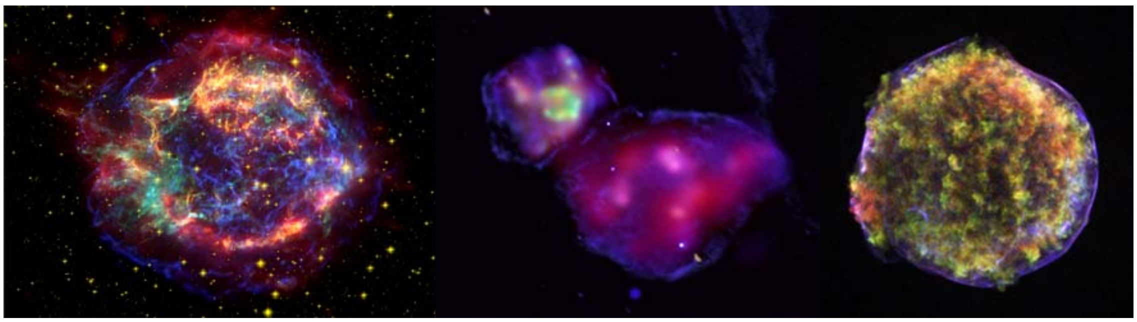
NATIONAL SCIENCE OLYMPIAD

Astronomy C Division Event
20 May 2006
Indiana University
Bloomington, Indiana



TEAM NUMBER________________
TEAM NAME____

INSTRUCTIONS:

1) Please turn in ALL MATERIALS at the end of this event.
2) Do not forget to put your TEAM NAME and TEAM NUMBER on both this page and at the top of both Answer Pages.
3. Only answers placed on the Response Pages will be counted.
4. This event and the answer key will be available on the Wright Center website:
http://www.tufts.edu/as/wright_center/fellows/sci_olympiad/sci_olympiad_astro.html
5. Good Luck! And May the Stars be With You!

SECTION A: Use Image Set A on Page 3 to answer the questions in this section.

(_1_) Image **25** shows NGC 2266. What type of object is this?
(_2_) In the direction of NGC 2266, the interstellar extinction allows only 15% of the light to pass through each kiloparsec of the interstellar medium. This object is 10,000 light years away. What percentage of its photons survive the trip to Earth?
(_3_) NGC 2266 is in the direction of the constellation shown in which image?
(_4_) What is the name of the massive star shown in Image **22**?
(_5_) What is the next evolutionary stage for this star (Image **22**)?
(_6_) This same star (Image **22**) is contained with two other images. What are they?
(_7_) What is the name of the black hole in the center of the Milky Way Galaxy (MWG)?
(_8_) Which image shows the black hole in the MWG?
(_9_) How long, in years, will it take for a star orbiting the center of the MWG at a distance of 100 AU and orbital speed of 1500 km/s to complete one orbit?
(_10_) Which image(s) shows the star Mira?
(_11_) What end products can result from this type of system?
(_12_) What is the name and number of the image showing a massive star-formation region?
(_13_) What is the constellation shown in Image **5**?
(_14_) Image **5** contains a rapidly rotating compact stellar object. Which other image shows this object, and what type of object is it?
(_15_) Which image contains a white dwarf that had an increase in brightness due to mass transfer from a companion star?

SECTION B: Use Image Set A on Page 3 and Image Set B on Page 4 to answer the questions in this section. If there is more than one answer, select the most obvious.

(_16_) Spectra **D** and **E** are optical segments from two different types of M stars; one on the main sequence, and the other on the supergiant branch. Which spectra is from a main sequence star?
(_17_) Which image on Page 3 shows a main sequence star with this type of spectra?
(_18_) What is the name of this main sequence star?
(_19_) What is the name and type of object in Image **15**?
(_20_) What is the main characteristic of the object in Image **15**?
(_21_) Which of the spectra on Page **4** best represents the object in Image **15**?
(_22_) List two images that show events that produced spectra like spectra **C**.
(_23_) The spike labeled with the number 1 in Spectra **C** represents what element?
(_24_) The curve in **A** on Page **4** was produced by the object in which image on Page **3**?
(_25_) Image **4** contains what type of object(s)?
(_26_) The object(s) in Image **4** are plotted on graph **G**. Are they group 1 or group 2?
(_27_) Which spectrum (1, 2, or 3) on plot **I** would be emitted by the objects in Image **4**?
(_28_) On graph **H** what is happening at number1?
(_29_) On graph **H** what types of objects are located at number 2? at number 3?
(_30_) Where on the H-R diagram will the central object in Image **20** be located in 10^9 yr?
(_31_) Where on the H-R diagram is Image **14** located?
(_32_) Which image on Page **3** is located at the position **S** on the H-R diagram?
(_33_) Which image on Page **3** is an end product of the evolution of an object that began in position **K** on the H-R diagram?
(_34_) Where did Image **22** begin on the H-R diagram? Where is it located at present?
(_35_) The reddish stars in Image **12** are located where on the H-R diagram?

