

It Takes a Village

Richard C Canfield 

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Abstract My parents taught me the value of a good education. My studies at the state universities of Michigan and Colorado and post-graduate studies at the University of Utrecht built on an interest in astronomy that dated back to high school. These institutions enabled me to have a rewarding fifty-year career focussed on the physics of the Sun. My work combined research and education at the High Altitude Observatory, University of Utrecht, Sacramento Peak Observatory, the University of California San Diego, the University of Hawaii, and Montana State University. My professional interests ranged from spectroscopic diagnostics and radiative transfer, especially of the flaring solar chromosphere, to the helicity of magnetic fields of active regions in the chromosphere, corona, and interplanetary medium, part of what is now called heliophysics and space weather. I am honored to have been recognized for my efforts as a scientific leader, mentor and teacher. I am lucky to have lived at a time when access to space led the field of solar physics to grow dramatically, including global studies of solar activity, the heliosphere, and space weather.

Keywords: Flares, Dynamics; Helicity, Magnetic; Magnetic fields, Corona

”It takes a village to raise a child”

A proverb that embodies the spirit of several African cultures: an entire community of people must provide for and interact positively with children for them to experience and grow in a safe and healthy environment.

1. Formative Years

I was born in 1937 at Henry Ford Hospital in Detroit, an industrial city in the north central United States. I spent my formative years in the state of Michigan, which is surrounded by the Great Lakes. I had an idyllic childhood. My earliest memory is watching construction equipment through a window of my parents’ first house. I also remember riding my tiny first bike smack dab into the side of

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Figure 1. My family circa 1949. With my mother, Emma Kemnitz Canfield, my father, Howard Lester Canfield, my sister, Susan Barbara Canfield, and my brother, James Anthony Canfield.

a car. Fortunately, after nearly 80 years of regular riding in Ann Arbor, Boulder, Sunspot, La Jolla, Kailua, and Bozeman, I have yet to repeat that experience. I attended Gabriel Richard elementary school in the suburban Detroit area, had nurturing teachers, hated swimming lessons, showed notable mediocrity on the piano and violin, decided that the Cub Scouts were cut and dried, enjoyed summer camp, listened to the Lone Ranger on the radio, rooted for heavyweight boxer Joe Lewis, and found girls inscrutable. The fundamentals of growing up haven't changed much.

My parents (Figure 1) grew up in much different family environments. My father was one of two children. He was born to Charles and Jessie Walker Canfield in Ann Arbor, Michigan in 1904. They were of English and Scottish/Irish ancestry. The Walkers came to Michigan by way of New York from the Massachusetts Colony and the Canfields came by way of New York from the Connecticut Colony. The Walkers were stonemasons, and many of their structures are still standing, including the famously evocative Victorian-era stone water tower in Ypsilanti. My father graduated from the University of Michigan in 1931 with a B.S. in Electrical Engineering. He worked for the Detroit Edison Company for 38 years. He took a leave of absence in 1962 for a 3-year assignment with the U.S. Agency for International Development in Seoul, Korea, and then returned to Detroit Edison, retiring in 1969. Thereafter, he worked full or part time for a nonprofit corporation advising on electric power generation in developing countries until 1981. He passed away at the age of 88 years.

In contrast, my mother was one of ten children. She was born in 1909 to Hermann and Otilie Seeger Kemnitz on a farm with no electricity or running water near Alpena, Michigan. Her parents were ethnic Germans born in Volhynia (now Ukraine), Russia in 1876 and 1888 respectively. The Kemnitz family immigrated to the United States in 1891 when Herman was 15; the Seegers in 1894, when Otilie was six years old. Both families settled on a farm near Wolf Creek in Wilson Township, Alpena County, Michigan. My mother's native language was German; she learned English when she went to school, first near the farm, and later in Alpena, the nearest town with a high school. Her first job, after high school and normal school, was teaching in a one-room schoolhouse. She later earned an A.B. degree in modern languages at what is now Eastern Michigan University, and taught high school German and English, primarily in Bucyrus, Ohio. She and my father had an active life centered around home, church, the Red Cross, and their international adventures. She passed away at the age of 98.

My brother, James Anthony Canfield, is a few years younger than I am. My sister, Susan Barbara Canfield, is another few years younger than him. Both graduated from the University of Michigan. My brother subsequently graduated from medical school at Pitt. He practiced as a neonatologist and a pediatrician throughout his career. My sister joined the US Navy, and was a national leader for women in the military, retiring as a captain. She was the first woman to serve as operations officer, navigator and then executive officer aboard ship in the US Navy. She also taught navigation and ship handling at the US Naval Academy in Annapolis.

As I was finishing elementary school, my family moved to St Clair, Michigan, which at the time was a sleepy little salt-mining town and bedroom community. Educational opportunities were limited; most kids were not college-bound. At this point a key decision was made: my parents decided, with my enthusiastic support, that I should go away to boarding school to get adequate preparation for whatever career I might choose. I was fortunate to get a scholarship at Cranbrook School, a college preparatory school near Detroit. I was predisposed to science, although I appreciated art and music, as well. As I look back at Eureka! moments at that stage of my life, it was both the physics and biology teachers who created them. When I arrived at Cranbrook, I was far behind my class level in mathematics. Even though my father tutored me for many hours in second-year algebra, I never fully recovered. To this day, even after taking many more graduate courses in mathematics than any other subject, my mathematics skills are nothing to brag about.

Cranbrook school was effective at motivating kids to study in ways that were effective, but not subtle. For example, every couple of weeks a list was posted, identifying students whose work was unsatisfactory. When you are as sensitive to the perception of your peers as a typical adolescent, that is strong motivation. However, many successful people graduated from Cranbrook in the 1950s: Rhodes scholars, a Heisman trophy winner, and even a U.S. presidential candidate. Notably, some principled classmates of mine were inspired to make meaningful contributions to society. My best friend, Al Henn, was one of them. He was drafted, and served as a medical corpsman in Vietnam. When he was discharged, he went to medical school. Later, inspired by the Peace Corps, he

dedicated his life to treating AIDS in Africa. He was one of 114 people killed when a Kenya Airways jet crashed in Cameroon in 2007.

At Cranbrook, I enrolled in special senior English because I liked writing. I can not do it particularly very well anymore, but I could years ago because of an outstanding teacher, Carl Wonnberger, who taught drama and English. It is amusing that he also tried to get his students to do things that I absolutely could not do, like memorize key passages in Shakespeare's *Macbeth*. However, he required a senior thesis, which strongly colored the rest of my life. I had been interested in astronomy since a young age – shortly after elementary school – when I built a simple telescope. I based my thesis on *Atoms, Stars, and Nebulae* (Goldberg and Aller, 1943). I was fascinated by that book. My thesis wasn't creative writing, but I learned a lot of astronomy.

Socially, I was a square peg in a round hole at Cranbrook, for at least two reasons. First, when my family moved to St Clair, I was put forward a half-year in school. Hence, my emotional and social development was behind that of my peers. Second, most of my Cranbrook classmates had grown up in a much more sophisticated societal environment. Many had the trappings of wealth, such as their own automobiles. Many of them went on to Ivy League universities and were ultimately successful in medicine, finance, business and the like. I chose to go to the state-funded University of Michigan because it was top-notch school, yet in-state tuition was very reasonable.¹ I am proud that I was able to support myself fully after my freshman year. Years before that time, I had my first jobs as a newspaper boy and a seasonal garden store helper at age 14, when one could first get a work permit. In subsequent summers I mowed lawns and worked as an unskilled laborer in greenhouses and construction of a school designed by no less an architect than I. M. Pei. He also designed the Mesa Laboratory of the National Center for Atmospheric Research (NCAR) in Boulder and the glass pyramid at the Louvre Museum in Paris, but that did not make setting forms or pouring concrete any easier.

2. Early Exposure to Research (1957-1970): McMath Hulbert Observatory, Kitt Peak, Research Assistantships, Utrecht

When I arrived at the University of Michigan, I was already gung-ho about astronomy. So, I did what any physicist would recommend you not do; namely, I signed up for a freshman-level course in astronomy. This is a serious mistake, really, because if you want to go into astronomy, you had better first build a foundation of physics and mathematics. As an undergraduate, I benefitted from research and teaching assistantships that gave me insight into various subfields of astronomy. Figure 2 shows the letter offering me my first job in astronomy,

¹Many decades ago in the United States, state-supported public universities such as the University of Michigan provided the avenue by which poor and lower middle class students could get a high quality university education. We now live in a period in which this possibility has vanished. The US, and some other countries, have experienced the shrinking of the middle class, an increase in poverty, and the division of society into the very rich and the poor. State and national economic policy and governance needs to change.

THE OBSERVATORY
OF THE
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN
August 21, 1956

Mr. Richard Canfield
446 Wellesley
Birmingham, Michigan

Dear Mr. Canfield:

Dr. Miller has told me of his interview with you, and
as a result I should like to offer you a quarter-time assistant-
ship in the Department of Astronomy for the academic year 1956-57
at a stipend of \$860.

When you come to Ann Arbor in September, will you please
get in touch with Mrs. Weddell so that the papers covering
your appointment can be completed. You should also see Dr. Aller
regarding the details of your work.

We look forward to having you work in the Department.

Sincerely,


Leo Goldberg

LG:KW

Figure 2: My first job offer in astronomy. For this research assistantship during the 1956-57 academic year, I worked for Bill Liller, measuring the relative intensities of emission lines of gaseous nebulae, recorded on chart-paper rolls. I used a mechanical device called a planimeter, which measured the area enclosed as I followed the charted signal with a stylus. Of course, it was just a routine task, but obviously everybody starts out simply and works his way up.

when I was only 18 years old and had just completed my freshman year. I was still wet behind the ears.

After my sophomore and junior academic years, in the summers of 1957 and 1958, I was a student assistant at the university's McMath-Hulbert Observatory. I found the observatory staff to be friendly and supportive. Orren Mohler, later the chair of the Department of Astronomy, was my supervisor and solar flare spectroscopy mentor. Peering into the eyepiece of a spectrograph, I struggled to learn how to recognize and record the spectra of flares on photographic glass plates. At the time, Keith Pierce was on the Observatory staff. He was hard at work designing what became the McMath-Pierce telescope at Kitt Peak. In the 1940s, Leo Goldberg was on the observatory staff, but he spent most of his time on war-related instrumentation. At the time of the letter in Figure 2 he was Observatory Director in Ann Arbor (University of Michigan Department of Astronomy). He went on to Cambridge (Harvard College Observatory), then Tucson (Kitt Peak National Observatory), becoming the most famous alumnus of the observatory. In the 1950s, the best-known scientist on the staff was Helen Dodson Prince. She was a pioneer of what is now called heliophysics, which includes study of the Sun and its physical connections to the heliosphere. The centerpiece of

heliophysics at that time was the International Geophysical Year (July 1957 to December 1958), an early approach to full-time observational coverage of the Sun-Earth system. Dodson Prince and Ruth Hedeman made observations of solar flares, and related what they saw to radio short-wave fade-outs due to ionospheric perturbations resulting from flare ultraviolet brightening.

A few years after my summers there, the staff at McMath-Hulbert included observer Bill Marquette. Bill went on to be the head observer at Big Bear Solar Observatory and a Chief Observer for the Max Millennium program (Section 6). I was the only student present during my two summers at McMath-Hulbert, but future solar scientists Sara Martin and Roger Kopp both spent summers there a couple of years later. Roger went on to graduate school at Harvard and a productive career at High Altitude Observatory and Los Alamos National Laboratory. Sara's memoir in this journal (Martin, 2015) includes her account of her summers as a student at McMath-Hulbert Observatory. Certainly the experiences Roger, Sara, and I had at the observatory were valuable and influential introductions to our subsequent research careers.

