Physics 310/610
Extragalactic Astronomy and Cosmology

Introduction

Am I in the Right Place?

Eric Carlson
"Eric"
"Professor Carlson"
Olin 306
OH: Mon, – Fri 11:30–12:45
or by appointment
Office: 336-758-4994
Cell: 336-407-6528
ecarlson@wfu.edu

Topics Covered:
- Galaxies
- The Universe

Everyone Pick Up:
- Syllabus
- 2 homework passes

Who are you?
https://forms.gle/ozpuEpgHCrX39ovR7

http://users.wfu.edu/ecarlson/cosmo2

Dr. Carlson's Schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
8:00					
9:00					
10:00		research		research	
11:00					
12:00	office hours	office hours	office hours	office hours	office hours
1:00	PHY 310/610		PHY 310/610		PHY 310/610
2:00	PHY 215		PHY 215		PHY 215
3:00	research		research		research
4:00	research		research	free food colloquium	
5:00					

- Come to any office hours
- Any free time can also be arranged by email, text, or phone call

Materials

- Texts:
  - "Galaxies in the Universe," 2nd edition by Sparks and Gallagher, available online for free from the library
  - Introduction to Cosmology, 2nd edition, by Ryden
- Scientific Calculator
- Metric Ruler
- *Maple* or similar program
- Laptop

https://ebookcentral.proquest.com/lib/wfu/reader.action?docID=307061

The Web

http://users.wfu.edu/ecarlson/cosmo2

Numerous materials can be found on web for this course:

- Link to the textbook
- Reading assignments
- Homework assignments
  - And solutions
- Handouts:
  - Units
  - Syllabus
  - Math Review
- Lecture slides
- Recorded lectures

Class Attendance and Seating

- Attendance is expected every day
- More than two unexcused absences count against your grade
- If you have an advance excuse, contact me (email)
- If you are ill, call/e-mail me OR bring Doctor's note

Class Participation

Class participation is 10% of your grade

- Ask lots of questions
- Answer my questions
- You will be called on

Homework

- About 1-3 problems per homework set
- Due on Wednesdays and Fridays
- Getting help is encouraged
  - Ask a friend
  - Ask me
  - Don't copy – this is an honors code violation
- Clarity counts
- Keep track of units
- Pay some attention to significant figures!
- Twice per semester, you may delay turning in your homework by one class day by using a homework pass

Homework:
- Homework A by Friday

Sample Problem 0.1

The gravitational acceleration on the surface of the Earth is $g = 9.80$ m/s^2. What is this in c/y?

$$g = 9.80\ \text{m/s}^2 \cdot \frac{c}{2.998\times10^8\ \text{m/s}} \cdot \frac{3.156\times10^7\ \text{s}}{\text{y}} = 1.031\ c/\text{y}$$

Exams

- Midterm and a final
  - Midterm, possibly evening of October 9, 7-9 pm
  - Final Wednesday Dec. 10, 2-5 pm

- Honors code violations will be turned in to the honor council
  - Normally, penalty is 1-term suspension and an irreplaceable F in the course

- Combination of computation and essay questions

Dotted Red Line – Easily derived from other formulas

Solid Red Line – Memorize this formula

Other colors – not on test

Dashed Red Line – Know how to use it

Grades

Percentage Breakdown:	
Homework	40%
Class Part.	10%
Midterm	20%
Final	30%

- Little if any curving
- Do not allow extra credit

Grade Assigned	
94% A	73% C
90% A-	70% C-
87% B+	67% D+
83% B	63% D
80% B-	60% D-
77% C+	<60% F

Pandemic Plans

- If there is a catastrophic closing of the university, we will attempt to continue the class
- Probably via **Zoom Link**

http://users.wfu.edu/ecarlson/cosmo2
ecarlson@wfu.edu
Cell: 336-407-6528

Units

Astronomy involves such large and small quantities that SI units are often inconvenient

Angles:

- A circle contains 2π rad or 360 degrees
- An *arc-minute* (′) is 1/60 of a degree
- An *arc-second* (″) is 1/60 of an arc-minute
- A *milli-arc-second* (mas) is 10^{-3} arc-second

$$2\pi \text{ rad} = 360^\circ$$
$$1' = \tfrac{1}{60}^\circ$$
$$1'' = \tfrac{1}{60}'$$
$$1 \text{ mas} = \tfrac{1}{1000}''$$

$$1 \text{ Å} = 10^{-10} \text{ m}$$

Distance:

- The Angstrom is sometimes used for wavelength
- The Astronomical Unit or AU is the (path averaged) distance between the Sun and the Earth
- The *light-year* (ly) is the distance that light goes in a year
  - Rarely used by real astronomers
- The *parsec* (pc) is defined in terms of the AU

$$1 \text{ AU} = 1.496 \times 10^{11} \text{ m}$$

$$1 \text{ pc} = \frac{1 \text{ rad}}{1''} \text{ AU}$$

$$1 \text{ pc} = 3.086 \times 10^{16} \text{ m} = 3.262 \text{ ly}$$

More Units

Energy:

- Electron volts (eV) and metric multiples used for individual particles

$1\ \text{eV} = 1.602 \times 10^{-19}\ \text{J}$

keV = 10^3 eV
MeV = 10^6 eV
GeV = 10^9 eV

Time:

- Days and Years are commonly used
- And metric multiples of years

$1\ \text{d} = 86{,}400\ \text{s}$

$1\ \text{y} = 3.156 \times 10^7\ \text{s}$

ky = 10^3 y
My = 10^6 y
Gy = 10^9 y

Temperature:

$k_B = 1.381 \times 10^{-23}\ \text{J/K} = 8.671 \times 10^{-5}\ \text{eV/K}$

- Normally in Kelvin (K)
  - Room temperature is 300 K
- For high temperatures, we will often give $k_B T$, where k_B is Boltzmann's constant.
  - Typical thermal energy is about 1-3 $k_B T$.

Solar Units: ⊙

- Stars and galaxies often compared to the Sun

$R_\odot = 6.957 \times 10^8\ \text{m}$

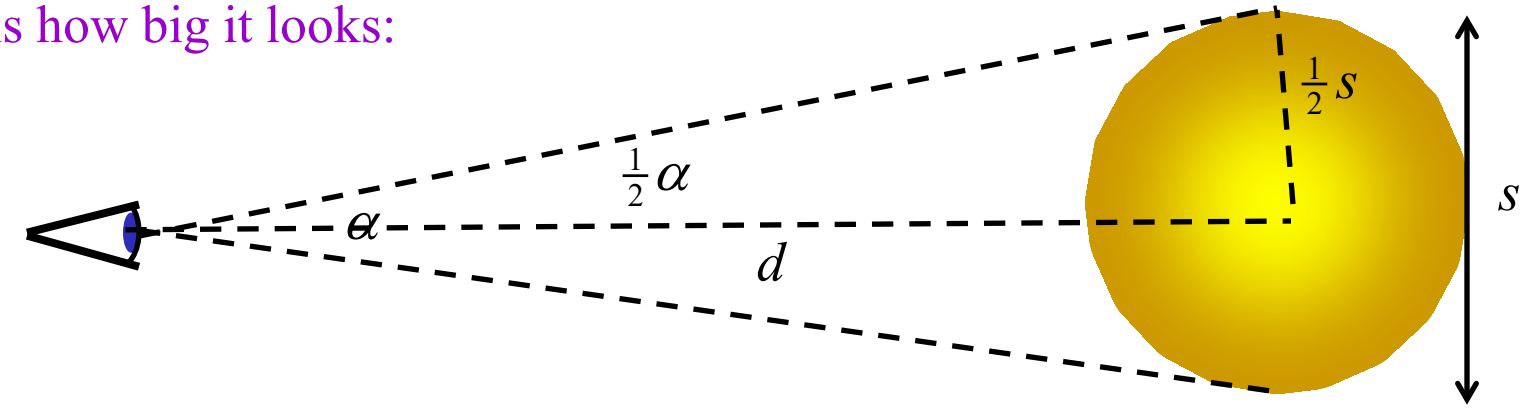
$M_\odot = 1.988 \times 10^{30}\ \text{kg}$

$L_\odot = 3.828 \times 10^{26}\ \text{W}$

$T_\odot = 5772\ \text{K}$

Angular Size and Small Angles

- The actual size of an object is how big it is:
- The angular size is how big it looks:

