Dark Puzzles  of the Universe

Saturday Morning Physics
(2007)

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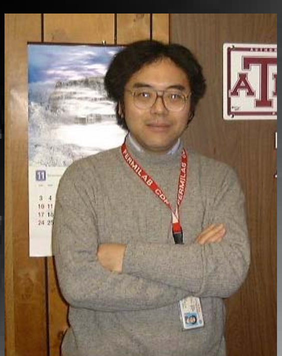
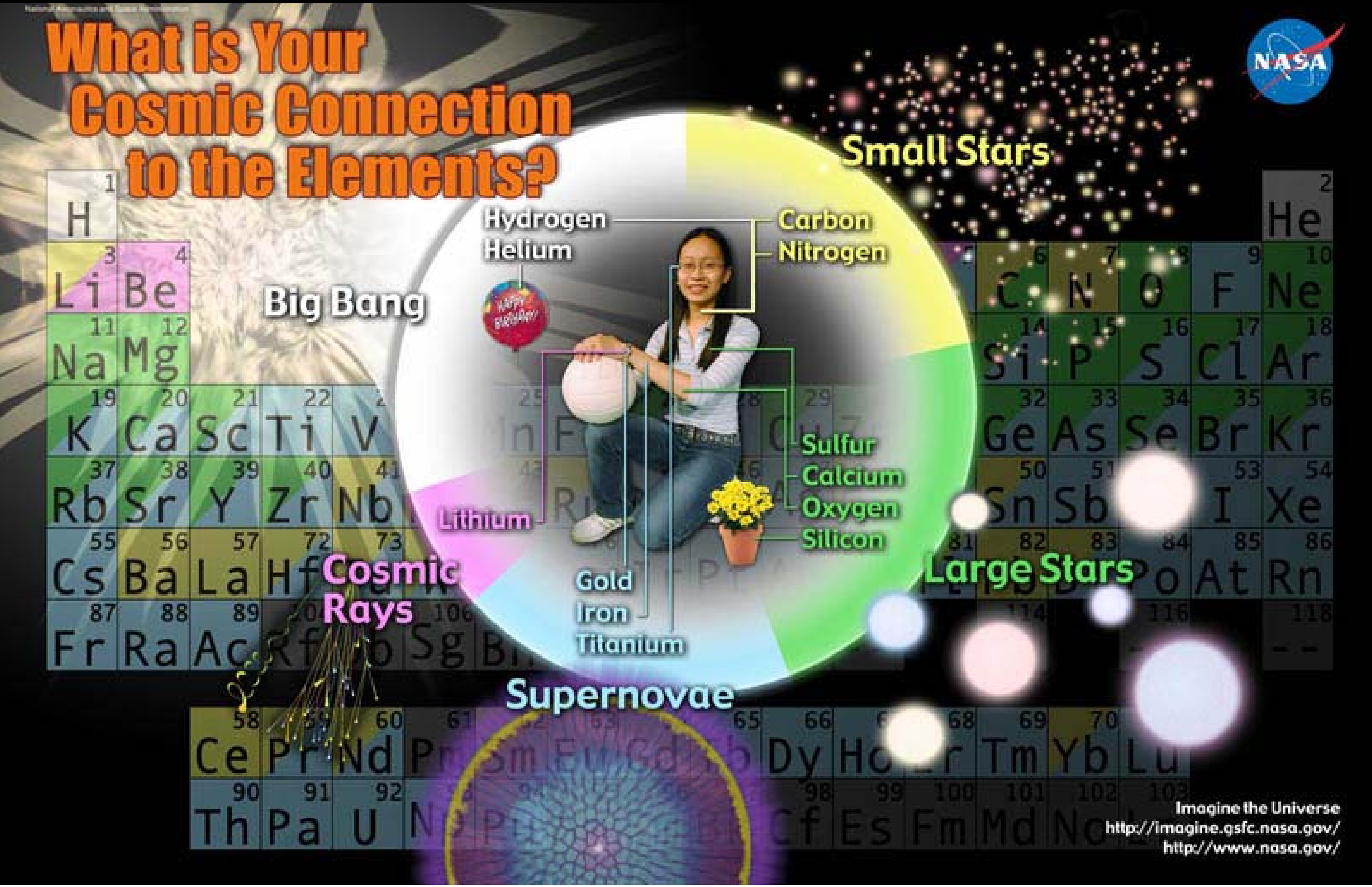
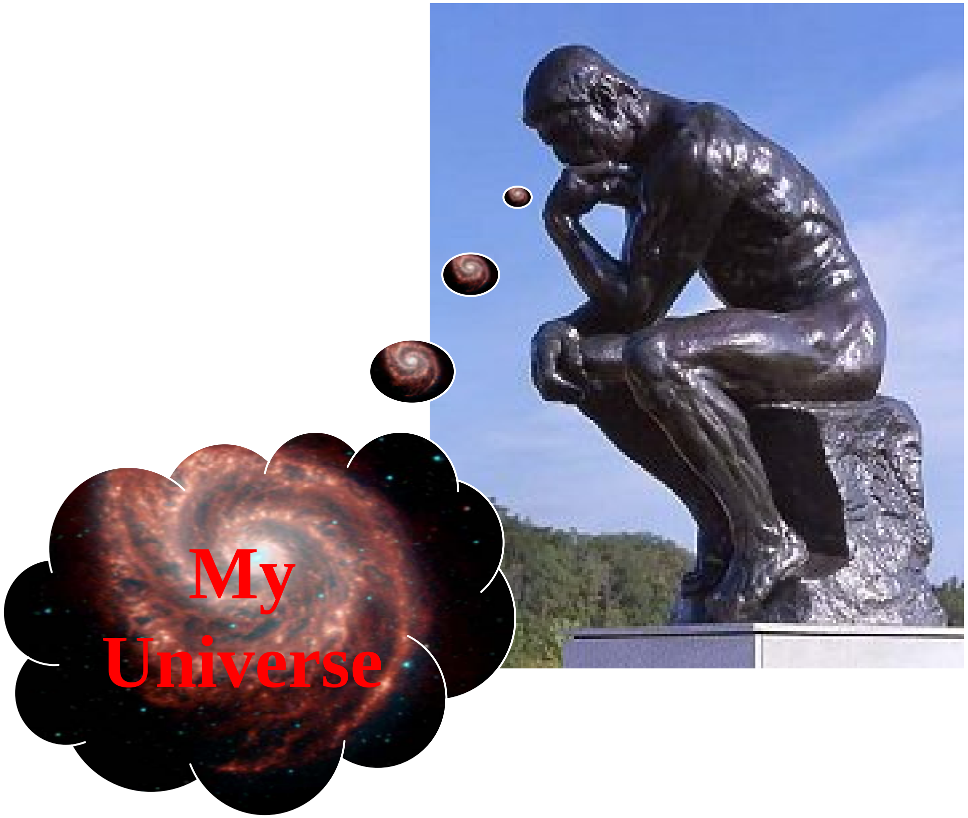
and
Prof. Teruki Kamon



Department of Physics
Texas A&M University

Question


What is Your Cosmic Connection to the Elements?
NASA
Small Stars
Big Bang
Hydrogen
Helium
Carbon
Nitrogen
Sulfur
Calcium
Oxygen
Silicon
Lithium
Gold
Iron
Titanium
Cosmic Rays
Large Stars
Supernovae
Imagine the Universe
http://imagine.gsfc.nasa.gov/
http://www.nasa.gov/


My
Universe

Message from the Universe

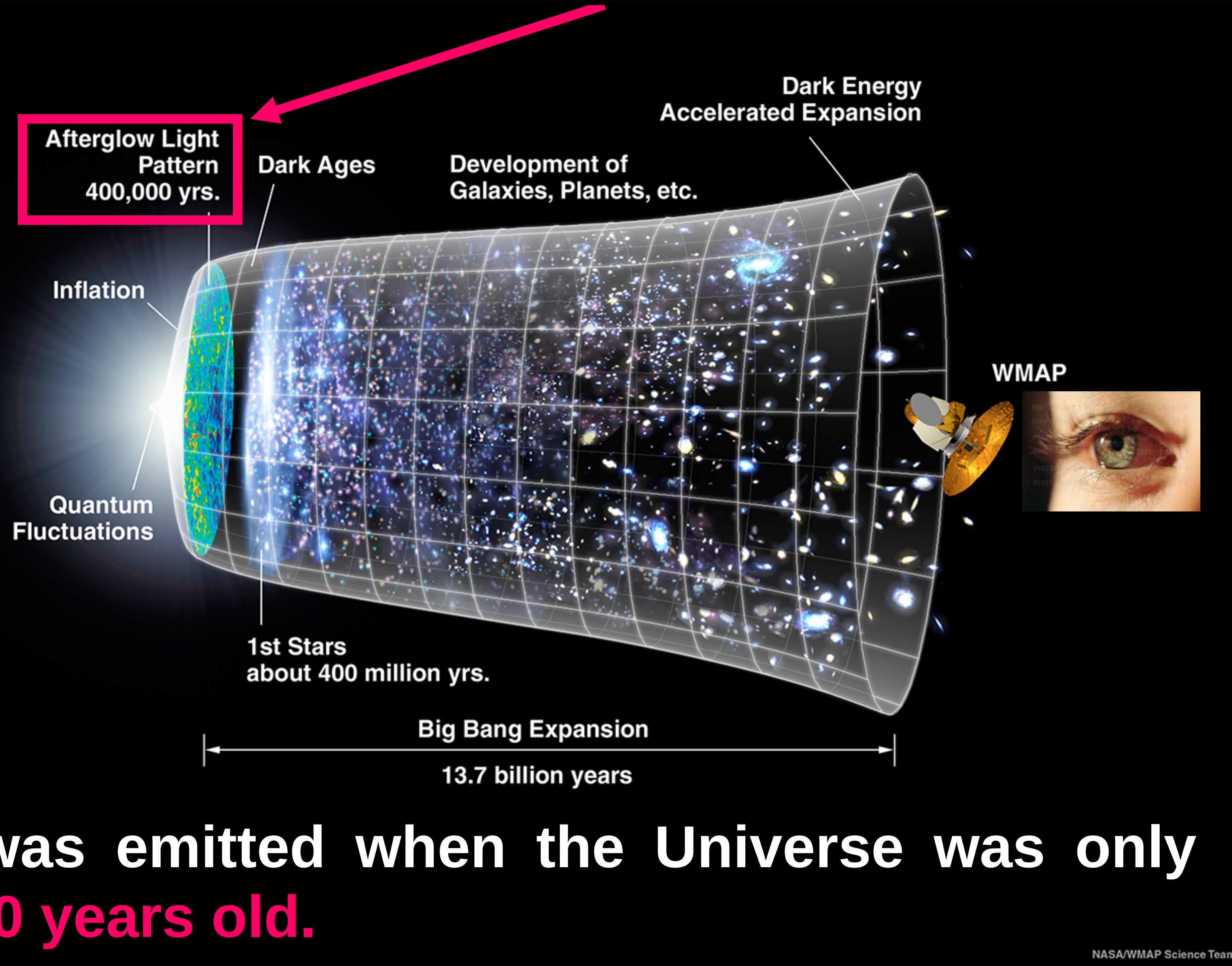
How do we measure the content of the Universe?

