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WILLIS H. FLYGARE
1936–1981

A Biographical Memoir by

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WILLIS H. FLYGARE

July 24, 1936–May 18, 1981

BY DAVID CHANDLER

MAY 18, 1981, WAS a rainy morning in Urbana, Illinois. My phone rang. It was Peter Beak. "Bill died," he said. "Bill" was Willis H. Flygare. He was a closest friend to Peter Beak, a mentor to me, husband of Ruth, and father of Karna, John, Amy, and Sarah. He was 44 years old. He was a great physical chemist. He died of amyotrophic lateral sclerosis (ALS; in America often called Lou Gehrig's disease).

Over the next two years the American Chemical Society would hold a memorial symposium honoring Bill Flygare, and both the *Journal of Chemical Physics* (vol. 78, no. 6) and the *Journal of Physical Chemistry* (vol. 87, no. 12), the primary physical chemistry publications of that time, would produce large memorial issues honoring him. The issue of the *Journal of Chemical Physics* alone contained 117 original research articles written by scientists throughout the world, filling 965 journal pages covering every imaginable facet of research in physical chemistry. It was the largest single issue of its kind, an unprecedented outpouring of respect and gratitude reflecting the significance of Bill's life. He was a remarkably productive and influential scientist. He was charismatic. He had an enthusiasm for life and a sense of humor that were difficult to match. Above all, as I try to describe in the following pages, he was brave.

EARLY YEARS

Bill Flygare was born on July 24, 1936, to Willis B. and Doris H. Flygare in Jackson, Minnesota. Jackson is a county seat in southern Minnesota, about 8 miles from Sherburn, where Bill Flygare grew up and went to high school. Sherburn is a small farming town, with a population of little more than 1,000. Bill's parents were of Scandinavian descent like many residents of this area. Strong family ties, with frequent and large gatherings of relatives and friends, marked his childhood. Discussions focused on the dramatic seasonal variations of the area and their effect on the regional agro economy and on the politics of the day, which was dominated by World War II and its aftermath.

Bill was the older brother to Tom (eight years younger) and Nancy (nine years younger). Their father owned a clothing store. In contrast to Bill's usual ways of dressing in later years, the store concentrated on relatively formal men's attire and had the motto "Bill Flygare Suits Me." In addition to their house in town, the family had a summer cottage adjacent to a lake and a golf course outside of Sherburn. Bill spent many summer hours boating, fishing, and golfing. His teenage years coincided with the expanded opportunities of the relatively optimistic postwar period in the United States. Bill was a good student, particularly interested in mathematics, physics, and chemistry. He was introduced to the building and construction trade during the summer months. He began by working as a carpenter's apprentice, and by the time he graduated from high school, he had his own construction crew building houses in his community. Years later in Urbana, Illinois, Bill would build and remodel parts of his house, as well as rental properties in which he invested.

Bill was a fine athlete, a natural leader, and competitive. Ruth Swansson first noticed Bill Flygare as an athlete. She

was a cheerleader for the neighboring Trimont High School. Bill led the Sherburn High School teams in football, basketball, and baseball against Trimont. He was gifted and handsome; she was very impressed. In later years, whether it was in pickup basketball games with Illinois students and faculty where he outclassed most, coaching his son's Little League team to win the Champaign-Urbana twin city championship, or smacking wild serves and forehands on a tennis court, he continued to play with the greatest possible enjoyment and wholesome competitive zeal. Describing Bill's approach to skiing down a mountain, Peter Beak would say, "It was best to arrive at the bottom in one piece, but it was not as important as being first."

HIGHER EDUCATION

Bill graduated from high school in June 1954. The subsequent fall he entered St. Olaf College in Northfield, Minnesota. He would later say of his first year in college that his chemistry, physics, and calculus courses were boring, but that he learned to read and write to his satisfaction. He was unusually facile in these skills, as I would often think when I worked with him in Illinois. By his third year of college his science and mathematics courses became interesting, and he began dating Ruth Swansson. Ruth had graduated from Trimont High School the previous spring, and she entered Gustavus Adolphus College that fall. St. Olaf and Gustavus colleges are within driving distance from one another, but Bill did not have access to an automobile. He would regularly hitchhike between the two schools to visit Ruth.

