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The Unmaking of the Medieval Christian Cosmos, 1500–1760: From Solid Heavens to Boundless Aether FREE

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the most common visualization of fluid motion is that of streamlines, the lines everywhere tangent to the velocity vector. In steady flows, the streamlines are the actual paths of infinitesimal fluid particles and are thus the pathlines. In unsteady flows, this is not the case. And while one can still define instantaneous streamlines—lines everywhere tangent to the particle velocity vector at a particular instant of time—the usefulness of such lines for unsteady flows is much less than it is for steady flows.

Since fluid particles move in a manner consistent with the forces acting on them, streamline patterns, particularly for steady flows, provide insight into the physics of the flows for which they are drawn. Every fluid dynamics text will illustrate its textual material with streamline figures. What the reader will find in Costas Pozrikidis's *Little Book of Streamlines* is very little text and a large compilation of such figures for a wide range of incompressible, mainly steady and two-dimensional (both planar and axisymmetric) flows. (Pozrikidis is professor of fluid mechanics at the University of California, San Diego, and author of the excellent advanced fluid dynamics text *Introduction to Theoretical and Computational Fluid Dynamics*, Oxford, 1997.)

The book contains four main sections: Irrotational Flow, Vortex Flow, Stokes Flow, and Miscellaneous (Flows). Each of these begins with a very brief—a half-page at most—description of the class of flows, and each particular flow is illustrated on one or more pages.

Because a fluid must flow tangent to any impermeable solid body, the reader, or, in this case viewer, of what is basically a collection of figures, may find many of the streamline patterns to be obvious. But many will not, and even the experienced worker in the field should find many of the figures unfamiliar and interesting, particularly, for example, in the Stokes flow section.

The price of the book makes it unlikely that students will be asked to purchase it as a supplement to a regular text in a course. Instructors of basic and more advanced fluid dynamics classes, on the other hand, may find it useful as a source of streamline patterns for many of the flows they discuss in their classes. (Software—FORTRAN 77 programs on a 3 1/2 floppy disk—for calculating the flows accompanies the book.)

One small criticism: The author explicitly states that he chose the origin of streamlines in most of the flows illustrated to give visually pleasing patterns, instead of choosing them so that the flow rate between neighboring streamlines is constant. This means that one cannot generally glean qualitative values of the velocities in these flows from the distance that the streamlines are from each other. This is a minor criticism, however, of what is otherwise a delightful and instructive collection.

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The Unmaking of the Medieval Christian Cosmos, 1500-1760: From Solid Heavens to Boundless Aether

William G. L. Randles
Ashgate, Brookfield, Vt., 1999. 274 pp. $85.95 hc
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Copernicus published his radical, Sun-centered cosmology in 1543. It took decades for it to gain scientific acceptance. Modern commentators typically have a problem with this delayed adoption of the new celestial blueprint. Why did it take so long? Were those folks dense or blinded by entrenched tradition? Although most scientists recognize the scorn that generally accompanies the phrase, "But that would require new physics!" it is difficult to transport this same reluctance to the Aristotelian climate of the 16th and early 17th centuries.

Part of the new physics eventually ushered in with the Copernican Revolution concerned the nature of the cosmic material. In the 1970s, historians of science argued passionately about whether Copernicus believed in solid celestial spheres and whether this helped drive him to a heliocentric model. Extensive searches failed to find that the solidity of the celestial spheres, or lack thereof, was an active problem in the first half of the 16th century. The issue emerged quite strongly after Tycho Brahe proposed his geo-heliocentric cosmology, in which the orbit of Mars cut through the Sun's orbital circle, and this caused him to espouse a liquid, or fluid, model. Peter Barker has recently argued that evidence from optics, and in particular a challenge from Jean Pena about the cause of celestial refraction, stimulated Tycho's adoption of the fluid spheres.

In *The Unmaking . . .*, William Randles, former director of studies at the School of Higher Studies in the Social Sciences, in Paris, dissects the "new physics" of the celestial medium with great patience and attention. Beginning with three early Christian attempts to reconcile scriptural hints with Greek cosmology, he moves on through the Middle Ages to his area of concentration, the Renaissance. Here he incorporates the recent insights concerning Pena's role. Particularly with respect to astronomical refraction, the 16th-century French natural philosopher challenged the classical Aristotelian notion of spheres of air, fire, and aether, which clearly influenced Tycho's thinking.

At this point religious stances became important. Robert Bellarmine, the cardinal whose conservative view of scriptural interpretation played a major role in the Galileo affair and who had once taught astronomy at the Louvain, was sympathetic to fluid spheres. Christopher Clavius, the leading Jesuit astronomer and a major textbook author, stuck with solid spheres and was cool or indifferent to Tycho's cosmology. But after Galileo discovered the phases of Venus, showing that the planet was circumsolar, the Ptolemaic arrangement was no longer viable; the choice was then between the Copernican and Tychonic geo-heliocentric theories. The Jesuits opted for the Tychonic cosmology to accommodate both the phases of Venus and the scriptural passages that seemed to call for a fixed earth. For them the question of a fluid medium was still an essential element for the discussion.

The debate over the physical nature of the heavens sets the stage for the central concern of Randles's account: the role of Heaven within the heavens—here called the Empyrean, the ultimate home for the blessed. The medieval sacred geography fixed the Empyrean immediately outside the spinning, starry sphere.

How to place Heaven in the new cosmologies was a major hang-up for Catholic philosophers in particular, and Randles discusses at length the opinions reflected in university textbooks in Catholic countries, where the Jesuit viewpoint was particularly strong. The introduction of Descartes's universe of vortices and indefinite extension created a special crisis in finding a physical place for Heaven, but the Cartesian cosmology paved the way for the vast inertial space of *Newton's Principia*.

