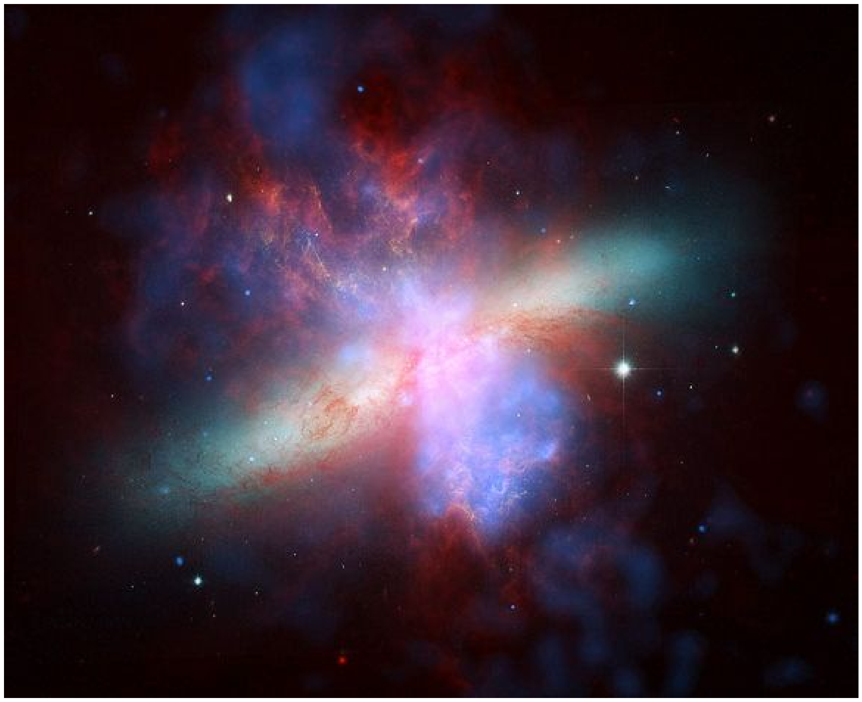
Astronomy: Division C Science Olympiad, Round 1 Tryout Test



Student Name:
Student Number:

DIRECTIONS

1. Write the answers that you want graded legibly on the answer sheet, along with your name and student number.
2. Work does not need to be shown; give three or more significant figures for any calculation questions.
3. The test consists of two sections: section 1 for DSOs, section 2 for Theory (Math, Conceptual). Please note that the images for either section are at the end of this test packet.
4. Point values for each question are indicated at the top of each section or at the end of a question. There are **132 total points**.

Section 1: **Deep Sky Objects (58 points)**

Use **Image Set A** to answer the following questions. An HR diagram is available at the end of Image Set A. All questions and sub-questions are two points. No partial credit is given for sub-questions.

1. Look at image 2 in Image Set A
    a. What is the object listed on the 2018-2019 DSO List is shown in image 2?
    b. In which region of the EM Spectrum was this image taken in?
    c. This object is currently interacting with a dwarf galaxy approaching from the top left. This dwarf galaxy contains a supermassive black hole in its center. What is this dwarf galaxy called, and what is a result of this interaction?
2. Look at image 4 in Image Set A
    a. Which object listed on the 2018-2019 DSO list does this represent?
    b. According to this light curve, what is the object's peak apparent magnitude?
    c. What type of event is depicted by this light curve? Be specific.
    d. This specific astronomical event resulted in an expanding shell of radiation, reflected off of local interstellar dust. What is this phenomena called?
3. Look at image 15 in Image Set A
    a. Which object does this image depict?
    b. What is the name of the object (not shown in the image) located to the right of this image frame?
    c. This object is part of a group of 34 galaxies. Gravitational interactions between this object and two other galaxies in this cluster have resulted in what phenomena?
    d. The galaxy located to the right of the depicted image is referred to as a starburst galaxy, or a galaxy with rapid star formation. What the reason for this enhanced star formation activity?
4. Look at image 6 in Image Set A
    a. What object on the 2018-2019 DSO list does this image depict?
    b. What part of the EM Spectrum was this image taken in?
    c. What specific process caused the formation of the long purple strip depicted in the image?
    d. What is the right ascension and declination of this object?
5. Look at image 1 in Image Set A
    a. What object on the 2018-2019 DSO list does this image depict?
    b. What element does the green hues in the image represent?
    c. This object has an envelope of hydrogen surrounding it, similar to all other types of objects in this category. What is abnormal about this object's hydrogen envelope?
    d. What is this object's apparent magnitude when taking into account the Milky Way's light obscuration?
6. Look at image 12 in Image Set A
    a. What object on the 2018-2019 DSO list does this depict?

