Astronomy

Science Olympiad Division C
Saturday, February 25, 2006
Case Western Reserve University

Names	School/Team
Total Score (out of 180 points)	

You have 50 minutes to complete this test.

1. Draw an HR diagram and indicate the locations of the following types of variable stars:
   a) Cepheids (I and II, if possible)
   b) RR Lyrae
   c) RV Tauri

   Label the Main Sequence, and the approximate position of our Sun.
   Also, draw the path (with arrows) that a star would take to evolve to a Supernova Type II.

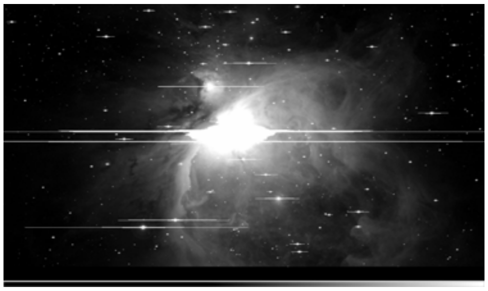
2. Attached is a page of Deep Sky Objects. Identify each one with its formal designation, as well as a brief description of what it is. For each object (when possible), say which other one it evolved from, and which it is evolving to.

3. If we were to replace our Sun with a Cepheid variable star, what would happen? What if we put an RR Lyrae star there instead? (Think also about how our seasons might be affected)

4. If you had the spectra of a star, what clues in it might tell you that that star is an (intrinsically) variable star? (Say, for example, that it's in a globular cluster of known distance.) What aspects of the variable star affect its spectral output?

5. Stars aren't the only thing that vary. Look at the video shown on the screen at the front of the room. Explain what's going on (both the distortions and the color changes), and how this affects the real observations of variable stars.

6. Identify this object: [Image from Case's telescope in Arizona, last March]

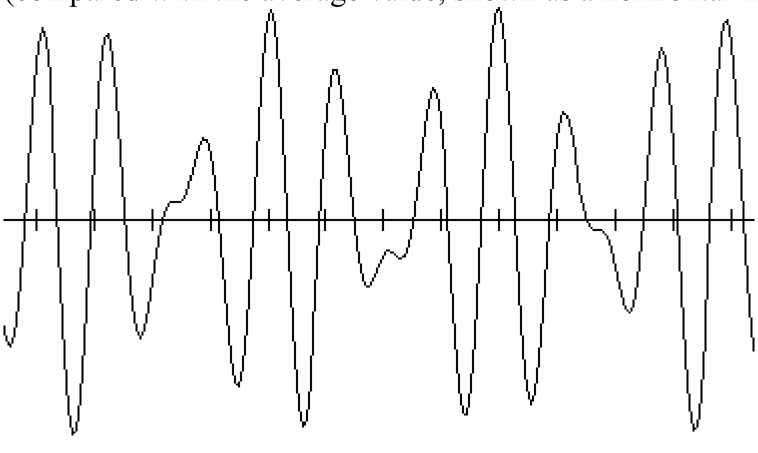


Identify this object: [Image from Case’s telescope on campus, last night]

What allows us to see this object? (Hint: not a telescope. What makes the object itself shine?)

7. Given the following masses of stars, tell what would happen to each, how they would evolve, and what they would end up being. Group similar types together as appropriate – for example if stars from 0.1 to 0.5 solar masses all behave identically, you only have to explain that once. (If some masses are impossible, indicate that.)
0.001
0.01
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.3
1.4
1.5
1.6
1.9
2.0
2.5
3.0
5.0
10
20
100

8. You observe a point source in the sky and get this graph of observed brightness over time (compared with the average value, shown as a horizontal line).



What does this pattern tell you about the point source's physical characteristics? Can it be explained with a single pulsating star? What kinds of systems are possible to explain it? (If you are familiar with the Fourier Transform, the Fourier transform of this light curve has two delta functions at specific frequencies.)

9. You observe a variable star, but because of divine intervention are able to also measure its volume. Even though the brightness is changing, the volume is not. How is this possible? Are there any examples of this in reality?

Non-radial pulsators – changing shape, not overall volume – alpha Cygni & ZZ Ceti

10. One of the most infamous naked-eye variable stars is currently around its peak brightness. What is it, what constellation is it in, and can you see it from Cleveland? If so, when?

11. For Cepheids, we are going to consider three of their properties: brightness, temperature, and size. How do these three properties depend on each other? That is, when the Cepheid is at its brightest, what is its temperature (relative to its own variations) and how big is it?

