Astronomy C10 / L&S C70U – Fall 2015 – Professor Alex Filippenko

Midterm Exam #2 — 13 November 2015

Print name: Solutions (A) **Sign** name: _____ Student ID #: _____

Print your GSI's Name: _____ Discussion section # (or day, time): _____

Print and sign your name on your SCAN-TRON 882 form. Under "subject," please put your GSI's name and your discussion section number.

CLOSED BOOK, CLOSED NOTES, NO CALCULATORS

Mark all answers on SCAN-TRON form 882. Use a #2 pencil. Completely fill in the appropriate bubble. *Be sure to thoroughly erase all altered answers and stray marks!*

For true/false questions: mark bubble **A** if the statement is *true*, and bubble **B** if *false*. For multiple choice questions: mark the bubble corresponding to the *single best answer.*

All 25 questions carry equal weight. Read each question *carefully* before answering. **There is no penalty for guessing.** If you need extra room for work, use the last (blank) page.

Turn in *both* this multi-page set of questions *and* your SCAN-TRON form.

DO NOT OPEN THIS EXAM UNTIL TOLD TO DO SO!!

Time limit: 45 minutes — **budget your time appropriately. GOOD LUCK!**

Possibly Useful Information

d (pc) $= 1/p$ (arcsec) $\quad d = vt \quad$ density $\rho = M/V \quad c = 3 \times 10^5$ km/s

For a sphere, $V = \frac{4}{3}\pi R^3$, $A_{\rm surface} = 4\pi R^2 \quad$ For a circle, $A = \pi R^2$, $C = 2\pi R \quad \pi \approx 3.14$

There are about 3.2×10^7 seconds per year, and 86,400 (roughly 10^5) seconds per day

Degrees Kelvin = degrees Centigrade + 273; Fahrenheit = (9/5)Cent. + 32 $\quad \theta \approx \lambda/D$

1 AU $= 1.5\times10^8$ km ≈ 8.3 light minutes $\quad$ 1 light year (ly) $\approx 63,000$ AU $\approx 9.5\times10^{12}$ km $\approx 10^{13}$ km

1 pc $= 3.26$ ly $\approx 3 \times 10^{18}$ cm $\approx 3 \times 10^{13}$ km $\quad$ 1 Å $= 10^{-8}$ cm $= 10^{-10}$ m $= 0.1$ nm

$60''$ (arcsec) $= 1'$ (arcmin), $60' = 1°$ (degree), $360°$ = full circle $= 2\pi$ radians = 24 hours

$\lambda_{\rm peak} T \approx 3 \times 10^6$ nm K $= 3 \times 10^7$ Å K $\quad \lambda f = c \quad P = 1/f \quad \mathcal{E} = \sigma T^4 \quad E = hf$

$z = (\lambda - \lambda_0)/\lambda_0 = \Delta\lambda/\lambda_0 \approx v/c$ if $v \lesssim 0.2c \quad z = \sqrt{\frac{1+(v/c)}{1-(v/c)}} - 1$ for all $v \leq c$.

$F = GM_1M_2/d^2 \quad M_1r_1 = M_2r_2 \quad L \propto M^4 \quad R \propto M^{0.75} \quad p + e^- \rightarrow n + \nu$

$R_{\rm S} = 2GM/c^2 \quad R_{\rm photon\ sphere} = 3GM/c^2 \quad M_{\rm Ch} = 1.4\ M_\odot \quad F = ma$

$L_{\rm thermal} = 4\pi R^2 \sigma T^4$ (for a sphere) $\quad b = L/(4\pi d^2) \quad E = mc^2 = m_0c^2[1 - (v^2/c^2)]^{-1/2}$

$v = H_0 d$, where $H_0 \approx 70$ km/s/Mpc $\quad \Omega = \rho/\rho_{\rm crit} \quad \rho_{\rm crit} = 3H_0^2/(8\pi G) \quad M = v^2R/G$

$N = R_* f_s f_p n_e f_l f_i f_c L$, where $R_* \approx N_*/T$ (N_* = # stars in galaxy, T = age of galaxy)

