BIOGRAPHICAL MEMOIRS

Morton Spitz Roberts

November 5, 1926–January 11, 2024
Elected to the NAS, 1983

A Biographical Memoir by Martha P. Haynes

Figure 1 Morton Roberts. *Credit: NRAO/AUI/NSF.*

Morton Spitz Roberts was a pioneer in the application of the radio 21-centimeter line of atomic hydrogen (HI line) for studies of the interstellar medium of galaxies, its relation to the stellar, dust, and dark matter components, and its importance to galaxy evolution. Over his career, Mort emphasized the use of large filled-aperture radio antennas to collect HI spectra of thousands of galaxies throughout the local universe. He took advantage of continuous improvements in telescopes and instrumentation to push the frontiers of 21-centimeter line research, including the setting of limits on the variation of fundamental constants over cosmic history and demonstrating clearly the flatness of the rotation curve of the Andromeda galaxy far beyond the edge of its stellar light, strong evidence for the existence of dark matter. He led the National Radio Astronomy Observatory (NRAO) through the completion of the Very Large Array and the development of the proposal for the Very Long Baseline Array. Over his career, he served on many boards and committees including as vice president of the International Astronomical Union and the American Astronomical Society. He was elected to the National Academy of Sciences in 1983.

Personal Life

Morton Roberts was born on November 5, 1926, in New York City to Dora Spitz and Solomon Goldberg. He grew up in Los Angeles and graduated from Roosevelt High School. Mort was born with a hole in one of the chambers of his heart and was hospitalized for most of a year when he was about twelve. This health worry instilled in him a dedication to exercise and healthy eating. In Charlottesville later in his life, he was known to walk to and from his office at NRAO just about every day. In his later years, the dog, naturally a Cavalier King Charles Spaniel, would take him for walks. It seems that this lifelong attention to exercise and diet helped him, despite this medical history, to reach the fine age of ninety-seven.

Mort graduated with a bachelor of arts degree from Pomona College in 1948 and remained in California to pursue a master's degree at the California Institute of Technology (Caltech). During this time, two important things happened in his life: the first detection of the radio HI 21-centimeter

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line and, even more important, his marriage to Josephine "Joey" Taylor, whom he had met through her college roommate. They married when Joey graduated and enjoyed seventy-two years of marital partnership, with Joey surviving him only briefly. Their daughter, Elizabeth Roberts Salgado, arrived fifteen years later and frequently joined them on their many travels and stays around the world. Innumerable astronomers visiting Charlottesville enjoyed stimulating conversations and wonderful dinners with Mort, Joey, Elizabeth, and their various pampered cats and dogs. Mort pursued his Ph.D. at the University of California, Berkeley and graduated in 1958.

Even after his retirement, Mort still went almost daily to NRAO to attend lectures, read papers and talk science. In 2013, he and Joey finally left their wonderful house in Charlottesville and moved to a retirement community in Alexandria, Virginia, only a short drive from Elizabeth's home. There they made new friends, enjoyed access to the arts in the Washington area, and tried to keep up with the activities of their three beloved grandchildren: Robert, Ted, and Elena Salgado. But he was also always eager to discuss with his astronomical friends the latest discoveries, controversies, and observational capabilities.

I was lucky enough to work under Mort's guidance as a graduate student in residence at NRAO and continued afterwards to collaborate with him and enjoy his company in various settings over the years. He was always exceptionally supportive of me, offering both encouragement and gentle advice. He entrusted me with the site directorship in Green Bank not long after I finished my graduate degree, an experience that in so many ways shaped my future career. In gratitude, my share of the 1989 Henry Draper Medal prize was used to purchase a new rowing double scull for the Cascadilla Boat Club emblazoned appropriately the *M. S. Roberts*.

Above all, Mort was a gracious gentleman, an inquisitive scholar, and always a perceptive observer of everything around him, including the Universe. He was a great listener, curious to hear interesting facts and anecdotes from anyone he interacted with. He simply loved learning, especially when he could tie together science with art, music, literature, and even everyday life. For example, he was extremely curious about the three-mirror experiment described in the *Paradiso* section of Dante's *Divine Comedy*. Mort believed that those lines demonstrated that Dante understood the concept of surface brightness, also of critical importance to the study of galaxies. His musing about Dante led his friends to track down a 1928 limited-edition copy of Dante's *La Divina Commedia* that included an illustrated plate showing Beatrice and the mirrors as the perfect gift for his "not-a-retirement party" in 1999.

