THE NEW PARIS TRANSIT CIRCLE[1]

OF the numerous instruments with which Leverrier enriched the Paris Observatory during the twenty years of his direction, the last which he was able to see completely installed was the new transit circle. This instrument was not, like all the others, constructed at the expense of the State; an inscription on the marble pillars that support it informs the visitor that it was presented to the Observatory by the generous munificence of M. Raphaël Bischoffsheim. This is not the only gift of M. Bischoffsheim to astronomy; the Observatory of Lyons is also indebted to him for its fundamental instrument.

The project of erecting a new meridian circle at the observatory goes back to the time of the debate raised before the Academy of Sciences on the subject of the transfer of the observatory to a site outside Paris. Those who would not admit the legitimacy of the complaints made by the adversaries of the present situation of the observatory, were obliged to admit that the great meridian room, constructed in 1830 by Arago, did not offer any of the guarantees necessary to observations of great precision. The thickness of the walls and of the double roof of that room, the small breadth of the openings, the nearness of the observatory buildings, the difference of level between the two faces north and south, must necessarily affect the equilibrium of the neighbouring layers of the atmosphere and hinder them from taking that horizontality which admits of the correction of the observations from the influence of refraction.

Since the astronomer cannot get rid of this troublesome influence, his first business ought then to be to reduce it to conditions in which it may be possible to calculate the effect. Thus what strikes the visitor admitted to the new meridian circle of the Observatory is the small building in which it is placed. In the middle of a green lawn rises a hut made entirely of sheet-iron, the roof formed of two plates which, by sliding upon rollers, may be separated from each other, and leave all the upper part of the building open. The walls are formed of two envelopes of thin iron, between which the air freely circulates, thus maintaining the whole structure at the temperature of the air itself. Large windows may also be opened, and the observer and the instrument be thus placed in the same conditions as if the observations were made in the open air. All these conditions are to avoid as far as possible the disturbances arising from atmospheric refraction, the greatest source of inaccuracy in astronomical observation. The only obstacle which may yet be a hindrance to perfection in the conditions of observation is the presence of those beautiful trees which make the terrace of the observatory a magnificent garden, but which store up the warm air during the day and slowly distribute it during the night. No doubt some day the astronomers will be obliged to sacrifice to the precision of their observations the enjoyment of this beautiful foliage.

The meridian circle is composed, as its name indicates, of two instruments: the meridian telescope, intended, by its association with an astronomical clock, to fix the moment of the passage of a star across the meridian of the place of observation, and the mural circle, which gives the measure of the angular distance of this same star from the pole or the zenith. When, forty years ago, Gambey constructed the two meridian instruments of the Paris Observatory, so justly celebrated and on the model of which those of most other observatories have been designed, he had to reconcile, by prodigies of skill, the lightness resulting from the means of construction then in use, with the rigidity of the parts necessary for precision of observation. It is the alliance of these two almost contradictory qualities which renders so interesting the instruments of that celebrated artist and especially his machine for dividing the circles, which the Baron Séguier has restored in the galleries of the Conservatoire. But there resulted from this at first the necessity of separating the measure of the two co-ordinates of the stars—the instant of the meridian passage and the polar distance. There also resulted the necessity which Gambey was under to fix on his mural circle of two metres in diameter, a telescope altogether insufficient in optical power.

A simple glance at the great meridian circle of the observatory, the western equatorial, the great telescope, the new instrument of M. Bischoffsheim, all from the workshop of the great mechanician, M. Eichens, shows the revolution which has been effected in the processes of construction. In place of instruments formed of pieces of sheet brass connected by simple screws or even soldered together, we have the bodies of the telescope of cast-iron bolted on axes of cast-iron and steel, strong and elegant in appearance; circles of bronze cast in a single piece and protected against all deformation by numerous cross-bars. It is the art of the engineer applied to the construction of astronomical instruments, with the power given by the choice of metals and the thickness of pieces, and the precision which the employment of engineering tools secures.