We look at the the oldest light which set out on its journey long before the Earth or even our galaxy existed.

This light forms the background of the Universe:
Cosmic Microwave Background (CMB)

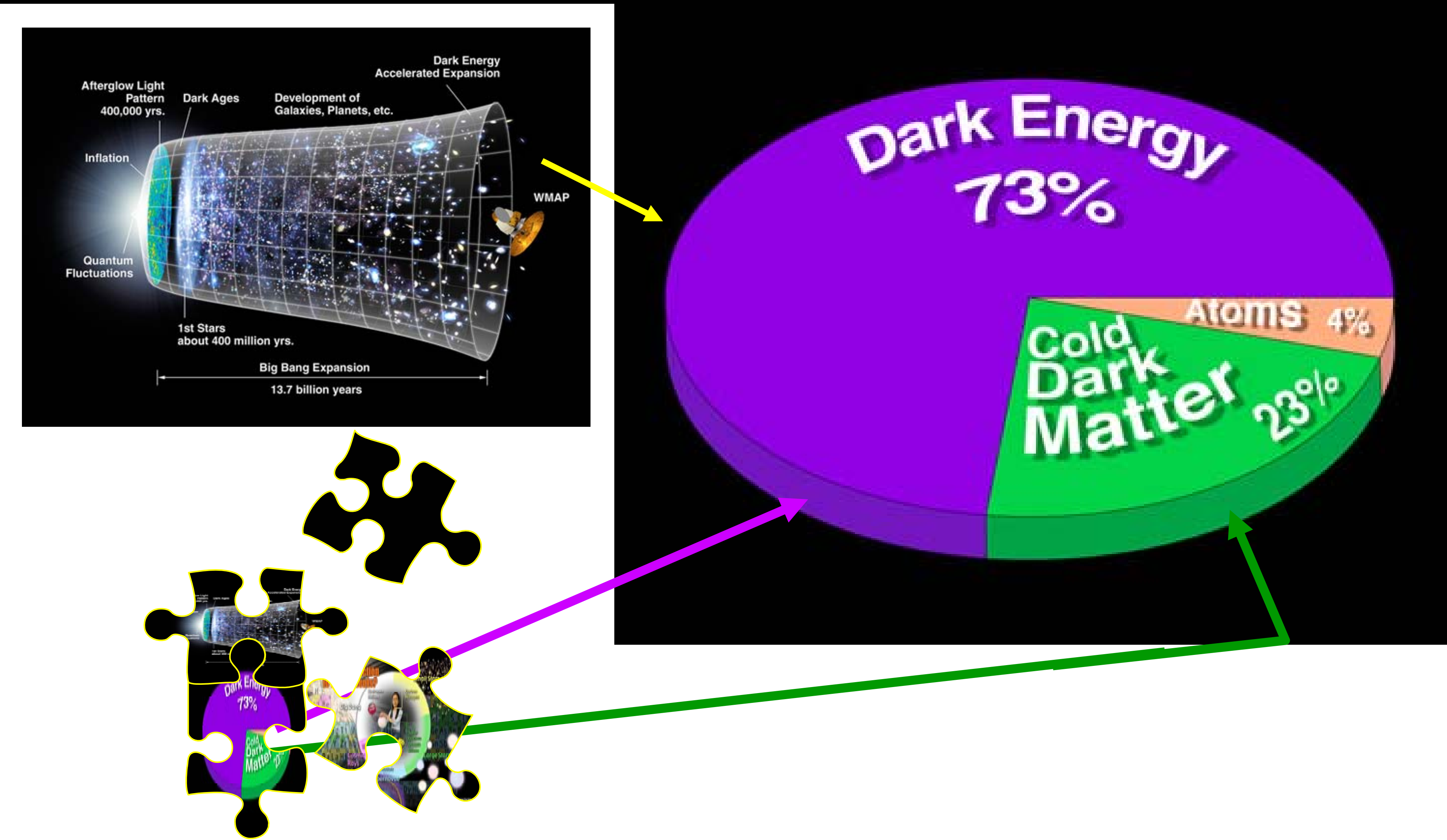
Measurement of this light tells us the story of the Universe.

The Most Distant Light



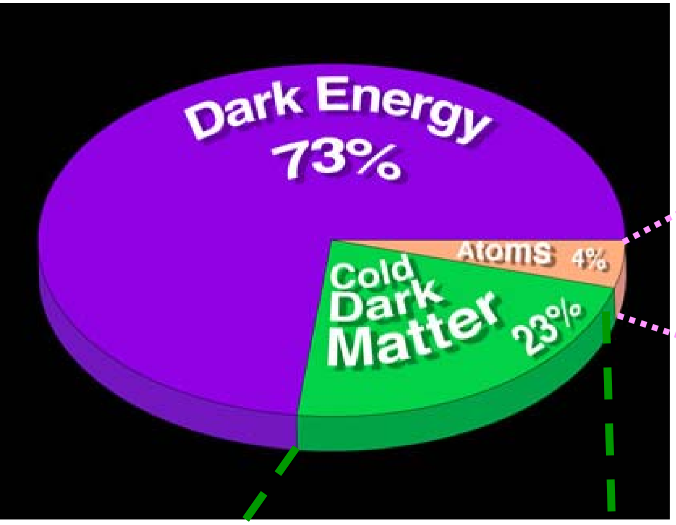
CMB was emitted when the Universe was only 380,000 years old.

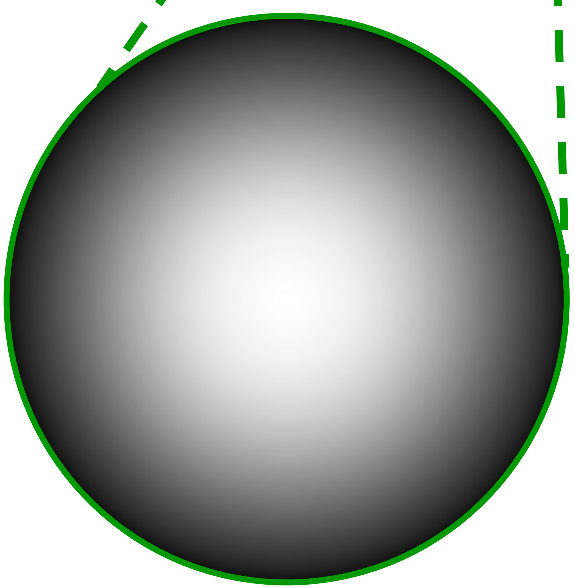
The Universe Pie



Today, we discuss DM.

Content of the Universe



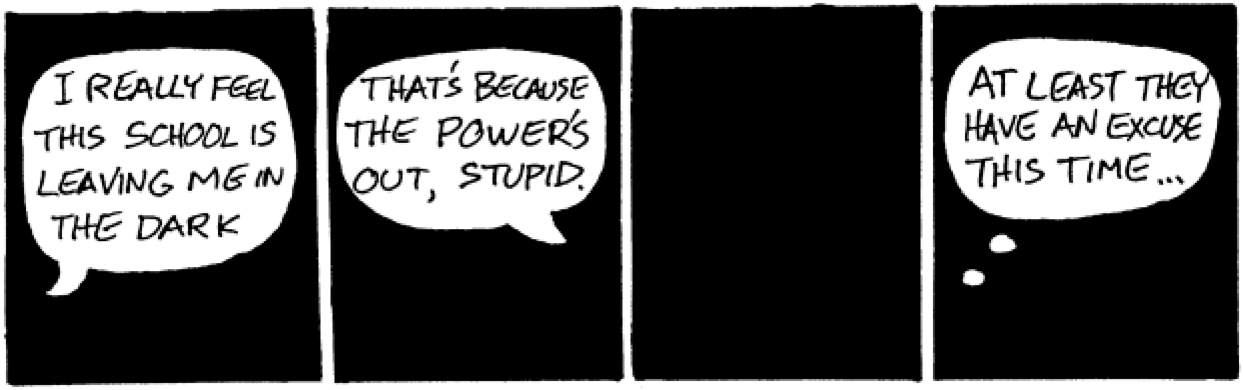


The 23% is still unobserved in the laboratory..

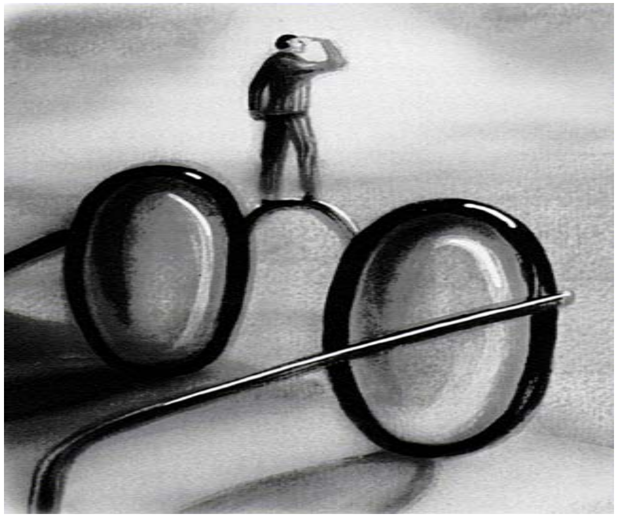
(This new matter can not be seen visually!)

We call this Dark Matter..

