MENZEL AND ECLIPSES

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1. Introduction

Eclipses played an important role in Donald Menzel’s life, and thanks to him they do in mine. In 1959, when I was a freshman, Harvard was trying to invigorate undergraduate education and started a project to bring senior faculty together with these first-year students. Underscoring the “Educator” portion of the title of this Centennial Symposium, Donald Menzel was one of the professors offering freshman seminars that first year. There were a dozen of us in the seminar, and a substantial fraction went on to be professional astronomers.

A total eclipse of the Sun began over Massachusetts on 2 October of that year (Figure 1) and Dr Menzel arranged for an airplane to fly his freshman-seminar students and Observatory staff members above the expected clouds. I remember well this early morning flight, and obviously was inspired by the phenomenon that proved to be the first of the thirty-two solar eclipses I have seen. But it was the science and the spectacle that enthralled at the time; for all I knew all eclipses occurred over Boston. I only recently learned that we freshmen were not add-ons to the staff but, rather, it was vice versa. Menzel wrote:

![Image of eclipse path]

Fig. 1. The beginning of the path of the total solar eclipse of 1959 (U.S. Naval Observatory Circular).
We had a most auspicious beginning. Shortly after the start of the term, a total
eclipse of the sun was scheduled to occur in the Boston area. The time was early
in the morning, and at that season of the year, clouds were almost inevitable. I
conferred with one of the high officials of Northeast Airlines, who generously
placed a plane [a DC-6] at our disposal. As passengers, in addition to my Seminar
Students, I included a few graduate students, faculty members, and McGeorge
Bundy, Dean of Faculty. We had a marvelous view of the event and obtained
some excellent photographs.

Menzel taught us about the Sun, of course, and I remember the Wednesday after-
noons in the Building A classroom with the lights off, the temperature rising, and
coronagraph movies showing. How lucky I was not only to have become interested in
the solar atmosphere but also to have my dozing off during every movie interpreted
in the most favourable way by D.H.M.: that I was bored and needed independent
work. Dr Menzel set me up with Hector Ingrao to work on experimental matters,
which led to my first published paper and to my career.

By the time I came on the scene, Menzel was just about my current age. He had
published in a wide variety of fields. In addition to the many scientific papers, he had
published several books, including books for kids and books for the general public.
These books included the Peterson *Field guide to the stars and planets*, with which
I am proud to be associated.4

In what follows, I have the benefit of a long autobiographical account written
by Menzel in 1974. He reported, for example, that just before his senior year as a
student at Denver University,

On June 8, 1918, as a Boy Scout, I had witnessed my first total solar eclipse.
There was also a Nova, a ‘new star’ in the constellation of Aquila, the brightest
so far in the century and second in brightness only to Sirius. But I saw it and
began to take an interest in astronomy and the constellations.5

2. *Observing Solar Eclipses*

Menzel received his Master’s degree in 1921,

and I accepted the offer of an assistantship at Princeton University.... During the
summers of 1922 and 1923, I accepted a research position with the renowned
Harlow Shapley of Harvard Observatory.... I also decided that I would like to
see the total solar eclipse of September 1923 from Catalina Island, California....
At Catalina Island I found hopes high for the eclipse, since the 30 days prior to
the event had been completely clear. But eclipse day found the sun covered with
clouds and we had to be content with a few scant views of the crescent of the
partial phases. Even so, I did not consider the eclipse a total loss, since I had the
opportunity of meeting a number of well-known astronomers, especially those
from the Yerkes Observatory, whose expedition I had been permitted to join.
Menzel and Eclipses