SECTION C: Use Figures 1 and 2 on Page 6 to answer the questions in this section.

A satellite in a circular orbit around the earth observes two star clusters, Cluster A and Cluster B. The satellite measures the position, apparent magnitude, and spectral class of stars in each cluster. Using that data, astronomers produced the two H-R diagrams shown in Figure 1 on the following page. During the course of its orbit, the satellite observes the position of a bright star in Cluster A to change by 0.00000008 arc seconds. Cluster A is known to be 5,000 pcs from earth and Cluster B has a parallax of 0.033 arc seconds as measured from earth. A planetary nebula, Nebula C - that is observed to have an angular diameter of 2 arc-minutes - appears in the same field of view as Cluster A.

(_36_) Which cluster is older?
(_37_) How old is Cluster A in years?
(_38_) Calculate the distance to Cluster B in Parsecs using trigonometric parallax.
(_39_) Calculate the distance to Cluster B in Parsecs using spectroscopic parallax.
(_40_) Which parallax method (spectroscopic or trigonometric) produces a larger distance value for Cluster B?
(_41_) What is the most likely cause of the discrepancy in these values?
(_42_) What is the radius of the satellite's orbit in km?
(_43_) A typical planetary nebula has a diameter of about 1 LY; how far away would you estimate Nebula C to be?
(_44_) Could Nebula C be a part of Cluster A?

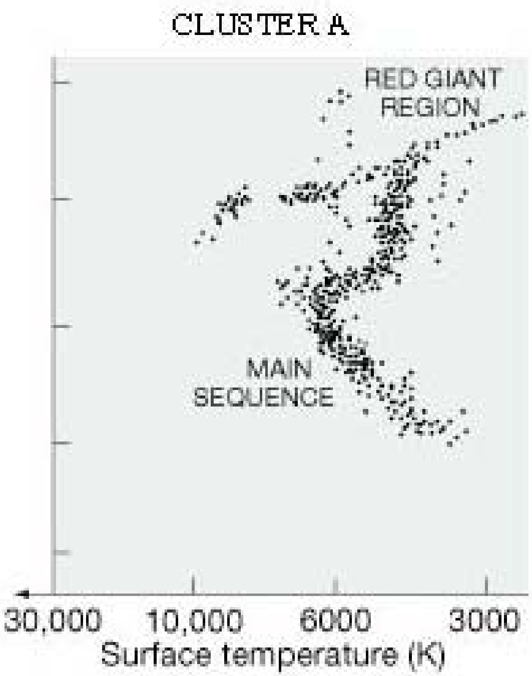
A binary star system contains two stars, Star X and Star Y. Star X has a mass of 2 solar masses. The binary system is observed to currently have a separation of 2 AU and a period of 10 months. Mass transfer is also observed to occur from Star Y to Star X.

(_45_) What is the combined mass of the system in solar masses?
(_46_) What is the mass of Star Y in solar masses?
(_47_) Which of these stars could evolve into a Wolf-Rayet star?
(_48_) Is the period of the system increasing, decreasing, or remaining constant?
(_49_) Is the distance from X to the center of the orbit increasing, decreasing or remaining constant?
(_50_) Is the angular separation of the system seen from earth increasing, decreasing, or remaining constant?

A binary star system containing two stars, Star Q and Star R, produces the light curve shown in figure two. During its orbit, the brighter star, Star Q, completely occults the light from Star R. Star R has a mass of 0.75 solar units, a radius of 1,000,000 km and an apparent magnitude of +11.6.

