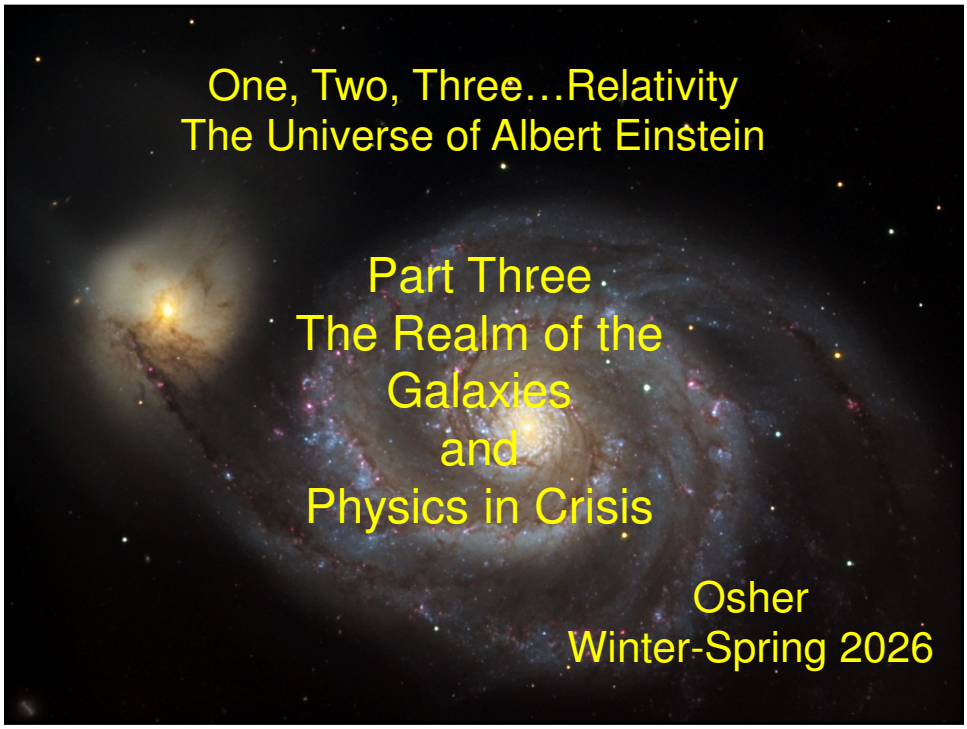
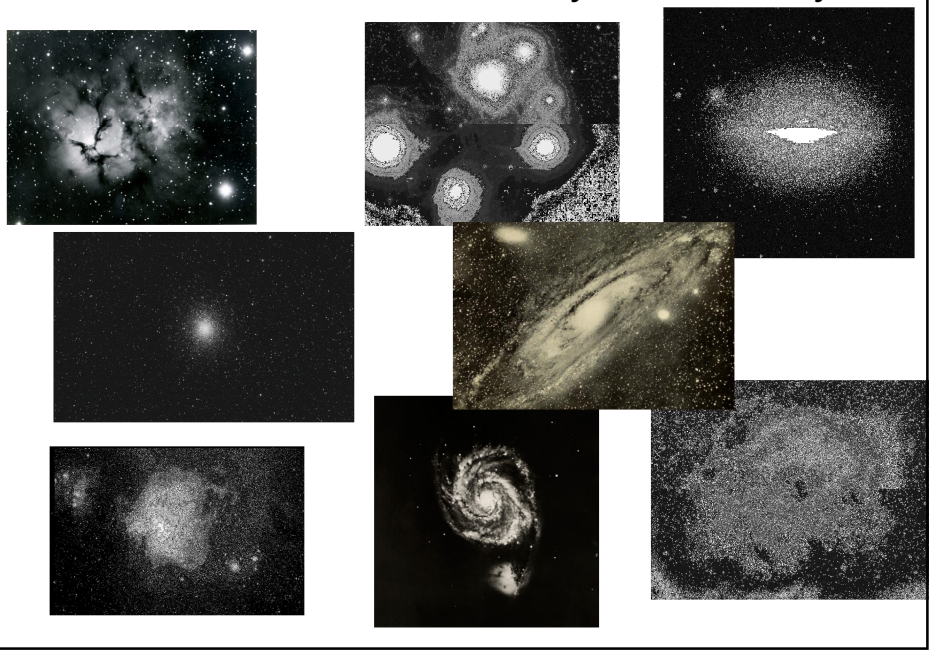
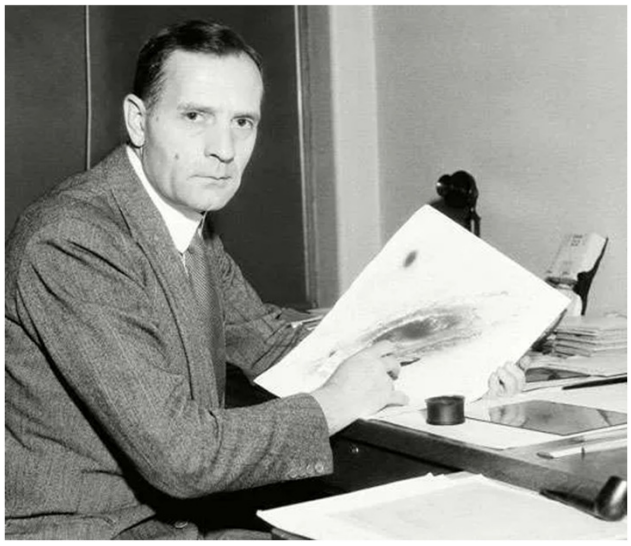


