

## Gerhard Herzberg (1904-)

The young assistant burst excitedly into the office of the Director of Pure Physics at the National Research Council in Ottawa. Dr. Gerhard Herzberg looked up from his desk with some annoyance. Herzberg thought of all the meetings and conferences he had to organize, the paper he was writing, the presentations he was preparing and the book on molecular spectra he was trying to finish. He didn't have time for this. The young technician was insistent. "You must come and see this," he said, "it's good."

Reluctantly, Herzberg got up from his chair and followed the man down a flight of stairs into a large dimly-lit room smelling of ammonia, ozone and hot electric wiring. They walked past strange equipment surrounded by vacuum tubes, pumps and snaking wires.

The big room was quiet except for a murmuring crowd that had gathered in the corner. Herzberg hurried over to see what they were looking at. A long thin strip of glass lay on a viewing screen with a seemingly random pattern of vertical lines blackening its surface. He recognized it instantly, shouting, "That's it!" and broke out laughing. "Eighteen years. I've been looking for you for eighteen years."

Dr. Herzberg had finally discovered the first spectrogram of methylene, a simple unstable chemical compound called a "free radical". It was a giant breakthrough in the field of chemistry. His reward would be the 1972 Nobel Prize.

### Young Gerhard Herzberg

Gerhard Herzberg was born on Christmas Day, 1904. Herzberg's father, Albin, who was the co-manager of a small shipping company, was born in a small German town called Langensalza. The family later settled in Hamburg, Gerhard Herzberg's birthplace.

When Herzberg was only ten years old, his father died. Herzberg's mother, Ella, emigrated to Wyoming in the United States, sending money to support Herzberg and his brother back in Germany. It was a difficult time for Herzberg, but he spent long hours immersed in his many passions- the least of which was certainly not **astronomy**.

As a twelve year old in Hamburg, Herzberg and a friend made a **telescope** by hand. They patiently ground the lenses for the telescope and placed them in hand-made mounts in a metal tube. And then, on clear nights, they would take the streetcar to a nearby park and look at the stars and planets. Little did Herzberg know that his interest in the night sky would lead to the naming of an **asteroid** in his honour!

### Student

Herzberg attended school in his hometown of Hamburg. Of great inspiration to Herzberg in these early years was his physics teacher, W. Hillers, at the time the editor of a well-known textbook on the subject. It was Hillers who first aroused Herzberg's interest in **atomic and molecular physics**.

Hillers introduced Herzberg to the revolutionary ideas of such great scientists as Ernest **Rutherford** and Niels **Bohr**, scientists who were laying the groundwork for **quantum theory**. Herzberg, however, was still extremely interested in astronomy and when he graduated from high school, it was that which he wished to study.

When a guidance councilor made inquiries at the **Hamburg Observatory** on Herzberg's behalf, the response was less than overwhelming. In fact, the director of the observatory told Herzberg that there was no point in thinking of a career in astronomy unless he had a private means of support.

Herzberg's mother was still sending money from the United States, but it was painfully obvious to Herzberg that he did not have such support. So on the advice of the director, Herzberg enrolled at the **Technical University** in Darmstadt to study the then emerging field of technical physics.

For his first two years at Darmstadt, Herzberg obtained a private scholarship from the *Stinnes Company*, a large ship-building and shipping company. In 1926, the company went bankrupt, but Herzberg secured another scholarship to see him through the remaining two years of his education.

At Darmstadt, Herzberg worked under Professor Hans Rau, the head of the Department of Physics. Rau was a

great influence on Herzberg and he encouraged his student to decide for himself what he wanted to study.

Herzberg decided to find the *spectrum* of  $Li^{2+}$ . He did not have a chance to study it, however, because his work led him to the spectra of simple nitrogen molecules and to the spectrum of  $H_2$ . Interestingly, some of the **absorption lines** in the  $H_2$  spectrum, which were recognized as possible contributions from  $H_3$ , foreshadowed Herzberg's discovery some 50 years later of the spectrum of that very molecule.

In 1928, at the age of 24, Herzberg completed his **doctorate** in physical engineering. He had already published twelve papers in **atomic and molecular physics** and consequently, he had no difficulty in obtaining a post-doctoral **fellowship** at the **University of Göttingen**, one of the best centers for physics at the time.

#### Aspiring Physicist

At Göttingen, Herzberg worked under **Max Born** and **James Franck**, two of the most brilliant **theoretical research** scientists of the era. Herzberg continued his work with nitrogen and made contributions to the development of **molecular orbital theory**. This work led to a better understanding of the electronic stability of some **diatomic molecules**.

