PHYS 3313 – Section 001
Lecture #1

Wednesday, Jan. 18, 2017
Dr. Jaehoon Yu

- Who am I?
- From Higgs to Dark Matter!!
- How is this class organized?
- What do we want from this class?
- What is Physics?
- Brief history of modern physics

Announcements

- Plea to you: Please turn off your cell-phones, pagers and computers in the class
- Reading assignment #1: Read and follow through appendices 3, 5, 6 and 7 by Monday, Jan. 23
  - There will be a quiz next Wednesday, Jan. 25, on these reading assignments
- Physics colloquium
  - 4:00pm Wednesdays
  - The 1st one is today by Dr. Frank Lu of Havard Med. School on optics

Physics Department
The University of Texas at Arlington
COLLOQUIUM

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Coherent Raman Scattering Microscopy for Label-Free Biomolecular Imaging, Rapid Surgical Pathology, and Image-Guided Precision Surgery

Dr. Frank Lu
Department of Neurosurgery at
Harvard Medical School and Brigham and Women's Hospital

Wednesday January 18, 2016
4:00 Room 101 Science Hall

Label-free microscopy is highly desirable in biology and medicine, to perform live imaging without affecting cell functions, or in vivo imaging of human with no fluorescent staining. While Raman spectroscopy has been used for molecular characterization for cancer detection with high sensitivity, it is not good at imaging due to the ultraweak signals. By coherently exciting and detecting the chemical bond vibration in molecules, coherent Raman scattering (CRS) microscopy, with two modalities of coherent anti-Stokes Raman scattering (CARS) and stimulated Raman scattering (SRS), has been used for label-free imaging of various biomolecules or drugs with high spatiotemporal resolution and high chemical specificity.

In this seminar, I will first review recent technical efforts that have greatly improved CRS imaging speed, detection sensitivity and spectral acquisition, and I will further present several label-free biomolecular imaging applications of the technology. In particular, transforming SRS microscopy for clinical use is a major direction of my research. Two scenarios will be highlighted:

(i) In brain tumor surgery, the goal is to maximize tumor removal without injuring critical brain structures. Achieving this goal is challenging as it can be difficult to distinguish tumor from nontumor tissue during surgery. While standard histopathology (e.g., H&E staining) provides information that could assist tumor delineation, it cannot be performed iteratively during surgery as freezing, sectioning, and staining of tissue require too much time. Label-free SRS imaging of lipid and protein in the fresh tissue specimen can be rendered into pathology-like images. By evaluating large-scale SRS data from 12 patients with a range of brain tumor types, and by correlating this data with the current clinical gold standard of histopathology, essential diagnostic hallmarks for glioma classification have been revealed. This work establishes the methodology and the first reference system for SRS label-free neurosurgical pathology to help neurosurgeon's decision-making during surgery.

(ii) For pathology-based cancer diagnosis, visualization of nuclear morphology provides the most important cytologic features. Microscopic imaging of DNA has to rely on the use of staining. Label-free Raman imaging of DNA has been demonstrated, but imaging in the fingerprint region is difficult for cells in interphase because of the very low DNA density, especially in fresh tissue. A new multicolor SRS approach has been developed to retrieve DNA signals from the strong lipid/protein background, realizing high-sensitive DNA imaging in vivo. Chromosome dynamics during cell division were captured. Label-free histology for skin cancer diagnosis was demonstrated. Together, the methodology of SRS label-free histopathology for rapid cancer detection and image-guided surgery has shown a great potential to impact on the current clinical practices of pathology and surgery.

The goal of my future research is to establish a new biophotonics program focusing on advanced coherent Raman and multiphoton imaging of single living cells, in vivo animals and fresh human tissue at the most translational frontier for neuro-oncology and neuroscience studies with extensive collaborations in the area.

Refreshments will be served at 3:30 p.m. in the Physics Library

Who am I?

- Name: Dr. Jaehoon Yu (You can call me **Dr. Yu**)
- Office: Rm 342, Chemistry and Physics Building
- Extension: x22814, E-mail: *jaehoonyu@uta.edu*
- My profession: High Energy Particle Physics (HEP)
  - Collide particles (protons on anti-protons or electrons on anti-electrons, positrons) at the energies equivalent to 10,000 Trillion degrees
  - To understand
    - Fundamental constituents of matter
    - Forces between the constituents (gravitational, electro-magnetic, weak and strong forces)
    - Origin of Mass
    - Search for Dark Matter and Making of Dark Matter Beams
    - Creation of Universe (**Big Bang** Theory)
  - A pure scientific research activity
    - Direct use of the fundamental laws we find may take longer than we want but
    - Indirect product of research contribute to every day lives; eg. WWW
  - Why do we do with this?
    - Make our everyday lives better to help us live well as an integral part of the universe

