



Crafting the quantum: Arnold Sommerfeld and the older quantum theory

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ABSTRACT

Arnold Sommerfeld (1868–1951) was among the most important students of the so-called ‘older’ quantum theory. His many contributions included papers in 1915 and 1916 extending Niels Bohr’s ‘planetary’ model of the atom beyond circular orbits and his incorporation of relativistic corrections in order to explain hydrogenic fine structure. Originally a realist in his use of Bohr’s model, Sommerfeld became increasingly disillusioned with model-building in general in the late nineteen-teens and early nineteen-twenties. This paper explores Sommerfeld’s use of the term *Zahlenmysterium* (number mystery) as a self-description of his physical methodology. Rather than reading talk of mysticism as mere pandering to irrationalist forces in Weimar Germany, as some have suggested, I argue that one should see it as a genuine description of the scientific method Sommerfeld increasingly advocated throughout this period. That is, Sommerfeld drew upon and modified talk of *Mystik* as a means of expressing his own ideas on the importance of aesthetics in what might otherwise be cast as mere guesswork in his phenomenological spectroscopy. Mysticism, properly defined, was an integral part of what Sommerfeld termed *die Technik der Quanten* (‘the craft of the quantum’).

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Ich kann nur die Technik der Quanten fördern, Sie müssen ihre Philosophie machen. (Sommerfeld to Einstein, 1922)¹

Kepler should have experienced today’s quantum theory. He would have seen the boldest dreams of his youth realised, not, admittedly, in the macrocosm of the stars, but in the microcosm of the atom. The shell structure of the atom is even more wonderful than the cosmography longed for by Kepler. (Sommerfeld, in 1925, p. 574)²

1. Introduction: *Technik* and *Atom-mystik*

In early 1922, the Munich professor of theoretical physics, Arnold Sommerfeld, wrote to Albert Einstein, reporting on the many successes of what was, even at that time, known as ‘the Sommerfeld school’. Sommerfeld was justifiably proud of himself and bragged

of the results achieved by a young man in only his third semester of study, Werner Heisenberg, who had just completed pioneering work in providing a model for the anomalous Zeeman effect. In spite of this, however, the situation was not ideal: ‘Everything works, but remains at the deepest level unclear’. That, however, was not Sommerfeld’s problem. Laying out the division of labour for the new physics, he wrote the words above: ‘I can only advance the craft of the quantum, you have to make its philosophy’. What it meant to craft the quantum is one of the questions considered below.

Before proceeding to an answer, however, a brief discussion of terminology is in order. *Technik* in contemporary German is commonly accorded one of three different English equivalents: ‘technique’, ‘technology’, or ‘engineering’. The phrase above has uniformly been translated as expressing Sommerfeld’s preference for ‘the techniques of the quantum’.³ Yet ‘technique’ in English has a connotation not necessarily intended in German, for it describes only ‘the mechanical or formal part of an art’; that part ‘distinct from

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¹ Sommerfeld to Einstein, 11 January 1922, document 50 in Eckert & Märker (2000–2004), Vol. 2, pp. 110–111.

² Sommerfeld (1968d [1925]); my translation.

³ See for example Cassidy (1992), p. 116; Nisio (1973), p. 77. That said, at least two scholars have identified Sommerfeld as either the ‘engineer’ (Serwer, 1977, p. 193) or the ‘technologist’ (Cassidy, 1992, p. 129) of the quantum.

general effect, expression, sentiment, etc.⁴ As a late nineteenth-century text on music phrased it: 'A player may be perfect in technique, and yet have neither soul nor intelligence'.⁵ Given Sommerfeld's defence of *Technik* against those who charged it with possessing 'a smaller degree of scientific rigour' than their own disciplines and the importance of technical applications in his own work, however, one would hardly expect him to share this sentiment.⁶ More generally, however, the formalistic implications of the word in English are less prevalent in the German. Grimm's nineteenth-century *Wörterbuch*, for example, offers the following definition: 'the artistic or craft activity and the sum of experiences, rules, principles, and know-how according to which, through practice, an art or craft is pursued'. Central to this understanding, as Norton Wise has argued in analysing Hermann von Helmholtz's use of the term, was a sense of the importance of an aesthetic sensibility for the *Techniker*.⁷

Aesthetics was essential for Sommerfeld's work on the quantum theory of spectral lines. The same man who would speak of an anti-philosophical, 'nuts and bolts' approach to the quantum would also, in the same period, wax lyrical about the harmonious 'number mysteries' that a study of spectral lines allowed one to glimpse.⁸ The preface to the first edition of the text that would become known as the 'Bible' of quantum spectroscopy, *Atombau und Spektrallinien* (*Atomic structure and spectral lines*), would, one suspects, make any hard-headed technician blush:

What we are nowadays hearing of the language of spectra is a true 'music of the spheres' within the atom, chords of integral relationships, an order and harmony that becomes ever more perfect in spite of the manifold variety. The theory of spectral lines will bear the name of Bohr for all time. But yet another name will be permanently associated with it, that of Planck. All integral laws of spectral lines and of atomic theory spring originally from the quantum theory. It is the mysterious organon on which nature plays her music of the spectra, and according to the rhythm of which she regulates the structure of the atoms and nuclei.⁹

