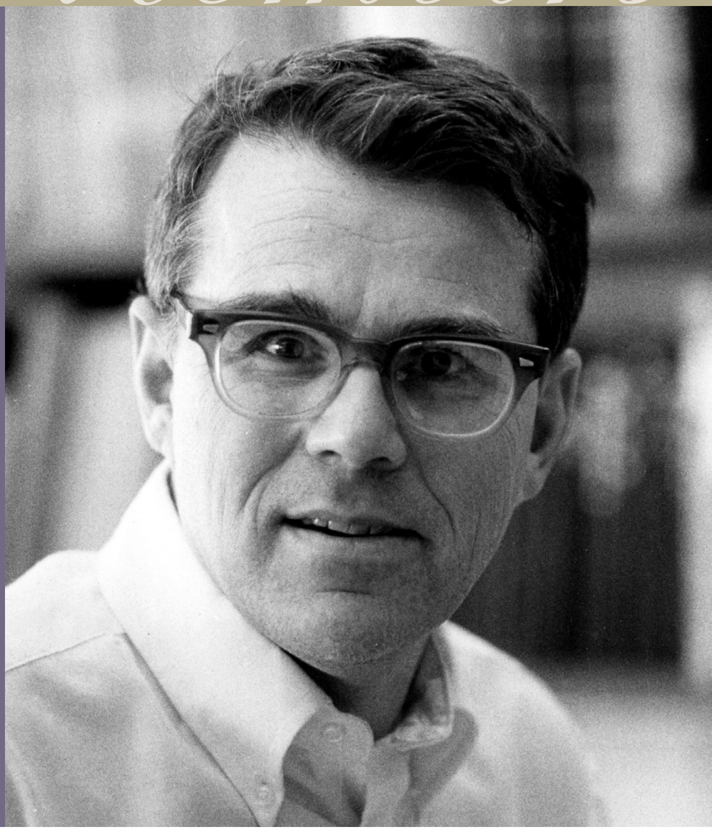
Gerry Neugebauer

1932–2014

BIOGRAPHICAL *Memoirs*



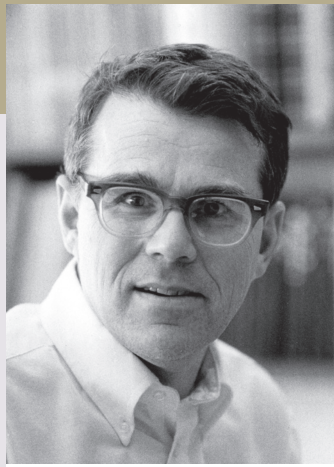
A Biographical Memoir by
B. Thomas Soifer

NATIONAL ACADEMY OF SCIENCES

GERRY **NEUGEBAUER**

September 3, 1932–September 26, 2014

Elected to the NAS, 1973



By B. Thomas Soifer

Gerry Neugebauer was one of a small band of experimental physicists who used their perspectives to create a new discipline within astrophysics. Together they founded what is now known as infrared astronomy. Gerry's commitment to innovative instruments and sky surveys exploring the unknown universe was matched by his commitment to the highest quality of published and archived data, which were vital to the creation of a dominant discipline in modern observational astrophysics. His discovery of many new kinds of celestial objects and phenomena, studies of which have remained vibrant subfields of astrophysics to this day, brought many others into the field that he helped invent.

Neugebauer did his undergraduate study at Cornell University and earned a Ph.D. from the California Institute of Technology (Caltech). After receiving his doctorate, he spent two years at the Jet Propulsion Laboratory in performance of his military obligation as a reserve officer, working on the Mariner 2 Spacecraft project. He then joined the Caltech faculty and remained there in successively higher positions, eventually becoming chairman of the Division of Physics, Mathematics and Astronomy, as well as director of the Palomar Observatory.

Gerry Neugebauer was born Gerhard Otto Neugebauer on September 3, 1932, in Göttingen, Germany. His father, Otto Neugebauer, was an eminent Austrian-born historian of the exact sciences, while his mother, Grete Neugebauer (née Bruck) was a mathematics student who assisted her husband in much of his work. Because Otto refused to sign an oath of allegiance to the Nazi regime after Hitler came to power the following year, he was barred from further employment in Germany. The family moved to Denmark in 1934, where Otto became a professor of mathematics at the University of Copenhagen, and then to the United States in 1939, where a position in the Mathematics Department of Brown University was created for him. The younger Neugebauer grew up in Providence and legally changed his name to Gerry (pronounced Gary) when he was a teenager. He earned a bachelor's degree from Cornell University in 1954 and a Ph.D. in 1960 from the California Institute of Technology (Caltech) in experimental high-energy physics, which he studied under Robert L. Walker.

