Sac Peak History: A Visitor's Perspective

John H. Thomas
University of Rochester

I have been closely associated with the Sacramento Peak Observatory for more than 45 years. I have spent a considerable amount of time at the Peak, as a visiting scientist and as a user of its telescopes and other facilities. This involvement has strongly influenced my research interests and constitutes a substantial part of my scientific career. I look back on this involvement with a great deal of gratitude and affection. In this brief essay, I offer a personal perspective on what Sac Peak has meant to the field of solar physics and to its visiting scientists, and I reminisce about life on the Peak and the scientific collaborations and friendships I forged there.

My connection to Sac Peak dates back to the inaugural AAS Solar Physics Division meeting in Huntsville in February 1970, where I first met Jack Evans, the observatory director. I presented a paper on trapped gravity waves and the solar chromospheric oscillations, co-authored with my Rochester colleagues Al and Patricia Clark. As an early observer of velocity fields on the Sun, Jack was quite interested in our paper, and he sought us out for a lively discussion afterwards. We found that we had a special connection because Jack had worked at the Institute of Optics at the University of Rochester during WWII. Our theoretical paper attributed the solar five-minute oscillations to internal gravity waves excited by newly formed bright granules: this excitation mechanism agreed with Jack's views at the time. (A few years later, the theoretical work of Roger Ulrich, John Leibacher, and Bob Stein, and the observations of Franz Deubner, established that the dominant five-minute velocity oscillations were associated with global acoustic modes, but subsequently granule-excited internal gravity waves were also observed, and local excitation by near-surface granular excitation of the *p*-modes proved to be correct.) Jack was apparently impressed with our work, because he invited us to spend some time at Sac Peak. I was able to accept his kind invitation and arranged to spend the full summer of 1971 at the Peak.

My family accompanied me to the Peak – my wife Lois, son Jeff (then age 4), and daughter Laura (then age 2). We drove from Rochester to Sunspot, a distance of over 2,000 miles, with a few sightseeing stops along the way. This was our first trip to the Southwest, and we were amazed at how different it was, scenically and culturally, from the Midwest or the Northeast. Living on top of a mountain, surrounded by desert, was a wonderful new experience for all of us.

In 1971, Sac Peak was entering its modern era. The Vacuum Tower Telescope, dedicated in October 1969, was then fully operational, and attention was turning to high-resolution studies of the Sun. The scientific staff then included Jack Evans (director), Dick Dunn, Jacques Beckers, George Simon, Dick Canfield, Steve Musman, Dave Rust, Dick Altrock, and Bill Wagner. The chance to interact with these outstanding scientists in such a beautiful and relaxed setting was a privilege.

I had a desk in the Hilltop Dome, in an office I shared with Bill Davis. Each morning, Bill would drive up from his ranch on the Sac Peak road to operate the 15 cm telescope and produce the daily sunspot drawing. It was a pleasure to get to know Bill and learn of his experiences as a cattle rancher in the Sacramento Mountains.

During the summer of 1971 there was a severe drought in southern New Mexico. The fire danger was high, the campgrounds in Lincoln National Forest were closed, and tourists were not allowed to use the Sac Peak road. Because of the drought, there were several black bears entering the observatory grounds to raid garbage cans – at first during the night, and later in broad daylight. This became a serious concern, as there were many young children on the Peak. When walking around the Peak at night, we got in the habit of clapping our hands so as not to come up to a bear unnoticed and startle it. Later in the summer, forest rangers trapped some of the local bears and moved them to another part of the national forest.

There was an active social life at the Peak in those days: informal dinner parties and events at the Community Center. Dick Faller, the staff photographer, organized a classic film series. Steve Musman organized a group hike down Dog Canyon, mostly for summer students and visitors. Legend had it that you don't find rattlesnakes at elevations above the West Side Road, but we encountered one at about 8000 feet. It was sunning itself in the middle of the trail and, fortunately, was easily avoided.

