James Van Allen discussing Earth's radiation belts.

Chapter 5. University of Iowa

My mother gave me a ride to Iowa City. Actually, I drove, about 200 miles east on Highway 30, which was two undivided lanes, one in each direction. Truck traffic and hills required vigilant passing. We talked little. I was anxious, moving to a different world.

We found Hillcrest dormitory. I picked up the room key, carried up my box of clothes and came back to the car. Mom wanted to leave this foreign place. She did not want to see my room, just get back on the road home. I took her box of cookies. Her last words were "be sure to write."

I knew that I had social deficiencies, in addition to academic and financial challenges, but I made little effort at social improvement. My roommate, Bob, was a nice guy, but I did not want to socialize. Luckily, he befriended a guy across the hall. Once that fellow joked at me – I slapped him defiantly, knocking his glasses off. They decided that I was strange, and left me alone.

Room and board the first year, $1000, depleted more than half of the money I had saved over 10 years. At the end of my freshman year I found a $25 per month room, on the 2nd floor of a house at 409 Iowa Avenue, where I would spend my remaining years in Iowa City

I was lucky to find a summer job that partially restored my bank account. Reitzel pipeline construction was putting gas pipelines into Denison. I only had to measure the length of pipe installed each day at the multiple locations of digging.

Back to Iowa City in the fall; I wanted to minimize costs, so that I would not need to work in the library shelving books, which I did as a freshman. Dinner was a TV dinner heated on a hot plate. Breakfast and lunch were cereal and milk, with some fruit and vegetables. My refrigerator was the space between the window and screen. My mother sent a shoebox of cookies and homemade candy every six weeks or so. So I began getting heavier from afternoon snacks.

Midway through my undergraduate years I made a serious mistake. While shopping at the grocery store, I put a tube of toothpaste in my pocket rather than in the shopping cart, the store owner saw it, and I was arrested for shoplifting.

That mistake could have erased my hard work – my grades were nearly straight A. When the judge saw my academic record and the fact that I had no prior offenses, he put off sentencing. It appeared that, if the store owner agreed, he likely would drop the charges.

However, I called the judge and told him that I had done a similar thing a few times before. He got angry, suggested that I must be trying to get thrown out of school, and ordered me to see a university psychiatrist. In reality, I only had qualms about not being honest when I knew that he was trying to help. Eventually the charges were dropped, and my official record was clean.

Why tell that story? It is easy to be too hard on yourself. Everybody makes mistakes. Don't give up on yourself, when you make a mistake. I made a lot of mistakes. Usually mistakes can be overcome. However, you had better minimize them.

There is another reason for the story. Think about this: what if I were black? Would that mistake have been eliminated from my record? Perhaps the justice system is color blind in Iowa City today? I'm not sure, but what about elsewhere? Laws alone do not assure equal opportunity.

Professor Satoshi Matsushima was head of the Astronomy program in the Department of Physics and Astronomy. Matsushima was hardly five feet tall and perhaps 100 pounds, but very energetic in his Astronomy course lectures. Sometimes he struggled in explaining astronomical concepts or geometry. That was o.k.; the course had a good text book.

Andy Lacis and I walked in the same direction after Matsushima's class. We even talked, which was the most extensive relationship that I had as an undergraduate. Andy had a short flat-topped haircut that made him look like a young Roger Maris, the Yankee's right-fielder. Andy was of Latvian origin – his family escaped from the USSR at the end of World War II and lived in a refugee camp in Germany until emigrating to the United States.

Andy and I dubbed Matsushima the "coach." If it was a term of endearment that would change during later battles. At least we were gaining some self-confidence. Physics is hard. I avoided taking any course taught by Prof. James Van Allen, Department Chairman and discoverer of Earth's radiation belts,[1] because I did not want him to know how ignorant I was.

I still felt that way as a senior about to graduate *Summa Cum Laude* ('with highest distinction') with a double major in physics and mathematics. That academic record only indicated that I had worked hard. For sure, I was not yet a scientist.

Prof. Matsushima gave Andy and me a push in the direction of becoming scientists. He identified us as the best students in his astronomy class and tried to persuade us to go to graduate school at Iowa. He gave us part-time, paying, jobs, doing some astronomical calculations.

Matsushima also made a clever suggestion that altered my career path and my life. He suggested that we take the Ph.D. qualifying exam as seniors. This exam was taken by physics students after a year of graduate study, unless they deferred it. The exam could be taken a maximum of two times. If passed, the student could enter a research path aimed at a Ph.D., with additional checkpoints at which the student's program might be terminated short of a Ph.D.

Matsushima said the exam would be good experience and help us pass the next year. In fact, we both passed easily, the first undergraduates to pass the Ph. D. qualifying exam.

Passing score was about 90. Andy's score, about 100, would have been higher, but he decided not to take the second day of the two-day exam – it was enough experience, he said, and really hard. Matsushima noticed Andy, and, like a little general, he hustled Andy into the exam, albeit hours after it started. I passed the exam, with a score of one hundred and something in the teens.

