Music of the Big Bang and Why it Matters to Fermilab

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Picture: Microwave Radio Telescope at 17,000' above Sea Level in Chile, South America

What We Do At Fermilab ?

Tackle the BIG questions:

- What is matter ?

- What is energy ?

- What is space ?

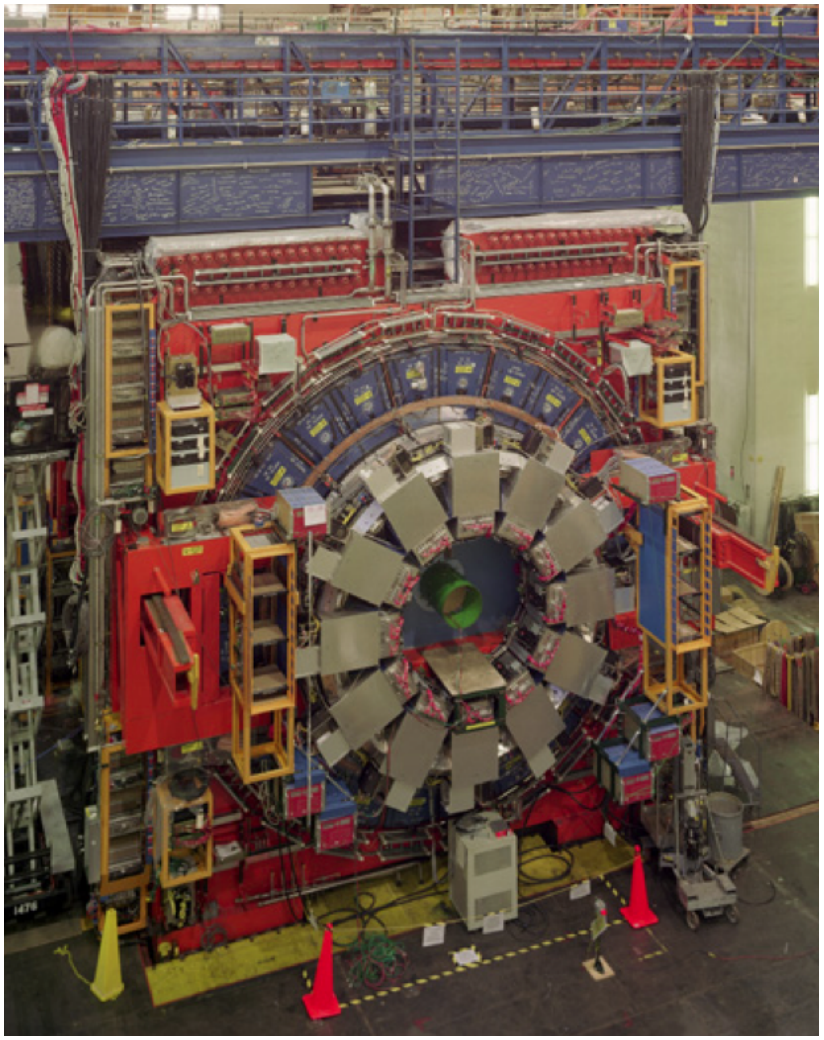
- What is time ?

Our Tools

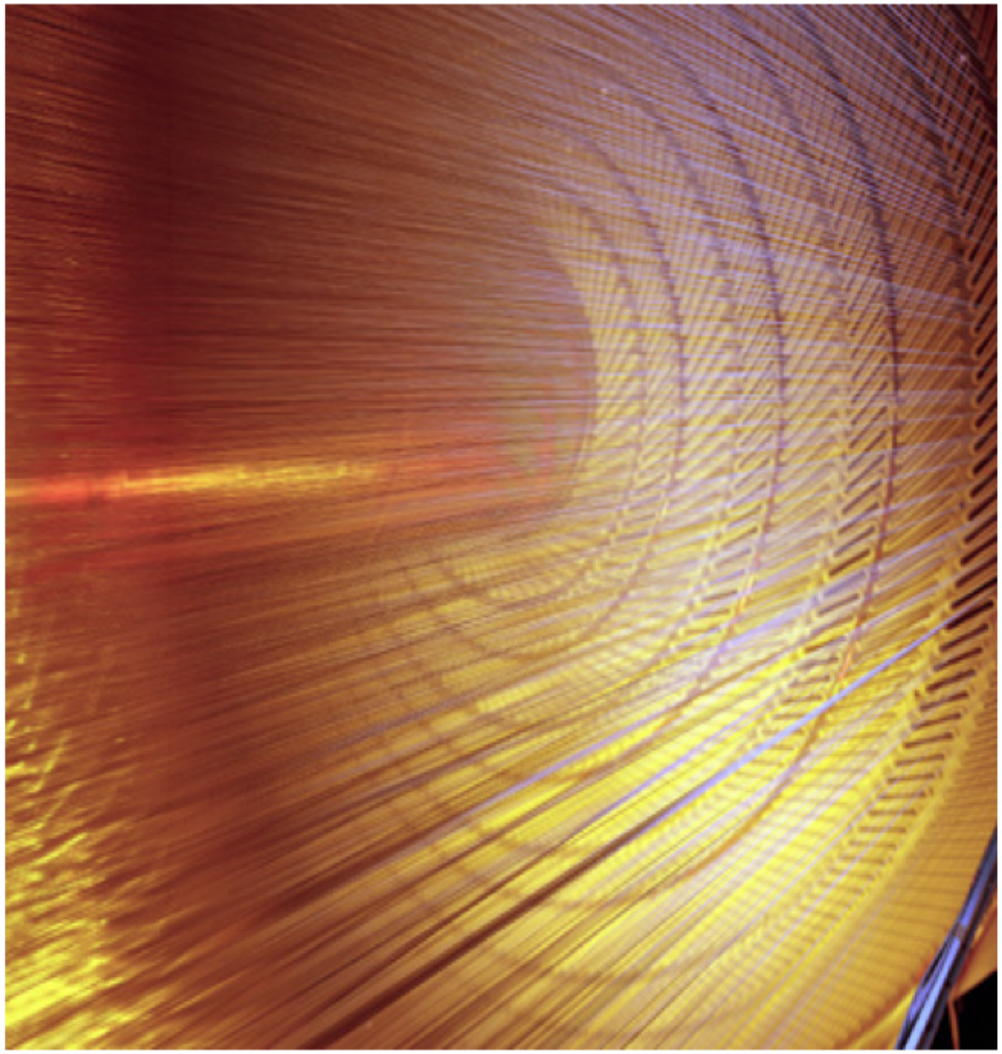
Giant Machines that generate particles moving near the speed of light.

