PHY1020
BASIC CONCEPTS IN PHYSICS I

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14 lectures/tutorials/past paper session

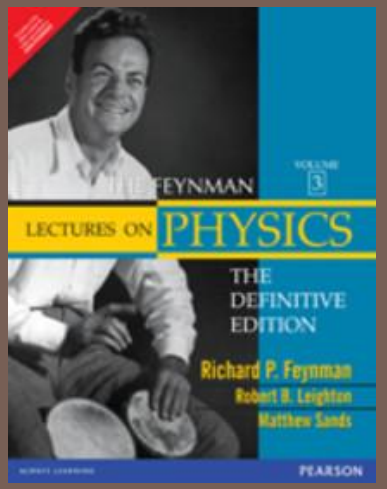
Project on one of the interesting fields in physics (30%)

Exam in January/February (70%)

RECOMMENDED READING

University physics, Harris Benson

The Feynman Lectures in Physics, Vol. I,
Richard Feynman



- V P Colletta, College Physics, Mosby
- H Benson, University Physics, John Wiley & Sons
- R Feynman, The Feynman Lectures in Physics Vol. I, Addison-Wesley
- http://www.phys.virginia.edu/classes/109N/home.html
- J Bronowski, The Ascent of Man, Little Brown & Co
- S Hawking, A Brief History of Time, Bantam

Textbooks should be read..

BASIC CONCEPTS IN PHYSICS I

Why Study Physics?

- What is Science?
- The nature of physical laws

Mechanics:

- The problem of motion;
- Kinematics in 1-D
- Kinematics in 2-D
- Dynamics
- Forces
- Energy
- Frames of references

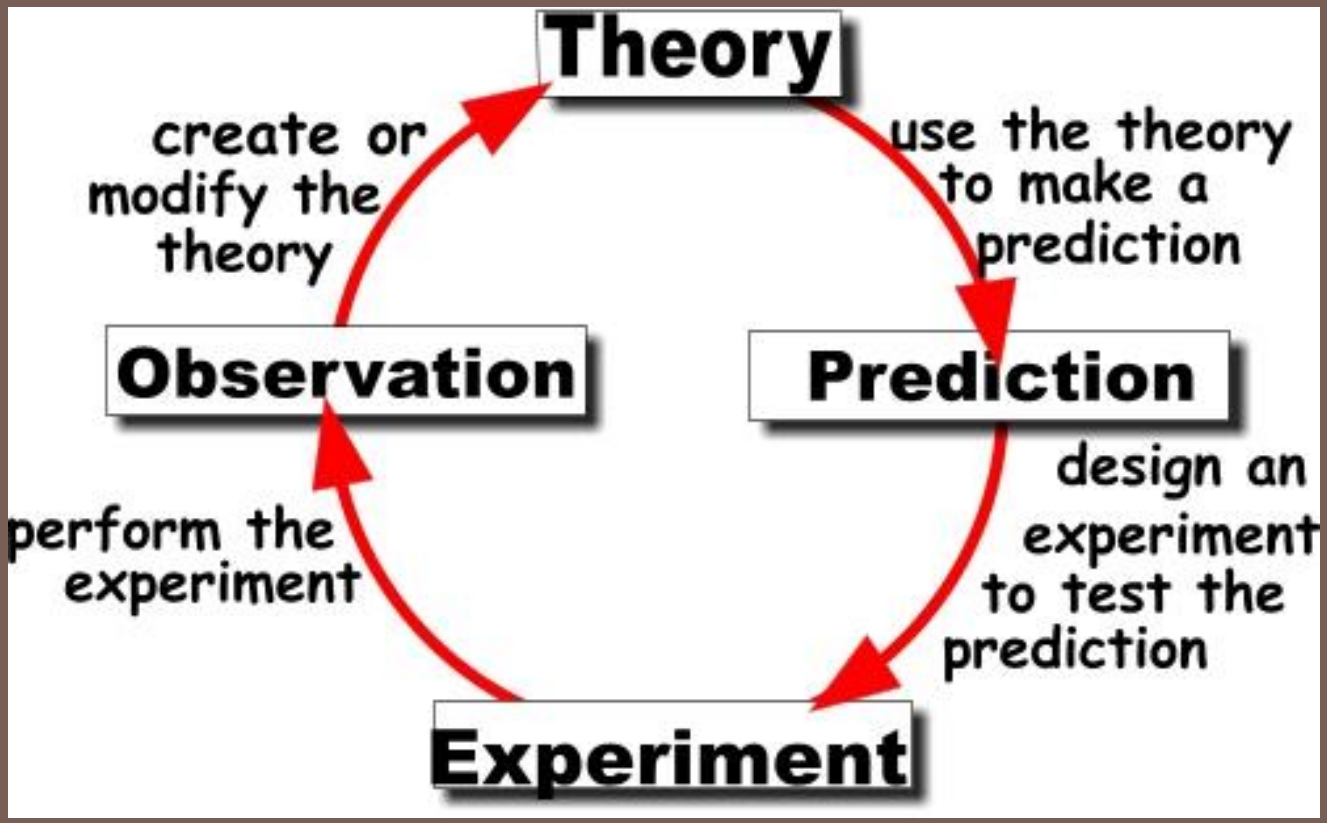
Thermodynamics and heat:

- Temperature and thermometry; Specific heat capacity;
- Latent heat; First law of thermodynamics;
- Entropy; Second law of thermodynamics; Heat engines

Contents, there will be more for part II

SCIENCE

The Scientific Method

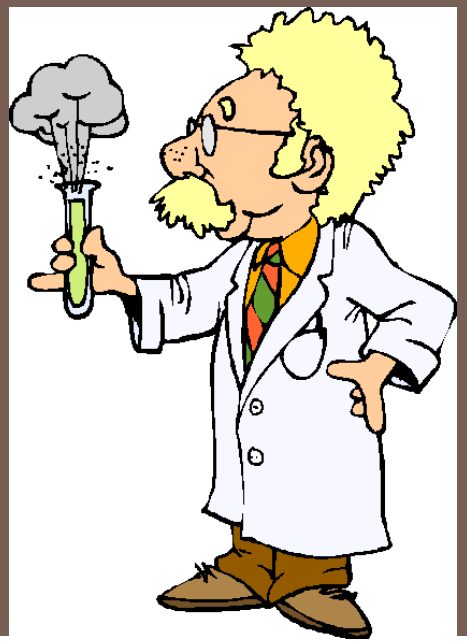


Science is a process not a eureka moment!

Physics and All The Rest

Chemistry – studies the motion of atom and molecules combine and transform through particle exchanges

Biology – Evolution of a system through dynamical changes in macroscopic structures



All science can be studied through physics!

