AT THE CONFLUENCE: PARTICLE PHYSICS AND COSMOLOGY

Particle Physics and Inflationary Cosmology

Andrei Linde

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Reviewed by Edward Kolb

An indication that the interdisciplinary field of particle cosmology has come of age is the appearance of textbooks on the subject. *Particle Physics and Inflationary Cosmology* by Andrei Linde is unique among recent books in that it does not attempt to cover all current topics in the field, but rather concentrates on the single subfield of inflation.

Much of the work in particle cosmology is speculative and still awaits the final verdict, to be provided by observation. It is impossible to say which, if any, current ideas—such as cosmic phase transitions, quantum cosmology, particle dark matter, inflation and so on—will remain as part of the ultimate picture of the evolution of the universe. What is certain is that the ideas resulting from the confluence of particle physics and cosmology are bold, imaginative and perhaps profound: Most conspicuous in this genre are the ideas of inflation.

Linde's foremost message is that inflation is not a single theory or a model, but rather an idea—an idea that at some early time there was a very rapid expansion of the volume of the universe. This basic idea has far-reaching implications for the subsequent development of the universe. While inflation is simple and beautiful, the implementation of the idea within a framework of particle physics has yet to produce a unique model. In fact Linde discusses many particle physics models that can lead to successful inflation. Given the unsettled state of affairs, one might think a book like this is premature. However, Linde takes the approach that the important point is developing the concept rather than concentrating on the details of any particular model. The idea of inflation is likely to outlive any of the models described.

While the title suggests a book devoted solely to inflation, it is much more. The first six chapters contain the most complete discussion to date of phase transitions in scalar field theories driven by high temperature or high density. In fact the development of the subject goes far beyond what is required to understand inflation. My only criticism of the book is that occasionally the author strays from inflation into related areas of his research.

Linde was one of the early pioneers in the field and continues to make important contributions. His landmark paper with David Kirzhnits on high-temperature symmetry restoration led to the idea that the energy density of the vacuum could change in a phase transition. This discovery was later exploited by Alan Guth in the scenario where the vacuum energy density dominates the universe during a phase transition, causing inflation. When it was realized that Guth's original model would not work, many "improved" versions of inflation emerged, some of which still survive as viable (if not compelling) models. No one has contributed more to the collection of inflationary models than Andrei Linde. The creativity, enthusiasm and imagination characteristic of his scientific career is evident throughout the book.

The book is addressed to the professional physicist and to the advanced graduate student. The level of presentation is demanding for those without a background in field theory, cosmology and general relativity. However, in the tradition of the great Russian texts of Landau and Lifshitz, Linde usually provides the reader with physical insights as a guide through the sometimes difficult and technical subject matter. Anyone who has had the pleasure of hearing one of Linde's lectures will be pleased to discover that he brings the same panache to his often amusing book.

Many reviews end with the traditional statement that the book is a must for all serious students of the subject. *Particle Physics and Inflationary Cosmology* should be read by a wider audience. The section on the possibility of a self-regenerating inflationary universe (in which parts are inflating even today), and the discussion of the creation of the universe from "nothing," are sure to excite the imagination of any reader curious about the origin of our universe and interested in the most exciting ideas in cosmology over the last decade.

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Technological Risk

H. W. Lewis

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This turned out to be a better book than I thought when I first started the book. Perhaps I was put off by Harold Lewis's too-frequently exercised and apparently incorrigible habit of using cute phrases and clever wording. Early on in my reading of the book, I considered recommending he rewrite the book, omitting two-thirds of the cleverness—still letting the whimsy show but sparing us the distraction of his (unnecessary) parenthetical remarks. But then I realized that Hal Lewis is incapable of not repeating every pun and unusual turn of phrase that pops into his brilliantly composed mind. And a person who would give us a controlled flow (as opposed to an incessant flow) of distracting (but clever!) anecdotes and phrases would

not be Hal Lewis.

Lewis is a professor of physics at the University of California, Santa Barbara, who teaches among other things, relativity. Back in 1975 he was asked by The American Physical Society to head a committee on nuclear reactor safety; this was the start of a 15-year cycle of recurring investigations of nuclear reactor issues. The Atomic Energy Commission and its regulatory successor, the Nuclear Regulatory Commission, responding to political pressures, was preoccupied with potential massive coolant loss as the greatest danger to reactor safety. Lewis was not convinced that studying the physics of reactors would lead to similar conclusions; he came up with his own list of the most likely problem areas: transient effects, slow leaks of coolant and human error. When the Three Mile Island accident happened in the late 1970s, sure enough, it exhibited the same problems Lewis had identified. After Chernobyl, Secretary of Energy John Herrington asked Lewis to conduct a study of the reactor in Hanford, Washington, a similar facility. The resulting recommendation was, "shut it down." This was eventually done.

