CHAPTER 4.2

Manchester at war: Bohr and Rutherford on problems of science, war and international communication

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Abstract

In October 1914 Bohr arrived for a second long stay in England, this time as a reader in Rutherford's physics department at Manchester University. While Bohr continued with his research on the atom, Rutherford, like his British colleagues, had to virtually stop his experimental research on the subject. Instead he dedicated his time for searching means to detect submarines. With former (British) students he carried out classified research in a water tank in the basement of the physics building. Bohr, a neutral citizen, could hardly miss the war research, but did not participate. In agreement with the Danish national position, he, rather, formed a bridge between British and German scientists and made an effort to keep the fragile connections between the belligerents, despite practical and psychological obstacles. Scientists on both sides, like Sommerfeld and more actively Rutherford, seemed to back Bohr's effort of maintaining international research in physics. At the same time, Rutherford presented ambivalence towards the war research. On the one hand he regret-

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ted that British scientists could not devote their "attention to the pure science problems." On the other he acknowledged the potential contribution of scientists to the war effort, and helped in their mobilization.

Key words: Niels Bohr; Ernest Rutherford; scientists and war; scientific relationships; World War One; War research; internationalism in science.

1. Introduction

In October 1914 Niels Bohr arrived to Manchester to take a temporary readership in mathematical physics. This was his second long stay in the city and the university. In 1912 he spent a few important months as a post-doc in Ernest Rutherford's laboratory. Now he came as a successful young theorist. His atom model, published in the previous year, had already been a success, even if its fame would grow in the following years. Some physicists had already realized the potential fruitfulness of Bohr's daring hypothesis, and others were impressed by its empirical adequacy. Of course, the theory suffered from quite a few problems. A major question was its theoretical or conceptual foundations. Bohr, himself, was less worried about this issue, but shared the concern regarding the applicability of his hypothesis to a wider range of atomic phenomena, both for finer experiments regarding one-electron-atoms and for multi-electron atoms. For him the 1913 trilogy on the constitution of atoms was the basis for further developments, rather than an established theory, and he was enthusiastic to continue working on atomic structure.[1] Manchester, arguably the world's most important centre for experimental research on the atom, seemed an excellent place to pursue the subject. Bohr's 1912 stay in Rutherford's physics department had been highly stimulating, and helpful for the developments of his ideas regarding the atom. Thus, In June 1914, Bohr seized Rutherford's invitation for a temporary readership in the latter's department,[2] expecting to enjoy the vibrant Mancunian research in atomic physics.

1. Kragh (2012).
2. Bohr (1981), pp. 594-595.

Bohr also had practical reasons for accepting Rutherford's invitation. From the beginning of 1913 he had tried to convince the authorities to establish a chair for theoretical physics in Copenhagen University for himself. As often happens, despite support from influential people, the realization of the position took more time than Bohr initially hoped. In the meantime he taught medical students. Manchester thus also offered a release from the annoyance of lecturing to the Danish medical students.[3] Bohr planned to stay for a year and then return to the new post. As it turned out, it took two years before he could begin his tenure as professor of theoretical physics in Copenhagen.

While normal bureaucratic and budget considerations slowed down developments in Copenhagen, World War One interfered with the fulfilment of Bohr's expectations in Manchester. The effect of the War was not felt all at once. Yet, research that was not directly connected to the war efforts came to a halt in stages. In winter 1916, Evan Jenkin Evans was the only one in Manchester, except Bohr himself, who carried out research on atomic physics. Apparently, however, the lack of active atomic research around him did not hinder Bohr's productivity. He continued with his investigation of atomic structure, which led to a considerable number of significant contributions. His publications from his Manchester period include an elaboration of his earlier ideas on atomic constitution, with a discussion of novel experimental results of Moseley, Stark and Franck and Hertz; corrections to the Balmer spectral formula due to relativity effects; a reply to a criticism by Nicholson; discussion of the absorption of α and β rays; and finally a refinement of quantum theoretical methods.[4]

Bohr's position was that of a temporary reader. Thus, unlike most 'quasi-free post docs' (to use Alexei Kojevnikov's term), who would stay later at his future institute, Bohr had to teach. Teaching took a considerable part of his time during the terms, as he had to prepare new courses in a foreign language. He taught thermody-

