Week 8
Measuring stars 2

Wednesday, Nov. 9

Today's learning objectives (Wed. Nov. 9)

- Describe spectral class and what causes absorption features to vary in stars
- Describe what luminosity is and what factors affect a star's luminosity
- Explain what the energy flux detected from a star means and how it is used to understand features of stars
- Describe the features of the H-R diagram
- Explain how the H-R diagram is used to categorize stars

Coming up:

- No class Friday: Happy Veterans' Day
- Next week: Life cycle of stars
- Homework 8 will be posted soon and will be due next Tuesday
- Exam 3 next Friday

Absorption line strength vary for different temperature stars

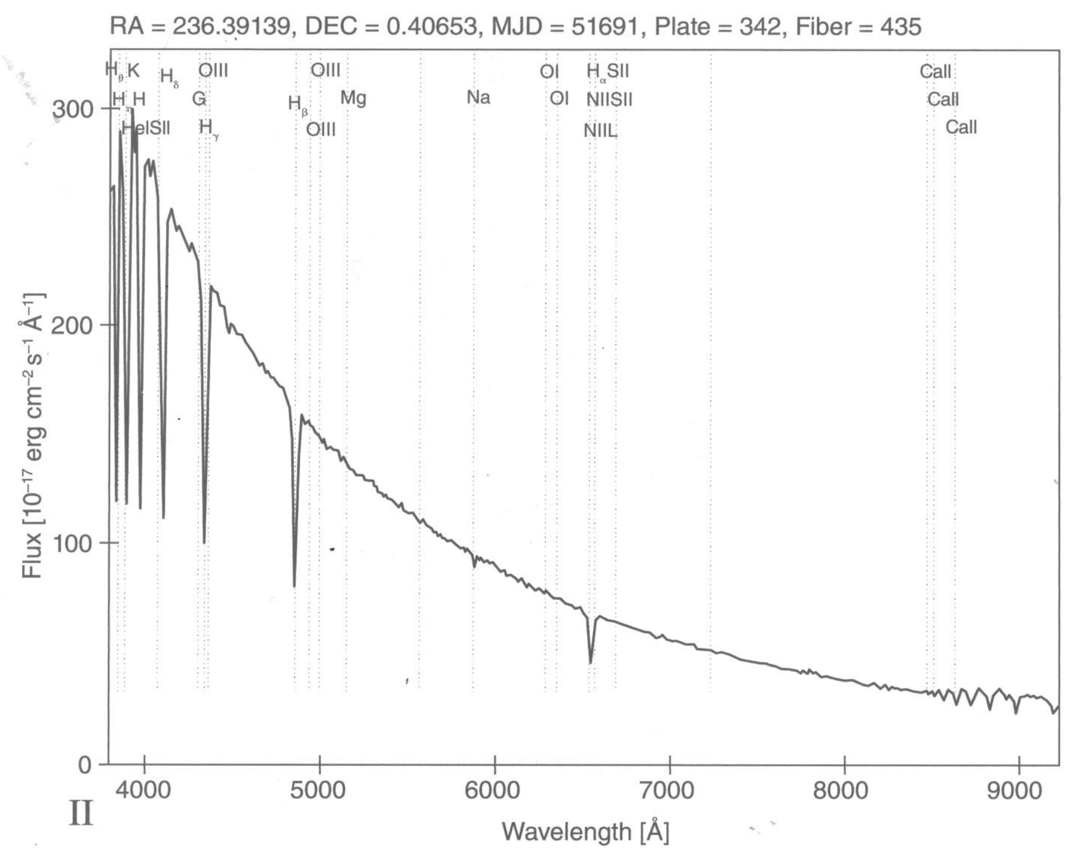


FIGURE 17.4

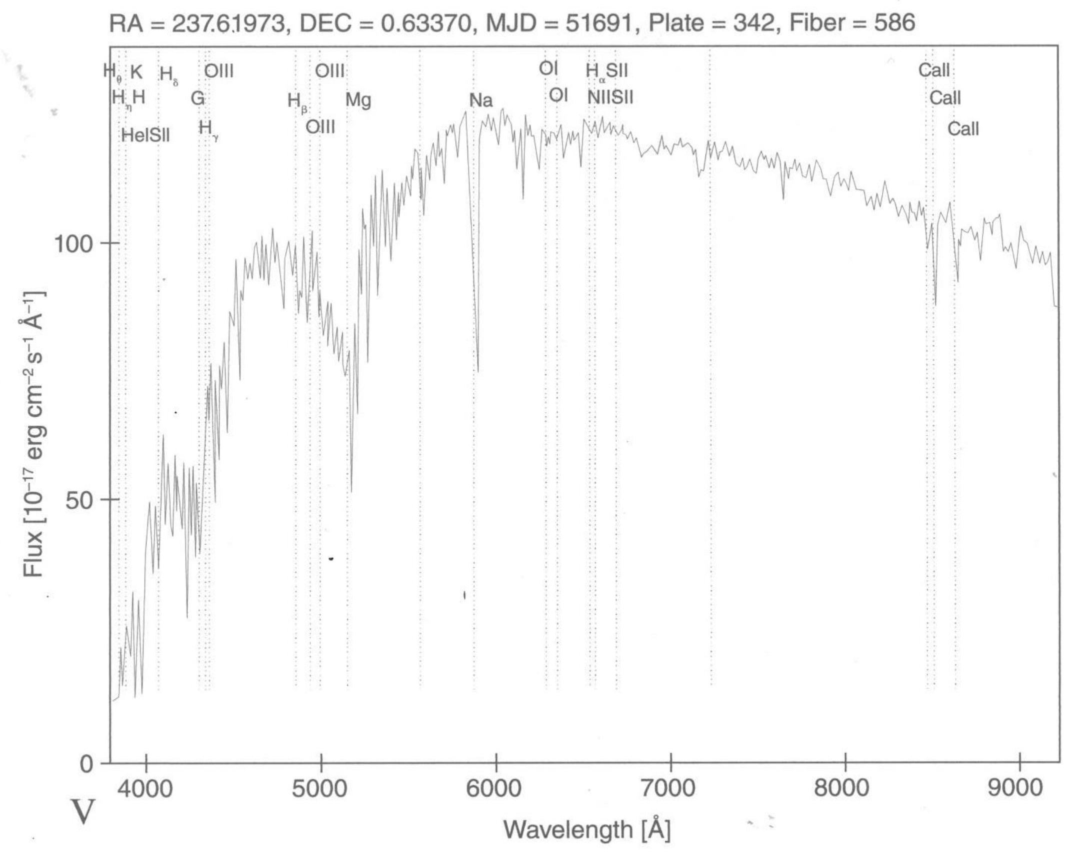
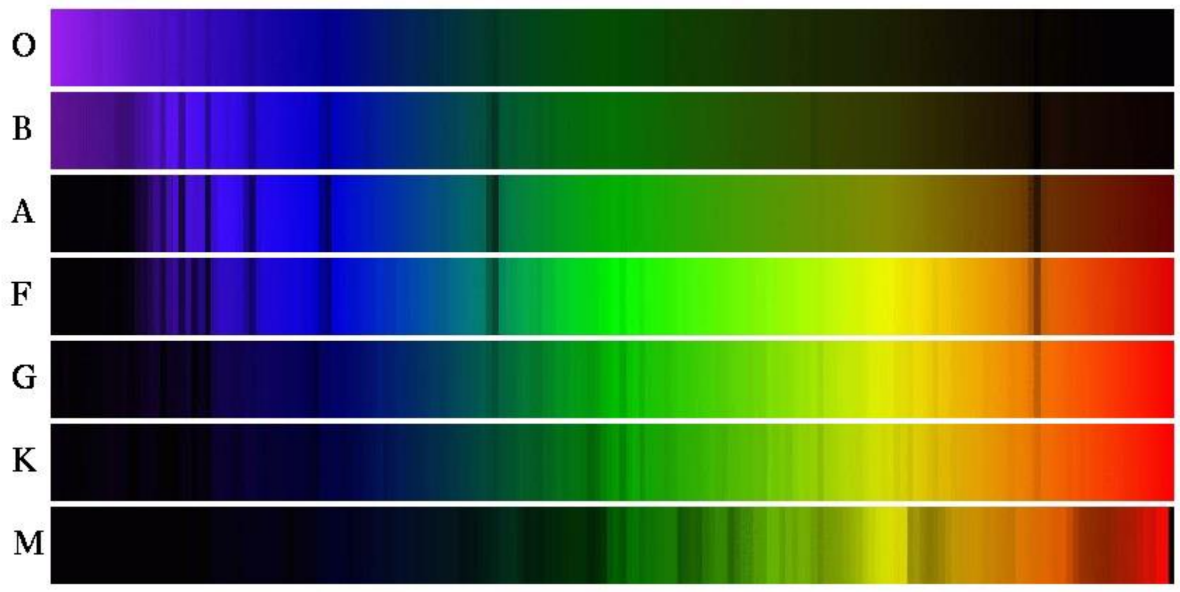


