Brentwood Science Olympiads Astronomy Exam 2019:

*The following exam was produced by coaches and students at Brentwood HS. Contributors: Josiah Sarceno, Alyssa Crespo, Bahvig Pointe, and Conrad Schnakenberg.

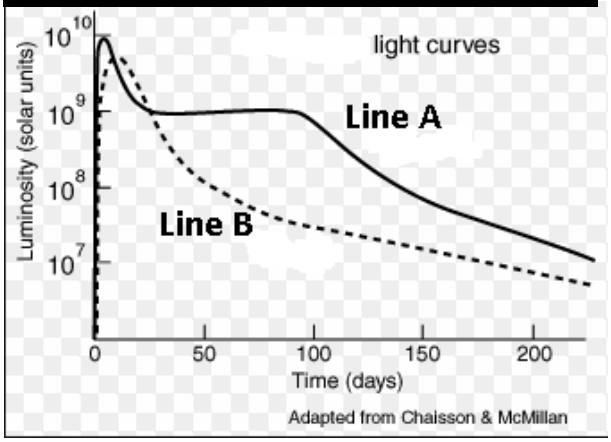
**The Math Section is used primarily to BREAK TIES.*

ASTRONOMY QUESTIONS IN
STELLAR EVOLUTION IN NORMAL AND STARBURST GALAXIES

Short Response Section Part I: All Questions worth 1pt:

1) What is the name of this galaxy?

a. IC 10
b. NGC 5128 (Centaurus A)
c. Messier 82
d. SN 2014 J



2) What do the light curves for "Line A" and "Line B" represent?

a. Line A is a RR Lyre Variable Star, but Line B is a Classical Cepheid Variable Star.

b. Line A is a Type I Supernova, and Line B is a Type II Supernova.

c. Line A is a Type II Supernova, and Line B is a Type I Supernova.

d. Both are Type Ia Supernova, but Line A is between a White Dwarf and a Red Giant. Line B is a collision between two White Dwarf stars.

3) What is the Chandrasekhar limit? What is its significance?

a. 9.4607×10^{12};Maximum solar mass of a white dwarf before it collapses
b. 1.4; Light years between the Milky Way Galaxy and Andromeda Galaxy
c. 9.4607×10^{12};Light years between the Milky Way Galaxy and Andromeda Galaxy
d. 1.4; Maximum solar mass of a white dwarf before it collapses

4) What is the Tully-Fisher relation?

a. Cyclic pattern of luminosity for a Type II Cepheid Variable
b. Relationship of size of type 2 supernovae to luminosity
c. Relationship of predicted number of red giant stars in a galaxy dependent on the galaxy's history of supernova activity
d. Relationship between mass or luminosity of a spiral galaxy and asymptotic rotation velocity or emission line width

5) What is this? (picture immediately to the right)

a. Sagittarius A*
b. Chandra deep field-south
c. Phoenix Cluster
d. IC 10

6) What is the name of a galaxy undergoing an exceptionally high rate of star formation?

a. hyper-stellar galaxies
b. starburst galaxies
c. ultraluminous galaxies
d. chaos emeralds

7) Why is SN2014J special?

a. It is the only type 1a supernova ever recorded to have contained both Boron and Krypton
b. It was the closest type 1a supernova discovered in decades
c. It predates the age of the universe
d. It is the largest type 1a supernova ever recorded in the Milky Way Galaxy

TRUE OR FALSE SECTION

8) A black hole is an ideal black body.

a. True
b. False

9) Planck's Law states that the velocity objects in speed move away from each other is proportional to their size.

a. True
b. False

10) RR Lyrae stars are used to measure extragalactic distances.

a. True
b. False

11. What is stellar evolution?

A. The later stage of a high-mass star.

B. A gigantic explosion in which a high-mass star throws its outer layers into space.

C. The process by which a star changes during its lifetime.

D. The actual brightness of an object.

12. What is a supernova?

A. An object whose gravity is so strong that nothing can escape.

B. A gigantic explosion in which a high-mass star throws its outer layers into space.

C. A measure of a star's color, which tells us how hot the star's surface is.

D. Emission nebulae composed of hydrogen.

13. What is the chemical composition of our Sun?

A. 25% hydrogen, 2% helium, 73% other elements.

B. 73% hydrogen, 25% helium, 2% other elements.

C. 50% helium, 23% hydrogen, 27% other elements.

D. 73% hydrogen, 2% helium, 25% other elements.

14. Who discovered M51?

A. Edwin Hubble.

B. William Parsons.

C. Charles Messier.

D. Canes Venatici.

15. What is another name for M51a?

A. **The Whirlpool Galaxy.**

B. SPT 0346-52.

C. IC 10.

D. M81.

16. Which galaxy is closest to NGC 5195?

A. Cen A.

B. ESO 137-001.

C. M100.

D. M51

17. Whose theory is this: "the observations that the father away a galaxy is, the faster it is moving away"?

A. Hubble.

B. Kepler.

C. Galileo.

D. Copernicus.

18. What is the proper order of the <u>Increasing</u> luminosity of stars?

A. Hypergiants-Supergiants-Bright Giants-Giants.

B. Giants-Bright Giants-Supergiants-Hypergiants.

C. Giants-Supergiants-Bright Giants-Hypergiants.

D. Bright Giants-Giants-Hypergiants-Supergiants.

19. Which policy does this belong to: "a solution of the Einstein-Maxwell equations in general relativity that describes the spacetime geometry in the region surrounding a charged, rotating mass"?

