

## Measuring Citation Impact of Bose's Paper Planck's Law and the Light Quantum Hypothesis

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### Abstract

This paper presents an overview of the most recent citation pattern in S.N. Bose's work on Planck's formula derivation and light quantum hypothesis, with a special focus on geographical distribution of citations received by him. This work is a quantitative assessment of the relevance and influence of the highly cited paper of the scientist under study and intends to ascertain from the number of citations received by Bose in later day publications. The main aim of this work is to assess how far pioneering S.N. Bose was and to trace how much perpetual quality has the derivation of Planck's formula, results and the value of results. Different potential source materials or tools such as Science Citation Index (SCI: five yearly cumulated hardcopy volumes) from 1945 onwards in the National Library of India in Calcutta, Websites including citation databases like Google Scholar etc. online have been consulted to prepare a citation history to his paper. The paper under study was further searched for citations as per Web of Science (SCI — online database) ranging from 1900 up to and including January, 2022. It can be concluded that a comparison may be made of the work of peer researchers in similar fields who have been bringing out for a wide range of time periods. But the distribution of citations limits their usefulness to pointing out the acuteness. Many a time delayed citations are not easily traceable as they occur highly scattered or via intermediary citations i.e. citing a source within a source (citing a secondary source of publication) that in turn cites the original. Furthermore, the time gap of the work of Bose and evidences in support of his interpretations is so large that the core (actual) citations to his fundamental works couldn't be detected.

**Keywords:** Citation, Impact, Core, Distribution, Interpretations

**Abbreviations:** SNB (S.N. Bose), SCI (Science Citation Index), WoS (Web of Science)

## INTRODUCTION

This paper presents an overview of the most recent citation pattern in S.N. Bose's work on Planck's formula derivation and light quantum hypothesis, with a special focus on geographical distribution of citations received by him. Satyendra Nath Bose (1894-1974), an Indian theoretical physicist started academic life at the University of Calcutta where he obtained a degree in Mixed Mathematics in 1915 and became a lecturer in Physics and Applied Mathematics in 1917. S.N. Bose later joined to the University of Dhaka and it was there in 1924 that he wrote his most popular paper "*Planck's law and the light quantum hypothesis*", which he sent to Albert Einstein for comments. Einstein, recognising the significance of Bose's paper, translated the paper into German and forwarded it to *Zeitschrift fur Physik* with his own comment. The paper was subsequently appeared in August 1924 in the aforesaid journal. S.N. Bose showed that the photons had a new property of being strictly identical. A greater number of elementary particles such as photons in the universe are 'Bosons', named after him. This paved the way of new concept which was in contrast to the then accepted basis, so-called Maxwell-Boltzmann theory (named after James Clerk Maxwell and Ludwig Eduard Boltzmann). The present study has undertaken citation analytical study of the most cited work of the pioneer scientist S.N. Bose (1894-1974) brought world's attention to Indian science through his work which was even endorsed by Einstein (1879-1955).

This work is a quantitative assessment of the relevance and influence of the highly cited paper of the scientist under study and intends to ascertain from the number of citations received by Bose in later day publications. This work intends to study the correlation of simple citation counts with various indicators or derivatives of citation parameters which emphasize one or another feature of the scientist's performance. The main aim of this work is to assess how far pioneering SN Bose was and to trace how much perpetual quality has the derivation of Planck's formula, results and the value of results.

## OBJECTIVES

Main objectives of this study are:

- (i) To measure the relative impact of the scientist and his paper by counting the number of times that the scientist or publication has been cited by other works. Actually, it is a measure of influence potential as indexed by attained impact over a period of time.
- (ii) To provide the average citations per year which indicate information regarding the relevance, impact and value of the publication.
- (iii) To present the geographical distribution of citations received by the Bose's paper.

## **METHODOLOGY**

The physical research paper of S.N. Bose was collected from his biography edited by Santimay Chatterjee [1]. Different potential source materials or tools such as Science Citation Index (SCI: five yearly cumulated hardcopy volumes) from 1945 onwards in the National Library of India in Calcutta, Websites including citation databases like Google Scholar, Wikipedia etc. online have been consulted to prepare a citation history to his paper. The paper under study was further searched for citations as per Web of Science (SCI — online database) ranging from 1900 up to and including January, 2022. The collected citation related data were then analysed. Results were presented both in tabular and graphical form. Geographical distribution of the citations received by the scientist was prepared in the tabular form. By and large, the citations those were received in other research papers or journal-articles (except e-publications and thesis) were taken into consideration. Self-citations were not considered for the present study. Only principal citing authors (first authors of the citing papers) and the countries where they were affiliated to were taken into account in the citation history of the physical paper.