Collide them to make new forms of Matter and Energy

Detecting new forms of matter and energy



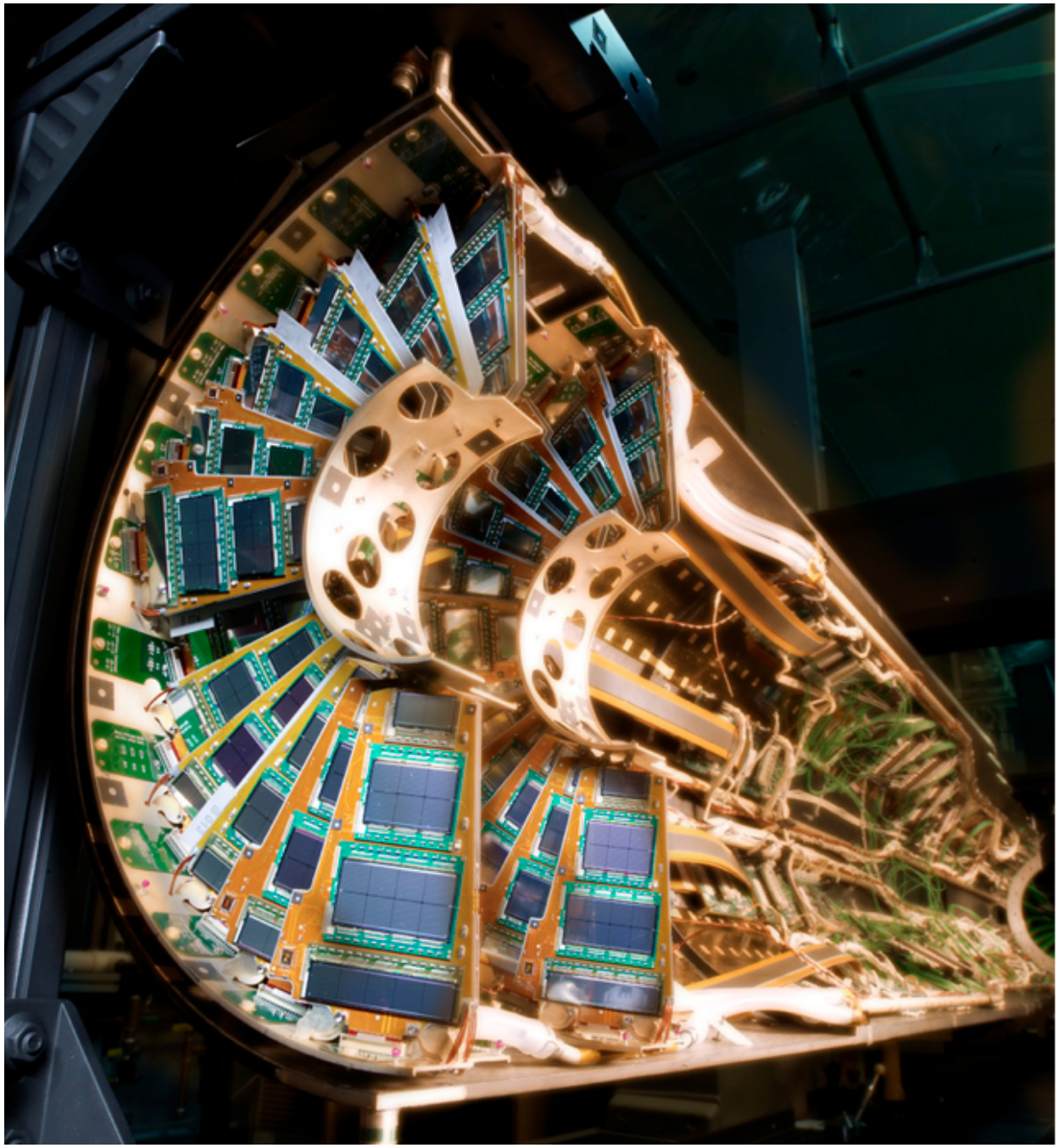
A Device to Track Charged Particles



Ingredients: Gas, thin wire, High Voltage, Electronics. (similar to a Geiger Counter)

Another
Device to Track
Particles

Ingredients: Silicon
Electronics Chips
(similar to a
Digital Camera)



The Incredible Nature of Matter and Energy

Matter and anti-matter can convert into Pure Energy.

Pure Energy can convert into different forms of matter

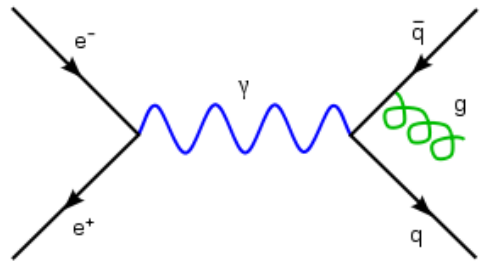


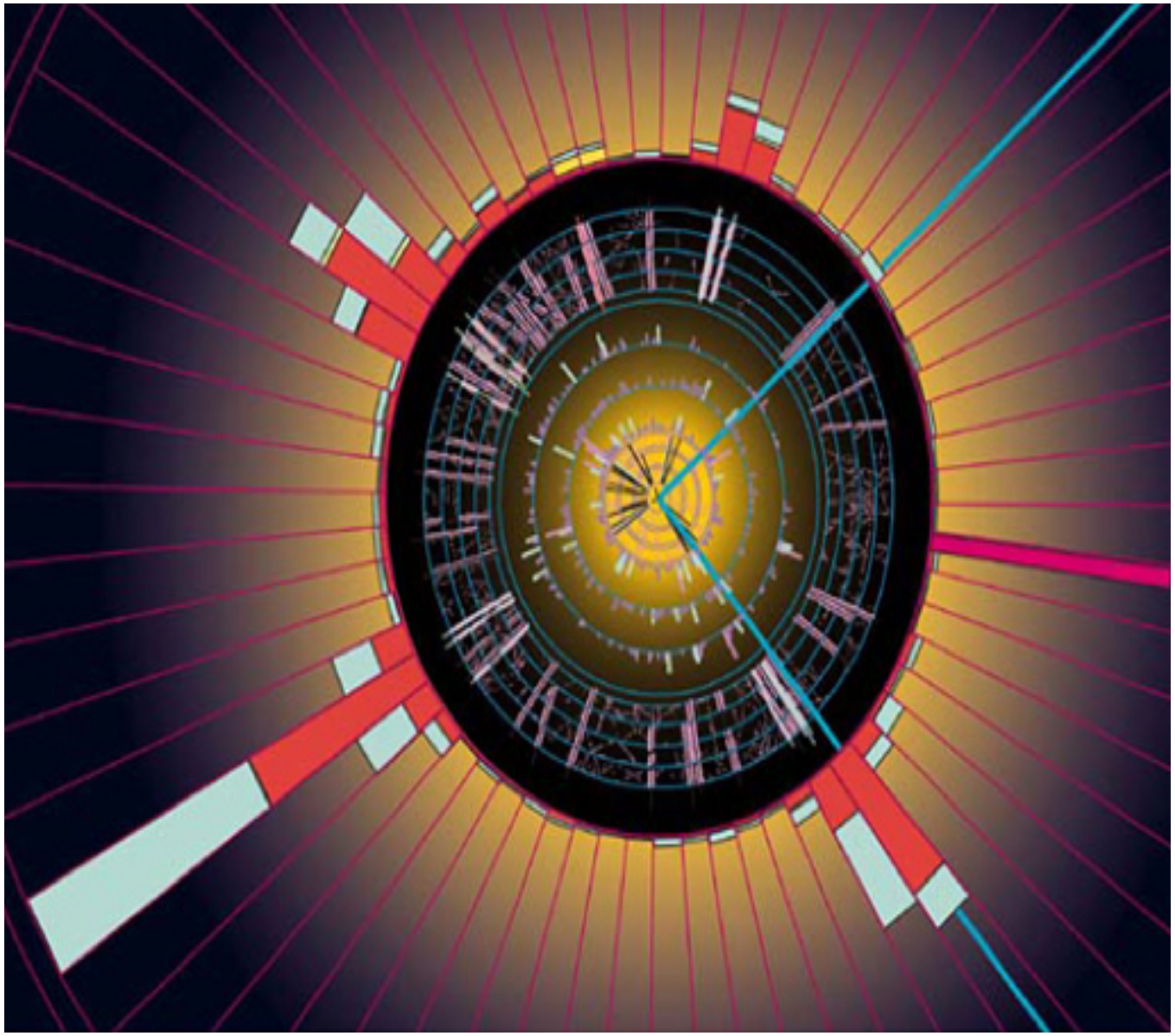
Diagram of "electron" and "positron" converting into a "photon".

"photon" exists for a very brief moment.

"photon" converts into a "quark" and an "anti-quark" and a "gluon".

Prof. Richard Feynmann of Caltech invented these diagrams as a tool to describe these conversions.