We always wonder…

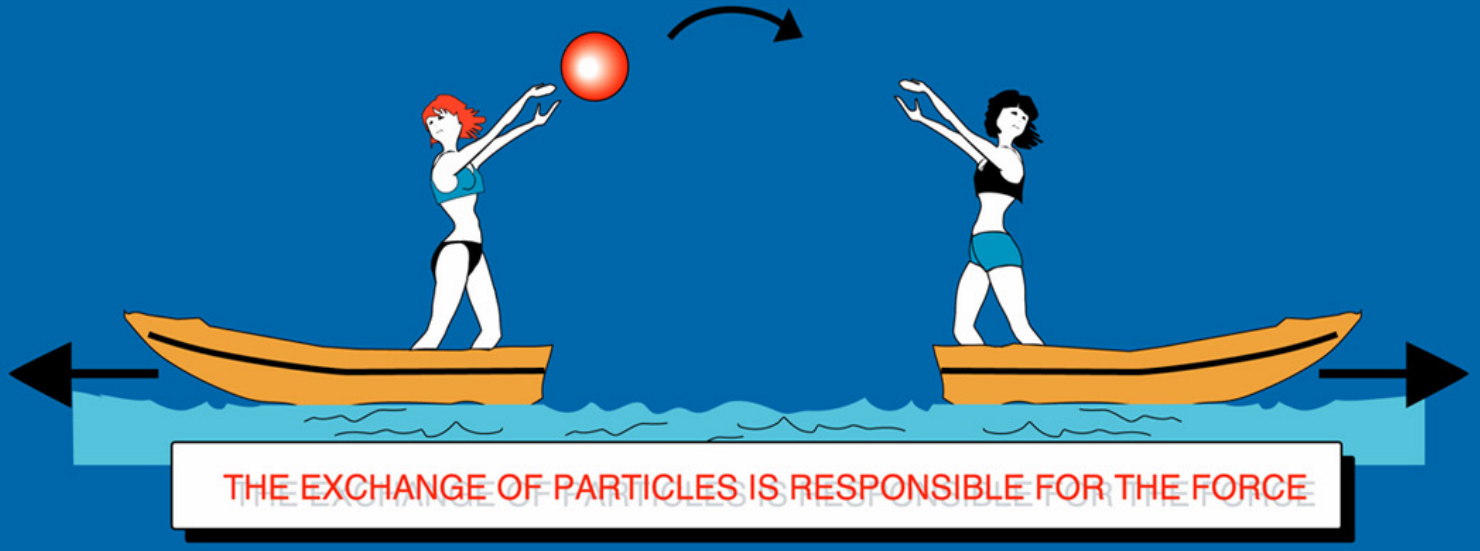
- What makes up the universe?
- How does the universe work?
- What holds the universe together?
- How can we live in the universe well?
- Where do we all come from?

High Energy Physics

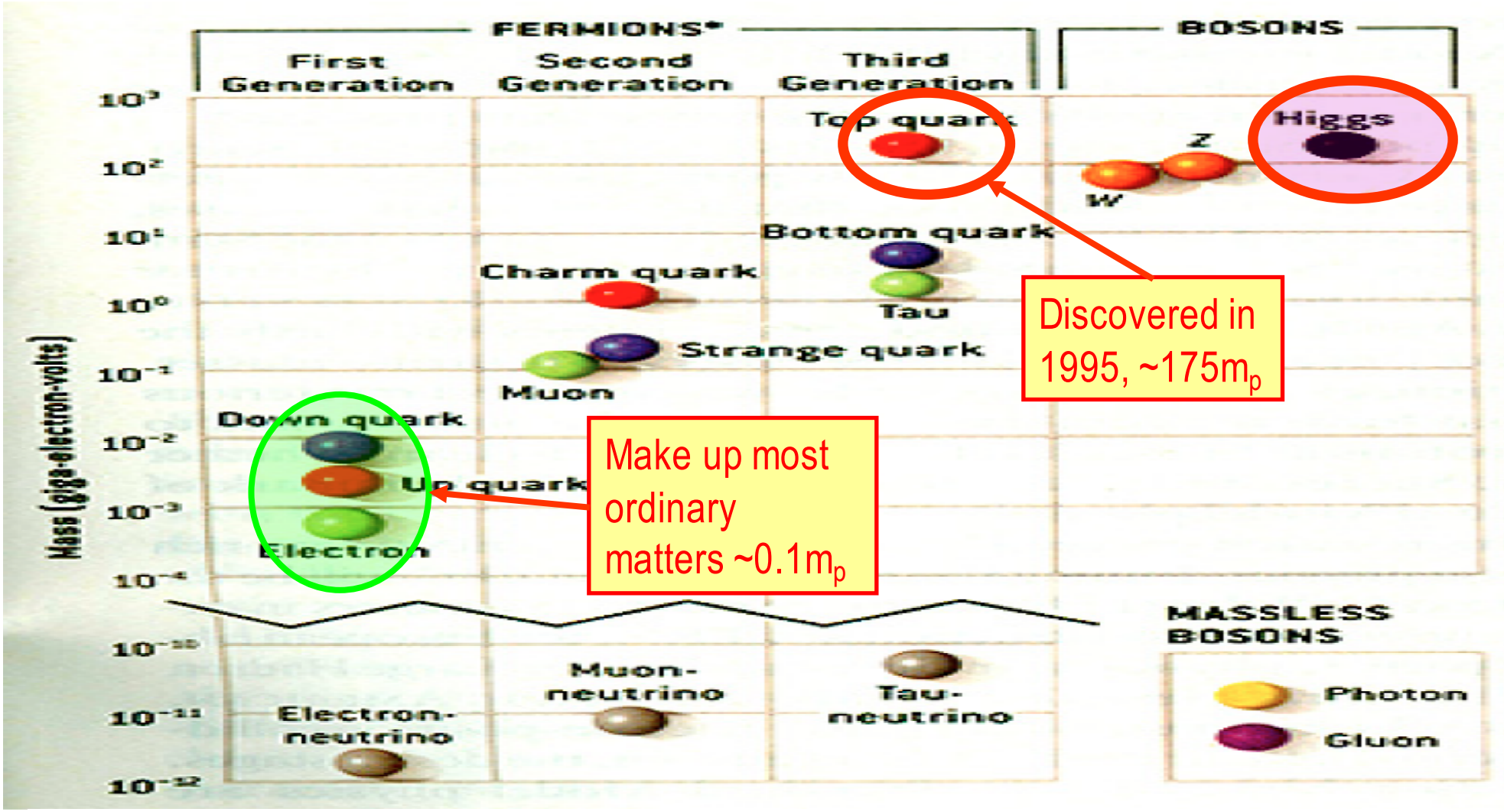
- Definition: A field of physics that pursues understanding the fundamental constituents of matter and basic principles of interactions between them.
- Known interactions (forces):
  - Gravitational Force
  - Electromagnetic Force
  - Weak Nuclear Force
  - Strong Nuclear Force
- Current theory: The Standard Model of Particle Physics