Mount Agung on Bali, erupting in 2017

So Van Allen noticed me. I was lucky. I should give the coach some credit. It is a bad idea to be a wallflower -- there were about 50 graduate students in physics. It is better to ask a question now and then, but be sure they are not foolish questions.

Van Allen, later when I was in graduate school, would suggest a research problem to me: why did Venus emit so much microwave radiation? He also appointed himself to be on my thesis committee. The latter action turned out to make all the difference.

Matsushima's motive, in pushing us to take the exam, was to show Van Allen that he had top students. Van Allen agreed that the Department should offer both Andy and me NASA traineeships. No more need to shelve books or shovel chicken manure, which I did one summer. The traineeships paid our graduate school expenses and provided a $200 per month stipend.

Presidents Eisenhower and Kennedy, as well as Congress, supported brainpower development to address the space challenge. Their approach was unlike that of today's government, which does not offer analogous support for the current challenge – science and engineering of clean energy – despite obvious merits for improving national infrastructure and economic competitiveness.

As Andy and I bent over the exam table, puzzling over knotty physics problems, a scientific experiment began to play out over our heads. Mount Agung, on the island of Bali in Indonesia, exploded on 17 March 1963, sending a massive cloud of ash and gas high into the atmosphere.

Lava flows from the eruption had a local effect, killing more than 1000 Indonesians. However, there would also be a global effect. Gas and dust blasted into the atmosphere reached heights of more than 10 miles, where stratospheric winds spread them all around the world.

Blissfully ignorant of this activity overhead, we began our graduate studies. Andy and I each intended to first get Master's degrees in astronomy before pursuing a Ph.D. in space physics, which was broadly defined to include anything from astrophysics to planetary science.

Once again, Prof. Matsushima had a fruitful idea. He suggested that we observe the lunar eclipse that would occur on 30 December 1963. His suggestion was spurred by the need to make use of the Astronomy section's small telescope, which was his responsibility.

On the 29th of December, Andy and I swept leaves, cobwebs and mice out of the little domed observatory on a hill in a cornfield just outside Iowa City. We were novice astronomers, but, fortunately, a longtime graduate student, John Zink, could help operate the telescope. We would attach a photometer to measure moonlight, sunlight reflected by the moon, at several wavelengths, in other words, measure the brightness of red light, blue light, and so on.

We met with Zink in the physics building to plan the observations. Prof. Van Allen happened by as we were talking. Zink used this as a chance to ask Van Allen for a reference letter. With a big smile, Van Allen said “Sure, I will tell them you came to Iowa as a very promising student and just petered out over time,” as he made a wiggly downward motion with one hand. Zink’s smile was uncomfortable, because he had been a student a long time. However, Van Allen’s good nature was so obvious that we were sure he would write a good letter.

Given Van Allen’s always pleasant, pipe-smoking, demeanor, I should have been comfortable talking with him. The problem was that I worried about my weak points. What if he asked me about the functioning of the photometer, a basic instrument, but a foreign contraption to me?

December 30 had the coldest night of the year. An Alberta Clipper poured Arctic air into the Midwest from western Canada. It was 15 degrees below zero Fahrenheit, 26 degrees below zero Celsius. Zink did the observations. There was no point to fool around teaching new kids on that night! We handed him what he needed, held his gloves if he had to take them off, and warmed the car up for him, so that we could take a break once during the observations.

We were surprised as the moon moved into Earth’s shadow. It disappeared entirely! Just black sky, where the moon had been. The moon in eclipse is usually visible, because some sunlight is refracted (bent) by Earth’s atmosphere or scattered by molecules or particles into the shadow.

It took little thinking to realize that something in Earth’s atmosphere was blocking the sunlight that normally gets passed into Earth’s shadow. The obvious candidate was stuff dumped into the atmosphere by the Mount Agung volcanic eruption. I jumped on this problem, quickly reading scientific papers, to stake out the topic for my Master’s thesis in Astronomy.

A Czech astronomer, Frantisek Link, had worked out the eclipse geometry, describing how light rays are refracted and scattered into Earth’s shadow. Once I understood Link’s equations, I had to write a computer program to calculate the brightness in the shadow. Then I could try a range of assumptions for the amount and distribution of volcanic aerosols in the atmosphere.

I spent weeks translating and studying Prof. Link’s book in German,[2] until I realized he had published almost the same thing in English in A*dvances in Astronomy and Astrophysics*!

In the end, I could estimate the aerosol amount in Earth’s stratosphere in December 1963. Also I concluded that similarly useful lunar eclipses, ones when the moon passes close to the center of Earth’s shadow, occur about once per year. Such aerosol information is valuable, because volcanic aerosols are a potential cause of climate variability.

I wrote a paper[3] based on this research that got published. Van Allen’s policy was that a paper in a peer-reviewed journal constituted a Master’s degree thesis. Therefore, I was free to get on with Ph. D. research.