Example I

- Formulation of the question
- Hypothesis
- Prediction
- Test
- Refinement of the Hypothesis
- Test new hypothesis
- and so it continues until the system is understood extremely well

How not to kill a basil plant! (in general)

Example II

The Earth will be destroyed on 21st December 2012 by a giant asteroid which cannot be observed until it happens

Is this a scientific statement of not?

Once More on Question Forming

Principles – These are extra laws that are necessary to make a prediction but that cannot be tested

Example: The energy of a system remains constant throughout a heating process

Explanation: To get characteristic constant (ex. specific heat capacity) we have to start off by saying that the system cannot create energy out of nothing

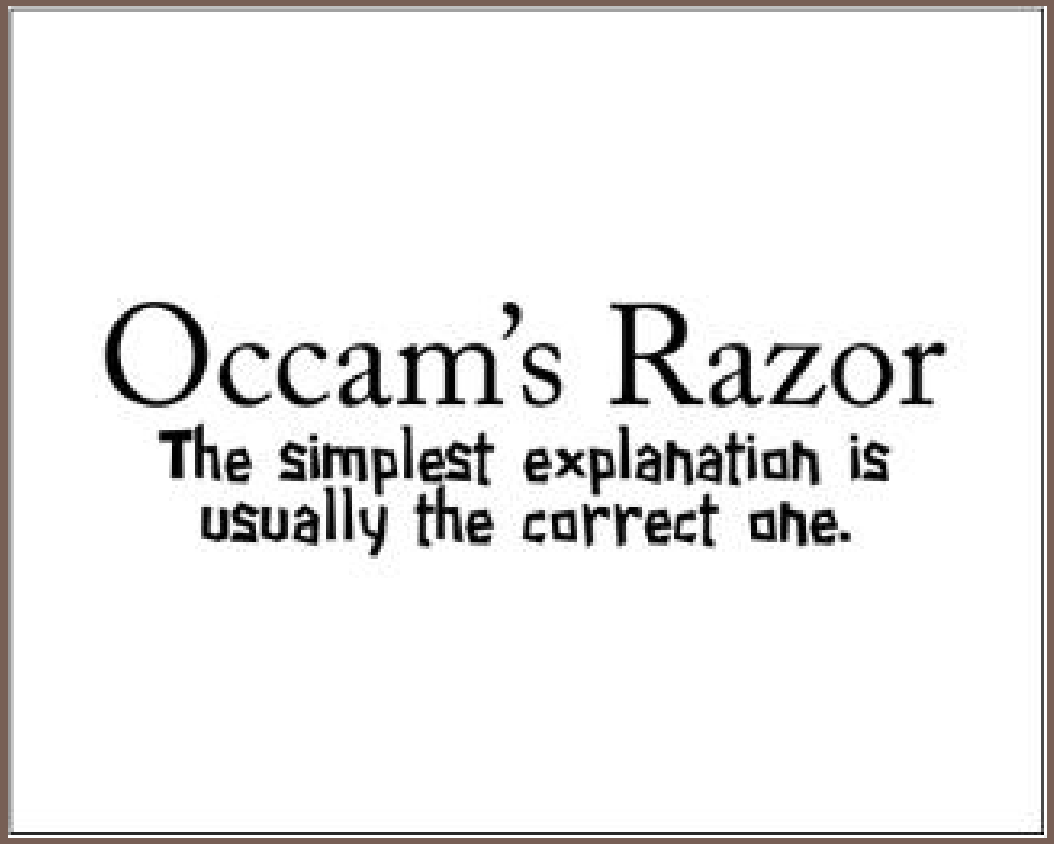
Axioms – These are the ideas that we can test, once we have all the necessary principles, through the scientific method

Example: The particles in a heating experiment move in a random fashion (ex. boiling water)

Test: If the container has a uniform distribution of bubbles emerging then this is true

What are the elements that go into forming a hypothesis?

