"Big Bang, Black Holes, No Math"

ASTR/PHYS 109 at Texas A&M

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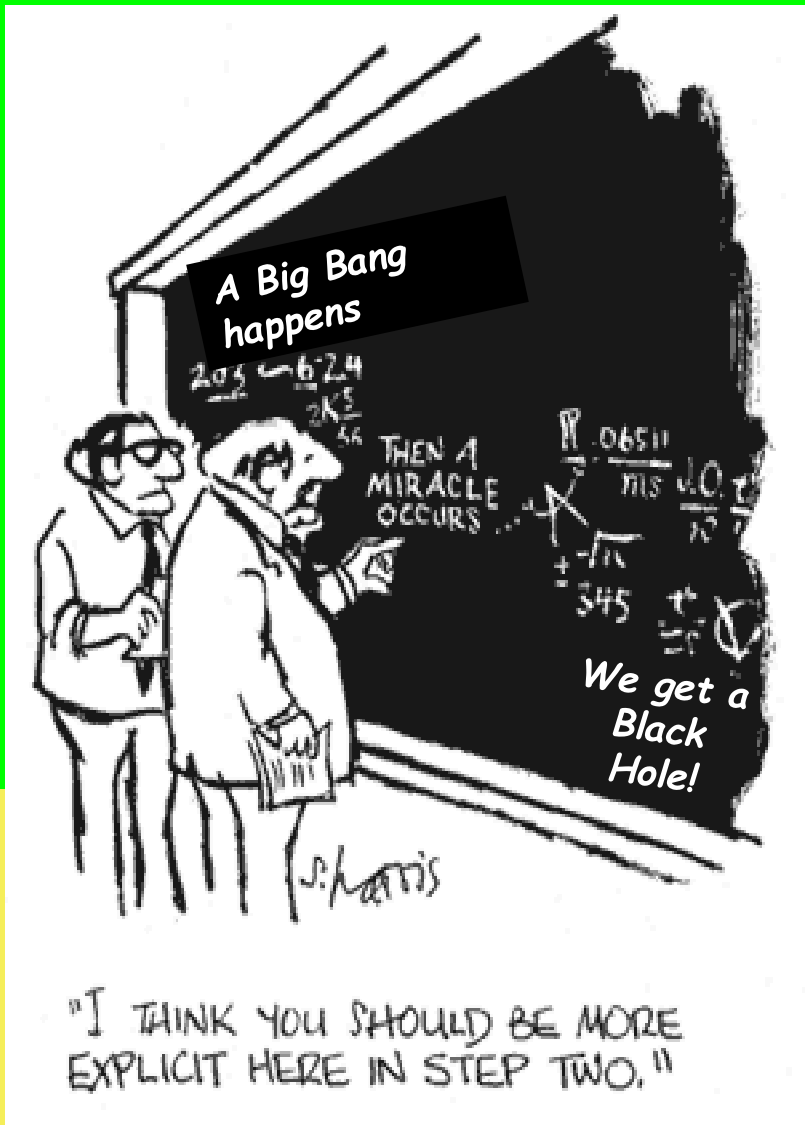


Talk Outline

- Motivation, Intended Audience and Class Goals
- Course Structure, Science Content
- How the course is run
  - Grades, Class room stuff, assignments etc.
- Status of the course and future plans

Motivation, Intended Audience and Class Goals

Other Names

Could have also called this course

- *Cosmology without the Math*
- *Cosmology for Poets*
- *Big Bang, Black Holes, Dark Matter*

Debuted in Spring 2007 (PHYS 289)

Now:

Cross listed as ASTR/PHYS 109

Tier 2 Science Distribution

Some Background

Teaching the course for many reasons

- It's REALLY interesting stuff
- Stomp out science ignorance
- Trying to educate future senators and donors
- Liberal Arts majors: 1st – 4th years
- Convey to them the wonder and excitement of the universe
- Make them realize this stuff is understandable
- Enable them to communicate the ideas and excitement to others

A Bone to Pick

I think there is WAY too much ignorance about science and science phobia

- Some of the many problems:
  1. Physics/Astronomy taught for people to USE rather than enjoy (physicists/engineers in training)
  2. Teaching physics/astronomy requires math, and lots of it, which makes it un-fun (or scary) for most people
  3. Taught by people who have forgotten what it was like to not understand

Communicating the Excitement: No Math

- A great deal of the excitement can be understood WITHOUT the math
  - They can enjoy music without being a musician or a composer
- I want them to go out into the world and effectively teach senators, kids, co-workers, etc. why this stuff is exciting and important

More on my goals

- I'm trying to teach them to "tell the story" like a lawyer to a Jury
- "Evidence based" decision making
- They are not "expert witnesses," they call witnesses and "tie it all together" to make the case to the jury

1. Do it in writing
2. Make it short and sweet

Inquiring Minds Want to Know

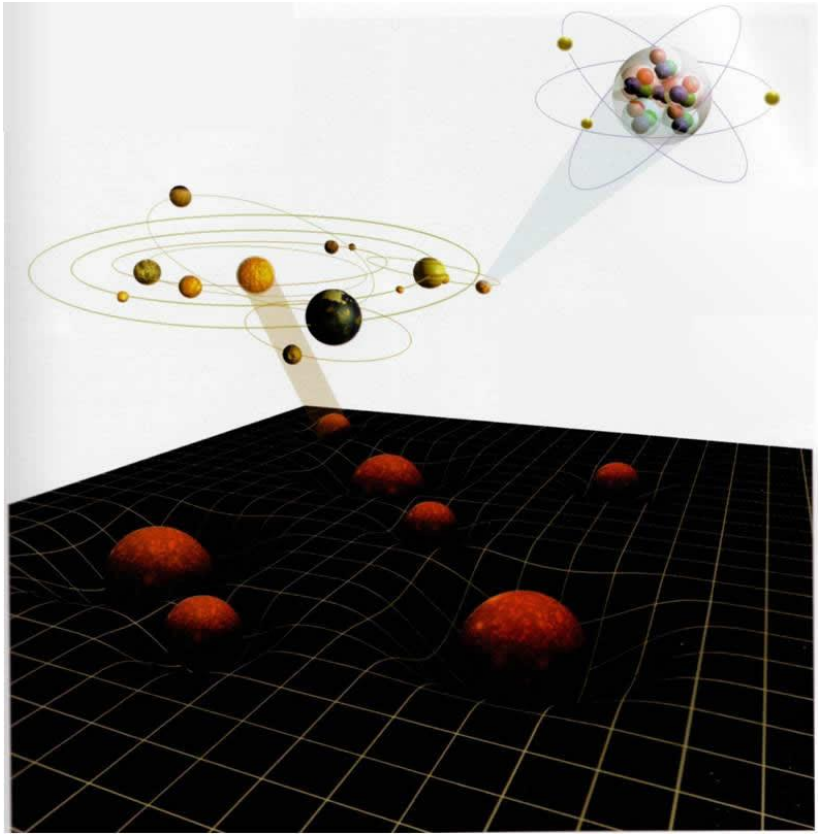
Spent a lot of time asking about THEY wanted to know and hear about

