San Joaquin County Regional Science Olympiad 2017 Astronomy 3-4-2017

Name_____ Name_____
School_____ Color_____

"When, according to habit, I was contemplating the stars in a clear sky, I noticed a new and unusual star, surpassing the other stars in brilliancy...There had never before been any star in that place in the sky...
I conclude, therefore, that this star is not some kind of comet or a fiery meteor... but that it is a star shining in the firmament itself, one that has never previously been seen before our time, in any age since the beginning of the world."—Tycho Brahe.

What's Tycho talking about? (1)_ **The supernova of 1572, which he famously observed and is named after him –Tycho's SNR__!!**

Bonus points !!: Who is this guy? What's he famous for? (In the world of astronomy he's famous for a lot of things, but I'm looking for something in the context of this year's topic) (2 points)

Instructions: Each team member is allowed a laptop OR a resource binder, as well as a programmable calculator. NO internet access. You may separate the test, but it MUST be re-stapled when you hand it in. Any missing sheets are just ....missing... and won't be graded. Tie breaker questions are noted.

I Multiple Choice (35 points, one per question). Circle the correct answer(s).

01. The amount of electromagnetic energy radiated from every square meter of the surface of a blackbody each second is

a. proportional to temperature.
b. inversely proportional to temperature.
c. proportional to temperature to the fourth power.
d. inversely proportional to temperature to the fourth power.
e. Both a and c above

02 Stars in the upper right part of the Hertzsprung-Russell diagram are always _____ when compared to stars near the middle of the diagram.

a. cooler
b. brighter as seen from Earth
c. larger and cooler
d. smaller and hotter
e. more massive

03. The B - V color index of a star indicates its

a. density.
b. total mass.
c. radius.
d. chemical composition.
e. surface temperature

04. The spectral classes from coolest to hottest stars are

a. MKGFABO
b. ABFGKMO
c. BOFGAKM
d. OBAFGKM
e YRWEHERE

05. The absolute magnitude of a star is: (1)

A. its apparent brightness in Watts per unit area
B. its apparent magnitude if it were seen from a distance of ten parsecs
C. the maximum mass the star will achieve in its lifetime in kg
D. the "wobble" measured due to the gravitational pull of its planets
E. its intrinsic luminosity in Watts

06. Why are astronomers much more interested in the luminosity of a star than its apparent brightness?

a. because luminosity can be measured exactly, but apparent brightness can only be roughly estimated
b. because the luminosity tells us how bright a star really is, while apparent brightness only tells us how bright it happens to look from Earth
c. because the luminosity also tells us what elements the star is made of, while apparent brightness cannot tell us a star's chemical makeup
d. because luminosity can tell us how bright it is inside the star, while apparent brightness only tells us about its outside layers
e. you can't fool me, there is no difference between luminosity and apparent brightness; they are merely different terms for the same property of a star

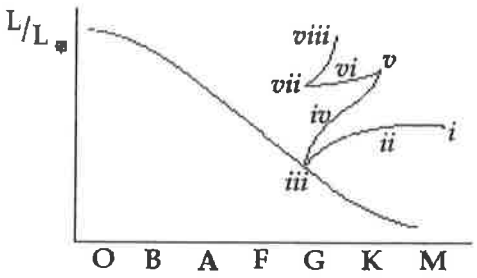
07. How is a luminosity class assigned to a star?

a. By combining the apparent magnitude with the star's parallax.
b. By measuring the period of variability in the star's apparent magnitude.
c. By studying the absorption lines in the spectrum of the star.
d. By observing the angular size of the star's image in a photograph or digital image.

08. Compared with the spectral lines in a super giant's spectrum, the lines in a main sequence star's spectrum are:

a. are more narrow.
b. are broader.
c. weaker.
d. stronger.
e. b & c

Questions 09-15 refer to the H-R diagram below that shows the life track of a low mass star like the sun, with various stages labeled with Roman numerals.



