- Midterm Exam
  - #&%?@)#$! IT
  - Posting scores
  - Finding out about missed questions
  - Reminder about dropping lowest of 3

Nature of Light

10/3 – Apparent versus Actual Brightness

10/6 – Electromagnetic Spectrum of Light

10/7-13 – Telescopes and Earth's Atmosphere, Light and Atoms (and survey) in Lab

10/8 – Blackbody Radiation

10/10 – Types of Spectra

10/13 – Analyzing Spectra

10/15 – Doppler Shift

How do we know about the properties of stars, planets, galaxies, etc.?

- Studying the light they emit, or the effects they have on light
- Studying particles that sometimes reach Earth – cosmic rays, cosmic dust, meteorites
- Studying the tiny variations in gravity between us and highly dynamic, often violent, events (like merging black holes) – gravity waves

Traxoline Soup

- Light
- Electromagnetic waves
- Electromagnetic radiation
- Radiation (not from radioactive material)
- Photons
- All the SAME thing!

How bright is it?

- How bright something appears to us:
  - **Flux**: amount of light per second *per unit area*
    - Sometimes also called **intensity**
  - **Apparent magnitude**
- How bright something really is (how much light/radiation/electromagnetic waves it gives off per unit time)
  - **Luminosity**: amount of light per second
  - **Absolute magnitude**: apparent magnitude if object placed 10 parsec (10 pc, ~33 light years) away from us

How bright is it?

- The relationship between flux (F) and luminosity (L):

$$F = \frac{L}{4\pi r^2}$$

- Another “inverse-square” law, like gravity
- For most objects in the universe, the only means we have of gauging distance.
  - Can “triangulate” distances for objects within ~3000 light-years.

Magnitudes

- A ranking system for flux and luminosity
  - Hipparchus' original system:
    - Ranking from 1 to 6 (brightest = 1, faintest = 6)
    - Some objects can have magnitudes <1, the faintest ones that we currently observe (e.g. with Hubble) have magnitude ~30

Magnitudes

- A ranking system for flux and luminosity
  - Pogson showed us what this meant: a *difference* of 5 magnitudes corresponds to a *factor* of 100 in apparent brightness. – a logarithmic scale
    - Other common logarithmic scales:
      - Richter scale
      - Decibels
      - Hurricane and tornado categories
    - Magnitude 30 = 6 factors of 100 = 1 trillion times fainter than magnitude 0, like Vega

Magnitudes

- Other common logarithmic scales
  - Richter scale, a difference in one corresponds to factor of 10 in “shaking amplitude”
  - Decibels, a difference in 10 corresponds to a factor of 10 in “loudness”
- Logarithmic scales… it’s all relative
  - Often need a common “zero point” to stay sane
  - For the magnitude system, used to use Vega for apparent magnitude=0

Magnitudes

- A ranking system for flux and luminosity
  - Pogson showed us what this meant: a *difference* of 5 magnitudes corresponds to a *factor* of 100 in apparent brightness. – a logarithmic scale
    - Each factor of 10 in apparent brightness = a difference of 2.5 magnitudes.
    - A difference in 1 magnitude = factor of $100^{1/5}$ (=2.512…) in apparent brightness
    - As a measure of brightness, magnitudes are a backwards system! Smaller magnitude number means brighter/more flux/luminosity.

Comparing Apparent and Absolute Magnitudes

- Flux and Luminosity are related by distance…

$$F = \frac{L}{4\pi r^2}$$

- … so are apparent (m) and absolute (M) magnitudes:

$$m - M = 5\log\left(\frac{r}{10\,pc}\right)$$

  - Objects closer than 10 pc have abs. mag. > app. mag.
  - Objects farther than 10 pc have abs mag. < app. mag.

Lecture Tutorials

- Break up into group of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - Apparent and Absolute Magnitudes of Stars (pages 33-34)
  - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.

Quiz

Using your observations from this week of Albireo, what can you say about the two stars under each of the following two assumptions:

1) the two stars are at the same distance;

2) the two stars have the same absolute magnitude.

Think

Pair

Share!

Imagine that you are viewing a star that has an apparent magnitude of 0.2 and is located 100 parsecs away from us. Which of the following is most likely the star's absolute magnitude?

A. -4.8
B. 0.1
C. 0.2
D. 0.3
E. 5.2

Pollux has an apparent magnitude of 1.1 and an absolute magnitude of 1.1. Epsilon Eridani has an apparent magnitude of 3.72 and an absolute magnitude of 6.1. From which of these stars do we receive more light at Earth?

A. Pollux
B. Epsilon Eridani
C. We receive the same amount of light at Earth from both stars.
D. It cannot be determined from the information given.

Through triangulation, we determine that four stars are all at the same distance. Their absolute magnitudes are 10, 7, -1, and -10. Which appears brightest from Earth?

A. The first one
B. The second one.
C. The third one.
D. The fourth one.

Electromagnetic Spectrum of Light

10/7-13 – Telescopes and Earth's Atmosphere, Light and Atoms (in lab)