3. On Bohr's dislike of teaching the medical student see e.g. Bohr to Hansen, 12 May 1915, in Bohr (1981), p. 517.

4. Pais (1991), p. 184.

namics, electrodynamics, electron theory and the kinetic theory of gases.[5] Since many young men, including lecturers, left for the War, teaching was left to Evans, Walter Makower, Rutherford and Bohr. In 1916, after Makower had been recruited for military service and Rutherford had become preoccupied with war research, Evans and Bohr divided the teaching between them.[6] Britain had not introduced conscription until March 1916. Yet, considering the high recruitment among university students in the early stages of the war, Evans and Bohr probably did not have many students.

2. Bohr's journey to Manchester

Bohr was due to arrive in Manchester on September 1st in time for the autumn term. The outbreak of the war, however, delayed his arrival in a month. In the summer before going to England, Niels and his younger brother Harald went for a vacation in Switzerland. They used the opportunity to attend scientific meetings in two important centres of German physics: Munich and Göttingen. Niels did not have an earlier direct contact with German physicists. Harald, on the other hand, a well-esteemed mathematician in his own right, had already stayed in Göttingen in 1912, and could connect Niels to prominent colleagues there, including Born and Debye. Niels and Harald arrived without prior invitation, yet the physicists in Göttingen, who had already learnt about Bohr's atom, asked Niels to give a talk on the subject, almost on the spot. Bohr based his talk on the one that he had given at the Danish Academy of Sciences and Letters in the previous December. He used the same talk in Munich, where he met, among others, Ewald, Sommerfeld and Wien. As Bohr himself later observed, in these talks he provided a first-hand exposition of his atomic theory, on which his audience had not worked before. While this surely helped spread Bohr's ideas, the meetings were also important for establishing connec-

5. Pais (1991), p. 166.

6. Bohr (1961), pp. 1096–1097, Bohr's memory was inexact regarding Rutherford's teaching, his contemporary letters shows that the Professor did teach at the first half of 1915, e.g. Niels Bohr to Harald Bohr, 15 April 1915, Bohr (1972), p. 577.

tions with German scientists. Thereby they helped him maintain relationships with German scientists during the war. The outbreak of the war found Niels and Harald in Germany, but they managed to catch the last regular ferry back to Copenhagen.[7]

After a few weeks of doubts, Niels and his wife Margrethe took the sea voyage to England. Due to the war, they took a detour around Scotland. Yet at that time the war was felt in Manchester only indirectly, most strongly through the absence of many young men. A few weeks after their arrival, Niels was cheerful and optimistic in his letter to Harald: "Even if less goes on here than formerly, it is great for me to be here. I go around and talk with everybody about their work, and I am looking forward to getting into a lot of things."[8]

Yet obstacles to normal scientific research did appear. The lack of personnel was the gravest and most obvious problem. The laboratory did not only miss most of its experimenters who served either in the army or worked for the military, but also its German glass blower, who was interned by the British authorities. Without a skilful glass blower, Bohr had to abandon his endeavour into experimental physics. Following his discussion with Makower, who also hosted the Bohrs during their first weeks in the city, the two collaborated in an experiment on the excitation of mercury atoms by electrons, to elucidate some of the results of Franck and Hertz. But they had to stop after their apparatus was broken by an accident.[9]

Another obstacle was the isolation from current German literature. Bohr stopped receiving issues of *Annalen der Physik* in December 1914. Nor did other German publications arrive in Manchester. Apparently the Germans experienced similar difficulties in receiving British journals and papers. While sending to neutral countries was not problematic in the first part of the war, restrictions became graver from early 1916; private individuals were no longer allowed to

7. Interview with Niels Bohr by Thomas S. Kuhn, Leon Rosenfeld, Aage Petersen, and Erik Rüdinger, 14. 11. 1962 (session 4), Transcript at <http://www.aip.org/history/ohilist/4517_4.html> (accessed 6.5.13); Pais (1991), pp. 164–165; Bohr (1981), p. 331, and letter to Oseen, 28 September 1914, Bohr (1981), p. 561.