But I was not yet a scientist. Technical ability is only a prerequisite; even a Ph.D. behind your name does not make you a scientist. Van Allen used a curious ‘original proposition’ method to help instill unbiased scientific objectivity. However, the making of a scientist is like learning from a Jedi master: it requires years of practice, and there is no guarantee that you will acquire the Force and be capable of carrying out fruitful, unbiased scientific studies.

This is the point for an interjection: a commentary on the sad state of my physical condition. This matter began with a letter from my sister Lois. She had seen a photo in a local newspaper of me looking through the telescope at the lunar eclipse.

"Is that the moon looking through a telescope?" My round face was the object of her jest. I weighed 130 pounds as a freshman, but a sedentary life and snacking made me round. The moon observing the moon in December 1963 was out of shape and weighed about 175 pounds.

It was time to get ready to face the real world! When I entered college I did not know quite what it would be like to come out the other end, but I liked to imagine that when I finished college I could have a beautiful girl friend. That was one reason to get in shape, but I had another reason.

I responded to Lois' goading: "just wait a few years, I'll show you!" This sparked her interest; her return letter asked: "Oh, what are you going to do?" I did not answer. My goal, to become an astronaut, would seem outlandish, given my physical appearance, shyness, and near-sightedness.

While a college freshman, I had done what any weakling American boy might do: I responded to one of the ubiquitous Charles Atlas advertisements. Atlas got sand kicked in his eyes by a bully on the beach, and then made himself into a muscle man. I was too busy with classwork, though, so I put the Atlas lessons in a drawer.

As a graduate student, I started doing the exercise Atlas said was most important. It is high cardio, focused on the pectoral and shoulder muscles, takes 3 minutes. It was not smart to do a single exercise, but it put me in decent shape at 160 pounds.

Later I will suggest a high-cardio 3-minute exercise for the largest muscles – thighs, buttocks, and the muscles supporting the body core, followed, after 4 minutes to catch your breath, by a 3-minute high-cardio modification of the Atlas exercise. If you are in your 20s, in 10 minutes a day it is easy to shape your body to its optimum, and then keep that body shape your entire life, if you have a healthy diet. I will come back to this later and be more explicit. It is important. It helps to make you an optimistic person, and to get up when you get knocked down.

Prof. Van Allen defined a specific rite of passage for Ph.D. candidates. Each candidate had to offer an 'original proposition' and defend it before a committee of five professors.

Ideas outside conventional wisdom were encouraged. We had to describe a plan for how we would evaluate the proposition. The plan had better not expose ignorance of sound physics.

Van Allen perhaps knew I was interested in planets, because, for Matsushima's Astrophysics class, I chose the atmosphere of Jupiter as my discussion topic. In any case, Van Allen told me about observations of high microwave radiation from Venus. He wondered whether this radiation was an indication that Venus had radiation belts analogous to those of Earth, the large donut-shaped regions of energetic charged particles that swaddle Earth.[1]

I read the published papers, hoping to get an idea for an 'original proposition' about Venus. Venus permitted a wide range of speculations, because the entire planet was blanketed by pale lemon-yellow clouds that prevented observation of the planetary surface.

Carl Sagan, an Assistant Professor at Harvard, and Jim Pollack, a post-doc with him, argued that the high microwave radiation was from a very hot planetary surface, kept hot by a strong 'greenhouse' effect. They believed that the Venus clouds were water ice, like cirrus clouds on Earth, which scattered sunlight to the ground, while the atmosphere contained water vapor and carbon dioxide that absorbed outgoing heat radiation. The Venus surface was thus kept warm, somewhat analogous to the way sunlight warms the air in an automobile with closed windows.[4]

Ernst Opik, an Estonian astronomer working at Armagh Observatory in Ireland, had a different idea, based partly on the color of Venus. He thought the clouds were desert dust suspended in the air by a continuous dust and sandstorm. He assumed that sunlight provided energy for the storms, which dissipated their kinetic energy into heat, thus warming the planetary surface.

To devise an original proposition, I had to first understand the weak and strong points of existing interpretations. I needed to find reasons to be skeptical about these existing interpretations.

One reason to doubt the Sagan and Pollack model for Venus was that the pale lemon color of Venus does not resemble water clouds. Perhaps the color of Venus could be explained easier with Opik's model of a dry, dusty atmosphere. However, Opik's model required continual storms to keep large dust particles in the air, which was perhaps a dubious assumption.

My proposition was related to Opik's model. The novel aspect was that the energy source was the interior of Venus, with this interior heat being trapped by micron-sized dust that could be kept aloft by slight breezes. For the sake of keeping the proposition plausible, I assumed only that the internal energy source on Venus was similar in magnitude to that on Earth.

There is a continual energy flow from Earth's interior to the surface of about one-tenth of a watt per square meter.[5] This energy comes from two sources: primordial heat left over from formation of Earth and radioactive decay of elements in Earth's mantle and crust.

Van Allen was the chair of the committee hearing my 'original proposition.' I spent time critiquing the other hypotheses for the high temperature of Venus, described the dust/insulation model, and discussed some ideas about how I might investigate the matter further.