The St. Olaf College faculty was overwhelmed with Bill Flygare's enthusiasm for learning. One of his teachers, Al Finholt, would later describe Bill's insistence that chemistry majors needed to learn large amounts of mathematics, physics,

and humanities. The faculty believed there was no realistic way to pack all that Bill wanted to learn into four years of courses. Bill nevertheless did absorb all this material, reading and learning by himself outside the regular program of courses. Indeed, self-reliance and confidence were invariants of Bill Flygare's personality, whether teaching himself science or fixing automobiles (his family car in Urbana was always an old one for that reason).

The knowledge and ways of thinking about nature that Bill acquired in his independent way were often unorthodox and underestimated by others. One of Bill's former students, Ben Ware, remarked that he initially confused Bill's unorthodox thinking for lack of extraordinary intelligence or insight. "Only after years of tolerating his special type of diversionary thinking," Ben wrote, "did I realize that that was actually [Flygare's] distinguishing genius."

At the start of Bill's fourth year of college in October 1957, the Soviet Union launched *Sputnik I*. This event was both exciting and frightening. The United States had yet to achieve such success. Many young Americans perceived a threat to their country, and it motivated them to pursue scientific careers. Bill was among those, and he applied to graduate school. Also during that fourth year, Bill obtained an automobile, and Ruth moved even closer to St. Olaf, to Minneapolis, where she was taking courses in nursing.

Bill graduated from St. Olaf in June 1958 with majors in chemistry, physics, and mathematics. Later that summer he and Ruth were married. They traveled west together, where Bill entered graduate school in chemistry at the University of California, Berkeley. There he blossomed. Bill took his Ph.D. in microwave spectroscopy under the direction of William D. Gwinn. He chose this area of research because it combined sophisticated experimental techniques with a strong theoretical component of molecular quantum mechanics.

Bill enjoyed both experiment and theory. He was brilliant with the former and fearless in his approach to both.

One hurdle for all Berkeley chemistry graduate students is an oral qualifying examination instituted long ago by Berkeley's founding chemist G. N. Lewis. In this examination students are required to explain and justify their research projects to a committee of faculty. The student's research advisor is not part of this committee. Through aggressive questioning the committee tries to determine the boundaries of the student's useful knowledge of physics and chemistry, and thereby decide whether the student is qualified to continue working toward a Ph.D. The examination takes place during the student's second year of graduate study. While many able students require two attempts before passing this daunting examination, Bill required only one, and he did more than just pass. The committee found it impossible to learn the extent of Bill's knowledge. There was simply nothing they could think of asking that he could not answer. The eminent Berkeley physical chemist Hal Johnston recalls Bill's performance to this day. No performance of any student he examined before or since matched it. "It was a joy," Hal says.

William Gwinn later wrote that Bill was additionally exceptional in his ability to work with others on a very high level and that he was particularly good in discussions of newly developing ideas. Such discussions were always friendly but far from detached or dispassionate. Indeed, Bill's participation in constructive scientific debate remained an integral part of the way he worked throughout his career. He would often change views and bias during a discussion. Original ideas would be greatly developed and expanded.

Bill spent long hours in the laboratory at Berkeley, "working like crazy," Ruth would say. But he would also take breaks to enjoy the city of San Francisco and the California countryside, hiking and skiing. These were wonderful times

for Bill and Ruth. They often thought they would like to eventually settle in the San Francisco Bay area. Their apartment was in a comfortable old building on Francisco Street. Today the building no longer exists. It was removed to build what is now the North Berkeley station for the commuter train line known as BART. In the mornings they would often walk together up the hill to campus, where Ruth would then take a bus to her nursing job at the Oakland Children's Hospital. Ruth would sometimes audit courses at the university, including Edward Teller's lectures on physics for laymen.