- Black Holes
- The Big Bang
- *How are stars formed?*
- *What is Dark Matter?*
- *How did we get from the Bang to the stuff out there we have today?*
- *Why do we believe in the Big Bang? What's the evidence the world isn't 6000 years old?*
- *What is Dark Energy?*

I bought Brief History of Time and didn't understand it…

What I Wanted

- Teach them about the "stuff" in the Universe
  - Big and small stuff
- What is the Evidence for all this stuff
- *A little cool physics*
  - Quantum Mechanics, General Relativity, Particle Physics
- *What are some of the questions scientists care about?*



If you knew enough about physics, you'd be interested in…

Course Structure and Science Content:

The Topics, in order, and how the papers interface with them

Structure of the Course

1. Introduction
2. Physics We Need
3. Evidence for the Big Bang
4. Evolution of the Universe
5. Big Objects and Black Holes
6. Early Times and the Fate of the Universe

Unit 1: Introduction

Ch. 1: Introduction
Ch. 2: Going Big
Ch. 3: Going small
Ch. 4: History and the Scientific Method

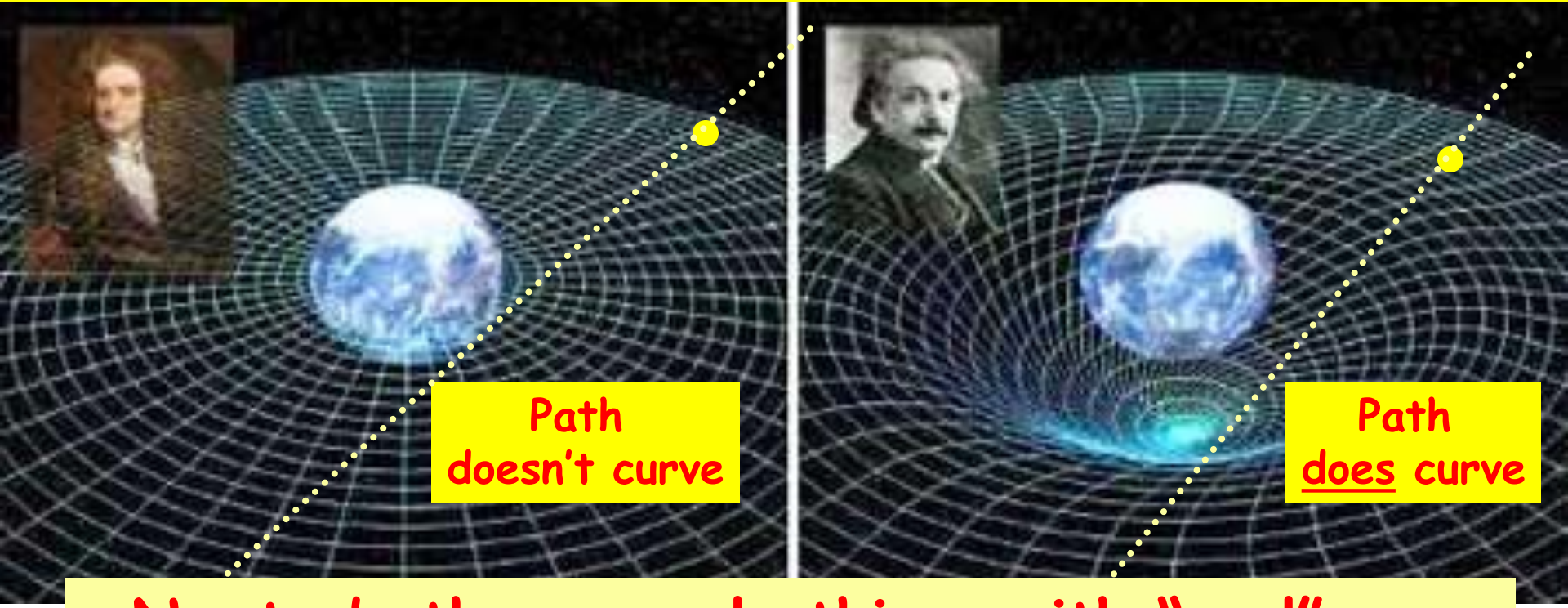
- *What is the "stuff" of the Universe?*
- Tell them what the evolution of the Universe produces
  - Describe the objects from the size of their nose out to 10^{24} m
  - Describe the objects from the size of their nose down to 10^{-18} m
- Tell them some history, not because it's important but because they can relate to it and because it teaches the model of evidence-based decision making

Unit 2: The Physics We Need

Ch. 5: Light and Doppler Shifts
Ch. 6: Gravity
Ch. 7: Atomic Physics and Quantum Mechanics
Ch. 8: Nuclear Physics and Chemistry
Ch. 9: Temperature and Thermal Equilibrium

- Light and Doppler Shifts to tell them how we observe things, also for Red-shifts and light in curved space-time
- Gravity and General Relativity to describe expanding space time, galaxy and star formation
- E&M and Quantum Mechanics and a little particle physics give us an understanding of
  - Atoms, Nuclear Physics, Chemistry and Spectral Lines to explain the evidence for atoms, stars, Universality, formation of atoms, nuclei etc.
- Temperature and Thermal Equilibrium is needed for the CMB and the relationship between temperature and average photon energy

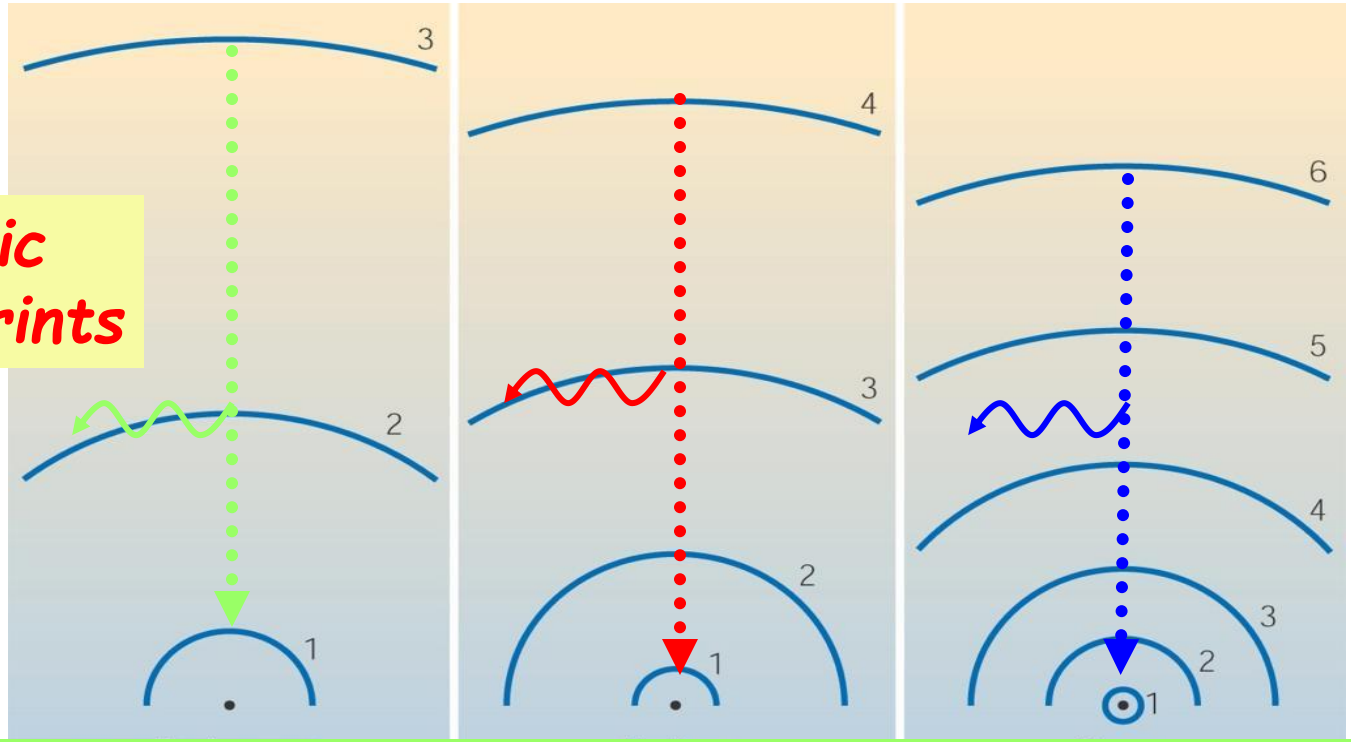
What happens to light as it goes past the Earth?