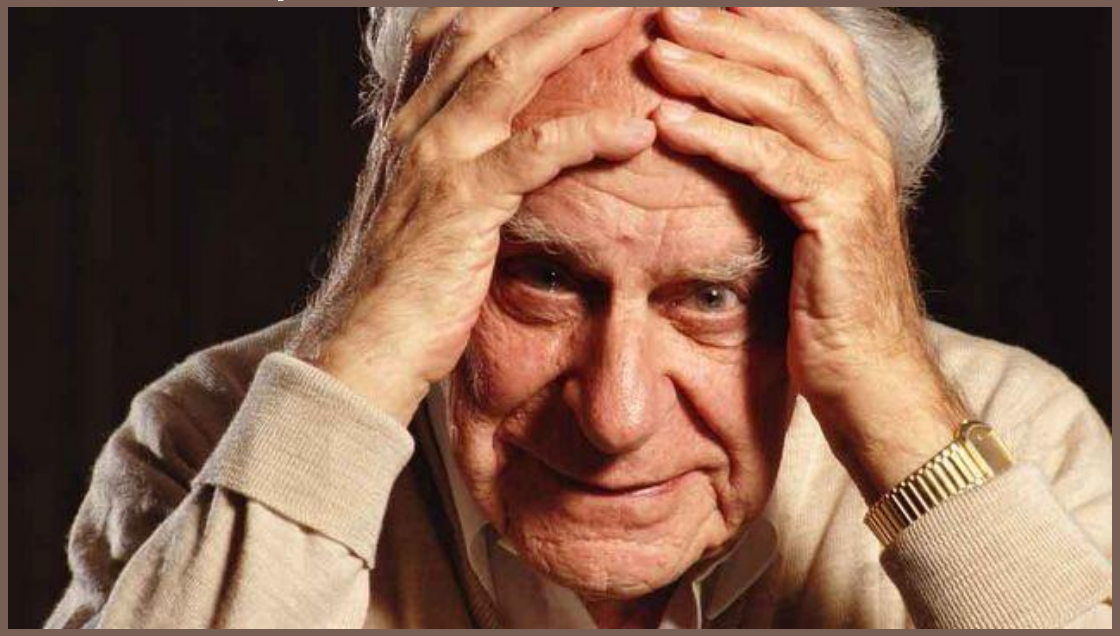
Occam's Razor



Logical Positivists vs. Falsification

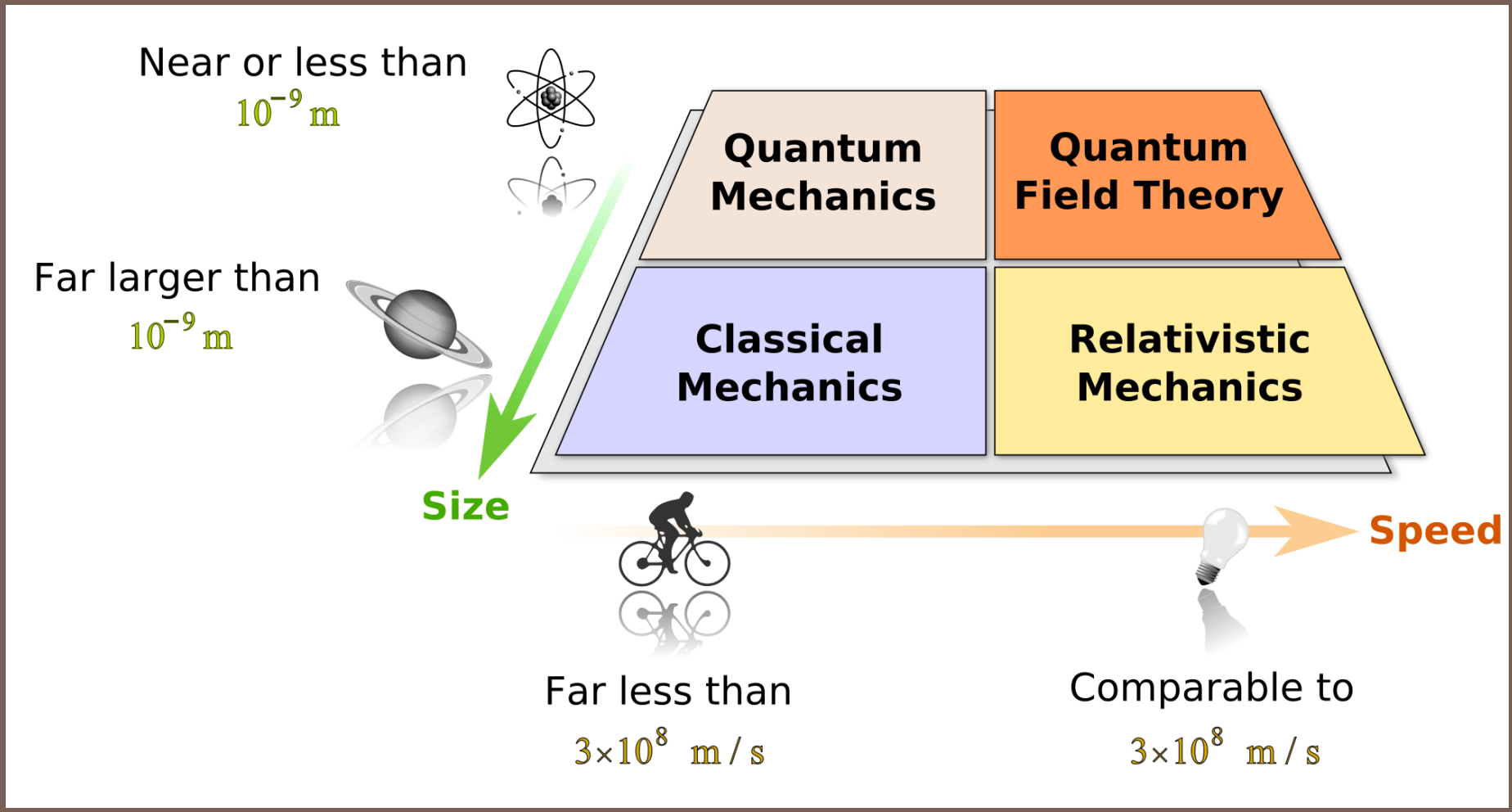
Logical positivists – Thought that a hypothesis is true if it can be verified (ex. Ayer)

Falsification – Karl Popper insisted that theories are not verified, they simple stand tests up to certain accuracies



Popper produced the grammar that we use today to talk about science!

A Question of Scale



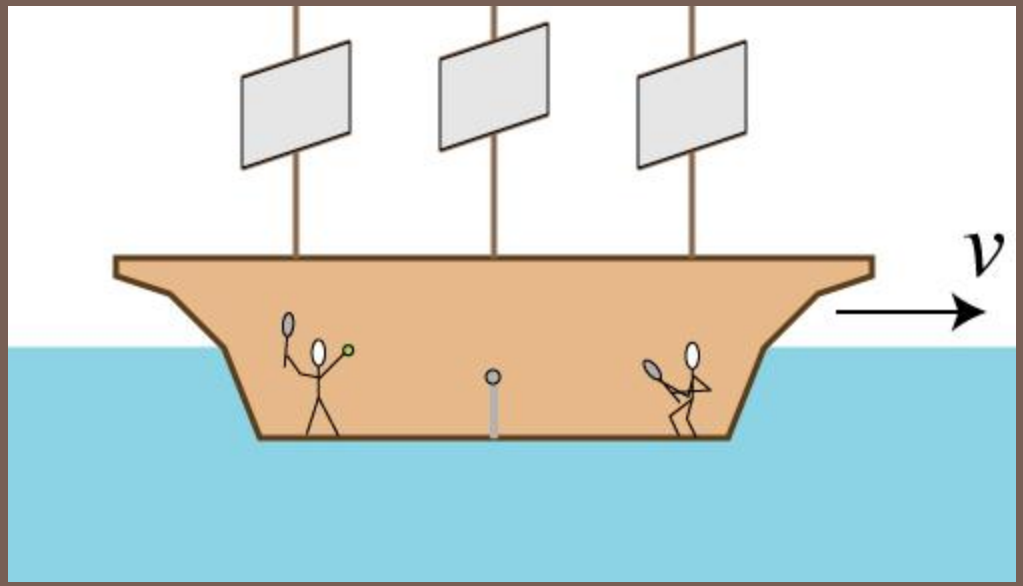
Approximate theories are fine to use sometimes

Galilean Relativity

Galilean relativity states that all physical laws are the same in all inertial (non-accelerating) frames

Is this a physical law (hypothesis) or a principle?

What does this say for experiments done on moving vehicles?

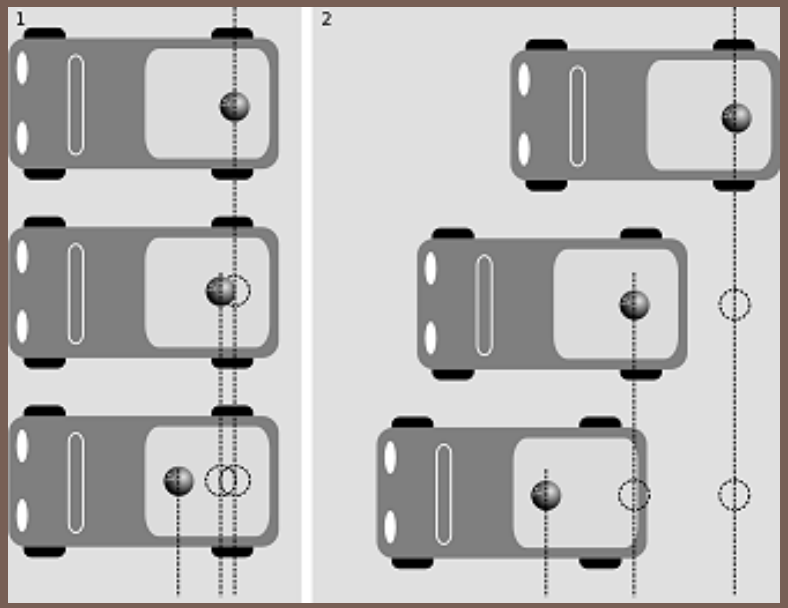


What will the tennis players see?

