WALTER BAADE, OBSERVATIONAL ASTROPHYSICIST,
(1): THE PREPARATION 1893–1931

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1. Introduction

Walter Baade was one of the great astronomers of the twentieth century. He opened up the fields of study of stellar and galactic evolution that have made up so much of astronomy in our time, but which were sterile and unproductive before his discovery of the two stellar populations. Baade was lucky in being in the right place at the right time, but he was able to make the most of the situation, in ways that none of his contemporaries could.

Baade was a unique person, a great scientist who was also a great human being; a German who was widely admired, loved and respected in America, which had twice fought bloody wars with his country; a great teacher who claimed he did not like to teach, a research scientist who was not a professor but who left a generation of astronomers he had advised and inspired behind him. Widely considered ‘only’ an observational astronomer, he had in fact had an excellent training in astrophysics, and collaborated in research with astrophysicists all his life. His aim was to understand the universe, and he took us far along the path toward it.

Baade’s great discovery of the two stellar populations did not come to him out of the blue at Mount Wilson Observatory in 1944. His whole life was a preparation for it; the discovery was the culmination of his career, begun twenty-five years earlier, as an observational astronomer who sought physical understanding. A little, undated notebook he started as a young scientific assistant at the Hamburg Observatory, probably in 1921, bears the title “Stellar evolution”. What it actually contains are charts and reductions of variable star measurements in the globular cluster M 53, and references to papers on the spectra of nebulae, including not only gaseous nebulae, but also galaxies like M 31. But this is in fact the path he followed to open up the whole field of stellar evolution.

When Baade gave an invited paper on the two stellar populations at a 1947 meeting of the American Astronomical Society, he began by reviewing the steps “which led to the recognition of two distinct types of stellar population. What I want to show is that this conception emerged gradually during the last 25 years.”1 That quarter-century began in Germany, where Baade was born, educated, and trained in research, and where he began his own work on variable stars, globular clusters, local-group galaxies, and distant clusters of galaxies. Hence in the present paper we shall discuss Baade’s preparation, mostly in Germany but including one year spent in the United States on a Rockefeller Fellowship, up to
the time he left his native country to take a permanent position on the Mount Wilson Observatory staff.

2. Early Life and Education

Walter Baade was born in Schröttinghausen, a small town in Westphalia in northwestern Germany, in 1893, early in the reign of the young Emperor Wilhelm II. He was christened Wilhelm Heinrich Walter Baade, but was always known simply as Walter Baade. His father, Konrad, was a school teacher and later principal, and Walter was the eldest of their four children. The future astronomer received a classical education at Schröttinghausen and at the Gymnasium in Herford, a larger city where his family moved when he was ten.

It was at about the age of fourteen that he first showed an interest in astronomy. In 1912, when he was nineteen, he entered the nearby University of Münster, where he studied for one year before transferring to Göttingen, a university with a tradition in astronomy going back to Gauss. Baade had been born with a congenital hip defect, which made him walk with a pronounced limp. It saved him from field service in the German army in the First World War, and perhaps saved his life.

At Göttingen Baade took courses in astronomy, mathematics, physics, and geophysics. His teachers included Leopold Ambronn and Johannes Hartmann in astronomy, David Hilbert and Felix Klein in mathematics, and Emil Wiechert in geophysics, all of them famous in their fields. He worked for Klein as his assistant, and then spent two years in the army auxiliary service at Ludwig Prandtl’s Institute for Experimental Aerodynamics in Göttingen, while continuing as a part-time astronomy student. Baade did his astrophysical thesis on the spectroscopic binary β Lyrae under Hartmann, measuring, reducing and analysing spectroscopic plates that had been taken at Potsdam, and he received his Ph.D. in the summer of 1919, nine months after the Armistice that marked the defeat of Germany and the end of the First World War.

3. Hamburg Observatory

In 1919 Mount Wilson was the most famous observatory in the world. Its 60-inch reflector had begun work in 1908, the largest telescope then built. With it an outstanding staff, directed by George Ellery Hale and headed by Walter S. Adams, has begun making brilliant discoveries on the astrophysical nature of stars. In 1919 the 100-inch went into operation, giving the Mount Wilson staff again the largest telescope in the world. Baade, who was especially interested in astrophysics and in stellar spectroscopy (in which he had done his thesis) wanted to go to Mount Wilson immediately, to do research with the 100-inch as an unpaid volunteer ‘assistant’, more or less the equivalent of a modern ‘post doc’. This is just what Henri Chrétien had done in 1909–10, with the 60-inch, under the sponsorship of Nice Observatory. However, Baade’s professors advised him that such a
program would be quite impossible for a German citizen, less than a year after the Armistice. The 26-year-old newly-fledged Ph.D. would have to get a job in his own, defeated country.

Baade had heard through a friend, a fellow Göttingen graduate, of an opening for an assistant at Hamburg Observatory, and wrote to its director, Richard Schorr, to apply for the job. Baade's teachers, Ambronn and Hartmann, recommended him strongly to Schorr, emphasizing his thorough training in classical astronomy and his strong interest in astrophysics. Baade was "clever and industrious", "very apt and thorough", and "a very pleasant and amiable person" (a recurring description of him all his life). Hartmann advised Schorr to "grab him". The Hamburg director did so, and Baade started work in October 1919. Edwin Hubble, who had completed his Ph.D. thesis on "faint nebulae" (galaxies) at the University of Chicago in 1917, and had then served as an infantry officer in the American Expeditionary Forces in France, had started work at Mount Wilson just a month earlier.

The Hamburg Observatory was actually located in Bergedorf, a village outside the smoke and the worst of the light pollution of the big port city. With his job, Baade was assigned a two-room apartment at the observatory where he was required to live; his friend had not been hired because he was married and all the apartments in the "Observatory dwelling" were for single men only. Thus did Baade qualify for his first observatory position! Schorr, then 48 years old, had been the director since 1902. He was not famous for any research he had done, but he had earned his Ph.D. at Munich under a great teacher of the previous generation, Hugo von Seeliger. Schorr, a short figure, always erect and well dressed, concentrated on keeping on good terms with the rich Hamburg merchants and the important local and national officials who controlled his institute's budget.

Hamburg Observatory's main instrument was its 1-metre (40-inch) reflector, the largest telescope in Germany. Baade, young and eager, intelligent and quick to learn, soon made himself a master observer. Schorr, who had supposedly been using it himself, was busy and greatly occupied by his administrative tasks. He put Baade in charge of the reflector in 1920. The young Ph.D. was patient and skilful in guiding the long photographic exposures, yielding the accurate positions of comets and asteroids which Schorr, a classical astronomer, considered the most important work in his observatory. But Baade, reading the *Astrophysical journal* and the *Mount Wilson Observatory contributions*, was much more interested in variable stars, globular clusters, and other astrophysical research he could do by direct photography. In 1921 he wrote to Harlow Shapley, the new director of Harvard College Observatory, and to the older Solon I. Bailey, its former acting director, both variable-star experts, to describe his own discoveries in the globular clusters M 53 and M 92, and in the Orion Nebula. These research projects were closely related to the concept of the two stellar populations, then still a quarter of a century in the future. Bailey replied, congratulating Baade on his results and encouraging him to go on with the work, while Henrietta S. Leavitt,
the discoverer of the period–absolute magnitude relation for cepheid variables which was to form the basis for so much of Baade’s later work, replied along similar lines for Shapley.7

In the summer of 1922 the Harvard director went to Europe for the International Astronomical Union meeting in Rome, and met Baade at Bergedorf. Shapley encouraged the young German to continue his observational program on the variable stars in globular clusters. Baade’s results, which Shapley recognized as highly accurate, were useful to him in mapping the distribution of the clusters in the Galaxy, and measuring the distance to its centre. At Baade’s request, Shapley emphasized the importance of this work to Schorr, urging him to let his impatient young observer spend more time on it. Baade began a concerted program to find variable stars in the Milky Way, and study their distribution, another problem related to his future two-population concept.8

Even in these first real research projects of his own, Baade went well beyond Shapley’s scientific ideas. In the globular cluster M 53, Baade found many additional ‘cluster-type variables’ (RR Lyrae variables in today’s terminology), more than doubling the number discovered at Harvard. Shapley had shown that all the variables of this type in a given cluster, pulsating stars with periods shorter than a day and with a range in brightness of the order of 0.5 to 1.0 magnitude, have the same median absolute magnitude. Furthermore, he had assembled convincing evidence that this median absolute magnitude is the same for all globular clusters. Thus the cluster-type variables formed the primary basis of Shapley’s distance determinations of globular clusters.

Nearly every globular cluster had at least a few cluster-type variables (Baade, like Shapley, adopted their presence as the definition of a globular cluster in doubtful cases) and only a few fairly bright examples, such as RR Lyrae itself, were known to exist outside globular clusters. However, Baade, searching his first plates of M 53, found two faint variable stars over half a degree from its centre, far outside the recognized limits of the cluster. Realizing their importance, he switched to larger plates, to cover a larger field and thus survey a larger area for other possible variable stars. With the Hamburg f/3 reflector, the coma was very bad near the edges of this 2.5° × 3.4° field, but Baade, a careful, diligent observer, was able to focus, centre, and guide the telescope so that at least the images were the same on every exposure. Eventually, he discovered five more variable stars in the larger area which he would have missed if he had continued to use the standard-size plates.