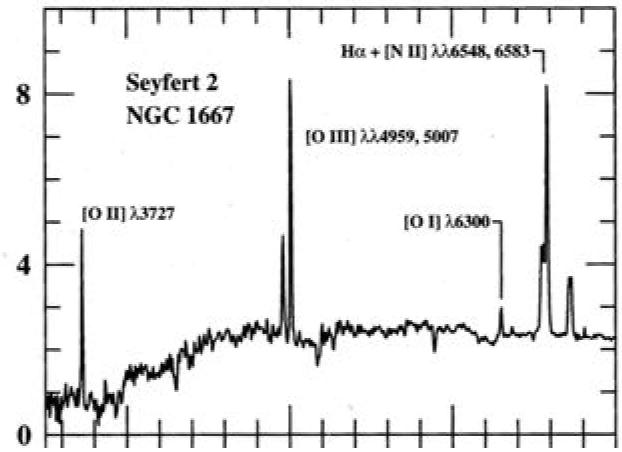
    b. What part of the EM spectrum was this image taken in?
    c. Recently, many black holes have been discovered around this object. What is a possible explanation for this?
    d. What type of object is this?
7. Which image depicts NGC 4993 in Image set A?
8. Which image depicts Messier 51 in Image Set A?
9. Which Image depicts the Phoenix Cluster in Image Set A?
    a. What part of the EM spectrum was this image taken in?
    b. What is the cause of the two "cavities", or holes in the blue hue, shown in the image?
    c. These cavities are often referred to as "Radio Bubbles". What structure is observed to encase these bubbles?

Section 2: Interpretation, Critical Thinking, Math, Theory (74 points)

Point values are given in [brackets] next to the subquestion/question. Partial credit may be awarded for nontrivial progress.

1. Globular clusters are spherical/elliptical objects that are packed with stars, the number density of stars generally increasing towards the center. Let us assume that a given globular is spherical, has approximately 500,000 stars, and has average density 0.4 stars/cubic pc (we will assume that this density is uniform throughout the cluster).
    a. Assuming the average star in this cluster is Sun-like, calculate the approximate mass of the cluster in kg and solar masses. [2]
    b. Using aforementioned assumptions, calculate the approximate radius of the cluster in m and pc. [4]
    c. Using the values you calculated, determine the gravitational potential energy (due to the cluster's self-gravity) of the cluster in J. [4] (If you were unable to get answers for (a) or (b), give an expression for the potential energy of a self-gravitating sphere of constant density with mass M and radius R).
    d. Assuming that the cluster is in a virialized state, calculate its kinetic energy and total energy. [4]
    e. Several globulars are thought to have intermediate mass black holes (IMBHs) at their cores. Let us suppose that this globular has an IMBH with 0.2% of the total mass of the cluster. Calculate the black hole's Schwarzschild radius in km. [3]
2. Let us suppose that we have discovered a new binary system, and it so happens that this system is a spectroscopic, eclipsing binary. The radial velocity curves show that the curve of star A has an amplitude of 32 km/s and that of star B has an amplitude of 10 km/s. We assume that the inclination angle of the orbit is 90 degrees (edge-on). From the radial velocity curves we also know that the period of the system is 243 days. From the light curve of the system, the maximum brightness is at 9 magnitudes, primary eclipse/transit is at 10 magnitudes, and secondary eclipse/ transit is at 9.3 magnitudes. We also gather from the light curve that the time between first contact and minimum light is 0.23 days.
    a. Calculate the mass ratio of star A to star B. [1]
    b. Calculate the mass of each star in solar masses. Why are the calculated masses a lower bound to the actual masses? [8]
    c. Calculate the semimajor axis for the center of mass (or the separation between the two stars) in AU, and then find the distance of each star from the center of mass in AU. [8]
    d. Calculate the radius of the smaller star in m and solar radii. [6]
    e. Find the ratio of the temperature of the cooler star to that of the hotter star. [4]