- Newton's theory: only things with "real" mass "feel" the force of gravity
- General Relativity: Objects with "Energy" move according to the curve of space-time, regardless of whether they have mass or not

Different energy levels for each different type of atom

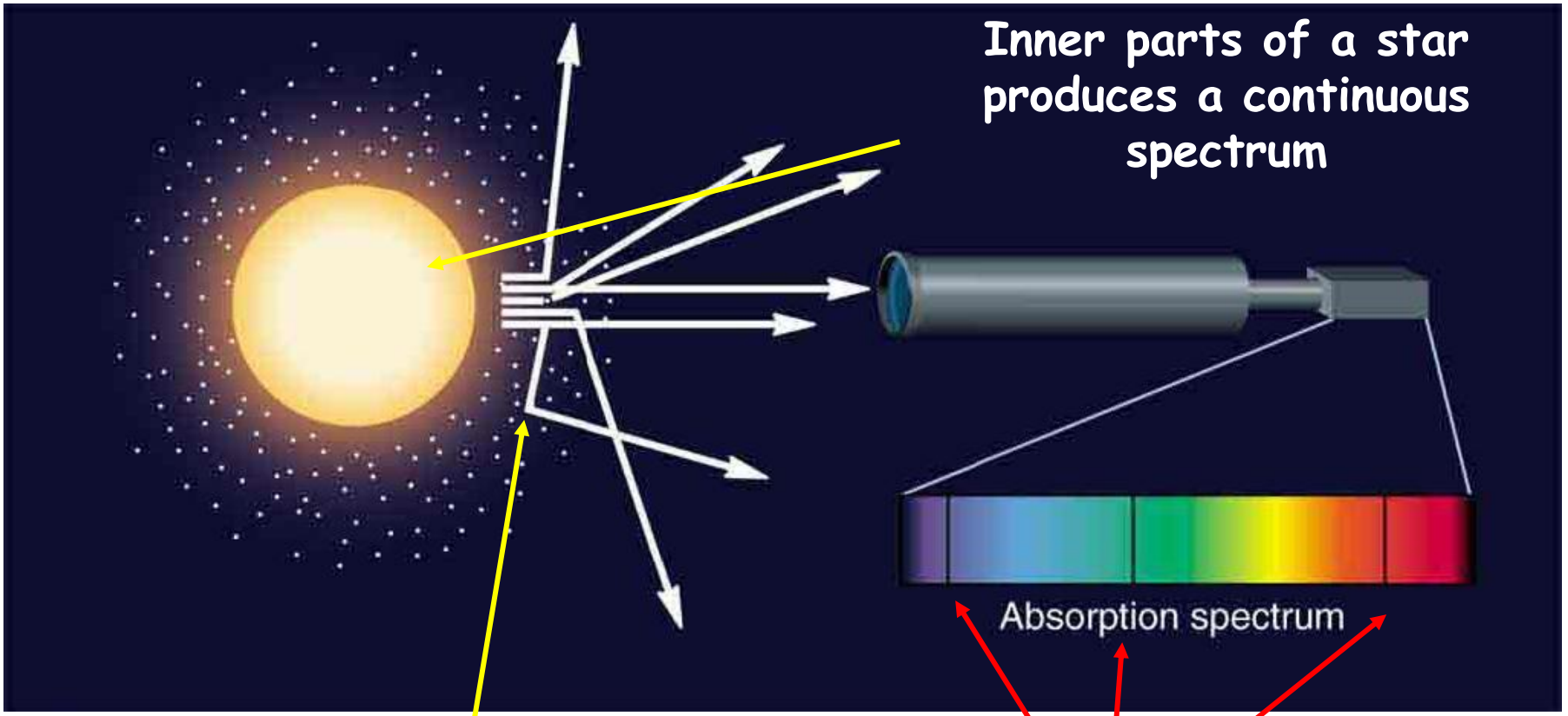
Atomic Fingerprints



Hydrogen Helium Boron

Can use light of different energies to identify atoms: Different Colors

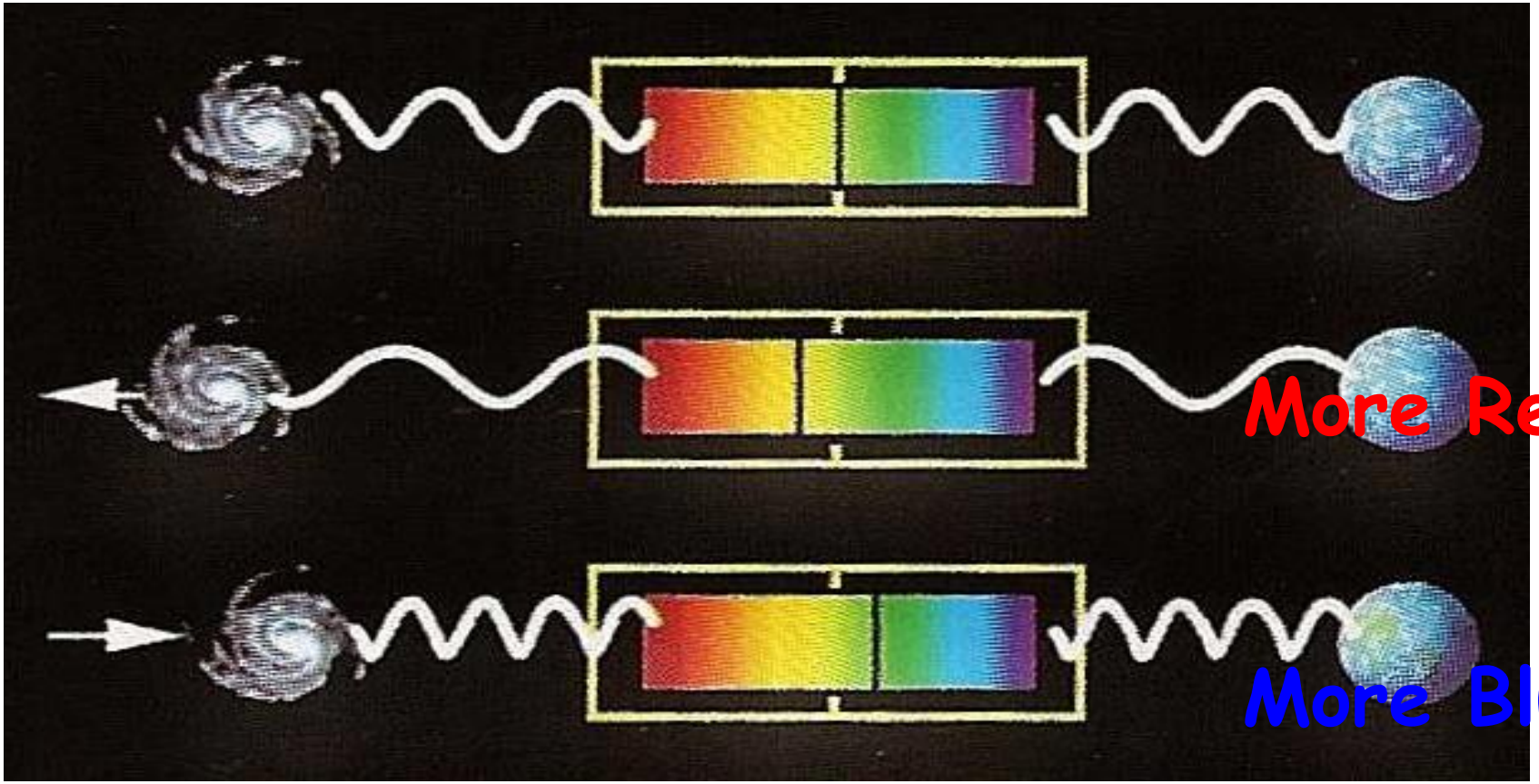
The Spectra of Stars



Outer parts absorb light at specific wavelengths

➔The light spectrum shows spectral lines!

A "moving" Spectral Line…



Short Paper 1

What is the evidence that Stars are made of Atoms?

Unit 3: The Evidence for the Big Bang

