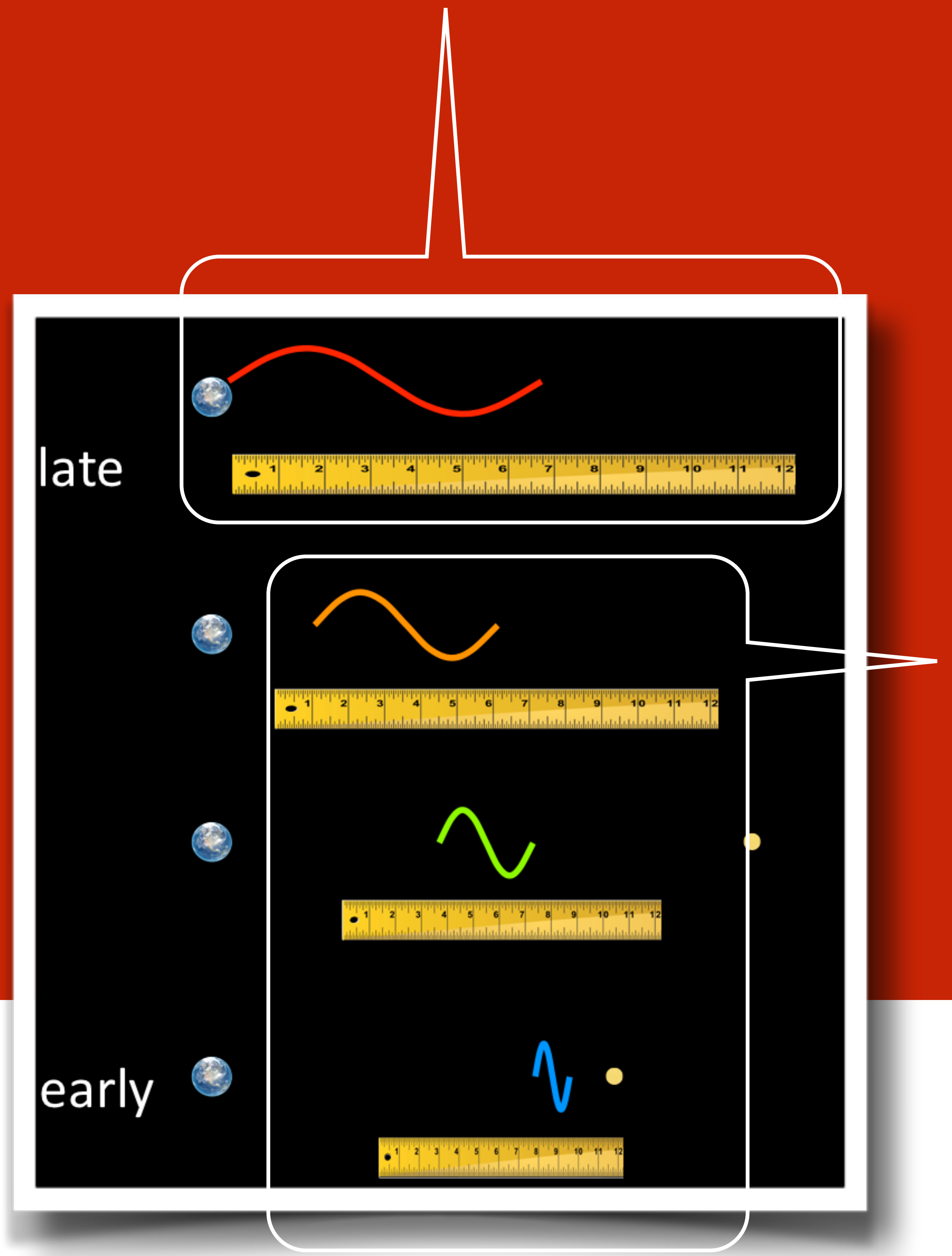


heavy species "freeze out": pairs cannot be created any more



at some point, they are too low in energy to do anything...they just hang around.
about 70,000 years after BB

remember



many high energy photons: create new particles, ionize atoms, disintegrate nuclei

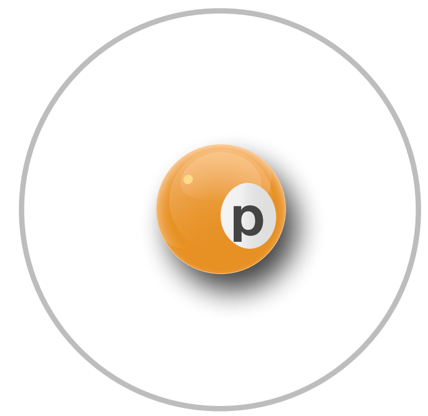
there is a magic point

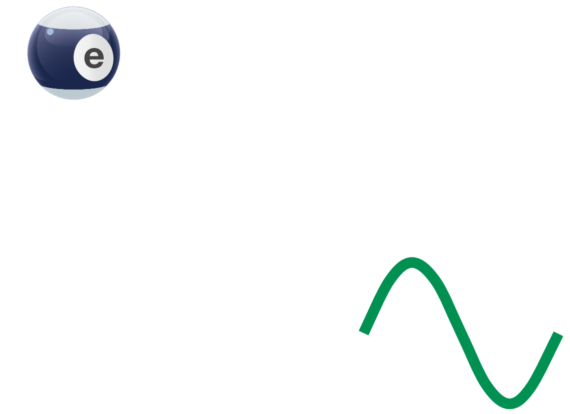
at which atoms can start to form

"recombination"

which is an odd name, since there wasn't a "combination" yet!

After protons, neutrons, and electrons are stable...



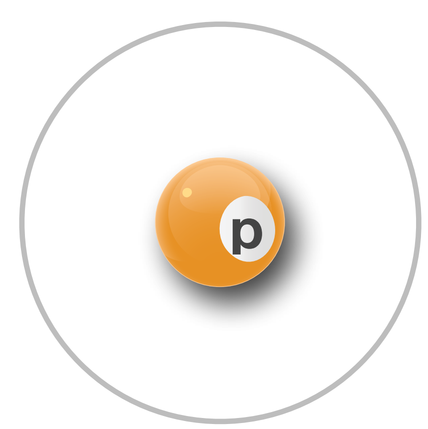


left-over photons ionize the baby Hydrogen atoms

The Universe consists of: a **plasma**...charged particles, unbound...freely moving around. Opaque.

At one point...about $10^{12\text{-}13}$ s - 370,000 y:

the photons don't have 13.6 eV of energy



Bingo.
We have H atoms (and He)

There's nothing else for the photons to do!

The Universe has suddenly become transparent to photons