



PART 2

Read the text below and answer questions 14–26.

THE SEARCH FOR DARK MATTER

A

The modern dark matter problem did not begin as a taste for invisible entities, but as a collision between observation and expectation. If most mass in a galaxy were in its luminous stars and gas, then orbital speeds should fall with distance from the centre, much as planets move more slowly farther from the Sun. Instead, astronomers found that many galaxies display “flat” rotation curves: beyond the bright central region, stars and gas continue to orbit at roughly constant speed, implying that mass keeps rising with radius. Earlier still, Fritz Zwicky’s analysis of the Coma Cluster in the 1930s suggested a similar discrepancy on larger scales: galaxies in clusters move too fast to remain gravitationally bound if only visible matter is present. In contemporary terms, the anomaly is a mismatch between baryonic matter (ordinary atoms) and the gravitational field inferred from motion—an inconsistency that demands either additional mass or revised dynamics.

B

The case for dark matter strengthened because it did not rely solely on galaxy rotation. Gravitational lensing, predicted by general relativity, allows astronomers to map total mass by measuring how foreground structures distort the light of background galaxies. In many clusters, lensing reconstructions reveal mass concentrations that do not align neatly with the distribution of luminous matter. The most cited illustration is the Bullet Cluster: a collision in which hot gas—the dominant baryonic component—was slowed by drag and left behind, while most of the gravitational lensing signal appeared displaced, tracking collisionless matter rather than the gas. Combined with patterns in the cosmic microwave background (CMB), which encode the primordial balance between matter and radiation, these observations contribute to the standard cosmological framework (Λ -CDM), where dark matter is treated as a non-luminous component that shapes large-scale structure without strong electromagnetic interaction.

C

Within particle physics, the leading candidate for decades was the WIMP: a weakly interacting massive particle that would be electrically neutral, long-lived, and abundant enough to account for the missing mass. WIMPs are attractive partly because of the “WIMP miracle”: particles with weak-scale interactions can naturally yield the observed cosmic abundance through freeze-out in the early universe. Many theoretical models, including some versions of supersymmetry, provide such particles as by-products of broader



attempts to extend the Standard Model. The experimental strategy is correspondingly straightforward in principle: if WIMPs occasionally scatter off atomic nuclei, then sufficiently sensitive detectors might record tiny recoil energies produced by these rare collisions.

D

This logic drove the construction of deep underground experiments designed to suppress background noise. To avoid cosmic rays and other spurious events, detectors are placed beneath mountains or in mines, and are built from ultra-clean materials. Several leading designs use liquid xenon because it can both scintillate (produce light) and ionise when struck, enabling discrimination between potential nuclear recoils and more common electron recoils. Over time, sensitivity has improved dramatically, and entire regions of WIMP parameter space—combinations of mass and interaction strength—have been ruled out. Yet the story has become a crisis of expectation: despite increasingly refined instruments, a universally accepted signal has not emerged. This is not a simple “failure”; null results are informative, but they steadily narrow the range in which the original WIMP paradigm can comfortably survive.

E

Not all physicists accept that unseen matter must be added to the universe. Modified Newtonian Dynamics (MOND) and related approaches propose that the laws governing motion or gravity change in regimes of extremely low acceleration, such as the outskirts of galaxies. MOND can reproduce many galaxy rotation curves using only baryonic matter, and it has had notable predictive successes at those scales. However, it struggles to explain clusters, lensing maps, and early-universe constraints simultaneously without reintroducing additional unseen components. In other words, MOND often fits galaxies but fails to provide a unified account across the full hierarchy of evidence. The debate therefore becomes methodological: a theory must explain not one anomaly but a network of phenomena that span galaxies, clusters, and the primordial universe.

F

As WIMP searches tightened, attention expanded to alternative candidates. One major contender is the axion, an extremely light particle originally proposed for reasons internal to particle theory but later recognised as a plausible dark matter component. Axions would not be detected by nuclear recoils in the same way as WIMPs. Instead, some experiments attempt to convert axions into photons in strong magnetic fields, looking for faint electromagnetic signatures that would indicate their presence. Other possibilities include sterile neutrinos and a broader “dark sector” with multiple particles and forces, reflecting the possibility that dark matter is not a single species. In this landscape, the absence of a



WIMP signal is not definitive disproof of dark matter; it is a prompt to widen assumptions about what the invisible component could be.

G

The search for dark matter thus occupies an unusual epistemological position. Cosmology can treat dark matter as a parameter because it improves predictive power: simulations that include it reproduce large-scale structure far better than models with baryons alone. Particle physics, by contrast, seeks a concrete entity—something that interacts, however faintly, with instruments and can be embedded in a broader theory. Progress may therefore come less from one dramatic detection than from convergence: improved lensing surveys, refined CMB measurements, new detector technologies, and theoretical models that remain consistent across scales. Whether the eventual answer is a particle, a modification of gravity, or a hybrid solution, dark matter remains a central example of how modern science navigates between inference and direct evidence.

Questions 14–18

Choose the correct heading for each paragraph.

List of Headings

- i The WIMP hypothesis and the logic behind nuclear-recoil searches
- ii Evidence beyond rotation curves, including lensing and colliding clusters
- iii A historical anomaly in motion that implied missing mass
- iv Why improved detectors have ended the debate completely
- v The experimental difficulty created by repeated null results
- vi A theory that modifies the laws of gravity instead of adding new matter
- vii Why ordinary matter alone explains flat rotation curves
- viii The argument that underground experiments cannot control cosmic rays
- ix The rise of axions as the only remaining candidate

14 Paragraph A

15 Paragraph B

16 Paragraph C

17 Paragraph D



18 Paragraph E

Questions 19–22

Choose **TRUE** if the statement agrees with the information given in the text, choose **FALSE** if the statement contradicts the information, or choose **NOT GIVEN** if there is no information on this.

19 The passage suggests that gravitational lensing allows astronomers to map mass independently of its luminosity.

20 The passage claims that Modified Newtonian Dynamics (MOND) successfully explains observations at all cosmic scales.

21 The passage states that research into WIMPs currently receives more financial funding than research into axions.

22 The passage indicates that the absence of a WIMP signal does not disprove the existence of dark matter.

Questions 23–26

Which paragraph contains the following information?

23 a mention of the specific chemical element used in deep underground detectors.

24 a reference to a theoretical framework that alters physical laws instead of proposing new matter.

25 a description of a candidate particle that might be detected using strong magnetic fields.

26 evidence derived from the separation of gas and mass during a cluster collision.

Answer Key

14. iii

15. ii

16. i

17. v

18. vi

19. TRUE



20. FALSE

21. NOT GIVEN

22. TRUE

23. D

24. E

25. F

26. B