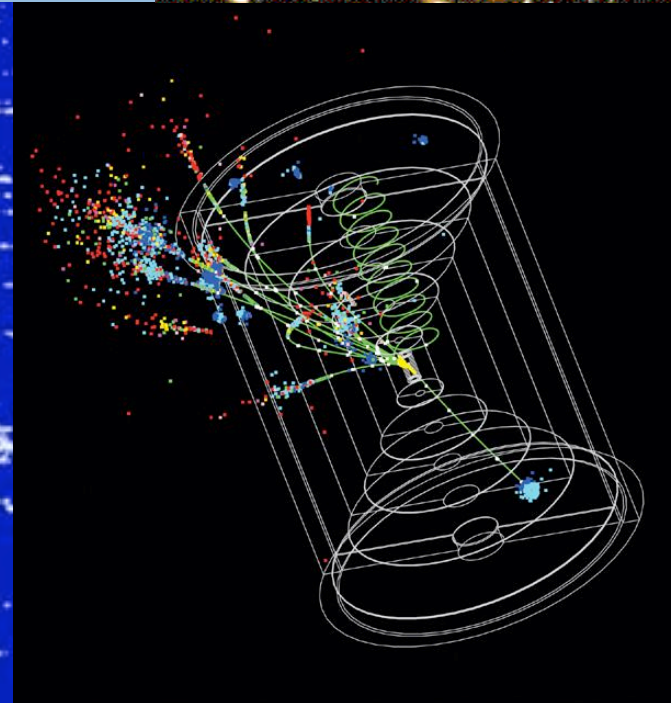
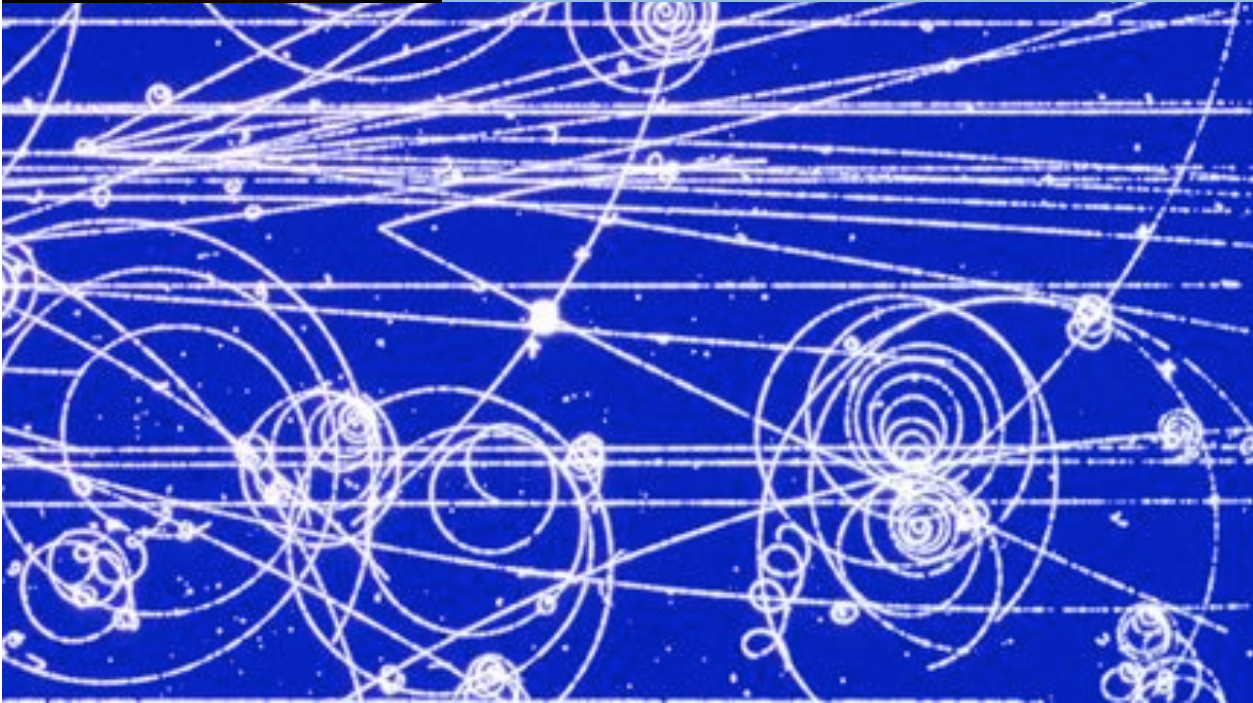


Particles, Energy, and Our Mysterious Universe



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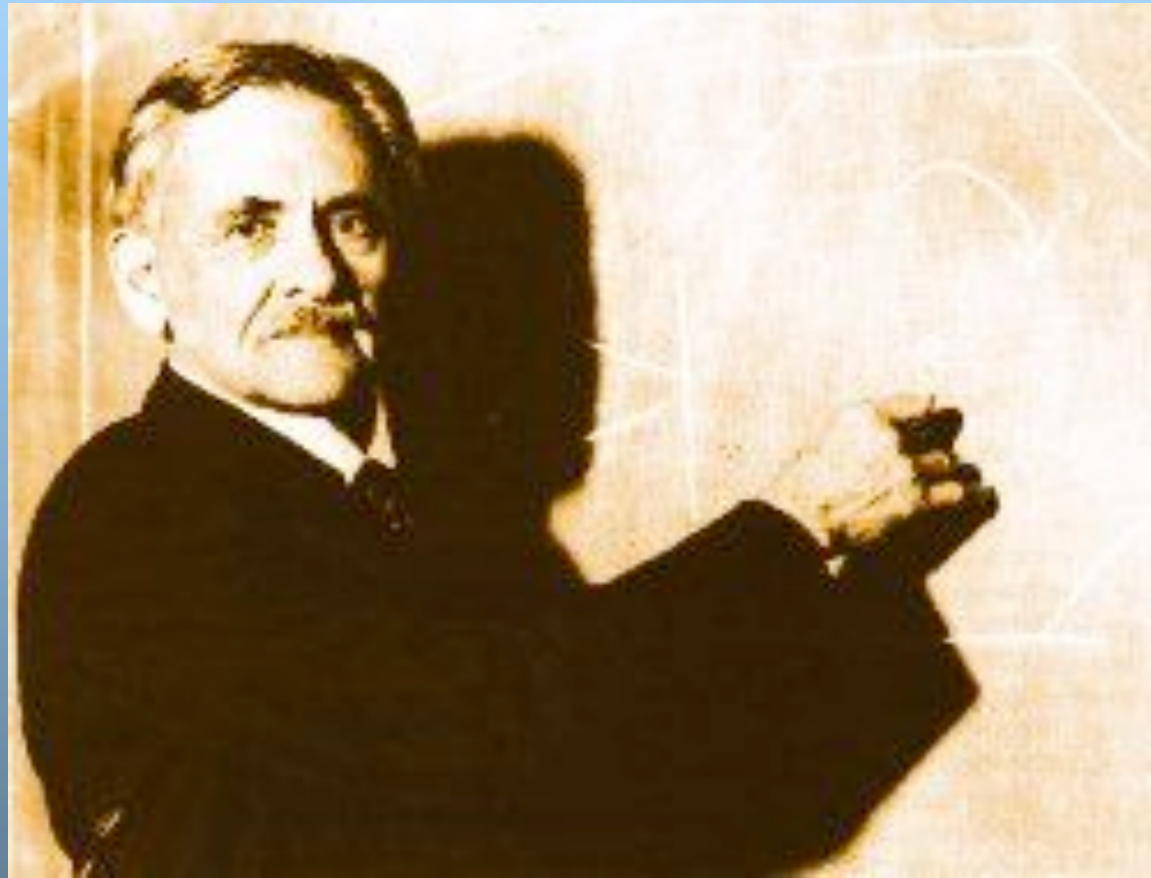
The End of Physics

"The more important fundamental laws and facts of physical science have all been discovered,

and these are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote."