A Digital Picture of Matter and Energy Conversion



Forms of Matter and Energy

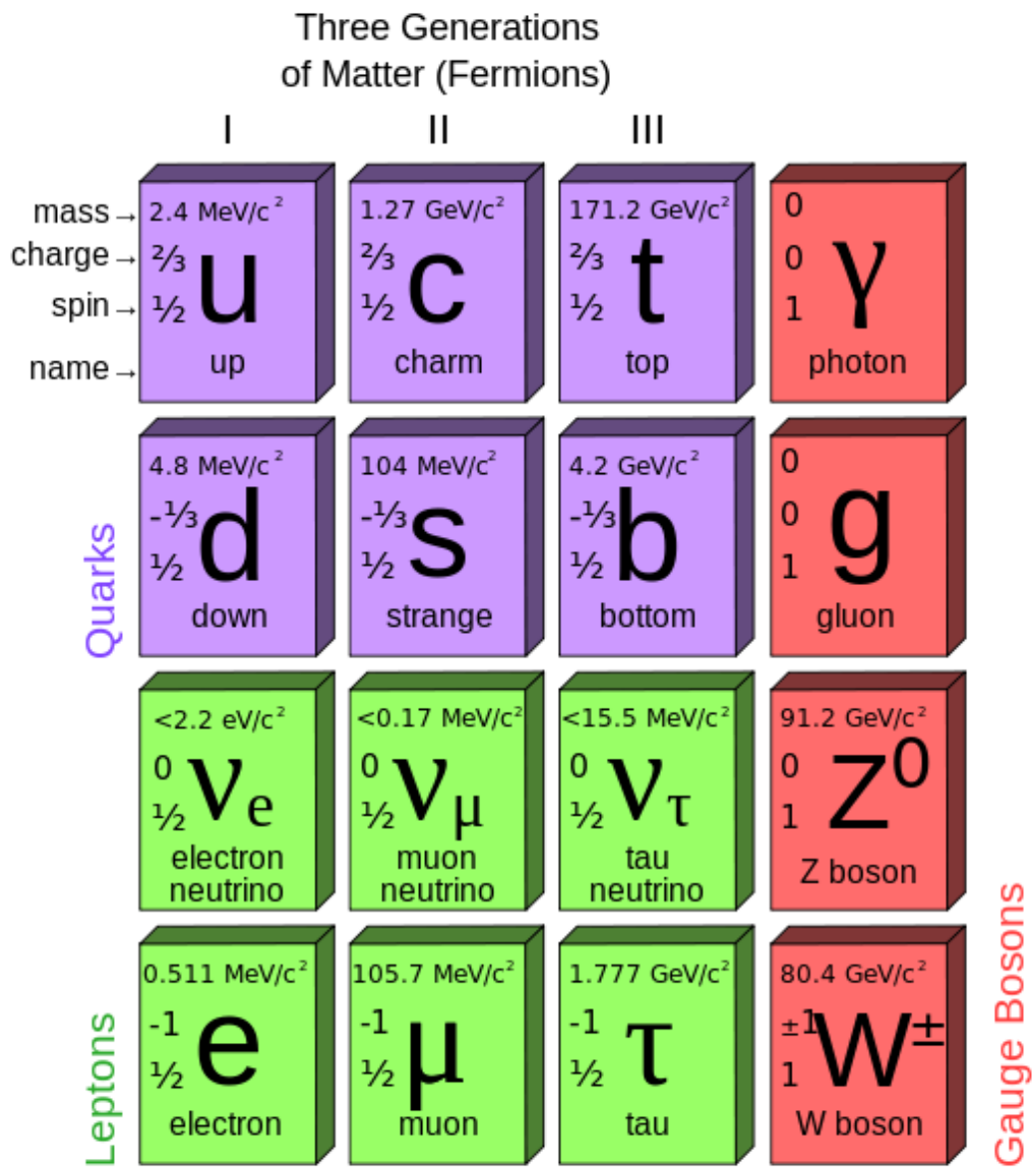
electron, photon,
up quark, down quark,
gluon, and gravity (not included)
describes almost all of
everyday life.

Other particles are important only
in EXTREME conditions:

Core of Nuclear Reactor
Nuclear Explosion
Core of the Sun
Collapse of a Black Hole
Supernova Explosion

and

The Big Bang

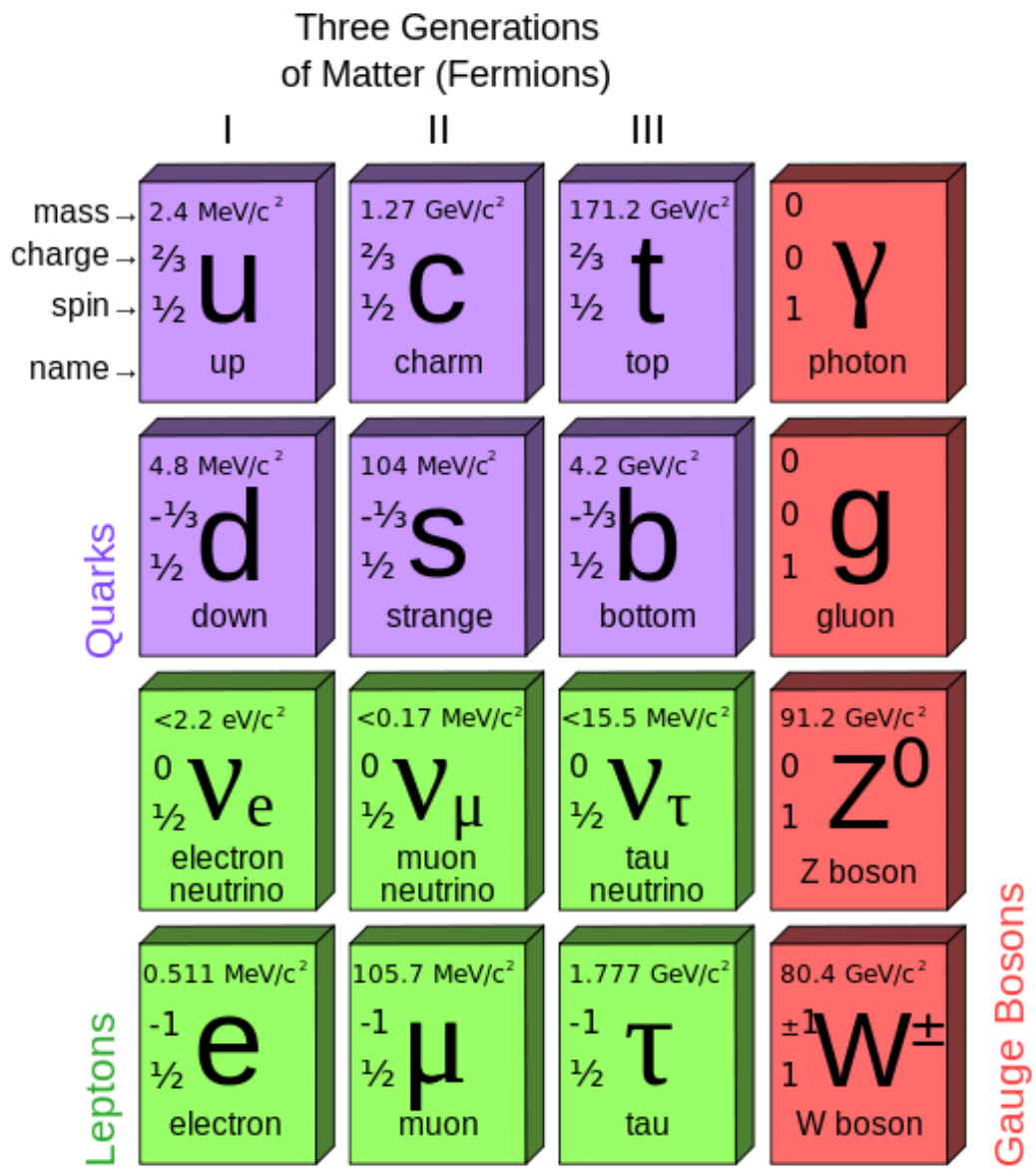


Particles Discovered at Fermilab

Tau Neutrino

Top Quark

Bottom Quark
(Nobel Prize for Dr. Leon Lederman.
Former Fermilab Director
Founder of IMSA)



Are There More Particles to be Discovered ?

We have a super accurate Mathematical Description of Particles and Energy.
It predicts the Existence of the **Higgs Particle** (a new form of Energy).

