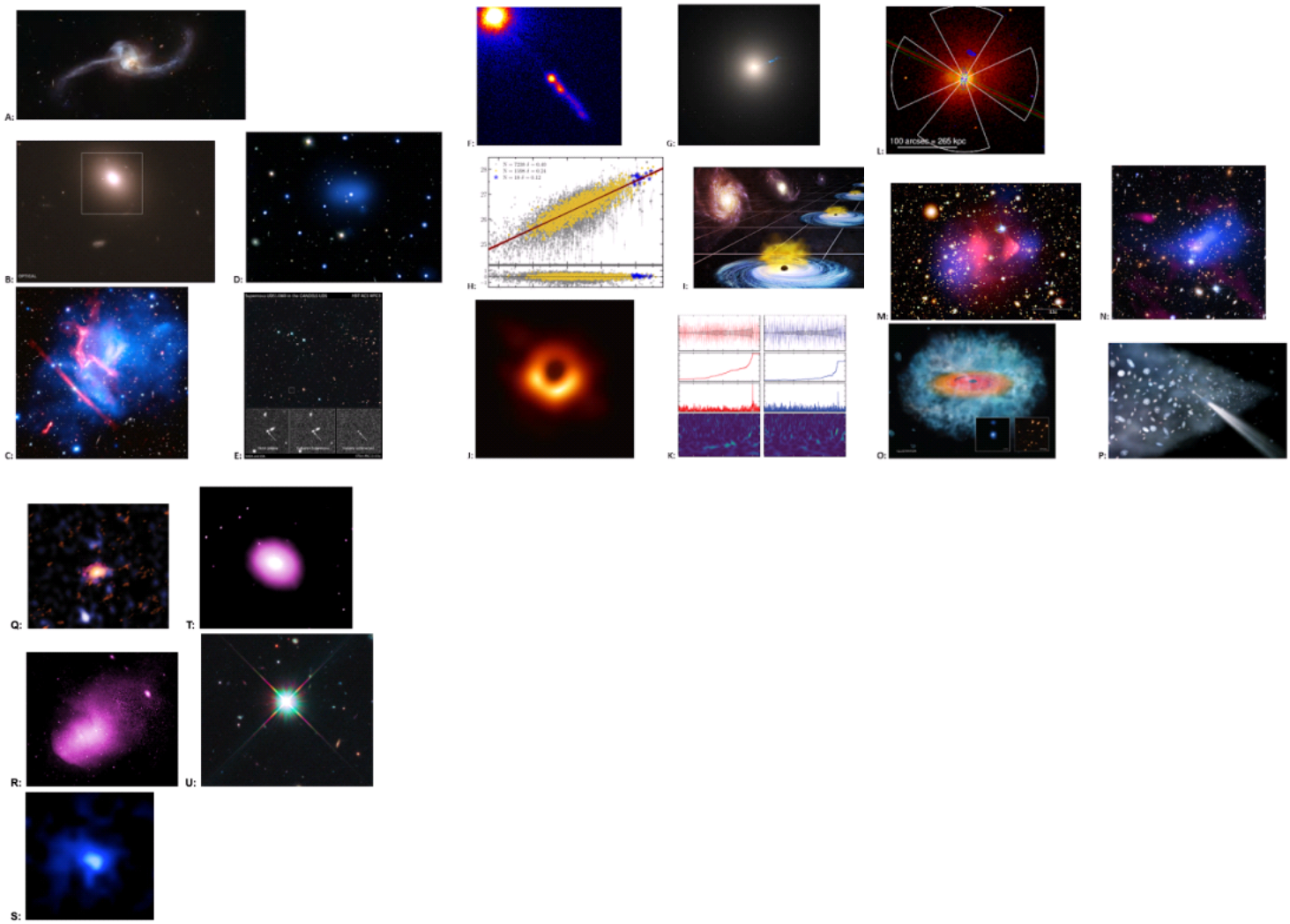
C - Astronomy - Rickards Invitational Div. C - 12-05-2020

Hello there! Welcome to the Rickards Invitational. You have 50 minutes to complete the following test, good luck!

Section A - DSOs

Use the following images for questions 1-17.



1. (6.00 pts) Answer the following questions about SN UDS10Wil (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. What type of object is it?
3. What is its redshift?
4. What constellation is it found in?
5. Who is it named after?
6. Who discovered it?

Expected Answer: 1. E 2. Type Ia Supernova 3. 1.914 (+/- 0.2) 4. Cetus 5. U.S. President Woodrow Wilson 6. David O. Jones

2. (6.00 pts) Answer the following questions about NGC 2623 (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. What types of objects merged to form this DSO?
3. About how many light years away is it?
4. What important future event could this DSO shed light on?
5. What Type Ia Supernova was discovered within this DSO?
6. This DSO is “super-luminous” in which regions of the electromagnetic spectrum?

Expected Answer: 1. A 2. Two spiral galaxies 3. 255 million light years (+/- 5) 4. Collision of Milky Way with Andromeda in 4 billion years 5. SN 1999gd 6. Radio waves and especially infrared

3. (6.00 pts) Answer the following questions about GRB 150101B (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. What does the GRB stand for?
3. Which telescope first detected it, and on which satellite?
4. What is the host galaxy of this DSO?
5. What new information does this DSO show about “kilonova” events?
6. What is the total energy output of this DSO in Joules?

Expected Answer: 1. B 2. Gamma Ray Burst 3. Burst Alert Telescope, on Swift Observatory Satellite 4. 2MASX J12320498-1056010 5. Shows that kilonova events may be more diverse and common in the universe than previously understood 6. 1.3 x 10^42 J (+/- 1e42)

4. (6.00 pts) Answer the following questions about JKCS 041 (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. About how many galaxies are contained within this DSO?
3. About how many parsecs away is this DSO?
4. What is the significance of this DSO?
5. What are the Right Ascension coordinates of this DSO?
6. What is the DSO’s redshift?

Expected Answer: 1. D 2. About 19 galaxies 3. 3.04 billion parsecs 4. Farthest galaxy cluster discovered, allowing us to peer into the past and see how these clusters first formed 5. 02h 26m 44s Right Ascension 6. 1.803 (+/- 0.2)

5. (6.00 pts) Answer the following questions about MACS 70717.5 + 3745 (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. How many separate galaxy clusters are involved in this DSO?
3. How does the movement of hot gas in the interstellar medium differ from the movement of galaxies in this DSO?
4. Which “kinetic” effect does the quick-moving subcluster of this DSO exhibit?
5. How can the gravitational lensing that this DSO causes be helpful to astronomers?
6. About how many light years wide is this DSO?

Expected Answer: 1. C 2. 4 separate galaxy clusters 3. The hot gas slows down more dramatically than the galaxies as they collide, because the galaxies are mostly empty space 4 Sunyaev-Zeldovich effect 5. Can brighten background galaxies, allowing them to be studied 6. 6.8 million light years (+/- 0.2)

6. (6.00 pts)
Answer the following questions about MACS J1149.5+2223 (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. Why does this DSO cause so much gravitational lensing?
3. One gravitationally lensed object is MACS1149-JD1. What is the significance of this object?
4. This DSO also gravitationally lenses a blue supergiant star, the most distant individual star to have been detected so far. What is the common name of this star? (one word)
5. Who discovered the star from the previous question?
6. Lastly, this DSO gravitationally lenses the supernova SN Refsdal. How long ago did SN Refsdal explode?

