mittee of the Royal and the Royal Astronomical Societies were preparing to occupy the Crimea. The weather in Norway was distinctly uncertain, and so they ought to scatter.

Mr. E. W. Maunder said Mr. Melotte and himself had been talking over the work which amateur astronomers could do in a total eclipse without any elaborate instruments. Now-a-days photographic plates were so rapid that it was by no means necessary that the telescopes should be equatorially mounted and clock-driven; short exposures with a fixed telescope could give quite good results. If the focal length of the camera was about 50 times the aperture, than half a second's exposure would be ample with a fine grain plate, and with plates like the Empress he should think a tenth of a second's exposure would be sufficient to get the prominences. If the observer wished to get a good record of the corona, half-a-second's exposure would be sufficient, but the focal length should be only 15 times the aperture.

The President said the particulars they had just heard about the eclipse were very valuable and interesting. The conditions of this eclipse appeared to be rather more favourable than when they went to Norway before. Their thanks were due to Dr. Crommelin for the trouble he had taken in going into the matter and explaining it to them.

Mr. P. J. Melotte exhibited a slide of the region around the two Nebulæ H.V. 14 and H.V. 15 Cygni (N.G.C. 6992, 6960), as an example of what could be done with a small lens.

The President said he thought the photograph was an extremely interesting one, and the question which would probably occur to many minds was, what must be the magnitude of that nebula. Mr. Melotte said the nebula extended over three degrees of angular measurement, and therefore, with average stellar parallax the numbers expressing the real dimensions of the nebula in space would rival those just mentioned by Mr. Holmes. He was afraid they had no time to finish their papers, and the Meeting would stand adjourned until October 29, when the Annual General Meeting would be held.

"Giant" and "Dwarf" Stars*.

We are working at Princeton along several lines—on the photographic determination of the position of the Moon, and on eclipsing variables—both observationally and theoretically; but I would like to talk now about some studies bearing upon stellar evolution, beginning with the relation between the spectral types of the stars and their real brightness. [Slide shown on screen.] This slide represents graphically the relation between the absolute

* An address given at the Meeting of the Royal Astronomical Society, 1913, June 13.

magnitude and spectrum of all the stars for which fairly reliable parallaxes have so far been obtained. I have added a number of recent determinations to those given in Kapteyn and Weersma's list, and have been pretty liberal in my definition of a "reliable parallax." For determinations of many of the spectra I am greatly indebted to Prof. Pickering and Miss Cannon. The vertical coordinates give the spectra, and the horizontal the absolute magnitude according to Kapteyn's definition, *i. e.* the magnitude which the star would appear to have if moved to such a distance that its parallax was $0''\cdot10$.

It is immediately conspicuous that one corner of the diagram is vacant (except for one star whose spectrum is very doubtful). There do not seem to be any faint white stars. All the very faint stars (say those more than fifty times fainter than the Sun) are very red, at least as red as Class K, while most of them are K 5 or M, and all the stars of Classes A and B, especially the latter, are many times brighter than the Sun.

On the other hand, the converse propositions are not true; there is no doubt at all that there exist many very bright red stars (such as Arcturus, Aldebaran, Antares, &c.). These are so bright that we can see them at enormous distances, and so we get a lot of them among the stars of the first three magnitudes, with small proper motions. The parallaxes of a good many of these have been observed with rather low individual accuracy; but by taking mean magnitudes and parallaxes for the stars of each spectral class, we can get pretty good mean values for their real brightness. The corresponding points are plotted as large circles in the diagram, and show that these stars are of about the same average brightness (say 80 times that of the Sun) whatever their type of spectrum.

The range in the real brightness of the stars of a given spectral class increases steadily with increasing redness from B to M, by about two magnitudes for each class.

More than this, among the reddest stars (K and M) there is a distinct separation into two groups. There seem to be no stars of Class M which are closely comparable with the Sun in brightness—they are either much brighter or much fainter. More than 100 stars of large proper motion have been investigated for parallax without any knowledge of their spectra, and it has later been found, when the spectra were investigated, that all those of about the Sun's brightness were fairly similar to the Sun in spectrum, so that it seems pretty certain that the absence of stars of spectrum M, similar in brightness to the Sun, cannot be a result of the process of selection, but must be a real phenomenon. There seem, therefore, to be two series of stars, one very bright and of almost the same brightness, whatever the spectrum, the other diminishing rapidly in brightness with increasing redness. The stars of Class B may be regarded equally well as belonging to either series, and the two groups intermingle for class A and are probably not really separated in Class F. These series were first noticed by Dr. Hertzsprung, of Potsdam, and called by him "giant" and "dwarf" stars. All I have done in this diagram is to use more extensive observational material. The dwarf stars, on the average, are a little over two magnitudes fainter for each spectral type than for the one preceding it in the Harvard classification (the Sun being very nearly typical of Class G). From this relation alone we find (allowing for the uncertainties of the observed parallaxes) that one can predict the real brightness of a dwarf star from a knowledge of its spectrum alone, with a probable error of only about three-quarters of a magnitude. We cannot find the corresponding amount for the giant stars; their parallaxes are too small.

