cluding the Azores, Madeira, Canaries, and Cape de Verde Islands); (2) *Oriental*, or, rather, *Central and Oriental African*; (3) *Western African* (from the Gambia to the Congo); (4) *Southern* (included by a line drawn from Kalabini to Limpopo, and comprising a portion of the eastern coast to the Mozambique); (5) *Malagasic* (*i.e.* the Lemur country with Madagascar). Various expeditions and other means by which materials have been obtained are mentioned, and a bibliographical list is given, in the introduction, of the numerous published works and papers on African Arachnida from the days of Linnæus to the present time. The Arachnida described and recorded in this first part are from Tunis, while the second part (published *loc. cit.* vol. xvi. 1881) simply contains an account of a collection of Arachnids from Inhambane (in the southern region), with some considerations on the Arachno-fauna of the Mozambique, of which a list of species is also added.

The Tunisian collection described in Part I. numbers 115 species of six orders: *Scorpionidea*, 6 species (Scorpiones, 5; Pseudoscorpiones, 1); *Solpugidea* (Solifugæ), 4; *Phalangiidea* (Opiliones), 4; *Araneidea* (Araneæ), 96; *Acaridea* (Acari), 5. Of the above, two new genera, and eleven new species (all but one of the latter—a pseudo-scorpion of a new genus) belong to the Araneidea. As might be supposed, the essential character of the Tunisian collection is South European or Mediterranean. Very different from these are the arachnids described and recorded in Part II. from Inhambane and the Mozambique. Here we have, though the number of species is very scanty, the true tropical character. Only 54 species are recorded, comprised in 43 genera, 20 families, and 5 orders. The larger part (35 species) belong to the *Araneidea*, of which 1 genus and 4 species are new. Coming now to the Arachnida recorded and described in Part III. from Scioa (in the eastern zoological province) we have 71 species belonging to 49 genera, 18 families, and 4 orders. A general catalogue is also added of Abyssinian Arachnida, which, including those from Scioa, number 124 species. It is noted as remarkable that no scorpions were contained in the collection from Scioa, and that 30 of the Arachnids recorded are new to science; also that only 12 of the Scioan species are common to the rest of Abyssinia.

The author enters into some other considerations on the distribution of the Arachnids of Abyssinia; but the researches and materials on which his observations are based appear as yet to be too scanty to sustain any very general conclusions. At the same time it must be acknowledged that the plan on which the author has worked, of bringing the materials of so large and varied a region as the African peninsula under the geographical divisions announced in the introduction to Part I. is a most useful one, and the work he has done so far is undoubtedly a valuable contribution to arachnological science.

O. P. C.

MR. BURNHAM'S DOUBLE-STAR MEASURES

THE recently published volume of the *Memoirs of the Royal Astronomical Society* contains a further series of measures of double stars by Mr. S. W. Burnham, made with the 18-inch refractor of the Observatory at Chicago. This series comprises measures of 151 double stars discovered by this eminent observer, which brings up the number of such objects discovered by him during the last ten years to no fewer than 1013, amongst which are included some of the most interesting stars of this class; also measures of a selected list of double stars, 770 in number, made chiefly in the years 1879 and 1880, with an appendix, the results of observations of several objects, as late as the middle of the past year. Every one who is interested in this branch of astronomical science will read with much regret one remark in Mr. Burnham's introduction: he writes:—"The present catalogue will conclude my astronomical work at least so far as any regular or systematic observations are concerned." He expresses himself modestly respecting his own labours—"In a field so infinitely large, one can accomplish but little at the most, and how much, or how little, the astronomers of a few centuries hence can perhaps best decide. . . . At this time I may venture to claim that my work in this field has been prosecuted with some enthusiasm, and for its own sake only, and that my interest has not been divided among several specialities."

But a higher estimate of Mr. Burnham's work in this particular line of observational astronomy to which he has devoted himself may be justly taken. To read of the discovery of upwards of a thousand double stars within a limited period by one observer, we might almost suppose we were living in the days of Sir William Herschel, when the heavens were comparatively an open field, and had not undergone the wide and close exploration which they had done when Mr. Burnham commenced his work. He has had, it is true, the advantage of instruments of the finest class, and we may believe an unusually acute vision; but he must have exercised an extraordinary and most meritorious amount of patience, perseverance, and care in the discovery and accurate measurement of such a list of double stars, and it will be gratifying to the astronomical world that such well-directed exertions have met with so exceptional a success.