He met his future wife, Marcia MacDonald, when both of them were Cornell undergraduate physics majors. They were married in 1956 and had two daughters, Carol and Lee. Marcia Neugebauer has had a distinguished career as a space physicist. She joined the Jet Propulsion Laboratory (JPL) in 1956 and formally retired in 1996 while continuing to do research to the present. (Gerry often described Marcia as the famous Neugebauer).

Gerry participated in ROTC at Cornell and was commissioned a second lieutenant upon completing his Ph.D. He served his subsequent military obligation at JPL, where he worked on the infrared radiometer for NASA's Mariner 2 spacecraft. The instrument was designed to measure, with high geographical resolution, the emission of Venus at 8.4 μm and 10.4 μm. The Mariner 2 encounter with Venus in 1962 was the world's first successful planetary mission and was the first of six NASA planetary missions on which Gerry was either the principal investigator or a co-investigator for an infrared radiometer instrument.

The Two-Micron Sky survey and early discoveries

Gerry returned to Caltech in 1962 as an assistant professor of physics and began working with Professor Robert Leighton. As experimental physicists wanting to exploit new technology in studying the universe, they built a telescope and equipped it with a modest 8-pixel array of lead sulfide (PbS) infrared detectors to conduct a survey of the sky at 2μm to explore the previously unobserved infrared region of the electromagnetic spectrum. While working on Mariner 2, Gerry had developed connections with the Santa Barbara Research Center (at the time a division of Hughes Aircraft), enabling him to obtain high-performance PbS sensors. Leighton designed and built a spun-cast-epoxy 62-inch-diameter parabolic mirror and a mount for the survey telescope. Gerry, working with Dowell Martz, a fellow scientist on the project, was responsible for the detectors, electronics, and data processing for the survey.

Gerry and Leighton conducted the first infrared survey of the sky with their purpose-built telescope at the Mount Wilson Observatory (about a 30-mile drive from the Caltech campus). The catalog that emerged from this survey contained many stars that were bright at 2 μm and had been overlooked as faint and uninteresting by astronomers working at visible wavelengths. The many thousands of bright infrared stars in their catalog revealed the richness of the infrared sky and motivated many astronomers and physicists to move into this area of astronomical research.

One of the hallmarks of the Two-Micron Sky Survey project was the number of extremely talented students, both undergraduates and graduates, whom Gerry attracted to the enterprise. Among the students were a future Nobel Laureate (Douglas D. Osheroff), a future Kavli Laureate (Jerry Nelson), and many other highly successful physicists and astronomers. These students played crucial roles in building the instrumentation, operating the survey telescope at Mount Wilson, and processing the data to create the groundbreaking *A Two-Micron Sky Survey: Preliminary Catalog*.

In the 1960s and ’70s astronomy was exploding with new discoveries as new technologies were brought to bear and telescopes capable of penetrating previously unexplored regions of the electromagnetic spectrum were trained on the heavens. Infrared astronomy was in its early discovery phase, and Gerry, with his group of students and postdocs, was at the center of the action. At the time, research was conducted primarily by individual astronomers with perhaps the help of a postdoc and/or a graduate student. By comparison, Gerry’s group of four or five graduate students and two or three postdocs plus undergraduates seemed huge and was nicknamed “the Infrared Army,” or IRA. Members of the IRA made observations of virtually any and every new kind of celestial object found via any means—radio, x-ray, optical, or infrared.

Gerry and his group explored in depth extreme objects discovered in the Two-Micron Survey. Amazingly, among the most extreme objects found, the red giant stars NML (Neugebauer, Martz, and Leighton) Cygnus and NML Taurus, were discovered even before the survey officially began, during the instrument commissioning. These stars were embedded in cocoons of dust and gas of their own making.

The bright infrared stars from the survey were found to be predominantly post-main-sequence stars that were ejecting the material of their outer envelopes as they evolved off the stellar main sequence. The conditions in those ejecta were ideal for the nucleation and growth of dust grains. The dust formed shells that efficiently absorbed the stellar light, obscuring the stellar sources—when looked for in visible light, and reemitted this energy at longer wavelengths. The dust in the circumstellar shells came to equilibrium temperatures of several hundred to more than a thousand degrees Kelvin, consistent with equilibrium between heating by absorbed starlight and cooling by thermal emission.