12. A variable star changes temperature over the course of its variations by 10 %. How much will its luminosity vary?

13. A solar sail works on the principle that light carries momentum, and transfers some of that on reflection. Given total reflection, the radiation pressure is given by

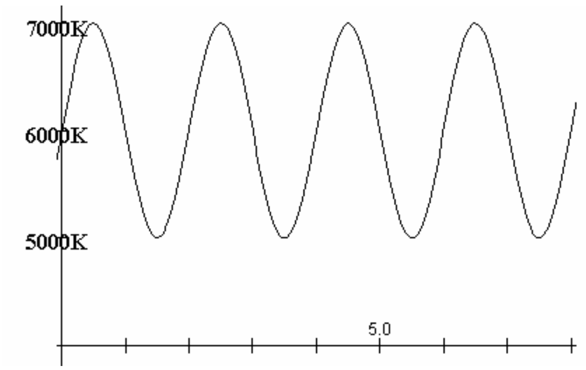
$$F_{rad} = \frac{\sigma T^4}{c}$$

Where T is the temperature, σ is the Stefan-Boltzmann Constant, and c is the speed of light. You are riding a solar sail away from a variable star, which varies on a period of one year. During your travels, over the course of the year, how can you describe your progress? That is, you start out a distance of 1 AU from the star at the beginning of the year, while the star is at maximum. Over the next 6 months, describe your acceleration as a function of the star's temperature. What does this mean about your velocity? (You may assume the solar sailing ship has a mass M.) If the radiation pressure is simply the equation stated above, how will it change as you move further away from the variable star?

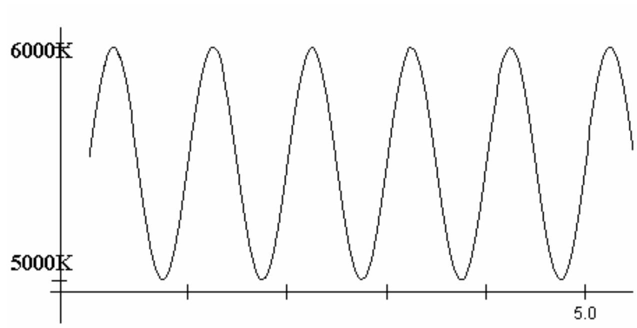
14. Variable stars have a complicated pulsation process. However, it can be approximated by following three parameters: opacity, temperature, and size. Explain what will happen in a pulsation by examining the following: If we apply a slight "squeeze" to a star, what will happen to the density? Pressure? Temperature? As a result, what will happen to the size? Opacity? After the size has changed, how will the density/pressure/temperature change accordingly? Recall in a normal star, when temperature increases, opacity decreases. Is this always the case? Are there important regions where opacity rises with rising temperature?

15. You have just discovered a new type of variable star, it is called a Mulsar. You have observed two of these Mulsars in an open cluster that is 20 kiloparsecs away. The temperatures are measured for each of these, and plotted below. On the y-axis is time in days, and the x-axis is temperature in Kelvins.

MULSAR 1



MULSAR 2

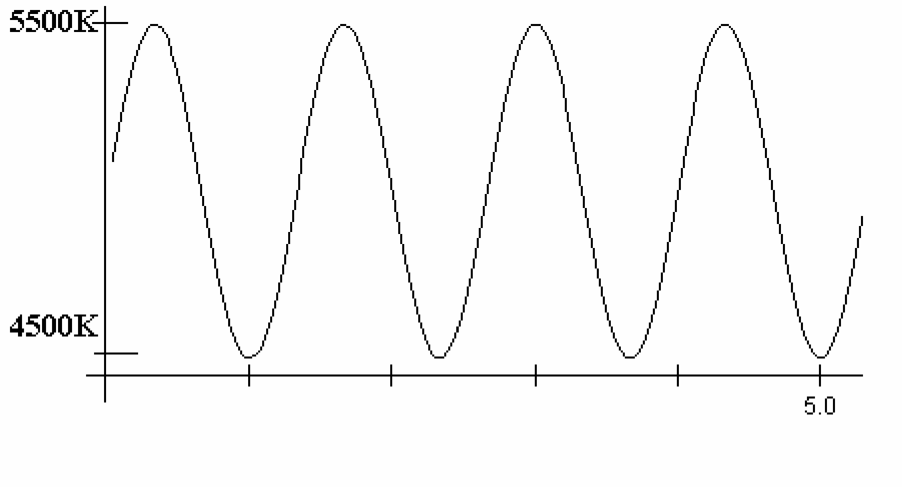


Based on these graphs, estimate the period of each Mulsar (in days).

Mulsar 1 has an observed apparent magnitude of 8, and Mulsar 2 has an observed apparent magnitude of 7. Calculate the absolute magnitudes of each Mulsar based on their given distance.

Make a plot of log(period) vs. absolute magnitude for these two mulsars. Your x-axis should be log(period), and go from -0.5 to 1. Your y-axis should be absolute magnitude, and go from -7 to -9. Plot these two Mulsars on the graph and label them. Draw a line between the two points, as well.

Now, you observe a third Mulsar, Mulsar 3. It has an apparent magnitude of 10. Its Temperature curve is observed and given below. By estimating the period from this curve, calculate the absolute magnitude of Mulsar 3 (using the graph you made above – find the absolute magnitude that correspond to the value of log(Period) that you find from the graph).



Now, calculate the distance to Mulsar 3, with the above information. Also calculate the parallax of Mulsar 3. Would this parallax be possible to observe from the Earth?