Table 1. Donald Menzel's eclipses.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 June 1918</td>
<td>Evergreen, Colorado</td>
</tr>
<tr>
<td>10 September 1923*</td>
<td>Catalina Island, California</td>
</tr>
<tr>
<td>28 April 1930</td>
<td>Camptonville, California</td>
</tr>
<tr>
<td>31 August 1932</td>
<td>Freyburg, Maine</td>
</tr>
<tr>
<td>19 June 1936</td>
<td>Southwestern Siberia (Ak Bulak)</td>
</tr>
<tr>
<td>9 July 1945*</td>
<td>Canada</td>
</tr>
<tr>
<td>30 June 1954</td>
<td>Minneapolis-St. Paul</td>
</tr>
<tr>
<td>2 October 1959</td>
<td>Atlantic coast of Massachusetts</td>
</tr>
<tr>
<td>15 February 1961</td>
<td>Northern Italy</td>
</tr>
<tr>
<td>20 July 1963*</td>
<td>Orono, Maine</td>
</tr>
<tr>
<td>20 May 1966</td>
<td>Athens/Sunion road, Greece</td>
</tr>
<tr>
<td>12 November 1966</td>
<td>Arequipa, Peru</td>
</tr>
<tr>
<td>7 March 1970</td>
<td>Miahuatlán, south of Oaxaca, Mexico</td>
</tr>
<tr>
<td>10 July 1972</td>
<td>Prince Edward Island, Canada</td>
</tr>
<tr>
<td>30 June 1973</td>
<td>western Mauritania</td>
</tr>
<tr>
<td>* cloudy</td>
<td>(Florence Menzel was at ten of them)</td>
</tr>
</tbody>
</table>

Annular eclipse

24 December 1973 | Pacific Coast of Costa Rica

Our mutual experiment in absentia

22 September 1968 | Siberia

Eventually, Menzel was to go on to the sites of a total of fifteen total solar eclipses (Table 1), whose paths covered the world (Figure 2). His interest returned to solar eclipses while a post-doctoral astronomer at the Lick Observatory.

In 1926, William Wallace Campbell was the Director of Lick Observatory. But he was also President of the University of California.... Dr. and Mrs. Campbell would sometimes visit the mountain for as long as a week or two. We became

![Fig. 2. The paths of eclipses that Menzel observed (courtesy of Jean-Paul Godard).](image-url)
very good friends. We had a great deal in common, including a basic interest in
that up-coming branch of astronomy: Astrophysics. No other member of the Lick
organisation had more than a passing interest in Astrophysics and I felt very much
alone, with no one to talk to, until Dr. Campbell visited the mountain.

Menzel did not enjoy his work on stellar spectra.

First of all, it was not my program and I had nothing to show for it, apart from
my job except mention in a long list of contributing observers when the catalogue
of radial velocities was finally published a number of years later.... Dr. Aitken
assigned me one further task, which indeed I found extremely enjoyable. In fact,
he had chosen me over a number of other possible contenders, since Professor
Russell had spoken highly of my abilities to analyse spectra.

Dr. Campbell had been to many total solar eclipses: 1898 in India, 1900
in Georgia, 1905 in Spain and 1908 in Flint Island of the South Pacific. He
had been to other total eclipses as well, but on the ones just mentioned he had
secured spectra of the sun’s chromosphere, the pinkish-hued atmosphere of the
sun that gives, when the moon covers the bright, shining surface, a spectrum
of bright lines.... Dr. Campbell had indeed secured a number of remarkable
spectra, including some by his own unique method: the moving plate.... This
assignment I found most exciting and, within less than a week, had made two
fairly important discoveries... [Figure 3]. The moving plates clearly depicted the
change from dark-line to bright-line spectrum at the moment of totality. I found,
first of all, that the change from dark to bright was quite sudden for lines coming
from “neutral” metals, whereas it was gradual for lines coming from “ionized”
metals.... My second discovery was the occurrence of some peculiar lines that
remained bright for a long time during the eclipse, often showing no indication
of an associated dark line. This was puzzling indeed and I carefully measured the
wavelengths of a couple of dozen of the most outstanding examples. Consulting
a list of wavelengths, I was surprised to see that most of them came from a group
of metals often referred to as “rare earths....

Years later, Charlotte Moore Sitterly confirmed the identifications of the 100 or so
“c-lines” Menzel had found.

Menzel did not find Lick hospitable scientifically. As he wrote,

Dr. Aitken, learning of my interest in theoretical astrophysics, periodically
scolded me for wasting my time. “After all,” he would say, “this is an Observa-
tory! Your responsibility is to make the observations and record them. Leave
the theory to the poor, underprivileged British astronomers, such as Milne and
Eddington, who don’t have an observatory....” From time to time he asked me
to report in detail on the tables I had produced of the lines of the flash spectrum
and their identification. He thought this was fine. These were the observations.
Publish them and get it over with.
My work on the flash spectrum piqued my desire to obtain such a record for myself. The projected solar eclipse of April 28, 1930, over California gave us the opportunity. The eclipse was unusual, in that totality was predicted to last for a single second. This meant that we could not expect to get a flash spectrum on both sides of the sun. Indeed, I developed an adaptation of Dr. Campbell’s moving-plate method for the purpose. Dr. Moore and I operated the instrument and obtained excellent spectra. One of the most startling features, which Doc found hard to believe, was the great intensity of the green and red coronal lines, which we photographed with an effective exposure of only one second.... From this single fact, we predicted that, under special circumstances, it should be possible to observe the spectrum of the sun’s corona outside of eclipses.7

