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Martin Schwarzschild (1912–1997)

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ABSTRACT. Martin Schwarzschild, the ASP Bruce Medalist for 1965, died on April 10, 1997. A refugee from Hitler's Germany who firmly embraced his adopted country, Schwarzschild not only solved a number of fundamental problems in stellar structure and evolution but also taught the rest of the astronomical community how to do so with his 1958 text, *Structure and Evolution of the Stars*. At about the time of his 1979 retirement, he turned to a completely different question of how to model spheroidal galaxies self-consistently and sent another generation of students and collaborators forward toward the still somewhat distant solution. It is impossible for anyone who ever interacted with Schwarzschild to remain entirely solemn when remembering him.

1. INTRODUCTION

The Schwarzschild family had for centuries lived in the Frankfurt (am-Main) Judengasse. Following emancipation of German Jews in the 19th century, they entered with enthusiasm into the country's economic, intellectual, and cultural life. Karl Schwarzschild, Martin's father, worked for some time in Göttingen before being appointed director of the Astrophysical Observatory outside Potsdam. He had assimilated to the extent of marrying a gentile,¹ and his sister was married to Robert Emden. In 1914, though past 40 years of age and in spite of his distaste for militarism, the elder Schwarzschild felt morally obliged to volunteer for service, following the German army first into Belgium with a scientific unit and subsequently onto the Eastern front. His presence on the Western front was taken by an allied scientist who encountered him there as an indicator that war service could not be very dangerous, or Germany's most distinguished astronomer would not have been allowed to participate. But, in 1916, Karl Schwarzschild contracted pemphigus, a painful skin disease, which killed him shortly after he had completed his last papers, one on ballistics and one on the solution to the Einstein field equations that bears his name (Schwarzschild 1916). Pemphigus was relatively common in the trenches of World War I, but is now quite rare, being concentrated in South America, especially Brazil (Berkow et al. 1987). It is an auto-immune disorder, and the modern treatment involves prednisone and other corticosteroids.

¹Thus the answer to "Was Martin Schwarzschild Jewish?" is technically no, since descent in this context is from the mother, but it made no difference come 1933.

Karl Schwarzschild's contributions to astrophysics are discussed in the Appendix.

2. BEFORE PRINCETON

2.1 Europe

Martin Schwarzschild was born at Potsdam on the 31st of May, 1912. After his father's death in 1916, the family re-



FIG. 1—The official photo of Bruce Medalist Schwarzschild. The award was 1965, but internal evidence (hairline and tie bar) suggest that the picture dates from the 1950's. (Courtesy ASP.)



FIG. 2—Schwarzschild and Lyman Spitzer, Jr. with a model of *Stratoscope I* in 1956 or 1957. The mission is also illustrated on Martin's tie. In their 50 years at Princeton, Spitzer and Schwarzschild were largely responsible not only for the growth of the astronomy department, achieved without loss of prestige, but for the tone and style of research and scientific discourse there. (Photo by Robert P. Matthews, Princeton University.)

turned to Goettingen. There he went to the Gymnasium and took his *Arbiture* (a school-leaving examination that qualified one for university) at Easter 1931. In his first three semesters at Goettingen University, Schwarzschild mainly studied mathematics under Prof. Courant. He spent one semester at Berlin University and returned to Goettingen, doing astrophysics under the supervision of Prof. Hans Kienle, the director of the Observatory, for five semesters, and also theoretical physics.

The preceding paragraph is drawn from a short autobiography that Schwarzschild wrote in 1935, and we continue in his own words:

"In order to obtain the doctorate, I first started with spectral photometry of Polaris [a low-amplitude Cepheid]. But the weather conditions of the winter 1934/5 were so bad that I did not get on so quickly as my situation seemed to demand. Therefore [strongly advised by both Kienle and Otto Heckmann to finish his degree and move on] I finally chose some problems in the pulsation theory, in which I had already been interested, for my thesis. I took the examination for the doctor degree in December 1935." This hand-written document is remarkable in that it shows handwriting that changed very little up to 1996 and a command of written English that was also nearly invariant (about one Germanism per page).

The published version of this thesis work, "Zur Pulsationstheorie der δ Cephei-Sterne," appeared in *Zeitschrift fuer Astrophysik* (Schwarzschild 1935). His last (ever) *Zeitschrift* paper came after he had already left Germany (Schwarzschild 1938), though he wrote both the pub-

lished version of his 1959 Karl Schwarzschild lectures and one semi-popular 1963 account of stellar evolution in German. Martin asked for Eddington's comments on the thesis paper and received back a long letter explaining why it was wrong (with which Martin eventually agreed).