09. During which stage is the star's energy supplied by gravitational contraction?

A) ii
B) iii
C) v
D) vi
E) viii

10. During which stage does the star have an inert (nonburning) helium core?

A) iii
B) iv
C) vi
D) vii
E) viii

11. During which stage does the star have an inert (nonburning) carbon core?

A) ii
B) iii
C) iv
D) vi
E) viii

12. Which stage lasts the longest?

A) i
B) iii
C) iv
D) vi
E) viii

13. What will happen to the star after stage viii?

A) It will explode in a supernova.
B) It will begin burning carbon in its core.
C) It will eject a planetary nebula.
D) It will collapse to make a neutron star.
E) It will gain mass until it collapses under its own weight.

14. In the end, the remaining core of this star will be left behind as

A) a white dwarf made primarily of carbon and oxygen nuclei and degenerate electrons.
B) a white dwarf made primarily of silicon and iron nuclei and degenerate matter
C) a neutron star.
D) a black hole.
E) a supernova.

15. If this star was more massive than the sun with an A spectral class, its end stage would be:

A) a non-degenerate white dwarf
B) a neutron star
C) a non-degenerate Helium-core star
D) a Herbig Ae Be star
E) a Wolf-Rayet star

Tie breaker 1: This type of star can be a component of which type of object on this year's Deep Sky Object list?

16. What is a planetary nebula?

A) a disk of gas surrounding a protostar that may form into planets
B) what is left of the planets around a star after a low-mass star has ended its life
C) the expanding shell of gas that is no longer gravitationally held to the remnant of a low-mass star
D) the molecular cloud from which protostars form
E) the expanding shell of gas that is left when a white dwarf explodes as a supernova

17. A planetary nebula

a. produces an absorption spectrum.
b. produces an emission spectrum.
c. is contracting to form planets.
d. is contracting to form a star.
e. is the result of carbon detonation in a 1 $M_{\odot}$ star.

18. Compared to the star it evolved from, a white dwarf is

A) hotter and brighter.
B) hotter and dimmer.
C) cooler and brighter.
D) cooler and dimmer.
E) the same temperature and brightness.

19. What mechanism does an isolated white dwarf use to generate energy?

a. Proton-proton chain
b. CNO cycle
c. Triple alpha process
d. White dwarfs don't generate their own energy.

20. As a white dwarf cools its radius will not change because

a. pressure due to nuclear reactions in a shell just below the surface keeps it from collapsing.
b. pressure does not depend on temperature for a white dwarf because the electrons are degenerate.
c. pressure does not depend on temperature because the white dwarf is too hot.
d. pressure does not depend on temperature because the star has exhausted all its nuclear fuels.
e. material accreting onto it from a companion maintains a constant radius.

21. If a binary star system contains a main sequence star and a white dwarf, which star was originally the least massive?

A. the main sequence star
B. the star that produced the white dwarf
C. the currently most massive star
D. the currently least massive star

22. Cataclysmic variables consist of a mass-losing star, a transfer stream of mass, a hot spot, a white dwarf and:

A. a supernova
B. an Algol star
C. an accretion disk
D. magnetic fields

23. When material expanding away from a star in a binary system reaches the Roche surface

a. the material will start to fall back toward the star.
b. all of the material will accrete on to the companion.
c. the material is no longer gravitationally bound to the star.
d. the material will increase in temperature an eventually undergo thermonuclear fusion.
e. c and d

24. The _____ are places in the orbital plan of a binary star system where a bit of matter can reach stability. The one located directly between the two stars is the point where the Roche lobes meet.

a. turnoff points
b. horizontal branch
c. Lagrangian points
d. synchrotron points
e. radiation belts

25. As mass is transferred through the inner Lagrangian point in a binary system toward a white dwarf, the material forms a rapidly growing whirl-pool of material known as a(n)

a. accretion disk.
b. Lagrangian reservoir.
c. Algol paradox.
d. planetary nebula.
e. supernova remnant.

26. A nova is almost always associated with

a a very massive star.
b. a very young star.
c. a star undergoing helium flash.
d. a white dwarf in a close binary system.
e. a solar like star that has exhausted its hydrogen and helium

27. If the theory that novae occur in close binary systems is correct, then novae should

a. produce synchrotron radiation.
b. occur in regions of star formation.
c. not occur in old star clusters.
d. all be visual binaries.
e. repeat after some interval.

