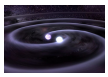
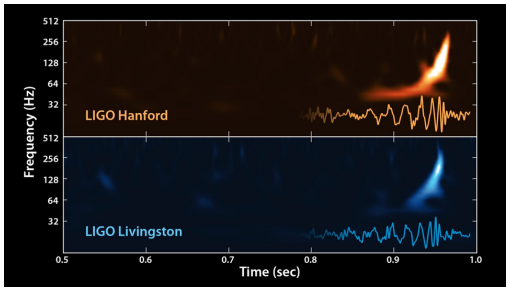


NOVA: Black Hole Apocalypse
Video Questions [Key]

Name: _____

Date: _____ **Class:** _____

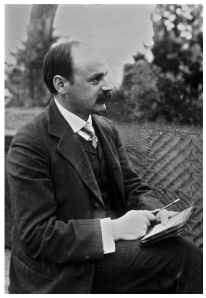
In 2015, the LIGO experiment observed the first known collision of two black holes. LIGO, the Laser Interferometer Gravitational-wave Observatory, is a groundbreaking, 50-year effort to record gravity waves emitted by extreme events in the universe. The observation of colliding black holes confirmed predictions made by Albert Einstein over a century ago. *Answer the following questions while watching* NOVA: Black Hole Apocalypse*. Select the correct multiple-choice response for each question. After the video, write the letter of each answer in the blank at the beginning of each question. The questions follow the same order as the information shown in the video.*



1. __B_. When did the LIGO experiment record a message?
   A) Jul 4, 2012 B) Sep 15, 2015 C) Aug 11, 2017
2. __B_. How many light years (ly) did the signal (chirp) travel to reach us?
   A) 2.5 million ly B) Over a billion ly C) 13.8 billion ly
3. __A_. According to Janna Levin, the waves from the two merging black holes resemble… A) vibrations on a drum B) an undulating Slinky
   C) kids jumping on a trampoline
4. __C_. How much power did the collision put out?
   A) 50x the sun B) 50x the Milky Way C) 50x the entire visible universe
5. __B_. How fast do waves of gravity travel?
   A) Speed of sound B) Speed of light C) 9.8 m/s^2
6. __A_. For 400 yrs. nearly all observations of the universe were in what form?
   A) Electromagnetic waves B) Gravitational waves C) Seismic waves
7. __B_. According to Levin, gravitational waves squeeze and stretch…
   A) red-shifted light from distant galaxies. B) the "fabric of space". C) lines of sight.
8. __B_. The black hole collision emitted some light, but was too dim to be seen from earth. A) True B) False
9. __A_. According to Levin, a black hole can pull things in, warp light, and…
   A) slow down time. B) destroy matter. C) emit particles.
10. __C_. According to Levin, what are black holes?
    A) An object B) Extruded spacetime C) Nothing but gravity
11. __C_. According to Levin, for a long time, what was one of the greatest mysteries?
    A) Stellar equilibrium B) Origin of the universe C) How gravity works
12. __B_. Isaac Newton's laws of motion work, but have become outdated and are no longer used.
    A) True B) False
13. __A_. According to Levin, what did Einstein realize about gravity?
    A) It had something to do with falling B) It disappeared in space C) It was a force like Newton described
14. __B_. At what speed would a moving apple become free falling?
    A) 767 mi/hr. B) 17,000 mi/hr. C) 9.8 m/s^2
15. __C_. What was Einstein's "extremely simple" concept about the mass of objects?
    A) It creates a force of attraction B) It is analogous to weight C) It bends space & time
16. __A_. According to Einstein's 1915 theory of general relativity, gravity…
    A) is curved space. B) is a force of attraction.
    C) is a relationship between mass & distance.
17. __B_. What was Karl Swartzschild the first to do? A) Predict the existence of neutron stars
    B) Make a connection between gravity & black holes C) Discover a pulsar
18. __A_. According to Swartzschild, what appeared when a star's mass was concentrated into a single point? A) A boundary B) A primeval atom C) A front

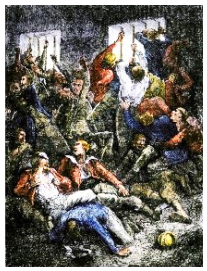
Newton

Einstein

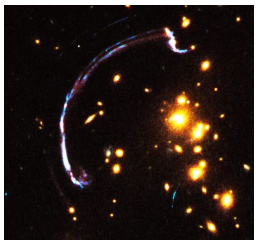


Swartzschild

19. __C_. Swartzschild discovered that any mass compressed into a small enough space creates what we today call…
    A) a strange, theoretical sphere. B) 6 impossible things before breakfast. C) a black hole.



