RITCHEY'S FIXED UNIVERSAL TELESCOPE

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George Willis Ritchey (1864-1945) was the prophet and builder of the first large American reflecting telescopes and a master of celestial photography. Ritchey worked closely with George Ellery Hale[1] and the Mount Wilson Observatory stands today as a monument to their collaboration. Ritchey is usually associated with the Ritchey-Chretien system, used in almost all large reflecting telescopes today. The largest telescopes in activity clearly demonstrate the validity of many of Ritchey's predictions, which seemed fantastic if not impossible to most of the astronomers of his day.

After the completion of the 100-inch, Ritchey devoted eight years to the study of a fixed, vertical, universal reflecting telescope, with a coelostat and cellular mirrors. This unusual telescope was designed mainly (in Ritchey's own words) "*to overcome the technical difficulties and the inconveniences of all kinds which are encountered with very large equatorial reflectors*". He also mentioned that "*this type (of telescope) is incomparably well adapted for the highest requirements of astronomical photography, and of astrophysical work with very large and elaborate accessory instruments*".

Ritchey's first designs of the fixed universal telescope were completed in March 1924. These included three concave 5 m mirrors and a coelostat with two 6 m plane mirrors. The six secondary mirrors (Newtonian – plane, Schwarzschild – concave, Cassegrain and Ritchey-Chrétien – convex) also of cellular construction, varied from 1.52 m to 1.83 m in diameter. A general view of this first fixed telescope is given in Figure 1. A later design which only Schwarzschild and Ritchey-Chrétien combinations are used is illustrated in Figure 2.

In these telescopes, the coelostat is far above the ground in order obtain the "*best atmospheric definition*". The coelostat and the mounting of the second large plane mirror rest upon the massive, horizontal summit of the inner building, which is of reinforced concrete. An outer building of strong steel that supports the dome, entirely separated from the inner one, acts as a protection from the wind, weather and sudden temperature changes. This outer building and dome are protected by exterior sheet-steel sun-shield and the two sheet-steels walls are separated by ample ventilation, and all are painted white.

Figure 1 shows two floors below ground level (marked Sol). In the first designs the vertical distance between floors 1 and 3 was 18 m, the vertical distance between floors 3 and 4, 26 m and the total height from floor 3 to the summit of the dome 53 m. The dome had a diameter of 32 m (fixed universal telescope of 5 m mirrors).

The second large plane mirror in the dome receives the stationary beam of light from the coelostat, and reflects it vertically downward, in the fixed vertical tube of the telescope. On the first floor three or more concave mirrors lie horizontally, face-up each with its mechanical flotation system and carriage (rolling on straight horizontal rails). These mirrors could me quickly moved into position with automatic adjustment and alignment with reference to the fixed vertical optical axis of the telescope.

[1] Ritchey's career is clearly intertwined with that of G.E. Hale in such a way that it is impossible to treat one without mentioning the other.

