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SIR C.V. RAMAN, DAME KATHLEEN LONSDALE AND THEIR SCIENTIFIC CONTROVERSY DUE TO THE DIFFUSE SPOTS IN X-RAYS PHOTOGRAPHS

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The Indian physicist Sir Chandrasekhara Venkata Raman (1888-1970) and the British crystallographer Kathleen Lonsdale (1903-1971) disputed over the priority of the discovery and the interpretation of diffuse spots on Laue photographs, and types of diamond. In this article, first a shorter review of the theories has been provided as given by different authors to explain the observed spots. Then with the help of Lonsdale's correspondence it is shown, how the editor of *Nature* and the German physicist Max Born supported her.

Key words : X-rays spectroscopy, Diffuse spots in Laue photographs, Lattice dynamic, Dame Kathleen Lonsdale, Chandrasekhara Venkata Raman, Max Born.

INTRODUCTION

Different biographies dealing with Raman's different aspects of life have been referred to in my previous paper[1]. As far Raman's scientific controversies are concerned—one of the well known is his dispute with theoretical physicist Max Born (1882-1970) due to the theory of lattice dynamics. The literature related to it and my own interpretation is given in a separate article[2]. In fact Raman's conflict with K. Lonsdale (1903-1971) due to the diffuse spots on Laue photographs (see Fig 1) was the starting point of the Born-Raman controversy. In this communication, first is provided a short biographical sketch of Lonsdale; then the independent

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'discovery' by the American, British and Indian physicists as well as the explanation put forward by them are discussed. Finally, the point of controversy that arose between Lonsdale and Raman with the possible causes behind it are analysed in the paper.

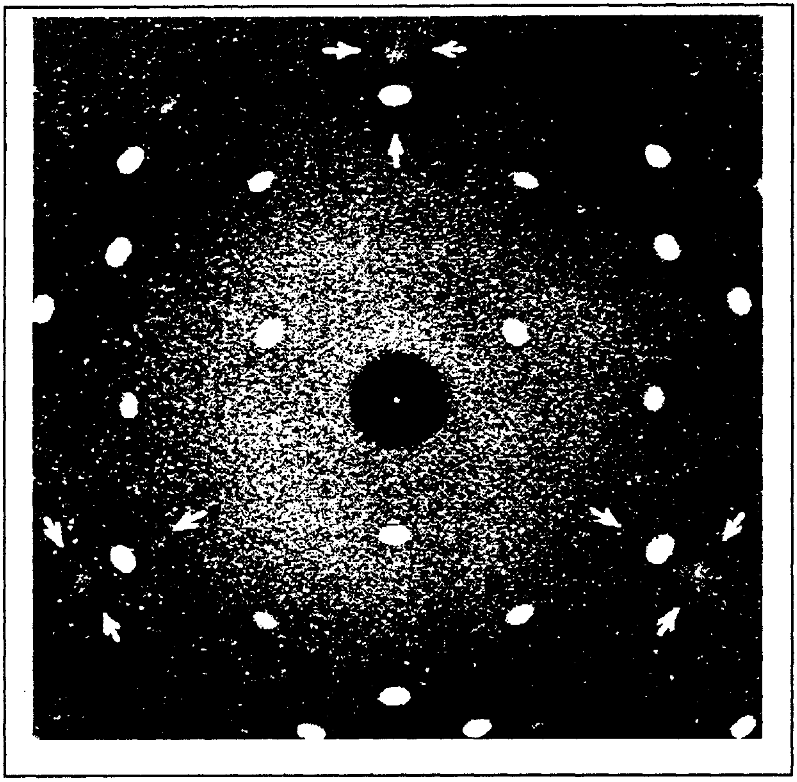

Fig. 1. A Laue photograph of diamond with Laue and diffuse spots. The three spots marked with radial arrows in the figure with the tangential arrows indicate the diffuse spots[3]

Dame Kathleen Lonsdale

In 1922, the tenth child of a postmaster, Kathleen Yardley received her education from the University of London, and joined the research team of the renowned physicist Sir William Henry Bragg (1862-1942). In 1927 she had to leave for Leeds as she got married to a fellow scientist, Thomas Lonsdale. There she worked as a part-time demonstrator at Bedford College. Her work on the structure of crystals of hexamethyl-benzene was her first scientific contribution. She found out that the benzene ring is flat and also determined its dimensions fairly close. In 1931 she rejoined W.H. Bragg's team at the Royal Institute London and stayed there until 1946.