The most extreme of those sources from the survey was named IRC+10216 (IRC standing for the Infrared Catalog—that is, the Two-Micron Survey catalog), which was found to be a "carbon star," an evolved star containing more carbon than oxygen in its atmosphere and thereby forming carbon rich dust (graphite) in its ejecta. This star was ejecting ~10^{-5} solar masses per year of material from its atmosphere and produced a cocoon of material ~1.4 times the mass of the Sun. It emitted more than 10^7 times the energy in the infrared than in the visible portion of the spectrum. All of those parameters had been totally unanticipated and led to a much different view of how post-main-sequence stars evolve.

With graduate student Eric Becklin, Gerry discovered what was referred to as the first "protostar," the "Becklin-Neugebauer" object in Orion. The BN star was found to be a ~600K blackbody with a luminosity about 10^5 times that of the Sun. It is about 7-10 times the mass of the Sun, totally enshrouded in gas and dust. In this case the dust was pre-existing in the cloud of gas from which the star formed. Virtually all of its luminosity emerged in the infrared portion of the electromagnetic spectrum.

This discovery led to the exploration of star-forming regions as rich environments in which to find and examine stars in the various phases of formation, from initial gravitational collapse to becoming young stars with remnant planetary-debris disks. This has become a full-fledged subfield of astronomy that continues vigorously to this day. Because visible-wavelength light cannot escape these extremely dusty environments, studies of star-forming regions are dominated by infrared, millimeter, and radio observations.

Again with Becklin, Gerry also found and studied in detail the star cluster at the center of our galaxy, the Milky Way. Because it is viewed through 30 magnitudes of visual extinction (that is, attenuation of emitted light by a factor of ~10^{12} beyond the usual $1/r^2$ dimming), the center of the galaxy cannot be detected at visible wavelengths. On the other hand, the attenuation of the light from the galactic center at 2μm is only ~2.5mag or a factor of 10. This enables astronomers to study the center of the galaxy in great detail at near-infrared wavelengths. Becklin and Gerry published together and with many additional collaborators an extensive series of papers elucidating the properties of the central region of the Milky Way. The early work on the galactic center focused on the properties of the stars and star cluster, but evolved into understanding other phenomena occurring in this environment of high stellar density.

The central region of the Milky Way has been a subject of active study since its definitive location was discovered in the mid-1950s by a team of Australian radio astronomers. In the last several decades, with the achievement on ground-based telescopes of diffraction-limited angular resolution at near-infrared wavelengths, this work has evolved predominantly into the study of the massive compact object at the center of the galaxy. Much of this work has been led by one of Gerry's last students before his retirement, Andrea Ghez (later a Crafoord Prize Laureate and NAS member), and focused first on demonstrating the existence of the supermassive black hole at the center of the galaxy and then on understanding its environment and the bizarre stars populating that region. While much of this work occurred after his retirement, Gerry had begun this field of study by pushing for the construction of the first diffraction-limited imaging capability at the Keck Observatory (see below). With this capability, observations with the Keck I telescope began in 1995 of stars orbiting the central mass of the galaxy.

In the 1960s and '70s Gerry's group led the way in discovering and understanding the brightest infrared sources in the sky: compact regions heated by newly formed massive young stars that had not yet emerged from their placental cocoons of gas and dust, as well as dust-enshrouded galaxy nuclei. Gerry and his group showed that the sites of massive star formation, discovered through the use of the new radio interferometers being constructed around the world, were prodigiously luminous in the infrared.

The infrared-bright galactic nuclei were mysterious in that the sources that powered their luminosities were unknown and widely debated. Gerry's team made observations that spatially resolved the nearest of these active nuclei, NGC 1068, at 10μm using the Palomar Observatory's 5m telescope. This was the definitive observation demonstrating that the predominant source of infrared radiation from these galactic nuclei was thermal emission from interstellar dust heated by the central energy source (much like the dust-enshrouded stars described above). Gerry and company showed that the quasars, discovered in the 1960s to be the most distant and luminous objects in the universe, were as prodigious at generating luminosity in the infrared as in the visible. His long-term program of monitoring the brightness variations of these objects showed that most of their infrared radiation was due to thermally reradiated emission from dust heated by a central luminosity source.