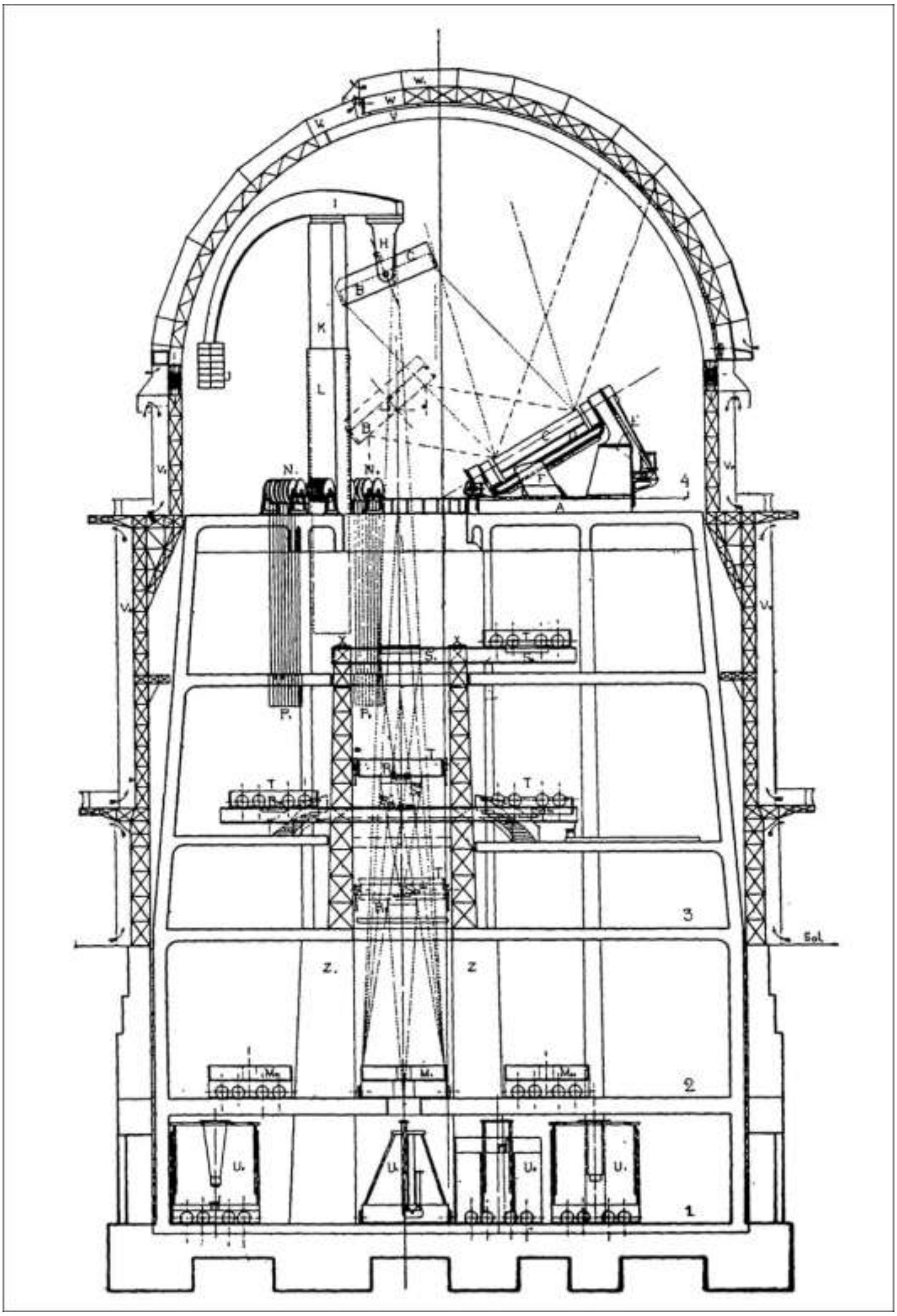

Figure 1- Ritchey's design for a fixed vertical telescope. The coelostat consisting of two large plane mirrors is at the top. The ground level is marked "Sol". A 5 m diameter primary mirror, Marked M, is in use, two others are on wheeled carriages on both sides of it. Several secondary mirrors, marked R and S may be used. Adapted from Ritchey, G.W. (1928) The modern photographic telescope and the new astronomical photography. Part I- The fixed universal telescope. *Journal of the Royal Astronomical Society of Canada*, 12 (5): 159-177.

