Reading Guide for December 3

from Gribbin and Gribbin, *From Here to Infinity*

Chapter 8. Cosmology

How did the universe begin? How did it become the way it is? How will it evolve? What is its eventual fate? These questions, unanswerable as they may seem, are yielding to the science of astronomy. The most astounding discoveries of astronomy in the twentieth century were in the area of **cosmology**. At the beginning of the twenty-first century, these and related questions of cosmology are the hottest research topics in astronomy.

For some reason, this chapter is not divided into sections. I will need to refer to rough page groupings to call attention to specific ideas.

pp. 188–191. This introductory section tells how Edwin Hubble discovered the relationship now known as Hubble's Law. The basic idea is that

- everything in the universe moves away from us, and
- the farther away from us something is, the faster it moves away.

This section tells how this fact was first uncovered; all subsequent observations have confirmed it.

pp. 192–193. Now this introduces another wrinkle to the law: Galaxies aren't so much moving away from us as space itself is stretching. What's the difference? Not much, at first glance; the galaxies get farther from us either way. One difference is that, with large enough distances, the separation between objects can increase faster than the speed of light. Another difference is that it is not necessary to define an unmoving "reference frame" relative to which everything else moves. See Fig 121 (p. 194) for an illustration.

pp. 194–195. In two paragraphs, the **big bang** model is introduced. You have surely already heard of this idea, but you may not know what makes astronomers take it seriously.

- According to the big bang model, what happened about 14 billion years ago?
- Again, according to the big bang model, what has been happening since then?
- What realization first led to the idea of a big bang?

End of pp. 195. This describes a particularly significant electromagnetic spectrum, the **cosmic background radiation** (CBR).

- Who discovered it?
- What are its characteristics?

- From what direction in space does it originate?

To explain this particular spectrum, the book must briefly explain how objects radiate thermally. This does not take up much space in the book, but follow it carefully.

- What does it mean that "different parts of the electromagnetic spectrum correspond to radiation with different temperatures"?

- How does the radiation emitted by an object correspond to the object's temperature?

- What is the "temperature" of the CBR?

p. 196. The first paragraph explains how we think the CBR became the way it is.

- What happened in the early universe to allow photons to "range freely through space"? (This means that the universe became transparent.)

- What was the temperature of the universe at that time?

- Why does the CBR now have a spectrum indicating a much colder temperature?

pp. 196–197. This reports that the CBR is not actually perfectly uniform in all directions.

- What does that tell us about the distribution of matter when the universe first became transparent?

- What would if mean if the CBR were perfectly smooth and uniform?

- How does the temperature variation in the CBR relate to the structure of the universe now?

The book does not explain why this is a significant finding. We know that the universe is the way that it is, so naturally the way it was in the past had to have been such that it would lead to the way it is today. So think about this for yourself: why did astronomers go to the trouble to make an instrument precise enough to measure this tiny variation? What did detecting this tiny variation tell them?

pp. 197–198. Now dark matter is brought into the discussion.

- What does the CBR tell us about dark matter in the universe?

pp. 198–199. This section describes possibilities for the "curvature" of the universe, which basically describes how parallel lines behave when extended for great distances.

- Do observations show the universe to be positively curved, flat, or negatively curved?

- What does the shape of the universe tell about the amount of energy in it?

Page 200's first full paragraph discusses **dark energy**, which has shown itself only in careful measurements of distances to galaxies. This is new stuff, and is not as firmly established as dark matter or nearly as well as big bang theory.

pp. 200–204. This gives an abbreviated history of the universe from 0.0001 seconds to one billion years after the big bang (about 13 billion years ago).

- What was the main process occurring during the first four minutes?
- When did photons decouple from matter?
- What happened between this time and 20 million years?

pp. 204–206. Here you are introduced to the idea of cosmic **inflation**, which refers to a more dramatic expansion of spacetime than even the standard big bang model requires.

- When in the history of the universe did inflation occur?
- Why does inflation cause spacetime to now appear flat?

Don't worry about quantum fluctuations and the birth of universes. This is, for now, pure speculation. In ten years, or maybe fifty, we will have a much better idea if the notion has merit.

from Tyson et al., *One Universe* (on web)

One Universe pp. 192–201

Where Does the Universe Go from Here? The question is simple enough, but astronomers and theoretical cosmologists take it very seriously and are trying to find the answer.

pp. 193–197. The key to predicting the fate of the universe lies in knowing how much mass is in the universe. Getting a handle on the elusive Dark Matter is a crucial piece of that puzzle. This section re-caps what you have already learned about dark matter.

pp. 198–199. This explains **dark energy**'s place in the mystery. This section gives the most accessible explanation I have found of why astronomers think that dark energy is am important part of the universe, all from an observation that the redshifts and distances of distant type 1a supernovas don't agree with each other. This book refers to dark energy as the **cosmological constant**.

pp. 199–201. Now that the preliminaries are taken care of, we can read what's in store for our universe. First, the Sun will change. The precise process is predicted to be different here and in our (more recent) main textbook, but the result is the end of all life on Earth either way.

Then the galaxy will be irreparably changed, then, in the far distant future, there will be no more stars, no matter how dim. Then what? What is left after there is nothing else to happen?