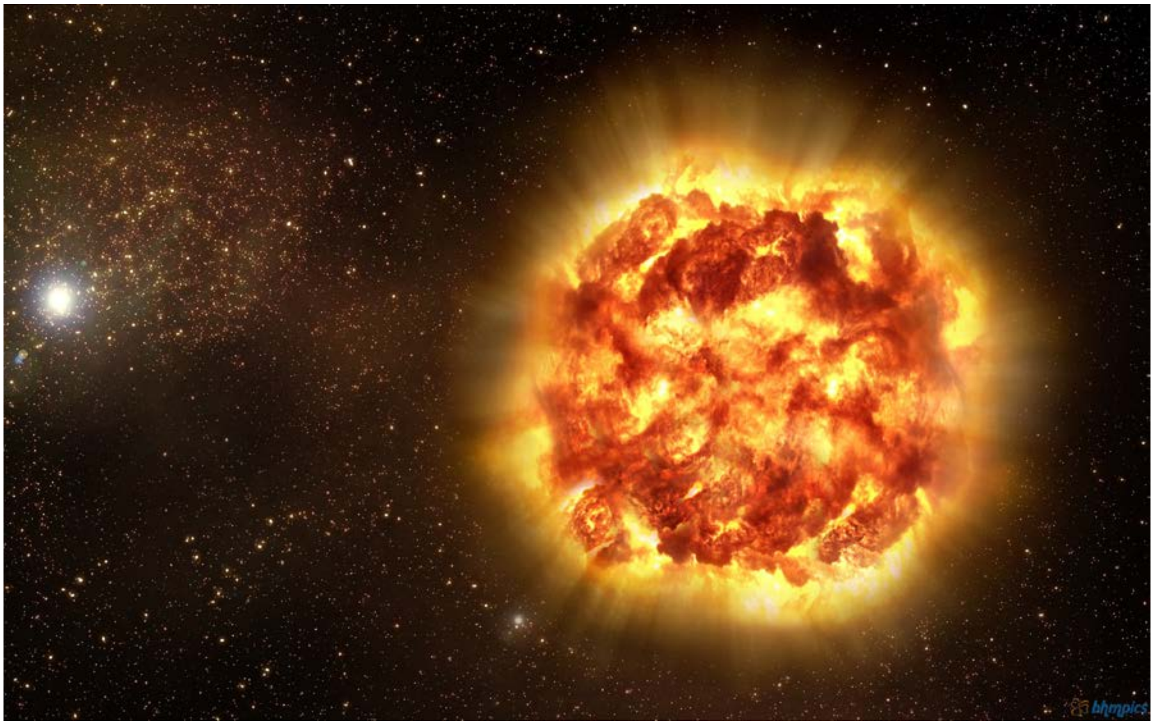
Science Olympiad
Astronomy C Regional Event
February 11, 2017
Maryland



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 at the top of all Answer Pages.

3) Write all answers on the answer pages. Any marks elsewhere will not be scored.

4) Good Luck! And May the Stars be With You!

<u>Section A: All questions in this Section are worth 2 points.</u>

Questions 1-2 refer to the object depicted in the image below

1. The image above was taken by the Chandra X-Ray telescope. What is the dominant source for the x-ray emission seen in this object?

2. This object has been considered as a possible example of a “standard candle” in astronomy. What relevance do standard candles hold for astronomers, and is it common for objects of this type to be one?

Questions 3-4 refer to the youngest known planetary nebula

3. What is the Henize catalog number of this object?

4. This object is known to display collimated outflows that vary in position angle with distance from its central star. What is thought to be the cause of this variation?

Questions 5-6 refer to one of the densest globular clusters in the Milky way

5. This object is notable for containing the first planetary nebula discovered within a globular cluster. What is this nebula’s name, and when was it discovered?

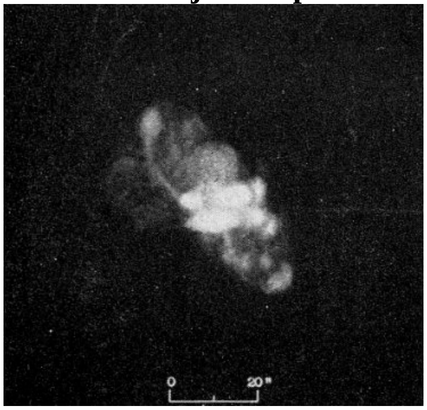
6. This cluster has undergone a process known as “core collapse”. What evidence exists of this process occurring?

