

**The sub-atomic world :
from the laboratory to
the edge of the Universe**

Understanding what makes up the world

The ingredients

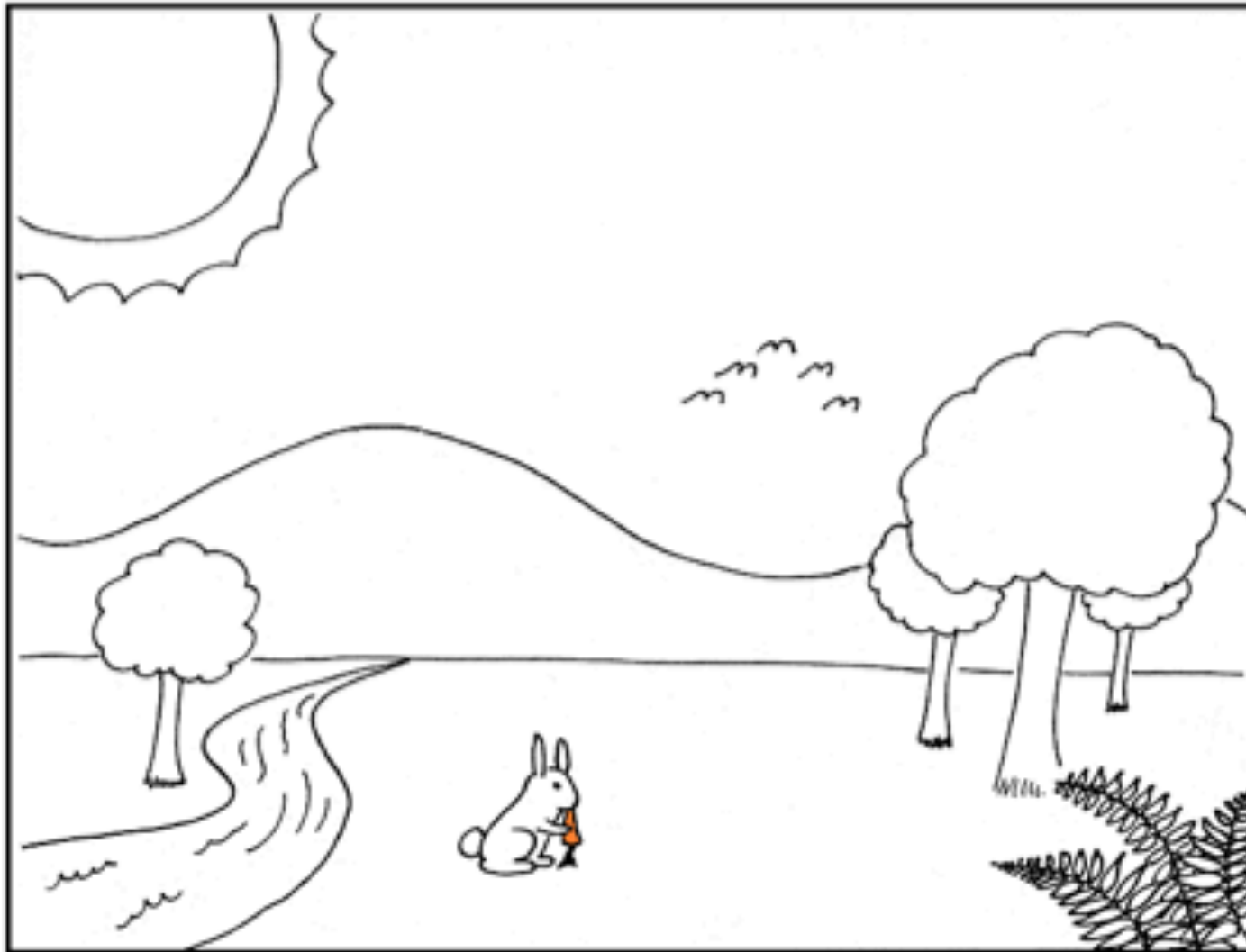


The physical laws



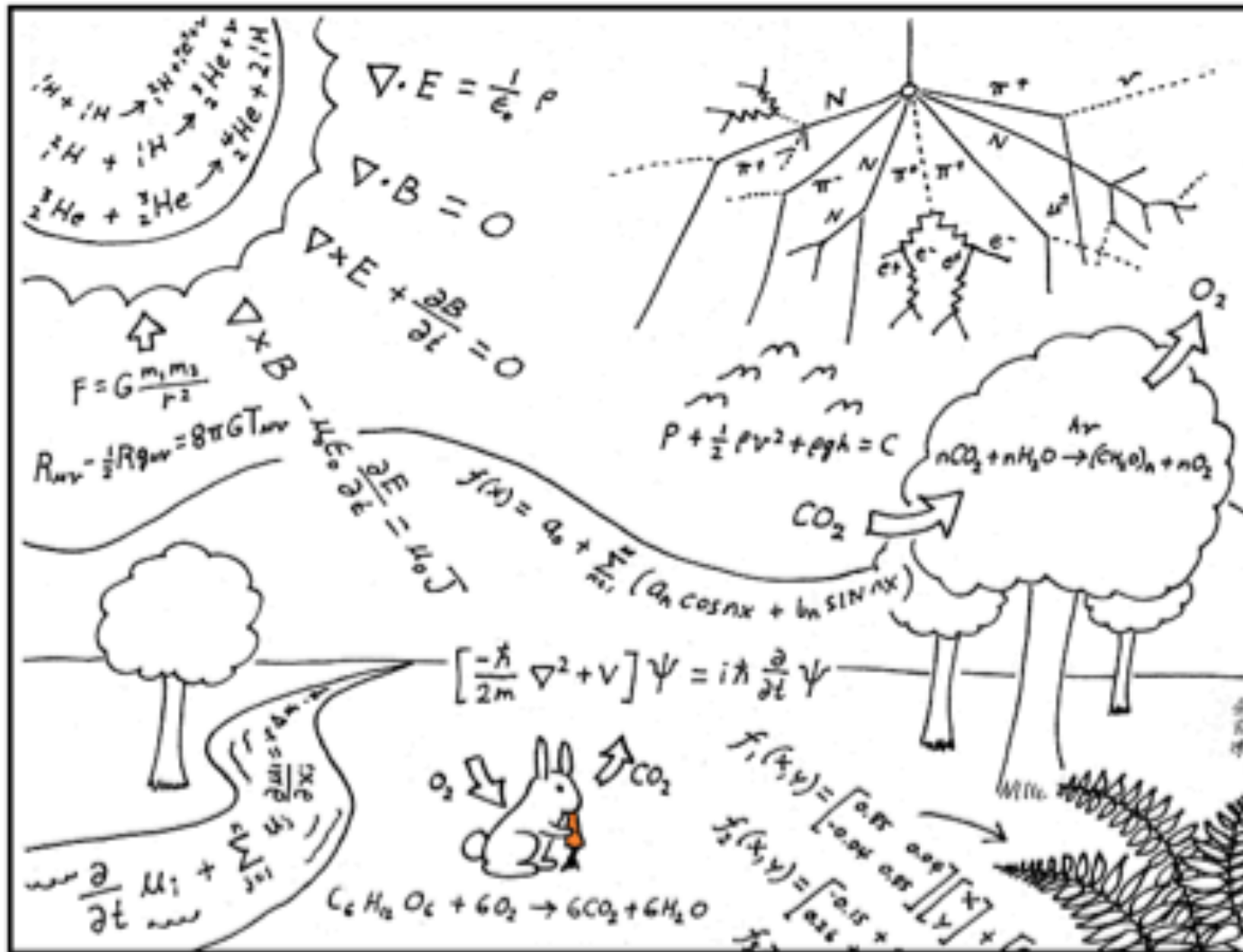
Understanding what makes up the world

How does a physicist view the world?



Understanding what makes up the world

How does a physicist view the world?



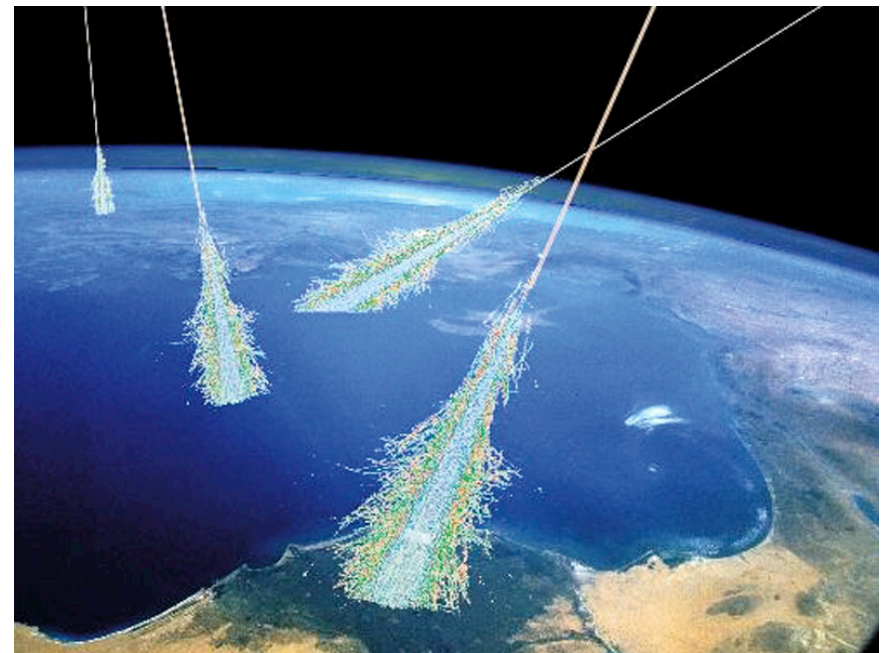
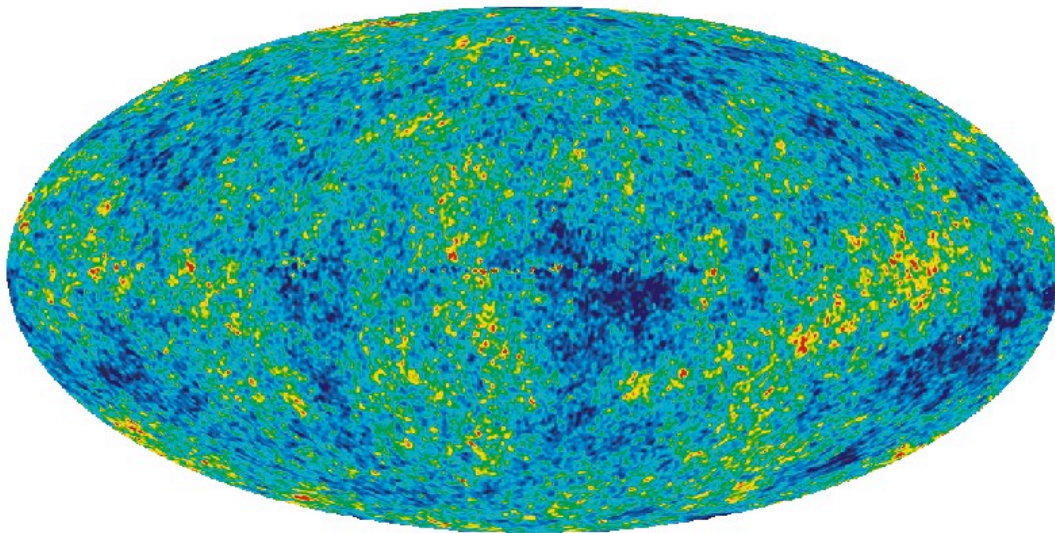
Understanding what makes up the world

How does a physicist view the world?

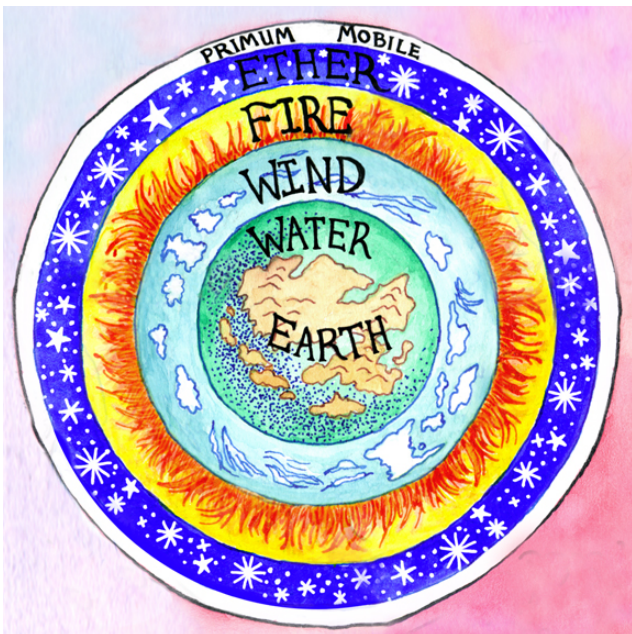


Understanding what makes up the world

The world we cannot see :
neutrinos ,
microwave background ,
cosmic rays



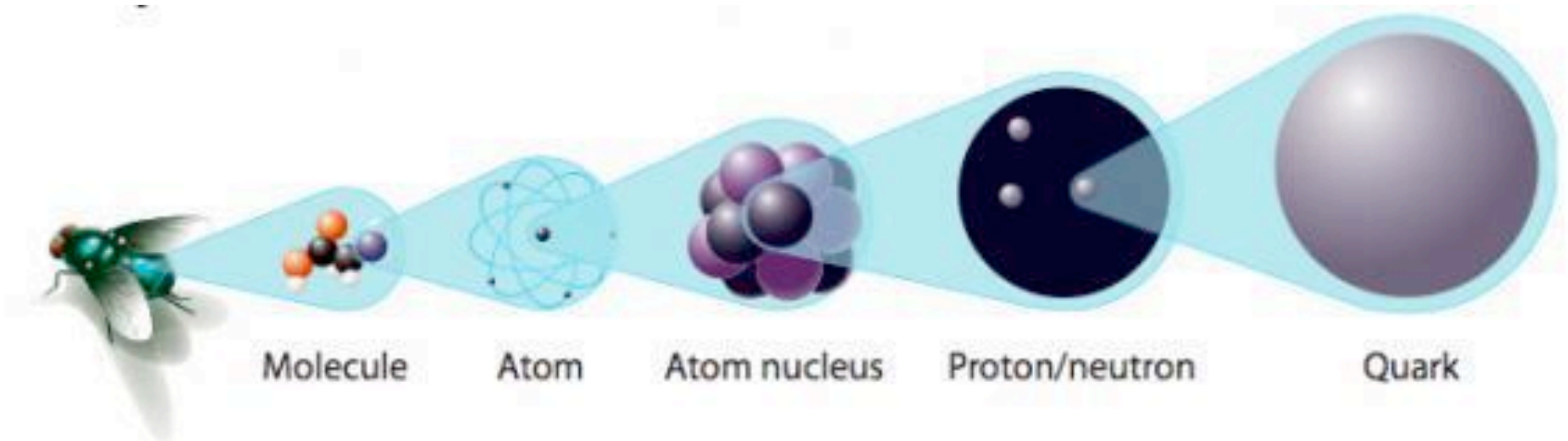
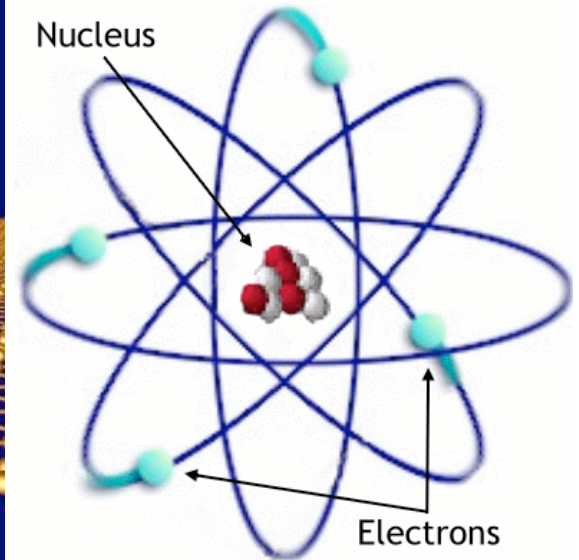
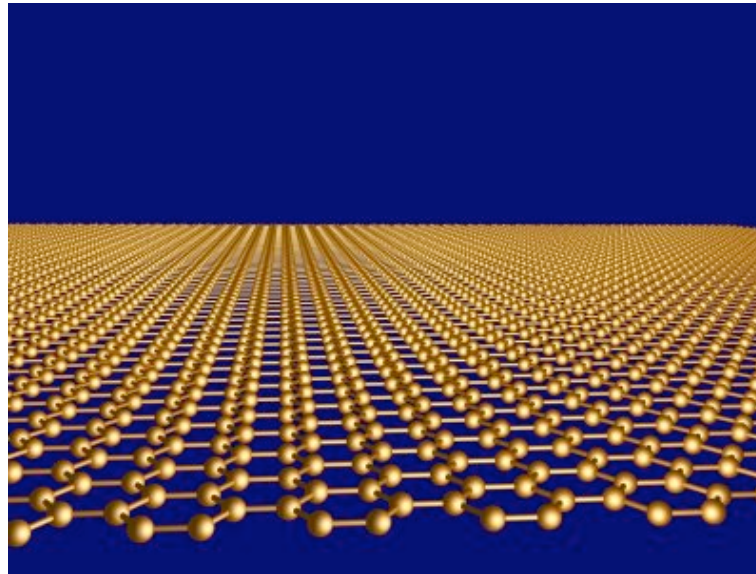
Fundamental particles



