THE CANADA-FRANCE-HAWAII TELESCOPE AND GEORGE WILLIS
RITCHEY’S GREAT TELESCOPES OF THE FUTURE

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ABSTRACT

George Willis Ritchey (1864–1945) was a pioneer maker, user and prophet of large reflecting
telescopes. His ideas were far ahead of the technology of his time, and as a result he seemed, in
his later years, a hopeless visionary to many of his contemporaries. This paper recounts in brief
form the story of Ritchey’s life and scientific career, and describes how many of his concepts were
achieved in modern form in the Canada-France-Hawaii telescope.

RÉSUMÉ

George Willis Ritchey (1864–1945) était un fabriquant pionnier, usager et prophète des grands
télescopes à réflexion. Ses idées étaient en avant de la technologie de son temps, et suite à cela dans
des années tardives, il semble qu’il était pour ses contemporains un pauvre visionnaire. Cet article
raconte en bref l’histoire de la vie de Ritchey et sa carrière scientifique, et décrit comment plusieurs
des ses concepts ont été réalisés en forme moderne pour le télescope Canada-France-Hawaii.

The 3.5-metre Canada-France-Hawaii telescope, atop Mauna Kea on the Big
Island of Hawaii, has produced outstanding new results in our knowledge of
the universe. Because of its large aperture, and the superb images it provides,
astronomers have been able to resolve and record the detailed structures within
nova and supernova shells, H II regions, and nearby galaxies, as well as of small
distant galaxies and the “fuzz” or nebulosity around many quasistar objects.
The CFHT has made it possible to do accurate photometry to formerly unreach-
ably faint apparent magnitudes in globular clusters, and thus trace the evolution
of low mass stars and date the early days of our Galaxy. It has made it possible
to obtain images and photometry of individual luminous stars, variable stars and
novae in more distant galaxies than ever before, and thus map the universe to
much greater distances. All this has been achieved by great technical advances
in the design and construction of the telescope and its imaging systems, and in
controlling the figure of the mirror, and the seeing in and near the telescope and
dome. Many of these advances have been described by McClure et al. (1989)
and by Racine et al. (1991).

Tremendous technical advances went into the CFHT (Racine 1981, Cayrel
1990). Its designers, builders, optimizers and users deserve great credit for all
they have done to make possible the observational exploration of the universe.
in space and time with the CFHT. Yet it is also instructive to realize how many of the advanced, modern ideas that went into it were foreseen by George Willis Ritchey in his plans for the “Great Telescope of the Future” over sixty years ago. Ritchey was far ahead of his time. His ideas were visionary, and he never succeeded in bringing into being one of the great large reflectors, designed for imagery of the faintest possible stars, nebulae and galaxies, which he prophesized. Most astronomers of his time regarded him as an impractical zealot, or even crazy, but his ideas have won out in our time. The “practical” observatory directors who opposed Ritchey and cast him aside now seem narrow minded, if not overly wedded to the traditions of the past.

Ritchey was born in a tiny hamlet in Ohio in the last full year of the American Civil War; he died in the outskirts of the megalopolis of Los Angeles in the last year of World War II. He was born in the just barely industrialized, eastward-facing America of Abraham Lincoln; he died in the technologically advanced, transcontinental nation of Harry Truman. When Ritchey was born the largest telescope in North America was the 18½-inch Clark refractor intended for the University of Mississippi, which ended up at Northwestern University’s Dearborn Observatory; when he died the largest telescope was the 200-inch reflector nearing completion on Palomar Mountain. Ritchey did not build either of those telescopes, but he was at the heart of the revolution in scale and technology which lay between them. (Osterbrock 1993)

