Maarten Schmidt

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A Biographical Memoir by Richard Green

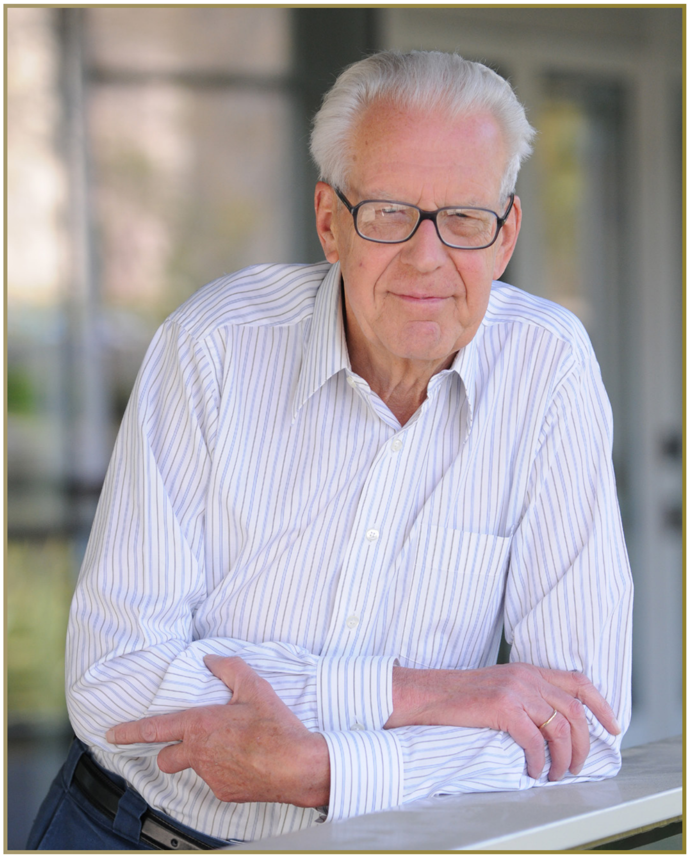

Figure 1 Maarten Schmidt. *Photo credit: Caltech.*

The name of astronomer Maarten Schmidt, Francis L. Moseley Professor of Astronomy Emeritus at the California Institute of Technology (Caltech), is indelibly associated with the first understanding of the high redshifts of quasars. His recognition of the spectral pattern in the quasar 3C 273, stretched and displaced beyond any expectation in the early 1960s, provided the key to interpreting the spectra of other quasars then in hand.[1] His location of the optically identified quasi-stellar radio quasar 3C 9 at ~3/4 of the way back in cosmic time forced the realization that much of cosmic history was available for study.[2] This "opening of the Universe" resonated with science reporters and the public, placing Schmidt on the cover of *Time* magazine in 1966.

But the deeper paradigm-breaking impacts came in multiple ways. Given the assertion that the redshifts corresponded to the enormous distances implied by the cosmic expansion in the Big Bang theory, these quasars then had to be more luminous than the entire stellar population of a large galaxy. In 1964, Greenstein and Schmidt conducted an exhaustive physical analysis of the characteristic emission lines and the optical variability of the two first radio quasars identified, 3C 273 and 3C 48.[3] They concluded that the power source was contained within a region less than a parsec in radius and for an extended lifetime "continued input of energy is required from some not directly observable source." That energy source needed to be much more efficient than the fusion furnaces inside of stars.

The popular alternative explanation was that quasars were relatively nearby. One possibility was that the redshifts were gravitational. Greenstein and Schmidt argued that ascribing the large redshifts entirely to gravitation from relatively close, extremely dense objects ran into major difficulties with the most straightforward photoionization structure producing the observed spectra. Another possibility, posited by Halton Arp and others, was that there was a non-cosmological component to redshifts attributable to high-velocity Doppler shifts, either from near-relativistic ejection of (small) quasars from nearby galaxies, or another undetermined mechanism.[4] Maarten was insistent that the simplest explanation was that the redshifts were cosmological, even if the energy source needed further explication. At that time, consideration of accretion onto supermassive black holes, the currently accepted model, had been limited to a few imaginative theorists. It is no coincidence that the Kavli Prize was awarded in 2008 not only to Maarten for his observational interpretation but also to Donald Lynden-Bell for his development of the black hole paradigm as explanation.