10/8 – Blackbody Radiation

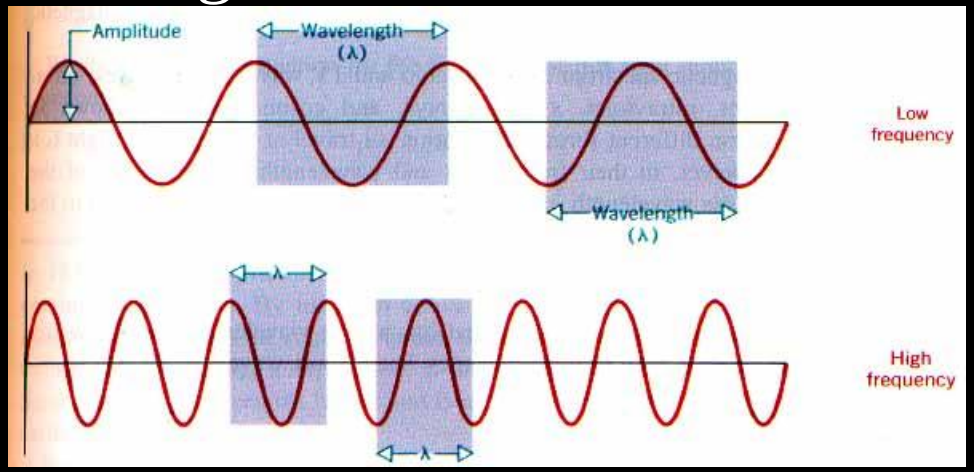
10/10 – Types of Spectra

10/13 – Analyzing Spectra

10/15 – Doppler Shift

EM Spectrum of Light

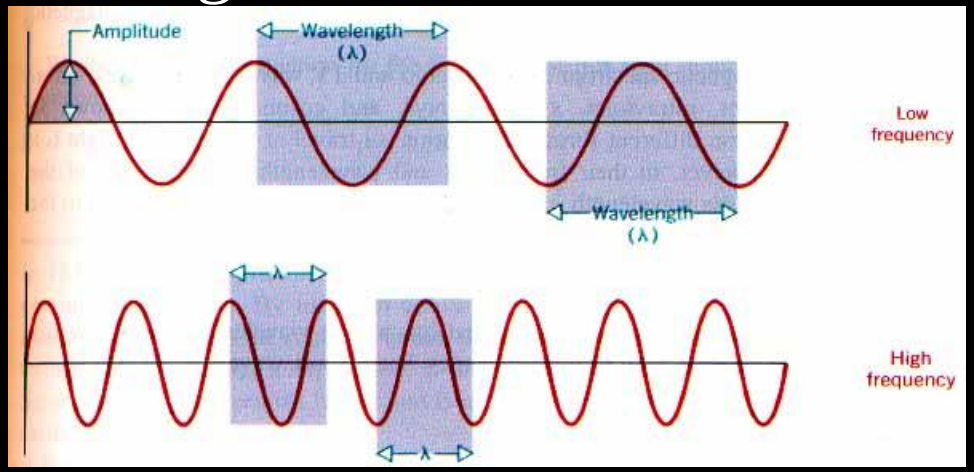
- Can think of light as a wave:



- What properties of a wave can be measured?
  - Amplitude: intensity of the light
  - Wavelength: distance from crest to crest
  - Frequency: number of crests passing a point
  - Polarization: direction of the oscillation

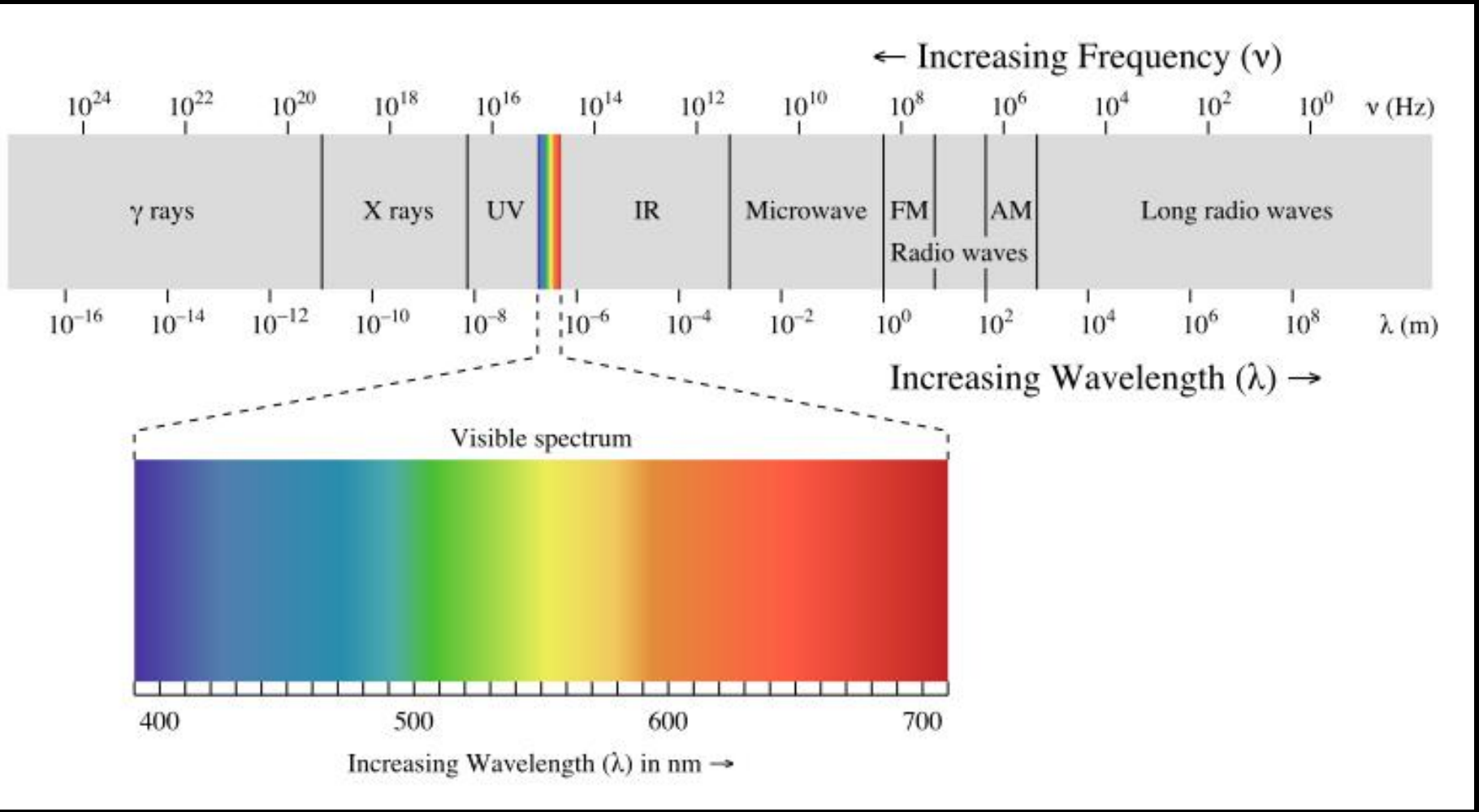
EM Spectrum of Light

- Can think of light as a wave:



- Relationships between properties:
  - Speed of light = wavelength × frequency = c (299792.458 km/s in vacuum)
  - Energy = h × frequency = h × c / wavelength

EM Spectrum of Light



Lecture Tutorials

- Break up into group of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - Electromagnetic Spectrum of Light (pages 45-47)
  - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.

Think

Pair

Share!

Which of the following is not a form of light?

A. Radio waves
B. Microwaves
C. X-rays
D. All of the above are a form of light.
E. None of the above is a form of light.

Which of the following has the shortest wavelength?

A. A photon of ultraviolet light
B. Blue electromagnetic radiation
C. An X-ray
D. A radio wave
E. Infrared radiation

Which of the following would be true about comparing gamma rays and radio waves?

A. The radio waves would have a lower energy and would travel slower than gamma rays.
B. The gamma rays would have a shorter wavelength and lower energy than radio waves.
C. The radio waves would have a longer wavelength and travel the same speed as gamma rays.
D. The gamma rays would have a higher energy and would travel faster than radio waves.
E. The radio waves would have a shorter wavelength and higher energy than gamma rays.

Which of the following has the least energy?

A. Radio waves
B. Visible light
C. X-rays
D. Infrared light
E. They all have the same energy.

Which of the following correctly arranges different forms of light in order of increasing energy?