28. A Type Ia supernova is believed to occur when

a. the core of a massive star collapses.
b. carbon detonation occurs.
c. a white dwarf exceeds the Chandrasekhar limit.
d. the cores of massive stars collapse.
e. neutrinos in a massive star become degenerate and form a shock wave that explodes the star.

29. Why do astronomers think Type Ia supernovae explode in binary star systems?

A. all white dwarfs are in binary systems
B. a white dwarf must gain mass to trigger the explosion
C. accretion disks require a mass-losing star
D. gravitational radiation requires two stars

30. White-dwarf supernovae are good standard candles for distance measurements for all the following reasons except which?

a. All white-dwarf supernovae involve the explosion of stars of nearly the same mass.
b. White-dwarf supernovae occur only among young and extremely bright stars.
c. White-dwarf supernovae are common enough that we detect several every year.
e. All white-dwarf supernovae have similar light curves, which makes them easy to distinguish from massive-star supernovae.
f. White-dwarf supernovae are so bright that they can be detected even in very distant galaxies.

31. Which of the following statements about a globular cluster is true?

A) All stars in the cluster are approximately at the same stage in evolution.
B) Most of the stars in the cluster are younger than 10 billion years old.
C) All stars in the cluster have the same chemical composition
D) All stars in the cluster have approximately the same mass.
E) There is an approximately equal number of all types of stars in the cluster.

33. The metal poor stars typical of a globular cluster are called what type stars?

a) Population II
b) Population III
c) Population I
d) Population IV
e) Population V

34. What do we mean by the main-sequence turnoff point of a globular cluster, and what does it tell us?

A) It is the point in a star cluster beyond which main-sequence stars are not found, and it tells us the cluster's distance.
B) It is the spectral type of the hottest main-sequence star in a star cluster, and it tells us the cluster's age.
C) It is the luminosity class of the largest star in a star cluster, and it tells us the cluster's age.
D) It is the mass of the most massive star in the star cluster, and it tells us the cluster's size.

35. Star cluster are important to our study of stars because

a. all stars formed in star clusters.
b. the sun was once a member of a globular cluster.
c. they give us a method to test the our theories and models of stellar evolution.
d. they are the only objects that contain Cepheid variables.
e. all of the above

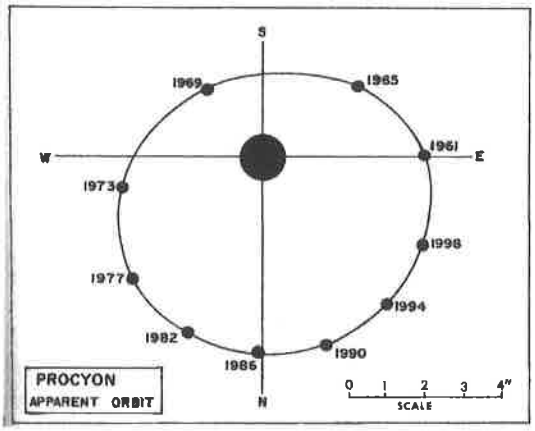
II Calculations (show all work for partial credits)

1. A star has an apparent magnitude of +6 and has a parallax of 0.0066 arc sec. If the star is on the main sequence, what is the spectral type of the star? (8)

2. A certain star has a temperature twice that of the sun and a luminosity 64 times greater than the solar value. What is it's radius in solar units? (5)

3. The drawing below depicts the orbit of the Procyon system, a binary system comprised of a spectral class F5 main sequence star and an extremely faint white dwarf (This is quite similar to Sirius).
For the purpose of this problem, assume that we are observing this orbit face-on. The parallax to this system has been measured to be $\pi = .286$ arc sec. (15)

A. Calculate the mass of the system. (10)



a. What is the period of Procyon's orbit?

b. What is the apparent angular size of the semi-major axis?

