 http://www.physics.mun.ca/~csteven/P3151/Exams/final.htm

Physics 3151 - Astrophysics II

FINAL EXAMINATION

April 15, 2006 9:00 A.M.

Please answer FIVE of the following SEVEN questions. All questions are of equal weight.
Please use cgs units in your calculations unless otherwise specified.
Read each question **carefully** before starting it.
You will find useful data (in cgs units) and formulae on the back page. *Good Luck!*

Problem #1.

(a) What is "Olber's Paradox"?

(b) Comment on what we know of galaxy evolution in light of Hubble's suspicions when he came up with his "Tuning Fork" diagram.

(c) What distinguishes "grand design" and "flocculent" spiral galaxies?

(d) Describe in some detail the two main theories of the formation of spiral arms.

Problem #2.

(a) A quasar with a measured redshift of $z = 2.50$ coincidentally lies exactly along the line of sight to a nearer giant elliptical galaxy having a measured redshift of $z = 0.10$. Describe what you would observe.

(b) If the intervening galaxy instead had an ellipsoidal mass distribution, what would you expect to see?

(c) Assuming the mass-to-light ratio of the foreground galaxy is 600 M_{Sun}/L_{Sun} (note that giant ellipticals contain much dark matter), and it has a visual luminosity $L_V = 4 \times 10^{10}\ L_{sun}$, what is its mass?

(d) Calculate the major dimension of what you see in part (a), expressing your answer in arcseconds.

Problem #3.

(a) A giant molecular cloud has a mass (including dark matter) of 2×10^{11} M_{sun}, a mean molecular mass μ=0.6, and a virial temperature of 4×10^5 K. At what density would the cloud become unstable and collapse to form a galaxy? If the cloud is roughly spherical, what would be its initial diameter? Express your answer in cgs units and parsecs.

(b) Approximately how long would it take the cloud in (a) to collapse, assuming an isothermal free-fall? Compare with a Hubble Time. Is this consistent with what we see in the early Universe?

(c) Describe the Milky Way's bimodal globular cluster population, and the ramifications this has on the possible formation mechanisms of our home galaxy.

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Problem #4.

(a) Distinguish between a "permitted" and "forbidden" emission line.

(b) The spectrum of a starburst galaxy is observed and the intensities (relative to $H\beta$) of doubly-ionized sulphur forbidden lines are measured to be I([SIII])λ6312 = 0.018, I([SIII])λ9069 = 0.125, and I([SIII])λ9532 = 0.335. Use the formula below to estimate the electron temperature in the S^{2+} zone if n_e = 100 cm^{-3}. (Iterate starting with 10^4K)

$$\frac{j_{\lambda 9532} + j_{\lambda 9069}}{j_{\lambda 6312}} = \frac{5.44\ e^{(2.28 \times 10^4)/T_e}}{1 + (3.5 \times 10^{-4}) n_e / T_e^{1/2}}$$

(c) Would you conclude, based on this temperature, that this starburst galaxy was metal-rich or metal-poor? Explain your answer.

(d) A planetary nebula is powered by a single white dwarf with an ionizing luminosity $Q(H^o)$ = 1.5 x 10^{47} s^{-1}, and has an electron density n_e = 1000 cm^{-3}. If the measured diameter of the nebula is 1pc, what is the filling factor ε ?

Problem #5.

(a) What is the "virial theorem"?

(b) A medium-rich galaxy cluster is observed to span about 0.5 degree on the sky. A Type Ia supernova (SNe) is observed in one of its galaxies to peak at +19.5 B-magnitudes and it is known that the foreground extinction in B towards the cluster is 0.4 mag. Approximately how distant is the galaxy cluster, and what is its radius (in Mpc)?

(c) If the dispersion of radial velocities for galaxies in the cluster is measured to be σ_r = 850 km s^{-1} , what is the virial mass of the cluster (in solar masses)? (*Hint*: take care to note the difference between σ and σ_r)

(d) If the total visual luminosity of the cluster is $L_V = 1.4 \times 10^{12}$ L_{Sun}, what is the mass-to-light ratio of the cluster and what does this tell you about the dominant form of mass in it?

Problem #6.

(a) What are the principal differences between Seyfert and radio galaxies?