A. General relativity.

B. Reissner-Nordstrom metric.

C. The Eddington limit.

D. Kerr-Newman metric.

20. Gravitational Waves are:

A. the only type of Energy waves capable of exceeding the speed of light in a vacuum.

B. energy waves only detectable by indirect means, such as the timing variations of pulsar systems.

C. Detectible when black holes converge, enter a decaying orbit, and finally merge.

D. First Observed with **GW150915**

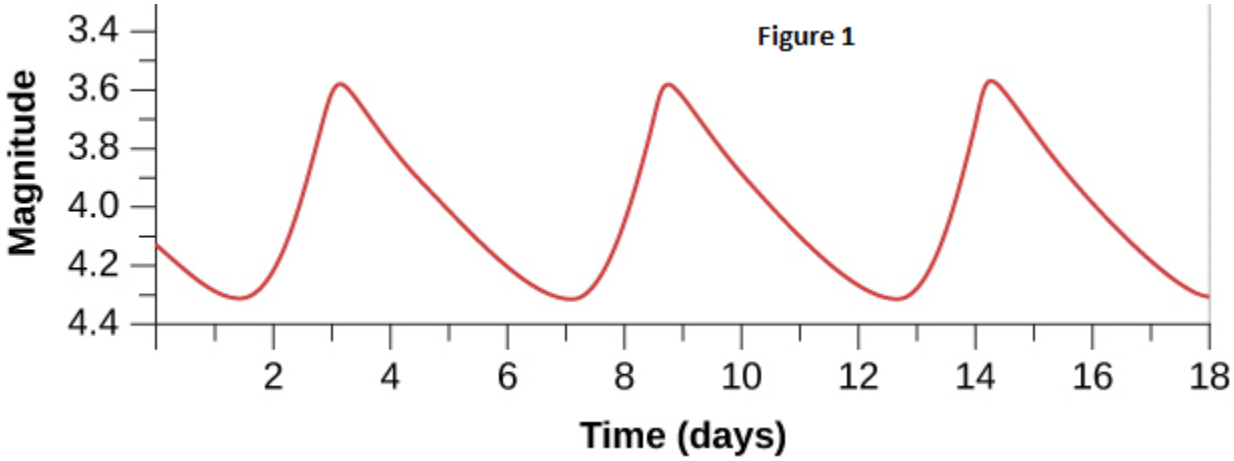
21) **A star (no matter what its mass) spends most of its life:**
A) as a protostar.
B) as a main sequence star.
C) as a T Tauri variable star.
D) as a red giant or supergiant.

22) **The Chandrasekhar mass limit is**
A) .08 solar masses.
B) .4 solar masses.
C) 1.4 solar masses.
D) 3 solar masses.

23) **What temperature is needed to fuse helium into carbon?**
A) 5,800 K
B) 100,000 K
C) 15 million K
D) 100 million K

24) **An iron core cannot support a star because**:
A) iron is the heaviest element, and sinks upon differentiation.
B) iron has poor nuclear binding energy.
C) iron cannot fuse with other nuclei to produce energy.
D) iron supplies too much pressure.

Please use “figure 1” for the next several questions:



