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BELATED NOBEL PRIZE FOR MAX BORN FRS

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In 1933 the reserved Physics Nobel Prize from the year 1932 was awarded to Werner Heisenberg (1901-1976) – one of the founders of quantum mechanics. The Nobel Committee [NC] ignored Max Born (1882-1970) and Pascual Jordan (1902-1980) who had worked with Heisenberg. Almost two decades later, in 1954, Born as a UK citizen was awarded the coveted prize. In the present paper the nomination letters, experts' reports and the reports of the NC, as well as, secondary literature are analysed to show why the Royal Swedish Academy of Sciences, Stockholm took so long to consider Born's achievements.

Key words: C.V. Raman, Lattice dynamics, Max Born, Nobel Prize, Pascual Jordan, Quantum mechanics, Werner Heisenberg

Introduction

It is a well-known fact that in the 1920s and 1930s renowned German physicists such as Arnold Sommerfeld (1868-1951), Werner Heisenberg and Max Born visited India. Indian Nobel Laureate C.V. Raman (1888-1970) was interested to establish theoretical physics at the Indian Institute of Sciences, Bangalore. For this purpose he invited Born – one of the founders of the quantum mechanics. However, due to various reasons latter's wish to stay for a longer time did not realize. In the beginning of the 1940s a controversy between Born and Raman started due to their differences on the theory of lattice dynamics.

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In the following paragraphs we shall see why the founder of the quantum mechanics and lattice dynamics was ignored by the Nobel Committee. Did the controversy between Born and Raman over lattice dynamics influence the decision of the Nobel Committee?

The history of quantum mechanics shows that Born's relations with young physicists like Wolfgang Pauli (1900-1958) and Werner Heisenberg were not always cordial as they were of the opinion that his theories were too abstract and had little relation with experiments. For instance, on the way to a meeting of the German Physical Society in the year 1925 Wolfgang Pauli told Max Born

> "Yes, I know you are fond of tedious and complicated formalisms. You are only going to spoil Heisenberg's physical ideas by futile mathematics."[1]

That is, what Born recalled, while writing on the foundation of quantum mechanics. In general, Born "tended to cultivate calculations for their own sake and place less emphasis on their connection with experiment". (Kragh, 2001). This made him an "outsider" in the physicists' community. The present paper deals with the history of the Nobel Prize for this unusual physicist. It is suggested that he had to wait so long for the Nobel Prize because:

1. The scientific community and the NC was of the opinion that he was not the discoverer of quantum mechanics
2. Swedish theoretical physicists, who evaluated Born's work for the Nobel Prize – such as Carl W. Oseen (1879-1944) and Ivar Waller (1898-1991), had a different understanding of a theory in physics than Born.
3. NC postponed Born's case in favour of its national and international politics.

In order to show Born's status among the scientific community a short review about his life and work is given in the following section (Born, 1975, Born 2002; Herman, 1962; Kemmer & Schlapp, 1975; Staley, 1992; Wolf, 1995; Cook, 2002; Greenspan, 2005).

Max Born and his Scientific Achievements – A Short Review

Max Born was born on December 11, 1882 in Breslau, Poland (today Wroclaw). He studied at the universities in Breslau, Heidelberg, Zürich,

Cambridge und Göttingen. He did his PhD (1907) and "habilitation" (1909) in Physics at the University of Göttingen. He taught at the universities of Berlin, Frankfurt am Main (1914-1920), and Göttingen (1921-1933). In 1933 he was forced to resign his position due to his Jewish origin. After short stays in Cambridge and Bangalore (India) he joined the University of Edinburgh in 1936 and stayed there until his retirement (1953). In 1939 Born and his family were granted British citizenship. After his retirement the family came back to Germany. One of the non-scientific landmarks of his life was signing the declaration of the "Göttinger 18" calling the German government to renounce the use of nuclear weapons (1957). He died in Göttingen on January 5th, 1970.

Scientific achievements

Born participated in the development of quantum mechanics, solid state physics and optics. He wrote 360 papers and books (Kemmer & Schlapp, 1971). He supervised the work of a number of notable students such as Victor F. Weisskopf (1908-2002), J. R. Oppenheimer (1904-1967), Max Delbrück (1906-1981), Friedrich Hund (1896-1997), Pascual Jordan (1902-1980) and Maria Goeppert-Mayer (1906-1972) in the 1920s and 30s who influenced science and politics in the following years.

Honours and awards

Born was a Fellow/Member of a number of scientific societies and academies. The Royal Society of London elected him its Fellow (1939) and awarded him the Hughes Medal (1950). He received the honorary membership of the Indian, Peruvian and Royal Irish Academies, and the Russian Academy of Sciences. He was a foreign member of the Royal Danish and Royal Swedish Academies and of the National Academy of Sciences of the USA. In 1948 he was honoured with the Max Planck Medal of the German Physical Society. In 1954 he was awarded the Nobel Prize. He was awarded honorary doctoral degrees by the Universities of Bristol, Bordeaux, Oxford, Freiburg / Breisgau, Edinburgh, Stuttgart, Oslo and Brussels. In his honour the Max-Born-Institute for Nonlinear Optics and Short Pulse Spectroscopy was founded in Berlin in 1991.

As we shall see later, Born was nominated for his researches in the fields of quantum mechanics and lattice dynamics. Particularly between 1946 and 1949 the nominators stressed on Born's achievements in the field of latter subject (see Table 1). In order to understand the decision of experts of the NC it will be worth to say a few words about Born-Raman controversy of their theories of lattice dynamics. To start with it should be mentioned that the following is summarised from the article "Max Born's role in the lattice dynamic controversy", which was published by one of us (Singh, 2001).