Bill progressed quickly in his research, and by the start of his third year in graduate school, William Gwinn had written to Herbert Gutowsky at the University of Illinois, recommending Bill for a faculty position: "Flygare is a very pleasant person with whom to work. He is married and has a wife who will be a great asset to him. I believe he has very good prospects for a future in academic life and I recommend him to you with enthusiasm."

In January 1961 Bill interviewed at Illinois. The faculty was impressed and offered him a job during the visit. Ruth had accompanied Bill on the trip. The last day of their visit they were scheduled to depart by airplane. It was the bitter aftermath of a snowstorm, and the Ozark Airline DC-3 planes that serviced Urbana-Champaign were grounded. Herb Gutowsky drove them to the Illinois Central train station to catch a late afternoon train to Chicago. As Herb unloaded them and their luggage in the subzero (Fahrenheit!) weather, Herb and Bill discussed intensely the resources needed and the opportunities available in Urbana for his development as a scientist. Ruth could see that Bill was very happy and excited, but the wind-chill factor concerned her.

Bill accepted the offer from Illinois, to begin working as a chemistry instructor in September 1961. Ruth was pregnant

with their first child. Karna was due in August but kept everyone waiting until September 13. Two days later Bill packed up their car and the attached U-Haul trailer and drove east with their pet cat on his shoulder. He made the drive from Berkeley to Urbana in less than three days, arriving just in time to teach his first class. Two weeks later Ruth and Karna arrived in Urbana. Bill met them at the airport and drove them to their first house on Bliss Drive, a University of Illinois rental property for new faculty. Another new chemistry instructor and his wife, Peter and Sandy Beak, had recently moved into a similar house two doors down. The Flygare's cat liked to sit on the Beaks' automobile. That is how the Beaks and Flygares got to know each other. It was a deep and lasting friendship, bringing Peter Beak to write many years after Bill's death, "I still miss him."

ILLINOIS

Bill Flygare would spend the next two decades, his entire career, at the University of Illinois. It was an extraordinary time at Illinois. Harry Drickamer, Herb Gutowsky, Jiri Jonas, Rudy Marcus, and others were among its stellar faculty. During that period, it was arguably the best physical chemistry program in the world. While Marcus is the only one to have actually won a Nobel Prize (for his theory of electron transfer reactions), Gutowsky (who developed the first ways to fingerprint molecules with nuclear magnetic resonance) and Drickamer (who pioneered high-pressure chemical physics) were equally deserving.

Bill quickly showed he was rightfully part of this heady group. Within five years of his arrival at Illinois, he was a full professor, and within six, MIT and the University of Chicago had courted him. Turning them down, he wrote, "The primary consideration is that I have a very large personal investment in the future at Illinois." Within 13 years

of his arrival, in 1974, he was elected to the National Academy of Sciences. More than 30 graduate students would eventually receive their Ph.D.s under his direction. He wrote the advanced physical chemistry textbook *Molecular Structure and Dynamics*, and he coauthored over 200 research papers, the last 25 being written during the last two years of his life while resisting the effects of a ravaging illness, about which I have more to say later.

As the numbers indicate, his students worked very hard. Bill demanded as much. He wrote, "New students are expected to . . . do new and interesting experiments. The experience gained in designing and constructing complex metal, glass, optical, electronic, high vacuum, and high pressure apparatus is vital to the student's future as a viable scientist. . . . A close union of theory and experiment is [to be] attempted."

Many students responded positively. One of those, Ben Ware, later explained: "I knew that science was supposed to be exciting and here was a man who carried that excitement with him and conveyed it to all who would listen. For me, and for many others of his students, he was a scientific pied piper whom we would have followed anywhere." Another, John Pochan, recalls Bill's love of athletic competition, and adds that Bill "enjoyed the scientific competition just as much." On one occasion, Pochan remembers, Bill and his students learned of another group closing in on a research problem that they too were trying to solve. Bill worked with his students for three days straight, day and night, finishing the project ahead of the competing group. "He expected a lot and he gave a lot," Pochan says.

