Jie Wang

Eye Beyond the Sky

27 Telescopes and Space Probes, from Hooker to JWST

Translated by
Xiaoyan Huang

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Mount Wilson Observatory: A Surprising Discovery that Kept Einstein Awake at Night

Mount Wilson Observatory

It was early 1930. The great physicist Albert Einstein was eager to depart for California, USA. One thing had been far more important than a single trip. His second wife Elsa traveled with him (Isaacson 2007) (see Fig. 1.1).

It was not simple to travel from Germany to the United States on the other side of the world before the advent of commercial flying. From Germany, Einstein traveled a train to Antwerp, Belgium, where he boarded a ship for the transatlantic crossing to New York City. After a little stopover, Einstein set sail from New York and sailed south along the East Coast through the Panama Canal, via the Canal to the Pacific Ocean, and then north along the East Coast of the Pacific Ocean before docking in Los Angeles. He spent a whole month on the road.

Although this was Einstein's second trip to America (Wikipedians, Albert Einstein 2023a), he had never visited the West Coast before. On the invitation of the California Institute of Technology (Pais 1994), he traveled all the way to the Golden State for a short academic stay. Yet another significant motive for Einstein's travel was to meet a new person in a fresh location. Edwin Hubble (1889–1953) (Smith 1998), a great American astronomer, was the target of his visit, and the Mount Wilson Observatory in California was the location he wished to explore. Hubble's observations at Mount Wilson

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Fig. 1.1 Albert Einstein with his second wife Elsa (*Source* United States Library of Congress)

Observatory revitalized not only Einstein's but all of humanity's perspective on the cosmos (Livio 2014). As a result of this discovery, the Mount Wilson Observatory has also made a significant contribution to the annals of astronomical literature.

Known as the "Founder of modern solar observation," American astronomer George Ellery Hale (1868–1938) (Wikipedians, George Ellery Hale 2023b) traveled to Mount Wilson, northeast of Los Angeles (Wikipedians, Mount Wilson Observatory 2023c) in 1904. At first sight, he was smitten with this mountain of treasure. This is due to the presence of an inversion layer, a rare form of meteorological phenomenon, above the Mount Wilson region. In most cases, the temperature will drop as you gain altitude. Nevertheless, due to a variety of complex factors, there are some locations that experience the exact reverse, and this phenomenon is known as the inversion layer (Runge and Patterson 2007) (see Fig. 1.2).

The atmospheric stability afforded by the inversion layer is Mount Wilson's main advantage. One of the most stable atmospheres in all of North America may be found atop Mount Wilson, making it an ideal location for astronomical studies (Rottman 2007) (see Fig. 1.3).

Fig. 1.2 George Ellery Hale (*Left, Source* The World's Work: A History of Our Time) surveyed Mount Wilson. (*Right, Source* Carnegie/Huntington Library)

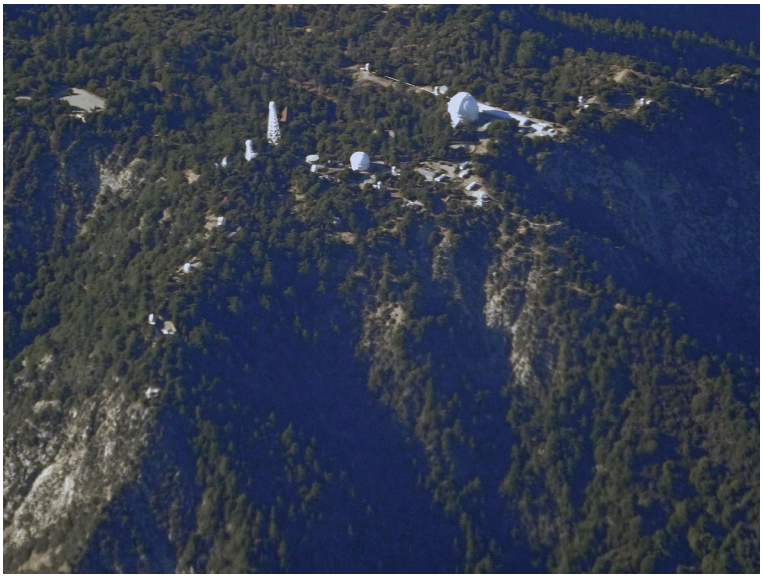

Fig. 1.3 Mount Wilson (*Credit* Jeffrey Beall)

In the immediate aftermath of Hale's discovery of this rich mountain, the most cutting-edge astronomical telescopes in the world were quickly relocated from the Yerkes Observatory to this new location (Osterbrock 1993). Therefore, the Mount Wilson Observatory was formally inaugurated.