This prediction came true with Lyot’s coronagraph, similarly to the way that Janssen’s observations of a bright chromospheric line at the 1868 eclipse had led to his successfully observing the chromosphere outside of eclipse. Menzel wrote:

On my return, I tried unsuccessfully to photograph the coronal spectrum with a
36-inch refractor. But I found that the amount of sunlight scattered by the numerous fine scratches on the objective completely obliterated the corona. A few years later, the French astronomer B. Lyot developed and invented the coronagraph and succeeded in photographing the coronal spectrum outside of eclipse.

Between eclipses and other observing chores, I continued my theoretical analysis of the flash spectrum and obtained some results that, to me, were extremely exciting, though many of the old-timers simply refused to believe them.

In particular, on the basis of the high intensity of helium and ionized helium lines, he concluded that the chromospheric temperature was higher than that of the photosphere.

Menzel published minor articles on several aspects of the flash spectrum and eclipses in the intervening years, while he was preparing his major paper.8

When, in the fall of 1930, after four years of concentrated work, I submitted my manuscript on the flash spectrum and the solar chromosphere to Dr. Aitken, he had — as I had expected — a fit. The publication was, I had to admit, a veritable tome about the size of a volume of the Encyclopedia Britannica. And I had stubbornly followed my own inclination, developing one of the first significant papers in the new Astrophysics.

Eventually, Menzel was allowed to publish his work.9 Menzel found large deviations from thermodynamic equilibrium in the emission lines of hydrogen and helium. He derived the curve of growth for emission lines. He identified hundreds of spectral lines and multiplets (Figure 4). Cecilia Payne’s initial results from analysing Harvard spectra,10 that hydrogen dominated solar abundances, needed observational backing. Menzel’s result that the mean molecular weight in the solar chromosphere was 2 persuaded Henry Norris Russell, and therefore others, that the light elements hydrogen and helium dominate the Sun and, eventually, the universe.

Leo Goldberg, in Menzel’s obituary in Sky & telescope, summarized:11

Among the chief results from this pioneering investigations were 1, a derivation of the abundances of the elements in the chromosphere; 2, a demonstration that the excited levels of hydrogen are overpopulated relative to a Boltzmann distribution; and 3, evidence that the neutral and ionized helium lines in the upper chromosphere and prominences are being formed in regions hotter than 20,000° Kelvin. The anomalously great intensities of the hydrogen and helium lines gave the first indication that the solar chromosphere was not simply a low-temperature extension of the photosphere.

As Menzel wrote,12 “I became addicted to solar eclipses at an early age. Seventeen to be exact”.

My next opportunity to observe a solar eclipse came on August 31, 1932. We selected a site at Freyburg, Maine, for our expedition. Again, Dr. Moore and
### Menzel and Eclipses

This section includes tables that may be useful for astronomical research. The tables cover various topics related to spectral lines and multiplets. The main focus is on providing a comprehensive resource for astronomers to utilize in their work.

#### Table 1: Spectral Lines

<table>
<thead>
<tr>
<th>Number</th>
<th>Line</th>
<th>Wavelength</th>
<th>Description</th>
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<td></td>
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<tr>
<td>025</td>
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<td>037</td>
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</table>

#### Table 3: Multiplets

<table>
<thead>
<tr>
<th>Number</th>
<th>Multiplet</th>
<th>Wavelength</th>
<th>Description</th>
</tr>
</thead>
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<tr>
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<td></td>
</tr>
<tr>
<td>003</td>
<td></td>
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</tr>
</tbody>
</table>

**Fig. 4.** Parts of the tables of spectral lines (Table 1) and of multiplets (Table 3) from Menzel’s 1931 tome.
I concentrated on the flash spectrum. We decided to employ an entirely new
technique, which has been more or less standard ever since. We called it the
‘jumping-film....’ It gave precise measures for a considerable interval during the
pre- and post-totality phases, exactly timed, which enabled us to determine the
density gradients in the sun’s atmosphere.