Baade had made himself as expert as it was possible to be in the photographic photometry of his day, and set up a magnitude sequence of local standard stars in the sky near the cluster by comparison with one of the published Harvard regions. He could thus determine accurately the magnitudes of the seven variables on each exposure, construct their light curves, and determine their periods. Five of the seven turned out to be cluster-type variables (one of the other two was an unknown type and the other was red and had a period longer than 20
days, and thus presumably a long-period variable).

From their apparent magnitudes and Shapley's standard value for the median absolute magnitude of a cluster-type variable, \( M = -0.23 \), Baade could then calculate the distances of the individual stars, ranging from 16,300 light years (the units he used) for the nearest to 63,800 l.y. for the farthest. The cluster itself was at 72,400 l.y., measured in the same way. From the unavoidable measurement errors, and the small range in absolute magnitudes of cluster-type variables (as then known), Baade wrote that it was possible that the furthest of the five might be at approximately the same distance as the cluster, but the other four clearly were not only far outside its limits as seen in projection on the plane of the sky, but also in distance from the Sun. Furthermore, their distances were very large, and since M 53 and the field around it are at high galactic latitude, \( b = +79^\circ \) (the reason Baade was studying it), these isolated cluster-type variables were very far from the galactic plane, contradicting the received ideas of the time.

Baade, no doubt with a touch of irony, wrote that from the investigations of J. C. Kapteyn and others "we know that in the regions of the galactic poles the star density of our Milky Way system falls practically to zero at distances 10,000 to 12,000 light years". But these variable stars which he had discovered "show that, far outside the proper Milky Way, in the system extended by the globular clusters, individual stars occur whose distances are comparable with those of the globular clusters". This was Baade's first published statement on a subject to which he was to come back time after time for the rest of his life. It culminated in his announcement of the two stellar populations twenty-two years later, and he was still following it up in the last year of his life, observing RR Lyrae variables in "Baade's window" near the galactic centre with the Mount Stromlo 1.9-metre telescope. In his 1922 paper Baade merely wrote that he was investigating another, even more distant globular cluster, NGC 5053.9

Along with the galactic structure work, Baade kept up his assigned observations of asteroids, and discovered a new comet, for which he received a medal from the Astronomical Society of the Pacific. Schorr was pleased with his skilled, hard-working assistant and gave him raises regularly, though the runaway German inflation made the value of his salary uncertain.10

The Hamburg director was a great believer in accumulating observational data for future use, even for programs in which he was not directly involved himself. Thus he participated in, or sent out, many solar eclipse expeditions. On 24 January 1925 an eclipse was to occur, whose path of totality ran mostly over the North Atlantic Ocean. Schorr arranged to observe it from a freighter of the Hamburg-American Line, which would steer its course to be in the track at the right moment. He took Baade with him to help operate the cameras with which they would record the corona and prominences. They sailed from Hamburg and were at sea for more than a week before the eclipse (Figure 1). The day was stormy and the ship was rolling, but the sky began clearing and they managed to take a series of plates at totality; twenty minutes later the sky was completely
Fig. 1. Walter Baade (left) and Richard Schorr (right) with the ship’s captain, in the North Atlantic during the 1925 solar eclipse expedition (Hamburg Observatory photograph).
overcast again. After another two weeks they reached Philadelphia, where Schorr and Baade disembarked. They spent ten days visiting observatories in the East, Sproul Observatory at Swarthmore College, Allegheny Observatory in Pittsburgh, the Naval Observatory in Washington, and Harvard. It was Baade’s first sight of the United States. He and Schorr had to sail back to Hamburg from New York in mid-February, but he wanted to return to America as soon as he could.\textsuperscript{11}

Schorr and Baade had seen Shapley in Cambridge. They both thought that the time was ripe for Baade to come to America now, to broaden his astronomical experience. Schorr asked Shapley, already one of the most powerful men in American astronomy, for his help. The Harvard director told him that he thought that by now a German could get a fellowship to come to the States and work, although he was not certain. He would recommend Baade to the International Education Board, the arm of Rockefeller philanthropy that provided the main source of American financial support for European scientists abroad and in the United States. If Schorr could make part of the support available from Hamburg, the Rockefeller Foundation would probably pay the rest, Shapley wrote. He himself recommended Baade strongly to the Board, as “one of the very best of the young German astronomers”, and went on to boast that American observatories were the acknowledged world leaders in astrophysics, so that rather than Americans going abroad to study in that subject as they had a generation before, now the Europeans wanted to come to the United States.\textsuperscript{12}

Baade filled out an application blank (his first communication written in English) in which he stated he could speak German and English, and could read those languages as well as French, Latin, Greek and Hebrew. He proposed to do “astrophysical observations and investigations” during a one-year visit to several American observatories. Schorr (who had undoubtedly insisted that Baade should delay his return no longer) recommended him strongly as “a very gifted young astronomer, well trained in both the mathematical and physical sides”, with excellent practical astronomical experience and observing skills. He stated that he would continue Baade’s salary while he was in America on leave, if he got the fellowship, but that because of “present conditions” (the Weimar Republic inflation) he could do no more.\textsuperscript{13} Shapley had advised Schorr well; Baade got the fellowship and an important reason why he did was the 295 marks (approximately $75) per month salary which the Germans would provide. It showed the right “attitude ... in not wishing to load off the whole ... cost on the I.E B.” and would serve as a good example “for the stimulation of others” in the eyes of the foundation executives. The Board would also give him $75 per month plus his travel expenses for the round trip from Europe, and within the United States.\textsuperscript{14}

Baade was overjoyed; he professed to consider the fellowship grant a “miracle” and thanked Shapley profusely. His plan was to spend some time at each of the four major observatories in the United States, and to visit the Dominion Astrophysical Observatory in Victoria, British Columbia, as well. Baade was working hard, finding distant variable stars in the Milky Way and globular clusters,
and puzzling over the observational criteria that distinguished the latter from ‘open’ or galactic clusters, another forerunner of his population concept still two decades in the future. Shapley was already spending much of his time in administration, fund raising, and advising others; his comments on Baade’s work were generally diffuse and vague. The hard-working young observer’s letters, by contrast, were sharp, concise, clear and insightful.  

Baade had originally intended to go to America to begin his fellowship year in the autumn of 1925, but he postponed his departure from Hamburg until the end of the following winter, to write up and publish some of his observational results. One of these papers was on a subject dear to Schorr’s heart, a long list of the positions of comets and asteroids Baade had measured from photographs he had taken with the 1-metre reflector. Among them were several objects that he had discovered himself, including Comet Baade (1922 II); 944 Hidalgo, an unusual asteroid with a mean distance near Jupiter’s but a large eccentricity and hence an aphelion closer to Saturn’s orbit; 1924 TD, another unusual asteroid (later named Ganymede); and 966 Muschi, a more typical one which he had somehow managed to get named for his future wife, in spite of the then rigid rule that asteroids must be given names of goddesses and other female figures from mythology (except Trojan asteroids, which were to be named for male heroes of Homer’s Trojan War). She was Johanna (often shortened to “Hanni”, or less formally “Muschi”) Bohlmann, a ‘technical assistant’ (meaning a computer who worked with a hand calculating machine). She had begun work at the Hamburg Observatory in the summer of 1920, less than a year after Baade.

The other three papers that he finished before leaving for America were on the subject he greatly preferred, cluster-type variables in and near globular clusters. One purely observational paper listed the seventeen additional variables he had found in M 53, the globular cluster for which he had earlier published his more exciting discovery of the five cluster-type variables in the field outside it. His new variables approximately doubled the number known within this cluster, as published by Shapley.

The other two papers dealt with NGC 5466, like M 53 a distant globular cluster at high galactic latitude. NGC 5466, because of its relatively small number of giant stars, and its relatively weak central concentration, could be considered in some ways a transition object, intermediate between a globular and an ‘open’ (galactic) cluster. Baade, however, searched it thoroughly and found fourteen variable stars in it, twelve of which he was able to establish as cluster-type variables. Their median apparent magnitudes, with Shapley’s new value for the mean absolute magnitude of these variables, $M = -0.23$, gave a distance to the cluster of 19,000 pc (the distance unit Baade was now beginning to use). The presence of these variables established for him that NGC 5466 is a globular cluster, though a relatively sparse, low-luminosity one. Nevertheless Shapley’s secondary distance method, based on the angular diameter of the cluster, worked satisfactorily, Baade showed.
In his other paper Baade announced the discovery of five cluster-type variables in the extended field outside this same cluster, which he had begun studying after finding the variables outside M 53. He stated that as a check, he had then taken similar plates centred on the north galactic pole, but he found no cluster-type variables there. Hence he was surprised, he claimed, to find the five variables in the NGC 5466 field, somewhat brighter than the variables within the cluster, and therefore certainly outside it in radial coordinate as well as in the plane of the sky. Here then was a second example of a field at high galactic latitude, with an unexpectedly large number of field cluster-type variables, far beyond the bounds of the conventional Milky Way, in the region of the globular clusters. Further observations were necessary, he stated, to see if there was a connection between the globular clusters and the field cluster-type variables.\textsuperscript{21}

Baade finally completed all four of these papers inside a month, near the beginning of 1926. He finished the observational paper at the end of January, before sailing from Hamburg early in February. He must have made the final revisions on the other three while he was crossing the Atlantic, for he landed in New York on 14 February 1925, and the dates on the published papers show that he completed them by 1 March. From New York Baade headed north to Cambridge and Harvard College Observatory, where he was to begin his fellowship year.\textsuperscript{22} He was the first German astronomer to come to the United States on a Rockefeller Foundation fellowship, although a few German physicists, including Otto Laporte and W. Oldenburg, had preceded him, beginning in 1924. After Baade, the next German astronomer to receive one of the fellowships was Albrecht Unsöld, for 1928–29.\textsuperscript{23}

4. \textit{Wanderjahr in America}

Harvard College Observatory was but the first stop in Baade’s fellowship year, which he had planned to spend in working visits to the major American observatories. At each he talked with everyone, saw what they were doing, and participated in the work, including observing. He did not stay at any of them long enough to carry through a research project on his own, nor did he even collaborate with any single American astronomer sufficiently fully to coauthor a paper. But Baade did learn an enormous amount about observational techniques (some of which he adopted or improved, others of which he recognized as not as good as his own), and about what the Americans considered the most important research problems of the day, and were working on themselves. Even more importantly, Baade learned to speak and write American English very expressively, and he became acquainted with most of the leading observational astronomers in the United States. His own obvious skills and interest in research, together with his attractive, outgoing personality made them all remember him.

