The Harvard summer school in astronomy

The annual conferences that Harlow Shapley organized from 1935 through 1942 fostered the growth of astrophysics in the US, and were the model that inspired similar sessions on other campuses.

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Professional astronomy in the 1920s and 1930s was a science in transition. Modern relativistic cosmologies were born, and three major areas of modern physics became central to progress in astronomy: quantum mechanics, nuclear physics and relativity.[1] The old empirical and qualititative methods of spectroscopic astronomy, methods that generated vast amounts of systematic knowledge of the spectra of the Sun and stars and the dynamics of stellar systems, were being supplemented by rational and quantitative methods. These new techniques promised to reveal not only the compositions of the Sun and stars, their sources of energy and their ages, but also the origin and ultimate fate of the universe.

Relatively few classically trained astronomers were at first able to take an active and creative part in the new astrophysics. In the late 1920s, a general awareness grew among astronomers that future progress in their field lay in the application of modern physical theory to the many problems that intrigued spectroscopic astronomers. But who was capable of doing this? In the early 1930s, the few institutions in the United States offering a doctorate in astronomy were producing an average of 10 PhDs per year.[2] Most of the graduate students wrote dissertations on classical subjects tied closely to the observational programs of their parent institutions and very far from astrophysics, the forefront of astronomy.

Harlow Shapley, the young director of the Harvard College Observatory, firmly believed at the time that in the future, "astronomy wasn't going to be only run by astronomers, but in the sort of new astronomy we are going to need physicists."[3] Until Otto Struve, the new director of Yerkes Observatory, launched a search in the 1930s for staff to strengthen training in theoretical astrophysics at the University of Chicago, he felt that the US had only one center for such training, and that was under Henry Norris Russell at Princeton. Russell was Shapley's teacher and a pivotal transition figure in the maturing of modern astrophysics. He lectured widely on the central role of physics in the new astronomy, stating in 1927 that astronomy had become a branch of physics, and that the boundary between the fields was practically nonexistent.

When Shapley succeeded Edward C. Pickering as director of the Harvard College Observatory in 1921, he quickly exploited the rich legacy of spectroscopic data that had been amassed there over the past four decades. While Pickering's staff had collected vast quantities of stellar spectra and brightnesses, Shapley collected staff and increased institutional focus and prominence in areas now identified with modern astrophysics. At Harvard and Radcliffe, he established an astronomy graduate program, which in 1923 attracted the brilliant Cambridge University student Cecilia Payne, and later brought in Donald Menzel as an instructor who also became a center of attraction for students desiring training in modern astrophysics.

Shapley's staff-building in the 1930s yielded impressive results. But these were the depression years, and it was far from clear that he was going to achieve the economic stability necessary to maintain the constant flow of professional visitors from abroad, the staff of young superstars, and funding for the best students. Shapley therefore looked for innovative schemes that would, on the one hand, increase Harvard expertise in modern astrophysics, but would also increase the prominence and prestige of Harvard astronomy, and thereby further ensure continuing support.

In this article I focus on one such

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Informal discussion during an afternoon tea at the Harvard summer school in astronomy, 1939. From left to right in the foreground are Bart Bok, Jan Schilt, Peter van de Kamp, Jan Oort and Harlow Shapley. (Photograph by Dorothy Davis Locanthi, AIP Niels Bohr Library, Dorothy Davis Collection.)

innovative scheme—the Harvard summer school in astronomy, which Shapley established in 1935 after several unsuccessful attempts. What Shapley's plans and motives were for the school, how he gained support for it and how it was structured help to illustrate the state of modern astronomy and astrophysics at Harvard and in the United States generally during the mid-1930s.

Also, the origins, development and influence of the Harvard summer school in astronomy, which was the first of its kind in the United States, reveal one way an emerging hybrid discipline sought to achieve the status of a fully integrated science. And finally, recalling this episode in the history of astronomical education and professional development aids in understanding the phenomenon of the growth of such summer schools and conferences, which are quite common today in hybrid disciplines.