Among the more noteworthy stars included in Mr. Burnham's new Catalogue (the fourteenth), which may be considered a continuation of that published in vol. xliv. of the same *Memoirs*, the following may be mentioned:—

1. 126 Tauri (β 1007), "a most remarkably close and difficult pair, one of the closest known"; magnitudes 6·0 and 6·2. With a power of 1400 there was only a slight elongation.

2. B.A.C. 346; Mr. Burnham thinks the principal star may be variable, and he is certainly correct in his surmise. Heis gives it as a naked-eye star 6·7 m, Gould 7·0 m., and it has been several times noted 8 m.; while the writer has recorded it as low as 9 m.

3. β 117; a star with a proper motion, according to Argelander, of 0″·438; measures in 1883 show a common motion of the components; their distance is 2″·2.

4. ζ Sagittarii; detected by Winlock, probably a retrograde motion of 225° in less than fourteen years; and evidently a change of 48° in less than three years, by Mr. Burnham's measures alone. It is an object for large instruments in the other hemisphere.

5. β Delphini (β 151).—A very rapid binary; since its detection by Mr. Burnham in 1873, there has been an increase in the angle of about 180°, and a diminution in distance from 0″·6 to 0″·25. He thinks "it may prove to have, with the single exception of δ Equulei, the shortest period known."

Mr. Burnham collects the measures of δ Equulei, and infers a period of revolution of about 10·8 years. Measures should be easy again in 1885.

6. 85 Pegasi (β 733).—The close pair was not measurable in 1882; the angle was about 323° at the epoch 1883·75. The mean annual motion is about 12°·5, at which rate the period would be less than thirty years.

In the introduction to the Catalogue will be found references to the publications where the thirteen previous ones are to be found.

MEASURING THE AURORA BOREALIS

THE study of the height of the aurora borealis above the earth's surface is, it will be easily conceived, of the greatest importance in understanding the nature of this phenomenon. Unfortunately the height of the aurora has always been, and is to some extent still, a moot point in natural science. There are, of course, not wanting estimates and observations relating to this question, but the general results of these, particularly of the earlier ones, are very contradictory. There seems, however, to be every probability of this problem being very soon solved.

As a basis for the measurements of the aurora we have generally selected the arcs or the more pronounced solitary streamers, when they have been clearly and simultaneously observed from two points situated some distance from each other, the apparent height or position in each place having been determined by comparisons with, and measurements of, stars. In consequence, however, of the rapid shifting both of appearance and position of the auroræ, this method is difficult and unsatisfactory, and these drawbacks may to a great extent explain the very divergent results which have been obtained by the same.

In order to give an idea of the manner and principle of measuring the auroræ in their simplest form I venture to describe the method I have been in the habit of following.

On March 17, 1880, a great aurora was observed at the 145 stations which I had established over the southern part of Norway, the west coast of Southern Sweden, and in Denmark. One of the characteristics of this phenomenon was a large broad arc, or, perhaps more correctly, band, which for a long time spanned the sky from east to west. In Bergen (Norway), where my own observatory was established, it remained for some time in the zenith, then moving a little to the south, but at the stations lying further north it was seen in the south, while at those south of Bergen it was seen in the north.

By its characteristic internal repose and slow motion this remarkable band was especially suited to establish the identity of this aurora at the various stations and to serve as a basis for its measurement. It had apparently, when in its most southern position, no connection with the types which appeared simultaneously in the north, the latter being streamers which it was impossible, from their rapid change of form and appearance to observe connectedly at the various stations.

If the various reports of this auroral phenomenon be examined, not the slightest doubt will remain of the object seen being the same, *i.e.* that the same arc was observed at the most southern as well as the most northern stations. The further we move southwards however—away from the same—the more the apparently observed height diminishes, until we find that at the most southern points it was seen merely as an ordinary low-lying arc. In Bergen no trace of an auroral phenomenon was seen south of the band in question, and the reports from the stations south of this place all agree that neither was any seen there. From this we may conclude with certainty that the auroral arc observed in the zenith of the horizon of Bergen was the identical one seen at all the southern stations, and that the line of demarcation of the phenomenon seen from that place was the absolute southern extension of the band.

