ISP209 Fall 2012
The Mystery of the Physical World

Professor Joey Huston

3230 BPS

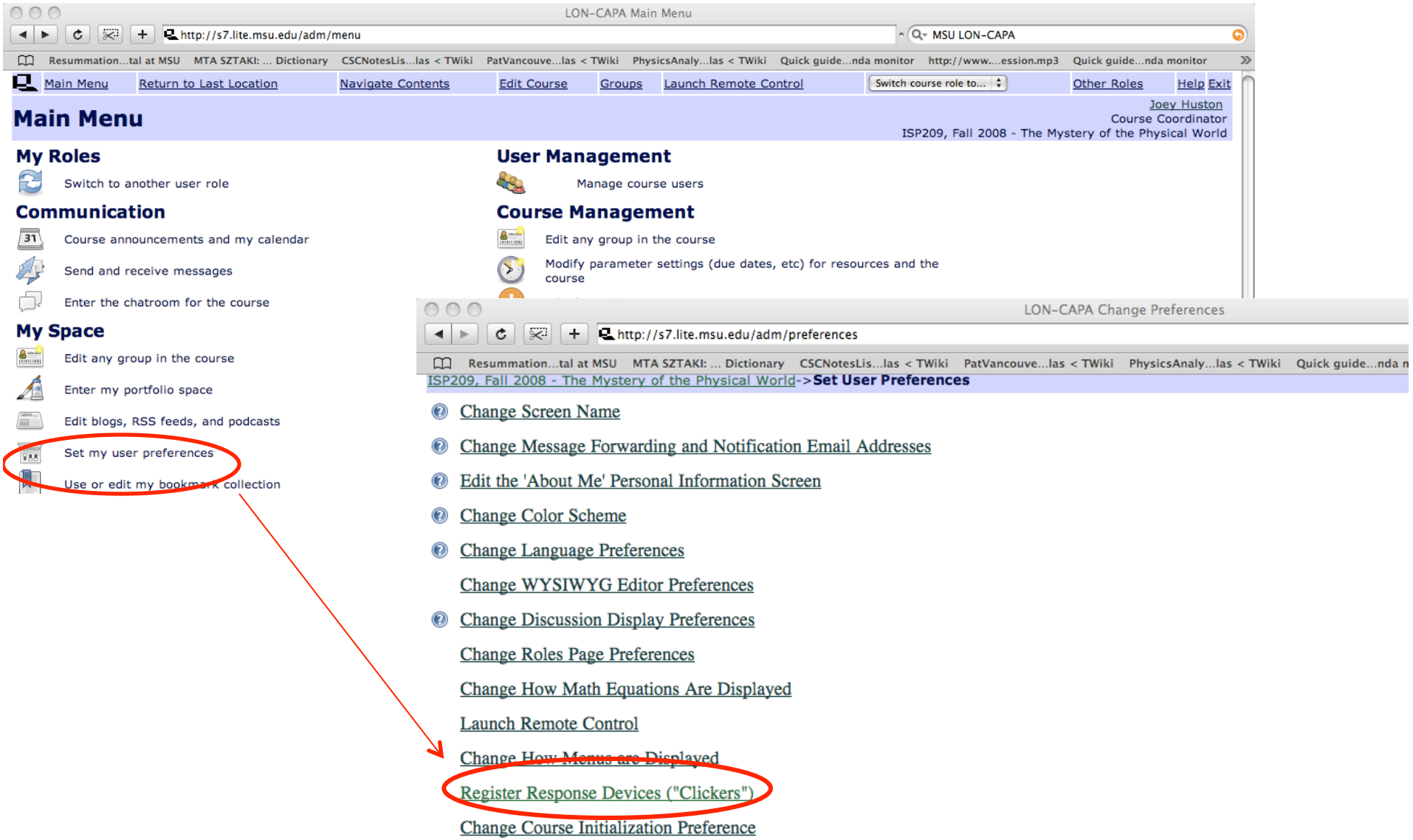
Syllabus

- Can be found at course website:
  - www.pa.msu.edu/~huston/isp209_f12/index.html
  - the web version will be the official one, and any changes to the schedule or curriculum will be noted there

Clickers

- The text and iclickers can be found at SBS and International Center book stores (and probably others as well)
  - iclickers are used for a number of courses at MSU, but the bookstores will also buy them back
- Please buy your iclicker and register it with LON-CAPA
  - please write down your iclicker serial number someplace safe because you will probably use it for other courses and I've been told the number rubs off
- Buy and register your clicker (with LON-CAPA) by Sept. 20 to get credit for quiz questions
- If your number is already worn off (and you don't know it), come see me at the end of Tuesday's lecture

iClicker in LON-CAPA



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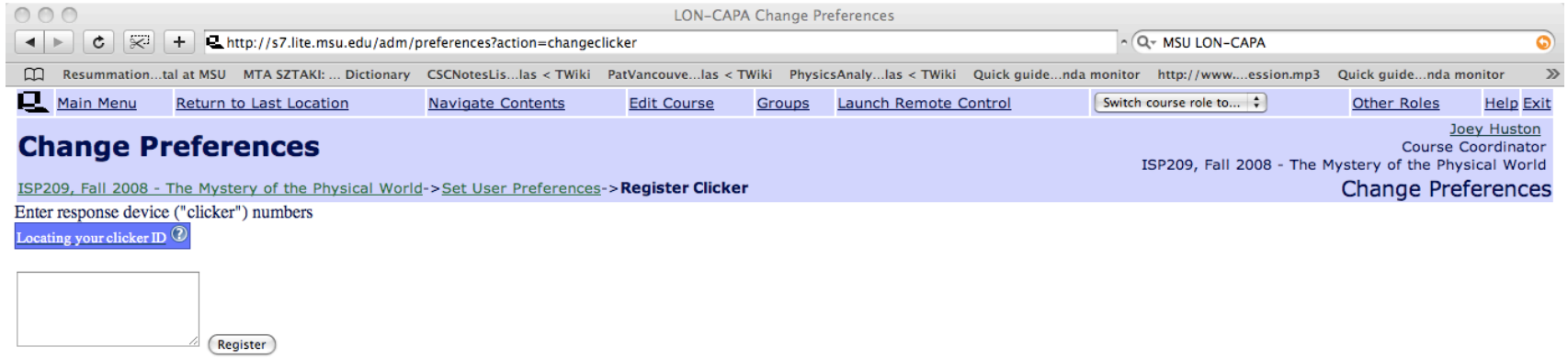
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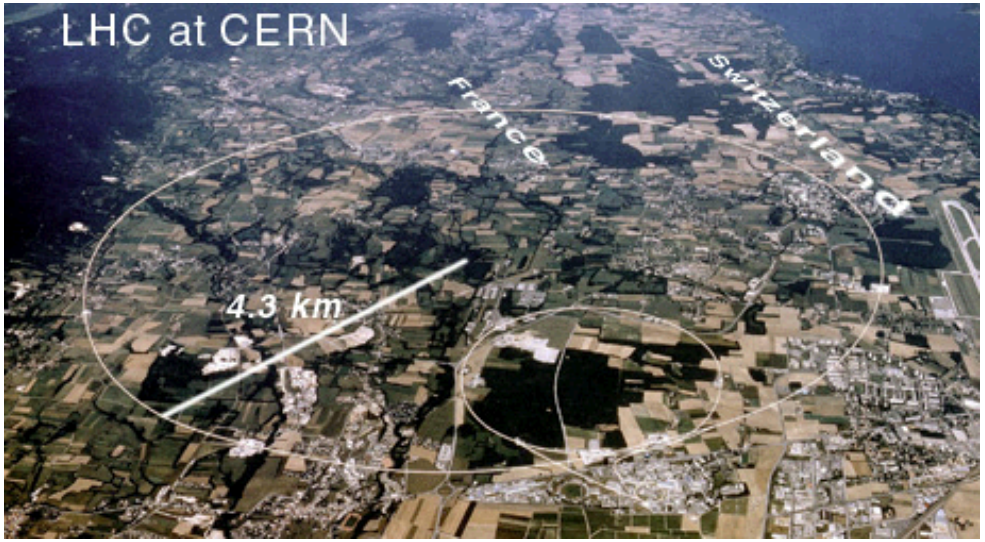
Joey Huston
Course Coordinator
ISP209, Fall 2008 - The Mystery of the Physical World
ISP209, Fall 2008 - The Mystery of the Physical World->Set User Preferences->Register Clicker
Change Preferences
Enter response device ("clicker") numbers
Locating your clicker ID
Register