No published accounts of the lectures, addresses or general proceedings of the Harvard summer school have been discovered. This article is based, therefore, upon surviving records of the summer school in Shapley's papers at Harvard, and upon extensive interviews with the many summer school participants, conducted in recent years under the auspices of the American Institute of Physics Center for History of Physics.

Origins of the summer school

Shapley used the University of Michigan summer school in theoretical physics as a model for the Harvard summer school. Established in 1927 by Harrison M. Randall, chairman of Michigan's physics department, the Michigan summer school became famous as a place to learn about the latest advances in modern physics through lectures by distinguished and active practitioners, and through intense leisure activities and informal living arrangements, all designed to bring people together to talk physics.[4] This model was tailor-made for the highly social Shapley, who, with Bart Bok and Harry H. Plaskett, attended one of the Michigan sessions and came away with the conviction to implement the idea at Harvard.[5]

Possessing both superabundant energy and legendary charisma, Shapley had a long and successful record of getting support for visiting scientists to lecture on their specialties. In 1929, Edward Arthur Milne from England, Svein Rosseland from Norway and Albrecht Unsöld from Germany gave lectures at Harvard on their stellar atmosphere research. Milne was in the United States to attend sessions of the Michigan summer school, and Shapley persuaded him to stop at Harvard. Unsöld was in the US to exploit Mount Wilson's spectroscopic plate collection and solar instrumentation.

Shapley was not a theorist, although he naively dabbled in occasional theoretical speculation. He liked to associate with the illustrious theorists who visited Harvard and he worked hard to get them to stay, as did Struve at Chicago. While the visits arranged by Shapley proved to be memorable, they were sporadic and piecemeal. His own attendance at the Michigan summer school in the late 1920s convinced him that institutionalizing these visits by distinguished theorists was the best way to develop a strong theoretical component at Harvard.

Plaskett, a junior Harvard faculty member from the Dominion Astrophysical Observatory in British Columbia, and a spectroscopist in need of a firmer understanding of physical theory, encouraged Shapley to reproduce the Michigan model at Harvard. Harvard did have a general summer program of courses for nonspecialists and graduate-level research courses. During these depression years, however, even the popular undergraduate courses were running a deficit—a poor situation because the summer school had to operate on a profit-making basis. Still,

Shapley initiated a plan in 1932 to invite several specialists in the summer, "as an entering wedge" for the summer graduate school.[6] But the plan failed.

After a poor showing that summer, the director of the summer school decided that the astronomy offerings should be dropped in favor of more profitable courses. Shapley sarcastically pointed out that by the same argument the summer school itself was a luxury, and so was the observatory and the entire astronomy program, so they should all be dropped. Shapley objected to the profit motive, and felt that the summer school was weak because of it. He pointed[7] to the prestige of the Michigan summer school and several other schools around the country, and added that Harvard could easily build up "the leading summer school of graduate astrophysics on the planet" at an expense of some $3000.

Shapley wished to provide continued advanced training in the summer months so that the observatory would not become dormant. Harvard College Observatory possessed the largest photographic and spectroscopic plate collection in the world—a vast and unique resource for stellar and galactic astronomy. Astronomers worldwide sought summer research appointments at the observatory, and for years Harvard's financial resources were sufficient to bring visitors for extended periods of time. With the depression, these resources disappeared, and Shapley knew that a program such as a Harvard graduate summer school in astronomy would offer replacement funds to bring in these visitors, who in turn would greatly enrich Harvard projects and prestige by their presence and collaborative efforts.

In the fall of 1934, Kirtley Mather, a geologist and strong campus ally of Shapley, became the new director of the Harvard summer school of arts and sciences. Through Mather, Shapley was finally granted the necessary funding, and plans went ahead for a summer school in astronomy in 1935. Shapley felt that with the requested $3000, primarily for stipends for outside lecturers, and "some vigorous volunteer help on the part of our own staff . . . it should not be difficult to make the Harvard department and Observatory a regular summer mecca for astronomers of the eastern colleges and universities. . . ."[8]

Shapley saw "glory, publicity, service, and scientific advance" in the graduate summer school, and believed it to be a pioneering effort in astronomy, as well as an example for other Harvard departments. Aside from examination of this rhetoric, one can get some indication of Shapley's goals by looking at whom he invited to lecture in the seven years of the summer school.

