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QUANTUM ELECTRONICS

Boris Stoicheff: Gerhard Herzberg — An Illustrious Life in Science

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This book is the biography of an outstanding scientist of the 20th century, Dr. Gerhard Herzberg, the winner of the 1971 Nobel Prize in Chemistry. Dr. Stoicheff mixes facts of science with historical sketches of the troubled century and depicts the main figures of science in this period with great details of their character and their interaction with one another. It is also a good tutorial for people entering this field, as well as it provides a long perspective of the field for experienced scientists. Such a book could only have been written by an active participant in these scientific endeavors, Dr. Stoicheff was in fact a colleague of Dr. Herzberg, or GH, as he was commonly called among his colleague, and worked in his Institute, the Division of Pure Physics from 1951 till 1964.

The book contains a set of references to the correspondence of GH and these references also point to many other aspects of the history of the period and the history of science. The book is made of four parts, a total of 23 chapters, illustrated by many photographs, some of which were contributed by colleagues and friends of GH, as well as two maps, one at the beginning and one at the end of the book, the first showing Europe and GH's important stations in Europe, while the last giving a sketch of North America, again showing the locations important in GH's life. One also finds a chronological listing of Herzberg's life, a selected bibliography connected with Herzberg, and each of the 23 chapters has individual references. An Appendix contains short biographies of the research staff of the Spectroscopy Laboratory at NRCC, a separate note on Nobel prizes, and a listing of Herzberg's books and publications, a summary of the outstandingly productive scientific work of GH.

Herzberg was born in Hamburg, Germany, in 1904 and his education started at the Realgymnasium at the Johanneum in Hamburg. His interest in atomic physics was awakened early by his science teacher, Wilhelm Hillers. Later the 20 year old Herzberg was discouraged against his aspirations to choose astronomy and astrophysics for his career by Dr. Schorr, the Director of the Hamburg Observatory. Nonetheless Herzberg's interest in astronomy remained active throughout his life and many of his contributions to molecular spectroscopy were in the field of astrophysics.

Hans Rau, Professor of Physics at the Technische Hochschule Darmstadt had a decisive effect upon Herzberg's scientific career, both as a teacher and also as a

research supervisor. He never insisted upon putting his name on the publications of Herzberg, even though he was his 'Doktor Vater', this served as a life-long example for Herzberg himself, who was always liberal with his coworkers in giving credit to joint scientific works and put his name on the papers only in cases he was closely connected with the work. Rau assigned Herzberg to the doctoral research topic of analyzing the spectrum of the hydrogen-like Li^{++} ion. Herzberg was unable to find this ion, but in the electric discharge spectra he planned to use for its observation he found an intense afterglow that he identified as the emission feature due to the N_2 molecule and its cation N_2^+. This started Herzberg on diatomic and polyatomic spectroscopic researches in addition to his interest in atomic spectroscopy. One of his early achievements was the recording of the full Balmer series of atomic hydrogen that became a textbook example in teaching atomic spectroscopy and ionization phenomena. Electric discharge spectra, plasma spectroscopy, remained a life-long interest for Herzberg who discovered many astrophysically important molecules using various forms of laboratory plasma spectroscopy.

Herzberg's life was decided by the emergence of the National Socialist system in Germany roughly in the period coinciding with Herzberg's university and early postdoctoral work. As Herzberg married Luise Oettinger of Jewish descent he was blocked by the Nazis from teaching and his scientific future in Germany was made impossible. As a result he had to search for a research and teaching position abroad, similarly to many of his eminent contemporaries displaced from Germany. Unfortunately Europe was not receptive to the needs of scientists rejected from Germany by fascism, mainly because of the economic difficulties in the wake of the depression in the 30's. Herzberg was advised to try countries like Holland, Turkey, Iran, India and China, and eventually he tried the United States also to work with Robert Mulliken in Chicago and other locations as well, but in vain. At 30 years of age Gerhard Herzberg had absolutely no work openings for him.