This revolution was begun in England about 1847 by the Astronomer-Royal, Sir George Airy. In 1863, M. Leverrier successfully installed a meridian circle greater still than that of Greenwich, and intended, like it, for the observation of the small planets. But these gigantic instruments, veritable siege-guns of long range, since they reach the farthest depths of the heavens, want, simply on account of their weight, one essential quality—they are not reversible. Whatever be the rigidity of the pieces, the instrument is subject, in each successive position, to flexions necessarily unequal, which the astronomer must investigate and measure in order to correct his observations. But this investigation and this measurement can only be made by turning round the instrument. It will be understood, in fact, that the apparatus, directed successively to the same point of the sky, first with one of its faces up, then the same face below, gives, if it is really perfectly rigid but elastic, two results differing equally from the truth, one *minus* and the other *plus*, so that the mean of the two observations gives the exact position of the star. It is this which may be expected from the new meridian circle of M. Bischoffsheim. Fig. 1 represents the telescope upon its car, which serves to raise it above its pillars and to turn it right round by a movement of rotation around a vertical axis.

Since 1852 M. Brunner has constructed small portable instruments answering to these conditions. Improved by his sons, by M. Rigaud, and by M. Eichens, these meridian circles are now only used in geodesic expeditions. In 1868 M. Eichens constructed for the observatory of Lima a reversible meridian circle, the telescope of which was 2·30 m. in length, and the object-glass 20 cm. in free opening. It is this model, successively improved, which has become, in the hands of the able constructor, the meridian circle of Marseilles (1876), and the circle given by M. Bischoffsheim (1877). The object-glass of the first was made by Léon Foucault, the two others are by M. Ad. Martin. The new observatory of Lyons, in the establishment of which M. André took an active part energetically sustained by the Administration, will soon possess a similar meridian circle, a little smaller (telescope of 2 m., object-glass of 14 cm. aperture, by M. Praczmowzki), the expense of which is borne by M. Bischoffsheim.

The illustrations which we give then show the perfected model meridian circle employed in observatories for the determination of the celestial co-ordinates of the stars. To be able to understand the use of the various parts of the instrument, it will suffice to describe a complete observation of a star.

Some minutes before the passage of the star across the meridian, the astronomer gives to the telescope such

[1] From an article in *La Nature* by M. C. Wolf.

an inclination that the star, carried on by the daily movement, will cross the field of the instrument. For this purpose the interior circles fixed on the axis of the telescope carry a rough scale which may be seen by means of a pointer telescope fixed on the east wall. A clamp which clasps the edge of this circle serves to fix the instrument. The observer then places himself on the observing chair in the position indicated on Fig. 2. The star soon appears, enters the field of view on the west and proceeds towards the east side. With the star the observer sees in the field of view a network of spider threads stretched vertically and traversed by a horizontal thread. Listening to the beats of the clock, he notes the second and the fraction of a second at which the star passes under each of the vertical threads; the mean of these times is the precise moment of the passage across the middle thread. At this same moment he slightly displaces the telescope by a

