Unit 4: Cosmology

Name: _____ Class / No: _____ Date: _____

Learning outcomes

- AST.4.1 — Theories of the origin of the universe
- AST.4.2 — The expansion rate and what the universe is made of
- AST.4.3 — Large-scale structures
- AST.4.4 — The possible end of the universe

Questions

1. (AST.4.1) Which observation most strongly refutes the steady-state theory?
   ○ A) The phases of the Moon ○ B) The cosmic microwave background
   ○ C) Sunspots ○ D) The elliptical orbits of the planets

2. (AST.4.1) What is the main reason the multiverse idea is scientifically controversial?

3. (AST.4.2) If H_0 = 70 km/s/Mpc, how fast does a galaxy 300 Mpc away recede?
   ○ A) 2,100 km/s ○ B) 7,000 km/s
   ○ C) 21,000 km/s ○ D) 300,000 km/s

4. (AST.4.2) If the measured H_0 gets larger, how does the estimated age of the universe change? Why?

5. (AST.4.2) Which of the following is evidence for dark matter?
   ○ A) The outer parts of galaxies rotating faster than expected ○ B) The Sun looking yellow
   ○ C) The Moon rising later each day ○ D) Distant supernovae looking faint

6. (AST.4.3) Order these from smallest to largest: Laniakea, Milky Way, Solar System, Local Group.

7. (AST.4.3) What feature of science does the 2025 update to what we know about the Andromeda collision show?

8. (AST.4.4) Which end is considered most likely with today's data?

   ○ A) Big Crunch ○ B) Big Freeze (heat death)

   ○ C) Big Bounce ○ D) The universe staying the same

9. (AST.4.4) Use the idea of entropy to correct the statement "When the universe reaches heat death, energy disappears."

Score: ____ / 9

Practical tasks

1. AST.4.1: Give each theory in the table a label — "tested by observation / testable / not testable for now" — and justify it in one sentence. Read about the roles of Einstein and Hubble in the records below. (SpaceTRC records: Einstein, Edwin Hubble, Dark energy)
2. AST.4.2: Calculate H_0 from this sample data: for d = 20, 50, 100, 200 Mpc, v = 1,450, 3,400, 7,100, 13,900 km/s. Find v / d for each galaxy, take the mean and calculate the Hubble time. (Expected mean ≈ 70 km/s/Mpc.) (SpaceTRC records: Edwin Hubble, Leavitt, Vera Rubin, Dark matter, Dark energy)
3. AST.4.3: Find the size and number of galaxies of Laniakea in two different reliable sources; write the values and the source types in a verification table. Read in the SDSS record what the survey measures. (SpaceTRC records: SDSS, Edwin Hubble, Nature · Laniakea (2014))
4. AST.4.4: For each scenario in the table, answer "which data support it, which contradict it?". Accept, suspend or refute the scenario, and justify your decision with the information in the dark-energy record. (SpaceTRC records: Dark energy, Dark matter, Einstein)

Answer key — Unit 4: Cosmology

1. B. The 2.725 K radiation arriving from every direction shows that the universe was once hot and dense; the steady-state theory cannot explain it.
2. Other universes cannot be observed directly, so it is debated whether the idea makes predictions that can be tested and falsified.
3. C. v = 70 × 300 = 21,000 km/s.
4. It gets smaller. The Hubble time is proportional to 1 / H_o: a universe that expands faster reaches its present size in less time.
5. A. Visible matter does not produce enough gravity to explain such fast rotation in the outer regions. Option D is evidence for dark energy.
6. Solar System → Milky Way → Local Group → Laniakea.
7. Scientific knowledge can be revised with new, more precise data; results should be given together with their uncertainties.
8. B. The expansion is accelerating and dark energy looks roughly constant, pointing to a universe that keeps expanding and cooling.
9. Energy does not disappear (it is conserved); at heat death energy is spread evenly everywhere and entropy is at its maximum. With no energy differences left, no work can be done.

Teacher note

In this unit it matters to make the line between established knowledge and open questions visible. At the end of each lesson, ask students to label a claim as “tested by observation”, “testable but not yet tested” or “not testable for now”.

Common misconceptions: (1) The Big Bang was an explosion at a point in space; in fact it is the expansion of space itself everywhere, and it has no centre. (2) Galaxies are flying away from us through space; the recession of distant galaxies comes mostly from the expansion of space. (3) Expansion makes everything bigger; structures bound by gravity (atoms, the Solar System, galaxies, the Local Group) do not expand. (4) Dark matter and dark energy are the same thing; one pulls and holds structures together, the other speeds up the expansion.