Early Career

After receiving his bachelor of arts from Pomona in 1948, Mort entered the newly established graduate program in astronomy at Caltech. One of his classmates was Allan Sandage, with whom he remained lifelong friends. At Caltech, both took on research projects related to the color-magnitude diagrams of globular clusters. During this period, Mort also held positions on the faculty at Occidental College and as a physicist at the U.S. Naval Ordnance Test Station in Pasadena. Although Mort moved to Berkeley after completing his master of science at Caltech in 1950, his first two publications[1,2] arose out of the early collaboration with Sandage on the behavior of RR Lyrae stars in the globular cluster Messier 3. Sandage went on to write his dissertation on the detailed study of that cluster itself, whereas Mort's thesis, completed at Berkeley in 1958, focused on using star counts for a comparison of the stellar luminosity functions of eight other clusters.

While at Berkeley under the influence of Harold Weaver, he expanded his thesis work on luminosity functions to the elliptical galaxy Messier 32,[3] noting the difference in the mass-to-light ratios derived for globular clusters and for "elliptical nebulae," a prelude to work later on dark matter in galaxies. Weaver had become convinced that studies at radio wavelengths had great potential to probe the interstellar medium and founded the Berkeley Radio Astronomy Laboratory the same year Mort completed his dissertation. In a taped interview from 1972,[4] he describes being exposed to radio astronomy in some guest lectures by Ronald Bracewell, then visiting from Australia, in an astrophysics class taught by Weaver. He stayed on at Berkeley as a National Science Foundation postdoctoral fellow and, driven by a feeling that globular clusters should contain dust and thus gas, undertook observations looking for atomic hydrogen in Messier 3 and 13 with the newly constructed 85-foot Howard E. Tatel antenna at NRAO in Green Bank.[5] Although unsuccessful, this was his first foray into what would become his future career centered on exploring galaxies via the 21-centimeter line from atomic hydrogen.

The Harvard Years

In 1960, Mort moved to Harvard University as a staff member in the nascent radio astronomy group led by Edward Lilley. He quickly took advantage of easy access to the 60-foot radio telescope at the George R. Agassiz Station, which had been completed in 1956. Although some of his first observations focused on the temporal variation of the decametric radiation from Jupiter, he quickly took up the study of HI in galaxies, expanding on Eugene Epstein's Ph.D. project.[6] In the 1972 interview, he discussed numerous anecdotes about his Harvard experience and his conversion from optical to radio astronomy. Not much was known about hydrogen in galaxies, so the topic was ripe for study and potentially of great

Figure 2 Allan Sandage, Vera Rubin, and Mort Roberts in 1999. *Credit: Martha Haynes.*

interest. Once, he made observations for half a night with the 61-inch optical telescope and then moved over for the second half of the night with the 60-foot. The optical telescope was under-performing and constantly being worked on, whereas the radio antenna was in top shape, so it was obvious which one was more satisfying to use. And although the 60-foot was not the largest radio telescope in the world, the low noise of its state-of-the-art maser receiver gave it a big advantage over other radio facilities, greatly reducing the needed integration time. Recognition of the need for advances in instrumentation, and not just in telescopes, would carry through to his future leadership roles at NRAO.

The easy access to the telescope and his general interest in galaxies spurred Mort to acquire 21-centimeter line observations of "enough galaxies to learn about galaxies."[7] Already at this very early stage of extragalactic 21-centimeter studies, Mort emphasized the importance of a holistic view of galaxies, looking for linkages between their stellar and gaseous components and later, their dark matter ones. In his early papers, Mort speculated on possible origins of the differences in fundamental properties such as the mass, luminosity, mass-to-light ratio, color, gas content, and metallicity of galaxies along the Hubble sequence. In 1963, he published a review paper[8] in the first issue of *Annual Reviews of Astronomy and Astrophysics* (*ARAA*) on the stellar and gaseous content of galaxies, followed soon thereafter by a popular article[9] in *Scientific American*.

Career at NRAO

With the commissioning of the 300-foot telescope in 1962 and the ongoing construction of the 140-foot telescope at Green Bank, Mort was perfectly suited to join the staff of NRAO in 1964, receiving tenure as a scientist a year later. At first, he lived in Green Bank, but in 1966 he moved to the newly established NRAO headquarters in Charlottesville, Virginia.

