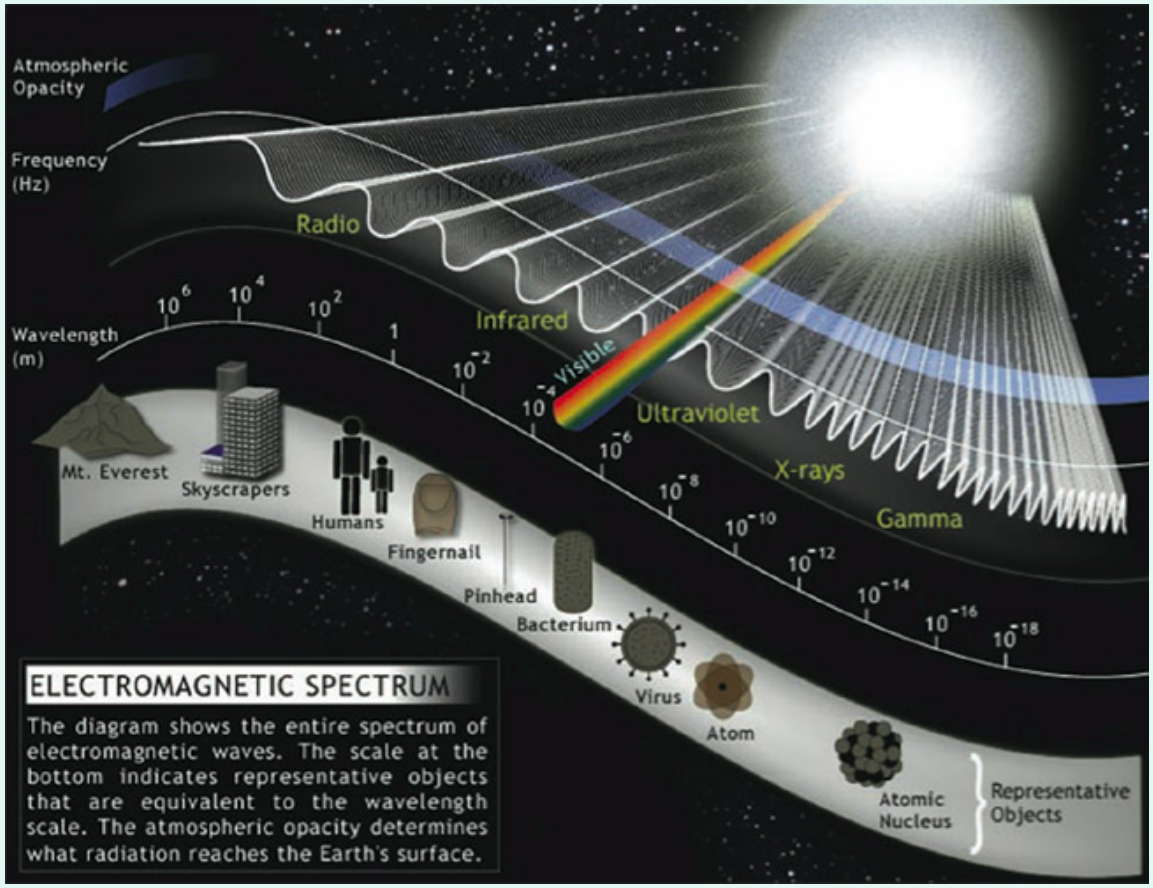
Astronomy 120

www.astro.yale.edu/astro120



Prof. Jeff Kenney

Class 3

May 30, 2018

Class website

main site:
www.astro.yale.edu/astro120

but most things also on canvas

textbook

- ***Universe*** (Freedman, Geller, Kaufmann) 10th edition
- E-book recommended (LaunchPad)
- website has link
- “hardcopies” (used, looseleaf) at Yale bookstore or through Amazon (10th or 9th or 8th editions are OK)

On-line Reading quizzes

→ Important to read textbook before class!

→Must complete by 12noon the day of the class!

Accessed from Canvas, “Quizzes”, “RQ Lxx” is the Reading Quiz for Lecture #xx

Homeworks

- ~2x weekly
- 1st HW due *this Wed May 30*
- 2nd HW due *this Fri June 1*

Help!?