8. Niels to Harald Bohr, 1 November 1914, Bohr (1972), pp. 569-571.

9. Bohr (1961), pp. 1096-1097.

send printed material also to neutral countries. For example, issues of scientific journals that Rutherford sent to Bohr in late 1916 were returned to the sender. Sending pamphlets and manuscripts also became very difficult.[10]

3. Bohr's role as mediator

Against these obstacles Bohr tried to maintain international scientific exchange and communication. His brother and mother in neutral Denmark served as a post station between belligerent countries. With their assistance Niels received and sent scientific papers and letters between the Central Powers and Britain. For example, he asked Harald for the issues of *Annalen der Physik* that he had not received and for a few other publications concerning the atom. Some of these publications were especially important for Niels's work. Following the reception of Debye's and Sommerfeld's papers on hydrogen molecules and spectra (see Michael Eckert's contribution to this volume), in autumn 1915, Bohr delayed and eventually withdrew the publication of his own paper on the topic. Atomic physics was clearly an international enterprise; since Bohr's own ideas were elaborated by his colleagues in Germany, he could not ignore their contributions. Harald further transmitted and translated into German letters between Niels Bohr and Sommerfeld. He also forwarded published papers, including some written by other British scientists, to Sommerfeld and the Austrian chemist Paneth. Interestingly, the Bohrs managed to forward British papers to scientists of the Central Powers also during the first half of 1916 despite the British restrictions.[11] Bohr extended the communication network also to his British colleagues, whom he informed about the results and ideas of their colleagues in belligerent states. Regarding his own research, it is unsurprising that Rutherford showed particular interest in the

10. E.g. Bohr to Fokker, 14 February 1916, Bohr (1981), p. 499, and Rutherford to Bohr, 13 December 1916, Bohr (1981), pp. 596-597.

11. E.g. Niels to Harald Bohr, 29 July 1915, Bohr (1972), p. 579; 10 October 1915, Bohr (1972), pp. 581-583 (mentions also letter and a paper sent to the Viennese chemist Fritz Paneth); Bohr to Sommerfeld, 19 March 1916, Bohr (1982), pp. 603-604; Sommerfeld to Bohr, 20 August 1916 in AHQP.

works on atomic spectra and x-rays by Sommerfeld, Epstein and Debye, which he received through Bohr.[12]

Bohr, thus, served as a mediator between scientists from Britain and from the Central Powers. He took on this role partly for practical reasons. Since scientific communication required the aid of residents of neutral countries, it was easier for a citizen of a neutral country than for a British citizen to find the people who could help him. Bohr relied on his family, a highly stable social unit. In his case he could also count on his brother's acquaintance with the subject matter and people involved. In addition it seems that the strong nationalism and chauvinism of the First World War, expressed by scientists on both sides, hindered correspondence between researchers from hostile countries. Both German and British scientists experienced difficulties in addressing each other directly; a Dane found it easier to address both. In writings, including in private letters, Bohr maintain a neutral position, expressing only his wish "that the present terribly sad state of the world may change soon."[13] That position had a strong resonance in Danish political culture, which saw the nation as neutral and as a possible cultural mediator between the British and the German blocks (see Knudsen's contribution to this volume). Bohr thus positioned himself in a similar place that his nation saw for itself in the international arena.[14]

Beyond delivering papers from one side to the other, Bohr tried to maintain the fragile link between the scientific communities of the hostile countries. For example, he was not content with sharing and discussing Sommerfeld and Debye's work with Rutherford, but he also took care to report Sommerfeld that "Rutherford was most interested in your work." That was true (as letters of Rutherford testify). Still, by informing Sommerfeld about Rutherford's interest, Bohr implied that the German work and scientists were respected in England even during the War, and that the link between the two communities was not totally cut. In this way, Bohr built a bridge between the two scientists, and thereby between their communities,

12. Rutherford to Bragg, 23 May 1916.

13. Bohr to Sommerfeld, 19 March 1916, Bohr (1982), p. 604.

14. See also Knudsen and Nielsen (2012).

as they were influential figures among German and British physicists respectively. One can thus discern a deliberate effort by Bohr to maintain an international community despite the hostilities. He continued with that after returning to Copenhagen, to which he invited both Sommerfeld and Rutherford. Sommerfeld had visited during the war; Rutherford arrived only in 1920. After the war Bohr made such an effort to restore scientific international cooperation public, fitting the national mediating policy of his country. This was not a novel turn of the now-famous and powerful professor. Bohr had made real efforts to reconcile scientists of belligerent countries already under the difficulties of the war and before releasing public statements in the friendlier situation of interwar Denmark.