Gerry's early work was done almost entirely with the ground-based telescopes of the Mount Wilson and Palomar Observatories (later the Hale Observatories). As an experimental physics group (Gerry took pride in being a professor of physics) he and his students and postdocs developed their own instrumentation that operated in the atmospheric windows from 1–20µm, as well as longer wavelengths (34µm and 1mm). Indeed, since the Infrared Army was a physics group, all graduate students were expected, as part of their Ph.D. training, to have instrumental components in their thesis projects. In parallel with the ground-based infrared astronomy exploration, other groups in this newly created field were exploiting telescopes on sub-orbital platforms (airplanes, balloons, sounding rockets) to show that many sources of celestial infrared radiation were even more luminous in the "far infrared"—that is, 30-300µm—than in the shorter-wavelength infrared windows accessible from the ground. The "infrared air force," led by Gerry's faculty colleague, Michael Werner, was a major contributor to developing airborne far-infrared astronomy.

The IRAS Project

Rapid progress in exploring infrared astronomy over the entire infrared (1-1000µm) portion of the electromagnetic spectrum motivated NASA to team with the space agencies of the Netherlands and the United Kingdom to begin the Infrared Astronomical Satellite (IRAS) project to conduct an all sky survey from 12 to 100 µm.[1] Gerry was the American co-chair of the international science team for this project from 1976, when it officially started, through the publication of the IRAS catalogs in 1985. His international co-chairs were first Reinder van Duinen and then Harm Habing, both from the Netherlands.

IRAS was an enormously challenging project, technically, managerially and politically. In addition to his immense technical contributions, Gerry also provided scientific leadership of the project, and his stature was necessary at times to hold the often-fractious science team together. Ultimately, the satellite was launched in January 1983 for a very successful 10-month mission. IRAS surveyed the entire sky to sensitivity levels 10-100 times deeper than previously achieved. (Occasionally, in small patches of the sky where

1 While the sky could be viewed through atmospheric "windows" that provided varying degrees of transparency from 1 to 20µm, the atmosphere even from the highest astronomical sites was virtually totally opaque from 30µm to 300µm. In addition, the thermal emission of the environment, both telescope and atmosphere, bathes the instruments in a flood of background photons that limits the sensitivity of observations through the shot noise in the incident photon flux. Alternatively, carrying a telescope above the atmosphere and cooling it to a temperature where its self-emission is negligible allows full transparency and a reduction in the background photon flux by 6 orders of magnitude, leading to a thousand-fold gain in sensitivity for a given-size telescope. Alternately put, in the 10µm atmospheric window a 1-meter-diameter telescope in space has the same sensitivity to point sources as a 30m-diameter-telescope on the ground.

Gerry Neugebauer, mid-career.
(Photo courtesy of the author.)

individual objects were observed for long periods by the most powerful ground-based or airborne telescopes, observations matched the sensitivity that IRAS achieved in a few seconds of observing.) IRAS detected and cataloged hundreds of thousands of infrared sources from our solar system to the distant universe, producing a compendium that was among the largest created by astronomers at that time.

Gerry's insistence on the highest quality in IRAS catalogs and atlases led to the publication of data that have been heavily used by the entire astronomical community since 1985. The rapid public release of IRAS data in forms that were scientifically usable by virtually anyone set a new benchmark for NASA astrophysics missions. The IRAS publications set the standard for NASA astrophysics missions to have very limited proprietary periods and for public access to all science data in readily usable forms.

Gerry's impact on the field of infrared astronomy through IRAS is immense but impossible to quantify. Two of the major scientific results from IRAS, the discovery of debris disks that are the residue from the star- and planet-formation process and ultraluminous infrared galaxies, remain forefront topics in astrophysical research. On a global scale the IRAS survey energized the entire astronomical community and led directly to the Infrared Space Observatory (ISO), the Spitzer Space Telescope, the Akari infrared telescope, the Wide-Field Infrared Survey Explorer (WISE), and the Herschel Space Observatory missions, as well as delivering compelling scientific results that have been a major component in the science justification of NASA's James Webb Space Telescope (JWST). In total the nations of the world have invested well over $12 billion in space astronomy missions that were the outgrowth of the trailblazing IRAS mission.

The Palomar Observatory and the Keck Observatory

While he was leading the IRAS science team, Gerry took on the role of director of the Palomar Observatory. In 1980 Maarten Schmidt, a professor of astronomy at Caltech, resigned as director of the Hale Observatories and recommended that it be split into facilities operated separately by the two partner institutions, Caltech and the Carnegie Institutions of Washington. Gerry was appointed first acting director and then director of Palomar, which was owned and operated by Caltech. He served in this position for 14 years.

