Science Olympiad

Hawk and Hornet Invitational

November 11th 2023

Astronomy C Answer Key

Section A

1. A
2. C
3. A
4. A
5. B
6. B, C
7. A
8. 0
9. Answers Below
    - B to A = A to C
    - C to D = D to B
10. Answers Below
    - Hyperbolic
    - Parabolic
    - Elliptical (Or Circular)
11. C
12. Transit method is out because orbital plane is not along our line of sight, Radial velocity is out because Ryan is high mass star but Oskar is the mass of Earth. This leaves Direct Imaging
13. C
14. B
15. B
16. D
17. O B A F G K M
18. Subdivision of stellar temperature class, 0-9, 0 being hottest, 9 being coolest
19. B
20. Answers Below

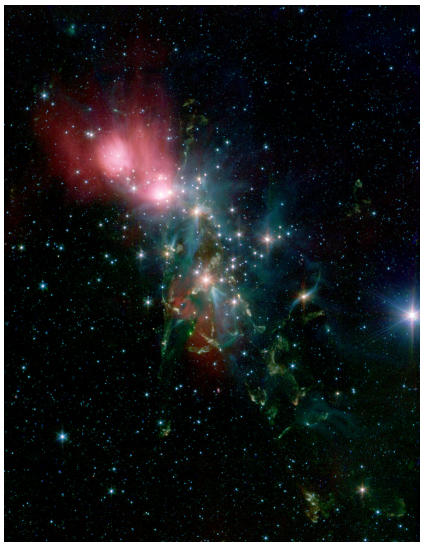
- Ib 5
- III 3
- IV 2
- Ia 6
- V 1
- II 4

21. Stars above 8 Solar Masses are shrouded by massive amounts of interstellar dust making them hard to see + They also collapse very quickly from a protostar to a main sequence star, so by the time they emerge from the dust, they are already fusing.
22. B, Henyey Track
23. A
24. B
25. A
26. C
27. A
28. A, D
29. C
30. Tidal

Section B

1.

a. Which image(s) show NGC 1333?



H

b. What telescope took that image?
   - **Spitzer Telescope**

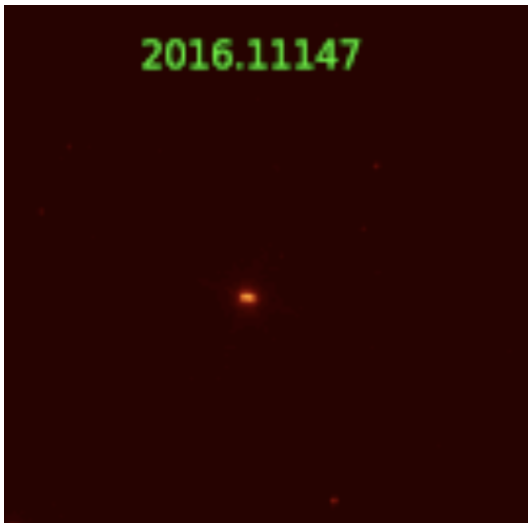
c. Why is the wavelength that the image was taken significant?
   - **Infrared light passes unhindered through interstellar material, making it suitable for observations of nebulae.**

d. What are the dimensions of NGC 1333 viewed from Earth? (in arcseconds)
   360” x 180”

e. _____ objects were discovered by the Hubble Space Telescope in NGC 1333
   - **Herbig-Haro**

f. The proportion of Low Mass Brown Dwarfs that have a stellar disk around them suggests what?
   - **Low Mass Brown Dwarfs in NGC 1333 form like planets are not stars**

2.



a. Which image(s) show Luhman 16?
   - **A**

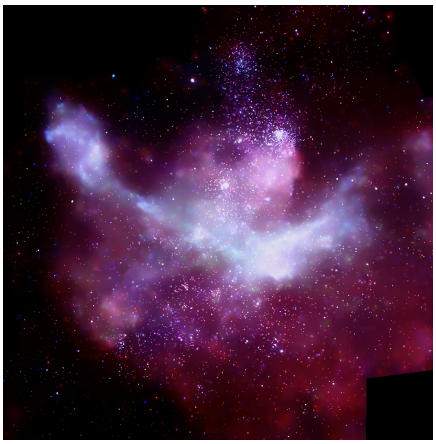
b. How far away is the system in parsecs?
   - **1.9938 pc**

c. What is the angular separation of the Luhman 16 AB system in arcseconds? What distance does this correspond to?
   - **1.5”, 3 AU**

d. Luhman 16 B is a special brown dwarf in that it is variable in luminosity: what is this variation caused by?
   - **Changes in the composition of cloud cover, of chlorides and alkali metals**

e. Despite Luhman 16 AB’s close proximity to the Solar System, why wasn’t it discovered earlier?
   - **Luhman 16 AB is located close to the galactic plane, densely populated by stars.**