The forces in Nature

TYPE	INTENSITY OF FORCES (DECREASING ORDER)	BINDING PARTICLE (FIELD QUANTUM)	OCCURS IN :
STRONG NUCLEAR FORCE	~ 1	GLUONS (NO MASS)	ATOMIC NUCLEUS
ELECTRO -MAGNETIC FORCE	~ 10^{-3}	PHOTONS (NO MASS)	ATOMIC SHELL ELECTROTECHNIQUE
WEAK NUCLEAR FORCE	~ 10^{-5}	BOSONS Z^{o} , W^{+} , W^{-} (HEAVY)	RADIOACTIVE BETA DESINTEGRATION
GRAVITATION	~ 10^{-38}	GRAVITONS (?)	HEAVENLY BODIES



HEP and the Standard Model

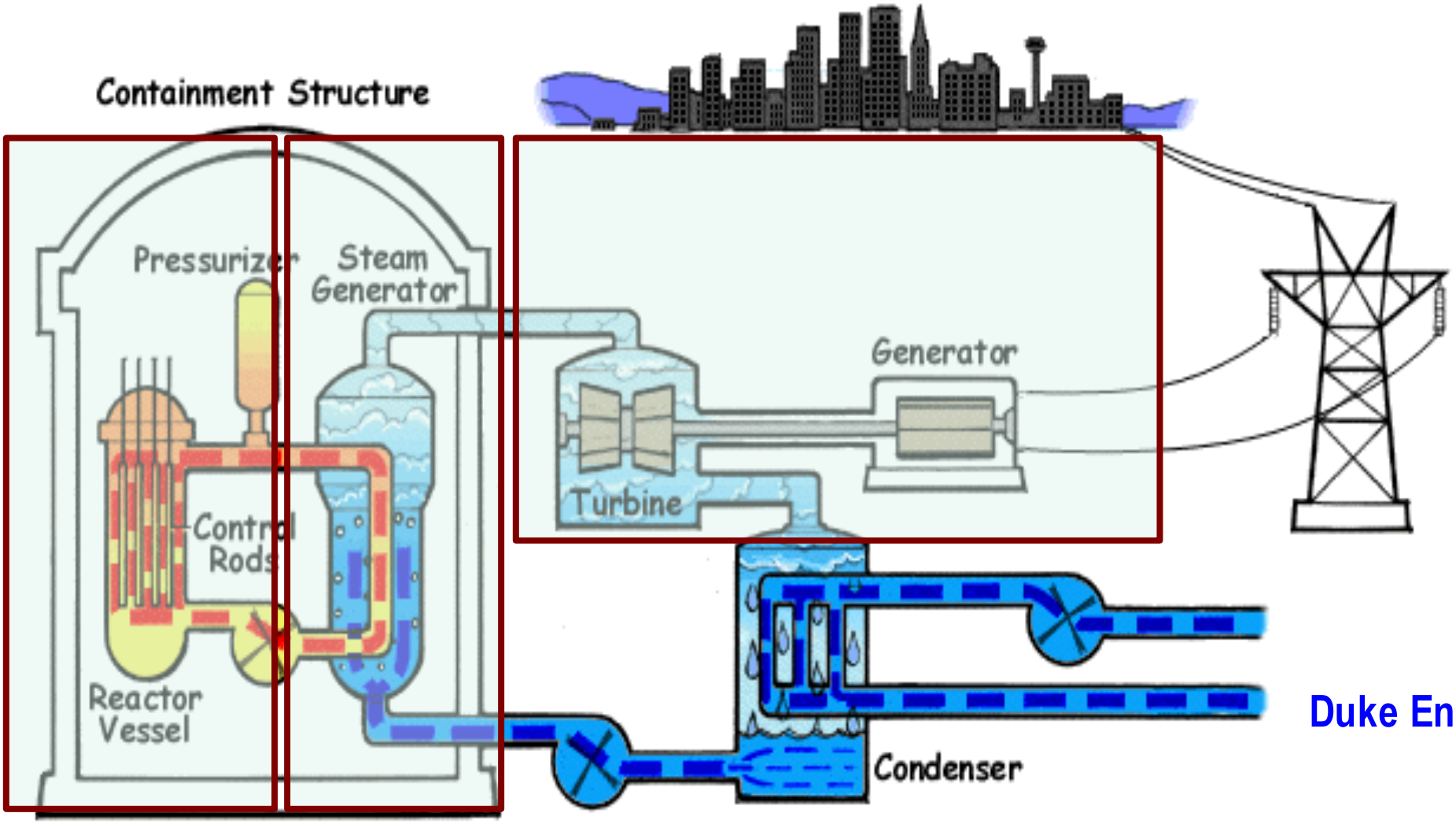


- Total of 16 particles (12+4 force mediators) make up all the visible matter in the universe! ➔ Simple and elegant!!!
- Tested to a precision of 1 part per million!

So what's the problem?

