

# Astro 301/ Fall 2005 (48310)



# Introduction to Astronomy

# Instructor: Professor Shardha Jogee TAs: David Fisher, Donghui Jeong, and Miranda Nordhaus

Lecture 20 = Tu Nov 8 Lecture 21 = Exam = Th Nov 10

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

#### Lecture 20: Announcements

- -- Homework 4 due back on Th Nov 10
- -- Exam 2 on Th Nov 10.
- See class website announcements for help session today for exam2
   + for exam 2 guidelines
- Students with SSD requirements for exam SHOULD SEE ME AFTER CLASS TODAY

#### **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
  - à Wien's Law: Relating surface temperature and color of the continuum emission
  - à 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 <---Today
- Light as a steam 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



- When the total flux from an object is separated <u>into the flux at different</u> <u>wavelengths</u>, and the intensity of the flux is plotted against wavelength, we get a <u>spectrum</u> for that object e.g., The figure above shows a spectrum.
- 2) The spectrum has 3 types of features:

continuum ermission, emission lines, absorption lines.

- 3) Amazingly, these features in the spectrum of an object can reveal to us
  - à its temperature , its total flux
  - à its chemical composition, (like a DNA genetic code)
  - à its recession speed, its distance

<u>Using the continuum spectrum of a star to estimate its</u> <u>surface temperature, total surface flux and radius</u> 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  $\lambda_{peak}$  that depends inversely on its temperature and is given by  $\lambda_{peak}$ = W/T where W = Wien's constant = 2.9 x 10<sup>-3</sup> m K
  - à For the Sun T=5800 K at surface:  $\lambda_{peak} = 5 \times 10^{-7} \text{ m} = \dots \text{ color}$ ?
  - à Hot stars have shorter  $\lambda_{peak}$  and tend to be bluer !

# **Temperature and Color of Stars:**



Center of M Way (HST)

- à 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)
- à BUT sometimes dust can cause an intrinsically hot blue star to look red by scatterring its light,



#### M80 globular cluster (HST)



#### Pleiades

## 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
- à The total flux (energy pr 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  $\sigma$  T4 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:

- à Atoms have a thermal energy due to their non-zero temperature T.
- à This thermal energy causes them to move randomly around and collide
- à 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.**
- à 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?



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

# **Dual Nature of Light:** Particle and Wave



Light = electromagnetic wave Light = stream of particles called photons

#### Louis de Broglie

Recherches sur la théorie des quanta Wave particle duality: Every particle has an associated wave Nobel Prize in Physics in 1929

## Structure of an Atom



Atom = Nucleus made of neutrons (neutral) and protons (+ve), surrounded by a cloud of negatively charged electrons
No of protons = No of electrons = Atomic Number à Net charge = 0

## Structure of an Atom



Electrons in an atom can only populate certain discrete quantized energy levels e, g., discrete levels for Hydrogen atom above

# **Emission and Absorption Lines from Atoms**



- Electrons only move between discrete energy levels
- So only photons of specific energies (i.e. wavelengths) are emitted or absorbed by a given atom



# **Emission and Absorption Lines from Atoms**

- à In-class animation: "De-excitation of an atom and production of photons"
- à In-class animation: "Production of Emission lines"



- à the discrete emission lines are due to the emission of photons <u>at specific</u> <u>wavelengths by bound</u> electrons that move from <u>a high to a low energy level</u>
- à the discrete absorption lines are due to the absorption of photons <u>at specific</u> <u>wavelengths by bound</u> electrons that move from <u>a low to a high energy level</u>

# **Characteristic Spectrum of Emission Lines from Atoms**



**Emission Spectra** 

- à Unique and characteristic set of discrete emission lines at specific wavelengths for a given atom
- à Fingerprint / DNA of an atom

# **Characteristic Spectrum of Emission Lines from Atoms**

![](_page_18_Figure_1.jpeg)

à In-class demo : Composition of Mystery gas