Classical (Newtonian) Mechanics

Armed with a way of thinking about the way observers measure the properties of objects Newton put together his laws of motion and his theory of gravitation (and Optics, etc..)

In this model space and time are absolute meaning that they appear the same (given a coordinate transformation) to everyone (a meter is a meter is a meter)



But more on this in the mechanics part of the course

Why is Galilean relativity important?

Problems in Absoluteness

Consider relativistic systems such as satellites moving very fast in their orbit (GPS) or fast moving particles in superconductivity

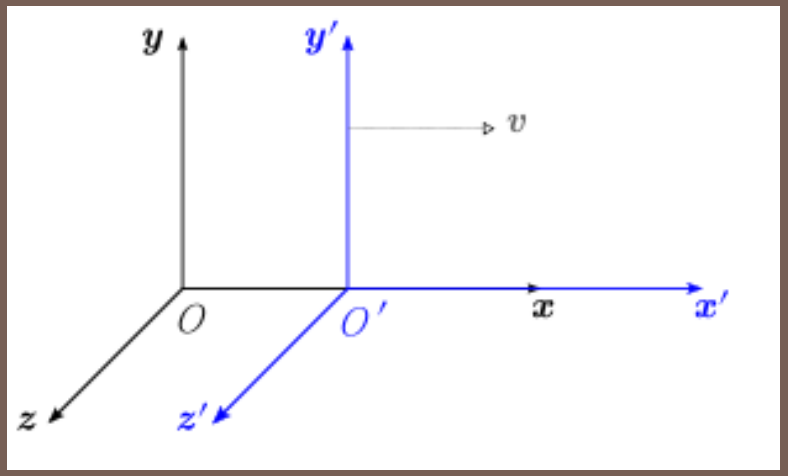
Einstein asked himself what a light beam would see if it were to cross another light beam?

In Newton's theory speed has no physical limit, but experiments have still not given us any way of going faster than light indicating something new to Newton

What happens with a little bit of extreme speed?

The Lorentz Relativity Component

"the feature of nature that says experimental results are independent of the orientation or the boost velocity of the laboratory through space" Neil Russell



Lorentz Transformations

$$x' = \gamma\left(x - \frac{v}{c}ct\right)$$

$$y' = y$$

$$z' = z$$

$$ct' = \gamma\left(ct - \frac{v}{c}x\right)$$

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \qquad \beta = \frac{v}{c}$$

We have to look at things a little differently

Einstein's Relativity Idea

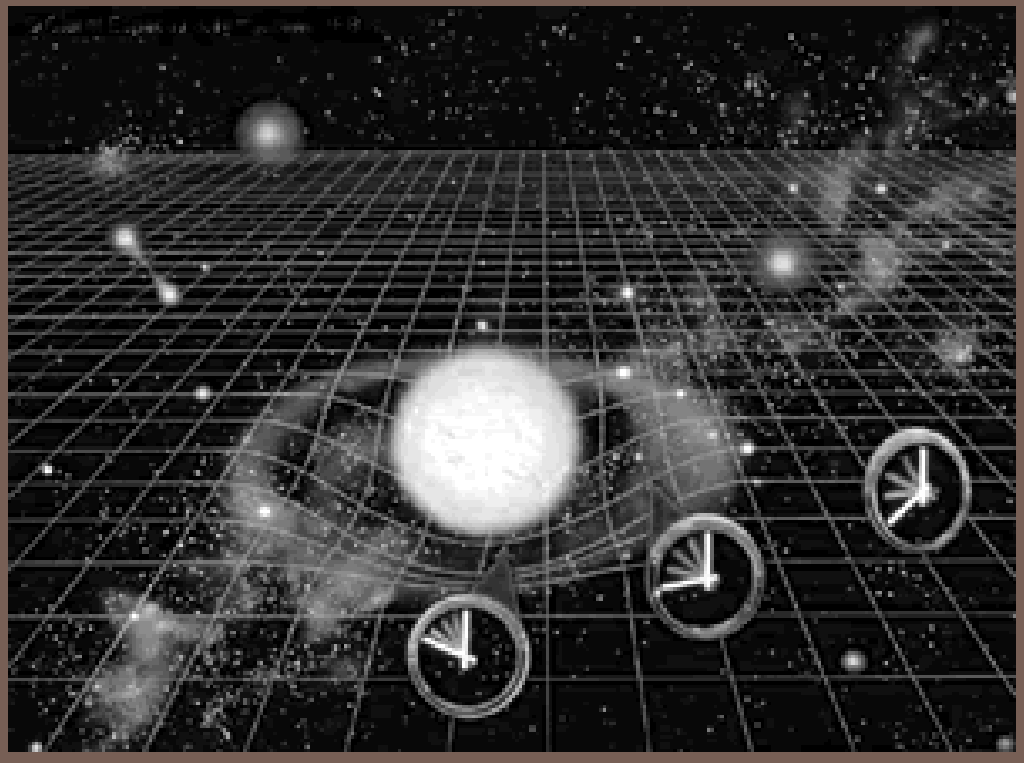
The new relativity idea that Einstein proposed had the following two principles at its bedrock:

1. The physical laws are the same in inertial frames – preserved from Newton in a sense, but with modifications due to the second principle
2. The speed of light is constant in ever inertial frame – this explicitly builds the experimentally significant value into the model

What's missing with Newton's theory?

Gravitation

Using a patch work of very small volumes of space this idea of Lorentz frames can even be used to build up a model of gravity in which the force of gravity is expressed as the curvature in the gluing of these regions of space

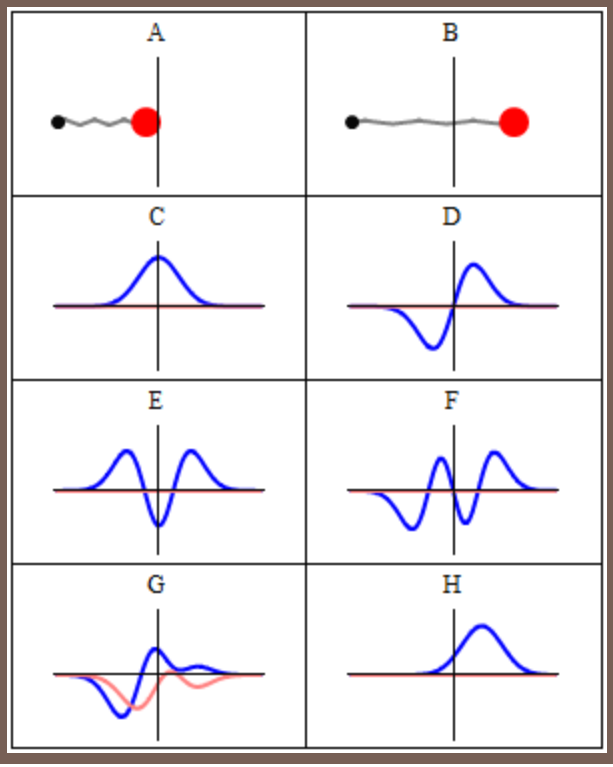


What is the modern concept of gravity?

