CARMAN HUDSON COSTAIN
(1932-1989)

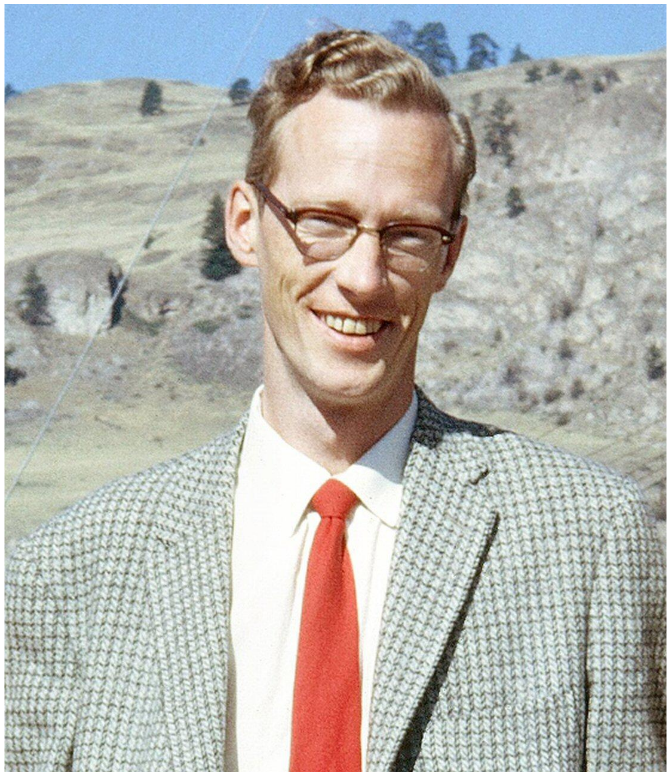
Photo credit: The Locke Family / NRC, DRAO Archive

Carman Hudson Costain was born on April 26, 1932 in Saskatoon, Saskatchewan, Canada. He was the fifth child and third son of Canadian-born Henry Hudson Costain and American-born Mary Elida Ekin. Henry Hudson Costain was the son of a Prince Edward Island farmer. The Costain ancestry can be traced to a John Costain who emigrated to Prince Edward Island from the Isle of Man in 1832.

Carman first became interested in electronics as a hobby while in high school in Saskatoon. He had summer jobs working on auroral radar backscatter studies - a specialty at the University of Saskatchewan owing to its high geomagnetic latitude and the influence there of radar and atmospheric researcher Peter Forsyth, who at times employed both Carman and his elder brother Cecil as undergraduate assistants.

Carman received his Bachelor's degree in Physics from the University of Saskatchewan in 1953. His interest in radio astronomy began that summer when he took a temporary job with Forsyth (who was then at the Defense Research Telecommunications Establishment at Shirley Bay near Ottawa) to construct a phase-switched two-dipole interferometer to monitor the ionospheric scintillations of the bright radio source Cassiopeia A. After spending that summer in Ottawa Carman returned to Saskatoon for his Master's studies. He built another phase switched interferometer there in order to study ionospheric scintillation of Cassiopeia A at both upper and lower culmination. Nine months of data collected there formed the basis for his Master's degree but (as he recounted in a 1974 tape-recorded interview with Woody Sullivan that is available online in the NRAO historical archives) this experiment made him more curious about radio astronomy itself than about using radio sources to study the ionosphere.

In 1955 it was not possible for a Canadian to do Ph.D. thesis work in radio astronomy within Canada. After considering possibilities for working in radio astronomy at Jodrell Bank in England, at the University of Sydney in Australia, or for doing upper atmosphere research at Cornell University, Carman decided to follow his elder brother Cecil's path by doing his Ph.D. In England at Cambridge University, where he was accepted into the radio astronomy group at the Cavendish Laboratory. (His college affiliation was with St. John's.)