The strong magnetic field of the Sun is concentrated in sunspots, which Hale and his team of scientists saw and studied after the Observatory was established. Furthermore, this was the first time that humans had ever been able to detect the magnetic field of a celestial body other than Earth. Yet,

Hale soon got concerned that the telescope's aperture was inadequate. When it came to telescope size, astronomers would never be satisfied (see Fig. 1.4).

Hale was talented in both scientific inquiry and the raising of funds. Donations to the Observatory came quickly after he approached affluent local merchants. It was at Mount Wilson Observatory in 1908 (Florence 2011) that the then-world's largest astronomical telescope was eventually built.

Mount Wilson Observatory was suddenly in the spotlight since it housed the world's most sophisticated telescope. Researchers from all over the flocked to this new site of astronomy. Among them was the legendary astronomer, Edwin Hubble (see Fig. 1.5).

Early in his career, Hubble conducted research at Yerkes Observatory (Christianson 1996). Once Hale relocated the telescope and constructed a new, larger one at Mount Wilson, Hubble began making regular trips there. Hubble was a vivacious young man who, in addition to studying astronomy and mathematics at the University of Chicago, was also a passionate boxer (information@eso.org n.d.). After finishing graduate school, he had several

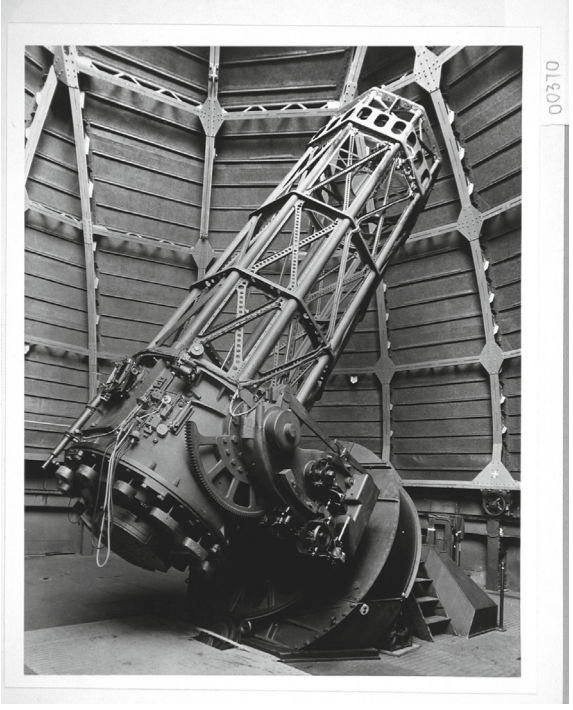

Fig. 1.4 The world's largest astronomical telescope with an aperture of about 1.5 m (60 in.) in 1908 (*Source* The Huntington Library, Art Museum, and Botanical Gardens)

Fig. 1.5 Edwin Hubble (*Credit* NASA and ESA)

career options open to him: he could go into astrophysics, mathematics, or the professional boxing world.

Fortunately for astronomy, Hubble ultimately committed his life to the field. When Hubble decided to devote himself to astronomy, the prevailing academic view held that the Milky Way was the entirety of the cosmos (This month in physics history: Edwin Hubble Expands our View of the Universe n.d.), that the universe was no larger than the diameter of the galaxy, and that all heavenly bodies were either near the galactic core or on its periphery, like our solar system. In any case, there are dissenting opinions. Astronomers first spotted a spiral nebula in the night sky as early as the seventeenth century. Despite the fact that modern amateur astronomers are all well aware that the nebulae that look like snowflakes in telescopes are actually galaxies, this was not always the case.

It wasn't until the Milky Way's spiral structure was confirmed that some began to speculate that the spiral nebulae might actually be other spiral galaxies.

If this view was correct, then our universe would not only be the Milky Way. There were galaxies outside of the Milky Way, which was equal to subverting the human vision of the cosmos. It would be a tremendous event. However, extraordinary claims require extraordinary evidence. Just making

outlandish predictions is not enough. In order to draw a scientific conclusion, evidence must be presented (see Fig. 1.6).

Hubble had been given the responsibility of figuring this out by the course of history. Where could he locate the evidence? Hubble couldn't shake off this lingering question.