The following day was his first on the Harvard Faculty. Later, he reported that he
had learned a great deal from the study of my flash spectra. 1932, as it so happened,
was the minimum of the sunspot cycle. Hence, the green coronal line was
extremely weak. Alternatively, the red coronal line was strong. From this fact
alone, I deduced that the atom responsible for the green line required higher
excitation than that for the red line. And, to support my conclusion, I noted
further that the flash spectrum underlying the area of the corona that showed
one rather intense green region also had strong lines of helium and ionized
helium. Since helium is an atom that requires very high excitation, I felt that
the association between the green coronal line and the strength of the helium
spectrum was no means a coincidence. Moreover, quantitative studies showed
that the helium lines throughout the flash spectrum were much fainter in 1932
than they had been back in 1905, when Dr. Campbell obtained his excellent
spectrum. Thus I inferred, there must be a close association between the inten-
sity of helium lines and the activity of sunspots.

Menzel’s development of the jumping-film spectrograph allowed him to get better
detail in the spectra. Menzel worked with Gavie Cilić, who was on a postdoctoral
year at Harvard, on the intensities of the Balmer series, which Menzel had measured
up to H₁₁, at the 1932 eclipse. They analysed the hydrogen spectrum and the cause of
its excitation. A major result was the derivation of the electron density in the lower
chromosphere from measurements of the Balmer continuum. Cilić died in 2000,
and his obituary in Astronomy & geophysics cites this important paper.

3. The Discovery of Deuterium

Of course, Menzel was doing other things than eclipses, and his next idea was an
important one. In a paper for Physical review with R. T. Birge submitted on 27 May
1931, on the basis of the system of atomic weights, he computed the atomic weights
expected for several elements and compared the results with mass-spectrograph
measurements by Aston. Birge and Menzel found agreement for carbon, nitrogen,
and helium. But then, “Of the elements that permit an accurate comparison of the
chemical and mass-spectrograph results, there remains only hydrogen”. Aston’s value
was discrepant from the chemical value slightly, but

outside the limits of error. It could be removed by postulating the existence of
an isotope of hydrogen of mass 2, with a relative abundance of $\text{H}/\text{H}^2 = 4500$. 

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It should be possible, although difficult, to detect such an isotope by means of band spectra.

The next year, also in Physical Review, Harold Urey, F. G. Brickwedde, and G. M. Murphy reported that “Birge and Menzel have shown that the discrepancy between the chemical atomic weight of hydrogen and Aston’s value by the mass spectrograph could be accounted for by the assumption of a hydrogen isotope of mass 2 present to the extent of 1 part in 4500 parts of hydrogen of mass 1”.

They went on to evaporate “large quantities of liquid hydrogen and collecting the gas which evaporated from the last fraction of the last cubic centimeter”. They increased the exposure time of their spectrograms enough to reach a ratio of 4500:1, and found faint spectral lines of what we now call deuterium. Indeed, “they were so weak that it was difficult to be sure that they were not ghosts of the strongly overexposed atomic lines”. In their sample that had been evaporated near the triple point instead of at the boiling point, the lines were stronger, and they finally confirmed that “The relative abundance in ordinary hydrogen, judging from relative minimum exposure time, is about 1: 4000, or less, in agreement with Birge and Menzel’s estimate”. (Brickwedde, fifty years later, reported that Aston later revised his result, invalidating the Birge and Menzel calculation, but that historically the calculation remains, as Urey reported in an addendum to his published Nobel lecture, “of importance in the discovery of deuterium. Without it, it is probable we would not have made a search for it and the discovery of deuterium might have been delayed for some time”). Indeed, there is more deuterium in the universe than any isotope other than those of helium.

4. Physical Processes in Gaseous Nebulae

The 1930s also set Menzel off on a major set of scientific studies, which began with a famous paper by Menzel and Pekeris in 1935 about absorption coefficients and hydrogen line intensities. This paper was followed by one by Menzel alone setting out a substantial research plan that was eventually to comprise eighteen research papers over the next eight years on the subject of physical processes in gaseous nebulae (Table 2). Unlike the Sun, these nebulae are transparent, so solutions are more readily obtained. James Baker was one of his major collaborators; he was coauthor on eight of the papers. Lawrence Aller joined the team in 1938, becoming coauthor or author of thirteen of the papers. Only Malcolm Hebb and the senior physicist George Shortley for two papers each, and Leo Goldberg for one paper, supplemented the basic team of Menzel, Baker, and Aller. Menzel must have liked sequential work, since he went on in the early 1950s to coauthor a set of three papers on radiative transfer with Hari Sen.

