PROLOGUE

Scientific histories of major developments are never complete except in the memories of those who lived through them, and memories die with each generation. The memories are sometimes preserved by survivors of an era, but the most important documents are in the published literature, written as the events unfolded. These developments and their consequences are what this book is about.

When the definitive history of twentieth-century astrophysics is written, the two most important advances cited will doubtless be (1) the knowledge of how stars form and evolve from dwarfs to red giants before subsiding into the white-dwarf graveyard and (2) how the universe, with its expansion, developed. These twin problems – stellar evolution and observational cosmology – are products of the twentieth century.

Astronomers working in 1900 could not have conceived the richness of the present synthesis relating stellar evolution and observational cosmology. The beginnings of the solutions to these two key problems came about largely because of the creation early in the period of three great observatories: Lick, Yerkes, and Mount Wilson.

Astronomer George Ellery Hale, who had hoped to solve the mystery of stellar evolution someday, proposed to the Carnegie Institution in 1903 that a new observatory be created. His persuasion succeeded (just as it had at Yerkes in the last decade of the nineteenth century and would do again at Palomar in the 1930s), leading to the formation of Mount Wilson Observatory in 1904.

The importance of the great observatories was that their astronomers could begin to obtain astrophysical data on stars and galaxies that would prove to be decisive for the synthesis. These data were of diverse kinds; at first they often appeared unrelated to wider problems. Yet the initial "blind" programs pioneered by the patriarchs of astronomy sowed the seeds of the new astrophysics, from solar and stellar physics to Galactic structure to cosmology – and, finally, to what is labeled "origins" research today. Indeed, it’s fair to say that the work at Mount Wilson was as important to the present world view of the new astronomy as the Darwin–Wallace field expeditions of the 1850s were in nurturing the revolutionary paradigm shifts from catastrophism to gradualism in geology and biology.
This book aspires to fill three purposes. The first is to relate the 1904 founding of the Mount Wilson Observatory, as well as the design, engineering, and construction of its main instruments. What did it take to bring on-line the multitude of innovative instruments that filled the observatory for half a century? What was it like to craft and maintain the two giant solar-tower coelostat telescopes? What about the 60- and 100-inch nighttime reflectors? This account will not overlook the auxiliary spectrographs, bolometers, photoelectric photometers, and the first astronomical interferometers.

The second aim is to describe the science that was accomplished at Mount Wilson – and which was eventually stitched together to form the quilt of stellar evolution and cosmology – from the first stunning results concerning the Sun in 1905 to the dawn of the Palomar era in the 1950s.

The third goal is to introduce the cast of colorful characters who populated Mount Wilson from the observatory’s founding in 1904 until its merger with Palomar in 1948. Highlighted will be the personalities of the staff astronomers who worked at the Mount Wilson Solar Observatory (as it was first called), as well as those of the many guest astronomers who visited Pasadena from all over the world.

Not every reader will have equal interest in all three aspects of the story, so pick and choose as you like. Skim the denser scientific passages while reading enough to retain the flavor of the whole.

A further word of caution about the prejudices of the author: I am an unashamed trumpeter of the observatory’s virtues and successes. My acquaintance with it began in 1941, when at the age of 15 I made a summer visit to the Santa Barbara Street offices. There I met the secretary of the observatory, Alfred Joy, who took my parents and me on a tour of the office building that would later become my work space for 50 years. A same-day car trip to the summit over a winding mountain road – on which, for the first time, I sensed fear in my father – gave me an unforgettable view of the legendary 100-inch Hooker reflector.

My professional association with the Mount Wilson Observatory began as a graduate student in astronomy at the California Institute of Technology in 1948 and continued with an appointment to the observatory’s scientific staff in 1952. That association remains active to this day.

My first years at the observatory overlapped with those of many second-generation astronomers as they neared retirement, or as they stayed on after retirement. In addition to Joy I came to know Paul Merrill, Harold Babcock, Roscoe Sanford, Edison Pettit, Seth Nicholson, Edwin Hubble, Milton Humason, and also of course the third generation of Ira Bowen, Walter Baade, Rudolph Minkowski, Olin Wilson, Ralph Wilson, Robert
Richardson, Robert King, and Horace Babcock. I had also met Walter Adams, Gustav Stromberg, John Anderson, John Strong, and Harlow Shapley.