$P^2 = kR^3$ [$k \approx$ constant $\approx 4\pi^2/(GM_1)$ if $M_1 >> M_2$]; in general, $P^2 = (4\pi^2R^3)/[G(M_1 + M_2)]$

For planets, $v \propto 1/\sqrt{R} \quad t_{\rm moving} = (t_{\rm rest})[1 - (v^2/c^2)]^{1/2} \quad L_{\rm moving} = (L_{\rm rest})[1 - (v^2/c^2)]^{1/2}$

(1) What is the closest location you could find material formed in a supernova?
(a) The Sun
(b) Earth's core
(c) The Crab Nebula
(d) Your body
(e) The center of the Milky Way Galaxy

(2) T or F. Edwin Hubble measured the apparent brightness of Cepheid variable stars in galaxies to determine distances, and he found that the more-distant galaxies are moving away from us faster than less-distant galaxies.

(3) Which one of the following statements about our Sun is TRUE?
(a) Both the core and the corona are much hotter than the photosphere.
(b) The Sun is a very active star, blasting waves of energy, solar flares, and winds continuously and uniformly with time.
(c) The apparent motion of sunspots on the Sun is caused mainly by Earth's orbit.
(d) Being an uncharged (i.e., neutral) star, the Sun does not have a magnetic field.
(e) Sunspots were first discovered recently, using telescopes in space.

(4) Which one of the following statements about the Doppler-wobble method is FALSE?
(a) The Doppler wobble is caused by the reflex motion of a star that has an orbiting planet.
(b) The Doppler wobble is larger for a planet that is far from a star than for one having the same mass that is near the star.
(c) The radial velocity of a star can be measured from its spectrum.
(d) The Doppler-wobble method, which led to the discovery of most exoplanets initially, is now second to the transit method in the total number of detected exoplanets.
(e) The Doppler-wobble method generally provides only a planet's *minimum* mass.

(5) T or F. In white dwarfs, brown dwarfs, and black dwarfs, "electron degeneracy pressure" prevents gravitational collapse.

(6) If you have already measured the surface temperature of star Medford, then to determine its radius you must also measure
(a) the amount of time it takes an exoplanet to transit across Medford's surface.
(b) the shift in stellar motion due to Doppler wobble.
(c) the changing position of star Medford throughout a night of observation.
(d) the wavelength of the peak of star Medford's spectrum.
(e) the distance to Medford and its apparent brightness.

$b = \frac{L}{4\pi d^2} \rightarrow L = 4\pi d^2 b$ But $L = 4\pi R^2 \sigma T^4$, so if we know L and T, we can determine R.

(7) Which one of the following statements is FALSE?
(a) Pre-main-sequence stars shine by releasing gravitational potential energy while contracting and heating up.
(b) Main-sequence stars shine by converting most of the mass of atomic nuclei into energy according to the equation $E = mc^2$. → (very little)
(c) A main-sequence star becomes a red giant as its helium core contracts, releasing energy and causing a hydrogen-fusing shell to fuse more vigorously.
(d) At some point in time, a sufficiently massive red giant can shine by fusing helium to carbon and oxygen in its core.
(e) White dwarfs shine primarily because atomic nuclei lose their kinetic energy.

(8) Suppose over the next year, Kyle goes outside (far away from any light pollution) on every clear night and counts individual stars with his unaided eyes (without binoculars, telescopes, or filters) along the plane of the Milky Way. What will he see? Why?

(a) He sees substantially more stars toward the center of the Milky Way Galaxy than away from the center; there are more stars near the center of the Milky Way Galaxy.

(b) He sees substantially more stars toward the center of the Milky Way Galaxy than away from the center; the nearest spiral arm to Earth is toward the center.

(c) He sees about the same number of stars toward the center of the Milky Way Galaxy and away from the center; dust absorbs and scatters much of the visible light from distant stars in the disk of the Milky Way Galaxy.