Let's start

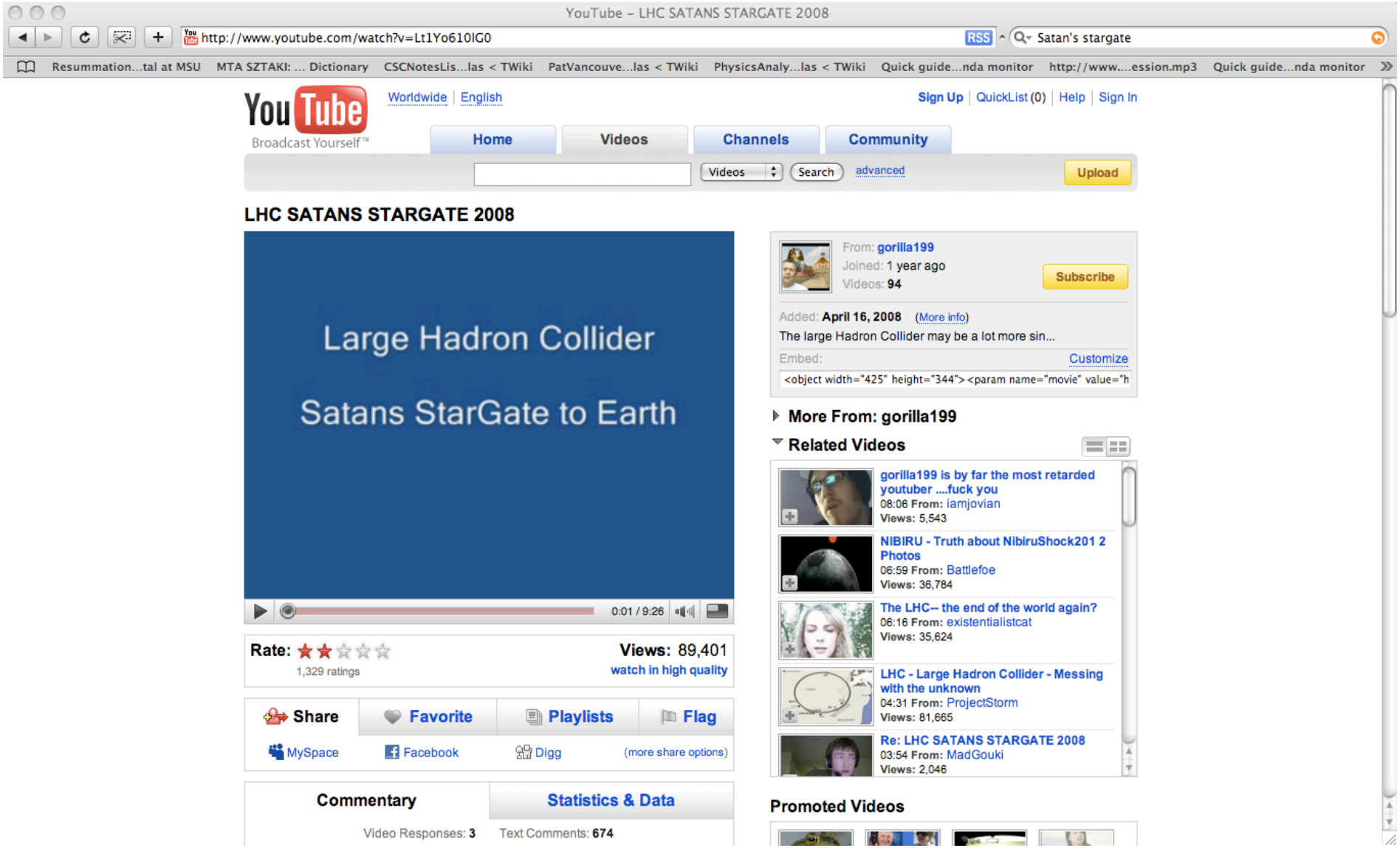
- …with the source of all knowledge, wikipedia (www.wikipedia.org)
- Physics is the science of matter and its motion, as well as space and time. It uses concepts such as energy, force, mass and charge. Physics is an experimental science, creating theories that are tested against observations.
- Broadly, it is the general scientific analysis of nature, with a goal of understanding how the universe behaves.
- Physics is one of the oldest academic disciplines, and through its modern subfield of astronomy, it may be the oldest of all.
- Today, physics is a broad and highly developed subject. Research is often divided into four subfields: condensed matter physics; atomic, molecular, and optical physics; high energy physics; and astronomy and astrophysics
- Most physicists also specialize in either theoretical or experimental research, the former dealing with the development of new theories and the latter dealing with the experimental testing of theories and the discovery of new phenomena.
- Despite important discoveries during the last four centuries, there are a number of unsolved problems in physics and many areas of active research.

What is high energy physics all about?

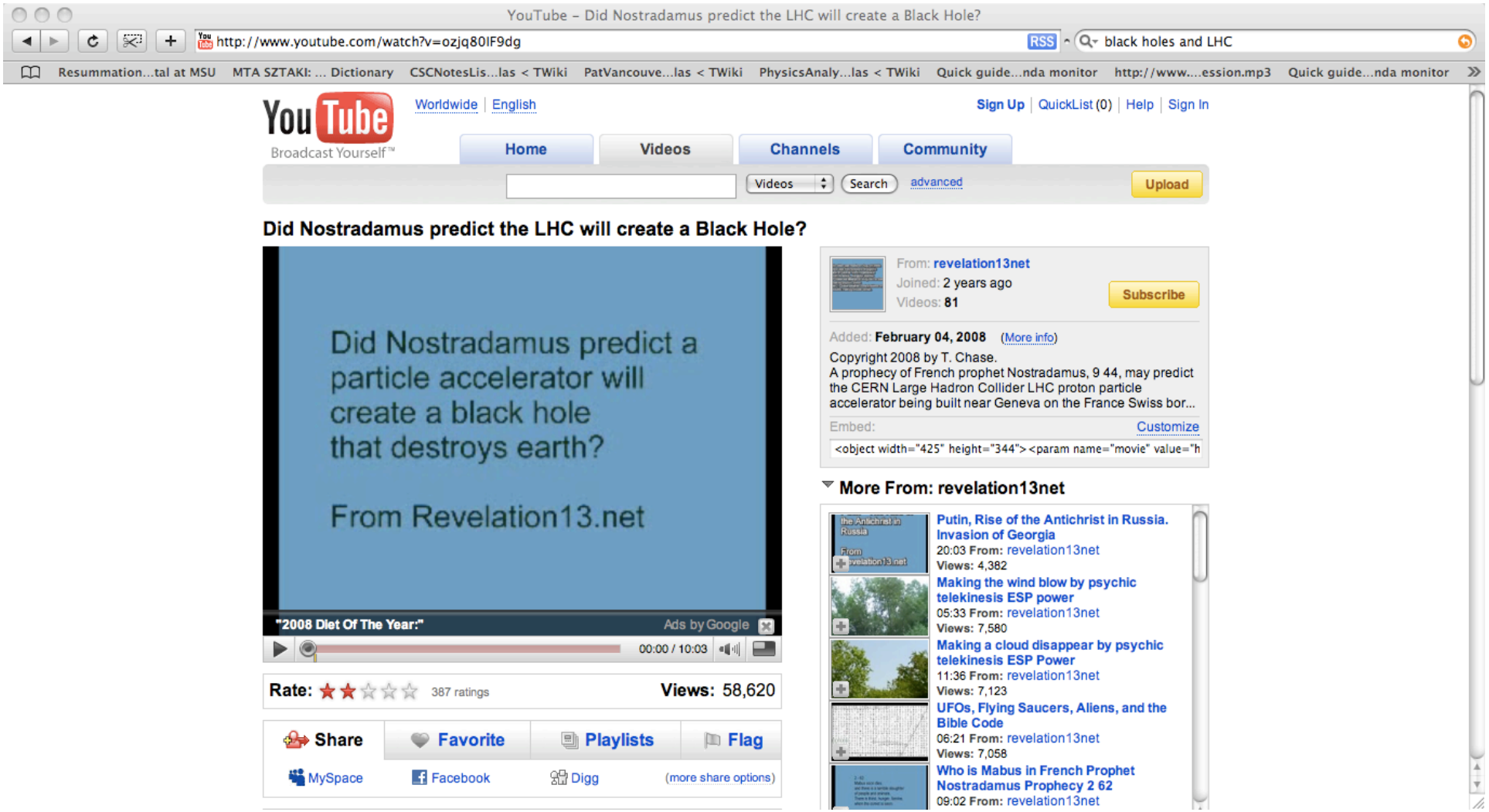
- In high energy physics, we are attempting to understand the fundamental laws and forces which govern the universe, as well as to discover all of its fundamental constituents
- We do it at large international laboratories such as CERN near Geneva, Switzerland, currently running



