LETTERS TO THE EDITOR

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The Origin of the Aurora Spectrum.

PROF. RAMSAY gives the wave-length of the principal line in his new gas as 5566. It will no doubt also occur to others that this is very near the wave-length of the aurora line, which Vogel has measured as 5569. It should be mentioned in connection with this line that Profs. Liveing and Dewar have observed one very near it at 557 in sparks taken in liquid oxygen. The second green line given by Prof. Ramsay as 5557, seems also to have been seen by these observers (*Phil. Mag.*, xxxviii. p. 237, 1894). ARTHUR SCHUSTER.

Manchester, June 10.

The Action of Electric Discharges on Photographic Plates.

REFERRING to the paper on this subject, read on May 16, by Mr. J. A. McClelland, at the Cambridge Philosophical Society, and reported in your issue of June 9 (p. 142), perhaps I may be allowed to mention that very similar experiments, with the deduction that the effect is chiefly due to light, and not to electrolytic or other action, were described by myself in a paper to Section A of the British Association, at its Edinburgh meeting in 1892, and will be found fully reported in the *Electrical Review* for August 26 of that year.

I do not know whether others have observed the fact that when strong sparks from an induction coil or influence machine are allowed to traverse the sensitive surface of an ordinary photographic dry plate, that a dark line, delineating the path of the spark, is immediately produced, and can clearly be seen without any necessity for photographic development. Further, that such lines, though faint to commence with, darken appreciably after a few minutes lapse of time, and still more so in the course of a few hours. This appears to indicate that whatever the precise action of the spark on the film, this action continues after it has once been started. Further, it is a curious fact that these lines, if examined with a magnifying glass, are always found to consist of two dark lines with a light space between them. This is specially noticeable immediately after the spark has passed, the space apparently filling up with lapse of time. A. A. C. SWINTON.

66 Victoria Street, London, S.W., June 10.

A High Rainbow.

ON Sunday afternoon, May 29, while sitting in my yard, my twelve-year-old son called my attention to a rainbow which he had discovered while lying on his back looking up at the sky. The local time here was 5.40 p.m., and the sun, therefore, about an hour and a half high. The bow was in the west, and about 70 degrees from the horizon, with its convex side to the sun. The colours were fairly well brought out, the red being on the convex side of the arc, and the violet on the concave side. The figure on p. 132 of Tait's "Light" shows a short arc near the zenith, which is a fair representation of what was seen here. I have not read an account of what was seen by Helvetius further than is contained in Prof. Tait's book, and do not know whether the arc seen by him near the zenith showed the rainbow colours. In this case I do not see any of the other halos seen by Helvetius. There were but few very thin clouds, and no rain at all. SIDNEY T. MORELAND.

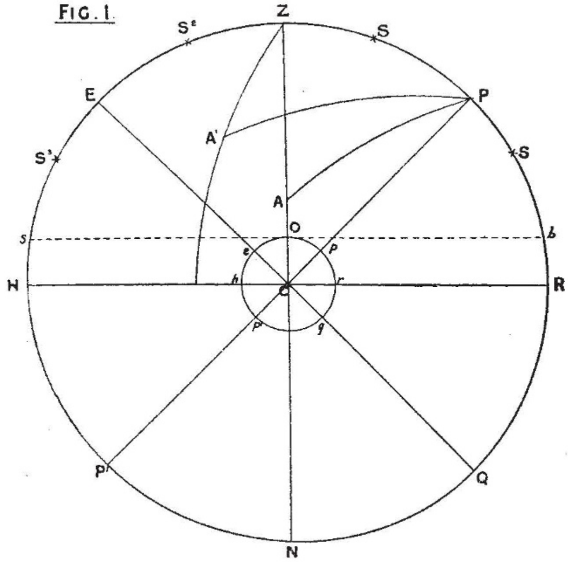
Lexington, Virginia, U.S.A., June 2.

NAUTICAL ASTRONOMY.

IF the compass is the navigator's sheet-anchor, the sextant is certainly his best bower; and just as the former was known, if not generally used in Europe, about a century before Flavio Gioia got the credit of discovering it, so the latter was invented by the transcendent genius of Sir Isaac Newton, more than half a century before it was re-invented by Hadley in 1731. Newton does not seem to have suggested its adaptability for navigational purposes, or if so, it was not sufficiently known or taken up, and I am not aware of any reason to suspect that Hadley knew of Newton's discovery.