- Why is the mass range so large ($0.1m_p$ – $175\,m_p$)?
- Is the new particle we've discovered really the Higgs particle?
- Why is the matter in the universe made only of particles?
- Neutrinos have mass!! What are the mixing parameters, particle-anti particle asymmetry and mass ordering?
- Why are there only four apparent forces?
  - Were they all unified at the Big Bang?

How does a nuclear power plant work?



Duke Energy

My 1000 year dream: Skip the whole thing!

Make electricity directly from nuclear force!

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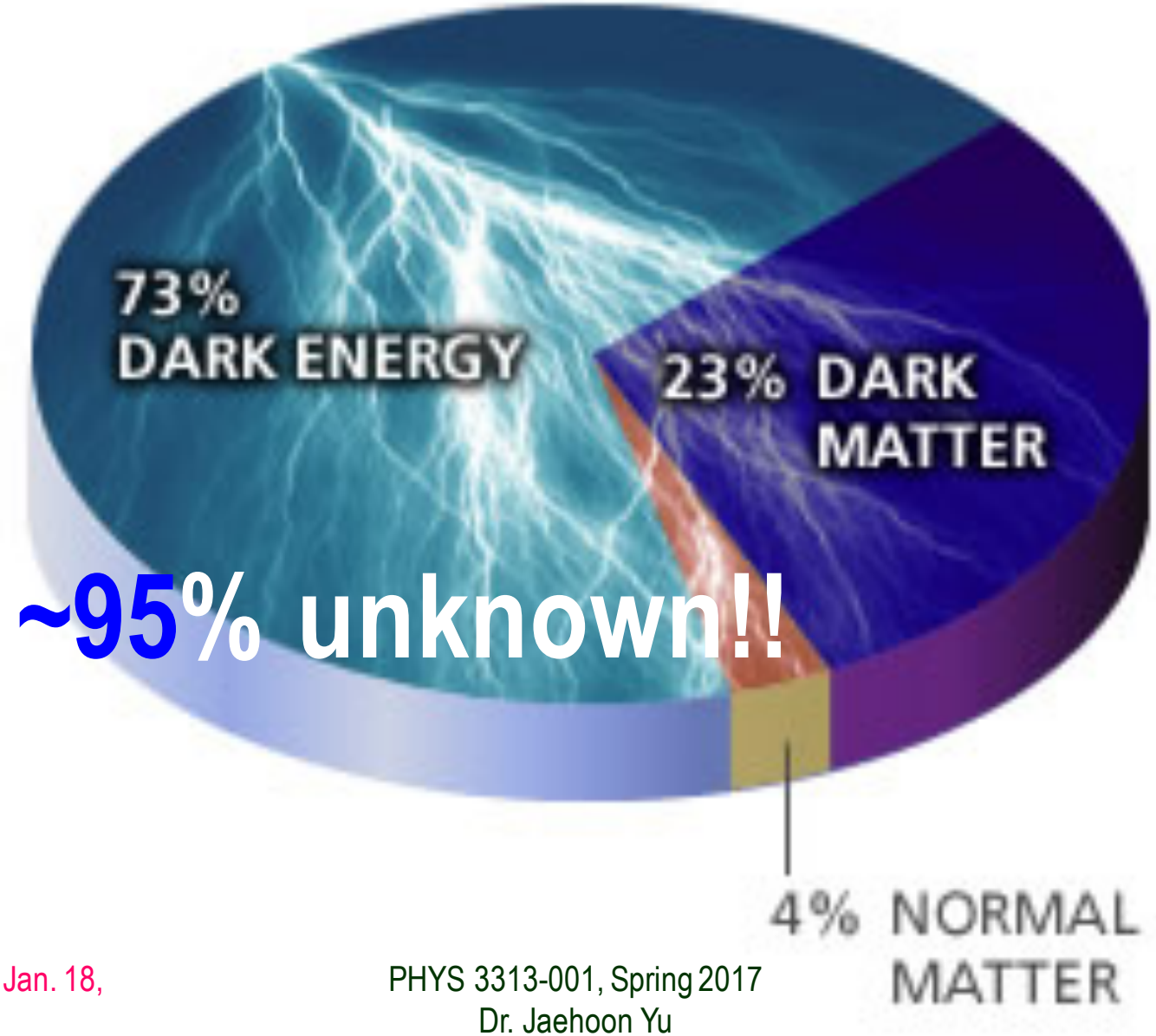
What makes up the universe?