25) **What is the Period of this Variable Star (figure 1):**

a) **5.7 days** c) 5.3 days e) 6.00 days
b) 4.4 years d) 3.4 years

26) **What is the average apparent magnitude of this Variable Star (figure 1):**

a) 4.3 c) 7.8 **e)3.9**
b) 4.0 d) 4.1

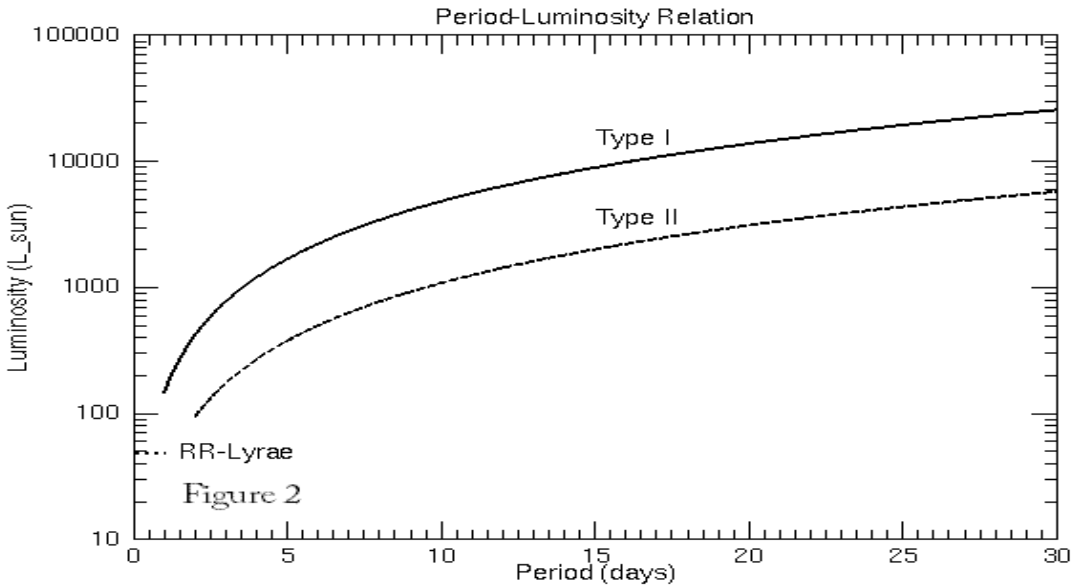


Figure 2

Use Figure 2 to help with the next two questions.

27) **Star “X” is a metal rich variable with a period of 5.0 days. What is its approximate Luminosity?**

a) 1000 (L_Sun) b) 300 (L_Sun) c) 400 (L_Sun) **d) 2000 (L_Sun)**

28) **Star "Y" is a Low Mass and metal poor variable with a period of 5.5 days. What is its approximate *Absolute Magnitude*?**

a) 300 (L_Sun) b) +6.98 **c) -1.66** d) 400 (L_Sun)

29) **Star "Z" has an apparent magnitude of -0.3 and an absolute magnitude of 4.1. What is its approximate *distance from us in light years?***

a) 1.3 b) 3.8 **c) 4.2** d) 4.4

30) **In terms of both Luminosity and Temperature- compare a Solar mass main sequence star to a white dwarf star.**

a) Both have the same temperature, but the white dwarf star has less visual absolute magnitude.

b) The White Dwarf Star has more temperature, but much less luminosity to the main sequence star.

c) The Solar mass Main Sequence star has more mass, and also greater luminosity than the smaller white dwarf star.

d) The Solar mass main sequence star will evolve into a white dwarf after passing the Red Giant Phase.

e) The star's spectral class changes from G to F.

31) **A G2 spectral type Star will mostly directly decay into which stellar remnant:**

a) Carbon-Oxygen White Dwarf c) Black Dwarf e) Black Hole

b) Oxygen-Neon-Magnesium White Dwarf d) Neutron Star

32) **A main sequence star of 28 Solar Masses will most directly decay into which stellar remnant:**

a) Carbon-Oxygen White Dwarf c) Black Dwarf e) Black Hole

b) Oxygen-Neon-Magnesium White Dwarf **d) Neutron Star**

33) **A main sequence star with an apparent magnitude of -3.2 and a distance of 1000 parsecs would most likely decay into which stellar remnant:**

a) Carbon-Oxygen White Dwarf c) Black Dwarf **e) Black Hole**

b) Oxygen-Neon-Magnesium White Dwarf d) Neutron Star

34) **A Red Giant star of 9 Solar Masses will most likely decay into which stellar remnant:**

a) Carbon-Oxygen White Dwarf
c) Black Dwarf
e) Black Hole
b) Oxygen-Neon-Magnesium White Dwarf
d) Neutron Star

35) **A star of approximately the same diameter of the Earth and a temperature of 10,000 K will most directly decay into which type of stellar remnant**:

a) Carbon-Oxygen White Dwarf
c) Black Dwarf
e) Black Hole
b) Oxygen-Neon-Magnesium White Dwarf
d) Neutron Star

36) **For a large mass star, place the "fuel" elements in order from the longest "burning" to those that are used up in Fusion Processes more quickly:**