…and no, the LHC is not



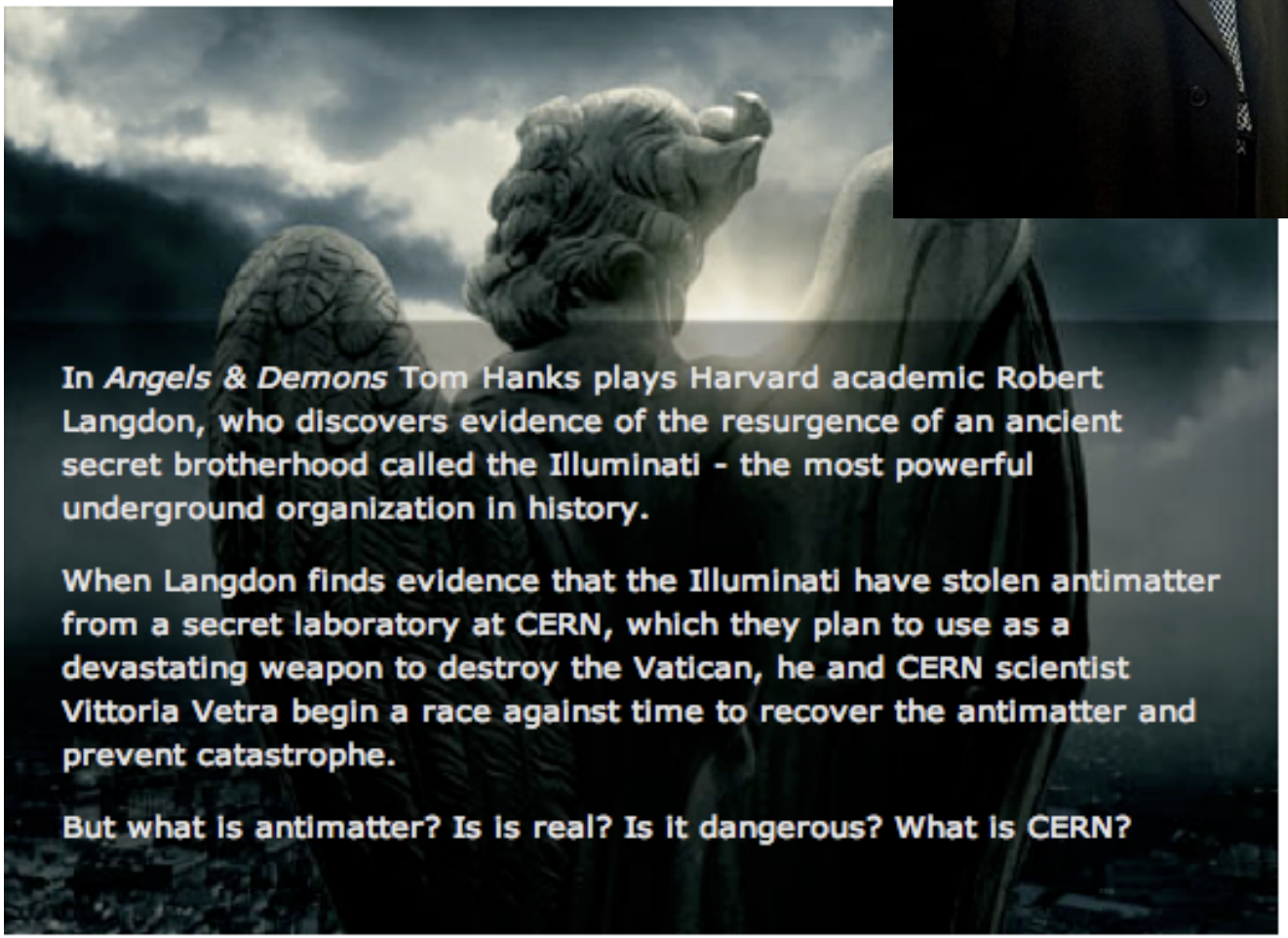
…nor did we



…but it's still fun to watch videos

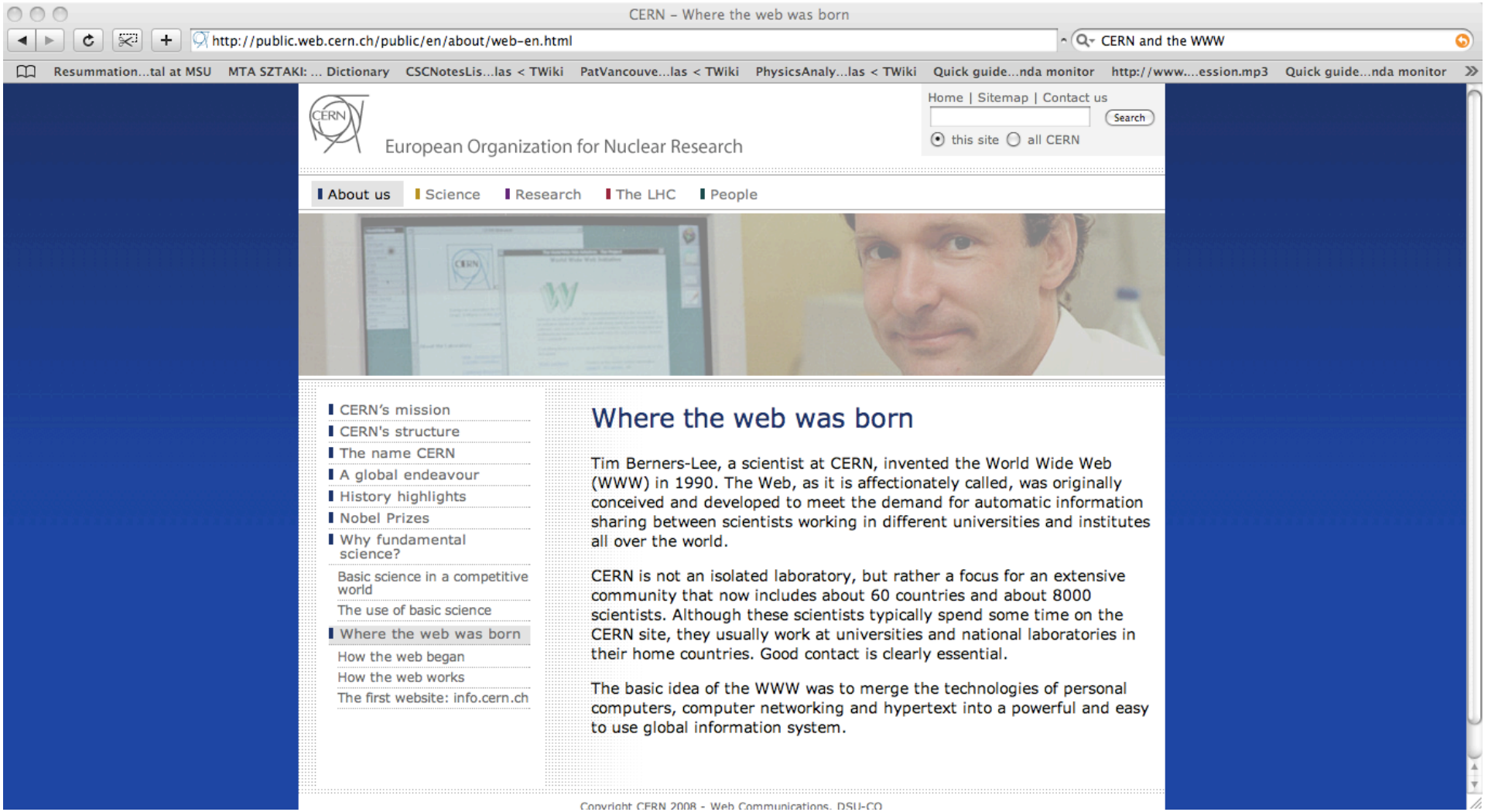
Tom Hanks at CERN

- We produce anti-matter, but not enough to blow up the Vatican



http://angelsanddemons.cern.ch/

…but we did


CERN – Where the web was born
http://public.web.cern.ch/public/en/about/web-en.html
CERN and the WWW
Resummation...tal at MSU
MTA SZTAKI: ... Dictionary
CSCNotesLis...las < TWiki
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The LHC
People
CERN's mission
CERN's structure
The name CERN
A global endeavour
History highlights
Nobel Prizes
Why fundamental science?
Basic science in a competitive world
The use of basic science
Where the web was born
How the web began
How the web works
The first website: info.cern.ch
Where the web was born
Tim Berners-Lee, a scientist at CERN, invented the World Wide Web (WWW) in 1990. The Web, as it is affectionately called, was originally conceived and developed to meet the demand for automatic information sharing between scientists working in different universities and institutes all over the world.
CERN is not an isolated laboratory, but rather a focus for an extensive community that now includes about 60 countries and about 8000 scientists. Although these scientists typically spend some time on the CERN site, they usually work at universities and national laboratories in their home countries. Good contact is clearly essential.
The basic idea of the WWW was to merge the technologies of personal computers, computer networking and hypertext into a powerful and easy to use global information system.
Copyright CERN 2008 - Web Communications, DSU-CO

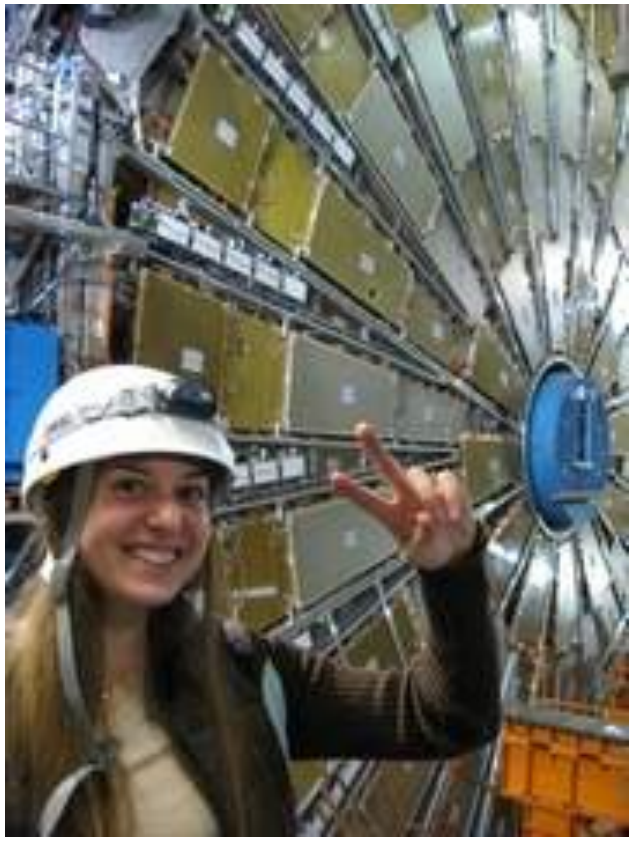
…and this is the home of

First picture ever posted on the web

I'll play some of their music this semester

…and we do have a rap song

- MSU grad's particle physics rap is YouTube hit
  - Katie McAlpine
  - With an intro from MC Hawking