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The End of Physics - 1894



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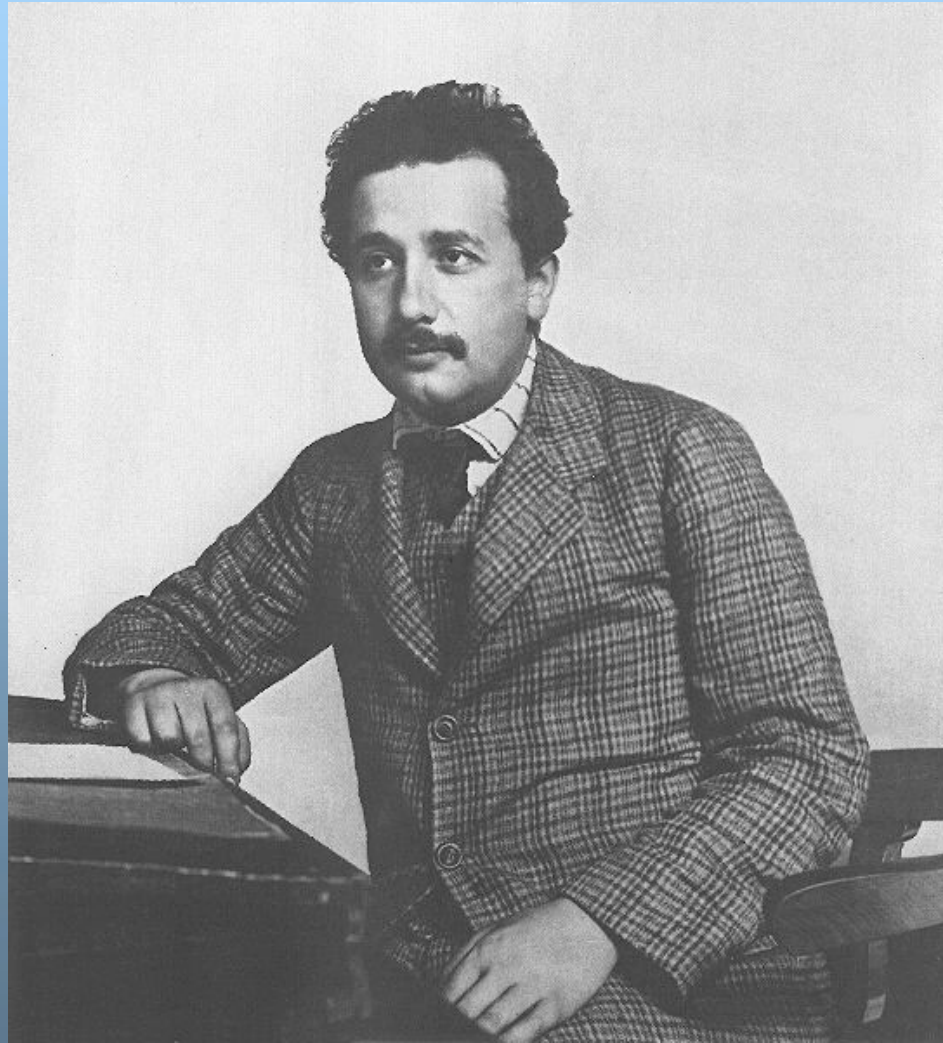
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The Miracle Year - 1905



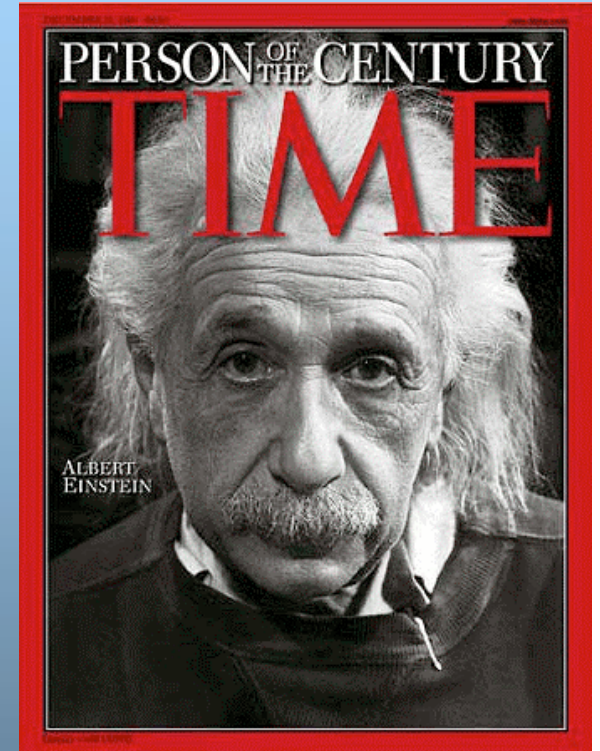
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Einstein's Theoretical Discoveries



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Relativity

- When a man sits with a pretty girl for an hour, it seems like a minute.
- But let him sit on a hot stove for a minute—and it's longer than any hour.
- That's relativity.



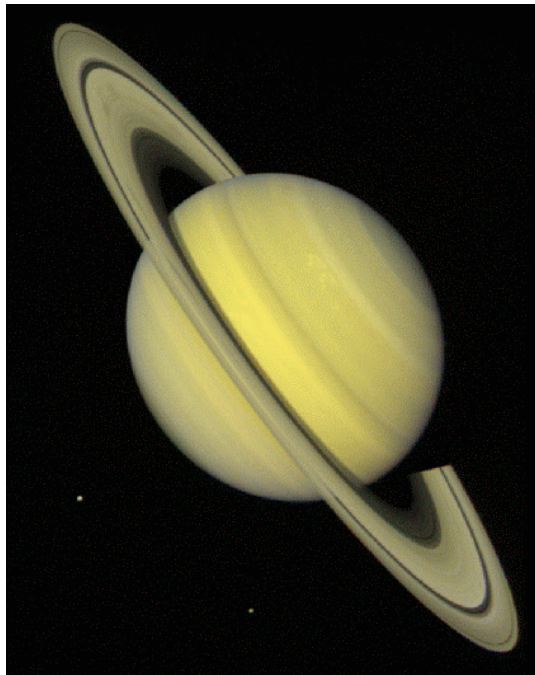
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Einstein's Dream



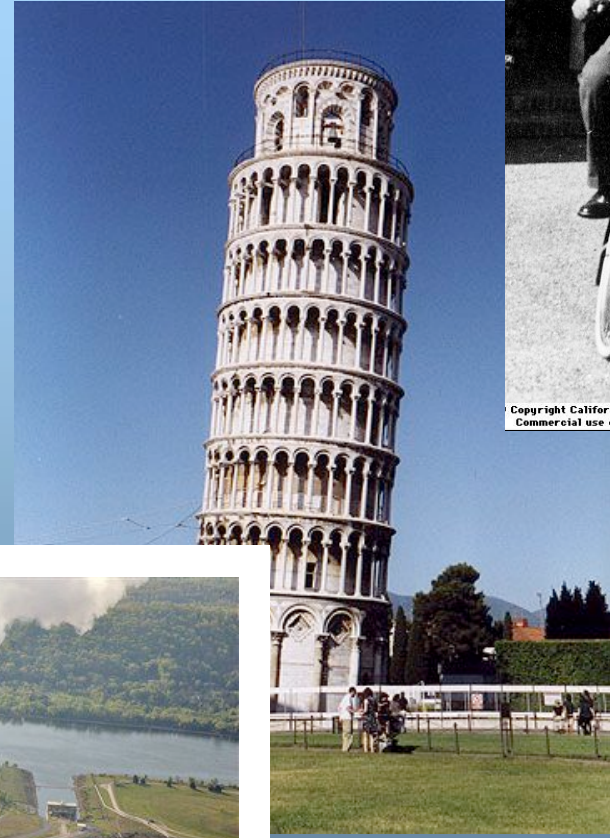
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Unification of Forces



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Modern scientific instruments



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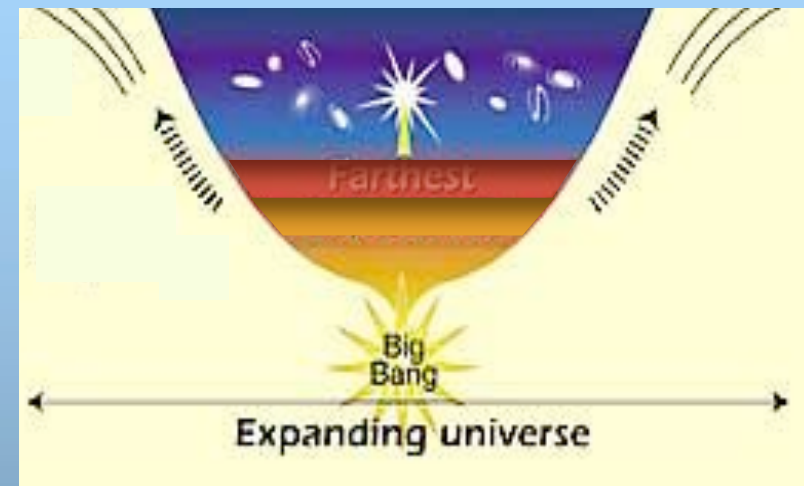
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The Big Bang