Reading Lewis's book is like spending a pleasant evening in his company. The book treats a subject with which he enjoys a comfortable familiarity, having labored in the vineyard for decades and become one of the most articulate and solidly based authorities on technological risk. A man who does not suffer fools lightly—or gladly—Lewis is too impolitic to be popular. The best thing about his approach to the subject is his willingness to call 'em as he sees 'em; the best thing about his book is that he sees 'em clearly and from a balanced viewpoint. Telling it like it is is a Lewis hallmark.

Lewis describes risk assessment as a product of the seriousness of a particular event and the likelihood that it will happen. He points out that we seldom go through a rational assessment of risk, but instead are frequently swayed by popular opinion about the dangers. For example, the typical driver is sure enough of his own abilities on the highway to discount the relatively high probability of an accident. On the other hand, in spite of a dearth of serious nuclear accidents in the US, many Americans have an inordinate fear of a nuclear catastrophe. Because of this fear, no new nuclear power stations have been licensed in the last decade. (I am also told that many Americans go to bed thinking they will awake to a nuclear holocaust started either by the Russians or ourselves; somehow I don't believe any of my generation ever went through such a phase. But most of us find the danger sufficiently real to lead us to support the Defense Department's spending a few billion a year on trying to deter nuclear conflict. And Stars Wars advocates support spending on defending against nuclear weapons.)

Lewis also points out that many people resent the assignment of a specific worth to human life, because they believe human life is essentially of infinite worth. But those same people probably buy life insurance and have little trouble deciding how much to buy.

When Jim Fletcher headed NASA, he urged Lewis to look at applying risk analysis to NASA's operations. NASA seemed to be allergic to risk analysis. When it came to linking their activities to accidents, most people there were not willing to look at the bottom line. According to the Rogers Commission, which analyzed the Challenger accident, NASA officials resisted admitting that anything they were doing was risky, and hence they were shocked by the failure of Challenger's strap-on rocket (a rocket that had exhibited problems on several previous launches). It is not apparent that NASA has changed; odds are that they will again be surprised by the next accident.

Lewis thinks the category of risk that may be the hardest to deal with is when natural risks are increased slightly by human activity. One of the many examples of this type of risk is chemical food additives. We know that various edible plants have invented insect repellents of their own; when we add chemical sprays to the total mix, how do we assess the increased risk of using such sprays on vegetables? Lewis says we do it through research over many decades, finding benign chemicals that reduce the risk to ourselves to "acceptable" levels. Fluorides added to toothpaste are an example of a good result from added chemicals, but even with an infinitesimal risk to our health, some people find it unacceptable and campaign against its use. Radiation from nuclear devices and power plants is dangerous to our health but is superimposed on a high level of natural radiation that we receive in any case. People living in Denver are exposed to much more natural radiation than the rest of us; does that mean they must be more careful about man-made effects?

Having spent years in aviation and space activities, I found Lewis's coverage of the risks, trials and tribulations of flying right on the mark. Aviation is a field he knows well, having flown his own plane in American skies for several decades. He did not fail to twit me about the Federal Aviation Administration's foibles and failings when I was the administrator of the agency; he has probably done the same with more recent administrators. Lately he has given up flying, feeling himself getting rusty at the controls and imagining unflattering headlines about an expert on technological risk flying to his doom in an avoidable accident.

But I never resented his criticism. How can one resent criticism from a constituent who knows the system well, loves to fly, appreciates what FAA does well and—like as not—has a string of new suggestions on how to make things better?

The same can be said about many of the book's subjects where Lewis is a real expert—especially nuclear power. As someone who thinks an inordinate fear of things nuclear has caused us to miss an opportunity to mitigate greenhouse gas production, he casts his weight with the majority of those nuclear experts who would vote to increase greatly our use of the nuclear option.

I was disappointed that he did not plug for the development of safer power reactors because I believe that they can be built; if built, they could be exploited by the nuclear industry's friends as a new departure from past practice, which in the public mind is linked with the US regulatory structure, which is perceived as being complacent. Something new is needed that is both better and more fault tolerant than the current stable of reactors, designed 30 years ago. A new approach would also provide a face saving way out for those who have identified themselves publicly as antinuclear, but who now see the reliance on coal and petroleum as having taken them down a dead-end street.

As I said earlier, the book got better as I went along and as I became more caught up by Lewis's tremendous grasp of his subject matter. And—I hate to say it—I rose above the problems caused by his tendency to overdo the parenthetical inserts; I realized eventually that I actually enjoyed most of the interruptions to my train of thought.

As one of the most active, knowledgeable and outspoken analysts of technological risk, Lewis is in an ideal position to write a book like this. And he has not disappointed.

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