Hubble used spectrum analysis as his approach (Hubble finds proof that the universe is expanding n.d.). After being dissected by the grating apparatus, every bright spot in the sky will reveal a colored spectrum. Hubble obtained and carefully studied as many spectra as possible from each nebula. The Andromeda Nebula, he discovered (NASA n.d.), has stellar properties and a spectrum very similar to the Sun's. Although William Huggins (1824–1910) (Wikipedians, William Huggins 2023d), a British astronomer, made the identical finding in 1864, the technology and data at the time were not nearly as precise. This time, Hubble and Hale knew for sure that the Andromeda Nebula was composed of many bright stars because Hale had

Fig. 1.6 Image of the Andromeda Nebula taken at the Yerkes Observatory in the early twentieth century (*Credit* Kippax, John R. (John Robert), 1849–1922)

independently confirmed the data collected by Hubble. Hubble also took photographs of the Andromeda Nebula using the Super Telescope at Mount Wilson Observatory (Hubble's Famous M31 VAR! plate n.d.).

Yet, establishing that the Andromeda Nebula is composed of stars does not indicate that it is a separate galaxy from our own. Due to the abundance of star clusters in the Milky Way, their finding was not particularly noteworthy. To Hubble, the key lies in pinpointing the Andromeda Nebula's distance. Given the circumstances, however, determining the distance to a dim star in the night sky was an extremely difficult job (see Fig. 1.7).

Larger telescopes, the bigger the better, were the only practical solution to this issue.

Hence, Hale reemerged, showcasing his fundraising prowess once again. He successfully invited Andrew Carnegie (1835–1919), a prominent philanthropist (Nasaw 2007), steel tycoon, and the world's second richest man at the time, to Mount Wilson Observatory, and then presented Carnegie with a popular scientific "lecture." Carnegie was finally impressed with him (Our history n.d.), and he donated $10 million, a staggering figure even by today's standards. Science popularization can play an important role in bringing in much-needed funding for scientific research, which is why almost all US research institutions place a premium on it.

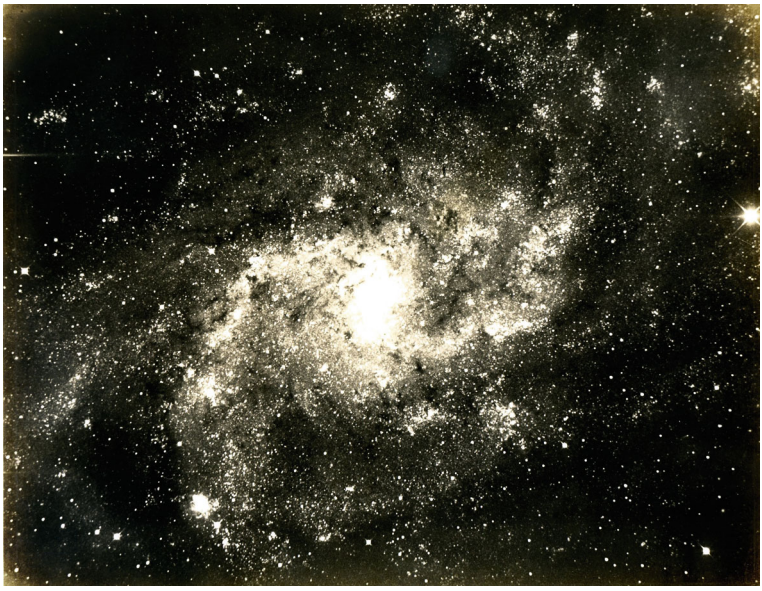

Fig. 1.7 Image of the Triangulum Galaxy taken at Mount Wilson Observatory in August 1910 (*Source* GALERIE GADCOLLECTION)

When viewed from this perspective, having money makes a lot of things a lot simpler to accomplish. The world's largest telescope, in terms of aperture, was erected on November 1, 1917 (Building the 100-inch Telescope n.d.). British poet Alfred Noyes (1880–1958) commemorated this event in his epic *Watches of the Sky* by writing (The Observatory, by Alfred Noyes n.d.):

> The explorers of the sky, the pioneers
>
> Of science, now made ready to attack
>
> That darkness once again, and win new worlds.

The name "Hooker Telescope" was given to this particular instrument over time (Florence 2011). It was with it that Hubble eventually discovered a means to calculate the length of the journey to the Andromeda Nebula (Hubble 1929) (see Fig. 1.8).

Cepheids are a type of variable star that undergoes periodic variations in luminosity and can be seen in the night sky. Cepheid variable stars have the potential to serve as the cosmological "standard candle" (Leavitt 1979) due to the consistent link between their absolute luminosity and their variable light period. The brightness of the light is inversely proportional to the square of the distance (Halliday et al. 2013). Measuring the apparent brightness is the same as measuring the distance if the absolute luminosity of the light source is known (see Fig. 1.9).

