Book Reviews

A Cosmological Postulate

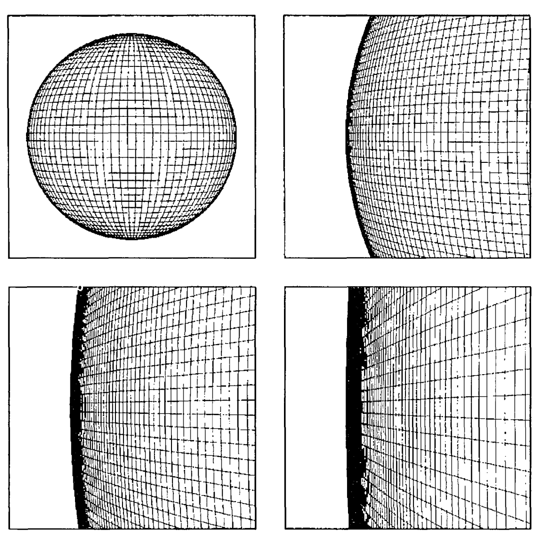
The Inflationary Universe. The Quest for a New Theory of Cosmic Origins. ALAN H. GUTH. Helix (Addison-Wesley), Reading, MA, 1997. xviii, 358 pp., illus. $25 or C$33.95. ISBN 0-201-14942-7.

The inflationary universe scenario postulates that at some time in the very early history of the universe a period of extremely rapid (superluminal) expansion occurred. Inflation is probably the single most important idea to arise in scientific cosmology since the early 1960s, when the foundations of modern big bang cosmology were laid. It potentially explains several observed features of the universe for which there is no other known explanation, as will be discussed below. The best ideas on why inflation might occur are inspired by exotic but established concepts of modern particle physics. Indeed, a period of inflation can be triggered by phase transitions of the sort that are predicted by particle physics models to occur under extreme conditions of temperature and density, such as occurred close to the big bang.

The intellectual origin of the inflationary universe scenario can be traced, with a precision unusual for modern science, to a specific date and author. On 6 December 1979 the author of the book under review, Alan Guth, realized that the models of particle physics he was analyzing for other purposes could, under reasonable assumptions, trigger an inflationary epoch. Equally important, he realized that the occurrence of such an epoch would answer some major cosmological riddles. There were partial anticipations before, and many refinements and applications were added later, but clearly Guth's contribution was the central one. Moreover, he is an exceptionally lucid and painstaking writer. It is uniquely fitting, therefore, that he should present this subject to the general public.

There are no equations in the text of the book, but much use of quantitative reasoning, graphic illustrations, and so forth. In other words, the book will be quite challenging for the innumerate, but otherwise generally accessible. It is an intellectually honest book that comes to grips with difficult concepts such as spontaneous symmetry breaking, black-body radiation, and percolation, even when doing so slows down the narrative. There is a helpful glossary, and some slightly more technical material in appendixes at the end. It may be dangerous for a fellow "expert" to pronounce on the matter, but I think the author has succeeded remarkably well in conveying the profound concepts vital to his story in a simple, but never simplistic, way.

The Inflationary Universe falls naturally into three parts. The first part, constituting roughly half the book, sets the stage. After two brief, eclectic chapters that seem to belong elsewhere, we settle down to a very nice account of standard big bang cosmology, and a brief but well-thought-out and coherent account of relevant parts of particle physics. The material is presented in the context of a narrative of discovery that—regarded as history—is inevitably oversimplified, but always in good taste.



"The inflationary solution to the flatness problem is illustrated by this sequence of perspective drawings of an inflating sphere. In each successive frame the sphere is inflated by a factor of three, while the number of grid lines is increased by the same factor. By the fourth frame, it is difficult to distinguish the image from that of a plane. In cosmology, a flat geometry corresponds to a universe with omega [the ratio of the actual mass density of the universe to the critical mass density] equal to one. Therefore, as inflation drives the geometry of the universe toward flatness, the value of omega is driven toward one." [From *The Inflationary Universe*]

This part flows smoothly into the heart of the book, which is a personal account of how the author came to discover the inflationary universe scenario, and—together with others—to refine and apply it. Especially interesting is his very detailed account of his actual line of reasoning, which evolved from work with Henry Tye attempting to reconcile grand unified models of particle physics (and their specific prediction of magnetic monopole production) with standard big bang cosmology. Guth's work was also heavily influenced by an earlier, visionary seminar by the late Robert Dicke. The story is presented "warts and all" and does not stint in describing early misconceptions and effects of the pressure of competition. Guth also mentions, rather too schematically I think, the dramatic recent developments in measurements of microwave background anisotropies that might within a few years allow a much more meaningful check of very-early-universe cosmology, including inflation.

Finally, there is a distinct change of tone in the final 50 pages or so, where significantly more speculative topics are taken up. Here the connection to established physical laws becomes much more tenuous and the relevance to any practically conceivable observations remote. Although the speculations are clearly labeled as such, the length and style in which they are presented belie the warning. It might have been better instead to elaborate more deeply on the equally fascinating and much more realistic prospects for learning more about the early universe from better mapping of the microwave sky and for finding the elusive "dark matter" that appears to constitute most of the universe by weight.

It seems appropriate, in this journal, to say a few words about the status of inflation as a scientific theory. In its simplest form, this idea immediately explains one of the most striking and yet, from the point of view of general relativity, most puzzling facts about the present-day universe, namely that its spatial geometry is approximately Euclidean: that the universe is "flat." As emphasized by Dicke, this fact is quite peculiar, because deviations from flatness tend to grow with time and the universe is quite old. Since expansion will tend to make even a curved surface become flat, a period of drastic inflation can resolve Dicke's puzzle. Related to this, inflation can explain the approximate homogeneity of the observed universe, which—as attested in the microwave background—was accurate to a part in ten thousand in the early history of the universe. Yet the homogeneity is not perfect, as the recent observations have revealed; indeed, the early universe must have contained the seeds that later, by gravitational accretion, grew into galaxies and other large-scale structures. Inflationary models offer a very promising way of getting insight into these inhomogeneities, by relating them to (inflated) quantum fluctuations.