An Evolving Population

Maarten also applied the skills he developed from using star counts to elucidate the structure of the Milky Way to the problem of the distribution of quasars with redshift. He found in his studies of both radio-loud and radio-quiet quasars that their number density per (co-moving) volume of space increased strongly with distance away from us, or with earlier cosmic time.[5,6] That result was validated repeatedly with subsequent samples showing increasing incidence of quasars from the present back to redshifts 2-3, when the Universe was only ~2 to 3 billion years old. The existence of that evolving space distribution falsified two major paradigms of the time (at least after the fact). The steady state theory held that there was no Big Bang and expansion, but a steady and uniform creation of new matter. The space distribution of any class of extragalactic object in that model must be uniform with cosmic time. That conflict was immediately apparent, leading the main steady state proponent, Fred Hoyle, to mount vigorous counterarguments until the evidence was unequivocal.[7]

Even within the expanding Universe paradigm, a popular understanding at the time was that all galaxies formed approximately 10 billion years ago,[8] and evolved at different (slow) rates, accounting for their differing morphological structures and young stellar content. The existence of a rapidly evolving cosmic sub-population provided an important initial challenge to the earliest explanations for the "cosmic tuning fork" configuration of elliptical and spiral galaxies as evolutionary progressions.

The central approach of Maarten Schmidt's scientific studies was to exploit the framework of statistically complete samples to derive the properties of a population, whether it was the evolution of quasar number density in cosmic time or the distribution of fundamental physical properties within the population. His series of three papers in 1972 provided a thoughtful analysis of the statistics of radio sources, separated into quasars and radio galaxies and then analyzed by radio frequency.[9,10,11] The radio galaxies also showed an increase in space density looking back in cosmic time, even when the rapidly evolving quasar population was separated from the overall radio source counts.

Subsequent Surveys

Maarten Schmidt worked with the author to survey a quarter of the celestial sphere to discover the brightest quasars distinguishable by strong ultraviolet flux relative to the vast majority of stars, the Palomar Bright Quasar Survey (a subset of the Palomar-Green Catalog of Ultraviolet Excess Stellar Objects). That statistically complete sample strongly reinforced the preliminary conclusions based on small samples from Schmidt's 1970 and 1972 papers that the population was strongly evolving from the present back to redshift 2 (when the Universe was only ~1/4 of its present age).[12]

Figure 2 Maarten Schmidt showing the controls of the Palomar 200-inch to a young admirer, 1980. *Photo courtesy of the author*.

The flux density limit of that bright sample was a very good match to the sensitivity of early astronomical orbital missions, such as the Einstein Observatory satellite, as well as the Very Large Array radio telescope, then under construction. Schmidt's work with Ken Kellermann and collaborators showed that the relative distribution of radio power was bimodal, with distinct radio-quiet and radio-loud populations of quasars.[13] Work on the X-ray observations of the PG quasars with Harvey Tannenbaum and collaborators led to the first determinations of the contribution of individual sources to the then-unresolved soft X-ray background.[14] Maarten pursued studies of the X-ray population of quasars for many years with colleague Günther Hasinger on samples from the ROSAT All Sky Survey, with the increased sensitivity of that satellite matched with the power of the W. M. Keck Observatory telescopes for spectroscopic follow-up.[15–18]

He recognized the potential of next-generation detectors when he teamed up with his postdoc, Don Schneider, and colleague Jim Gunn to perform a transit survey for emission-line objects. The Palomar Observatory 200-inch telescope was parked at zenith, and the new charge-coupled diode array (CCD) detector was clocked at the sidereal rate to integrate briefly on the full scene as it was dispersed through a prism. Their complete sample of Lyman alpha emitters showed that there was a peak in quasar activity in the redshift range 2-3 when the Universe was ~2 to 3 billion years old; approaching earlier cosmic times, the incidence of quasars then started to decrease.[19] This peak was later shown to correspond to the peak in star-formation density as well, leading to the branding of this maximum in activity as “Cosmic Noon.”[20] That survey was the basis for the technique of the Sloan Digital Sky Survey enabled by Gunn’s extraordinary detector and scientific expertise.