Problems of a Smaller Scale

On the very small scale our idea of particles becomes fuzzy in the sense that the outcome of a measurement can be predicted *statistically* and not absolutely!

Classical particle on a spring



Quantum particles that are not moving

Moving particle in the quantum regime

How does the world work on the small scale?

Schrődinger's Cat

In the traditional experiment a cat is placed inside of a box with a killing device that depends on a nuclear reaction. The cat is always in a superposition of being both dead and alive, classically we would expect the cat to one either one of these two possibilities

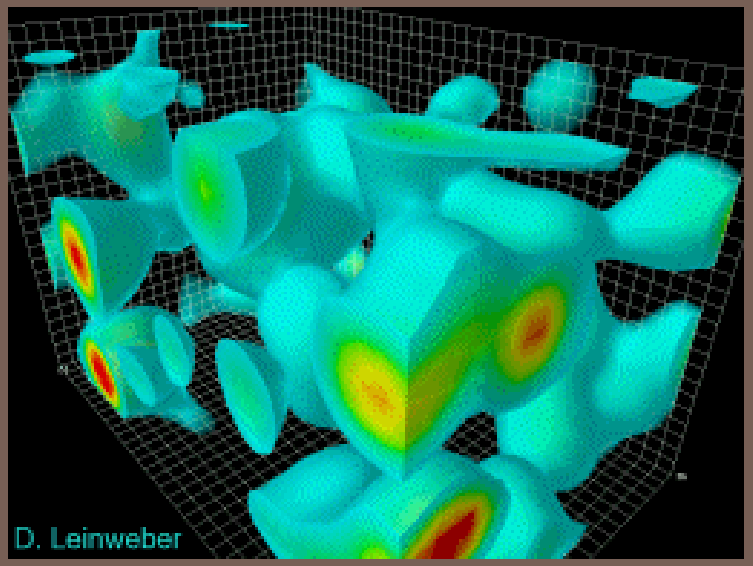
Depends on observation to collapse the wave function!

Does the outcome of an experiment wait for us?

A Universe made of Waves

Consider now empty space, surprisingly we find that due to random fluctuations the minimum point of energy does not turn out to be zero!

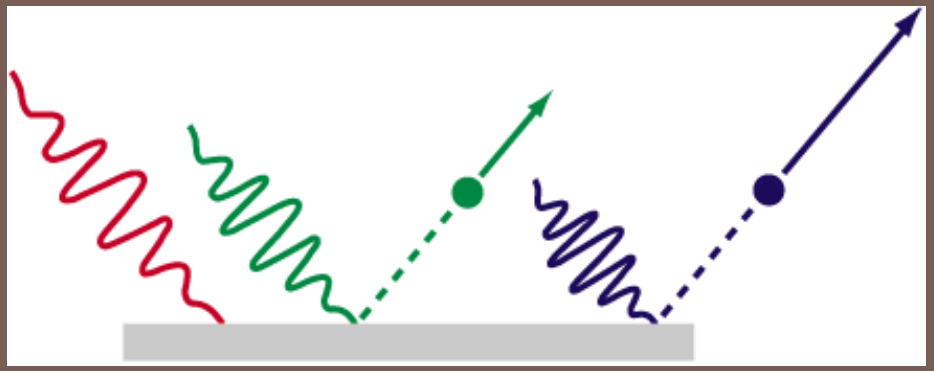
This means empty space is literally composed of particles flashing into and out of existence is a random but organized fashion!



What about the space between matter?

The so-called Wave-Particle Duality

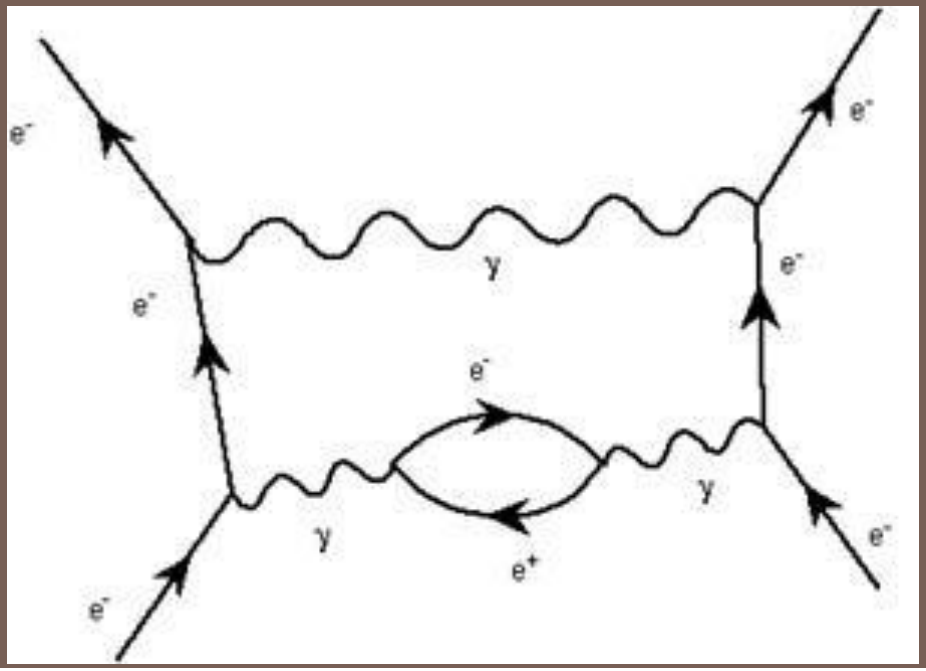
Phenomenon	Explained with Waves	Explained with Particles
Reflection	✓	✓
Refraction	✓	✓
Interference	✓	⊗
Diffraction	✓	⊗
Polarization	✓	⊗
Photoelectric effect	⊗	✓



Which part of the duality appears where?