Carman married Martha Leona "Lee" Leopold in Saskatoon on September 5, 1955. Later that month the newlyweds crossed the Atlantic on the Canadian Pacific liner "Empress of Scotland". Carman immediately began graduate work in the Cambridge radio astronomy group headed by Martin Ryle, under the direct supervision of Francis Graham-Smith.

His first project at Cambridge was to set up an interferometer to monitor the November 1955 lunar occultations of the Crab Nebula. Those observations proved problematic, but the experience he gained led to successful observations of the occultation that followed in January 1956 and to Carman's first radio astronomy paper: *"Radio Observations of a Lunar Occultation of the Crab Nebula"* with Bruce Elsmore and George Whitfield, published in the Monthly Notices of the Royal Astronomical Society, Vol. 116, pp.380-385 (1956).

Carman's early work at Cambridge was done at the old Rifle Range observing site off Grange Road. In 1957 the Cavendish Laboratory's acquisition of a much larger site 8 km south-west of Cambridge at the former Lord's Bridge Air Ammunition Park made possible the project that became the main part of his Ph.D. thesis – a large telescope designed to survey the whole northern sky at 38 MHz. His earlier attempt to study the galactic emission at this frequency with an antenna at the Rifle Range that had been used for solar studies by John Blythe in 1954 showed that the structure of the emission was too complex to be mapped adequately with that antenna. A plan was therefore made to build a dedicated corner-reflector array to map the galactic emission and discrete sources at 38 MHz at the new site. The then-novel approach was to combine data from many interferometer baselines between a long East-West corner reflector array and a smaller "portable" corner reflector segment that could be moved to many locations in the North-South direction. This approach was an early example of the radio image-forming method known as "aperture synthesis", for which Martin Ryle was awarded the Nobel Prize for Physics in 1974.

In 1956 Carman extended his stay in Cambridge for three more years in order to design, build and commission the 38-MHz aperture synthesis array under Graham-Smith's supervision. He also made the first observations with it, including a scaled-array study of the galactic radio spectrum. At Martin Ryle's urging he also looked into the feasibility of using those data to estimate the integrated extragalactic nonthermal background brightness. That quantity was


The 3300-ft East-West arm of the 38-MHz aperture synthesis telescope built by Carman Costain at Lord's Bridge
(Photo credit - Alan Bridle)

significant for the cosmological interpretation of Ryle's radio source counts at the time of his famous dispute with Fred Hoyle over using the counts as evidence against the Steady State Theory. (I inherited this task with a mandate to extend Carman's analysis to lower frequencies as part of my Ph.D. Thesis.) Carman also made a preliminary study of the North Galactic Spur, which remained a feature of great interest to him. The all-sky survey was completed and published in 1966 by Phil Williams, Sidney Kenderdine and John Baldwin (*"A Survey of Radio Sources and Background Radiation at 38 Mc/s"*, Memoirs of the Royal Astronomical Society, vol. 76, pp. 53-110).

A significant diversion to Carman's work on the 38-MHz survey occurred when Sputnik One was launched into Earth orbit on October 4 1957, He dropped all else he was doing to work night and day with Bruce Elsmore and George Whitfield to improvise a way to detect Sputnik's radio signals and thus to study the satellite's orbital decay. He later recalled that feverish effort with satisfaction as an example of the teamwork that existed among the Cambridge radio astronomy students and staff at the time.

Teamwork was also needed to provide the motive power for the moving corner reflector element of his 38-MHz antenna at Lord's Bridge, which had to be manually carried from one interferometer station to the next. This was a strenuous task that I was told only Carman himself ever accomplished unaided. More often, a group of students with strong backs went out to Lord's Bridge from the Cavendish Lab to hoist and move the traveling corner reflector, a procedure that was artfully acknowledged in the final survey paper in 1966 - which remarked that *"Through the unstinting exertions of all members of the radio astronomy group both past and present the observations were carried to a successful conclusion."*

The ad hoc response to the Sputnik launch may have contributed to the fact that Carman and Lee returned to Canada in 1959, with their son David - born in Cambridge in 1958 - before Carman had finished writing his Ph.D. thesis.   He joined the newly formed Dominion Radio Astrophysical Observatory (DRAO) upon his return to Canada in 1959, finished his thesis, and received his Ph.D. - the first awarded in radio astronomy to any Canadian - in 1960.