Ritchey’s grandfather with his whole family, including Ritchey’s father, emigrated from Northern Ireland to the United States in 1841. Both of them were skilled workers with their hands, who operated a mill. They were cabinet makers who soon owned a flourishing furniture company in Pomeroy, Ohio, which went broke because they were far better craftsmen than businessmen. Ritchey’s father, James, married Eliza Gould, an orphan who could trace her ancestry back to the Mayflower and Plymouth Plantation. George Willis Ritchey, their second son (his older brother died at the age of sixteen) grew up in Pomeroy, Evansville, Indiana, and Cincinnati. He became a skilled cabinetmaker too, and worked alongside his father and grandfather in several furniture companies. He attended the then new, tiny University of Cincinnati for two years, taking a drawing and design course one year, and a scientific course the second. During it he worked as an assistant at the Cincinnati Observatory, which had started life as a separate, largely amateur-oriented organization, but then had become part of the university. There Ritchey read the papers and articles of Henry Draper and A.A. Common on reflecting telescopes, and he had his own little “laboratory” (or shop) in his home. In it he began to make small astronomical telescope mirrors, teaching himself each step in the process, and then improving it. He married, moved to Chicago in 1888, and got a job as a teacher at its Manual Training School. Again he soon had his own home optical laboratory, where he
continued to improve his skills in making the highest quality flat, spherical and parabolic mirrors, and designing telescopes around them.

There in Chicago in 1890 Ritchey first met George Ellery Hale. Scion of a very wealthy family, Hale was four years younger than Ritchey, and had just graduated from the Massachusetts Institute of Technology. He had been interested in the “new astronomy”, astrophysics, from early youth, and his father, president of a hugely successful elevator company, had provided a live-in tutor, a private school, telescopes, spectrographs, and travel to Europe to encourage his son’s devotion to science. Young Hale had his own private laboratory and observatory, built around a grating spectrograph and a heliostat, for solar spectroscopy, in the family mansion in Kenwood, a fashionable suburb in the south side of Chicago. For his son’s senior thesis, which he did at Harvard College Observatory under the supervision of Edward C. Pickering, William E. Hale ordered and paid for a large spectrograph, modelled in part on Lick Observatory’s, but even better equipped than it. When Hale graduated from M.I.T., his father built him his own private Kenwood Physical Observatory, with an especially designed 12-inch refractor, optimized for solar research. Ritchey soon began doing occasional optical and machinist jobs for Hale, as an unpaid volunteer, at Kenwood.

About that time William Rainey Harper was bringing into being, with John D. Rockefeller’s money, the new University of Chicago. Its site was in Hyde Park, little more than a mile south of Hale’s observatory. In 1892 Harper appointed the young astrophysicist, then 24 years old, an associate professor, but with no salary for the first three years. He was to work at his own observatory with graduate students, but would have no undergraduate teaching duties. Furthermore Hale’s father agreed to convey the entire observatory, with its telescope and instruments, to the university if Harper succeeded in raising $250,000 or more for a larger telescope within three years.

Just a few months later the persuasive president, aided by young Hale, did succeed in signing up Charles T. Yerkes, an unscrupulous, flamboyant street-railway magnate, as the donor of the largest refracting telescope in the world, the 40-inch. Its lens was made by Alvan G. Clark, its mounting by Warner & Swasey, and it was completed and erected at Williams Bay, Wisconsin, 70 miles from Chicago, in 1897.

Ritchey and Hale, however, were convinced that reflectors, not refractors, were destined to be the “monster telescopes” of the future, for all the reasons we know so well today. The little 10- and 12-inch reflecting telescopes which Ritchey had made in his shop at home were to them the harbingers of the great telescopes of the next century. While the 40-inch refractor was still under construction, Hale persuaded his father to order from France the glass disk for a 60-inch mirror for a monster telescope. Ritchey handled the negotiations with the St Gobain Glass Company, and by 1896 he was working full time for Hale.
as an optician, his salary paid by William E. Hale. Thus at the Yerkes dedication in the fall of 1897, the assembled astronomers saw Ritchey rough grinding the 60-inch disk in the optical shop in the basement of the observatory.

With the 40-inch, Ritchey (1900) pioneered in long focal-length photography of the Moon, globular clusters, and bright nebulae. He recognized from the beginning the overriding importance of concentrating the starlight in the smallest possible images. He developed the method of taking direct photographs through a yellow filter, onto orthochromatic plates, to use the light in the visual spectral region for which the refractor was designed. This gave far superior images, and hence recorded much fainter stars, than the older photographs taken on the blue-sensitive plates, using a "photographic corrector," a third lens mounted in front of the visually corrected doublet. On a long-focus refractor, subject to considerable flexure, these three-element systems were almost impossible to keep in alignment. With the 40-inch Ritchey developed precise guiding to a fine art, using a precisely machined double-slide plateholder of his own design to eliminate the small errors in the telescope drive system. He also had conceived and installed a primitive system for interrupting the exposure during moments of poor seeing when the images blew up, a flap shutter which the night assistant could open or close at Ritchey's order, without disturbing the telescope. Later he built a similar system which he could operate himself, using a bulb in his mouth, communicating air pressure through a tube to a mechanism to open or shut the flap.