Eventually he was lucky to get a position in Canada, as a result of the help provided by a former coworker of him in Darmstadt, Dr. John W.T. Spinks who spent some time with Herzberg in 1933–34 to learn spectroscopy for his photochemical studies. Spinks initiated the process for obtaining a position at the University of Saskatchewan, and the President of the University, Walter Murray made efforts to help Herzberg to come to Canada. Eventually he offered Herzberg a guest professorship in the Department of Physics. Herzberg decided after some hesitation and accepted the position Murray offered him. His hesitations were induced by the remote location of Saskatoon in Canada from the main research centers there and from the United States, as well as by the absence of spectroscopic research facilities in Saskatoon. This decision opened up an opportunity for him that he would probably have never had in troubled Europe. The repulsive effect of fascism had on Herzberg created a unique opportunity for him in the New World.

The decisive turn of events in the life of Gerhard Herzberg came when after ten years (1935–45) in Saskatoon and three years (1945–48) in the United States (Yerkes Observatory in Wisconsin and the University of Chicago) he obtained an invitation from the National Research Council of Canada (NRCC) in Ottawa (1947)

that opened up a long and productive, happy period during which Herzberg and his colleagues elevated molecular spectroscopic science in Canada to a world-leading status. Herzberg became Director of the Division of Physics in 1949 at NRCC. Herzberg's new spectroscopy laboratory, the fifth established in his career, concentrated on fundamental problems, the spectroscopy and structure of simple gaseous molecules, and also atomic spectroscopy, always aiming at the highest spectral resolution attainable.

Herzberg tried to set up independent research units for theoretical physics, plasma physics and solid state physics, but none of these became long lasting entities, even though important research was done in low temperature solid state physics, and plasma physical research continued in various forms utilizing lasers. Theoretical physics did not survive as an independent Section as various groups developed their own theoretical support.

Gerhard Herzberg's original group of spectroscopists consisted of Alexander E. Douglas, Hin Lew, Donald A. Ramsay, Cecil C. Costain, Boris Stoicheff, then later John W.C. Johns, James K.G. Watson, Jon T. Hougen, Takeshi Oka, Philip R. Bunker and Klaus P. Huber. The height of the scientific life at NRCC was attained in 1965, before the government support started to drop. In a picture taken in 1968 of the group of the Spectroscopy Laboratory in front of the entrance to the 100 Sussex Drive NRCC building most of the staff and some visitors can be seen, see page 243 of the book. J. Shoosmith, Herzberg's personal technician was so much valued by GH that he featured in many group photos, his work was acknowledged in many papers and for some very important ones Herzberg included Shoosmith as a coauthor.

The book provides a detailed history of the National Research Council of Canada that started to grow phenomenally during and after the World War II when people recognized the enormous importance of science and technology in modern wars. Herzberg was nominated to NRCC at a time when science policy in Canada was ready to embrace his view that the best science is done by strongly motivated individuals, and that administration of science is not meant to plan, design regulate and control science, but to help it by all possible means and should refrain from encroaching upon the designs each scientist builds for himself or herself to do the job.

Herzberg built a fortress of spectroscopy at NRCC composed mainly of high resolution equipment applied in atomic and molecular research, and was quick to adopt emerging new tools, such as lasers, Fourier transform spectrometers, molecular beam spectrometeres, etc. One method perfected in Ottawa was flash photolysis for the study of free radicals in the gaseous phase. Although George Porter and Reginald G.W. Norrish received a Nobel Prize for this method, flash photolytic techniques were in use in Herzberg's labs before the UK scientists received their grand prize. Herzberg developed flash photolysis to study absorption spectra that characterize mainly the ground molecular states from which optical excitation occurs. This was the method used for the discovery of spectra and spectral characterization of a number of chemically very important free radicals such as CH_2 and CH_3.