As the director, Gerry led a major renovation of the 200-inch Hale telescope, bringing it up to the standards of a modern major research facility by improving the image quality through renewing the backing structure of the primary mirror, improving the thermal environment of the dome, and upgrading the pointing system of the telescope. He pushed the Caltech astronomy faculty to bring to the telescope new instrumentation that used the revolutionary new light sensors—charge-coupled devices (CCDs) in the visible and IR-array detectors in the infrared—to maintain its competitive position in astronomy. He was also involved in the first efforts at Palomar to achieve diffraction-limited spatial resolution in the visible and near infrared, with interferometry and speckle imaging.

Early in Gerry's directorship—that is, in the early 1980s—the enormous gains in the detection efficiencies of light sensors were coming to an end as new technologies were leading to sensors with quantum efficiencies approaching unity and noise performance being limited by shot noise in incoming photon flux. To make the next round of advances in ground-based astronomy it was time to start considering new, next-generation telescopes at the very best sites in the world. At this time the University of California, under the leadership of Jerry Nelson (then at Lawrence Berkeley National Laboratory, was studying a radically new approach to building large telescopes with segmented mirrors), while other groups were investigating telescope designs with large monolithic mirrors.

Gerry recognized the importance of Caltech's being part of one of these next-generation telescope projects and led the Caltech astronomy faculty in evaluating the possibilities. Ultimately, under his leadership and guidance, Caltech opted to join UC and was able to raise, through a grant from the W. M. Keck Foundation, the funds to build first the Keck I telescope and then the Keck II telescope. The resulting project, the W. M. Keck Observatory, was the first and remains the dominant example of the current generation of large ground-based observatories.

Gerry was deeply involved in this project. The group that he led, the Caltech infrared astronomy group, delivered two major instruments to the Keck Observatory under its lead instrument builder, Keith Matthews. The Near Infrared Camera (NIRC) was the first scientific instrument deployed on the Keck I telescope, in March 1993. Its successful demonstration of near-infrared imaging occurred just as NASA was deciding whether to join the Keck Observatory as a major partner. The demonstration, with NIRC, of the success of the segmented mirror concept was crucial to NASA's joining the Keck Observatory. The NIRC was enhanced with a "speckle imaging" capability that first enabled the Keck I telescope to probe, at diffraction-limited resolution, the center of our galaxy and begin the work that ultimately demonstrated the existence of a supermassive black hole there. The NIRC2 instrument was delivered to the Keck II telescope and became the workhorse diffraction-limited imager behind the Keck adaptive-optics system. Since its commissioning in 2001, NIRC2 has played the central role in tracing the stars orbiting the central supermassive black hole at the center of the Milky Way. Caltech's infrared astronomy group also played a major role in developing the first successful multi-object spectrograph in the near infrared (MOSFIRE), now operating on the Keck I telescope.

In addition to being one of the world's leading researchers and director of the Palomar Observatory from 1988 to 1993, Gerry was chairman of the Division of Physics, Mathematics and Astronomy at Caltech (equivalent to a deanship at other schools). The fact that he could handle these three full-time positions was a tribute to his energy and his commitment to Caltech. He was Caltech's Howard Hughes Professor of Physics from 1985 to 1995 and the Robert A. Millikan Professor of Physics from 1995 to 1998, when he became the Millikan Professor emeritus.

Working with Gerry Neugebauer

From a distance Gerry could be quite intimidating. His reputation as a demanding mentor was daunting to some. But if one was lucky enough to get past the first impressions, Gerry proved an enormously generous and kind mentor and friend. He would go out of his way to support his colleagues and students in any way he could. He took great pride in his students and their accomplishments, and always gave them top billing in publications.

One of the trademarks of Gerry's style was his energy. He pushed his students, postdocs, and colleagues, but none more than himself. In the era before the laptop computer and the Internet, he was in the office or in the lab nearly every evening and weekend, working on projects with his team. In leading by example he was able to get more from his students and postdocs than they thought they were capable of. This lesson was perhaps his most valuable contribution to those who were part of the Infrared Army.

Gerry Neugebauer (in khaki shorts and blue shirt) with Dan McCammon at a festschrift for Gerry held in 1992. (Photo courtesy of the author.)

