Illustrated Interviews.

No. L.—SIR HOWARD GRUBB, F.R.S., F.R.A.S., Etc., Etc.

By William G. FitzGerald.

THE poverty of Ireland is such, that superficial observers are apt to wonder whether any good thing can really come out of that distressful country. However this may be, visitors to Dublin are at least certain of finding whole-hearted, joyous hospitality on every hand—and big telescopes on the Rathmines road. For it is here that Sir Howard Grubb has his extensive astronomical works, wherein nearly all the giant telescopes of the Old World have been built.

It is impossible to speak of these things, knowing the facts, without being impressed by the romance and mysticism that surround them—just as certain heavenly bodies are themselves encircled by indefinable halos. How many ecstatic hours does the astronomer spend at the "eye-end," high up on his scaffold-like observing chair, communing with other worlds during the darkest hours of the night? No wonder, then, that the making of colossal "equatorials" should be replete with wondrous incident, and the details of their history almost beyond belief.

At an early age Sir Howard Grubb's father, the late Mr. Thomas Grubb, F.R.S., manifested a decided leaning towards mechanics, and about the year 1840 he became engineer-in-chief to the Bank of Ireland. "Years before this," remarked Sir Howard to me, "he had taken up optics as a hobby, and had actually constructed a small observatory, with a nine-inch reflecting telescope."

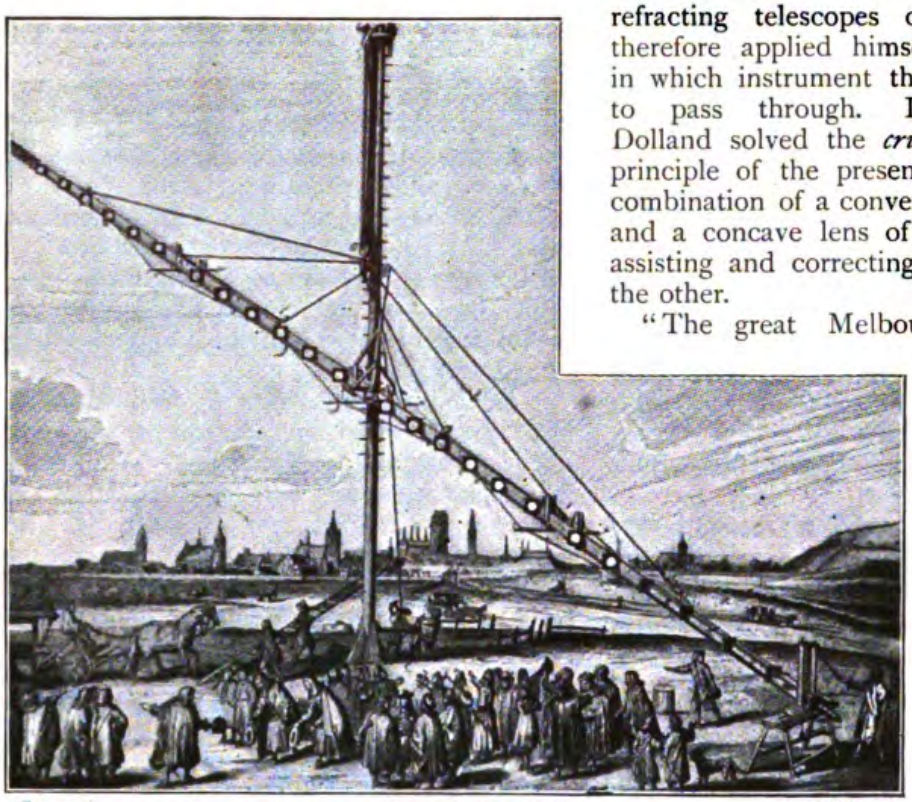
The interesting subject of this interview was born in Leinster Square, Dublin, in 1844, and is, of course, a Trinity man. His father gave him the choice of entering the Royal Engineers or pursuing optical work; he chose the latter.

Now, I must endeavour to avoid dry, technical details, wearisome enough at any time, but peculiarly out of place here. Well, then, it seems there are two distinct kinds of telescopes—refractors and reflectors. In the first of these you look *through* a convex lens at a star, while in the latter you don't look through anything; you merely behold the reflection of the image in a concave mirror. In both telescopes the image of the distant object is viewed through an eye-piece, or magnifying lens. Now, that's plain enough so far, isn't it? Reflectors are far less costly than refractors. An object-glass 18in. in diameter is perhaps worth £1,000; a mirror of the same size costs £100.

SIR HOWARD GRUBB, F.R.S., IN TRINITY COLLEGE ROBES.
From a Photo. by Werner & Son, Dublin.

"The first refractors," said Sir Howard, "those of the seventeenth century, were very imperfect."

They were. No matter what heavenly body was regarded through them, it appeared "all 'ighly coloured." This was owing to the use of a simple lens, which permitted the different rays that make up white light to



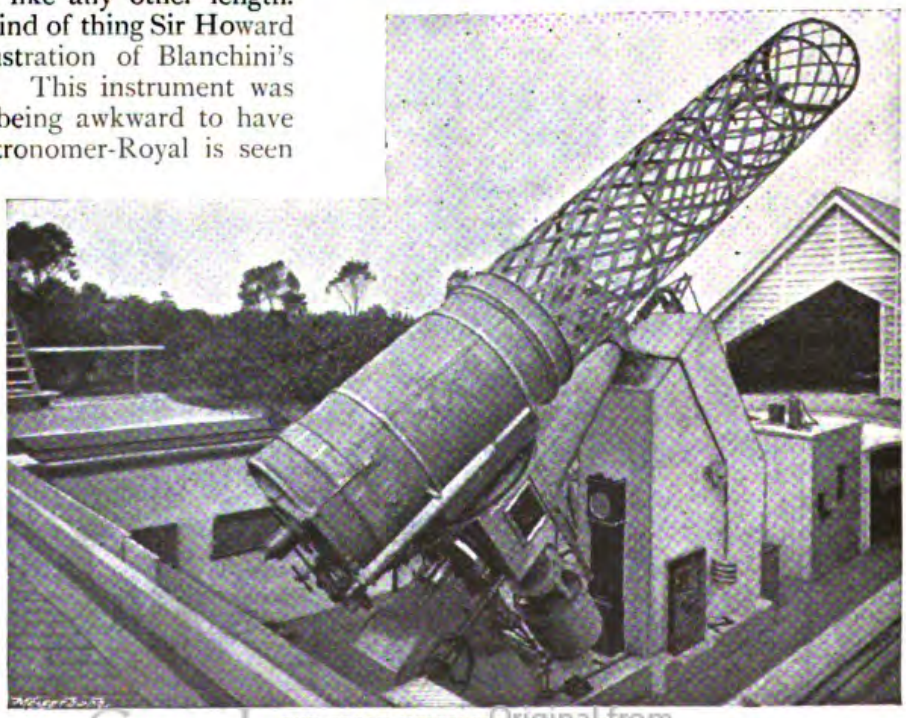
From an] THE BLANCHINI TELESCOPE. *[Old Print.*