Questions 7-8 refer to the binary systems J0751 and J1741

7. These systems are both known for being potential progenitors to what new type of object? Describe this type of object.

8. By what process will the objects in these binaries produce this new object? What is the most likely fate of these objects?

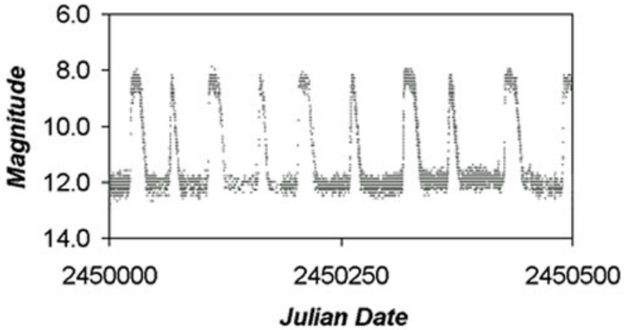
Questions 9-10 refer to the objects depicted in the image below



9. The central object in this image is possibly the hottest known white dwarf. What is the name of this white dwarf? What about the larger object in which it resides?

10. What is suggested by the chaotic structure of the larger object?

Questions 11-12 refer to the object depicted in the chart below



11.This object is considered a prototype of what type of object?

12.Why is this object so popular for observations compared to others of its type? Give at least two reasons.

Questions 13-14 refer to NGC 2392, commonly known as the Eskimo Nebula

13. What property of NGC 2392 has led to its nickname as the Eskimo Nebula?

14.What have observations by the Chandra space telescope revealed about this object's x-ray activity, and what might explain this?

Questions 15-16 refer to Tycho's Supernova Remnant, one of the few recorded supernovae that was visible to the naked eye

15. How has the discovery of Tycho G within the remnant strengthened the case for the existence of the remnant itself?

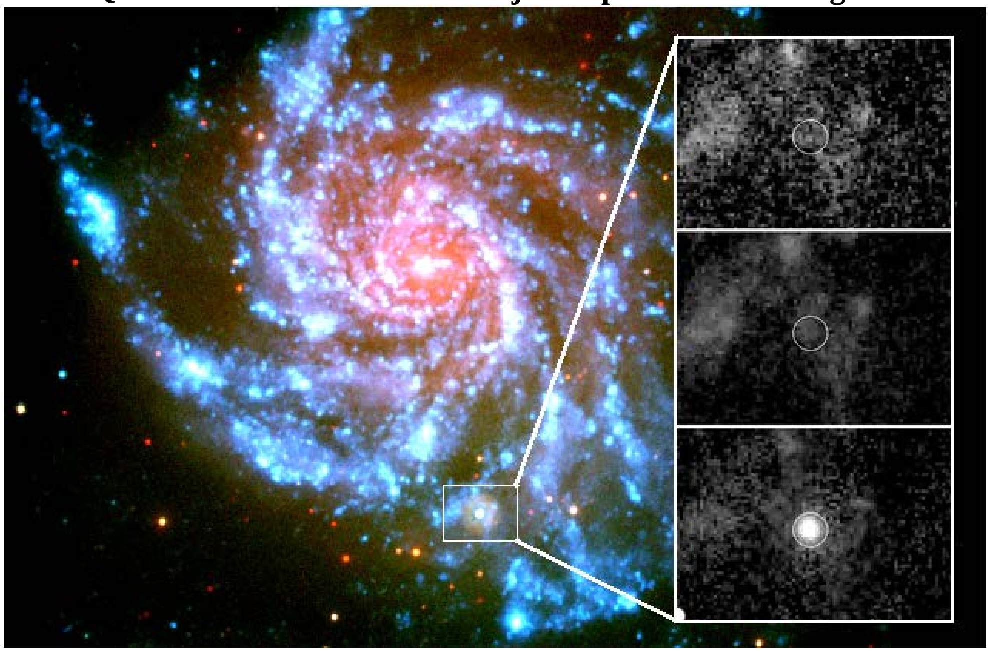
16. Unlike most objects of its type, the stellar debris of Tycho's SNR has kept pace with its expanding outer shock wave. What is the most likely explanation for this behavior?

Questions 17-18 refer to the object depicted in the image below

17. This image is a composite of two images of the same object at different wavelengths. Which parts of the image correspond to which regions of the electromagnetic spectrum?