Armed with its new facilities and instruments, NRAO hosted an extremely exciting scientific environment, with a vibrant and innovative research and technical staff. Mort was somewhat distinctive among them because he did not study "radio sources" and preferred to identify himself as an "extragalactic astronomer" rather than a "radio astronomer." From the beginning, Mort viewed galaxies as the sum of separate but intertwined constituents: the stellar populations traced at optical wavelengths, the multi-phased interstellar medium, and later, the dark matter. Much of his work sought to understand the physical processes driving galaxy evolution over cosmic history. His early review in *ARAA*[10] pointed out the importance to galaxy evolution of the timescale on which its gas is converted into stars, defined simply as the ratio of the mass in gas (at the time only atomic hydrogen) to the star formation rate and dubbed later by Sandage[11] as the "Roberts time." Today, of course, it is recognized that stars form out of molecular clouds so that the "gas depletion timescale" should reflect the multiphase gas, but already in 1963, Mort realized that the retention, consumption, and depletion of the gas reservoir are critical factors in galaxy evolution.

Over the course of his career, he searched for quantitative clues to constrain the processes that govern star formation history, using the HI 21-centimeter line to measure the gas mass and to map the distribution of atomic hydrogen in and around galaxies. He was deeply involved in the scientific planning and analysis of the ASTRO-Ultraviolet Imaging Telescope on the *Columbia* and *Endeavour* Space Shuttle missions, looking especially at the bluest stellar populations of nearby normal galaxies. Notable collaborations with David E. Hogg and Joel Bregman focused on understanding the multiphase interstellar medium in early-type galaxies. He was also intrigued by possible environmental impacts on gas retention and conversion, leading to studies of tidal features in loose groups and the HI deficiency of cluster galaxies. He wrote numerous review papers on the general properties of galaxies, culminating in our 1994 review[12] that attempted a quantitative synthesis, in the era before efficient and digital wide-area surveys, of how the fundamental physical properties of galaxies vary across the Hubble sequence.

Mort played a leading role in the discovery of extragalactic 21-centimeter line absorption, beginning with his detection of absorption in Centaurus A in 1970[13] and three years later, in the quasar 3C 286.[14] At the end of 1975, Mort and his collaborators, including Art Wolfe, Bob Brown, and the graduate student (me, who punched the cards used to control

the telescope during the observations), followed up on the occurrence of an optical outburst in the BL Lac object AO 0235+164 to detect HI absorption at 932 MHz.[15] This detection provided a robust demonstration of the coincidence of the optical and radio redshift at what for those days was "high" redshift, z~0.52. The coincidence, within the errors, of the radio and optical absorption-line redshifts set a first limit on the variation of fundamental atomic constants over cosmic time, in that case, one-third of the age of the Universe.

Early on, Mort pointed out the usefulness of the global HI line width to estimate total dynamical mass and its advantage as a distance-independent quantity, although he also noted its biases and the complications that need to be understood. His understanding of the rough relation between luminosity and linear diameter for galaxies of similar morphology led to work with Vera Rubin, Norbert Thonnard, Kent Ford, and John Graham[16] to measure the dipole motion of the Local Group, as was also seen in the Cosmic Microwave Background. Although their analysis produced a result that is inconsistent with those derived from more modern data, it spurred the use of the 21-centimeter line as a cosmological tool.

From his very early study of Messier 32,[17] he was intrigued by the large value of its mass-to-luminosity ratio M/L compared to that found for globular clusters: was this evidence of a very different stellar population than that found in the Milky Way, or was there "missing mass"? Mort recognized that because the HI disks of galaxies extend far beyond the visible edge of the starlight, the HI line can be used to trace the rotation curve to large radial distances, and he set out early on to map the HI distribution in large nearby galaxies. Using the newly commissioned 300-foot telescope at Green Bank, he pointed out that the derived HI velocity field along the major axis in Messier 31, the Andromeda galaxy, was inconsistent with that expected for a simple thin rotating disk.[18] The more extensive rotation curve he derived a few years later with Bob Whitehurst[19] clearly traced the remarkable flatness of the rotation curve of M31 at large radii R~ 30 kpc, well beyond the one derived from optical emission lines earlier by Vera Rubin and Kent Ford.[20] The HI result was met with much skepticism initially, but the general flatness of rotation curves outside the stellar disk was quickly confirmed via HI maps of numerous other galaxies and today remains a strong argument for the existence of dark matter.