At Yerkes Ritchey (1901) also built the first professional-quality reflecting telescope in America, the 24-inch reflector (which is now in the Smithsonian Institution in Washington). He had made the mirror for Hale in Chicago; then took over the design and building of the whole telescope in 1899, when he went on the university payroll as superintendent of instrument construction. He was saddled with an earlier design, which he could not scrap because the parts had already been bought, but he was able to work in some of his own more advanced ideas. With this reflector, a fast f/4 system completed in 1901, Ritchey obtained an outstanding series of photographs of nebulae (a term which included galaxies in those days). The superior design, mechanical stability, and optics of the 24-inch enabled him to surpass the earlier photographs taken with the 36-inch f/5.7 Crossley reflector at Lick Observatory, which had awakened American astronomers to the potentialities of reflecting telescopes a few years before.

Ritchey's photographs with the 40-inch refractor and 24-inch reflector, exhibited by Hale at the meeting of the Astronomical and Astrophysical Society of America (now the American Astronomical Society) in Washington at the end of 1901, aroused wide attention. Ritchey became well known to astronomers, and at the invitation of Samuel P. Langley, secretary of the Smithsonian Institution, published a 51-page paper "On the Modern Reflecting Telescope and the
Making and Testing of Optical Mirrors” in 1904. It rapidly became a classic (Ritchey 1904a). That same year he published, in a University of Chicago volume, a selection of his photographs of the Moon, clusters, nebulae, and comets, taken at Yerkes (Ritchey 1904b).

Hale realized, even before he began building Yerkes Observatory, that there were far superior sites in the West, but he knew that his father, a fanatic Chicago booster, would not consider them. Soon after William E. Hale died, near the end of 1898, his son began speaking openly of locating a University of Chicago remote station in California. It was to be a “solar observatory,” built around the 60-inch reflector on which Ritchey was working, which was intended to be used to compare stellar spectra with the Sun’s. Hale quickly picked Mount Wilson, and the first real research instrument he moved out was the Snow solar telescope, a 24-inch aperture, f/30 fixed, horizontal reflector fed by a heliostat, which Ritchey had built. He had originally planned an even larger, longer focal-length telescope of this type, for planetary and lunar photography, but Hale had him build the Snow telescope for solar work. The first version, erected in a wooden shelter at Yerkes Observatory, had burned in a disastrous fire before it produced any results, but the new one, on Mount Wilson, was a great success. By 1905 Hale managed to get financial support for his new Mount Wilson Solar Observatory from the Carnegie Institution of Washington. He broke away from the University of Chicago, bringing his first team, Ritchey, young astronomer Walter S. Adams, and observing assistant Ferdinand Ellerman, with him from Yerkes. The 60-inch disk, still Hale’s personal property, financed by his father, came too.

Ritchey (1901) had published his first design for the 60-inch telescope while he was still in Williams Bay. It incorporated his flotation principle for defining the position of the primary mirror accurately, but balancing off most of its weight against a system of weighted levers to minimize flexure, which he wrote that he had developed in his laboratory in 1891 (Ritchey 1897). In Pasadena he completed the 60-inch mirror and the mechanical parts of the telescope, and had it installed and in operation on Mount Wilson by the end of 1908. It incorporated interchangeable “cages,” for the Newtonian flat and the three Cassegrain and coude secondary mirrors, making it possible to align each mirror rigidly and accurately, but shift rapidly between them. The dome was designed to maximize air circulation, and Ritchey’s plan included a small refrigerating plant, to keep the primary mirror and its cell at the expected night-time temperature through the long, hot Mount Wilson summer and fall days (Ritchey 1909). This feature was not actually installed, however. The 60-inch reflector was enormously successful. With its long focal length, Ritchey (1910a, b, c) obtained even better direct photographs of the Moon and clusters (at the Cassegrain focus), and of nebulae, galaxies and comets (at the Newtonian focus). At the meeting of the International
Union for Cooperation on Solar Research which Hale organized in the summer of 1910, Ritchey showed the assembled astronomers visual objects with the 60-inch on each of the three nights they were on the mountain, and exhibited each day photographs he had taken with it.

