CAS AS 312: Stellar and Galactic Astrophysics
Professor Thomas M. Bania   Spring 2017

LECTURES: Tuesdays (T) and Thursdays (R) in CAS 502 from 11:00 a.m. to 12:15 p.m.

OFFICE HOURS: Professor Bania's office is in CAS 514G. He can be reached by phone (x3652) or email (bania@bu.edu). His office hours are: Tuesday & Thursday: 2 pm to 3:30 pm; Wednesday 2 pm to 3 pm. Other times can be arranged by appointment.

REQUIRED TEXTS: I urge you to explore on-line procurement of:
- *Introductory Astronomy & Astrophysics*, Fourth Edition, by Zeilik and Gregory, Saunders College Publishing. ISBN 0030062284
- *An Introduction to Programming with IDL*, by Ken Bowman, 2006 Academic Press. ISBN 9780120885596

RECOMMENDED TEXTS:
- *Linux in a Nutshell*, Sixth Edition, by Siever, Love, & Robbins, 2009 O'Reilly. ISBN 9780596154486
- *Learning GNU Emacs*, Third Edition, by Cameron, Elliot, Loy, Raymond, & Rosenblatt, O'Reilly. ISBN 9780596006488

GRADES: Your final semester grade will be based upon performance in the following: (1) two in-class exams (20% each); (2) a final exam (20%); and (3) homework problem sets (40%).

EXAMS: Two exams will be held during normal lecture periods. They are *tentatively* scheduled for Thursday, 2 March 2017, and Tuesday, 18 April 2017. These exams will test, respectively, material from the first and second halves of AS 312. *The FINAL EXAM will be held in room CAS 502 on Thursday, 11 May 2017 from 1230 to 1430.* This is a comprehensive exam that covers all the material in the course. By University policy this exam time cannot be altered.

Stellar and Galactic Astrophysics traditionally discusses the basic physics of radiation; spectral analysis; the distances, motions, and physical properties of stars; stellar interiors and atmospheres; stellar evolution; clusters of stars; the interstellar medium; and the content, structure, and dynamics of the Milky Way Galaxy.

This course is normally taken by students in their Sophomore year who are majoring in Astronomy, Astronomy and Physics, or Geophysics and Planetary Sciences. It is a required course for both Astronomy concentrations. The prerequisites are MA 124 and PY 212 or PY 252. The details of astrophysical phenomena will be explored at an intermediate level.

The Astronomy Department faculty wants our majors to become computer savvy early in their undergraduate careers. Because of this, AS 312 will not be a comprehensive survey course of a large number of topics in Stellar and Galactic Astronomy, but rather it will cover fewer topics in more detail. This semester we shall cover aspects of the following topics: the nature of light and how it propagates through space and matter; the structure and evolution of stars; the nature and physics of the interstellar medium; and the structure and evolution of our Milky Way Galaxy. These topics appear in Chapters 8 through 20 of the Zeilik and Gregory text.

A major part of your effort this semester will be to learn how to program a computer to make precise astronomical calculations. There will be computer homework and computer examples will be part of the lectures. You will be programming in IDL, the Interactive Data Language. Originally developed in the 1970's at LASP in Boulder, CO, IDL is currently the industry standard data analysis software used by the Astronomical and Space Physics communities. In addition to IDL, you will learn to use the Linux operating system and the Emacs text editor.

Details of the computer assignment protocols will be announced in class. You will be using an Astronomy Department computer, GLaDOS, for all your AS 312 assignments. You will be able to login to GLaDOS remotely. You can thus write programs from anywhere in the world if your laptop is connected to the Internet.

Bring your laptop computer to the first lecture so that we can configure your machine to have access to GLaDOS. You MUST have a laptop that runs either the Microsoft Windows or Mac OS operating system. Most notebook/notepad devices are not sufficiently powerful to be used in AS312.

Homework Problem Sets Problem solving is an integral part of AS 312. There will be homework problem sets assigned approximately weekly. **The homework assignments are always due by 5pm on the date specified in my mailbox in room CAS 514** (the Astronomy Department Main Office complex).