FIGURE 17.6

Absorption line strength vary for different temperature stars

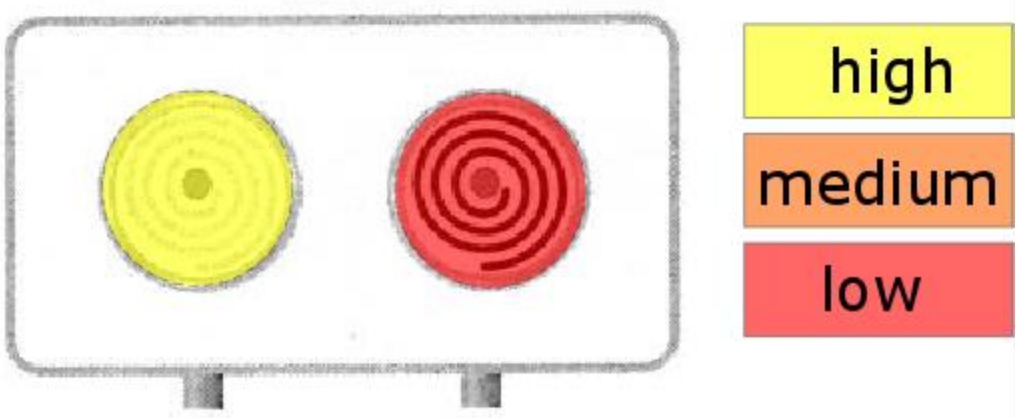


Class	Temperature	Apparent color	Hydrogen lines	Other noted spectral features
O	≥ 30,000 K	blue	Weak	ionized helium lines
B	10,000–30,000 K	blue white	Medium	neutral helium
A	7,500–10,000 K	white to blue white	Strong	ionized calcium (weak)
F	6,000–7,500 K	white	Medium	ionized calcium (weak)
G	5,200–6,000 K	yellowish white	Weak	ionized calcium (medium)
K	3,700–5,200 K	yellow orange	Very weak	ionized calcium (strong)
M	≤ 3,700 K	orange red	Very weak	Titanium oxide lines

- Temperature controls how elements absorb, because temperature controls the energy of photons that interact with electrons in atoms

Which of these burners would boil a pot of water more quickly?

A. Left
B. Right
C. Cannot tell



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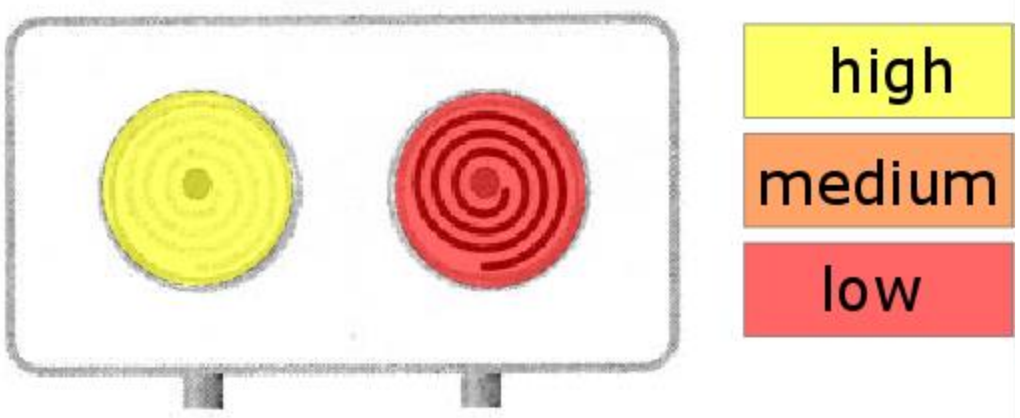
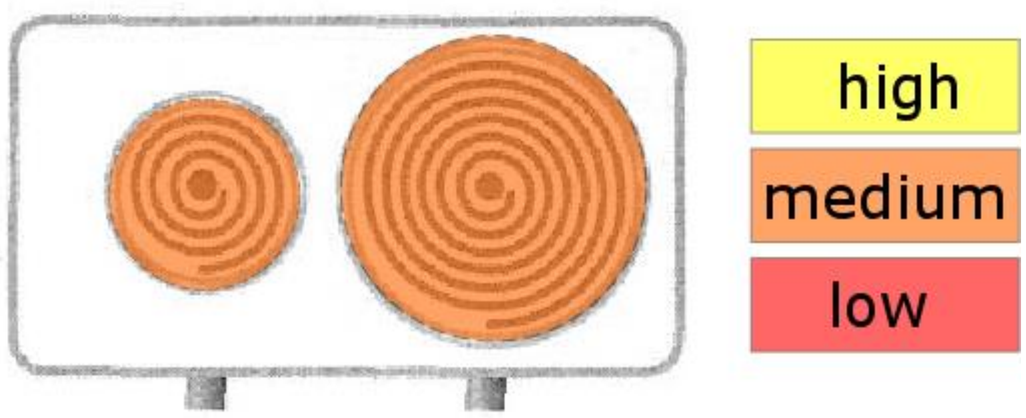


Left is hotter and gives off more energy

Which of these burners would boil a pot of water more quickly? (assume the pot is as large as the big burner)

A. Left
B. Right
C. Cannot tell



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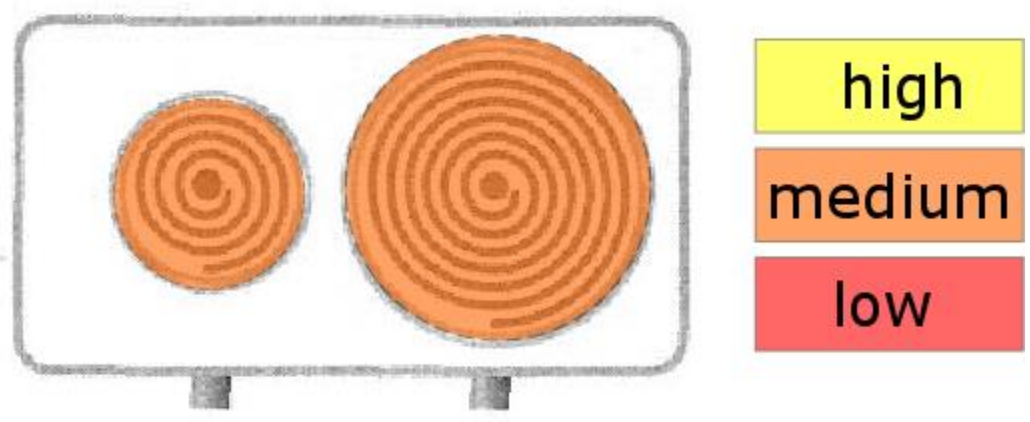
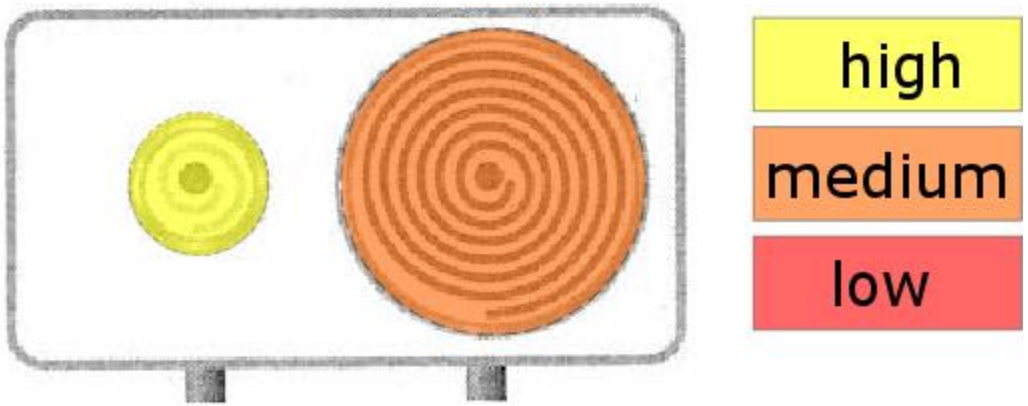


Right is larger surface area and gives off more total energy

Which of these burners would boil a pot of water more quickly?