View of the Universe – Early 20th Century



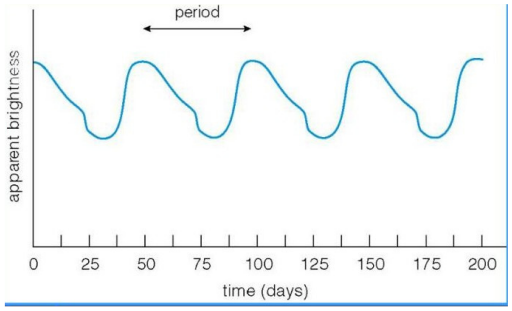
Early 20th Century Astronomy
The Universe Was the Milky Way

Edwin Hubble (1889-1953)
The Realm of the Galaxies



Hubble expands the size of the Universe, 1924

- Observations at Mt. Wilson observatory
- Variable star → periodic change in brightness
- Cepheid variable stars as distance markers (correlation of period with star's inherent brightness)
- Galaxies are distinct from nebulae and outside the Milky Way (itself a galaxy)
- First published in *The New York Times*



The Size of Space
The Light Year

Speed of light = 186,000 miles per sec

A photon travels one billion miles in 1.5 hours.

A photon travels 5,580,000,000,000 miles in one year.

The time it takes light to reach us from deep space objects gives a glimpse as to the vastness of the universe.

Moon = 1.28 sec

Mars (closest) = 182 sec (3 min)

Sun = 8.3 min

Pluto = 5.3 hr

Proxima Centauri = 4.25 years

Center of the Milky Way ≈ 28,000 years

.

The light that we view from the Andromeda Galaxy has been traveling towards us for …

TWO and a HALF MILLION YEARS!

The Cosmological Redshift

DETOUR

Train Whistles and the Doppler Effect

Sound is a wave.

Pitch of a Train Whistle

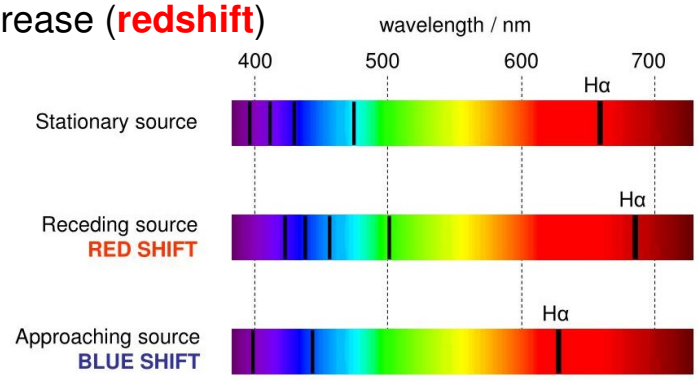
- Increases if Train is approaching
- Decreases if Train is receding

Called the Doppler Effect

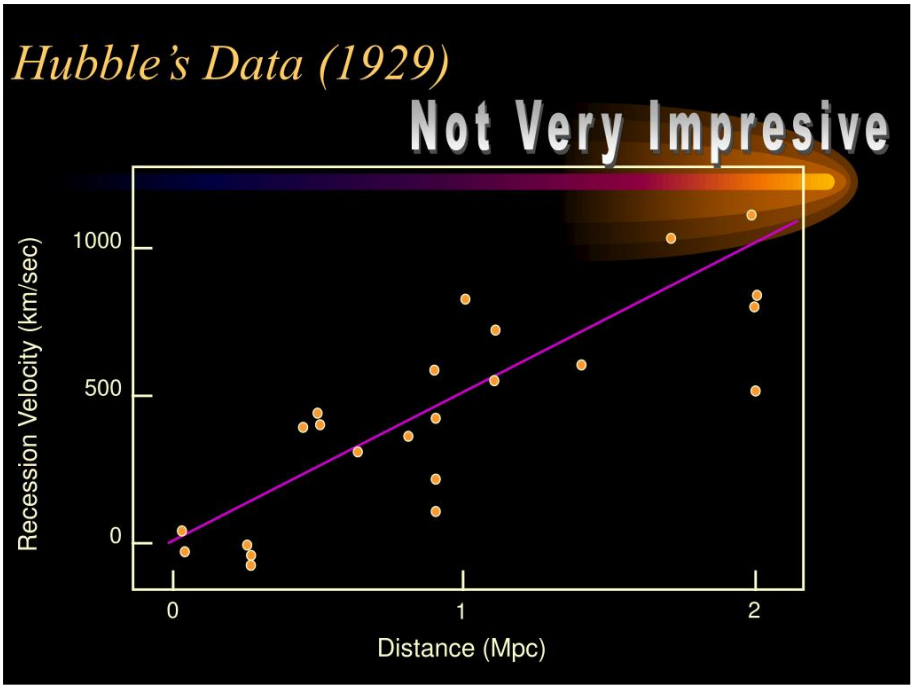
- 1929 Hubble publishes the measured redshifts of 46 galaxies
- Derives linear relationship between redshift and distance of galaxies
- Off by a factor of ~7 but better data validates model