Life at the University of Michigan was not all work. I joined a fraternity, whose attributes (fortunately) went well beyond the stereotypical frat-boy behaviors. Yes, it introduced me to parties, beer, hazing, and stag flicks – things far from my high school experience. On the other hand, I had many bright and well-rounded fraternity brothers. A great example is my fraternity roommate and "little brother", Ron Merrill, now Professor Emeritus of Earth and Space Sciences at the University of Washington. Be assured, at the time I knew him he had a wild side, but in 2002 he was awarded the Fleming Medal of the American Geophysical Union for his original research and technical leadership in geomagnetism.

After I finished my undergraduate studies at the University of Michigan, I spent two years as a graduate student in astronomy there. Several of my fellow astronomy graduate students went on to professional positions after graduation: Charles and Anne Pyne Cowley (later at Michigan and Arizona State, respectively), Peter Boyce (American Astronomical Society), David Gray (Western Ontario), Steve Maran (NASA GSFC), and James Kaler (Illinois). More senior students included Ed Spiegel (Columbia) and Ben Peery (Indiana and Howard), both of whom were very approachable. Decades later, I had the privilege of working with Steve in the context of his duties as Press Officer for the American Astronomical Society. He coined the phrase "S Marks the Spot" for an impactful NASA press release on S-shaped structures that my colleagues and I showed had predictive value for coronal mass ejections (CMEs). I had a teaching assistantship for these two years, and I found that teaching could be rewarding for all involved. I held elementary astronomy lab sections for Prof. Hazel Marie Losh, who was known for her enthusiasm for football players: "A for athletes, B for boys, and C for coeds". Among my graduate classes was one on stellar structure, taught by Lawrence Aller. You could tell where you stood in his opinion when he assigned students specific spectral regions in stellar atmosphere model-building exercises. If you were assigned the region of a significant spectral feature, e.g the Balmer jump, you knew you were OK in his eyes.

After two years as an astronomy graduate student I realized that I needed to remedy my inadequate background in physics and mathematics. It was at that stage of my life that I married Karen Senob (now Karen Sundwick), a fellow University of Michigan student who was as academically oriented as I was. I spent a third graduate year at Michigan taking upper level and graduate physics and mathematics classes. I struggled with them. Commuting an hour each way from Royal Oak, where Karen was working in her first year of teaching, to Ann Arbor exacerbated the problem. I guess those classes paid off, but they were traumatic. I knew it was time to move on to solar physics, which appealed to me more than other fields within astronomy. The key person in my decision to leave Michigan for graduate school in Colorado was Edith Müller. She was a research associate in Ann Arbor at the time I knew her. She went on to become the General Secretary of the International Astronomical Union from 1976 to 1979, and a full professor in Geneva. She was very friendly and astute. She held the solar physics faculty at the AG department of CU and the associated HAO in high regard, and it was obvious that it was a good match to my interests. I applied there, as well as Berkeley and Harvard, which also had solar programs. However, when I took remedial courses in mathematics and physics in that third graduate year, I did not get good marks. I was accepted at Berkeley, but did not get an assistantship, and didn't want to study where I could not get one.

In the Fall of 1962 I started graduate studies in the Astro-Geophysics (AG) Department of the University of Colorado (CU). That interdisciplinary department exposed me to the phenomena of the broader field of what is now called heliophysics. Some faculty members were associated with the High Altitude Observatory (HAO), a division of the National Center for Atmospheric Research (NCAR). In addition to solar physics, some were studying atmospheric physics, others ionospheric physics using radio astronomy. The subject I chose for my thesis work, namely non-LTE radiative transfer, was one of the specialties of the department. NCAR's CDC 7600 super-computer enabled my thesis and post-doctoral research with Grant Athay, who was a world leader in the study of solar active regions and radiative transfer. I took a very basic radiative transfer course from John Jefferies, who went on to establish the University of Hawaii as a major astronomy center, including solar physics. He later became director of the National Optical Astronomy Observatories, which eventually included the National Solar Observatories (NSO). I enjoyed a valuable MHD course from Friedrich Meyer. Many of my contemporaries went on to successful careers in solar physics; those with whom I had valuable professional interaction after graduation included Loren Acton at Lockheed and Montana State, Dave Rust at Johns Hopkins, Dick Fisher, Bill Wagner, and Dave Bohlin at NASA, and Dick Altrock at Sacramento Peak. To date, four graduates of the AG Department have been awarded the Hale prize of the American Astronomical Society's Solar Physics Division (AAS/SPD) for outstanding contributions to the field of solar astronomy.

Solar coronal research has changed dramatically since the time of the 1963 North American eclipse expedition whose Colorado participants are shown in Figure 3. In 1963 it was known that the structure of the corona varied with the solar cycle, but coronal mass ejections (CMEs) were yet to be discovered.



Figure 3. Members of the 1963 Colorado total solar eclipse expedition. Faculty included Julius London (Chair, AG Department, to the left of the telescope, in a white shirt with a pocket protector); John Firor (Director, HAO, 1961-1968, similarly attired behind the other end of the telescope); Gordon Newkirk (Director, HAO, 1968 - 1979, far right). Students included Bill Deutschman, me, Elaine Deutschman, Bill Henze, Dick Dietz (left to right, starting to the right of London).

To determine whether any transient coronal events took place during the time span (hours) of the eclipse, each student in the class built a copy of the small telescope on the table and took it to one of several locations along the North American total eclipse path from the Aleutians across Canada to Maine. No significant coronal changes were observed during the several hours that elapsed as the umbra traversed the eclipse path. I was stationed at the center of the path near Sourdough, Alaska. Eclipse day was partly cloudy, and I found myself speeding along the main highway between Anchorage and Fairbanks 20 minutes before totality, when it was obvious a small cloud was headed directly in front of the Sun at the key moment. I and several others succeeded to get photos. Some just had stories to tell. The department chair, a fine atmospheric physicist despite being all thumbs, burned an impressive hole in the focal plane shutter of his camera.

The combination of academics and outdoor recreation in Colorado made me a confirmed Westerner. Fellow graduate students shared many interests outside the classroom. Bill Henze (University of Alabama) and I climbed many a 14-er, sometimes on snowshoes or skis. At Winter Park, I learned how to stay on a T-bar ski-tow when partner Dick Dietz (Colorado State) fell off. Mark Gordon (National Radio Astronomy Observatory) and I cycled the canyons near

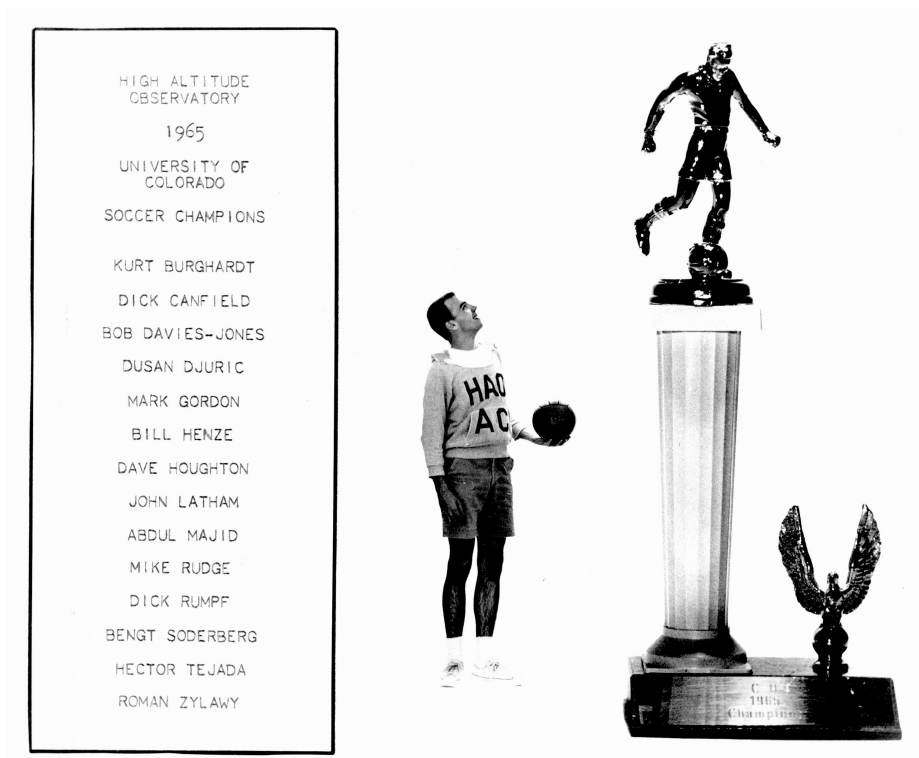


Figure 4. The High Altitude Observatory team won the University of Colorado intramural soccer competition in 1965. This triumph was commemorated with a trophy that office-mate Bill Henze (above) and I deemed inappropriately small. Photoshop may not have been around in 1965, but my photographic darkroom skills were up to the task.

Boulder. Joe Ajello (NASA/JPL) and I secured a handball championship for HAO. The HAO soccer and softball teams were a good way to socialize and let off steam. We had our share of ringers from NCAR on the teams, e.g. first baseman (and National Academy of Sciences member) Ray Weymann. The soccer team won the CU championship in 1965 (Figure 4), with lots of help from NCAR postdocs. Graduate school in Colorado was fun. Perhaps that is why I didn't squeak through the PhD comprehensive exams until the third try!

During a couple of summers while in grad school in Boulder, I worked on the late stages of construction of the McMath-Pierce telescope at Kitt Peak. Charles Slaughter (Kitt Peak National Observatory) and I used surveying equipment to precisely measure the rails along which the primary mirror runs, at an incline that matches the latitude of Kitt Peak. On one occasion, while working with Charles and Keith Pierce, I lost my footing, tumbled head over heels, and landed on my bottom facing downward between the rails on the slippery aluminum panelling that lined the interior of the telescope. The incline of $31^{\circ} 57'.5$ fostered rapid acceleration, which I managed to stop only by pounding my heels into the panelling. Neither Keith nor I ever forgot that event.

I made my My PhD thesis observations with the McMath-Pierce telescope. To deal with atmospheric seeing effects, I learned a lot about Fast Fourier Transform image restoration techniques from Jim Brault (Brault and White, 1971). I made center to limb observations of the profiles of several weak spectral lines of the rare earth cerium in the quiet sun. My analysis implied that the source function of these lines departs from local thermodynamic equilibrium as a consequence of dominance by radiative scattering and the weak and complex atomic structure of rare earths. It was of little consequence to solar physics; it has garnered only 16 scientific citations in 50 years since its publication.

One of the important functions of a thesis advisor is to get his or her students a good first position after graduation. Grant Athay contacted Kees de Jager at the University of Utrecht, in the Netherlands. Kees arranged a postdoctoral fellowship with the Netherlands Organization for Pure Research (ZWO). In 1969 Karen and I packed up our three young children, Robert, Paige, and John (Walker), who ranged in age from just a few months to five years, and set out for our European experience. In Utrecht, we received a warm welcome. At the Observatory and in everyday life, Marcel Minnaert, Kees and Prisca Zwaan, Aert Schadee, Max Kuperus, and Rob Rutten were thoughtful and helpful in innumerable ways. They helped us adjust to the Netherlands; we were certainly innocents abroad. I picked up a VW square-back at the factory, and we used it to tent camp through England, Scandinavia, and parts of both eastern and western Europe. We lived in the small town of Hollandsche Rading. While I commuted to Utrecht, Karen dealt with shopping and the kids, and Walker went to school. He quickly became bilingual, and he's been good at languages ever since! Early in our stay Karen and I had an amusing experience, which shows that one can become known in various ways, some fleeting and some enduring. One measure of celebrity is name recognition. Our time in Utrecht provided two starkly contrasting examples. On one hand, my mentor was Kees De Jager, General Secretary of the IAU from 1967 to 1973 and former director of the observatory at Utrecht. He founded the journal you are reading. To a typical reader of this journal, he had good name recognition. On the other hand, our Utrecht baby sitter, Sylvia Kristel, went on to celebrity as Emmanuelle in the ground-breaking soft porn film series of that name from 1973 - 1979. You can guess who has the better name recognition with the European man on the street.²

²In October 2019, I gave an invited talk at a meeting celebrating the 50th anniversary of Sacramento Peak Observatory. Rob Rutten was one of the meeting organizers. He has a good sense of humor, and is fun to tease. Shortly after Karen and I arrived in Utrecht in the winter of 1968-69, Rob courteously invited us for a skating outing on a nearby frozen canal. Sylvia Kristel baby-sat the kids. After skating, she made a strong impression talking with Rob as they returned to Utrecht together by train. At the 2019 Sac Peak meeting Rob gave a talk on the temporal fine structure of the chromosphere. Immediately after his talk, I gave mine, entitled "Reminiscence: - Flares, Pranks, and Fine Structure". I closed with one last prank: I reminded Rob that I had long ago introduced him to fine structure, and briefly showed a tastefully revealing public relations photo of Sylvia. Some time later, I polled a participant in the 50th anniversary meeting, and found that he could not remember any of my talk's content, other than the photo of Sylvia "au naturel".