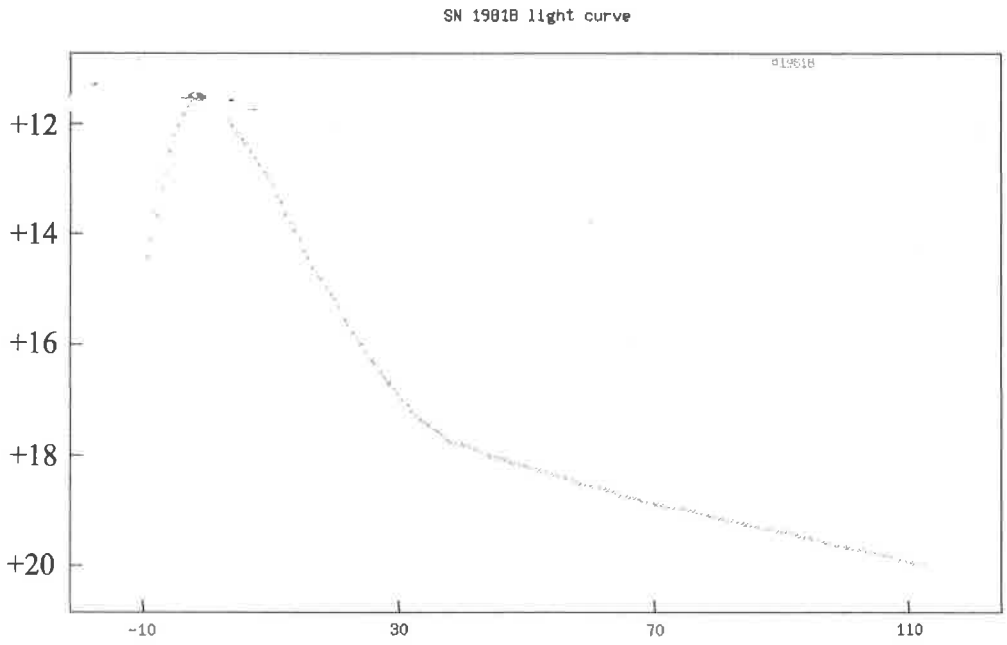
c: What is the distance to Procyon?

d: What is the linear size of the semi-major axis? Express your answer in Astronomical Units (AU).

e: What is the total mass of both stars in the Procyon system, in terms of solar masses?

B. The stars have radial velocities of 15km/s and 25 km/s. What are the individual masses of the stars? (10)

4 Type Ia Supernova light curve (10)

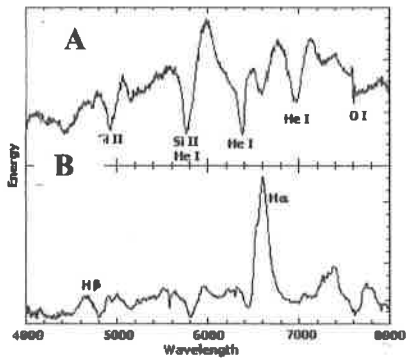


(A) What is the typical absolute magnitude of this type of star?

(B) What is the maximum apparent magnitude of this star.

(C) Calculate distance in light years from the Earth to this star.

(D) Which of these spectra could be from this star? Why?



(E) Recent studies using supernovae show that the rate of the expansion of the universe is due to something astrophysicists call .

III SKETCH PROBLEM (30 points) Please draw a sequential diagram of the evolution of a double degenerate Type 1a Supernova progenitor system, beginning with a pair of main sequence stars. The diagram should show the evolution of the system from the main sequence to its final state. Please identify the different evolutionary stages of the stars in the system, and where appropriate note the corresponding deep sky objects from this year's official list on the diagram. For full credit, show two possible endings for this system. And indicate why these might occur.

IV Identification and Short Answer (points shown) Refer to image sheet at end of exam.

1. **1A.** Which image shows the x-ray light curve of an "Ultra-Short Period Double-Degenerate Binary System"? (1)__ **Image** . What is this system's name ? (1) __

What wavelength is represented in the light curve? (1)___ ___. What is the system's period?

1B. This system is composed of two (1) __ in a close orbit.

1C. Based on your knowledge of this system, is it also an example of a "super-Chandrasekhar double-degenerate system? Briefly describe why or why not and how an astronomer might come to this conclusion.(3)

1D. (1) _ predicts that a binary star system such as this should emit (1)__ _____ which rush away at the speed of light and transport out of the system, causing the the stars to (1) __ ___.