have their own way, thereby inducing "chromatic aberration" in the telescope—and mental aberration in the infuriated astronomer.

The only way out of this difficulty was to make the instrument of enormous focal length; which is just like any other length. But you will see the kind of thing Sir Howard means from the illustration of Blanchini's telescope here shown. This instrument was kept in the open air, being awkward to have in a house. The Astronomer-Royal is seen receiving the King, while his assistants manipulate the enormous telescope — which, by the way, was between 200ft. and 300ft. long. The man on top of the pole suggests the bear-pit at the Zoo, but doubtless he had his heart in the work.

Sir Isaac Newton seems to have given up all hope of curing the chromatic aberration that afflicted the refracting telescopes of his day, and he therefore applied himself to the reflector, in which instrument the light has no glass to pass through. In 1758, however, Dolland solved the *crux* by inventing the principle of the present "object-glass"—a combination of a convex lens of crown glass and a concave lens of flint glass, the one assisting and correcting the performance of the other.

"The great Melbourne reflector," Sir Howard said, "may be considered the first big telescope I had to do with; that was in 1866. The order really came through our own Royal Society, who were consulted by the University of Melbourne when the construction of the instrument was resolved upon." This telescope is next shown; it is still considered a very fine reflector, the mirror being 4ft. in diameter, and the total length 35ft. "During its construction," remarked my delightful host, "the works were placed under my own superintendence, my father being pretty fully occupied at the



THE GREAT MELBOURNE REFLECTOR.
From a Photograph.

Bank of Ireland. Moreover, this Melbourne telescope practically brought our optical works into being; for the moment the order was given, my father bought a piece of ground at Rathmines and erected temporary workshops, machinery, and furnaces, suitable for casting the 4ft. speculum mirror. The Melbourne telescope took two years to make, and cost about £4,600.

"First of all," pursued Sir Howard, "we bought two tons of fine copper and one of tin. When this metal was mixed, the two small furnaces were removed, and a very large one built, capable of containing a cast-iron pot weighing one and a half tons and holding two tons of metal.

"The first actual casting took place on the 3rd July, 1866, but for three weeks previously the annealing oven had to be kept fired night and day with a mixture of coke and compressed peat. At last the whole mass of brickwork, and 12 tons of sand on top, were well heated, so we lifted the great pot by its crane and placed it in position on its cast-iron cushion. The furnace was then loosely filled with turf, and lit at the top at 1 p.m.

"Everything went on grandly till evening, and we thought to put the first charge in the pot at three o'clock the following morning. Knowing that next day would be a little trying, I went to bed early, leaving word that I was to be called at 3 a.m. At 12.30 a messenger rushed into the house with the cheerful news that the works were in flames; the almost red-hot chimney had set fire to the roof. I rose quicker than usual, and was presently playing on the blazing timbers with a garden-hose. This was no good, so I just sawed away the beams from around the shaft, and then let the roof flare away. I felt like Nero, rather; only more so, considering the outlook for our big mirror.

"After this we charged the pot with the first 2cwt. of metal, which behaved well; but at ten o'clock the same morning, trouble began. The chimney's roar decreased, and the furnace became dull, as though tired of the whole business already. No wonder; it was fairly choked with the ashes of that awful peat we used. We had to begin stoking, only it was killing work. You see, we had to get on top of the furnace and the molten metal to do it. We all took spells, and when each man gave up, he dashed out, panting, into the open air. Then the metal began to solidify, and things looked desperate. We expected to be ready to pour at 5 or 6 p.m., and had therefore asked a few scientific friends round to see the operation; so you can imagine how we were placed. The heat had to be got up somehow, so we resolved to make the chimney higher. There were lots of bricks about, and in twenty minutes the shaft had grown 6ft.—no easy job, I can tell you, with a great flame mounting high into the air out of it.

"At this point the men grew listless and exhausted, so my father and I set to work ourselves, with the best results. We mixed coke with the peat and the furnace revived; so did the men. At 11 p.m. all was ready for pouring; but so excited were the men by this time that we had to call them into another room and warn them about the serious and dangerous operation they were about to conduct.

"The bed of hoop was placed in position by the crane, and the ring of loam put round it. The pot stirrups were placed on the crane, and every man was at his place. I leaped on to the annealing oven and ordered the furnace cover to be removed. Great flames instantly leaped from the furnace. The four men at the crane hauled on, and out came the mighty red-hot pot, with its mass of molten metal; the cushion came too—stuck to the bottom. I skimmed the pot myself; but here I want to give you a notion of the awful, withering heat of the place. The room was small. Besides the monstrous red-hot pot and its glowing contents, there were the melting furnace, the open furnace for heating the hoop bed, and, lastly, the fifty tons of red-hot brickwork that formed the annealing oven. I'm a strong man, but the moment I *did* reach the open air I fainted away."