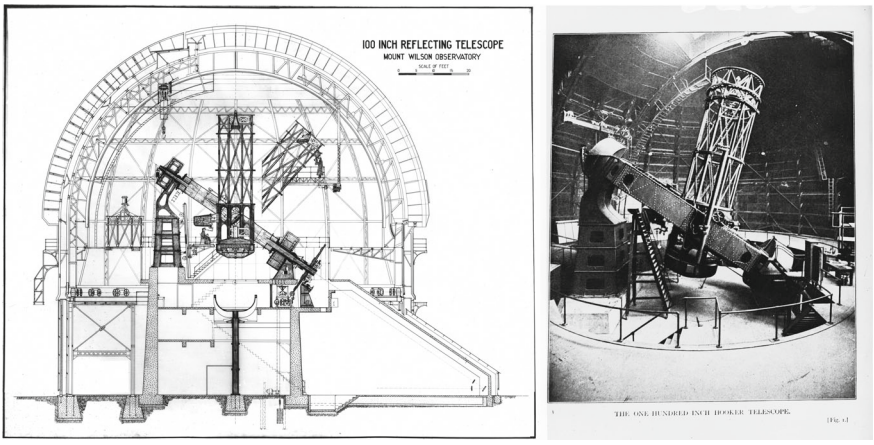

Fig. 1.8 Hooker telescope (*Left, Source* The Huntington Library, Art Museum, and Botanical Gardens) (*Right, Source* The History Trust of South Australian, South Australian Government Photo)

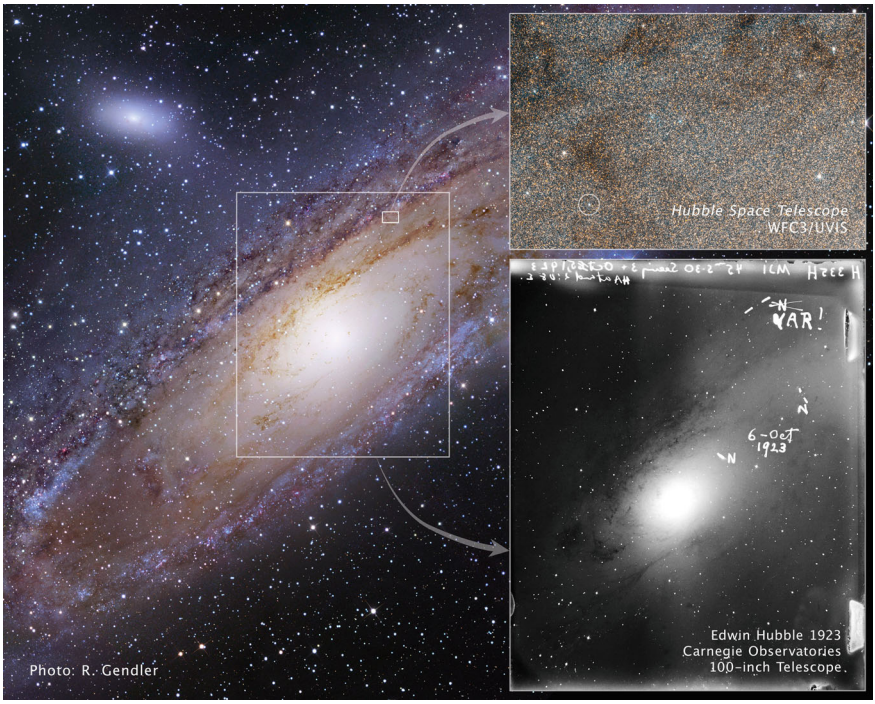

Fig. 1.9 Snapshots of the star that changed the universe (*Credit* NASA, ESA and Z. Levay (STScI). *Credit* NASA, ESA and the Hubble Heritage Team (STScI/AURA))

With the Super Hooker Telescope, Hubble obtained multiple images of the Andromeda Nebula, from which he identified 34 Cepheid variable stars. Then he meticulously spent over 2 years determining the absolute luminosity of these Cepheids by tracing their light cycle curves. He was able to determine the distance between these Cepheid variables and the Earth by basing his calculations on the apparent brightness of the variables in the telescope (see Fig. 1.10).

Hubble estimated that the Andromeda Nebula was roughly 900,000 light-years away (the most recent data puts it at 2.54 million light-years) (Hubble 1979), well beyond the Milky Way's diameter. The Andromeda Nebula is unequivocally not a part of our galaxy in any way.