- Fundamental Physics needed to understand Big Bang



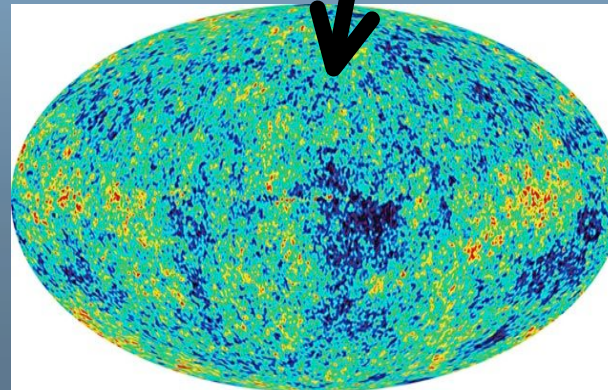
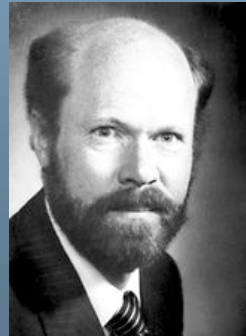
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The Cosmic Fireball



- Visible remnant of the Big Bang



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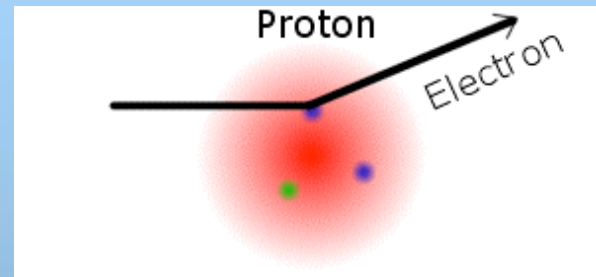
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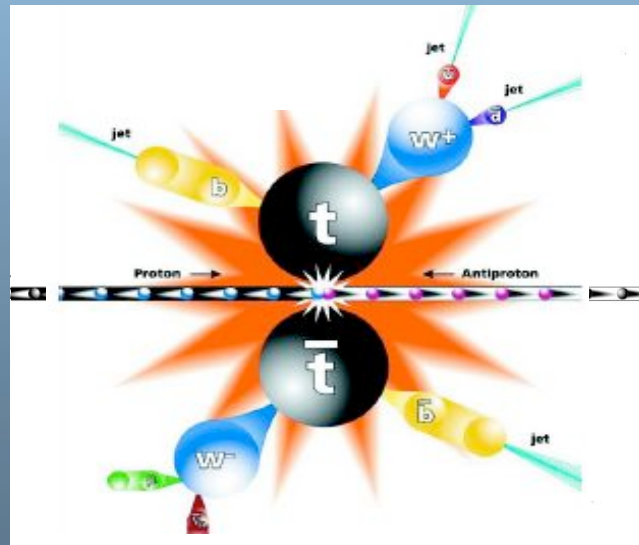
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Particle Accelerators and Colliders

1. Super-microscope

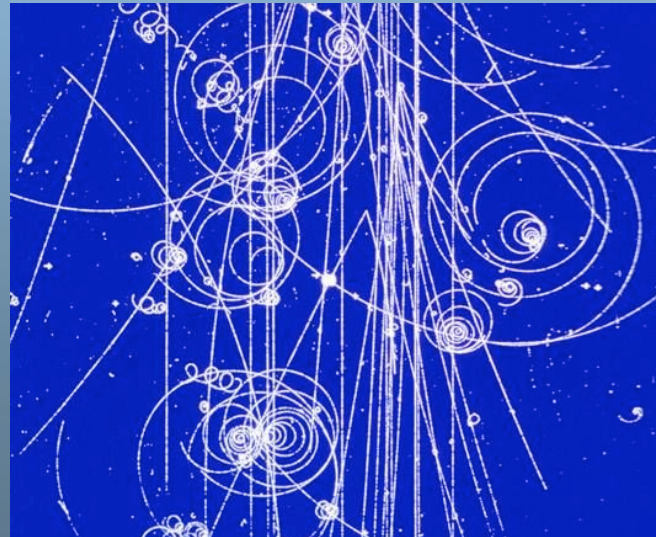
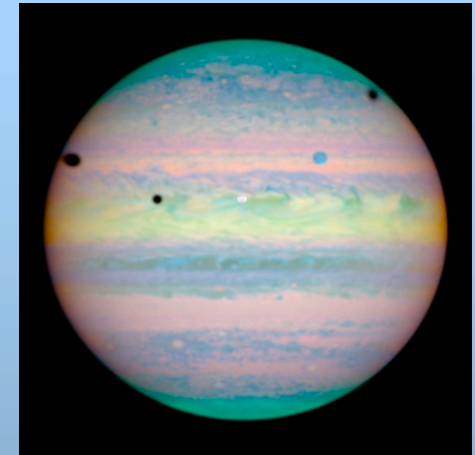


2. Creation of massive matter ($E=mc^2$)



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What is matter?



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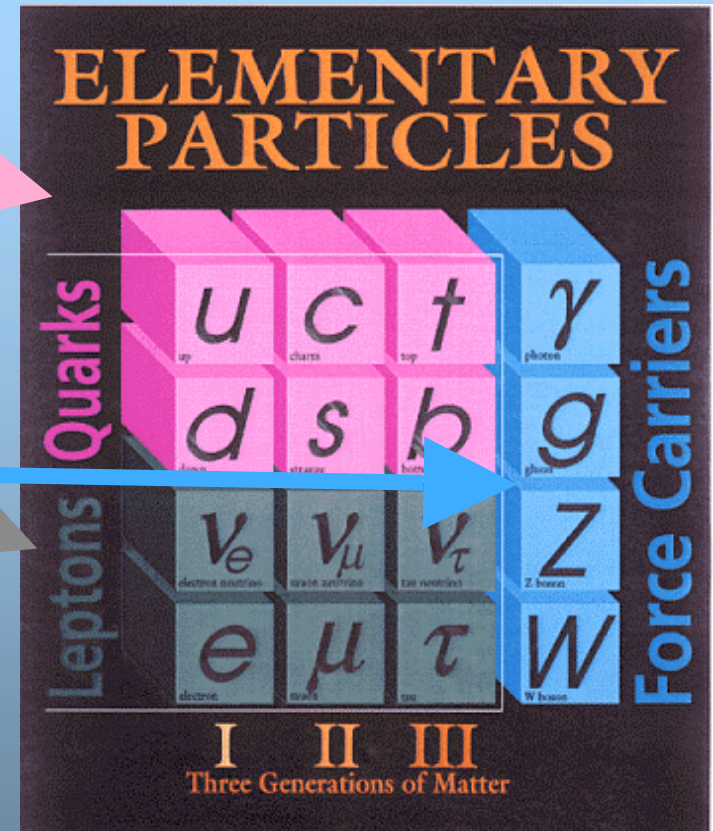
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What is matter?

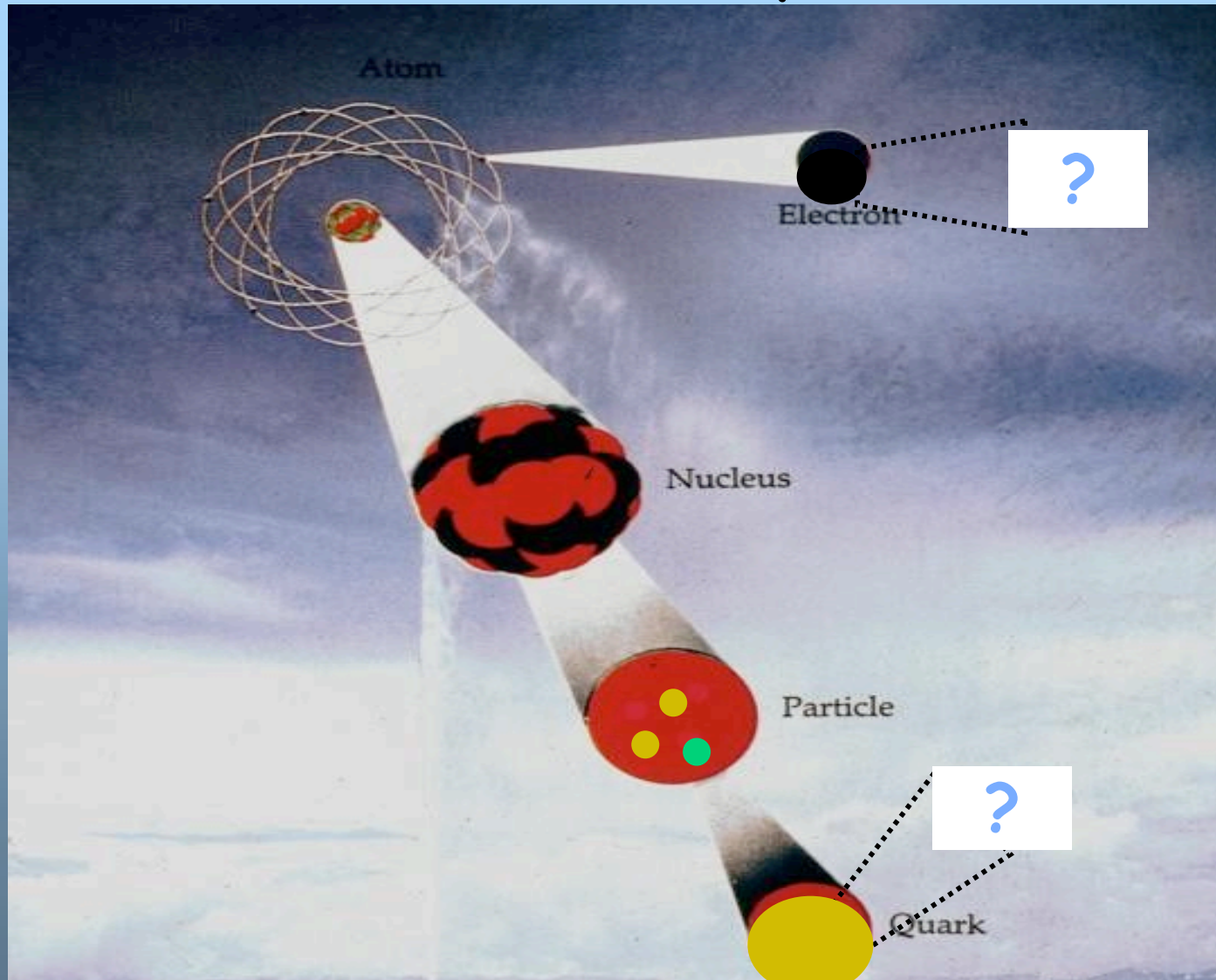
- **Quarks**
 - combine to make protons and neutrons
- **Leptons**
 - eg. electron, neutrino
- **Force Carriers**
 - defines behavior of matter