Expected Answer: 1. N 2. It is extremely massive 3. It is a very distant dwarf galaxy, one of the oldest galaxies ever found 4. Icarus 5. Lead astronomer Patrick Kelly 6. 9.34 billion years ago (+/- 0.1)

7. (6.00 pts) Answer the following questions about 1E 0657-56 (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. What is the more common nickname for this DSO?
3. What is the approximate temperature of the intracluster medium within this DSO, in electronvolts?
4. How does baryonic matter within this DSO behave differently from dark matter?
5. The energy output of the collision that created this DSO is equivalent to that of about how many typical quasars?
6. The location of gravitational lensing within this DSO provides evidence against what major astronomical theory?

Expected Answer: 1. M 2. Bullet Cluster 3. 17.4 (+/- 2.5) keV 4. Baryonic matter is slowed down by drag force but dark matter is not, causing a separation 5. 10 typical quasars 6. Modified Newtonian Dynamics (MOND) or modified gravity

8. (6.00 pts) Answer the following questions about H1821+643 (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. What type of object is this DSO?
3. According to the cooling flow theory, how does the intracluster medium within this DSO cool?
4. Filaments of what entity absorb X-rays between Earth and this DSO?

5. What 2 ionized elements largely compose the entity from the previous question?
6. The discovery of this entity helped to solve what major problem in astrophysics?

Expected Answer: 1. L 2. Quasar 3. By emitting X-rays 4. Warm-Hot Interstellar Medium (WHIM) 5. Oxygen and Hydrogen 6. Missing Baryon Problem

9. (6.00 pts) Answer the following questions about GOODS-S 29323 (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. What constellation is this DSO located in?
3. This DSO contains a “seed” for what type of object?
4. What problem relating to the above object did the discovery of this DSO solve?
5. What are the Declination coordinates of this DSO?
6. What is the DSO’s redshift?

Expected Answer: 1. O 2. Fornax 3. (Supermassive) Black Hole 4. The problem of how supermassive black holes got so big so quickly in the early universe 5. -27 degrees, 48’, 30’’ 6. 6.06 (+/- 0.1)

10. (6.00 pts) Answer the following questions about H2356-309 (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. In what direction does this DSO’s radiation jet point?
3. As a result of the previous answer, what is the DSO classified as?
4. Research into this DSO shows that there is a large reservoir of what substance in the Sculptor Wall?
5. About how many light years away is this DSO?
6. What is the redshift of this DSO?

Expected Answer: 1. P 2. Directly towards us 3. Blazar 4. Warm-Hot Interstellar Medium (WHIM), or ionized oxygen 5. 2 billion light years 6. 0.165 (+/- 0.1)

11. (6.00 pts) Answer the following questions about PSS 0133+0400 and PSS 0955+5940 (6 points available)

1. Which of the images on the image sheet depicts these DSOs? (or objects like them)
2. Which two constellations are they located in?
3. How do these DSOs help astronomers as “standard candles”?
4. What relationship related to these objects is shown in Image H?
5. How do these DSOs compare to other standard candles like Type Ia Supernovae?
6. When photographed with X-rays, in what color are these DSOs usually depicted?

Expected Answer: 1. I 2. Pisces and Ursa Major 3. Their luminosity can be easily determined because it is very consistent, allowing astronomers to find the distance to them and nearby objects with distance modulus 4. The relationship between UV and X-ray flux 5. They are more luminous than other standard candles, so they allow us to see very far away and also far back into the past 6. Bright pink

12. (6.00 pts) Answer the following questions about GW151226 (6 points available)

1. On what date was the signal first detected, and by what observatory?
2. What type of object created this signal?
3. Why couldn't this object be observed directly, without the use of this particular signal?
4. What formula approximates the total energy output of the object that produced this signal?
5. The discovery of this signal provides further evidence for what major theory in astrophysics?
6. Image K depicts results from this DSO. What location collected the red data, and what location collected the blue data?

Expected Answer: 1. December 25, 2015, by LIGO Observatory 2. Merging binary black hole system 3. A black hole system does not emit any light, so gravitational waves are the only way to detect it 4. (speed of light or c)^2 * (1 solar mass) 5. General relativity 6. Hanford collected the red data, Livingston collected the blue

13. (6.00 pts) Answer the following questions about M87 (10 points available)

1. Which of the images on the image sheet is of this DSO, as imaged by the Hubble Space Telescope?
2. There is a notable part of this image other than the galactic core. What phenomenon does it represent?
3. Who discovered this DSO, and what did they catalog it as?
4. What is the Hubble classification of this galaxy?
5. Which other image from the image sheet is of this DSO, as imaged by the Event Horizon Telescope?
6. What was the significance of EHT's ability to take this image?
7. What region of the EM spectrum was used to take this image?
8. The DSO is a very strong source of what type of electromagnetic radiation?
9. This DSO forms the core of which larger supercluster?
10. What has this DSO been nicknamed due to its great significance to astronomy?

Expected Answer: 1. G 2. Blue plasma jet 3. Charles Messier, who cataloged it as a nebula 4. E0p (supergiant elliptical galaxy) 5. J 6. It was the first (and so far only) black hole to be imaged 7. Radio waves 8. Gamma rays 9. Virgo Supercluster 10. The Smoking Gun

14. (6.00 pts) Answer the following questions about 3C 273 (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. How does this DSO compare to other quasars in brightness and distance from us?
3. Which other quasar was this DSO identified along with?
4. Where does the energy emitted from the jet come from?
5. How long, in light years, is the DSO's energy jet?
6. What type of galaxy is this DSO found in?

Expected Answer: 1. F 2. It is brighter and closer than most other quasars 3. 3C 48 4. Gas from the accretion disk rapidly falling towards the supermassive black hole at the center 5. 200 thousand light years 6. Giant elliptical galaxy

15. (6.00 pts) Answer the following questions about DLA0817g (6 points available)

1. Which of the images on the image sheet is of this DSO?
2. What other name is this DSO usually known by?
3. Which two “Arrays” were used to discover this DSO? Which of the two took the image from part a?
4. What type of galaxy is this DSO, and how is it distinguished from other galaxies?
5. How does the age of this DSO contradict previous models about galaxy formation and evolution?
6. What new method of galaxy growth does this DSO provide evidence for?

Expected Answer: 1. Q 2. Wolfe Disk 3. Atacama Large Millimeter Array (ALMA) and Karl G. Jansky Very Large Array (JVLA). This image was taken by ALMA. 4. Large rotating disl galaxy - distinguished by a flattened circular volume of stars (galactic disk) 5. It is more recent than expected, showing that galaxies may form and evolve faster than predicted - this contradicts models of gradual galaxy growth 6. “Cold Mode Accretion” - cool gas forms a galaxy very quickly

16. (7.00 pts) Answer the following questions about the Chandra Isotropic Universe Survey (7 points available)

1. Which two properties of galaxy cluster gas did this survey relate?
2. How are findings of this survey affected by the expansion speed of the universe?
3. What is “isotropy,” and what do the findings of this survey suggest about the concept?
4. What is the main possible explanation of the findings that does not concern isotropy?
5. Which two images on the image sheet depict findings of this survey?
6. Of the two objects in the images, give the name of the one that has the higher redshift.
7. Of the two objects in the images, give the name of the one that was observed for longer by the survey.