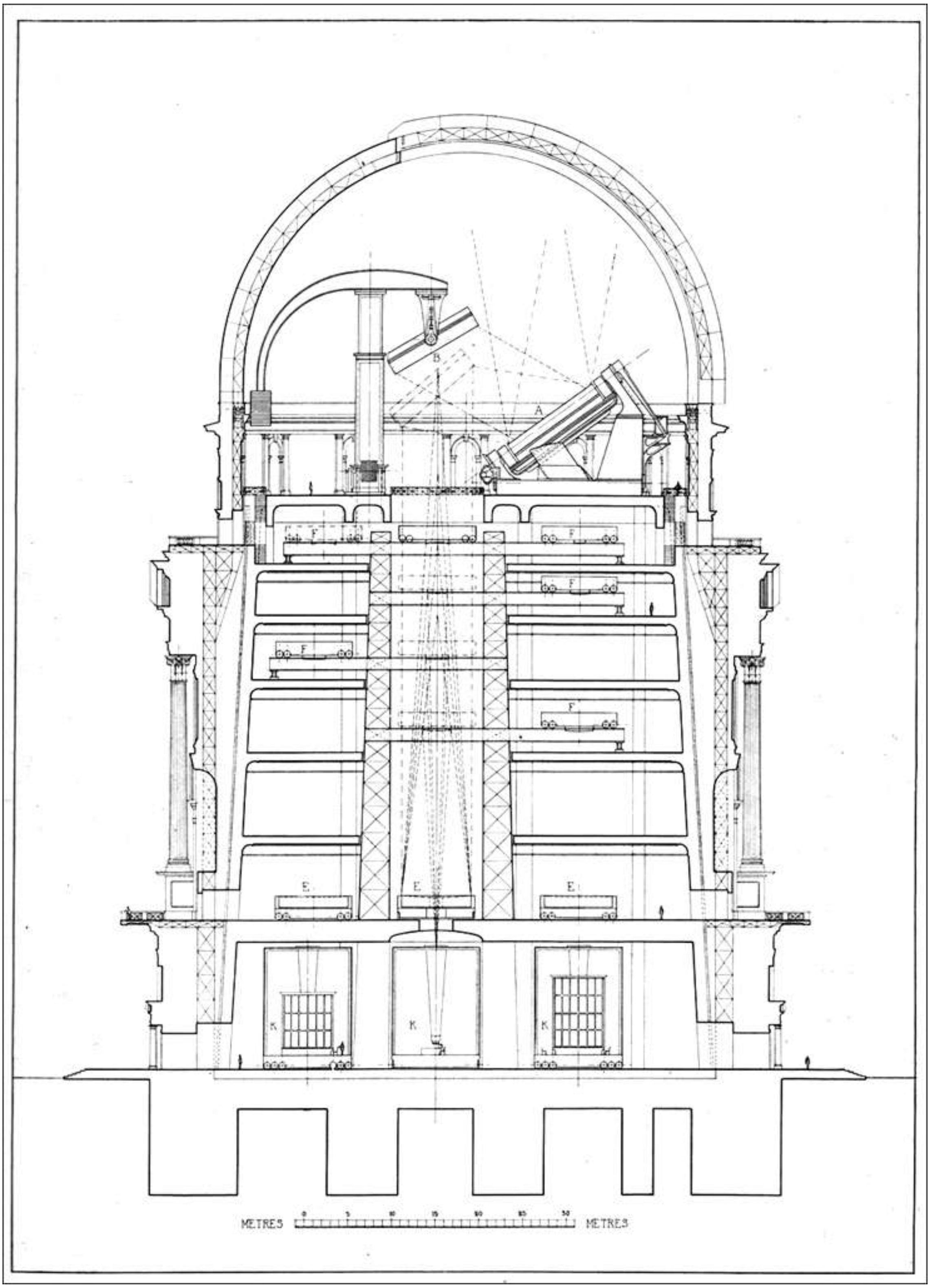

Figure 2- Ritchey's design for a 8 m fixed vertical Universal Telescope. Note the human figures that show the gigantic scale of this instrument. Adapted from Ritchey, G.W. (1929) *L'Évolution de l'Astrophotographie et les Grands Télescopes de L'Avenir*. Société astronomique de France.

In the first design the three large concave mirrors were: Newtonian (paraboloidal) and Cassegrain combinations (Schwarzschild and Ritchey-Chrétien). The secondary mirrors were also supported by a flotation system and roll into position with automatic adjustment and alignment. The accessory instruments (spectrographs, bolometers, radiometers, interferometers, photographic apparatus…) could be rolled smoothly, on straight horizontal rails, into position. Whatever the size of the telescope, the interchange from any combination to another could be accomplished in a few minutes.