(_51_) What is the luminosity of Star Q in solar units?
(_52_) What is the luminosity of Star R in solar units?
(_53_) What is the apparent magnitude of Star Q?
(_54_) How many times more energy per unit surface area is emitted by Star Q?
(_55_) What is the separation of the two stars in km?
(_56_) What is the distance to the star system in parsecs?
(_57_) What is the mass of Star Q?
(_58_) What is the absolute magnitude of Star R?

Figure 1:



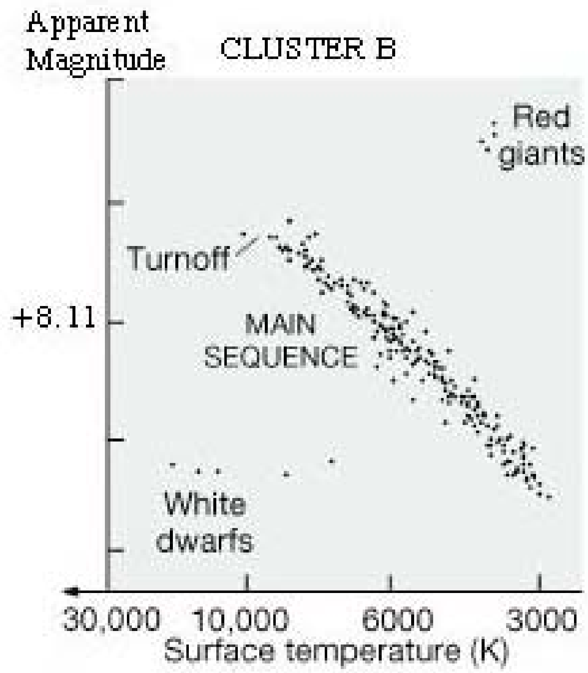
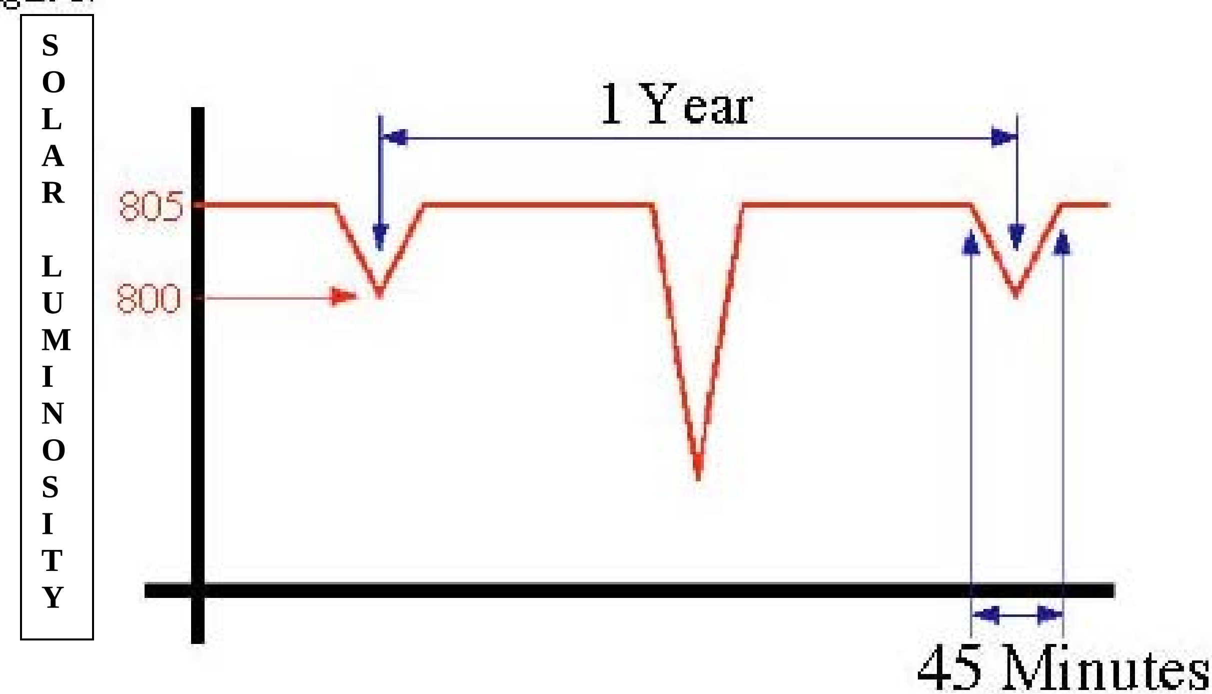


Figure 2:



SECTION D:

To answer questions 59 and 60, use Figures 1 and 2 on Page 8. These light curves for supernovae 1990N and 1987A were constructed from optical data in the red band.

