Chapter 2
Before We Begin

Unthinking respect for authority is the greatest enemy of truth.
(Albert Einstein in a letter to Jost Winteler, c. 1901)

Before we get to physics and cosmology, there are some things I need to deal with. I'll begin with the most important thing.

Why Should You Believe Me?

Why should you believe what you read? Why should anyone believe what a scientist is saying?

Here's an analogy that might be helpful. Suppose you've completed a crossword, and somebody suggests that your solution may be wrong even though it fits the clues. From that question, you know that you're dealing with someone whose never done a crossword. You will have to explain that although it's logically possible for your solution to be wrong, the fact that the words mesh with each other makes it very unlikely.

A piece of established science is a bit like the solution to a crossword. It starts with observations which are a bit like the clues. Then it makes sense of the observations through a theory which is a bit like the meshing of the answers. It's logically possible that the result is incorrect, but so unlikely that it's not worth thinking about.

Of course there is always a scientific frontier, where research is still in progress and we're not sure what is correct. That's as if you had only completed the top half of your crossword when someone suggested that the answers may be wrong. You would have to admit the that some of the answers near the bottom might be wrong because they wouldn't be as firmly embedded with each other as those higher up, which you can be sure about.

Something that the crossword analogy doesn't capture, is the issue of accuracy. A measurement can always be made more accurate, and a theory sometimes requires modification in the face of more accurate observations. As we'll see, Newton's theory of gravity was modified by Einstein, and Maxwell's theory of electromagnetism was modified when quantum physics came along. Currently accepted theories will no doubt require modification in the future. But the key word here is modification; the old theory will still be valid within some accuracy. Most importantly, the central facts are not going to change. Atoms definitely exist and the Earth definitely goes round the Sun.

New Words

There are new words in this book, as well as words whose meaning in physics is different from the usual one. There are also some abbreviations. New words and abbreviations are essential to produce something readable. Without them, the sentences would become too long to read. It would be like doing without the words 'cow', 'grazing' and 'field', to write 'some adult female cattle are biting off and chewing long green leaves, in an enclosed area of the countryside that contains no bare ground'.

The meaning of each word or abbreviation is explained the first time it appears, and is summarised in the Glossary. If it's going to be used a lot it appears in boldface **like this**.
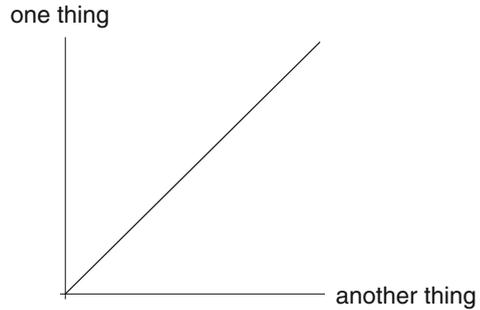
As the book contains so many new ideas, you will need to take it quite slowly, with regular breaks to give yourself time to think. You can't digest all of the information in an afternoon, any more than you could digest several meals. You may also want to take a break to access a website, for further enlightenment on some particular topic.

About Mathematics

The body of the book is mostly descriptive, with hardly any mathematics. Appendix A amplifies what is said in the body of the book, and some of it uses mathematics.

Although the body of the book is free of mathematics, it does contain numbers. I need to explain three things about the numbers. The first is a piece of notation that allows us to write down very small and very big numbers, without using a lot of zeros. You may know already that 2^3, say, means $2 \times 2 \times 2$ and that 2^{-3}, means $1/2^3$. Using this notation we write say 1.5×10^{15}, instead of $1,500,000,000,000,000$, and 1.5×10^{-15} instead $0.000,000,000,000,001,5$. This is much better than exhibiting the zeros and leaving the reader to count them.

Fig. 2.1 One things is
proportional to another

The second thing has to do with accuracy. I have stated, for instance, that the
Universe is 13.8 billion years old but that's not exact. The age of the Universe
is almost certainly between 13.0 and 14.6 billion years, but 13.8 billion is just a
best guess. Given that situation, there would be no point in giving more than two
figures. It would be nonsense to write that the age is 13.872 million years. On the
other hand, I'll be writing later that the rest energy of the electron is 0.511 MeV.
(Don't worry for now what 'rest energy' and 'MeV' are.) In fact, we know that it's
0.51099891 MeV with pretty high accuracy, but to write that would have cluttered
the page to no purpose. I'll give the numerical values of things without comment
in the rest of the book. In some cases the number I give is a bit uncertain. In other
cases, I could have given it much more accurately.

The third thing is the meaning of the word 'magnitude'. If a quantity can be
either positive or negative, its magnitude is its numerical value. So 8 and −8 both
have magnitude 8.

Throughout the book, I will use the phrase '**proportional to**'. When we say
that one thing is proportional to another, we mean that the two things depend on
each other in such a way that doubling one means doubling the other, tripling one
means tripling the other, halving one means halving the other and so on. As shown
in Fig. 2.1, this means that a graph of one thing against the other is a straight line
passing through the point where both quantities are zero. 'One thing' might be the
distance travelled by something moving in a straight line with constant speed with
'another thing' being the time taken to travel that distance.

The History of the Universe
Lyth, D.H.
2016, XII, 120 p. 39 illus., 14 illus. in color., Softcover