3.



a. What DSO is shown in Image B?
   - **Carina Nebula**

b. What part of the EM spectrum is the image taken in?
   - **X-Ray**

c. What telescope took the photo?
   - **Chandra**

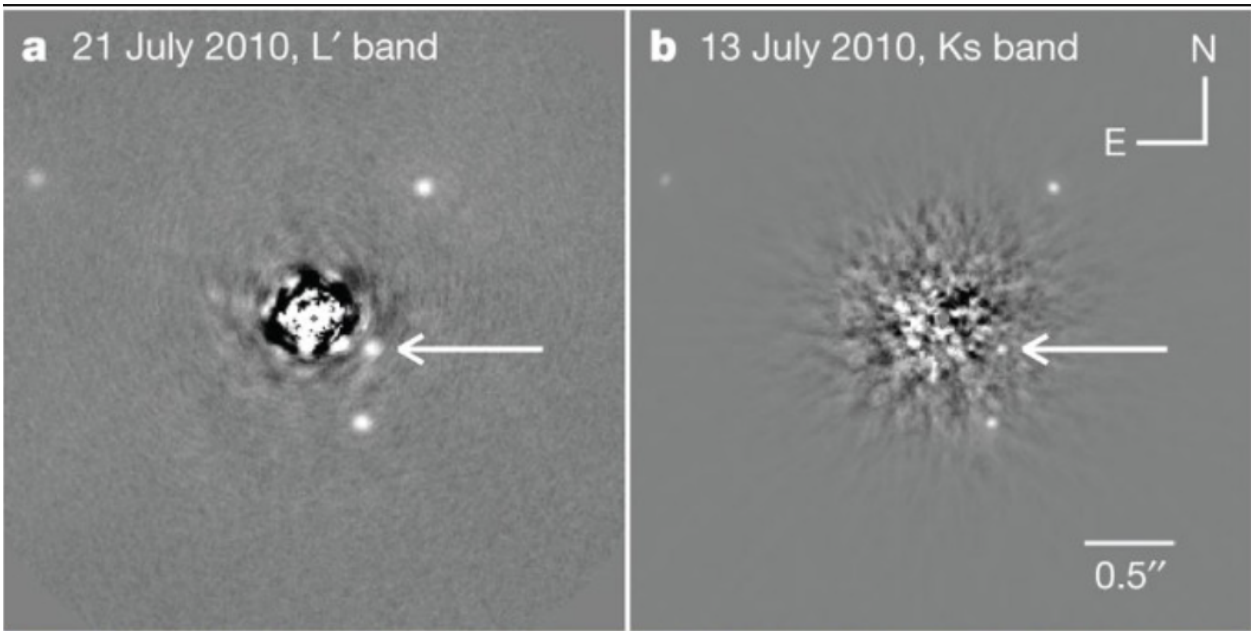
d. What angular area does this DSO take up in the sky in degrees^2?
   - **4 degrees^2**

e. In 1827, _____ erupted and caused astrophysicists to develop new models of stellar evolution
   - **Eta Carinae**

f. There are 8 known _____ in this DSO
   - **Open Star Clusters**

4.

a. What image(s) show HR 8799?



- **G**

b. What is significant about the method used to discover the exoplanets?
   - **Use of direct imaging**
c. Some of the planet's spectra in the system show similarities with T-Type Brown Dwarfs, what absorption bands would we expect from some of the planets in the system?
   - **Methane**
d. What telescope took a timelapse of the HR 8799 system's orbits? What spectrum was used?
   - **Keck Observatory, Infrared**
e. In 2009. The Spitzer Space Telescope discovered a dust halo between some of the planets' orbits. Why is this significant?
   - **Indicates the planets have not settled into their final orbits**