Existence of Dark Matter



We know the dark matter exist

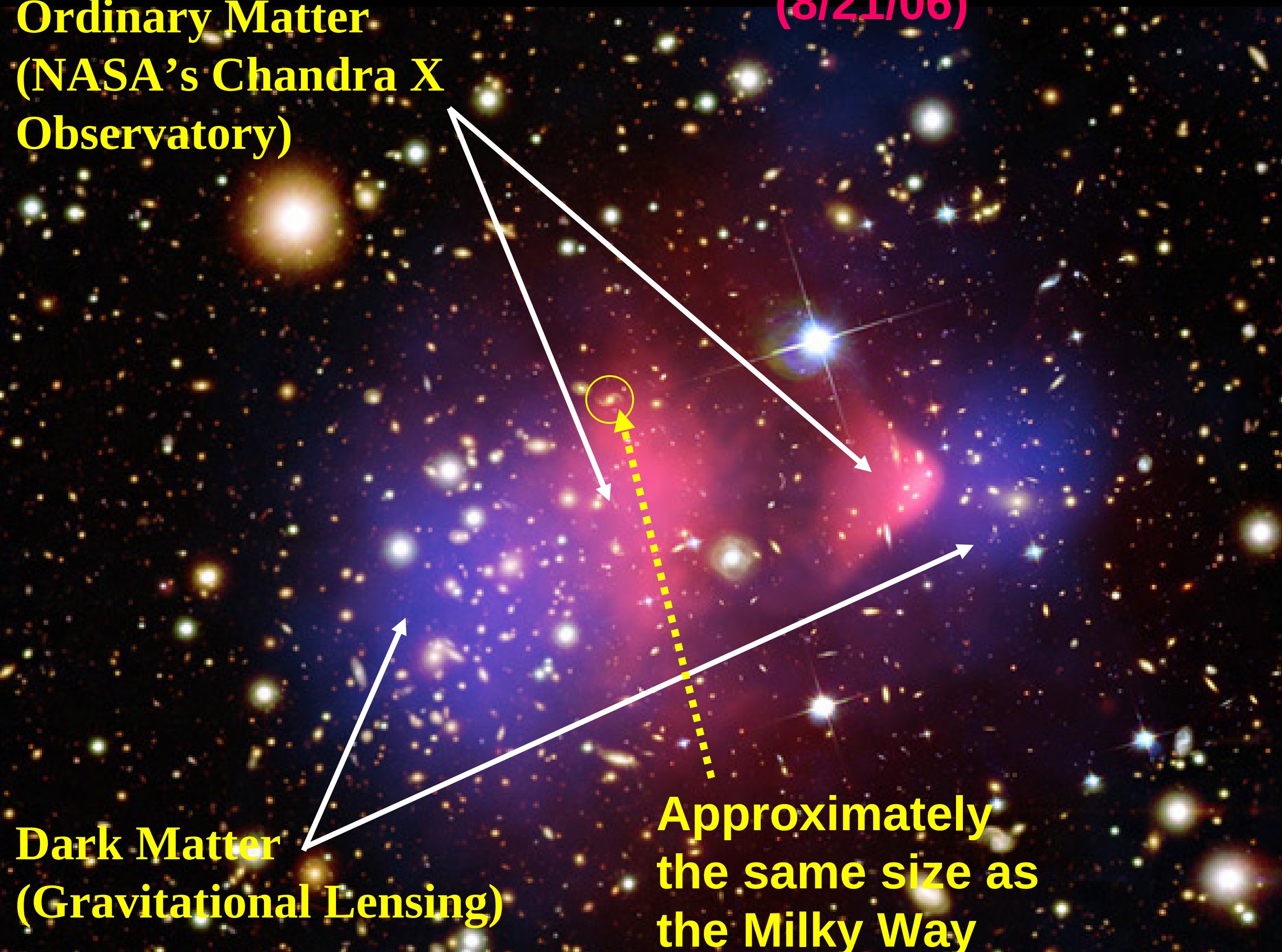


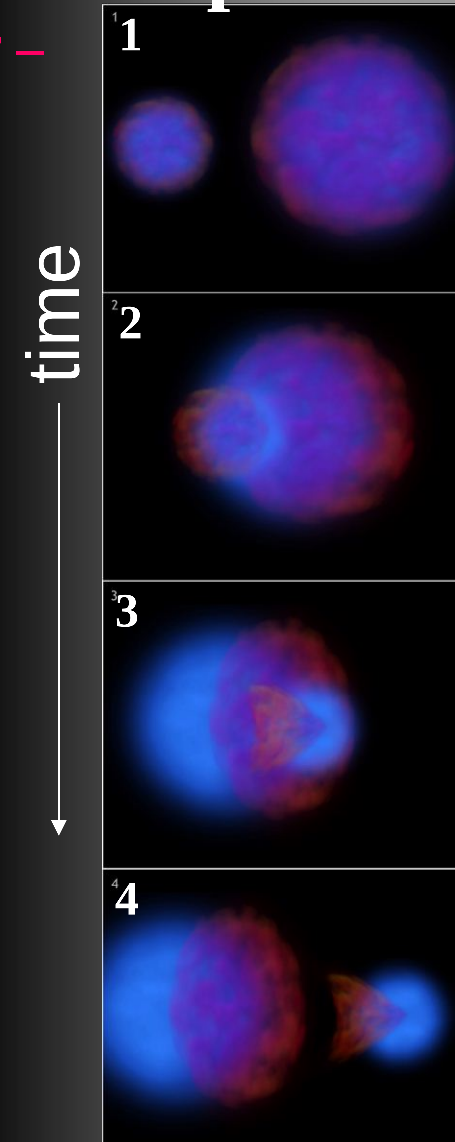
Collision of the galaxies

Rotation curves of the galaxies

Cosmic Collision of 2 Galaxy Clusters
splitting normal matter and dark matter apart

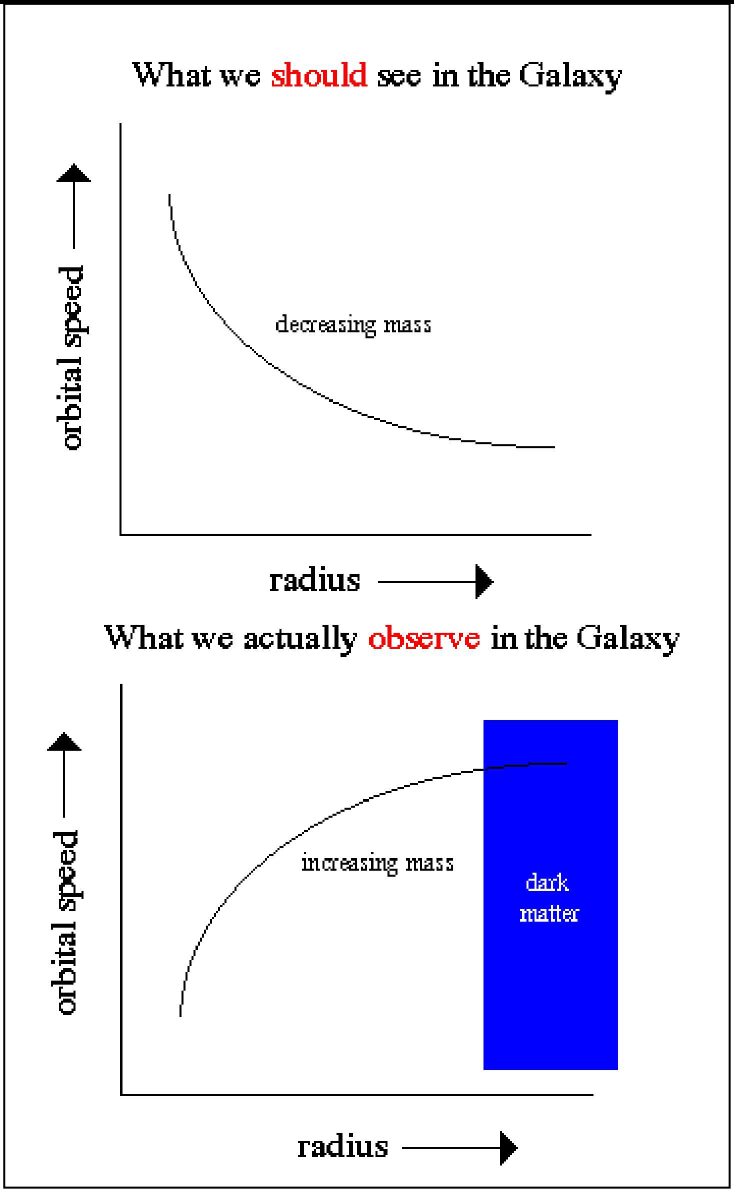
– Another Clear Evidence of Dark Matter –
(8/21/06)