TUTORING:

All hours are drop in. No appointments required

QR/SC Tutoring – begins Tuesday 5/29

Tuesdays, Wednesdays, Thursdays: 4:30pm-6pm (Astr, Eng, Math, Phys, Stat)

Location: SML 116C in the Center for Teaching and Learning (301 York Street)

Professor:

email jeff.kenney@yale.edu

Office Hours: by appt

astronomy is a science

but it differs from other sciences since it is a

remote, observational science

UNIVERSE SENDS US:

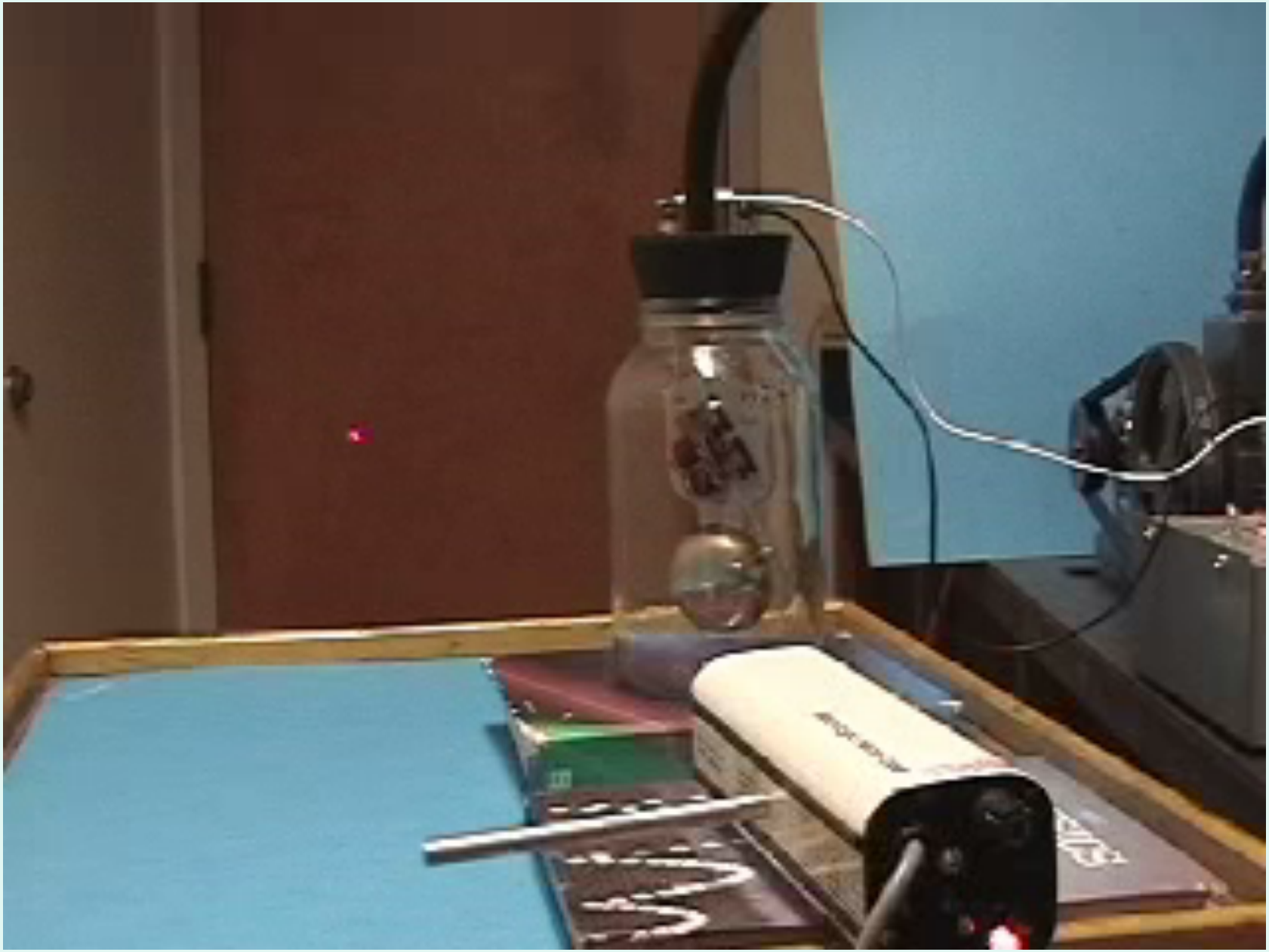
- LIGHT
- COSMIC RAYS
- NEUTRINOS
- GRAVITATIONAL WAVES

but most of the information we get at present comes from LIGHT

most of the information we get about universe comes from LIGHT

important for us to understand:

- the nature of light
- what makes light
- how light interacts with matter



LIGHT: needs no medium

- A form of energy that can travel through space without any medium/stuff/substance to carry it.

- That's a good thing – otherwise we couldn't see the universe!!

the space between the galaxies

A. is a vacuum

B. has a very low density of gas

C. has an density of gas like earth's atmosphere but the gas is ionized

D. contains some stars

E. is not very expensive

SPEED of LIGHT:

SPEED of LIGHT: high, nearly constant, same for all observers

high – nothing can travel faster (fast but not infinite)

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in vacuum:

c= $3x10^5$ km/s (or $3x10^8$ m/s)

all wavelengths travel at same speed

e.g., Blue light goes the same speed as red light

X-ray light goes same speed as IR light

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light travels a bit slower in than a vacuum &

different wavelengths move at slightly different speeds

(longer wavelengths travel at slower speeds -- this causes differential refraction)

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BUT for our purposes in this class, speed of light is nearly constant & same for all wavelengths

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same for all observers, independent of their motion?!? (special relativity)

LIGHT: waves or particles?