In the pages that follow I will introduce you to the full spectrum of these geniuses, these visionaries, these eccentrics motivated by personal animosities – as well as, of course, a raft of just plain determined scientists and engineers who worked hard to get a tough job done. Many of the stories set down here I learned straight from the lips of these patriarchs. Some may even be true. I have recorded them faithfully, as they were told to me. I have also drawn freely on my memory of the numberless nights I spent atop the mountain in the company of storytellers. These have been freely recalled – as has been my understanding of the scientific fields that unfolded from observations and interpretations made at Mount Wilson and at the beginnings of Palomar.

The reader should be warned that the book is an informal history. It is not the narrativethat would be constructed by professional historians, with their citations of letters, administrative documents, extensive interviews, and other original sources. With the exception of the first four chapters, the materials here draw liberally on the nearly 800 papers published in the Mount Wilson Contribution series in the Astrophysical Journal from 1904 to 1949, as well as the nearly 200 Mount Wilson Communications to the National Academy of Sciences. Many of the biographical sketches are likewise based on the Biographical Memoirs of the Academy.

For astronomers who might read the book, I wanted to re-create the spirit of high adventure that infused those first Mount Wilson astronomers – the men and women who believed that the enterprise in which they were engaged bore such enormity that it transcended normal intercourse. Other readers, I hope, will enjoy the account they find here of the early days of astrophysics as experienced by a fourth-generation Mount Wilson astronomer.

To learn more

Previous histories of the Mount Wilson Observatory have given less emphasis to solar physics than the rather intense focus you will find here. Those wishing to read more widely will find that Explorer of the Universe (1966), Helen Wright’s comprehensive biography of George Ellery Hale, centers on his founding of the three largest observatories of their times. David Woodbury’s Glass Giant of Palomar (1938), Ronald Florence’s Perfect Machine (1992), and Don Osterbrock’s Pauper and Prince: Ritchey, Hale and Big American Telescopes (1993) are all important, yet each concerns itself primarily with the observatory’s construction, development, organization, and administration. Helen Wright’s Palomar: the World’s Largest Telescope (1952) carries the saga into the Palomar era.
Part I

BEFORE THE BEGINNING (1542–1904)
A TELEGRAM

The date is December 20, 1904. The place is the front range of the San Gabriel Mountains, 5500 feet (1675 m) above the rough-hewn village of Pasadena, California. At Martin's Camp, in the saddle between 5000-foot-high Mount Harvard and the still-higher summit of Mount Wilson, a phone rings.

Since 1889, the camp has been a stopping place near the summit of Wilson's Peak (as it was called at the time) for hikers, horsepackers, and tourists heading from the front range of the San Gabriels into the rugged backcountry. Seemingly tame when viewed from the valley, the San Gabriels were then and still are a daunting challenge, spiderwebbed with wild and nearly inaccessible canyons, ridges, and peaks soaring almost 10000 feet (3000 m) high only 35 miles (56 km) east of the California coast.

Martin's Camp was one of two resorts near the summit of Mount Wilson. It and the larger Strain's Camp (Fig. 1.1) offered meals and overnight lodging in tents. To reach the camp, adventurers from the valley would pay three dollars to ride on the back of a mule from the nearby village of Sierra Madre.

From the peak, the Rattlesnake Trail still descends to the West Fork of the San Gabriel River—a favorite fishing place for the many scientists who would make Mount Wilson famed for its astronomical observatory. From the river, trails climb into the backcountry and eventually drop into Antelope Valley, which today contains the cities of Palmdale and Lancaster. Other trails make their way into the high desert beyond Wrightwood to Victorville, northeast of the 4259-foot (1298 m) Cajon Pass. In 1904, almost all of this—including the front range of the San Gabriels—was wilderness.

With the phone call to Martin's Camp, George Ellery Hale, age 37, was about to become the founder and director of the legendary Mount Wilson Solar Observatory of the Carnegie Institution of Washington. On that December day in 1904, the slight and wiry Hale had arrived at Martin's Camp on his way to the summit of Wilson's Peak. Over the previous 12 months, he had made this trip frequently to visit the site of his Yerkes Solar Expedition at Wilson's Peak. The path to the summit followed one of two routes: the steep, narrow Little Santa Anita Canyon Trail from Sierra Madre, or the newer (but still just four-foot-wide) Mount Wilson Toll Road from Eaton Canyon.
Hale had arrived in Pasadena in December 1903 as the leader of an astronomical expedition from the Yerkes Observatory of the University of Chicago. His officially articulated mission to the University authorities was to explore the feasibility of building a temporary solar observatory on Mount Wilson. Much more ambitious was his hidden agenda at that time: Hale hoped to convert the temporary expedition into a permanent new observatory.

