ASTRONOMICAL INSTRUMENTS

The Telescope.

The instruments used in modern astronomy are amongst the finest triumphs of mechanical skill in the world. In a great modern observatory the different instruments are to be counted by the score, but there are two which stand out pre-eminent as the fundamental instruments of modern astronomy. These instruments are the telescope and the spectroscope, and without them astronomy, as we know it, could not exist.

There is still some dispute as to where and when the first telescope was constructed; as an astronomical instrument, however, it dates from the time of the great Italian scientist, Galileo, who, with a very small and imperfect telescope of his own invention, first observed the spots on the sun, the mountains of the moon, and the chief four satellites of Jupiter. A good pair of modern binoculars is superior to this early instrument of Galileo's, and the history of telescope construction, from that primitive instrument to the modern giant recently erected on Mount Wilson, California, is an exciting chapter in human progress. But the early instruments have only an historic interest: the era of modern telescopes begins in the nineteenth century.

During the last century telescope construction underwent an unprecedented development. An immense amount of interest was taken in the construction of large telescopes, and the different countries of the world entered on an exciting race to produce the most powerful possible instruments. Besides this rivalry of different countries there was a rivalry of methods. The telescope developed along two different lines, and each of these two types has its partisans at the present day. These types are known as *refractors* and *reflectors*, and it is necessary to mention, briefly, the principles employed in each. The *refractor* is the ordinary, familiar type of telescope. It consists, essentially, of a large lens at one end of a tube, and a small lens, called the eye-piece, at the other. The function of the large lens is to act as a sort of gigantic eye. It collects a large amount of light, an amount proportional to its size, and brings this light to a focus within the tube of the telescope. It thus produces a small but bright image, and the eye-piece magnifies this image. In the *reflector*, instead of a large lens at the top of the tube, a large mirror is placed at the bottom. This mirror is so shaped as to reflect the light that falls on it to a focus, whence the light is again led to an eye-piece. Thus the refractor and the reflector differ chiefly in their manner of gathering light. The powerfulness of the telescope depends on the size of the light-gatherer. A telescope with a lens four inches in diameter is four times as powerful as one with a lens two inches in diameter, for the amount of light gathered obviously depends on the *area* of the lens, and the area varies as the *square* of the diameter.

The largest telescopes at present in existence are *reflectors*. It is much easier to construct a very large mirror than to construct a very large lens; it is also cheaper. A mirror is more likely to get out of order than is a lens, however, and any irregularity in the shape of a mirror produces a greater distorting effect than in a lens. A refractor is also more convenient to handle than is a reflector. For these reasons great refractors are still made, but the largest of them, the great Yerkes' refractor, is much smaller than the greatest reflector, the one on Mount Wilson, California. The lens of the Yerkes' refractor measures three feet four inches in diameter, whereas the Mount Wilson reflector has a diameter of no less than eight feet four inches.

But there is a device whereby the power of these giant instruments, great as it is, can be still further heightened. That device is the simple one of allowing the photographic plate to take the place of the human eye. Nowadays an astronomer seldom spends the night with his eye glued to the great telescope. He puts a photographic plate there. The photographic plate has this advantage over the eye,