While acting as my local Ph.D. supervisor during my secondment to the DRAO from the Cavendish Laboratory in 1965/66, Carman urged me to complete as soon as possible: *"Write only what you need to get your degree as fast as you can, so you can get on with your own science"* was his advice. I suspect that sentiment stemmed from his experience of finishing a Ph.D. thesis while simultaneously starting his professional research career and raising a young family - which grew to include second son Robin, daughter Leslie and third son Philip.

Once at the DRAO, Carman worked with the new observatory's 25-m single dish while starting to plan for his major project a T-shaped dipole array to survey the galactic radio emission and measure discrete radio source flux densities at 22 MHz with about one degree angular resolution.

John Bolton, Carman Costain and John Galt at the completed 22 MHz array in January 1965
(Photo creditt: The Locke Family / NRC, DRAO Archive)

Unlike his 38-MHz synthesis array in Cambridge, the new 22-MHz array at DRAO was a filled-T configuration in which 624 full-wave dipoles provided all of the interferometer spacings between the 1.3-km East West arm and the 440-m North-South arm simultaneously, This configuration allowed the meridian transit pencil beam to be formed in real time so that periods of quiescent ionospheric scintillation and refraction could be fully exploited.

The 22-MHz array was designed so that the signal from dipoles in the arm overlap region was fed into both the East-West and North-South arm transmission lines so that the largest-scale structure of the galactic emission would be represented as accurately as possible in the final survey data, The array was completed in 1964 by Carman working with engineer David Lacey, radio astronomer Rob Roger and technician Jack Dawson. Construction of the wooden support structure began in 1962 but the transmission lines, phasing networks and electronics were a hands-on effort by the four array staff members.

Preliminary observations with it showed that ionospheric conditions over Penticton were even more favorable for decametic radio astronomy than had been anticipated, so in 1964 it was decided to build a second T-shaped array at the DRAO to map the galaxy and to study discrete sources at 10 MHz. That project was headed by John Galt, who then worked with a series of staff seconded to the DRAO in various ways from the Cavendish Laboratory – Peter Scheuer in 1964, Chris Purton in 1964-65, me in 1965-66, and Jim Caswell in 1967-69. Although Carman was not formally part of the 10-MHz array project, his deep understanding of how the ionosphere affected decametric radio observing, and his mentoring of the younger contingent from Cambridge (especially me) who were directly involved in it, were important to its success.

The 22-MHz array began to take data at a time before digital computers were ubiquitous in radio astronomy. Data reduction for its unique data product – the all-sky survey - was done at first in remote computers in Vancouver and in Ottawa. Unfortunately, this meant that the survey data reduction proceeded only very slowly until the DRAO acquired its own on-site computer(s).

One unexpected result was, however, evident from direct visual inspection of the 22-MHz project's real-time chart records: a few of the discrete sources appeared brighter than expected from their higher-frequency spectra, implying that their low-frequency emission is enhanced by steep-spectrum components. In particular, the 22-MHz emission from the Coma Cluster had an (apparently) extended component that was not then known from observations at higher frequencies. While the resolution of the 22-MHz array was insufficient to show whether this steep-spectrum component was in fact a single extended emission region or a blend of several discrete sources, it sparked Carman's interest in how extragalactic sources in rich clusters of galaxies might evolve to have steeper spectra than those in other environments. I recall many long winter nights spent with him at the DRAO in 1966 discussing astrophysical issues that have since been clarified by direct imaging of steep-spectrum “tails” and “relics” in galaxy clusters by a new generation of low-frequency arrays.