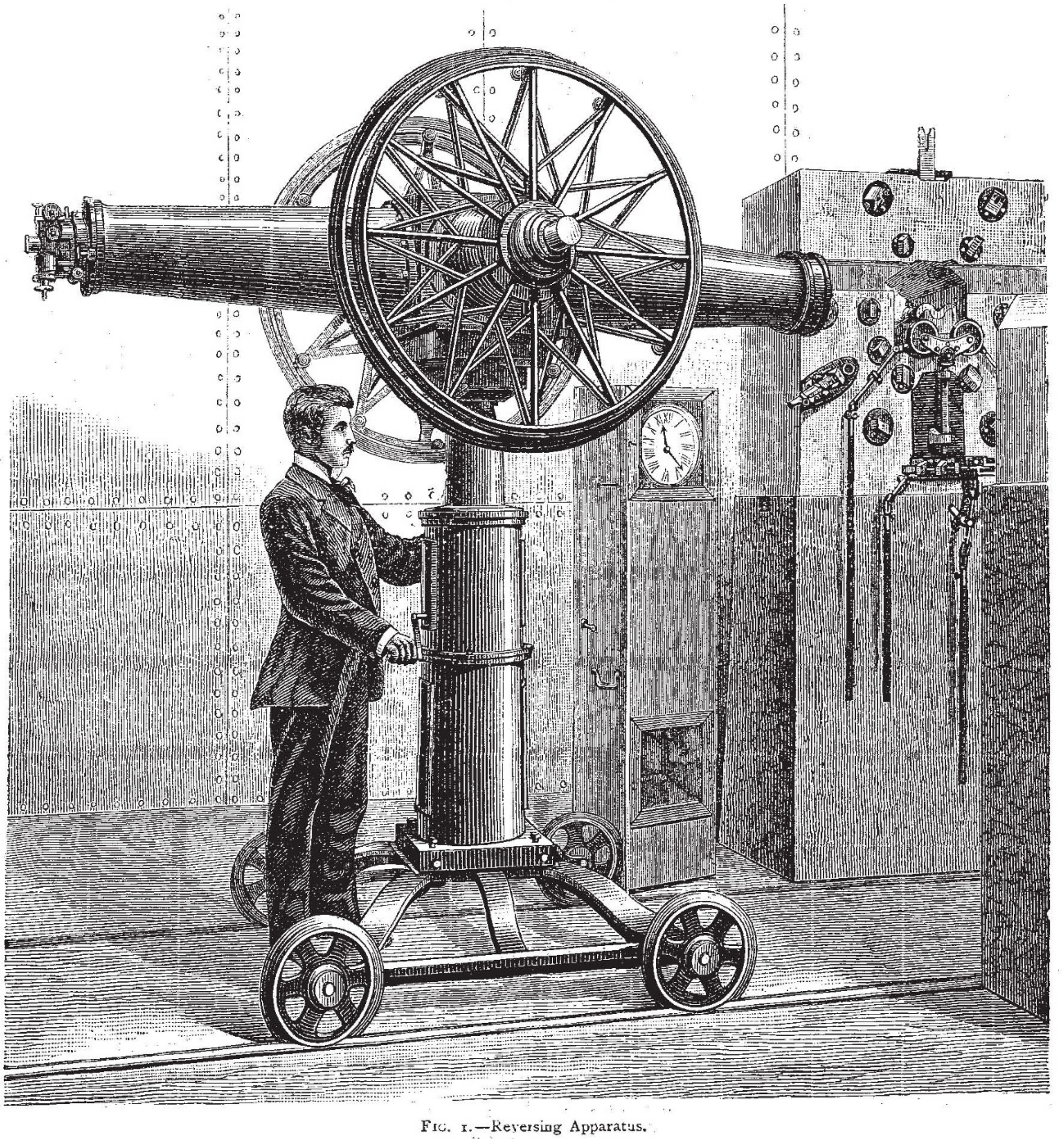

FIG. 1.—Reversing Apparatus.

movement given to the clamp and brings the star under the horizontal thread. The direction of a line determined by the crossing of this thread and the middle vertical one and the optical centre of the object-glass is that along which the star is seen at the moment of its passage across the middle thread. To fix this direction it is necessary to connect it with two points of an absolute fixity. For this purpose the telescope is provided with a circle of a metre in diameter, the limb of which is very finely and very exactly divided; this turns with the telescope in front of six microscopes permanently fixed to the east pillar. M. Eichens has adopted for these microscopes the arrangement devised by Sir George Airy for the meridian circle of Greenwich. The tube of each of these is formed by the side of a hole pierced in the block of marble which forms the upper part of the pillar; the positions of these microscopes is then permanently fixed to that of the wall,