a) Hydrogen, Helium, Argon, Neon, Iron

b) Hydrogen, Helium, Oxygen, Neon, Carbon, Magnesium, Silicon

c) Hydrogen, Helium, Silicon, Argon

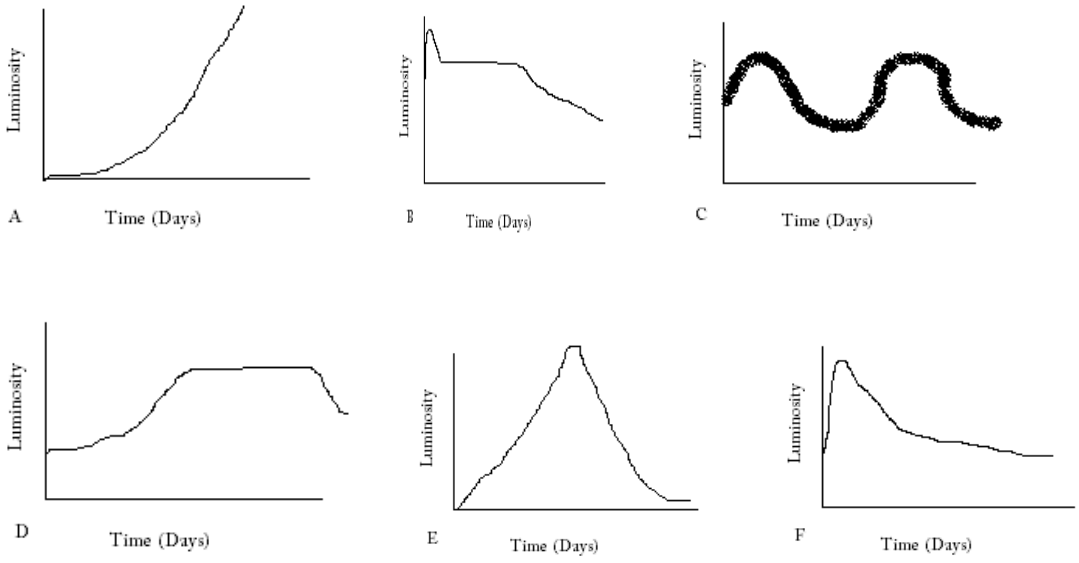
d) Hydrogen, Oxygen, Helium, Neon, Iron

e) Hydrogen, Helium, Carbon, Oxygen, Neon, Magnesium, Silicon.

37) **What is a "Strange Star"?**

a) A proven form of degenerate matter which exists between Neutron Stars and Black Holes.
b) Theoretical type of degenerate matter in which the star consists entirely of Quarks.
c) A theoretical hybrid of a neutron star and a quark star; a core of "strange quarks" is surrounded by a shell of Neutrons.
d) Another name for a Preon Star.
e) A temporary stable form of a "Black Hole" which persists for several thousands of years before final collapse due to neutron degeneracy pressure.

38) **Which graph (most) correctly depicts a typical Type II Supernovae event for our Galaxy: B**



39) **If the theoretical *Helium White Dwarf* star were to be discovered, what would that prove?**

a) It would show that the universe is much older than we currently think it is.

b) That the *Carbon-Oxygen* model for the Sun's progress into degenerate matter is invalid.

c) It would provide conclusive proof that the *Big Bang* theory is correct

d) That the gravitational upwelling of a *White Hole* actually exists as a counter to *Black Holes.*

e) It would verify the Khazzoom-Brooke's postulate.

f) That *Helium* the main product of *Hydrogen Fusion* in a stellar core.

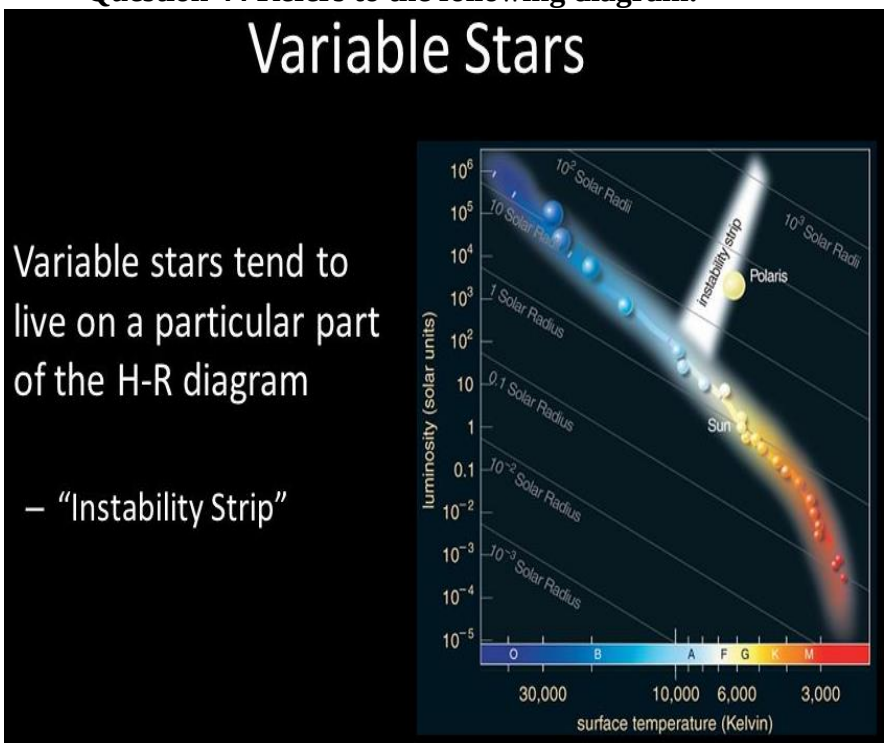
40) **Virtually all the carbon-rich dust in the plane of the galaxy originated in**
A) low-mass stars.
B) high-mass stars.
C) planetary nebulae.
D) white dwarfs.
E) brown dwarfs.

