dome-shaped hood, which is fixed a little above the arc itself. A rather long arc is burnt, and the effect is very similar to that produced by the Bremer lamp, only the light is of a slightly different colour. This lamp is also said to be three times as efficient as an ordinary arc.

We have not space at our disposal to describe the exhibits fully. There is one other, however, which deserves special comment on account of its ingeniousness and possibly great importance. This is the Partridge "Sparklet" fuse, exhibited by Messrs. Elliott Brothers. This fuse is designed more especially for high-tension circuits carrying heavy currents. When the fuse in such a circuit goes an arc forms, and in order to prevent this burning, either a very long fuse or some form of oil fuse is used. In Mr. Partridge's "Sparklet" fuse a short length only is used, and the terminals of the fuse wire are connected to an ordinary sparklet such as is now a familiar article for making soda-water. The arc when it forms burns between the two sparklets, and in a very few seconds one or other of these is burnt through; the carbon dioxide immediately rushes out through the hole and blows out the arc. It will readily be understood that the more current the circuit is carrying, and the more power there is in the arc, the sooner will the sparklet burn through, and also the hole being larger the more certain it will be in its action. At the Agricultural Hall a model fuse was shown working a circuit of 2500 volts. The current was small, only about 6 amperes, the power being therefore about 15 kilowatts; yet the arc was blown out in less than three seconds. Two sparklets are used, one at each end of the fuse, in case one should be defective; but this precaution has never been found necessary during all the experiments and trials that have been carried out. For the past eighteen months the apparatus has been in practical use, and has proved, it is said, thoroughly satisfactory. Mr. Partridge is certainly to be congratulated on a very ingenious idea; it remains to be seen whether it will prove a sufficient cure for all the troubles that are likely to be met with now that large-power high-tension circuits are becoming common. M. S.

THE ASTROGRAPHIC CHART.

IT is probably well known, even to those who are not astronomers, that an astronomical enterprise of considerable magnitude was initiated fifteen years ago, and is steadily, although somewhat slowly, progressing towards completion. In the year 1887 a conference of astronomers met at Paris to consider the best means of cooperating to make a complete map of the heavens on a large scale, and with all possible attention to accuracy, by photography. As the outcome of this conference, eighteen observatories of various nationalities undertook the work, the whole sky being divided up into eighteen zones; a zone assigned to each observatory with due regard to its geographical position. A standard pattern of photographic telescope was chosen, and all the eighteen observatories obtained instruments of the required type and set to work. The enterprise being in several respects entirely new, it has been necessary to guide the procedure in the light of experience acquired; and conferences assembled at Paris in the years 1889, 1891, 1896 and 1900 to report progress and compare notes. At the last of these conferences a second enterprise was undertaken. The small planet Eros, discovered in 1898, was to make a particularly close approach to the earth in the winter of 1900–1, thus affording an opportunity, the like of which would not recur for thirty years, of determining the solar parallax; it was felt that, although the main object of the association of observatories (viz. the formation of the Astrographic Chart) was not yet attained, still the advantages to astronomy which would result from utilising this exceptional opportunity were too great to be neglected, and it was resolved that the cooperating observatories should add to their programme the photographic observation of the little planet during the months October 1900 to February or March 1901. In connection with this second enterprise it has been found necessary to circulate a large amount of statistical material, such as approximate positions of the planet on different dates and of all the well-known stars lying near his path in the heavens, lists of the observations made at the different observatories, so that one might know how to match plates with another, and so on. The energy of the director of the Paris Observatory (who has from the first acted as director of the whole work) in printing and circulating this material has been most noteworthy. We have recently received the *ninth* circular relating to Eros, which is itself a pamphlet of 200 pages quarto, and represents a vast amount of work. In the first place, M. Lœwy discusses, in two long memoirs (supplementing a former one already published), what accuracy is obtainable from measures of photographic plates and what precautions are necessary to obtain that accuracy. The discussion is concerned with a number of minute details, and involves the adjustment of conflicting advantages, so that there is room for difference of opinion in the conclusions; but there can be but one opinion of the value of the material patiently collected and tabulated by M. Lœwy, which can be examined in the light of any hypothesis preferred. The second part of the ninth circular gives, among other useful information, ephemerides of the planet Eros and of the sun, calculated to eight significant figures for every six hours—almost a new departure in such work, the only precedent being afforded by the investigations of Sir David Gill on the planets Victoria, Iris and Sappho, whereby he clearly showed that eight figures were necessary to represent the accuracy of heliometer measures. To advance one decimal place is of course a step of the gravest importance, and to Mr. Hinks, of the Cambridge Observatory, belongs the credit of being the first to show that an accuracy can be obtained from photographic measures of the Eros plates of the same order as that which led Sir David Gill to ask for an eight-figure ephemeris.