On the other hand, Sommerfeld reacted with palpable fury when the *Sddeutsche Monatshefte* contacted him—one suspects after reading utterances like the one above—to write an article on astrology. 'Doesn't it strike one as a monstrous anachronism', he raged, 'that in the twentieth century a respected periodical sees itself compelled to solicit a discussion about astrology? That wide circles of the educated or half-educated public are attracted more by astrology than by astronomy? That in Munich probably more people get their living from astrology than are active in astronomy?' In spite of having 'no illusions' about his ability to hold back

the growing tide of irrationalism that threatened to wash away the remnants of a reasoning European culture, Sommerfeld pledged to 'throw myself decisively against it'.¹⁰

Yet it was not only the editors of newspapers, nor the 'half-educated public' that perceived Sommerfeld as espousing an irrational, or at least a rational approach to the physical world. His colleague, the professor of experimental physics at Munich, Wilhelm Wien, snidely (if wittily) referred to Sommerfeld's work not as *Atomistik*, but *Atom-Mystik*, a phraseology that Wien's students apparently adopted as well.¹¹ This private—or at least intra-faculty—jibe became public when Wien delivered a Rectoral address at Munich in 1926, on the 'Past, present and future of physics'. Among the lecture's main topics was the modern atomic theory, and the developments that followed the introduction of the Bohr model. It did not mention Sommerfeld—almost certainly in the audience at the time—by name, a reproach (even an insult) in itself.¹² Even more telling, Wien closed with a discussion of the hope offered by Schrödinger's new wave theory of removing talk of mysticism from quantum theoretical research:

Now Schrödinger is trying to ascribe the whole numbers of the quantum theory to similar characteristic vibrations [*Eigenschwingungen*], the actual physical meaning of which admittedly still remains dark. If that were really to succeed, then the special role which whole numbers play in the quantum theory would also here be eliminated, also here number-mysticism would be supplanted by the cool logic of physical thought; probably not to the joy of everyone. Because mysticism exercises a greater attraction on many minds than the cold and clinical mode of thought of physical contemplation. I am far from wanting to attack mysticism as such. There are many areas of spiritual life from which mysticism cannot be shut out, but it does not belong in physics. A physics in which mysticism rules or only participates leaves the ground from which it draws its strength and ceases to deserve the name.¹³

If Wien took the talk of mysticism in Sommerfeld's work at face value, and perceived in it a disturbing and widespread tendency towards the denial of the 'cool logic of physical thought', Max Born took a more cynical (if thereby more supportive) position. On the occasion of Sommerfeld's sixtieth birthday, Born suggested that:

He occasionally speaks with gentle coquetry of number-mysticism in spectral laws; but he means by that nothing philosophically dark, but only the statement that so far one has still not come directly behind these laws. The word should be once again a lure for spurring on young brains to restless research; because he who is in Sommerfeld's school, for him is mysticism only there to be vanquished.¹⁴

⁴ Oxford English dictionary (2008), 'technique'.

⁵ Ibid., '1884 GROVE Dict. Mus. IV. 66'.

⁶ Sommerfeld (1903); Seth (Forthcoming).

⁷ Wise (Forthcoming). I am indebted to Norton Wise for drawing my attention to this point and for the chance to read a chapter of his forthcoming monograph.

⁸ Sommerfeld (1920c). For another attempt to reconcile Sommerfeld's 'pragmatism' with this talk of mysticism, see Benz & Sommerfeld (1975), pp. 120–123.

⁹ Sommerfeld (1923), p. viii. This first English edition is a translation of Sommerfeld (1922), *Atombau und Spektrallinien* (3rd ed.). Where the German is identical between the third German edition and earlier editions, I have used Brose's translation.

¹⁰ Sommerfeld (1968i [1927]); translation above taken from Forman (1971), p. 13. Sommerfeld distanced himself from the implications of his own previous evocations of a Keplerian 'music of the spheres' by noting that 'around 1600 the attitude to religious and world-view questions must have been necessarily very different to the attitude around 1900 and that the mature Kepler in his own researches himself overhauled his youthful ideas, the *Mysterium cosmographicum*' (Sommerfeld, 1968i [1927], p. 580).

¹¹ Werner Heisenberg discussed the antagonism between Wien and Sommerfeld's institutes in Kuhn (1963), p. 16.

¹² The response to this aspect of Wien's talk was not positive. As Heisenberg phrased it: 'I do remember that Willy Wien gave, when he was rector of the University, a speech about atomic physics and never mentioned the name of Sommerfeld. Everyone felt that this is a thing that one can't do because Sommerfeld after all was a very famous and certainly very good physicist. So there was lots of trouble between the two ...' (Kuhn, 1962, p. 10).

¹³ Wien (1926), p. 15.

¹⁴ Born (1963[1928]). Born may have had in mind something like the specific situation he would later describe involving Fritz London, who arrived at Göttingen in the late 1920s. 'He wanted to work on philosophy for his thesis—the philosophy of the new quantum mechanics. And I said, "No, my fellow. You must do real work—calculations. Work out a special problem. Before that I wouldn't give you any such question, even if I knew one." And he was quite intolerable and insisted on having such a fundamental problem—the other didn't interest him. I tried to persuade him and Franck tried and although he seemed like a nice kind of fellow, we couldn't do anything with him. And since I knew no way, I wrote to Sommerfeld to see whether he would like to take him, for I knew that Sommerfeld had much more interest in young people than I had. And so I sent him to Sommerfeld, and Sommerfeld put him right. He persuaded him by the force of his personality to do a very simple and straightforward calculation. I don't know what it was, but he got his thesis and he never became a philosopher again' (Kuhn & Hund, 1962, p. 27). Cf. Sigurdsson (1991), pp. 217–218.

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