Herzberg's interest in molecular orbital theory led him to a second post-doctorate year at the **University of Bristol**. At Bristol, Herzberg was thrust into an English speaking environment for the first time. He had some difficulties at first, but he still managed to produce some interesting results.

Herzberg studied the *spectrum* of  $P_2$  and came across the spectrum of **CP**, the only one in existence at the time. Good fortune was now coming Herzberg's way, for it was at about that time that he married his first wife, Luise Oettinger. She was to collaborate on some of the problems with which Herzberg was engaged.

In 1930, Herzberg returned to Darmstadt to give specialized lectures without pay. He earned a small salary managing undergraduate research labs and carried out his own research.

For five years, Herzberg concentrated on **spectroscopy**. He worked with many other young scientists and published, among others, a major paper dealing with **polyatomic molecules**. This paper was a collaborative effort with Edward Teller, a gifted researcher and friend.

In 1933, the year the **Nazi Party** took power in Germany, a young **physical chemist** named J.W.T. Spinks arrived in Darmstadt from the **University of Saskatchewan**. Herzberg had never heard of Saskatchewan, but for almost an entire year, he and Spinks worked on the spectra of such molecules as **HCl**, **HCN** and **C<sub>2</sub>H<sub>2</sub>**.

Later that year, the political climate in Germany worsened. Herzberg was notified that he would be dismissed from the university because his wife was Jewish. Realizing that he would have to leave Germany, he asked Spinks, now back in Saskatchewan, if the Canadian could help him find employment in Canada.

Spinks in turn asked for the help of the President of the University of Saskatchewan, Dr. Walter C. Murray. Murray was aware that at 30, Herzberg was already one of the world's leading molecular physicists, so he wrote to both the **University of Toronto** and the **National Research Council** on Herzberg's behalf.

Given the **economic situation** of the time, neither institution could offer Herzberg a position. So, with the help of the **Carnegie Foundation** of New York, the University of Saskatchewan opened its doors to him.

In 1935, the Herzbergs arrived in Saskatoon with only **ten German marks** each in their pockets, the amount they were allowed to take with them from Germany. Luckily, they were able to bring with them some much needed spectroscopic equipment from Germany, which came into good use because the University of Saskatchewan was in dire need.

#### Prairie Physicist

In Saskatchewan, Luise gave birth to Paul and Agnes. Paul was to become a psychologist, teaching at **York**

University and Agnes was to become a mathematician, teaching mathematical statistics at **Imperial College** in London.

With the little amount of spectroscopic equipment that was available to him, Herzberg continued his theoretical work on molecular and atomic **spectroscopy**. This work led to the first three of his six classic books on the subject, entitled *Molecular Spectra and Molecular Structure*.

In 1939, things improved for Herzberg. With the help of a grant from the American Philosophical Society, he was able to build a spectrograph that would later help in a number of interesting studies. These studies led to the determination of the structure of **B<sub>2</sub>**, and to the discovery of the **spectrum** of **CH<sup>+</sup>**.

At the **University of Saskatchewan**, Herzberg was also able to reproduce in the laboratory unassigned spectral lines which were present in the spectra of comets. It was the first time this had been accomplished and it was of great interest to astronomers.

In 1945, one such laboratory at the **University of Chicago** offered Herzberg the extensive and advanced facilities of its renowned **Yerkes Observatory**. Herzberg had never forgotten his earlier ambitions to be an astronomer and despite his affection for Saskatchewan, the offer was too great to pass up.

#### Father of Molecular Spectroscopy

At the Yerkes Observatory, Herzberg was almost exclusively engaged in research. Although he did teach a course on **spectroscopy**, his main job was to set up a spectroscopic laboratory in the basement of the building. There, he obtained many spectra of **astrophysical** importance, including the ultraviolet **spectrum** of **O<sub>2</sub>**, a molecule he had started to study at Darmstadt.

At the end of 1947, Herzberg received an offer from the **National Research Council** to set up a new spectroscopic laboratory in Canada with the promise of adequate funding for equipment and personnel. The offer was engineered by Ned **Steacie**, the then Director of the Division of Chemistry.

So, in August 1948, Herzberg left the Yerkes Observatory to begin work in Ottawa. It is a decision that he has never regretted.

When after only a short time at the **NRC**, Herzberg was offered the position of Director of the Physics Division, he accepted. He was excited by the opportunities available to him at his new home, by the lack of administrative responsibilities and by the freedom afforded to him and the other scientists.