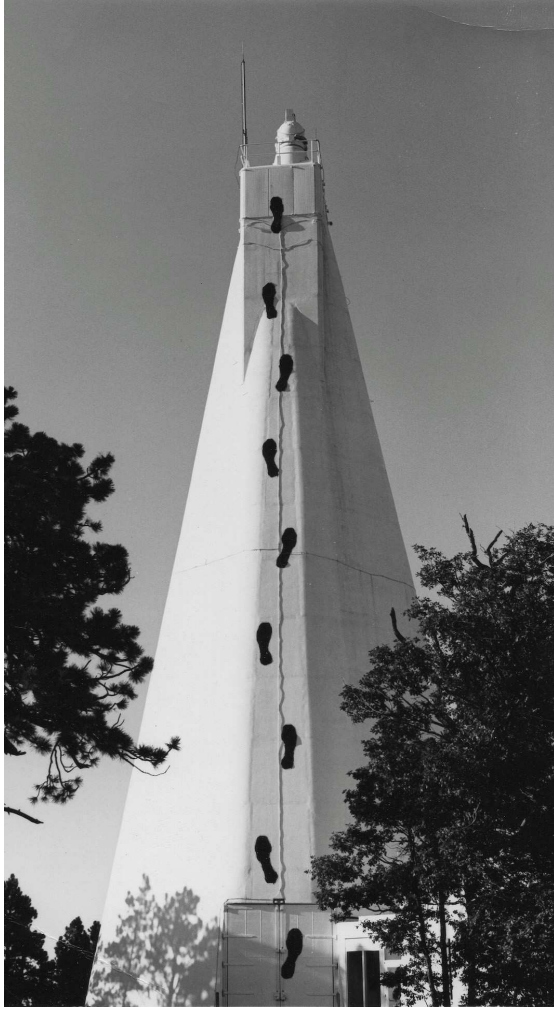


Figure 5: The famous footprints on the 40 m Dunn Solar Telescope at Sacramento Peak Observatory. Summer students provided assistance with both research and pranks. The footprints were simply manila paper cutouts, spray painted black, taped to the outside of the tower. They were installed by summer student Rodney Schultz, an expert rock climber from CU. Logistics, art work, and support were provided by Rodney's wife Bev, fellow summer student Spiro Antiochos (then at Stanford), my wife Karen, and me. For decades, the perpetrators were not known. DST designer Dick Dunn was not amused. The only clue was the faintly visible outlines left over from spray-painting the offending footprints on the floor of the garage attached to a house at the top of Hound Dog Hill. Photo courtesy Dick Faller.

3. Sacramento Peak (1970-1976): Flares, Pranks, and Pots

I spent six years at Sacramento Peak Observatory, located at 2700 m elevation in the tiny town of Sunspot, New Mexico. Director Jack Evans provided steady leadership, and senior scientists Dick Dunn and Jacques Beckers were knowledgeable but busy. Several fellow CU graduate students were at SPO at the time: Dave Rust, Bill Wagner, Dick Fisher, and Dick Altrock. My research transitioned from radiative transfer studies to flare modeling, which proved more broadly relevant to solar and heliospheric physics. International visitors provided good company (both science and music), stimulating exposure to the formative days of helioseismology (Franz Deubner, see Bahcall, 1999) and chromospheric evaporation in solar flares (Hirayama, 1974). Regular research seminars and a journal club, as well as summer student interaction, were stimulating. Tennis with George Simon (great at clever shots that drove me nuts) and Pinky Nelson

Artists selected

Three Otero County artists will participate in the 1976 New Mexico Arts and Crafts Fair. The annual event, held at the State Fairgrounds in Albuquerque, features several hundred artists and craftsmen from the state.

Accepted to participate in this year's fair were painters Martha Julian and Cathy Flores and potter Dick Canfield.

Canfield has been working with pottery for several years as a member of The Gallery, La Luz. He has participated in shows at the art center and has taught primitive pottery and wheel-thrown ceramics. His work at the fair will include functional stoneware, straw-fired planters, and raku.

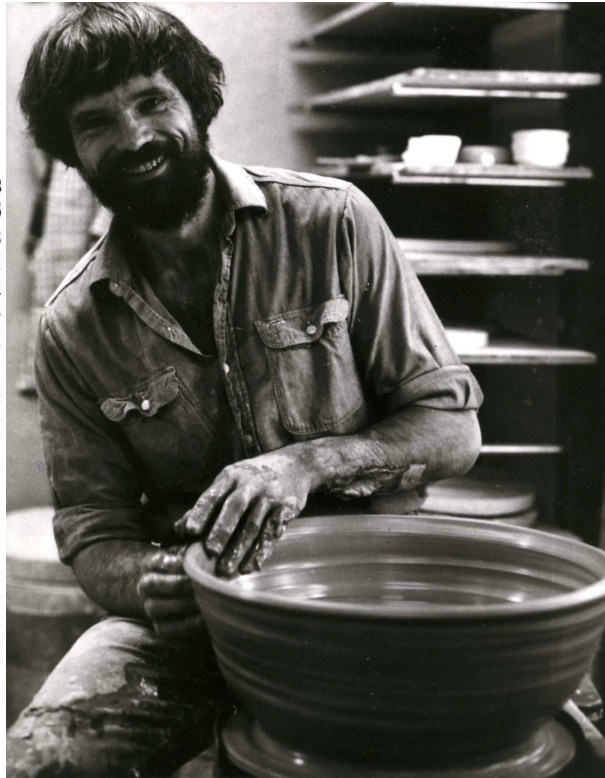


Figure 6. (Left) A clipping from the Alamogordo (New Mexico) Daily News, Sunday, June 20, 1976, one month before I left Sac Peak for San Diego. (Right) Throwing a planter at the Sac Peak pottery facility in 1975. I still have this pot, having moved it to California, then Hawaii, then Montana! Photo courtesy Christy Ott.

(who did the Solar Maximum Mission repair during his astronaut career) and student/staff volleyball were common athletic pursuits, along with Dog Canyon hiking and ski touring. Student pranks were a regular feature (Figure 5).

In my experience, it is stimulating to reinvent yourself from time to time. For me, this meant changing my focus to solar flares. From high resolution filtergrams and magnetograms, Dave Rust (paper presented at Flare Buildup Study Workshop, 1975 September) made a strong observational case for association of flares with the photospheric emergence of magnetic flux and its reconnection to older fields. Dick Fisher and I were very stimulated by this idea (Canfield and Fisher, 1976). The observations suggested triggering of the flare by emergence of new magnetic flux, as well as the geometry of the reconnected field during the flare. While visiting HAO, I had a conversation about this with another visitor, Eric Priest. The result was an early version of the so-called emerging flux flare model in which a current sheet forms between new and old flux systems. When the electric current density in this sheet exceeds a critical value, rapid magnetic reconnection takes place (Canfield, Priest, and Rust, 1975; Heyvaerts, Priest, and Rust, 1977). This and other work on solar flares was a rewarding change from

The Gallery, La Luz is again offering classes in primitive pottery. These classes include construction, decoration, and firing of various types of pots. Among techniques to be taught are pinch, coil and paddle construction. Only local materials are used, and early classes involve gathering, preparing and testing of materials. The instructor, Dick Canfield, states that no previous experience with pottery is required for the course, however, gathering materials can involve strenuous exercise and requires a lack of inhibition. Ten class sessions will be held, on Sunday afternoon, beginning March 21. Registrations for the class will take place on Friday, March 12, at the art center. Basic fee for the course will be \$45. Class enrollment will be limited to ten persons. Further information may be obtained by calling 437-0753, evenings and weekends.



Primitive pottery making will be taught by Dick Canfield at classes opening soon at The Gallery, La Luz.

Figure 7. (Left) Another clipping from the Alamogordo (New Mexico) Daily News. (Right) Pots created in my primitive pottery class, using coil and paddle construction and stone-polished dung firing techniques common among the indigenous peoples of the American southwest.

line formation studies. Lesson learned: don't just soldier on, take a calculated and well-informed risk.

The years at Sac Peak were a period of change. The remote mountain town of Sunspot was an interesting mixture of work and play, with both pros and cons. Walker, Paige, and Robert look back fondly at their idyllic life in the woods. Tower telescope head observer Horst Mauter, photographer Dick Faller, Karen, and I developed a pottery studio at Sac Peak. For me it was a time of personal struggles. In 1974 Karen and I divorced. She, Paige, and Robert moved to Albuquerque, while Walker stayed with me in Sunspot. She earned a PhD in History from the University of New Mexico, She went on to a successful career as a Professor of History and department chair at Southern Oregon University in Ashland. She retired as an emeritus professor in 2007.

After a few years at Sac Peak I toyed with a change of career from solar physics to ceramics (Figure 6). While working at Sac Peak I taught primitive pottery (Figure 7) at a local gallery, in the nearby artists community of La Luz. Note that the clipping in Figure 7 includes a line saying that gathering materials requires a lack of inhibition. Black on black earthenware such as is shown in Figure 7 is fired in a reduction atmosphere fueled with dried cattle dung. I have an amusing recollection of a student questioning, in colorful terms, having actually paid to attend my classes, during which she collected firing material from the New Mexico desert and crumbled it with her bare hands. Of course, pottery activities had to be juggled with solar research. In 1976 I missed the AAS/SPD meeting, which conflicted with the New Mexico State Arts and

Crafts fair (Figure 6). Clearly a decision needed to be made – art or science. I decided that I made a better solar physicist than a potter.

4. University of California, San Diego (1976-1985): Flares, Students, and Advisory Groups

On the 4th of July, 1976, the 200th anniversary of the U.S. Declaration of Independence, I set out in a U-Haul truck with all my earthly possessions across the southwestern U.S. desert to San Diego. My choice of solar physics research at UCSD was inspired by Hugh Hudson, then at the Center for Astrophysics and Space Science and the Department of Physics. In the mid-1970s, Hugh was working on many different subjects, which included solar flares, with outstanding students – Charley Lindsey and Martin Woodard in particular – and was supporting himself. Being Hugh, he was traveling the world, literally and figuratively. At UCSD I had access to the Vacuum Tower Telescope (now the Dunn Solar Telescope, DST) of Sac Peak, through visitor observing proposals, and the computing facilities of NCAR. Jack Zirker, then director of Sac Peak, insightfully put into place new focal plane CCD instrumentation at the DST, enabling innovative flare imaging spectroscopy (detailed in the appendix of Acton et al., 1982). I got initial funding for solar flare research from the Air Force Research Laboratories program managed for many years by Henry Radoski. There was no turning back.

