the inflammable gases invariably preponderate. On one famous occasion a certain Professor lecturing in the Royal Institution lit up the room for a time with the gas from a meteorite. An examination of such incandescent gases with a spectroscope gives a spectrum similar to that of a comet.

Or take the composition of the meteorites themselves. Carbon is a common element. The specimen presented to this Astronomical Society is one of this type, rich in carbon. Other elements occur of course, such as Sodium and Iron, but these are not inconsistent with the theory that the composition of meteorites resembles the composition of comets.* Thus we are forced to the conclusion that comets and meteors are practically the same substances in different forms. They are similar in composition and they move in the same orbits. Comets are known to have disappeared and their places taken by meteors. Comets in one sense resemble nebulæ. Nebulæ are the stuff out of which suns are made, comets are the stuff out of which meteors are made.

We have come to the end of this lecture. To those who would know the purpose that comets serve in the economy of Nature we have no reply to-night; we can only direct them to the words of the inspired writer, "Oh, Lord, how manifold are all thy works, in wisdom hast thou made them all."

The Great Star Map

By A. B. Chatwood, B.Sc., F.R.A.S., A.M.I.C.E.

The title which I have chosen for this evening's lecture, "The Great Star Map," does not indicate very clearly my subject, which is the Astrographic Chart and Catalogue: the title is due to Professor Turner and I adopted it as I could think of none better.

Perhaps I cannot do better than at once give you some idea of the nature and magnitude of the work carried by my title.

It comprises a map produced entirely by photography showing stars down to the 14th magnitude, say 150,000,000 star images. This map will consist of 22,180 sheets, about 17 or 18 inches by 22 inches, a single copy would form a pile 33 feet high and weigh about 4,000 lbs. The second portion of the work is a catalogue of the positions and magnitudes

* Sodium and Iron, in particular, were conspicuous in the spectrum of Moorhouse's Comet.

of all stars down to the 11th magnitude determined from a second set of photographs and containing about 9 or 10 million star measures. This catalogue, in volumes about 12″ × 10″, would take up about 30 feet of shelf room and weight ⅝ ton.

This work could, of course, not be carried out by a single observatory, it has been divided into 19 sections which have been undertaken by different observatories representative of a dozen countries.

It cannot be supposed that the Governments of a dozen different countries would have allowed it to be undertaken and provided the necessary funds—perhaps 80 lacs of rupees—unless astronomers had been able to show that the work had a serious object and was likely to lead to results commensurate with its cost. Although valuable results have already been achieved the original object was simply to store up a mass of data which would enable future generations to make advances in astronomical knowledge based on more accurate and extensive data than are available to us.

It is interesting to trace the causes which led us to the undertaking :—

As you are aware, the earliest star maps were made for astrological purposes and, later, maps were required for the use of sailors. About 1674 it was suggested that the angular distance of the Moon from the brighter stars—"the method of lunar distances"—could be utilized by sailors for obtaining their longitude : Flamsteed pointed out that no sufficiently accurate charts or catalogues then existed. Charles II, then King of England, at once founded Greenwich Observatory to remedy the defect and appointed Flamsteed the first Astronomer Royal. Half a century later Bradley became Astronomer Royal, and, among many other achievements, laid the foundation of our present knowledge of the positions of the stars. At this time only the brightest stars were observed.

Later on when attention was called to the fact that one term of Bode's Series or Law, with which you are all familiar, had no planet to represent it, it was suggested that the term might be represented not by a single planet—which would certainly have been discovered—but by a number of smaller bodies. Search was made and in a comparatively short time four minor planets were discovered. Further search was for a long time fruitless, although now several hundreds have been catalogued.

The search for these small bodies resembling telescopically faint stars necessitated the use of charts showing not only the bright stars but also the faint ones. With such charts it was possible to detect a minor planet by its motion relatively to these faint stars.

The process of making such charts by plotting measures made in the telescope with a micrometer and filling in the fainter stars by estimation is familiar to you. The *method*, however, is not important to our subject but the *fact* that there was great need of accurate maps showing faint as well as bright stars. This led in the first place to the charting of the Zodiac—in or near which minor planets might be expected to be found—in Berlin and also by Chacornac in France whose work was continued by the brothers Henry.

The work we are considering would of course have been impossible had it not been for the improvements in photography which only took place between 1850 and 1880.

About 1850 or soon afterwards the Americans, Bond and Rutherford, had done some work in stellar photography with wet collodion plates, and in 1857 Bond wrote a letter, which is remarkable, to the Hon. Wm. Michell; in this letter he clearly forecasts that the sensitiveness of plates will be increased: that larger instruments will be constructed and erected under better climatic conditions and he pointed out the great accuracy of the photographic process. He concluded his letter by saying:

"There is nothing, then, so extravagant in predicting a future application of photography to stellar astronomy on a most magnificent scale."

These forecasts have all been justified by subsequent events. It is noteworthy that Rutherford found the accuracy of the photographs so great that he was unable to do them justice with any micrometer screw then obtainable; he therefore abandoned his astronomical work and devoted himself to the perfecting of the screw. It is probably to Rutherford's work in this direction that much of the development of modern tool-making and engineering is due.

