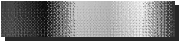



Topic D
"Part 5. Radiation Laws"
 (Web Version: 03-06-01)

1

Continuous Spectra
 Importance & Uses


2

Continuous Spectra

- Appearance 
 - What *cannot* do — chemical identification (Why?) ↗
 - What *can* do — obtain temperatures of objects
- Real Stellar Spectra 
 - Usually show *dark lines*
 - Also show a *continuum*
 - A temperature indicator!

3

Radiation Laws See Fig. 7


Three laws characterize continuous spectra
(Listed in *Study Guide*, Fig. 7)

- Planck
- Wien
- Stefan-Boltzmann


Why important? — Can determine temperature

4

A Note: Black and White

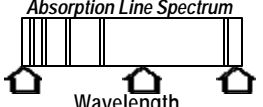
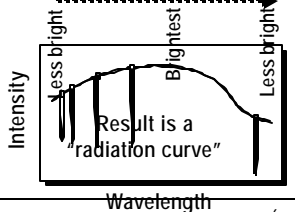
Stars show this 

But spectrograms usually not in color
(B/W easy to produce)

Get used to this 

5

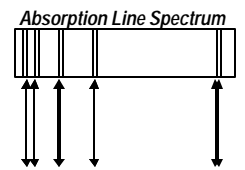
Radiation Curves

- Stellar spectra look like 
- Measure intensity (brightness) from end to end (with "light meter")
- Graph results → 

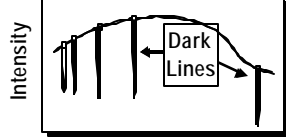
6

Dips Show Lines

- Stellar spectra look like
- Measure intensity (brightness) from end to end (with "light meter")
- Graph result



Absorption Line Spectrum



Intensity

Dark Lines

Wavelength

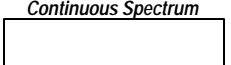
7

Erase Lines

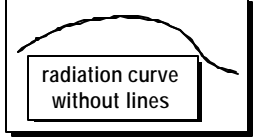
If erase lines from graph . . .

Looks like a continuous spectrum

Now analyze as if *spectrum has no lines!*



Continuous Spectrum



Intensity

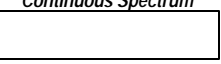
radiation curve without lines

Wavelength

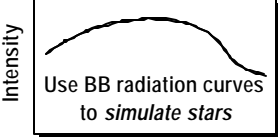
8

Perfect Radiators

- Invent "idealized radiator"
- Often called a black body (BB)
- Simplifies understanding of radiation
- Stellar radiation curves (lines erased) often resemble BB's



Continuous Spectrum



Intensity

Use BB radiation curves to simulate stars

Wavelength

9

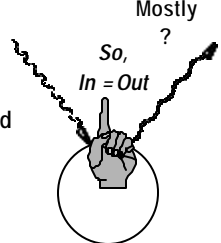
Cool Black Bodies

At room temperature

- Absorb *all* incoming radiation
- Radiate back *all* radiation received
- Then — why look black?

Answer . . .

Most radiation emitted in ?



Mostly ?

So, In = Out

10

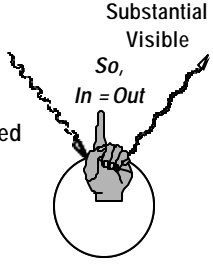
Hot Black Bodies

Heat Black Body

- Absorbs *all* incoming radiation
- Radiates back *all* radiation received
- Now looks bright — why?

Answer . . .

Significant radiation emitted in ?