A. Yup
B. Nope



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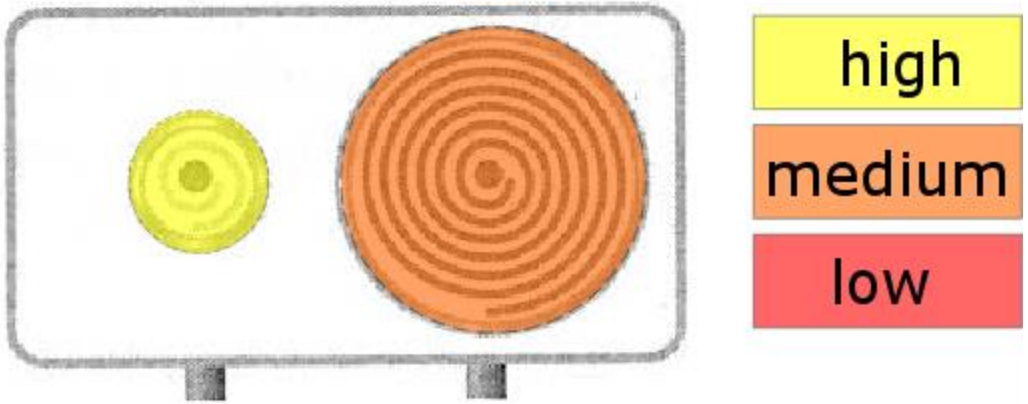

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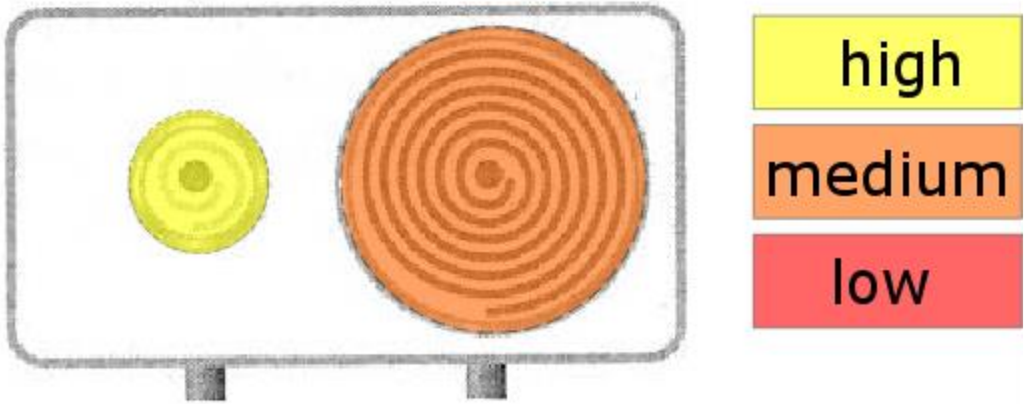
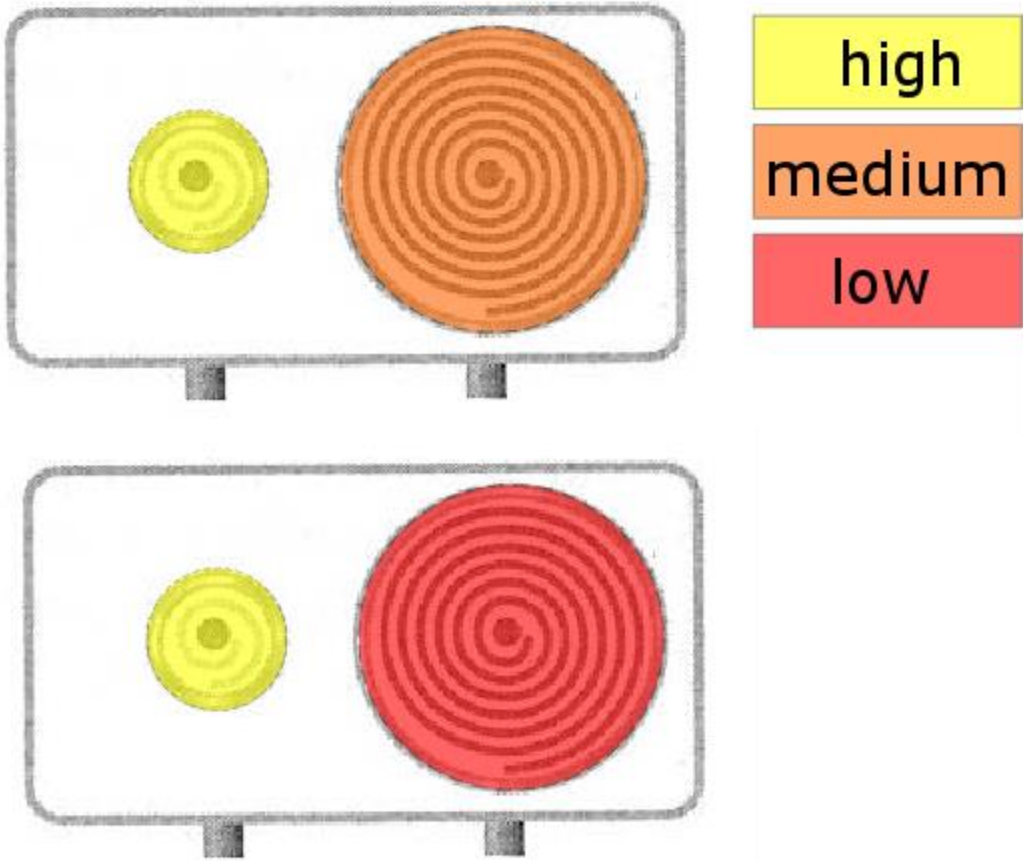


We cannot tell. It would depend on hot different the temperatures are, and whether the small burner's temperature can make up for its smaller surface area.

Can you assume that a hot burner will boil water more quickly than a cooler burner?