41. What is the line along which Protostars move in the H-R diagram?
a. Celsius Line
b. Initial Phase Line
c. Hayashi line
d. Tauri Line

42. Which of these is a believed process for the creation of stars in a starburst galaxy?
A. Tidal interactions
B. Galaxy mergers
C. The presence of a galactic bar
D. All of the above - they all result in the accumulation of substantial amounts of gas and dust in the central regions of the galaxy, resulting in rapid star creation

43. A white dwarf will eventually cool down to a _____
A. Protostar
B. Nebula
C. Brown Dwarf
D. Black Dwarf

Question 44 Refers to the following diagram:



44. What types of stars would you find at the top of the instability strip shown in the HR diagram shown above?
a. W Virginis Stars
b. Wolf-Rayet Stars
c. RR Lyrae Stars
d. Cepheid Variables

45. What is the defining characteristic of starburst galaxies?
a. Accelerated star development
b. Decelerated star development
c. Classified as irregular systems
d. Lack of tenuous gas/intergalactic medium

Math Section Part II: *For each question in this section show ALL work. State all equations. Simply writing the correct answer will not give you maximum credit. Each question is worth up to 4 points and it is THIS section which is used to break ties.

46. A star has an absolute magnitude of 4.5 and a distance of 5 parsecs. Calculate the apparent magnitude of the star.

Converting between absolute and apparent magnitude

$$m - M = 5 \log \left(\frac{d}{10} \right)$$

m => apparent magnitude of the star
M => absolute magnitude of the star
d => distance between the star and the earth

$m - M = 5 \log d - 5 \log$

m-M = 5logd10
m-4.5 = 5log510
m = 5log510+4.5 =
2.99485...3 magnitudes

47. What is the period of a satellite orbiting earth that has a semi-major axis length of 40 km?

The square of a satellite's period is directly proportional to the cube of the length of its semi-major axis

Newton's version of Kepler's Third Law p2= 42GMa3
If the units are as follows:
T = Earth years
A = Astronomical Units (aka AU, based on a = 1 AU for Earth)
M = solar masses
Then 42GM=1, and the equation can be expressed as follows:
p2=a3

Plugging the given values we get…

p2= a3
p2=(40)3
p2= 64000
p = 252.9822...253 years

48. Galaxy NGC 4442 is 120 Mpc away. If the Hubble Constant is 68 km/s/Mpc, how fast should NGC 4442 be moving due to the expansion of the Universe?

Hubble's Law: $V_r = Hd$
V_r : Velocity Recession of Gravity
H : 20 km/s/Mpc (Mpc - megaparsecs)
D : Distance (Mpc)

v = 68 120 = 8200 km/s

49. An absorption feature of calcium usually has a wavelength of 3934 Å, but it is observed in a galaxy to have a wavelength of 4002 Å. How fast is this galaxy moving, and is it moving towards or away from you?

Doppler Shift: v= c/

C : Speed of light (3108m/s)
: Shift in the wavelength of a feature in the spectra (Measured in Angstroms)
: Actual Wavelength of Feature (Actual Angstroms)

= 4002 - 3934 = 68 Å.

Since this is a positive value, the object is moving away from us. Now you can plug the values into the formula -
v= c/
v = 3.0 x 10^{5} x 68 / 3934
v = 2.04 x 10^{7}/3934
v = 5186 km/s

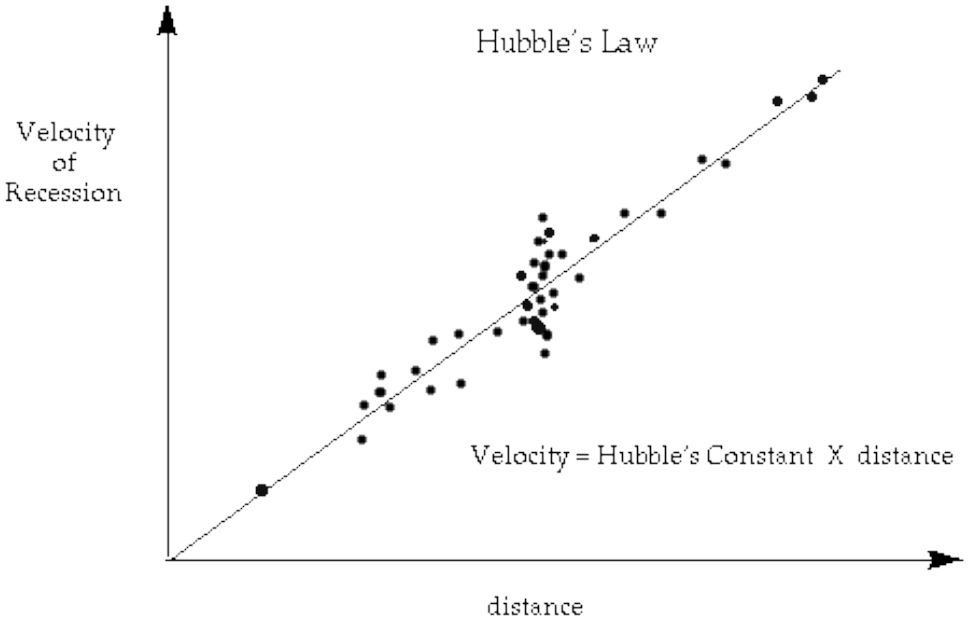
50. An absorption feature of calcium usually has a wavelength of 3934 Å, but it is observed in a distant galaxy to have a wavelength of 8209 Å. What is the redshift?

