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NOBEL PRIZES IN QUANTUM MECHANICS: A STATISTICAL APPROACH

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The present article presents a systematic overview of the Nobel Prize winners over the last 115 years in Physics, particularly one of its branches — quantum mechanics, based on the data available over the same period. An attempt has been made to show the trend lines of the area of research in quantum mechanics in this period. Quarter-wise analysis of the prizewinners is also presented. Various factors such as beneficiary Universities, respective countries, and age factors of Nobel laureates are discussed. The results of statistical analysis are discussed in the light of the implications for novices, who have a keen interest to know more about the development of quantum theory.

Key words: Nobel laureates, quantum mechanics, statistical analysis.

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I. INTRODUCTION

The Nobel Foundation based in Sweden has been awarding the most prestigious Nobel Prize for more than a century, to carry out the final will of the Swedish chemist and inventor Alfred Nobel who wished to recognize people whose work has conferred the greatest benefit to mankind. The prizes are awarded in five different fields for outstanding work, i.e. in Physics, Chemistry, Economics, Medicine (Physiology), Literature and Peace. The prize has achieved an enormous social fame internationally for the performance given by the laureates in their respective fields. Nobel Prize had proven that it becomes a social force, which not only shapes the organization, individuals but also improves the living standard of human beings through the elaborated theories especially in science. According to Alfred Nobel's will, the award and its selection criteria is administered by the Nobel Foundation, consisting of five member committees which are bound to Royal Swedish Academy of Sciences. On the death anniversary of Nobel that is on December 10 every year the award is presented in Stockholm. Each winner receives a medal and a monetary award prize, which is varied every year [1–3].

The Nobel Prize in the area of Physical sciences was established in 1901. It was meant to felicitate the person who invented or discovered the most groundbreaking research in the respective field. Laureates get public recognition and testimony for their work and are expected to play a vital role for deciding future policies in improving technological developments. Due to the fame that makes Nobel Prize a prestigious award internationally, common researchers are always eager to know about the field of study interests as well as background of the winner. The statistical analysis of all the Nobel prizes in the respective field is also of curiosity and general scholarly interest. Details of Nobel laureates always add flavors in a student's educational life. Currently, abundant demographic analysis has been done by a number of people about the winners, mostly in all the mentioned five areas. However, scarce literature is available about the specialized field. In this article, a systematic analysis of Nobel laureates in quantum mechanics is presented over a period from 1901 to 2015. The main thrust of the statistical analysis is to elaborate the key areas to which the winners had contributed, owing to which the quantum theory has developed in the last century. Along with the Nobel winning concepts, there are many such discoveries and inventions which were excluded from the award viz. Einstein's mass-energy relation was the famous one. It also excludes the contributors before the 20th century such as Newton, Galileo, Faraday, etc. for their pioneer work, which really helped experimental and theoretical physicists to develop as a specific subject in scientific community. On the similar line, researchers in quantum mechanics, which were supposed to be considered for the award, but excluded and not been recognized, introduced few concepts. In the current article, a special highlight is given on these theories. The article also provides an overview of the laureates along with their respective award winning areas, which may be significant enough for those who are interested and has plans to enter a fascinating field of the quantum world [7–11].

II. ON QUANTUM MECHANICS AND ITS DEVELOPMENT

Before going into a detailed analysis of the award winners and their remarkable work, it is essential to overview the basic notions and building blocks of quantum mechanics. This will facilitate to emphasize the significance of the award winning concepts.

In the early decades of the nineteenth century, it was well known that the Newtonian mechanics could describe the motion of rigid and celestial bodies. However, these laws failed to elucidate the motion of subatomic particles but, on the other hand, quantum theory had a great success at it [4].

Quantum mechanics plays a decisive role at the micro level. The transistor, electron microscopes and the laser based on quantum concepts are a few examples to mention. Moreover, superconductivity, photonics, spintronics and nanotechnology, which promise to give a completely different and better shape to the existing technologies, are also the outcome of quantum mechanics and speak of an importance of the theory [5].

The discovery of a dual nature of matter and waves had been a landmark in quantum theory. This changed the entire perception about these notions. In 1900, one year prior to the inception of Nobel prizes, Max Planck laid a foundation stone of quantum mechanics, with the quantum theory of black body radiation; through which he proposed that the electromagnetic radiations are emitted in discrete bundles and not continuous. The bundle of energy is an integral multiple of frequency of radiation. which later was termed as "quanta" and led to the stepping-stone for quantum mechanics. A couple of years later, one of the greatest physicists: Niels Bohr coined the term "quantization" which assumes that angular momentum changes discontinuously with certain discrete values. The concept of a bundle of energy packets, now known as photons, has its origin during the same period, which resolved the mystery of the hydrogen atom spectrum and orbital motion of electrons unexplained classically. It is believed that this was the end of the classical era.