UCSD turned out to be an ideal place for me at that time of my life. The libraries were fantastic, as were the recreational facilities. I joined the X- and Gamma-ray astrophysics group led by Larry Peterson as a research physicist. Larry, Hugh, Richard Lingenfelter, Rick Rothschild, Jim Matteson, Richard Mushotsky, Mike Pelling, Duane Gruber and Bill Baity were all welcoming and helpful. Famous physicists and chemists (e.g., Nobel Prize winners Hannes Alfvén and Harold Urey) and astrophysicists (e.g., Margaret and Geoffrey Burbidge) abounded on the faculty, and they drew equally famous colloquium speakers (e.g., Nobel Prize winner Frances Crick, of double helix fame). Geoffrey, in particular, was lively and interactive, although sometimes I needed two beers at the end of the day. I got my personal life together after group secretary Carol Barry introduced me to Deb. We were married in March, 1978 (Figure 8). For the last forty-four years Deb has been a loving, patient, and supportive wife for me, step-mother for Walker, Paige, and Robert, and mother for Chelsea. As well, she communicates well with Karen! I was the custodial parent for Walker, and he benefitted from the good schools and beaches of Torrey Pines and North San Diego County. It's no surprise that both Walker and Robert adopted surfing, which served them well 10 years later in Hawaii!

The bright graduate students of the UCSD Physics department were a delight to work with. In most cases, I started them on flare observations from Sac Peak or numerical modeling using NCAR and local computers. After several flare-related publications Paul Ricchiazzi wrote his PhD thesis in 1982 on a static model of chromospheric heating in solar flares. He went on to Mission Research Corporation and the Institute for Computational Earth System Science, at UC



Figure 8. With Hugh Hudson on March 25, 1978, when Deb and I were married in our back yard in Solana Beach, California. Hugh inspired me to set out for California; Deb made it all worthwhile. She has been a wise and loving wife, mother, stepmother, grandmother, great-grandmother and life's companion for over four decades of adventures.



Figure 9. The UCSD solar group at journal club, also known as heliobeer, in 1983. Left to right: Chang-Hyuk An, Hugh Hudson, Bernie Jackson, Mike Elcan, Todd Gunkler, George Fisher, Sandy McClymont, me, and Martin Woodard. Participants are obviously amused by Hugh's remarks. Look at the facial expressions. Chang-Hyuk An seems to find them hard to believe. Todd Gunkler seems to be making mental notes for the Hugh Hudson jokes shown in Figure 10 (below).

It's the latest rage:
 HUGH HUDSON JOKES!

Q) How many Hudsons does it take to change a light bulb?
 A) Two -- one to write the proposal and one to hire the grad student.

Q) Why did the Hudson cross the road?
 A) He heard there was a meeting on the other side.

Q) Why would Hugh Hudson buy a Japanese car?
 A) Homesickness.

Q) What generates more wind power than Ronald Reagan talking?
 A) Hugh Hudson waving his hands.

Q) What would cause a massive pile-up on the road?
 A) Hugh Hudson explaining something to a traffic cop.

Q) What's black and white and red all over?
 A) Hugh Hudson arguing with a penguin.

Q) What does Hugh Hudson call research that produced absolutely nothing?
 A) A paper with a null result.

Figure 10. Hugh Hudson jokes, written in 1983 by graduate student Todd Gunkler (Figure 9). If you know Hugh well, you can fully appreciate them.

Santa Barbara. I regard Paul, the lead author of the SBDART radiative transfer model heavily used in meteorology, as one of the two students to whom I handed off my "RT" baton (the other being Ken Gayley, below). Three of my UCSD PhD students went on to university teaching careers. In 1984 Todd Gunkler wrote his thesis on innovative CCD imaging spectroscopic observations of $H\alpha$ line profiles of solar flares, obtained at the Sac Peak DST. He taught physics as a professor at Delta College until his death in 1997. Todd is among the "heliobeer" journal club participants shown in Figure 9, and his keen sense of humor shows in the Hugh Hudson jokes in Figure 10. In 1989 David Tamres wrote his thesis on theoretical studies of proton beams in solar flare loops. He retired as an emeritus professor from the Physics Department of the University of Wisconsin, Stevens Point in 2016. In 1990 Ken Gayley wrote his thesis on hydrogen line diagnostics in impulsive flares. He is currently an Associate Professor of Physics and Astronomy at the University of Iowa, and has collaborated extensively on radiative transfer in stellar winds with former UCSD postdoctoral fellow Stan Owocki (Section 4).

The exception to flare-related theses was that of Richard C. (Rick) Puetter. We wrote several papers together on spectral line formation in the emission line regions of QSOs. Working with Rick added more to my understanding of radiative transfer than any class I ever took or taught. He finished his thesis "Observational and Theoretical Study of the Hydrogen Spectrum of Quasi-Stellar Objects" in 1980. Incredibly bright, productive, and ambitious, he became interested in pixon image processing. His resume currently includes 350 scientific and technical publications, and he is presently President and Chief Scientist of Pixon Imaging, Inc, in San Diego.

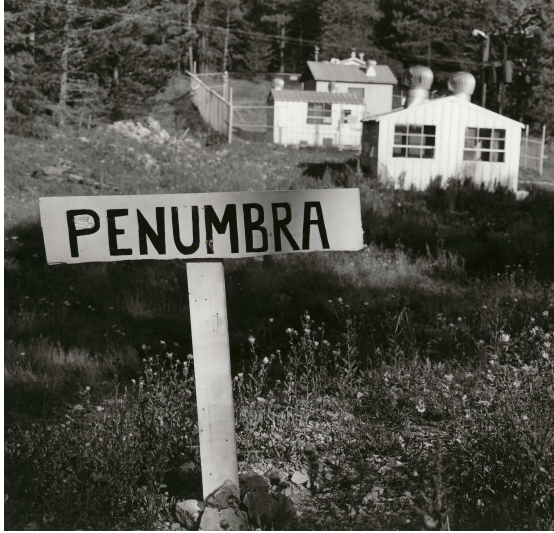


Figure 11: This sign near the front road entrance to Sunspot, New Mexico was a summer student prank at Sac Peak in the 1970s. It identified the sewage treatment plant on the outskirts of Sunspot as Penumbra, New Mexico. I used this photo in my take-off on Ron Moore's Neighborhood meeting talk on "The Structure of the Penumbra"

Working with Rick Puetter was associated with a joke talk at one of the informal California "Neighborhood" meetings. My planned talk on the Lyman to Balmer $L\alpha/H\alpha$ ratio in solar flares and QSOs developed uncertainties just a day before the meeting. Rather than simply cancel, I decided to deliver a joke talk on "The Fine Structure of THE Penumbra", stimulated by the title of Ron Moore's preceding talk on the program (my emphasis on THE is intended to indicate "the one and only"). I proceeded to deliver my joke talk, berating Ron, bombastically claiming that he had it all wrong. I asserted that THE Penumbra was the site of THE sewage treatment plant on the outskirts of THE Sunspot, the site of Sacramento Peak Observatory, and anyone can clearly see that the fine structure is just weeds (see Figure 11). The audience totally cracked up; their reaction was more enthusiastic than that to any other talk in my entire career. Ron took the joke graciously, and later (Section 7) took the opportunity to note that my idea stinks. Ron remains one of the most creative people in solar physics.

George Fisher's study of the radiative hydrodynamics of flare loops heated by impulsive bursts of energetic electrons is a model for relevance to a substantial theme of current research. The total number of citations of the three refereed papers that comprise the main chapters of his thesis (Fisher, Canfield, and McClymont, 1985c,b,a) presently exceeds 850. His thesis and directly related work was distinguished by state of the art numerical modeling combined with compelling physical analysis. This is evidenced by application of the secondary useful operator (Kurtz, Chyla, and ADS Team, 2020) to the NASA/ADS database. The three papers that comprise Georges thesis are at the top of the list of 1707 useful papers you will find in this manner on the topic of chromospheric evaporation, behind only Hirayama's seminal work mentioned in Section 3. Subsequently, George has mentored multiple postdoctoral fellows, including award-winners Dana Longcope, Brian Welsch, and Masha Kazachenko (Section 6). After leading substantial national collaborations in modeling of solar electric and magnetic

fields as a Senior Scientist in the Space Sciences Laboratory of the University of California, Berkeley, he retired in 2020.

Tom Metcalf finished his thesis "Flare Heating and Ionization of the Low Solar Chromosphere" in 1990. Between then and his untimely death in 2007 he made key contributions to vector magnetic field ambiguity resolution, RHESSI pixon image reconstruction (stimulated by fellow PhD student Rick Puetter), the hemispheric helicity sign distribution, and non-linear force-free magnetic field modeling (see also Section 5).

I worked with two postdoctoral fellows at UCSD. Stimulated by Ed Shoub's work on the invalidity of local thermodynamic equilibrium in the solar transition region (Shoub, 1983), Stan Owocki and I studied the role of nonclassical electron transport on lines formed in the lower transition region. Stan went on as a professor in the Department of Physics and Astronomy at the University of Delaware, where he had notable success in studies of radiatively driven stellar mass loss and computational magnetohydrodynamics. Chang-Hyuk An collaborated with several solar group members on magnetic and thermal stability at UCSD, and later went on to Huntsville, where he worked with Ron Moore, Steve Seuss, and others. He is the person from whom I learned my trademark expression "hard to believe".

When Sandy McClymont joined the UCSD solar physics group from UC Berkeley as an Assistant Research Physicist, the entire group benefitted. I met Sandy through his thesis advisor, John Brown (Figure 12), who motivated my interest in flare modeling and spectroscopy. Sandy modestly and generously shared his impressively deep understanding of both physics and numerical methods with fellow researchers and graduate students throughout our tenure at UCSD, and later in Hawaii as well. George Fisher and I were the main beneficiaries, but he also played a key role in the work of Yuhong Fan, K. D. Leka, Tom Metcalf, Alex Pevtsov, and Litao Jiao. His extensive notes on numerical methods for modeling the radiative hydrodynamics of 1D flare loops with radiative transfer effects were referred to as "The Bible". It was Sandy who led our transition in numerical modeling from gas dynamics to magnetohydrodynamics. He is without a doubt one of the brightest, most modest and most thoughtful people I know.

Participation in advisory committee activities for NASA, NSF, and the National Academy of Sciences during the 1970s and 1980s was inspiring and broadening. It was a pleasure to serve from 1976-1980 on the NAS Committee on Solar and Space Physics chaired by NAS member and James Clerk Maxwell Prize winner Charlie Kennel. The CSSP also had as members space plasma physicist Fred Scarf and fellow solar physicists Bob MacQueen (then HAO Director) and Tom Holzer, winner of the AGU's Macelwane Award in 1978. That subsequently led to membership from 1980-83 in the NAS Space Science Board (now the Space Studies Board), which offered interaction with the leaders of space science. Those I particularly enjoyed were NAS member A. G. W. Cameron, astrophysicist and planetary scientist (chair in 1980-81), NAS member and Arctowski Medal winner Tom Donahue (chair in 1982-83); NAS member Jim Van Allen, who was instrumental in establishing the field of magnetospheric research in space; NAS member Ed Stone, director of Jet Propulsion Laboratory in Pasadena,

California from 1991 to 2001; NAE member and APS Fellow Lou Lanzerotti; APS, AGU, AAAS and AIAA Fellow Tom Krimigis; planetary scientist, astrophysicist, author, and science communicator Carl Sagan; and theoretical and mathematical physicist and mental adventurer Freeman Dyson, FRS. All of the interactions were informative, and often awe-inspiring, but one was amusing. On one occasion, I was late for a SSB meeting at some park-like location I have since forgotten. Freeman Dyson was also late for the meeting, to which he was literally running. If you knew him, you know that he was more than a bit awkward. He came dashing pell-mell around a blind corner, and crashed into me, at full tilt. Fortunately, neither of us was hurt. Unfortunately, none of his intellect rubbed off on me.