The appearance of so much important literature in connection with this second enterprise, the photographic observation of the planet Eros, naturally suggests a glance at the state of affairs with regard to the main work, the Astrographic Chart itself. It is, as remarked in the first sentence of this article, some fifteen years since the work was initiated, and it should by this time be possible to form an estimate of the probable outcome and the approximate date of completion. It must be confessed that the original estimate of the time required has already been seriously exceeded. In the letter which summoned the conference of 1887 it is stated that:—

"Ce grand travail . . . pourrait être facilement exécuté en quelques années si dix ou douze observatoires bien répartis sur le globe pouvaient se partager convenablement la tâche."

The phrase "quelques années" is somewhat indefinite, but it may be assumed that those who assembled in 1887 would have been shocked to learn that after a lapse of a dozen years scarcely one-fifth of the work projected had been accomplished. Indeed, many who are tolerably familiar with the general course of events may be startled to hear this statement made; and yet a glance at the last comprehensive report available (see R.A.S. *Monthly Notices*, vol. lxi. p. 280) shows it to be only too true. It was decided to work on such a scale that 11,000 plates would be required to cover the sky, and this number was to be repeated four times, twice with short exposures (of 6 minutes, 3 minutes and 20 seconds), and twice with long exposures (40 minutes). The plates of the first series (catalogue plates) were to be measured, and the measures printed and published; those of the second series

(chart plates proper) to be reproduced in facsimile. In June, 1900, the state of affairs was as follows :—15,000 of the 22,000 catalogue plates had been *taken*, but only 4000 had been measured; and the measurement is of course by far the most serious part of the work. Of the 22,000 chart plates required, less than 4000 had been taken, and only a small portion of these had been reproduced and published. So that the fraction of the whole programme accomplished in a dozen years can certainly not be put higher than one-fifth.

Does this mean, then, that it will take sixty years to finish the whole? It is earnestly to be hoped that this would not be a legitimate inference, and fortunately there are good sound reasons why it should not be. The years immediately succeeding 1887 were naturally devoted to experimental work, of which a large amount has been necessary. This was foreseen at the outset; witness, for instance, the words of the veteran Otto Struve in his opening address :—

"En effet, l'Astronomie pratique possède aujourd'hui, dans la Photographie, un instrument de la plus haute valeur et qui, probablement avec le temps, facilitera énormément nos études épineuses. Mais restons sobres dans nos prévisions. Pour le moment, nous ne devons regarder la Photographie que comme un instrument très précieux, *mais dont l'étude reste encore à compléter*."

But it will probably be agreed that the amount of work necessary to "complete the study" has exceeded expectation.

Beyond the preliminary experiments which might have been foreseen by an individual worker, much time has been spent in a well-meant endeavour to secure uniformity in the work, which has, after all, not been very successful. Thus a large part of one year was lost in attempts to devise an obscuring screen which should diminish the light received from the stars in a known ratio, and ultimately secure uniformity in the limiting brightness (or rather faintness) of the stars charted; but this attempt was at last abandoned in favour of the simpler method of fixing a definite time of exposure, which might have been adopted from the first. Or going further back in the history, it must be remembered that although a standard pattern of telescope was adopted in 1887, it took a considerable time, not only to make the eighteen instruments required, but for the makers to find out how to make them. Thus it would be fair to estimate that in 1900 the work had been in actual progress, not for a dozen years, but for less than half that period; so we need not fear that the completion of the work is still half a century off. Nevertheless, he would be sanguine who should reduce this prospective limit below twenty years, unless some very drastic measure is adopted in the near future. Some of the cooperating observatories are well advanced with their work, but others are far behind. In 1900 there were actually three which had not started at all, and these have been struck off the list and replaced by three new ones. We have good reason for anticipating energetic action from these new comers, but it must be remembered that they start a dozen years at least behind their colleagues.

This great delay in the execution of the work has been prominently mentioned because it demands most serious attention if the original scheme is to be carried out in any real manner. Even without the addition of the Eros work there was sufficient cause for anxiety; with that important and unforeseen addition there is reason for alarm. It is to be hoped that the dangers may be realised and obviated within the next few years.