18. How do astronomers believe this object was created? How has this been confirmed?

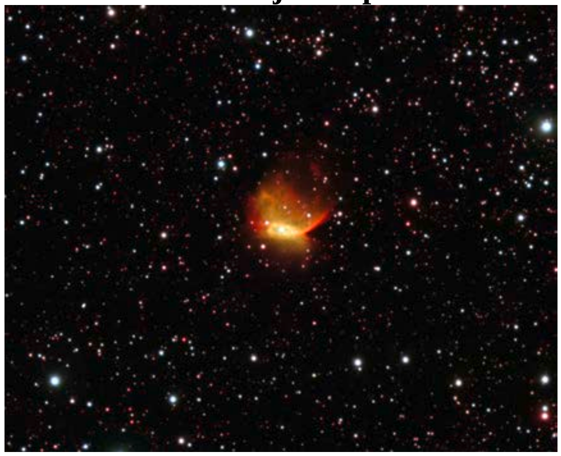
Questions 19-20 refer to the object depicted in the image below



19. What is significant about the event depicted in the right-hand inset of this image?

20. How will observation of this event impact our current models for stellar evolution?

Questions 21-22 refer to the object depicted in the image below



21. The image above was taken by ESO's Very Large Telescope, and depicts the ultimate fate of stars up to 8 solar masses. Why is this object shaped so asymmetrically?

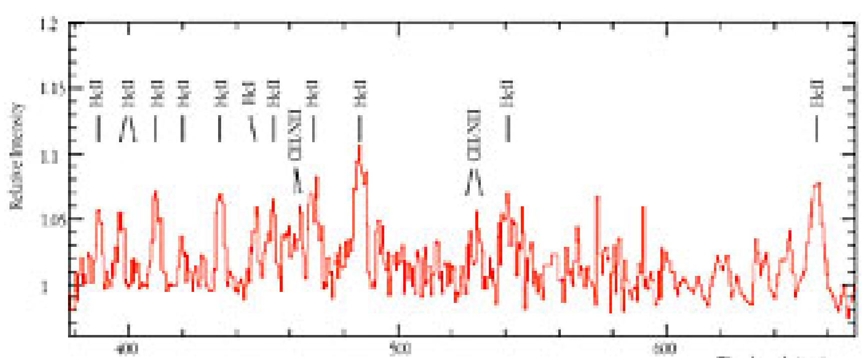
22. What is the eventual fate of this object? Why is this so significant?

Questions 23-24 refer to the objects depicted in the image below

23.What is causing the dynamic instability seen in the object on the right?

24. Describe the process occurring in the image above.

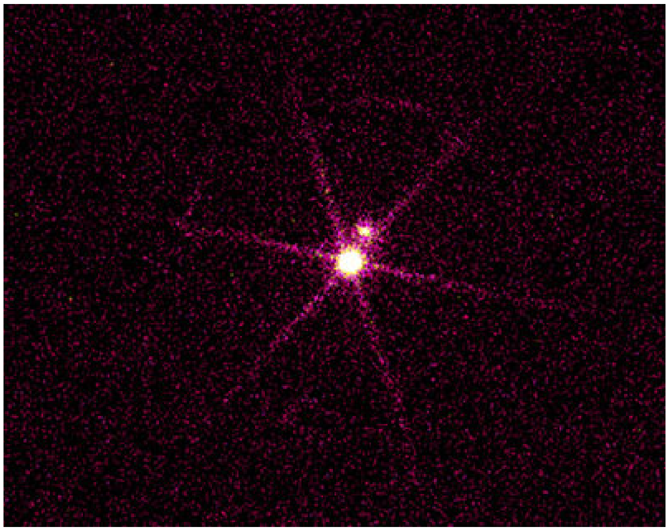
Questions 25-26 refer to the object depicted in the chart below



