The Danish Observer, the German Mathematician, and the Center of the Universe

Tycho & Kepler: The Unlikely Partnership That Forever Changed Our Understanding of the Heavens

Kitty Ferguson
Walker, New York, 2002. $28.00 (402 pp.). ISBN 0-8027-1390-4

Reviewed by Gale E. Christianson

Kitty Ferguson has made her reputation as a historian of science who writes for a broad general audience. Among her well received works are *Stephen Hawking: Quest for a Theory of the Universe* (F. Watts, 1991), *Prisons of Light: Black Holes* (Cambridge U. Press, 1996), and *Measuring the Universe* (Walker, 1999). In her most recent book, *Tycho and Kepler*, the author recounts the famous tale of two highly gifted natural philosophers, one the greatest naked-eye observer in history, the other the formulator of the first mathematical laws of the heavens.

A product of great wealth and privilege, Tycho Brahe ruled the island of Hven—a gift from the king of Denmark—like a medieval lord. There, by virtually enslaving the resident population, he built Uraniborg, the world's most advanced observatory. Charting the night skies with massive instruments of his own design, he accumulated a trove of precious data, the accuracy of which set him apart from all astronomers, living and dead.

It was also on Hven that Tycho developed his idiosyncratic model of the universe. Opposed to the Copernican system for religious reasons, yet fully cognizant of the growing anomalies in the Ptolemaic model, he fashioned a grand compromise. In Tycho's system, Earth was an immobile body around which the Sun revolved, and the five planets then known revolved around the Sun.

Johannes Kepler, by contrast, came from humble circumstances. The son of a ne'er-do-well mercenary who was often absent from home for years at a time, he had grown up with a major inferiority complex reinforced by his small stature and the poor eyesight that barred the way to a life of observation. His strength, too, lay in the opposite direction of Tycho's—a great theoretical mind fired by a capacity for mathematics that can only be described as genius.

Only after 16 chapters of prologue do the principals finally meet at Benatky Castle outside Prague. Tycho, unable to control his mercurial temper, has severed all ties to the Danish king and court and cast his lot with Emperor Rudolph II, one of the great scientific patrons of the day. After corresponding with Kepler and reading his published work, Tycho decides to take a chance on the young astronomer, though he is very uncomfortable with Kepler's Copernican leanings.

A symbiotic, albeit stormy, relationship ensues, which Ferguson recounts in colorful detail. Tycho's data, especially that apparently showing an eccentric orbit of Mars, is exactly what Kepler requires to transform astronomical theory into scientific fact. An aging Tycho comes to realize that without Kepler to interpret and analyze his work, all could be lost. On his deathbed, the Danish nobleman begs the German commoner to renounce the heliocentric system: "Let me not seem to have lived in vain." Kepler, of course, does nothing of the kind. Instead, he spends the following years plowing through Tycho's precious data, eventually wringing out of it his famous three laws of planetary motion while failing, by the skin of his teeth, to solve the riddle of gravitation.

The story is one well known to historians of science and doubtless to many general readers as well. Still, it is a tale well worth the retelling. Ferguson is a fine writer and milks the double drama of clashing personalities and scientific discovery for all they are worth without crossing the line into fiction. The scientific concepts are clearly delineated, and the reader will deeply appreciate the many enlightening diagrams and photographs. Although *Tycho and Kepler* is not a work of original scholarship, it is a captivating story drawn from the greatest subject known to humankind—the very universe itself.

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Color Space and Its Divisions: Color Order From Antiquity to the Present

Rolf G. Kuehni
Wiley, Hoboken, N.J., 2003. $99.95 (408 pp.). ISBN 0-471-32670-4

Rolf Kuehni's *Color Space and Its Divisions* is an inclusive mosaic of the history of color-order systems, that is, useful arrangements of color, from the time of the preclassical Greeks to the present. One particular scheme invented by Johann Lambert and described in his 1760 book *Photometria* illustrates how such a system might be used. As quoted in Kuehni, "Caroline wants to have a dress like Selinda's. She memorizes the color number from the pyramid and will be sure to have the same color. Should the color need to be darker or go more in the direction of another color, this will not pose a problem" (page 55). Lambert's pyramid is only one of many color-order systems. Using it, as is evident from Lambert's example, is similar to navigating with a map. Not surprisingly, then, color-order systems are sometimes called color atlases.

A color atlas would seem easier to create than a world map, if only because it requires less travel. However, color atlases are prone to what Kuehni calls fragility (page 309)—their color samples fade and they are difficult to use.

Many of those difficulties are perceptual. Change of illuminant may cause the samples in a color atlas to undergo a perceived "continental drift" or worse. Samples that are distinct under one light may look the same under another, so the continental-drift analogy even includes subduction! Changes in an observer, especially aging, can also lead to such drift effects. In addition, the perceived color of the object one tries to match from the atlas depends on the colors of neighboring objects. If you are unconvinced, try spray-painting a large piece of white paper with yellow fluorescent paint after laying a few coins on the paper to block the paint. When you remove the coins and view the paper in sunlight, the unpainted area will look dark purple. How could Caroline match Selinda's dress under such conditions?