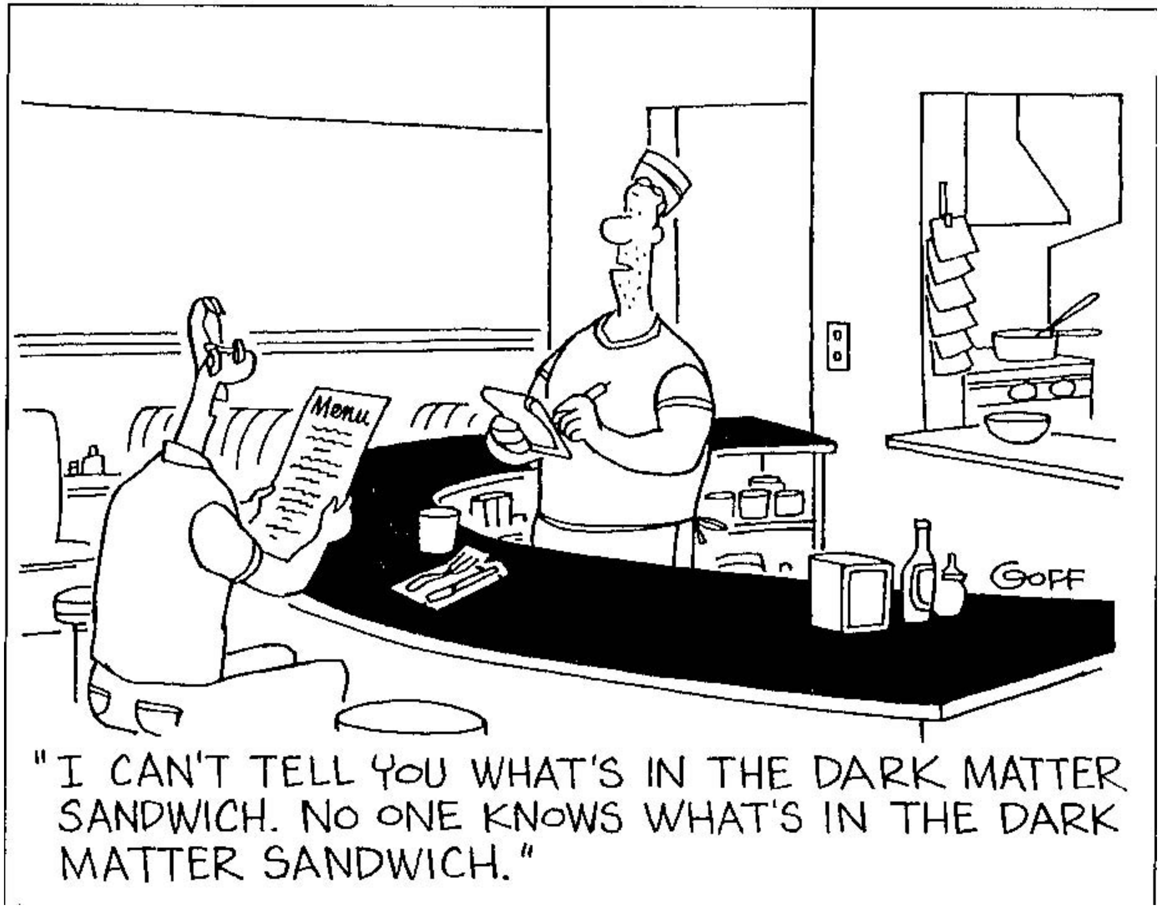
Rotation Curves of the Galaxies

Old observation



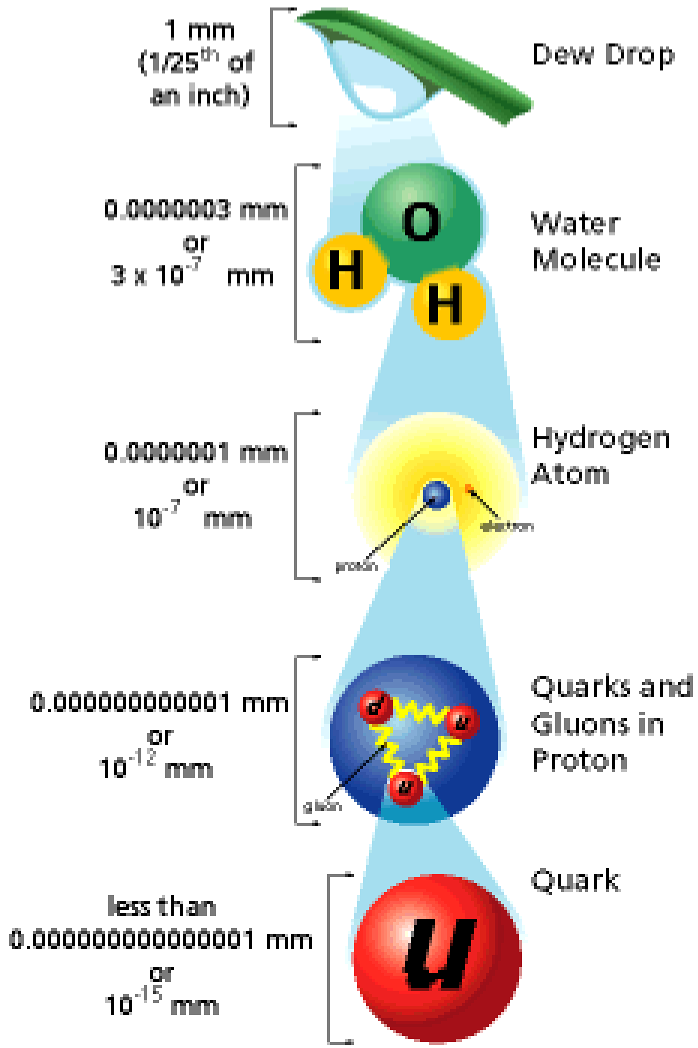
What is Dark Matter?

Neutral and long-lived object



Can it be one of the known particles?

Building Blocks of Matter



What are the elementary particles?

Zoo: 12 Particle Animals

The elementary particles are fundamental building blocks of matter.

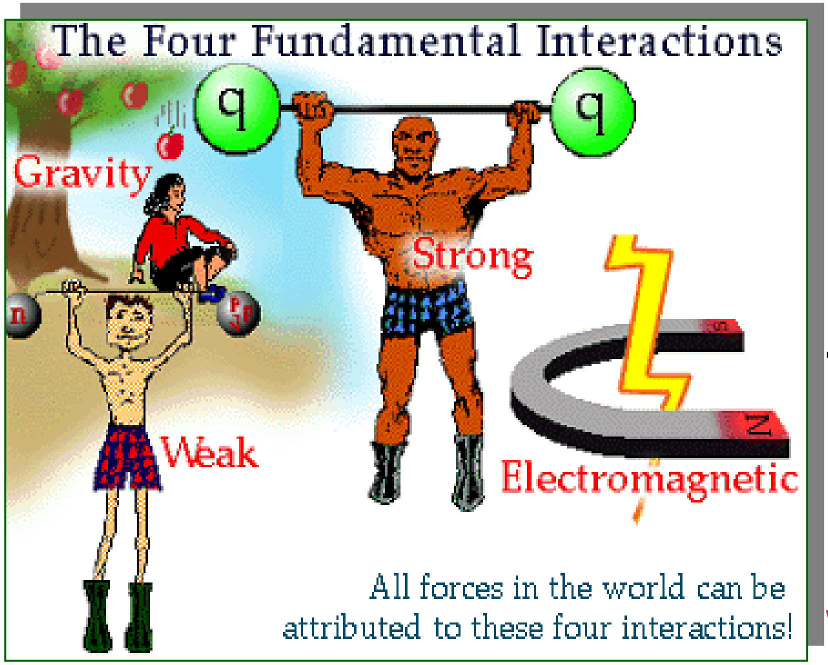
6 Types of Quarks

6 Types of Leptons

All masses in MeV.

ANIMAL MASSES SCALE WITH PARTICLE MASSES

Fantastic Four



Gluons (g) for strong force

Quarks experience them.

Protons & neutrons form.

Photons (γ) for electromagnetic force

Quarks, leptons (other than neutrinos) experience this force.

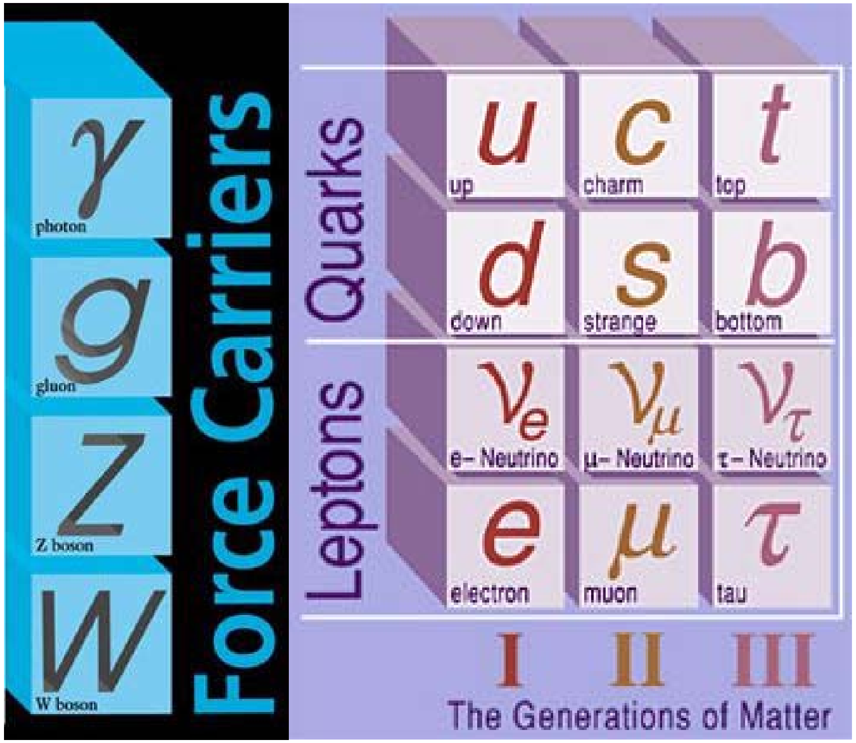
W's for weak forces

Quarks, leptons experience this force.

NOTE : Graviton (G) (☹ *not found*) carries gravitational force.

The Standard Model

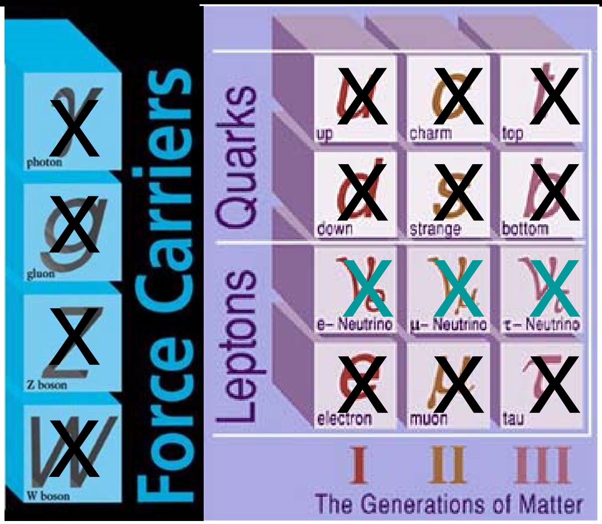
The Standard Model is a model which describes all these particles and 3 of 4 forces:



We have confirmed the existence of SM in the laboratory experiments.

So, can it explain our Universe?

Dark Matter Particle?



Quarks, electron, muon, tau particles, and force carriers can not be the dark matter, since their interactions are stronger than what we expect.

Neutrinos can, but they have other problems.

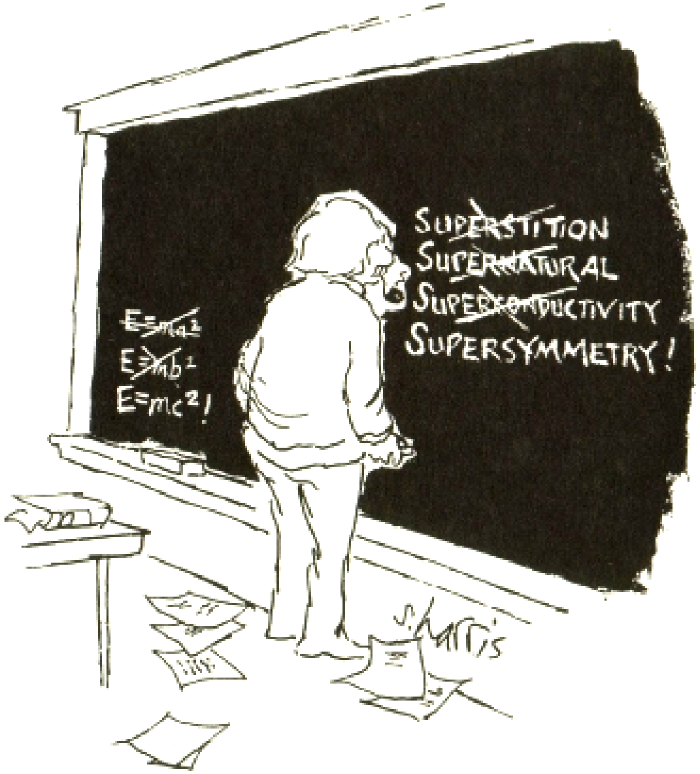
We need a new model, called Supersymmetric Standard Model or SUSY. This model has a new charge-less (neutral) particle: Neutral-ino

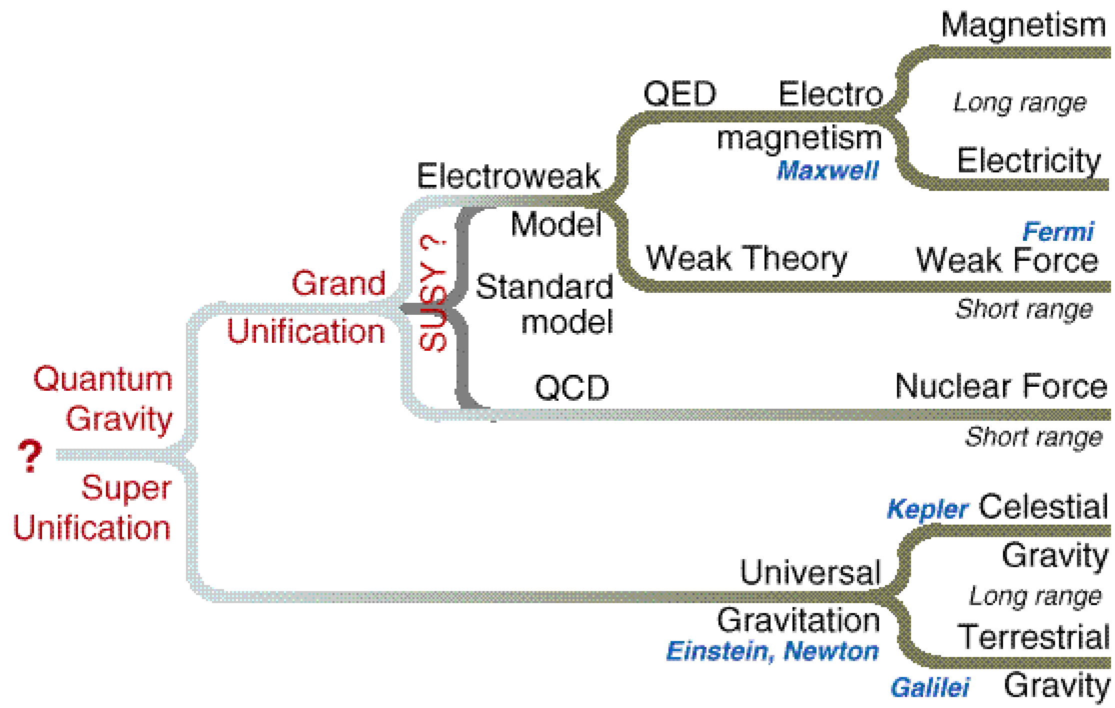
1) What is the new model?