3. Shown at right is the spectrum of a Seyfert 2 galaxy. Answer the following questions.
    a. In general, what do you notice about the widths of the lines? What does this indicate about the characteristic speeds that contributed to these widths? [4]
    b. What type of spectral line is [O III]? How do these types of lines arise? [4]
    c. Give one difference between this spectrum and the spectrum of a typical Seyfert 1. [2]
    d. Why are X-rays less often measured from Seyfert 2's as compared to Seyfert 1's? [3]
    e. What does the relative intensity of the H alpha line indicate about the composition of the line-producing environment in NGC 1667? [2]



4. At right we have the rotation curve for NGC 3198 with error bars shown.
    a. At approximately what orbital velocity does the rotation curve level off? What is the approximate error in this estimate? [2]
    b. At the radius where the rotation curve appears to level off, calculate the mass intrinsic to this radius in kg and solar masses. [3]
    c. Rotation curves of solar system objects and other systems are expected to follow a Keplerian decline. What does this mean and how does this rotation curve differ? [4]
    d. Calculate the mass internal to R for R=22 kpc. What does this indicate about the proportionality between mass and radius and mass and rotational velocity for the flat part of the rotation curve? [4]
    e. How does this support the existence of dark matter? [2]

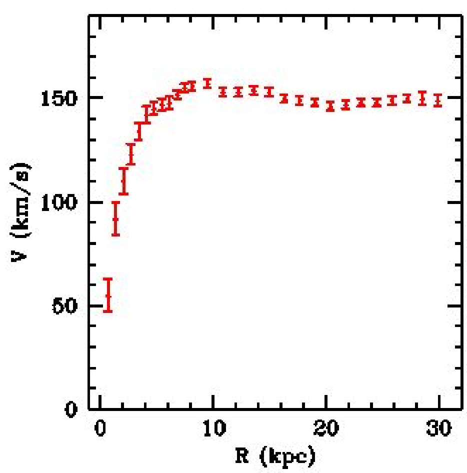
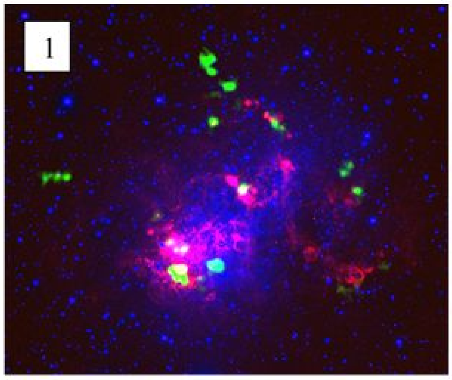


Image Set A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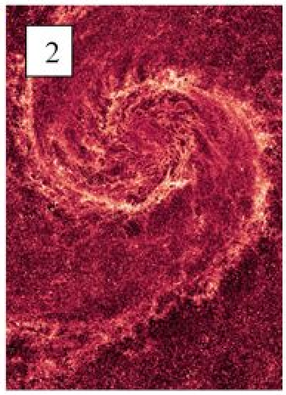
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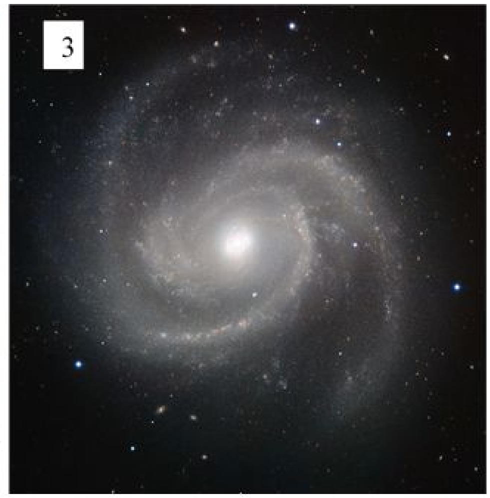
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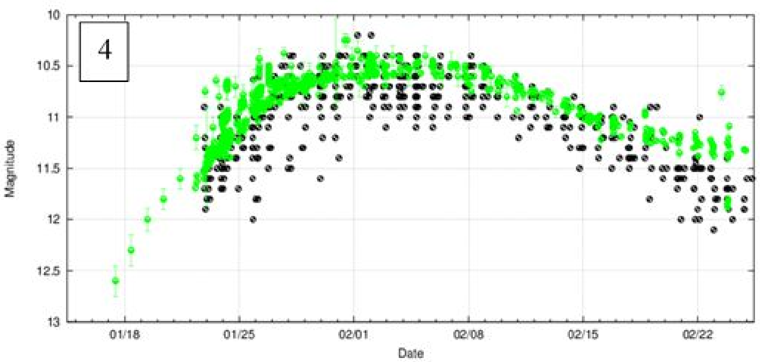
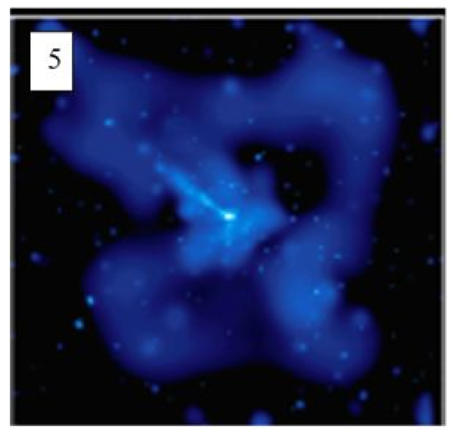