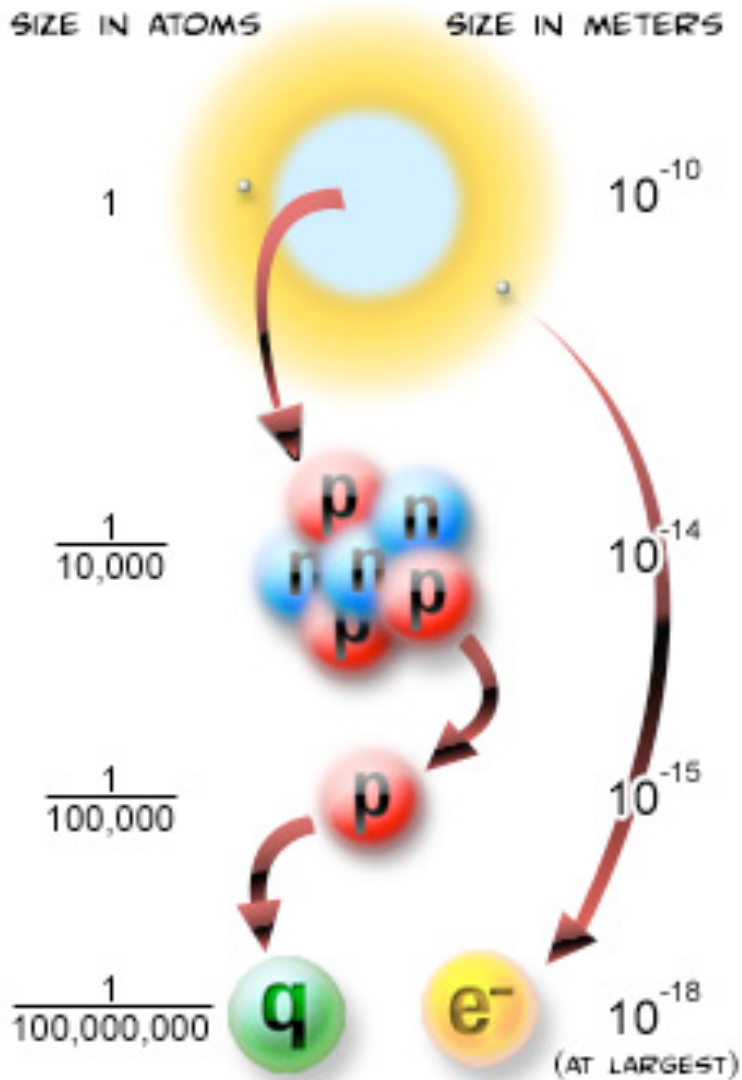
Our understanding
has moved from
philosophy to
experiment



Fundamental particles



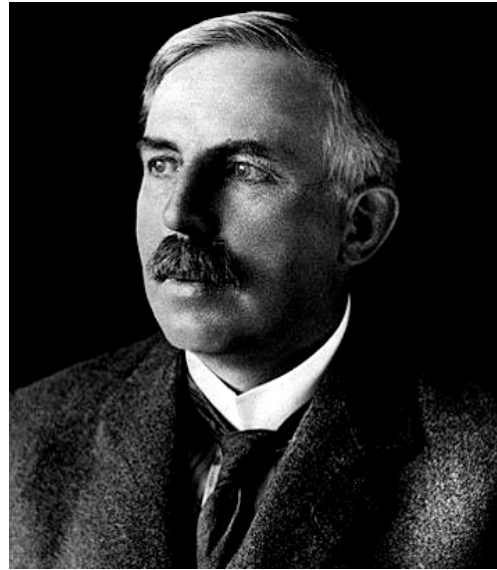
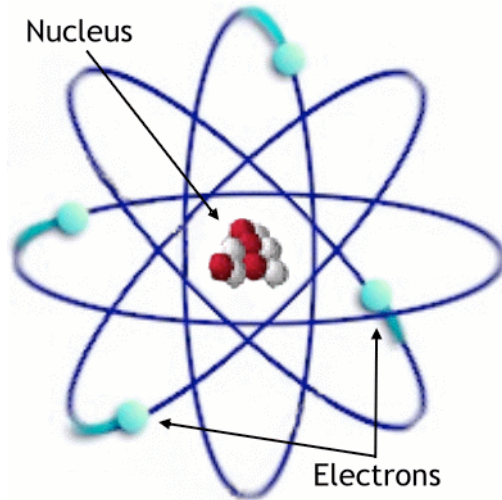
Fundamental particles



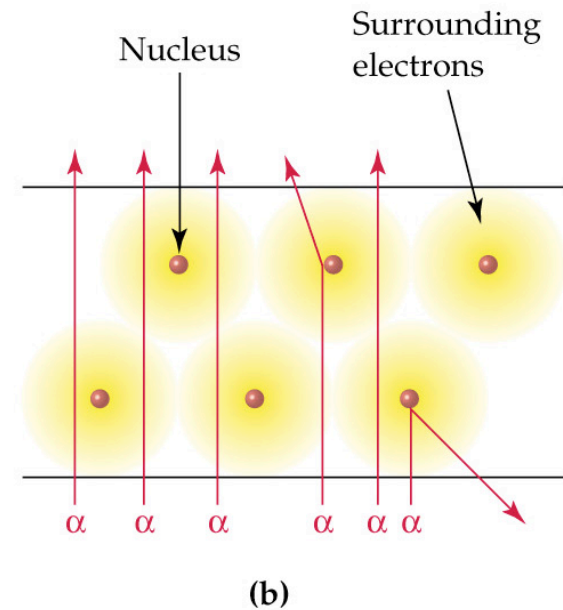
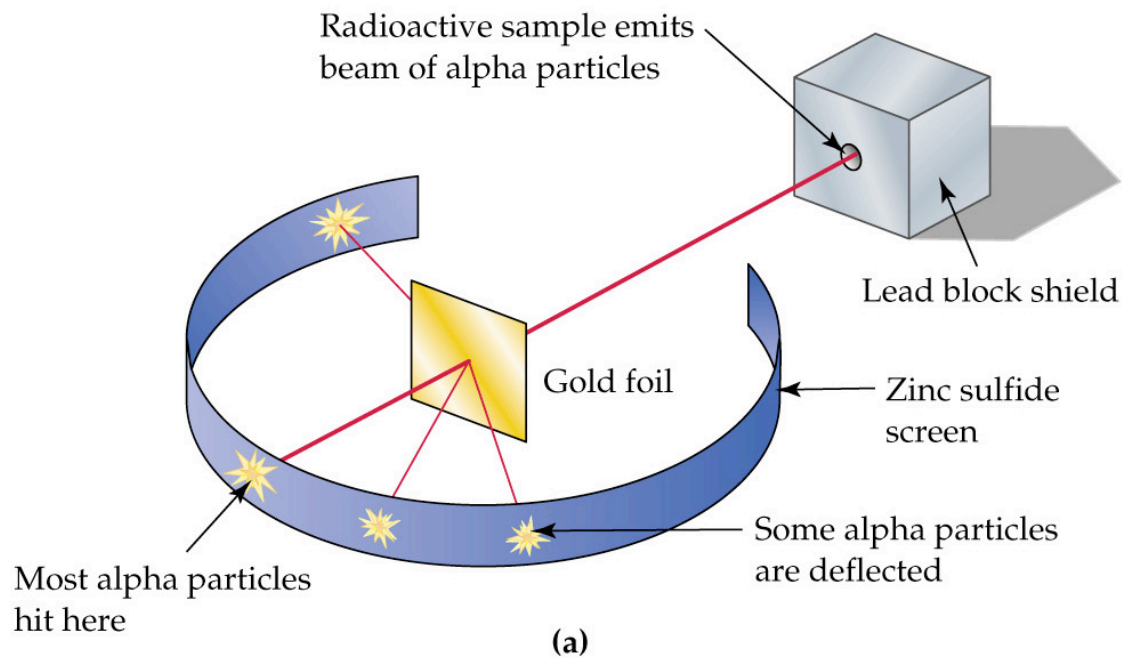
If the Earth is like an atom,
a city is like a nucleus ...
a human is like a quark ...



Gold foil experiment



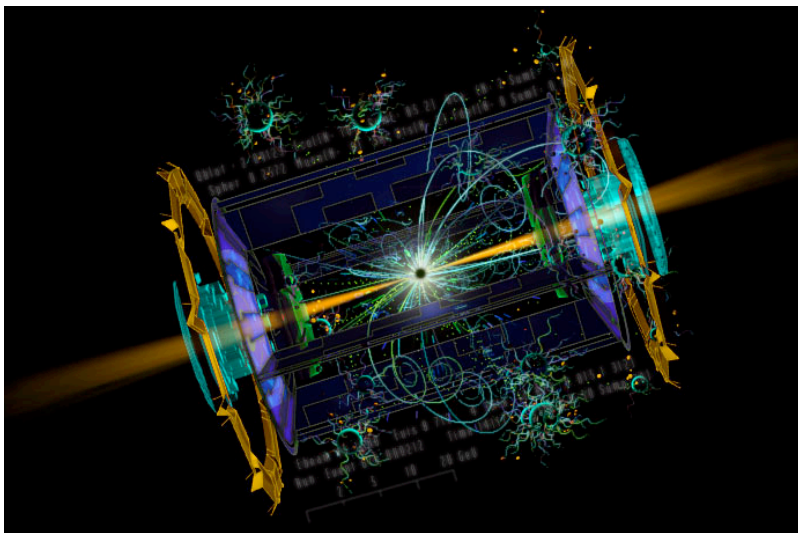
Ernest
Rutherford,
1911



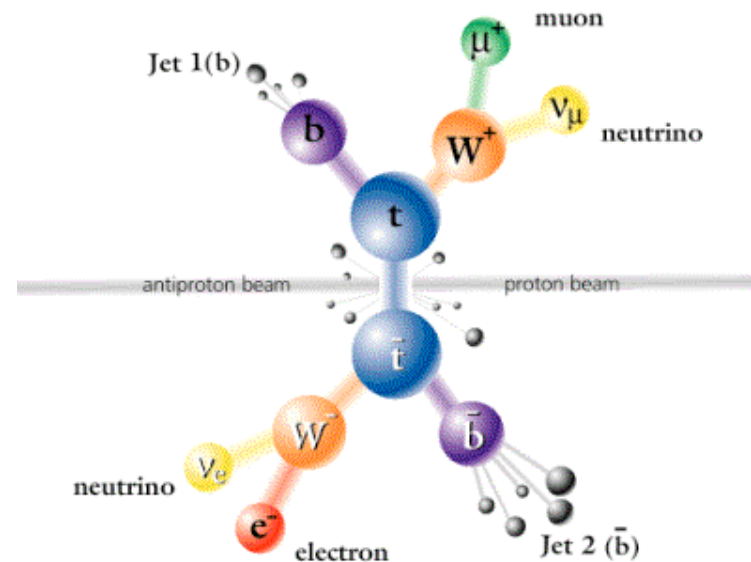
Discovery of the top quark

2.4 MeV $\frac{2}{3}$ u up	1.27 GeV $\frac{2}{3}$ c charm	171.2 GeV $\frac{2}{3}$ t top
4.8 MeV $-\frac{1}{3}$ d down	104 MeV $-\frac{1}{3}$ s strange	4.2 GeV $-\frac{1}{3}$ b bottom

Lifetime 10^{-24} seconds!

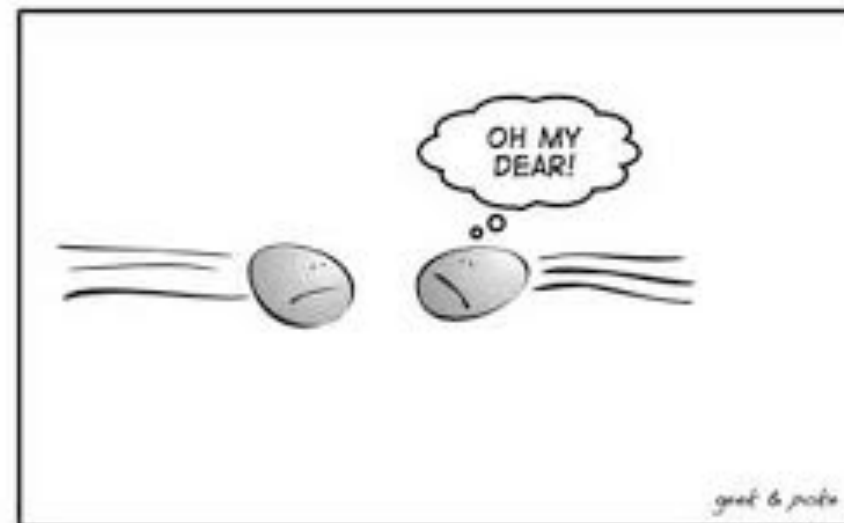
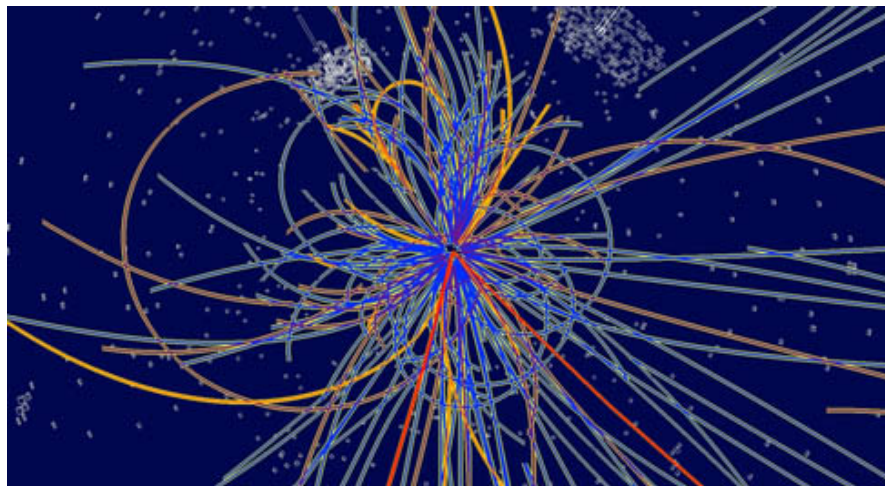
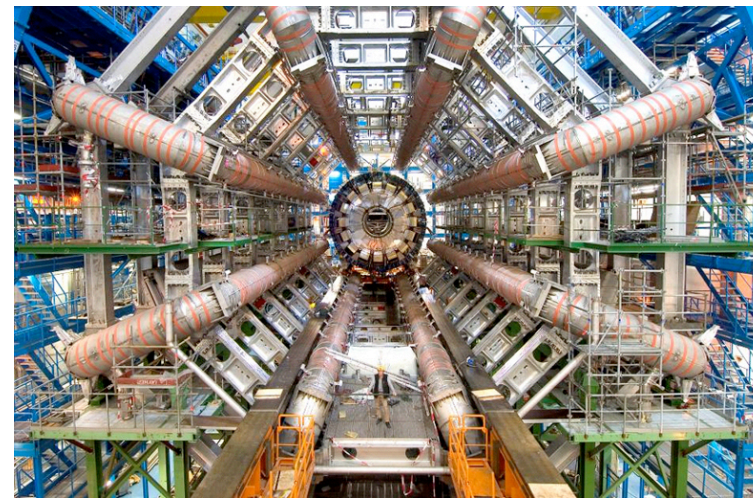
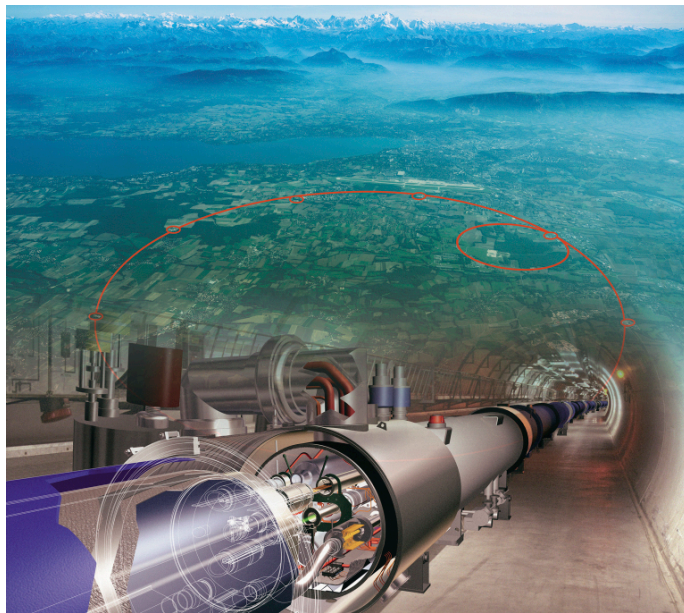


Fermilab, Chicago, 1995



Large Hadron Collider

Now running collisions at 8 TeV !

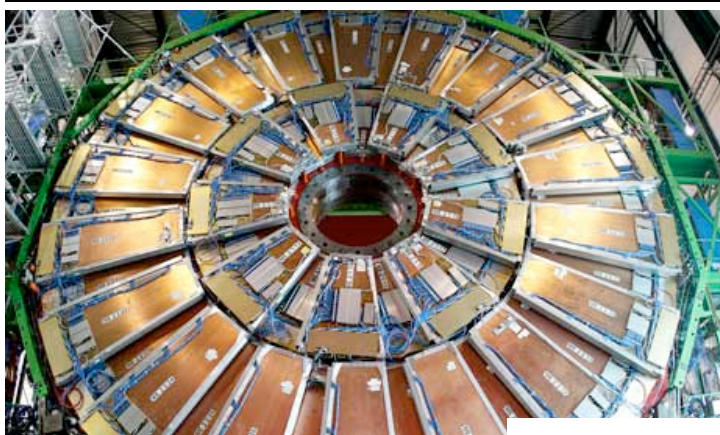


LATELY INSIDE THE LHC:
2 PROTONS 0.00000000000000000001 SEC BEFORE THE COLLISION

Particle physics in the news - I

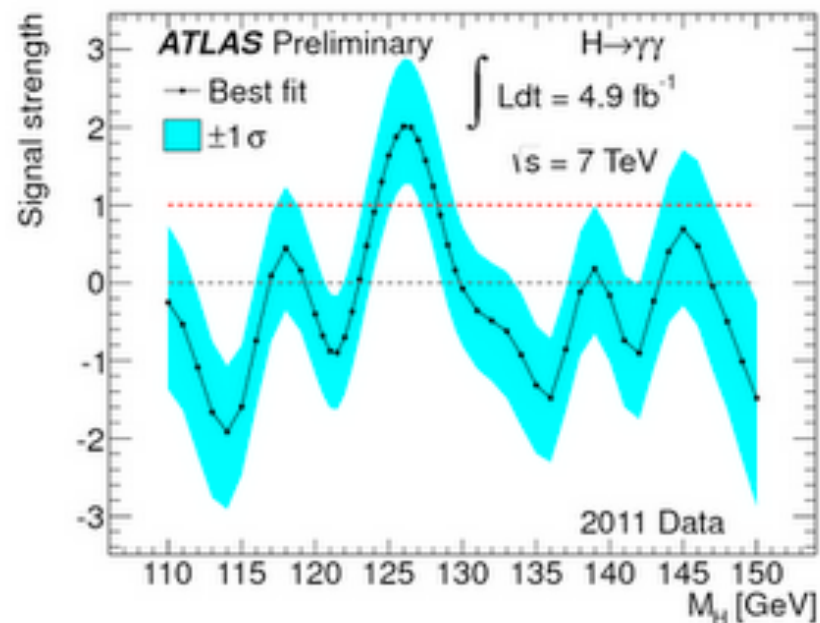
Excitement as Higgs boson seminar set to announce latest LHC findings

Two teams at the Large Hadron Collider (LHC) will go public with their latest results in the search for the Higgs



The magnet core of the CMS detector at the LHC. Physicists Photograph: AP

The runup to Christmas looks exciting for the Geneva. Staff at the laboratory have arranged December at which the latest results in the search for the Higgs boson will be made public. The presentation is due to happen during the Christmas holidays.