Baade stayed at Harvard for two-and-a-half months, until the end of April. He saw Shapley, then just forty years old, almost daily. The young Harvard director

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Fig. 2  Walter Baade at Yerkes Observatory in 1926 (Yerkes Observatory photograph).
dominated his large staff, and carried out a formidable volume of research, based on the effort of a corps of hard-working assistants, many of them women, who alternately loved him for his warm personality and hated him for exploiting them. Most of the observational data came from relatively small cameras, operated by assistants at Cambridge, at a nearby darker-sky site, and at the Harvard southern station at Arequipa, Peru.\textsuperscript{24} Although Shapley had done excellent globular-cluster research, and was beginning his work on galaxies, which at the least was important in defining the problems, Baade was clearly not impressed by his mass-production approach.\textsuperscript{25} Baade must have met Cecilia Payne (later Payne-Gaposchkin), the brilliant young astrophysicist, deeply interested in stellar spectroscopy, whom Shapley had brought to Harvard on a fellowship after she had taken her first degree at Cambridge, England, in 1923. After she completed her Ph.D. thesis at Radcliffe, which became the influential book \textit{Stellar atmospheres}, Shapley put her to work on (photographic) photometry, the technique Baade was particularly interested in exploring. No record of their impressions of one another survives, but years later she was to worship Baade's research on galaxies, and to edit his posthumous book \textit{Evolution of stars and galaxies}.\textsuperscript{26}

From Harvard Baade moved on to Yerkes Observatory, for the months of May and June (Figure 2). Its director, Edwin B. Frost, had been a graduate student in Germany for two years, and knew Schorr well. The Hamburg director had carefully prepared the way for his young protégé, Baade, whom Frost welcomed to the observatory. Scientifically, it was in its long, slow decline under Frost, a singularly uncreative astronomer locked into the traditions of the past. However, Baade there met Frank E. Ross, an outstanding expert in astronomical photography and photometry, and the young Otto Struve, who had come to Yerkes as a graduate student in 1921 straight from the remnant of the defeated White Russian army in Turkey, had earned his Ph.D. in 1923, and had immediately become the most productive member of the Yerkes staff. Ross was an irreverent, completely unpretentious scientist, with a keen wit and a sharp eye for the foibles of humanity, and he and Baade got along famously all the rest of their lives.\textsuperscript{27}

From Yerkes Baade went on to the Dominion Astrophysical Observatory, in Victoria, British Columbia, for a few days. Its 72-inch reflector had been the largest telescope in the world from 1917, when it went into operation, until 1919, when the Mount Wilson astronomers began making regular observations with the newly completed 100-inch. The DAO director, John S. Plaskett, welcomed Baade and showed him what was still the second largest reflector in existence. It was devoted largely to measuring radial velocities. Baade was no doubt interested, but anxious to move on to the California observatories.\textsuperscript{28}

From Victoria he travelled to San Francisco, probably by ship, and then on to Lick Observatory, which Schorr had visited himself in 1923, after a trip to a total solar eclipse in Mexico. Baade arrived at Mount Hamilton on 5 July, and spent the entire month there. Schorr had introduced him in advance, as at all the other American observatories, as a very well prepared scientist, eager to learn,
who was also “ein sehr netter Mensch” (“a very nice person”), and Robert G. Aitken, the associate director, was pleased to welcome him to the little mountain-top community. Lick had earlier been the most important observatory in the west, but its antiquated 36-inch refractor and its Crossley reflector (also a 36-inch) had been overshadowed since 1908 by the bigger telescopes on Mount Wilson. Aitken was a classical visual double-star observer, and Baade apparently worked most closely with William H. Wright, who was doing nebular research with the Crossley reflector, and to a lesser extent with Joseph H. Moore, who supervised the radial-velocity program, and Robert J. Trumpler, the young Swiss who had been Ambronn’s student at Göttingen before Baade. In his report after his return to Germany in 1927, Baade put Lick in the second rank of American observatories, with Yerkes, below Mount Wilson, and in his later reminiscences it figured largely as the location of stories about hard-working astronomers who still managed to do respectable work with old telescopes.29

Finally, at the end of July, Baade went on to Mount Wilson, his primary goal ever since he had received his Ph.D. Its director, Walter S. Adams, was generally less enthusiastic about visiting astronomers from abroad than Shapley or Frost, but he too welcomed Baade to take part in the ongoing research at Mount Wilson. Adams already knew of Baade from his published work on photographic photometry with the Hamburg reflector.30 Photometry was a Mount Wilson specialty, the elderly Frederick H. Seares the expert in it. His chief program was determining an accurate magnitude sequence to as faint a limit as possible at the north celestial pole, and transferring it to the Kapteyn selected areas all around the sky. Seares, like Adams, Frost and many other top American research astronomers of their generation, had done graduate work in astronomy in Germany. Baade worked closely with him, concentrating especially on standard sequences in selected areas he would use himself, and secondary sequences in the globular clusters and Milky Way fields he had observed or would observe at Hamburg. After his return to Germany Baade corresponded frequently with Seares about his latest photometric results, and used them in his own papers.31

Baade had begun to observe two fields in the Milky Way before leaving Hamburg, and in Pasadena was particularly struck by one of the variables he had found in Cygnus. Its period was 15.8 days, and its light curve an “exact copy” of W Virginis, a cepheid variable, but its apparent magnitude, together with its absolute magnitude from the standard period–luminosity relation, corresponded to a distance of 163,000 light years, so large it was “next to impossible”. He obtained additional exposures at Mount Wilson, and confirmed the period and apparent magnitude. He believed that probably an “obscuring cloud” (interstellar extinction) was the problem, but noted that this variable star was interesting in itself, because the Danish astronomer Einar Hertzsprung had recently found that the absolute magnitude of W Virginis itself did not seem to agree with ‘the’ period–luminosity relation. This discrepancy lay at the root of the difference between the period–luminosity relations of Populations I and II, and the consequent
doubling of the scale of the universe, which Baade was to come to understand a quarter of a century later.

During that same six months, Milton Humason obtained a 75-hour exposure of the spectrum of the nucleus of M 31, the Andromeda Nebula, which appeared to show that it is composed of dwarf G stars like the Sun. He had earlier found the same result for the slightly brighter nucleus of M 32, its companion. And Edwin Hubble confirmed, with the 100-inch, that the recently discovered Wolf-Lundmark-Melotte Nebula was indeed an irregular galaxy of the Magellanic Cloud type. It was a glorious time to be at Mount Wilson.

Baade must also have had many discussions with Hubble, then carrying out his epoch-making work showing spiral and irregular nebulae to be galaxies, based on identifying cepheid variables in them. Baade himself had discovered three of the brightest variables in M 33 in 1921 with the Hamburg 1-metre reflector, but had never published any details about them. Almost certainly they were among the rare, very bright, irregular variables that John C. Duncan and Hubble later reported in this bright, nearby spiral galaxy. Certainly when Baade returned to Germany in 1927, he carried with him not only the 60-inch plates of his fields that he had taken himself, but also some plates Hubble had obtained with the 100-inch, and lent to him.

During his six months in Pasadena, Baade also wrote and published two important semi-theoretical papers. One was his announcement of the method (now called the Baade method) of determining the radius and absolute magnitude (as functions of time) of a pulsating variable such as a cepheid variable, by integrating the observed radial velocity curve. Shapley had demonstrated, only a few years previously, that cepheids are not eclipsing binaries, as had earlier been supposed, and Baade's paper showed how the presumed "orbital parameters", derived from the entire velocity curve, could be used to give the most accurate values of the necessary integrals. The key idea of Baade's method is that the time integral of the velocity between two phases of equal temperature gives the difference in radius between them, while the magnitude difference between them gives the ratio of radii. The method was later improved by A. J. Wesselink, who removed Baade's assumption that the star radiates as a black body, and it is this later form of the Baade-Wesselink method that is used today.