4
10
10.5
11
11.5
12
12.5
13
Magnitude
01/18
01/25
02/01
02/08
02/15
02/22
Date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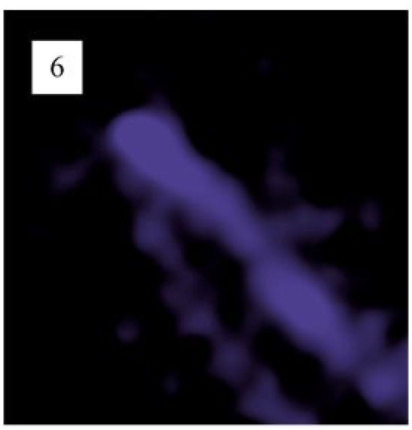
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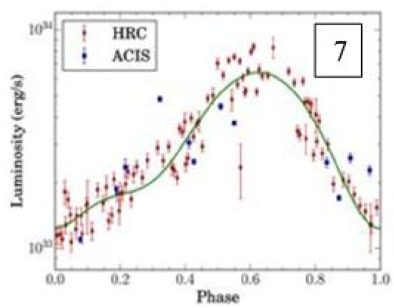
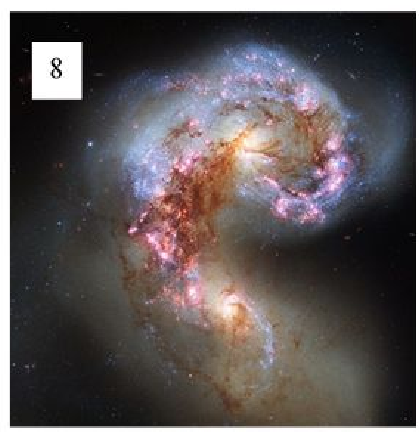