For some students, however, and for some colleagues as well, Bill was hard to take. As with all people, his strength could also be a weakness. He was often impatient with those who could not keep up with his train of thought, and he

was intolerant of those he felt did not work hard enough. Since his thoughts were quick, often unorthodox, and sometimes not quite right, his impatience could be inappropriate. While many found it stimulating to talk science with him—which invariably meant formulating new ideas, arguing, reformulating or refining, arguing again, and so forth—others found the exercise overwhelming. A few would go away insulted. A famous physical chemist once wrote asking a question concerning one of Bill's long and detailed papers on the molecular Zeeman effect. Bill felt that the answer to the question was clearly spelled out in the paper and that the scientist was lazy and possibly insulting not seeing as much. He wrote back answering the question and adding gratuitously "with friends like you, who needs enemies."

By the fall of 1966 the Flygare research group had eight graduate students and four postdoctoral assistants. It would remain close to this size for the next 15 years. Experiments were being done on high-resolution microwave spectroscopy, microwave-microwave double resonance and rotational relaxation, and matrix isolation infrared spectroscopy. They were able to routinely measure the small splittings of rotational transitions caused by spin-rotation interactions, and in this way they studied many systems of chemical interest. Before then others had been able to observe these splittings only in a few special cases. The Flygare group's observations were particularly influential because Bill's theoretical work established their relationship to molecular electronic structure and the nuclear magnetic shielding of a molecule.

Leading this large group of research students in such a varied range of projects required special skill, all the more remarkable as Bill had just turned 30 the previous summer. Rick Shoemaker, who joined the group during that time, recalls that Bill would usually suggest possible research projects, but then encourage the students to work on their

own. He would regularly look to see that his students were making good progress, usually every day, and take an active role when students were struggling. He had the more advanced students instruct the newer students on how to operate and maintain equipment, and he encouraged capable students to pursue well-designed projects of their own making. "He came across more as a wise older brother than a research director or manager," Rick says.

At the 1967 American Chemical Society meeting Bill reported the measurement of a molecular magnetic susceptibility anisotropy by microwave spectroscopy. These results on formaldehyde, published in 1968, were made possible by Bill's exploitation of the molecular Zeeman effect. In a previous theoretical paper he had analyzed the principles of the molecular Zeeman effect and established that molecular quadrupole moments could be measured directly by using both the linear and quadratic field Zeeman effect. With this and related connections his group's subsequent measurements of the molecular Zeeman effect determined molecular *g*-values, magnetic susceptibility tensor elements, molecular quadrupole moments, second moments of electronic charge distributions, and in some cases the signs of the electric dipole moments for about 90 molecules. In 1969 alone Bill and his students published over 20 papers exploiting the molecular Zeeman effect.

This body of work attracted wide attention, and it catapulted Bill into the National Academy of Sciences. The results of these experiments seemed important at the time. It was believed that knowledge of molecular dipole and quadrupole moments would significantly contribute to a good understanding of intermolecular forces. In current times, however, it is understood that intermolecular forces and their manifestations, especially in condensed phases, are more complicated than those numbers reveal. Further, experiment

is no longer required for these quantities because theoretical quantum chemistry can now provide the information easily and reliably. In retrospect, therefore, the results of Bill's Zeeman effect measurements seem less important than the training provided to the students who helped make the measurements. A postdoctoral student with Bill during that time, J. J. Ewing, says that "a key aspect of the experience was that working with Bill on spectroscopy helped prepare people for a diversity of careers that took many of us a long way from . . . [traditional] chemical physics." Indeed, the diversity includes optics, uranium enrichment, liquid crystal and polymer physics, laser development, as well as other fields. Recalling his own professional development in the field of eximer lasers, Ewing says the connection to high-resolution spectroscopy appears weak, but "the 'close union of theory and experiment' that Bill pitched was always in my mind."

