Class 3 notes: Chapter 2

Dr. Steen

30 Aug 2017

To bring:

- Ukulele
- IR thermometer
- Contigo mug + Knoxville Mercury coffee mug

Announcements:

- Canvas discussion board; review of "muddiest" issue in previous lecture
- Homework: Due Sept 7
  - Policy: it is acceptable to do these as a group
  - Include name of each group member on document
- Seriously, spend time with the homework key

Quiz

Lecture

Radiative transfer

- Heat is energy of molecules bouncing around
  - The more bouncing energy, the hotter the thing is
  - Thus "a thermometer is like an atomic speedometer" because temperature is just a measure of the speed, or bounciness, of atoms and molecules.
- You can transfer heat in 3 ways
  - Conduction: molecules bounce into each other, thus spreading the bounciness

- Convection: bouncy molecules move from one place to another. (A game of Hot Potato is an example of conduction.)
- **Radiation**: Atomic bounciness is transformed into light, which strikes a different atom, making the second atom bouncier.

- In space, there are no atoms to bounce. **The only way to transfer heat energy across a vacuum is by radiation.**
  - This is why a really good Thermos works: There's only one way to transfer heat energy across a vacuum, instead of 3.

Light and energy

- All waves follow the relationship $\lambda = \frac{c}{\nu}$ where λ is the wavelength (m or cm), c is the speed of the wave (m/s or cm/s) and ν is the frequency (ν)
  - Remember that all of these are also related to wavenumber n, by $n = {}^{1}/_{\lambda}$
  - See Archer Fig. 2-1
- Higher frequency (shorter wavelength, higher wavenumber) light carries more energy, according to the relationship $E = h\nu = {}^{hc}/_{\lambda}$, where h is a fundamental constant called Planck's constant.
  - Q: what is the relationship between energy and wavenumber?
- We use different names to talk about light with different wavelengths/wavenumbers/frequencies - **but fundamentally they are just different colors of light**

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  Group question: Why does my Contigo coffee mug so much better than my
  Knoxville Mercury coffee mug at keeping my coffee hot?
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Blackbodies, or Why is everything lit up all the time?

- (Draw organic molecule) Chemical bonds are what hold molecules together.
- Archer uses the metaphor of weights on a spring for chemical bonds. I like to use the metaphor of a guitar, but really they're communicating the same idea.
- Chemical bonds act like little guitar strings - they tend to 'ring' at certain frequencies (see Archer Fig. 2-3)
- Light can 'ring' these guitar strings - that is, if light of a given frequency strikes a molecule that 'rings' at that same frequency, the light will transfer its energy to the molecule, thus heating it up
- **THIS RINGING GOES BOTH WAYS**: If a bond can 'ring', it can be 'rung'; this fact is known as the Kirchoff effect. That is to say, if a bond can absorb energy from light, it can lose energy by emitting light. **That**