The committee was satisfied. If the dust/insulation model had low probability of being reality on Venus, that was not a problem. In one sense, low probability of a proposition increased its merits as a learning tool, because it forced me to be skeptical of my proposed interpretation.

The research would be pursued in Japan. Prof. Matsushima received a grant to spend a year at the Universities of Kyoto and Tokyo. Matsushima did not want to risk losing his students to another professor, and Andy and I liked the idea of spending a year in such an exotic place.

Before going to Japan, I would fix two things that had bothered me a long time. I could afford some luxuries: $200/month from NASA exceeded my living expense with a $25/month room.

First, I wanted to ditch my thick glasses. Mainly I wanted to be more attractive to girls, but also it might help my case to be an astronaut. Years later, I had the lenses in my eyes extracted and replaced with lenses that provided excellent vision for both reading and distance. However, that technology was not yet available, so in 1965 I got contact lenses

Second, I wanted to fix my crooked front teeth. An orthodontist told me it would take two years. Dejected, I called a professor in the College of Dentistry. He suggested that I consider capping the teeth, and he recommended an Iowa City dentist. Dr. Gingerich looked at the four crooked front teeth, each with a discolored filling, and said that, of course, they should have permanent caps. In one week, days before leaving to Japan, a forever problem was fixed.

Unfortunately, these actions addressed only superficial deficiencies.

Chapter 6. Exotic Japan

Kyoto, in the fall and winter of 1965, exposed more of Prof. Matsushima's students than one of them should care to admit. Andy and I entered a different world in Japan. Kyoto was the capital of Japan for 1000 years, until the imperial family moved to Tokyo in the 1800s. Temples and gardens of Kyoto are revered by the Japanese as the center of traditional culture and Buddhism. Andy paid more attention to the cultural opportunity, and he studied the difficult language, so he could interact with the people. I didn't think much about those things, and I relied mainly on Andy to find our way around.

The International Student House was a newish two-story building on a hill in a Kyoto suburb. From there we walked on a narrow street that wound down the hill, houses so close to the path that Japanese voices spilled into the street. A broad street at the bottom of the hill had a trolley to Kyoto. People pretended not to stare – Westerners were scarce in Kyoto then. Changing to a second trolley in Kyoto, we got to the edge of the Kyoto University campus. There a broad road and path skirted the outfield of a baseball diamond, where a lone outfielder shagged flyballs.

The Institute for Astrophysics, our destination, was an old building with darkened windows. We understood why, later, on a cool winter day: during a lecture, a student got up, put coal in the stove, and stoked it noisily. Japan was still a developing country in 1965.

Andy and I followed Prof. Matsushima into the office of Prof. Sueo Ueno, the esteemed senior scientist of the Institute for Astrophysics. Prof. Ueno, a pale, thin man, smiled and bowed deeply, a Japanese tradition. We were just students, but guests. We bent awkwardly in return.

It did not matter. Prof. Ueno eagerly showed us his papers. They were full of long equations describing transfer of radiation through a medium. The radiation could be sunlight, or heat, or neutrons, and the medium might be a cloud, the ocean, interstellar space, or a nuclear reactor.

Prof. Ueno's 'invariant imbedding' equations had a sterling pedigree, originating with V. Ambartsumian and developed further by the genius S. Chandrasekhar, both giants in the field of astrophysics. Ueno showed us a paper on such-and-such, and asked: "might you be interested?" His politeness to lowly students demanded a "yes," but I could say it honestly, because I wanted to do calculations for Venus.

Prof. Ueno smiled happily as we left his office. I had a pile of his papers. Most of these papers were probably not relevant to my plans, but I hoped to use Ueno's invariant imbedding method to calculate how the brightness of Venus changes across the face of the planet.

Venus, observed through a telescope, is a bright, pale lemon-yellow ball, but its brightness is not uniform over the face of the planet. Venus is less bright toward its edge, the 'limb' of the planet. This is called 'limb darkening.'

My idea was to calculate limb-darkening for different 'models' of the Venus atmosphere using Ueno's invariant imbedding method. One model would be for a dusty atmosphere. Another would have water-ice clouds, similar to cirrus clouds, as suggested by Sagan and Pollack. Then I could check which model agreed better with observations of Venus.

I struggled for weeks, writing computer programs. Luckily, Kyoto University had just acquired an IBM computer that used punched cards, rather than the earlier punched paper tape. That meant, when I found a mistake in my program, I could usually fix it by replacing one card.

The merit of Ueno's numerical invariant imbedding method was that it could incorporate realistic scattering particles. Dust and cirrus ice crystals scatter light in different directional patterns, and dust absorbs part of the sunlight that hits it, while cirrus particles scatter it all.

After months of work, I showed that limb-darkening was different for ice and dust. However, Venus observations had a substantial 'error bar' or uncertainty, especially in data near the planet's limb. Either dust or ice clouds could fit the observations within the error bars. I was forced to conclude that better observations were needed.