Born-Raman controversy and theory of lattice dynamics

In 1912 from Germany Walter Freidrich (1883-1968), Paul Knipping (1883-1935) and Max von Laue (1879-1960) discovered that crystals diffract X-rays. The interference pattern is to be observed in the form of spots. Two years later, Peter Debye suggested that due to the thermal vibrations of the atoms in crystal these spots must accompany by diffuse spots. Among the physicists who studied theoretically the phenomenon of diffuse spots were Swedes Ivar Waller (1898-1991) and Olov Hilding Faxén (1892-1970). In the late 1930s American, British and Indian physicists suggested various theories to explain the experimental results, which were observed in their laboratories. Raman was of the opinion that Debye's and Born's theories, which predict continuous vibration spectra, were incorrect. In particular he was against Born's theory. According to the theory contained an ad hoc concept of cyclic boundary condition, that is, in the theory it was assumed that the crystal had an infinite length. For Raman the concept did not reflect the real physical world. Raman, who had observed the vibration line spectra, in 1947, formulated an alternative theory to explain his experimental results. Born was unable to explain the line spectra with his theory. About the sharp observed lines, Erwin Schrödinger (1887-1961) wrote to Born in a letter of March 2, 1942 as follows:

> The only interesting argument in R's paper is the experimental fact, that the Raman-lines and some other optical indications of the "optical lattice frequencies" are "absolutely sharp". (I don't think that anybody, who read these things will pay much attention to *any other* argument than this). That seems convincing. People will say, well, there is, of course, some blunder in his theoretical arguments, as usually, but that he finds those lines Sharpe, we believe him. So something must be wrong with the other people's theories.

As Born's correspondence shows, even in the late 1940s the situation has not changed in Born's favour. On April 26, 1948 he wrote to Rudolf Peierls (1907-1995) that "the whole matter is very disagreeable to me because nobody supports me in this unpleasant dispute, though all privately say that they are on my side". In the end Peierls came to help. In a letter of February 1, 1951 he wrote to Born that Raman agrees with the concept of linear chain, but he does not accept this for three dimensional problem. On October 31, 1951 Peierls sent a letter to Raman, which indicates that the latter was appreciative of former's ideas on the lattice boundary condition. Peierls' article appeared in 1954 in vol. 20 of the *Proceedings of the National Institute of Science*, India on pages 121-126. In the same year, it was reproduced as appendix by Born and K. Huang in "*Dynamical Theory of lattice dynamics*".

So far the sharp line in vibration spectra were concerned, in 1953 Leon van Hove showed that they correspond to those frequencies that have zero group velocity in Born's theory.

Nobel Prize for Quantum Mechanics – Heisenberg vs. Born

In the late 1920s the physics community saw Heisenberg's quantum mechanics and Erwin Schrödinger's wave mechanics as great achievements in the field of theoretical physics. For the Physics Nobel Prize for the year 1928 Edgar Meyer (1879-1960) from the University of Zürich nominated Heisenberg and E. Schrödinger (1887-1961).[2,3] These nominations were not taken seriously as the NC did not require experts' reports on the achievements of these physicists. The prize for this year was reserved and in 1929 awarded to the British physicist Owen W. Richardson, FRS (1879-1959). A year later both (Heisenberg and Schrödinger) were nominated three and ten times respectively. In 1930 Born was nominated for the first time by the German physicist Peter Pringsheim (1881-1963) for a shared Prize with Heisenberg for the foundation of the new quantum mechanics.[4] At the same time Heisenberg was nominated by five other persons (Crawford, Heilbron et al., 1987). The NC proposed the Indian physicist C. V. Raman (1888-1970), and the Swedish Academy of Sciences, which takes the final decision regarding the prize made its decision in his favour. He received the prize for his work on light scattering and the discovery of the effect named after him.[5]

For the year 1931 the Physics Nobel Prize was reserved and not awarded as none of the nominees was seen as worthy of the Prize. [6] A year later it was permanently reserved under the bylaws:

> "If it be deemed that not one of the works under examinations attains to the standard of excellence above referred to, the sum allotted for the prize or prizes shall be withheld until the ensuring year. Should it even then be found impossible, on the same grounds, to make any award, the amount in question shall be added to the main fund …."[7]

In 1932 Heisenberg had seven nominations, while nobody nominated Born. Under Heisenberg's nominators were: Niels Bohr (1885-1962), Albert Einstein (1879-1955) and Wolfgang Pauli.[8] Once again the Academy did not find the right candidate, and the prize was reserved for the year. For the next round (1933) new nominations followed – none in favour of Born, but ten for Heisenberg. They were supported by theoretical as well as experimental physicists like Enrico Fermi (1901-1954), William L. Bragg (1890-1971), N. Bohr, James Franck (1882-1964) and C. W. Oseen.[9] It leaves no doubt that the scientific community saw Heisenberg as the founder of quantum mechanics. Now, the question arises why the scientific community did not consider Born's contribution? The answer is simple: The scientific community gave credit for the discovery according to the published material. Heisenberg's paper on "*Über quantentheoretischeUmdeutung kinematischer und mechanischer Bezie hungen*" (Quantum theoretical re-interpretation of kinematic and mechanical relations) was seen as the first one on quantum mechanics (Heisenberg, 1925). The paper was aimed to formulate a quantum mechanic theory, which should be based on observable parameters. About two months later Born and Jordan sent "*Zur Quantenmechanik*" (On quantum mechanics) to the same journal. In it the authors stated that they had extended Heisenberg's theory, which from a mathematical point of view was incomplete (Born & Jordan, 1925). Also written in 1925 but published a year later, the second part of the paper by Born, Heisenberg and Jordan followed (Born, Heisenberg & Jordan, 1926).

