Astronomy 1144 HW 4 Solutions

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1: Red dwarf (e.g., an M star) implies low-mass. Low-metallicity implies Pop II. Perpendicular through the disk implies *not* a disk-like orbit. Thus, this is likely an old, Pop II star from the stellar halo of the Milky Way.

2: Before Big Bang Nucleosynthesis, the universe was too hot for nuclei like He and Lithium to exist. After/during this epoch it was cool enough for such nuclei to exist.

3: The Schwarzschild radius of a black hole is the "point of no return." It is linearly proportional to the mass of the black hole: $R_S = 2GM/c^2$, where M is the black hole mass. Thus, if a black hole is more massive, it has a larger R_S. Therefore, black hole A has an R_S 5 times bigger than black hole B.

4: The main sequence lifetime is proportional to $t_{\rm MS} \sim 1/M^3$. Thus, a star 2 times more massive has a main sequence lifetime that is $2^3 = 8$ times shorter. This expression follows from the concept that the main sequence lifetime is proportional to the total fuel, divided by the rate at which the fuel is spent. A star has a total fuel reservoir of M. On the main sequence, most stars obey the relation $L \propto M^4$. Thus, the main sequence lifetime is $t_{\rm MS} \sim Mc^2/L \sim M/M^4 \sim 1/M^3$.

5: 0.1 and 100 $M_\odot$. The minimum mass is set by the mass at which it is possible to have H fusion. For $M < 0.1\,{\rm M}_\odot$, the core is not hot enough for H fusion, and thus the object is not a star (it would be a super-Jupiter or "brown dwarf"). The physics of the upper mass limit is not known. We simply do not observe stars with much larger than $100\,{\rm M}_\odot$.

6: 25 degrees is 25×3600 arcsec. The star is moving at 0.13 arcsec/year. Thus, it traverses 25 degrees in $25 \times 3600/0.13 \simeq 690,000$ yr.

7: The speed of a photon in vacuum is constant. It does not depend on energy.

8: $V = H_0 D$. Bigger D implies bigger V. Galaxy A is closer by a factor of 2, and therefore has smaller V by a factor of 2.

9: $B = L/(4\pi D^2)$. Start at 1AU. If you increase D by a factor of 10, the brightness decreases by a factor of 100. If you increase D by a factor of 10^7, B decreases by 10^{14}. So, you need to go 10^7 AU distance in order for the Sun to be 10^{14} times fainter. Convert to parsecs: $10^7/200,000 = 50$ parsecs.

10: Wien's law states that the peak wavelength of a radiating blackbody scales as $\lambda_{\rm peak} \sim 1/T$. That is, hotter things have smaller $\lambda_{\rm peak}$ (bluer, higher frequency) and cooler things have longer $\lambda_{\rm peak}$ (redder, smaller frequency). So, if the sphere decreases in temperature by a factor of 2, $\lambda_{\rm peak}$ increases by a factor of 2. The luminosity of a blackbody sphere is $L = 4\pi R^2 \sigma T^4$. R is constant. If T decreases by a factor of 2, the luminosity then decreases by a factor of $2^4 = 16$.

11: CNO cycle. Stars more massive than about $1.2\,{\rm M}_\odot$ burn H on the main sequence via the CNO cycle, whereas stars less massive than this burn H on the main sequence via the pp chain.

12: Residual heat. Neutron stars are born when the cores of massive stars collapse at the end of their evolution. After a core-collapse supernova, a neutron star is left behind. The neutron star has no energy generation process (no fusion, no fission, no nothing). So, it just radiates its stored heat and then eventually just fades out.

13: About 1 minute.

14: True.

15: Inflation is used to argue why the universe is isotropic, homogeneous, and smooth. Without it, we would expect large temperature fluctuations in the CMB, large density fluctuations all over the universe at early times, and for the universe to be much less smooth.

16: The luminosity changes by a factor of $100/0.0001 = 10^6$, but the temperature stays constant. Since the luminosity of a blackbody sphere is $L = 4piR^2\sigma T^4$, and since T is constant, the ratio of the two luminosities is $L_1/L_2 = (R_1/R_2)^2$, which implies that the radius has to increase by $R_1/R_2 = (L_1/L_2)^{1/2} = (10^6)^{1/2} = 10^3$.

17: For $V < c$, the redshift is approximately $z = V/c$. Therefore, a galaxy with a higher redshift has higher apparent recession velocity. Because $V = H_0 D$, this implies larger distance for the higher redshift object. A factor of 5 in redshift is a factor of 5 in V, which is a factor of 5 in D.

18: During the Planck Epoch, we think that the 4 forces of nature were unified in a single super-force.

19: On the giant branch, a low-mass star has an inert He core and a H-burning shell. At the top of the red giant branch the star goes through a He flash and He starts burning in its core.

20: During/after recombination, the universe was cool enough for electrons to combine with nuclei to make atoms.