

Topic D

"Star Light" ("Part 1: E-M Spectrum")

(Web Version: 08-15-01)

1

Radiation from the Stars

Analysis in Science

2

Overview

- Nature of Electromagnetic Radiation
 - Types of radiation & EM spectrum
 - Atmospheric transparency
- Astronomical Detectors
 - Photographic plate, Photoelectric multiplier & CCD
 - Spectrograph
- Spectra
 - Kirchoff's Laws & Types of Spectra
 - Three Radiation Laws & Temperature

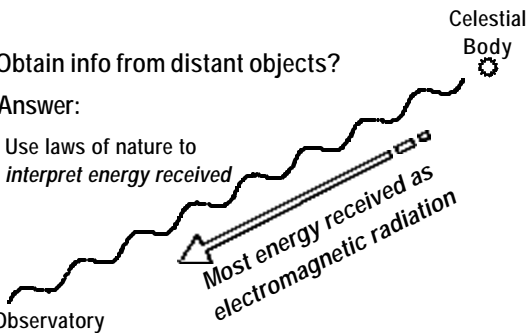
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Part 1. The Electromagnetic Spectrum

4

How Do We . . .

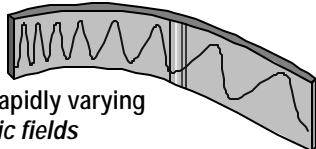
- Obtain info from distant objects?
- Answer:
Use laws of nature to *interpret energy received*



5

Electromagnetic Radiation


- A form of energy . . . moves
 - Information from one place to another
 - Through a *vacuum*
 - At constant speed (*fast but finite*)
- Consists of linked, rapidly varying *electric & magnetic fields*



6

Alternate Names

- Electromagnetic radiation *or* energy
- EM energy or radiation
- Often just “radiation”
- “Light” . . . but misleading since




“Light” is a particular “type of radiation”

7

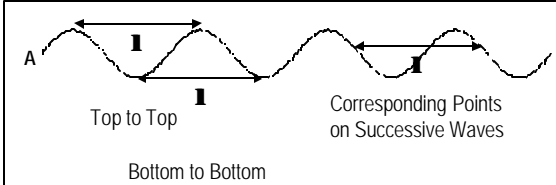
Electromagnetic Radiation

Transfer of energy by

- **Waves:**  Changing electromagnetic fields *or*
- **Photons:** ○ Carriers of EM energy
 - discrete particles of energy
 - no mass
 - no electric charge

8


Wavelength (λ)



Corresponding Points on Successive Waves

9

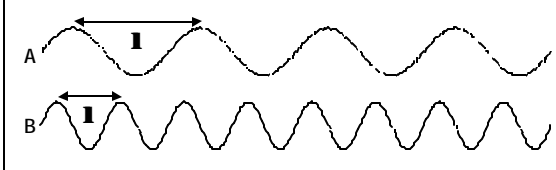
Amplitude



Do not confuse *amplitude* with *wavelength*

10

Red vs. Violet



Red waves are about twice as long as violet/blue light

11

Electromagnetic Spectrum

- **Spectrum** — definition?
“An ordered arrangement of related items”
- EM Spectrum
“Arrangement by wavelength”
- See *Study Guide*, Table 8

12

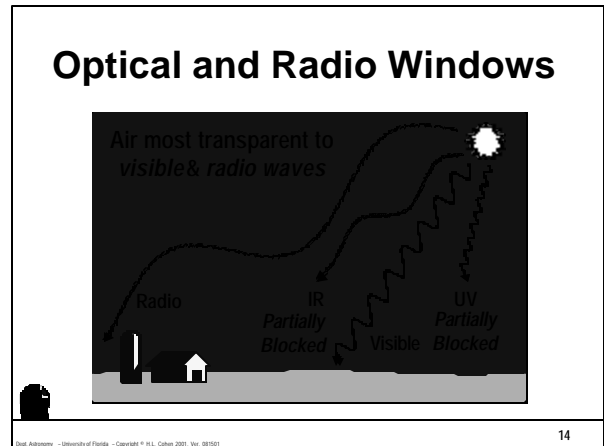
Table of the EM Spectrum*

Designation	Wavelength	Frequency	Photon Energy	Atmospheric Transparency
Gamma Rays	< 0.1 nm	Very Small	Very Large	Very Poor
X-Rays	0.1 – 10 nm			Very Poor
Ultraviolet	10–380 nm			Poor
Visible Light	380–750 nm			Excellent
Infrared	750–110 nm			Poor
Microwave	0.1 mm			Fair–Good
Radio	> 10 cm	Very Large	Very Small	Very Good

Note factor of two!