…in front of my experiment

…and we did

- Discover the Higgs bosons

Physicists Find Elusive Particle Seen as Key to Universe

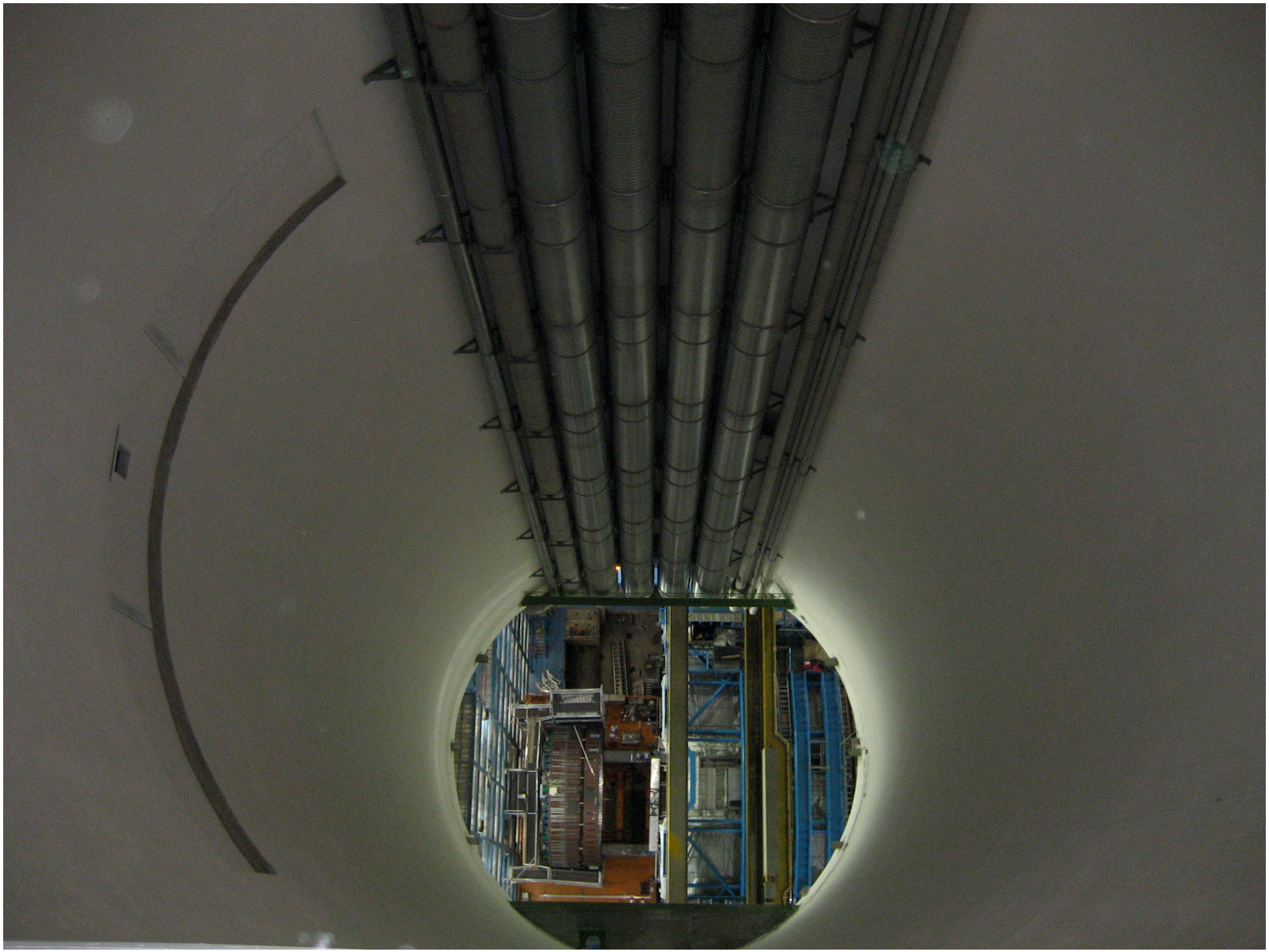
Pool photo by Denis Balibouse

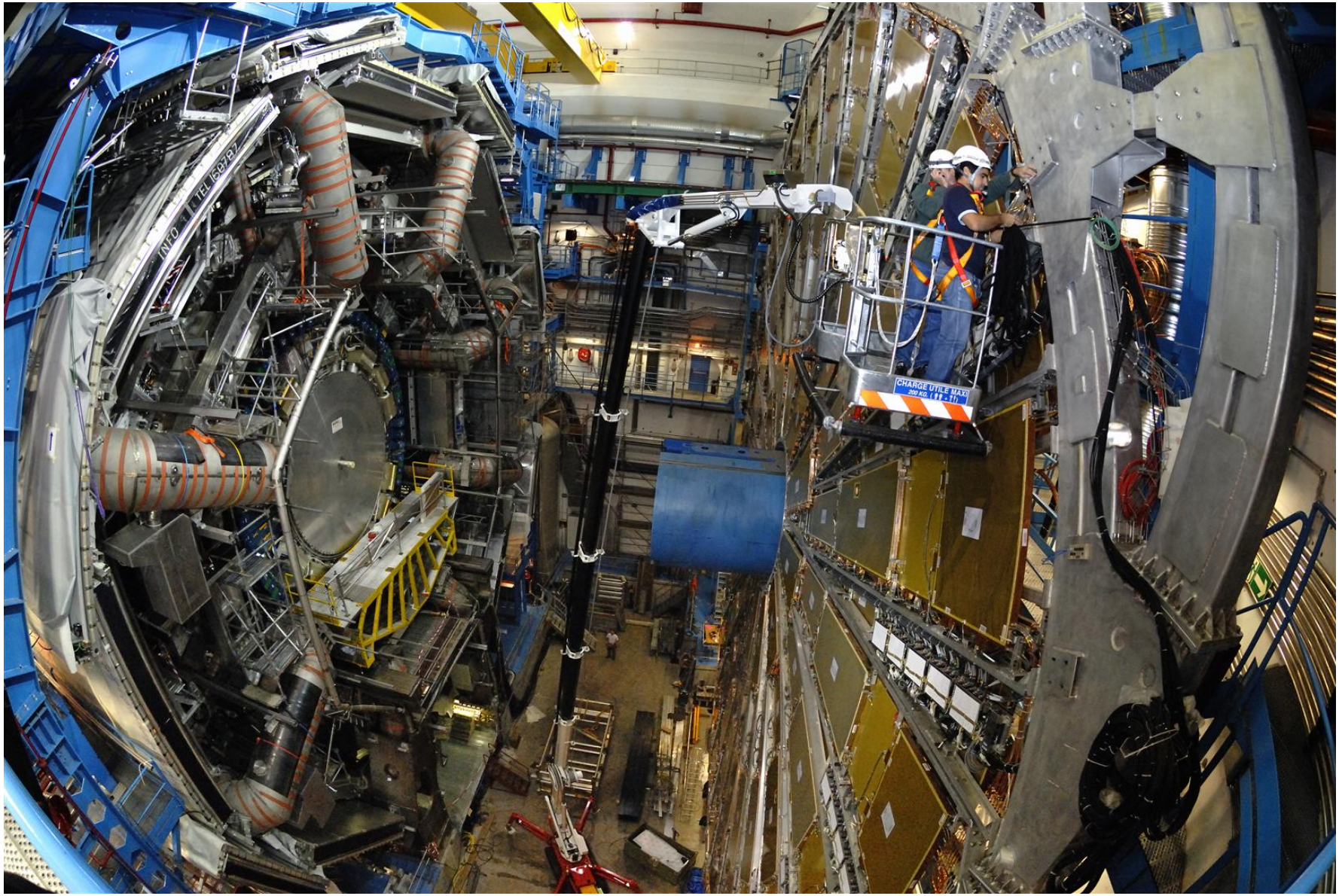
Scientists in Geneva on Wednesday applauded the discovery of a subatomic particle that looks like the Higgs boson.

By DENNIS OVERBYE
Published: July 4, 2012 | 122 Comments

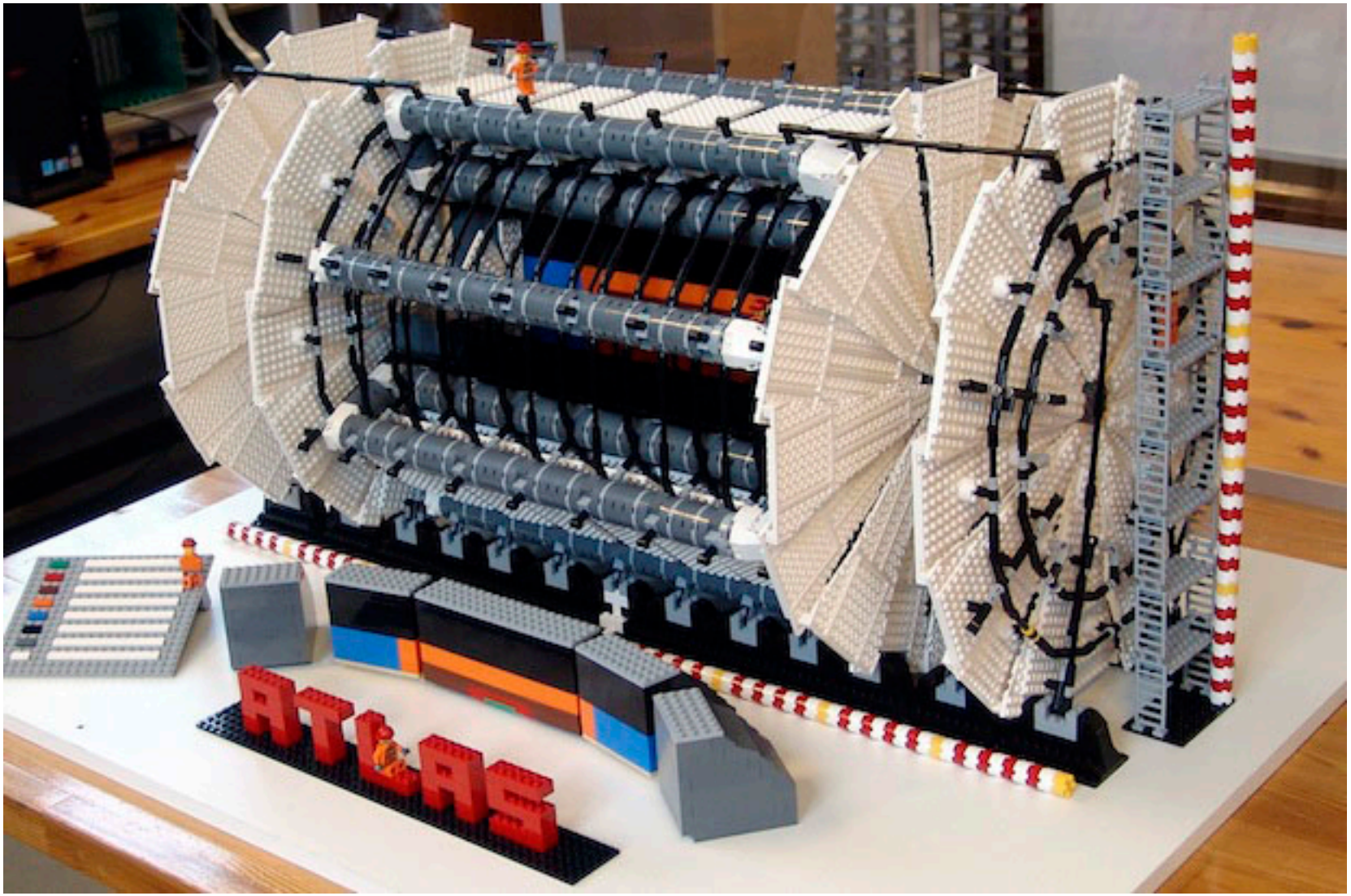
I didn't get there early enough for a seat.

Looking down (100 m) into my experiment




CHARGE UTILE MAXI
200 KG

Lego model of ATLAS



Etyomology of physics

- Φυσιζ (physis) is a Greek theological, philosophical and scientific term usually translated into English as nature
- Aristotle spoke of physics (the study of natural things) in contrast to metaphysics (the study of philosophy)

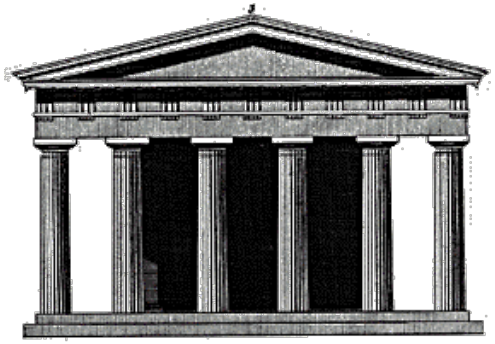
Plato Aristotle

Two Questions

- The TWO most fundamental questions about the universe are:
- What is it made of?
- How is it all held together?

Four Elements…

- The Hunt for the answers to those two questions has been going on for a very long time.
- It really started with the Greeks.