The metal was poured in about six seconds, and the extraordinary spectacle is depicted in the illustration on the next page. Every man wore a large apron and gauntlets of thick felt, with an uncanny-looking calico hood, soaked in alum, drawn completely over his head. This hood was provided with large, glistening talc eyes. These weird figures flitted about in the ghastly light of the intense soda-flame that leaped from the great furnace, and the windows were filled with the eager faces of fascinated spectators.

There was another hitch: the now solid speculum, or mirror, wouldn't come off its bed, in spite of the efforts of six ghostly individuals, who almost pulled the four-ton crab off the ground. It was a glorified—and inverted—version of the young housewife who couldn't manage to open the door of the oven in which her best cake was spoiling. If that metal disc had remained

CASTING THE METAL MIRROR FOR THE MELBOURNE TELESCOPE.
From the Picture by Sir Howard Grubb.

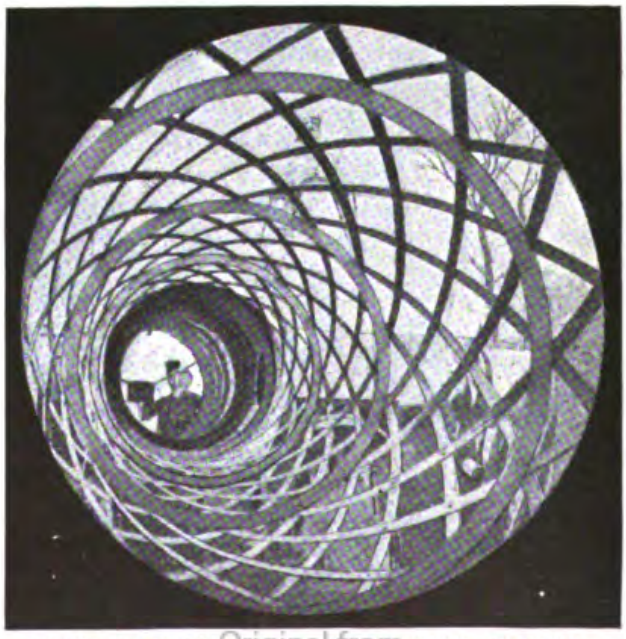
there much longer, with its temperature running down, it would be worse than useless. But why couldn't they get the thing into the oven? Well, some metal had got into interstices and formed solid pins that kept it in the bed. At last somebody jumped upon the taut chain—Blondin-like—and a second or two later the mirror was in the oven.

"At 1 a.m. on the 4th July," said Sir Howard, "I got home, having laboured continuously in that frightful place for twenty-four hours."

And this casting was defective; still, all concerned knew better next time. The men were drilled every day for a fortnight before the second and third castings, which were conducted in perfect silence. A doctor was in attendance, and he had at least one patient—a man who apparently tried to get into the mould before the metal.

I have treated this at some length, mainly because it was Sir Howard's troublous Rubicon, beyond which lay universal fame. In the next curious photograph we are looking down the lattice tube of the great Melbourne reflecting telescope into the famous mirror, whose casting has just been described. Sir Howard himself took this photograph, and his reflection is seen in the 4ft. mirror at the far end.

The highly polished surface of these mirrors, I need hardly say, needs the utmost care; and in this connection Sir Howard tells a funny story. The famous American astronomer, Professor Pickering, of Harvard, was once journeying to Arequipa, or some other astronomical Eldorado, escorted by a company of soldiers, who carried his scientific impedimenta. Having nothing to do one



LOOKING DOWN THE TUBE OF THE MELBOURNE TELESCOPE.
From a Photo. by Sir Howard Grubb.

day in camp, one of these fellows set to and *pipe-clayed* the mirror of the Professor's big reflector, causing that man of science horrible agony of mind, to say nothing of a return journey of hundreds of miles for another instrument.

The next epoch in the history of Sir Howard Grubb's establishment is marked by the introduction of the "New Astronomy," which called for photographic telescopes. It seems that in 1882 Dr. Gill, the Cape astronomer, was expecting a distinguished visitor—the comet of that year—which he made arrangements to photograph, using only an ordinary photographic lens. When he came to examine his plate, however—which is here reproduced—he found, to his amazement, that an enormous number of stars had also impressed themselves on the plate; reminding one of the street views of London, which contain lots of unwelcome idlers who evidently resolve to be "in the picture."

DR. GILL'S PHOTOGRAPH OF THE 1882 COMET, WHICH LED TO A REVOLUTION IN BIG TELESCOPES.
From a Photograph.

This very photograph led to the international survey of the heavens, undertaken by sixteen of the principal observatories of the world. Each astronomer had his celestial farm, or zone, mapped out for him in degrees; and he was to ignore all heavenly "stock" below a certain magnitude. Notes were to be ultimately compared, charts drawn, and catalogues printed, as though for a sale at Christie's.

An astronomical photographic congress met in Paris in 1887, and its members resolved to have special instruments made. Sir Howard then put in hand seven photographic telescopes, respectively for Cork, Greenwich, Oxford, Cape Town, Mexico, Sydney, and Melbourne. These were of uniform size—double-barrelled arrangements, carrying a 13in. photographic and a 10in. visual telescope. The testing of the seven object-glasses used up thousands of plates at Rathmines, and the work was carried on incessantly night and day for eighteen months.

I can't go into the effect of this photographic arrangement; it simply revolutionized astronomy. Of new minor planets, you are told proudly, thirty-three were discovered in 1893; and several lost planets—poor things!—were re-discovered by our celestial police, and conducted safely into the observatories—or, at any rate, records of them. But let me illustrate this pretty game of hide and seek. Minor planet Sappho, who had maintained a decent position in heavenly society for years, suddenly disappeared. Her description was known to the proper authorities, and the Press took up the case. At last Dr. Isaac Roberts, F.R.S., got a clue, and set a photographic snare for Sappho. She fell into it, and here she is shown, surrounded by a ring or collar (*not* really in the photo.), presumably to frustrate further escapades of a like kind.

MISSING PLANET, SAPPHO, FOUND BY A PHOTOGRAPHIC TELESCOPE.
From a Photograph.