Herzberg began assembling a group of young spectroscopists, many of whom were appointed under Steacie's **Post-doctorate Fellowships Program**. These young scientists were to specialize in experimental techniques for studying the microwave, infrared, visible and vacuum ultraviolet regions of the **electromagnetic spectrum**.

One such scientist that benefited immeasurably from his experience at the NRC under the postdoctorate fellowships program in the early 1950s was Canada's second Nobel Laureate in chemistry, John **Polanyi**.

In the fall of 1959, one of Herzberg's greatest accomplishments was realized: the spectrum of **methylene**. Methylene, a molecule whose spectrum Herzberg had been trying to obtain since his time in Saskatoon, is of interest to scientists because of its role in the theories of chemical structure. Of **astrophysical** importance as well, methylene's spectrum enables scientists to identify methylene in **interstellar objects**.

That fall, when Herzberg's research technician had come into his office at Sussex drive in Ottawa, Herzberg had been terribly busy. In fact, he had been so busy that it took the insistence of the technician for Herzberg to walk down the flight of stairs to the lab below.

In the lab, crowds of people had gathered. Amidst the pungent smell of ammonia and ozone, Herzberg was to view for the first time the **spectrum** of a molecule for which he had been searching for eighteen years.

The problems that Herzberg had been having in obtaining the spectrum of methylene were the result, at least

in part, of the experimental technique employed to produce the methylene.

In earlier experiments, Herzberg had produced methylene by decomposing **ketene** with a **mercury lamp**. Unfortunately, ketene itself absorbed where the **absorption lines** of **CH<sub>2</sub>** occurred and the spectrum was hidden from view. It was in the labs at the **NRC** that Herzberg decided to use **diazomethane** to produce the methylene instead. It was only then that the first spectrum of methylene was observed.

Finding the spectrum of methylene was perhaps Herzberg's greatest accomplishment. He has often maintained that it is such moments of discovery that remain the most satisfying of his long career.

At the NRC, Herzberg continued to build his labs into the foremost centre for **spectroscopy** worldwide. He became interested in other **free radicals** such as **BH<sub>2</sub>**, **SiH<sub>2</sub>**, and **H<sub>3</sub>**. He also studied more stable **polyatomic molecules** such as **CHF<sub>3</sub>**, and **CO<sub>2</sub>**.

Herzberg's years at the NRC were the busiest of his life. Every Saturday and holiday, except Sundays and Christmas Day, from 1960 to 1965, Herzberg worked on the third volume of his series *Molecular Spectra and Molecular Structure*. It was incredibly difficult work, but the volume was finally published in 1966.

It was also during these years at the NRC that Herzberg did most of his traveling. For the Indian Science Congress, he traveled to India, where he saw the **Himalayas**. He met the **Dalai Lama**, who at that time was still in power in Tibet and saw the **Taj-Mahal**. Herzberg also traveled to the former Soviet Union, Australia, Japan and to Iran.

#### Distinguished Research Scientist

In the summer of 1969, at the Ninth International Symposium on **free radicals** in Banff, Alberta, Herzberg was appointed the **NRC's** first Distinguished Research Scientist. The appointment relieved him of all administrative responsibilities, allowing him to concentrate on his research even beyond his then approaching 65th birthday.

In 1971, Herzberg's wife Luise died. She had been of tremendous assistance to Herzberg throughout his career and had herself been working on upper atmosphere problems at the Department of Communications in Ottawa at the time of her death.

That same year, Herzberg traveled for a second time to the former Soviet Union, where he presented lectures in Moscow and Leningrad. Shortly before leaving Leningrad for Moscow, Herzberg was informed by the Secretary of the Foreign Department of the Academy of Science, that he had won the **Nobel Prize**. What Herzberg did not know was the area in which he had won: physics or chemistry.

Herzberg had always considered himself a physicist, as his training indicates. But chemists had long attached great importance to his accomplishments, especially his work with **free radicals**. When Herzberg walked off the train in Moscow into a hastily assembled news conference, he still did not know in which area he had won. As it turned out, Herzberg had been awarded the Nobel Prize in chemistry.

In 1972, Herzberg married his second wife, Monika Tenthoff, the niece of a close friend from his high school days.

Herzberg's productivity did not end with the awarding of the Nobel Prize in 1971. He did, however, become swamped with requests to give lectures and his productivity during the years immediately after the award was severely restricted.

In 1974, at an international meeting in Mont. Tremblant, Quebec, the **NRC** announced the formation of a new Institute of Astrophysics. The Herzberg Institute of Astrophysics was to carry out all astronomical and astronomy related activities at the NRC. It was one of Herzberg's greatest honours.

