

DONALD MENZEL AND THE BEGINNINGS OF THE HIGH ALTITUDE OBSERVATORY

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Introduction

“I am proudest of the observatories that I have built in the West, not only the one at Climax and its Boulder headquarters, but also the Sacramento Peak Observatory, and the Harvard Radio Astronomy Observatory at Fort Davis, Texas.” Donald H. Menzel wrote this to his cousin in 1961, as he looked back upon a career studded with numerous diverse and noteworthy accomplishments.² In the light of this remark, it is especially fitting that two of the articles contained in this issue should deal with his efforts to establish these observatories. Here I shall describe Menzel’s initial efforts to build the first of his three Western observatories: the High Altitude Observatory (HAO) that was sited at Climax and Boulder, Colorado. A separate article addresses his subsequent efforts to develop the Sacramento Peak Observatory in New Mexico.³

The HAO traces its foundation to an open house held on a pleasant Sunday in September 1940, at the newly constructed observatory located high atop the Continental Divide, at Climax. Here, the Divide drops to an elevation of 3450m at Fremont Pass, where the Climax Molybdenum Company⁴ had been in operation since 1916. At this juncture, the operation went by several appellations. The Harvard College Observatory (HCO) Director, Harlow Shapley, referred to it as the Climax Station. Menzel called it the Fremont Pass Station. The *Denver Post* announced it as the Climax Solar Observatory. Its entire staff consisted of its Superintendent, Walter Orr Roberts, a 25-year-old Harvard graduate student, and his bride of less than three months, Janet N. Smock (Figure 1).

In April 1946, the operation was incorporated as a not-for-profit corporation affiliated with Harvard and the University of Colorado based in Boulder, Colorado. The official title of the corporation was the High Altitude Observatory of Harvard University and the University of Colorado. Its official governing body was a Board of Trustees selected jointly by the two university presidents, James B. Conant of Harvard, and Robert L. Stearns of Colorado. The HAO maintained this basic legal structure until December 1961, when it was formally dissolved and subsequently reincorporated as the University Corporation for Atmospheric Research (UCAR). This action was a legal prelude to its amalgamation into the new National Center for Atmospheric Research (NCAR) that was created by Alan T. Waterman and the National Science Foundation (NSF).⁵ The first President of UCAR and Director of NCAR was the same Walter Orr Roberts who had hosted the open house on Fremont Pass back in the autumn of 1940. Today, Menzel’s first Western observatory continues to operate as the division of NCAR that is devoted to the study of the Sun and its influences on



FIG. 1. Janet Smock Roberts and Walter Orr Roberts became adept at improvising the domestic creature comforts from their isolated abode high atop the Continental Divide. The bookshelf just above Walter's left shoulder holds some of the Laboratory notebooks cited in ref. 72. They are labelled "B-1", "B-2", "B-3", and "B-4". From this knowledge, one can date this photograph to sometime during 1946. Courtesy of the Archives of the National Center for Atmospheric Research.

the Earth, its upper atmosphere and the nearby space environment.

The scope of this article is limited to the years leading up to the construction and the initial successful operation of the coronagraph at Climax. Menzel's connection with his first Western observatory was intimate and continued beyond this point, lasting well into the late 1950s. By 1955 his responsibilities as Shapley's successor, his close association with operations at the Sacramento Peak Observatory, and his successful efforts to bring the Smithsonian Astrophysical Observatory into the Harvard orbit, were drawing his attention away from the HAO and its program. It is nevertheless clear from the opening quote of this section that he always felt a strong affinity for the HAO and was proud of its many successes.

Genesis of an Idea

Menzel took up his appointment at the HCO on 1 September 1932, one day following the total solar eclipse that passed across Maine and the Cape Cod peninsula. Menzel observed the eclipse from Fryeburg, Maine, as a member of the Lick Observatory team, while the teenage Roberts journeyed from his home in West Bridgewater, Massachusetts, to catch the same event from Cape Cod.⁶ Perhaps the die was then cast that these two would eventually become lifelong friends, and that they should work together to build the first coronagraph to operate in the Western Hemisphere.

The desire to view the corona of the Sun at will, and without the infrequent assistance of the Moon, surely occurred to those who regularly undertook difficult journeys to witness total solar eclipses in the nineteenth century. The problem attracted the attention of many of the great solar astronomers and astrophysicists, notably Sir William Huggins, Charles A. Young, Henri Deslandres, William H. Pickering, George E. Hale and Annibale Riccò, but it eluded a resolution until the successes of Bernard F. Lyot at the Pic-du-Midi in the summer of 1930. From there he was able to view the inner corona of the Sun by means of an artificial eclipse created by a novel instrument of his own design — the coronagraph.⁷ It was a coronagraph of a similar design that formed the basis for the eventual development of the observing station at Climax, and indeed, Lyot personally played a significant part in the development of the Climax instrument. Lyot succeeded where many others had failed, thanks to the periods of exceptionally clear “coronal” seeing available on the Pic-du-Midi, and to his careful and methodical assessment of all the sources of diffuse background light within the instrument’s optics. By the time of the 1932 eclipse, his feat was widely known and highly praised.⁸

Sometime after his arrival at HCO, Menzel took up in earnest this same problem of imaging the solar corona outside of an eclipse. It is unclear for how long he had been intrigued by this celebrated problem, or what transpired to bring him to act on developing a solution. Much later, he simply stated that his eclipse studies had led him to believe “it should be possible to study that faint appendage of the solar atmosphere outside of [an] eclipse”. He and his cousin, Zack E. Gibbs, began work in the laboratory to “develop a sort of television scanner which, [they] hoped, would enable [them] to pick up the fine structural details of the corona”.⁹ Gibbs was living in Rochester, New York, early in the summer of 1933, and he planned to meet with his cousin at the HCO station at Oak Ridge, Massachusetts, during July 1933. Their correspondence gives no indication that they were contemplating a joint solar project at that time.¹⁰ Presumably the laboratory work Menzel refers to developed after their meeting at Oak Ridge.

There can be little doubt that Menzel was aware of Lyot and his efforts at the Pic-du-Midi. The Fourth General Assembly of the International Astronomical Union (IAU) convened in Cambridge, Massachusetts, on 2 September 1932, with the new HCO staff member in attendance.¹¹ There, he and his Princeton mentor, Henry Norris Russell, listened as Lucien D’Azambuja related Lyot’s successes in observing the

corona outside of an eclipse. Russell was sufficiently impressed to devote one of his monthly *Scientific American* columns to recounting Lyot's exploits, predicting "a rapid advance in our knowledge [of the corona] as a result of M. Lyot's insight and ingenuity".¹² In September 1933, Menzel's young protégé, Lawrence H. Aller, wrote to his HCO preceptor pointing out that Roy K. Marshall had translated two of Lyot's original articles into English for the *Journal of the Royal Astronomical Society of Canada*.¹³ In his preface Marshall wrote: "The new readers who will be garnered through the medium of this translation will have to judge for themselves whether they believe the great step has been made. Dr. Lyot's results look convincing, and it is hoped that he has opened up a new way to study the elusive corona."¹⁴ Even Shapley endeavoured to bring Lyot's efforts to his young solar astrophysicist's attention. While Menzel was in the Soviet Union for the June 1936 eclipse, Shapley wrote to him urging that he "read [in the *Comptes rendus*] the paper by Lyot, page 1259, April 6, 1936, concerning work on the corona. Then try to see the coronagraph in a thorough and technical way and talk the matter over [with Lyot]" on his way back to the States via Paris. Shapley prophesied: "we may develop out of the French work and Lyot's work some useful systematic enterprise."¹⁵ Indeed, it may have been Shapley who penciled "*Menze*" in the margin next to the index entry for Lyot of the vol. xliv of *L'Astronomie* (1935) that still resides at the HCO Library.

Another who was convinced of Lyot's success was A. Melvin Skellett of the Bell Telephone Labs, and Menzel's alma mater, Princeton University. In a paper read before the National Academy of Sciences on 23 April 1934, he begins: "On a day of remarkable atmospheric transparency with his apparatus at the top of Mt. Pic-du-Midi, Lyot was able to obtain images which showed several faint irregularities of light around the sun's disc. These apparently were coronal features." But Skellett then diverges sharply from the typical hagiography by asserting: "The excellence of his work and apparatus leaves little to be hoped for in the way of improvement." He despairs that Lyot's "method gives no promise for any but the innermost part of the corona". Thus, in the remainder of his paper, he proposes a new method employing the technique of television to discriminate between the glare of the sky and the feeble brightness of the corona.

Let us suppose that the image of the sky around the sun's disc is scanned by a small opening behind which a photoelectric cell is placed and that the scanning is done in a spiral path around the sun starting at the limb. As the spot passes over the hoods, arches and streamers of the coronal image the photoelectric current will consist of a number of components of different frequencies. Now if we pass this current through appropriate electrical filters we may eliminate the direct current component due to skylight and telescopic glare as well as the low frequency components that arise as a result of the radial progression of the scanning hole, leaving, presumably, only the high-frequency components due to the corona and inhomogeneities caused by poor seeing.¹⁶

Although he must have been aware of, and to some extent motivated by, these

developments in the early 1930s, Menzel characteristically set out on his own independent program to detect the solar corona during daylight. His first correspondence with Lyot starts in February 1938. A letter addressed to Skellett first appears late in 1935. In his public and private writings on this subject it is curious that neither Lyot nor Skellett is favoured with a citation, or even recognition, until quite late in the coronagraph program. This is all the more remarkable because Menzel, like his mentor Russell, was an avid expositor of matters astronomical in the semi-popular journals and magazines of the time.¹⁷

First Tentative Steps

Menzel lamented,

Progress was slow [on the coronagraph program] largely because Dr. Shapley, as usual, refused to make available to me any appreciable financial support from the observatory budget. He made it very clear to me that, if I wanted any funds, I would have to go out and raise them myself.¹⁸

In seeking a source of funding, Menzel opted for the government, and in particular, the Department of Agriculture. His attempt to fund the Harvard-MIT eclipse expedition to Ak-Bulak for the June 1936 eclipse probably left him frustrated with the stinginess of the private sector during the depths of the Great Depression. While the War Department would today seem like a more appropriate choice, one must remember that the “War to End All Wars” had concluded just twenty years earlier, and the strategic value of predicting radio blackouts was not yet anticipated.¹⁹ Menzel decided to approach the Department of Agriculture and its visionary and scientifically oriented Secretary, Henry A. Wallace.

Harvard and HCO already enjoyed well-established connections with Secretary Wallace. Wallace had received an honorary degree from President James B. Conant at the commencement activities of 1935.²⁰ Shapley and Wallace shared duties overseeing the activities of the Science Service, founded by E. W. Scripps and administered by Watson Davis.²¹ Later, Shapley and Wallace would speak out against the deepening Cold War.²² Wallace was the keynote speaker at the Boston meeting of the American Association for the Advancement of Science late in December 1933. Writing in the *Scientific monthly*, Otis W. Caldwell described his address as “fundamental”. Wallace, a scientist by training, advocated the “use of engineering and science to the end that man may have a much higher percentage of his energy left over to enjoy the things that are non-material and non-economic”.²³ Menzel was probably aware of Wallace’s “broad interest in basic science”, and, perhaps relying in part upon the Conant-Shapley connections, he decided to plead his case with the influential New Dealer.

Sometime in 1935, Menzel initiated a correspondence with Wallace, and “received a cordial invitation to call upon him the next time” he was in Washington. At their first meeting in Wallace’s office, Menzel “told him that no one had established a firm connection between solar activity and weather, although a few scientists thought that

they had detected an eleven-year cycle in the rainfall. What we needed”, he stressed, “was a new and more sensitive index of solar activity than the arbitrary sunspot number”. The corona, Menzel reasoned, was a natural index, and the coronagraph was the means to carry out synoptic observations of its evolution. Menzel wisely made no guarantees, but he argued that if one “could only predict that the next growing season would be hot or cold, wet or dry, late or early, even that information would be of inestimable value to the farmer”.²⁴

Faced with an economic depression, a Dust Bowl raging across the central plains, and his innate conviction that science was the key to improving the human condition, it is not hard to imagine that Wallace would be receptive to Menzel’s thoughtful proposition. Wallace apparently approved a small grant for the development of the coronagraph and a memorandum of understanding was negotiated between Conant’s office and the Bureau of Agricultural Economics (BAE) in January 1936. Menzel was officially designated an “agent” of the BAE, effective 15 February 1936. And at the beginning of March, Hobart W. French, Jr, Harlan True Stetson, and Mary L. Chambers were added to the grant’s payroll.²⁵ Menzel’s coronagraph project had begun in earnest.