## **LITERATURE REVIEW**

The phrase 'citation profile' was used in the title of Sinha & Ullah's paper [2] for the similar study. Several bio-bibliometric studies were prepared using the phrases like "citation pattern", "citation analysis", "bibliometric indicators" etc. in the title of the papers of various information scientists [3-8]. Sinha and Bhatnagar [9] probably first conducted a biobibliometric study in 1980 and used the terms "information profile" for quantitative measuring of the scientific productivity of a plant pathologist. The phrase "citation profile" was used in the title of Sinha and Ullah's paper [10] for the quantitative study. 'Biobibliometrics', however, the term was first used by Sen and Gan [11] in 1990 to define as the quantitative and analytical method for discovering and establishing functional relationships between bio-data and bibliodata elements. There are many biobibliometric studies, but have hardly been used the term 'biobibliometrics' in the titles of the papers except for Sen & Gan [11] and Tiew [12]. Kalyane and Kalyane [13] first used the phrase "scientometric portrait" to carry out biobibliometric studies on scientists. Kalyane and Devarai [14], Kalyane and Samanta [15], Devarai and Ramesh [16] used the term 'informetrics' in the titles of their papers. However, there was continuous use of the phrase "scientometric portrait" to measure the scientific productivity of individual scientist except for Kademani, Kumbar & Surwase [17] who used the terms "informetric portrait" in the title of their paper. "Scientometric profiles" have also been used by the author in the title of his Ph.D. thesis to conduct a scientometric study considering some Indian scientists altogether [18]. There have been a number of studies following the line of work initiated by Sen and Gan [11]. These are Kalyane and Kalyane [19]; Kalyane and Kademani [20]; Kalyane [21]; Kalyane and Munnolli [22]; Kalyane and Sen [23]; Kademani and Kalyane [24] and Kademani et al [25].

### CITATIONS OBTAINED BY THE BOSE'S PAPER PLANCK'S LAW AND THE LIGHT QUANTUM HYPOTHESIS [<sup>26]</sup>

Table 1 gives the geographical distribution of citations received by S.N. Bose and the percentage of citations to the corresponding countries where first authors of the citing articles were affiliated. Among the top research workers who were citing his paper from the USA with 146 (26.84%) citations followed by Germany with 86 (15.81%) citations, India with 44 (8.09%) citations, the UK with 28 (5.15%) citations, Italy and France both with 27 (4.96%) citations. It is also seen that the most of the citing authors were from related fields of physics and only about twenty to twenty five researchers cited the paper of S.N. Bose in their biographical works or works related to history and philosophy of science.

**Table 1:** Country-wise distribution of citations received by the paper of S.N. Bose [<sup>27-31</sup>]

1	2	3	4	5
Ranks	Geographical locations of the institutions where citing authors affiliated to	Citations received	Percentage of citations	Cumulative percentage
1	USA	146	26.84	26.84
2	Germany	86	15.81	42.65
3	India	44	08.09	50.74
4	UK	28	05.15	55.89
5	Italy	27	04.96	60.85
6	France	27	04.96	65.81
7	China	26	04.78	70.59
8	Russia	14	02.57	73.16
9	Australia	11	02.02	75.18
10	Japan	10	01.84	77.02
11	Spain	9	01.65	78.67
12	Canada	9	01.65	80.32
13	Poland	9	01.65	81.97
14	Switzerland	9	01.65	83.62
15	Brazil	7	01.29	84.91
16	Netherlands	6	01.10	86.01
17	Hungary	6	01.10	87.11
18	New Zealand	6	01.10	88.21
19	Austria	5	00.92	89.13
20	Turkey	5	00.92	90.05
21	Belgium	4	00.74	90.79
22	Portugal	4	00.74	91.53
23	Greece	4	00.74	92.27
24	Ukraine	4	00.74	93.01
25	Sweden	4	00.74	93.75
26	Ireland	3	00.55	94.30
27	Denmark	3	00.55	94.85
28	Mexico	3	00.55	95.40
29	Iran	3	00.55	95.95
30	Norway	2	00.37	96.32
31	Israel	2	00.37	96.69
32	Singapore	2	00.37	97.06
33	Cameroon	2	00.37	97.43

34	Serbia	2	00.37	97.80
35	Czech Republic	2	00.37	98.17
36	South Africa	1	00.18	98.35
37	Chile	1	00.18	98.53
38	Cuba	1	00.18	98.71
39	Algeria	1	00.18	98.89
40	Argentina	1	00.18	99.07
41	Uzbekistan	1	00.18	99.25
42	Bangladesh	1	00.18	99.43
43	Luxembourg	1	00.19	99.62
44	Kenya	1	00.19	99.81
45	Iraq	1	00.19	100.00
<b>Total</b>		<b>544</b>	100.00	

Table 2 shows that the scientists from the European countries cited the paper of Bose much greater than the citations from the scientific communities of American and other countries. The main reason is that the highly cited paper (1924) brought him instant international recognition.