Schwarzschild's first stop outside Germany was two weeks at Leiden Observatory in late December, where he finished up a short observational paper improving the elements of BB Cen (Schwarzschild 1936) and interacted with Einar Hertzsprung. Hertzsprung recommended him for a position at Swarthmore College, for which Arthur Beer, another German-Jewish astronomer who had taken refuge in England somewhat earlier, had also been considered. Hertzsprung gives his "impression that his [Schwarzschild's] theoretical foundation and ability is considerably above the average and I think that he will be able as a teacher to communicate his knowledge to others... He appears to be a very modest young man, who is extremely interested into various astronomical problems... he is both congenial and cooperative. One feels in his behavior the suppressed position, which the race, to which he partly belongs, undergoes under the present conditions in Germany." The letter was addressed to Prof. John A. Miller, then director of Sproul Observatory and one gathers from it and from subsequent exchanges among Hertzsprung, Miller, and the college President Frank Aydelotte that the international scientific community was very much aware of at least the early stages of the German treatment of Jewish intellectuals.

Schwarzschild clearly retained very friendly feelings for Hertzsprung, and, in his 1961 invited discourse at the Berke-

ley General Assembly of the International Astronomical Union, he spoke directly to him: “Indeed, I would think that it must be to you, Professor Hertzprung, cause of appreciable puzzlement to have watched throughout your life a stream of eager theoreticians working hard on these problems and succeeding to understand even by now only the most obvious features in the diagram which you plotted for the first time more than fifty years ago.” (Schwarzschild 1962).

In any case, nothing came of the Swarthmore appointment, and Schwarzschild’s first post-doctoral position was in Oslo, Norway (1936–37) as a Nansen Fellow with Rosse-land. The fellowship was named for the Arctic explorer, Fridtjof Nansen (1861–1930), also the inventor of the Nansen passport (issued by the League of Nations after World War I to stateless persons to enable them to have some status and to travel), and so was presumably intended specifically for people whose relationship with their native lands was not a happy one. During that year, Schwarzschild prepared the remainder of his thesis for publication and wrote on the then-vexed problem of the source of stellar energy.

2.2 America

After a brief visit to England, Schwarzschild moved on to a three-year Littauer Fellowship at Harvard College Observatory. During that period, he contributed three *Circulars* to their series, concerning Cepheid light curves and the variables in the globular cluster M3, and was elected to the International Astronomical Union at its 1938 General Assembly in Stockholm. Both Harlow Shapley and Cecilia Payne Gaposchkin had been strong supporters of his candidacy for the Fellowship, and the three years of relative job security were crucial to his settling into the new country and back into research.

His first academic appointment was as a lecturer in Astronomy at Columbia University (1940–44), followed by an assistant professorship (1944–47). Columbia’s Rutherford Observatory was, apparently, a low-budget operation in those days, and Enrico Fermi, then part of the physics department, was prone to introduce “Schilt and Schwarzschild, Director and Directee.” By 1947, however, a paper on their new photometer had three authors in addition to the D & D. Schwarzschild was elected to the American Astronomical Society and to Sigma Xi (the scientific research society), and his papers from Columbia touched on stellar pulsation, convection, and rotation.

There was also a foreshadowing of the work for which he is now best known and most honored in a pair of co-authored papers in the 1941 and 1947 volumes of *Review of Scientific Instruments*, called “Automatic integration of linear second-order differential equations by means of punched-card machines” and “Automatic integration of linear sixth-order differential equations by means of punched-card machines.” These two papers were, of course, separated by World War II.

“Like father like son,” Martin Schwarzschild, appalled by what the Nazis were doing in Europe and recognizing that many of his students would soon be drafted and be risking their lives for the country that had provided him refuge, en-

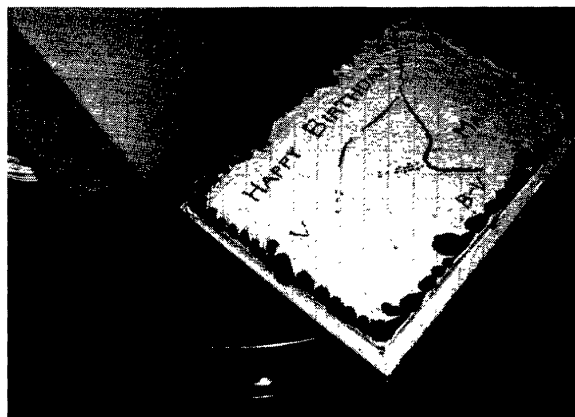


FIG. 3—The cake at Martin’s 50th birthday party. We note that the AGB was not yet officially part of the HR diagram of a globular cluster. (Courtesy John Gaustad.)

listed in the US Army as a private (the only rank available to a non-citizen) shortly after the attack on Pearl Harbor. Soon after giving his last lecture in theoretical astrophysics, he found himself at the southern tip of Manhattan, loading garbage with recruits from Harlem, which was in the same army district as Columbia. A little later, someone discovered that he had ability in mathematics and gave him the job of teaching the subject in a school for officers. Martin wanted a more direct involvement in the war effort. He passed a set of exams that qualified him to attend Officers’ Candidate School when he became a US citizen in 1942. In due course, Second Lieutenant Schwarzschild requested a transfer to the fighting front.