4. War research in Manchester

Although Bohr kept a neutral position in writing, he did hope for a British victory, and most probably expressed that in personal conversations with his colleagues. This attitude is implied in a letter that he sent to Rutherford two weeks after the Allies' victory. Congratulating his British colleague for the "defeat of german (sic) militarism," he added:

> I remember, as if it was yesterday, all the times I sat in your study and you developped (sic) for me your views on the different phases up and down through which the war went, and how your unflinching belief in a happy end was always able to comfort me, however downhearted I could feel myself at times.[15]

This preference, however, did not make him a part of the British war effort. It probably did, however, help to make Bohr's British colleagues less anxious about the possibility that he would learn something about the subject of their war research. The physical condi-

15. Bohr to Rutherford, 24 November 1918, in Rutherford's papers at Cambridge university archives and a copy at Bohr's paper in Niels Bohr Archive, both available also in AHQP. For Bohr's joy for the results of the war see also Bohr to Richardson 25 January 1919 (AHQP).

tions in Manchester and Bohr's personal relationships hardly allowed keeping full secrecy from him. Most of Rutherford's war research was done at the basement or the ground floor of the physics department building, by the corridor through which everyone, including the Dane, passed.[16] The latter most probably knew that his colleagues were researching on means for submarine detection.

Considerable war-related research began in Manchester in the summer of 1915. Only around that time was science itself, rather than individual scientists, mobilized on large scale for the war effort on both sides. It took quite a few months of stalemated warfare for officers, politicians and civilians to realize that the war would neither change its character nor end soon. Some of them, although far from all, recognized that scientific knowledge and methods could be helpful in developing military technology for the specific needs of the war. In Britain the replacement of Churchill by Balfour as the First Lord of the Admiralty led to the establishment of its Board of Research and Invention in July 1915.[17] Rutherford was nominated to the Board's general panel and to its subcommittee, which dealt with submarine detection, among other things. Submarine detection became also the topic of Rutherford's own research, which he pursued with characteristic energy for about two years.[18] Until the second summer of the war, Rutherford continued with his research on the atom and x-rays. On June 1st 1915, Bohr could still justify his stay for another year in Manchester by reference to laboratory work related to his own theoretical undertaking. He commented that "[t]he work at the laboratory is going nearly as usual although there are much fewer young people than usual, and especially no foreigners expect me." As much as the research at that stage could be seen

16. I thank Neil Todd for the detailed information regarding the location of the water tank.

17. Galvez-Behar (2005); Roussel (1989); MacLeod and Andrews (1971); Seth (2010), p. 74.

18. In May 1917 Rutherford went to the US, where he informed American scientists about the progress of their British colleagues. Apparently, after his return, and the closure of the Board in September 1917, he could find time for atomic research although he was still engaged in war research (Hughes 2008); but see also Rutherford's letter to Bohr 11 May 1918, in the Niels Bohr Archive and AHQP.

as "nearly usual," very soon it changed. In February 1916 Bohr wrote to his former teacher that "Rutherford is giving all his time to work in connection with the war."[19]

For this war research, Rutherford recruited two young lecturers Harold Gerrard from the adjunct department of electrical engineering and his former student Albert B. Wood from the University of Liverpool. The three experimented "with various possible sound-receivers for use under water," until October.[20] Then Gerrard and Wood left for the naval experimental station, and Rutherford continued the research with two students, James H. Powell and J.H.T. Roberts, and with his laboratory assistant William Kay. Detecting submarines by the noise they make with under-water microphones, termed hydrophones, continued to be Rutherford's main effort. From summer 1915 until after Bohr had left Manchester the group followed two major lines of research. In the first they examined the underwater behaviour of different diaphragms and microphones informed by the mathematical theory of Horace Lamb. For this research Rutherford no longer consulted papers on electrons and radioactivity like those authored by Wilhelm Wien, but turned to reading the works of his cousin Max Wien on issues like the telephone diaphragm. The second line of inquiry included testing, improving, designing and constructing particular hydrophones. Designing receivers sensitive to the direction of sound occupied much of Rutherford's attention, leading, among other results, to a joint patent with another established physicist, William H. Bragg, who at the time headed the naval experimental station.[21]