Ch. 10: The Exploding Universe
Ch. 11: Expanding Space-Time
Ch. 12: The Cosmic Background Radiation

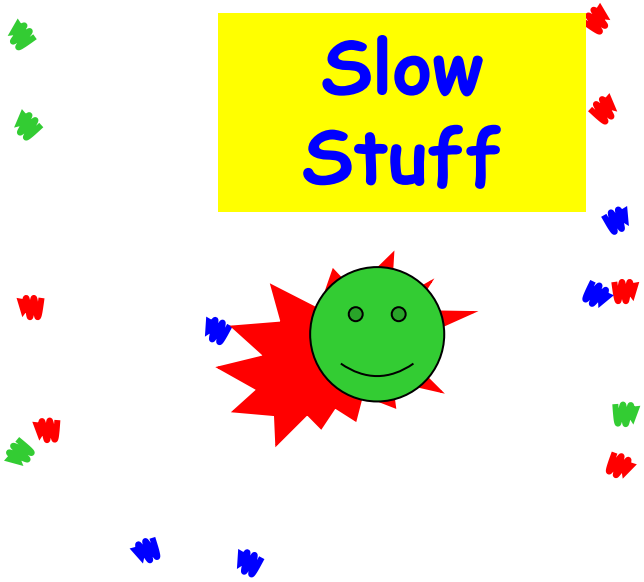
- Describing the main pieces of evidence for the Big Bang
- Galaxies moving away from us (Red-shifts)
- Hubble's law
- The difference between an explosion INTO space and an explosion OF space
  - *Do we really believe we're at the center of the Universe any everything is expanding around US?*
- Why the CMB is such a compelling piece of evidence
- Photons and how they bust apart nuclei and atoms
- Dropping temperatures

If We're at the Center

Equal amounts of stuff on each side

Slow Stuff

Fast Stuff



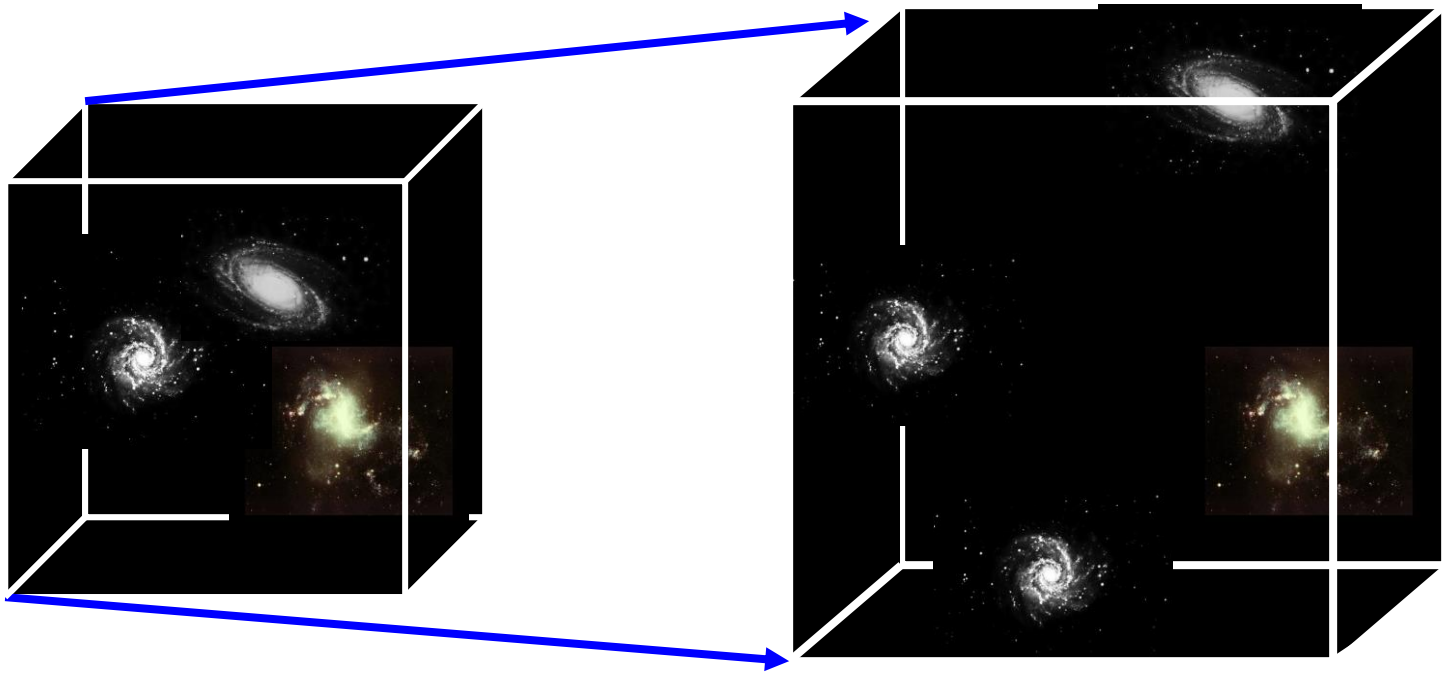
Medium Speed

Consistent with what we observe!