He joined an army intelligence unit in Italy, where the Allied forces were pushing the German Army northward. His particular task was to analyze the effectiveness of US bombing, especially of bridges. One can imagine the reaction of the officers *in situ* when asked by a stranger with a heavy German accent, “Please tell me how your bombs are aimed,” and he spent an occasional night in the brig, maintaining his usual, cheerful calm, partly to avoid embarrassing his captors when the truth came out. Sorting things out at various times involved checks with headquarters, the intervention of an English officer on similar assignment, and a New York truck driver, whose primary job seems to have been to say, slowly and firmly and in suitable dialect, “Ee’s OK, see.” Schwarzschild was awarded the Legion of Merit and the Bronze Star for his wartime service. Soon after completing OCS and before going overseas, he had had two photographs taken, and had asked Chandrasekhar (in a letter signed, “Sergeant, US Army”) to collect them and deliver the “serious” one to his future wife, Barbara Cherry. Forty-some years later, at IAU Symposium No. 127 in Princeton, Chandra handed over the second, “smiling”, portrait that Martin had not deemed suitable. It appears here as Fig. 6.

Stellar astronomy at Princeton had been badly damaged by the retirement of Henry Norris Russell, and the University wisely offered positions simultaneously to Schwarzschild and to Lyman Spitzer, Jr. (1914–1997). Each regarded the other’s presence as a major incentive for coming, and they remained friends and colleagues for the next 50 years, dying within less than two weeks of each other. Schwarzschild was

named to the Higgins chair in 1951 and retained the title of Senior Research Associate after his official retirement in 1979.

3. THE STELLAR SCHWARZSCHILD

From 1947 onward, Schwarzschild's interest in pulsating variables gradually tapered away, and his work in stellar astronomy consisted of three intertwined strands that cannot be separated chronologically. These were stellar population studies, the structure and evolution of post-main-sequence stars (much of this in collaboration with Richard Härm), and theory and observations of solar and stellar convection, including the results from *Stratoscope*.

3.1 Stellar Populations

The first paper on which Barbara and Martin Schwarzschild appear as co-authors dealt with the correlation between spectra of F-type stars and their space velocities. Published in 1950 (Schwarzschild and Schwarzschild 1950), it is one of three nearly simultaneous discoveries of the association between heavy-element abundances and stellar populations (in the sense of Baade 1944). The other two were papers by Nancy Grace Roman (1950) and Wilhelmina Iwanowska (1950), though Morgan, Keenan, and Kellman had already mentioned the weakness of CN features in high-velocity stars in their classic 1943 atlas of stellar spectra. Curiously, the 1958 monograph mentions his own work and that of Iwanowska, but not that of Roman.

It is not always obvious from the titles of the stellar population papers just what ideas are lurking in them. For instance, Schwarzschild, Spitzer, and Wildt (1951) is called "On the difference in chemical composition between high- and low-velocity stars," but it includes the then-revolutionary idea "that all type I stars have been formed from the interstellar clouds." Spitzer and Schwarzschild (1951), "The possible influence of interstellar clouds on stellar velocities," develops the idea that radiation pressure from existing stars will cause the clumping of dust grains and so begin the compression of gas and dust into new generations of stars. The whole idea of star formation as an on-going process was then regarded as very speculative, and Spitzer (1996) had been strongly discouraged from working on it by three more senior astronomers (whom he declined to identify, on the grounds that one of them was still living).

Baum and Schwarzschild (1955) used the ratio of high- to low-luminosity stars in the outskirts of M31 and its satellite NGC 205 as a population indicator. The method was a measurement of the ratio of the number of stars that could be counted (to $m=23$ by MS and BS) to integrated surface brightness (found by Baum). Like most geographically separated co-authors, both parties procrastinated. Finally, Baum received a draft from Schwarzschild with a plea to expedite his contribution, along with the comment that he had "very little legs to stand on" in pressing for promptness.

Schwarzschild himself worked relatively little on binary stars. He did, however, guide the thesis of Donald Morton (1960). This began as an observational investigation of the Algol paradox (the fact that the less massive star was usually the more evolved). But it developed into the first calculation

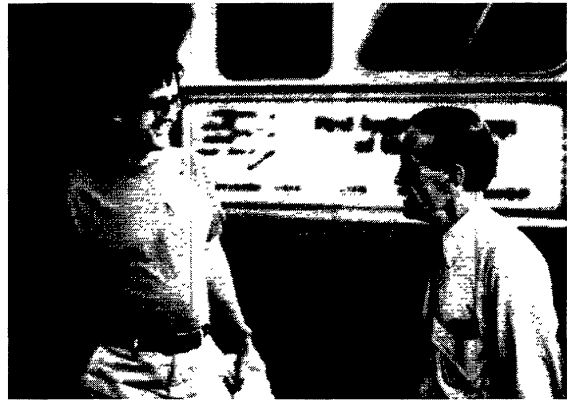


FIG. 4—John Gaustad and Martin Schwarzschild at the Madison, WI AAS meeting in 1978.

that showed conclusively that, when the more massive star filled its Roche lobe, mass transfer would occur on the Kelvin–Helmholtz time scale until the mass ratio had been more than reversed. In the next decade, three groups (none of them including Morton or Schwarzschild) followed up on this vital discovery to develop our modern understanding of close binary evolution (see, e.g., Paczyński 1971).