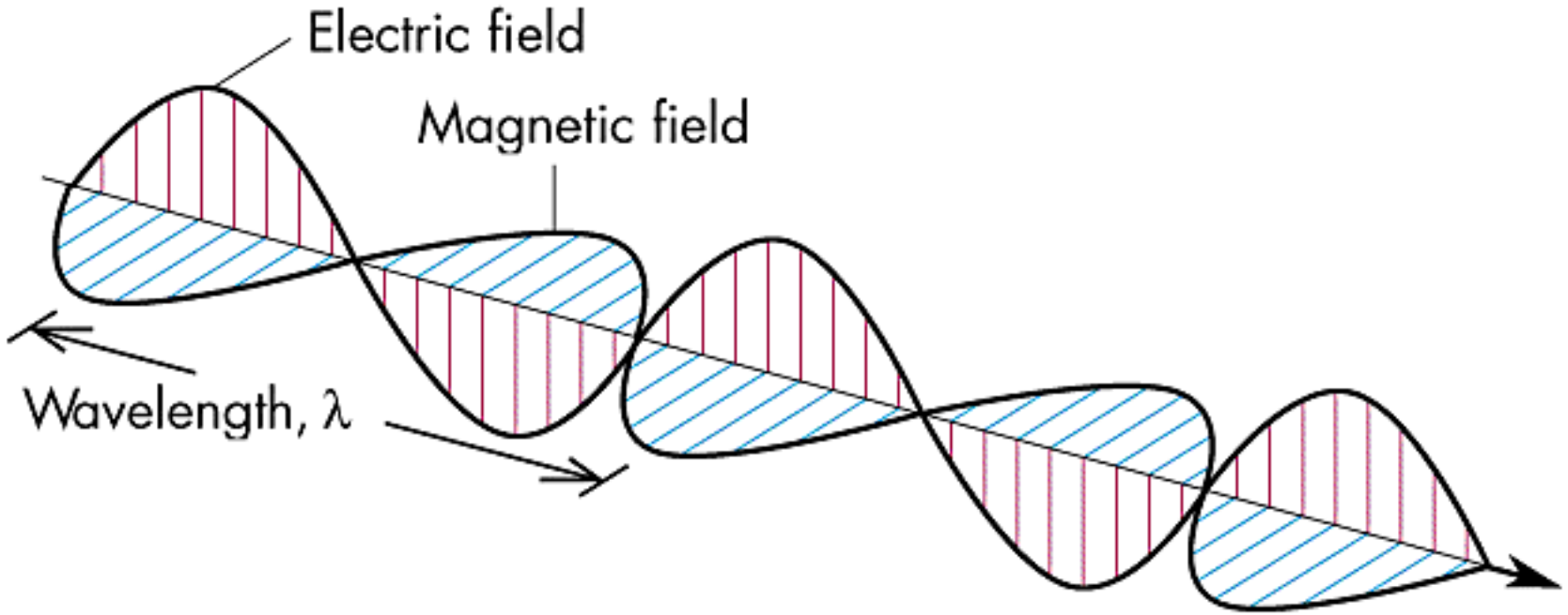


- These are related through the distance
- Sketch a right triangle as shown
- Then we have $\sin\left(\frac{1}{2}\alpha\right) = \frac{\frac{1}{2}s}{d}$
- Using the small angle approximation, we have $\sin(\theta) \approx \theta$
- So we have $\frac{1}{2}\alpha = \frac{\frac{1}{2}s}{d}$

$$\boxed{\alpha = \frac{s}{d}}$$

Physics "Review"

Electromagnetic Waves

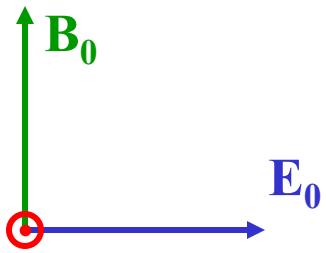


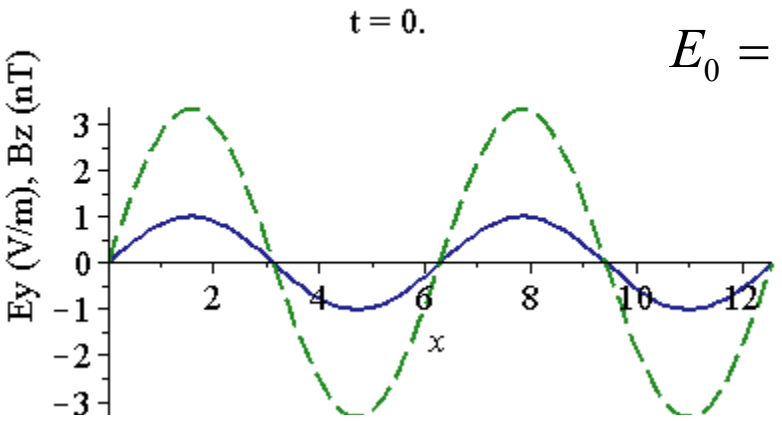
- More than 99% of what we know about the universe comes from observing electromagnetic waves

