

Big Bang, Black Holes, No Math

ASTR/PHYS 109

Dr. David Toback
Lecture 7

Prep For Today (is now due) - L7

- Reading:
 - BBBHNM Unit 2
- Pre-Lecture Reading Questions
 - eCampus quizzes (all 6)
 - Unit 1 Revision (if needed): Stage 1 due date postponed until Monday
 - Let us know if you were misgraded
 - Unit 2: Stage 1
- End-of-Chapter Quizzes
 - Chapter 4

Next Set of Topics: Physics We Need

Finished our introduction

- Big and small things in the Universe
- Evidence and the Scientific Method

Next we move on learn some of the physics we need in order to understand why scientists have confidence in the Big Bang Theory

Overview of Physics We Need

- Cosmology, the big bang and black holes are some of the most interesting things that can be understood
- However, to UNDERSTAND them better, and the EVIDENCE for them, we need to learn some physics

The Topics

- Some stuff we need learn a little about:
 1. Light and Doppler Shifts
 2. Gravity, General Relativity and Dark Matter
 3. Atomic Physics and Quantum Mechanics
 4. Nuclear Physics and Chemistry
 5. Temperature and Thermal Equilibrium
- We won't spend too long on each, just enough to get back to the big picture...
- Since there is no perfect way to present them (they all tie into each other) we'll just start somewhere and get going...

Back to the Big Picture

Questions we're trying to answer:

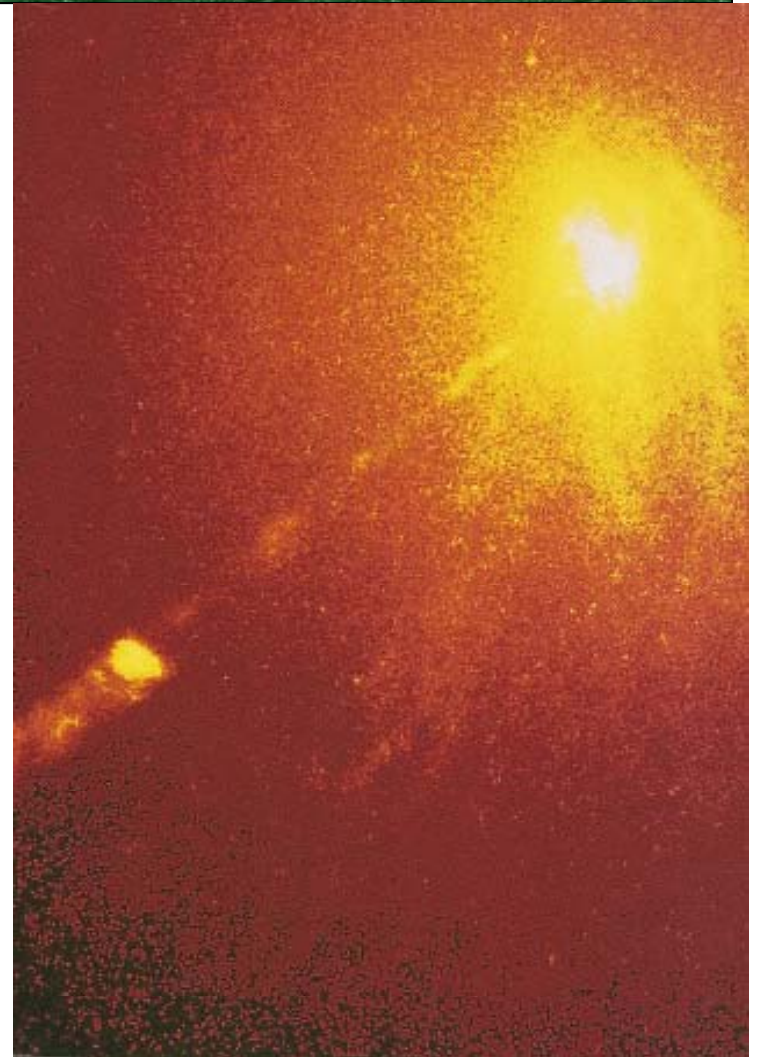
- *How did the Universe come into being?*
- *How did it evolve into what we know today?*
- *What is the evidence for all of this?*

Light

What we know about
the universe comes
from multiple places

One of the most
important is from
looking at both outer
space and inner
space

Need to know more
about the "*light we
see*"



