AstroClarinet's Astronomy C Test: Answer Key

All questions are 1 point unless marked otherwise. 110 points total.
PM me if you have any questions or see something potentially incorrect. Errata will be posted on my userpage.

Section A (33 pts):
A1: A **(2)**
A2: C
A3: B **(2)**
A4: B
A5: D
A6: D **(2)**
A7: B
A8: C **(2)**
A9: A
A10: D
A11: A
A12: B
A13: C **(3)**

A14: **(5 total)**

- They will merge to form a new galaxy called Milkomeda/Milkdromeda (1), which will be a giant elliptical galaxy (2); this will effectively end the existence of both the Andromeda and Milky Way galaxies.
- NGC 2623 is thought to be similar to what the Milky Way-Andromeda collision could be like (2).

A15: **(5 total)**

- Any answer between medium and old age is acceptable (1).
- The age of the star cluster can be determined by looking at the age of the stars at the main sequence turnoff point. The turnoff point of this cluster is at the B-V color index of 0.4, which corresponds to redder stars. Cooler, redder stars tend to live longer, so this star cluster has a medium to old age (2).
- This could differ from the actual age of the cluster because the main sequence turnoff point method assumes that all the stars formed at the same time and/or have the same chemical composition (2 if either are mentioned).
- (note: M15 is actually a very old globular cluster)

A16: **(4 total)**

- $\Omega = \Omega_B + \Omega_D + \Omega_\Lambda + \Omega_{rel} = 0.100 + 0.400 + 0.730 + 0.000700 = 1.23$
- A Ω (density parameter) greater than 1 corresponds to a "spherical" or "closed" universe, with positive curvature. Parallel light rays converge. (2)
- A closed universe would most likely end with the "Big Crunch". Gravity would slow down and stop the expansion of the universe. The universe would then shrink and collapse into a point. (2)

Section B (26 pts):
B1: E
B2: B
B3: E
B4: C
B5: D
B6: X-ray and optical **(1 pt only if both are listed)**
B7: B
B8: C
B9: Gravitational lensing of background objects showed that most of the mass was concentrated around the stars and galaxies, when it should have been concentrated around the intracluster medium. Therefore, scientists concluded that there was invisible extra mass around the galaxies—dark matter. **(3)**
B10: X-ray, radio, and optical **(2 pts only if all 3 are listed)**
B11: B
B12: D
B13: B
B14: M87* is larger, less obscured, and varies over longer time periods (moves less in the sky) than Sagittarius A*. **(4 pts if 2 are listed; 2 pts if 1 is listed)**
B15: B **(2)**
B16: Infrared
B17: D
B18: C **(2)**

Section C (34 pts):
C1a: 1.50
C1b: 5170 ly **(2)**
C2: 242 nm (2); ultraviolet (2) **(4 total)**
C3a: 1.57-1.59 times **(5)**
C3b: Dark matter could be adding to the mass of the galaxy, changing its gravitational effects on the stars in it. **(2)**
C4: 3.49-3.51 Gpc **(5)**
C5: 87.0-89.0 μm **(4)**
C6: -300. km/s **(2)**
C7a: -19.8 **(5)**
C7b: 1.05×10^7 pc or 8.32×10^6 pc **(4 if 1.05×10^7 pc, or 2 if 8.32×10^6 pc)**

Section D (17 pts):
D1: GRB 150101B **(2)**
D2: B **(3)**
D3: 1.40×10^4 to 2.30×10^4 ly **(4)**
D4: 2.28×10^{17} Hz and/or 3.95×10^{17} Hz (the corresponding energies were 942 eV and 1634 eV)**(4 if one or both are listed)**
D5: D **(2)**
D6: A **(2)**

Math question explanations:

C1a: $B - V = 0.5 - (-1) = 0.5 + 1 = 1.5$

C1b: $d = 10^{\frac{m-M+5}{5}}$

- $d = 10^{\frac{10-(-1)+5}{5}}$
- $d = 1584.89\ \text{pc} = 5170\ \text{ly}$

C2: $\lambda_{max} = \dfrac{b}{T} = \dfrac{2.90 \times 10^{-3}\ \text{m} \cdot \text{K}}{12000\ \text{K}} = 2.42 \times 10^{-7}\ \text{m} = 242\ \text{nm}$

C3a:

- $4\ \text{kpc} = 8.25 \times 10^{8}\ \text{AU}$, $10\ \text{kpc} = 2.06265 \times 10^{9}\ \text{AU}$
- $p^2 = a^3 \left(\dfrac{4\pi^2}{GM}\right)$ (we don't have to consider the masses of the stars since they are so small compared to the galaxy)
- $\dfrac{p_1^2}{p_2^2} = \dfrac{a_1^3(\cancel{4\pi^2/GM})}{a_2^3(\cancel{4\pi^2/GM})}$
- $\sqrt{\dfrac{p_1^2}{p_2^2}} = \sqrt{\dfrac{(4\ \text{kpc})^3}{(10\ \text{kpc})^3}}$
- $\dfrac{p_1}{p_2} = 0.253$
- $v = \dfrac{2\pi r}{p}$
- $\dfrac{v_1}{v_2} = \dfrac{\cancel{2\pi} r_1/p_1}{\cancel{2\pi} r_2/p_2}$
- $\dfrac{v_1}{v_2} = \dfrac{r_1 p_2}{r_2 p_1} = \dfrac{4\ \text{kpc}}{10\ \text{kpc}}(0.253)^{-1} = 1.58$

C4:

- $\dfrac{v}{c} = \dfrac{(z+1)^2 - 1}{(z+1)^2 + 1} = \dfrac{(1.9+1)^2 - 1}{(1.9+1)^2 + 1} = 0.7875$
- $v = 0.7875c$
- $v = 0.7875(3 \times 10^8\ \text{m/s}) = 2.36 \times 10^8\ \text{m/s} = 2.36 \times 10^5\ \text{km/s}$
- $v = H_0 d$
- $2.36 \times 10^5\ \text{km/s} = 67.7\ (\text{km/s})/\text{Mpc}\ (d)$
- $d = \dfrac{2.36 \times 10^5\ \cancel{km/s}}{67.7(\cancel{km/s})/\text{Mpc}}$
- $d = 3490\ \text{Mpc} = 3.49\ \text{Gpc}$

C5:

- $z = \frac{f_{rest}}{f_{obs}} - 1$
- $9.11 = \frac{f_{rest}}{335.5\ \text{GHz}} - 1$
- $\frac{10.11}{335.5\ \text{GHz}} = f_{rest}$
- $f_{rest} = 3392\ \text{GHz} = 3.392 \times 10^{12}\ \text{Hz} = 3.392 \times 10^{12}\ \text{s}$
- $\lambda = \frac{c}{f} = \frac{3 \times 10^8\ \text{m/s}}{3.392 \times 10^{12}\ \text{s}^{-1}} = 8.84 \times 10^{-5}\ \text{m} = 88.4\ \mu\text{m}$

C6:

- $z = \frac{v}{c}$
- $v = cz$
- $v = (3 \times 10^8\ \text{m/s})(-0.001001)$
- $v = -300300\ \text{m/s} = -300\ \text{km/s}$

C7a:

- $M_{max}(B) = -21.726 + 2.698\Delta m_{15}(B)$ (the original Phillips relationship)
- $M_{max}(B) = -21.726 + 2.698(|10.3 - 11.0|)$
- $M_{max}(B) = -21.726 + 2.698(0.7)$
- $M_{max}(B) = -19.8374 \approx -19.8$

C7b:

- Using value from C7a (-19.8):
  - $d = 10^{\frac{m-M+5}{5}} = 10^{\frac{10.3-(-19.8)+5}{5}} = 1.05 \times 10^7\ \text{pc}$
- Using -19.3:
  - $d = 10^{\frac{m-M+5}{5}} = 10^{\frac{10.3-(-19.3)+5}{5}} = 8.32 \times 10^6\ \text{pc}$

D3: $D = \frac{Xd}{206265} = \frac{(2")(1.7 \times 10^9\ \text{ly})}{206265} = 16500\ \text{ly}$

D4:

- $942\ \text{eV} = 1.51 \times 10^{-16}\ \text{J},\ 1634\ \text{eV} = 2.62 \times 10^{-16}\ \text{J}$
- $E = hf,\ f = \frac{E}{h}$
- $f = \frac{1.51 \times 10^{-16}\ \text{J}}{6.63 \times 10^{-34}\ \text{J} \cdot \text{s}} = 2.28 \times 10^{17}\ s^{-1}$, $f = \frac{2.62 \times 10^{-16}\ \text{J}}{6.63 \times 10^{-34}\ \text{J} \cdot \text{s}} = 3.95 \times 10^{17}\ s^{-1}$