The Expanding Universe

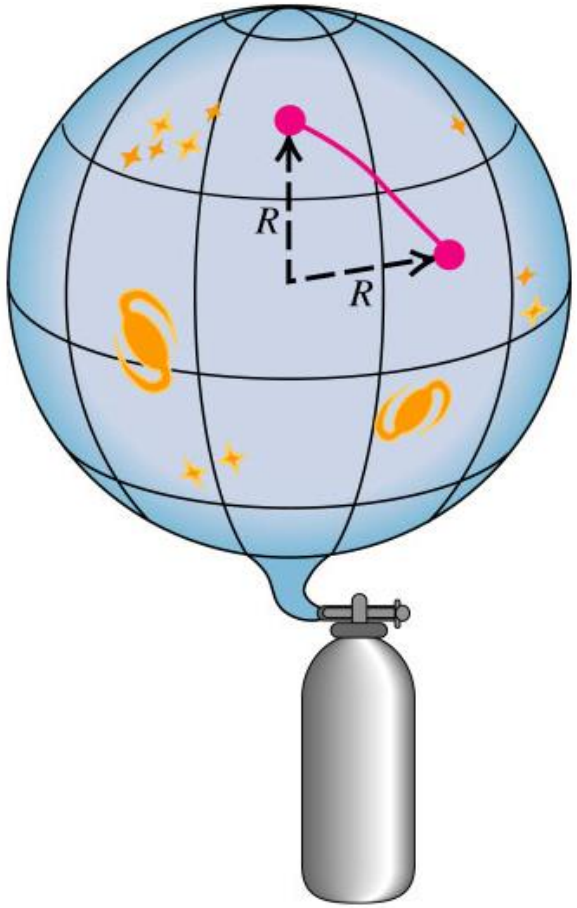
It's not galaxies moving through space

Space is expanding, carrying the galaxies along!



Balloon Example

- Can think of Space-Time like the SURFACE of a balloon
  - This is a two dimensional example
  - There is no *inside*, space IS just the surface
- As space-time expands, the distance between any two spots increases, but there is no spot ON THE SURFACE that is the center of the expansion



Short Paper 2

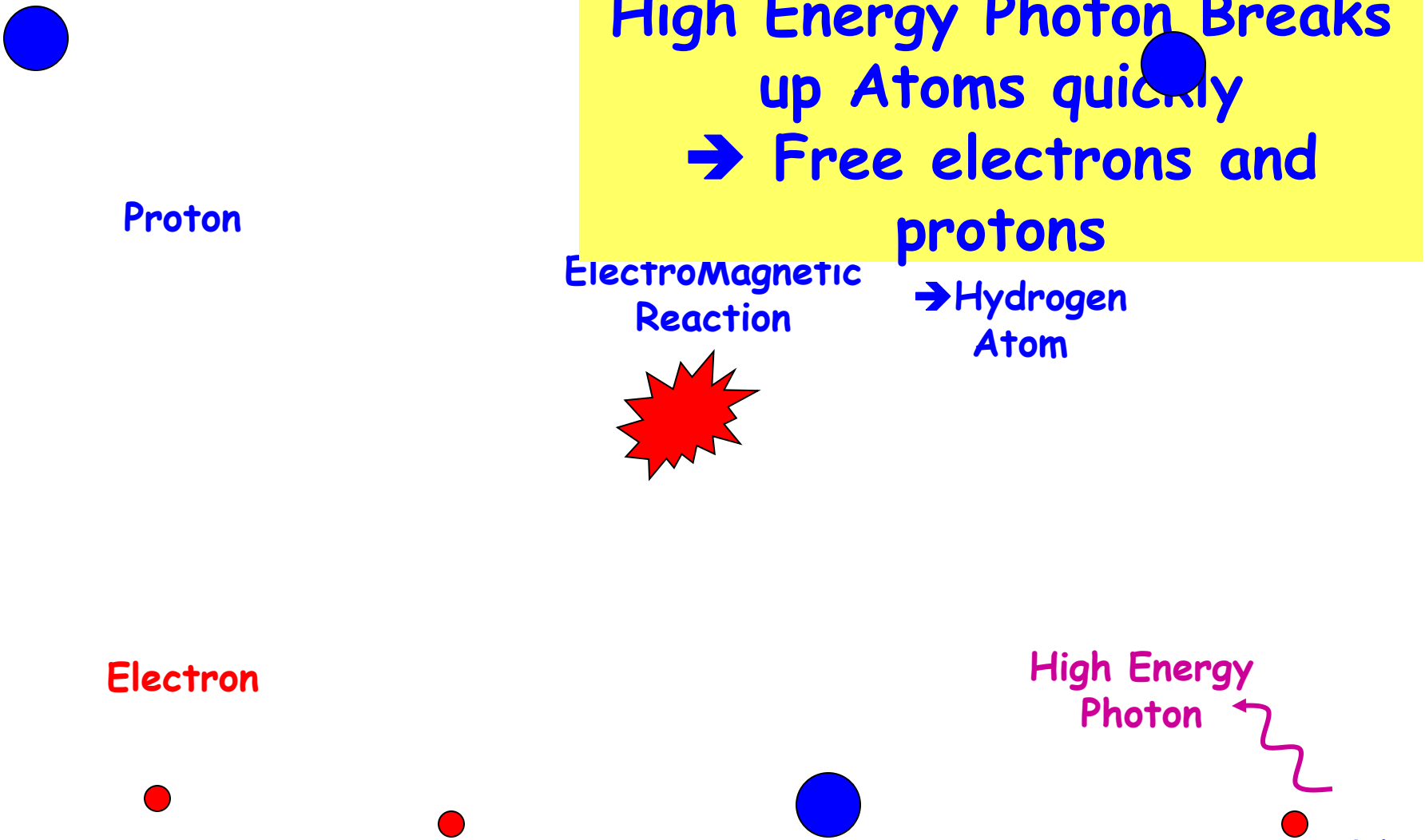
What is the evidence for the Big Bang?

Unit 4: Evolution of the Universe

Ch. 13: The Early Universe
Ch. 14: After The First Three Minutes

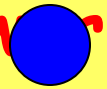
- *A Brief History of Time*
- What's going in the Universe is basically about what happens as the temperature drops
- Photons get less energetic, on average, and can't bust stuff apart
  - 10^{-6} sec: Can't bust apart Protons
  - 3 Minutes: Can't bust apart heavy nuclei
  - 300K years: Can't bust apart atoms

Atoms in the Early Universe



Atoms at Lower Temperatures

Proton



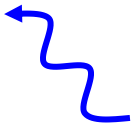
At these lower temperatures photons can't easily break up atoms