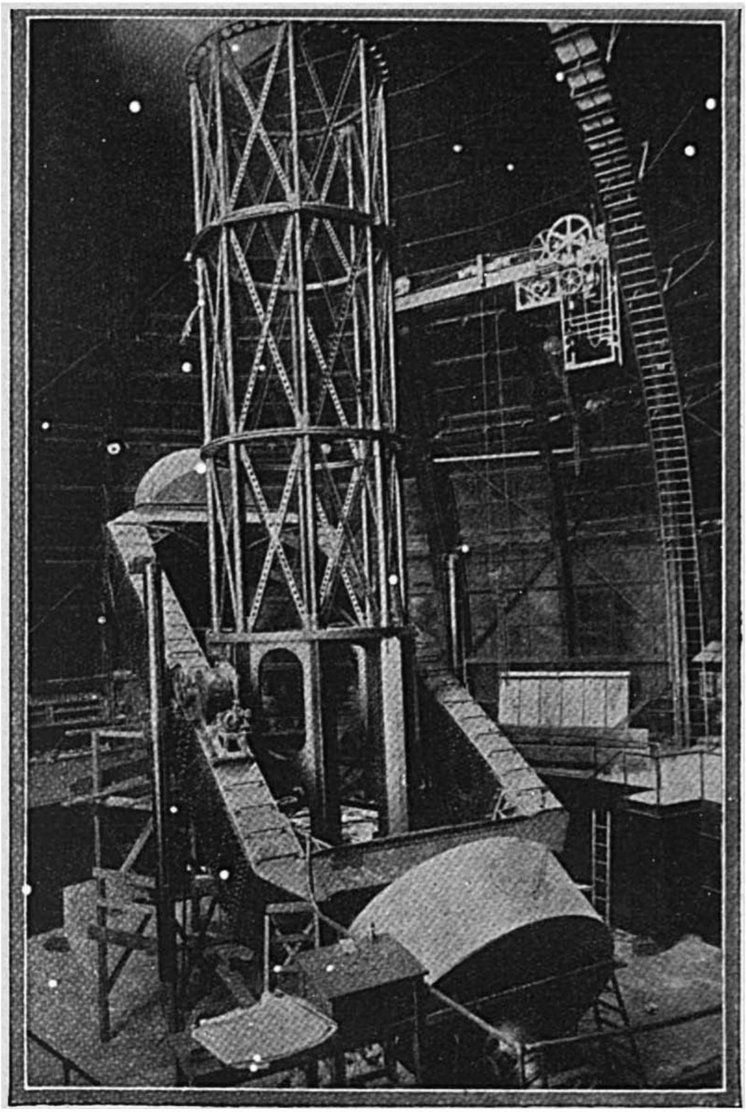


Photo: H. J. Shepstone.

100-INCH TELESCOPE, MOUNT WILSON.

A reflecting telescope: the largest in the world. The mirror is situated at the base of the telescope.

that it builds up impressions. However long we stare at an object too faint to be seen, we shall never see it. With the photographic plate, however, faint impressions go on accumulating. As hour after hour passes, the star which was too faint to make a perceptible impression on the plate goes on affecting it until finally it makes an impression which can be made visible. In this way the photographic plate reveals to us phenomena in the heavens which cannot be seen even through the most powerful telescopes.

Telescopes of the kind we have been discussing, telescopes for exploring the heavens, are mounted *equatorially*; that is to say, they are mounted on an inclined pillar parallel to the axis of the earth so that, by rotating round this pillar, the telescope is enabled to follow the apparent motion of a star due to the rotation of the earth. This motion is effected by clock-work, so that, once adjusted on a star, and the clock-work started, the telescope remains adjusted on that star for any length of time that is desired. But a great official observatory, such as Greenwich Observatory or the Observatory at Paris, also has *transit* instruments, or telescopes smaller than the equatorials and without the same facility of movement, but which, by a number of exquisite refinements, are more adapted to accurate measurements. It is these instruments which are chiefly used in the compilation of the *Nautical Almanac.* They do not follow the apparent motions of the stars. Stars are allowed to drift across the field of vision, and as each star crosses a small group of parallel wires in the eye-piece its precise time of passage is recorded. Owing to their relative fixity of position these instruments can be constructed to record the *positions* of stars with much greater accuracy than is possible to the more general and flexible mounting of equatorials. The recording of transits is comparatively dry work; the spectacular element is entirely absent; stars are treated merely as mathematical points. But these observations furnish the very basis of modern mathematical astronomy, and without them such publications as the *Nautical Almanac* and the *Connaissance du Temps* would be robbed of the greater part of their importance.

