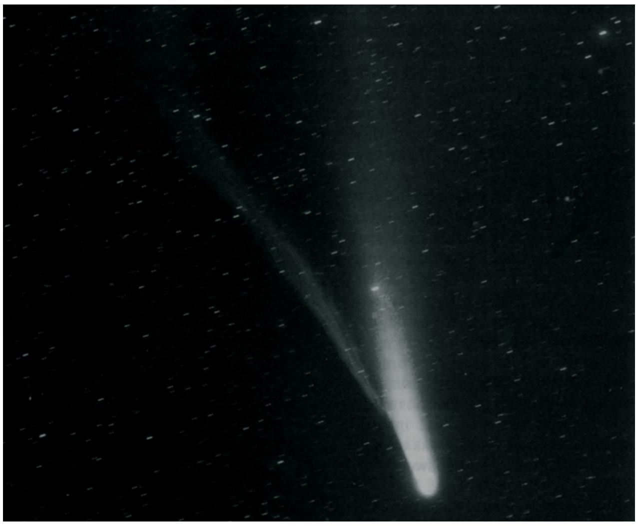
I & I News

New Series No. 17 | Newsletter of the Instruments and Imaging Section | 6 April 2014

It seems in order to mark what would have been the 100th birthday of Jack Bennett. His name is less well known to the younger generation, but he ranks among those accomplished visual observers who can still be a source of inspiration. This note is followed by an ingenious design for an observatory, an account of George Hole's telescope, and a story of competition, rivalry, and claims of precedence that have arisen occasionally between British and Continental mathematicians and natural philosophers (scientists) – perhaps the most well known examples being Newtonian fluxions and Liebnizian calculus, and the oft-repeated tale of the discovery of Neptune. William Gascoigne invented the micrometer around 1640, and others invented it (supposedly independently) a few years later. However, disputes and claims of precedence extended over more than a century. And the writers were not subtle with their pen. These days it is improbable that the words 'and not the French' will appear in the title of a published paper. Finally, there is an astronomical and geophysical 'thought for the day', reflecting on whether we are more gullible and superstitious today than we were in the Middle Ages.

Bob Marriott, *Director*



Comet Bennett 1969i. (Photograph by Michael Hendrie.)

Jack Bennett with his comet-seeker. (Photograph by Patrick Moore.)

John Caister Bennett (1914–1990)

Bob Marriott

Jack Bennett was born on 6 April 1914 in Estcourt, Natal. Although interested in astronomy during his youth, it was not until after the Second World War that he began to observe comets regularly, and in the early 1960s he began a methodical search.

He made independent discoveries of Comet Everhart in 1964 and Comet Rudnicki in 1967, and on 16 July 1968 discovered a supernova in Messier 83 (NGC 5236 in Hydra): SN1968L – the first extragalactic supernova discovered visually. His cometary work subsequently proved more fruitful, however, when on 28 December 1969 he discovered an 8th-magnitude comet near Achernar (α Eridani, declination ~–57°) which subsequently became one of the greatest comets of the twentieth century. This was comet 1969i (now redesignated C/1969 Y1). Another cometary discovery came in 1974, but it did not fulfil its promise, and disappeared into obscurity. Throughout these years he also recorded systematically all objects that could be mistaken for a comet in his own telescope, thereby compiling the 'southern Messier' catalogue.

In 1970 the Astronomical Society of Southern Africa awarded Bennett the Gill Medal for services to astronomy; in 1971 he was awarded the Association's Merlin Medal and Gift; in 1976 he received the AAVSO Nova Award for his discovery of SN1968L; in 1977 the 12½-inch reflector and observatory of the Pretoria Centre of the ASSA was named after him; in 1986 he received an honorary MSc degree from the University of Witwatersrand; and in 1989 the asteroid VD 4093 was named after him on the recommendation of its discoverer, Rob McNaught.

Brian Marsden has written: 'Jack Bennett was as accomplished an amateur astronomer as one could meet – yet also one of the most modest and unassuming. Although best known for his discovery of comet 1969i, which went on to become one of the greatest of the twentieth century, he was never aggressively competitive about his comet hunting, generally being quite content to make accidental discoveries of comets that were already known, and being magnanimous enough to encourage other amateur astronomers.'

In his Presidential Address to the Astronomical Society of Southern Africa in 1969, Bennett quoted Michael Hendrie (Director of the BAA Comet Section 1977–87): 'More powerful apparatus is available today for the study of comets, and it is obviously important that a constant supply of objects should be found so that this may be used to good effect. Apart from studies of the physical behaviour of comets, orbital data are needed for statistical and dynamical analysis ... There is much that amateur observers can do towards increasing the number of objects for study.'

These days, of course, with the advent of surveys such as the International Scientific Optical Network and the Lincoln Laboratory Near-Earth Asteroid Research project, opportunities of precedence for visual discoveries are diminished, though this does not prevent amateurs from contributing valuable observations.

Mileaway Observatory

Paul Whitmarsh

In 2006 I moved from the light-polluted skies of London's outer suburbs to rural East Sussex, where I could indulge my love of the deep sky. The dark sky of Sussex is a great improvement on my old London home, as I can now see the Milky Way by stepping out of my back door. However, I still needed to set up my telescope for each observing session. For a three-hour observing window I was taking around 1½ hours to set up and align, and then, after observing, I had to dismantle the equipment, leaving me with probably an hour or so for imaging or observing.

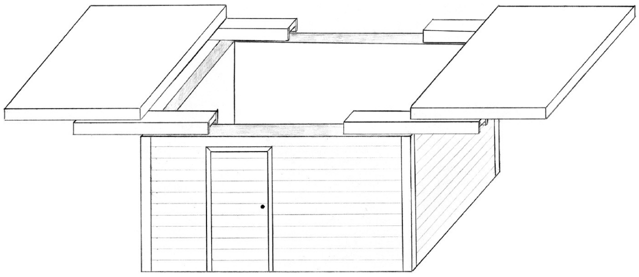
As I still work in central London, with a 5.45 am start and a two-hour commute each way, staying up past midnight on a work day is not an option. I needed a permanent set-up, and in June 2009 I took delivery of an Astro Engineering pier. I needed to find a spot for it in the garden which would offer me the best views and, more importantly, where it would be acceptable to my wife. The pier stayed in the garage throughout the remainder of 2009 while I tried out several places in the garden for observing, and explaining how the observatory would fit in amongst the flower beds. Fortunately, my wife Jeanette is very understanding of my passion for astronomy. So, if I could find a spot where the observatory was not too obvious from the house and not in the middle of the flower bed, then I could proceed.