Light has Wave properties

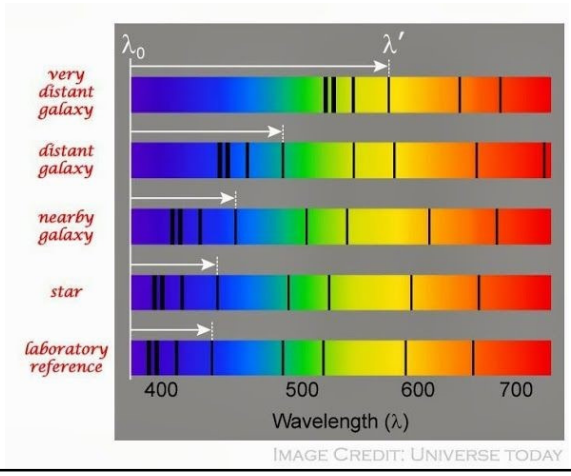
- Wavelenght of an approaching light source will decease (**blueshift**) – **The Joke**
- Wavelength of a receding light source will decrease (**redshift**)



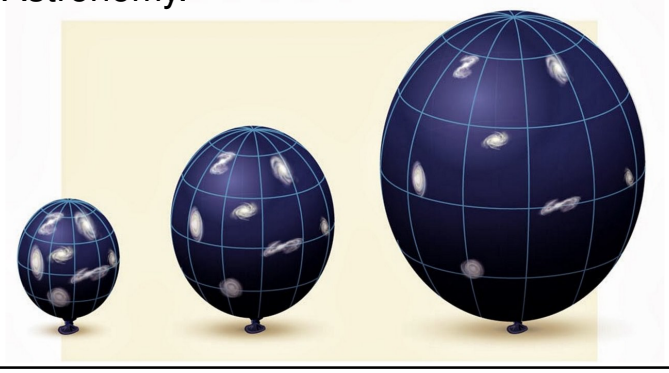
Note: For this to be observable, light source must be moving a high fraction of the speed of light relative to observer



Outside the Local Group of galaxies, it appears that the more distant a galaxy, the greater its REDSHIFT.
Most popular explanation for this
The Universe is EXPANDING.



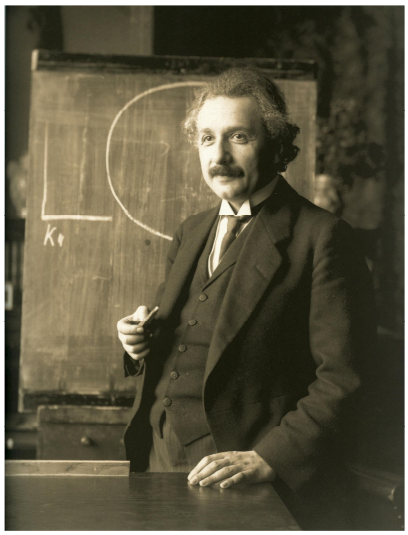
- Hubble never claimed that the redshift proved that the universe was expanding, and he repeatedly expressed caution about interpreting the redshift as a Doppler effect.
- Hubble never received a Nobel Prize. At the time, the Nobel Prize in Physics did not include Astronomy.



The Cosmological Constant Λ

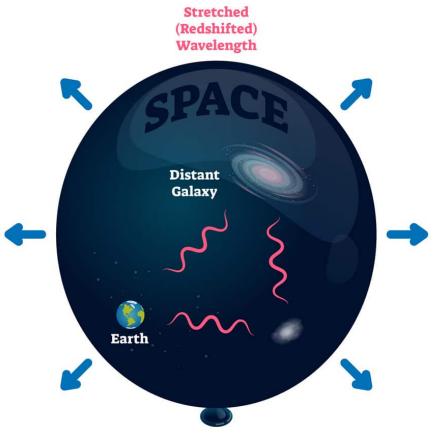
"Dr. Einstein, please make up your mind."

- When Einstein introduced his General Theory of Relativity in 1915, the Universe was thought to be Static
- To keep the Universe from collapsing due to gravity, Einstein added the Cosmological Constant Λ to his theory



The Cosmological Constant (cont.)

Considering Hubble's evidence for an expanding Universe, in the 1930s, Einstein removed the Cosmological Constant from his theory

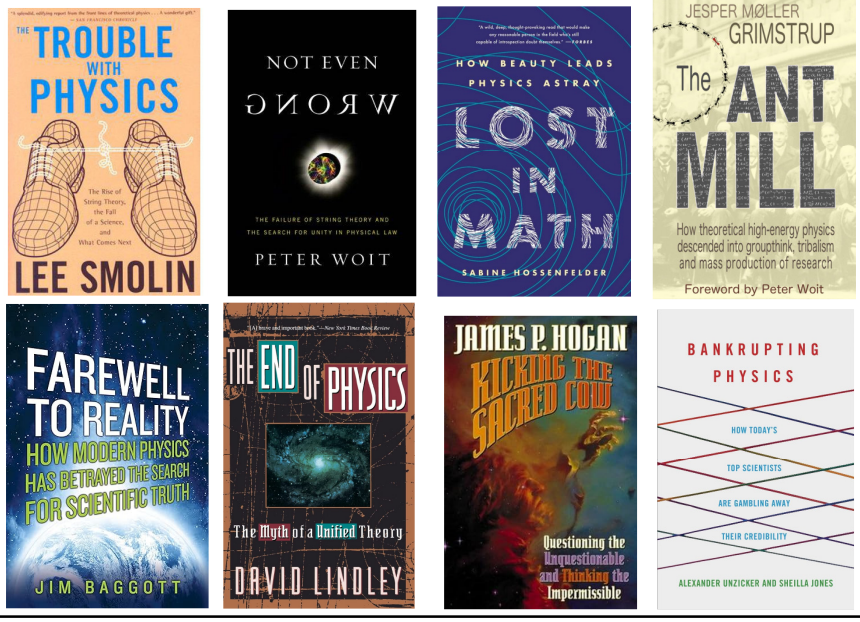


The Cosmological Constant (cont.)