Highest Impact and Pioneering Studies

It is of interest to note that, although Maarten Schmidt is best known for his career-long work on quasars, his most highly cited single paper is on the global star formation properties of galaxies. He derived the dependence of the rate of star formation on the surface density of interstellar gas, taking into account the exchange of gas between stars and the interstellar medium along with the stellar initial mass function. The Schmidt Law, then expanded into the Kennicutt-Schmidt Law, has been one of the most robust relationships characterizing the complex interplay of the uptake of interstellar gas and its return to the interstellar medium, as well as the build-up of the fusion-product heavy elements through that exchange.[21]

It is also of interest to note that Maarten’s own enthusiasm might have been highest for his first major discovery. He was among the first to perform radio observations of the hydrogen 21-centimeter line and was assigned, along with Gart Westerhout, to map the distribution of hydrogen in the Milky Way. Maarten’s assignment was the mapping of the gas interior to the Sun’s orbit. He described in a reminiscence the pure excitement of plotting the iso-density contours and seeing the inner spiral structure of the Milky Way for the first time.[22]

Attributes of a Great Scientist

The question I ponder to this day is what made Maarten such a great scientist? For one, he was persistent—I used to say like a dog with a bone in chewing a problem over and over until he understood it. He just would not let a challenging result sit without a defensible interpretation. Cracking the redshift of the quasar 3C 273 is the example we all know.

He was particularly good at striking a balance in seeking astrophysical explanations that might have been somewhat outside the then-accepted framework, but not too far. He found unexpectedly high redshifts because he was willing to look. He favored the cosmological framework of the expanding Universe, so he was willing to accept the consequence of tremendous energies from black holes, in preference to exotic alternatives. That choice has withstood the test of time and a deluge of subsequent data.

Maarten was extraordinarily creative and intuitive in applying traditional techniques in very novel ways. His use of star-counting methods to determine the distribution of quasars in cosmic time is a prime example. A classical statistician would not have used his V/Vmax method to find the best fit for the changing quasar space density.[i] But Maarten had his tables, calculated by hand (actually with his circular slide rule), which gave him deep intuitive understanding of the contribution of each object in a pioneering small sample to the overall result.

He was truly “old school,” in that he would choose one or two collaborators with special expertise (or dedication to hard work), and pursue his projects to completion. Over the course of his active academic career, he advised a limited number of graduate students: Robert Wilson, Bruce Peterson, Donna Weistrop, Richard Green, Rick Edelson, and Irwin Horowitz. Robert Wilson went on to share the 1978 Nobel Prize in Physics for his role in the discovery of the cosmic microwave background.

Excerpts from a Life

Reflection on a life’s work is enriched by consideration of a life’s story. Maarten’s is told compellingly in his own words in his autobiography on the Kavli Prize website.[23] His father Wilhelm was lead accountant in the Hague; his mother Annie Wilhelmina (née Haringhuizen) was a housewife; and his brother Cees was an academic and researcher of Medieval Dutch language. Maarten reported that his appreciation of the dark night sky was cultivated during the blackouts in Nazi-occupied Netherlands when he was an early teen in his hometown of Groningen. Looking through his uncle’s amateur telescope awakened his lifelong passion, prompting him to assemble his own telescope and read deeply and extensively about astronomy. After graduating in physics, math, and astronomy from the University of Groningen in 1956, Jan Oort offered him an assistantship at Leiden Observatory. He worked with Oort in characterizing the Oort Cloud of distant comets and then was sent to western Kenya to be one of two observers establishing precise declinations of stars from an equatorial observatory. He would share fond recollections on cloudy nights around the Palomar billiard table about the satisfaction and self-reliance required to obtain those observations—connecting banks of car batteries as emergency power and staying alert for marauding leopards.

Maarten served in institutional and community leadership roles, some of which were particularly challenging. He was executive officer for Caltech’s Department of Astronomy for three years before being appointed chair of Caltech’s Division of Physics, Mathematics, and Astronomy in 1975. The author remembers the challenge of being a Ph.D. thesis student and needing to make hard-to-get appointments with a watchdog administrative assistant to discuss his progress. Maarten’s recollection in his Caltech biographical interview was that he would initially be annoyed by the interruption of his administrative focus, but then take real joy in being pulled back to thinking about research.