5. Eclipse Expeditions

To return to the post-1932 eclipse era, Menzel’s next opportunity to test his ideas about the intensities of the coronal lines was at the 19 June 1936 eclipse, whose
Jay M. Pasachoff

Table 2. “Physical processes in gaseous nebulae” (a series of papers in the Astrophysical Journal).

Menzel: I. Physical processes in gaseous nebulae: I. Absorption and emission of radiation, 1937
Menzel, Baker: II. Theory of the Balmer decrement, 1937
Baker, Menzel: III. The Balmer decrement, 1938
Menzel, Aller, Baker: IV. The mechanistic and equilibrium treatment of nebular statistics, 1938
Baker, Menzel, Aller: V. Electron temperatures, 1938
Aller, Baker, Menzel: VI. The equations of radiative transfer, 1939
Baker, Aller, Menzel: VII. The transfer of radiation in the Lyman continuum, 1939
Aller, Baker, Menzel: VIII. The ultraviolet radiation field and electron temperature of an optically thick nebula, 1939
Shortley, Menzel: IX. On the excitation of fractional multiplets by electron capture, 1940
Hebb, Menzel: X. Collisional excitation of nebulium, 1940
Shortley, Aller, Baker, Menzel: XI. Strength of forbidden lines in p\(^2\), p\(^3\) and p\(^4\) as a function of coupling, 1941
Menzel, Aller: XII. The electron densities of some bright planetary nebulae, 1941
Menzel, Aller, Hebb: XIII. The electron temperatures of some typical planetary nebulae, 1941
Aller: XIV. Spectrophotometry of some typical planetary nebulae, 1941
Goldberg: XV. The statistical equilibrium of neutral hydrogen, 1941
Menzel, Aller: XVI. The abundance of O III, 1941
Menzel, Aller: XVII. Fluorescence in high-excitation planetaary nebulae, 1941
Aller, Menzel: XVIII. The chemical composition of the planetary nebulae, 1945

path went from Greece into Siberia. As he wrote, “Dr. Shapley did not object to my expedition, provided that I not call on him for any financial support from observatory funds”. He thus teamed up with M.I.T., especially to make use of its shop. They borrowed optical equipment from Lick and Yerkes, and received donations from over forty businesses. His expedition\(^{23}\) included thirty-eight members, more than half the foreign visitors who observed that eclipse. He benefited from the assistance of Boris Gerasimovich, Director of the Pulkova Observatory in Leningrad. Only much later did his friendship and association with Gerasimovich cause him trouble, when he was investigated by anti-Communist zealots in the 1950s.

In 1936, Menzel’s team joined Gerasimovich’s expedition in Ak Bulak, a tiny village in southwestern Siberia, now in Kazakhstan, for two minutes of totality. His three months in Russia, transporting and setting up 14 tons of equipment, makes any of today’s expeditions pale in comparison.\(^{24}\) In Siberia, they travelled three days by private railway car, and then operated their experiments from that car and two baggage cars, which were placed on a siding. Less than three days before the eclipse, some of the local people dropped the largest spectograph. Menzel reports that he “worked continuously, without sleep, for a full 56 hours”.

... the morning of eclipse day dawned clear. But heavy clouds shortly began to form, and presently the sky was completely overcast. We did obtain occasional, fleeting glimpses of the sun at ‘first contact,’ ... but the situation was so unfavorable that ... I commented that I would sell out for about two kopeks. But the cooling that occurred with the progress of the eclipse caused the clouds to drop into lower, warmer layers of air, where they began to dissipate. As totality
approached, the sky became completely clear. We carried out our program
without a single hitch.

Though scientifically the expedition was a big success, Gerasimovich himself was
sent to a work camp in Siberia, in spite of Menzel’s and Shapley’s invitation for him
to come to Harvard, and it was in Siberia that he died.