By then Hale had obtained from John D. Hooker the money to buy a 100-inch disk, and Ritchey had started preliminary designs for the telescope. This project was to prove his downfall at Mount Wilson Observatory. The total mass of glass required for the mirror was much larger than the St Gobain works could prepare in a single casting. They had had to combine glass from three ovens into one mould, and the resulting blank was filled with layers of bubbles. At first Ritchey and Hale had rejected it, but after years of experiments the French could do no better, and in the end the 100-inch reflector was built around the first disk which had been delivered.

Ritchey had seen how much worse the effects of coma, the off-axis aberration that elongates the images of a conventional reflector and draws them out into little fan-shaped patterns, was for the 60-inch than for the 24-inch. He realized it would be even worse for the 100-inch, and that it would make the telescope’s usable field very small. Ritchey also had noticed that the coma of the 60-inch of its f/15 Cassegrain focus was much smaller than at its f/5 Newtonian focus. He thought the Cassegrain secondary had reduced the coma of the primary mirror. This is not the way we would describe it today, but it is not completely wrong, either. Ritchey asked his assistant, Henri Chrétien, a young visiting astronomer from Nice Observatory, to see if he could calculate a different form for the Cassegrain secondary of the 100-inch, which would eliminate coma altogether. Chrétien, superbly trained in mathematics and theoretical optics at the Sorbonne, immediately began calculating and soon saw that modifying the form of the primary alone would not do it, but that if both the primary and the secondary had different shapes, coma could be completely eliminated. This was the invention of the Ritchey-Chrétien system. Ritchey wanted to use it for the 100-inch. Hale and Adams, by now his “first astronomer,” soon to become assistant director, then acting director, and ultimately director himself, vetoed the idea. Unlike Ritchey, they saw the main use of the telescope in stellar spectroscopy, for which coma is no problem, since only the star at the centre of the field is observed. They incorrectly believed that a Ritchey-Chrétien telescope could only be used at a single focal ratio, and would therefore be too inflexible. Actually a Ritchey-Chrétien primary mirror cannot be used alone, at the Newtonian or prime focus, as a paraboloid can, and as a Cassegrain it can eliminate coma only at a single focal ratio. But it can be used for spectroscopy at other focal ratios, as a Cassegrain and as a coudé, just as a paraboloid can. Ritchey explained this to Hale and Adams, but they were convinced it would be a mistake to build the world’s largest telescope as a Ritchey-Chrétien. They were right; it was an
absolutely untried system at the time, but in refusing to allow Ritchey to make
a smaller, experimental telescope of this design they were wrong, and held back
the progress of astronomy. Ritchey appealed to Hooker, the donor of the money
for the 100-inch mirror, who was far more interested in beautiful photographs
of nebulae than in stellar spectroscopy. Hale managed to head off this end run,
and never trusted Ritchey again. He turned the design of the 100-inch over to
others, including Francis G. Pease, Ritchey’s former assistant. Hale kept Ritchey,
with his superb optical skills, at work on the 100-inch paraboloidal mirror. It
was a long, slow process, with many problems along the way, but ultimately he
finished it. The primary mirror was installed in the telescope and tested in the late
summer of 1917. The secondaries were delayed by World War I; Hale, Ritchey
and Adams converted the Mount Wilson optical shop into a plant that turned
out 2500 prisms for the Army within ten weeks. But the 100-inch was ready
for use by December 1918, and it went into regular operation in the summer of
1919. The mirrors which Ritchey made were superb; the 100-inch primary was
generally considered by opticians to have been unmatched in optical quality by
subsequent large telescopes until the Kitt Peak reflector of the 1960s.

But Ritchey never got to use the 100-inch. He was unceremoniously fired,
on a charge of disloyalty, on October 31, 1919. He had finished the mirror,
and he was no longer needed. He was 56 years old, but he received no pension
whatsoever, and only $2,000, little more than six months’ salary, as his final and
total severance payment. Hale was the most powerful astronomer in America;
no other observatory or university would arouse his enmity by hiring Ritchey.
All he could do was retire to his lemon and orange ranch in Azusa, where he
scrabbled out his existence for the next four and a half years, dreaming of the
great telescopes of the future.