I had not learned much, but I could use it for one chapter in my Ph. D. thesis. If Ph.D. stands for 'piled higher and deeper,' I had something for the pile, but I needed something better.

Meanwhile, a package from Carl Sagan arrived. I had written a letter to Sagan describing my 'original proposition' and asking for one of his 'in press' papers.

Sagan sent much more than I requested. The package contained several papers that he and his post-doc Jim Pollack wrote, and a two-page letter. Carl explained why he thought that my dust model could not be correct, and why his (and Jim Pollack's) interpretation of a strong greenhouse effect with carbon dioxide, water vapor and ice clouds was a more likely model.

Sagan went to a lot of trouble to respond to a letter from a student he did not know. Biographers of Sagan paint a mixed picture of him as a person. Our interactions included cases where we had differences of opinion, for example, when he asked me to make simulations of the climate effect of nuclear war. In every case, he was understanding and generous. I liked him a lot.

A NASA poster appeared on the bulletin board at the Institute for Astrophysics and struck me with wonder. It was an advertisement for post-doctoral positions at NASA Centers in the United States. Could this change, from fantasy to plausibility, my hope to be an astronaut?

One paragraph described the Goddard Institute for Space Studies in New York: "The Institute for Space Studies conducts theoretical research in … the physics of planetary bodies and their atmospheres. The program includes basic studies in meteorology and theories of turbulence, convection and radiative transfer." This was the research that I hoped to get into more deeply!

Thereupon, I committed a grave sin, in Prof. Matsushima's view. I sent a letter to Prof. Van Allen on 10 February requesting that he write one of the four reference letters required by NASA. I said that I thought I could finish my Ph.D. thesis by August.

Prof. Van Allen, in his return letter, dated 15 February 1966, said he was pleased that my thesis work was going well, but an August degree seemed impractical. The thesis would be due by early July; also Prof. Matsushima would not return from Japan until September. He said that my defense could be arranged in early autumn. He sent a cc of his letter to Prof. Matsushima.

An explosion ensued on the top floor of the Institute for Astrophysics. I was summoned to Prof. Matsushima's office. He was standing. His face was red. His first words were "you are not my friend!" He held in one hand the letter from Van Allen.

Friction between graduate students and advising professors is common. The student-professor relation, in principle, is mutually beneficial. Students need guidance. The professor may have limited time for research and limited skills in developing areas such as computer programming.

But how much does the student owe the professor? Conflict can occur with publications. If you ask the professor and student their contribution to a paper, the sum often will exceed 100 percent.

Matsushima was appropriately a co-author on our paper interpreting the lunar eclipse after the Mount Agung eruption. He suggested the observations and obtained Link's book in German. I did the research on my own and wrote the first draft of the paper.

The problem was the length of indentured service. I wanted to escape after three years in graduate school, while Matsushima expected a longer period of research and paper writing.

NASA required four reference letters. One had to be from the Ph.D. adviser. If I went to Matsushima first, there was zero chance that he would approve of the application.

So I first sent requests to three other people, including Van Allen. I aimed to get the process started before Matsushima could stop it. It was a tricky thing to do. Science today might be a tricky business. Certainly I thought so in my middle age, when I did not encourage my children to go into science as a career. Let's reconsider the matter later.

I suspect that Prof. Van Allen understood my situation. His letter ended: "However, we can arrange an examination in early autumn at a mutually agreeable time. Meanwhile, I see no reason why you should not apply for a post-doctoral fellowship, stating your exact situation. I have forwarded your application to NRC/NAS."[6]

Prof. Van Allen had done exactly what I needed! No wonder Matsushima's face looked as if blood vessels were about to burst. Van Allen's letter was more important than his. Besides, if he refused to write a letter, it would look bad to Van Allen. Matsushima did not yet have tenure.

Meanwhile, at age almost 25, I had my first girlfriend. This story is more embarrassing than my shoplifting episode. There is little to be learned from it, so I may cut it before publication.

I spent a lot of time in the library. The librarian was a Japanese girl, about my age. Let's call her Kamana. Her English was good. Our communication problem was my extreme shyness. Luckily the 1960s were a different era. Human-to-human contact was not fraught as it is today.

Once, in checking out books, our hands touched accidentally. When it happened a second time, I wondered if it was accidental, and I started thinking about her. She was attractive, but I had never asked a girl for a date. The matter was solved a week later, when I couldn't find a book in the shelves. This time when our hands touched I was in tune with her. I even looked in her eyes without averting my gaze. There is nothing as wonderful, I think, as a passionate kiss with a personable woman who is aching to be kissed, not kissed by anybody, but kissed by you.

That's not the embarrassing part. It was how to go further. It so happens that Andy and I were about to buy a car, a used mid-1950s Mazda. Mazdas are a nice car now, but in the 1950s they were pretty much a tin can. That was o.k. with us. Andy wanted the car for more convenient transportation. Andy was from the sophisticated end of Iowa, but I was from the country west.

