Their primary characteristics are that they show strong broad-emission lines in their optical spectra, their images appear to be starlike, they are often variable in their radio or optical flux and they have large redshifts. Their similarity in optical wavelengths to the nuclei of comparatively nearby Seyfert galaxies was seen, and it was argued that there was continuity between the Seyferts with a redshift $z < 0.01$ and the quasars with very large redshifts (average $z > 1$).

The implication was that they are all nuclei of galaxies with a wide range of intrinsic luminosities. Hence the term "active galactic nucleus." They emit flux that may be variable and can extend all the way from gamma rays to radio waves, with a complex optical spectrum dominated by a nonthermal optical continuum having broad emission lines and a rich absorption spectrum for objects with large redshifts. Observations with the Hubble Space Telescope have demonstrated that some of the low-redshift active galactic nuclei are the nuclei of galaxies, but this has not been firmly established for quasi-stellar objects in general, although it is widely believed to be true.

Despite the fact that many astronomers are now working on active galactic nuclei, very few monographs have been written on them. Bradley Peterson, in *An Introduction to Active Galactic Nuclei* has put together a straightforward account of their basic properties and the ways in which they are being investigated. He discusses their physical properties, the way that they may have evolved and the attempts that are being made to use them to investigate the universe at large redshifts. He also describes the unification idea: that a Seyfert 1 or Seyfert 2 galaxy, a BL Lacertae object, a radio galaxy and a radio-emitting quasar may all have the same basic characteristics but that we are seeing the same kind of machine in each case at different orientations in space and with a wide range of intrinsic powers.

Overall, the ideas are outlined clearly and, as far as it goes, the monograph can be recommended as a basis for a graduate course. The major difficulty that I have in giving this book a strong recommendation is that the whole subject is handled in a way that suggests that the answers to a number of basic questions first discussed in the early days—for example, in the first monograph on the subject, (*Quasi-Stellar Objects* by Geoffrey Burbidge and Margaret Burbidge, W. H. Freeman, 1967) are well established. In doing this, Peterson is certainly going along with majority opinion, and it is unfortunate for him that I happen to be one of those who believe that some of the basic questions have not been answered correctly.

The basic problem in understanding quasi-stellar objects and active galactic nuclei comes from our lack of a true understanding of the nature of the redshifts of those objects. Can the redshifts all be treated as shifts associated with the expansion of the universe? From the earliest days, this question was asked. There were several reasons for this. There is a good correlation between redshift and apparent brightness (distance) for normal galaxies—the Hubble law—which historically was the evidence that led to our belief in the expanding universe, but there is almost a complete absence of such a relation for quasars. Also, the rapid variability of quasars leads to the so-called Compton paradox, which can be avoided only by assuming that highly relativistic expansion and/or beaming of the flux towards us is taking place, or by assuming that the objects are much closer than their redshifts indicate. To explain the scatter in the redshift apparent-magnitude diagram, one must argue that a wide range of intrinsic luminosities is involved. To explain the rapid variability and expansion seen at radio wavelengths, superluminal motion and beaming are invoked. With these assumptions, it is possible to retain the cosmological redshift hypothesis.

However, direct evidence summarized by Halton C. Arp in his 1987 book *Quasars, Redshifts and Controversies* (Interstellar Media) and by me and others in a series of papers published in recent years, shows that some quasars with large redshifts are physically associated with comparatively nearby bright galaxies that have very small redshifts. Also, it has been shown in a number of papers that there are strong statistical correlations between faint galaxies with redshifts $z \le 0.2$ and quasars that have redshifts greater than 1. Very recently, some x-ray sources, identified in the ROSAT (Röntgensatellite) survey with quasars having large redshifts, show geometric configurations suggesting that they have been ejected from comparatively nearby galaxies with active nuclei.

From all of this work, it is reasonable to conclude that some parts of the redshifts of some active galactic nuclei are not cosmological in origin. If this is the case, as I believe, the repercussions will sooner or later change drastically the direction of research in this field.

In these days of bandwagon science, the tendency to ignore data that do not fit the current paradigm has been accentuated. It is particularly bad in this field, where many of the players believe that the stakes—observing time on the best telescopes, faculty appointments, research funds and prestige—are so high.