According to the Statutes of the Nobel Foundation "a work may not be awarded a prize, unless it by experience or expert scrutiny has been found to be of such outstanding importance as is manifestly intended by the will."[10] The expert who wrote reports on the achievements of Born, Heisenberg and Schrödinger for the NC was C. W. Oseen – a professor of theoretical physics.[11]

Until 1932 Oseen had opposed Heisenberg and Schrödinger. Surprisingly enough, in 1933 he nominated not only the two but also W. Pauli. The reason for this turn was the information given to Oseen by I. Waller.[12] He told the former that Paul Dirac's theoretical and experimental findings supported Heisenberg and Schrödinger's work. Dirac had predicted the existence of a positively charged electron (later renamed as positron), which was confirmed experimentally. This was interpreted by Oseen as "a discovery that 'transformed one of the most difficult reservations against the new atomic theory (Friedman, 2001). "The prize for the year 1933 went to Schrödinger and Dirac, whereas Heisenberg got the reserved prize from the year 1932. Born was excluded as already in 1930, in his report Oseen noted that the original idea was from Heisenberg: although it was extended by Born and Jordan. Thus the question of sharing the prize between Born and Heisenberg did not arise. Apart from that one cannot ignore Jordan, while giving the prize to Born.[13]

In the beginning Oseen opposed a prize for quantum and wave mechanics as for him these theories were not yet complete. He was of the opinion that "Either a theory was fully capable of explaining all relevant phenomena or it was not worth recognition."[14] In order to understand Oseen's attitude it is important to consider the understanding of a theory prevailing in the Swedish physicists' community, to whom he belonged. For instance, in 1918 Hilding Faxén (1892-1970) – a student of Oseen and later a physics professor in Stockholm – wrote an article on the theory of relativity. In it he stated:

> "Einstein seems to have understood theory [as such] the goal of physics and this is typical of the younger. Older persons, who have lived through many theories (…) are more inclined to be satisfied only with factual knowledge, i. e., experimentally demonstrated theories and they are sceptical when it comes to theories which cannot be verified."[15] (Emphasis in original)

This exactly fits to Oseen's way of thinking. According to K. Grandin

> "as far as quantum physics was concerned, Oseen hoped for lucid concepts that might lay the foundation for the new theoretical technologies and thus make them more intelligible."[16]

Not surprisingly, "the concept of indeterminism of Heisenberg and Schrödinger was met by him with considerable scepticism and resistance."[17]

For the Physics Nobel Prize for the year 1934, the Dutch physicist Dirk Coster (1889-1950) made multiple proposals. In the first place he nominated Pauli for his work in the field of atomic physics, in particular the principle named after him. Secondly Born was mentioned who was proposed for the development of lattice dynamics and his contribution to atomic physics, in particular to matrix mechanics. The third candidate Arnold Sommerfeld (1868-1951) was nominated for the development of the relativistic theory of fine structure of spectra and electron theory of metals.[18] Coster wrote,

> "Beyond doubt, out of these three physicists [Pauli, Born, Sommerfeld] I would recommend the first one most warmly because it seems to me that his intervention in the theory was mostly guided by inventive ideas; it has shown that the Pauli principle in particular was an extremely important contribution for the comprehension of atomic structure."

In the same letter he also proposed the experimental physicists Otto Stern (1888-1969), Walther Gerlach (1889-1979), Clinton J. Davisson (1881-1958) and Lester H. Germer (1896-1971). He wrote that as the Committee has awarded the Nobel Prize for theoretical physics for the years 1932 and 1933, he suggests considering experimental physics for the prize this time.[19]

For the year 1934 Oseen prepared a report on Pauli's and Born's achievements. In the beginning, the author stated that as in 1933 a detailed report had been written on Pauli's activities, thus he would concentrate on Born's work. In the end he came to the conclusion that if one sees Born's contribution to atomic physics, it is evident that he published his work with Jordan, which came out shortly after Heisenberg's fundamental idea. Pauli and Born had reformulated Heisenberg's approach. However, Born's major contribution to atomic physics is the new interpretation of Schrödinger's wave function, that is, the motion of particles is determined by probability laws, which are determined by causality. This had been proved correct. Apart from that, Born had supported the development of atomic physics[20]. Then he compared Pauli with Born and found the achievements of the former ground-breaking. He imposed the question whether Pauli or Born or the both should be awarded the Nobel Prize. Without clearly answering, he pointed out that for atomic physics two prizes had been awarded in the past. If it is to be done again, certainly Pauli and Born would stand in the first

row, however, they are not alone, Jordan had equally contributed compared to Born. Using Jordan's name seems to be pretext by Oseen as the editors H. Nielsen, K. Nielsen (Aaserud, 2001, p. 586) have shown that a candidate cannot be awarded with a NP if he is not nominated for that particular year. Obviously Jordan had no chance to share the NP with Born. Independent of Jordan's political views during the National Socialism, the same argument can be applied to state that he had no chance to get the NP as according to the available documents, he was not nominated. For the year 1934 the Committee found none of the nominees worthy of the Nobel Prize. It was reserved and never awarded.

In 1939, Born was proposed by the Italian Tullio Levi-Civita (1873-1941) for the theory of relativity, lattice dynamics, quantum and wave mechanics and statistical interpretation of wave mechanics. [21] In response to the nomination by Levi-Civita and Coster (in 1934), Oseen supplemented the report for the NC. As before, he argued that already two prizes had been awarded for quantum mechanics, thus there was no reason to award a third prize for the same discovery. So far Born's contribution to the theory of relativity was concerned, the work was considered to be too old. Oseen commented that Born tried for the fusion of quantum mechanics and theory of relativity, which was not quite novel. And further, he stated, "still it cannot be seen that it has done great service to the science and is worthy of the Nobel Prize".[22] Also "Born's lattice dynamics theory is not worthy of the Nobel Prize", stated Oseen.[23] Thus Oseen rejected Born's claim in all the fields of his research. Considering the facts stated under "the controversy on the lattice dynamics theory", Oseen was absolutely right. Born extended the theory after 1940s. The prize for the year 1939 was awarded to the American E. O. Lawrence (1901-1958) – "for the invention and development of the cyclotron and for results obtained with it, especially with regard to artificial radioactive elements. " This decision of the NC was made on the basis of the intention to establish good relations with American colleagues and institutions. The man behind the move was Manne Siegbahn (1886-1970) who wanted to build a cyclotron in his own laboratory.[24] Meanwhile the European continent was facing the Second World War. The Nobel Prize for Physics for the years 1940, 1941 and 1942 were never awarded. For the year 1943, the prize was reserved and awarded to Otto Stern in 1944.