The first session

In 1935, Shapley invited Struve, Jan Oort, Antonie Pannekoek and Ira S. Bowen to be his primary outside lecturers. Struve, director of the Yerkes Observatory, practiced spectroscopic astrophysics and advocated the blending of astronomy and theoretical physics. Oort, of Leiden, made the first observational demonstration of the differential rotation of our galaxy. Pannekoek, the oldest summer-school participant, was legendary in statistical astronomy and spectroscopy. Only Oort was unable to attend the 1935 sessions, although he came in later years.

These three invitees were astronomers. The fourth, Bowen, was approached because, as Shapley noted to Mather, he was "more physical than astronomical." Bowen specialized in optics and laboratory spectroscopy. A student and associate of Robert A. Millikan, he had in 1927 discovered that nebulium, the enigmatic strong spectral feature of nebulae first detected in the 1860s, was caused by forbidden transitions of ionized oxygen and nitrogen. MIT also invited Bowen to participate in its summer conferences in spectroscopy that year, so Shapley hoped to share Bowen with MIT, and saw the liaison as a fruitful step that would be good for astronomy, physics, Harvard and MIT. He noted to Mather: "The MIT Group will in turn feed into our longer and more serious astrophysical efforts."

Struve's presence would be beneficial to many of the Harvard staff, including Menzel, Fred Whipple, Theodore Sterne and Cecilia Payne (Payne-Gaposchkin after 1934), all of whom were interested in stellar atmospheres. Both Bowen and Menzel were concerned with the nature of nebulae. Pannekoek could aid in Bok's research on galactic structure and Whipple's interest in the spectrophotometry of Cepheid variables. Shapley told Bowen that Payne-Gaposchkin and Menzel would both follow Bowen's lectures closely, but that because most astronomers were relatively untutored in physics, some elementary groundwork had to be laid.

Shapley also needed assistant lecturers and demonstrators. He turned to past students and also brought in promising junior faculty from other universities and observatories. His former students were delighted at the prospect of a summer at Harvard. Shapley offered a chance "to gather here in a pleasant group a lot of sources of astronomical inspiration and information. . . ." To this, Peter Millman replied[9] that he was very anxious to keep studying and learning, "and in a place like Toronto where there is no group interested in astronomical research I think that something like [the] advanced summer school is very important." Toronto had just installed a 74-inch reflector, so it was not due to lack of instrumentation that Millman longed for Harvard.

To increase enrollment, Shapley advertised in *Science* and in such astronomical publications as *Popular Astronomy* and *The Telescope*. Notices even appeared in local newspapers. Clearly, he hoped to attract many teachers of astronomy who could benefit from renewed contacts with practicing astronomers and physicists.

The summer school's first year included courses on the structure of the Milky Way, organized by Bok, "Cosmic Physics" with Bowen and Menzel, "Astrophysical Problems" with Pannekoek, and "Stellar and Interstellar Problems" with Struve. There were also general courses for undergraduates, refresher courses, as well as a series of topical seminars—Shapley's famous "Hollow Squares" colloquia—and popular evening lectures given in conjunction with the Amateur Telescope Makers of Boston. The "Hollow Squares" seminars, named for the arrangement of the tables, centered around short presentations of work in progress, or recent articles in the literature, and were free-for-alls that allowed for the fruitful exchange of ideas. They have been recalled by a good number of participants as memorable and valuable experiences.

Shapley put Bowen and Menzel together as co-lecturers on "Cosmic Physics"—the application of atomic theory to the study of gaseous nebulae and to the interpretation of stellar and nebular spectra. Menzel had already contributed considerably in this area, and throughout the remainder of the decade, he collaborated with a number of younger Harvard staff and students to produce a long and seminal series of studies on ionization phenomena in gaseous nebulae. Of course, Shapley made no secret of such manipulations. In writing to potential outside lecturers, he often noted their value to the research interests of his own staff.