We have a precise understanding of matter and its behavior

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The Structure of Matter



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Symmetries of particles

- 1928, Paul A.M. Dirac
 - Theory of the electron



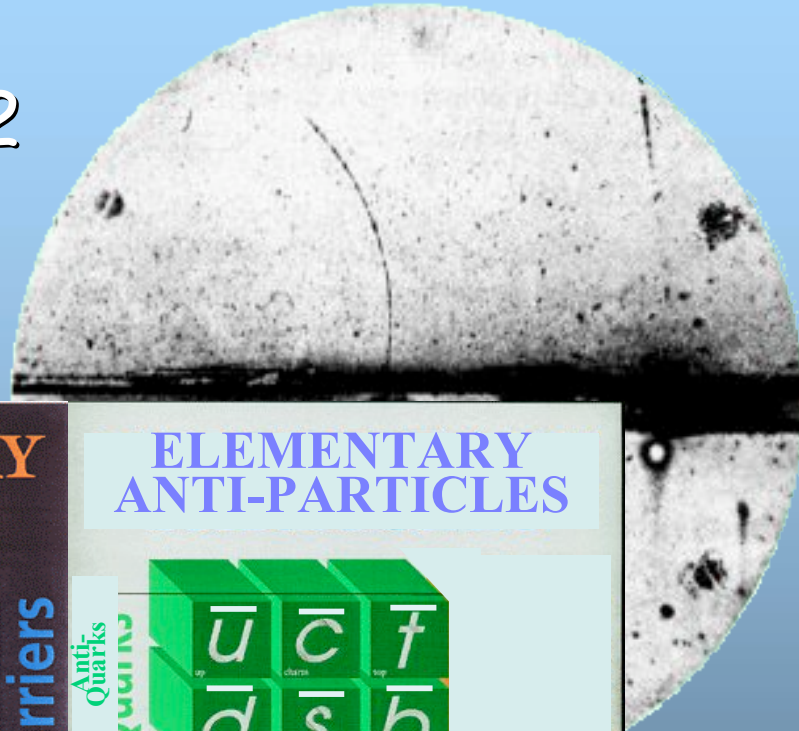
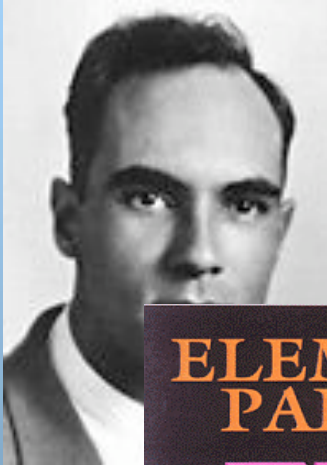
- Hypothesized ANTI-MATTER

DOUBLED THE NUMBER OF
FUNDAMENTAL PARTICLES

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Discovery of Anti-Matter

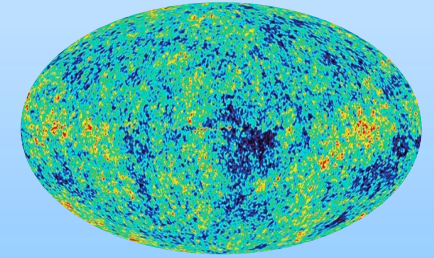
- 1932



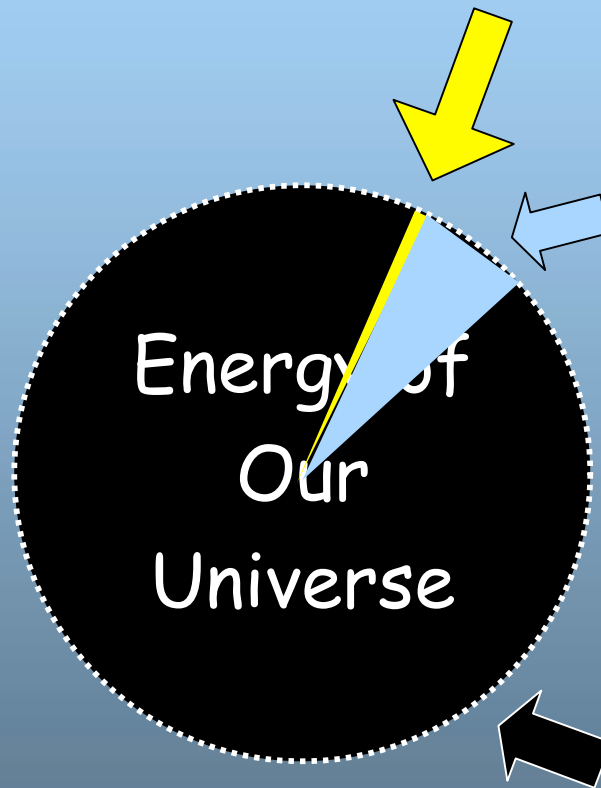
ELEMENTARY PARTICLES				ELEMENTARY ANTI-PARTICLES			
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	$\bar{\nu}_e$ electron antineutrino	$\bar{\nu}_\mu$ muon antineutrino	$\bar{\nu}_\tau$ tau antineutrino	Force Carriers
	e electron	μ muon	τ tau	\bar{e} positron	$\bar{\mu}$ antimuon	$\bar{\tau}$ antitau	
Quarks	u up	c charm	t top	\bar{u} anti-up	\bar{c} anti-charm	\bar{t} anti-top	Anti-Force Carriers
	d down	s strange	b bottom	\bar{d} anti-down	\bar{s} anti-strange	\bar{b} anti-bottom	
			γ photon				
			g gluon				
			Z Z boson				
			W W boson				
I II III Three Generations of Matter				I II III Three Generations of Matter			