Failures

In the spring of 1936, coronagraph design and construction were the least of BAE-agent Menzel’s immediate concerns. He had an appointment with a solar eclipse in remote (modern day) Kazakhstan on the morning of 19 June, and an entire expedition to outfit and get there and back. He sailed for Europe on 8 April and returned on 6 August.²⁶ During his absence, French (Figure 2) began work on the design of the instrument and the procurement of the necessary lenses and materials. The written record is silent on what progress was made during this first summer or the ensuing autumn of 1936. Menzel was obviously occupied for some time after his return reaping the fruits of his very successful eclipse harvest.²⁷ The lack of tangible progress may well be hinted at by an exchange of letters between Menzel and George W. Gray, the Secretary of the New York City chapter of the Harvard Alumni Association. In January 1937 Gray wrote to Menzel asking for additional information on a cooperative project between the BAE and Harvard University, as described in the report of the Secretary of Agriculture for 1936. Menzel cautioned that Gray should not mention this project in the article he was writing for the Alumni Bulletin, citing the preliminary nature of the investigation.²⁸

The spring of 1937 brought a one-year extension of his contract with the BAE. Undeterred by the apparent lack of substantive progress, Menzel unveiled a radical new proposal for a “Physical Laboratory for the Study of Solar Terrestrial Relationships”. This laboratory was to be sited at HCO’s Oak Ridge Station, which he termed “probably one of the most favorable sites in New England”.²⁹ The plan called for the Agriculture Department to provide \$80,000 in one-time construction costs, and to supply the annual operating budget of some \$12,000 per year. HCO would



FIG. 2. Hobart W. French, Jr., at work on the development of a guiding device for the coronagraph, in Cambridge (see also Fig. 8). Courtesy of the Archives of the National Center for Atmospheric Research.

contribute in kind and maintenance costs estimated to be the equivalent of \$8,000 per annum. This modest proposal was sent to Menzel's grant officer at the BAE, Larry F. Page, and directly to Secretary Wallace. Menzel also solicited letters of support from Karl T. Compton, President of Massachusetts Institute of Technology (MIT), and Professor Harry R. Mimno of Harvard's Physics Department. He travelled to Washington at the end of April 1937 to lobby for his proposal, and his eloquence and the substance of his contributions to the general discussions clearly impressed those present. This good showing on his part was probably responsible for the extension of the current contract, but it failed to secure immediate funding for the augmented program.³⁰ Secretary Wallace deferred a decision on the proposed "establishment of a solar physics laboratory as a cooperative enterprise between Harvard University and this Department" pending completion of Chaim L. Pekeris's theoretical studies of the effect of the solar ultra-violet radiation on the ozone layer.³¹ The matter then seems to have been summarily dropped by all parties involved.

If progress was meagre, failures were abundant. We learn of amplifiers that were insufficient for their purposes, and compound objective lenses that scattered too much light and had to be replaced by simple lenses. Despite being the "most favorable" site in New England, Oak Ridge's skies were nevertheless found to be too murky.³² Even a cursory glance at Lyot's papers would have permitted circumnavigation of many of these pitfalls. But in Menzel's defence, it should be noted that despite BAE

funding it was necessary for him to beg and borrow additional materials and support. Often these donations and gifts were substandard, woefully inadequate, or worse, inappropriate for their intended purposes. It was not possible to decline such dubious offers of assistance without offending the donor, thereby impacting the future support not only of the coronagraph program, but also the wide-ranging efforts of the entire HCO.

A good case in point was the Mico Instrument Company, operated by Byron W. St. Clair. St. Clair was a member of the Observatory Visiting Committee. This group was charged with overseeing the activities and advising Shapley on the future plans of the Observatory.³³ At some point, St. Clair magnanimously offered the services of his outfit to undertake the construction of the coronagraph. It would later become painfully apparent that the requisite care and precision necessary for the construction of such a delicate optical device were wholly beyond the capabilities of Mico. To deal with difficulties like these, Menzel was forced to enlist the aid of other friends and colleagues, while maintaining cordial relations with the flawed operation. At times, such a delicate balancing act proved too difficult to sustain. Late in 1937, Menzel sought the guidance of Gustave Fassin, a member of Brian O'Brien's Institute of Applied Optics based in Rochester (Figure 3).³⁴ Fassin's opinion of the Mico operation was less than flattering: "I have little respect for an instrument maker [St. Clair] who claims that he can work to a precision of 1/100th of a micron."³⁵ Menzel's reply provides an excellent sense of his predicament.

I am between two fires. The money I have received for the building of the machine is contingent on the condition that it be built by the Mico Instrument Company. In consequence, I am forced to abide by Mr. St. Clair's decision on instrument design. I appreciate your designs, and have told Mr. St. Clair that. On the other hand, I can make no claim of being an instrument designer.³⁶

A Change of Plan

By mid-1937 Menzel needed to get his program turned around and headed in a more profitable direction. It may well have been O'Brien's participation in the 1937 Harvard Astronomy Summer School that provided the impetus and confidence Menzel needed to make some drastic changes.³⁷ He wrote to Edward D. Tillyer of the American Optical Company, describing his project and asking if American Optical would be able to manufacture a simple lens to replace the "disappointing" compound lens. Menzel explained, to detect

the corona behind the glare of the sky, I am using an electrical scanning device. The image of the corona and glare is scanned with a small hole. The light passes through an aperture and falls on a photoelectric cell. The current is amplified and the constant component due to the glare is eliminated electronically. The final fluctuating current, which should correspond to the coronal light, is used to operate a glow tube and a photograph is obtained.



FIG. 3. Brian O'Brien makes precise adjustments on a complicated optical bench at the Institute of Applied Optics, in Rochester. Courtesy of Rush Rhees Library, University of Rochester.

Tillyer's response was sobering: "All I can say is that you have a hard job. One might design away the reflections but not the diffusion."³⁸ American Optical did eventually supply a 3" plano-convex lens that was the first objective used in the coronagraph, but it was not of sufficient quality to permit coronal observations.

O'Brien's summer visit to Cambridge may have catalyzed the extensive, and highly profitable, collaboration between Menzel and Fassin. Sometime during July/August of 1937, after glumly informing his BAE program manager that they had "obtained some photographs that closely resemble the corona, but are not entirely certain we have eliminated the glare",³⁹ Menzel made the momentous decision to abandon the current designs and adopt a Lyot-type coronagraph system. On 29 September, he mailed his new copy of Dyson and Woolley's *Eclipses of the Sun and Moon*⁴⁰ to Fassin, noting: "They give quite a detailed discussion of the Lyot equipment." He then inquired if Fassin would be "willing to furnish us with a working drawing of such a spectrograph, so that we can estimate more exactly the cost of construction". He had not, however, given up complete hope on his original concept, adding: "in view of the fact that our scanning equipment would work most effectively in a mounting of this sort, provision should be made for placing the scanning system within the telescope."⁴¹ Harvard's optical genius, James G. Baker, was called upon to design

a new 5" simple lens, and the Perkin-Elmer Company was enlisted to fabricate the optical components of the instrument. Further, a plane diffraction grating, ruled by Johns Hopkins's R. W. Wood, and boasting 14,000 lines per inch, was commandeered from the 1936 eclipse equipment.⁴²

Having adopted Lyot's design, Menzel was quick to follow suit and apply the methodology as well. He contacted his colleague, William H. Wright, now the Director of the Lick Observatory, and asked if space could be found on Mt Hamilton for him to test the coronagraph during the summer of 1938. Although located at 1280m and so not nearly as high as the Pic-du-Midi (2900m), Mt Hamilton offered a significant improvement over the humid sea-level conditions prevailing at Oak Ridge and Cambridge. Wright was delighted to welcome Menzel back to Lick.⁴³ The next step was to enclose the coronagraph optics in a light, but sturdy, frame that would maximize the portability of the instrument. Here, Menzel had an ace up his sleeve. Lightweight "DowMetal" had made the 1936 eclipse expedition possible (Figure 4).



FIG. 4. Willard H. Dow (left) and Donald H. Menzel (right) inspect eclipse equipment made of lightweight "DowMetal", at the Dow Chemical Company in Midland, Michigan. This equipment travelled to Ak-Bulak as part of the Harvard-MIT expedition to the 19 June 1936 eclipse. Courtesy of Suzanne Menzel Synder and the Archives of the National Center for Atmospheric Research.

The publicity that followed in the popular press had been ample compensation for Dow Chemical Company's donation of the material and labour. Dow's President, Willard H. Dow, was therefore only too happy to support Menzel's new enterprise.⁴⁴ The potential marketing-value of having built the enclosure for the first coronagraph to operate in the Western Hemisphere was not to be lightly overlooked.

Thus, by the close of 1937, Dow, Perkin-Elmer, and the Institute of Applied Optics were all on the team. Agriculture Department support continued to keep French employed. Space was being prepared for the coronagraph at Lick Observatory. And, thankfully, Mico was now relegated to working on some minor mechanical accessories, such as the guiding assembly and the declination drive.

Disaster

Early in 1938, Menzel finally wrote to Lyot declaring

I have some hopes myself of building a coronagraph and I should be greatly indebted to you for any information you can give me. I have, of course, followed your various publications, but I should appreciate having reprints of any that you have available.

Lyot was most cordial in his response. He suggested the two should meet at the upcoming IAU General Assembly in the autumn, and he enclosed the requested papers. He also provided Menzel with one of his direct photographs of the corona.⁴⁵

Despite the encouragement from Lyot, the program was encountering new difficulties. "You should know at once that during the past couple of weeks we have run into several serious setbacks with our coronagraph", Menzel cautioned Wright. He added: "We have run into delays in every conceivable way, with drawings, with castings, and with machine work. I think that I have solved the problem of financing, but these other delays, which I should have allowed for, make it uncertain as to when the instrument will be ready to ship [to Lick]."⁴⁶ Three weeks later, Menzel again wrote to Wright:

The final delay, and the one which I feel puts the final quietus on any chance of getting to California this summer, is the death in an explosion of the chief engineer [John Hoy], who was the only one at Midland [Michigan, Dow's manufacturing facility] who had all the details of the machine. Their organization has been sufficiently disturbed, and the spectrograph has been temporarily shelved, and I shall find it necessary to make another trip out there to oversee personally all of the final stages of the building. The additional delay of a month to six weeks will make it impossible to go to California. I was extremely broken up over the death of this engineer, who was my best friend at Midland. I can scarcely believe that two weeks ago today I was fishing with him at his camp.⁴⁷

Meanwhile, the BAE was beginning to lose interest in, and patience with, their coronagraph program. Now entering its third year of operation, it had precious little

to show in the way of accomplishments. The program officer successfully managed to transfer the program from his jurisdiction to the Weather Bureau. The Bureau promptly reduced the commitment level to one that just covered French's salary. Menzel was forced to "raise \$5,000 from a half a dozen different sources, which will just cover the cost of making the instrument itself".⁴⁸ One of the sources was Julius F. Stone, whom Menzel had met during his tenure at the Ohio State University from 1925 to 1926. The spectrograph was christened the "Franz Stone" spectrograph in honour of the deceased father of this generous Trustee of Ohio State.⁴⁹

With the summer now free, Menzel decided to attend the Sixth General Assembly of the IAU at Stockholm, in the first week of August 1938. One of the undisputed high points of the meeting was "a remarkable motion-picture film of prominences and the corona obtained without an eclipse" presented by Lyot. So great was the acclaim that