Outline for Light

1. Light is a wave...
2. ...and a particle
3. Light is REALLY fast,
but does have a finite
speed
4. Doppler effect

Part 1: Light is a Wave

- The light we see is a "wave", like waves on an ocean
- Best described by it's wavelength

Wavelength



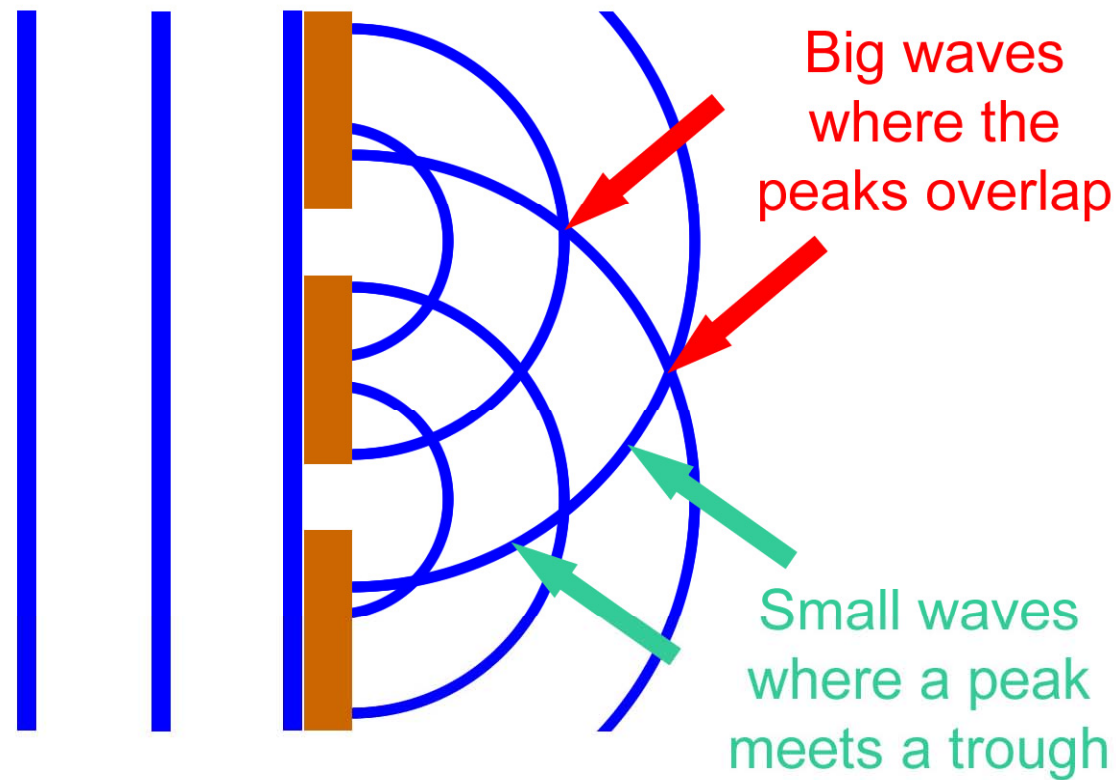
Big Bar
Holes,

Why do we believe light is a wave?