2. **2A** Image 11 shows a binary star system whose primary is the prototype for a specific type of variable star. What is the name of the star (1) _
What type of variable star is it? (1) ___ __ What are the components of the system itself ? (1)

2B Which image shows the light curve of the variable star? (1) ___**Image** _____.
What is its period (1)? _ _____.

2C This type of variable star is a (1) _ __ in the very late stages of stellar evolution, on the (1) _ _____ branch.

2D Astronomers believe this system is a leading candidate for the (1) model of Type 1a supernova progenitor.

2E Which image shows the result of this star plunging through the ISM at ~130 km/s? (1) _ __

2F Where does the material in the "tail" come from, and how is it formed? (3)

3. **3A.** Which image shows a planetary nebula in the Gemini constellation? (1) _ **image** __Name this planetary nebula (1) _ _____.

3B Describe the process by which a "planetary nebula" is formed: (3)

3C What do astronomers think caused the complex filamentary structures in this nebula? (2)

3D This is a composite image created using data from Hubble and Chandra. What color(s) are represented by the Chandra data? (1) What does the Chandra data show? (2)

3E What might account for this unusual data and what does this suggest to astronomers about the nature of the object? (3)

4. **4A** Image 8 shows the HR diagram of NGC 1846. What type of object is NGC 1846? (1)

_ _.

4B What is peculiar about the diagram and how does it differ from those of typical examples of this type of object? (3)

4C A planetary nebula has been discovered in NGC 1846. Why is this unusual? (3)

4D How do astronomers think that NGC1846 actually formed ? What characteristics of the stars in This object led the astronomers to these conclusions? (3)

5. **5A.** Which object is shown in image 7? (1) _____.
What type of object is this? (1) _____.

5B Chandra observations of the x-ray emissions of this object (as revealed in the image) indicate that the explosion that created this object was likely highly non-uniform and unusually energetic. What do they think happened here? What do they call this type of explosion? (3)

Researchers believe what happened in G1.9+0.3 is a "delayed detonation," where the explosion occurs in two different phases. First, nuclear reactions occur in a slowly expanding wave front, producing iron and similar elements. The energy from these reactions causes the star to expand, changing its density and allowing a much faster-moving detonation front of nuclear reactions.

6. **6A** Which image shows the light curve of a dwarf nova? (1) **Image** _____.
Which object is associated with this light curve? (1) _____. This object is considered the prototype of a subclass of dwarf novae known as(1)_____ stars.

6B As a cataclysmic variable star, this system is composed of a (1)_____ primary in a close orbit with a (1) _____ that has filled it's (1)_____.The strong gravity of the primary pulls material from its companion into a swirling (1)_____.

6C Briefly outline the favored theory of how the outbursts from this star are formed. Include the name of the theory.(4)

7. **7A** (1 point) Which image shows SNR 0509-67.5?

7B (3 points) Astronomers have recently observed and analyzed the original spectra of this supernova and determined that it was a Type 1a supernova. How did they do this, since the original supernova was visible about 400 years ago, but was unobserved at the time?

7C (4 points) Astronomers believe that the progenitor for this Type 1a supernova was a **double degenerate** system. Briefly describe the components of this type of progenitor system, as compared to the other commonly accepted system.

7D (2 points) How did astronomers come to this conclusion?

8. **8A.** (3 points) Which image shows the Chandra image of the Dog Star and it's "pup" ? **Image**
The "pup" is more commonly known as: which is a:

8B (5 points) Briefly describe how the 19th century astronomer Friedrich Bessel inferred the presence of the "pup" in this binary system. Be sure and include the name for this type of binary system.

8C (3 points) The Dog Star is known as the brightest star in the sky. Yet in the Chandra image, it is very dim while the "pup" appears very bright. Based on your knowledge of these stars and their places on the HR diagram, explain why this is so.

9. 9A (5 points) What is the Hubble law? What is the difference between the Doppler effect and cosmological redshift?