Soon after the close of the 1935 sessions, Mather asked Shapley about his plans for the next year, noting the importance of 1936 as Harvard's tercentenary. Shapley responded[10] that it would be no difficulty to bring a distinguished body of astronomical visitors to Harvard again because

> The 1935 Summer School of Astronomy apparently made a great impression among American and European astronomers. Five prominent European astronomers

Harlow Shapley. (From AIP Niels Bohr Library, Shapley Collection.)

have already slyly hinted as to their availability, and the comments that are coming in from American astronomers have been most gratifying. It was an astonishingly good job. It should help to indicate to other departments that the name and reputation of Harvard are both assets in any attempt to do first-class graduate work in the summer school.

Endorsements from 1935 session participants were indeed positive, although surviving letters all postdated Shapley's remarks to Mather. From Pannekoek, Shapley received a warm letter[11] in late October supporting the school,

> . . . where young astronomers gather to hear and discuss some important selected parts of science in full, as a unit, whereas in ordinary conferences of Astronomical Societies the attention is divided in[to] a big number of small separate points. I am glad I was able to attend to this experiment.

Part of Shapley's success in getting astronomers to participate derived from his talent to make them feel their specialties were being respected. To Frank Schlesinger, director of Yale University Observatory and a major figure in positional astronomy, Shapley indicated that in 1936 the astrometric offering would expand to include lectures by Peter van de Kamp, then of the University of Virginia and an ardent disciple of Schlesinger's photographic techniques. Schlesinger, who participated in the 1935 sessions, in turn heartily endorsed[12] the summer school as a "feast of thoroughly cooked dishes," and expressed personal satisfaction at being one of the cooks.

While the primary accomplishment of the 1935 session was to increase contact with modern issues in observational astrophysics, it also succeeded in bringing attention to the existence of Harvard's astronomical programs. The following years did see an increase in the modern physics offerings, but the emphasis remained within observational areas, even though many unique interdisciplinary topics were developed.

Subsequent sessions

For the 1936 sessions, Shapley planned a multidisciplinary course to attack the problem of the cosmic time scale. Thus he invited lecturers in physics, geology and astronomy. He asked Alfred C. Lane from Tufts to speak on the age of the Earth, Georges Lemaître to lecture on the expanding universe and derived cosmological time scales, and Knut Lundmark, a Swedish specialist in observational cosmology and a general encyclopedist, to talk on various aspects of cosmology and the history of astronomy. Others invited included Schlesinger and Russell and, from the Harvard staff, Whipple to talk on the theory of orbits, Sterne on theoretical modeling of stellar interiors and stellar time scales, and Bok to speak on the general problem of time scales, especially the problem of the vast differences between time scales derived from different measurements—disruption times of star clus-

James Baker's summer school diary—annotated excerpts

Student's view. James Baker took this photograph during the 1935 summer session. It shows Bark Bok (center) engaged in conversation, with Otto Struve (left) and Peter Millman (right) looking on. (Photograph courtesy of Owen Gingerich.)

Twenty-year-old James Baker arrives at Harvard from Louisville, Kentucky, on the first of July, 1935. After a stop at the local YMCA for a map and a shower, he walks to the observatory and immediately runs into Bart Bok, who appears "very keen and speaks very quickly but with a peculiarly Hollandish accent. He is very interesting." Within hours Baker attends lectures by Donald Menzel on planetary nebulae, and by Bok on stellar statistics: "He began with some fierce-looking equations, although I believe it's mostly my ignorance of the notation and symbols." That evening there is a meeting at the observatory; next week there will be a joint spectroscopic conference at MIT and a picnic at Oak Ridge.

