



## BOOKS: ASTROPHYSICS

## The Heart of the Matter

Roger Blandford

In 1908, one year before Ernest Rutherford found that a gold atom has a tiny nucleus occupying  $10^{-15}$  of its volume, the Lick Observatory's Edward Fath discovered that the galaxy NGC-1068 also contains a nucleus, one bright in hydrogen emission lines. Although Rutherford immediately understood the implications of his discovery (which led successively to atomic, nuclear, and particle physics), it took astronomers another half century to develop the telescopes and instrumentation necessary for comprehending what Fath had glimpsed. Perhaps a lack of imagination delayed our understanding, but it is now clear that, like NGC-1068, most normal galaxies, including our own, contain massive black holes, which occupy about  $10^{-30}$  of their host galaxy's volume. For nearby galaxies, these holes are mostly dormant and detectable only through their gravitational influence on surrounding stars and gases. But when the universe was about 20 percent of its present age, nearly 1 percent of these black holes were supplied with enough fuel to outshine their galactic hosts. By converting the gravitational binding energy of gas just before it was swallowed, these black holes produced a "megaton" of energy for every kilogram of matter consumed. We call such objects quasars because they are "quasi-stellar" in appearance to the optical astronomer. We now know that they are only the most prominent among an assortment of lesser lights, known by such names as blazars, radio galaxies, Seyfert galaxies, and low-ionization nuclear emission regions (LINERs), which have been diligently studied for over 40 years.

These active galactic nuclei (AGN) provide the title and the subject of a new graduate-level text by Julian Krolik, an experienced and distinguished researcher at Johns Hopkins University. Somewhat surprisingly, Krolik's is the only recent book devoted entirely to this subject from the perspective of a theorist. It starts with a discussion of the definition, identification,

and distribution of AGN. This is followed by a relativistic description of black holes and of the gas that accretes onto them though an orbiting disk; gas that can some-

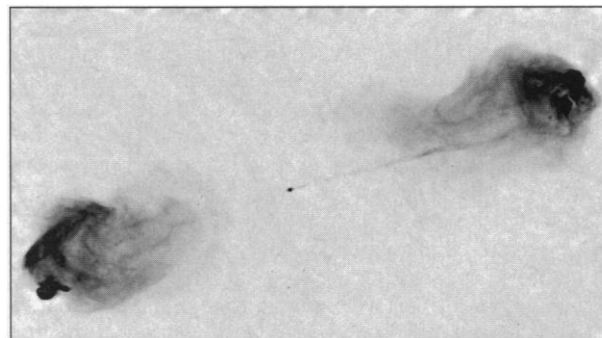
times escape its grisly fate by being diverted into a fast outflow or a pair of antiparallel jets formed with ultrarelativistic speeds. AGN radiate throughout the electromagnetic spectrum, from the lowest radio frequencies to TeV gamma rays. Krolik provides a comprehensive discussion of the many, distinct mechanisms thought to be responsible for this emission in the different classes of objects. As he carefully explains, this is not, however, the same as describing what we actually observe. The

emissions can be heavily processed by absorption or strongly beamed by special relativistic aberration and Doppler boosting when they originate in a jet. Krolik concludes with an attempt to place galactic nuclei in the context of their host galaxies. He returns to the book's starting point by speculating about the physical factors that trigger and curtail the AGN stage in the normal life cycle of most ordinary galaxies.

The study of AGN is, by necessity, heavily phenomenological. Krolik makes an admirable attempt to do justice to the observational complexities and uncertainties while presenting the tentative, physical framework within which most of us now interpret these observations. The subject requires interweaving a large number of fundamental ideas drawn from physics and astrophysics. To keep the book's length within bounds, Krolik addresses graduate students or active researchers who have already mastered the basics of radiative transfer, atomic astrophysics, nonthermal emission mechanisms, general relativity, cosmography, and magnetohydrodynamics. (For those who have temporarily forgotten such material, compact summaries of the most important results are embedded in the text and appendices; other read-

ers, for whom the material is new, must brace themselves for some long evenings with supplementary texts.) The prose is clear, and the formal derivations didactic, with a realistic balance between simplicity and rigor. The text offers a useful guide, well matched to the research literature, despite using the awkward vocabulary of the field. We do not yet have enough understanding of how the accreting gas flows, blows, and glows for anyone to write a confident treatise that is logically organized by physics and stripped of superfluous, taxonomic baggage.