The summer student program was in full swing that summer, with about a dozen students on the Peak. The annual staff-student volleyball game became a hot issue, because of the large number of visitors. Some staff members felt that only regular Sac Peak staff should play on the staff team. In the end, a compromise was worked out – a three-way tournament, with the addition of a team of visitors. The visitors team included Hermann Schmidt, Franz Deubner, and a few young NASA scientists who were spending time at the Peak on assignment. To the chagrin of the regular Sac Peak staff, our visitors team won the tournament. One benefit of my stay was getting to know Hermann Schmidt and Franz Deubner. Hermann invited me to spend time in Munich at the Max-Planck-Institute for Astrophysics, and I arranged to spend a year there on sabbatical leave in 1973-74. During that year, Franz organized an informal meeting on solar oscillations in Freiburg, which I attended.

The Big Dome, later named the Evans Solar Facility.

Shortly after I arrived at the Peak, Jack Evans suggested I might want to do some observing at the Big Dome. I had no previous experience in solar observing, but with the expert help of the staff observers, Lou Gilliam and Eddie Coleman, I was able to carry out a simple observing project

studying the spatial relation between plages in the photosphere and chromosphere. Photographic observations were taken using the East bench dual camera setup designed by Jacques Beckers, with the solar image fed by the 30 cm coelostat. One camera recorded images of photospheric plages using an RG 1 red filter, and the other took images through a tunable 0.5 angstrom H alpha filter at several different wavelength offsets to get height resolution in the chromosphere. The observations were made in July and August during the typical one-hour period of good seeing in the early morning. The results showed spreading of facular area with height and inclinations consistent with spreading magnetic flux tubes, but I had no simultaneous magnetic field measurements to confirm this. I submitted a brief paper on these results to Solar Physics, which was roundly rejected as offering nothing new or better. This might well have discouraged me from any further observational work, but somehow it didn't.

Until my first visit to Sac Peak in 1971, I was strictly a theoretician. My research had been in fluid dynamics and magnetohydrodynamics, with some applications to the Sun, but I was not fully committed to work in solar physics. That summer at the Peak convinced me to devote much of my research to solar physics, and it also introduced me to solar observations. Later, I broadened my research to other areas of stellar astrophysics, working with colleagues at Rochester and elsewhere, and this led to my joint appointment as professor of astronomy in addition to my appointment in mechanical and aerospace sciences.

I spent all or part of four other summers at Sac Peak, in 1975, 1977, 1979, and 1981, again accompanied by my family. Each time we drove to Sunspot from Rochester and explored more of the Southwest. We saw the Grand Canyon, Mesa Verde, Santa Fe and Taos, and many other interesting places. Nearer to Sunspot, we visited Carlsbad Caverns, picnicked at White Sands, and attended a rodeo on the Mescalero Apache reservation. We all loved being at the Peak, and for our children, it became their summer camp. They each made a return visit to Sac Peak after graduating from college.

Thomas family at Sac Peak in 1981

In July and October of 1975 I carried out a second observational study, this time at the Vacuum Tower Telescope (VTT), in collaboration with Steve Musman and with guidance from Dick Dunn. These observations were motivated by theoretical work I had done on the running penumbra waves in the sunspot chromosphere, discovered independently by Hal Zirin and Ron Giovanelli. The theoretical model I developed with my student Alan Nye suggested that these waves should also be observable in the photosphere. We measured Doppler velocities in photospheric and chromospheric lines simultaneously, using the Echelle spectrograph and the linear diode array. (The echelle spectrograph, designed by Jack Evans, was the first major instrument at the VTT. The linear diode array, designed by Dick Dunn, came

online in 1973.) We did indeed see running penumbral waves in the photosphere (Musman, Nye, and Thomas 1976), but they had some puzzling differences from the chromospheric waves. One incident during our observing runs stands out in my memory. On the second day of observing I arrived early and had to relocate the Fe I 557.6 nm spectral line in the spectrograph. I scanned the eyepiece along the spectrum until the shade of green seemed to match up with the color I remembered from the day before, and to my surprise, there was the desired spectral line right in the center of the eyepiece image. I wonder if I had some special ability to recollect exact shades of color, or if anyone can do this.