At present, there are but two firms in the world who can produce big discs of optical glass—one in Birmingham and the other in Paris. The latter has made by far the largest object-glasses the world has yet produced; and I am greatly indebted to the courteous principal, M. Mantois, for information concerning a most fascinating business. The processes of manufacture are guarded as a sacred secret—exactly as in the case of Chartreuse or Benedictine liqueur; but one thing, at least, is certain. The workmen may spend a lifetime over their crucibles, and yet never be sure that the cooled mass of rough glass will not turn out utterly useless.

ROUGH BLOCK OF CROWN GLASS FOR THE YERKES TELESCOPE. (Weight 5cwt.)

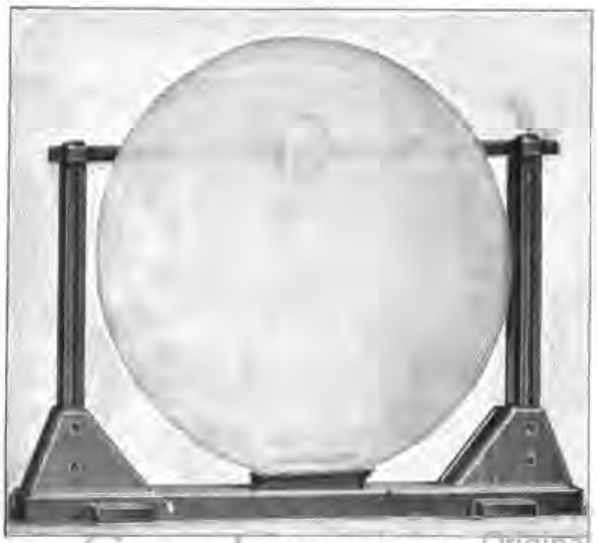
The previous illustration shows in the rough an enormous block of crown glass weighing more than a quarter of a ton, as taken from the furnace in December, 1887. It was a proud day for M. Mantois, for in this very block were the makings of the superb object-glass of the Yerkes telescope of Chicago—positively the largest in the whole world; however, more of this instrument hereafter. Bits of the crucible are seen clinging to the block in the picture.

Now, you mustn't run away with the idea that all M. Mantois has to do is to cut a chunk from this enormous block, polish it

GLASS DISC SHIVERED TO ATOMS IN THE OVEN DURING THE LAST MOULDING.

roughly, and then send it along to Sir Howard Grubb. Nothing of the kind. There are no end of cuttings, bakings, and mouldings to be gone through; and as every one of these processes is more dangerous than its predecessor—by reason of the increasing value of the disc—you may well imagine that the business is a trifle wearing. Fortunately giant telescopes aren't made every day. Next is given a reproduction from a photograph showing an almost perfect disc of crown glass shivered to fragments in the oven during the very last moulding. Could anything be more maddening? "The makers of ordinary glass," remarked Sir Howard, "are — or used to be—constantly writing to me to know why they couldn't supply me with big discs. I told them I didn't know; at any rate, they can't make optical glass."

The next illustration depicts the great 40in. crown lens of the Yerkes telescope



THE 40IN. DISC FOR THE YERKES TELESCOPE (LARGEST IN THE WORLD).

immediately after the last moulding. This, in brief, is the history of the preparation of the rough object-glass. Only bear in mind that there are countless other processes at Sir Howard's works; and after a disc has been polished and "figured" for *three years*, it may be ruined in five minutes. No wonder a celebrated English astronomer declared he regarded a perfect object-glass as a beautiful work of art—just as an artist would look upon a Corot or a Velasquez. The principal building at the Dublin establishment was erected in 1874, in order to accommodate the 27in. Vienna refractor. It is a square of about 70ft., and springing from this is a twelve-sided hall, 42ft. in diameter, itself resembling the interior of an observatory.

"Now, Sir Howard," said I, "supposing some friend of science offers to present a big telescope to an observatory—what's the very first thing to be done?"

"Find out the conditions the instrument is required to fulfil," was the prompt reply. "Latitude is an important condition," pursued Sir Howard, "and one that would alter the design very greatly. For instance, Greenwich is 51deg. north, and the Cape of Good Hope 33deg. south.

"Meanwhile, the glass is ordered, as the time taken by the manufacturer is very variable. I may get a 20in. disc in six months (phenomenal this), or—as in the case of the 28in. object-glass for the Greenwich telescope—I may have to wait three years for it. No fewer than sixteen failures were encountered during the making of this latter disc, owing merely to the presence of air bubbles and such-like faults. The defects were finally got rid of by chipping, and sawing with a wire supplied with emery and water. Thickness? Oh! the proportion is about an inch and a quarter for every foot in diameter. As a rule, the discs are either 'personally conducted' from Paris, or are heavily insured. When received from Mantois the glass is worth its weight in silver; but when my men have finished with it, it is worth at least three times as much."

POLISHING AN OBJECT-GLASS.
From a Photo. by Sir Howard Grubb.

"What do you do the moment the glass arrives?"

"First of all put a rough polish on it, and then carefully examine it for defects. If the disc is no good, we send it back; but if it is as perfect as it is possible to get it, we find out what curves shall be given it during the 'figuring' processes. The glass then goes into the grinding-room, sand and water being first used to get down gross irregularities on the surface. Then comes emery, from the coarsest to the finest, this being the labour of many months. Lastly, the finest jewellers' rouge is used for polishing."

One of the greatest difficulties in polishing an object-glass is to rest it on a perfectly even surface. The lens *has* been floated in mercury; but Sir Howard's present plan is to place the glass upon a number of automatically adjusting points coated with Archangel pitch.

The polisher is seen at work in the next picture. He has just laid on a coating of rouge, and is guiding the peculiar machine which rubs over the face of the disc with a motion closely resembling that of a human operator. This is one of the final processes of polishing, and is called "local touching." To merely put a good polish on a complete object-glass would take no longer than three days for each surface, or twelve days in all. This polish, however, might be worse than useless, the great art being to get the "figure," or uniformity of curve, absolutely perfect.