If Mulsar 3 varies by 10% in temperature (as shown on the graph), how much does it vary in magnitude? (do this by using the Stefan-Boltzmann law to compare luminosities, and the magnitude-luminosity relationship to compare magnitudes) Don't worry about exact numbers, just compare them in ratios or percents.

Calculate the peak wavelengths for the emissions from each of the 3 Mulsars.

But wait, there's more! Remember that variable stars are expanding and contracting. If Mulsar 4 is another Mulsar that you are observing, and you know that its radius changes between 3 solar radii and 2 solar radii with a period of 1 day, and that it follows a sine curve, find the maximum speed at which the "surface" of Mulsar 4 is moving. Do this by first setting up an equation for the radius of Mulsar 4 as a function of time, like $R = a*\sin(\pi*period*t) + b$.

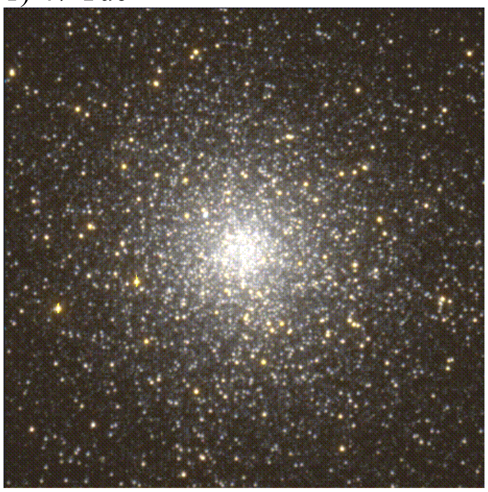
With this equation of position, the velocity is given by $v = \pi*period*a*\cos(\pi*period*t) + b$. You know that the maximum velocity will happen when the cosine term goes to one, so $v_{max}=\pi*period*a$. What is the maximum surface velocity for this Mulsar?

Mulsar 4 has a strong H-alpha line at 6562.81Å (rest wavelength). What will the observed wavelength be, as measured a short distance away from it? Since it will vary, give the maximum and minimum values of it.

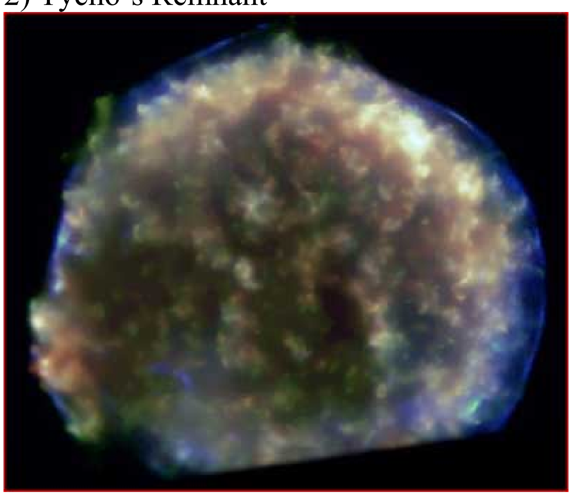
Finally, Mulsar 5 is observed. It has a peak wavelength of 6000 Å – find its temperature. It has an apparent magnitude of 8, and an observed period of 2.5 days. What is its distance?

DSO:

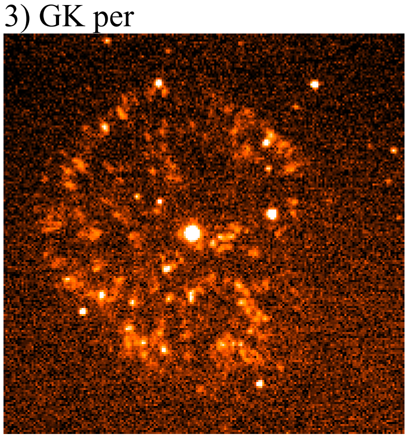
1) 47 Tuc



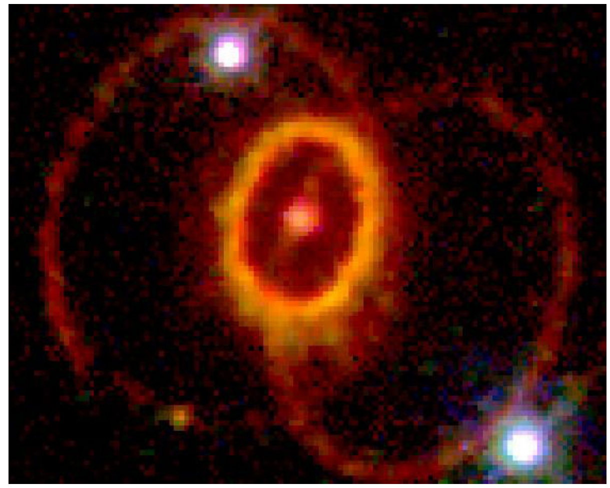
2) Tycho’s Remnant



3) GK per



4) SN 1987a



5) DEM L316