Peterson is well aware of the work just mentioned. While he may not believe that it is correct, he is going too far when he omits any mention of it. This is partisanship of the worst kind.

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Perfect Form: Variational Principles, Methods, and Applications in Elementary Physics

Don S. Lemons
Princeton U. P., Princeton, N.J., 1997. 117 pp. $39.50 hc ($19.95 pb)
ISBN 0-691-02664-5 hc (0-691-02663-7 pb)

Variational principles are ubiquitous in physics. They provide a simple yet elegant framework within which all elementary physics can be presented. The physical principles are as fundamental as the physical laws usually taught to undergraduates, and arguably more so—see, for example, Cornelius Lanczos's *The Variational Principles of Mechanics* (Dover 1986.) Nonetheless, the typical undergraduate physics or engineering student's exposure to variational principles or methods is limited to Hamilton's principle and a derivation of Lagrange's equations of motion.

Don S. Lemons has recognized the potential benefits to students of exposure to variational principles early in their careers. This appears to have motivated him to write *Perfect Form*, an introductory text on variational principles and methods. Readers of *Perfect Form* are assumed to have limited background knowledge in mathematics and physics: partial differentiation, simple integration, geometrical optics and particle mechanics. The most technically demanding aspect of the text is the solution of an ordinary differential equation by separation of variables.

In just 117 pages, the author succeeds in conveying a sense of the delightful history and philosophy surrounding the development of variational principles (although the scope of the text is necessarily limited). He begins each chapter with a quote from one of the great figures of the subject's development and includes within each chapter numerous footnotes with references to specific sources. I found these footnotes to be—in almost but not every instance—reliably informative and accurate. At the end of each chapter, Lemons includes several problems that are heavily referenced throughout the text. Such references go far in helping the reader to reach beyond the specific examples in the main text. The book also includes—in chapter 1—a brief philosophical discussion of final cause. I know of no other textbook on the subject that specifically brings this topic to the forefront of discussion, and Lemons should be congratulated for his wisdom in doing so.

In balancing between variational principles and methods, Lemons has chosen to emphasize the principles. He discusses, through didactic examples, Fermat's principle, the principle of minimum potential energy, Maupertuis's (and Jacobi's) principle of least action and Hamilton's principle. To the author's credit, the distinction between Lagrange's application of the principle of least action (chapter 5) and Hamilton's principle (chapters 6 and 7) is eventually made quite clear; the reader may have to wait until chapter 7, however, for all of chapters 5, 6 and 7 to fall into place.

The calculus of variations is touched on, but only briefly, in the second chapter. Those seeking a more complete and precise introduction to the calculus of variations may refer to almost any of various books of that title. I can strongly recommend Richard A. Silverman's translation of *Calculus of Variations* by I. M. Gelfand and S. V. Fomin (Prentice-Hall, 1963). Though generally for a more advanced audience, the first chapters of that text can be digested by any calculus student who can follow an ε-δ proof.

Perfect Form is the only text of which I am aware that covers the subject of variational principles and methods at the beginning undergraduate level. More advanced mechanics students, seeking a book with more complete coverage of variational principles and their history, may wish to consult Lanczos's *The Variational Principles of Mechanics*. If, on the other hand, I were approached by an enthusiastic freshman seeking recommendations for summer reading on variational principles, I might find myself torn. On one hand, I might recommend the delightful and very accessible *Mathematics and Optimal Form*, by Stefan Hildebrandt and Anthony Tromba (Scientific American, 1985), which seems to have been substantially revised and rereleased, by Springer-Verlag in 1996, under the title *The Parsimonious Universe*. On the other hand, Lemons's book includes material that is techni-

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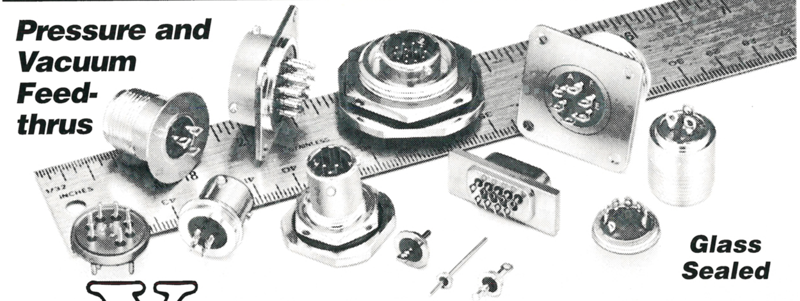

