PH.D. QUALIFYING EXAMINATION
Department of Astronomy
August 22, 2005
9:00am - 1:00pm

DAY ONE

Name: ____________________________

Student #: _________________________

The exam sheets are inside this envelope and are not fastened together. Astronomy Program students MUST do the FIRST problem and SIX more problems from the remaining SEVEN. When you are finished, please put the questions and your answer sheets back in the envelope in the correct order. Be sure the student number given you by the proctor is on every page of your answers.

Physical Constants

$c = 3.00 \times 10^{10}$ cm/s
$G = 6.67 \times 10^{-8}$ dyn cm^2/g^2
$h = 6.63 \times 10^{-27}$ erg s
$k = 1.38 \times 10^{-16}$ erg/K
$m_p = 1.67 \times 10^{-24}$ g
$a = 7.56 \times 10^{-15}$ erg cm^{-3} K^{-4}
$e = 4.80 \times 10^{-10}$ esu
$m_e = 9.11 \times 10^{-28}$ g
$\sigma = 5.67 \times 10^{-5}$ erg cm^{-2} K^{-4} s^{-1}

$R_{\upsilon} = 6.96 \times 10^{10}$ cm
$M_{\upsilon} = 1.99 \times 10^{33}$ g
$L_{\upsilon} = 3.90 \times 10^{33}$ erg/s
A.U. $= 1.50 \times 10^{13}$ cm
1 year $= 3.16 \times 10^{7}$ s
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1.) GENERAL ASTRONOMY (Mandatory Question)

a) Why are IR and radio telescopes useful for exploring the structure of the Milky Way Galaxy? Describe a set of observations that could determine the mass of a black hole at the center of the Galaxy. Be as specific as possible about the observational constraints for your project. (60 pts)

b) Answer ONLY ONE of the Following: (40 pts)

b1) What are the Ahorizon@ and Aflatness@ problems in cosmology? Describe how inflation can resolve these issues. Include a sketch of the scale factor of the universe as a function of time for a flat universe without a cosmological constant and for a universe with a cosmological constant.

b2) At the level you would use when speaking to the general public, describe the science goals of any of the current NASA missions designed to explore the Solar System.

2.) Astrophysical Shocks

a) Write down the three Rakine-Hugoniot shock jump conditions for a plane-parallel adiabatic shock in an ideal gas that relate pre-shock physical quantities ρ_1, u_1, P_1, (mass density, speed normal to the shock, and pressure, respectively) and post-shock physical quantities ρ_2, u_2, P_2. Allow the ratio of specific heats γ to be different on the two sides of the shock. Each jump condition expresses conservation of a physical property. Name what it is for each condition. (36 pts)

b) Consider the case of an outflow with a speed of 50 km/s running into dense molecular gas in the ISM. Use the results of part (a) to estimate the expected post-shock temperature. Explain your assumptions and approximations. (40 pts)

c) Outflows at these speeds do occur in molecular clouds and yet H_2 is not dissociated! Explain why this is surprising given your answer in part (b). It is now understood that the shocks in these flows are not well described by the relations in part (a). Explain. (Hint: The Ashocks@ that do occur are called C-type shocks. What are they?) (24 pts)

3.) Galaxy Morphology

a) Briefly describe the major morphological differences between an Sa and Sc galaxy and describe the dominant stellar populations within these galaxies. Include a sketch of the expected surface brightness profile for these galaxies (label the axes with realistic values, in physical units such as arcsec and mag/arsec^2). (25 pts)

b) Explain why a galaxy=s central surface brightness does not depend on its distance (for low redshift galaxies). What does a central surface brightness of 21 mag arsec^{-2} in the B-band correspond to in solar luminosities per square parsec ($L_\odot pc^{-2}$)? Recall, $M_{B\odot} = 5.48$. (25 pts)

c) Sketch a typical rotation curve for an Sc galaxy. Label the axes with realistic values (in physical units, such as kpc and km/s). Also include a sketch showing the decomposition of the rotation curve into the appropriate baryonic and non-baryonic components. Describe how the decomposition is obtained, including a brief description of the required observations. (25 pts)

d) Consider the case of a stellar population dominated by two bursts of star formation separated by several Gyr. If the SSP for the first burst can be approximated by $M_B \sim -13$ and a (B-V) color of 0.8, and the second burst can be approximated by $M_B \sim -12$ and a (B-V) color of 0.4, what is the V-band magnitude of this galaxy? What is the integrated color? (25 pts)

4.) Supernova Energetics

a) Suppose that the iron core of an evolved 15 $M_\odot$ star reaches the Chandrasekhar mass and collapses to become a neutron star. Estimate the amount of gravitational energy that is released in ergs. Discuss your assumptions. (40 pts)

b) Suppose that the envelope of the star is ejected with a velocity of 10^4 km/s. Compute the amount of kinetic energy that is carried away in the escaping envelope material. (20 pts)

c) If the resulting type II supernova has an optical luminosity of 10^{10} $L_\odot$ for a characteristic time of one month, what amount of energy is radiated? (20 pts)

d) Compare your results from parts (a), (b), and (c). What accounts for any remainder of the released gravitational energy? Cite any observational evidence supporting your conclusion. (20 pts)

