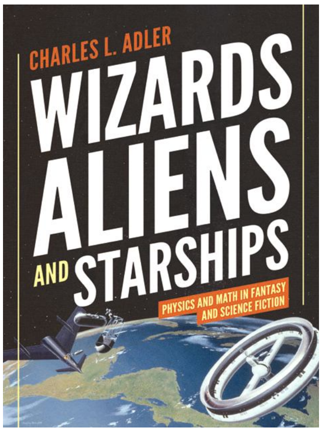

Wizards, Aliens, and Starships: Physics and Math in Fantasy and Science Fiction. Charles L. Adler. Princeton University Press, 41 William Street, Princeton, New Jersey, USA. 2014. 392 pp. Price: US$ 29.95/£19.95.

Adler's book delivers exactly what its title promises: an analysis of core tropes in science-fiction and fantasy stories from a physicist's viewpoint. These tropes could be examined from other viewpoints, but as Adler clarifies in the prefatory notes, 'physics is the science central to this book'. To make his analysis work, Adler needs to make a subtle assumption, namely that unless otherwise specified, story-worlds have the same logical and ontological properties as this, our actual world. This means, for instance, that since the angles of an Euclidean triangle add up to 180° in our world, the angles of a triangle in the story-world must also add up to 180°. If it does not, then the object is not an Euclidean triangle. Maybe it is a hippogriff.

Adler discusses the physics of hippogriffs. He also considers the physics of giants, merpersons and wormholes. He discusses the many subtleties to consider in setting stories on alien worlds, the improbability of easy, cheap space travel, the design of space elevators, Kardashev's energy usage-based taxonomy of civilizations, the search for extraterrestrial life, and what could happen if we did establish contact with an alien civilization. There are surprises in almost every section and I have no doubt this book would be a great ancillary text for an undergraduate course in physics. The analytic methods will not faze anyone who is trudged through Resnick and Halliday and there is just enough offhand commentary to stimulate curiosity.

My favourite section was the discussion of the candle-lit dining hall in Harry Potter's Hogwarts. Adler reminds us of the hundreds of candles supposedly illuminating this vast hall and then, with a few deft strokes, using basic but deep principles from luminosity physics, demonstrates the limitations of such a scheme. Candles, we learn, are terrible light sources. Only 1% of their light is available in the visible spectrum as opposed to 10% for a tungsten light bulb. Even if one of Dumbledore's minions magically produces thousands of candles on a daily basis to cheerily illuminate the faces of our future heroes, the administration will have to deal with the angry complaints about the hot wax dripping into the spotted dick pudding.

Of course, the fan's response to such objections will be that this kind of analysis misses the point. But Adler is not missing the point. He is respectful of what writers are trying to do. Still, the science in science-fiction and magic in fantasy are rarely arbitrary (though authors like Rowling skate very close to indifference). Authors like Larry Niven, Poul Anderson and other so-called hard science fiction authors care a great deal about getting the physics right in their stories. Similarly, Orson Scott Card's book on fantasy writing emphasizes how the magic must be logically consistent within the story. So it is not only interesting but also reasonable to ask what physics has to say about imaginative leaps like transporters, wormhole navigation and aliens who live in the cores of stars.

On the other hand, the kind of analysis Adler undertakes raises an old literary quarrel: what does it mean for a fictional event or object to be probable? What makes a story likely? It is not just science fiction that has to deal with this problem. For example, Dryden in his 1679 preface to *Troilus and Cressida* remarked:

> 'To invent therefore a *probability*, and to make it wonderful, is the most difficult undertaking in the art of poetry; for that which is not wonderful is not great, and that which is not probable will not delight a reasonable audience.'

The key difference however lies in what the literary tradition means by 'probability' and what scientists mean by it. In the literary tradition, there has been little change from Aristotle's characterization of probability as a social truth, namely 'a generally approved proposition: what men know to happen or not to happen, to be or not to be…'[1]. But in the scientific tradition, probability has been objectified[2], divorced from what people may believe to be true.

This is an important difference because it shows literature is not really concerned with probability, but instead with plausibility. The two are related but also distinct. Highly probable events can be implausible (example, the birthday paradox) and plausible claims may be very improbable (example, curing prostate cancer through a vegetarian diet). The permissible is another category altogether.

Plausibility is a psychological concept, while 'physical' probability is an empirical one. Consequently, Adler has little interest in the plausibility of a trope. His analysis is focused on how likely is that the story's claims are supported by physics. His fundamental orientation, as it were, is to point out the many limitations. Reality – that is, physics – imposes on our imaginations. Space is vast, biology is incredibly fragile, conservation laws determine all processes, and brute economic realities check our wilder fantasies. Adler is an optimist on the whole, but it is hard to avoid concluding that technology is a lot more limited than science fiction imagines. We live in a largely barren, stupendously vast and mostly hostile universe.

But this conception of nature is not necessarily universal. Adler's orientation might be characteristic of a certain cultural stance. Frank McConnell[3] in a perceptive essay on getting rid of the term 'hard science fiction' makes the (plausible) case that science fiction – Western science fiction – as a whole revolves around the idea of the 'impermeability and the hostility of matter'. Of course, Adler could justifiably argue that physics is universal, that conservation laws are true, no matter what the 'cultural stance' and that his arguments are scientifically sound.