2) Can the neutralino be observed and consistent with the dark matter content of the Universe?

Dream of Unification

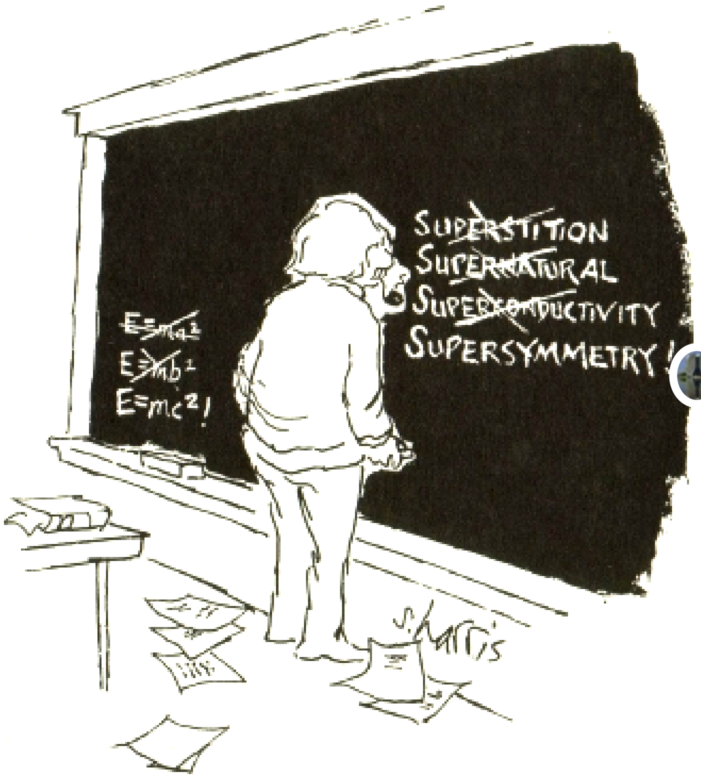
Physicists always dream about unification of all the forces.



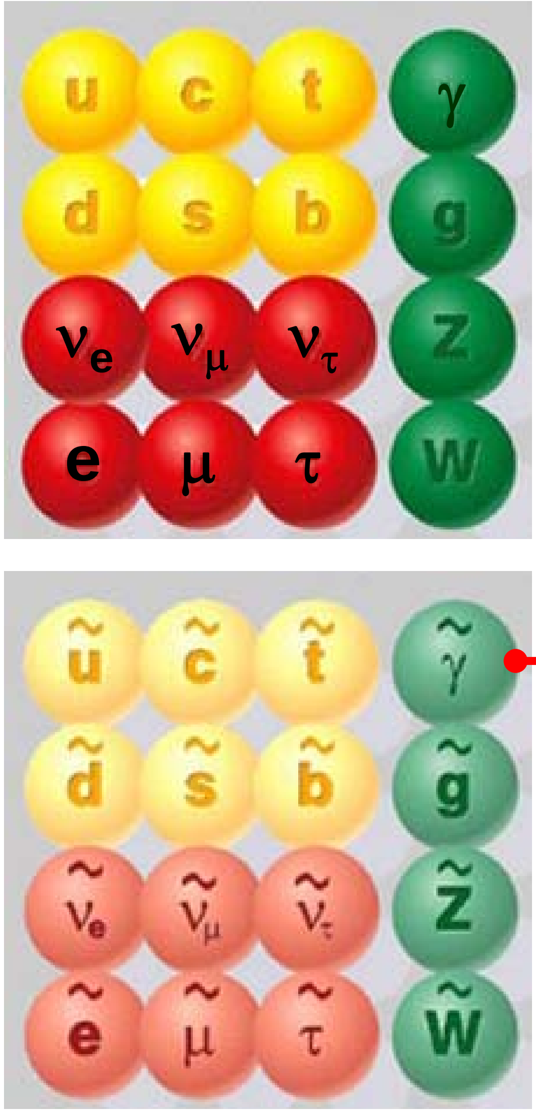


The grand unification of the forces occur in the SUSY model.

Mirror Reflection



Supersymmetric Reflection

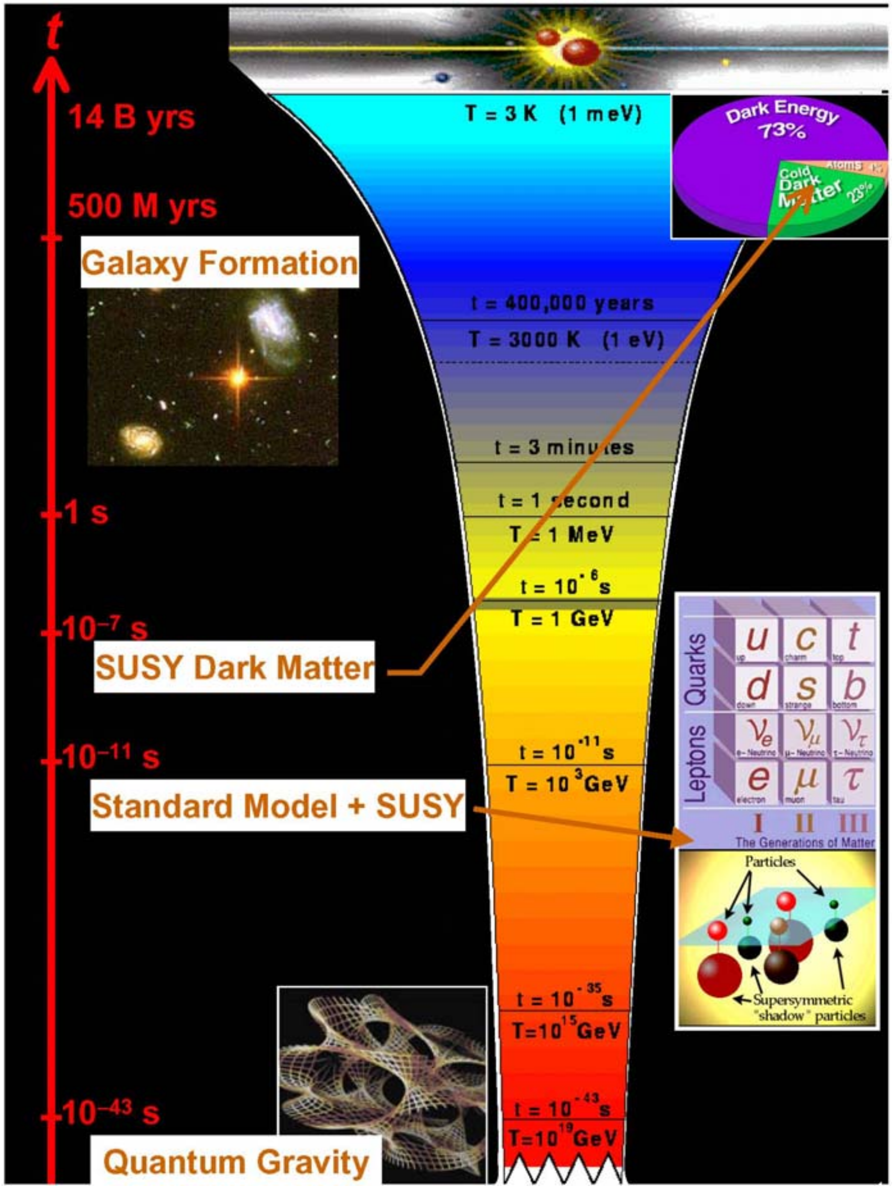


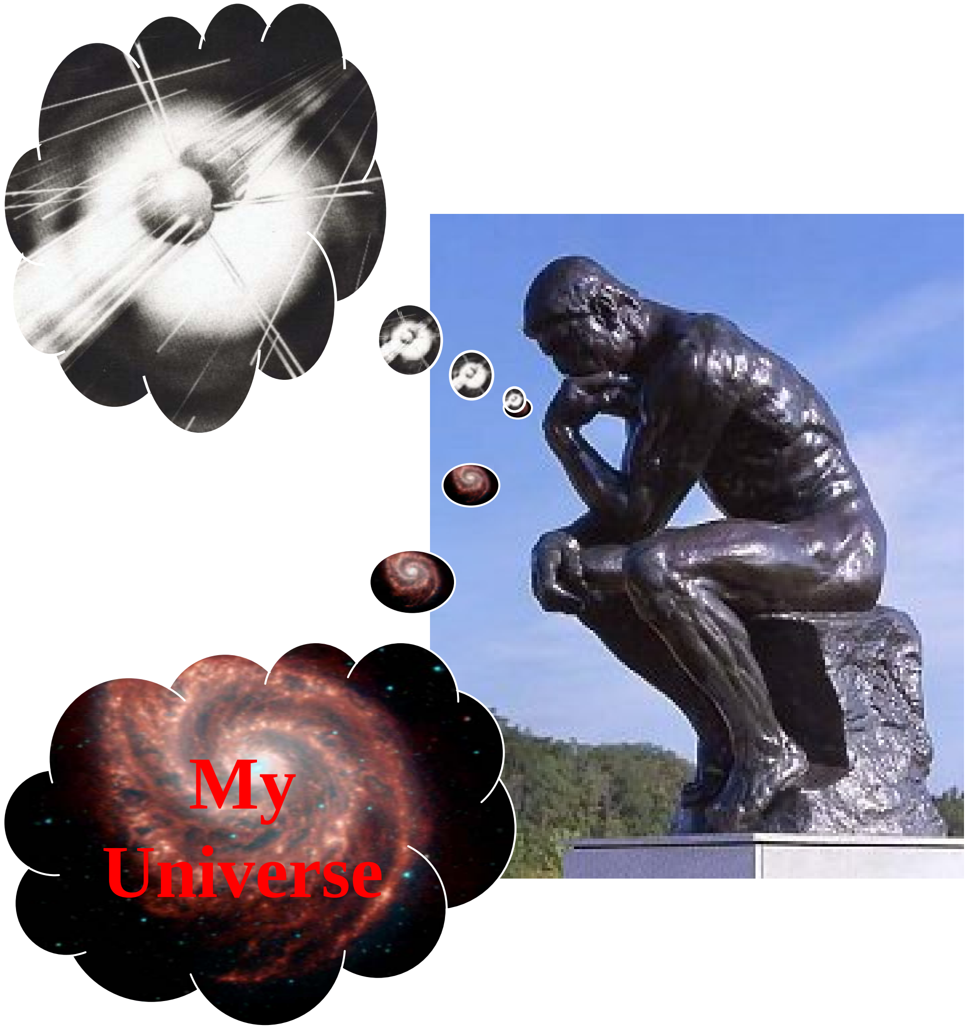
Renamed as "chi one zero" $\tilde{\chi}_1^0$

But, one of them is neutralino.
This is a leading candidate for dark matter particle.