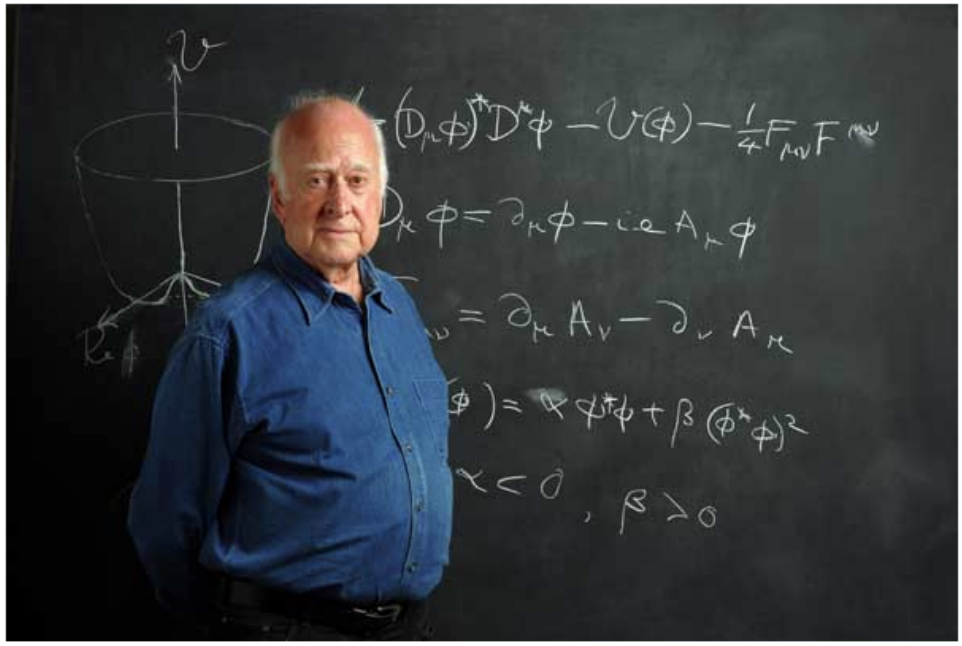
The **Higgs Particle** has a Special Role:

- It is a "glue" that slows down matter. Otherwise, all matter would fly apart at the speed of light.

- Life could not exist without the Higgs.

- Dr. Leon Lederman called this the "God Particle".

- *Physicist could be on the verge of discovering the Higgs Particle this year.*



Predicted by Prof. Peter Higgs of the University of Edinburgh

Are There More Particles to be Discovered ?

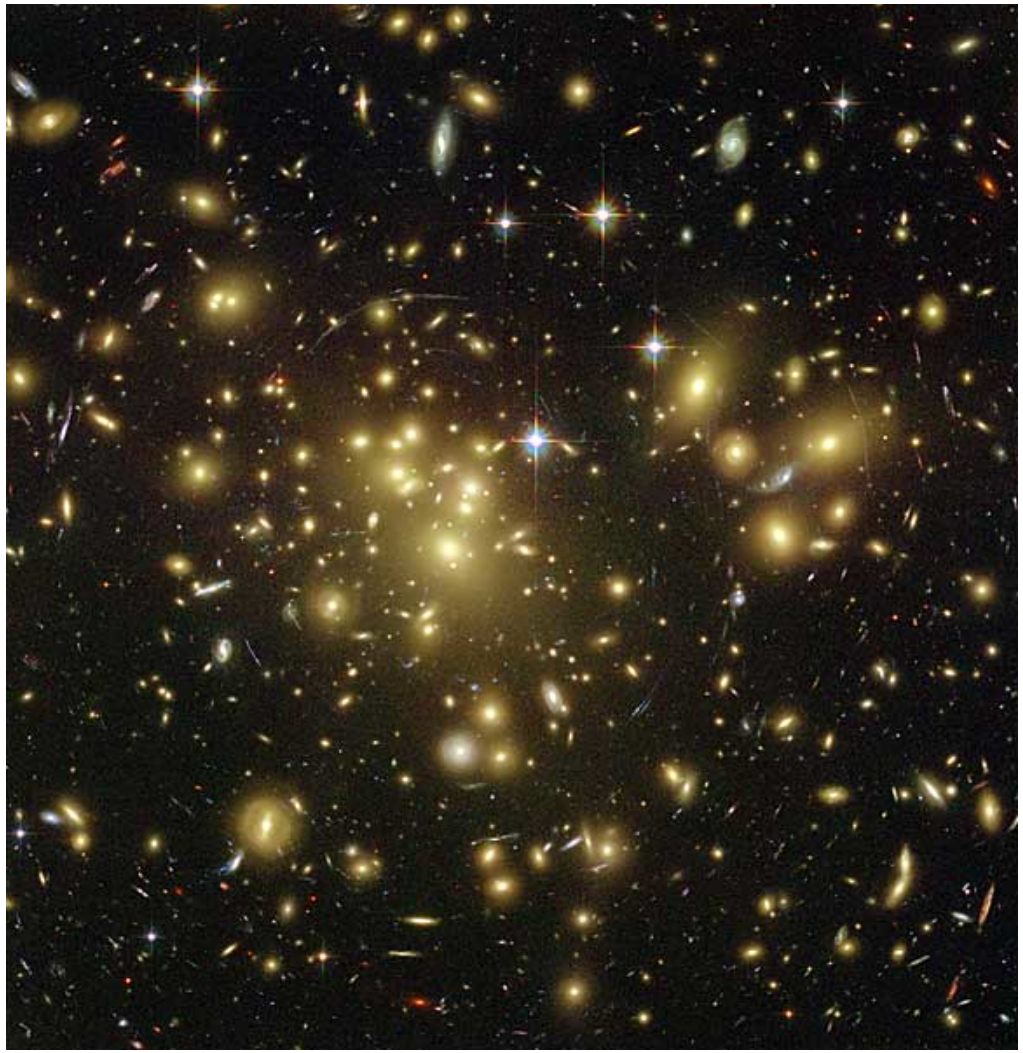
We expect a NEW form of matter called "DARK MATTER"

5x more abundant than the matter we already know !

We know it exist using indirect evidence*

Our theories don't tell us much about DARK MATTER.

There is huge race at Fermilab to discover the nature of DARK Matter.



Picture from Hubble Space Telescope

* Similar to how Astronomers discovered Neptune, by noticing distortions in the orbit of the outer planets

Why We Care About the Big Bang

- *Not just a sitcom*

- The Big Bang is the ultimate EXTREME ENVIRONMENT where:

  - undiscovered forms of matter and energy are created !

  - Space and Time are themselves Created !

- *Our Man Made Machines are too Weak to recreate these Conditions*

Fun Facts About the Big Bang

- New forms of Matter and Energy are Created.

- Space and Time are Created.

Very Strange Concepts ! Albert Einstein was the first to describe these concepts with his theory of Relativity.