On our first date Kamana and I drove to Kyoto for dinner – and a couple of drinks. Then we went walking, holding hands, in the entertainment district, an area with 'love hotels' on every street. Most couples in Japan did not marry before their mid or late twenties, so there was a booming business for places where they could spend an hour or two together. These were nice, reputable places. But no one told me about them. Perhaps Kamana did not want to seem experienced.

In any case, I did what I thought Midwestern guys did. We got in the car to drive out of the city to a private place. Unfortunately, I was slightly inebriated – I should not have been driving.

I drove straight out of town on Gojo Street, some distance without incident. We got to an area with agricultural fields at a lower elevation than the street. At one intersection there was a path down to the edge of the field and under the street. We could not wait longer. I steered onto the path, but the wheels on my side slipped off the path.

The car rolled over twice, shattering windows on both sides, coming to rest on its top. We were tossed about, but could open the doors and get out. The only injury was a small cut on one of Kamana's calves. We climbed to the street, laughing at the upside down Mazda. There were soon several Japanese people, looking at our predicament. I decided to wait until morning to get assistance to recover the car. We caught a taxi, and I went back to the International House.

I will not forget the look on Andy's face. First, for a second or two, it was a look of anger – what had this idiot done to our fine Mazda? Then he began thinking. I suggested that we find a vehicle repair place with the capability to lift the car back to the road. It would be a big challenge for Andy's budding Japanese speaking ability.

Andy had a better idea. We should go first thing in the morning to Prof. Matsushima and reveal the mess. Matsushima would do everything possible to avoid a scandal in the media. He had brought his two fine students to Japan to show off, not to be made a fool of.

So the next morning we were standing on the road by the rice field as a crane slowly lifted the sorry Mazda back to the road. Matsushima watched, stone-faced. He said that the neighbors standing around were saying that the young American and a Japanese girl were laughing as they crawled out of the car – they could not possibly have been sober. I supposed that they were wondering who the foolish driver was.

The car still ran fine. We replaced the windows. It looked a little banged up, but it served its purposes. Andy had a girlfriend, a young Chinese lady, and I went out regularly with Kamana, even learning the merits of the Kyoto entertainment district.

In late February 1966, Matsushima, Andy and I had to leave Kyoto for the University of Tokyo, for the second half of our year in Japan. A few days before we left, the boy friend of Kamana's girl friend suggested to me that Kamana was willing to go with me to Tokyo.   But I did not want a bigger commitment. I wanted to focus on space science research, to enhance the chance of becoming an astronaut. And I felt that I was still way behind where I should have been.

Tokyo is not quite 300 miles from Kyoto. The trip by car now, with today's roads and vehicles, is probably less than six hours. For us it was more than 24 hours.

Our little Mazda was not meant for mountain climbing. The roads were narrow, crooked, and went through towns. Signs were in Japanese and not always clear. Day became night. We used the sky to check our direction. The Mazda began to vibrate. We found that one of the engine's fan blades was bent. Andy fooled with it a few times, then broke it off.   That helped for a while, but vibrations grew again. Andy broke off the opposite fan blade, for symmetry. That reduced vibrations, but the motor overheated. We had to stop and let it cool off. Night changed to day as we approached Tokyo, and the time between overheats became shorter and shorter. We chugged into Tokyo at midday and found our way to the International House.

Tokyo was different. We were in Shinjuku district, a beehive, lights rivaling Broadway. The International House seemed out of place, an old, grey building, on a side street, but even this street hardly slept. Down the street was a pachinko parlor, scores of machines in rows – a cross between a slot machine and a vertical pinball machine. You buy a pile of chrome marbles and feed them into the pachinko machine – with little control on the ball's destination, but at least you can't cause a game-ending 'tilt.' A ball in the correct hole, releases a bunch of marbles to your tray below. The jackpot hole yields enough marbles for a prize. It's so noisy, you should wear earmuffs. The popularity of pachinko, with even housewives playing, was puzzling.

I had no time for pachinko. I read scientific papers or worked on my thesis into the wee hours. I took a walk before bed, as late as 3 AM, when there were still people on Shinjuku streets. A few times there were boys in black samurai dress, going through a ritual with long sticks or swords.

What to do for a Ph.D. thesis? I was fretting. My 'original proposition' -- that the Venus clouds were fine dust that helped keep the surface warm – was a longshot. It could still make a Ph.D. thesis, as long as there was no evidence proving it to be wrong.

I had better hurry up and finish. The Soviet Union planned to send entry probes to Venus. They would measure the composition of the air and probably take pictures. Their data would likely prove whether my interpretation based on 'remote sensing' was right or wrong.

Remote sensing is all we can do, unless we travel to the planet. We can measure radiation coming from Venus to Earth. The radiation, covering the entire spectrum from long radiowaves to high energy gamma rays (Figure 6.1), includes sunlight reflected by Venus and energy emitted by Venus. However, the only energy that penetrates Earth's atmosphere, so it can be measured at the ground, is in (1) radio waves and microwaves, and (2) infrared and visible radiation, as shown by the white regions on the top bar of Figure 6.1.