5.) Jupiters

a) Consider a planet of mass M_p in circular orbit about a star of mass M_s at a distance d. Find an expression for the distance d_s of the center of the star from the center of mass of the star-planet system. Assume that M_p □ M_s. Evaluate d_s for the Sun-Jupiter system ($M_J = 10^{-3}\ M_\upsilon$, d = 5.2 AU) and compare your result with the radius of the Sun $R_\upsilon = 7 \times 10^5$ km). (30 pts)

b) Find an expression for the velocity v_s of the star=s center of mass in the star-planet center-of-mass frame. Evaluate the value of v_s for the Sun-Jupiter system and discuss your result. Based on the expression for v_s, what sorts of planets are favored by searches for extrasolar planets that detect periodically varying Doppler shifts of the parent star? (40 pts)

c) Compare the spin angular momentum of the Sun with the orbital angular momentum of Jupiter. (You may make a simple assumption about the internal structure of the Sun for estimating its angular momentum but explain what you assume.) Discuss the significance of your finding for explaining why the formation of planetary systems appears to be a common feature of star formation. (30 pts)

6.) Dark Matter/Energy

a) What is $\Omega_{total} = \rho_o/\rho_{crit}$ thought to be today (August 2005)? What geometry does this imply? Discuss specific experimental evidence for this value. What fraction of the total energy density in the universe is in baryonic, nonbaryonic, and dark energy? (40 pts)

b) Dark Matter. There are really two dark matter problems: (1) baryonic dark matter and (2) nonbaryonic dark matter. What is the evidence for baryonic dark matter? What is the evidence for nonbaryonic dark matter? How are the Lyman α forest observations of quasars thought to be related to the baryonic dark matter problem? (40 pts)

c) Dark Energy. What is the experimental evidence for dark energy? What is dark energy? (20 pts)

7.) Stellar Astronomy

a) Two main sequence stars, A and B, have the following characteristics: $m_v(A) = 9.5 = m_v(B)$; E(B-V) towards A = 0.50, E(B-V) towards B = 0.00; B.C.(A) = 3.2, B.C.(B) = 1.0; D(A) = 2080pc, D(B) = 13.8pc; $T_{eff}(A) = 28{,}000$ K, $T_{eff}(B) = 3{,}480$ K. Find the ratio of the radius of star A to that of star B. What is the approximate spectral type of each star? (25 pts)

b) Sketch the evolutionary track for a solar-metallicity $5M_{\upsilon}$ star from the ZAMS to a cooling white dwarf. Along the track, please indicate what thermonuclear reactions are occurring and where they occur in the stellar interior. For example, you might highlight a part of the track and label it ACNO-cycle H-burning in a shell@. Mark and label other significant features of the track. (25 pts)

c) Estimate the number of white dwarfs in the Milky Way disk. Clearly state your assumptions and explain your reasoning carefully and completely. (50 pts)

8.) Spectroscopic Observations

a) Suppose you wish to study atmospheric oscillations in V = 10 mag cluster stars with the MOS/Hydra spectrograph on WIYN. The experiment requires that the integration times be 5-min with S/N = 300 per resolution element, per exposure. You need at least 100 Ang of spectral coverage at 3750 Ang, and you would like to obtain as high a spectral resolution as possible.

Using the spectrum of the V = 10 star Feige 66 in Fig. 3, plus other information in the tables, choose the appropriate setup parameters with regard to:

Fiber cable: ____________

Grating: _______________

Filter: _________________

Spectral Resolution: ____________ (Ang)

NOTE: 1) Grating KPC-10B (Fig 3) can be considered equivalent to grating 860 @ 30.9 in Table 3. 2. For this high S/N, you may ignore all noise sources except signal shot noise. SHOW YOUR WORK. (50 pts)

b) With regard to the terminology used in the attached write-up, please define these terms and describe their relevance. (50 pts)

1) 2048 Thinned Tek (24 micron pixels)
2) blaze angle
3) echelle
4) blue optical fiber

PH.D. QUALIFYING EXAMINATION
Department of Astronomy
August 23, 2005
9:00am - 12:30pm

DAY TWO

Name: ____________________________

Student #: _________________________

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1.) Photodissociation Regions

a) What wavelength or energy range of photons causes photodissociation regions (PDR=s)? Why and how? (25 pts)

b) Explain how H_2 is formed and dissociated in the ISM. (25 pts)

c) How is a PDR heated? How is it cooled? (25 pts)

d) Describe the emission spectrum of a PDR in the mid to far infrared. (25 pts)