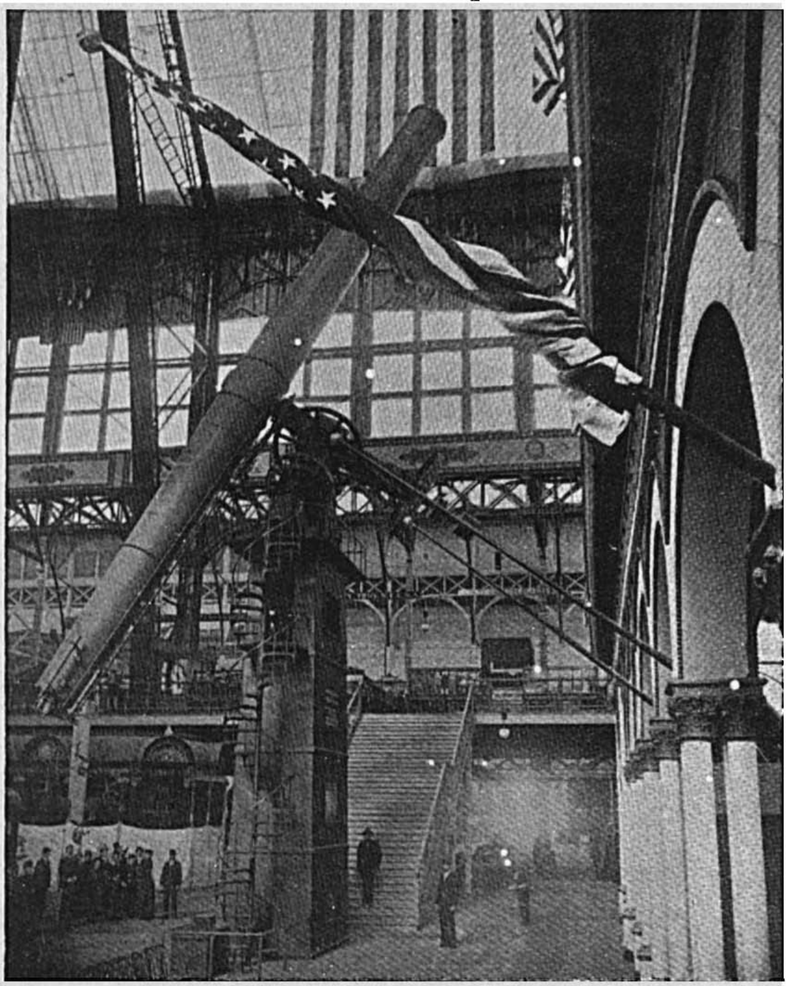


Photo: H. J. Shepstone.

40-INCH YERKES TELESCOPE.

Showing the dimensions of the greatest refractor in the world. The floor of the observatory rises or falls several feet according as the telescope is inclined, thus enabling the observer to remain at the eye-piece.

§ 2

We have already learnt something of the principles of the spectroscope, the instrument which, by making it possible to learn the actual constitution of the stars, has added a vast new domain to astronomy. In the simplest form of this instrument the analysing portion consists of a single prism. Unless the prism is very large, however, only a small degree of dispersion is obtained. It is obviously desirable, for accurate analytical work, that the dispersion—that is, the separation of the different parts of the spectrum—should be as great as possible. The dispersion can be increased by using a large number of prisms, the light emerging from the first prism, entering the second, and so on. In this way each prism produces its own dispersive effect and, when a number of prisms is employed, the final dispersion is considerable. A considerable amount of light is absorbed in this way, however, so that unless our primary source of light is very strong, the final spectrum will be very feeble and hard to decipher.

The Spectroscope.

Another way of obtaining considerable dispersion is by using a *diffraction grating* instead of a prism. This consists essentially of a piece of glass on which lines are ruled by a diamond point. When the lines are sufficiently close together they split up light falling on them into its constituents and produce a spectrum. The modern diffraction grating is a truly wonderful piece of work. It contains several thousands of lines to the inch, and these lines have to be spaced with the greatest accuracy. But in this instrument, again, there is a considerable loss of light.