My original plan was to site the observatory next to the garage. However, after a trial observing run I discovered that this would not be suitable, as the lights of cars arriving at our neighbours would shine directly into the observatory. The next option was the top lawn, which had the advantage of the lowest point on the hedge; but it would be far too obvious from the house, so that was not suitable. Finally, I tried a site halfway up the garden, where the ground is a good 4 feet lower than the level of the house, and where the shrubbery would provide another good 3 feet of camouflage. The only problem was that this is the highest point of the hedge; but dropping the height of the hedge was not an option, as our neighbours keep horses in the adjacent paddock, and we did not want either Ozzie or Henry in the garden.

So, armed with a site and a pier, all I needed was a design. I bought a set of the Springer 'small observatory' books and read them through, looking for inspiration and learning from the experiences of others. I sketched out a few ideas from a lift-off box, a wooden clam, and a counter-balanced roof. However, having no experience in building anything except flat-pack furniture, I was not able to realise any of the designs. Over Christmas 2009 I mentioned my plans to my brother-in-law, Phil Smith. He borrowed my set of books, and I thought no more of it. However, when early in the new year he asked me about my requirements, I stipulated the following:

- No external support for a roll-off roof.
- Maximisation of view to the horizon.
- Small footprint: 10 x 10-foot plot.
- Must fit in the garden and not predominate.
- No need for me (at 6 foot 3 inches) to be able to stand up inside with the roof closed.
- Must meet my budget for materials.
- Must be able to take a C8 or 4-inch refractor on a Losmandy G11 mount.
- Must be able to withstand high winds.
- Must be large enough to accommodate three people.

A few weeks later, Phil called me to tell me that he had produced a design for a cantilever roll-off roof observatory. The roof would split in the middle and roll off on a set of carriages. There would be no external supports for the roof, and the fully opened observatory would look like an open tool-box.



Phil had drawn up a set of plans, and I could not wait to see them. They looked very interesting. The dimensions of the observatory were based around the standard size of wooden sheeting, with double-skinned walls. The exterior would be 8 feet square, with an interior of approximately 7 feet square. The wall height with the roof off is 4 feet, and the roof and carriages provide an extra foot. Phil was concerned that I would not be able to stand up in the observatory, but I assured him that this would be acceptable, as most of the time when I was inside the roof would be open. He carried out some investigations into the dimension of timbers required for the carriages by visiting a local timber yard. His thinking was that if it could hold a weight of 13 stone then it should be acceptable, with the projected 4 stone for each half of the roof. He then built a prototype carriage set. To test the concept he sat my sister Alison on the end, and then proceeded to roll out the carriage. Having proved the carriage design, it was time to break the ground.

Before doing anything else, however, I spoke to all my neighbours, explained what was planned, and ensured that they had no objections. My immediate neighbour even offered to order the timber for me. I ordered the ballast and cement, which was delivered at the beginning of May. However, a business trip to New Delhi delayed breaking the ground until the end of May, when we finally started to dig the foundations for the pier.

We had planned a 1-metre-square foundation block, but we hit the iron pan at a depth of 800 mm, which seemed to be good point to stop. Then we mixed and poured the concrete. As I have already mentioned, the hedge at the site was at its tallest, standing about 5 feet, and the pier is about 4 feet high, so using a cut-down water-butt we raised the height of the pier foundation by 8 inches. With the mount on the pier, the telescope would have a clear view over the hedge to the horizon. Once the concrete had set we mounted the pier, though another two months would pass before we started the next phase. Good to his word, my neighbour Neil had ordered the timber and hardware required. Phil had built all four sets of carriages, and by mid-August we were ready to begin building. We had a full team to help: Phil, Mick, Mike, and myself, with Jeanette, Cristina, and Alison providing refreshments.

The observatory is built on six stilts – off-cuts from a recently removed telegraph pole. The top of the floor is built level with the base of the pier, and the floor is double-skinned and fully insulated. The walls of the observatory are standard, built in sections, and the inner skin was attached with a nail gun. It is the roof design that I believe is unique. It is made

of two 8 x 4-foot sections which are insulated and double-skinned. The advantage of double-skinning is that a flat underside minimises the opportunity for the wind to lift the roof. The roof sits on two sets of carriages secured by an eye and beam to guide it as it rolls off. Fully rolled off, its weight is taken by the walls.

The carriages are made from pieces of pressure-treated pine, with a set of six wheels on each, and a set of guide rails to keep the wheels in line. There are four carriages per roof section – two sets of two – and each carriage rolls back by 2 feet to achieve a fully open aperture of 4 feet for each roof section. Cable routs were then cut, the walls were insulated, and the outer skin was applied. The whole structure was covered in roofing felt to provide a waterproof skin. At the end of the first day the observatory looked like an oversized chocolate box.

Over the following few weeks, Phil and Alison continued to work on the observatory. The sides were covered with shiplap, and the roof carriages were designed so that their height was a multiple of the shiplap depth. So, when closed the roof carriages look like a continuation of the walls. We had a few problems with rolling of the roof. The first problem arose when opening the roof, as each set of carriages would open at different rates, resulting in a skew as the roof was rolled back. This was caused by the top carriages starting to move before the lower carriage had reached its stop. To rectify this, on either side we used two latches which are released only once the lower carriage has rolled to its stop. The second problem was encountered as the roof rolled out, as it became heavier and more difficult to move as the fulcrum point moved and more pressure was applied to the eye and I-beam on the carriages. The solution to this was to move the fulcrum point out by adding two rollers on the outer wall – one for each carriage – giving support to the roof as it rolls out. Following these modifications the roof moves with ease. A final modification was to make the weather boards that run the height of each corner fold outwards as the roof is opened. They do not offer any additional support for the weight of the roof, but by acting as a barrier they prevent my walking into the roof when it is open, and aid stability to the roof in higher winds when in the open position. As the roof is split in the middle and rolls either side, a method was needed to provide a weatherproof central join. This was achieved with a strip of rubber standing up (the type used on garage doors), and a recessed baton running the full width, with the rubber seal fitting into the recessed baton. Draft-excluding strips on the faces of each roof section produced the final seal.

The observatory has survived torrential rain and a foot of snow with no leaks. Once fully enclosed in shiplap the chocolate box became the sauna, and was in need of a disguise. To make it less conspicuous I painted it with a dark green wood-stain. The interior walls are painted matt black, and for the floor I used a textured paint. The matt-black walls were a good choice, allowing excellent dark adaption. The G11 mount was installed and levelled, and the process of polar aligning the mount began.

As fully expected, the weather has been dreadful since the observatory was completed, and it seems to have become a real cloud magnet, though on a few clear nights it has been a dream to use. Instead of my occupying 1½ hours to set up and dismantle the equipment, the observatory is ready in five minutes, and in an emergency the roof can be closed within thirty seconds. Following one of the observing runs the equipment was dripping with dew, so I closed the observatory, expecting to have to wipe down everything the following day; but there is a good flow of air in the observatory, and on inspection the following day, everything was dry.