- 1998: Evidence published that indicated the expansion of the Universe was accelerating
- It's Back! Λ put back into equations.
- About 68% of the mass-energy density of the universe attributed to ***DARK ENERGY***.

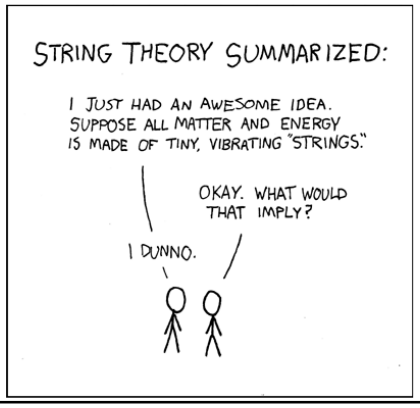
Photo of Dark Energy

Is Physics in Crisis?



Physics in Crisis?

- Since 1930s no new breakthroughs in fundamental physics of the magnitude of Relativity and Quantum Theory
- Since 1970s, progress in fundamental physics has appeared to increasingly stagnate
- Lack of progress often disguised by confusion with technological (engineering) progress



THE PARTICLE ZOO

1897 – J. J. Thomson discovers the electron

1932 – James Chadwick discovers the neutron

1932 – Carl Anderson detects the positron

1936 – Carl Anderson discovered the *muon*, ~200x mass of an electron

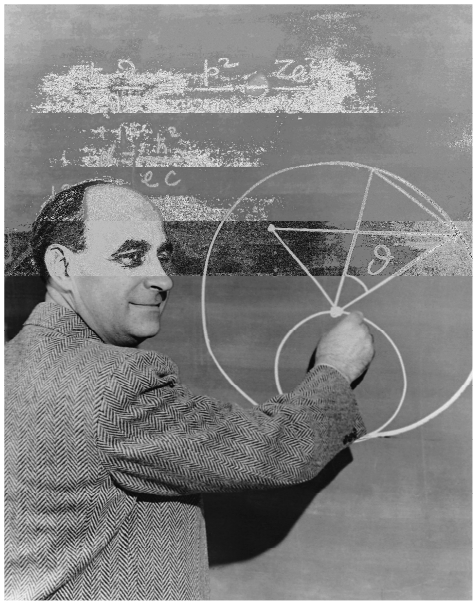
1947 – Cecil Powell discovers the *pion* in cosmic rays, 273x mass of an electron

1956 – Clyde L. Cowan and Frederick Reines detect the neutrino

- 1947 Positive and negative kaon
- 1950 Neutral lambda particle
- Etc.

What was going on?

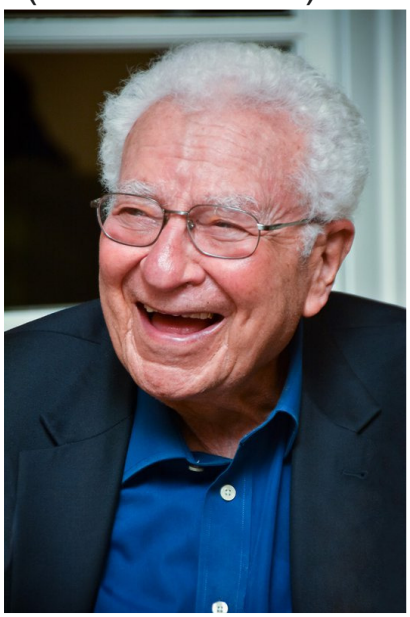
One physicist expressed the prevailing sense of frustration: "… the finder of a new elementary particle used to be rewarded by a Noble Prize, but such a discovery now ought to be punished by a $10,000 fine."



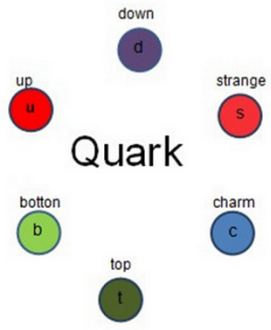
When asked by Leon Lederman what he thought about the discovery of a particle named the K-zero-two, Enrico Fermi replied,
“Young man, if I could remember the names of these particles I would have been a botanist.”

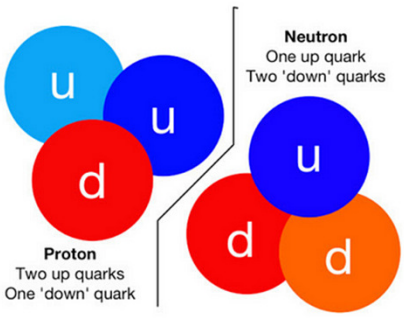
Murray Gell-Mann (1929 – 2019)

- Quarks
- Quantum chromodynamics (strong nuclear force)
- Eightfold way
- Nobel Prize in Physics 1969



1964 - Gell-Mann and, independently, George Zweig, postulate the existence of quarks





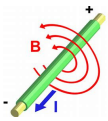
Quarks possibly first detected in 1968 at the Standard Linear Accelerator Center (SLAC)

- *Confinement*: Quarks always appear as pairs or triplets. No way to break them apart into singles.
- Does it make sense to talk about parts of something that cannot be divided into parts?
- Quarks have to be consistent with the exclusion principle.
- To get around that problem, physicists invented *Colors* in order to make it okay for identical quarks to live together in the same place.
- Colors are unobservable. Introduced solely to keep the theory from contradicting itself.