To get a check on all this, the second diagram shows the relation between absolute magnitude and spectrum for all the stars belonging to the four moving clusters whose distances have so far been determined by comparison of radial velocities and convergent proper motions—the Hyades, the Ursa Major group, Mr. Boss's 61 Cygni group, and the conspicuous group in Scorpius discovered independently by Kapteyn, Boss, and Eddington. The stars of the different groups are distinguished by different signs in the diagram. It is clear that most of the stars in all the groups are "dwarf stars," and that exactly the same relation between real brightness and spectrum holds here as in the previous case. A few aberrant red stars of great brightness, such as γ and δ Tauri in the Hyades and Antares in Scorpio (which is 2500 times as bright as the Sun), clearly belong to the series of giant stars.

The large circles and crosses represent the results of Boss, Campbell, and Kapteyn, derived from the parallactic motions and radial velocities of large numbers of naked-eye stars. You see there appears to be a good deal of discordance. I have not time to go into this as I would like, but I may say that Boss uses only the small proper motions, Campbell the small and middle-sized ones, and Kapteyn all, including the biggest. For Class M *all* the dwarf stars are invisible to the naked eye (though one of them is the second nearest star in the heavens), and so all the results refer to the giant stars alone, and agree very well. For Class K, a few dwarf stars very near us are visible, but they all have big proper motions, and are excluded by both Boss and Campbell, whose results again agree, representing the giant stars. For Class G a good many dwarf stars are visible to the naked eye (since we can see them farther off). Some of these have big and some middle-sized proper motions, but practically none have small ones. So Boss gets giant stars alone, Campbell a mixture of the two, averaging fainter, and Kapteyn a mixture with more dwarf stars in it, averaging still fainter.

But I must go on to the next slide, for there is not nearly time enough for the explanations and qualifications which I would like to make.

We have now to explain the existence of these two kinds of red stars. The absolute magnitude of any star may be regarded as a function of its mass, density, and surface-brightness.

We can eliminate the mass in the case of double stars. If we know the parallax we can, of course, find the actual mass. It is worth remarking that the masses of those visual binaries whose parallaxes are well determined show a remarkably small range (from about 8 times the Sun's mass to about 0·7, including all the effect of errors of parallax). The spectroscopic binaries give us a few instances of systems of mass 20, or at most 35 times that of the Sun, but I have never been able to find reliable evidence of the existence of a lucid star with mass less than about one-quarter that of the Sun. The apparent exceptions, when investigated, have always been found due to bad parallaxes or other errors, sometimes very curious. Finally, Ludendorff has shown that the stars of Class B are undoubtedly considerably more massive than the general run of the others.

More important for our immediate purpose is the fact that, for any visual binary for which we know the orbit, we can assume the mass to be that of the Sun, and compute a hypothetical parallax (as Doberck has done), which will usually be pretty near the truth. But for us at present this hypothetical parallax is better than the real one, for if we calculate the apparent brightness with its aid we get a set of data similar to our previous ones but with the differences of mass, whatever they may be, eliminated, so that the results now depend on surface-brightness and density alone. The number of systems for which orbits have been computed is small, but by a statistical process it is possible to use all the double stars known to be physically connected, however slow their relative motion. If we saw the orbit in plan, and it was a circle, we would only have to know the distance and relative velocity of the stars to compute all we wanted. The actual distances and velocities are diminished by foreshortening by different amounts for different stars. But it is an easy piece of analysis to find the average effect of this (and of the probable eccentricity of the orbits), and also to find out how many cases there will be out of a thousand in which our assumption of the average relation will lead to an error of given magnitude. We thus find that the statistical process gives the absolute magnitude with a probable error of only about half a magnitude. We can now use many systems whose periods must be many thousands of years, so that we get in all fully 550 stars for our diagram, in which all the data refer to the brighter component of each pair.

The next slide shows the same old series of giant and dwarf stars even more clearly than before, on account of the greater number of stars. All the previous relations are reproduced with remarkable exactness.

