The Command of Light: Rowland's School of Physics and the Spectrum by George Kean Sweetnam

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Reviewed by
J. Brian Pitts
University of Notre Dame
jpitts@nd.edu

This book discusses the work of Henry A. Rowland (1848–1901), professor of physics at Johns Hopkins University, careful experimenter, and inventor of the concave diffraction grating, along with the work of Rowland's students and associates and their influence. This influence pertained to the invention of an important experimental apparatus, the institutionalization of American physics in the American Physical Society and elsewhere, the study of the solar spectrum, the improvement of this apparatus by eliminating misleading 'ghost' lines, the contribution of spectral data to atomic physics and quantum theory, and the establishment of the field of astrophysics involving stellar spectra and its institutionalization especially in observatories and the *Astrophysical Journal*.

Sweetnam's book is interesting, well written, and informative about its intended subject matter. It is the first to treat Rowland's work in such detail. The main body of the text, which was the dissertation of the late G. K. Sweetnam, is augmented by a preface by Charles Gillispie and a detailed introduction by dissertation supervisor M. Norton Wise. Sweetnam succumbed suicidally to depression in 1997, so the publication of his work as a book was effected by others. Keeping track of the cast of dozens of figures is facilitated by the useful index. While one notices occasional errors in proofreading and limitations in the typesetting of equations, comprehension is not adversely affected. Concerning biographical details for Rowland, Sweetnam evidently feels no need to duplicate the sketches that are available. Thus, one must learn from elsewhere important facts about Rowland's life such as that he married in 1890 and that his premature death was due to diabetes. Sweetnam aims to cover Rowland's life just as it was relevant to the founding of a research school

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devoted to the study of light, as Gillispie's preface observes. The author argues, persuasively to me, that Rowland formed a school devoted to the empirical study of light centered at Johns Hopkins University. The school displayed at least 12 of the 14 characteristics that Gerald Geison associates with research schools.

Whereas an older tradition in the history of science could be internalist to the point of neglecting the spatio-temporal embodiment of scientific theories and experiments, and some more recent scholarship has attended so heavily to external social and institutional factors as to slight the scientific theories and data, Sweetnam strikes an attractive balance between externalism and internalism. Perhaps the heavily experimental flavor of the work of Rowland and his associates lends itself to such a balance. Close contact with apparatus and data leaves little room for factors other than the scientific ideas to play a dominant role, much as the 17th-19th century advocates of inductivism intended. Sweetnam makes use of Rowland's and others' papers and correspondence as sources. The list of archival sources [217] indicates that considerable travel and labor must have been invested to consult all the sources used.

While some members of Sweetnam's cast are unfamiliar to much of the contemporary physics community, their connection to important institutions and figures now remembered, especially in connection with atomic and quantum physics and astrophysics, is shown quite effectively. Two early examples come from Rowland's own life. Rowland benefited from early recognition and publication assistance by James Clerk Maxwell. Before filling his duties as a new professor at the new Johns Hopkins University, Rowland was able to spend time in Helmholtz' laboratory in Germany. One theme of Rowland's work and that of his school was internationalism. It is not surprising that the physics community in a young and geographically isolated nation such as the United States of America in the late 19th century needed European connections to flourish. What is more noteworthy is that, in no small part due to Rowland and his school, American physicists, though not theoretically innovative at that time, made important contributions to physics through instrumentation and experimentation. Thus, the work of American physicists made necessary new theoretical ideas in atomic and quantum physics, though the generation of those ideas was typically left to Europeans. Rowland's concave diffraction gratings made their way around the country and around the scientific world. The gratings were important in the study of solar and stellar spectra. The latter fact connected Rowland's school with pioneers in American astrophysics, who founded astrophysical observatories to study stellar spectra rather than the positions of heavenly bodies.

Sweetnam's treatment of the relevant physics seems generally sure-footed. His willingness and ability to discuss scientific instrumentation and present a few formulas presumably are benefits of his undergraduate training and his work as a science journalist. He expects a tolerable acquaintance with classical electromagnetic theory, optics, and modern atomic physics from his reader for full comprehension. Given the importance of the diffraction grating to Sweetnam's story, perhaps a brief explanation of diffraction and diffraction gratings would be useful here. Diffraction is an optical phenomenon that, unlike reflection by mirrors or refraction by lenses, is completely dependent on the wave nature of light. Diffraction gratings can be made out of many substances, but their key feature is a set of closely spaced lines that are made by a ruling engine and that affect light differently from the material on which the lines are made. A diffraction grating poses spatially periodic obstacles to the propagation of light, so the resulting pattern of alternately constructive and destructive interference produces, respectively, bright and dark patches at regular distances. The nature of the interference depends on the wavelength of the light. Unlike the toy mathematical problems in elementary physics texts, realistic physical light sources produce light that corresponds to the sum of light of various wavelengths, intensities, and polarizations. The mathematical breakdown of a mathematical function of space and time into components with a given wavelength is a Fourier transform from physical space to wavelength space. Diffraction gratings perform something like a Fourier transform on physical light sources, because the mathematical relationship between the grating spacing and the light-component wavelength dictates where constructive or destructive interference occurs for a given wavelength. Studying the resulting diffraction patterns reveals various wavelengths of light at various intensities. If a single element can be isolated and used as a source, then one can ascertain the spectrum of that atom. Such spectra revealed much about the energy levels and thus the atomic structure of elements, information important in constructing modern atomic theory. Getting good results from a diffraction grating—results that readily display nature rather than the construction of the grating, one wants to say—requires extreme mechanical precision in the construction and operation of the ruling engine. Thus, certain ruling engines and their stewards play a key role in Sweetnam's story. Rowland was an early master at this work, as were a few others of his school later on. Sweetnam does not neglect the craftsmen on whom Rowland relied.