The other paper was written jointly by Baade and Wolfgang Pauli, then a young docent and brilliant theorist of relativity and quantum mechanics at Hamburg University. Baade had met Pauli when he first came to Hamburg in 1921, and they remained close until the great physicist died in Zürich in 1958. Baade supplied the idea and the stimulus for their paper; Pauli provided the theoretical physics know-how necessary to carry out the calculations. They showed that using the best known data on the \( f \)-values (essentially, spectral line and band strengths) of atoms and ions observed in comets, including Na, CO\(^+\) and \( N_2^+ \), the observed curved shapes of comet tails could be quantitatively understood to result from light pressure from the Sun's observed spectrum. The idea of light
pressure as the repulsive force operative on comet tails dated back many years, but it was generally believed to operate on dust; their paper showed that it could also be understood to act directly on atoms and molecules.37

Both these papers demonstrated Baade’s easy familiarity with the latest, most quantitative observational data of astronomy, and his strong desire to understand and explain them in physical terms. He published these two papers, written at Mount Wilson Observatory, in Germany, to which he was soon to return. Baade left Pasadena in mid-January 1927, stopped at Harvard for several days to work on the plates that had been taken for him there of two fields he was investigating in the Milky Way, and sailed from New York on the Thuringia in early February.38

In his year in America, Baade had himself obtained a lot of scientific data, which formed the basis of several of his later papers. He had met many American astronomers, and they had all formed a good impression of him. He had learned to speak and write fluently in English, which he now began using in his letters to the United States. Financial problems were even more severe in Germany than they had been the previous year and the frequently cloudy skies were no better than ever. Baade was disappointed by Europe when he first got back, and confessed to feeling “very miserable”, an unusual state for the normally ebullient Baade. Very probably he was already hoping for a job at Mount Wilson, which in fact was to come just four years later. But in March 1927 he buckled back down to work at Hamburg Observatory.39

5. Back at Hamburg-Bergedorf

Baade arrived at the Hamburg Observatory in Bergedorf on 15 February 1927, and by 1 March he was back to a full observing program with the 1-metre reflector. Now, however, his horizons were widened by his stimulating visit to Mount Wilson. One of the first objects he photographed, as soon as it came around in the sky to where he could get it, was NGC 6822, the nebula that Hubble had just proved is ‘extragalactic’, or as we would say today, a galaxy. It was the first nebula for which Hubble had published all his detailed observational data on the cepheid variables, luminous blue stars, and gaseous nebulae within it, proving it was actually a “remote stellar system” within what came to be called the Local Group. At Mount Wilson Baade and Hubble had certainly discussed this paper, as well as Hubble’s later and even more important publications on the spiral nebulae M 33 (published in 1926) and M 31 (still work in progress while Baade was in America, and published in 1928). The young German astronomer wanted to jump into this work himself, as deeply as he could with his smaller telescope in a poorer climate.40

Schorr, his director, realized that Baade’s growing reputation would soon bring him attractive job offers from rival observatories, and so he secured Baade’s promotion to Observator, the post that traditionally led to the directorship. Baade
got the appointment in September 1927. Accordingly, the following summer when Kasimir Graff, the senior Observer, left Hamburg to become the director of Vienna Observatory, Baade became Schorr’s heir apparent.41 A year later Johannes Hellerich, formerly assistant at Kiel, was appointed to succeed Graff as the junior Observer, but Schorr always considered him as well below Baade in potential for the future.42

That same year Baade published a paper, based mostly on his earlier Hamburg material (now strengthened by magnitude sequences he had obtained at Mount Wilson) on the numbers of variable stars in his two Milky Way fields, in Sagitta and Cygnus. In both fields, he reported, there were about nine variables per square degree down to magnitude 14.2 or 14.4, and in each case by far the most numerous type was eclipsing binaries, followed by long-period variables, cepheids and irregular variables. These fields, near the galactic plane, are representative of what Baade was to call Population I fifteen years later, and the eclipsing variables he was to use as a marker of its presence.43 He also published his paper on NGC 5053, which he had begun years earlier at Hamburg, and had continued at Mount Wilson, with help from Hubble in the form of a 100-inch plate of this star cluster. It is a relatively loose cluster, with not many stars visible in it, and thus apparently an ‘open’ or galactic cluster. But its high latitude means it is far from the galactic plane, a property of globular clusters. That was the reason Baade had investigated it. He found nine variable stars in it, all ‘cluster-type’ variables, clearly indicating that it is a sparse globular-cluster, 19 kpc from the galactic plane (according to the then accepted distance scale), not an open cluster. He verified this by showing that the non-variable stars had the same luminosity function (numbers per unit magnitude interval) as those in M 3, a typical rich globular cluster, but that there were only about one-fourth as many stars in NGC 5053 as in M 3. Such extreme cases were always interesting to Baade, and at the end of his paper he pointed out that NGC 6366 is an even lower-luminosity globular cluster than NGC 5053.44 Shapley, to whom Baade had been writing in English since his return from the United States, called Baade’s paper “one of the most interesting contributions to the problems [of understanding star clusters] of the last year or so”.45 At about this time Baade was pointing out to Shapley the growing evidence Trumpler was finding at Lick Observatory, that interstellar extinction by dust particles exists, modifies the colour of stars, and makes them appear systematically more distant than they actually are. Shapley did not want to accept these observational results, because he knew they would vitiate his distance determinations to clusters, and hence the scale of the Galaxy that he had determined. The younger Baade was eager for new knowledge; the older Shapley was fighting to preserve old triumphs.46

In the summer of 1927 Baade had a relaxing interlude from observing with the reflector, a second total solar eclipse expedition with Schorr. This one was in Lapland, just a little north of the Arctic Circle. The Hamburg party, consisting of Schorr, Baade, Bernhard Schmidt (the optician), and a mechanician, made
the trip from Germany to Narvik, Norway, by coastal steamer, and then continued to the site Schorr had chosen at Jokkmukk, Sweden, by train and then car. Four other Hamburg astronomers and the young Dutch astronomer Willem Luyten, then at Harvard, came by the land route through Sweden and joined them there. The eclipse day, 29 June, was clear and they got all their plates; then returned by the road, sending their equipment back on the slower ship.47

Schmidt, an Estonian by birth, had lost his right hand and arm 'experimenting' with gunpowder as a boy, but in spite of this handicap had become an outstanding maker of telescope mirrors. Fourteen years older than Baade, Schmidt had been trained in vocational schools in Sweden and Germany, and had been making professional-quality mirrors since 1901. He had first come to Hamburg Observatory in 1918, as a free-lance optician who contracted to build a horizontal reflecting telescope for Schorr. The postwar inflation had driven him back to Estonia, but in 1926 he returned to Bergedorf, while Baade was in America. Schmidt carried out several more or less independent photographic projects at the Hamburg Observatory, and produced mirrors to the director's order.48
Walter Baade

Two years later Schorr stayed home himself, but sent Baade and Schmidt to the Philippine Islands to observe the solar eclipse of 9 May 1929. They sailed from Hamburg in early February, via the Suez Canal, and reached Manila a month and a half later. From there it was on by a smaller ship to the island of Cebu (Figure 3), where they located their telescopes near the University of Manila group’s site. 9 May was clear, but as the eclipse progressed, clouds began to form, and during the last 20 seconds of totality covered the Sun. Nevertheless, the photographs they obtained were usable. Because of the heat, they took the plates to Cebu City, where a commercial laboratory allowed them to use a cooled darkroom to develop them. Then, after packing their equipment for shipment, they left Cebu on 28 May, and Manila on 4 June, and finally arrived back in Germany after another voyage of a month and a half.

The lively young Baade and the morose Schmidt hit it off well, and on the long voyages out and back, and the boring two months in the little village of Sogod, Cebu, they had time to discuss subjects under the Sun — and stars. During their five months together Baade and Schmidt went over, time after time, the need for a fast, wide-field, coma-free reflecting telescope, to photograph large areas of the sky, in order to search efficiently for variable stars, nebulae, galaxies, or even planets. Within a year Schmidt, who a few years earlier had been experimenting with unconventional two-mirror systems, hit on the brilliant idea of using a primary spherical mirror (which is coma-free) with a thin glass corrector-plate at its centre of curvature, to remove spherical aberration. Thus the Schmidt camera (or telescope) was born, and in 1931 Schmidt himself was able to publish photographs taken with the “original Schmidt”, a 44-cm aperture, f/1.75 instrument.

The 1929 trip to the Philippines was Baade’s third and last eclipse expedition. Schorr had assigned him to go on all of them because he knew Baade had the observing skills and cool judgement necessary to get data during the tense few minutes of totality, with no chance to postpone the observations or to readjust the equipment and try again later. Nothing was ever done with any of these data; Schorr believed it was Hamburg Observatory’s duty to obtain them so they would be available for posterity, but he made no effective efforts to get anyone to reduce and analyse the spectrograms and direct photographs of the chromosphere and corona that he, Baade, and Schmidt brought back from their trips to the North Atlantic, Lapland and Cebu. Various Hamburg business firms, especially steamship lines, subsidized the expeditions, which, in terms of their results, were more combined publicity ventures and junkets than anything else. Baade had no choice but to go on these trips, and he doubtless enjoyed them at the time and kept Schorr, Schmidt and the members of the parties in high spirits. But all his life he regarded taking data for an unspecified purpose as a complete waste of time.