The next photograph represents Sir Howard himself using the spherometer, which is a three-legged arrangement with a screw in the middle. The central screw can be so turned that all four points rest evenly on the glass. Then, if you place your warm hand on

SIR HOWARD GRUBB TESTING AN OBJECT-GLASS.
From a Photo. by Sir Howard Grubb.

the surface for a moment, the spherometer will spin round like a top. This is because you have raised "bumps" on the glass, and the amazingly sensitive instrument has been upset, gyrating slowly by way of protest. At the moment this photo. was taken, there were seven discs in this workshop, their actual value being £7,250.

Many other tests are resorted to, but they are of a highly scientific kind; the most interesting, by the way, is the "artificial star" test of the object-glass, the "star" being an electric glow-lamp fixed many yards away.

An excellent notion is given by the next reproduction of the enormous dimensions of these telescopes. The men are seen putting together the main sections of the tubes for the new Greenwich 26in. instrument. When finished, big telescopes are sent in sections to their destination, and put together under the astronomer's own supervision.

LIFTING ON THE GREAT CROSS-HEAD OF THE GREENWICH 26IN. TELESCOPE.
From a Photo. by Sir Howard Grubb.

"I sent a large instrument to one of the Colonies some time ago," remarked Sir Howard, "and an inexperienced assistant was sent up to put it together. When he found two parts that wouldn't fit together one way, he didn't waste time in trying them another. Not he. He just sent them down to the nearest railway shop and had a bit turned off here, and a little shaved off there, until the parts were made to fit as he wished them. The result was that the telescope was wrongly mounted, and, therefore, didn't answer expectations; the error was not, however, detected for some years."

PUTTING TOGETHER THE TUBES OF THE GREENWICH 26IN. TELESCOPE.
From a Photo. by Sir Howard Grubb.

On the occasion of my own visit to Sir Howard's establishment, the 26in. Greenwich photographic Equatorial telescope was in hand; and the next illustration shows the process of lifting on the great cross-head—quite an engineering feat. By the way, talking of the dispatch of finished telescopes, the packing of an object-glass is something of an undertaking. It is first of all stripped of its cell, or frame, and then stitched in between cushions of felt, stuffed with wadding. Next it is placed in a box with a liberal supply of soft material all round, and then

INSERTING THE "SPIDER-LINES."
From a Photo. by Sir Howard Grubb.

this box is in turn packed in a big case, 8in. larger every way, the intervening space being dexterously filled with sofa springs. In the case of the Greenwich 28in. lens, it took six stalwart sailors to take it on board the steamer.

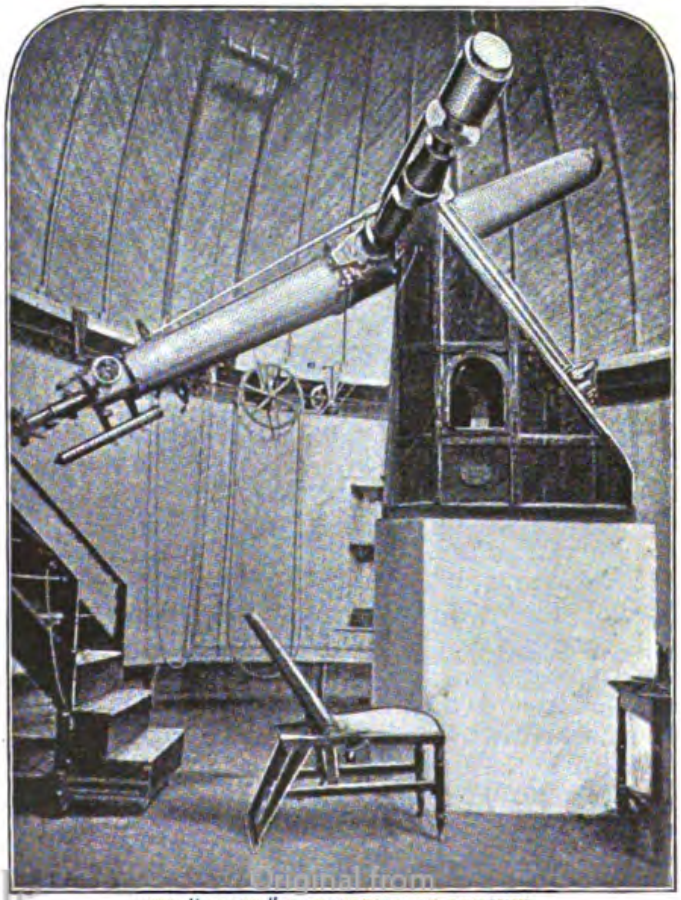
In fact, it would take whole volumes to describe the infinite care bestowed upon every part of these wondrous instruments. The teeth of the great sector, or toothed arc, are cut under a microscope. Into the sector the screw works which drives the whole instrument round to follow the apparent motion of the stars.

This photo. shows Sir Howard's son inserting the "spider-lines" into the micrometer, or eye-piece, of a giant telescope. He has just drawn out a single web from the nest and is holding it up, with a piece of wax at the lower end to keep it stretched, preparatory to laying it into its place in the micrometer. The "wires," as they are called, are placed transversely at the eye-end of the telescope in order to locate the heavenly body under observation. So fine are these "spider-lines" that 10,000 placed side by side, without touching, would not cover the space of 1in. September is the best month for obtaining these nests.

"On some occasions," remarked Sir Howard, "we have procured very fine threads from the nests of Mauritius spiders, these being much tougher than the ordinary webs found in this country. And it often happens," he went on, "that when a telescope has been left unused for a length of time, a spider gets into the tube and finds its way to the threads stretched across the sliding-bars of the micrometer. The insect invariably cuts away these threads—which have cost poor, bungling man an immense deal of trouble to place there—and substitutes an elegant, but vexing, design of its own."