It's in there somewhere! World of physics ecstatic as first hard evidence of God particle is found by CERN researchers

- The Higgs boson helps glue the universe together, but it has never been observed - until now

By [Rob Waugh](#) and [Ted Thornhill](#)

UPDATED: 12:43 GMT, 14 December 2011

One of CERN's most senior physicists this afternoon announced firm evidence for the existence of the elusive Higgs Boson, or God particle.

Particle physics in the news - II

Particles break light-speed limit

Neutrino results challenge cornerstone of modern physics.

Geoff Brumfiel

An Italian experiment measuring the speed of particles known as neutrinos, researchers are cautiously scrutinizing the finding that they may have broken modern physics — the long-held belief that nothing can travel faster than the speed of light — by a few metres per second.

The experiment is called OPERA (Oscillation Project on Emulsion-tRacking Apparatus).

OPERA Admits That Faster Than Light Neutrino Measurement May Have Been An Error

A few months ago, when the OPERA Collaboration announced that they had measured neutrinos

Leaders of Faster-Than-Light Experiment Step Down

by Edwin Cartledge on 30 March 2012, 1:15 PM | [8 Comments](#)

[Email](#) | [Print](#) |

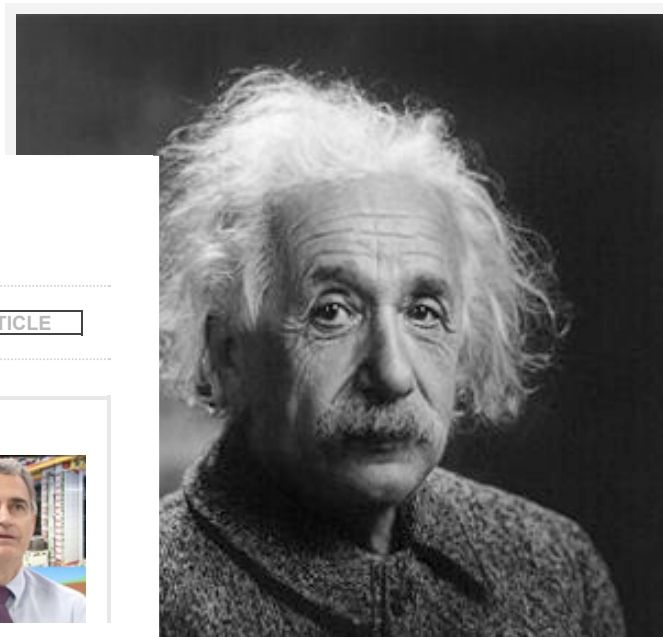
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ROME—Two leaders of the OPERA collaboration, which stunned the world in September when it announced data suggesting that neutrinos could travel faster than the speed of light, have stepped down. The resignation of Antonio Ereditato as spokesperson and Dario Autiero as physics coordinator of the study followed a vote of no confidence, held yesterday by leaders of the individual groups within the collaboration, who said they had lost confidence in the OPERA collaboration's ability to

[ENLARGE IMAGE](#)



Fundamental particles

Fermions

matter particles

Quarks

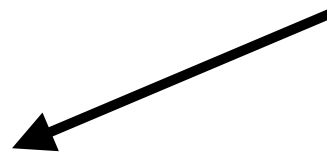


Leptons



Three "generations"

fo:



Neutrinos

Electrons

Fundamental forces

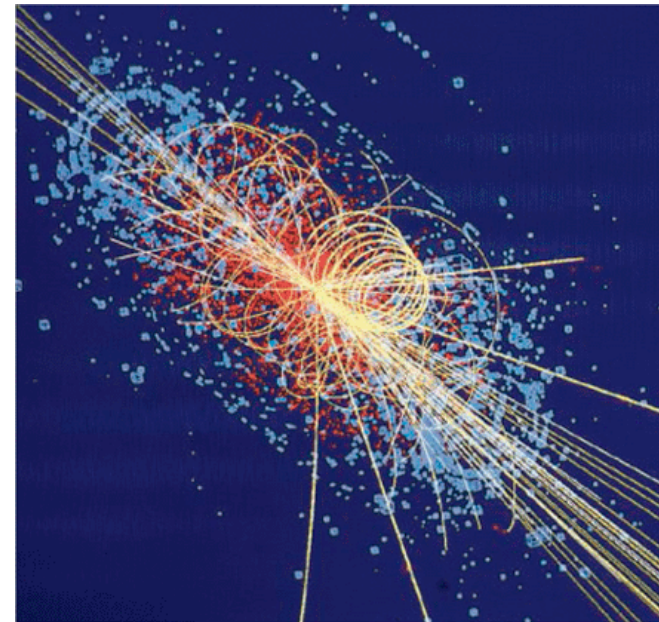
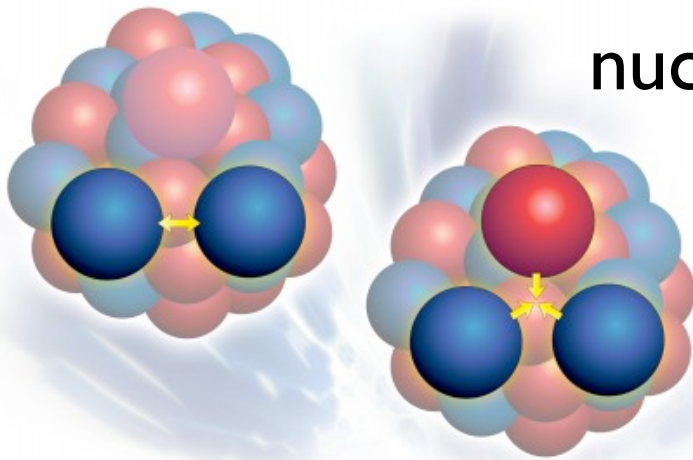
Electromagnetism



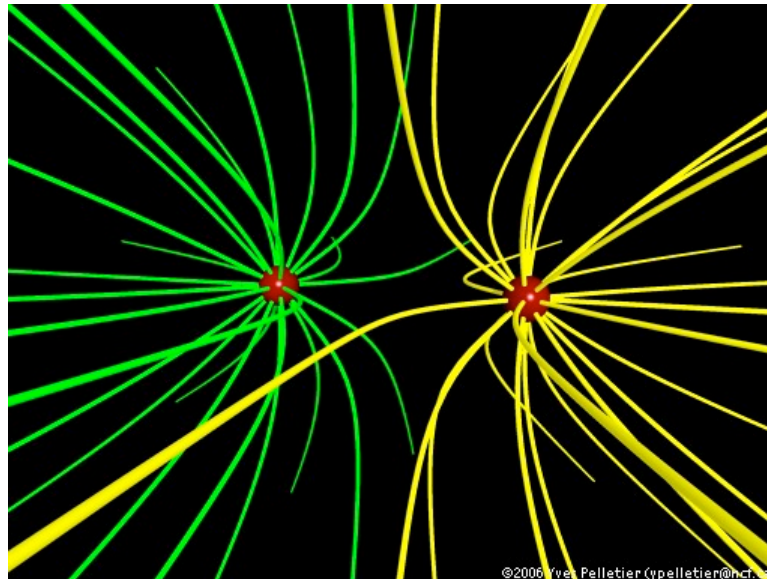
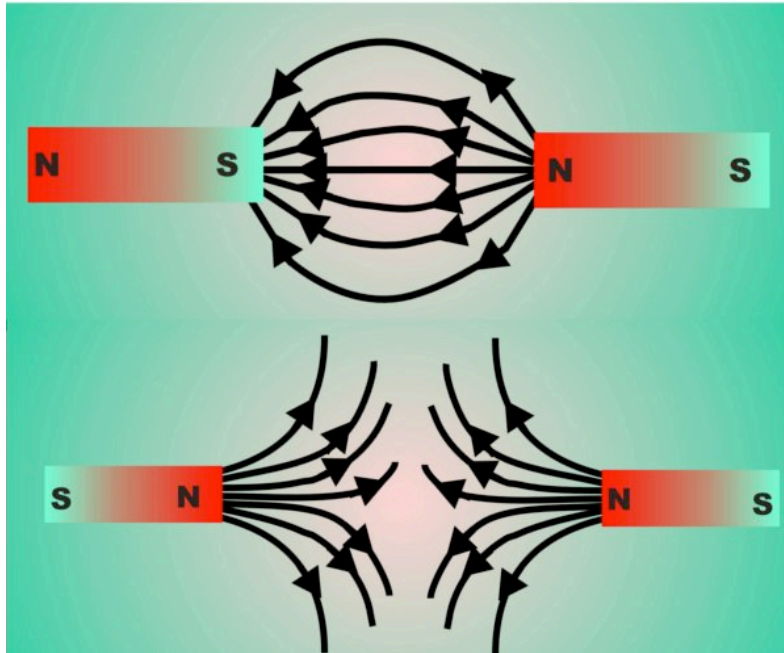
Gravity



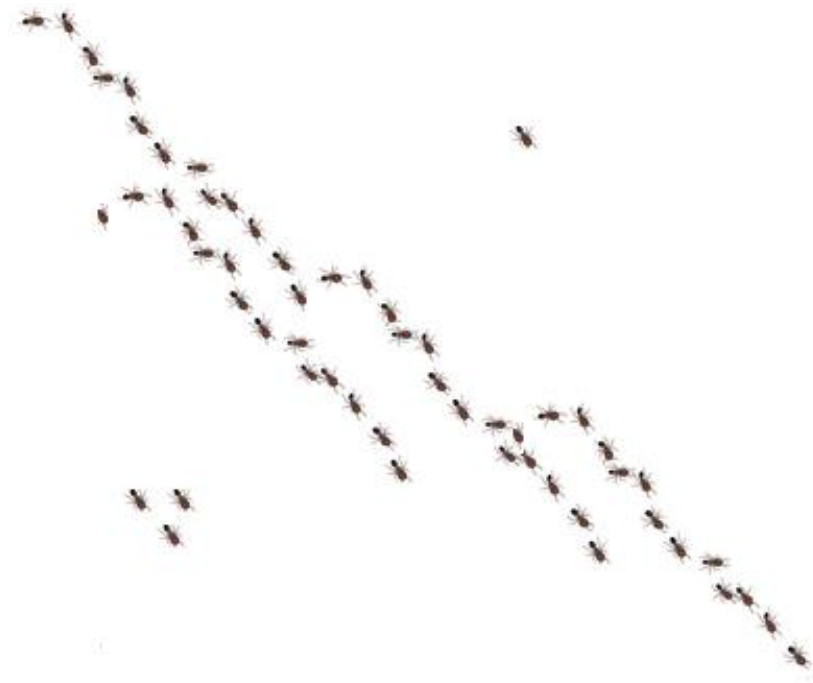
Strong/weak nuclear forces



Fundamental forces



Particles
continuously
interacting ...



The “standard model”

Fermions

matter particles

Quarks



Leptons



Gauge bosons

force carriers



photon



gluon



Z boson



W boson

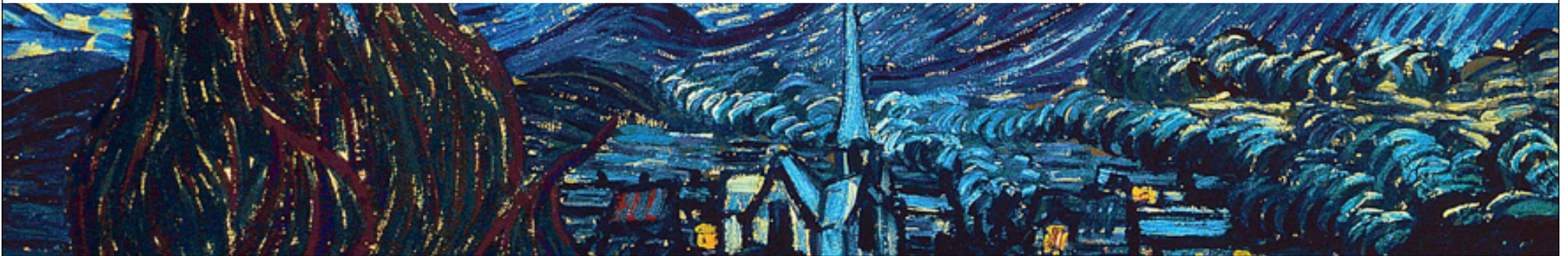
Higgs boson

origin of mass



The “standard model”

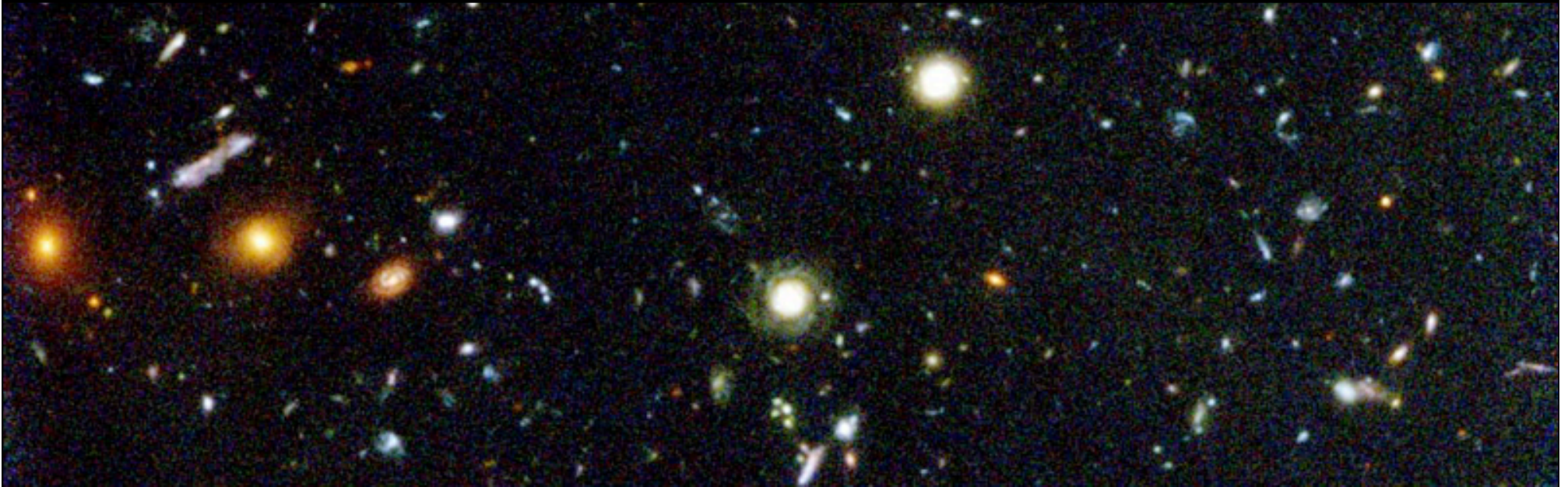
- Why can't we predict a particle's **mass**? (e.g. neutrinos)
- What is **dark matter**?
- Where is all the **antimatter**?
- How does **gravity** fit in?