Substantial Visible

So, In = Out

11

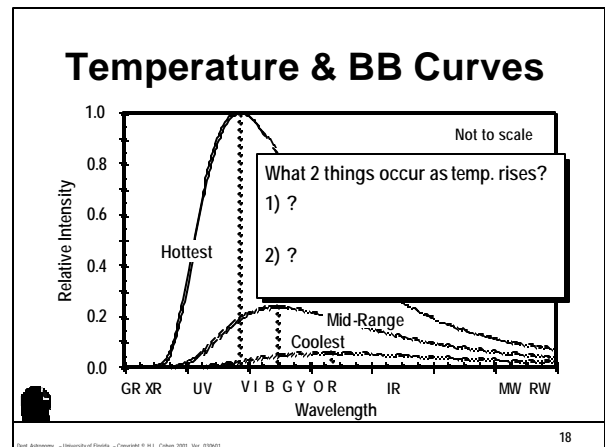
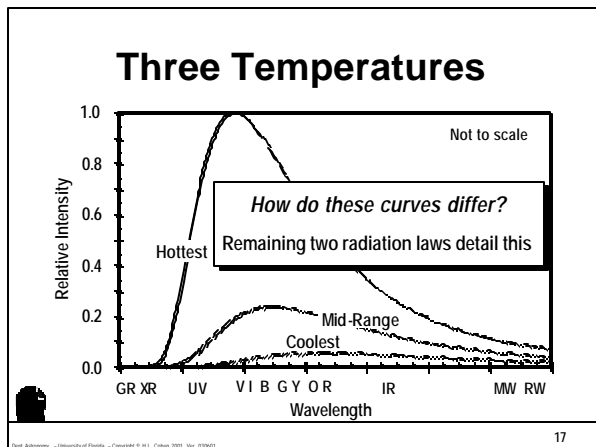
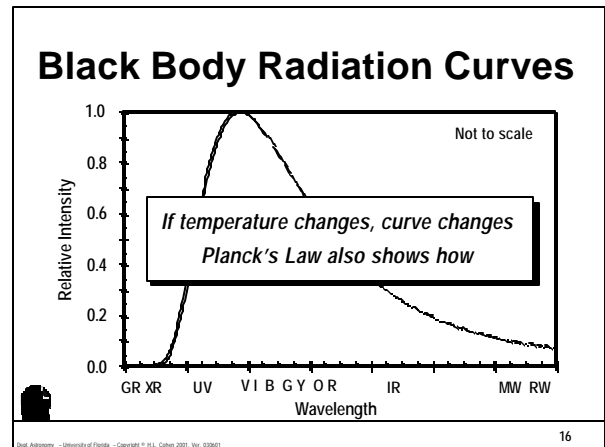
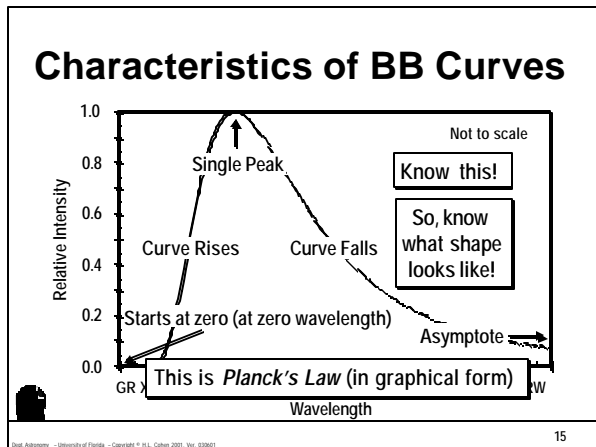
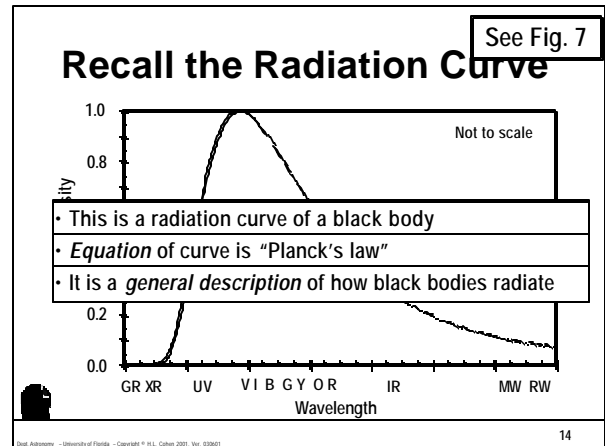
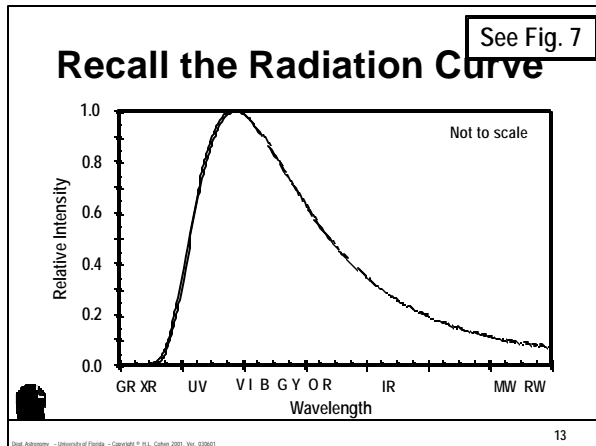
The Radiation Laws