One example of the 22-MHz survey identifying what would become a seminal object for this emerging field of study was the recognition that a previously known but unremarkable radio source in the direction of the galaxy cluster Abell 2256 was unexpectedly bright on the 22-MHz survey chart records (Costain, C.H., Bridle, A.H. and Feldman, P.A. *"Decametric Radio Identification of an Extragalactic X-ray Source"*, Astrophysical .Journal, vol.175, pp. L15-L18 (1972)) . Abell 2256 has since been shown to be a merger product - and 50 years later its complex low-frequency radio emission is the "poster child" for studies of interactions between the ejecta of radio galaxies and magnetic fields in the hot intracluster gas (see, for example, Breuer et al.,*"The Mergers in Abell 2256: Displaced Gas and its Connection to the Radio-emitting Plasma",* Monthly Notices of the Royal Astronomical Society, vol.495, pp. 5014-5026 (2020) and Rajpurohit et al. *"Deep Low frequency Radio Observations of Abell 2256 I . The Filametary Radio Relic"*, Astrophysical Journal, vol.927, pp. 80-101 (2022)).

Carman was inspirationally enthusiastic about all aspects of low-frequency radio astronomy, ranging from the theory and design of the array antennas, to understanding the effects of the ionosphere on the data, to handling the demanding computational needs of aperture synthesis, to exploring the astrophysics of the classes of cosmic radio source to which low-frequency instruments are especially sensitive.

The 22-MHz array's sky survey was finally fully reduced and published in 1999, ten years after Carman's untimely death (Roger, R.S., Costain, C.H., Landecker, T.L., and Swerdlyk, C.M., "*The Radio Emission from the Galaxy at 22 MHz"*, Astronomy and Astrophysics Supplements, vol.137, pp 7-19).

In the early 1970's Carman turned his attention to the DRAO's 21-cm hydrogen-line Synthesis Telescope which grew from three 8.5-m paraboloids (two movable along on an East-West track) to become its next major instrument, eventually with seven elements. Carman played a leading role in this telescope's design and also in the development of the software necessary for its successful operation.

He also became active in the leadership of the Canadian Astronomical Society from 1974 to 1982, serving on its Board of Directors and then becoming its President from 1978 to 1980. During that period and thereafter, he promoted the concept of a Canadian Long Baseline Array (CLBA), a project intended to provide a set of antennas all across Canada dedicated to the science of very-long-baseline interferometry, an active research field that had been pioneered by staff at the National Research Council (NRC) and in several Canadian universities. This ambitious project eventually reached the highest priority for funding by the NRC, but the federal government nevertheless declined to fund it, thereby ceding the field to the Very Long Baseline Array (VLBA) operated by the U.S. National Radio Astronomy Observatory (NRAO).

In 1984 Carman was called to Ottawa to assist with a proposed upgrade of the 46·m radio telescope at the Algonquin Radio Observatory (ARO) for use at mm wavelengths. While there he worked on using holography to measure the surface figure of the reflector to an accuracy of a few tenths of a millimeter – but in 1986 the upgrade project was abruptly terminated by budget cuts and ARO was closed as a national radio astronomy facility. Carman then returned to DRAO to develop improved imaging techniques for the Synthesis Telescope, a project he was working on at the time of his death on December 21, 1989.

Away from his professional career, Carman played an active role in the social life of Penticton as a member of the Penticton Rotary Club and as an avid golfer and curler. His interest in electronics as a hobby extended to building his own color TV set, which he completed just in time to allow a large gathering to watch the Apollo 11 Moon landing at his and Lee's house on 20 July 1969.

Carman Costain was a true pioneer of radio astronomy in Canada, and I am honored to have had him as my Ph.D. Thesis supervisor for the year that I spent at the DRAO in 1965/66.

Alan H. Bridle
September 2022