A. Infrared, Visible, Radio, Ultraviolet, Gamma rays, X-rays
B. Ultraviolet, Gamma rays, Infrared, Radio, X-rays, Visible
C. Radio, Infrared, Visible, Ultraviolet, X-rays, Gamma rays
D. Visible, Radio, Infrared, X-rays, Gamma rays, Ultraviolet

Blackbody Radiation

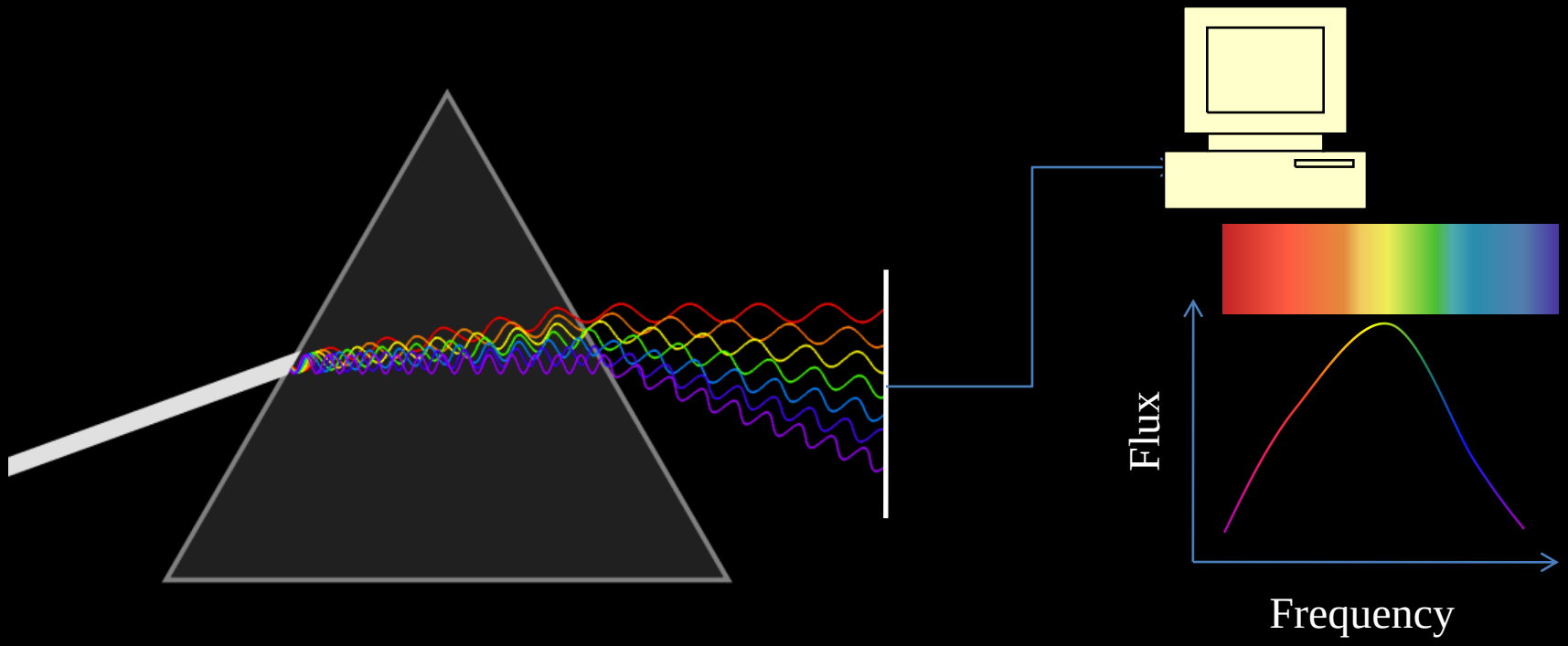
10/10 – Types of Spectra

10/13 – Analyzing Spectra

10/15 – Doppler Shift

Spectroscopy

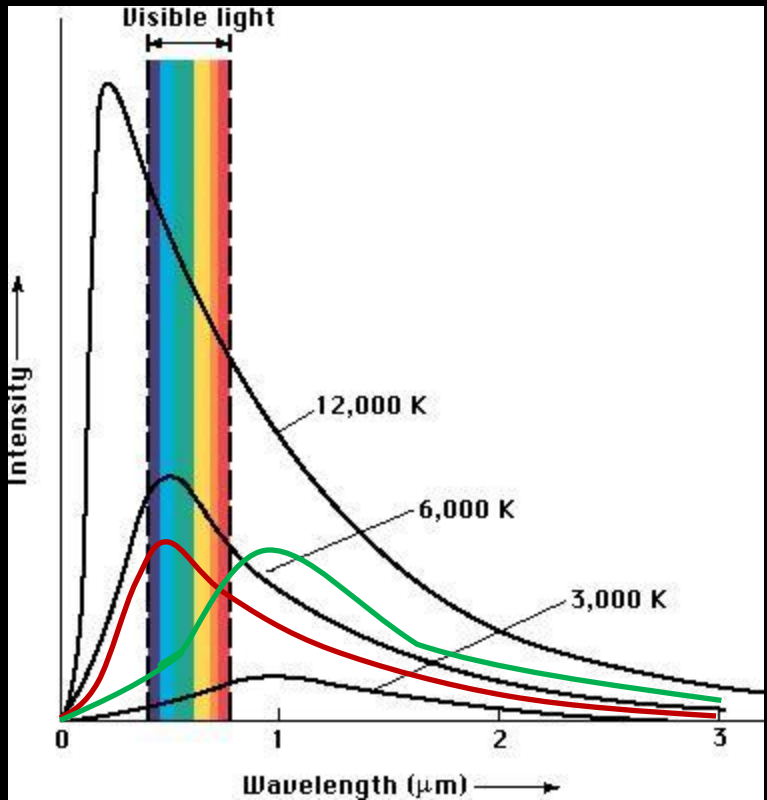
- Can take the light from an object and *disperse* it into its constituent rainbow of *wavelengths* (or frequencies, or energies, or colors)



Blackbody Radiation

- Blackbody radiation = radiation from anything that has a (single) temperature
  - Also sometimes called *thermal* radiation

• Spectrum of a blackbody rises to a peak and then falls.
  • Wavelength of peak determined *uniquely* by the temperature
    • Overall color
  • What determines how high the peak is?
    • size
    • temperature



Lecture Tutorials

- Break up into group of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - Blackbody Radiation (pages 57-60)
  - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.