Having placed a strip of pipe insulation around the gap between the floor and the concrete pier foundation, I noticed that this insulation had been nibbled by mice. Fortunately, I discovered this before they returned and began to eat the cables for the mount. With wire mesh used for small animal cages, I blocked the access, and since doing so I have not seen evidence of mousey invasion.

I am grateful to my brother-in-law for designing a superb and unique observatory.

Uckfield, East Sussex paul.whitmarsh@googlemail.com

George Hole's observatory
Patcham, Sussex

Journal of the British Astronomical Association, 51 (1941), 329

This is an open-air observatory with, up to a few months ago, a 9½-inch reflector as its principal instrument, ably seconded by one of 6 inches. Now, however, a 14-inch instrument has been finished and installed. This an equatorial fork mounting of more or less standard design, its unusual features being: (1) it is constructed entirely of reinforced concrete; (2) the method of rotating the polar axis. The concrete fork was cast in a wooden mould, the various bearings, reinforcing, and so on, being in position before filling with concrete.

The 8-inch diameter main bearing is a cast-iron angle ring of L section, with 1-inch faces placed as near the top of the fork stem (or polar axis) as possible. A second identical ring is placed 4 inches farther down the stem, to take the pressure exerted by the clamping screws of the right ascension slow motion. The two Y-shaped bearings for the declination axis, which form the top of each fork arm, were assembled out of 2 x ¼-inch section steel bar, and are well keyed into the concrete by rods threaded into them, and bent at all angles to prevent movement. Great care was taken to get the centre lines of the polar and declination axes precisely at right angles, and further adjustment can be carried out by using sheet steel shims, there being tapped holes in one of the declination bearings for fixing these if necessary.

The main reinforcing is of 2-inch steam pipe running up the centre of each arm and down the polar axis. Angle braces were inserted across the corners of the fork, where most of the strain is taken, and plenty of smaller iron was wound and interlaced all round this main structure. On the bottom of the reinforcing rod running down the polar axis is located the bottom bearing, being 3 inches in diameter. The base of the fork is of 8 x 4-inch rectangular section, and the arms taper from this to 6 x 3 inches at the top. There is also a tapering rib up the side of each arm and under the fork base. The making of the mould was the biggest part of the job.

This fork rotates in roller bearings set in a concrete cradle, cast with four lugs for bolting to the main foundation angle block, and carrying fixing studs for the top half of the main bearing, and the bridge that carries the RA slow motions. These are well seen in the photograph, and the hour circle is also visible. Rotation is controlled by a steel girder type arm carried on a ring which encircles the polar axis, and can be rigidly clamped to it at any point. This arm carries a sliding box, to compensate for changes in radial length, which is moved by a swivel nut along a fixed screw, driven by hand with a Hooke's joint. This screw is set at 14 inches from polar axis centre, and is thus equal to a worm-wheel of twice the size. It gives a controlled motion of 15–20 degrees, and thus allows objects to be followed for an hour or more before it is necessary to unclamp and reset. The hand control can be fixed to either end of the driving screw.

The tube is of timber, built up with four hexagonal formers (halved, glued and screwed at the angles) and six longitudinal members. It is solid round the mirror (there is of course a door) and open lattice-work from the balancing point. The flat and eyepiece mounts are carried at the top of a lattice-work cylinder which drops into the end of the main tube, and rotates in bearings at each end. This was made as long as possible (3 feet) in order to preserve adjustments when rotated, and I have found that it is quite satisfactory. The internal lattice cylinder accounts for the maze-like appearance of the tube top in the photograph. The large mirror, its cell and the tube bottom have been described in a recent paper, the only point being that the cell and cover cap are now totally enclosed in a sheet-metal box with a removable weather-tight lid, forming a 'cell within a cell'.

The declination slow motion arm is pivoted on a hollow cast-iron stud, 3 inches diameter, in line with the centre of declination axis, and is counterpoised. It can be clamped solid with the fork arm and further adjustment obtained with an extending screw, working through a swivel nut in the end of the girder work arm.

The whole of this declination gear is counterpoised by a weight fixed to the other fork arm. The clamping screw, slow motion screw, and declination circle are well seen in the photograph. All adjustments are within easy reach of the observer at the eyepiece, except the RA clamp, and it is hoped to alter this soon. The fork is large enough to allow the tube to swing clear through it, and, with an eye to the future, the whole telescope tube and mount has been made large enough to take an 18-inch mirror. It is, in fact, an 18-inch telescope working with a 14-inch mirror.

In conclusion, the use of concrete enables the worker to eliminate expensive metal castings, the points to remember being these. As concrete is not as strong as iron, there must be more of it to do the same job (all sections must be larger). Adequate reinforcing must be provided to any point taking strain, and properly prepared bearings must be incorporated wherever motion is to take place. These last must be well keyed into the parent mass, and this can only be done if they are in position in the mould before pouring in the concrete.

The construction of a cell for a 14-inch telescope mirror

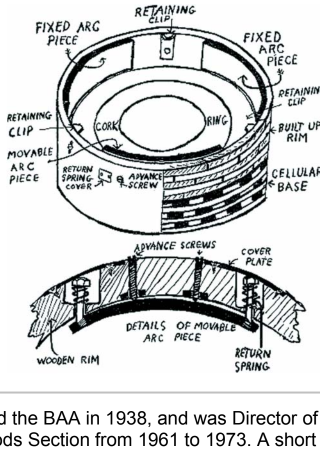
George Hole

Journal of the British Astronomical Association, 51 (1941), 95

On completing this mirror of 14 inches aperture, 2 inches thickness, and 98 inches focal length, I found that, owing to the war, metallic castings for the cell were unobtainable. It was therefore necessary to find an effective substitute.

In view of the weight of the mirror – some 27 pounds – the cell construction advocated by the late Canon Ellison, calling for a stout metal rim, was not used. Instead, a base-board of ⅜-inch plywood was marked with a circle an inch larger than the mirror, and enough arc pieces were cut out of ½-inch mahogany to form a rim 2½ inches deep, 1 inch wide, and 15 inches internal diameter. These pieces were assembled on the base-board, and glued and screwed together, taking care to cross the grain. When dry it was detached, and cleaned up on the inside with hand tools and glass-paper. Two arc pieces, carefully fitted to the curve of the mirror edge, and of a thickness enough to centralise it, were permanently fixed to the inside edge of rim, at 120 degrees and 240 degrees. They are lined with velvet and are 8 inches long. The third arc piece, of the same size as the others, was made adjustable. It was made of brass bent to curve, and had two bolts threaded into it, one at each end. These were bent or 'set' until they were parallel, and slipped through two brass-lined holes in the rim. They carry nuts and two short springs countersunk into the thickness of the rim, which return the adjustable arc. Flush cover plates are fitted over the ends of the bolts, and are all of the mechanism that is visible. Two pointed bolts, working in tapped inserts in the rim, serve to advance the arc until it positions the mirror. The arc is also velvet lined. By these means the mirror is located, and held immovable, yet without nipping it.