Dr. B. Lyot, by special request, repeated the projection of his extraordinary film of prominences and the corona. Judged by the spontaneous applause which this film received on both of the occasions when it was exhibited and by the demand for its second showing, it might well be regarded as the scientific highlight of the program.⁵⁰

After the meeting, Menzel accompanied Lyot back to Meudon where they continued their discussions on the redesign of the HCO coronagraph. During the early summer of 1938, the HCO coronagraph had been modified to conform to a Coudé mounting. This permitted the light to be brought down the polar axis and out to a fixed spectrograph without an increase in the number of reflections. Menzel noted that during his visit to Meudon, "Lyot drew from his desk drawer plans for another spectrograph and coronagraph that differed in only minor ways from the plans proposed here at Harvard".⁵¹ Lyot gave Menzel valuable advice on selecting an observing site and must have shared his enthusiasm and plans for utilizing narrow-band transmission filters. A casualty of the Meudon/Stockholm summit was the last vestige of the original 1935 scanning coronagraph concept. In a terse memo to Shapley issued after his return, Menzel remarked: "In view of the Lyot meeting, it now seems preferable to redirect toward photography, otherwise the goals of the program remain the same."⁵²

Westward Ho

With the close of 1938, the HCO coronagraph program was back on track, and thanks to Lyot's openness and generosity, it was now headed toward success in "Lyot", as opposed to "Skellett", style. But Menzel's coronagraph could now be at best the *third*, rather than the second, coronagraph in operation thanks again to Lyot's willingness to share. During the summer of 1937, Max Waldmeier apprenticed himself to Lyot at the Pic-du-Midi, and subsequently convinced his supervisor, William O. Brunner, of the benefits of reproducing Lyot's success at the Zürich Observatory's Arosa station (1900m). Unlike Menzel, Waldmeier was satisfied to copy Lyot's design and

concept with minor modifications. He was interested in making immediate use of the instrument for a long-term synoptic program of coronal observation. Thus, despite his relatively late start compared to Menzel, Waldmeier made his first observations of the coronal green line at the Arosa station late in November 1938.⁵³

The question of where to site the HCO coronagraph occupied Menzel for most of 1939. During the summer of 1938, O'Brien and his wife had travelled to Colorado to visit her family. Largely on his own initiative, O'Brien hiked about in the mountains searching for an "advantageous site for a solar observatory". Menzel had considered a summer station situated on Mt Evans (4350m), and a winter station in his hometown of Leadville (3100m), Colorado. But O'Brien's preliminary investigations had produced only a limited number of localities where ideal conditions could be found. The principal choice was narrowed to the summit of Independence Pass (3690m), on the highway linking Leadville and Aspen.⁵⁴

Menzel planned an extensive reconnaissance mission of his own to Colorado in the spring of 1939. The trip had several objectives. Not only was he following on O'Brien's cursory examination of several locations, but he was also hoping to identify local sources of Colorado funds to invest in the buildings and infrastructure. To aid him in the first task, he and French had developed an illumination meter to monitor the turbidity and transparency of the atmosphere in a quantitative fashion, and his father, Charles T. Menzel, had agreed to accompany him on his mission.⁵⁵ The second task was made easier by Menzel's commission to act as representative of Conant and the Harvard Committee for National Scholarships to solicit funds to support scholarships for students from the Rocky Mountain region. To make this possible, he was provided with introductions to influential Harvard Alumni in Colorado, and he could count on their assistance in reaching other civic-minded and philanthropic individuals and organizations.⁵⁶ The question of support for an observatory of the HCO based in Colorado could easily arise in the course of these discussions.

Menzel was careful to publicize his activities. The front page of the Sunday *Denver Post* of 28 May 1939 carried an impish photograph of the young Menzel above the headline, "Colorado May Get Big Solar Observatory". The article noted that Colorado was the first state to receive consideration for the installation, and offered Menzel's opinion that the coronagraph "may give new insight into long-range weather forecasting, radio fading, the aurora borealis, and other phenomena". The article brought him solicitations and suggestions of excellent sites from as far away as Albuquerque, New Mexico, but it had little effect on the purse strings of Colorado's wealthy patrons.⁵⁷

Despite his very best efforts, Menzel was unable to gain an audience with Harvard's wealthiest Colorado-based alumnus, Spencer Penrose, the brother of Pennsylvania politician Boles Penrose. Penrose's attorney, Charles L. Tutt, flatly stated that his client was "thoroughly disgusted with Harvard for giving an honorary degree [in 1935] to Secretary Wallace". In December 1939, Spencer Penrose passed away at his Broadmoor estate, subsequently surrounding his fortune with uncertainty for

several years. Approaches to the banking magnate and University of Denver patron, John Evans, failed to elicit any support, nor was Menzel able to secure a commitment from Claude K. Boettcher or Miss Helen Bonfils, the publisher of the *Denver Post*.⁵⁸ With the more mundane business executives and corporate officers he fared better. He established a warm personal relationship with William C. “Billy” Sterne, the president of the Public Service Company of Colorado, and he made the acquaintance of the mining engineer and amateur astronomy historian Stephen A. Ionides.⁵⁹ Through Ionides, he gained a crucial letter of introduction to the president of the Climax Molybdenum Company, Max Schott.

Father and son’s efforts to select the optimum site for the coronagraph met with its own set of surprises. They found that “very high mountains, such as Mt. Evans [4350m] or Pike’s Peak [4300m] were often cloud capped”, and subject to “rising and falling air currents [and] turbulence [that] tended to blur the image of the sun, whose edge appeared to wave back and forth unsteadily”. In the 1930s and ’40s these Front Range peaks were often subject to obscuration by the dust blowing across the high plains to their east. The Menzels then turned their attentions to mountain passes, “through which the air tended to sweep through smoothly without undue turbulence”. They concurred with O’Brien’s preliminary assessment that Independence Pass provided the best conditions, but it lacked electricity, and would have to be abandoned during the winter months from October to May, when the highway was closed. Their second choice, Loveland Pass (3660m), lacked both water and electricity, although efforts were made by the State Highway Department to keep the road passable throughout the winter. They were thus forced to consider their third choice, Fremont Pass (3450m), the site of the Climax Molybdenum Mine (Figure 5).⁶⁰

At the slight expense of elevation, Climax offered the entire infrastructure necessary to maintain a year-round observing facility. The essential facilities were already in place for the community of eight hundred miners and their families that lived on Fremont Pass through all four seasons.⁶¹ Highways and the Colorado & Southern Railroad serviced Fremont Pass. About 15 miles to the south and west of the pass was Menzel’s old hometown of Leadville. Denver was approximately 100 miles to the east, but to reach this destination required the successful negotiation of the aforementioned Loveland Pass. The Denver & Rio Grande Rail line accessed Denver by a circuitous route that crossed South Park, after heading south out of Leadville along the Arkansas River Valley.

On 14 October 1939, Menzel wrote to Max Schott, president of the Climax Molybdenum Company, enclosing his letter of introduction kindly supplied by Ionides. He spoke of the excellence of the Climax site and the unique scientific capabilities of a high-altitude laboratory/observatory. Menzel offered to meet with Schott at his New York offices, and promised he would bring a 16-mm motion picture of solar “volcanic eruptions”.⁶² This film was a copy of the one Lyot had presented at the IAU meeting in Stockholm. Menzel had quickly appreciated the persuasive powers of this medium, not only on scientists but also upon philanthropists and businessmen alike. He had in fact given another copy of this film to Stone, in an effort to cultivate



FIG. 5. A summer view of the Fremont Pass Station looking toward the northeast, c. 1946. Bartlett Mountain, which contained 95% of the known supply of the world's molybdenum reserves at this time, lies behind the house. The effects of the Climax Molybdenum Company's cave-in mining are apparent from the catastrophic subsidence on the southwest flank of the mountain. The unique conical-dome design was necessary to accommodate the 300' + of snow that fell on Fremont Pass each winter. Courtesy of the Archives of the National Center for Atmospheric Research.

continued benefits to the HCO and his own personal program.

By any standard, the meeting at the CMC's corporate headquarters was a tremendous success for Menzel. Schott must have taken a very personal interest in Menzel and his struggles. Perhaps Schott saw in Menzel and his tribulations a replay of his efforts to establish the Climax Mine in 1916. Whatever underlay Schott's actions remains unclear. What was clear, was that Menzel emerged from his initial interaction with Schott possessing far more than he could have possibly hoped for. Not only was Schott willing to set aside some land on the Climax site for the observatory, but he even offered to construct the buildings, free of charge, to Menzel's specifications. As if this was not already an over-abundance of riches, the Climax Molybdenum Company made a cash donation of \$6,000 to the coronagraph project, and the individual members of the company's Board of Directors contributed an additional \$4,000 of their personal monies to the cause.⁶³

Schott's generosity and deliberate action make an interesting contrast to the retiring role of the public sector. Colorado's Governor, Ralph L. Carr, wrote: "I am sorry that there are not state funds available to assist in this praiseworthy activity, but [I] find

that the public pocketbook is already rather light.”⁶⁴ And in the summer of 1939, the Weather Bureau declined to continue funding to support French’s activities. French was forced to leave in the middle of the project and to take up an appointment with O’Brien’s Institute of Applied Optics.⁶⁵

Enter Walter Orr Roberts

Although French departed in the summer of 1939, his place was taken up that autumn by a fresh, energetic, graduate student, Walter Orr Roberts. Two years after the 1932 eclipse, Roberts enrolled at Amherst College, where he majored in physics and minored in mathematics. Thanks to his interest in a campus recruiting effort, he was able to spend the summer of his senior year working for the Eastman Kodak Company. Through Kodak, he secured a modest graduate fellowship. He used it to attend Harvard with the intent of studying physical chemistry under Otto Oldenberg. By Roberts’s own admission, this course of study — especially the course in quantum mechanics given by Wendell Furry — was not particularly suited to him.⁶⁶ In January 1939 he walked into Harlow Shapley’s office to see if he could change his major to his first intellectual love: astronomy.⁶⁷ Roberts’s natural facility with optical equipment and cameras made his pairing with Menzel an obvious choice, and a boost for the coronagraph program. In between courses he worked with French during the spring of 1939, although his participation was most likely that of a casual assistant.

By the late spring of that year the coronagraph was ready to be taken out to Oak Ridge, and run through its initial battery of tests (Figure 6). A maintenance department truck was borrowed for the occasion. French and Roberts enlisted the aid of George Z. Dimitroff, Richard M. Emberson, and Rodney M. Scott, and it was assembled and set up on its pier on 25 May. No sooner had this been accomplished, than a severe thunderstorm passed over the site with strong winds. Despite the application of protective tarpaulins the instrument was thoroughly soaked. The next morning when Shapley arrived to supervise the acquisition of publicity photos, it was agreed that the bright orange rust would first have to be covered with paint.⁶⁸

This inauspicious start foreshadowed the outcome of the tests. The instrument was severely out of balance, and “any attempt to adjust the micrometer heads set the objective end swinging through one-half inch or more”. The flexure was such that even “a moderate breeze kept [the objective] constantly in motion”. The field lens was out of optical alignment with no mechanism provided for making adjustments. Further, the Mico declination drive motors were essentially useless. In his report, French lamented:

Actual tests show they have no starting torque, and in fact will not start at all unless nearly full line voltage is applied; they will not run steadily at any intermediate speed. Increasing the load or decreasing the voltage stalls them.⁶⁹

Such was the condition of the instrumentation left to Roberts when French was forced to move to Rochester with the cancellation of the Department of Agriculture



FIG. 6. Donald H. Menzel stands next to the coronagraph deployed for testing at the Oak Ridge Station of the Harvard College Observatory. This was the photograph that accompanied the Harvard press release of 28 April 1940. Courtesy of the Archives of the National Center for Atmospheric Research.

grant. After his final exams, Roberts had left for Kodak to continue his summer work there, and to explain to his superior, C. E. Kenneth Mees, that he had left Oldenberg and physical chemistry for Menzel and astronomy. Roberts later recalled Mees's characteristic response to his worries that Kodak would be displeased with how he was using their scholarship: "You just do a good job and it doesn't matter what field you are in."⁷⁰

Near the end of that summer, French and Roberts renewed their acquaintance when the former arrived at Rochester to begin his new career. French wrote to Menzel:

Last week we looked up Roberts and spent a pleasant evening hashing over the coronagraph — past, present, and future. He seems to be just as enthusiastic as ever about it, and was very interested in the way the new arms had succeeded in eliminating the vibration. We discussed various points, and I attempted to present an unbiased viewpoint, so that he would not be prejudiced in the event that he takes up where I left off.⁷¹

And take up with enthusiasm where French left off was exactly what Roberts did; the first entry in his laboratory notebook is dated 28 September 1939 and is titled "focusing test".⁷²

Construction

In writing to Harvard's chief financial officer on 5 April 1940, Schott reported: "At a meeting of our Board, yesterday, the transaction was finally approved and authorized, and as soon as the lease properly executed is received by us, we shall be pleased to forward a check for \$6000 to the Treasurer of Harvard University." The lease, valid for 5 years with the option of an additional 5-year renewal, allowed Harvard use for its purposes of a 100-ft square (0.23 acre) plot of land situated just south and east of the main mining operation.⁷³ It sat on the Continental Divide, at an altitude of 11,520 feet (3550m) on a spur of rock descending from McNamee Peak known as Ceresco Ridge. With this land, funding, and the promise of free material and construction labour to be supplied by the Climax Molybdenum Company in place, Menzel's first observatory was finally about to become a reality.