Baade did in fact receive an important job offer in Germany soon after his return from his fellowship year in the United States. Just as he arrived back at the observatory in Bergedorf, his friend Pauli sent him a note reporting that he had
learned that Jena University wanted to appoint Baade as director of its observatory, to succeed Otto Knopf, who was retiring. Always sarcastic, Pauli wrote that he did not know how large a telescope Jena had (in fact it was an 8-inch refractor), but he was sure that its weather could not be worse than Bergedorf’s. The official invitation came in January 1928, and Baade went to Jena to look over the situation and negotiate. His demands were high; he would come, he said, if Jena would get a 1-metre reflector (as large as he had at Hamburg) at a remote site outside the city, with a Cassegrain spectrograph, a staff of four assistants and shop personnel, new measuring machines and a greatly expanded astronomical library. He provided a detailed conceptional plan of his dream observatory. Baade wanted to do frontier research, not become the figurehead director of a tiny, old-fashioned observatory. Jena was the home of the Zeiss Optical Company, and Baade and the Thuringen educational authorities hoped that its Carl Zeiss Foundation would finance the new observatory. It was not to be, however; the amount required was far too high, particularly in those uncertain days of Weimar Republic inflation. When he learned he would not get the new observatory in Jena, Baade tried to use the offer to persuade Schorr and the Hamburg authorities to move their 1-metre telescope to a better site, but that too was out of the question.

In the end Baade declined the Jena directorship. Knopf, who had hoped that Baade would come as his successor, was sorry to learn of his decision, but believed that the young man had proved his idealism. However, Baade “respectfully” reported to the Hamburg authorities that he had declined a 2,000-Mark raise to remain at Bergedorf, and hoped that they would “consider this circumstance” in the near future. Schorr was overjoyed that Baade would stay, and recommended him strongly for a raise, describing him as “one of the most proficient young astronomers, both in the theoretical field as well as in the theoretical physics and mathematics that are so important for the development of modern astronomy, who also is outstandingly gifted in the practical observing art, and has a series of important results to show”. Baade would not have been happy if he had seen that in this letter the first three of these “important results” were his discoveries of the “especially interesting” asteroids Hidago (far outside the normal asteroid belt, beyond Jupiter’s orbit) and Ganymede (whose orbit is highly eccentric and whose perihelion distance is just outside the Earth’s orbit), as well as Comet Baade. These were the traditional subjects dear to Schorr’s heart, but after them the director also cited Baade’s latest nebular work. Very probably he received the raise although there is no accessible record of it.

More importantly in the long run, the Jena offer had been for an associate professorship as well as the directorship of the observatory. Thus the Jena faculty had demonstrated their opinion that Baade, who had a strictly research position at Hamburg and did no teaching there, was competent to lecture at the university level. Hence Baade could confidently apply for his Habilitation, the right to teach as a professor in a German university. He forwarded the necessary documents to the dean of the Mathematical-Physical faculty at Hamburg, and
was granted his Habilitation immediately, in December 1928.\textsuperscript{57} The next month, Baade delivered his inaugural lecture, on “The extragalactic nebulae as stellar systems”. This was to be the topic of much of his research for the rest of his life. His observational investigations of the nearest of these ‘extragalactic nebulae’ was to lead directly to his discovery of the two stellar populations fifteen years later.\textsuperscript{58} The day after the lecture Johanna Bohlmann resigned her position as a technical assistant at Hamburg Observatory, and she and Baade were married a few days later, just before he embarked for the Philippines. He was then 36 years old; the vivacious, attractive “Hanni” was just six months younger. They never had children, but they remained close until the day he died, thirty-one years later.\textsuperscript{59}

No text or notes have turned up of Baade’s inaugural lecture, but it probably had some areas of overlap with a lecture which he gave on “Recent investigations on extragalactic stellar systems” on 8 September 1930, at a meeting of a German scientific society roughly equivalent to the British Association for the Advancement of Science. The manuscript of Baade’s lecture shows that it was an excellent talk on the whole universe, aimed at scientists with no professional knowledge of astronomy (as most of those present at the inaugural lecture would also have been). After the introduction Baade briefly described the speculations of Thomas Wright, Kant and Lambert that there are star systems other than our Milky Way, then up through the surveys of the sky by William Herschel to Hubble and cepheid variables. Baade estimated that there were roughly two million “extragalactic star systems” within reach of the largest telescope of the day, the Mount Wilson 100-inch reflector. He told of clusters of galaxies, and of the velocity–distance proportionality that Hubble had discovered only a few years before. How to understand the result was a question for the future. Probably this understanding would come through the questions raised recently by Eddington, de Sitter and Lemaître. Whatever the solution would be, the last word had not been spoken, but the overriding meaning was that in the observed redshifts of extragalactic systems “we possess for the first time results of experience on which the structure of the universe [had made] itself felt”.\textsuperscript{60} This investigation of the early stages of the structure of the universe through observational studies of the redshifts of the galaxies (and quasars) has become one of the most active areas of research of the 1980s and 1990s.

This talk was well organized and at just the right level for its audience. Another, earlier talk he gave to the Scientific Society of Hamburg University in December 1927, on “The distances and dimensions of the extragalactic nebulae”, was much the same. It dealt with the observational determination of the distances to the nearby galaxies, and included a long section on the Hauptnova (‘chief nova’, Baade’s early word for a supernova, a very new concept at that time) in M 31.\textsuperscript{61}

Even before his inaugural lecture, Baade had begun publishing new, important results on ‘extragalactic nebulae’. In 1928 he had first photographed IC 1613 with
the Hamburg reflector, and recognized that it was not at all a nebula, as Max Wolf in Germany had reported, nor a group of small nebulae, as Heber D. Curtis at the Lick Observatory had thought. With his superior photographs Baade could see in fact it was a ‘star cloud’ (or dwarf irregular galaxy) of the same type as the Magellanic Clouds and Hubble’s NGC 6822. The brightest stars in it were very faint, with magnitudes from 17th to 18th. The small nebulae Curtis had seen were giant emission nebulae within it. Since the brightest stars were more or less the same magnitude as in NGC 6822, and the small nebulae roughly the same size, IC 1613 was at approximately the same distance as it. Thus it was one of the nearest galaxies known, a result “not without interest” as Baade put it.62

That same year he also discovered, with the Hamburg reflector, a “noteworthy new cluster of nebulae in Ursa Major”. He had noticed what appeared to be a “rare concentration” of faint “nebulous stars” off the axis of one of his plates, taken for another purpose. Following it up with long exposures centred on the concentration, he could see that it was a cluster of small, faint (extragalactic) nebulae containing about 160 objects to his plate limit. He showed it was a real concentration, and that its luminosity function was similar to that of the well-known Virgo cluster, which had been studied by Shapley and Adelaide Ames. From the relative magnitudes of a local maximum in the two luminosity functions, he calculated that his new cluster was 15 times more distant than the Virgo cluster, or using Shapley’s and Ames’s distance for the latter, $15 \times 10^6$ light years away. Baade’s new cluster of galaxies, which a few years later was dubbed UMa 1, was to play an important role in Hubble and Humason’s observational extension of the redshift–distance relation at great distances.63

In that same highly productive year, 1928, Baade also for the first time obtained direct plates with the Hamburg 1-metre telescope of two objects he was to work on very effectively for the rest of his life. One was NGC 147, which he was to resolve into stars with the Mount Wilson 100-inch in 1943, showing that it was a dwarf elliptical companion of the giant Andromeda spiral galaxy and one of the defining examples of a pure population II system. The other was M 1, the Crab Nebula, which he and others were to prove was the remnant of a supernova of nearly a thousand years ago, observed by Chinese astrologers, and one of the brightest radio sources in the sky.64

In 1930 Baade published an important paper on the very distant, high-latitude globular cluster NGC 4147, based on plates he had taken all the way back to 1920. Shapley, who had discussed this object previously, had not found any ‘cluster-type’ variables in NGC 4147, and had assigned distances of 51 kpc and 24 kpc to it in successive papers, illustrating graphically the uncertainties of secondary distance-determination methods. Baade did find three cluster-type variables in it (they are very faint in this distant cluster), and from his magnitude transfers from Selected Area 82, newly measured by Seares, determined the distance more accurately as 20 kpc, very nearly perpendicular to the galactic plane.65

Besides the RR Lyrae variables within NGC 4147, Baade found five more
outside the cluster, in the extended field around it that his plates covered (about 8 square degrees). Of these only one or at most two were at roughly the same distance as NGC 4147; from their apparent magnitudes one of the others was certainly much closer than it, and two others more distant. This confirmed his previous result, found in the fields around the other two high-latitude globular clusters M 53 and NGC 5466. The variables at roughly the same distance as each cluster could conceivably have escaped from it, but the others could not have done so. Baade emphasized this important result, that isolated ‘cluster-type variables’ occur in the same large volume as the globular clusters, extending out to distances of 25 kpc perpendicular to the galactic plane. This connection is “expressed”, he wrote, by the high space velocities that the members of both groups have. These isolated RR Lyrae variables are distributed everywhere in the sky, he continued, for he had found roughly comparable numbers of them even in his Milky Way fields in Cygnus and Sagitta.66 As he put it more graphically in a letter he wrote to Shapley while he was working up these results:

Perhaps you will remember that some years ago I found rather high numbers of faint cluster variables in high galactic latitudes. Just now I have finished the search for faint cluster variables in two other fields of high latitude. Result: again 5 resp{ectively] 6 faint variables of this type per 8 [square degrees]. Since in my fields in Cygnus and Sagitta I found practically the same numbers it seems reasonable to assume that I observed only the general distribution of cluster variables and that the concentration is spurious. The cluster variables in the Cygnus cloud then would be interlopers of the large nonrotating system as they are in our own neighborhood. The fact that no cluster is known which belongs physically to our nearer system whereas they are frequent in that sparse but very e[x]tended system of globular clusters (nonrotating system of Lindblad & Oort) makes me always wonder.67

Baade was here already very close to his idea of two stellar populations, and he kept “wondering” about it (and working on it) until he could announce the full concept in 1944: the flat, rotating population I system, identified by the blue stars of the Milky Way, exemplified here by the Cygnus and Sagitta fields, and the spherical, nonrotating (or slowly rotating) population II system, exemplified by the globular clusters and RR Lyrae variables.

