exceptional conditions in this region. Mr. Wilson refers to the spiral appearance of this great cloud and to the high velocities observed in spiral nebulæ, nebulæ which may be considered as isolated island universes similar to our Milky Way system, suggesting that the great cloud may afford an opportunity for the study of detailed characteristics of spiral nebulæ.

Part vi., the last of the series of the important contents of this volume, is contributed by Mr. W. H. Wright, and deals with the subject of the wave-lengths of the nebular lines and general observations of the spectra of the gaseous nebulæ (pp. 193–268). The matter falls under three headings: (1) The measurement of wave-lengths and the intensities of the nebular lines; (2) the study of the nebular nuclei; and (3) the investigation of the distribution of nebular radiations throughout the nebulæ; and is accompanied by a series of plates, which demonstrate, more than text can do, the fine definition and great scale of the photographs of the spectra of the nebulæ which served as his data. Fig. 7 is an illustration of the spectrum of N.G.C. 6818, taken with the slitless spectrograph with an exposure of four hours. It does not seem that the statement could be contradicted that the wave-lengths and intensities of the nebular lines deduced will be used as a standard in this branch of physical astronomy for some time.

This research is very opportune, because more detailed facts were required to help in the unravelling of the relationships between nebulæ as such, nuclei of nebulæ, and bright-line stars such as Wolf-Rayet stars. As the whole problem of the nature of stellar evolution is that of the solution of the relationship between nebulæ and stars, the study of the question is of vital importance. The idea of a falling temperature continuing throughout the whole life-history of a star has more recently given place to the hypothesis, apparently a very natural one, of a star in its early career increasing in temperature, reaching a maximum of development and temperature, and afterwards cooling until the invisible stage is reached. In the light of these hypotheses Mr. Wright, as the result of his research, expresses his view as follows:—

> There are at present two general conceptions as to the nature of stellar evolution, one of which assumes a falling temperature throughout the period of a star's development, while the other predicates a rise to maximum and a subsequent decline; both of these views assume the nebula as the primordial state. As between these two hypotheses, the present observations undoubtedly favour the first, since they add to the proof that the gaseous nebulæ are associated only with the hot stars.

While the above is one of the main conclusions derived by Mr. Wright from this research, there are many other points of particular interest to which limitations of space forbid reference in this article.

It is interesting to compare a direct photograph of a nebula with its spectrum taken with a slitless spectrograph. Nebulæ when photographed with the latter instrument present remarkable varieties of form and size corresponding to different nebular lines in the spectrum, while the direct photograph shows only a form resulting from the integration or the fitting together of the component images of the different forms and sizes. The prismatic images afford a means, therefore, of detecting the differences in distribution of the component gases of the nebula, and indicate that the view of a nebula in a telescope or on a direct photograph is not the best means of studying the complex structure of these bodies.

In conclusion, it may be stated that this addition to the University of California Publications is a valuable contribution, and sustains the high standard of the researches which emanate from the Lick Observatory under the able directorship of Prof. W. W. Campbell.

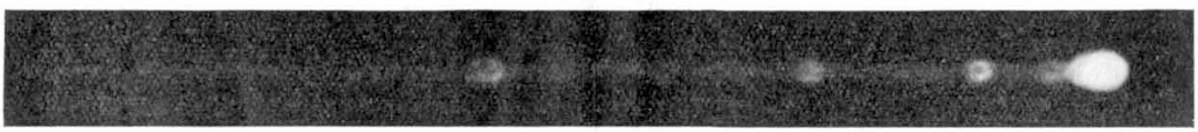

FIG. 7.—The spectrum of N.G.C. 6818, which records images of a variety of shapes and sizes, most of them having the appearance of a horse-shoe, the open end of the shoe lying to the north. Some of the images show mottlings or condensations scattered along the shoe or ring. (W. H. Wright.)

The Importance of Meteorology in Gunnery.

By DR. E. M. WEDDERBURN.

AT the commencement of the war the knowledge of the effect of wind and of the density of the air on the flight of a shell was elementary. It was assumed by the gunners that the wind was of the same direction and strength at all heights reached by the projectile, and that the density of the air decreased with altitude according to an artificial convention. The corrections for wind and density which the gunner was taught to apply were supposed to be referable to the meteorological conditions observed by him at the battery, but he was not taught how these conditions should be observed, nor that the observation of surface air temperature was an exceedingly difficult matter.