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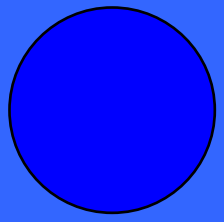
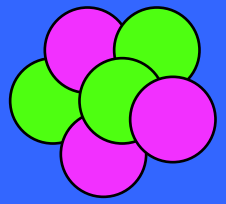
- Why are there only four apparent forces?
  - Were they all unified at the Big Bang?
- Is the picture we present the real thing?
  - What makes up the remaining ~95% of the universe?
- Are there any other particles we don't know of?
  - Big deal for the new LHC Run!
- Where do we all come from?
- How can we live well in the universe as an integral partner?

Accelerators are Powerful Microscopes.

They make high energy particle beams that allow us to see small things.



seen by
low energy beam
(poorer resolution)



seen by
high energy beam
(better resolution)

Accelerators are also Time Machines.

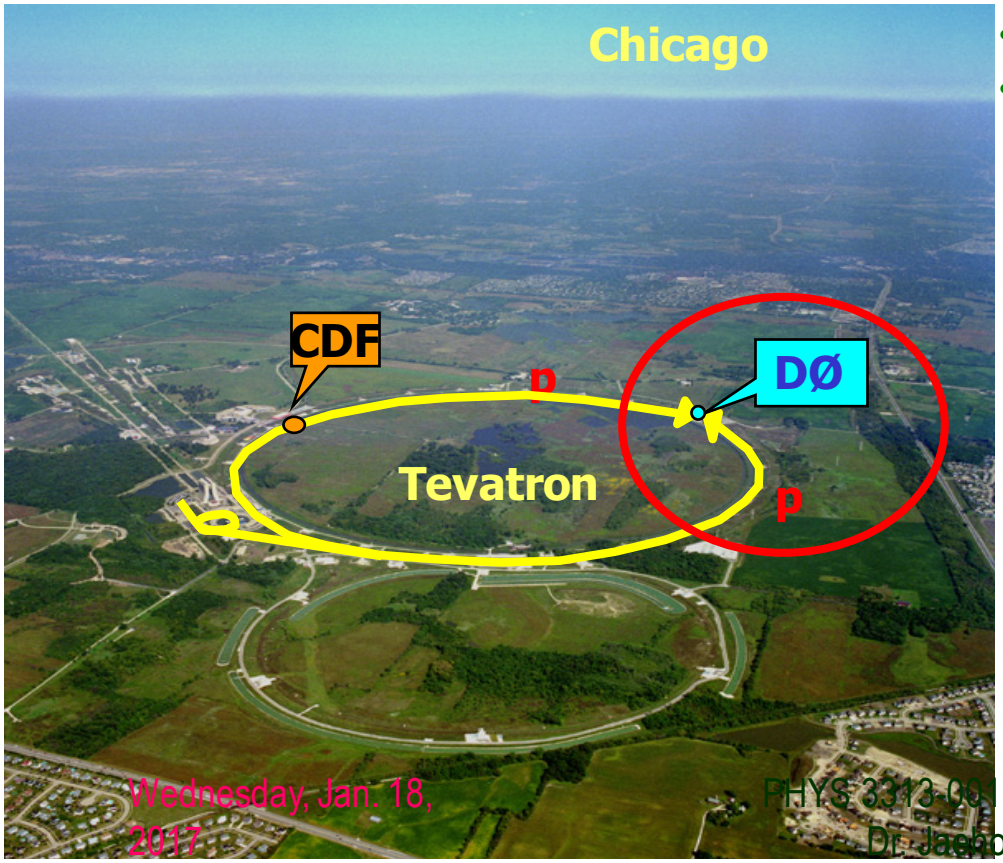
They make particles last seen
in the earliest moments of the universe.

Particle and anti-particle annihilate.