Mindful of such difficulties, Kuehni traces the development of color-order systems. The earliest system considered is that of Xenophanes, a natural philosopher who lived in the 6th century BCE. Plato and Aristotle proposed one-dimensional scales that didn't include green or blue. The natural philosopher Avicenna introduced the first multidimensional color scale in the 10th century. The notion of color circles began in the Middle Ages with limited scales that physicians used to classify urine. Another expression of the circle idea, by Sigfrid Forsius, occurred in the 16th century. It was Isaac Newton who brought the circle idea to maturity; he used the spectral colors he got from a prism and identified the center of the circle with white. Kuehni suggests that Newton chose seven basic colors to reinforce an analogy with musical tones, and that he invoked a nonspectral purple to complete his color circle in conformity with the one-octave tonal circle derived by René Descartes.

By now, you may have guessed that Kuehni does not credit physicists with all the answers and breakthroughs in color science. That message, although implicit, emerges eloquently from his arrangement of the mosaic tiles of his history. The book describes a number of color-order systems, many more than just the several most popular, and supports its discussion with more than 500 references. Newton, though, receives less than three pages, and that includes a figure juxtaposing Descartes's tonal and Newton's color circles. Hermann von Helmholtz, Hermann Grassmann, James Maxwell, and Erwin Schrödinger together receive about five pages, replete with five figures.

As a retired industrial color expert with a book on colorant formulation to his name, Kuehni understands well the physics of color measurement. However, he views perception rather than physics as the proper reference point for creating a color-order system. He seems reluctant to encumber either his history or the perceptual basis of color order with the ideas of basic colorimetry. For example, only in a single sentence (page 164), does one find a definition of tristimulus values: three weighted wavelength integrals of the light spectrum that represent the stage of vision that commences with a luminous stimulus and ends with the absorption of light by the photopigments of the eye. When Kuehni calls tristimulus space nonlinear (page 347), he clearly is relating that space to the space of perceived colors and not to physical light intensity, because tristimulus coordinates are linear in intensity.

Consonant with the perceptual emphasis, Kuehni enumerates such techniques for quantifying perception as color naming, magnitude estimation, and visual thresholds. Such efforts precede Newton; an interesting application is Francis Glisson's 1677 scale to classify the color of hair. Kuehni also exhaustively describes attempts to create color-order systems in which equal distances correspond to equal perceived-color differences. His discourse includes many models, some non-Euclidean, that connect light to perceived color. Fortunately, Kuehni defers the detailed model descriptions until after he has defined tristimulus values.

As a physics-oriented color scientist, I find the physical colorimetry to be sketchy and not tutorial. For example, Kuehni's brief discussion of tristimulus values is not grounded in such general principles as the Grassmann laws, which declare the linearity of color matching and hence the primacy of those values. Indeed, Kuehni doesn't mention Grassmann's laws at all. Instead, he launches into the warts of the CIE system that conventionally represents tristimulus values. Although Kuehni's statements are accurate, they will not teach novices.

In all fairness, Kuehni's abruptness of style is even handed and perhaps necessary for a book of such a wide historical scope. No mindset, ancient or modern, receives a long discussion. Each contribution, however, is explained briefly and reported traceably. I only hope Kuehni will add an author index to his next edition to increase the value of the large reference list.

My recommendations: Dip into *Color Space and Its Divisions* as a sightseer, historian, or philosopher. Read it as a color scientist who wants to know who did what first. But do not expect a tutorial.

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Magnetic Materials: Fundamentals and Device Applications

Nicola A. Spaldin
Cambridge U. Press, New York, 2003. $110.00, $40.00 paper (213 pp.). ISBN 0-521-81631-9, ISBN 0-521-01658-4 paper

Today's Web surfers rely on magnetic devices to navigate the Internet, but their ancestors were navigating the high seas with magnetite compass needles hundreds of years ago. Thus, the impact of magnetic materials on science and technology is a phenomenon both ancient and modern. Magnetic materials currently excite the pioneering spirit in condensed matter physics (see, for example, the article by Neil Mathur and Peter Littlewood in PHYSICS TODAY, January 2003, page 25). They also spur the entrepreneurial spirit, giving us data storage, sensors, motors, and transformers—to name some of the major applications.

Why then has there been no appropriate entry-level text for beginners? Existing texts do cover basic principles and applications, but the length and level of detail are unsuitable for an initial overview by undergraduates, graduates, or researchers new to the field. But now all that has changed. Fortunately, a good introductory book on magnetic materials is no longer an oxymoron.

Nicola Spaldin's *Magnetic Materials: Fundamentals and Device Applications* is well written and hard to put down. It quickly takes the reader on an epic journey from the most basic principles of magnetism to the cutting edges of technology. Those who complete the odyssey will develop a coherent overview of magnetism and magnetic materials past, present, and future.

Spaldin is an associate professor in the materials department at the University of California, Santa Barbara (UCSB). Using various theoretical and computational methods, she examines the fundamental physics of new magnetic materials that may be technologically important. She has taught with much enthusiasm across a range of levels and has won several awards in the process. She has been granted NSF funding to improve the quality and relevance of graduate education at UCSB and has participated in international science education and outreach programs. Her passion for undergraduate teaching is reflected in the contents and style of her book.

Topics are developed in a concise manner and are efficiently interrelated. That interrelationship is particularly apparent in the opening text of each chapter. For example, in one chapter, diamagnetism is presented as an extension of the atomic physics that explains spin and orbital moments. In a subsequent chapter, paramagnetism is discussed as an effect that tends to overshadow diamagnetism. And in the next chapter, ferromagnetism and other types of magnetic order are developed out of paramagnetism using