

Name: \_\_\_\_\_ Date: \_\_\_\_\_

## Answer Key: Dare to Scale the Cosmic Horizon: 10th Grade Cosmology Challenge

Students calculate redshift, evaluate dark matter evidence, and analyze the nucleosynthesis ratios that define our understanding of the universe's evolution.

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**1. In the context of Lambda-CDM cosmology, how does the discovery of the 'Bullet Cluster' (1E 0657-558) serve as critical evidence for the existence of dark matter over modified gravity theories?**

**Answer:** B) The spatial separation between the visible matter and the center of mass suggests non-interacting matter.

In the Bullet Cluster, the visible hot gas (baryons) was slowed by electromagnetic interaction, while the gravitational lensing (mass) passed through unimpeded, indicating dark matter is collisionless and distinct from visible matter.

**2. True or False: According to the Big Bang Nucleosynthesis model, the observed 3:1 mass ratio of Hydrogen to Helium in the early universe is a primary piece of evidence for a hot, dense origin of the cosmos.**

**Answer:** A) True

The abundance of light elements, specifically the ratio of roughly 75% hydrogen and 25% helium, matches theoretical predictions of nuclear fusion occurring in the extremely high temperatures of the early universe.

**3. When observing a distant Quasar, an astronomer notes that the spectral lines are shifted toward longer wavelengths. This phenomenon, known as \_\_\_\_\_, suggests the space between galaxies is stretching.**

**Answer:** A) Cosmological Redshift

Cosmological redshift is caused by the expansion of space itself stretching the light waves as they travel, which is distinct from the local Doppler effect caused by individual stellar motion.

**4. How do Type Ia Supernovae serve as 'Standard Candles' to reveal the presence of Dark Energy?**

**Answer:** B) Their consistent peak luminosity allows scientists to calculate distance vs. redshift, proving accelerated expansion.

Because Type Ia Supernovae have a predictable peak brightness, comparing how faint they appear to their known luminosity allows astronomers to measure their distance and discover that the universe's expansion rate is increasing.

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**5. The theoretical 'Epoch of \_\_\_\_\_' refers to the moment roughly 380,000 years after the Big Bang when photons were finally able to travel freely through space.**

**Answer:** C) Recombination

During Recombination, electrons combined with protons to form neutral hydrogen, making the universe transparent and releasing the Cosmic Microwave Background radiation.

**6. True or False: The Cosmological Principle states that on a sufficiently large scale, the universe is both homogeneous (the same everywhere) and isotropic (the same in all directions).**

**Answer:** A) True

This principle is the cornerstone of modern cosmology, implying that we do not occupy a special or central location in the universe and that laws of physics are universal.

**7. Identify the primary difference between the behavior of Spiral galaxies and Elliptical galaxies regarding star formation.**

**Answer:** C) Spirals maintain ongoing star formation in their disks; Ellipticals are largely 'red and dead' with little gas.

Spiral galaxies contain abundant interstellar medium (gas and dust) to fuel new stars, whereas Ellipticals have mostly exhausted their gas supplies, resulting in populations of older, cooler stars.

**8. Vera Rubin's analysis of \_\_\_\_\_ suggested that galaxies must contain significant amounts of invisible mass because stars at the edges of galaxies orbit as fast as those near the center.**

**Answer:** A) Galaxy Rotation Curves

Rubin found that rotation curves were 'flat' rather than dropping off as expected by Newtonian gravity based on visible light, providing evidence for a dark matter halo.

**9. True or False: The 'Great Attractor' is a massive supermassive black hole at the exact center of the observable universe that all galaxies are orbiting.**

**Answer:** B) False

The Great Attractor is a gravitational anomaly in intergalactic space, likely a massive supercluster of galaxies, and the universe has no 'center' or central object that everything orbits.

**10. What is the likely fate of the universe if the density of dark energy remains constant and continues to dominate the total energy density?**

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**Answer:** C) The Big Freeze (Heat Death): The universe will expand forever, cooling until it reaches thermodynamic equilibrium.

Current data suggests an 'open' or 'flat' universe where dark energy causes infinite expansion, leading to a state where all energy is uniformly distributed and no more work can be performed (Heat Death).