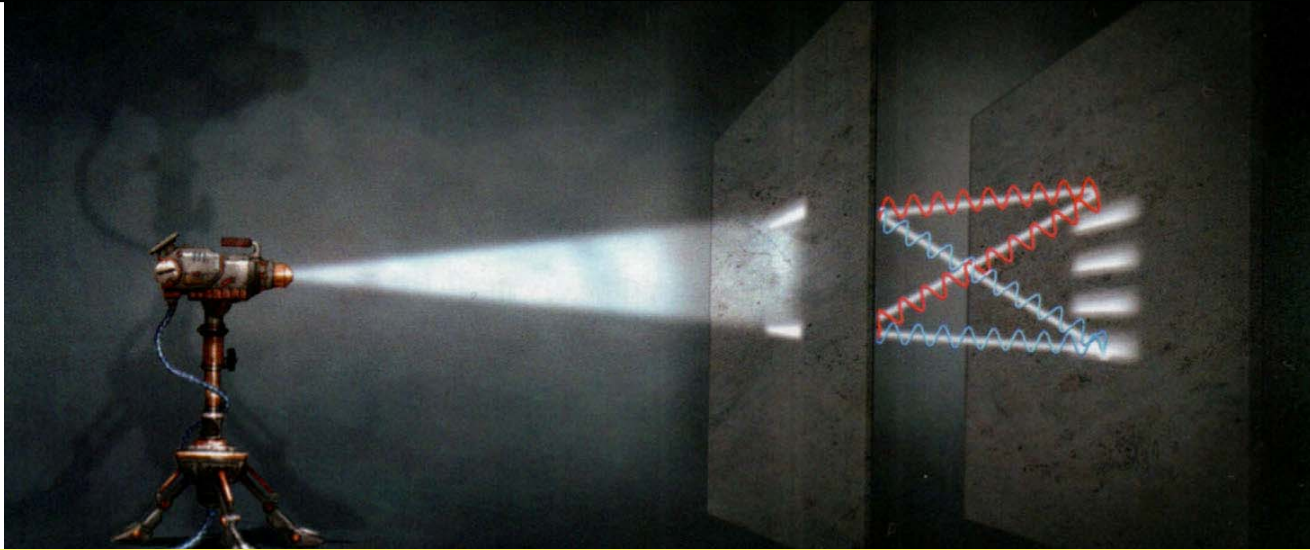
- Water and Sound are also both waves
 - *Does light behave like water or sound?*
- Can “see” water waves hitting a wall and what happens to them when they hit **two small openings in a wall**

Water waves moving towards a wall

You are
in the
sky
looking
down at
the
waves
as they
go by



Why do we believe light is a wave?



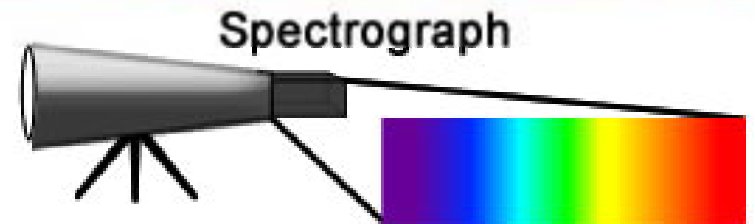
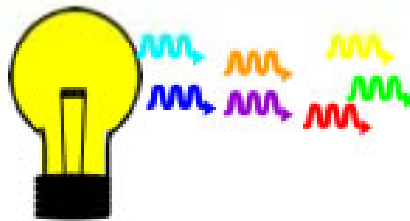
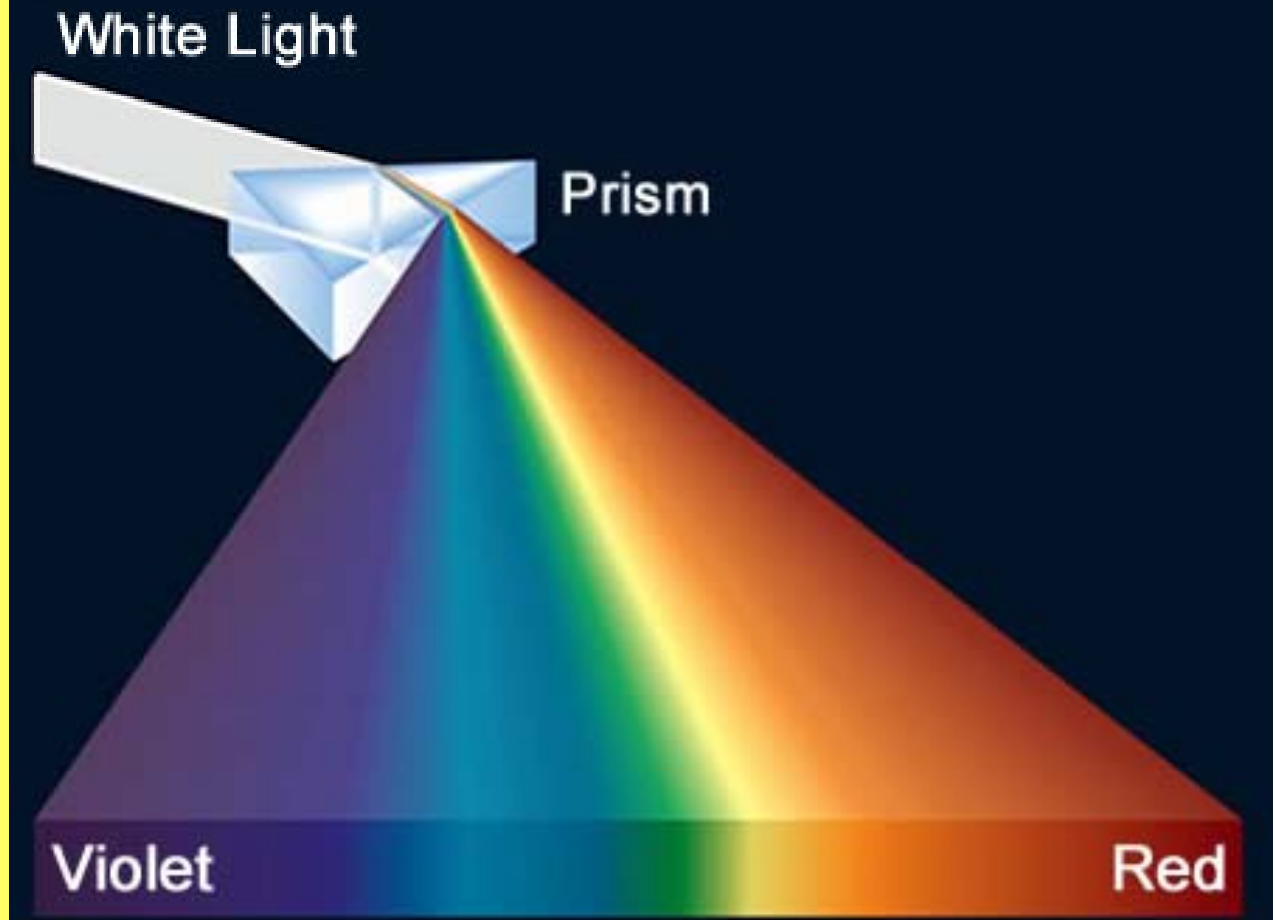
Shine light from a laser at two small holes in a wall and see what comes out on the wall behind it