We have said that every substance has its own distinctive spectrum, and it might be thought that, when a list of the spectra

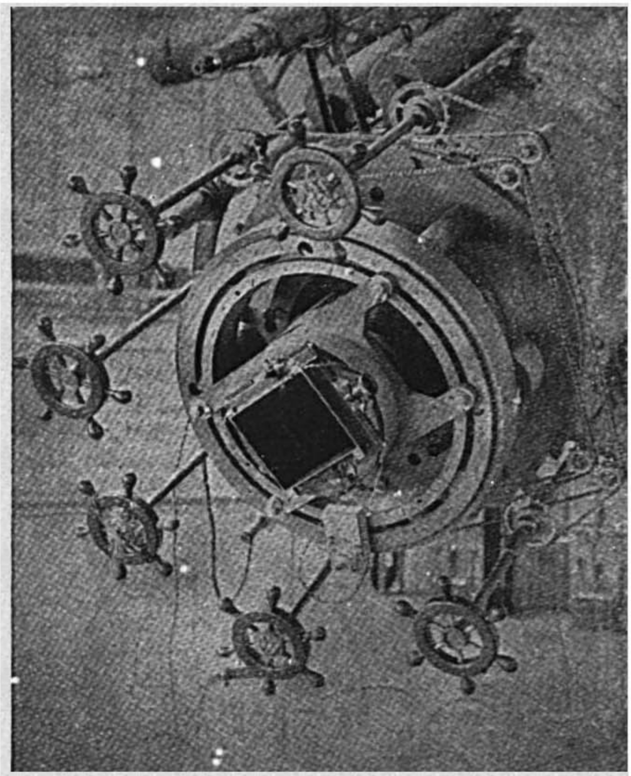
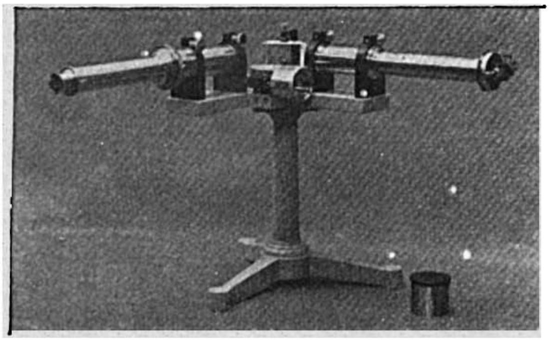


Photo: H. J. Shepstone.

THE DOUBLE-SLIDE PLATE HOLDER ON YERKES 40-INCH REFRACTING TELESCOPE.

The smaller telescope at the top of the picture acts as a "finder"; the field of view of the large telescope is so restricted that it is difficult to recognise, as it were, the part of the heavens being surveyed. The smaller telescope takes in a larger area and enables the precise object to be examined to be easily selected.

of different substances has been prepared, spectrum analysis would become perfectly straightforward. In practice, however, things are not quite so simple. The spectrum emitted by a substance is influenced by a variety of conditions. The pressure, the temperature, the state of motion of the object we are observing, all make a difference, and one of the most laborious tasks of the modern spectroscopist is to disentangle these effects from one another. Simple as it is in its broad outlines, spectroscopy is, in reality, one of the most intricate branches of modern science.



MODERN DIRECT-READING SPECTROSCOPE.

(*By A. Hilger, Ltd.*)

The light is brought through one telescope, is split up by the prism, and the resulting spectrum is observed through the other telescope.

BIBLIOGRAPHY

(The following list of books may be useful to readers wishing to pursue further the study of Astronomy.)