Nobel Prize Decisions in the Turmoil of Changing Politics and Strategies

For the Physics Nobel Prize for the year 1945 Einstein, Hendrik A. Kramers (1894-1952) and John H. van Vleck (1899-1980) nominated Pauli[25]. He was awarded the prize "for the discovery of the Exclusion Principle", also called the Pauli Principle. With that the major actors of quantum mechanics except Born had been honoured.

Born's nominations between 1946 and 1949 show that most of the nominators changed their strategy, namely, they proposed him either for his work on lattice dynamics or statistical interpretation of wave mechanics (see table 1). In 1946 no report was prepared on Born's work.

Table 1. Born's nominators between 1945 and 1949

Nomination for the Year	Nominators	Nominees	Field of Research for which Born was nominated
1946	L. de Broglie[27] (France)	H. Yakawa[28,] Pauli & Born	All important fields of physics
1947	J. Franck[29] (USA)	Born	Lattice dynamics
	E. Fermi[30] (USA)	Born	Lattice dynamics
	C. Bialobrzeski[31] (Poland)	Born, P. Auger, P. M. S. Blackett, D. W. Kerst, B. Rossi, R. Serber	Lattice dynamics
1948	E. Fermi[32] (USA)	Born	Lattice dynamics
	J. Franck[33] (USA)	Born	Lattice dynamics
	C. A. Coulson[34] (UK)		Lattice dynamics, quantum theory, non-linear field theory, theory of reciprocity, theory of liquids
	G. D. Preston[35] (UK)	Born	Lattice dynamics and x-ray scattering, kinetic theory of condensed matter
1949	H. Niewodniczánski & J Weyssenhoff[36] (Poland)	Born	Quantum and wave mechanics, lattice dynamics, statistical interpretation of wave mechanics, theory of relativity
	J. Franck[37] (USA)	Born	Lattice dynamics
	E. Madelung[38] (Germany)	Born & W. Bothe	Statistical nature of wave mechanics

"In order to heed the Cambridge, Massachusetts lobby" the Prize for the year was awarded to the American Percy W. Bridgman (1882-1961).[26]

In 1947 Franck in his proposal emphasized the applications of Born's theory of lattice dynamics as follows:

> "In the recent literature that work has become more and more important – in chemistry so far as the fundamental constant of electron affinity is concerned, in the field of fluorescence and phosphorescence, in the field of low temperature work (thermo-conductivity of crystals), and in the field of practical applications (television and other fields in which the so-called colour centers play a role)."[39]

In the nomination letter, Franck also put moral pressure on the Committee by emphasizing that the Swedish Royal Academy of Sciences during the last decade had honoured most of the great theoretical physicists, but one man belonging to that group, Professor Max Born of the University of Edinburgh, had been left out.

Neither the moral pressure nor the scientific achievements convinced the NC. In 1947 the prize was awarded to the British physicist from Cambridge University Edward V. Appleton (1892-1965) the reason being Henning Pleijel – one of the Committee's members who was going to retire – supported his case. This decision has been interpreted by historians as a "retirement gift" from the Academy to Pleijel.[40]

As we see in Table 1, Born was nominated again in 1948. In this year, the NC asked its expert to supplement the report. The expert was Ivar Waller – a theoretical physicist and an expert on x-rays scattering and lattice dynamics.[41] In the first paragraph of the report, he summarised: Fermi, Franck, Charles A. Coulson (1910-1974) and George D. Preston (1896-1972) have nominated Born. Fermi and Franck say that the award should be given to Born for his work on lattice dynamics, in particular ions lattice. They both stress the importance of this work in the understanding of phosphorescence phenomena. They also say that Born contributed to other branches of physics. C. A. Coulson proposed Born for his contribution to practically all branches of theoretical physics. Preston's proposal, which is not clearly formulated, seems to argue that the prize should be awarded for the work on lattice dynamics and scattering of x-rays in crystals.[42] Waller further noted that Oseen had reported Born's achievements in the field of quantum mechanics.

Also his work on non-linear field theory had been reported and not been found worthy of the Nobel Prize. He (Waller) agrees with the previous report. Thus he (Waller) would concentrate on lattice dynamics. Now, Preston argued in favour of Born for the theory of lattice dynamics and x-ray interference. Waller stated that it is worth considering Born's contribution on the theory of lattice dynamics as proposed by Franck and Fermi, but Born himself had said that it is necessary to revise the theory thoroughly, which he wanted to do in the future. How far Waller was influenced by Born-Raman controversy is difficult to say. Being an expert in the field he must had seen the drawbacks (such as not be able to explain sharp lines in vibration spectra) in Born's theory at this stage. Thus he used Born's own argument against him: "it is necessary to revise the theory thoroughly."