ILLINOIS, MIDDLE YEARS

I first met Bill Flygare in late January 1970 during my interview trip to Illinois. Bill was the chair of the recruiting committee, so it was to his office that I went when I first arrived. With a hint of the belly laugh and sense of humor I later knew well, he greeted me and immediately entered into a conversation about my scientific interests. He was much younger than one would expect of someone so accomplished and well known, and he was more casually dressed than the standard professorial attire of the time. Despite the youthful and casual appearance, he was intense! No one had ever before seemed so focused on what I was talking about. I was excited when he described his own work and showed me his laboratories that were filled with seemingly every kind of instrument plus the huge magnet required for his observations of molecular Zeeman splittings. At the time, Bill was finishing his work on the Zeeman effect and

was developing a new interest in dynamic light scattering. When I returned to La Jolla, where I was doing a postdoctoral year, I told my wife, Elaine, about this amazing man, and she knew we would be moving to Urbana.

Bill was introduced to light scattering by his student Ben Ware. Ben's first research advisor had recently left Urbana to take a position at the University of Minnesota. Ben decided to remain in Urbana and work with Bill, provided Bill would be willing to study some type of biophysical problem. Since Ben was a fine student and Bill feared nothing new, he agreed to the conditions and in the spring of 1970 he purchased the makings of a new light scattering laboratory. That summer, while Ben was assembling the laboratory, Bill took off to La Jolla, California, to work for a month with the Materials Research Council, a group of about 20 scientists that advised the Materials Science Office of the Advanced Research Projects Agency (ARPA).

The U.S. Department of Defense created ARPA (now DARPA) during the late 1950s. The Materials Research Council still exists but now with the name Defense Sciences Research Council. The mission of the Council, together with a second ARPA group known as JASON, is to bring the most current ideas and outstanding advice on science and technology to the U.S. military. The JASONs focus on classified issues, while members of the Council do not. The Council, when Bill worked on it, included such notables as Nicolaas Bloembergen, Walter Kohn, and Robert Schrieffer. They would assemble each summer and work together to tackle technical problems of timely concern to the military. Bill was part of this group during the late 1960s and the 1970s, and he served as the chair of its Steering Committee during the middle 1970s.

At some point during the workshop that summer in 1970, Bill heard a lecture on blood and blood plasma and how

components are typically analyzed using the technique of electrophoresis. Ben Ware recalls that "[Bill] got the idea that we could effectively do electrophoresis spectroscopically using quasi-elastic light scattering. He did a few calculations and called me. I was having trouble getting the equipment together to do any simple experiments, and it annoyed me that he was off on an idea that was beyond anything we could do. . . . When I told him that we should do the standard experiments before moving on, he said, 'Ben, this is NEW!' with such passion that I knew we were on this new track."

Bill had carried out a set of calculations to derive how light scattering coupled with electrophoresis would permit high-resolution multicomponent analysis of blood plasma. Specifically, because of their different net charges, different components would have different Doppler shifts in the presence of an electric field. Bill's calculations suggested that the broad spectrum of Doppler lines due to diffusion would not obscure the distinctive electrophoretic shifts of the various components. Unfortunately, Bill had made some mistakes with dimensional constants and factors of π. When Ben corrected the mistakes, it seemed that the electrophoretic shifts were only a small fraction of the diffusion widths. "I hoped that this would dissuade him. It did not," Ben says.

In the fall of 1970 Bill and Ben were pursuing this area of research. The results of their efforts would become known as "electrophoretic light scattering." This topic and also Bill's simultaneous interest in astrophysical observations occupied many lunchtime conversations. Along with light scattering Bill's group was following up on their high-resolution microwave work with radio astronomy. I had just started my career in Urbana as an assistant professor, and I was yet to have a research group of my own. I would tag along and listen to Bill arguing with and cajoling his students to reach for what

less confident people might think impossible. In part, this motivation spurred Ben Ware to consider a new design for his light-scattering cell and improved signal-processing equipment.

While exploring various technological ideas for light scattering throughout the 1970-1971 winter, a crucial piece of theoretical insight was still missing. The break came when Ben considered that electrophoretic Doppler shifts increase relative to diffusion widths as the light-scattering vector is decreased. With a newly designed sample cell he realized he would be able to resolve the Doppler shifts by doing experiments at very low scattering angle. That spring Ben observed the first measurable electrophoretic shift and verified that it was properly proportional to field strength and to scattering vector. This success attracted significant attention and led to Ben acquiring an assistant professorship at Harvard. They patented the technique, though it is now overshadowed by new gel electrophoresis techniques.