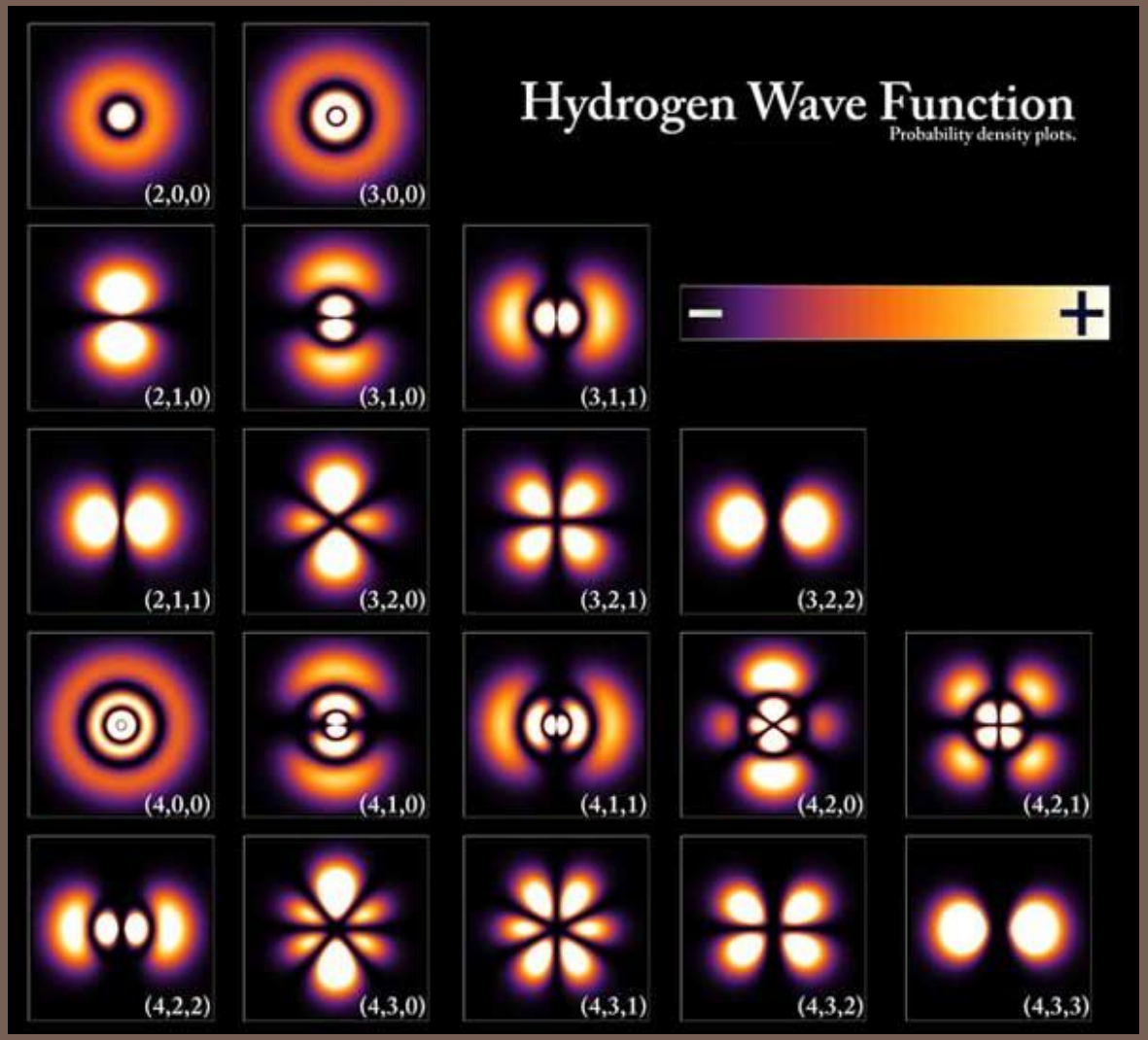
Introducing Lorentz Again

The problem with quantum mechanics is that is did not undergo the Lorentz relativity revolution, that is it still uses Galilean relativity, Quantum Field Theory attempts to solve this problem by building up the same theory with Lorentz relativity but this is extremely difficult and has many problems to deal with still



