tial differential equations, including solitons. This last area, along with nonlinear interaction of laser beams, appears to be a specialty of the authors.

The text starts with a wide-ranging, 60-page tour of nonlinear phenomena, aided by computer explorations using the accompanying Maple software. Like Francis Moon's *Chaotic and Fractal Dynamics* (Wiley, 1992), one of the book's strengths is the diverse selection of examples from mechanical, chemical, electronic, fluid and many other physical systems. As one who does research in fluid instabilities and chaos in mechanical systems, I recognized many old friends. Another strength of the book is the diversity of approaches that the student is encouraged to take.

The text, software and accompanying laboratory manual allow the reader to examine nonlinear physics in complementary ways. In the text, three chapters create a foundation of qualitative, analytical and numerical tools before the rest of the book focuses in turn on limit cycles, forced oscillators, chaotic systems, iterated maps and nonlinear waves. The laboratory manual is perhaps the first freestanding book to accompany a text on this topic, and its 28 relatively simple experiments provide benchtop verification of the behavior of nonlinear systems.

The thoroughly annotated Maple files accompanying the text provide a parallel track, reinforcing concepts and encouraging further explorations. Indeed, this text simultaneously serves as an excellent, structured introduction to Maple V release 4. I found the Maple environment to be efficient and the commands surprisingly intuitive. For example, I easily adapted the authors' examples to use of Maple in exploring the dynamics of particles in a Paul trap, gaining several useful insights to this problem. This is just the sort of tool I wish I had found during my initial readings on nonlinear dynamics. Readers who wish to pursue more specialized computations on, say, the properties of chaotic attractors, will want to supplement this environment with software such as the package provided by Helena Nusse, James York, Eric Kostelich and Brian Hunt, in the second edition of Nusse and York's *Dynamics: Numerical Explorations* (Springer-Verlag, 1997).

One drawback of the Enns–McGuire book is its rather limited treatment of bifurcations. The topic is not dealt with at any length until late in the book and then mostly in the context of iterated maps. Many research experiments in nonlinear systems proceed by variation of a control parameter, and a book such as this could convey the excitement and insight gained from watching new physical behavior result from a succession of bifurcations. The important topic of Hopf bifurcations—perhaps a suitable model for my old friend the marginal oscillator detector—is not even mentioned in the text. Also, the linear stability analysis of singular points in two-dimensional flows seems a bit restricted: In this context, the Jacobian matrix is not mentioned, and the student may wonder how to generalize the stability analysis to higher dimensional systems. I prefer the treatment of stability and bifurcations in Steven Strogatz's *Nonlinear Dynamics and Chaos* (Addison-Wesley, 1994). Finally, it is surprising that a book seeking to give a wide-ranging introduction to nonlinear physics omits treatment of Hamiltonian systems.

Choices of coverage must, of course, be made to keep a book like this of reasonable length and accessibility. On the whole, the authors have chosen well, and the trio of text, Maple-based software and lab manual gives the newcomer to nonlinear physics quite an effective set of tools. Basic ideas are explained clearly and illustrated with many examples. There is an ample set of problems and suggestions for further exploration. Thus, this text–software–manual trio will serve well for both undergraduate senior-level lecture courses and independent study, perhaps alongside or closely following a reading of the second edition of Gregory Baker and Jerry Gollub's *Chaotic Dynamics: An Introduction*, (Cambridge U. P., 1996). I recommend that students also get a taste for ongoing research through a multiauthored survey like *The Nature of Chaos*, edited by Tom Mullin (Oxford U. P., 1993). For readers wishing a more thorough grounding in chaotic dynamic systems, I would strongly recommend follow-up study of the above-mentioned book by Strogatz or, at a more advanced level, Edward Ott's *Chaos in Dynamical Systems* (Cambridge U. P., 1993). This is clearly an extended course of study, and one for which *Nonlinear Physics with Maple* provides a good, balanced start.

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An Introduction to Active Galactic Nuclei

Bradley M. Peterson
Cambridge U. P., New York, 1997. 238 pp. $69.95 hc ($27.95 pb) ISBN 0-521-47348-9

Quasi-stellar objects, or quasars, were first identified through radio astronomical techniques in the early 1960s.

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 $z \leq 0.2$ 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 ref-