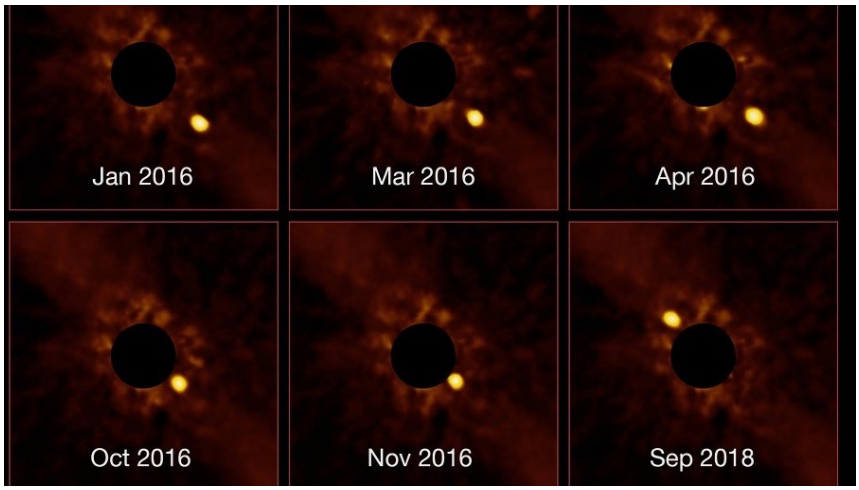
5.

a. What DSO is depicted in Image D?
   - **Beta Pictoris**

b. Glare from the parent star is blocked using what tool?
   - **Occulting Mask**

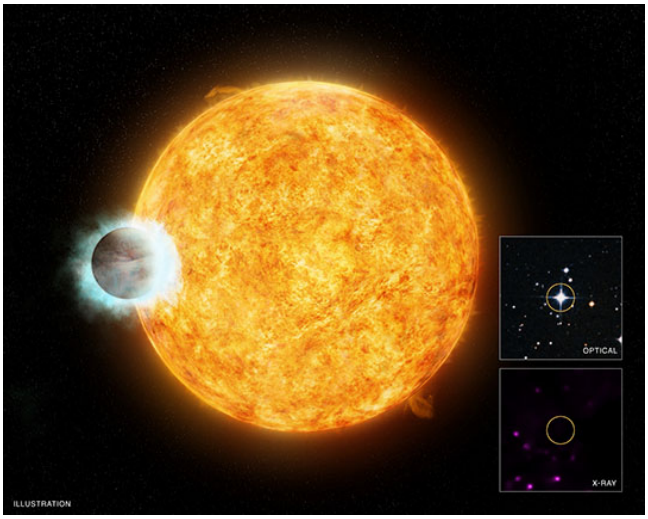
c. What is the apparent magnitude of this DSO?
   - **3.861**

d. The spectrum of this DSO was seen to have some variability, what was the source of this?
   - **Comet-like objects evaporating after getting too close to the parent star**



6.

a. What image(s) shows Wasp-18b (Either the Exoplanet or Parent Star)
   K **N**



b. What method of detection was used for Wasp-18b?
   - **Transit**

c. By what factor of flux does Wasp-18b receive from its parent star, than Earth does from the Sun?
   - **~7.23 * 10^6 times as much**

d. Why is Wasp-18's X-ray emission surprising to Astronomers?

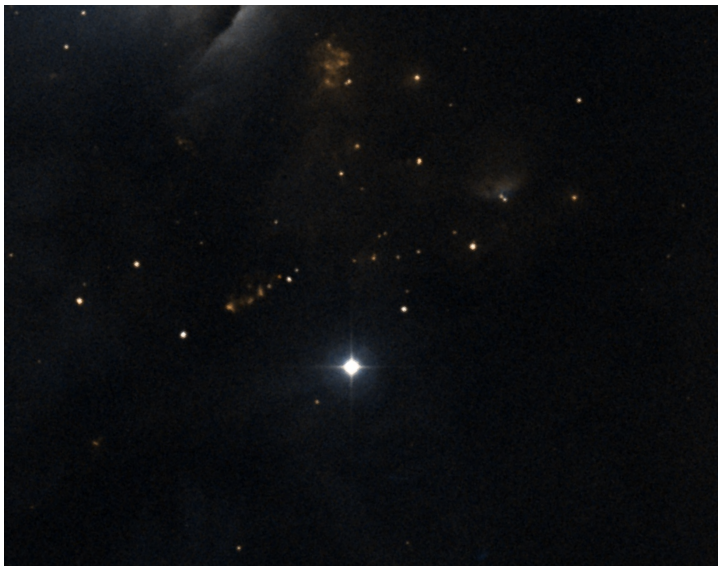
- **As stars age, their X-ray/magnetic activity decreases. Because Wasp-18 is only between 500 million to 2 billion years old, it should be giving off a lot of X-rays, but the Chandra X-ray telescope detected none**

e. What is the apparent magnitude of Wasp-18? Is it visible to the naked eye?
   - **9.273, No**

7.

a. Which image(s) show HH 7-11?