The waves make patterns on the wall the same way water waves do

(Physics 202 & 208)

The Wavelength of Light

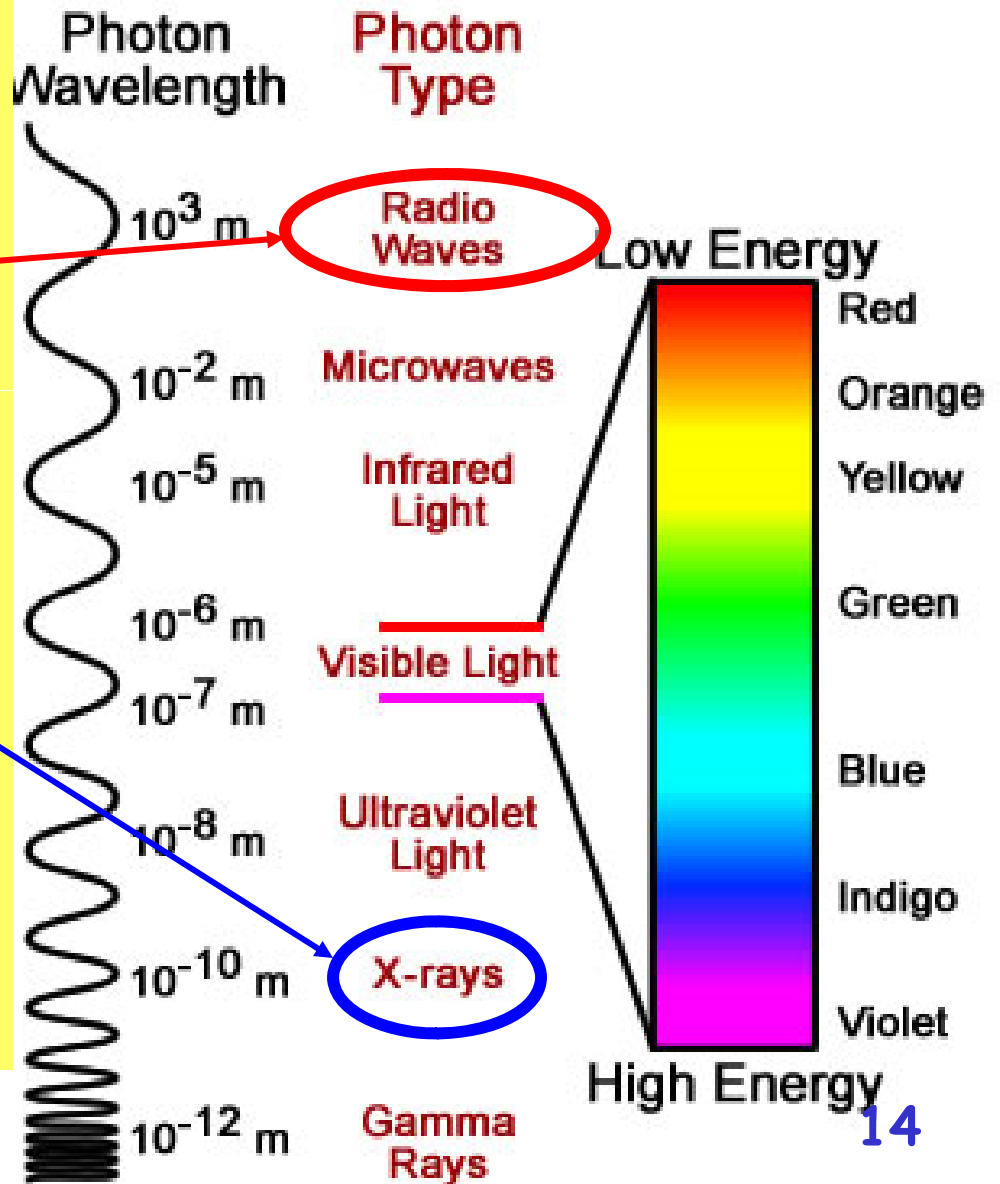
- Shine white light at a prism and it breaks up into its different colors
- Each color has a different wavelength which we can measure