During that same year,1975, Franz Deubner was a visitor at the Peak and he carried out observations of solar *p*-modes at the VTT. A year earlier, he was the first to resolve the ridges of power in the *k*-omega diagram that established that the 5-minute oscillations were global acoustic modes. His new observations at the Tower provided much better resolution of the ridges, and allowed him, together with Roger Ulrich and Ed Rhodes, to measure solar differential rotation in the near-surface layers (Deubner, Ulrich, and Rhodes 1979), thereby ushering in the new and rich field of helioseismology.

The Dunn Solar Telescope

Steve Musman and I continued to collaborate for a few years, and we shared many interests. He was Alan Nye's advisor when Alan was a summer student at the Peak, and he served on Alan's PhD oral examining committee in 1975. Later, Steve spent a semester as a visiting faculty member at Rochester, on leave from Sac Peak.

In 1976 came the transition of Sac Peak from Air Force to NSF sponsorship and AURA management. To an outsider, the transition seemed to go smoothly. Even the BOQ (Batchelor Officers' Quarters) was easily renamed as the VOQ (Visiting Observers' Quarters)! (For an account of the transition, and many other aspects of Sac Peak history, see Zirker 1998.)

I made several other observing runs at the VTT over the next twenty years. I shall describe a few of them here because they illustrate the progress of instrumentation and observing methods at the Tower over these two decades. (For a more complete discussion of the telescopes and instrumentation at Sac Peak, see the article by Steve Keil in this volume.) In 1980 I collaborated with Lawrence Cram, then on the Sac Peak staff, and Alan Nye in observations of dynamical phenomena in sunspots, using the echelle spectrograph. We obtained photographic spectra, which provided higher resolution than the linear diode array but required long hours at the "fast" microphotometer in the basement of the Main Lab. The most important result of these observations was our study

of five-minute oscillations in a sunspot, which led to our Nature paper introducing the concept of sunspot seismology (Thomas, Cram, and Nye 1982).

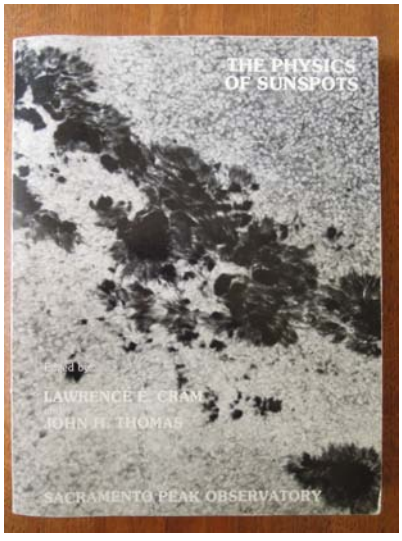
In early 1982, Lawrence Cram was preparing to leave Sac Peak and return to Australia, and he suggested that I might like to collaborate with a bright new Sac Peak staff member, Bruce Lites. Lawrence introduced me to Bruce, and Bruce and I found that we had several areas of common interest. In May 1982, we made some observations with the echelle spectrogtraph and 100 x 100 diode array of sunspot oscillations, and this data was later used by my student Toufik Abdelatif to study the interaction of solar *p*-modes with a sunspot (Abdelatif, Lites, and Thomas 1986). With another student, Mark Scheuer, I developed a theoretical model of the three-minute umbral oscillations in sunspots that as resonant modes of magneto-atmospheric waves, and I wanted to see how this model might match up with observations of the oscillations at different heights in the umbral photosphere and chromosphere. Bruce and I designed an observing program, again with the echelle spectrograph and 100 x 100 diode array, using the spectral lines Ti I 630.4 nm, formed in the low umbral photosphere, and Fe I 543.4, formed in the low umbral chromosphere, just above the temperature minimum. We did observing runs in January and June of 1984, shortly after Sac Peak and the Kitt Peak solar staff and facilities merged to form the National Solar Observatory. The results showed that the umbral oscillations have the characteristics of a resonant mode trapped in the low photosphere (Lites and Thomas 1985), consistent with our theoretical model. In 1985 we were able to carry out similar observations, together with simultaneous observations by Joe Gurman of the transition-region line C IV 154.8 with the Ultraviolet Spectrometer and Polarimeter (UVSP) aboard the *Solar Maximum Mission* satellite (Thomas, Lites, Gurman, and Ladd 1987), further revealing the vertical structure of the resonant modes of umbral oscillation.