The square tube of the fixed telescope consisted of four strong steel vertical square columns. The combinations and focal ratios planned for the mirrors included: (i) one Schwarzschild type with one large concave mirror and a small concave mirror, giving a very large field and a small focal ratio (*f/*3); (b) one Newtonian with a paraboloidal mirror (*f/*6); one Ritchey-Chrétien with one large concave and small convex mirrors (*f/*6.8); one low power Cassegrain combination (*f/*12) and one high power Cassegrain combination (*f/*30).

All these plans were made by Ritchey while working at the Mount Wilson observatory (1910-1924). During the period of 1924-1828 Ritchey develops new designs for the fixed telescope in the optical shop of the Paris observatory in co-operation with Henri Chrétien.

Ritchey did not publish his plan for a fixed universal telescope until 1927. He claimed that he had been working on these designs since 1919, the year G.E. Hale fired him from the Mount Wilson Observatory.

In these new plans, without changing the general design or the mechanical arrangements of the universal type, the Newtonian and Cassegrain combinations were omitted in favor of the Schwarzschild and Ritchey-Chrétien designs. These included five combinations and focal ratios instead of the six described above. Four large concave primary mirrors and five small secondary mirrors were described:

(i) Schwarzschild (*f*/2.75);
(ii) Schwarzschild (*f*/4);
(iii) Ritchey-Chrétien (*f*/6.8);
(iv) Ritchey-Chrétien (*f*/12);
(v) Ritchey-Chrétien (*f*/20).

Ritchey mentioned the advantages of the fixed universal telescope as follows:

A- Convenience, comfort and safety for the observers;
B- Ease of use of accessories (photographic, spectrographic…);
C- Every known configuration of reflecting telescopes can be used;
D- In long-exposure photography (direct and spectrographic) all mirrors in use (with the exception of the coelostat plane mirror) are stationary throughout the exposure;
E- The coelostat rotates only one-half as fast as that of an equatorial telescope;

A few drawbacks/limitations were also identified:

A- Large plane mirrors are subject to deviations from optical flatness as a result of temperature change (the use of cellular mirrors can be a solution to this problem);
B- All fixed type of telescopes are subject to additional loss of light by reflection from one to two large mirrors;

C- The fixed telescope is not adapted for the observation of the whole sky. If a declination of 30º is considered, the telescope can be used without serious loss of light through a range of about 40º (from 12ºN to 52ºN)[2].
D- Difficulties in interchanging mirrors and accessory equipment.

Ritchey planed to install three fixed universal telescopes at different latitudes in order to cover the whole sky (33ºN, 0º and 33ºS) each working at no farther than seventeen degrees from the zenith and covering about 78% of the whole sky (from 50ºN to 50ºS).

The advantage of using these combinations of telescopes is stressed by Ritchey based on his own experience while working at the Mount Wilson observatory.