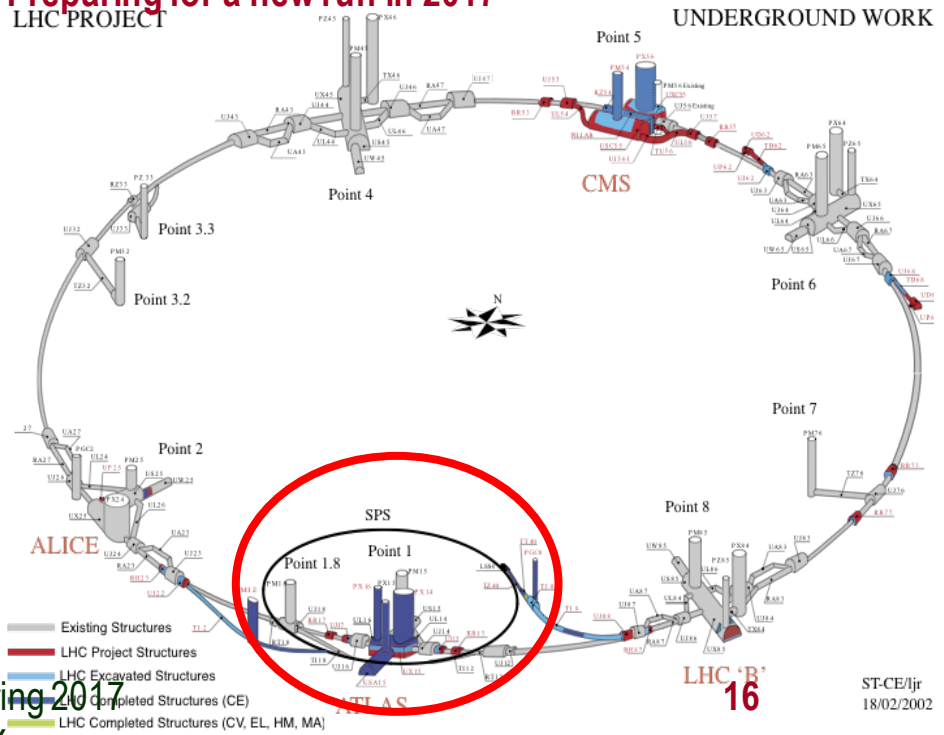
$$E = mc^2$$

Fermilab Tevatron and LHC at CERN

- World's Highest Energy proton-anti-proton collider
  - 4km (2.5mi) circumference
  - E_{cm}=1.96 TeV (=6.3x10^{-7}J/p➔ 13M Joules on the area smaller than 10^{-4}m^2)
  - Equivalent to the kinetic energy of a 20t truck at the speed 130km/hr
    - ~100,000 times the energy density at the ground 0 of the Hiroshima atom bomb
  - **Tevatron was shut down in 2011**
  - **Vibrant other programs running, including the search for dark matter with beams!!**



- World's Highest Energy p-p collider
  - 27km (17mi) circumference, 100m (300ft) underground
  - Design E_{cm}=14 TeV (=44x10^{-7}J/p➔ 362M Joules on the area smaller than 10^{-4}m^2)
  - ➢ Equivalent to the kinetic energy of a B727 (80tons) at the speed 310km/hr
    - ➢ ~3M times the energy density at the ground 0 of the Hiroshima atom bomb
- **Large amount of data accumulated in 2010 – 2013**
- **Beam returned 2015 after a 2 yr shutdown**
- **Preparing for a new run in 2017**