The rim was fixed to the baseboard with glue, and this was built up to 2 inches thickness by the cellular method advocated by Professor Ritchey for wooden polishers. Nine long bolts right through rim and base finished the fixing. The outside was cleaned up, and a ring of cork, ¼-inch thick, was glued to the inside for the mirror to rest on. Three retaining clips, sliding in sheet-metal guides, were fixed to the inner edge of the rim, and held by bolts threaded into them through slots cut in the rim. Pieces of cork are cemented to the clips where they contact the optical surface. The whole cell rests on a triangular frame to provide for 'remote control' squaring on, and can be moved out of centre on this to provide further adjustment. In use, I have been unable to detect any signs of flexure or movement in the mirror, and knife-edge tests show no deformation of figure in any position where I have been able to apply them, although I suppose that theoretically it must be present.



George Hole joined the BAA in 1938, and was Director of the Instruments and Observing Methods Section from 1961 to 1973. A short film of him with his 18½-inch reflector in 1949 can be viewed on the British Pathé website:

http://www.britishpathe.com/video/garden-telescope/query/Telescope

... and a Brighton bus is named after him:

http://history.buses.co.uk/history/fleethist/607gh.htm

William Gascoigne's micrometer

Bob Marriott

It is a matter of record that William Gascoigne invented telescopic sights and the micrometer, but in 1666 – more than two decades after Gascoigne's death at the Battle of Marston Moor (2 July 1644) – Adrien Auzout published a paper in which he claimed that he and Jean-Félix Picard were the first to make highly accurate measures of the diameters and parallaxes of the Moon and planets. This was soon afterwards disputed by Richard Towneley, while Robert Hooke published a paper on Gascoigne's micrometer; but in 1687, Philippe de la Hire credited Auzout and Picard with the invention. In 1717, William Derham provided abundant documentary evidence of Gascoigne's precedence; but in that same year, de la Hire again credited Auzout and Picard. Finally, more than a century after Gascoigne's death, John Bevis considered it his duty to inform the scientific community yet again that the later claims of priority of invention were not justified. The story is presented here in their own words.

Adrien Auzout

An extract of a letter written Decemb. 28, 1666, by M Auzout to the publisher, concerning a way of his, for taking the diameters of the planets, and for knowing the parallax of the Moon

Philosophical Transactions of the Royal Society, 1 (1666), 373

I did apply my self the last summer to the taking of the diameters of the Sun, Moon, and the other planets, by a method which one M Picard and my self have esteemed by us the best of all those that have been practis'd hitherto; since we can take the diameters to second minutes, being able to divide one foot into 24,000 or 30,000 parts, scarce failing as much as in one only part, so as we can in a manner be assur'd, not to deceive our selves in 3 or 4 seconds. I shall not now tell you my observations, but I may very well assure you that the diameter of the Sun has not been much less in his apogee than 31 m 37 or 40 sec, and certainly not lesse than 31 m 35 sec, and that at present in his perigee it passes not 32 m 45 sec and may be lesse by a second or two. That, which is at the present troublesome, is that the vertical diameter, which is the most easie to take, is diminisht, even at noon, by 8 or 9 sec because of the refractions, which are much greater in winter than summer at the same height; and that the horizontal diameter is difficult because of the swift motion of the heavens.

As for the Moon, I never yet found her diameter less than 29 m 44 or 45 sec, and I have not seen it pass 33 m, or if it hath, it was only by a few seconds. But I have not yet taken her in all the kinds of situations of the apogees and perigees which happen, with the conjunctions and quadratures. I do not mention all what can be deduced from thence, but if you have persons at London that observe these diameters, we may entertain our selves more about this subject, another time. I shall only tell you, that I have found a way to know the parallax of the Moon, by the means of her diameter. If on a day, when she is to be in her apogee of perigee, and in the most boreal signes, you take her diameter towards the horizon, and then towards the south, with her altitudes above the horizon. For, if the observation of the diameters be exact, as in these situations the Moon changes not considerably her distance from the Earth in 6 or 7 hours, the difference of the diameters will shew the proportion there is of her distance, with the semi-diameter of the Earth. I do not enlarge, because that as soon as one hath this idea, the rest is easie. The same would yet be practis'd better in the places where the Moon passes through the zenith, than here; for the greater the difference is of the heights, the greater is that of the diameters. I do not note (for it easily appears) that, if one were under the same meridian or the same azimuth in two very distant places, and took at the same time the diameter of the Moon, one would do the same thing, though this method goes not to preciseness.

From what has been said, may be collected the reason of the observation, which M Hevelius made in the last eclipse of the Sun, touching the increase of the Moon's diameter about the end. I am exceeeding glad that a person, who probably knew not the cause of it, has made the experiment: but it is strange that until now no astronomer has foreseen that that should happen, nor given any precepts for the change of the Moon's diameter in the eclipses of the Sun, according to the places where they should happen, and according to the hour and height the Moon should have. For, what hapned in that eclipse of augmentation would have faln out contrarily if it had been in the evening; for the Moon, which in that eclipse, that began in the morning, was higher about the end than at the beginning, was nearer us, and consequently was to appear bigger. But if the eclipse should happen in the even'ng, she would be lower at the end, and therefore more distant from us, and consequently appear lesser. So also in two different places, whereof one should have the eclipse in the morning, and the other at noon, the Moon should appear bigger to him that hath it at noon. And the must likewise appear bigger to those, who shall have a lesser elevation of the pole under the same meridian, because the Moon will be nearer them.

Richard Towneley

An extract of a letter written by Mr Richard Towneley to Mr Croon, touching the invention of dividing a foot into many thousand parts, for mathematical purposes

