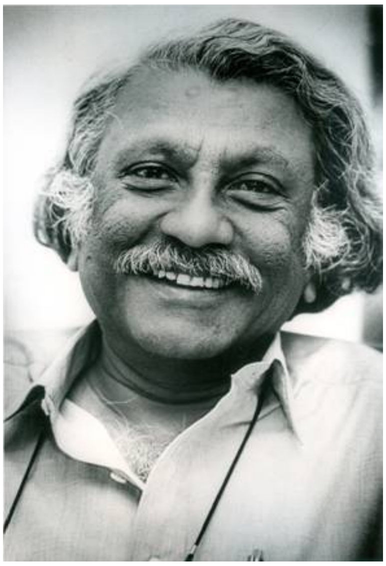

Venkataraman Radhakrishnan (1929-2011)

Contributed by R. Nityananda and W.M. Goss

The Indian radio astronomer, V. Radhakrishnan, widely known as ‘Rad’, was born on 18 May 1929 in Madras. He grew up in Bangalore, taking a bachelor’s (undergraduate) degree in physics at the Central College of the Mysore University. This remained his only degree until he received an honorary doctorate from the University of Amsterdam in 1996. His early fascinations were for motor vehicles, and for radio equipment, put together with World War II surplus components. This became a lifelong love and deep, hands on, understanding of all kinds of electronic gadgets, machines, as well as sailing and flying.

Rad set out in 1953 to the UK, for travel and adventure rather than academics. He worked for the Rank organisation, a major film company. Travelling to Sweden in 1955, he joined O. Rydbeck’s group at the Onsala field station of the electronics department of Chalmers Institute of Technology in Gothenburg, Sweden, purely as a technician. He recounts being puzzled by his first encounter with a siderial clock[1], amusing indeed for a future astronomer. He worked with Ellder and Höglund building a receiver for the neutral hydrogen line at 21cm. This was one of Rydbeck’s pet projects, though lack of a large dish hampered the Onsala efforts. In this period, Rad also got to know Hein Hvatum, who later had a major leadership role at the NRAO in the US. The hydrogen line and fluent Swedish stayed with Rad all his life.

In 1955, the California Institute of Technology invited John Bolton, the pioneering Australian radio astronomer [2], to set up the Owens Valley Radio Observatory. Rad was hired by Bolton in 1958 to work there - he must have carried a strong recommendation from Rydbeck, very likely for his technical skills. A 1960 abstract authored with Bolton [3] reports early work on the absorption of the hydrogen line and is the first published evidence of Rad moving into astronomy. He has related that his lone degree was absolutely crucial to Caltech being able to employ him at all.

The Owens Valley interferometer with its polarisation capability was put to good use in Rad's study of Jupiter with J.A. Roberts[4]. This revealed the angular extent (two or three times the size of the planet) and polarisation of the radiation at 30 cm., confirming the suggestion by Drake of 'van Allen' type belts of energetic particles trapped in the planet's magnetic field. While the data was not extensive enough to make an image, a pioneering analysis[5] of polarised interferometry with Seielstad and Morris laid the foundation for such work in the future. Uniquely (for him), this paper has a complicated equation, occupying four lines in the Astrophysical Journal, in which he derived the response of an interferometer in the most general case of arbitrarily and differently polarised feeds and an arbitrary polarisation distribution over the source.

This period saw pioneering work at Owens Valley combining the emission and absorption spectra of atomic hydrogen in the Galaxy to constrain the spin temperature optical depth, and density in the intervening clouds. The interferometer played an essential role to ensure that one was sampling the same gas in both emission and absorption. While the absorption comes solely from material in the line of sight to the compact background source, a single dish sees emission from regions surrounding that line of sight, for which a poorly determined correction was made in earlier work. The interferometer can cancel much of that emission, while retaining the contribution of the compact component. The resources at Owens Valley (a single channel spectrometer) were quite limited by later standards. Nevertheless, Rad's paper[6] with two Caltech graduate students, B.G.Clark and R.W. Wilson, established this technique, improved the estimates of temperatures and sizes of clouds, and concluded presciently that

> "There would seem to be little doubt that extended 21-cm absorption studies offer the most promising way of investigating the temperature, density, and velocity distribution of the interstellar medium."