Remote sensing is still needed, even after entry probes directly sample the Venus atmosphere, for the sake of putting the local entry probe measurements in a global context. Also remote sensing can reveal additional information not obtained by entry probes.

I could see two good ways to expand my radiation calculations to extract more information on the Venus clouds and atmosphere: (1) calculate how sunlight becomes polarized when it is reflected by Venus, (2) calculate absorption by different gases of the sunlight reflected by Venus.

Never mind, for now, what those mean exactly. I realized that either one of those tasks would probably take at least two years. I was already in my third year of graduate school and had spent six years in Iowa City as a troglodyte. I wanted to finish my thesis and enter the real world.

I had stuff for the front sections of a thesis. I reviewed all models proposed for Venus, including the 'Ionosphere models' that were Prof. Van Allen's initial interest. Although various Ionosphere models had been suggested, I could describe discrepancies with remote sensing data for all of them. For all practical purposes, they could each be ruled out.

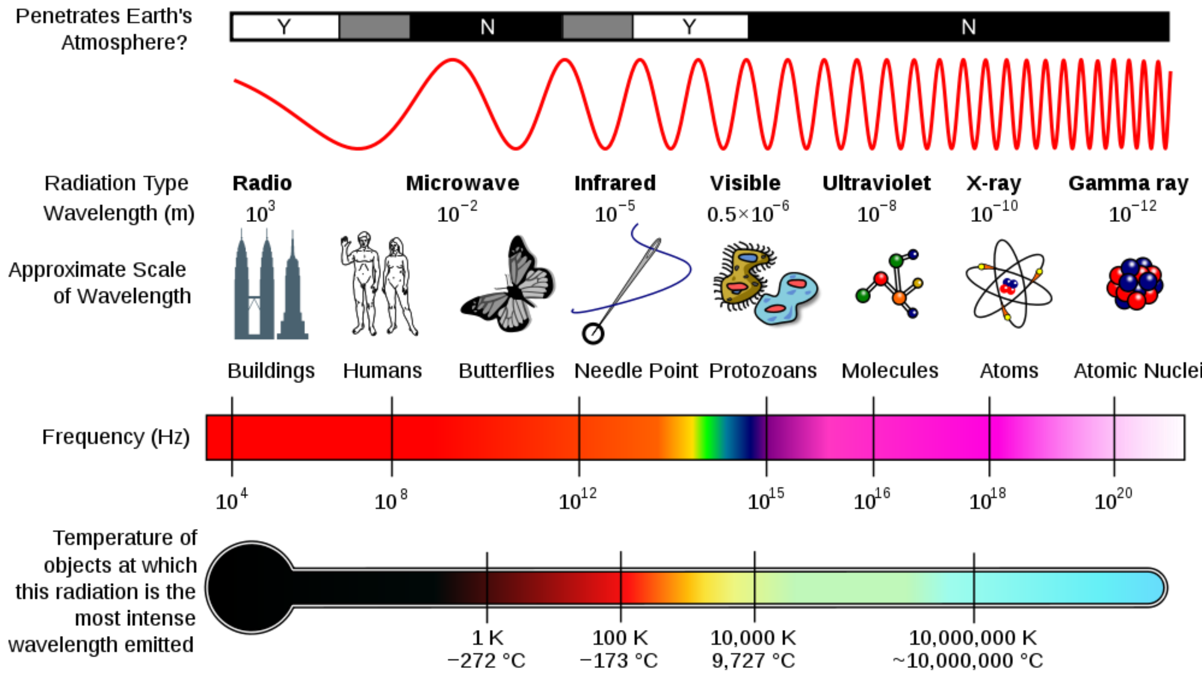

Figure 6.1. Electromagnetic spectrum (credit: NASA via Wikipedia)

The Greenhouse model of Sagan and Pollack seemed to be the most plausible of existing models, but there was something fishy about it. They assumed a large water vapor amount to explain the greenhouse warming, but observations did not reveal much water. And to explain microwave data, they needed clouds of just the right properties – or, they suggested, maybe there was dust in the air near the surface. That was ad hoc, so it was another weakness of their model.

I could do one more thing: check whether my Dust model was consistent with microwave observations of Venus. I found that the amount of dust required to yield the atmospheric opacity (opaqueness) implied by microwave observations was the same as the amount of dust needed to keep the planet hot by blocking heat radiation. So at least the Dust model was self-consistent.

Meanwhile, I was in a contest with Prof. Matsushima. I submitted my application for a NASA post-doc position on 10 February 1966, including a list of four references. In a letter dated 23 March the NAS/NRC said that they had three reference letters, but not Matsushima's.

Prof. Matsushima said he wrote the letter, but the secretary was not good and probably lost it. He did not keep a copy. I needed a new reference form from NAS/NRC. On 2 April I requested it, but, after worrying, on 17 April I sent a letter to NAS/NRC explaining the situation. Could I seek a letter from an alternative Iowa professor? They refused to change their requirement, but on 23 May, they sent a letter, saying that they had received the form from Matsushima.