2 very different models of light

Waves -- electromagnetic (EM) waves (classical physics)

Particles -- photons (quantum physics)

NATURE of LIGHT: classical

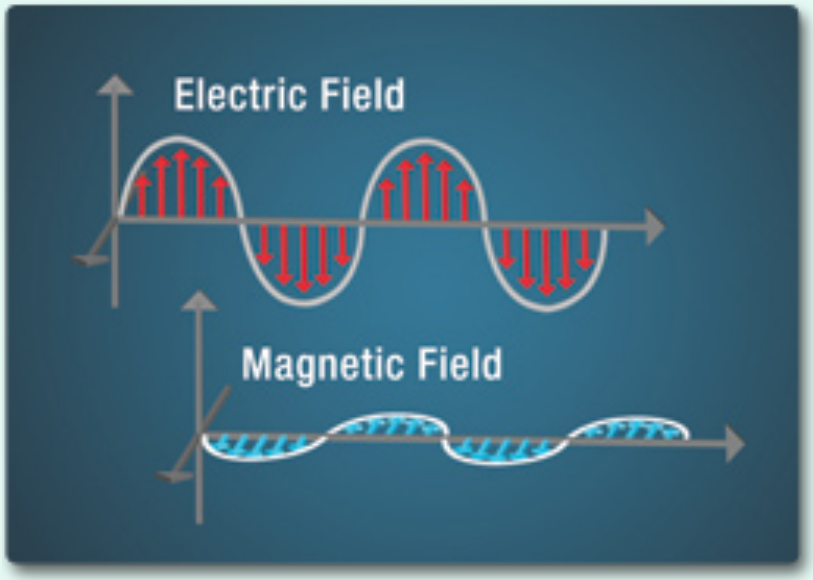
Classically, light is an electromagnetic (EM) wave with 5 fundamental properties

1.
2.
3.
4.
5.

NATURE of LIGHT: classical

Classically, light is an electromagnetic (EM) wave with 5 fundamental properties

1. speed of propagation c
2. direction of propagation
3. wavelength λ (or frequency ν)
4. polarization (E field direction)
5. intensity



classical EM wave at 1 instant of time (snapshot)