Now

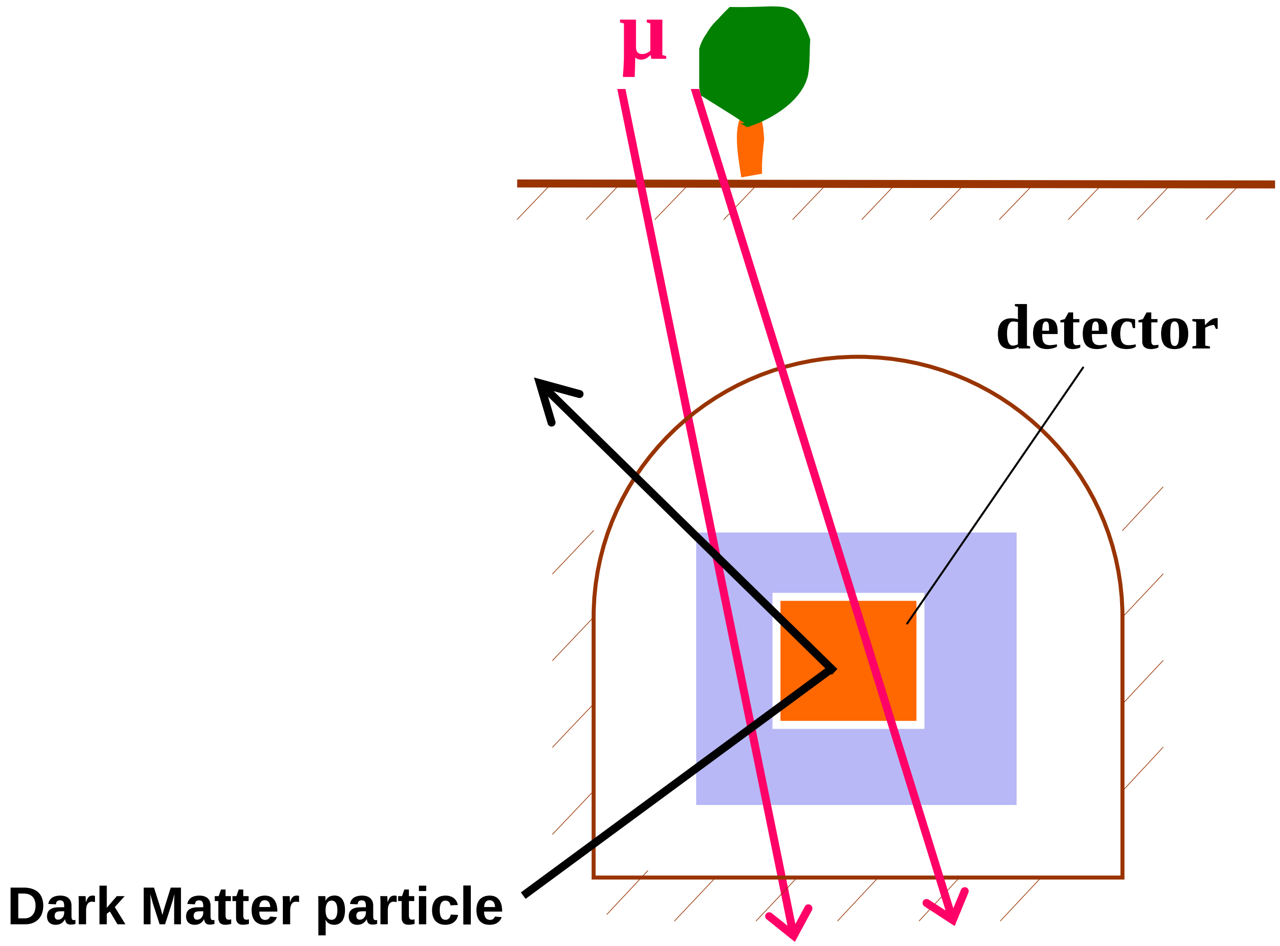
~ 0.0000001 seconds




My
Universe

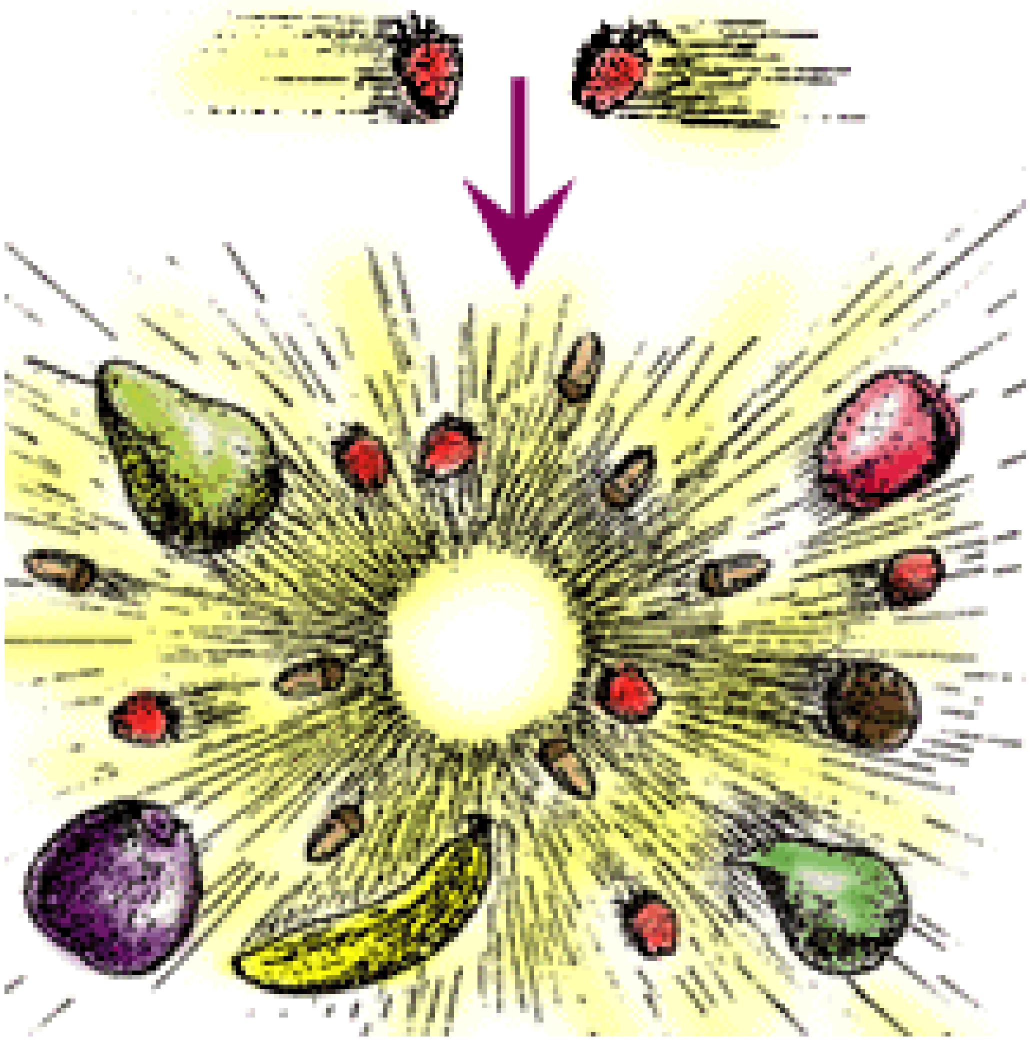
How Can We See Them in the Lab?