(d) He sees about the same number of stars toward the center of the Milky Way Galaxy and away from the center; we are very close to the center of the Milky Way Galaxy.

(e) He sees more stars away from the center of the Milky Way Galaxy than toward the center; the supermassive black hole at the center is preventing the visible light near the center from getting to us.

(9) Which one of the following statements about active galactic nuclei (AGN) is FALSE?

(a) Jets of particles and light are sometimes seen originating from AGN.

(b) The luminosity of AGN depends on the rate at which matter is swallowed by the central supermassive black hole.

(c) The great width of the emission lines in AGN reveals the presence of supernovae ejecting matter at high speeds.

(d) The energy-generation mechanism in AGN is more efficient than nuclear fusion.

(e) The variability seen in AGN gives an upper limit (i.e., maximum value) on the physical size of the emitting region.

(10) Which one of the following statements about core-collapse supernovae is FALSE?

(a) They explode primarily because of a runaway chain of nuclear reactions.

(b) They occur when the iron core mass reaches roughly the Chandrasekhar limit.

(c) They sometimes produce pulsars.

(d) They occur in very massive stars.

(e) They release most of their energy in the form of neutrinos.

(11) T or F. If an absorption line of hypothetical element Suessium is normally found at a wavelength of 1000 nm (nanometers) in a laboratory gas at rest, then it will appear to have a wavelength of about 1050 nm in the spectrum of a galaxy that has redshift $z = 0.05$.

$z \approx \frac{v}{c} \longrightarrow v = zc = (0.05)(3\times10^5\ \text{km/s}) = 15{,}000\ \text{km/s}.$

$\frac{\Delta\lambda}{\lambda} = z = \frac{v}{c} = \frac{15{,}000}{3\times10^5} = 5\times10^{-2} = 0.05,$ so $\Delta\lambda = (0.05)(1000\ \text{nm}) = 50\ \text{nm}$, and $\lambda = 1050\ \text{nm}$

(12) Suppose two stars in a binary system, Star Louis and Star Nat, are in highly eccentric elliptical orbits about their common center of mass (CM). When Star Louis is at its farthest point from the CM, which one of the following is TRUE?

(a) Star Nat is at its closest point to the CM.

(b) Star Nat is at its farthest point from the CM.

(c) Star Louis has the maximum velocity it will have during its orbit.

(d) Star Nat has the maximum velocity it will have during its orbit.

(e) The question doesn't make sense; a common CM is not possible when elliptical orbits are highly eccentric.

(Galaxies are too far away for the parallax method)

(13) T or (F) If Star Goni is in a galaxy 3 times the distance from Earth of a different galaxy containing Star Deepthi, then Star Deepthi will have a measurable parallax angle that is three times larger than the measured parallax angle of Star Goni.

(14) Which one of the following statements about exoplanets and the transit method is FALSE?

(a) The brightness of a star that is orbited by a transiting exoplanet dims proportionally to that planet's surface area.

(b) Planets in an "edge-on system" (orbital plane along the line of sight) are more likely to be detected using the transit method than planets in a "face-on system" (orbital plane perpendicular to the line of sight).

(c) Different planets orbiting a single star can result in different amounts of dimming of that star's apparent brightness.

(d) The transit of a planet across a star can give us the opportunity to study that planet's atmosphere.

(e) Rocky planets are easier to detect than gas giants with the transit method because rocky planets are much denser than gas giants.

(15) Which one of the following statements related to black holes is FALSE?

(a) A "wormhole" may connect two separate universes, or different locations in our own Universe.

(b) Gamma-ray bursts are highly beamed jets of radiation found in distant galaxies that can result from the merging of a neutron star and a black hole.

(c) The presence of black holes can be inferred from their gravitational influence on stars and gas surrounding them.

(d) A rotating black hole has a larger event horizon than a nonrotating black hole with the same mass. ← (smaller)

(e) Black holes can gradually lose mass when only one particle from a "virtual pair" produced outside the event horizon falls in, leaving the other one free to escape.

(16) (T) or F. Most elliptical galaxies contain relatively little gas and dust and consist almost entirely of old stars.