Later in 1923, the French physicist Louis de-Broglie explained the wave nature of particles. In 1924, the Indian Physicists Satyendra Bose along with Albert Einstein formulated the appropriate statistical law for the particles (now called "Bosons") known as Bose–Einstein distribution law. In 1925, Uhlenbeck and Goudsmit discovered the spin of electron, one of an important property in quantum mechanics. A theoretical matrix mechanics was developed by Werner Heisenberg in the same year, which after a few decades further elaborated by Max Born and Pascal Jordan provided a statistical touch to the wave function. This initiated a specialized branch named nonrelativistic quantum theory. In 1926 wave mechanics was invented by Schrodinger with the specialized wave function Ψ, which turned out to be another formulation of mathematical quantum theory. Wolfgang Pauli explained wave theory (1927) by using spin concept and in 1928 Paul Dirac formulated the relativistic version of quantum mechanics. The period, 1920 to 1930, will always be remembered as a crucial decade which witnessed the revolutionary development of quantum mechanics.

The theory was then applied for inventing fascinating applications like maser/lasers (Charles Townes–Nicolay Basov–Aleksander Prokhorov), quantum electrodynamics (Julian Schwinger–Richard Feynman), quantum Hall effect (Klaus Von Klitzing), etc. Even in the 21st century it has been demonstrated that this theory is still emanating an exciting phenomenon such as controlling quantum states which is necessary to develop a new generation of quantum computers [4–6].

Despite its success to explain matter and energy in terms of their basic building blocks, solving the mystery of ultraviolet catastrophe, behavior of elementary particles at the atomic level, etc. quantum mechanics is still treated as an abstract theory due to the wrong perceptions and avoiding application oriented visual approach towards the theory. However, the enormous contribution of quantum mechanics and its patrons led to the most fascinating award, the Nobel Prize, a number of times.

III. THE ANALYSIS

The analysis of Nobel Prize admiration for contributors in quantum theory was accomplished by developing a data bank comprising of details of laureates along with their countries, field of research, year in which they were felicitated, organization in which the work was being carried out, etc.

To know the respective field of research, the Nobel lectures were reviewed in detail proceeding from which the core area for award was identified. Table 1 presents compilation of the database. The analysis also includes the fact that the Prizes were not awarded to individuals or any organization in the field of Physics in the years 1916, 1931, 1934, 1940–42.

The analysis based on the quarter century in which prizes were awarded, age of laureates, their nationality, university, etc. is presented in the following sections.

A. Quarter

The quarter-wise awards won by laureates are presented in Figure 1. The first quarter of the 21st century is considered as a fifth quarter of the prize.