On 28 April, Harvard issued a press release describing the new enterprise along with a photograph of Menzel standing next to the instrument deployed at Oak Ridge. Due credit was given to Lyot in the release as the original inventor of the coronagraph. Menzel, however, had the foresight again to emphasize the potential societal benefits of the coronagraph in the same manner he had used with Secretary, and soon-to-be Vice-President, Wallace some four years earlier. The *New York Times* noted that

Dr. Menzel expects observations of the solar corona to have an immediate practical importance for the forecasting of such electric storms as that which crippled the world's communication services on Easter Sunday. Such storms probably arise from bombardment of the earth by solar electric particles when the earth is brushed by a long wisp of the corona, he said. By close observation of the

changes in the corona it may become possible to predict such bombardments and prepare for them.⁷⁴

To commemorate this success for Harvard and its Observatory, Conant extended a cordial invitation to Schott and his wife to dine with him in the President's mansion on 4 May. Clearly nonplussed by the call from academe, Schott nonchalantly regretted his "inability to avail myself of this opportunity to meet Mrs. Conant and yourself as well as members of the Faculty". He stated simply that "company affairs are responsible; I must leave for the West at the latest on Saturday of this week".⁷⁵

Meanwhile, Roberts had been working diligently to correct the weak points noted in French's farewell report. The 2 November 1939 entry in his notebook gives a comprehensive list of twenty-one "things needed to be done", ranging from the mundane ("paint black inside of camera tube") to major efforts in design and implementation ("guiding mechanism for telescope")! The latitude Menzel had delegated to his able graduate student is indicated by item 17: "Design bldg, dome, etc. for Colorado install." By late January 1940, the new and improved coronagraph was being reassembled at Oak Ridge for a second suite of tests. This time it achieved passing marks. The first photograph of a prominence was obtained on 9 March and was later reproduced in the June 1940 issue of *The sky*.⁷⁶ Roberts paid special attention to the construction of a camera assembly powered by a rapid electronic film advance. This would enable the HCO coronagraph to make movies of the sort Lyot and Robert R. McMath had pioneered.⁷⁷

Menzel left for Climax on 9 May 1940, to supervise the construction of the observatory buildings and to renew his fund-raising activities in Colorado. By the end of the month Menzel reported to Shapley: "Work here is progressing splendidly. Yesterday they leveled off approximately 7000 square feet on the top of the hill and built a connecting road. Today they are excavating."⁷⁸ Given Schott's generous lead, Colorado's business tycoons and society leaders were more willing this time around to part with some of their dollars. True to past form, however, they were still counting the nickels and dimes. Mahlon D. Thatcher, the President of the First National Bank of Pueblo, and one of the principal trustees of the late Spencer Penrose's El Pomar Foundation, pressed Menzel to find a manner to incorporate the coronagraph project in Colorado. Subscriptions that went to Harvard University, a foreign corporation according to Colorado statutes, would not be exempt from gift taxes under Colorado law. Similar concerns had arisen in 1939 during Menzel's scholarship drive through the state. At that time, Harvard Dean George Plimpton suggested the formation of an "overall corporation to receive all capital gifts for the coronagraph and scholarships". Early in 1940, Menzel asked Harvard's Treasurer, William H. Claffin, to look into the matter and advise him on the merits of such a move from the standpoint of the Harvard Corporation.⁷⁹

Colorado tax law might therefore have been part of the motivation for Menzel to seek a loose association between the HCO enterprise and his alma mater, the University of Denver (DU). The Colorado banking mogul and DU patron, John



FIG. 7. Donald H. Menzel (left) and William C. “Billy” Sterne (right) share a lighthearted moment during one of Menzel’s trips to Denver. Courtesy of Harvard University Archives.

Evans, had contributed heavily to the construction and support of the Mount Evans Laboratory. This high-altitude facility was a joint venture between DU and the MIT, which focused primarily on cosmic ray studies.⁸⁰ Perhaps Menzel was betting that a similar high-altitude coronagraph laboratory jointly sponsored by DU and Harvard would benefit from this precedent. Shapley’s reaction to this scheme was less than enthusiastic:

The proposal of an affiliation with the University of Denver startled me somewhat, and at first sight [I] was pretty annoyed for a reason that you no doubt foresaw. There have been half a dozen failures when we have tried to force our collaboration on some institution where there was not already a continuing hire of a Harvard-trained young astronomer. I am probably the only member of this staff who can name a single individual at the University of Denver. It is of course (your Alma Mater) one of the highest seats of learning in America (rotten pun); but most people don’t know it.⁸¹

The response from DU's Chancellor, David S. Duncan, was downright cold.

It is needless to say that Mr. Evans was interested in work of this character as is evidenced by the High Altitude Laboratory on Mt. Evans. He also thought the affiliation of Harvard University and the University of Denver in this project might have many possibilities, but he did not feel that he was in a position to do anything financially at this time. As I stated to you, the University under its present budget would not be able to do anything of a financial nature.⁸²

Colorado or Bust — Busted

The three months preceding Roberts's departure from Cambridge to meet up with Menzel and take charge of the facilities under construction on the Ceresco Ridge were filled with activities. Last minute testing of the camera assembly and guiding motors was hurriedly completed at Oak Ridge before the equipment was disassembled, crated, and packed for shipping to Colorado. The freight charges and the cost of a one-way train ticket for the recent recipient of Harvard's prestigious Agassiz Fellowship, were Shapley's contributions to the effort. Roberts, however, proposed that slight savings might be had if the funds were used to purchase a vehicle that he would drive to Colorado and transport the fragile optical components of the assembly and the spectrograph grating. He indicated that his uncle, Walter S. Orr, a prominent New York attorney who represented General Motors Corporation, might be able to arrange the donation of a small car or truck. Although this corporate gift did not materialize, Shapley was persuaded to follow Roberts's plan. A used 1934 Graham Paige sedan was purchased for \$150, through a garage in Brockton well known to Roberts's father. The agreement was that Roberts would personally be responsible for the incidental expenses of gas, oil, and maintenance along the way.⁸³

Roberts had also come to the conclusion that the isolation of life in a cabin, snow-bound for eight months of the year, was not to his liking. His operation of the new Western observatory was predicated upon his fiancée, Janet N. Smock, being permitted to travel west and join him on Fremont Pass. The two had met the previous year, and had set a wedding date of 8 June 1940. There was apparently some reluctance on the part of Menzel and Shapley to acquiesce to this condition, but in retrospect it would appear that they had no other viable option. Their worries were rapidly dispelled. Shapley soon informed Menzel, still at Climax, "The new Mrs. Roberts came in the other day. If her head is as good as her smile, and her heart as good as her manner, the Climax Station will be off to a good start".⁸⁴

On the day of departure, 15 July 1940, the heavily loaded Graham Paige pulled out of West Bridgewater and headed for the sweeping blue skies of the west. They got no further than Wellesley, about 30 miles outside of Boston, before they had their first of many blowouts. A major breakdown occurred outside of Pontiac, Michigan, and a car was sent by McMath to fetch the two beleaguered travellers and bring them to the shores of Lake Angelus for recuperation and animated discussions about

the solar work being carried out at the McMath-Hulburt Observatory. Roberts was no doubt very much impressed by the prominence motion pictures McMath was making. After a brief stop in Chicago, the couple headed out into the scorched Dust Bowl that was the high plains at that time. In the midst of a record heat wave, they sought occasional comfort in air-conditioned movie theatres. The water pump gave out and stranded them near Lincoln, Nebraska. As Janet Roberts noted many years later, “This agreement [to cover the incidental expenses] we would later regret. By the time we reached Climax, our costs for fuel and repairs had greatly exceeded the purchase price of the car!”⁸⁵

The withering heat had depleted both cash and patience. On 23 July, Roberts sent telegrams to Climax and Cambridge. To Menzel he wired: “Stranded repairs. Need thirty cash. Wire by Western Union, Columbus Nebraska. Oh for Alaska.”⁸⁶ The next day, Shapley reported to Menzel:

A considerable joy around the Observatory and summer school [in astronomy] was provided by the Nebraska Refugees who appealed for help. The telegram, which read ‘Repairs depleted cash. Check useless, need twenty, wire by Western Union to Hastings, Nebraska. Walter Orr Roberts’, was posted on the bulletin board as Climax Bull. #1: ‘Colorado or Bust.’⁸⁷

The Graham Paige, now officially known as ‘Busty’, limped into Denver, where Menzel met the Roberts. The equipment was transferred to Menzel’s more dependable vehicle for the long haul up to Climax. Janet Roberts recalled:

The road [over Loveland Pass] was narrow, graveled two lanes, which climbed relentlessly, doubling back on itself in sharply angled switchbacks. My nervousness was heightened by the steep drop-off of the mountain on one side and the gouged-out cliffs that shadowed the road on the other.

Menzel was fond of recalling that on the final ascent of Fremont Pass, as “we passed through the ghost town of Kokomo, I maliciously drew up in front of the most ramshackle houses in town and, as the newlyweds were about to stop behind me magnanimously said, ‘here is your honeymoon cottage. I hope you will be very happy here’”.⁸⁸

The house and observatory were not completed until 15 August, so the Roberts spent their first two weeks housed at the stylish, but ageing, Hotel Vendome in downtown Leadville. During this period Menzel took pride in showing them his favourite haunts around his old hometown. For wedding presents he “had given both Walter and Janet complete outfits for trout fishing”, and “lost no time initiating them into the pleasures of hiking, fishing, and camping in the Colorado mountains”.⁸⁹

The Fremont Pass Station

The Hollow Square voted 14 to 7 in favor of the Climax Station of Harvard Observatory instead of Fremont Pass Station of Harvard Observatory. But nobody

is satisfied with either, on further thought. ‘Fremont Pass’ suggests a bad bridge hand to [Fred L.] Whipple. [Fletcher G.] Watson doesn’t like any word ending in ‘ax’.⁹⁰

With these words did Shapley describe the deliberations to choose a proper name for Harvard’s new Western observatory. Despite the lopsided vote, and Whipple’s objection, the official adopted name would eventually become the Fremont Pass Station of the Harvard Observatory. Perhaps this was due in part to Max Schott’s reluctance to have too much attention drawn to the Climax Molybdenum Company after the débâcle of his 1935 *Fortune* interview that led to the article published the following year (see ref. 62), or to the fact that they owned the copyright on the name “Climax”. It might simply have been the name Menzel wanted for the operation.