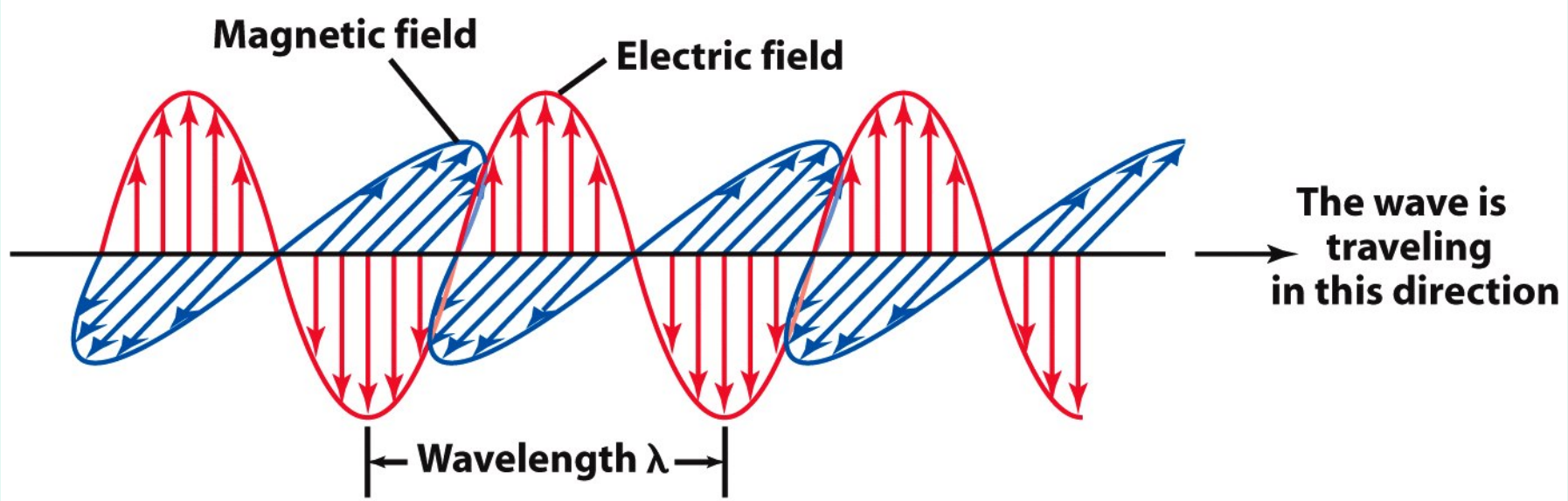
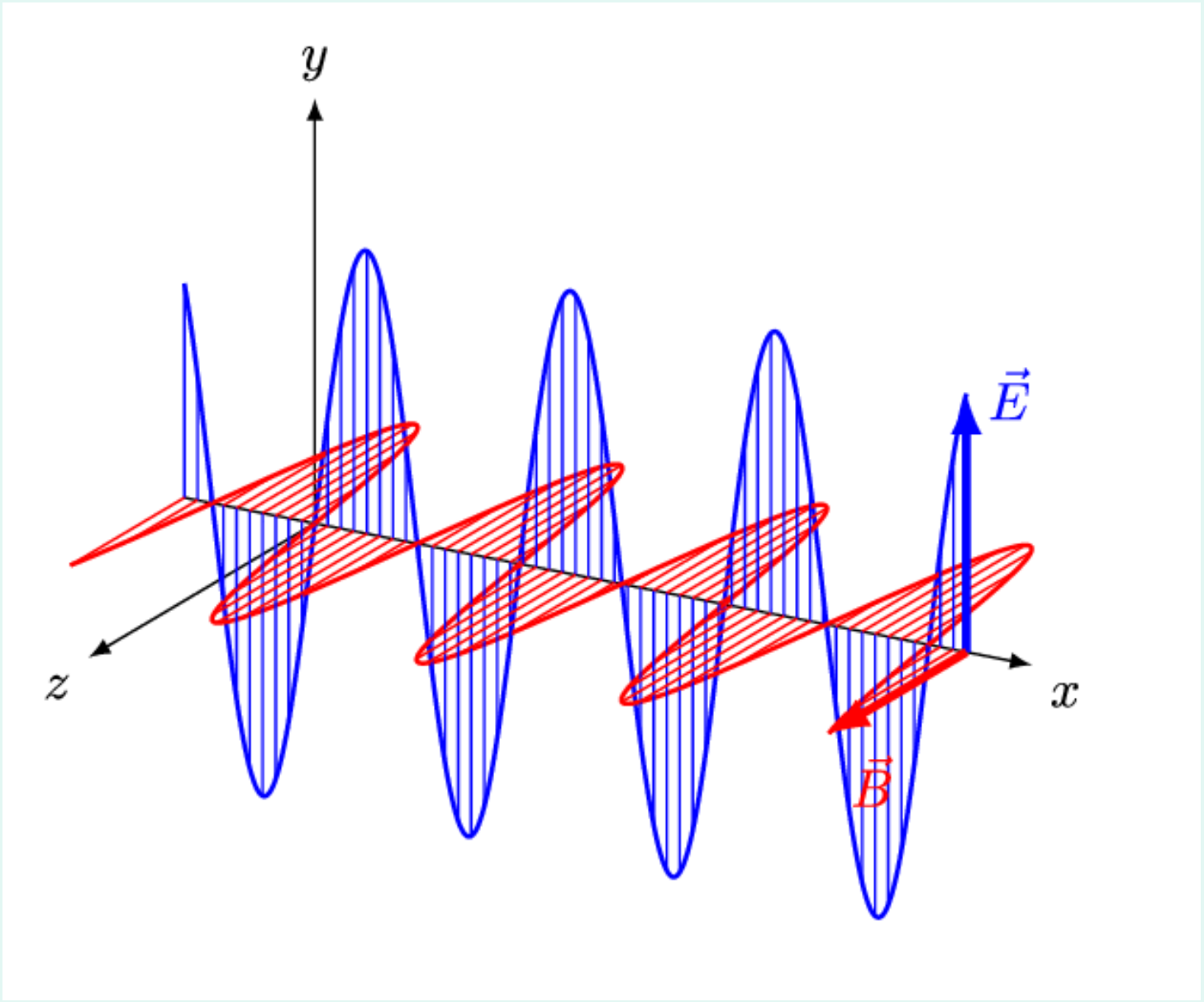


Figure 5-6
Universe, Eighth Edition


y
z
x
$\vec{E}$
$\vec{B}$

connection between wavelength & frequency

If you stand in 1 place and let EM wave pass you, the E field will make $\nu = c/\lambda$ oscillations per second (ν=frequency)

Period = P= $2\pi/\nu$

Since c=constant, either λ or ν is equally good for characterizing EM waves

In both water waves & EM waves, the energy moves outwards, but the disturbance (water molecules) moves up and down