Mort mentioned in the 1972 interview that during his time at Harvard, Ed Lilley had brought up the possibility of "black galaxies," blobs of hydrogen but no stars. Perhaps as a result of that comment, Mort and I spent time as part of my Ph.D. thesis hunting for intergalactic hydrogen clouds in groups and clusters of galaxies, but we also noted that many thousands of HI line observations of galaxies conducted in the "position switch" observing mode very rarely produced a serendipitous HI line detection in the off-source position: there just is not a large population of HI "galaxies" without optical counterparts. This result still stands, with the caveat that faint stellar components may be only barely visible because of their extremely low surface brightness. As Mort advised this young astronomer, the proof of the discovery of a bona fide "dark galaxy" requires skeptical checking to rule out the host of conspiratorial alternatives, such as debris from tidal interactions, extremely low-surface-brightness stellar components, sidelobe contamination and/or terrestrial radio frequency interference. Over the years, we found numerous cases of "almost-but-not-quite dark" galaxies as well as mysterious and irreproducible line signals, likely from satellites emitting, despite agreements, inside the protected band around the HI 21-centimeter line.

Leadership, Management, and Service

As a service organization with a mission to provide cutting-edge facilities to the scientific community, all NRAO staff contribute to the observatory's mission in innumerable ways, and this sense of service to the community was part of the staff ethos in which Mort fully shared. In 1969, he moved back to Green Bank for a year as assistant director responsible for all aspects of the operation of the site. In his 1972 interview, he speculated that Otto Struve accepted the position of director of the newly established NRAO in part because of a sense of duty when the search committee was having trouble finding someone to accept the position. Mort found himself in a similar position and agreed with some reluctance to become NRAO director, serving from 1978 to 1984. During those years, NRAO was transforming into a much larger and more complex institution with the completion and early operation of the Very Large Array in New Mexico and the design and development of the Very Long Baseline Array. At the same time, budget cuts forced redirection and reductions in the staff and the scope of operations in Green Bank, and, because of budget limitations, NRAO was forced to prioritize between the VLBA and a 25-meter filled-aperture millimeter telescope, causing inevitable tension within the organization and the radio astronomy community. Having done his duty, Mort was happy to return to the scientific staff as NRAO senior scientist focusing again on his extragalactic studies. Upon his retirement in 2002, he retained the title of emeritus senior scientist and continued to ponder the nature and evolution of the galaxies.

In addition to the National Academy of Sciences, Mort was a member of the American Astronomical Society, the American Association for the Advancement of Science, the International Astronomical Union, and the International Scientific Radio Union (URSI) and was a fellow of the American

Academy of Arts and Sciences. Over his career, Mort served on a large number of advisory and oversight boards of societies, academic institutions, observatories, and journals. He served as vice president of the International Astronomical Union and twice as its treasurer, chair of its U.S. National Committee, vice president and councilor of the American Astronomical Society and council member of the American Association for the Advancement of Science. Among many committees, he chaired the Committee on Astronomical Motion Pictures of the American Astronomical Society between 1966 and 1972, perhaps reflecting his lifelong interest in film. He was awarded the Royal Astronomical Society's 2022 Honorary Fellowship for Astronomy in recognition of his service to the astronomical community.

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REFERENCES

1 Roberts, M. S., and A. Sandage. 1954. Group characteristics of the RR Lyrae stars in M 3. *Astron. J.* 59:190–191.

2 Roberts, M. S., and A. Sandage. 1955. The region of instability for RR Lyrae stars in the color-magnitude diagram for M3. *Astron. J.* 60:185–196.

3 Roberts, M. S. 1956. A theoretical luminosity function for the elliptical nebula M 32. *Astron. J.* 61:195–198

4 M. S. Roberts, interview by Woodruff T. Sullivan III in Groningen, Netherlands, August 18, 1972, Oral History, NRAO/AUI Archives, https://www.nrao.edu/archives/items/show/15148.