The culmination of Gerhard Herzberg's life was his award of the Nobel Prize in Chemistry in 1971. The Nobel Prize was given to Herzberg for his contributions to the knowledge of the electronic structure and geometry of molecules, especially free radicals. In his book *The Spectra and Structures of Simple Free Radicals: An Introduction to Molecular Spectroscopy* (Dover Phoenix Editions, 2003) Herzberg defined free radicals as chemically unstable molecules (that sometimes have unpaired electrons, but sometimes are, however, closed shell entities). Free radicals have central roles in chemistry as in many chemical reactions (especially in the gaseous phase and in plasmas) the reaction path often proceeds through free radicals. In addition, Herzberg has contributed immensely to the clarification of the structure and spectra of molecular ions, mainly positive but also negative ions. Molecular ions and free radicals have special roles in astrophysics and astrochemistry and indeed many of them were discovered in various astrophysical sources, such as comets, stellar photospheres and interstellar environments, using the laboratory data and interpretation Herzberg and his colleagues provided.

Additional recognition was given to Herzberg as cited in the Nobel Prize for his work in setting up the Spectroscopy Laboratory at NRCC, Ottawa and elevating it to World summit, and his books on atomic and molecular spectroscopy (altogether six books) that became the 'bible' for spectroscopists in the whole World, and are still very much in demand. The greatest circulation among his books was achieved by Atomic Spectra and Atomic Structure (Dover, New York, 1944), both because of the great tutorial value of this book and the great role atomic spectroscopy plays in physics and chemistry.

Perhaps the most interesting astrophysically oriented spectroscopic discoveries of Herzberg and his Colleagues were connected to atomic and molecular hydrogen and the positive ion of triatomic hydrogen, H_3^+. The latter has a very important role in astrochemistry, in the formation of molecules in interstellar space. The story of H_3^+ in spectroscopy is an exciting one and Boris Stoicheff gives ample details for it. Herzberg started looking for the electronic spectrum of H_3^+ already during his university years, and while to date there are open questions concerning the electronic spectrum of this ion, the vibrational infrared spectrum of H_3^+ was found and completely clarified by Takeshi Oka, helped in this work by James K.G. Watson. During these studies Herzberg found the electronic spectrum of H_3 in emission.

There is yet another subject that kept Herzberg's busy throughout his life; the problem of the so-called diffuse interstellar bands (DIB's) in astrophysics and astronomical spectroscopy. There are more than 300 such broad features in absorption that have been puzzling the astrophysical and spectroscopical community since 1935. It now appears that they might be connected to large, carbon containing molecules but other molecular sources have also been suggested. Herzberg always believed that the source of DIB's must be molecules and not, e.g. interstellar dust.

Herzberg was a busy traveller and he also visited Hungary. There is little account in the book of Boris Stoicheff about these visits, on some of them he was accompanied by his first wife, Louise. Most of these visits were made on the invitation by Professor István Kovács at the Department of Atomic Physics, Polytechnical

Fig. 1. Dr. Gerhard Herzberg in his office, October 1985

University of Budapest. The last visit of Herzberg occurred in 1985 when he gave a lively talk on the spectra of molecular ions in Budapest. The talk was recorded and a paper appeared in *Fizikai Szemle* (*Physical Review* of the Roland Eötvös Physical Society, Hungary) in the form of an imaginary interview that was conducted by the present author (Nemes László: "A molekulaionok színképei: beszélgetés G. Herzberggel", *Fizikai Szemle*, Vol. **35** (1985) 1–6, in Hungarian).

The author of this book review also spent three months at the Herzberg Institute of Astrophysics in 1985, and during this time he took some photographs of GH. One of them is copied here to show Herzberg when he was 81 years old.

Herzberg died in 1999 at home. The World lost one of the great scientists of all times, and certainly the most important spectroscopist who helped to create a large edifice physically in the form of the Spectroscopy Laboratory at NRCC, Ottawa and spiritually the edifice of one of the most beautiful and useful branches of the physical and chemical sciences; molecular spectroscopy. I strongly recommend the acquisition of Boris Stoicheff's book for all scientific libraries in Hungary, in Europe and everywhere. It is going to be a very useful educational tool.

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