A. Yup
B. Nope



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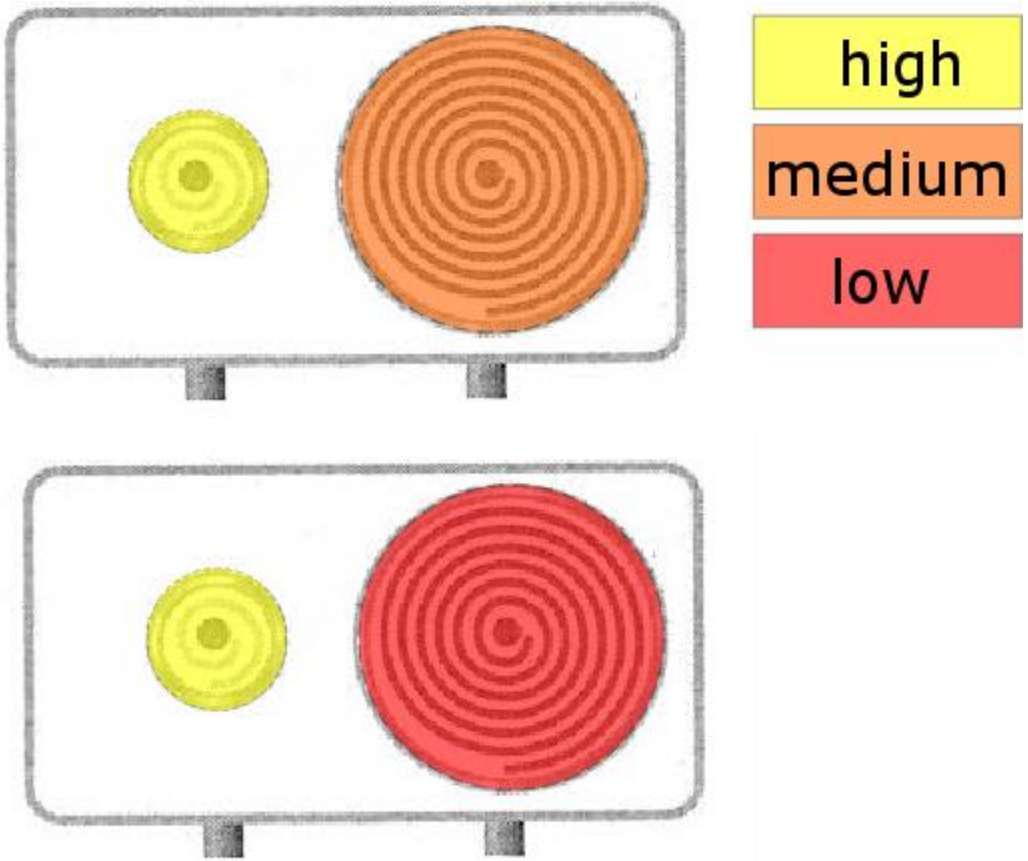
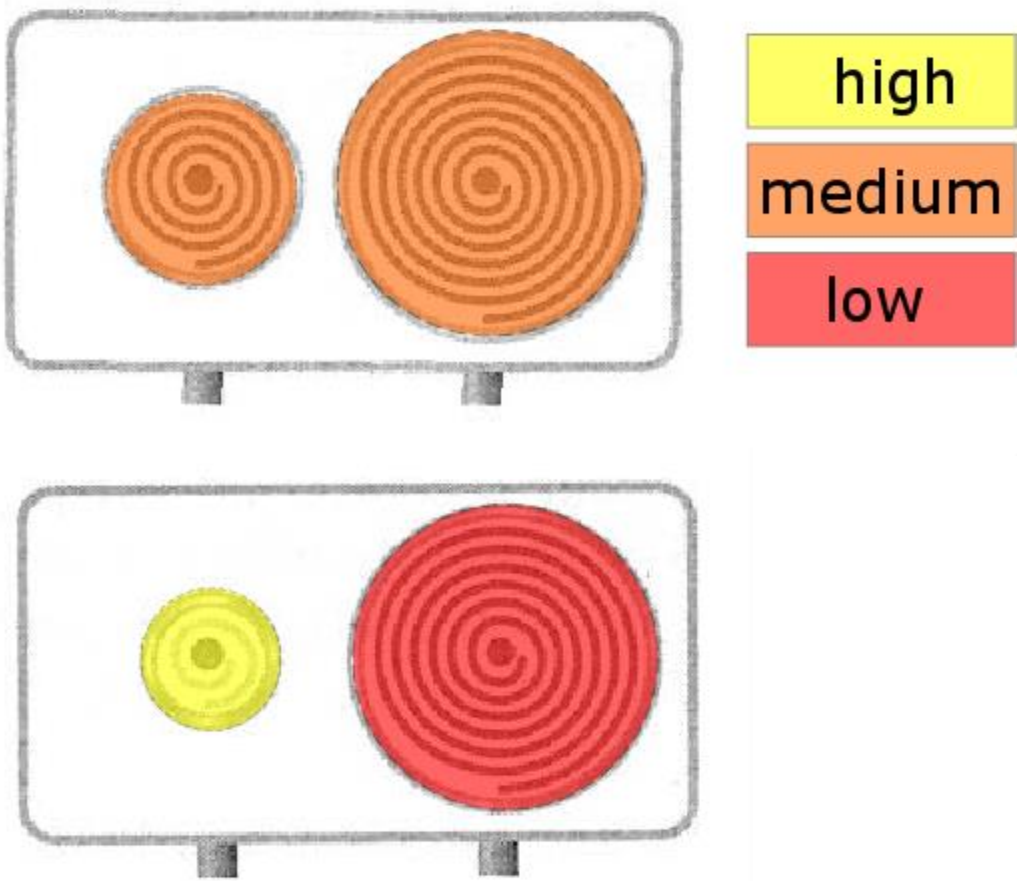


We cannot. As before, it would depend on hot different the temperatures are, and whether the small burner's temperature can make up for its smaller surface area. For example, the assumption might work for the bottom set of burners but not for the top set.

Can you assume that a large burner will boil water more quickly than a small burner?

A. Yup
B. Nope



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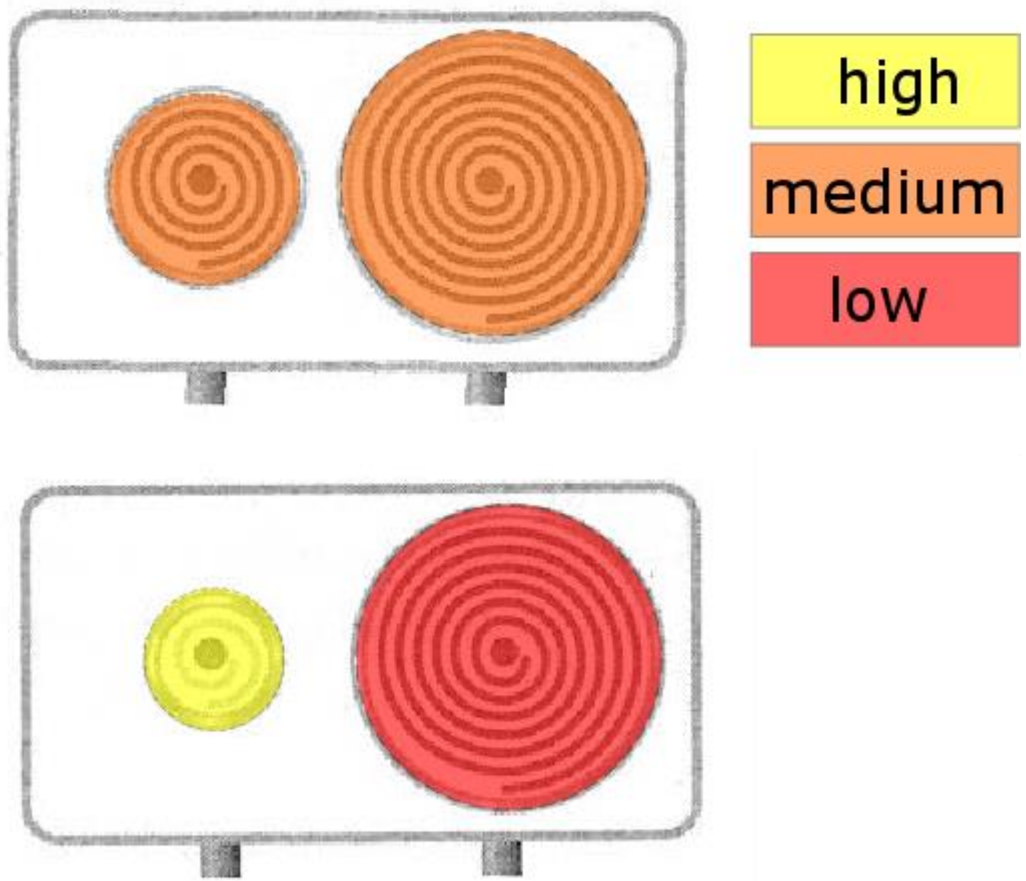

We cannot. As before, it would depend on hot different the temperatures are, and whether the small burner's temperature can make up for its smaller surface area. It would be true if the temperatures of the burners are fairly close, but not necessarily if their temperatures were very different.

What controls the time it takes a burner to boil a pot of water?