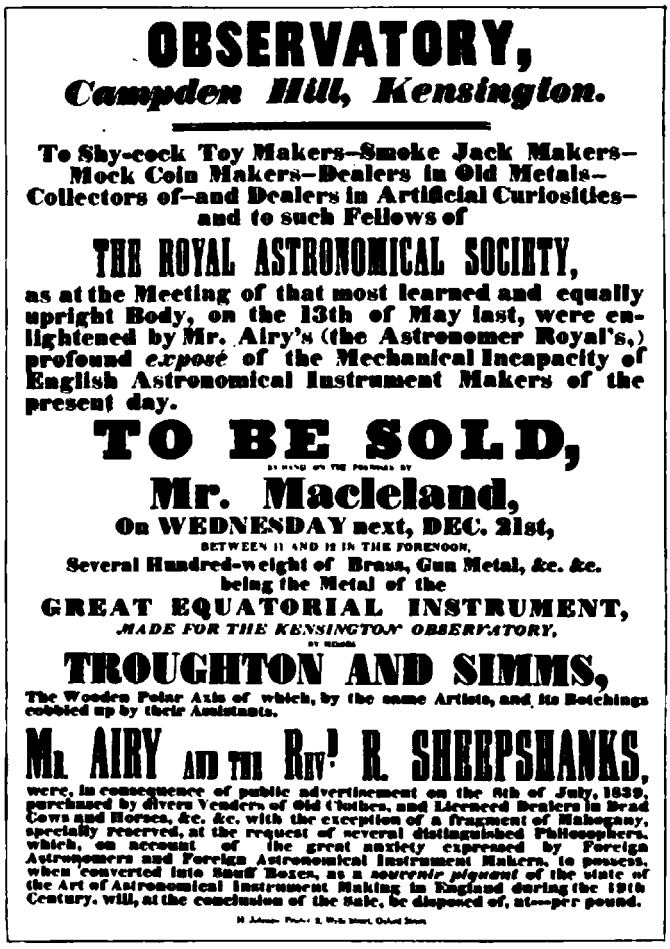
The "South" Equatorial at the Dunsink Observatory, near Dublin, is a telescope with a history. To be exact, the object-glass only should claim this distinction; the instrument is shown here. In 1835 a Mr. Cooper, of Markree Castle, in Sligo, heard that a 12in. object-glass had been made by Cauchoix, of Paris; and as this was at that time something of an optical *rara avis*, he resolved to possess it. On his way to Paris, Cooper called upon Sir James South in London, he being the greatest authority of his day on matters telescopic. Sir James gave his visitor sundry hints as to testing, and away went Mr. Cooper.

Finding the whole instrument satisfactory, he arranged with Cauchoix for its purchase, a cheque for about £1,200 to be sent on his



THE "SOUTH" EQUATORIAL AT DUNSINK.

return home. On the homeward journey Cooper again called on Sir James South, in whose mind his high eulogies roused envious thoughts. Off to Paris darted Sir James, the moment Cooper left for Ireland; and the eager knight carried the purchase-money in his pocket. Sir James saw and was conquered. He knocked up Cauchoix at an unearthly hour of the morning, paid the £1,200, unscrewed the object-glass, and then hurried back with his prize towards London. Later the same morning the transaction came to the ears of M. Arago, the Imperial astronomer, who rushed to the Minister of the Interior with a pitiful tale. It would be a standing disgrace to France, said he, if that beautiful object-glass left the country. Travelling was slow in those days, and the Home Secretary was touched. He at once set the telegraph to work to stop Sir James, but the old semaphore system failed to do what was required of it, and the fugitive got safely away. Cooper was furious, of course, but calmed down when Cauchoix promised to make him a bigger disc; which somehow suggests the nursery.