**Table 2:** Continent-wise distribution of citations received by the paper of S.N. Bose [27-31]

1	2	3	4	5	6	7
Ranks	European countries where citing authors affiliated to	No. of Citations	American countries where citing authors affiliated to	No. of Citations	India and other countries	No. of Citations
1	Germany	86	USA	146	India	44
2	UK	28	Canada	9	China	26
3	France	27	Brazil	7	Russia	14
4	Italy	27	Mexico	3	Australia	11
5	Spain	9	Chile	1	Japan	10
6	Switzerland	9	Argentina	1	New Zealand	6
7	Poland	9			Israel	2
8	Netherlands	6			Singapore	2
9	Hungary	6			Cameroon	2
10	Turkey	5			S. Africa	1
11	Austria	5			Cuba	1
12	Belgium	4			Algeria	1
13	Portugal	4			Bangladesh	1
14	Greece	4				
15	Ukraine	4				
16	Sweden	4				
17	Ireland	3				
18	Denmark	3				
19	Iran	3				
20	Czech Republic	2				
21	Serbia	2				
22	Norway	2				
23	Uzbekistan	1				
24	Luxembourg	1				
25	Kenya	1				
26	Iraq	1				
<b>Total</b>		<b>256</b>		<b>167</b>		<b>121</b>

Table 3 represents the citation profile of S.N. Bose's most cited paper *Planck's law and the light-quantum hypothesis* [26], 1924 received 544 citations in 99 years (difference between the years of first and last citation) and it has been citing from its publication year i.e. 1924 and it was last cited in 2022 (till the date of last accessed SCI and WoS). It is also seen that the Indian research workers who rarely cited (44 times) his paper in their respective contributions in 9 Indian journals on the related field of study. Bose got at an average of 5/6 citations by this paper per year. Out of 544, 42 citations received by the *Physical Review A*, 17 citations by the *Zeitschrift fur Physik*, 17 citations by the *Physics Letters A*, 17 citations by the *Journal of Physics B*, 13 citations by the *Physical Review B*, 11 citations by the *Journal of Physics A*, 8 citations by the *American Journal of Physics*, 5 citations received by the *Current Science* and the rest 414 citations by different journals.

**Table 3:** Citation profile of Bose's paper [26-29]

<b>1</b>	<b>Name of the Paper</b>	<i>Planck's law and the light quantum hypothesis</i>
<b>2</b>	<b>Subject</b>	Quantum Physics
<b>3</b>	<b>Year of Publication</b>	1924
<b>4</b>	<b>No. of Pages</b>	4
<b>5</b>	<b>No. of References</b>	Appended no references
<b>6</b>	<b>No. of References to Indian Journals</b>	-
<b>7</b>	<b>No. Cited</b>	544
<b>8</b>	<b>No. of Average Citations per Year</b>	5
<b>9</b>	<b>Median age of Citations</b>	82
<b>10</b>	<b>Modality of Citations</b>	37
<b>11</b>	<b>No. of Citations in Indian Journals</b>	9

William A. Blanpied, an American physicist who referred the seven (7) papers of S.N. Bose in the *American Journal of Physics* in 1972. But, all the seven papers of Bose were cited by Blanpied in a biographical work on S.N. Bose — "*Satyendranath Bose: co-founder of quantum statistics*". He did not cite any of the papers of Bose in his core physical papers. Blanpied's citations do not indicate the actual importance of the papers of Bose. But it has been known from his biography that Bose sent his manuscript of the paper once rejected by the editors of the *Philosophical Magazine* to Albert Einstein, the German Physicist. *Zeitschrift fur Physik*, a German peer reviewed scientific journal of physics, published his paper that had received a maximum number (544) of citations. The paper in which Bose derived Planck's quantum radiation law, which he was able to do by counting states by identical properties would later prove seminal in theorizing the field of quantum statistics. Einstein opined that Bose's derivation of the Planck formula signifies an important step forward in the formulation of quantum statistics and the German scientist did not forget to state that the method considered in his paper yields also the quantum theory of ideal gases. Einstein's comment on the paper of S.N. Bose may prove the worth and importance of his papers.