ElectroMagnetic Reaction

➔Hydrogen Atom

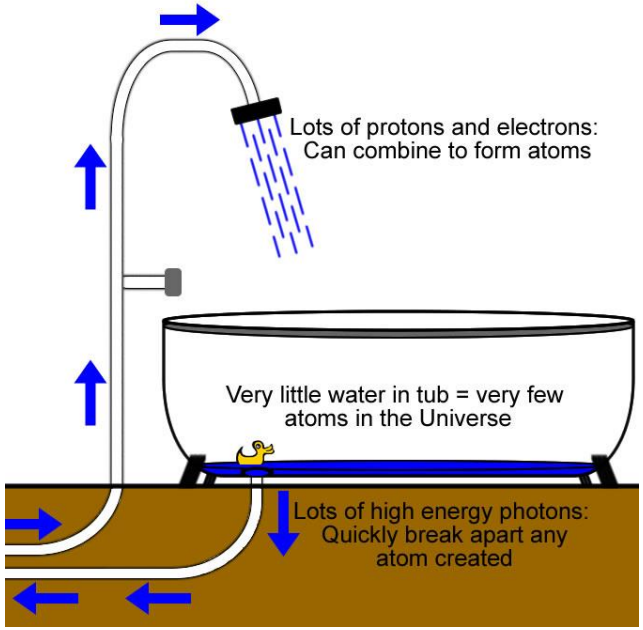
Electron

Photon

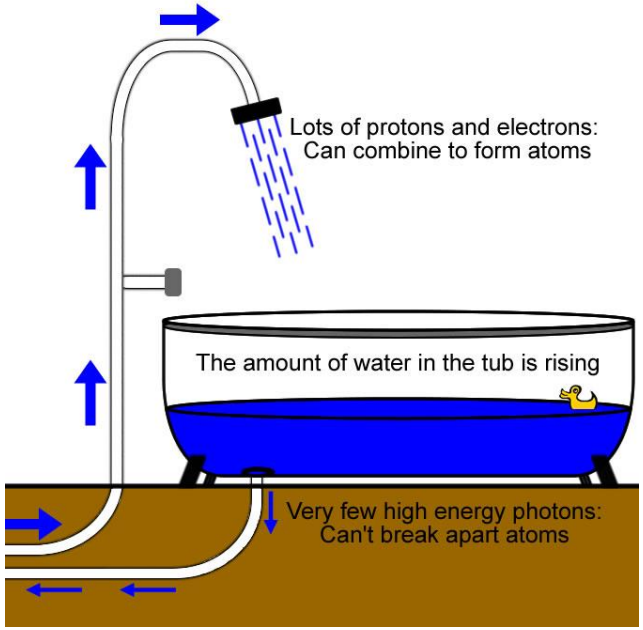


Atoms in the Universe

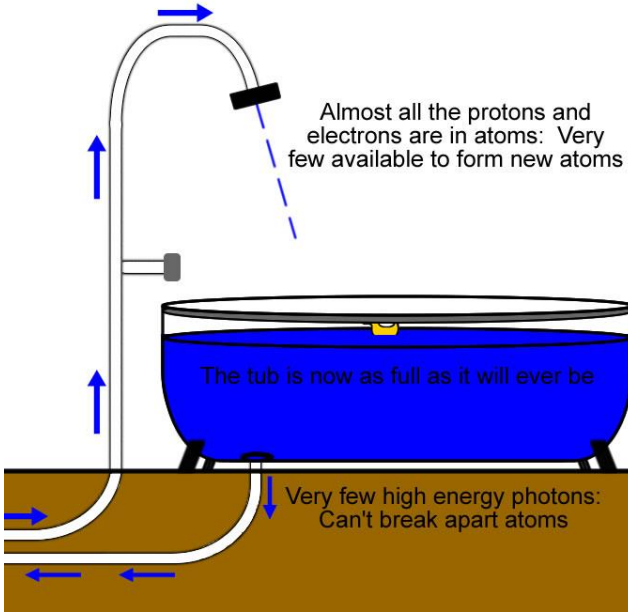
Early Universe



A Couple hundred Thousand Years Later



These days



Unit 5: Big Objects and Black Holes

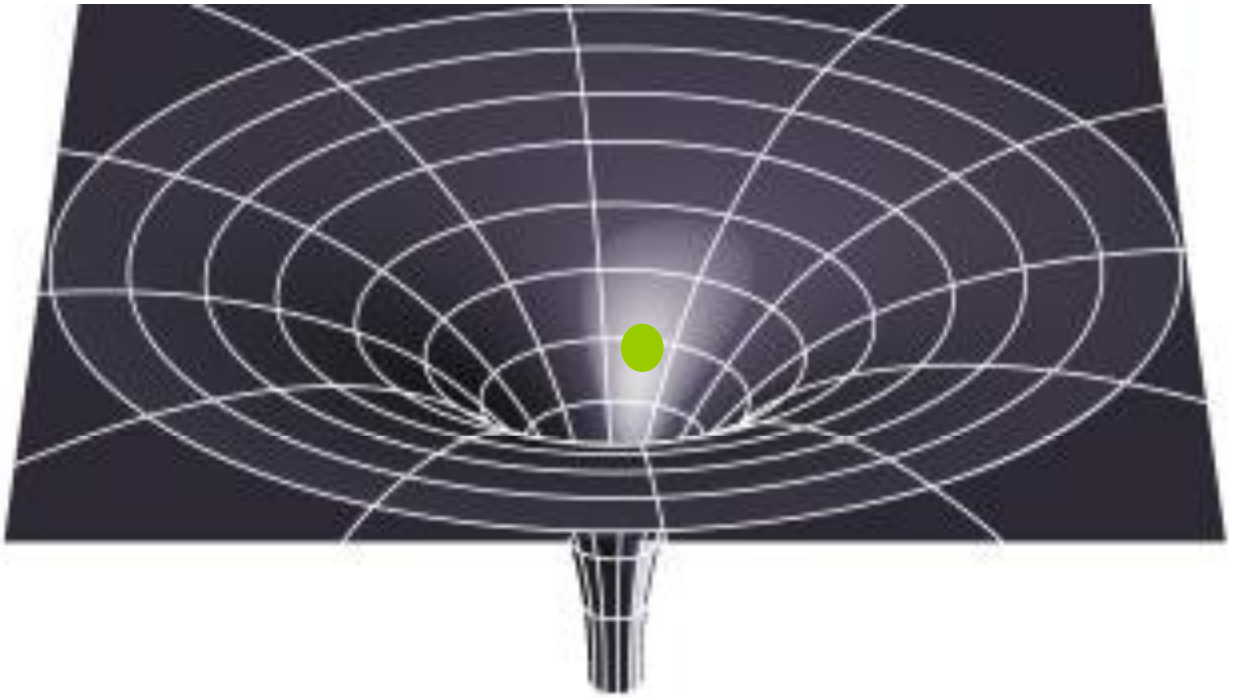
Ch. 15: Galaxy Formation
Ch. 16: Stars
Ch. 17: Black Hole Formation and Properties

- From a Billion years after the Bang until today
- Galaxies, Stars and (some) planets basically form the same way
- The life and death of different kinds of stars → A black hole is just a "kind of star"
- *What is a Black Hole? How is it created? What are some of the cool things about it?*

An Astronaut Near a Black Hole

Light falls in and never comes back

The same thing is true for our Astronaut



Short Paper 3

- *Why should we not be worried about high energy collisions at the LHC producing a Black Hole?*