2.) Stellar Structure

a) Show from the Virial Theorem that, for a spherical star of ideal gas with zero surface pressure, the average temperature T_{ave} = constant times M/R, where M and R are the stellar mass and radius. (30 pts)

b) Determine the precise value of the constant in part (a) if the gas is monatomic and the star is well approximated by the density structure of an n=3 polytrope. (20 pts)

c) Using part (a), using the line which divides the region of electron degeneracy from nondegenerate gas in the log T versus log ρ plane, and using additional information as needed, explain why stars of different masses have such different end stages of their evolution. Graph paper is provided if you feel that a diagram is necessary for a good answer (probably true). (50 pts)

3.) Variable Stars

A K band light curve (Fig 3.1) and a radial velocity (Fig 3.2) curve for the RR Lyrae star V9 in the globular cluster 47 Tucanae are presented below. The data are taken from a paper by Storm et al. (1994, AAp, 291, 121). The period of the pulsation is 0.736852 days and its intensity-averaged, dereddened, apparent K magnitude is 12.66. According to Carney et al. (1993, PASP, 105, 294) the B-V color at maximum light is B-V=0.20, while at minimum light B-V=0.50. A B-V vs. temperature calibration is provided below (Fig 3.3).

a) Estimate the ratio of the radius at minimum light to the radius at maximum light. (40 pts)

b) From the ratio of radii and the radial velocity curve, estimate the radii (in solar radii) at minimum and maximum light (40 pts)

c) Estimate the distance to 47 Tuc in parsecs. (20 pts)

4.) Black Hole Tides

a) Consider a star of mass M_s and radius R_s located at a distance d from a black hole of mass M_{bh}. Find an expression for the magnitude of the tidal acceleration at the surface of the star, along the line of centers of the star and the black hole. (60 pts)

b) Suppose that the tidal acceleration is equal to the gravitational acceleration at the star=s surface due to its self gravity. Use this condition to find the radius d, of the tidal-breakup sphere around the black hole for stars of radius M_s and radius R_s.
(20 pts)

c) Assuming that the supermassive black hole at the center of the Milky Way Galaxy has a mass of 4×10^6 M_{υ}, determine if a 1 M_{υ} white dwarf would reach the Schwarzschild radius of the black hole before it were tidally disrupted. Assume that R_{wd} . 0.01 $R\upsilon$.
(20 pts)

5.) A Galaxy Collision

a) Suppose that the Milky Way and M31 are each described by a flat rotation curve that extends to 100 kpc from the galaxy with a rotation velocity of 220 km/s. Use this to estimate the mass of each galaxy. Assume that each galaxy has a luminosity of 2×10^{10} $L_\odot$. Estimate the overall M/L ratio and discuss the implications for the content of the galaxy halos. (30 pts)

b) Now suppose that the two galaxies are just beginning to fall together from their present separation of 700 kpc. Assume that there is no transverse motion. Estimate the amount of time required for the two galaxies to collide. (Approximate each galaxy as a point mass.) Also estimate the speed of the galaxies at a separation of 100 kpc. (50 pts)

c) Discuss the likely result of a such a collision between the Milky Way and M31 including both transient effects and the long-term outcome. (20 pts)

6.) Multiwavelength Observations

a) Astronomical instruments and techniques are strongly shaped by the character of the absorption by the medium through which a source is observed, plus the nature and strength of the background. For each of the wavelengths listed below, describe the conditions of absorption and of background, with regard to their effect on astronomical observations. (Be as quantitative as you can; however, correct qualitative answers will receive partial credit.) For both the absorption along the line of sight and the background radiation, describe the relevant atomic processes. (60 pts)

1) 100A (space-based X-rays)
2) 850A (spaced-based UV)
3) 3200A (ground-based near-UV)
4) 8000A (ground-based near-IR)
5) 3.5-microns (ground-based IR)
6) 3.5-microns (space-based IR)

b) Consider the measurement of a source on a moonless night in which you obtain S/N = 20 in 10 min, and for which the sky background is contributing a flux equal to that of the star. Your next run is under moonlit conditions for which the sky is now 5 times brighter. How long will you have to expose under these conditions to retain S/N = 10? (You may ignore all noise sources except sky background noise.) SHOW YOUR WORK. (40 pts)

7.) Galaxy Catalogs

a) What is Malmquist bias? Describe the effects of Malmquist bias on the derivation of galaxy scaling relations such as the Tully-Fisher relation. (25 pts)

b) What is the difference between a luminosity distribution and a luminosity function? Sketch examples of both for galaxies in the local volume. (25 pts)

c) Sketch a diagram showing how the local density effects the number of ellipticals, spirals, and S0 galaxies. (25 pts)

d) Assume that all galaxies in some class have the same luminosity and have constant space density. Derive an expression for the expected number counts vs. apparent magnitude assuming we live in Euclidean universe. (25 pts)