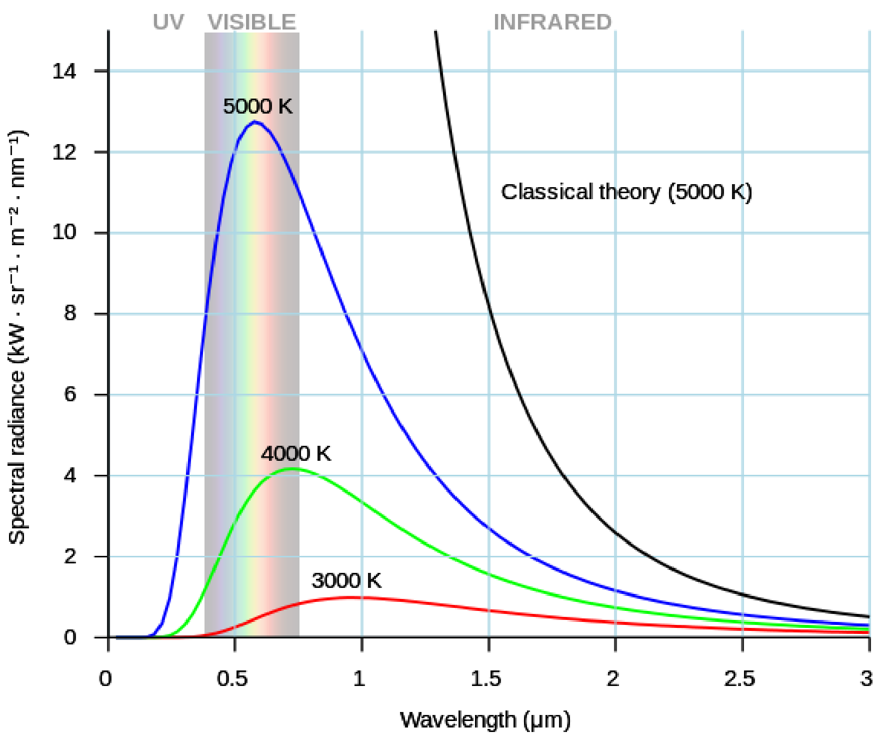

Figure 1: examples of blackbody curves

is why all objects emit light, just due to the fact that they have a temperature.

- We imagine a theoretical object that can ring perfectly well at all frequencies. We call that theoretical object a "blackbody".
  - There's no such thing as a "perfect" blackbody, but most solids and liquids are "good" blackbodies - that is to say, they can absorb and emit light pretty well at most frequencies.
  - Remember the Stefan-Bolzmann equation: $I = \epsilon\sigma T^4$. The emissivity, ϵ, is an indicator of how good of a blackbody the object is. (1 = perfect blackbody, 0 = worst possible blackbody).
    `Group question: What is the temperature of the universe? (See fig below)`

Some more formulae - only pay attention to these if you feel like it

- A few other useful relationships (don't memorize these, but if you spend some time with them, they might help you understand blackbody radiation a bit better)
  - Wien's displacement law: the wavelength at which maximum intensity per unit wavelength is emitted is given by:

$$\lambda_{max} = \frac{2.9 \times 10^{-3}\mathrm{K} \cdot \mathrm{m}}{T}$$

  - Spectral radiance B as a function of wavelength and temperature is given by:

$$B_{\lambda,T} = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_b T}} - 1}$$

One of the most amazing plots in all of science:

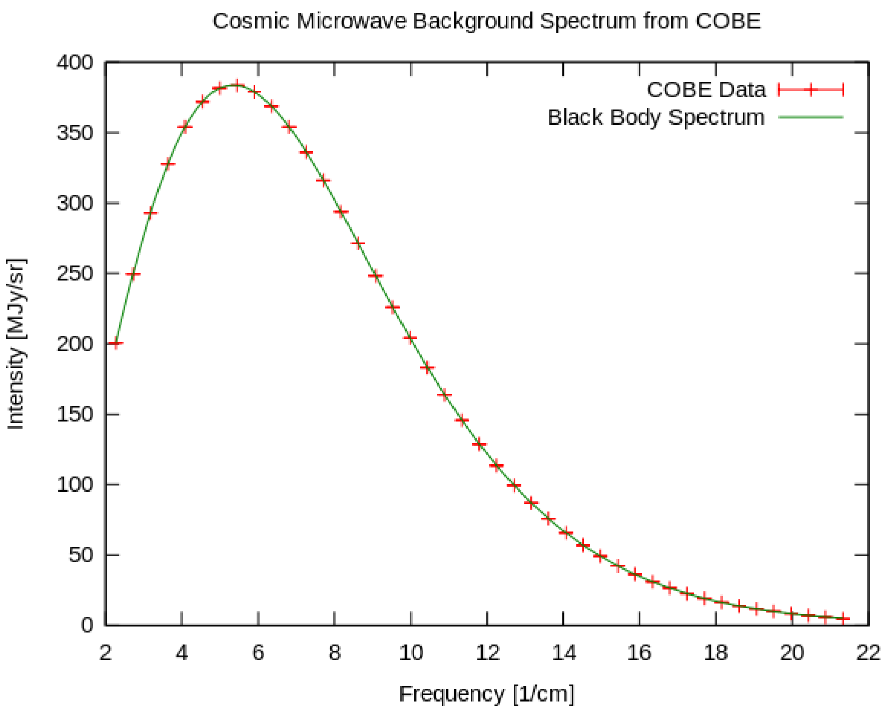

Figure 2: Cosmic Microwave Background Radiation