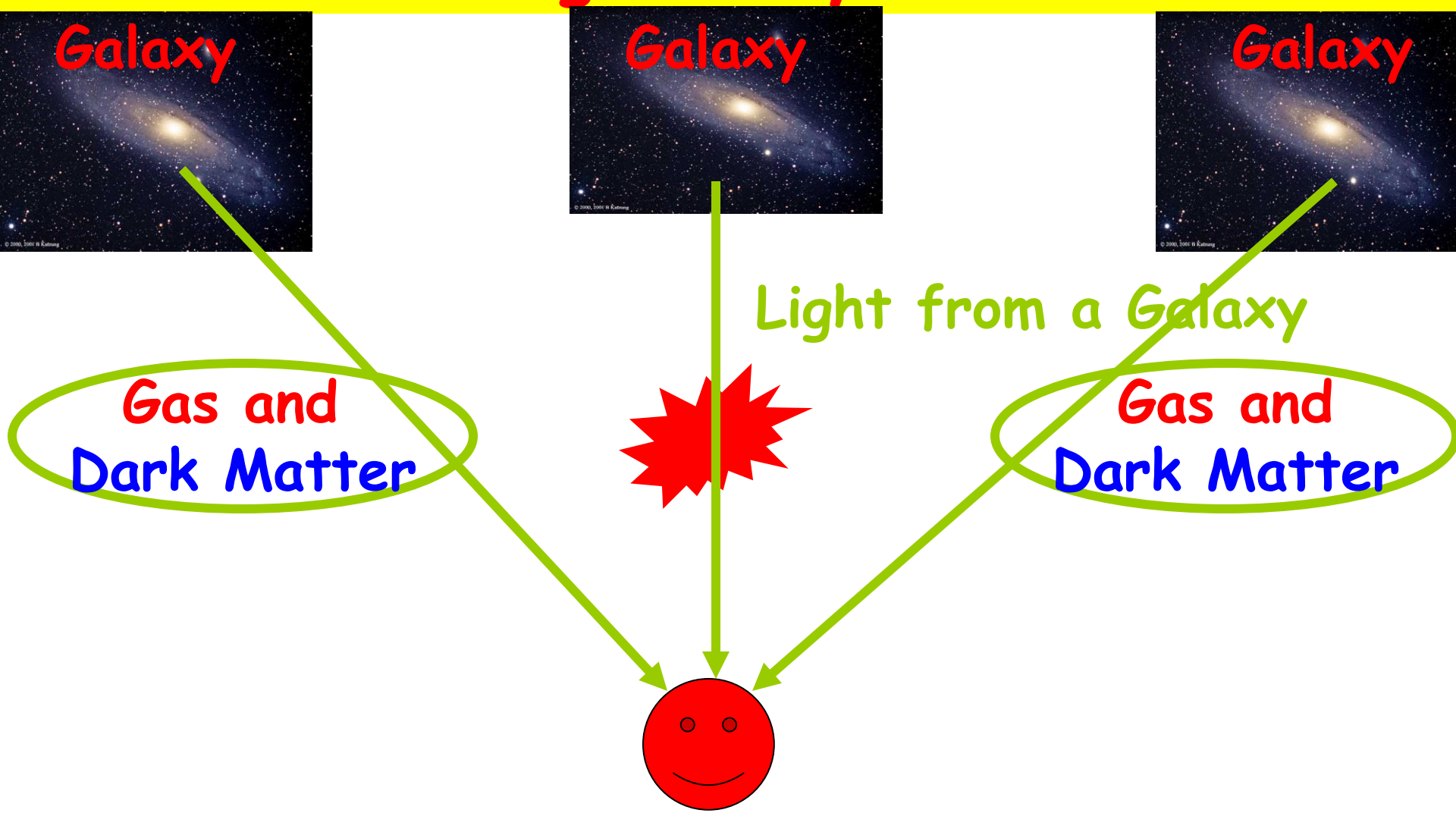
Unit 6: Early Times and the Fate of the Universe

Ch. 18: Possible Fates of the Universe
Ch. 19: Dark Matter
Ch. 20: Particle Physics
Ch. 21: Inflation
Ch. 22: Dark Energy

This is essentially the rest of the topics we/they care about most

- *What happened before 10^{-6} sec?*
- *Will the Universe expand forever? Why or why not? Big Crunch?*
- *What is Dark Matter and what is it's role in cosmology?*
  - Evidence
- *Is it a particle? Might it all be tied together?*
- *What is Dark Energy and how does it tie in?*
  - Evidence

Fun Evidence for Dark Matter as Particles
Colliding Galaxy Cluster

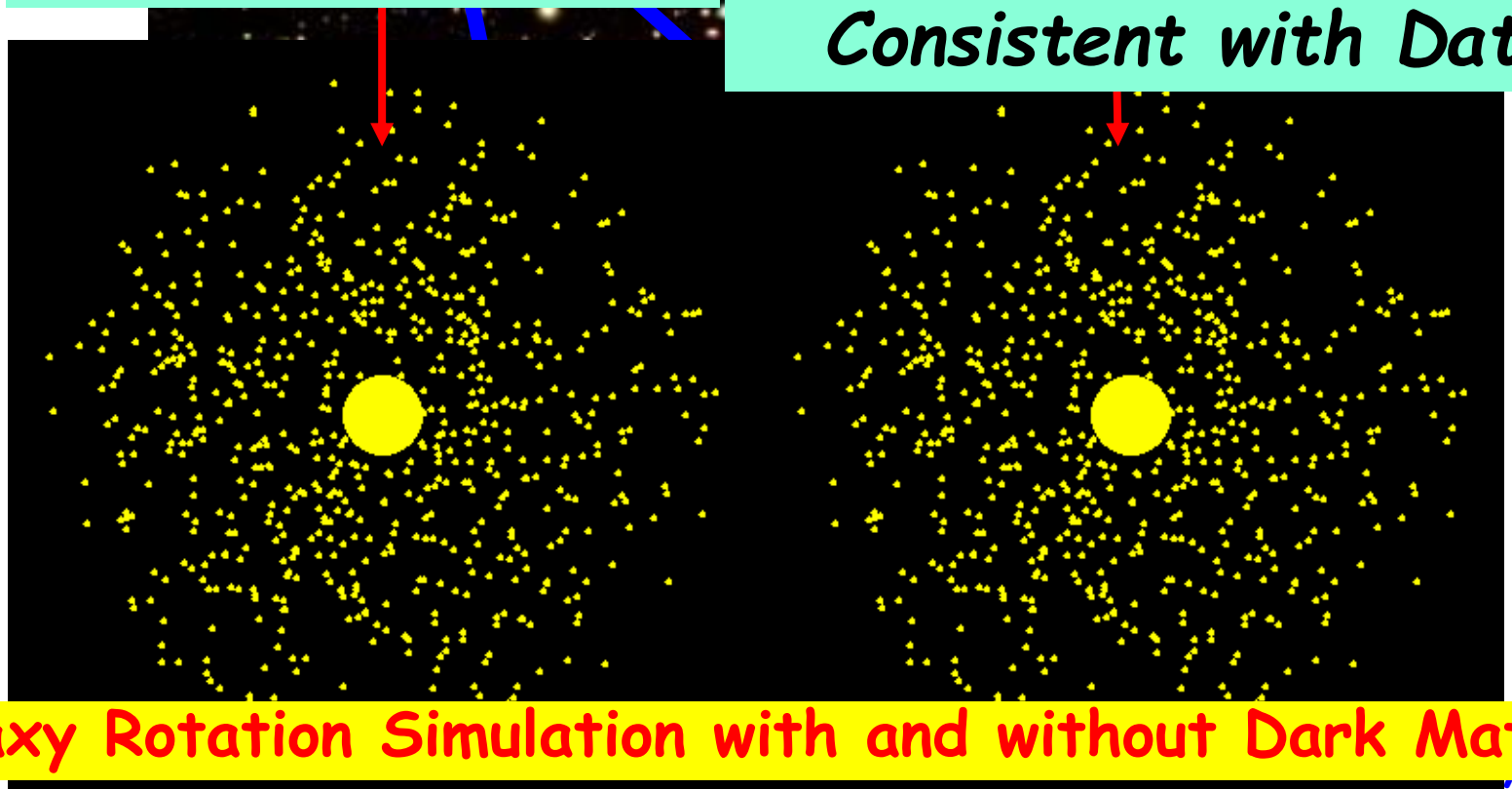


Blue (Dark Matter) is the mass as measured by gravitational lensing:
Pass through → Weakly I