NATURE of LIGHT: quantum

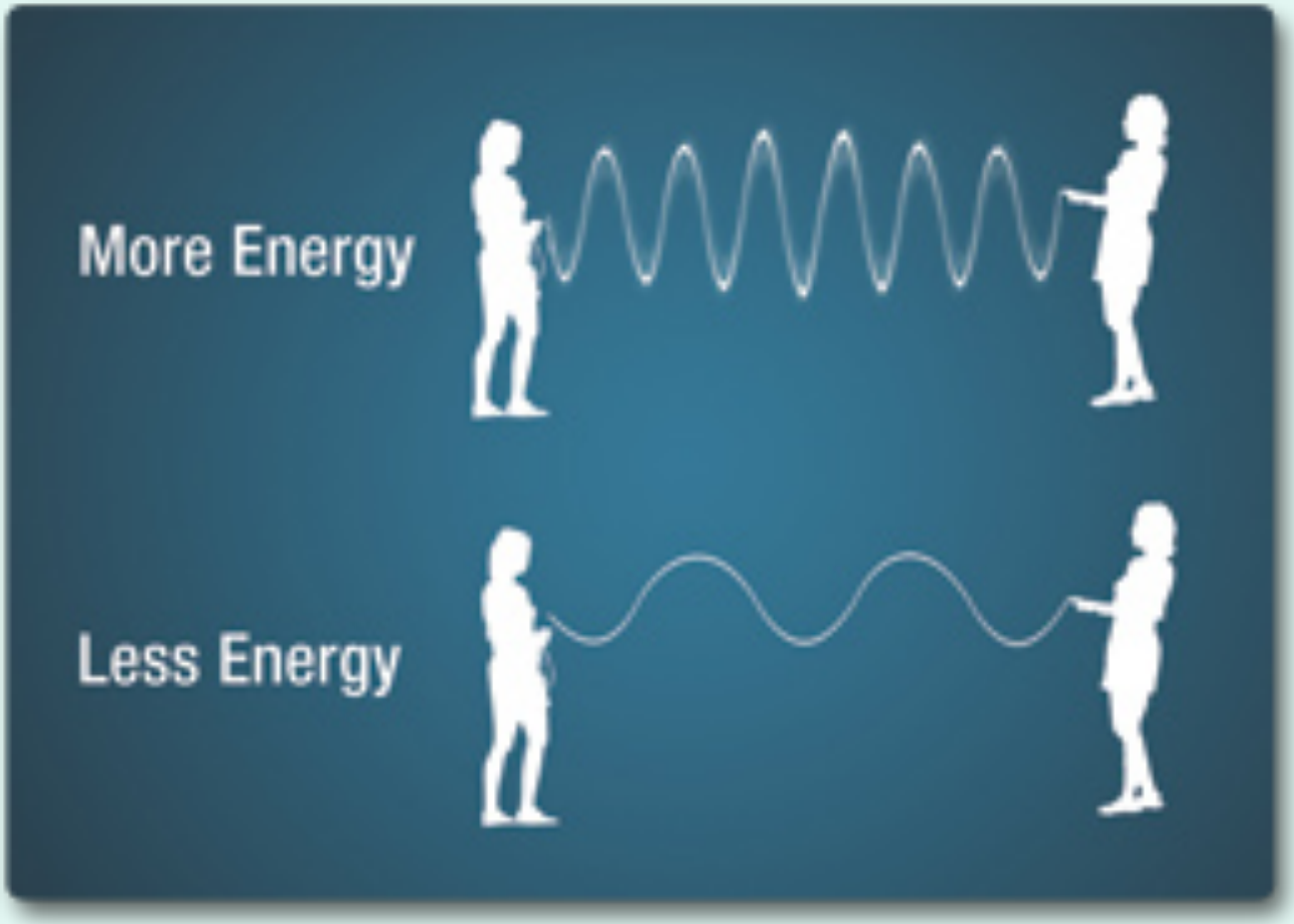
Quantum mechanically, we now know that light comes in discrete packets of energy E called photons (photon = ‘wave packet’)

In this sense, photons can be considered a ‘particle’ as well as a ‘wave.

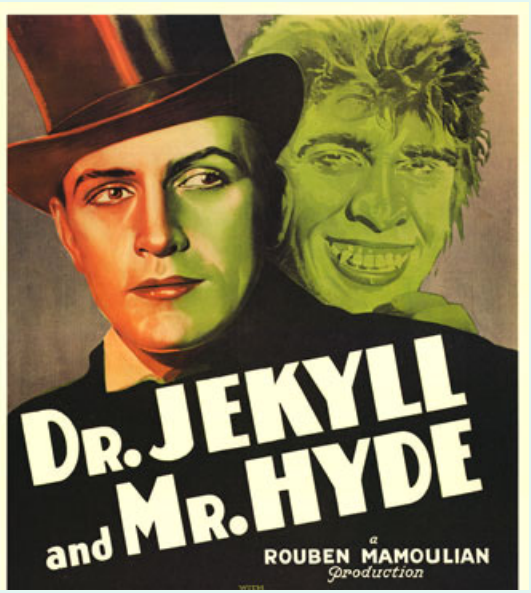
$$E = h\nu = hc/\lambda$$

h = Planck’s constant = 6.625×10^{-34} J sec

A wave with higher frequency/short wavelength has more energy



wave-particle duality of light & matter



one of the most important and surprising aspects of nature
(& described via Quantum Mechanics)