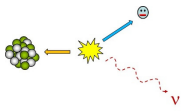
The Forces of Nature

Gravitational

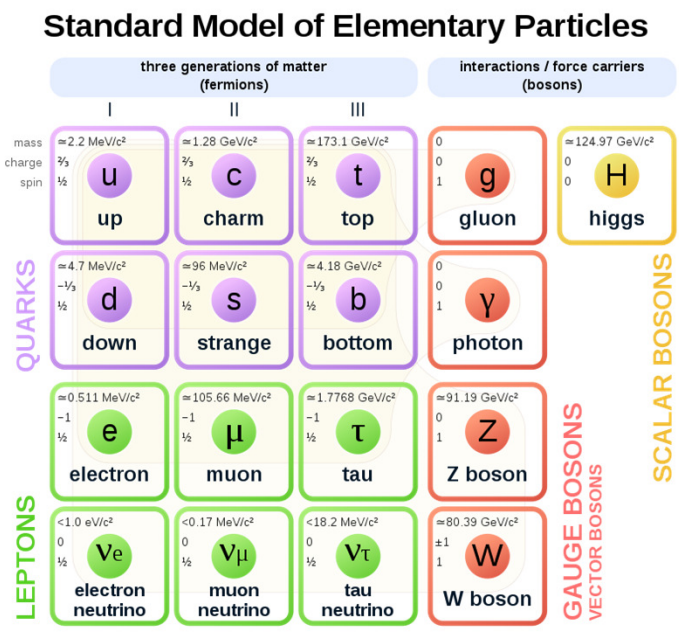
Electromagnetic



Weak Nuclear

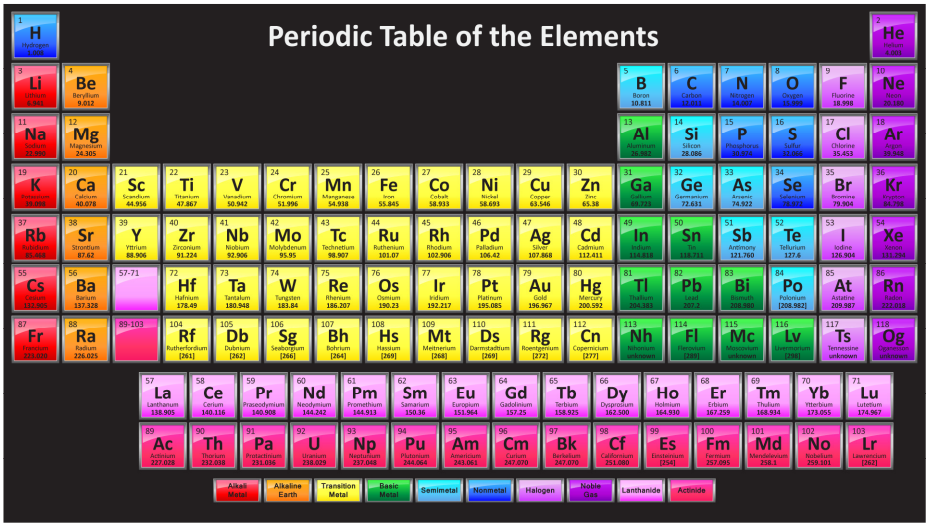


Strong Nuclear



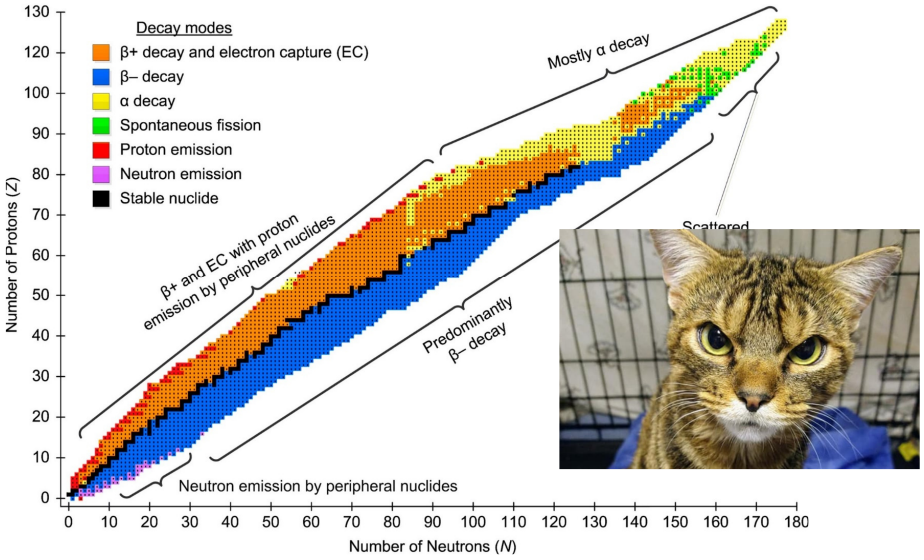
Predicts almost all known particles and forces (aside from gravity) with great accuracy (?)

Quantum theory 'predicts' this!