But when we turn to the contemplation of what has been accomplished, there is good reason for satisfaction. To take first the series of catalogue plates, with short exposures of a few minutes only. Each observatory has to take about 1200 of these, and the area of the sky covered by each is a square of two degrees in the side, so that sixteen full moons arranged in solid square formation would just about cover this area. On each plate there are some 300 or 400 star-images on the average; but this is an average from which the deviations are large. A plate exposed near the Milky Way, even for a few minutes only, shows thousands of stars, whereas if the telescope be pointed to a region distant from the Milky Way, the number may fall below 100. Taking the average as 350, there are on the 1200 plates which form the share of one observatory some 400,000 star-images; and it is the business of that observatory, after taking the plates, to measure carefully the relative positions of all these images and publish the results. Moreover, it has been found advisable to make these measures at least twice over, so that we may put the total number at something like a million. It will readily be conceded that this is a gigantic piece of work for a single observatory to carry out, and it is a great thing to be able to say that some of the observatories are already in sight of its accomplishment. Others, as has been admitted, have not yet commenced the work, but they will enter upon it with all the advantages of following an example already set, and we may consider that the greatest difficulties have been overcome.

This portion of the work affords another reason for satisfaction. Mention has been made of some preliminary experimental work which produced no positive result, but other such investigations have had more fortunate issues, especially the research on the best method of measuring the plates. In 1887 there were at least three different methods which might be adopted, and corresponding to each of these there was a choice of patterns for the instrument to carry it out. The proper method for measuring stellar photographs has now been practically settled, and though there is diversity of opinion as to the best actual instrument, the relative advantages of the different forms are becoming tolerably well known. It will be realised how definite an advance has here been made when it is remembered that an eminent astronomer, in reviewing the possibilities in 1887, dismissed the method which has since been universally adopted as obviously inferior to the others and not worthy of consideration. The test of experience had, in fact, not been applied, and the result of its application may be regarded as a valuable scientific asset.

Let us turn now to the other set of plates, the chart plates as they are called, similar in every way to the catalogue plates, except that they are exposed to the sky for a much longer time (forty minutes at least, instead of three or six), and hence contain thousands of stars instead of hundreds. It is proposed that these plates shall be reproduced on paper by some process which depends on the automatic action of light only, and is thus free from the imperfections incidental to human agency. The exact process has not been formally specified, and it is open to any observatory to circulate ordinary contact prints, for instance, if such can be made without losing too many of the fainter star-images. Up to the present time, however, the only reproductions of chart plates which have been published are in heliogravure. The French observatories (Paris, Algiers, Toulouse, Bordeaux) and the Observatory of San Fernando, in Spain, have produced and circulated most beautiful enlargements (twice the linear dimensions) of some of their chart plates made by heliogravure, and there are many reasons why we may hope that their example will be universally followed. To begin with, the charts are really beautiful to look at—as might be expected from the French, they have produced something æsthetically satisfactory. Secondly—a matter of infinitely more importance astronomically—the charts

are wonderfully accurate. It has been shown that the places of stars can be measured from them with an accuracy almost equal to that obtainable from the original glass negatives. Finally, they are presumably permanent—far more so than the glass negatives, unless the toning process recently suggested by Sir William Crookes is adopted and found as successful as is expected. Against these manifest advantages is, unfortunately, to be set the costliness of the process. It is estimated that to reproduce its 1200 plates in this way each observatory must have a sum of about 10,000*l.* at command, independently of the actual time spent in the work. This sum is large, but not prohibitive. Five observatories are apparently already provided with it; in the interests of uniformity in a magnificent piece of work, may it be hoped that in some way or other the remaining shares will be taken up? If the paper reproductions were (as it was at one time supposed they would be) mere playthings of no scientific value, such expenditure might have been deprecated. But it has been demonstrated that they are accurate beyond expectation, that, in fact, an observatory provided with copies of this kind for the whole sky could in a few minutes obtain the place of any star down to the 14th magnitude with an accuracy equal to that with which the best meridian observations can be made. It seems probable that the outlay is as good a one as can be made with our present imperfect knowledge of the requirements of the future.

