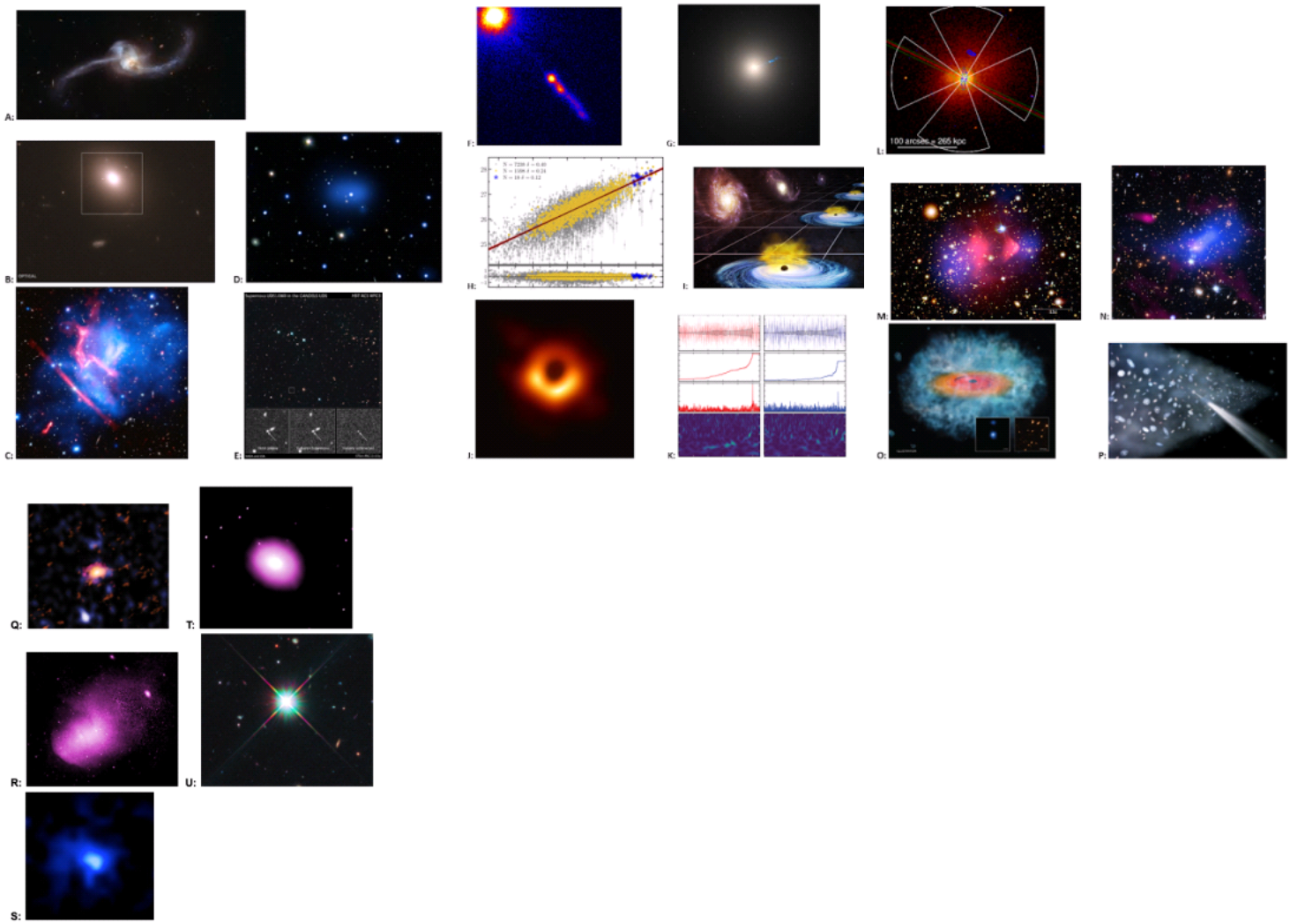
Astronomy C - Astronomy - Rickards Invitational Div. C - 12-05-2020

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?

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?

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?

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?

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?

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?

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?

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?

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?

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?

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?

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?

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?

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?

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?

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.

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?

Section B - General Knowledge

I. Stars (Questions 18-117)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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?

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

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

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

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

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

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

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

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

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

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?

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

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

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

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

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?

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

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

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

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

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

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

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

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

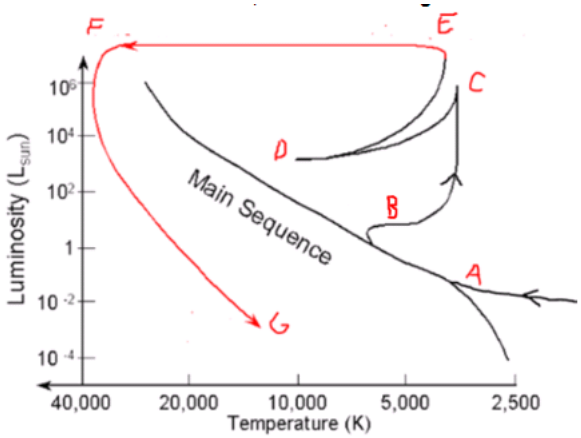
67. (1.00 pts) What is the name of the subclass of Type II Cepheids with the longest pulsation period?

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

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

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

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?

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

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

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

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

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

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?

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

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

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

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

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

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

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

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

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

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

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

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?

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?