3.2 Stellar Structure and Evolution

All early models of the Sun and stars assumed chemical homogeneity, from the time of Lane and Emden down to Eddington and beyond. Indeed, Schwarzschild's (1946) first model Sun was a homogeneous one, with the helium abundance adjusted to make luminosity and radius come out right, with the known mass and age. Papers by Ernst Öpik (1938) and by Fred Hoyle and Raymond Lyttleton (1939) had already provided the first indication that chemical inhomogeneity could help to give red giants their extended envelopes. Schwarzschild realized that temperature-dependent fusion would lead to an inhomogeneous Sun before his 1946 paper actually appeared, and attempted to withdraw it; but it was too late, and "On the helium content of the Sun" was widely cited for a number of years, though fundamentally wrong. Incidentally, that particular Sun also had a convective core, because it ran on the CN cycle rather than the proton-proton chain, and Schwarzschild was an initial skeptic in 1950 when J. Beverly Oke told him that the *pp* chain was actually the relevant process.

The next step was inhomogeneous, but non-evolving, models for red giants (Schwarzschild and Li Hen 1949; Oke and Schwarzschild 1952, the latter still with a convective core and so applying to stars more massive than the Sun). month to evolve a star from the main sequence up the red-giant branch. Now, of course, one spends the month debugging one's program, which then runs in 7.3 seconds or thereabouts.

Gravitational contraction and heating of the exhausted core of a massive star of solar composition appear in Sandage and Schwarzschild (1952, one of the first papers that "evolves" stars in the modern sense). Hoyle and Schwarzschild (1955) did the same thing for model stars of less than solar metallicity and masses not much larger than one solar mass, and, looking at an HR diagram for M3, de-

rived an age of 6.5 Gyr. Apparently the age would have come out rather smaller if the paper had been written by Schwarzschild alone and rather larger if by Hoyle alone. This was their only joint effort and permitted the award of the 1994 Balzan Prize to the pair (it can be split only in the case of collaborators). Their working styles were clearly very different and perhaps did not mesh easily. Martin's description is that, on the one hand, Fred could generate ideas at a rate of 10 per day that it was his job to winnow through, while, on the other hand, at the end of a computing run, Martin wanted to see all the intermediate results, while Fred just wanted the final luminosity and effective temperature.

The co-author you have been waiting for (and perhaps Schwarzschild had been too) arrived in 1955. The first of their 22 papers over 22 years was actually Härm and Schwarzschild (1955) and dealt only with numerical integrations. This was unquestionably Härm's forte. Hoyle is supposed to have said that he thought he was as smart as Schwarzschild, but he knew he was not as good a computer as Härm. The methods of numerical integration were soon applied to a range of stellar problems, and we can follow, in their joint papers, the Sun and stars of other masses and compositions off the main sequence (Schwarzschild, Howard, and Härm 1957), up the red-giant branch (Schwarzschild and Härm 1962, where cores become hot enough for helium ignition), on to the horizontal branch (Schwarzschild, Härm, and Hartwick 1967), into helium flashes on what we now call the asymptotic giant branch (Schwarzschild and Härm 1967, 1972), until finally a planetary nebula is ejected and we are left with a cooling blue core (Härm and Schwarzschild 1975).

One tends to forget how early in this sequence the classic monograph (Schwarzschild 1958) was written. *Structure and Evolution of the Stars* was completed in November 1957. At that time, helium ignition had just been achieved for the most massive stars, while stars of lower masses were trying to burn a degenerate fuel and were expected to run away or explode. Schwarzschild thought this might lead to a completely convective star (no longer the best bet, but it would still be a nice way to make certain blue stragglers and R Coronae Borealis variables). He ended the discussion of advanced evolutionary phases by saying: "Ahead of us stretches a large territory of stellar evolution as yet hardly explored. In it we recognize many of the most fascinating types of stars: the supergiants, the pulsating variables, the blue stars of Population II, perhaps the Wolf-Rayet stars and the nuclei of planetary nebulae, surely the novae and supernovae." Much of the rest of the book is similar in tone, with author and reader engaged together as "we" trying to understand things. This apparently derives from the book having been largely dictated (on a Dictabelt) and later transcribed, with some smoothing of the English by Barbara Schwarzschild, to whom the volume is dedicated.

The 1957 preface indicates that the book is meant "for temporary use... and thus to help prepare the next developments." My copy is the 1965 Dover edition and cost \$2.25. It is still occasionally raided for good definitions and compact derivations of the basic quantities and relationships of stellar structure. "Temporary," no. "Prepare," definitely yes.