After Ben's graduation, Bill remained interested in light scattering, turning his attention to using the technique to probe orientational correlations between small molecules in liquids. His experiments on this topic proved to be complementary to ideas I was developing on the theory of molecular liquids. But in the midst of figuring it all out, neither of us recognized the complementarities. We argued about the science quite a bit, often heatedly, even in public. On at least one such occasion, we shocked our students and a few of our colleagues. Early on I would worry about whether Bill appreciated my ideas. But as I gained confidence I understood that the intensity of these interactions reflected our personalities rather than our ideas. The interactions helped me learn to use scientific debate constructively to develop and persuade others of my ideas. Bill's last paper on the

topic of intermolecular correlations in liquids is unequivocal about his agreement with my theoretical work.

During this period, in the middle 1970s, Bill turned his attention back to high-resolution microwave spectroscopy, now in the time domain. He was devising techniques that resembled the free induction decay and pulse methods exploited with nuclear magnetic resonance spectroscopy. He was thinking and working with concepts like quantum coherence and dephasing in his characteristically unconventional ways. A young physical chemist interviewing for a faculty position in Urbana at that time talked to Bill about these things. Bill was unimpressed with the candidate's understanding. The candidate did not get a job offer from the University of Illinois, but he did get one from the California Institute of Technology. Some 20 years later this Caltech chemist was awarded a Nobel Prize for work done with time-resolved spectroscopy.

ILLINOIS, FINAL YEARS

By the summer of 1977 Bill's efforts with time-domain microwave spectroscopy seemed to be nearing fruition. His student Bill Hoke had nearly finished the work that he would submit the next spring as his Ph.D. thesis, "Transient Rotational Relaxation Studies and Fourier Transform Microwave Spectroscopy." The techniques described there were important elements in a new and powerful spectroscopy that Bill and his students Terry Balle, Ed Campbell, and Mike Keenan would invent during the next 18 months. Also by that summer the first signs of disease appeared that would make this invention Bill's last contribution to science. Weakness in his right hand plus annoying sensations in his right wrist and arm caused him to seek medical advice. In late September he was told that he was suffering from ALS, and that he would die from this disease, most likely within

two years; Bill would actually survive for nearly four more years.

After learning of his illness, Bill kept a diary from late September through mid-October 1977, which he used to collect his thoughts and help plan for the short future left to him. No one but Bill knew of the diary until after his death. Ruth found it while cleaning out his office. Bill was most concerned about the effect of his illness on Ruth and their children. The diary is laced with the hope that his condition was misdiagnosed. By the end of these weeks, however, with second opinions solicited from doctors across the country, the truth was unambiguous. His right hand and arm were far gone, and damage could already be detected in his other limbs. Eventually the disease would make it impossible for him to talk, and finally lead to suffocation.

Later that fall, Illinois's senior theorist Rudy Marcus was offered an appointment at Caltech, and it soon became clear that he would accept the offer. Bill saw his own failing health together with Marcus's imminent move as a significant blow to the physical chemistry program at Illinois. He convinced Harry Drickamer and Herb Gutowsky that a recruiting effort was necessary. Drickamer and Gutowsky were the only physical chemistry colleagues who knew of Bill's condition at the time. In the late 1970s at Illinois, support from Drickamer and Gutowsky was sufficient to proceed. Offers were tendered in the spring of 1978 to the theorist Robert Zwanzig and to the experimentalist George Flynn. Both recruiting efforts failed. The subsequent year furtive plans to attract the British experimentalist Alan Carrington ended quickly when Carrington expressed no interest in leaving England. Attempts aimed at Bill Miller and John Tully proved similarly unsuccessful. Finally, the theorist Peter Wolynes, then an assistant professor at Harvard, accepted an offer to join the Illinois faculty. This move strengthened the theory

program at Illinois for a few years, but no similar quality senior appointment was made in experimental chemical physics.