Philosophical Transactions of the Royal Society, 2 (1666), 457–8

Finding in one of the last *Philosophical Transactions*, how much M Auzout esteems his invention of dividing a foot into near 30,000 parts, and taking thereby angles to a very great exactness; I am told I shall be look't upon as a great Wronger of our Nation should I not let the World know that I have, out of some scatter'd papers and letters that formerly came to my hands of a gentleman of these parts, one Mr Gascoigne, found out that before our late Civil Wars he had not only devised an instrument of as great a power as M Auzout's, but had also for some years made use of it, not only for taking the diameters of the planets, and distances upon land; but had farther endeavour'd, out of its preciseness, to gather many certainties in the heavens; amongst which, I shall only mention one, *viz.* the finding the Moon's distance, from two observations, of her horizontal and meridional diameters: Which I the rather mention, because the French astronomer esteems himself the first that took any such notice, as thereby to settle the Moon's parallax. For, our countryman fully consider'd it before, and imparted it to an acquaintance of his, who thereupon proposed to him the difficulties that would arise in the calculation; with considerations upon the strange niceties necessary to give him a certainty of what he desired. The very instrument he first made I have now by me, and two others more perfected by him; which doubtless he would have infinitely mended, had he not been slain unfortunately in His late Majesty's Service. He had a *Treatise of Opticks* ready for the press; but though I have used my utmost endeavour to retrieve it, yet I have in that point been totally unsuccesful: but some loose papers and letters I have, particularly about this instrument for taking of angles, which was far from perfect. Nevertheless, I find it so much to exceed all others, that I have used my endeavors to make it exact, and easily tractable; which above a year since I effected to my own desire, by the help of an ingenious and exact watchmaker in these parts: since which time, I have not altogether neglected it, but employed it particularly in taking the distances (as occasion served) of the *circum-jovialists*, towards a perfect setling their motion. I shall only say of it, that it is small, not exceeding in weight, nor much in bigness, an ordinary pocket-watch, exactly marking above 40,000 divisions in a foot, by the help of two indexes; the one shewing hundreds of divisions, the other, divisions of the hundred; every last division, in my small one, containing $^{1}/_{10}$ of an inch; and that so precisely, that, as I use it, there goes above 2½ diameters to a second. Yet I have taken land-angles several times to one division, though (for the reason mention'd by M Auzout) it be very hard to come to that exactness in the heavens, *viz*. the swift motion of the planets. Yet, to remedy that fault, I have devised a *rest*, in which I find no small advantage, and not a little pleasing those persons who have seen it, being so easie to be made, and by the observer manag'd without the help of another: Which second convenience, my yet nameless instrument hath in great perfection, and is, by reason of its smallness and shape, easily appliable to any telescope. Sir, if you think this invention, thus improv'd, worthy to be taken notice of by the curious, you may command a more perfect description of it, or any of the observations either Mr Gascoigne or my self have made with it.

Robert Hooke

A description of an instrument for dividing a foot into many thousand parts, and thereby measuring the diameters of planets to a great exactness, &c. as it was promised, Numb. 25

Philosophical Transactions of the Royal Society, 2 (1666), 541–4

If the residence of the worthy promiser of this instrument, Mr Richard Towneley, had not been so remote from London, nor some other impediments intervened (after it was come to hand), first on the publisher's, then on the engraver's side, the following particulars concerning the same, promised some months ago, had been imparted to the publick a good while before this time. For the draught of the Figures, representing the new instrument it self, and the description of the same, we are obliged to the ingenuity of Mr Hook.

The first, second, and third figures do represent the several parts of this instrument; the fourth figure, part of the telescope, with the instrument applied to it; and the fifth, the rest, on which the whole reposeth.

The first figure represents the brass box with the whole instrument (excepting only the moveable cover) and the screws, by which it is fixt to the telescope. In this figure (aaaa) is a small oblong brass box, serving both to contain the screws, and its sockets or female screws, and also to make all the several moveable parts of the instrument to move very true, smooth, and in a simple direct motion. To one end hereof is screwed on a round plate of brass (bbbb) about 3 inches over; the extream limb of whose outside is divided into 100 equal parts, and numbred by 10, 20, 30, &c. Through the middle of this plate and the middle of the box (aaa) is placed a very curiously wrought screw of about the bigness of a goose quill, and of the length of the box, the head of which is by a fixed ring or shoulder on the inside, and a small springing plate (dd) on the outside, so adapted to the plate that it is not in the least subject to shake. The other end of this screw is by another little screw (whose small point fills the center or hole made in the end of the longer screw for this purpose) render'd so fixt and steady in the box that there appears not the least danger of shaking. Upon the head of this screw without the springing plate, is put on a small index (ee), and above that a handle (mm) to turn the screw round as often as there shall be occasion, without at all endangering the displacing of the index, it being put on very stiff upon a cylindrical part of the head, and the handle upon a square. The screw hath that third of it, which is next the plate, bigger than the other two thirds of it, by at least as much as the depth of the small screw made on it. The thread of the screw of the bigger third is as small again as that of the screw of the other two thirds. To the grosser screw is adapted a socket (f) fasten'd to a long bar or bolt (gg), upon which is fasten'd the moveable sight (h), so that every turn of the screw promotes the sight (h) either a thread nearer, or a thread farther off from the next fixt sight (i). The bar (gg) is made exactly equal and fitted into two small staples (kk), which will not admit of any shaking. There are 60 of these threads; and answerable thereto, are made 60 divisions on the edge of the bolt or ruler (gg); and a small index (l) fixt to the box (aaa) denotes how many threads the edges of the two sights (h) and (i) are distant; and the index (ee) shews on the circular plate what part of a revolution there is more, every revolution, as was said before, being divided into 100 parts. At the same time that the moveable sight (h) is moved forwards or backwards, or more threads of the courser screw, is the plate (pp in Fig. 2) by the means of the socket (q) to which it is screwed, moved forward or backward, or more threads of the finer screw; so that this plate, being fixt to the telescope by the screws (rr in Fig. 2) so as the middle betwixt the sights may lye in the axis of the glass, however the screw be turn'd, the midst betwixt the sights will always be in the axis, and the sights will equally either open from it, or shut towards it.