A. The temperature of the burner
B. The size of the burner
C. The total energy coming from the burner
D. The total temperature coming from the burner

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A. The temperature of the burner
B. The size of the burner
C. **The total energy coming from the burner**
D. The total temperature coming from the burner

Total energy is a function of the temperature and size (surface area) of the burner.

Which of these does not affect how much energy is coming from a burner?

A. The temperature of the burner
B. The radius of the burner
C. The area of the burner
D. They all affect the amount of energy

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If two burns with the same temperature are used to boil equal amounts of water, and one burner boils water more quickly, what can you conclude about the two burners?

A. The burners put out the same amount of energy
B. The burners have the same radius
C. The burners have different areas
D. All of these are true

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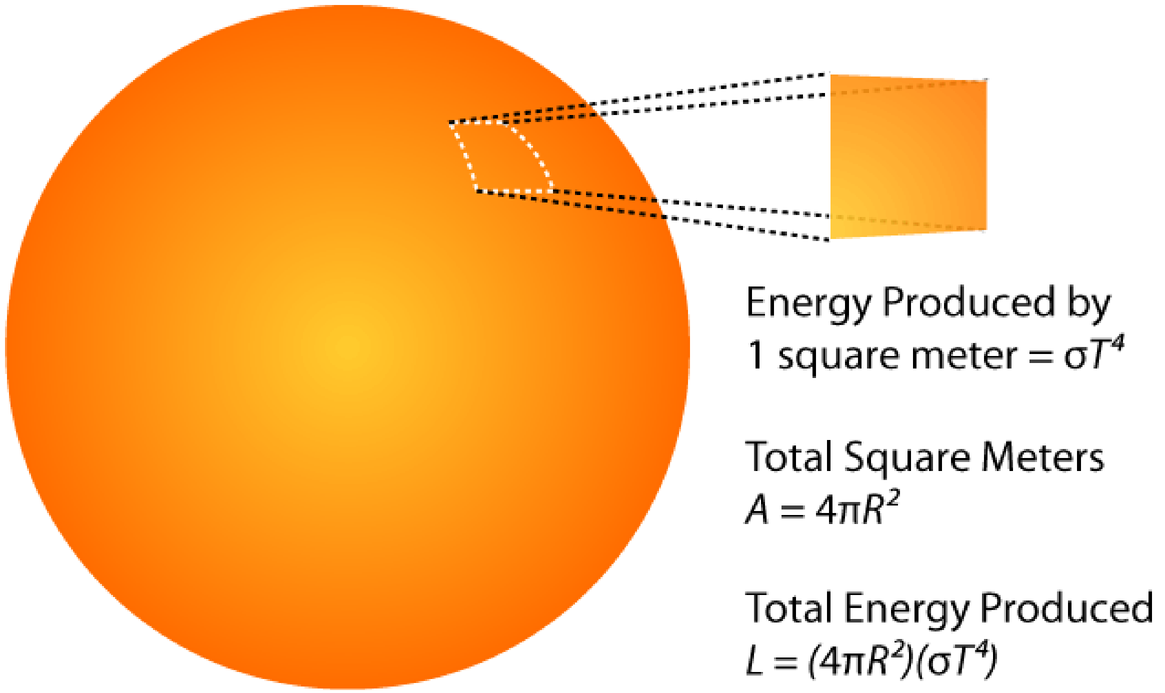
Total energy is a function of the temperature and size (surface area) of the burner, so one of these must change/differ if there is evidence for a difference in energy output.

The properties of blackbody radiation let us calculate how **bright** an object is.

- What about the total energy emitted by an object?
- **Luminosity:** energy per time
  - = flux multiplied by the area of the spherical shell the light is emerging from
  - $L = \sigma T^4 \times 4\pi R^2$



Quick Quiz: If Star A and Star B have the same temperature, but Star A's radius is twice that of Star B, how much more luminous is Star A?

A. 2x as much

B. 4x as much

C. 8x as much

D. 16x as much

E. Cannot be determined

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For help practicing and seeing how radius and temperature affect luminosity, see: http://astro.unl.edu/mobile/Luminosity/LuminosityStable.html

Quick Quiz: If Star A is twice as hot as Star B, but Star B has a radius twice that of Star A, which star is more luminous?

A. Star A

B. Star B

C. Star A & Star B have equal luminosities

D. Cannot be determined

Quick Quiz: If Star A is twice as hot as Star B, but Star B has a radius twice that of Star A, which star is more luminous?

A. Star A

B. Star B

C. Star A & Star B have equal luminosities

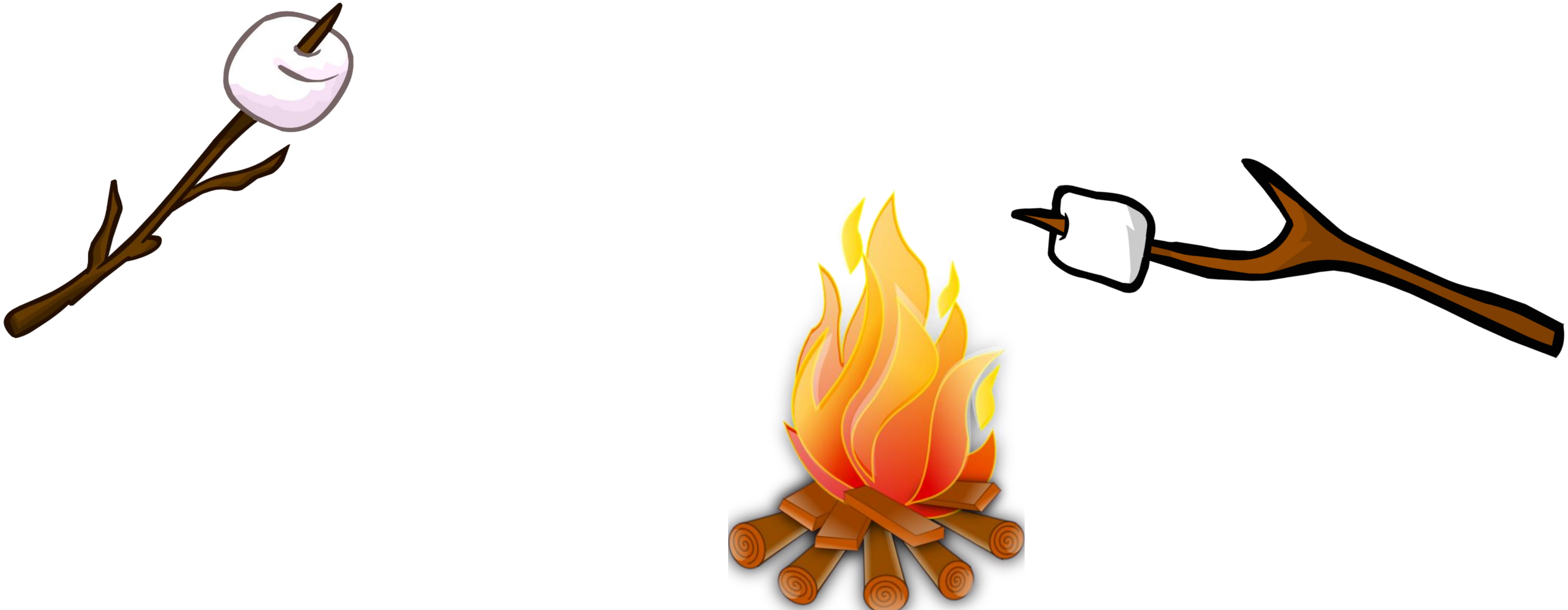
D. Cannot be determined

Which marshmallow will roast more quickly?

