Decide whether each statement is true and explain why it is or is not.

1. (Ch. 16, #18) *Strange as it may sound, most of both the mass and energy in the universe may take forms that we are unable to detect directly.*

   **This statement is TRUE.** Although galaxies contain trillions of stars and lots of gas and dust, this makes up only a small part of the matter in the universe. The galactic rotation curve, the motion of galaxies in clusters, and gravitational lensing of galaxy clusters all suggest that a lot more matter resides in and between galaxies than what we see, which is known as dark matter. The total amount of dark matter is estimated to be 6 times as much as that of visible matter. Furthermore, to explain the accelerating expansion of the universe, the Big Bang theory require the universe to contain much more energy to push the universe outwards, known as dark energy. The total amount of dark energy is about three times the sum of detectable matter and dark matter.

   **In short,** the normal matter only counts for about 4% of the total mass of the universe. A lot more is in the forms of dark matter and dark energy.

2. (Ch. 16, #20) *We can estimate the total mass of a cluster of galaxies by studying the distorted images of galaxies whose light passes through the cluster.*

   **This statement is TRUE.** Since light is a type of matter, it is affected by gravity. When photons pass near a huge amount of matter (like galaxy clusters) their paths will be altered, which causes the images of distant galaxies to be distorted or even multiplied. This is known as gravitational lensing. By studying the distorted images, scientists can calculate how much the light has bended, which enables them to compute the mass of the cluster by Einstein’s theory of general relativity.

   **In short,** people can get the mass of galaxy clusters through the effects of gravitational lensing.

3. (Ch. 17, #18) *According to the Big Bang theory, the cosmic microwave background was created when energetic photons ionized the neutral hydrogen atoms that originally filled the universe.*

   **This statement is FALSE.** At the end of the Era of Nuclei, when the cosmic microwave background (CMB) was theoretically emitted, the Universe was finally cooling enough that ionized nuclei could capture electrons and become neutral atoms (before this time, any neutral atoms were ionized again right away). This was important because, without an abundance of free electrons around to bump into, photons emitted by these atoms were able to travel through space. The radiation from this time is known as the CMB.

   **In short,** this statement is incorrect because in order for photons to be able to travel unobstructed, the opposite had to happen - atoms that were ionized before became neutral.
4. (Ch. 17, #19) While the existence of the cosmic microwave background is consistent with the Big Bang theory, it is also easily explained by assuming that it comes from individual stars and galaxies.

**This statement is FALSE.** Stars are so hot that their thermal radiation will peak at a much higher temperature, say, several thousands or tens of thousands Kelvin. Thus, stars cannot provide an explanation of the CMB. In galaxies, there might be some regions of cold gas clouds which have temperatures close to the CMB and provide some thermal emission at these temperatures. However, the distribution of this cold gas is not close to isotropic, unlike the CMB. Furthermore, there is no way for all the gas clouds in galaxies to stay in the same temperature.

**In short,** stars are too hot to be a CMB source, and cold gas clouds in galaxies are not isotropic and have varying temperatures.

5. (Ch. 17, #21) The theory of inflation suggests that the structure in the universe today may have originated as tiny quantum fluctuations.

**This statement is TRUE.** Quantum mechanics says that energy fields in the universe (e.g. electric fields, magnetic fields, or even gravitational fields) are distributed unevenly in very tiny scales. However, although energy is intrinsically distributed non-uniformly, those tiny fluctuations are not strong enough to explain the observed fluctuations in the CMB. Therefore, they cannot have formed the structures of the universe. However, if we allow an inflation stage in the Big Bang history, it will cause the scale of the cosmos to be enlarged, and the quantum fluctuations can exist on a much larger scale after the inflation, known as giant quantum fluctuations. Those giant quantum fluctuations finally form the structure in the universe.

**In short,** the tiny quantum fluctuations are magnified by inflation of the universe and finally form structures.

*All above problems are copied from the text:* The Essential Cosmic Perspective, 3rd Edition.