9B Which University of California (Berkeley) Astrophysicist shared the 2011 Nobel Prize in Physics *"for the discovery of the accelerating expansion of the Universe through observations of distant supernovae"*. (1)

A. Alex Filipenko
B. Saul Perlmutter
C. Gibor Basri
D. Peter Nugent

9C Briefly explain the science behind this discovery. (4)

10. **10A** Which Image shows Henize 3-1357 (the Stingray Nebula) (1) **Image**

10B What type of object is this? (1)

10C Briefly describe the observed evolution of this object and it's central star over the past 40 years or so: (5)

10E What is unusual about this behavior and what do astronomers think caused it? (4)

10D What is the name of the central star?(1) (tie breaker # 2)

11. **11A** Which object is shown in image 6 ? (1) . What type of object is it? (1)

11B This object has been termed "the first unequivocal determination of a super-Chandrasekhar double-degenerate system". Describe this system, and its importance.

12. **12A** Which image shows Tycho's Supernova Remnant (SN 1572)? (1) **Image** This supernova was first visible in 1572, and subsequently faded from view. It was rediscovered in the twentieth century, using wavelengths.(1) This particular image was created using data gathered by which of the NASA's Great Observatories? (1)

12B Using the same method used to determine the nature of SNR 0509 +.03. astronomers have confirmed that this object was a (1) What specific spectral information led them to this conclusion ?

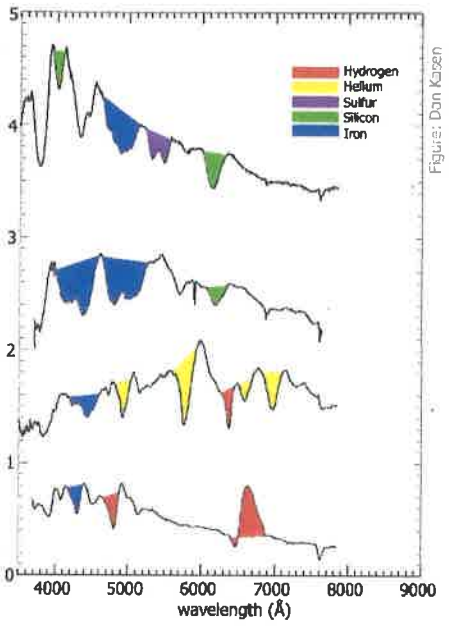
12C In 2004, astronomers made a significant discovery about Tycho's SNR. What was it and what is the strongest evidence supporting this discovery?(2) What does this suggest about the nature of SN1572's progenitor.(1)

13. **13.** **13A** Which Image shows an AM CVn system? (1) **Image** What does the acronym stand for (they're named after their type star)? (1) Be honest, can you pronounce it?

13B These systems consist of two white dwarfs in a binary system. Looking at the image, which one is more massive, the small one or the big one? (1) Support your answer (no pun intended) (3)

13C Describe these AM CVn systems. How do they work (3) and what are two possible end results for them? (3)

14. **14A** The image below illustrates the spectra of different types of supernovae. Please identify (by circling) which spectrum corresponds to a Type 1a SN (1).



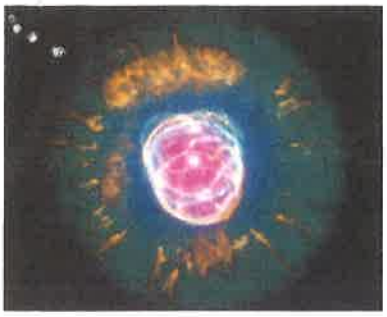
14B What are the specific spectral features that distinguish Type Ia supernovae from other types.(2)

What is another fundamental criteria for Type 1a supernova? (1)

14C there is currently great debate as to the possible progenitors for a Type 1a supernova. Please identify and describe the two leading progenitor models. (2)

14D Describe some of the evidence for each model (6)

2017 SJ Regional Astronomy Image Sheet



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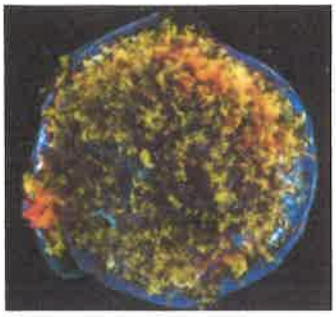