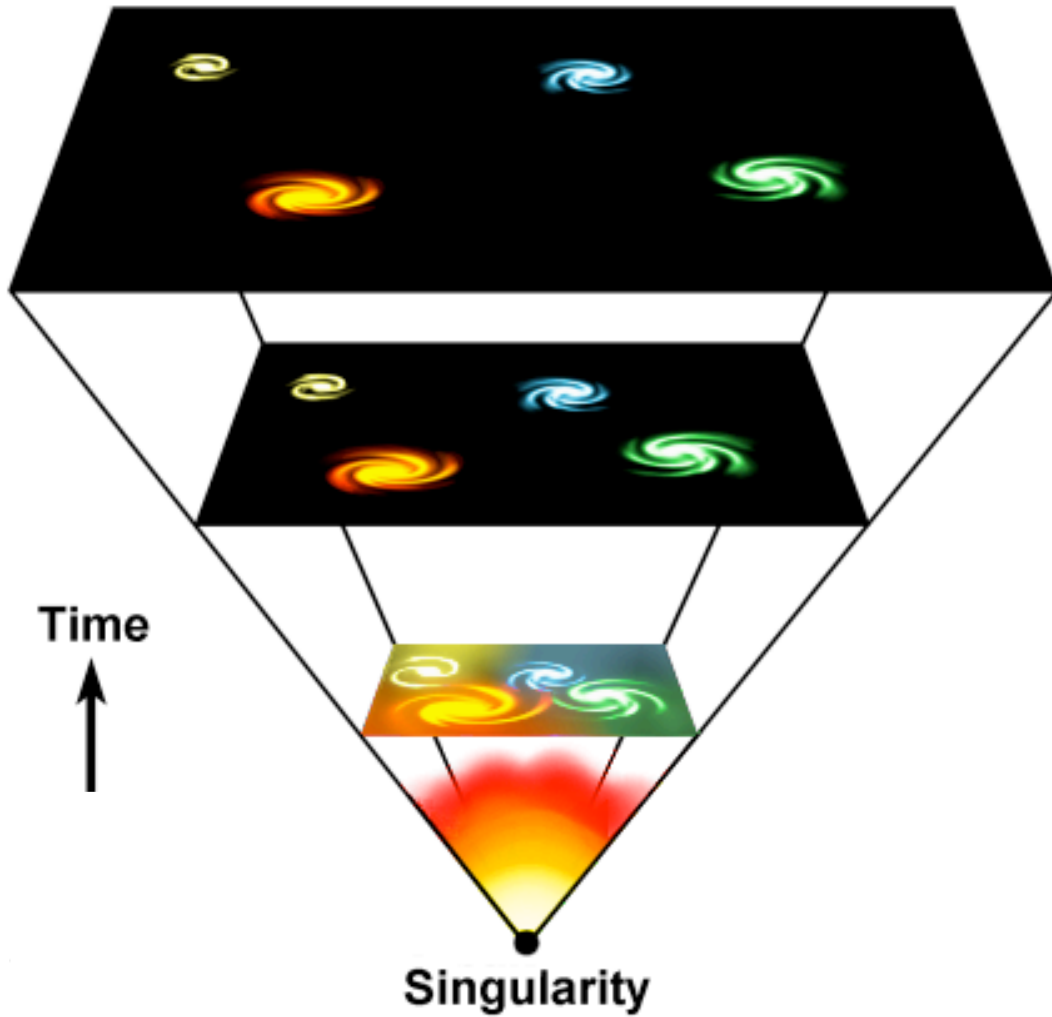
The “standard model”



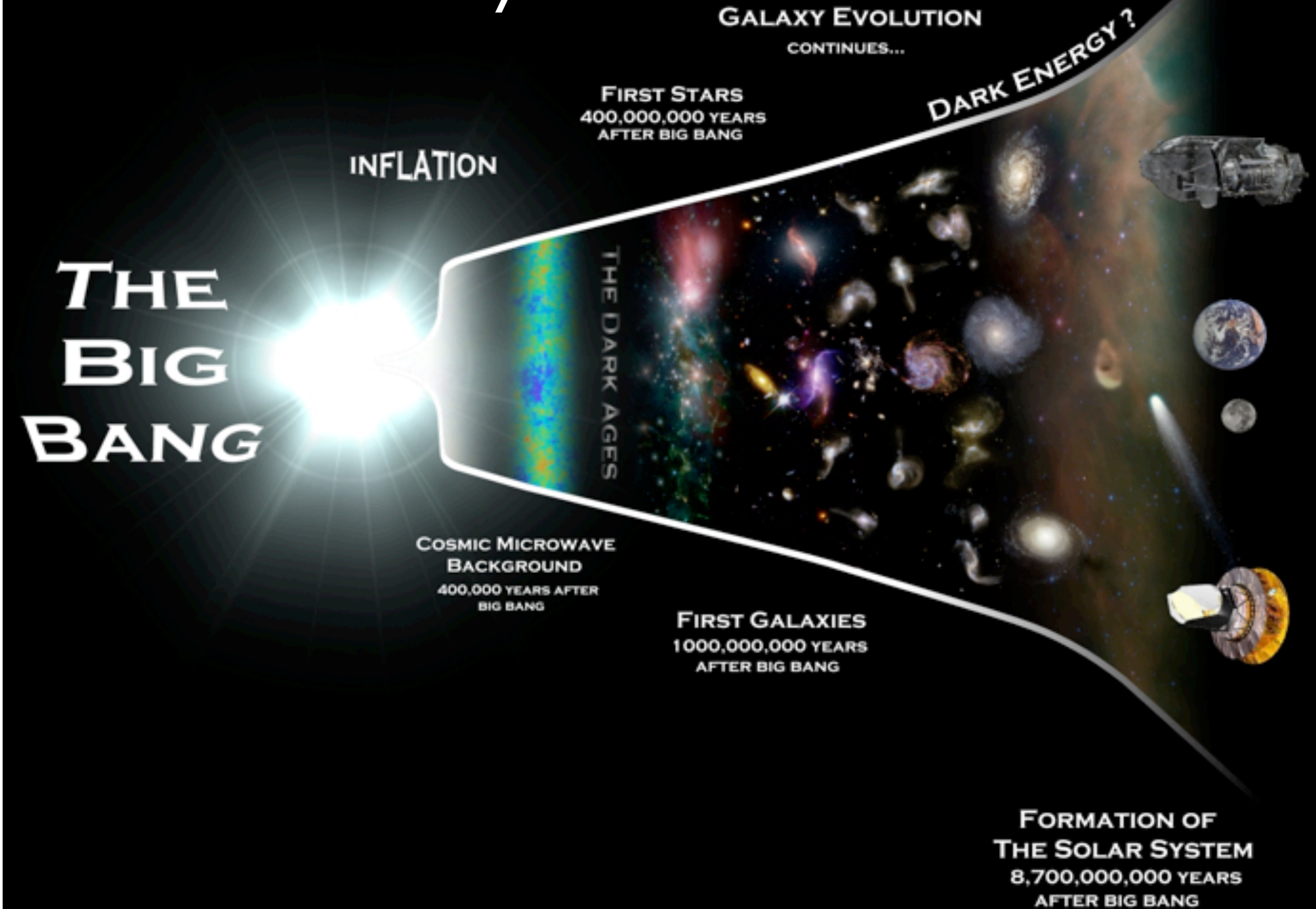
Where astronomy fits in



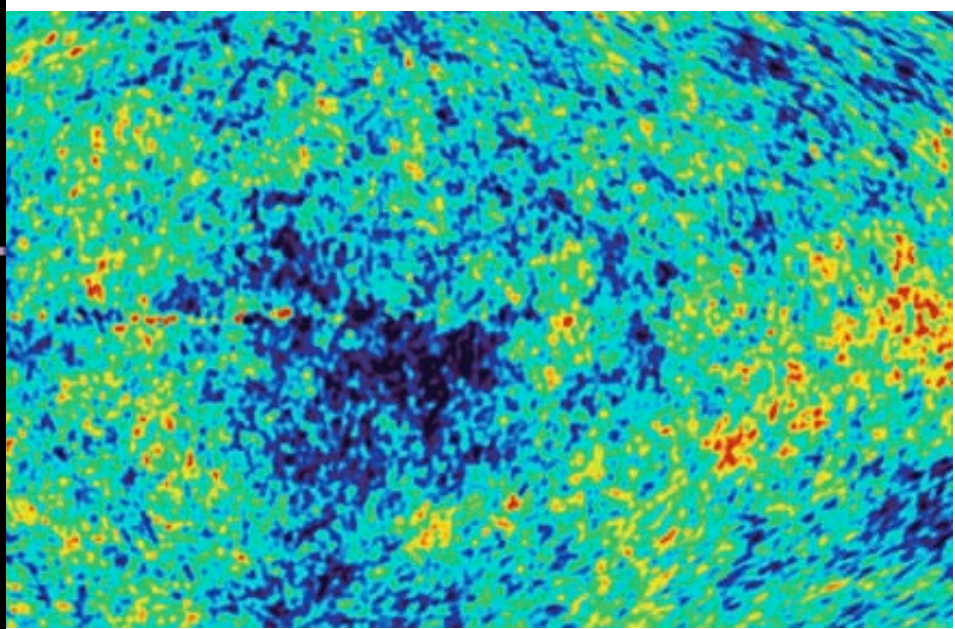
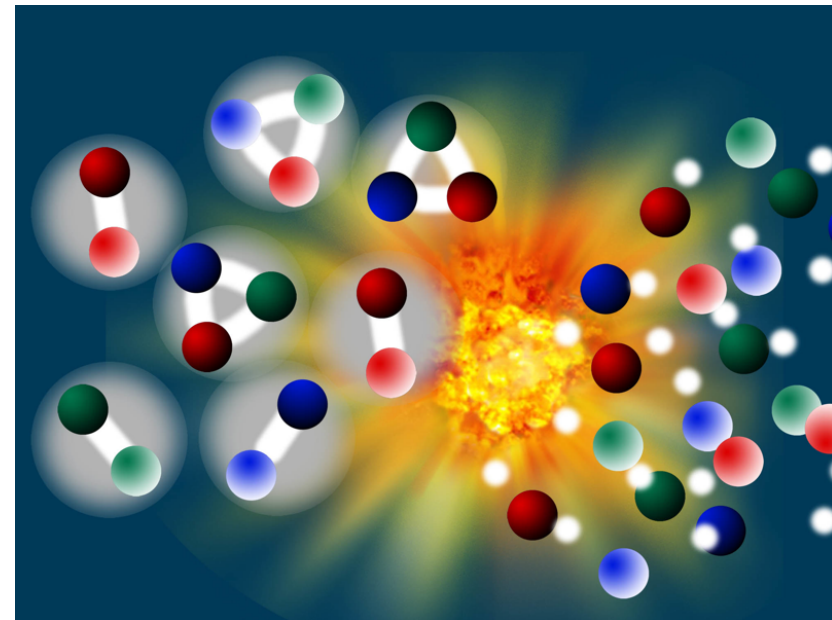
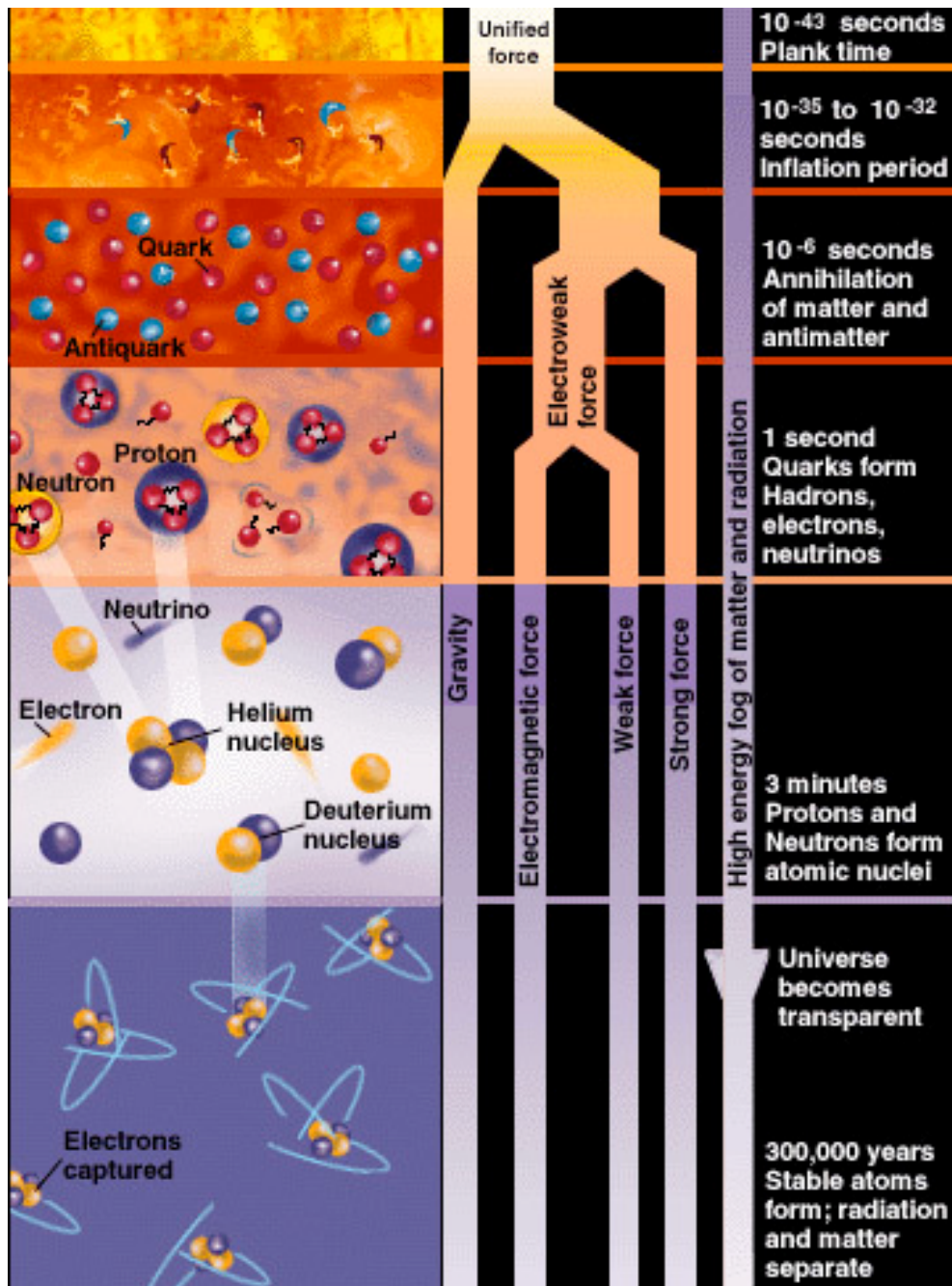
Where astronomy fits in



Where astronomy fits in



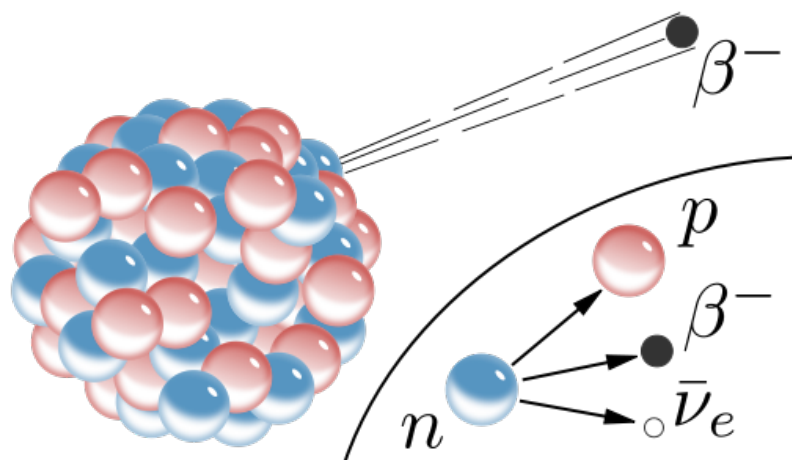
Where astronomy fits in



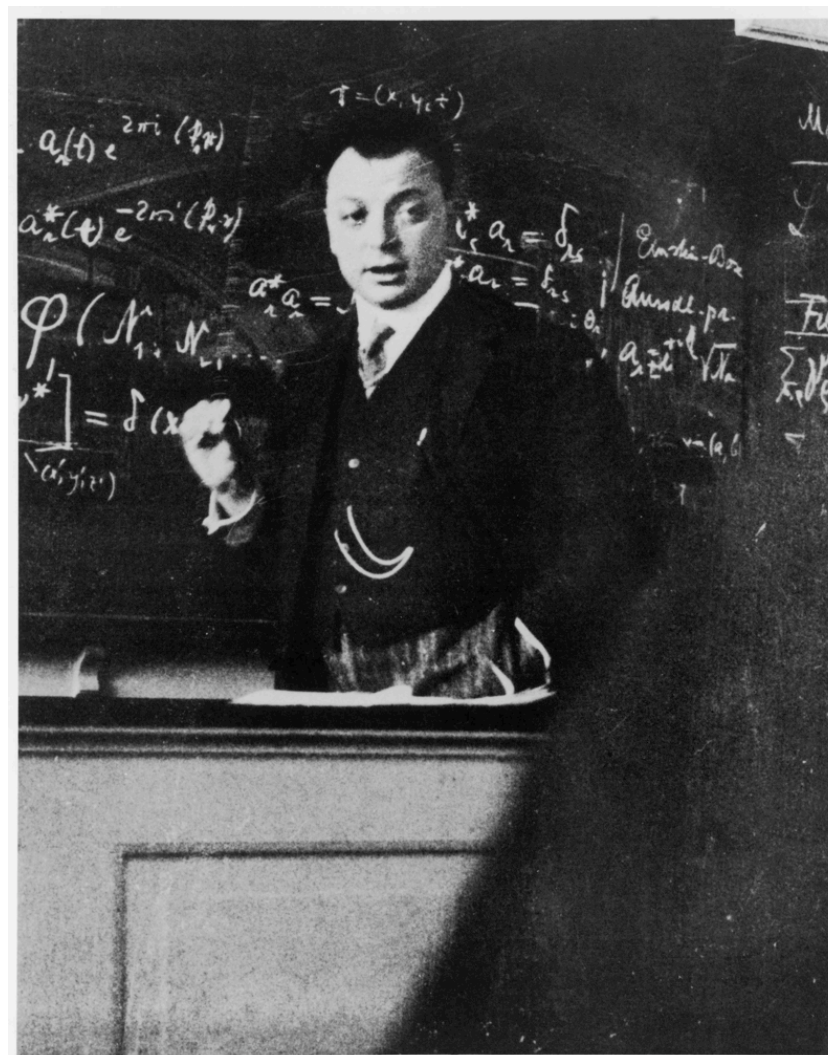
Neutrinos



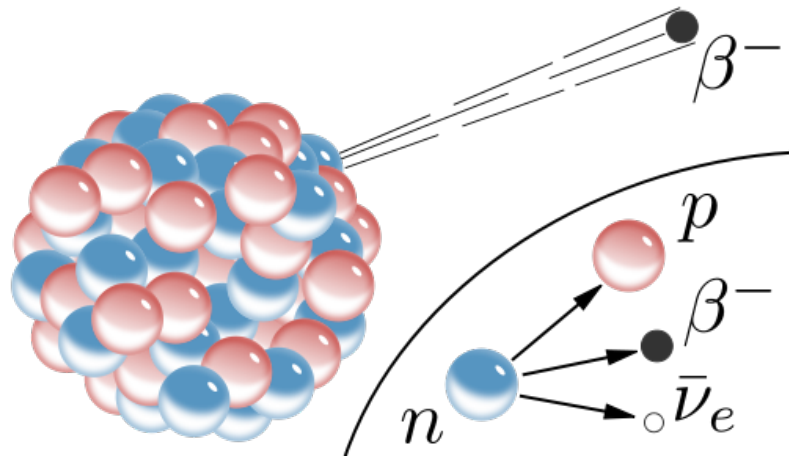
Neutrinos



Wolfgang Pauli
(Nobel Prize 1945)