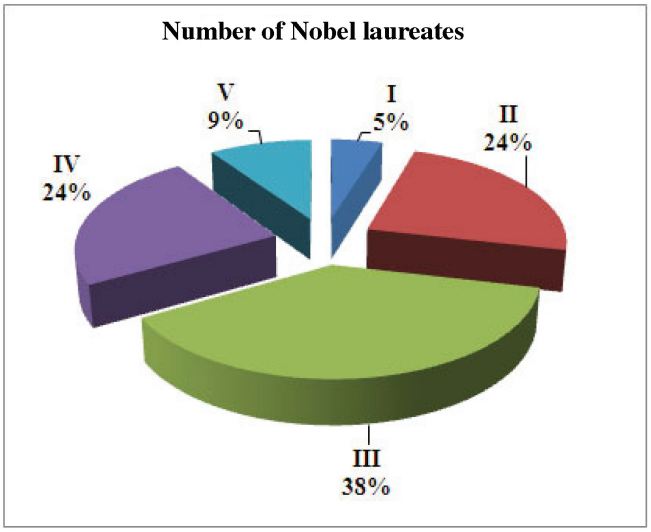

Fig. 1. Quarter-wise distribution

S.N.	Name of Scientists	Nationality	University	Field of Research	Year of Award
1	Max Planck	Germany	Munich	Discovery of quanta	1918
2	Prince Louis de Broglie	France	Sorbonne	Wave nature of matter	1929
3	Werner Heisenberg	Germany	Munich	Creation of quantum mechanics	1932
4	Erwin Schrödinger	Austria	Vienna	New productive form of atomic theory	1933
5	Paul Dirac	G. Britain	Cambridge	New productive form of atomic theory	1933
6	Wolfgang Pauli	Austria–USA	Munich	Exclusion Principle	1945
7	Max Born	Germany	Goettingen	Statistical interpretation of the wave function	1954
8	Walther Bothe	Germany	Berlin	Coincidence method and his discoveries made therewith	1954
9	Charles Townes	USA	Cal Tech	Fundamental work in the field of quantum electronics, led to maser-laser principle	1964
10	Nicolay Basov	USSR	Moscow	Fundamental work in the field of quantum electronics, led to MASER-LASER principle	1964
11	Aleksander Prokhorov	USSR	Moscow	Fundamental work in the field of quantum electronics, led to MASER-LASER principle	1964
12	Sin-Itiro Tomonaga	Japan	Kyoto	Fundamental work in quantum electrodynamics	1965
13	Julian Schwinger	USA	Columbia	Fundamental work in quantum electrodynamics	1965
14	Richard Feynman	USA	Princeton	Fundamental work in quantum electrodynamics	1965
15	Klaus von Klitzing	Poland–Germany	Wuerzburg	Discovery of quantized Hall effect	1985
16	Robert Laughlin	USA	MIT	New form of quantum fluid with fractionally charged excitations	1998
17	Horst Störmer	Germany–USA	Stuttgart	New form of quantum fluid with fractionally charged excitations	1998
18	Gerardus 't Hooft	Netherlands	Utrecht	Quantum structure of electroweak interactions in physics	1999
19	Martinius Veltman	Netherlands	Utrecht	Quantum structure of electroweak interactions in physics	1999
20	David Wineland	USA	Harvard	Experimental methods measuring and manipulation of individual quantum systems	2012
21	Serge Haroche	France	Marie Curie	Experimental methods measuring and manipulation of individual quantum systems	2012

Table 1. Database for the analysis.

B. Age of laureates

The statistical analysis shows that there is a wide distribution of awards to laureates of different age groups. This is more elaborated in Figure 2.

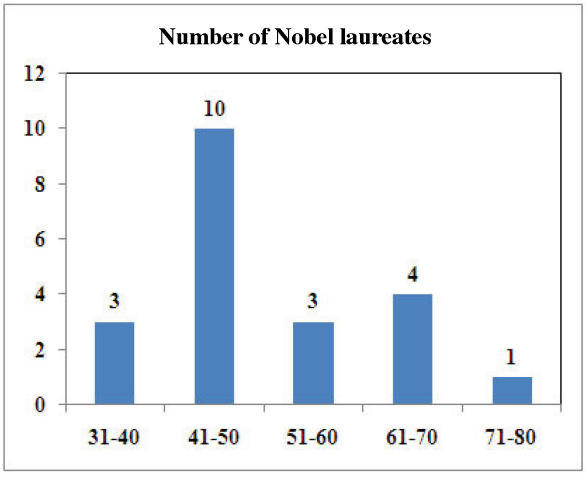

Fig. 2. Age-wise distribution

The above histogram indicates that Heisenberg, Dirac and de-Broglie got their Nobel prize before the age of 40, which was too young for physicist as compared to other fields. Max Born was the eldest one who was awarded at the age of 72 for his fascinating work in statistical interpretation of wave function. It is aparent from the graph that the majority of the laureates got the prize between the age of 41 and 50 in the mid of their career.

C. Nationality

Figure 3 illustrates the analysis based on native country of the prizewinners.

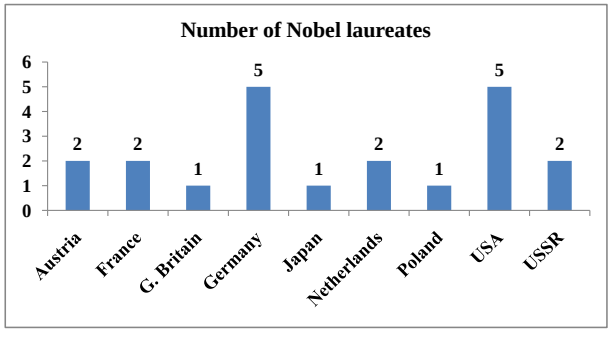

Fig. 3. Nationality and the number of laureates

Though Wolfgang Pauli & Horst Störmer had the US citizenship, their homelands, that is, Austria and Germany are considered for the analysis. Likewise, Klaus von Klitzing is considered as Polish. Figure 3 indicates that most number of quantum physicists were from Germany and USA (Equal in number). Here most important thing to be noted is that the Germans were the first who initialized the research work in quantum theory, afterwards, in the second half of the century, the physicists from the USA won the prestigious prize. This may be attributed to a high standard of universities in Germany prior to the world wars, as compared to that of the USA and other countries. Japan is the only Asian country that succeeded into grabbing Nobel in the area of quantum mechanics (Tomonaga won the prize for his pioneering work in quantum electrodynamics along with Schiwinger and Feynman; both from the USA).