25. What has the data found in the chart above told astronomers about this object's surface temperature?

26. What other DSO is expected to end its life in the same way as this one?

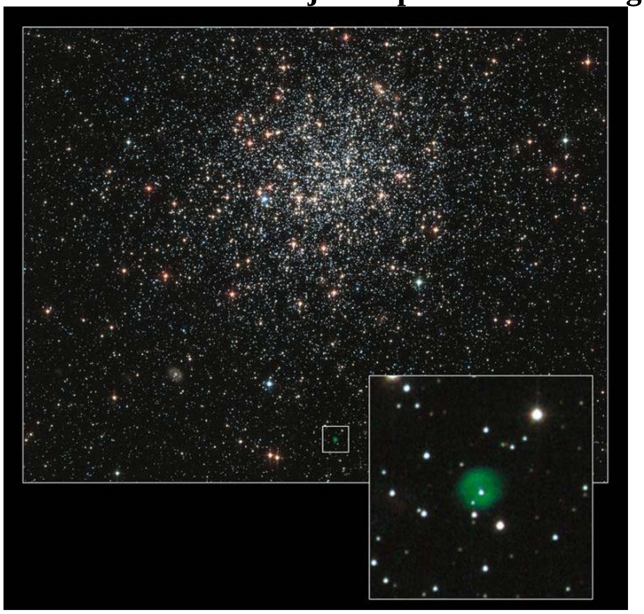
Questions 27-28 refer to the object depicted in the chart below



27. What is the name of the brighter object in this image?

28. How might the ultimate fate of the system in this image be altered if the distance between the two companions was significantly lessened?

Questions 29-30 refer to the object depicted in the image below



29. With which telescope was the above image taken?

30. Why is the presence of the green bubble in the above image so problematic in considering the nature of this object?

Section B: All questions in this Section are worth 1 point.

31. Which of the following CANNOT produce a Type Ia supernova?
    a. The merging of two white dwarfs, both of 0.5 $M_\odot$
    b. The merging of two white dwarfs, one of 0.98 $M_\odot$ and the other of 0.4 $M_\odot$
    c. Accretion of mass onto a white dwarf by a subgiant companion
    d. Accretion of mass onto a white dwarf by a giant companion

32. What mass range is required to produce an oxygen-neon-magnesium white dwarf?
    a. 4.5-6 $M_\odot$
    b. 6-8 $M_\odot$
    c. 8-10.5 $M_\odot$
    d. 10.5-12 $M_\odot$

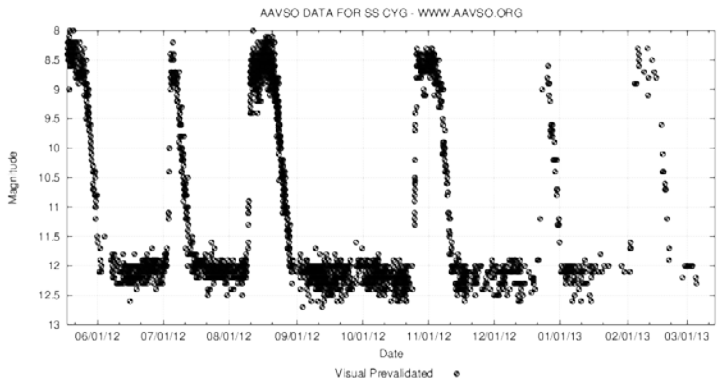
33. Which subclass of white dwarf does NOT exhibit a helium-dominated atmosphere?
    a. DA
    b. DB
    c. DC
    d. DZ

34. Open clusters and globular clusters have which of the following characteristics in common?
    a. Tightly gravitationally bound
    b. Relatively young and active
    c. Have been found within spiral galaxies
    d. Often illuminate surrounding gas to produce HII regions

35. The Shapley-Sawyer Concentration Class system is used to categorize:
    a. White dwarfs based to the concentration of heavy elements in their atmosphere
    b. Galaxies based on the percentage of variable stars contained within them likely to erupt cataclysmically
    c. Planetary nebulae based on the abundance of hydrogen in their spectra
    d. Globular clusters based on the density of stars in their center

36. The Chandrasekhar Limit is:
    a. About 1 $M_\odot$
    b. A by-product of the Pauli exclusion principle
    c. Proportional to the luminosity of a white dwarf
    d. All of the above

37. Which of the following is most likely to form an accretion disk?
    a. A white dwarf orbiting a black hole
    b. Two main-sequence stars in a binary system
    c. A black hole merging event
    d. A blue supergiant and white dwarf binary system



38. The above light curve corresponds to a:
    a. Mira variable
    b. Recurrent nova
    c. Type Ia supernova
    d. AM CVn system

39. Which of the following is NOT a property of Mira variables?
    a. Intrinsic variability
    b. Presence on the asymptotic giant branch
    c. Eventual death in supernova events
    d. Infrared amplitudes in excess of one magnitude

40. True or false: Type Ia supernovae are primarily distinguished from Types Ib and Ic by their lack of an oxygen absorption line.
    a. True
    b. False

