# Light, Thermal Radiation

- What can we learn by analyzing light?
  - Example of globular cluster
- Thermal radiation
  - Radiation of warm bodies

- See if your name was registered. Click.
- Register your clicker if you have not already
  - E-mail me your number.
  - H-ITT records your answers, but I want to give credit to a person, not to a clicker number.
- Homework 3 is ready on angel.
  - Due at 6:00am on Tues, 30th.

- First Test is Thurs, Feb 1st
  - About 30 multiple choice questions
    - Some require working with models such as phases of Venus & zodiac (Fig 2.12).
  - Click on Study Guide & 2005 Test on Syllabus.
  - Class of 25th is last class on test
  - How to study
    - Identify Big Ideas
    - Practice models & examples
    - Do 2005 test
    - Go over homework & clicker questions
  - Missouri "Show Me" Club
    - Mon 29th, 7:00-8:00pm, 1415 BPS

# Light

- Almost all we know about astronomy comes from analyzing light.
- Example: globular clusters
  - Around 1915, Harlow Shapley figured out the distances to the Milky Way's globular clusters.
  - What do you notice about the light of the globular cluster M10?

Globular Cluster M10

# Light

- Almost all we about astronomy comes from analyzing light.
- What do you notice about the light of the globular cluster M10?
  - Color: Red stars are brighter than blue stars ⇒ Red stars are giants, about the size of the earth's orbit.
  - Spectra show M10 has much less oxygen (and other elements heavier than Li) than sun ⇒ M10 is very old, one of the first systems to have formed
  - Spectra shows the speed of M10 is very fast compared to that of stars near the sun ⇒ orbits of globular clusters are long & thin, whereas sun's is almost circular

**Globular Cluster M10**

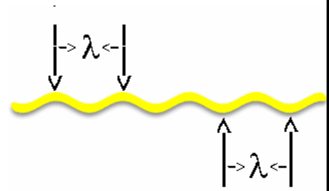
# Wavelength, Frequency

- Wavelength $\lambda$ = distance between successive crests.

  m meter

  nm nanometer ($10^{-9}$m)

  Å angstrom ($10^{-10}$m)
- Wave moves at speed of light c.
- Frequency is rate at which crests pass.
  - $f = c/\lambda$
  - Cycles/second; Hertz



# Light is quantized

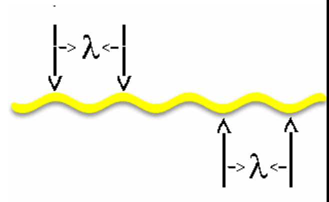
- A photon is a quantum, the smallest amount, of light.
- A photon carries energy

  $E = h\,f = h\,c\,/\,\lambda$ (h is Planck's constant)

  - A photon can do an amount of work E
    - Give an electron its energy
    - Make an electron move faster
- A photon carries momentum

  $p = h\,f\,/c = h\,/\,\lambda$

  - A photon can give a push
    - Push an electron against pull of gravity




The E-M wave in action link

# Thermal radiation

## (Blackbody Radiation)

- Any object that absorbs light also emits light.
  - If not, it would get hotter and hotter. Could get energy for free.
- A perfect absorber (perfectly black) emits a characteristic spectrum of light. (Called thermal or black-body radiation.)
  - Intensity depends only on
    - Temperature
    - Area
- A non-perfect absorber (grey body) with emissivity $\varepsilon$ absorbs a fraction $\varepsilon$ and reflects a fraction $(1-\varepsilon)$.
  - Intensity is $\varepsilon$ that of thermal radiation.

## Infrared camera—Seeing with infrared eyes

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- Thermal infrared
  - Wavelength is 8,000-12,000 nm
  - An object with a temperature of 300K emits most of its light in the thermal infrared.
  - Does infrared light show the same thing as visible light?

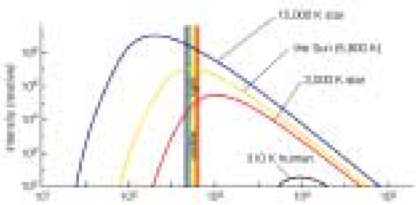
- Q1 As viewed with an infrared camera, why is my earlobe darker than my lips?
  A. My earlobe has less area than my lips.
  B. My earlobe has less emissivity.
  C. My earlobe is cooler.
- Q2 The emissivity of a mirror is
  A. approximately 0.
  B. approximately 1.
- Q3 As viewed with an infrared camera, the window is dark because
  A. It is cold and emissivity is 1.
  B. There is little infrared radiation in sunlight.
  C. It is cold and emissivity is 0.
  D. Emissivity is 0.

## Thermal Radiation

- Heat up hot plate (or a star)
  - It glows more brightly as it gets hotter
  - It changes color as it gets hotter

| | Temperature | | | Color |
|---|---|---|---|---|
| | $^{o}$K | $^{o}$C | $^{o}$F | |
| Completely cold. | 0 | -273 | -459 | Does not emit light |
| Body temperature. | 310 | 37 | 99 | Infrared |
| Blowtorch. | 4000 | 3727 | 6740 | Red-hot |
| Blast furnace. | 6000 | 5727 | 10,340 | White-hot |
| Hotter still. | 7500 | 7227 | 13,040 | Blue-hot |

## Black-Body Spectrum



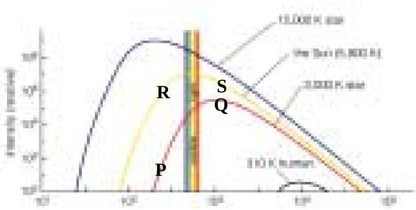
**Wavelength [nm] ➔**
**🡐 Energy**

- Peak wavelength given by Wien's Law.
  - $\lambda_{max}$ = 0.0027m-K / T
  - hotter objects have peak at smaller $\lambda$.
- Total energy emitted per s *per unit surface area* is given by Steffan-Boltzmann Law:
  - E = $\sigma$ $T^4$
  - Increase with temperature is very steep: factor of 2 for a factor of 1.2 in T

- Characteristic shape
  - Sharp drop towards higher energy.
  - Slow drop towards lower energy.
- Star is an approximate black body.
  - Sun is an approximate 5800-K black body.
- The Big Bang is an exact 2.7-K black body.

interactive Wien's law

## Black-Body Spectrum

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- Q4: There is light in a dark room. The plausible reason is
  a. It is impossible to cover the windows completely
  b. My eyes see blotchy light in a dark room
  c. Everything in the room emits infrared light, which our eyes cannot see.
- Q5: A hot object emits more infrared radiation than a cool object. An example of this is
  a. Q & S
  b. P & R
  c. R & S
  d. R & Q
- Q6: S1: A hot star always emits more light than a cool star. S2: The sun is pretty bright at infrared wavelengths of 10,000nm.
  a. S1 is true; S2 is true.
  b. S1 is true; S2 is false.
  c. S1 is false; S2 is true.
  d. S1 is false; S2 is false.

interactive Wien's law