Again, neither the expert nor the NC saw Born's scientific work worthy of a Nobel Prize. The Nobel Prize in Physics 1948 was awarded to the British physicist Patrick M. S. Blackett (1897-1974). The American nominator Arthur H. Compton (1892-1962) had emphasized on his wartime contributions in anti-submarine warfare and air defence. Also John D. Bernal (1901-1971) nominated Blackett. Both British, they were known as left wing physicists and believed in organizing science for its use for social development. The Social Democrats in Sweden and some of the scientists such as Siegbahn had similar political views:

> "Moreover, Swedish scientists were increasingly fearful of the escalation of American and British nuclear militarism; voices such as Blackett's which appealed for international control, found a sympathetic audience."[43]

The forgoing discussion shows that the Physics NPs during that time went to either those who were involved in "big science" or those who were "politically active" or worked for the war effort. Born belonged to none of them. His work on quantum mechanics was done in the 1920s and the beginning of the 1930s. During his Edinburgh time most of his research was on lattice dynamics, which was much disputed as he was involved in a controversy with the Indian Nobel Laureate C.V. Raman[44]. During the controversy Born developed the theory of lattice dynamics in detail. According to Born's typical way, it was based on complicated mathematical ideas. It can be judged from the fact that it found its complete confirmation in 1962 (Brandmuller & Munchen, 1971). According to Ramaseshan,

> "Elaborate calculations (not fully carried out till the advent of computers …) were needed to predict the simplest of optical and thermal properties from the Born theory. Lacking the notion of singularities in the spectrum, again not to come for a decade, the sharp features seen in the Raman scattering found no explanation."[45]

This once again underlines Born's intelligence and mathematical abilities. For him a theory had its own existence, independent of its immediate experimental verification. These views were not in agreement with Swedish physicists who had chosen for an "intermediate theoretical physics." This term has been introduced by the Swede historian of science K. Grandin and describes a kind of doing theory which stands between merely calculating for the sake of experimentalists and speculating on fundamentals thus adjudicating theories a right of their own.[46]

Born's Offensive and Seeking for Support

As Table 2 shows between 1950 and 1954 Born was nominated by several scientists. Between 1950 and 1953 other candidates received the Nobel Prizes. The existing literature does not give clues which factors other than scientific achievements played a role for the decision of the Academy.

The year 1950 was a double anniversary: Fifty years since the energy quantum formula by Max Planck (1858-1947) and twenty-five years since the discovery of quantum mechanics. At the time of the anniversaries Heisenberg was presented as a hero, while Born's contribution was neglected. This annoyed him[47], and at last he became more offensive. In a public lecture he stated as follows:

> "When Heisenberg published the fundamental paper in which he cleared quantum theory from classical remnants and formulated it in terms of transition amplitudes, he was my assistant, very brilliant but very young, and not very learned. In fact he did not exactly know what a matrix was, and as he felt stuck he asked my help. After some effort I found the connection with the matrix calculus, and I remember my surprise when Heisenberg's quantum condition turned out to be the matrix equation $qp - pq = ih$. If Heisenberg were here instead of myself he would tell you the same story. The matrix form of quantum mechanics was first published by myself in collaboration with my pupil Jordan (Born, 1953)."

And further:

> "However, I have not, and never had, a particular preference for the matrix method. When Schrödinger's wave mechanics appeared I felt at once that it demanded a non-deterministic interpretation, and I guessed that $|\psi|^2$ was the probability density; but it took some time before I had found physical arguments in favour of this suggestion, namely collision phenomena and transitions under external forces. Now the strange thing happened that Heisenberg first disagreed and accused me of treason against the spirit of matrix mechanics. But he soon came round and produced the wonderful reconciliation of particles and waves with the help of his uncertainty relation."

We shall see below, which affect this lecture had in the decision of the NC and its expert.

Neither Born's biographies nor autobiography showed that he ever asked others to nominate him for the Nobel Prize. However, Franck's letter dated December 4, 1953 indicates that he had sought support. In part the letter reads:

> "Quickly a few lines in answer to your letter of November 25th. Do not worry about the proposals for the Nobel Prize in physics and chemistry at this time. … May I, therefore, tell you more or less in confidence what I am doing? I always discuss the matter with Fermi. Sometimes we come to an easy agreement; for instance, when we proposed your name; sometimes we do not. Then we go our separate ways. This time I have not yet discussed the matter with Fermi but will do so if I possibly can before I leave on the 14th of December for Durham …."[48]

As we see from Table 2 in 1954 in a joint letter Franck and Fermi nominated Born again. Another nomination from the USA was by Emilio Segré (1905-1989) who nominated Born for the statistical interpretation of quantum mechanics.

Better late than never

In 1950 three Scandinavians - Niels Bohr, Christian Möller (1904-1980) and Torsten Gustafson (1904-1987) nominated Born. In 1952 the first two repeated their proposals. As we shall see below, the appearance of Bohr as a nominator influenced the decision. In 1954 Fermi and Frank in a joint letter nominated Born. Three more proposals were sent from the USA, France

Table 2: Born's nominators after 1950

Nomination for the Year	Nominators	Nominees	Field of Research for which Born was nominated
1950	N. Bohr[49] (Danmark)	Born & H. Kramers	Statistical interpretation of wave mechanics, constitution of matter
	C. Möller[50] (Danmark)	Born & H. Kramers	Development of atomic theory
	T. Gustafson[51] (Sweden)	Born & H. Kramers	Statistical interpretation of wave mechanics, constitution of matter, atomic theory
	C. Bialobrzeski[52] (Poland)	Born & C. F. Powell	Statistical interpretation of quantum mechanics, atom physics, lattice dynamics
1951	C. Sardon[53] (France)	Born	Quantum- and wave mechanics
	W. Heitler[54] (Switzerland)	Born	Fundamentals of quantum mechanics, in particular statistical interpretation
	I. Supek[55] (Zagreb)	Born & A. Sommerfeld	Quantum mechanics
1952	A. Landé[56] (USA)	Born	Lattice dynamics, matrix mechanics
	S. Fianchetti[57] (Italy)	Born	Combining electromagnetic theory with relativity, quantum mechanics, statistical interpretation of wave mechanics
	N. Bohr[58] (Danmark)	Born & H. A. Kramers	Statistical interpretation of wave mechanics, constitution of matter
	C. Möller [59] (Danmark)	Born & H. A. Kramers	Atomic theory
1953	C. A. Coulson[60] (UK)	Born	Lattice dynamics, quantum theory, non-linear field theory, theory of reciprocity, theory of liquids
	W. Heitler[61] (Switzerland)	Born	Quantum Mechanics, lattice dynamics
	H. H. Staub[62] (Switzerland)	Born	Quantum mechanics, statistical interpretation of wave mechanics, lattice dynamics

