NOVA: Black Hole Apocalypse Video Questions

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. _____. When did the LIGO experiment record a message?
 - A) Jul 4, 2012 B) Sep 15, 2015 C) Aug 11, 2017
- 2. ____. 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. _____. 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. . How much power did the collision put out?
 - A) 50x the sun B) 50x the Milky Way C) 50x the entire visible universe
- 5. . How fast do waves of gravity travel?
 - A) Speed of sound B) Speed of light C) 9.8 m/s²
- 6. _____. For 400 yrs. nearly all observations of the universe were in what form?
- A) Electromagnetic waves B) Gravitational waves C) Seismic waves
- 7. 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. _____. The black hole collision emitted some light, but was too dim to be seen from earth. A) True B) False
- 9. _____. According to Levin, a black hole can pull things in, warp light, and...
 - A) slow down time. B) destroy matter. C) emit particles.
- 10. _____. According to Levin, what are black holes?
 - A) An object B) Extruded spacetime C) Nothing but gravity
- 11. _____. 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. Isaac Newton's laws of motion work, but have become outdated and are no longer used. A) True B) False
- 13. 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. _____. At what speed would a moving apple become free falling?

A) 767 mi/hr. B) 17,000 mi/hr. C) 9.8 m/s²

- 15. . 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. _____. 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. _____. 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. _____. According to Swartzschild, what appeared when a star's mass was concentrated into a single

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Swartzschild





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- 19. ____. 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. ____. Which process uses atoms to power stars? A) Fission B) Fusion C) Combustion
- 21. _____. According to E. Glikman, stars are born... A) in litters. B) continuously. C) in galaxies.
- 22. _____. 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. _____. According to N. Imara, stars are like living creatures, and the life of a star depends upon...A) composition. B) mass. C) gravity.
- 24. _____. Which element do all stars start out fusing? A) Hydrogen B) Helium C) Lithium
- 25. _____. 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. ____. Which element is a "dead end" for massive stars? A) Hydrogen B) Iron C) Uranium
- 27. ____. The collapse of a massive star creates what type of explosion? A) Nova B) Kilonova C) Supernova
- 28. ____. 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. _____. Pre-eminent astrophysicists in the 1930-50s believed that black holes were actually real.A) True B) False
- 30. _____. Who coined the term "black hole", based on an infamous Calcutta prison?
 - A) Swartzschild B) Wheeler C) Bell Burnell
- 31. _____. 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. ____. Stars greater than or equal to _____ times the sun's mass will collapse into a black hole. A) 3 B) 7 C) 10
- 33. _____. At a black hole's event horizon, nothing can escape, not even light. A) True B) False
- 34. _____. 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. _____. 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. _____. 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. _____. An astronaut passing into a black hole will become...
 - A) spaghettified. B) pulverized. C) obliterated.
- 38. _____. 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. _____. 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. _____. 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. _____. Our eyes perceive only a narrow part of the electromagnetic spectrum. A) True B) False
- 42. _____: Electromagnetic radiation includes waves of many different _____: Radio waves, microwaves, infrared, ultraviolet, x-rays, and gamma rays. A) intensities B) frequencies C) velocities







Bell Burnell

- 43. _____. 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. _____. What was the first x-ray source found in the constellation Cygnus?A) Cygnus X-1 B) Veil Nebula C) Deneb
- 45. _____. According to Levin, pairs of orbiting stars locked together by gravity are called...A) doppelgangers. B) twins. C) binaries.
- 46. _____. What is the red and blue color change of moving stars named?
 - A) Hubble's Law B) Doppler shift C) Scintillation
- 47. ____. The star discovered by P. Murdin had a period of ____ days. A) 2.9 B) 5.6 C) 332
- 48. _____. What was Murdin's estimate of the mass of the invisible partner (in solar masses)? A) 3 B) 6 C) 15
- 49. _____. Why did Sir Richard Woolley think that black holes were "fanciful"? A) He had a feud with SchwartzschildB) They were not supported by Einstein's theory C) California hippies were talking about them
- 50. _____. Who did Kip Thorne make a bet with? A) Stephen Hawking B) Sir Richard Woolley C) Mark Reid
- 51. _____. According to M. Reid, what is absolutely fundamental in astronomy? A) Mass B) Distance C) Brightness
- 52. _____. 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. _____. 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
- 54. _____. Reid's 10-telescope solution has a diameter of...
 - A) the size of the earth. B) the continental US. C) the Atlantic Ocean.
- 55. _____. At 6000 ly away, Cygnus X-1 equals how many solar masses? A) 3 B) 6 C) 15
- 56. _____. According to Levin, what surrounds Cygnus X-1?
 - A) Planetary system B) Accretion disk C) Star cluster
- 57. _____. Particles closest to the black hole whip around at... A) 1/2 light speed B) 186,000 mi/s C) 6000 light years
- 58. _____. 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. _____. 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
- 60. _____. 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. _____. According to P. Natarajan, Cygnus X-1 is like a breathing, fire-eating...
 - A) goddess. B) angel. C) demon.
- 62. _____. According to Levin, how many black holes have been found in our galaxy?
 - A) 1 B) At least 20 C) Millions
- 63. _____. 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. _____. Every element has a unique spectral "_____", which reveals the chemical make up of stars. A) fingerprint B) barcode C) signature