The principal use the navigator puts the sextant to is that of measuring the altitudes of heavenly bodies—that is, the angle at his eye subtended between the object and the visible horizon. Now the *rational* horizon may be defined as the plane perpendicular to the plumb-line through the earth's centre, or the circle traced by the meeting of this plane with the celestial concave. The *sensible* horizon is generally defined as a plane parallel to the former through the eye of the observer; but this can only coincide with the *visible* horizon if the eye of the observer is at the surface of the earth—as if he were immersed in the sea, till a horizontal line from his eye would be a tangent to the sphere at that point. But the eye of the observer is always above the surface of the sea; and the more it is raised, the more the visible horizon is depressed, and a correction called "dip" has to be applied to an altitude measured to it, to reduce it to what it would have been had the eye been at the sea-level. Again, before this *apparent* altitude can be used for position-finding, it has to be still further corrected for

FIG. 1.



refraction, due to the bending of the rays of light, in passing through the earth's atmosphere, and in the case of sun, moon, or planet for parallax, to reduce it to the angle at *the centre of the earth and to the rational horizon.* Both these corrections are zero when the body is in the zenith, and a maximum at the horizon. Parallax is the angle at the observed body, subtended by the semi-diameter of the earth under the feet of the observer, which will be reduced to a point when the body is in the zenith. If the body has an appreciable semi-diameter, it has to be applied to the altitude of the limb to get that of the centre.

In the diagram (Fig. 1), let H E Z P R Q N P′ represent a meridian of the celestial concave, and the inner circle the corresponding meridian of the earth; let Z be the zenith, N the nadir, P and P′ the poles of the heavens, being the points in the celestial concave, which would be perforated by the earth's axis if indefinitely produced: then H R will represent the rational horizon, the plane of which, passing through C, is normal to the plumb-line Z O N, *s* O *b* will represent the sensible horizon (O being the position of the observer), E Q, the plane of which is normal to P P′, will be the equinoctial, whose plane coincides with that of the terrestrial equator. On a meridian from E Q towards either pole, the declination of a heavenly body (corresponding to latitude on the earth) is measured, and from the first point of Aries (the celestial meridian passing through which is the prime meridian of the heavens) right ascension is measured round eastward, instead of east and west, as longitude on the earth.

Now let the reader imagine his eye to be at C, that the earth is a transparent sphere, and that it and its atmosphere are absolutely free from refrangibility, then every point in the celestial meridian would be seen through its prototype on the surface of the earth, and any and every angle at C, measures the same arc of the celestial meridian, and of the one on the surface of the earth. Now, what is true here holds good for every other meridian—every other great circle of the celestial concave, and the one that has the same plane on the earth's surface.

