Astronomy 150: Killer Skies
Lecture 19, March 5

Assignments:

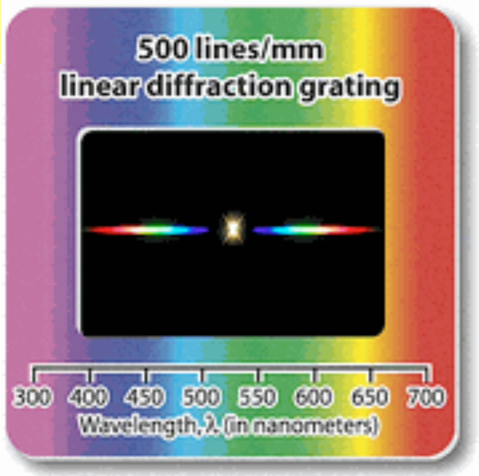
- HW6 due Friday at start of class
- Night Observing continues this week

  last week! go when you get the chance!

Last time: Solar Storms

Today: How typical is the Sun? Properties of Stars

Pick up (and then return)
a diffraction grating
- boxes in front and back of room
- acts like a prism
- try it!



CLICK IMAGES TO ENLARGE

http://apod.nasa.gov/apod/ap030207.html

Imagine

- Astronomers are the first to know.
- Neutrino detectors around the world are overwhelmed by the blizzard of signals
- Gamma and x-ray telescopes are quickly blinded by the bright light from the object
- Then in the night sky a star gets brighter and brighter, easily seen with the naked eye and still getting brighter.
- Can easily be seen during the daytime!
- The first supernova in 400 years!

Imagine

The power grid collapses

The sky around the star is blue!

Gamma Rays have already destroyed the ozone layer, we just don’t know it yet.

Severe sunburn, but UV radiation will kill off phytoplankton, the base of the food chain

A new mass extinction is happening!

As you die blissfully, you wonder what Brian was going to talk about this week.

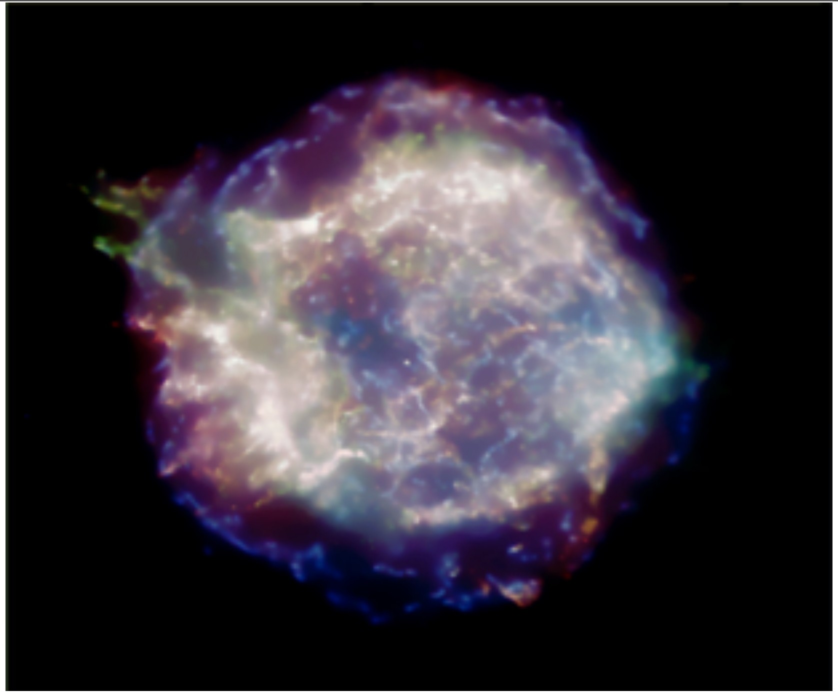
Top 10 Ways Astronomy Can Kill you or your Descendents

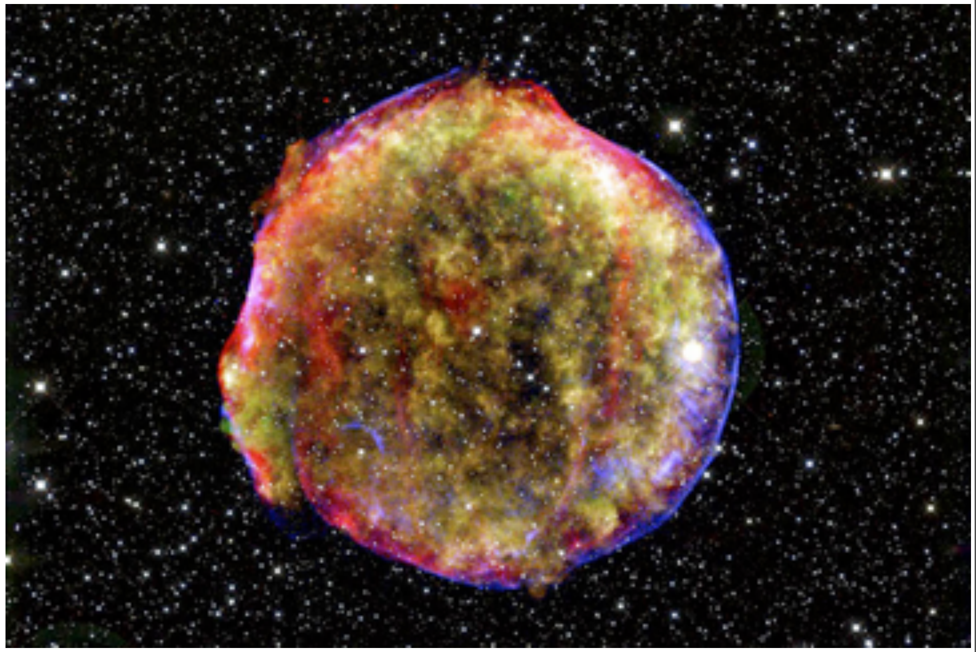
4. Supernova in the face!