One of the more interesting discoveries at Herzberg's labs, was the discovery of the water ion, **H<sub>2</sub>O<sup>+</sup>**, in the tale of the comet Kahoutek.

In the following years, Herzberg turned his attentions to molecular ions such as  $\text{HeH}^+$ ,  $\text{HeNe}^+$  and  $\text{H}_3^+$ . His work with  $\text{H}_3^+$  led to the discovery of the *spectrum* of  $\text{H}_3$ , a stroke of luck.

Herzberg had not been looking for  $\text{H}_3$ , but with the help of one of scientists' greatest friends, serendipity, Herzberg was to realize one of the high-points of his career. It was a fitting discovery, too, for it completed his work started some 50 years earlier as a graduate student at Darmstadt.

#### Gerhard Herzberg: Inductee

Herzberg continues to be active in research today, but in his spare time, he enjoys listening to music, his favourite being the Mozart quartet for flute, violin, viola and cello.

The NRC has given Herzberg the opportunity to continue his spectroscopic work well beyond the normal retirement age. He continues to be a valuable resource and a productive and honoured member of the scientific community.

One of his current interests is the spectrum of  $\text{NH}_2^+$ . The origin of the spectrum is still unknown to him, but he suspects some of the *spectral lines* are indicative of  $\text{NH}_2^+$  and he intends to prove it. Herzberg would also like to make one or two more major discoveries of new *free radicals* or *molecular ions*.

Herzberg's honours are numerous. The Canadian Association of Physicists has named an award after him and a research fellowship is awarded annually in his name. Interestingly, the *Canadian Bank Note Company Limited* has produced a steel plate engraving of Dr. Herzberg, which was presented to him in 1994.

In 1987, perhaps the most fitting honour was bestowed on Herzberg. In that year, an *asteroid* was officially named in his honour.

#### Positions/Awards

- President of the Canadian Association of Physicists
- President of the Royal Society of Canada
- Vice-president of the International Union of Pure and Applied Physics
- Fellow of the Royal Society of Canada (1939)
- Fellow of the Royal Society of London (1951)
- Companion of the Order of Canada (1968)
- Foreign Associate of the National Academy of Washington (1968)
- Medaille de l'Université de Liege (1950)
- Henry Marshall Tory Medal, Royal Society of Canada (1953)
- Joy Kissen Mookerjee Gold Medal, Indian Assn. for the Cultivation of Science (1954)
- Gold Medal, Canadian Association of Physicists (1957)
- Medal of the Society for Applied Spectroscopy (1959)
- Medaille de l'Université de Liege (1960);
- Medaille de l'Université de Bruxelles (1960)
- Pittsburgh Spectroscopy Award, Spectroscopy Society of Pittsburgh (1962)
- Frederic Ives Medal, Optical society of America (1964)
- Willard Gibbs Medal, American Chemical Society (1969)
- Gold Medal, Professional Institute of the Public Service of Canada (1969)
- Faraday Medal, Chemical Society of London (1970)
- Royal Medal, Royal Society of London (1971)
- Linus Pauling Medal, American Chemical Society (1971)
- Nobel Prize in chemistry, Swedish Royal Academy of Sciences (1971)
- Chemical Institute of Canada Medal (1972)
- Madison Marshall Award, American Chemical Society (1974)
- Earle K. Plyler prize, American Physical Society (1985)

- Jan Marcus Marci Memorial Medal, Czechoslovak Spectroscopy Society (1987)
- Minor Planet 3316=1984 CN1 officially named "Herzberg" (1987)

### The Science Today

When Herzberg started his career, no one had seen a molecule in space. These days, scientists at the Herzberg Institute's Dominion Astrophysical Laboratory (DAO) use daily state-of-the-art *optics* and light recording devices to study, amongst other things, *star clusters*, *quasars* and *black holes*. Two large telescopes in Victoria, British Columbia and a large 3.6 m. Canadian-French-Hawaiian *telescope* in Hawaii scan the night sky as DAO scientists try to unravel the chemical and physical processes that govern matter in the Universe.

In the past, DAO astronomers have gained recognition for the first accurate mapping of the *Milky Way* and for their discovery of the exact nature of SS433, an unusual *binary system*. Using the 1.8 m. telescope in Victoria, DAO scientists were able to determine that the large star in the system is losing matter to the strong gravitational pull of its smaller and denser companion star. Currently, DAO scientists are working to define the properties of *dark matter* by measuring its effect on the structures of galaxies.