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

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

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

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

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?

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

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

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

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

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.

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

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

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?

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?

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

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

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

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?

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

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

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

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

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

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

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

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

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?

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.

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

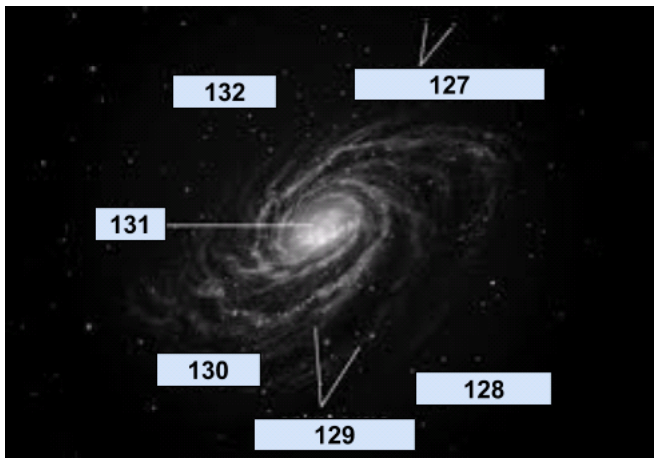
120. (1.00 pts) Why is Hubble's Tuning Fork Model inaccurate with its evolutionary track?

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?

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

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

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?

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

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

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

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

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

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?

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

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

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

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.

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?

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?

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?

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?

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?

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

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?

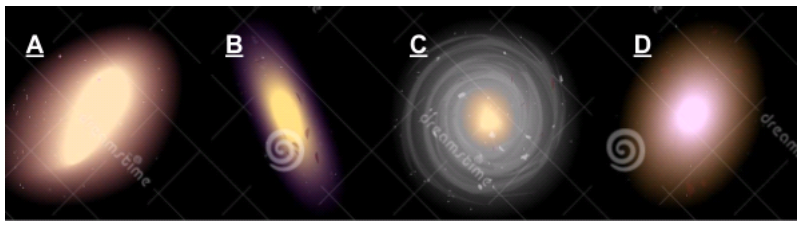
- A) 1 keV
- B) 6 keV

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?

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?

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

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

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.

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.

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.

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?

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)

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?

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?

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?

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?

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?

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.

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

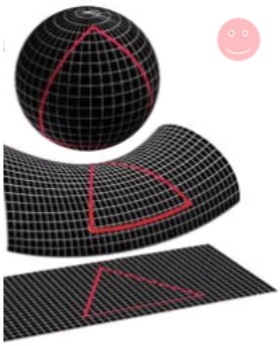
a) This, along with two other equations, are all part of a set of equations known as the _____ equations.

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.

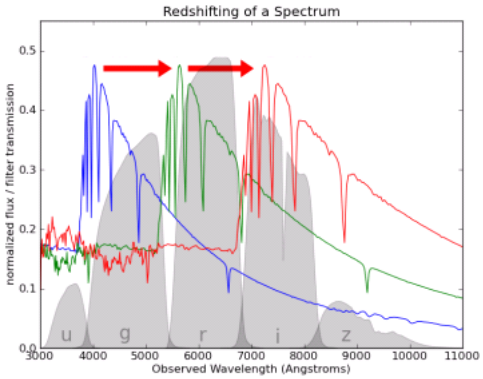


Sphere:

Saddle:

Flat Plane:

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.

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.

169. (11.00 pts)

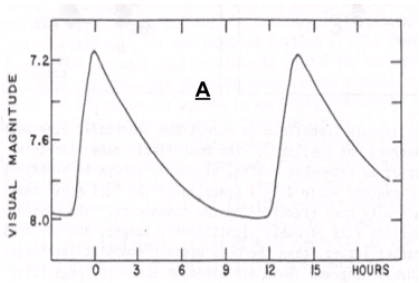
Here are a bunch of light curves; I want you to be able to determine specific values for certain objects depending on which light curve you need.

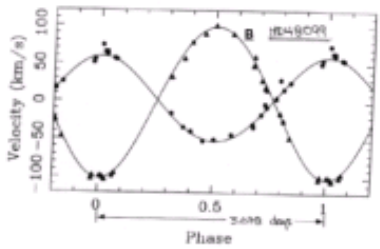
a) (2 points) Identify the graph that would have an absolute magnitude of -19.5, and then determine how far away it is if it has an apparent magnitude of -4.00.

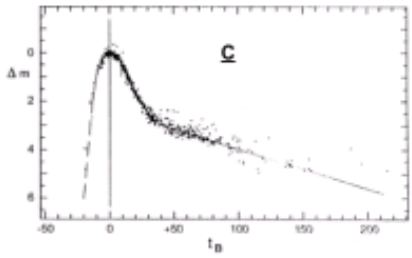
b) (3 points) Determine the mass ratios between the larger and smaller stars in the spectroscopic binary star system. Identify the graph you use for this problem. Show what calculation you did and then the simplest answer.

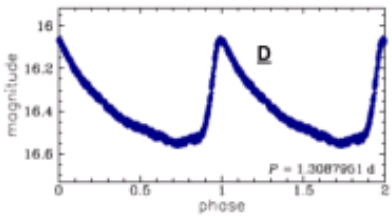
c) (3 points) Determine the distance of the Cepheid variable star in parsecs. Again, identify the graph that you use and the absolute magnitude that you determine.

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.









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