"*Let us assume that immediately after dark, atmospheric definition is at 5 on a scale of 10 (on a scale o 1 to 10: 1 to 2 being very bad; between 2 and 3 being usable only with the smallest focal ratio of 2.75 to 1; 5 being moderately good and 10 being the most perfect ever seen), the observer therefore changes to the combination best adapted for moderate seeing, that is a medium focal length of 6.8 to 1, a medium magnifying power for a very fine climate. He begins a long-exposure photograph of a spiral nebula with this combination, and continues it for two hours, when he notices that the wind is gradually increasing and the definition gradually falling. When, in another half-hour, definition has gone down to 4, which is his low limit for this focal ratio, his assistant change the mirrors to a different combination (focal ratio of 4. He puts away in a dark drawer the plate-holder and its guiding eyepieces used for the photograph begun earlier, and he continues with a this combination a long exposure photograph of a very faint, extended nebula which he had begun on the preceding night. Definition continues between 3 and 4 until midnight; if it had fallen as low as 3 he would have changed to the lowest-power combination. At midnight he has secured the full time of exposure desired for this photograph. Since definition continues the same he starts another long-exposure photograph of another faint extended nebula. At one o'clock he notices a decrease in the wind, and a very marked improvement in definition, so marked that he goes out on the balcony of the dome, expecting to see a low fog forming in the valleys around and below the observatory. He finds that this is so, and he returns to the telescope and to work, to see whether definition continues to improve rapidly, or goes downward again. Within half an hour definition goes gradually up tp 7, as the wind dies down to a dead calm. He knows that with this calm, and with this low fog he may expect extraordinary definition (seeing), perhaps as high as 8 or 9. He cannot afford to waste such precious conditions on low power work, and he does not need to do so, because he has a quickly interchangeable telescope. He takes a chance, and changes to the highest-power combination, with a focal ratio of 20, and to the photographic accessory instrument for planetary photography with very high powers. He is not taking a serious chance, because he can change back to another combination, if necessary, in four minutes. Definition improves to 9 and to 9.5. It is his great, long awaited opportunity, the one supreme hour of a thousand! He and his assistants work quickly, skillfully, smoothly, in photographing very bright planetary nebulae and planets with magnifying powers of many thousand diameters. Every known invention for their convenience, comfort, facility and speed in their strenuous work of guiding, occulting, re-focusing, with extremely high magnifying powers, is provided and at hand, in the stationary, constant-temperature laboratory containing this high-power photographic apparatus. All of the extreme speed and skill, like those of the virtuoso, which they have acquired by long training with the double-slide practice-machine, stand them in good stead now, and enable them to photograph smaller details and more delicate contrasts of shading and color that any eye can detect visually with the same aperture. But without the quickly*

[2] Ritchey mentions that most of the long exposure astrophotography with large apertures should be only attempted at a maximum distance of fifteen to twenty degrees from the zenith.

interchangeable telescope the nearly perfect atmospheric conditions, which occur so rarely, and which continue for so short a time, could not have been taken full advantage of, unless, indeed, a complete, separate telescope, fitted for photographic work with the highest powers, had been kept always ready and waiting for such conditions".

In 1928, Ritchey revealed his plan to build a large fixed telescope at the edge of the Grand Canyon in Arizona (Figure 3) and the following year he finally published his book "*The Development of Astro-photography and the Great Telescopes of the Future*". This relatively short book includes many illustrations in large format was written in English and French. The book summarizes Ritchey's work and his own ideas related to the building of large reflectors. It includes the best astrophotographs taken by Ritchey with the 24-inch refractor and 24-inch reflector of the Yerkes Observatory and with the 60-inche reflector of the Mount Wilson Observatory. He also conveys the evidence that spiral nebulae are galaxies, a concept he advanced in 1917 based on the observation of several novae. In this book Ritchey proposed plans for 8 m fixed telescope (Figure 2) and a 6 m equatorial fork mounted reflector (Figure 4). He also proposed building a chain of five fixed vertical observatories at several latitudes (0º, 16ºN and 16ºS, 36ºN and 36ºS).

Figure 3- Ritchey's drawing of a fixed vertical telescope at the edge of the Grand Canyon.