Clark went on to deepen this work in his PhD thesis, and later played a crucial role in the building, operation and upgrades of the Very Large Array and Very Long Baseline Array of the NRAO, USA, which dominated the world of radio astronomy for decades. Wilson moved to the Bell Telephone Laboratory at Holmdel and, with Penzias, discovered the cosmic microwave background in 1965, for which both shared half of the 1978 Nobel Prize for physics.

Rad's long standing ambition to sail the oceans was fulfilled in 1964-65. He acquired a 35 foot three hulled saiboat – the Cygnus A – and started from England, heading for Sydney, Australia. The Atlantic crossing was with Dave Morris and Dan Harris, and the Pacific leg with Sid Shaw replacing Dan Harris [7]. He had been invited to join the renowned radio astronomy group of the CSIRO, where Bolton was now the director of the Parkes observatory with its 64m dish.

One of his first ventures at the Parkes observatory was to lead a team, building and using a spectral line interferometer to study the state of hydrogen in our Galaxy. This used the same basic emission/absorption technique with much improved instrumentation and sky coverage. Five papers giving a detailed account of this landmark work fill an entire volume of the Astrophysical Journal Supplement[8]. This study formed a strong observational basis for the idea of a multiphase interstellar medium in approximate pressure and thermal balance, analysed theoretically by Field, Goldsmith, and Habing[9]. Another notable contribution, with Brooks and Murray, was the solid confirmation of the Zeeman effect in the hydrogen towards Orion A, [10] and hence a measurement of the magnetic field of about 50 microgauss, following earlier work by Verschuur. The line has a width measured in tens of kilohertz, while the magnetic field causes opposite shifts of the two circular polarisations of the order of a hundred Hertz. The measurement therefore calls for extreme control over systematic errors in the spectral and polarisation response of the entire system.

The discovery of pulsars in 1967 galvanised all radio astronomy groups, and CSIRO was no exception. In work with Manchester, the slowdown of the Vela pulsar as well as its 'glitch' – a small decrease in period over a short time – were discovered[11]. Rad's paper in Nature[12] with Cooke, Komesaroff, and Morris laid out the detailed arguments for pulsars being compact rotating objects, with the polarisation swing within the pulse playing a crucial role. His later paper[13] with Cooke has become a classic. They established the frequency independence of this polarisation swing and used this to propose the now standard model of pulsar radiation originating from charged particles accelerated along magnetic field lines. In both the hydrogen line interferometry and pulsar work, Rad ensured that those making a strong technical contribution were among the authors.

In 1972 Rad accepted an invitation[14] from the Raman Research Institute (RRI) to return to India as its director, after the death of the founder (and his father), the Nobel Prize winning physicist C.V. Raman. This could not have been an easy decision. He was doing very well in Australia, and had consciously walked away from Bangalore and from the shadow of his father two decades earlier. In the intervening years, he had stayed away from administration and disliked bureaucracy in any form. Perhaps, the challenge of a totally new venture which he could shape, starting from scratch, appealed to him. Some call from his roots in Bangalore might also have played a role even though he was, and remained, very much a world citizen – certainly not conventionally patriotic or home bound.

Under his leadership (1972-1994), the institute grew to establish successful programs in radio astronomy and different branches of physics. A radio astronomy laboratory was set up which has undertaken many projects over more than three decades. This lab was led by N.V.G. Sarma, who moved from the TIFR radio astronomy centre at Ooty, with Rad playing an active role in some of the projects. An early, major, collaboration with

Ch. V. Sastry of the Indian Institute of Astrophysics, also in Bangalore, saw the RRI group playing a major part in building and using two low frequency radio observatories – Gauribidanur, India (34.5 MHz) and Mauritius (150 MHz).

One pioneering contribution was Rad's paper[15] with G. Srinivasan. Within weeks of the discovery of the 1.5 millisecond pulsar 1937+21 in 1982, they interpreted the object as 'recycled', a term they coined for the increase in angular momentum due to accretion from a companion. They extended this idea to understand an entire population of low field short period pulsars.