The consideration of what this means in actual weight of paper brings home to us in a striking manner the magnitude of the whole enterprise. If the 22,000 maps are completed in the style adopted by the French, the sheets when piled one on the other would form a column thirty feet high and weighing nearly two tons! The most elaborate star atlas which has been produced up to the present time can be bound as a single, though rather large, volume, which could be added to any library without sensible disturbance. But not so with a copy of the Astrographic Chart; it is a matter for the serious consideration of each fortunate possessor where and how he shall store the sheets and ensure their preservation. There is not likely, of course, to be any real difficulty in doing this, the point is only mentioned here to illustrate the novelty of the departure rendered possible by photography.

As there is an obvious danger of not being able to carry out this vast programme (for which, it will be remarked, not only scientific labour, but much hard cash is required, and the latter may not be easy to extract from reluctant Governments), it is reassuring to know that there is at least one good alternative. We might carry out the work much more economically with a different type of instrument, though at the cost of some obvious advantages. The type selected in 1887, a refracting telescope of 11½ feet focal length, allows us to photograph an area of the sky at one exposure limited to two degrees square, and 11,000 plates are required to cover the whole sky. Two other types were considered and rejected. The first was the reflecting telescope, with a concave mirror in place of a lens. The area satisfactorily photographed at one exposure with a reflector is even smaller, and the number of plates required for the whole sky consequently greater. Though the reflector has distinct advantages in cheapness and in light-grasping power which have recommended it for other classes of work, there is no doubt that it was rightly rejected for the Astrographic Chart; all our experience subsequent to 1887 has tended to confirm this view. The third possibility open to the conference of 1887 was the use of a doublet lens, such as is familiar in an ordinary camera. The lens of a camera is made up of two lenses (each of which is itself double) separated by a definite interval, where a "stop" may be inserted. A photograph could be taken with one of these lenses alone, but only a comparatively small portion of the picture near the centre would be in good focus; the combination is made to give a larger "field." If such a doublet lens is used to photograph the sky, we get a much larger field at one exposure, and can cover the sky with fewer plates. The claim has recently been made that twenty or thirty plates would suffice to cover the sky instead of 11,000! Of course the results would be on a correspondingly smaller scale, and this extreme procedure is not to be contemplated as an alternative to the large and accurate charts with which a start has already been made. But if we could reduce the 10,000*l.* required to (say) 1000*l.*, we are in the region of the possible or even the probable, and this only means reducing the number of plates required in the ratio of one to ten, or increasing the area covered by each in the same ratio. We may take it as fairly well established that a doublet will satisfactorily cover a field at least ten times as large, in area of the sky, as the single lenses at present in use for the work of the chart.

The question naturally arises whether these facts were realised in 1887, and if so, how the single lens came to be preferred to the doublet. The discussion on the type of instrument to select took place on April 18, 1887, and the *procès-verbaux* are given on pp. 36–43 of the official account of the conference. Twenty-six distinguished astronomers were present, and eighteen of them took part in the debate. *The photographic doublet was not even mentioned.* At the present time this circumstance is almost bewildering. At the end of the volume a letter is printed from Prof. E. C. Pickering (who most unfortunately was not able to attend the conference) advocating the use of the doublet, and giving detailed suggestions for the whole work which commend themselves, in the light of subsequent experience, as admirable. But his views received no attention; the debate was confined almost entirely to the relative advantages of reflectors and refractors, and the proper size to be adopted for the latter, and it must be confessed that an opportunity was lost. Since that time Prof. Pickering, using doublets, has charted the whole sky himself many times over, while the associated observatories have not yet accomplished a third of their programme. It must not be forgotten that their programme includes much more than the mere charting of the sky, viz. the measurement of some plates and the reproduction of others; but even making this allowance, the discrepancy between what he has done single-handed and what has been done on the plan preferred at Paris in 1887 is sufficiently serious.

The fact is that astronomers generally were afraid of the doublet in 1887, and some of them have not yet lost their mistrust. They were afraid that so fair a promise was too specious; that, in fact, the gain in extent of field over the refractor must be accompanied by a corresponding loss in accuracy. At the time no definite information was forthcoming on this point, and it must be admitted that even now our knowledge is far from complete. It is not so easy as it might seem to test pictures of the stars for the minute accuracy necessary to an astronomer, and it may still be proved that the choice of the refractor in 1887 was, from the point of view of getting the greatest attainable accuracy, a wise one. But, on the other hand, it has been shown that the mistrust of the doublet was largely unjustifiable; its accuracy is of a high, if not of the very highest, order. It is not even now too late to follow the excellent advice which was offered in 1887 only to be ignored. By adopting the doublet the chart plates might be completed in a reasonable time and at a reasonable cost, though on a smaller scale.

H. H. TURNER.