Expected Answer: 1. Temperature and X-ray Luminosity 2. They are largely independent of expansion speed because the observed properties are not affected by expansion 3. Isotropy is the property of the universe being the same in all directions, but the findings of the survey suggest that the universe may not be isotropic because some areas of the universe seem to be moving away faster than others 4. That galaxy clusters were rapidly moving together due to gravity rather than cosmic expansion, leading to errors in luminosity estimations 5. R and T 6. RXCJ1504 (0.215 > 0.056) 7. Abell 3667 (150 hrs > 45 hrs)

17. (6.00 pts) Answer the following questions about the Hubble CANDELS Survey (6 points available)

1. Which of the images on the image sheet is of a high-redshift galaxy discovered by this survey?
2. Image __ was also taken by this survey. How does the distance to the object in this image compare to the distance to the object in the image from part a?
3. What produced the X-shaped beams of light in Image __?
4. About how many hours did it take Hubble to gather the data to create these images?
5. Which two cameras on board Hubble were used to create these images, and how do the wavelengths they utilize differ?
6. Which two “cosmic” eras did this survey seek to explore?

Expected Answer: 1. S 2. The object in Image U is closer than the one in Image S 3. Hubble diffraction spikes - optical artifacts from telescope mirror design 4. About 1450 hours (+/- 50) 5. WFC3 and ACS. While WFC3 observes near-infrared, ACS is purely optical 6. “Cosmic Dawn” and “Cosmic High Noon”

Section B - General Knowledge

I. Stars (Questions 18-117)

18. (1.00 pts) What element/molecule is most prevalent in a GMC?

Expected Answer: Molecular hydrogen (H2)

19. (1.00 pts) How are planetary nebulae usually produced?

Expected Answer: Released by the collapse of an intermediate-mass star (red giant) into a white dwarf

20. (1.00 pts) What are the three main types of diffuse nebulae?

Expected Answer: Emission, reflection, and dark

21. (1.00 pts) Describe an event that could trigger gravitational collapse in a GMC.

Expected Answer: Nearby supernova, gas cloud collision, or galaxy collision

22. (1.00 pts) At what wavelengths do collapsing protostellar clouds tend to release energy, and why?

Expected Answer: Long wavelengths, like infrared, because the dust absorbs the rest

23. (1.00 pts) What is the term for when the kinetic energy of gas pressure is balanced by the internal gravitational force?

Expected Answer: Hydrostatic Equilibrium

24. (1.00 pts) When a collapsing cloud meets the condition above, what is the resulting object called?

Expected Answer: Protostar

25. (1.00 pts) Where on an HR diagram would such an object be located?

Expected Answer: Far-right, height depends on mass but usually near the bottom

26. (1.00 pts) What does YSO stand for?

Expected Answer: Young Stellar Object

27. (1.00 pts) If accretion upon a YSO produces two plasma jets along its axis of rotation, what is the resulting object called?

Expected Answer: Herbig-Haro Object

28. (1.00 pts) What is the main difference between a Class 0 YSO and a Class III YSO?

Expected Answer: A Class III YSO releases energy at shorter wavelengths than a Class 0 YSO (it is also generally older and farther along in development)

29. (1.00 pts) What is the Hayashi Track?

Expected Answer: The path that low-mass YSOs generally follow as they grow to become MS stars

30. (1.00 pts) What event usually causes a star to leave the Hayashi Track?

Expected Answer: Beginning of nuclear fusion (hydrogen burning) at the Zero Age Main Sequence

31. (1.00 pts) How does the Henyey Track differ from the Hayashi Track?

Expected Answer: Henyey Track is a special path that higher mass stars follow after they branch off from the Hayashi track; while the Hayashi track is more vertical (decrease in luminosity), the Henyey track is more horizontal (luminosity constant, increasing temp)

32. (1.00 pts) What is the forbidden zone, and where is it located relative to the Hayashi track?

Expected Answer: Region where no star can exist in hydrostatic equilibrium, to the right of the Hayashi track

33. (1.00 pts) If a star’s mass is too low to embark on the Hayashi track, what is it usually called?

Expected Answer: Brown Dwarf

34. (1.00 pts) What element is especially abundant in T-Tauri stars?

Expected Answer: Lithium

35. (1.00 pts) What is the analog of a T-Tauri star within a higher mass range?

Expected Answer: Herbig Ae/Be Star

36. (1.00 pts) What is the name of the dust formation around a star that may form planets

Expected Answer: Protoplanetary/Circumstellar Disk

37. (1.00 pts) How does the radius and surface gravity of a pre-MS star compare to that of an MS star?

Expected Answer: Radius is generally larger, meaning surface gravity is lower

38. (1.00 pts) How does a pre-MS star generally produce energy? (Hint: what mechanism?)

Expected Answer: Kelvin-Helmholtz Mechanism of gravitational contraction – star produces energy by contracting (converts gravitational potential energy into radiation), then heats up and expands a bit, then contracts again, and so on, each time gaining a little energy

39. (1.00 pts) How did astronomers disprove the theory that all stars use the above mechanism?

Expected Answer: By calculating how long the Sun would last under K-H mechanism – only millions of years, not billions

40. (1.00 pts) What happens when a gas cloud exceeds its Jeans mass?

Expected Answer: Gravitational force overcomes pressure and the cloud begins to collapse, forming stars

41. (1.00 pts) If the temperature of a gas cloud increases, how will the Jeans mass be affected?

Expected Answer: Jeans mass will be increased – a hotter cloud is more resistant to collapse and condensation, because the faster-moving particles produce higher pressure, so a greater mass is needed for gravity to overcome the pressure

42. (1.00 pts) If the density of a gas cloud decreases, how will its Jeans length be affected?

Expected Answer: Jeans length will be increased – if the cloud is less dense and the same size, it will be less massive so less prone to collapse; thus, the size (Jeans length) must be increased to cause collapse

43. (1.00 pts) If a gas cloud's density is multiplied by 16 and its temperature is quadrupled, by what factor will the Jeans mass change?

Expected Answer: The actual formula for Jeans Mass is directly proportional to sqrt(T^3/p), so multiplying the top by 4 and the bottom by 16 yields sqrt(64/16) = sqrt(4) = 2. The Jeans Mass will be twice as large.

44. (1.00 pts) What conditions usually must be present within a star for radiative energy transport to be dominant over convective transport?

Expected Answer: Low opacity and low temperature gradient

45. (1.00 pts) Which form of energy transport dominates in stars below 0.5 solar masses?

Expected Answer: Convection

46. (1.00 pts) How does energy transport in the core of a solar-mass star differ from its envelope?

Expected Answer: Radiation dominates in core, convection dominates in envelope

47. (1.00 pts) How does the temperature in the core of a solar-mass star differ from that of its envelope?

Expected Answer: Temperature in core is much hotter than in envelope

48. (1.00 pts) How does the temperature of the Sun’s corona compare to that of its photosphere?

Expected Answer: Temperature of corona is much hotter than in photosphere

49. (1.00 pts) By what process does the Sun fuse hydrogen?

Expected Answer: Proton-Proton Chain (PPC)

50. (1.00 pts) What type of radiation does this process mainly produce?