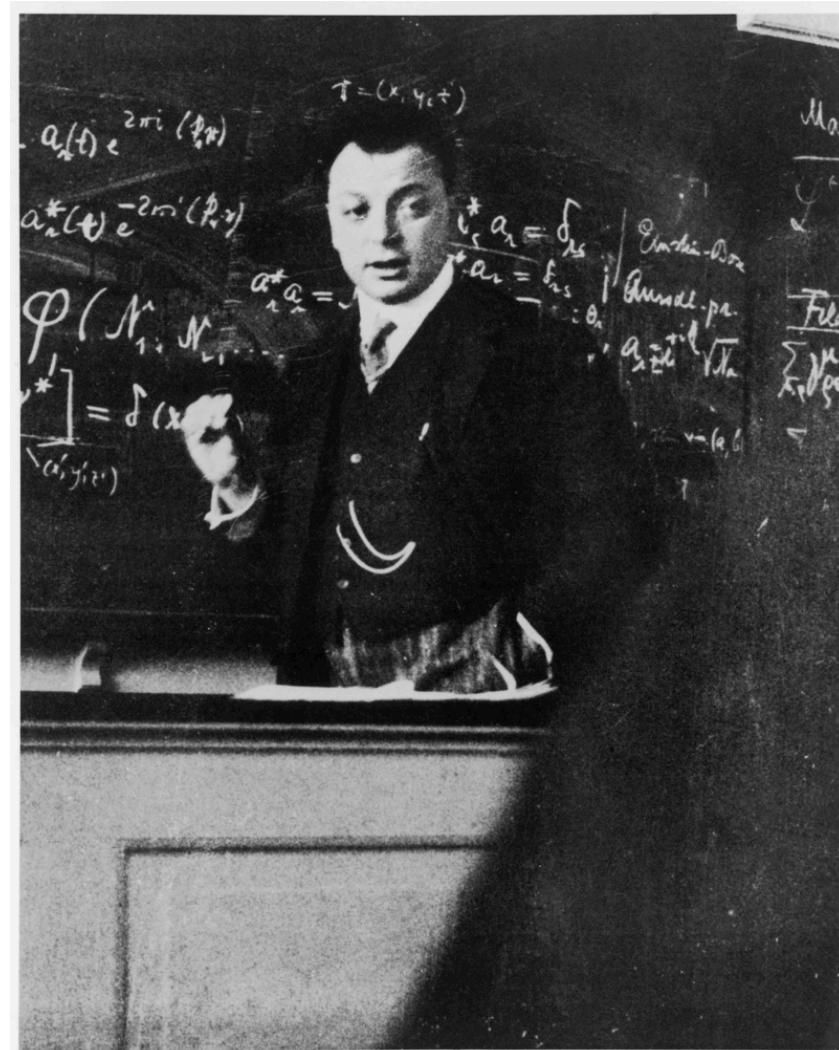


Neutrinos

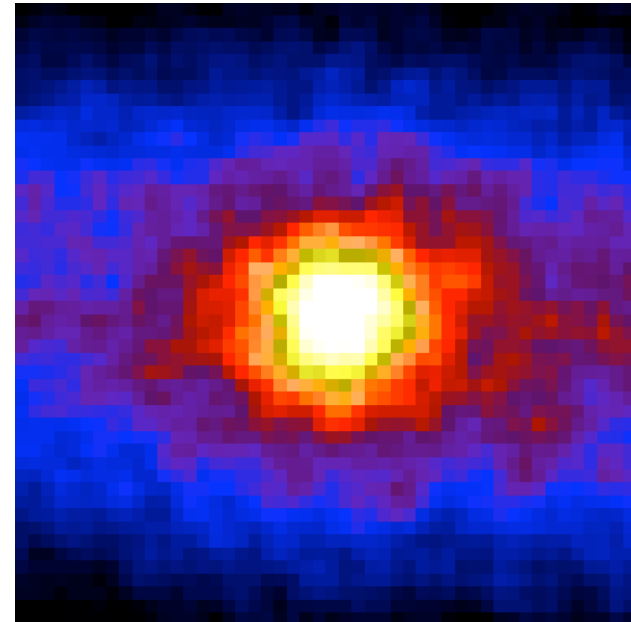
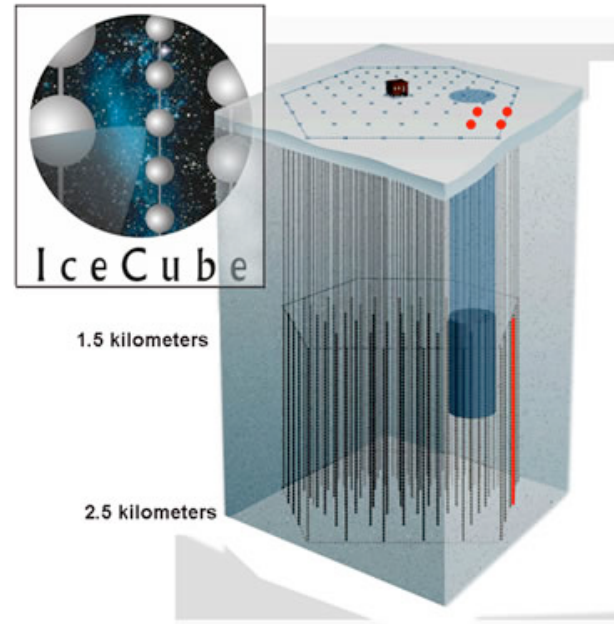
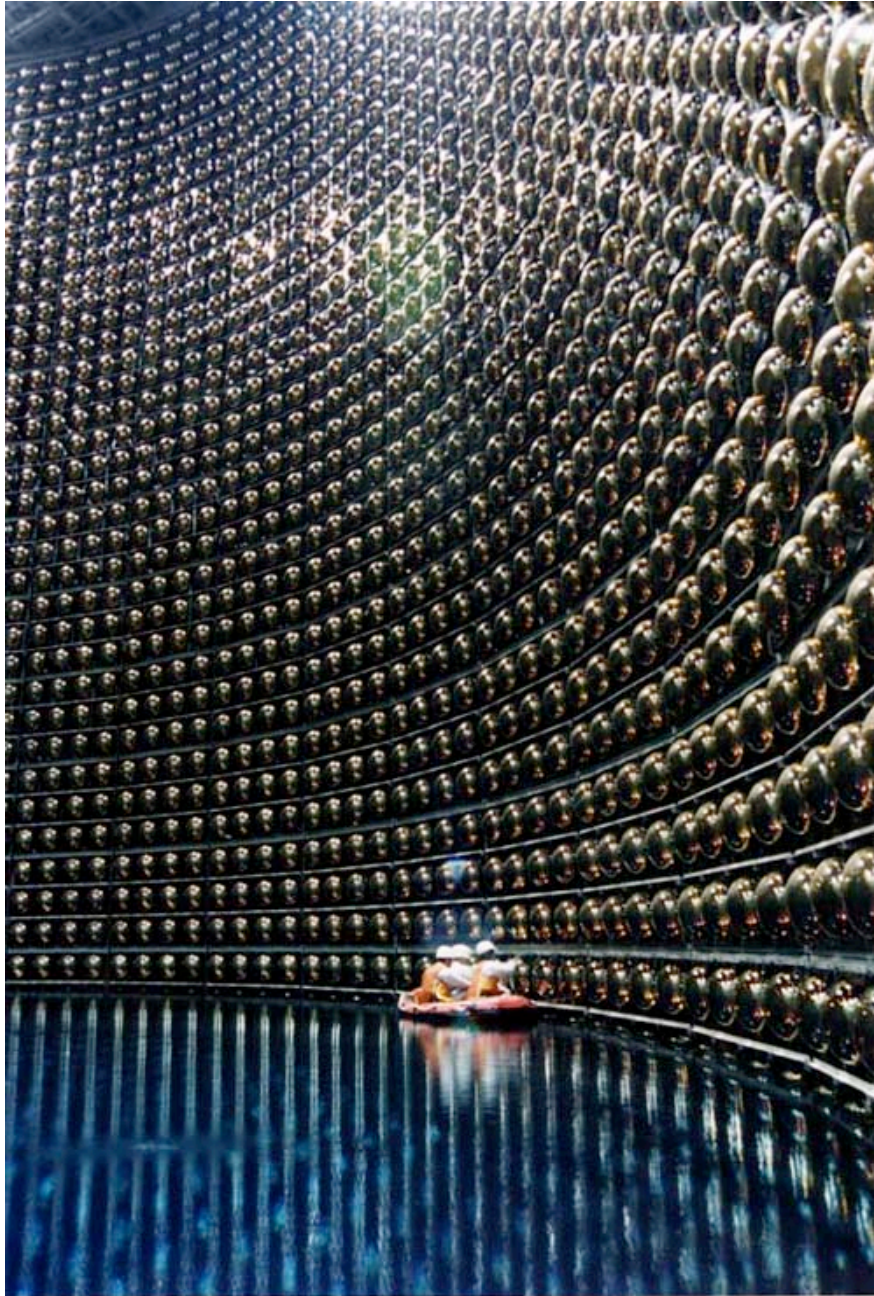


I have done something very bad today in proposing a particle that cannot be detected. It is something no theorist should ever do

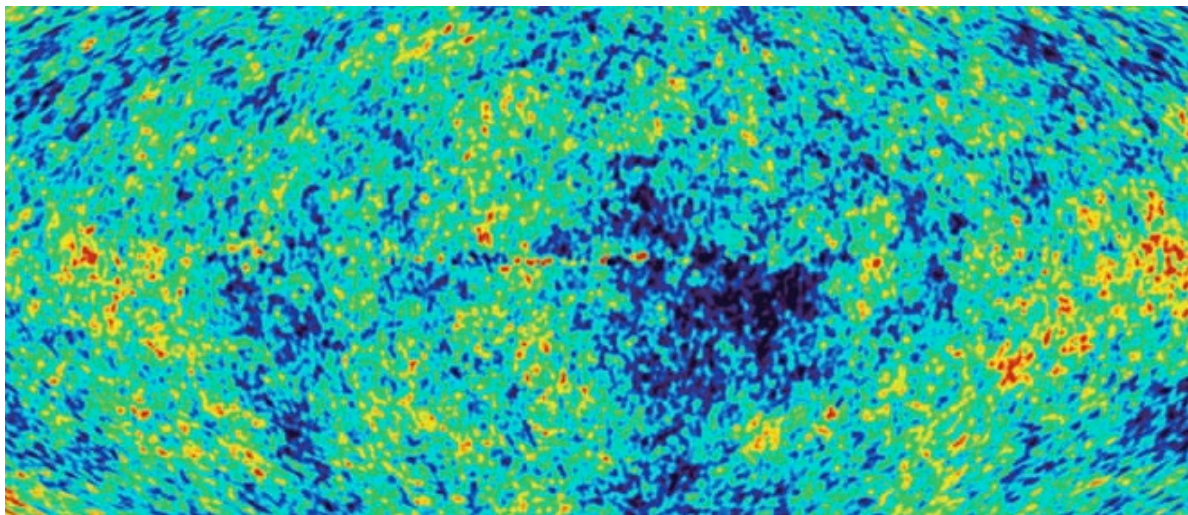
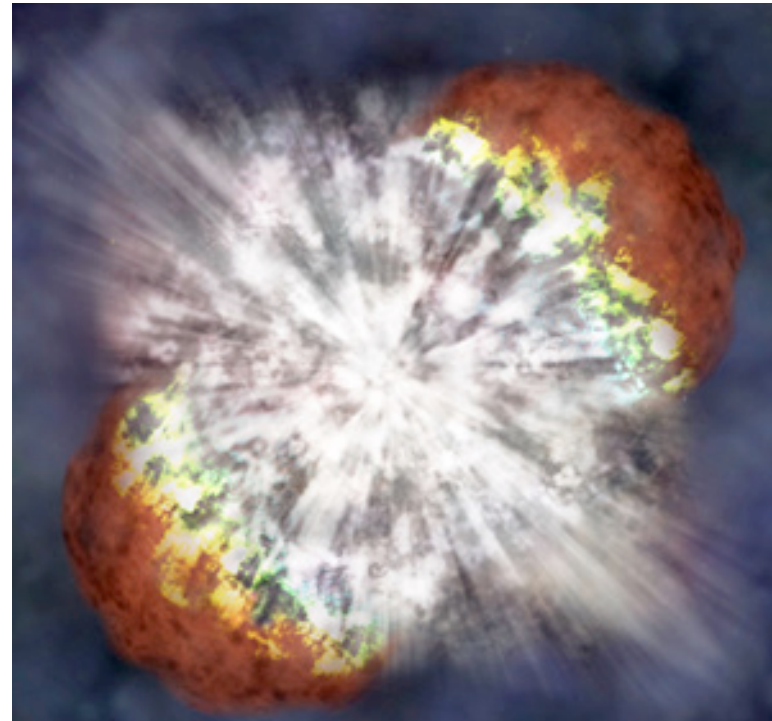
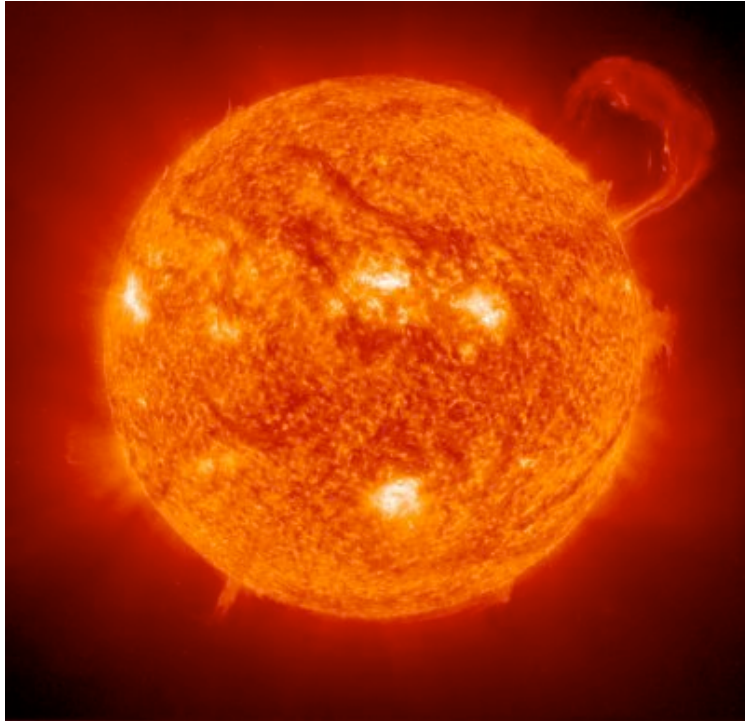
Wolfgang Pauli
(Nobel Prize 1945)



Neutrinos

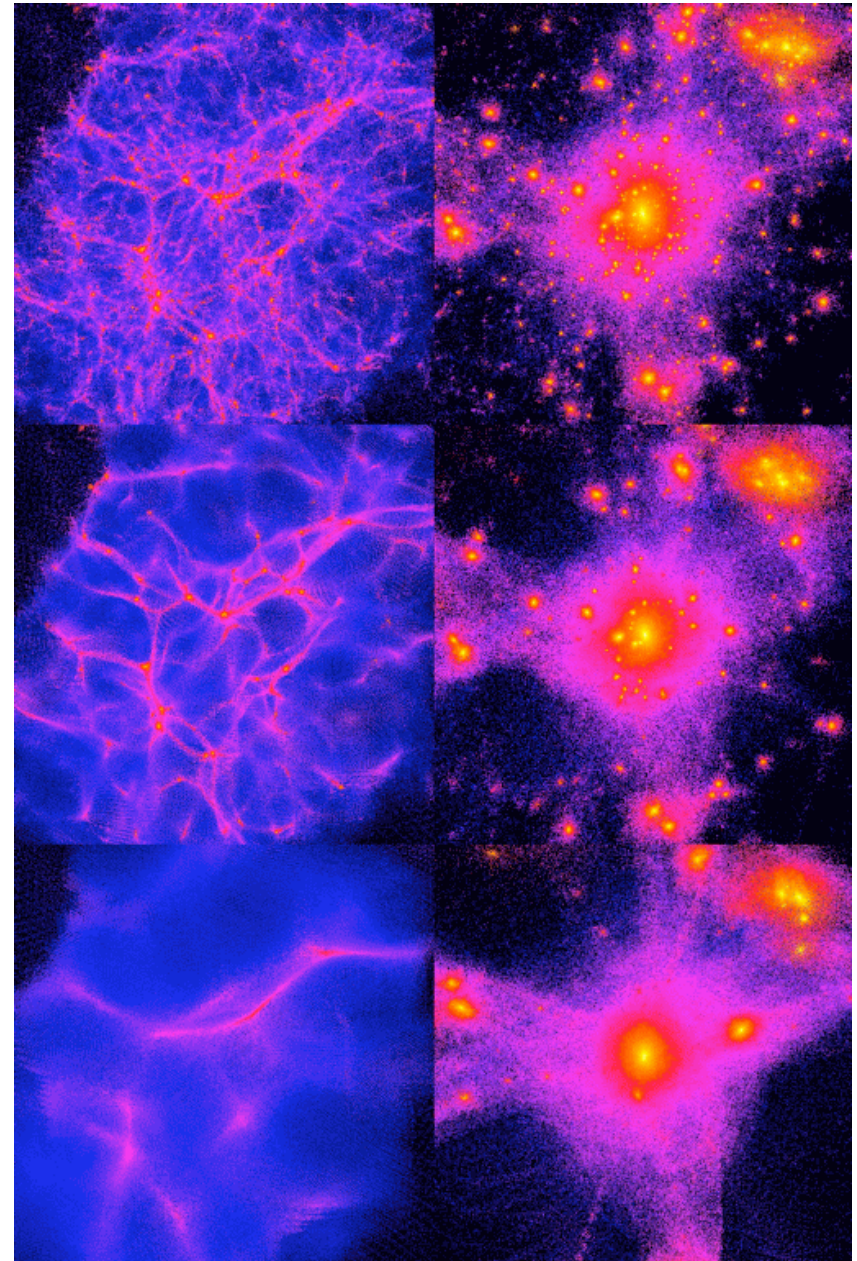
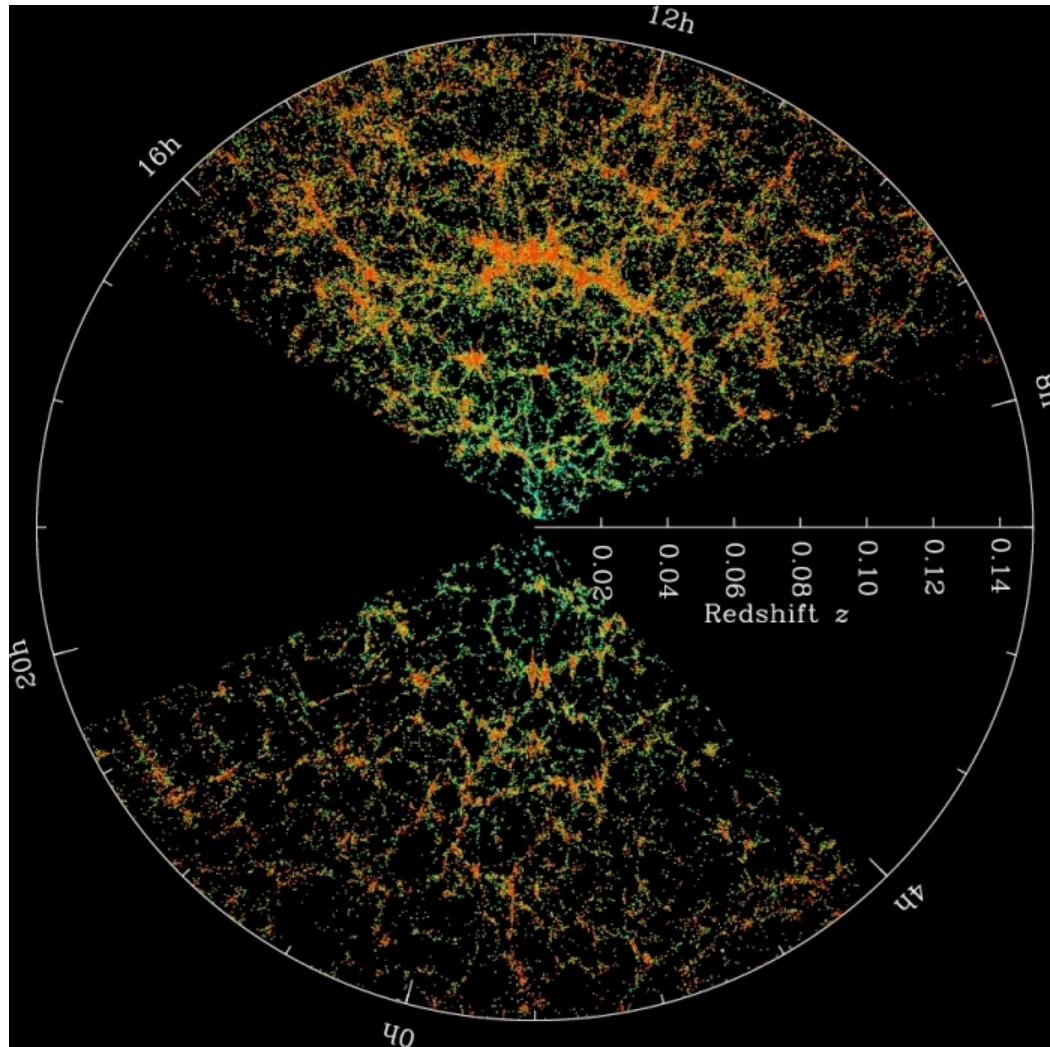