In 1943 she had to spend one month in prison as she refused to pay fine of 2 Pounds, which was imposed on her for not registering for civil defence duties during the Second World War. In the same year she received her first invitation to take part in a scientific meeting organised by the founder of wave mechanics, Erwin Schrodinger (1887-1961), in Dublin. The subject of the meeting was the thermal vibration of atoms and molecules in crystals.

For the first time in the history of the Royal Society, two women were elected as Fellows in the 1940s. Lonsdale was one of them[4]. This election was due to her achievements in the field of thermal diffuse spots and other work in crystallography. In 1946 she was appointed as a reader in crystallography and later professor of chemistry at the University College London. In 1956 she was honoured as "Dame of the British Empire". From 1959 to 1964 she was General Secretary of the British Association for the Advancement of Science and in 1968 became its president.

It seems she was not much interested in theories, as her dictum was *"You do the experiment-don't fuss about what theory says"*[5]. Her major scientific achievements were: in the field of thermal diffuse pattern she showed that in the case of long wave lengths the diffuse scattering is related to the elastic constants of the crystal; the diffuse pattern can be used to determine the molecular orientation; some effects are structure sensitive and not temperature sensitive and must be due to disorder in the crystals, and not to thermal vibration[6].

The Diffuse Spots on Laue Photographs

In 1912 the German physicists Max von Laue (1879-1960), Walther Friedrich (1883-1968) and Paul Knipping (1883-1935) established the fact that a crystal diffracts X-rays[7]. But the determination of crystal structure with X-rays is due to the British physicists William Henry Bragg and

William Lawrence Bragg (1890-1971) who had shown that reflected X-rays pattern obtained in a Laue-photograph is characteristic of the crystal and not of the incident X-rays[8]. In 1914, Peter Debye (1884-1966), a theoretical physicist and physical chemist, suggested that due to thermal vibration of atoms in a crystal, the Laue spots should be accompanied by diffuse spots[9]. In order to extend this work and to explain the diffuse streaks observed by W. Friedrich[10,11,12], the Swedish physicists Olov Hilding Faxen and Ivar Waller studied the position, intensity and the effect of the nature of radiation on the background scattering[13,14,15,16,17].

Now, one may wonder when Laue-photographs were being taken from their time of discovery and also theoretically much was known about the background scattering, then why did the experimentalists neglect this issue ?

Some of the reasons are as follows: Firstly, the theories were too complicated, as either they contained parameters like the inter-atomic forces[18], which were unknown or were 'mathematically laden'. About Faxen's theory, the British experimentalist G.D. Preston lamented:

> "The theory is exceedingly complex-so much so that Faxen did not predict any general background such as observed. It is probable that Faxen's theory does in fact contain all the information required to analyse the pictures but it is not in a readily available form for comparison with experiment, with the exception of one approximate formula...."[19]

And also,

> "The theory of Faxen which takes account of all the waves which can be transmitted through the crystal becomes exceedingly complex. So much so that the implications of his investigations have lain concealed in a mass of mathematical symbolism for over fifteen years."[20]

Secondly, the intensity of the diffuse spots being very low, a long time of exposure was required. For instance the American scientist A.R.P. Wadlund exposed the film for 15 hours[21]. Lonsdale who wrote a detailed report on the diffuse spots had quoted a reference from *Physical Review,* in which an exposition time of 150 hours is reported[22]. Thirdly, diffuse spots are observed only if the Bragg-law (representing relation between lattice spacing, glancing angle of incident ray and the wavelength) is not completely but nearly fulfilled. Lastly, and that is a more important factor, the importance of diffuse beckground scattering was not rightly judged by the scientific community. It was only after the claim on the priority of the discovery and an entirely different explanation by an important person like Raman that intensive investigations started. Shortly after the controversy began, one of the investigators emphasized the importance of diffuse spots as follows :

> "It should be stressed that we have in the diffuse scattering phenomenon a much finer method of exploring the vibrational spectrum of a crystal than is possible by studying, for example, the specific heat"[23].

Also the Royal Society judged rightly the importance of this topic and saw it worth to organise a discussion on this issue on February 6, 1941 and publish it in its proceedings[24].