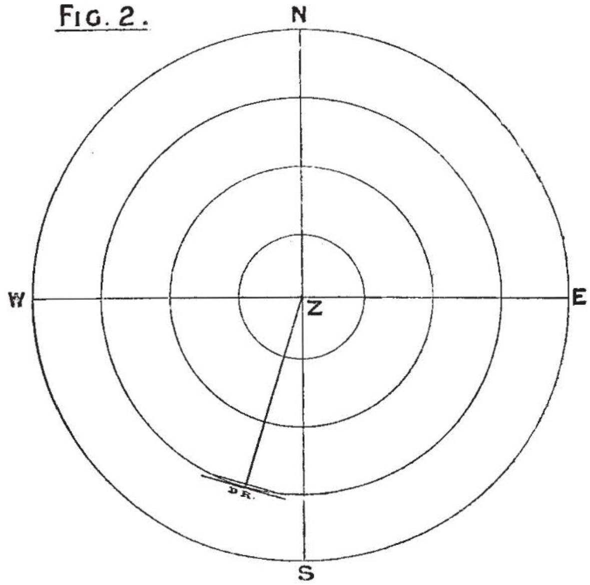
The latitude of a place is the arc of a meridian, intercepted between the place and the equator, consequently *e* O is the latitude of O; but *e* O and E Z are both measured by the angle *e* C O, and E Z = P R, each being the complement of P Z, which accounts for one of the best-known rules in nautical astronomy, viz. that the altitude of the pole = the latitude of the place; so that if there was a star at P, its altitude would give the latitude without any further computation. Let S, S′, &c., be the positions of stars on the meridian. But very little consideration will make it clear that if the observer can measure one of the arcs S R, S^1R, S^2H, or S^3H, and at the same time get the star's declination from the *Nautical Almanac*, it is a mere question of addition and subtraction of arcs to obtain the latitude. P S is the complement of the declination, and $PS + SR = ES^1 - ZS^1 = ES^2 + ZS^2 = ZS^3 - ES^3 = EZ$, the latitude of O. This is known as finding the latitude by the meridian altitude. It gives one line parallel to the equator, on which the ship must be situated. To fix her position on it, we must get another line to cross it, which passes through the position of the vessel, when, manifestly, she must be at the point of intersection. The nearer the cross is to right angles the better. To do this we must find the time, and thence by comparison with the time at the prime meridian (Greenwich is now accepted by most nations as the prime meridian), the meridian on which the ship is situated. Neglecting minor differences and irregularities, the sun appears to revolve round the earth in twenty-four hours, or at the rate of 15° in an hour. Now if we find that it is 9 a.m. at the ship, when it is noon at Greenwich, the ship must be in longitude 45° W. If, on the other hand, the chronometer showed 5 a.m. the vessel would be in longitude 60° E. The Greenwich time may be calculated from a lunar observation, which the perfection of the modern chronometer and the shortening of voyages have driven out of the field. To get the time at ship, we have recourse to spherical trigonometry, or rules and tables based on it, to calculate the hour angle. The sun's westerly hour angle is the apparent time at place (A.T.P.), which is converted into mean time (M.T.P.) by applying the equation of time, which, like declination, &c., is supplied by the *Nautical Almanac*. If the body observed is a star, we get the M.T.P. by adding to the hour angle the star's right ascension, and subtracting that of the mean sun, which is a transposition of the well-known and useful equation, ✱'s hour-angle = M.T.P. + mean ⨀'s R.A. − ✱'s R.A. which we use for time azimuths, and for finding when a body will cross the meridian, for when hour angle = 0

M.T.P. = ✱'s R.A. − mean ⨀'s R.A.

Now, just as the simplest way of getting the latitude is by a body on the meridian, so the best way of calculating the time for longitude is by using the altitude of the sun or a star on the prime vertical (*i.e.* the vertical circle passing through the E. and W. points of the horizon). If, by means of this altitude, or any other way, we could tell the exact instant that the body was on the prime vertical, there being a right angle in the triangle A P Z (Fig. 1), we could calculate the time by right-angled spherics from any two of the three sides, colatitude, polar distance and zenith distance, or their complements latitude, declination and altitude. But in practice, whilst it is easy to get the meridian altitude, it is impossible to be sure of getting the altitude exactly on the prime vertical. It is, however, comparatively easy to observe a body near enough to the prime vertical to be very favourably situated for finding the time by oblique spherics (or formula deduced from it), and thence the longitude; and this, combined with the meridian altitude, is perhaps the simplest and most favourable method of fixing the position at sea. However desirable, it is by no means necessary that the body be near the prime vertical, though, generally speaking, the further it is removed from it, the less favourable the conditions, till at last the triangle becomes an impossible one.

Every particular star is, at every instant of time, in the zenith of some spot on the surface of the earth. At any given instant of time, let Z, in the accompanying figure,

FIG. 2.