Scientifically, the 1936 eclipse substantiated Menzel’s prediction that the coronal
green line would be much stronger at that maximum phase of the sunspot cycle than
it had been at the previous eclipse.25 Remember that in the 1930s, the cause of the
coronal green line and the coronal red line were still said to be from “coronium”,
though the periodic table had been filled in long since and only “helium” remained
as an element discovered at an eclipse. Menzel’s work was one of several lines of
evidence at the time that the corona was indeed hot. Grotrian had reported that
electrons moving rapidly in a hot corona could broaden the photospheric absorption
lines so much that they became all but invisible. He reported that he might even
have detected a broad dip in the spectrum from the strong ultraviolet lines, though
Menzel and I showed in PASP in the 1960s that his supposed detection was below
the film accuracy.26 The topic remains a current one, rejuvenated by theoretical work
by Lawrence Cram in Australia in the 1970s and by observational work by several
groups, including my own, at recent eclipses.27

CCD two-dimensional detectors now allow observations to be made at the 1 percent
photometric accuracy needed to provide temperatures to a few hundred thousand
kelvins. Ichimoto’s group from Japan and my own group made spectral and polariz-
ation observations at the 1994 eclipse.28 Davila and Reginald and my own group
made observations at the 1999 eclipse to provide coronal temperature maps with
this method, useful to compare with maps from SOHO based on permitted spectral
lines observed in the ultraviolet rather than the forbidden lines that were the subject
of Menzel’s studies.

In any case, with the work of Bengt Edlén in the early 1940s, identifying the
coronal green line as coming from thirteen-times ionized iron and the coronal red
line as coming from ten-times ionized iron, the problem of “coronium” was solved.
The corona is millions of degrees, as we see every day with X-ray observations from
Yohkoh and with far ultraviolet observations from SOHO’s Extreme-ultraviolet Imaging
Telescope and from TRACE, both observing at the wavelengths of highly-ionized
spectral lines that come only from atoms at temperatures at millions of kelvins.29

Menzel’s war service was interesting and complicated, and prevented him from
pursuing eclipse work. He writes,29 “Hence it was not until 1945, near the end of
the war, that I was able to organize another expedition. I was still an officer in the
U.S. Navy, on active duty, but our studies of the effects of solar activity on radio
propagation had convinced the high command of the value of such basic research”.
Collaborating with the director of the Dominion Observatory and with the Canadian
spectroscopist Gerhard Herzberg, they involved amateur astronomers in the expedi-
tion, a forerunner of Menzel’s work with amateurs of Educational Expeditions
International (EEI), now Earthwatch, at the 1972 eclipse, years later. Unfortunately, heavy clouds obscured the eclipse for them.

In 1954, faced with bad weather forecasts for an early morning eclipse, Menzel decided to observe the eclipse from the air near Minneapolis. He was disappointed in the photographs, though, because of the plane’s motion, and more disappointed when it turned out to have been clear on the ground.

By 1959, he had revised his popular book, from the Harvard Series on Astronomy, Our Sun, whose first edition had been ten years earlier. The book was the basis for an award-winning television show, “Our Mr. Sun” (1956), which is still readily available on videotape, and to the influence of which there are many testimonies posted on the World Wide Web. In his many books (Table 3) Menzel discussed not only the Sun but also the rest of astronomy and, famously, English grammar and writing style.

The 1959 eclipse, my first with him, we have already discussed. In 1961, he took some people, including students, to northern Italy. They saw the eclipse in perfect weather over the Mediterranean. On 20 July 1963, he went to Maine for the eclipse, and was clouded out. In 1966, he saw two eclipses. The first was from midday between Athens and Cape Sunion, in Greece. It was an annular eclipse so close to total that one could take spectra of not only the chromosphere but also the corona. In November 1966, he saw the total eclipse from an Indian village near Aréquipa, Peru. He worked there with his old friend Fernando de Romaña, a Peruvian amateur astronomer.

In 1968, I was to join him on an eclipse expedition to the Soviet Union. He had a formal invitation to visit. But in the aftermath of the Soviet invasion of Prague, exchanges were cancelled and so was our expedition. We sent some apparatus to a Russian colleague, who produced polarization measurements for us.

1970 was the year when I worked with him as the Menzel Research Fellow in the
Harvard College Observatory, my first postdoctoral year and the first time since my freshman year I had official relations with him. Although I had remained at Harvard for my graduate work, my Ph.D. had been with Bob Noyes and Gene Avrett (on the fine structure of the solar chromosphere as observed from Sac Peak and Kitt Peak). Menzel had graciously drawn the frontispiece for my thesis (Figure 5). As Menzel reports, “In February of 1970, from a small Indian village in southern Mexico, I viewed what was my most spectacular eclipse. Never had I seen such a perfectly clear sky. A deep blue right up to the edge of the sun”.