With students and colleagues, Rad worked on many aspects of pulsars and the interstellar medium, and on instrumentation. By personal example, searching questioning, and intense discussion, he built a unique atmosphere. At its height, people doing theory, experiment, instrumentation and observation talked to each other and shared a common spirit. Astronomers all over the world held him in high regard and responded readily to his invitation to visit RRI – Peter Scheuer, Ron Ekers, Hanbury-Brown, Ed van den Heuvel, Jerry Ostriker, to name just a few. The younger group around Rad benefited hugely from these visits.

Rad developed a good working relationship with the radio astronomy group of the Tata Institute of Fundamental Research, (TIFR) headed by Govind Swarup, which had completed the novel Ooty radio telescope in 1970 for studying radio sources by lunar occultation. It was agreed early on that the RRI lab would build a new spectral line backend for the Ooty telescope, which was then mainly in use for continuum work. This was used by Rad and his graduate student K.R. Anantharamaiah (Anantha) to place an upper limit on the abundance of deuterium towards the galactic centre[16]. Anantha later carried out an extensive survey, with the same telescope, of low frequency recombination lines coming from diffuse ionised gas in the galactic plane. This was inspired by theoretical work, also at RRI, by Peter Shaver, which brought out the importance of stimulated emission.

With another graduate student, A.A. Deshpande (Desh), Rad continued observational work on pulsars, now at the very low frequency of 34.5 MHz of the Gauribidanur radio telescope. Desh and he later collaborated on Rad's other pet themes – signals and noise in radio astronomy, and the relationship of the Vela pulsar with its supernova remnant[17], among others.

Rad strongly supported the Giant Metrewave Radio Telescope project of the TIFR group, which was launched in the mid 1980's. A critical first generation front end (L-band, including the hydrogen line) and back end (for pulsar work) were built at RRI. These were used for the 'first light' science observations of extragalactic atomic hydrogen, and of pulsars by the NCRA group. No MoU was signed for these collaborative projects, a good example of Rad's style.

Rad delivered the Invited Discourse on pulsars at the 1985 IAU General assembly in New Delhi, India. His Milne Lecture[18], delivered at Oxford University in 1987, was on “The message of astronomical polarisation”. A meeting in honour of Hanbury-Brown’s 70th birthday in 1986 gave him a chance to air his views, (mostly critical and old school) on “Modern technology and its influence on astronomers”[19]. His NRAO Jansky lecture in 2000 was on “Astronomy’s devices”, always a favourite theme with him.

Rad was elected a Foreign Associate of the US National Academy of Sciences and a Foreign member of the Royal Swedish Academy. He served on advisory boards of major observatories in Australia, the Netherlands, and the US. He was President of the URSI Commission on Radio Astronomy (1981-83), and a Vice-President of the IAU (1989-91).

In the 1990's, Rad took up building and flying – and even once crashing – microlight aircraft. In his last decade, he went back to the sea, building the “Eldemer”, a twin-hulled sailboat of his own novel design, with a rigid wing instead of a sail, funded by the Aeronautics Development Board. Well after his eightieth birthday and against well meant advice, he sailed from Kochi on the west coast of India to Oman in the Persian Gulf. He came back westwards to Malaysia via India. He then took a break in Bangalore, before the next leg of his planned trip around the globe, but this did not happen. On March 2nd 2011, he was his usual self at a pre-conference dinner in RRI, quizzing the visitors with paradoxes, and leaving only by midnight. He died early in the morning of March 3rd.[20] He was survived by his wife, Francois-Dominique, his son Vivek, married to Namrata, and two granddaughters, Veda and Surya.

Acknowledgements: Our thanks to Krishna at the RRI trust, and Manjunath at the RRI library, for much help with material on and by Rad, and to Robyn Harrison who edited “Radio Astronomers at Sea” (reference 7 below).

Notes and references:

1. Radhakrishnan, V. “Olof Rydbeck and early Swedish radio astronomy: A personal perspective”. Journal of Astronomical History and Heritage 9 (2), 139-144 (2006). This article also has Rad’s own brief account of his time in Onsala.