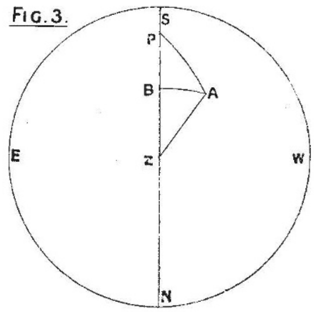
be this spot, as it would be seen from the zenith; then the concentric circles represent circles of equal altitude on the earth's surface, *i.e.* everywhere on the outermost circle the star will be on the horizon (neglecting refraction, &c.). On all places in the next circle the altitude will be $22\frac{1}{2}°$, on the next 45°, &c.; and, of course, there may be an infinite number of imaginary circles between the spot under the star and the outer circle, which brings it on the horizon. Now, it is evident that at whatever point on any of the above circles an observer may be situated, a tangent to the circle at that point will be at right angles to the bearing of the body; but a small portion of the circle may be represented by a similar portion of the tangent, and it is evident that the larger the circle (which is equivalent to the smaller the altitude), the longer the portion of its circumference that may with impunity be treated as a straight line. This straight line is known as "a line or position." The line of position obtained from a meridian altitude differs from all others in this, that the ship is not only on the circle of equal altitude, but on its vertex,[1] and the tangent may be assumed as of infinite length.

[1] Compare figure in paper on "Navigation," (p. 104) illustrating composite sailing, where, however, the circles that touch the parallel are great circles.

The line of position by an altitude for time was first discovered by Captain Sumner, who, being doubtful of what latitude he was in, worked an observation with three different latitudes. On projecting these positions on the chart, he found that all three were in a straight line, which produced, led to the Smalls light, whose bearing he thus had, without knowing how far it was away. He steered along the line till he found it. He did not observe, however, that this line was at right angles to the sun's bearing, nor would it have shortened his problem if he had, because it then took as many figures to calculate one longitude and the azimuth as two longitudes with different latitudes. In these days, when azimuths can be taken out of tables by inspection, nearly half the figures are saved by using the azimuth to obtain the line of position.

Thus, no matter what the bearing of a heavenly body, if we can observe its altitude and the corresponding time at Greenwich, it will afford us some information as to the position of the ship. If it is on the meridian, with a minimum of labour we get the latitude in the simplest and most accurate way available to the navigator. If it is not too far in azimuth from the meridian, there are plenty of methods by which the observation can be reduced to the corresponding meridian altitude, and the latitude obtained. If it is on the prime vertical, the line of position will be a portion of a meridian. If it is on any intermediate bearing, the line of position will be at

FIG. 3.



right angles to the bearing of the body, through the latitude by account, and the longitude deduced from it and the observation. Any two lines of position, provided they do not cross at such an oblique angle that the intersection is ill-defined, will fix the position of the vessel. When the star is so far from the meridian, and the time too uncertain to be favourable for working as an ex-meridian, and yet too far from the prime vertical to give an accurate hour angle, the new navigation, originated by the French, and introduced into England by Captain Brent and Messrs. Williams and Walter, R.N.,[1] gives a better line of position than the older methods. By it you calculate the *altitude* for the position of the ship by dead reckoning. If this agrees with the observed altitude (corrected), the line of position is at right angles to the bearing of the star, through the position by D.R. If, however, the observed altitude is, say, 10′ greater than that calculated, the ship must be that much nearer the spot on the earth where it was in the zenith at the moment of observation; so you lay off 10 miles (1 sea mile being practically 1′ of a great circle) from the D.R. position, in the direction of the star, and through this point rule the line of position at right angles to the bearing; or the corrections for the D.R. latitude and longitude may be calculated by trigonometry (see Fig. 2).

The triangle A P Z (see Figs. 1, 3, 4 and 5) is the most important in nautical astronomy. Up to this, I have only referred to it as a means of finding hour angles (angles at P); but not only is it also used for finding azimuths (angles at Z), for if the time be accurately known, we can utilise it for finding the latitude by a star with a large hour angle. To make it clearer, and avoid complicating Fig. 1, I give figures here on the plane of the horizon. In these, let A represent three different stars, and from A let fall a perpendicular on the meridian. Then right-angled spherics can be utilised, and the latitude obtained with fewer figures than by the new navigation. Either before or after the ✳ or ✳s shown in the figure, are obtained for latitude, observe one on or near the prime vertical, for longitude and time, which will give accurately the hour angles of the latitude ✳s, allowing, of course, for any easting or westing made between the observations. Then

$$\text{Sin AB} = \sin h \sin p,\ \tan \text{PB} = \cos h \tan p \text{ and } \cos \text{ZB} = \sin a \sec. \text{AB}$$

h being the hour angle, p the polar distance, and a the true altitude. The sum or difference of PB and ZB = the colatitude. This method is even shorter than it appears at first sight (because the logs. can be taken out in pairs), and is concise and accurate when the data is trustworthy, and, even if the hour angle is doubtful, will give a good line of position.