At a conference of the American astronomical community in 1925, Hubble reported the results, which immediately caused a stir. Hubble's findings were rapidly accepted because they were so precise and carefully documented. It's fair to say that he single-handedly widened humanity's view of the cosmos (Bartusiak 2010).

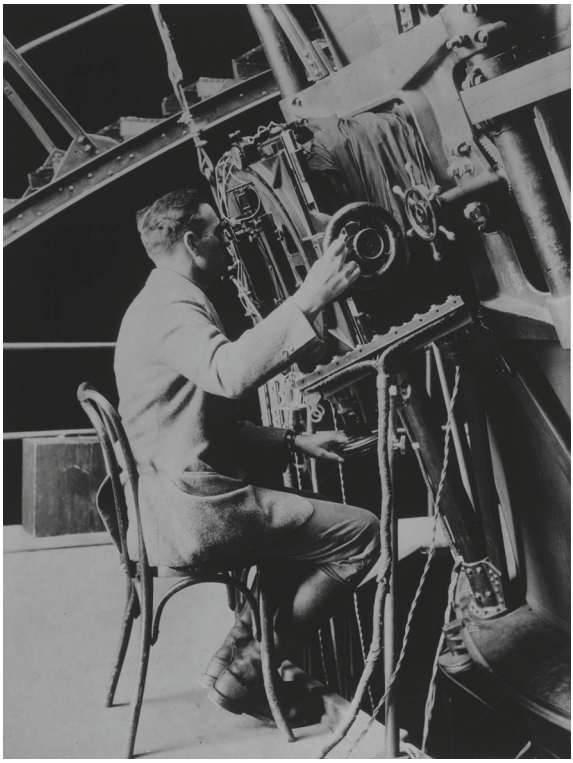

Fig. 1.10 Hubble operated the Hooker telescope. (*Source* The Huntington Library, Art Museum, and Botanical Gardens)

Edwin Hubble and the Mount Wilson Observatory were at the forefront of astronomical discovery at the time. In addition, Hubble did not cease his investigation into the universe. He maintained the Hooker telescope's gaze on the faraway galaxies, and he was about to solve another incredible cosmic enigma.

Hubble discovered, after a series of follow-up observations and calculations, that most galaxies, with the exception of Andromeda, were receding from us. Hubble found that the ratio of a galaxy's recession speed to its distance is constant after analyzing and summing the recession speeds of all galaxies (Hubble 1929). To put it another way, galaxies are receding from us, and the further they are, the faster they are receding. We call this Hubble's law, also known as the Hubble-Lemaitre (Einstein, Die Grundlage der allgemeinen Relativitätstheorie 1923) law (see Fig. 1.11).

Aside from the accelerating expansion of the universe, no other explanation seemed viable. Hubble's findings caused an uproar in the astronomical community, akin to "raising up a hornet's nest." The theory of a continually

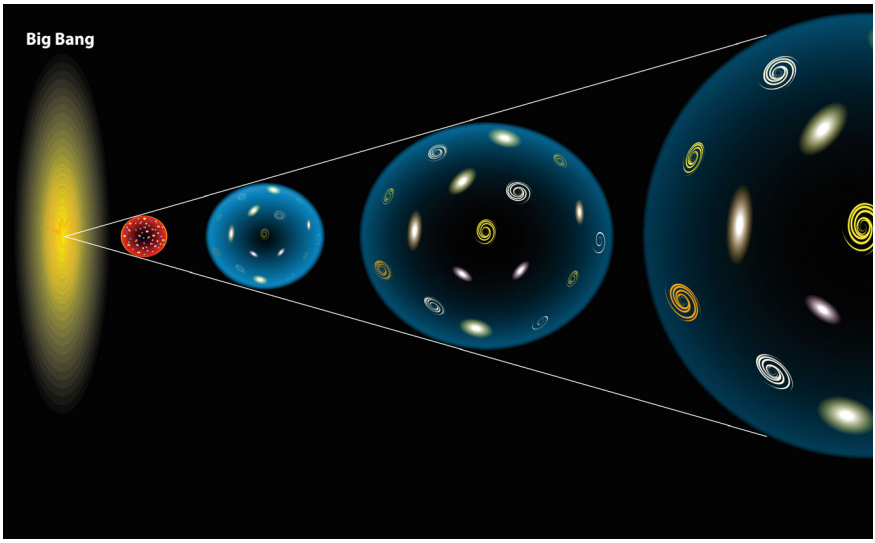

Fig. 1.11 Expanding universe (*Credit* Depositphotos/edesignua)

expanding universe is now widely recognized in the scientific community. But the concept of an expanding universe was revolutionary at the time. After receiving the news, Einstein, who was living on the opposite side of the planet, was also greatly astonished. He was unable to keep calm and felt compelled to travel to the United States in order to visit Hubble.

