Astronomy Tryout Exam

Name(s): ______________________________

Team: ______________________________

Use the Image Set corresping to the section of the exam. All answers should be written on the answer sheet, and given in the correct number of significant figures. Partial credit may be given for partially correct answers. Questions are worth two points unless otherwise noted. Questions asking for wavelength ranges should be answered in radio/infrared/optical/ultraviolet/x-ray/gamma.

Section A

1. Image 7 shows the light curve for which Deep Sky Object?
   (a) What is the Arabic (i.e. common) name for this object?
   (b) Which type of specific variability does this object exhibit?
2. Which image depicts the object that could be the Milky Way's youngest black hole? What is its name?
   (a) What wavelength range was this image taken in?
   (b) Data from Chandra and other telescopes indicates that the explosion of this object is highly asymmetric. Give one piece of evidence for how this conclusion was reached.
3. Geminga and B0355 are two pulsars with both quite similar and different characteristics. An image of these is shown in (1). Both of these objects' nebulae both have the same shape, however they appear quite different; why is this?
   (a) (1 point) What is the name of the shape formed by each of these objects?
   (b) (4 points) Despite having similar morphology, the received spectrum of these two are not at all the same. What are the major wavelength ranges of light for each of these objects and why are they different?
4. The supernova event SN 1987A was one of the most influential events in astrophysics in the past few decades, leading to both confirmations and exceptions of long-held astronomical theories about stellar evolution.
   (a) SN 1987A was the first nearby supernova to be observed using modern optical equipment, however it was significantly less bright than expected based off observations of more distant supernovae. The cause of its subluminous nature was discovered when its progenitor was discovered to be what type of giant star?
   (b) (3 points) Spectroscopic measurements of the lines of a certain isotope of a certain element confirmed the presence of this element in type II supernovae. What was the element, and which wavelength ranges were used to make this observation?
   (c) An image of the supernova remnant is shown in (2). There are three rings, one inner and two outer. What causes the inner ring to shine?
5. Which image depicts a "cluster of clusters" containing many young, massive stars? What is the Sharpless Catalogue number for this DSO?
   (a) What wavelength band was this image taken in?

(b) Radiation from these stars ionize the hydrogen gas around them. What is the name for this type of region?

6. Image 12 depicts which DSO in the optical?
   (a) This object contains a supernova remnant. Estimates of the mass of the supernova progenitor are between 25 and 40 solar masses. This existence of which elements in the remnant lead to this conclusion?
7. Image 14 is an x-ray image the x-ray binary M82 X. Which component pointed to (purple/blue) is X1 and X2, respectively?
   (a) The x-rays emitted by this object have radiation pressure that push inward falling objects outward. However, X-2 is so bright in the x-ray that its radiation pressure is 100 times greater than that needed to rip the star apart. What is the name for this limit X-2 has violated where a star cannot be any brighter?
   (b) What is one given explanation for how X-2 can surpass this physical limit?
8. S Doradus is a variable star in the Large Magellanic Cloud. It belongs to two classes of variables, S Doradus variables and Luminous Blue Variables (LBVs). What is the relation between these two classes?
   (a) Image 13 shows a different member of these classes. What is its name, and what causes the observed nebula surrounding it?
9. Which image depicts V766 Cen, one of the largest stars discovered?
   (a) Although this star was first classified as a yellow hypergiant, this star appears to more likely be what type of less evolved star?
   (b) This star is losing mass so quickly through stellar wind some of it has ended up on the secondary component. What is this process called?
10. Circinus X-1 is an interesting case study of observational astronomy, and has many special characteristics. Image 10 depicts this DSO in the x-ray; note the concentric rings around it. What are the rings, i.e. what causes them to shine?
    (a) Measurements of these rings allowed astronomers to recalculate what property of this object, leading to stunning conclusions about its nature?
    (b) (4 points) One of these conclusions is that this object may be a black hole, as opposed to a neutron star as previously thought. Give two pieces of evidence used to justify the black hole hypothesis.
11. Image 3 depicts a supernova remnant, and 8 is a close-up view of the object that caused the explosion. What is the name of this object (i.e. the thing that caused the explosion, not the DSO itself), and what category of objects does it fall into?
    (a) In image 8 there is a ring around the center of the object. Give a leading hypothesis explaining the existence of said ring.
12. ASASSN-15lh is recorded as having been one of the most intrinsically bright transient objects observed in astronomy, peaking at -23.5 abs. mag. However, due to its peculiar nature, a cause for the explosion has eluded astronomers. What are two hypotheses given for what this event may have been?
    (a) What is peculiar about the spectrum of this event/object?
13. Which image contains RCW103, a galactic type II supernova remnant?
    (a) This object is a magnetar, a special type of neutron star characterized by extremely strong magnetic fields. What other property of RCW103 makes its nature as a magnetar peculiar?
14. One object from the DSO list remains unmentioned. Which object is this?
    (a) According to the Astronomy webinar, how many of each type of object are in the DSO section of the rules?