One type of experiment: in deep underground



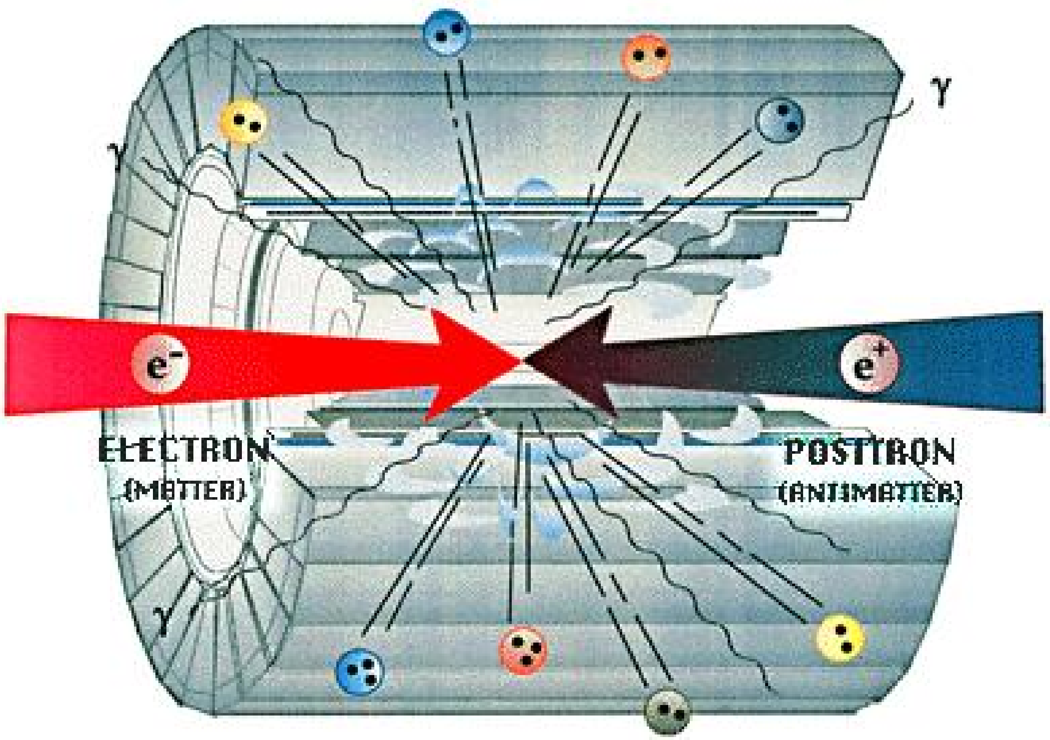
Collider

One promising way: In collisions



Particle Collider

One promising way: In particle collisions

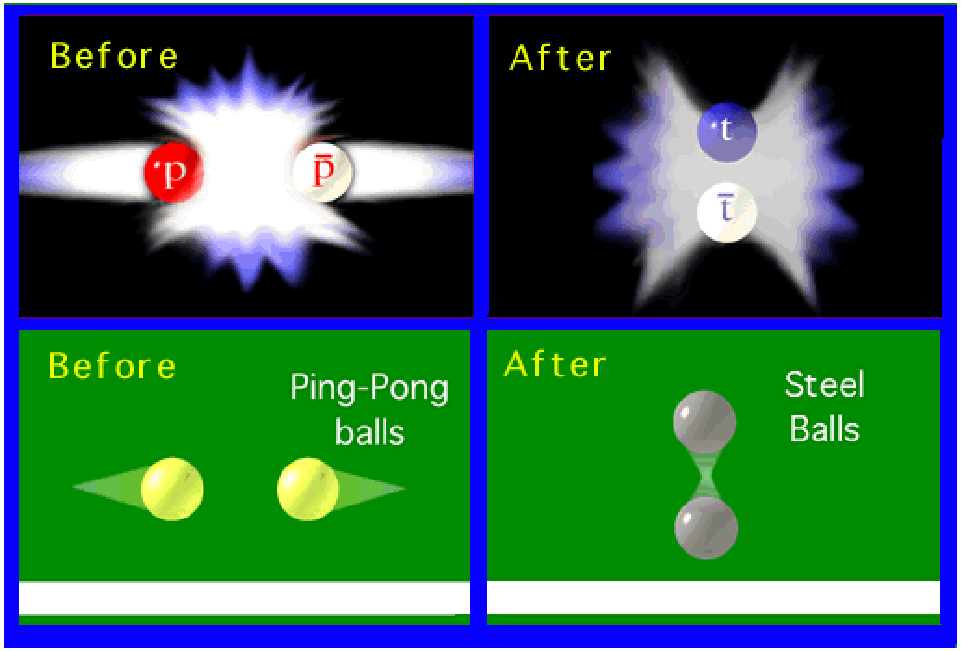


➪ **Tevatron and Large Hadron Collider**

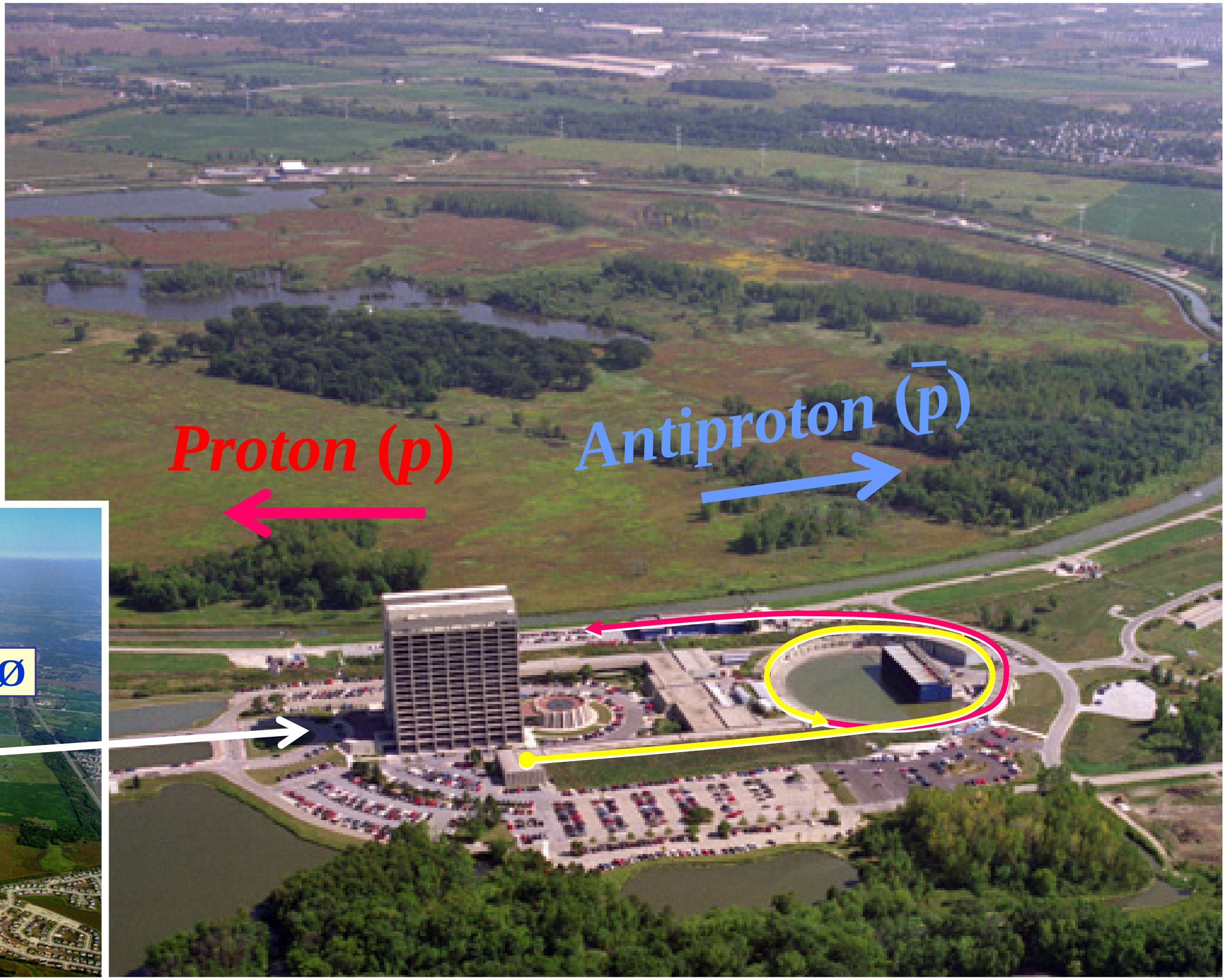
Physics Magic: Ping-pong balls → Steel Balls

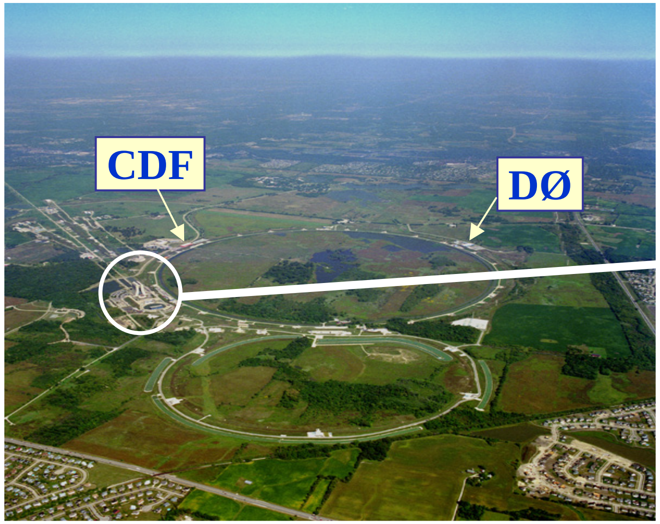
$$E = mc^2$$

Proton and ant-proton collision can produce the Standard Model particles like heavy top quarks (~180 times heavier than a proton!)



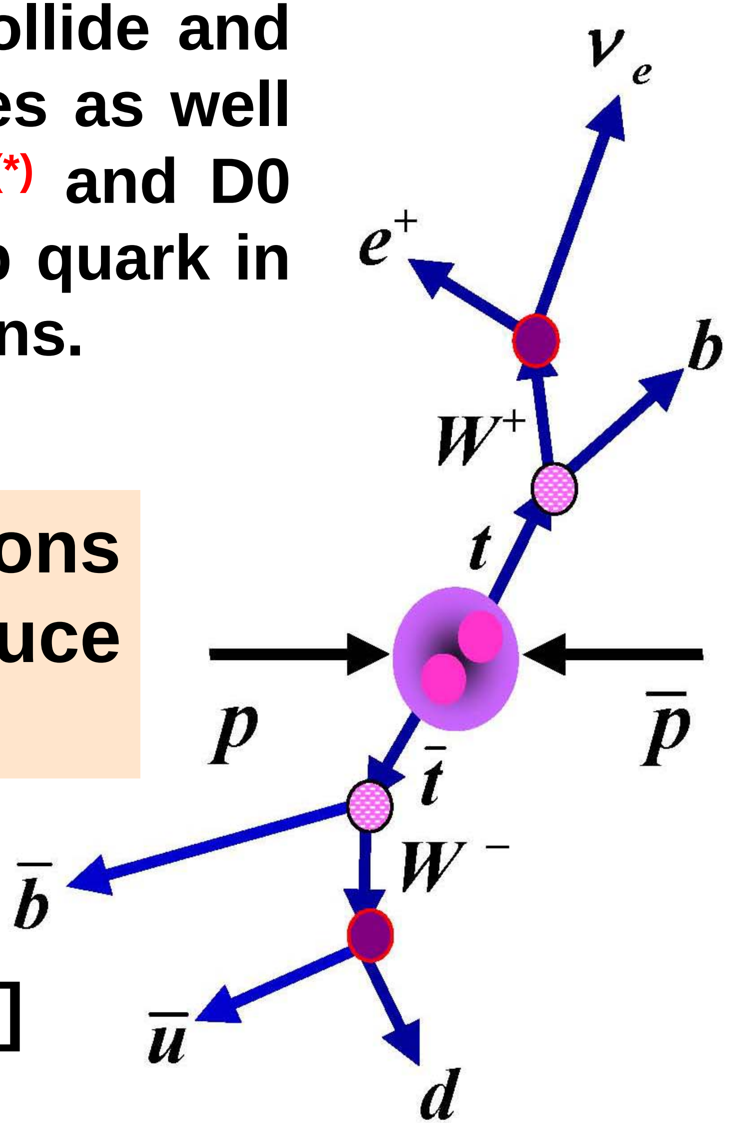
Tevatron at Fermilab





Pattern Recognition

[Tevatron] proton and anti-proton collide and produce the Standard Model particles as well as New Particles. In 1995, the CDF(*) and D0 collaborations co-discovered the top quark in ~4 trillion (4,000,000,000,000) collisions.