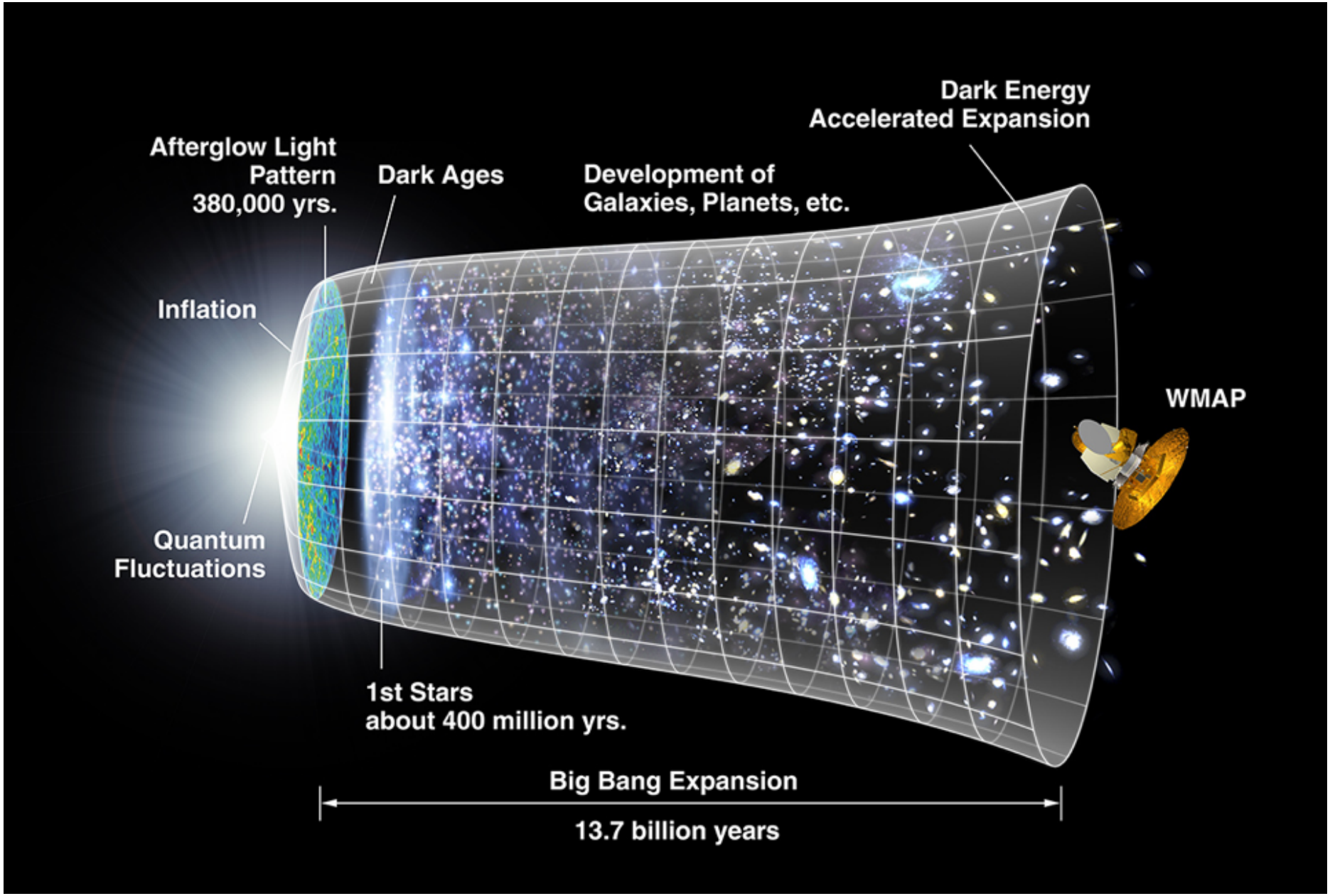
Physicists are still struggling with these concepts !

Even more Bizarre Objects May Exist

Cosmic Strings
Dark Matter
Super Symmetric Higgs
Extra Gauge Bosons
Extra Dimensions
Heavy Neutrinos
Magnetic Monopoles
Primordial Gravitational Waves

The "Inflaton Particle" created Space and Time. We call this event "Inflation". It acts like ANTI-GRAVITY

History of the Universe



Inflation

Universe grew from size of an atom to a size of a grape fruit

in 10^{-35} seconds

(0.0000000000
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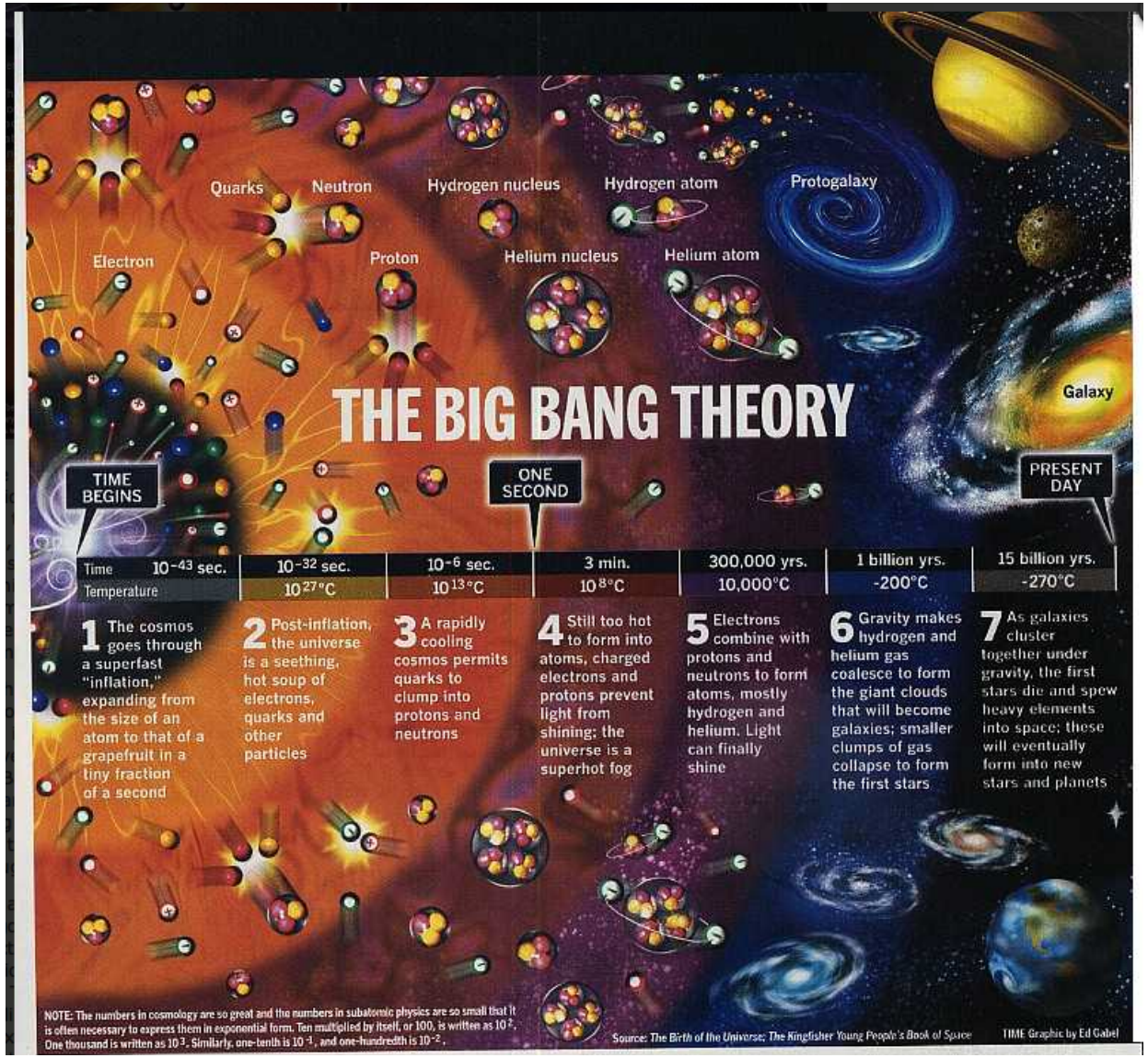
00001 seconds)