neither model is completely right

conceptual models are just analogies to permit easier understanding

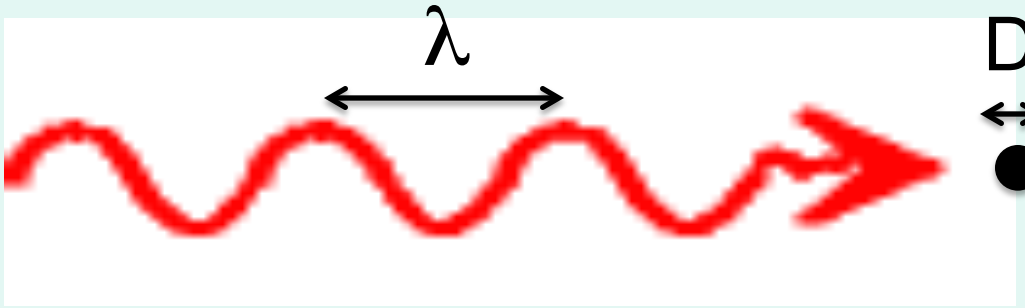
- in some experiments it acts more like a wave
- in some experiments it acts more like a particle

it depends on the size of the thing it is interacting with

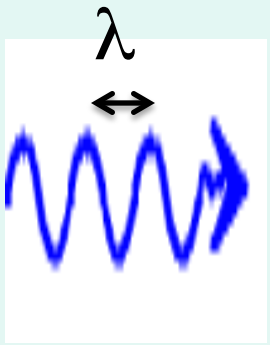
whether light acts like a wave or particle depends on the *size of the thing it is interacting with*

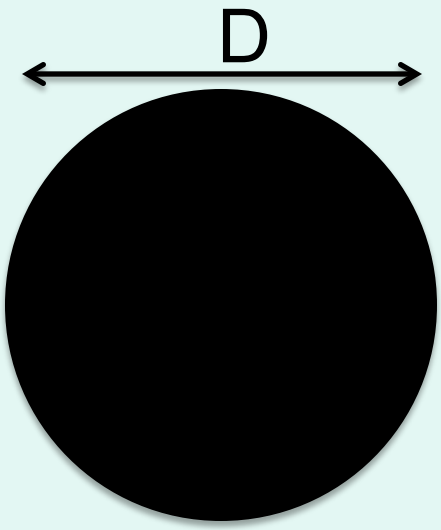
λ > D so acts like wave

if wavelength of light is larger than the thing it's interacting, it acts like a wave



if wavelength of light is smaller than the thing it's interacting, it acts like a particle





think of boat in ocean!