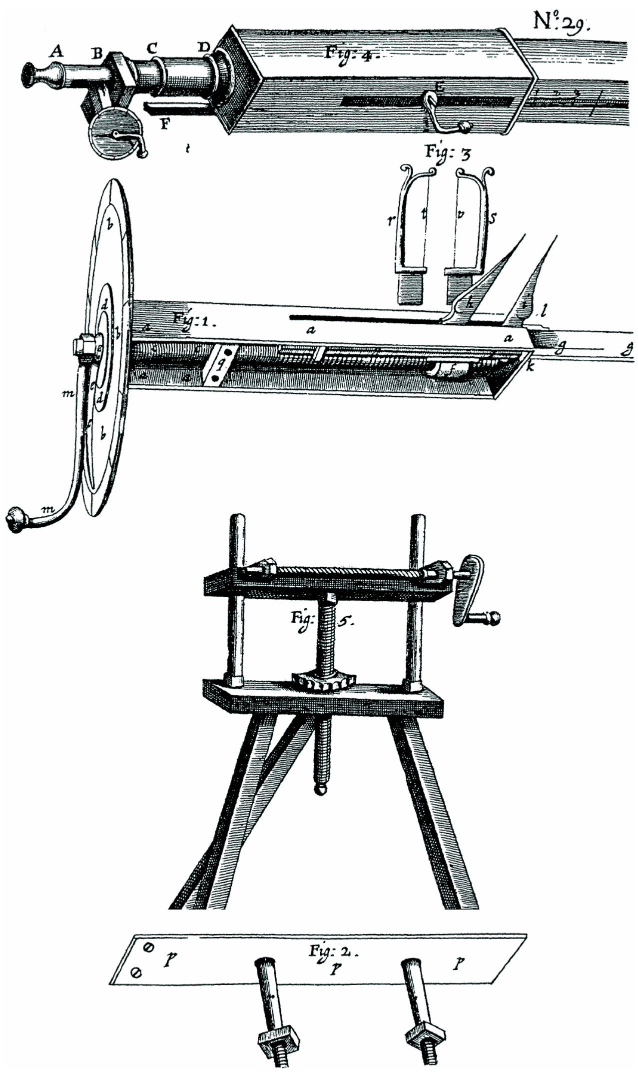


Fig. 2 represents the moveable cover containing the screws, to be by the bookseller cut off by the pricked line (xxx) from the paper, and to be fitly placed on Figure 1, according to the pricked line (yyy) answering thereto; that by the taking off, as it were, or folding up of this cover, the inward contrivance of the screws and sights may appear.

And because it is conceived by some ingenious men that it will be more convenient, instead of the edges of the two sights (h and i) to employ two sights fitted with hairs, therefore is added Figure 3, representing the two sights (r and s) so fitted with threads (t and u) that they may be conveniently used in the place of the solid edges of the sights (h and i).

The fourth figure represents how the screws are to be put on. The tube AD is divided into 3 lengths, of which (as in ordinary ones) BC is to lengthen or contract, as the object requires. But AB is here added, that at A you may put such eye-glasses as shall be thought most convenient, and to set them still at the distance most proper for them, indexes or pointers, which here are supposed to be at B, which length alters also in respect of divers persons' eyes. E is a screw, by which the great tube can be fixt so, as by the help of the Figures any smaller part of it can immediately be found, measuring only, or knowing the divisions on BC, the distance of the object-glass from the pointers. F is the angular piece of wood that lies on the upper screw of the rest. This rest is represented in Fig. 5.

As for a description of the uses of this ingeniously contrived and very curious engine, the reader is desired to look back to the before-alleged Numb. 25.

William Derham

Extracts from Mr Gascoigne's and Mr Crabtree's letters, proving Mr Gascoigne to have been the inventor of the telescopick sights of mathematical instruments, and not the French

Philosophical Transactions of the Royal Society, 30 (1717), 603–10

In Monsieur de la Hire's first part of his *Tabula Astron.*, published in 1687, I find an invention which was undoubtedly our countryman Mr Gascoigne's, ascribed to Monsieur Picard, and that is, the application of telescopick sights to astronomical instruments. Mr de la Hire's words are, 'Paucis abhinc annis D. Picard insignis Astronomus, atque in eadem Academiâ (Regia Scientiarum) Socius, Dioptrarum crenas ab instrumentis sustulit, eorumque loco substituit Telescopia; quae res Prestytis et Myopibus', &c. In which words it is not indeed expressly said that Mr Picard was the inventor of this way, but only that he applied telescopes. But by reason it implies that it was that curious and ingenious gentleman Mr Picard's invention, and it is in effect claimed as such in Monsieur Auzout's account of the telescopick micrometer, in the *Philos. Tran*. No. 21, therefore I think my self in duty bound, to do that young but ingenious gentleman, Mr Gascoigne, the justice to assert his invention to him; by reason all his papers, that by the late ingenious Mr Towneley's diligence could be picked up, are now (together with Mr Towneley's own papers) in my hands.

As for the invention of the micrometer, which Mr Auzout claims as his and Monsieur Picard's, I shall say little to it, Mr Towneley having sufficiently prov'd it to be Mr Gascoigne's, in the *Philos. Transac*. No. 25. And the descriptions and draughts of that, and some other instruments of that kind, are now by me, in Mr Gascoigne's own hand, to confirm Mr Towneley's account, if occasion were.

And as Mr Gascoigne was the first that measured the diameters of the planets, &c. by a micrometer, so I shall prove that he was the first that applied telescopick sights to astronomical instruments. In a long letter to his sagacious friend Mr Crabtrie, of Jan. 25, 1640/1 (wherein he describes his micrometer, and shews his way of finding the refractions, the Moon's parallax, and how he measured the diameters of the planets) Mr Gascoigne tells him how the measuring glasses, which he had been speaking of, might be applied to a quadrant.

> If [saith he] here [that is, in the distinct-base] you place the scale that measures – or, if here an hair be set, that it appear perfectly through the glass – you may use it in a quadrant, for the finding of the altitude of the least star visible by the perspective wherein it is. If the night be so dark that the hair or the pointers of the scale be not to be seen, I place a candle in a lanthorn, so as it cast light sufficient into the glass; which I find very helpful when the Moon appeareth not, or it is not otherwise light enough.

In another letter, dated on Christmas Eve 1641 (wherein he describes the wheel work of his micrometer, and shews how he could apply it to the taking of three points; and specifies his observations of the diameters of the Sun and Moon; and mentions a theory he had contriv'd of the Sun; etc. and saith what pains he had taken in the anatomy of the eye) he tells Mr Crabtrie how he had applied his telescopick sights to a sextant. Saith he:

> Mr Horrox his theory of the Moon I shall be shortly furnished to try. For I am fitting my sextant for all manner of observation, by two perspicills with threads. And also I am consulting my workman about the making of wheels like β, γ, δ, ε of diagr. 3 [this diagram is wanting in the letter] to use two glasses like a sector. If I once have my tools in readiness to my desire, I shall use them every night. I have fitted my sextant by the help of the cane, two glasses in it, and a thread, so as to be a pleasant instrument, could wood and a country-joiner or workman please me.

In another letter (the date of which is worn out, but is, in Mr Crabtrie's hand, called his 10th letter to him) he saith:

> I have given order for an iron quadrant of five foot, which will give me the 1,000th part of one degree, which shall be furnished like my first scale; only my workman is so throng [a Yorkshire phrase for fully employed] for my father, that I fear it will not be finished before the eclipse. I have caused a very strong ruler to be exactly made, and intend to fit it with cursors of iron, with glasses in them and a thread, for my sextant.

To these I could have added many other passages of the like nature; but these may be sufficient to shew that Mr Gascoigne, as early as 1640, made use of telescopes on quadrants and sextants, as well as in his invention of the micrometer. What commendations these contrivances got him, and what expectations they raised in some of the astronomers of that time, particularly in two of the most acute of that age, Mr Horrox, and Mr Crabtrie, may be seen in the same Mr Crabtrie's letters to Mr Gascoigne, which are also in my hands. Some passages of which I shall recite, and at the same time give the Society a taste of what those curious letters do contain.