Wave Equations Summarized

- Waves look like:
- Related by: $\omega = ck$
- Two independent solutions to these equations:

$$\mathbf{E}(x,y,z,t) = \mathbf{E}_0 \sin(kx - \omega t)$$
$$\mathbf{B}(x,y,z,t) = \mathbf{B}_0 \sin(kx - \omega t)$$



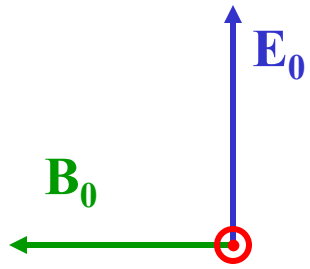


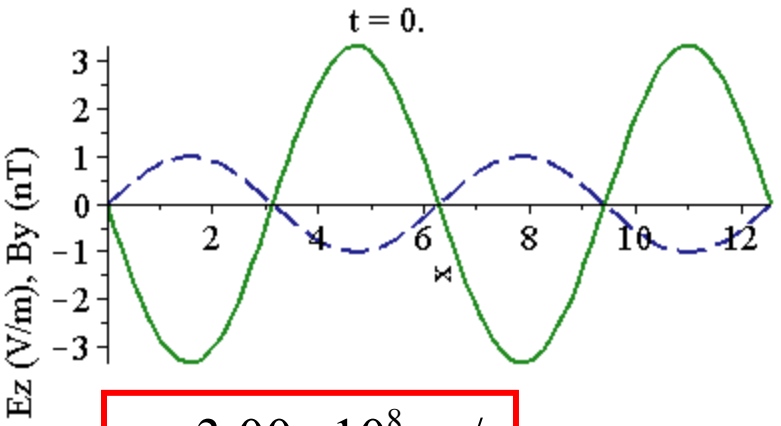
$$E_0 = cB_0$$

$$E_{y0} = cB_{z0}$$

or

$$E_{z0} = -cE_{y0}$$





$c = 3.00 \times 10^8$ m/s

- Note that **E**, **B**, and direction of travel are all mutually perpendicular
- The two solutions are called *polarizations*
- We describe polarization by telling which way **E**-field points

This page stolen from PHY 114

Frequency and Wavelength

- The quantity *k* is called the *wave number*
- The wave repeats in time
- It also repeats in space

$$\mathbf{E} = \mathbf{E}_0 \sin(kx - \omega t)$$

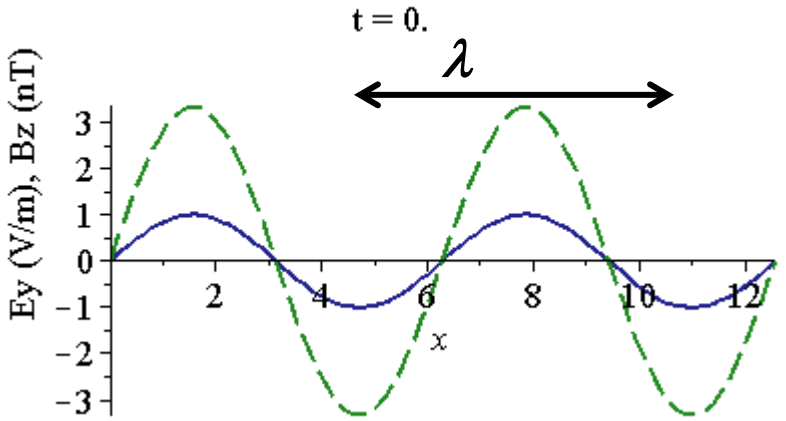
$$\mathbf{B} = \mathbf{B}_0 \sin(kx - \omega t)$$

$$\nu = 1/T$$

$$\omega = 2\pi\nu$$

$$\omega = ck$$

$$k\lambda = 2\pi$$



- EM waves most commonly described in terms of frequency or wavelength

$$c = \frac{\omega}{k} = 2\pi\nu\frac{\lambda}{2\pi}$$

$$c = \lambda\nu$$

Note that in *this class*, frequency is denoted by ν, not by f

The Electromagnetic Spectrum

- Different types of waves are classified by their frequency (or wavelength)