LHC @ CERN Aerial View

CMS

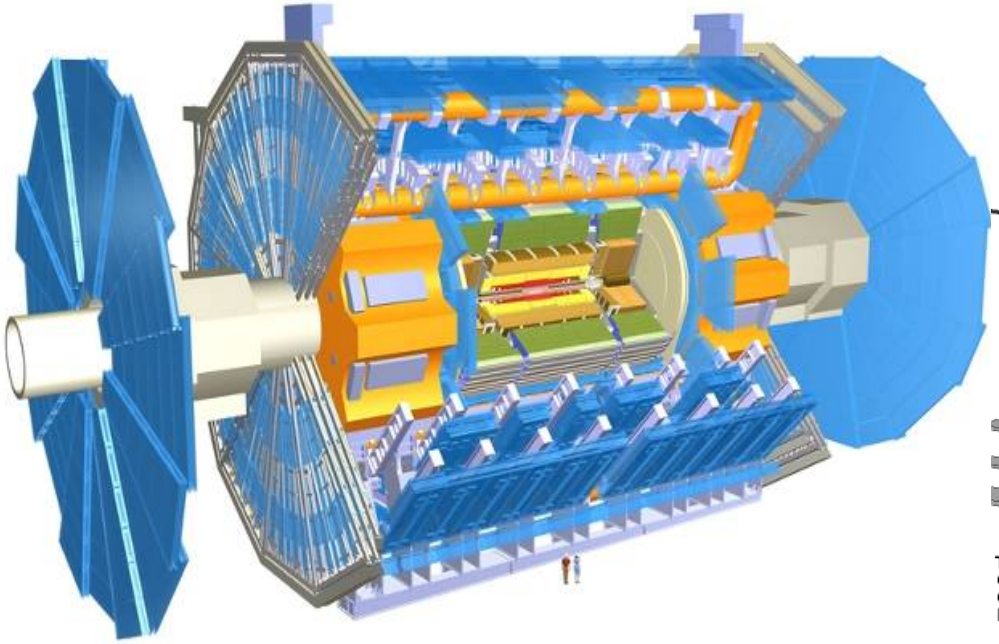
France

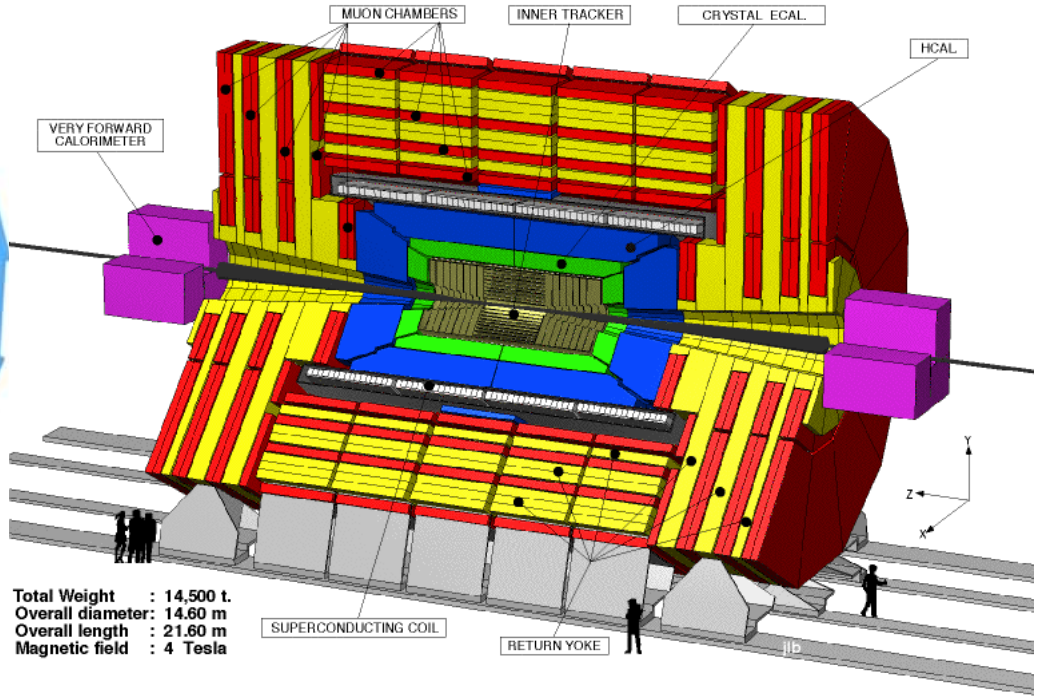
Geneva Airport

ATLAS

Swizerland

The ATLAS and CMS Detectors





- **Weighs 7000 tons and ~10 story tall**
- Records **200 – 400 collisions/second (out of 50million)**
- Records approximately **350** MB/second
- Records ~2 PB per year ➔ **200*Printed material of the US Lib. of Congress**