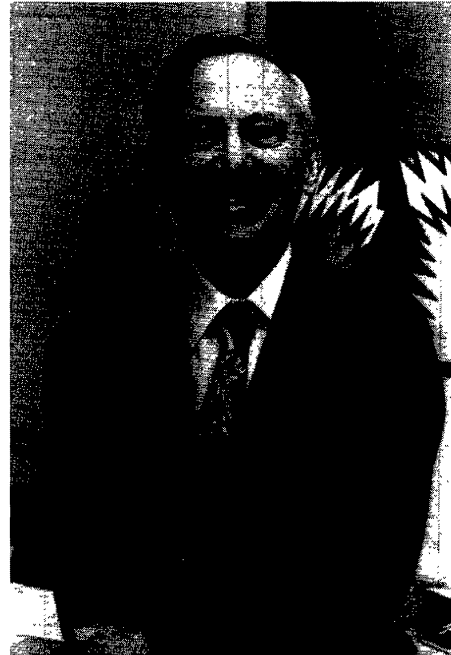


FIG. 5—A 1982 official portrait, clearly taken at 10 AM (by Robert Mathews of the Communications Department of Princeton University).

3.3 Solar and Stellar Convection and *Stratoscope*

Schwarzschild early recognized the importance of a correct treatment of convection in stellar structure calculations, but he also developed an interest in solar granulation and its relationship to photospheric turbulence and convection for their own sake (e.g., "On the turbulent velocities of solar granules" Richardson and Schwarzschild 1950 and later papers with F.N. Frenkiel and with Richardson). The issue at the time was whether the granulation we see, which is only partly resolved from good, ground-based sites, represented convection cells themselves—what we would now call convective overshoot—or something else.

A critical step occurred at one of the famous working lunches for Princeton astronomers in the early 1950's. One afternoon, he reported, the discussion focused on solar convection and turbulence and the true nature of the solar photosphere. Lyman Spitzer and James Van Allen agreed that what was needed was a balloon telescope. But Lyman was deep in fusion and Van Allen in the use of particle detectors in the earth's atmosphere (though the discovery of the belts that bear his name lurked with the *Explorer* satellite some way in the future). According to Martin, he was the only other person at the table. "They both looked at me. That is how I got involved in *Stratoscope*."

In any case, Schwarzschild assumed primary responsibility for the project, and *Stratoscope I* carried a 12-inch (30 cm) diffraction-limited telescope to 30 km on flights in 1957 and 1959. These returned roughly 16,000 photographs, each a 2 msec exposure (Friedman 1986). A report of early results in *Science* won the AAAS Newcomb-Cleveland prize for outstanding paper of 1957 (and see, e.g., Schwarzschild 1959 "Photographs of the solar granulation taken from the *Stratosphere*"). Analysis of these images provided strong evidence

that the granulation truly represented convection cells. An important factor was the polygonal structure of the bright granules, with continuous dark lanes separating them. These would never have been seen if Schwarzschild had followed early advice to use instruments that would directly measure the brightness correlation function of the solar surface rather than producing images. Later analysis revealed the umbral dots or bright points that represent suppressed convection in sunspots.

Stratoscope II, a 36-inch, flew a number of times in the 1960's and early 1970's, bringing back near-infrared spectra of Mars (Woolf et al. 1964) and of cool stars and images of the nuclei of M31 (Light, Danielson, and Schwarzschild 1974) and NGC 4151 (Schwarzschild 1973) unblurred by atmospheric seeing. *Stratoscope* was a forerunner not only of the *Hubble Space Telescope* but also of the Kuiper Airborne Observatory, because Schwarzschild and his collaborators were the first to exploit the fact that terrestrial water vapor is confined largely to the troposphere. Thus you don't have to get entirely out of the atmosphere to see astronomical objects in the infrared, just into the dry stratosphere.

The Schwarzschilds generally travelled to Texas for the *Stratoscope* launches. Palestine, the small town nearest the balloon facility, was not much like either Princeton or Goettingen, and the visitors and locals puzzled each other a good deal, but it was clear that friendly feelings had triumphed when the Schwarzschilds were given their own key to the local bird sanctuary.

Martin returned one last time to the nature of photospherical convection to predict (Schwarzschild 1975) that red giants and supergiants should have very large cells. Recent imaging of Betelgeuse with the *Hubble Space Telescope* has shown this to be the case.

4. SELF-CONSISTENT MODELS OF ELLIPTICAL GALAXIES AND OTHER SPHEROIDS

Schwarzschild had first looked at the mass distribution and mass-luminosity ratio in elliptical galaxies in 1954. This paper (Schwarzschild 1954) contained the first suggestion that very old (hence very faint) white dwarfs, left behind by an early generation of F stars, might be a significant contributor to the total mass, an idea which has been revived very recently in connection with the detection of gravitational lensing by MACHOs in the halo of our own galaxy.