Neutrinos

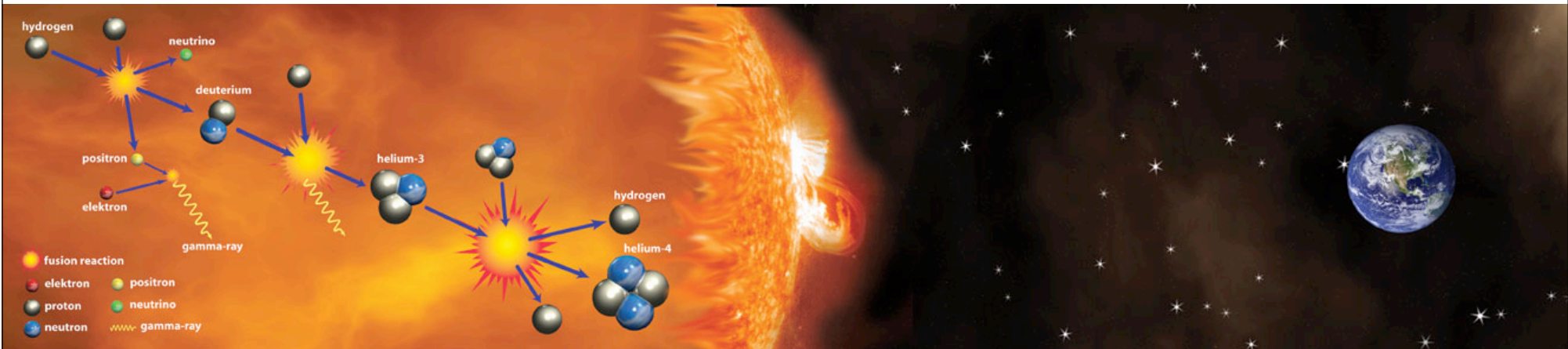


Neutrinos fill
the Universe!

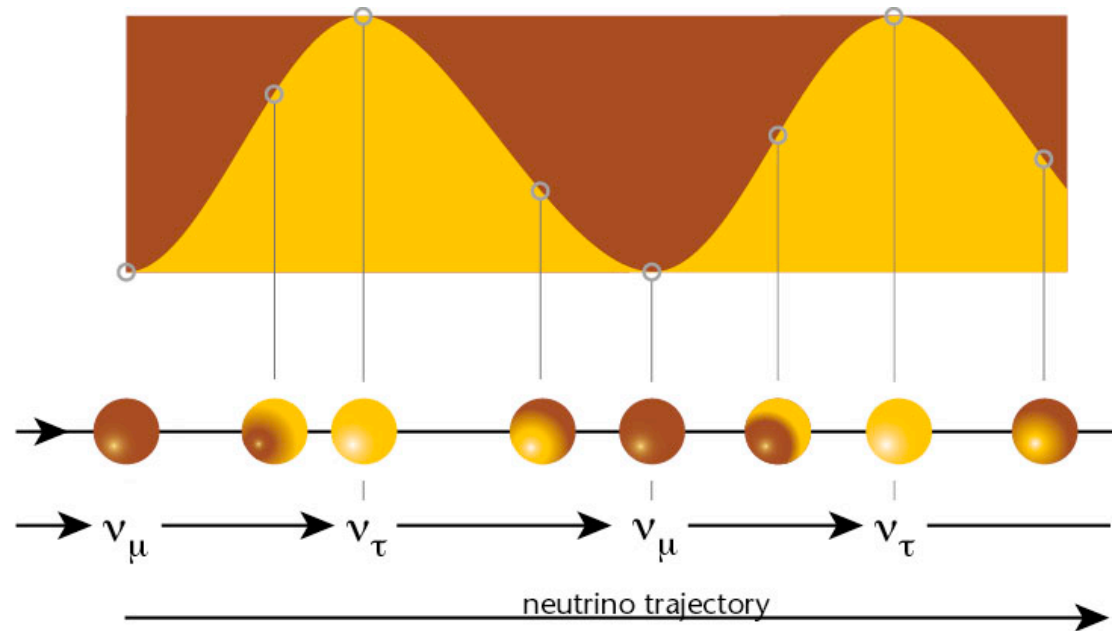
Fun physics fact - neutrinos affect the Universe



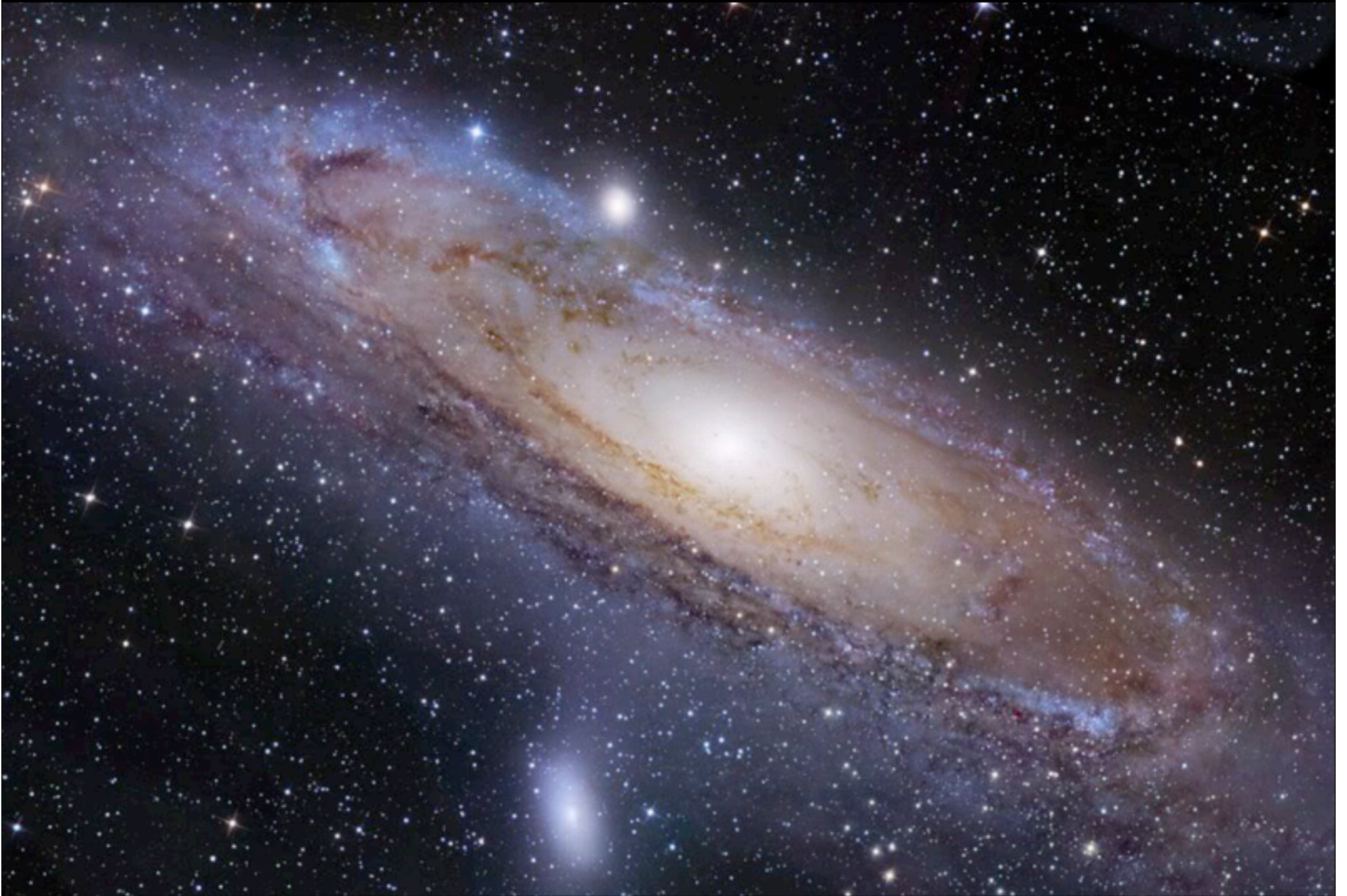
Fun physics fact - neutrinos oscillate in type!



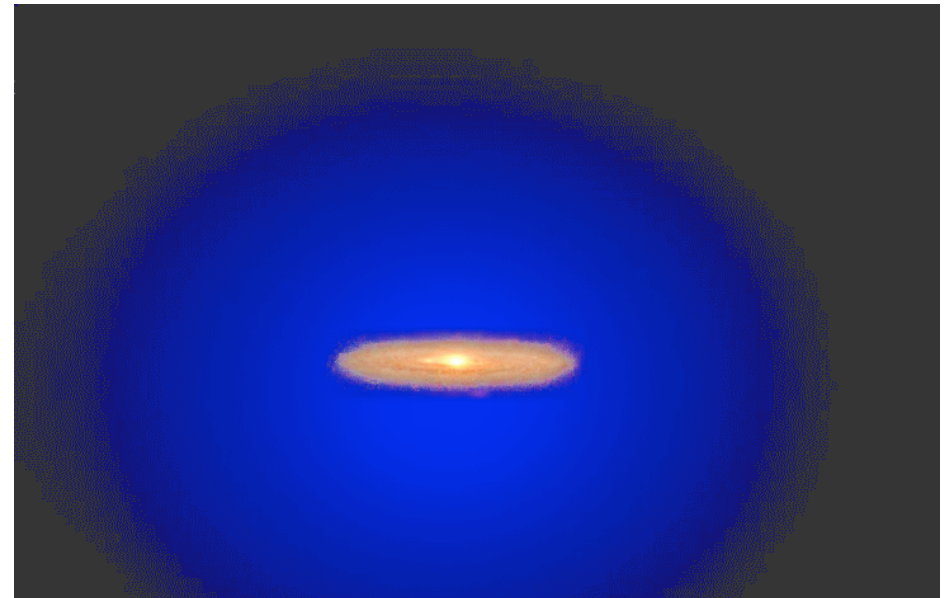
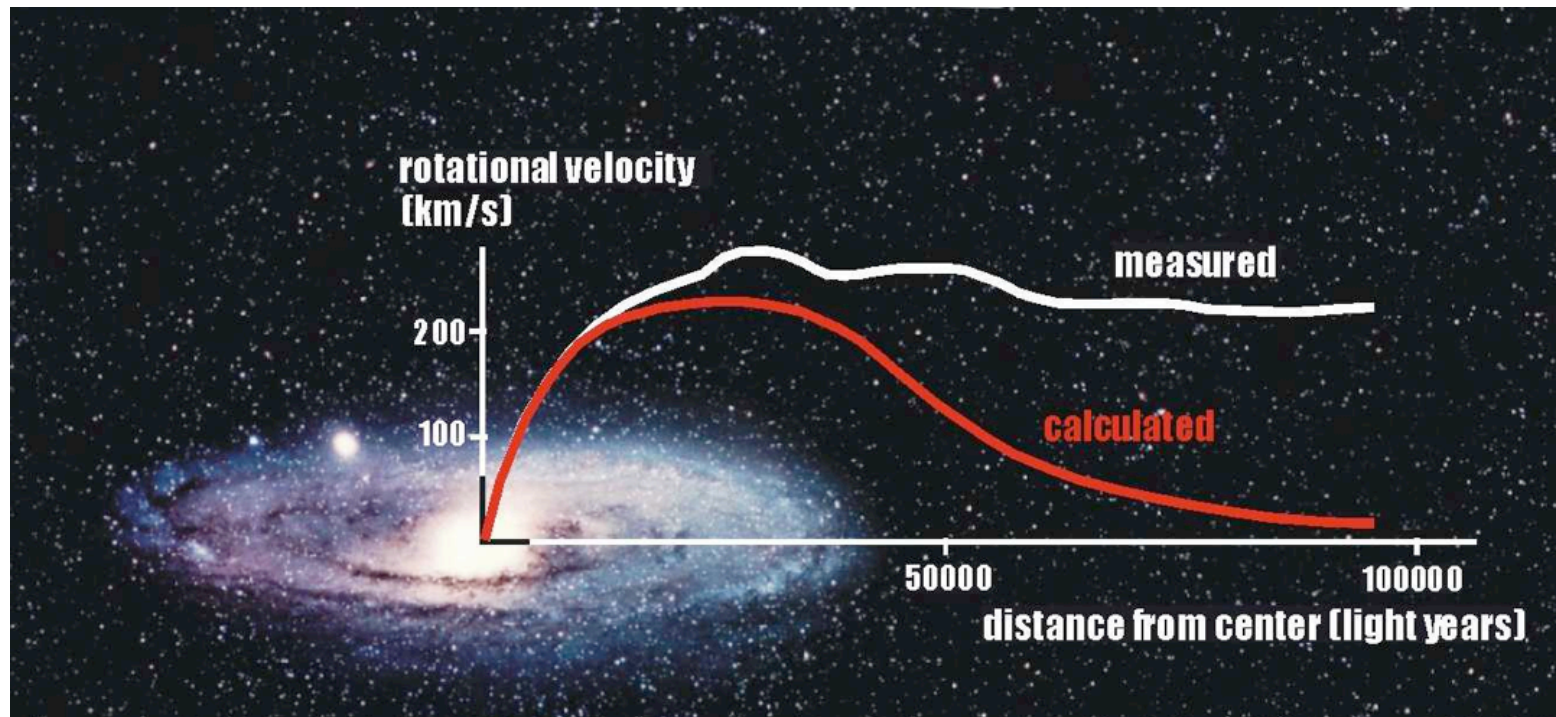
Solar neutrino problem ...