I



L

b. What is the name of the star that is causing the emission of HH 7-11?
   - **SVS 13**

c. HH 7-11 seems to be aligned linearly in the sky. What does this indicate about the source star?
   - **The source star is emitting jets of ionized gas on its poles that cause it to collide with interstellar dust that the poles are facing, hence why HH 7-11 seem to be aligned linearly**

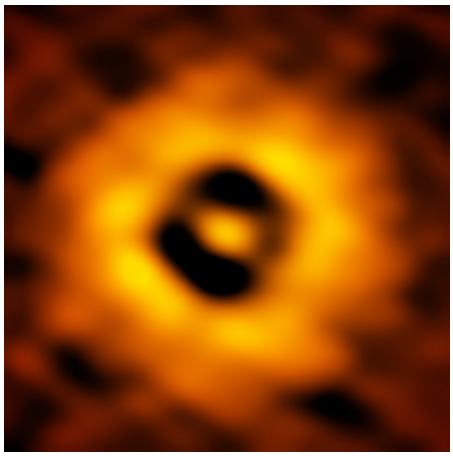
d. The HH 7 Bow Shock in the HH 7-11 system marks the end of _____
   - **The outflow from SVS 13**

e. Which of the Herbig-Haro Objects is located closest to the source star?
   - **HH 11**

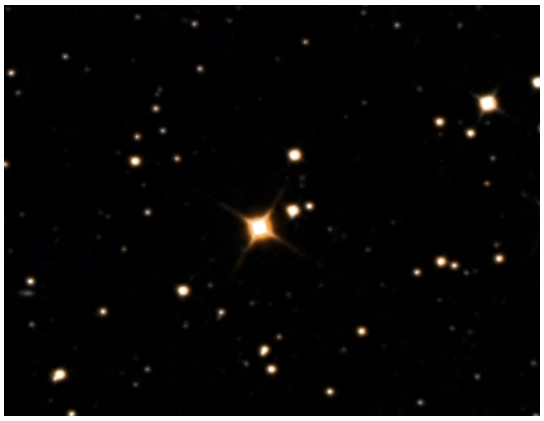
8.

a. What image shows TW Hya?

C



F



b. TW Hya is significant for being the _____ _____ star to Earth

- **Anything mentioning that it is the closest T-Tauri star to Earth**

c. TW Hya is not yet a main sequence star. If it were to become a main sequence star, what would its spectral classification be?

- **K2V (Answers must include the V for main sequence)**

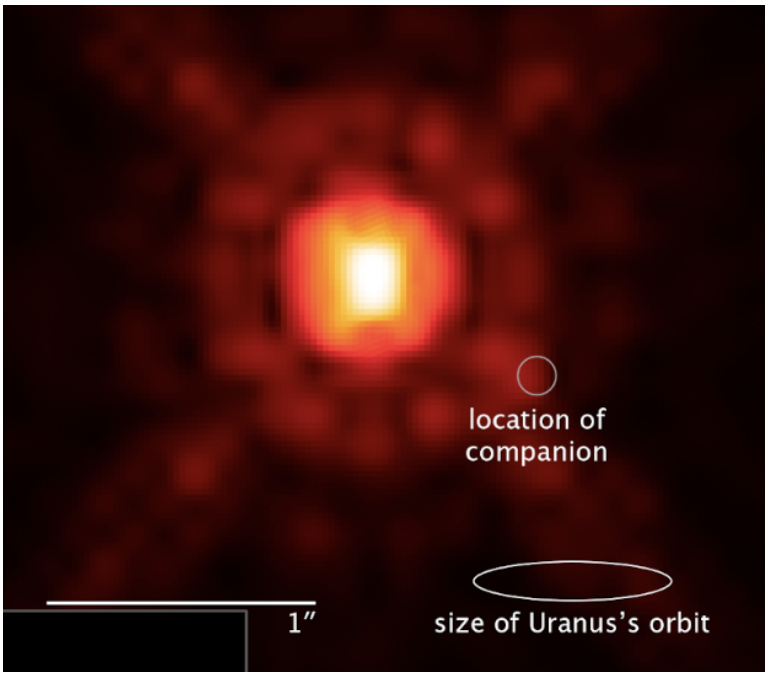
d. Surprisingly, in 2016, an organic chemical essential to life was detected in TW Hya's debris disk. It was _____