Expected Answer: Gamma rays

51. (1.00 pts) How many hydrogen atoms are used up in each iteration of this process?

Expected Answer: 4 H atoms

52. (1.00 pts) How much energy (in MeV) is produced by a single iteration of this process?

Expected Answer: 26.73 MeV

53. (1.00 pts) If the core temperature of the Sun was doubled, yet it still used this same process, approximately how many times greater would the energy production rate be?

Expected Answer: 16 times faster (proportional to T^4)

54. (1.00 pts) What other elements are utilized in the “II” branch of this process?

Expected Answer: Lithium and Beryllium

55. (1.00 pts) By what process does an MS star of 5 solar masses mainly fuse hydrogen?

Expected Answer: CNO Cycle

56. (1.00 pts) What catalysts are used in this process?

Expected Answer: Carbon, Nitrogen, and Oxygen

57. (1.00 pts) The energy production rate of this process is proportional to about what power of the core temperature?

Expected Answer: 18 (+/- 4)

58. (1.00 pts) At about what mass (in solar masses) do both energy production processes contribute equally to the energy generation of an MS star?

Expected Answer: 1.2 solar masses (+/- 0.1)

59. (1.00 pts) A 3-solar-mass Main-Sequence star is about how many times more luminous than the Sun?

Expected Answer: L is proportional to M^4, so 81 times more luminous. Accept any answer from 46-81 because various exponents can be used from 3.5 to 4.

60. (1.00 pts) About how many times longer will the Sun remain on the Main Sequence than the star from the previous question?

Expected Answer: Lifetime is proportional to 1/M^3, so 27 times longer. Accept any answer from 15-27 because various exponents can be used from 2.5 to 3.

61. (1.00 pts) In what region of the Main Sequence are variable stars usually located?

Expected Answer: Instability Strip

62. (1.00 pts) How does radial pulsation of a variable star differ from non-radial pulsation?

Expected Answer: Radial pulsation involves pulsation of the whole star, while non-radial pulsation involves pulsation of only part of the star

63. (1.00 pts) What is the term for the study of a star's interior using its pulsations?

Expected Answer: Asteroseismology

64. (1.00 pts) What two different pulsation "modes" are used by pulsating variables?

Expected Answer: g-mode (gravity is the restoring force) and p-mode (pressure is the restoring force)

65. (1.00 pts) How does the size and luminosity of a classical Cepheid generally compare to that of the Sun?

Expected Answer: Many times larger and more luminous than Sun

66. (1.00 pts) How does the metallicity of a Type II Cepheid compare to that of a Classical Cepheid?

Expected Answer: Type II Cepheid has much poorer metallicity (lower metal percentage)

67. (1.00 pts) What is the name of the subclass of Type II Cepheids with the longest pulsation period?

Expected Answer: RV Tauri

68. (1.00 pts) Name the “valve” and “mechanism” involved in Cepheid pulsation.

Expected Answer: Eddington valve and Kappa (K) mechanism

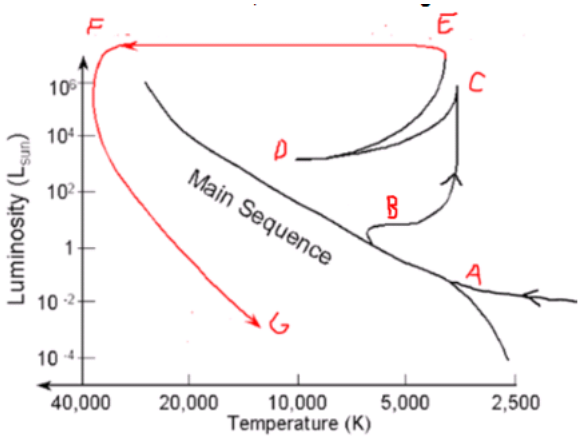
69. (1.00 pts) Which stellar population does the Sun belong to, and why?

Expected Answer: Population I - relatively high metallicity, and fairly young

70. (1.00 pts) Why is the mass range of Population III stars not known very precisely?

Expected Answer: Because Population III stars are only hypothetical and have barely been observed, as they mainly existed only in the early universe

For questions 71-86, consider the image below.



71. (1.00 pts) What mass range (in solar masses) of stars could be expected to follow this path along the HR Diagram?

Expected Answer: 0.5-8 solar masses (or any mass range close to this that contains 1 solar mass)

72. (1.00 pts) What is the name of branch B?

Expected Answer: Red Giant Branch

73. (1.00 pts) What event causes a star to enter branch B?

Expected Answer: Core exhausting its hydrogen supply or stopping hydrogen fusion

74. (1.00 pts) During branch B, how does the size and temperature of the star's core change?

Expected Answer: The core contracts and becomes hotter

75. (1.00 pts) What force counteracts these changes to the core?

Expected Answer: Electron degeneracy pressure

76. (1.00 pts) What event occurs at letter C?

Expected Answer: Helium flash - core reaches the temperature to begin helium fusion

77. (1.00 pts) The event at letter C produces a lot of energy. Why is this boost in luminosity not visible from outside the star?

Expected Answer: It is absorbed by the outer layers of the star, causing a thermal expansion

78. (1.00 pts) What is the name of the branch between letters C and D?

Expected Answer: Horizontal Branch

79. (1.00 pts) What fusion process is used by the star during this branch?

Expected Answer: Triple Alpha Process

80. (1.00 pts) What event occurs at letter D?

Expected Answer: Core exhausts helium supply or stops helium fusion

81. (1.00 pts) What is the name of the branch between D and E?

Expected Answer: Asymptotic Giant Branch (AGB)

82. (1.00 pts) What elements make up the star's core as it travels along this branch?

Expected Answer: Carbon and Oxygen

83. (1.00 pts) At letter E, what gas formation does the star produce?

Expected Answer: Planetary Nebula

84. (1.00 pts) What is the star known as when it reaches letter G?

Expected Answer: White Dwarf

85. (1.00 pts) At what letter on the diagram would RR Lyrae stars most likely be found?

Expected Answer: D (instability strip, red giant)

86. (1.00 pts) Between what two letters would the star most likely undergo "thermal pulses"?

Expected Answer: D and E (AGB)

87. (1.00 pts) How does the density of a white dwarf compare to a Main-Sequence star?

Expected Answer: Much higher density

88. (1.00 pts) What 2 elements compose most white dwarfs, and why are those two the most common?

Expected Answer: Carbon and Oxygen - white dwarf is just the remaining core of a red giant, and red giant's core is usually carbon and oxygen because it doesn't reach the temperature to burn these elements

89. (1.00 pts) If a very low-mass star became a white dwarf, what other element could be found in the dwarf's spectrum? Why?

Expected Answer: Helium - the star never reached the temperature to completely burn helium, so core still contained some helium

90. (1.00 pts) If a very high-mass star became a white dwarf, what additional elements could be found in the dwarf's spectrum? Why?

Expected Answer: Neon and Magnesium - the star reached the temperature to burn some carbon before becoming a white dwarf, creating neon and magnesium in the core

91. (1.00 pts) How do white dwarfs "die" over time?

Expected Answer: Since they have no way of producing energy, they eventually become dimmer and dimmer until they fade from view as black dwarfs

92. (1.00 pts) How abundant are “dead” white dwarfs compared to “living” dwarfs?