He became the director of the Hale Observatories in 1978. That organization allowed astronomers from Caltech and the Carnegie Observatories to share time on the telescopes run by the two institutions at Palomar, Mount Wilson, and Las Campanas Observatories. Maarten recognized structural difficulties with the joint-appointment approach from the two institutions; the leadership of Caltech and Carnegie accepted his recommendation that the two institutions sever their joint astronomical relationship to run and use their own facilities. At the time, the astronomers reacted badly to the change. Maarten would point out in later years that the subsequent competition led to the production of the Keck and Magellan Telescopes and now the projects for the Thirty Meter Telescope and Giant Magellan Telescope, significantly enriching the observational capabilities of a broad community.

Maarten was chair of the board of directors of the Association of Universities for Research in Astronomy (AURA). At the time, AURA received the funding and was responsible for the oversight of the National Optical Astronomy Observatory (NOAO, now NOIRLab) for the National Science Foundation and the Space Telescope Science Institute for NASA. He deftly guided discussions during the contentious time of NOAO's selection of the primary mirrors for the Gemini Observatory's telescopes. He served as president of the American Astronomical Society and made sure that the society's national advocacy represented the priorities of the National Academies' Decadal Survey on Astronomy and Astrophysics rather than devolving into promotion of individual competing projects. When he returned to departmental life and then emeritus status, he directed his statistical analysis prowess to characterizing the distribution of gamma ray bursts, going back to the satellite data stream to get a clean definition of the selection function.

We cannot know its relationship to creativity, but his friends and colleagues know that family was a source of pride and happiness to Maarten. He was devoted to his wife, Cornelia (Corrie) Tom Schmidt. She was an accomplished fabric artist and would say that when your husband has been on the cover of *Time,* you need to do something to distinguish yourself. They were very loving and strict parents of their three daughters: Els, Marijke, and Anne.

Honors and Awards

Maarten Schmidt earned numerous honors and prizes over the course of his long career. In 1978, he was awarded the Henry Norris Russell Lectureship of the American Astronomical Society. His prizes include the Helen B. Warner Prize of the American Astronomical Society (1964), the Karl Schwarzschild Medal of the German Astronomical Society (1968), the Gold Medal of the Royal Astronomical Society (1980), the Golden Plate Award of the American Academy of Achievement (1980), the James Craig Watson Medal from the National Academy of Sciences (1991), the Catherine Wolfe Bruce Gold Medal from the Astronomical Society of the Pacific (1992), and the Kavli Prize for Astrophysics (2008). He was a member of the American Academy of Arts and Sciences, the National Academy of Sciences, the German Academy of Sciences Leopoldina, and the American Philosophical Society and was a Correspondent of the Royal Netherlands Academy of Arts and Sciences. And in 2001, an asteroid was named for him: 10430 Martschmidt.

Final Word

In the end, Maarten Schmidt's extraordinary legacy can be attributed to his application of scientific rigor, whether it was to an exciting and totally unexpected discovery like quasars or a basic phenomenon like star formation in galactic disks. That care was exemplified in a comment by the fastidious editor of the *Astrophysical Journal,* Subrahmanyan Chandrasekhar, who wrote in a footnote to Schmidt's 1970 paper:

> The *Astrophysical Journal* has up till now not recognized the term "quasar"; and it regrets that it must now concede: Dr. Schmidt feels that, with his precise definition, the term can no longer be ignored.[24]

Even more importantly, the kindness and wisdom that shone through Maarten Schmidt's smiling photographs was a genuine reflection of the inner man. Maarten never talked down to anyone, whether junior colleagues or students, and treated everyone as intellectual equals, with a common interest of understanding the Universe. That decency, complemented by his integrity and dogged persistence as an astronomer, left an indelible legacy in the field of extragalactic astronomy.

Acknowledgments

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Note

i The V/Vmax method is a computation of the average for a statistically complete sample of the ratios of the volume out to the observed distance of each source to the volume accessible to that source if it were moved out to the observed flux limit of the sample. In a Euclidian Universe, that average would be 0.5. A population with evolving space density departs from that value. The weighting function that brings the average back to 0.5 describes the change in space density with distance. Maarten used this approach successfully to model the scale height of Milky Way stellar populations and brought this very powerful technique into the modern cosmological vernacular by applying it to cosmological volumes with distances dependent on redshift.

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