The experimental work on the diffuse spots in the late 1930s

In 1938-39, A.R.P. Wadlund[25] (USA), G.D. Preston[26] (England) and Raman and P. Nilakantan (India) reported the existence of 'new' diffuse spots on Laue-photographs. After Raman and Nilakantan announced "A New X-rays Effect"[27], Lonsdale attracted the attention of the scientific community to J. Laval's[28,29,30] (France) work that was even older than that of Wadlund and Preston.

In United States, Wadlund found such spots in the case of Sodium- and Potassium Chloride, but had not provided any explanation for them[31]. However W.H. Zachariasen proposed that the diffraction is not due to strain in the crystals but due to the structure of crystal, as its layers/ blocks scatter[32]. He had also shown that Debye's well known formula for the intensity of diffuse spots is incorrect, and the intensity of the diffuse scattering varies much more rapidly with the scattering direction and exhibits a series of diffraction maxima[33]. He gave its experimental verification in the case of rocksalt crystal[34]. Another American, G.E.M. Jauncey gave similar formula for the position of diffuse spots as Zachariasen[35]. Unfortunately, the American physicists had to discard their work. About it, on Jan. 5, 1942 Zachariasen wrote to Born that, "we have joined the war too and I believe that further work on diffuse scattering in this laboratory will have to be postponed for the duration".

In England, Preston from National Physical Laboratory, while experimenting to find out the age-hardening process in alloys observed streaks or 'ill-defined' spots[36]. He suggested that the spots could be due to the presence of small groups, consisting of an atom and its neighbours, which [groups] diffract X-rays more or less independently. Preston rejected Faxen's thermal theory (namely the spots are caused by X-rays scattered due to the thermal vibrations of atoms in a lattice), as he was of the opinion that the shape and position of spots observed, in the case of aluminium, did not agree with Faxen's formula[37].

W.H. Bragg suggested that as the crystal consists of a number of groups of atoms and each group diffract the rays independently. The positions of the spots in a pattern are independent of the size of the group. With a geometrical diffraction formula he was able to explain the position of extra spots in diamond[38]. He also suggested that the thermal movements of the atoms do not affect the geometry of the diffraction pattern, so long as the dimensions of the crystals are not changed[39]. He showed that without taking into consideration the thermal conditions or elastic properties of the crystals the position of spots in the case of calcite, diamond and sylvine could be explained[40].

W.L. Bragg supported Debye and Faxen-Waller thermal theories[41].

At an earlier stage experimentalist Lonsdale did not fix herself to a particular theory[42,43], but later interpreted her results in terms of the theory of Faxen and Waller.

From India, Raman and Nilakantan suggested that the modified reflections come into existence due to the vibration of the crystal lattice, which is quantum mechanically excited by the incident X-rays[44].

The Controversy

The dispute started due to a Raman-Nilakantan communication as they were of the opinion that they had discovered a new type of diffuse spots in crystal[45,46]. To which Zachariasen[47], and I.E. Knaggs and K. Lonsdale et al. pointed out that before Raman's discovery not only Preston but also others had observed similar spots[48]. Whereas G.E.M. Jauncey from the States stressed, "we believe that the effect ... was first established by Wadlund for continuous X-radiation and by Laval [France] for monochromatic X-rays"[49].

Raman, who in between had developed his theory of quantum reflection and supported within a series of experiments[50,51,52,53] replied to the above criticism as follows :

> "While the literature does contain numerous observations on diffuse streaks and spots in Laue pattern for which very varied explanations had been put forward, I wish to point out that the existence of a distinct new type of specular X-rays reflexion of a dynamical kind by the lattice planes of a crystal was for the first time recognised and its physical character elucidated in the publications from this Institute [IIS]."[54] (Emphasis in original).

Lonsdale reacted again and observed that Raman and Nilakantan, who described the diffuse spots as *"A New Type of X-ray Reflection"*, now ignored all the experimental and theoretical work on the subject[55]. Raman replied that Debye and Waller's theories, which are based on thermal vibrations of atoms and are derived on the basis of classical mechanics, predict entirely different intensity, sharpness, geometric positions, and behaviour of diffuse spots at low temperatures than observed by him[56]. Also he was of the opinion that these theories are based on Born's postulate of cyclic boundary condition, which is an ad hoc assumption as it assumes an infinite crystal to calculate the forces among particles. Raman's school saw it as an idealised system[57], which has nothing to do with a real crystal. Also Raman observed that,

> "The recognition that Born's postulate does not correctly represent the infra-red vibrations of a crystal lattice is thus as important for the present subject as an appreciation of the fact that the classical mechanics does not correctly determine the results of an interaction between the X-rays and the crystal latticed."[58].