Before it is possible, however, from the observations before us to measure the height of the arc, it is necessary to ascertain its direction and its position in space relatively to the localities on the surface of the earth from which it was seen. In the main the point of culmination of ordinary auroral arcs is in the direction of the magnetic north of the place of observation, and the arcs themselves follow approximately the magnetic parallels. I found, however, from careful calculations that the apex of this arc deviated some 10° west from the magnetic meridian, and that its course or strike was at an angle of about 25° with the geographical parallel circles.

The calculation of the height of the arc rests on the following principle. If in Fig. 1 S and S′ denote points of observation, C the centrum of the earth, and P two points in the aurora borealis situated in the same perpendicular plane through S and S′, whose angles above the horizon h and h' have been determined at each station, and the longitude and latitude of each place is known, it is possible (by a well-known trigonometrical formula, viz. $\cos d = \cos (l - l') \cos b \cos b' + \sin b \sin l'$, where l and l' indicate the longitude and b and b' the latitude of the two places, and d the distance or great circle between the two) to find the arc S S′, which is equal to S C S′. From this again S S′ ($\frac{1}{2}$ S S′ = sin $\frac{1}{2}$ S C S′) is found. Further, $\angle\, x = x' = \frac{1}{2}$ S C S′. One knows, therefore, in the triangle S P S′, the side S S′ and the angles P S S′ and P S′ S, so that its other parts, as for instance P S, may be ascertained by means of some simple trigonometrical calculations. If P S is known, we further obtain, in the triangle P S C, S C, which is equal to the radius of the earth, and the angle P S C = $90° + h$. From this P C is found, and, subtracting S C, the perpendicular height of P above the earth's surface is determined. Finally, if ∠ P C S is ascertained, the point on the earth above which P is situated perpendicularly is found.

In practice the matter is, however, not quite so simple. The method presupposes thus that P lies in the same

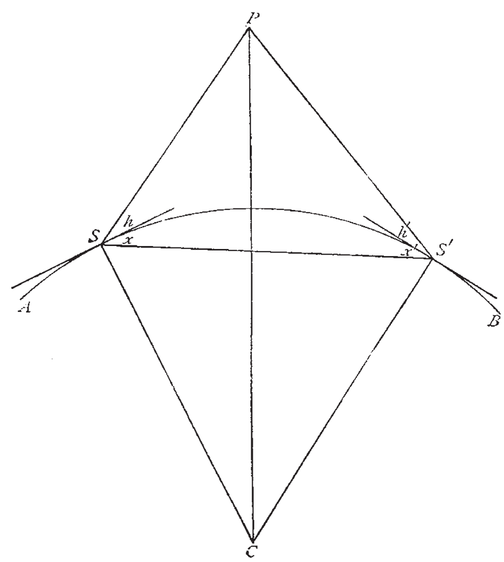

Fig. 1.

vertical plane as both points of observation, which would rarely occur, but still it retains its adaptability, even if P only indicates a point in the upper or lower edge of the auroral arc, the culminating point of which has been determined in both places, provided that these lie in the same plane perpendicularly in the longitudinal axis of the circle, or may at all events be referred to such a common plane.

It is, however, far more difficult to overcome another drawback. Provided that the arc has a perceptible thickness in relation to its horizontal breadth, those parts of the upper or lower edge of the arc which present themselves to the various observers cannot always be referred to the same parts of the arc, in consequence of the circumstance that the apparent breadth, particularly with the lower arcs, is due to a combination of both the real breadth and thickness of the arc.

If a, b, c, d in Fig. 2 represent the circumference of a circle observed from the points A, B, C, assuming that the line of demarcation of the arc north and south is parallel with the inclination needle, the point a will denote the upper (southern) edge for A and B, for C on the other hand b; and, in a similar manner, the lower (northern) edge is determined by the point d for A and B, c for C, &c.