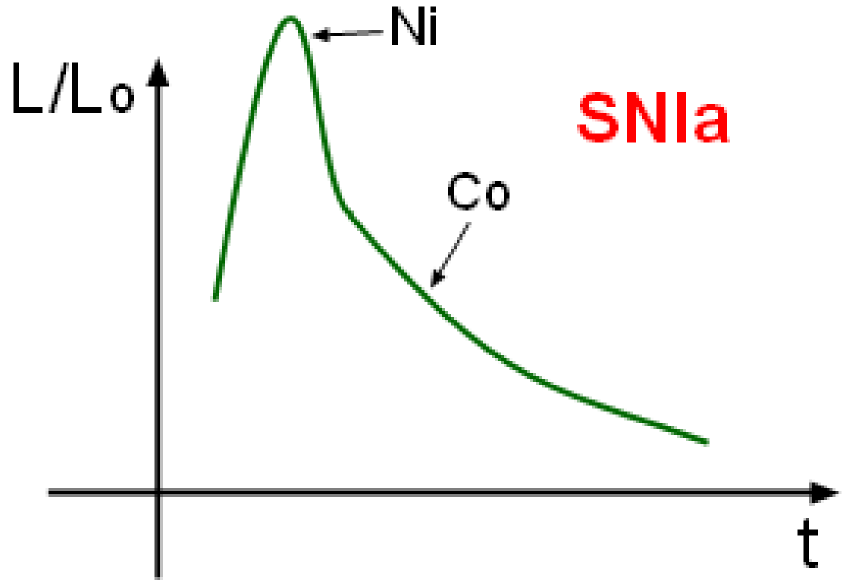
41. What role does electron degeneracy pressure play in determining the Chandrasekhar Limit?

42. Following neutronization, what must first occur before neutron drip begins in a newly-forming neutron star?

43. How do classical novae differ from dwarf novae?

44. How are DAV and DBV white dwarfs similar? How are they different?

45. How are millisecond pulsars formed?



46. The above image shows the standard light curve of a Type Ia supernova. Which elements dominate the spectra at peak luminosity? During decay? Why does this shift occur?

47. Why has the full death of a white dwarf never been observed?

48. Briefly describe how a carbon detonation event begins, and how it results in a Type Ia supernova.

49. How did planetary nebulae play a role in the chemical evolution of the Milky Way?

50. What is a Thorne-Żytkow object?

Team Number: ______ Team Name: ________________________________

Total Score:

Section Score:

Maryland Regional Event 2017 – Answers Section A

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Team Number: _____ Team Name: ______________________________

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Use the space below to continue any answers that do not fit on the lines given:

Team Number: ______ Team Name: ________________________________

Section Score:
/20

Maryland Regional Event 2017 – Answers Section B

31. ______ **32.** ______ **33.** _______ **34.** ______ **35.** ______ **36.** ______ **37.** ______

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Team Number: ______ Team Name: _____KEY_____________________

Total Score:

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Maryland Regional Event 2017 – Answers Section A

1. __Synchrotron radiation__

2. __ Standard candles are astronomical objects of known brightness used as indicators of astronomical distance. Being a Type Ia SNR, it is very common for such an object to be a standard candle.__

3. __3-1357__

4. __ Monotonic precessional motion or a more chaotic "wobbling", perhaps involving a companion object. __

5. __ Pease 1, in 1928__

6. __ The cluster's core is extremely small compared to the rest of it (~0.14' in angular diameter), but still contains half of the cluster's mass __

7. __ AM Canum Venaticorum variables (AM CVn). These objects consist of a white dwarf drawing material from a secondary compact companion __

8. __ As they age, the systems will produce gravitational waves, which will cause their orbits to gradually decrease. Upon reaching a certain minimum separation, the smaller, heavier white dwarf will begin to accrete material from its companion. Their most likely fate is as Ia supernovae (NOT Type Ia SNs!)__

9. __ Dwarf is HD 62166, resides in NGC 2440__

10. __ It suggests that the central white dwarf shed its outer mass several times throughout its lifetime, each time in a different outward direction.__

11. __ Cataclysmic variable__

12. __ It is bright, it is nearby, and it has a low hydrogen column density (few hydrogen particles between it and us)__

13. __ It is a double-shell planetary nebula, displaying two distinct shells of ejected material__

14. __ Observations have shown it to have unusually high levels of x-ray emission, suggesting an interaction between a pair of binary stars within the nebula __