After the above-mentioned publication there was no more discussion on priority, but the dispute was extended to the spots and their interpretation by different theories.

Proving the existing theories

Waller had given a formula to explain the position of diffuse spots as well as the lattice spacing. Using Waller's concept and also his own, Raman investigated these two factors in the case of rock salt. The results agreed better with the latter theory[59]. Waller had also suggested that the diffuse spots might be due to strain or temperature[60]. In order to check the former issue, Raman studied the bire-fringences as they manifest stress in a material. He observed that the nature of artificial bire-fringences, created by stress on the material was not different from that of diamond lattice. Thus he concluded that the strain is a macro effect and has nothing to do with the structure of diamond[61].

Now, the diffuse spots are nothing but photographic images of the vibration spectrum. Raman's school studied the vibration, scattering, fluorescence and absorption spectra. Not only diamond but also sulphur, phosphorous and quartz exhibited line spectra[62,63]. Apart from that with scattering and luminescence experiments on diamond a number of monochromatic frequencies, that did not find explanation in Debye's theory, were observed. These observations led Raman to believe that other theories, which predict continuous vibration spectra, were not correct.

Raman's challenge to the above-mentioned criticism did not remain unanswered. Lonsdale, Born, Gale (editor of *Nature*), who were supported by W.L. Bragg, reacted.

Response to Raman's criticism

Lonsdale adopted a two-fold strategy; namely she concentrated herself on the experimental side and at the same time took help of the theoretical physicist H.A. Jahn. He calculated the theoretical curves for diffuse light in the case of sodium and proved that their shape is the same as predicted by the Faxen-Waller theory[64,65,66]. Thus Raman's argumentation that the observed shape of diffuse spots is different than predicted by the Faxen-Waller theory was countered. They also showed that the Faxen-Waller theory (which was completed in Waller's dissertation) is capable of explaining the spots, if the elastic constants of the crystal are taken into consideration[67]. However, Lonsdale-Smith could not give any explanation for the temperature independent diffuse spots in some diamonds. But they had shown that one type of diamond shows 'primary' and 'secondary' diffuse spots, while the other type shows only 'primary' diffuse spots[68].

The second part of Raman's criticism (i.e., the vibration spectrum) was left for Born to reply. How Born responded to this criticism has been explored by me in a separate paper. Here without going into detail, at relevant places, Born's reaction will be quoted in the following discussion.

BEHIND THE STATE—THE ROLE OF NATURE

Before starting with this section, it should be mentioned that it would be wrong to interpret this dispute as a 'East-West' or 'British-Indian' controversy, as there are evidences to show that the editors of the prestigious *Proceedings of the Royal Society of London*[69,70] and *Progress in Science* remained neutral. However, the story was different in the case of *Nature*. For instance, Preston was asked by the editor of *Nature* to write a review on the symposium of papers on quantum theory of X-rays reflection published in the *Proceedings of the Indian Academy of Sciences* in october 1941. Before the review was published, according to the wish of Lonsdale and Born a number of changes were made as will be shown with the help of Lonsdale's correspondence.

On February 27, 1942 Lonsdale wrote to Born that,

> "I have had two telephone conversations with Mr. Gale, the editor of *Nature*. He tells me that Preston, although less critical of Raman than we are, has (to use his expression) "come down heavily on our side of the fence". He also said that he would take the three papers [Three papers appeared as joint article from M. Born, K. Lonsdale and H. Smith, under the title-Quantum theory and Diffuse X-ray reflexions, *Nature* 149 (1942), 402-405] (yours, Preston's and ours) to Cambridge, where he lives, and informally discuss with Sir Lawrence whether anything more is needed."[71]

Again on March 5, 1942, she wrote to Born,

> "I expect, your reactions on reading the proof of Preston's article[72] will have been the same as mine. The first part is all right, but he makes several wrong inferences in summing up Raman's symposium: 1. He implies that only Raman's theory gives a frequency change reflection. 2. He supposes that Raman refers to movements of the atoms with the molecule, in molecular compounds. 3. He assents to Raman's claim that his theory is a "quantum-mechanical" one, and that the thermal treatment is a "classical" theory. I have discussed these points with Preston, by telephone, and he has agreed to alter them..."[73].