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BALL, *The Story of the Sun.*
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LOWELL, *Mars and Its Canals.*
NEWCOMB, *Popular Astronomy.*
NEWCOMB, *The Stars: A Study of the Universe.*
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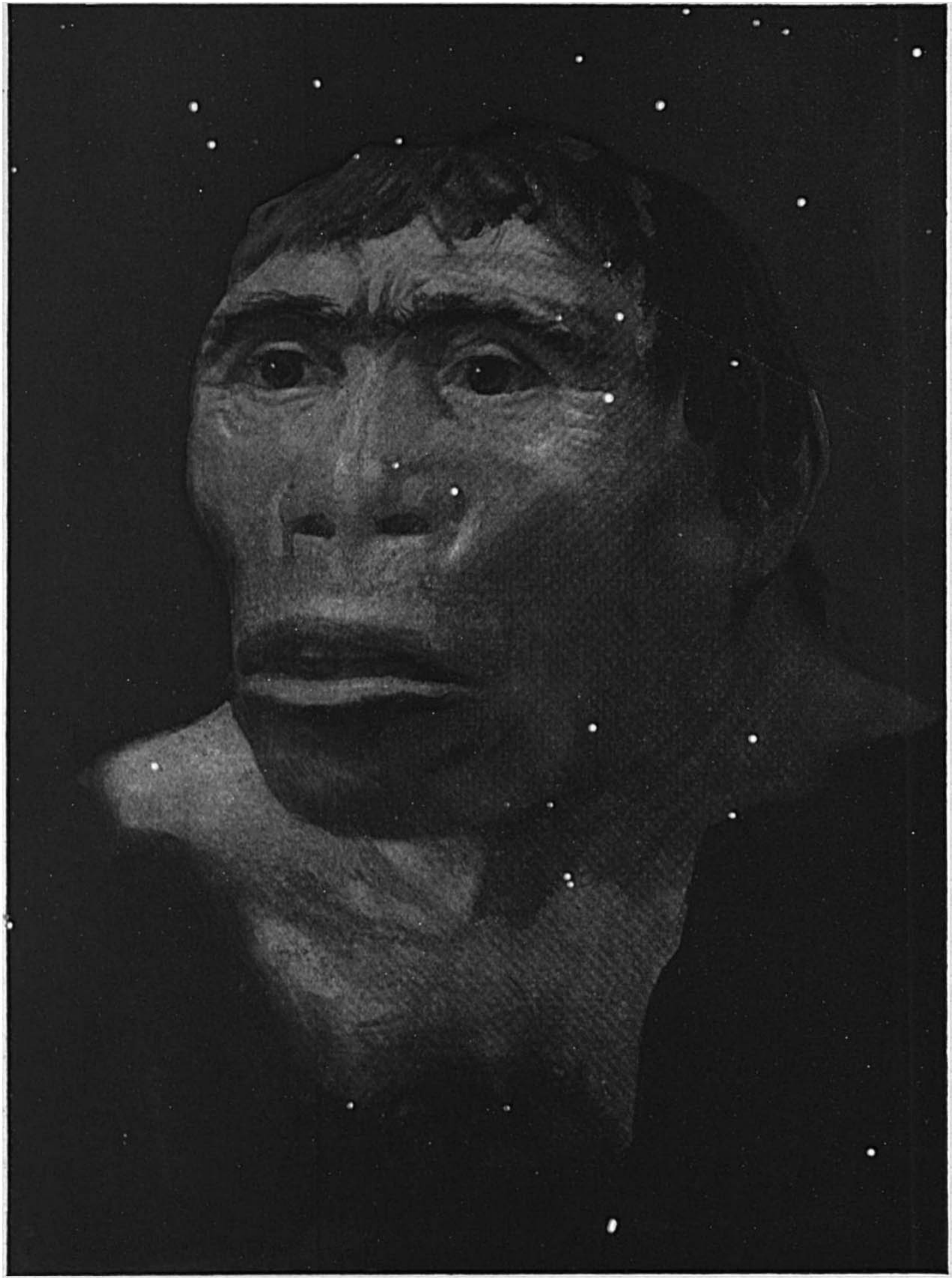

A RECONSTRUCTION OF THE JAVA MAN
(*Pithecanthropus erectus*).
See *The Ascent of Man*, p. 110.