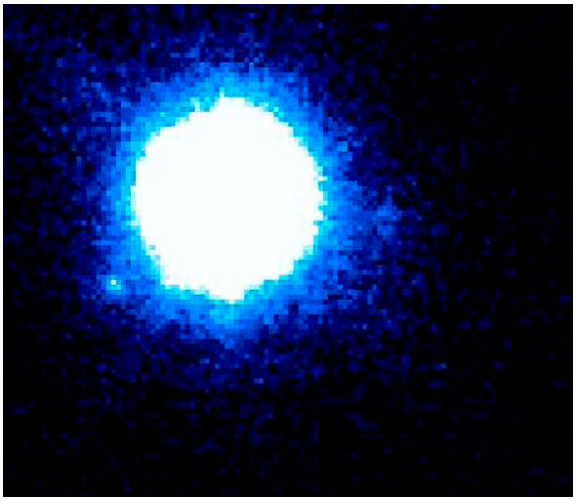
- **Methanol**

9.

a. What images show 2M 1207?

J **M**





b. How far apart in arcseconds is 2M 1207B from 2M 1207A? Could this be achieved (disregarding brightness) with a commercial telescope?
   - **0.778", No**

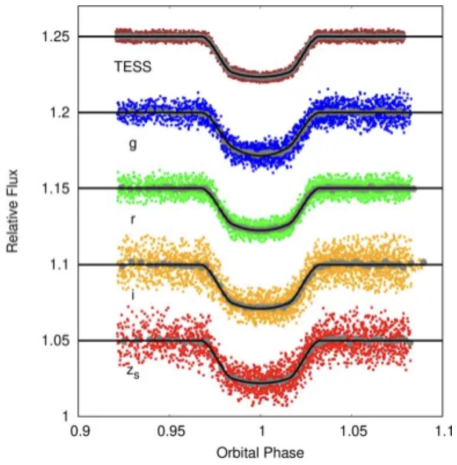
c. The initial distance estimate to the 2M 1207 system was 70 pc, but in 2005 a new distance estimate was given to be ~53 pc using the Moving-Cluster method. Describe how this method works
   - **Taking proper motions of all stars in a star cluster - all the stars from our point of view would move towards a convergence point. Finding the angle of a star's proper motion relative to the convergence point and radial velocity we can use trigonometry to calculate the distance**

d. Why is that image of 2M 1207 significant?
   - **First direct image of an exoplanet outside the solar system**

10.

a. Which images show WASP-43b?

N **O**



b. It was thought that WASP-43b's orbit was decaying. How was this disproven? What telescope disproved it?

- **Data from the TESS telescope gave precise transit timings of WASP-43b and showed no change in orbital period**

c. Given the Apparent magnitude of WASP-43 as 12.4, how many times dimmer is WASP-43 than Sirius (-1.46)?

- **~350000x**

d. WASP-43 was detected using the transit method, but how was it detected again using a similar method?

- **Occultation/Secondary Eclipse, when the exoplanet passes behind the parent star, an extremely shallow dip in the light curve is seen**

e. What spectral class is WASP-43? Is this star more dense or less dense than the Sun?

- **K7V, More.**

Section C

1. Oskar the planet orbits around Ryan the star. Ryan the star has a surface temperature of around 10,000 K and a radius of 1,638,400 km. Oskar the planet is the same size as Earth and orbits with a semi-major axis of 2 AU.

a. What is the luminosity of Ryan in solar luminosities?

49.76

$$L = 4\pi\sigma R^2 T^4 = 4\times 3.14\times 5.67\cdot 10^{-8} W/m^2K^4\times(1,638,400,000m)^2\times(10,000K)^4 = 49.76L_\odot$$

b. At what wavelength, in nanometers, does the blackbody curve of Ryan peak? What region of the electromagnetic spectrum is this in (X-ray, ultraviolet, visible, infrared, radio)?