Red part from x-ray observations
Slowed→Particles with Standard Model

Simulation without Dark Matter

Simulation with Dark Matter
Consistent with Data



Galaxy Rotation Simulation with and without Dark Matter

Short Paper 4

How could the discovery of Supersymmetry help us understand the Universe (Dark Matter Paper)?

More on How the Course is Run

Textbooks

- *Big Bang, Black Holes, No Math (Toback)*
  - *Under contract with Johns Hopkins University*
  - *Doing requested revisions*
- *Briefer History of Time* (Hawking)
- *Theory of Everything* (Hawking)
- *Stephen Hawking's Universe* (Filkin)
- *The First Three Minutes* (Weinberg)

"B

Grades

The course grade is:

1. In-class quizzes which are designed to stimulate discussion and test lecture preparation assignments: 15%
2. Papers: Four short papers (20% each)
3. eLearning quizzes: 5%

No in-class exams or final

eLearning Quizzes

For each Unit there is a test bank of questions in eLearning

Questions are designed to help remind/teach them of some of the concepts and facts that they need for the course

"Bad news:"

- To pass the course need to get a ***perfect score on all of them***

"Good news:'

- I allow them to take as many attempts as they want until they get a perfect score

Small fraction of the grade. Just rescales the overall class mean

Class Time

- I expect them to be alive and engaged during the class
  - Interactive Engagement
  - I ask THEM to answer lots of questions
- Required to do the reading *BEFORE* lecture
- Ready to be discuss and write about the ideas

"In-Class" Quizzes

- There are in-class quizzes
- Usually the are required to write down questions they have about the chapter reading before class or during discussions
  - Graded
  - Tell them that higher quality work means I'll make the quizzes easier
  - If they don't do the reading or listen during class I give quizzes on "*what did we discuss last time?*"
- Specially designed handout that describes how all this is graded

More on the Papers

Short and sweet

- *Can you tell the story in two pages?*
- *Can you explain it to your Senator?*
- *George Mitchell?*
- *Governor Perry?*
  - None of these people have taken the class (no jargon)

Grading is all based on well prepared rubrics

Course Status and Future Plans

- Still learning and improving
- Textbook will be published soon
- Future plans and Goals
  - Bigger enrollment
  - Calibrated Peer Review for lots of papers
  - Need a lab
  - Coordinate with 101 as a Tier 1 course

"Bi


End of Lecture

http://bigbang.physics.tamu.edu/

Unit 1: *Introduction*

Ch. 1: Introduction
Ch. 2: Going Big
Ch. 3: Going small
Ch. 4: History and the Scientific Method

Unit 2: *Physics We Need*

Ch. 5: Light and Doppler Shifts
Ch. 6: Gravity
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Unit 3: *Why We Believe in the Big Bang*

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Papers (part 1)

Two Short Papers (2 pages each, no jargon, written for Senators to read)

Short Paper 1: *What is the evidence that stars are made of atoms?*

Short Paper 2: *What is the evidence for the Big Bang?*

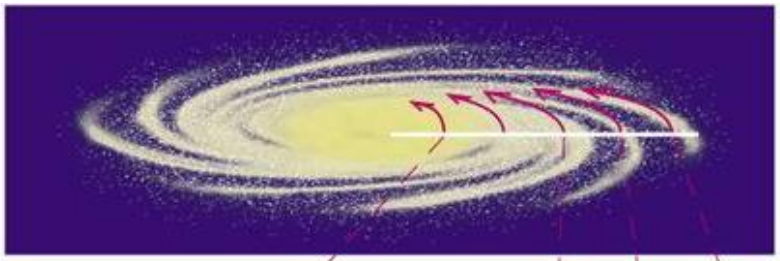
Papers, Part 2

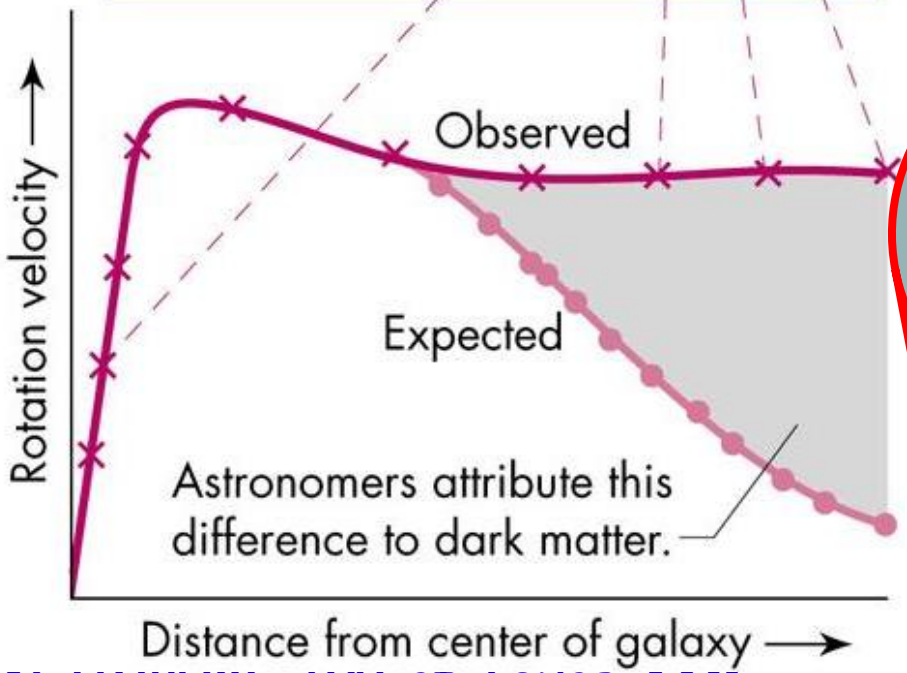
Two Options

- **Research Paper**
  - Pick a topic beyond what is presented in class, learn more about it and write it up in 5 pages
    - Will probably keep this option for honors students only in the future
- **Two More Short Papers**
  - *Why shouldn't we be worried about the creation of Black Holes at the LHC?*
  - *How could the discovery of Supersymmetry help us understand the Universe (Dark Matter Paper)?*

Dark Matter in Astronomy and Cosmology

Galaxy Rotation Data





Cosmic Microwave Background Data from WMAP