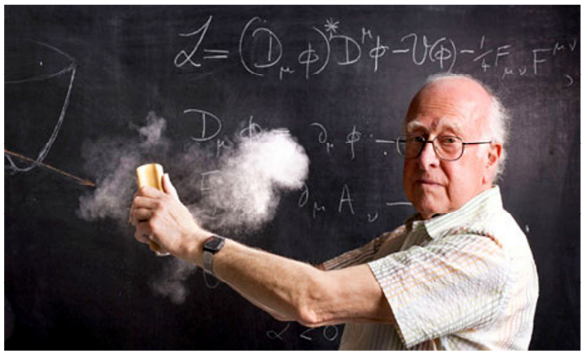
The Standard Model does **NOT** 'predict' this

The Chart of the Nuclides



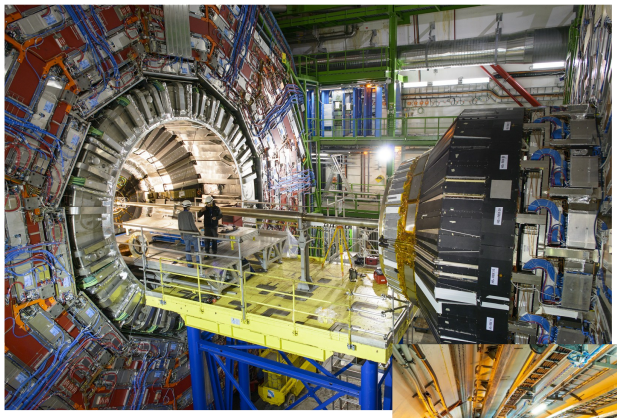
The Higgs Boson (The God Particle)

- Assumption that mass is not an intrinsic or primary property of the particles that make up matter.
- Peter Higgs (1929 -) predicts the Higgs boson in a 1964 paper. Reported found in 2012.



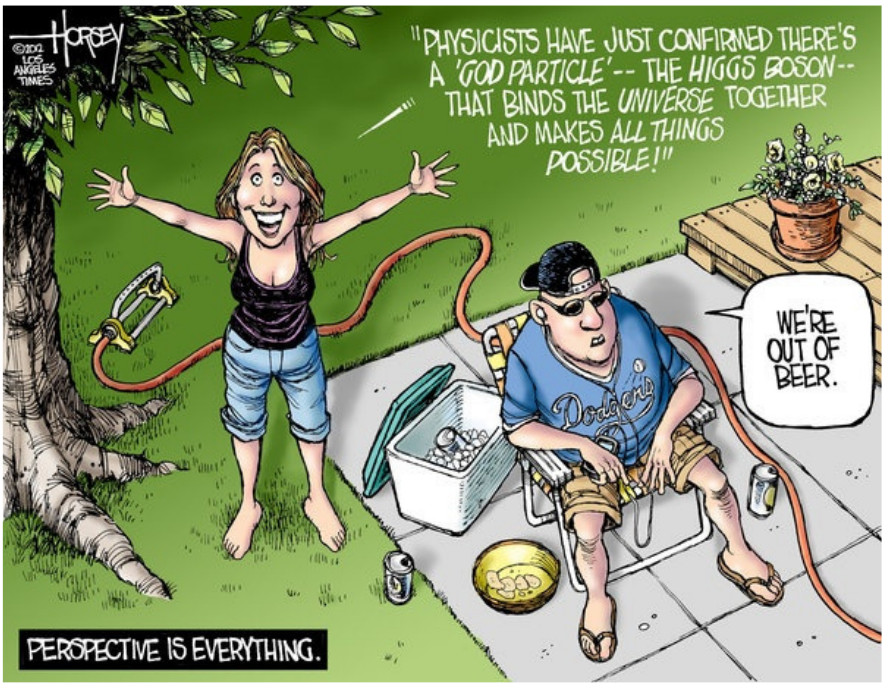
Peter Higgs: Nobel Prize in Physics, 2013

Large Hadron Collider (LHC)



Protons accelerated to high energies in a tunnel 17 miles circumference

- Concerns that when the Large Hadron Collider started up it would create a mini-black hole and destroy the Earth.
- Because of numerous startup problems experienced by the LHC, it was proposed that 'nature' was protecting its secrets from humanity.
- LHC produces a lot of "background" noise due to huge number of proton collisions
- Noise is 12 orders of magnitude larger than the signal that would identify the Higgs.
- As if from 7 million liters of beer drunk at the Oktoberfest, a single drop of an unexplained nature leaked out.



How are things going in the world of particle physics?

"If you follow the news in particle physics, then you know it comes in three types.

1. It's either that they haven't found that thing that they were looking for, or
2. they've come up with something new to look for which they later reported not having found, or
3. it's something so boring you don't even finish reading the headline."

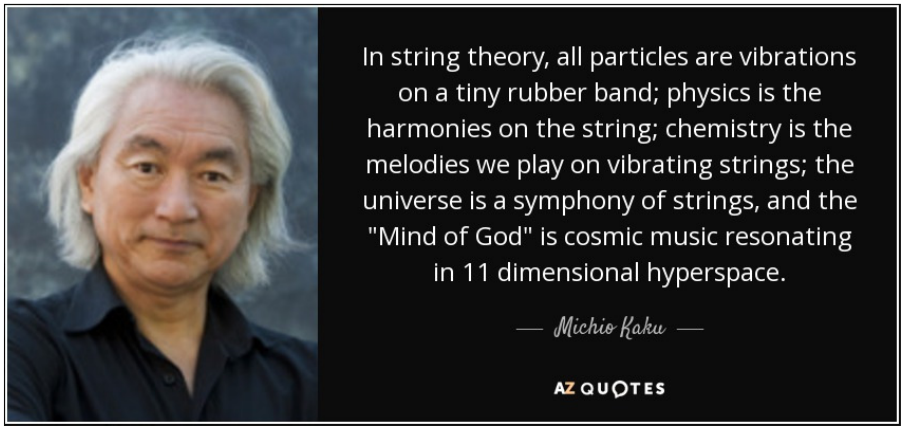
-- Sabine Hossenfelder, "What's Going Wrong In Particle Physics" video, February 2023.