In fact Preston changed the content of his proof as is evident from the published review. In the communication Preston compared different theories and about Raman's work he wrote: *Although Sir C.V. Raman is confident that his quantum mechanism is essential, it must be admitted that the thermal-elastic theory does give a reasonably accurate account of the observed facts.*[72]

The changes made by Preston were still not to the satisfaction of Lonsdale and Born. On March 9, 1942 Lonsdale wrote to Born that

> "He (Mr. Gale) has agreed to ask the printer to send us all revised proofs so that you can see whether Preston's alternations are satisfactory. If they are not, and if, after correspondence, you cannot persuade Preston to alter his article, he is willing to publish our letters separately."[75]

It seems that Preston did not make further changes. Thus Born-Lonsdale article[76] appeared a week later[77].

The above correspondence leaves no doubt that the editor of *Nature* did his best to give better chances to Raman's opponents.

One of Lonsdale's letters show that W.H. George was asked by Gale to write a review on Raman's symposium on specific heat in a purely descriptive way so that Raman had not a chance to complain[78].

At the same time, after a talk with Lonsdale and Gale, M. Blackman from the Trinity College Cambridge was *"prepared to enter the list against Raman on the question of specific heat curves"*[79]. Together with Born he replied to Raman. They were of the opinion that Raman had calculated his data of specific heat by superimposing a few Einstein's functions according to his interpretation[80]. To Raman's objection on cyclic conditions, they admitted that this was a reasonable approximation, and this method is well accepted by the mathematicians[81]. However, they had nothing to say "about the physical proof of the cyclic boundary condition" as demanded by Raman. Similarly they did not discuss the critical point of appearance of sharp lines in the vibration spectra, though Erwin Schrodinger attempted to push Born in this direction in a letter of March 2, 1942. They did not contribute anything.

Although "Born's authority was much greater than Raman's"[82] it was not great enough to convince everyone. About that Lonsdale wrote to Born:

"I think we shall have to answer him (Raman) *because, as you say, some people are still uncertain whether or not he is right"*[83]. Thus, in order to convince "uncertain" persons, the scrutiny of the experts was sought.

Seeking help from the authorities

Peter Paul Ewald (1888-1985) who was at that time in Belfast, Debye and Schrodinger were encouraged to enter the debate. Ewald did not show much interest towards this issue. He declared that although he was interested in diffuse spots he had no time[84]. As far as Debye was concerned, Gale sent him a letter in which he summed up the whole situation about the controversy. At the same time Lonsdale sent reprints to him once again. Born was also asked by Lonsdale to contact Debye directly[85]. Though Debye did not oppose Raman directly by writing an article for *Nature*, in a private letter he wrote to the editor that *"Perhaps I should mention to you right now that in many respects I cannot agree with Sir C.V. Raman"*[86].

Schrodinger's reply indicates that he received a letter from Born in which the latter lamented that Raman attacked him violently[87]. Schrodinger responded in a letter, which reads:

> "In regards the explanation of the anomalous X-rays-reflections, I am not well informed, but I have formed an idea of it, somehow-probably from reading a letter to *Nature* of yours and from short glimpse at the thick Raman-pamphlet (...). I read with some care Raman & Nilakantan's paper of 10.X.1941, p. 356 ff, especially the experiments with diamond. ... In a word, I find the whole thing a complete blunder. If R. [Raman] has not gone off his wits, I have."[88].

Schrodinger who had formed his views quickly, without realising and understanding the experimental facts gave the above statement. After discussing with one experimentalist (Mr. Peng) he came to know that the extraordinary spots were due to Cu-α radiation[89]. Once he realised his mistake, in his next communication he informed Born about it.

Though Schrodinger morally supported Born, he saw rightly that there was something convincing in Raman's work. He suggested to Born that

> "Either you or Mrs. Lonsdale, in a future publication, should give a simple derivation of Raman's funny formula that fits quantitatively with his experiments! For if you don't, people with or no clear insight into theory will believe that his formula can

only be derived in his lunatic way and, since it is so well supported by experiment, they will take that to be a confirmation of this lunatic way of thinking"[90].

Schrodinger who in between had derived a formula for the position of the diffuse spots was asked by Born to publish it[91]. It seems that Schrodinger's formula was never published because it supported W.H. Bragg's theory, as a letter Lonsdale wrote to Born reveals[92]. It reads:

"I am very much afraid that if Schrodinger intervenes at this stage with what is exactly repetition of Sir William's arguments, he will hopelessly confuse the whole issue. ... I will send him copies of all our papers ... and I do hope you will be able to persuade him to read them and to consider the later experimental results before he does anything more. ... I do want to avoid further confusion of the issues as far as it can be avoided."[93].

