Quiz 3 Feedback

1. Why are both the emission and the absorption lines from a specific ion at the same wavelengths? How are they produced?

Both emission and absorption lines involve having an electron move between two specific orbits – energy levels – with energies that are unique to the ion. Therefore, the **differences** in energies is also fixed by the ion. The energy of the photon that is emitted or absorbed must be equal to this difference in energy, and photons of a specific energy have a specific corresponding frequency and wavelength. Therefore the wavelengths must always be the same.

Electron Jumps in Atoms

1. cont'd.   What happens in atoms to produce each type of line?

- Electrons must **gain** energy in order to jump *from a lower energy level to a higher one.* This uses up a photon: creates an absorption line.
- When electrons fall *from a higher to a lower energy level*, they **lose** energy by emitting a photon. This creates an emission line with a specific wavelength.
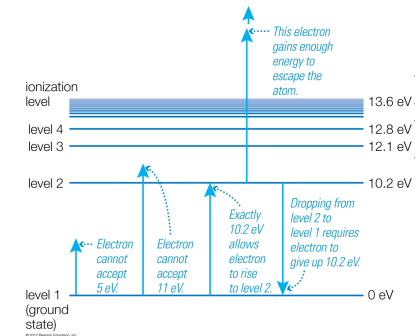

Figure credit: Bennett et al. The Essential Cosmic Perspective, 6e

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Emission and absorption of light by atoms

When an atom absorbs light, the photon energy must be exactly equal to the energy needed to make an electron jump from a lower-energy orbit to a higher-energy one.

When an atom emits light, a photon is created; the energy of the photon must be exactly equal the energy lost when an electron falls from the higher to the lower-energy state.
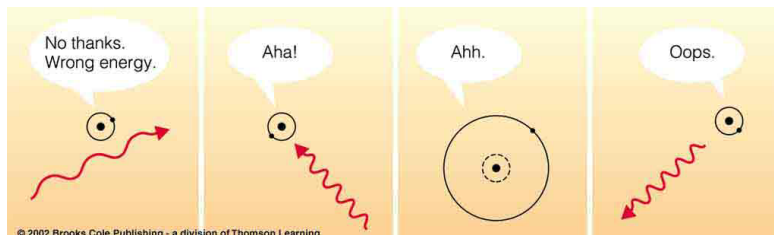
Credit: slide from Prof. J. Lacy

Quiz 3 Feedback

2. Describe two **different** methods for determining the surface temperature of a stars.

We talked about this on both Sep. 20 and again on Sep. 25. There are basically two approaches: (1) use some aspect of the thermal (continuous) spectrum, or (2) use the spectral type, which is based on which absorption lines you see.

There are several ways to use the continuous spectrum to get temperature, including finding the wavelength of peak intensity, or looking at the "color," the balance between red and blue light. These are based on the laws of thermal radiation. Using spectral type, we use the principle that temperature controls whether an element is present in neutral or ionized form, or in a molecule, and which energy levels the electrons occupy.

Laws of Thermal Emission

2. Hotter objects emit more intensely at shorter (bluer), cooler objects at longer wavelengths. (Wien's Law)

The higher the temperature of a blackbody, the shorter the wavelength of maximum emission (the wavelength at which the curve peaks).
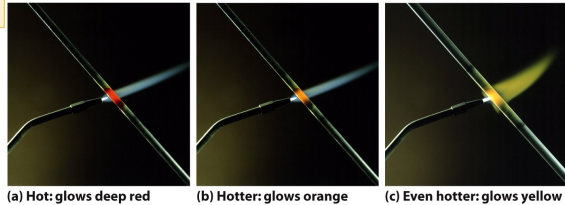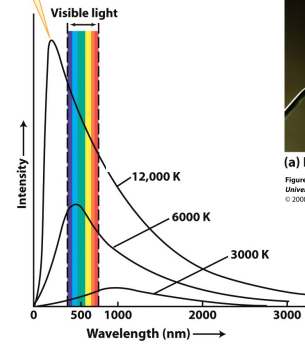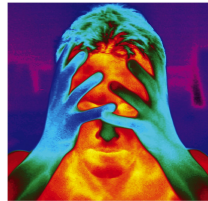
Visible light

12,000 K
6000 K
3000 K

Intensity

Wavelength (nm)

(a) Hot: glows deep red   (b) Hotter: glows orange   (c) Even hotter: glows yellow

Figure 5-9
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Humans "peak"
in infrared light.