Although he then did not touch an E galaxy for more than 20 years, 22 of his last 25 papers, from 1976 to 1993, deal with one aspect or another of the structure and dynamics of spheroidal star systems. The topic as a whole is an enormously complicated one (for instance, de Zeeuw and Franx 1991). A common approach is to assume some particular gravitational potential, calculate what the stellar velocity dispersion and surface brightness should be for stars inhabiting that potential, and then compare the results to observations. Schwarzschild added the constraint that the sum of the orbits in the potential should give back the potential you started with. (This has to be true if most of the mass is in stars; it need not be if non-stellar dark matter dominates). The problem clearly demands a high level of both analytic

and numerical skills, and one cannot claim that it has been yet fully solved.

Data from the middle 1970's had begun to indicate that real ellipticals were probably triaxial and tumbling, and this was undoubtedly one of the motivations leading Schwarzschild to tackle the problem. Possible orbits in such potentials include an assortment of boxes, tubes, and bananas, not much resembling the conic sections of our youth. Under the circumstances, one should perhaps not be surprised that one of the important results of the program was a non-uniqueness theorem: different combinations of orbits can reproduce the same equilibrium triaxial model (Schwarzschild 1982; de Zeeuw, Hunter, and Schwarzschild 1987).

Perhaps the best compact way to indicate the significance of the endeavor is to list Schwarzschild's co-authors on the sequence of papers and to note that they include many of the most productive younger people now working on topics in stellar dynamics. They are Maria Teresa Ruiz, T. B. Williams, Gary Heiligman, Jeremy Goodman, T. S. van Albada, C. G. Kotanyi, Julia Heisler, David Merritt, Mario Vietri, Stephen Ratcliff, K. M. Chang, Peter Teuben, Edwin Turner, Tim de Zeeuw, Christopher Hunter, Jordi Miralda-Escude, Changbom Park, and Joanna Lees. Several of his later students also completed theses in this area without appearing as co-authors.

Some of the later collaborations were largely remote ones. After his 1985 heart attack, Schwarzschild heeded the advice of his doctors to take things a bit easier, at least to the extent of working fewer hours per day, usually from home. Continuation of the work on elliptical galaxies was made possible by the loan of a Princeton computer and close cooperation with Tim de Zeeuw, who also assisted in guiding some of the later students and post-docs. Some of this work is still to be published.

5. SCHWARZSCHILD AND THE SCIENTIFIC COMMUNITY

From about 1953 onward, honors, prizes, memberships in honorary societies, and so forth arrived at roughly yearly intervals, from organizations in at least eight countries. These included D. Sc.'s from Swarthmore, Columbia, and Princeton, academy memberships in Belgium, Norway, and Denmark as well as the US National Academy of Sciences, and, most recently the 1994 Balzan Prize (shared with Fred Hoyle, which Schwarzschild was unfortunately unable to travel to accept), 1996 election as a foreign member of the Royal Society (London), whose membership charter he signed in Bohdan Paczyński's office on a page brought from England by Martin Rees, and the 1997 National Medal of Science, awarded posthumously. With so many, a little confusion is permissible. His CV lists the "Charles Darwin Lecture of the Royal Astronomical Society" in 1969; it is actually the George Darwin Lecture.

He was a member of many scientific societies, serving the International Astronomical Union as President of the Commission on Stellar Constitution (1958–64) and as a Vice President (1964–70), and becoming a life member of the Astronomical Society of the Pacific as a result of his Bruce Medal. His contribution to the American Astronomical Soci-



FIG. 6—The “smiling officer” portrait, taken just before Martin left for active service in World War II (courtesy Barbara Schwarzschild).

ety was particularly important. Schwarzschild was elected to a vice presidency in 1967 and to the presidency for the term 1970–72, but his predecessor as president, Albert Whitford, was *hors de combat* with a broken leg at a critical period in AAS history, and it was, therefore, Schwarzschild who largely oversaw the transfer of ownership of the *Astrophysical Journal* from the University of Chicago to the Society. He was also the guiding light in preventing the threatened breakup of the society in the late 1960’s, when workers in solar physics, high-energy astrophysics, and planetary science came to feel that the AAS was no longer serving their needs. The solution was topical divisions, which are not quite like those of any other scientific society (see Trimble 1998 for further details and Schwarzschild’s own description of the process). In the interests of keeping the AAS alive and healthy for the long term, he insisted that endowments and capital funds should be tapped only to the extent that their growth exceeded the rate of inflation.

Schwarzschild was aware, earlier than most of the community, of the need for scientists to interact with the rest of society. His October 1967 address, “When to send your telescope afloat” (upon receipt of the Albert A. Michelson Award of Case Western Reserve University) included the following statement: “At the present time, however, many of us scientists are moving into research undertakings of such physical magnitude that our successes and failures, just as those of the politicians, are becoming accessible to public scrutiny, and since they consume large public funds, they should properly be under such public scrutiny.” He also accepted the responsibility for communicating the excitement and importance of science to the rest of the world, and he believed that this was more important than getting the details exactly right or giving credit to the right people in any one



FIG. 7—Barbara and Martin Schwarzschild in their retirement home in Newtown, PA in 1995. Internal evidence indicates that they remained fond of birds. (Photo by John Gaustad.)

program, story, or press release. This has been known for generations in the film industry (“There is no such thing as bad publicity”) but has been harder for scientists to accept.