Nomination for the Year	Nominators	Nominees	Field of Research for which Born was nominated
1954	E. Fermi & J. Franck[63] (USA)	Born	Lattice dynamics, statistical interpretation of quantum mechanics, Born approximation in collision processes
	E. Segré[64] (USA)	Born	Statistical interpretation of quantum mechanics
	M. Pauthenier[65] (France)	Born & L. Neel	Quantum mechanics, lattice dynamics
	H. Fröhlich[66] (UK)	Born	Statistical interpretation of quantum mechanics

and UK (see Table 2). According to the report of the NC for the year 1954, fifty-three nominators sent proposals (in time, that is before Feb. 1st, 1954) and nominated 35 persons. From the nominees Walter Bothe (1891-1957) was nominated seven times and Born five times. Twenty-five from the list were nominated only once.[67]

Once again I. Waller supplemented the report. As usual he gave a short statement about the nominators' views. He drew attention to the fact that in the past Born had been nominated by Bohr, Möller and Gustafson for a shared prize together with the Dutch physicists Hendrik A. Kramers (1894-1952). In the concluding part of the report for the year 1954, Waller emphasized that it is necessary to refer to Niels Bohr's proposal from the year 1950, as credit goes to Born for the formulation of the statistical principle of wave mechanics, which helped for the further development of wave mechanics and its applications in different atomic processes.

Now, what about lattice dynamics for which Born was nominated again and again? Waller stated that in 1934 Oseen found Born's work on lattice dynamics not worthy of a Nobel Prize. In 1948 Waller complimented the report. It was stressed that Born had improved the theory. He dealt with dynamical, electromagnetic and optical properties of the crystals in terms of quantum mechanics. With it he was able to give a theory for the Raman effect in crystals, and could explain the fine details observed in sodium chloride crystals by Rappal S. Krishnan (1911-1999). However, it was suggested to postpone the decision about the Nobel Prize as Born had said

that in the future he was going to revise the lattice dynamics theory in a book. In the report for the year 1954 Waller stated that

> "(According to recent information, the publication of the book has been delayed, as Born's co-author, one of his students, has returned to China, which makes the cooperation difficult. The last correction is now sent to the publisher)"[68] [parenthesis in original].

Waller was of the opinion that independent of completing his previous work in the new book, Born's contribution was fundamental for the development of lattice dynamics. After reporting Born's work from the very beginning (1913), in the end he stated it would be of interest to quote E. Fermi's letter of January 30, 1947. Waller reproduced the letter, which contained the practical applications of lattice dynamics, as well as, the statement that Born has been omitted, while the other great theoretical physicists had been honoured in the past.[69]

There is no doubt that the Born-Raman controversy on lattice dynamics theory lead to the development of the theory and attracted the attention of the scientific community. The expert of the NC rightly judged not to award the NP for this subject as according to the bylaws it did not give an impression of a "discovery. "As the moral pressure from various sides was high, Waller found a different way to give credit to Born for his achievements.

The reporter Waller stated that

> "as noted in the introduction, on the first instance, this year Born has been nominated for his achievements, that is, the reformulation of the quantum mechanics, in particular for his discovery and the formulation of the statistical interpretation of the quantum mechanics" (emphasis added).

It fitted to the founder's will, according to which the prize should be awarded to the person *"*… who shall have made the most important discovery or invention within the field of physics (Fant, 1995, pp. 441-443). "(Emphasis added)

Careful revision of a former decision**:** In Oseen's report from the year 1934, it was reported: "Born's great achievement could be seen in the field of atomic physics, that is, the interpretation of Schrödinger's wave function". . . . "This is valid even today", wrote Waller. In the previous report, Oseen

wanted to consider Jordan's contribution, if the prize was awarded. Waller stated that the statistical interpretation of the quantum mechanics was done by Born alone (Born, 1926).[1] These are the main achievements for which he had been nominated this year. Now, the statistical interpretation principle was proposed independently by Born and Paul A. M. Dirac (1902-1984) nearly at the same time. Waller noted for the Committee that Born has priority over the discovery as Dirac's paper published in the *Proceedings of the Royal Society A* [112 (1926), 661-77] was dated August 26, 1926 whereas Born's article containing the statistical interpretation was received on June 25th, 1926 by the *Zeitschrift fürPhysik*.

With the report Waller sent the above two quoted paragraphs from Born's lecture as an attachment. Seemingly, with it he wanted to underline Born's authority over Heisenberg.

In order to strengthen Born's case, Waller wrote that after World War II, nominations in favour of Born had increased. This clearly showed the importance of Born's achievements, in particular in the field of fundamental principles and methods in quantum mechanics.

From the foregoing discussion we see that Waller's report was positive and well argued. It had the elements like "discovery", its practical applications, recognition by the scientific community, and in particular scrutiny by eminent Scandinavian N. Bohr. Most importantly, it was not critical to the previous decisions of the NC and its expert. As we shall see below the NC shared the same view with its expert.