Section B

Cepheid variables are one of the most important objects in the history of astronomy. They led to the confirmation of other galaxies, gave the first estimates for Hubble's Law, and set the standard for most of the cosmologic distance ladder. When answering questions about Cepheid variables, use the following equation for the period-luminosity relation of type I Cepheids:

$$M_V = -2.80 \log_{10} P - 1.43 \tag{1}$$

Where P is the period in days and M_V is the absolute visual magnitude.

1. Image 1 shows a radial velocity plot of a Cepheid variable star, with a light curve directly below.
   (a) Which letter represents the maximum rate of expansion of the radius of the star?
   (b) Which letter represents the smallest diameter of the star?
   (c) (4 points) Suppose that in its rest frame, the star emits light with a peak wavelength of 400.00 nm. What average wavelength of light would an observer from Earth see based on the radial velocity?
   (d) (4 points) Given that this star is a classical Cepheid, how distant is the star in parsecs?

2. X-ray binaries are peculiar objects associated with the final stages of star formation, and are found in many of the DSOs for this year's competition.
   (a) (4 points) Image 2 shows a radial velocity curve for x-ray binary MCW 656. What are the approximate masses of components A (lower amplitude velocity) and B (higher amplitude) respectively in solar masses?
   (b) (4 points) What are the barycenter distances for A and B, respectively in AU?
   (c) (2 points) Given that component A is a main-sequence star, what is its spectral class? (Just the letter, not subcategory)
   (d) (2 points) Given that component B is a compact object, what type of object is it likely to be?
   (e) (2 points) What is the radial velocity of MCW 656 in km/s? Is it moving towards or away from us?
   (f) (4 points) Given (2) below, calculate the time it will take the system to merge from gravitational radiation in years.

$$t_{merge} = \frac{5}{256} \frac{c^5}{G^3} \frac{r^4}{(m_1 m_2)(m_1 + m_2)} \tag{2}$$

   Where t is the expected time for the merger to occur, G is the gravitational constant, c s the speed of light, m_1 and m_2 are the component masses and r is the separation between the two components.

3. Neutron stars have many interesting properties, such as their strong magnetic fields, short rotational periods, and small radii. This question examines the scale of these properties quantitatively.
   (a) (4 points) Let's first look at rotational period. Suppose a 5,120 km radius white dwarf, with a rotational period of 22.5 minutes and a magnetic field $3.5 * 10^5 G$, collapses into a 10 km radius neutron star via accretion induced collapse. Ignoring other affects of accretion induced collapse and given that the angular momentum of the rotation is conserved, what is the rotational period of the new neutron star in seconds?
   (b) (4 points) Magnetic flux is given by the surface integral $\Phi = \int_S \mathbf{B} \cdot d\mathbf{A}$. This roughly means the flux is equal to the product of an object's magnetic field and its surface area. Given that the magnetic flux of the star remains constant before and after collapse, what is the magnetic field in Gauss of the neutron star?
   (c) (4 points) The loss of energy of the neutron star results in its luminosity, and can be estimated by $\frac{dE}{dt} = \frac{-16\pi^4 B^2 R^6}{6c^3 P^4}$. What is approximately the luminosity of our neutron star in Watts?

4. (a) (4 points) Image 2 shows a plot of nuclear binding energy vs atomic mass number. Explain why, at the end of stellar evolution for massive stars, fusion is no longer a source of energy for keeping hydrostatic equilibrium.
   (b) (4 points) Image 3 is a spectrum for an observed type II supernova. Given the H-alpha rest wavelength is 656.3 nm, what is the redshift z of the supernova?
   (c) (4 points) Using a value of 70 km/s/Mpc for the Hubble constant, calculate the distance to the supernova in part (b) in Mpcs.
   (d) (4 points) Give a brief explanation for differences in the progenitors for Type II-n and Type II-b supernovae.
5. Images 4 and 5 of SN 1572 were taken in 2003. SN 1572 had a peak apparent visual magnitude of -6 and a peak absolulte visual magnitude of -19.5. The crosshairs on the images are placed in order to enable measurement of the diameter of the object. The scale of the image is 0.015 arcminutes per pixel (see "Image" values).
   (a) (4 points) What area of the sky does this object cover, in square arcminutes?
   (b) (4 points) Assuming that the object has expanded at a uniform rate, what is its speed of expansion, in km/s?
   (c) (4 points) Assuming that the progenitor star shed 1 solar mass when it went supernova, how much kinetic energy was released in the event, in ergs?