Weather patterns in southern California had suggested that the observing conditions for astronomy on Mount Wilson would be far superior to those allowed by the severe winters, cloudy skies, and turbulent air of the upper Midwest. (Since 1893 the Yerkes Observatory has been sited on Lake Geneva, Wisconsin, 60 miles north of Chicago.)

Hale had spent most of 1904 reconnoitering Mount Wilson from his base in Pasadena. He then began preparing to locate on the mountain a solar telescope that would be large enough to significantly advance solar physics.

As director of the Yerkes Observatory, Hale had received in early 1903 a relatively small grant of $10,000 (about $200,000 in 2004 dollars) from the Carnegie Institution of Washington, which had been founded just a year earlier to lead the US role in science worldwide (Chapter 4). The grant was designed to determine Mount Wilson’s suitability for a temporary solar observatory – an idea first advanced in 1902 by astrophysicist Samuel Pierpont Langley, Secretary (that is, director) of the Smithsonian Institution. Langley
had written part of a report for the Astronomy Advisory Committee of the new Carnegie Institution to its first Board of Trustees. His goal, he stated in the report, was to devise a means of measuring the solar constant that would yield a significantly more accurate value of the Sun’s energy output than was known at the time.

The solar constant

The solar constant is a fundamental number that gives the amount of energy received from the Sun by a detector on Earth. Its units are the energy received per second per unit area of the detector. The value can be described as, for example, the number of watts received over a square meter of receiving area placed perpendicular to the incoming solar rays, or the number of ergs per second per square centimeter of the detector. The measured value is about one kilowatt per square meter.

Knowing the value of the solar constant and the distance to the Sun gives the total energy generated and radiated by the Sun in all directions per second: a power of $4 \times 10^{26}$ watts, or $4 \times 10^{33}$ ergs per second.

As Smithsonian director, Langley had also been appointed to the new Carnegie Board of Trustees. His membership on the five-man Astronomy Advisory Committee – set up to advise the full board on opportunities for the institution to support astronomy – gave Langley added influence with the Carnegie Institution. After he had contributed to the Astronomy Committee’s 1902 report, however, Langley’s interests shifted from pure solar research to investigating the possibilities of powered flight in manned aircraft.

The new Carnegie Institution had a unique charter. Whereas most universities of the time focused on teaching rather than original research, the Carnegie Institution’s mandate was “to encourage investigation, research and discovery in the broadest and most liberal manner, and the application of knowledge to the improvement of mankind.” To accomplish this, the institution would assign “the exceptional man to every department of study, whenever and wherever found, and enable him, by financial aid, to make the work for which he seemed especially designed his life work.”

The 1903 tests of the Mount Wilson site were to be made with a fixed-direction telescope known as a coelostat (Chapter 5), which the Yerkes Observatory had lent to Hale. The plan – at least as it was formally presented to the Carnegie board through its Executive Committee – was to place on Mount Wilson nothing more than a temporary solar observatory.

Yet Hale’s plans, as usual, were far grander than the official pronouncements set out as the short-term goals of the Yerkes Expedition. In his heart, Hale envisioned a permanent solar observatory replete with several large solar telescopes. The jewel in the observatory’s crown would be a titanic nighttime
A telegram

reflector that would enable astronomers to make comparable physical measurements of the stars in order to "solve the problem of stellar evolution."

By the middle of 1904, Hale had spent nearly $25,000 on his "long-term permanent plan," exceeding the budget of his Carnegie grant by $15,000. Much of the money had been used to set up support facilities and optical and mechanical labs in Pasadena for building "temporary" telescope mountings on the mountain. Construction workers employed by local contractors also had to be paid. A machine shop had to be fitted out in Pasadena, and a smaller one established on the mountain. Machine tools and construction equipment were needed at the site. Temporary quarters from which Hale and his staff could direct these difficult operations also had to be developed in Pasadena and on the mountain.

In February 1904, Hale had arranged for the "temporary" transfer of three Yerkes astronomers – Walter Adams, Ferdinand Ellerman, and George W. Ritchey – from Wisconsin to Pasadena. Because the Yerkes budget could not cover their salaries, Hale paid the three men out of his own pocket for the first half of 1904. (His father’s generosity had made Hale independently wealthy.)