λ < D so acts like particle

electromagnetic spectrum

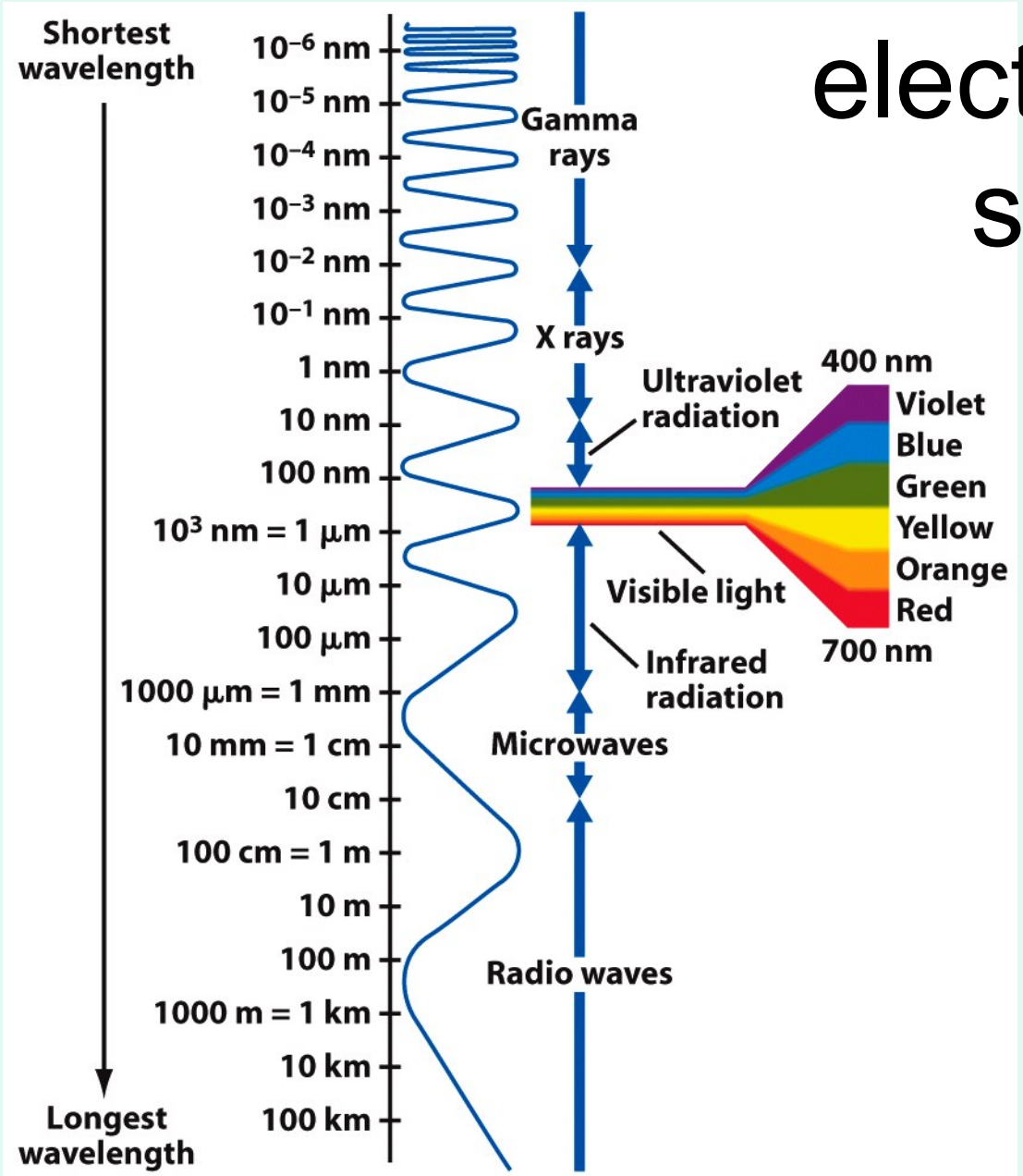
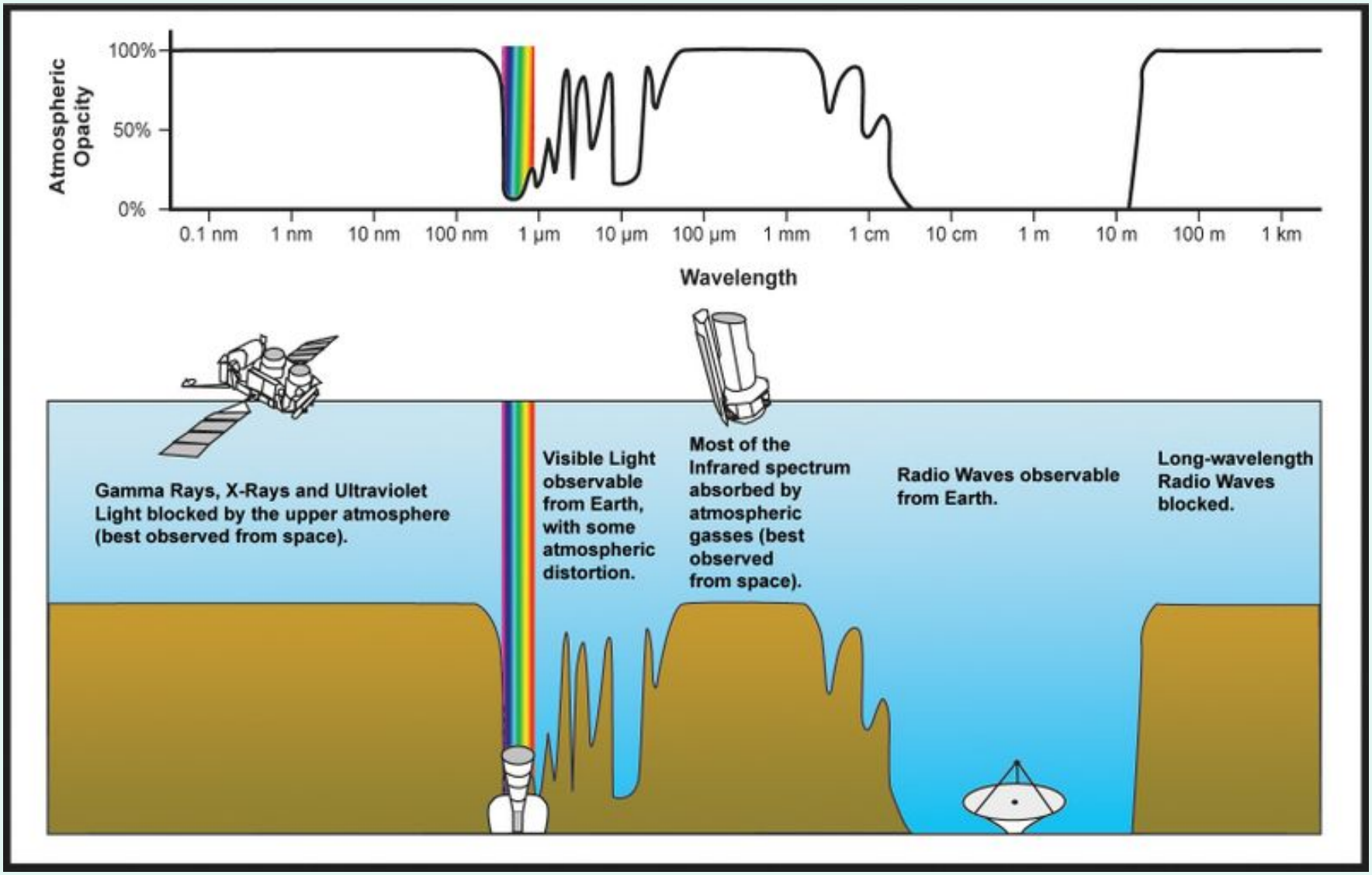