Menzel and I had built a spectrograph for the occasion to take wide-field coronal spectra, with a Schmidt-camera design by Jim Baker (Figure 6). It was quite an education to watch and assist Menzel and Baker set up the spectrograph for testing in the Building A classroom at the Observatory. I learned about shims, about tightening screws by hand, and about a host of other tricks of the trade that one doesn’t learn from reading books. We had the support of a grant from the Committee for Research and Exploration of the National Geographic Society, and on our return were able to publish a popular story about the expedition in National Geographic magazine, a separate activity of the Society from the research committee. Our observations were made in exceptionally clear conditions, perhaps the best that obtained until the African eclipse of 2001.

Our observations were so successful that on returning to Cambridge, Mass. from Mexico, Menzel and I decided to look ahead immediately to the 1973 eclipse, at 7 minutes and 4 seconds at its peak the second longest in the saros series (second only to the preceding eclipse in the sequence, in 1955) and almost as long as theoretically possible. We put a large National Geographic map of Africa up on Dr Menzel’s office door, and I plotted the points from the eclipse predictions. I looked at the zone in which the eclipse exceeded 7 minutes and searched for the nearest city: Timbuktu.

Fig. 5. One of Menzel’s drawings of the Sun. It was the frontispiece to the author’s Harvard Ph.D. thesis, 1969, and was subsequently coloured.
I hadn’t even known Timbuktu existed. Sure enough, Menzel and I were within weeks on a plane to the Sahara desert reconnoitring. We went to Agadez in Niger and Timbuktu in Mali. Though the trip was one of the most fascinating of my life, we decided that the Sahara desert two hours north of Timbuktu was not a desirable place to bring tons of equipment, a decision endorsed by a dust storm in the Sahara for much of the next couple of years.

First we did a joint expedition to Prince Edward Island, Canada, for the 10 July 1972 eclipse. We involved a young machinist and amateur astronomer, Dennis di Cicco, now a distinguished editor at Sky & telescope. We took our big Baker-designed coronal spectrograph. Unfortunately, the weather on the ground was partly hazy. Though one could see the eclipse through the clouds, it impeded the observations.

Finally, Menzel and I coordinated our activities for the 30 June 1973 eclipse, but we went to different places. Menzel took a group and a set of scientific experiments to Mauritania, with the assistance of EEI. They were to have over 6 minutes of totality there, but a high chance of obscuration by dust. I went with the official NSF US team of astronomers to northern Kenya for more than 5 minutes of totality, a somewhat higher chance of clouds, but a better chance of dust-free skies. In the event, a dust storm came up in Mauritania, dropping transparency to 10 percent. They did image the corona and its polarization. We had clear weather in Kenya, where our principal
experiment was observing the ratio of the infrared spectral lines of twelve-times-ionized iron, using a new kind of electronic detector, a silicon vidicon.

That series ended Menzel’s total eclipses. The Menzels had a retirement home in Costa Rica, and the annular eclipse of 24 December 1973, was visible there. Joined by a group of amateurs, Menzel observed the eclipse. Dennis di Cicco’s well known series of views on a single frame showing the progression of the annular eclipse, which graced the cover of *Sky & telescope* and many a wall, was taken there.

6. The Value of Eclipse Observations

I will let Menzel have the last word on eclipses, since he expresses sentiments with which I heartily agree.

Although space research and coronagraphs have lessened the need for eclipse observations, there are nevertheless still problems and puzzles concerning the physical conditions of the sun’s outer atmosphere, especially of the corona, which can best be resolved only at such events. Hence, I predict that for some decades to come, astronomers will continue to observe eclipses. But even when no more scientific gain is to be expected, people the world over will continue to enjoy the experience of such an observation, and its beauty.... Science itself has contributed enormously to human knowledge, by making it possible for mankind to observe and enjoy a spectacle which, centuries earlier, nearly everyone regarded with superstitious fear.

Acknowledgments

Menzel’s eclipse work was sponsored in his later years by the Committee for Research and Exploration of the National Geographic Society, and I am grateful for their sponsorship of my own eclipse research as well since our joint expedition in 1970. My recent expeditions have also been supported by grants from the Atmospheric Sciences Division of the National Science Foundation, most recently through ATM-0000575.