Unfortunately, the navigator has often to work with data that are more or less doubtful. In the triangle, A P Z, he uses the three sides to find the hour angle (P). Of

FIG. 4.

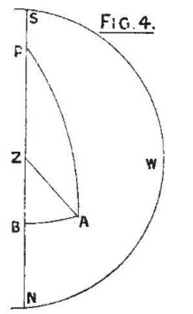
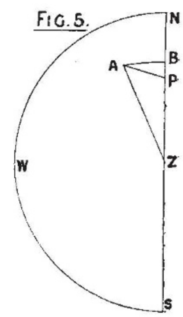


FIG. 5.



these the polar distance is accurate; the latitude is often doubtful enough to affect the hour angle, though not generally the line of position, and the altitude may be vitiated in various ways. It therefore behoves him to take his observations in a way that errors, that he can neither detect nor avoid, will neutralise each other. Few human eyes are optically perfect; the best sextants, though beautiful instruments, are not absolutely faultless, and their errors are liable to alter by a knock or jar; the sea horizon is fickle, and refraction uncertain; but the whole of these errors may be minimised, if not absolutely eliminated, in the resulting latitude—for example, by observing (Fig. 1) the ✳'s S^1 and S^2. With about the same altitude, their refraction will probably be similarly affected; the horizon is *generally* subjected to the same influences all round; the personal and instrumental errors may be taken as constant, for the same observer and sextant, at any particular time and place when the altitudes are somewhat similar. Suppose the sum of these errors to be −2′, and unallowed for, the effect would be, in each case, to make S^1 and S^2 appear nearer Z than the truth; and while each resulting latitude would be 2′ wrong, the mean would be correct.

Again, in the single altitude problem (Figs. 3, 4 and 5), if the time had been calculated by two stars, one east and the other west, the time and thence the hour angles of the latitude ✳s would be less liable to the foregoing errors; and if the three stars were taken and worked for latitude, each would be a check on the others, and opposite bearings would tend to neutralise errors of

[1] "Exmeridian Altitude Tables and other Problems," by these authors, is an excellent work.

altitude. At the same time, single observations very generally give sufficient accuracy for all the purposes of navigation, though they are not to be so absolutely relied on as a systematic set.

I must not conclude without another word on the lunar method of finding the Greenwich time, which I dismissed rather summarily, further back, in favour of chronometers. For long voyages across the ocean, when a vessel is from fifty to one hundred days without sighting land, lunars may still be used, as before the days of steam, not so much for finding individual longitudes as for *rating the chronometers*, and for this purpose it is essential that a series of distances be measured on each side of the moon, and the mean of all the easterly ones, meaned with the average result of those taken to the westward, to eliminate as far as possible personal and instrumental errors. An expert lunarian, who practises regularly, may find out by experience about how much on each side, single distances, measured east or west, would place his ship; otherwise, the result of a single lunar could not be relied on to give the longitude to nearer than $\frac{1}{2}°$ or 30′, even if taken under favourable circumstances. In a steamer vibration almost precludes the observation, and the chronometers ought seldom to be 5s., and never 30s. wrong. In ports where there are not time-balls, the chronometer errors can be found accurately with the artificial horizon, observing, if possible, ✳s east and west, or the ☉ and ☽, or even by the ☉ alone. It is generally possible to verify the errors at sea by sighting land, or even to get a fair rate, by observing ✳s E. and W. of meridian to the sea horizon. An error in the chronometer does not alter the *direction* of a line of position, but moves it bodily E. or W.

As an example of the use of a single line of position, suppose a steamer to be approaching Cape Finisterre from the Channel, and only able to obtain one observation, the sun right ahead. The line of position, being at right angles to her path, will be a good check on her speed, but none whatever on the course she has made good. On the other hand, if the sun (or star) had been observed on her beam, the line of position would be no check on the speed, but would indicate the course made good, and whether, if it was continued, it would clear the land. In soundings, a line of position may be combined with the depth of water to fix the position.