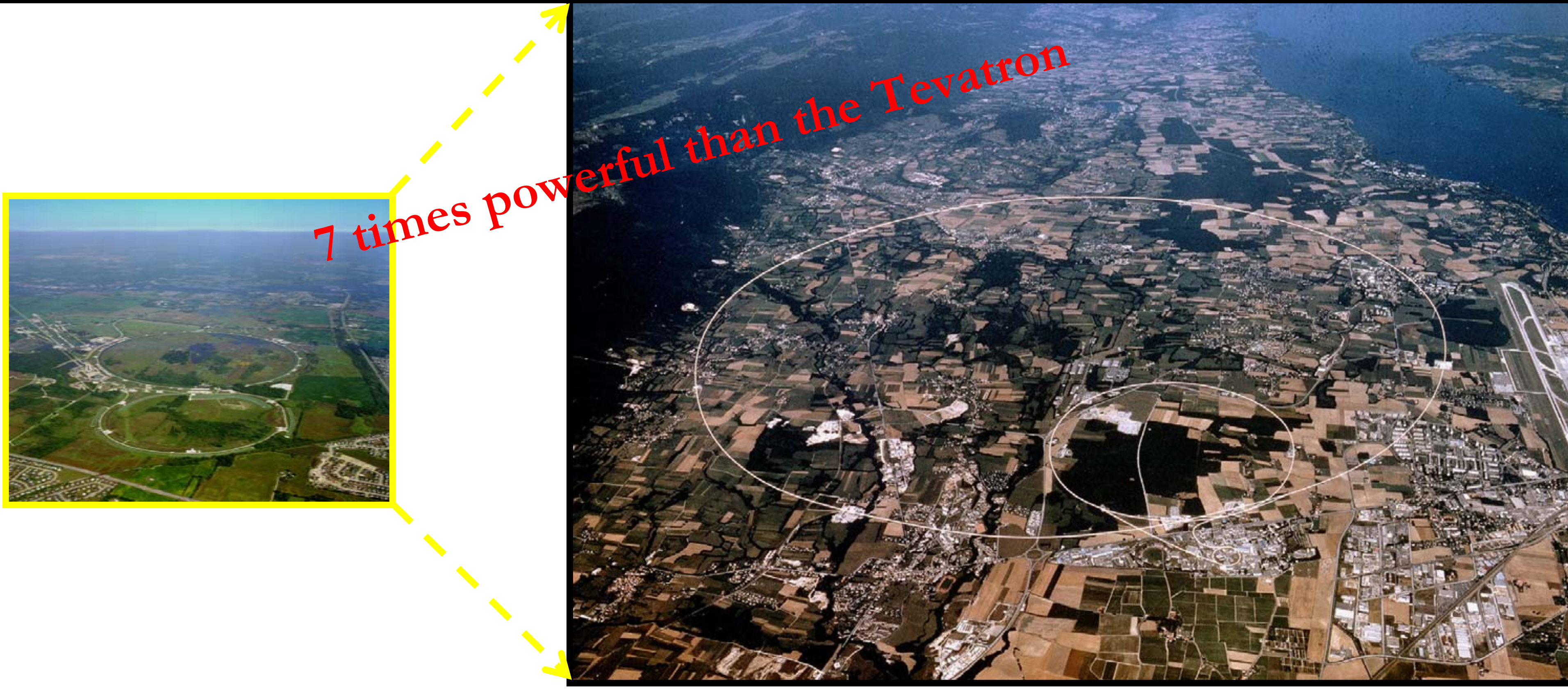
[Q] We have 100 trillion collisons today. Can the Tevatron produce the neutralinos?

[A] May not ☹

[the neutralinos can be heavier.]

(*) The TAMU group is one of charter members of the CDF collaboration.

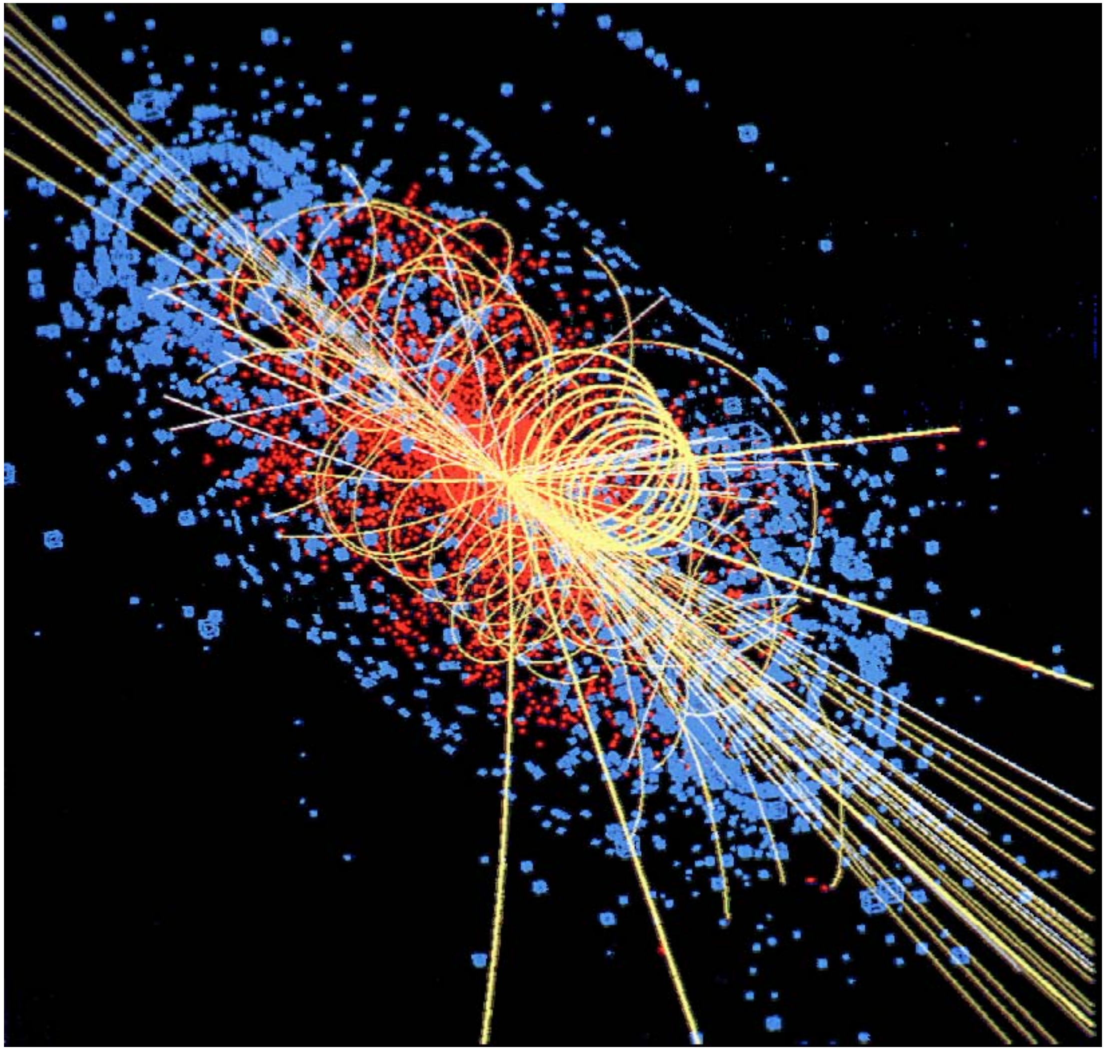
Large Hadron Collider (LHC)



The LHC at CERN, scheduled for the first proton-proton collisions in 2007 in Switzerland, will have the smashing power of 14 Tera electron Volts (14,000,000,000 eV) - far larger than any other machine ever built. Two experimental groups, called ATLAS and CMS(*), will record the first collisions by the end of 2007.

(*) The TAMU group is a member of the CMS collaboration.

Collisions as We Imagine …

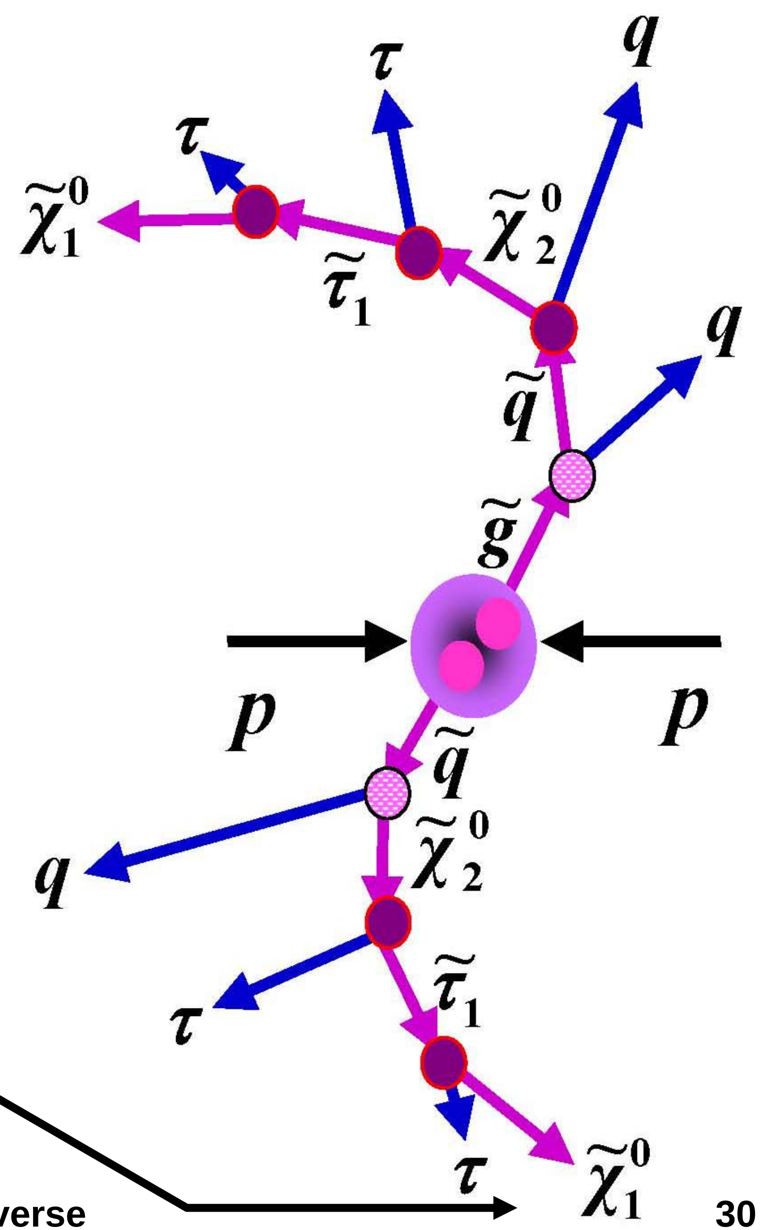


More Pattern Recognition

How do we produce the neutralinos at the LHC?

We have to extract this reaction out of many trillion pp collisions.

neutralinos (dark matter particles)



How do you know that the neutralinos (we will observe) at the collider are responsible for the dark matter content?

We measure the masses (m) of the particles at the LHC.

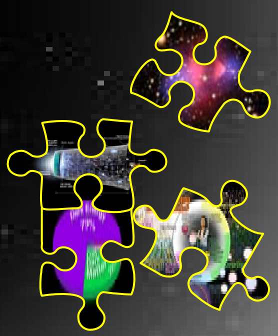
We calculate the dark matter content (Ω) in the new model of the Universe.

$$\Omega = x(m) \times y / z + g \times h(m) - p(m) / q + r(m) \times 45 / 100 + 60 \times u_r(m) \times t_y + d \times s(m) + j(m) \times p(m) = 0.23$$

Conclusion

So far in the laboratories we have seen the particles responsible for 4% of the universe.

The upcoming experiments will try to probe the nature of 23 % of the universe: dark matter.



Challenge:

73% of the universe is still a major puzzle.
Not yet understood theoretically!

So far in t e seen the particles re universe.

The upcon to probe the natur erse: dark matter.

73% of the puzzle.

Not yet un

Any Question?