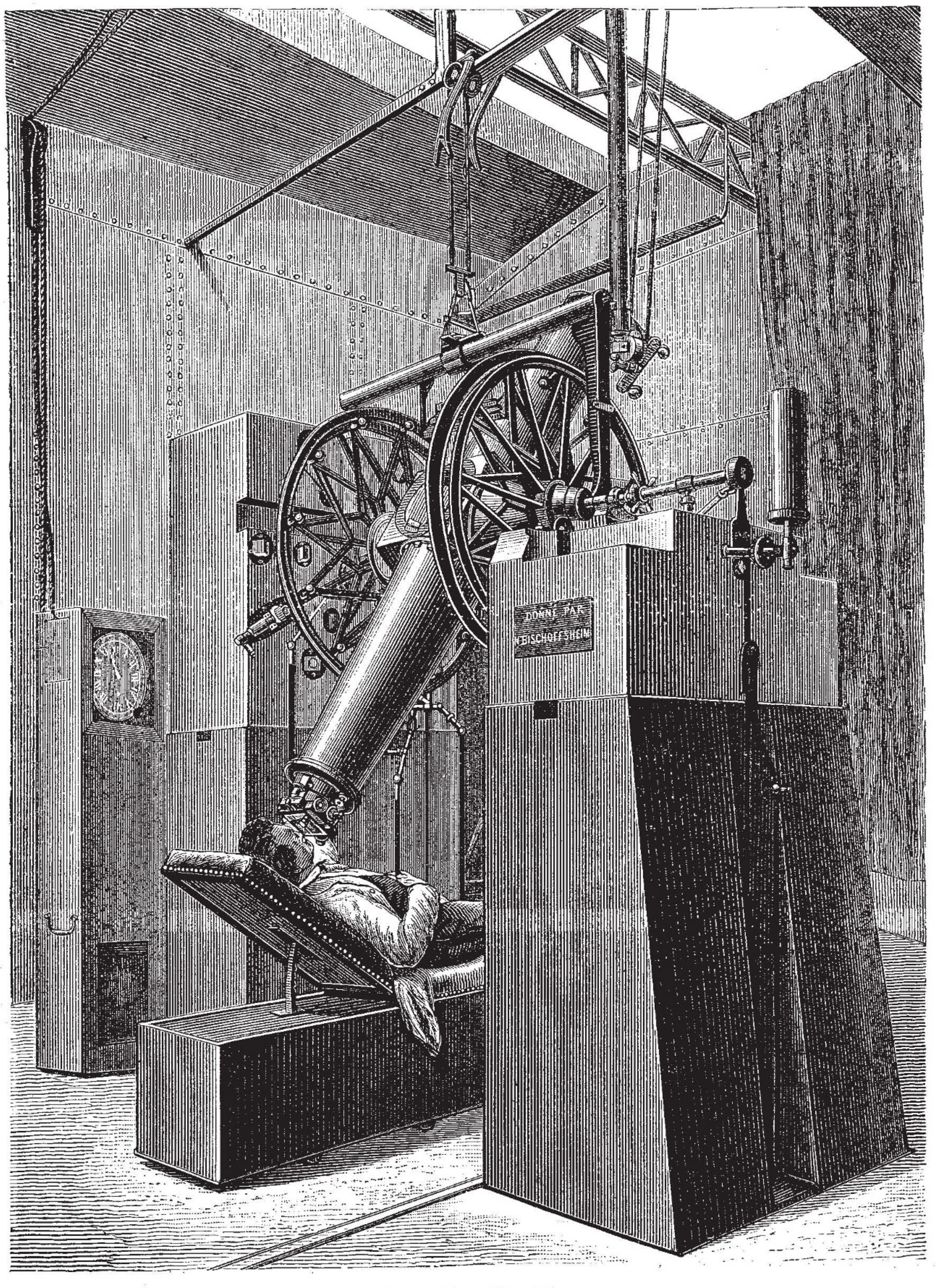

FIG. 2.—Taking an Observation

and can only change by a displacement of the wall itself. Other orifices admit to the circle the light of a lamp and enable the divisions to be read. These are drawn at every five minutes of the circle, which then bears 4,320 equidistant marks; each microscope is provided with a micrometer which enables the tenths of a second of arc to be observed.

If now, by observations of the pole star at its upper and lower transits, the observer determines in the same way the direction of the telescope looking to the pole, the angle comprised between that direction and that of the telescope directed to the star will give the polar distance of the star. If by means of a mercury bath he determines the direction of the telescope when its optical axis is vertical, he will ascertain in the same way the distance of the star from the zenith.

These observations may be made in the two positions which the telescope takes before and after being turned round. This is why it carries two cast-iron circles roughly graduated and two brass circles finely graduated on silver, which on the reversal of the instrument are substituted for each other before the pointer-telescope and the fixed microscopes. The arrangement of these circles insures a perfect symmetry to the instrument, an essential condition if we wish to prevent irregular deformations.

But these operations will only give the co-ordinates of the star if they are made with an instrument set in the meridian of the place. It is necessary then that the telescope should turn round a horizontal axis, that it should be perpendicular to that axis, and that the plane which it describes in turning should pass through the pole of the earth. A level, which the illustration represents resting by two forks upon the pivots of the telescope, but which during the observations is raised by means of a crane fixed to the ceiling, serves to measure and correct the inclination of the axis of rotation. By turning it upon a long support the perpendicularity of the optical axis on the axis of the pivots can be assured. Two supports are to be constructed, one on the north, the other on the south; the latter only has been made. Finally the astronomical observation of the pole star indicate if the last of the three conditions is fulfilled.