REFERENCES

1. Soon after I first met Donald Menzel, we observed a total solar eclipse together. I am eternally grateful to Donald and Florence Menzel for a wide variety of things they have done for me, intellectually and personally, so it was a particular pleasure to be invited to speak on “Menzel and eclipses”. The day of the Menzel Symposium was the anniversary of a famous 11 May eclipse, one plotted by Edmond Halley. See Jay M. Pasachoff, “Halley and his maps of the total eclipses of 1715 and 1724”, *Astronomy & geophysics*, xl (1999), 2.18–2.21.

2. Menzel’s Freshman Seminar, Fall 1959: *Four who became astronomers*: Ken Janes, Professor and former Chair, Boston University; John Leibacher, former Director, National Solar Observatory; Don Goldsmith, former professor, astronomy author; Jay Pasachoff, Professor and Observatory Director, Williams College and, during 1969–70, Donald H. Menzel Research Fellow in the Harvard College Observatory, a position funded in honour of D.H.M. for a five-year term by his friend Edwin Land of the Polaroid Corporation. *Other members*: Nan (Evans) Krien, daughter
of Jack Evans, director of the Sacramento Peak Observatory; John Fryer, now of Washington, DC; Richard Goodman, now professor of mathematics, University of Miami; Tony Rossmann, now a lawyer, San Francisco; Margaret (Horton) Weiler, now of Bradford, NH; K. Paul Smith, Aloha, OR; Aquila Chase, now of Santa Barbara, CA; Jeff Hill, Washington, DC, lawyer, Office of Management and Budget.

3. Quotations throughout will be taken from Menzel’s unpublished Autobiography (1974), a 681-page double-spaced typescript. I thank Florence Menzel, Elizabeth Menzel Davis, and Suzy Menzel Lindeman Snyder for permission to read and to quote from this autobiography. Copies have been deposited at the Niels Bohr Library, American Institute of Physics, College Park, Maryland, and the Harvard University Archives.

4. Menzel’s first edition of the Peterson field guide to the stars and planets was published in 1964. I wrote the second edition, which was published as Menzel and Pasachoff in 1993, the third edition, which was published as Pasachoff and Menzel in 1992, and the fourth edition, which was published in my name in 2000. The book is published by Houghton Mifflin, which was purchased by VivendiUniversal in 2001.


Menzel and Eclipses

G. Baker, Julian W. Feiss, Fred L. Whipple, John W. Evans, Ernest H. Taves, and Leo Goldberg. Goldberg writes: “He continued to be fiercely loyal to his former students long after they had departed from Cambridge. I never saw the letters of recommendation he wrote for me, but Harlow Shapley once told me he had read one that even made him squirm a bit.”


19. Because I have been investigating the faint radio spin-flip line of interstellar deuterium since 1972, it was a surprise and pleasure to find out that Menzel’s theoretical work led to the discovery of that important isotope. See J. M. Pasachoff and W. A. Fowler, “Deuterium in the universe”; updated from Scientific American, no. 230 (May 1974), 108–18, in Particle physics in the cosmos, ed. by Richard A. Carrigan, Jr, and W. Peter Trower (New York, 1988), 51–63.


21. The papers were republished as D. H. Menzel, Selected papers on physical properties in ionized plasma (New York, 1962).


25. Based on observations from the 1936 eclipse: William Petrie and Donald H. Menzel, “The wave lengths of new coronal lines”, ApJ, xxvi (1942), 395–8; he also has some mention of his 1936 results in Astronomical journal, lii (1946), 47, a long abstract from the 1–2 February 1946, American Astronomical Society meeting held in New York City. Donald Osterbrock has found biographical information about Petrie in American men of science. Born in 1914, he got his Master’s in Physics in 1942 and his Ph.D. in 1943 at Harvard. Later in life, he was Chief Scientist of the Canadian...
Defense Research Board and carried out auroral research. Osterbrock concludes, from the writing style, that Petrie may have made the measurements in the summer of 1942 and written the paper. Menzel was busy with war-related projects at the time. No doubt, other scientists also published results based on the joint Harvard-MIT expedition that Menzel had headed.


29. See daily solar observations from the Solar and Heliospheric Observatory (SOHO) at [http://sohowww.nascom.nasa.gov](http://sohowww.nascom.nasa.gov) and at [http://www.spaceweather.com](http://www.spaceweather.com).