Now if the determination of the apparent height of the upper edge for A and C is taken as a basis for calculation, the height of the same cannot be ascertained therefrom, but from the crossing point of the lines A *a* and C *b*, and so forth. A great many other variations may also be met with according to the dimension and position of the arc. Generally, however, when the arc lies on one side of both places of observation, the edges observed in the respective places are identical.

In the following simple manner I have succeeded in referring the various places of observation to the vertical plane of Bergen, where my own observatory is situated, in order to find the arc S S′ in Fig. 1. The direction of the arc I have, in accordance with observations, let form an angle with the circles of latitude of 25°. I have constructed a globe with the circles on a large scale in Mercator's projection, on which the various stations have been denoted. Through the place "Bergen" a straight line is drawn under an angle of 25° with the circles of latitude, while the perpendicular distance of the various stations from this line has been determined in the construction and by direct measurements. The stations whose observations are so complete that the angle of the arc above the horizon has been determined have been combined with Bergen. I have succeeded in forming nineteen such combinations. The heights of the arc calculated at these

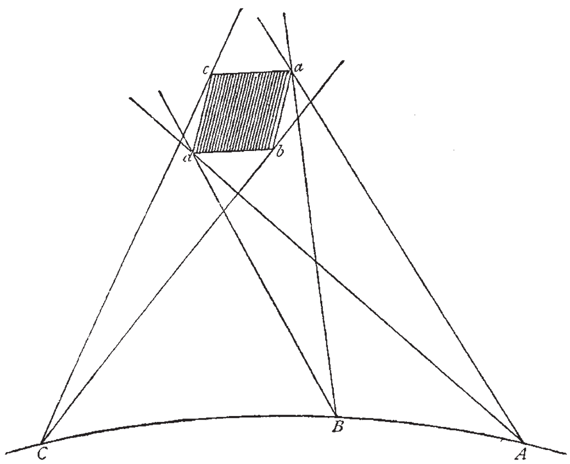

Fig. 2.

stations vary somewhat, but not very much, and if an average is taken we find that the value of the height of this arc above the earth's surface was most probably 146·95 km.

It further appears that the observations were not exact enough to obtain an estimate of the thickness of the arc, so that we can only accept the figure given above as an average one, *i.e.* an average of the distance of the uppermost and lowest layers from the surface of the earth.

If we compare the height arrived at in this case with those obtained through previous researches, we shall find that it agrees to some extent with the value of the arcs measured in recent times. They differ, however, greatly from old ones. Thus Prof. Fearnley finds, through observing sixteen auroral arcs from *one* spot, in Christiania, by an ingenious theoretical method, that the average height in these cases was 27·15 geographical miles, or 201·5 km. Newton found, by the same method, that the average height was 130 English miles, or 209·3 km., while Nordenskjöld, by a similar method, has come to the conclusion that it is 190 km. The French expedition established at Bossekop during 1838-39 obtained no reliable statistics on this point, owing to the small distance between the two points of observation, viz. 15·6 km. But from the results obtained it seems that the height must be sought between 100 and 200 km.

In opposition to this Bergman fixes the height at 753 km., Boscovich at 1328 km., and Mairan at 780 km. More in correspondence with our result Dalton found the height of the auroral arc to be 241 km., and Backhouse found the three measured by him to lie between 81 and 160 km. On the other hand, Franklin found at Cumberland House (North America) that several auroræ which he measured had a height only of 11·3 km. In fact, the *savants* who have studied the aurora borealis in the Arctic regions appear to agree that it does not attain the height given above as the results of researches further south.