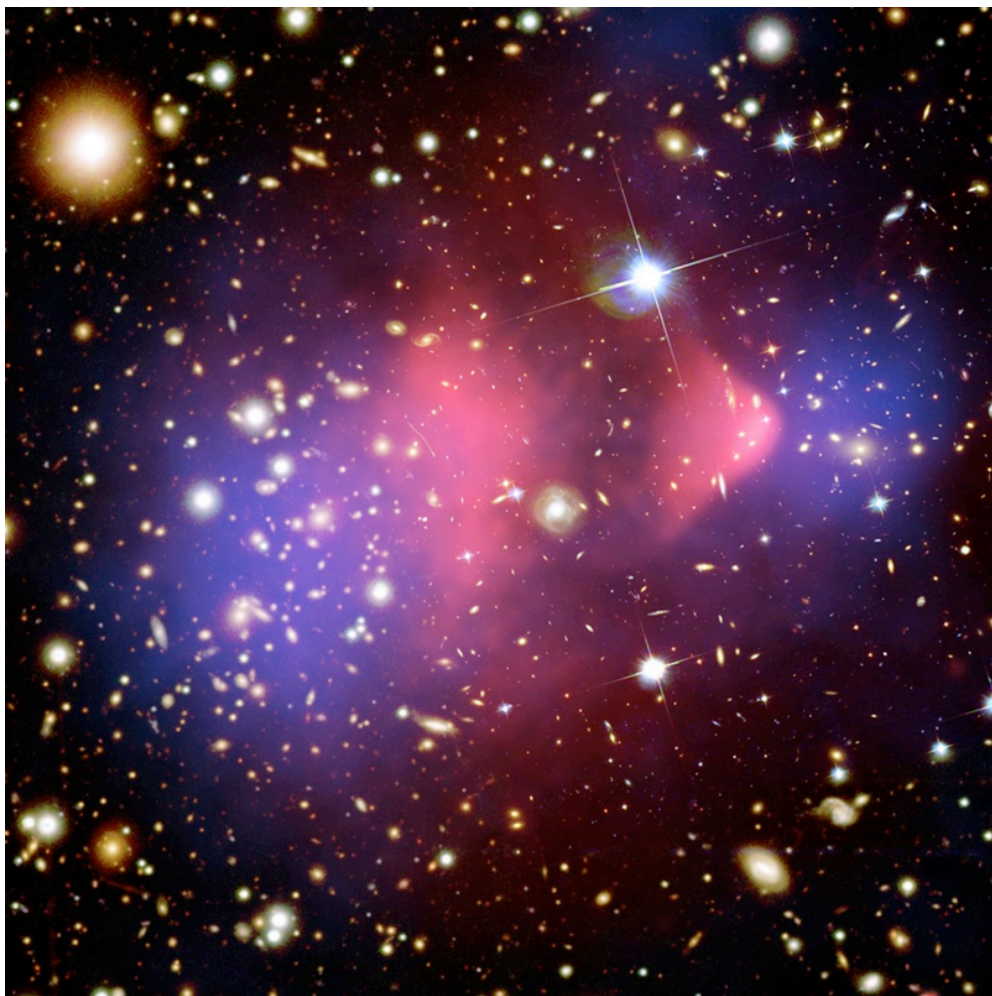
Dark matter



Dark matter

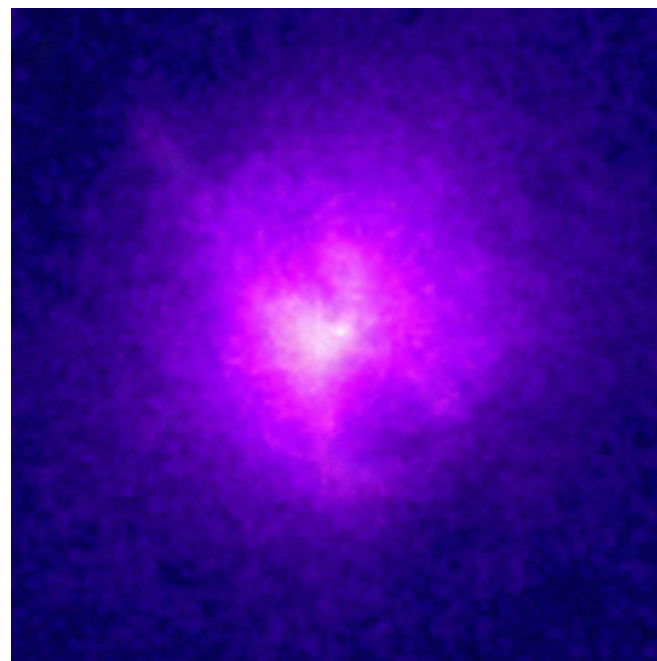
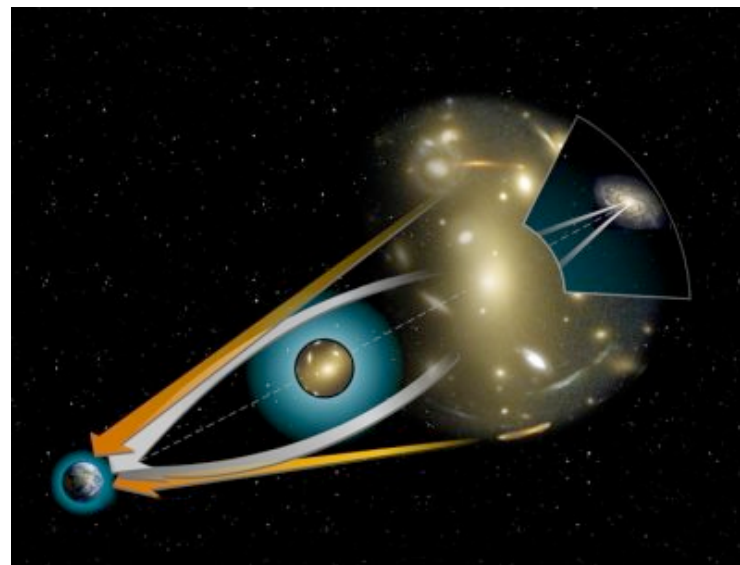


Dark matter



Blue : mass probed by lensing

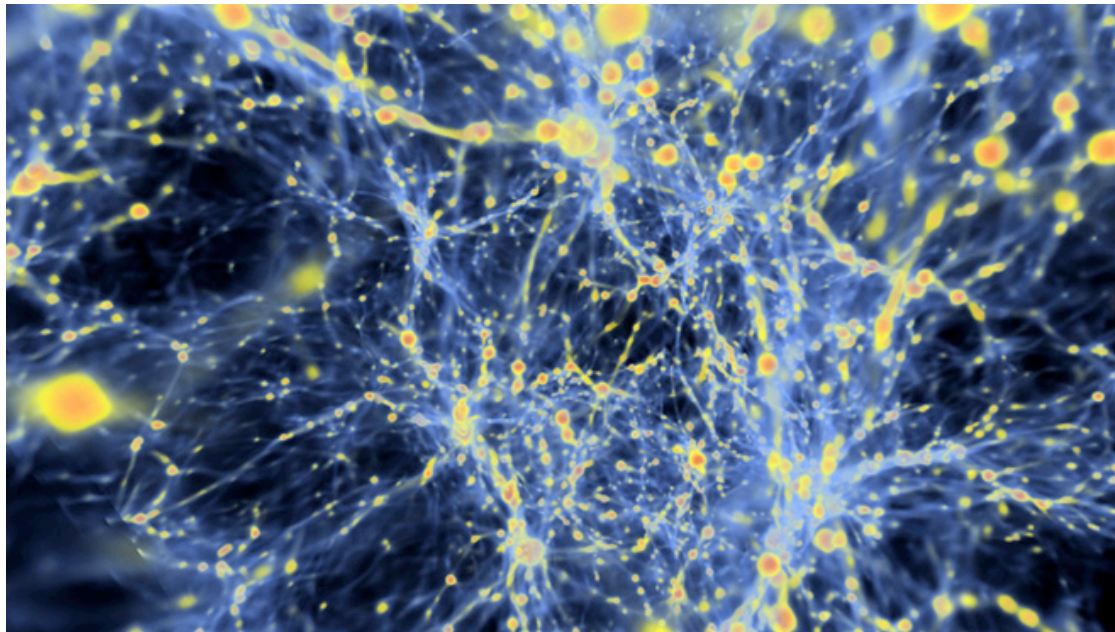
Red : atoms probed by X-rays



Dark matter

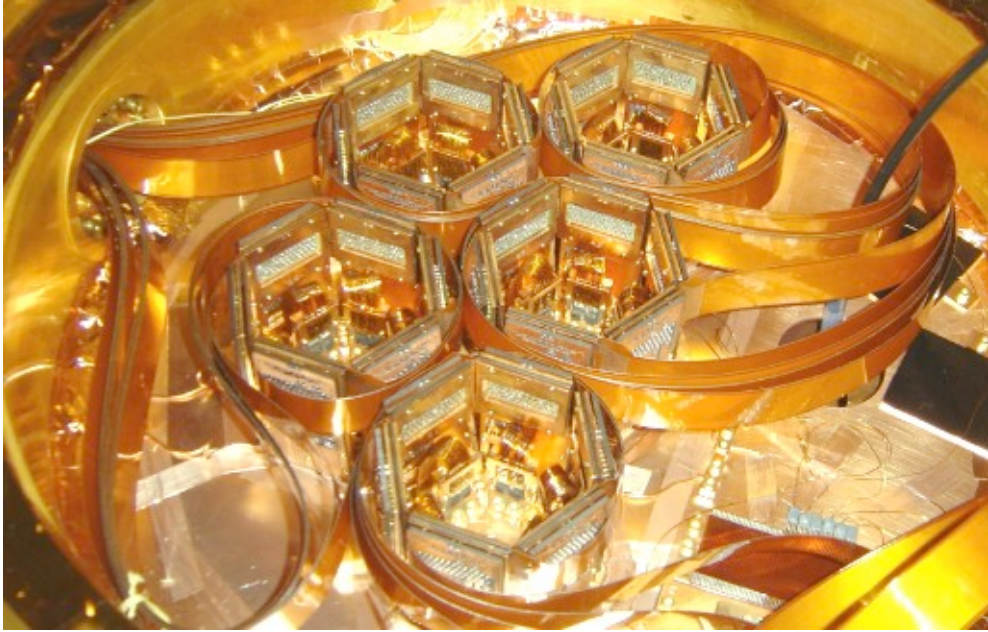


Lumps of rock?



Sub-atomic
particles?

Dark matter

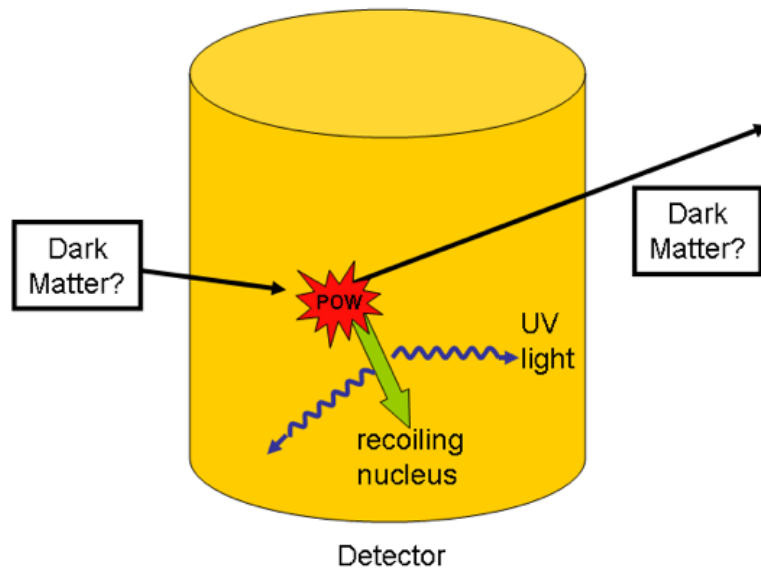


CDMS gives possible evidence for dark matter

Dec 18, 2009 [9 comments](#)



Are there any WIMPs inside?

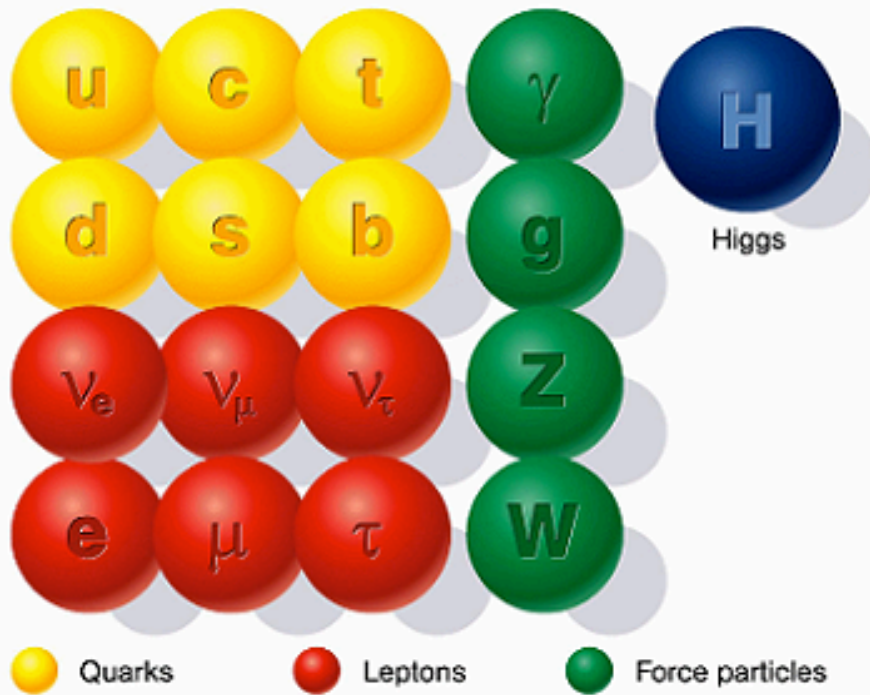


For weeks physicists have been speculating whether the CDMS-II collaboration based in the US has detected the first direct evidence for dark matter, one of the universe's most mysterious entities. Now the evidence is out in the open – although it's not quite as strong as some had hoped.

In a preprint submitted to the *arXiv* server yesterday, the CDMS-II team claim to have detected two "events" that are characteristic of dark-matter constituents known as weakly interacting massive particles, or WIMPs. However, they point out that there is a one-in-four chance that these events could be background noise.

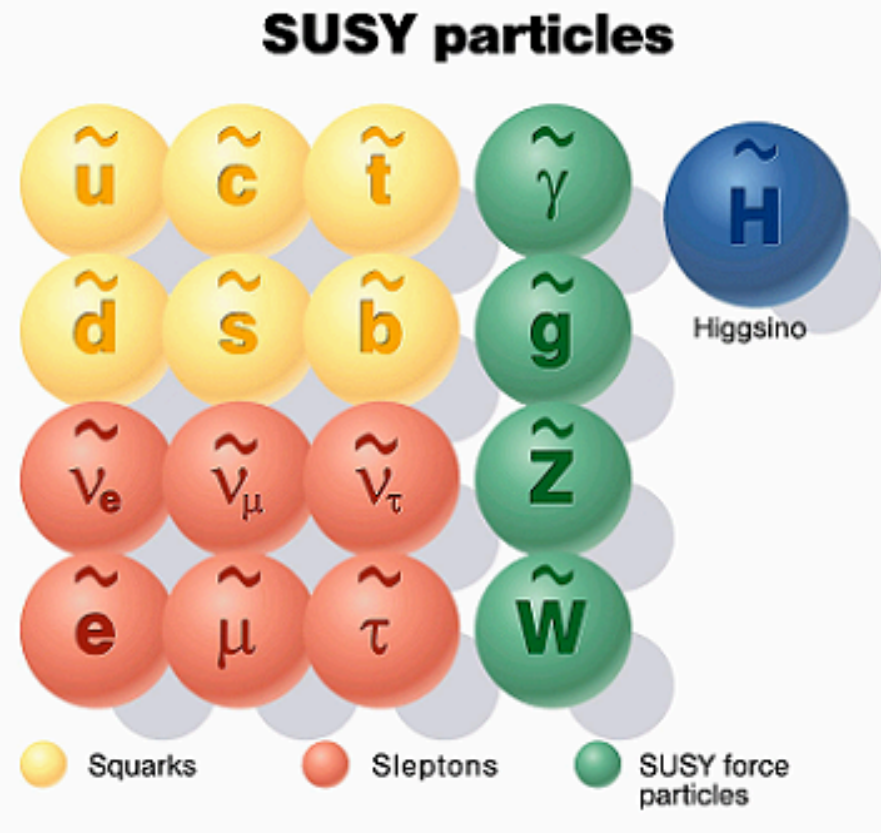
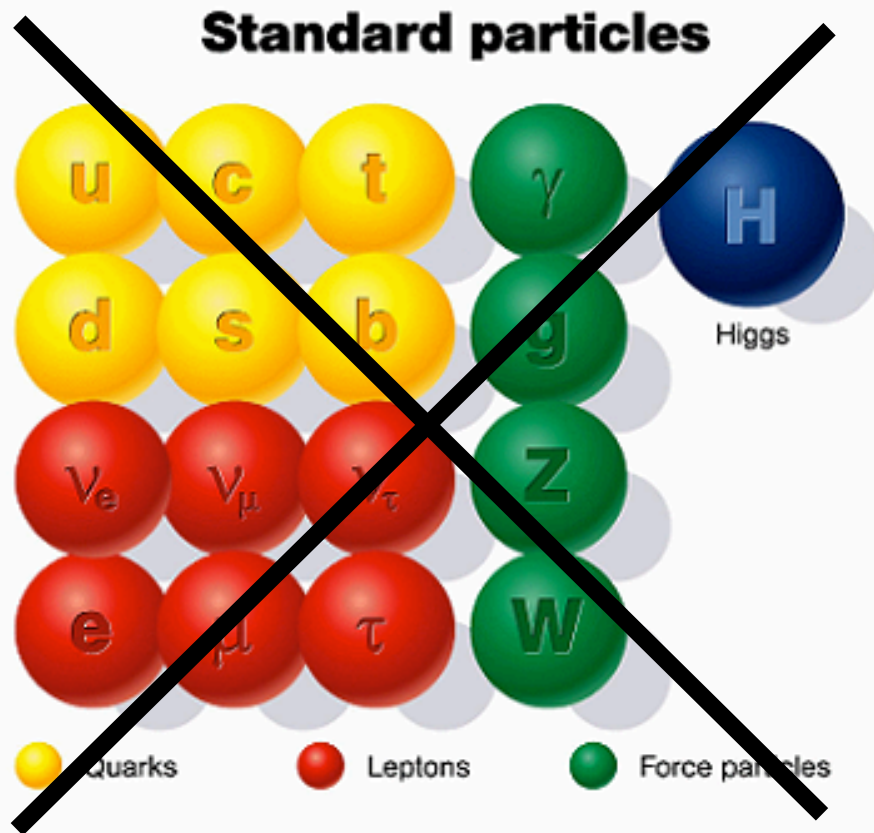
Dark matter

Standard particles



Theorists are trying to come up with new particles ...

