Astro C10, Quiz 2
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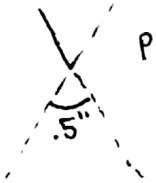
Favourite book: The Name of the Wind

Show all work; I can only give partial credit if you write *something* down. Possibly useful information & equations are on the back side. You are all fantastic – good luck, and may the odds be ever in your favour!

1. **Life, the Universe, and Everything**
Star Ben[1] is a main sequence star that you observe for 6 months between December and July.

(a) Much to your unsurprise[2], Star Ben appears to be in a different location in the sky in July than in December. The location on the sky has shifted by 0.5". How far away is Star Ben?



$p = \frac{.5''}{2} = .25''$ $\quad d = \frac{1}{p} = \frac{1}{.25''} =$ **4 pc**

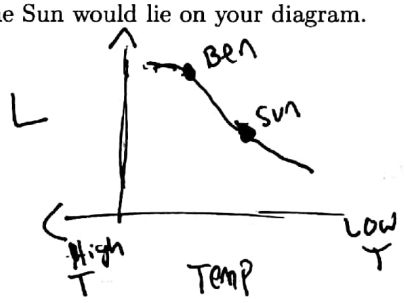
(b) You take a spectrum of Star Ben and determine Ben to be of spectral type O, with a peak wavelength of $\lambda \approx 100nm$. What can you say about Star Ben's mass, compared to that of the Sun? What about radius and temperature?

$(100 < 500)$ $\lambda_{peak,Ben} < \lambda_{peak,\odot}$ therefore, by Wien's Law, $T_{Ben} > T_\odot$

$R_{Ben} > R_\odot$
$M_{Ben} > M_\odot$
$T_{Ben} > T_\odot$

because, for MS stars, hotter things are more massive & more massive things are larger

(c) Draw an HR diagram. Label your axes. Draw the main sequence on it. Roughly sketch where Star Ben and the Sun would lie on your diagram.



Ben has higher temp so lies farther left on HR diagram than Sun. (and you know it must lie along MS)

(d) $H\alpha$ is the name of the $E_2 \rightarrow E_3$ transition in Hydrogen. It occurs at $\lambda = 656.28$ nm. In Star Ben, you see this line vary over time, with a period of 2 months, between 656.26 and 656.31 nm. Give a possible explanation for this.

We are observing Hα doppler shifted (blue & redshift). The fact that λ changes regularly with time implies that something is causing the star to move towards, then away from us.
One explanation of this is a "wobble" due to an orbiting planet tugging on the star.

[1] this is a *different* Star Ben than the one featured on last weeks' worksheet
[2] I hope...

(e) Upon looking more closely, you find that Star Ben is actually in a binary system! This allows you to determine the mass of Star Ben. You find Ben's mass to be $20M_\odot$. Given the measurements of Ben's properties described so far (apparent angular shift, spectrum, mass), how could you deduce the radius of Star Ben? You don't need to do any actual calculation (though you are certainly welcome to, if it helps) – a description in words will suffice.

Given mass & peak wavelength.
λ_{peak} gives temp by Wien's law.
$L = 4\pi R^2 \sigma T^4$ & $\left(\frac{L}{L_\odot}\right) = \left(\frac{M}{M_\odot}\right)^4 \rightarrow L = L_\odot \left(\frac{M}{M_\odot}\right)^4$

$4\pi R^2 \sigma T^4 = L_\odot \left(\frac{M}{M_\odot}\right)^4$

(f) Your friend Sarafina proposes that the companion star is a white dwarf. Is this explanation plausible? Why or why not?

NO.
A WD is remnant of low mass star. ($< 8 M_\odot$)
Low mass stars live much longer ($t_{MS} \propto \frac{1}{M^3}$)
So, not possible to have a WD in binary sys. with a more massive star that hasn't even finished its MS time yet.

(g) If Star Ben's companion is a black hole of unknown mass, what is the minimum total *initial* mass of the binary system?

$M_{Ben} = 20 M_\odot$
We know BHs form from massive stars ($M > 8 M_\odot$)
BH progenitor of the BH needs to be more massive than Ben (since it died first)

$M_{min} = 2 M_{Ben} = 40 M_\odot$

(h) If the companion is a main-sequence star of mass 2 $M_\odot$, how much fainter is it than the Star Ben?

$$\left(\frac{L_{Ben}}{L_{comp}}\right) = \left(\frac{M_{Ben}}{M_{comp}}\right)^4$$

$$\frac{L_{Ben}}{L_{comp}} = \left(\frac{20 M_\odot}{2 M_\odot}\right)^4 = 10^4$$

→ Companion is 10^4 times fainter than Ben.

A smattering of stuff you may or may not need:

$\lambda_{max} T = .002898$ meter-Kelvin
$\lambda_{peak,\odot} \approx 500$nm
The Sun is a G-type star.
$b = \frac{L}{4\pi d^2}$
$p = 1/d$ (units: arcseconds, parsecs)
$V = \int\int\int dV$
$L_{star} = 4\pi R^2 \sigma T^4$
$L \propto M^4$
$t_{MS} \propto \frac{1}{M^3}$
$< f >= \int f(x) P(x) dx$
Only Boring Astronomers Find Gratitude Knowing Mnemonics