Big Bang, Black
Holes, No Math Top

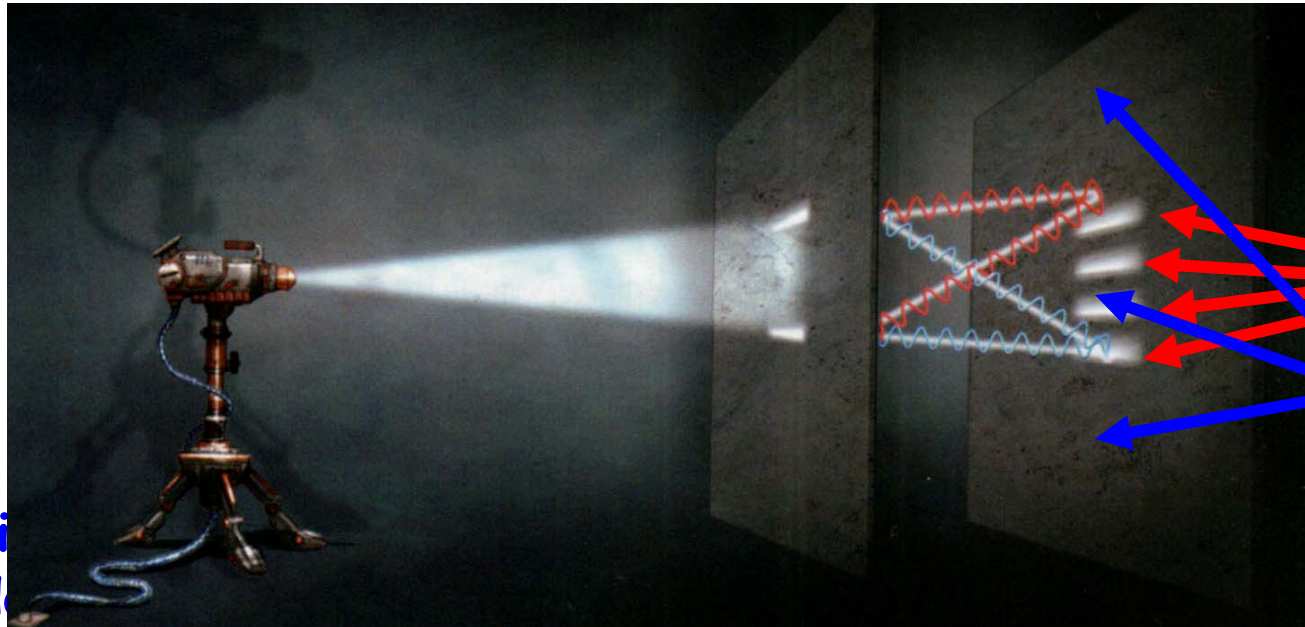
Light is more than the colors we see

You may have thought of **Radio Waves** and **X-rays** as different things, but they are just light with different wavelengths