NSF and NASA committees deepened my knowledge of, and enthusiasm for, helioseismology. I fondly recall a late-70s meeting of the Optical/Infrared Working Group of the NSF Astronomy Advisory Committee at which eminent astronomer Robert Kraft immediately and enthusiastically picked up on the stellar implications of what was obviously his first GONG briefing on helioseismology. Chairing the NASA Solar Oscillations Science Working Group in the early 1980s gave me an equally interesting update on what I had picked up during the early days of helioseismology, when I was at Sac Peak.

Another memorable function was an ad-hoc meeting I organized at UCSD, to advocate for the repair of the Solar Maximum Mission. Group participants, who included Loren Acton, Peter Sturrock, and Hugh Hudson among others, wrote a white paper that provided scientific advocacy for the successful astronaut-manned Solar Maximum Mission repair that NASA so strongly wanted to try. To me, it was a happy turn of events that one of the two astronauts who did the actual repair was my Sac Peak tennis buddy Pinky Nelson. It's a small world.

5. University of Hawaii (1985-1996): Flares, Helicity, Mees Solar Observatory, and Yohkoh

The combination of observing facilities on Maui and a tenured professorship led me to leave UCSD for the University of Hawaii. I taught an introductory astronomy course for undergraduates and a radiative transfer course for graduate students. I was able to build a research group that had an outstanding mix of skills and personalities that fostered collaboration and creativity. Mees Solar Observatory offered a dedicated observing facility, ideal for solar activity studies that required synoptic observations and large databases. Frequent productive and collegial interactions among the faculty, staff, and students took place between theorists, observers, and instrumentalists. Collaboration with the US-Japan Yohkoh mission was rich and stimulating to all concerned. Although graduate students were fewer in number compared to UCSD, they wrote outstanding theses and went on to make significant contributions to solar physics.

When Sandy McClymont and UCSD graduate students David Tamres, Ken Gayley, and Tom Metcalf came with me from San Diego we joined an established solar group consisting of Frank Orrall, Marie McCabe, Don Mickey, Barry Labonte, Charley Lindsey and graduate students Doug Braun and Rob Ronan.

Figure 12: (Left) With two key influences on my transition to solar flare research, John Brown (center) and Eric Priest (right), at the Flares 22 meeting in Ottawa, Canada in May, 1993. We are giving our answers to the rhetorical question "Where does the action take place in solar flares?" Relevant publications are Brown's classic paper on the temperature structure of chromospheric flares heated by non-thermal electrons (Brown, 1973) and the emerging flux model for solar flares (Canfield, Priest, and Rust, 1975, Heyvaerts, Priest, and Rust, 1977)



In subsequent years Barry, Sandy, and I brought in new blood with a wide variety of skills and interests: Hugh Hudson, George Fisher, Ed DeLuca, Alexei (Alex) Pevtsov, Ed Lu, Gianna Cauzzi, Kevin Reardon, Jean-Pierre Wuelser as well as graduate students K D Leka, Matt Penn, Yuhong Fan, Kristen Blais, Renate Kupke, Litao Jiao, and visitors Don Melrose, Ian Craig, Daniel Gomez, and Zoran Mikic (Figure 13). Before our arrival the Mees Solar Observatory already had good working staff comprising supervisor Wayne Lu, electronics technician Les Hieda and software engineer Elaine Kiernan. Subsequently successful instrument proposals and support of the Yohkoh mission enabled hiring a key electrical engineer, Mark Waterson, three observers including Daryl Koon and Gary Nitta, and utilized Manoa engineering and software staff including Herb Ryerson and Buzz Graves.

I was one of four US Co-Investigators for the Yohkoh mission (Acton et al., 1992), which was launched in 1991. My participation in this mission, and the associated extensive Hawaii contribution, arose from the high-minded views of how science is done held by George Withbroe at NASA headquarters and Loren Acton, the US Principal Investigator for the SXT (Tsuneta et al., 1991). They bought into the notion that the mission was strengthened, without unreasonable increase in cost, by including in the Yohkoh investigation appropriate theory and ground-based observing. Hawaii scientists (Hugh Hudson, Tom Metcalf, Jean-

Pierre Wuelser, Barry LaBonte, K. D. Leka) contributed in many ways to the Yohkoh mission. And, of course, neither Loren nor our Japanese collaborators ever minded a Yohkoh meeting in Hawaii. I spent many months in Japan, in the stimulating company of Loren Acton, Bob Bentley, Hugh Hudson, Alphonse Sterling, Sam Freeland, and Greg Slater. The leaders of the Yohkoh solar community, including Takeo Kosugi, Saku Tsuneta, Kazunari Shibata, Tetsuya Watanabe, sensei including Tadashi Hirayama, Yutaka Uchida, Eijiro Hiei (whom I had known long before Yohkoh), and Yoshiaki Ogawara were all very welcoming and supportive.

Prior to Yohkoh the main instrument at Mees was the Haleakala Stokes Polarimeter (HSP, Mickey, 1985). Don Mickey and the Mees staff made several enhancements to prepare it for routine operation as a vector magnetograph, including linear array detectors and a fiber feed to the echelle spectrometer, permitting its removal from the spar to a more stable environment, and improved quarter-wave plates. Barry Labonte and the Mees staff set up its data reduction and archiving pipeline for routine daily operation. As part of NASA's support for the Yohkoh mission, Mees Solar Observatory was staffed for long observing days, seven days a week. The resulting large database paid off handsomely when efficient procedures for quantification of the overall twist of active region magnetic fields were developed by Tom Metcalf and Alex Pevtsov. Major scientific results came in several forms related to magnetic helicity and topology (Berger, 1984). The large Mees database of photospheric vector magnetograms from the HSP enabled the latitude and solar cycle variation of the twist of active region magnetic fields (Pevtsov, Canfield, and Metcalf, 1995; Pevtsov et al., 2008) to be compellingly inferred despite a dataset that was intrinsically noisy, not owing to poor statistics or instrumentation, but rather to the origins of twisted magnetic fields in the turbulent convection zone. This topic had wallowed in uncertainty ever since George Ellery Hale's time (Hale, 1908). This result launched Alex Pevtsov on a career as one of the world's leading experts on helicity over a range of solar and heliospheric spatial and temporal scales. Another very fundamental result, which took good advantage of the spectral flexibility of the HSP combined with creative data analysis (Metcalf et al., 1995), was Tom Metcalf's demonstration that the chromospheric magnetic field of an active region does not become force-free until about 400 km above the photosphere.

The Mees CCD Imaging Spectrograph (MCCD, Penn et al., 1991), with improvements funded by NASA to support the Yohkoh mission, was a productive workhorse.³ It was a focal-plane package for the existing ~1970s coronagraph telescope and Coude spectrograph. Because the improvements included a fast active-mirror guiding system, the data were a substantial improvement on the CCD focal plane setup I used at the DST at Sac Peak (Section 3). Key people in its early development were Don Mickey, Barry Labonte, Matt Penn, Herb

³The large NASA-funded collections of H α MCCD imaging spectra and IVM vector magnetograms of active regions during Yohkoh, recovered from many hundreds of Exabyte tapes, are available at the Virtual Solar Observatory (<https://virtuelsolar.org> or <https://nso.edu/data/vso/>). Additionally, they can be found at <https://www.nwra.com/IVM/> and <https://www.nwra.com/MCCD/>.

Ryerson, and Buzz Graves in Honolulu and Elaine Kiernan at Mees. In the Yohkoh era Jean-Pierre Wuelser took overall responsibility for the system and Kevin Reardon became the go-to M CCD expert. The M CCD provided $H\alpha$ imaging spectroscopic observations of active region dynamics, flares, and surges to accompany the observations from the Yohkoh hard and soft X-ray telescopes, HXT and SXT. X-ray jets were a discovery of the Yohkoh SXT (Shibata et al., 1995). Canfield et al. (1996) combined M CCD, Imaging Vector Magnetograph and Yohkoh SXT observations of nine events observed as jets in X-rays and surges in $H\alpha$, associated with moving magnetic bipoles. They developed a magnetic reconnection model that achieved the ultimate in recognition of effective communication in solar physics, namely inclusion in Hugh Hudson’s *Solar Cartoon Archive* <https://www.astro.gla.ac.uk/cartoons/index.html>.

The Yohkoh mission provided strong motivation for the Imaging Vector Magnetograph (IVM, Mickey et al., 1996), which was built with funding by both NASA and NSF.³ It used a tunable Fabry-Pérot filter and CCD cameras to image active region magnetic fields in three dimensions with high spectral, temporal, and spatial resolution. In less than 10 minutes it produced a vector magnetogram with field of view larger than what the HSP could produce in a day! Key people in its development were Don Mickey, Barry Labonte and K. D. Leka in Honolulu and Mark Waterson and Mark Weber at Mees. In the Yohkoh era Tom Metcalf took overall responsibility for the system.⁴ The IVM was operated to make vector magnetograms for nearly all NOAA solar active regions starting in 1992, which enabled statistical studies of pre-flare magnetic fields by K. D. Leka, Barry LaBonte, and collaborators. K. D.’s home-run thesis demonstration (Figure 14) that magnetic flux emerges into the visible solar atmosphere carrying electric currents (Leka et al., 1996) used the IVM with support from both the M CCD and the HSP. It was a great example of what happens when a student makes a timely and well-informed choice of thesis topic in astute consultation with a “village” of experienced researchers. In another result, the large database of IVM vector magnetograms enabled co-alignment of magnetic features with M CCD imaging spectra in order to relate the sites of $H\alpha$ surges and X-ray jets to moving magnetic features, and develop a model of magnetic reconnection (see previous paragraph).

Mees and its instrumentation were far from the full story of the obvious success of solar research in Hawaii in the mid-80s to mid-90s. I attribute much of it to the friendly and creative collaboration of Sandy McClymont, George Fisher, and their students and colleagues. Enthusiastic theorists included Ed DeLuca, Yuhong Fan, and visitors Don Melrose, Ian Craig (both working with Sandy) and Daniel Gomez. Their collegial approach enriched everyone’s research. Another obvious example of “village” is the mentoring that was part of Yuhong Fan’s outstanding thesis. She carried out a magnetohydrodynamic simulation of flux

⁴The IVM design considerations and Hawaii experience with it directly influenced the SDO/HMI design and data-pipeline implementation (Scherrer et al., 1995). Tom Metcalf’s algorithm (Metcalf et al., 2006) is used for resolving the 180° magnetic field direction ambiguity, providing publicly released data from that instrument, as well as the Hinode spectro-polarimeter (Lites et al., 2013), that is physically meaningful and interpretable.

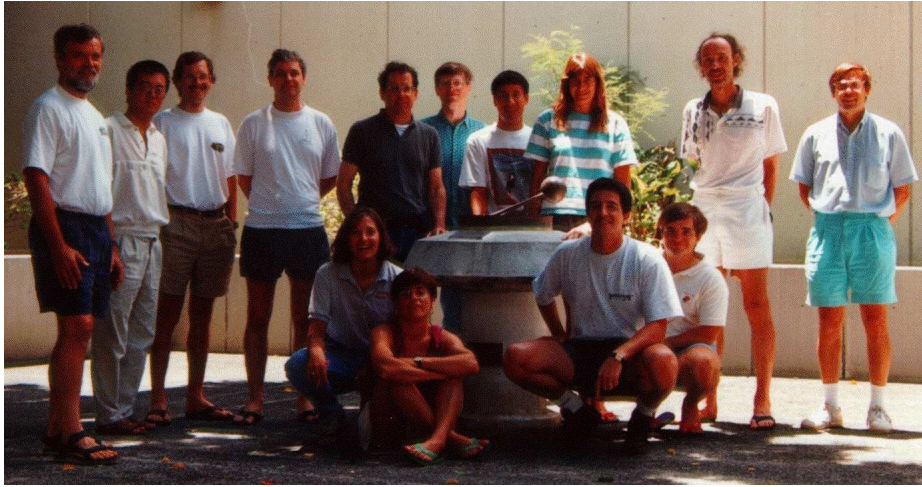


Figure 13. The Institute for Astronomy Solar Group in 1994. Left to right, back row: Me, Litao Jiao, Jean-Pierre Wuelser, Tom Metcalf, Hugh Hudson, Barry Labonte, Ed Lu, Rene Kupke, Sandy McClymont, Alex Pevtsov. Front row: K. D. Leka, Gianna Cauzzi, Daniel Gomez, Kevin Reardon.