An official open house for the new facility was held on Sunday, 8 September 1940. The next day, the *Denver Post* boasted that four hundred visitors were shown through the house and attached observatory, referred to simply as the Climax Solar Observatory. The story rated a front-page setting and featured photos of the building and the Roberts standing on either side of the coronagraph within the conical dome (Figure 8). Menzel was unfortunately not on hand for the festivities, but needed to hurry back to attend to matters in Cambridge after his long stay in Colorado. His presence was missed by John (Jack) W. Evans, Jr. Evans was on his way west to resume his appointment at Mills College and the Chabot Observatory in Oakland, and he happened to be passing through the Rocky Mountains at an opportune time to make the acquaintance of Roberts and the new Harvard coronagraph.⁹¹ He wrote:

We are sorry to miss you at Climax the other day. Even the presence of the Ionides by no means compensated for the loss! However, we did have a delightful visit with the Roberts family who more than live up to the HCO traditions of hospitality. I was disappointed not to have a look at the corona, but I enjoyed seeing the coronagraph and discussing it with Walter more than anything else I did this summer.⁹²

Later, Evans would come to play a very prominent role in the coronagraph and the operations up on Fremont Pass, principally through the application of his polarized-quartz monochromator to the coronagraph. In his letter, he foreshadows this work by confessing, “one thing that puzzles me about coronagraphs in general is the matter of chromatic aberration in the first image [formed by the plano-convex simple lens]”.⁹³

Evans’s inability to see the corona at Climax had nothing to do with the weather, and everything to do with the coronagraph. The fact of the matter was that the coronagraph did not work, and the corona would not be observed through the Climax instrumentation until October 1941. It is telling that Menzel remained encouraging and understanding in his numerous letters to Roberts during this very trying time.⁹⁴ While Roberts was battling the physical problems, Menzel was fighting the financial ones, and no doubt, his job would have been made much easier with films and photographs

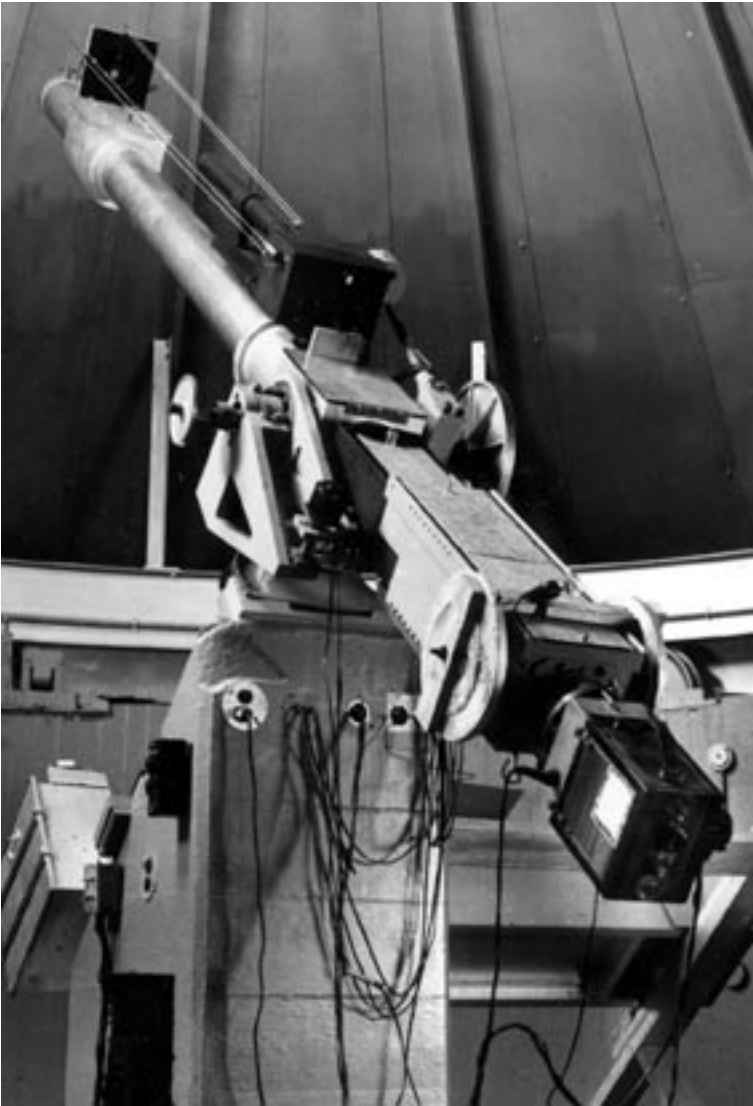


FIG. 8. The coronagraph on its pier inside the conical dome at Climax. The black box (lower right corner) is the camera assembly, and the white box (with handle, lower left corner) is the spectrograph, which is fed through the polar axis (hidden by the concrete pier). The photoelectric guiding mechanism, perfected by Walter Orr Roberts, is painted black, and is affixed to the top half of the telescope. Courtesy of the Archives of the National Center for Atmospheric Research.

of the successful scientific data being produced at the Fremont Pass Station.

Roberts had to suppress several annoying sources of diffuse light that overwhelmed the faint coronal radiation. Although great effort had been taken to select and carefully polish the simple 3" objective lens, the quality of this lens was simply not up to the standards necessary for coronal work. The Mico Instrument declination drive motors were too erratic to keep the occulting disk coincident with the solar disk to the required precision. Thus, the brilliant photospheric light would intermittently spill out over the occulting disk and fog the film and dazzle the eye during the course of tracking the motion of the Sun. The location of the observatory also turned out to be very unfortunate. On Ceresco Ridge it was located to the south and east of the main ore processing facilities. As the prevailing winds are from the north and west, the sky conditions at the observatory were severely compromised by blowing dust and other debris, as well as by smoke from the trains pulling into the Climax siding from Leadville. Throughout the eight months of winter, the snow was able to cover the particulate matter on the ground, and this was generally when the best observing was to be had. In the summer months, short periods of excellent conditions were possible immediately after heavy rainfall had cleared the air. Through his cleverness and innovation, as well as helpful correspondences with Lyot, Roberts was eventually able to overcome these difficulties and fashion a working coronagraph by the autumn of 1941.⁹⁵

Menzel faced the overwhelming task of finding a stable source of funding for Roberts's salary and the mounting costs in material and optical components necessary to make the coronagraph work. The cultivation of individual patrons was a time-consuming operation with a low rate of success. In a tabulation of gifts in money and kind to the Climax Observatory through early 1941, there are over 39 distinct sources with the median donation being \$200. The largest donor was the Climax Molybdenum Company, of course, followed by the Agriculture Department, and the Science Associates of Harvard University.⁹⁶ Typical of the thorny nature of public fund-raising was the following scathing response from Schott when Menzel inquired if additional donations might be forthcoming:

It now appears that outside of the \$6,000 contributed by the Climax Molybdenum Company and the \$4,000 contributed by the officials of the Company, the only amounts which have been raised are the \$1,950 mentioned in your letter. I feel that in view of the results obtained you should have no difficulty in enlisting the financial support of societies, and possibly the U.S. government, as well as your own University.⁹⁷

Menzel's proposal to the Rockefeller Foundation for \$10,000 was rejected,⁹⁸ and even Conant reminded him, "it is understood that no individual member of the University, nor any group of friends of the University, would be authorized to ask for money, in any campaign, or to approach any individual prospective donor without specific authorization from the President of the University".⁹⁹

In a very real sense, the U.S. entry into the War on 7 December 1941 provided the

deus ex machina for the Climax funding woes. That, and Roberts's finding that excess brightness of the east limb corona in the coronal green line (530.3nm) was generally a good indicator of subsequent magnetic storm activity several days later, turned the tide.¹⁰⁰ At the end of January 1942, Menzel's close friend and colleague, Joseph C. Boyce, wrote to him in his capacity as a Technical Aid to the National Defense Research Committee (NDRC). Boyce pointed out that through Svein Rosseland he had heard of the German interest in ionospheric phenomena.¹⁰¹ A subsequent meeting with John H. Dellinger of the National Bureau of Standards led to the decision to forward all available solar data to Dellinger so that he might be able to ascertain their correlation, if any, with ionospheric phenomena. In so far as their coronagraph data were unique, Menzel was quick to see an opportunity to keep Roberts and Climax afloat indefinitely. Boyce and Menzel together gained Dellinger's approval to designate the Climax Observatory a national defence project. By July 1942 stable government funding was in place that would last through the end of the war.¹⁰²

Conclusion

It is clear that the first of Menzel's Western observatories was able to develop its roots and eventually thrive and prosper thanks to his tenacity and his unusual ability to deal with financial, scientific, and personnel setbacks. Perhaps he wistfully had these heroic labours in mind when he penned the statement to his cousin that is reproduced at the start of this article. He was not deterred by harsh words or unkind fates, and he had the good sense to reinvent his project as the conditions demanded.

The foregoing narrative also provides unique insight into the funding climate for basic scientific research that prevailed between the two world wars. One clearly observes the painful transition between research sponsored by munificent patrons, like Carnegie and Rockefeller, and the post-war era when government support would become the rule. Conant's interdict prevented Menzel from approaching the funding giants, as these sources were to be reserved for the support of the whole university. The second tier of plutocrats proved to be less forthcoming with their gifts and were inclined to place earmarks upon their expenditures. Consequently, we can infer from the primary source materials that Menzel spent an inordinate fraction of his time hustling to support his coronagraph program. Shapley's ten-year head start on Menzel allowed him to secure most of the traditional private funding sources for the Observatory proper, which he was generally unwilling to share with his junior faculty. This policy had little effect on Bart J. Bok, or Cecilia Payne-Gaposchkin, but Menzel and Whipple were initially frustrated in their efforts, until the abundance of government funding eventually turned the tables to their advantage and against Shapley. In retrospect, it thus seems natural that a factional line within the Observatory should have developed with Menzel and Whipple on one side and Shapley, Bok, and Payne-Gaposchkin on the other.¹⁰³ Roberts would eventually align himself with the latter group in terms of funding preferences, and would rediscover for himself the pitfalls of the private sector that his teacher and preceptor knew all too well.

Menzel is certainly the ‘father’ of the HAO. Without the opportune actions of several less-visible personages, however, the enterprise would ultimately have failed. One must credit (i) Henry Wallace’s extraordinary scientific vision and his willingness to extend the boundaries of scientific research far beyond the acceptable status quo; (ii) Hobart French’s loyalty to the program and his conscientious work on the essential task of creating the physical instrument; (iii) Brian O’Brien’s wise counsel and encouragement; (iv) Lyot’s unique scientific generosity in sharing his expertise and his methods; (v) Walter Orr Roberts’s unbounded enthusiasm coupled with a natural aptitude for mastering scientific instrumentation; (vi) Max Schott’s unusual, and unequivocal, financial support of an endeavour from which he could reap no personal or professional benefit; and (vii) Harlow Shapley’s whimsical sense of humour and his poignant wisdom in charting a course for all concerned that left them stronger and more fulfilled, at the risk of engendering their sustained personal enmity.

Acknowledgments

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REFERENCES

ABBREVIATIONS USED

(a) *Archival Sources*

HUA: Harvard University Archives, Pusey Library, Cambridge, MA.

HUG 4567.5: Donald H. Menzel, General correspondence, 1932–1944, includes 9 boxes with the material arranged sequentially and alphabetically within each year.

UAV 630.22: Harlow Shapley, Director’s correspondence 1930–40.

CUA: Archives, University of Colorado at Boulder, University Libraries, Campus Box 184, Boulder, CO.
Walter Orr Roberts Papers:

Box 6: Harvard University, 1940–1945 folder.

Box 17: Correspondence, 1940–1957, Menzel.

Box 21: Shapley, Menzel folders.

RUA: Department of Rare Books and Special Collections, Rush Rhees Library, University of Rochester, Rochester, NY.

Institute of Applied Optics folder.

PR File 1:12, Brian O'Brien.

DUA: Special Collections, Penrose Library, University of Denver, 2150 E. Evans Ave, Denver, CO.

Donald H. Menzel Papers, 3 boxes.