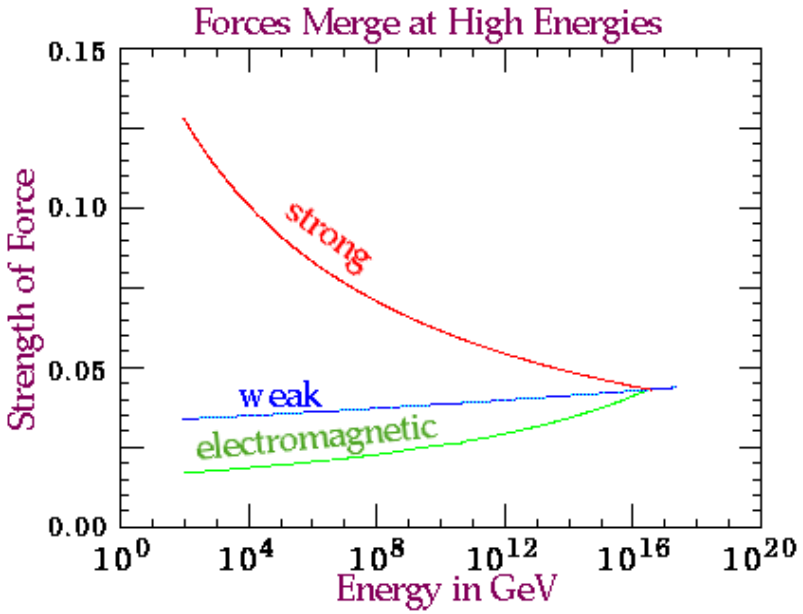
…and Two Forces

- There were two fundamental forces:
  - love
  - strife
- This picture is a tad too simple
- We'll try to see something of the current complexity in this course
- …and maybe keep track of some of the breaking physics news

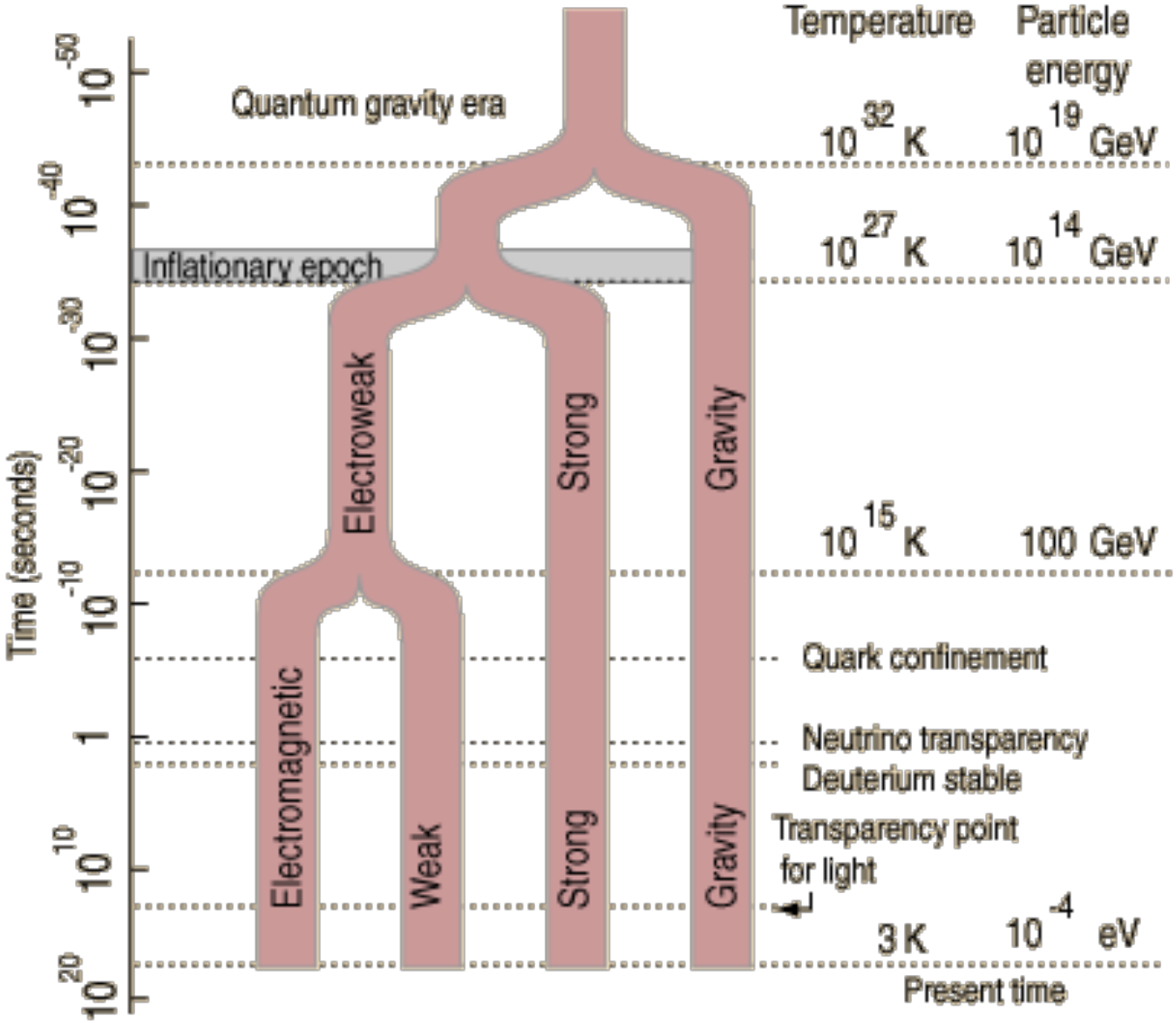
Forces

- We know of four fundamental forces
  - strong
  - weak
  - electromagnetic
  - gravitational
    - this is one of the puzzles; why is gravity so much weaker than the other forces?
    - it may be because of the universe having extra dimensions through which gravity but not the other 3 forces, can propagate

- And that the higher in energy we go, the more similar these forces become
  - one of the aims of high energy physics

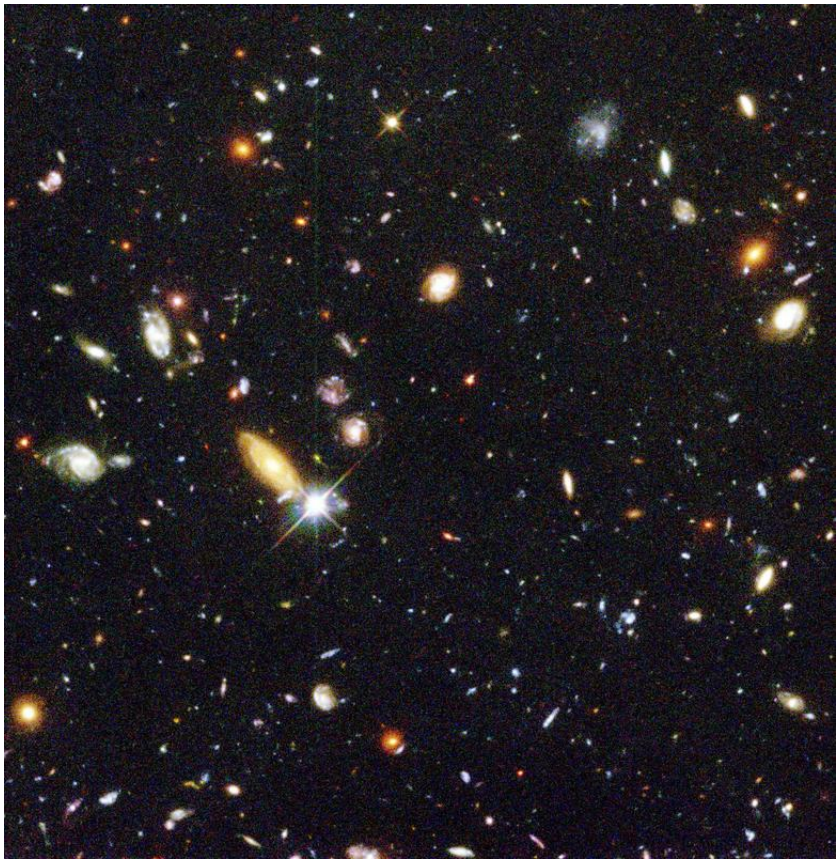


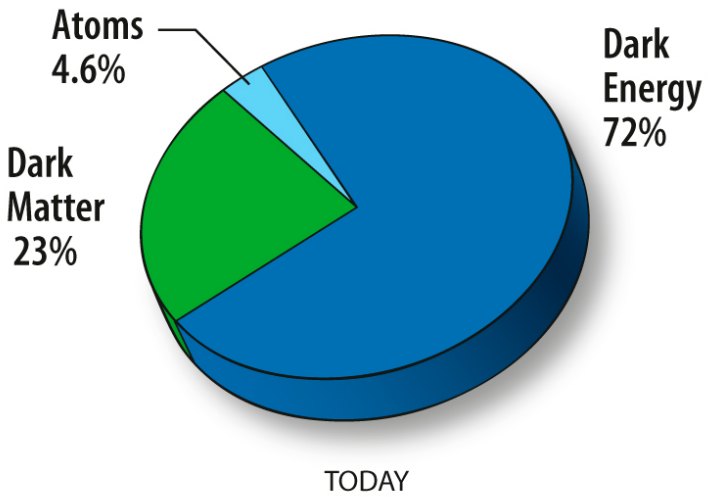
Probing back in time



What the universe is made of

We can look throughout the universe with the Hubble space telescope and we find that everything we can see is a small part of the stuff the universe is of