On the other hand, it has to be admitted that the phenomena so far explained by the inflationary scenario are both few in number and not entirely characteristic: the flatness of the universe had been a working assumption of many cosmologists earlier, and the simplest (scale-invariant, or Harrison-Zeldovich) spectrum of inhomogeneities, which inflation models tend to give as a first approximation, was also hypothesized well before, by its namesakes. Also, the existing models of particle physics that give inflation are only metaphorically related to concrete world-models and contain some disturbingly "unnatural" features, in the form of unexplained small parameters. Most troubling of all, perhaps, is that the fundamental mechanism that drives inflation, the negative pressure associated with the energy density of empty space, is closely related to perhaps the weakest point in current physical theory, the problem of the cosmological constant. Roughly speaking, the issue is as follows. We know by observation that space devoid of matter, in the present state of the universe, does not weigh very much. Strange though it sounds, this familiar fact is baffling to modern physicists, because according to our theories apparently empty space is actually highly intricate and structured. At any rate, we do not understand why empty space weighs so little now, and in order to have inflation we must believe that it was not so—in a big way—in the early universe. Thus there remain challenges to derive and test more distinctive consequences of inflation and to root it more firmly in physical theory.

All this is just to caution, as Guth himself does repeatedly, that there continue to be lively debates on the fundamentals of scientific cosmology. It is undeniable, and truly remarkable, that the terms of these debates are increasingly set by Guth's extremely bold, yet coherent and not implausible, extrapolation of known physical laws to produce an epoch of cosmic inflation. Anyone interested in ideas, or the history of ideas, should read his book.

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Nonhuman Kindness

Good Natured. The Origins of Right and Wrong in Humans and Other Animals. FRANS DE WAAL. Harvard University Press, Cambridge, MA, 1996. viii, 296 pp., illus., + plates. $24.95 or £16.50. ISBN 0-674-35660-8.

Is morality unique to humans or does it have an evolutionary history? In this well-written, provocative book, de Waal argues that moral behavior can be found in nonhuman species, most clearly in great apes, but also in monkeys and nonprimate species.

Three conditions lead to the evolution of morality: an individual's dependence on a social group to find food or defend against enemies or predators; mechanisms for cooperation and reciprocal exchanges within a group; and individuals having disparate interests that must be resolved in order to preserve the benefits of living in a social group. Conflicts of interest between individuals over access to resources arise constantly, but organisms must develop mechanisms for resolving conflict to maintain social stability. The drawbacks to competition can be bodily harm, disruption of a social relationship, or harm to group unity. The defense of community or group occurs when each individual or its kin will benefit from the maintenance of the group. Thus, de Waal argues, social animals have evolved to inhibit actions that disrupt group harmony and to balance private interests with peaceful coexistence. In his view the evolution of morality can be explained in terms of individual and kin selection.

This framework coupled with clear operational definitions allows the scientific study of moral behavior. Reconciliation, the increased likelihood of positive or affiliative behavior between two actors closely following an aggressive interaction, compared with control rates of affiliation between the same actors, was first documented in chimpanzees but has now been reported in a wide variety of animals. The importance of reconciliation and the likelihood of its occurrence are related to species differences in dominance structure. However, important aspects of reconciliation are learned. Rhesus macaques were cross-fostered with stump-tail macaques, which have a higher rate of reconciliation than rhesus. The rhesus reconciled with increasing rates until they reached the same rate as the stump-tails, although they still used rhesus-typical behaviors. The high rate of reconciliation was maintained after the stump-tails were removed, suggesting that learning of reconciliation is not only possible but long-lasting.

Nonhuman primates adjust submissive and reconciliation behaviors in response to population density. Chimpanzees housed in small indoor cages in the winter have higher rates of submission and lower rates of aggression than they do in a much larger outside facility where they live in the summer. Rhesus macaque populations studied in densities varying over 646:1 ratios showed very small differences in aggression rates but increased the frequency of grooming, submissive, and appeasement gestures as population density increased. The commonly held view that aggression is a byproduct of increased density is not supported. Rather, primates appeared to be sensitive to potential problems of greater density and increased the rate of friendly and reconciliation behaviors.

Reciprocal behavior is found in the sharing of food. Wild chimpanzees share meat from hunting in a strategic way to support male allies and females, and captive chimpanzees show reciprocal food-sharing behavior, giving to those who have given to them in the past. Capuchin monkeys do not show active donation of food to others but tolerate food scrounging by those they are close to socially. Nonhuman primates do not share resources as extensively as humans do, but the foundation for sharing and reciprocity exists.

Monkeys adjust their behavior with mentally retarded or physically handicapped individuals, suggesting a rudimentary sympathy, and chimpanzees show consolation toward victims of aggression. Evidence is provided for active enforcement of social rules on young primates by adults. All these well-documented examples suggest that morality is not unique to human beings but has origins in nonhuman animals.

The book is written for a lay audience, but the scientific underpinnings of the research are presented in extensive notes that describe many of the empirical data on which the book is based. Four photo essays on Closeness, Cognition and Empathy, Help for a Friend, and War and Peace support the book's main points and are much more powerful than mere words. The central idea of this book, that interindividual conflict is fundamental but that mechanisms for restraining conflict and maintaining a community are equally important for social organisms, is an important message for scientists and nonscientists alike. *Good Natured*, written for a general audience but with strong scientific foundation, communicates this message in a clear and responsible way.

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