The tendency of modern navigation is to become too stereotyped—to do everything by tables, which obscure the mental vision, and to relegate to the bookshelf that knowledge of theory which, combined with practical experience, is the surest guide to the navigator in deciding on the best way of utilising his observations, and which method, in any particular case, will give him the best line of position. If theory is not the only thing that will teach him, that while when the sun culminates near the zenith, he can get good observations for time within a few minutes of its passing the meridian, a Sumner line derived from such observation would be almost useless, owing to the smallness of the circle of equal altitude; it will certainly make him acquainted with the fact in a tenth of the time that unaided experience will. Some of the so-called short methods are only short because of preliminary calculations that are not counted by the authors in the work, and which may all go for nothing if some particular altitude is not obtained, that a passing cloud may render it impossible to measure; or else they involve several vexatious interpolations, which are quite as much trouble, and, if performed mentally, much more liable to error, than taking out and adding up a few lines of logarithms.[1]

[1] Every aspiring young navigator should make himself acquainted with spherical trigonometry, especially with "Napier's Analogies," which combine the brevity of short methods and special tables with the accuracy of pure mathematics. He should also accustom himself to drawing the figures for his problems till he can see the triangle in his mind's eye without a diagram.

Finally, it is better to get several observations of different bodies at (or about) the same time, than two of the same, with the requisite interval for change of bearing, because one of these observations has to be reduced to what it would have been if taken at the same place as the other, and the reduction may be vitiated by errors of the run, as explained in the paper on "Navigation," which it is one of the great objects of nautical astronomy to detect and be independent of. J. F. RUTHVEN.

THE LONDON UNIVERSITY BILL.

ALL friends of scientific and educational progress will be glad that the second reading of the London University Statutory Commission Bill was carried in the House of Commons on Tuesday without a division, and has been referred to the Standing Committee on Law. We are thus brought within sight of a long-delayed and much-needed reform, and all who have assisted in educating public opinion upon the measure, with the object of removing the unreasonable obstruction placed in its way, may congratulate themselves upon the success which their efforts have at last achieved. It is not to the credit of Ministers that a scheme of such deep importance to the best interests of the country should have been permitted to languish for so long a period, seeing that the necessity for establishing a teaching university in the metropolis is admitted by practically all public bodies connected with science and higher education in London. Had they possessed the courage of their convictions the measure would have passed into law without difficulty in 1896 or 1897, and its withdrawal upon each occasion must be counted as a lost opportunity. The opposition which then threatened the scheme would doubtless have collapsed so completely as it did on Tuesday, when it received so little support that the measure was agreed to even without a division. We reprint from the *Times* some parts of the speech made by Sir John Gorst in moving the second reading, and of the speeches which followed.

Sir John Gorst commenced by giving a general history of the scheme for a teaching University, and pointed out that the present Bill is based on the report of the Cowper Commission, which unanimously recommended that there should be no second University in London, and that the necessary modification of the constitution of the London University should be effected by means of a statutory Commission. He continued: "I should like to inform the House of the various bodies by which this scheme has been considered and accepted. It has, first of all, been accepted by the Senate of the University of London by a majority of 22 to 2—practically a unanimous acceptance by the Senate of the University of London. It has been accepted by the Royal College of Physicians, by the Royal College of Surgeons, by the Society of Apothecaries, by University College, by King's College, by the Bedford College for Women, by the twelve medical schools which exist in London, by six theological colleges, by the Society for the Extension of University Teaching, by the Technical Education Committee of the London County Council, by the Corporation of the City of London, by the City and Guilds Institute, by the Polytechnic Council, by the Royal Society, and all the other learned societies in London; and, finally, it has been accepted by the Convocation of the University. I say it has been accepted by the Convocation of the University of London because, by the charter of the University, a particular mode is specified in which the Convocation of the University of London shall express its opinion on the subject. The Convocation expresses its opinion by a meeting at which discussion takes place, and at which a vote is given by the persons there present. Such a meeting of Convocation has been held, and this present scheme has been approved in that legal and formal manner in which the charter of the University requires the opinion of Convocation to be expressed—by a majority of 460 to 239."

Referring to the views of graduates as shown by voting papers, Sir John Gorst said, "Even assuming that the existing graduates of the University of London were unanimous in their