(_59_) Which supernova occurred closer to Earth, 1990N or 1987A? Explain.

(_60_) Identify both 1990N and 1987A as type Ia or type II supernova events.

For questions 61 and 62, use Table 1 and Figure 3 on Page 9.
Bremsstrahlung radiation occurs in a hot gas where electrons are stripped from their nuclei, leaving a population of electrons and positive ions. When an electron passes close to a positive ion, the strong electric forces cause its trajectory to change. This acceleration causes the electron to radiate electromagnetic energy which produces a continuous X-ray spectrum. In addition, emission lines of elements can appear superimposed on this spectrum.

(_61_) Measure the distance in cm between 2 KeV and 2.5 KeV on Figure 3. Use your scale and Table 1 to identify the elements labeled 1-3 in Figure 3.

(_62_) What type of supernova event most likely caused SNR G292.0+1.8?

For questions 63-69, use figures 4 and 5 on Page 10.
Cen X-3 is a rotating variable star whose brightness in X-rays changes as a "hot spot" rotates in and out of our view. The power spectra were produced from light curves generated by DS9. For a given signal, the power spectrum gives a plot of the portion of a signal's power (energy per unit time) falling within given frequency bins.

(_63_) Find the acceleration due to gravity on the surface of a white dwarf. Let the mass of a white dwarf be approximately one solar mass or 2.0×10^{30} kg, and its radius approximately that of Earth or 6.4×10^{6} m.

(_64_) Find the acceleration due to gravity on the surface of a neutron star. Let the mass of a neutron star be two solar masses or 4×10^{30} kg and its radius be 10 km.

(_65_) From the DS9 power spectrum above, determine the period of rotation of Cen X-3 to one decimal place.

(_66_) Determine the centripetal acceleration of material on the surface of Cen X-3 assuming that it is a white dwarf.

(_67_) Determine the centripetal acceleration of material on the surface of Cen X-3 assuming that it is a neutron star.

(_68_) Is it more likely that Cen X-3 is a white dwarf or a neutron star? Explain.