There was good cause for Einstein's surprise. Even before he proposed the general theory of relativity in 1916, Einstein discovered that its equation led to an inference that the universe was dynamic, either expanding or contracting. However, this conclusion ran counter to Einstein's intuition. Both his intuition and his naive cosmology led him to the conclusion that something must be missing from his calculations if the cosmos is not in a constant, static state. Then, after much trial and error, Einstein included a "cosmological constant" (Einstein, Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie 2005) in the equations of general relativity to keep the cosmos from oscillating.

To confirm Hubble's startling discovery of an expanding universe, Einstein must travel to Hubble's observatory in person.

On the morning of January 29, 1931, Hubble and his wife drove Einstein to Mount Wilson Observatory as promised (Christianson 1996), the pleasant sea breeze in California having blown away the winter cold. On the way, Einstein told Hubble's wife, "Your husband's work is fantastic," from the depths of his heart. When Einstein saw the enormous telescope at the observatory, he became entranced like a child and forgot to go. After being shown

Fig. 1.12 Einstein (Left) visited Mount Wilson Observatory (*Source* Associated Press/ Caltech Archives). Einstein (second from left) with Hubble (first from right) (*Source* The Huntington Library, Art Museum, and Botanical Gardens)

the telescope by the crew, Albert Einstein took one glance at Hubble, flashed a grin, and remarked to everyone else there, "Hubble proved my prediction by using this telescope" (see Fig. 1.12).

By having Einstein accepted and acknowledged, Hubble and Mount Wilson Observatory gained widespread attention. Every major scientific prize there was, with the exception of the Nobel Prize, had been bestowed upon Hubble. Because there was no precedence for the field of astronomy to be given the Nobel Prize when Hubble was alive (Lee 2011), and the scientific community of the time did not consider astronomy and physics to be the same scientific discipline, hence Hubble did not receive the Nobel Prize in Physics that he deserved.

The discoveries that Hubble made at the Mount Wilson Observatory have had a profound impact on our understanding of the universe, and have ensured that both Hubble and the observatory will go down in astronomical history as landmarks. Mount Wilson Observatory is a lighthouse if Hubble is a beacon for mankind to enlighten the universe and guide humans to explore the cosmos in the proper way (see Fig. 1.13).

In 1986 (VT 100-Inch n.d.), the historic mission of the Hooker telescope was successfully fulfilled, and it was subsequently deactivated. With the advancement of science and technology, the Hooker Telescope was outfitted with an adaptive optics system in 1995. This reinvigorated the exceptional "Knight General" and led to its reactivation. The telescope continued to be a significant instrument for astronomers all around the world to use as they uncovered new parts of the cosmos in the years that followed.

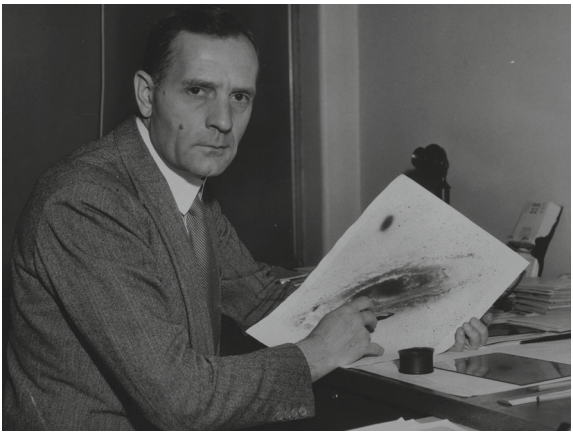

Fig. 1.13 Hubble was examining a map of galaxies in 1931. (*Source* The Huntington Library, Art Museum, and Botanical Gardens)

Several thousands of people visit the Mount Wilson Observatory each year, almost as if they were making a pilgrimage to see the site where humanity's understanding of the cosmos was forever altered (see Fig. 1.14).

Humanity's ultimate inquiry, in my opinion, is "What is the universe?" In terms of magnitude, this issue is unrivaled. There is no word big enough to capture the magnitude of the disparity between humanity and the cosmos. It's incredible, though, that we humans, who are so insignificant compared to the cosmos, have figured out how to view the big picture. The origin of human civilization's comprehension of the universe can be traced back to Hubble's epic tale at the Mount Wilson Observatory, and through it we gain a profound appreciation of how science speaks with evidence. Even a genius like Einstein needs to see proof before he'll change his mind because all reasonable conclusions must be founded on evidence.