Despite the difficulties in recruiting and despite the ominous diagnosis, Bill was determined to make the most of what remained. He published his book *Molecular Structure and Dynamics*, which is based upon the course that he created to teach entering graduate students a working knowledge of quantum mechanics and spectroscopy. In the late winter of 1978 he began to anticipate how his group's developments of time-domain microwave spectroscopy might soon lead to the possibility of determining structures of transient or weakly bound molecular species. He and his students imagined studies of van der Waals complexes, such as argon clustering with hydrogen halides. The techniques that would make these studies possible were not yet completely developed. But forever confident, Bill began to make plans for comprehensive studies of many systems, an onslaught on nature not unlike those he had carried out in the 1960s. Unlike that earlier decade, however, Bill would now have neither sufficient energy nor remaining life to properly lead the effort. His group would need another senior scientist. Bill spent considerable time in the fall of 1978 thinking about whom that person might be. He made a decision, and then planned a trip to England, where he would introduce himself to the prospect.

Anthony ("Tony") Legon remembers that he first met Bill on a snowy day in January 1979. Tony was then a young faculty member at University College London, collaborating with D. J. ("Jim") Millen. Tony and Jim had succeeded at observing and analyzing the rotational spectra of a few hydrogen-bonded complexes, not unlike the systems that Bill hoped to study. Bill turned up at their laboratory and asked Tony whether he was due any sabbatical leave and whether he would like to spend some time in Urbana. Tony

answered yes to both questions. They arranged for Tony to arrive in Illinois at the start of the 1979-1980 academic year. The actual arrival date was four months later because Tony's wife gave birth to their son, Anthony, in November 1979.

Between Bill's visit to London and Tony's arrival in Urbana, Bill had phoned Tony with "typical Flygare enthusiasm," Tony recalls. Bill was reporting to Tony the first working of a pulsed-nozzle Fourier-transform microwave spectrometer. Terry Balle had been able to synchronize a microwave $\pi/2$ pulse with gas pulsed into a Fabry-Perot cavity. This synchronization was the crucial final element required for this new spectroscopy. It was May 18, 1979, exactly two years to the day before Bill would die. The following day Balle worked with another Flygare student, Ed Campbell, and used the new spectrometer to detect strong rotational transitions of the hydrogen bound Ar-HCl complex. Bill called Tony Legon with this news. "He could see immediately all the wide range of possibilities for the technique and could not contain himself," Tony says.

Bill and his students quickly wrote the first report of this technique. It was published as a communication in the September 15, 1979, issue of the *Journal of Chemical Physics*. Simultaneously Bill contacted the National Science Foundation and arranged for a creativity extension of his current funding that provided an additional $135,000 per year for the next two years. A series of studies were then carried out on hydrogen halide molecules bound to rare gas atoms. The impressive spectra and structural analysis of these van der Waals molecules formed the basis for research lectures that Bill would give that fall. One of these was given at Columbia University in New York City. While listening to his brilliant presentation, Columbia faculty could see that Bill was not well, and Bill sensed as much. The next morning he was scheduled for meetings at Columbia, but instead he

simply returned home to Urbana. George Flynn was among those that Bill was supposed to meet with. George phoned me in Urbana to express his concern. It was no longer possible to hide the sad truth that Bill was dying.

On Tony's arrival in January 1980 the Flygare group moved quickly with his help to apply their new spectrometer to systems with chemically interesting interactions: first CO complexes with HCl, HBr, HF, and next ethene-HX, ethyne-HX, cyclopropane-HX. Bill's physical condition was rapidly deteriorating, and he could no longer do the experimental work. He was nevertheless an important presence in the laboratory. Tony remembers: "[Bill] was quite ill. He was sitting with me while I was working at the spectrometer. He said: 'Aren't you lucky. You are the first person in the Universe to see that molecule.' His enthusiasm was unattenuated by his condition." The program of measurements they had mapped out seemed too voluminous to conquer in a reasonable period of time, especially since there was only one of these remarkable spectrometers. The students decided to work in shifts, exploiting this piece of equipment 24 hours a day.