Ritchey’s deliverance came from France. In 1923 a wealthy French engineer
and his wife, Assan and Mary Dina, promised to provide the money to build a
large reflecting telescope for their country at a mountain-top observatory. It was
to be a 2.65-metre (104-inch) reflector, which would make it the largest telescope
in the world, just surpassing the 100-inch. Ritchey was hired to make the mirror.
He arrived in Paris in the spring of 1924, and soon made it clear that he intended
to build a much larger telescope than a mere 2.65-metre. He set up his laboratory
in the Paris Observatory and began planning for a 5-metre or 6-metre reflector.
The project never really got off the ground, for Dina turned out not to be nearly
as rich as he said he was, and his promised observatory disappeared in a barrage
of law suits between himself and the government officials and professors who
thought he was working with them. Dina died in 1928, and the big telescope
was never built.

But Ritchey spent seven years in France, planning and experimenting. Always
he emphasized the need for very large telescopes, and of the smallest possible
images, to reach to the faintest possible magnitudes, to record the finest possible structures, and to resolve the closest possible companions, and the stars in globular clusters as close to their dense centres as possible. He realized that really big telescope mirrors could not be made from single, thick glass disks; they would be too heavy, and deform too much under their own weight. Ritchey's solution was to make "built-up" cellular disks, consisting of top and bottom disks, each only a few inches thick, separated by ribs or spacers of the same
type of glass, cemented between them. The spacers were to have holes in them, or be arranged so that forced air, driven by a fan, could circulate between them, keeping the mirror at a uniform temperature. Thus Ritchey’s concept was very similar to the “egg-crate” or Angel mirrors of today, except that he could not cast the disks as units, but instead tried to build them up by cementing pieces of glass together. Ritchey had proposed this plan for the 100-inch at Mount Wilson, when the original disk appeared unusable, but Hale had vetoed the idea. Ritchey had experimented with the process in his home shop in Pasadena, where he had succeeded in making a 20-inch built-up disk. In France he and his assistants made a 16-inch, and ultimately a 60-inch, which however cracked in the annealing process. Cementing the pieces of glass together so that they were not strained required finer dimensional tolerances, and more sophisticated processing and clamping methods than Ritchey had at his disposal in the 1920s.

Ritchey emphasized the importance of the very best site for the telescope, for he realized the overriding importance of fine seeing for reaching the faintest possible magnitudes. After the French project collapsed, Ritchey spoke openly of world-wide searches for the absolutely best sites. In an interview with an American science writer in 1927, he described his plan for a 10-metre telescope, which he hoped to erect at a high, dry, even-temperature, low-latitude site, contiguous to the Pacific Ocean. Probably he was not thinking of Mauna Kea, but it is a good description of it!

Another of Ritchey’s often expressed ideas was to vary the observing programme to fit the seeing, using the hours of very best seeing for the most important exposures, with the longest focal lengths, then shifting to shorter focal lengths when the seeing blew up. He therefore planned to make not only the secondary mirrors, but the primary mirrors themselves, interchangeable. Thus he planned fixed vertical telescopes, with their primary mirrors horizontal, at ground level, fed by a coelostat, consisting of two large plane mirrors, mounted vertically above them in a large, domed tower. The primary mirror sent the light back up the tube, and a secondary mirror, mounted above it but below the coelostat, directed the light back down the tower, through a hole in the primary, to the focal plane below. Each primary was to have one or more secondaries, and in a typical design there were three or four different primaries, which could be used interchangeably. Each primary and secondary was to be mounted on a carriage which ran on rails, so they could be taken in and out of the beam rapidly, but aligned in advance, with their positions defined by pins. In Ritchey’s first plan, which he brought with him from Azusa, there were three 4-metre primaries, one a conventional paraboloid, one a Ritchey-Chrétien, and one a Schwarzschild, another coma-free system especially suitable for short focal-ratio, wide-field photography, but requiring a tube or tower quite large in comparison with its focal length. (No large one has ever been built and used for research). The coelostat mirrors were to be 5 metres in diameter. A later plan, which he drew
Fig. 2—One of Ritchey's designs for a fixed, vertical telescope, with 5-metre primary mirrors, and 6-metre plane coelostat mirrors. From JRASC, 22, 159, 1928.
up in France, called for a system with four 5-metre primary mirrors, two of them Schwarzschild's and two Ritchey-Chrétien's, and correspondingly larger coelostat mirrors. Ritchey also designed an equatorially mounted reflector, with "only" a single Ritchey-Chrétien primary, and several secondaries, but his heart was clearly in the fixed vertical telescopes. However, they were far too expensive to build; one would cost approximately four times as much as an equatorial, for the same aperture, according to estimates made at the time. Ritchey visualized not one of them, but five, spaced along one meridian from northern latitudes to southern.