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Probing the Big Bang



- The stars are a very small fraction

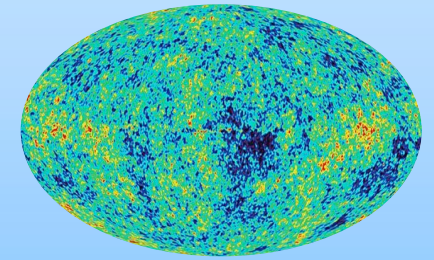


• Additional ordinary matter,
Still a small fraction
about 4 percent

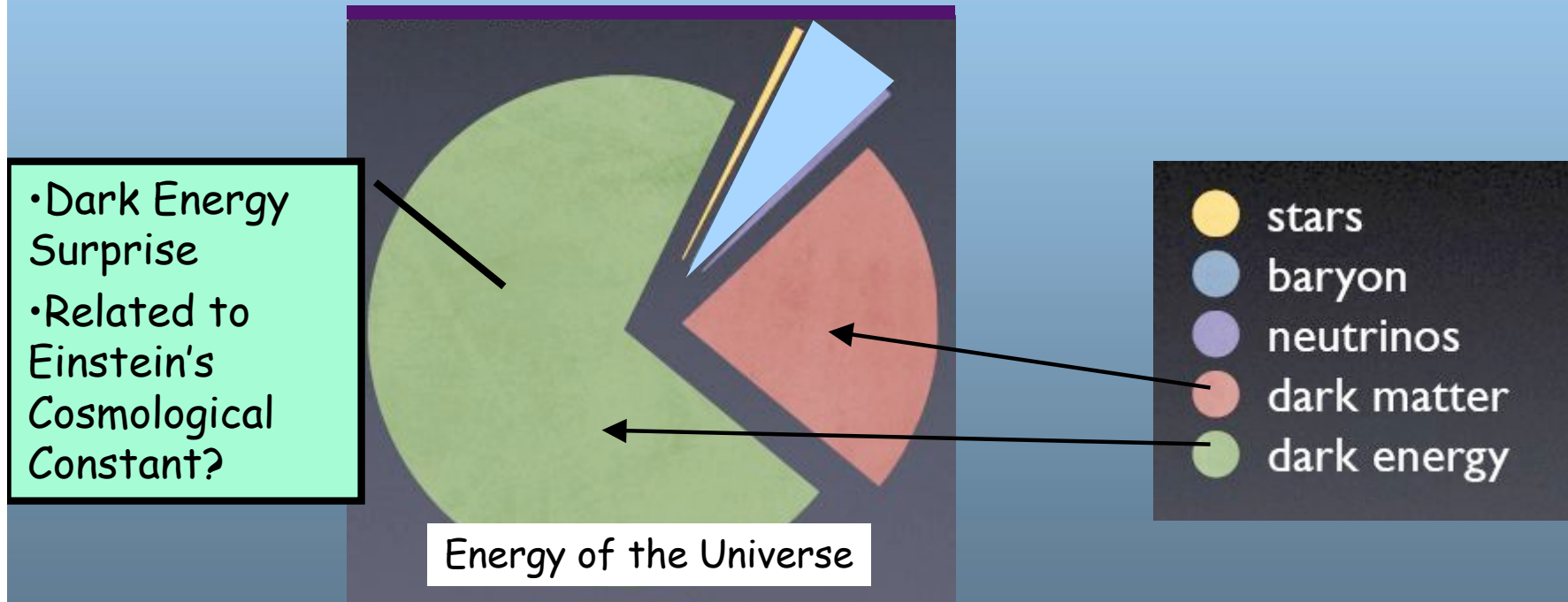
• Anti-matter miniscule

• What is the rest?

Probing the Big Bang

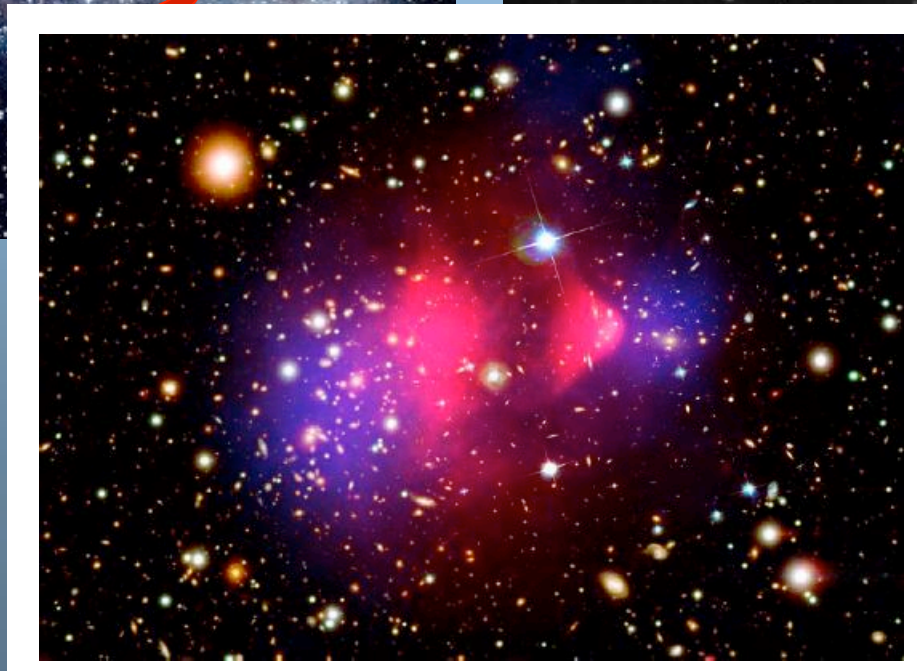
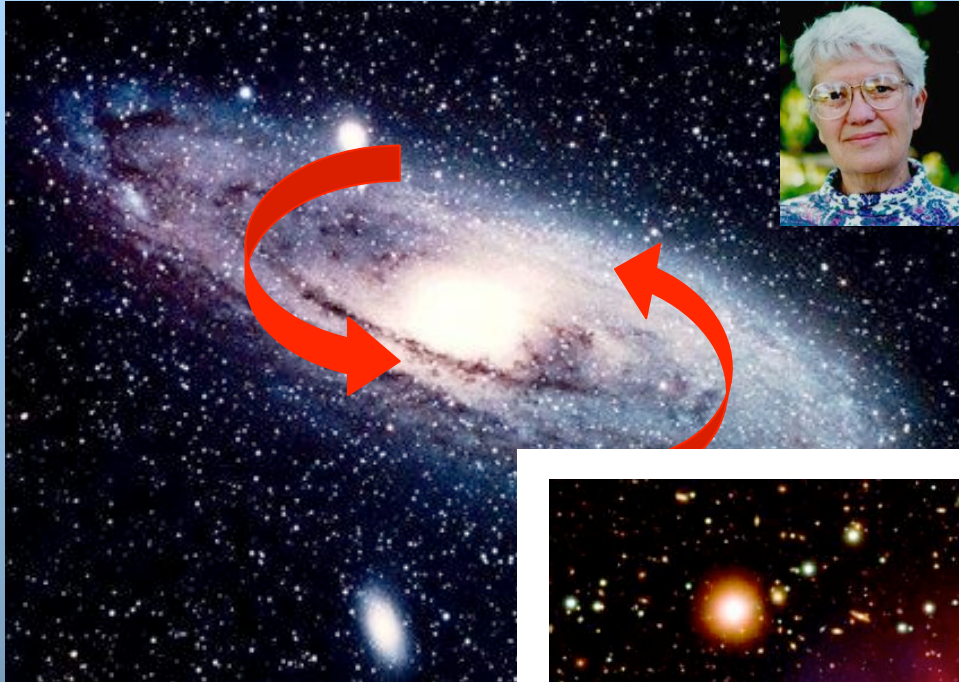


- The dominant “weight” of the universe appears to be dark matter and dark energy



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Dark Matter



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The Dark Side Controls the Universe