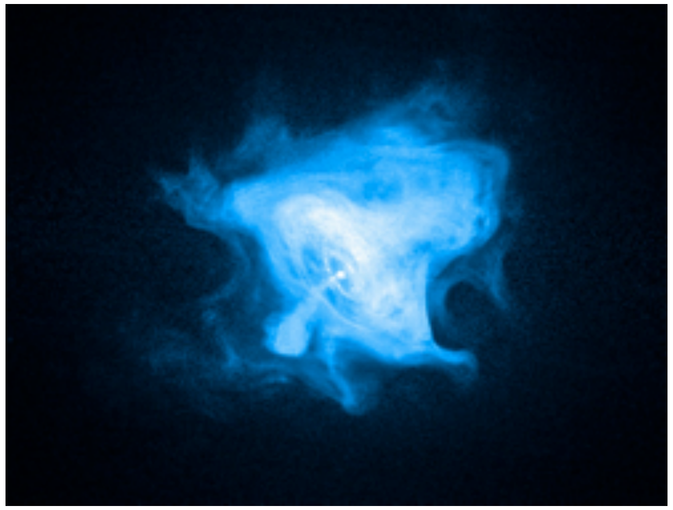
Extreme energy! Can destroy the ozone layer!

http://www.youtube.com/watch?v=0J8srN24pSQ

Killer Stars: Threat Assessment







Space beyond the solar system is filled with stellar weapons of mass destruction!

- exploding stars: supernovae
- death rays: gamma-ray bursts
- black holes

these all come from the lives and deaths of stars

so to understand the threat, we need to understand stars

- what are stars like? masses, sizes, luminosities?
- how far away are they?
- how are they similar to the Sun? different?
- how common are the most dangerous events?

The Astronomer's Toolbox

From here on out, we will be interested in (and worried about!) objects beyond the solar system

- These are too far to visit!
- at least with current technology

But don't give up hope: we can still learn a lot even when stuck on Earth (or in orbit around it)

Talk to you neighbor, and come up with a list:

From Earth, what are things we can directly measure about stars?

- More than one right answer!

Click A when you are finished

Star Properties?

What can we directly measure?

Hard-nosed list:

- position on sky
- color/spectrum
- intensity/brightness
- time changes (if any) in the position, color, brightness

All other information (all the really interesting stuff!) is indirect!

Lesson:

⇒ can only measure light!

can look but can't touch!

⇒ need to understand light to understand stars

Light

Light deeply connected to

- electric charge,
- electric and magnetic forces

Experiments show:

- changing E force generates M force
- changing M force generates E force

And so:

1. E&M linked: “electromagnetic force”
2. EM disturbances can travel through space: each regenerates the other:

   $E \rightarrow M \rightarrow E \rightarrow M \rightarrow \ldots$

electromagnetic waves = “EM radiation”

Light Waves

light is a type of wave:

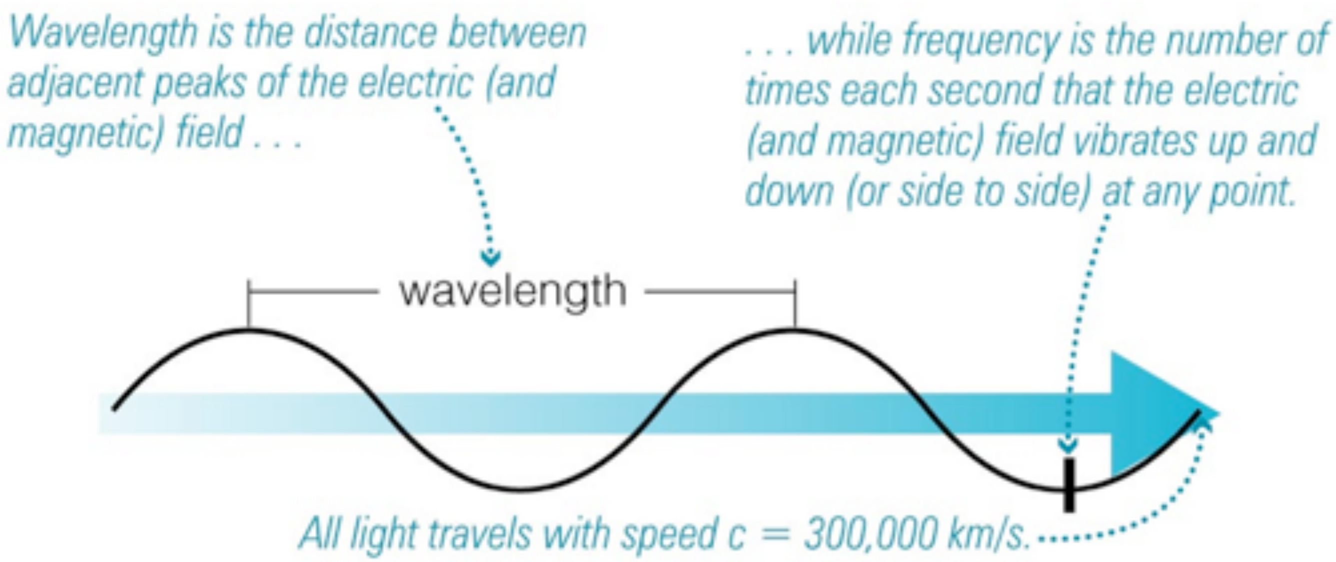
a wave is oscillating disturbance in a medium

wave can travel, medium does not

Demo: Illini waves!

Wave snapshot:

- **wavelength λ (greek: lambda)**
  size of one cycle → wave "ID number"
- **intensity I**
  "strength" of wave = "height of peaks"



Wave snapshot at one instant of time

Demo: slinky:

- **pulse**
- **same wavelength, diff't intensities**

Q: Sound waves: how do we experience λ? I?

Q: Light waves: how do we experience λ? I?

Waves: Sound vs Light

Sound:

sound wavelength $\lambda \leftrightarrow$ pitch

- high pitch (treble): small λ
- low pitch (bass): large λ

sound intensity = loudness

Light:

light $\lambda \leftrightarrow$ color

- visible light: larger λ: more red
- smaller λ: more blue