Figure 1. Apparent Magnitude vs. Time

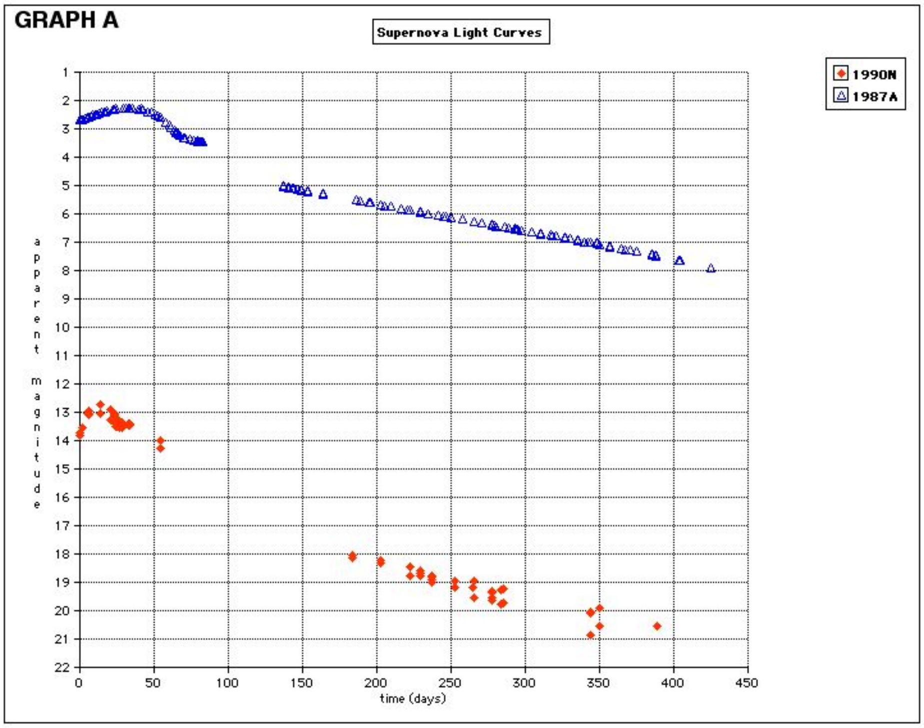


Figure 2. Absolute Magnitude vs. Time

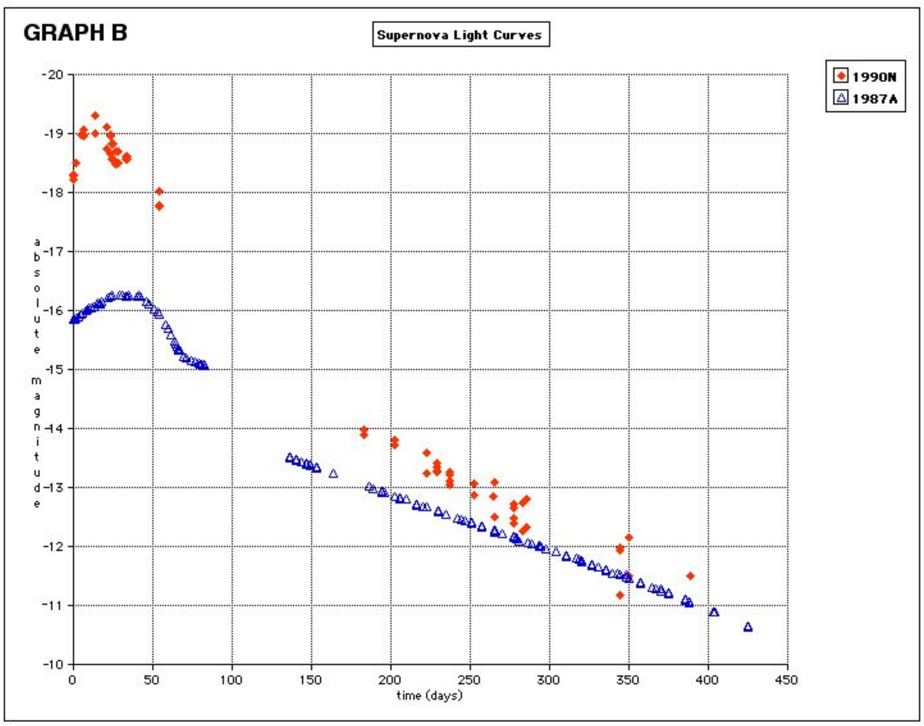


Table 1. Energies of X-ray Emission Lines

element	Energy (Kev)	element	Energy (Kev)	element	Energy (Kev)
O	0.18	Ne	1.02	Ar	3.32
Mg	0.27	Mg	1.33	Ar	3.69
C	0.31	Mg	1.45	Ca	3.86
O	0.66	Si	1.84	Ca	4.95
Fe	0.80	Si	1.87	Fe	6.47
Fe	0.81	Si	1.98	Fe	6.54
Ne	0.92	S	2.42	Fe	6.97
Ne	0.93	S	2.44	Fe	7.80

