# Astronomy 404
# Stellar Astrophysics

## MWF 1:00-1:50pm, 134 Astronomy Bldg.

## Course Description

**Introduction to astrophysical problems, with emphasis on underlying physical principles; includes the nature of stars, equations of state, stellar energy generation, stellar structure and evolution, astrophysical neutrinos, binary stars, white dwarfs, neutron stars and pulsars, and novae and supernovae.**

**Physics of stars:**
**How do we determine physical parameters of stars?**
**What do spectra of stars tell us?**
**How are stellar spectra formed? - stellar atmosphere**
**How are stellar radiation generated? - stellar interior**
**The Sun – the nearest guinea-pig star**
**How do stars evolve?**
**What makes stars pulsate?**
**How do stars end their lives?**
**What is the afterlife of stars?**
**What if stars have close binary companions?**

***This is the hardest 400-level course, but you will be happy that you took it…***

## Prerequisite: Physics 213, 214

Physics 213 is a calculus-based, introductory course in thermal physics. Topics include:

- First and second laws of thermodynamics including:
  - kinetic theory of gases
  - heat capacity
- heat engines
- introduction to entropy and statistical mechanics
- introduction to free energy and Boltzmann factor
- many, many applications.

Students are expected to have a good understanding of:

- classical mechanics
- differentiation and integration of simple functions

and some familiarity with:

- basic statistics.

Physics 214 is a calculus-based, introductory course in quantum physics. Topics include:

- Interference and diffraction
- photons and matter waves
- the Bohr atom
- uncertainty principle
- wave mechanics.

Students are expected to have a good understanding of:

- classical mechanics
- electric potential
- ray optics

and to:

- be able to differentiate and integrate simple functions
- be familiar with partial derivatives and basic complex number algebra.

**Instructor:** Prof. You-Hua Chu
123 Astronomy Bldg
yhchu@illinois.edu
M 2-3pm

**TA:** Yixian Cao
233 Astronomy Bldg
ycao17@illinois.edu
Th 2-4pm (Rm 236 – Atlas Room)

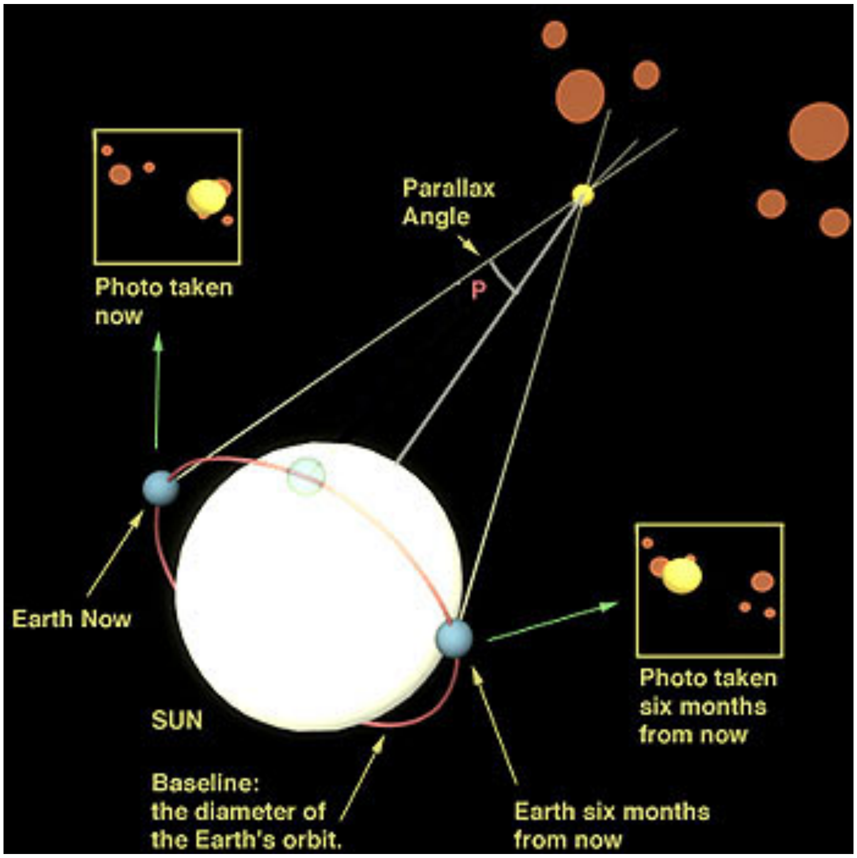
**Textbook:**
Carroll and Ostlie,
An Introduction to Modern Astrophysics, 2nd Ed.