2. A good place to learn more about Bolton is an obituary, of which Rad is a co-author. Bolton was probably the only person whom Rad ever described as a mentor, though by nature, he was keen on learning anything he was interested in from anyone. “John Gatenby Bolton 5 June 1922 - 6 July 1993” Wild, J.P., and Radhakrishnan, V. Biographical Memoirs of Fellows of the Royal Society Volume 41. Published 1 November 1995. https://doi.org/10.1098/rsbm.1995.0005

3. Radhakrishnan, V., Bolton, J.G., Astronomical Journal, 65, 498 (1960)

4. Radhakrishnan, V., & Roberts, J.A. Physical Review Letters, 4, 293 (1960)

5. Morris, D., Radhakrishnan, V., & Seielstad, G. A. Astrophysical Journal, 139, 551 (1964)

6. Clark, B.G., Radhakrishnan, V., Wilson, R.W. Astrophysical Journal, 135, 151 (1962)

7. Martin Ryle and his wife Rowena were close friends of Rad and played major roles in planning the trip. They were present when the boat departed Felixstowe, England on 31 May 1964. After 19 months crossing the Atlantic and Pacific Oceans via the Panama Canal, Cygnus A arrived in Sydney, Australia in December 1965. Details of the voyage are provided by a small book written by WM Goss, David Morris and Geetha Sheshardri from 2016: "Radio Astronomers at Sea: Martin Ryle and V. Radhakrishnan Correspondence, 1963-1966: The Voyage of the 'Cygnus A' from the UK to Australia". Copies can be obtained from millergoss@gmail.com.

8. The Parkes Survey of absorption towards discrete sources. Astrophysical Journal Supplement Series, 24, 1-166, (1972)
The five articles deal with the instrumentation, the observations towards extragalactic sources, galactic sources including some close to the plane, and draw detailed conclusions about distances to the sources, optical depths, temperatures, and statistical properties of the clouds of neutral atomic hydrogen in the interstellar medium of our Galaxy. They are co-authored with, in different combinations, J.W. Brooks, W.M.Goss, Peggy Lockhart, J.D. Murray, U.J. Schwartz, and R.P.J. Whittle.

9. Field, G.B., Goldsmith, D.W., Habing, H.J. Astrophysical Journal, 155, L49 (1969)

10. Brooks, J.W., Murray, J.D., Radhakrishnan, V. Astrophysical Letters, 8, 121 (1971)

11. Radhakrishnan, V., Manchester, R.N. Nature, 222, 228 (1969)

12. Radhakrishnan, V., Cooke, D.J., Komesaroff, M.M., Morris, D. Nature, 221, 443 (1969)

13. Radhakrishnan, V., Cooke, D.J. Astrophysical Letters, 3, 229 (1969)

14. The actual sequence of events, which included finding government funding for the RRI, was quite complex and has been meticulously elucidated by R.K. Kochhar, Current Science, 104, 1194 (2014). It is noteworthy that the astrophysicist S. Chadrasekhar (also a first cousin of Rad!) played a significant part in this.

15. Radhakrishnan V., Srinivasan G. Current Science, 51, 1096 (1982)

16.Anantharamaiah, K.R., Radhakrishnan, V. Astronomy and Astrophysics, 79, L9 (1979)

17. Vela, its X-ray nebula, and the polarization of pulsar radiation. Radhakrishnan V., Deshpande, A.A. Astronomy and Astrophysics, 379, 551 (2001)

18. Radhakrishnan, V. Quarterly Journal of the Royal Astronomical Society, 30, 181 (1989)

19. Radhakrishnan, V. Proceedings of the workshop to celebrate Hanbury Brown's 70th birthday,1986: Modern technology: its influence on astronomy. Eds. Boksenberg, A., Wall, J.V. Cambridge University Press, (1990) p 303

20. Two obituaries: Nityananda, R., Current Science, 100, 1090 (2011) addressed to the Indian scientific community, and Nityananda, R. and Goss W.M. https://www.iau.org/administration/membership/individual/2221/ for the IAU membership. This current article is a greatly expanded version of the second.

Dave Morris and Rad after tying up in Sydney, 1966