intensity = brightness

The Speed of Light

Light is very fast! So fast that it was a feat to measure the speed in lab now known quite well

$$
\begin{aligned}
c &= \text{constant} \\
&= 299,892,458 \text{ meters/sec} = 300,000 \text{ km/sec} \\
&= 670 \text{ million mph}
\end{aligned}
$$

enormous–but not infinite!

→ finite speed of light hugely important for astronomy

→ telescopes are time machines Q: how?

note: light speed c is same for all λ

Q: what would happen if this were not true?

The Electromagnetic Spectrum

EM waves can have λ
outside of visible range

- already saw demo: ordinary remote controls emit invisible flashes: infrared!

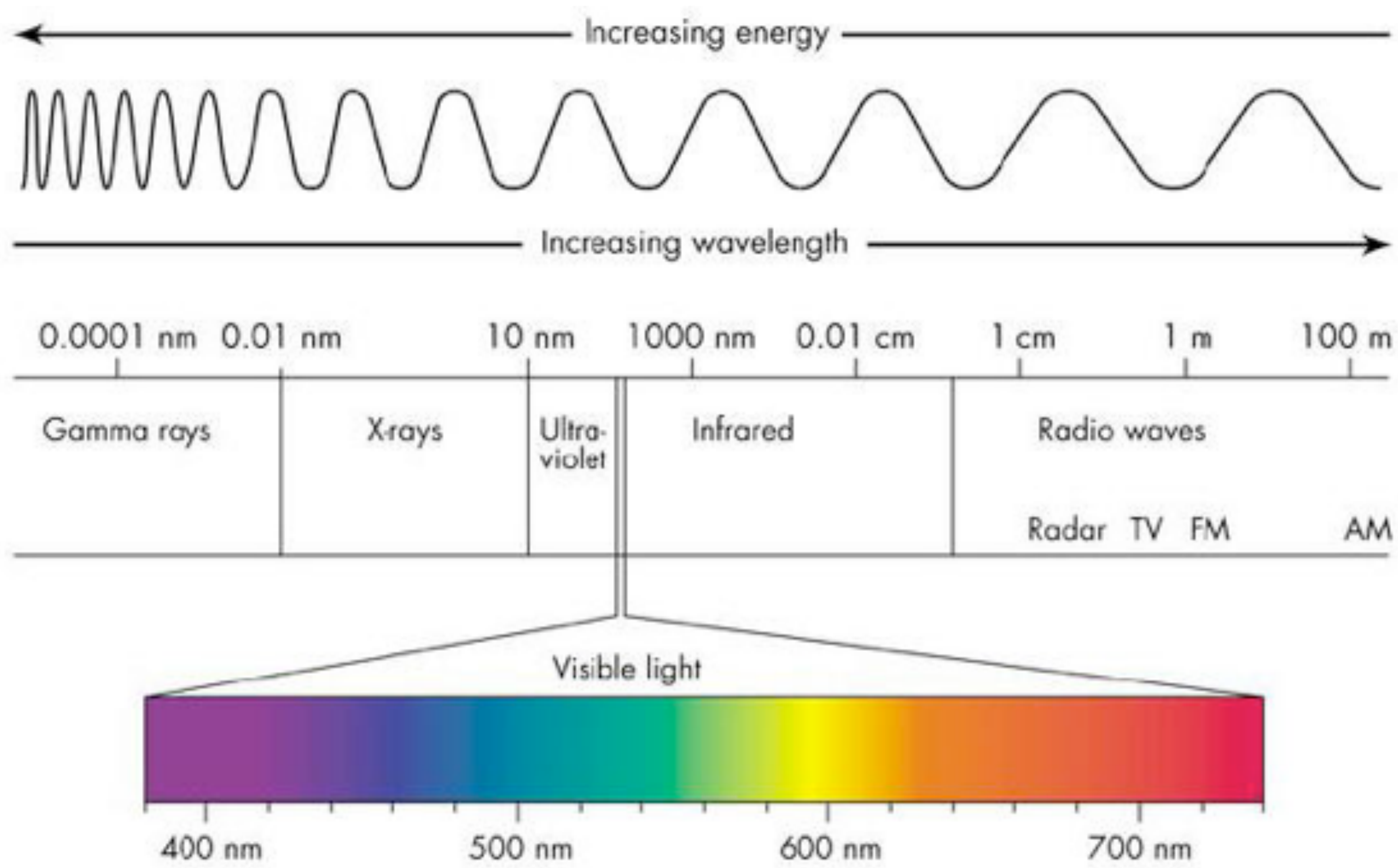
In general, light is combination of pure waves with different λ