A. Left

B. Right

C. Same



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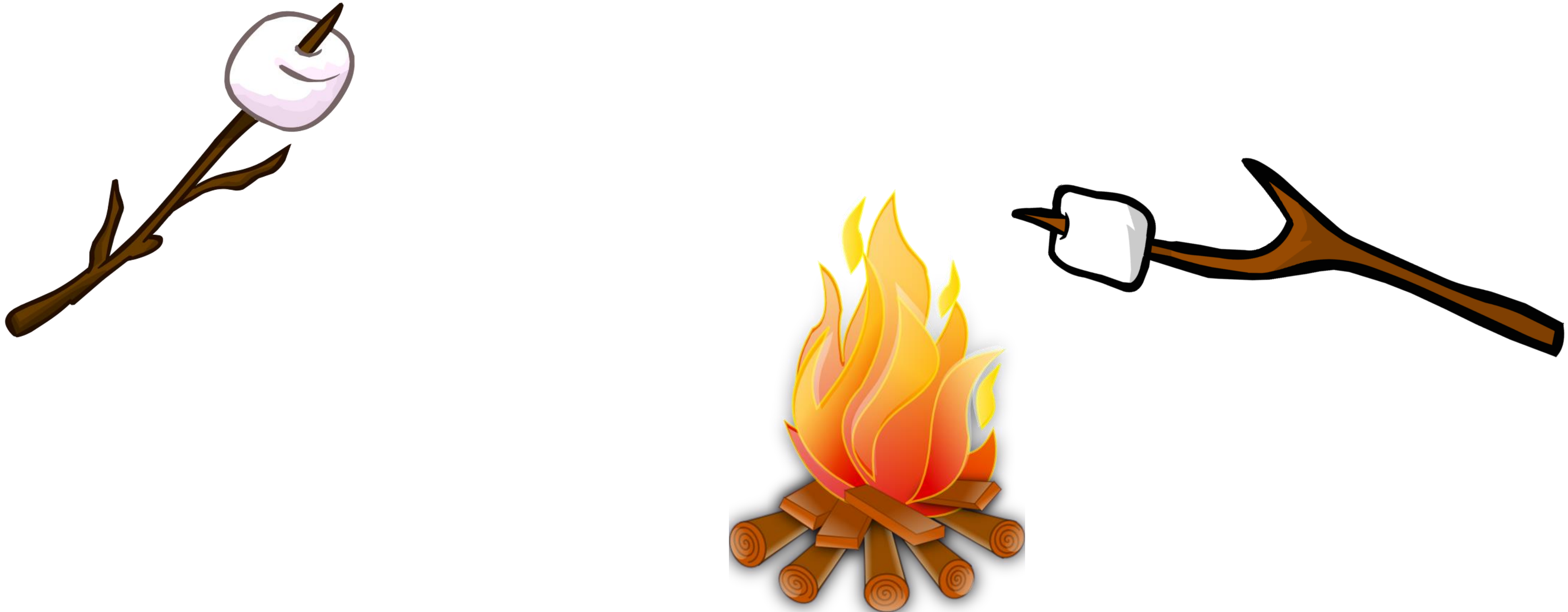


Which Earth be hotter?

A. Left
B. Right
C. Same

Which Earth be hotter?

A. Left

B. Right

C. Same

On which Earth would a telescope collect more photons from the star?

A. Left
B. Right
C. Same

On which Earth would a telescope collect more photons from the star?

A. Left

B. Right

C. Same

On which Earth would the flux of energy from the star be greatest?

A. Left
B. Right
C. Same

On which Earth would the flux of energy from the star be greatest?

A. Left

B. Right

C. Same

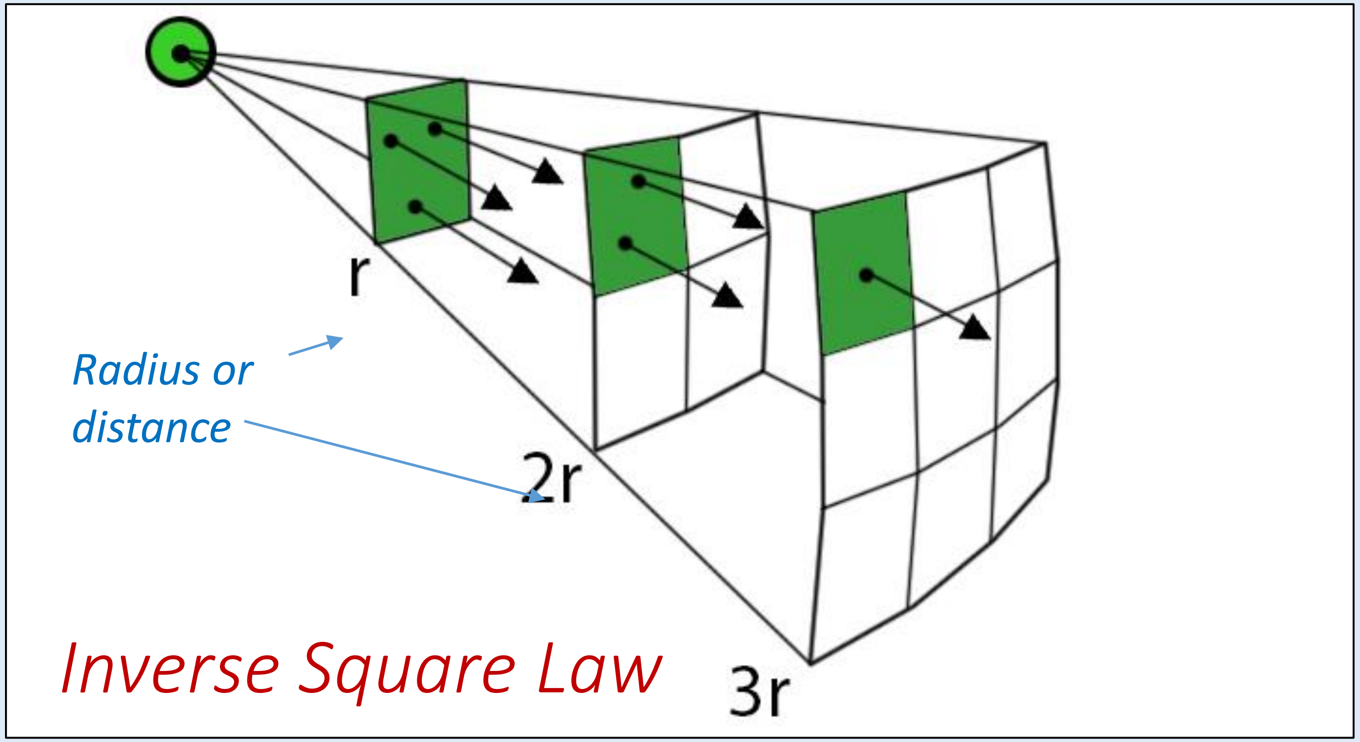
Which star will appear brightest to observers on Earth?

A. Left
B. Right
C. Same

Which star will appear brightest to observers on Earth?

A. Left
B. Right
C. Same

The measured energy coming from a star depends on how far away it is?



An object's brightness declines as 1 over the **square of its distance**.

$$\frac{1}{d^2}$$

The measured energy is the ***detected flux***.

$$F_{detected} = \frac{L}{4\pi d^2}$$

(L = luminosity)