Learn order not wavelengths

* See Study Guide, Table 8



Atmospheric “Windows”*

Designation	Wavelength	Frequency	Photon Energy	Atmospheric Transparency
Gamma Rays	< 0.1 nm	Very Large	Very Large	Very Poor
X-Rays	0.1– 10 nm			Very Poor
Ultraviolet	10–380 nm			Poor
Visible Light	380–750 nm			Excellent
Infrared	750–110 nm			Poor
Microwave	0.1 mm			Fair–Good
Radio	> 10 cm			Very Good

Optical Window

Radio Window

* See Study Guide, Table 8

Ultraviolet (UV)

- Blocked by ?
 - A form of oxygen (O)
 - Oxygen in air mostly O₂
 - ____? is O₃
- Some UV penetrates
 - Cause of skin tanning
 - Skin pigmentation nature's defense

$O_3 = O + O + O$

Infrared (IR)

- Blocked by? and?
 - _____?
 - _____?
- Some IR penetrates
 - Some IR observations from ground possible
- IR observatories
 - High altitude & arid

Visible Light*

Designation	Wavelength
Violet	380–420 nm
Indigo	420–450 nm
Blue	450–490 nm
Green	490–570 nm
Yellow	570–590 nm
Orange	590–630 nm
Red	630–750 nm

$\left. \begin{array}{l} \text{Violet Wavelengths } 1/2 \text{ Red Wavelengths} \\ \text{Red Wavelengths } 2x \text{ Violet Wavelengths} \end{array} \right\} \text{Learn types \& order (not wavelengths)}$

* See Study Guide, Table 8

Speed of EM Radiation

Radiation travels at same speed (in vacuum)
regardless of wavelength

- Speed called "c" or "speed of light" (a "misnomer")
- How fast? **Answer:** 300,000 km/sec or 186,000 mi/sec

19

How Fast is "c" ?

- Earth to Moon & back at 186,000 mi/sec
— How long does it take?
- Answer
 - $240,000 \text{ mi} \div 186,000 \text{ mi/sec} = ? \text{ seconds one way}$
 - $2 \times ? \text{ sec} = ? \text{ seconds round-trip}$

20

Long Distance Telephone

- Long distance by communication satellite
- Altitude 22,500 mi
 - One way trip about 50,000 mi (Earth → Satellite → Earth)
 - Round-trip about 100,000 mi
- Can you sense delay?

21

How Fast is "c" ?

- Earth to Sun & back at 186,000 mi/sec
— How long does it take?
- Answer
 - $93,000,000 \text{ mi} \div 186,000 \text{ mi/sec} = ? \text{ sec one way}$
 - $? \text{ sec} \div 60 \text{ sec/min} = ? \text{ min}$

22

Light – Time for 1 AU

Remember this — Travel time for *One AU*

About 8 minutes per AU

Remember This!

(Makes it fast & simple to calculate other times!)

23

How Long to Pluto?

- If a space craft travels at speed of light, how long?
- Answer ("quick way")
 - $40 \text{ AU} \times 8 \text{ min/AU} = ? \text{ min}$ (approx.)
 - $? \text{ min} \div 60 \text{ min/hr} = ? \text{ hours!}$ (approx.)

24

Frequency

- EM radiation also typed by *frequency*
- Definition

waves passing per second

or

cycles per second

(Now called a *Hertz* or *Hz*)

25

See Study Guide Table 8

EM By Frequency & Energy

Designation	Wavelength	Frequency	Photon Energy	Atmospheric Transparency
Gamma Rays	< 0.1 nm	3×10^{12} MHz	Very Large	Very Poor
X-Rays	0.1 – 10 nm			Very Poor
Ultraviolet	10–380 nm			Poor
Visible Light	380–750 nm	500×10^6 MHz		Excellent
Infrared	750–110 nm			Poor
Microwave	0.1 mm			Fair–Good
Radio	> 10 cm	100 MHz*	Very Small	Very Good

* If wavelength = 3 meters (middle of FM radio band)

26

Energy Confusion

- Energy types often confused
- Reason . . . energy constantly *transformed*
- What other forms of energy are these mistaken for?
 - ?
 - ?