20. __B_. Which process uses atoms to power stars? A) Fission B) Fusion C) Combustion
21. __A_. According to E. Glikman, stars are born… A) in litters. B) continuously. C) in galaxies.
22. __C_. How are stars distributed? A) In a normal curve
    B) Thousands of big stars, & a few small stars C) Thousands of little stars, & a few big stars
23. __B_. According to N. Imara, stars are like living creatures, and the life of a star depends upon...
    A) composition. B) mass. C) gravity.
24. __A_. Which element do all stars start out fusing? A) Hydrogen B) Helium C) Lithium
25. __C_. In a star, what balances the inward crush of gravity to keep the star from collapsing?
    A) Its mass B) The electromagnetic force C) The outward-moving pressure of nuclear fusion
26. __B_. Which element is a "dead end" for massive stars? A) Hydrogen B) Iron C) Uranium
27. __C_. The collapse of a massive star creates what type of explosion? A) Nova B) Kilonova C) Supernova
28. __A_. The unstoppable collapse of the remaining core of a massive star results in…
    A) a black hole. B) an immense explosion. C) the formation of new stars & planets.

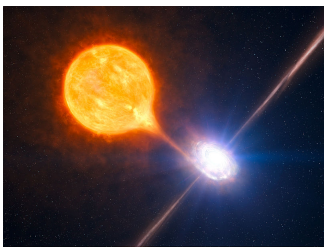


29. __B_. Pre-eminent astrophysicists in the 1930-50s believed that black holes were actually real.
    A) True B) False
30. __B_. Who coined the term "black hole", based on an infamous Calcutta prison?
    A) Swartzschild B) Wheeler C) Bell Burnell
31. __A_. What did graduate student Jocelyn Bell Burnell discover in 1967?
    A) A neutron star B) X-rays in space C) Radio emissions from the sky
32. __C_. Stars greater than or equal to ____ times the sun's mass will collapse into a black hole. A) 3 B) 7 C) 10
33. __A_. At a black hole's event horizon, nothing can escape, not even light. A) True B) False
34. __A_. What is the term for the bending of light due to a black hole's extreme gravity?
    A) Gravitational lensing B) Entanglement C) Hubble's Law
35. __B_. What happens to time inside a spaceship near a black hole? A) It speeds up relative to earth
    B) It slows down relative to earth C) It rapidly increases & approaches a minimum, never reaching zero
36. __C_. To an observer on board a spaceship near a black hole, a spacewalking astronaut would appear to take how long to reach the event horizon? A) A few minutes B) Thousands of years C) Millions to billions of years
37. __A_. An astronaut passing into a black hole will become…
    A) spaghettified. B) pulverized. C) obliterated.

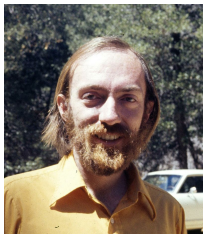
Bell Burnell

38. __B_. What is the term for an infinitely small point, where all understanding of space and time breaks down? A) Primeval atom B) Singularity C) Event horizon
39. __B_. According to Levin, how can black holes be investigated?
    A) By direct observation using powerful telescopes
    B) By observing their effect on their surroundings
    C) By studying the type of electromagnetic radiation that they emit
40. __C_. What did Bell Labs engineer Karl Jansky discover in 1931, and rocket-mounted Geiger counters later discover?
    A) Neutron stars & black holes B) Galactic & solar rays C) Radio emissions from the sky, & X-rays in space
41. __A_. Our eyes perceive only a narrow part of the electromagnetic spectrum. A) True B) False
42. __B_. Electromagnetic radiation includes waves of many different ____: Radio waves, microwaves, infrared, ultraviolet, x-rays, and gamma rays. A) intensities B) frequencies C) velocities

43. __C_. Which type of radiation is emitted by objects at temperatures of millions to tens of millions of degrees?
A) Radio waves B) Visible light C) X-rays