In 1882 the gelatine plate, which is so greatly superior to the collodion plate in sensitiveness, was in common use; some amateurs at the Cape attempted to obtain photographs of the great comet of that year, which no doubt many of you remember, but were defeated by the fact that the image moved on the plate and so gave confused images: Sir David Gill, then Astronomer Royal at the Cape, hearing of this, invited them to come to the Observatory and strap their cameras to the equatorial telescope which was driven by clockwork to counteract the effect of the Earth's rotation. Some excellent results were obtained in this way.

A correspondence ensued between Sir David Gill and Admiral Mouchez, French Government Astronomer, which resulted in an invitation being issued to all the world's leading astronomers to attend a conference at Paris. This conference took place in 1887 and was attended by 56 astronomers representing 19 countries.

In the meantime Dr. Common in England had utilized photography in producing with his reflecting telescopes the excellent photographs of nebulæ which are so well known: and the Henry Brothers of Paris, who have already been mentioned as carrying on the charting begun by Chacornac, had with infinite skill and patience produced an object glass of 13½″ aperture specially suited to photography. As you are well aware, the ordinary visual object glass is adjusted to bring the yellow and green portions of the spectrum to the best focus, as this is the portion of the spectrum which is most active in vision; but the vision of the photographic plates, if one may be permitted the expression, is most acute for the blue and violet rays so that the curves of the usual crown-flint object glass intended for one purpose are not suitable for the other.

The conference of 1887 marks a distinct epoch in the history of astronomy as it originated what may be called "co-operative astronomy." I should like, if I may, to express here an opinion which I hold very strongly, and to express it with all the force I can: it is that astronomy, the science on which we are all so keen, has reached a stage when co-operative work is essential, and that the work of half a dozen astronomers, whether amateur or professional, working in co-operation is of far more value than the work of the same half-dozen working independently.

Many important decisions were arrived at at the conference of 1887; the first of course was that observatories all over the world should co-operate and that this co-operation should be used to produce a complete series of star charts and maps.

The next decision arrived at was that an object glass of the ordinary type, but specially corrected for photography should be used. Dr. Common was naturally in favour of reflector, but he did not fail to point out its disadvantages especially its fickle behaviour under unfavourable atmospheric conditions. Pickering, of America, advocated what has now come to be known as a doublet, a combination of four lenses exactly similar to a large photographic lens, and it is probable, I think, that if the excellent work done by this type of lens had then been available that it would have been adopted.

The object glass which was, however, adopted was one of the ordinary type corrected for photography with which the excellent work shown by the Henry Brothers had been done.

Another decision which has had far-reaching results was that of impressing a network of lines carefully ruled at right-angles and equally spaced on the photographic plate before development.

Although it was well known that the gelatine film was not subject to such distortion as would be noticeable in ordinary photography, it was yet looked on with suspicion and it was considered likely that it might suffer from distortion which would be noticeable in stellar photography. The impression of the carefully ruled network of line now known as a "reseau," a name which is also applied to the ruled silver on glass plate from which it is printed, would enable distortion to be easily detected.

This decision led to a result, due I believe to Professor Turner, without which I do not think that there could have been the slightest hope of ever carrying the work through. When it was found that the distortion of the film was negligible he suggested that it would be quicker and better to utilize the reseau lines as fiduciary marks from which to measure the position of the star images than to use a micrometer screw.

This has been accomplished by fitting a scale divided on a glass diaphragm in the common focus of the objective and eye piece of the measuring microscope. In practice this scale divides the space between two reseau lines into 100 parts and positions are estimated to $\frac{1}{10}$ of this, that is to say, $0''\cdot3$ of arc or approximately $\frac{1}{5000}$ part of an inch.

I pointed out earlier in my lecture that the original object with which this work was undertaken was the amassing of data for the use of future generations : but happily important and valuable results have been obtained during the course of the work.

It has been thought that our Sun was one of the stars of a cluster, and counts of stars on our plates has so strengthened this presumption that it may be considered as a definite result.

I show slides of two stellar clusters, you will notice a great concentration of stars towards the centre. Recent work by Mr. Plummer and others leads us to believe that if we were situated in the centre of one of these clusters and counted the stars of various magnitudes we should find that the ratio of the number of stars of any magnitude to that of one magnitude brighter would be about 2.

If now we make an assumption as to the distribution of stars in space, for example that stars are distributed uniformly through space and are intrinsically equally bright, the latter part of the assumption is not of course correct, so we will refer to it later.

If we take this hypothesis of uniform distribution we may, as you will see, for the sake of definiteness and without invalidity, assume the stars of different magnitudes to be uniformly distributed over the surfaces of spheres of different radii, the radii being determined by the convention as to magnitudes such radii would be starting from the 2nd magnitude

10 16 25 40 63 100 etc.

On this assumption the ratio of the number of stars of any magnitude to that of one magnitude brighter would be 4.

