January 4th, 2020

Las Vegas Invitational

KEY: Astronomy C

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Questions?
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Directions:
Unless otherwise stated, each sub-question is worth two points.

1 Answer Key A: Questions 1-4

1. (a) 3C 273 (+1), Synchroton (+1)
   (b) PSS 0133+0400 (+1), Inverse Compton scattering (+1).
   (c) 152156.48+520238.5 (+1), 2.9 (+1)
   (d) MACS1149-JD1 OR PCB2012 3020 (+1), MACS J1149.5+2223 (+1)
   (e) NGC 2623 (+1); merger has stopped (+0.5), the nucleus is shared between the two (+0.5) even if it isn't in the optical
   (f) GW151226 (+1), 8.9 M_{sun} (+1)
   (g) H2356-309 (+1), Blazar (+1)
   (h) Bullet cluster (+1), supersonic speeds OR "mach" OR any mention of "faster than speed of sound" (+1)
   (i) MACS J0717.5+3745 (+1), X-ray (+1)
   (j) M87 (+1), 5-7c (+1)
2. (a) $r_g < r_s(+1); r_{photon} > r_s(+1)$
   (b) 3-5 microarcseconds
   (c) 6-8 e 9 M
   (d) 1-3 e 10 km
   (e) 3-10 e 4 s
   (f) The radius of the inner-most stable circular orbit (ISCO)
   (g) Interaction with other matter and magnetic fields (+2) OR the initial jet is restricted/confined/influenced by external gas (+2) OR accept anything that considers the environment in the vicinity of the jet and black hole (+2)
   (h) Accept any answer less than 10 years (+2).
3. (a) Friedmann Equation
   (b) Fluid OR Wave Equation
   (c) Acceleration Equation
   (d) 1-4 e -18 s-1
   (e) 1-3 e -26 kg/m3
   (f) The universe is growing, expanding, getting bigger.
   (g) The second term OR the $\frac{}{3}$ OR the cosmological constant term.
   (h) Positive.
4. (a) M3-M7
   (b) 2,500-3,400K
   (c) 9-11
   (d) A6-F4
   (e) 2.5-4 M
   (f) Thinner (+1), less pressure broadening (+1)
   (g) DZ
   (h) C (+1), any mention of white dwarf (+1)
   (i) i. Sun: proton-proton chain. (+1)
   ii. A: CNO Cycle; this is not the same as the sun. (+1)

iii. B: proton-proton chain; this is the same as the sun. (+1)

iv. C: no fusion; this is not the same as the sun. (+1)

(j) B AND C (+1), any mention of globular cluster OR older (+1)

(k) A AND C (+1), any mention of open cluster OR younger (+1)

(l) B AND C (+1), any mention of globular clusters, older, high velocity stars, or dark matter (+1).

(m) Absorption of photons (+1) by elements in intervening cloud or surface of star or object (+1).

(n) Absorption of photons (+1) by elements in intervening cloud or surface of star or object (+1).

2 Answer Key B: Questions 5-8

5. (a) 1.4-1.5 e 11 m
   (b) 206265 AU
   (c) 206265”
   (d) 1.9-2 e 30 kg
   (e) 5770-5780 K
   (f) 4.83
   (g) -26.74
   (h) 3.1-3.2 e 7s
   (i) 0.5-1
   (j) 9000-1100K
   (k) 50-100 R
   (l) $\mu = 5 \log \frac{d}{10}$
6. (a) WO
   (b) High rotation (+1) and high expansion velocities (+1)
   (c) P Cygni Profile
   (d) Purple
   (e) Type Ic supernova (+1) There would be no He lines OR any mention of triple alpha process (+1)
   (f) High (+1), any mention of younger or star forming (+1)
   (g) i. Younger: any mention of star forming, massive stars. (+1) Older: any mention of more metallic environment, more stellar winds. (+1) Younger one dominates. (+2)
   (h) One point for each of the following, up to a maximum of two points: Core collapse SN, Gamma ray burst, BH-NS or BH-BH merger.
   (i) Yes (+1). Mergers typically have increased star formation (+1).
   (j) Any of the following up to a maximum of two point: enrich with high winds (+1) OR supernova progenitors (+1) OR ionize nearby matter with hot radiation (+1)
7. (a) 4-6 days
   (b) 375 - 425 days
   (c) -1.5 - -2
   (d) 3000 - 4000 pc
   (e) 40-60 km/s
   (f) 300-500 R
   (g) 5-8 M
   (h) 15-35 R
   (i) 0.2 - 2 kg/m3
   (j) Any type of giant star (+2)
8. (a) 400-600 km/s/Mpc
   (b) 65-80 km/s/Mpc
   (c) 64-70 km/s/Mpc
   (d) 0.33-0.37
   (e) i. A. 5-7e17 seconds (+2)

B. 1-3e26m (+2)

C. 1-3e-35 s-2 (+2)

(f) i. A. Motion caused by expansion of the universe (+2)

B. -3H*potential (+2) OR not real friction (+2) OR like adiabatic damping of gravitational waves (+2) OR any mention of inflation (+2).