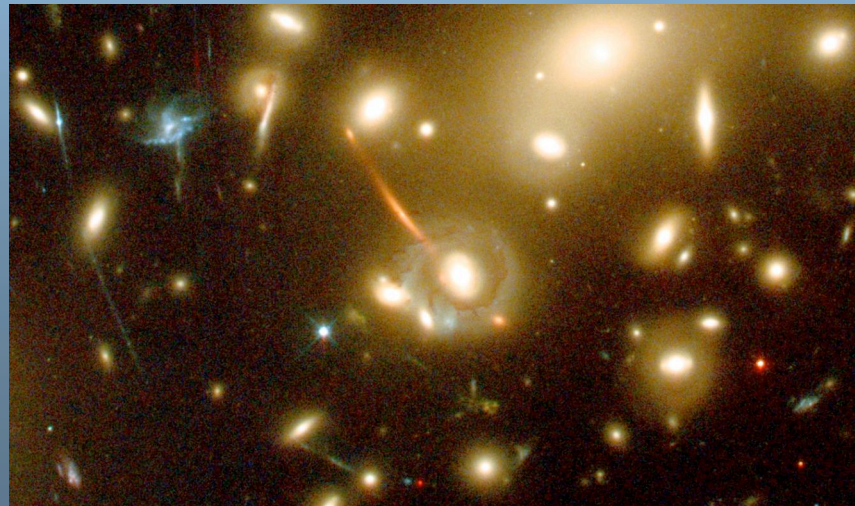


Dark Matter

HOLDS IT TOGETHER

Dark Energy

DETERMINES ITS DESTINY



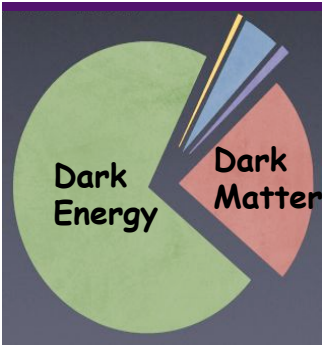
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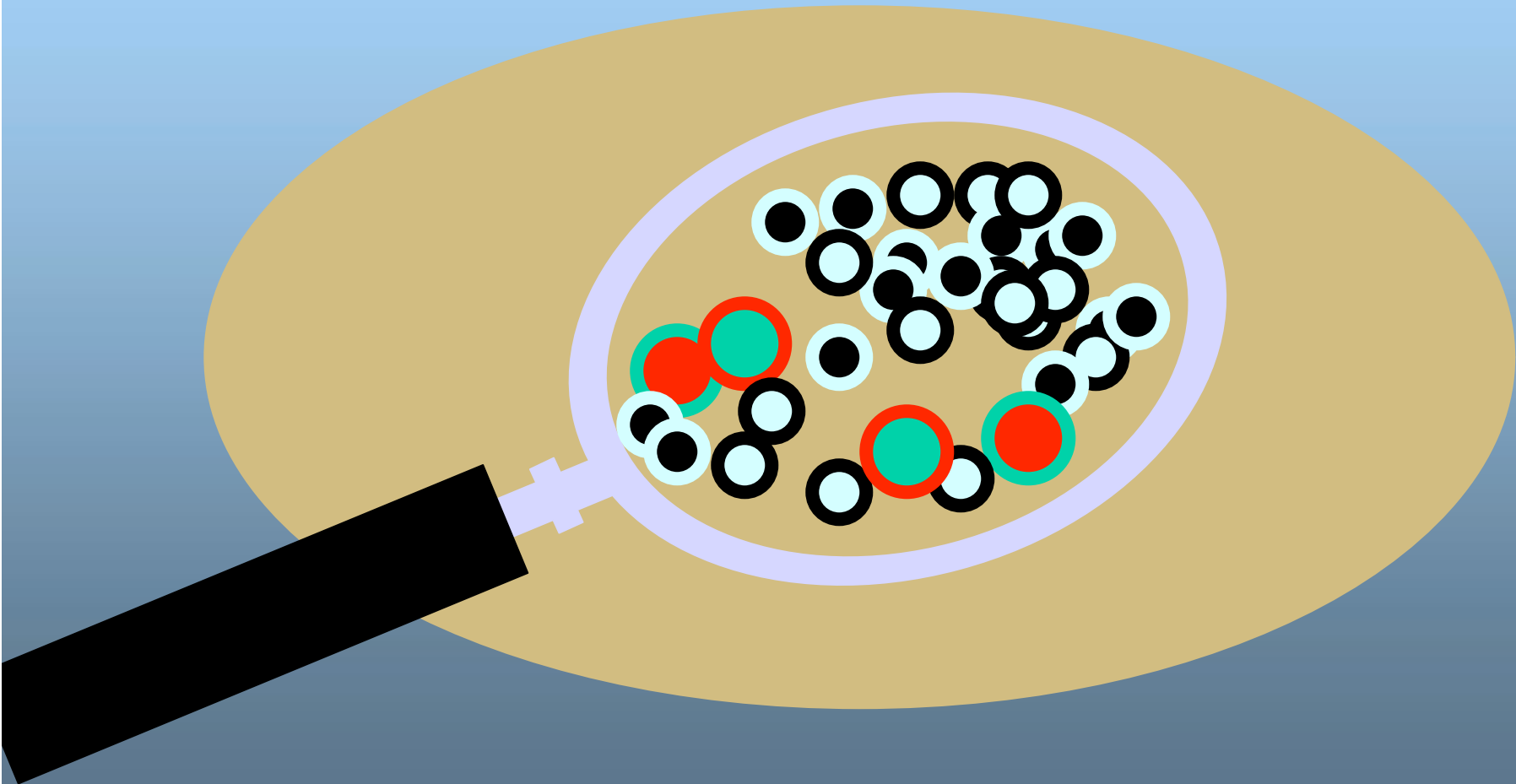
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The Dark Energy Something from Nothing?



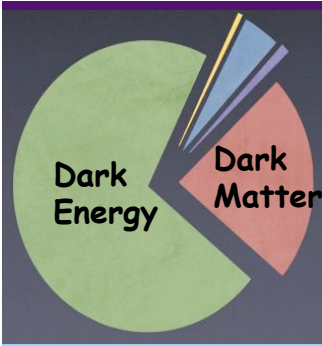
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The Dark Energy Something from Nothing

Quantum Fluctuations Create a "Dark Energy"
- Cosmological constant

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Calculating Dark Energy

1,000,000,000,000,000,000,000,000,
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000,000,000,000,000,000,000,000

times too big

$$E_o = \frac{1}{4\pi} \hbar \omega$$

vacuum energy is the sum of all the simple harm

$$E_o = \sum_j \frac{1}{4\pi} \hbar \omega_j$$

(λ) for the scalar field. This sum may be evalu
go to infinity. The periodic boundary conditio
eger values of n . There are then $Ldk/2\pi$ discre
es an integral:

$$E_o = \frac{1}{4\pi} \hbar L^3 \int \frac{\omega}{(2\pi)^3} d^3k$$

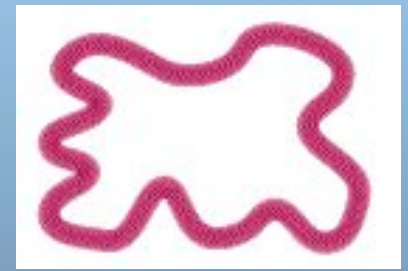
pose a cutoff at a maximum wavevector k_{max} :

$$\rho_{vac} \equiv \lim_{L \rightarrow \infty} \frac{E_o}{L^3} = \frac{\hbar k_{max}^4}{32\pi^3}$$

SuperString Theory



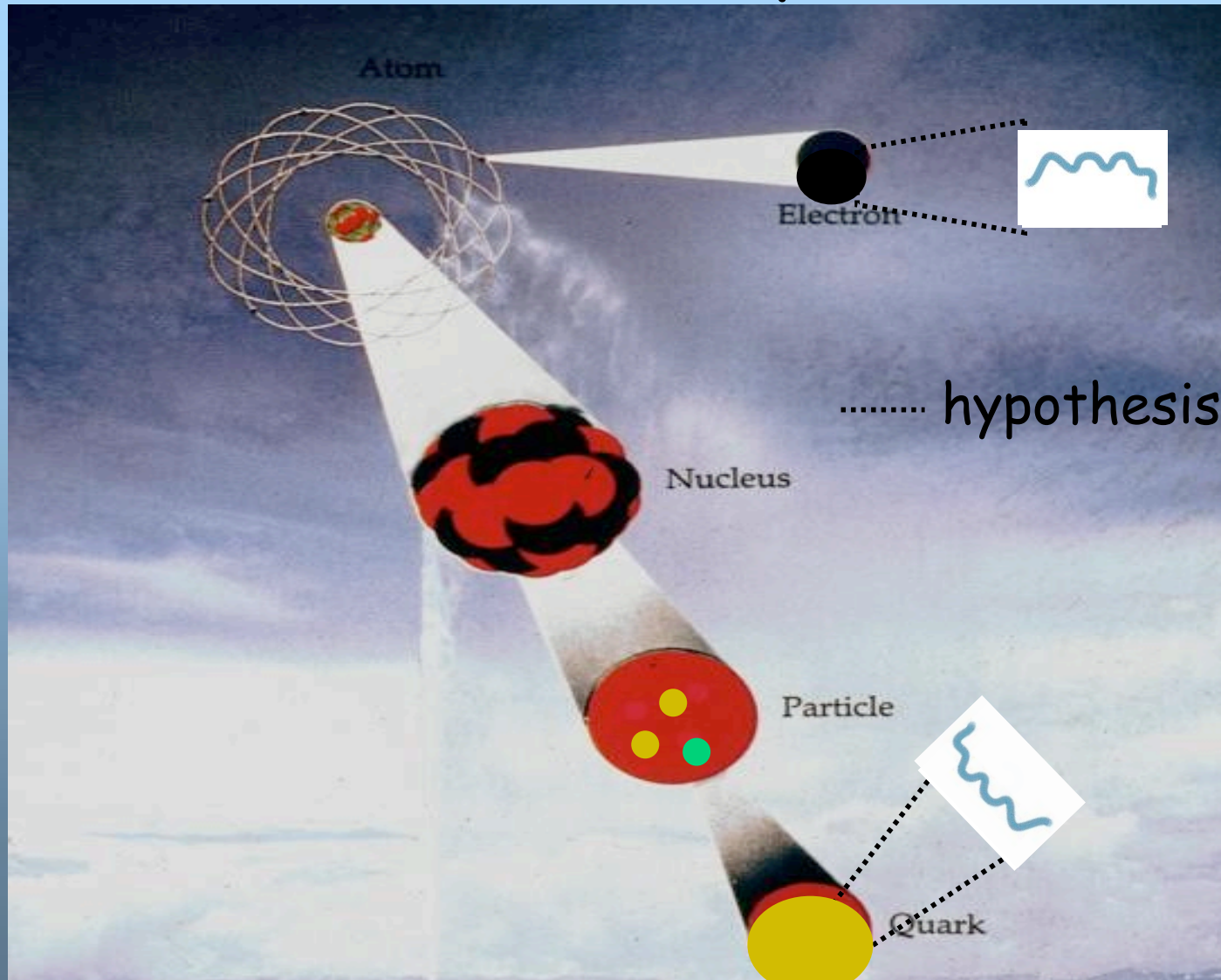
- Unifies all particles and all forces
 - gravity with quantum mechanics
- Fundamental particles are represented as vibrations on string