Red Shift: z = / (Same as Doppler Shift, but we skip the last step of calculating velocity)

~~C : Speed of light (3108m/s)~~
: Shift in the wavelength of a feature in the spectra (Measured in Angstroms)
: Actual Wavelength of Feature (Actual Angstroms)

= 8209-3934 = 4275 Å.

Since this is a positive value, the object is moving away from us. Now you can plug the values into the formula -
z= /
z = 4275/3934
z = 1.09

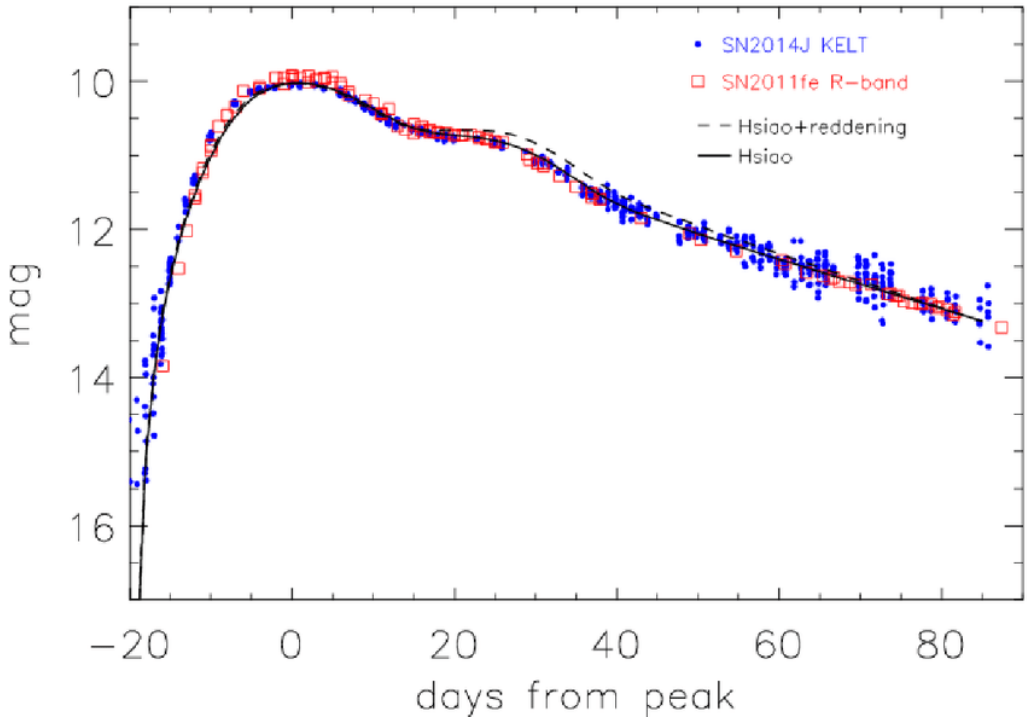


51. What would be the distance to a galaxy with a recessional velocity of 60,000 km/s? Please give your answer in millions of Parsecs to an accuracy of three significant figures.

Solution:

60,000 km/s = 73.8 km/sec/Mpc X D = 813 Mpc

52. Calculate the Distance to this Supernova based on its light curve data. Please express your answer in Mpc to an accuracy of three significant figures.



Solution: SN2014J is a type Ia supernova, which should (by definition) have an absolute magnitude of -18. According to this light curve, the apparent magnitude appears to be 10 *(this is actually a little off, SN2014J should show about an "11" which makes me wonder about the accuracy of this curve I found).

$$\underbrace{m - M}_{\text{Distance Modulus}} = 5 \log_{10}(\tfrac{r}{10})$$

So:
10 – -18 = 5 Log10 (r/10)
28 = 5 Log10(r/10)
5.6 = Log10 (r/10)
398107.17055349725077025230508775 = r/10
3981071.70553497250770252305087 75 = r

r= 3.98 X 10^6 pc

Or 3.98 Mpc. *Accept any answer +/- 20% as long as the math is correct, different equations can be used to calculate this phenomena.

BONUS (+1 pt): What celestial body is closest to this distance from Earth?

(Answer: M82, Cigar Galaxy, NGC 3034)

53. Determine the Distance in Mpc to a galaxy with an inclination-independent measured rotation of 250 km/s, and an apparent magnitude of 16.0 mags (H-Band).

$$M_H^i = -9.50(logW_R^i - 2.50) - 21.67 \pm 0.08$$

MiH = -9.50 (log **250** – 2.50) -21.67 +/- 0.08

MiH= -20.700

Distance Modulus:

$$\underbrace{m - M}_{\text{Distance Modulus}} = 5 \log_{10}(\tfrac{r}{10})$$

16.0 - -20.7 = 5 Log10 (r/10)

7.34 = Log (r/10)

21877616.2395 = r/10

218776162.395 = r = 218.8 Mpc

Word Substitution Section Part III: *In each paragraph there is an incorrect 'word' or incorrect 'phrase'. Tell us what to replace and offer a correct substitution in this section. Each Question is worth 2 Points.