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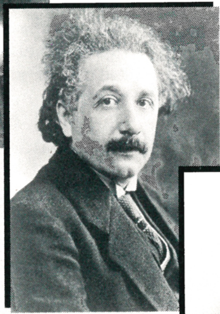

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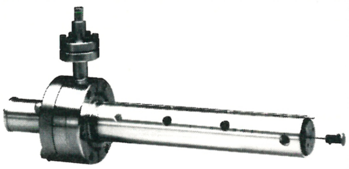

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Paul E. Barbone
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Fractal River Basins: Chance and Self-Organization

Ignacio Rodriguez-Iturbe and Andrea Rinaldo
Cambridge U. P., New York, 1997. 547 pp. $100.00 hc
ISBN 0-521-47398-5

The relevance and usefulness of fractal geometry in the study of many different physical phenomena have increasingly been recognized since the appearance of Benoit Mandelbrot's *The Fractal Geometry of Nature* (Freeman, 1983). Fractal geometry has become a basic tool in the analysis of physical systems characterized by complex spatial structures. More recently, development of the theory of self-organized criticality by Per Bak and collaborators has provided a conceptual framework for studying systems characterized by similarly complex temporal patterns and their relation to the emergence of complex structures.

In *Fractal River Basins*, Ignacio Rodriguez-Iturbe and Andrea Rinaldo show how these two modern concepts can be harnessed to address a problem that has been of major interest to civilized societies throughout history: the nature of river basins, their physical structure and evolution. This synthesis provides a conceptual and mathematical framework within which the rich variety of river networks and their underlying order can be investigated. It may thus be viewed as the first monograph devoted to a branch of the Earth sciences that Mandelbrot suggested should be called potamology (from the Greek word for river).

The book is aimed at two scientific communities that have been largely separate in the past: hydrologists (and Earth scientists in general), who may appreciate the application of novel theoretical tools to their traditional field of research, and physicists familiar with those tools who may be intrigued by their application to an additional set of physical phenomena. The authors therefore face the considerable challenge of presenting recent research results while providing the necessary background material in hydrology, fractal geometry and self-organized criticality for the benefit of the two communities.

The result of these efforts is a dense and bulky (540-page) volume that is nevertheless a pleasure to read. The writing is clear, and the introductory material is provided in a straightforward manner. The book's organization is generally good, although there is some intentional repetition of material from chapter to chapter. Short abstracts at the beginning of each chapter clearly describe the content and focus attention on the chapter's main points. The text is packed with figures and photographs, which contribute considerably to its readability and are indispensable to any discussion of complex geometrical structures. For a first edition, there are few typographical errors in the text, and I spotted no obvious substantial errors or misstatements.

The first part of the book (chapters 1–3) is devoted mostly to providing the necessary background and introducing the theoretical tools that will be applied in subsequent chapters. The hydrology and geomorphology of river basins are reviewed in the first chapter. The relevant concepts of fractal geometry and the fractal and multifractal characteristics of river basins are presented in the next two chapters. The authors analyze the geometry of real and simulated landscapes and demonstrate the unity behind the variety of structures of natural river networks. Special emphasis is given to observational evidence of self-similarity and self-affinity in river basins. The methods used to extract this information from digital elevation models are carefully explained. This part introduces an unusually large number of technical terms and mathematical symbols, a few of which are similar enough to make some confusion possible. It would have benefited from the inclusion of a detailed list of symbols and a glossary.

The second part (chapters 4–7) is devoted to a theoretical discussion of the structure and evolution of river basins, most of which is based on recently published work by the authors and their collaborators. Introducing the principle of minimal energy expenditure in river basins, the authors construct a model of optimal channel networks and demonstrate its implications to the formation of statistically self-similar patterns. The theory of self-organized criticality for the dynamics of fractal growth is applied to the analysis of the development of fluvial landscapes. The close connection between optimal channel networks and fractal structures is discussed as a joint consequence of optimality and random-