Astro 301/ Fall 2005
(48310)

Introduction to Astronomy

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Lecture 18+19 = Tu Nov 1 + Th Nov 4

http://www.as.utexas.edu/~sj/a301-fa05/
Lecture 18: Announcements

-- Homework 4 handed out today

-- Quiz 4 today based on Lectures 14 to 17 + movie

-- Exam 2 on Nov 10.
Recent and Upcoming topics in class

- Waves
- Basic properties of waves: Wavelength, Frequency, Speed, Energy
- Types of waves: sound, surface, electromagnetic

- Light as Electromagnetic Waves
- Dual nature of light: light as electromagnetic waves or as photons
- The electromagnetic spectrum: wavelengths, frequency, speed
- Processing of Electromagnetic Waves

- Luminosity and Total Flux of a distant object
- Using the continuum spectrum of a star to estimate its surface temperature, total surface flux and radius
  - Wien’s Law: Relating surface temperature and color of the continuum emission
  - Stefan-Boltzmann law: Relating surface temperature and surface continuum flux

- Using the particle model of light and the discrete energy levels in an atom to explain emission and absorption lines
- Light as a stream of photons.
- Dependence of a photon’s energy on its wavelength or frequency
- Discrete energy levels in an atom
- Using emission and absorption lines to trace chemical composition of a star
Waves
Different types of waves: surface wave, sound waves, EM (light) waves,
Waves: Wavelength, Frequency, Speed, Energy

In-class animation: Anatomy of wave
Light as Electromagnetic Waves
Light as Electromagnetic Waves

<table>
<thead>
<tr>
<th>Type of EM wave</th>
<th>TYPICAL WAVELENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma rays</td>
<td>$10^{-16}$ m</td>
</tr>
<tr>
<td>X rays</td>
<td>$10^{-12}$ m</td>
</tr>
<tr>
<td>Ultraviolet</td>
<td>$3 \times 10^{-7}$ m</td>
</tr>
<tr>
<td>Visible</td>
<td>$4$ to $9 \times 10^{-7}$ m = Violet, blue, green, yellow, orange, red</td>
</tr>
<tr>
<td>Infrared</td>
<td>$10^{-6}$ m to $10^{-4}$ m</td>
</tr>
<tr>
<td>Radio</td>
<td>$10^{-3}$ m to m</td>
</tr>
</tbody>
</table>

![Graph showing the electromagnetic spectrum with wavelengths and energies]]
Light as Electromagnetic Waves

in-class demo: Electromagnetic Spectrum
Visible Part of Electromagnetic Spectrum

In-class animation: Visible light

Wave shown in extreme slow motion.

- Frequency: $4.29 \times 10^{14}$ Hz
- Wavelength: 700 nm
- Speed: $3 \times 10^8$ m/s
Processing Electromagnetic Waves

Dispersing while light into its basic colors
Processing Electromagnetic Waves
Concept of ‘color’ of an object

- Light bulb emits white light.
- Mirror reflects light.
- Cones and rods in human eye absorb light.
- Glass transmits light.
- Sun emits light.
- Snow: Absorbs some light, which aids melting. Scatters most light, so it looks bright.
- Ground: Absorbs some light (heats it up). Scatters some light (which is how we see it).
- Tree: Absorbs all colors except green. Reflects (scatters) green.

Opaque Red Chair: Absorbs all colors except red. Reflects (scatters) red.
Opaque Blue Shirt: Absorbs all colors except blue. Reflects (scatters) blue.
**Lecture 19: Announcements**

-- Group email sent to class regarding typo on question 1a. The mass of nucleus should read $19.9162 \times 10^{-27}$ kg.

-- I will leave immediately after class today for a committee meeting.
   IF YOU NEED TO TALK TO ME PLEASE DO SO BEFORE CLASS OR DURING OFFICE HOURS TODAY.

-- Exam 2 on Nov 10.
Luminosity and Total Flux of an object

1. Demo: Bright star-near-or-lum

2. In-class notes
1) When the total flux from an object is separated into the flux at different wavelengths, and the intensity of the flux is plotted against wavelength, we get a spectrum for that object e.g., The figure above shows a spectrum.

2) The spectrum has 3 types of features:
   - continuum emission, emission lines, absorption lines.

3) Amazingly, these features in the spectrum of an object can reveal to us:
   - its temperature, its total flux
   - its chemical composition, (like a DNA genetic code)
   - its recession speed, its distance
Using the continuum spectrum of a star to estimate its surface temperature, total surface flux and radius
Wien’s Law: Relating surface temp. and color of continuum!

- The spectrum of a star has a shape that depends only on its temperature $T$!

- Wien’s law: A star will emit its maximum flux at a wavelength $\lambda_{\text{peak}}$ that depends inversely on its temperature and is given by $\lambda_{\text{peak}} = \frac{W}{T}$ where $W = \text{Wien’s constant} = 2.9 \times 10^{-3} \text{ m K}$

For the Sun $T=5800$ K at surface: $\lambda_{\text{peak}} = 5 \times 10^{-7} \text{ m} = \ldots$ color?
Hot stars have shorter $\lambda_{\text{peak}}$ and tend to be bluer!
Temperature and Color of Stars:

From Wien’s law: blue stars are hotter while red stars are cooler. The temperature in turn may tell us something about age and mass of stars (e.g., massive stars tend to be hot and blue)

BUT sometimes dust can cause an intrinsically hot blue star to look red by scattering its light,
**Stefan-Boltzmann law: Relating surface temp. and surface flux**

- Wien’s law describes at what wavelength a star emits most of its flux.

- Stefan-Boltzmann law describes the TOTAL flux of the star over ALL wavelengths. The total flux (energy per second per unit area) emitted over ALL wavelengths at the surface of a star (or black body) depends only on its surface temperature $T$ of the star and is equal to $\sigma T^4$, where $\sigma$ is the Stefan-Boltzmann constant.
Physical reason for Wien’s law and Stefan-Boltzmann law?

In a macroscopic body (blackbody) at a temperature $T$:

Atoms have a thermal energy due to their non-zero temperature $T$. This thermal energy causes them to move randomly around and collide. When many atoms (with bound $e$-) collide at many different speeds, the electromagnetic interactions between charged particles ($e$, $H^+$) lead to the emission of photons with a continuous range of wavelengths.

The shape of resulting thermal or blackbody spectrum depends only on $T$. 
Using the particle model of light and the discrete energy levels in an atom to explain emission and absorption lines
How to explain emission and absorption lines?

the underlying continuum emission emitted over a continuous range of wavelengths is thermal radiation emitted by the body, according to its temperature $T$
the discrete emission lines are due to the emission of photons at specific wavelengths … what accounts for such emission at these specific wavelengths?
How do such emissions tell us about the chemical composition of the source!

the discrete absorption lines are due to the absorption of photons at specific wavelengths… what accounts for such absorption at these specific wavelengths?