When an Army Meteorological Service was established in 1915 it was a small unit which had to justify its existence, and in the course of exploring fields of usefulness it found the artillery ready and anxious for improved meteorological information. The shell from a high-velocity gun may rise to a height of 20,000 ft. or more, and surface conditions may be a very misleading guide. But to ask the gunner to use detailed observations of wind and of atmospheric pressure and temperature at different heights up to 20,000 ft. under active service conditions, and without previous training, was useless. The meteorologist, having found a sphere of usefulness, had to put his information in a form in which it could be used with the existing artillery organisation. It is already suggested in some quarters that the meteorological service adequately met the artillery's requirements during the war without any peace-time organisation, and that therefore it is unnecessary now to keep any close *liaison* between the gunner and the meteorologist. In the writer's view this is a great mistake. The meteorological service was able to help the gunner by doing work which the gunner could have done if he had received the proper training, and it is necessary that he should do this work for himself in order to make the best use for his particular gun of data supplied to him by the meteorologist.

The artillery organisation for meteorological corrections consisted in the supply to gunners of tables of variations in line and range produced by winds constant in velocity and direction at all heights and of variations in range produced by changes in surface temperature and pressure, based on the assumption that the ratio between the actual air density and that assumed in the construction of the range table was the same at all heights. It was a fairly obvious first step to suggest that the gunner should be supplied with a fictitious wind such that, when used with the usual table of variations, the proper correction was applied for the cumulative effect on the projectile before reaching the target of a wind varying with height. Such a wind came to be called the equivalent constant wind, or the ballistic wind, and methods of estimating it were investigated simultaneously by the Meteorological Section, R.E., and the Anti-Aircraft Experimental Section (A.A.E.S.) of the Munitions Inventions Department (M.I.D.). At first the investigations were entirely independent and from different points of view, but later they were continued in close cooperation under the sympathetic guidance of the Ordnance Committee.

An initial difficulty of great importance was that the ballistic wind is not the same for any two trajectories, even for the same wind distribution. But, fortunately, the height to which a projectile rises when fired on the flat is nearly the same for all projectiles which have the same time of flight, and also the length of time which such projectiles spend in any particular stratum of the atmosphere is nearly the same. Thus, though the range of a high-velocity gun may be double that of a howitzer for the same time of flight, yet the projectiles in each case rise to nearly the same height, and are affected by the same winds for nearly the same length of time. To a first approximation, therefore, the ballistic wind is the same for every projectile having the same time of flight, and if a selection of such winds for different times of flight is given to the gunner, he can choose the one most nearly suited to the conditions under which a shoot is taking place.

As a first approximation, in the calculation of the ballistic wind it was assumed that the atmosphere was stratified into several layers, and that in each layer the wind was constant in velocity and direction, though varying from layer to layer. It was further assumed that the effect of the wind in any layer on a projectile was proportional to the time spent by the projectile in that layer and to the density of the air. "Weighting factors" for the portion of the total displacement of the projectile caused by unit wind in any layer were thus determined. Subsequent mathematical analysis showed that the "weighting factors" varied materially for each different trajectory, and also differed for winds across and along the line of fire. Considerable refinements were introduced for the analysis of experimental shoots on which the construction of range tables was based. The researches of the A.A.E.S., M.I.D., though principally directed towards anti-aircraft gunnery, included careful and detailed discussions of variations in the trajectory of a shell produced by varying wind and density, and made the careful analysis of such experimental shoots possible. For a considerable period, however, the facilities afforded by the field meteorological service in the different theatres of war made possible much greater accuracy of correction than had been aimed at in the experimental shoots from which range tables were compiled. Ultimately average weighting factors, deduced from theoretical factors computed in a large number of cases, were adopted for different times of flight, and the method of constructing the ballistic wind for use in the field became standardised.