44. __A_. What was the first x-ray source found in the constellation Cygnus?
A) Cygnus X-1 B) Veil Nebula C) Deneb
45. __C_. According to Levin, pairs of orbiting stars locked together by gravity are called…
A) doppelgangers. B) twins. C) binaries.
46. __B_. What is the red and blue color change of moving stars named?
A) Hubble's Law B) Doppler shift C) Scintillation
47. __B_. The star discovered by P. Murdin had a period of ____ days. A) 2.9 B) 5.6 C) 332
48. __B_. What was Murdin's estimate of the mass of the invisible partner (in solar masses)? A) 3 B) 6 C) 15
49. __C_. Why did Sir Richard Woolley think that black holes were "fanciful"? A) He had a feud with Schwartzschild
B) They were not supported by Einstein's theory C) California hippies were talking about them
50. __A_. Who did Kip Thorne make a bet with? A) Stephen Hawking B) Sir Richard Woolley C) Mark Reid
51. __B_. According to M. Reid, what is absolutely fundamental in astronomy? A) Mass B) Distance C) Brightness
52. __C_. What provides two different vantage points to observe the parallax of a distant star such as Cygnus X-1?
A) Satellites B) Interferometry C) Earth's motion
53. __C_. Which example is used to demonstrate the miniscule angle to be measured?
A) A diameter smaller than a proton B) A grain of rice on the moon
C) Lincoln's nose on a penny in San Francisco, viewed from New York



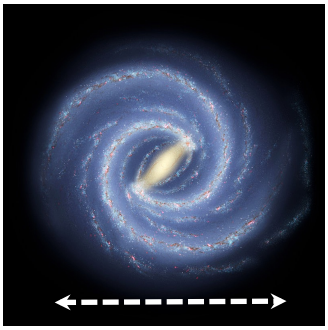
Thorne

54. __A_. Reid's 10-telescope solution has a diameter of…
A) the size of the earth. B) the continental US. C) the Atlantic Ocean.
55. __C_. At 6000 ly away, Cygnus X-1 equals how many solar masses? A) 3 B) 6 C) 15
56. __B_. According to Levin, what surrounds Cygnus X-1?
A) Planetary system B) Accretion disk C) Star cluster
57. __A_. Particles closest to the black hole whip around at… A) ½ light speed B) 186,000 mi/s C) 6000 light years
58. __B_. Why does Cygnus X-1 emit X-rays? A) Its surrounding cloud of debris acts as a "light filter"
B) Colliding particles heat up to millions of degrees C) The star is moving rapidly towards us
59. __C_. What is Cygnus X-1 doing to its companion star?
A) Orbiting in 5.6 years B) Causing it to wobble C) Stripping material off the star

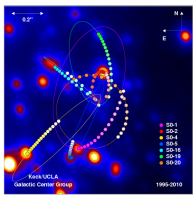
Hawking

60. __A_. According to Levin, what is one of the most striking and enigmatic features of Cygnus X-1?
A) Enormous jets B) Miniscule parallax angle C) Accretion disk
61. __B_. According to P. Natarajan, Cygnus X-1 is like a breathing, fire-eating...
A) goddess. B) angel. C) demon.
62. __B_. According to Levin, how many black holes have been found in our galaxy?
A) 1 B) At least 20 C) Millions
63. __C_. Why were the mysterious objects named "QUASi-stellAR radio sourceS" (quasars)?
A) They were thought to be massive stellar corpses B) They were named for a well-known television maker
C) They looked like stars, but emitted radio energy
64. __A_. Every element has a unique spectral "____", which reveals the chemical make up of stars. A) fingerprint B) barcode C) signature

65. __B_. First discovered by Maarten Schmidt, the red shift of the spectrum of hydrogen in quasars indicates that…
    A) they are relatively nearby objects. B) they are moving away from us at "fantastic speed".
    C) they represent an unusually cool type of star.
66. __B_. Ever since its creation nearly 14 billion years ago in the Big Bang, the universe has been…
    A) static. B) expanding. C) speeding up.
67. __C_. What is the likely energy source of quasars? A) Chemical energy B) Nuclear fusion C) Gravity
68. __C_. The supermassive black holes that power quasars must be how large?
    A) About 15 suns B) 4 million x the sun's mass C) Millions to billions of suns
69. __B_. The Milky Way's center lies in the direction of which constellation? A) Orion B) Sagittarius C) Centaurus
70. The Milky Way is a spiral galaxy, with 100s of billions of stars drawn together into a wide, thin, slowly rotating disk.
    Match each feature of the Milky Way Galaxy to its size in light years:



    __C_. Distance across the disk — A) 1,000 ly
    __A_. Thickness of the disk — B) 26,000 ly
    __B_. Distance from the solar system to the Milky Way center — C) 100,000 ly
71. __C_. Since we live inside the Milky Way, the galaxy appears to us as…
    A) a faint glow extending along the ecliptic. B) a giant candy bar.
    C) a band of stars & dust, a "milky way".
72. __B_. In the 1990s, how did Andrea Ghez study the Milky Way's center?
    A) By using a small telescope B) By tracking individual stars orbiting the center
    C) By studying the distribution of globular star clusters
73. __A_. High altitude and low humidity make ____ the ideal place for astronomy. A) Mauna Kea B) Cyprus C) LA
74. __A_. What declassified military technology does the Keck Telescope use to compensate for atmospheric distortion?
    A) Adaptive optics B) Charge-coupled devices (CCDs) C) Laser interferometer
75. __C_. What does Keck use to create an "artificial star"? A) Jupiter or Venus B) Satellite C) Laser
76. __B_. Inside the telescope, what changes shape up to 2,000 times per second to reverse atmospheric distortion? A) The spider B) Deformable mirrors C) Encoders



77. __A_. Ghez's annual images show that stars near the Milky Way's center are moving at what phenomenal speeds? A) Up to 10 million mi/hr. B) 17,000 mi/hr. C) 9.8 m/s^2
78. __B_. Based upon the orbiting stars, what is the mass inferred for the black hole at the Milky Way's center? A) About 15 suns B) 4 million x the sun's mass C) 100 million x the sun's mass
79. __C_. Which innovation made it possible to determine if black holes exist in other galaxies?
    A) Adaptive optics B) Multi-messenger astronomy C) The Hubble Space Telescope
80. __B_. How did astronomers measure the average speed of stars in distant galaxies? A) Creating time-lapse movies
    B) Measuring the red & blue shifts of light C) Imaging individual stars near the centers
81. __A_. Martin Schwarzschild's method enabled astronomers to ____ of galaxies.
    A) make models B) calculate the size C) estimate the distances
82. __B_. What did "the Nukers" need to add to their galaxies to match the Hubble observations?
    A) Dark energy B) Black holes C) Redshifts

Ghez

83. __B_. Supermassive black holes at the centers of galaxies appear to be rare and uncommon.
    A) True B) False
84. __A_. The Andromeda Galaxy, located 2.5 million light years away, visible in a clear sky from earth, with an extremely massive object at its center, is also known as… A) M31. B) M42. C) M104.

85. __A_. If Andromeda's black hole were dropped in our solar system, Mercury, Venus, Earth, and ____ would all be trapped inside the event horizon. A) Mars B) Jupiter C) Saturn

86. __C_. How massive is the black hole at the center of the Andromeda Galaxy?
A) About 15 suns B) 4 million x the sun's mass C) 100 million x the sun's mass

87. __B_. What causes Andromeda's accretion disk to appear above and below the poles?
A) Rapid rotation B) Gravitational lensing C) Enormous jets

88. Summary: *Match each black hole to its size in solar masses*

__C_. Andromeda Galaxy	A) 15
__A_. Cygnus X-1	B) 4 million
__B_. Milky Way	C) 100 million

89. __B_. Andromeda's black hole is the largest known. A) True B) False

90. __A_. How are black holes believed to grow?
A) Absorption of gas B) Converting energy into mass C) Retention of virtual particles

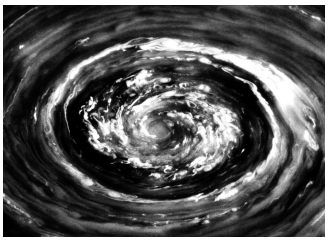
91. __B_. Orbiting up to 86,000 miles above the Earth, the Chandra Observatory takes high-resolution images of objects that emit… A) radio waves. B) x-rays. C) gamma rays.

92. __B_. Why was James Guillochon's transient object (smudge) more likely to be a black hole devouring a star, not a black hole being born in a supernova explosion? A) It only lingered for a few months
B) The signal has continued for more than 10 years C) The black hole was quiet & completely dark

93. __C_. What is the term for the deformation a star experiences as it wanders to close to a black hole?
A) Flaying B) Spaghettification C) Tidal disruption

94. __A_. What does the timing problem refer to? A) The oldest quasars in the early universe
B) The discovery of quasars in the early 1960s C) Obtaining telescope time within a season of visibility

95. __C_. With the Eddington "speed limit", what will not allow a black hole to feed and grow too fast?
A) Distance B) Tidal effects C) Light pressure