NCARA: Archives, National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO.

AIP/CHP: Center for the History of Physics, Neils Bohr Library, American Institute of Physics, One Physics Ellipse, College Park, MD.

Donald H. Menzel's *Autobiography* is catalogued as IC33968.

The location for primary sources follows the first citation of the item.

(b) *Individuals*

DHM	Donald H. Menzel
WOR	Walter Orr Roberts
HS	Harlow Shapley

1. HAO is a division of the National Center for Atmospheric Research, which is sponsored by the National Science Foundation.
2. DHM to M. H. Bruckman, 6 January 1961 [courtesy of Chas. Andresen].
3. See R. P. Liebowitz, "Donald Menzel and the creation of the Sacramento Peak Observatory", *Journal for the history of astronomy*, xxxiii (2002), 193–211.
4. An excellent account of the Climax Molybdenum Company is provided by S. A. Voynick, *Climax: The history of Colorado's Climax molybdenum mine* (Missoula, MT, 1996).
5. The history of NCAR through 1970 can be found in E. L. Hallgren, *The University Corporation for Atmospheric Research and the National Center for Atmospheric Research 1960–1970: An institutional history* (Boulder, CO, 1974). This document draws heavily on primary source materials and provides a thorough, if dry, accounting of the key facts and personages involved in the NSF's decision to create a centre for research in the atmospheric sciences. Chap. 3 is devoted to the HAO. See also, G. T. Mazuzan, "Up, up, and away: The reinvigorating of meteorology in the United States: 1958–1962", *Bulletin of the American Meteorological Society*, lxxix (1988), 1152–64.
6. J. H. Moore, "The Lick Observatory-Crocker eclipse expedition to Fryeburg, Maine, August 31, 1932", *Publications of the Astronomical Society of the Pacific*, xlv (1932), 341–52, describes the Lick-Crocker expedition. On WOR's participation, I have relied on conversations with his sister, Jean Roberts Reller, from May 2000. She emphasized WOR's fascination with photography, optics and astronomy as a teenager. Their father, she recalled, was not interested in the 31 August 1932 eclipse. It was therefore necessary for WOR to find his own way to a favourable site to view the eclipse.
7. For a comprehensive treatment of Lyot's coronagraph work, see K. Hufbauer, "Artificial eclipses: Bernard Lyot and the coronagraph, 1929–1939", *Historical studies in the physical and biological sciences*, xxiv (1994), 337–94. For additional commentary consult A. Dollfus, "Bernard Lyot, l'invention du coronographe, et l'étude de la couronne: Un cinquantenaire", *L'astronomie*, xcvi (1983), 107–28, 315–29; J.-M. Malherbe, C. Coutard and T. Roudier, "La fondation de l'observatoire et les débuts de l'astronomie au Pic du Midi (1852–1947): Dernière partie", *ibid.*, cv (1991), 1–9; M. Gros, "Bernard Lyot (1897–1952)", *ibid.*, cxi (1998), 8–12. A discussion of the failed attempts is provided by G. E. Hale, "On some attempts to photograph the solar corona without an eclipse", *Astronomy & astrophysics*, xiii (1894), 662–87; *idem*, "On some attempts to detect the solar corona in full sunlight with a bolometer", *Astrophysical Journal*, xii (1900), 372–5; G. Blunck, "Die Photographie der Sonnenumgebung ausserhalb der Finsternisse", *Astronomische Nachrichten*, ccxxxi (1928), cols 337–42; H. Kienle and H.

- Siedentopf, "Beobachtung der Sonnenkorona ausserhalb der Finsternisse", *ibid.*, ccxxxv (1929), cols 9–10; B. J. Becker, "Priority, persuasion, and the virtue of perseverance: William Huggins's efforts to photograph the solar corona without an eclipse", *Journal for the history of astronomy*, xxxi (2000), 223–43.
8. See the analysis in Hufbauer, *op. cit.* (ref. 7).
 9. DHM, *Autobiography* (1974), a 681-page double-spaced typescript (copies have been deposited at the Niels Bohr Library, American Institute of Physics, College Park, Maryland, and the Harvard University Archives). The treatment of various episodes in his life and the factual bases for these events can be uneven at times in this quixotic and fascinating retrospective. Where it is possible, I have always used primary source material before reliance upon this work.
 10. Z. E. Gibbs to DHM, 30 June 1933, HUA/HUG.
 11. See, for example, "The International Astronomical Union", *Popular astronomy*, xl (1932), 453–9; Hufbauer, *op. cit.* (ref. 7).
 12. H. N. Russell, "The eclipse, bad weather, and a new way out", *Scientific American*, cxlvii (1932), 338–9.
 13. L. H. Aller to DHM, 25 September 1933, HUA/HUG. The original articles translated by Marshall were B. Lyot, "L'étude de la couronne solaire en dehors des éclipses", *L'astronomie*, xlv (1931), 248–53; *idem*, "La photographie de la couronne solaire en dehors des éclipses et son étude au spectrohéliographe", *ibid.*, xlvi (1932), 272–87.
 14. Marshall's preface is in B. Lyot, "The study of the solar corona without an eclipse", *Journal of the Royal Astronomical Society of Canada*, xxvii (1933), 225–34, 265–80. A note in the *New York Times* that appeared on 13 May 1934 (VIII, 6:5) states: "From the observatory of the University of Michigan comes news of the discovery by Dr. Roy K. Marshall and Dr. D. H. Menzel (Harvard) of neon and of 'double ionized' oxygen in certain very hot, blue-white stars in Orion which have temperatures of about 36,000 degrees F". DHM and Roy K. Marshall, "Neon absorption lines in stellar spectra", *Proceedings of the National Academy of Sciences*, xix (1933), 879–81. This provides strong evidence that DHM and Marshall were in professional contact during the time when Marshall translated Lyot's articles.
 15. HS to DHM, 27 May 1936, HUA/UAV, Box 42. HS's correspondences with Lyot appear to predate DHM's. Both HS and Lyot attended the Fifth General Assembly of the IAU, held in Paris during the summer of 1935, and it was likely that they came into contact then, see S. A. Mitchell, "The Paris meeting of the International Astronomical Union", *Popular astronomy*, xliii (1935), 478–83.
 16. A. M. Skellett, "Proposal of a method of observing the solar corona without an eclipse", *Proceedings of the National Academy of Sciences*, xx (1934), 461–4. A similar contribution appears as A. M. Skellett, "A method designed for observing the solar corona without eclipse", *Physical review*, xlv (1934), 649. Another flurry of publications, both popular and scientific, appears six years later: A. M. Skellett, "The coronaviser", *The sky*, iv (1940), 12–14; "The coronaviser", *The telescope*, vii (1940), 54–56; "The coronaviser, an instrument for observing the solar corona in full sunlight", *Bell System technical journal*, ix (1940), 249–61. See also, "Corona seen by television", *Science news letter*, xxxvi (1939), 294; "82-inch telescope in use; view corona by television", *ibid.*, 404–5. Both Skellett and his coronaviser simply vanish from the literature following these contributions. A penetrating, but positive, assessment of the instrument is H. W. Babcock, *Astrophysical journal*, xcvi (1942), 242–53. The dénouement of the coronaviser may well be traced to the unfortunate fact that it was never deployed at an altitude surpassing that of the Cook and McDonald Observatories.
 17. For a sampling of DHM's popularizations of astronomical discoveries and issues, see "The planetary nebulae", *Astronomical Society of the Pacific leaflet*, #46 (1932); "The world of atoms", *ibid.*, #55 (1933); "What is light?", *ibid.*, #67 (1934); "Why take the Sun for granted?", *Scientific monthly*, xli (1935), 65–69; "Why take the Sun for granted?", *The telescope*, ii (1935), 76–83; *New York Times*, 14 June 1936; "Aurora Borealis", *The telescope*, v (1938), 44; *Christian Science Monitor*, 17 August 1938; "Theoretical problems of stellar absorption lines", *Popular astronomy*, xlvii (1939), 6–22, 66–79, 124–40; "Problems of the solar corona", *Proceedings of the American*

- Philosophical Society*, lxxxi (1939), 107–24; “Some unsolved problems in astrophysics”, *Astronomical Society of the Pacific leaflet*, #125 (1939). As the Editor of *The telescope* from May 1937 onward, he contributed numerous small articles and commentaries. None of these contributions mentions Lyot, Skellett, or the coronagraph.
18. *Autobiography* (ref. 9).
 19. The increased popularity of radio had certainly drawn some attention in the literature to magnetic storms and periods of radio communication disruption. See, for example, E. O. Hulburt, “Radio and the outer atmosphere”, *Scientific monthly*, xxxi (1931), 73–76; A. E. Kennelly, “Cosmic disturbances of the Earth’s magnetic field and their influence upon radio communication”, *ibid.*, xxxv (1932), 42–56.
 20. For the honorary degree, awarded to Wallace in 1935, see J. G. Hershberg, *James B. Conant: Harvard to Hiroshima and the making of the nuclear age* (New York, 1983), 90. Note the later negative impact this innocuous event would have on DHM’s fund raising efforts with the Harvard Alumnus, Spencer Penrose (see ref. 58). A profound and illuminating survey of a very complicated Wallace is given by J. C. Culver and J. Hyde, *American dreamer: A life of Henry A. Wallace* (New York, 2000).
 21. See W. Davis, “The twentieth anniversary of Science Service”, *Scientific monthly*, liv (1942), 291–2, marking the twentieth anniversary of the Science Service. Notice HS and Wallace sitting next to each other (with Vannevar Bush in the background) in the illustration that accompanies this article.
 22. HS, *Through rugged ways to the stars* (New York, 1969), provides a framework to assess HS’s politics and his affinity with Wallace and the Independent Movement. A specific, and notorious, example of their collaboration concerns the so-called Waldorf Peace Conference, held in New York City in late March of 1949. Much was written in the popular media about this event with a slant not particularly friendly to HS or Wallace, e.g. “Red visitors cause rumpus”, *Life*, 4 April 1949, 39 seq., and numerous articles appearing in the *New York Times* on 26 and 27 March 1949. The House Un-American Activities Committee issued their own report condemning this gathering, *Review of the Scientific and Cultural Conference for World Peace, arranged by The National Council for the Arts Sciences and Professions, and held in New York City on March 25, 26, and 27, 1949*, which makes for some interesting, if at times bizarre, reading.
 23. O. W. Caldwell, “The Boston meeting of the American Association for the Advancement of Science”, *Scientific monthly*, xxxviii (1934), 189–94. The full text of Wallace’s speech was reprinted in H. A. Wallace, “The social advantages and disadvantages of the engineering-scientific approach to civilization”, *Science*, lxxix (1934), 1–5, and it reads true even many decades later. This article provides ample evidence that Wallace would be approachable on the issue of supporting research with potential societal impacts. A later contribution, H. A. Wallace, “Research — The yeast in the loaf of agriculture”, *Scientific monthly*, xlii (1936), 5–29, expands on this theme and makes an ambiguous reference in the final paragraph to what might well have been DHM’s new coronagraph project.
 24. *Autobiography* (ref. 9). I have tried to date DHM’s trip to visit Wallace based upon the letters cited in ref. 25, and the *Scientific monthly* article cited in ref. 23. I was unable to locate any primary source materials connecting DHM and Wallace, or his Agriculture Department, before the correspondence listed in ref. 25.
 25. The basic sources are J. D. Black to DHM, 2 January 1936, 15 January 1936; J. A. Becker to DHM, 20 February 1936; C. L. Harlan to DHM, 9 March 1936, all HUA/HUG. Black was based in Harvard’s Economics Department, while Becker and Harlan were with the Bureau of Agricultural Economics, the division Wallace presumably decided to saddle with DHM’s anointed proposal. On French and Chambers, little background information is available. Stetson, of course, was well known for his semi-popular books on the Sun, and operated out of the neighbouring Massachusetts Institute of Technology. What, if anything, he contributed to DHM’s program except for his name-recognition does not appear in the records. Only French, as we shall see, made tangible and long-term contributions to the effort.