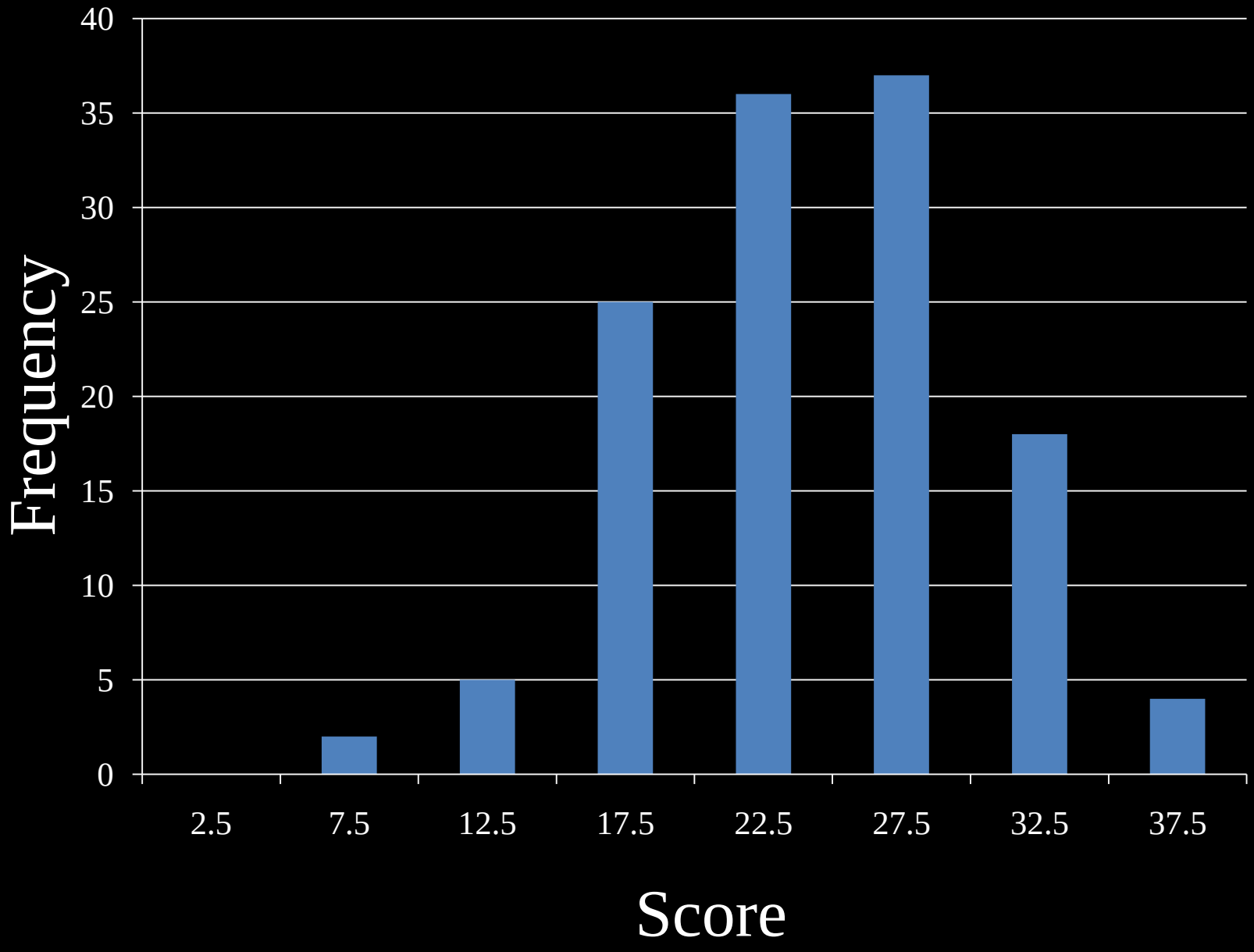
Think

Pair

Share!

A lump of lead is heated to a high temperature. Another lump of lead that is twice as large is heated to a lower temperature. Which lump of material appears bluer?

A. The cooler lump appears bluer.
B. The hotter lump appears bluer.
C. Both lumps look the same color.
D. Cannot tell which lump looks bluer.


40
35
30
25
20
15
10
5
0
Frequency
2.5
7.5
12.5
17.5
22.5
27.5
32.5
37.5
Score

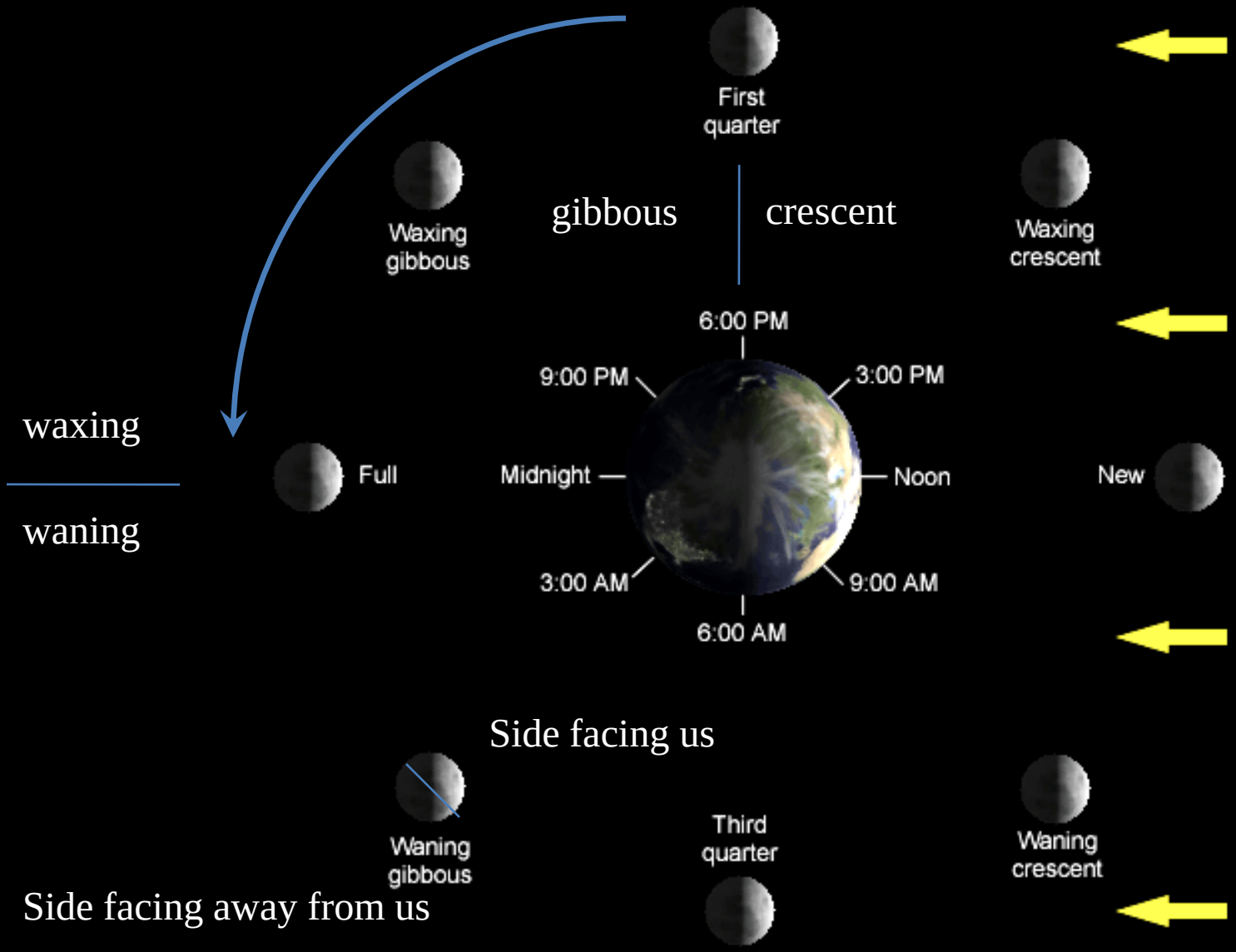
Where is our solar system in the Milky Way?