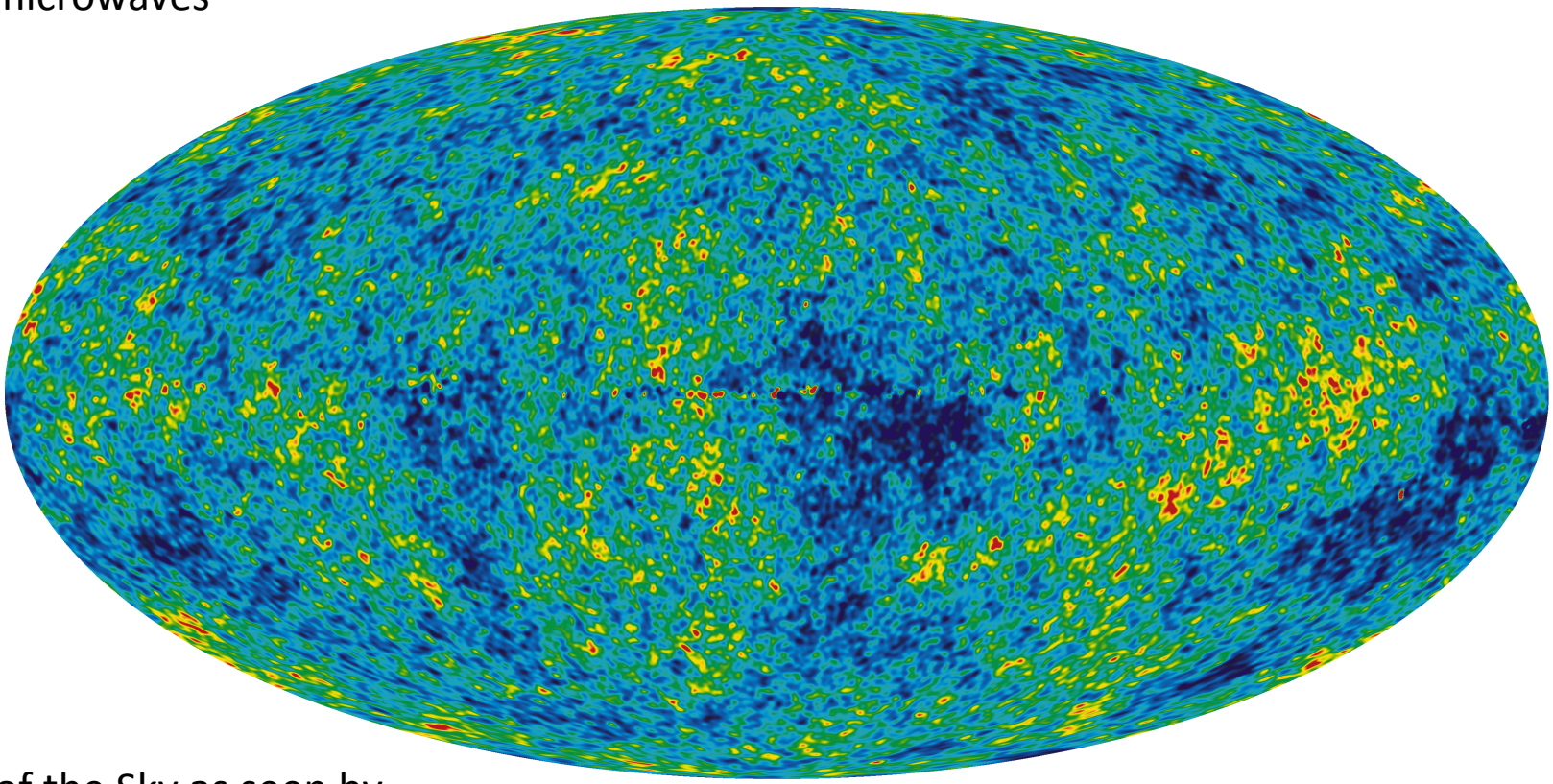
Mysterious new Force (like anti-gravity) that made the Universe Grow so fast.



How We Study the Big Bang

Light emitted 380,000 years after the Big Bang contains huge clues about the Big Bang.

Today, this light appears to us as microwaves



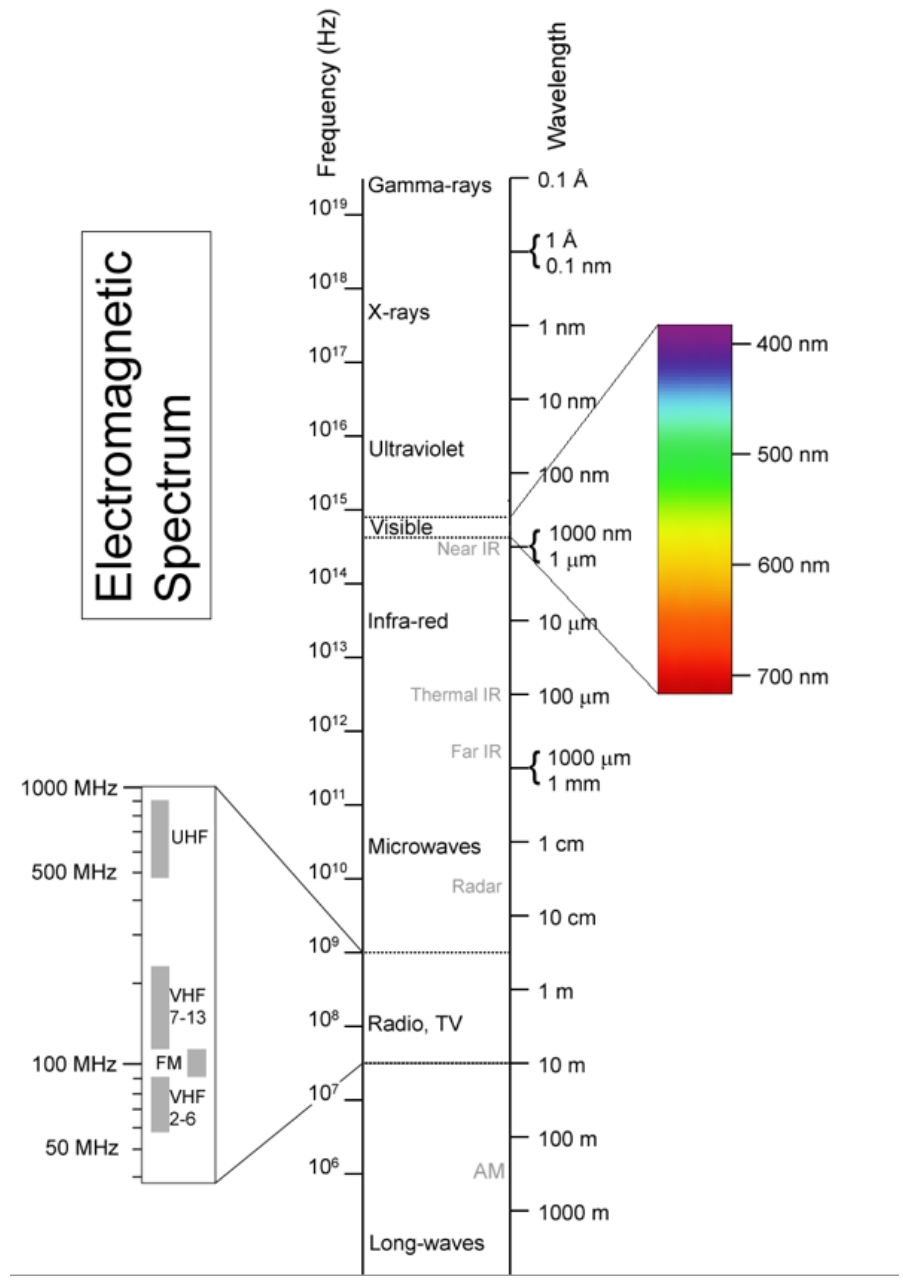
Map of the Sky as seen by a Microwave Telescope

The Spectrum of Light

Light comes in a variety of colors ...

Our eyes can see only a small fraction of the “Electromagnetic Spectrum”

We need special tools to see the full spectrum.