The above discussion shows that Lonsdale, Gale (editor of *Nature*) and Born were unsuccessful in winning the public support of Debye, Ewald and Schrodinger.

Neither the forgoing discussion nor Lonsdale's correspondence discloses the full grounds for the group's opposition to Raman. In the following section some possible causes are suggested.

Possible Reasons for Hostility

It will be helpful to check Raman's political views about the British, as for historical reasons, it is likely that there were reserves between Indian and British scientists.

Raman, who was proud of his culture and propagated his countrymen not to be mere learners of western science[94], believed in the international character of science. Already very early while addressing the convocation at the University of Mysore on August 24, 1929 Raman stated: *"Knowledge is universal by its very nature. A fact of nature newly discovered is a discovery whose significance or utility cannot be altered by the colour of the discoverer's skin or his nationality"* (Private copy by the RRI).

There is hardly any evidence to prove that like most of the Indian scientists, Raman protested against the colonial Government before 1940s. Particularly during the Second World War, Raman was one of those who supported the British cause. For example, a local newspaper dated July 4, 1940 published Raman's statement, which he gave while addressing at a public meeting convened by the Mysore War Fund Committee. The statement reads :

> "We in India are so sunk in stupor, bred and peace, that we are in this country have not realised the reality of the terrible danger we are in. I wish Hitler or Mussolini would send a few planes and bomb a few of our cities, like Bangalore, Madras, Bombay, Calcutta, Karachi and Lahore. That would make the whole India war-minded more effectively than thousands of meetings. ... If only people in India realised what the present Germany and Italy were, they would understand that they would get it in the neck from Germany if they did not prepare early enough to assure a British victory." (Emphasis in original).

But as the scientific controversies went on, he changed his opinion about the British. In the middle of the 1940s delegates were sent to England to work for 'post war' programmes, but Raman refused to join them. In 1946 at the occasion of the annual session of the Ceylon Association of Science, while talking about types of diamonds he observed that *"India cannot claim to have obtained her independence until that stolen diamond [Raman pointed out to the diamond named the 'Kohinoor', which was taken away by the Colonial Government from an Indian King] was returned to her"*[95]. Whether Raman's opponents had political motives is difficult to say with the help of available documents, However, what seems to be certain is that at that stage Raman became a serious challenge to the existing theories of lattice dynamics and their supporters like Lonsdale due to the following reasons:

(a) He was able to propagate his views using mass media and scientific journals. For instance the *Proceedings of the Indian Academy of Sciences* was an international periodical being received by the British scientists: W.H. Bragg, Sir Frederick Gowland Hopkins (1861-1947), Sir J. Russel, Sir Owen William Richardson (1879-1959), Archibald Vivian Hill (1886-1977), Paul Adrien Maurice Dirac (1902-1984); Americans: Robert Andrews Millikan (1868-1953), Arthur Holly Compton (1892-1962); *German:* Arnold Sommerfeld (1868-1953), Werner Heisenberg (1901-1976), Friedrich Paschen (1865-1947); *French:* Irene Curie Joliot (1897-1956); *Swede:* Kai Manne Georg Seigbahn (1886-1978); *Danish:* Niels Bohr (1885-1962) and *Dutch:*

Laureate Pieter Zeeman (1865-1943)[96]. For instance, in America to make his theory known and to counter his opponents Raman sent the *Proceedings of the IAS* to Leonard Benedict Loeb, who on February 25, 1942 responded to Born as follows, "I have received the complimentary copy of the symposium of papers on the 'quantum theory of X-ray reflection'". Loeb stated that although these papers were somewhat outside his own field, yet he read them with considerable interest. In order to make them more generally available to the Department he turned the volume over to the department library".

(b) Another scientific journal *Current Science* was under Raman's influence. Apart from that the local Indian newspapers were propagating Raman's views. Some of the head-lines mentioned are: *"Specific Heat of Solids—Sir C.V. Raman's New Revolutionary Theory—Investigations on X-rays Reflection"*[97], *"New Concept of the Solid State—Sir C.V. Raman on his Investigations"*[98] *"The Structure of the Diamond-Sir C.V. Raman's Lecture"*[99], *"New Approach to Matter—Sir C.V. Raman on the Structure of Matter"*[100] and, *"Secret of the Diamond"*[101].