In Mr Crabtrie's second letter, which is of October 30, 1640; after a very clear demonstration that the solar spots are not planets at a distance from the Sun, but something adhering to, or very near the Sun's body; and also after a no less clear demonstration of the errors of Lambert's Hipparchian diagram, his lunar parallax, his doctrine of eclipses, and indeed his whole lunar astronomy, together with divers other curious matters, too many to be specified: after this, I say, Mr Crabtrie saith thus:

> Something I am sure you were telling me concerning a way of observing the places of the planets by your glasses. But I have not a little lamented that my time cut me so short, when I was with you, that I could not more fully ruminate and digest those strange inventions which you shewed me, and told me of. My lassitude after an unexpected and unacquainted journey; my unpreparedness for those cogitations (not intending that journey the day before) and the multiplicity and variety of the novelties you shewed me, so wholly distracted my thoughts into admiration, that I cannot now give my meditations any reasonable account of what I saw: but must intreat you, in a few lines, to rub up my memory, and tell me again what you shewed me, and the extent of those your inventions. Which I desire, that I might consider, and rejoice to consider, how much and wherein Urania's structure will grow to perfection by your assistance: and that (what in me lies) I may help you to remember when and wherein your inventions and observations will be of most use. I should also desire you to inform me what bigness of a quadrant

you conceive to be large enough for observation with your devices. For I am e're long going to Wigan, 12 miles from hence, where much brass is cast; and then I could see whether I could procure such an one cast. You told me (as I remember) you doubted not in time to be able to make observations to seconds. I cannot but admire it and yet, by what I saw, believe it: but long to have some farther hints of your conceit for that purpose. One means, I think, you told me was, by a single glass in a cane, upon the index of your sextant, by which (as I remember) you find the exact point of the Sun's rays. But the way how, I have quite forgotten, and much desire. Your device for the exact division of a quadrant, by dividing 11 degrees into 10 parts, I did then understand, but do not now fully remember. If it might not be too much trouble to you, I should intreat you to give me such a paper-demonstration thereof as you shewed me, and two or three lines plainly of the use thereof, how to find those small parts. I lost the little paper, wherein I noted the Moon's diameter, which we observed when I was with you: I pray you send it me, if ... [&c] ... I cannot conceal how much I am transported beyond my self with the remembrance (of that little I do remember) of those admirable inventions which you shewed me when I was with you. I should not have believed the world could have afforded such exquisite rarities, and I know not how to stint my longing desires, without some further taste of these selected dainties. Happier had I been, had I never known there had been such secrets, than to know no more, but only that there are such. Of all desires the desire of knowledge is most vehement, most impatient: and of all kinds of knowledge, this of the mathematicks affects the mind with most intense agitations, I doubt not but you can experimentally witness the truth whereof, and one time or other have been no stranger to such thoughts as mine. And therefore although modesty would forbid me to request any thing (until you give me leave) but what you please voluntarily to impart, yet the vehemence of my desire forceth me to let you know how much I desire, and how highly I should prize any thing that you should be pleased to communicate to me in those optick practices. Could I purchase it with travel, or procure it for gold, I would not long be without a telescope for observing small angles in the heavens; nor want the use of your other device of a glass in a cane upon the moveable ruler of your sextant (as I remember) for helping to the exact point of the Sun's rays. But seeing Urania is ... [&c]

Thus was the most ingenious Mr Crabtrie transported with Mr Gascoigne's devices, although at that time far less perfect than they were in a short time after. And no less affected was the incomparable Horrox, as Mr Crabtrie sets forth, in his third long letter of Dec. 18, 1640, which hath these words:

My friend Mr Horrox professeth, that little touch which I gave him of your inventions, hath ravished his mind quite from it self, and left him in an extasie between admiration and amazement. I beseech you, Sir, slack not your intentions for the perfecting of your begun wonders. We travel with desire till we hear of your full delivery. You have our votes, our hearts, and our hands would not be wanting, if we could further you.

And then after many curious matters (which would take up too much of the Society's time to relate) he thus proceeds:

Your diagrams for perspectives I have viewed again and again, and cannot sufficiently admire your indefatigable industry, and profound ingenuity therein. I am much affected with the symbolical expressions of your demonstrations. I never used them before (but I will do) yet I understand them all at the first sight, and see well the truth of your demonstrations.

To these I shall only add one passage more, and this because it shews some other of Mr Gascoigne's exquisite contrivances, or at least the accuracy of what are mentioned; and that is in Mr Crabtrie's letter of Dec. 6, 1641, at the beginning of which he saith:

That which you give me a full projection of was above my hope: and if the screws keep an exact equality of motion forward in each revolve, it is a most admirable Invention; and with the other accommodations, I had almost said without compare. But that the divisions of a circle should be measured to seconds, without the limb of an instrument, or that distances, altitudes, inclinations, and azimuths should be taken all at one moment, without the limb of an instrument likewise, and each to any required number of parts; or that the diameter of Jupiter should be projected in such prodigious measures as you speak of, &c. were enough to amuse and amaze all the mathematicians in Europe, and may indeed be rather a subject of admiration than belief, to any that hath not known your former inventions to exceed vulgar (I had almost said humane) abilities. And for my part, I must confess modesty so checks my ambitious desires, that I dare scarce hope such miracles should ever be produced in real practice to such exactness.

Then (to give the Society a further taste of those letters) follows an account of the agreement of Mr Horrox's theory of the Moon with Mr Gascoigne's observations; and also very curious ratiocinations, and a disquisition about finding the parallax of the Sun and Moon, and their distance from the Earth. In which he censures Morinus's braggs, &c. and then saith that:

No man that hath written of the diagram [of Hipparchus] understood it fully, or described it rightly, but only Kepler and our Horrox; for whose immature death [which was suddenly, and about the age of 25] there is yet scarce a day which I pass without some pang of sorrow.

Thus, among many, I have related some of the passages of Mr Gascoigne's and Mr Crabtrie's letters relating to telescopick sights. From whence it is very manifest, that long before the French gentleman's claims, our countryman Mr Gascoigne had made use of those sights in his astronomical instruments; particularly in two or more sorts of micrometers (as I plainly find) and in his quadrant and sextant. And had it pleased God to have given him a longer life, we might have expected greater things from his pregnant and sagacious wit, for he was scarce 20 years of age when he held these correspondencies with Mr Crabtrie. And at the age of 23 he was killed at Marston-Moor-Battle, on July 2,1644, fighting for King Charles I. His father was Henry Gascoigne Esq, of Middleton, between Leeds and Wakefield.

Philippe de la Hire

Construction d'un micrometre universel pour toutes les eclipses de soleil et de lune, et pour l'observations des angles

Mémoires de l'Académie Royale des Sciences
Paris: Lambert et Durand, 1717, pp. 57–67.