The Cosmic Microwave Background

Radio Antenna used to discover the Cosmic Microwave Background

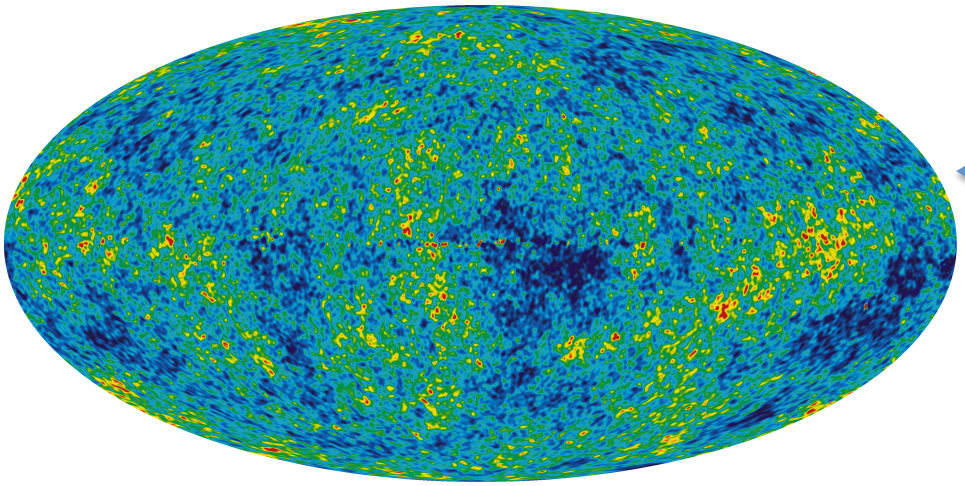
The Big Bang After Glow is called the "Cosmic Microwave Background"

Discovered by Arnold Penzias and Robert Wilson in 1965.

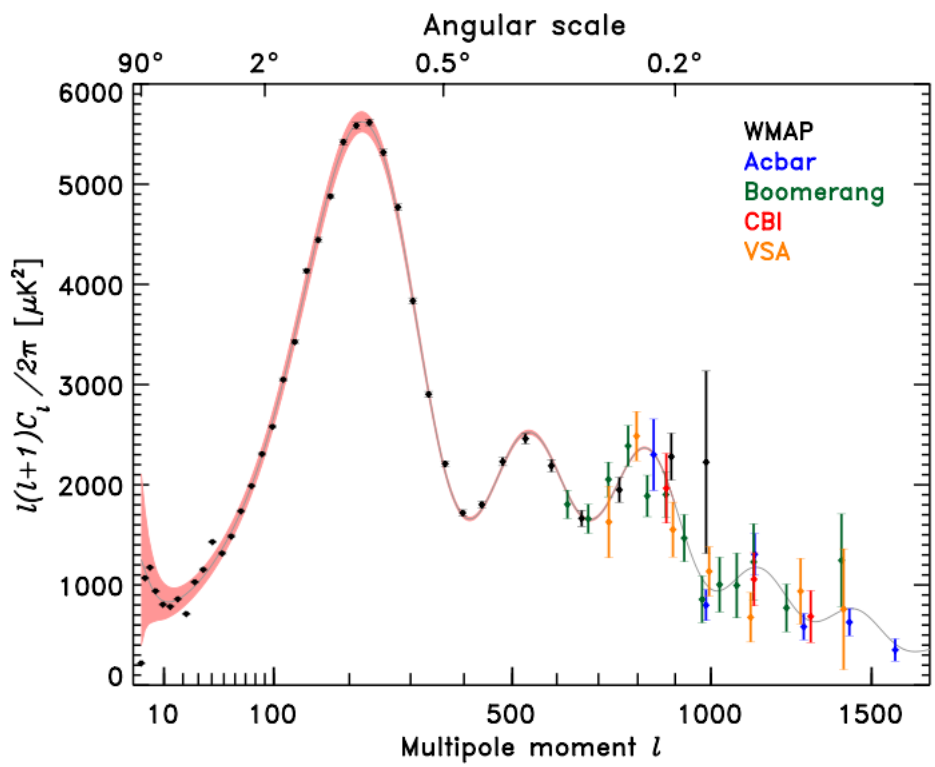
Confirmed the Big Bang Theory Prediction

Nobel Prize awarded in 1978.

We are still studying this light today



A Mathematical Representation of the Cosmic Microwave Background



In the Early Universe, there is not much space. Things bumped into one another constantly.

The "bumping" generated Sound Waves in the Early Universe.

We see evidence of the sound waves in the Cosmic Microwave Background.

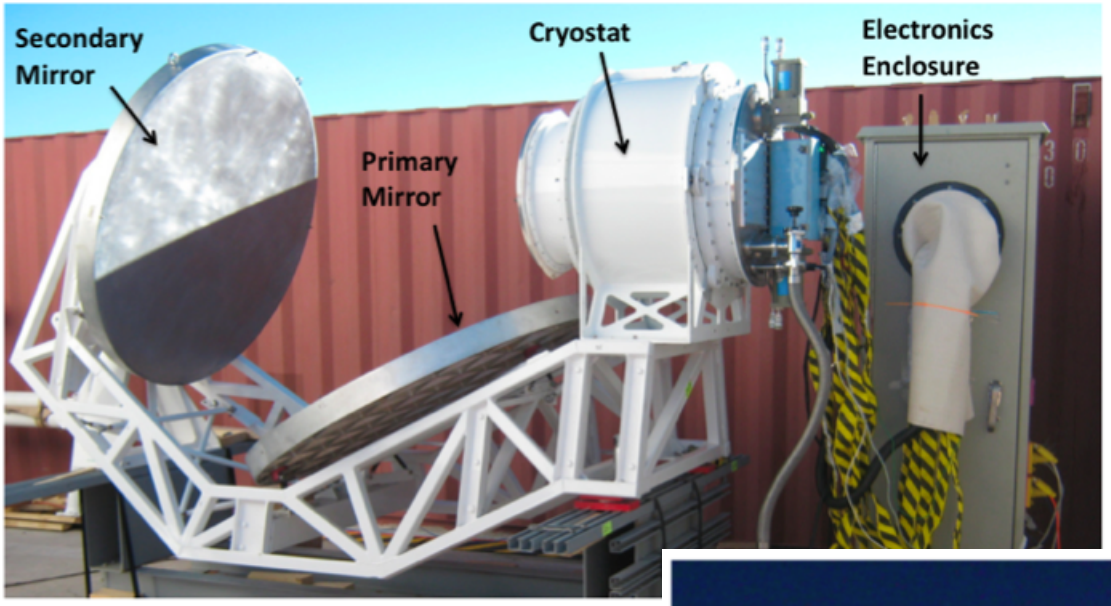
Height and location of the bumps tells us about: Inflation, Dark Matter, Dark Energy.

We Are Still Studying the Cosmic Microwave Background

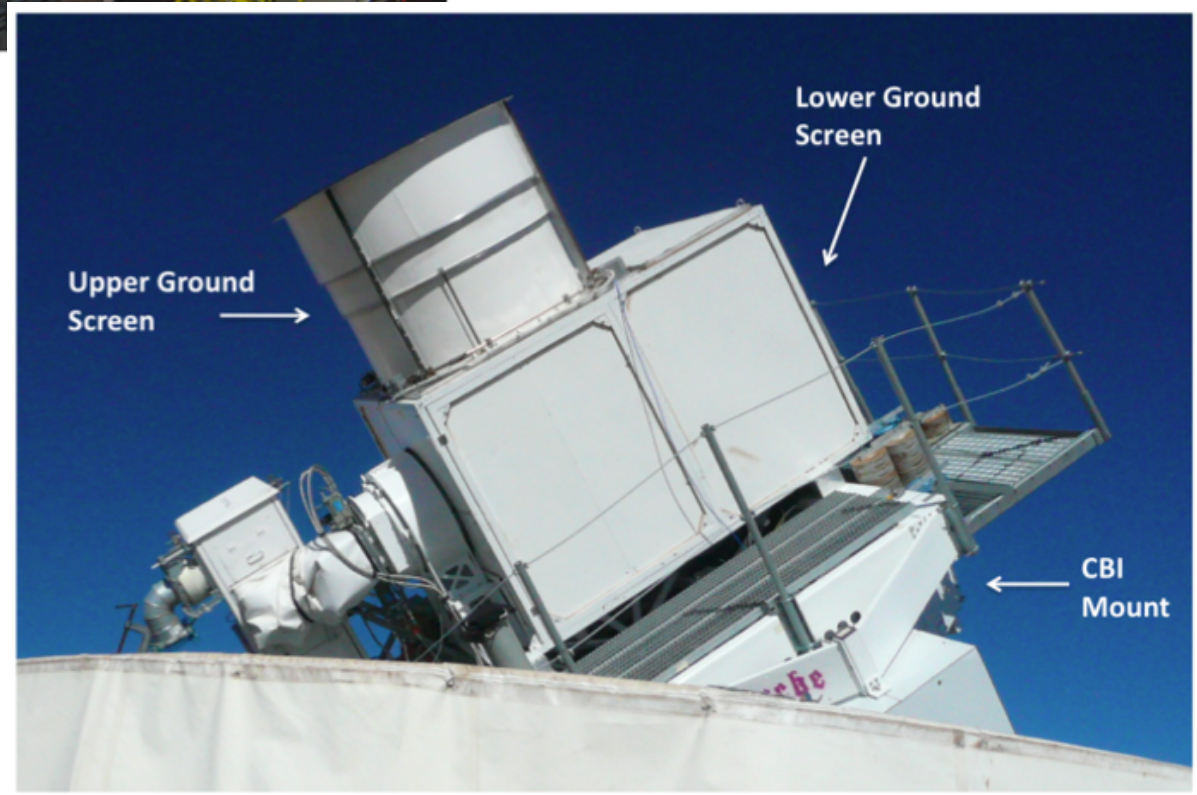
Huge Advances in Microwave Technology over 40 years