Three laws characterize continuous spectra

- Planck
- Wien
- Stefan-Boltzmann

(Listed in *Study Guide*, Fig. 7)


12



Second Radiation Law

Three laws characterize continuous spectra


- Planck General description of radiation
- Wien Peak shifts toward shorter wavelengths if T increased


(Brightness unequal) 

Brighter here if *hotter* Brighter here if *cooler*

19

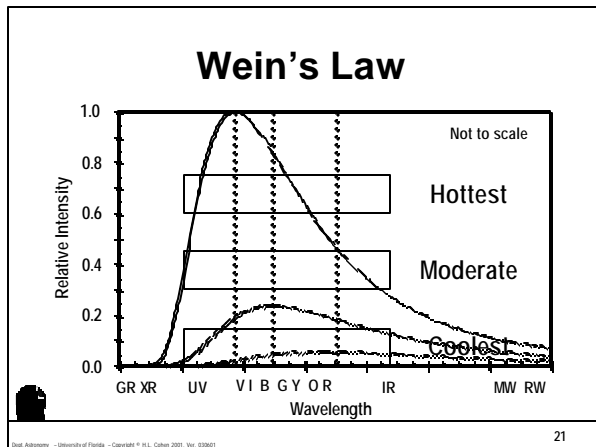
Wein's Law

In Color 

In B/W 

Increasing Wavelength \rightarrow

20

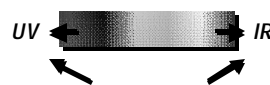


Second Radiation Law

Three laws characterize continuous spectra

- Planck General description of radiation
- Wien Peaks shifts toward shorter wavelengths if T increased

Peak can even shift into *UV* or *IR*



Brighter if *hotter* Brighter if *cooler*

22

Second Radiation Law

Three laws characterize continuous spectra

- Planck General description of radiation
- Wien Peak shifts toward shorter wavelengths if T increased

Mathematical Statement

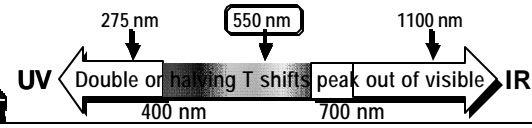
$\text{Wavelength of Radiation Peak} \propto \frac{1}{\text{Temperature}}$

Inverse proportion

23

A Consequence

- Recall — Wavelength of violet (400 nm) about half of red (700 nm)
- Consequence — Suppose temperature of Sun
 - Doubled (6,000 $\text{\textcircled{R}}$ 12,000 K), peak moves into UV
 - Halved (6,000 $\text{\textcircled{R}}$ 3,000 K), peak moves into IR



24

A Consequence

Conclusion

Stars with more than about twice or one-half of Sun's temperature have radiation peaks in UV or IR respectively