Ast 309N (47760)

Temperatures from Spectral Shape or Color

Stars of different temperatures have different relative amounts of light at different colors: more blue than red, or vice versa.
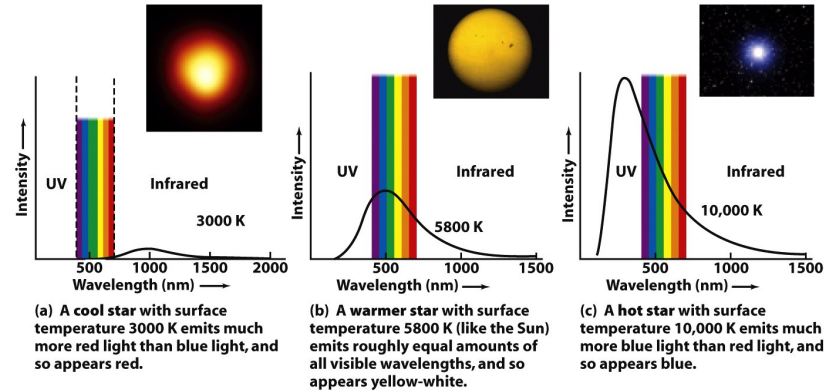
Intensity — UV — Infrared — 3000 K — Wavelength (nm) — 500 1000 1500 2000

Intensity — UV — Infrared — 5800 K — Wavelength (nm) — 500 1000 1500

Intensity — UV — Infrared — 10,000 K — Wavelength (nm) — 500 1000 1500

(a) A **cool star** with surface temperature 3000 K emits much more red light than blue light, and so appears red.

(b) A **warmer star** with surface temperature 5800 K (like the Sun) emits roughly equal amounts of all visible wavelengths, and so appears yellow-white.

(c) A **hot star** with surface temperature 10,000 K emits much more blue light than red light, and so appears blue.

Figure 17-7
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Temperatures from Absorption Lines

Another method of determining a star's surface temperature is by examining the **absorption lines** in its spectrum. The system of **spectral types** was developed at Harvard Observatory in the 1890's by Annie Jump Cannon and her colleagues.

Figure 17-10
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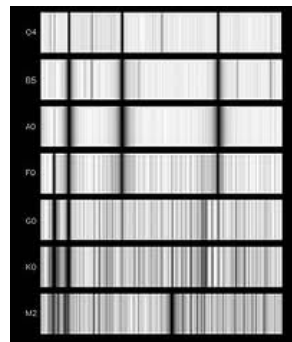
How Spectral Types Work

- Spectral types are **defined** by which absorption lines of various elements, ions, and molecules, are seen in a star's spectrum and the relative strengths of these lines.

- Spectral type <u>is not</u> (usually) determined by composition.

- Instead, the vast majority of stars have **the same** surface composition: roughly ¾ H, ¼ He, 2% other elements.

- Molecules can survive only at low temperatures; as T rises, they break up into separate atoms. As T rises further, the atoms start to become ionized.

- Temperature determines *which ions* or molecules of each element are abundant, and *which energy levels* contain most of the electrons, which in turn determines the number and relative strengths of the absorption lines you see.

Common Misunderstandings

"You get the temperature of the star from its luminosity… its brightness … apparent brightness and distance."

•All of these are wrong. Luminosity is a *different* property than temperature. Knowing just luminosity or brightness is not sufficient information to derive the temperature.

•You can **only** do so if you *also* know the surface area or radius. Then, in principle, you can use the Stefan-Boltzmann law of thermal radiation, in the form: $L = 4\pi R^2 \sigma T^4$.

•However, this relation is **almost never** used to derive the temperature of a star, because it is virtually impossible, at least at present, to measure the radius of a distant star. Instead, as explained on Sep. 25, we determine L and T by other methods, and find R from the above equation.

Radius from Luminosity & Temperature

- The luminosity of a star is:

  Surface Area × Energy emitted per unit S.A. =

  $(4\pi R^2) \times (\sigma T^4)$ = Luminosity

- So, if you know L and T, for example, you can calculate R from this formula.

- This is, *in practice*, the way most stellar radii are estimated (indirectly, from L and T).

- A luminous star of low T must be *large;* a high-T star can only have a low luminosity if it is *very small*.

Common Misunderstandings

"You get the temperature of a star by looking to see whether it has emission lines, absorption lines, or a continuous spectrum."

•All stars essentially have absorption lines on a thermal (continuous) spectrum. If there are emission lines, those come from low-density hotter gas above the surface.

"You get temperature from the mass."

•The mass of a star tells you where it will be on the Main Sequence, hence its luminosity and temperature. But this works *only for Main Sequence stars*, and the question did **not** specify that this is a Main Sequence star.

"You look at where the star is in the HR diagram."

•There is no HR diagram in the sky where we can read off a star's position! You have to *determine* a star's temperature, as well as its luminosity, before you can plot it in the diagram.

Review: How Stellar Properties are Measured
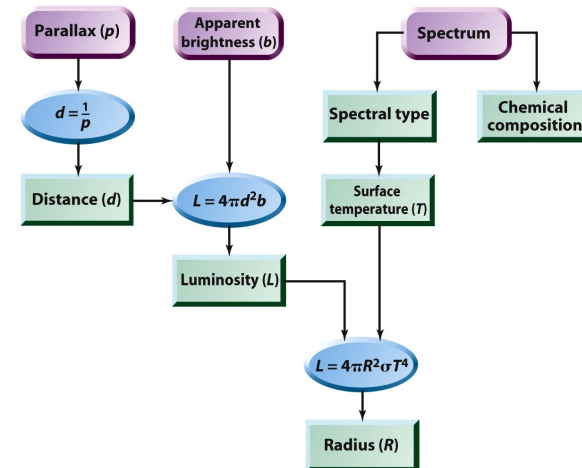

Figure 17-14
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