$c = \lambda \nu$

- Boundaries are arbitrary and overlap
- Visible is 380-740 nm

λ Increasing

f Increasing

Radio Waves
Microwaves
Infrared
Visible
Ultraviolet
X-rays
Gamma Rays

Know these, in order

These too

Not these

This page stolen from PHY 114

Photons and Quantum Mechanics

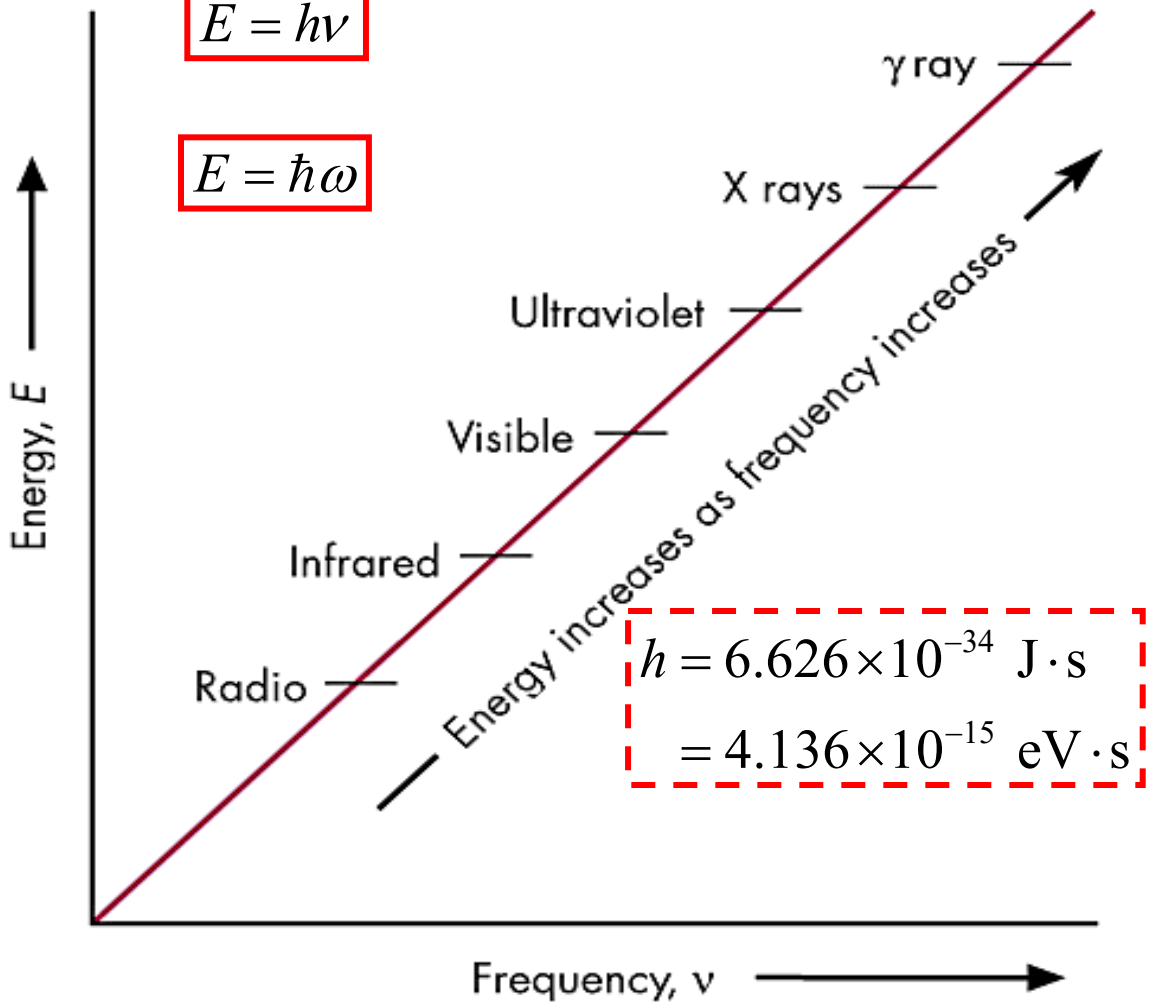
- Classically, a wave can have any amount of energy, from 0 to ∞
- But in quantum mechanics, it comes in packets whose energy is proportional to their frequency
- h is called Planck's constant
- Can also be written in terms of $\hbar$, the *reduced Planck constant*, and the angular frequency

$$\hbar = 1.055\times10^{-34}\ \text{J}\cdot\text{s} = 6.582\times10^{-16}\ \text{eV}\cdot\text{s}$$

- The individual packets of energy are called *photons*

$$E = h\nu$$

$$E = \hbar\omega$$



$$h = 6.626\times10^{-34}\ \text{J}\cdot\text{s} = 4.136\times10^{-15}\ \text{eV}\cdot\text{s}$$