He thought that the *Apollo* program had been right and important not so much for the scientific or defense implications, but for the impetus it gave to education in science and mathematics and for the psychological effect of having risen to a major technological challenge, so that it made sense to say, “If we can go to the moon, we ought to be able to clean up the air” (or whatever).

The Schwarzschild style of lecturing, often without slides, overheads, or other modern aides memoires (and sometimes without notes), would not do for most of us. “I write you down...” generally meant that the equation was one he carried in his head. But his general advice, that an oral presentation should focus on one or two main ideas without a clutter of supporting detail, is worth remembering. He had definite views on what a scientific meeting should be like, and opposed for as long as possible the introduction of parallel sessions at the AAS, where they could only contribute to the fragmentation of the subject. That the first few years of parallel sessions were not grouped by subtopic seems to have been partly due to his influence.

Schwarzschild was an active participant in colloquia and meetings even when he was not the speaker. He advised new AAS officers chairing sessions that it was their duty to ask a question after each presentation if no one in the audience did, so that the speaker would feel that his work had been understood and appreciated. And his summaries of Princeton colloquia, “Let me see if, in my meager way of understanding, I can repeat what you have said,” were famous, perhaps even infamous. “Well, I think we should thank *both* our speakers,” as chair Bahcall remarked after Martin’s summary of a seminar by de Zeeuw in the 1980s. His ability to summarize and clarify what a speaker had said did not preclude disagreeing with it, and, like Eddington, he sometimes refused to believe an observation until it was confirmed by theory and could, occasionally, be rather pointed in doubting that any such theory was possible.

“His students were his children” is a cliché, but a true one. From Malcolm Savedoff, who encountered Schwarzschild first at Columbia in 1947, to Thomas Statler (PhD

1986), all remarked on the extent to which he conveyed respect for their work, enthusiasm for astronomy, and personal welcome. At least two of his Columbia PhD students are still members of the AAS, Emilia Beleserene and Geoffrey Keller. Of the Princeton cohort, of (at least) 23 PhD students, one (Isadore Epstein) predeceased his advisor and several others are retired or have gone on to other kinds of activities. But Andrew Skumanich, Robert Howard, Ray Weymann, Donald Morton, Steve Musman, Tom Dennis, Allen Sweigart, Maria Ruiz, Thomas Statler, Mario Vietri, and Joanna Lees are still active members of the community and will be known to many readers. He was ready to talk about science at any time and any place, even after several intense days of conferencing, and Christopher Hunter remembers what he calls “The first and only Lake City International Stellar Dynamics Symposium” where the two carried on work begun at an official nonlinear astronomy workshop at the nearest motel where they could find rooms.

We are rapidly approaching what can only be called “Schwarzschild stories,” some of the best of which are really one-liners, but which require a certain amount of setup. For instance, every eponymous scientist has to solve the problem of what to call the effect, equation, or whatever, that has been named for him. Schwarzschild had a special problem, and normally spoke of “the criterion for convective instability,” but, if hard pressed, would call it “my father’s criterion.”

His tact was legendary. “Yes, but do you think you have underestimated the time required, by a factor of, perhaps, three?” (to Tom Statler). “Peter, are you sure????” (to Teuben). “Yes, but will you still have enough to eat?” (to an undergraduate who had just bought his book). Legendary, but subject to limitations. “If you have your PhD, I am Martin. If not, I am Professor Schwarzschild” (to a young astronomer at an AAS meeting, overheard by the present author, who has herein taken full advantage of having a PhD). And, as a description of how to lecture, “First I tell them what I’m going to say; then I say it; then I tell them what I have said. Maybe one of the three times they are listening.”

Even Homer nods. A 1948 paper that has often been cited as a prescient contribution to our understanding of coronal heating uses “noise energy transport.” And Schwarzschild mentioned to Paczyński many years ago that it actually violates the second law of thermodynamics in transferring energy from a relatively cool to a relatively hot system without paying the required price elsewhere. “Oh. I would die if there were dwarf carbon stars,” he said to Howard Bond in the 1970s. On this one, he was wrong *de facto* (for there are such), but right *de jure* (for they are close binaries after mass transfer from a star that is now a white dwarf).

And finally from Ray Weymann, the gist of a conversation in the fall of 1956, when he and Don Morton were the two first-year graduate students in Princeton astronomy, attempting to survive a course taught by Prof. Q.

MS: Well, Don, how are things going?
DM: (very polite and respectfully): Oh, just fine thank you, Dr. Schwarzschild, we are working very hard, but learning a lot and enjoying our courses.

MS: Um, isn’t that right, one must work extremely hard as a graduate student, but, um, isn’t that right, one must get enough sleep too!

RJW: (somewhat brasher, slightly obnoxious other first-year graduate student from adjacent cubicle) Excuse me, Dr. Schwarzschild, but I’m having a bit of trouble with Dr. Q’s lectures.