I have here only mentioned a few of the very divergent values obtained in measuring the aurora borealis, but I

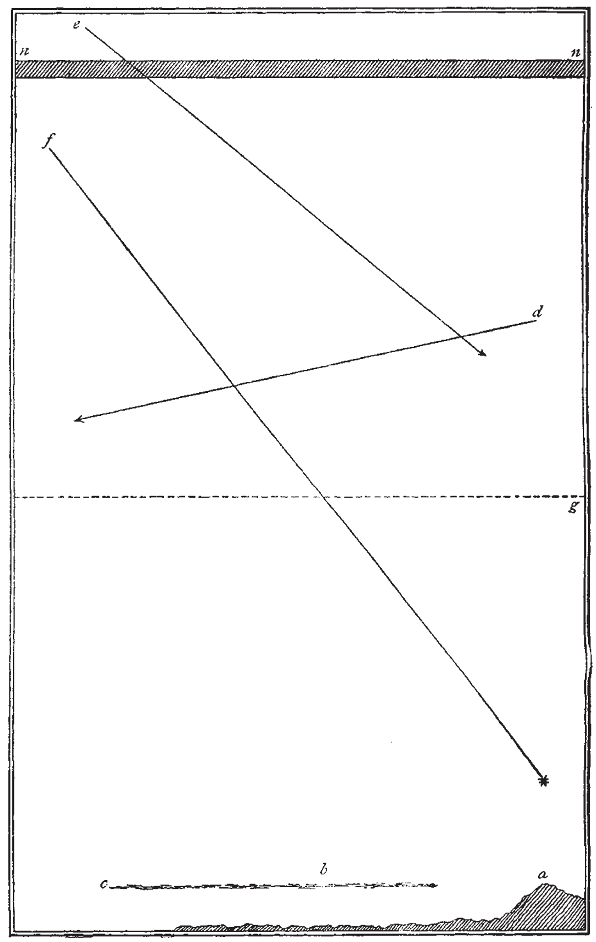

Fig. 3.

do not believe it will be of any service to append more, as the values range from 0 to 2000 km.

In Fig. 3 I have attempted to illustrate the height of the aurora referred to by me by comparing it with other well-known heights. The scale is 1 mm. = 1 km. Below is drawn a profile of Norway from Bergen in a direction E. 25° N. The heights here range to upwards of 5000 feet. Above *n n* indicates the arc of the aurora in its height of 146·95 km. The thickness given is wholly approximate, and probably too small. For comparison is inserted, *a*, the highest mountain in the world (Mount Everest, 8839 m.); *b*, the greatest height reached by man (Glaisher and Coxwell in their balloon on September 5, 1862, 31,800 feet); *c*, the estimated height of the cirrus clouds (25,000 feet); *d*, the plane of the August meteors—beginning and ending (155 and 98 km.); *f*, the point of appearance and disappearance of the large meteor which was seen on March 4, 1863, in England, Holland, Belgium, and Germany (134 and 26 km.); and finally *g*, the hypothetical height of the atmosphere (10 geographical miles = 74 km.).

With regard to the results of the measurements of the aurora which I effected during last winter at Kautokeino, in conjunction with the stations at Bossekop and Sodankylä, I may be brief, from the circumstance that the observations made at the latter station are not to hand, while the material at my disposal requires a more careful analysis than I have as yet been able to bestow upon it.

I must, however, state that a preliminary examination of the observations made in the plane Kautokeino-Bossekop has led to the important discovery that the aurora borealis, at all events in this locality, lies in a plane at least 100 km. above the earth. I have examined all the observations made simultaneously at the two stations, and have not found the slightest indication of the aurora descending to a level in which it would only be visible at one of them, while there seems to be no reason for assuming that the types observed were not identical, when due regard is paid to the difference in the height above the horizon of the two stations.[1] The distance between Kautokeino and Bossekop is about 107 km.

I have, on the principle indicated in Fig. 1, made a series of preliminary measurements of the lower edge of auroræ observed at both stations, having selected only those where there cannot be the least doubt as to identity, from which I have obtained the following values in kilometres:—76·0, 79·9, 84·6, 93·6, 97·7, 98·2, 99·0, 100·0, 100·6, 107·0, 116·6, 124·1, 124·9, 131·9, 141·6, 144·9, 149·0, 163·6.

If the average of these eighteen measurements is taken, the average height of the lower edge will be 113 km., *i.e.* a result which is in perfect harmony with the later observations referred to above.

To give any definite results of the studies of the thickness of the arcs, the length of the streamers, &c., is, of course, impossible, until the material has been carefully sifted. I may here in passing observe that we must in all estimates of the height of the aurora borealis be content with approximate figures; this lies in the nature of the case, apart from inaccuracies in the measurements which it is impossible to avoid. The aurora borealis has, in common with clouds, no absolutely defined and fixed line of extension, either downwards nor upwards. We must therefore rest content with ascertaining only approximately the height of the plane in which the aurora borealis appears.