any beam of light can be broken down into some distribution of intensities:

- different brightness at diff. λ = spectrum

Q: spectrum of laser pointer?

Q: spectrum of white light?



Technology Tim's Terminology Tip: "Radiation"

Warning!

meaning of "radiation" in Physics, Astronomy, Cosmology is different from "radiation" in everyday talk!

In Physics, Astronomy, Cosmology...and more importantly... In this course and on the exams:

- radiation = movement of energy through space
- carried by particles or waves

Examples: ordinary visible light! e.g., flashlight, sunlight, starlight, ...

completely benign and indeed necessary for life!

- but also invisible EM waves: radio, UV, X-ray...
- and even non-EM particles: neutrinos...

Beware Confusion: "radiation" so defined is not radioactivity!

Glowing Bodies

- Everything we know is in fact giving off light– as long as it has a temperature (above absolute zero = 0 K), it is glowing.
- The higher the temperature the shorter the wavelength it glows in– compare the person on the right (in the near infrared) and a light bulb (in the visible).



http://www.x20.org/thermal/thermal_weapon_sight_TIWS320.htm

Absolute Zero

Recall:

matter made of atoms

atoms always in random motion

- faster random speeds: hotter
- slower random speeds: coller

If cool until no random motion:

- can't cool any further
- coldest possible temperature
- absolute zero

Temperature Scales

everyday temperature scales:

- **Farenheit**:

  water freezes at 32°F, boils at 212°F

- **Celcius/Centigrade:**

  water freezes at 0°C, boils at 100°C

In both scales, negative temperatures exist, not mysterious

But lowest possible temperature

→ "absolute zero" at −273°C = −459°F

define **Kelvin scale**

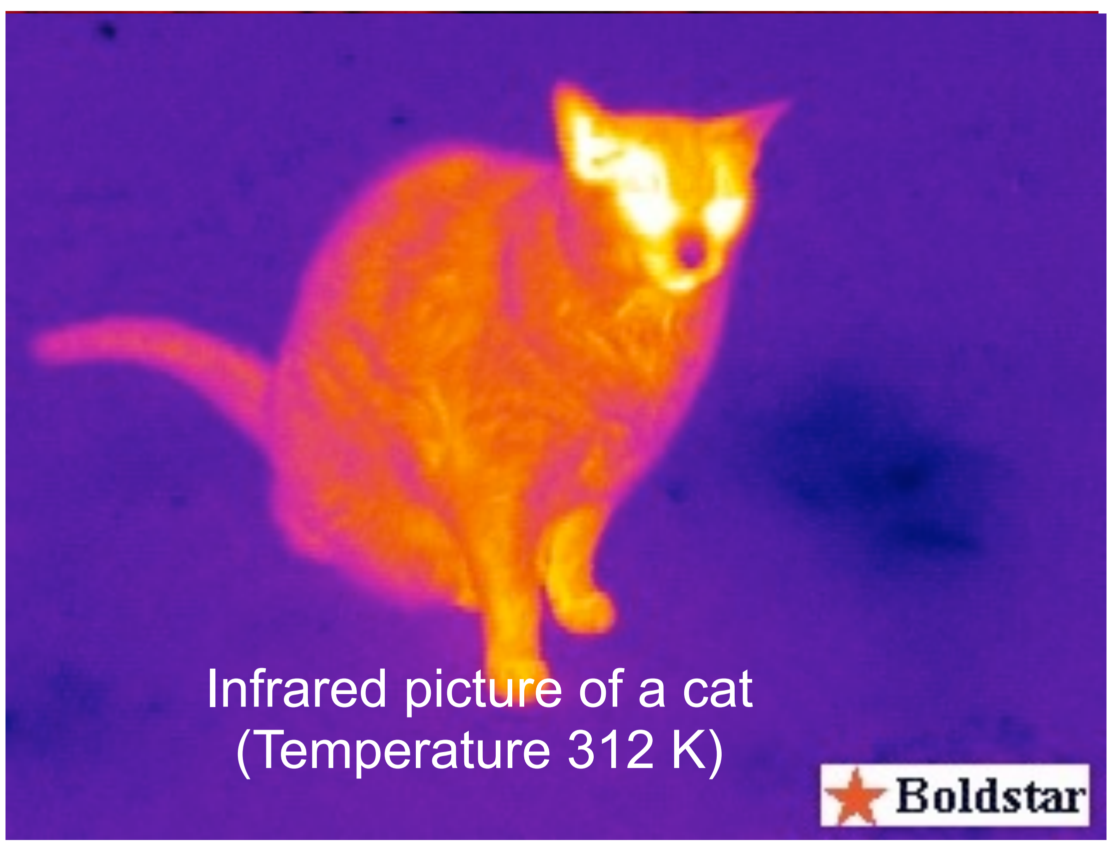
$$T(K) = T(C) + 273^\circ$$

so T (K) = 0 at absolute zero

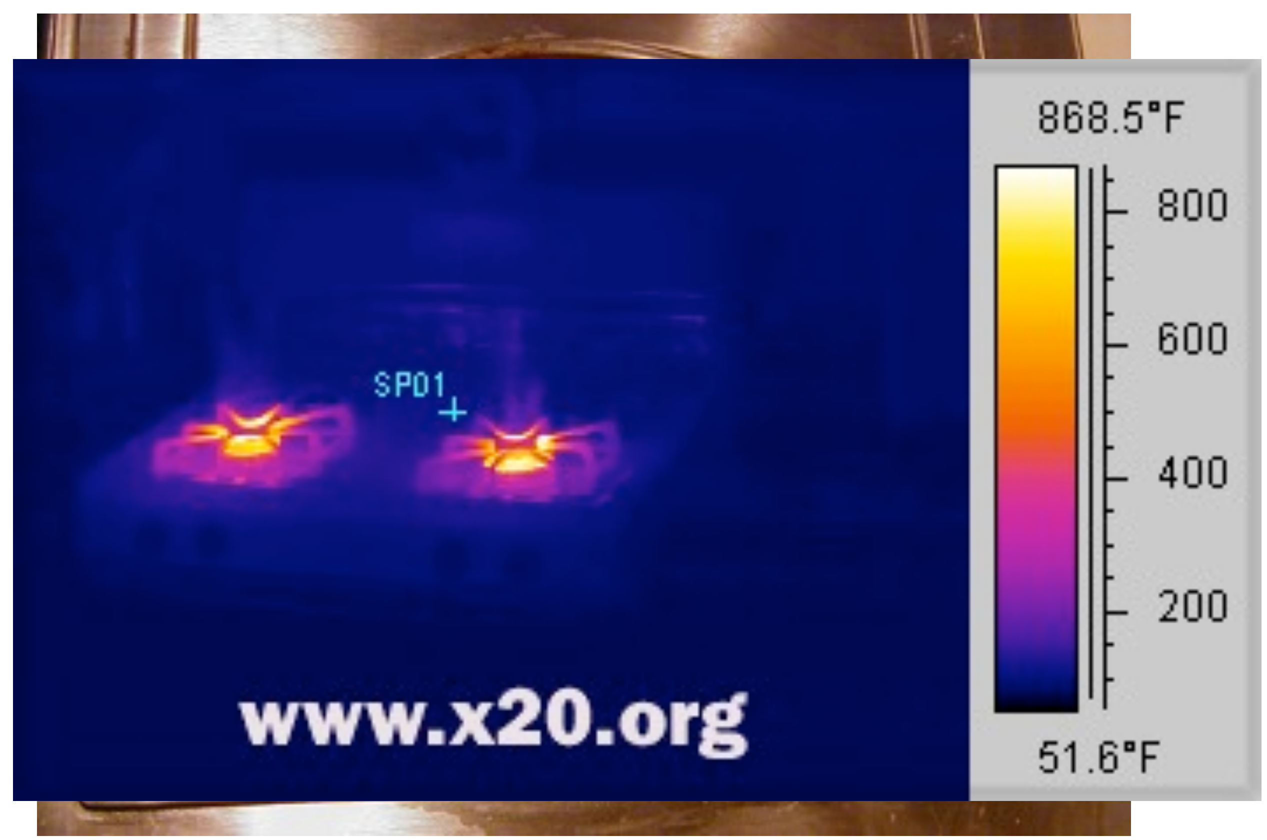
room temperature ≈ 30°C ≈ 300 K

Blackbody Radiation

- Light that objects emit because of their temperature is called blackbody radiation
- Blackbody radiation is composed of a continuous spectrum of wavelengths
- The hotter an object gets, the more intense and shorter wavelength (blue-er) its blackbody radiation becomes