Considering now our assumption that all stars are intrinsically equally bright as erroneous : let us assume them to be of 2, 3, 4, or any number "n" degrees of brightness and we shall find that our ratio will be greater than 4 for the first "n" magnitudes and 4 for the remainder. And whatever reasonable assumption we make we cannot get a ratio smaller than *four.*

Counts of the number of stars of each magnitude from 2 to 6 on our photographic plates give us a ratio of about 3 which can be accounted for by the existence of a solar cluster containing about 740 stars and for which no other explanation has been up so far forthcoming.

Up to now we have considered only the brighter stars and have considered our solar cluster as limited; if we considered our clusters as extending indefinitely we should not account for the ratio which we find on our plates and we are bound to look further for an explanation of our discrepancy.

Professor Kapetyn has suggested, for quite other reasons that space is permeated by matter which absorbs light in very much the same manner as a fog but of course to a much smaller extent. Fog, as you know, absorbs blue rays much more readily than red rays, so that lights seen through a fog always look yellower or redder than they really are. Kapetyn has estimated the density of this matter pervading space as such that it will absorb one-half the luminosity of a star in a journey of 40,000 billion miles. That there must be matter in space is very reasonable as we see matter constantly driven off from the Sun's corona and from comets. Professor Newall devoted his Presidential Address to the Royal Astronomical Society in 1909 to this subject.

Counts of stars on our photographic plates give, as I said, a ratio of about 3 and also show that the more distant stars are more red in colour than those nearer to us. Also, although with certain limitations doubling the exposure of a photographic plate doubles the effect on the plate, yet it does not when we are photographing stars give us as many extra stars as it should if there were no-light absorption in space.

From these counts Professor Turner has estimated that the "fog in space" is such as to absorb one-half the luminosity of a star in 4,000 billion miles, an estimate of its density which while ten times as great as Kapetyn's is considering the difficulty of the subject in very good accordance.

We thus have as results of this work the existence of :—a solar cluster of about 740 stars—fog in space.

Another result not strictly of this work but of work arising out of it and out of the discovery of Eros in 1900 is the determination by Mr. A. R. Hinks from photographs taken in various parts of the world of the solar parallax. A determination which has given us our distance from the Sun with a probable error of less than 27,000 miles.

In some cases plates have had to be repeated for various reasons, and a comparison of these corresponding plates has shown that the work will lead to the determination of a large number of proper motions. Until 9 or 10 years ago it was assumed that these proper motions were entirely at random. Kapetyn, however, suggested that this was not so but that the stars were moving generally in two streams. This has been confirmed by Dyson, and Eddington has from examination of these plates recently shown that these two streams have fairly definite points of apparent convergence.

The plates intended for reproduction as star charts are exposed three times, the plate being displaced in such a way that the three exposures form a small equilateral triangle. Mr. Baillaud found in one case, I believe also in others later on, that one of the images of a star did not at all resemble the other two : on investigating this—and every little discrepancy is well worth investigating—it was found that owing to the intervention of clouds one of the exposures had been made on one night and the other two on the next : he suspected the discrepancy to be due to the fact that this star was a short period variable, a suspicion which was afterwards confirmed.

I need not remind you of the discovery of Nova Geminorum by Mr. F. A. Bellamy at Oxford, a discovery which was also due to the investigation of a discrepancy in this work.

I have now given you a brief sketch of the magnitude of the complete undertaking, of the various causes which led up to it and of the results which it has already been responsible for ; I will now conclude my lecture by giving you some idea of how the work is carried out and of the enormous amount of detail and figuring involved ; by the help of the slides I shall now show and explain to you.

Slides of an astrographic telescope, and slides of a complete set of record sheets of one plate were then shown and explained by the lecturer.

Jupiter, the Giant Planet

BY THE REV. J. MITCHELL, M.A., F.R.A.S.

THE subject of my lecture to-night is Jupiter, the Giant Planet, and it is fitting that this lecture should be delivered on a Thursday (Jupiter's Day or বৃহস্পতিবার).

The name Jupiter is a most appropriate one. Mythologically, Jupiter was supreme among the gods. As Zeus, he was the earliest, the greatest and the most renowned deity in the Greek Pantheon. As Jupiter, he was also the chief deity of the Romans. In the Solar system he is supreme, for he is the largest in size among the planets. He is almost supreme in brightness, only Venus surpassing him in this respect. When Jupiter and Venus appear side by side in the heavens, *i.e.*, when they are near conjunction, they present a most brilliant spectacle. Such a spectacle I well remember witnessing in the evening sky in January 1892, about 22 years ago, and the impression it made on my mind will never be effaced.

During the greater part of last year Jupiter was a brilliant object in the southern sky, and its altitude being about 45° it was favourably situated for an observer in this latitude, but our friends in England were not so fortunate, for Jupiter's altitude being only 17° no serious telescopic work could be done. It was, therefore, hoped that all possessors of telescopes living in lower latitudes would make good use of their opportunity. Fortunately for our Society, early in July, the mounting of the 7″ Merz refractor, belonging to the Observatory of the Indian Association for the Cultivation of Science, was completed, and Mr. Raman, to whose energy that mounting is largely due, lost no time in turning it on Jupiter. I also, in Bankura, used my 5″ Cooke on the planet on almost every favourable night. Between us, for we (to