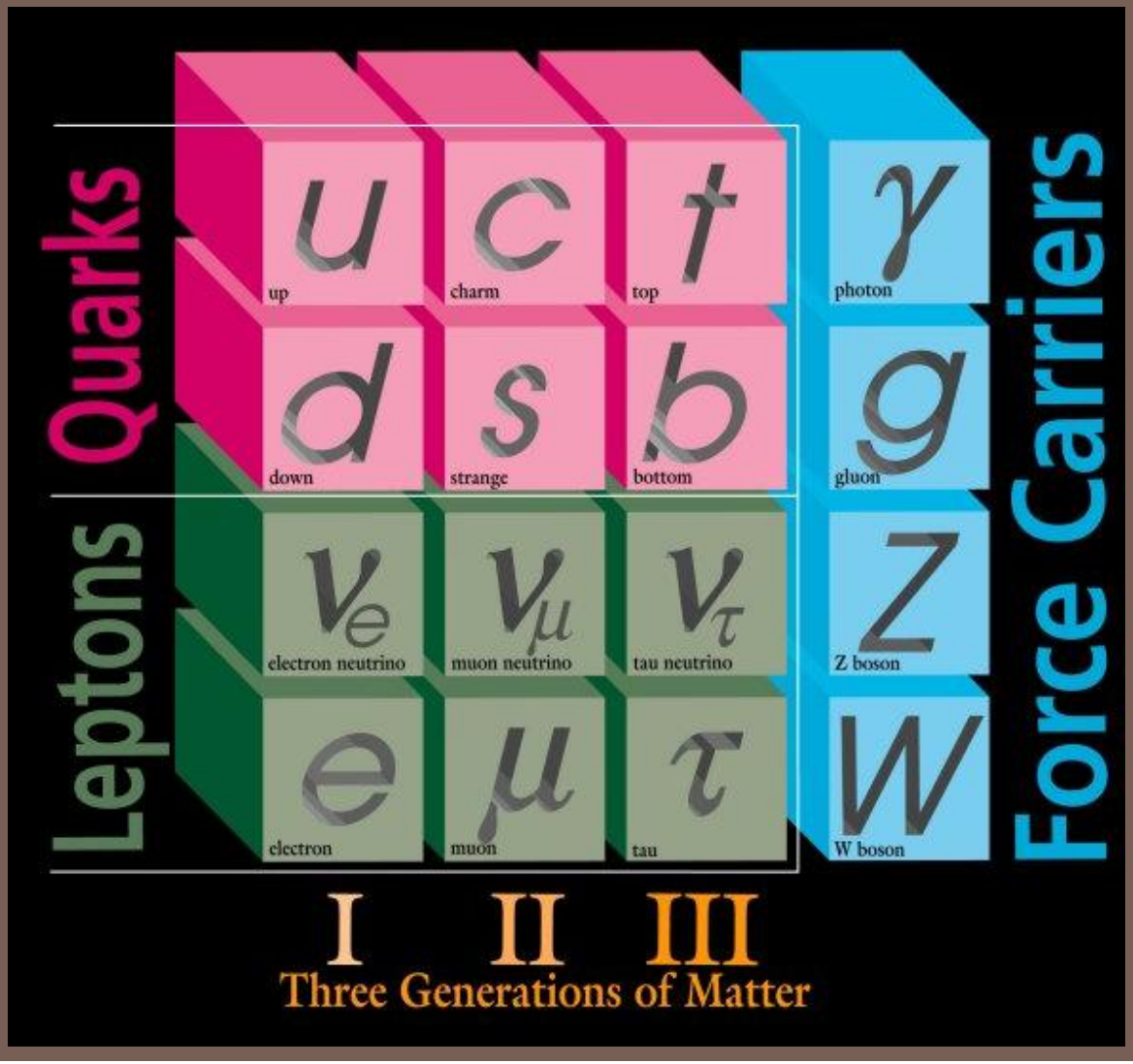
Explaining Atoms and particles

Particle and atom models can be built up using this idea of quantum field theory to build up an accurate model of the way they work in reality



What can this model do?

Particle Physics and The Standard Model



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Higgs boson

Why do you think this is called 'Standard'?

The Math behind the Standard

$$\mathcal{L}_{GWS} = \sum_f (\bar{\Psi}_f (i\gamma^\mu \partial\mu - m_f)\Psi_f - eQ_f \bar{\Psi}_f \gamma^\mu \Psi_f A_\mu) +$$

$$+\frac{g}{\sqrt{2}} \sum_i (\bar{a}_L^i \gamma^\mu b_L^i W_\mu^+ + \bar{b}_L^i \gamma^\mu a_L^i W_\mu^-) + \frac{g}{2c_w} \sum_f \bar{\Psi}_f \gamma^\mu (I_f^3 - 2s_w^2 Q_f - I_f^3 \gamma_5) \Psi_f Z_\mu +$$

$$-\frac{1}{4}|\partial_\mu A_\nu - \partial_\nu A_\mu - ie(W_\mu^- W_\nu^+ - W_\mu^+ W_\nu^-)|^2 - \frac{1}{2}|\partial_\mu W_\nu^+ - \partial_\nu W_\mu^+ +$$

$$-ie(W_\mu^+ A_\nu - W_\nu^+ A_\mu) + ig' c_w (W_\mu^+ Z_\nu - W_\nu^+ Z_\mu|^2 +$$

$$-\frac{1}{4}|\partial_\mu Z_\nu - \partial_\nu Z_\mu + ig' c_w (W_\mu^- W_\nu^+ - W_\mu^+ W_\nu^-)|^2 +$$

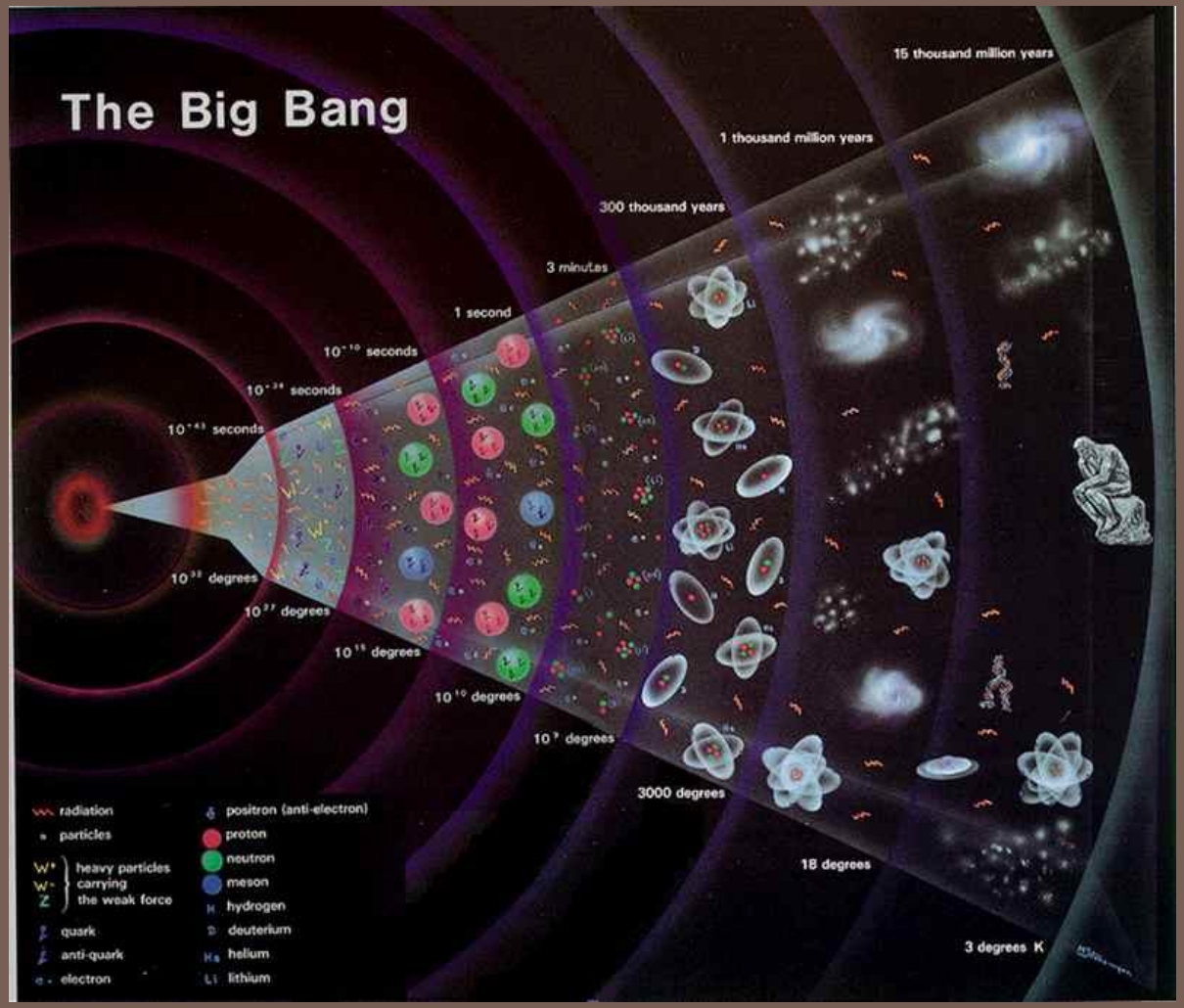
$$-\frac{1}{2} M_\eta^2 \eta^2 - \frac{g M_\eta^2}{8 M_W} \eta^3 - \frac{g'^2 M_\eta^2}{32 M_W} \eta^4 + |M_W W_\mu^+ + \frac{g}{2} \eta W_\mu^+|^2 +$$

$$+\frac{1}{2}|\partial_\mu \eta + i M_Z Z_\mu + \frac{ig}{2c_w} \eta Z_\mu|^2 - \sum_f \frac{g}{2} \frac{m_f}{M_W} \bar{\Psi}_f \Psi_f \eta$$

A little complicated..