Infrared picture of a cat
(Temperature 312 K)



Visible-light picture of a stove element
(Temperature ~ 400 K)

Blackbody Radiation

useful to define an ideal substance:

- a perfect absorber of light: "blackbody"
- absorbs all λ, reflects none

  Q: what would such a thing look like?

  Q: what are real substances almost like this?

  Q: what everyday object is nearly the opposite of this?

- in practice: most objects are well approximated as blackbodies

blackbody absorbs radiation

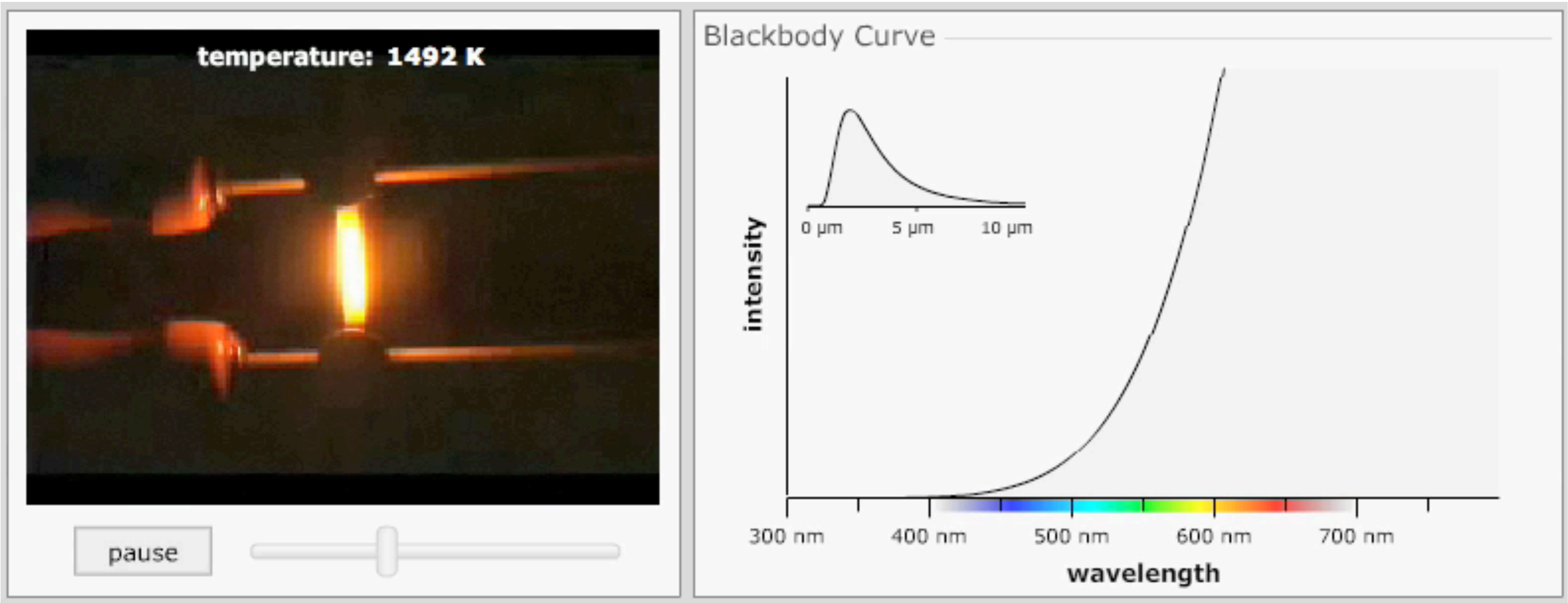
→ heats

→ re-emits according to T

"blackbody radiation" = thermal radiation

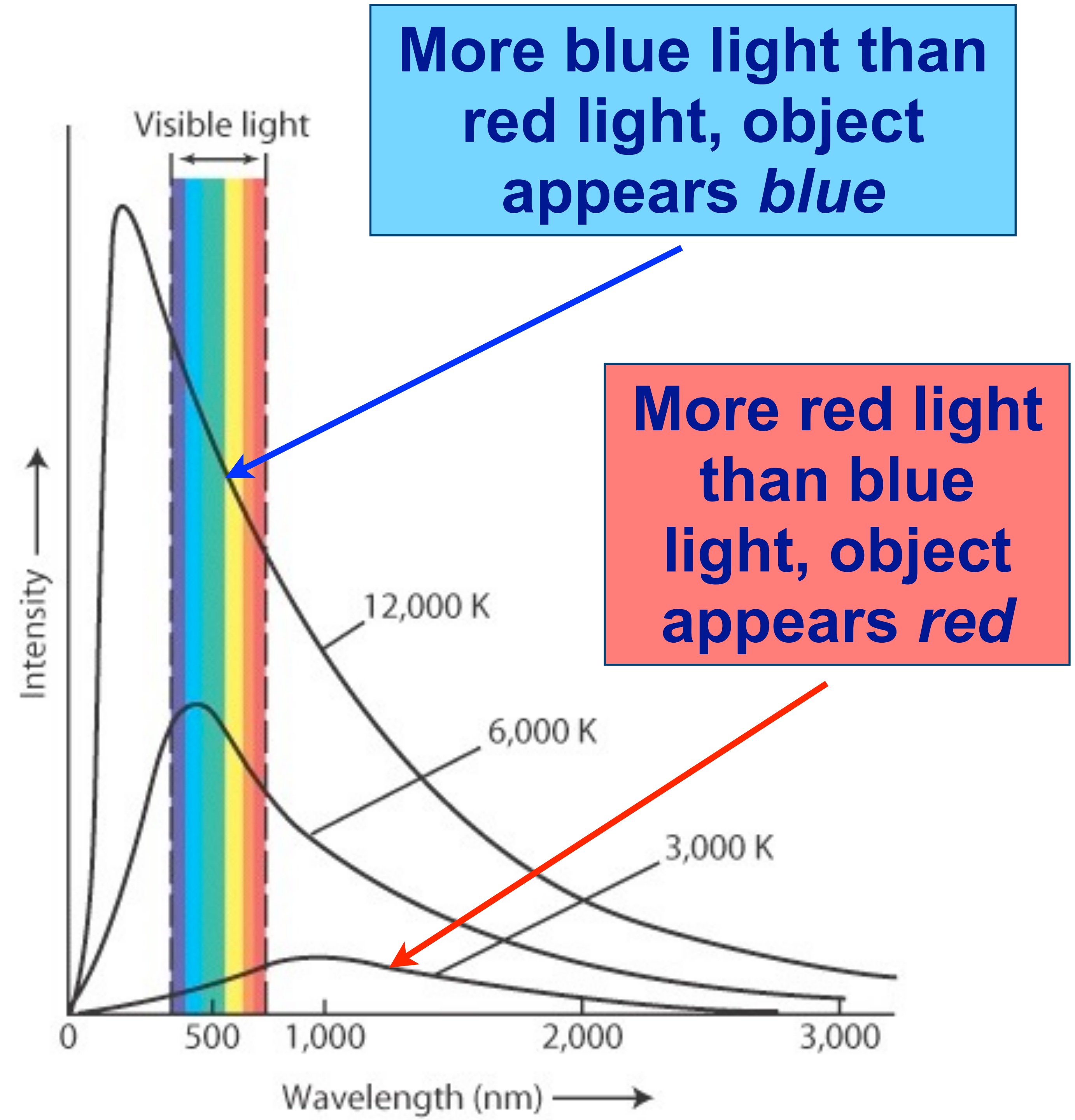
glow due to temperature not at absolute zero