MS: I See. And what is that, Rray?

RJW: Well, Dr. Q. mumbles, and frankly I haven’t been able to understand a thing he says during his lectures.

MS: Um, isn’t that right, we have all been trying to work extremely hard on Q to get him to improve on that.

RJW: Yes, but that’s not the only problem. His writing is so bad, and the surface of the blackboard is so bad, that I can’t read anything he writes either.

MS: (3 second pause, then) Vell, Gut. Then there are no contradictions.

Oral history interviews with Schwarzschild from 1975, 1977, and 1979 are available at the Neils Bohr Library of the American Institute of Physics. Extensive obituaries should appear in the Biographical Memoires of the National Academy of Sciences and of the Royal Society (London).

Martin is survived by his wife and early collaborator Barbara Cherry Schwarzschild, by his sister Agathe Thornton, *quondam* professor of classics at the University of Dunedin, New Zealand, and by countless friends and admirers within the astronomical community. Some years ago, his accidental namesake Martin Rees noted, in connection with a lecture scheduled at the Cavendish Laboratory, that it was “a poor astronomer who won’t walk across the street to hear Martin Schwarzschild.” We are all enormously the poorer that this will no longer be possible.

I am deeply indebted to Schwarzschild’s students, friends, and co-authors who provided information for this account. These include John Gaustad (who uncovered some fascinating documents in the Swarthmore College files, provided all the photographs, and commented on the first draft), Leon Mestel (author of an obituary that appeared in the *London Independent*), Donald C. Morton (who recalled the early interaction with Eddington and some army stories), Christopher Hunter (who was there in 1986 when Chandra handed over the 40-year old picture of Martin to Barbara), John Bahcall (who transmitted a complete CV and some thoughts), Neta Bahcall (who provided the list of Schwarzschild’s students at Princeton), Bohdan Paczyński (for a copy of his obituary written for BAAS and an account of the paper that violated the second law of thermodynamics), J. Beverly Oke (for the proton-proton and other stories), Malcolm Savedoff (for tales of both Columbia and Princeton, including the days of stellar-structure-by-Marchant and the origins of *Stratoscope*), John Bahng (for the description of how the monograph was written), William Baum (for an account of the Schwarzschild’s time at Mt. Wilson and some of MS’s attitudes toward the AAS), and Thomas Statler, Peter Teuben, William Saslaw, and Ray Weymann for characteristic Schwarzschild stories. Barbara Schwarzschild has, very gen-

erously, read all these pages, corrected and commented on many items, and, very naturally, felt that more could be said, and better. I am, finally, indebted to Martin himself for a letter (handwritten on 16 December 1996 without a cross-out or correction) describing the origins of the Divisions of the American Astronomical Society.

APPENDIX: THE ELDER SCHWARZSCHILD

Today we associate the name of Karl Schwarzschild primarily with his December, 1915, solution of the Einstein equations, describing the space–time around a point or spherical mass (the Schwarzschild metric, solution, radius, and so forth) and secondarily with the criterion for the onset of convection in a homogeneous gas whose temperature gradient becomes too steep (Schwarzschild 1906). Closer to his own time, however, he was also known for (a) observations and analysis of the tail of Comet Halley, demonstrating its extreme tenuity, (b) the invention of the concept of local thermodynamic equilibrium and its use in describing the structure of a solar or stellar atmosphere in radiative equilibrium, (c) measurements and calculations of the variation of the depths of solar absorption lines from center to limb and of continuum limb darkening (in a completely convective photosphere, the limb would be completely dark), and (d) the Schuster–Schwarzschild (“reversing layer”) approximation to the problem of radiative transfer and line formation (Schuster 1905, Schwarzschild 1914; the other extreme is the Milne–Eddington approximation where the ratio of line to continuum opacity is constant with depth), and the associated Schwarzschild–Milne integral (Milne 1928; Eddington, 1929), (e) contributions to stellar kinematics, including a heuristic justification for parallaxes based entirely on apparent magnitudes and proper motions and the development of the concept of the velocity ellipsoid as a way of describing the space motions of nearby stars (Schwarzschild 1907, 1908; the opposite here is the star streams of Kapteyn 1905). It is perhaps significant that, in Aller’s (1963, 1954) classic textbooks of stellar atmospheres and interiors, the atmospheres volume has roughly equal numbers of references to the work of Karl and Martin Schwarzschild, while the interiors volume mentions only the work of Martin.

As you might expect, KS’s name does not appear on the published version of every idea he had. A telling example was his persuading Hans Rosenberg to try plotting the luminosity versus a color indicator for stars in the Pleiades, shortly before KS moved from Goettingen to Potsdam in 1909, and also shortly before Hertzsprung and Russell had very similar ideas. It appears as Rosenberg (1910). The complete papers of the elder Schwarzschild, with summaries in English of the German originals and a biographical introduction, have been published in three volumes by Springer-Verlag.

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