In his correspondence with Shapley, Baade always discussed his quantitative results in detail, giving estimates of the probable errors of the magnitudes and derived distances, and outlining their physical meaning as he understood it at the time. Shapley, on the other hand, tended to gloss over details, but was fond of striking phrases, such as “delightfully faint” RR Lyrae variables, and the “nice thrilling puzzle” of the meaning of the isolated RR Lyrae variables. Baade could admit his own mistakes (which often led, when recognized, to further understanding) such as the distance he had derived for the Cygnus cloud, which now appeared “meaningless” to him, while Shapley tended to blame his failure to find the
RR Lyrae variables in NGC 4147, or to recognize the importance of "the fairly uniform distribution of cluster type variables", on one of his former assistants, who had been "not very expert". But Shapley was very glad to have Baade's "interesting" and "important" results, which he said he planned to mention in a colloquium discussion very soon (before Baade had published them), and wrote that he was sure that Baade's value of the distance to NGC 4147 was "essentially correct".68

Baade by this time was a very well-known, highly respected research worker, a superb observer who knew how to get every item of datum that was possible out of the detectors of his day, photographic plates. He had been experimenting with orthochromatic and panchromatic plates combined with various colour filters for several years, and knew just what they could and could not do. He was considered an expert on wide-field photography, and on the recently developed Ross lens, the best wide-field system then in existence (just before Schmidt had discovered the principle of his eponymous system, and announced it). Frank E. Ross had invented his own four-element lens system, and Baade had met him at Yerkes Observatory, discussed it with him there, used Ross's own camera, and persuaded Schorr to have a 4-inch model made for Hamburg Observatory.69

When the asteroid Eros, so small that it is almost always too faint to observe, swung very close past the Earth in 1930, it was quickly discovered, and several visual observers detected rapid variations in its apparent magnitude. These, if true, would be evidence that the asteroid was not spherical and was spinning on an axis, presenting different areas to the Sun and Earth as it did so, thus modulating the light it reflected. Baade, the expert in photographic photometry, devoted three nights to measuring accurately these variations, using his well-honed techniques, including setting up sequences of standard stars by comparison with the north polar sequence. He confirmed the variations, which had an amplitude of 1.0 magnitude and a period of 2 hours, 38 minutes (or double that value if the light curve had a more complicated form, with alternate maxima different). He also measured Eros's mean photographic and photoelectric magnitudes accurately, confirming that its colour index was approximately the same as the Sun's, and hence that its reflectivity (or albedo) was more or less the same as for other previously known asteroids, and establishing that the new one with the very peculiar orbit was "like" them in some sense.70 Earlier that same year, Clyde Tombaugh had discovered Pluto at Lowell Observatory, and in the autumn Baade determined several highly accurate positions for it, as other observers had done before him. The next spring he measured the distant planet's magnitude accurately.71 These were not highly creative projects, but they both required a fairly large telescope, and a highly skilled observer to carry them out. They were exactly the kind of astronomy that Schorr understood, approved highly, and praised in his recommendations for Baade.

Most of Baade's research at Hamburg was along much more astrophysical lines. He had met Rudolf Minkowski, a physicist who specialized in optics and spectroscopy, at Hamburg in the early 1920s. Minkowski had been interested in
astronomy from childhood (his father was a well-known professor of medicine, and his uncle, Hermann Minkowski, was the world-famous professor of mathematics, first at Zürich, then in Göttingen). Through their friendship Minkowski began collaborating with Baade on an astrophysical research program, to measure the line profiles of some of the strongest emission lines in the Orion Nebula at very high spectral resolution. They had probably begun discussing the physical idea of the program before 1927, when the origin of these lines (except for the well-known hydrogen and helium lines) was unknown. Measuring the widths of the lines would give a chance of determining the atomic weights of the elements that emitted them, if the main internal motions in the nebula were thermal rather than mass motions. However, in 1927 the Caltech laboratory spectrophotist Ira S. Bowen (many years later to become Baade’s director at Mount Wilson and Palomar Observatories) broke the puzzle and identified the other strongest lines as ‘forbidden’ lines of ions of oxygen, nitrogen, and neon, never produced in the laboratory. After that the motivation for the program changed to learning something about the mass motions in the nebulae from the line profiles, which was possible now that the atomic weights of the gases that emitted them were known. The instrument they used, with the Hamburg reflector, was a Fabry-Perot interferometer, an especially advantageous device for obtaining very great spectral resolution on a single spectral line at a time, together with reasonable sensitivity, particularly for an extended light source such as a laboratory gas tube or an area in the Orion Nebula. Besides taking part in their discussions of this important astrophysical problem, Baade’s other main contributions were to provide the link with Schorr and hence permission to use the reflector, and to help with the observations in the initial stages. Minkowski provided the ties to the Fabry-Perot interferometer and to the other two Hamburg laboratory spectroscopists who collaborated on the project, Fritz Goss and Peter P. Koch. Using the delicate interferometer under observing conditions in the dome required a long learning process, and many modifications to the instrument. The paper was not completed and published until two years after Baade had left Hamburg. He was listed as the first author (the four were named in alphabetical order) but it is obvious that he had little to do with the instrumental ideas that went into the paper, nor with the data reduction, analysis and discussion. For many years this was the only paper that contained results on nebular line profiles at very high resolution, and it was widely quoted and referenced.72

By the end of his years at Hamburg, Baade was recognized as one of the most important observational astrophysicists in Germany. In 1924–25, when Herman Zanstra, the young Dutch theoretician, spent a year at the Hamburg Physical Institute, Baade not only suggested that he work on planetary nebulae but also in fact supplied the crucial idea for the ‘Zanstra method’ which has proved so fruitful for the study of these objects. Zanstra returned to the Hamburg Observatory in 1930 to work with Baade in applying the method at the telescope. The next year the equally young Albrecht Unsöld came to work with Baade on measuring the
profile of the strong Hα absorption line in A stars.73 Both Zanstra and Unsöld were to become world experts in their respective fields.

In the summer of 1931, as Adolf Hitler and his Nazi party were gaining wide support in Germany, Baade completed a paper, on a second, even fainter and therefore more distant cluster of nebulae which he had discovered in Ursa Major. He had recognized it on one of his plates, which he followed up with several more long exposures. Even on the best of them the individual galaxies were barely brighter than the increasingly light-polluted night sky at Bergedorf.74 Five years later Humason, at Mount Wilson, succeeded in measuring the radial velocity of this cluster as \(4.2 \times 10^4\) km sec\(^{-1}\), the largest redshift then known.75

That same summer Baade also sent to press a paper, listing brief descriptions of many ‘extragalactic nebulae’ he had observed, fifty-four in all, giving brief descriptions in the style used earlier by Curtis at Lick Observatory, and Hubble at Mount Wilson. This paper summarized the results of many long nights of observing, in which Baade had honed his skills with the reflector, and had learned the detailed forms of many galaxies, the similarities between them, and the differences among them. One was NGC 147, which he described as “Very faint, structureless oval 7’×2’, P-A 155°, spiral?”. He did not yet understand this object as one of the dwarf, elliptical companions of the giant Andromeda spiral galaxy, but when he did, thirteen years later, it was the key to his recognition of the two stellar populations. Among the nebulae he reported on in his Hamburg paper, four were actual gaseous nebulae, one of them IC 443, which Baade described “as a smaller example of the well known Cirrus nebula in Cygnus (NGC 6995) to which it has a striking similarity in form”.75 Later, at Mount Wilson and Palomar Observatories, Baade was to recognize that both these nebulae are the optically visible manifestations of expanding shock waves about the remnants of supernovae tens of thousands of years old.

6. Mount Wilson to Stay

Baade finished his last three papers at Hamburg, including one on the variable star RS CVn, just before leaving permanently for the United States.76 Adams, the director at Mount Wilson Observatory, had offered him a regular staff position, and Baade had jumped to accept it. He was finally getting the opportunity he had wanted so badly twelve years before, to go to America and observe with the big telescopes, and this time he was going to be paid to do it (instead of coming as a volunteer, as he had hoped back in 1919), and to stay.

Mount Wilson Observatory was a research institution, not connected with any university but operated by the Carnegie Institution of Washington, endowed by funds from the enormously successful Scottish-American entrepreneur, Andrew Carnegie. Adams, an extremely productive stellar spectroscopist, had been the director since 1923, and he was responsible for recommending appointments of new staff members to John C. Merriam, the C.I.W. president, a geologist.
Adams had begun his campaign to hire Baade in the autumn of 1930, no doubt after many quiet conversations with his senior colleagues at Pasadena. Seares, then 58 years old, was tired of observing. He had begun when the 60-inch went into operation at Mount Wilson in 1909, and he had had enough of the long, tiring nights at the telescope. He planned to continue in charge of the observatory’s photometric program, but with a younger man to help him, who could take the plates at the telescope, and work with him on reducing them to measure the magnitudes and colours of the stars. Baade was probably the greatest expert in the world in this subject outside the Mount Wilson staff, and a most respectful, friendly, attractive figure as well, whom Seares had come to know and like during the months the young German had spent in California. In frequent correspondence Baade had asked intelligent questions, reported his results, and kept the older man informed of his progress. Whom better could Seares recommend to Adams for the job?