D. University

If the University of Prize Winners is analyzed (shown in Figure 4) it can be observed that Munich in Germany is the only university that got three Nobel laureates, i.e. Planck, Heisenberg and Pauli. Next comes with Utrecht in the Netherlands which got two Nobel laureates winning the prize in the year 1999 for their work in elucidating the quantum structure of electroweak interactions in physics. It is very strange to observe that not a single university from the USA and UK exists that won more than one Nobel prize in the field of quantum physics, while such universities as Columbia, Princeton, MIT, Cambridge, Oxford got more than two Nobel winners in the field of Chemical sciences, Physiology, etc.

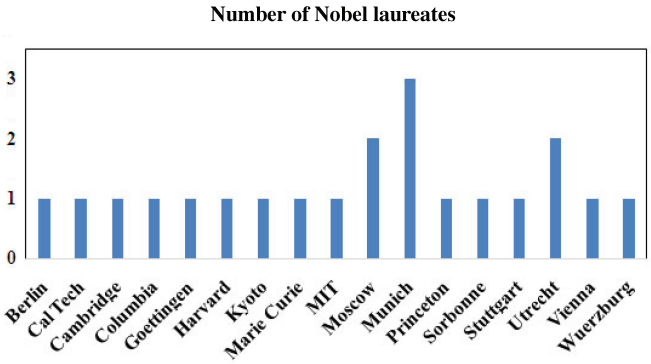

Fig. 4. University-wise distribution

E. Great scientists but not Nobel laureats

There are many researchers in quantum mechanics who introduced novel concepts that contributed significantly to the development of the theory and were supposed to be considered for the award, but excluded and without being recognized. Some of them are listed in Table 2 along with their field of research.

S.N.	Name of the Scientists	Field of Research
1	A. Sommerfeld	His noteworthy contribution includes inception of the azimuthal and spin quantum number, a pioneering work in fine-structure consonant. He had been the supervisor for doctoral work for more Nobel prize winners in Physics than any other to date.
2	Paul Ehrenfest	He has made a significant contribution in relation between statistical and quantum mechanics, theorem for average motion of wave packet, etc.
3	Wentzel, Kramer and Brillouin	Developed the WKB approximation method for weak potentials
4	Hilbert	Significant formulation of Hilbert space for the mathematical basis of quantum theory.
5	Clebsch and Gordon	Defining coefficients in angular momentum and relativistic equations.

Table 2. Eminent scientists without the Nobel prize

It was observed that Universities and colleges had paved a path for the advancement in research in the field of quantum mechanics. Pre-World War I era was most fruitful for the universities in Germany resulting in a high standard research work as compared to other European countries. However, after the 1950's, new institutes emerged in to USA and other developed countries and were honored with the association of most of the recipients of Nobel Prizes.

IV. KEY FINDINGS

Our analysis highlights some of the key findings listed as below:

1. Only 11% of total laureates in Physics untill 2015 got the prize for their contribution in the field of quantum mechanics.
2. Most of the key discoveries (38%) occurred in mid 20^{th} century.
3. The majority of the laureates were awarded the prize between the ages of 30 and 75.
4. Germany and USA show a momentous contribution in developing quantum mechanics.
5. Munich in Germany gave three Nobel laureates which is much higher than any other university for same field.
6. However, some of the researchers were unfortunate not to have receive the prestigious award, but they left their impact in the field of quantum mechanics owing to their pioneering contributions.

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НОБЕЛІВСЬКІ ПРЕМІЇ З КВАНТОВОЇ МЕХАНІКИ: СТАТИСТИЧНИЙ ПІДХІД

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У статті подано систематичний огляд нобелівських лауреатів із фізики за останні 115 років в одній із галузей — квантовій механіці — та зроблено спробу показати загальну тенденцію досліджень. Аналіз зроблено від моменту створення квантової теорії за двадцятип'ятирічними періодами. Обговорено різні чинники:вік нобелівських лауреатів, університети, де вони працювали, та відповідні країни. Результати статистичного аналізу можуть зацікавити читачів, які хочуть більше дізнатися про розвиток квантової теорії.