Memories

N. R. Sheeley, Jr.

913 Dresden Ct., Alexandria VA 22308, USA

Abstract. This paper highlights some events in solar research, beginning at Caltech in 1959 when Leighton described a technique for obtaining high-resolution observations of solar magnetic fields, and extending to 1971 when his ideas were being pursued with the new spectroheliograph and 82 cm solar image at the Kitt Peak National Observatory.

1. Introduction

I have changed the title of this presentation from ‘Historical Reminiscences’ to ‘Memories’. Memories can be pronounced more easily and memories can be stored in what J. K. Rowling called a ‘pensieve’ for later review. In her series of books about Harry Potter, a pensieve was a basin that Professor Albus Dumbledore used as a kind of time machine to show Harry what Hogwarts School was like when Harry’s father and mother were students there. The memories took the form of wispy silver threads that swirled around the pensieve. Now, with the help of this magic wand, I will review some memories of what it was like at Caltech and Kitt Peak during the years that 5-minute oscillations were being observed with the spectroheliograph. Each time that I wave the wand and say the magic word, ‘suivant’, a new memory will appear.

2. The Memories

Suivant! Figure 1 appears. It is February 1959 and we are looking at the weekly calendar of events that has been posted on the bulletin board in the east wing of the Norman W. Bridge Laboratory of Physics at Caltech. The calendar shows that Professor R. B. Leighton is scheduled to speak about ‘Solar Magnetic Fields in Active Regions’ at the Physics Research Conference on Thursday February 26. He will tell the faculty and graduate students about the observations of the Sun’s magnetic field that he obtained the previous summer with the spectroheliograph at the 60-foot tower on Mount Wilson. That was an opportune time for him to be trying out his new technique for mapping the Sun’s magnetic fields because 1958 was the peak of the largest sunspot cycle in many years and there were many large active regions for him to observe. It is interesting and probably no coincidence that Leighton’s contributions to solar physics began at the time of this unprecedentedly large sunspot maximum. His manuscript titled ‘Observations of Solar Magnetic Fields in Plage Regions’ had arrived at the office of the Astrophysical Journal just three days earlier, acknowledging that his graduate student, Bob Noyes, had helped with the measurements (Leighton 1959a). A second graduate student, George
Simon, attended that Physics Research Conference and was inspired to join Leighton and Noyes in their observational study of the Sun.

The weekly calendar also shows that Leighton was scheduled to speak about the Sun’s magnetic fields at a public lecture in that same lecture hall the next evening. It was an exciting time to be discussing such things with the International Geophysical Year (IGY) during July 1, 1957 – December 31, 1958, the launches of Sputnik on October 4, 1957 and Explorer I on January 31, 1958, and the start of the National Aeronautics and Space Administration (NASA) on October 1, 1958.

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<th>THURSDAY, February 26</th>
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<tr>
<td>Varsity Tennis, UC, Riverside at Caltech, 3:15 P.M.</td>
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<td>Civil Engineering Seminar, 206 Engineering, 4 P.M.</td>
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<td>“Future Water Yield of the Lower Colorado River,” Mr. Carl P. Vetter, Consulting Engineer.</td>
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<td>Physics Research Conference, 201 Bridge, 4:45 P.M.</td>
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<tr>
<td>“Solar Magnetic Fields in Active Regions,” Prof. R. B. Leighton, C.I.T.</td>
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<tr>
<td>Informal Music Seminar, Dabney Hall Lounge, 7:30 P.M.</td>
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<td>“The Structure of the Symphony: The symphonies of Beethoven Nos. 4, 5 and 6,” Mr. David I. Schuster, C.I.T.</td>
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<td>Open to the public.</td>
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<th>FRIDAY, February 27</th>
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<tr>
<td>Seminar in Fluid Mechanics, 110 Kerckhoff, 3 P.M.</td>
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<td>“Poiseuille Flow,” Mr. Eli Rehbock, C.I.T.</td>
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<td>Varsity Swimming, Long Beach State at Caltech, 4:35 P.M.</td>
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<tr>
<td>Friday Evening Demonstration Lecture, 201 Bridge, 7:30 P.M.</td>
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<tr>
<td>“Solar Magnetic Fields,” Dr. Robert B. Leighton, Associate Professor of Physics. Open to the public.</td>
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<th>SATURDAY, February 28</th>
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<tr>
<td>Varsity Baseball, Claremont-Harvey Mudd at Caltech, 12:30 P.M.</td>
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<td>Varsity &amp; Frosh Track, SCIAC Relays at Claremont, 1 P.M.</td>
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<td>Frosh Tennis, Pomona at Caltech, 1:30 P.M.</td>
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<tr>
<td>Varsity Tennis, Caltech at Pomona, 1:30 P.M.</td>
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Figure 1. Part of the weekly calendar of events at Caltech in February 1959. The Physics Research Conference on solar magnetic fields may have inspired George Simon to join Leighton and Noyes in their study of the Sun.