2 July: "Things are happening here so rapidly that I can hardly keep up. . . ." Baker registers for Otto Struve's course, "Stellar and interstellar problems," noting "It's going to be very technical." "All four of the lectures have assumed a preknowledge of the subjects. . . . Dr. Bok is certainly very nice . . . very witty . . . he was about to give me $15 to register . . . but Miss Mohr found out that I can have my money anytime." Baker also attends lectures by Ira Bowen and Antonie Pannekoek.

3 July: ". . . Dr. Bok hunted me up . . . and provided a desk. . . . Everyone treats me with courtesy and consideration. . . . This afternoon I attended the first colloquium and had tea beforehand. . . . I walked around the campus. . . . The place is covered with antiquity and majesty."

5 July: "I wonder what I may do research upon? . . . Among the students one hears of comparators, calculating machines, densitometers, photoelectric photometers, and other modern improvements. The atmosphere here at Harvard is one of the main charms. . . . We had tea and cakes again at the colloquium and talked a great deal. . . ."

6 July: "I'm sure that I shall want a brief vacation after Summer School is over. I've never studied just one subject for such a long time before."

13 July: "Books are almost entirely disregarded and original papers are read. I attended a beautiful lecture on the local cluster by Dr. Bok . . . and attended a . . . colloquium after tea. The colloquium was excellent. Subject: 'The Color Temperatures of the Stars,' by Dr. Pannekoek. I certainly admire this old astronomer of about 65. He is probably the best lecturer here and has done an enormous amount of work. He and Dr. Bok spoke Dutch today."

15 July: "Dr. Bok gave me a book today which he said wasn't on my book list. I'm becoming very much interested in the lectures on the Milky Way."

17 July: "I've just been to a very interesting colloquium on the time-scale, from which we concluded that our atoms are something like 3×10^{10} years old. . . . [At] the class conference . . . I was instructed to learn about nebulous stars and to begin some kind of research upon them."

18 July: "After reaching magnificent MIT, we listened to about six lectures on spectroscopy. (Even the blackboards go up and down by electric motors and the lighting is excellent.) Afterwards a few of us visited the spect. lab. downstairs. One room contained a 21-foot circular spectrograph and another a ten meter spectrograph completely free of the building, a building within a building. We saw interferometers . . . photography, all elements and sources of excitement, 60 000 line gratings in the original, etc."

19 July: "Meeting men who have been myths in the past to me is common p[lace] now. Present today [at the picnic] were Dr. K. T. Compton, Struve, Bok, Menzel, Bowen, Boyce, Wolf, Mack, Whipple, and other dignitaries. Dr. Bowen, famous for identification of nebular lines, drove me 30 miles back to Cambridge, and discussed ordinary affairs with his wife and me."

24 July: "My original research went to pieces on nebulous stars because the looked-for abnormal reddening was due to Dr. Struve's not reading the whole article and the author's misuse of the term 'color-excess.' Now I have a very good problem on determining the distribution of cosmic calcium clouds in the Galaxy, [to] stellar distances of 300 [parsecs] by the galactic rotation method." Struve advises Baker in this research, but Bok cautions that Plaskett obtained no results by this method.

28 July: Menzel advises Baker on courses for the fall. "I shall probably take Astrophysics, Stellar Statistics, Introduction to Astronomical Research, Theoretical Physics, and either Complex Variables or Theory of Functions. . . ."

3 August: ". . . a most unusual and enjoyable day. All of us obtained rides for the 50-mile journey [from the observatory to the summer beach home of a friend of Shapley's for archery, baseball, deck tennis and swimming]. After watching Dr. Shapley sit down by himself on the lawn, take out his bottle of rubbing alcohol and put in a variety of ants (300 species in Massachusetts), we ate lunch."

19 August: "Dr. Shapley gave me a nice project in working on Beta Lyrae. . . . I afterwards spoke to Dr. Bok who told me that I had gotten an A in my course. . . . I also purchased my first paper for 10 days. I knew nothing of Will Rogers' or Post's deaths nor of the impending diplomatic crises."

