view, much that is wrong in policy and posture, and more emphasis on them is not likely to be helpful.

But these are small quibbles about a book that is filled with trenchant criticism of our dependence on nuclear arms and contains in its postscript a biting assessment of arms control efforts as well.

GEORGE RATHJENS
Massachusetts Institute of Technology

Popular Lectures on Mathematical Logic

W. Hao
273 pp. Van Nostrand, New York, 1981. $24.95

This book, a published version of lectures given at the Chinese Academy of Science in 1977, is intended for any reader who wants to know what comprises some of the most interesting and fruitful parts of mathematical logic. Written by an eminent logician (the author of two well-known books, *Logic, Computers and Sets* and *From Mathematics to Philosophy)*, the book is at once testimony to the enormity of the author's contributions to the field and an excellent survey of important topics in modern mathematical logic.

After an initial history of the subject from about 1980, the book deals with formal systems, the role of computers, open mathematical and logical problems, first-order logic, computability and set theory. Obviously there is no attempt to cover all of mathematical logic. Instead Wang Hao treats us to those portions with which he is thoroughly familiar: ∀∃∀ formulas of predicate logic, formalization of predicative set theory, finite axiomatizability, automatic theorem proving, search for new axioms in set theory, formulation of Turing machine theory in terms of computerlike models, decidability and tiling problems.

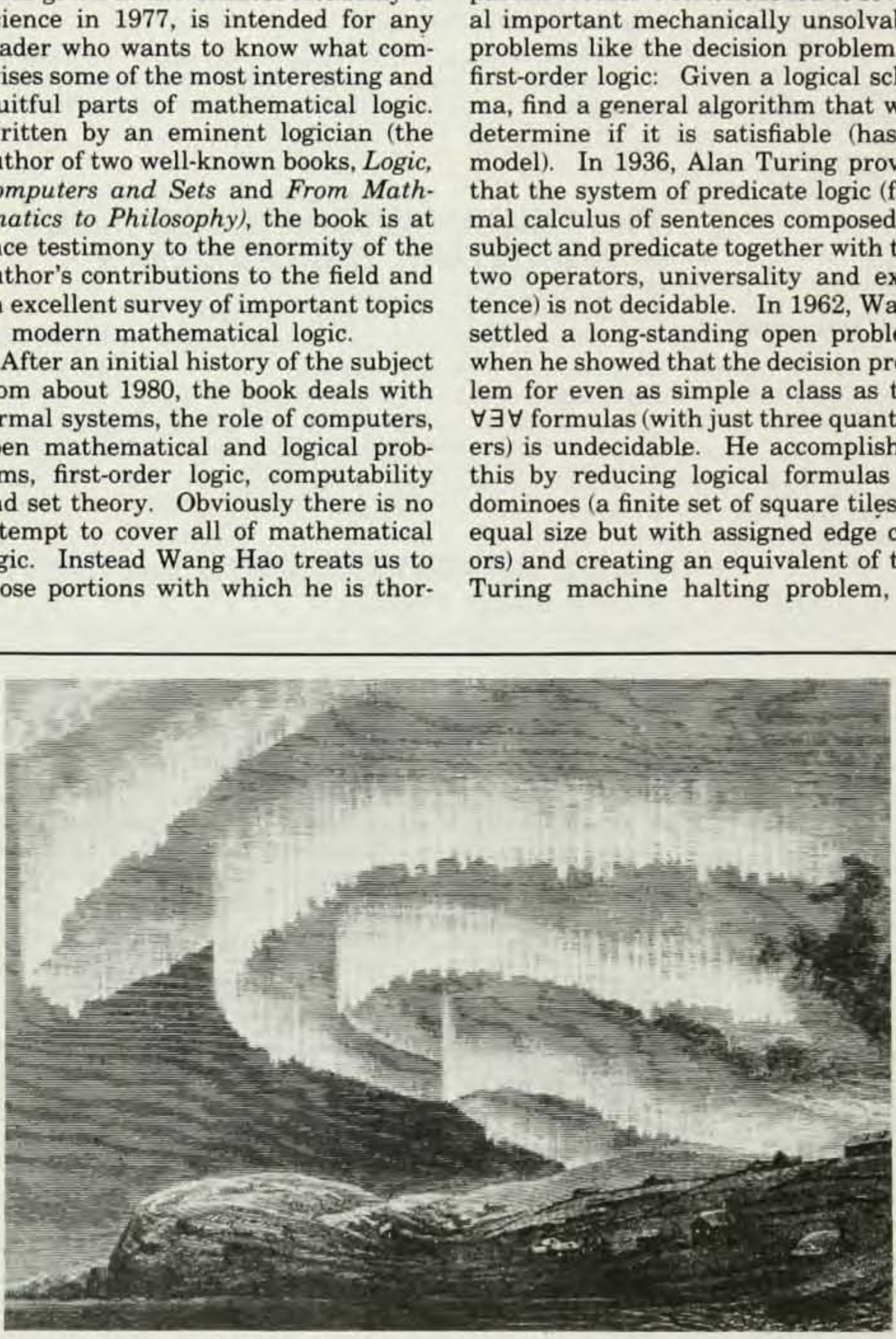
Most of the chapters begin with early results and end with open problems. Only proofs of very important theorems are presented. One finds excellent coverage of Cantor's and Godel's work, lucid accounts of constructability and forcing, and extensive material on computers and computability.