15. __ Tycho G stands as the most likely candidate for the larger, main-sequence star that would have contributed the mass necessary to ignite its white dwarf companion into a Type Ia supernova__

Team Number: _____ Team Name: _____KEY_________________

16. __ It is thought that much of the energy of the expanding shock wave is going into the acceleration of atomic nuclei to near-light speeds__

17. __ The red ring bordering the object is optical data, while the bluish-green clouds contained within it are imaged in x-ray__

18. __ It is believed that this is the remnant of a white dwarf merger (double-degenerate) Type Ia supernova, confirmed by the absence of any central object in the remnant__

19. __ This is the youngest Type Ia supernova yet detected__

20. __ It will provide a particularly accurate measurement of the initial condition and evolution of Type Ia supernovae, resulting in more precise distance estimates for other Type Ia SNs__

21. __ The nebula is not the result of a single star, but rather of a binary system of two white dwarfs__

22. __This object will eventually end it life in a white-dwarf merger to produce a Type Ia supernova. This is the first documented case of a supernova candidate through white-dwarf merger.__

23. __ The star, Mira, is thermally pulsing every 10,000 years, with each causing it to increase in luminosity and thus pulse stronger than the previous time.__

24. __ The smaller companion on the left, Mira B, is accreting matter from the solar wind of its larger companion to form a protoplanetary disk.__

25. __ The stars that make up this system have a very high surface temperature__

26. __ Henize 2-428 (or any variation thereof)__

27. __Sirius B__

28. __ The brighter companion (a white dwarf) companion would likely begin accreting material from its enormous companion, eventually exploding in a Type Ia supernova__

29. __ Hubble Space Telescope__

30. __ The bubble represents a planetary nebula, the result of a Sun-like star at the end of its life. This would represent an enormous age disparity between it and the other stars in the globular cluster in which it is found, and possibly a second main-sequence-turn-off.__

Section Score: /20

Team Number: ______ Team Name: _____KEY_____________________

Maryland Regional Event 2017 – Answers Section B

31. __A__ **32.** __C__ **33.** __A __ **34.** __C__ **35.** __D__ **36.** __B__ **37.** __D__

38. __B__ **39.** __C__ **40.** __B__

41. __ In a main-sequence star, outward pressure due to nuclear fusion acts as a balancing force to gravity, preventing the star from collapsing. In white dwarfs, this balancing force is electron degeneracy pressure. The Chandrasekhar limit falls where enough mass has been added to the white dwarf that EDP is no longer sufficient to balance the force of gravity__

42. __ The minimum-energy arrangement of the neutronized nuclei in the star must result in some neutrons being found outside of the nuclei__

43. __ Classical novae are a result of fusion and detonation of hydrogen on the surface of the accretor, whereas dwarf novae are thought to be caused by instabilities within the accretion disk itself__

44. __ They are similar in that they are both compact white dwarf systems exhibiting variability. They are different regarding their spectra, where DAVs have only hydrogen absorption lines and DBVs have only helium ones.__

45. __ When in a binary system, a neutron star can accrete mass from its companion, which subsequently adds to the mass of the neutron star and increases its angular velocity to millisecond-level rotational speeds__

46. __ At the peak, Type Ia spectra are dominated by intermediate-mass elements ranging from oxygen to calcium, while after time they are dominated by heavier elements synthesized during the explosion. This is because initially, the detected light is coming almost exclusively from the outer layers of the explosion, where the lighter elements resided. The heavier elements, which were found near the core of the white dwarf, are buried in the erupted matter and only appear once the outer layers have faded to transparency__

47. __ The timeframe along which a white dwarf cools to the point of no longer emitting significant heat or light (i.e. a black dwarf) is longer than the current age of the universe__

48. __ When a white dwarf is created, it often contains carbon in its core. When it has accreted enough mass to pass the Chandrasekhar Limit, the white dwarf exerts enough pressure to fuse this carbon. This fusion releases heat, which is initially counteracted by electron degeneracy pressure, allowing for a runaway fusion process that continues until EDP is overpowered and the star erupts in a violent thermonuclear flare.__

49. __ Planetary nebulae eject elements forged in their parent stars deep into the interstellar medium, providing the materials necessary for stars to form, often of relatively high metallicity due to the nature of the ejected material__

50. __ A theoretical object in which a neutron star has collided with a larger star and embeds itself within it, orbiting its core__