[Translated by the Director]

There is no doubt that the micrometer is one of the tools most useful in the practice of astronomy. Its perfect construction is due to Messrs Auzout and Picard, as can be seen in a printed paper entitled 'Extract of a Letter from M Auzout of December 28, 1666, to M Oldenburg, Secretary of the Royal Society of England, concerning the way for taking the diameters of the planets', &c. As this had become rare, I thought it best to preserve a record of the invention, and to honour those who invented it by reprinting it in the posthumous works of the gentlemen of the Academy produced in 1693.

It is by means of this instrument that we have determined exactly the eccentricities of the Sun and the Moon by comparing their apparent diameters throughout their motions; and the ease it provides for observing very small distances between the celestial bodies and even the diameters of the planets has been used extensively to develop all of astronomy. With this instrument, eclipses of the Sun and the Moon are very easily observed, and I have always made great use of it in when the opportunity serves me.

[The 3,000-word description of the instrument is not included here]

John Bevis

A letter from Dr Bevis to Mr James Short, F.R.S., concerning Mr Gascoigne's invention of the micrometer

Philosophical Transactions of the Royal Society, 48 (1753), 190–2.

Although Mr Towneley, in his letter to Dr Croon, printed in the *Philosophical Transactions*, No. 25, p. 457, has sufficiently made appear that the invention of the micrometer was Mr Gascoigne's, and that he applied it to measuring small angles in the heavens, and for settling the Moon's parallax, long before Messieurs Auzout and Picard thought of any such matters; yet are the French astronomers at every turn for giving it to these their countrymen, without so much as once mentioning the name of Mr Gascoigne.

No sooner had the late Dr Derham restor'd the application of telescopic sights to quadrants to its true author Mr Gascoigne, than M de la Hire, who never made the doctor any reply on that head, took occasion, in the memoirs of the Royal Academy of Sciences for 1717, to ascribe this contrivance of the micrometer to M Auzout, in conjunction with M Picard; alleging, for proof, an extract of a letter, dated Dec. 28, 1666, from M Auzout to M Oldenburg, and printed in *Phil. Trans*. No 21. Several others have since copied M de la Hire's assertion, and last of all, M Bouguer, in the memoirs of the Royal Academy of Sciences for 1748, lately published, wherein he describes an instrument, which he calls an heliometer; the contrivance whereof seems in every respect the same as that sent about ten years ago to the Royal Society, by Servington Savery, Esq.

I have now before me the copy of a letter of Mr Gascoigne to Mr Oughtred, which I made myself from the original, written in 1640–1; which original was in the possession of the late William Jones, Esq, F.R.S., and is now in the library of the Right Honourable the Earl of Macclesfield. It consists of several sheets of paper, all about his invention for measuring small angles to seconds; where he not only gives the geometrical and optical principles of his contrivance, and the construction of the instrument, but also a series of observations actually taken therewith; some of which I shall transcribe.

			'	"	
1640	Aug. 5	Jupiter's diameter	0	51	
		Mars's "	0	38	
	Dec. 24	Mars's "	0	25	
		Venus's "	0	25	
1640	Aug. 25	Moon's semidiam.	15	17	h 8 p.m.
	Sept. 19	" "	15	11	
	Oct. 9	" "	16	36	
	10	" "	16	36	
	27	" "	15	38	h 7 p.m.
	29	" "	15	41	
	30	" "	15	43	
	31	" "	15	49	

These may suffice to prove, that Mr Gascoigne's micrometer was not a mere thing in embryo, but brought to a good degree of perfection above forty years before that of the French gentlemen was ever so much as mention'd.

As I Please

George Orwell

Tribune, 27 December 1946

Somewhere – I think it is in the preface to *Saint Joan* – Bernard Shaw remarks that we are more gullible and superstitious today than we were in the Middle Ages, and as an example of modern credulity he cites the widespread belief that the Earth is round. The average man, says Shaw, can advance not a single reason for thinking that the Earth is round. He merely swallows this theory because there is something about it that appeals to the twentieth-century mentality. Now, Shaw is exaggerating, but there is something in what he says, and the question is worth following up, for the sake of the light it throws on modern knowledge. Just why do we believe that the Earth is round? I am not speaking of the few thousand astronomers, geographers, and so forth who could give ocular proof, or have a theoretical knowledge of the proof, but of the ordinary newspaper-reading citizen, such as you or me.

As for the Flat Earth theory, I believe I could refute it. If you stand by the seashore on a clear day, you can see the masts and funnels of invisible ships passing along the horizons. This phenomenon can only be explained by assuming that the Earth's surface is curved. But it does not follow that the Earth is spherical. Imagine another theory called the Oval Earth theory, which claims that the Earth is shaped like an egg. What can I say against it?

Against the Oval Earth man, the first card I can play is the analogy of the Sun and Moon. The Oval Earth man promptly answers that I don't know, by my own observation, that those bodies are spherical. I only know that they are round, and they may perfectly well be flat discs. I have no answer to that one. Besides, he goes on, what reason have I for thinking that the Earth must be the same shape as the Sun and Moon? I can't answer that one either.

My second card is the Earth's shadow: when cast on the Moon during eclipses, it appears to be the shadow of a round object. But how do I know, demands the Oval Earth man, that eclipses of the Moon are caused by the shadow of the Earth? The answer is that I don't know, but have taken this piece of information blindly from newspaper articles and science booklets.

Defeated in the minor exchanges, I now play my queen of trumps: the opinion of the experts. The Astronomer Royal, who ought to know, tells me that the Earth is round. The Oval Earth man covers the queen with his king. Have I tested the Astronomer Royal's statement, and would I even know a way of testing it? Here I bring out my ace. Yes, I do know one test. The astronomers can foretell eclipses, and this suggests that their opinions about the solar system are pretty sound. I am therefore justified in accepting their say-so about the shape of the Earth.

If the Oval Earth man answers – what I believe is true – that the ancient Egyptians, who thought the Sun goes round the Earth, could also predict eclipses, then bang goes my ace. I have only one card left: navigation. People can sail ships round the world, and reach the places they aim at, by calculations which assume that the Earth is spherical. I believe that finishes the Oval Earth man, though even then he may possibly have some kind of counter.

It will be seen that my reasons for thinking that the Earth is round are rather precarious ones. Yet this is an exceptionally elementary piece of information. On most other questions I should have to fall back on the expert much earlier, and would be less able to test his pronouncements. And much the greater part of our knowledge is at this level. It does not rest on reasoning or on experiment, but on authority. And how can it be otherwise, when the range of knowledge is so vast that the expert himself is an ignoramous as soon as he strays away from his own speciality? Most people, if asked to prove that the Earth is round, would not even bother to produce the rather weak arguments I have outlined above. They would start off by saying that 'everyone knows' the Earth to be round, and if pressed further, would become angry. In a way Shaw is right. This is a credulous age, and the burden of knowledge which we now have to carry is partly responsible.