Homework Problem Set Format Rules Solutions to problem sets MUST:

(1) be written in INK;
(2) be written on clean, lined, white 8.5x11 inch paper, without "burstable" sides;
(3) be written on only the front side of the page;
(4) contain only one problem solution per single-sided page;
(5) be highly legible; and
(6) be submitted in proper numerical sequence.

Obviously you can use more than a single page for a given problem, what is expressly forbidden is multiple problem solutions on a single page.

I will not grade any problem set solutions which fail to adhere to this format.

Late Work In the real world, missing deadlines has dire consequences (e.g., failure of a NASA mission to launch on time could make it unable to answer the questions it was designed to address — representing a tremendous waste of taxpayer dollars). The AS 312 late policy for homework is equally dire. Failure to turn in an assignment on the designated date, by the designated time, in the designated format will result in a zero score for that assignment.

Attendance & Absences The lecture meetings are a vital component of the course — every meeting should be attended by every student. An attendance sheet will be circulated at every lecture. Be sure to sign you name on the attendance sheet every lecture.

Academic Conduct You are expected to be familiar with the *CAS Academic Conduct Code*. Misconduct involves more than just cheating on the exams. All work handed in for credit must be your own. I encourage you to study together, but to submit the homework assignments separately. You may help each other to find how to solve a problem, but you must present your own discussion and steps needed to achieve the solution. You must take care not to work so closely with a classmate that your answers are nearly identical. If you need help, please see me. I am required to report suspected cases of academic misconduct to the Dean's Office. Penalties for academic misconduct may include suspension or expulsion from the University.

There will be no Web site for this course.

Formulae and Constants

$c = \lambda\nu$

$\lambda = \lambda_0(1 \pm v/c)$

$\lambda = \lambda_0[(1 + v/c)/(1 - v/c)]^{1/2}$

$E = h\nu$

$E(n) = (2\pi^2 me^4 Z^2 h^{-2}) * (1 - n^{-2})$

$E(n = \infty) = 13.6$ eV

$E(n = 1) = 0$ eV

$1/\lambda_{ab} = Z^2 R(1/n_b^2 - 1/n_a^2)$

$N_u/N_l = (g_u/g_l)e^{-(E_u - E_l)/kT}$

$N_{i+1}/N_i = (A/N_e)(kT)^{3/2}e^{-(\chi_i/kT)}$

$I_\lambda(T)\Delta\lambda = \frac{(2hc^2)}{\lambda^5}[1/(e^{hc/\lambda kT} - 1)]$