A. Near the center.
B. About half-way between the center and the edge.
C. Near the edge.
D. None of the above.

If the Moon was full seven nights ago, what time of day/night should you look to see the Moon at its highest point in the sky today/tonight?

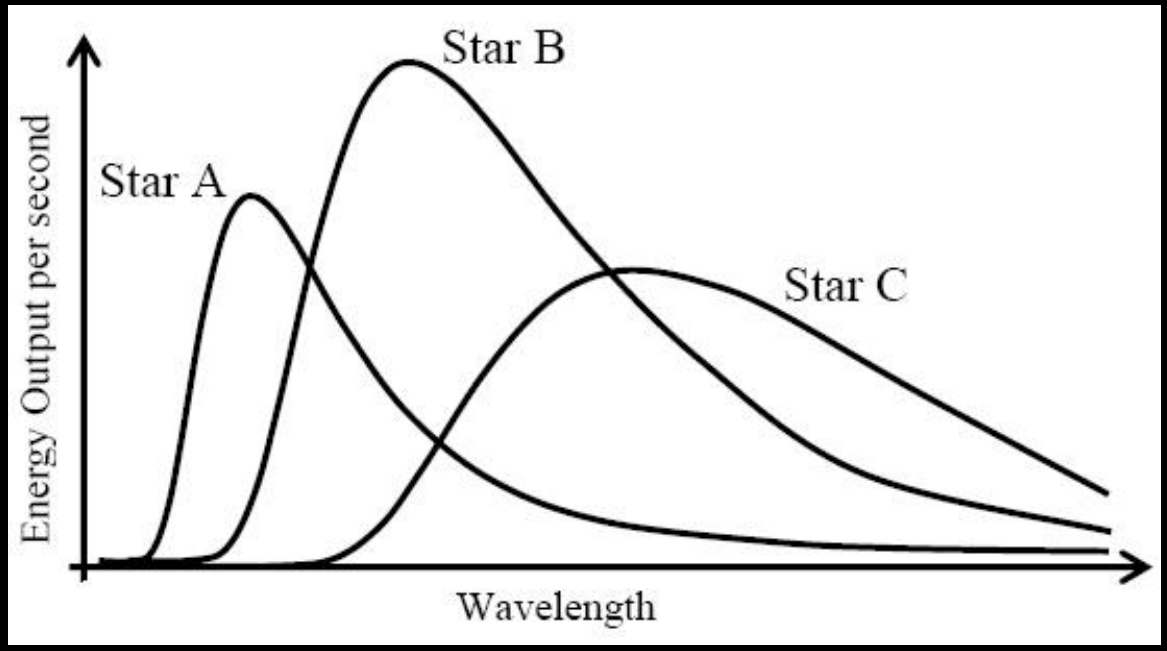
A. Around 6AM.
B. Around 12PM (Noon).
C. Around 6PM.
D. Around 12AM (Midnight).

Phases of the Moon: Traxoline



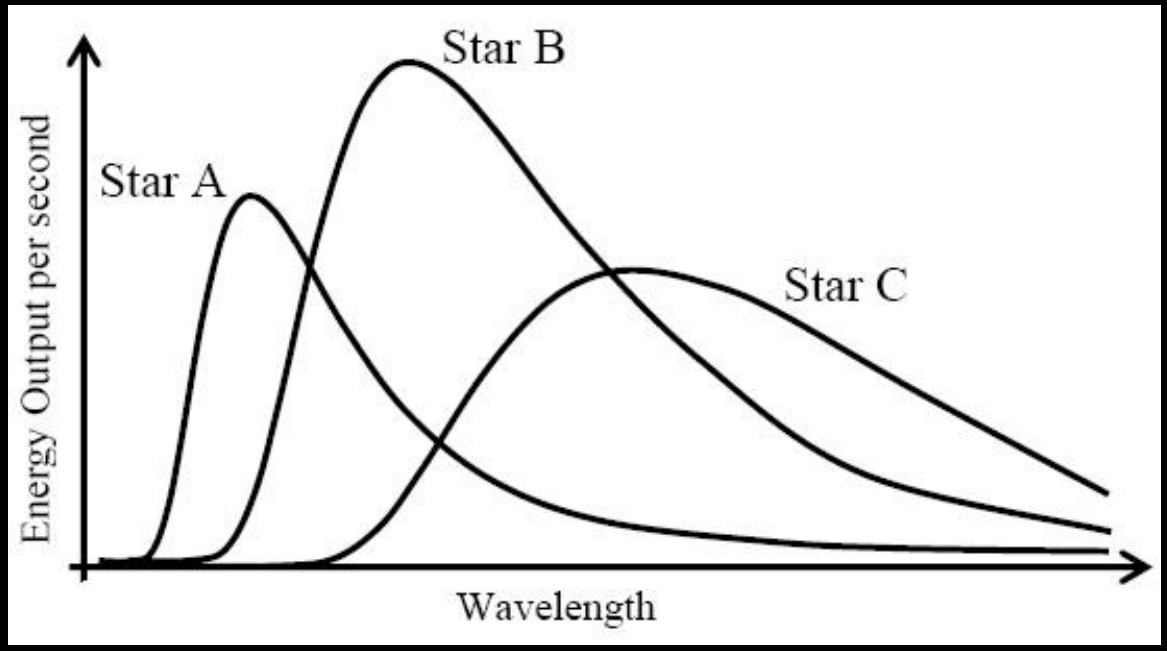
The graph at the right shows the blackbody spectra for three different stars. Which of the stars has the highest temperature?