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Excerpted from letters and diaries compiled by Elizabeth Baker and James Baker, 9 August 1983, and kindly made available by Owen Gingerich.

Harvard summer school, 1936 session. Seated, left to right: Loring B. Andrews, Donald H. Menzel, Fred L. Whipple, Knut Lundmark, Leon Campbell Sr, Harlow Shapley, Meg Nad Saha, Theodore Sterne, Rupert Wildt, Jenka Mohr, Paul Merrill, Sergei Gaposchkin. Standing, left to right: Henrietta Swope, Carroll Anger Rieke, Florence Campbell Bibber, Leah Allen, James Cuffey, Helen Dodson, James G. Baker, Carl Seyfert, Alice H. Farnsworth, Harold Lane, Helen L. Thomas, Wallace Eckert, Lois Slocum, Frances W. Wright, Jesse Greenstein, George Z. Dimitroff, Rita Paraboschi (Mrs. Cuffey), Herbert Grosch, unidentified, Elizabeth Baker, Barbara Cherry (Mrs. Martin Schwarzschild), John Evans, Charlotte Klein, Daniel Norman, William Calder, Frank K. Edmondson, Richard Emberson, Richard Leary, Leo Goldberg, Dorrit Hoffleit, Rebecca Jones, Bart J. Bok, Sidney W. McCuskey, Samuel L. Thorndike, (Bancroft Sitterly or Martin Schwarzschild?), Arthur Sayer. (Photograph courtesy of R. S. Choudhury. Identifications courtesy of James Baker, Owen Gingerich and Martha Liller.)

ters, rates of stellar evolution, the Hubble constant.

This second year was the most active and hectic year of the summer school's short life. Plans continually changed. Lemaître could not attend, and a difficult situation arose when Harvard imposed a loyalty oath upon all outside lecturers, demanding that they pledge allegiance not only to the United States, but to the Commonwealth of Massachusetts. Many initially declined; Schlesinger of Yale noted that if Connecticut were to go to war with Massachusetts, he would have to side with his own state. Shapley was humiliated by this outrageous requirement, and eventually had it waived, but not before Lane was dropped from the roll. Replacing Lane was William D. Urry of MIT, a specialist in meteorite ages and a frequent collaborator with those at Harvard interested in meteoritics, including the Estonian peripatetic genius Ernst Öpik. Another replacement was the recent German emigré, Rupert Wildt from Göttingen, who was one of the first of many Europeans to enjoy the support of the Harvard summer school in seeking a haven from the iniquities of the Nazis.

To observe Harvard's tercentenary in proper style, Shapley planned commemorative ceremonies and symposia. He invited the American Astronomical Society to have its 1936 summer meetings at Harvard, and asked many people to stay the entire summer. Shapley invited Meg Nad Saha, primarily as a representative of India to the tercentenary, secondarily as a participant in the summer school, and finally as a commentator at the AAS meetings. Shapley thought it was most important to bring Saha, "who is the father of the Saha Theory and therefore the grandfather of about forty Harvard Observatory papers and five hundred from elsewhere."[13] Saha, the first to apply the theory of ionization to solar and stellar atmospheres in 1920, was an attraction for many younger astronomers, as well as for Russell, who was to lecture on the composition of the stars, and for Pannekoek, who lectured on the stellar temperature scale. According to Shapley, Saha would be in good company at Harvard that summer, as Niels Bohr, Werner Heisenberg, Albert Einstein, Arthur Compton, Arthur Eddington and Millikan would be there. While we do not know how many of these people actually came, we do know that Shapley did not hesitate to advertise the possibility as an inducement for others to attend.