(c) Being the only Nobel Laureate in Asia in the field of physics he was something special. The masses flocked to hear him. Once a local newspaper reported under the title, "Sir C.V. Raman's lecture-People banned entry without police pass!—Pressmen kept out "Thus it is evident that Raman was a 'phenomenon'. Even his capability of writing a speech was also highly developed. For instance, Raman's opponent, Lonsdale wrote to Born that the editor of *Nature* Gale had a communication from Raman, and "the trouble is, however, that his article is like some political speeches; it sounds so impressive and is delivered with such authority that it is difficult to realise that it is pure nonsense"[102].

(d) During the Second World War, the colonised countries were certainly not pro-Western. At this stage, Raman started emerging as a leading figure on the Asian continent. In 1942 the Chinese Physical Society honoured him[103]. On December 11, 1943 while addressing at a college he told that the Chinese Government has invited him for six months to acquaint their students with his new theory of the solid state. He also informed that Dr. Ta Woo of China would come to the IIS to work together with Raman[104].

(e) Apart from that the political situation at that time was in Raman's favour. Due to the war the western scientists had to change their projects and work for war efforts[105,106]. On the other hand, Raman was free to choose his field of research, and boost his theories.

(f) Raman's work was more than qualitative as the theory and experiments were supporting each other as was evident from different publications on spots in the Laue photographs[107,108,109,110].

It seems under these circumstances, the only way to stop Raman's "right or wrong theories" and promote others was to refute Raman's ideas in India and England. Lonsdale remained unsuccessful in India as *Current Science* refused to publish her paper[111]. But in England the situation was different.

Closing thf dispute

In order to complete the Lonsdale-Raman story, it should be mentioned that on the basis of diffuse spots and other studies, Raman suggested that the face-centred cubic lattice of diamond does not only show a tetrahedron but also an octahedral symmetry in positive and negative. Thus there are not only two but four types of diamonds[112,113]. Lonsdale, who has rechecked the two types of diffuse spots in diamond as suggested by Raman responded that *"This is a startling theory, for it implies the existence of a number of allotropic forms of all crystals of carbon compounds; but Raman supports his theoretical speculations with a wealth of interesting experimental evidences"*[114]. However, Raman argued that Lonsdale's studies on diamond's diffuse spots cannot give full information as for symmetry reasons diamonds structure cannot be determined with this method.

After the above-mentioned dispute, there was peace between the two. As far as their personal contacts were concerned at least once-in 1948-Raman met Lonsdale at the first meeting of *The International Union of Crystallography* in Harvard in 1948[115].

Raman's theories, which were based on experimental results and intuition were able to explain lattice spacing, intensity and position of diffuse spots. Also one could calculate the specific heat and line spectra with a reasonable accuracy[116]. But in the case of diamond he was not quite correct. Today we know that nearly 98% of natural diamonds contain impurities like nitrogen (which is present at several different types of aggregates), hydrogen and boron[117]. Thus the temperature independent extra spots and some properties studied in diamond by Raman's school were due to impurities.

Conclusions

In the late 1930 the research in the field of lattice dynamics revived an impetus due to the dispute on the priority of the discovery and the difference in opinion on the origin of the background scattering. It was also during this epoch that the importance of background scattering in crystals was recognised. The controversy clearly shows that the dispute among different scientists may lead to the progress in science, as the competitors try to disprove others ideas and imposed his own views. In the above case, Londsdale concentrated on the study of diffuse spots in detail and thus established different facts related to the spots and properties of crystals. On the other hand her opponent Raman chalked out a long programme to study crystals. In this process established a strong group of physicists in Bangalore who later contributed to the development of crystallography in India.

Raman who had financial resources and manpower would have needed a modern theoretical physicist as well as an established crystallographer to discuss his results. He worked isolated and did not sought support or suggestions from others.

Raman who established the *Proceedings of the Indian Association for the Cultivation of Sciences*, the *Indian Journal of Physics* and the *Proceedings of the Indian Academy of Sciences* knew the importance of having his own scientific journals. It was only due to these facts that he survived the attacks of strong institutions like *Nature* and some of the people from the Royal Institute London.

Though nothing definite can be concluded about the intention of Raman's opponents to refute his ideas, yet it is suggested that it was intended to diminish Raman's influence in the scientific community, as his theories were simple and well supported by experiments, thus more appealing.

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