26. For a travel-log of DHM's eclipse adventures, see his series of dispatches to the *New York Times*, 4, 6, 30 May; 14, 21, 22 June; 22 July and 7 August 1936. Also, H. Hemmendinger, "While the Sun is eclipsed", *The telescope*, iii (1936), 51–55; DHM, "The Harvard-MIT eclipse expedition", *Publications of the Astronomical Society of the Pacific*, xlviii (1936), 164–7; I. C. Gardner, "Observing an eclipse in Asiatic Russia", *National Geographic magazine*, lxxi (1937), 179–97.
27. For example, DHM and J. C. Boyce, "Eclipse in Ak Bulak", *Technology review*, xxxix (1936), 18–21, 36, 38, 40, 42, 44; DHM, J. C. Boyce, H. Hemmendinger, R. d'E. Atkinson and W. R. Brode, "The design and operation of the Harvard-MIT 1936 eclipse equipment", *Annals of the Astronomical Observatory of Harvard College*, cv (1937), 87–98.
28. G. W. Gray to DHM, 16 January 1937, and DHM's subsequent reply, both HUA/HUG.
29. DHM to L. F. Page, 1 April 1937, HUA/HUG. The Oak Ridge Station was located appropriately near the town of Harvard, MA, some 30 miles to the northwest of Cambridge. That this might have been one of the most favourable sites in New England for nighttime observation did not imply that coronal observations could be achieved through the overlying column-mass of atmosphere. This point DHM neglected to make in his proposal.
30. C. F. Sarle to DHM, 13 May 1937; L. F. Page to DHM, 7 July 1937, both HUA/HUG.
31. H. A. Wallace to DHM, 20 May 1937, HUA/HUG. DHM and Pekeris were not only Cambridge neighbours, but certainly well acquainted. They had recently collaborated on a widely cited paper on atomic physics, DHM and C. L. Pekeris, "Absorption coefficients and hydrogen line intensities", *Monthly notices of the Royal Astronomical Society*, xcvi (1935), 77–111.
32. DHM to C. F. Sarle, 29 June 1937; DHM, "Investigation of solar variability" (Cambridge MA, unpublished report dated 31 March 1939), both HUA/HUG. This report manages to convey the sense that the difficulties mentioned in the text arose as a matter of course and were dispatched in a similar fashion. It was clearly intended for public consumption and did not acknowledge the atmosphere of angst and frustration that surrounds much of DHM's correspondences on this subject during the period 1935–38.
33. See HS's correspondences with St. Clair, HUA/UAV, Box 49.
34. On the Institute of Applied Optics, see W. B. Rayton, *The future of optics in America* (Rochester NY, unpublished report dated 30 January 1933), RUA. Fassin's career and activities are somewhat obscure, but O'Brien (1898–1992) had a distinguished career in optics. He worked in a variety of areas, achieving his first notice with work on the exploration of the stratosphere in the mid-1930s (Explorer II), and subsequent measurements of the thickness of the ozone layer. During the Second World War he developed an instrument called the Icaroscope, which permitted pilots to see approaching fighters using the sun at their back for camouflage. For this service, he was awarded the Presidential Medal of Merit in 1948. Perhaps O'Brien's best-known invention was a motion picture lens made of artificial sapphire possessing a high index of refraction and low dispersion. Michael Todd first used this lens with great fanfare for the filming of *Oklahoma!* A charming piece on Todd and O'Brien is J. Sayre, *Life*, 7 March 1955, 140–2, 144, 146, 148, 151–2, 157.
35. G. Fassin to DHM, 9 April 1938, HUA/HUG.
36. DHM to G. Fassin, 12 April 1938, HUA/HUG.
37. DHM to L. H. Aller, 3 April 1937, HUA/HUG. On the Harvard Observatory's Summer School program, see D. H. DeVorkin, "The Harvard summer school in astronomy", *Physics today*, xxxviii (1984), 48–55.
38. DHM to E. D. Tillyer, 8 June 1937; reply, 9 June 1937, both HUA/HUG.
39. DHM to C. F. Sarle (ref. 32).
40. F. Dyson and R. v. d. R. Woolley, *Eclipses of the Sun and Moon* (Oxford, 1937), 108–10. According to Hufbauer, *op. cit.* (ref. 7), Lyot made every effort to supply Dyson and Woolley with his best photographs, and fully disclosed the instrument design in order to secure his claims to the development of the first successful coronagraph.

41. DHM to G. Fassin, 29 September 1937, HUA/HUG. This letter is remarkable not only for the dramatic change of direction, but also DHM's tone and outlook, relative to his correspondences preceding this letter. One gains the impression that the proverbial light at the end of the tunnel had finally been sighted.
42. DHM to G. Fassin (ref. 41), "Investigation of solar variability" (ref. 32), WOR, "Preliminary studies of the solar corona and prominences with the Harvard coronagraph", Harvard University Ph.D. thesis, 1943 (hereafter "Thesis"), 40. Wood, incidentally, was also one of the many who tried their luck at observing the corona outside of an eclipse and failed, e.g. R. W. Wood, "The problem of the daylight observation of the corona", *Astrophysical journal*, xii (1900), 281–6.
43. W. H. Wright to DHM, 24 December 1937, HUA/HUG. On the relationship between Wright and DHM see D. E. Osterbrock, "Young Don Menzel's amazing adventures at Lick Observatory", *Journal for the history of astronomy*, xxxiii (2002), 95–118.
44. DHM to W. H. Dow, 11 April 1938, HUA/HUG. Dow (1897–1949) met an untimely end in an airplane crash, *New York Times*, 1 April 1949. DHM obviously enjoyed a cordial relationship with this giant of American manufacturing. A good example of the publicity afforded to Dow Chemical Company by the Ak-Bulak eclipse expedition is the article by DHM and J. C. Boyce (ref. 27), and especially the advertisement "DowMetal's Place in the Sun" that immediately follows on p. 43.
45. DHM to B. Lyot, 23 February 1938; B. Lyot to DHM, 3 April 1938, 25 May 1938, all HUA/HUG. The tone of these letters strongly suggests that Lyot and DHM were not personally acquainted at this time, although each knew of the other's work. Lyot, for example, was interested in seeing data from the Ak-Bulak eclipse expedition relating to the chromospheric and coronal emission lines that had been detected by the Harvard-MIT group. He managed to obtain some of these data in exchange for information on his coronagraph.
46. DHM to W. H. Wright, 2 May 1938, HUA/HUG.
47. DHM to W. H. Wright, 26 May 1938, HUA/HUG. DHM's complete sense of despair at this lowest point of his coronagraph project is evident from this letter to Wright.
48. C. F. Sarle to DHM, 28 January 1938, 18 June 1938; DHM to C. F. Sarle, 11 June 1938, all HUA/HUG.
49. DHM to J. F. Stone, 19 September 1938, HUA/HUG. On DHM's first encounter with Stone, see *Autobiography* (ref. 9). Stone (1854/5?–1947) seems to have had a personal weakness for funding spectrographs, and having them named for his family; see for example R. R. McMath, "The Julius F. Stone spectroheliograph for the determination of solar atmospheric radial velocities", *Publications of the Observatory of the University of Michigan*, viii (1941), 141–7. For some additional background on Stone, see the *New York Times*, 27 July 1947.
50. F. C. Leonard, "The International Astronomical Union meeting at Stockholm, Sweden, 1938 August 3–10", *Popular astronomy*, xlvi (1938), 538–47; Hufbauer, *op. cit.* (ref. 7).
51. DHM, "Investigation of solar variability" (ref. 32), relates the episode about Lyot pulling a paper with similar plans from his desk drawer. Figure 7, of B. Lyot, "A study of the solar corona and prominences without eclipses", *Monthly notices of the Royal Astronomical Society*, xcix (1939), 580–94, shows the disadvantages of Lyot's third and final coronagraph relative to the Coudé concept. This superior design provided for a mirror that would reflect the coronal image down the polar axis to the spectrograph assembly, or when removed from the beam would permit the coronal image to pass straight down the telescope assembly and into the camera unit. Unfortunately, this mirror was placed before the field lens, which then had to be duplicated along both the photograph and spectrograph beams. This led to additional complications as pointed out by WOR in his thesis (ref. 42).
52. DHM to HS, 18 November 1938, HUA/HUG.
53. The account provided here is taken directly from Hufbauer, *op. cit.* (ref. 7). Max Waldmeier (1912–2000) is an enigmatic figure in solar astronomy. He clearly appreciated the value of the coronagraph for advancing the understanding of solar–terrestrial connections earlier than anyone else, and he produced a voluminous bounty of coronal data following the first successful

- observations at Arosa late in 1938. That he failed to achieve much of an impact given his diligent and meticulous work is therefore quite remarkable. He succeeded Brunner as the Director of Eidgenössische Sternwarte in 1945 and held that position for the next 34 years.
54. O'Brien's activities are recounted in *Investigations of solar variability* (ref. 32), and DHM's concept for a two-site operation is first mentioned in DHM to Julius F. Stone (ref. 49).
 55. The instrument developed with French is briefly described in DHM, "Investigations of solar variability" (ref. 32). A more advanced instrument of this nature was subsequently devised by John W. Evans, Jr. and employed in site-selection for the second of DHM's Western observatories. See for example J. W. Evans, Jr., "A photometer for measurement of sky brightness near the Sun", *Journal of the Optical Society of America*, xxxviii (1948), 1083 seq. For the participation of DHM's father, Charles T. Menzel (1871–1943), see *Autobiography* (ref. 9).
 56. DHM to T. B. Knowles, 12 May 1939; DHM, "Committee on National Scholarships" (Cambridge MA, unpublished report dated 7 October 1939), both HUA/HUG. Thomas Knowles was an active member of the Rocky Mountain Harvard Club, and an executive in the real estate business.
 57. R. J. Moos to DHM, 29 May 1939; J. P. Murphy to DHM, 2 June 1939, both HUA/HUG. Moos was the Mayor of the mining town of Victor CO, and Murphy represented the Albuquerque Chamber of Commerce. The latter attempted to convince DHM of the superiority of the Sandia Mountains. It is interesting to note that the second of DHM's Western observatories would be located in the Sacramento Mountains, further south of the Sandia's, to compensate for the poor observing duty cycle of Climax.
 58. DHM, "Committee on National Scholarships" (ref. 56). For Spencer Penrose (1865–1939), see his obituaries in the *Denver Post*, and *New York Times*, both 7 December 1939. On Claude Boettcher (1875–1957), consult Geraldine B. Bean, *Charles Boettcher, a study in pioneer Western enterprise* (Boulder CO, 1976). Helen G. Bonfils (1889–1972) and her elder sister were embroiled in litigation over the \$25,000,000 estate left after the death of their father and mother in 1933 and 1935, respectively. Miss Bonfils succeeded her father as the publisher of the *Denver Post*, and the director of the Frederick G. Bonfils Foundation (established in 1927). See her extensive obituary in the *Denver Post*, 6 June 1972, for more details on her life and charitable activities.
 59. W. C. Sterne to DHM, 24 October 1940; S. A. Ionides to DHM, 10 August 1939, both HUA/HUG. Billy Sterne (1898–1948) was a flamboyant Harvard alumnus who shared with DHM the profound enjoyment of an excellent hand of Bridge. He went on to become one of the original members of the HAO Board of Trustees in 1946. Ionides (1880–1943), and his daughter Margaret L. Ionides, were serious historians of astronomy. They wrote several articles for *Popular astronomy* and contributed to the *Publications of the Astronomical Society of the Pacific* leaflet series ("Astronomy in ancient Greece", #145 (1941); "Astronomy in ancient Egypt", #153 (1941)). It is ironic that DHM was less than generous in his review of their book, *Stars and men* (New York, 1939), for *The telescope*, vii (1940), 71. DHM had succeeded Loring B. Andrews as Editor of this magazine in May 1937. Some background on Stephen Ionides may be found in his obituaries, R. G. Aitken, "Bernard Benfield, John D. Galloway, and Stephen A. Ionides", *Publications of the Astronomical Society of the Pacific*, lv (1943), 92–95; *Denver Post*, 28 January 1943; *Rocky Mountain News*, 29 January 1943.
 60. *Autobiography* (ref. 9).
 61. The standard miner's joke was that Climax had nine months of winter and three months of poor skiing. Voynick, *op. cit.* (ref. 4), provides excellent background and numerous photographs of the mining operation, as it existed in 1939. The Climax Molybdenum Company (CMC) had spent in the neighbourhood of \$4,000,000 during 1936 alone in providing amenities and housing facilities in an attempt to mitigate the harsh climate's influence on their employee turnover rate. Some of the new facilities included a school, bowling alleys, a movie theatre, and even an indoor swimming pool. The CMC provided for a private clinic, hospital, and medical doctor on the site. This unusual example of corporate social enlightenment was entirely the work of Max Schott. The costs were well-justified by the fact that the mine was processing 12,000 tons of ore per day by December 1938.