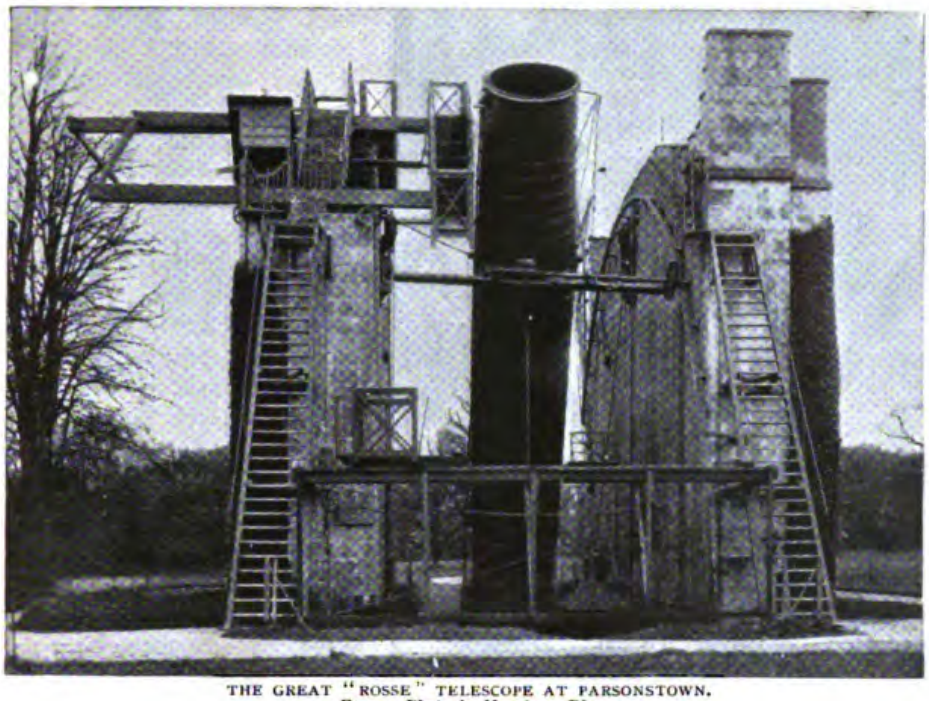

OBSERVATORY,
Campden Hill, Kensington.
To Shy-cock Toy Makers—Smoke Jack Makers—Mock Coin Makers—Dealers in Old Metals—Collectors of—and Dealers in Artificial Curiosities—and to such Fellows of
THE ROYAL ASTRONOMICAL SOCIETY,
as at the Meeting of that most learned and equally upright Body, on the 13th of May last, were enlightened by Mr. Airy's (the Astronomer Royal's,) profound *exposé* of the Mechanical Incapacity of English Astronomical Instrument Makers of the present day.
TO BE SOLD,
Mr. Macleland,
On WEDNESDAY next, DEC. 21st,
BETWEEN 11 AND 12 IN THE FORENOON,
Several Hundred-weight of Brass, Gun Metal, &c. &c.
being the Metal of the
GREAT EQUATORIAL INSTRUMENT,
MADE FOR THE KENSINGTON OBSERVATORY,
TROUGHTON AND SIMMS,
The Wooden Polar Axis of which, by the same Artists, and its Botchings cobbled up by their Assistants.
MR. AIRY AND THE REV. R. SHEEPSHANKS,
were, in consequence of public advertisement on the 6th of July, 1839, purchased by divers Venders of Old Clothes, and Licensed Dealers in Dead Cows and Horses, &c. &c. with the exception of a fragment of Mahogany, specially reserved, at the request of several distinguished Philosophers, which, on account of the great anxiety expressed by Foreign Astronomers and Foreign Astronomical Instrument Makers, to possess, when converted into Snuff Boxes, as a *souvenir piquant* of the state of the Art of Astronomical Instrument Making in England during the 19th Century, will, at the conclusion of the Sale, be disposed of, at—per pound.

SIR JAMES SOUTH'S SATIRICAL PLACARD.

Sir James South had the glass mounted at his observatory at Kensington, but he soon complained that it had been badly mounted by those intrusted with the work; at least, it didn't satisfy *him*, so he fell out with everybody concerned. Eventually his wrath was directed towards the instrument itself, which he actually demolished with a big hammer, saving only the object-glass. Here is a facsimile of Sir James's own satirical placard, advertising the sale of the various parts of the telescope. About the year 1865 Sir James offered to present the object-glass to Trinity College, Dublin. The Board, however, were a little embarrassed at this, because South's notion of mounting a telescope differed from that of every other authority. Presently his death got them out of the muddle, and they commissioned Mr. Thomas Grubb, Sir Howard's father, to mount the glass. The "T.C.D." Board also purchased from Mr. Grubb an Equatorial mounting which he had exhibited in Dublin in 1853, and in London in 1862. So once more the "South" object-glass got into working order; and it has been used ever since by Dr. Brunow, Sir Robert Ball, and lately by Dr. Rambaut, at the Dunsink Observatory, six miles out of Dublin. It was with this identical instrument that Sir Robert Ball made his celebrated series of observations to determine the distance of some of the fixed stars.

"None but the initiated," remarked Sir Howard, "know the infinite difficulty of producing a perfect object-glass of large size; therefore is there a limit to the size of refracting telescopes. Why, in point of actual size the Lick and Yerkes instruments—with apertures respectively of 36in. and 40in.—are nowhere compared to Lord Rosse's 72in. reflector, which was constructed fifty years ago! Plainly, then, the colossal telescope of the future is the reflecting telescope, for I am convinced that perfect metal mirrors could be cast up to 10ft. in diameter."

On the next page is a capital view of the famous Rosse reflector at Birr Castle, Parsonstown, King's County. It was photographed specially for this article by Mr. Edward Morrison, of Parsonstown. Dr. Otto Boeddicker was kind enough to furnish some details.



THE GREAT "ROSSE" TELESCOPE AT PARSONSTOWN.
From a Photo. by Morrison, Birr.

This mighty instrument was built by William Parsons, third Earl of Rosse; the 6ft. mirror weighs 3½ tons. "It was cast," writes Dr. Boeddicker (who is shown on the telescope), "under infinite difficulties at the forge at Birr Castle; and, of course, it lies at the bottom of the great tube. This mirror reflects the light rays of any celestial object towards the middle of the tube. Here a second small plain reflector catches them and throws them off at right angles to the side, where the eye-piece is placed. Thus, the different galleries become necessary, as the observer has to stand always at the mouth of the tube. The latter is 51ft. long; its diameter is 6ft. at the ends, and 7ft. 6in. in the middle, so one can walk through it with an open umbrella.

"The telescope is supported in a very ingenious manner between two walls of solid masonry, 50ft. to 60ft. high, and 8ft. to 13ft. thick; and it forms a striking feature of the beautiful park. The little house below, between the walls, contains a driving clock, added by the present Earl." The original cost of this instrument was about £12,000, but many improvements have since been effected.

Sir Howard Grubb tells many interesting stories. Here is one. An astronomer of European reputation was on one occasion so intent upon his observations, that he was quite oblivious of the fact that the mighty telescope was imperceptibly gliding round by clockwork. The result was that at length his eye was nearly gouged out between the end of the instrument and the observatory wall; and had not his cries brought assistance, he must have been killed.

Yet another story of an ardent observer. He was a wealthy private man, who had established an observatory at his own splendid residence. He yearned to do something for astronomy, so you can imagine his excitement when, looking through his refractor one day, he beheld — a new planet! Feeling sure of a place in history a niche or two above Columbus, who discovered a comparatively mean New World, our amateur lay low for a night or two taking notes and measurements. Then he invited a lot of big astronomical people down to his place to behold his epoch-making find; whereupon one of these cold, impassive gentlemen calmly declared that Mr. So-and-so's heavenly body was merely a speck of dirt on the eye-piece—just ordinary dirt.

But let us come to the famous Lick telescope, whose very name suggests the eclipse of all others. James Lick was an organ and piano maker—a Pennsylvania man—who died at San Francisco in October, 1876. Apart from his success in business, he had amassed enormous wealth from land investments; and he left three millions of dollars to be devoted to public uses, 700,000 to be set aside for an observatory.

Mr. Lick wanted to be buried near this observatory, so his remains were removed from the city in 1887, and interred in a suitable vault which had been prepared in the brick foundations of the mighty equatorial that bears his name.