Wang discusses one of the great achievements of mathematical logic in this century, the development of methods to prove that certain classes of problems are not solvable. The idea of partial recursive functions led to several important mechanically unsolvable problems like the decision problem of first-order logic: Given a logical schema, find a general algorithm that will determine if it is satisfiable (has a model). In 1936, Alan Turing proved that the system of predicate logic (formal calculus of sentences composed of subject and predicate together with the two operators, universality and existence) is not decidable. In 1962, Wang settled a long-standing open problem when he showed that the decision problem for even as simple a class as the ∀∃∀ formulas (with just three quantifiers) is undecidable. He accomplished this by reducing logical formulas to dominoes (a finite set of square tiles of equal size but with assigned edge colors) and creating an equivalent of the Turing machine halting problem, to decide for any Turing machine (abstract computing device) whether it will eventually halt when the initial tape is blank. The solution to this problem produces the solution to decision problems for all quantifier classes. This is important because the complexity of a logical formula is directly related to the number and order of its quantifiers, and a measure of the complexity of a mathematical problem is given by the structure of its equivalent logical formulas.

The three appendices "Dominoes and the Infinity Lemma," "Algorithms and Machines" and "Abstract Machines" represent areas where the author has made singular contributions. Each provides an excellent introduction to the subject. One of the most interesting features is the set of footnotes, rich in historical and anecdotal detail. In part this compensates for the lack of a comprehensive bibliography. As for the index, it is painfully poor.

What Wang has accomplished in this book is a clear account of the interrelationships between widely different topics and their relative importance, all of this with an historical perspective in mind. In eschewing comprehensiveness, he has given instead a humanist's approach to mathematical logic.

FRANCINE ABELES
Kean College



Rendering of an aurora seen from Bossekop, Norway, 1839, from *Majestic Lights: The Aurora in Science, History, and the Arts*, by R. H. Eather. 323 pp. American Geophysical Union, Washington, D. C., 1980. Courtesy Widener Library, Harvard University.

Cosmic X-Ray Astronomy

D. J. Adams
145 pp. Hilger, Bristol, 1980 (US dist: Heyden, Philadelphia). $29.50

From the first detection of an extrasolar source in 1962 to the launch of the Einstein Observatory in 1978, the purview of x-ray astronomy has expanded from a few bright binary stars harboring accreting collapsed companions to virtually every type of astrophysical system known, from nearby normal stars to the most distant galaxy clusters and quasars. As of this writing, however, the field is at a critical point. With the demise of the Einstein satellite in April of this year, there is no operating x-ray observatory in orbit. The next opportunity for x-ray observations of any sort are from a small European satellite scheduled for launch in eighteen months; the next US x-ray facility is more than five years away.

Such a forced hiatus is rare in any field of inquiry, but it provides an ideal opportunity for compiling histories and summarizing progress to date. Unfortunately, D. J. Adams has done neither in this monograph. Working at the University of Leicester in the early 1970s, Adams developed payloads for sounding rockets and the British x-ray satellite Ariel V, but for the last five

years has devoted himself to infrared instrumentation. As a result (one assumes), many of his references are from before 1976, rendering the book half a decade out of date in a field barely thrice that old. Although it bears a 1980 copyright, for example, the book excludes all of the major advances achieved with the Einstein telescope; the only mention of the Observatory is a useless and repetitive "prediction" that significant new results will be forthcoming.

Who the book's intended audience is, is obscure. Adams spends time explaining concepts like luminosity and flux but assumes complete familiarity with the eccentric nomenclature of stellar spectral classification. One of the six chapters is devoted exclusively to a development of the basic equations for various astrophysically important radiation processes, but the following discussion of individual x-ray sources and source classes is rather vague and qualitative. The cover flap suggests the book is for undergraduate students and amateur astronomers; I found the style (turgid), level of detail (uneven), and approach unsuitable for either group, although the book might conceivably be useful as a secondary reference for an advanced undergraduate course in observational astrophysics.