Expected Answer: Technically, no true black dwarfs have been found, because the process of a white dwarf dimming takes a very long time. Even very old white dwarfs still emit some light. So black dwarfs are much less abundant than white dwarfs if they exist at all.

93. (1.00 pts) The fusion of what element is hypothesized to cause a white dwarf to undergo a Type Ia Supernova?

Expected Answer: Carbon

94. (1.00 pts) Name and describe the two main progenitor models of Type Ia Supernovae.

Expected Answer: Single Degenerate Model - white dwarf accretes mass from a non-white-dwarf partner, causing it to pass Chandrasekhar limit. Double Degenerate Model - white dwarf merges with another white dwarf, causing it to pass Chandrasekhar limit.

95. (1.00 pts) Which of the two models may pose a problem for the use of Type Ia Supernovae as standard candles, and why?

Expected Answer: Double Degenerate Model - since 2 white dwarfs merge, mass may be greater than Chandrasekhar, causing the final absolute magnitude to be inconsistent.

96. (1.00 pts) What isotope’s radioactive decay causes the characteristic luminosity peak on the light curve of a Type Ia Supernova?

Expected Answer: Nickel-56

97. (1.00 pts) What two quantities related to Type Ia Supernovae are connected by the Phillips relationship?

Expected Answer: Peak luminosity, and rate of luminosity decay

98. (1.00 pts) What type of supernova can be caused by neon burning in a star from 8-12 solar masses?

Expected Answer: Electron Capture Supernova

99. (1.00 pts) How does the duration of neon burning in a supergiant compare to the duration of oxygen burning?

Expected Answer: Much shorter duration - about 0.3 years compared to 3 years

100. (1.00 pts) Fill in the blanks: The burning of the element _____ produces _____, which decays into _____, an element that cannot be fused by the star.

Expected Answer: Oxygen, Nickel(-56), Iron(-56)

101. (1.00 pts) Why can the third element from the previous question not be fused?

Expected Answer: Iron has the highest binding energy per nucleon out of any element, so it takes more energy to fuse than it releases, meaning the star cannot feasibly fuse it

102. (1.00 pts) A core collapse supernova occurs when the supergiant’s inert core surpasses what mass limit?

Expected Answer: Chandrasekhar Limit (1.4 solar masses)

103. (1.00 pts) How does the light curve of a Type II-P supernova differ from that of a Type II-L supernova, and why?

Expected Answer: Type II-L's luminosity decreases linearly from its peak, while Type II-P's luminosity plateaus for a little while before decreasing. This is because Type II-P supernovae retain their hydrogen envelope, thus causing greater opacity that keeps photons within the dying star for longer and results in a flatter light curve.

104. (1.00 pts) If a Wolf-Rayet Type WC star undergoes core-collapse, what type of supernova will most likely result? What about a Type WO star?

Expected Answer: Ib, Ic

105. (1.00 pts) Out of the two supernova types from the previous question, which one's luminosity usually decays faster?

Expected Answer: Ic

106. (1.00 pts) Which population of star would be most likely to undergo a pair-instability supernova, and why?

Expected Answer: Population III - theorized high mass and low metallicity, conducive to pair-instability supernova

107. (1.00 pts) How does the peak wavelength emitted by a neutron star compare to that of the Sun?

Expected Answer: Neutron star surface temperature is very hot, so peak wavelength would be much shorter.

108. (1.00 pts) To the nearest solar mass, what is the maximum mass of a neutron star? What force holds up the star against gravity before reaching this mass?

Expected Answer: 2 solar masses, held up by neutron degeneracy pressure

109. (1.00 pts) The conservation of what physical property results in the high rotation rates of neutron stars?

Expected Answer: Angular Momentum (mass decreases, so rotational speed increases to conserve momentum)

110. (1.00 pts) SGRs are theorized to belong to which specific class of neutron star?

Expected Answer: Magnetars

111. (1.00 pts) Name 3 potential candidates or components of nuclear pasta.

Expected Answer: Possible answers include: superfluid neutron-degenerate matter, degenerate strange matter, pions, kaons, quark-degenerate matter

112. (1.00 pts) Briefly describe the “spin down” process of neutron stars.

Expected Answer: As time goes on, a neutron star will slowly radiate its energy away through radiation beams (for a pulsar) or moving magnetic field (for a normal neutron star). Thi causes the neutron star to lose energy, gradually slowing its rotation rate.

113. (1.00 pts) Describe two mechanisms by which a neutron star’s rotation rate may increase.

Expected Answer: Accretion - star gains mass from a companion, which “recycles” it, causing it to become a millisecond pulsar with a much faster rotation. Starquake - random crus fluctuation causes star to lose some mass, gaining rotational speed through conservation of angular momentum (a “glitch”)

114. (1.00 pts) A binary involving a neutron star usually will emit what type of electromagnetic radiation?

Expected Answer: X-ray

115. (1.00 pts) Describe two different processes by which a black hole may form.

Expected Answer: Type II Supernova in a star above about 20 solar masses, or accretion onto a neutron star that surpasses the Tolman-Oppenheimer-Volkoff limit

116. (1.00 pts) What is the difference between the Kerr metric and Kerr-Newman metric for black holes?

Expected Answer: Kerr metric includes only angular momentum as a black hole property, while Kerr-Newman metric adds on electric charge

117. (1.00 pts)
To an observer outside a black hole watching something fall in, the object will take an infinite time to reach the event horizon. Why, then, does the object rapidly disappear from view?

Expected Answer: The light from the object is intensely gravitationally redshifted, becoming dimmer rapidly enough that the object disappears from view

Section B - General Knowledge

II. Galaxies (Questions 118-147)

118. (3.00 pts) Explain the two theories about early galaxy formation, and then say which is more plausible at the moment.

Expected Answer: The top-down theory states that matter joined into a massive conglomerate that eventually broke down into smaller pieces that became stable galaxies, while the bottom-up theory states that matter gravitationally merged together from spread out chunks that eventually grouped together. The bottom-up theory is currently favored. (+1) For explaining the Top-Down theory (+1) For explaining the Bottom-Up theory (+1) For saying the Bottom-Up theory is favored

119. (2.00 pts) How would the curve of star formation of an elliptical galaxy look from the Big Bang to now?

Expected Answer: It would have an early burst of star formation, but some time afterwards there is essentially no star formation (+1) For mentioning an early starburst (+1) For mentioning no star formation when approaching modern day

120. (1.00 pts) Why is Hubble's Tuning Fork Model inaccurate with its evolutionary track?

Expected Answer: Elliptical galaxies do not evolve into spiral galaxies, which is what the tuning fork implies by going left to right

121. (2.00 pts) Could I use Virial Theorem to find the time-averaged potential energy of a gravitationally bound galaxy? Why or why not?

Expected Answer: Yes you can, because the stars can act as the discrete particles that are all gravitationally bound to each other, thereby abiding to the rules of Virial Theorem (+1) For saying yes (+1) For saying that the stars are discrete particles that are gravitationally bound to each other.