Saha saw the opportunity to spend the better part of the summer at Harvard as a happy thought. He was isolated in Allahabad, and was not able to pursue astrophysics there. This opportunity to travel rekindled many of his research interests. En route to Harvard, Saha attended Bohr's conference on nuclear physics at Copenhagen in June 1936, and brought with him to Harvard a transcript of the conference. At the last moment, Shapley asked Saha to give a colloquium on the proceedings of that conference. In those years, astronomers were becoming aware that the key to understanding the energy source of the Sun and stars was to come from nuclear physics. Several at Harvard, including Bok and Sterne, were interested in such problems, as were many of Harvard's visitors and short-term lecturers, such as Martin Schwarzschild and S. Chandrasekhar. After 1938 and Hans Bethe's announcement of a fusion mechanism that explains the power of the Sun, Shapley made sure that a representative from nuclear physics was in attendance at the summer school. He couldn't bring Bethe, who had his pick of choice summer research appointments, but in 1939 he did manage to bring Robert Marshak, one of Bethe's young students and collaborators.

As in 1935, the 1936 summer sessions dealt heavily with spectroscopic astrophysics. With people from Mount Wilson, Yerkes, Harvard and elsewhere in attendance, a fair fraction of the country's spectroscopic workers capable of applying physical theory were together discussing mutual interests.

Henry Norris Russell and Harlow Shapley traveling to the 1938 International Astronomical Union meeting in Stockholm. (Photograph by Dorothy Davis Locanthi, American Institute of Physics Niels Bohr Library, W. F. Meggers Collection.)

Another theme of the AAS meetings and tercentenary sessions was a "Joint Session of Mathematicians and Astronomers," again organized by Shapley. Here, Eddington discussed "cosmological constants," and Tullio Levi-Civita spoke on "relativistic problems of several bodies." The heavy dose of mathematical cosmology proved quite stimulating to Bok and to Princeton cosmologist Howard P. Robertson, and encouraged Shapley to include a course by Robertson on the theory of relativity in two following summer sessions.

Shapley noted to himself early in October 1936 that he wanted Robertson to return to teach an extensive course on mathematical relativity. Shapley asked John Slater of MIT to introduce quantum mechanics to astronomers, and Brian O'Brien of Rochester to review stratospheric exploration techniques and ultraviolet solar research. Saha also visited in 1937, and both he and O'Brien discussed in detail their hopes for balloon-borne stratospheric solar observatories. Shapley also invited Charles Edward Kenneth Mees of Kodak, a longtime friend of astronomy, to give lectures on photographic theory.

Robertson, who was already a recognized figure in mathematical cosmology, looked forward to returning to Harvard in 1937, chiefly because it would give him a chance to become more familiar with observational cosmology, specifically observational aspects of general relativity. He and Shapley corresponded frequently on various matters of mutual interest, which widened during the summer of 1937. Bok recalls that Robertson's lectures and contributions to the Hollow Squares seminars were stimulating highlights. Robertson later noted to Shapley that his summer contacts rekindled an interest to examine the two-body problem in general relativity, the luminosities of receding galaxies and the dynamics of stellar systems.

The 1937 sessions, now called "Summer Conferences," came through on a balanced budget. An elated Mather was thus shocked to learn that no astronomy would be offered in 1938, because all astronomers would be traveling to Stockholm for the International Astronomical Union general assembly. However, the conferences resumed in 1939, and continued through 1942, when the war disrupted all normal activities of the Harvard College Observatory.

In the last three years of the summer school's existence, Robertson, Slater and Marshak attended. Lyman Spitzer, then of Yale, discussed his recent revelations that ruled out the encounter theory as an explanation of the origin of the solar system and forced astronomers to rethink how the system could be formed at all. Russell visited again and talked on many different topics, and many prominent displaced scientists from Europe lectured. Starting with the 1937 session, Menzel became the general manager of the program. His participation ensured a strong, consistent focus on the application of techniques of modern physics to problems in astrophysics.

Influence of the summer school

From what we have seen, it is clear that the summer school was not founded for the presentation of formal papers, or for the formal review of current research. Its purpose was advanced training, and retraining, of professional astronomers, students and teachers. However, the summer school was far more complex in motive and structure than this. It was a product of three conditions: the problem of ensuring the survival and continued health of a scientific institution during hard economic times, the remarkable blend of Shapley's social and professional styles, and the need for classically trained astronomers to learn the techniques of modern physics.