Another advancement in the capabilities of the VTT came with the introduction of the Universal Birefringent Filter (UBF) and the multi-diode array (MDA). The UBF, designed by Jacques Beckers and built by Zeiss, can rapidly tune to different wavelengths, allowing fast time series of velocity and magnetic measurements. In 1989 Bruce Lites and I used the UBF to make Doppler velocity measurements in the Fe I 557.6 nm line, using a polarizing beam splitter in order to record two images simultaneously, in 0.025 nm bandpasses in the two wings of the line. The images were recorded on two 256 x 520 CCD arrays, at a rapid cadence of once every 6 seconds. We obtained some excellent data sets on sunspots and the surrounding photosphere. Tim Brown and Tom Bogdan at HAO joined us in the data analysis, and we published two papers based on the data. In one, we showed that a small fraction of the solar surface emits a disproportionate amount of acoustic energy, lending support to the idea that the solar *p*-modes are excited by localized sources near the surface (Brown, Bogdan, Lites, and Thomas 1992). The other paper presented measurements of the absorption of *p*-modes by sunspots, first observed by Doug Braun, Tom Duvall, and Barry LaBonte. Our observations provided better spatial resolution and allowed us to extend the measurement of absorption to higher horizontal wavenumbers and to modes of higher radial order (Bogdan, Brown, Lites, and Thomas 1993).

The next major advance in instrumentation at the Tower came in about 1992 with the introduction of the Advanced Stokes Polarimeter (ASP: see Lites et al. 1993). In 1993, Bruce Lites and I used the ASP to measure the vector magnetic field, velocity field, and intensity in and around sunspots. I was fortunate to have a ten-day observing run with generally clear weather and excellent seeing in October 1993, and I obtained several very good date sets. My graduate student Donald Stanchfield participated in the data reduction and analysis. Among other results, we were able to confirm Thomas Rimmele's discovery that the Evershed flow is mostly confined to narrow, elevated, nearly horizontal channels extending across the penumbra and sometimes beyond, and we showed that these flow channels were associated with the darker penumbra filaments and weaker, more horizontal magnetic fields (Stanchfield, Thomas, and Lites 1997). We also used these high-quality data sets to study *p*-mode absorption, umbral oscillations, and magnetic field fluctuations in a sunspot, and moving magnetic features in the surrounding moat.

Solar observations became a significant part of my research efforts. In looking over my list of publications, I find that 21 of them involve observations made at the Dunn Solar Telescope (as the VTT is now known), over a span of 25 years. I don't claim to be a real observer – I have never developed an instrument, or a new observational technique – but with the help of a few patient colleagues who are real observers, and the outstanding observing staff, I was able to do some significant solar astronomy. This has greatly enriched my career. Here I would like to acknowledge the generous collaboration of my observational mentors Dick Dunn, Jacques Beckers, Steve Musman, Lawrence Cram, and Bruce Lites, and the expert assistance of the Sac Peak observing staff – Lou Gilliam and Eddie Coleman at Big Dome, and Horst Mauter, Howard DeMastus, Dick Mann, Fritz Stauffer, Gary Phillis, Steve Hegwer, Roy Coulter, and Brian Armstrong at the DST.