This book arrives at a fortuitous time, when there is a resurgence of interest in the study of galactic nuclei and quasars. As Krolik discusses, black hole masses have been measured in about 30 galaxies and, arguably, the black hole spin has been estimated in a couple of instances. This has given a decidedly quantitative edge to the models. Furthermore, NASA's orbiting Compton Observatory has shown that relativistic jets are gamma-ray fires that outshine by orders of magnitude the radio smoke with which the jets have traditionally been studied. With the addition of the detailed spectroscopy made possible by the Keck telescopes, the striking Hubble images of quasar host galaxies, and other new observations, we are seeing a rapid reduction in the range of possible answers



**Strong signaler.** Early radio astronomy observations revealed that many bright radio sources have the form of double lobes with a galaxy located midway between them. Cygnus A (6-cm wavelength image) has a linear extent of ~120 kpc.

to the fundamental questions, "How, why, and when do these sleek, cosmic machines really work?" There is a strong sense, which comes across well in Krolik's account, that the time is ripe for a new synthesis. It is precisely this anticipation that makes the subject so exciting.

Looking to the near future, after the three scheduled x-ray telescopes (the United States's Chandra, Europe's XMM, and Japan's Astro-E) are launched, we should be poised to learn much more about the innermost secrets of AGN. Therefore it is unfortunate that high-energy astrophysics

**Active Galactic Nuclei**  
From the Central Black Hole to the Galactic Environment  
by Julian H. Krolik  
Princeton University Press, Princeton, NJ, 1999. 620 pp. \$99.50, £60. ISBN 0-691-01152-4. Paper, \$39.50, £23.95. ISBN 0-691-01151-6.

## SCIENCE'S COMPASS

has been allowed to decline in many graduate programs at a time when it ought to be growing. This contrast underscores the timeliness of Krolik's text. I hope that *Active Galactic Nuclei* will help educate the next generation of AGN researchers, whose discoveries will require it to be extensively revised in a few years time.

### BROWSEINGS

**Beauty and the Beast.** The Aesthetic Moment in Science. *Ernst Peter Fischer. Translated by Elizabeth Oehlkers.* Plenum Trade, New York, 1999. 216 pp. \$25.95. ISBN 0-306-46011-4.

Fischer, a historian of science, examines aesthetic aspects of research and discovery. He concludes that notions of beauty and harmony are important components of both the scientific mind and process, and he urges that they be given greater consideration.

**Disasters by Design.** A Reassessment of Natural Hazards in the United States. *Denise S. Mileti.* Joseph Henry (National Academy Press), Washington, DC, 1999. 371 pp. \$47.95. ISBN 0-309-06360-4.

Building on findings from the past two decades, Mileti and his contributing authors

propose a redirection of research and policy for natural and technological hazards. They advocate the adoption of sustainable development principles as the best means of reducing the financial and social burdens of disasters.

**Metapopulation Ecology.** *Ilkka Hanski.* Oxford University Press, Oxford, 1999. 323 pp. \$85, £45. ISBN 0-19-854066-3. Paper, \$45, £22.50. ISBN 0-19-854065-5.

Hanski offers a state-of-the-art review of the ecological dynamics of metapopulations, assemblages of local breeding populations. Because the world is patchy, and becoming more so, this synthesis of current research (including the author's substantial contributions to the field) will be of particular interest to conservation biologists.

**Walther Nernst and the Transition to Modern Physical Science.** *Diana Kormos Barkan.* Cambridge University Press, Cambridge, 1999. 300 pp. \$64.95, £45. ISBN 0-521-44456-X.

Nernst, the 1920 Nobel laureate in chemistry, made substantial contributions to our understanding of solutions, chemical equilibria, and the behavior of matter at

high temperatures. Barkan's scientific biography examines his work at the intersection of chemistry, physics, and technology in turn-of-the-century Germany.