By summer 1915 the war, then, was strongly felt at Manchester University. Most of the research of those who stayed in Manchester was devoted to war-related issues. Rutherford's administrative roles on the board and submarine committee took him out of town to occasional meetings. Earlier, when the strongest effect of the war re-

19. Bohr to Christiansen, 1 June 1915, Bohr (1981), pp. 494-495; Bohr to Fokker, 14 February 1916, Bohr (1981), p. 501.

20. Wood (1962), p. 10.

21. Katzir (2012). On the use of Max Wien's work see Rutherford to Bragg, 11 November 1916.

sulted from the absence of many young men, Bohr could still regard the situation as "nearly usual." This was no longer so, when the war directly affected the activities of the civilians who stayed at home. It is this strong effect of the First World War on the life and activities of civilians that characterized it as a "total war." The mobilization of science, scientists, engineers and technicians to the war was one important aspect among those that made the war total. Rutherford took part in the civilian mobilization to the war effort. So did his university, which continued paying his and his mechanician's salaries and a fellowship for Roberts, and provided facilities for the war research. [22] In effect, the university helped to fund the war.

Still a total war does not mean that all moments and aspects of life were directed at defeating the Central Powers. This was not even the case at the front, and clearly was not at the "home front." People continued living their lives and also followed interests unrelated to the war. Evans, for example, pursued his research on the atom. Bohr continued correspondence across the borders including with Germans, even under restrictions unknown in peacetime. He could also find interest in the scientific problems of his concern among those left in Manchester. Rutherford had hardly conducted any atomic research himself in 1915-16, but he did continue to show great concern for atomic physics. During this period he discussed with Bohr the Dane's own ideas and those of Sommerfeld and Debye.[23] So while not surrounded by physicists actively investigating the atom, as he had expected, Bohr still enjoyed the interest, discussion and encouragement of Mancunian physicists. Regarding his known preference to elaborate his ideas through dialogue,[24] this interest in his research certainly contributed to his productivity during his stay in Manchester.

22. Rutherford to Paget, 3 April 1916, in "Rutherford's file."

23. For Rutherford's own research see in addition to the quotations from Bohr and his letters (see below), in his research notebooks held at Department of Manuscripts & University Archives, University Library, Cambridge, and Hughes (2008). On his interest in atomic physics see Niels to Harald Bohr 10 October 1915, Bohr (1972), and Rutherford to Bragg, 23 May 1916.

24. Cf. J.L. Heilbron, "Nascent Science - The scientific and psychological background to Bohr's Trilogy," in Aaserud and Heilbron (2013), and Beller (2001).

5. Rutherford's attitude towards the war research and international cooperation

Rutherford himself was quite ambivalent about war research. He devoted almost all his research time for the task, but he was not happy about it. At the end of a letter to Bragg from May 1916 that discusses submarine detection, Rutherford expressed regret that he and his colleagues could not study the atom. He told Bragg about Sommerfeld and Epstein's recent progress in explaining "the finer points of the hydrogen and other spectra," and about Debye's new experiment with x-ray diffraction in silica powder and benzol, a subject of particular interest for Bragg. He then commented:

> It is a great pity that the work in England on this subject [atomic and x-ray physics] has stopped so completely. The neutrals and the Germans seem now to be collaring that field rapidly. . . It is a pity that it is so difficult for us now to devote our attention to the pure science problems.[25]

Unlike the impression implied by Rutherford, German scientists were also distracted from "pure science" by war research. Sommerfeld lingered with his extension of Bohr's model by his work on "problems of war physics."[26] Like Bohr, Debye was a neutral citizen working in a belligerent state. P. S. Epstein was a Russian subject who worked under police surveillance in Munich.