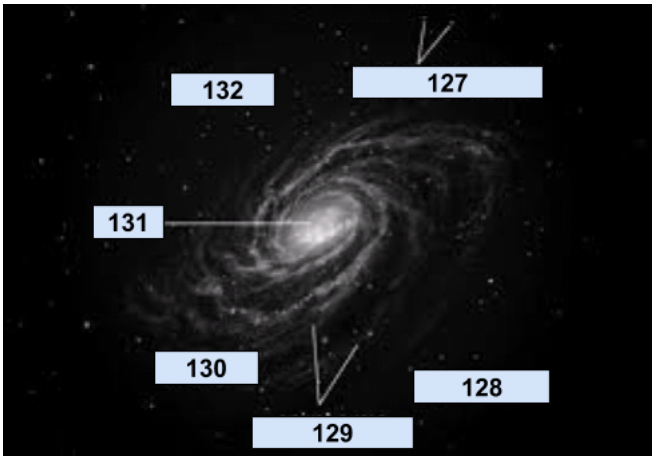
122. (1.00 pts) Our galaxy has about how many stars?

Expected Answer: Any number within 100-400 billion is acceptable for this answer

123. (1.00 pts) What type of galaxies would the LMC and SMC be classified as?

Expected Answer: Irregular galaxies

For questions 124-139, use the diagram below to identify the anatomy of a galaxy. Note that some answers COULD be repeated.



124. (1.00 pts) What features does box 127 point to?

Expected Answer: Globular clusters

125. (1.00 pts) Which region is indicated by box 128?

Expected Answer: Halo

126. (1.00 pts) Which features does box 129 point to?

Expected Answer: Spiral Arms

127. (1.00 pts) Box 130 encompasses the entire spiral. What is this area called?

Expected Answer: Note: This is supposed to be the entire spiral. This should be a freebie. Disk

128. (1.00 pts) What does box 131 point to?

Expected Answer: Bulge

129. (1.00 pts) What region is indicated by box 132?

Expected Answer: Halo

130. (1.00 pts) What kind of interaction occurs between galaxies where the galaxies phase through each other but then lack enough momentum to escape each other's pull?

Expected Answer: Galaxy collision

131. (1.00 pts) Our galaxy is in a satellite interaction with two other galaxies right now. Which two are they?

Expected Answer: Large Magellanic Cloud and Small Magellanic Cloud (LMC and SMC respectively) (+0.5 for each correct response given)

132. (1.00 pts) At the end of the Toomre Sequence, you are left with what kind of galaxy?

Expected Answer: Elliptical Galaxy

133. (1.00 pts) The most prominent types of galaxies in this Universe are of what kind?

Expected Answer: Dwarf galaxies

134. (3.00 pts) Compare and/or contrast the age, color, and metallicity of stars in the center of Sa/SBa galaxies and Sc/SBc galaxies.

Expected Answer: Sa/SBa galaxy stars in the bulge are old, red stars that have low metallicities, while Sc/SBc galaxy stars that are in the bulge are young, blue stars with high metallicities. (+1) For the correct contrast in age, where Sa/SBa is old and Sc/SBc is young (+1) For the correct contrast in color, where Sa/SBa is red and Sc/SBc is blue (+1) For the correct contrast in metallicity, where Sa/SBa is low metallicity while Sc/SBc is high metallicity

135. (2.00 pts)
Keplerian predictions of the rotation curves of spiral galaxies do not match up with experimental data as one goes away from the center. Why do you suppose this is so?

Expected Answer: Dark matter contributes more mass to the outside of the galaxy such that it can maintain the same rotational speed as for the majority of the part of the spiral galaxy. (+1) For mentioning dark matter (+1) For saying that the rotational speed is consistently maintained through gravitational pulling

136. (1.00 pts) We have never seen which of the following galaxy types yet?

- ○ A) E1
- ○ B) E4
- ○ C) E7
- ◉ D) E9

137. (1.00 pts) Am I more likely going to find open clusters or globular clusters in large elliptical galaxies?

Expected Answer: Globular clusters

138. (1.00 pts)
It's possible that we have early "galaxies" that will never have the conditions to even begin star formation. They just have dark matter and gas laying around. What is the term for these types of objects?

Expected Answer: Protogalaxies

For questions 139, 140, and 141, we'll discuss the everlasting argument for the discovery of galaxies.

139. (1.00 pts)
Two large figures in astronomy continually argued the size of the Universe and the nature of "nebulae" within the early 20th century. While we never had a winner in this debate, someone else was able to settle the debate by examining a supposed "nebula" that was actually a galaxy. Based on the kind of technology people had in the early 20th century, what is the name of the galaxy that they looked at?

Expected Answer: Andromeda Galaxy

140. (1.00 pts) Who was the astronomer that managed to resolve this great debate?

- ○ A) Henrietta Swan Leavitt
- ◉ B) Edwin Hubble
- ○ C) Edward Barnard
- ○ D) Subramanyan Chandrasekhar

141. (2.00 pts) What type of star(s) did the astronomer investigate to solve the conflict?

Expected Answer: (+2) Hubble looked at Cepheid Variable stars.

142. (2.00 pts) What two parameters cause superclusters of galaxies to expand with Hubble expansion?

Expected Answer: Large size and low density (+1) For saying large sizes of superclusters (+1) For saying low densities of superclusters

143. (1.00 pts)
Within galaxy clusters exists a bunch of heated gas that ranges around a certain temperature. Which of the following is the reasonable temperature for this heated gas?

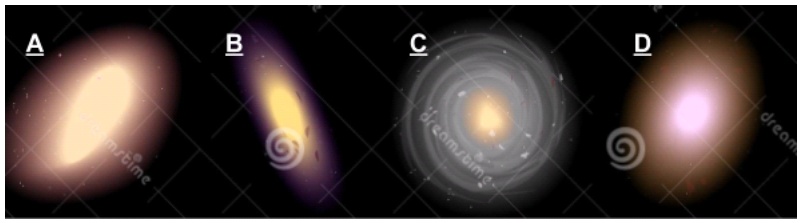
- ○ A) 1 keV

- (●) B) 6 keV
- ( ) C) 25 keV
- ( ) D) 130 keV

144. (1.00 pts) The heated gas mentioned in 146 can emit radiation with a specific kind of radiation. What kind of radiation is it?

Expected Answer: Bremsstrahlung Radiation

145. (4.00 pts) Use the following image to answer the parts of this question.



1. What type of galaxy is shown in image A?
2. What type of galaxy is shown in image B?
3. What type of galaxy is shown in image C?
4. What type of galaxy is shown in image D?

Expected Answer: 1. Irregular 2. Lenticular 3. Spiral 4. Elliptical

146. (1.00 pts) About how many spiral galaxies in this Universe are barred spiral galaxies?

Expected Answer: About 60-70%

147. (1.00 pts) What is the currently proposed theory as to how the spiral arms in spiral galaxies formed?

Expected Answer: Density waves propagated through the outer mass and creating such spin.

Section B - General Knowledge

III. Cosmology (Questions 148-164)

148. (1.00 pts) The ΛCDM model includes all but which of the following as a major component of the Universe?

- A) Dark Energy
- B) Dark Matter
- C) Baryonic Matter
- D) Electromagnetic Radiation

149. (4.00 pts) Identify the order of these events starting from modern day back to Big Bang. Use the letter for your answer.

A: Baryon asymmetry leaves just the light and stable particles known as protons and neutrons

B: Cosmic Microwave Background Radiation is about 3 K

C: The moment that visible light red-shifted into infrared radiation

D: Nuclei, electrons, and photons all exist, but electrons can't bind to the nuclei because it's still too hot to do so.