Adams could truthfully describe Baade to Merriam, in a preliminary memorandum, as “one of the most promising younger astronomers of the world”. His “observational experience” was “wide”, his “knowledge of theoretical astrophysics ... excellent”. Baade had “used reflecting telescopes for many types of work and has shown marked skill and resourcefulness”, while “[m]uch of his best work has been in photometric investigations, a field in which additional assistance is needed greatly at Mount Wilson”. Best of all, Baade had already spent some time at the observatory “and his ability and personal characteristics made a strong appeal to the members of our staff”, not least to Adams himself. Superficially friendly to visiting foreign astronomers, the director was at heart hostile to most of them, as he revealed in personal letters to his closest friends, including Charles G. Abbot, a solar radiation expert who shared Adams’s New England background. Adams had been outspokenly anti-German during the First World War, and his attitude had not changed, although he had become less vehemence. Yet Baade’s engaging personality had won him over. Adams wrote to Merriam that he was “not certain that it would be possible to secure Dr. Baade at Mount Wilson” but he thought there was a chance, because he knew Baade was discouraged about his opportunities for research at Hamburg “where a very elderly director of conservative tendencies gives him little encouragement in developing his methods and ideas”. Hence, Adams suggested, with the future of Mount Wilson in mind, that “if the plans and resources” of the C.I.W. “justif[ied] the expenditure”, he would like to offer Baade a position at a salary of $3,000 a year. Adams’s summary and analysis of Baade’s qualifications and potentialities were excellent, and in fact he was eager to come.

Adams requested Ross, at Yerkes Observatory, to ask Baade if he would accept the job if it were offered to him. Ross had been Baade’s mentor during his two months at the Wisconsin observatory, and now that the 200-inch project was underway, he was spending increasing amounts of time in Pasadena, as an optical consultant and designer. Baade replied directly to Adams that he was “deeply
obliged” for the “splendid opportunity”, and “[o]f course ... would be very glad to accept such a position”. He enclosed a short curriculum vitae, and stated that his salary at Hamburg was $3,000 a year, but that the conditions there were “so abnormal” (the inflation and continuing crisis of the Weimar government) that he did not know how to compare it with a U.S. salary and would prefer for Adams to “make a proposition”. 79

The Mount Wilson director, now sure his man would come, then made a firm recommendation to Merriam that Baade be hired at a salary of $3,300 per year, emphasizing his importance for Seares’s photometric program. Merriam approved, Adams cabled the offer to Baade in Hamburg, and he accepted. 80

Adams, an experienced director, knew exactly how to handle the head of his institution in Washington and the research astronomer in Germany he wanted to hire for his staff. He had prepared the way perfectly with both of them, and the well-oiled negotiations went through flawlessly. Yet it is probable that Adams did not reveal all he was thinking. Mount Wilson Observatory’s research program in those years was devoted almost entirely to amassing data on the Sun and the stars, in order to understand their physical nature, just as at all other advanced observatories of the time. Hubble had begun his pioneering studies on the galaxies and the universe, and had already made great strides in opening up new horizons. His work had already caught the attention of astronomers everywhere, and of the public. Already in 1931 he was linked in the press with Albert Einstein, the greatest scientific personality in the public imagination of the time. Adams and Hubble were almost compete antitheses, with their New England and Southern backgrounds, one dour, retiring, organizationally oriented, operating behind the scenes, dedicated to long, hard work, the other personable, outgoing, individually oriented, flamboyant, a loose cannon who worked hard, but played hard as well. Within a few years Hubble was to be going around Adams and Merriam to get what he needed directly from the Carnegie trustees themselves. Sixteen years later, after he had retired, Adams, in a bitter letter to his successor, Ira S. Bowen, revealed his deep distaste for Hubble, whom he claimed had “done little work of the first order for twenty years” (i.e., since 1927) and “at sixty is still eager for notoriety and has his press agent continuously at work”. 81

Almost certainly Adams realized well before 1930 that it would be prudent to have another astronomer on his staff who could be counted on to do important research on galaxies and globular clusters, but who would be a respectful team player, more amenable to direction from above than the prima donna from Missouri. Baade fitted the bill perfectly, or at least he did in 1931, and that was no doubt the “future of Mount Wilson Observatory” which Adams had in mind when he recommended him for the job.

Schorr realized that there was no chance to hold Baade at Hamburg against this offer from the land of clear skies and big telescopes. The previous year he had recommended Baade strongly for the title of professor at the university, which would bring him an additional salary of 1,000 Marks per year. 82 Baade had not
received the appointment, probably because of the economic situation. Now Schorr transmitted Baade’s resignation, to be effective at the end of September, to join the Mount Wilson staff. It was a great honour that a German astronomer, and particularly one from Hamburg Observatory, had been appointed to permanent staff of the largest telescope in the world, Schorr wrote. Clearly Baade should go not merely as Observator of the Hamburg Observatory, but as a professor in the Hamburg University. Furthermore, since the appointment would end on 30 September, it would not cost much to make the appointment now, he added. The canny Hamburg senators could understand this reasoning, and Baade finally was promoted, just two months before his job ended.83

Because of the German inflation, Baade had no savings, and he received no travelling expenses from the Carnegie Institution. It was impossible for him to borrow the money for his and his wife’s passages to America, and he had to appeal to Adams for an advance on his salary. Although the director professed to be surprised by the thought that Baade “had had no opportunity to lay aside any savings”, he passed on this request to Merriam, emphasizing that the young German’s case was “special” and therefore “[c]ertainly ... need not be taken as a precedent for the future”. Although Merriam did not authorize a direct loan from Carnegie funds, Adams was able to tell Baade he could advance him $900 “from some private funds which we have available at the Observatory” and that he could buy his steamship tickets.84

With the Carnegie influence behind him, and his professorship in hand, Baade had no trouble getting an immigration visa to America. All his letters to Adams were polite and respectful, but not fawning; he dealt with the issues directly and pleasantly.85 Evidently he made the same impression in person on the American consular officials in Hamburg. On 31 August 1931, Baade and Muschi sailed from Bremen on the Hamburg-America steamship Los Angeles, bound for San Pedro, on the month-long voyage via the Panama Canal.86

When he reached America, Baade was superbly trained for the research that lay before him. He had had a long schooling at the outstanding German university of the time, where his teachers had been among the leaders of German science. On completion of his Ph.D., he had secured a job in which he almost instantly became the main observer with the largest telescope in Germany, a reflector like the really big telescopes at Mount Wilson. Although he chafed under Schorr’s conservative direction, Baade had plenty of time to do his own research programs, on the globular clusters which were at that time the key to mapping our Galaxy, and which were to become, in Baade’s hands, the key to recognizing the two stellar populations. He had the skill, drive and ability to carry out these programs, and the pleasant but persistent personality that enabled him to meet and become confidants of such important scientists as Shapley and Ross in his own field of research, as well as Adams and Frost among the directors. Baade’s year in America as the first German International Education Board fellow in astronomy had introduced him to many other, younger
astronomers as well, and had broadened his horizons to include research on galaxies and clusters of galaxies. On his return to Germany he had been offered a superficially more important directorship, but had turned it down to stay in active telescopic research. He had already begun to make important new contributions on the local group and on distant clusters of galaxies with the Hamburg reflector. He had already discovered, in incomplete form, many of the ideas of the two stellar populations. Baade was better prepared to use the big telescopes at Mount Wilson than Hubble had been when he arrived there in 1919, than Shapley in 1914, than Seares in 1909, even than Adams himself in 1904. Probably Baade was better prepared than anyone else had ever been, when he arrived at Mount Wilson Observatory in October 1931.

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REFERENCES

Abbreviations used:

(a) Archival Sources

HCO Harvard College Observatory Records, Harvard University Archives,
    Pusey Library, Cambridge, Massachusetts
    S. I. Bailey Director’s Papers
    Harlow Shapley Director’s Papers

HHL Mount Wilson Observatory Collection, Henry E. Huntington Library,
    San Marino, California
    Walter S. Adams Papers
    Walter Baade Papers
    Ira S. Bowen Papers

HO Hamburg Observatory, Hamburg, Germany

RAC Rockefeller Archive Center, North Tarrytown, New York
Walter Baade

International Education Board Records

SLO Mary Lea Shane Archives of the Lick Observatory, University of California, Santa Cruz

YOA Yerkes Observatory Archives, Williams Bay, Wisconsin

Director's Papers

(b) Individuals

WSA Walter S. Adams
RGA Robert G. Aitken
WB Walter Baade
EBF Edwin B. Frost
CPG Cecilia Payne-Gaposchkin
JCM John C. Merriam
FER Frank E. Ross
RS H. Richard Schorr
FHS Frederick H. Seares
HS Harlow Shapley

(c) Publications

AN Astronomische Nachrichten
MAG Mitteilungen der Astronomischen Gesellschaft
MHSG Mitteilungen Hamburger Sternwarte Bergedorf
VJS Vierteljahrschrift der Astronomischen Gesellschaft
ZFA Zeitschrift für Astrophysik

1. [WB], “Entwicklung der Fixsterne” [a notebook], HHL; [WB], [text for invited paper at AAS meeting, symposium at Perkins Observatory, 30 Dec. 1947], 15 pp., large handwritten sheets, HHL.