and we don't know what dark matter and dark energy are

dark matter may be composed of supersymmetric particles

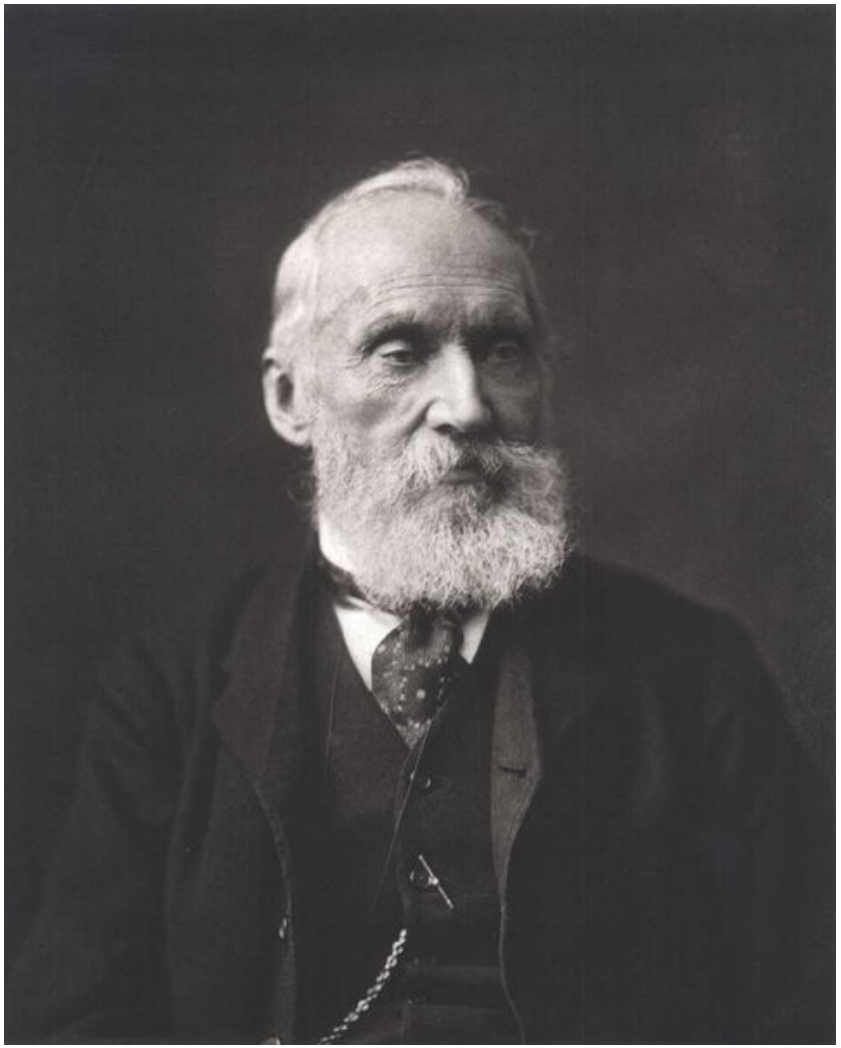
dark energy acts as a form of anti-gravity; the galaxies are accelerating away from each other

Mathematics

- Mathematics is the language of science and in particular the language of physics
- Equations of science provide compact expressions of relationships between concepts
- Although we are going to side-step most of the difficult math in this course, the mathematical structure of physics will be evident in the equations encountered

Lord Kelvin

- “When you can measure what you are talking about and express it in numbers, you know something about it.”
- The temperature scale used most often by scientists is named after Kelvin

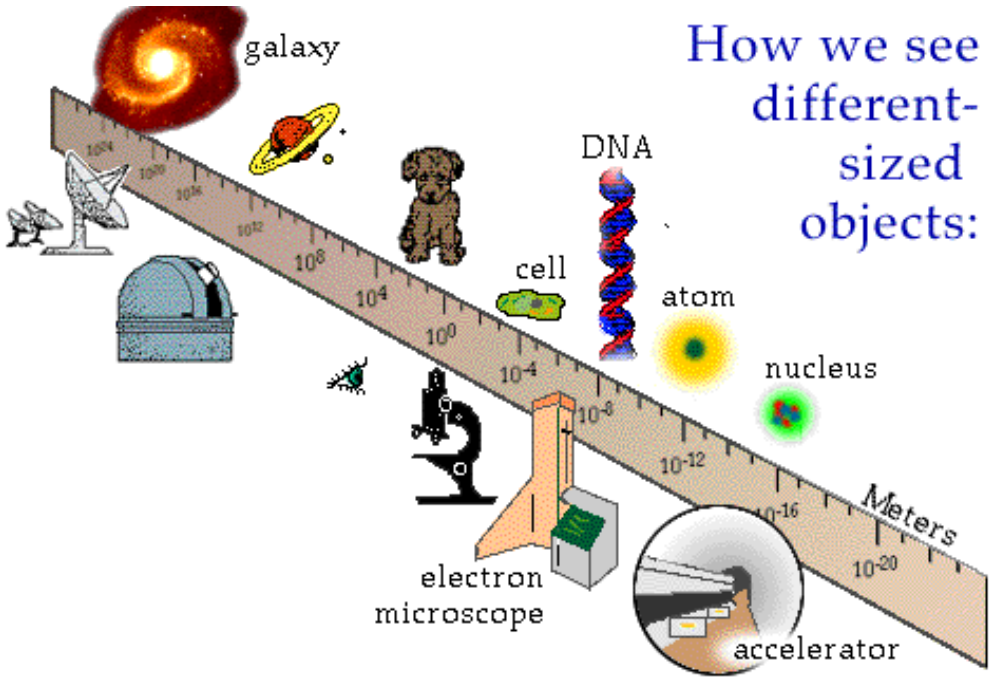


Scientific notation

- We need it for both large and small numbers
  - 10,000=1x10x10x10x10=10^4=1x10^4 (or 1 E04)
  - 10x10x10…(n times)=10^n
  - 0.0001=1/10/10/10/10=10^{-4}=1X10^{-4}(or 1E-04)
- To multiply two numbers, add exponents
  - 10^4 x 10^5 = 10^{4+5}=10^9=1,000,000,000
- To divide two numbers, subtract exponents
  - $10^4/10^5=10^{4-5}=10^{-1}$=0.1

Units

- Will often see instead of just m(eters)
  - mm (10^{-3} m)
  - μm (10^{-6} m)
  - nm (10^{-9} m)
  - pm (10^{-12} m)
  - fm (10^{-15} m)
- …or going the other way
  - km (10^{3} m)



Where do we run into large numbers?

