Problem Set 1: Navigating the Night Sky and the Evolution of Stars [Answer Key]

Answer each question in 1 or 2 complete sentences, showing your work (math equations or illustrations) as needed.

1. You're an astronomer, and you've been tasked to go to Griffith Observatory (latitude 34.1184° N, longitude 118.3004° W) to look at the Hercules Globular Cluster (AKA M13). M13 is located at right ascension (RA) 16h 41m 41s, declination (δ) 36° 27' 35", at the center of the constellation Hercules. You plan to drive up to Griffith on February 18th.
   a. At what time will the cluster be directly overhead?

Griffith Observatory is 118.3004 degrees west of the prime meridian. We first convert this to hours minutes and seconds:

$$\frac{118.3004 \ deg}{15 \ deg/hr} = 7.89 \ hr = 7 \ hr \ 53 \ min \ 24 \ seconds$$

That means whatever RA is overhead at the prime meridian (Greenwich, England, longitude=0) will be overhead in Pasadena 7 hours and 53 minutes later. At midnight Jan 1st, Sirius (6h 45m) is overhead at midnight, so Hercules will be overhead in about 9 hours 56 minutes, or at 9:56am UTC, so it will be overhead in Pasadena at:

Hercules will be overhead in Greenwich at 16:41, or 4:41pm UTC, so it will be overhead in Pasadena at:

$9h \ 56m \ 41s \ = \ 9.9447 \ h$
$9.9447h \ + \ 7.8866 \ h \ = 17.83 \ h \ = \ 17{:}49{:}48$ UTC

Or, converting this to PST, we subtract 8 hours to get 09:49:48 PST.

But remember, the stars drift by 4 minutes per day; February 18th is the 31+18=49th day of the year, so the Hercules cluster appear in the sky $49 \times 4min \ = \ 196min \ = \ 3.26 \ hr$ earlier than it did on January 1st. Adding this to our time:

$9.8313h - 3.26\,h = 6.571\,h = 06{:}34{:}16$ PST

So the cluster will be directly overhead at 6:34am…seems like it'll be a little bright out…

      b. Between what times will the Hercules cluster be visible to you? (In other words, what time will it rise and set?)

Let's assume we can see all the way to the horizon, the full 180 degrees of the sky. This is 90 degrees to the East and West; First we convert 90 degrees to hours:

$$\frac{90}{15} = 6\ hours$$

So we can see cluster *approximately* from 6 hours before it's overhead and 6 hours after, or from **12:34am - 12:34pm PST**.

      c. Why might it be difficult to observe the Hercules Cluster?

The cluster will be overhead at 6am, when the sun is rising! So we won't be able to see it in February from Griffith Observatory.

      d. What would be a better time of year to observe the Hercules Cluster?

We want the cluster to be overhead at night, preferably around midnight, so we need to find how long it'll take the cluster to appear 6.5 hours earlier. If the cluster is overhead 4 minutes earlier every day, the number of days we need to wait is:

$$\frac{6.5\ hours \times 60\ minutes}{4 minutes} = 97.5\ days \approx 3.2\ months$$

So we should come back in May for a good view of Hercules!

2. Antares (AKA α Scorpii) is a red supergiant star, and the brightest star in the constellation Scorpius. One day you take a Hawaiian vacation and observe Antares with the V-band (507-595 nm) filter on the Keck Telescope. You start with some research and find that Antares has an intrinsic V-band magnitude of -5.28 and is located 170 parsecs away from Earth.

   a. When you measure Antares's V-band magnitude, you find it is $m_V = 0.91$ (remember, positive magnitudes are *fainter* than negative magnitudes). Why does Antares appear fainter than what your research showed?

Antares appears fainter for two reasons: (1) the light experiences interstellar extinction from the dust in the interstellar medium, which makes it appear fainter. (2) the observed brightness follows the inverse-square law, so it appears fainter the farther away it is from Earth.

   b. How much interstellar extinction A_V does the light from Antares experience? (*Hint:* $m_V = M_V + A_V + 5log_{10}(d/1pc) - 5$, *and* $log_{10}(170) = 2.23$)

For Antares, we know the apparent magnitude $m_V = 0.91$, the absolute magnitude $M_V = -5.28$, and the distance $d = 170\ pc$. We want to find A_V, so lets rearrange the equation:

$A_V = m_V - M_V - 5log_{10}(d/1pc) + 5$

Then we plug in our values for Antares:

$A_V = 0.91 - (-5.28) - 5log_{10}(170pc) + 5$

$A_V = 0.04$

So the extinction is A_V = 0.04

    c. Antares is a supergiant star, so it has finished fusing lighter elements into Iron in its core, and its outer layers are expanding. It's a *red* supergiant, so its mass is around 15 times the mass of the Sun. Do you think Antares will evolve into a white dwarf star, a neutron star, or a black hole and why?

First, since the core is already Iron, we know Antares won't become a white dwarf star; this is because the heaviest elements white dwarf stars form are Oxygen, Carbon, and Magnesium. They aren't massive enough to fuse Iron. So Antares will become either a neutron star or black hole; we don't know which because we don't know the core mass.