Figure 14. Celebrating K. D. Leka's successful thesis defense in the courtyard of the Institute for Astronomy, University of Hawaii. Manoa, 1995. From beginning to end, K. D.'s graduate experience was a model of preparation for, and execution of, thesis research. See Section 8 for insight into of this general topic, and the acknowledgements section of her thesis <http://hdl.handle.net/10125/9353> for specifics.

tubes rising through the convection zone (Fan, Fisher, and Deluca, 1993) with the guidance of George Fisher and Ed DeLuca. She showed that the Coriolis force induces a flow along a rising flux tube, which explains the well-known leading/following asymmetry of sunspot areas. She strengthened and extended this result under the guidance of both George and Sandy in Fan, Fisher, and McClymont (1994). Now a leading solar physicist at HAO in Boulder, she has come a long way thanks to her intellect, integrity, and determination.

Helmut Abt, the award-winning managing editor of the *Astrophysical Journal* from 1971 to 1999, once called me aside at an AAS meeting to compliment me on the high level of our solar group research and productivity relative to the Institute of Astronomy as a whole. Of course, the tropical ambience created a lifestyle that both group members and visitors enjoyed. Thanks to our skilled executive secretary, Janet Biggs, the group ran like a top and several national and international meetings were memorable successes.

The Hawaii years were part of a long and productive collaboration with Tom Metcalf, with whom I co-authored 19 refereed publications. Tom was a wizard of data analysis methods. Tom's work includes the development of innovative data analysis methods for vector magnetograms and hard x-ray imaging. His fitting method for quantifying the overall twist of active region magnetic fields was critical to processing the large HSP dataset for hemispheric helicity studies (Pevtsov, Canfield, and Metcalf, 1995; Pevtsov et al., 2008). The minimum energy method for resolving the 180° ambiguity in vector magnetograms (Metcalf, 1994) was critical to an on-going line of ground and space-based instruments.³ The pixon algorithm, developed by fellow UCSD graduate students Rick Puetter and Robert Pina, was a key component of imaging hard X-rays with both the Yohkoh and the RHESSI hard X-ray telescopes (Metcalf et al., 1996; Hurford et al., 2002). I also benefitted directly from Tom's life-long love of the sea and sailing. We shared ownership of a catamaran, with which skimming over the clear waters of Kailua Bay was an obscenely pleasant pursuit. He was the son of loving and gracious parents, Fred and Marilyn Metcalf. They generously memorialized him after his untimely passing (Leka, 2007) by establishing the AAS/SPD Metcalf Travel Award Program to help young people get a start in solar research.

6. Montana State University (1996-2018): Sigmoids, Heliophysics, RHESSI and Max Millennium

In 1996, when continued vitality was blocked in Hawaii, I moved to a research professorship in the Physics Department of Montana State University. A few years earlier fellow Colorado graduate and Yohkoh collaborator Loren Acton had started a solar physics research group there, at his undergraduate alma mater. The leaders of the Physics department (Bill Hiscock, then John Hermanson and Dick Smith) and the University were supportive. I did whatever I could to encourage the growth of the group. Within a few years of Loren's arrival three tenure-track faculty (Dana Longcope, Charles Kankelborg, and Jiong Qiu) and the first crop of graduate students (Figure 16) were on board. Alex Pevtsov

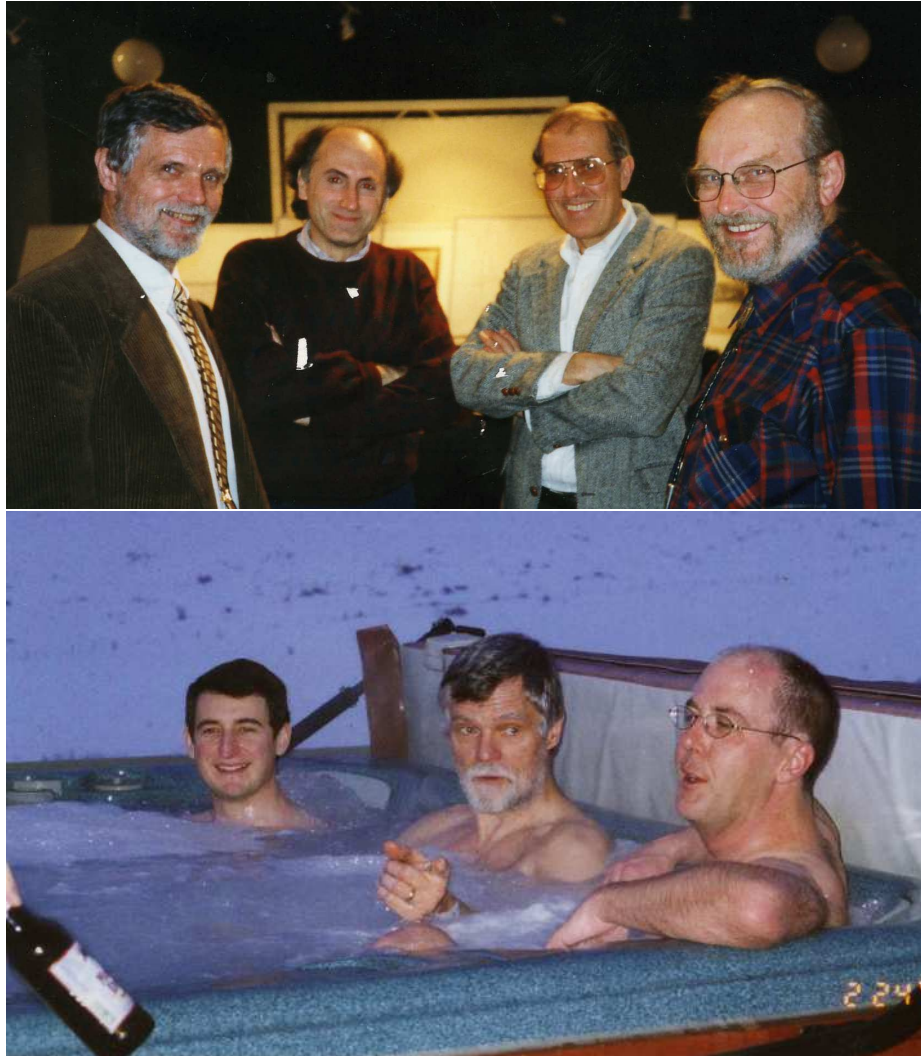


Figure 15. Two takes on the theme of colleagues and baths. (Top), Bath with an upper case B): A rare picture of me wearing a tie, with long-time friends Spiro Antiochos (NRL/NASA), Dave Rust (Johns Hopkins), and Loren Acton (Lockheed/MSU), at the Yokohama conference on Magnetic Reconnection in the Solar Atmosphere, in Bath, England, March 1996. (Bottom), bath with a low case b): with MSU colleagues Charles Kankelborg and Dana Longcope, celebrating the successful relocation of my 900-pound hot tub, in February, 2001. I recruited nine strong colleagues to help with this task (100 pounds each!), including Loren Acton, who at a key moment shrewdly changed his role from grunt to leadership while the rest of us groaned and moaned.



Figure 16. The Montana State University Solar Group in 1998. Left to right, standing: Tim Slater, Mark Weber, Brian Handy, Charles Kankelborg, David McKenzie, me, Michelle Larson, Alisdair Davey, Brian Welsch. Kneeling: Dana Longcope, Alex Pevtsov, Meredith Wills, Loren Acton.

came with me from Hawaii. Distinguished visitors came from time to time, notably Eric Priest and Arnab Choudhuri, who worked primarily with Dana Longcope. World-wide high-speed internet was rapidly changing how and where space science was done. Even in remote Montana, a state with about three times more cattle than people, high-speed internet made it possible to do first-class research. Although hardly a major player, MSU now has an exceptional award-winning faculty in solar physics, as well as an undergraduate physics program that serves bright Montana high school students well. Physics and engineering undergraduate Sean Sandborg worked with me and Alex Pevtsov, and won a Goldwater prize. Zachary Blehm, working with Bob Leamon, me, and Alex Pevtsov, was co-author of a refereed research publication on the role of the kink instability in solar eruptions. Zachary Holder was the first author of a paper (Holder et al., 2004) written with Dibyendu Nandi, Rebecca McMullen, Bob Howard, and Alex Pevsov on the tilt and twist of active regions, which has garnered 50 citations to date! As well, high school students participating in the American Indian Research Opportunities program were exposed to science, engineering, and mathematics. Factoring in outdoor recreation, Montana is a spectacular place (Figure 15).

Interest in magnetic helicity in solar physics grew dramatically during my scientific career, particularly in my Hawaii and Montana years. Aspects of interest included: (1) which processes generate magnetic helicity in the solar interior; (2) how helicity is transformed when magnetic field rises through the convection

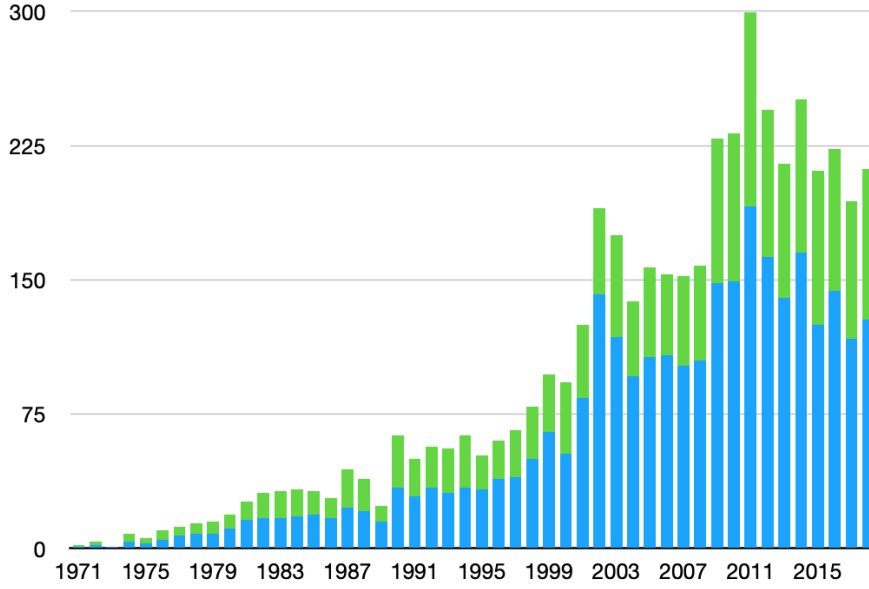


Figure 17. The growth of helicity studies in solar physics over my career, measured by the annual number of refereed (blue) and total (green) research publications in the NASA ADS database as of the time of writing whose abstracts contain the words solar and helicity. Contributions to this figure of which I am most proud are: latitude variation of the helicity of photospheric magnetic fields of active regions (Pevtsov, Canfield, and Metcalf, 1995); evidence that magnetic flux emerges already carrying current (Leka et al., 1996); AGU Conference on magnetic helicity in space and laboratory plasmas (Brown, Canfield, and Pevtsov, 1999); relation between sigmoidal morphology and eruptive solar activity (Canfield, Hudson, and McKenzie, 1999); properties of interplanetary magnetic clouds and geomagnetic storms associated with eruptions of coronal sigmoids (Leamon, Canfield, and Pevtsov, 2002); predictions of energy and helicity in large eruptive flares (Kazachenko et al., 2012).

zone; (3) what the role of magnetic helicity is in magnetic reconnection and flare activity; and (4) how the helicity of the solar wind and interplanetary magnetic field is related to that of the solar convection zone and photosphere. Figure 17 shows the long-term growth in solar helicity research over almost five decades, and the caption relates it to research publications in which I played a role.