DAVID HELFAND
Columbia University


THE BETTMANN ARCHIVE, INC.

Gay-Lussac, Scientist and Bourgeois

M. Crosland
333 pp. Cambridge U. P., New York, 1979. $36.00

In this new biography, Maurice Crosland rescues the discoverer of Gay-Lussac's law and the inventor of the Gay-Lussac tower from obscure eponymity. Joseph-Louis Gay-Lussac (1778–1850) is revealed to be an industrious and skilled but cautious investigator, whose research ideal was to uncover the quantitative relationships governing physico-chemical phenomena and whose mature interests turned increasingly toward applied science.

Crosland also locates him in his time and place—the first half of the nineteenth century in France—when science could be made the basis of a new kind of middle-class professional career. In this regard Gay-Lussac was certainly a successful prototype. He achieved scientific renown and a highly rewarded career. He attained key positions in the French scientific establishment: membership in the First Class of the Institute (1806); a professorship in the Paris Faculty of Sciences (1809); and a chair at the *Ecole Polytechnique* (1810). Crosland shows how Gay-Lussac acquired and exploited these positions in building his career and demonstrates effectively how the various stages in the construction of the career influenced Gay-Lussac's scientific interests.

The educational reforms of the Revolution made possible the training necessary for such a life in science. Young Joseph-Louis, son of a provincial lawyer whose circumstances had been much reduced by the political cataclysm, came to Paris in 1795 to complete his schooling and prepare for a profession. Probably he intended to follow his father into the law. Away from parental supervision he was seduced by mathematics and entered the recently founded *Ecole Polytechnique* in 1797. The original aim of this famous school, which has played a large role in the training of the French bureaucratic elite, was to provide a general scientific education preparatory to entry into one of the "applied" schools such as the Artillery School, the School of Mines and the School of Bridges and Highways. The curriculum was dominated by mathematics, mechanics, chemistry and engineering drawing. Although Gay-Lussac seemed destined for a career in civil engineering and was in fact enrolled at the School of Bridges and Highways for about a year, he had been spotted in his last year at the *Polytechnique* by the great French chemist Claude-Louis Berthollet, who admitted the young *polytechnicien* to his household and laboratories and guided his transition from science student to scientific researcher. The main site of this transformation was Berthollet's country house at Arcueil on the outskirts of Paris. At Arcueil, too, France's greatest mathematical astronomer and physicist, Laplace, had his suburban retreat. Here the two pre-eminent scientific figures of Napoleonic France gathered around them a coterie of young scientists whose research they fostered in their laboratories and whose careers they sponsored in the halls of the Parisian scientific establishment. The group, called the Society of Arcueil (the subject of a previous book by Crosland), was actually a private research school that provided the facilities and support that we now associate with graduate training. The importance of Gay-Lussac's association with the Arcueil circle can be seen both in his research productivity and in his success in reaching key positions.

The influence of Arcueil also reached down into the content and style of Gay-Lussac's science. Not surprisingly, given the interests of the leading luminaries, the boundaries between physics and chemistry at Arcueil were indistinct. It is noteworthy that Gay-Lussac's research in this period included work on the thermal expansion of gases (he was the first to publish the relationship now known as Charles's law), on the earth's magnetic field, and on capillary attraction, as well as on more conventional chemical topics.

For the patronage of Arcueil, however, Gay-Lussac paid with a loss of scientific independence and originality. He was never able to claim full significance for or to exploit the law of combining volumes in terms of the new chemical atomism propounded by Dalton, since his mentor Berthollet was a resolute opponent of the law of fixed proportions, which was the basis of Daltonian atomism. Likewise the conclusions drawn from his excellent work with Thenard on the gas that Humphrey Davy named chlorine were hedged in by Berthollet's continuing loyalty to Lavoisier's oxygen theory of acids.

As Gay-Lussac emerged in the teens and twenties as an authority in his own right, the influence of Arcueil receded (although the loyalty never diminished), and his work became more exclusively chemical. He also became a scientific expert, writing official memoirs and instructions to advise the government and industry on technical matters. He was appointed Assay Master at the Paris Mint in 1829, a post which virtually doubled his income. In the 1830s and 40s came his lucrative association with the Saint-Gobain chemical works, to which he sold the patent on the Gay-Lussac tower for a considerable sum of money. Gay-Lussac's scientific career thus became linked to the nascent industrial world of the nineteenth century. When he entered politics in the 30s as a member of the Chamber of Deputies, he was a spokesman for business interests. His outspoken views on the evils of government regulation of industry would