Regrets for leaving atomic physics and anxiety of losing ground in the field did not mean that Rutherford objected to the war research as such. On the contrary, Rutherford called for the application of science for military ends. He believed in the practical value of scientific research for technology in general and for the needs of the war in particular. When Wood told Rutherford that he was planning to join the air force, the Mancunian professor suggested that he would contribute more to Britain by doing research for the Navy than by flying. A few months later, in September 1915, in his

25. Rutherford to Bragg, 23 May 1916.

26. See Eckert's contribution in this volume.

obituary of Henry Moseley, Rutherford expressed the same view in public:

> Our regret for the untimely end of Moseley is all the more poignant that we cannot but recognise that his services would have been far more useful to his country in one of the numerous fields of scientific inquiry rendered necessary by the war than by exposure to the chances of a Turkish bullet.[27]

He did not question the importance of fighting and winning the war and the conclusion was thus clear. Yet, there is a difference between what one believes one should do and what one wishes to do. Following his judgement, Rutherford devoted his research to the war, but he still wished that the situation would be different and that he could have returned to "pure science problems." Bohr showed empathy with this position in his post-war letters to Richardson and Rutherford. "[H]ow happy you must be now again to be able to work in the laboratory as in old days," he wrote the latter.[28] Rutherford's attitude can explain his early partial return to atomic physics in late 1917. Other researchers, like Rutherford's former students Robert Boyle and Wood, found their war research interesting enough to pursue connected questions after the armistice.

Rutherford's ambivalence towards the war research might have been connected to what seems to be openness towards his German colleagues. In later years Bohr recalled that "[w]ith his liberal human attitude, Rutherford had tried to obtain permission for the [German] glass blower to continue his work in England in the war time."(Bohr 1961, 1097) An attempt to reduce hostility towards German scientists among his compatriots can be seen in a comment that he made in the above-mentioned letter to Bragg:

> It is interesting to note that both neutrals and the Germans are quite

27. Rutherford (1915), p. 34; Wood (1962), p. 10.

28. Bohr to Rutherford, 24 November 1918. See also Bohr to Richardson, 25 January 1919.

> appreciative in their references to the work of yourself, Moseley and others, in this field. They always speak of the Laue-Bragg theory of diffraction.

Recognition is almost always a sensitive issue among practitioners. During the war it became also a contentious national issue. In late 1914, Wilhelm Wien wrote a proclamation that urged German scientists to oppose the "unjustified English influence" and to prefer authors using their own language in citations and attributions. Sommerfeld exposed a similar worry about the credit given to German scientists after the war. In a letter to Bohr he appreciated

> the extraordinary liberal and faithful manner with which you acknowledge in your papers [of December 1918] my own results and those of my disciples. Thereby the colleagues in the hostile countries, who otherwise tend to deny German accomplishments, will be forced to realize that even during the war German science could not be suppressed.[29]

With the nationalistic overtones that end the quote, it is not surprising that Sommerfeld was among the sixteen who signed Wien's proclamation, although with some reservations; Sommerfeld thought it would be wiser not to publish it but to keep it for internal guidance. Still, his signature did not seem to influence his practice; Rutherford found that Sommerfeld, like his colleagues, continued to give due credit to British authors.

More significantly, the Mancunian physicist regarded the German fair practice as worth noting for his British colleagues. In this step he tried to lessen his compatriots' hostility towards German scientists, which grew during the war. Rutherford reported that the enemy was fair to the British, implying that the British should behave similarly towards the Germans. Thereby he tried to remove one unnecessary source of mutual anger between the scientists of the belligerent states. Rutherford, then, seemed to keep his commit-

29. Quoted in Michael Eckert, "Sommerfeld's 'nursery': The emergence of the Munich quantum school" (unpublished manuscript).

ment to restoring the international character of science after the end of the war, a task later taken on by Bohr. Apparently, Rutherford's attitude was not so far from that of his young Danish guest. As discussed above, being a citizen of a neutral state, which saw its task as mediating between the two sides, Bohr could be and was more active in maintaining the fragile connections between physicists behind the two sides of the front line. It is an open question whether Bohr influenced Rutherford, the senior influenced the junior, or, more plausibly, they mutually enhanced their earlier belief in the merits of international scientific research, which they made efforts to keep despite the impediments introduced by the war.

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