(17) Suppose Galaxy Imad has a redshift of 0.02 while Galaxy Sammie has a redshift of 0.10. Roughly how much older is the light we are seeing from Galaxy Sammie than from Galaxy Imad?

(a) 2 times older
(b) 5 times older
(c) 8 times older
(d) 25 times older
(e) Light from the two galaxies has been traveling to us for the same amount of time.

$\frac{0.10}{0.02} = 5$ $\quad z = \frac{v}{c} \rightarrow v = cz$

$v = H_0 d \longrightarrow d = \frac{v}{H_0}$, so Sammie is 5× farther away than Imad.

(18) T or (F) The "solar wind" coming from the Sun consists mostly of photons, and they can interact with Earth's magnetic field. ← (No, charged particles)

(19) If the amount of fuel available during the main-sequence stage of a star's life is proportional to the star's mass (M), and the luminosity of a main-sequence star is proportional to the fourth power of the mass (M^4), then what can we say about a star's main-sequence lifetime?

(a) It is proportional to $1/M^5$.
(b) It is proportional to M^5.
(c) It is proportional to M.
(d) It is proportional to $1/M^3$.
(e) It is proportional to M^3.

$t \propto \frac{M}{L} \propto \frac{M}{M^4} = \frac{1}{M^3}$

Be sure you answer question #20 correctly (6 points off if incorrect)!

(20) Jake Duncan, the Head GSI for this class (Astronomy C10 / L&S C70U, Fall 2015),
(a) is a graduate student at UC Berkeley.
(b) lives on a moon orbiting Saturn.
(c) is actually a punk rock star in disguise.
(d) can't possibly be human, because he's made of pure niobium and plutonium.
(e) was brought to Earth from the Moon during the Apollo landings in the early 1970s.

(21) What is the best explanation for a spiral galaxy's "flat" rotation curve?
(a) We expect a flat rotation curve if a central mass dominates, as in the case of a supermassive black hole in the center of the galaxy.
(b) The radius of the supermassive black hole at the center is proportional to its mass.
(c) There is a lot of dark matter that is far from the center of the galaxy.
(d) There is a dense clump of dark matter near the central supermassive black hole.
(e) There are many supermassive black holes near the edge of the galaxy.

(22) T or F Stars whose initial mass is 2 $M_\odot$ should generally end their life as neutron stars, since their mass exceeds the Chandrasekhar limit, the maximum mass of white dwarfs. (final mass is relevant.)

(23) Suppose from far away you observe Saundra fall toward a nonrotating black hole. Which one of the following statements is TRUE?
(a) After crossing through the event horizon and returning to where you are, Saundra will have aged less than you.
(b) Time would appear to be moving more quickly for Saundra, from your point of view.
(c) Time would be moving more quickly for Saundra, from her own point of view.
(d) Saundra could enter a stable circular orbit at the "photon sphere" of the black hole.
(e) If it is a higher-mass black hole, the tidal forces on Saundra at the event horizon will be weaker than with a lower-mass black hole.

(24) Quasars _____.
(a) emit most of their light at radio wavelengths.
(b) emit most of their light from a region comparable in size to a galaxy.
(c) are more numerous now than they were billions of years ago.
(d) have spectra that were initially difficult to interpret because of their large redshifts.
(e) cannot be at redshift $z > 1$, since the equation $v = cz$ would imply that they move away from us faster than the speed of light (which is impossible).

(25) Which one of the following is NOT a consequence of Einstein's general theory of relativity?
(a) If nonrotating matter is compressed into a radius of $2GM/c^2$ or smaller, it becomes a black hole, not allowing light or anything else to escape.
(b) Light loses energy as it moves away from a neutron star's surface.
(c) The major axis of Mercury's elliptical orbit slowly rotates.
(d) Light from distant galaxies is bent by foreground clusters of galaxies.
(e) The distance separating two pulsars in a binary system gradually increases, as gravitational waves are released and gravity weakens. (decreases)

End of Examination