

unknowns (also 40) that must be solved to find the desired coordinate transformation. By contrast, from the geometrical point of view, the result is a direct consequence of the ability to construct a coordinate system based on geodesics passing through the given point.

In addition, there are a few flaws in Low's treatment of general relativity that are worthy of mention. First, Low's use of point particle sources is valid only in the context of linearized gravity; the fully nonlinear Einstein equation with point particle sources does not make mathematical sense. Second, no adequate warning is given to the reader of the highly gauge-dependent nature of the gravitational stress tensor. Finally, the claim in section 7.6 that dx^μ is a contravariant vector is in direct conflict with standard mathematical usage of that terminology. In fact, $\{dx^\mu\}$ is a basis of covariant vectors, with μ labeling the elements of this basis. The fact that the coordinate bases for two different coordinate systems are related by the same formula that applies for the transformation of the components of a contravariant vector does not make dx^μ a contravariant vector.

Despite these criticisms, I feel that Low's book provides a valuable introduction to electromagnetism and gravitation at the graduate level and will be of particular use to aspiring theoretical particle physicists.

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Yerkes Observatory, 1892–1950: The Birth, Near Death, and Resurrection of a Scientific Research Institution

▶ Donald E. Osterbrock
U. Chicago P., Chicago, 1997.
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ISBN 0-226-63945-2

Yerkes Observatory, located in southern Wisconsin, was founded exactly a century ago. From the beginning it was a world leader in what was called the "new astronomy," astrophysics, the application of spectroscopy and photography to the study of the physical processes of stars and interstellar gas. Donald Osterbrock's *Yerkes Observatory, 1892–1950*, however, deals only peripherally with the astronomy produced at Yerkes; rather, it is a detailed chronicle of the men, organizations, academic politics and finances that

shaped the institution's checkered history over the tenure of its first three directors, George Ellery Hale, Edwin Frost and Otto Struve. Osterbrock, former Lick Observatory director and Yerkes astronomer (as a graduate student), has scoured major archives to piece together his detailed story.

Born almost simultaneously with its parent University of Chicago, Yerkes was headed first by Hale, an innovative astronomer and master fund-raiser even in his twenties. With money from the archetypal railroad tycoon Charles Yerkes and strong support from the university's first president, William Harper, Hale oversaw the first staff appointments and the installation of a 40-inch-diameter refracting telescope, then and now the largest of its type in the world. Hale soon realized, however, that the technology of large mirrors was such that the future of astronomy lay with reflectors and that, furthermore, these should be located on mountaintops with good weather. (One staff astronomer observed, "Yerkes is a pleasant and easygoing place where we sometimes see the stars.")

In 1904 Hale secured another large grant, this time from Andrew Carnegie, and set off to build a 60-inch reflector and found Mt. Wilson Observatory in California. This left Yerkes in the less skilled hands of genial Edwin Frost, who remained director for three decades (during the last of which he suffered complete blindness). Osterbrock describes the decline in the quality of the staff and research under Frost's management style (he calls it the "near death" of the institution). But there was one bright appointment, that of Otto Struve, White-Russian soldier and refugee and scion of an astronomical family, who joined the staff in 1921.

Although Struve had established himself as an extremely productive researcher, it was unexpected and controversial to name this "foreigner" a "boy director," at age 35, in 1932. Over the next two decades Struve, tightly partnered with university president Robert Hutchins, transformed the observatory into arguably the finest astrophysics institution in the world. With the founding of McDonald Observatory in 1939, Struve established an 82-inch reflector at a first-rate site in Texas. He swept out Frost's deadwood and hired an international cast of scientists who either were or were soon to become world leaders in astrophysics: Gerard Kuiper (Holland), William Morgan (US), Bengt Strömgren (Denmark), Jesse Greenstein (US) and, most notably, Subrahmanyan Chandrasekhar (India). When Struve hired him in 1936, "Chandra" had already

developed the theory of white dwarf stars, for which he was to receive a Nobel Prize 50 years later, but had suffered from intellectual and racial prejudice. It is telling that Struve also had to overcome resistance to Chandra's dark skin, and once resorted to the following rationale with a dean: "His complexion is of course quite dark but his features are quite different from those of the American Negro."

Osterbrock's account is a blend of a detailed chronology and a history. He supplies myriad details of hirings and firings, negotiations between astronomers and administrators and the financial shaping of the observatories. The book nicely lays out the ways in which varying research-management styles and personalities of directors can mightily influence the course of science. But, although such information is indispensable for assembling the history of 20th-century astronomy, there is little guidance to a larger context: Why should the reader care about Yerkes Observatory and the machinations of its staff? Nor is this study set into the larger context of the voluminous historical research on scientific institutions. Nevertheless, the book is solidly researched, full of fascinating stories and, for historians and astronomers, an important reference about one of the key American observatories of this century.

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An Introduction to X-ray Crystallography

▶ Michael M. Woolfson
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(\$37.95 pb)
ISBN 0-521-41271-4 hc
(0-521-42359-7 pb)

We have had to wait almost 30 years for the second edition of Michael M. Woolfson's widely acclaimed text, *An Introduction to X-ray Crystallography*. In a sense, it is humbling that so little has changed in the basic principles of crystallography during that time; almost all of the clever ideas were current, or at least well into formation, in 1970, when the first edition was published. The present-day revolution in crystallography is, after all, in its numerous applications to biology and materials science.

Crystallography is the epitome of interdisciplinary science. Its foundations are squarely in the physics of diffraction. Today, its numerous users are largely interested in structural