Alex Pevtsov and I had perceived this growing interest in the helicity of photospheric magnetic fields while we were in Hawaii, and the time frame of our initial publications together spanned our mutual transition to Bozeman. Alex and I did our best to encourage this growth through a special session at an AGU meeting – the Escher-print T-shirts are collector’s items, and Mitch Berger has the framed print!. We also proposed and led a successful AGU Chapman Conference on Magnetic Helicity in Space and Laboratory Plasmas (Brown, Canfield, and Pevtsov, 1999), held at NCAR. In my fantasies, I can see a bump in Figure 17 at about the right time. In any case, Alex’s contribution to our collaboration was huge. It is testimony to his confidence that moving his young family from the USSR to Hawaii in 1992 was the right thing at the right time (shortly after the dissolution of the Soviet Union in December 1991) and to my

confidence that I could get him a postdoctoral appointment in Hawaii. I fondly remember meeting him and his young family when they got off the plane in Honolulu with all his worldly possessions in a few small packages and a negligible amount of highly devalued currency in his wallet. For his first few months in Hawaii the family lived in Sandy McClymont's guest house. I can still hear little Alexander (Sasha) calling "Dyadya Deek" as I drove away after a visit one evening. He's grown more than a little by now (see Figures 19 and 21).

My primary interest later in the Yohkoh mission, after moving to Montana, was the helicity of solar coronal and interplanetary magnetic fields. The large size of the SXT database was both a blessing and a curse, but the SXT movie database on video disk (thanks to Loren Acton and Greg Slater), combined with eyeballs and brains, was the ideal analysis tool. Many hours in front of a video monitor, two experienced collaborators (David McKenzie and Hugh Hudson), and one patient MSU undergraduate (Zach Blehm) yielded a visual classification of active regions according to their soft X-ray morphology (sigmoidal or non-sigmoidal) and activity (eruptive or non-eruptive flares), which we combined with active region size (sunspot area). Other key members of this "village" were fellow MSU physics faculty members Dana Longcope and Jeff Adams, both experienced in statistics of samples of dichotomous variables. Their expertise enabled us to extract a strong and important result: active regions are significantly more likely to be eruptive if they are either sigmoidal or large (Canfield, Hudson, and McKenzie, 1999).

The obvious implication of this result for identification of solar active regions that are more likely to erupt caught the eye of NASA. The NASA press machine swung into motion. American Astronomical Society Press Officer Steve Maran (my former fellow astronomy graduate student at Michigan) coined the name "S Marks the Spot", and the rest is a lesson in public outreach. I saved a file of clippings from all over the globe. In the printed press, it made the New York Times, the Washington Post, Scientific American, and hundreds of other news outlets worldwide. On line, it was the Astronomy Picture of the Day on March 16, 1999, *viz.* <https://apod.nasa.gov/apod/ap990316.html>. On television, it made the network evening news and CNN. For me, the key people who saw it live were my department chair, my college dean, and my mother in law. She was obviously the most important; everybody needs points with his mother in law. A side benefit was an invitation to deliver the talk "The Sun-Earth Connection in the Space Age" in the 1999-2000 Distinguished Leaders in Science series in the imposing National Academy of Sciences auditorium in Washington, DC.

Broadening my focus to helicity in a larger heliophysics context resulted in funding for a great deal of rewarding work by several postdoctoral fellows:

- Tetsuya Magara, Ph.D. in Solar Physics from the University of Kyoto, Japan, studied with Dana Longcope several helicity-related aspects of flux tube emergence, including energy and helicity injection rates and formation of sigmoid structure.
- Robert Leamon, Ph.D. in Physics from the University of Delaware, Newark, studied with me, Alex Pevtsov, and several REU students relationships between active region magnetic fields, eruptions of sigmoids, magnetic clouds, and geomagnetic storms.

- Stephane Regnier, Ph.D. in Physics from the Inst. d'Astrophysique Spatiale, Orsay, studied with me and Tahar Amari self and mutual helicities in coronal magnetic configurations, including a particularly well-observed active region that demonstrated the importance of complex topology compared to twist.
- Dibyendu Nandi, Ph.D. in Physics from the Indian Institute of Science, Bangalore, very productively studied with me, Dana Longcope, Alex Pevtsov, Piet Martens and several graduate students and undergraduates. Subjects included Taylor relaxation, magnetic helicity, flux tube twist and dynamics, and dynamos comparing observations and theory.

From the point of view of lessons learned, it is important to elaborate on the MSU Research Experiences for Undergraduates (REU) program in solar physics. I started the program in 1999 with just one student, and it became a formal NSF REU program when Piet Martens secured a grant to support it. Each summer 5 - 10 undergraduates from the US and abroad worked together in a "bullpen" pursuing real solar research. This highly collaborative environment proved to be a great example of a "village". It involved several MSU faculty who were key in its execution, including Piet Martens, David McKenzie, Dana Longcope, and Jiong Qiu. Eric Priest, visiting from St Andrews to enjoy research collaborations and beautiful Montana summers, made a huge contribution to this program for many years, through his teaching skill and outgoing and caring personality. Yet another noteworthy element of this program was active mentoring of the undergraduates by MSU graduate students and postdocs: Trae Winter, Angela DesJardins, Bob Leamon, Dibyendu Nandi, and Maria Kazachenko. Several tens of REU alumni are active in research today, around the world. Those with whom I worked include Emily McLinden (now at McDonald Observatory), Scott Waitukaitis (Leiden University), Michael Hahn (Columbia University), Alexander Russell (University of Dundee), Thomas Schad (National Solar Observatory), and Christopher Lowder (Southwest Research Institute). St. Andrews graduate student participant Anthony Yeates went on to win the AAS Solar Physics Division Karen Harvey prize for early career research.

The two MSU physics graduate students whom I mentored went on to successful careers in quite different aspects of university research and education. Angela Colman Des Jardins worked with me as an undergraduate, and nominated me for the MSU Alumni- Chamber of Commerce Award for Excellence as a mentor. I received this award in 1999. She stayed at MSU for graduate school, and wrote her RHESSI-supported thesis (with crucial input from Brian Dennis and Dana Longcope) on the topology of magnetic reconnection in solar flares. Prioritizing family values, she stayed in Bozeman, and went on to an assistant research professorship in the Physics Department at MSU. Her focus has been undergraduate research and education. She is now the director of two successful NASA-funded programs that support space science throughout Montana, the Montana Space Grant Consortium and the Montana NASA EPSCoR program, and a winner of a recent Bozeman "20 under 40" award.

Maria (Masha) Kazachenko wrote her thesis on predictions of reconnected flux, energy and helicity in eruptive solar flares, with crucial mentoring from



Figure 18. A happy PhD student, Maria (Masha) Kazachenko, after her 2010 thesis defense, with me, Jiong Qiu, and Dana Longcope. Both Jiong and Dana epitomize the role of university professors in research. Both are winners of the AAS/SPD Harvey Prize, which is awarded in recognition of a significant contribution to the study of the Sun early in a person’s professional career. As well, in 2021 Dana was awarded the National Academy of Sciences Arctowski Medal “for decades of research into storage and release of magnetic energy around the sun, creating a framework for understanding solar events and bridging theory and observation”. The icing on the cake was his 2022 selection for membership in the National Academy of Sciences.

Dana Longcope and Jiong Qiu (Figure 18). After graduation she spent eight years at the Space Science Laboratory of the University of California Berkeley, under the guidance of my outstanding former student George Fisher. Masha is currently an assistant professor in the Astrophysical and Planetary Sciences Department of the University of Colorado, and a researcher at the National Solar Observatory, in Boulder. She teaches courses, mentors graduate students and postdoctoral fellows, carries out research on data-driven modeling of coronal magnetic fields, organizes preparation for data from the powerful Daniel K Inouye Solar Telescope, and carries out statistical studies of flares.

When Masha started working with me, I had only recently realized that bright sigmoidal X-Ray structures are an indicator of imminent solar eruptions (Rust and Kumar, 1996). I gave her a simple data analysis project that was a test of the idea that the brightening of these structures was due to reconnection of their active-region magnetic fields with the large-scale solar magnetic field. At first, we made slow progress; in hindsight, this was due to the fact that she had to beat down my confirmation bias. I had previously worked with two summer undergraduate students, and had succeeded in bringing them around to

my point of view. However, Masha was a completely different matter. She used well-defined criteria, clear reasoning, and objectivity - important characteristics of a successful scientist - to get correct and credible results (Canfield et al., 2007), which were quite different from my initial expectations.

As a consequence of my long involvement with solar flare research, I was a Co-Investigator for NASA's Ramaty High Energy Spectroscopic Imager (RHESSI). Bob Lin was the Principal Investigator, and Brian Dennis was the Mission Scientist and lead Co-Investigator. Their catholic view of the role of ground-based observing and theory in RHESSI resulted in support for both Angela Colman Des Jardin's thesis on hard X-ray foot-points and magnetic topology and the Max Millennium program *viz.* <http://solar.physics.montana.edu/max-millennium/> at MSU. This program was established to coordinate solar flare observations of both space-based and ground-based observatories. The main tool for this coordination was the Message of the Day, an email heads-up that identified the solar active region of greatest interest to flare observing programs. Each day one of several volunteer Chief Observers issued this message predicting when and where flares of greatest interest will occur. The most experienced of these dedicated solar observers was (and still is) Bill Marquette, whose deep experience came from McMath Solar Observatory (Section 1) in the 1970s, and primarily Big Bear Solar Observatory "BearAlerts" (Zirin and Marquette, 1991) thereafter. As for the other Max Millennium Chief Observers, you don't have to be Irish to be a good one (for example, Ying Li), but it obviously helps: *viz.*, Peter Gallagher, Ryan Milligan, Shaun Bloomfield, Claire Raftery, James McAteer, Aoife McCloskey, and several other talented University College Dublin PhD students.

7. We Should All Be So Lucky: Canfield Fest, Hale Prize, Retirement, and Family

In August 2010 George Fisher and Yuhong Fan organized a "Canfield fest" in my honor, with help from current and former students and colleagues K.D. Leka, Dana Longcope, Hugh Hudson, Alex Pevtsov, and Boon-Chye Low. The event was a workshop nominally devoted to the dynamics and diagnostics of solar magnetic fields and plasmas (Fan, Fisher, and Leibacher, 2012), held at NCAR in Boulder. Figure 19 shows many of the participants at the workshop itself, and Figures 20 and 21 at the reception. I am proud that the scope of the workshop spanned so many areas of solar physics and astronomy in which I worked, including observation, data analysis, theory and modeling, and as many young people as grey-beards (see Figure 19). I am particularly pleased that the thesis publication dates of my PhD students in Figure 21 span more than three decades, from 1977 (Robert Stencel, Emeritus Professor of Astronomy, Denver University) to 2010 (Maria Kazachenko, Assistant Professor of Astrophysical and Planetary Sciences, University of Colorado). As well, it includes the authors of two highly cited PhD theses, George Fisher (Retired Research Physicist, University of California, Berkeley) and K. D. Leka (Senior Research Scientist, Northwest Research Associates, Boulder), REU students, and equal numbers of



Figure 19. Participants in the 2010 Canfield Fest. Front row: Tom Schad, Hugh Hudson, Lyndsay Fletcher, me, George Fisher, Maria Weber, Mei Zhang, Anna Malanushenko, Elena Pevtsov, Yuhong Fan. Middle row: Ron Moore, Spiro Antiochos, Dana Longcope, Bill Abbett, Alexander Pevtsov, Maria Kazachenko, Mitch Berger, Jiong Qiu. Back row: Chris Lowder, Ben Lynch, Charley Lindsey, Martin Woodard, Jack Campbell, Rudy Komm, K.D. Leka, Alex Pevtsov, Adam Kowalsky. Copyright UCAR, photo by Carlye Calvin.

men and women. Finally, Figure 19 even includes PhD students of PhD students of my PhD students!

