

Corrections to (and Clarifications of) Bryson's Book

1. (p. 11). The electromagnetic radiation from the Big Bang reaches Earth in the form of microwaves. This is not really due to long time it took to get to us, *per se*. The radiation started as visible light, but its wavelength has gotten stretched in the meantime by the expansion of the universe. The increase in wavelength results in a decreased frequency: The formerly visible light now has a much lower frequency, in the microwave range. If the universe were not expanding, it wouldn't matter how long the light took to get to us: it would arrive with the same frequency it started at, and would still be visible light.
2. (p. 11, bottom). The following phrase needs clarification: "They had found the edge of the universe, or at least the visible part of it..."
First of all, this is not really the "edge," but just something close to it. More importantly, the "edge of the universe" means the edge of our *observable universe*. Our observable universe is just that part of the whole universe that we can in principle observe from Earth, today. It consists of all parts of the universe that are close enough to us that light or other electromagnetic waves would have had enough time to get to us since the Big Bang. The Cosmic Microwave Background is just the electromagnetic radiation left over from shortly after the Big Bang. Therefore, the part of that radiation that is reaching us *here, today*, has been traveling almost since the Big Bang, and is therefore coming from parts of the universe that are almost at the outer edge of what is possible in principle to observe *here, today*. In other words, it comes almost from the edge of our observable universe.
3. (p. 12, top). See item 1 above. It's not "time and distance" that have converted the photons to microwaves, but the expansion of the universe.
4. (p. 16, bottom half). There are three possible fates of the universe: collapsing in on itself, expanding forever, or "in between" (slowing expansion but never quite stopping). Until about five years ago, physicists believed that these fates were completely determined by the density of energy in the universe: high, low, or "just right" (the "critical density"). Bryson is repeating this (outdated) view. However, we now know

that the fate of the universe is not necessarily tied to its energy density — if some of the energy is so-called “dark energy,” it can change the fate of the universe without necessarily changing the total energy density.

It is true (as Bryson alludes to) that the energy density does determine the “shape” of the universe: “closed,” “open,” or “flat.” But the density or shape is not necessarily related to the fate of the universe.

We will talk a little about the shape of the universe and “dark energy” at the end of the course.

5. (p. 17). Bryson describes the universe as “boundless but finite” — he says that if you went far enough in one direction you would come back to where you started. This is misleading, because a universe that is “boundless but finite” is only one of the three possibilities for the shape of the universe mentioned in point 4 above. The “boundless but finite” option is the “closed” option. We have no idea whether this is the way our universe really is. The other two shapes (“open” and “flat”) are both infinite in extent, and those are also reasonable possibilities. In fact, we have good evidence that our observable universe (a small part of the whole thing) is very flat. But we have no information about the shape of the whole thing!

6. (p. 37). Bryson is wrong when he says that supernovae are needed to forge elements like carbon and iron. These elements are made inside stars well before they become supernovae, and in fact most stars that make carbon never become supernovae at all. (The ones that make iron do tend to become supernovae eventually, but the iron is made before that.)

It is true, however, that supernovae are needed to make most elements that are *heavier* than iron (atoms with bigger nuclei than iron’s). Elements such as gold, silver, lead, tin, mercury are indeed made almost exclusively in supernovae. That is the reason those elements are so rare!

7. (p. 62). It is a tribute to Newton’s genius that his estimate of the Earth’s mass is consistent with modern, very precise, determinations. But when Bryson says that “all of this merely confirmed estimates made by Newton 110 years before Cavendish,” he misrepresents what science is about. Most of scientific progress comes from measuring things more accurately, which allows very sensitive tests of scientific theory and understanding. Bryson should remove the word “merely” from his sentence!

8. (p. 120). Saying that Einstein’s paper on the nature of light made television possible is a bit of a stretch. His work gave a first explanation of the way in which light

knocks electrons off a surface. The process is used in TV cameras, but development of television depended much more on the solving of technological issues (such as making the process efficient, learning how to transmit the data, *etc.*) than on a detailed understanding of the physical process.

9. (p. 125). The baseball doesn't pick up 0.000000000002 grams of mass "on its way to home plate"; the extra mass is something the baseball has as soon as it leaves the pitcher's hand. Since mass is just another form of energy ($E = mc^2$), the baseball has this extra mass due to its energy of motion.
10. (p. 126). Bryson is taking the analogy with the sheet of stretched rubber too far. The shape of a sheet of rubber with various heavy objects placed on it is a reasonable analogy to the shape that space-time has in the presence of massive objects. The big difference in shape is that the sheet is a two-dimensional object (East/West, North/South, if it is horizontal), whose stretching into the third dimension (up/down) is possible for us to picture. Real space-time is four-dimensional, whose stretching (perhaps into higher dimensions!) is impossible to picture.

However, Bryson gives the wrong picture when he says that gravity is analogous to the "attraction" of a smaller ball, rolled across the sheet, to a larger object on the sheet. In the sheet analogy, the fact that the small ball rolls toward the larger one is due to the *Earth* pulling the small ball into the indentation created by the larger object. It is not due to the larger object *itself* pulling in the small ball. This is different from the real gravitational attraction between two objects, which doesn't need a third object (the Earth, in Bryson's analogy) to make it work.