- String is miniscule
 - Atom is 10,000,000,000,000,000,000,000,000 x bigger
- Space is ten-dimensional (not 3D!)
- A matching set of particles appear
 - the super-partners of ordinary particles

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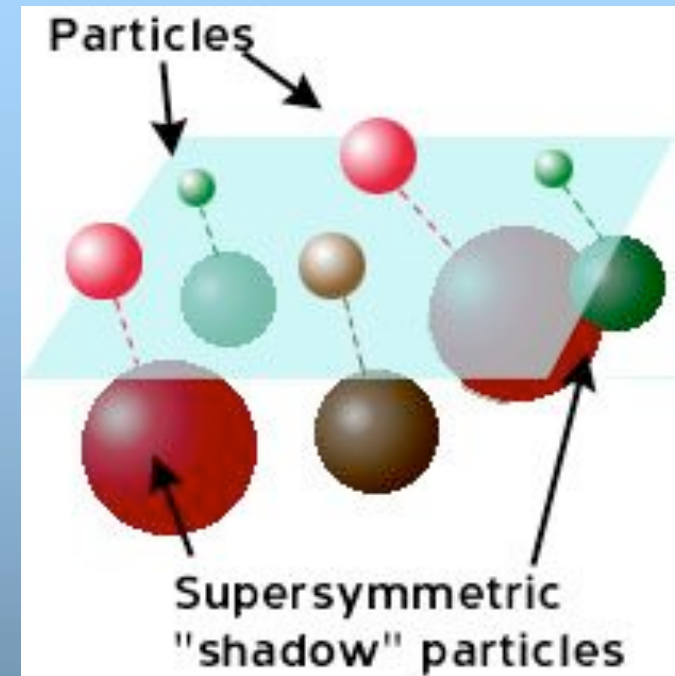
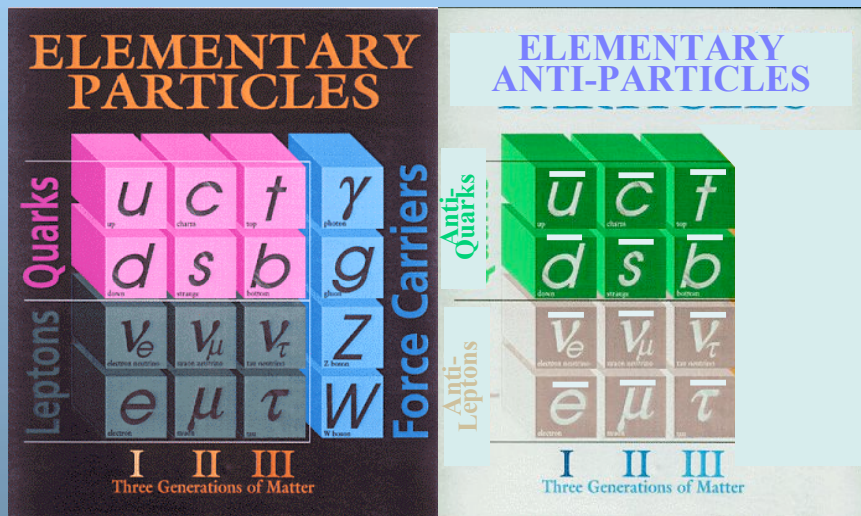
The Structure of Matter



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Supersymmetry and Strings

- History repeats?