Harvard graduate student James Baker's letters, partially abstracted in the box on page 52, and the correspondence

and lecture notes of other participants, reveal that the summer school sessions were intense and happy times—a dream world for young students suddenly immersed in the intense Harvard atmosphere of study and play. Expertise on modern physics was readily accessible, as were the best spectroscopic data for projects assigned or self-created. And the Harvard atmosphere indeed survived, year-round, during these otherwise hard years.

In 1937, Shapley prepared for Mather a summary of the value of the summer school. He observed that it was unique in astronomy, bringing together leading astronomers, physicists, college instructors and students for mutual enrichment and refreshment. All participants, felt Shapley, gained insight into both old and new problems through the many technical discussions and informal contacts. Shapley was supported by many testimonies from those who attended. Pannekoek came away with an increased understanding of the physics behind the stellar temperature scale and a better appreciation for the physical meaning of stellar spectra. Saha's excitement for astrophysical problems was rekindled. The summer school helped Marshak gain access to computational resources at MIT and in New York that could further his studies of stellar structure, and in 1940 Bok reveled in William W. Morgan's successful defense of his new two-dimensional spectroscopic classification for stars in discussions with Menzel, Payne-Gaposchkin and Russell.

Shapley pointed out that new research programs emerged from the weekly "Hollow Squares" discussions, as well as from the numerous contacts visitors had with each other and with the data resources available at Harvard. Thus Robertson looked anew at various astronomical phenomena in the light of relativity theory, while others used the Harvard plate vault during their visits, and acknowledged its value in subsequent research.

Beyond gaining training in, and increased awareness of, new research programs, some participants, mainly the younger ones, enjoyed and profited from professional exposure at the summer school. One astronomer recalls that after he gave a lecture with Russell in the audience, Russell recommended him for the vacant directorship at Sproul Observatory: Thus Peter van de Kamp got the resources that allowed him to embark upon his life-long astrometric study of binary systems.

The most elusive legacy of the Harvard summer school, but possibly the most lasting, was the great emotional feeling of collegiality the experience offered. Harvard astronomy under Shapley was unique. Upon returning to India after the 1936 session, Saha wrote[14] to Shapley: "After two months at your observatory, one gets a bit spoiled and would very much like to have the characteristic Harvard, or—should I say the Shapley atmosphere!" The remarks of at least a dozen physicists and astronomers interviewed support this statement.

Bok recalled that on the average 50 to 60 people were drawn each year to all or part of the summer session, and that most were astronomers because few physicists had begun to appreciate the amenability of astronomical problems to physical explanation. It was usually impossible to tell how many people were actually in attendance at the summer sessions, because so many were constantly dropping in for shorter informal visits. Among those officially enrolled, according to surviving records in the Harvard University archives, astronomers did comprise the majority. One can identify some 65 astronomers who participated in some way during the first three years. Of these, 27 were from Harvard, 9 were from overseas, 13 were from large astronomical institutions and 16 were from smaller teaching institutions. Fourteen states were represented, as was Canada. The most prominent names were Europeans, and in addition to the 65 astronomers, one can identify 13 physicists.

The Harvard summer school in astronomy did not survive World War II. The ever-widening war changed many activities and priorities. In 1942, Harvard University went on a 12-month academic schedule, and special summer sessions designed for wartime training replaced all regular summer-school activities.

After the war, Shapley's political and social activities drew him away from the observatory, and his administration became more distant and indirect. Many activities ceased to function with their pre-war vigor, and one of the casualties was the summer school. It reverted to its original pre-1935 character, offering a small collection of introductory courses and a few directed research programs.

The legacy of the Harvard summer school in astronomy is not only the research it fostered as a forum for the introduction of modern physics into classical spectroscopic astronomy, but also the post-war summer schools founded elsewhere by Harvard participants. Organizers of conferences at Michigan, Berkeley and elsewhere recall the Harvard summer school as a memorable and intensely human episode in the maturing of modern astrophysics in America.

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