Some of the things particle physicists have looked for but have yet to find:

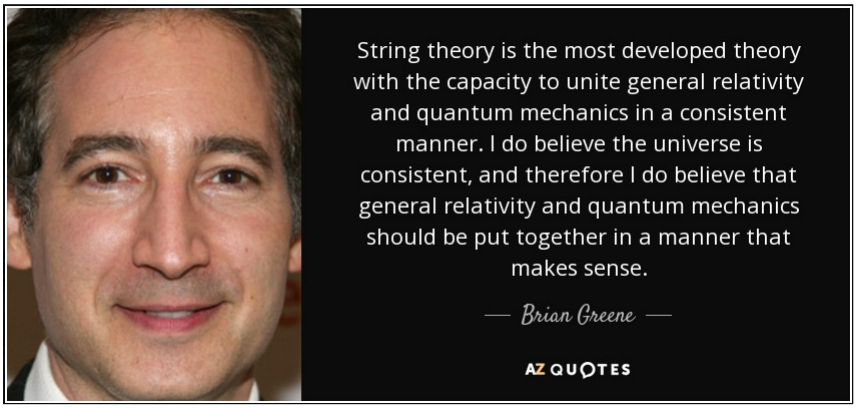
- Supersymmetry
- Proton decay
- Dark matter
- Wimps (Weakly Interacting Massive Particles)
- Axions
- Sterile neutrinos

Hope is that more and more powerful particle accelerators will lead to success.

String Theory



In a television interview, Kaku predicted that the Large Hadron Collider would prove string theory, allow us to look at time before the Big Bang, and discover whether our universe had collided with others.



The beauty of string theory is the metaphor kind of reality comes very close to the reality. The strings of string theory are vibrating the particles, vibrating the forces of nature into existence, those vibrations are sort of like musical notes. So string theory, if it's correct, would be playing out the score of the universe. – Brian Greene

String Theory – What is it?

- Replace point-like particles with tiny, one-dimensional, vibrating *strings*.
- M-theory requires 11-dimensions …
- actually, er, superstring theory requires 10 dimensions.
- No, wait, bosonic string theory needs 26 spacetime dimensions.
- So how do we get from whatever the latest number of dimensions might be to 4-dimensional spacetime of our universe?
- We simply cram everything into a Calabi-Yau manifold.

String theorist after a hard day theorizing.

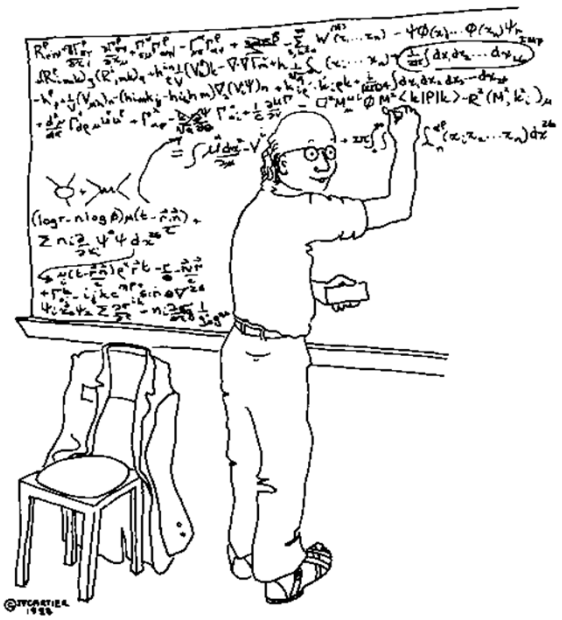
Questions?

Just one. Is string theory actually science since its predictions are untestable?

"I just think too many nice things have happened in string theory for it to be all wrong. Humans do not understand it very well, but I just don't believe there is a big cosmic conspiracy that created this incredible thing that has nothing to do with the real world." – Edward Witten

"Some string theorists prefer to believe that string theory is too arcane to be understood by human beings, rather than consider the possibility that is might just be wrong."
– Lee Smolin
"… it's not even capable of being wrong, or being falsified, or being showed to be wrong." – Peter Woit
"String theory is the most successful theory in the history of science. It can explain every imaginable universe there is …
except the one we live in!"

Lee Smolin describes the incredulous amazement with which a particle physicist replied to his doubts about extra dimensions: "But do you mean you think it's possible that there are *not* extra dimensions?"



"At this point we notice that this equation is beautifully simplified if we assume that space–time has 92 dimensions."

The "Free Parameter" Problem

- A variable in a model whose values are not determined by the model's principles and must be empirically determined through observation or experiment, or *adjustment to fit data*.
- The Fewer "Free Parameters," the Better.
- Number of Free Parameters are increasing, not decreasing.
- Standard Model of particle physics → ~20 Free Parameters. For example, coupling constants and masses.

The Search for a TOE

No, not this kind of Toe

TOE as in "Theory of Everything"
Unites the four "forces of nature" into a coherent framework.
Unites Relativity and Quantum Theory
→ Quantum Gravity

Has Physics had more Groundbreaking Innovations recently than ever before?
2015 Dutch Study – counted adjectives used in scientific papers

- Frequency of the words "unprecedented," "groundbreaking," and "novel" increased by 2,500 percent or more from 1974 to 2014
- Runners-up were "innovative," "amazing," and "promising," with increase of more than 1000 percent

If everything is groundbreaking and novel, nothing is.