5 Roberts, M. S. 1959. A search for neutral atomic hydrogen in globular clusters. *Nature* 184:1555–1556.

6 Epstein, E. E. 1964. Atomic hudrogen in galaxies. *Astron. J.* 69:490–520

7 M. S. Roberts interview, 1972.

8 Roberts, M. S. 1963. The content of galaxies: Stars and gas. *Annu. Rev. Astron. Astrophys.* 1:149–178.

9 Roberts, M. S. 1963. Hydrogen in galaxies. *Sci. Am.* 208:94–107.

10 Roberts, M. S. 1963.

11 Sandage, A. 1986. Star formation rates, galaxy morphology, and the Hubble sequence. *Astron. Astrophys*. 161:89–101.

12 Roberts, M. S., and M. P. Haynes. 1994. Physical parameters along the Hubble sequence. *Annu. Rev. Astron. Astrophys.* 32:115–152.

13 Roberts, M. S. 1970. The detection of 21-centimeter hydrogen absorption arising from within the radio galaxy Centaurus A. *Ap. J.* 161:L9.

14 Brown, R. L., and M. S. Roberts. 1973. 21-centimeter absorption at ≈ = 0.692 in the Quasar 3c 286. *Ap. J*. 184:L7.

15 Roberts, M. S., et al. 1976. Detection at z≈0.5 of a 21-cm absorption line in AO 0235+164: the first coincidence of large radio and optical redshifts. *Astron. J.* 81:293–297.

16 Rubin, V. C., et al. 1976. Motion of the galaxy and the local group determined from the velocity anisotropy of distant Sc I galaxies. II. The analysis for the motion. *Astron. J.* 81:719–737.

17 Roberts, M. S. 1955. On the color and the mass-luminosity ratio of globular clusters and the elliptical nebula M 32. *Publ. Astron. Soc. Pac.* 67:327–328.

18 Roberts, M. S. 1966. A high-resolution 21-CM hydrogen-line survey of the Andromeda nebula. *Ap. J.* 144:639.

19 Roberts, M. S., and R. N. Whitehurst. 1975. The rotation curve and geometry of M31 at large galactocentric distances. *Ap. J.* 201:327–346.

20 Rubin, V. C., and W. K. Ford Jr. 1970. Rotation of the Andromeda nebula from a spectroscopic survey of emission regions. *Ap. J.* 159:379–404.

SELECTED BIBLIOGRAPHY

1963 The content of galaxies: Stars and gas. *Annu. Rev. Astron. Astrophys*. 1:149–178.

1973 With R. L. Brown. 21-centimeter absorption at ≈ = 0.692 in the Quasar 3C 286. *Ap. J.* 184:L7–L10.

1975 With R. N. Whitehurst. The rotation curve and geometry of M31 at large galactocentric distances. *Ap. J.* 201:327–346.

1976 With R. L. Brown et al. Detection at z≈0.5 of a 21-cm absorption line in AO 0235+164: the first coincidence of large radio and optical redshifts. *Astron. J.* 81:293–297.

1976 With V. C. Rubin, N. Thonnard, and W. K. Ford Jr. Motion of the galaxy and the local group determined from the velocity anisotropy of distance Sc I galaxies. II. The analysis for the motion. *Astron. J.* 81:719–737.

1978 Twenty-one centimeter line widths of galaxies. *Astron. J.* 83:1026–1035.

1979 With M. P. Haynes and R. Giovanelli. A detailed examination of the neutral hydrogen distribution in the Leo triplet NGC 3632, 3627, and 3628. *Ap. J.* 229:83–90.

1993 With D. E. Hogg and A. Sandage. The dependence of the cool matter content on galaxy morphology in galaxies of types E/S0, S0, and Sa. *Astron. J.* 106:907.

1994 With M. P. Haynes. Physical parameters along the Hubble sequence. *Annu. Rev. Astron. Astrophys.* 32:115–152.

1998 With M. P. Haynes et al. Asymmetry in high-precision global H i profiles of isolated spiral galaxies. *Astron. J.* 115:62–79.

2001 With D. E. Hogg, J. N. Bregman, and M. P. Haynes. Hot and cold gas in early-type spirals: NGC 3623, NGC 2775 and NGC 1291. *Astron. J.* 121:1336.

2008 With D. E. Hogg, M. P. Haynes, and R. J. Maddalena. Diffuse HI disks in isolated galaxies. *Astron. J.* 134:1046–1060.