**Course Requirements:**

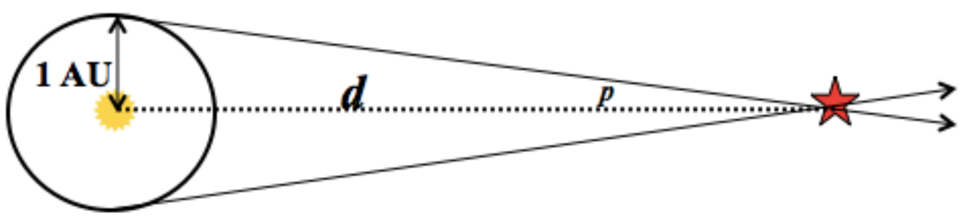
| | |
|---|---|
| Reading and lecture attendance | |
| 11 homeworks | 50% |
| 2 hour exams | 25% |
| final exam (cumulative) | 25% |

**Homeworks:**
* 11 homeworks – you can drop the worst one
* assigned 1 week before due date
* late homework will be discounted

**Exams:**
Close-book, 8"x11" crib sheet allowed




## Distance to stars - trignometric parallax




**Measure the RA & Dec of the star (against the background stars, or celestial sphere) at two opposite ends of the Earth's orbit. The angular difference between the two coordinates is 2*p*. The distance between the Sun/Earth and the star is**

$$d = 1 \text{ AU} / \tan p \approx 1/p \text{ AU} \approx 206{,}265/p'' \text{ AU} = 1/p'' \text{ pc}$$

$$1 \text{ pc} = 3.086 \times 10^{16} \text{ m} = 3.26 \text{ ly}$$

**Shortcut:** $1'' \times 1\ \text{pc} = 1\ \text{AU}$

**Example:**

**A binary system is at distance of 5 pc and the two stars are separated by 0.5". What is the distance between the two stars?**

| | | |
|---|---|---|
| Ground-based observations | ~ 0.1″ | $d$ = 10 pc |
| ESA Hipparcos Space Astronomy Mission | ~ 0.001″ | $d$ = 1 kpc |
| NASA Space Interferometry Mission | ~ 0.000004″ | $d$ = 250 kpc |
| ESA Gaia mission (map the Galaxy) | ~ 0.00001″ | $d$ = 100 kpc |

## The Magnitude Scale

**Hiparchus used visual magnitude.** $m = 1$ **for the brightest star,** $m = 6$ **the faintest**

**Human eyes respond logarithmically. 5 magnitude corresponds to a factor of 100.**
**1 magnitude =** $100^{1/5} = 2.512$

**The "brightness" of a star measures the radiant flux** $F$**, energy received per unit time per unit area (joules** $s^{-1}\ m^{-2}$**), is**

$$F = \frac{L}{4\pi r^2}$$

**where** $L$ **is the luminosity and** $r$ **is the distance to the star.**

**(** $1/r^2$ **is called the Inverse Square Law)**

**The observed radiant flux of a star can be converted to *apparent magnitude*, using zero-point calibration specific for the wavelength band of the observation.**

**But stars are at different distances, so their apparent magnitudes cannot be used to rank their luminosities. Need to know the distance and convert the magnitude to an absolute scale.**

***Absolute Magnitude* is the magnitude of a star at 10 pc.**

## Two stars with fluxes $F_1$ and $F_2$,

$F_2 / F_1 = 100^{(m1-m2)/5}$ **or**

$m1 - m2 = -2.5 \log_{10}(F_1 / F_2)$

$m$ = **apparent magnitude,** $M$ = **absolute magnitude**

$100^{(m-M)/5} = (d / 10\ \mathrm{pc})^2$

$d = 10^{(m-M+5)/5}$ **pc**

$m - M = 5 \log_{10}(d / 10\mathrm{pc}) = 5 \log_{10} d - 5$

$m - M$ **is called the Distance Modulus (DM)**

**The Large Magellanic Cloud at 50 kpc, DM = 18.5**