62. DHM to M. Schott, 14 October 1939, HUA/HUG. Max Schott (1876–1955), like Ionides, is a fascinating but reclusive personality. The best source remains Voynick, *op. cit.* (ref. 4), and the infamous article on Schott and Climax Molybdenum Company (CMC) that appeared as “Element number forty-two”, in *Fortune*, xiv/4 (October 1936), 105–9, 187–8, 190, 192, 194, 197. As Voynick points out, this article induced two spectacular lawsuits when it was realized that Schott and CMC had actually prospered through the Great Depression. A share of CMC stock worth \$1 in 1928 had an equivalent value of \$1200 by 1935. The Schott family’s 200,000 shares of CMC stock, as well as the comparable holdings of the remainder of the Board of Directors, were therefore ripe targets for litigation. Interestingly, Schott was in the midst of these legal actions during 1940/1941, when his unexpected generosity made the Climax Observatory possible. Perhaps characteristically, Schott’s obituary reveals little about the man, *New York Times*, 11 November 1955.
63. M. Schott to DHM, 5 April 1940; M. Schott to H. A. Wood, Jr, 5 April 1940, both HUA/HUG.
64. R. L. Carr to DHM, 18 March 1940, HUA/HUG. Ralph L. Carr (1887–1950) was Colorado Governor from 1939 to 1943. DHM fared no better in his attempt to rouse the partisanship of Colorado Congressman Edward Thomas Taylor (1858–1941), against the growing California monopoly on astronomical observatories, e.g., DHM to E. T. Taylor, 14 April 1939, HUA/HUG.
65. DHM to C. F. Sarle, 27 November 1939, HUA/HUG.
66. WOR granted several interviews during his lifetime; in many of them he discusses his personal career and education. The most extensive dates from 1983 and was conducted by David DeVorkin as part of the American Institute for Physics Oral History Program, AIP/CHP. The version I have used is the original transcript from this interview, edited by WOR’s own hand, which will herein be referred to as *WOR83*, NCARA. A fragment of a full transcript from an interview conducted in 1966 by an unknown person also contains much material on this early period of WOR’s life. This fragment bears the title, *Early history of the High Altitude Observatory*, and will be designated *WOR66* in what follows. A much-abbreviated repetition of this same material was published as WOR, “Variations in the Sun and their effects on weather and climate”, *Proceedings of the American Philosophical Society*, cxxiii (1979), 151–9. In 1989, Janet Smock Roberts wrote a delightful 50-page manuscript, *Glory hole*, which recounts her adventures with WOR from 1939 through their departure from Climax in 1947. I have drawn liberally from these four sources, and the *Autobiography* (ref. 9) in reconstructing the sequence of events laid out in the text.
67. *WOR83* (ref. 66), 28. WOR recalled that HS quickly turned the conversation in the direction of his studies on ants, by physically turning the special lazy-susan style desk in his office to the compartment with bottles of preserved ants. On HS and his fascination with ants, see HS, *op. cit.* (ref. 22).
68. Hobart W. French, Jr, “Preliminary tests of coronagraph” (Cambridge MA, unpublished report dated 23 June 1939), HUA/HUG. This document appears to be French’s final report of his activities to DHM before he left for Rochester. It contains a list of recommendations for improvement after the disappointing showing in the May 1939 testing episode.
69. French, “Preliminary tests of coronagraph” (ref. 68).
70. WOR’s recollection of this conversation with C. E. K. Mees is from *WOR83* (ref. 66), 36. For background on Mees, see W. Clark, “Charles Edward Kenneth Mees, 1882–1960”, *Biographical memoirs of Fellows of the Royal Society*, vii (1961), 173–97.
71. H. W. French, Jr, to DHM, 14 September 1939, HUA/HUG.
72. WOR’s “Laboratory notebooks” comprise ten volumes that follow sequentially from the first entry of vol. i, 8 September 1939, through 6 September 1950 of vol. x. With the passage of time, these gradually evolved from traditional lab notebooks to daily logs of solar activity and drawings of the shape of the corona. A complementary set of notebooks was devoted to recording daily weather conditions at the observatory. Different hands are evident in these notebooks, indicating the rapid turnover in part-time assistants who aided WOR with his observing activities, NCARA.
73. Schott to Wood (ref. 63).
74. See, e.g., *Leadville Herald Democrat*, *Denver Post*, *New York Times*, and the *Christian Science*

- Monitor*, all 29 April 1940. The Easter Sunday storm was arguably the strongest in many decades, and it thus gained a significant amount of coverage in both popular and scientific circles, for example, J. A. Fleming, “The great magnetic storm”, *Scientific monthly*, 1 (1940), 475–80.
75. M. Schott to J. B. Conant, 29 April 1940, HUA/HUG.
 76. WOR, “Laboratory notebooks” (ref. 72), i, 5; DHM, “Harvard coronagraph in Colorado”, *The sky*, iv (1940), 3–4.
 77. See the *New York Times*, 5 September 1936; B. J. Bok, “The Harvard tercentenary meeting of the American Astronomical Society”, *Scientific monthly*, xliii (1936), 375–8; D. B. McLaughlin, “The fifty-sixth meeting of the American Astronomical Society”, *Popular astronomy*, xlv (1936), 467–71; J. Leclerc, “Le film à la société astronomique de France”, *L’astronomie*, lii (1938), 425–6.
 78. DHM to HS, 24 May 1940, HUA/HUG.
 79. DHM to W. H. Claffin, 9 May 1940, HUA/HUG.
 80. J. C. Stearns, “The Mount Evans laboratory”, *Scientific monthly*, xlvi (1938), 242–8. John Evans (1884–1978) was the President of the First National Bank of Colorado and a Trustee of the University of Denver. His grandfather, of the same name (1814–97), was the second territorial governor of Colorado, and the founder of both Northwestern University and the University of Denver. Evanston IL, and Mt Evans, were both named in his honour.
 81. HS to DHM, 20 May 1940, HUA/HUG.
 82. D. S. Duncan to DHM, 25 July 1940, HUA/HUG.
 83. Here, again, I have drawn heavily on the four primary sources listed in ref. 66. Walter S. Orr (1891–1961) was also a long-time Trustee of Amherst College, *New York Times*, 26 September 1961.
 84. HS to DHM, 22 June 1940, HUA/HUG.
 85. Roberts, *Glory hole* (ref. 66). The term “glory hole” was used by the miners to describe the gradual subsidence and collapse of material sitting above an underlying network of tunnels and cuts made lower in the mountain. The uniformity of the molybdenum ore in Bartlett Mountain made this extremely efficient and cost effective type of mining possible at Climax.
 86. WOR to DHM, 23 July 1940, HUA/HUG.
 87. HS to DHM, 24 July 1940, HUA/HUG.
 88. *Autobiography* (ref. 9). Also *WOR83*, *WOR66*, and Roberts, *Glory hole* (ref. 66).
 89. *Autobiography* (ref. 9).
 90. HS to DHM 29 May 1940, HUA/HUG. On Fletcher G. Watson (1912–97) see *Harvard University gazette*, 15 May 1997.
 91. John W. “Jack” Evans, Jr (1909–99) was unrelated to the Evans family of Denver and Evanston. Evans obtained his Ph.D. degree at Harvard just before WOR arrived, and subsequently took a position at the Chabot Observatory. During the war he came east to Rochester and worked with Brian O’Brien. He joined WOR as HAO’s second scientific staff member in June 1946. His private home, on 973 Grant Place, was HAO’s first office site in Boulder. He left HAO in 1952 for a distinguished career as the Director and visionary scientific leader of DHM’s second Western observatory, located near the summit of Sacramento Peak, in southern New Mexico.
 92. J. W. Evans, Jr, to DHM, 3 September 1940, HUA/HUG.
 93. J. W. Evans, Jr, to DHM (ref. 92); J. W. Evans, “The quartz polarizing monochromator”, *Publications of the Astronomical Society of the Pacific*, lii (1940), 305–11; *idem*, “El filtro birrefringente”, *Ciencia é investigación*, iii (1947), 365 seq.
 94. DHM to WOR, 11, 21, 30 October 1940; 20 November 1940; 21 December 1940; 8, 17 January 1941; 5 June 1941; 14 July 1941; 6 October 1941, all CUA.
 95. “Thesis” (ref. 42), 36–49.
 96. *Gifts to Climax Observatory* (Cambridge MA, undated report), HUA/HUG 4567.5, 1940 I–Z, 1941 A–C. Also, *WOR66* (ref. 66). The list ranged from corporations, Sears Roebuck Company (miscellaneous merchandise), Public Service Company of Colorado (power transformer), American Radiator and Standard Sanitary Corporation (\$50), Timken Roller Bearing Company

- (roller bearings for the dome), Owens-Corning Fiberglas Corporation (insulation), B. F. Goodrich Company (rubber sheeting for the dome skirt), Daniels & Fisher (rugs), Kansas City Structural Steel Corporation (the observatory dome), to private individuals like the bon vivant Billy Sterne (electric stove and radio).
97. M. Schott to DHM, 15 May 1941, HUA/HUG.
 98. F. B. Hensor to DHM, 19 May 1941, HUA/HUG. Hensor was the Associate Director of Natural Sciences for the Rockefeller Foundation. It is a sobering fact that DHM's proposal was rejected in less than two weeks time from when it was mailed.
 99. J. B. Conant to DHM, 21 May 1941, HUA/HUG.
 100. There are several slants on this particular issue in the two interview transcripts, and the article in *Proceedings of the American Philosophical Society* (ref. 66). I have presented the line that is essentially common to all. The "Thesis" (ref. 42), and the "Laboratory notebooks" (ref. 72), are unfortunately silent on this issue. See also J. H. Dellinger, "Direct effects of particular solar eruptions on terrestrial phenomena", *Physical review*, 1 (1936), 1189; *idem*, "Sudden ionospheric disturbances", *Journal of terrestrial magnetism*, xlii (1937), 49–53; R. S. Richardson, "Relation between bright chromospheric eruptions and fade-outs of high-frequency radio transmission", *Publications of the Astronomical Society of the Pacific*, ii (1937), 82–86; M. Waldmeier, "Sonneneruptionen und ionosphärische Störungen", *Zeitschrift für Astrophysik*, xiv (1937), 229–41; *idem*, "Untersuchungen an der grünen Koronalinie 5303 Å", *ibid.*, xix (1939), 21–44; *idem*, "Vergleichende Beobachtungen an den Koronalinien 5303, 5694, und 6374 Å", *ibid.*, xx (1941), 172–94; A. G. McNish, "The great geomagnetic storm of September 18–19, 1941", *Scientific monthly*, liii (1941), 478–81.
 101. J. C. Boyce to DHM, 30 January 1942; DHM to J. C. Boyce, 2 February 1942, both HUA/HUG. Boyce (1903–83) accompanied DHM on the eclipse expedition to Ak-Bulak in 1936.
 102. DHM to WOR, 2 February 1942, 12, 25 March 1942, all CUA.
 103. For example, D. H. Levy, *The man who sold the Milky Way: A biography of Bart Bok* (Tucson AZ, 1993), 74–95.