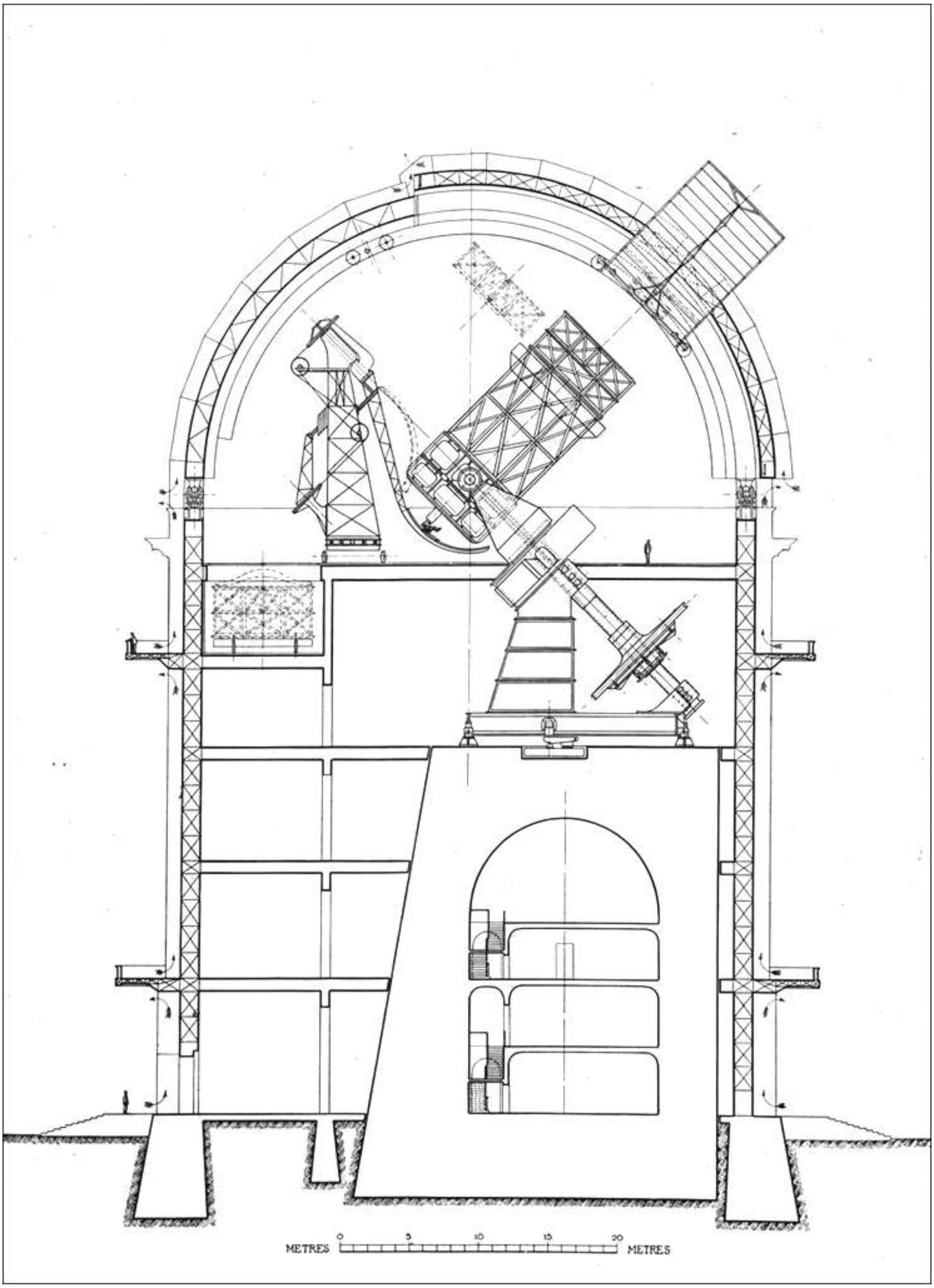

Figure 4- Ritchey's design of a 6 m equatorially mounted Ritchey-Chrétien telescope. An observer was drawn at the curved movable arm behind the primary mirror. Note the size of the human figures on the floor and ground.

Ritchey's ideas were far ahead of his time. The fixed vertical telescopes were never built. Ritchey was an outstanding craftsman; he developed and perfected the methods for making large reflector telescope mirrors that were the best at the beginning of the twentieth century.

His outstanding astronomical photographs received lots of attention. The Ritchey-Chrétien design, cellular mirrors, thermal control of telescope mirrors, mountings and domes, rapid changes of telescope configurations to take advantage of the best seeing conditions never achieved success during his life time. The fixed vertical telescope is another example of Ritchey's prophetic views that never achieved any recognition from his peers, at least to date.

Figure 5- M51. 60-inch telescope, 10h 45m exposure (April 7 and 8, 1910). G.W. Ritchey.

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