2. O. Heckmann, Sterne, Kosmos, Weltmodelle: Erlebte Astronomie (Munich, 1976) contains many facts of Baade's life and career, and is used as a source throughout this paper. Heckmann's obituary article (ref. 3 below) is reprinted in it, but without the list of Baade's publications. Another good obituary article, emphasizing his training and early life in Germany, is A. A. Wachmann, “Walter Baade”, Die Sterne, xxxvi (1960), 204–7. Th. Schmidt-Kaler, “Walter Baade wissenschaftliche Genealogie”, Die Sterne, lxix (1994), 90–100 gives a complete account of Baade's education and of his teachers' research careers.


7. WB to [S. I. Bailey], 4 May 1921, WB to [HS], 7 May 1921, S. I. B[ailey] to WB, 2 June 1921, H. S. Leavitt to WB, 15 July 1921, HCO.


10. RS to WB, 12 Apr. 1920, HO; WB to W. W. Campbell, 7 Apr. 1923, SLO.


12. RS to HS, 15 Feb. 1925, HS to RS, 13 Mar. 1925, HCO; HS to International Education Board, 13...
Mar. 1925, RAC.
13. WB to International Education Board, 11 Apr. 1925, RS to A. Trowbridge, 12 Apr. 1925, RS to HS, 14 Apr. 1925, HO.
15. WB to [HS], 13 Apr., 1 June, 13 July 1925, HS to WB, 14 Apr., 2 May, 20 June, 3 Aug. 1925, HCO.
18. See ref. 6.
20. WB, "Der kugelförmige Sternhaufen NGC 5466", MHSB, vi (1926), 61–65.
22. W. Lund to Commissioner of Immigration, 14 Feb. 1926, RAC.
23. "List of I-E-B Fellowships, Germany", 10 May 1939, RAC.
25. It is impossible to know certainly or to document Baade’s impressions of American astronomy in 1926–27, for he was far too diplomatic to express them openly. He may have written about them to close personal friends in Germany (such as Hanni Bohlmann, his future wife), but if he did, no letters have survived in archives known to me. However, he was remarkably consistent in most of his views all of his life. My comments in this entire section are therefore based on my own memories of Baade’s later attitudes, expressed in many conversations I had with him in the years 1953–58, of lectures I heard him give (in which he was by then much less guarded than in his letters) at the University of Michigan in 1953 (mimeographed notes exist, prepared by the auditors, which give a little of the flavour of his remarks), of a Caltech graduate course which he gave and I attended, and of several colloquia I heard him give in those years. They are also based on the mimeographed notes from a graduate course he gave at Harvard in 1958, prepared by R. B. Rodman from a tape recording, which were eventually published in facsimile as WB, Evolution in stars and galaxies (Ann Arbor, 1980). These notes served as the basis for the book, WB, Evolution of stars and galaxies (Cambridge, 1963), ed. by CPG, who had organized and attended the course. She believed that the original notes reproduced too much of Baade’s “very personal and often critical tone” which was “quite appropriate in a lecture but most unfortunate on a printed page” and cut all vestiges of it out of the book. (CPG to J. H. Oort, 14 Nov. 1960, HHL.)
29. RS to RGA, 14 Oct. 1923, 15 Feb. 1924, 29 Oct. 1925, WB to RGA, 21 Dec. 1925, 2 June, 13 July 1926 (telegram), RGA to WB, 7 June 1926, SLO.
32. WB to [HJS], 7 Oct. 1926, HCO.
33. See ref. 6.
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34. WB, "Der Sternhaufen NGC 5053", AN, cccxxii (1927), cols 193–9.
35. WB, "Über eine Möglichkeit, die Pulsationstheorie der δ Cephei-Veränderlichen zu prüfen", AN, cccxxviii (1926), cols 359–62.
38. WB to [W. Lunt], 20 Dec. 1926, RAC; HS to WB, 15 Feb. 1927, HCO.
39. WB to [HJS], 5 Mar. 1927, HCO.
41. Higher Educational Authorities, Hamburg to [Hamburg] Observatory, 21 Sep. 1927, HHL; ditto, 10 Nov. 1927, HO.
42. RS, "Hamburg Bergedorf", VJS, lxiv (1929), 193–212.
43. WB, "Untersuchung von zwei Milchstrassenfeldern auf Veränderliche", AN, cccxxii (1927), cols 65–70.
44. See ref. 34.
45. HS to WB, 16 Jan. 1928, HCO.
46. WB to [HJS], 20 Aug. 1928, HS to WB, 5 Sep. 1928, HCO.
47. See ref. 40; also W. J. Luyten, "Total solar eclipse of July 29, 1927 at Jokkmukk", Popular Astronomy, xxxvi (1928), 75–76.
49. WB, "Bericht über die Hamburgische Sonnenfinsternis-Expedition nach den Philippinen", [–15 June 1929], [15 pp. typed report], HO.
52. [W.] Pauli to [WB], 2 Mar. 1927, HHL.
53. WB to Higher Educational Authorities, Hamburg, 2 Jan. 1928, HO; WB to Herr Oberregierungsrat [Stier], [Jena], 14 Jan. 1928, HHL.
54. Herr Oberregierungsrat Stier to WB, 5 Apr. 1928, WB to Herr [Stier], 18 Apr. 1928, [WB], "Denkschrift über den Ausbau der Jenaer Sternwarte" [typed 7-page plan], 3 May 1928, WB to Prof. [Straubel], 4 May 1928, WB to Herr Oberregierungsrat [Stier], 4 May 1928, Herr Stier to WB, 26 June 1928, HHL.
55. O. Knopf to WB, 19 Apr., 27 Sep. 1928, HHL.
56. WB to Higher Educational Authorities, Hamburg, 18 Sep. 1928, RS to ditto, same date, HO.
57. WB to Dean of the Mathematical-Physical Faculty, Hamburg University, 7 Dec. 1928 (endorsed as approved 12 Dec. 1928), HO.
58. Printed announcement of inaugural lecture, Hamburg University, 30 Jan. 1929, HO.
60. WB, "Neue Untersuchungen über extragalaktischen Sternsysteme" [typed 13-page manuscript], "After a lecture at the Scientific Researchers Day at Königsberg", 8 Sept. 1930, HHL.
61. WB, "Über die Entfernungen und Dimensionen der extragalaktischen Nebel" [handwritten text for a lecture to the Naturwiss. Verein zu Hamburg], 19 Dec. 1927, HHL.
62. WB, "Der Nebel NGC II 1613", AN, cccxxii (1928), cols 407–8; see also ref. 40.
63. WB, "Über einen bemerkenswerten neuen Nebelhaufen in Ursa Major", AN, cccxxiii (1928), cols 65–70.
64. See ref. 42.
65. WB, "Der kugelförmige Sternhaufen NGC 4147", AN, cccxxix (1930), cols 353–8.

67. WB to HS, 8 Apr. 1930, HCO.

68. WB to [HS], 15 Feb. 1930, HS to WB, 27 Feb., 22 Apr. 1930, HCO; see also ref. 65.

69. WB to [J. G. Hagen], 15 Nov. 1929, 24 Jan. [1930], Vatican Observatory Archives, Vatican City.


71. WB, "Beobachtungen des Pluto an Spiegelteleskop der Hamburger Sternwarte", *MHSB*, vii (1931), 44.


73. H. Zanstra, "An application of the quantum theory to the emission of light by diffuse nebulae" (ms.), July 1925, RAC; RS, "Hamburg Bergedorf", *VJS*, lxvi (1931), 164–83; *ibid.*, lxvii (1932), 199–214.


77. WB, "Über der Periode von RV Canum ven"

78. WSA, "Memorandum regarding Dr. Baade of the Hamburg Observatory", [–15 Sep. 1930], HHL.

79. WSA to FER, 22 Dec. 1930, WB to [WSJA], 20 Jan. 1931, FER to WSA, 5 Feb. 1931, HHL.


81. [JCM] to E. Hubble, 27 Apr. 1929, WSA to JCM, 19 Mar. 1934, JCM to WSA, 21 Mar. 1935, CIW; WSA to I. [S. Bowen], [–5 Dec. 1947], CIT.

82. RS to the University Authorities, Hamburg, 25 Jan. 1930, HO.

83. WB to the University Authorities, Hamburg, 20 Apr. 1931, RS; *idem*, 20 Apr. 1931, Extract from proceedings of the Hamburg Senate, 22 June 1931, HO.

84. WB to [WSJA], 11 Apr. 1931; WSA to JCM, 30 Apr. 1931; WSA to WB, 18 May 1931, HHL.

85. JCM to WB, 23 May 1931; WB to [WSJA], 10 June, 22 July, 1931; WSA to WB, 30 June 1931; [WSA], "To whom it may concern", 30 June 1931, HHL.

86. WB to [WSJA], 22 July 1931, HHL; "Prof. Dr. Baade departs for America", *Bergedorfer Zeitung*, 1 Sep. 1931.