A word on the illumination of the system of cross wires visible in the eye-piece. During the day they stand out on the clear background of the sky; at night the same effect is obtained by means of a ray of light proceeding from a gas-lamp fixed on the west pillar, the rays of which are sent towards the eye-piece by a small prism fixed in the middle of the telescope. A screen with a variable opening, or cat's-eye, permits the intensity of the light to be proportioned to the brightness of the star observed. Finally, for very weak stars a very simple mechanical arrangement suppresses all light in the field, and brings it to bear on the wires, which appear as luminous lines on a background absolutely dark.

The long illness of M. Leverrier did not permit him to push on, so actively as he would have wished, the preliminary investigations of this beautiful instrument, among which we must mention one, long and difficult —the divisions of the two circles. It will, without doubt, be facilitated by this circumstance, that, traced by means of the dividing machine constructed by M. Eichens, the lines present a regularity and a finish altogether favourable to precision.

The astronomers of the observatory will hold it a point of honour to take advantage as soon as possible of the magnificent apparatus which they owe to the generosity of M. Bischoffsheim.

FETICHISM IN ANIMALS

MR. HERBERT SPENCER, in his recently published work on the "Principles of Sociology," treats of the above subject. He says: "I believe M. Comte expressed the opinion that fetichistic conceptions are formed by the higher animals. Holding, as I have given reasons for doing, that fetichism is not original but derived, I cannot, of course, coincide in this view. Nevertheless, I think the behaviour of intelligent animals elucidates the genesis of it. I have myself witnessed, in dogs, two illustrative cases." One of these cases consisted in a large dog, which, while playing with a stick, accidentally thrust one end of it against his palate, when, "giving a yelp, he dropped the stick, rushed to a distance from it, and betrayed a consternation which was particularly laughable in so ferocious-looking a creature. Only after cautious approaches and much hesitation was he induced again to lay hold of the stick. This behaviour showed very clearly the fact that the stick, while displaying none but the properties he was familiar with, was not regarded by him as an active agent, but that when it suddenly inflicted a pain in a way never before experienced from an inanimate object, he was led for the moment to class it with animate objects, and to regard it as capable of again doing him injury. Similarly in the mind of the primitive man, knowing scarcely more of natural causation than a dog, the anomalous behaviour of an object previously classed as inanimate, suggests animation. The idea of voluntary action is made nascent; and there arises a tendency to regard the object with alarm, lest it should act in some other unexpected and perhaps mischievous way. The vague notion of animation thus aroused will obviously become a more definite notion, as fast as development of the ghost-theory furnishes a specific agency to which the anomalous behaviour can be ascribed."

The other case observed by Mr. Spencer was that of an intelligent retriever. Being by her duties as a retriever led to associate the fetching of game with the pleasure of the person to whom she brought it, this had become in her mind an act of propitiation; and so, "after wagging her tail and grinning, she would perform this act of propitiation as nearly as practicable in the absence of a dead bird. Seeking about, she would pick up a dead leaf or other small object, and would bring it with renewed manifestations of friendliness. Some kindred state of mind it is which, I believe, prompts the savage to certain fetichistic observances of an anomalous kind."

These observations remind me of several experiments which I made some years ago on this subject, and which are perhaps worth publishing. I was led to make the experiments by reading the instance given in the "Descent of Man," of the large dog which Mr. Darwin observed to bark at a parasol as it was moved along a lawn by the wind—so presenting the appearance of animation. The dog on which I experimented was a Skye terrier—a remarkably intelligent animal, whose psychological faculties have already formed the subject of several communications to this and other periodicals.[1] As all my experiments yielded the same results I will only mention one. The terrier in question, like many other dogs, used to play with dry bones by tossing them in the air, throwing them to a distance, and generally giving them the appearance of animation, in order to give himself the ideal pleasure of worrying them. On one occasion, therefore, I tied a long and fine thread to a dry bone and gave him the latter to play with. After he had tossed it about for a short time I took an opportunity when it had fallen at a distance from him and while he was following it up, of gently drawing it away from him by means of the long and invisible thread. Instantly his whole demeanour changed. The bone which he had previously pretended to be alive now began to look as if it really were alive, and his astonishment knew no bounds. He first approached it with nervous caution, as Mr. Spencer describes, but as the slow receding motion continued, and

[1] See especially an article on "Conscience in Animals," in *Quarterly Journal of Science* for April, 1876.