(b) A QSO is appears as a faint blue star on the sky with an apparent visual magnitude V=15.6. When observed with a spectrograph, Hβ (λ_{rest} = 486.1 nm) is seen shifted to 660.0 nm. What is the QSO's redshift, and if the foreground extinction in the V-band is 0.2 mags, what would be its absolute V-magnitude and approximate luminosity (take M_{sun}=+4.76)?

(c) Taking the luminosity in (c) to be at the Eddington limit, find the mass and Schwartzchild radius of the QSO's central black hole (in AU's). If the mass-energy conversion efficiency is 10%, what is the accretion rate onto the source? (Express in M_{sun} yr^{-1})

(d) Taking the inner radius to be twice the Schwartzchild radius, calculate the characteristic temperature of the accretion disk in (c). In what part of the EM spectrum would this be brightest?

Problem #7.

(a) What is a BLRG and how does it differ from a NLRG?
Sketch (in words and/or otherwise) the general features of a typical AGN.

(b) What is a "Lyman-α forest"?

(c) A neutron star has a mass of 1.5 M_{Sun} and a diameter of 20 km. If an Fe XVI photon (λ_o = 36.08 nm) is emitted from the surface, at what wavelength will it be observed from Earth?

(d) The continuum of an AGN can be described by a power law, $F_\nu = C\ \nu^{-\alpha}$. For a particular Seyfert galaxy's nucleus the spectral index $\alpha = 1$, and the luminosity is $L = 5 \times 10^{46}$ erg s^{-1}. If L arises from the integral of the power law over all visible frequencies, integrate the power law from $\nu_1 = 10^{10}$Hz to $\nu_2 = 10^{25}$Hz to obtain the constant C in terms of L. The number of hydrogen-ionizing photons emitted by the AGN per second ($Q(H^o)$ can be found by dividing the power law by $h\nu$ and integrating again, this time from $\nu_H = 3.29 \times 10^{15}$Hz to $\nu_2 = 10^{25}$Hz. If 2% of the narrow-line region is filled with clouds, which have a density of 10^{4} cm^{-3}, what is the radius of the narrow-line region of this AGN?

$\alpha_B = 2.6 \times 10^{-13}$ cm^{-3} s^{-1}

$G = 6.67 \times 10^{-8}$ dyne cm^2 g^{-2} (= g^{-1} cm^3 s^{-2})

$M_{Sun} = 1.99 \times 10^{33}$ g

$R_{Sun} = 6.96 \times 10^{10}$ cm

$L_{Sun} = 3.83 \times 10^{33}$ erg s^{-1}

$H_o = 73$ km s^{-1} Mpc^{-1}

1 pc = 3.09×10^{18} cm

1 AU = 1.5×10^{13} cm

$c = 3.00 \times 10^{10}$ cm s^{-1} = 3.00×10^5 km s^{-1}

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

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

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

$\int x^{-1} dx = \ln(x)$

$\lambda_{max} T = (500\text{nm})(5800\text{K})$

M_B^{max} (Type Ia) = -19.2 +/- 0.2

$R_S = 2GM_{bh} / c^2$

$t_{ff} = [\, 3\pi \,/\, (32 G \rho_o) \,]^{1/2}$

$\sigma = [\, 3GM \,/\, 5R \,]^{1/2}$

$\nu_\infty \,/\, \nu_o = [\, 1 - 2GM/r_o c^2 \,]^{1/2}$

$M_J = [(5kT)/(G \mu m_H)\,]^{3/2} \; [3/(4\pi \rho_o)]^{1/2}$

$z = (\lambda_{obs} - \lambda_{rest}) \,/\, \lambda_{rest}$

$R_S = [\, 3\, Q(H^o) \,/\, 4\pi \varepsilon \alpha_B n_e^2 \,]^{1/3}$

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

$d = (c/H_o)\; [(z+1)^2 - 1] \,/\, [(z+1)^2 + 1]$

$L_V / L_{Sun} = 100^{(M_{sun} - M_V)/5}$

$L_{ED} \sim 1.5 \times 10^{38}\, (M/M_{Sun})$ erg s^{-1}

$L_{disk} = \eta \, Mdot \, c^2$

$T_{disk} = [\, (3\, G\, M\, Mdot) \,/\, (8\pi \sigma R^3)\,]^{1/4}$

$\Theta_E = [\, (4GM/c^2)(d_S - d_L) \,/\, d_S d_L \,]^{1/2}$