Figure 5-7
Universe, Eighth Edition

Atmospheric opacity



The fact that human eyes are sensitive only to those wavelengths to which the atmosphere is transparent is evidence for:

A. evolution
B. Creator
C. time travel
D. coincidence
E. we don’t know

All kinds of EM radiation are fundamentally the same, differing only by frequency (or wavelength or energy). Why do they seem so different to us ?

A. because we can only see visible light

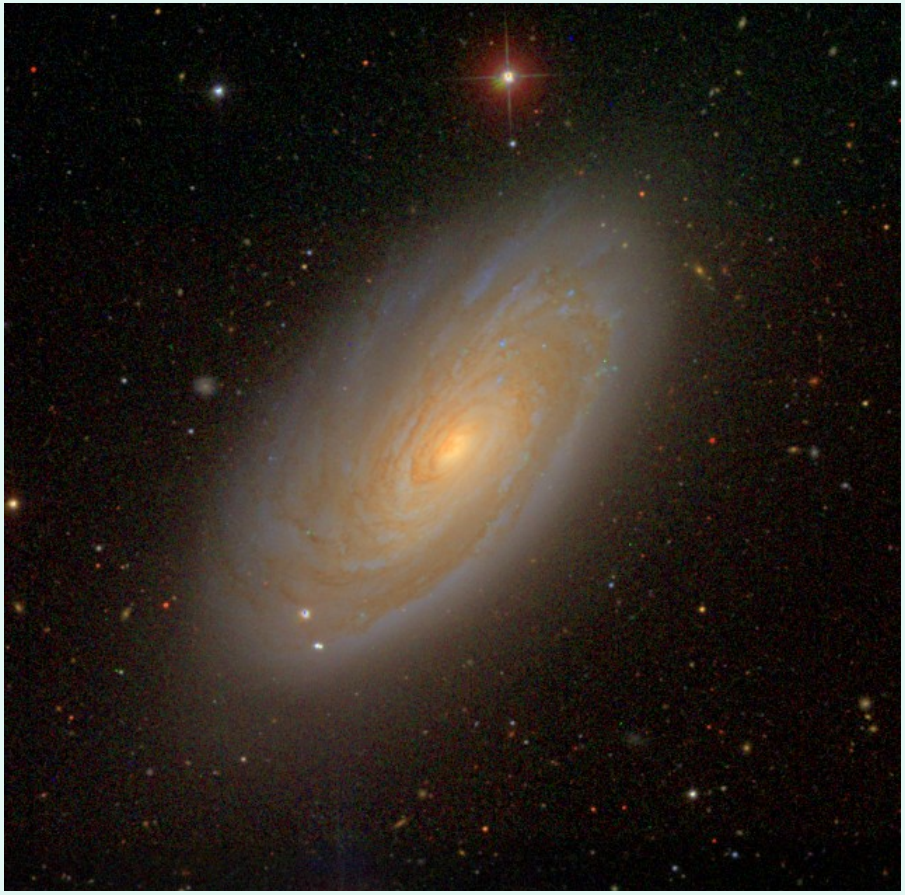
B. different wavelength photons actually have other fundamental differences besides wavelength

C. because they interact with matter very differently

D. describing light as EM radiation oversimplifies their nature

E. I like colors

Spiral Galaxy: Optical vs. Infrared



Optical image
(Ground-Based telescope)

Near-Infrared Image
(Spitzer Space Telescope)