That the aurora generally appears at a height of 100 km. or more above the earth's surface does certainly not preclude the possibility of its appearance on some occasions much nearer the earth. In fact there are a considerable number of reports in our hands which imply that this is really the case. Thus observers aver that they have seen auroræ below the clouds, in front of mountains and icebergs and coasts, and even on the very ground. These assertions have been greatly doubted as being the result of the imagination, or optical illusions, but with what justice I will not venture to say. For my own part I can only say that during my long stay at Kautokeino I had unfortunately often enough occasion to observe auroræ and clouds simultaneously, but although always paying the closest attention to this particular point I have never seen even a fragment of an aurora in front of or below the clouds. Even the most intense development of light, colour, and motion occurred always above what seemed to be the very highest-lying clouds.

[1] The experiences of Prof. Lemström at Sodankylä (NATURE, vol. xxvii. p. 389), which seem to point in a different direction, I intend to discuss on another occasion.

When the entire material relating to the study of the aurora borealis has been collected from the various international circumpolar stations, sifted and carefully analysed, the question of the height of the aurora borealis will not, I believe, long remain one of the unsolved problems of nature. Until then the reader must remain content with the discoveries I have indicated in this paper.

SOPHUS TROMHOLT

COUNT DU MONCEL

COUNT THEODORE DU MONCEL, whose death we briefly announced last week, was born at Paris on March 6, 1821. His father had been a General of Engineers under Louis Philippe, and the son was at one time destined also for the army. When but eighteen years of age he showed a predilection for scientific pursuits, and published two treatises on perspective, treated mathematically and artistically. He was also at this time an enthusiastic archæologist and traveller. In 1847 he published a volume entitled: "De Venise à Constantinople à travers la Grèce," illustrated with lithographic plates drawn by himself. His family objected to his democratic pursuits, and became estranged from him. In consequence he determined to adopt science as a profession. But not having studied at the Ecole Polytechnique, nor at the Ecole Centrale, he lacked those scholastic recommendations without which, in France, promotion is so difficult. A professorship being absolutely closed to him, he became a scientific writer, and devoted his attention chiefly to electricity. In the years which followed he zealously sought to acquaint himself with every new discovery and invention which was made; and his industry in collecting and disseminating information on electric science was immense. During the years 1854-1878 he published at intervals in five volumes, his well-known "Exposé des Applications de l'Electricité," a work which, though it relates chiefly to inventions and instruments now superseded by newer forms so abundantly poured forth during the past few years, nevertheless maintains its place as a standard work of reference in electric technology. Since 1878 Count du Moncel published several volumes containing popular expositions of various branches of the science. His work on the Telephone and Microphone has been translated into English; so also has his work on Electric Lighting, and that on Electricity as a Motive Power. Thoroughly in his element as a writer for the scientific press, and more of a journalist than a man of science, Count du Moncel nevertheless distinguished himself by a series of valuable contributions to science, chiefly in the form of papers read before the Académie des Sciences. His researches on the properties of electromagnets and on the conductivity of badly-conducting bodies are worthy of mention. To du Moncel we owe the observation that the variation produced by pressure in resistance offered at the point of contact between two conducting bodies—a phenomenon well known before his time—is more marked in certain bodies than in others, wood-charcoal being one. In this observation he laid the foundation for the subsequent applications of this principle made by Clérac and by Edison. Du Moncel was also an inventor, and obtained a gold medal at the Exposition of 1855 for the collection of instruments exhibited by him, including an electric water-indicator, an electric anemograph, an electric recorder of improvised music, a recording galvanometer, and sundry telegraphic instruments. From 1860 to 1873 du Moncel was occupied as electrician to the administration of telegraphs; but he quitted the post somewhat abruptly in 1873 in consequence of disputes in the administration. In 1874 he was elected a member of the Académie des Sciences, in which body he was very active in bringing forward accounts of all discoveries in his favourite science. It was he who thus successively intro-