**Science Without Laws.** *Ronald N. Giere.* University of Chicago Press, Chicago, 1999. 295 pp. \$25, £17.50. ISBN 0-226-29208-8.

Giere rejects the Enlightenment view of science as a "uniquely rational activity leading to the discovery of universal truths." In these essays, he argues for considering science as the development of "more or less abstract models of specific aspects of the world."

**Understanding Quantum Mechanics.** *Roland Omnès.* Princeton University Press, Princeton, NJ, 1999. 321 pp. \$35, £21.50. ISBN 0-691-00435-8.

Writing for beginning students and experienced physicists, mathematicians, and philosophers, Omnès provides a comprehensive overview of the conceptual framework of quantum mechanics. Organized using logically consistent histories, his updating of the Copenhagen interpretation incorporates recent research on the decoherence effect and the correspondence between quantum and particle physics.

### NOTA BENE: THEATER

## A Gamete Gambol

If a woman in her late thirties who is determined to become a mother seems an unlikely subject for a play, then Carl Djerassi, the chemist who synthesized the first contraceptive pill, may be an even more unlikely playwright. But in the wry and witty *An Immaculate Misconception*\*, an eleven-scene science-in-theater play, Djerassi jettisons his contraceptive beginnings to delve into the thespian world of conception.

Melanie Laidlaw, a widowed career scientist, is wondering if she has left it too late to have a baby. But Melanie, unlike her contemporaries, has a certain advantage—she happens to be a reproductive biologist who has perfected a new technique, ICSI (intracytoplasmic sperm injection), that dramatically increases the chances of fertilizing a human egg in the laboratory. With her clinical collaborator, the fiendish Felix, she prepares for the ultimate test of ICSI: the injection of a single sperm into a human egg and implantation of the resulting embryo into the egg donor. The desire for motherhood prompts Melanie to use her own eggs for the crucial experiment but, after much soul searching, she eschews the sperm bank in favor of a sperm sample from her lover, Menachem, an Israeli nuclear engineer. Predictably, her carefully "hatched" experiment starts to go wrong when she discovers that because of a radiation accident, Menachem is infertile. This problem is set to sink the experiment and Felix (unbeknownst to Melanie) decides to fix it with a sperm donation of his own.

In between the capers, the play airs some of the ethical and social issues raised by in vitro fertilization (see essay on p. 53). Who owns gametes and how crucial is donor consent? What determines paternity: a complement of genes or the

dedication of a loving father? Are scientists playing God when they manipulate conception? Should technology be used to extend the age at which women can conceive? Melanie's decision to not tell Menachem of her plans for his sperm provides one of the play's funniest moments—our heroine secretly sneaking a used condom into a dewar flask of liquid nitrogen—as well as the backdrop against which the protagonists heatedly debate sperm ownership and donor consent. Through Melanie's son, Adam, "the first ICSI baby," the play considers the issue of paternity. The artful switching of sperm samples by Felix casts uncertainty upon the identity of Adam's genetic father; yet the final scene leaves us in no doubt that Adam's real father is Menachem.

But there are two premises upon which the plot hinges that stretch one's credulity. It seems doubtful that Melanie, at 37, would try a new in vitro fertilization technique (untested in humans) before seeing if she could conceive Nature's way. Even more unlikely is the notion that a reproductive biologist would risk fertilizing a human egg with sperm that might carry genetic abnormalities.

Nevertheless, *An Immaculate Misconception* appeals because of the unusual plot, the well-drawn characters, and the simple but effective touches of modern technology, such as a screen on which e-mail exchanges between Melanie and Menachem appear during scene changes and the screening of real video footage of ICSI (courtesy of UCSF) as Melanie performs the first-ever injection of a single sperm into a human egg.

It is encouraging to see modern science brought to life through theater, one of the most ancient and artistic forms of communication.

—ORLA SMITH

\**An Immaculate Misconception* will be performed from 15 August to 6 September 1999 in the Unadilla Theater in Marshfield, Vermont, USA.