Thermal Radiation



Two Properties of Thermal Radiation

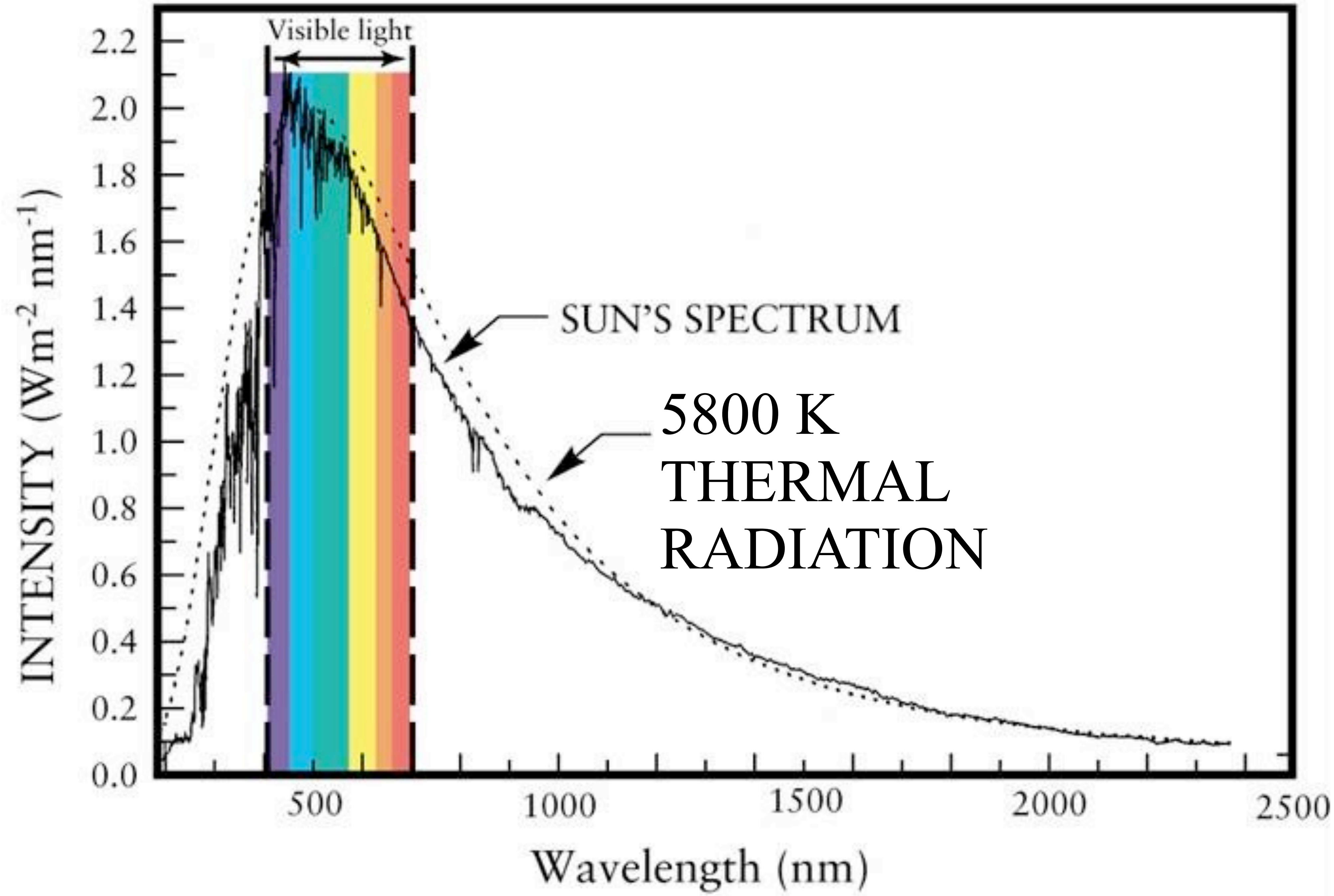
1. Hotter objects emit more light per unit surface area at all wavelengths
2. The hotter an object is, the shorter is the wavelength of its maximum output
3. color reveals temperature!



The color of thermal radiation can tell us an object's temperature!

The temperature of a lava flow can be estimated by observing its color (about 1500 K)

The Sun's Spectral Curve

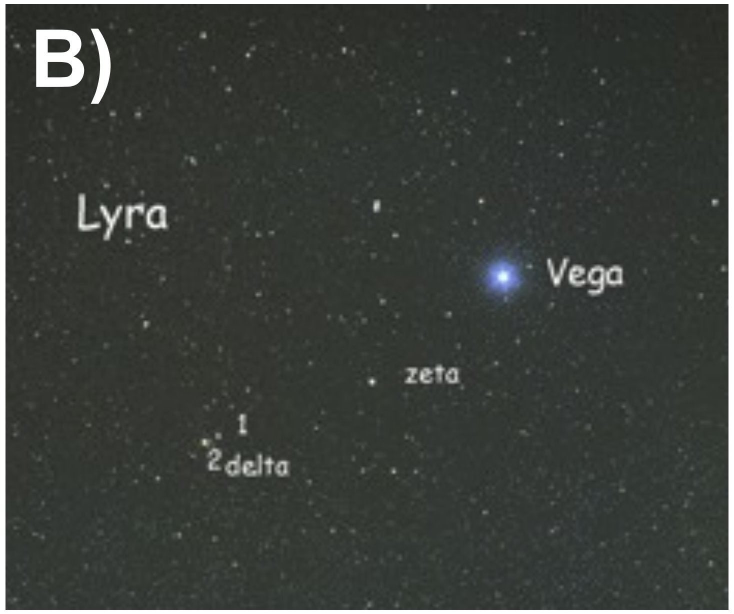


The Sun's spectral curve reveals its surface temperature to be 5,800 K!

i>clicker question

Which star is hotter?

A. Capella (yellow)
B. Vega (blue)
C. Antares (red)



Color me..

White hot Sirius to a red supergiant Betelgeuse

Still Why Different Colors

So, stars have different colors, thus temperatures.

Why different temperatures?

Stay tuned....

What about the brightness of stars?

iClicker Poll: Naked Eye Stars

Vote your conscience!

On a clear night, outside of a city,

about how many stars can you see with the naked eye?

A. More than the number of people in a packed movie theater
B. More than the number of people at sold-out Memorial stadium
C. More than the population of Illinois
D. More than the population of the Earth

Star Light, Star Bright

to naked eye, in clear sky: about 6000 (!) stars visible over celestial sphere

- about 3000 at any one night
- Memorial Stadium capacity:
  60,000 people = 10 x visible stars!
- ...but this is just the “tip of the iceberg”

many many more stars exist but unseen by naked eye

stars appear to have different brightnesses

- brightest (other than Sun): Sirius – “dog star”

Memorial Stadium:
More Illini fans than visible night sky stars