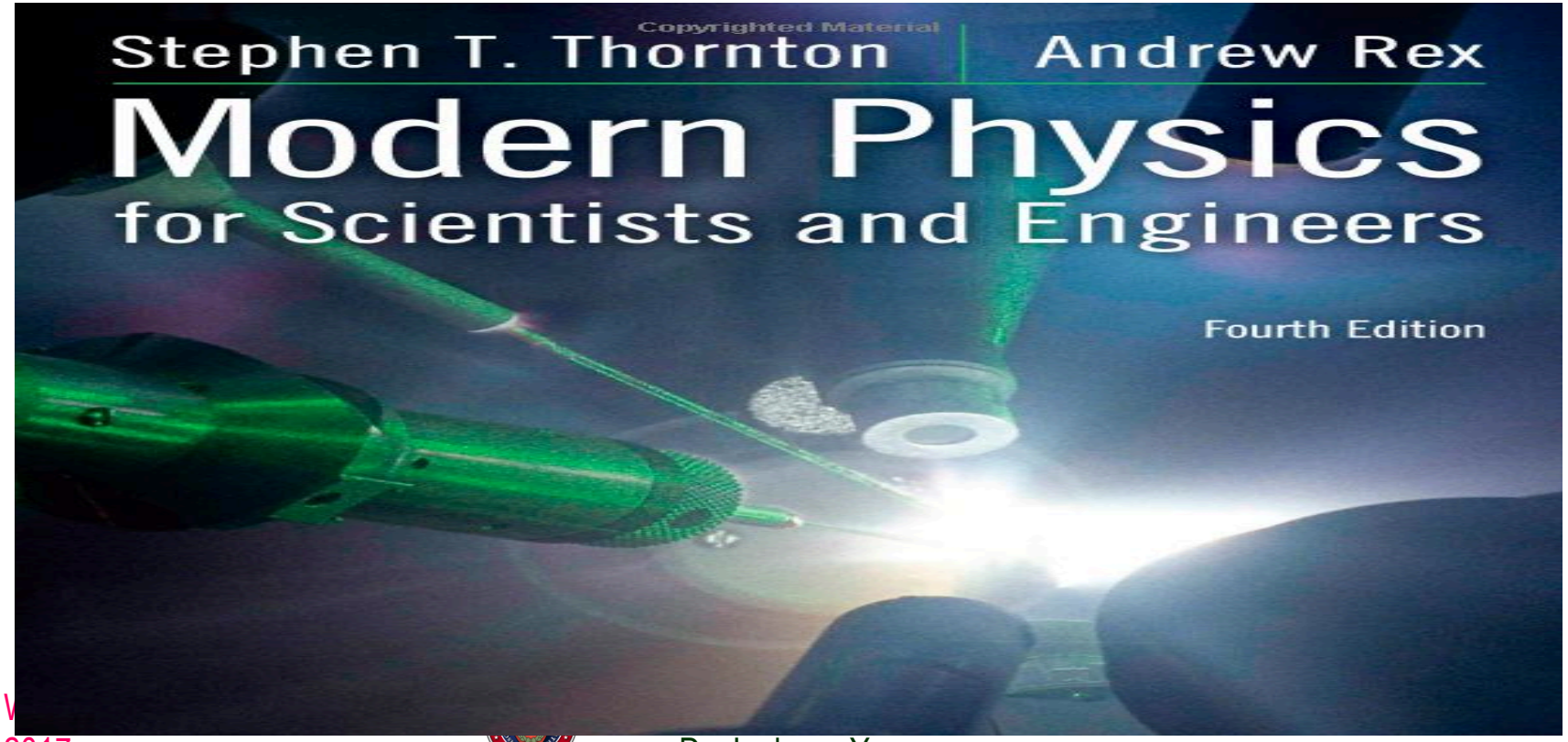
200x

Information & Communication Source

- Course web page: http://www-hep.uta.edu/%7Eyu/teaching/spring17-3313-001/spring17-3313-001.html
  - Contact information & Class Schedule
  - Syllabus
  - Homework
  - Holidays and Exam days
  - Evaluation Policy
  - Class Style & Communication
  - Other information
- Primary communication tool is e-mail: Make sure that your e-mail at the time of course registration is the one you most frequently read!!
- Office Hours: 2:30 – 3:40pm, Mondays and Wednesdays or by appointments

Textbook

- Title: Modern Physics for Scientists and Engineers
  - 4^{th} edition
- Authors: S.T. Thornton and A. Rex
- ISBN: 978-1-133-10372-1



Evaluation Policy

- Homework: 30%
- Exams
  - Mid-term Exam (Wed., Mar. 8): 20%
  - Final Comprehensive Exam (11 – 1:30pm, Wed, May. 3): 25%
  - Missing an exam is not permissible unless pre-approved
    - No makeup test
    - You will get an F if you miss any of the exams without a prior approval
- Group Research Project: 15%
- Pop-quizzes: 10%

100%

- Extra credits: 10% of the total
- Grading will be done on a sliding scale
- 55% of the grade is in your hand!!

Homework

- Solving homework problems is the only way to comprehend class material
- Consists of a lot of reading, deriving and writing
- Each homework carries the same weight
- **ALL** homework grades will be used for the final grade
- Home work will constitute **30% of the total**
  - A good way of keeping your grades high
- Strongly encouraged to collaborate
  - Just make sure to submit your own answers written in your OWN way!!

Group Research Projects

- Detailed studies on important discoveries and theories that set the foundation of modern physics
- Final project consists of
  - A 5 - 7 page paper each : 10% of the total
  - A 10+2 minute power point presentation for each group: 5% of total
- Report Due and Presentation Dates
  - Presentation: Monday, Apr. 24 and Wednesday, Apr. 26
  - Report Due: At the beginning of the class on Wed. Apr. 26

Research Topics

1. Blackbody radiation
2. Michelson–Morley Experiment
3. The Photoelectric Effect
4. The Brownian Motion
5. Compton Effect
6. Discovery of Electron
7. Rutherford Scattering
8. Super-conductivity
9. The Discovery of Radioactivity

Attendances and Class Style

- Attendances:
  - Will be taken randomly
  - Will be used for extra credits
- Class style:
  - Lectures will be on electronic media
    - The lecture notes will be posted on the web **AFTER** each class
  - Will be mixed with traditional methods
  - Active participation through questions and discussions are **STRONGLY** encouraged ➔ Extra credit….
  - Communication between you and me is extremely important
    - If you have problems, please do not hesitate talking to me

Extra credit

- Up to 10% addition to the total
  - Could boost a B to A, C to B or D to C
- What constitute for extra credit?
  - Random attendances
  - Physics Colloquium Participations
  - Strong participation in the class discussions
  - Special projects
  - Watch the valid planetarium shows
  - Many other opportunities

Valid Planetarium Shows

- Regular running shows
  - Phantom of the Universe – Fridays at 6:00, Saturdays at 6:00pm
  - Astronaut – Sundays at 1:30pm
- Shows that need special arrangements
  - Black Holes (up to 2 times)
  - Bad Astronomy, Cosmic Origin, Experience the Aurora
  - From Earth to the Universe, IBEX, Ice Worlds, Magnificent Sun
  - Mayan Prophecies, Nanocam, Stars of Pharaoes
  - Two Small Pieces of Glass, Unseen Universe: The Vision of SOFIA
  - Violent Universe, We are Astronomers
- How to submit for extra credit?
  - Obtain the ticket stub that is signed and dated by the planetarium star lecturer of the day
  - Collect the ticket stubs
  - Tape all of them on a sheet of paper with your name and ID written on it
  - Submit the sheet at the end of the semester when asked

What can you expect from this class?

- All A's would be perfect for you, wouldn't it?
  - But easy come easy go
  - Must put in efforts to make it last and meaningful….
- This class is going to be challenging!!
- You will earn your grade in this class.
  - You will need to put in sufficient time and sincere efforts
  - Exams and quizzes will be tough!!
    - Sometimes problems might not look exactly like what you learned in the class
    - Just putting the right answer in free response problems does not work!

What can you expect from this class?

- But you have a great control of your grade in your hands, up to 45%!!!
  - Homework is 30% of the total grade!!
    - Means you will have many homework problems
      - Sometimes much more than any other classes
      - Sometimes homework problems will be something that you have yet to learn in class
      - Exam's problems will be easier that homework problems but the same principles!!
  - Group research project: 15%
  - Extra credit 10%
- I will work with you so that your efforts are properly rewarded