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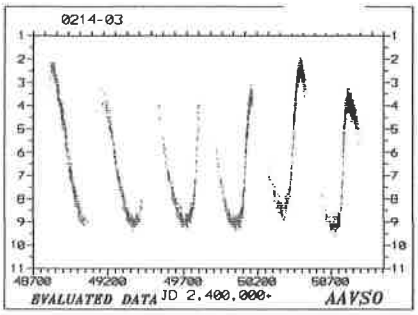

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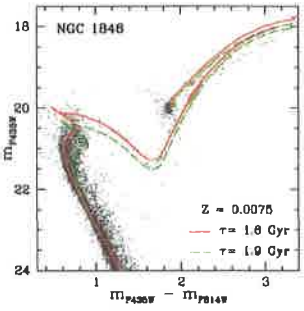

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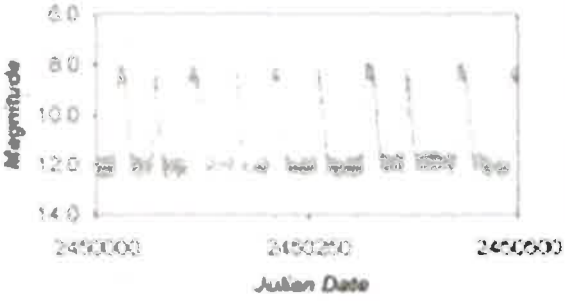

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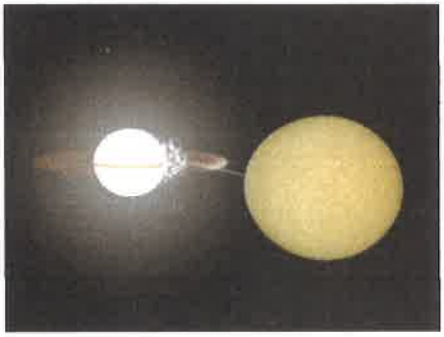

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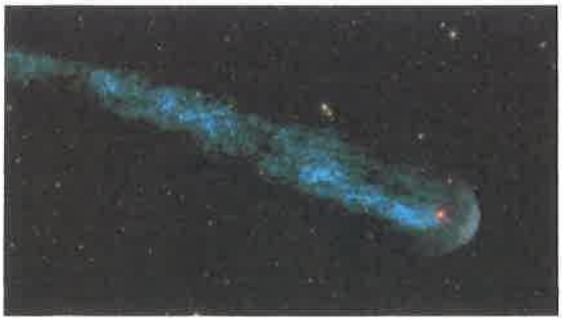

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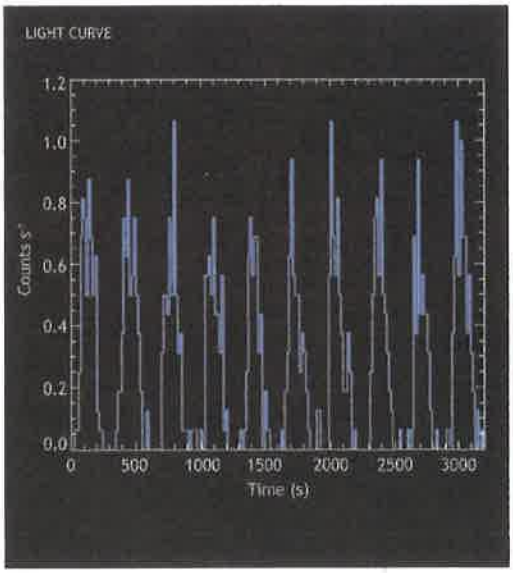

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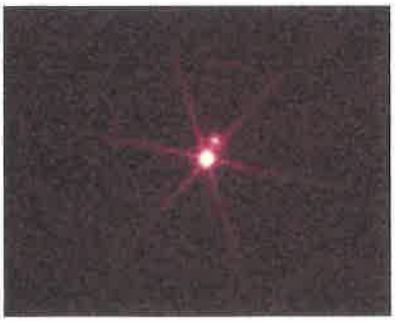

14.