One of Sac Peak's major contributions to solar physics has been the series of summer workshops it has held in Sunspot, beginning with a meeting on solar velocity fields in 1977. These workshops have provided a forum for new research results in a relaxed setting and have attracted scientists from all over the world. I was fortunate to be a co-organizer, with Lawrence Cram, of the fourth summer workshop, on the Physics of Sunspots, held in 1981. The workshop was attended by sixty scientists, including ten from abroad, and featured ample time for discussion, led by the session chairs Hermann Schmidt, Eugene Parker, Cornelis Zwaan, Jacques Beckers, Per Maltby, Robert Howard, and Myron Smith. What a pleasure it was for Lawrence and me to work with these outstanding scientists, all more senior than us. A significant outcome of this workshop was the "Sunspot sunspot" model umbral atmosphere, constructed from the papers presented in a session organized by Kees Zwaan and computed by Eugene Avrett. This model atmosphere was used in several publications over the



Proceedings of the 1981 workshop on sunspots

next few years. Another novel feature of the workshop was Steve Vogt's invited review of starspots, a subject in its infancy at that time. Many of us attending the workshop learned about the magic of Doppler imaging for the first time. As was the case for the three earlier workshops, the proceedings were published in-house by Sac Peak, from camera-ready copy provided by the authors. Sometime later, the proceedings of the workshops began to be published more professionally by the Astronomical Society of the Pacific.

Young astronomers at the 2005 workshop

Picnic at White Sands during the 2005 workshop

In more recent years, my involvement with Sac Peak and the NSO has been mostly through work on numerous committees. In a way, my service on these committees has been a way of repaying the tremendous debt I owe to the institution for enhancing my career in solar astronomy. My work on these committees has kept me in reasonably close touch with the activities of the observatory and its scientific and support staff. My committee service began with a four-year term on the NSO User's Committee, beginning in 1983. I later served on three different search committees for the director of NSO: in 1984, leading to the appointment of Bob Howard; in 1992-93, leading to the appointment of Jacques Beckers; and in 1997-98, as chair, leading to the appointment of Steve Keil. I served on the AURA Observatories Visiting Committee (OVC) for their visit to the NSO in 1993, and then served a full four-year term on the OVC in 1997-2001, during which we visited Kitt Peak, Cerro Tololo, and the NSO. I also served on the scientific advisory committee for the Advanced Technology Solar Telescope (now the DKIST) in its early days (1999-2002).

The most interesting and challenging of my NSO-related committee assignments was my service on the AURA-appointed panel to evaluate and rank the proposals from institutions to serve as host of the new NSO headquarters. There were eight proposals, and after an initial review we eliminated two of them. Our panel then made three-day visits to each of the six remaining sites in March 2011. The panel consisted of an interesting mix of scientists, technical staff, and administrators, both external and from within the NSO. The other panel members were Jim Kennedy (chair), Thomas Rimmele

(NSO), Priscilla Piano (NSO), Kim Streander (NSO), Val Schrader (STSI), Art Poland (George Mason University), and Oskar von der Lühe (Kiepenheuer Institute). I thought that the makeup of the panel was just right, with expertise in all areas that go into supporting the NSO headquarters. We traveled together for almost a month, and got to know each other very well. In the end, we ranked the proposals, with two of them standing well above the others. After subsequent discussions within AURA, NSO, and the proposing institutions, the University of Colorado at Boulder was chosen as the host site. The move of the Tucson and Sunspot staff to the new NSO headquarters in Boulder is now well underway. Soon the DKIST will be operational, the staff will all be in place in Boulder, and the NSO will enter a new era. Meanwhile, New Mexico State University and its partner institutions intend to keep the DST operational at Sac Peak, concentrating on synoptic observations and long-term trends. I wish them well in this important effort.

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