A. Star A
B. Star B
C. Star C



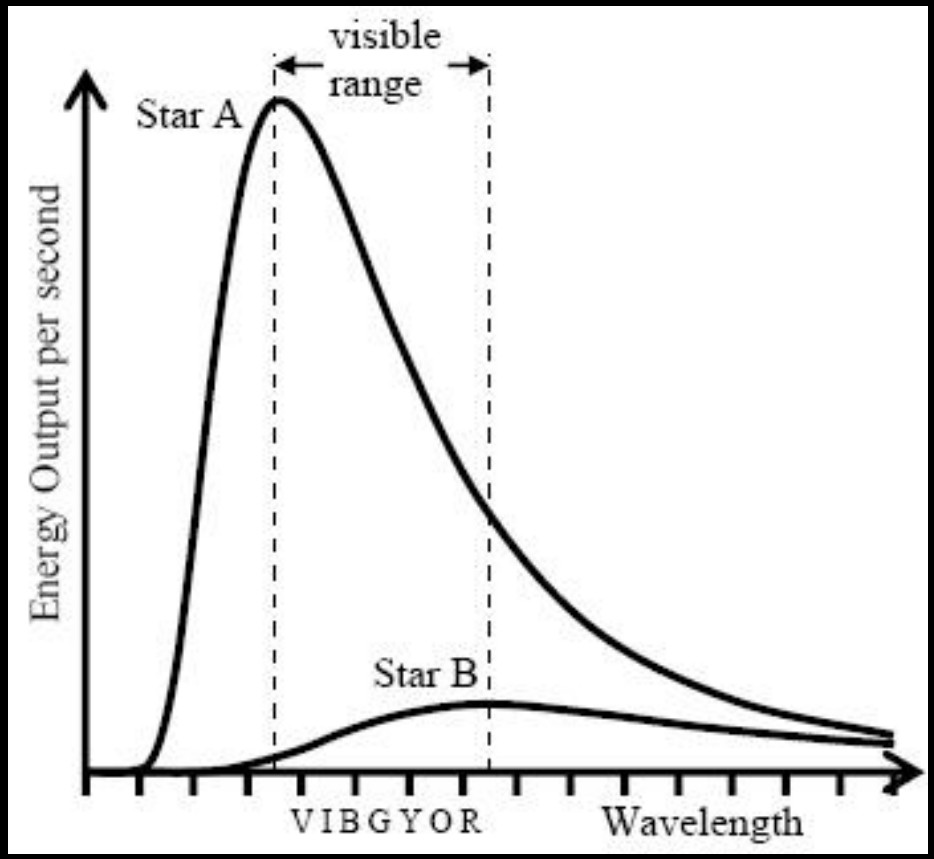
The graph at the right shows the blackbody spectra for three different stars. Which of the stars has the largest size?

A. Star A
B. Star B
C. Star C



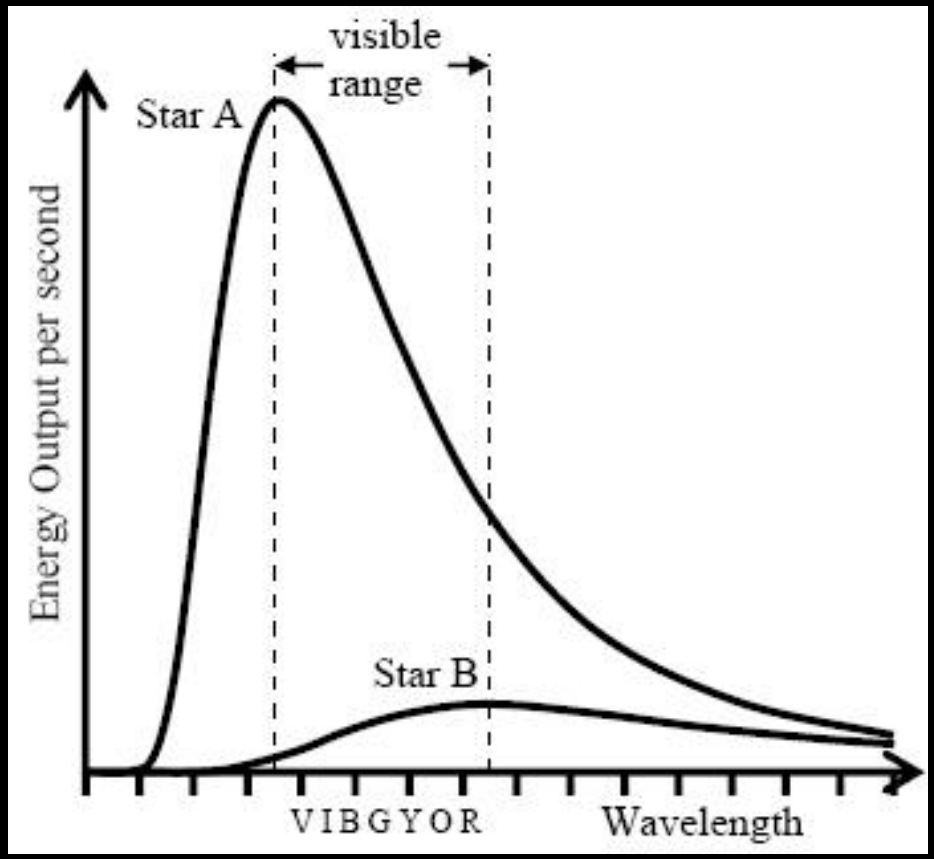
Use the graph at the right to determine which of the two stars (A or B) has a higher temperature.

A. Star A
B. Star B
C. Both stars have the same temperature.
D. The relative temperatures cannot be determined from the information available.



Use the graph at the right to determine which of the two stars (A or B) is larger.

A. Star A
B. Star B
C. Both are the same size.
D. The relative sizes cannot be determined from the information available.



Types of Spectra

10/13 – Doppler Shift

Types of Spectra

- Blackbody radiation and rainbows are examples of a *continuous* spectrum.
  - i.e., a spectrum that doesn't have breaks in it
- But not everything produces a complete rainbow in its spectrum…
  - To understand why, we need to understand the structure of atoms, and how light and atoms interact…