We may therefore conclude that the differences between the giant and dwarf stars do not arise from differences of mass. The giant stars must either have low density or great surface-brightness, and the reverse is true of the dwarf stars.

To proceed further, we must study the eclipsing variables—the only stars whose densities can be directly determined. In the last year or two Mr. Shapley and I have worked out orbits for 87 of these stars. The next slide shows what distribution of absolute magnitudes we would get among these stars due to the differences in density alone, if they all had the same mass and surface-brightness as the Sun.

Most of these stars are of Class A, though there are a fair number of B's, and about as many ranging from F to M.

The first type stars are much alike in density, while those of the second type show a much wider range, and appear to avoid just those densities (between 0·02 and 0·2 times that of the Sun) which the first type stars strongly favour.

By comparing this diagram with the last we find that the stars of Class A, if of the same mass and surface-brightness as the Sun, would be of absolute magnitude 3·0, while if simply of the same mass as the Sun, but with their own surface-brightness, they would be of absolute magnitude 1·0. Hence these stars, for equal surface, average two magnitudes brighter than the Sun. Similarly, we find that the surface-brightness of stars of Class B exceeds that of the Sun by $3\frac{1}{2}$ magnitudes, and that of Class F by one magnitude.

The great brightness of the giant stars of Classes G and K can be completely explained by assuming that they have densities like those of a number of the eclipsing variables of similar spectra, with surface-brightness even less than that of the Sun.

The very faint stars of spectra K 5 and M, even if as dense as platinum, must be almost three magnitudes fainter, surface for surface, than the Sun. We see thus that the series of dwarf stars is one of slowly increasing density from B to M, while among the giant stars the density must decrease very rapidly from B to M, or increase from M to B.

As almost everybody will agree that a star contracts as it grows older, this leads us to suppose that the giant stars of Class M represent a very early stage of evolution, the other giant stars later stages according to whiteness, Class B a stage near the middle of evolution, and the dwarf stars later stages, ending with the faintest and reddest among them.

All this is in entire accordance with the theories of Lane and Ritter, and with Sir Norman Lockyer's conception of stars of increasing and decreasing temperature (though the criteria for distinguishing the two are quite different from Lockyer's). A mass of gas in equilibrium under its own gravitation and radiation, must, as is well known, grow hotter as it contracts, so long as it remains built upon the same model, and the density is low enough for the simple "gas laws" to hold. At higher densities the mass becomes less compressible, the temperature rises more slowly, reaches a maximum, and finally falls off. Lord Kelvin some years ago estimated that the maximum temperature would be reached when the central density was about one-tenth that of water.

It is less well known, but equally easy to prove, that the more massive the body of gas is, the higher will be its maximum temperature.

Such a mass of gas, when it began to shine, would be red and of low surface-brightness, but of very low density and great surface, so that its total light-emission would be large. As it contracted it would grow smaller, hotter, whiter, and increase in surface-brightness, so that its light-emission would not change much. But after reaching its maximum temperature it would grow colder, redder, and duller as it grew smaller, and then it would fall off in brightness very rapidly. These characteristics are exactly those of the dwarf stars, while the giant stars match equally well the theoretical behaviour of stars of rising temperature. A crucial test of the theory is that the actual densities of the stars of Classes A and B, which are almost certainly the hottest, are quite of the order of magnitude at which Lord Kelvin predicted that the temperature should be a maximum.

As one more example how this theory explains apparently unrelated facts, take the masses of the stars. Only bodies of unusually large mass should reach the very highest temperatures, so it is not surprising to find that the hottest stars (Class B) are actually unusually massive. Again, a body of very small mass would be a very poor "self-heating" affair (as one of my students once put it); and this gives a reason for the rarity (indeed the apparent absence) of stars of very small mass—such bodies never get hot enough to shine of any account.

The fact that Jupiter and Saturn, though comparable in density with a number of the stars, are dark bodies confirms this explanation.

In conclusion, let me say that I hope anyone who has any criticisms to make will do me the favour of telling me of them, and thank you for your attention to this hurried account of things, which I hope to get in print next year. H. N. Russell.

The Origin of the Constellations.

So few persons take an interest in this subject that it was a great pleasure to see in the April number of the *Observatory* that Mrs. Evershed was writing upon it and was raising such pertinent questions—questions which, so far as I am able, I shall be delighted to answer if the Editors can accord me the space, for it is not possible to put the replies as briefly as the enquiries.

I should say that Ptolemy, not Aratus, is, in the main, our only real authority for the positions of the ancient constellations, for he alone enables us to identify the actual places on the sphere of