During the school year, Leighton was busy teaching a course in modern physics. The course was required for undergraduate physics majors, but also included some beginning graduate students including one student who always wore a brown suit and asked lots of questions. ‘The guy in the brown suit’ turned out to be George Zweig, who became famous a few years later for predicting the existence of particles that he called ‘aces’ (according to the graduate-student grapevine), but which one of his research advisors (Murray Gell-Mann) called quarks. Leighton’s course notes evolved into a book, ‘Principles of Modern Physics’ (Leighton 1959b), which was published just in time for our class to use it in the fall of 1959. Leighton created a kind of competitive camaraderie by offering a 50 cent piece for each bonafide error that we could find in his book during that first academic year of its use. In Blacker House, we facetiously called ourselves the ‘Blacker Physical Society’ and took pride in obtaining several of those prestigious 50 cent pieces.¹ During the spring term, we invited Leighton to dinner.

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¹By this time, Leighton had been promoted to a full Professor of Physics, but the book listed him as an Associate Professor. Although several of us pointed out this mistake, Leighton would not give 50 cents for recognizing the error.
in our Blacker House dormitory. In those days, traditional dinners were served in the
dining rooms of the four student houses, so it was not unusual to invite a professor or
visiting dignitary for the evening meal.

Suivant! Figure 2 appears. We are now in the Blacker courtyard after that evening
meal in the spring of 1960. Leighton is shown in the middle, flanked by some of his un-
dergraduate students, each wearing the coat and tie that were required at those evening
meals. On Leighton’s right, Neville Black holds the new book, ‘Principles of Modern
Physics’, complete with its dust jacket, showing the tracks of particles produced in a
high-energy spallation reaction. I am at Leighton’s left, probably wondering how to
be conversational without revealing my ignorance of an important principle of modern
physics. Within a few months, Leighton, Noyes, and Simon would obtain the historic
Doppler observations of the 5-minute oscillations and the giant convective cells that
they called supergranules (Leighton 1960).

![The Blacker Physical Society](image)

Figure 2. Robert Leighton, flanked by some of his undergraduate students. From
left to right, Al Hales, Rick Lindman, David Cassel, Neville Black (holding
Leighton’s new book, ‘Principles of Modern Physics’), Robert Leighton, Neil Shee-
ley, Jerry Parker, Mike Thomson, and Eric Adelberger. A few months later, Leighton,
Noyes, and Simon discovered the 5-min oscillations and the supergranulation.

Suivant! Figure 3 appears. Now, it is January 1961 and we are back at the bulletin
board in East Bridge Lab. Leighton is scheduled to describe those Doppler observations
from the summer of 1960 in a Physics Research Conference titled ‘Velocity Fields in
the Solar Atmosphere’, scheduled for Thursday January 19, 1961. Note also that Har-
vard Professor Cecilia Payne-Gaposchkin is scheduled to give a talk on ‘The Spectrum
of R Coronae Borealis’ at the Astrophysics Research Conference on Wednesday and
Figure 3. Calendar of events at Caltech, listing the talk that Bob Leighton gave at the Thursday afternoon Physics Research Conference on January 19, 1961. Leighton described the discoveries that he and his two students, Bob Noyes and George Simon, had made during the previous summer.

that the Final Doctorate Examination of Martin Emery Nordberg is scheduled for Friday with Professors Barnes, Fowler, and Weidenmuller on the committee. In 1960-1961, I was working in Kellogg Lab with Charlie Barnes and taking courses in nuclear physics from Willie Fowler and Hans Weidenmuller and I have a vague recollection of a student named Nordberg. As a physics student, I almost never attended Astrophysics Research Conferences and had no knowledge of who Cecilia Payne-Gaposchkin was. Now, I see that I could have crossed paths with that historical figure by attending her talk on Wednesday. However, I did attend Leighton’s Physics Research Conference on Thursday, and I remembered it 1.5 years later when I joined his group in August 1962, on the same day that Bob Noyes had (and passed) his Final Doctorate Examination. Meanwhile, during the summer of 1961, Leighton, Noyes, and Simon pursued their 1960 discoveries, obtaining improved observations and analyzing them for publication (Leighton et al. 1962).

Suivante! Figure 4 appears. This figure shows a Doppler Difference (left) and a Doppler Sum (right), obtained on July 1, 1961 by subtracting and adding two successive Doppler spectroheliograms of the central part of the solar disk (Leighton et al. 1962). Because the two Dopplergrams were obtained by scanning the spectroheliograph slowly from right to left across an area and then by scanning from left to right across the same area, their difference and sum show contrast as a function of time run-
Figure 4. Doppler Difference and Doppler Sum images, obtained by subtracting and adding two Ba II 4554 Å Dopplergrams that had been obtained by scanning an area slowly in one direction and then in the opposite direction, respectively.

ning from left to right. In the Doppler Difference, the contrast is small at first because the Doppler field has not changed appreciably in the brief time to reverse the scan direction. However, after a while, the Doppler field changes and the contrast increases. The contrast reaches a maximum after about 100 seconds and then decreases to a minimum again, suggesting that the Doppler field returns to its initial configuration after 275 – 300 seconds. Leighton et al. (1962) concluded that the surface of the Sun was oscillating radially with a 5-minute period. In the Doppler Sum, the contrast is large at first when the time difference is small and the field has not yet changed. However, the contrast decreases to a minimum after about 100 seconds and then increases again after 200 – 300 seconds. The lack of a perceptible signal in the Doppler Sum after half an oscillation period led to two additional conclusions. First, the oscillations had to be on the Sun and not in the Earth’s atmosphere, the instrument, or in the photographic procedures. Second, the oscillations were not weak perturbations of another strong velocity field, but instead the oscillations were the only radial photospheric motions that were resolved on their images.