Expected Answer: B C D A

150. (2.00 pts)
Supposedly, when there were extremely high energies, three major forces had all merged into one, singular force that did not separate into all three. This raised the possibility of another epoch within the chronology of the Universe. Name this theory.

Expected Answer: Grand Unified Theory or GUT Theory

151. (1.00 pts) Which of the following is least related to Special Relativity?

- A) Lorentz Factor
- B) Velocity
- C) Gravity
- D) Frame of Reference

152. (1.00 pts) List the 3 factors that the Cosmological Principle assumes.

Expected Answer: Homogeneity, isotropy, and universality. All three must be given to receive one point.

153. (2.00 pts) One particular tensor helps govern the size and geometry of spacetime. What is the name of this tensor, and explain what the value itself represents?

Expected Answer: This is the metric (tensor), and it can be a loose generalization of the gravitational potential of Newtonian Gravitation. It captures the structure of spacetime. (+1) For identifying the name as the metric (tensor) (+1) For saying that it can generalize gravitational potential of Newtonian Gravitation

154. (2.00 pts)
Sandy has been flying in a rocket since 1990 and managed to travel 30 light-years in comoving coordinates. What is the proper distance that she travelled in light-years, and how do you know? (Hint: Scale factor)

Expected Answer: Sandy still only travelled 30 light-years in proper distance, because the current scale factor is 1, meaning that the comoving distance is equal to proper distance as of right now. (+1) For saying 30 light-years (+1) For saying that the scale factor of 1 implies that comoving distance and proper distance are the same right now.

155. (1.00 pts) Which of the following is least related to the Steinhardt-Turok model for the Universe?

- A) Big Crunch
- B) Big Rip
- C) Big Bounce
- D) Cyclic Model
- E) All of these are equally important

156. (1.00 pts) What scalar field was a proposed explanation for the accelerating expansion of the Universe?

Expected Answer: Quintessence

157. (1.00 pts) What is the shape of the Universe?

- A) Parabaloid
- B) Ellipsoid
- C) Double Cone
- D) Hyperbaloid of Two Sheets
- E) We do not have enough evidence to confirm the shape yet

158. (2.00 pts) Why does the Cosmic Microwave Background look uneven?

Expected Answer: This is a result of the Sachs-Wolfe Effect, where photons in the CMB have been gravitationally redshifted. (+2) For mentioning either Sachs-Wolfe Effect OR said that photons in CMB were gravitationally redshifted.

159. (2.00 pts)
Say that part of the primordial density perturbation had a 2% increase in photon density in a certain location. Which of the following occurrences could be supported by Cosmic Inflation?

- A) There is a 1% decrease in neutrinos in the same location
- B) There is a 1% increase in baryons in the same location
- C) There is a 2% decrease in neutrinos in the same location
- D) There is a 2% increase in baryons in the same location

160. (2.00 pts) Why can the energy density become less and less of a factor in the Universe's total energy?

Expected Answer: Because volume increases and the wavelengths of the photons also stretches, the amount of energy begins to decrease and the energy density subsequently becomes less dense. (+1) For saying volumetric increase of the Universe (+1) For saying that the wavelengths of the photons also increase/stretch

161. (1.00 pts) Which of the following did Big Bang Nucleosynthesis NOT produce?

- A) Deuterium
- B) Tritium
- C) Helium-4
- D) Lithium
- E) All of these were produced during Big Bang Nucleosynthesis

162. (1.00 pts) If our Universe is flat, how much of the Universe is composed of dark energy in the energy density of the Universe?

- A) 4%
- B) 23%

◉ C) 73%

○ D) 80%

163. (1.00 pts) Ripples within the curvature of spacetime that manage to move at light speed are known as what?

Expected Answer: Gravitational waves

164. (2.00 pts) What two properties of the phenomena listed in question 169 make them extremely useful in observing certain objects within our Universe?

Expected Answer: The waves will not get distorted by matter or electromagnetic radiation, so we get a clear view of the gravitational wave Universe, and we are able to detect gravitational waves from sources that do not produce electromagnetic radiation, like black holes. (+1) For saying that waves do not get distorted by matter or EM radiation (+1) For saying that sources that would not produce EM radiation would be observable with gravitational waves

Section C - Mathematics

165. (14.00 pts)
Why is the Universe not uniformly bright? If the universe were infinitely large, every line of sight would terminate at a star. Kepler held on to an interesting mathematical argument tha said the Universe was thereby confined to a finite volume where the light just hasn't reached the ends yet. We'll investigate the argument he made in this problem and how it has been solved today. Assume that the Universe has a uniform density of D everywhere with the amount of stars (with a total mass M) and volume. The number of stars is proportional t brightness, which we'll label B.

Imagine a sphere with a radius of R and volume V, and the radius is composed of infinitely tiny yet finite amounts of length, all of them being dR (so if you combine the infinite amounts of lengths of dR together, you will eventually get R). With each added dR, the volume also changes, and rate at which the volume increases with this formula: dV=4R2dR. A the very edge of the sphere is the "last" dR, and it contains a certain number of stars, dm, within that hollow sphere shell that encompasses just the volume, dV, in that last dR. No further calculus should be needed to answer this question, just algebra.

a) (12 points) Using this info, determine why Inverse Square Law does not solve the paradox with math and explanation.

b) (2 points) If Inverse Square Law cannot resolve the conflict, suggest a way that the paradox can be resolved, and what evidence proves such.

Expected Answer: (+2) For knowing that the number of stars and thus luminosity is proportional to R2 within the galaxy (+2) For using the density formula in at least one valid way (+3) For knowing that Inverse Square Law states that brightness is proportional to 1/R2 within a volume (+3) For connecting the two relationships and noting that they will cancel out (+2) For saying that Inverse Square Law does not justify this because more light is added with more stars, thus meaning that the net brightness does not decrease and thus have the time to be able to spread enough light out

166. (17.00 pts)

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}$$

(17 points) This is one of the many important cosmological equations that one should investigate should they be looking into the expansion of the Universe. ρ is the mass density of the Universe, a is the scale factor k is spatial curvature of the Universe, and Λ is the cosmological constant

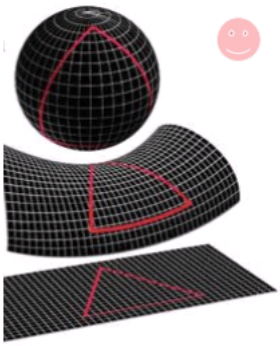
a) This, along with two other equations, are all part of a set of equations known as the _____ equations.

b) (2 points) We need to make two assumptions about the Universe when modeling with this equation. What assumptions are they?

c) (4 points) Derive an equation that would tell us what the critical density (ρc) of the Universe is in terms of any of the variables/constants shown above except “a” and its time-derivative in the equation (Hint: Two of the three terms on the rightmost equation will be 0)

d) (4 points) The density parameter can be expressed as our current mass density over the critical density of the Universe. Interpret how the Universe would change over time should the density parameter be less than 1.

e) (6 points) Here are some shapes that model the major outcomes of Universal expansion; determine the most specific range of the density parameters for each shape.