Dark matter

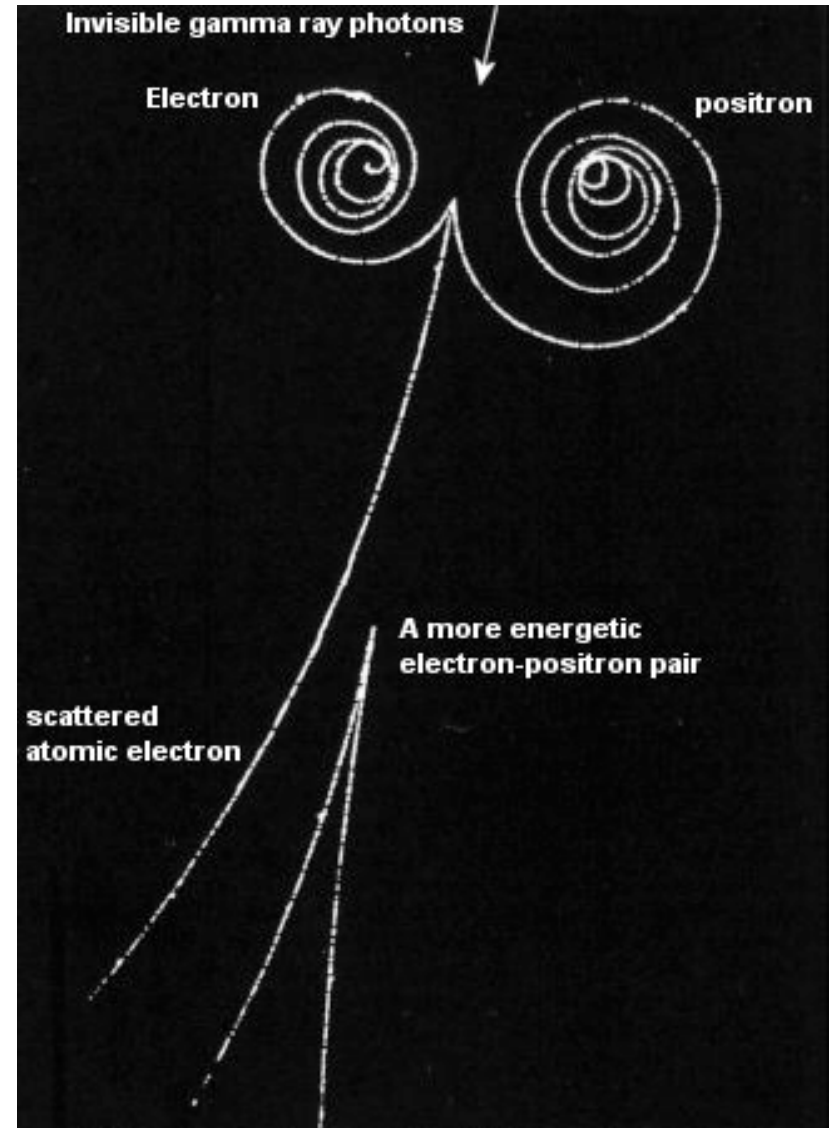
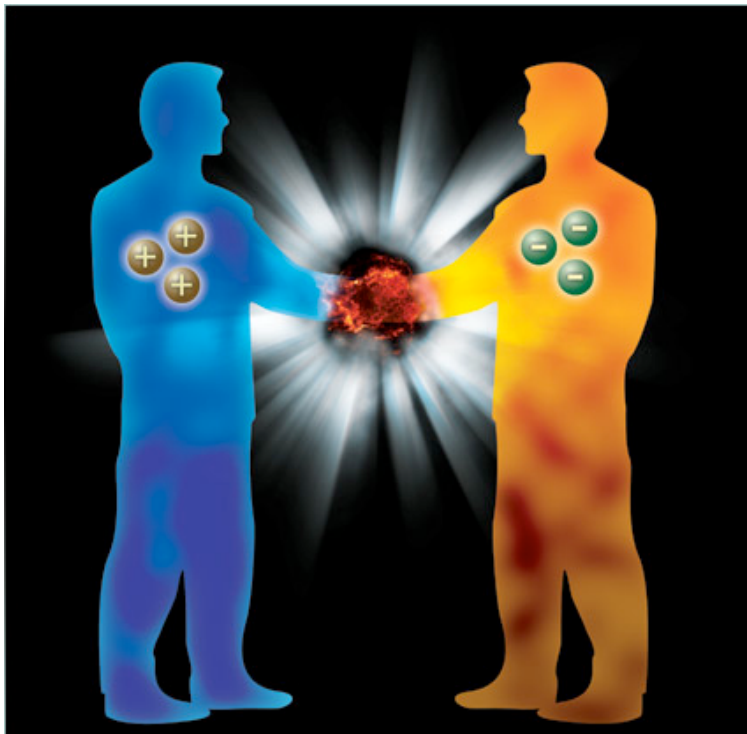
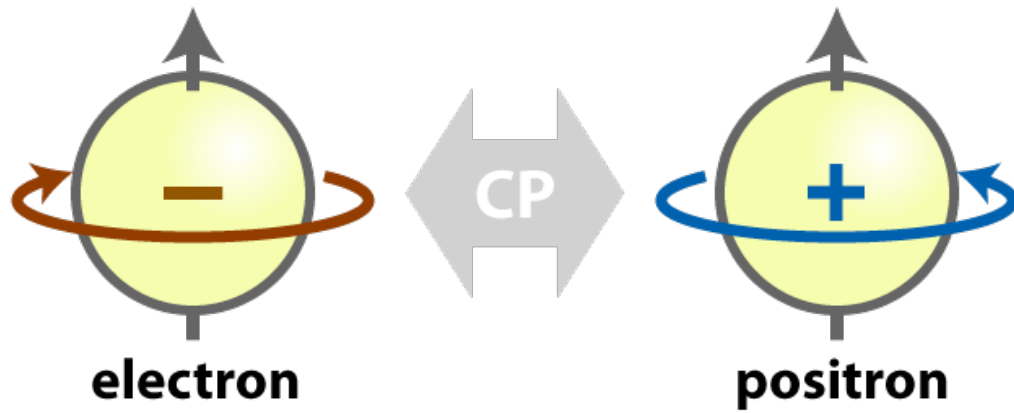


Theorists are trying to come up with new particles ...

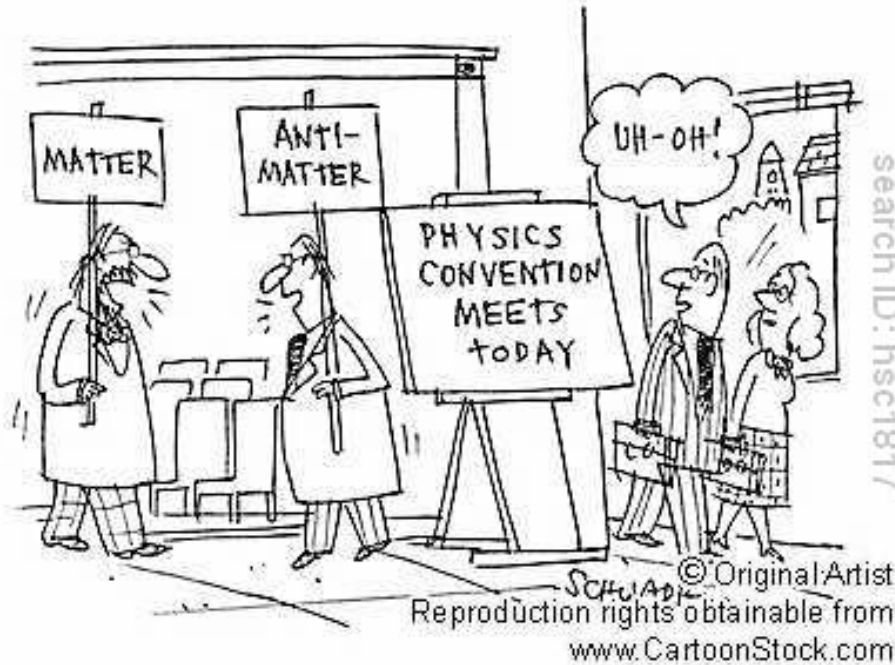
Anti-matter



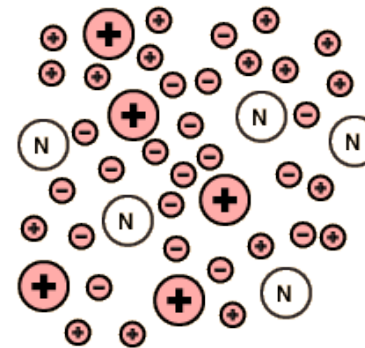
Anti-matter



Anti-matter



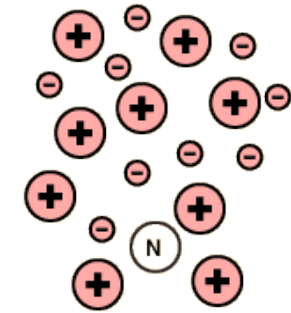
Hot, early universe



Protons = neutrons
equal population

Electrons = positrons
equal population

Present universe



Protons outnumber
neutrons almost 9 to 1

Electrons = protons in
population, almost
no positrons.

10,000,000,001

10,000,000,000

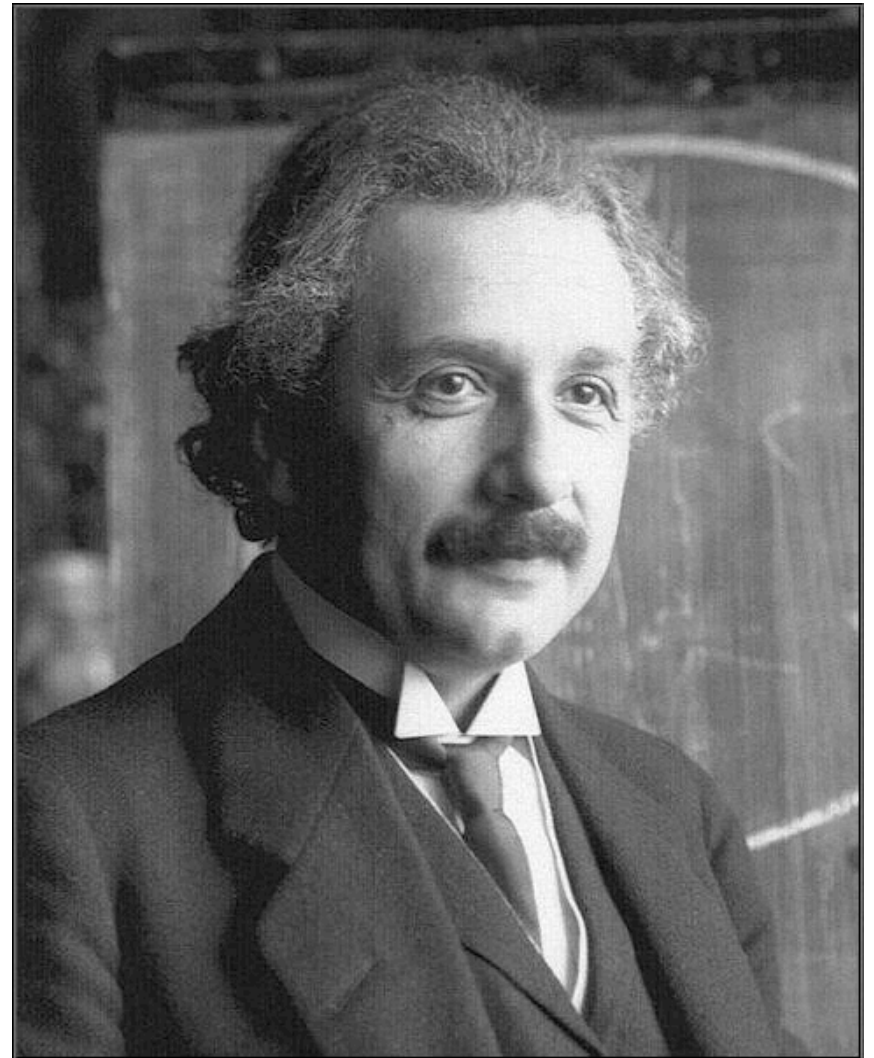
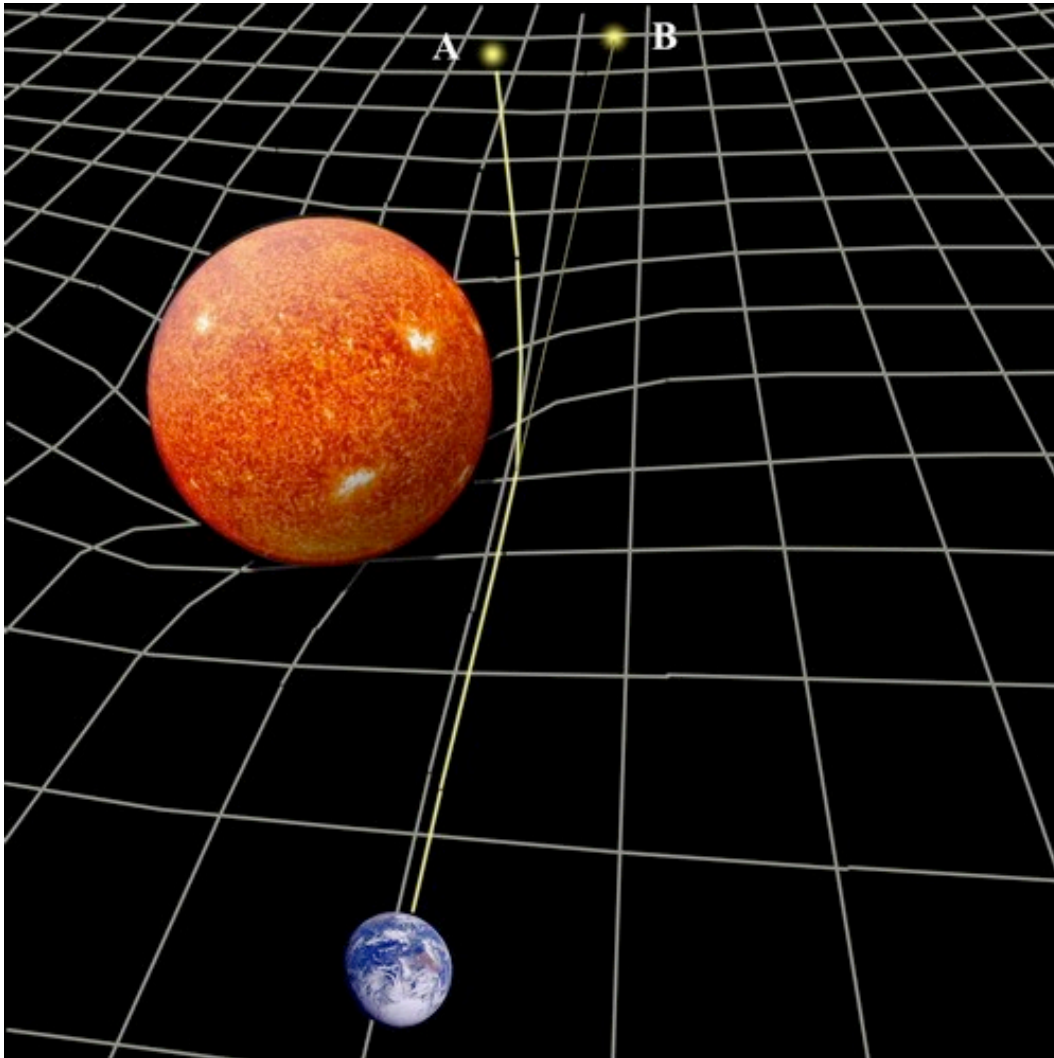
MATTER

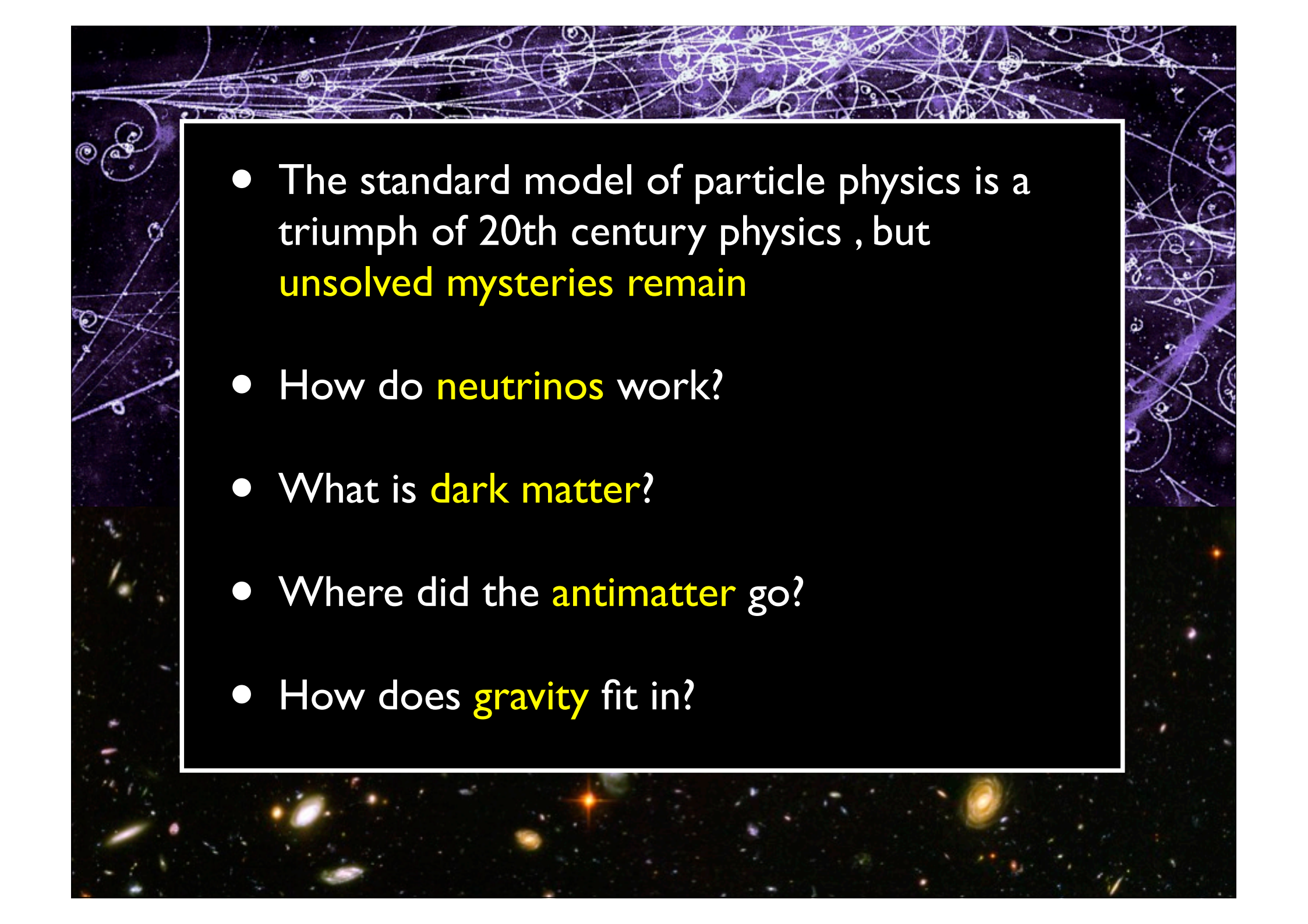
ANTI-MATTER

What caused the
imbalance between
matter and anti-matter?

Gravity

Gravity doesn't fit. What is the force carrier?



- 
- The standard model of particle physics is a triumph of 20th century physics , but **unsolved mysteries remain**
 - How do **neutrinos** work?
 - What is **dark matter**?
 - Where did the **antimatter** go?
 - How does **gravity** fit in?

Thank you for coming !