While Sweetnam's treatment of the scientific matters involving electromagnetism, optics, and atomic and quantum physics seems generally sound, his occasional brief forays into the special and general theories of relativity could use a bit more nuance. The claim that special relativity had 'ruled out' an electromagnetic ether [155], notwithstanding its retention in 1913 by Joseph Ames, is a remarkably strong claim that would have surprised the prominent H. A. Lorentz. Thus, Ames is faulted for theoretical conservatism, but perhaps not justly. A more usual and defensible view is that the ether had been stripped of most or all of the mechanical properties that made positing it seem worthwhile. Even this view itself might represent a later consensus available only once most grew accustomed to the idea that electromagnetic oscillations need not be the oscillations of any mechanical thing, a claim that is more readily accepted nowadays due to early and authoritative instruction of the young. Concerning general relativity, several interesting early (and in some cases now rejected) experiments touching the general theory of relativity are discussed. One wishes, however, that Sweetnam had been more explicit about which theories were in competition and on what grounds, in discussing the gravitational red shift in the 1910s [192]. Newtonian gravity was empirically adequate (apart from worries about Mercury's perihelion precession) but imperiled theoretically by its instantaneous action at a distance, in contrast with electromagnetic retarded action by an intervening field or medium. Perhaps Newtonian gravity's most natural successor was Gunnar Nordström's scalar theory of gravity, which generalized Newton's theory to a relativistic local field theory. Nordström's theory was conceptually acceptable, but it did even less well than Newton's theory regarding the anomalous precession of Mercury's perihelion (though unseen matter could be invoked, not so unlike the dark matter and dark energy posited today for analogous difficulties). While observation of a gravitational red shift would confirm general relativity against Newtonian gravity, it would give no advantage over the more serious competition in Nordström's theory. By contrast, gravitational light bending was predicted by Einstein's general relativity but not by Nordström's theory. Details about the confirmation of gravitational theories, though discussed imperfectly by Sweetnam, are admittedly peripheral to his project. They are worth mentioning because the issues are intrinsically interesting and not too widely understood.

As Wise's introduction and Sweetnam's opening chapter mention, Rowland came from a line of Presbyterian ministers. This ancestry left its mark on his scientific work. Rowland's interest in science was preceded by his father's amateur scientific interest. Rowland the physicist found science to be a morally improving enterprise of diligent and disinterested search for truth by empirical investigation of the creation; this enterprise of pure science was distinguished from applications for the purpose of profit. Sweetnam observes, with little elaboration, that for Rowland the physicist there was no conflict between science and religion. While contemporary historians of science and religion such as David Lindberg, Ronald Numbers, John Hedley Brooke, David Livingstone and others have adequately refuted the Draper-White warfare thesis (that conflict between science and Christian theology has been the generic form of interaction) as a piece of polemical fiction, its lingering in the news media makes continued critique useful.

That said, Sweetnam's remarks are somewhat superficial in failing to sketch what form Rowland's reconciliation of science and theology actually took. Probably, most intelligent and unbiased observers have thought that the Christian Scriptures, in addition to asserting core theological claims (the Triune nature of God, the Incarnation of God the Son as Jesus of Nazareth, and the atonement for human sin in the crucifixion of Jesus, his subsequent resurrection from the dead, and the like), also make some truth claims (whatever their detailed form) about the real history of the world's creation, the fall into sin, the judgment in Noah's flood, the election of Israel, the rescue of the Jews from Egypt, and so forth. It is not just obvious why it is a reasonable procedure to reject or significantly pare down the latter set of claims, while embracing the former at full strength, as Rowland (one is left to suppose) did. Perhaps Sweetnam, like so many, has conflated the acts of interpreting a text and believing it. If the credibility of the testifier is impugned on earthly matters, is the testifier still trustworthy on heavenly matters (as Jesus wonders in John 3:12)? It seems more consistent either to reject both or to accept both. If it is inadequate merely to announce that an apparent conflict is unreal, then it is disappointing that Sweetnam did not inquire into Rowland's resolution.

The meager light that Sweetnam sheds on Rowland's views on science and theology is perhaps enhanced a bit by the revelation that the Rev. Henry A. Rowland (presumably the father of our physicist), who was ordained to the ministry *ca* 1830 and deceased *ca* 1860, sided with the New School (the more liberal side) in the 1830s in response to a Presbyterian church split.[1] Sweetnam occasionally quotes the minister-grandfather of Rowland the physicist and suggests parallels between the works of the two men, but the parallels sometimes seem largely metaphorical and the quotations largely decorative. Further elaboration could bring clarity here.

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[1] So I am informed by Rev. Dr. Peter J. Wallace, historian of 19th-century Presbyterianism, who discovered this in undertaking his research for Wallace 2004.