Part 2: Light is a particle

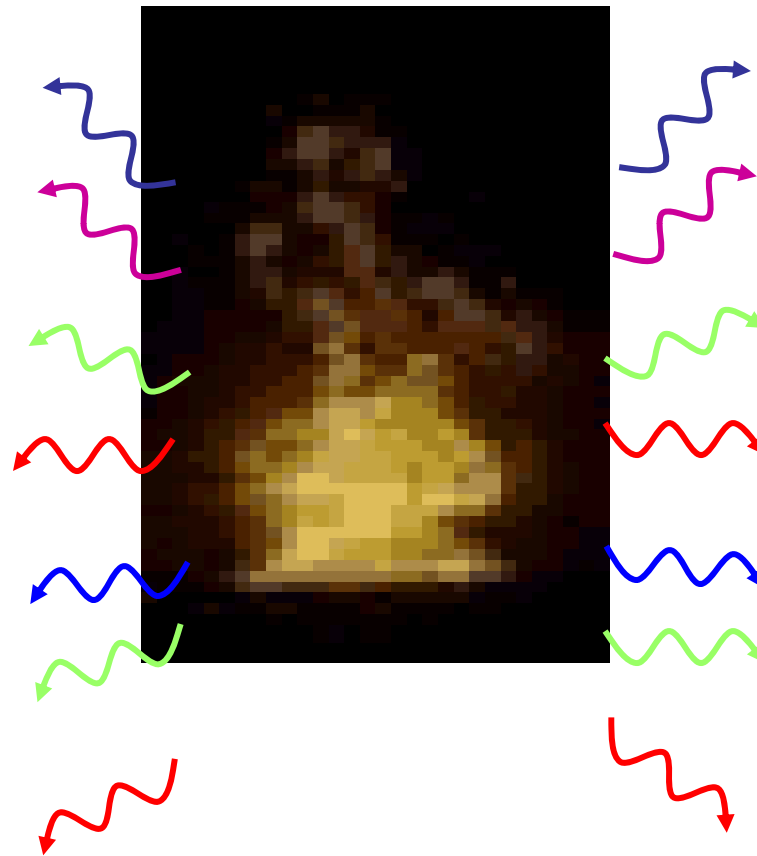
- *What if we look at smaller and smaller "amounts" of light?*
- The light we see is actually LOTS of particles all moving together
- Call these Photons



Lots of
photons where
its bright

Very few
photons where
its dark

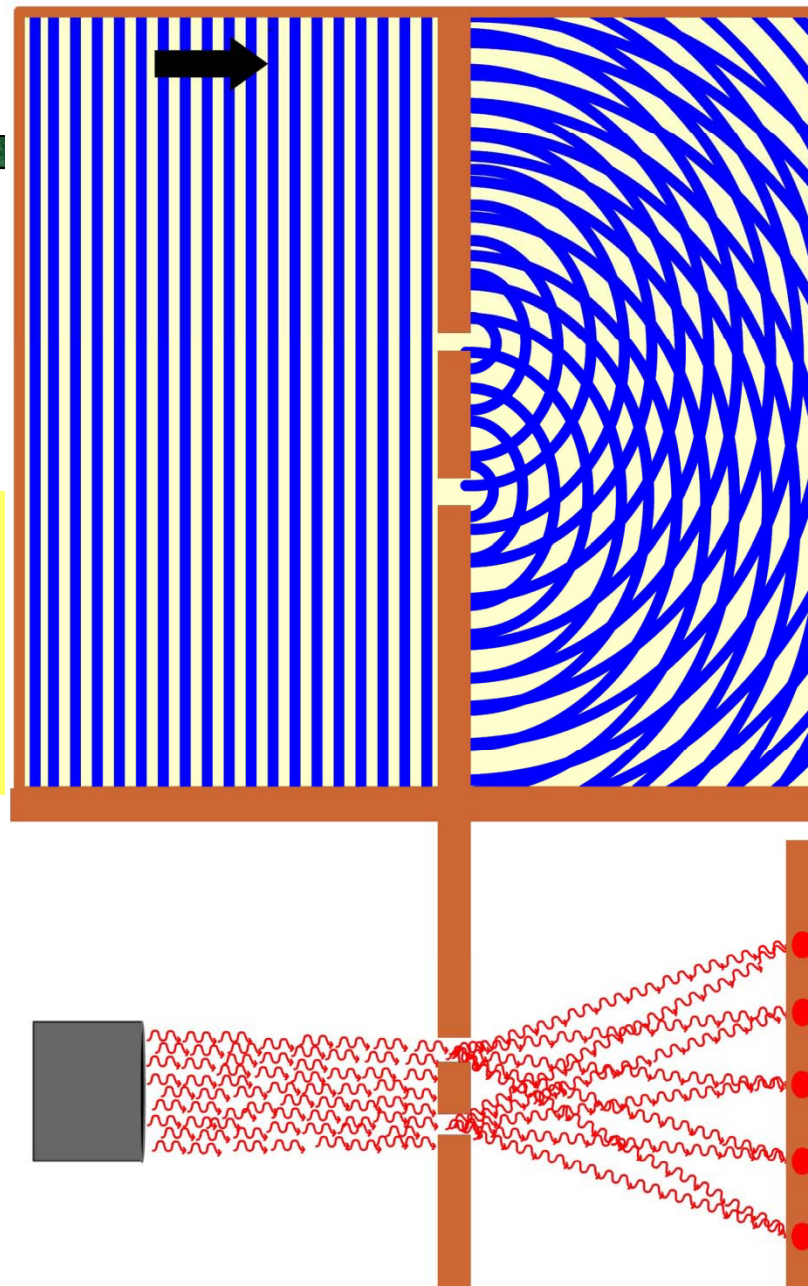
White Light = Lots of Different Color Photons