- 6.02 X 10^{23} atoms in one mole of gas
- String theory predicts that there may be 10^{500} possible universes
  - we'll find out more when we talk about The Elegant Universe at the end of the course
- Gravity is ~ 10^{-40} of the strength of the other 3 forces
- Planck scale in subatomic physics is ~10^{-36} m

Significant figures

- In science, numerical values as a result of experimental measurements are only known to a certain number of digits, which are known as significant figures
  - for example, if you are measuring a distance with a meter stick (with mm divisions), you may quote a measurement as 91.5 cm, but not 91.5176 cm, or event 91.5000 cm
  - …note that you would not quote it as 91.5 (with no units)
- Rule-of-thumb
  - if a numerical answer is required for the homework, use 3 significant figures
- To reduce the number, round up or down
  - 5.67898 to 3 sig figures is 5.68
  - $3.34997X10^{-2}$ to 3 sig figures is $3.35X10^{-2}$ (3.35E-02)
- When a scientists says that the Earth is 4.5 billion years old, that means that the number is between 4.45 and 4.549.. billion years

Scientific method

- Modern scientific method may be traced back to Galileo (1564-1642) and Francis Bacon (1561-1626)
- Greeks worked 'upward' or 'downward', reaching conclusions about the physical world by reasoning from arbitrary assumptions (axioms)
- A modern scientist works 'upward', first examining the way the world actually works, and then building a structure to explain the findings

- No cookbook for scientific method, but some common elements

1. Observe: closely observe the physical world around you. Any unexplained observations?
2. Question: make an educated guess (a hypothesis) that might resolve the puzzle
3. Predict: predict consequences of the hypothesis
4. Test predictions: do experiments or make calculations to test the predictions
5. Draw a conclusion: formulate the simplest general rule that organizes the 3 main ingredients: hypothesis, predicted effects, and experimental findings

Scientific method

- In common usage, a fact is something that is changing and absolute
- In science, a fact is generally a close agreement by competent observers who make a series of observations about the same phenomenon
- As observations change, facts can change
- For example, it was once a fact that the universe is unchanging and permanent
- Today, it is a fact that the universe is expanding and evolving
- What changed? The observations, especially early in the 20th century, as telescopes became more powerful, and astronomers, especially Hubble, realized that the galaxies in the universe are rushing away from each other
- A scientific hypothesis is an educated guess that that is only presumed to be factual, i.e. a theory, when supported by experiment

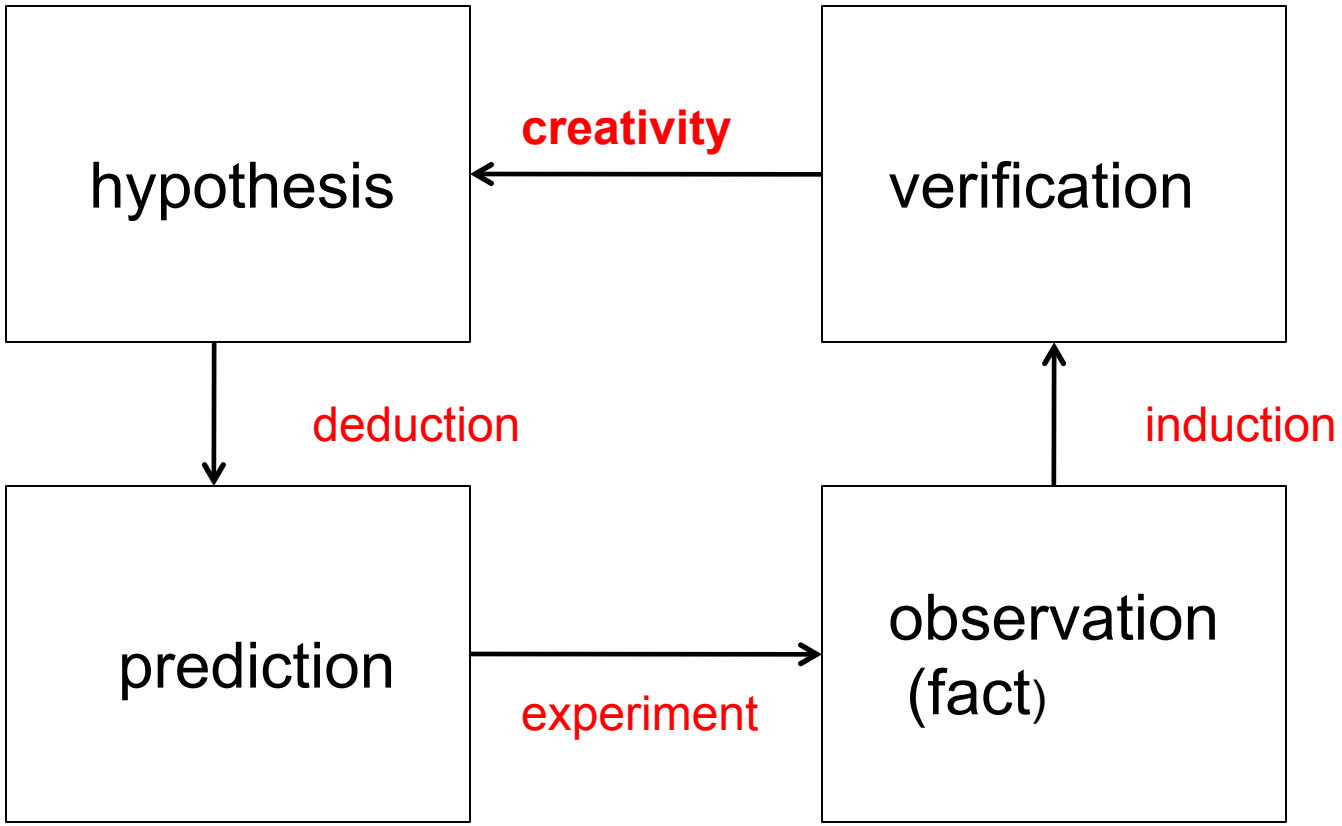
Galileo and the leaning tower of Pisa

- Aristotle held that bodies fall at a speed according to their weight
  - because of air resistance, a very light object will fall more slowly than a heavy object, but he was making a universal statement
- This held for 2000 years
- Galileo (supposedly) performed an experiment dropping two objects of different weights (a cannon ball and a musket ball) from the tower
- Their weights were very different but they hit the ground at approximately the same time (air resistance may be slightly different)
- Despite his authority, Aristotle was wrong
- Amazing (from our modern perspective) that no one ever tried the experiment before

Scientific theory

- In common usage, people speak of a theory as a best guess or a hunch, what we have called in the previous transparencies, a hypothesis
- For scientists, a theory is a synthesis of a large body of information that encompasses well-tested and verified hypotheses about certain aspects of the world
  - cell theory in biology
  - metallic bonding in metals in chemistry
  - universal gravitation in physics
- Before a theory is accepted, it must be tested by experiment, and make one or more new predictions, different from those made by previous theories
- Theories are not immutable; they evolve as they go through stages of redefinition and refinement
  - Newton's theory of universal gravitation describes a wide range of phenomena in the universe
  - but is only an approximation in regions of strong gravitational fields
    - Einstein's theory of general relativity
  - and does not work at the Planck scale (~10^{-36} m)
    - string physics???

Scientific method



Occam's razor

- "entia non sunt multiplicanda praeter necessitatem"
- …or "entities must not be multiplied beyond necessity"
- …or "all other things being equal, the simplest solution is the best"

William of Ockham: 14th century Franciscan friar

Scientists can easily be wrong

- "Heavier-than-air flying machines are impossible."
  - Lord Kelvin, president , Royal Society 1895

Pseudoscience

- Fake science
- Lacks key ingredient of evidence and having a test for wrongness
  - if data does not agree with hypothesis, then data is assumed to be wrong
- Exploits the controversies and inadequacies in a competing theory
  - “If it isn’t Tuesday, it must be Saturday” argument
- Portrayed as an underdog being punished by the scientific community
- People who do pseudo-science do not publish in peer-reviewed scientific journals
  - and they usually do not use mathematics

Example

Science

- Theory of evolution
  - arose as a result of a vast amount of observation by a large number of observers
  - predicts that fossils will be found in a chronological sequence
  - for example, if fossils of dogs were to show up in Pre-Cambrian rocks, would be a serious challenge for the theory

Pseudo-science

- intelligent design/ creationism
  - not falsifiable
  - things are made the way they are
  - points to problems with evolution as evidence for intelligent design
    - If it's not Tuesday, it must be Saturday

- Which of these statements is a scientific hypothesis?
  1. Atoms are the smallest particles of matter that exist
  2. Space is permeated with an essence that is undetectable
  3. Albert Einstein was the greatest physicist of the 20th century

- Which of these statements is a scientific hypothesis?
  1. **Atoms are the smallest particles of matter that exist**
  2. Space is permeated with an essence that is undetectable
  3. Albert Einstein was the greatest physicist of the 20th century