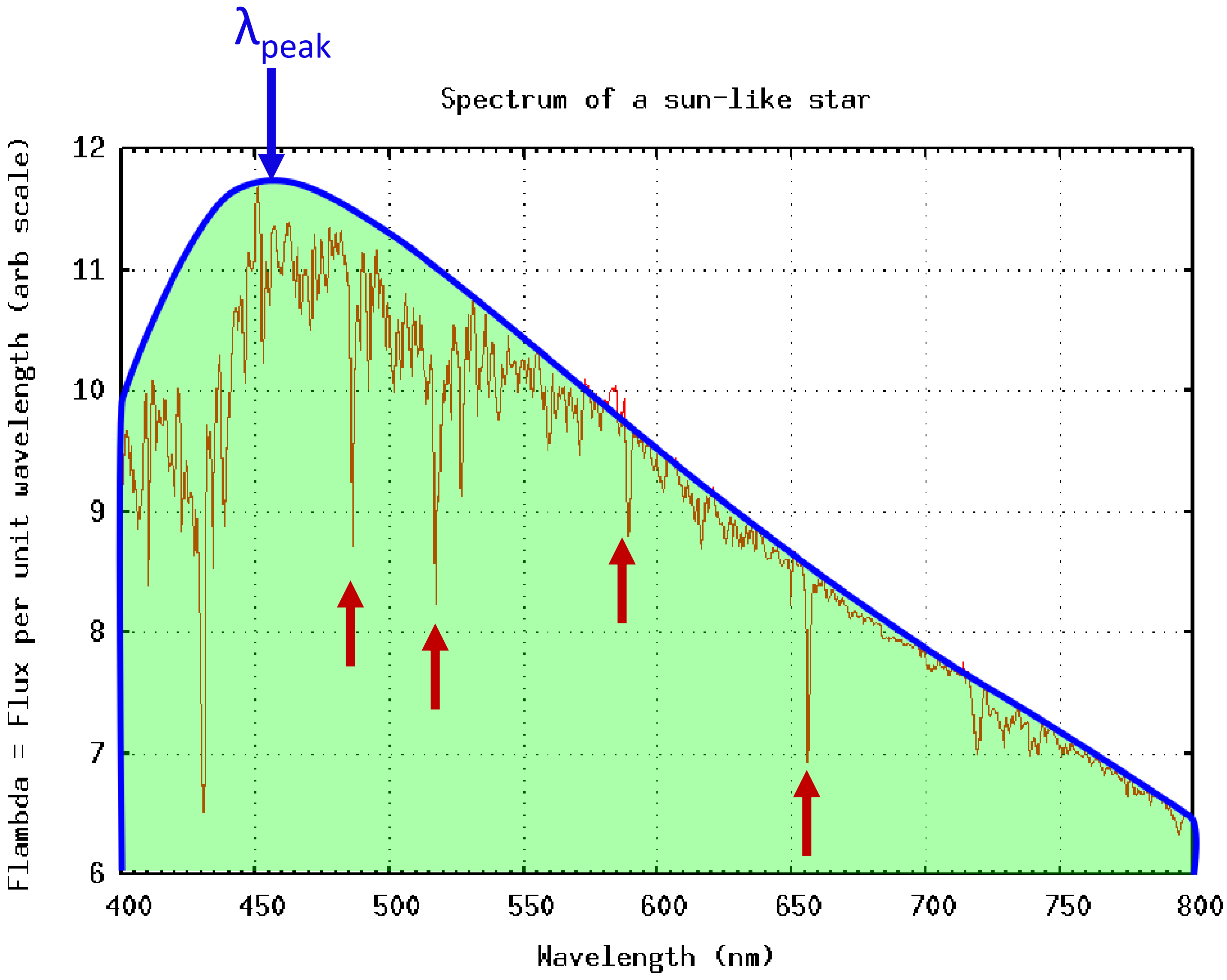
Note: Be careful to use the correct units for any calculations.

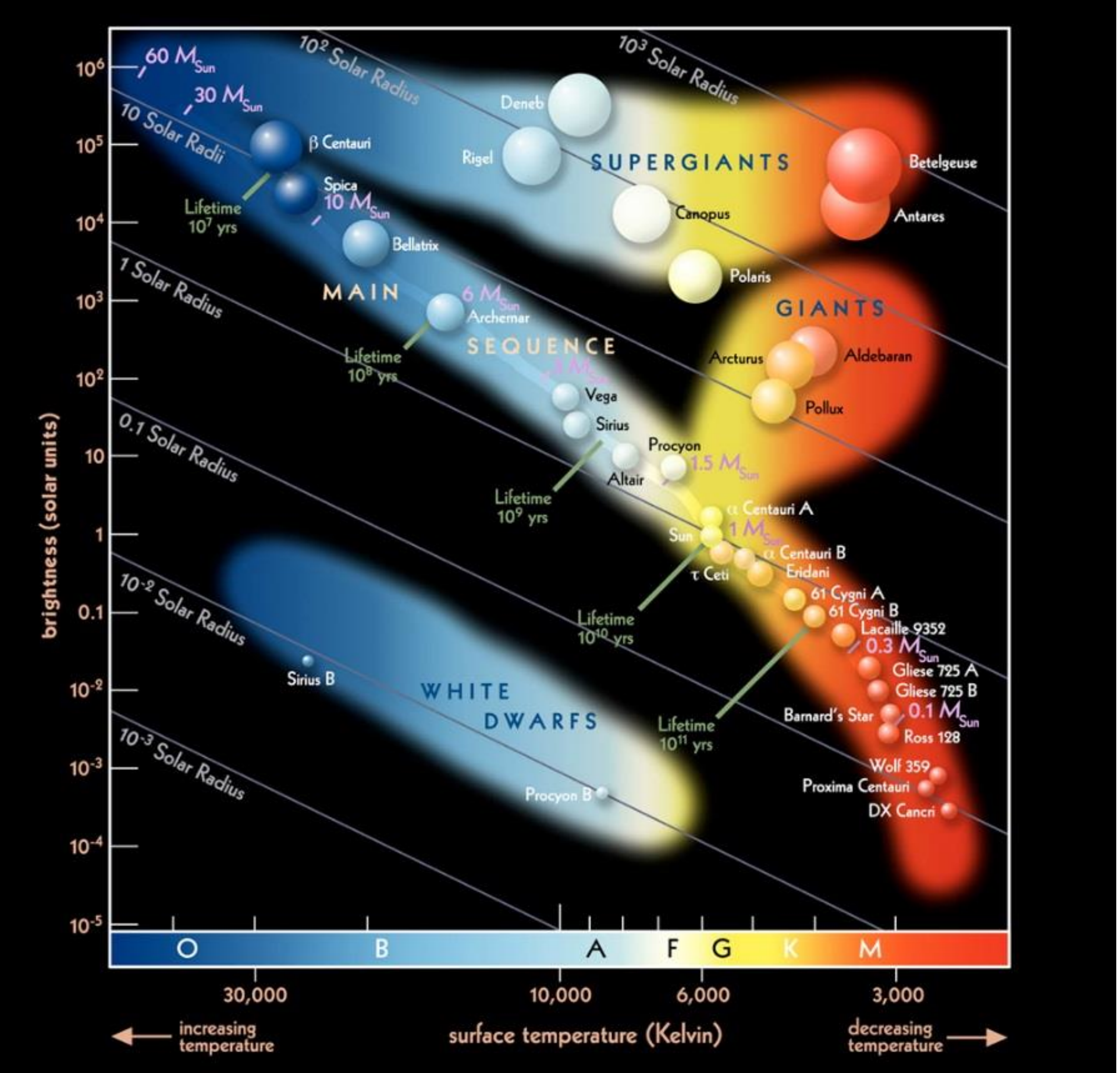
- *Luminosity is in Watts*
- *Flux is in Watts/m^2*
- *Therefore, distance needs to be in m*

So…

We have some really important properties we can tell about stars from measuring spectra

1. **Element composition** from absorption features
2. **Temperature** from blackbody curve (λ_{peak})
3. **Luminosity** from:
   - Detected flux (area under the blackbody curve)
   - Distance to star from Earth (from parallax measurements)





Using the really important features of stars:

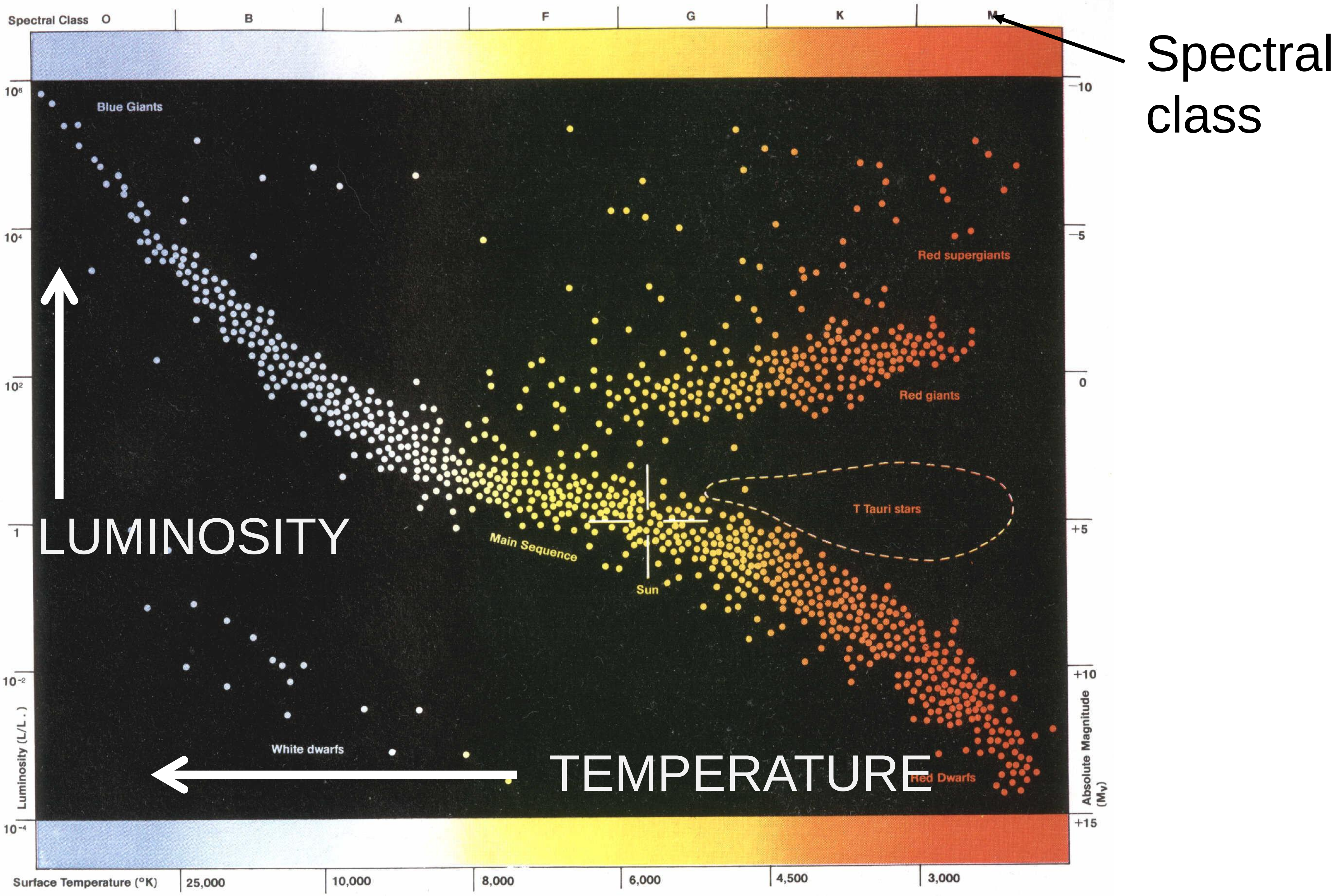
The Hertzsprung-Russell (H-R) Diagram

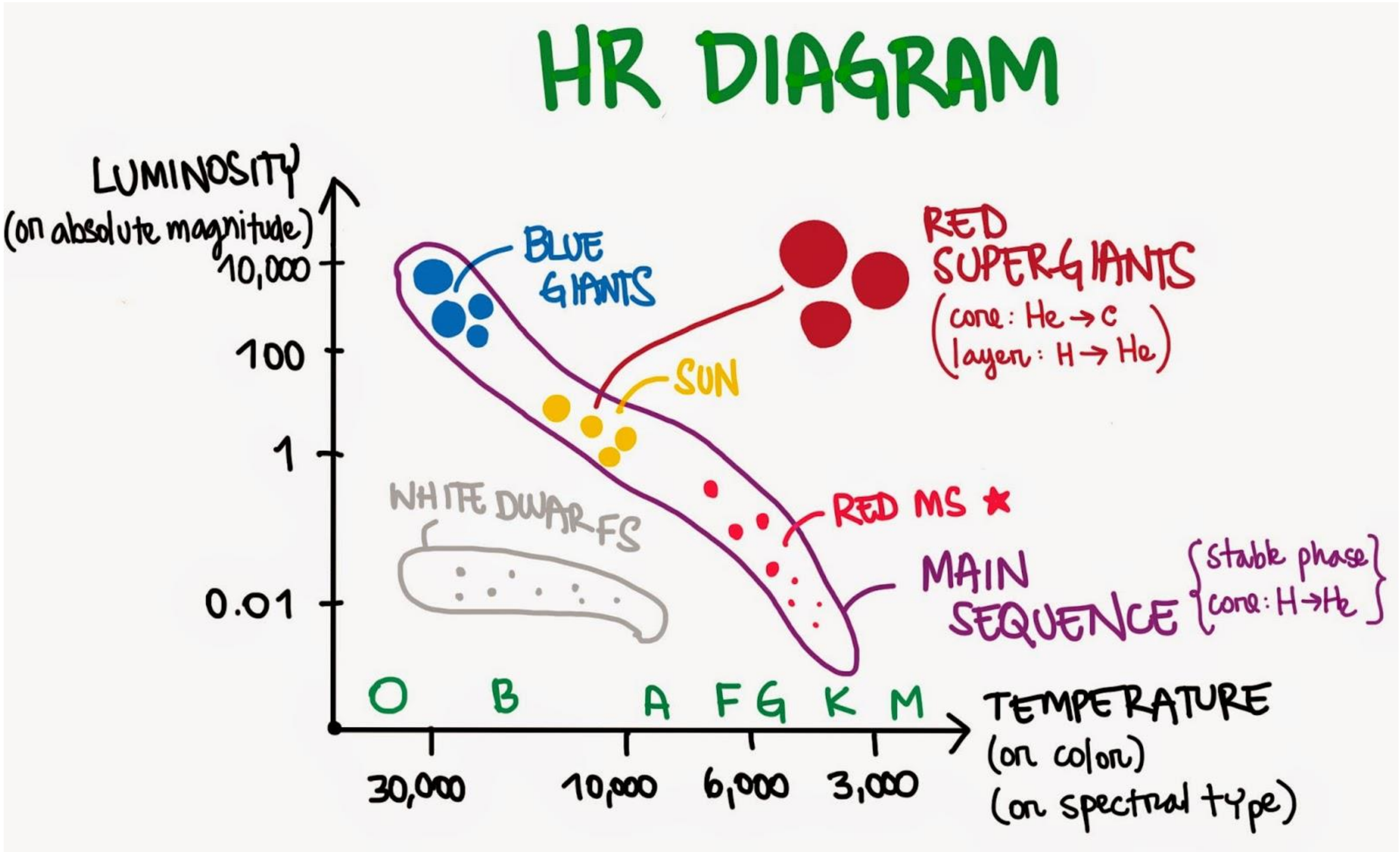
- With H-R diagram, we can plot the very important features of stars
- Then we can categorize and group them

I wonder what those categories and groupings might tell us…

The Hertzsprung-Russell Diagram

The principal means by which astronomers organize data on the luminosity (brightness) and surface temperatures of stars is by the construction of a Hertzsprung-Russell (H-R) diagram. In this figure the hottest, brightest stars are at top left while the coolest, faintest stars are at bottom right. The diagonal band of stars running from upper left to lower right is known as the Main Sequence and comprises those stars which are converting hydrogen to helium in their cores under stable conditions. The point on the Main Sequence at which a given star is found during this evolutionary stage depends on the star's mass, with the blue giants being the most massive and the red dwarfs the least massive of Main Sequence stars. Stars in other stages of their life are found elsewhere in the H-R diagram, for example as a red giant (upper right) or as a white dwarf (lower left). The spectral class of a star (top) depends on the excitation and ionization level of the atoms present in the stellar atmosphere; these in turn depend primarily on the atmospheric temperature. The spectral class of a star is thus closely linked to its surface temperature, as seen here.





http://rhc-astro101.blogspot.com/2014/04/discussion-ix-hr-diagram-and-nebulae.html

If we can measure the distance to a star, blackbody radiation lets us calculate how ***large*** it is.

$$L = \sigma T^4 4\pi R^2$$

so solve for R to get:

$$\sqrt{\frac{L}{4\pi\sigma T^4}} = R$$

Remember we can write L as:

$$F_{detected} \times 4\pi d^2 = L$$

Combining the last two equations:

$$\sqrt{\frac{F_{detected}\ d^2}{\sigma T^4}} = R$$

Moral of the story: if we can measure a star's flux and temperature from its spectrum, AND measure how far away it is, we'll be able to calculate its size!