Opinion of the NC and Decision of the Royal Swedish Academy of Sciences

After giving the formal information regarding the number of nominators and nominees as well as the valid number of proposals the NC noted that Born had been nominated a number of times in the past. The reports on his achievements were prepared in 1934, 1939 and 1948. In the present year Waller wrote a new report. On Born's work on lattice dynamics the Committee made only a passing remark. So far as Born's achievements in quantum mechanics were concerned, the Committee repeated Oseen's views.[70] To support its decision the Committee referred to Bohr's letters from the years 1950 and 1952. Further the NC argued as follows:

> "In general Born's contribution in the quantum mechanics can be emphasized for which he has been nominated in 1950 and 1952. Professor Born contributed for the rational formulation of quantum mechanics and in particular, his original investigation, the introduction of the statistical interpretation of wave mechanics. It has been useful for the later development of quantum mechanics and the description of different nuclear processes."[71]

In the report it was further stated that many times in the past the Committee has considered primarily Born's work on the reformulation of quantum mechanics for the Nobel Prize; but it was found that other proposals should be considered first. The fact that after 1939 Born was nominated many times by different persons indicates the thankfulness of the scientific community for Born's scientific achievements, in particular for quantum mechanics. Its application has been extended in the previous years due to new methods in dealing with the interaction between electrons and an electromagnetic field (emphasis added). Particularly with the last sentence the formal condition for awarding the Prize was fulfilled. In the end the NC proposed that the Prize should be awarded to:

> Professor Max Born, Edinburgh, for his fundamental research in quantum mechanics, especially for his statistical interpretation of the wave function and Professor Walter Bothe, Heidelberg, for the invention of the coincidence method and his discoveries made therewith (Underlined in original).[72]

Why did the NC take so long for this decision in favour of Max Born? The Committee justified it as follows: "In both cases the major achievements were brought carefully thirty years ago, …. . The meaning of the respective achievements was manifested in the previous years. "[73] The Royal Swedish Academy of Sciences, which is not forced to accept the NC's proposal, decided equally. Born, who himself was often a nominator became Nobel Laureate in 1954.[74]

Unofficially Born got the news about the NP at the end of October, 1954. Officially he was informed on November 3rd, 1954. Born who already had lost hope, wrote a letter to his supporter J. Franck after getting the good news and thanked him. "I have not expected it with my almost 72 years but now the joy is great".[75] After attending the Nobel Prize ceremony on December 10, 1954, he wrote a letter to his son as quoted by Greenspan:

> "As I am too old to use the Nobel money for research, I think I will come nearest to Alfred Nobel's intentions by attacking the prostitution of science for war and destruction."[76]

In fact this was done by him as in 1957 he asked the physicists, in particular the Nobel Laureates to denounce the use of nuclear weapons.

Conclusions

The forgoing paragraphs show that the NC and its experts have taken their decision with care. In the case of Born, he and his supporters found that unfairness was done to him by awarding the Nobel Prize to Werner Heisenberg alone. However, the careful study of the Nobel Prize documents shows that the expert presented his report on the basis of the publications, following the rule: First come, first served. The Committee took Heisenberg's first publication as a base for its decision, thus excluding Born and Jordan.

Born had an entirely different understanding of a theory in physics. He saw it as an independent entity, which does not require immediate experimental verification. Thus he did not fit to the conceptions of theoretical physics which were held by the Swedish theorists who advised the NC and in the 1920s and 1930s only began to establish this area of scientific research. The Swedish "intermediate theoretical physics" was based on a close cooperation between theory and experiment for which Ivar Waller was an outstanding example. Evidently, a scientist's way of thinking about the relation between theory and experiment which does not fit to the main stream views can make him an outsider within the community – as was the case with Max Born.

So far Born-Raman controversy on the theory of lattice dynamics, and consequently development of this field was concerned, the experts of the NC evaluated Born's contributions correctly. From the controversy they saw that Born's theory was not completely developed until 1954. Thus before that they did not give their decision in favour of this work. It can be concluded that, indirectly, the controversy influenced the decision of the experts.

Born's Nobel prize story also shows the dilemma of a decision making organisation – the NC – which has to consider national and international interests, but also to follow particular guidelines. Though the NC was aware of Born's achievements and up to some extent was willing to honour him,

it had to make decisions which fit to the national and international politics of the country.

It has been shown by the historian Finn Aaserud that N. Bohr was a successful nominator because "he was a particularly respected physicist", and he was scientifically and politically "astute" (Aaserud, 2001). Thus referring to Bohr's name in the expert's and NC's reports, in order to push the decision in Born's favour, was a successful strategy. Born's NP story suggests that the decisions can be influenced by making use of renowned authorities within a community.

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NOTES AND REFERENCES

1. Born, 1978, p. 218. See also, Hendry, 1984, p. 73.
2. Crawford, 2002, p. 106.
3. If not specified, the language of the nomination letters is English. The reports of the NC as well as its experts are in Swedish.
4. P. Pringsheim to NC, Jan. 25, 1930 (Original in German).
5. C. V. Raman and K. S. Krishnan from India, and G. S. Landsberg and L. I. Mandelstam from Russia discovered the same effect nearly simultaneously; but the NC was of the opinion that the Russians did not make the discovery independently. For more detail on NC's decision, see; Singh and Riess, 2001