290 nm

$$\lambda_{peak} = \frac{2900000}{T} = \frac{2900000}{10000} = 290nm$$

c. What is the equilibrium temperature of Oskar, assuming full redistribution of heat around the planet and an albedo of 0.8? Would liquid water be stable on the planet, assuming that the atmospheric surface pressure of Oskar is equal to that of Earth?

349.92 K, so water would be liquid

$$T_p = T_\odot(1-a)^{1/4}\sqrt{\frac{R_\odot}{2D}} = 10,000K(1-0.8)^{1/4}\sqrt{\frac{1,638,400km}{2\cdot 299195741km}} = 349.92K$$

2. The star Sirius lies 2.64 pc away from Earth. The orbits of Sirius A and Sirius B vary from 3” to 11”. The orbital period of the system is 50.128 years.

a. What is the minimum and maximum distance (in AU) from Sirius A to B?

7.92 AU, 29.043 AU. (Use small angle formula)

$$\theta = 206265\frac{D}{d}$$

$\theta =$ Angular Diameter (arcsecs)
$D =$ Diameter
$d =$Distance

b. What is the total mass of the Sirius Star System? (In Solar Masses)

2.5152 (Kepler’s Law)

c. If the apparent magnitude of Sirius is -1.46 and the difference in brightness between Sirius A and B is 9120x, what is the apparent magnitude of Sirius B?

8.44 (Pogson’s Ratio)

3. The star WASP-12 was recorded to have radial velocity amplitude of 226.5878 m/s over a period of 1.0914 days. The orbital inclination is 83.37 degrees.

a. If there is suspected to be a planet around this star, what would its mass be (in kilograms)?

2.79 * 10^27 kg (Use the Binary Mass Function)

$$f(M_x, M_c) = \frac{(M_x \sin i)^3}{(M_x + M_c)^2} = \frac{P(V_c \sin i)^3}{2\pi G}.$$

b. Assuming the star's luminosity is evenly distributed across its surface, what is the change in apparent magnitude as the planet passes in front of the star? The radius of the planet is 1.90x the radius of Jupiter (which is 6.6911 * 10^7 m) and the radius of the star is 1.657 solar radii.

0.01447

$$\Delta m = -2.5 \log\left(\frac{\pi r_{star}^2 - \pi r_{planet}^2}{\pi r_{star}^2} \right)$$

c. If the solar luminosity of WASP-12 is 4.05x and the planet orbits at 0.0234 AU, the planet would receive how many times more flux than Earth does?

7396.45x (Inverse Square Law)

4. A binary star system in a circular orbit consisting of a K3IV star and a White Dwarf have a combined semi-major axis of 1.3 AU. The solar luminosities of the K3IV and the White Dwarf are 9.22 and 0.056 respectively. The White Dwarf is accreting mass at a rate of 10^-6 Solar Masses a year.

a. What is the combined absolute magnitude of the star system?

2.4114

$$m_{total} = -2.5 \log\left(10^{-\frac{2}{5} m_1} + 10^{-\frac{2}{5} m_2} \right)$$

b. If the solar masses of the K3IV and the White Dwarf are 1.7 and 1.08 respectively, how far is each star from the barycenter of the system? (In AU)

K3IV: 0.505 AU, WD: 0.795 AU (Binary Star Formulas)

c. What is the orbital velocity of each star? (In km/s)

K3IV: 16.931 km/s, WD: 26.655 km/s

Conservation of Momentum

$$m_1 m_2 = m_2 v_2$$

d. What is the rate of energy generation of the accreting mass onto the White Dwarf? (In Solar Masses) (Hint: Do something to the Gravitational Potential energy equation and assume distance between two stars is constant)
0.1215 Solar Lum

$$L \approx \frac{GM_a\dot{M}}{R_a}$$ ← accretion rate, units g s^{-1} (often expressed in Solar masses per year)

e. What is the absolute magnitude of the system now? By what factor is this system brighter than just the White Dwarf and K3IV Star with no accretion?
2.3973, 1.013 or 1.3%
(Absolute magnitude formula and Pogson's Ratio)

f. How much time will it take for the White Dwarf to surpass the Chandrasekhar Limit in years?
360,000 years

g. Because the K3IV Primary Star is losing mass, in 360,000 years, what is the combined semi-major axis of the system? How much has it changed since when we first saw the system?
1.3 AU, Change of 0.00 AU (No mass is leaving the system)