Astronomy in general, but not cosmology in particular, continued to flourish in the Catholic countries, as

John Heilbron's *The Sun in the Church* (Harvard, 1999) makes clear. Tycho's geo-heliocentric compromise, well supported by the Jesuits, was a dead end from the standpoint of physics, as both Kepler and Galileo perceived. The kind of progress in physics leading to Newton was thoroughly heliocentric and hence was seriously compromised if not killed in the geo-heliocentrically oriented Catholic countries.

Randles does a thorough job on the topic of his title, the unmaking of the medieval Christian cosmos, tracing the Catholic Church's final coming to terms with the new astronomy by dropping any claims to a specific sacred geography/cosmology. But this must not be confused with a discussion of the European adoption of the Copernican system. His account is much too narrow and blinkered for that. Galileo's rhetorical role and his search for Copernican arguments quite outside the nature of the spheres isn't considered here. There was a great deal more to the new physics than simply defining the nature of the space above us or finding a place for Heaven.

As a sourcebook on "from solid heavens to boundless aether," as the subtitle puts it, Randles's book is excellent, filled with extensive quotations and citations of relatively obscure 16th- and 17th-century authors. It offers a rich, new perspective on parts of the transition to the heliocentric cosmology. But as a comprehensive, synthetic account of that revolution, too much is lacking. It's great as vitamins, but where's the protein?

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Classical Electrodynamics

Julian Schwinger, Lester L. DeRaad, Jr, Kimball A. Milton and Wu-yang Tsai
Perseus Books, Reading, Mass., 1998. 569 pp. $60.00 hc
ISBN 0-7382-0056-5

As most physicists know, Julian Schwinger was a brilliant lecturer. His death in 1994, at the age of 76, raised the urgent question: How might his lectures be preserved and made available to a much wider audience? *Classical Electrodynamics* provides the answer, at least for his lectures on that subject. We must all be grateful to the authors Lester L. DeRaad, Kimball A. Milton, and Wu-yang Tsai.

Classical Electrodynamics is based on Schwinger's 1976 lectures at UCLA, which DeRaad, Milton, and Tsai attended as graduate students and postdoctoral fellows. By 1979, they had produced a manuscript of these lectures, aided by detailed notes supplied by Schwinger. Following later extensive revisions by Schwinger, the manuscript lay dormant for years. After Schwinger's death, the three junior authors revived their manuscript but excluded later material provided by Schwinger which, they claim, might have made the book less accessible to students.

The authors succeeded very well in preserving Schwinger's uniquely elegant style as well as his original and inimitable approach to the subject matter, both of which I well recall from my own attendance of Schwinger's electrodynamics lectures soon after my arrival as a new graduate student at Harvard in 1946. (Schwinger was on the Harvard faculty from 1945 until his departure for UCLA in 1966).

It is natural to compare this text to the very well-known and highly regarded graduate text, also called *Classical Electrodynamics*, by J. David Jackson (Wiley), whose third edition also appeared 1998. Jackson follows the conventional approach of starting with a thorough discussion of electrostatics; he presents Maxwell's equations and macroscopic electromagnetism almost one-third into the book. Schwinger's lectures start with Maxwell's equations, derived in the first chapter in a heuristic way. The treatment of electrostatics begins later, almost one-quarter into the book and after an introduction to special relativity. For Schwinger, the action principle plays a dominant role; it is introduced fairly early, and two chapters are devoted to it. Jackson mentions it only in passing.

Both books do a fine job on special functions, introducing them as they are needed, although Schwinger's lectures give a little more of their properties. This is consistent with his mathematically somewhat more sophisticated approach. Synchrotron radiation and wave guides are two topics to which Schwinger contributed a great deal, as is also reflected in the book.

The omission of Schwinger's later work is unfortunate in at least one respect: It prevents inclusion of Schwinger's 1983 paper solving the old 4/3 problem of electromagnetic energy–momentum in a very general way; this work is covered in Jackson's third edition.

In view of the large number of (short) chapters, DeRaad, Milton, and Tsai provide a guide to those chapters that they consider inessential and those (18 out of 52) that they suggest skipping on first study. There are plenty of exercises at the end of the chapters, chosen to supplement the material presented in the text. The units are Gaussian throughout, following Schwinger's usage.

Just one little gripe: A problem that has caused a great deal of confusion in the past, radiation from uniformly accelerated charges, is discussed and is given a fine and correct treatment. But that chapter confuses the reader by introducing the subject with an unphysical problem setting (nonrelativistic motion with constant acceleration over an infinite time interval), which, not surprisingly, has a physically nonsensical answer (no radiation emission at any frequency). The authors would have done better to omit that introduction.

This is an excellent textbook, full of interestingly presented material. One can learn a great deal from it, but it does require a little more sophistication than do other texts, both in the subject matter and in the powerful use of mathematics.

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General Relativity: A Geometric Approach

Malcolm Ludvigsen
Cambridge U. P., New York, 1999. 217 pp. $74.95 hc ($27.95 pb)
ISBN 0-521-63019-3 hc (0-521-63976-X pb)

Many physics and engineering students are genuinely curious about general relativity but are frightened away by its mathematical complexity. Malcolm Ludvigsen's *General Relativity* may help many students to overcome this problem, at least on the conceptual level. His textbook is written for final-year undergraduate mathematics or physics students; it may work for engineering students as well, if they are sufficiently motivated.

The main purpose of the book, as the author states it, "is to describe, in as simple a way as possible, our present assumptions about the nature of space, time, and spacetime." He reaches the goal almost perfectly. This short, elegant book describes the major ideas of special and general relativity with unprecedented clarity and mathematical depth (for its level). Reading it reminded me of the feel-