1. Most astronomers think a major component of the universe is something they refer to as dark matter. What observable effect does this dark matter have?

The observable effect of dark matter is the gravitational attraction which it produces.

Give three examples where astronomers have invoked dark matter to explain observed phenomena.

(1) Dark matter is invoked to explain the flat rotational curves of galaxies.

(2) Dark matter is needed to hold clusters of galaxies together.

(3) Dark matter is needed to explain the growth of the largest structures in the universe, starting from the very small fluctuations seen in the cosmic background radiation.

2. The most popular theories of the big bang include something called inflation. At what point in time is this inflation thought to have occurred? What problems do cosmologists feel such inflation can solve?

Inflation is supposed to have occurred $10^{-30}$ sec after the big-bang.

It explains why the cosmic microwave background in different parts of the sky (coming from parts of the universe that, without inflation, would have never been able to communicate) is almost exactly the same. It also can explain why space is “flat” (i.e., why the curvature is zero).

3. From the data in the text, find the total mass of all the terrestrial planets (and their moons) in units of the Earth’s mass. Find the total mass of all the giant planets in the same units. Compare the two values. How does the mass of all the planets in the solar system compare to the mass of the Sun?

From Table 11.1 (p 262), the total of Mercury, Venus, Earth and Mars is 1.99 Earth masses. To include the Moon, we find from p 291 and p 548 that the mass of our Moon is $7.35 \times 10^{25} / 5.97 \times 10^{27} = 0.0123$ Earth masses. So the total for Terrestrial planets is 2.0023 Earth masses.

The total mass of the giant planets is, from Table 11.1, just the sum of Jupiter, Saturn, Uranus and Neptune, which is 444 Earth masses. The ratio is thus $2.00/444 = 0.0045$. The terrestrial planets are only about 0.45% the mass of the giant planets.

The mass of all the planets is 446 Earth masses. On p 263, we see that the Earth is 1/329,000 the Sun’s mass. Thus all the planets amount to only 446/329,000 = 0.00136 of the Sun’s mass.

4. Compounds of nitrogen are not nearly as abundant in the soil and water as silicon or iron. But nitrogen plays a much larger role than they do in the chemical composition of living cells. How do we explain this?

See p 166 of the text. Nitrogen atoms are able to share more than one electron with carbon, and thus make strong but breakable double bonds with carbon. Silicon or iron cannot make such a variety of compounds with carbon.
5. If we are going to discuss "life in the universe", we probably should have some workable **definition of life**. But it seems that it is not simple to produce a satisfactory definition.

(a) Goldsmith and Owen (p164) say *The most distinguishing characteristics of matter that we call “alive” are the abilities to reproduce and evolve*. What objections might be raised if we try to use this as a “definition” of life?

On the one hand, this definition may be too broad. For example, computer viruses could even qualify as alive! It may also include some molecules which pre-date what most people would consider life on Earth which could reproduce and evolve. On the other hand, it may be too narrow. For example, most people would consider a sterile species of animal (e.g. a mule) which cannot reproduce to still be alive.

(b) Why is there a problem (at least for this course!) in defining life in terms of the basic molecular components like DNA and RNA, which biologists have found in all living organisms?

In searching for life elsewhere in the universe we should be more broad- or open-minded about what we try to find. The chemistry of life on other planets may be different than it is here on Earth.

(c) Propose your own definition, or search the web for one you think satisfactory (or at least interesting). Cite your sources.

Lots of valid ideas here: you could talk about metabolism & entropy, complexity, a cellular structure (or at least some sort of boundary), etc.

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