That is indeed correct. But I raise the issue of cultural stance to point out how Adler's discussions all too often delight in throwing cold water on various possibilities than seeing ways out of various necessities. It is not that he always ignores ways around limitations, but by and large, when it comes to the fictional imagination, I think his preference is to place his foot on the brake rather than the accelerator. Perhaps it is related to the fact that a scientist is rarely happier than when he is demonstrating folk beliefs to be badly mistaken.

It would not be important if this were not a book intended for impressionable minds. Kierkegaard talked about the two broad categories of despair. The first, the despair of possibility, arises from the lack of any necessities, a deficiency in vitamin N, let us say. The second sorrow, the despair of necessity, arises from the lack of possibilities. Adler's book is a wonderful cure for the first ailment, a deficiency in vitamin N. But if one is suffering from a lack of possibilities, the cure is not to be found in Adler's book.

I do not wish to imply the book depressed me. It did not. I admired the precision of the prose, the clarity of Adler's examples, his sense of humour and the ever-fascinating ability of physics to cut through to the heart of the problem. Reading this book reminded me why I loved physics as a teenager. Adler mentions in a couple of places how an early exposure to a couple of Poul Anderson's essays on the science in science fiction led him to a career in physics and this present work. In fact, the book is dedicated to Anderson. It is a fitting tribute. The best recommendation I can give this book is that it will help ensure that other bright teenagers will also find a lifelong interest in science.

1. Aristotle, *Prior Analytics*, Book II, chapter 27, Jenkinson, A. J. (translator).
2. Even Bayesian probability in all its many subjectivist incarnations is indifferent as to who holds a particular belief or their opinions on Bayes' update rule.
3. McConnell, F., In *Hard Science Fiction* (eds Slusser, G. E. and Rabkin, E. S.), Southern Illinois University Press, IL, USA, 1986, pp. 14–23.

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Annual Review of Nuclear and Particle Science, 2013. Barry R. Holstein, Wick C. Haxton and Abolhassan Jawahery (eds). Annual Reviews, 4139 El Camino Way, P.O. Box 10139, Palo Alto, CA 94306, USA. Vol. 63. 556 pp. Price: US$ 92.00.

This volume is a collection of 20 delightful articles at the forefront of research in particle physics and nuclear physics and cosmology. As is often the case in this series, an eminent scientist is honoured by a detailed discussion of his/her life's work. The first article in the book by Luth is entitled 'Wolfgang K. H. Panofsky: Scientist and arms-control expert', which is a self-explanatory title. This eminent scientist was born in Germany in 1919 and emigrated with his parents to USA and later went on to become the founder and first Director of the Stanford Linear Accelerator Centre. He made immense contributions to the field of accelerator physics and also devoted his time to issues of policy and science planning and was an advisor to several Governments. Indeed, as a person of conscience, 'Pief' as he was known to friends, also devoted his mind and attention to the important issue of arms control and international security, thereby transcending the boundaries of a traditional scientist's range of activities. While many of these issues may have been important in the by-gone days of Cold War, in the coming years and decades such issues of engagement of scientists to problems of nations and society would take on a different complexion, and the lives of persons such as Panofsky are well worth the time of scholars and young persons.

This book being a part of the *Annual Review of Nuclear and Particle Science* series, it is therefore fitting that there should be an article on nuclear physics and particle physics. In the modern era, the laws of the Universe on the largest scales (cosmology) and more conventional large scales (astrophysics) go hand in hand with those at the smallest scales, as the laws of microscopic physics bear their imprint on the cosmos.

If one were to start looking at this admirable collection of articles, one may wish to look at the article 'Search for superheavy nuclei' by Hamilton *et al.*, which reports the discovery of several superheavy nuclei. One learns in school that the heaviest naturally occurring nucleus is an isotope of uranium, which has 92 protons, and a significantly larger number of neutrons are required to supply the binding force to fight off the Coulomb repulsion between the protons. Indeed, in the atomic number–neutron number plane, there is only a small range of allowed values, and any deviation from this stability region leads to the spontaneous emission of either protons or neutrons or fission of nuclei. Over the course of the 20th century, the alchemists' dream of producing new elements was realized and this article captures the excitement of experimental effort and discusses the development of new facilities.

It may also be recalled that many nuclei are (beta-) unstable because of the presence of the weak interactions, which operate at the quark level. Since neutrons and protons are made up of quarks, it would lead to the decay of one of these, which in turn would lead to the decay of either a neutron or a proton, which in turn would lead to the decay of the nucleus, to a lighter and more stable nucleus. There is the exotic possibility of 'double beta decay' when a nucleus would decay through the emission of two electrons and two anti-neutrinos (or two protons and two neutrinos) (in contrast to an even more exotic, so-called beyond the standard model process of the decay with no (anti-) neutrinos). This process was proposed by Maria Goeppert-Mayer, one of the two women physics Nobel laureates in the 114 year history of the Prize. Only in the last couple of decades, this has been seen in the laboratory, in various fascinating experimental situations and has been indirectly inferred from the study of radioactive rock-bearing samples. This has been reviewed in the article 'Two-neutrino double-beta decay' by Ruben Saakyan.

The properties of the elusive neutrinos themselves continue to fascinate particle physicists, and indeed the last couple of decades have proved to be fruitful ones, with the notoriously difficult neutrino experiments turning into precision experiments. In 'The LSND and miniBooNE oscillation searches at high Δm^2', Conrad *et al.* discuss in great detail the design and analysis of the Liquid Scintillation Neutrino Detector (LSND) and the (Mini)Booster neutrino experiment, where the latter was designed to check the results of the former, which are best explained in terms of the existence of a 'sterile' neutrino. In the article 'Status