I was awarded the George Ellery Hale Prize by the Solar Physics Division of the American Astronomical Society in 2013. The citation reads "The 2013 Hale Prize is awarded to Richard Canfield for his pioneering work on dynamics and radiation in solar flares and on the origins and implications of magnetic helicity in active regions, as well as his role as a leader and mentor." If you have read this far into this memoir, you are qualified to rate this award as anything from appropriate to hogwash. I chose my Hale prize talk title to relate to research done by Hale himself: "Twisting and Writhing with George Ellery Hale – Magnetic Helicity from Turbulent Convection to Space Weather". I delivered the Hale Prize talk in two versions. At the 2013 Indianapolis meeting of the AAS *viz.* http://solar.physics.montana.edu/canfield/talks/AAS_Hale_talk.pdf, the audience included a wide range of acquaintances ranging from a recent MSU REU student to fellow Michigan astronomy graduate student and AAS press officer Steve Maran! At the Bozeman meeting of the Solar Physics Division I was joined at the podium by no less than five previous Hale Prize winners (Figure 22). The Bozeman meeting version of my talk, available at *viz.* <https://spd.aas.org/prizes/hale/previous/>, includes lists of mentored postdoctoral, doctoral, graduate, undergraduate, and research students, of which I am very proud!



Figure 20. Group photographs from the 2010 Canfield Fest reception. Top, with some of my heroes of creativity: Dana Longcope, Deb Haydon-Canfield, Lindsay Fletcher, Hugh Hudson, Eric Priest. Bottom, with Hawaii colleagues Alex Pevtsov, Yuhong Fan, K.D. Leka, George Fisher, Sandy McClymont.

After all this hoopla, it was time to retire completely, which I did in 2018. My approach to retirement was gradual. In 2005 I had started what I often referred to as my "practice retirement" – part-time employment. I fully retired fifteen years later, at age 81. My last community service activity (other than almost inevitable proposal review panels) was as Co-Leader of the Pre-Event Physics Working Group, at the RHESSI/SOHO/TRACE Workshop in Sonoma, CA, in 2004. My last PhD student, Maria Kazachenko, defended her thesis "Creation of Twisted Flux in Solar Flare Eruptions" in 2010. My last invited talks were the Hale Prize talks in 2013. My last research contribution, "Performance of Major



Figure 21. Group photographs from the 2010 Canfield Fest reception. Top, left to right: with Montana colleagues Chris Lowder, Jiong Qiu, Anna Malanushenko, Dana Longcope, Alexander Pevtsov, Elena Pevtsov, Alex Pevtsov, Loren Acton, Deb Haydon-Canfield, Evelyn Acton, Masha Kazachenko. Bottom: PhD students George Fisher, Masha Kazachenko, K.D. Leka, and Bob Stencel.

Flare Watches from the Max Millennium Program (2001 - 2010)”, Bloomfield et al., was published in 2016. My last research contract, which funded the Max Millennium Program, ended in 2018. I still have inevitable work-related reference-letter writing activities, but I have a lot of family activities to finish up. I’m not getting any faster, so I’d better get going!

When I retired, my family became my primary daily activity. It’s common knowledge that the one person with whom you need to clear your retirement is your spouse: he or she is going to have to deal with having you around all the



Figure 22. Six Hale Prize winners at the 2013 Bozeman meeting of the Solar Physics Division of the AAS. Left to right: With Spiro Antiochos, collaborator on a variety of professional activities, as well as the footprints on the Sac Peak Dunn Solar Telescope (1971); Loren Acton, fellow CU AG graduate student (1960s), NASA shuttle astronaut, and Yohkoh collaborator; Hugh Hudson, my inspiration for taking up a university-based research position at UCSD (1976) and a stimulating contributor to a wide variety of topics; Jack Harvey, fellow CU AG graduate student (1960s) and model scientist for all of us to follow, and Eric Priest, with whom I first interacted in the early 1970s when we both visited HAO, the most positively interactive colleague of my career. Photo courtesy David Hathaway.

time. To compound the problem, Montana State University kicked all retirees out of its recreational facilities, so I don't even get a chance for my daily swim! The final blow was the COVID-19 pandemic, which closed indoor facilities to all but the reckless, and discouraged interaction with my MSU colleagues.

As a result of the career I chose, and how I chose to live it, my family is spread from coast to coast and beyond in the United States. My two older children, Walker and Paige, and their families, as well as my brother and sister, all live on the East Coast. My younger son Robert and his family live in Hawaii, and my younger daughter and family live in Montana. Deb's family lives mostly in California and Connecticut, though her 92 year old Mom now lives in Bozeman. We use Zoom, FaceTime, and the phone to keep in touch. When my parents left me an inheritance, I took advantage of it to provide my family communication, financial security and a better life, primarily through education and home ownership. Maintenance of family ties has been manifested as family reunions, such as the one shown in Figure 23. These week-long events took place from coast to coast every year or two starting in 2007. COVID-19 ended that in 2019, by which time the grandkids were beginning to leave the nest one by one, and great-grandkids were already entering the picture.



Figure 23. Participants in the family reunion held at Lake Wallenpaupack in Northeast Pennsylvania, 2019. I am in the back row, in the SPAM T-shirt, a memento of my years in Hawaii. To my left are my wife Deborah Haydon-Canfield, my sister Susan Canfield, and my former wife Karen Sundwick. Next to Karen is her sister Ruthie Smith, my son in law Brian Berry, my younger daughter Chelsea Berry, and my youngest grandson Bode Berry. To my right are my son in law Tim Macke, my brother Jim Canfield, younger son Robert Canfield and his wife Kimiko Bristow-Canfield. In the front row (left to right) are my older son Walkerr, his wife Kristi, my older daughter Paige and her daughter Esther Macke. Next are my first great-grandson Kainoa Bristow-Canfield, and my granddaughters Maia and Kailey Bristow-Canfield. Next, in the green shirt, my grandson Mark Canfield (Walker's younger son), and my eldest grand-daughter Arielle Bristow-Canfield, Kainoa's mother. Deb, a retired neonatal nurse, is Chelsea's mother. Karen, an emeritus professor of history, is the mother of Walker, Paige, and Robert. All three were born in Boulder, while I was a graduate student there. Walker is an information technology security officer for the US Government Services Administration, working near Boston. Paige is a graphic designer living in rural Vermont. Robert is a family nurse practitioner in Hawaii. Chelsea was born in La Jolla, while I was at UCSD. She is a neonatal nurse, living in Bozeman. I'm proud of them all!

8. Insights

Two significant historic events took place during the time period of Section 2. On October 4, 1957, the Soviet Union launched the first artificial earth orbiting satellite, Sputnik I, just a year after I received my first job offer in astronomy (Figure 2). On July 20, 1969, Neil Armstrong became the first human to step on the moon. As a postdoctoral fellow, I watched the event with colleagues, gathered around Henk van Beuren's television in his office at Sterrewacht Sonnenborg in Utrecht. Never underestimate the roles of luck and good timing.

You have no control over the biggest events, but you can control how you anticipate their consequences. This applies to both technological and intellectual advances. The biggest technological advance during my career was obviously access to space, with dramatic consequences for *in situ* sampling, exploration, and remote sensing in spectral, spatial, and temporal domains. For me, that meant participating in the Skylab, SMM, RHESSI and Yohkoh missions, in-

tegrated with ground-based observations and numerical modeling. I benefitted from advances in computing power in studies of radiative transfer and flare hydrodynamics. Intellectual advances in the field as a whole included the birth of helioseismology (beautifully summarized by Bahcall (1999)), in which I was only tangentially involved, and the conservation properties of magnetic helicity (Berger, 1984), in which I chose to participate in the framework of heliophysics, solar-terrestrial relations, and space weather. The lesson: pick your course with your eyes and mind open for constant change.

Choose a thesis topic of importance to current solar physics. Get advice from all accessible people, from current PhD students on up.⁵ Identify resources that are both available and necessary for potential topics. Make use of NASA/ADS to identify active topics and scientists. Read abstracts and full papers found through ADS secondary "useful" operator searches. Participate in research seminars, colloquia, journal clubs. Participate in REU programs in whatever role is appropriate to your current station in life. Make sure you have access to the resources you will need. Evaluate short and long-term jobs taken up by recent PhDs from your university.

Seriously consider whether a university career is for you. Interaction with students promotes intellectual vitality and depth of understanding, and therefore university life can be very rewarding, other things being equal. Tenure matters, but make sure you know the price (Sections 3 and 5). If you are confident that you have thoroughly evaluated the web of pros and cons in your own life, tenure is just one of many considerations.

Keep in mind that there is more than one way to skin a cat. Some of my former students, postdocs and colleagues have enjoyed notable success in something other than the standard teaching and research career path, e.g.: Ed Lu (astronaut and space entrepreneur, Section 5), Pete Worden (Brigadier General USAF, NASA Center Director, Section 3), Michelle Larson (Planetarium CEO, Section 6), Rick Puetter (pixons and imaging entrepreneur, Section 4), David Tamres and Brian Welsch (small college professors, Sections 4 and 6 respectively). And, of course, there is room in the world for artists and artisans (Section 3), as my daughter Paige has so capably demonstrated (<https://carvedesignsvt.com>). Keep your options open! In my opinion, it's doing something you truly enjoy that matters most.

As sure as God made little green apples, in observational solar physics and data analysis, a statistically significant study trumps a one-off study any day (Sections 5 and 6). In my case, the two best examples are my collaborations on the global distribution of the twist of active regions (Pevtsov, Canfield, and Metcalf (1995)) and the roles of active region size and twist in coronal eruptions

⁵In 2017 the Center for History of Physics at the American Institute of Physics started a NASA-funded a three-year study to document the history of heliophysics, solar-terrestrial relations, and space weather. I was one of about fifty people in these fields who participated in oral history interviews focusing on their education, training, career, and other relevant aspects of their professional lives. Obviously this archive is a great source of insights. At this time only a fraction of these interviews are on line, e.g., that of space weather expert Louis Lanzerotti *viz.* <https://www.aip.org/history-programs/niels-bohr-library/oral-histories/45609>.

(Canfield, Hudson, and McKenzie, 1999), both of which have proven to be very useful to subsequent researchers.

Finally, reinvent yourself from time to time. It is difficult for me to exaggerate the importance of my transitions from Sac Peak to San Diego to Hawaii to Montana. It is equally difficult for me to exaggerate the importance of my transition from spectral line formation and radiative transfer to solar flares to polarimetry, magnetic helicity, and the magnetic connectivity of the Sun to the heliosphere. I believe that these transitions were critical for creative innovation.⁶

9. Acknowledgements

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⁶In this memoir I have from time to time referred to one or another of the 6 Cs: collaboration, communication, content, critical thinking, creative innovation, and confidence. They are as essential to scientific research and education as they are to early child development (Golnikoff and Hirsh-Pasek, 2016). Success in any career, not just solar physics, depends on all of them. Three more Cs are comments, clarifications, and corrections. Please don't hesitate to email me with any of them This memoir is not a living history, and it is certainly imperfect, so I plan to submit errata as make this memoir more useful.

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