- The supersymmetric particles have just the properties expected of Dark Matter

Particles, Energy, and Our Mysterious Universe

Large Hadron Collider (LHC) Geneva, Switzerland



Nearing
Completion

Begins operation
later early
next year

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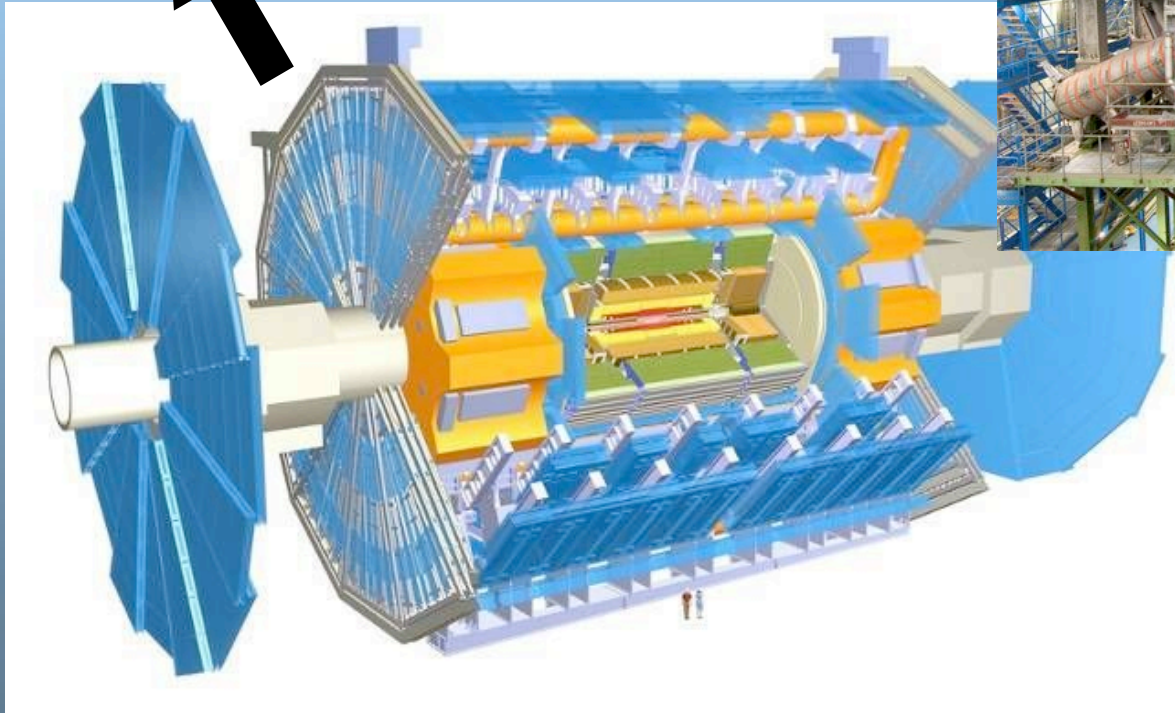
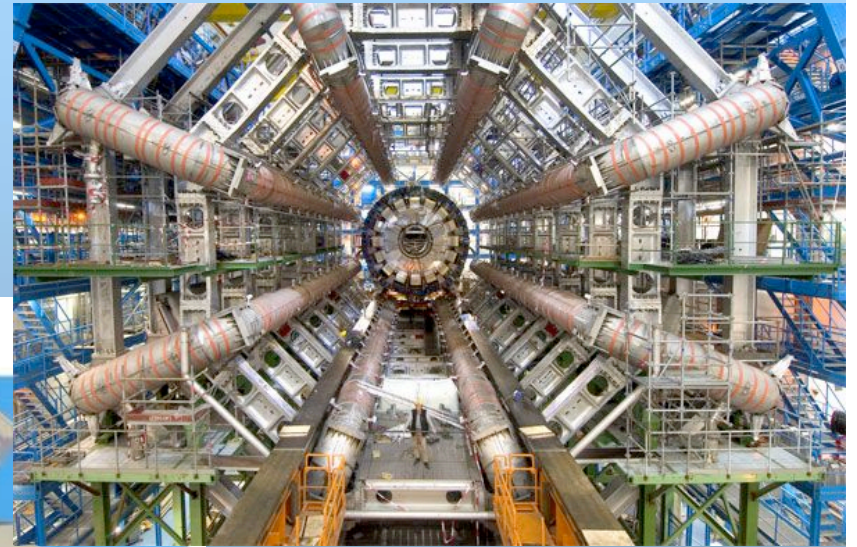
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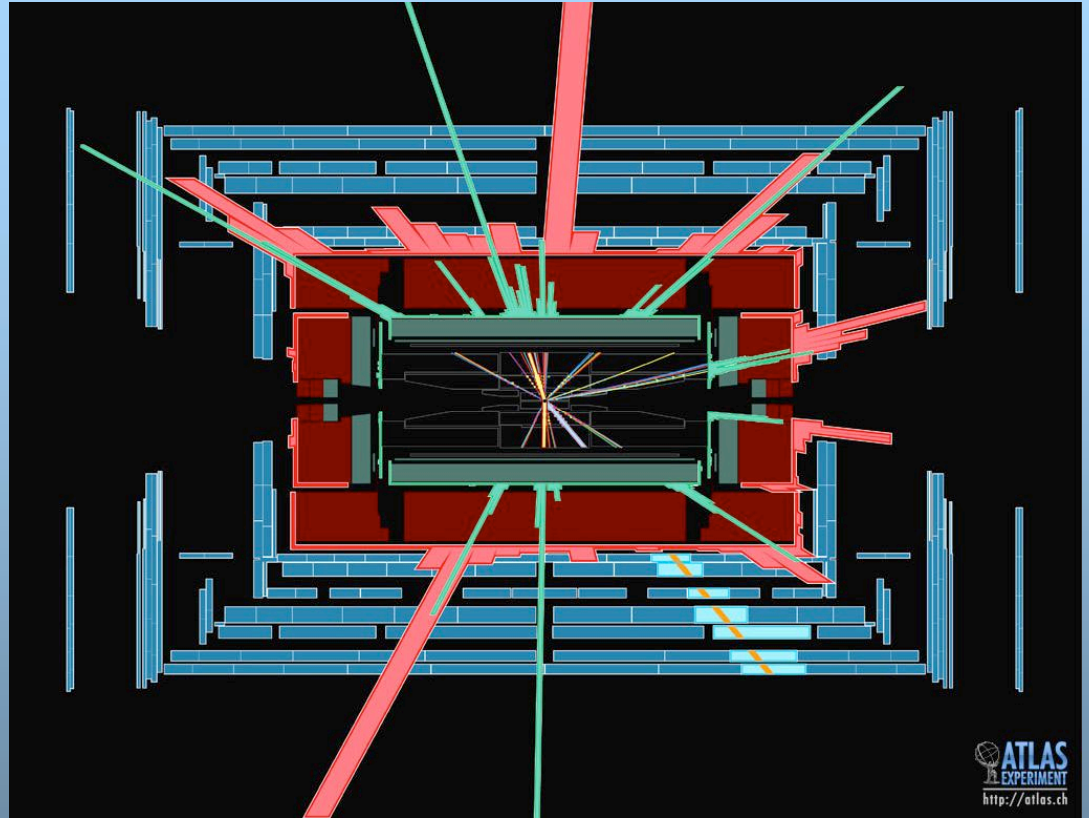
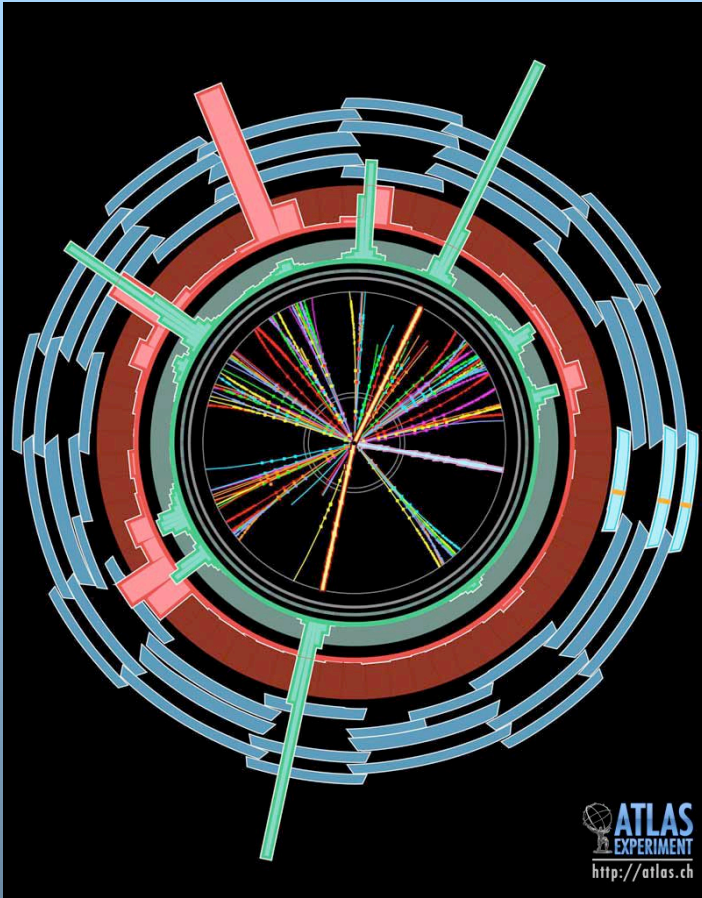
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LHC Detector - ATLAS





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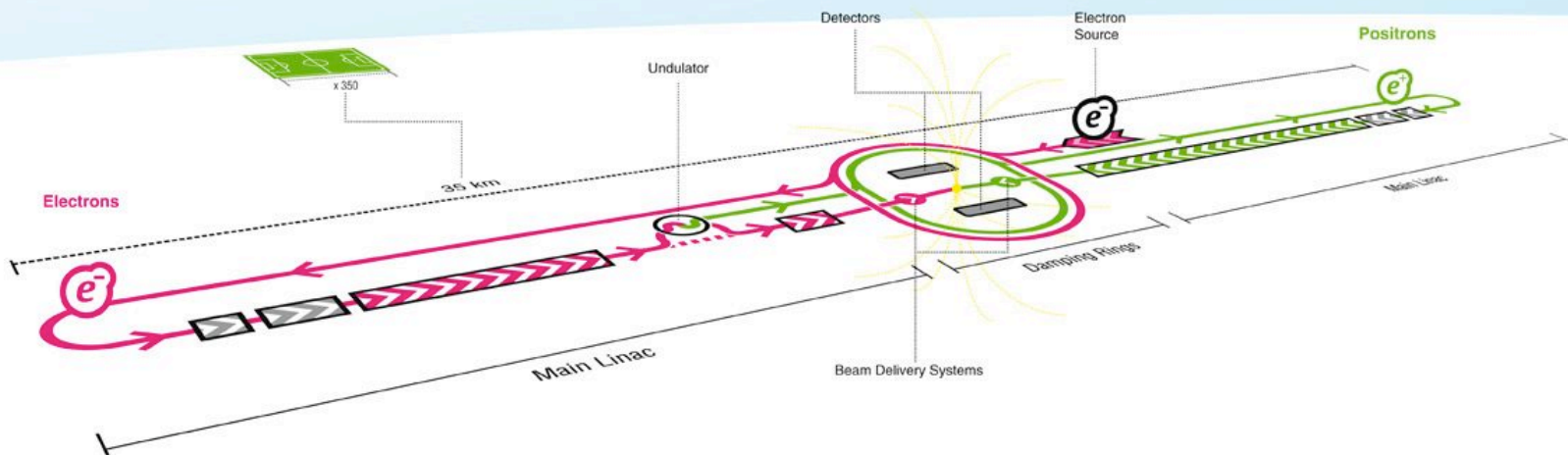
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International Linear Collider (ILC)



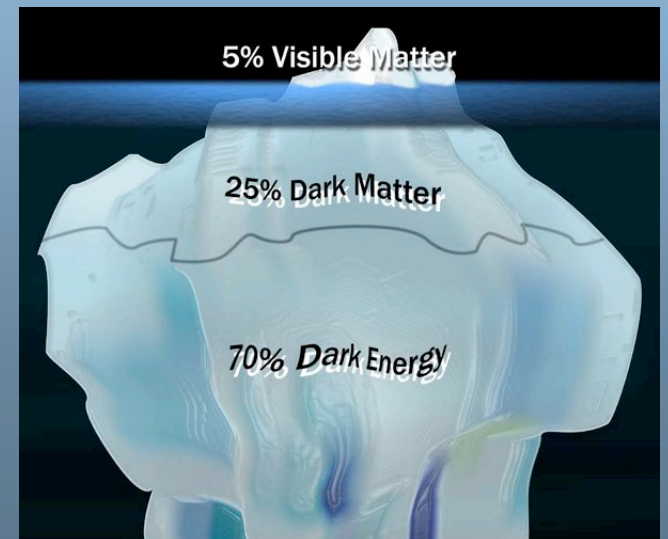
Under
development

Planned to begin
operation last
half of next decade

Our Mysterious Universe

- We are on the eve of a revolution in physics
 - Many mysteries
 - Solutions appear near
 - Deeper understanding of the universe itself
- Dark Matter particles - may appear soon in particle collider experiments
- Also
 - Gravity waves
 - Higgs Boson
 - Extra Dimensions
 - Other AMAZING Things

Stay Tuned!



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Acknowledgements

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