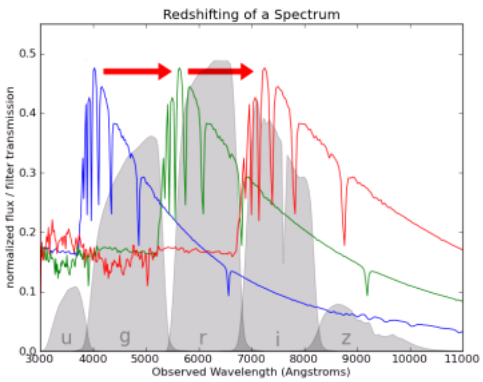
Sphere:

Saddle:

Flat Plane:

Expected Answer: a) Friedmann Equations b) Homogeneity and isotropy (+1) For saying homogeneity or even distribution of material everywhere (+1) For saying isotropy or even distribution of the properties of the Universe everywhere c) (+2) For working with only the leftmost term on the right side of the equation (+2) For saying that Pc=(3H^2)/(8piG) d) The density parameter being less than 1 would allow the Universe to infinitely expand outwards, and if that is the case, it will continue to expand for an indefinite period of time until we reach the Cold Death. (+2) For mentioning an indefinite expansion of the Universe (+2) For mentioning the Cold Death or the fact that the Universe will simply cool down to its death e) Sphere: Greater than 1 Saddle: Less than 1 Flat Plane: Equal to 1 (+2) For each one correctly identified

167. (10.00 pts)



Seen here are a bunch of spectra with some of them being redshifted. We’ll be focusing on the original spectrum, which is colored blue, and the green spectrum being the current galaxy we are interested in observing. Disregard the red spectrum and arrows.

a) (2 points) Unshifted Hydrogen-Alpha of the Balmer series is within which gray-colored region of the graph?

b) (2 points) Has the green spectrum been redshifted or blueshifted? Show your understanding by incorporating Doppler Shift into your answer.

c) (4 points) Let's say somehow we managed to obtain the distance of this object to be 1789.806 Mpc, and instead we are trying to determine Hubble's constant with this data. Approximate the constant with these numbers in km/s/Mpc. Mention your redshift and recessional velocity values for work points. Numbers should be at least 3 significant figures.

d) (2 points) Approximate the age of the Universe with your Hubble constant in years.

Expected Answer: a) Region r b) It's been redshifted; as the galaxy starts to move away, the pulses of light become stretched out further in distance, since the source is moving away from the observer, thus causing a Doppler Shift away from the viewer. (+1) For saying redshifted (+1) For mentioning how the source has a velocity going away from the observer c) Final answer of bout 67 km/s/Mpc (accept within 66.152-67.885 km/s/Mpc) (+1) For having a redshift around 0.395-0.405 (+1) For having a recessional velocity around 118400-121500 km/s (+2) For having an answer of about 66.15-67.89 km/s/Mpc d) It is about 1.457 × 1010 years. (+1) For having a numerical answer of either 4.537-4.656 x 1017 (seconds) OR 1.438-1.475 x 1010 (years) (+1) For having the answer in YEARS, not seconds.

168. (8.00 pts)
You probably want some much easier math bits after all of that hard work. This problem should serve as a very nice breather. Complete the following (If it asks for a number, go to 3 significant figures):

a) (1 point) How many parsecs are in an AU?

b) (1 point) Convert 69 solar masses into grams.

c) (2 points) If our stomach was a perfect mass to energy converter, how many kilograms of Technetium do I need to consume to get a 2500 Calorie intake? Show the formula you used as well.

d) (2 points) Show the Stefan-Boltzmann Law we'd use if in an alternate Universe, stars were right circular cylinders and had 0.5 emissivity. Define the variables.

e) (1 point) Type out the formula used to help define the distance of one parsec, but type the one that gives out a distance in parsecs. Define all variables once again.

f) (1 point) If Star A is 3 magnitudes higher than Star B, write the luminosity ratios between Star A and B.

Expected Answer: a) 4.85x10^(-6) pc b) 1.37x10^33 g c) About 1.16-1.17x10^(-10) kg (+1) For showing E=mc^2 (+1) For having an answer of about 1.16-1.17x10^(-10) kg d) L=(πrh+πr2)σT4 where r is the radius of the circle, h is the height of the cylinder, L is the luminosity of the star, and T is the temperature of the star. (+1) For having an equation that is equal to the one shown above (+1) For correctly defining all variables (they do not have to be represented the same way, but the operational definitions must be correct) e) 1/p=d, where p is the parallax in arcseconds and d is distance in parsecs. f) 1/6.31

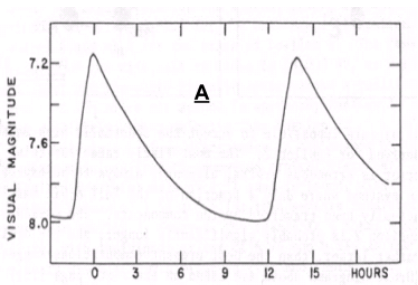
169. (11.00 pts)
Here are a bunch of light curves; I want you to be able to determine specific values for certain objects depending on which light curve you need.

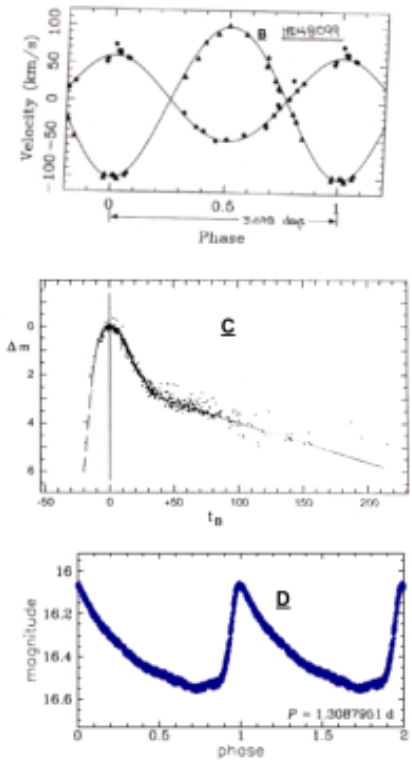
a) (2 points) Identify the graph that would have an absolute magnitude of -19.5, and then determine how far away it is if it has an apparent magnitude of -4.00.

b) (3 points) Determine the mass ratios between the larger and smaller stars in the spectroscopic binary star system. Identify the graph you use for this problem. Show what calculation you did and then the simplest answer.

c) (3 points) Determine the distance of the Cepheid variable star in parsecs. Again, identify the graph that you use and the absolute magnitude that you determine.

d) (3 points) Determine the distance of the RR Lyrae variable star in parsecs. Again, identify the graph that you use and the absolute magnitude that you determine.





Expected Answer: a) (+1) For saying graph C (+1) For saying a distance of about 12500-12600 parsecs b) (+1) For using/saying graph B (+1) For showing a ratio with the numbers 60 and 100 in them (+1) For saying that the ratio of the larger to smaller star is ⅗ or 0.6 c) (+1) For using/saying graph D (+1) For determining the absolute magnitude -1.75 to -1.76 (+1) For determining the distance of the star to be about 40738-40926 parsecs d) (+1) For using/saying graph A (+1) For determining the absolute magnitude -0.856 to -0.857 (+1) For determining the distance to be about 430-530 parsecs

Congratulations on finishing! Don't forget to check your answers. Once you do, feel free to submit. Good luck on your other events!