6. E. Crawford shows that some of the Members of the Committee deliberately tried to reserve the prize permanently, as with the money the Academy could equip and maintain research laboratories in physics and chemistry, the Nobel Institute. See E. Crawford and Frängsmyr, 1989
7. Crawford, 1987, p. 230
8. Crawford, 2002, p. 124
9. Crawford, Heilbron, et al., 1987, p. 132
10. Crawford, 1987, p. 230
11. For C. W. Oseen's contribution to the development of theoretical physics in Sweden, and in particular his supporting of it within the NC, see Grandin, 2000
12. For more detail on I. Waller's understanding of a theory and scientific achievements, see K. Grandin, 2008, pp. 193-214.
13. Report of the NC 1930.
14. Friedman, 2001, pp. 172-175
15. Elzinga, 2006, p. 179.
16. Grandin, 2000, p. 213
17. Elzinga, 2006, p. 77
18. D. Coster to the NC, Dec. 14, 1933 (Original in German).
19. D. Coster to the NC, Dec. 14, 1933 (*ibid*)
20. Expert Report, March 9, 1934.
21. T. Levi-Civita to NC, Dec. 30, 1938 (Original in French).
22. According the will of the founder Alfred Nobel (1833-1896) the prize should be awarded for such discoveries, which "*shall have conferred the greatest benefit on the mankind*. "See E. Crawford, 1987, p. 217. Here, Oseen strictly follows this rule.
23. Expert Report, March 10, 1939.
24. Friedman, 2001, p. 231
25. Crawford, 2002, p. 172, 173
26. Friedman, 2001, p. 248
27. L. de Broglie to NC, Jan., 18, 1945 (Original in French). The letter reached the NC on Feb., 9, 1945. The nomination was considered for the year 1946.
28. H. Yakawa is not mentioned by Crawford, see E. Crawford, 2002, p. 175.
29. J. Franck to NC, Jan. 23, 1947.

30. E. Fermi to NC, Jan. 30, 1947.
31. C. Bialobrzeski to NC, Jan. 16, 1947 (Original in French).
32. E. Fermi to NC, Oct 27, 1947.
33. J. Franck to NC, Jan. 16, 1948.
34. C. A. Coulson to NC, Jan. 2, 1948.
35. G. D. Preston to NC, Jan. 27, 1948.
36. H. Niewodniczánski & J. Weyssenhoff to NC, Jan. 26, 1948 (Original in French). Probably the letter arrived later than the 1st of Fabruary 1948, thus was considered by the Committee for the year 1949.
37. J. Franck to NC, Jan. 25, 1949.
38. E. Madelung to NC, Jan. 22, 1949 (Original in German).
39. J. Franck to NC, Jan. 23, 1947.
40. R. M. Friedman, 2001, p. 254.
41. Ivar Waller (1898 - 1991) on Oseen's suggestion started with lattice dynamics and studied the work of M. Born, P. Debye, CG Darwin and T. von Kármán. In 1923 he was in Göttingen and worked under James Franck. He also attended Born's seminar on the structure of matter. Starting with Peter Debye's theory of lattice dynamics, he developed the theory of x-ray diffraction and scattering by lattice vibrations of a crystal. His intention was to connect the atomic theory with experimental results which was becoming more and more complex. K. Grandin, 2000, p. 214.
42. Expert Report, June 18, 1948.
43. Friedmann, 2001, pp. 256-257.
44. For the Born-Raman controversy, see Singh, 2001, and Sur, 1999.
45. Ramaseshan, 1988, p. XV.
46. Grandin K., in: Beretta, M., Grandin, K., and Lindqvist, S., 2008, pp. 193-214, especially 194.
47. Greenspan, 2005, p. 285.
48. J. Franck to M. Born, Dec. 4, 1953.
49. N. Bohr to NC, Jan. 26, 1950 (Original in Danish).
50. C. Möller to NC, Jan. 26, 1950 (Original in Danish).
51. T. Gustafson to NC, Jan. 28, 1950 (Original in Swedish).
52. C. Bialobrzeski to NC, Jan. 13, 1950 (Original in French).
53. C. Sardon to NC, Jan, 20, 1951 (Original in French).

54. W. Heitler to NC, Dec. 12, 1950.
55. I. Supek to NC, Oct. 25, 1950 (Original in French).
56. A. Landè to NC, Jan. 12, 1952.
57. S. Fianchetti to NC, Jan. 25, 1952.
57. N. Bohr to NC, Jan. 31, 1951 (Original in Danish). The letter reached the Committee on Feb. 2, 1951, so it was considered for the year 1952.
59. C. Möller to NC, Jan. 31, 1951 (Original in Danish). Like Bohr's letter, Möller's letter was considered for the year 1952 as it reached the Committee on Feb. 9, 1951.
60. C. A. Coulson to NC, Dec. 23, 1952.
61. W. Heitler to NC, Jan. 15, 1953.
62. H. H. Staub to NC, Jan. 23, 1953.
63. E. Fermi and J. Franck to NC, Jan. 21, 1954.
64. E. Segré to NC, Dec. 28, 1953.
65. M. Pauthenier to NC, Jan. 28, 1954 (Original in French).
66. H. Fröhlich to NC, Jan. 26, 1954.
67. Report of the NC, Sept. 20, 1954.
68. Expert's Report, (undated), 1954.
69. Expert's Report, (undated), *ibid*.
70. Report of the NC, Sept. 20, 1954.
71. *ibid*.
72. *ibid*.
73. *ibid*.
74. In his first nomination Born proposed Max Planck. M. Born to NC; Nov. 20, 1918 (Original in German). His second nomination followed with J. Franck. M. Born and J. Franck to NC, Jan. 18, 1927 (Original in German). They proposed that either the Prize should be awarded to the American Arthur H. Compton (1892-1967) for the discovery of the effect, named after him or Otto Stern (1888-1969) and Walter Gerlach (1889-1979) should get the prize for the evidence of the quantum space in magnetic field. Born's next candidate was Otto Stern. M. Born to NC, Jan. 24, 1931 (Original in German). During the Second World War Born nominated the British physicist Patrick M. S. Blackett (1897-1954); M. Born to NC, Dec. 11, 1944. About ten years later he proposed Lise Meitner (1878-1968); M. Born to NC, Jan. 20, 1954.
75. Greenspan, pp. 298-299.
76. Greenspan, p. 300.

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