Vera C Rubin 1928–2016

Pioneering astronomer and RAS Gold Medalist whose observations confirmed the existence of dark matter, remembered by **Neta A Bahcall**.

Vera Rubin was born Vera Florence Cooper on 23 July 1928 in Philadelphia, the younger of two daughters of Philip and Rose Cooper. The family moved to Washington DC when Vera was 10. She became fascinated with astronomy at a young age, watching the stars, building a telescope and attending amateur astronomy meetings. Vera applied to Vassar College because astronomer Maria Mitchell had taught there (1865–88), and because Vassar had telescopes that students could use.

Vera graduated in 1948, the only astronomy major in her class, and married Robert Rubin on 25 June. He was 21 and working on his PhD at Cornell; she was 19 and joined him there for her master's in astronomy. There, she explored the velocity distribution of galaxies, beginning a life-long fascination with galaxies.

In 1951, Vera and Bob moved back to Washington, where she began her PhD at Georgetown University, working with George Gamow. Her thesis investigated the spatial distribution of galaxies, revealing that they were clumped rather than uniformly distributed in space – a surprising and important result that took years to recognize and pursue. After receiving her PhD in 1954, Vera taught at Georgetown until 1965, when she joined Carnegie Institution's Department of Terrestrial Magnetism (DTM) in Washington, where she flourished and remained for the rest of her career.

"How could you possibly live on this Earth and not want to study the universe?"

Evidence for dark matter

Vera's most seminal scientific contribution was establishing that stars orbit their galactic centres with speeds that remain constant to the outer parts of galaxies – the famous flat rotation curves of spiral galaxies. The unexpected excess speed at galaxies' outskirts requires excess mass beyond that seen in stars and gas. The observations provided crucial evidence for the existence of dark matter, first suggested by Fritz Zwicky in 1933 and based, similarly, on larger than expected observed velocities of galaxies in clusters of galaxies, thus requiring dark matter in clusters. Vera's flat rotation curves implied that galaxies are embedded in large dark matter halos. We now know that these halos contain most of the mass in the universe, and that dark matter makes up 85% of the cosmic mass-density – profoundly affecting the evolution of the universe.

Vera's work was carried out with long-time colleague Kent Ford, who built the first electronic optical detector in astronomy: the DTM image-tube spectrograph (now at the National Air and Space Museum in Washington). This enabled the precise measurements of galaxy rotations. Rubin and Ford's first rotation curve was measured for the Andromeda galaxy (1970). A larger sample of spiral galaxies was then observed (by Rubin, Ford and Norbert Thonnard 1978), all showing the same remarkable flat rotation curves to the outer parts of galaxies. These results, now routinely reproduced in textbooks, convincingly confirmed the existence of dark matter. At that time, rotation curves were also observed in radio wavelengths using the 21 cm line of neutral hydrogen, tracing the rotation of hydrogen gas discs that surround spiral galaxies; Morton Roberts (1966, Roberts & Rots 1973) and others, found similar flat rotation curves. Both sets of data were critical in revealing the constant rotation speeds of galaxies and thus the need for dark matter.

Vera worked on the topics she loved – galaxy spectra, dynamics and large-scale structure – throughout her career. She discovered, among others, a counter-rotating galaxy, where some stars orbit clockwise and some counterclockwise; "What a joy!" she exclaimed. She was delighted by finding polar-ring or interacting galaxies and other exotic systems. Her passion for astronomy, for observations, and for understanding galaxies never waned. "How could you possibly live on this Earth and not want to study the universe?" she asked.

Champion of women in science

Vera was a passionate champion of women in science. She inspired and supported women for faculty positions, for awards, for conference talks; if a conference listed too few women lecturers she told the organizers to add more. When a colleague asked her to advertise his new astronomy programme, she declined: "If I was a bright student I will not apply to your programme because you have no women on your faculty." Vera tells her story and the challenges she faced as a woman astronomer in an illuminating article (Rubin 2011). Anecdotes include a college interviewer who suggested she consider a career painting astronomical objects rather than doing research, and the fact that she was denied observing time on the Palomar telescope because women were not allowed until the 1960s. Never deterred, Vera advised others: "Don't let anyone keep you down for silly reasons. Keep doing what you love." She did.

Vera's achievements have been recognized by awards including the US National Medal of Science, the Gold Medal of the RAS, the Gruber Cosmology Prize, the NAS Watson Medal, and honorary degrees.

Vera was an inspiring mentor and role model to generations of astronomers. Cheerful, enthusiastic, and kind – Vera was loved by all. "Vera Rubin was a national treasure as an accomplished astronomer and a wonderful role model for young scientists," said Carnegie president Matthew Scott.

She passed away in Princeton NJ, on 25 December 2016. She is survived by three of her children, David, Karl and Allan (her astronomer daughter Judy died in 2014), her sister Ruth, five grandchildren and a great-granddaughter. She will be sorely missed by all. ●

AUTHOR

Neta A Bahcall is the Eugene Higgins Professor of Astrophysics at Princeton University, NJ, USA. She was a close colleague and friend of Vera Rubin.

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