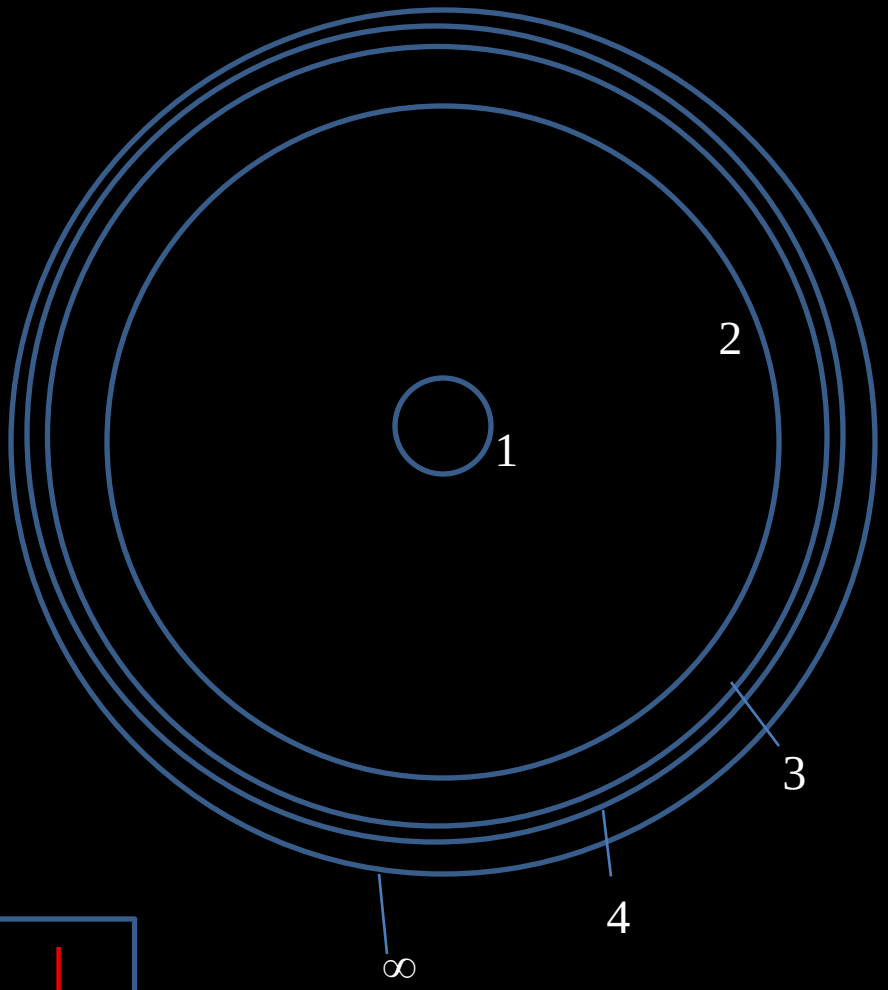
Quantum Theory 1050

Structure of atoms is described in a field of physics called *quantum theory*.

1. Atoms consist of a nucleus with electrons in orbit around the nucleus.
2. The “size” of an orbit is related to how much energy the electron has.
3. Quantum theory describes why any arbitrary energy is not allowed – only certain, discrete energies are allowed.

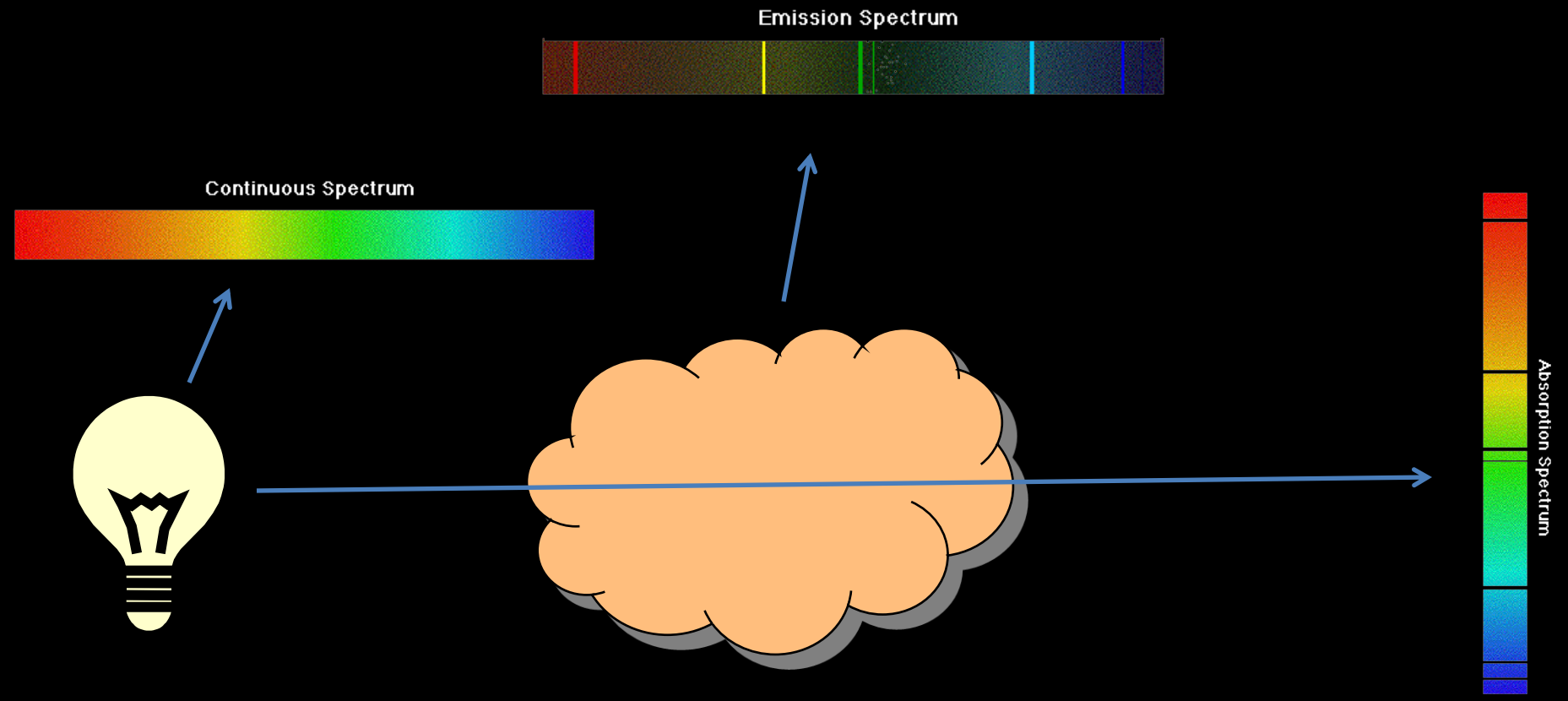
Quantum Theory 1050

- Example to the left is the allowed energy levels in a hydrogen atom.
- Higher energy levels are spaced closer together in energy.
- Supplying electrons with the right amount of energy can move them up to higher energy levels...
  - Light of certain energies(=frequencies) can do this by being *absorbed*.
  - Conversely, light of those same frequencies can be *emitted* by hydrogen atoms by electrons moving down to lower energies.
  - The pattern of energies than can be absorbed/emitted is unique to different elements and compounds.



Kirchoff's Laws

- When do we see *emission lines*, and when do we see *absorption lines*?



Lecture Tutorials

- Break up into group of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - Types of Spectra (pages 61-62)
  - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.

Quiz

- Do the “Analyzing Spectra” Lecture tutorial outside of class (either on your own or in a group). [And also “Types of Spectra”!!]
- When you have finished, have this checked in one of the following ways:
  - MarkDan during lab or office hours
  - Jackie during SI (MW)
  - Rajib outside office hours
- If done before Thursday, you will receive full quiz credit. (Thursday or later will receive no credit.)

Think

Pair

Share!