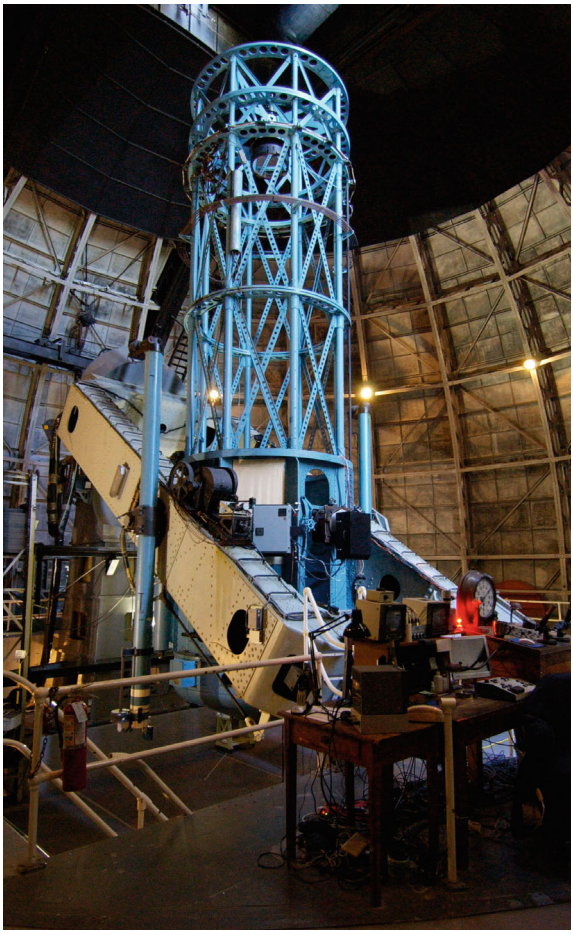

Fig. 1.14 Hooker telescope at Mount Wilson (*Credit* Ken Spencer)

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2

Parkes Radio Telescope: When a Star Shines with a More Intense Light than a Galaxy

Parkes Radio Telescope

Parkes, a small town in southeast Australia, was battered by an unusual storm on July 21, 1969. The last time it poured was a very long time ago. The dry dust on the ground was carried up by the 110 km/h storm, generating a sandstorm that obscured the Sun and made Parkes as dark as night in the middle of the day.

The tallest structure in the entire town of Parkes is a 64-m radio telescope named after the town (CSIRO, Parkes radio telescope, Murriyang 2023).

A dreadful cracking sound was coming from this telescope as its bowtie antenna swayed in the wind. Five astronomers were on standby in the control room at the massive antenna's base. They had to find a means to protect the radio telescope while getting ready to do something no one had ever done before: broadcast the Moon landing live (Bird 2019) (see Fig. 2.1).

"If the wind hasn't died down by the time the Moon rises, the live broadcast is doomed." Neil Fox Mason, the telescope's operator, didn't even squint as he went about his work.

East, where the Moon was rising, was where the wind was coming from. It's easy to envision what would happen if a 64-m-diameter "umbrella" were exposed to a force 12 gale. And yet, 380,000 km away on the Moon, astronaut Neil Armstrong had already donned his spacesuit and was getting ready to decompress the space capsule (NASA, July 20, 1969: One giant leap for mankind 2015b).

"In human history, this marks a significant step forward. Whatever the scenario may be, we shall use maximum effort to achieve success." Parkes

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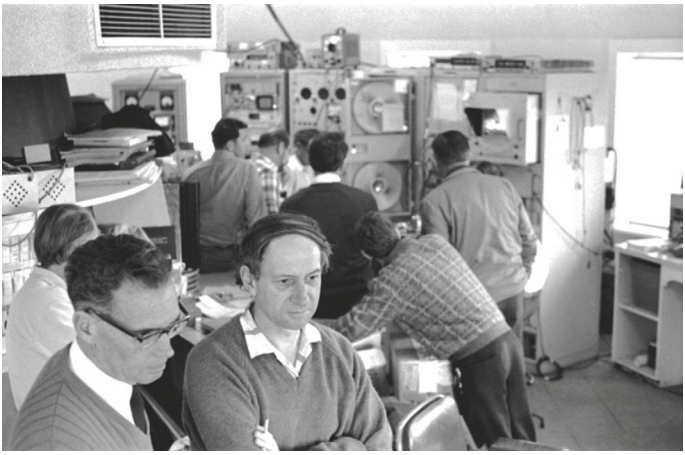

Fig. 2.1 Parkes' control room in charge of the 1969 moon landing live broadcasting (*Credit* CSIRO). © Copyright CSIRO Australia, (10 August 2020)

Observatory director and vocal supporter of the live lunar landing program John Bolton (1922–1993) (Sullivan 1994) gave the talk. Bolton had signed a contract with NASA (see Fig. 2.2).