54. Although hidden from us at optical wavelengths by the enshrouding dust, massive stars are formed out of the available gas. They emit copious amounts of microwave wavelengths which is absorbed by the surrounding dust and reemitted at infrared wavelengths, making starburst galaxies among the most luminous infrared objects in the Universe. Ironically, it is the rapid rate of star formation that ultimately terminates the period of starburst. Supernova explosions and stellar winds from the newly formed massive stars can be sufficient to sweep the gas from the galaxy thereby halting all further star formation.

Replace: "microwave" with "ultraviolet"

55. Though gravitational waves were predicted to exist in 1916, actual proof of their existence wouldn't arrive until 1974, 20 years after Einstein's death. In that year, two astronomers working at the Arecibo Radio Observatory in Puerto Rico discovered a binary pulsar--two extremely dense and heavy stars in orbit around each other. This was exactly the type of system that, according to general relativity, should radiate gravitational waves. Knowing that this discovery could be used to test Einstein's audacious prediction, astronomers began measuring how the period of the stars' orbit changed over time. After eight years of observations, they determined that the stars were getting closer to each other at precisely the rate predicted by general relativity if they were emitting gravitational waves (which would magnify energy from the system and cause the stars to get closer and closer together). This system has been monitored for over 40 years and the observed changes in the orbit agree so well with general relativity there is no doubt that it is emitting gravitational waves.

Replace: "magnify" with "remove"

56. Black holes are near-perfect black bodies, in the sense that they absorb all the radiation that falls on them. It has been proposed that they emit black-body radiation (called Persig radiation), with a temperature that depends on the mass of the black hole.

Replace: "Persig" with "Hawking"

57. An ultraluminous X-ray source (ULX) is an astronomical source of X-rays that is less luminous than an active galactic nucleus but is more consistently luminous than any known stellar process (over 1039 erg/s, or 1032 watts), assuming that it radiates isotropically (the same in all directions). Typically there is about one ULX per galaxy in galaxies which host them, but some galaxies contain many. The Milky Way has not been shown to contain a ULX. The main interest in ULXs stems from their luminosity exceeding the Eddington luminosity of neutron stars and even stellar black holes. It is not known what powers ULXs; models include beamed emission of stellar mass objects, accreting supermassive-mass black holes, and super-Eddington emission.

Replace: “supermassive” with “intermediate”

58. We can look at our own solar system, the Milky Way, to get an example of this. The Milky Way is comprised of two parts: a disk and a halo. Most of the stars in the disk are relatively young and were likely formed in the Milky Way itself. The stars in the halo, on the other hand, are much older, more ancient stars. Most scientists believe that these ancient halo stars were formed in neighboring systems or galaxies but were sucked into the Milky Way due to its larger gravitational pull.

Replace: “solar system” with “galaxy”.

Part IV. Image Matching Section (2pt/ea): 30 points.

***For each "Clue" please find the Matching name of the DSO from the event book (+1 point) and ALSO the correct Image from the image sheet provided (for +1 point):**

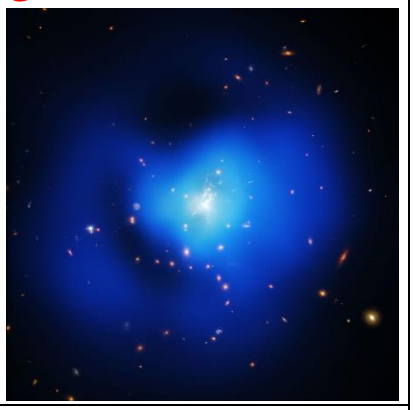
Q#	DSO CLUE	NAME of DSO	IMAGE NUMBER FROM DOC
59.	Bright Blast of radiation discovered in M82	SN 2014J	D
60.	A favorite of Amateur Astronomers, the collision of two small galaxies.	Centaurus A or NGC 5128	K
61.	Extreme new star formation in the early Universe.	SPT 0346-52	J
62.	GW170817	NGC 4993	G
63.	Amazing Merger.	Abell 400/NGC 1128/3C 75	N
64.	Slow star formation due to gas stripping.	ESO 137-001	B
65.	Potential harbinger for the future of the Milky Way and Andromeda.	Antennae Galaxies	O
66.	Starburst galaxy, but one with high metallicity and a higher ratio of WR stars .	IC 10	A
67.	Exceptional Starburst structure of unusually massive size. Highest X-Ray Source.	Phoenix Cluster	C
68.	They have theirs. This one is ours.	Sagittarius A	E
69.	Virgo Neighbors.	M81 / M82	F
70.	Starburst galaxy oddly deficient in neutral hydrogen.	M100	M
71.	Example of "Feedback" keeping galaxies from becoming too large.	NGC 5195	I
72.	Very curious Fornax X-Ray Bursts.	Chandra Deep Field South (CDF-S)	L
73.	Dynamical Mass Segregation	47 Tucanae/X9	I