$(M_1 + M_2)P^2 = a^3 = (a''/\pi'')^3$

$\lambda_{MAX}T = 3$ mm K

$F = \sigma T^4$

$M_{bol}(\odot) - M_{bol}(*) = 2.5log(L*/L\odot)$

$M_{bol} = M_V + BC$

$r_1 = V_1 P/2\pi$

$R_p/a = \pi(t_2 - t_1)/P$

$M_V(\odot) = +4.75$ mag

$G = 6.67 \times 10^{-8}$ dyne cm^2 gm^{-2}

$k = 1.38 \times 10^{-16}$ erg K^{-1}

$M_\odot = 2.0 \times 10^{33}$ gm

$R_\odot = 7.0 \times 10^{10}$ cm

$T_\odot = 5770$ K

$m_V(\odot) = -26.74$

$logN(m) = 0.6m + C$

$v_t = d\,sin\mu \approx \mu d$

$V^2 = v_r^2 + v_t^2$

$V = v_r/cos\theta$

$v_r = \Theta cos\alpha - \Theta_0 sin\ell$

$v_t = \Theta sin\alpha - \Theta_0 cos\ell$

$A \equiv -(R_0/2)(d\omega/dR)_{R_0}$

$v_r = A\,d\,sin2\ell$

$B \equiv A - \omega_0$

$\Theta(R_{min}) = v_{r,max} + \Theta_0 sin\ell$

s(m degree^{-1}) $= 0.01745\,f_{\text{meters}}$

$\theta''_{min} = 1.22 \times 206,265 \times (\lambda/d)$

$c = 3.0 \times 10^{10}$ cm s^{-1}

$sin(\theta) = (m\lambda)/L$

$\pi'' = 1/d_{pc}$

$m_1 - m_2 = -2.5\,log(F_1/F_2)$

$m - M = 5\,log(d) - 5$

$R = 10.96776\,\mu m^{-1}$

$m - M = -5\,log(\pi'') - 5$

$L = 4\pi R^2 \sigma T^4$

$B_\nu(T) = \frac{2h\nu^3}{c^2}[e^{h\nu/kT} - 1]^{-1}$

$G(M_1 + M_2)P^2 = 4\pi^2 a^3$

$M_1 a_1 = M_2 a_2$

$P = (g/\kappa)\tau$

$log(L*/L\odot) = 1.89 - 0.4M_{bol}(*)$

$a = VP/2\pi$

$r_2 = V_2 P/2\pi$

$R_s/a = \pi(t_4 - t_2)/P$

1 eV $= 1.602 \times 10^{-12}$ erg

$h = 6.63 \times 10^{-27}$ erg s

$m_H = 1.67 \times 10^{-24}$ gm

$L_\odot = 3.8 \times 10^{33}$ ers s^{-1}

$1AU = 1.5 \times 10^{13}$ cm

$\sigma = 5.67 \times 10^{-5}$ erg cm^{-2} s^{-1} K^{-4}

$\lambda_V = 5500\mathring{A}$

$v_\odot^2/R_\odot = GM_G/R_\odot^2$

$v_t = 4.74\mu''d = 4.74(\mu''/\pi'')$

$tan\theta = v_t/v_r$

$\pi'' = 4.74\mu''/v_r tan\theta$

$v_r = R_0(\omega - \omega_0)sin\ell$

$v_t = R_0(\omega - \omega_0)cos\ell - d\,\omega$

$v_r = -2A(R - R_0)sin\ell$

$v_t = d(A\,cos2\ell + B)$

$R_{min} = R_0 sin\ell$

$v_{r,max} = 2AR_0(sin\ell)(1 - sin\ell)$

$$dP/dr = -GM(r)\rho(r)/r^2$$

$$P(r) = n(r)kT(r)$$

$$\mu = [2X + (3/4)Y + (1/2)Z]^{-1}$$

$$dL/dr = 4\pi r^2 \rho(r)\epsilon(r)$$

mass defect = 0.0286 AMU

$$m - M = 5\,log(d) - 5 + A$$

1 Joule = 10^7 ergs

1 Å = 10^{-8} cm

1 inch = 2.54 cm

R_{earth} = 6378 km

$$P^2 G(M_1 + M_2) = 4\pi^2 a^3$$

$$A_V = 3.1E(B - V)$$

$$R_H = 10.96776\,\mu m^{-1}$$

$$I_\nu = I_\nu(0)\,e^{-\tau_\nu} + S_\nu\,(1 - e^{-\tau_\nu})$$

R_0 = 8.5 kpc

Θ_0 = 220 km s^{-1}

$$dM/dr = 4\pi r^2 \rho(r)$$

$$n(r) = \rho(r)/\mu(r)m_H$$

$$L(r) = [-64\pi\sigma r^2 T^3(r)]/[3\kappa(r)\rho(r)](dT/dr)$$

$$E = mc^2$$

$$V^2/R = GM/R^2$$

$$e^X = 1 + X \quad \text{(for } X << 1)$$

1 pc = 3.086×10^{18} cm

m_e = 9.11×10^{-28} gm

$$V_{cone} = (1/3)\,\pi R^2 H$$

M_{earth} = 5.98×10^{27} gm

$$\Delta V = \sqrt{3kT/m}$$

$$\lambda_{max} = 2.898\,[mm]/T[K]$$

$$R_\infty = 10.973732\,\mu m^{-1}$$

1 atmosphere (atm) = 10^6 dyn cm^{-2}

$$V_{LSR} = R_0 sin\ell[\omega(R) - \omega_0]$$

$$\mu = (M_1 M_2)/(M_1 + M_2)$$