His energy was boundless and infectious. He was approachable by all, never taking on the trappings of his many honors and important positions. He was Gerry to everyone, from the Caltech president to professorial colleagues to all of his students. He signed most of his communications with his computer center initials, GXN (since he didn't have a middle name, and the Caltech computer center required three-letter account names, he was assigned X as his middle initial). He wandered the Caltech campus in his standard uniform, blue oxford shirt and khaki shorts, throughout the year. As he took on the administrative responsibilities of the Palomar directorship or the division chairmanship, one could tell if he had an important meeting coming up, because he'd change into long pants for that meeting,

B.Thomas Soifer, Keith Matthews and Gerry Neugebauer. (Photo courtesy of the author.)

and revert to his "uniform" immediately thereafter. He was revered by virtually all of the students and postdocs who passed through his group.

For everyone who wrote a paper with Gerry, it was something never to be forgotten, a true learning experience. Before word processing, in the era of cut and paste, he would go through countless drafts, always pushing his team members to clarify their thinking and their language. He was a stickler for proper grammar and usage. Once you survived writing a paper with Gerry, your standards were forever raised.

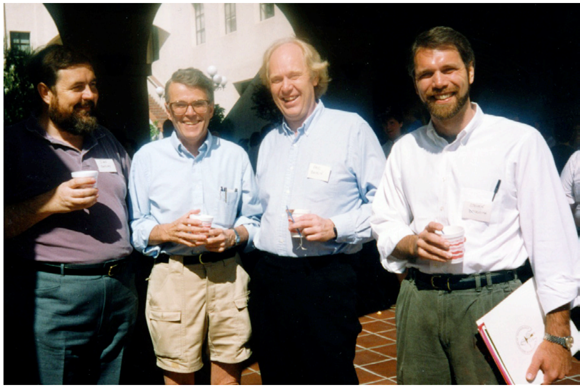
Retirement

After Gerry became the Robert A. Millikan Professor emeritus in 1998, he continued his research, predominantly analyzing data from the Keck Observatory for several more years. In 2002, he and Marcia moved to a retirement community outside Tucson, Arizona. He held an adjunct appointment at the University of Arizona. As far back as the early 1990s, however, he started showing the symptoms of spinocerebellar ataxia, a genetic disorder that had afflicted his mother. Over the years it left him increasingly unable to use his limbs. Ultimately, when he was no longer able to use a computer keyboard, he had to give up research, but he continued to maintain an active interest in astronomy done at the Keck Observatory and with the Spitzer Space Telescope.

For a person who was such a force and so physically active, such limitations were frustrating, but he took his increasing physical impairment with grace and good humor. He died from complications of spinocerebellar ataxia on September 26, 2014.

Gerry Neugebauer's accomplishments and contributions were recognized through many forms. He was the Richtmyer Lecturer and received the American Institute of Aeronautics and Astronautics (AIAA) Space Science Award in 1985. He was a California Scientist of the Year, the George Darwin Lecturer of the Royal Astronomical Society, and recipient of the American Academy of Arts and Sciences's Rumford Prize in 1986.

He received NASA Exceptional Scientific Achievement Medals in 1972 and 1984. He was the Henry Norris Russell Lecturer (lifetime achievement) of the American Astronomical Society in 1996 and received the Herschel Medal of the Royal Astronomical Society in 1998 and the Bruce Medal of the Astronomical Society of the Pacific in 2010. In 1973 he was, like his father before him, elected to the National Academy of Sciences. He became a member of the American Academy of Arts and Sciences in 1975 and the American Philosophical Society in 1986.



Left to right: Ian Gatley, Gerry Neugebauer, Eric Becklin, and Steve Beckwith at a *festschrift* for Gerry held in 1992. (Photo courtesy of the author.)

Gerry Neugebauer was one of the most influential physicist/astronomers of the twentieth century. A founder of a core discipline of modern astrophysics, he made his mark not as much by inventing new technologies as by focusing on understanding celestial objects discovered in infrared sky surveys and by other means. He guided instrumentation development, recognizing its importance for the advancement of astronomy. He placed a premium on high-quality and reliable data, taken either from the ground or from space. His work in many areas led to new insights and major advances in our understanding of how the universe works. The students and postdocs who passed through his group have followed in his footsteps to become leaders in the world of astrophysics and beyond. Gerry was an explorer who loved the discovery of science. This tradition is his legacy to all those whom he touched.

I thank Gerry's wife, Marcia, and daughter Carol, as well as Keith Matthews, Mike Werner, Eric Becklin, and Mary Anna Soifer for help in preparing and reviewing this memoir.

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