Examples

Sirius
12,000 K

Betelgeuse
3,000 K

275 nm 550 nm 1100 nm

UV ← Double or halving T shifts peak out of visible → IR

400 nm 700 nm

25

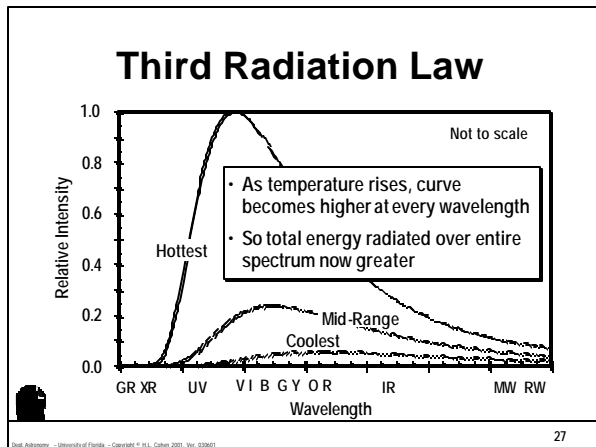
Second Radiation Law

Example of Wein's Law

See *Study Guide*

Example Worked Problem #3

26



Total Energy Radiated

Let E_{Tot} = Total energy radiated

Star

1 sq m

1) Over entire spectrum

2) Through some area (say a square meter)

Not from whole star (So star's radius irrelevant)

then $E_{Tot} \propto T^4$ where T = Temperature

28

Summary: Radiation Laws See Fig. 7

Three laws characterize continuous spectra

- Planck General description of radiation
- Wien Peak shifts *toward shorter wavelengths* if *T* increased [$WL_{pk} \propto 1/T$]
- Stefan-Boltzmann *Total energy radiated* (over entire spectrum) increases if *T* increased [$E_{Tot} \propto T^4$]

29

Here's How it Works

Star A: $T_A = 12,000$ K

Star B: $T_B = 6,000$ K

then

$$\frac{E_{Tot \text{ of A}}}{E_{Tot \text{ of B}}} = \frac{(12,000 \text{ K})^4}{(6,000 \text{ K})^4} = \frac{(2)^4}{(1)^4} = \frac{16}{1}$$

If can measure ratios of total energies emitted, can find how temperatures compare

See Study Guide Example #4

30

A Few Examples

Common objects illustrate the radiation laws

- Celestial bodies
- Household items

31

Color of the Sun?

Before you answer remember

(The word 'answer' is circled in the original image)

32

The Solar Impression

Impression of Sun's color tailored by viewing Sun near horizon

33

So . . . Color of the Sun?

34

Range of Star Colors

- bluish
- bluish-white
- whitish
- yellowish-white
- yellowish-orange
- orangy

Typical star colors

- Range — bluish to orange
- Whitish most common

Books may call some red

- Exaggerated!
- Most too hot to appear red

See *Study Guide* Table 11, next-to-last column (Know)

35

See Star Colors for Yourself

Look at bright stars — eye can't see color if brightness low

36

Wien's Law and Color

Changing color of many hot objects a consequence of Wien's Law

- Results from a shifting *distribution* of color
- Everyone has experienced Wien's Law

Watch a stove burner heat and change color (or heating element or light bulb filament)

37

Watch a Stove Burner Heat

————— Burner Heats —————>

Visible only because of reflected room light

Off Dull Red Orange-Red Bright Orange

Visible light undetectable (most radiation emitted as IR)

Color Change
Wien's Law
Increasing Brightness
Stefan-Boltzmann

(Burner does not become hot enough to show further changes)

38

Light Bulb on Dimmer Switch

————— Filament Heats —————>

Bulb Off Dull Red Dim Orange Bright Yellow Brilliant Yellow-White

39

Side Note: Planck's Law

- Many tried to find equation for BB curve
- That is, a relation between
 - Intensity
 - Wavelength
 - Temperature
- Early attempts failed (example follows)

40

Example of Early Attempt

41

Why Planck Succeeded

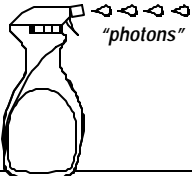
- Like Kepler — threw away old ideas
- Previously . . .
 - Radiation visualized as water flowing continuously from a hose
- Success due to new hypothesis about radiation (Recall Kepler did same for celestial motions)

42

What Planck Did

Planck postulated . . .

- Radiation bundled into particles of energy
- Energy packets called *photons*
- Radiation spurts like water from a spray bottle or water gun
- Each "spurt" or "packet" like a photon



"photons"

43

What Resulted . . .

Planck derives equation fitting black body curves

~~$$I = 2\pi hc^2 \lambda^{-5} \frac{1}{e^{hc/\lambda kT} - 1}$$~~

(Do not have to know this !!)

Today BBs sometimes called *Planck radiators*

44