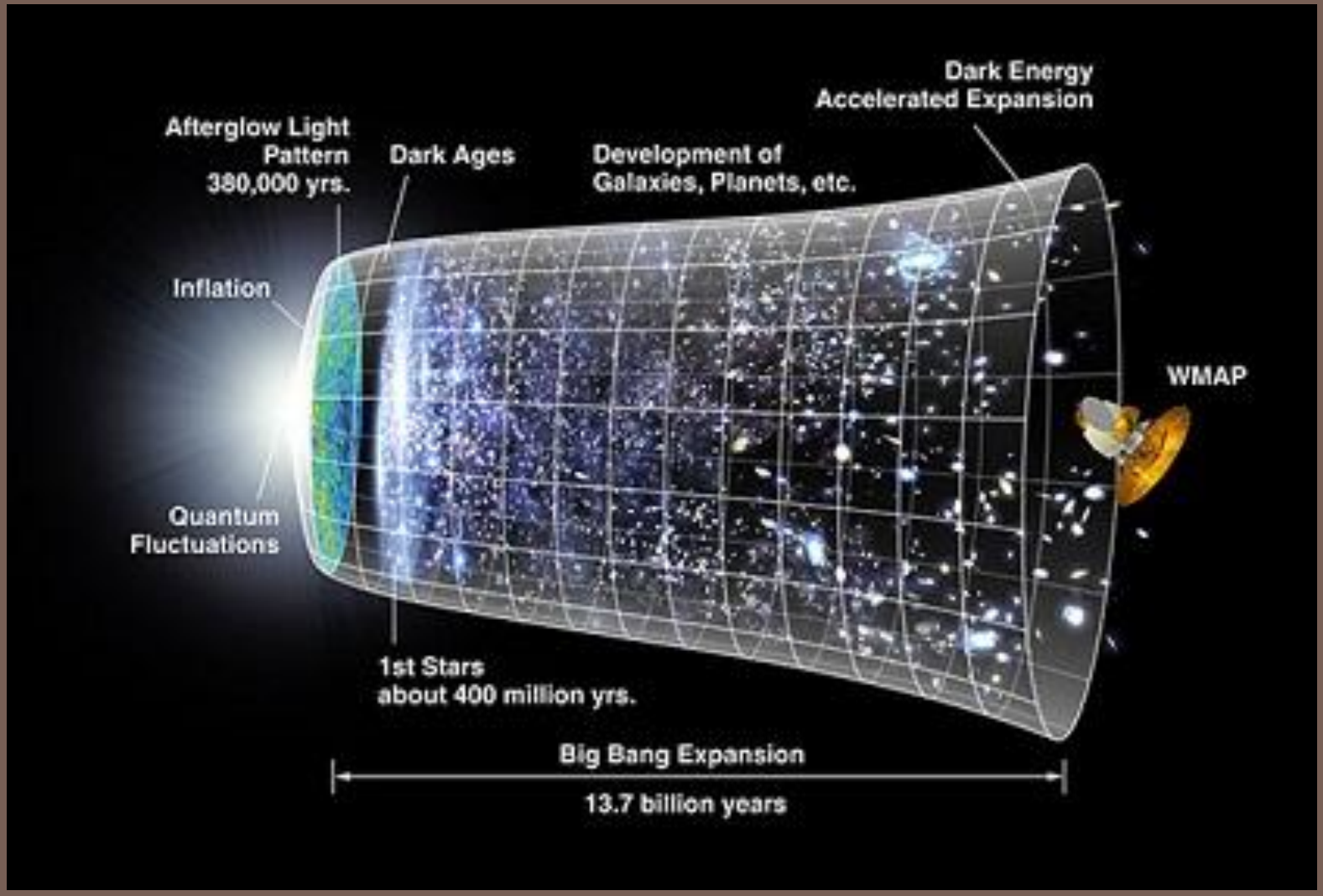
Bridging the Extremes

Looking back over time the Universe must of started in a very dense primordial plasma of very energetic particles!



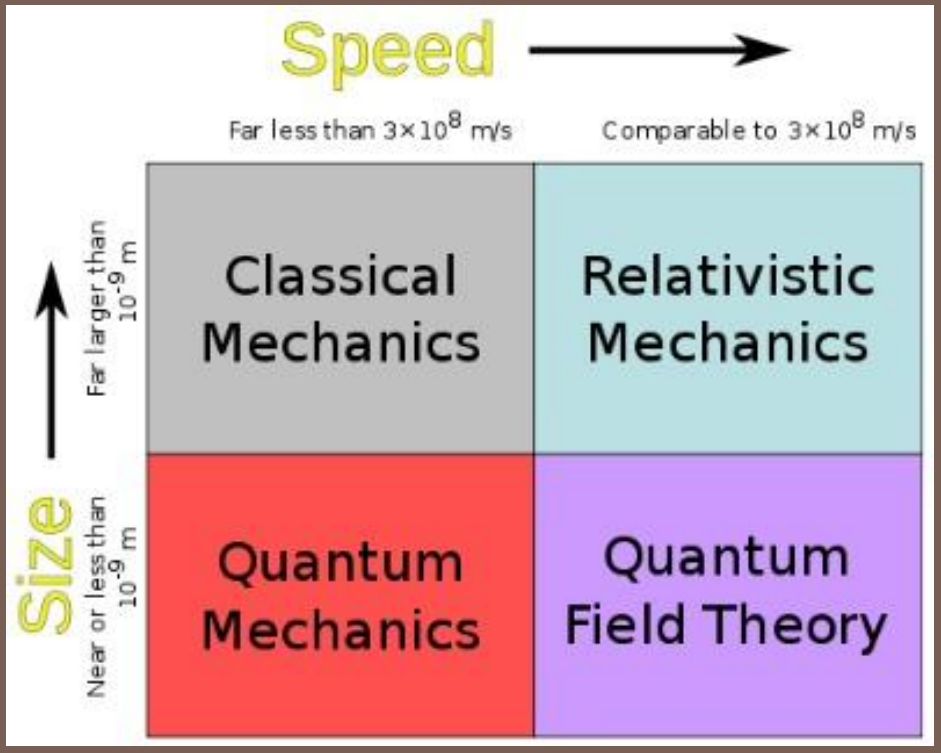
Cosmology is where both these extremes meet

To End at the Beginning



This is the whole of Foundational Physics

Keep in mind that this is how we break up physics!



The End