Then, in July, the NAS/NRC sent a letter offering me the post-doc position at the NASA Goddard Institute for Space Studies! First, I was in shock – somehow I had not expected it all to work out. Then I realized that I had a problem – I still needed to write the dissertation that I was supposed to defend upon return from Japan.

Another complication arose upon returning to Iowa: an announcement of a "limited number of career appointments for scientists to serve as astronauts." Application deadline: 8 January 1967.

I sent a letter asking if my near-sightedness disqualified me. Answer: exceptions are possible, depending on other qualifications. So I had even more pressure to finish my thesis.

Thesis defense was scheduled for December. The committee was supposed to receive the thesis a few weeks before the defense, but, Prof. Matsushima said, students were often late in delivery. I gave the first half of the thesis to Matsushima and said that the second half was almost done, but he suggested changes, which he had the right to do.

"Van is angry at you! You missed the deadline" Prof. Matsushima declared when I came in the next week. I had never seen Prof. Van Allen angry, so I was skeptical, but worried. Matsushima had a big smile. I felt that I had been tricked. But I knew it was my own fault. I had been too slow. I should have worked harder in Japan and finished the thesis there.

Fortunately, I could reschedule. Unfortunately, I agreed with Matsushima's suggestion of 23 January, the latest date allowed by the Graduate College. Van Allen's note accepting the new date attached Matsushima's letter to Van Allen requesting the change. Matsushima's letter included a statement that he wanted to be sure that my thesis "contains the whole material to make a paper publishable in the most competent journal such as the Astrophysical Journal. As long as I stay at Iowa as a person responsible for Ph.D. degrees granted in the astronomy area, I wish to make this a criterion for judging whether a thesis is acceptable for the degree or not."

Yikes. Not only had I chosen a schedule that allowed no time for revisions if the committee found any problems, Matsushima was trying to impose an added requirement. I was annoyed that I had put myself in such a tight situation. I began working really hard, sleeping only 4-5 hours per night. The thesis was long – it turned out to be 278 pages – how could I avoid flaws that would require revision? Even typing requirements were strict.

I put off the astronaut application. I could apply in the next round, within a few years. Better to focus on my thesis and NASA research. Any success would make a future application stronger.

January 23: why was the committee taking so long? I had been sent out of the room, while they had their formal discussion of my oral 'defense of thesis.' I had answered all questions well, I thought.

Finally the door opened. Van Allen had a big smile and Matsushima was dour. I felt a rush of relief. Van Allen extended his hand, "Congratulations," no changes in the thesis were needed. I could deposit it with the Graduate College. I would get my degree at the winter Commencement.

We chatted a few minutes. Prof. Van Allen said that he hoped I would write a paper based on the thesis before leaving to New York, so that the University, not NASA, received credit. That explained why Matsushima was subdued. There was no requirement that I write a paper, only a suggestion. Matsushima no longer had any authority over me.

It took a few weeks to write the paper. I took it to Matsushima's office and asked him to submit it to the Astrophysical Journal, so the address would be the University of Iowa. He was surprised to see that he was co-author. It felt good to see him happy – bygones were bygones – and I owed him for his help getting the NASA traineeship and suggesting the lunar observations.

Prof. Matsushima had helped prepare me for later battles that would be more difficult and traumatic than those in Iowa City. First, however, as a pacific, innocent Iowa boy, I would spend two years as a privileged post-doc in the marvelous world of New York City in the 1960s.

[1] Prof. Van Allen had a Geiger counter on Explorer 1, the first U.S. satellite, launched January 31, 1958, for the purpose of measuring cosmic rays, energetic electrically charged particles. Such charged particles are continuously emitted by the Sun, carried outward in a 'solar wind.' Van Allen's instrument found that a large amount of these charged particles were temporarily trapped by Earth's magnetic field in large donut-shaped 'belts' encircling Earth.

[2] Link, F.: Die Mondfinsternisse, Leipzig, Akademische Verlagsgesellschaft, Geest & Portig, 127 pages, 1956.

[3] Hansen, J.E. and S. Matsushima: Light Illuminance and Color in Earth's Shadow, *J. Geophys. Res.*, **71**, 1073-1081, 1966.

[4] Water vapor (H_2O) and carbon dioxide (CO_2) absorb heat radiation from Earth's surface, so they serve as a 'blanket' keeping the surface warmer than it would be without the gases. H_2O is the stronger absorber on Earth, where the ocean provides a nearly limitless supply, but H_2O is condensable, so the amount in the air depends on temperature. Thus CO_2 is the 'control knob' that determines the amount of atmospheric H_2O and global temperature.

[5] Thus a 100-watt light bulb emits 1000 times more energy, as heat and light, than 0.1 watt. Averaged over the entire Earth's surface, day and night, Earth absorbs about 240 watts per square meter of solar energy, so the flow of energy from Earth's interior is much less than one-tenth of one percent of solar energy absorbed by Earth.

[6] The National Research Council of the National Academy of Sciences administers post-doc positions for NASA.