96. __B_. What is the term for the creation of black holes within a cloud of gas?
A) Nucleosynthesis B) Direct collapse C) Nuclear fusion

97. __C_. What are formed when portions of a cloud collapse and begin nuclear fusion?
A) Nebulae B) Hydrogen atoms C) Stars

98. __A_. According to Levin, what are tornadoes and water in a bathtub an example of?
A) A vortex B) Fluid mechanics C) Dangers

99. __A_. How large were the initial masses (seed masses) of the gas clouds that may have formed supermassive black holes in the early universe?
A) From 10 to 100 thousand x the sun's mass B) 4 million x the sun's mass C) 100 million x the sun's mass

100. __B_. According to Levin, galaxies are… A) the fundamental building blocks of our universe.
B) mind-bogglingly huge. C) foul & pestilential congregations of vapors.

101. __A_. The bigger the galaxy, the ____ the black hole at its center. A) bigger B) smaller C) lesser

102. __C_. In a galaxy, what is produced by a black hole that makes it impossible for stars to form nearby?
A) Mass B) Entropy C) Heat

103. __B_. Designed to look in the infrared, what will be humanity's most powerful telescope ever?
A) Hubble Space Telescope B) James Webb Space Telescope C) Event Horizon Telescope

104. __C_. Which group consisting of 8 telescopes is attempting to take a picture of a black hole?
A) Hubble Space Telescope B) James Webb Space Telescope C) Event Horizon Telescope

105. __B_. The silhouette of a black hole in a gas cloud will likely resemble…
A) a void. B) a donut. C) a disk.


Weiss

106. __A_. An added benefit of the detection of gravitational waves would be…
A) proof that black holes exist. B) confirmation of the Ptolemaic theory.
C) the justification for a large, expensive project.

107. __C_. In 1970, the problem of gravitational waves caught the attention of which experimental physicist?
A) Kip Thorne B) Sir Richard Woolley C) Rai Weiss

108. __B_. According to the physicist, what terrible problem did early musical records have? A) When loud, the music sounded wonderful B) When the music was quiet & low, an annoying hissing noise was heard
C) Only discrete parts of the wave were captured, leading to a less rich sound

109. __A_. A sound wave compresses and expands air, a gravitational wave compresses and expands…
A) space, & everything in it. B) the ether. C) virtual particles.

110. __C_. What was used to calculate the exact distance to the moon? A) Eclipses B) A stopwatch C) Light

111. __A_. What ingenious design would use lasers and mirrors to measure the expansions and contractions of space?
A) Adaptive optics B) Charge-coupled devices (CCDs) C) Laser interferometer

112. __C_. If a gravitational wave hits, the difference in length between the two arms of the structure would be…
A) the size of an atom. B) the size of the nucleus of an atom. C) 100 x less than an atomic nucleus.

113. __B_. Why was LIGO extremely controversial? A) Its practical benefit was questioned
B) Getting it funded C) The extreme difficulty of making such small measurements

114. __C_. Along with noise, what was a potentially crippling problem with the LIGO experiment?
A) Jiggling electrons B) Mantle convection C) Quantum fluctuations

115. __A_. Along with Louisiana, where was another complete LIGO installation built?
A) Washington state B) Los Alamos C) Fermilab

116. __B_. Why was another LIGO installation required?
A) In case one facility broke down B) To completely eliminate false signals
C) To provide more research opportunities for graduate students

117. __C_. Jokingly, what was the Robert Schofield's greatest contribution to LIGO?
A) Dishonesty B) Mendacity C) Laziness

118. __C_. The black hole merger detected in Sep 2015 created a single, larger black hole of ____ solar masses.
A) 29 B) 36 C) 62

119. __B_. According to Levin, what has LIGO recorded since the first black hole merger in Sep 2015?
A) New quasar discoveries B) Several more black hole collisions C) Numerous supernovas

120. __A_. What did Rai Weiss, Kip Thorne, and Barry Barisch receive in October 2017?
A) The Nobel Prize B) The Order of Knighthood C) Asteroids named in honor

121. __C_. Astronomy has always been about seeing the universe. With LIGO, scientists can now ___ the universe.
A) taste B) hear C) touch


Levin

122. __A_. In August, 2017, LIGO detected gravitational waves from the merger of 2 neutron stars. Telescopes were also able to see ____ from this event.
A) light B) empty space C) a black hole forming

123. __B_. The size and number of black holes is decreasing. A) True B) False