These were not the first studies of van der Waals molecules, but they were the most far reaching and comprehensive. A competing group at Harvard using different techniques soon appreciated that they could not match the ease and speed with which the "Balle-Flygare" spectrometer probed these systems. Considering that work today, more than 20 years later, Berkeley spectroscopist Richard Saykally writes, "Bill Flygare's greatest contribution was the development of the Balle-Flygare Fourier transform microwave spectrometer, which affected nothing less than a total revolution in the field of microwave spectroscopy. The sensitivity, simplicity and generality of this design permit a wide variety of applications. . . . Perhaps a hundred of these

instruments are currently in operation around the world, and are used for the study of molecular species ranging from extremely weakly-bound clusters like KrNe to novel inorganic donor-acceptor complexes."

Results were pouring out, but Bill was no longer able to hold a pen. A year earlier he had switched to writing with his left hand, but now even his left side was incapacitated. In addition, his speech was becoming inaudible, so dictation was becoming problematic. Art Gaylord provided a tool that would enable Bill to continue communicating. Art had recently joined the Illinois technical support staff after obtaining a Berkeley Ph.D. as William Gwinn's last graduate student. He fashioned one of the original Apple II computers so that Bill could type by simply dropping his hands onto the keyboard. A ball would pass along a menu on the screen, and striking the keyboard instructed the computer to branch to the item adjacent to the ball. The alphabet was one such item, and a touch of the keyboard at that point instructed the printer to type the letter adjacent to the ball. For the next several months Bill would write in this way, one stroke at a time.

The group's results generated significant excitement throughout the chemical physics community. In November 1980 Bill received notification that he had been selected as the next recipient of the Irving Langmuir Award from the American Physical Society. A group of us assembled that afternoon to congratulate Bill for being honored by this most prestigious recognition in chemical physics. He came to the party only briefly, as he was overwhelmed with emotion. It was the only time we observed Bill upset by his illness. Tony Legon recalls: "The [Langmuir] Award provided a focus for all those conflicting thoughts that he must have had at that time and especially because he knew he was a great scientist whose life was about to be cut short at its zenith."

Over the next six months Bill's group would continue its productive march. Tony returned to England in January 1981, but the people working to carry on had now swollen to include seven new students along with those that had been there at the start of the project: Terry Balle, Ed Campbell, and Mike Keenan. Through the weekend of May 16 and 17 Bill remained scientifically active and in touch with his group, but he was having difficulty breathing and his lungs were beginning to fill with fluid. Bill passed away early that rainy Monday morning, at home, in Ruth's arms. A memorial service was held two days later. Referring to Bill in a written eulogy, Harry Drickamer would quote from Shakespeare's Hamlet, "He was a man, take him all in all. We shall not look upon his like again." The next winter the Flygare family scattered Bill's ashes across the mountainside above Aspen, Colorado, where Bill had so often loved to ski.

PROLOGUE AND ACKNOWLEDGMENTS

Bill's life ended more than two decades ago, but his influence continues. Writing this memoir has given me the opportunity to learn many heartfelt things about this influence. His children have all become interesting and productive adults with children of their own. Ruth remains lovely and healthy. She has remarried, to Vern Halberstadt. Vern was a widower. Together they melded a family of six children and ten grandchildren. Much of what is described in this memoir I learned from conversations with Ruth and the materials she provided. Bill's greatest concerns were for the health and future of his wife and children. It seems clear to me that Bill succeeded at building a foundation for their lives that served them well.

Peter Beak remains an active member of the Illinois Chemistry Department. Ben Ware is currently vice-president for research at Syracuse University. John Pochan is a materials

scientist with Kodak. Rick Shoemaker is a professor at the Optical Sciences Center of the University of Arizona. J. J. Ewing lives in Seattle, where he is president of Ewing Technology Associates. Tony Legon now lives in Exeter, England, where he is a professor and fellow of the Royal Society. Each of these people has generously written to me describing their work with Bill and the impact his energy and enthusiasm had on their lives. Several others have provided helpful information that I have used in this memoir, including David Buckingham, Henry Ehrenreich, John Flygare, Richard Saykally, and Jeremiah Sullivan.

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