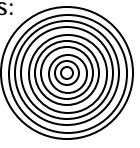
27

Radio Energy

- Often confused with ?
- ? . . .

vibrations transmitted through materials:

A disturbance . . .
moving through a medium . . .
passing energy . . .
from one particle to another

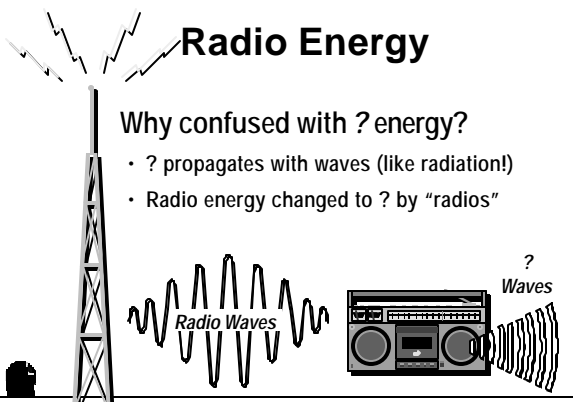


28

Radio Energy

Why confused with ? energy?

- ? propagates with waves (like radiation!)
- Radio energy changed to ? by “radios”

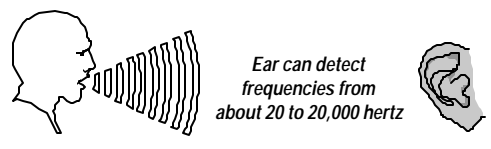


29

Radio to ? (& Back Again)

We transform radio into ? because . . .

- We have no receptor for radio
- We do have a receptor for ?



Ear can detect frequencies from about 20 to 20,000 hertz

30

Radio Astronomers

Sometimes add to confusion!

Astronomers occasionally convert radio energy from celestial objects to ?

Example — Jupiter

Jupiter

Radio Waves

Jupiter Radio Presentation

31

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Speed of Sound

- Fast by human standards (like radiation)
- But value *much less* than speed of light

Recall speed of light —

300,000 km/sec or 186,000 mi/sec

32

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Speed of Sound

- What is speed of sound (in air near sea level)
 - 1100 ft/sec = 750 mi/hr
 - 330 m/sec = 1200 km/hr
- Cars often travel 10% of this
- Aircraft

10% of 750 mph = 75 mph

- Commercial — almost this fast (500–600 mi/hr)
- British–French Concorde & military faster than sound

33

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Thunderstorms

Lightning Flash
(186,000 mi/sec)
seen almost
instantaneously

Do you know how to tell how far away is a thunderstorm?

34

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Thunderstorms

Thunder (sound) travels about 1000 ft / sec

I heard the *thunder* 2 seconds after I saw the *flash*.

35

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Thunderstorms

1000 ft/sec x 2 sec

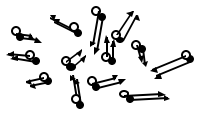
The storm is only “two thousand feet” away! We should get home.

36

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Infrared Energy

- Often confused with *heat energy*
- Heat energy
 - Form of energy associated with random motions of atoms and molecules
 - Faster the motions . . . greater the heat



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Infrared Confusion

Because infrared energy

- Often called “infrared heat” or “heat rays”
- Easily changed to heat
- Emitted by *warm* objects in *detectable* amounts

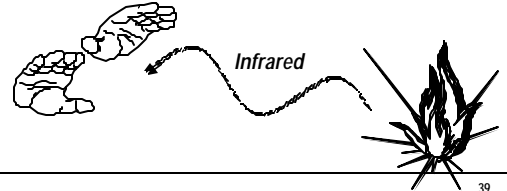
(Cold objects also emit infrared but in lesser amounts)

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Detection of Infrared

What *human organ* can detect *infrared* if amount of infrared radiation large?

Answer — the ? (felt as sensation of heat)



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Some Animals Do Better

- Some animals have “heat-sensitive” organs
- Example — some snakes have “pit organs”
 - One on each side between eye & nostril
 - Others along lip of upper jaw
 - Useful for hunting at night!

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