When Lick fixed upon Mount Hamilton for his observatory he stipulated that a decent road should be made to it at the expense of Santa Clara County. This was commenced in 1876, the road, twenty-six miles long, costing 78,000 dollars, and connecting the observa-

THE LICK TELESCOPE AT MOUNT HAMILTON OBSERVATORY.
From a Photograph.

tory with San José, the nearest railway station. Of course, there was a mighty fuss preliminary to the whole undertaking. In 1875 it was suggested that Mr. S. W. Burnham, the well-known double star observer, should be asked to visit the place chosen, and report upon things. This he did in 1879, taking with him a 6in. telescope. He remained several months there, in camp, and then sent in an enthusiastic report. He had spent "forty-two first-class nights," and "only seven of medium quality" (who doesn't know those nights?). Mr. Burnham also said he had made a large number of measures of known double stars, and discovered forty-two new pairs; which smacks somewhat of the sartorial artist. A dreadful lot of hard work was involved in the preparing of the foundations. In some places the peak had to be lowered 32ft.; and altogether more than 72,000 tons of rock had to be cleared away. And *such* rock! Prof. A. Wendell Jackson, of California University, plaintively described it as "of a character between grey wacke and arcose"; from which it is obvious that the rock was of a peculiarly truculent sort. A brick factory was rigged up on top, and 2,600,000 bricks were turned out. Telephone lines were also laid. By November, 1882, an 85,000-gallon reservoir was established on Mount Kepler, 2,393ft. distant; you see, the whole district was distinctly astronomical. The main observatory building, 4,200ft. above sea-level, is one story high, and connects the two chief domes. Of these the one at the south end is 75ft. 4in. in diameter, and contains the gigantic 36in. refracting telescope, just depicted. The hall connecting the two domes is 191ft. long; and the construction is of the strongest, for the wind sometimes careers along up here at seventy or eighty miles an hour. The sliding slit in the dome through which the telescope looks is 9ft. 6¾in. wide. The tube is 57ft. long, and the whole instrument weighs 40 tons. The object-glass alone, with its cell, weighs 532lb. The driving-clock weighs one ton, and the revolving dome 70 tons.

The Lick telescope didn't hold its record long, for Mr. Charles T. Yerkes, of Chicago, up and said to the University: "Here's a million dollars; if you want more you can have it. Only lick the Lick." And they did. The Yerkes telescope, next depicted, as shown in the Chicago Exhibition, has an object-glass 40in. in diameter—4in. larger than the one in the Lick instrument. I have already shown the gigantic block of rough glass from which this superb object-glass was prepared. The tube of the instrument is 64ft. long, and the total weight is seventy-five tons. This telescope is to be located at Geneva Lake, Wisconsin.

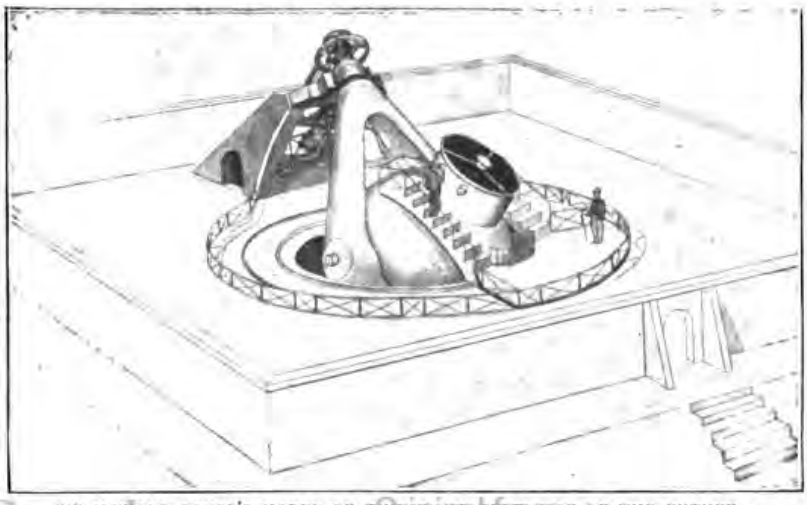
Sir Howard is of opinion that a pair of 48in. discs will be shown at the Paris Exhibition of 1900. A difference of an inch only all round an object-glass may make a difference of £1,000 in the total cost. The Yerkes telescope is to have a lifting floor, and other appliances such as those designed

THE YERKES TELESCOPE (LARGEST IN THE WORLD) SET UP IN THE CHICAGO EXHIBITION.
From a Photograph.

for the Lick instrument by Sir Howard Grubb. The lifting floor does away with the scaffold-like observing "chair"; and when the telescope is pointed, the astronomer simply presses an electric button and the whole floor glides up until the eye-piece is nice and handy. The value of this will be evident from the fact that when the Lick telescope is horizontal, the eye-piece is nearly 30ft. above the ordinary level of the observatory floor.

Here is Sir Howard Grubb's design for the telescope of the future; *it is to be a floating telescope!* — a reflector, and one which shall dwarf all others. As at present constructed there must be a limit to the size of monster telescopes, for though the weights increase enormously with increase of size, the accuracy and delicacy of movement of the largest telescopes must be even greater than with the smallest. Sir Howard has thoroughly worked out the details of his scheme. The instrument would take from three to five years to construct, and would cost about £33,000. The length of the tube would be 80ft., and it is to pass through a ball 25ft. in diameter, which floats in a gigantic tank or reservoir. The proposed mirror is 1½ft. thick and, if a 10ft. one, would weigh from six to seven tons.

"There is no need," remarked Sir Howard, "to dilate upon the incalculable benefit such an instrument would be to astronomy and to science generally. If the idea were brought forward in America, it would be taken up by some wealthy patron of science." Here we have a 100-ton telescope carried on an equatorial axis, without exerting a single ton of its weight. Perhaps one of our own millionaires will come forward with the £33,000, since immortalization is offered at this price, to say nothing of his name being writ large on the stars of heaven.



SIR HOWARD GRUBB'S MODEL OF THE GIANT TELESCOPE OF THE FUTURE—FLOATING IN WATER.