7
HRC
ACIS
Luminosity (erg/s)
0.0
0.2
0.4
0.6
0.8
1.0
Phase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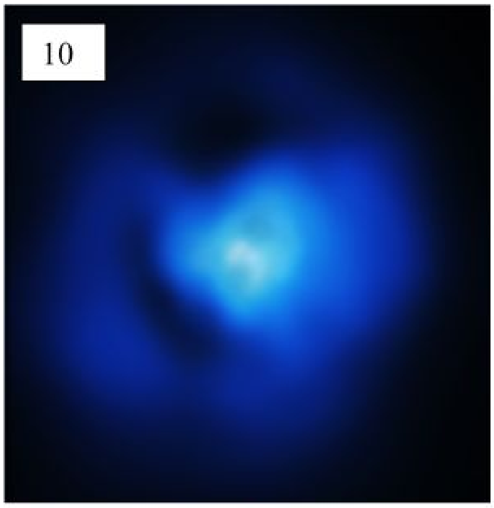
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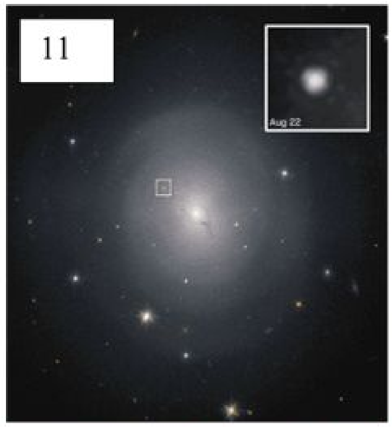
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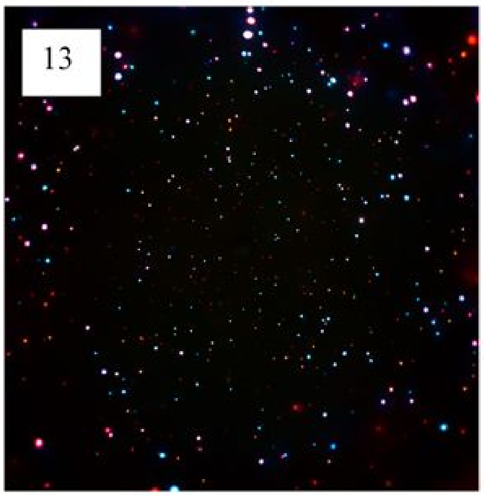
12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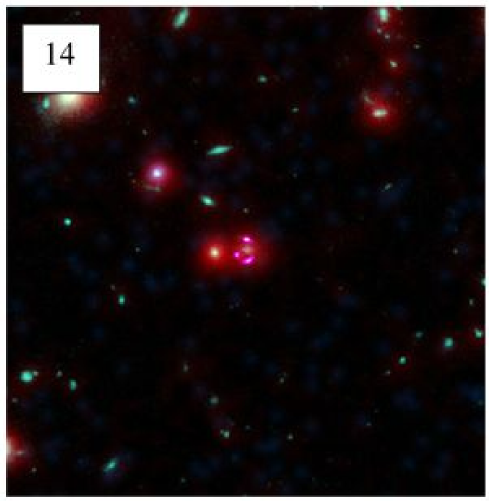
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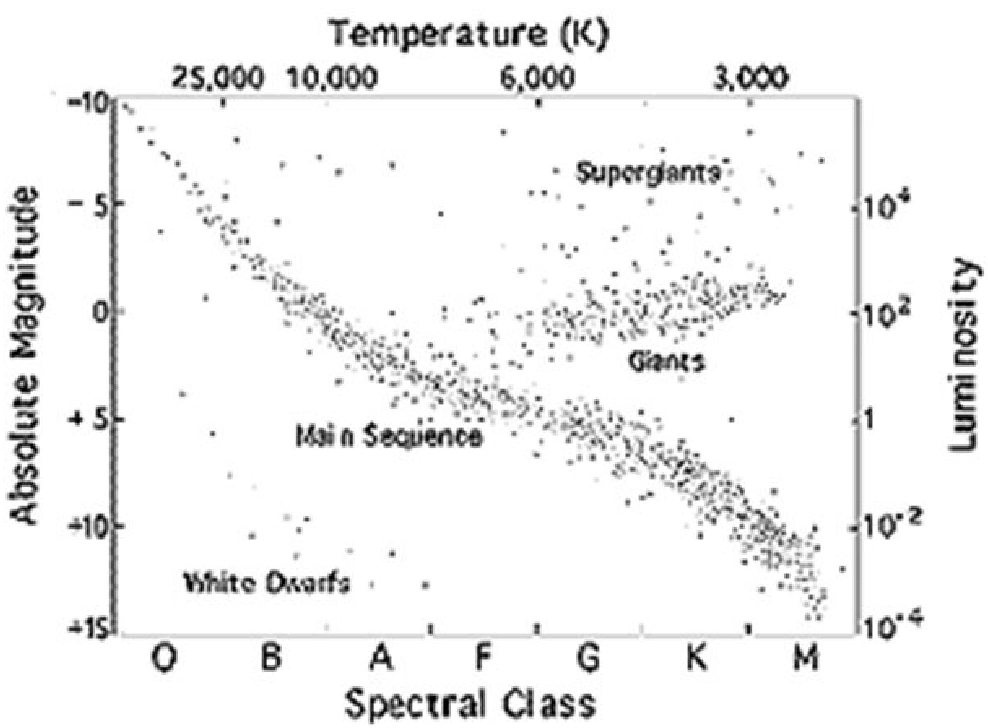
15


Temperature (K)
25,000 10,000 6,000 3,000
Absolute Magnitude
-10
-5
0
+5
+10
+15
Luminosity
10^4
10^2
1
10^-2
10^-4
Supergiants
Giants
Main Sequence
White Dwarfs
O B A F G K M
Spectral Class