In the absence of prior authorization from the Carnegie Board of Trustees, this was highly irregular. Furthermore, the Carnegie Institution had given no guarantee that the Yerkes Expedition would be anything but temporary. Hale knew his payroll ploy was risky, but in the end he made no secret of his actions – nor of his ambitions for a permanent observatory. This mix of careful planning and impulsive action in a single bold masterstroke would come to characterize Hale’s career.

Taking the doctor's advice

George Hale’s enthusiastic gamble of his own money to establish a national solar observatory got some crucial support from New York surgeon John S. Billings.

The loan document drawn up by Hale was titled “This Declaration, made this 7th day of September, 1904, by me, George E. Hale, of Pasadena, California, to and in favor of the Carnegie Institution of Washington, D.C., Witnesseth: “. It was co-signed by Hale’s wife as a witness and was dated before the late September 1904 meeting of the Executive Committee.

Before that meeting, Billings – having presumably seen the September 7 declaration – heartened Hale to proceed by divulging a snippet from his own background: "During the Civil War I expended on one occasion seventy-five thousand dollars, without authority of law. I was ultimately sustained, but in such cases no one can foresee the outcome. The only thing for you to do is to report fully, in person, to the Executive Committee at its next meeting."

The historical record shows Hale did just that the next day.

At the urging of John S. Billings, a noted surgeon and the director of the New York Public Library (as well as an influential member of the Carnegie
A telegram

Trustees), Hale formally reported his actions to the institution in a declaration dated September 7, 1904. The document clearly stated Hale’s hope for a permanent observatory, but it also gave strong assurances that freed both the Carnegie Institution and the University of Chicago from the onus of covering any expenses above those promised by the initial $10,000 Carnegie grant.

This document appears to have become central to later decisions made by the Board of Trustees. It read, in part:

In the proper expenditure and most practicable use of the said grant of $10,000.00, I, without authorization of said Carnegie Institution, but deeming such action both economical and essential in the development of the mutual plans of all interested in said work, have made arrangements personally and entered into contracts for construction, equipment, and otherwise aggregating about the sum of Fifteen thousand ($15,000.00) Dollars at the date hereof in excess of said $10,000, believing all of said time that said Carnegie Institution would make a further grant.

NOW, THEREFORE, I declare, and further do covenant and agree to and with said Carnegie Institution that the making of said arrangements and contracts – in excess of said grant of $10,000.00 – was and is in all respects my sole personal action, in no wise authorized by or binding upon said Carnegie Institution, and I do covenant and agree to save and keep said Carnegie Institution free, safe and harmless from each and all of said liabilities so by me personally incurred.

The declaration drives home the magnitude of Hale’s gamble in silently lobbying to transform the temporary Yerkes Expedition into a major Carnegie commitment for a permanent observatory. The $15,000 he put on the line from January through September 1904 would be equivalent to about $300,000 today.

No decision by the Carnegie Board for a Carnegie Observatory – permanent or temporary – had been made up to the time of Hale’s September 1904 declaration about his wider plan. In Hale’s defense, however, he had received private hints from various members of the Carnegie Executive Committee that the wider plan would be looked on favorably by the Trustees – among them Charles D. Walcott, who was not only secretary of the Carnegie board but also director of the United States Geological Survey. Nonetheless, Hale had set up shop in Pasadena and begun permanent installations on Mount Wilson on the basis of nothing more bankable than his own tenuous hope.

Lacking formal board action but laden with expenses that were growing by the day, Hale had become desperate by December 1904. It was thus a worried man who reached Martin’s Camp on December 20, 1904, resting there before climbing the final half-mile to the Mount Wilson summit.

A telegraph operator in Pasadena had placed the telephone call to Martin’s Camp. Upon lifting the receiver to his ear, Hale heard the operator say that a telegram had just been received “from a Mr. Walcott, who signs himself..."
A telegram

Secretary of what he calls the Executive Committee of a group that calls itself the Carnegie Institution of Washington.”

Taken aback, Hale asked the operator to read the telegram. It was then he learned that “The Executive Committee has appropriated $150,000 a year for two years and has authorized the immediate execution of the larger plan.”

With that generous bequest, the Mount Wilson Solar Observatory became a reality – if only on paper. A path had opened up, beckoning the 37-year-old Hale to create what would become the world’s greatest astrophysical observatory. There, in concomitant concert with other observatories, would the foundations be laid for modern astrophysics, stellar evolution, the structure of the Galaxy, stellar and galactic dynamics, and observational cosmology.