Opposite appears to be true.
New data in elementary particle physics require higher energy, more expensive particle accelerators.
Since theories are cheap and plentiful but experiments are expensive and few, how do we select which theories are worth testing?
Absent observational tests, the most important property a theory must have is **peer approval**.

Fundamental Physics
- Mechanics
- Electromagnetism
- Thermodynamics
- Relativity
- Quantum Theory

No significant advances in Fundamental Physics since the 1930s.

WHY?

Physics is becoming dominated by mathematical and speculative theorizing.
A TOE would include untested and untestable assumptions.
Outside the scope of Science.

Theoretical physics has come to dominate experimental physics.
One reason is cost.
Too many physicists see Reality in equations.

Originally, the Nobel Prize in Physics was not awarded for Theory.
Of late, often awarded for theories.

Entrenchment of Relativity and Quantum Theory have killed theoretical innovation in physics.

Unless your idea is derived from or is compatible with Relativity and Quantum Theory, it is dead on arrival.

- Many scientists today have an undisclosed conflict of interest between funding and honesty.
- University budgets are increasingly challenged.
- Even tenured researchers are now expected to constantly publish well-cited papers and win grants, both of which require ongoing peer approval.

- Most research papers are either unread or unreadable.

Being open about the shortcomings of one's research means sabotaging one's chances of future funding, and possibly one's career.

"Laws, like sausages, cease to inspire respect in proportion to how much we know about how they are made." – John Godfrey Saxe

Note that Einstein's classic paper in which he introduced the Theory of Special Relativity had a single author and NO Peer Review.

ON THE ELECTRODYNAMICS OF MOVING BODIES

By A. Einstein
June 30, 1905

It is known that Maxwell's electrodynamics--as usually understood at the present time--when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena. Take, for example, the reciprocal electrodynamic action of a magnet and a conductor. The observable phenomenon here depends only on the relative motion of the conductor and the magnet, whereas the customary view draws a sharp distinction between the two cases in which either the one or the other of these bodies is in motion. For if the magnet is in motion and the conductor at rest, there arises in the neighbourhood of the magnet an electric field with a certain definite energy, producing a current at the places where parts of the conductor are situated. But if the magnet is stationary and the conductor in motion, no electric field arises in the neighbourhood of the magnet. In the conductor, however, we find an electromotive force, to which in itself there is no corresponding energy, but which gives rise--assuming equality of relative motion in the two cases discussed--to electric currents of the same path and intensity as those produced by the electric forces in the former case.

Examples of this sort, together with the unsuccessful attempts to discover any motion of the earth relatively to the "light medium," suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest. They suggest rather that, as has already been shown to the first order of small quantities, the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good.[1] We will raise this conjecture (the purport of which will hereafter be called the "Principle of Relativity") to the status of a postulate, and also introduce another postulate, which is only apparently irreconcilable with the former, namely, that light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body. These two postulates suffice for the attainment of a simple and consistent theory of the electrodynamics of moving bodies based on Maxwell's theory for stationary bodies. The introduction of a "luminiferous ether" will prove to be superfluous inasmuch as the view here to be developed will not require an "absolutely stationary space" provided with special properties, nor assign a velocity-vector to a point of the empty space in which electromagnetic processes take place.

The theory to be developed is based--like all electrodynamics--on the kinematics of the rigid body, since the assertions of any such theory have to do with the relationships between rigid bodies (systems of co-ordinates), clocks, and electromagnetic processes. Insufficient consideration of this circumstance lies at the root of the difficulties which the electrodynamics of moving bodies at present encounters.

"People find it very hard to believe in an observation if they don't have a theory to explain it."-- Geoffrey Burbidge

Presenter's experience: Fellow professor said he couldn't credit experimental results since they were not consistent with theory.

"*Today's scientists have substituted mathematics for experiments. They wander off through equation after equation and eventually build a structure which has no relation to reality."* - Nikola Tesla

Over reliance on theory versus observation

"The principle of relativity is actually a *metaprinciple* in the sense that it is not itself a law of physics, but instead is a pattern or rule which (Einstein asserted) must be obeyed by *all* laws of physics, no matter what those laws might be, no matter whether they are laws governing electricity and magnetism, or atoms and molecules, or steam engines and sports cars. The power of this metaprinciple is breathtaking. Every new law that is proposed must be tested against it."

-- Kip S. Thorne, *Black Holes & Time Warps: Einstein's Outrageous Legacy*

Less we forget…

- "The great tragedy of science - the slaying of a beautiful hypothesis by an ugly fact." – Thomas Huxley
- "All models are wrong, but some are useful." – George E.P. Box, British statistician

Since the mathematicians have invaded the theory of relativity, I do not understand it myself anymore.

– Albert Einstein, Quoted in Carl Seelig, *Albert Einstein: A Documentary Biography,* 1956

As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality.

-- Albert Einstein, Address to the Prussian Academy of Sciences, Berlin, Jan. 27, 1921

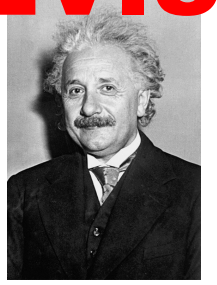
Presenter's favorite quote:

"Life is too short for experiments."

– Anonymous theoretical physicist

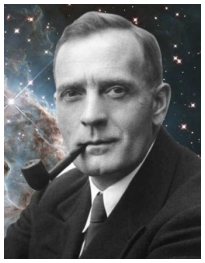
"The Joke" REVISITED

Werner Heisenberg



Albert Einstein

Erwin Schrodinger



Edwin Hubble


Coming Attractions