In due course, following the Bose's line of work, the Italian-American physicist Enrico Fermi <sup>[32, 33]</sup> and the British physicist P.A.M. Dirac <sup>[34]</sup> independently showed that the electrons follow a different set of rules. The extension of SNB's theory to particles of arbitrary mass and non-zero chemical potential by Einstein <sup>[35-37]</sup>; the Fermi-Dirac <sup>[32-34]</sup> Statistics for electrons, Werner Karl Heisenberg and Wolfgang E. Pauli <sup>[38, 39]</sup> for the quantisation of the electro-magnetic field, and quantum electrodynamics by Dirac <sup>[40]</sup>. To enquire the relation between particle type and the statistics which it followed left by Pauli <sup>[42]</sup> who presented that the integral spin particles obeyed both the Bose and Fermi Statistics. A.J.W. Sommerfeld <sup>[41]</sup> clearly showed the real possibilities of quantum statistics by introducing Fermi-Dirac Statistics to metal physics. Fritz London <sup>[43, 44]</sup> suggested in his condensed phase that super fluid Helium should be related to Bose-Einstein condensation phenomenon. S.N. Bose also discovered the very important concept in particle physics such as the spin of elementary particle in the same paper. Indeed, his work became the crucial connection between the earlier quantum theories of Max Planck, Neils Bohr and Albert Einstein and the modern quantum mechanics of P.A.M. Dirac, W. Pauli, and W.K. Heisenberg.

The almost innate disinclination of the western scientists to recognise the research of an Indian scientist, i.e. non-western scientist may also have played its role here. It has been noticed that the western scientists are not eager to pay much attention to a momentous work of an Indian scientist at the primordial stage. However, they are ready to confer honours to the same Indian scientist if one of their fellow brethren acknowledged the epoch-making work of the same person. Indian history of science bears witnesses of these kinds of stereotype service to Indian science by the western scientist. As an instance, it may be said that what citations SNB's first paper of 1924 <sup>[26]</sup> received were for the endorsement of his paper by the renowned German physicist Einstein. Else, it would be a difficult task for him to receive such a big number of citations to the same paper.

It is worth mentioning that the huge number of citations (544) out of which almost all foreign citations received by the Bose's paper clearly indicates the international accreditation and perpetual quality of his research works and thus proved to be a pioneering one. Furthermore, this highly cited work also reveals that the Bose Statistics undoubtedly made it possible through the opening of new doors to the achievement of modern physics with what is now may be called Higgs Boson (popularly known as "God particles").

## **Findings**

Major contribution of an individual scientist or the team efforts not only serves the purpose of true documentation of scientific productivity but also acts as an indicator of a successful or glorious research team cognizance. This research publication by S.N. Bose thrived Bengal science and as such raised Indian science to the landscape of world science generating purely new experimental outcomes by undertaking studies of basic research of the emerging fields of modern physics. Thus, this

scientometric work elucidates the gradual progress of early modern science of Bengal and its role in the evolution of the modern science research in India.

It has been found out that S.N. Bose's paper *Planck's law and the light-quantum hypothesis* (1924) received 544 citations in 99 years (difference between the years of first and last citation) by his aforesaid paper which has been citing since its year of publication and was last cited in 2022 (the year upto which last accessed). It has been also found that the time-lag between the year of publication of S.N. Bose's most cited paper and its first citation is nil i.e. zero. Smaller time-lag implies how contemporary the paper is or how far it is connected with the evolving research area. Usually "zero time-lag" indicates the much deedful or rapidly outspreading research domains.

Out of total citations (544), the researchers from the USA cited S.N. Bose's most cited paper with 146 (26.84%) citations followed by Germany with 86 (15.81%) citations and India with only 44 (8.09%) citations. Although, predominating by the scientists from European countries over the scientists of American and other countries is evident in the continent-wise distribution of citations to his paper.

It is also seen that the Indian research workers who rarely cited his paper in their respective contributions in 9 Indian journals on the related field of study. As per the median age of citations, the most cited paper of S.N. Bose received first half (272) of citations in 82 years and rest half (272 citations) received only in 17 years. This shows that the highly cited paper of the scientist received citations rapidly in last 14/15 years back from the year last accessed WoS i.e. 2022. Notably, the number of average citations per year he obtained is 5.

## 7 CONCLUSION

This study may be helpful to get an idea regarding the paper's past citations and the regularity of citation patterns. It can be suggested that a comparison may be made of the work of peer researchers in similar fields who have been bringing out for a wide range of time periods. But the distribution of citations limits their usefulness to pointing out the acuteness. Many a time delayed citations are not easily traceable as they occur highly scattered or via intermediary citations i.e. citing a source within a source (citing a secondary source of publication) that in turn cites the original. Furthermore, the time gap of the works of Bose and evidences in support of his interpretations is so large that the core (actual) citations to his fundamental works couldn't be detected.

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