An Experiment with Fermilab Involvement.

17,000’ above Sea Level
Chilean Andes
Extremely Dry Environment



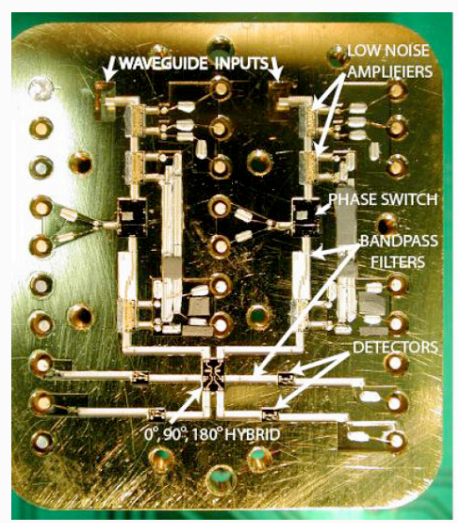
The Microwave Telescope

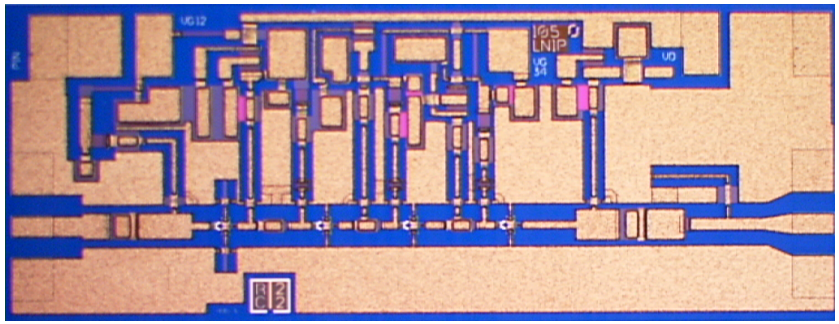


50% less Oxygen than at Sea Level

Scientists work in a pressurized room !

Some Technological Advances in Detecting the Cosmic Microwave Background





95 GHz electronics developed at Caltech, NASA Jet Propulsion Lab, and Northrop Grumman

Graduate Students and PhDs at the University of Chicago assembling the electronics

Closing Thoughts

At Fermilab, we tackle the BIG questions:

- What is matter ?

- What is energy ?

- What is space ?

- What is time ?

A particle Accelerator At Fermilab

But our tools evolve, and we invent new tools.

Accelerators are just one tool among many.

Closing Thoughts

I didn't have time to cover:

- The Mysterious Neutrino

- Do Neutrinos they move faster than light ?

- Anti-matter

- Dark Matter

- Dark Energy (a kind of Inflation)

A very exciting time for Science and Fermilab

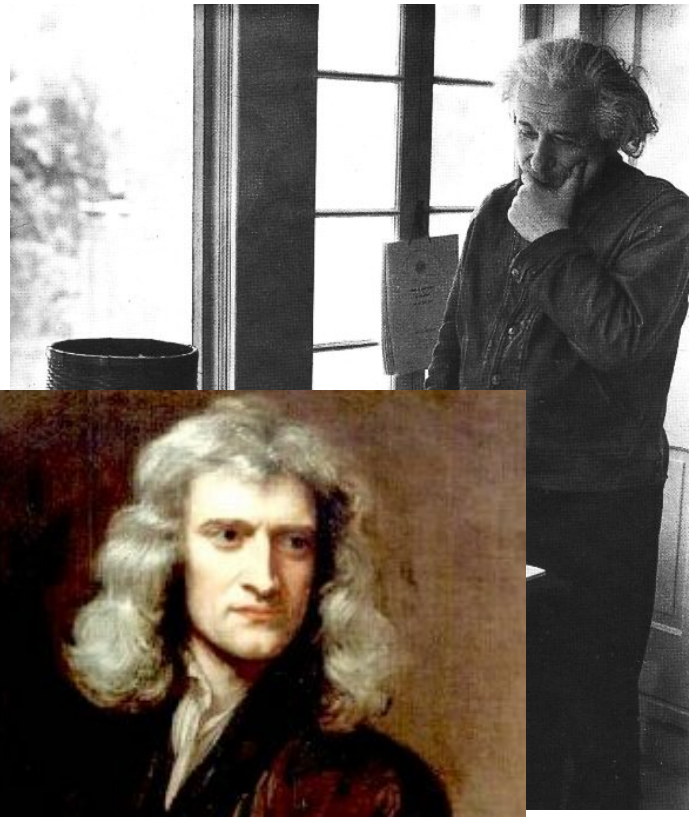
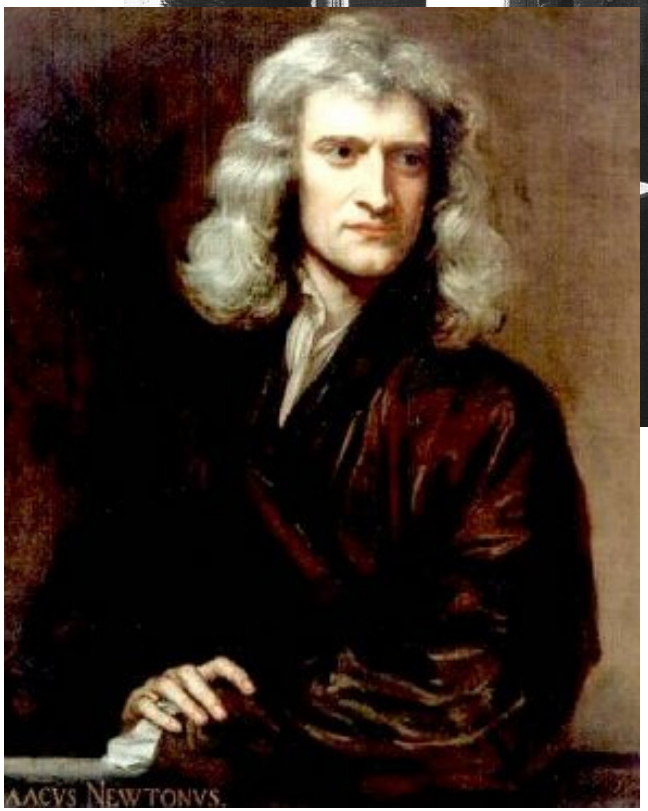
Concluding Thoughts

Thank you !!

We are grateful for the public support !!

We have a huge obligation to do our best and not waste the precious resources given to us:

- We develop technology that benefit the economy.

- We train students, engineers, scientist to do *great* things, because our nation needs them to do *great* things.

- We are following the successful legacy set for by Newton and Einstein.