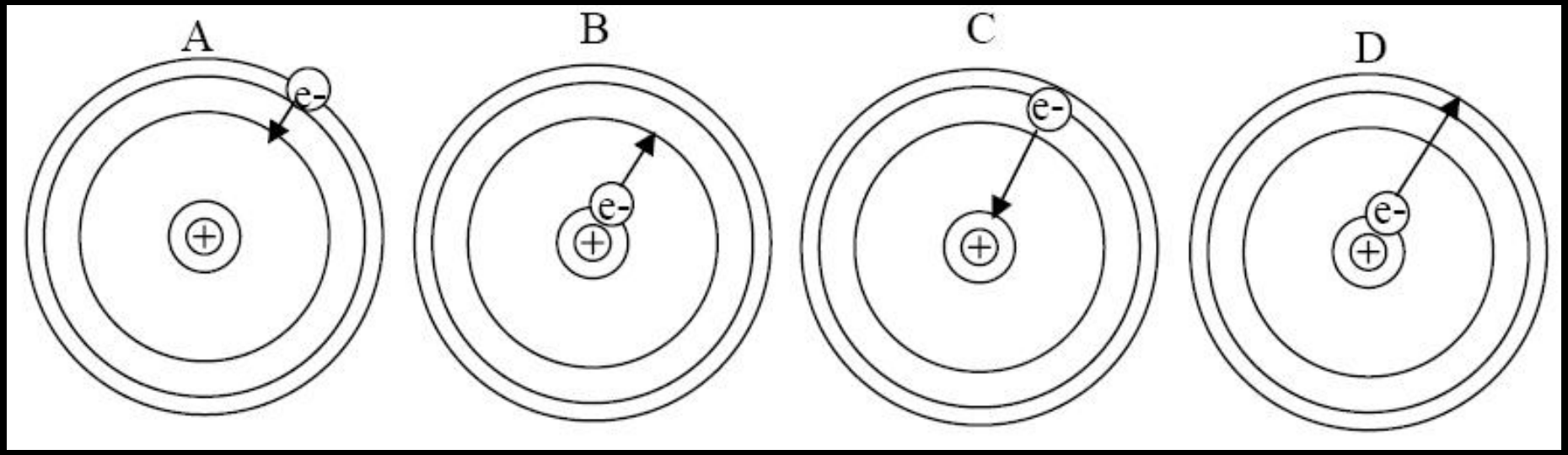
Which of the following spectra is produced by the Sun?

A. Absorption spectrum
B. Emission spectrum
C. Continuous spectrum
D. The Sun does not produce a spectrum.

If you analyze the light from a low density object (such as a cloud of interstellar gas), which type of spectrum do you see?

A. Absorption spectrum
B. Emission spectrum
C. Continuous spectrum
D. A low density object does not produce a spectrum.

Which atom would be absorbing light with the smallest wavelength?



Doppler Shift

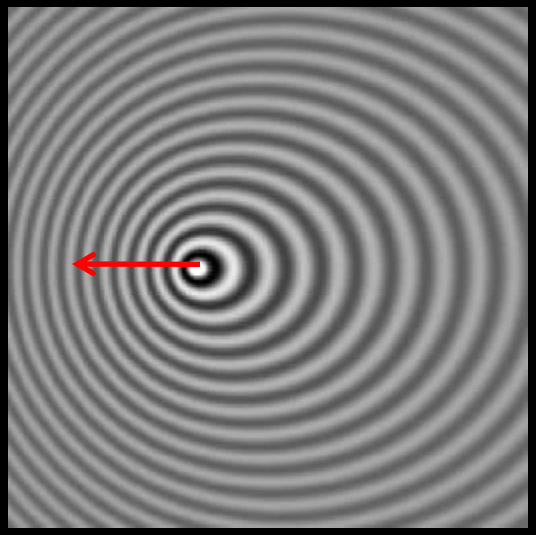
10/15(?)-24 – Solar System

10/27 – Review for Midterm Exam 2

10/29 – Midterm Exam 2

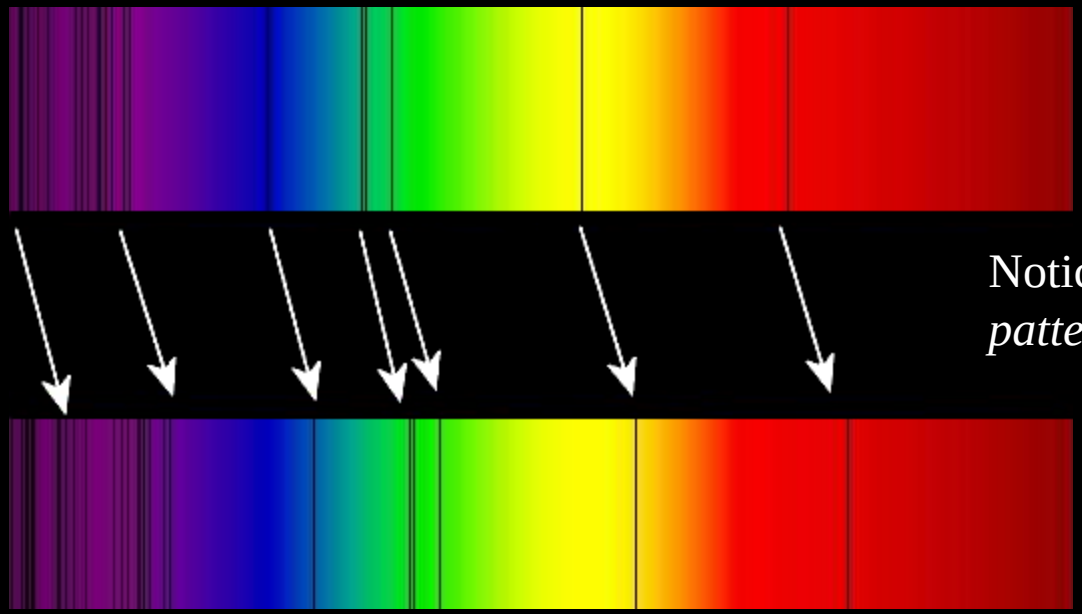
Doppler Shift

- The motion of objects toward or away from you affects the spectrum that you observe.
- Objects moving toward you will have their spectrum shifted to shorter wavelengths/larger frequencies
  - Shorter wavelengths → more blue → blueshift
  - The waves gets compressed
  - Anything that is a wave (e.g., sound)
  - Amount of shift depends on speed only
- Moving away → redshift
- ONLY motion toward or away



Doppler Shift

- Wait! Changing temperature also shifts wavelength, right? How can you tell temperature change from velocity?
  - Answer: Absorption/Emission lines!



Notice the *same pattern* of lines!!!

Lecture Tutorials

- Break up into group of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - Doppler Shift (pages 73-77)
  - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.