In France Ritchey did finally make the world’s first Ritchey-Chrétien reflector, a little 0.5-metre telescope. He and Chrétien exhibited it at the French Academy of Sciences in 1927. Ritchey hoped to use it to take an outstanding series of photographs which would prove its capabilities, as he had with the Yerkes 24-inch and the Mount Wilson 60-inch, but he could not do it. He had only an antiquated mounting, erected at a poor site in central France, with no assistants. He himself, 62 years old and by then blind in one eye, was incapable of the feats of guiding he had achieved 25 years earlier. He had no results to show, and seemed a failure.

But Ritchey wrote a series of articles, summarizing his ideas on telescope design and astronomical photography. Translated into French, they were published in L'Astronomie, the Bulletin of the Astronomical Society of France (Ritchey 1928a, b, c, d, e, f). Soon thereafter they appeared, slightly rearranged and revised, in their original English in the Journal of the Royal Astronomical Society of Canada (Ritchey 1928g, h, i, j, 1929a, b). E.M. Antoniadi and C.A. Chant, the editors of L'Astronomie and the JRASC respectively, deserve great credit for providing these forums for Ritchey's ideas. No American astronomical magazine of the time, such as the Publications of the Astronomical Society of the Pacific or Popular Astronomy would touch these articles; Hale and Adams had driven Ritchey and his ideas out of his own country. Yet in France and England he received many honours; his Thomas Young oration, delivered before the Optical Society in London, is a clear, persuasive, brief account of his ideas (Ritchey 1928k).

Much of this same material, revised extensively and superbly illustrated by many of Ritchey's astronomical photographs from Yerkes and Mount Wilson, went into his book L'Évolution de l'Astrophotographie et les Grands Téléscopes de l'Avenir (Ritchey 1929c). Printed in parallel texts in French and English on facing pages, it is his best long statement of his telescope ideas. The cover shows a planned observatory at the edge of the Grand Canyon, probably not in reality a very good site, though Ritchey insisted that it was. Ritchey’s book was very favourably reviewed in France and Great Britain, but ignored in his native land.

Ritchey returned to the United States at the end of 1920. He managed to convince Captain J.F. Hellweg, the superintendent of the U.S. Naval Observatory,
Fig. 3—Ritchey’s design for a 6-metre, equatorially mounted Ritchey-Chrétien reflector. Note the human figure on the observing floor, and the other one seated on the observing arm behind the Cassegrain focus, giving a graphic idea of the scale of the telescope. The original caption read: “A equatorially mounted observer’s carriage and an automatic, exterior tube-extension are shown. The dome is about 25 per cent larger than the largest observatory domes now in use.” From JRASC, 22, 303, 1928.
to let him undertake the job of building a 40-inch Ritchey-Chrétien reflector for it. Completed in 1934, it was the world’s first actual research telescope of this type. Erected at the Naval Observatory’s poor site in Washington, already suffering from light pollution, and with no experienced photographic observers on its staff, the telescope was an apparent failure. Ritchey went home to Azusa, where he died in 1945. Only long after his death were his dreams of a huge telescope, optimized for direct imagery, erected on a superb site, with positive control of the local environment to preserve the best possible seeing, and with arrangements to change rapidly between foci to maximize the use of the available seeing, realized in the CFHT. Although it is not a Ritchey-Chrétien, nor a fixed vertical telescope, it exemplifies Ritchey’s analytic search for perfection, and his attention to detail in matching the telescope and environment to the observing programme.

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