Hawking



- 65. _____. 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. _____. 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. _____. What is the likely energy source of quasars? A) Chemical energy B) Nuclear fusion C) Gravity
- 68. ____. 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. ____. 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:

- _____. Distance across the diskA) 1,000 ly_____. Thickness of the diskB) 26,000 ly_____. Distance from the solar system to the Milky Way centerC) 100,000 ly
- 71. _____. 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. _____. 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. _____. High altitude and low humidity make _____ the ideal place for astronomy. A) Mauna Kea B) Cyprus C) LA
- 74. _____. 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. _____. What does Keck use to create an "artificial star"? A) Jupiter or Venus B) Satellite C) Laser
- 76. _____. 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. _____. 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/s²
- 78. _____. 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. _____. 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. _____. 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. _____. Martin Schwarzschild's method enabled astronomers to ______ of galaxies.A) make models B) calculate the size C) estimate the distances
- 82. ____. What did "the Nukers" need to add to their galaxies to match the Hubble observations?A) Dark energy B) Black holes C) Redshifts
- 83. _____. Supermassive black holes at the centers of galaxies appear to be rare and uncommon.A) True B) False
- 84. _____. 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.





Ghez

- 85. _____. 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. _____. 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. _____. What causes Andromeda's accretion disk to appear above and below the poles? A) Rapid rotation B) Gravitational lensing C) Enormous jets
- 88. <u>Summary</u>: Match each black hole to its size in solar masses
 - _____. Andromeda Galaxy A) 15
 - _____. Cygnus X-1 B) 4 million
 - _____. Milky Way C) 100 million
- 89. _____. Andromeda's black hole is the largest known. A) True B) False
- 90. _____. How are black holes believed to grow?
 - A) Absorption of gas B) Converting energy into mass C) Retention of virtual particles
- 91. _____. 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. _____. 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. _____. 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. _____. 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. _____. 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. _____. What is the term for the creation of black holes within a cloud of gas?
 - A) Nucleosynthesis B) Direct collapse C) Nuclear fusion
- 97. _____. What are formed when portions of a cloud collapse and begin nuclear fusion? A) Nebulae B) Hydrogen atoms C) Stars
- 98. _____. According to Levin, what are tornadoes and water in a bathtub an example of? A) A vortex B) Fluid mechanics C) Dangers
- 99. _____. 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. _____. According to Levin, galaxies are... A) the fundamental building blocks of our universe. B) mind-bogglingly huge. C) foul & pestilential congregations of vapors.
- 101. _____. The bigger the galaxy, the _____ the black hole at its center. A) bigger B) smaller C) lesser
- 102. _____. 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. _____. 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. _____. 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. _____. The silhouette of a black hole in a gas cloud will likely resemble...A) a void. B) a donut. C) a disk.
- 106. _____. 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. _____. 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. _____. 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 sound wave compresses and expands air, a gravitational wave compresses and expands... A) space, & everything in it. B) the ether. C) virtual particles.
- 110. _____. What was used to calculate the exact distance to the moon? A) Eclipses B) A stopwatch C) Light
- 111. _____. 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. _____. 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. _____. 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. _____. Along with noise, what was a potentially crippling problem with the LIGO experiment? A) Jiggling electrons B) Mantle convection C) Quantum fluctuations
- 115. _____. Along with Louisiana, where was another complete LIGO installation built?A) Washington state B) Los Alamos C) Fermilab
- 116. _____. 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. _____. Jokingly, what was the Robert Schofield's greatest contribution to LIGO?A) Dishonesty B) Mendacity C) Laziness
- 118. _____. The black hole merger detected in Sep 2015 created a single, larger black hole of _____ solar masses. A) 29 B) 36 C) 62
- 119. _____. 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. _____. 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. _____. Astronomy has always been about seeing the universe. With LIGO, scientists can now _____ the universe. A) taste B) hear C) touch
- 122. _____. 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. _____. The size and number of black holes is decreasing. A) True B) False