Suivant! Figure 5 appears. It is nine years later, and we are in Tucson Arizona, looking at data obtained with the spectroheliograph and 82 cm solar image at the Kitt Peak National Observatory on August 26, 1970. With the larger image, faster film, and more powerful developer, we could now obtain maps of relatively large solar areas in only 20 seconds, compared to a few minutes with the Mount Wilson spectroheliograph. This meant that a series of Doppler Differences and Sums could be made during
a 5-minute oscillation period and compared at different phases of the oscillation. Referring to Figure 5, we can see in the 2.5-minute Doppler Sum (third panel) that the non-oscillating elements of the velocity field consist of granules and clumps of granules, whose speeds are upward and whose sizes are smaller than the irregular elements of the oscillatory field shown in the 2.5-minute Doppler Difference (fourth panel). In their quantitative measurements, Sheeley & Bhatnagar (1971) found that the amplitudes of the granular motions were comparable to those of the oscillating elements. Thus, the higher spatial and temporal resolution of the Kitt Peak instrument showed that the 5-minute oscillations were superimposed on the strong and longer-lived convective motions of the photospheric granulation.

Arvind Bhatnagar was the driving force behind this work. While visiting Caltech from India, Arvind discussed the 5-minute oscillations with Bob Leighton, who then called me to arrange for Arvind to visit Kitt Peak to obtain Doppler observations with
our new spectroheliograph. So Arvind joined our spectroheliograph group and spent part of the summer making observations like those shown in Figure 5.

Suivant! Figure 6 appears. It is around July 1, 1970, and several of us are in the apartment where Marybeth and I lived at that time. This photograph was taken by Sacramento Peak Observatory astronomer Dick Dunn, who was in Tucson visiting his niece. Arvind is in the center foreground and Marybeth and I are at the left. Nearly eclipsed by Arvind is Sou-Yang Liu, who was using the spectroheliograph to observe bright points in the K line for his thesis with Elske Smith at the University of Maryland. On his left is Dick Shine, who was observing solar K-line emission for his thesis with Jeffery Linsky at the University of Colorado. Next to Dick is Bruce Gillespie and his first wife. Bruce had just graduated from the University of Michigan and was helping with the spectroheliograph observations that summer. He later joined the staff of the Solar Division at Kitt Peak and eventually became site manager at the Apache Point Observatory in New Mexico. Arvind returned to India and founded the Udaipur Solar Observatory, which is one of the six sites of the Global Oscillations Network Group (GONG) and a major contributor to solar physics research in India.

Figure 6. Arvind Bhatnagar (foreground center), with (left to right) Marybeth and Neil Sheeley, Sou-Yang Liu, Dick Shine, Bruce Gillespie and his first wife at the Sheeley’s apartment in Tucson around July 1, 1970. Sacramento Peak astronomer Dick Dunn took the photograph.

Suivant! Figure 7 appears. A year later, Harvard undergraduate, Joe Gurman, captured the flavor of our spectroheliograph activities in this impressionistic drawing. It is not ‘oil on canvas’ like a painting by Monet, but might be called ‘pencil on computer card’. You can see the observer with his arms ready to cut through the solar beam to place calibration ‘zaps’ on a slow scan of the spectrum line. You can also see the oscilloscope used to monitor the position of the line profile relative to the positions of the spectroheliograph slits. If a student were to record the scene today, it would be with an iphone more powerful than the mainframe computer that read those computer cards.
3. The Transition

Now, as we emerge from the pensieve, we can appreciate that the exciting new results from the rest of this meeting will soon be swirling around the pensieve as wispy, silver-threaded memories. Therefore, I will now give this magic wand to 5-year-old Aline Dole-Barban so that she can take it to the 77th NSO workshop ‘Celebrating 100 Years of Seismology of the Sun and Stars’ and retrieve those memories. Here is the wand, Aline. Good luck.

Acknowledgments. I am grateful to Loma Karklins of the Caltech Archives for finding the calendars, shown in Figures 1 and 3. Figure 2 is from the 1960 Caltech undergraduate yearbook, ‘The Big T’, where the photograph was incorrectly titled ‘Math Club’. We are all indebted to the Math Club President, Al Hales, for thinking of this clever way of getting the photo into our yearbook and thereby saving it for posterity.

References