RATER SCORE : Max Score 118 Points

A

B

C



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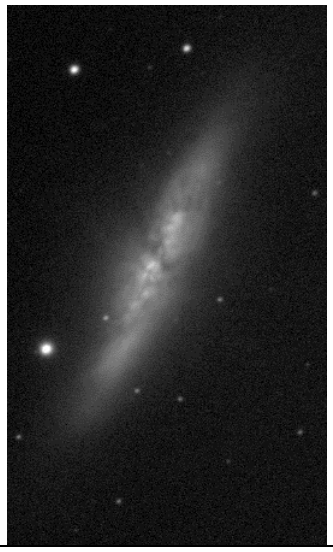

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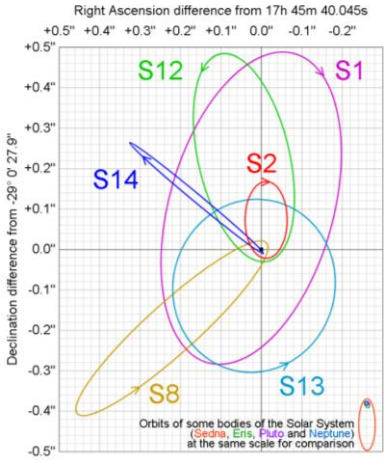
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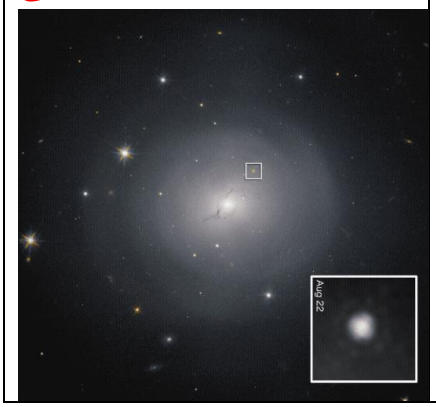
+0.5" +0.4" +0.3" +0.2" +0.1" 0.0" -0.1" -0.2"
Declination difference from -29° 0' 27.9"
+0.5"
+0.4"
+0.3"
+0.2"
+0.1"
0.0"
-0.1"
-0.2"
-0.3"
-0.4"
-0.5"
S12
S1
S2
S14
S8
S13
Orbits of some bodies of the Solar System
(Sedna, Eris, Pluto and Neptune)
at the same scale for comparison

F

G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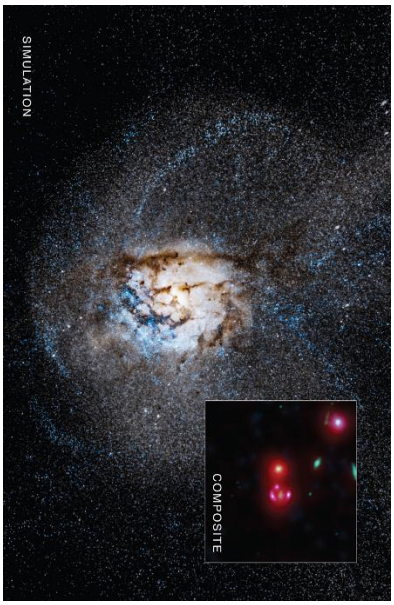

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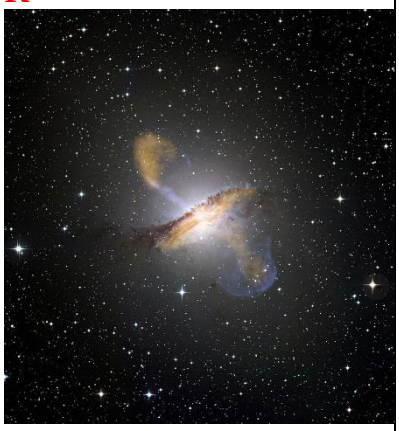

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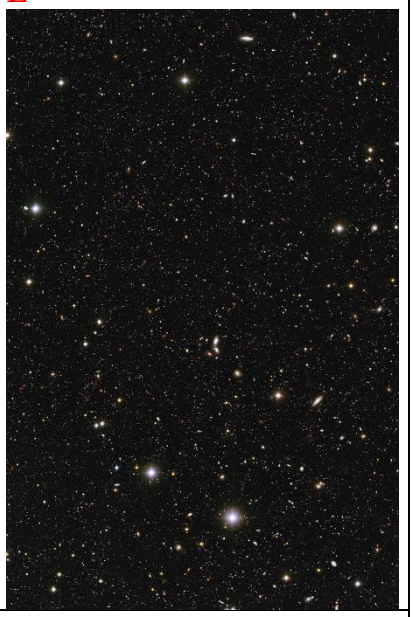

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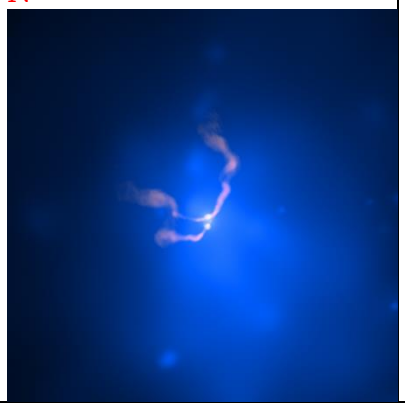

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