The second step was the introduction of the idea of ballistic density—a fictitious density such that when used with the usual tables of variations the proper correction is applied for the effect of an abnormal vertical distribution of density. Fortunately, the pressure and temperature which practically determine the air's density may be considered separately. If it is assumed that the vertical temperature distribution is known and remains unchanged while changes in pressure are registered at the surface of the earth, it is easily shown that there are proportional changes in pressure, and therefore in density, at all heights. Thus the surface barometer reading affords a real, though partial, index of the density of the air at any height. From this the third step followed—the idea of a ballistic temperature such that when used in conjunction with surface pressure the ballistic density was arrived at. Methods of computing density weighting factors were developed by the A.A.E.S., M.I.D., and by using these factors temperature weighting factors were computed (which allowed for the variations in the vertical pressure distribution consequent on any variation in the temperature distribution). Here, again, the factors vary for each trajectory, but the differences between trajectories are considerably less than in the case of winds, and there was little difficulty in arriving at the best average factors to employ for field use.

By the employment of wind and temperature weighting factors, very numerous meteorological observations were made available for the use of gunners in the most convenient form. Ballistic winds and temperatures for several selected times of flight were telegraphed to the batteries at frequent intervals, and the information given in the meteorological telegrams, in conjunction with the barometric pressure measured at the battery, gave the gunner data which required no reduction, but could be used directly for applying corrections from the range table. It is, of course, essential that the results of meteorological observations should be provided "red hot" to the gunners, and methods of computation were so perfected, and so high a degree of skill was attained, that the calculation of ballistic winds from pilot-balloon observations kept pace with the observation of the balloon itself, and no time was lost in putting the information in the form in which it was readily usable by the gunner.

A single concrete example may suffice to illustrate the importance of the methods which were introduced by the meteorologists.

If a projectile were fired due south, with a time of flight of 50 sec. (*i.e.* rising to a height of about 10,000 ft.), under the following weather conditions, viz.:—

Height in ft.	Wind Velocity f.s.	Wind Direction °	Temperature ° F.	Barometer
Surface	8	110	50	
2,000	40	175	40	30·00 in. (Normal)
4,000	45	185	30	
6,000	50	190	19	
8,000	45	190	8	
10,000	60	185	−2	

Then, if surface conditions are used for arriving at the appropriate corrections to apply, we have for a certain gun that the wind will reduce the range of the gun by 13 yards and deflect the projectile towards the west 60 yards. The surface temperature being 10° F. below the range table normal of 60° F., the range will be further reduced by 42 yards—a total loss in range of 55 yards.

But the ballistic wind for the above conditions is a wind of 44 f.s. from direction 185°, and the ballistic temperature is 36° F. For the same gun and projectile this wind would produce a deflection towards the east of 35 yards, a decrease in range due to wind of 600 yards and to abnormal temperature (and density) of 407 yards—in all more than 1000 yards. Thus the corrections applied by pre-war methods would have entailed in this case an error in range of about 1000 yards, and in line of about 100 yards.

Instead of anti-aircraft gunnery being considered as a special department of gunnery, it is more logical to consider fire on the flat as a specially simple case of the more general science of gunnery. In a very real way the development of the science was due to the researches of the A.A.E.S., M.I.D., and to the methods employed by that department in the analysis of fuse trials and in the calibration of guns. For anti-aircraft fire under active service conditions the application of meteorological corrections did not reach the same degree of organisation as for fire on the flat, for the application of corrections is a much simpler problem in the latter case. But in experimental work full account was taken of all the meteorological information available. Thus one of the main sources of errors in shooting was eliminated, and the investigation of many ballistic problems made possible.

Obituary.

S. Ramanujan, F.R.S.

SRINIVASA RAMANUJAN, whose death was announced in NATURE of June 3, was born in 1888, in the neighbourhood of Madras, the son of poor parents, and a Brahmin by caste. I know very little of his early history or education, but he became a student in Madras University, and passed certain examinations, though he did not complete the course for a degree. Later he was employed by the Madras Port Trust as a clerk at a salary equivalent to about 25*l*. a year. By this time, however, reports of his unusual abilities had begun to spread, and, I believe owing to the intervention of Dr. G. T. Walker, he obtained a small scholarship which relieved him from the necessity of office work and set him free for research.

I first heard of Ramanujan in 1913. The first letter which he sent me was certainly the most remarkable that I have ever received. There was a short personal introduction written, as he told me later, by a friend. The body of the letter consisted of the enunciations of a hundred or more mathematical theorems. Some of the formulæ were familiar, and others seemed scarcely possible to believe. A few (concerning the distribution of primes) could be said to be definitely false. There were no proofs, and the explanations were often inadequate. In many cases, too, some curious specialisation of a constant or a parameter made