The wind died down a little as the Moon rose slowly over the horizon, but it was still too gusty for the telescope to operate safely. As the massive antenna gently swung eastward, a historic live broadcast was initiated, reaching 600 million people around the world (Sarkissian 2001) (see Fig. 2.3).

When it came to this live streaming, Parkes wasn't the only radio telescope that got involved. The Honeysuckle Creek Radio Telescope in Canberra, Australia, and the Goldstone Deep Space Communication Complex in California, USA were also contributing to this endeavor (Harland 2011). In contrast to the other two tracking stations, the live signals provided by Parkes were of such high quality (Orchiston et al. 2006) that NASA only relied on them throughout (see Figs. 2.4 and 2.5).

During the Cold War era of the 1960s and 1970s, when the United States and the Soviet Union were vying for dominance, common folks frequently mistook this Australian space exploration instrument for Soviet or American. What is this mysterious Parkes radio telescope, anyway, that even in the worst of storms could send back significantly clearer signals than any other radio telescope? This chapter will detail its story for you.

Radar technology advanced quickly during World War II due to military demands. The Radiophysics Laboratory was the first Australian organization dedicated to radar research.

Fig. 2.2 Parkes radio telescope at daytime (*Credit* Depositphotos/NickRH)

The Council for Scientific and Industrial Research of Australia (CSIRO) founded this laboratory back in those days to perform covert radar studies (Robertson 1992). By the early 1950s, the Radiophysics Laboratory had become the largest, most diverse, and most successful research center of its kind (Haynes et al. 1996). Historically speaking, this is the only instance where Australian scientific research institutions have been on the cutting edge of developing fields (see Fig. 2.6).

Once upon a time, the terms radar and radio telescope were used interchangeably. The earliest radio telescopes frequently repurposed components

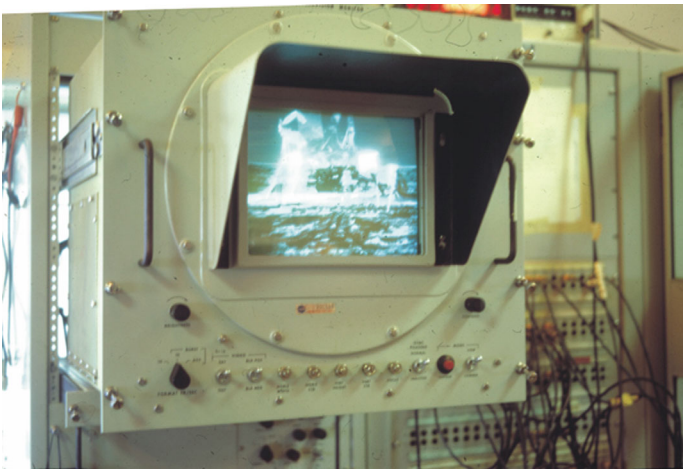

Fig. 2.3 Of the moonwalk on the monitor in the control room (*Credit* CSIRO). © Copyright CSIRO Australia, (1996)

Fig. 2.4 The 70-m antenna at Goldstone (*Credit* NASA JPL/DSN Status–Planetary Sciences Advisory Committee)

from decommissioned radars. Despite their lack of sophistication, these makeshift radio telescopes uncovered numerous extragalactic radio sources, which aided in the development of larger telescopes (Sullivan III 2009).

Fig. 2.5 Honeysuckle creek radio telescope (*Credit* National Museum of Australia/ Hamish Lindsay and Colin Mackellar)

In those years, Taffy Bowen (1911–1991) oversaw research and development at the Radiophysics Laboratory (Haynes et al. 1996). He rose to prominence in the field after developing a miniature radar that could be mounted on a fighter aircraft (Buderi 1998). On the other hand, progress in radio astronomy could be found in every region of the planet. Australia could not rely entirely on such antiquated machinery if it wished to keep its then position of preeminence. It's imperative that they procure the finest telescope available.

The primary distinction between radio astronomy research and the production of small radars is that the former not only does not generate profits but actually loses money. Australian politicians, who were notoriously