Waves move this way



Another
view...



Big waves
where the
peaks overlap

Small waves
where a peak
meets a trough

Lots of photons
where it is bright

Very few
photons where
it is dark

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Topic 1: Light and Doppler Shifts

The Energy of Particles

We can think about Energy in many ways

- One way is the “energy of motion”
 - Kinetic Energy in the language of PHYS 201 and 218
- For a particle (with mass) in motion:
 - The higher the speed the particle has, the more energy it has
 - The more mass the particle has (the heavier it is) the more energy it has

Clicker Question for Energy

Which has more energy? (Which will do more damage to a tree?)

1. *A) A Prius moving at 10mi/hr or
B) An SUV at 10mi/hr?*
2. *A) An SUV moving at 10mi/hr or
B) An SUV moving with 60mi/hr?*
3. *A) A Prius moving at 60mi/hr or
B) An SUV moving at 10mi/hr?
C) Depends on the masses of the
Prius and the SUV*

Photons

What do we know about photons?

- Photons are a type of particle
 - Like an electron or proton
- Higher energy → smaller wavelength
- Has no mass, but does have energy
 - Aside for those of you who are interested: It has momentum

A Particle and a Wave

- Actually it's really more complicated than that
- Light is both a wave and a particle... can describe it as either... it has properties of both

Part 3: The Speed of Light



*"Not just
a good
idea,
it's the
law!"*

d

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Light has a Finite Speed

Light has been measured to have a specific speed

- 3×10^8 meters per second
- 186,000 miles per second
- 1 foot per nanosecond
- Really FAST
- The fastest speed allowed

Maxwell's Theory

- 1865: James Clerk Maxwell and others showed light was a wave and calculated its expected speed
- Gave the observed speed of light!
 - Confidence that his theories were correct
 - We can now measure the speed of light to incredible precision

$2.99792458 \times 10^8 \text{ m/s}$



A Light-Year

- Some things are so far away that it's easier to express their distance in light-years
 - Light travels at 3×10^8 meters/second and there are $\pi \times 10^7$ seconds/year \rightarrow $\sim 10^{16}$ m in a light-year

Time Machine

- The Sun is 8 light-minutes away, so we are seeing the Sun as it was 8 minute **AGO**
- If a star is a light-year away and it must have taken a year for the light to get to us, we are observing the star the way it was a year ago
- If we look at light from something billions of light-years away, we are “observing” things that happened billions of years ago

Prep For Next Time - L7

- **Reading:**
 - (BBBHNM Unit 2)
- **Pre-Lecture Reading Questions**
 - eCampus quizzes (all 6)
 - Unit 1 Revision (if needed): Stage 1
 - Let us know if you were misgraded
 - Unit 2: Stage 2
- **End-of-Chapter Quizzes**
 - If we finished Chapter 5 then End-of-Chapter Quiz 5 (else just Chapter 4)