Figure 3. Bremsstrahlung Spectrum of SNR G292.0+1.8 generated by DS9

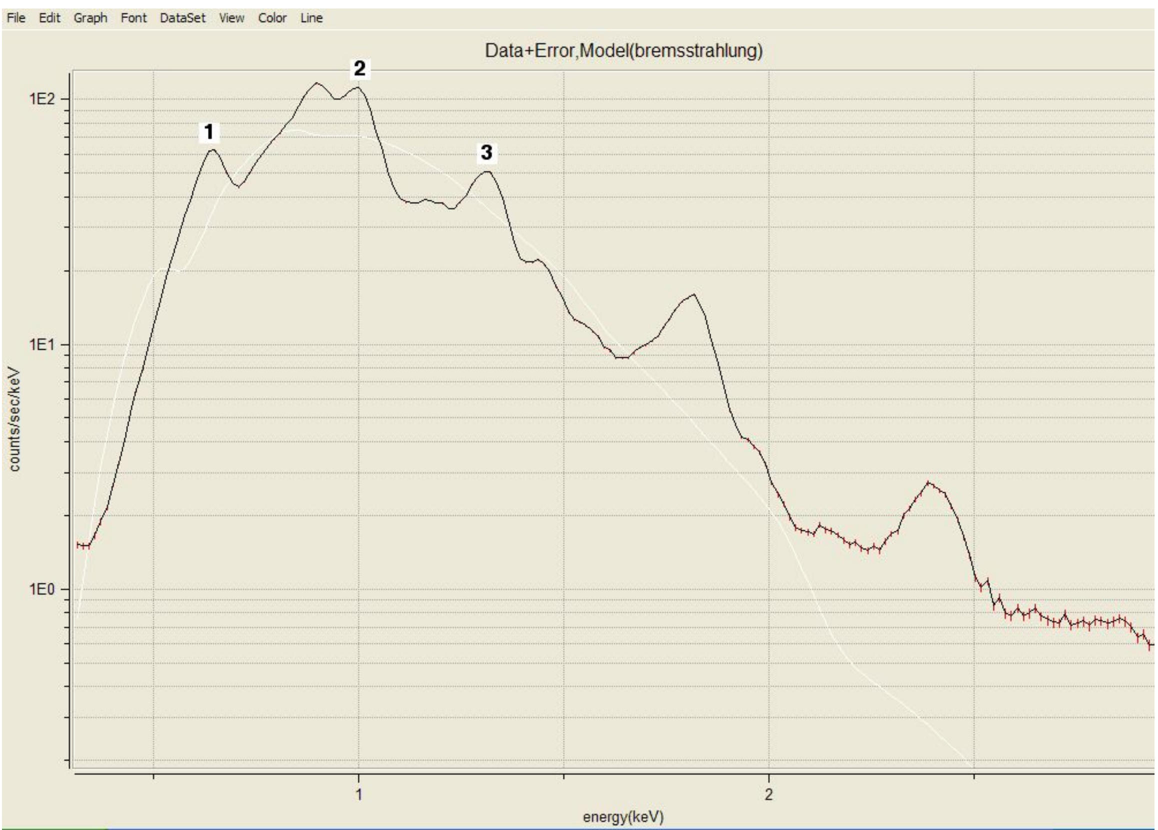


Figure 4. Cen X-3 Power Spectrum generated by DS9

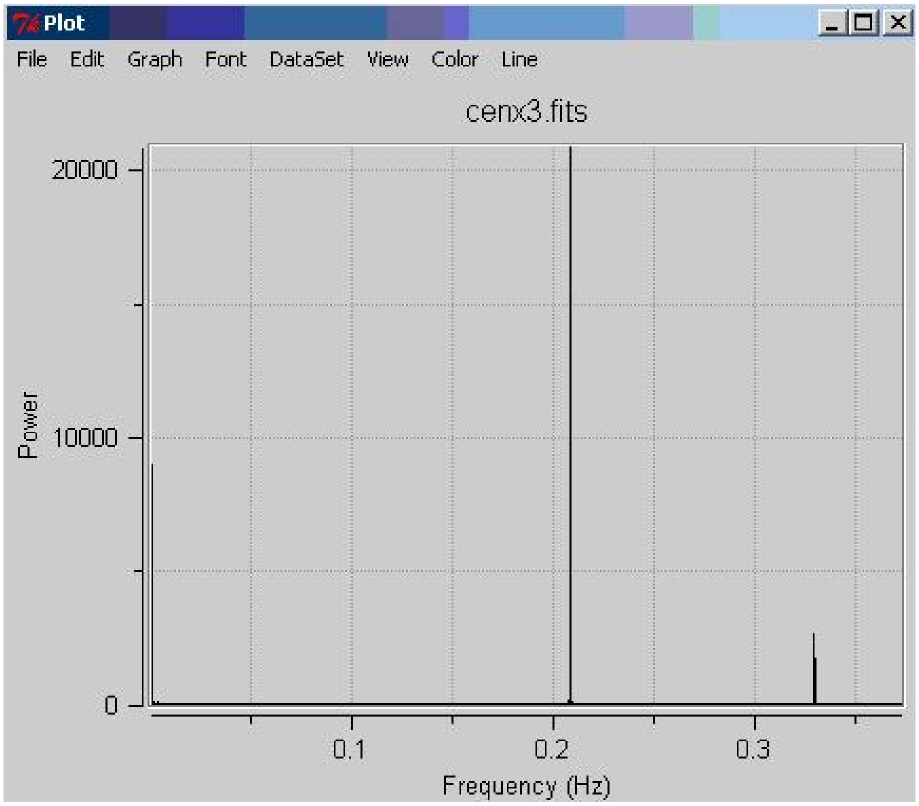


Figure 5. Cen X-3 Power Spectrum Zoom generated by DS9